1997-97

Dup

TÜBİTAK

TÜRKİYE BİLİMSEL VE
TEKNİK ARAŞTIRMA KURUMU

THE SCIENTIFIC AND TECHNICAL
RESEARCH COUNCIL OF TURKEY

Elektrik, Elektronik ve Enformatik Araştırma Grubu

Electric, Electronics and Informatics Research
Grant Committee

COST 238
PREDICTION AND RETROSPECTIVE IONOSPHERIC MODELLING OVER EUROPE (PRIME)
(Avrupa Üzerinde İleriye ve Geriye Dönük Öngörü-Kestirim için İyonosfersel Modelleme)

192 E 076

PROJE NO: COST 238
(EEEAG)

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MART 1995
ANKARA

Proje Sonuç Raporu İçeriği

Kısaltmalar; Deyimler

- AB - Avrupa Birliği.
- AFP - Avrupa Fonu Projesi.
- B - Batı.
- BÜ - Boğaziçi Üniversitesi.
- CCIR - International Radio Consultative Committe.
- COST - European **C**ooperation in the Field of **S**cientific and **T**echnical Research.
- COST 238 - PRIME Projesi.
- COST 251 - IITS Projesi.
- D - Doğu.
- DFT - Discrete Fourier Transform.
- Dispersion : ayırganlık.
- Drag : ortamın oluşturduğu sürtünme.
- EEAG - Elektrik Elektronik ve Enformatik Araştırma Kurumu.
- EM - Elektromanyetik.
- Eniyileme : optimization.
- EW - Electronic warfare.
- Extrapolation : dış değerleme.
- Fading : sönümlenme.
- foF2 - F2 bölgesindeki iyonosfersel kritik frekans (ionospheric critical frequency).
- HF - High frequency.
- IITS - **I**mproved Quality of Service in **I**onospheric **T**elecomunication **S**ystems Planning and Operation.
- IMF - Interplanetary Magnetic Field.
- Interpolation: ara değerleme.
- Ionosonda : iyonosonda.
- K - Kuzey.
- LUF - Lowest Usable Frequency.
- Median : ortanca.
- MOU - Memorandum of Understanding.
- MUF - Maximum Usable Frequency.
- Multipath : çok yollu.
- Navigation : yöngüdüm.
- nT : nanotesla.
- Oblique sounding: İyonosonda kullanılarak bir açıyla sonda ölçümü.
- ODTÜ - Orta Doğu Teknik Üniversitesi.
- Phase Coherence: evre uyumluluk.
- Plazma aralığı: plasma pause.
- Post event : olay sonrası.
- PRIME - **P**rediction **R**etrospective **I**onospheric **M**odelling Over **E**urope.

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2. Önsöz

COST 238 : Prediction and Retrospective Ionospheric Modelling over Europe (PRIME) bir Avrupa Topluluğu uzaktan iletişim (tele communication) projesidir. Türkiye'de projeyi, TÜBİTAK, Elektrik Elektronik ve Enformatik Araştırma Grubu(EEEAG) Yürütme Sekreterliği 1 7 1992 ile 1 3 1995 tarihleri arasında desteklemiştir (EK (2-1,2,3)).

4. Şekiller ve Çizelgeler

4.1.Şekiller

Sayfa

4.2. Çizelgeler

5. Öz (Abstract)

5.1. Öz

Yer atmosferinin yaklaşık olarak 50 ile 1000 km yükseklikleri arasında serbest elektrik yüklerinin çoğunlukta olduğu bölgesi ' iyonosfer ' adıyla anılmaktadır. İyonosfer, güneş EM radyasyonunun atmosferdeki nötr bileşenlerle etkileşmesi ve enerjik parçacık yağışı sonucunda oluşur. İyonosfer, bu ortamdaki elektrik yüklü bileşenleri etkileyen fotokimyasal ve dinamik süreçler nedeniyle nitel ve nicel olarak sürekli bir değişim içindedir. Radyo dalgalarının yayılımında çok önemli denetim işlevi gören elektron yoğunluklarının sergiledikleri günlük değişimlerin güvenilir bir şekilde modellenmesi oldukça güçtür. Buna karşın, örneğin, yüksek frekans (HF) radyo dizgelerinin desteklenmesinde ve hava-uzay araştırmalarında elektron yoğunluğu modelleri gerekmektedir. Diğer bir değişle, elektron yoğunluklarının yüksekliğe bağlı olarak dağılımındaki değişmeler 10 kHz (VLF) ve 30 MHz (HF) bandında yayılan radyo dalgalarının yayılma karakteristiklerini çok fazla etkiler ve sağlanabilecek radyo hizmetlerinin tipi ile niteliği üzerinde kısıtlamalar getirirler. Örneğin, sayısal iletişim tekniklerinden olduğunca yararlanabilmek için yayılma kanalının tümüyle bilinip anlaşılması gerekir. Ayrıca radyo planlaması ve radyo devrelerinin parametrelerinin kısa dönemdeki frekans yönetiminin, eniyilemesi için bu tür modeller kullanılarak kestirilmiş veriler gerekmektedir. Havacılık-uzay ve radyo dizgelerinin 'olay sonrası' (post-event) incelenmesinde geriye dönük elektron yoğunluğu modelleri gereklidir. Bu modeller, 'artık-var-olmayan' geçmiş verilere dayandığından çok güvenilir olmalıdır.

PRIME kapsamında, 35°K ve 55°K enlemleriyle 10°B ve 30°D boylamları arasında kalan Avrupa bölgesinde, HF iletişim dizgelerine ilişkin dalgaların yayılmasında iyonosfersel etkilerin öngörülmesi için iyonosfer elektron yoğunluklarının modeli yapılmıştır.

5.2. Abstract

The objectives of the project, embodied in the agreed Memorandum of Understanding are: 'to develop techniques for using synoptic ionospheric sounding information taken from existing measuring equipments to generate models of the ionosphere needed to estimate ionospheric propagation effects on telecommunications system'(EK (5.2)). The project was initiated on 7 March 1991 and had duration of four years.The Member States of Germany, Netherlands, Spain and United Kingdom initially signed the MOU. Later Signatories are Belgium (17 October 1991), France (6 February 1992), Greece (24 July 1991), Italy (6 November 1991), Sweden (17 December 1991), and Turkey (17 February 1992).

Following a review of requirements for improved models to those currently available internationally, efforts are being directed towards separate goals concerning: (i) long-term prediction models that can be made available months or years in advance, and so represent 'smoothed' estimators, (ii) short-term forecasting and models for a particular day and hour and (iii) models representative over periods of about 10 minutes on a given day, needed as collateral data to various remote-sensing applications. The work has been structured within five Topic Areas each as follows:

- Working Group 1 (WG1) - Vertical sounding
- Working Group 2 (WG2) - Oblique sounding
- Working Group 3 (WG3) - Instantaneous mapping
- Working Group 4 (WG4) - Forecasting
- Working Group 5 (WG5) - Monthly median mapping and modelling

6. **Proje Ana Metni**

Avrupa Üzerinde İleriye ve Geriye Dönük Öngörü Kestirim İçin İyonosfersel Modelleme

6.1. Giriş

6.1.1 Konu

Radyo devrelerinin ileriye dönük planlanmasında ve bu devrelerde olabilecek bir aksama anında, kullananlara frekans değiştirmeleri yönünde yapılacak uyarılar için öngörüler, eski günlerde, MUF, LUF, 'işaret/gürültü oranı', ortalama yükseklik açıları verileriyle sınırlanmıştı. Her ne kadar, bu tür ön görülerin yararları tartışılmazsa da iletişim teknolojisindeki gelişmeler iyonosfersel öngörüye isteği artırdı. İleri dizgeleri kullananlar, kendi dizgelerine ilişkin parametreler cinsinden, o dizgeler için yapılmış öngörülere gerek duymağa başladılar. Bunlara örnek olmak üzere:

(i) 'multipath', 'dispersion', 'fading' vb. karakteristiklerinin öngörülmesi gereken iletişim dizgeleri,

(ii) 'total time delay' alıcı frekans bandında 'phase coherence', genlik 'scintillation' olasılığının ve derinliğinin bilinmesini gerektiren uydu dizgeleri,

(iii) yayılma zaman gecikmelerinin bilinmesi gereken 'navigation' dizgeleri,

(iv) erim ve açı düzeltmelerinin bilinmesi gereken radarlar sayılabilir. Ayrıca radyo dizgeleri tasarlanırken öngörü olarak 'median' değerlerle birlikte , ortalama davranıştan farklı olabilen tekil,örneğin,'en-kötü' koşullar hakkında da bilgi sahibi olmak gerekmektedir (Davies, 1981).

İyonosfersel 'öngörü' leri kullananlar da şöyle sıralanabilir (Davies, 1981;Bradley, 1988):

(i) iletişim . 'surveillance' ve 'navigation' dizgeleri için dizgenin tarayacağı alanı ve kullanacağı frekansları planlamak ve tasarımlamak üzere uzun süre amaçlı öngörülere gerek duyanlar,

(ii) 'navigation' ve 'zamanlama' dizgelerine güvenilir konum ve zaman saptanması gerekir. Bunun için dalgaların yansıdığı iyonosfer katmanlarının kararlılığı hakkında öngörüye gerek duyanlar,

(iii) iyonosferin E,F bölgelerinden yansıyan, D bölgesinde yutulan radyo işaretleriyle yayın yapanlar,

(iv) atmosfersel 'drag' nedeniyle kısalan uydu ömürleriyle ilgilenenler,

(v) radyo astronomi ve uydu izleme gibi iyonosferin olumsuz etkide bulunduğu konularda araştırma yapanlar.

Öngörü gereksinimleri, kullanılan dizgenin karmaşıklığı ve gelişmişliğine bağımlıdır. Özetlenirse, radyo planlanmasında radyo devreleri parametrelerinin 'eniyilemesi' ve kullanılacak frekansların düzenlenmesi için öngörü verilerine dayanan yakın gelecek modellerinin bilinmesi çok önceden gerekmektedir. Güneşin öngörülmeyen bir etkinliği sonucunda, iyonosferde dolaylı ve doğrudan olan herhangi bir olayın, havacılık-uzay ve radyo dizgelerinde yarattığı değişikliklerin araştırılması, incelenmesi için ise geriye dönük çalışmalar yapılmalıdır. 'Artık var olmayan' veriye dayanılarak yapılacak olan bu tür araştırmalar için kullanılan modeller çok güvenilir olmalıdır. Bradley (1989), radyo-dizgeleri gereksinimleri için geliştirilmesi gereken iyonosfersel elektron yoğunluğu modellenmesi işini üç ayrı grupta toplamaktadır :

- Devre ve hizmet planlanması için aylık 'median' modeller,
- Geçmiş bir olayın etkisini anlamak, tanı yapmak, devre eniyilemesi için saatlik modeller,
- Uzaktan algılamada, örneğin, ufuk ötesi radar ve hedef yeri saptanması için veri yorumlanmasında, bir olayın etkilerini olay geçtikten sonra ve 'hemen hemen gerçek zamanda' incelemek için gereken 10-15 dakikalık modeller.

Şu anda kullanılan modellerin en günceli CCIR (International Radio Consultative Committee)'ninkidir. CCIR, sınırlı dikey iyonosonda verisine dayalı, sayısal yöntemler kullanılarak hazırlanmiş modelleri benimsemiştir. Fakat, günlük ve kısa dönem öngörüleri güvenilir değildir. Klasik model verileri dikey sonda ile elde edilmektedir. Bunlar eğimli sonda verileriyle desteklenebilmektedir. Ayrı ayrı toplanmış bu verilerden yararlanılarak "interpolation/extrapolation" yöntemiyle oluşturulan iyonosfer elektron yoğunluğu modeliyle, zaman içinde ileriye dönük öngörü yapılmaktadır.Son yıllarda 'thermospheric' rüzgar kuramı ile orta enlemlerde geliştirilen modeller kullanılmaktadır. Bu modellerle yapılan öngörüler, 'interpolations' gibi standart sayısal yöntemlere göre üstünlük sağlamaktalarsa da yeni modellerin üretilmesi gerekmektedir.

Avrupa,iyonosfer sondaları ağını barındıran, geçmiş dönemleri kapsayan verileriyle güncel modelleri geliştirmek, denemek için özel olanaklar sunan bir bölgedir. Ayrıca, Avrupa, yüksek enlemlerde enerjik parçacık yağışının yarattığı güçlüklerden, ekvator enlemlerinde elektron yoğunluklarında gözlenen anormal davranışlardan daha az etkilenmektedir. Bu nedenlerle, 1988 yıllarından beri süren ön çalışmalarla elde edilen birikimin değerlendirilmesi için bir proje yapılmasına karar verilmişti.Bu karar, 7 Mart 1991 günü resmen PRIME projesi olarak örgütlenmiş ve ilgili protokol Avrupa Ortak Pazarı COST 238 projesi adıyla imzalanmıştır. Proje 6 Mart 1995 günü resmen bitmiştir. TÜBİTAK yönünden ise projenin Türkiye'deki parasal desteği 1 Mart 1995 günü son bulmuştur.

6.1.2 Amaç

PRIME'nin ana amacı 35°K ve 55°K enlemleriyle ,10°B ve 30°D boylamları arasında birikmiş ve birikecek iyonosfersel sonda verileri kullanılarak, uzaktan iletişim (telecommunication) dizgeleri üzerinde iyonosfersel yayılma etkilerini öngörmeye yarayacak modellerin oluşturulmasını sağlayacak teknikleri geliştirmektir (Bradley, 1991). Şekil 1 PRIME'ın coğrafyasal ilgi alanını sergilemektedir .

6.1.3 Kapsam

Tüm 'radyo-dalgaları-yayılma öngörülerinin' en önemli ögelerinden biri iyonosfer elektron yoğunluğu modelidir. Bu nedenle, model çalışmaları PRIME projesi kapsamında beş ana başlık altında yürütülmüştür. Bu başlıklarla tanımlanan beş alandaki çalışmalar proje süresince, 6 Mart 1995 tarihine kadar sürdürülmüştür. Projeye üye olan gruplar seçtikleri alanlarda PRIME'a katkıda bulunmuşlardır. Ancak projenin kendisi tümüyle tek amaca doğru yönlendirilmiş bir etkinlikti (MOU, 1991). Çalışma alanları aşağıda sıralanmıştır :

(i) İyonosfer sondası ile dikey yönde ölçme yapmak (vertical sounding): Bu çalışma alanında günlük-saatlik iyonosfersel ölçümler yapılmaktadır. İyonosonda temel olarak, frekans değiştirilerek 'pulse' yayabilen bir radar aygıtıdır. Aygıt, doğrudan bir radyo dalgası paketçiğinin (pulse) iyonosfere ulaşıp geri dönmesi için geçen zaman süresini frekansa bağımlı olarak ölçmektedir. Eğer verici ve alıcı aynı konumdalarsa sonda, dikey sonda (vertical sounder) olarak anılmaktadır. Bu grupta geçmiş verilerle bir veri tabanı oluşturulmuş ve yeni veriler toplanmıştır. Ayrıca verilerin aynı ölçeğe göre tanımlanmaları da sağlanmıştır.

(ii)İyonosfer sondası ile bir açıyla ölçme yapmak (oblique sounding): Bu tür ölçmede verici ve alıcı farklı konumlardadır.

(iii)Konumsal ilişki (spatial correlation) çalışmaları: Bunlar, farklı yerlerde oluşturulmuş veri grupları arasında, verilerin alındığı konumlara göre veriye dayalı bir bağıntının saptanması çalışmalarıydı.

(iv)Zamana bağlı ilişki ve öngörü tekniklerinin geliştirilmesi: bunun için geçmiş veya şu anda toplanmakta olan veriler kullanılarak öngörü teknikleri geliştirme çalışmaları sürdürülmüştür.

(v)İyonosferin elektron yoğunluğu haritasının çıkartılması ve modellemesi yapılmıştır.

Türkiye'de sonda ölçmeleri ve öngörü tekniklerinin geliştirilmesi çalışmaları sürdürülmüştür.

6.1.4 Yöntem

PRIME projesine katılmamız aşağıda özetlendiği gibi iki alanda planlanmış ve gerçekleştirilmiştir:
(i) Türkiye'deki ilgili kuruluşların (O.D.T.Ü., B.Ü., Genel Kurmay Başkanlığı, T.R.T., P.T.T. ve Telsiz Genel Müdürlüğü) ortaklaşa saptayacağı bir konumda dikey iyonosonda istasyonunun kurulması ve günlük kritik frekans ölçümlerine başlanması planlanmış ve önerilmişti. Doğal olarak bu istasyon için teknik desteğin, özellikle T.R.T. , P.T.T. ve Telsiz Genel Müdürlüğünden alınması bekleniyordu. Bu kuruluşlardan Telsiz Genel Müdürlüğü, doğrudan parasal yardımın 1991-1992 bütçe yılında olası olamayacağını, ancak ilke olarak böyle bir girişimi destekleyebilmek için özen göstereceklerini sözlü olarak bildirmişti. Ancak, o zamanki EEEAG yürütme sekreterinin kendisinin doğrudan bu konuyu Telsiz Genel Müdürlüğü'ne sorması

üzerine resmi, olumlu bir yanıt alınamamıştı ve TÜBİTAK, proje önerisindeki bu maddeyi onaylamamıştır. Ancak, konunun önemi nedeniyle, resmi kuruluşların bu konuya hak edilen önemi göstermemesine karşın, proje yürütücüsü COST 238 başkanlığının yardımıyla bir yıl boyunca, B.Ü. Kandilli Rasathanesi'nde saatlik kritik frekans ölçümlerini yapmıştır. Bu ölçümler Polonya Uzay Araştırmaları Merkezi yapısı KOS dikey sondası (VI) ile gerçekleşmiştir. Bu ölçme kampanyasında Avrupa'da seçilmiş 'grid' noktalarında ölçmeler, 15/6-15/7 1993 tarihleri arasında 24 saat boyunca her 15 dakikada ve diğer zamanlarda her 30 dakikada bir olmak üzere 8/5 1993 ve 21/4 1994 tarihleri arasında tekrarlanmıştır.

Kandilli ölçüm verileri, PRIME projesi için geliştirilmiş olan MQMF2 (A.Mikhailov,1992) modeliyle de karşılaştırılmıştır. MQMF2 modeli geliştirilirken Kandilli verileri kullanılmadığı için deneysel sonuçların model ile uyum içinde olmaları, bağımsız bir denetleme işlevini görmüştür.

İ.Ü. Fen Fakültesi Jeofizik Bölümünde Prof. Dr İhsan Özdoğan ve çalışma grubu 1963 ile 1968 yılları arasında, bir NATO projesi çerçevesinde, Fatih Ormanları'nda kritik frekans ölçmüşlerdi. Bu verinin Bulat ve arkadaşları tarafından sağlandığı bölümüyle 1993-1994 yıllarında ölçülen kritik frekanslar karşılaştırıldı ve 'solar-cycle' (güneş dönemi) etkisi veride araştırıldı.

Şekil 2'de PRIME veri bankasına katkı sağlayan VI ile ilgili bu çalışmanın sonucu sunulmaktadır. Görüldüğü gibi Kandilli-İstanbul veya Türkiye'nin katkısı % 0.3 dür. Bu bir başlangıçtır ve İstanbul bir 'grid' noktasıdır artık.

(ii) Model çalışmalarıyla ilgili olarak Türkiye'de yapılan araştırmalar, ayrıca gezegenlerarası manyetik alanın(interplanetary magnetic field -IMF-) B_z bileşenindeki yön değiştirmelerinin iyonosfersel plazma üzerindeki olası etkilerini içermiştir.

Gezegenlerarası manyetik alanın (IMF) B_z bileşeninin iyonosferde önemli etkileri olduğu kanıtlanmıştır (Tulunay,1991;Hapgood et.al,1991). IMF güneşten kaynaklanır ve birbirine ters doğrultularda B_z içeren kesimlere (sector) ayrılır. Güneş, her 27 günde bir döndükçe bu kesimler yer tarafından süpürülür ve IMF'nin güney bileşeni yerin manyetik alanıyla kaynaşarak (merging) sonuçta yere yakın uzaya güneşsel, manyetosfersel parçacık yağışına neden olur.

COST 238:PRIME projesinin Türkiye'de yapılan bu bölümünde, gezegenler arası ortamın iyonosfersel kritik frekansler üzerindeki olası etkileri araştırılmış ve iyonosfersel değişkenliği (variability) oluşturan bir faktör olarak bu olası etkinin nicelleştirilmesine çalışılmıştır. Bu nedenle üç farklı veri tabanıyla çalışılmıştır. Veri uzunluğu, çeşitli PRIME istasyonları için farklı da olsa 1967 ile 1992 yıllarını kapsamaktadır. Burada sunulan sonuçlar on beş PRIME istasyonunun verisiyle yapılan çalışmalardan elde edilmişlerdir. Gezegenlerarası ortamı, gezegenlerarası manyetik alan verileri temsil etmektedir. Bu veri, R-EXEC adıyla yönetilen ve US NSSDC tarafından hazırlanan veri tabanından, iyonosfersel kritik frekanslar ise (foF2), CNET Fransa'daki PRIME veri tabanından alınmışlardır. Veri çözümlemesi için oluşturulan yöntem 'superposed epoch analysis' (spe) yöntemidir. Kritik frekansların olağan değişimlerinden kurtulmak için 'control' değerleri yaratılmıştır. Bu işlem için gereken diğer güneşsel veya iyonosfersel manyetik etkinlik indisleri ise 'World Data Center-C',

İngiltere'den alınmıştır. IMF B_z büyüklüğünün bir saat içindeki değişimi 11.5 nT olan 'olay'lar seçilmiş, spe çözümlemeleri yapılmıştır. İyonosfersel değişkenliğin mevsime bağımlılığı ayrıntılı olarak incelenmiştir. 'Mevsim', 'günün farklı saatleri', iyonosfer ortamına giren enerji miktarındaki değişim ve bunun sonucunda fiziksel, kimyasal vb. süreçlerin hızlarının değişimi, ortamın iletkenliğinin veya ortamla ilgili diğer özelliklerin değişimi anlamına gelmektedir.

6.1.5 Projenin Sağladığı Katkılar

Özellikle Türk mühendis ve araştırıcılarına gerekli bilimsel ve teknik uzmanlık deneyimi sağlanırken uluslarası işbirliği olasılıkları artmıştır.

Bilime, radyo dalgalarının yayılımına dönük modelleme yönünde katkı yapması beklenen bu proje, karmaşık ölçmeleri içerdiğinden teknolojik yönüyle de önemli olmuştur. Ayrıca çalışma sonuçları Türkiye'de geçerli CCIR Standartlarının yeniden düzenlenmesinde de kullanılacaktır.

Türkiye'de yapılan deney düzenli ve devamlı veri toplanmasını, PRIME kapsamında iyonosfersel modelleme yapılmasını sağlayabilmiştir.Türkiye iyonesferine ilişkin yeterli veri olmadığından bu çalışma böyle bir boşluğu doldurması nedeniyle de bilimsel bir katkı oluşturmuştur.

Avrupa Birliği (AB) Uzaktan-İletişim Projelerinden biri olan PRIME-COST 238'e Türkiye'nin katılması bilimsel ve teknolojik çağdaş bir işbirliğine girmemiz anlamına gelmiştir. Türkiye'nin gelişmiş ülkeler arasında aradığı yeri bulabilmesi, bu tür ilişkileri olabildiğince geliştirmesi, bilimsel, teknolojik bilgi ve veri üretmesiyle gerçekleşebilecektir. Bu tür bir işbirliğinde karşılıklı ilişkilerle bilgi ve teknoloji aktarımı kolaylaşmış, gelişmiş örnekler yakından izlenebilmiştir. Bu tür Avrupa Birliği projelerinde etkin bir biçimde yer almak doğal olarak, Avrupa Topluluğu'na girme yönünde, dolaylı da olsa önemli, olumlu etkiler yapacaktır .

Proje önerisinde tanımlanan çalışmaların tümü planlandığı gibi tamamlanmıştır. Özetle,

- Dikey sonda ölçümleri, TÜBİTAK'ın onayladığı projede yer almamasına karşın, kişisel çaba, B.Ü. Kandilli Rasathanesi'nden katılan araştırmacıların, yöneticilerin anlayışlı davranışları, ve ana parasal katkı, aygıt, bilgi kullanımı, AB PECO projesinden destek sağlanması sonucunda başarılmıştır. Bu başarıya bir gösterge de COST 238 Yönetim Kurulunun üç ay için saptadığı desteği, üç ay sonunda bir yıllık bir süre için uzatmış olmasıdır.Proje yürütücüsü, Dr. I. Stanislawska ile ortaklaşa bir proje önerisini Avrupa Birliği (AB) PECO projeleri programına sunmuş, parasal olanak sağlamıştır. KOS, Polonyalı araştırıcılar tarafından getirilmiş, ayrıca Türk tarafına bilgi, görgü arttırmak için Polonya Uzay Araştırmalar Merkezi'nde geçirilecek birer haftalık iki burs da sağlanmıştır.

- IMF B_z nin foF2 üzerindeki olası ilişkileri veri tabanında verisi olan tüm PRIME istasyonları için taranmış ve nitesel, nicesel yönden olası etki tanımlanmıştır.
- TÜBİTAK'a, sunulan proje önerisinde olmayan bir konuda da Türkiye olarak bir katkıda bulunuldu. Şöyle ki, 1975 yılında ODTÜ Elektrik Elektronik Mühendisliği Bölümü öğretim üyelerinden Prof. Dr.Hakkı Oranç, bir AGARD projesi çerçevesinde, polarimetre ile ATS 6 uydusunun 'Faraday Rotation' işaretlerini almış, Dr. Y. Tulunay da bu işaretleri kullanarak Ankara iyonosferi üzerindeki toplam elektron miktarını(TEC) hesaplamıştı (Tulunay 1978).

1993'deki COST 238 Graz Yönetim Kurulu toplantısında, uydularla TEC ölçümlerinin önemi tekrar gündeme gelmiş ve aylık TEC veri setlerinin PRIME veri bankasına eklenmesine karar verilmiştir. Bu kapsamda, Y. Tulunay Ankara İyonosferi ile ilgili TEC verilerini ilgili WG'da tanıtmış ve bu veriler PRIME veri bankasına katılmışlardır (EK (6.1.5)-1)

6.2.Gelişme

6.2.1 Temel İlkeler

Çalışmanın dayandığı temel ilkeler, varsayımlar, başlangıç noktalar COST 238 MOU'da ayrıntılı bir biçimde sunulmuştur.

6.2.2 Veriler

Araştırmayı oluşturan veriler özetle şunlardır (Tulunay 1991) :

- PRIME veri tabanındaki kritik frekans (foF2) verileri. Bu veriler çoğunlukla saatlik verilerdir. Bazı durumlarda iki güneş dönemini kapsamaktadırlar.
- Özel ölçme kampanyalarında elde edilen 15 dakikalık veya 30 dakikalık foF2 verileri.
- Çeşitli uydulardan toplanmış olan gezegenler arası manyetik alan verileri .
- World Data Center C: 'Rutherford Appleton Laboratory' veri tabanlarından elde edilen çeşitli, manyetik, fiziksel etkinlik, süreç indisleri. Örneğin, 'control' foF2 eğrisi oluşturulurken günlük Ap indisleri kullanılmıştır.

6.2.3 Verilerin İlişkilendirilmesi

Bu verilerle yapılmış olan veri çözümlemeleri, oluşturulan taslak modeller, arkalarındaki fiziksel yorum, tüm proje süresince çeşitli COST 238 çalışma grubu

(Working Group)-WG- toplantılarında (Workshop) sunulmuş, daha sonra basılmaları için dergilere yollanmıştır. Bulgular, 'sonuç' bölümünde ayrıntılı olarak tanımlanacaklardır.

6.3. Sonuç

6.3.1 Taşınabilir Dikey Sonda Kampanyası (Transportable Ionosonde Campaigns)

COST 238: PRIME projesi kapsamında taşınabilir dikey sonda kampanyası ilk olarak 6 5 1993'te, KOS 89/2 iyonosondasının B.Ü. Kandilli Rasathanesine (41°K, 29°D) konmasıyla başlatıldı. Gözlemler 21 4 1994'te bitti ve KOS 89/2, Yunanistan'ın Xanthi (41°K,25°D) şehrine taşındı.

Veri çözümlemesi sonucunda PRIME proje alanının bu kesimindeki F bölgesi iyonosfer karakteristikleri ortaya çıkarıldı. Manyetik Ap indisleri kullanılarak, manyetik olarak etkin dönemlerin olası etkileri foF2 verilerinde incelendi. İstanbul'a yakın diğer foF2 verileriyle, Kandilli verileri karşılaştırıldı. Bu çalışmalara koşut olarak, foF2 verileri, bağımsız bir şekilde kuramsal olarak geliştirilmiş olan MQMF2 modeliyle karşılaştırıldı. MQMF2 ile elde edilen ve günlük saatsal değişimi yansıtan kuramsal eğriler, deneysel foF2'ların oluşturduğu günlük saatsal eğrilerle uyum içindeydiler. Bunlara ek olarak Kandilli foF2 verileri, İstanbul'da 1963-1969 yıllarında ölçülmüş olan benzer verilerle karşılaştırıldı.

Kandilli verileri kullanılarak iki tane model çalışması gerçekleştirildi.
(i) Bunlardan birisi aylık 'median' foF2 değerleriyle yapılandır. Bu model foF2 parametresini 'spherical-harmonics mapping' ifadesinde tanımlamıştır. Bu modelde bağımsız değişkenler, günlük ve mevsimsel zamandır. Güneş etkinliğini, bu aşamada içermemesi modelin gücünü azaltmaktadır. Bu boyutun modele kazandırılması ilerideki çalışmalardan biri olacaktır.

(ii) İkinci model çalışması 15 dakikalık ve 30 dakikalık verilerle yapılmıştır. Bu çalışmada Roma (42°K,13°D), Sofia (43°K,23°D), Poitiers (47°K,0°D) ve Lannion (49°K,3°D) verileri de Kandilli (41°K,29°D) verileriyle birlikte çözümlenmişlerdir. 'Discrete Fourier Transform' (DFT) yöntemiyle çözümlenen veriler için, 'Clean Spectrum' algoritması (Roberts et al.1987) uygulanmıştır. Bu algoritma, özellikle veride eşit aralıklı olmayan kesintiler olduğu için seçilmiştir. Sonuçlar $\alpha = 0.05$ güvenirlilik sınırında anlamlı bir şekilde model oluşturmaya elverişlidir. Bu yöntemin daha incelenmesi ve denenmesi gerekmektedir ve çalışmalar ileride de sürdürülecektir.

EK(6-3-1)-1,2,3,4,5,6 ve 7'de, sonuçları burada kısaca özetlenen çalışmalar özgün bir şekilde sunulmuşlardır.

6.3.2 Gezegenlerarası Manyetik Alanın (IMF) Öngörü -Kestirim-de İyonosfer Plazması Üzerindeki Etkileri (The Effects of the IMF on the ionospheric Plasma for Forecasting)

Bu raporda, 'kestirim' veya ' öngörü' sözcükleri 'prediction' ve 'forecast' terimleri için kullanılmıştır. Her ikisi de iyonosferdeki değişmeler anlamındadırlar. Ancak, her ikisini de önce tanımlamak yararlı olacaktır. Wilkinson ve arkadaşlarının açıkladığı gibi 'Prediction' uzun sürelidir. Örneğin, ortamdaki süreçleri başarılı bir fiziksel veya deneysel 'prediction' tanımlayabilir. Ancak bu 'prediction' tam olarak, bu olayların hangi anda, günde olduğunu söyleyemez. Uygulamada, örneğin, HF hizmetleri, hizmetin nasıl uygulanacağını, farklı güneş etkinliği düzeyleri için planlamaktadır. Özetle, 'prediction' sözcüğü, iyonosferin farklı durumları (states) için kullanılmaktadır.

'Forecast' sözcüğü, zamana ilişkin bilgi eklendiğinde kullanılmaktadır. Bir 'forecast' belli bir zaman süresi içindir ve iyonosferin gün-be-gün değişkenliğiyle bağdaşır. 'Forecast' lar bir anlamda belirsizlik ögesi içerirler. Eğer belirsizlik düzeyi gerçekçi bir şekilde verilebilirse 'forecast' bilimsel bir deneme olabilir. Buna karşın, eğer belirsizlik düzeyi büyükse 'forecast'ın değeri çok azalır. Uygulamada, 'forecasting' ve gerçek zaman verileri arasında kurulacak bir bağın açıklığa kavuşması çok önemli bir konudur.

İyonosfersel 'forecast'lar, başarılı bir güneşsel ve manyetosfersel 'forecast'a bağımlıdırlar. Ancak şu anda güneşsel-manyetosfersel alanlara ilişkin sınırlı bilgi olması, iyonosfersel 'forecasting' i kısıtlamaktadır (Wilkinson ve ark., 1992).

Bu bölümde 'forecast' için öngörü veya kestirim sözcükleri kullanılacaktır. Ancak bu sözcükler, veya varılmış olan araştırma sonucunun sınırı yukarıdaki açıklamaların ışığında değerlendirilmelidir.

COST 238: PRIME projesinin ODTÜ'de yapılan bu bölümünde, IMF verileri, IMF B_z yönüne göre ayrıştırılmıştır. IMF B_z nin kuzeye veya güneye dönüşlerinin foF2 verileri üzerindeki olası etkileri araştırılmıştır. foF2 değerlerinin ortalama-manyetik-sakin dönem değerlerinden sapma, δfoF2, verileri, IMF B_z güneye döndüğünde bundan etkilenmektedirler. δfoF2 verisinin 'decile' değerleri 4-5 MHz arasında değişmektedir. Ortalamada,kritik frekanslar, kendilerinin manyetik-sakin dönemlerdeki değerlerinin altındadır.Ancak, artı δfoF2 değerleri de gözlenmektedir. Bu çalışmanın sonuçları özetlenirse, iyonosfersel-F- bölgesinin gün-be-gün değişimleri IMF'in konumundaki değişmelere bağımlıdır. Eksi B_z değerleri belirgin iyonosfersel etkiler yaratmaktadır. IMF'in foF2'daki değişkenliği istatistiksel bir şekilde nitelendirilmiştir. Buna göre en büyük etki, yüksek 'geomagnetic' enlemlerde, 'equinox'lar yakınında, güneşsel-'geomagnetic' etkinliğin fazla olduğu dönemlerde, geceyarısında gözlenmektedir. Eksi B_z 'olay'ları ($B_z \leq$ -2nT) sonucunda, yüksek manyetik enlemlerde, yıllık ortalamada, δfoF2 değerleri -1.0 MHz kadar değişmektedir. Aynı enlemlerde 'olay'lar yazın, ortalamada -1.3 MHz kadar etkilerini arttırabilmektedirler. Bu sonuçlar, 'median' değerlere dayanılarak yapılmış olan modellerle elde edilebilecek olan değerler kullanılırken enleme, günün saatine ve güneşsel-'geomagnetic' etkinliğe bağımlı olarak, foF2'lardaki IMF bağımlılığının etkilerinin de dikkate alınması gerektiğini göstermektedir.

Bu bölümle ilgili olarak yapılmış olan çalışmaların sonuçları EK (6.3.2)-1,2,3,3a,4,5,6,7,8,9,10,11,12'de sunulmuştur.

Bu eklerden EK(6.3.2)-3a , 'forecasting'e ilişkin olan çalışmanın önemini belirtmek için özellikle sunulmuştur. Trieste, İtalya'da yapılan 6. PRIME Yönetim Kurulunu izleyen 'Workshop', URSI, COSPAR ve IAGA'nın ortaklaşa düzenledikleri 'Workshop On Off-Median Phenomena and the International Reference Ionosphere' ile çakıştırıldı. Bu toplantıda sunulan bildiri 'Advances in Space Research'de basıldı(EK(6-3.2)-3). Basım sırasında, hakem ve editor Prof. Karl Rawer'in 4.6.1994 tarihli telefax mesajında *'the chairman has decided that papers dealing with the main subject of the symposium ("Off-Median Phenomena....") are considered as invited papers. Yours is perhaps the best contribution in this category. So it gets 10 pages.......'* denmektedir.

EK(6.3.2)-11, PRIME enlemlerinde elektron yoğunluğu çukurunun etkilerinin araştırılmasına ilişkin olarak başlatılan çalışmanın ilk sonuçlarını içermektedir. Bu sonuçlar, 9. ve son PRIME Yönetim Kurulunda, ilgili gündem maddesinde sunulmuştur. Çukur, manyetosfersel plazma aralığının iyonosferdeki izdüşümüdür. EK(6.3.2)-11'de verilen on üç referansdaki çalışmalarında, Y.Tulunay, geçmişte bu çukurun 'plazma aralığının' izdüşümü olduğunu kanıtlamış, ve çukurun davranışını ayrıntılı bir şekilde nicel ve nitel olarak bilim dünyasında sergilemiştir. Bu çalışmalar 500-600 km'deki uydu verileriyle gerçekleştirilmiştir. foF2 değerleri ve elektron yoğunlukları birbirilerine bağımlıdır. Bu nedenle, manyetosferin devinimini, dolayısıyla güneş,manyetosfer ilişkilerini iyonosfere yansıtan elektron yoğunluğu çukuru, HF servislerinde kullanılacak modellerde bir parametre olarak düşünülmelidir. Bu çalışma COST 251'de de sürdürülecektir.

6.3.3 Öneriler

6.3.3.1.COST 251: IITS (**I**mproved Quality of Service in **I**onospheric **T**elecommunication **S**ystems Planning and Operation) projesi COST 238:PRIME projesinin devamı olacaktır. Bu raporun 6.3.1 ve 6.3.2 maddelerindeki çalışmalar , COST 251 çerçevesinde de sürdürülecektir. COST 251, COST 238 sonuç modellerinin dizgeler üzerinde denenmelerini ve daha da geliştirilmelerini amaçlamaktadır.

6.4. TÜBİTAK ve Dışındaki İlişkiler

. COST 238'e parasal ana destek TÜBİTAK'ca sağlanmıştır.
. B.Ü. Kandilli Rasathanesi, COST 238'e bir Araştırma Fonu Projesiyle(AFP) katılmışlardır. Bu projenin yürütücüsü Doç.Dr.Atila Özgüç, ve arkadaşları Dr.Tamer Ataç, Levent Altaş, Oryal Barlas'dır. Kandilli ekibi dikey iyonosonda kampanyasında ölçme işlemlerini başarıyla sürdürmüşler, bu veri sayısal hale

geçirildikten sonra veri çözümlemesi işlerini yapmışlardır. B.Ü. Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü Müdürü Prof. Dr. A. M. Işıkara,, ilke olarak projeyi benimsemiş ve olası desteği belli sınırlar içinde sağlamıştır.
. AB PECO desteği Y.Tulunay ve I.Stanislawska'nın ortaklaşa sunduklari proje

önerisinin onaylanmasıyla sağlanmıştır. Bu iş, Polonya Uzay Araştırmaları Merkezi'nden (Varşova) dikey sondanın Kandilli Rasathanesi'ne getirilmesi, Türkiye'den götürülmesi, bilgi, görgü ve veriyle ilgili sayısallaştırma işlemileriyle ilgili olarak iki Türk araştırıcıya Polonya'da geçirilmesi için sağlanan birer haftalık desteği içermiştir.

Destek ile ilgili yazılar EK(6.4)-1,2,3,4' te sunulmuşlardır.

6.5. TÜBİTAK Tarafından Alınması Gereken Önlemler, Uygulama Özeti:

Lütfen Ek(6.5)-1'e bakınız .

EK(6.5) -1

Uygulama Özeti:

Uzaktan haberleşmede, ortamın,dalganın yayılma niteliği ve niceliğine yaptığı etkiler, doğrudan, M.S.B. Genel Kurmay Başkanlığını, Kara, Hava ve Deniz Kuvvet Komutanlıklarını, T.C. Ulaştırma Bakanlığı Telsiz Genel Müdürlüğünü, Türk Telekomunikasyon A.Ş. (TÜRKSAT)'ni, PTT Genel Müdürlüğünü, tüm üniversitelerdeki Elektrik, Elektronik, Fizik, Uzay Bilimleri Bölümlerini ilgilendirmektedir. Konunun önemini vurgulamak için 'HF 95: Nordic HF Conference'ına (1995) ilişkin tanıtıcı yazının bir bölümünü buraya aktarıyorum.

HF communications technology has advanced significantly over the last few years, with significant trends towards a higher degree of automation and signal processing that now can be cost-effectively implemented to achieve affordable performance even in small systems. Multimedia communications is a 'buzz-word', both in the sense of various types of information to be passed over HF and that HF may be one of several alternative media for communications. Automatic networking aspects and information transparency play an increasing role to achieve full subscriber connectivity, area coverage and highly reliable communications with HF possibly being only one of several available communications alternatives.

In many applications HF communications is the primary and sometimes the only way to solve communications to serve defence and government agency purposes. Electronic warfare (EW) such as position finding, surveillance and jamming are important aspects, both from the communications and EW point of view. Defence forces are the major professional users of the HF spectrum as far as numbers are concerned, and defence applications are the technology driver in HF communications.

ANMA:
Bu rapor Sn.Ş.A.Baykal, Sn. A.Kaya, Sn.S. Karatepe tarafından yazılmış, Sn. Y.Parıldayan tarafından çoğaltma işlemleri yapılmıştır

7.Kaynaklar

Bradley P.A.,	Ionospheric informatics and empirical modeling, *COSPAR XXVII Plenary Meeting*, Helsinki, 20 July (1988).
Bradley P.A.,	Private Communication, (1989).
Bradley P.A.,	PRIME iş toplantısı, Abingdon, İngiltere, (4-6 Kasım 1991).
Bradley P.A.,	COST 238 First Annual Report, (1992).
Davies K.,	Review of recent progress in ionospheric predictions, *Radio Science*, **6**,No.6, p.1407-18 (1981).
Hanbaba R.,	COST 238 Biennial Report, (1994).
Hapgood M.A., Tulunay Y.K. Lockwood M., Bowen G.A., Wıllıs D.M.,	Variability of the Interplanetary Medium at IAU over 24 years: 1963- 1986, Planetary Space Sci., **39**, pp. 411-423, (1991).
HF95	HF Towards the 21st Century, Nordic HF Conference, Nordic Radi Society, Fårö, Sweden 15-17, August (1995).
Mikhailov A.,	Private Communication, (1991).
MOU	Memorandum of Understanding for the implementation of a European Research Project on prediction and retrorespective ionospheric modelling over Europe (PRIME) (COST Project 238), European Co-operation In The Field of Scientific and Technical Research-*COST, secreteriat, Brussels, COST/260/91*, (1991).
Roberts D. H., Lehar J., Dreher J.W.,	*'Clean Spectrum' Algorith, Astronomical Journal* **93**, p.968, (!987).
Tulunay Y.	Influence of the Interplanetary Medium on Mid-Latitude Ionospheric Variability, *NATO 0753/87, Belgium*, (1991).
Tulunay Y.,	The Behaviour of Ionospheric Total Electron Content Over Ankara, *AFGL-TR-0300, USA*, (1978).
Wilkinson P.J., Cole D.G., Bradley P.A., Danilov A., Klobuchar J.A., Miller R., Szuszczewicz E.P.,	Working Group Final Report,Ionospheric Section-private copy, (1992).

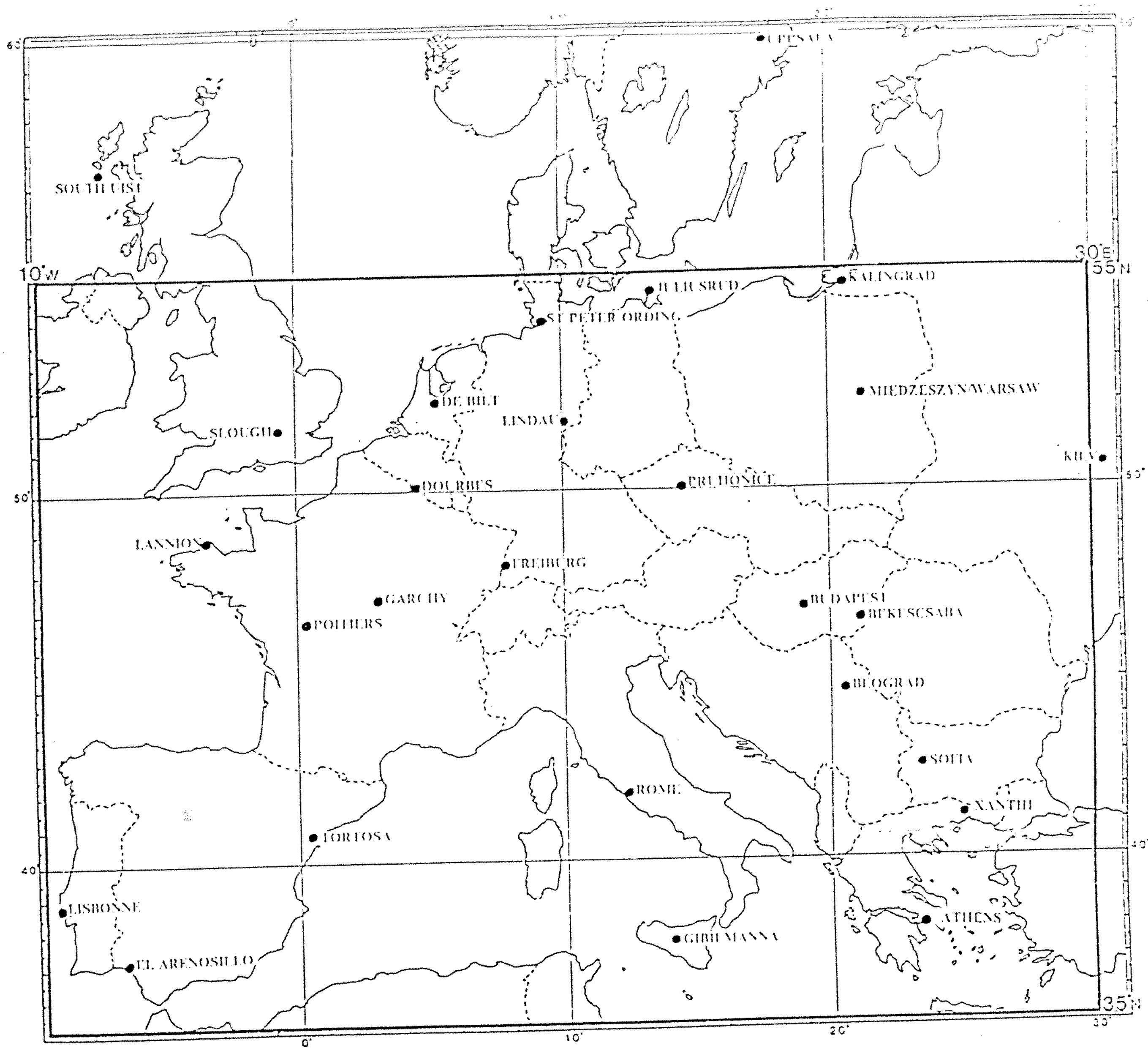

Figure 1 - Map showing the PRIME area of Europe between latitudes of 35-55°N and longitudes of 10°W - 30° E. Also indicated are the locations of vertical-incidence ionosondes contributing to the data bank (Bradley, 1992)

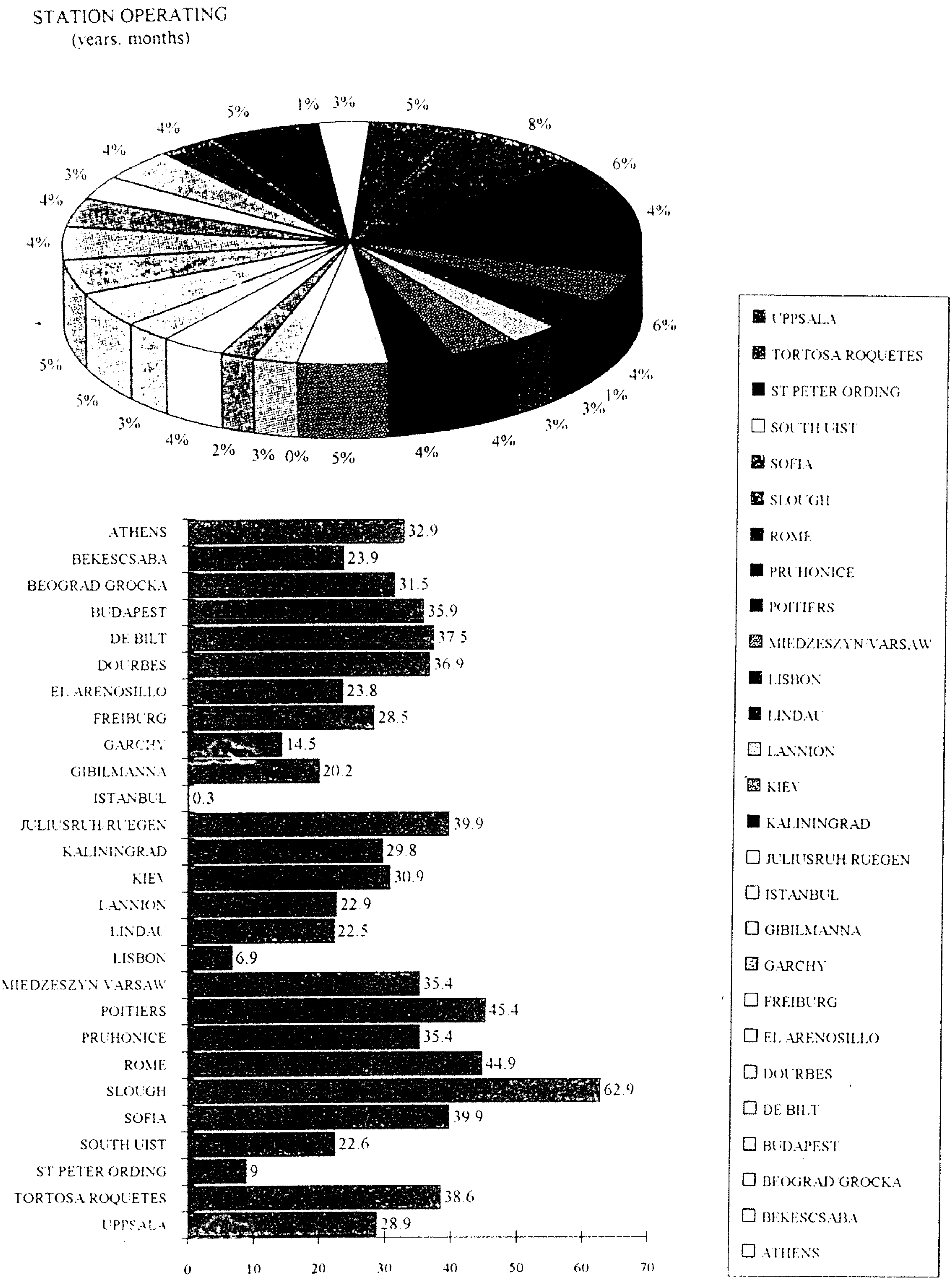

Figure 2 - Vertical-incidence ionosondes contributing to the data bank (Hanbaba, 1994)

Çizelge 1.MOU'yu İmzalayan ve 'Actıon'a Katılan COST Üyesi Olmayan Kuruluşlar

Belgium
Czech Republic
France
Germany
Greece
Italy
Netherlands
Poland
Spain
Sweden
Turkey
United Kingdom
Academy of Sciences, Bulgaria
Institude of Applied Geophysics, Russia
Institude of Terrestrial Magnetism,Ionosphere and
Radiowave Propagation, Russia

8.Ekler **Sayfa**

EK (2.1)

T. C.
BAŞBAKANLIK
KANUNLAR ve KARARLAR
GENEL MÜDÜRLÜĞÜ

BAKANLAR KURULU KARARI

91/ 2408

Bilimsel ve Teknik Araştırma için Avrupa İşbirliği Örgütü (COST) bünyesinde yürütülen COST 238 sayılı ve "Avrupa Üzerinde İleriye ve Geriye Dönük İyonosferik Modelleme" başlıklı projeye katılmamız amacıyla, sözkonusu projeyle ilgili Ortak Niyet Beyanını Hükümetimiz adına imzalamaya, AT Nezdindeki Türkiye Daimi Temsilcisi Büyükelçi Cem Duna'nın yetkili kılınması; Dışişleri Bakanlığı'nın 9/10/1991 tarihli ve ATUY-II/2094-6400 sayılı yazısı üzerine, 31/5/1963 tarihli ve 244 sayılı Kanunun 1 inci maddesine göre, Bakanlar Kurulu'nca 3 /11 /1991 tarihinde kararlaştırılmıştır.

TURGUT ÖZAL
CUMHURBAŞKANI

MESUT YILMAZ
BAŞBAKAN

E. PAKDEMİRLİ Devlet Bakanı ve Başb. Yrd.	F. KURT Devlet Bakanı	M. R. TAŞAR Devlet Bakanı	I. AYKUT Devlet Bakanı
M. V. DİNÇERLER Devlet Bakanı	K. İNAN Devlet Bakanı	I. AKÜZÜM Devlet Bakanı	C. TUNCER Devlet Bakanı
S. ARAS Devlet Bakanı	E. KOÇAK Devlet Bakanı	M. ÇEVİK Devlet Bakanı	E. C. GÜLPINAR Devlet Bakanı
B. SÖNMEZ Devlet Bakanı	A. A. ALBAYRAK Devlet Bakanı	S. BİLGE Adalet Bakanı	H. B. DOĞU Milli Savunma Bakanı
S. ÇAKMAKOĞLU İçişleri Bakanı	I. S. GİRAY Dışişleri Bakanı	A. KAHVECİ Maliye ve Gümrük Bakanı	A. AKYOL Milli Eğitim Bakanı
H. ÖRÜÇ Bayındırlık ve İskan Bakanı	Y. ERYILMAZ Sağlık Bakanı	S. YALINPALA Ulaştırma Bakanı	I. TUNCAY Tarım ve Köyişleri Bakanı
M. EMİROĞLU Çalışma ve Sosyal Güvenlik Bakanı	R. K. YÜCELEN Sanayi ve Ticaret Bakanı	M. ARICI Enerji ve Tab. Kay. Bak.	G. MARAŞ Kültür Bakanı
B. AKARCALI Turizm Bakanı	M. KALEMLİ Orman Bakanı	A. T. ÖZDEMİR Çevre Bakanı	

Dosya No.

COMMISSION
OF THE EUROPEAN
COMMUNITIES

Directorate-General XIII
Telecommunications, Information Industries and Innovation

Brussels, 13th February, 1992
EB/MM/hb/101
DG XIII/D1

Prof T. Birand
TÜBITAK
Atatürk Bulvari 221
Kavaklidere
TR-06100 Ankara

Dear Prof Birand,

We are happy to inform you that the COST 238 Management Committee has unanimously approved the membership of Turkey. Your country representative can continue to participate as observer until the Memorandum of Understanding is signed.

Yours sincerely,

E. Ballabio
Secretary COST Telecommunications

c.c. Mr E. Gonzalez-Sanchez, Council of Ministers
Mr N. Roulet, Chairman CSO
Mr J. Dwyer, Chairman TCT
Mr F.R.Ergül, TCT Representative for Turkey
Prof P. Bradley, Chairman COST 238
Prof Y. Tulunay, COST 238 Representative for Turkey

Bât. B24 1/150, Rue de la Loi 200, B-1049 Brussels, Belgium. Telephone: direct line 299 0232, secretariat 299 0233, fax 299 0248

EK (2.3)

ARAŞTIRMA PROJESİ DESTEKLEME SÖZLEŞMESİ

DESTEK MİKTARI

13. Projeyi desteklemek amacıyla Kurum'ca ....586.600.000.-.......... TL. destek sağlanacaktır.

14. Bu sözleşme ..1 Temmuz 1992.......... tarihinden ..1 Mart 1995.......... tarihine kadar yürürlüktedir.

15. Bu sözleşme ile öngörülen toplam maddi destek miktarı ve buna ait ödeme planında, Kurum'a tahsis edilen bütçe imkanları ile Kurum'a nakit akışında meydana gelebilecek kısıntıların sebep olacağı aksamalar mücbir sebep olarak kabul edilir ve bundan ötürü taraflar sorumlu tutulamaz.

SÖZLEŞMENİN UZATILMASI

16. Proje Yürütücüsünün gerekçeli başvurusu üzerine, proje süresi ilgili Grup Yürütme Komitesi'nin kararı ile, yüzde elliye kadar uzatılabilir.

İKAMETGAHIN DEĞİŞTİRİLMESİ

17. Bu protokolla ilgili yazışma ve tebligat birinci maddede yazılı adrese yapılır. Proje Yürütücüsü adresini değiştirdiği takdirde bunu en geç 10 gün içinde Kurum'a bildirmeye mecburdur. İkametgâh değişikliği bildirilmemiş ise eski ikametgâha gönderilen yazı ve tebligat yeni ikametgâha yapılmış sayılır.

GENEL HÜKÜMLER

18. Bu sözleşmede hüküm bulunmayan hallerde, 27 Mart 1991 tarihinde 20827 Sayılı Resmi Gazete'de yayınlanmış olan Türkiye Bilimsel ve Teknik Araştırma Kurumu Araştırma ve Geliştirme Projelerini Teşvik ve Destekleme Esaslarına İlişkin Yönetmelik hükümleri uygulanır.

19. Sözleşme giderleri Kurum tarafından ödenir.

20. Anlaşmazlık halinde yetkili merci, Ankara Mahkeme ve İcra Daireleridir.

BAŞKAN	PROJE YÜRÜTÜCÜSÜ
Kemal GÜRÜZ	Yurdanur TULUNAY ODTÜ Havacılık Müh.Böl.

EUROPEAN CO-OPERATION
IN THE FIELD OF
SCIENTIFIC AND TECHNICAL RESEARCH
- COST -

Secretariat

Brussels, 30 April 1991

COST/260/91

N O T E

Subject: Memorandum of Understanding for the implementation of a European Research Project on prediction and retrospective ionospheric modelling over Europe (PRIME)
(COST Project 238)

Delegations will find attached hereto the text of the abovementioned Memorandum of Understanding, signed in Brussels, on 7 March 1991.

MEMORANDUM OF UNDERSTANDING
FOR THE IMPLEMENTATION OF A EUROPEAN RESEARCH PROJECT
ON PREDICTION AND RETROSPECTIVE IONOSPHERIC
MODELLING OVER EUROPE (PRIME)
(COST PROJECT 238)

The Signatories to this Memorandum of Understanding, declaring their common intention to take part in a European research project on Ionospheric Modelling have reached the following understanding:

SECTION 1

1. The Signatories intend to co-operate in a project to promote research into the ways of producing more accurate models of the European ionosphere.

2. The main objective of the Project is to develop techniques for using synoptic ionospheric sounding information taken from existing measuring equipment to generate models of the ionopnere needed to estimate propagation effects on HF telecommunication systems. Limitations in current propagation prediction arise mainly from ionospheric model uncertainties. Improved predictions are needed for the design and operation of radio circuits, for the interpretation of the data they yield and for the planning of radio services.

3. The Signatories hereby declare their intention of carrying out the Project jointly, in accordance with the general description given in Annex II, adhering as far as possible to a timetable to be decided by the Management Committee referred to in Annex I.

4. The Project will be carried out through concerted action, in accordance with the provisions of Annex 1.

5. The overall value of the activities of the Signatories under the Project is estimated at approximately ECU 400 000 per Signatory overall at 1990 prices.

6. The Signatories will make every effort to ensure that the necessary funds are made available under their internal financing procedures.

SECTION 2

Signatories intend to take part in the Project in one or several of the following ways:

(a) by carrying out studies and research in their technical services or public research establishments (hereinafter referred to as "public research establishments");

(b) by concluding contracts for studies and research with organizations (hereinafter referred to as "research contractors");

(c) by contributing to the provision of a Secretariat and/or other co-ordinatory services or activities necessary for the aims of the project to be achieved;

(d) by making information on existing relevant research, including all necessary basic data, available to other Signatories;

e) by arranging for inter-laboratory visits and by co-operating in a small-scale exchange of staff in the later stages.

SECTION 3

1. This Memorandum of Understanding will take effect for four years on its signing by at least four Signatories. This Memorandum of Understanding may expire on the entry into force of an agreement between the Community and the non-Community COST member countries having the same aim as that of the present Memorandum of Understanding. This change in the rules governing the project is subject to the prior agreement of the Management Committee.

2. This Memorandum of Understanding may be amended in writing at any time by arrangement between the Signatories.

3. A Signatory which intends, for any reason whatsoever, to terminate its participation in the Project will notify the Secretary-General of the Council of the European Communities of its intention as soon as possible, preferably not later than three months beforehand.

4. If at any time the number of Signatories falls below four, the Management Committee referred to in Annex I will examine the situation which has arisen and will consider whether or not this Memorandum of Understanding should be terminated by decision of the Signatories.

SECTION 4

1. This Memorandum of Understanding will, for a period of six months from the date of the first signing, remain open for signing, by the Governments which took part in the Ministerial Conference held in Brussels on 22 and 23 November 1971 and also by the European Communities.

The Governments referred to in the first subparagraph, and the European Communities may take part in the project on a provisional basis during the abovementioned period, even though they may not have signed this Memorandum of Understanding.

2. After this period of six months has elapsed, applications to sign this Memorandum of Understanding from the Governments referred to in paragraph 1 or from the European Communities will be decided upon by the Management Committee referred to in Annex I, which may attach special conditions thereto.

3. Any Signatory may designate one or more competent public authorities or bodies to act on its behalf in respect of the implementation of the Project.

SECTION 5

This Memorandum of Understanding is of an exclusively recommendatory nature. It will not create any binding legal effect in public international law.

SECTION 6

1. The Secretary-General of the Council of the European Communities will inform all Signatories of the signing dates and date of entry into effect of this Memorandum of Understanding and will forward to them all notices which he has received under this Memorandum of Understanding.

2. This Memorandum of Understanding will be deposited with the General Secretariat of the Council of the European Communities. The Secretary-General will transmit a certified copy to each of the Signatories.

Geschehen zu Brüssel am siebten März
neunzehnhunderteinundneunzig.

Done at Brussels on the seventh day of March in the year
one thousand nine hundred and ninety-one.

Fait à Bruxelles, le sept mars mil neuf cent
quatre-vingt-onze.

Für die Regierung der Bundesrepublik Deutschland

Por el Gobierno del Reino de España

Voor de Regering van het Koninkrijk der Nederlanden

For the Government of the United Kingdom of Great Britain and Northern Ireland

CO-ORDINATION OF THE PROJECT

CHAPTER I

1. A Management Committee (hereinafter referred to as "the Committee") will be set up, composed of not more than two representatives for each Signatory. Each representative may be accompanied by such experts or advisers as he or she may need.

The Governments which took part in the Ministerial Conference held in Brussels on 22 and 23 November 1971 and the European Communities may, in accordance with the second subparagraph of Section 4(1) of the Memorandum of Understanding, participate in the work of the Committee before becoming Signatories to the Memorandum without, however, having the right to vote.

When the European Communities are not a Signatory to the Memorandum of Understanding, a representative of the Commission of the European Communities may attend Committee meetings as an observer.

2. The Committee will be responsible for co-ordinating the Project and in particular, for making the necessary arrangements for:

(a) the choice of research topics on the basis of those provided for in Annex II, including any modifications submitted to Signatories by the competent public authorities or bodies; any proposed changes to the Project framework will be referred for an opinion to the Technical Committee "Telecommunications" (COST);

(b) advising on the direction which work should take;

(c) drawing up detailed plans and defining methods for the different phases of execution of the Project;

(d) co-ordinating the contributions referred to in subparagraph (c) of Section 2 of the Memorandum of Understanding;

(e) keeping abreast of the research being done in the territory of the Signatories and in other countries;

(f) liaising with appropriate international bodies;

(g) exchanging research results among the Signatories to the extent compatible with adequate safeguards for the interests of Signatories, their competent public authorities or bodies and research contractors in respect of industrial property rights and commercially confidential material;

(h) drawing up the annual interim reports and the final report to be submitted to the Signatories and circulated as appropriate; drawing up a non-confidential report to be submitted annually to the Technical Committee "Telecommunications" COST;

(i) dealing with any problem which may arise out of the execution of the Project, including those relating to possible special conditions attached to accession to the Memorandum of Understanding in the case of applications submitted more than six months after the date of the first signing.

3. The Committee will establish its rules of procedure.

4. The Secretariat of the Committee will be provided at the invitation of the Signatories by either the Commission of the European Communities or one of the Signatory States.

CHAPTER II

1. Signatories will invite public research establishments or research contractors in their territories to submit proposals for research work to their respective competent public authorities or bodies. Proposals accepted under this procedure will be submitted to the Committee.

2. Signatories will request public research establishments or research contractors, before the Committee takes any decision on a proposal, to submit to the public authorities or bodies referred to in paragraph 1 notification of previous commitments and industrial property rights which they consider might preclude or hinder the execution of the Projects of the Signatories.

CHAPTER III

1. Signatories will request their public research establishments or research contractors to submit periodical progress reports and a final report.

2. The progress reports will be distributed to the Signatories only, through their representatives on the Committee. The Signatories will treat these progress reports as confidential and will not use them for purposes other than research work. In order to assess better the final data on the project, the signatory States are invited, for the preparation of the final report, to state the approximate level of spending at national level arising from their involvement in the said project. The final reports on the results obtained will have much wider circulation, covering at least the Signatories' public research establishments or research contractors concerned.

CHAPTER IV

1. In order to facilitate the exchange of results referred to in Chapter I, paragraph 2(g), and subject to national law, Signatories intend to ensure, through the inclusion of appropriate terms in research contracts, that the owners of industrial property rights and technical information resulting from work carried out in implementation of that part of the Project assigned to them under Annex II (hereinafter referred to as "the research results") will be under an obligation, if so requested by another Signatory (hereinafter referred to as "the applicant Signatory"), to supply the research results and to grant to the applicant Signatory or to a third party nominated by the applicant Signatory a licence to use the research results and such technical know-how incorporated therein as is necessary for such use if the applicant Signatory requires the granting of a licence for the execution of:

- work in respect of the Project;

- research and development work within the framework of the applicant Signatory's projects in the same field;

- research and development work within the framework of any associated European project undertaken subsequently and in which all or several of the Signatories may be prepared to take part.

Such licences will be granted on fair and reasonable terms, having regard to commercial usage.

2. Signatories will, by including appropriate clauses in contracts placed with research contractors, provide for the licence referred to in paragraph 1 to be extended on fair and reasonable terms, having regard to commercial usage, to previous industrial property rights and to prior technical know-how acquired by the research contractor insofar as the research results could not otherwise be used for the purpose referred to in paragraph 1.

Where a research contractor is unable or unwilling to agree to such extension, the Signatory will submit the case to the Committee, before the contract is concluded; hereafter, the Committee will state its position on the case, if possible after having consulted the interested parties.

3. Signatories will take any steps necessary to ensure that the fulfilment of the conditions laid down in the present Chapter will not be affected by any subsequent transfer of rights to ownership of the research results. Any such transfer will be notified to the Committee.

4. If a Signatory terminates its participation in the Project, any rights of use which it has granted, or is obliged to grant, to, or has obtained from, other Signatories in application of the Memorandum of Understanding and concerning work carried out up to the date on which the said Signatory terminates its participation will continue thereafter.

5. The provisions of paragraphs 1 to 4 will continue to apply after the period of operation of the Memorandum of Understanding has expired and will apply to industrial property rights as long as these remain valid, and to unprotected inventions and technical know-how until such time as they pass into the public domain other than through disclosure by the licensee.

GENERAL DESCRIPTION OF THE PROJECT

1. Introduction

The ionosphere, which is the region of ionised atmosphere that exists primarily at heights of 50-1 000 Km above the Earth's surface and is produced by solar-ionising radiation and energetic particles precipitating from the magnetosphere, has a profound effect on radiowave propagation. Whilst on the one hand it provides the means of global communication at HF via successive ionospheric reflection, often with minimal losses, its extreme spatial and temporal variability lead to great differences in received signal characteristics. Not only are raypaths continually changing but also amplitudes fluctuate. There are systematic diurnal, seasonal and solar-cycle variations which depend on geographical position, but also large irregular variations which limit radio circuit optimization.

Circuit design is concerned with the selection of transmitting and receiving sites, the choice of operating frequency bands, transmitter power, types of antenna and modulation. Use is made of propagation predictions structure to quantify system reliability over the intended period of operation and its dependence on different design parameters.

Frequency management involves inspection of propagation predictions to select the best frequency on a given occasion from among those assigned, licensed and available. Radio service planning is co-ordinated internationally under the auspices of the International Telecommunications Union (ITU) and includes compatibility analyses with internationally adopted propagation predictions applied to co-channel and adjacent channel transmissions.

Propagation predictions are also required for the interpretation of data collected by over-the-horizon radar and passive sensing systems where target locations need to be estimated. The ionosphere too can have a significant effect on Earth-space links depending on frequency and types of signal involved. Factors such as refraction, group delay, dispersion, Faraday rotation and absorption can be quantified with propagation predictions.

An important element of all propagation predictions is an ionospheric model. This should relate to all the propagation path and apply to the period of operation. In practice, long-term models based on monthly median conditions, together with some statistical indication of day to day variability suffice for design and planning.

Retrospective models for specific occasions are needed for post-event studies, for example in the diagnosis of system deficiencies. Forecast models are wanted for frequency management. An important need for radar and sensing systems is to have models for individual days averaged over periods of around 10-15 minutes corresponding to data integration times.

A distinction is drawn between ionospheric modelling which involves specifying the variations of electron density with the height and geographical position for a given epoch and ionospheric mapping which is concerned with the geographical variations of individual parameters of the height profile. Hence maps form a component of models.

In the past, international mapping development has been co-ordinated via Working Groups of the International Radio Consultative Committee (CCIR) of the ITU and the International Union of Radio Science (URSI). Whilst URSI is still active in profile development there is currently no ongoing programme of work in mapping within either organization.

The CCIR has adopted global long-term ionospheric maps based on a numerical fit to limited vertical-incidence sounding data from past epochs, but these lack spatial structure for many applications. They suggest approaches to trying to perturb these maps on a daily basis, either by extrapolation from previous data sets, or by establishing correlations with precursor or geophysical disturbance indices, but existing operational procedures for daily or shorter-period predication are of limited accuracy and questionable value.

Conventional sources of mapping data are from established vertical-incidence sounders. These could be supplemented by other techniques including information from oblique incidence links. For all requirements there are needs to interpolate/extrapolate spatially among the measurements and in the case of predictions also to project in time.

Some success has been achieved in recent years by the use of thermospheric wind theory at middle latitudes to provide better spatial interpolations than are possible by standard numerical methods. Nonetheless it is evident that the current generation of maps and associated models should be improved.

The European region offers a unique opportunity to review what is possible with present-generation models and to try to develop better models for different applications. Specifically Europe has the bast available data set of past vertical-incidence soundings going back over many years, and despite the closure of a few sounders there remains one of the most dense networks.

There are also plans to establish additional sounders. Further, Europe is an area free from the complications that arise at high latitudes due to particle precipitation and at low latitudes where there are marked ionisation gradients, ionisation irregularities and considerable variability associated with the movements of the so-called "equatorial anomaly". Techniques developed for the European theatre may be adaptable for use elsewhere later.

2. Objectives of the Project

The main objectives of the Project are:

- to investigate the feasibility and to develop the potential for generating improved prediction and retrospective models of the ionospheric electron density over the European area bounded between latitutdes of 35°N and 55°N and longtitudes of 10°W and 30°E (see map of Fig. 1) in order to meet established needs of radio system designers and users

- to produce sample retrospective sets of such models

Assuming a successful outcome of the Project, a next phase of work would involve the synoptic production of model sets, near real-time dissemination of these to selected radio users and interaction with the users in order:

- to optimize the form of the model sets to satisfy requirements

- to investigate and quantify the degree of practical improvement achieved compared with the use of models generated in accordance with present techniques and data.

3. Proposed research activities

The work will be arranged under five topic headings and will continue within each of these areas throughout the duration of the Project. Not all organizations will wish to participate in all topic areas, but the Project as a whole is seen as a common activity directed to a single goal:

(a) Vertical sounding - carrying out synoptic daily-hourly ionospheric measurements (VI) and routine scaling of the associated ionospheric characteristics, together with more rapid sequence soundings on selected co-ordinated campaign days.

(b) Oblique sounding - carrying out selected soundings (OI) and associated data analyses, developing autoscaling techniques and comparing measurements with model results.

(c) Spatial correlation studies - establishing techniques for spatial interpolation between data sets.

(d) Temporal correlation and prediction techniques - investigating approaches to forecasting, either from past data sets, or in terms of external precursor information.

(e) Ionospheric mapping and modelling - developing optimum numerical techniques and producing representative model sets.

The vertical and oblique-sounding groups will provide data to be used by the spatial correlation and forecasting groups. Their results will then yield new information for use by the mapping and modelling group. The interactions between these different groups are shown schematically in Figure 2.

4. Suitability of the COST framework for the Project

The following benefits are anticipated:

(a) the establishment of viable combined teams with sufficient size and resources to achieve the desired objectives, whereas at present no one country has the necessary available trained staff effort;

(b) the channelling of resources to common goals of value to all;

(c) the generation of a single standardized European ionospheric data base for use in national studies;

(d) although requirements exist for worldwide models, the middle-latitude European ionosphere is best suited for first studies of this type because it is relatively benign and has the geographically densest network of existing ionospheric sounders;

(e) a framework is provided for co-ordinating effort within the participating countries where delegates are drawn from PTT administrations, universities and other research centres;

(f) strengthened technical and scientific effort becomes available at a national level in some countries;

(g) the setting up of a Committee whose members are directly involved with the research ensures a highly productive framework for the dissemination and correlation of results, ideas and information;

(h) the transfer of technology from those countries with a more extensive ionospheric research background to engineers and scientists in countries relatively new to this field of study;

(i) the creation of an infrastructure for the collection and validation of ionospheric data and the synoptic production of model sets for radio users in an operational extension of the project.

5. Appropriate forms of co-operation

The suggested form of co-operation is that Signatories are represented in the Management Committee (MC) by delegates who should be expected to:

- attend and contribute to meetings of the MC: typically three meetings annually;

- be involved in an active programme fitting in with the objective and time scale of the project;

- take responsibility for specific items of the project;

- seek at least annually the advice of the Technical Committee Telecommunications (TCT) to achieve a working liaison between the project and other related COST telecommunications and teleinformatics projects;

- set up national working groups for specific items;

- be responsible for liaising between the MC and national research groups in the participating countries.

When necessary the MC may arrange a working interlaboratory comparison of results, technical meetings, workshops, laboratory visits and staff exchanges, etc., in order to achieve a rapid exchange of information.

6. Technical programme

6.1. Vertical sounding

Work will be concerned both with assembly of data banks of past measurements and with collecting new data. A variety of different types of ionospheric sounding instruments have been and are in use within Europe. Some data are available only as film records; others as paper records. Not all useful past data have been analysed. Whereas some standard scalings are available only in printed bulletins, in other cases they have also been produced in computer-readable form.

In generating a PRIME data bank, particular attention will be paid to content and to data verification. The aim will be to add to the data bank once established and keep it current. It will be interrogated in different ways to identify the most appropriate data sets to serve the varying needs of the other PRIME groups.

One particular difficulty with standard soundings is that they occupy a minute or less to collect and are carried out systematically only once an hour. In this regard they represent under-sampled effective snapshots of the ionospheric state.

Within-an-hour variability due to the presence of travelling disturbances can be considerable. The changes are especially great at dawn and dusk. It is planned to supplement studies of past data sets with new more frequent soundings on selected days with sounding intervals of 5 or 7 1/2 minutes.

6.2. Oblique sounding

Although conventional sources of ionospheric model data come from vertical-incidence sounders, the additional use of oblique sounders offers the possibility both of testing the accuracy of the models that have been developed and of providing additional equivalent midpath information. Specifically, oblique links can be established fairly readily on a time-share basis with vertical soundings between pairs of stations of the same manufacture, given the necessary beamed antennas and recording arrangements.

It is planned to take separate soundings over paths between two transmitting installations and a single receiver. Recording schedules will be chosen to yield results representative of the different diurnal, seasonal and solar-cycle features.

Records will be stored in a digital data base which may form a part of the data base of vertical soundings. Other past European data sets will also be examined. As for vertical sounding, there are international rules for the scaling of oblique-incidence soundings. Initially scaling will be undertaken manually but there is merit in acquiring an auto-scaling capability, either self generated or making use of procedures already under commercial development.

The two principal investigations that will be carried out are the comparison of maximum observed frequencies with ray-tracing estimates derived from model electron-density distributions and the development of a preferred technique for inverting the oblique-incidence measurements to equivalent midpath electron-density profiles.

6.3. Spatial correlation studies

Following techniques developed in meteorology, calculations will be made of correlation distances of deviations of electron density from the local median value under different conditions. Analyses will be carried out over different time periods to determine any systematic trends such as with season or magnetic activity, with comparisons both in terms of local and universal time.

In particular, correlation distances will be compared when using instantaneous hourly values and medians for successive soundings over different fractions of an hour.

Ways of relating correlation coefficients to weighting functions by which first estimate values are changed by measured values will be considered, including different approaches to first estimate determinations and iteration techniques to match to multiple measurements.

In any operational modelling procedure a dynamic approach to correlation distance determination seems preferable using nearest past measured values. How such a scheme could be implemented will be studied. A new survey will be made of available options to model profile specification.

6.4. Forecasting and temporal correlation studies

There are three possible approaches to short-term forecasting:

(a) extrapolation from past measurements

(b) establishing a correlation with precursor indices, and

(c) monitoring solar-terrestrial phenomena in advance of their effects being detected in the ionosphere.

Several options to past measurement extrapolation exist with different weighting arrangements. These will be studied to see if any general trends emerge, particularly to examine any dependence on whether days are magnetically quiet or disturbed.

Correlations of electron-density data values from the monthly median on individual days with magnetic disturbance indices will be established for varying time lags between disturbance and ionospheric response.

The extent to which use can be made of satellite particle-flux detection data, VLF phase change data and inter-planetary scintillation data likely to become available will be considered.

6.5 Ionospheric mapping and modelling

Mapping and modelling will parallel the work on spatial and temporal correlation. Specifically, the aims will be to formulate appropriate numerical techniques to represent in the most accurate and efficient ways structures that have been generated.

Spherical-harmonic analysis procedures adopted in current CCIR maps will be modified for regional mapping and compared with alternate grid-point value storage techniques to establish their relative merits.

Consideration will be given how best to express electron density height-profile data. Whether these will be in terms of separate mapping of the individual profile parameters, as a height grid, or involving families of coefficients is yet to be determined. Finally a representative selection of models will be generated.

7. Envisaged cost of the activity in the Project

At present in some countries an active research programme is already under way. However in others there is a need to expand the size of the existing teams. Most of the work is concerned with data analysis making use of existing computing facilities, but some equipment procurement is needed for the oblique-sounding experiments. In particular, one new transmitting installation, new receiving antennae and recording arrangements are required.

Since the results of these experiments form an important component of the project as a whole in validating the generated ionospheric models, costs are to be borne equally by all signatories independent of the equipment locations.

Signatories are expected to promote an active national involvement by means of appropriate funding. The level of funding for new experimentation (equipment expenditure) will be shared between signatories. This funding is appropriate for the installation and operation of two transmitting and one receiving stations.

In addition funding should be made available for the work of the Management Committee. In particular this includes:

- co-ordination of national efforts

- preparation of contributions to the Committee meetings

- travel expenses.

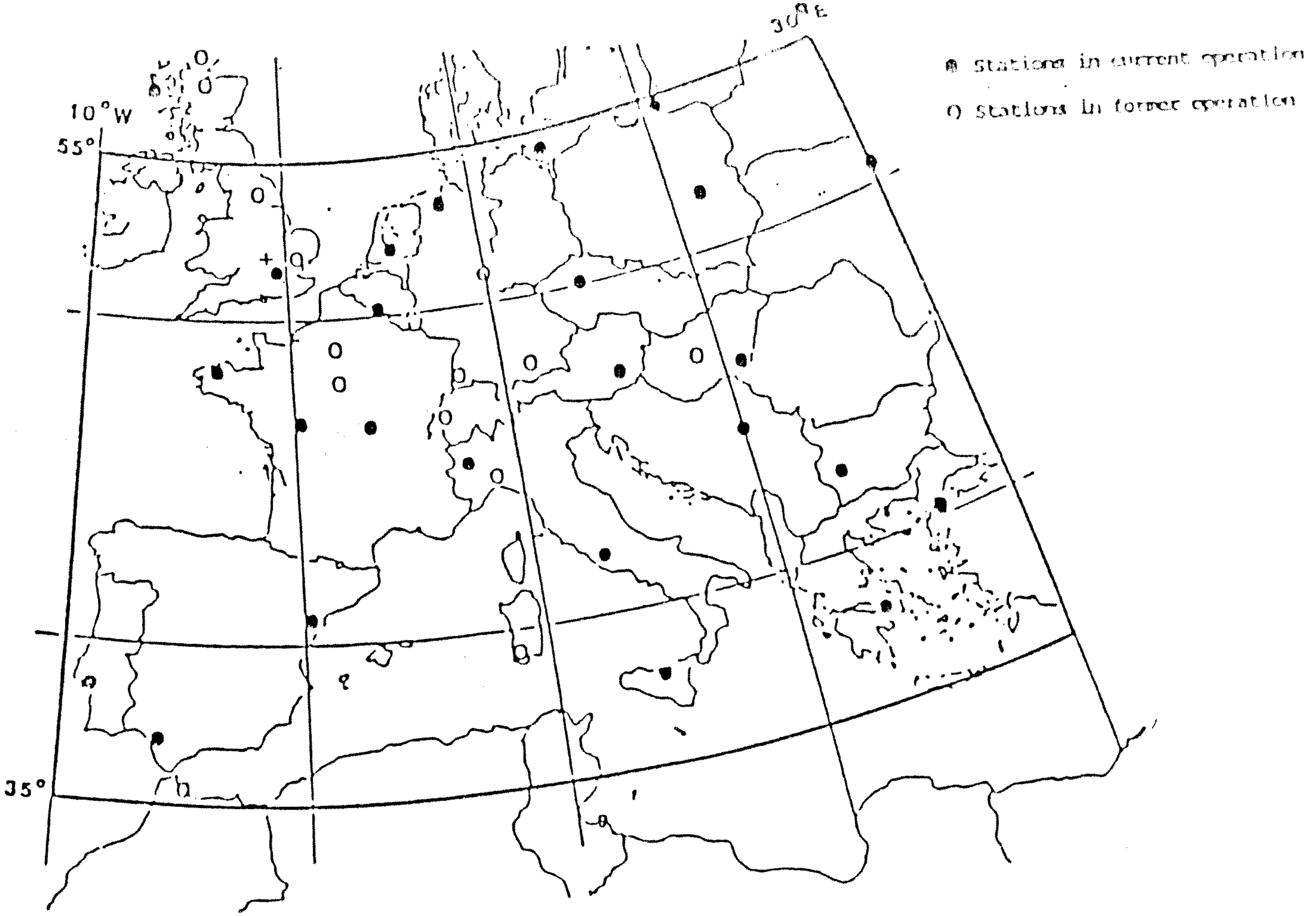

Fig 1   Prime area and locations of vertical sounding stations

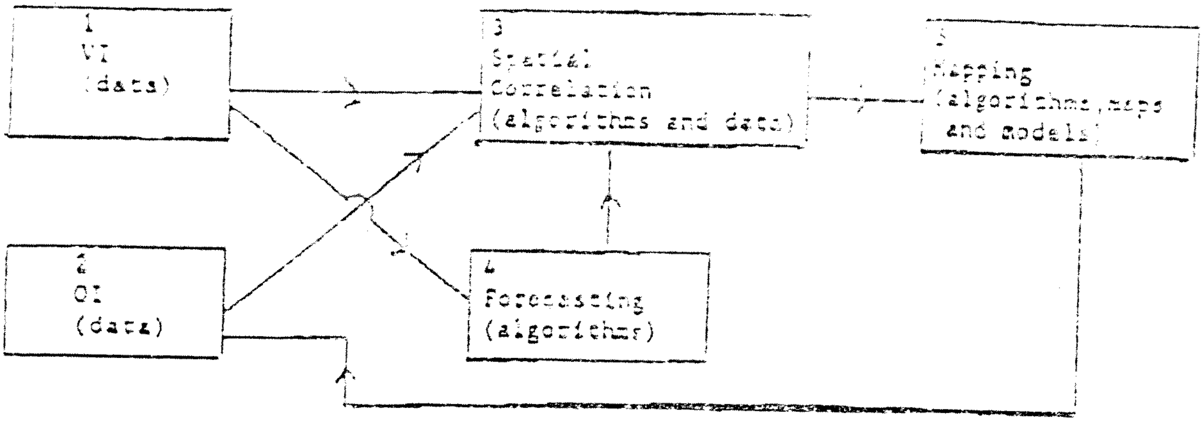

Figure 2: Interactions between the different groups

Features:
(a) the spatial correlation group uses both VI and OI data to formulate algorithms
(b) the forecasting group uses a variety of data sources including VI data to formulate algorithms
(c) sample mapping data and modelling sets are produced by the spatial correlation group using VI and OI data (retrospective maps) and forecasting algorithms (forecast maps)
(d) the mapping group develops mapping algorithms and applies these to the mapping and modelling data sets that have been produced by the spatial correlation groups
(e) maps and models are tested by the OI group

COST 238 : PRIME
5th MC AND WORKSHOP
WG - 5 (WP - 7a)
TURKISH TEC DATA
FROM MEASUREMENTS IN ANKARA

Yurdanur Tulunay
METU, Ankara

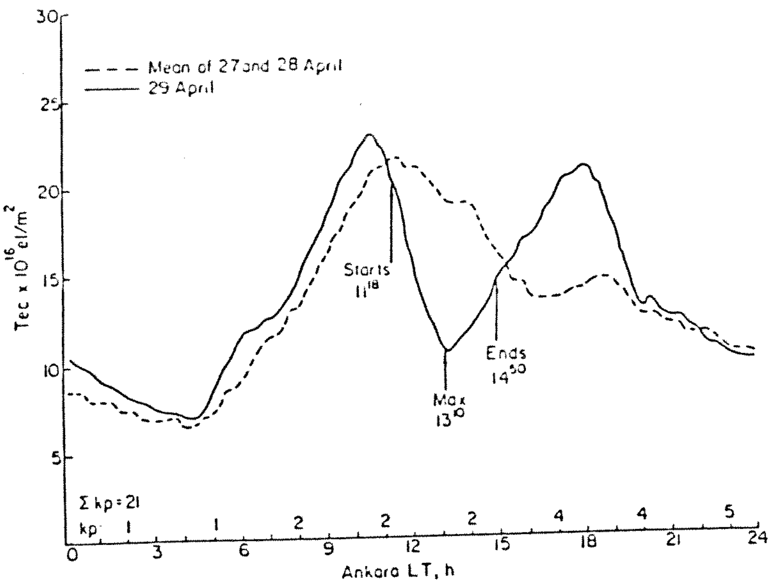

FIGURE 1 The diurnal variations in TEC obtained during the solar eclipse of 29 April 1976. The transparency gives the diurnal variations of the f_0F_2 that correspond to a magnetically quiet day and to the solar eclipse day.

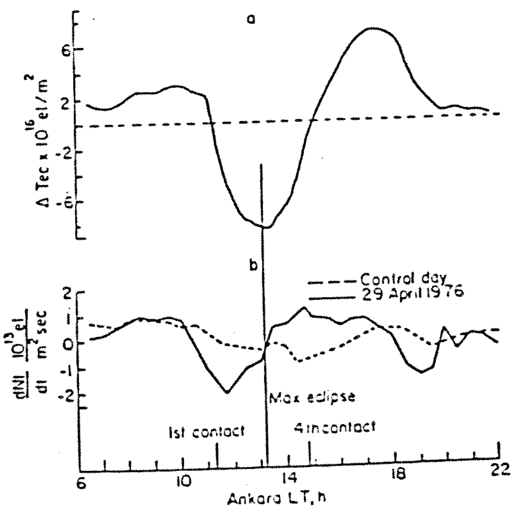

FIGURE 2 The diurnal variations of TEC and the time rate of changes of the TEC obtained both on the control days and on the solar eclipse day.

Acknowledgements. The polarimeter was supplied through the grant AFOSR 75-2800. All the f_0 F_2 data used for this study were obtained from the WDC-CI and the authors express their thanks to Mr. R. W. Smith. The authors also wish to thank to Dr. Oranç and Mr. C. Gerçeker who provided the Faraday signal data, and to Dr. J.A. Klobuchar for his valuable technical assistance.

REFERENCES

[1] Davies, K., Fritz, R.B., and Grubb, R.N., J. Environ. Sci. 4, 31 (1972).

[2] Klobuchar, J.A., Privake communication (1975).

ANKARA TEC DATA DURING THE SOLAR ECLIPSE OF 29.4.1976

The results of the computations have been presented in the form of diurnal curves in order to investigate the effect of the solar eclipse of 29 April 1976 on the TEC over Ankara longitudes.

On the eclipse day, unfortunately, the magnetic activity index Kp was increased to 4 around 1500 hours indicating the existence of a moderate magnetic substorm. Therefore, it is very difficult to distinguish the effects of the eclipse phenomenon on the TEC data from the effects of high magnetic activity. Summarizing, the unusual features observed in the TEC on the eclipse day are:
(1) the decrease in TEC well before the first contact;
(2) the unexpected increase in the TEC well after the fourth contact. The time differences due to the altitude variations can not along explain the early decrease seen in the TEC data. If the diurnal variation of the TEC on the eclipse day is considered as the representative of the data at the subionospheric level, i.e.420 km., the parallel behavior of the f_0F_2 data indicates that downward diffusion alone may not be responsible for the observed changes in the TEC data. The well known difficulty in interpreting the effects of an eclipse on the topside ionosphere is once more noted in this work.

THE BEHAVIOUR OF TEC OVER ANKARA

In this investigation, the diurnal and monthly mean diurnal variation of the total electron content (TEC) with local mean time (LT) and the response of TEC to high magnetic activity have been studied.

While the geostationary satellite ATS 6 (Davies, et al., 1972) was located at 35^{o}E longitude, the Faraday angular rotation of its planepolarized 140 MHz transmissions was measured by a polarimeter in the Electrical Engineering Department of the METU, Ankara (40^{o}N, 33^{o}E, L=1.45), between October 1975 and August 1976. The input to the recording system was a cross-yagi antenna (Oranç and Gerçeker, 1975). The polarization angle was recorded on a strip chart recorder. The location of the sub-ionospheric point was (36^{o}N, 33^{o}E).

The Faraday rotation angles were obtained by the standart method (Klobuchar, 1975), and hence the TEC was computed. The "$n\pi$" ambiguity was removed by making use of the critical frequency data obtained from the WDC-C1 for two ionosonde stations near the sub-ionospheric point.

The computed results are presented as diurnal variations for single days and monthly means. Maximum daytime TEC values were observed in April ($\approx 20 \times 10^{16}$ el/m^2) and minimum in January ($\approx 9 \times 10^{16}$ el/m^2); maximum night-time values were observed in April ($\approx 3 \times 10^{16}$ el/m^2). The response of TEC to the high magnetic activity associated with substorms was found to depend greatly on the time of day when the storm occurred.

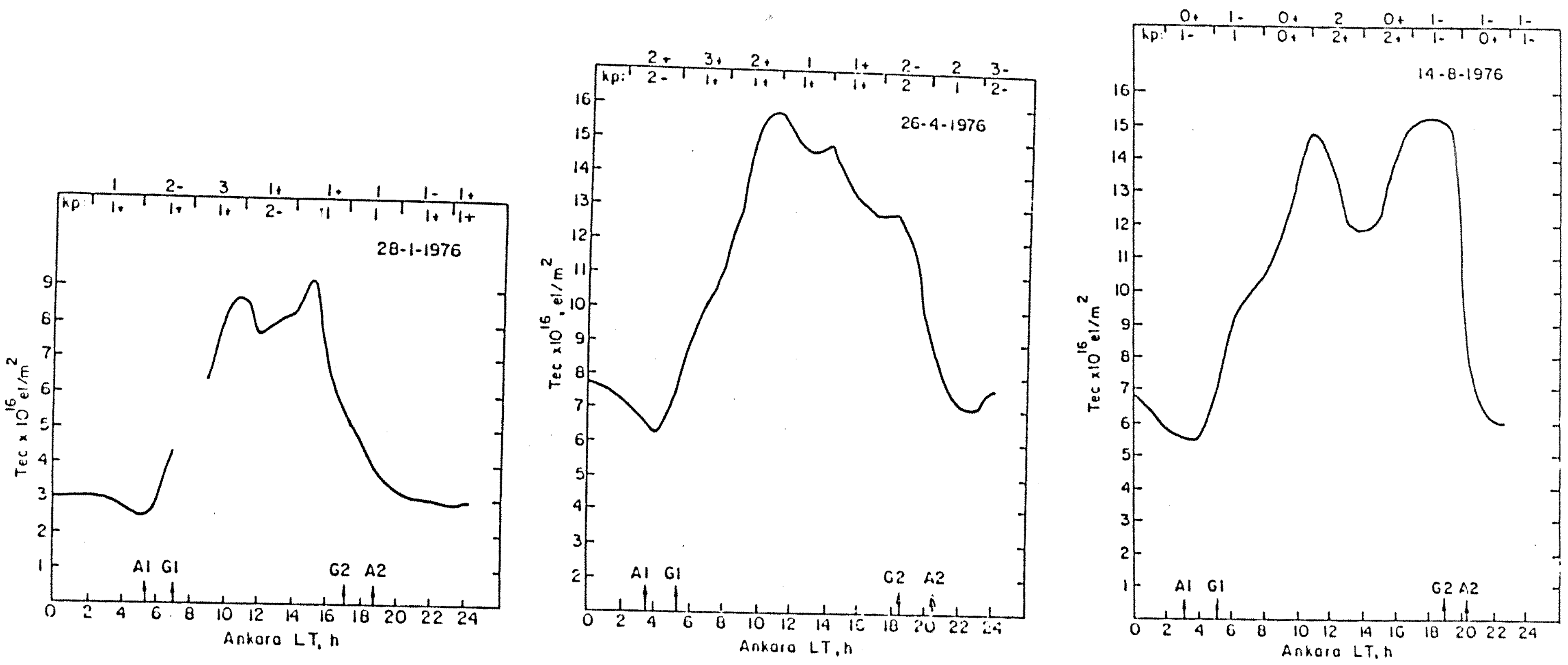

Figure 1 Some typical examples of daily TEC variation in local mean time (LT) on magnetically quiet periods. G1, G2 indicate ground level sunrise and sunset respectively; A1, A2 sunrise and sunset respectively at 400 km altitude. Top scales : previous day and same day values of $3h$ - K_p .

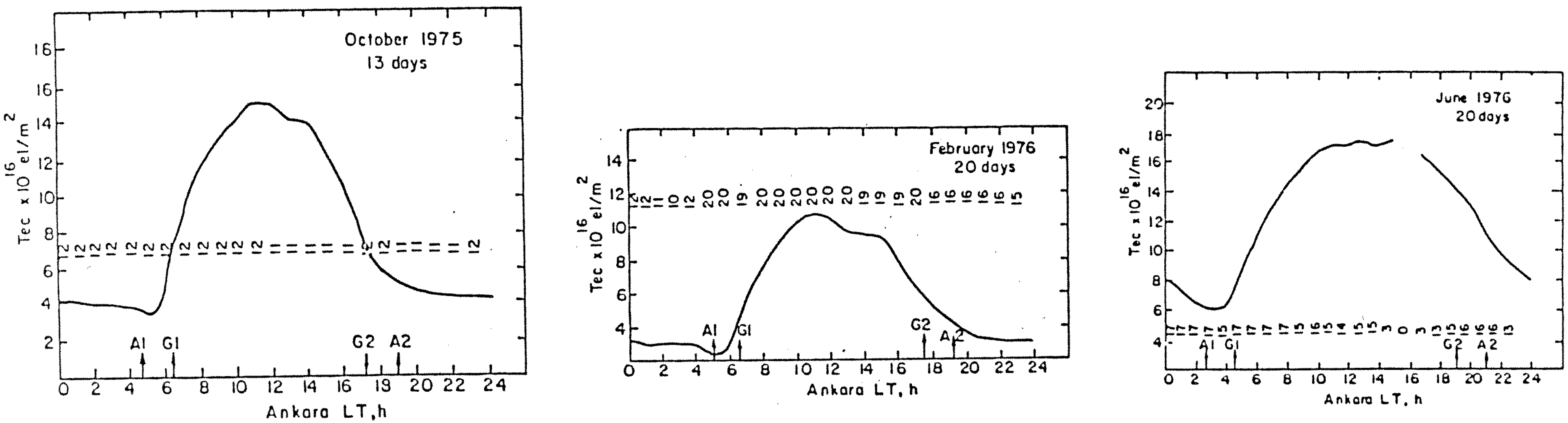

Figure 2 Monthly averaged TEC variation in local mean time (LT). C1, C2 indicate ground level sunrise and sunset respectively; A1, A2 sunrise and sunset respectively at 400 km altitude.

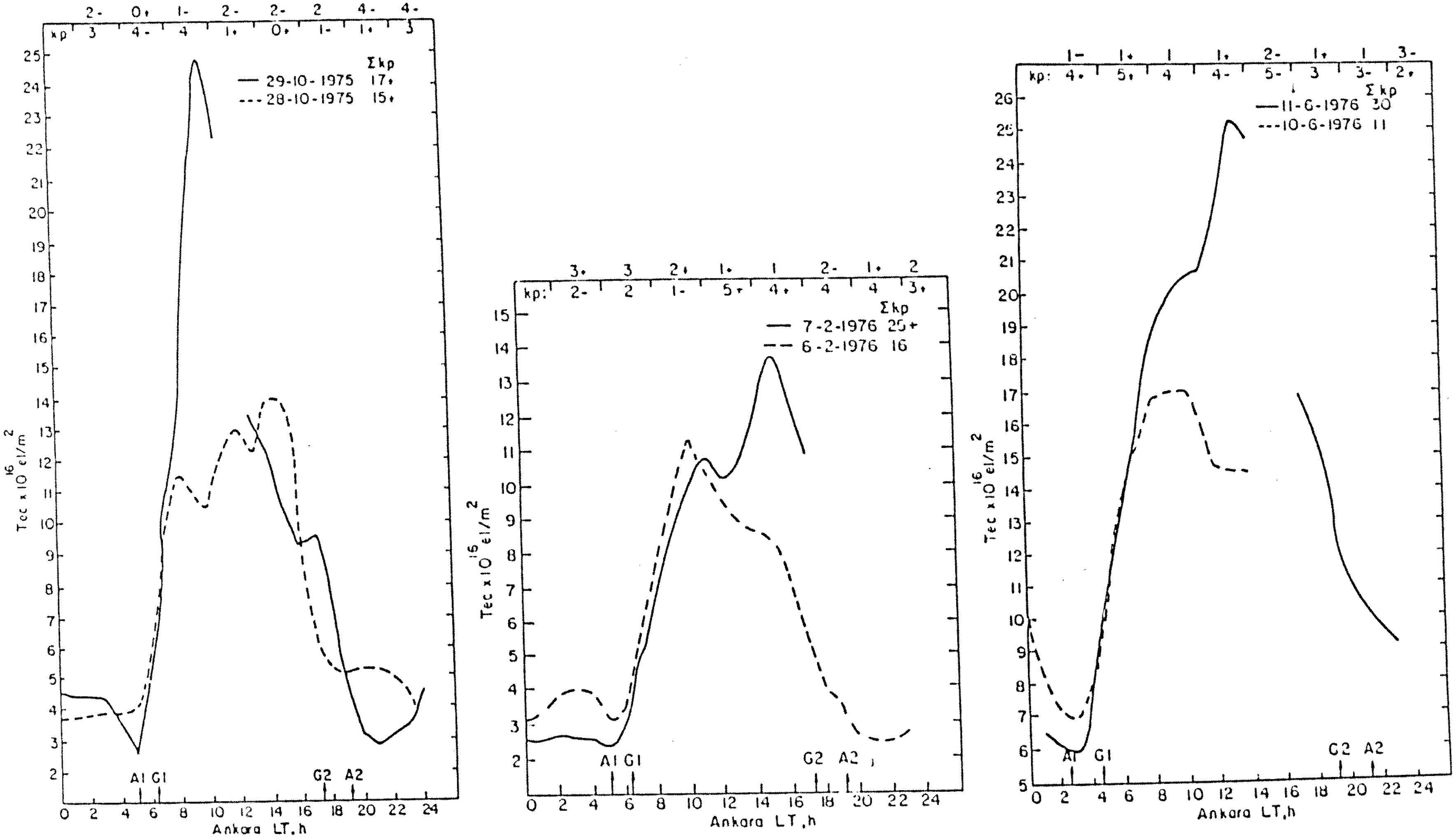

Figure 3 TEC variation in local mean time (LT) on occasions of high magnetic activity is shown by the solid line, and for low magnetic activity (on the previous day) by the dashed line. G1, G2 indicate ground level sunrise and sunset respectively at 400 km altitude.

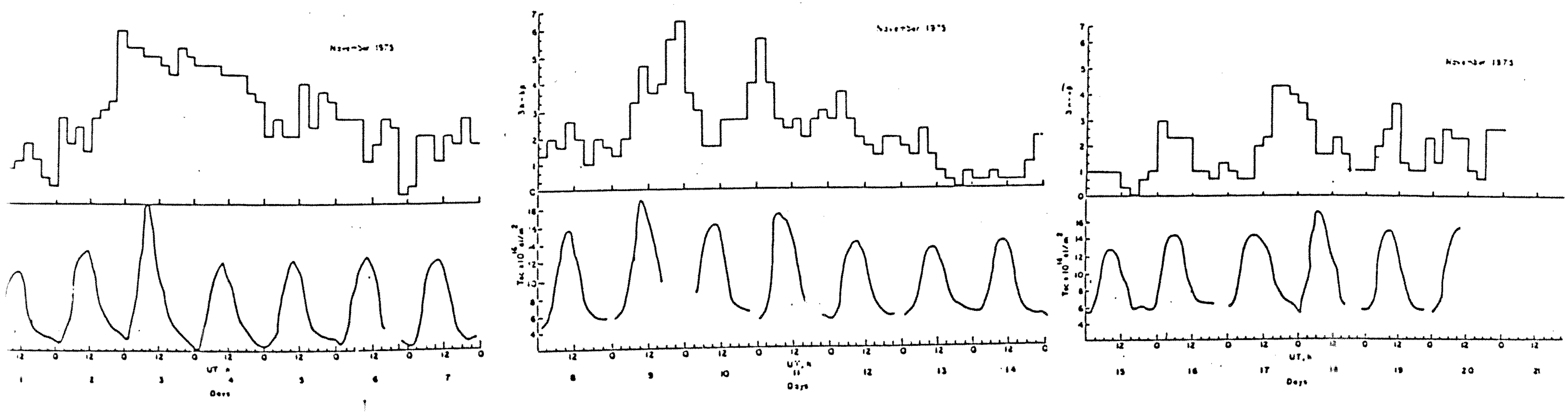

Figure 4 Temporal variation of TEC during a magnetically active period in November 1975. On the upper part of the figures changes in the $3h$ - K_p magnetic activity index are plotted in universal time (UT).

EK (6.3.1)-5

Transportable ionosonde in PRIME project

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Introduction

PRIME project uses vertical-incidence ionospheric characteristics as foF2 and M(3000)F2 from all European ionosonde stations existing now and in the past. But the European ionosonde net does not cover the whole area of PRIME interest and moreover this stations are distributed irregularly. The temporarily deploying of additional ionosonde in the required region was proposed to provide a data for generation an instantaneous maps. The temporary ionosonde was planned to deploy in a series of few-week campaigns in selected areas outside the correlation distances from neighbouring fixed ionosonde sites. It means 350 km far in N-S direction and 500 km in E-W. The proposed sites of the ionosonde was the compromise between the requirements of PRIME purposes (Gibson and Bradley, 1991) and technical possibilities.

Models

The study of correlation distances of foF2 in different heliogeophysical situation for midlatitude stations shows some specific features. For this study, prepared rather for proving the made choice of site, the differences between measured daily-hourly foF2 values were determined for each considered station to eliminate the daily trend. The cross-correlation coefficients were calculated between all available stations for the years 1966-1990. The list of the stations in respect of the considered years is presented in table 1.

The presentation of these coefficients in the dependence of N-S and E-W distances measured leads to conclusions:

However the maps presented in coordinates in degrees and in kilometers show the elliptical correlation, the axial ratio of a to b parameters of ellipse is much more degenerated if coordinates are presented in degrees rather than in kilometers. The axial ratio of the ellipse is also different for different

FIRST RESULTS FROM THE TRANSPORTABLE IONOSONDE CAMPAIGN

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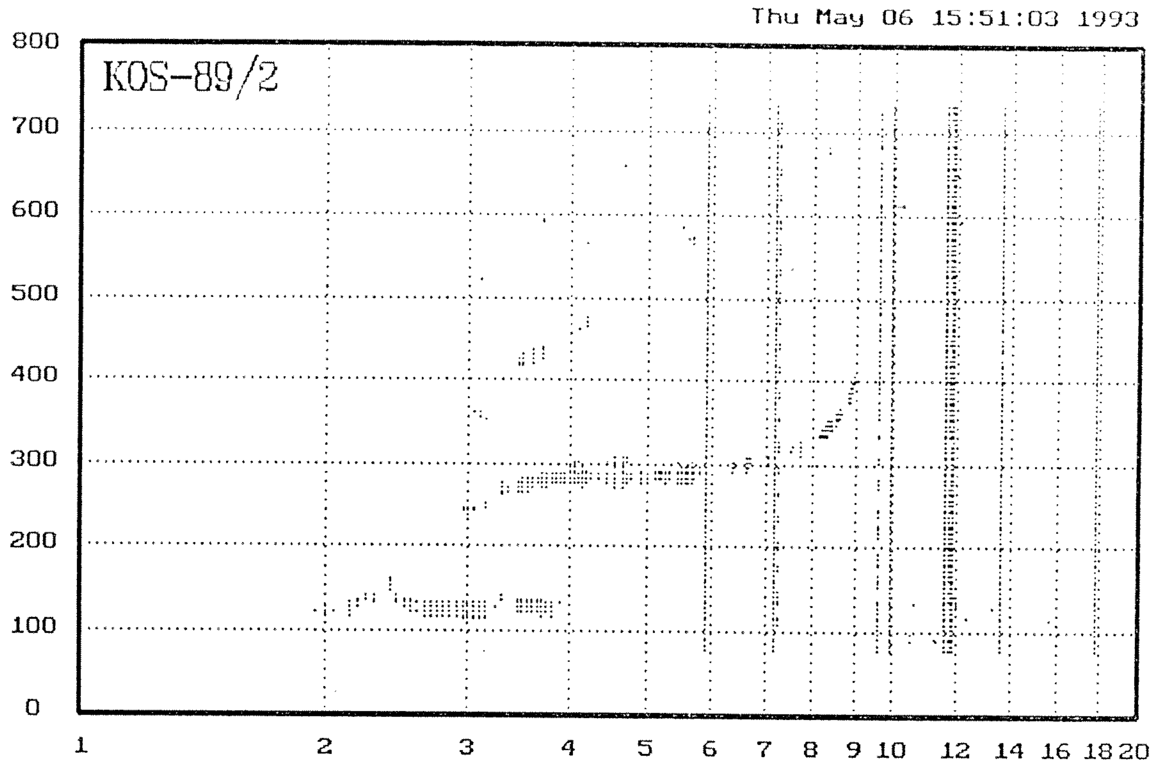
The first transportable ionosonde campaign in COST238 (PRIME) project was started on May 06 1993. The transportable ionosonde KOS89/2 made in Space Research Centre of Polish Academy of Sciences is used. The ionosonde is installed on the campus of B.U. Kandilli Observatory in Istanbul (41°N 29°E), in Turkey. It is expected that the measurements will be provided till the spring next year. The data have been obtained at half hourly intervals with the exception during June 15 and July 15 1993 when they will be obtained at every 15 minute intervals

At the next five pages the first rough ionograms together with elaborated characteristics are presented. All ionograms were made on the 6-th of May, between 15 and 17 UT. The upper figure at every page represents the displayed and scanned onto the monitor ionograms with the computer control system. They are headed with the actual sounding date and time. Height markers are at 100km intervals up to 800km. Frequency markers are evently spaced along the axis every 1MHz. The recorded ionograms are then evaluated using IPSP (IONOGRAM PROCESSING SOFTWARE PACKAGE) programmes prepared by I.Kutiev from Geophysical Institute Bulgarian Academy of Sciences. The lower figures at every page presents the interpretation of the ionograms. All results will be published later.

Acknowledgements: This work has been supported by Community's Action for Co-operation in Sciences and Technology with Central and Eastern European Countries ERBCIPECT926008 and by Turkish Research Council, Bogazici University Research Fundation. The autors thanks Prof.Dr. A.M.Isikara for providing support at Kandilli Observatory. Thanks are also due to Telsiz Genel Mudurlugu for assisting with licensing and custom clearance.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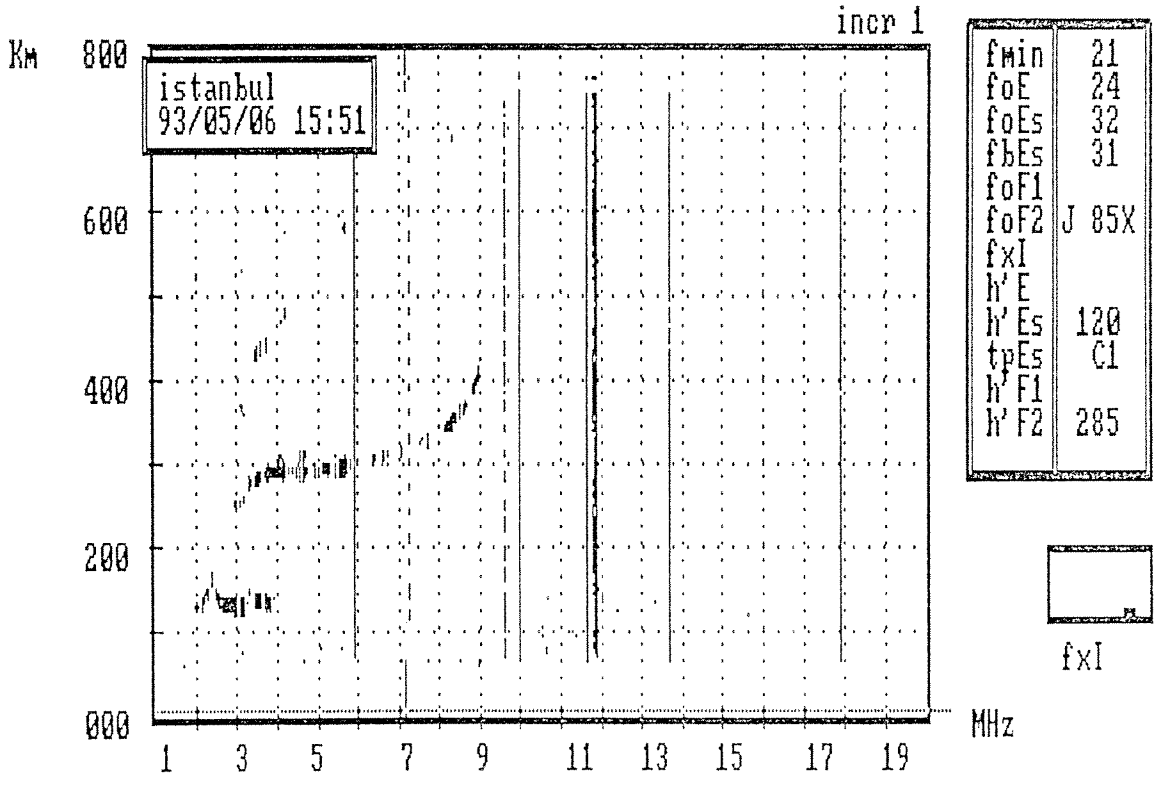
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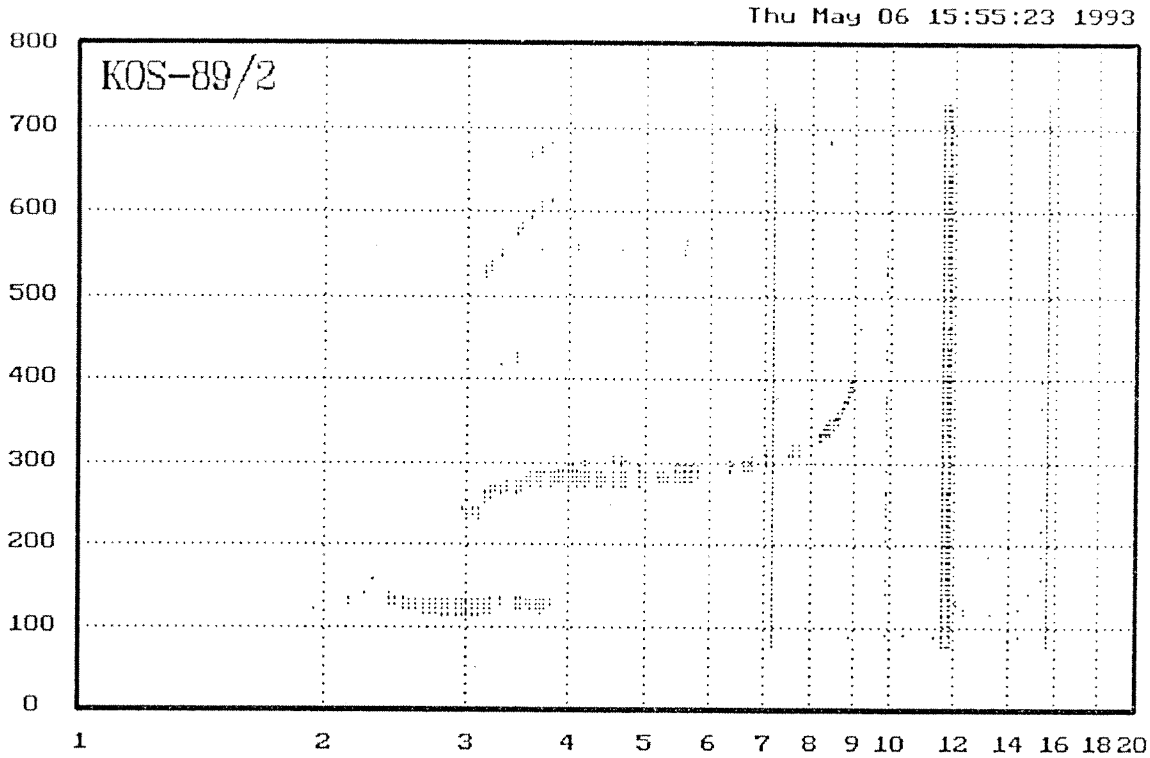
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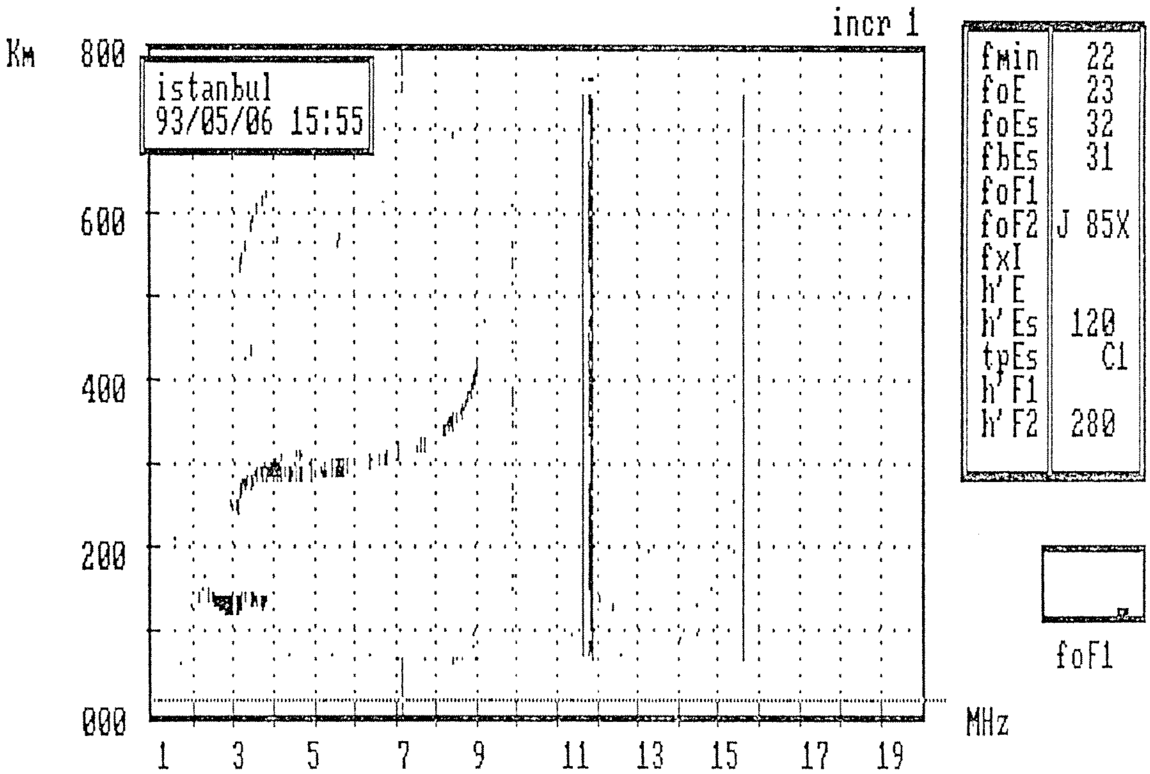
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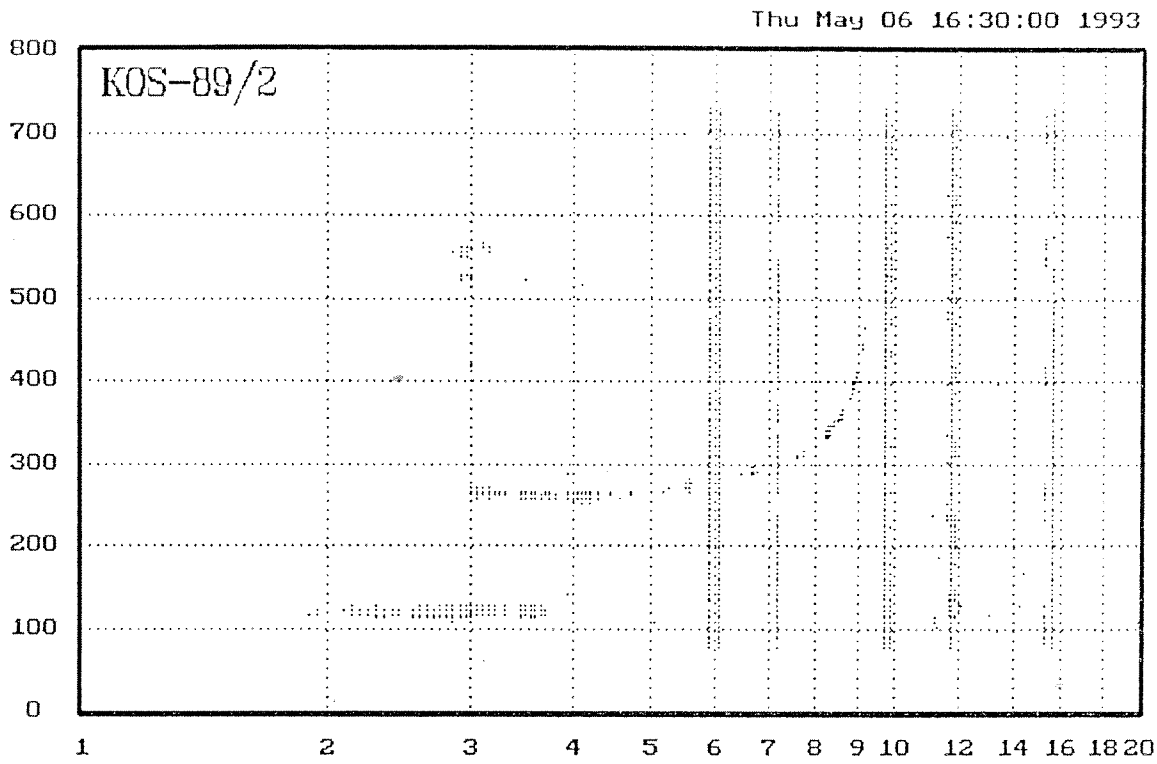
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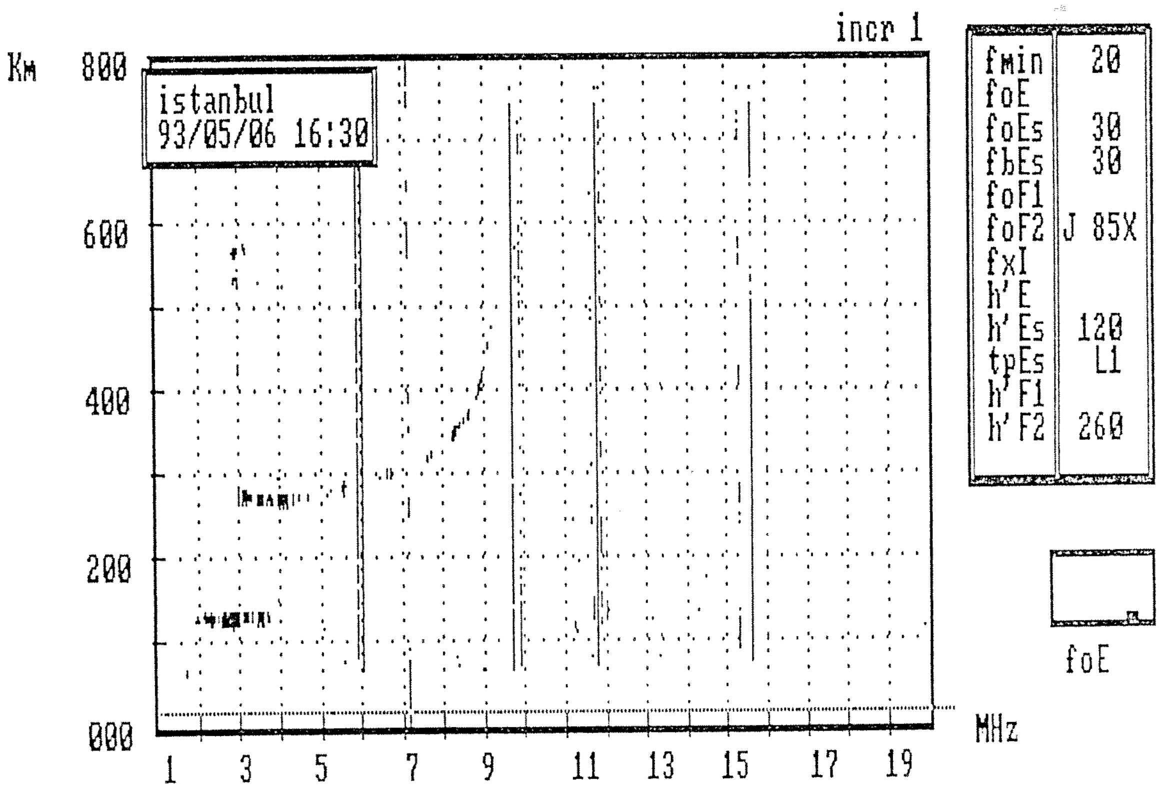
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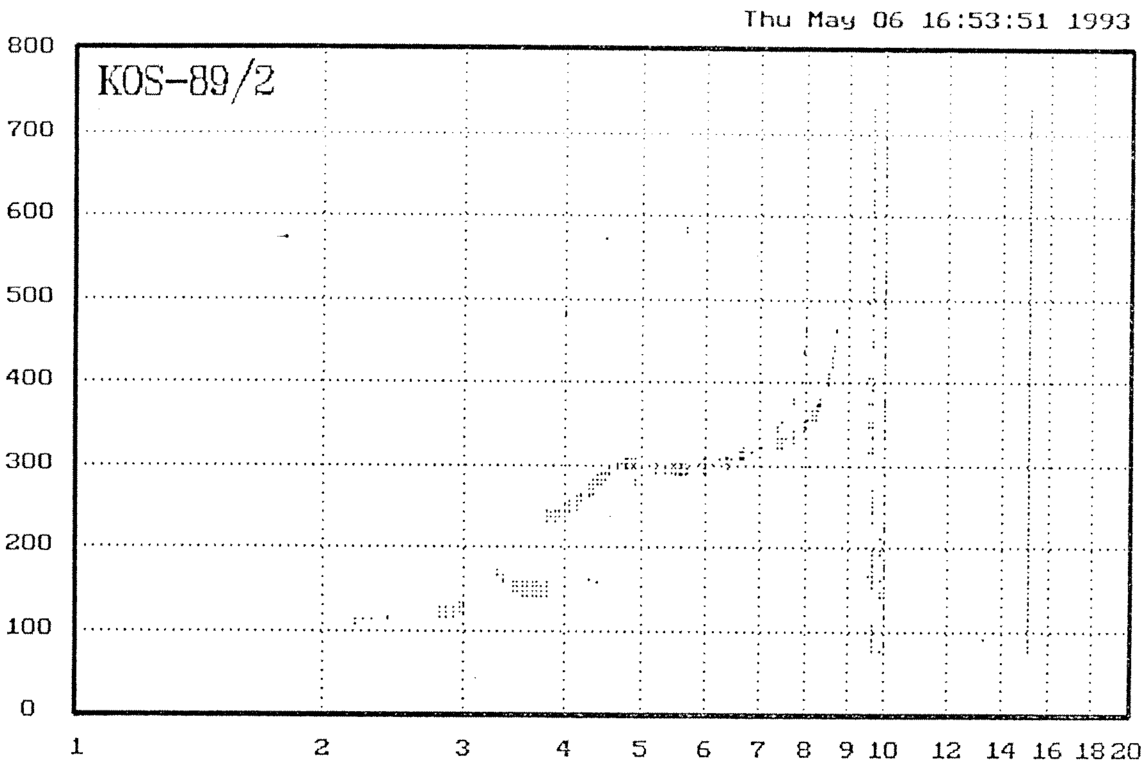
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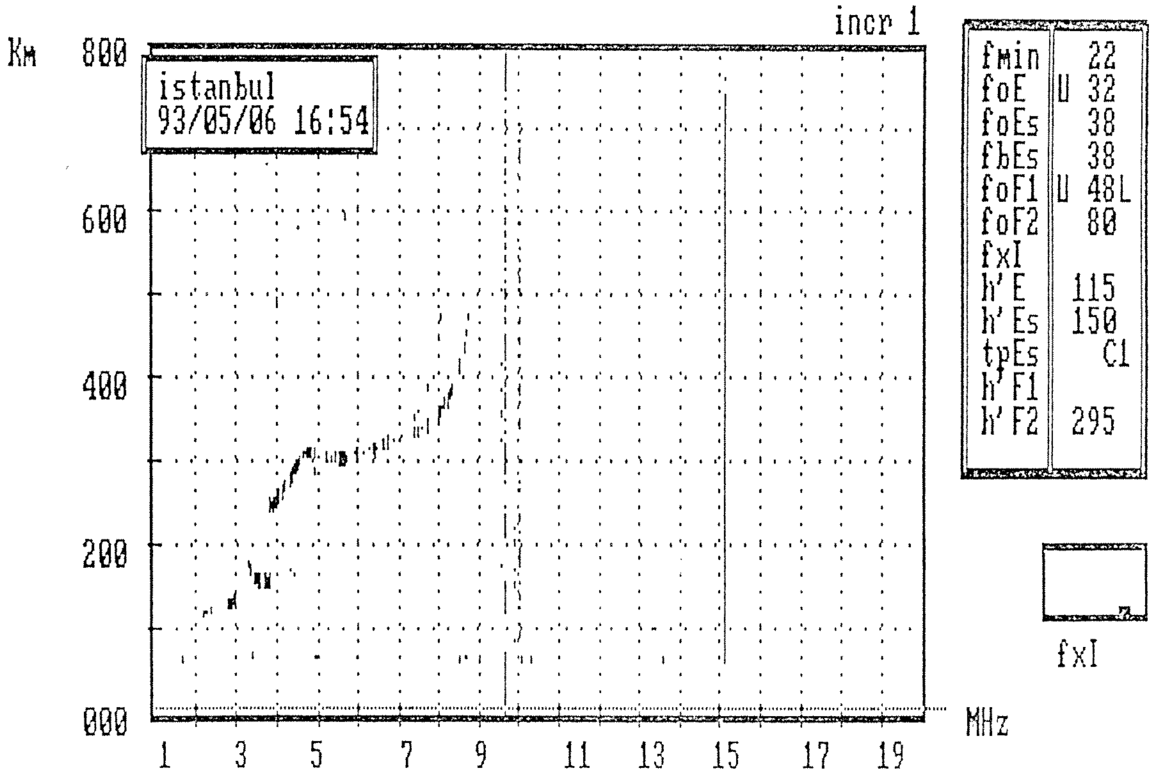
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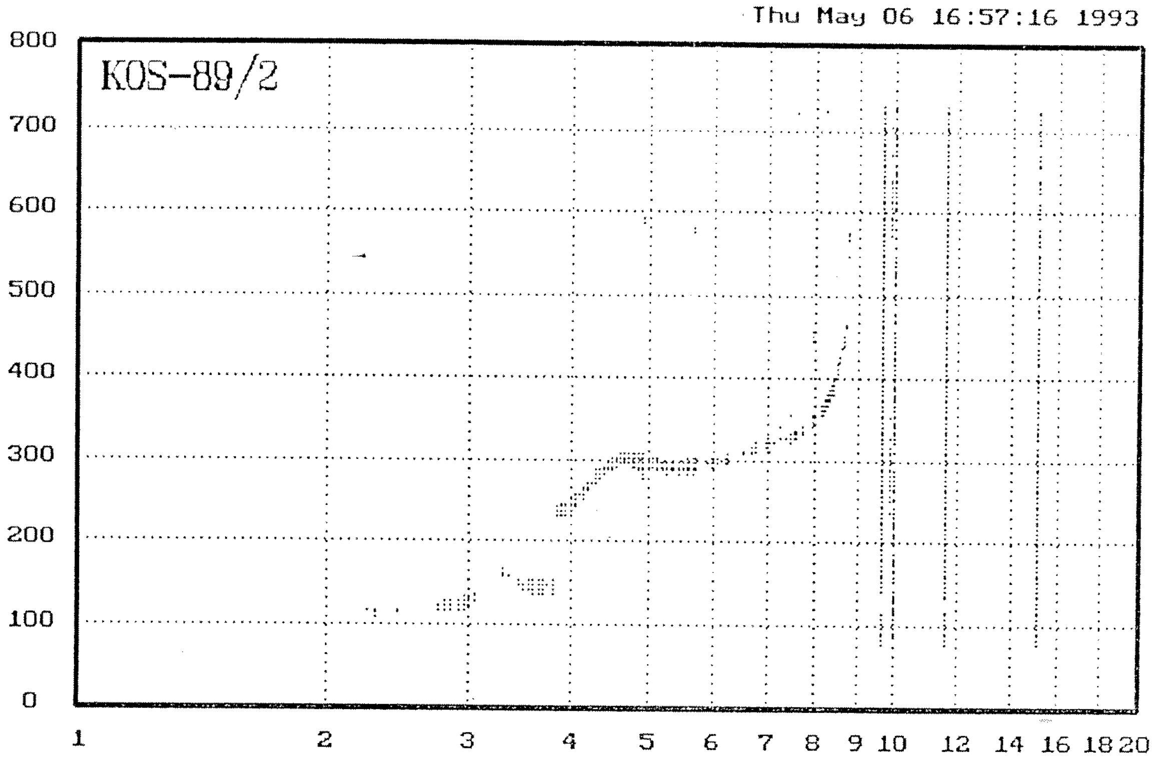
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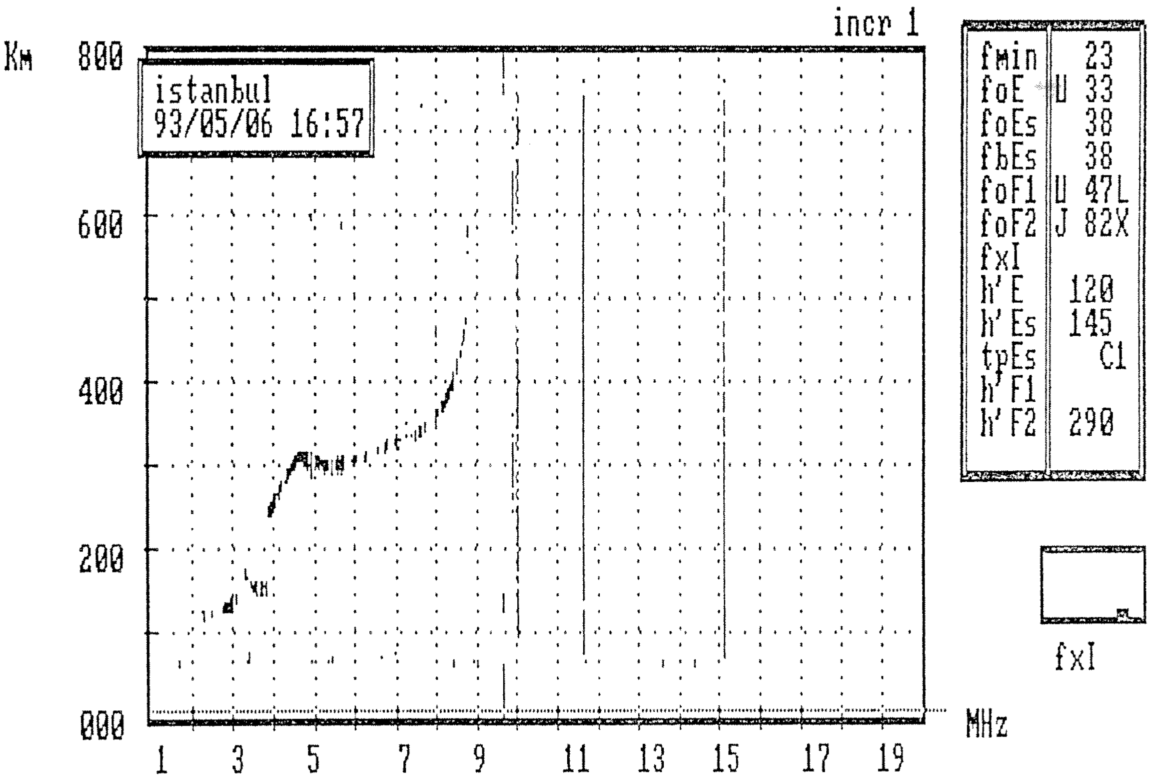
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THE CHARACTERISTIC BEHAVIOUR OF THE F REGION IONOSPHERE OVER İSTANBUL DURING 1966, 1967, 1968, 1972 AND 1993

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Abstract

One of the objectives of the COST238:PRIME project was to conduct single-station vertical ionosonde (VI) campaigns in order to provide further data for single station modelling and map testing purposes. One of such VI experiments took place in Turkey almost for one year.In the present work some results of the data analysis and model testing were considered.

1.Introduction

A Polish make vertical ionosonde (VI) (Rokicki et al. 1993) was operated for about one year starting on May 8, 1993. The period of experiment coincided with the descending branch of the solar cycle 22. The ionosonde was installed on the campus of the B.U. Kandilli Observatory (KAND) in Istanbul (41°N, 29°E). The data were obtained at half hourly intervals. Two 15-minute campaigns were organised between June 15 - July 15 and October 15 - October 31 intervals. The results of the foF2 data analysis have been presented here in order to determine the characteristic behaviour of the F region ionosphere over İstanbul. The possible influence of the magnetically active periods have been incorproted by employing the magnetic Ap indices. The KAND data have also been compared with the data obtained at ROME (1983), SOFIA (1972, 1983), ATHENS (1972, 1983), and İSTANBUL (1963 - 1968). A further comparison was done by using a theoretical model of MQMF2 (Mikhailov, 1993) with the observed Istanbul and KAND foF2 data in 1966 and 1993 respectively.

2. Data Analysis

(i) Morphological Studies:

The half hourly foF2 data obtained at the KAND have been used to illustrate the morphological structure of the F2 region ionosphere over İstanbul. Since there were some missing data due to either power cuts, or delays in digitising etc., the missing data were filled by some computed values based on a criterieon by employing the magnetic daily Ap indices. That is, two sets of control values of the half hourly foF2 when Ap <6 and Ap≥ 6 were chosen. Thus, for a particular day, depending on the magnetic activity index of Ap <6 ar Ap≥ 6, an average of half hourly foF2 values for those days were obtained. This provided two sets of data for each month. And then, half hourly control medians for each day of the months were subtracted from the actually observed half hourly critical frequencies. Such control median values are referred as adjusted medians from now on.

Table 1 summarises the extreme values observed in the data. For example, in the spring equinox and in the June solstice the maxima in the KAND foF2 values were, observed around the sunset hours; whereas, the minima in the KAND foF2 values were observed just before the sunrise hours in general. However, in May the data recovery was poor after the sunset. Therefore, the smallest median values of 4.0 ± 2.1 MHz observed around 21:00(h) is believed not a reliable typical value. Unlike what was observed in May and June, the maximum values of KAND foF2 were observed just before the local noon during the autumn equinox. Summarising, in June and September the gradient between the daytime and nighttime KAND foF2 values is less than that of the observed in May and October 1993 as exhibited in Figure 1. It is interesting to note that the semiannual seasonal anomaly is observed in the October daytime median values of the KAND foF2 data.

Figure 2 facilitates a comparison of the recent KAND data with the data that had bee obtained in Istanbul (Bulat et al. 1963) between the years 1963 - 1966 which included minimum the solar cycle 20. The same analysis were extended with data between the years 1967, 1968 whe the ascending branch of the solar cycle took place. The 1993 KAND foF2 data were compared turn with those of 1963, 1964, 1965, 1966, 1967 and 1968 İstanbul foF2 data in order to see th solar cycle dependence of the ionosphere above Istanbul. As seen in Figure 2, there seems a positi linear dependence between the sunspot numbers, and the critical frequencies.

In order to compare the hourly monthly medians of the KAND data with other independent obtained data, Athens, Sofia and Rome which are geomagnetically very close to İstanbul wer chosen. The data from those cities were chosen from those years when the monthly averag sunspot numbers were similar to those of the 1993 values, in the descending branches of the sol cycles. Figures, 3 (a,b) show the results of this comparison for the almost equal solar activit intervals. As seen in this figure the KAND foF2 median values are somehow below th corresponding data of the other three stations.

(ii) Model Studies:

The objective of this section is to compare the observed İstanbul and KAND foF2 data in th years of 1966 and 1993 respectively for the months of May, June, September and October. Th model used here is MQMF2 model developed at the Institute for Applied Geophysics, Russi (Mikhailov et al. 1993). Figure 3 shows the results of this analysis. As seen in this figure th computed and the observed foF2 values are quite similar, in general with one exception in Octobe during daytime both in 1966 and 1993. In general, the agreement between the observed and th calculated data is the best in the pre-sunrise hours for May, June, September 1966 and for Ma September, October 1993. The disagreement between the observed and the model data is the wors during daytime or around dusk hours in September, October 1966 and in October 1993, magnitud wise. The computed values in October 1993 are lower than those of the measured ones durin daytime compared with those of the October 1966 data. This discrepancy arises mainly, since th predicted values of the MQMF2 in October 1966 are higher in magnitude than those of the Octobe 1993.

The MQMF2 model was developed by using ionospheric data which did not include neithe Istanbul nor Kandilli (Mikhailov et al. 1993). Therefore, this independent check of the model wit experimental data proves to be promising.

Acknowledgement: The authors would like to thank Dr. A.V. Mikhailov who provided the MQMF model and Mr. H. Sizun who provided some data from the COST 238 data base. Thanks are due t TUBITAK EEEAG for supporting the COST 238: PRIME Project. The last but not the least thank are also due to Prof.Dr. A.M. Işıkara for providing administrative support for the experiment to b realized on the Campus of the Kandilli Observatory. The text was typed by Gülhakiye Cangül.

References:

BULAT, T. et al.: (1963-1969) Ionospheric Data, Publication of Istanbul Univ. Ionospheric Research Center.

MIKHAILOV, A.V., MIKHAILOV, and M.G. SKOBLIN, M.G. (1993) Monthly median foF2 and M(3000)F2 ionospheric model over Europe, *Preprint of Institute for Applied Geophysics, Russia.*

ROKICKI A, I., ZBYSZYNSKI, STANISLAWSKA, Z., Tulunay, Y., Özgüç, A., Ataç, T., Altay, L., and Barlas, B.(1993) *Proceedings of PRIME COST 238 Workshop, Graz*, pp.297

HANBABA, R., (1993) *Catalogue No:3 of European Ionosonde Data in the COST 238 Databank*, Publicaciones del Observatorio del Ebro, Memoria No. 16, Roquetes,(Tarragona) Spain.

Figure Captions:

Figure 1 : The superimposed diurnal median values obtained at the KAND station during May, June, September and October 1993.

Figure 2 : The diurnal variations of the monthly median values obtained in Istanbul (a) during 1963 - 1965 and 1993; (b) during 1966 - 1968 and 1993.

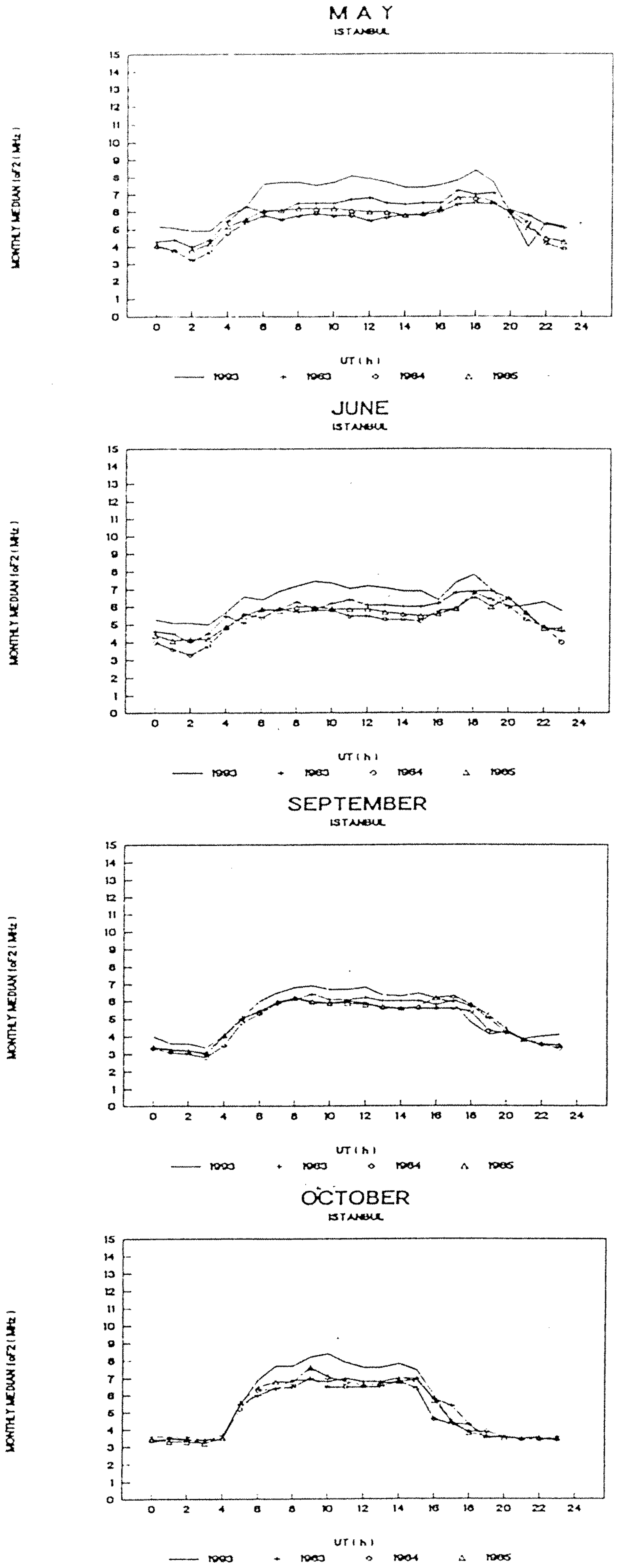
Figure 3 (a,b). : The diurnal variation of the monthly median values obtained in Rome (1983); Sofia (1972 and 1983); Athens (1972 and 1983) and KAND (1993) at similar solar cycle conditions.

Figure 4 : The comparison between the observed foF2 data in İstanbul (1966) and KAND (1993) with those of the computed MQMF2 model (Mikhailov et al. 1993).

TABLE 1

Some statistical values of the observed KAND foF2 data

1993 MONTH	Sunrise Sunset		Max. median Value		Min. median value		Extremes of obs. values	
	UT (h)	UT (h)	UT (h)	foF2 (MHZ) ± 1sd.	UT (h)	foF2 (MHZ) ± 1sd.	UT (h)	foF2 (MHZ)
MAY	03:00	17.30	17:30	8.5 ± 1.2	02:00	4.9 ± 0.7	17:30 - 03:30	10.6 - 2.9 = 7.7
JUNE	02:30	17.30	17:30	7.9 ± 0.9	02:30	5.0 ± 0.6	17:30 - 01:00	9.4 - 3.5 = 6.9
SEPTEMBER	03:30	16:00	09:30	7.0 ± 0.8	03:00	3.4 ± 0.3	07:30 - 23:00	9.4 - 2.7 = 6.7
OCTOBER	04:30	15:30	09:30	8.6 ± 1.2	03:00	3.2 ± 0.4	10:00 - 22:30	11.3 - 2.4 = 8.9



1993 1963 1964 1965

Figure 2 (a) : The diurnal variation of the monthly median values obtained in İstanbul during 1963-1965 and 1993.

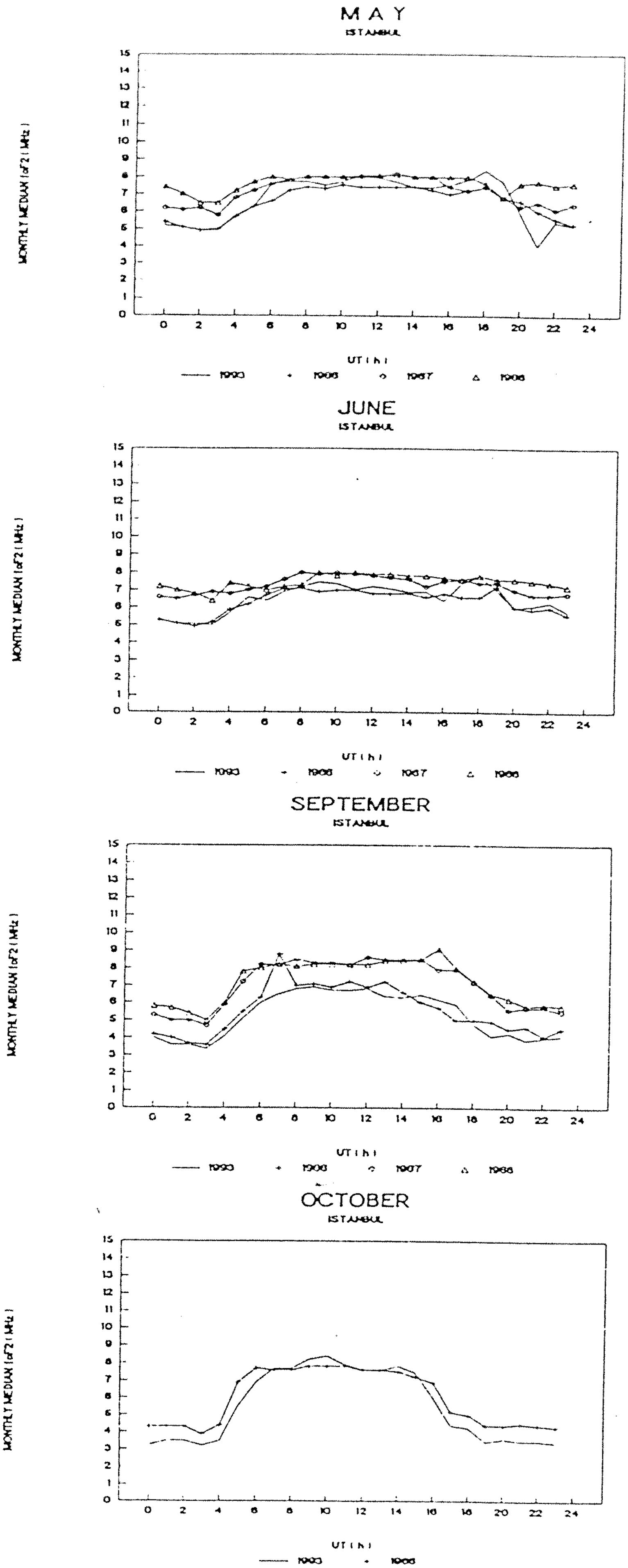


Figure 3 (b) : The diurnal variation of the monthly median values obtained in İstanbul during 1966-1968 and 1993.

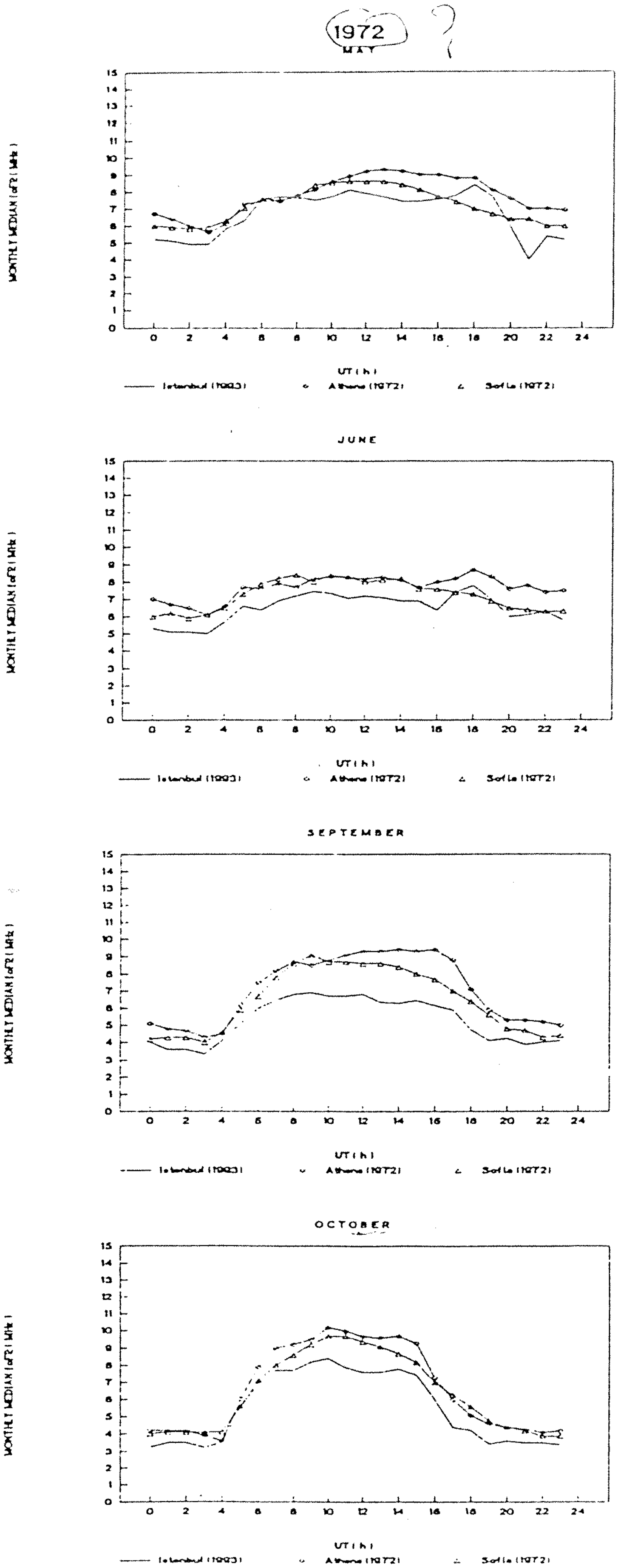


Figure 3 (a) : The diurnal variation of the monthly median values obtained in Rome (1983); Sofia (1972 and 1983); Athens (1972 and 1983) and KAND (1993) at similar solar cycle conditions.

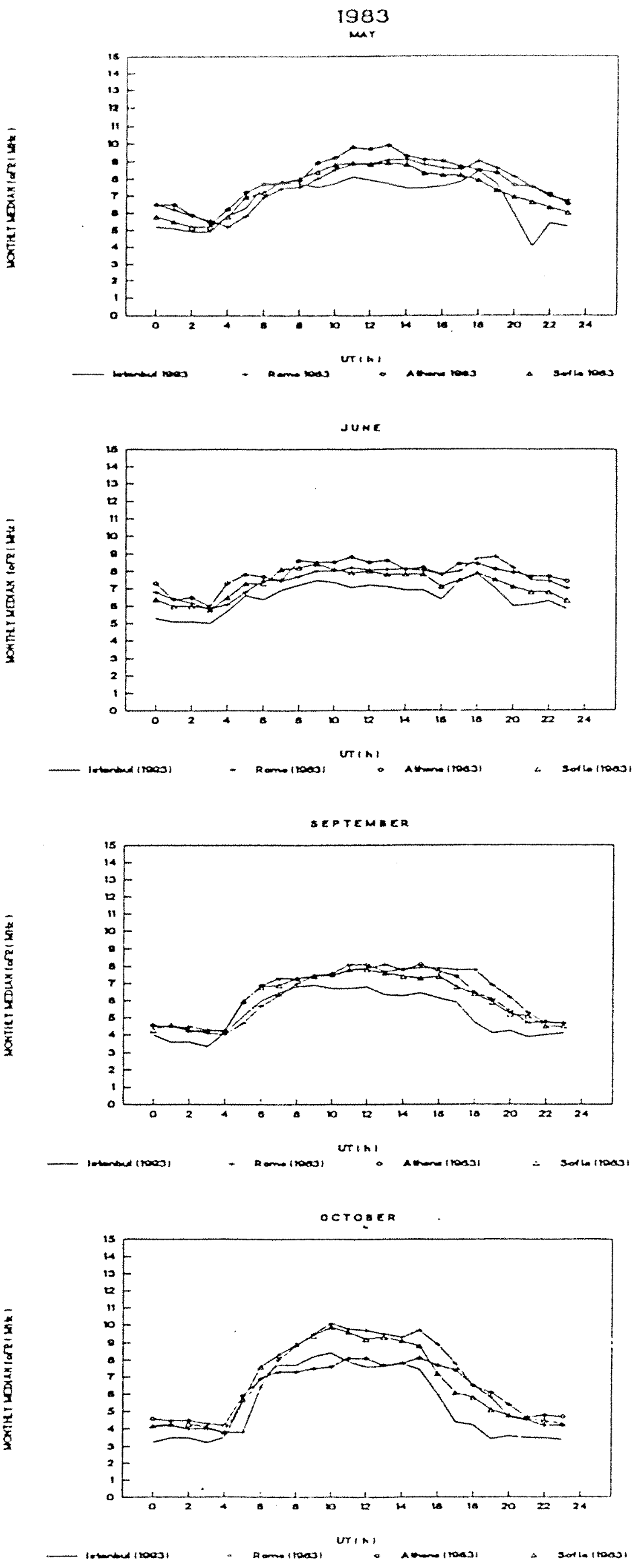


Figure 3 (b) : The diurnal variation of the monthly median values obtained in Rome (1983); Sofia (1972 and 1983); Athens (1972 and 1983) and KAND (1993) at similar solar cycle conditions.

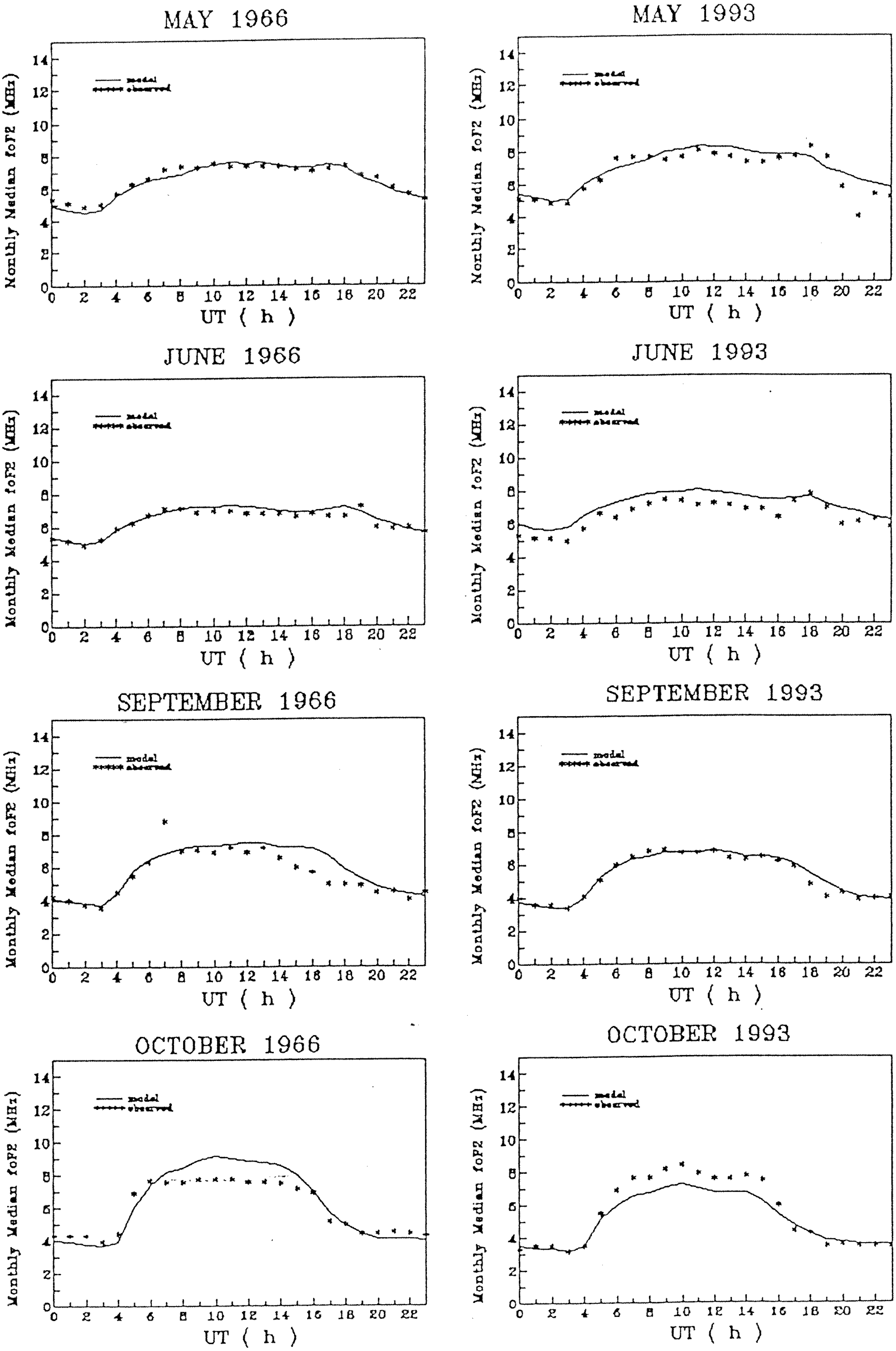


Figure 5: The comparison between the observed foF2 data in İstanbul (1966) and KAND (1993) with those of the computed MQMF2 model (Mikhailov, et al. 1993).

THE IONOSPHERIC foF2 DATA OVER ISTANBUL AND THEIR RESPONSE TO SOLAR ACTIVITY FOR THE YEARS 1963-1969 AND 1993

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Abstract:

A Polish make vertical ionosonde (VI) has been operated at the Kandilli Observatory in Istanbul, almost for one year (May 1993 - April 1994) as a part of PRIME COST 238 project. The critical frequencies have been obtained for every half hour intervals. The data obtained with this campaign, at the descending branch of the solar cycle 22, and the data measured earlier in Istanbul for the whole cycle 20 were analysed and the characteristic behaviour of the F2 region ionosphere over Istanbul has been determined. Then several markers of the solar cycle activities in terms of the monthly relative sunspot numbers, F10.7 cm solar radio flux and solar flare index, and the magnetic daily index of Ap have been employed. in order to seek the possible influence of the solar and ionospheric activities on the critical frequencies obtained in Istanbul. As a result, to take solar flare index as a solar activity index is more reliable for the determination of the quiet ionospheric days. It is shown that to make ionospheric prediction and modelling to take the minimum and the maximum time values of the solar activity is more convenient.

1. INTRODUCTION

It is well known that the ionospheric electron density of the F2 layer and thus the critical frequency foF2 depend strongly on solar activity. However, the law of this dependence is not yet established neither the index of solar activity to be used. It is customary to use sunspot number as an index of solar activity, although several other indices, solar or ionospherically derived, are also used. Although the sunspot number seems to be convenient for use because of its long series of reliable observations; but some other indices are available regularly since some decades already. Lastovicka (1993) emphasised the necessity of taking into account the solar flares, particularly in short-term prediction of ionospheric radio propagation. He added that although solar flares are relatively rare phenomena, they considerably affect the whole ionosphere, some times making radio wave propagation impossible.

All solar indices show the 11-year solar cycle and their behaviours with respect to foF2 seems to be virtually identical. On the other hand, Mikhailov et al. (1992) stated that a one to one correspondence could be obtained if an ionospherically derived index is used. Sizun (1992) suggests that a second-degree polynomial should be used separately for the rising and falling parts of the solar cycle to account for saturation and hysterisis effects. Kane (1992) reported to use a multiple regression equation of two variables, one being a solar index and the other the geomagnetic Ap index; but he concludes that even solar flux and Ap together do not explain the foF2 variations.

In this study, we compare some solar indices with Ap index, to show which is more convenient for taking as a solar index for the ionospheric studies. Further more, we examine foF2 values for the different phases of 11-year solar activity cycle.

2. DATA AND ANALYSIS

A Polish make vertical ionosonde (VI) has been operated at the Kandilli Observatory in Istanbul, almost for one year (May 1993 - April 1994) as a part of PRIME COST 238 project. In this study, we use two sets of ionospheric data; for the years between 1964-1969, the data measured by Istanbul University, Geophysics department, and for the year 1993, the data measured by Boğaziçi University, Kandilli Observatory (Rokicki et al. 1993). For solar indices we use daily Zurich sunspot numbers (Rz), daily solar radio flux measured at 10.7 cm (Sf), and daily solar flare index (Fi). The flare index, which was firstly introduced by Kleczek (1952),

$$Q = i \cdot t,$$

gives roughly the total energy emitted by the solar flare. In this relation, i represents the intensity scale and t the duration (in minute) of a flare. The year of 1964 corresponds to the minimum of solar cycle 20 while the year of 1969 corresponds the maximum time of the same cycle. The year of 1966 and the year of 1993 represent the ascending branch of cycle 20 and the descending branch of the cycle 22, respectively. We choose the ionospheric quiet day by assuming when the geomagnetic daily index of Ap is less than 6. We examine those quiet days by comparing Ap index versus daily solar indices. Ap index, as well as the other two solar indices Rz and Sf were taken from "Solar-Geophysical Data, prompt reports". The solar flare index was calculated by ourselves.

Total number of quiet days for the time interval which we studied is 1583 days. Relations of the geomagnetic activity with the solar activity is shown in Figure 1. In this figure Ap index is compared with Rz, Fi, and Sf values in three dimensional form. In Figure 2, hourly medians of foF2 values are plotted as a function of time for the four epoch months (e.g. March, June, September, and December). Left panel of this figure shows the minimum and the maximum epochs of solar cycle 20, and the right panel shows the ascending branch of cycle 20 and descending branch of cycle 22.

3. RESULTS AND DISCUSSION

In this study we try to show which solar activity parameter is more convenient for the ionospheric prediction. If we examine Figure 1, we see that for the ionospheric quiet days ($Ap < 6$), only the Fi values stand between little Ap values. Rz and Sf indices show mostly equal distribution between 0-5 Ap values. This means that, even if a geomagnetic activity index is less, in some of those days, some more sunspot groups may be observed on the sun; and those sunspot groups may emit radio flux in a high rate, but may not produce flare. Thus we may obtain a little Ap index but a high Rz and Sf values. Although Kouris et al. (1993) reported that the behaviour of the monthly-median values of the critical frequency of the F-layer, foF2, with respect to any index of solar activity may be used, but to determine an ionospheric quiet day only solar flare index value, Fi, seems more reliable, because of its distribution between low Ap (0-5) values (see Figure 1). Therefore we can conclude that solar flare index is more convenient solar activity parameter to use in ionospheric prediction and modelling.

During the ionospheric quiet days (Ap < 6), of course, solar activity should be very low. Hourly median foF2 values of those days are plotted as a function of time for some specific epochs of solar cycle 20 and 22. In Figure 2, at the left panel which shows the minimum (1964) and the maximum (1969) epochs of solar cycle 20, the medians of foF2 of the maximum epochs are always 2-3 MHz higher than the minimum epoch's ones. In contrary, during the ascending (1966) and the descending (1993) epochs the medians of foF2 show almost the same values. This result is not in agreement with Sizun's (1992) findings. He reported that a second-degree polynomial should be used separately for the rising and the falling parts of solar cycle. Because of the difference of the duration rate of sunspot groups on the ascending and the descending parts of solar cycles, to take sunspot numbers as a solar activity index, may be caused this discrepancy. Therefore, instead of the ascending and the descending branches of the solar cycle activity, we should use the maximum and the minimum epoch values as solar activity index for the prediction and the modelling of the ionosphere.

Acknowledgement: This work was partially supported by TUBITAK and Boğaziçi University, Research fund. Solar flare, solar radio flux, sunspot and Ap index data used in this study were provided by WDC-A for Solar-Terrestrial Physics, NOAA E/GC2, 325 Broadway, Boulder Colorado 80303, USA.

References

Kane, R.P., Solar cycle variations of foF2, J. Atm. Terr. Phys. 54, 1201-1205, 1992.

Kleczek, J., The calculation of solar flare index, Publ. Centr. Inst. Astron. No. 22, Prague, 1952.

Kouris, S. S., L.F. Alberca, E.M. Apostolov, R. Hanbaba, Th. D. Xenos, and B. Zolesi, Proposals for the solar-cycle variation of foF2 (Part II), in PRIME Studies with emphasis on TEC and Topside Modelling, 89-90, Graz University, Graz, 1993.

Lastovicka, J., Solar flare occurrence and ionospheric disturbances, in PRIME Studies with emphasis on TEC and Topside Modelling, 229-235, Graz University, Graz, 1993.

Mikhailov, A., and V. Mikhailov, A new ionospheric index, in Proceedings of the PRIME/URSI, Memoria 16, 218-221, 1992.

Rokicki, A, I. Stanislawska, Z. Zbyszynski, Y. Tulunay, A. Özgüç, T. Ataç, L. Altaş, and O. Barlas, First results from the transportable ionosonde campaign, in PRIME Studies with emphasis on TEC and Topside Modelling, 229-235, Graz University, Graz, 1993.

Sizun, H. Influence of solar activity to foF2 values, in Proceedings of the PRIME/URSI, Memoria 16, 205-217, 1992.

FIGURE CAPTIONS

Figure 1. The distribution of the solar activity indices on the chosen ionospheric quiet days (Ap < 6). Fi indicates daily solar flare index, and Rz, shows daily Zurich sunspot numbers, and Sf, daily solar radio flux (10.7 cm).

Figure 2. Hourly medians of foF2 values on the chosen ionospheric quiet days, for the four epochs of a solar activity cycle.

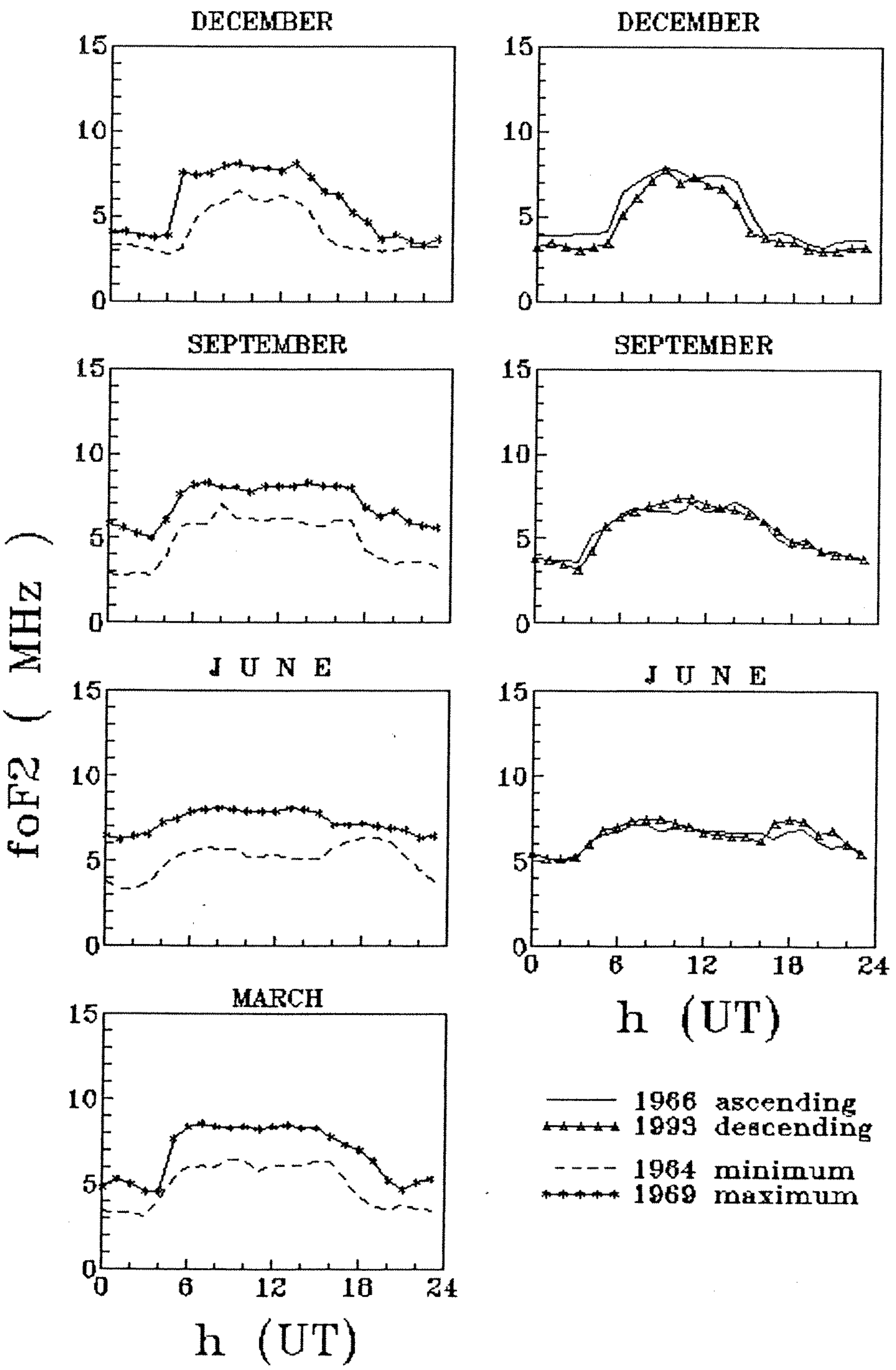

DECEMBER
SEPTEMBER
J U N E
MARCH
foF2 (MHz)
h (UT)
0
6
12
18
24
5
10
15
1966 ascending
1993 descending
1964 minimum
1969 maximum

Fig. 2

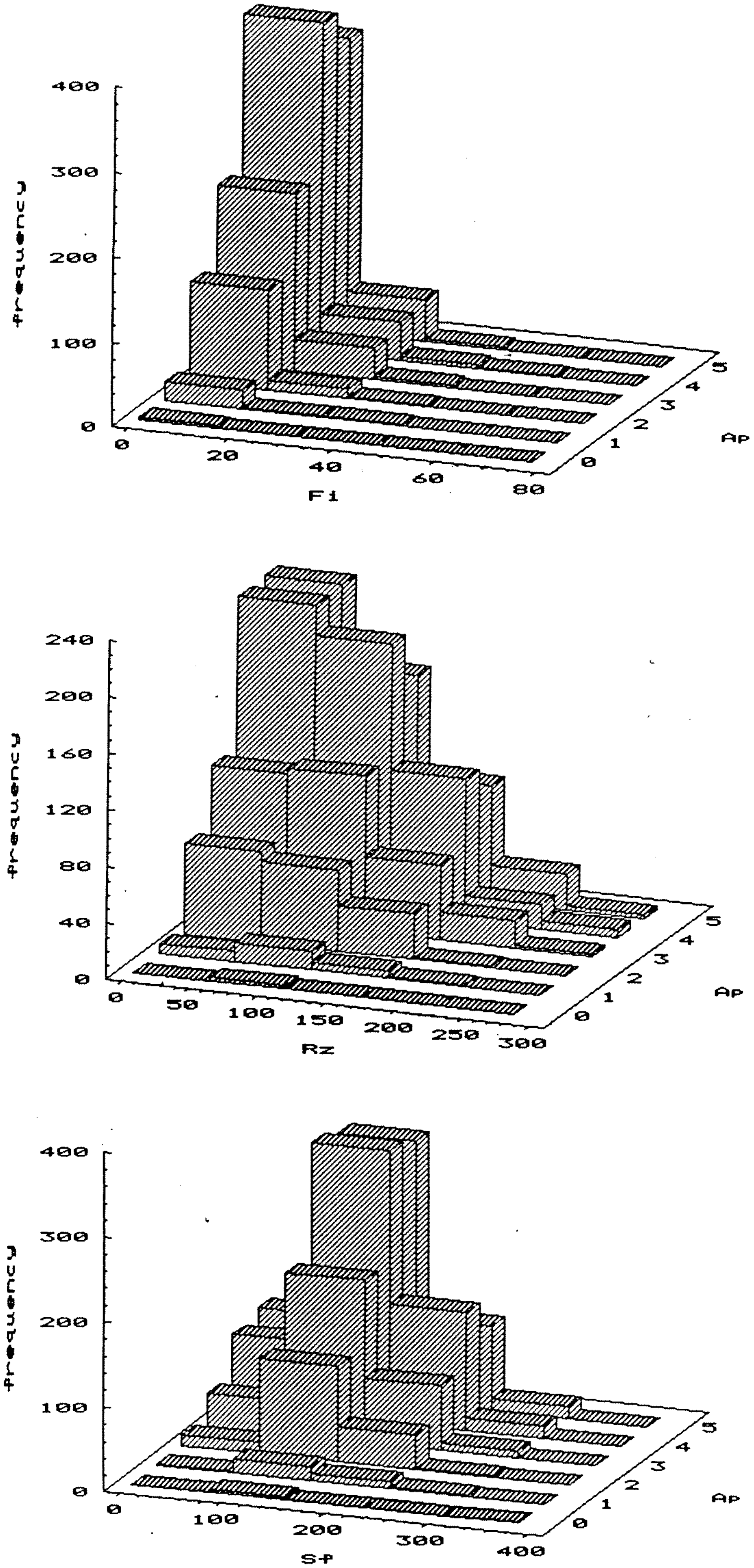
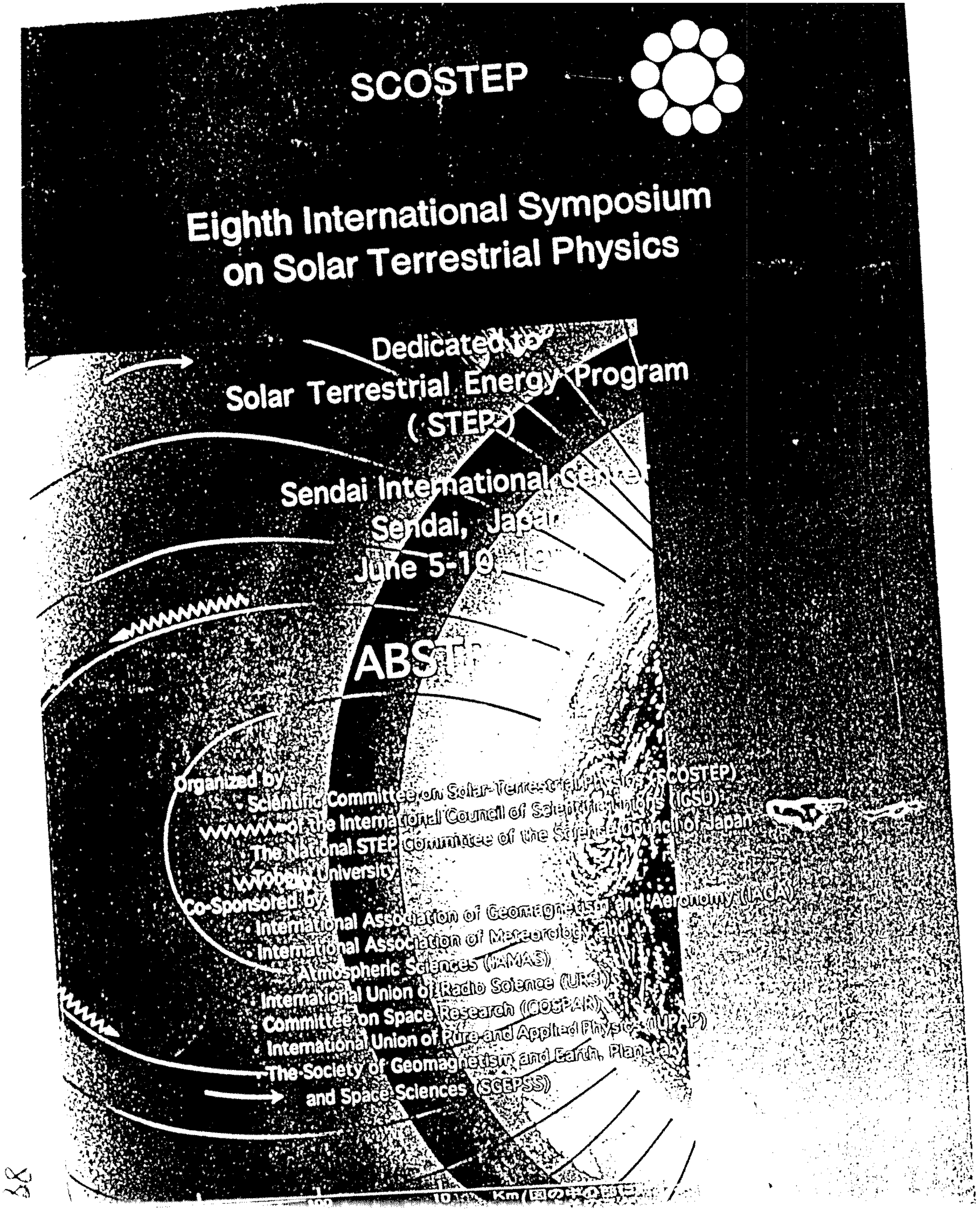

400
300
200
100
0
frequency
0
20
40
60
80
Fi
0
1
2
3
4
5
Ap
240
200
160
120
80
40
0
frequency
0
50
100
150
200
250
300
Rz
0
1
2
3
4
5
Ap
400
300
200
100
0
frequency
0
100
200
300
400
Sf
0
1
2
3
4
5
Ap

Fig. 1



PD3-013

THE IONOSPHERIC foF2 DATA OVER ISTANBUL AND THEIR RESPONSE TO SOLAR ACTIVITY FOR THE YEARS 1963 - 1969 AND 1993

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A Polish make vertical ionosonde (VI) has been operated at the Kandilli Observatory in Istanbul, since 8 May 1993. Since then the critical frequencies have been obtained for every half hour intervals. The data obtained at the descending branch of the solar cycle 22, were analysed and the characteristic behaviour of the F2 region ionosphere over Istanbul has been determined. Then several markers of the solar cycle activities in terms of the monthly relative sunspot numbers, solar flare index, F10.7 cm radio flux and the magnetic daily index of Ap have been employed. in order to sook the possible influence of the solar and ionospheric activities on the critical frequencies obtained in Istanbul. The preliminary analysis of the results hint the possibility of a positive correlation between high solar activity and the critical frequencies. In order to facilitate a comparison between the observed and predicted values of the foF2, a model MQMF2 (Mikhailov et al. 1993) was adopted and the validity of the observations and the solar cycle effects have been discussed from both experimentally and theoretically obtained diurnal variation of the data under consideration. The possible influence of the magnetic disturbances have been sought by employing the magnetic Ap and solar flare indices.

Mikhailov, A.V., Mikhailov, V.V., and Skoblin, M.G.:1993, Pre-print of Institute for Applied Geophysics, Russia.

COST238(PRIME)
EINDHOVEN 16 MY 1994

LOCAL MODEL OF THE IONOSPHERE ABOVE ISTANBUL

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ABSTRACT

The paper presents the first, very rough model of foF2 parameter above Istanbul. This model is based upon monthly medians foF2 measurements made during almost one year PRIME campaign at the campus of Kandilli Observatory in Istanbul, since 6 May 1993 until 21 April 1994.

INTRODUCTION

The monthly medians foF2 measurements made during almost one year PRIME campaign at the campus of Kandilli Observatory in Istanbul, since 6 May 1993 until 21 April 1994, were the base for ionospheric model above Istanbul (Rokicki et al., 1993). Model describes foF2 parameter in the spherical-harmonics mapping expressions. The performed representation of the foF2 values depends on the daily time T and seasonal time Y (Stanisławska et al. 1991).

$$foF2 = f(Y,T) \qquad where \quad Y \in (0, 2\Pi),\ T \in (-180, 180)$$

$$f(Y,T) = a_o(Y) + \sum_{j=1}^{N_j} [a_j(Y)\cos(jT) + b_j(Y)\sin(jT)]$$

$$b_j(Y) = C_{j,o} + \sum_{k=1}^{N_k} [C_{j,k}\cos(Y) + D_{j,k}\sin(Y)]$$

$$a_j(Y) = A_{jo} + \sum_{k=1}^{N_k} [A_{j,k}\cos(kY) + B_{j,k}\sin(kY)]$$

The best order of every regression is found from the analysis of the equation.

$$\sigma_m = \frac{\delta_m^2}{n-m-1} = minimum$$

RESULTS

The ionograms provided by Kandilli Observatory every 15 minutes, half hourly, or hourly intervals were elaborated in Space Research Centre in Warsaw. Till now not all parameters were elaborated. The list of considered medians is presented in table I. Months from May until December 1993 are take for model calculations, while the rest of mont from 1994, since January until April are used for testing.

Table I. The list of considered medians and respective measurement intervals.

Month	Intervals
May	Half hourly
June	hourly
July	hourly
August	half hourly
September	half hourly
October	hourly
November	half hourly
December '93	half hourly
January '94	half hourly
February	half hourly
March	half hourly
April	half hourly

For this analysis parameter σ_m were calculated until the proper m is found for which σ_{m+1}, σ_{m+2} are not much different than σ_m. In that case m is chosen as the best order of the approximating polynomial.

Table I σ_m calculated for every month and for different order of N_j since 1 to 6.

Month \ N_j	1	2	3	4	5	6
May	36.17	17.45	14.62	5.46	4.96	4.71
June	22.67	8.63	8.26	6.20	3.75	1.97
July	19.20	7.88	7.14	3.50	2.68	2.36
August	38.12	12.91	12.89	6.60	5.85	4.98
September	19.79	16.91	5.61	4.97	3.68	3.01
October	37.95	32.14	11.62	10.65	6.55	2.64
November	44.17	15.88	12.77	7.64	7.83	3.49
December	50.61	11.16	10.69	5.01	4.23	2.47

Table III σ_m calculated for every set of daily time approximating coefficients for seasonal order N_k since 1 to 3.

Time \ Season	1	2	3
Time approx. 1	11.98	3.42	5.34
	13.40	2.72	3.29
	17.41	5.39	9.80
Time approx. 2	11.97	3.36	5.50
	13.37	2.65	3.21
	17.52	5.59	9.32
	3.17	0.94	0.77
	5.77	4.33	7.39
Time approx. 3	11.97	3.37	5.49
	13.37	2.65	3.21
	17.52	5.58	9.33
	3.17	0.95	0.77
	5.76	4.33	7.40
	3.13	1.57	0.22
	5.34	4.04	2.54
Time approx. 4	11.97	3.38	5.45
	13.38	2.67	3.24
	17.49	5.53	9.46
	3.18	0.95	0.79
	5.72	4.30	7.51
	3.14	1.55	0.25
	5.35	4.06	2.60
	2.47	3.04	1.78
	1.82	4.14	0.01
Time approx. 5	11.97	3.38	5.47
	13.38	2.66	3.22
	17.50	5.55	9.41
	3.18	0.95	0.78
	5.74	4.31	7.45
	3.13	1.56	0.24
	5.34	4.05	2.58
	2.50	3.00	1.50
	1.81	4.08	0.01
	1.41	0.89	0.09
	1.03	0.59	1.36
Time approx. 6	11.97	3 37	5.48
	13.38	2.66	3.22
	17.50	5.56	9.39
	3.17	0.95	0.78
	5.74	4.32	7.45
	3.13	1.56	0.23
	5.34	4.05	2.57
	2.51	2.98	1.50
	1.80	4.05	0.01
	1.41	0.89	0.09
	1.03	0.59	1.36
	0.97	1.42	1.20
	2.05	0.96	2.52

Table II presents results (σ_m) of daily time approximation of foF2 during different months for the daily time order N_j since 1 to 6. Seasonal approximation is analyzed for the seasonl time order N_k since 1 to 3, for every order of daily time approximation. Results are presented in table III. Quiet good approximation for daily time is around 4, however for October is 5. So the best order is 5. The best seasonal time approximation is 2. Even if the order is growing the accuracy of approximation becomes worst. In that case the number of coefficients is 55. Two examples of calculations of foF2 using the chosen set of coefficients are presented at figures 1 and 2. foF2 is calculated for February and March 1994. The percentage deviation of the model from the obtained medians for these months gives relatively high values; 73% and 49% respectively. However from a such small amount of data none can expect better results. This paper presents only the first step of analysis based upon the medians, rather the method than results. The main stress is pushed to the analysis how is the method for coefficients obtaining not to real results.
The presented model has many disadvantages. The most important one is lack of solar activity dependence. This will be the next step of our investigations.

REFERENCES

Rokicki, A., I.Stanisławska, Z.Zbyszyński, Y.Tulunay, A.Ozguc, T.Satac, L.Atlas, O.Barlas, (1993), First results from the transportable ionosonde campaign, PRIME studies with emphasis on TEC and topside modelling, Universitaet Graz, Austria, 1993.

Stanisławska I., Z.Kłos, K.Stasiewicz, (1991), Local Model of the ionosphere based upon ata from Miedzeszyn Station, Working Book, III Workshop PRIME, Instituto Nazionale di Geofisica, 161-164.

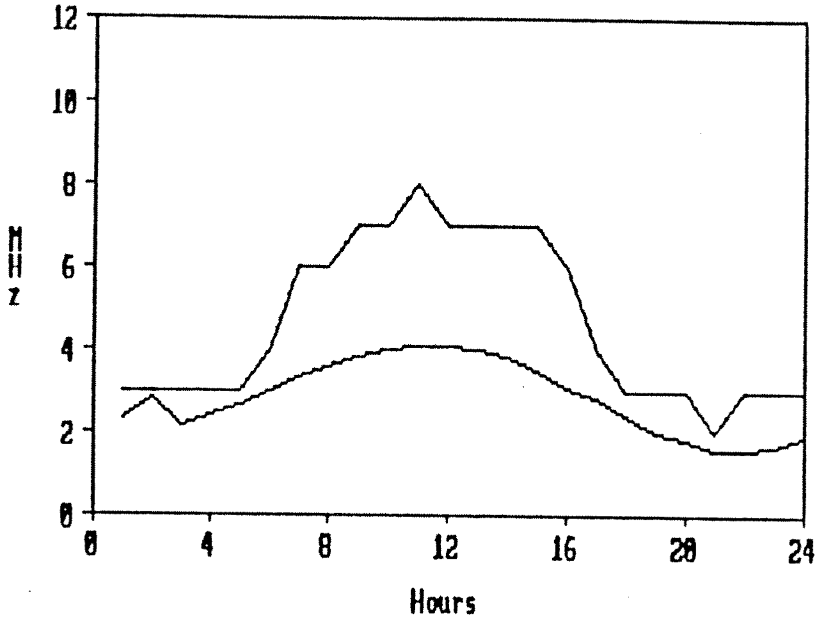

Figure I. Median and modelled values for February 1994.

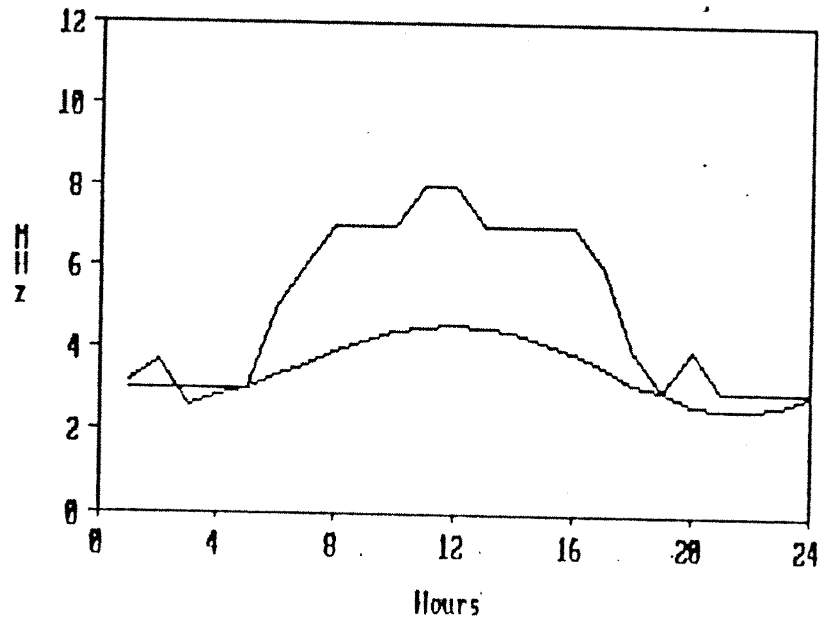

Figure II. Median and modelled values for March 1994.

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COST 238 (PRIME) 'WORKSHOP ON
PRIME STUDIES AND TOPSIDE
MODELLING'
GRAZ, AUSTRIA, 10 TO 12 MAY 1993

Poster paper

A049 'Turkish TEC data from measurements in Ankara' (WP-7a)

Kritik Frekansın (FoF2) Güneş Aktivitesine Bağımlılığı

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GİRİŞ

Dünya atmosferi, iyonize bileşenlerinin ve nötral gazların kimyasal ve termik özelliklerine bağlı olarak bir çok katmana ayrılmıştır. Üst katmanlarından biri olan iyonosfer de kendi içerisinde D, E, F_1, F_2 olmak üzere dört ayrı bölgeye ayrılmıştır. İyonosferde termik enerjili iyon ve elektronların sayısı çok fazladır. Bu durum elektromagnetik dalgaların yayılmasını güçlendirmektedir. Atmosferin nötral bileşenlerinin iyonizasyonu atmosfere giren güneş ışınımının etkisiyle olmaktadır, bu duruma bağlı olarak iyonosferdeki elektron yoğunluğu; bulunulan yerin enlemine, gece ile gündüze, mevsimlere ve ayrıca güneşin aktivite çevrimlerine bağlı olarak değişmektedir.

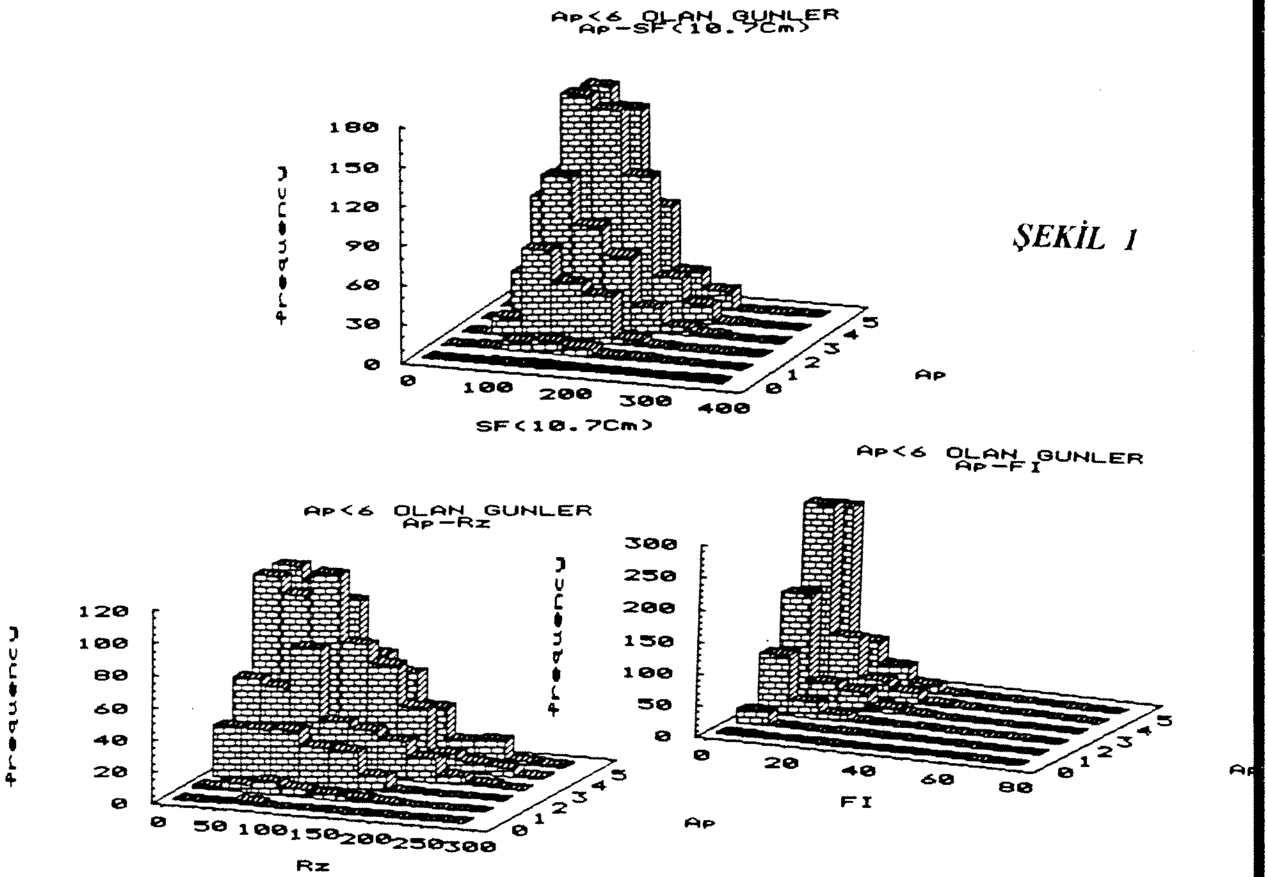
Gezegenimiz üzerinde gerek uluslararasında gerek uzayla yapılan haberleşmelerde iyonosfer önemli rol oynamaktadır. Avrupa ülkelerinin katıldığı PRIME COST 238 adlı projeyle İstanbul da dahil olmak üzere Avrupa kıtası üzerindeki iyonosfer modelini oluşturmak için, Mayıs 1993' den Nisan 1994' e kadar B.Ü.Kandilli Rasathanesinde Polonya Uzay Bilimleri Merkezine ait dikey İyonosonda aracı ile iyonosferik parametreler ölçüldü. Söz konusu parametrelerden biri olan kritik frekans "foF2", F_2 tabakasının yansıtabildiği en yüksek frekans olup haberleşme sırasında çok önemli rol oynamaktadır. 19. Güneş aktivite çevrimi (1954-1964) için Kane (1992) çevrimin çeşitli göstergeleri olan değişik indislerle foF2 nin ilişkisini araştırmış ve bu iyonosferik parametrenin doğrudan güneş aktivitesi ile ilişkili olduğunu göstermiştir. Öte yandan Gulyaeva (1993) jeomagnetik aktivitenin düşük olduğu günlerde iyonosferin sakin iyonosfer olarak tanımlanabileceğini belirtmektedir. Bu çalışmada 1964 ile 1969 yılları arasında İstanbul Üniversitesi Jeofizik bölümünün İstanbul'da yaptığı ölçümler ve Mayıs 1993 den Nisan 1994 sonuna kadar B.Ü.Kandilli Rasathanesinin ölçüm sonuçları kullanılarak İstanbul üzerindeki iyonosfere ait foF2 değerlerinin güneş aktivitesinin en düşük olduğu günlerde, güneş aktivite çevrimi ile ilişkisi araştırıldı.

GÖZLEMLER VE ANALİZ

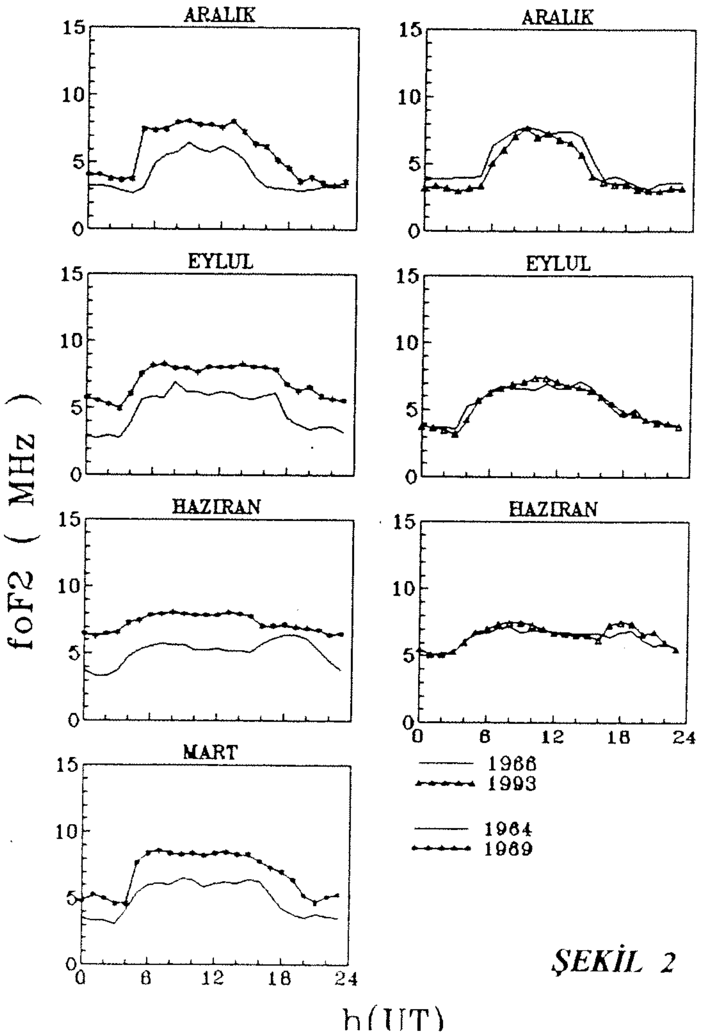
Jeomagnetik aktivite indisi Ap Dünya üzerindeki standart istasyonlardan ölçülen yerel magnetik alanın H, D, ve Z bileşenlerinden itibaren hesaplanır. Bu bileşenlerde bir saat içerisinde gözlenen en şiddetli değerler seçilerek bunların üç saatlik zaman aralıkları için ortalamaları alınır. Bu değerlerin günlük ortalamasıda o günün global Ap indisini oluşturmaktadır.

Çalışmamızda Ap indisinin 6 dan küçük olduğu günlerde iyonosferin sakin olduğu kabul edildi. O günler için güneş aktivitesininde durumunu görmek üzere üç ayrı güneş aktivite indisinin o günlerdeki değerleri ele alındı. Çevrimlerin uzun dönemli değişimleri ile ilgili bilgi edinmede genellikle güneş leke sayılarından ve güneşin 10.7'Cm de ölçülen radyo akısından oluşturulan indisler kullanılmaktadır. Bunun yanısıra iyonosferdeki elektron yoğunluğunu doğrudan etkilediğini bildiğimiz güneş fler aktivitesi içinde indisler oluşturulmuştur. Çalışmamızda kullandığımız bu indislerden güneş leke sayıları R_z ve güneş radyo akısı SF 10.7Cm ve jeomagnetik aktivite indisi Ap için günlük değerler "Solar-Geophysical Data prompt reports" dan alındı. Kleczek'in (1952) oluşturduğu yöntemle hesaplanan güneş fler indisi çalışmamızda gözönüne aldığımız yıllar için Knoska ve Petrasek (1984) ve Ataç (1987) tarafından hesaplanmıştır. Fler indisi Fİ içinde günlük değerler bu kaynaklardan alındı. Ele aldığımız 1964, 1969 ve 1993 yılları 20. güneş çevriminin çıkış kolu ile 22. güneş çevriminin iniş koluna denk düşmektedir. 1964-1969 ve 1993 yılları süresince Ap<6 olan günlerin sayısı 1583 olarak tespit

(9. Ulusal Astronomi Toplantısı, 5-7 Eylül 1994)
ODTÜ, Ankara



ŞEKİL 1



ŞEKİL 2

edildi. Bu günlere ait güneş aktivite indisleri ile jeomagnetik aktivite indisinin ilişkisi Şekil 1 de gösterildi. Öte yandan aynı günlerde ölçülen foF2 değerlerinin saatlik ortalamaları mevsim dönümlerine denk düşen aylar Mart, Haziran, Eylül ve Aralık ayları için hesaplandı. Bu hesaplarda kullanılan foF2 değerleri 1964, 1966, 1969 yılları için İstanbul Üniversitesi, 1993 yılı içinde B.Ü. Kandilli Rasathanesi kaynaklarından alındı. Elde edilen sonuçlar Şekil 2'de gösterildi.

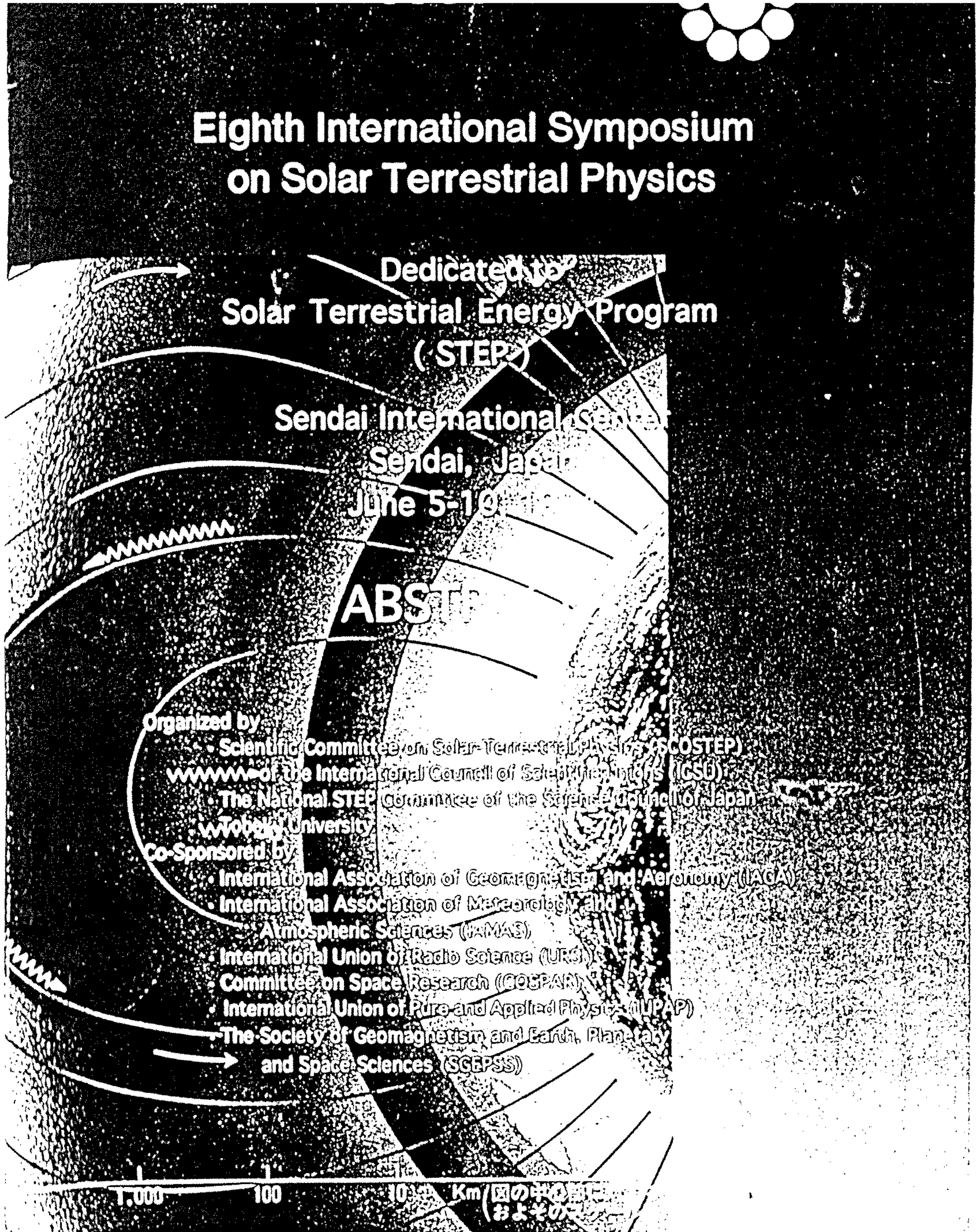
SONUÇLAR VE TARTIŞMA

İyonosfer için sakin günler olarak kabul ettiğimiz Ap<6 olan günlerde güneş aktivite indislerinden sadece fler indisinin kendi ölçeği içerisinde en küçük değerlere yığıldığı Şekil 1'den görülmektedir. Bu karşılaştırma sırasında diğer iki indisi gözönüne aldığımızda durum değişmekte, yığılma neredeyse bütün değerlere eşit olarak dağılmaktadır; yani jeomagnetik aktivite indisi Ap<6'da olsa böyle günlerin bir kısmında güneş yüzeyinde fazla sayıda leke görülmekte ve yüksek oranda radyo akısı gelmekte ama o günlerin hemen hepsinde fler olayı çok az meydana gelmektedir.

Güneş aktivitesinde günlük ani değişimleri en iyi belirleyen indis fler indisidir. Bu bağlamda jeomagnetik aktivite indisinden itibaren belirlediğimiz sakin günlerde güneş aktivitesi de en sakin durumundadır. Seçilen bu sakin günler için ölçülmüş foF2 değerleri 20. güneş çevriminin minimum evresi 1964 yılı, maksimum evresi 1969 yılı, çıkış kolunun ortası 1966 yılı ve 22. güneş çevriminin iniş kolunun ortası 1993 yılı için Şekil 2'de karşılaştırıldı. 1969 yılına ait ayların foF2 değerlerinin 1964 yılınınkilerden 2-3 MHz daha büyük ölçüldüğü görüldü. Öte yandan 1966 yılı ile 1993 yılında ölçülen foF2 değerlerinin Şekil 2' den de görüleceği üzere aynı aylar için hemen hemen aynı gidimde olduğu bulundu. Bu da bize güneş aktivite çevrimleri süresince maksimum evrede iyonosferin iyon yoğunluğu bakımından belli bir doygunluğa ve çevrimlerin iniş ve çıkış kollarının aynı evresinde aynı mertebede olduğunu göstermektedir. Bu durumun iyonosferik parametrelerin önceden belirlenmesi sırasında önemle gözönüne alınması gerektiği açıkça ortaya çıkmaktadır.

KAYNAKLAR

Ataç,T.:1987, Astrophys. and Space Science 135,201-205.
Bulat,T. ve diğ.:1963-1969,Publication of Istanbul Univ. Ionospheric Research Cen. Ionospheric Data.
Gulyaeva,T.:1993, Prime Cost 238 Workshop part I, 129136.
Kane, R.P.: 1992, J.atmos.Terr.Phys. 54,1201.
Kleczek,J:1952,Publ.Centr.Astron.Inst. Czechoslovakia, No.22
Knoska,S.and Petrasek,J.:1984,Contr.Astron.Obs.Skalnate Pleso 12, 165.



AD3-002

IONOSPHERIC VARIABILITY OVER ISTANBUL

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At a given time-of-year and phase in the solar cycle, the ionosphere exhibits regular diurnal, seasonal variations at mid-latitudes as plasma co-rotates with the Earth. In order to study the day-to-day variability of the foF2 about these regular diurnal variations, some form of "quite-time" diurnal variation must be subtracted from the variations observed. In order to achieve this, for each hourly value of foF2 all quite-time soundings with 15 days of the sounding in question were identified; quite-time values were identified as when the simultaneous magnetic Ap index was less than 6. The mean quite-time value at the same UT was then subtracted from the value actually observed; the resulting value is here termed δfOF2 (Tulunay et al. 1991, Hapgood et al. 1991, and Lockwood et al. 1993).

Using critical frequencies, foF2 from several PRIME ionosonda stations covering a geographic area (35°N, 55°N and 10°W, 30°E) the orientation of the interplanetary magnetic fields (IMF) on the critical frequency of the ionospheric F-layer at mid and high latitudes is further investigated. The critical frequencies are studied in conjuction with simultaneous satellite measurements of the IMF. The seasonal dependence of the results have been discussed. In particular, significant effect of polarity changes IMF B_z are revealed.

A reversal of the polarity of IMF B_z component between hourly data points was named an "Event" provided that change in the magnitude of $|Bz|$ is greater than 1 nT. Results presented in this paper reflect the effects of major Bz changes. That is a set of very large events where the IMF change $|B_z|$ exceeded or equal 11 nT. The results of the analysis revealed that determinings of the IMF B_z can contribute in day-to-day variability of the mid-latitude densities.

References:

Tulunay, Y. Willis, D.M., Lockwood, M. and Hapgood, M.A.:1991 Final Report of the project, NATO 0753/87.
Hapgood, M.A., Lockwood, M., Bowe, C.A., Willis, D.M., and Tulunay, Y.: 1991, Planet. Space Sci. 39, 411.

THE SPECTRAL ANALYSIS OF THE foF2 DATA OBTAINED AT FIVE PRIME SITES DURING A 15 MINUTE CAMPAIGN IN JUNE 1993

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ABSTRACT

During the COST 238: PRIME project there was a campaign of 15-minute intervals of the foF2 soundings at Kandilli, Rome, Sofia, Poitiers and Lannion. The campaign took place for one month in June 1993. The spectral analysis of the data by using a Fast Fourier Transform (FFT) algorithm proved itself to be a relatively easy method to reconstruct the original data at the confidence level of $\alpha=0.05$.

INTRODUCTION

A Polish made vertical ionosonde (VI) was installed at the Kandilli Observatory where it worked successfully for almost one year between 6 May 1993 and 21 April 1994 (Rokicki et al., 1993). During this period there was a mutual agreement between several experimenters to hold a measurement campaign of 15-minute intervals in addition to the usual measurement interval of every half hours. The purpose of the whole exercise had been to improve the instantaneous mapping and modeling of the ionospheric critical frequencies(foF2) over Europe as to fulfill one of the objectives of the COST 238: PRIME project (Bradley, 1990).

METHOD OF ANALYSIS

The foF2 data were obtained at equal intervals of time, that is, either at every fifteen minutes or on the half hours continuously. However, due to several reasons the available data had breaks in a random manner. Therefore, it is a difficult task to employ a standard FFT algorithm in the spectral analysis of the foF2 data. However, the algorithm referred as "clean spectrum" by Roberts et al. (1987) here takes care of the data gaps.In this algorithm the successive data gaps in time are treated as windows. That is, the available valid data between two successive data gaps are treated as windowed. The length of the rectangular window is determined each time by the existing data gap.

The results of the analysis are presented here in two groups. (i) the Discrete Fourier Transform (DFT) analysis of the 15-minute long foF2 data obtained at Kandilli(41^{O}N;29^{O}E); Rome(42^{O}N,13^{O}E); Sofia(43^{O}N,23^{O}E); Poitiers(47^{O}N,0^{O}E) and Lannion(49^{O}N,3^{O}E).These stations, geographically, cover a latitudinal zone of (41^{O}N-49^{O}N) and longitudinal zone of (3^{O}W-29^{O}E). The dipole magnetic coordinate coverage of these stations are between 41^{O}N and 52^{O}N; and between 80^{O}E and 104^{O}E. (ii) DFT analysis of the half hourly foF2 data obtained at Kandilli.

RESULTS

(i) Results of the 15 - minute campaign in June 1993:

Figures 1(a,b,c,d,e) illustrate the foF2 values during the 15-minute campaign in June 1993. Except for Kandilli, the data coverage is very good. However, in the case of Kandilli, there are several missing foF2 values. As seen in Figures 1(b,c,d,e) the highest foF2 values were observed in the beginning of June 1993. In the beginning of June 1993 there was a considerably large magnetic storm as marked with the 3-hour planetary magnetic index (3h-Kp). The (3h-Kp) index was 6 on 4 June 1993 between 12-14.9 hour UT. The storm continued on 5 June 1993 and gradually died out on 7 June 1993. During this period an important reduction in the foF2 values is very clear in Figure 1(f). It is thought that this reduction in the foF2 values was due to that ongoing sub storm activity. In figure 1(f) the Lannion foF2 values were chosen to illustrate to how the foF2 and the planetary 3h-Kp indices varied in June 1993. Later in that month, on June 24, there was another substrom and the 3h-Kp value was 5- between 9-11.9 hour UT. In a similar way the foF2 values exhibited a reduction with respect to their general daily variation again.

Figures 2(a,b,c,d,e) show the results of the DFT analysis by the algorithm "clean spectrum" of Roberts et al. (1987). The data employed were those which had been obtained during the 15-minute campaigns.The "power" may be in any appropriate units. The "power" spectrum exhibited several important maxima in the frequency domain as seen in these figures.Table 1 summarizes some numerical results of the analysis. The periods corresponding to power amplitudes greater than 5.5 in appropriate units are listed either as hours or days for the five stations mentioned. The power amplitudes are normalized with respect to the maximum amplitude obtained by the "clean spectrum" program of Roberts et al (1987). The power amplitudes, then expressed as per-cents in Table 1. The fundamental period is 23.9 h for all the stations except Kandilli. The second harmonic is observed at 11.9 h for all the five stations. The scarcity of the Kandilli foF2 data during the 15-minute campaign is thought to be the reason for the Kandilli harmonics obtained to appear different in hierarchy than those of the other four stations.

Figures 3(a,b,c,d,e) exhibit those frequencies whose power amplitudes were greater than 5.5 in appropriate units. This time, the relative powers are indicated in time domain on logarithmic scales so that they can be investigated distinctly.

Figures 4 (a,b,c,d) illustrate the scatter diagrams of the foF2 values during the 15-minute campaigns which took place in June 1993. On the figures, the Rome, Sofia, Poitiers and Lannion foF2 values are plotted versus Kandilli foF2's.Number of the data points making the scatter diagram and the cross correlation coefficients are also indicated on the figures. At the significance level of $\alpha=0.05$ the cross correlation coefficients calculated are slightly more significant for (Rome-Kandilli); (Sofia-Kandilli); than those of obtained for (Poitiers-Kandilli); and (Lannion-Kandilli).This might be due to the effect of the geographical separation of the Stations with respect to each other. Table 2 summarizes the results which can be steted based on the output of the figure 4 (a,b,c,d).

Figures 5(a,b,c,d,e) exhibit the scatter diagrams of the observed foF2 values during the 15-minute campaign and the foF2 values generated by the inverse Fourier transform by the "clean spectrum " program Roberts et al. (1987) . The generated data are referred as "synthetic" on the figures. The number of iteration steps in obtaining the clean spectrum was 100. The highest cross correlation coefficient for this exercise was obtained for the case of Kandilli since the observed , available data were as small as 264. Table 3 summarizes the results which can be stated based on the output of the figure 5 (a,b,c,d,e)

Table 3 summarizes the cross correlation coefficients of the foF2 values obtained at the pairs of the PRIME stations of interest.From the cross correlation coefficients exhibited in this table, at the significance level of $\alpha=0.05$, there seems to be not much difference between Kandilli, Rome, Sofia, Poitiers and Lannion. Figure 6 is a typical good example to illustrate how good the foF2 values of Lannion and Poitiers resemble each other at the significance level of $\alpha=0.05$.

(ii) Results of the analysis by using the foF2 data obtained at every half hour at Kandilli:

Figure 7 shows the results of the DFT analysis by using the "clean spectrum" program of Roberts et al. (1987) for the, almost one year long foF2 values of Kandilli. The fundamental period in the Kandilli data turns up to be 23.8 h almost agreeing with those of the other four stations of interest. The spectrum results of the Kandilli data are exhibited in Table 1(b).

Figure 8 shows the scatter diagram of the observed Kandilli foF2 values and those computed (synthetic) by the inverse DFT by the program of the Robert et al. (1987).

CONCLUSION

There are several very good DFT algorithms available. However, most of these programs take care of the data of a time series which are sampled continuously during the period of interest. The VI experiments made the foF2 available at equal sampling periods. Yet, due to the reasons which are not relevant here there are always gaps in time in the data. Therefore, the "clean spectrum" by Roberts et al. (1987) has the advantage over most of the other similar algorithms. This DFT program takes care of any data which are sampled at even intervals with data gaps.

The ultimate goal of this work is to be able to provide the user an analytical expression or "model", so that, by putting in the independent variable time, one can obtain which frequency to use within the limitations of statistics.

This paper provides a preliminary "model" which only depends on time. The "model" is made by using the DFT coefficients for the major eighteen frequencies obtained in 100 iterations of the "clean spectrum" program of Roberts et al. (1987). Table 4 shows the major frequencies in (1/hour) (or periods in hour); the corresponding DFT coefficients a's and b's for Kandilli, Rome, Sofia, Poitiers, Lannion; and both their means and medians for the cases if there are more than one entry. By using the median values and the mean DC component of 61.02 MHz the analytical expression of the "model" is expressed in Equation 1.

$$f_oF2(t) = 61.02 + 2\sum_{i=1}^{18} 2[a_i Cos(2\pi f_i t) - b_i Sin(2\pi f_i t)] \qquad (x0.1)\ MHz \quad (1)$$

A very preliminary test of Equation 1 is made by computing the foF2 values for Lannion, in June 1993 at 15-minute intervals. Figure 9 shows the observed foF2 values for Lannion in June 1993. Superimposed is the foF2 values computed by using Equation 1. There were N=2763 data points involved in the analysis. The cross correlation coefficient between the measured and the computed foF2 values is R=0.67. At the significance level of α=0.05, it seems that both the computed and the observed foF2 values do come from the same population. One may thus conclude that, although there are differences in details, the general tendency of the curve obtained by the "model" is very similar to the observed one. Therefore, it seems very encouraging to improve Equation 1 further along the lines mentioned in this paper.

ACKNOWLEDGMENT: The authors thank to Drs. Ü. Kızıloğlu, A. Esendemir, and E. Tulunay for the most constructive discussions on the "clear spectrum algorithm" and the results of the analysis. The research activity reported in this paper was partly supported by the EEEAG of TÜBİTAK; METU; B.Ü. Kandilli Observatory; PAS, SRC. The text is typed by Sn. G.Cangül.

REFERENCES

1. Bradley, P.A. — 1991COST 238: PRIME (Prediction and Retrospective Ionospheric Modeling over Europe), MOU, COST/260/91
2. Roberts, D.H., Lehar J., Dreher, J.W. — 1987 "Clean Spectrum" Algorithm, Astronomical Journal 93 p.968
3. Rokicki, A., Stanislawska I., Zbyszynski, Z., Tulunay, Y., Özgüç, A., Ataç, T., Altaş, L., Barlas, O. — 1993 First Results From the Transportable Ionosonde Compaign, PRIME Studies With Emphasıs On TEC And Topside MODELING, Wissenschaftlicher Bericht No.2/1993/Teil 2 Universitat Graz, Austria p.297.

Figure 1. The foF2 values obtained in June 1993 during the 15-minute campaign and superimposed is the computed (synthetic) foF2 values as obtained by the inverse DFT by Roberts et al. (1987) for (a) Kandilli; (b) Rome; (c) Sofia; (d)Poitiers; (e)Lannion; (f) (foF2-foF2mean) for Lannion and the planetary 3h-Kp values versus the days of June 1993.

Figure 2.The spectrum of the foF2 values obtained in June 1993 during the 15-minute campaigns for (a) Kandilli; (b) Rome; (c) Sofia; (d) Poitiers; (e) Lannion. The DFT program employed is due Roberts et al. (1987).

Figure 3.The normalized per-cent relative power of the major harmonics of those displayed in Figure 2 versus time in hours, for (a) Kandilli; (b) Rome; (c) Sofia; (d) Poitiers; (e)Lannion

Figure 4.The scatter diagrams constructed between foF2 values for (a) Rome, (b) Sofia; (c)Poitiers Number of the common data points and the cross correlation coefficients for each case are exhibited on the top of the figures.

Figure 5.The observed foF2 values are plotted versus the foF2 values computed by the DFT program of Roberts et al. (1987), for (a) Kandilli, (b) Rome, (c) Sofia, (d) Poitiers, (e)Lannion in June 1993. Number of data employed during the analysis and the cross correlation coefficients are also indicated separately on he figures.

Figure 6.The highest cross correlation coefficient is obtained between the foF2 values obtained at Lannion and those of Poitiers. This figure exhibits this fact as a scatter diagram during the 15-minute campaign in June 1993.

Figure 7.The DFT spectrum of the foF2 values obtained at Kandilli between 6 May 1993 and 21 April 1994 at every half hours. The algorithm and the program is due Roberts et al.(1987). The portion of the figure around 0.1×10^{-4} MHz is magnified to resolve the harmonics in the small frame below.

Figure 8.The observed foF2 values of Kandilli between 6 May 1993 - 21 April 1994 and the ones generated (synthetic) by the inverse DFT by Roberts et al. (1987) are scattered in this figure.

Figure 9.The observed foF2 values at Lannion in June 1993 duringthe15-minute campaign,superimposed is the data calculated by using Equation 1. The cross correlation coefficient between the observed data and the calculated data is exhibited along with the number of data points employed on the figure.

TABLE CAPTIONS

TABLE 1.a) The spectrum of the foF2 values obtained during the 15-minute campaign at five PRIME Stations. The periods corresponding to "power" amplitudes greater than 5.5 in appropriate units are listed in hours or days.

TABLE 1.b) The spectrum of the foF2 values of the Kandilli data which were obtained between 6 May 1993 and 21 April 1994.

TABLE 2. The cross correlation coefficients between critical frequencies obtained at several PRIME stations during the 15-minute campaign.

TABLE 3. The cross correlation coefficients between critical frequencies at obtained at several PRIME stations and their generated data (synthetic).

TABLE 4. The eighteen major frequencies (1/hour) (or periods in hour); the corresponding DFT coefficients of a_i 's and b_i 's; their means, medians for the five PRIME stations of interest.

TABLE 1(a)

PERIOD		STATION NAMES				
		Kandilli (41N;29E)	Rome (42N;13E)	Sofia (43N;23E)	Poitiers (47N;0E)	Lannion (49N;3W)
Hour	Day (approx.)	% rel. power	% rel. power	% rel. power	% rel. power	% rel. power
0.5		5.8				
0.93		9.132				
0.9		9				
3.4		6				
6		7		7		
11.9		28	52	64	90	89
12.4		6				
16		100				
23.9			100	100	100	100
34.7	1.4		7			
35.1	1.5			8		
47.9	2			7		
48.8	2		6			
75.8	3.2			10		
77.8	3.2		10		16.6	20
110.7	4.6			10		
125.2	5.2		9			
130.9	5.5				13	10
134.4	5.6	24				
159.9	6.7			8	26	28
205.6	8.6				23	23
221.5	9.2		11			
319.8	13.3		16	8		
479.8	20			8		
564.4	23.5	8				
719.7	30		8		9.6	14
1439.5	60			9		

TABLE 1(b)

PERIOD		Kandilli
Hour	Day(approx.)	% rel. power
7.9		7
11.9		10
12		11
12.1		7
12.11		12
12.2		6
23.5		8
23.8		100
23.9		13
24.1		6
24.2		66
716	29.9	6
16109	671	10

TABLE 2

Station	N	Kandilli	Rome	Sofia	Poitiers	Lannion
Kandilli	264	1	0.33	0.32	0.29	0.27
Rome	2680	0.33	1	0.75	0.86	0.84
Sofia	2642	0.32	0.75	1	0.73	0.73
Poitiers	2744	0.29	0.86	0.73	1	0.96
Lannion	2673	0.27	0.84	0.73	0.96	1

TABLE 3

Station	Cross Correlation Coefficient
Kandilli-Kandilli	0.997
Rome-Rome	0.963
Sofia-Sofia	0.949
Poitiers-Poitiers	0.973
Lannion-Lannion	0.973

TABLE 4

FREQ. (1/h) (x 10E- 4)	PERIOD (h)		Kandilli	Rome	Sofia	Poitiers	Lannion	MEAN	MEDIAN
84.03	11.9	a	2.68	-0.37	-3.08	-2.46	0.52	-0.54	-0.37
		b	0.24	-3.09	-0.33	2.33	3.38	0.51	0.24
41.84	23.9	a		-3.75	-3.87	-2.71	-1.19	-2.88	-3.23
		b		-2.14	-0.18	2.62	3.42	0.93	1.22
28.82	34.7	a		-0.57				-0.57	-0.57
		b		-0.98				-0.98	-0.98
28.49	35.1	a			-0.77			-0.77	-0.77
		b			-0.82			-0.82	-0.82
20.88	47.9	a			0.35			0.35	0.35
		b			0.92			0.92	0.92
20.49	48.8	a		-0.62				-0.62	-0.62
		b		0.81				0.81	0.81
13.19	75.8	a			1.09			1.09	1.09
		b			-0.49			-0.49	-0.49
12.85	77.8	a		1.32		1.31	1.31	1.31	1.31
		b		-0.28		-0.81	-0.92	-0.67	-0.81
9.03	110.7	a			1.19			1.19	1.19
		b			-0.39			-0.39	-0.39
7.99	125.2	a		-0.22				-0.22	-0.22
		b		-1.29				-1.29	-1.29
7.64	130.9	a				-0.99	-0.91	-0.95	-0.95
		b				-0.92	-0.68	-0.80	-0.8
6.25	159.9	a			0.95	1.91	1.92	1.59	1.91
		b			0.52	0.27	0.15	0.31	0.27
4.86	205.6	a				-1.49	-1.52	-1.51	-1.505
		b				-0.98	-0.82	-0.90	-0.9
4.51	221.5	a		-1.29				-1.29	-1.29
		b		-0.66				-0.66	-0.66
3.13	319.8	a		1.62	2.04			1.83	1.83
		b		0.55	0.97			0.76	0.76
2.08	479.8	a			-0.31			-0.31	-0.31
		b			-1.02			-1.02	-1.02
1.39	719.7	a		-1.19		-1.17	-1.33	-1.23	-1.19
		b		0.29		0.05	0.19	0.18	0.19
0.69	1439.5	a			-0.59			-0.59	-0.59
		b			0.99			0.99	0.99

$$f_oF2(t) = 61.02 + 2\sum_{i=1}^{18} 2\left[a_i \cos(2\pi f_i t) - b_i \sin(2\pi f_i t)\right]$$

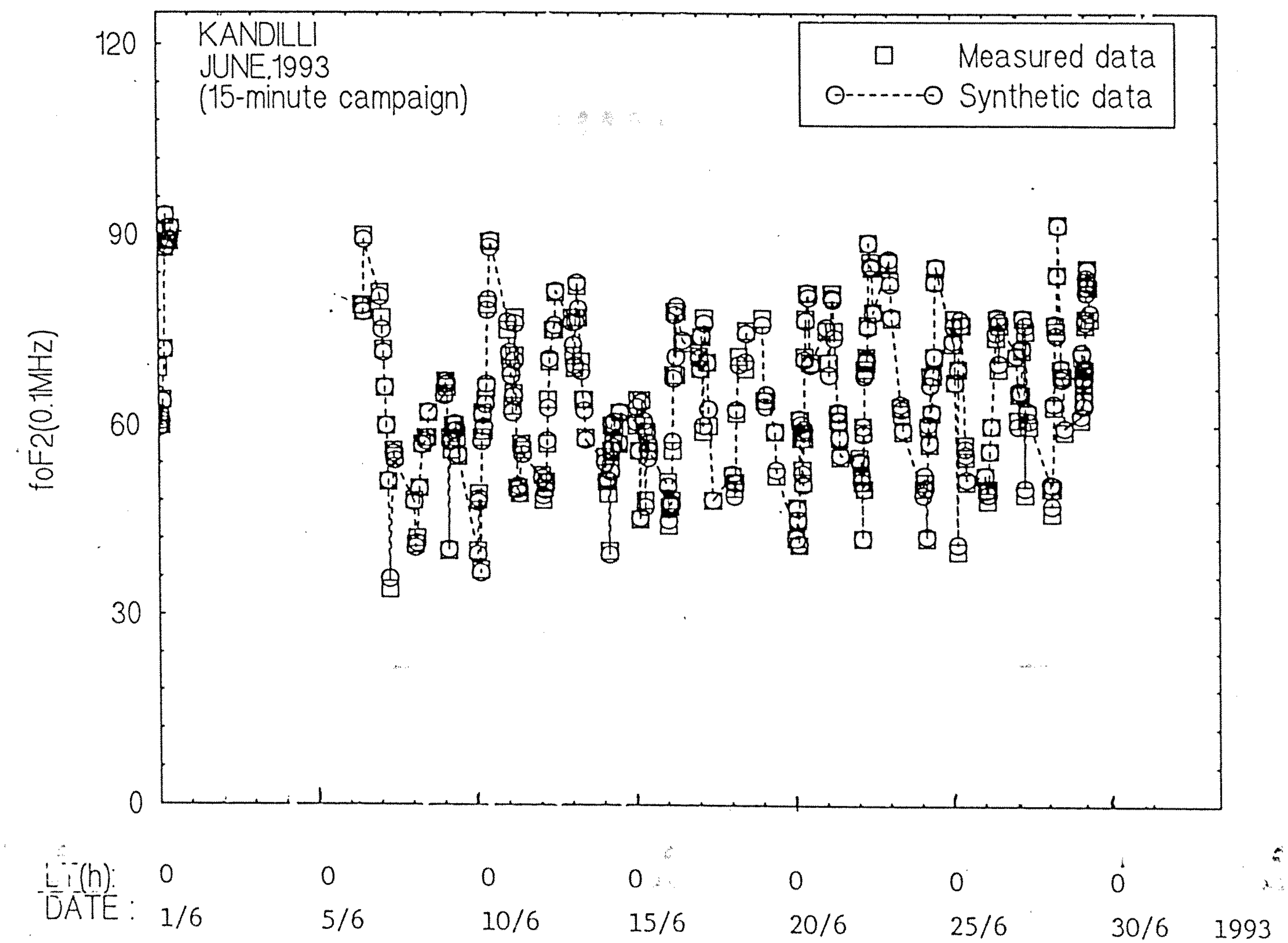
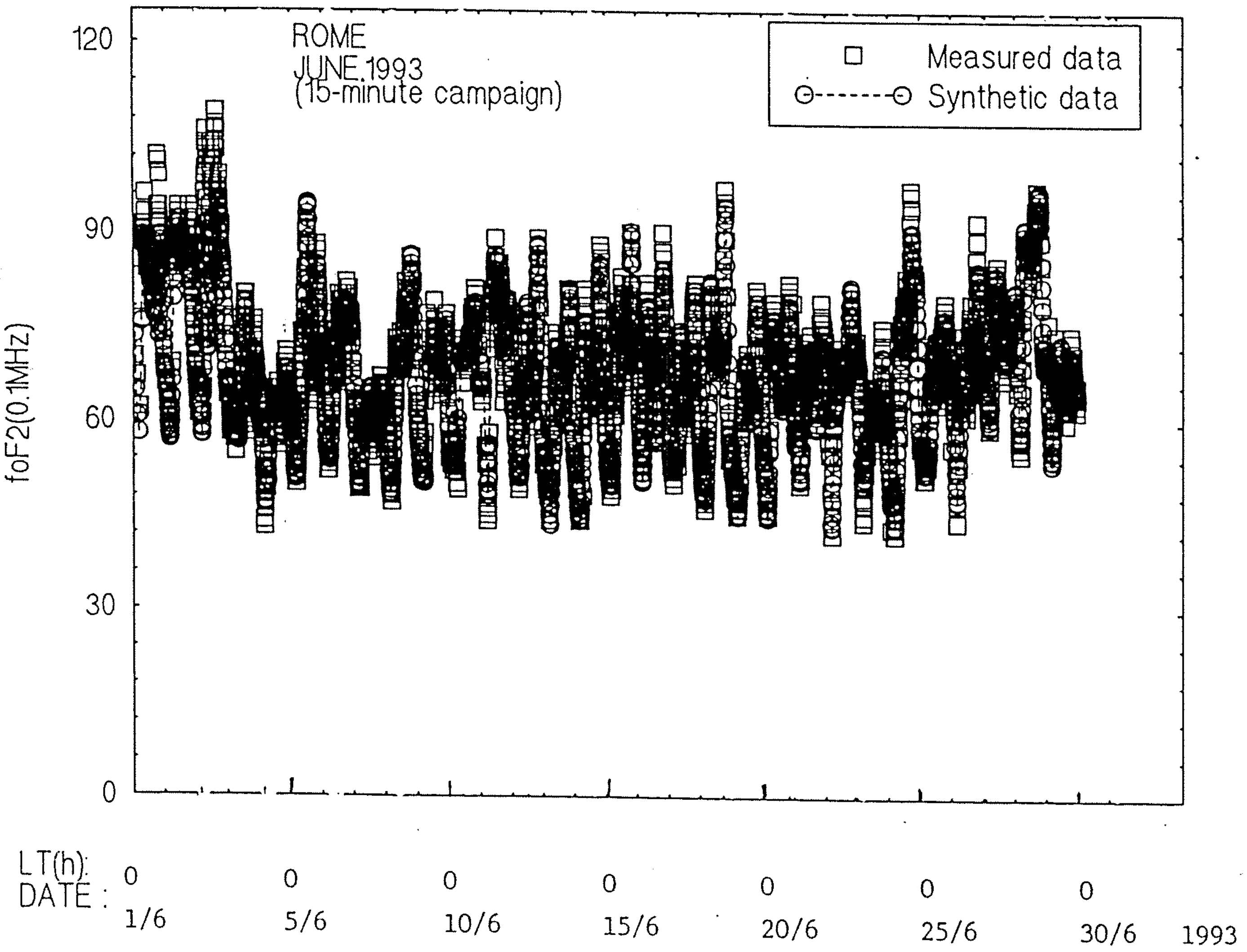
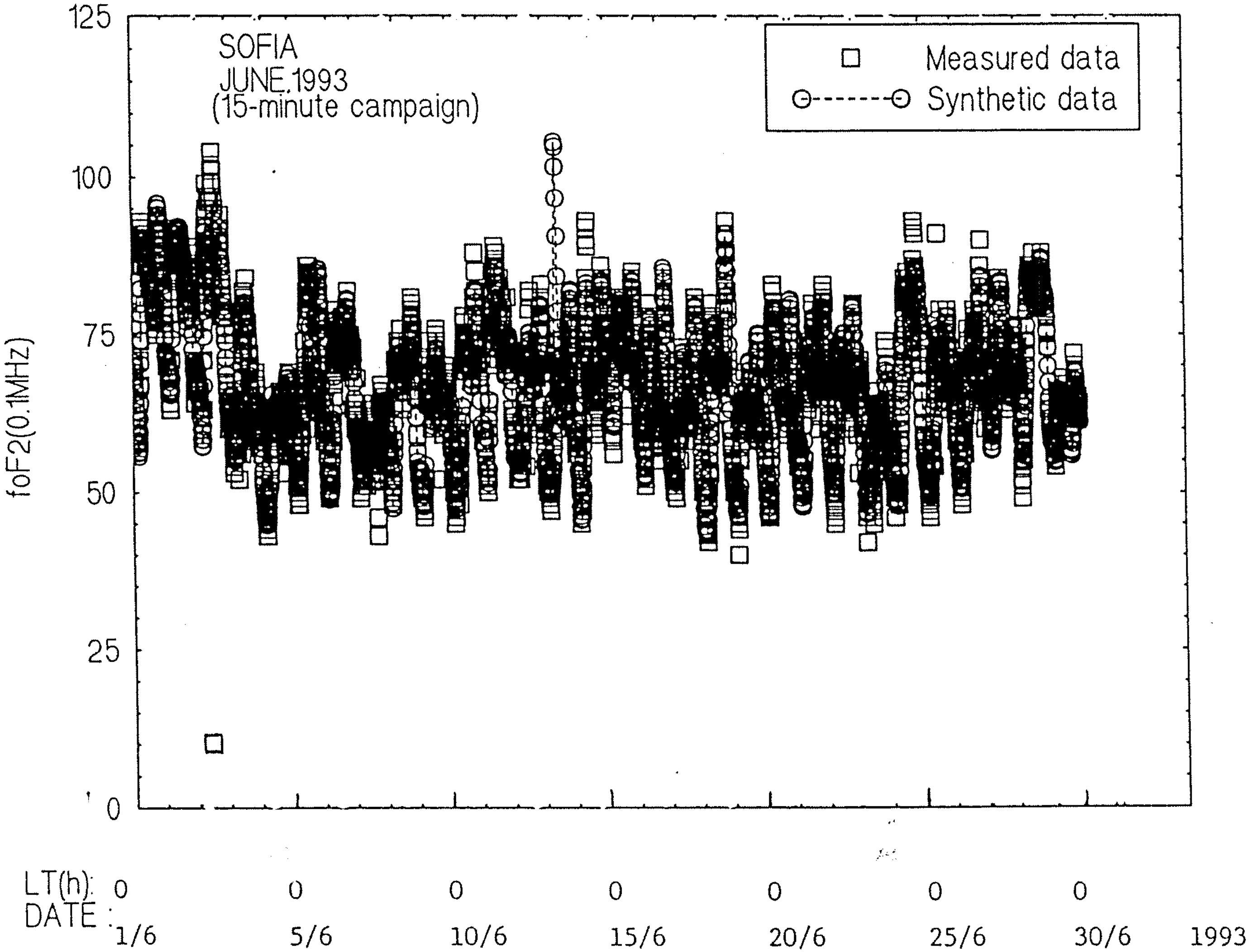

KANDILLI
JUNE,1993
(15-minute campaign)
Measured data
Synthetic data
120
90
60
30
0
foF2(0.1MHz)
LT(h):
DATE :
0
1/6
0
5/6
0
10/6
0
15/6
0
20/6
0
25/6
0
30/6
1993

Figure 1 (a)


ROME
JUNE 1993
(15-minute campaign)
Measured data
Synthetic data
foF2(0.1MHz)
120
90
60
30
0
LT(h):
DATE :
0
1/6
0
5/6
0
10/6
0
15/6
0
20/6
0
25/6
0
30/6
1993


SOFIA
JUNE.1993
(15-minute campaign)
Measured data
Synthetic data
foF2(0.1MHz)
125
100
75
50
25
0
LT(h): 0
DATE : 1/6
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5/6
0
10/6
0
15/6
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20/6
0
25/6
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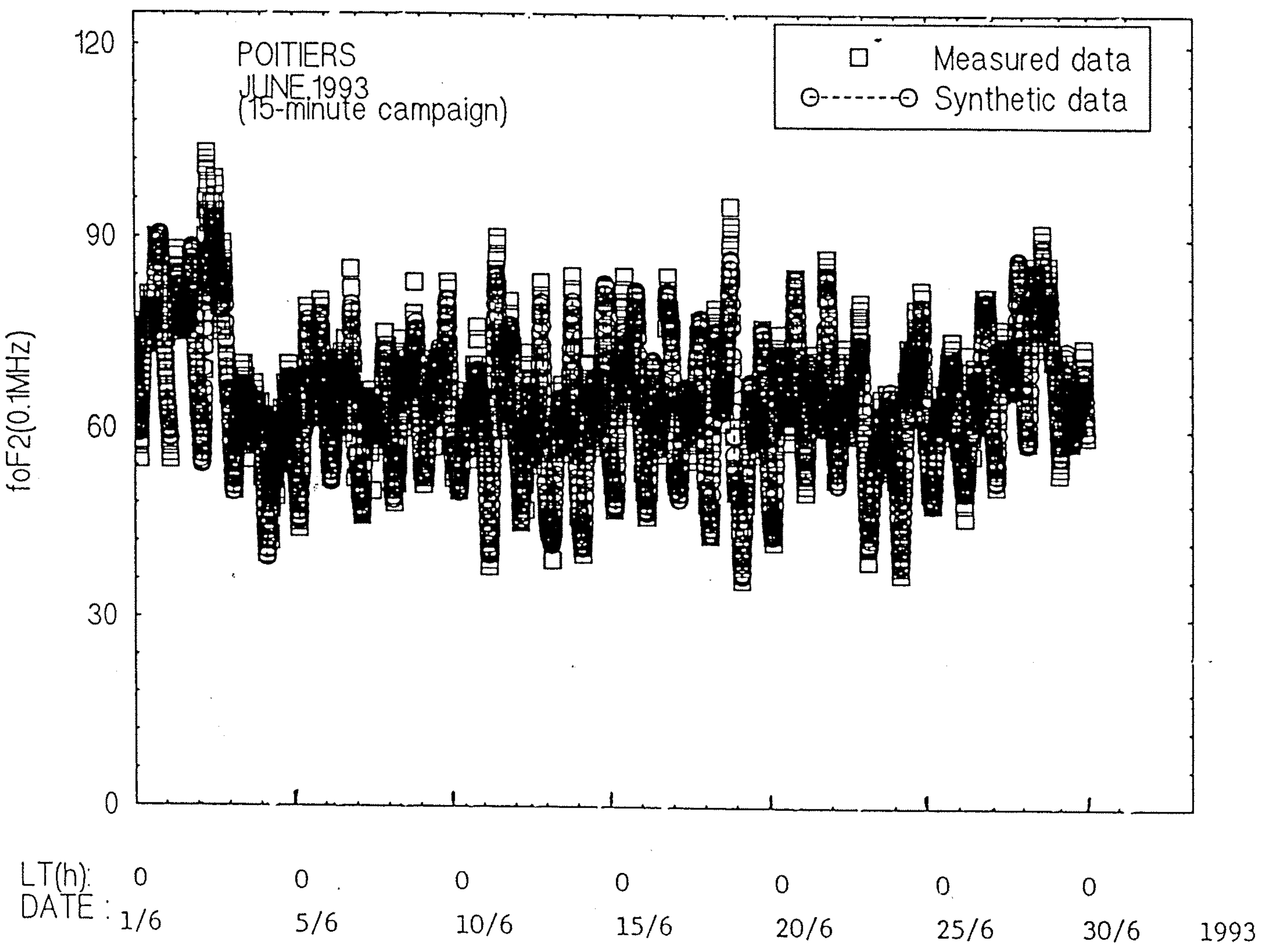
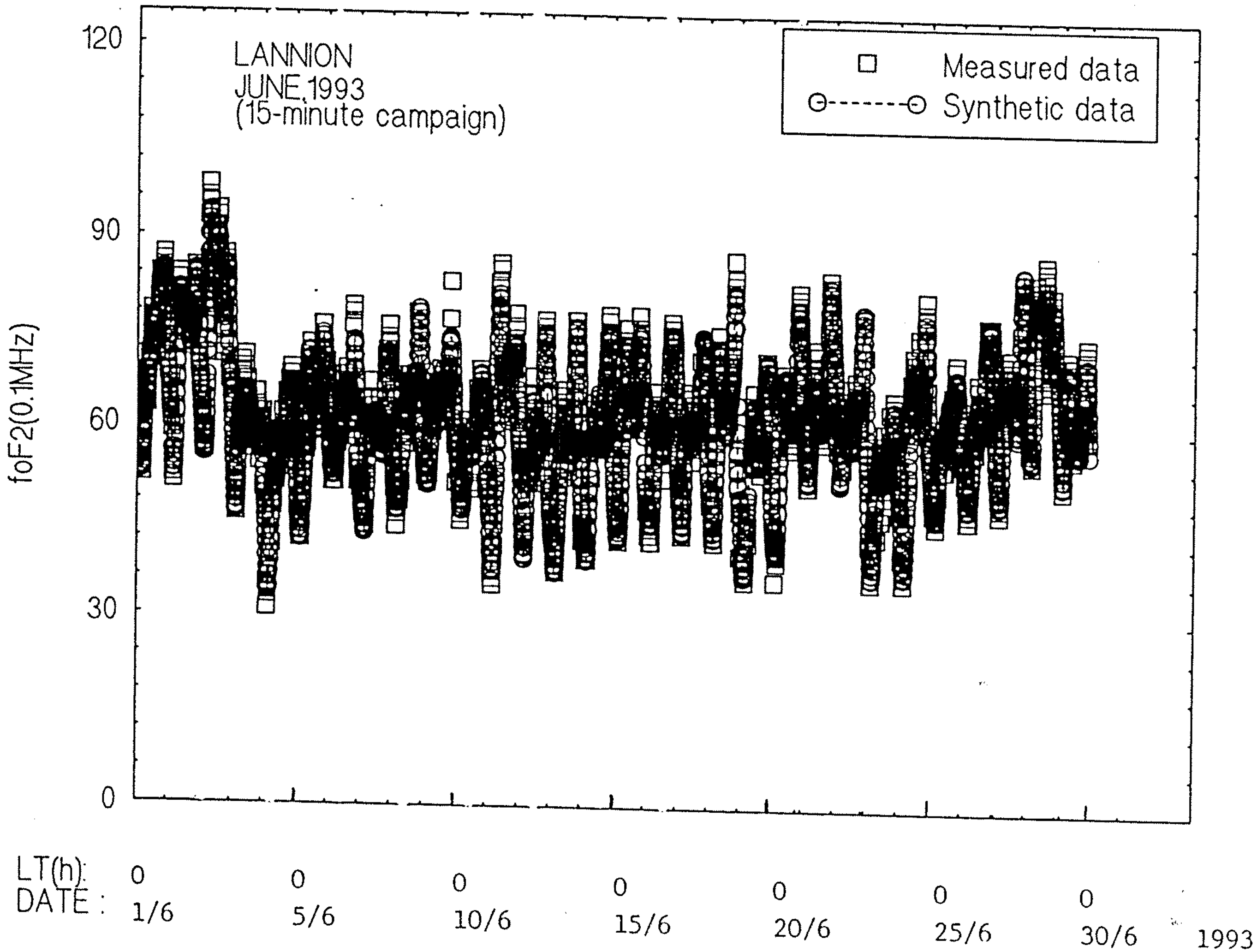
30/6
1993



POITIERS
JUNE 1993
(15-minute campaign)
Measured data
Synthetic data
foF2(0.1MHz)
120
90
60
30
0
LT(h):
DATE :
0
1/6
5/6
10/6
15/6
20/6
25/6
30/6
1993

Figure 1 (d)


LANNION
JUNE,1993
(15-minute campaign)
Measured data
Synthetic data
foF2(0.1MHz)
120
90
60
30
0
LT(h):
DATE :
0
1/6
0
5/6
0
10/6
0
15/6
0
20/6
0
25/6
0
30/6
1993

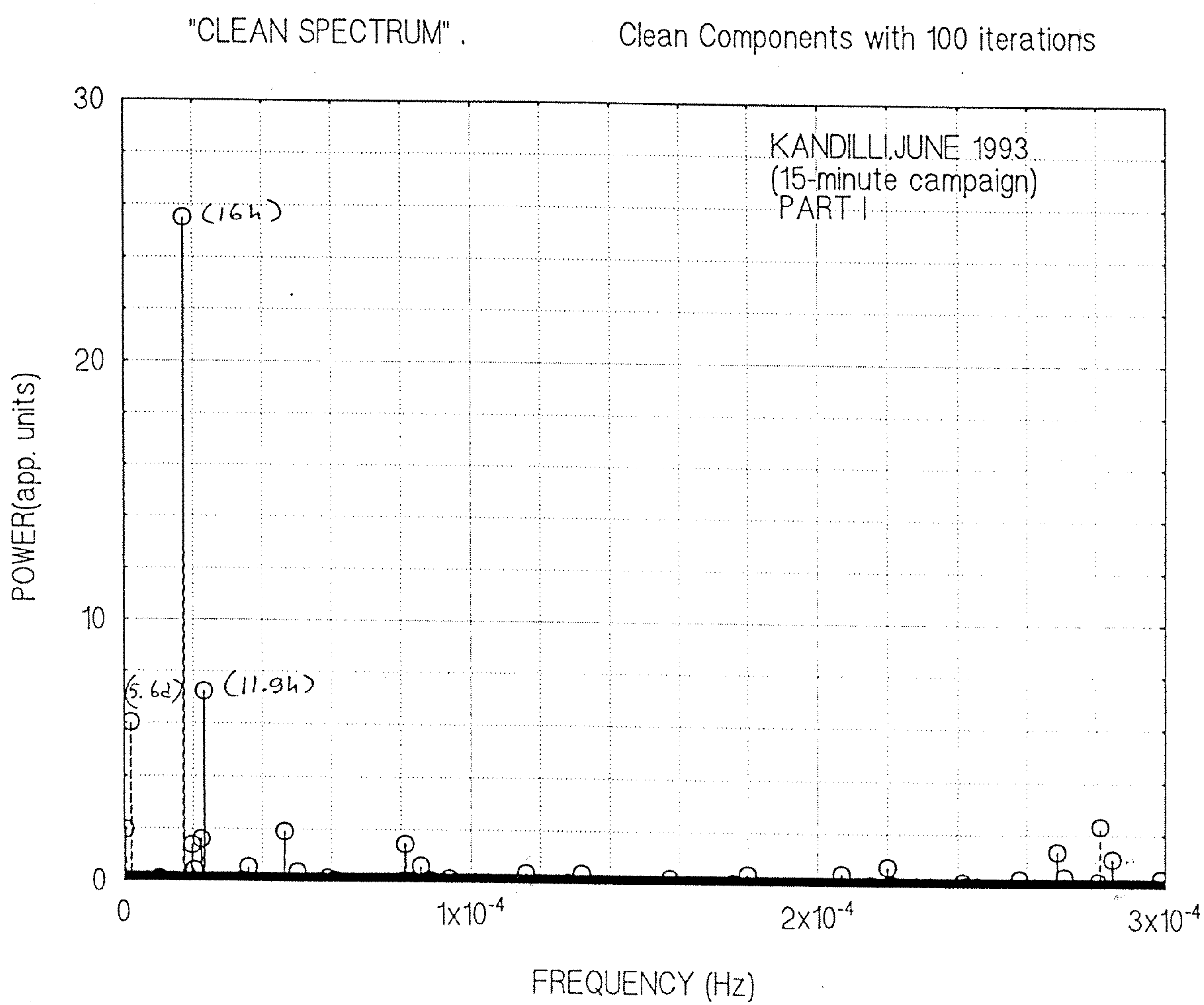

"CLEAN SPECTRUM" .
Clean Components with 100 iterations
KANDILLI,JUNE 1993
(15-minute campaign)
PART I
(16h)
(11.9h)
(5.6d)
POWER(app. units)
FREQUENCY (Hz)
0
10
20
30
1x10-4
2x10-4
3x10-4

Figure 2 (a-1)

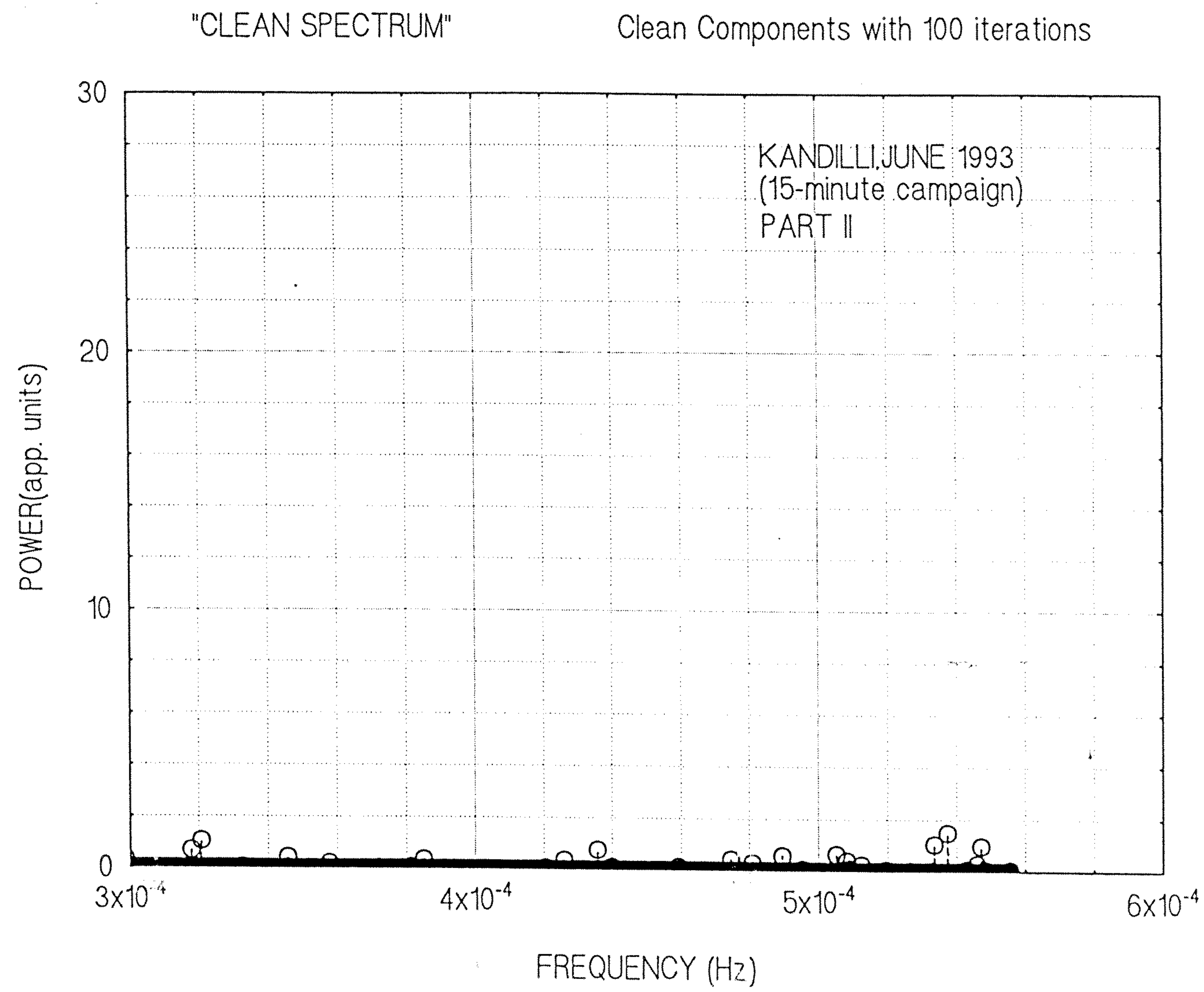

"CLEAN SPECTRUM"
Clean Components with 100 iterations
KANDILLI,JUNE 1993
(15-minute campaign)
PART II
POWER(app. units)
30
20
10
0
3x10^-4
4x10^-4
5x10^-4
6x10^-4
FREQUENCY (Hz)

Figure 2 (a-2)

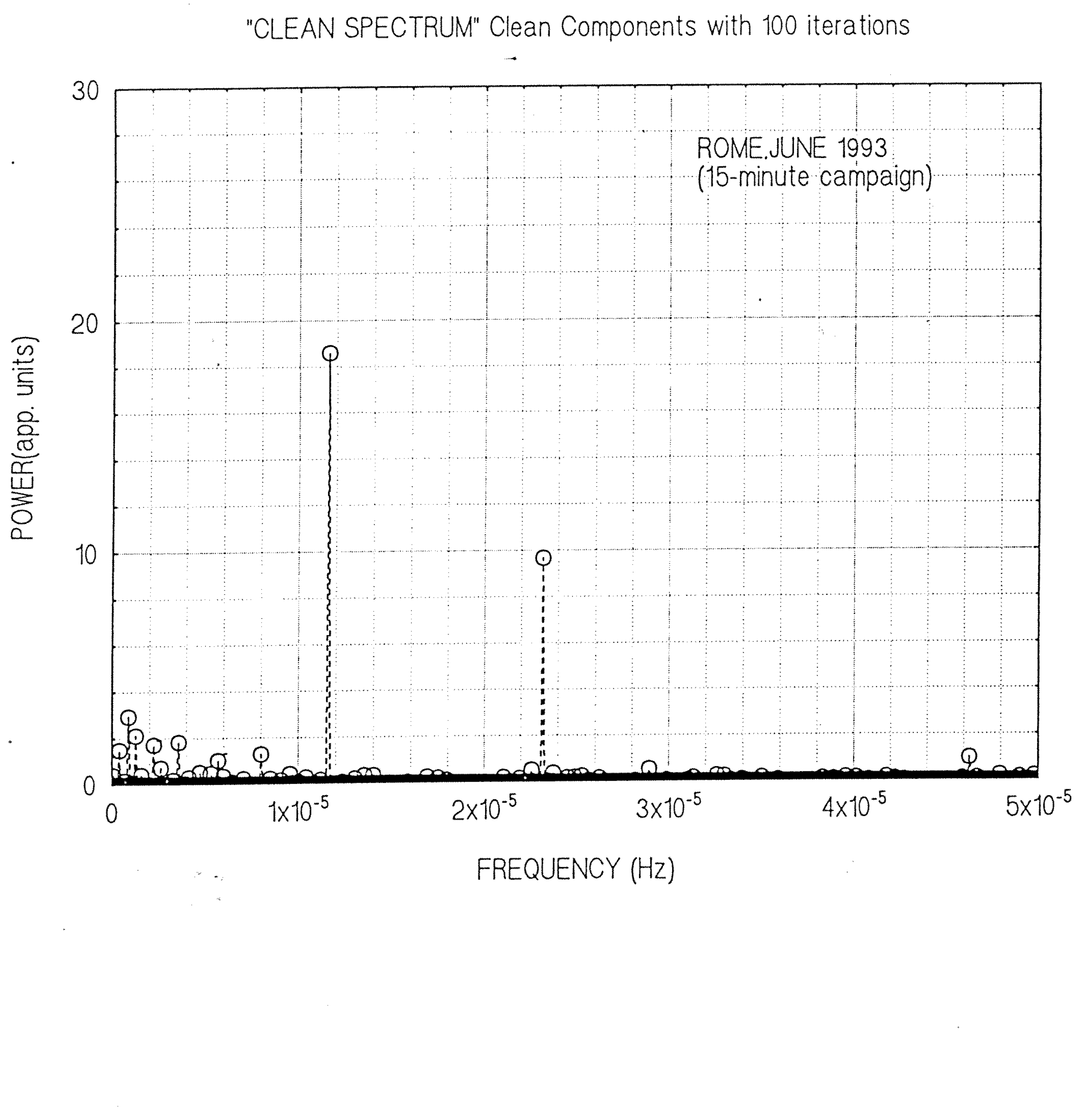

"CLEAN SPECTRUM" Clean Components with 100 iterations
ROME,JUNE 1993
(15-minute campaign)
POWER(app. units)
FREQUENCY (Hz)
0
10
20
30
1x10^-5
2x10^-5
3x10^-5
4x10^-5
5x10^-5

Figure 2 (b)

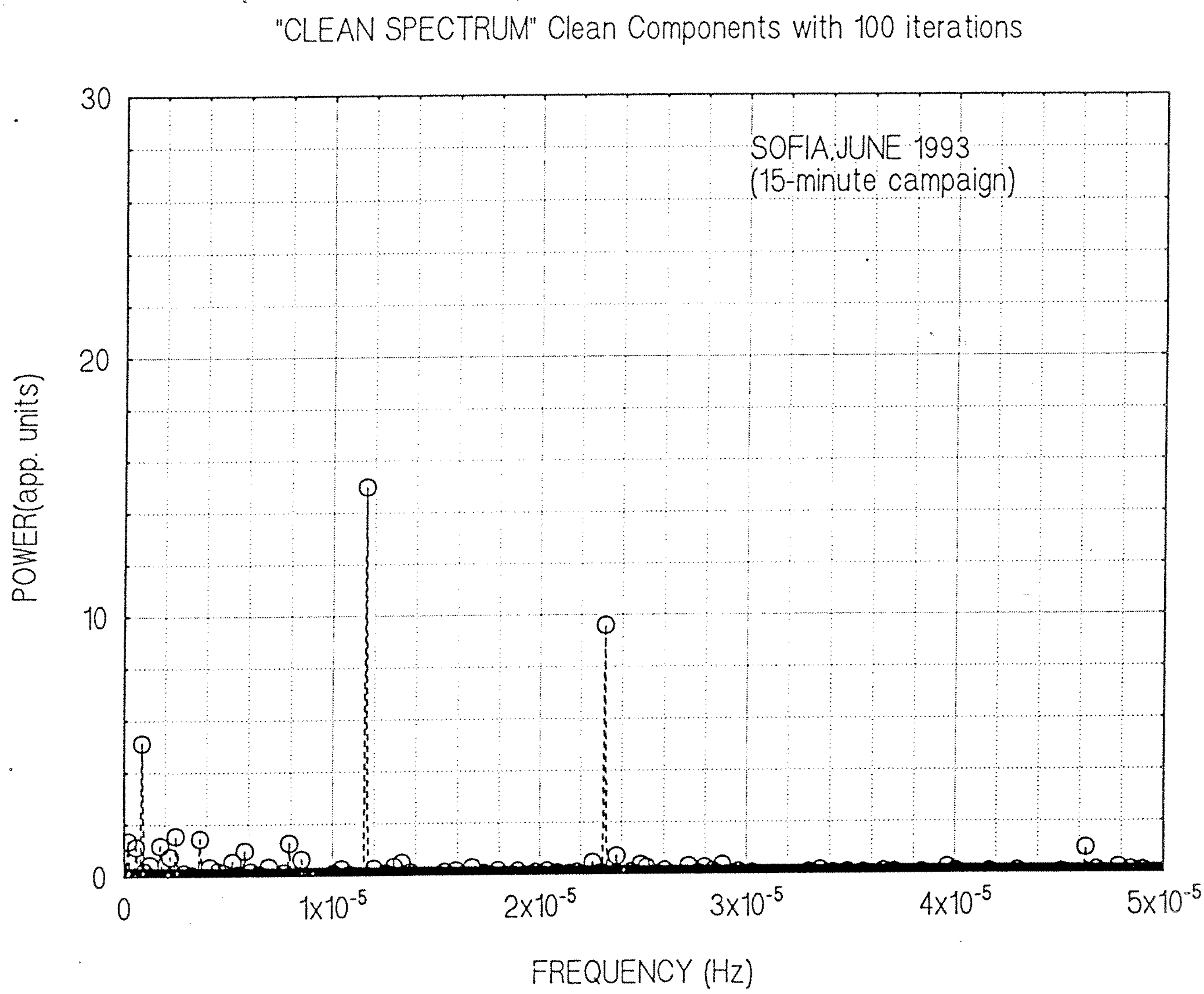
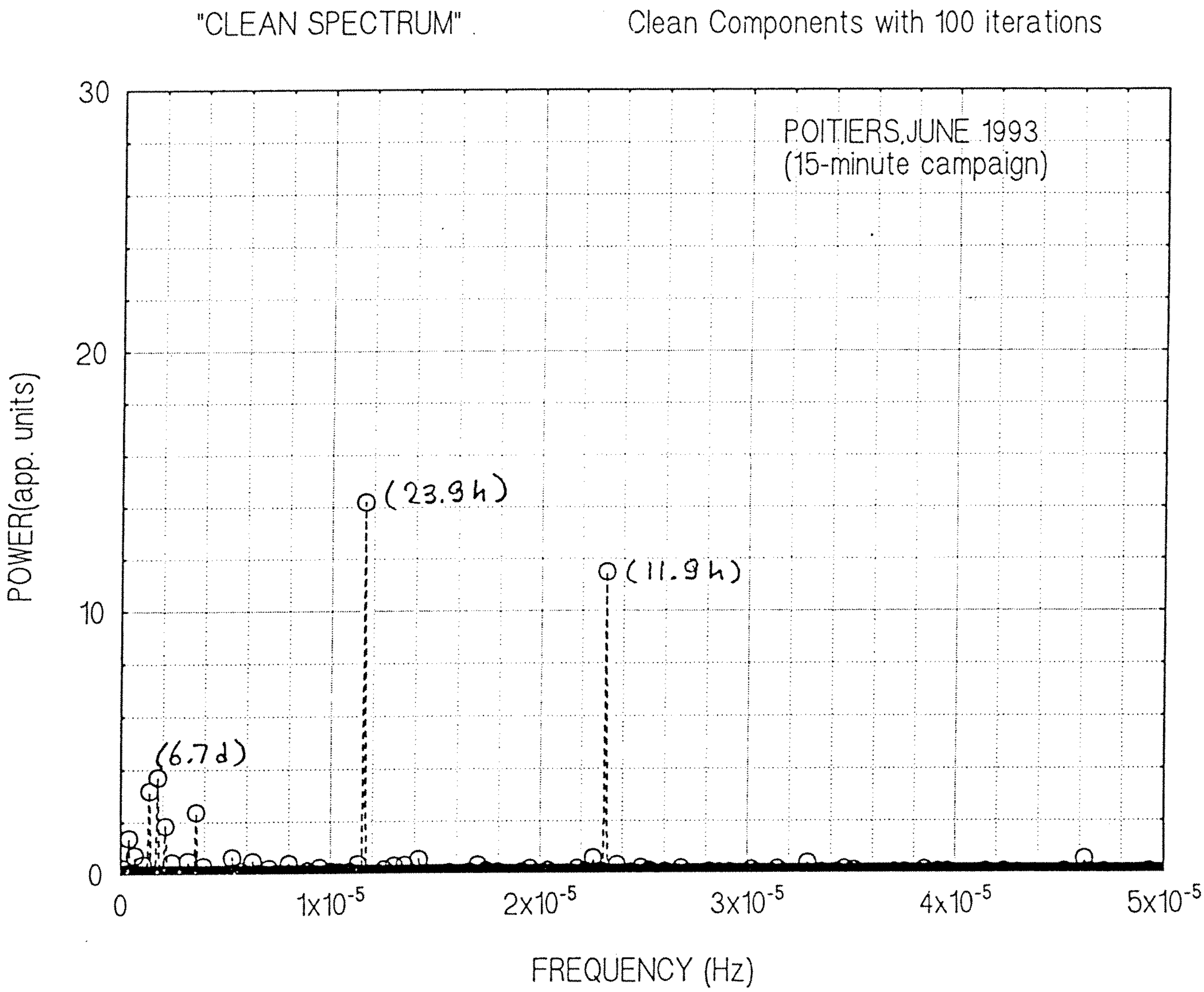

"CLEAN SPECTRUM" Clean Components with 100 iterations
SOFIA,JUNE 1993
(15-minute campaign)
POWER(app. units)
30
20
10
0
0
1x10^{-5}
2x10^{-5}
3x10^{-5}
4x10^{-5}
5x10^{-5}
FREQUENCY (Hz)

Figure 2 (c)



"CLEAN SPECTRUM".
Clean Components with 100 iterations
POITIERS,JUNE 1993
(15-minute campaign)
(23.9h)
(11.9h)
(6.7d)
POWER(app. units)
FREQUENCY (Hz)
0
10
20
30
0
1x10-5
2x10-5
3x10-5
4x10-5
5x10-5

Figure 2 (d)

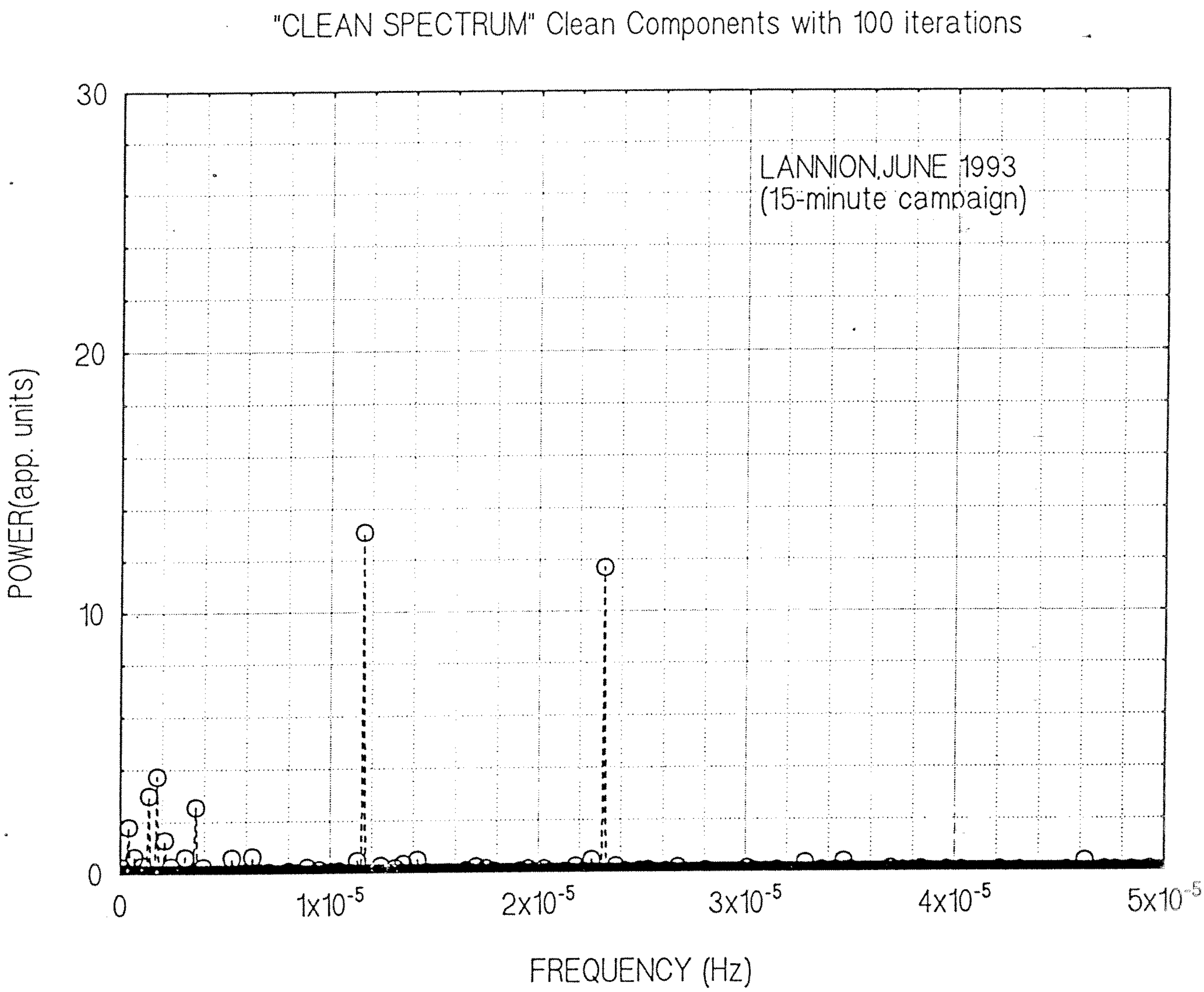

"CLEAN SPECTRUM" Clean Components with 100 iterations
LANNION,JUNE 1993
(15-minute campaign)
30
20
10
0
POWER(app. units)
0
1x10-5
2x10-5
3x10-5
4x10-5
5x10-5
FREQUENCY (Hz)

Figure 2 (c)

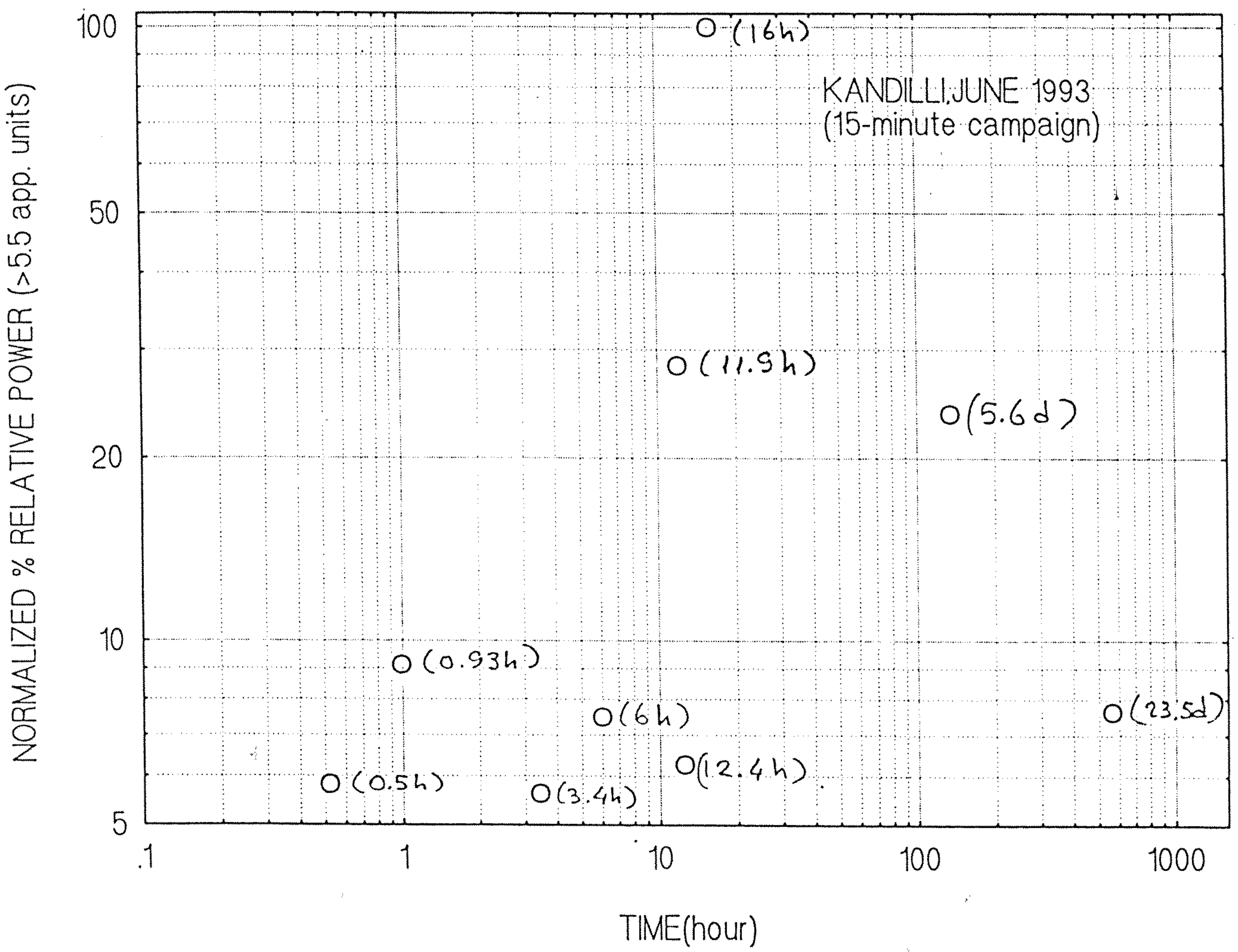

KANDILLI,JUNE 1993
(15-minute campaign)
NORMALIZED % RELATIVE POWER (>5.5 app. units)
TIME(hour)
100
50
20
10
5
.1
1
10
100
1000
(16h)
(11.5h)
(5.6d)
(0.93h)
(6h)
(23.5d)
(12.4h)
(0.5h)
(3.4h)

Figure 3 (a)

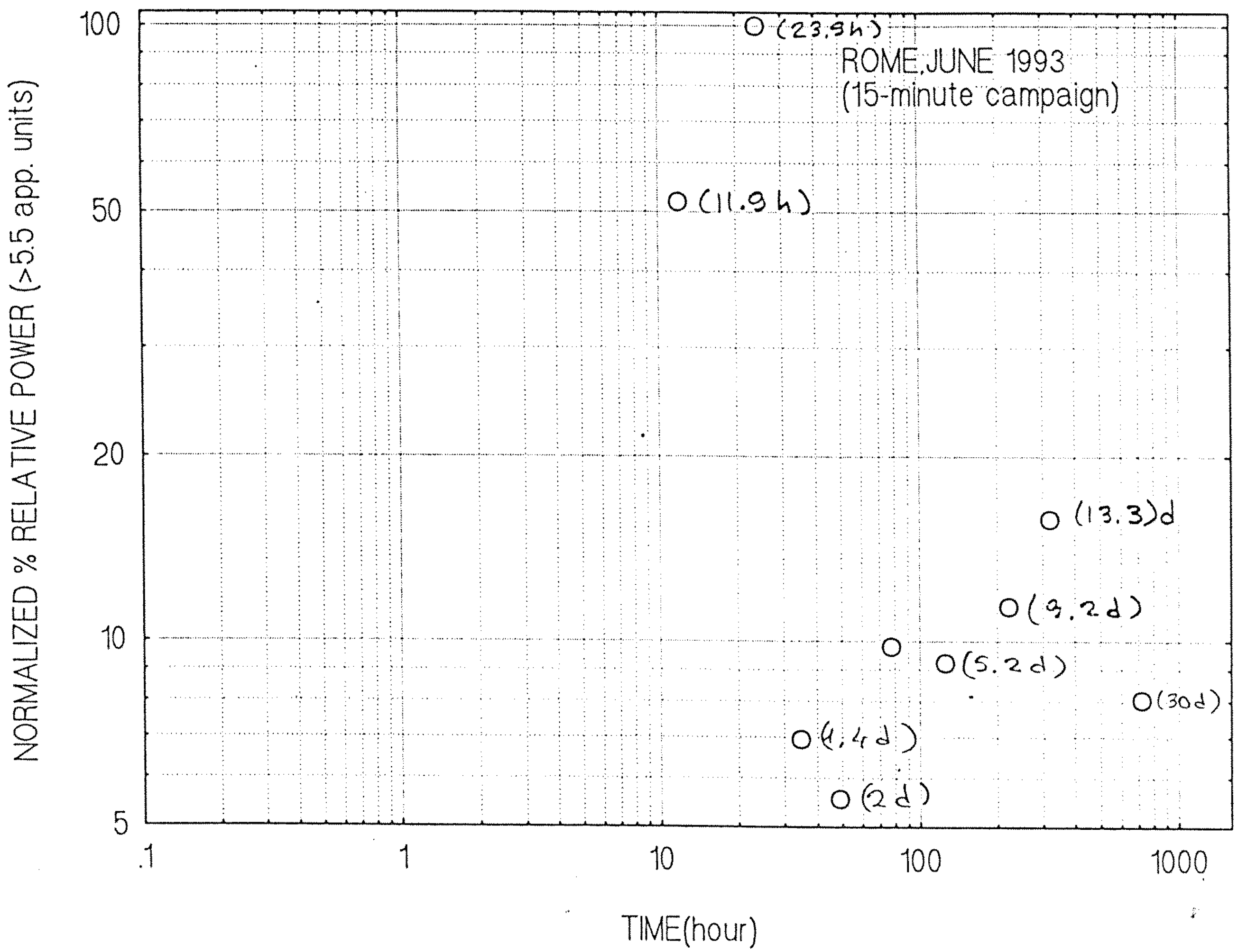
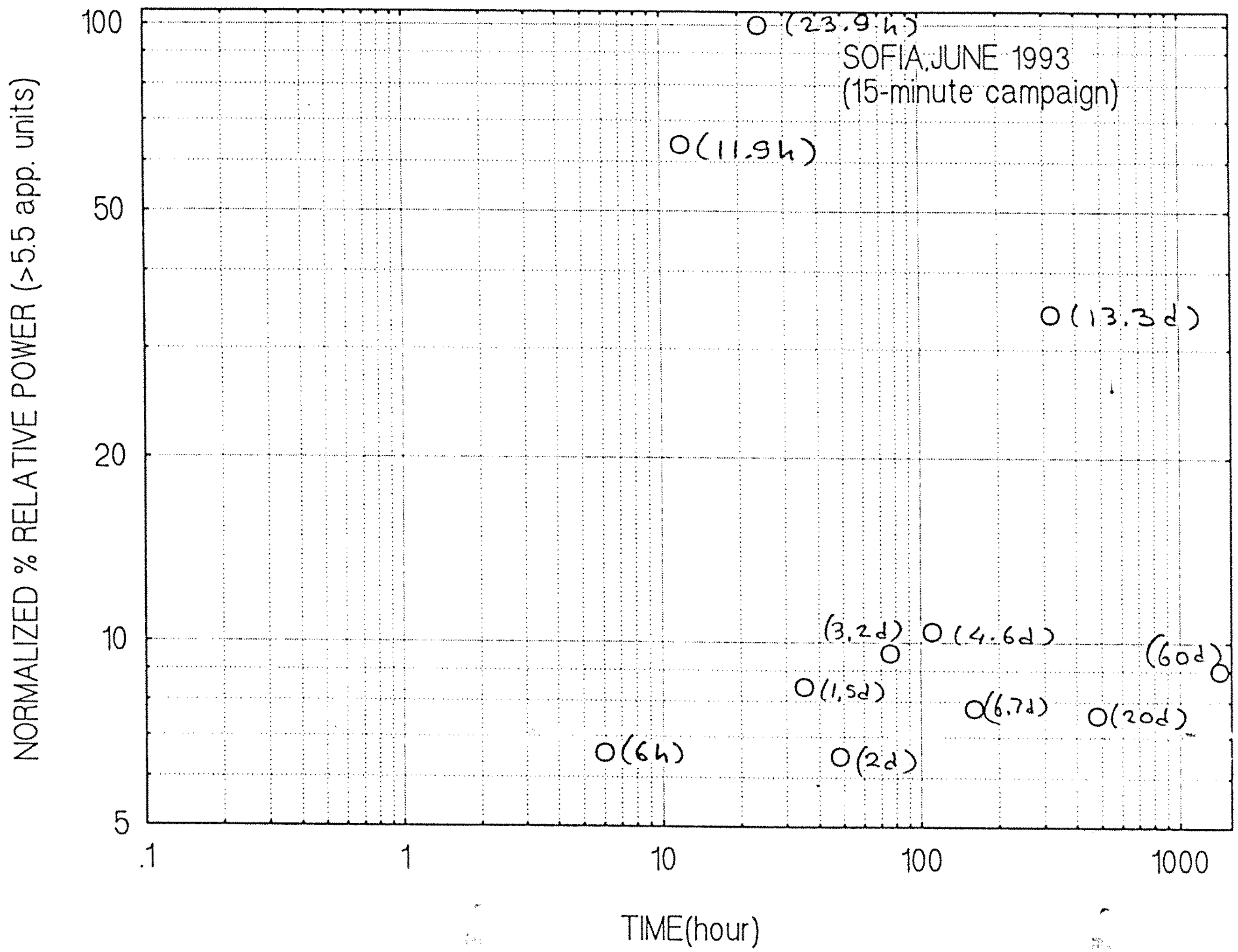

ROME,JUNE 1993
(15-minute campaign)
NORMALIZED % RELATIVE POWER (>5.5 app. units)
TIME(hour)
100
50
20
10
5
.1
1
10
100
1000
(23.9h)
(11.9h)
(13.3)d
(9.2d)
(5.2d)
(30d)
(2d)

Figure 3 (b)



SOFIA,JUNE 1993
(15-minute campaign)
NORMALIZED % RELATIVE POWER (>5.5 app. units)
TIME(hour)
100
50
20
10
5
.1
1
10
100
1000
(23.9h)
(11.9h)
(13.3d)
(3,2d)
(4.6d)
(60d)
(1,5d)
(6.7d)
(20d)
(6h)
(2d)

Figure 3 (c)

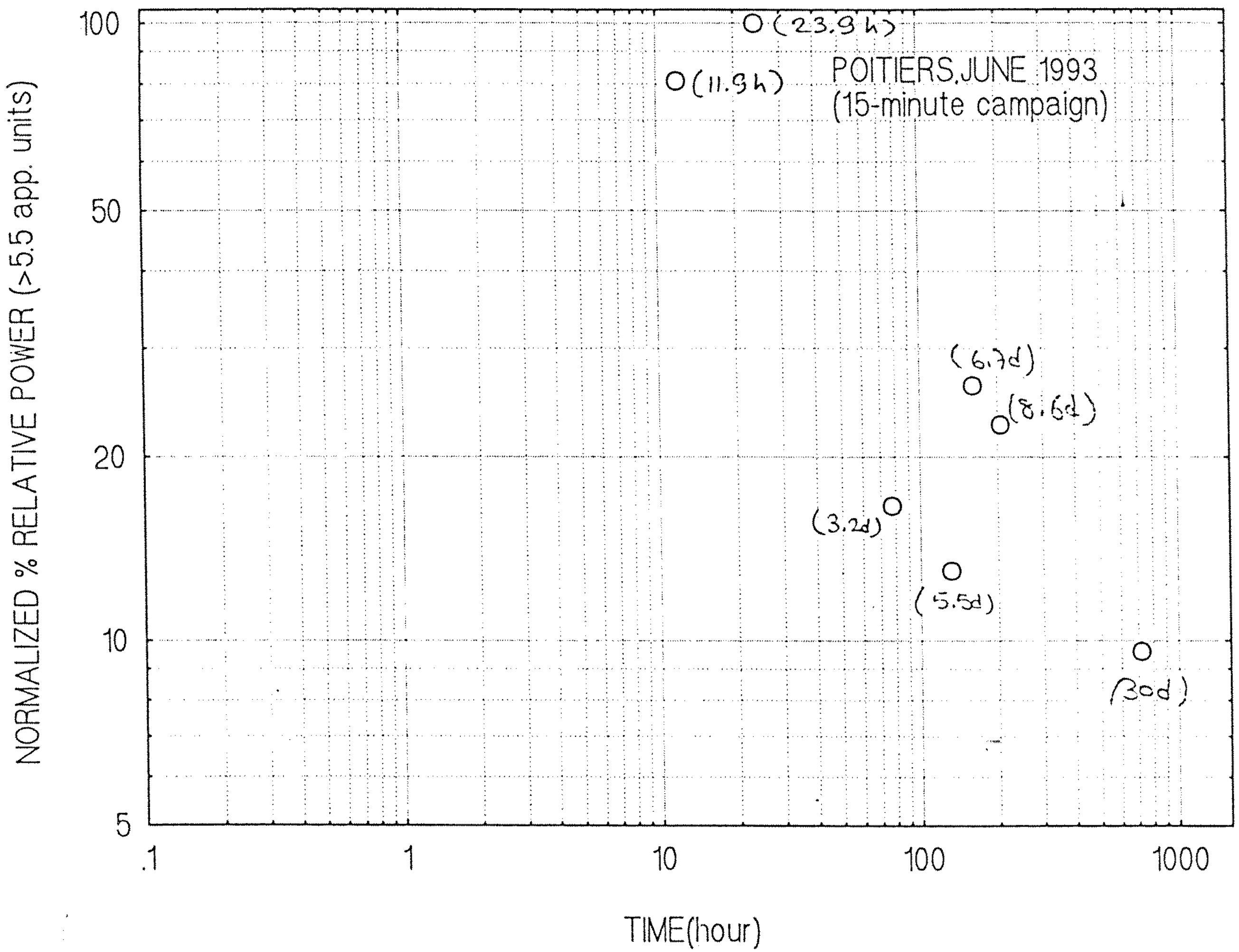
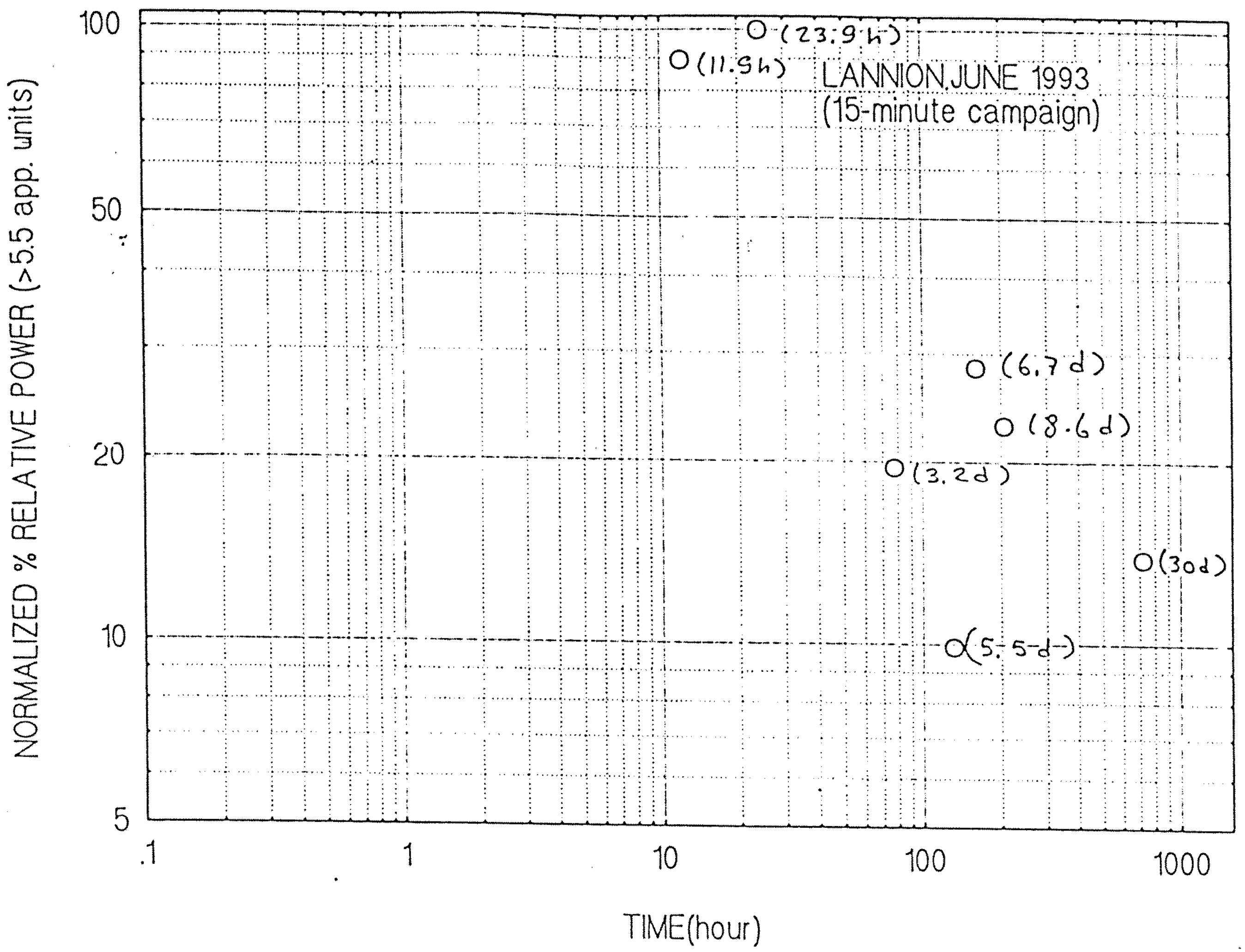

POITIERS,JUNE 1993
(15-minute campaign)
NORMALIZED % RELATIVE POWER (>5.5 app. units)
TIME(hour)
100
50
20
10
5
.1
1
10
100
1000
(23.9h)
(11.9h)
(6.7d)
(8.6d)
(3.2d)
(5.5d)
(30d)

Figure 3 (d)



100
50
20
10
5
.1
1
10
100
1000
NORMALIZED % RELATIVE POWER (>5.5 app. units)
TIME(hour)
LANNION,JUNE 1993
(15-minute campaign)
(23.9h)
(11.9h)
(6.7d)
(8.6d)
(3.2d)
(30d)
(5.5d)

Figure 3 (e)

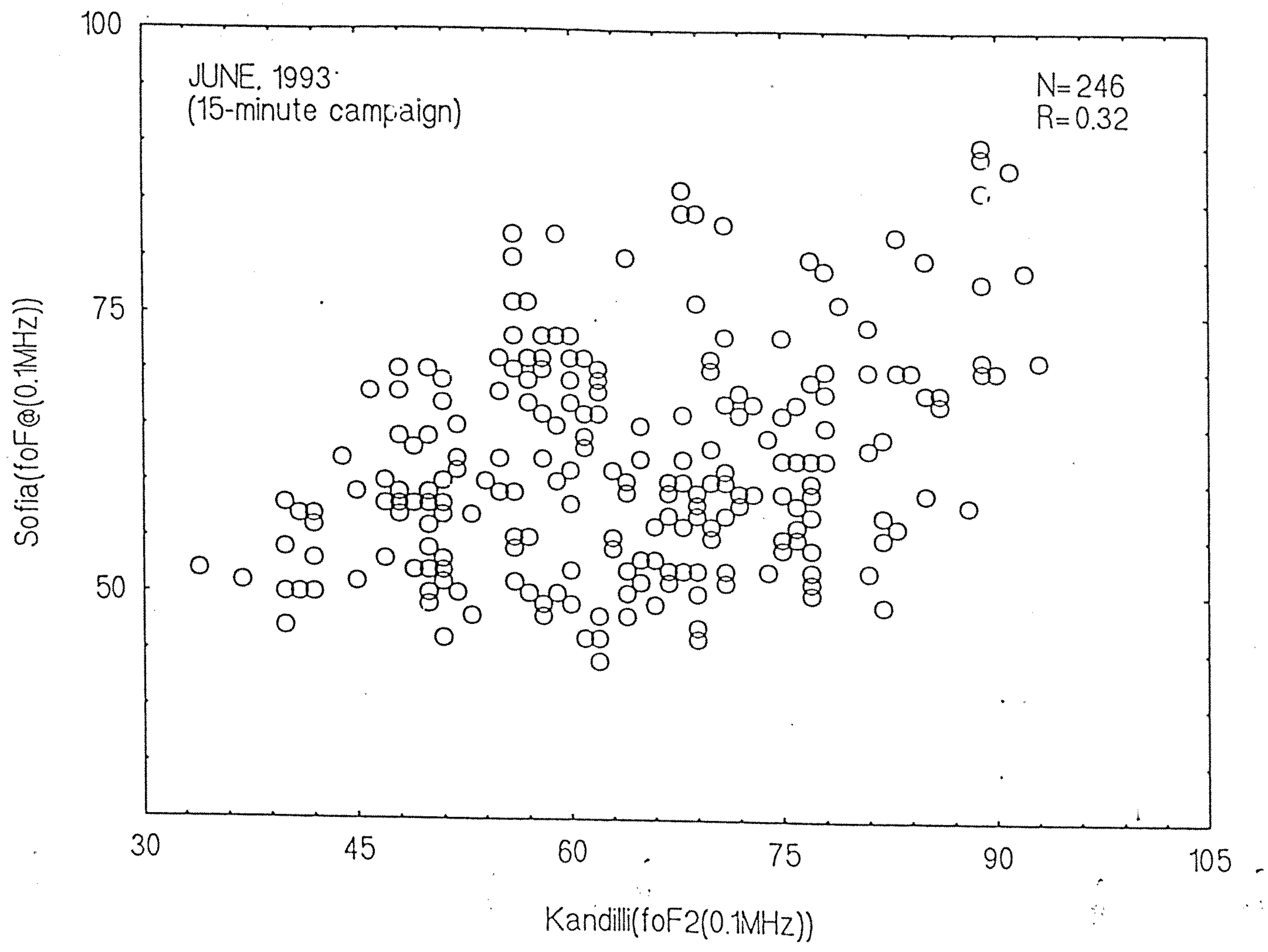
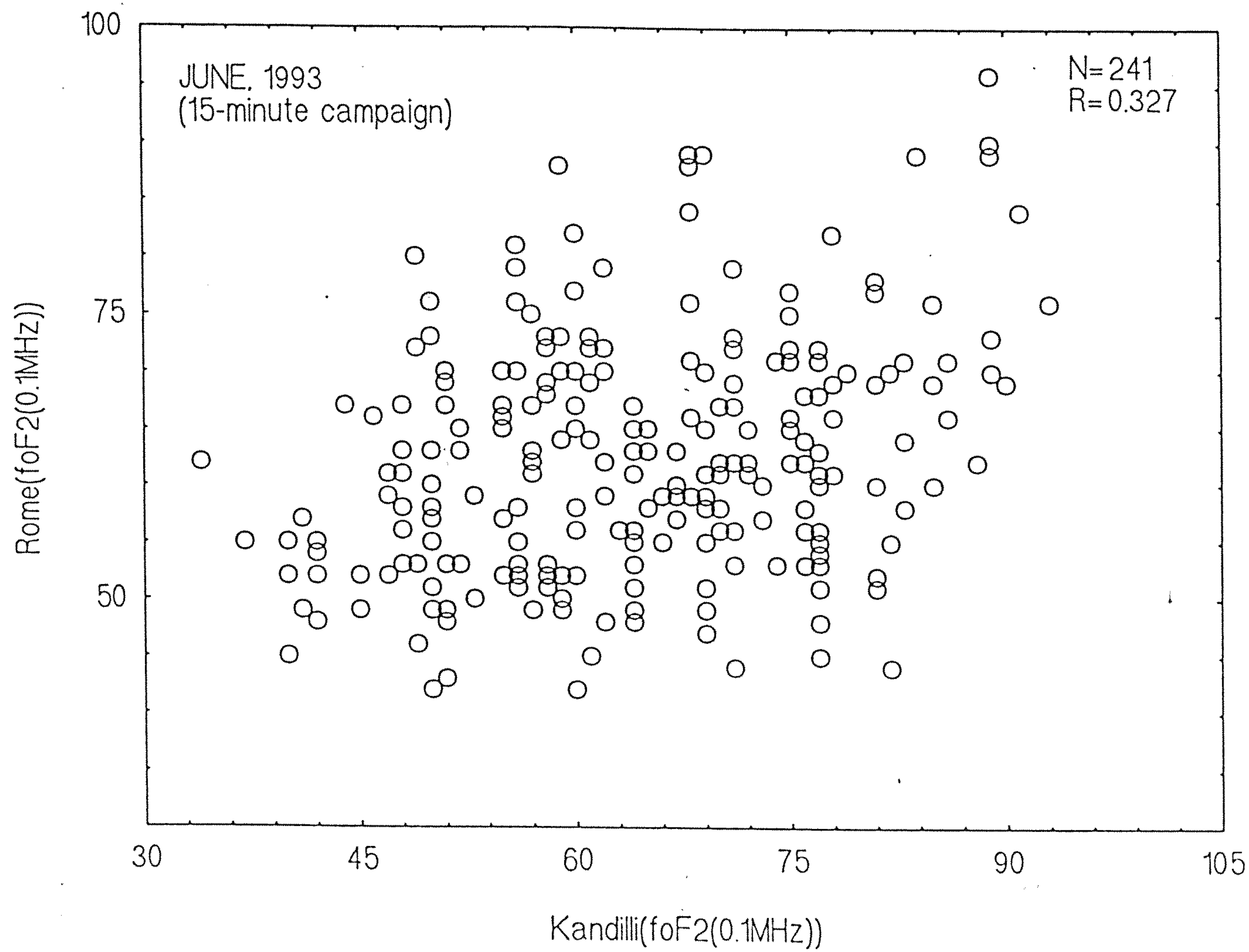

JUNE, 1993
(15-minute campaign)
N=246
R=0.32
100
75
50
30
45
60
75
90
105
Sofia(foF@(0.1MHz))
Kandilli(foF2(0.1MHz))

Figure 4 (a)


JUNE, 1993
(15-minute campaign)
N=241
R=0.327
100
75
50
30
45
60
75
90
105
Rome(foF2(0.1MHz))
Kandilli(foF2(0.1MHz))

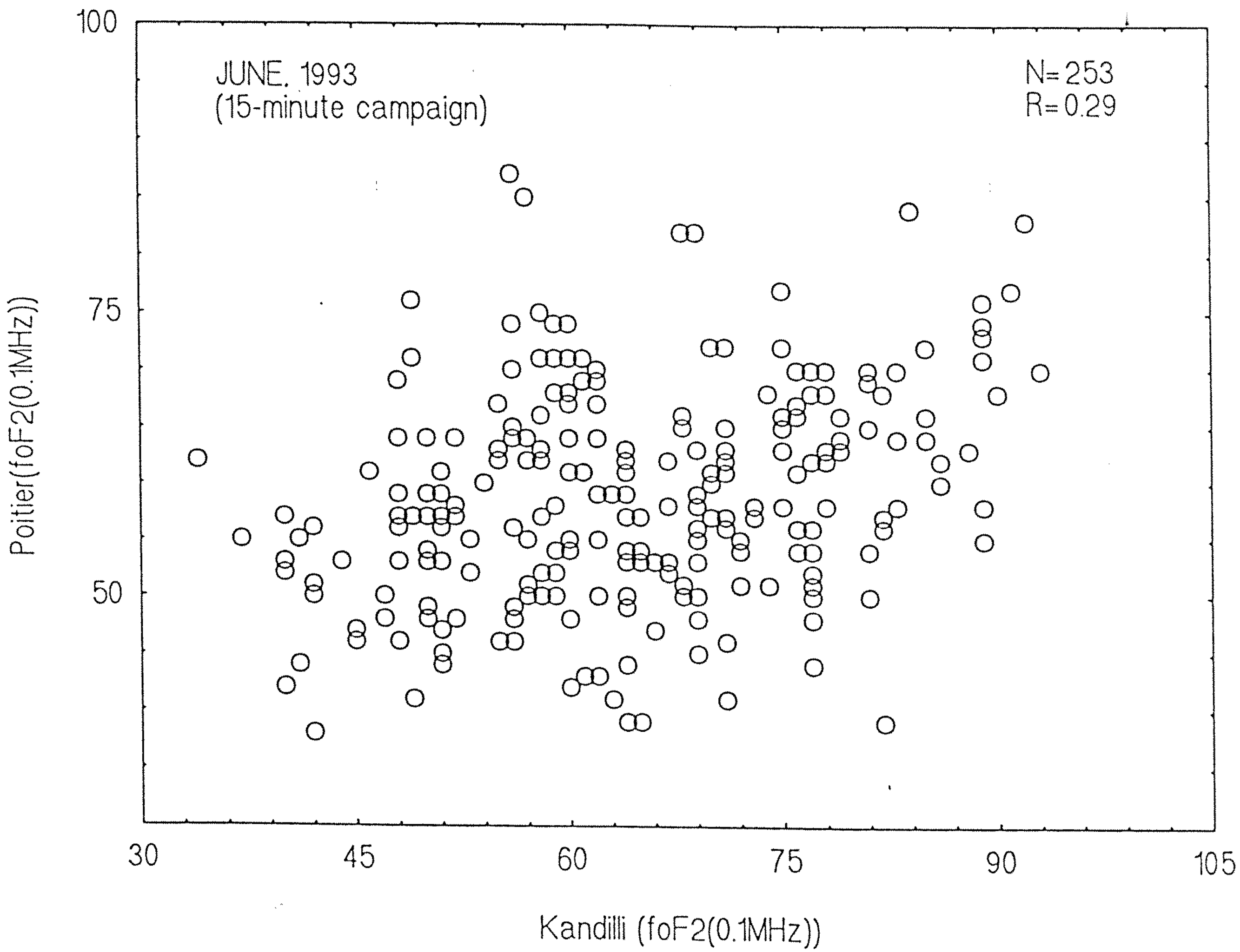

JUNE, 1993
(15-minute campaign)
N=253
R=0.29
100
75
50
30
45
60
75
90
105
Poitier(foF2(0.1MHz))
Kandilli (foF2(0.1MHz))

Figure 4 (c)

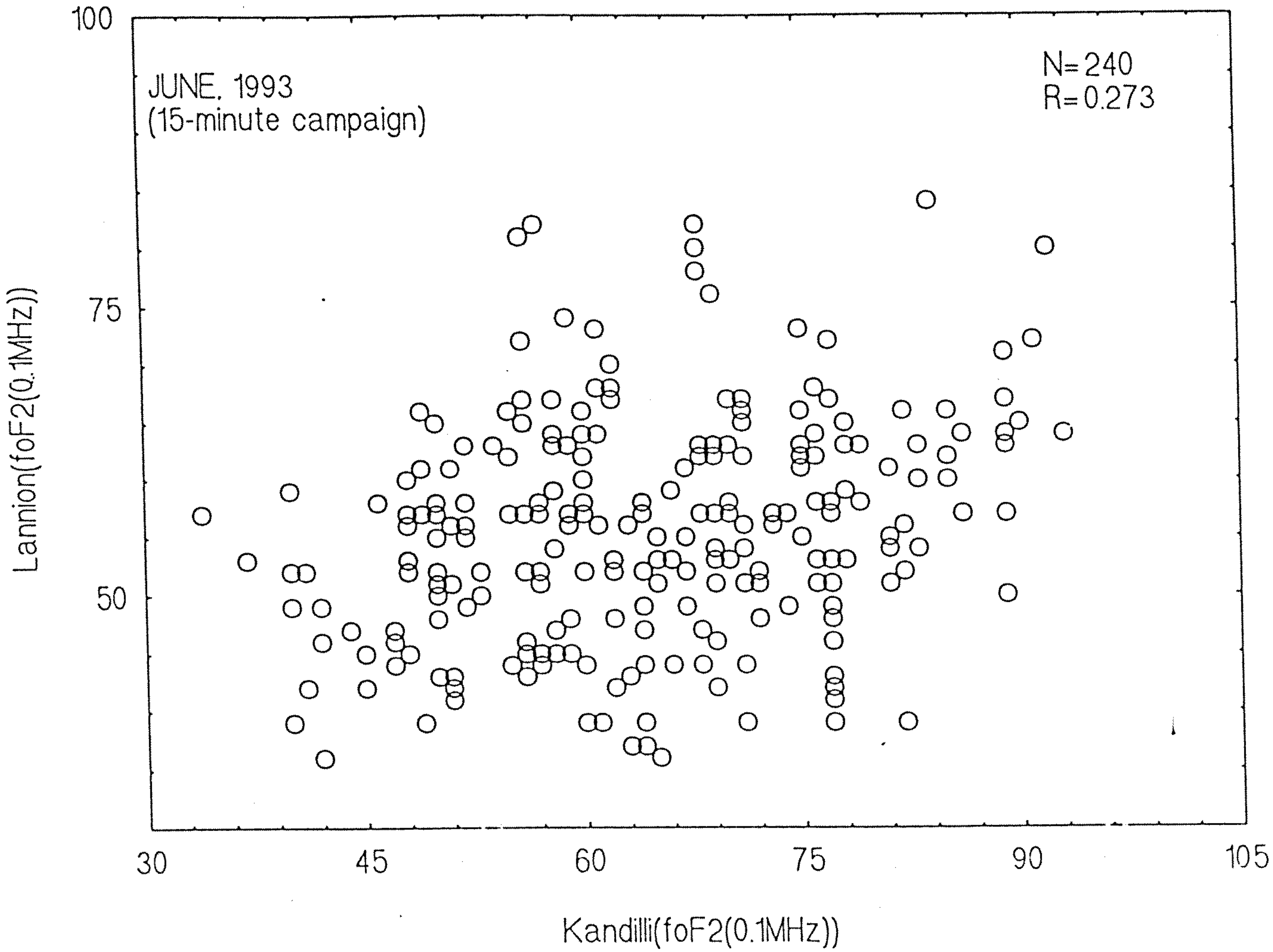

100
75
50
30
45
60
75
90
105
JUNE, 1993
(15-minute campaign)
N=240
R=0.273
Lannion(foF2(0.1MHz))
Kandilli(foF2(0.1MHz))

Figure 4 (d)

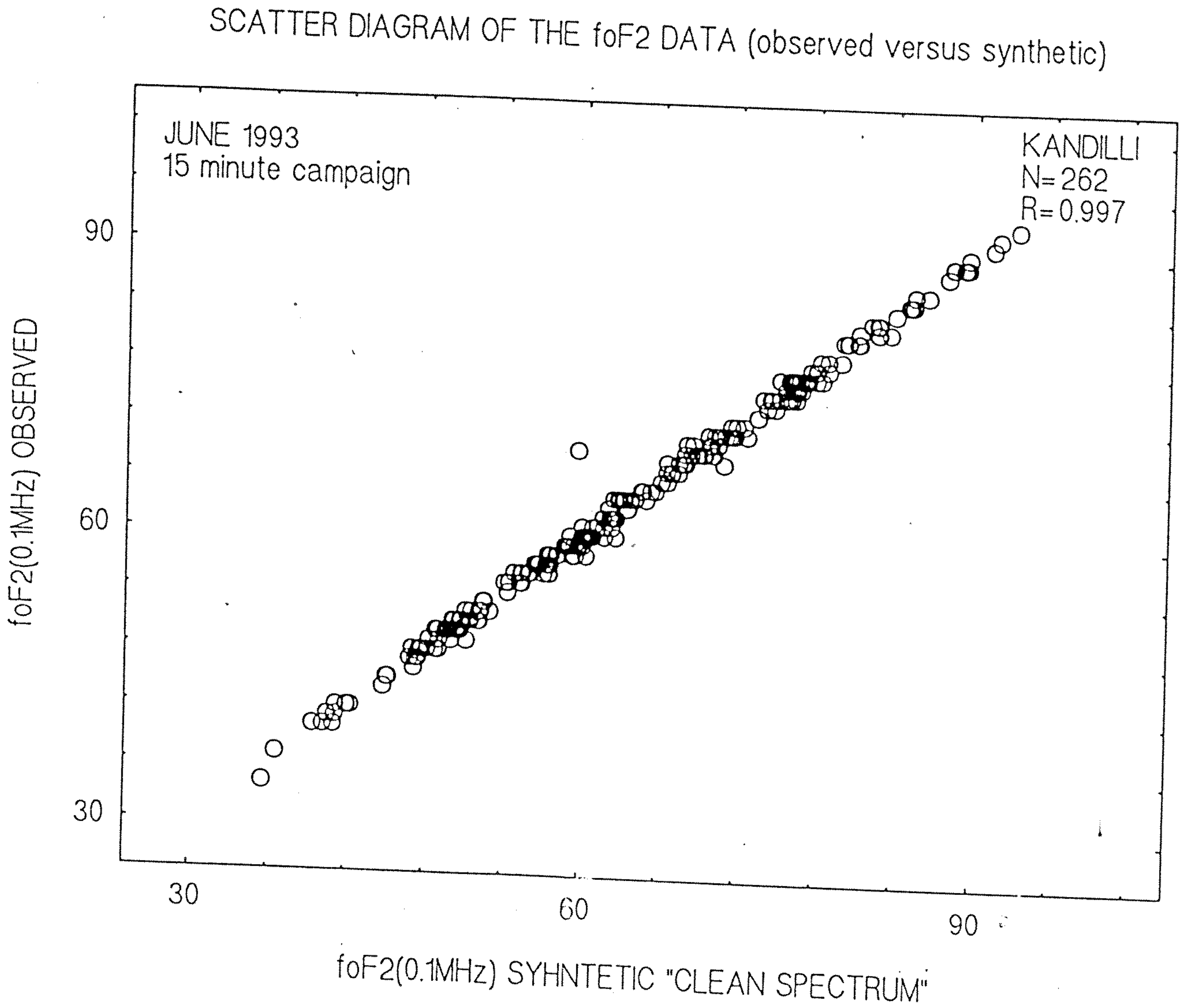

SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)
JUNE 1993
15 minute campaign
KANDILLI
N=262
R=0.997
90
60
30
foF2(0.1MHz) OBSERVED
30
60
90
foF2(0.1MHz) SYHNTETIC "CLEAN SPECTRUM"

Figure 5 (a)

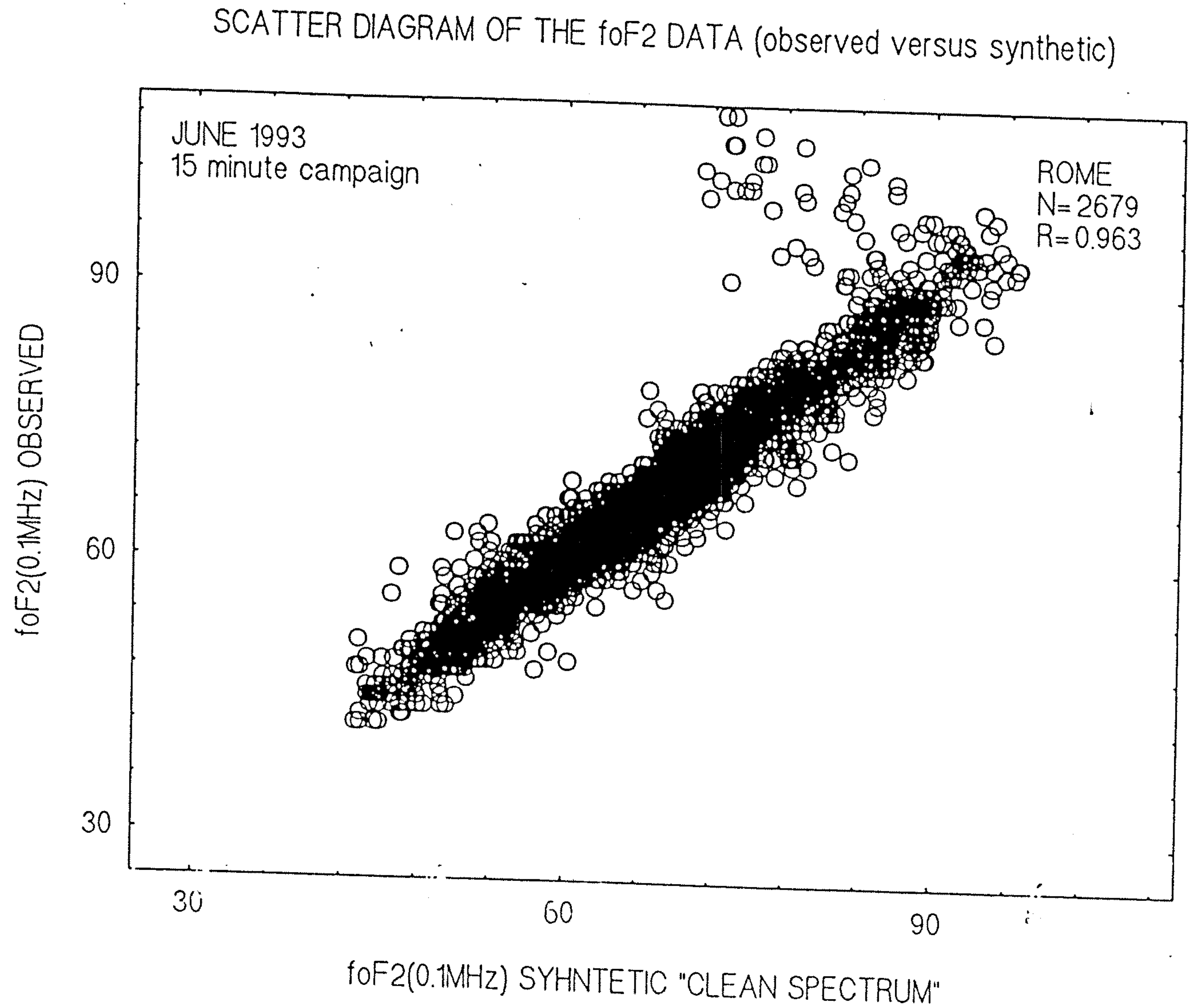
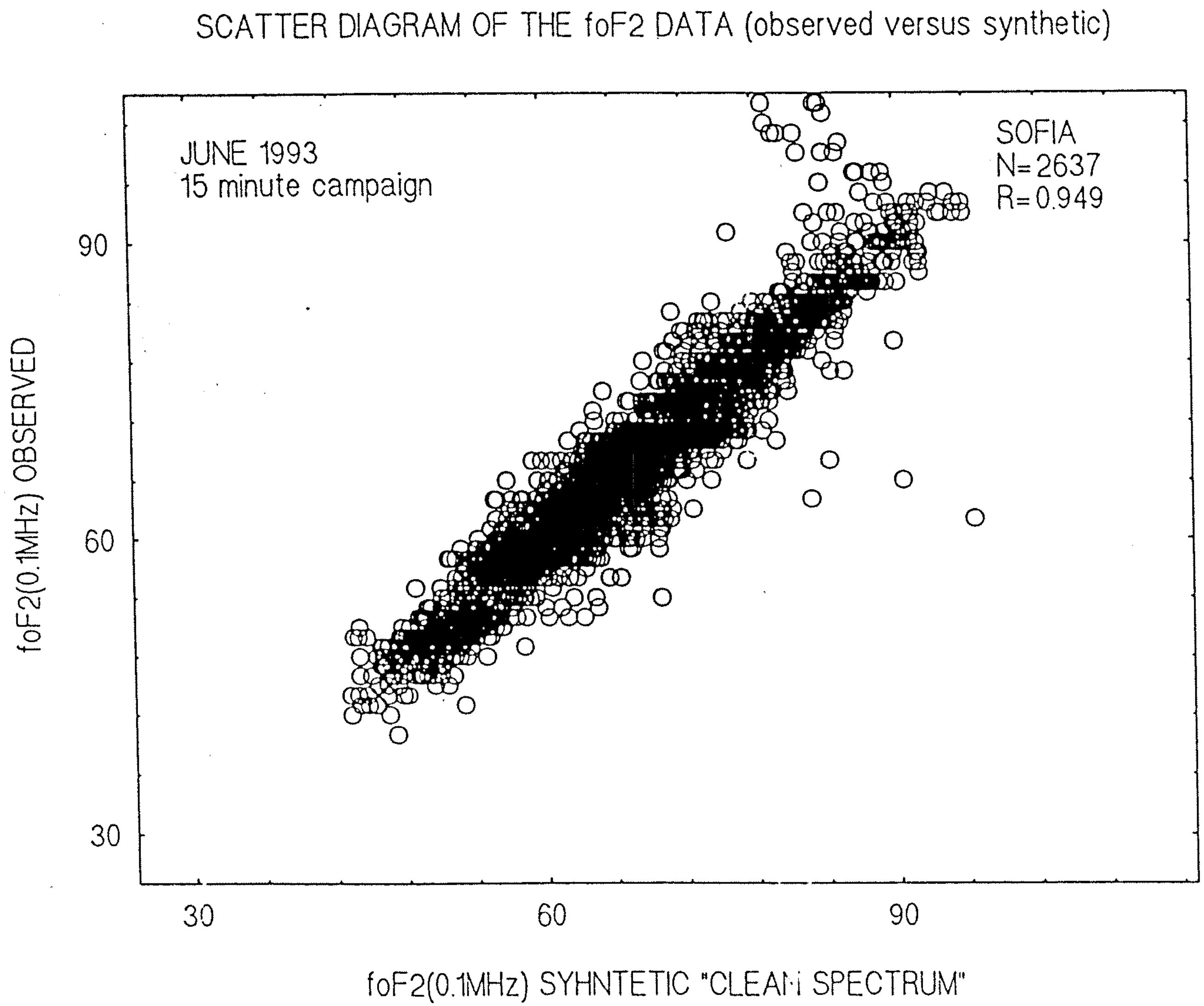

SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)
JUNE 1993
15 minute campaign
ROME
N=2679
R=0.963
90
60
30
foF2(0.1MHz) OBSERVED
30
60
90
foF2(0.1MHz) SYHNTETIC "CLEAN SPECTRUM"

Figure 5 (b)



SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)
JUNE 1993
15 minute campaign
SOFIA
N=2637
R=0.949
90
60
30
foF2(0.1MHz) OBSERVED
30
60
90
foF2(0.1MHz) SYHNTETIC "CLEAN SPECTRUM"

Figure 5 (c)

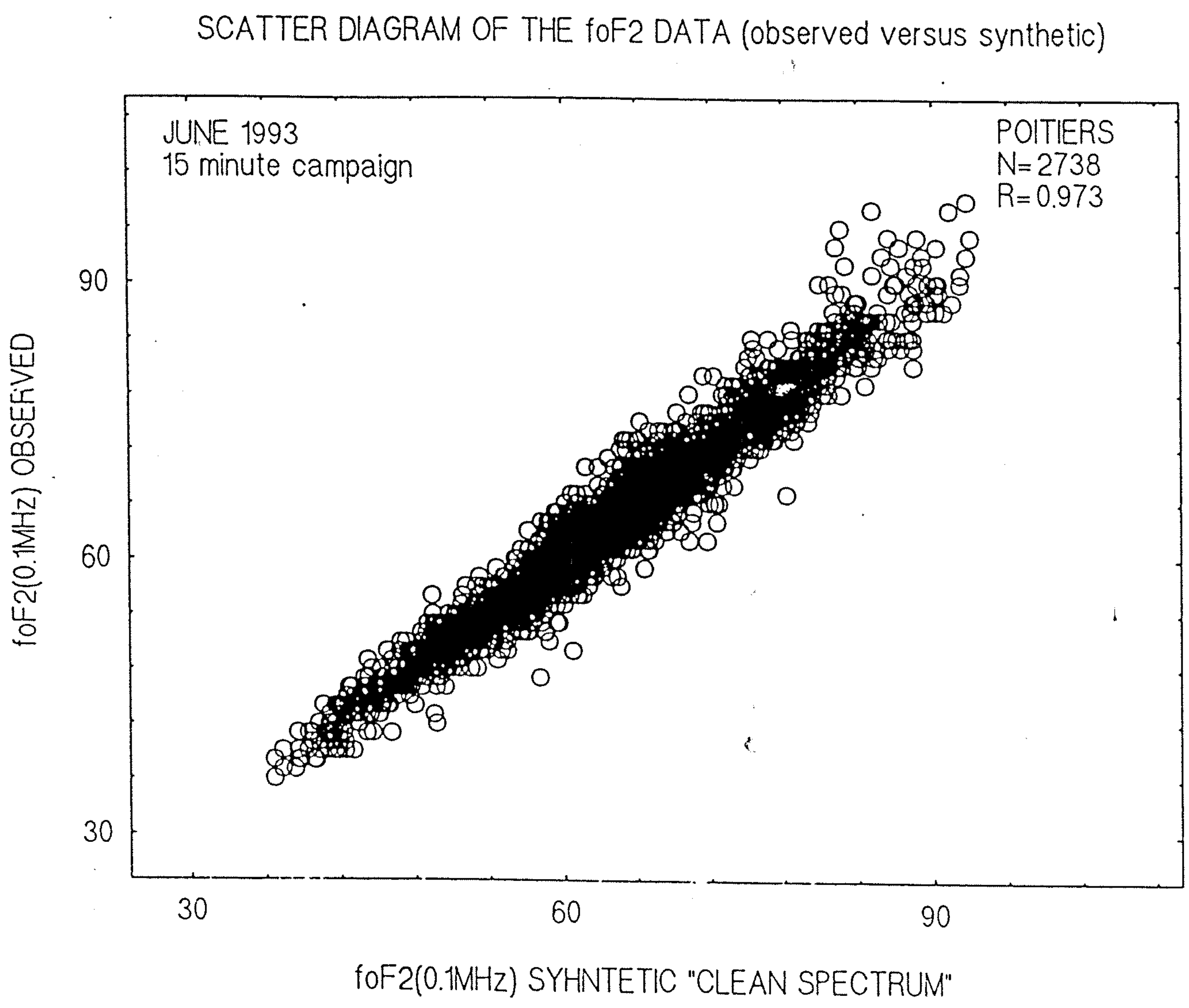
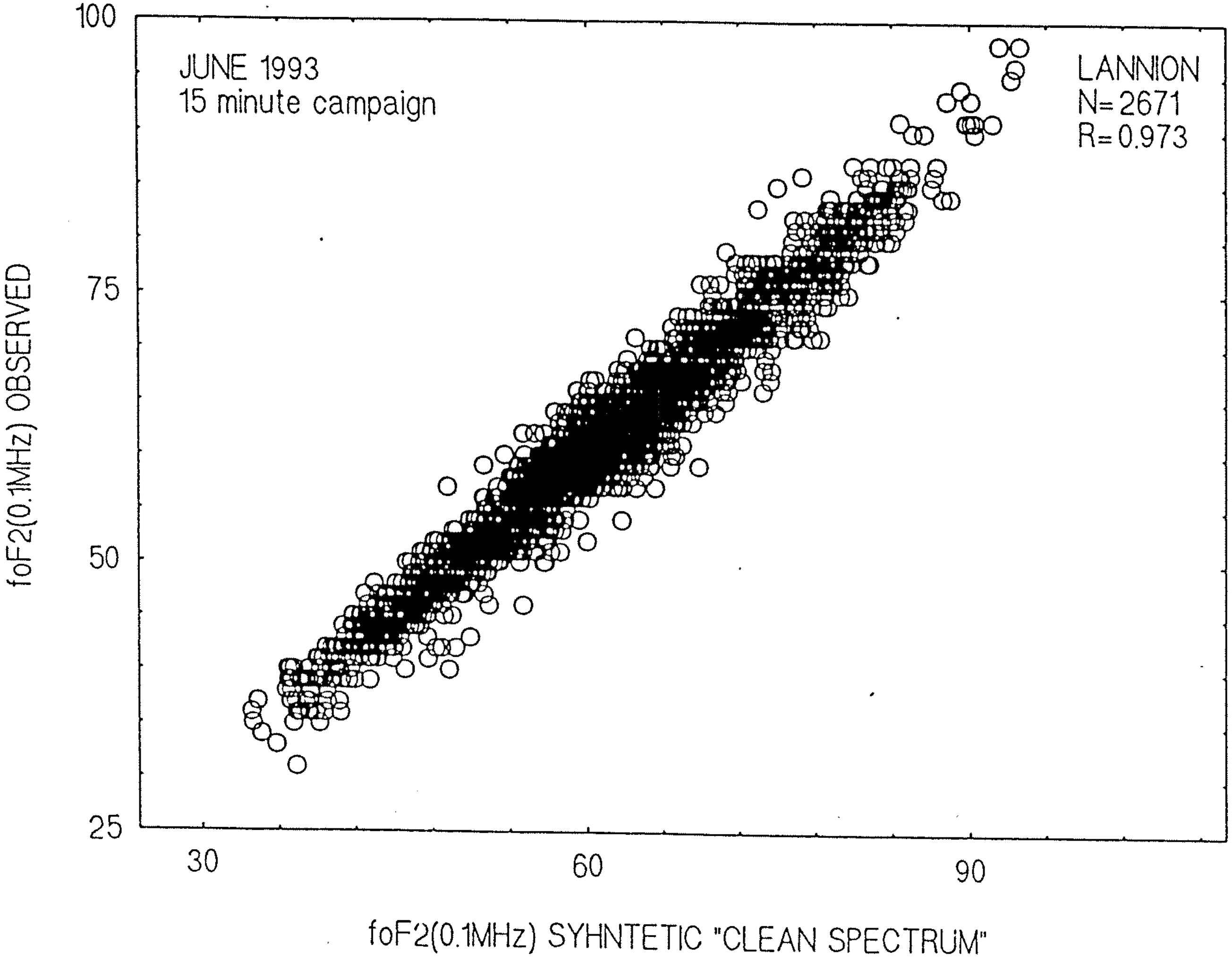

SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)
JUNE 1993
15 minute campaign
POITIERS
N=2738
R=0.973
90
60
30
foF2(0.1MHz) OBSERVED
30
60
90
foF2(0.1MHz) SYHNTETIC "CLEAN SPECTRUM"

Figure 5 (d)

SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)



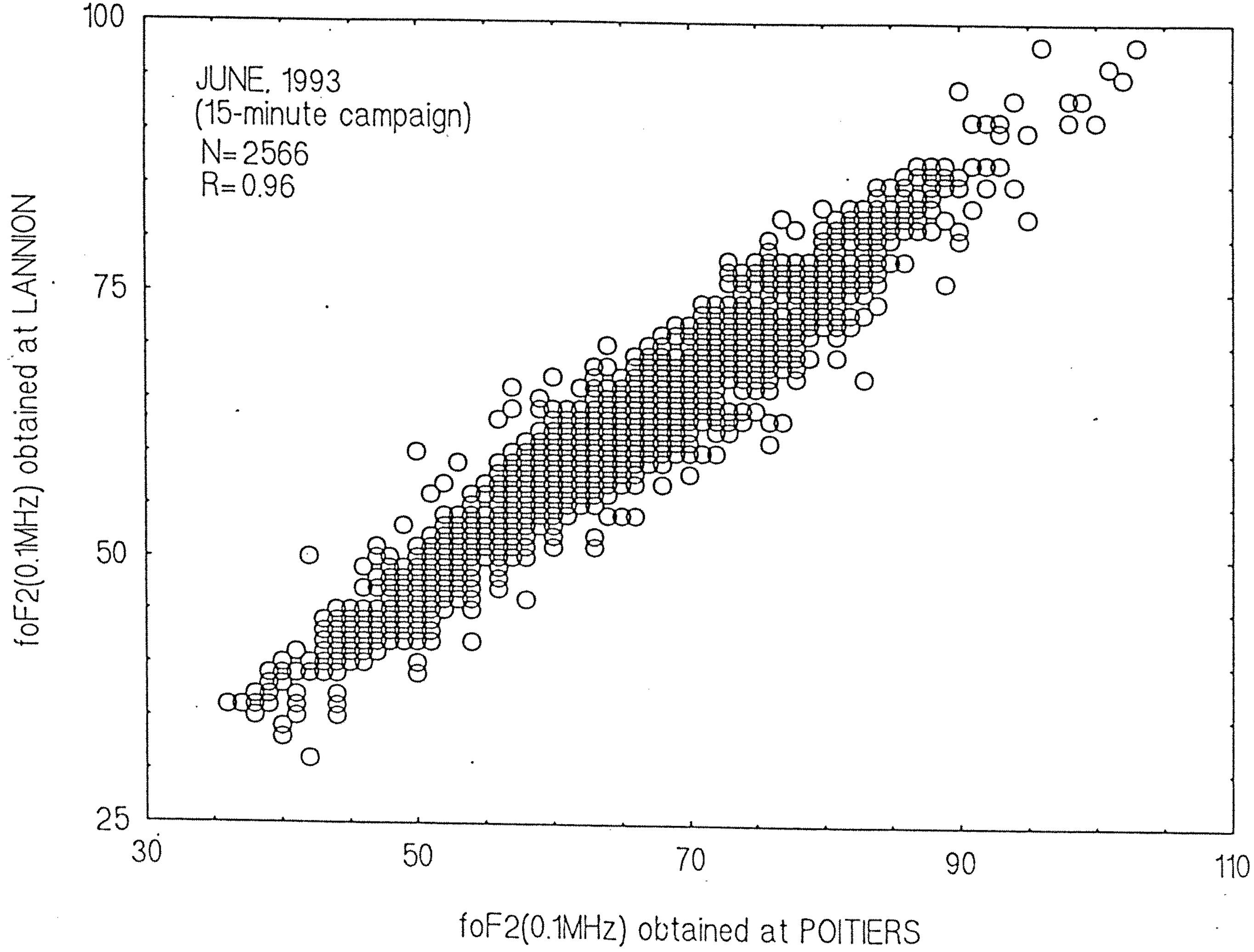

JUNE, 1993
(15-minute campaign)
N=2566
R=0.96
100
75
50
25
30
50
70
90
110
foF2(0.1MHz) obtained at LANNION
foF2(0.1MHz) obtained at POITIERS

Figure 6

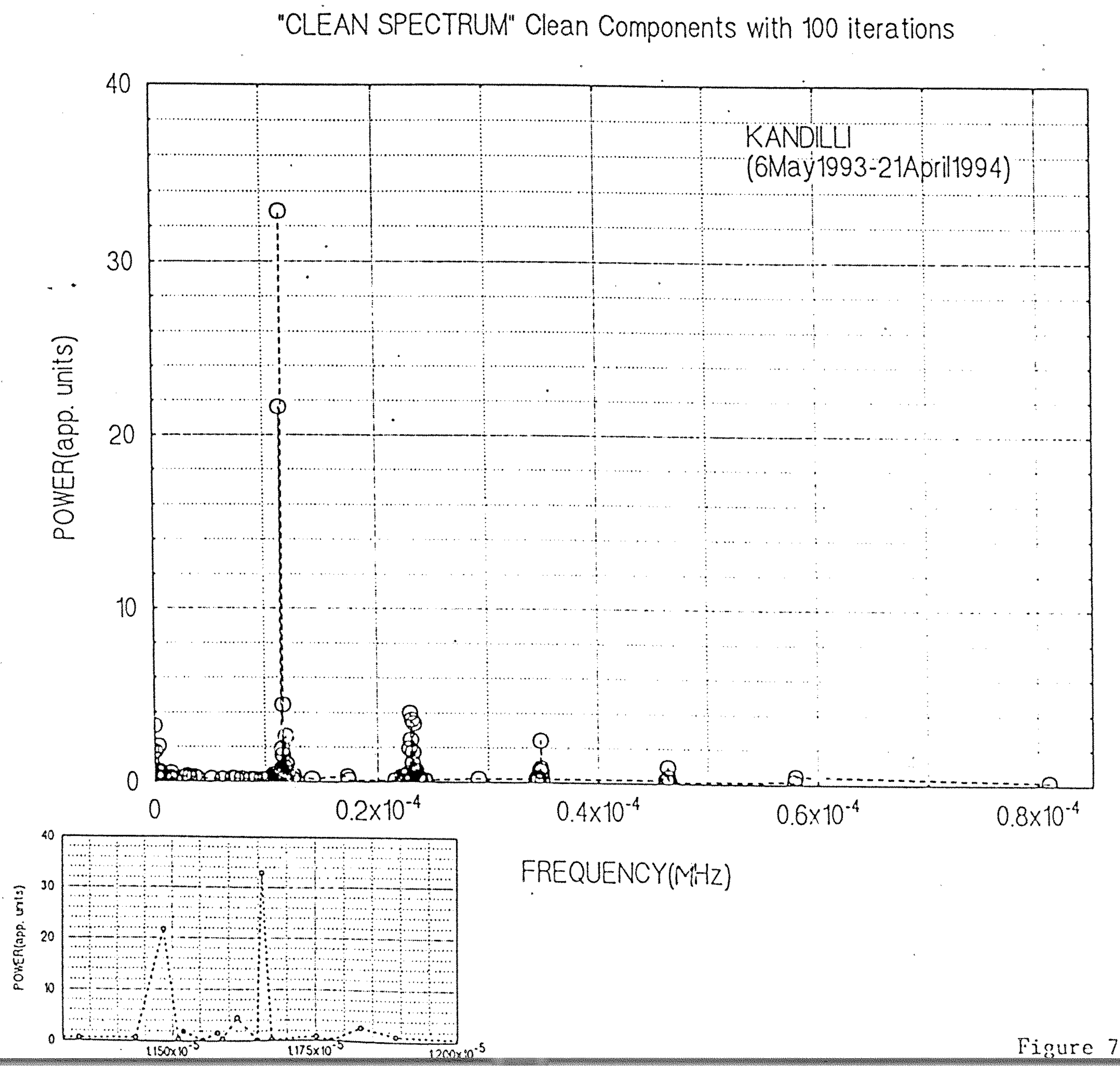

"CLEAN SPECTRUM" Clean Components with 100 iterations
KANDILLI
(6May1993-21April1994)
POWER(app. units)
40
30
20
10
0
0.2x10^-4
0.4x10^-4
0.6x10^-4
0.8x10^-4
FREQUENCY(MHz)
1.150x10^-5
1.175x10^-5
1.200x10^-5

Figure 7

SCATTER DIAGRAM OF THE foF2 DATA (observed versus synthetic)

KANDILLI
6May1993-12April1994

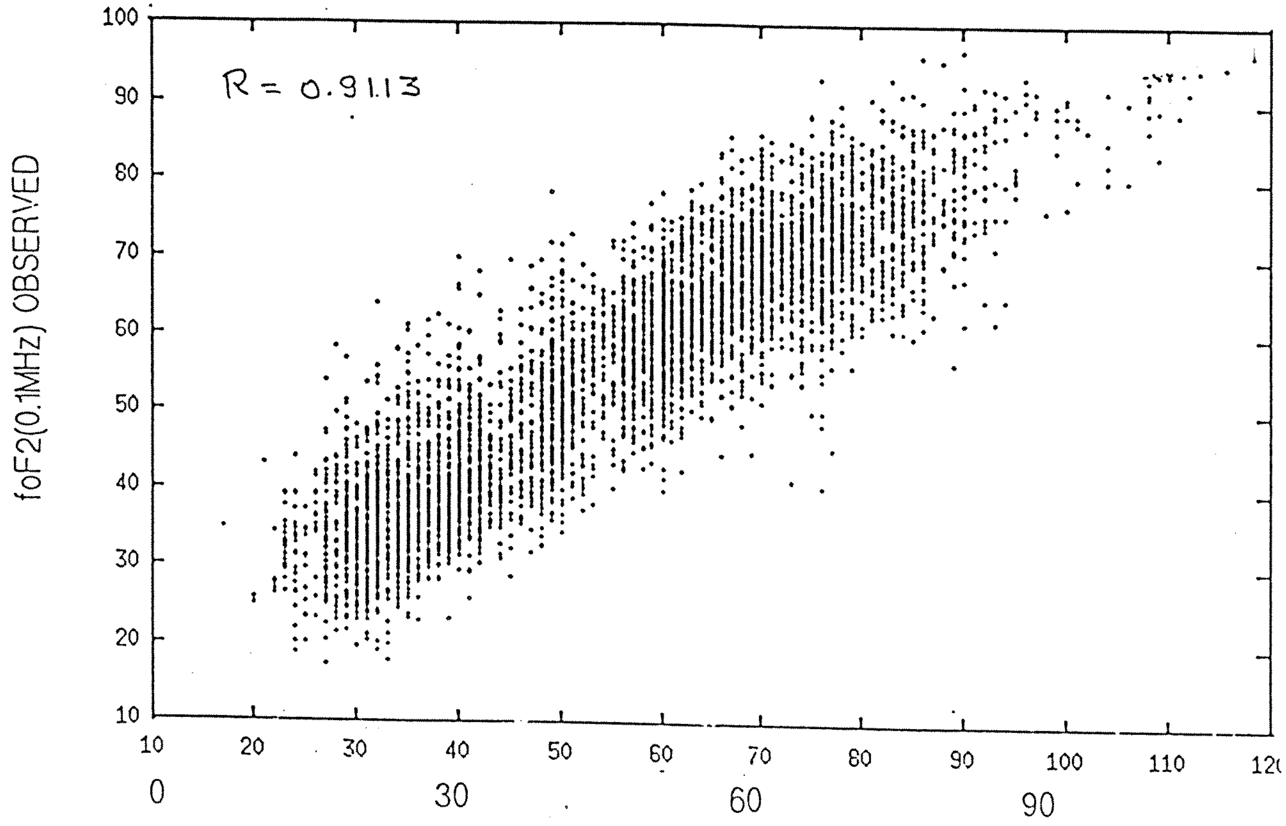


Figure 8

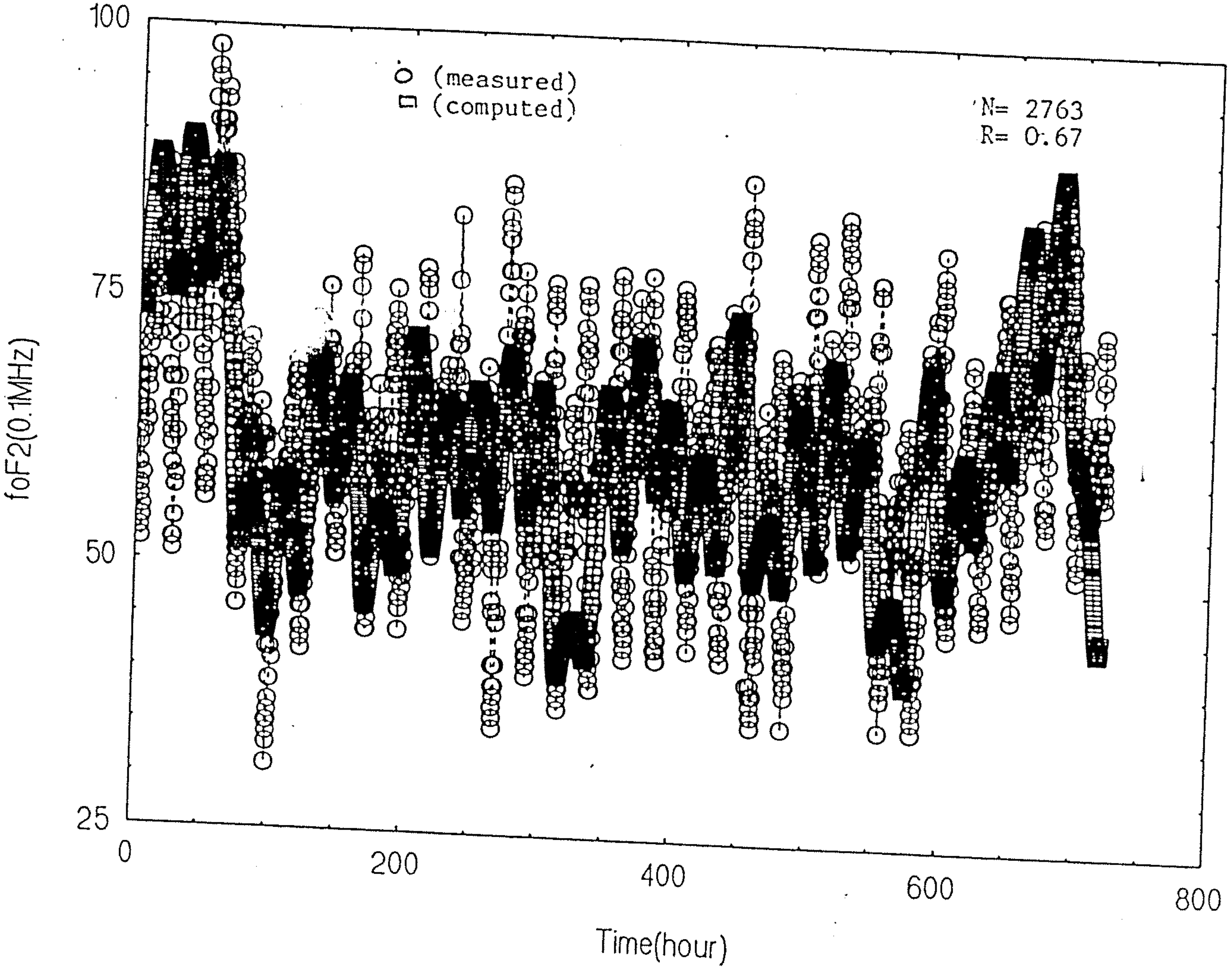

100
75
50
25
foF2(0.1MHz)
0
200
400
600
800
Time(hour)
O (measured)
□ (computed)
N= 2763
R= 0.67

Figure 9-1

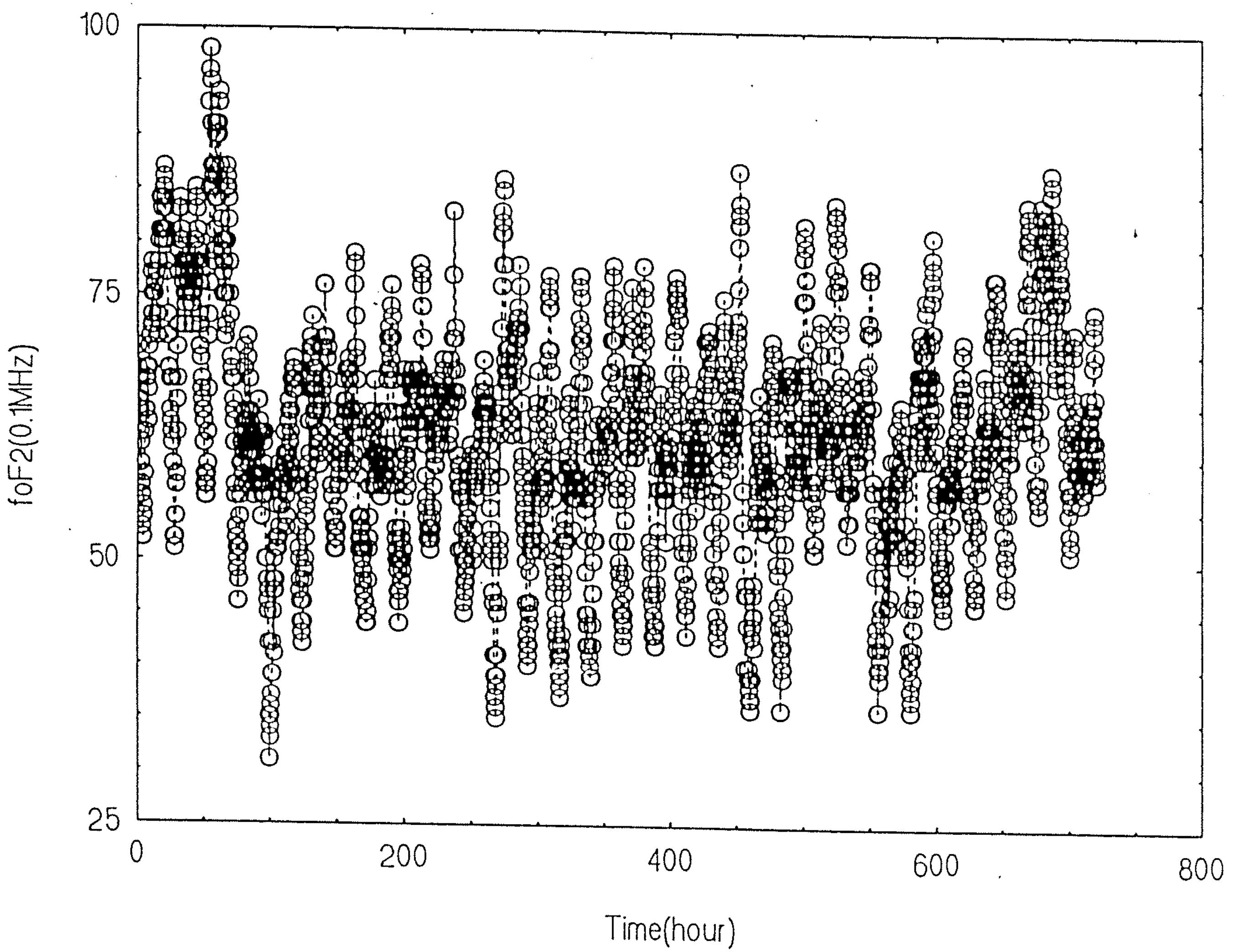


Figure 9-2

EK (6.3.2)-1

May - June 1993

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS

Publicaciones del Observatorio del Ebro

Memoria nº 16

DATA VALIDATION OF IONOSPHERIC MODELS AND MAPS (VIM)

PRIME/URSI Joint Workshop

ROQUETES (Tarragona)
1992

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IMF AND ITS POSSIBLE EFFECTS ON foF2 OBTAINED AT TWO ALMOST CONJUGATE STATIONS, SLOUGH AND ARGENTINA ISLAND

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OBJECTIVE

Tulunay et.al., (1991) investigated the possible effects of the orientation of the IMF on mid-latitude ionosphere by employing the Slough foF2 data between 1967 and 1986. This work has been extended further and the analysis was repeated in order to include the critical frequencies of Argentina Island ionosonde station also. In order to facilitate a comparison the same method of data analysis was adopted. For this purpose, the regular diurnal, seasonal and solar cycle variations in the foF2 data were removed by subtracting the mean of foF2 for the same UT on all the magnetically quiet days ($Ap < 6$) within 15 days. This yields the deviation from the average quiet-time value δFoF2. The data are sorted according to the polarity of the IMF B_z and the effect of changes in that polarity (i.e. northward and southward turnings) are discussed, previous studies have investigated the effect on the mid-latitude ionosphere of IMF sector boundaries impinging upon the magnetosphere, during which the B_x component of the IMF changes polarity between "toward" and "away" orientations.

RESULTS

We considered polarity changes in IMF B_z, with no consideration of the IMF sector structure.

Figures 1S, 2S, 1AI, and 2AI show the results of superposed epoch studies for the $|\delta B_z| > 11.5$ nT IMF B_z turnings. In all plots the IMF change occurred at time zero. The horizontal axis gives the time (in hours) relative to the IMF B_z polarity change, and the vertical axis shows the mean value of δfoF2. The means for each IMF B_z turning time are shown with error bars of plus and minus one standard error in that mean. Part (a) of all the Figures is for the period covering April to September for Slough (Summer) and October to March for Argentina Island (Summer), whereas part (b) is for the period October to March for Slough (Winter) and April to September Fort Argentina Island (Winter) of each year of available data. Figures 1S(a), 1AI(a), 1S(b), and 1AI(b) are for the southward turning events, figures 2S(a), 2AI(a), 2S(b), and 2AI(b) are for the northward turning events.

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Figure 1 shows clear minima in the average δfoF2 during the day after the southward IMF turnings. These minima are at δfoF2 of -1.6 MHz and -1.0 MHz in Summer, -1.2 MHz and -0.6 MHz in Winter at the Slough and Argentina Island respectively. The values before the IMF Bz turnings (events) are, however, not always zero, indicating that many non quiet-days are present. The peak change which can be attributed to the southward IMF turnings is about 1.2 MHz for Summer for both stations, whereas, this peak change in winter is 1.2 MHz for Slough and 0.6 MHz for Argentina Island. The foF2 values do remain somewhat depressed (by about 0.3 MHz - 0.5 MHz) for the subsequent four days.

Figure 2 shows and unexpected result, namely that the northward turning are also followed by depressions of foF2 for both stations in Summer. The Winter case, however for both stations indicate that, especially, for the Argentina Island, there is no significant depression following the IMF B_z Turnings. Even though it is not very clear, somehow, all the northward cases show some evidence for a positive phase to the variation.

Considering the standard errors in the means, these values are plus and minus about 0.2 MHz for both stations for all cases, and hence are considered highly significant. Results imply that the IMF B_z effect on mid-latitude densities could be a contributory effect in day-to-day variability.

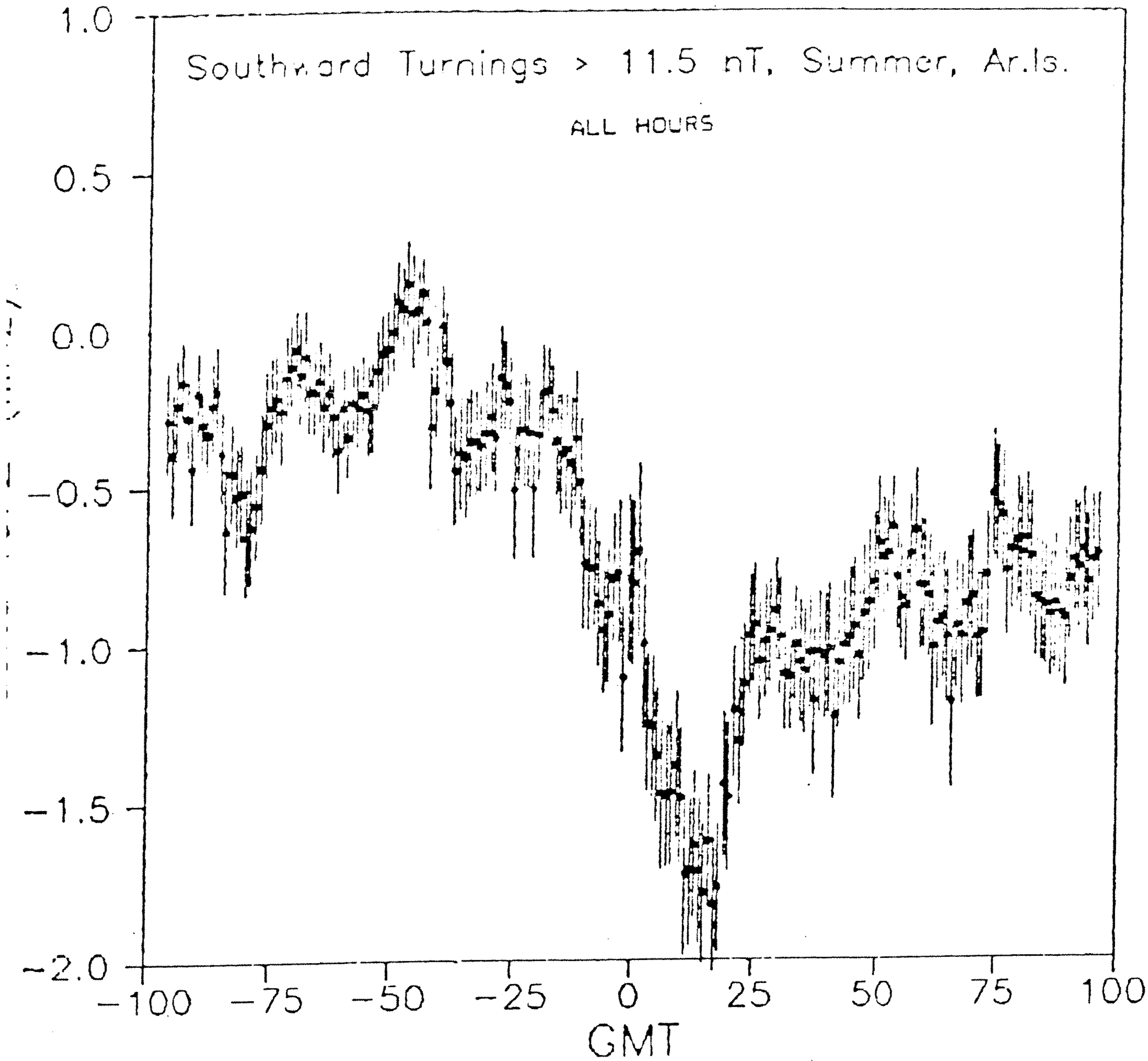
Southward Turnings > 11.5 nT, Summer, Ar.Is.
ALL HOURS
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−100
−75
−50
−25
0
25
50
75
100
GMT

FIGURE 1AI (A)

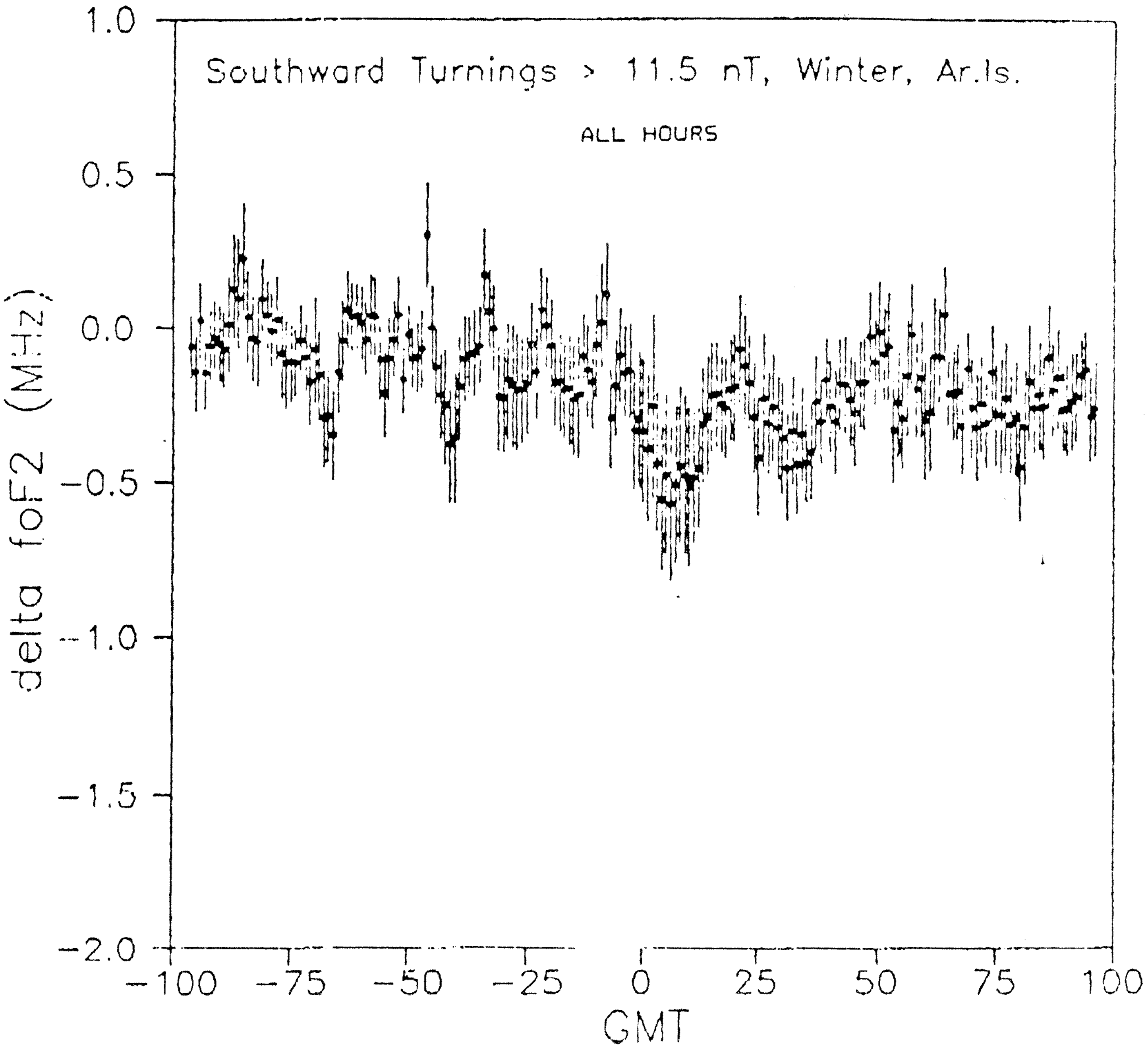
Southward Turnings > 11.5 nT, Winter, Ar.Is.
ALL HOURS
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
delta foF2 (MHz)
−100
−75
−50
−25
0
25
50
75
100
GMT

FIGURE 1AI (B)

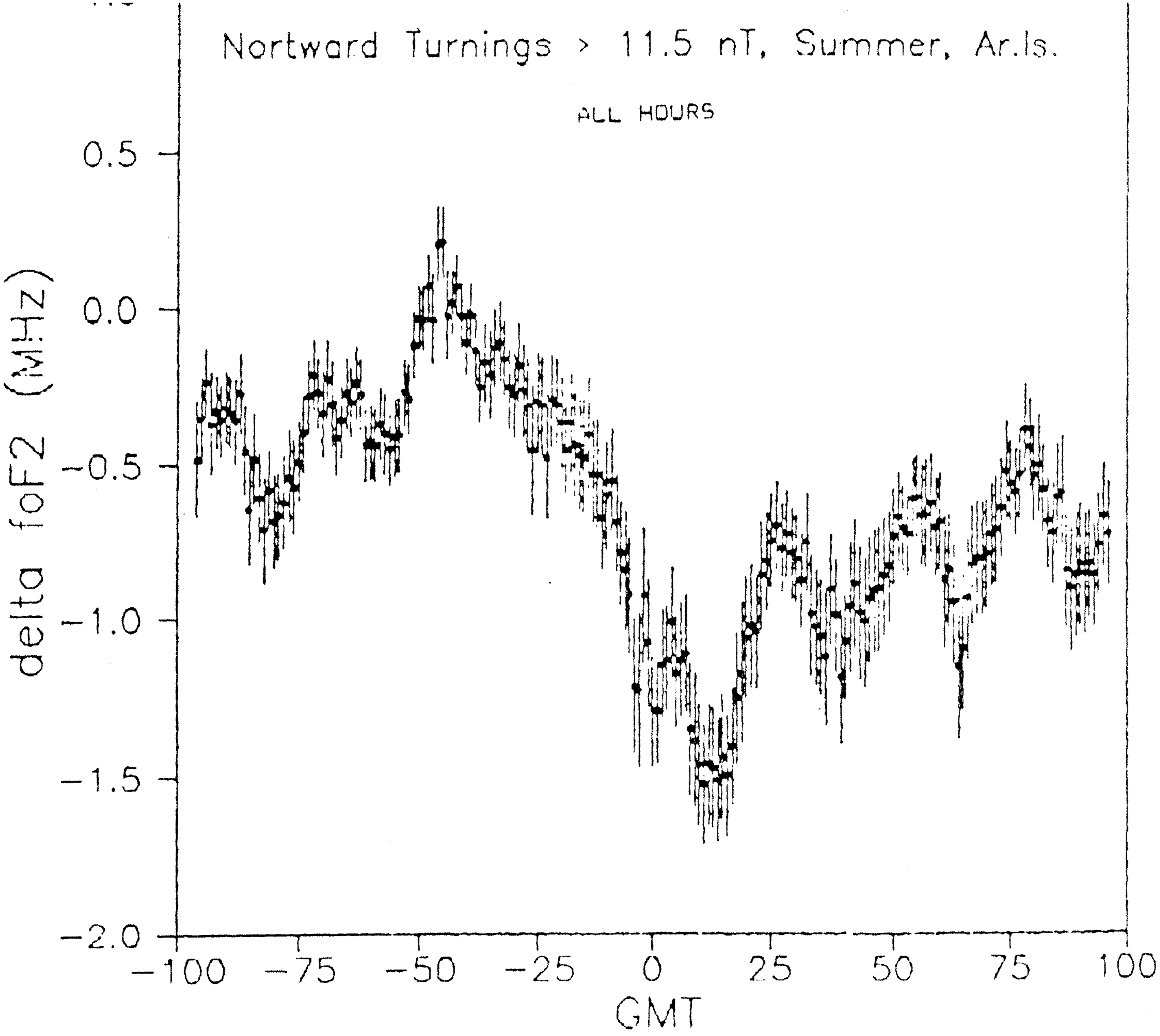

FIGURE 2AI (A)

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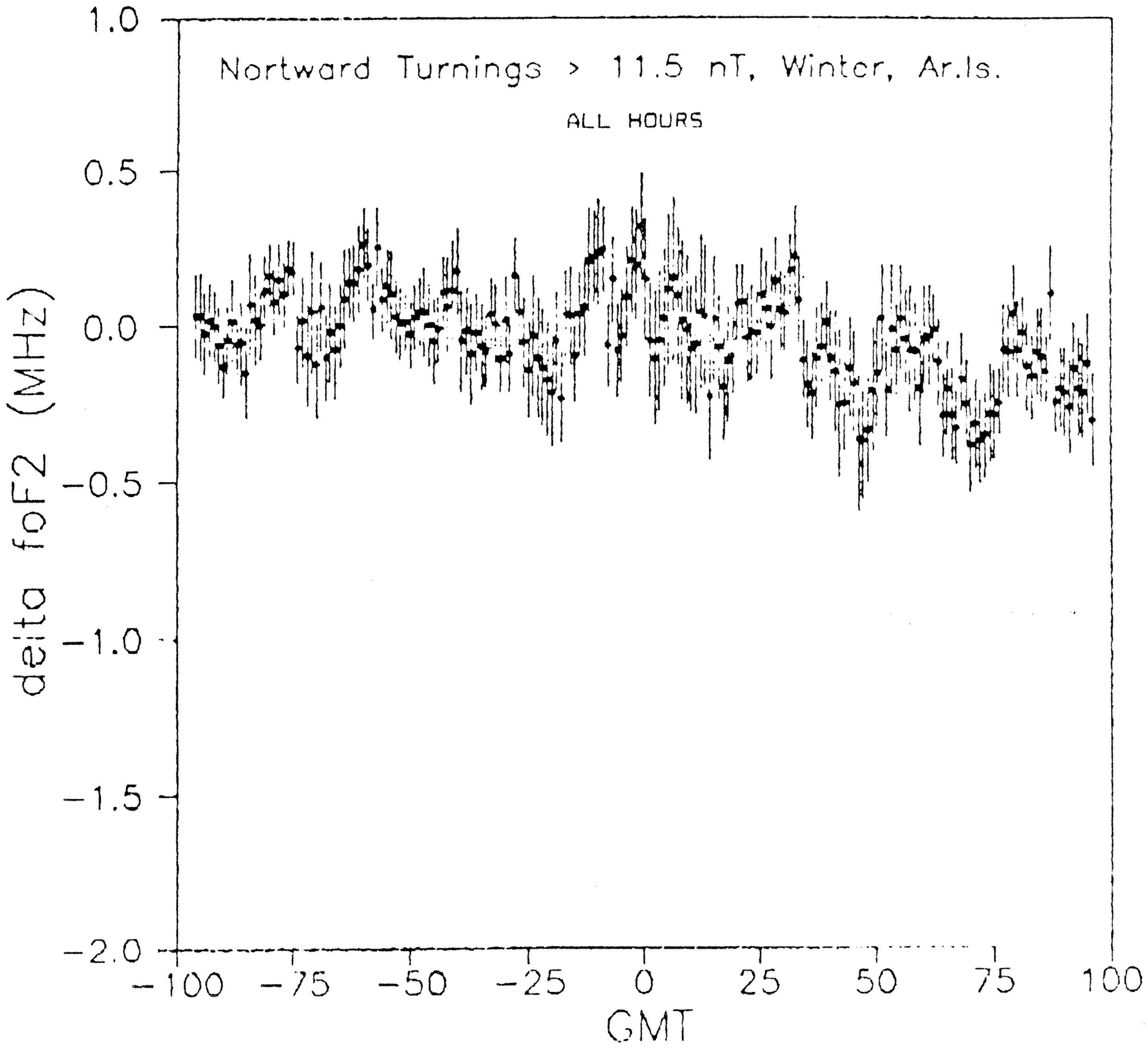

Nortward Turnings > 11.5 nT, Winter, Ar.Is.
ALL HOURS
delta foF2 (MHz)
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−100
−75
−50
−25
0
25
50
75
100
GMT

FIGURE 2AI (B)

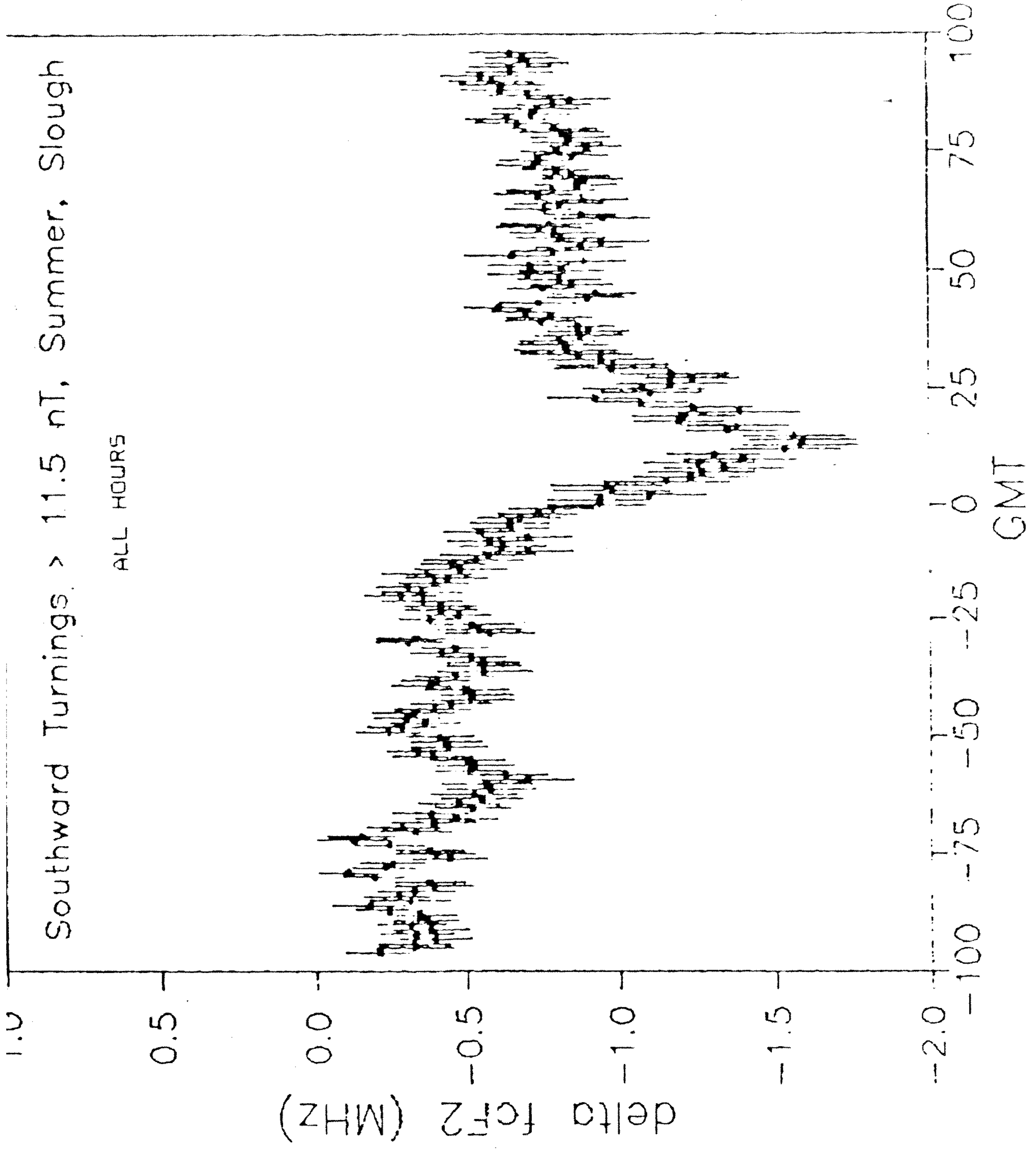
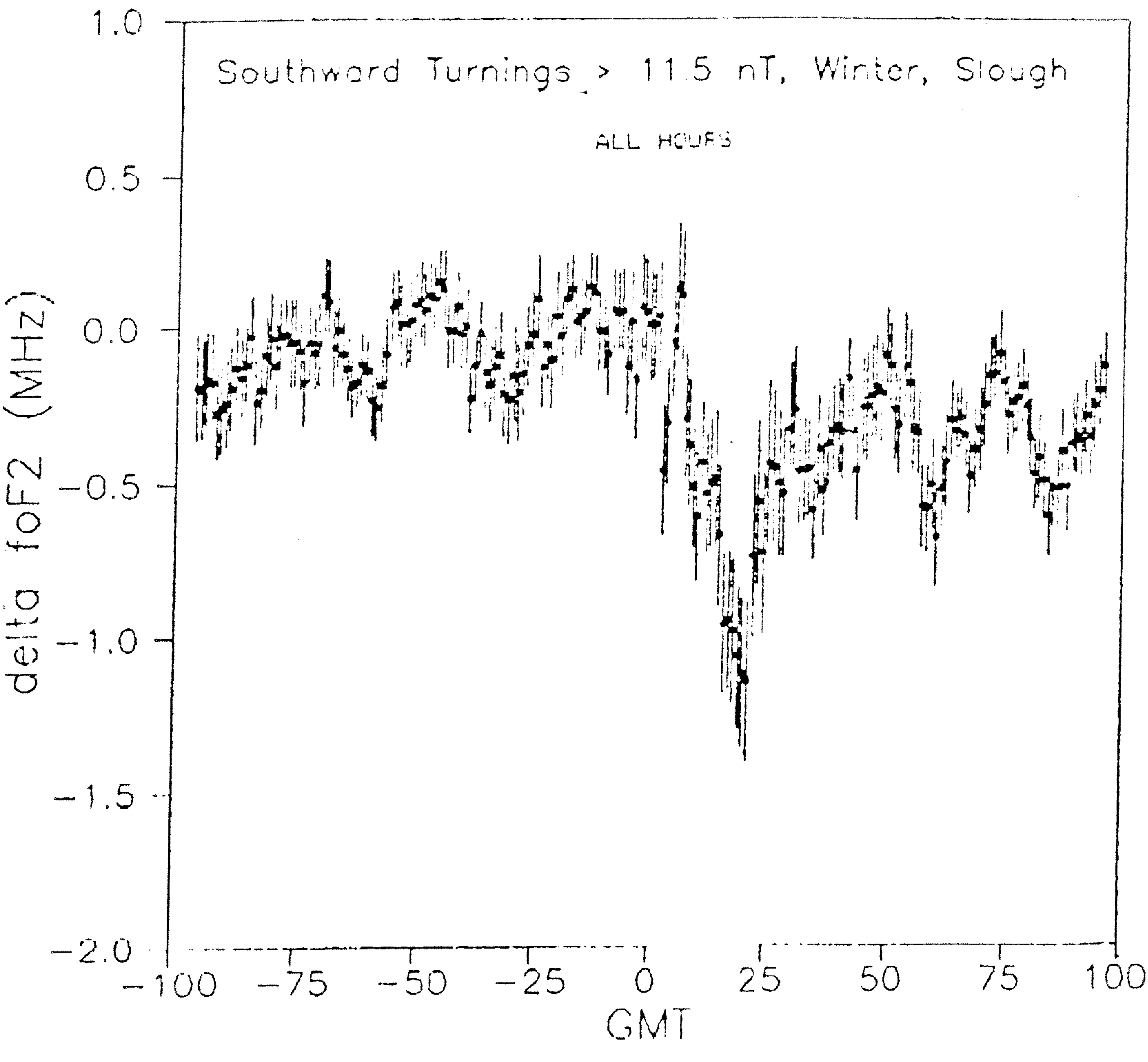

Southward Turnings > 11.5 nT, Summer, Slough
ALL HOURS
delta foF2 (MHz)
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-100
-75
-50
-25
0
25
50
75
100
GMT

FIGURE 15 (A)



Southward Turnings > 11.5 nT, Winter, Slough
ALL HOURS
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
delta foF2 (MHz)
−100
−75
−50
−25
0
25
50
75
100
GMT

FIGURE 15 (B)

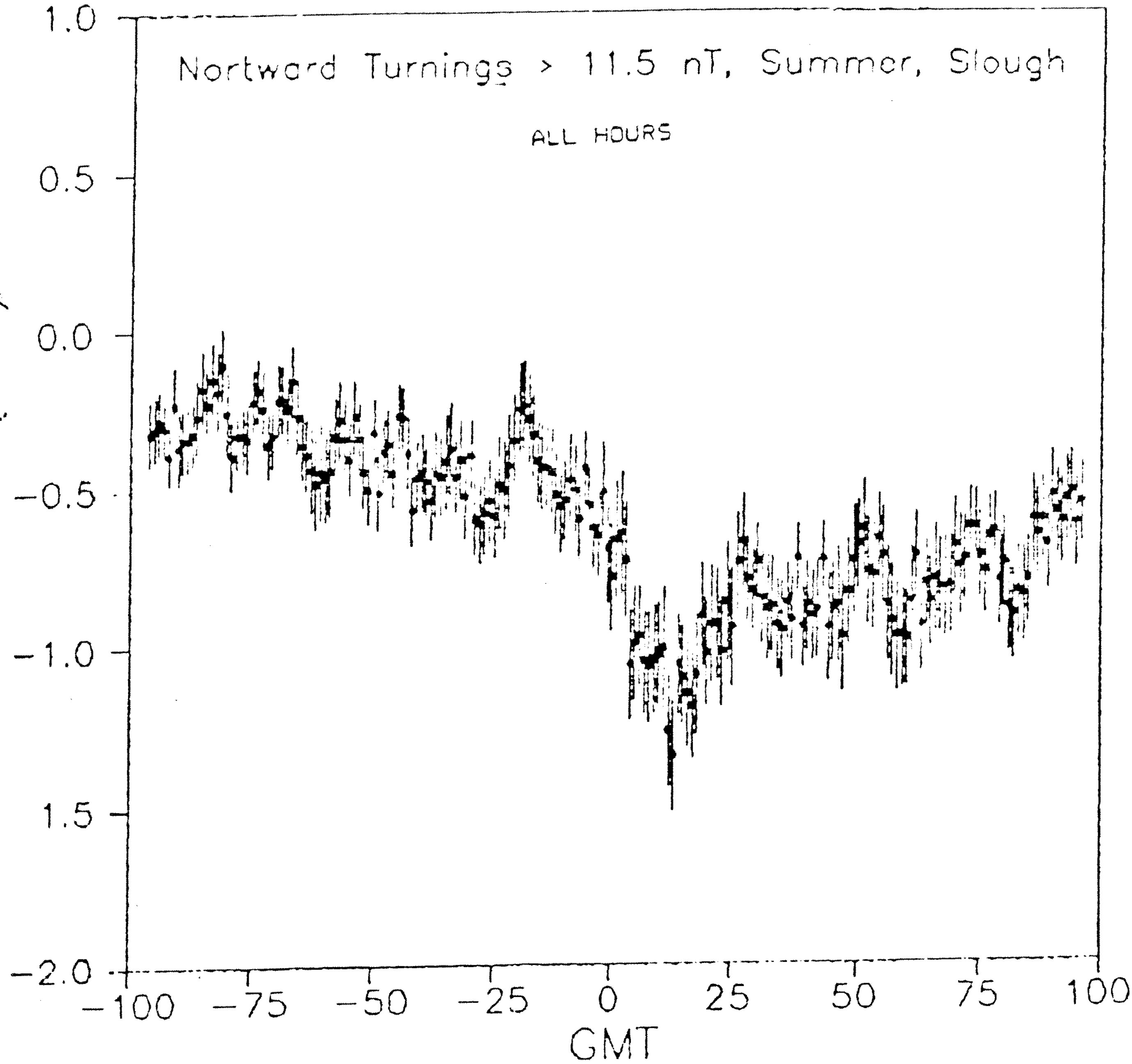


FIGURE 25 (A)

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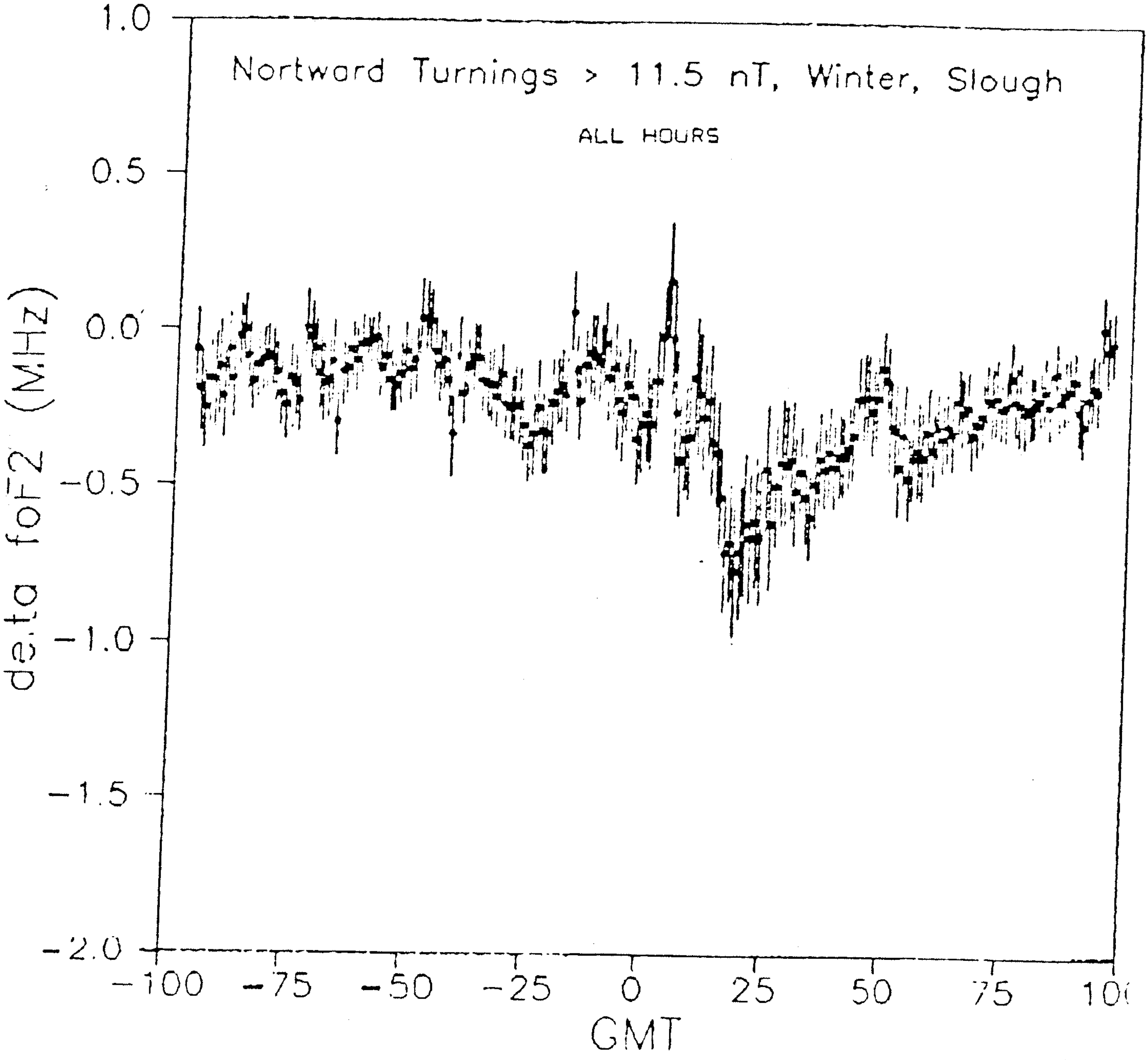
Nortward Turnings > 11.5 nT, Winter, Slough
ALL HOURS
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
delta foF2 (MHz)
−100
−75
−50
−25
0
25
50
75
100
GMT

FIGURE 25 (B)

EK (6.3.2)-2

Planet. Space Sci., Vol. 39, No. 3, pp. 411-423, 1991
Printed in Great Britain.

0032-0633/91 $3.00+0.00
Pergamon Press plc

VARIABILITY OF THE INTERPLANETARY MEDIUM AT 1 a.u. OVER 24 YEARS: 1963–1986

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and

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(*Received in final form* 9 *August* 1990)

Abstract—A survey is presented of hourly averages of observations of the interplanetary medium, made by satellites close to the Earth (i.e. at 1 a.u.) in the years 1963–1986. This survey therefore covers two complete solar cycles (numbers 20 and 21). The distributions and solar-cycle variations of IMF field strength, B, and its northward component (in GSM coordinates), B_z, and of the solar-wind density, n, speed, v, and dynamic pressure, P, are discussed. Because of their importance to the terrestrial magnetosphere/ionosphere, particular attention is given to B_z and P. The solar-cycle variation in the magnitude and variability of B_z, previously reported for cycle 20, is also found for cycle 21. However, the solar-wind data show a number of differences between cycles 20 and 21. The average dynamic pressure is found to show a solar-cycle variation and a systematic increase over the period of the survey. The minimum of dynamic pressure at sunspot maximum is mainly due to reduced solar-wind densities in cycle 20, but lower solar-wind speed in cycle 21 is a more significant factor. The distribution of the duration of periods of stable polarity of the IMF B_z component shows that the magnetosphere could achieve steady state for only a small fraction of the time and there is some evidence for a solar-cycle variation in this fraction. It is also found that the polarity changes in the IMF B_z fall into two classes: one with an associated change in solar-wind dynamic pressure, the other without such a change. However, in only 20% of cases does the dynamic pressure change exceed 50%.

1. INTRODUCTION

Since the concept of magnetic reconnection between the interplanetary magnetic field (IMF) and the geomagnetic field was first introduced as a possible explanation of aurorae by Hoyle (1949) and as a source of magnetospheric and ionospheric convection (and associated ionospheric currents) by Dungey (1953, 1961), the importance of the North–South (B_z) component of the IMF has been increasingly recognized. This component is known to influence a great many characteristics and parameters of the terrestrial plasma environment, including: (i) the voltage placed across the magnetosphere by the solar-wind flow (mapped to the transpolar voltage across the ionospheric polar cap) (Reiff *et al.*, 1981; Doyle and Burke, 1983; Wygant *et al.*, 1983); (ii) the pattern of ionospheric flows (Heelis, 1984; Heppner and Maynard, 1987; Holt *et al.*, 1987; Etemadi *et al.*, 1988) and currents (Friis-Christensen *et al.*, 1985); (iii) the location and width of the dayside "cusp" aurora (Carbary and Meng, 1988; Newell *et al.*, 1989); (iv) the occurrence of magnetic activity (Schatten and Wilcox, 1967; Arnoldy, 1971; Baker *et al.*, 1981, 1983; Clauer *et al.*, 1981; Bargatze *et al.*, 1985), including magnetospheric substorms (Rostoker and Fälthammer, 1967); (v) the patterns of neutral thermospheric winds (Killeen *et al.*, 1985); (vi) the occurrence of characteristic particle and field signatures termed "flux transfer events" (FTEs) near the dayside magnetopause (Rijnbeek *et al.*, 1984; Berchem and Russell, 1984) and many other phenomena, too numerous to include here. Therefore the distribution of values for this component of the IMF (at the Earth) is of great interest if we are to understand the possible states and configurations of the coupled ionosphere–magnetosphere–thermosphere system.

Recently, there has been much interest in the response time of the terrestrial system to changes in B_z. In particular, two separate response times have become apparent. On the dayside, Nishida (1968a, b)

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reported that statistically the DP-2 current system responded to B_z on time-scales of a few minutes, a finding consistent with a number of case studies (Pellinen *et al.*, 1982; Nishida and Kamide, 1983; McPherron and Manka, 1985; Clauer and Kamide, 1985). Recently, Etemadi *et al.* (1988) have shown statistically that dayside ionospheric flows respond with similarly short time-scales, again in keeping with a number of case studies (Rishbeth *et al.*, 1985; Lockwood *et al.*, 1976; Todd *et al.*, 1988; Clauer and Friis-Christensen, 1988). On the nightside, however, the DP-1 ionospheric currents have been shown to respond on rather longer time-scales (typically about an hour) (Schatten and Wilcox, 1967; Arnoldy, 1971; Baker *et al.*, 1981, 1983). The presence of these two separate response times has also been inferred from studies of the response of geomagnetic indices to impulses in the IMF by the linear prediction filter technique (Clauer *et al.*, 1981, 1983; Bargatze *et al.*, 1985). Similarly, auroral substorm activity has been divided into two distinct processes termed the "directly-driven" (Rostoker *et al.*, 1987; Akasofu, 1981) and the "unloading-loading" or "storage" system (McPherron, 1972). We note, however, that Rostoker and Pascal (1990) describe both peaks in the impulse response function in terms of the directly-driven system, the more delayed response being relatively stronger when the pre-existing magnetic activity is low.

Lockwood *et al.* (1990) have discussed these observations of response times in terms of magnetic reconnection and conclude that the dayside flow and current patterns, with their short (about 10 min) response to changes in B_z are dominated by magnetic reconnection at the dayside magnetopause. The nightside flows and currents, on the other hand, are dominated by reconnection in the geomagnetic tail, with their longer (hour) response times to southward IMF turnings. Imbalances in the rate at which reconnection proceeds at these two locations are reflected as expansions and contractions in the ionospheric polar caps, as has been observed and quantitatively modelled by Holzer *et al.* (1986). A further complication is that almost immediate responses appear to be triggered in the tail by some northward turnings of the IMF (Rostoker, 1983), i.e. the reconnection rate in the tail may increase just as that at the dayside magnetopause decreases. Most models of ionospheric flows, horizontal currents and field-aligned currents assume that the system is in a steady state, i.e. that dayside and nightside reconnection rates are equal and the polar cap is constant in size. This conflicts with theories of substorms in which imbalances between these reconnection rates are inherent (Russell and McPherron, 1973; Hones, 1979). Lockwood *et al.* (1990) used the modelling by Siscoe and Huang (1985) to point out that these imbalances will fundamentally alter the patterns of flows and currents, which at no time in the cycle of polar-cap expansion and contraction will have the same form as the steady-state models.

It is therefore important to study how stable the IMF is in general. If the IMF usually exhibits prolonged periods of constant B_z, the system may attain a steady state (constant polar cap area) or a constant oscillation about a mean state (regular oscillations in the polar cap area). If, however, the IMF B_z component varies on time-scales comparable with, or shorter than, the response time of nightside reconnection, neither a steady state nor regular oscillations will be established. It is therefore of interest to study the persistence of a given IMF B_z to determine which of these states applies to the actual magnetosphere–ionosphere system. Because of the dependence of parameters like the transpolar voltage on the IMF B_z component, it is thought that magnetic reconnection is the dominant process for driving magnetospheric convection [see reviews by Cowley (1984) and Reiff and Luhmann (1986)]. However, the presence of some continued convection (with anti-sunward flow over the polar caps) during periods of northward IMF, when reconnection at the subsolar magnetopause is not expected to be efficient, indicates a second type of momentum transfer across the magnetopause, which is often termed a "viscous-like interaction" (Axford and Hines, 1961; Cowley, 1984; Reiff and Luhmann, 1986). Such an interaction moves closed field lines anti-sunward into the geomagnetic tail. A number of mechanisms have been proposed for this interaction including wave-driven diffusion of magnetosheath plasma across the magnetopause, "impulsive penetration" of magnetosheath plasma, "gradient drift entry" and Kelvin–Helmholtz waves (see review and discussion by Hill, 1983). Moreover, recent observations and theories have added another mechanism which would be dependent on solar-wind flow. The recent observations have shown that transient ionospheric flows can be generated by transient pulses in solar-wind dynamic pressure (Farrugia *et al.*, 1989; Sibeck *et al.*, 1989). These otherwise anomalous observations have been explained by Southwood and Kivelson (1990) and Lee (1991) and the theories have an interesting implication in that closed field lines in the ionosphere will be moved anti-sunward by both increases and decreases in solar-wind dynamic pressure. This excitation of convection by solar-wind buffeting was first suggested by Dessler (1964). The short-term variability of solar-wind dynamic pressure may also, therefore, be of importance to the general

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behaviour of the ionosphere–magnetosphere system. In addition, large changes in dynamic pressure have long been known to generate changes in the terrestrial magnetic field, as first suggested by Chapman and Ferraro (1931). If increased effects in field strengths precede a full geomagnetic storm they are called storm sudden commencements (SSCs): increases and decreases which are not associated with storms are termed sudden impulses (SIs). These usually also excite geomagnetic pulsations.

The location of the dayside magnetopause is known to be altered by both dynamic pressure changes and variations in reconnection rate. Increases of the former compress the magnetosphere, whereas increases of the latter "erode" the dayside magnetopause by transferring magnetic flux from the dayside into the tail (Aubry *et al.*, 1970, 1971; Holzer and Slavin, 1978).

In this paper, we investigate some of the questions about the variability of both the IMF B_z component and the solar-wind dynamic pressure using a 24-year sequence of interplanetary observations. We then discuss implications for the terrestrial coupled ionosphere–magnetosphere system. Hirshberg (1969) first suggested that the distribution of IMF values may show a solar-cycle variation. However, early studies of the interplanetary medium failed to find systematic solar-cycle dependence [see reviews by Hundhausen (1975) and Neugebauer (1975)]. As longer sequences of data became available, solar-cycle variations were found in both the solar wind (e.g. Gosling *et al.*, 1976) and the IMF (e.g. Siscoe *et al.*, 1978; Slavin *et al.*, 1986). In Section 4 of this paper we extend the earlier work by using 24 years of data to study two complete solar cycles.

Rostoker *et al.* (1988) have considered the stability of the B_z component in relation to the response times of the ionosphere–magnetosphere system. These authors used data from the *IMP*-8 satellite, averaged over 15.36 s, for a 9-month period and calculated the distribution of the intervals between times when B_z passed through zero. Hence this is an estimate of the distribution of durations for which the IMF maintained a southward or northward orientation. These authors took a typical response time of the magnetosphere to be 2 h and found that B_z was stable for longer than this for only 15% of the time. As pointed out by these authors, a problem with using these high time resolution data is that the periods of stable B_z can be interrupted by a single 15-s data point of the opposite polarity which, in reality, would almost certainly have a negligible effect on the magnetosphere–ionosphere system. Also, no account was taken of the magnitude of the swing in B_z. In this paper, we avoid these problems by considering hourly averaged data (Section 5). This is rather longer than desirable, considering that the response time is of order 2 h, but does have the advantage that the variation of the distribution (of periods of stable sense of mean B_z) over two solar cycles can be investigated. It must be noted here that a substorm cycle could be completed in a period of less than an hour, and that this could be in response to IMF changes on sub-hour timescales which may not be apparent in the hourly averages used here. However, we may still make some deductions about the likelihood of the ionosphere–magnetosphere system reaching a steady state from hourly IMF averages. This is because if the hourly averages do not maintain a constant polarity of B_z, the magnetosphere will not attain steady state: if hourly averages do maintain a constant B_z polarity, the magnetosphere may or may not attain steady state. As well as the variations in B_z polarity on sub-hour timescales discussed above, variations in the magnitude of B_z, without polarity changes, may be sufficient to prevent steady state. Therefore the fractions of time that the IMF hourly averages are of constant B_z polarity represent maxima for the fractions of time for which the magnetosphere will be in steady state. In reality, we would expect a steady magnetosphere for somewhat smaller fractions of time than those given here, which therefore represent upper limits.

Lastly, in Section 5.3, we consider the changes of the solar-wind dynamic pressure which accompany polarity changes in the B_z component of the IMF, given their possible role in the excitation of ionospheric flows. Such flows may be transients due to these discrete changes in dynamic pressure (Sibeck, 1990). However, we also discuss the possibility that large scale, quasi-steady convection is generated by continuous buffeting of the magnetosphere by the solar wind.

2. DATA SOURCES

The data used in this work have been taken from a compilation of solar wind plasma and IMF data prepared by the US National Space Science Data Center (NSSDC), using data supplied by a number of experimental groups. This data product, known as the Omnitape, contains hourly averages of all solar wind plasma and IMF data available to the NSSDC (Couzens and King, 1986). The data were recorded on a number of spacecraft: *IMP*-1, *IMP*-3 to -8, *AIMP*-1 and -2, *OGO*-5, *HEOS*, *VELA*-2 to -6, *ISEE*-1 to -3. The Omnitape dataset is updated as new data become available from experimenters.

The dataset available to us covers the period 2

November 1963–31 May 1987. Within this period we have examined only those cases for which both plasma and magnetic field data are available simultaneously. This restricts our analysis to the period 27 November 1963 to 4 April 1986. Within this period there are 101,558 hourly values available out of a total 195,960 hours possible (an average availability of 52%). Data coverage is limited for a number of reasons. The two most important of these are: (i) the limited availability of telemetry stations to receive data from the spacecraft that monitored the solar wind and IMF; and (ii) all these spacecraft, with the exception of *ISEE*-3, spent only part of each orbit in the solar wind.

The coordinate system used to present the magnetic field data is the geocentric–solar–magnetospheric (GSM) system (Russell, 1971). This was chosen as it makes the IMF B_z component nearly parallel to the magnetic dipole axis of the Earth. Thus it is a good representation of B_z for studies of IMF–magnetosphere coupling by magnetic reconnection.

The data used in this study were read off magnetic tape and stored on-line in a number of databases which operate under a formal database management system called R-EXEC (Read, 1986). This system was developed at the Rutherford Appleton Laboratory for the manipulation of scientific data and has proved invaluable in this work, as it facilitated the implementation of many different analyses.

3. DISTRIBUTIONS OF IMF AND SOLAR-WIND PARAMETERS

Figure 1 shows the distributions of observed solar wind and IMF parameters derived from the dataset described above. The distributions are drawn between the largest and the smallest of the hourly averaged values observed during the 24-year period. Figure 1a shows the distribution of solar-wind speed, v, which ranged between 250 and 950 km s^{-1}, with a mode value of 370 km s^{-1}. This is broadly consistent with results from surveys of smaller solar-wind datasets (e.g. Gosling *et al.*, 1971; Gosling, 1972). Figure 1b shows the distribution of solar-wind densities which ranged up to 83 cm^{-3}, with a mode value of 6 cm^{-3}. The upstream solar-wind dynamic pressure is $P = nmv^2$. Taking the mean mass of the solar wind, m, to be 1 a.m.u. (i.e. the solar wind is assumed to be predominantly protons and electrons), P is found to have ranged up to 28 nPa, with a mode value of 3 nPa (Fig. 1c). All these solar wind distributions are considerably skewed. Figure 1d shows that the magnitude of the IMF varied between 0 and 85 nT. (Note that one hourly mean was zero—which means that on one occasion, the average total field was less than 0.1 nT.) The mode value is 6 nT, about which the distribution is much less skewed than in Fig. 1a–c. This IMF field strength distribution is very similar to those for 1967–1974, as presented by King (1976).

Figure 1e shows the distribution of B_z values in GSM coordinates. Values ranged between −31 and 27 nT, but the distribution is almost completely symmetrical about a mode value of zero. (The calculated mean value is 0.014 nT, with a standard deviation of 3.3 nT.) This indicates that, over the two solar cycles examined, the values of B_z are normally distributed and northward and southward fields occur with equal frequency.

As in the case of the solar wind parameters, these IMF distributions are very similar to those reported from smaller datasets (e.g. Siscoe *et al.*, 1978).

4. SOLAR-CYCLE VARIATIONS

Because of their importance to the terrestrial magnetosphere–ionosphere system, we here investigate the solar-cycle variation in IMF B_z and solar-wind dynamic pressure, P. The variation of the magnitude of the IMF has been studied for cycles 20 and 21 by Slavin *et al.* (1986). For the IMF study we have followed the method Siscoe *et al.* (1978) employed for cycle 20: for each calendar year we took all hourly values of the magnitude of B_z and then calculated the mean of these values, $\langle|B_z|\rangle$, and the standard deviation associated with that mean, σ_{B_z}. These annual means and standard deviations are plotted as solid lines in the upper two panels of Fig. 2. The dashed lines give the corresponding variations of IMF field strength, i.e. $\langle|B|\rangle$ and σ_B. For comparison the annual mean sunspot number, $\langle R\rangle$, is plotted in the bottom panel. There is a clear solar-cycle variation in both the mean magnitude of B_z and in its standard deviation, as reported by Siscoe *et al.* (1978) for a single solar cycle. Our results extend their work and show that these solar-cycle variations in the characteristic properties of B_z also occurred in cycle 21. The amplitude of these variations was larger in cycle 21 than in cycle 20; this behaviour is similar to that for $\langle R\rangle$ and other solar indices such as the solar radio flux. It can be seen that the variation in B_z largely reflects that in B, i.e. there is no detectable variation in the elevation angle of the IMF.

Figure 3 shows the solar-cycle variation in solar-wind dynamic pressure, and the factors which contribute to it. Again the variation of mean sunspot number is plotted at the base of the figure for comparison [part (f)]. Figure 3a shows the mean solar-wind density, $\langle n\rangle$. For cycle 20 there appeared to be a clear anti-correlation of $\langle n\rangle$ with sunspot number.

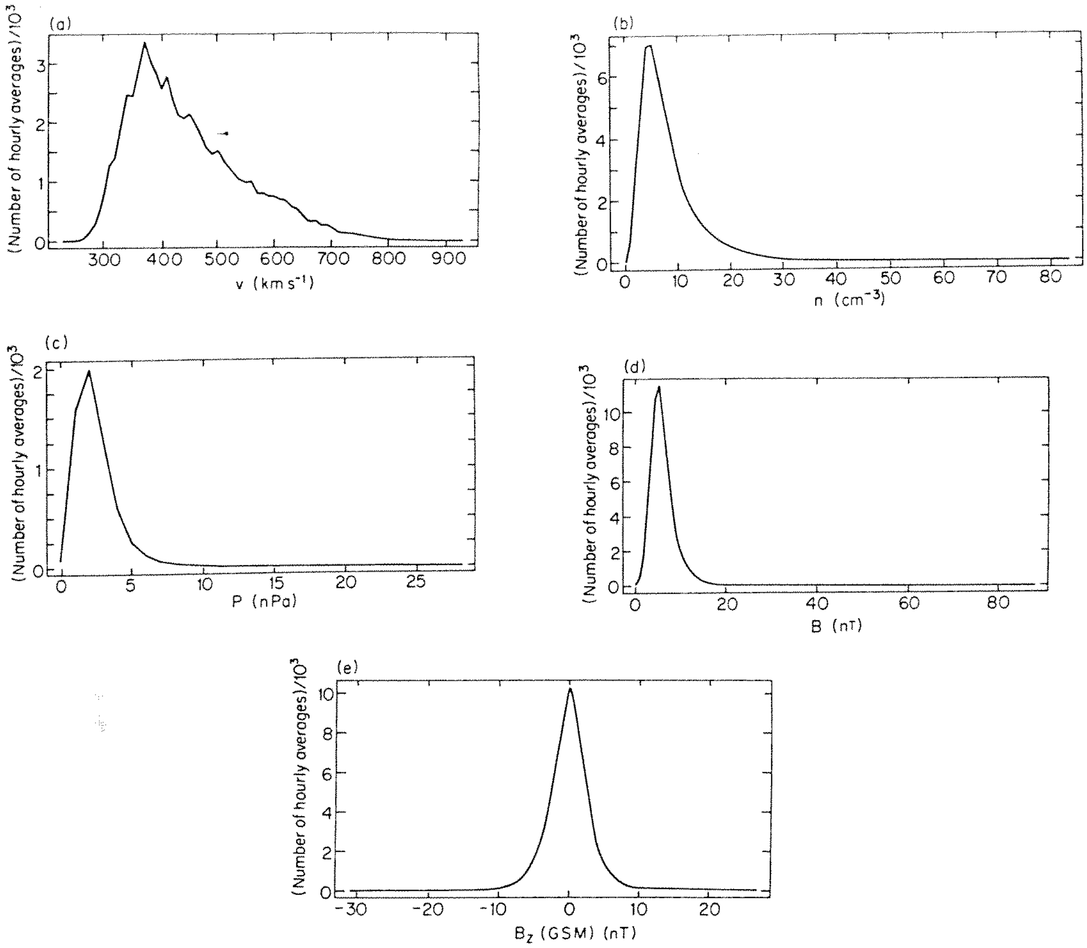

FIG. 1. DISTRIBUTIONS OF IMF AND SOLAR-WIND VALUES FOR THE WHOLE DATASET.
(a) The solar-wind speed, v; (b) the solar-wind density, n; (c) the solar-wind dynamic pressure, P; (d) the IMF field strength, B; and (e) the northward component of the IMF (GSM coordinates) B_z.

This anti-correlation was noted in data for part of this cycle by Diodato *et al.* (1974) (see also Neugebauer, 1975). However, this anti-correlation cannot be seen for cycle 21, despite this cycle giving much larger $\langle R \rangle$. Rather, after about 1972 there is a gradual increase in $\langle n \rangle$. Part (b) shows the corresponding annual means of the standard deviations of the hourly mean values, $\langle \sigma_n \rangle$. This can be seen to follow the density quite closely, again indicating an anti-correlation with $\langle R \rangle$ during cycle 20, but a gradual increase during cycle 21.

The variation of the mean solar-wind speed, $\langle v \rangle$, is shown in part (c) and the mean of the hourly standard deviation of speeds, $\langle \sigma_v \rangle$, is shown in (d). The mean speed appears to be somewhat elevated in the falling phase of the cycle: the only exception to this is for 1963, for which the data are very sparse. The variability of speeds also peaks when $\langle R \rangle$ is falling: this occurred early in the falling phase in cycle 21 but somewhat later in cycle 20. This effect was not noted in early surveys of this variation (e.g. Gosling *et al.*, 1971; Diodato *et al.*, 1984; Neugebauer, 1975), probably because they did not have much data from this phase of the cycle. These earlier surveys tended to show high-speed streams to be most common at the peak of cycle 20 (e.g. Intriligator, 1974) and this may be the cause of the small peak in $\langle v \rangle$ for 1968; however, no such effect is seen for solar maximum years of cycle 21. However, Gosling *et al.* (1976) did find mean flow speeds to be greater in sunspot minimum and declining phase years 1962, 1973 and 1974, and the spread of the distribution of speeds also to be considerably greater for these years. This is consistent with the peak in $\langle v \rangle$ and $\langle \sigma_v \rangle$ for these years in Fig. 3. Gosling *et al.* ascribe the larger mean

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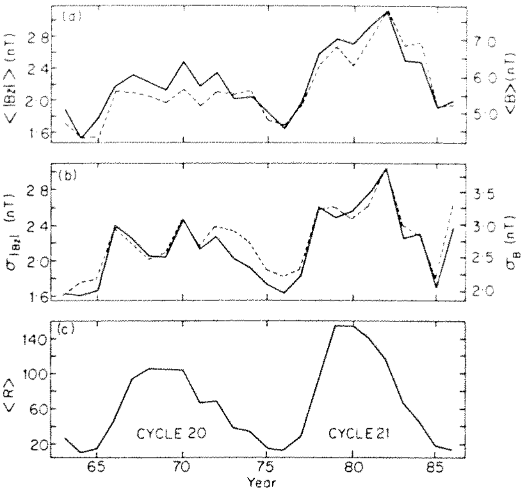

Fig. 2. Solar-cycle variations in out-of-ecliptic component of the IMF (GSM coordinates).
The solid lines and left-hand scales are for annual values of (a) the mean magnitude of B_z and (b) the standard deviation of the magnitude of B_z. The dashed lines and the right-hand scales are the equivalent variations for the IMF strength, B. The lowest panel (c) gives the mean international sunspot number, R.

and spread of the distribution to extremely high-speed flow streams, as observed in minimum and declining phase years by Bame *et al.* (1976).

Figure 3 shows that annual means of n vary by a factor of about 2 and that $\langle\sigma_n\rangle/\langle n\rangle$ is roughly constant and of order 0.1. By contrast, $\langle v\rangle$ varies by a factor of only about 1.3 and $\langle\sigma_v\rangle/\langle v\rangle$ is about 0.02. Even allowing for the square-law dependence on velocity, we find that most of the variability in solar-wind dynamic pressure on sub-hour time-scales originates from the variability in solar-wind density. On yearly time-scales variations in both density and velocity contribute to dynamic pressure variability.

The variation of annual means of hourly dynamic pressure values is given in Fig. 3e. The data appear to show a long-term trend over the 24 years, with values typically 50% higher at the end of the period than at the beginning. Superposed on this is a solar cycle variation, with lower dynamic pressure at sunspot maximum for both cycles. Interestingly, however, parts (a) and (c) show that the minimum at the peak of cycle 20 arises mainly from lower values of the mean solar-wind density, whereas that at the peak of cycle 21 arises more from lower solar-wind speeds.

5. SOUTHWARD AND NORTHWARD TURNINGS OF THE IMF

5.1. *Definition of "events"*

The main objective of this investigation was to examine major reversals of B_z, the North–South component of the interplanetary magnetic field. These reversals are important events which should cause significant changes in the terrestrial magnetosphere. We therefore identified "events" as times when there was a reversal of the polarity of B_z between adjacent hourly mean values. As a secondary condition, we required that the magnitude of B_z was greater than 1 nT for both hourly values.

The magnetic-field data were analysed using a computer program which searched for events using the criteria defined above. A total of 6018 events were found for the 24-year period.

5.2. *Duration of stable IMF* B$_z$ *conditions*

To estimate the duration of stable IMF conditions, we determined the interval following each event for which B_z maintained the same polarity. Cases in which data gaps occurred before B_z changed sign were excluded from this analysis. Figure 4 shows the number of occasions that a particular interval of stable B_z sign occurred in the dataset. Note that the minimum

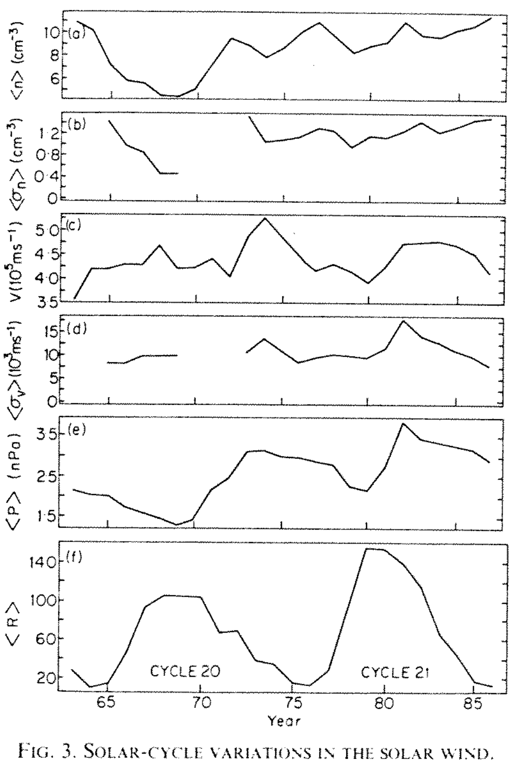

Fig. 3. Solar-cycle variations in the solar wind.
Annual means of: (a) the solar-wind density, n; (b) the hourly standard deviation of n values, σ_n; (c) the solar-wind speed, v; (d) the hourly standard deviation of v values, σ_v; (e) the dynamic pressure, P; and (f) the international sunspot number, R.

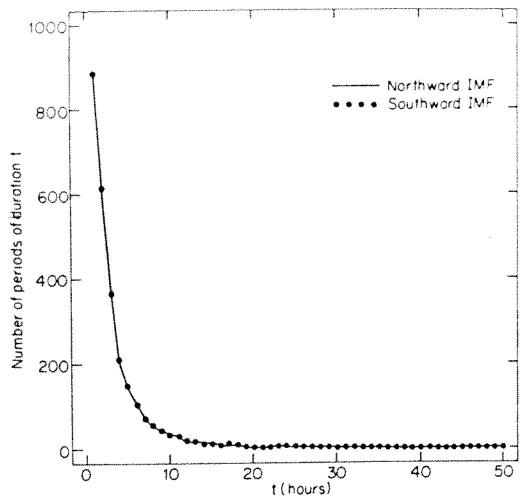

FIG. 4. THE STABILITY OF THE IMF.
(a) The number of B_z polarity changes for which B_z subsequently had a constant sense for a time t, as a function of t.

interval shown in the figure is 1 h. This is the case that B_z changes sign again at the hourly value immediately following the event and so B_z has constant sign for only 1 h at most.

The intervals following northward and southward turnings of B_z are shown separately in Fig. 4, as a solid line and data points, respectively. The two distributions are almost identical. Thus we can conclude that the stability of the IMF is independent of the sign of B_z.

To quantify the stability of B_z, we have determined the number of cases for which the sign of B_z is stable for 2 h or more. For the total dataset we found that this number was 2007 out of a total of 5277 cases in which the period of stability could be measured. This amounts to 38% of all cases. The total duration of these periods (during which the polarity of B_z does not alter for more than 2 h) is 12,369 h, which is 12.2% of the total number of hours in the study. This result is similar to the equivalent fraction of 15% reported by Rostoker *et al.* (1988). However, a number of factors should be noted. Rostoker *et al.* employed 15-s IMF values, giving much greater time resolution, but meaning that periods of stable IMF could be interrupted by a single data point giving B_z of opposite polarity—this will tend to have reduced this percentage. On the other hand, some periods of stable IMF B_z polarity will have been lost in our study because they did not start with a 2 nT change in B_z or because they were interrupted by a data gap.

In this paper, we wish to investigate the solar-cycle dependence of the stability of IMF B_z. Therefore we have also calculated the number of cases for which the B_z polarity is stable for more than 3 h for each year. The results are shown as a fraction of the total number of cases in the upper panel of Fig. 5. For comparison, the annual sunspot numbers are shown in the lower panel. There is considerable variation in this fraction between about 10 and 40%. There is some evidence for a solar-cycle variation, with clear and deep minima of this fraction occurring around the 1965 and 1986 minima in $\langle R \rangle$. There is also a minimum around the 1976 sunspot minimum, but it is much less marked (at around 27%) and is not significant, when compared, for example, with the minimum observed at the 1968 solar maximum.

Hence it seems there may well be a solar-cycle variation in the stability of the polarity of the IMF B_z, but the minimum between cycles 20 and 21 was not as clear cut as might have been expected. This could even indicate an underlying 22-year cycle, rather than the 11-year cycle, although why variability of B_z should be different for one polarity of the solar field from that for the other is unclear. However, there is certainly great variability in the fraction of time that the IMF is stable, evaluated on an annual basis. It is important to continue to monitor the IMF and extend this study of the variability of B_z over cycles 22 and 23, in order to establish that there is indeed a 22-year cycle in its stability of polarity.

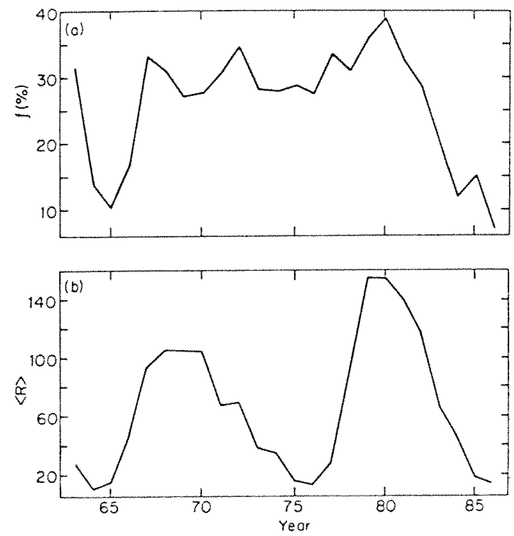

FIG. 5. (a) ANNUAL FRACTION OF CASES FOR WHICH B_z HAD A CONSTANT SIGN FOR THREE OR MORE HOURS FOLLOWING A MAJOR REVERSAL OF THE B_z SIGN (UPPER PANEL).
The fraction is given as a percentage. For comparison, annual sunspot numbers are shown in (b).

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5.3. *Changes in solar wind dynamic pressure*

We have also investigated whether there is any possible link between B_z polarity changes and variations in the dynamic pressure of the solar wind on the hour-to-hour time-scales discussed above. We have calculated the pressure changes and changes in B_z for the 6018 events defined in Section 4.1. To look for any relationship between these two datasets we used the 3-D histogram shown in Fig. 6 (a traditional scatter plot was unsatisfactory because the large numbers of points obscured detail). This plot shows the number of events along the vertical axis, bins also being colour-coded by this parameter, according to the given colour scale. The two horizontal axes show the change in IMF B_z in the events, ΔB_z, and the percentage change in the hourly mean of the solar-wind dynamic pressure, $\Delta P/P$, where P is the value before the event. The histogram suggests that there are two populations of events:

(a) events in which there is no significant pressure change associated with the change in the sign of B_z. These events are represented by the prominent ridge at zero pressure change;
(b) events in which there is a pressure change coincident with the change in B_z sign. These are represented by the broader distribution.

Note that there are no events for $|\Delta B_z| < 2$ nT, because of the definition of events employed (as given in Section 5.1). It is of interest to note that for the class (a) events (i.e. $\Delta P \approx 0$) the mode value of $|\Delta B_z|$ is 3 nT, i.e. there are more events (by a factor of about 2) for which B_z changes by 3 nT than when it changes by 2 nT; this is true for both northward and southward turnings. For class (b) events, the pressure change may not be causally associated with the IMF change, but the two could just occur at the same time by a chance occurrence. The importance of class (b) events is that it would be difficult to distinguish between the causes of any terrestrial disturbances.

The distributions are roughly symmetric about the central ridge, showing that when southward and northward turnings are accompanied by a pressure change, it is as likely to be a rise in dynamic pressure ($\Delta P > 0$), as a fall ($\Delta P < 0$). This is true for both northward and southward turnings. There is some asymmetry at large $\Delta P/P$ because P tends to be larger for falls in dynamic pressure (relating as it does to the conditions before the event). Although the most common events are ones for which there is no pressure change ($\Delta P/P = 0$), this only makes up 12% of the total events. However, in 38% of events $|\Delta P/P|$ is less than 5% and for 58% of events it is less than 10%. We conclude that most southward/northward turnings are not accompanied by significant (>10%) changes in dynamic pressure. Only 2% of southward and northward turnings are accompanied by dynamic pressure changes exceeding 50%.

6. DISCUSSION AND CONCLUSIONS*

We find the distributions of solar-wind and IMF parameters from this survey over two solar cycles to be much the same as the corresponding distributions that were presented from data for all or part of cycle 20 (Gosling *et al.*, 1971, 1976; Neugebauer, 1975; Diodato *et al.*, 1984; King, 1976). However, on examination of the solar-cycle variations we find a number of differences between solar cycles 20 and 21. The most notable of these is that the clear anti-correlation of annual means of solar-wind density and sunspot numbers, as reported previously for cycle 20 (Diodata *et al.*, 1974; Neugebauer, 1975), is hardly evident at all in cycle 21. Like Gosling *et al.* (1976), we would ascribe the increase in the mean and spread of the distribution of solar-wind speeds in the declining and minimum phase of the solar cycle to increased occurrence of high-speed streams, as noted by Bame *et al.* (1976). However, we find in cycle 20 that these peaks were just 2 years before sunspot minimum, whereas for cycle 21 they were 4 years before the minimum for $\langle \sigma_v \rangle$ and 3 years before for $\langle v \rangle$. The solar-cycle variation of $\langle |B_z| \rangle$ and $\langle \sigma_z \rangle$, reported for cycle 20 by Siscoe *et al.* (1978), is repeated in cycle 21 and both parameters reflect the larger maximum of the later solar cycle. The reappearance of a secondary minimum in both these values at sunspot maximum suggests that this is a real effect.

The solar-cycle variation in $|B_z|$ shows that there is a larger mean magnitude of the out-of-ecliptic IMF component at sunspot maximum and that the spread of values is also greater then. (Note that values are given here in GSM coordinates, but the differences tend to average out and the same statement is true in GSE coordinates.) Taken in isolation, this larger variability in $|B_z|$ would suggest that the stability of the polarity of B_z (quantified here as the fraction, f, of polarity changes for which B_z subsequently retains the same sense in two hourly averages) would be smaller at sunspot maximum. In fact, we find that, if anything, f is larger at sunspot maximum—showing deep minima near the solar minima of 1964 and 1986, and a weak minimum near 1976. There is considerable variability in f, ranging between 10 and 40%.

The significance of the fraction f is that it is a maximum estimate of the likelihood that the terrestrial ionosphere–magnetosphere system attains a steady state. As discussed in the Introduction, if f is

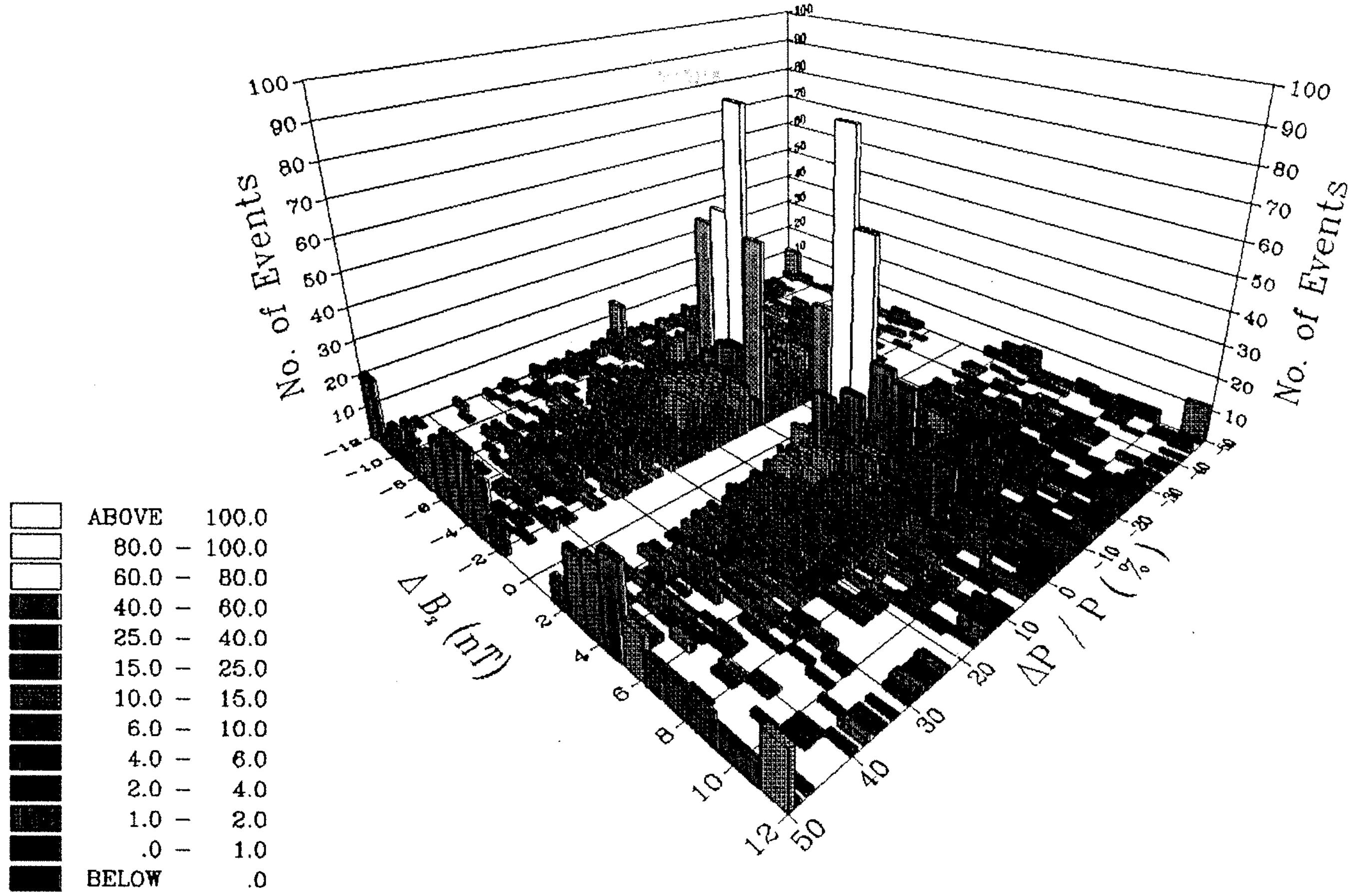

FIG. 6. THREE-DIMENSIONAL HISTOGRAM SHOWING THE RELATIONSHIP BETWEEN B_z CHANGES AND FRACTIONAL DYNAMIC-PRESSURE CHANGES AT MAJOR REVERSALS IN B_z POLARITY.

The empty band aligned along the $\Delta B_z = 0$ axis arises from the definition of major events, i.e. $|B_z| > 1$ nT before and after the event. The high counts at the edges of the plot arise because extreme values outside the ranges given by the horizontal axes, have been accumulated and plotted there.

large we would expect the terrestrial system to attain a steady state often, or show regular oscillations—although we must also remember it may show non-steady responses to any variations in B_z on time-scales of less than the 1-h resolution of the data used here. In fact we find for all years f is less than 40 % (and for some years it is as low as 10%) indicating that more often changes in polarity occur before a steady-state situation can be achieved. Allowing for responses to sub-hour variations, the terrestrial system will, in reality, achieve steady state for even smaller fractions of time than the values of f given above. We conclude, as did Rostoker *et al.* (1988), that steady-state convection in the ionosphere–magnetosphere system will rarely, if ever, be achieved. We also note that the steady state may be particularly rare at every second solar minimum, although more data are required to confirm this 22-year cycle.

We find northward and southward IMF orientations to be equally common and that the distribution lifetimes of periods of constant orientation are the same for northward and southward pointing fields.

To investigate the implications for the terrestrial magnetosphere–ionosphere system of these findings concerning the solar wind, we have evaluated the solar-cycle variation of solar-wind dynamic pressure. We find a clear solar-cycle oscillation superposed on a long-term trend throughout the period studied. The trend appears to show a 50% increase in solar-wind dynamic pressure over the 24-year period. The cause of this trend is not apparent, and it may be related to the larger solar activity observed during cycle 21. The solar-cycle variation shows dynamic pressure is a maximum in solar minimum years, and vice versa. However, the variation is more complex than the means of P suggest, as in cycle 20 the variation of solar-wind density dominates, whereas in cycle 21 the variations in both speed and density are important. As a result, the magnetopause will be compressed to locations nearer the Earth, on average, during sunspot minimum years. Using the equations given by Schield (1969) (see also Farrugia *et al.*, 1989) we estimate the magnitude of both the gradual change and solar cycle variation in the location of the magnetopause to be about 1 R_E.

We also found that neither southward nor northward turnings of the IMF are accompanied by major dynamic-pressure changes (only 2% show fractional changes in P exceeding 50%). Hence there is little likelihood that phenomena attributed to reconnection (for example erosion of the dayside magnetopause or onset of enhanced convection following a southward turning of the IMF) were really caused by a concurrent change in solar-wind dynamic pressure. It should be noted that we have only studied changes in the hourly means of the dynamic pressure. To evaluate the likely effect of shorter-term solar-wind dynamic pressure variations, and the proposed buffeting effect as a driving mechanism for convection, we must study the standard deviation associated with the hourly means of P, σ_P. Because the solar-wind density, n, is not uncorrelated with the solar-wind speed, v, we cannot use the equivalent standard deviations, σ_n and σ_v, to compute σ_P. Rather, to evaluate σ_P we must return to the 1-min data from which the hourly means were computed. This study is currently being undertaken and will be reported elsewhere. However, we note that the fractional variability in n (σ_n/n) is much greater on sub-hour time-scales than that in v (σ_v/v) and hence the former is the dominant contributor to the variability of P on these time-scales.

Acknowledgements—This work was supported by NATO Collaborative Research Grant 0753/87 and the U.K. Science and Engineering Research Council. We thank Orhan Gokcol for his help in developing Fortran programs for data analysis. We also thank Brian Read for his work in developing the R-EXEC database management system employed by WDC-C1 and which was widely used in this analysis and Vipul Davda for the colour plotting software. We thank the many experimental groups who supplied solar-wind and IMF data to NSSDC, whom we thank for compilation and provision of the Omnitape.

REFERENCES

Akasofu, S. I. (1981) Energy coupling between the solar wind and the magnetosphere. *Space Sci. Rev.* **28**, 121.

Arnoldy, R. L. (1971) Signature in the interplanetary medium for substorms. *J. geophys. Res.* **76**, 5189.

Aubry, M. P., Kivelson, M. G. and Russell, C. T. (1971) Motion and structure of the magnetopause. *J. geophys. Res.* **76**, 1673.

Aubry, M. P., Russell, C. T. and Kivelson, M. G. (1970) Inward motion of the magnetopause before a substorm. *J. geophys. Res.* **75**, 7018.

Axford, W. I. and Hines, Co. O. (1961) A unifying theory of high-latitude geophysical phenomena and geomagnetic storms. *Can. J. Phys.* **39**, 1433.

Baker, D. N., Hones, E. W., Jr., Payne, J. B. and Feldman, W. C. (1981) A high time resolution study of interplanetary parameter correlations with *AE*. *Geophys. Res. Lett.* **8**, 179.

Baker, D. N., Zwickl, R. D., Bame, S. J., Hones, E. W., Jr., Tsurutani, B. T., Smith, E. J. and Akasofu, S. I. (1983) An *ISEE*-3 high time resolution study of the interplanetary parameter correlations with magnetospheric activity. *J. geophys. Res.* **88**, 6230.

Bame, S. J., Asbridge, J. R., Feldman, W. C. and Gosling, J. T. (1976) Solar cycle evolution of high speed solar wind streams. *Astrophys. J.* **207**, 977.

Bargatze, L. F., Baker, D. N., McPherron, R. L. and Hones, E. W., Jr. (1985) Magnetospheric impulse response for many levels of geomagnetic activity. *J. geophys. Res.* **90**, 6387.

Berchem, J. and Russell, C. T. (1984) Flux transfer events at the magnetopause: spatial distribution and controlling factors. *J. geophys. Res.* **89**, 6689.
Carbary, J. F. and Meng, C.-I. (1988) Correlation of cusp width with $AE(12)$ and B_z. *Planet. Space Sci.* **36**, 157.
Chapman, S. and Ferraro, V. C. A. (1931) A new theory of magnetic storms I. The initial phase (continued). *J. geophys. Res.* **36**, 171.
Clauer, C. R. and Friis-Christensen, E. (1988) High-latitude dayside electric fields and currents during strong northward interplanetary magnetic field: observations and model simulation. *J. geophys. Res.* **93**, 2749.
Clauer, C. R. and Kamide, Y. (1985) DP1 and DP2 current systems for March 22, 1979, substorms. *J. geophys. Res.* **90**, 1243.
Clauer, C. R., McPherron, R. L. and Searles, C. (1983) Solar wind control of the low-latitude asymmetric magnetic disturbance field. *J. geophys. Res.* **88**, 2123.
Clauer, C. R., McPherron, R. L., Searles, C. and Kivelson, M. G. (1981) Solar wind control of auroral zone magnetic activity. *Geophys. Res. Lett.* **8**, 915.
Couzens, D. A. and King, J. H. (1986) *Interplanetary Medium Data Book—Supplement* 3. National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Maryland, U.S.A.
Cowley, S. W. H. (1984) Solar wind control of magnetospheric convection, in *Achievements of the International Magnetospheric Study, IMS*, p. 483. Noordwijk, Netherlands.
Dessler, A. J. (1964) Length of the magnetospheric tail. *J. geophys. Res.* **69**, 3913.
Diodato, L., Moreno, G., Signorini, C. and Ogilvie, K. W. (1974) *J. geophys. Res.* **79**, 5095.
Doyle, M. A. and Burke, W. J. (1983) *S*3-2 measurements of polar cap potential. *J. geophys. Res.* **88**, 9125.
Dungey, J. W. (1953) Conditions for the occurrence of electrical discharges in astrophysical systems. *Phil. Mag.* **44**, 725.
Dungey, J. W. (1961) Interplanetary magnetic field and the auroral zones. *Phys. Rev. Lett.* **6**, 47.
Etemadi, A., Cowley, S. W. H., Lockwood, M., Bromage, B. J. I., Willis, D. M. and Luhr, H. (1988) The dependence of high-latitude dayside ionospheric flows on the North–South component of the IMF, a high time resolution correlation analysis using EISCAT "POLAR" and AMPTE UKS and IRM data. *Planet. Space Sci.* **36**, 471.
Farrugia, C. J., Freeman, M. P., Cowley, S. W. H., Southwood, D. J., Lockwood, M. and Etemadi, A. (1989) Pressure-driven magnetopause motions and attendant response on the ground. *Planet. Space Sci.* **37**, 589.
Friis-Christensen, E., Kamide, Y., Richmond, A. D. and Matsushita, S. (1985) Interplanetary magnetic field control of high-latitude electric fields and currents determined from Greenland magnetometer data. *J. geophys. Res.* **90**, 1325.
Gosling, J. T. (1972) In *Solar Activity Observations and Predictions* (Edited by McIntosh, P. S. and Dryer, M.). M.I.T. Press, Cambridge, Massachusetts.
Gosling, J. T., Asbridge, J. R., Bame, S. J. and Feldman, W. C. (1976) Solar wind speed variations—1962–1974. *J. geophys. Res.* **81**, 5061.
Gosling, J. T., Hansen, R. T. and Bame, S. J. (1971) Solar wind speed distributions 1962–1970. *J. geophys. Res.* **76**, 1811.
Heelis, R. A. (1984) The effects of interplanetary magnetic field orientation on dayside high-latitude convection. *J. geophys. Res.* **89**, 2873.
Heppner, J. P. and Maynard, N. C. (1987) Empirical high-latitude electric field models. *J. geophys. Res.* **92**, 4467.
Hill, T. W. (1983) Solar wind–magnetosphere coupling, in *Solar-Terrestrial Physics* (Edited by Carovillano, R. L. and Forbes, J. M.), p. 261. D. Reidel, Higham, Massachusetts.
Hirshberg, J. (1969) Interplanetary magnetic field during the rising part of the solar cycle. *J. geophys. Res.* **74**, 5814.
Holt, J. M., Ward, R. H., Evans, J. V. and Oliver, W. L. (1987) Empirical models for the plasma convection at high latitudes from Millstone Hill observations. *J. geophys. Res.* **92**, 203.
Holzer, T. E., McPherron, R. L. and Hardy, D. A. (1986) A quantitative empirical model of the magnetospheric flux transfer process. *J. geophys. Res.* **91**, 3287.
Holzer, T. E. and Salvin, J. A. (1979) A correlative study of magnetic flux transfer in the magnetosphere. *J. geophys. Res.* **84**, 2573.
Hones, E. W., Jr. (1979) Transient phenomena in the magnetotail and their relation to substorms. *Space Sci. Rev.* **23**, 393.
Hoyle, F. (1949) Magnetic storms and aurorae, in *Some Recent Researches in Solar Physics*, pp. 102–104. Cambridge University Press, Cambridge.
Hundhausen, A. J. (1975) Solar activity and the solar wind. Comments on. *Astrophys. Space Phys.* **6**, 63.
Intriligator, D. S. (1974) Evidence of solar cycle variations in the solar wind. *Astrophys. J.* **188**, 123.
Killeen, T. L., Heelis, R. A., Hays, P. B., Spencer, N. W. and Hanson, W. B. (1985) Neutral motions of the polar thermosphere for northward interplanetary magnetic field. *Geophys. Res. Lett.* **12**, 159.
King, J. H. (1976) A survey of long-term interplanetary magnetic field variations. *J. geophys. Res.* **81**, 653.
Lee, L. C. (1991) Generation of field-aligned currents by pressure pulses in the magnetosheath. *Geophys. Res. Lett.* (submitted).
Lockwood, M., Cowley, S. W. H. and Freeman, M. P. (1990) The excitation of convection in the high-latitude ionosphere. *J. geophys. Res.* **95**, 7961.
Lockwood, M., Eyken, A. P. van, Bromage, B. J. I., Willis, D. M. and Cowley, S. W. H. (1986) Eastward propagation of a plasma convection enhancement following a southward turning of the interplanetary magnetic field. *Geophys. Res. Lett.* **13**, 72.
McPherron, R. L. (1972) Substorm related changes in the geomagnetic tail: the growth phase. *Planet. Space Sci.* **20**, 1521.
McPherron, R. L. and Manka, R. H. (1985) Dynamics of the 1054 UT March 2, 1979, substorm event: *CDAW* 6. *J. geophys. Res.* **90**, 1175.
Neugebauer, M. (1975) Large-scale and solar-cycle variations of the solar wind. *Space Sci. Rev.* **17**, 221.
Newell, P. T., Meng, C.-I., Sibeck, D. G. and Lepping, R. P. (1989) Some low-altitude cusp dependencies on the interplanetary magnetic field. *J. geophys. Res.* **94**, 8921.
Nishida, A. (1968a) Coherence of geomagnetic DP 2 fluctuations with interplanetary magnetic variations. *J. geophys. Res.* **73**, 5549.
Nishida, A. (1968b) Geomagnetic DP 2 fluctuations and associated magnetospheric phenomena. *J. geophys. Res.* **73**, 1795.
Nishida, A. and Kamide, Y. (1983) Magnetospheric processes preceding the onset of an isolated substorm: a case

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study of the March 31, 1978 substorm. *J. geophys. Res.* **88**, 7005.

Pellinen, R. J., Baumjohann, W., Heikkila, W. J., Sergeev, V. A., Yahnin, A. G., Marklund, G. and Melnikov, A. O. (1982) Event study on pre-substorm phases and their relation to the energy coupling between the solar wind and magnetosphere. *Planet. Space Sci.* **30**, 371.

Read, B. J. (1986) Scientific Data Manipulation in a Relational Database System. Rutherford Appleton Laboratory Report RAL-86-084.

Reiff, P. H. and Luhmann, J. G. (1986) Solar wind control of the polar cap voltage, in *Solar Wind–Magnetosphere Coupling* (Edited by Kamide, Y. and Slavin, J. A.), p. 453. Terra Scientifica, Tokyo.

Reiff, P. H., Spiro, R. W. and Hill, T. W. (1981) Dependence of polar cap potential drop on interplanetary parameters. *J. geophys. Res.* **86**, 7639.

Rijnbeek, R. P., Cowley, S. W. H., Southwood, D. J. and Russell, C. T. (1984) A survey of dayside flux transfer events observed by the *ISEE*-1 and -2 magnetometers. *J. geophys. Res.* **89**, 786.

Rishbeth, H., Smith, P. R., Cowley, S. W. H., Willis, D. M., Eyken, A. P. van, Bromage, B. J. I. and Crothers, S. R. (1985) Ionospheric response to changes in the interplanetary magnetic field observed by EISCAT and AMPTE-UKS. *Nature* **318**, 451.

Rostoker, G. (1983) Triggering of expansive phase intensifications of magnetospheric substorms by northward turnings of the interplanetary magnetic field. *J. geophys. Res.* **88**, 6981.

Rostoker, G., Akasofu, S.-I., Baumjohann, W., Kamide, Y. and McPherron, R. L. (1987) The roles of direct input of energy from the solar wind and unloading of stored magnetotail energy during magnetospheric substorms. *Space Sci. Rev.* **46**, 93.

Rostoker, G. and Fälthammer, C.-G. (1967) Relationship between changes in the interplanetary magnetic field and variations in the magnetic field at the Earth's surface. *J. geophys. Res.* **72**, 5853.

Rostoker, G. and Pascal, F. (1990) Dependence of the response of the magnetosphere–ionosphere current systems on the preconditioning of the auroral oval and on the level of the solar–terrestrial interaction. *Can. J. Phys.* **68**, 74.

Rostoker, G., Savoie, D. and Phan, T. D. (1988) Response of magnetosphere–ionosphere current systems to changes in the interplanetary magnetic field. *J. geophys. Res.* **93**, 8633.

Russell, C. T. (1971) Geophysical coordinate transformations. *Cosmic Electrodyn.* **2**, 184.

Russell, C. T. and McPherron, R. L. (1973) The magnetotail and substorms. *Space Sci. Rev.* **15**, 205.

Schatten, K. H. and Wilcox, J. W. (1967) Response of geomagnetic activity index *Kp* to interplanetary magnetic field. *J. geophys. Res.* **72**, 5185.

Schield, M. A. (1969) Pressure balance between the solar wind and magnetosphere. *J. geophys. Res.* **74**, 1275.

Sibeck, D. G. (1990) A model for the transient magnetospheric response to sudden solar wind dynamic pressure variations. *J. geophys. Res.* **95**, 3755.

Sibeck, D. G., Baumjohann, W. and Lopez, R. E. (1989) Solar wind dynamic variations and transient magnetospheric signatures. *Geophys. Res. Lett.* **16**, 13.

Siscoe, G. L., Crooker, N. U. and Christopher, L. (1978) A solar cycle variation of the interplanetary magnetic field. *Solar Phys.* **56**, 449.

Siscoe, G. L. and Huang, T. S. (1985) Polar cap inflation and deflation. *J. geophys. Res.* **90**, 543.

Slavin, J. A., Jungman, G. and Smith, E. J. (1986) The interplanetary magnetic field during solar cycle 21 : *ISEE-3/ICE* observations. *Geophys. Res. Lett.* **13**, 513.

Southwood, D. J. and Kivelson, M. (1990) The magnetohydrodynamic response of the magnetospheric cavity to changes in solar wind pressure. *J. geophys. Res.* **95**, 2301.

Todd, H., Cowley, S. W. H., Lockwood, M., Willis, D. M. and Luhr, H. (1988) Response time of the high-latitude dayside ionosphere to sudden changes in the North–South component of the IMF. *Planet. Space Sci.* **36**, 1415.

Wygant, J. R., Torbert, R. B. and Mozer, F. S. (1983) Comparison of *S*3-2 polar cap potential drops with the interplanetary magnetic field and models of magnetopause reconnection. *J. geophys. Res.* **88**, 5727.

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Adv. Space Res. Vol. 15, No. 2, pp. (2)35–(2)44, 1995

0273–1177/95 $7.00 + 0.00

VARIABILITY OF MID-LATITUDE IONOSPHERIC foF2 COMPARED TO IMF-POLARITY INVERSIONS

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ABSTRACT

Potential effects of the IMF-orientation on the mid-latitude ionosphere are further investigated using critical frequencies foF2 from six ionosonde stations. For a period of 15 days around each inversion of B_Z, excluding all days with Ap >=6, a quiet standard diurnal variation was determined by day-by-day averaging for each hour UT. The regular diurnal, seasonal and solar cycle variations were then removed from the data by substracting from these the quiet standard value. The so obtained differences δfoF2 were sorted after the IMF polarity. Distinct effects of northward and southward inversions were found so that a large part of the day-to day variability may be attributed to IMF B_Z polarity changes.

INTRODUCTION

Effects of the Interplanetary Magnetic Field (IMF) upon foF2 were studied since 1991 with data of Slough and Argentine Island /1, 2, 3/. The present study uses the same type of investigation but is applied to the data of six European stations engaged in the PRIME project. It is restricted to effects of B_Z inversions at mid-latitudes. The IMF is known to exert a controlling influence on the magnetosphere and the high latitude ionosphere. Its North-South component is of primary importance here since magnetic reconnection is the dominant mechanism by which energy, mass and momentum are transferred from the solar wind flow into the terrestrial magnetosphere as was first suggested by Dungey /4, 5/. This paper includes a few more results of recent investigations in which ionospheric critical frequencies from 1967 to 1984 of Dourbes, Kaliningrad, Lannion, Poitiers, Slough and Uppsala were employed. These data were studied in conjunction with simultaneous satellite measurements of the IMF. Significant effects of polarity changes in the B_Z component of the IMF (z in GSM) have again been revealed.

BASIC DATA

The data concerning the interplanetary medium wer taken from the compilations of the US National Space Science Data Center (NSSDC) /6/. The IMF data had to be transformed into the GSM coordinate system that is particularly indicated when considering transfer of momentum and energy from the interplanetary medium into the ionosphere. The available data set covers a period from 2 Nov.1963 to 31 May 1987, thus two full solar cycles (numbers 20 and 21). Only cases within this time for which both plasma and magnetic field data were simultaneously available have been examined. A survey to these data has been published by Hapgood et al. /1/. This restricted our analysis to the period 27 Nov. 1963 to 4 Apr.1986. Out of a maximum possible number of 195960 h we disposed of not less than 101558 usable hours so that the statistical availibility was 52 %. For this period /7/ the distributions of the relevant inter-

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planetary parameters such as solar wind speed and density, IMF strength and B_z can be found in Figure 1 of /1/. The ionospheric critical frequency data were taken from the COST238:PRIME data base at the French Centre National des Etudes de Télécommunication (CNET) /8/.

At midlatitudes, for a given season and phase in the solar cycle, the ionosphere exhibits regular diurnal variations (as the plasma co-rotates with the Earth). In order to study the day-to-day variability of the ionosphere around these regular diurnal variations, the "quiet-time" diurnal variation must be subtracted from the observed variations. This was achieved for each hour UT in the following way: within a 15 days interval around the day in question a mean value of all quiet daily values (to that hour) was determined and taken as "quiet" value to the day in the interval centre. "Quiet" was defined by the magnetic Ap-index which had to be less than 6.

The difference of the so found "quiet" value against the observed *foF2* is called δ*foF2*. Only ionospheric data available in digital form were employed and this further restricted the considered period to 1967 to 1984. Figures 1 and 2 show the distributions of *foF2* and δ*foF2* for the entire period. Table 1 (in Appendix A summarizes a few statistical results obtained with these data.

As can be seen from these Figures and Table 1 *foF2* varied by between -8.8 and +7.4 MHz. Figure 1 includes the regular diurnal and annual/seasonal variations as well as any other variation falling under the term "day-to day variability". Figure 2 shows the distributions of δ*foF2* values that correspond to major northward and southward B_z inversions. The distributions are slightly skewed, the most probable value appears between -0.1 amd 0 MHz. The upper and lower deciles (listed in Table 1) range between 2.3 and 2.5 MHz. This is the true day-to-day variability in which all quiet variations have been taken out. When comparing these values to the most common values of *foF2* it is apparent that the day-to-day varaibility is a quite important phenomenon which may cause serious problems in practical applications.

DEFINITION OF IMF EVENTS

In order to study the effects of IMF polarity changes (δB_z in GSM) the data were searched for all south-and northward inversions. After /1/ a change of sign between hourly data points was called an "event" when $|B_z|>1$ nT for both data points. Thus the requirement was polarity change and a change in value of at least 2 nT. In this way we found a total of 6018 events. As a subset of these we considered "major events" in which B_z retained its polarity during extended periods (4 h at least) before and after the inversion. This condition was met in 310 cases.

Another classification of events was after the size of the change in B_z. Following /1/ we defined such "large events" by the condition that the value changed by at least 10 nT.

EFFECTS ON THE MID-LATITUDE IONOSPHERE

Figures 3 show results of superposed epoch studies of "large events". Time zero is the event. The abszissa gives this time (in h), while the ordinate shows the mean value of the change, δ*foF2*. The results for all stations were superposed in both Figures 3. Minima of δ*foF2* are apparent around some 20 hours after the event, very pronounced with northward inversions (Figure 3a). This is a most important effect; the average over all stations of the change in value is -1.3 MHz for northward and -1.4 MHz for southward inversions. There occur some minor variations (with an order of magnitude of about 0.2 MHz) before the event too and changes of the same order appear also after the event. This is understandable since many non-quiet days were necessarily contained in the data sets. When comparing to Figures 2 it appears that the magnitudes δ*foF2* of these major effects cover a large part of the total

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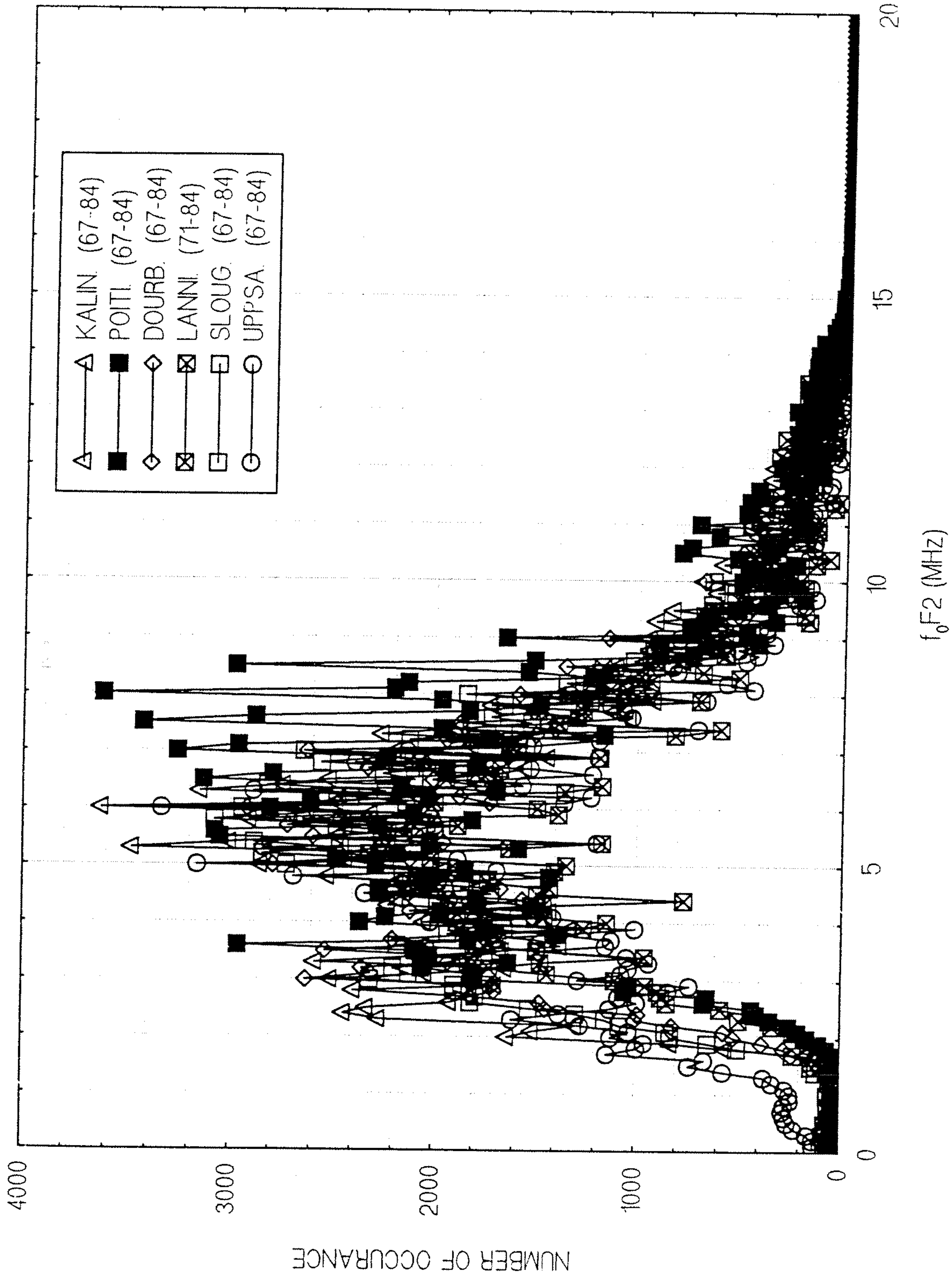


Fig.1. Distribution of all critical frequencies *foF2* for our full data set (six PRIME stations).

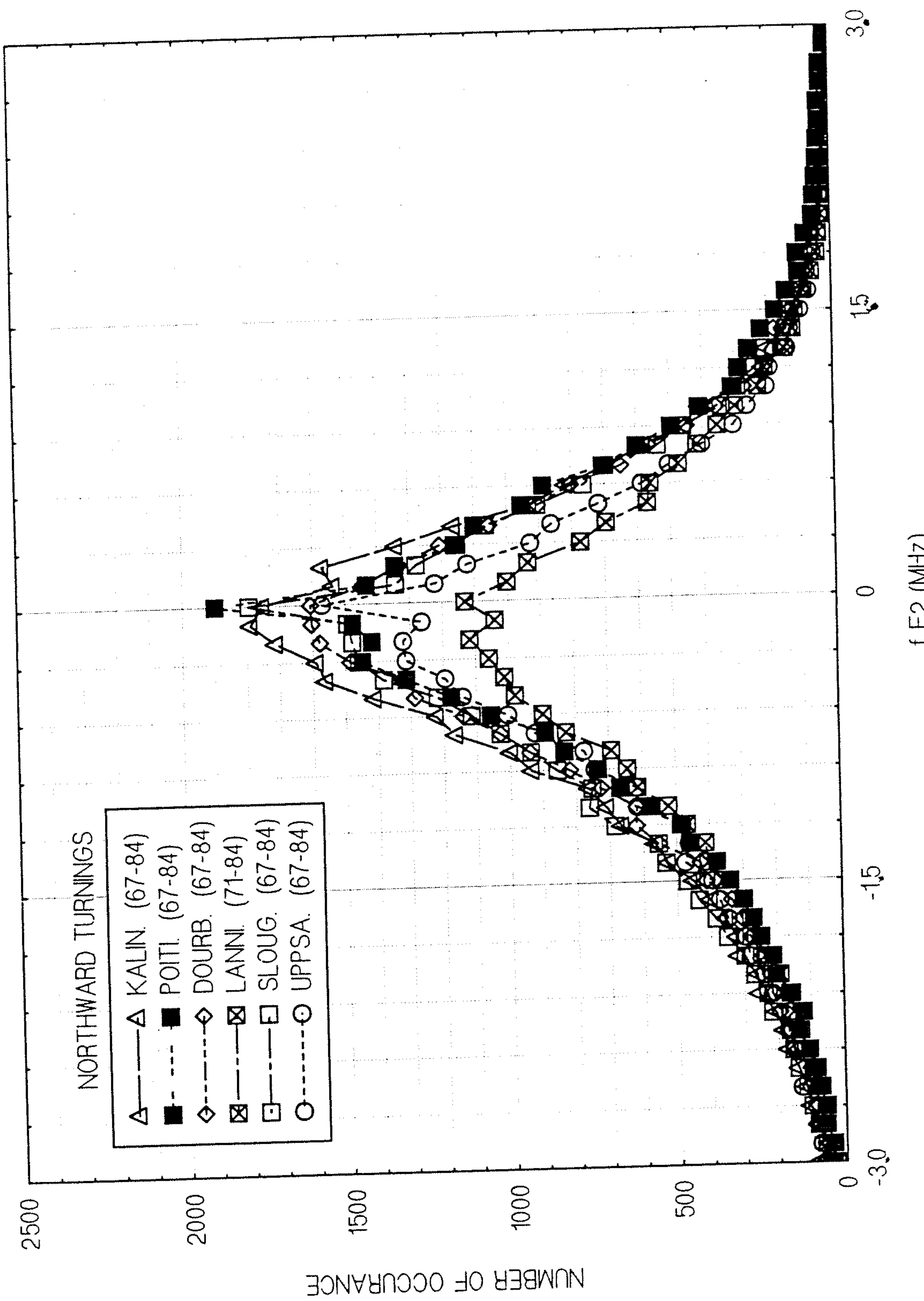
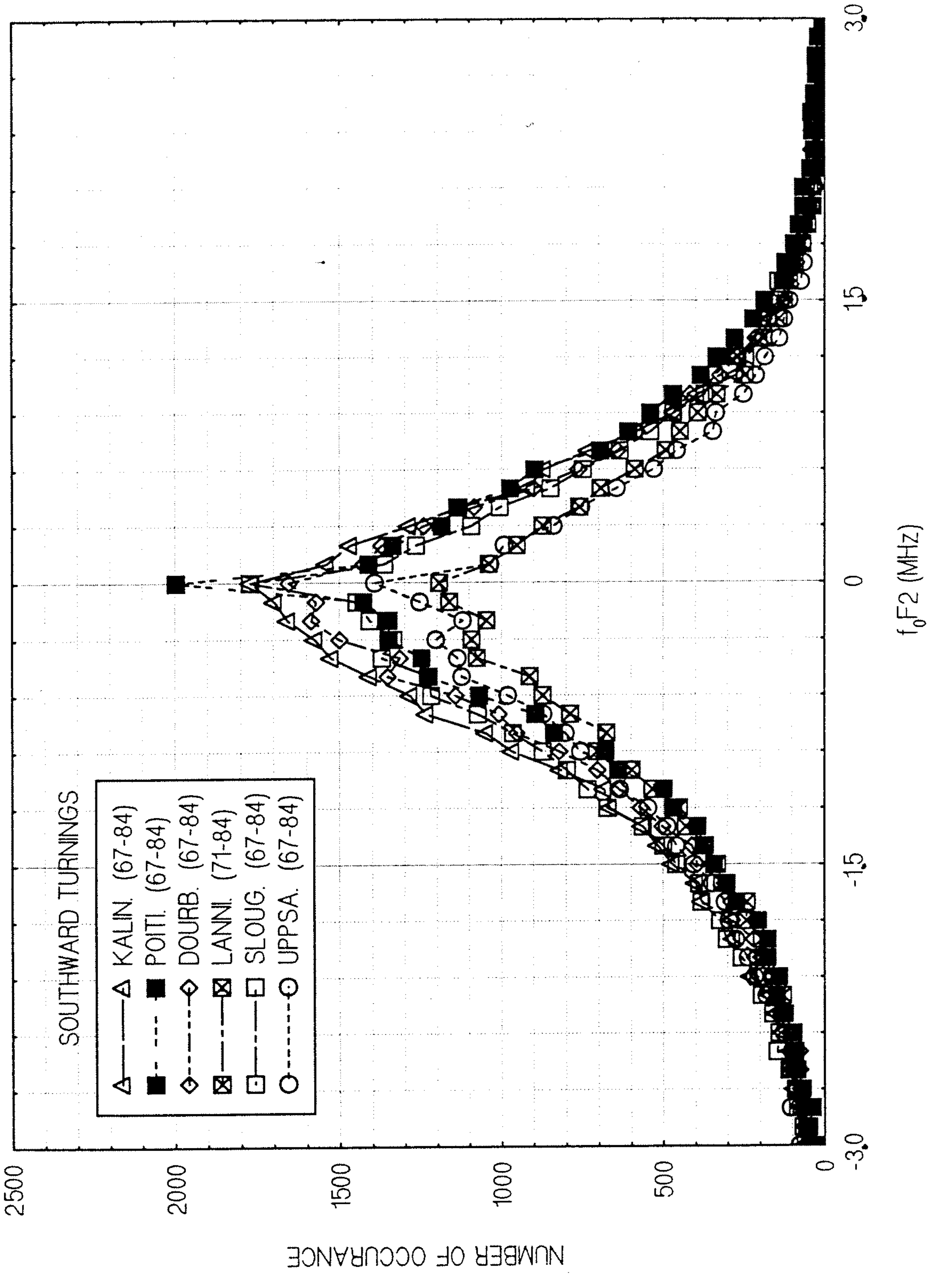


Fig.2. Distributions of the deviations from quiet conditions. for the δfoF2. data set to Figure 1 [a - northward, b - southward inversions].



b - southward inversions1.

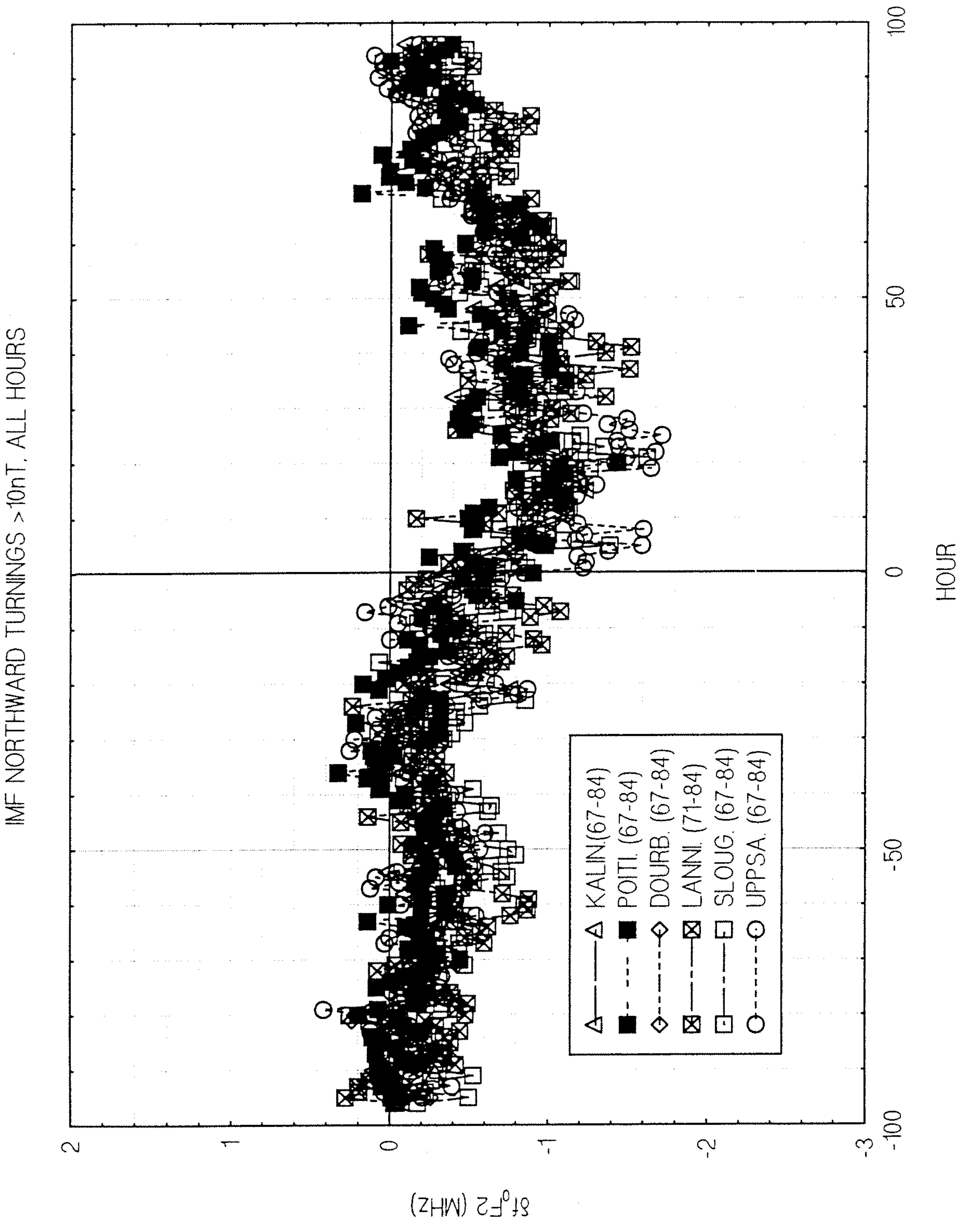
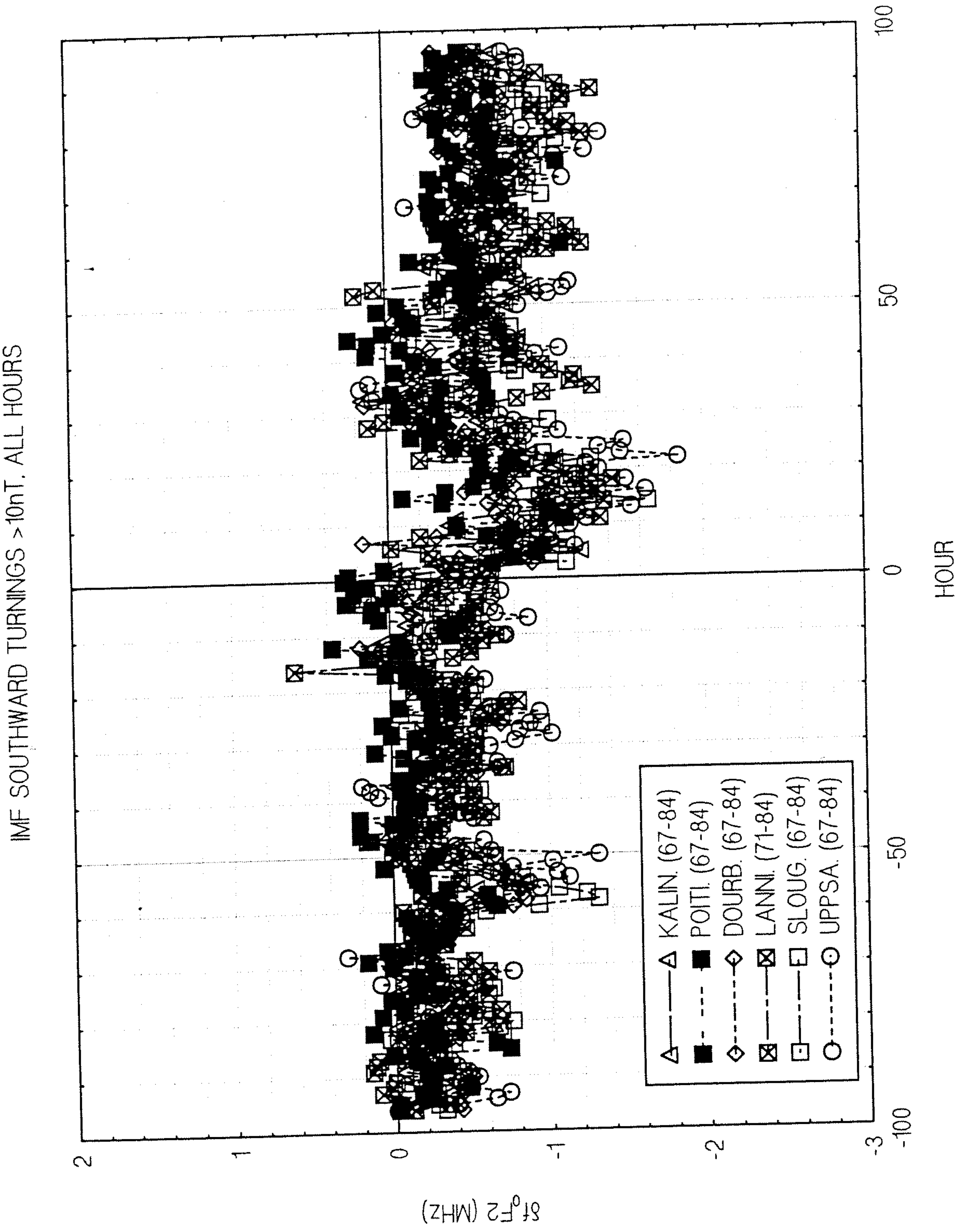


Fig.3. Superposed-epochs plots of mean $\delta foF2$ as function of event time. [a - northward, b - southward inversions].



b - southward inversions].

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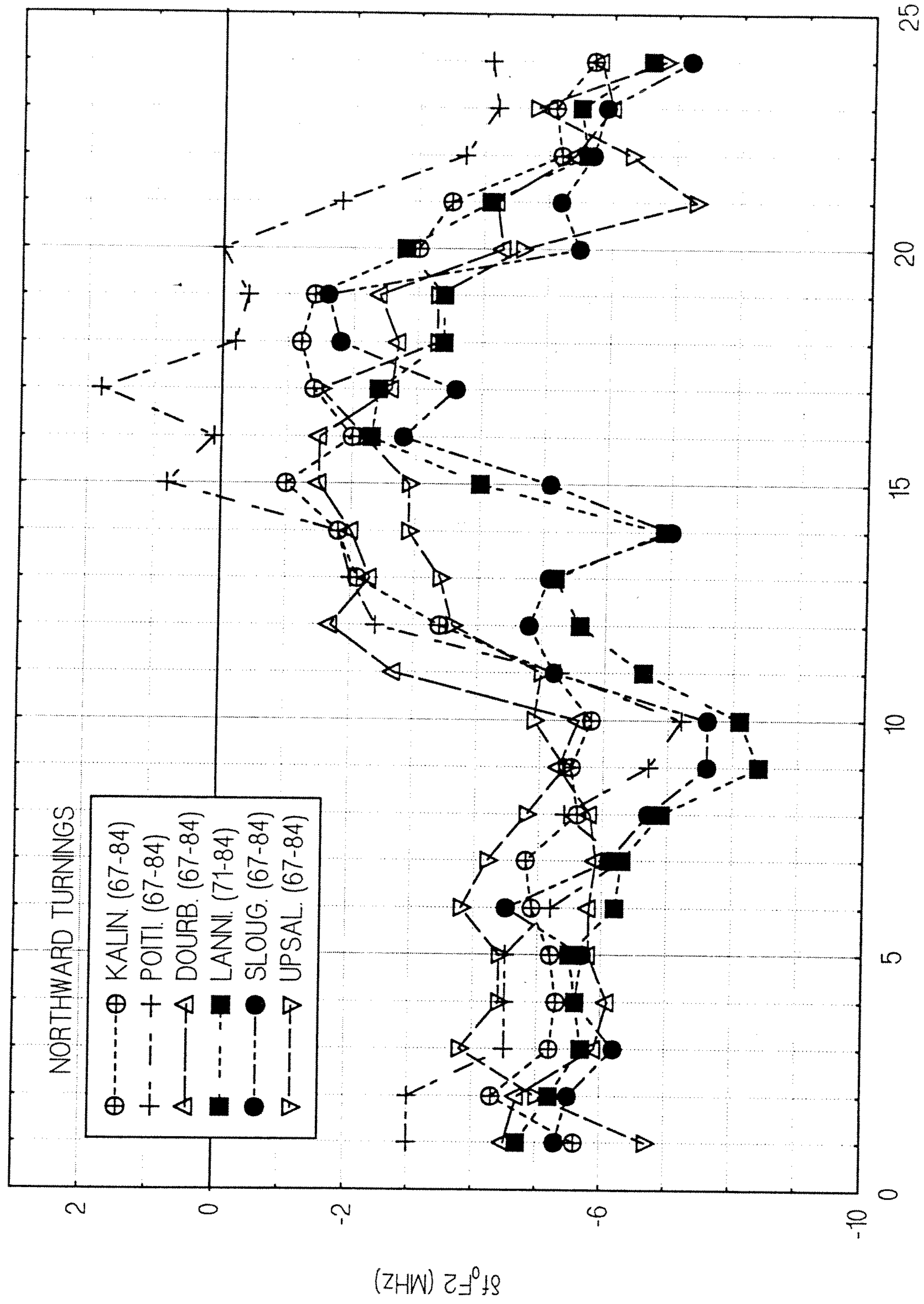
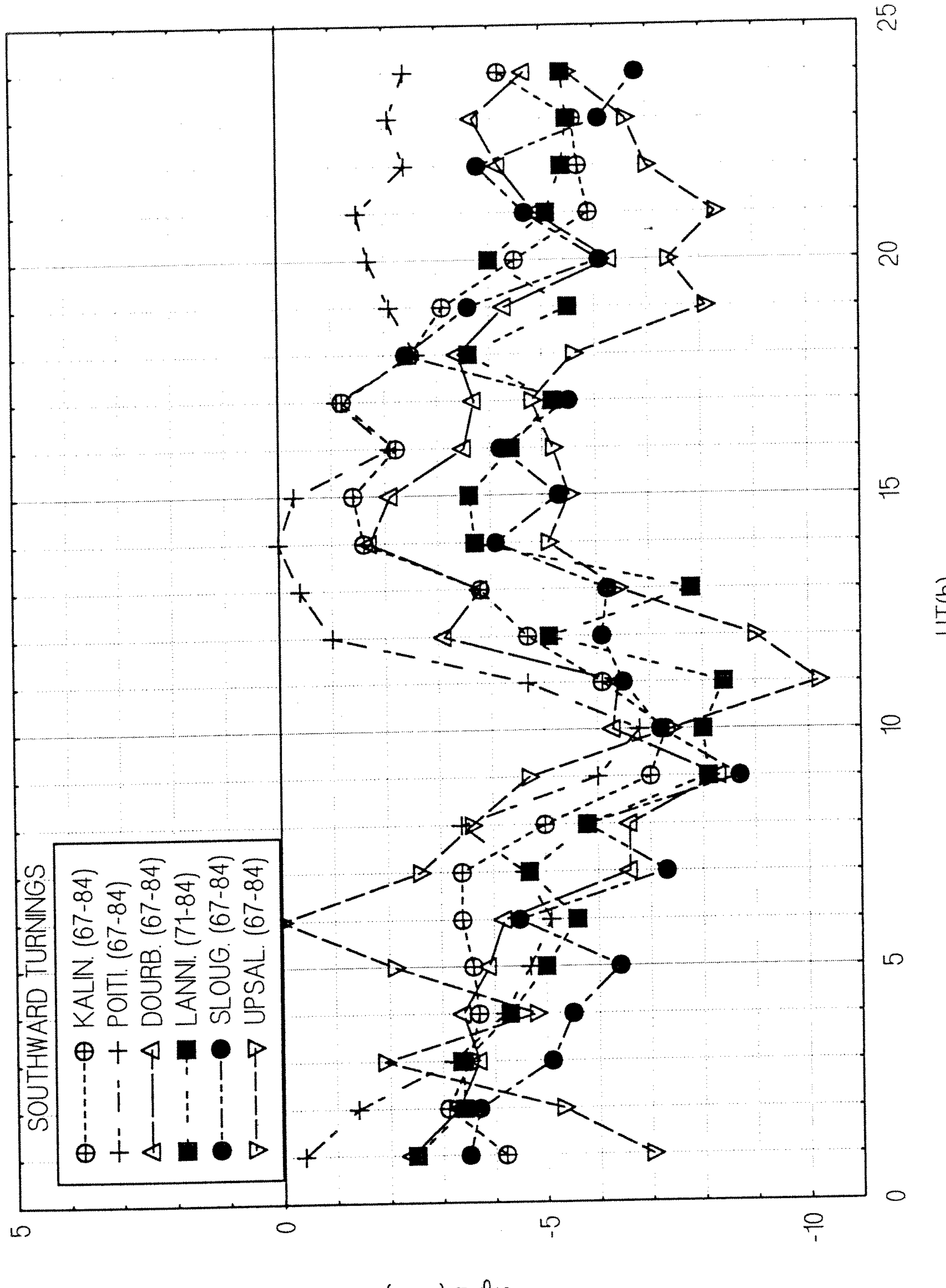


Fig.4. Mean diurnal variation of δ*foF2* for each of the six PRIME station

[a - northward,



b - southward inversions].

observed variability. This impiles that inversions of B_z contribute considerably to the day-to-day variability of the electron density.

Figures 4 exhibit the average diurnal variation of $\delta foF2$ (one curve for each observatory). It is interesting to note that the maximum deviation from "quiet conditions" occurs near dusk whereas we find the smallest deviation near dawn.

CONCLUSIONS

Our studa of critical frequencies at six PRIME ionosonde stations reveals that much of the observed day-to-day variability is related to changes in the orientation of the B_z component of the IMF. Both, north-and southward inversions seem to produce depressions in *foF2*. For the major events, however, the greater effects seem to be linked with southward inversions. Even though in such "large events" the polarity had been preserved during three hours before the event it was pretended in /1/ that a northward inversion may still reflect the effect of a southward inversion that had taken place earlier.

AKNOWLEDGEMENT

This work was supported by TUBITAK. The outhor thanks Mr.R Hanbaba and Mr.H.Sizun for providing the ionospheric data. He further thanks Y.Gülbatar and S.Göre for computer programming.

REFERENCES

1. M.A.Hapgood, M.Lockwood, G.A.Bowe, D.M.Willis and Y.K.Tulunay, Planet. Space Sci. 39, 411 (1991).

2. Y.Tulunay, D.M.Willis, M.Lockwood and M.A.Hapgood, *Final Report NATO project 0753/87* (1991).

3. Y.Tulunay and S.Rahman, *COST 238:PRIME Workshop* (1992).

4. J.W.Dungey, *Phil.Mag.Roy.Soc.* 44, 725 (1953).

5. J.W.Dungey, *Phys.Rev.Lett.* 6, 47 (1961).

6. D.A.Couzens and J.H.King, in: *Interplanetary Medium Data Book, Suppl.3,* NASA GSFC, Greenbelt Md.USA, 1986.

7. M.Lockwood, M.N.Wild and Y.Tulunay, *J.Atmos.Terr.Phys,* in press.

8. R.Hanbaba and H.Sizun, private communication (1992).

9. M.Lockwood, private communication (1993).

4-6-94

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FAX: (49) 761 13425

to Professor Yurdanur TUNULAY, Fac.of Engineering,
Middle East Technical University, ANKARA
FAX 0090 312 21011 10

ref.: your paper on "Temporal and Spatial Variability..." ; your FAX 30-5-94

Dear Colleage Tulunay,

I realize that apparently my letter of Feb.28 was lost and so the proposed - mainly minor language - changes could not be applied. Since on the other hand time is now running out, I decided to have the text typed here. I ask for your agreement to this exceptional procedure, in particular:

1 - to change the title in a way that (instead of an organization) the main *geophysical* aspect is mentionned:
VARIABILITY OF MID-LATITUDE IONOSPHERIC foF2
COMPARED TO IMF-POLARITY INVERSIONS

2 - I generally replaced the word *turning* by *inversion*.

3 - Reworded ABSTRACT:
Potential effects of the IMF-orientation on the mid-latitude ionosphere are further investigated using critical frequencies foF2 from six ionosonde stations. For a period of 15 days around each inversion of B_z, excluding all days with Ap >=6, a quiet standard diurnal variation was determined by day-by-day averaging for each hour UT. The regular diurnal, seasonal and solar cycle variations were then removed from the data by substracting from these the quiet standard value. The so obtained differences δfoF2 were sorted after the IMF polarity. Distinct effects of northward and southward inversions were found so that a large part of the day-to-day variability may be attributed to IMF B_z polarity changes.

4 - Chapter headings:
INTRODUCTION
BASIC DATA
DEFINITION OF IMF EVENTS
EFFECTS ON THE MID-LATITUDE IONOSPHERE
CONCLUSIONS

5 - REFERENCES ordered *by number of appearance*

6 - No aknowledgement to the typist (since typed here)

The Chairman has decided that papers dealing with the main subject of the symposium ("Off-median phenomena..") are considered as invited papers. Yours is perhaps the best contribution in this category. So it gets 10 pages, namely 3 pages text + 7 pages Figures. Your Table 1 goes into an Appendix.
Inform me by FAX about your agreement to the above.

With my best souvenir
Sincerely yours

Karl Rawer

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Influence of the interplanetary magnetic field on the variability of the mid-latitude F2-layer

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ABSTRACT

The structure of the interplanetary magnetic field (IMF) is responsible for an essential part of the variability of the ionospheric plasma as demonstrated by investigations of the influence of IMF sector boundary crossings as well as of ΔBz-changes (defined from satellite observations) to the maximal electron density of the F2-layer at different stations in mid-latitudes. It could be shown that negative Bz-values cause distinct negative ionospheric effects. Maximal effects were detected at high geomagnetic latitudes (ionospheric response decreases with decreasing latitude), high solar/geomagnetic activity, equinoxes and night-time conditions.

1. INTRODUCTION

As known from satellite observations as well as ground-based geomagnetic measurements in high latitudes the interplanetary magnetic field (IMF) in the Earth's orbital plane is subdivided into more or less regular sectors with a magnetic field directed away from (A-polarity) or towards the sun (T-polarity). Beside its direction each IMF sector can be characterized by its vertical magnetic component Bz in the solar-magnetospheric coordinate system. After *Dungey (1961)* and *Russell and McPherron (1973)* this Bz-component plays a dominant role in the energy transfer from solar wind into the Earth's magnetosphere. A negative Bz-component should favour this energy transfer whereas positive Bz-values should reduce such an energy input. Therefore, sectors with negative Bz-values are called pro sectors and sectors with positive Bz-values anti sectors. As shown in detail in *Bremer (1988)* an IMF with A-polarity induce positive Bz-values during the spring half-year and negative Bz-values in the autumn half-year, whereas an IMF with T-polarity causes inverse signs of Bz, respectively. The most marked ionospheric effect should be expected during changeover of IMF polarity, the so-called IMF sector boundary crossings. The ionospheric response to such sector boundary crossings is summarized in Chapter 2.1.

Beside the Bz-changes during these more or less regular sector transitions, in satellite data also more irregularly occurring Bz-changes of shorter duration are detected. During such events which often last only some hours marked Bz-changes can be observed. The ionospheric response to such events with $\Delta Bz <$ -2nT is presented in Chapter 2.2.

2. EXPERIMENTAL RESULTS

2.1 Ionospheric response to IMF sector boundary crossings

In this Chapter we want only to describe the influence of IMF sector boundary transitions on the critical frequency of the F2-layer, foF2. The influence on other ionospheric parameters is described in *Bremer (1992)*.
To derive the mean ionospheric response during sector boundary crossings we calculated for each sector transition the following expression

$$dfoF2 = \frac{\overline{foF2}(pro) - \overline{foF2}(anti)}{\overline{foF2}} \cdot 100\% \qquad (1)$$

Here $\overline{foF2}$ (pro) and $\overline{foF2}$ (anti) are mean values of foF2 during 4 days before or after the sector boundary crossings at pro or anti sector condition, whereas foF2 is the mean value of foF2 during 8 days around the sector crossing. Using foF2 noon values of Juliusruh dfoF2 values after equ. (1) were calculated for 643 sector boundary crossings (1957-1982) after dates published by *Svalgaard (1978)* and *Wilcox (1982)*. The results are summarized in the histogram shown Fig. 1. The mean deviation of foF2 during pro sector compared with anti sector condition is $\overline{dfoF2}$ = -2.6%.

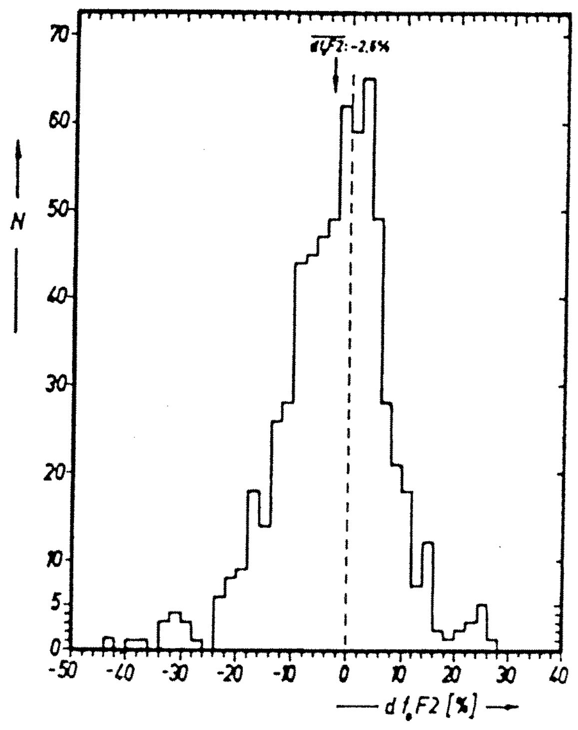

Fig. 1 : Histogram of dfoF2-values derived after equ. (1) during IMF sector boundary crossing using foF2 noon values of Juliusruh during 1957 - 1982.

Inspite of the large scatter of the individual events this mean deviation is statistically significant different from zero (confidence level 99.9% after t-test, *(Taubenheim, 1969)*. The relatively broad distribution points to the high ionospheric variability which is caused by other factors than IMF polarity changes (e.g. variability of solar radiation, internal atmospheric processes). Therefore, the ionospheric response to IMF sector transitions can only be detected by mean values, in individual cases, however, the IMF effect may be masked by other ionospheric processes.

Using the same data as included in Fig. 1 the mean ionospheric response to IMF sector boundary crossings are investigated in dependence on season (winter : November - February, summer : May - August, equinox : March, April, September, October), for different levels of solar activity (Rmin : months with R12 ≤ 40, Rmax : months with R12 ≥ 110) as well as for high geomagnetic activity (months with Ap ≥ 18). The results are compiled in Tab. 1. In general during equinoctial months the IMF effect is most pronounced for all levels of solar and geomagnetic activity whereas the effect is smallest during winter. With increasing solar activity the effect becomes stronger, and the most marked ionospheric response is observed during months with high geomagnetic activity. The maximal effect has been derived for high geomagnetic activity during equinoxes with dfoF2 = -7.2%.

Tab. 1 : Mean foF2 deviation dfoF2 [%] calculated after equ. (1) with foF2 noon data of Juliusruh during IMF sector boundary crossings in dependence on season

	Year	Wi.	Su.	Eq.
1957 - 1982	-2.6	-1.3	-2.1	-4.5
R12 ≤ 40	-1,7	-1.0	-1.3	-2.8
R12 ≥ 110	-4.8	-3.2	-4.3	-6.8
Ap ≥ 18	-6.6	-5.6	-5.9	-7.2

The results presented in Fig. 1 and Tab. 1 were derived from foF2 noon data (11 - 13 LT) only. To get an impression about the diurnal variation of the IMF effect, in Fig. 2 mean dfoF2-values are presented for four different times during the day (sunrise : 6 LMT, noon : 11 - 13 LMT, sunset : 18 LMT, midnight : 23 - 1 LMT). Here again foF2 data of Juliusruh have been used for the whole year, but for the period of high solar activity only (1978 - 1982). During all times we observe a negative effect, most marked near midnight (-6.9%) and smallest near noon (-4.9%).

All results presented until here are restricted to Juliusruh (54.63°N, 13.38°E). In Fig. 3 mean dfoF2-values are presented in dependence on geomagnetic latitude using foF2-data (noon, whole year) of nine stations of the northern hemisphere for high solar activity (1978 - 1982, some low latitude stations 1967 - 1974). In the PRIME region (geogr. lat.: 35° - 55°N; geomag. lat.: 30...38° - 49°...57°N) the negative effect in dfoF2 becomes markedly smaller with decreasing latitudes (-5% near 55°, -0.7% near 35°).

In Figs. 1-3 and Tab. 1 all IMF sector boundary crossings have been used independent of their direction. In Tab. 2 the results are, however, subdivided into IMF transitions from anti → pro sectors and from pro → anti sectors. In all cases independent of solar and geomagnetic activity the anti → pro sector transitions cause stronger ionosphere effects.

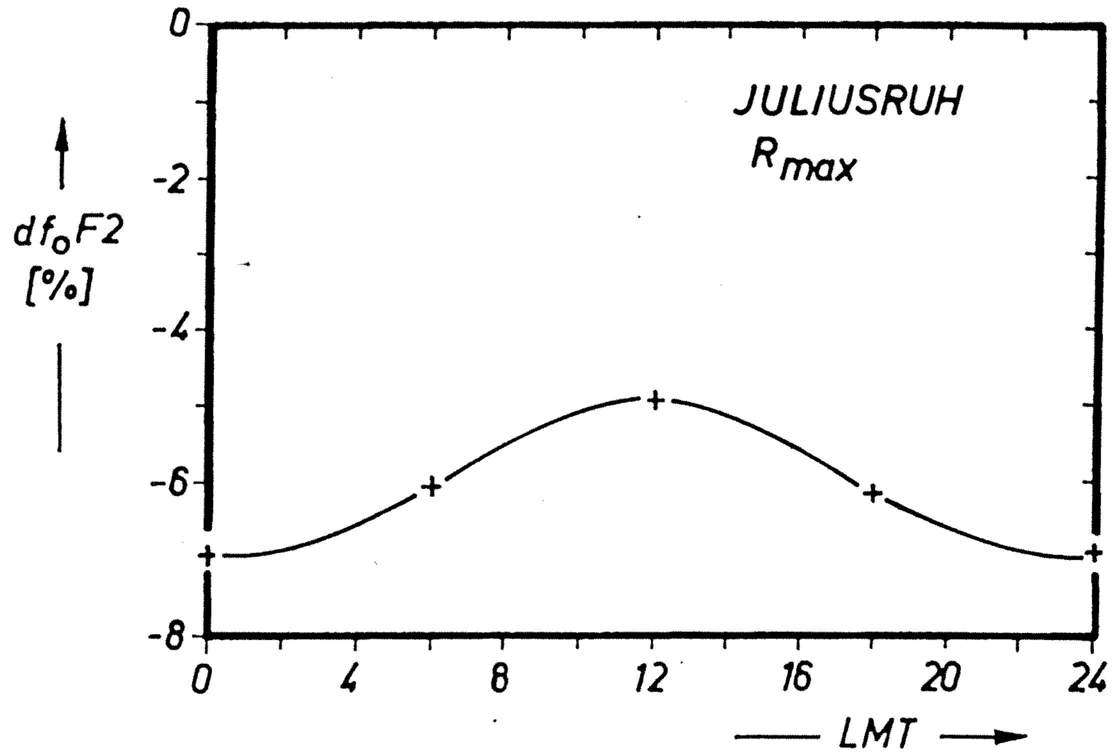

Fig. 2 : Diurnal variation of dfoF2-values derived after equ. (1) during IMF sector boundary crossings using foF2 values of Juliusruh at high solar activity (1978 - 1982)

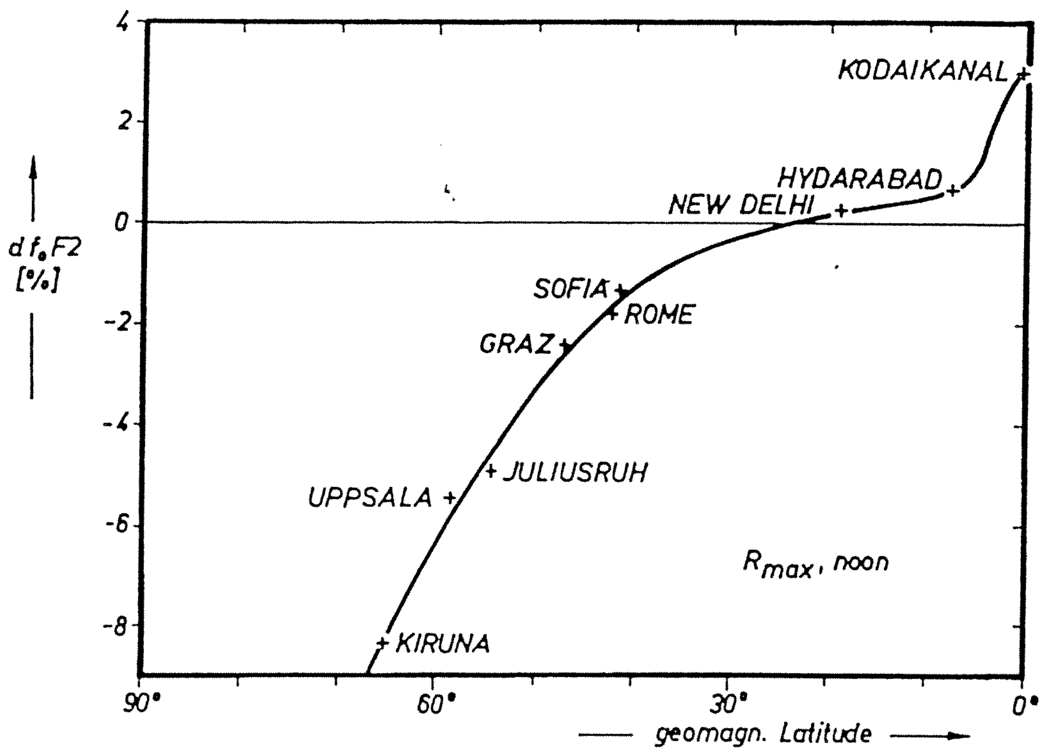

Fig. 3 : Mean variation of dfoF2-values derived after equ. (1) during IMF sector boundary crossings in dependence on geomagnetic latitude at high solar activity (1978 - 1982 or 1967-1974)

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Tab. 2 : Mean foF2 deviation dfoF2 [%] as in Tab. 1 but subdivided for anti → pro as well as pro → anti sector transitions

	1957-1982	R12 ≥ 110	R12 ≤ 40	Ap ≥ 18
anti → pro :	-3.2	-5.9	-2.2	-7.7
pro → anti:	-2.1	-3.6	-1.2	-5.4

2.2 Ionospheric response to negative Bz events

As described in detail in Tulunay (1994) from satellite measurements of the solar wind and the IMF during the period from 1963 until 1986 special events were selected with southward turning of the IMF. Here clearly defined events were chosen with Bz-changes $\Delta Bz \geq -2nT$ and the same Bz polarity both 4 hours before and 4 hours after the turning. For the investigations of the ionospheric response during such negative Bz events differences δfoF2 of the observed critical frequencies of the F2-layer from undisturbed "quiet-time" values are estimated. The "quiet-time" values are derived for each hour from 15 days around the Bz-event using only data of those days with Ap less than 6.
The general ionospheric response is presented for some stations in *Tulunay (1994)*: starting from a relatively constant δfoF2 level before the effect (near zero or slightly negative) δfoF2 decreases often some hours before the Bz-effect, reaches a marked minimum at the first day after the IMF southward turning and recovers during the following days. The maximum ionospheric effect (difference between minimum value and nearly constant level before the effect) is presented in dependence on geomagnetic latitude in Fig. 4 using data of the whole year for 11 stations in mid-latitudes. The ionospheric effect is presented in MHz (left axis) and in per cent (right axis) using as reference value the mean value foF2 = 6.1 MHz of all foF2 data analyzed. Similar as in Fig. 3 the ionospheric effect presented in Fig. 4 is negative in the whole latitudinal belt and becomes smaller with decreasing latitude (-15%...-3%). The same analysis was made for the summer as well as winter half-year separately. The results are shown in Fig. 5. Also here during both seasons negative effects are observed decreasing in amplitude with decreasing geom. latitude. The effects during the summer half-year (-18...-8%) are, however, markedly stronger than during the winter half-year (-11%...-5%).

3. DISCUSSION

In all Figures and Tables shown above it could be demonstrated that foF2 in mid-latitudes is typically reduced during IMF with negative Bz-values. This effect is, however, often only detectable by statistical methods as the ionospheric variability is not only caused by IMF changes. Nevertheless, an essential part of the ionospheric variability is due to IMF polarity changes.
After Figs. 3-5 the ionospheric effect caused by the negative vertical component of the IMF decreases with decreasing geomagnetic latitudes, vanishes near 25° geom. latitude and becomes positive near the geomagnetic equator. This latitudinal variation corresponds well with the variation of ionospheric storms *(Matsushita, 1959)*. Therefore, it seems to be quite reasonable to consider the ionospheric effects caused by negative Bz-components as small ionospheric storms (for theory of ionospheric storms see : *Rishbeth, 1975; Hargreaves, 1992; Prölss, 1993)*.

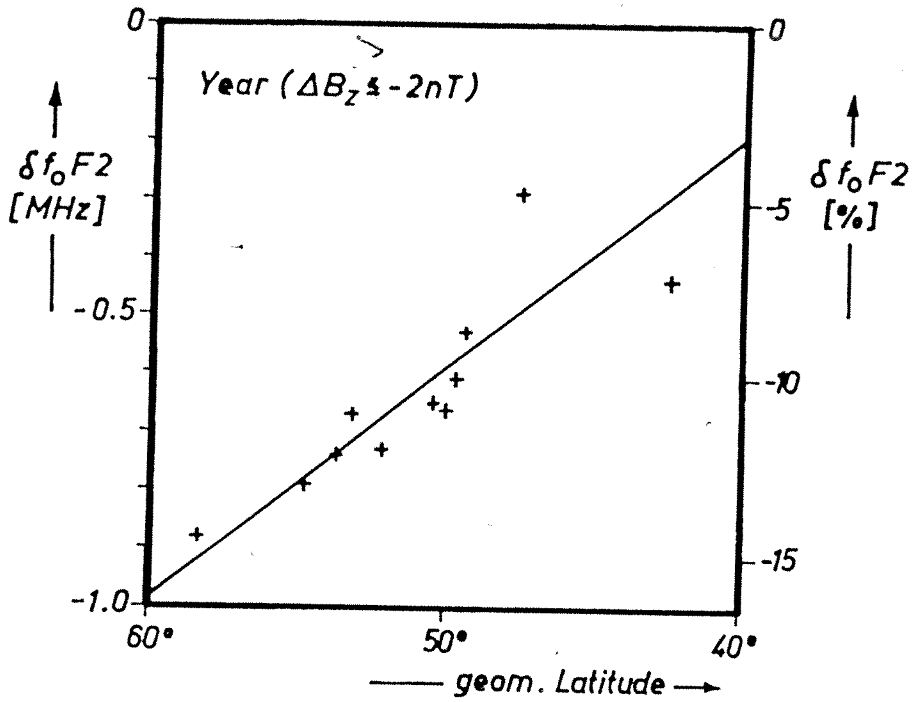

Fig. 4 : Mean ionospheric response δfoF2 due to IMF events with ΔBz ≤ -2nT in dependence on geomagnetic latitude (data from 1963 - 1986)

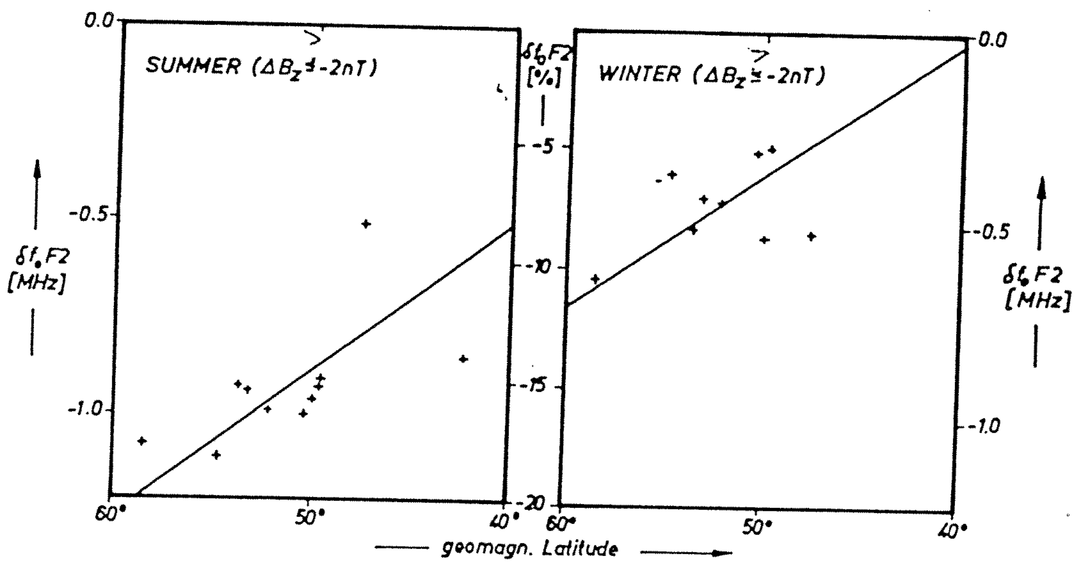

Fig. 5 : Mean ~~ionosoheric~~ ionospheric response δfoF2 as in Fig. 4, but data are subdivided for summer and winter half-year.

The energy input ε from the solar wind into the magnetosphere can be approximated by an empirical formula derived from *Perreault and Akasofu (1979)*

$$\varepsilon = v\, B^2 l_o \sin^2 \vartheta/4 \qquad (2)$$

with the velocity of the solar wind v, the magnitude of the IMF B, the constant l_o=7 Earth's radii and the polar angle ϑ in the y-z-plane of the solar-magnetospheric coordinate system. Due to the term $\sin^2\vartheta/4$ the energy transfer ε is maximal for ϑ=180°, i.e. during times with negative Bz-values.

The seasonal differences in Tab. 1 seem to be reasonable. As shown in *Bremer (1988)*, the Bz-values in the IMF pro (-Bz) and anti sectors (+Bz) are maximal near equinoxes. Therefore, during this time the strongest ionospheric events during IMF sector boundary crossings should be expected. The differences of the ionospheric effects between summer and winter (Tab. 1, but also Fig. 5) can be explained by the well-known fact that during winter time ionospheric storms are sometimes positive at mid-latitudes whereas during other seasons negative storms clearly dominate *(Hargreaves, 1992)*.

Whereas the ionospheric response to IMF sector transitions at low solar activity is relatively small, the effect becomes stronger during high solar activity and especially during periods of high geomagnetic activity (Tab. 2). This phenomenon may be caused by an increasing energy input ε from the solar wind into the Earth's magnetosphere and ionosphere during these periods due to increasing solar wind speed as well as increasing magnetitude of the IMF. The maximal effects were observed at high geomagnetic activity during equinoctial months (-7.2%).

The influence of the IMF sector structure seems to be more effective during night-time as demonstrated by the diurnal variation in per cent (Fig. 2) with maximal ionospheric effects near midnight (-6.9%) and a smaller response during noon (-4.9%).

Significant differences have also been observed between ionospheric effects caused by sector boundary transitions from pro → anti sectors (-3.2% in all data from 1957 - 1982) and anti → pro sector transitions (only -2.1%). This may be connected with the fact that the ionospheric plasma changes for anti → pro sector transitions are more steeper than the changes for pro → anti sector transitions *(Bremer, 1988, 1992)*.

In general the ionospheric effects caused by IMF sector transitions (Figs. 1-3, Tab. 1-2) are not so strong than those caused by the -ΔBz-events (Figs. 4-5). The reason of this difference is the markedly higher energy input from solar wind into the Earth's ionosphere after equ. (1) during the -ΔBz-events due to essentially higher -Bz-values.

4. CONCLUSIONS

Regular Bz-changes during IMF sector transitions as well as sudden and more irregular occurring Bz-variations as observed by satellites cause typical changes in the ionospheric F2-layer plasma. These effects are one important source of the variability of the foF2-region plasma. The effect is more dominant at the upper latitudinal border of the PRIME area and becomes smaller at lower latitudes.

A prediction of such effects is difficult. One simple possibility to predict the IMF sector structure with the dates of sector boundary crossings could be the use the mean solar magnetic field as observed by the Stanford Observatory *(BREMER, 1994)*. The prediction of short-term ΔBz-variations which are often the origin of ionospheric storms seems, however, to be impossible until now.

5. REFERENCES

Bremer, J., The influence of the IMF sector structure on the ionospheric F-region, J. atmos. terr. Phys. **50**, 1988, 831-838.

Bremer, J., Influence of the IMF on the ionospheric plasma of the D-, E- and F-layer, Publ. del. Observatorio del Ebro, Memoria No. 16 Roquetes (Tarragona), 1992, 403-409.

Bremer, J., The mean solar magnetic field as on indicator of IMF, Scientific Rep. COST Document COST 238 TD(94) 010, Eindhoven 1994, 129-136.

Dungey, J. W., Interplanetary magnetic field and the auroral zones. Phys. Rev. Lett. **6**, 1961, 47-48.

Hargreaves, J. K., The solar-terrestrial environment, Cambridge Atmospheric and Space Science 5, Cambridge University Press, 1992.

Matsushita, S., A study of the morphology of ionospheric storms, J. Geophys. Res. **64**, 1959, 305-321.

Perreault, P., and S.-I. Akasofu, Study of geomagnetic storms, Geophys. J. Roy. Astron. Soc. **54**, 1978, 547-573.

Prölss, G. W., Ionosphärische Stürme - Ideen im Widerstreit, Kleinheubacher Ber. **36**, 1993, 363-377.

Rishbeth, H., F-region storms and thermospheric circulation, J. atmos. terr. Phys. **37**, 1975, 1055-1064.

Russell, C.T., and R.L. McPherron, Semiannual variation of geomagnetic activity, J. Geophys. Res. **78**, 1973, 92-108.

Svalgaard, L., Interplanetary sector structure 1947-1975, SUIPR-Rep. No 629, Stanford, Ca. U.S.A., 1976.

Taubenheim, J., Statistische Auswertung geophysikalischer und meteorologischer Daten, Akad. Verlagsgesellschaft Geest u. Portig K. G., Leipzig, 1969.

Tulunay, Y., Interplanetary magnetic field (IMF) and its possible effects on the mid-latitude ionosphere III, Scientific Rep. COST Document COST 238 TD (94) 010, Eindhoven 1994, 137-151.

Wilcox, J. M., Tabulation of well-defined boundaries in the interplanetary magnetic field, Private Communication, 1982.

Interplanetary Magnetic Field (IMF) and Its Possible Effects on the Mid-Latitude Ionosphere: III

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Abstract
Using critical frequencies, foF2 from the Lannion, Slough, Poitiers, Garchy, Dourbes, Rome, Juliusrud, Gibilmanna, Pruhonice, Uppsala, Kaliningrad, Miedzeszyn, Sofia, Athenes, Kiev ionosonda stations, the possible effects of the orientation of the IMF on mid-latitude ionosphere are further investigated. This time, the southward polarity changes in IMF Bz with consideration of seasonal effects were considered only. The same method of analysis were employed in order to facilitate a comparison between the recent results presented here with those of appeared in the preceeding papers in the series. That is, the regular diurnal, seasonal and solar cycle variations in the foF2 data were removed by subtracting the mean of the foF2 for the same UT on all magnetically quite days (AP<6) within 15 days around the IMF B_Z turnings (Tulunay, 1994).

1. Introduction

Radio waves of a wide range of frequencies, from very low frequency (VLF) to high frequency (HF) (broadly 3 kHz to 30 MHz) can be propagated to great distances via the ionosphere. The day-to-day variability of the height distribution of F-region ionospheric electron densities greatly influences the propagation characteristics of HF waves. Of particular importance is the peak density of the ionospheric plasma, which is proportional to the square of the "critical frequency" of the F-layer, foF2 (the largest frequency of the ordinary wave which the F-layer reflects back to a vertical-incidence sounder). The foF2 value can be used to compute the "maximum usable frequency" (MUF) of HF waves using a so-called M-factor (e.g. Lockwood, 1983). The day-to-day variability of foF2 has remained unpredictable, despite many scientific studies to find its origins (Aravindan and Iver, 1990). This unpredictable variability greatly limits the efficiency of operation of communication, radar and navigation systems which employ HF radiowaves (Bradley, 1991: Lockwood, et al., 1993).

The objective of this paper is to search further the possible effects of the orientation of the interplanetary magnetic field (IMF) on the critical frequency of the ionospheric F-layer at mid-latitudes. The IMF is known to a controlling influence on the magnetosphere and high-latitude ionosphere. Of primary importance here is the north-south component of the IMF, in accordance with magnetic reconnection being the dominant mechanism by which energy, mass and momentum are transferred from the solar wind flow into the Earth's magnetosphere, as first suggested by Dungey (1953, 1961). The thermospheric winds driven at high latitudes "storm time circulation" pattern, and the composition changes observed in the neutral thermosphere due to the high latitude heating by auroral particle precipitation are known to exert a strong influence on the peak density of F-region plasma. The winds blow the plasma up the magnetic field lines for the equatorward and down the magnetic field lines for the poleward winds to altitudes of lower/greater plasma loss. The changes in the ratio of molecular to atomic density of the neutral species may result some induced changes in the balance between palsma production and loss (see for example Risbeth et al., 1989; Lockwood, 1991). Even though, most of the features of the Earth's magnetosphere and high latitude ionosphere which are controlled by the IMF B_Z component are confined to high-latitudes, via the action of the neutral thermosphere the IMF controlled flows at high latitudes are expected to have some influence on the F reglan ionosphere (see for a full discussion by e.g. Lockwood et al., 1993). This paper includes some more results of the recent work conducted by employing frequencies from the fifteen PRIME ionospheric stations between 1967 and 1984. The critical frequencies are studied in conjuction with simultaneaus satellite measurements of the IMF. In particular, significant effects of polarity changes of IMF B_Z (in GSM) and the seasonal effect on the results are revealed. In order to improve the statistics a larger subset of the IMF B_Z turnings (key data) have been employed this time.

2. The data sets

The data concerning the interplanetary medium used in this work have been taken from a compilation of solar wind plasma and IMF data prepared by the US National Space Science Data Center (NSSDC). The data were supplied by a number of experimental groups and they were recorded by a number of spacecraft close to the Earth: IMP-1, IMP-3 to-8, AIMP-1 and 2, OGO-5 HEOS, VELA-2 to-6, ISEE-1 to 3 (Couzens and King, 1986). The data were stored on-line in a number of data bases which operated under a formal management system called R-EXEC. This system was developed at Rutherford Appleton Laboratory (RAL) for the manipulation of geophysical data (Hapgood et al., 1991). The IMF data were transformed into the GSM co-ordinate system because, as discussed above, that is the most relevant to transfer of momentum and energy from the interplanetary medium into the ionosphere. The IMF data set available covers a period from 2 November 1963 to 31 May 1987. This period covers two complete solar cycles. That is numbers 20 and 21. Within this period, only the cases for which both simultaneous plasma and magnetic field data were available were examined and the results of a survey of these data concerning the interplanetary medium have been published by Hapgood et al. (1991). This restricted the analysis to the period 27 November 1963 to 4 April 1986. Within this period, there were 101558 hourly values available out of a total 195 960 h possible i,e, there is an average availability of IMF data of 52 %. Figure 1 of Hapgood et al. (1991) gives the distributions of the relevant interplanetary parameters (solar wind speed and density, and IMF strength and B_Z component) for this period (Lockwood, 1991; Lockwood et al., 1993).

The ionospheric critical frquency data used here were taken from the COST 238:PRIME data base at the CNET Laboratories. (Hanbaba and Sizun, 1993). The critical frequencies were obtained from the ionosonde stations at Lannion, Slough, Poitiers, Garchy, Dourbes, Rome, Juliusrud, Gibilmanna, Pruhonice, Uppsala, Kaliningrad, Miedzeszyn, Sofia, Athenes, Kiev whose geographical coordinates are given in table I. In this table periods of data coverage are also exhibited.

At a given time-of-year and phase in the solar cycle, the ionosphere exhibits regular diurnal variations at mid-latitudes as the plasma co-rotates with the Earth. In order to study the day-to-day variability of the ionospheric densities about these regular diurnal variations, some form of "quiet-time" diurnal variations must be subtrated from the variations observed. In order to achieve this, for each hourly value of foF2 all quiet-time soundings with 15 days of the sounding in question were identified: quiet-time-values were defined as when the simultaneous magnetic Ap index was less than 6. The mean quiet-day control value, was then subtracted from the value actually observed: the resulting value is here termed δfoF2. Only ionospheric data which were available in digital form were employed. Figure 1 exhibits the diurnal behaviour of the quiet-day foF2 control values for Slough. Superimposed on the annual control (or-quite-time) values (outs) when the southward IMF B_Z turnings occurred, are the control (or-quite-time) values correspondig to the winter period of six months centered on the winter solstice, and the summer period of six months centered on the summer solstice. For both of the winter and summer diurnal control curves the main criterion was the southward turning of the IMF B_Z. Figures 2 (a, b, c) show the diurnal variation of the control values of the ionospheric critical frequencies, foF2, obtained at the 15 PRIME Stations of interest, annually, for winter and summer periods durig the southward IMF Bz turnings. As clearly seen in figures 1, 2 (a, b, c) that the winter foF2 control values are greater in magnitude than those of the summer ones. This seasonal anomaly do not appear before, at, approximately, 07 h UT and after dusk hours.

Figure 3 exhibites the latitudinal behaviour of the δfoF2 at constant UT hours. In general, δfoF2 is greater at low latitudes than those of the higher latitudes. The maximum spread in the values of δfoF2 range between -0.7 to +0.7 MHz at low latitudes ,and at the other extreme, they range -0.7 to -0.2 MHz at the highest latitude, that is at Uppsala. Figure 4 is the diurnal variation of the annual, summer and winter δfoF2 for all observations in the periods of interest. Largest deviations of the critical frequencies from quiet-time values occur around 10 h UT and the smallest deviations are near dusk. Due to the seasonal anomaly the winter δfoF2 values are nearer to zero in the winter curve.

As seen from table 1, for the major southward IMF Bz turnings the distributions of δfoF2 are skewed with the most common (mode) values between -0.2 and 0.0 durning summer, winter, or annually (all seasons) for the PRIME stations of interest. The upper and lower decile values as listed in table I range between 0.7and 1.5 MHz; -2.1 and -0.5 MHz annualy, and between 0.5 and 1.7 MHz ; -2.3 and -1.3 MHz during summer; 0.8 and 1.4 MHz; -1.7 and -0.7 MHz during winter. Hence, the day to day variability, not accounted for by regular quite-time variations amount to a spread between 1.7 and 3.1 MHz for the data under consideration. 1.7 and 3.1 MHz when compared with the most common values of foF2; i.e. around 6.1 MHz, once more, it has become apparent that, the day-to-day variability presents an important problem in practice (Tulunay, 1994).

3. Definition of IMF events

In order to study the effects of IMF Bz polarity changes, the data were searched for all southward and northward turnings (in GSM). Following Hapgood et al. (1991). a reversal of the polarity of the IMF B_Z component between hourly data points was named an "event" (with start time t_1 and finish time $t_2 = t_1 + 1$ h) provided that $|B_Z| \geq 1$ nT for both these two data points. Hence the IMF Bz was required to change polarity and to change in magnitude by at least 2 nt. A total of 6 018 events were defined in this way.

The numbers of events for various categories can be summarized as follows:

1) about 49 % of all the events were northward an 51 % of them were southward turnings of the IMF;
2) for 24 % of the events neither B_X nor B_Y polarity reversals took place during the period of 8 around the B_Z reversal (i.e. from $(t_1 - 3)$ h to $(t_2 + 3h)$ (T or A events);
3) for 42 % of the events there was a reversal of either B_X or B_Y during a B_Z reversal, while the other component kept the same sign for the 8 h period;
4) for 3 % of the events there were reversals of both B_X and B_Y during the B_Z reversal;
5) for 31 % of the events there were either data gaps in the 8 h period or there were multiple B_X and/or B_Y crossings.

It is interesting to note that in only 3 % of cases does a B_Z change accompany a gardenhose orientation sector boundary crossing and 24 % of B_Z changes did not relate to any change in polarity of either of the other 2 components.

The well-defined cases (2, 3 and 4) do show the predominance of the garden-hose orientation, as at the time t_1, they fall into the following classes:

i) 47 % had B_X positive and B_Y negative;
ii) 42 % had B_X negative and B_Y positive;
iii) 5.5 % had B_X positive and B_Y positive;
iv) 5.5 % had B_X negative and B_Y negative.

Hence in 89 % of these well-defined cases, the garden hose orientation applied before the B_Z polarity change. The results presented in this paper belong to the $\Delta Bz < 0$ data with the size of the change of B_Z is greater or equal to 11.5 nT of this subset.

4. The effects of the southward IMF Bz turnings annually, during summer and winter on the mid-latitude ionosphere

Figure 5 a-c shows the results of the superposed epoch studies for the $|\Delta B_Z| \geq |$ 11.5 nT events described above. The effect of the annual southward IMF B_Z turnings is represented in figure (5 a) annually, in (5 b) for winter and in (5 c) for summer. In all plots the IMF change occurred at time zero. The horizontal axis gives the times in hours relative to the IMF B_Z polarity change, and the vertical axis shows the mean value of δfoF2. The best fit curves of the data exhibited in figure 5 (a-c) show clear minima in the average δfoF2 during the day after the southward IMF turnings. These minima are at δfoF2 of -0.7 MHz in the annual, -0.6 MHz in the winter and -1.22 MHz in the summer results. The values before the events, are however, not always zero, indicating that many non quiet-day values are present (Tulunay, 1994) the average δfoF2 values before the event are -0.13 MHz, -0.09 MHz, -0.29 MHz for the annual, winter and summer results respectively. Thus, the peak change in δfoF2 which can be attributed to the southward IMF Bz turnings are, approximately, 0.57 MHz, 0.51 MHz, 0.93 MHz for the annual, winter and summer results on the average. The peak change is the largest for Juliusrud with 0.79 MHz and the smallest for Kiev with 0.17 MHz for the annual results; for the winter results the corresponding values are for Poitiers with 0.85 MHz, for Dourbes with 0.33 MHz; and for the summer results the corresponding valus are for Juliusrud with 1.39 MHz, and for Athene with 0.58 MHz. On the average the percent peak deviation is larger in the winter results than those of the summer results with respect to the values obtained before the events. The magnitude of the changes described here are a large part of the total variability reported before in the figures 2 (a-c) of Tulunay (1994). Thus, the results imply that the southward turning of the IMF B_Z can contribute in day-to-day variability of the mid-latitude densities. In particular, the day to day variability seems season dependent and the results reported here show that winter is more favourable for such variabilities.

5. Conclusions

This study of critical frequencies from fifteen PRIME stations reveals once more that much of the day-to-day variability of the mid-latitude ionosphere may be related to the orientation of the southward IMF Bz. This variability is quantified as the peak change of δfoF2. The winter foF2 values in general and the day-to-day variability seems to be larger than those of the winter and annual values exhibiting the ionospheric winter anomaly.

Acknowledgements

This work was supported by TUBITAK. The author thanks Mr.R. Hanbaba and Mr.H. Sizun for providing the ionospheric critical frequencies. Thanks are also due to Ş.Baykal and Y.Gülbahar for data analysis and computer programming and G.Cangül for typing the text.

REFERENCES

ARAVINDAN, P. and K.N. IVER (1990): Day-to-day Variability in ionospheric electron content at low latitudes, *Planet. Space Sci.* **38**, 743

BRADLEY, P.A. (1991): Improvements in mapping the critical frequency of the F2 layer, *Adv. Space Res.*

COUZEN, D.A. and J. KING (1986): *Interplanetary Medium data Book*, NSSDC, Goddard Space Flight Center, U.S.A., supply. 3.

DUNGEY, J.W. (1953): Conditions for the occurrence of electrical discharges in astrophysical systems, *Phil. Mag.*, **44**, 725.

DUNGEY, J.W. (1961): Interplanetary magnetic field and the auroral zones; *Phys. Rev. Lett.*, **6**, 47.

HANBABA, R. and H.SIZUN (1993): Private Communication

HAPGOOD M.A., M. LOCKWOOD, G.A. BOWE, D.M. WILLIS and Y.K. TULUNAY (1991): Variability of the interplanetary medium at 1 a.u. over 24 years: 1963-1986, *Planet. Space Sci*, **39**, 411.

LOCKWOOD, M. (1983): Simple M factor algorithm for improved estimation of the basic maximum usable frequency of radiowaves reflected from the ionospheric F-region, *IEE Proc.*, **130** (4), 296.

LOCKWOOD, M. (1991): Private Communication.

LOCKWOOD, M., M.N. WILD and Y.TULUNAY (1993): To be submitted for publication.

RISBETH, H., G.L. WRENN, A.P. VAN EYKEN and A.S. RODGER (1989): *Antarctic Special Topic*, 9-21.

TULUNAY, Y. and S.RAHMAN (1993): IMF and its possible effects on foF2 obtained at two almost conjugate stations Slough and Argentine Island I, data validation of ionospheric models and maps (VIM)

(Publicationes del Observatorio del Ebro, Roquetes, Spain), *Memoria*, 16.

TULUNAY, Y., P.M. WILLIS, M. LOCKWOOD and M.A. HAPGOOD (1991): The Interplanetary magnetic field and its possible effects on mid latitudes, *Final report* of the project, NATO 0753/87.

TULUNAY, Y., (1994): Interplanetary magnetic field and its possible effects on the mid-latitude ionosphere: II, *Annali Di Geofisica*, (in press)

FIGURE CAPTIONS

Figure 1. The quiet-time (control) diurnal variations of the Slough foF2 data during the IMF southward turnings. (Wins, sums, outs stand for winter, summer and all seasons or annual)

Figure 2. The quiet-time (control) diurnal variations of the foF2 data obtained from 15 PRIME stations during the IMF southward turnings, a) for all seasons (annual); b) for summer; c) for winter.

Figure 3. The latitudinal variation of the δfoF2 for the 15 PRIME stations of interest during the IMF southward turnings.

Figure 4. The diurnal variation of the annual (outs), summer (sums), winter (wins) δfoF2 during the IMF southward turnings.

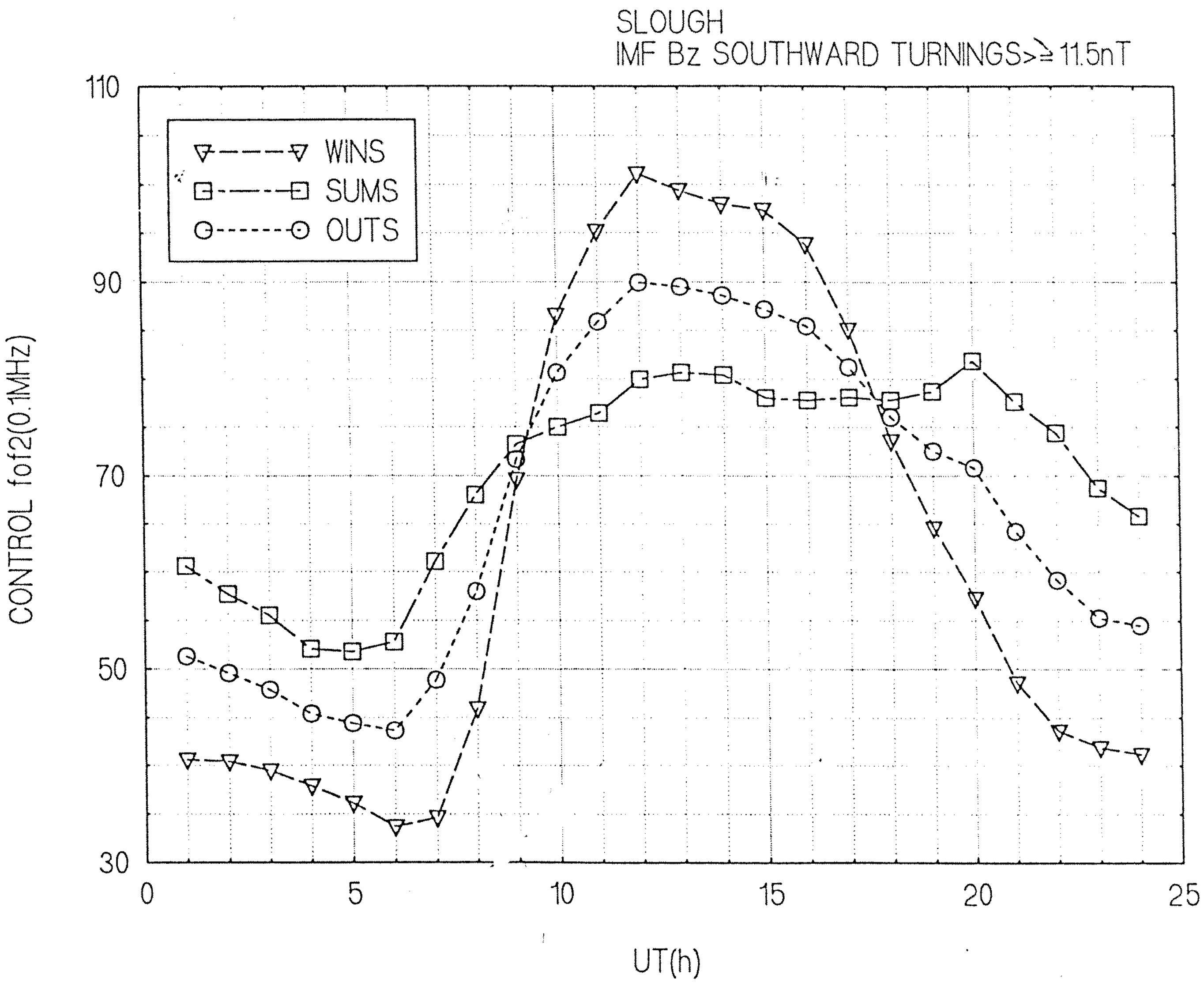
Figure 5. Superposed epoch plots of mean δfoF2 as function of event time a) for all seasons, b) for winter; c) for summer during the IMF southward turnings. Event time zero is the time of southward turning events of the IMF B_Z.

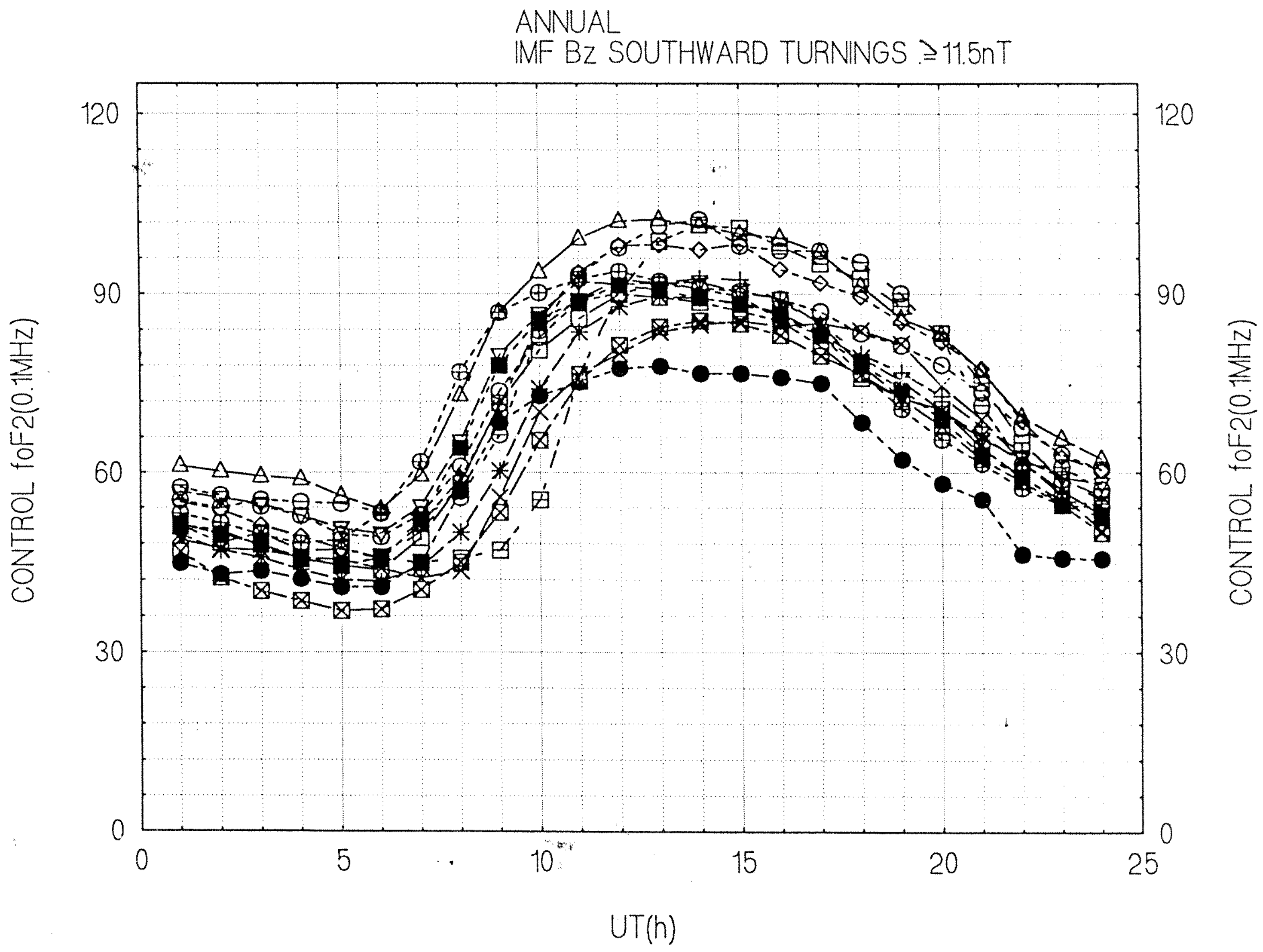
Station Names ;Geog.Coord; Data Coverage			ANNUAL DELTA foF2 (0.1MHz) MAJOR SOUTHWARD IMF Bz TURNINGS					
			MIN VALUE	MAX VALUE	MEDIAN	MODE	LOWER DECILE	UPPER DECILE
LANNION	(49N;3W)	(71-84)	-8.9	5	-0.3	-0.1	-1.8	0.9
SLOUGH	(51N;1W)	(67-84)	-8.5	4.8	-0.2	0	-1.7	0.9
POITIERS	(47N;0E)	(67-84)	-9.1	4.9	-0.1	0	-1.5	1
GARCHY	(47N;3E)	(69-73)	-3.7	4.4	-0.1	0	-1.2	0.7
DOURBES	(50N;5E)	(67-84)	-9.2	6	-0.2	0	-1.6	0.9
ROME	(42N;13E)	(67-72;76-84)	-7.2	5.8	-0.1	0	-1.5	1.1
JULIUSRUD	(55N;13E)	(74-84)	-9.2	4.3	-0.3	0	-1.9	0.8
GIBLMANNA	(38N;14E)	(76-80;83-91)	-3.2	3.9	0.1	0.2	-0.9	1.5
PRUHONICE	(50N;15E)	(67-68;76-84)	-6.5	4.5	-0.2	0	-1.7	0.8
UPPSALA	(60N;18E)	(67-84)	-8.4	6.3	-0.3	0	-2	0.8
KALININGRAD	(55N;21E)	(67-84)	-8.6	5.9	-0.2	0	-1.7	0.8
MIEDZESYN	(52N;21E)	(67-84)	-7.9	7.5	-0.2	0	-2.1	1
SOFIA	(43N;23E)	(67-74;76-83)	-7.5	4.3	-0.1	0	-1.7	1.1
ATHENES	(38N;24E)	(67-74;76-84)	-4.5	4.9	0	0	-1	1.2
KIEV	(51N;31E)	(67-84)	-5.4	5	0	0	-1.1	1

Station Names ;Geog. Coord; Data Coverage			WINTER DELTA foF2 (0.1MHz) MAJOR SOUTHWARD IMF Bz TURNINGS					
			MIN VALUE	MAX VALUE	MEDIAN	MODE	LOWER DECILE	UPPER DECILE
LANNION	(49N;3W)	(71-84)	-8.9	5	-0.1	-0.1	-1.4	1.3
SLOUGH	(51N;1W)	(67-84)	-8.5	4.8	-0.1	0	-1.4	1.1
POITIERS	(47N;0E)	(67-84)	-9.1	4.4	0	0	-1.1	1.3
GARCHY	(47N;3E)	(69-73)	-3.7	4.4	0	0	-0.9	0.8
DOURBES	(50N;5E)	(67-84)	-9.2	6	0	0	-1.2	1.1
ROME	(42N;13E)	(67-72;76-84)	-7.2	5.8	0.1	0	-1	1.4
JULIUSRUD	(55N;13E)	(74;84)	-9.2	4.3	-0.1	-0.2	-1.5	1.1
GIBILMANNA	(38N;14E)	(76-80;83-91)	-2.2	3.3	0.2	0.4	-0.7	1.3
PRUHONICE	(50N;15E)	(67-68;76-84)	-6.5	4.5	0	0	-1.3	1
UPPSALA	(60N;18E)	(67-84)	-8.4	6.3	-0.1	0	-1.7	1
KALININGRAD	(55N;21E)	(67-84)	-8.6	5.9	-0.1	0	-1.3	1
MIEDZESZYN	(52N;21E)	(67-84)	-7.9	7.5	0	0	-1.7	1.3
SOFIA	(43N;23E)	(67-74;76-83)	-5.6	4.3	0	0	-1.3	1.3
ATHEN	(38N;24E)	(67-74;76-84)	-3.6	4.9	0.2	-0.1	-0.7	1.4
KIEV	(51N:31E)	(67-84)	-5.4	5	0	0	-1	1.1

Station Names ;Geog.Coord; Data Coverage			SUMMER DELTA foF2 (0.1MHz) MAJOR SOUTHWARD IMF Bz TURNINGS					
			MIN VALUE	MAX	MEDIAN VALUE	MODE	LOWER DECILE	UPPER DECILE
LANNION	(49N;3W)	(71-84)	-8.8	3.9	-0.4	0	-1.9	0.7
SLOUGH	(51N;1W)	(67-84)	-8.3	4.4	-0.4	0	-1.9	0.6
POITIERS	(47N;360W)	(67-84)	-8.4	4.9	-0.3	0	-1.8	0.7
GARCHY	(47 N;3E)	(69-73)	-3.1	3	-0.4	0	-1.5	0.5
DOURBES	(50N:5E)	(67-84)	-8.3	4.2	-0.4	0	-1.9	0.6
ROME	(42N;13E)	(67-72;76-84)	-6.9	3.5	-0.3	0	-1.9	0.8
JULIUSRUD	(55;13)	(74-84)	-7.8	3.4	-0.4	0	-2	0.6
GIBILMANNA	(38N;14E)	(76-80;83-91)	-3.2	3.9	-0.1	-0.9	-1.5	1.7
PRUHONICE	(50N;15E)	(67-68;76;84)	-6.2	3.1	-0.4	0	-2	0.7
UPPSALA	(60N;18E)	(67-84)	-7.2	2.9	-0.4	0	-2.1	0.6
KALININGRAD	(55N;21E)	(67-84)	-7.2	3.7	-0.4	0	-2	0.6
MIEDZESYN	(52N;21E)	(67-84)	-6.7	2.9	-0.4	0	-2.3	0.7
SOFIA	(43N;23E)	(67-74;76-83)	-7.5	4.2	-0.4	-0.1	-2.1	0.9
ATHEN	(38N;24E)	(67-74;76-84)	-4.5	3.8	-0.2	0	-1.4	0.9
KIEW	(51N;31E)	(67-84)	-3.3	2.3	-0.1	0	-1.3	0.7

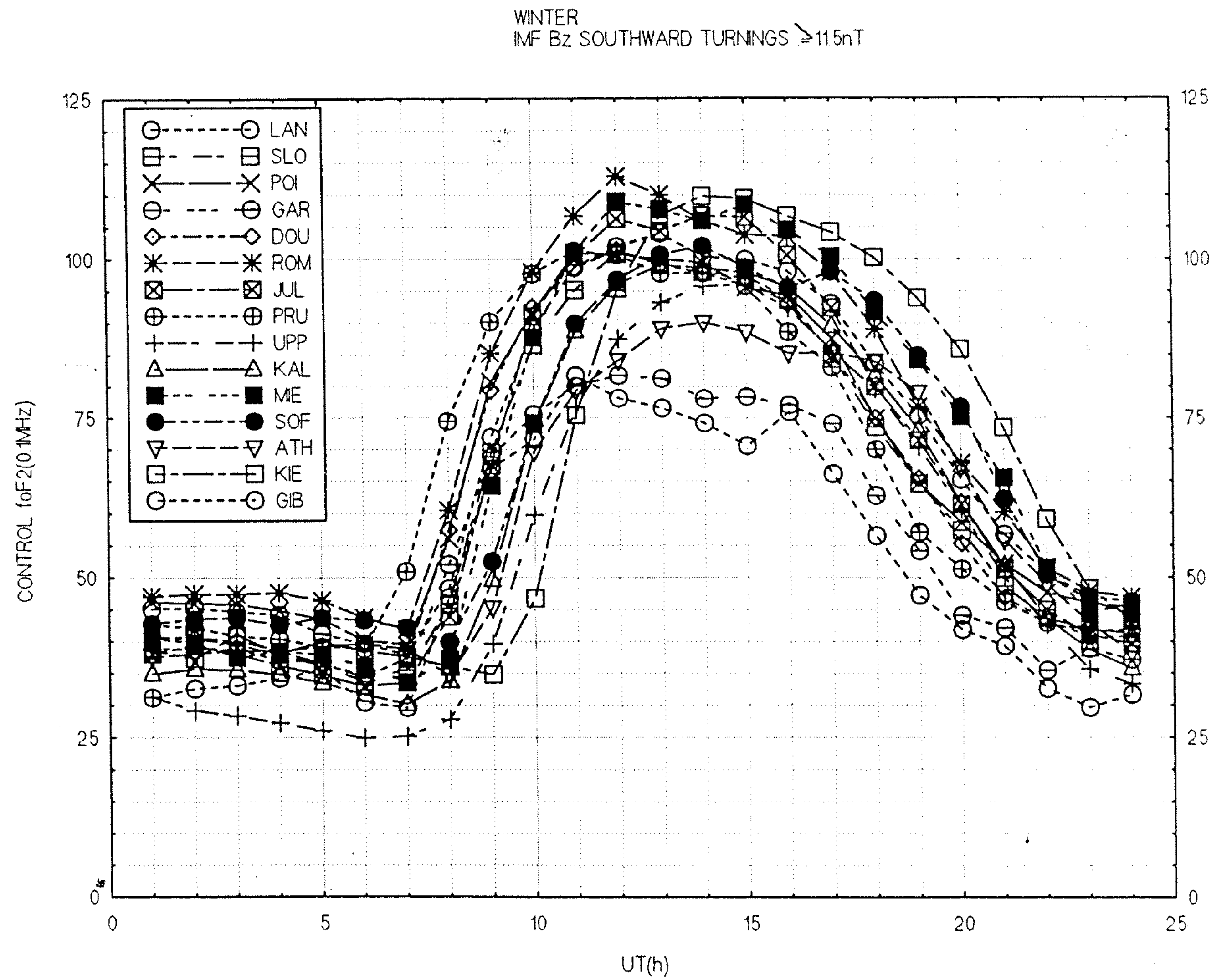
TABLE 1 (a, b, c) Some Statistical Results

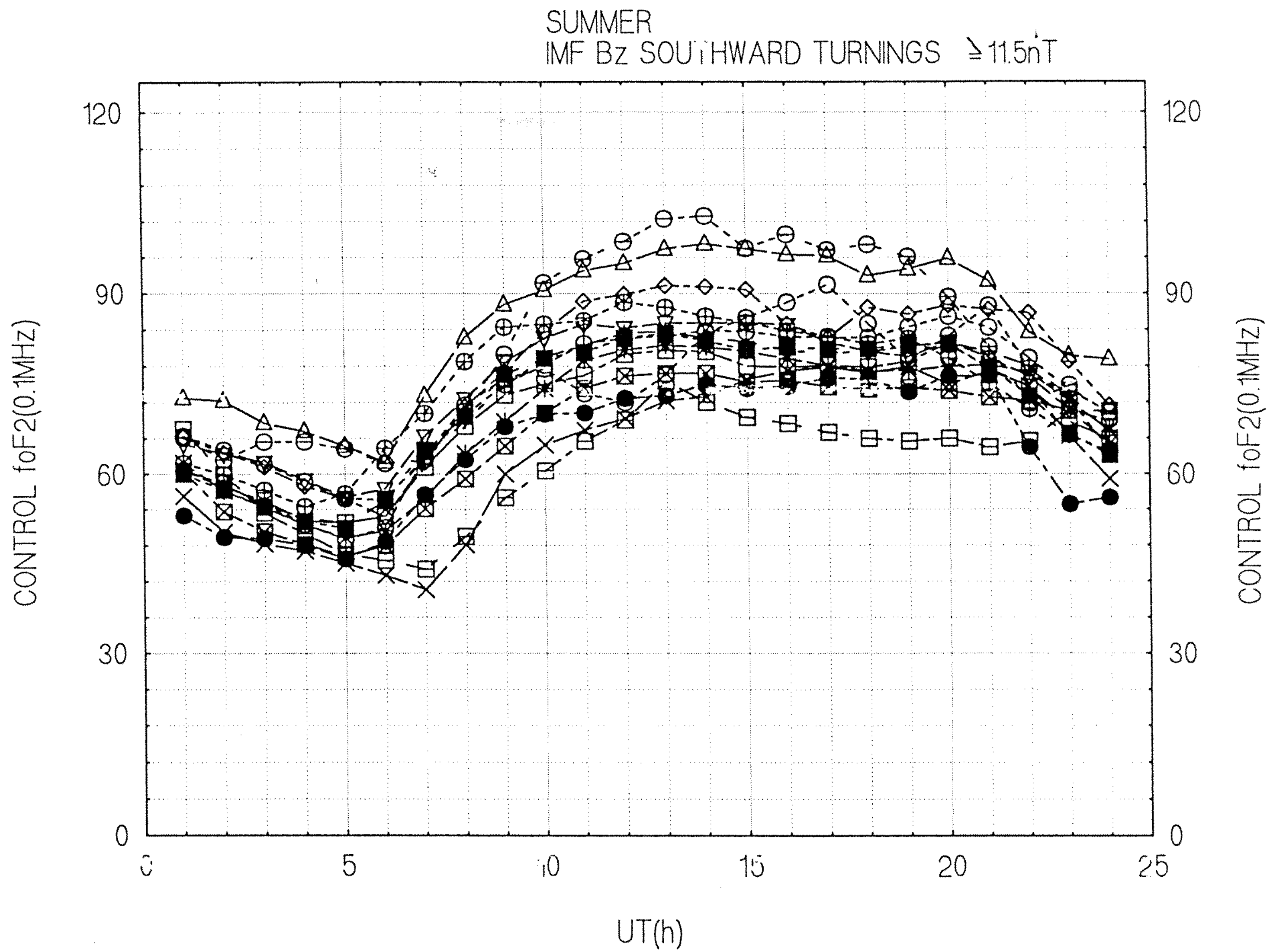

SLOUGH
IMF Bz SOUTHWARD TURNINGS>≥11.5nT
WINS
SUMS
OUTS
CONTROL fof2(0.1MHz)
110
90
70
50
30
0
5
10
15
20
25
UT(h)



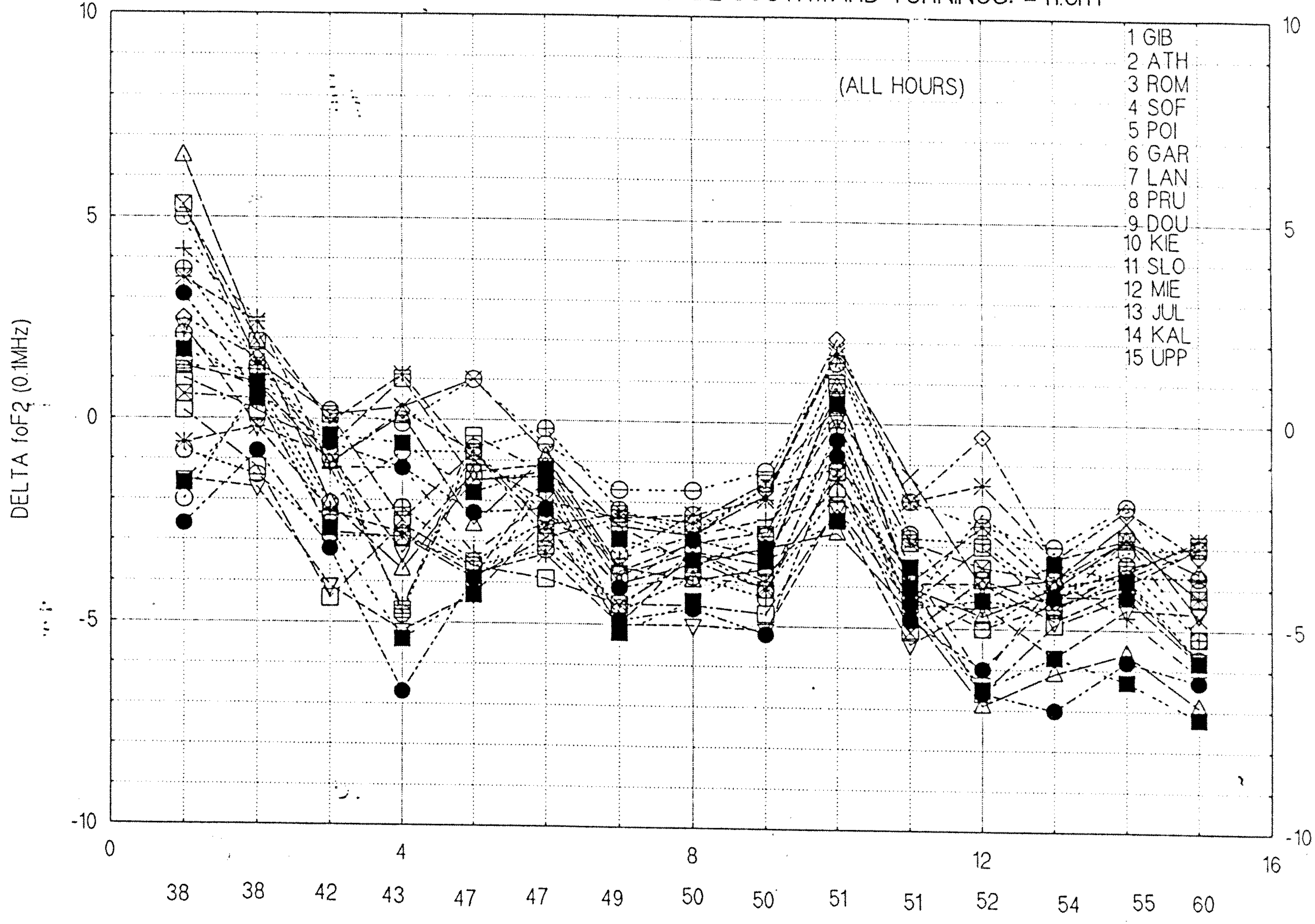
ANNUAL
IMF Bz SOUTHWARD TURNINGS ≥11.5nT
CONTROL foF2(0.1MHz)
UT(h)
0
5
10
15
20
25
0
30
60
90
120

185


WINTER
IMF Bz SOUTHWARD TURNINGS ≥11.5nT
LAN
SLO
POI
GAR
DOU
ROM
JUL
PRU
UPP
KAL
ME
SOF
ATH
KIE
GIB
CONTROL foF2(0.1MHz)
UT(h)
0
5
10
15
20
25
0
25
50
75
100
125

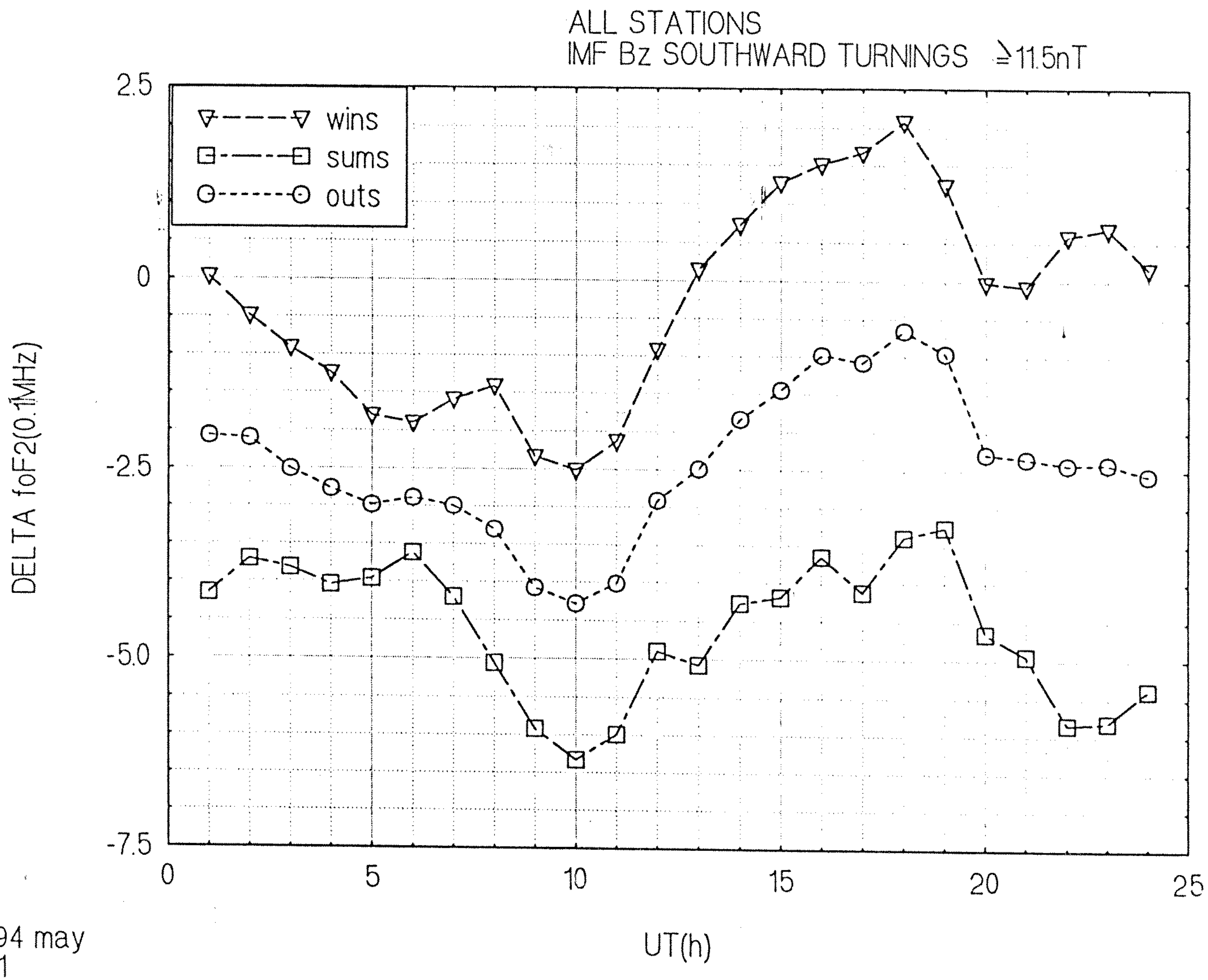

SUMMER
IMF Bz SOUTHWARD TURNINGS ≥11.5nT
CONTROL foF2(0.1MHz)
UT(h)
0
5
10
15
20
25
30
60
90
120

ANNUAL
IMF Bz SOUTHWARD TURNINGS. ≥11.5nT

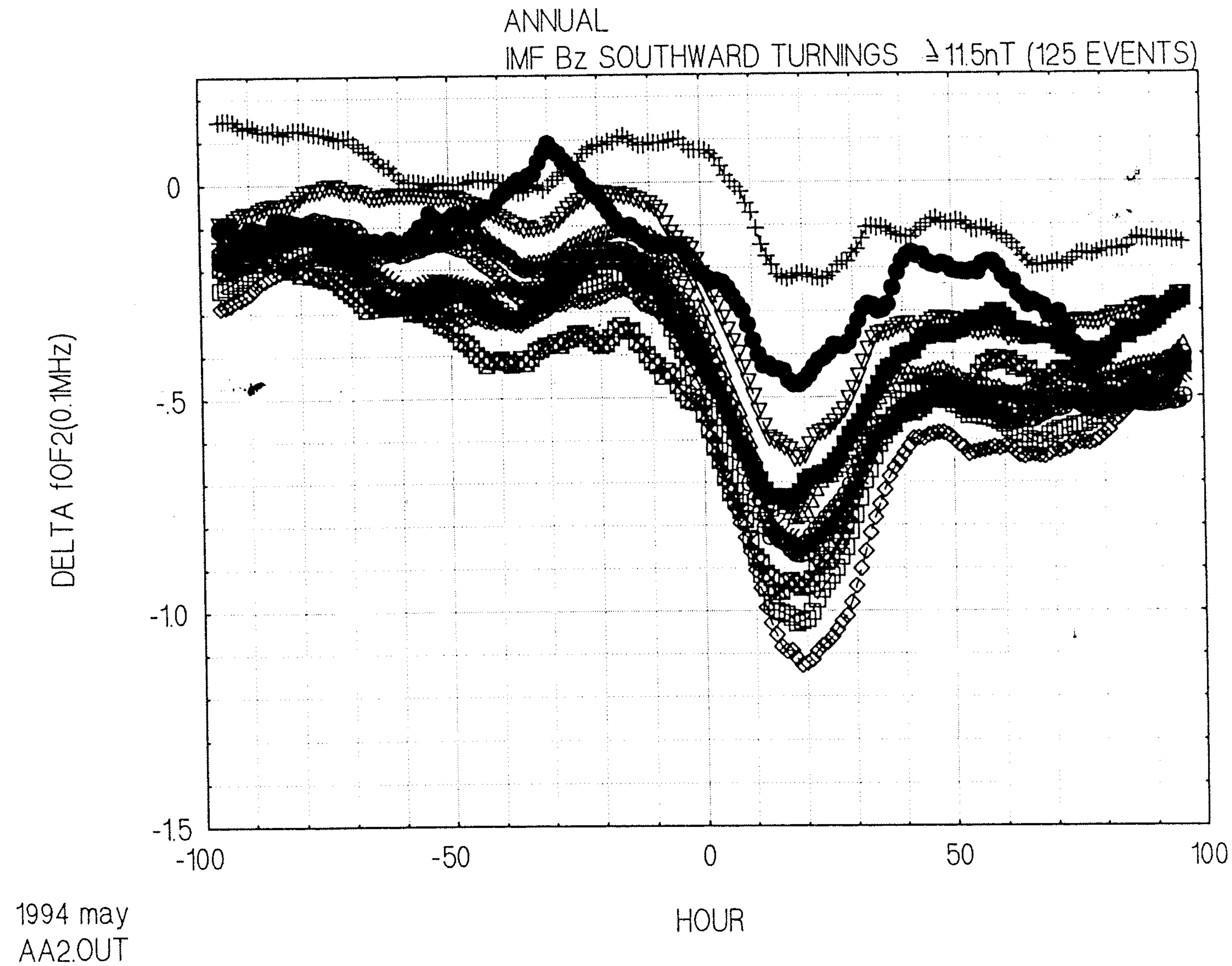


1994 may
OUTS.AVD

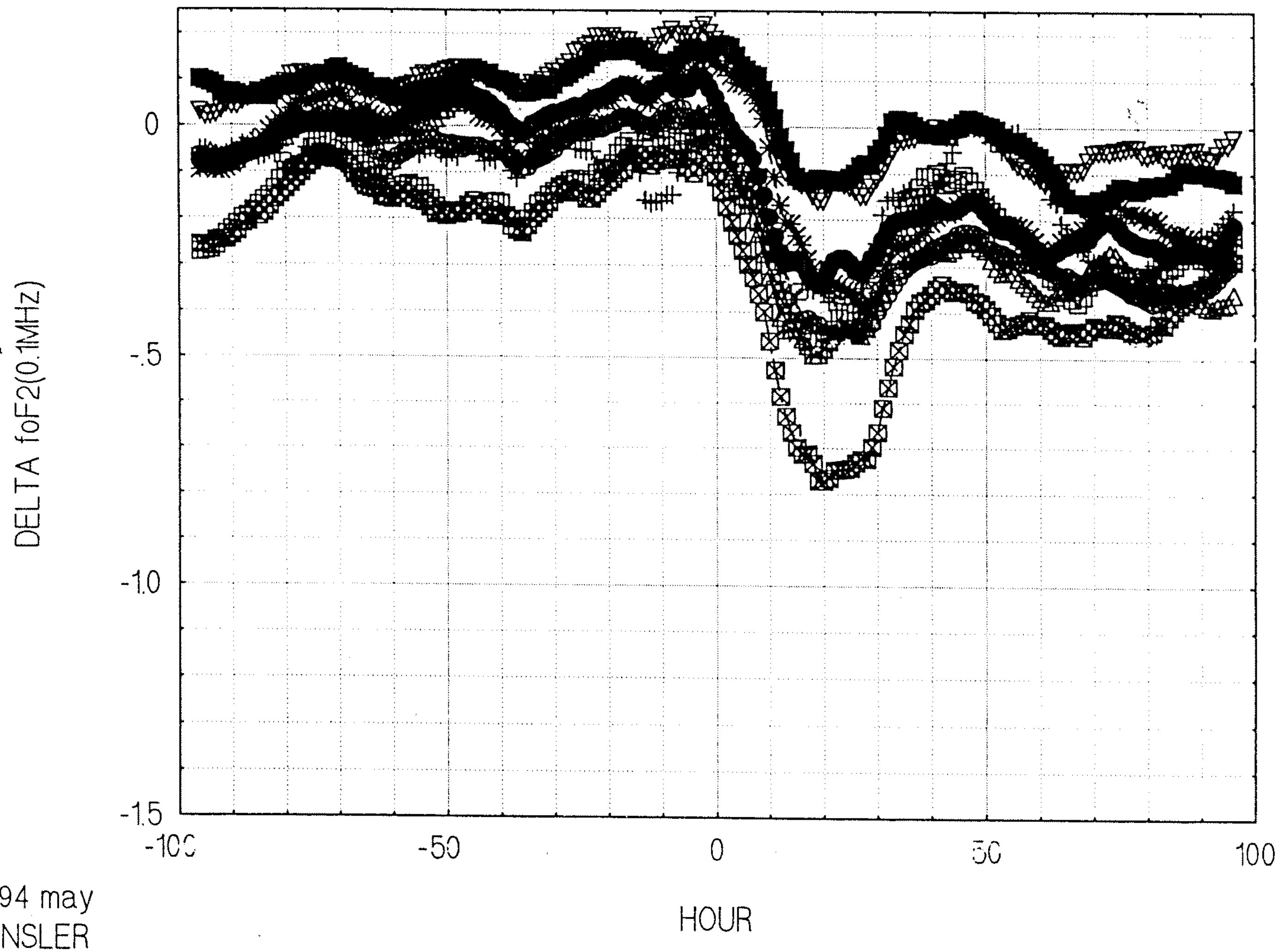
188


ALL STATIONS
IMF Bz SOUTHWARD TURNINGS ≥11.5nT
wins
sums
outs
DELTA foF2(0.1MHz)
UT(h)
2.5
0
-2.5
-5.0
-7.5
0
5
10
15
20
25

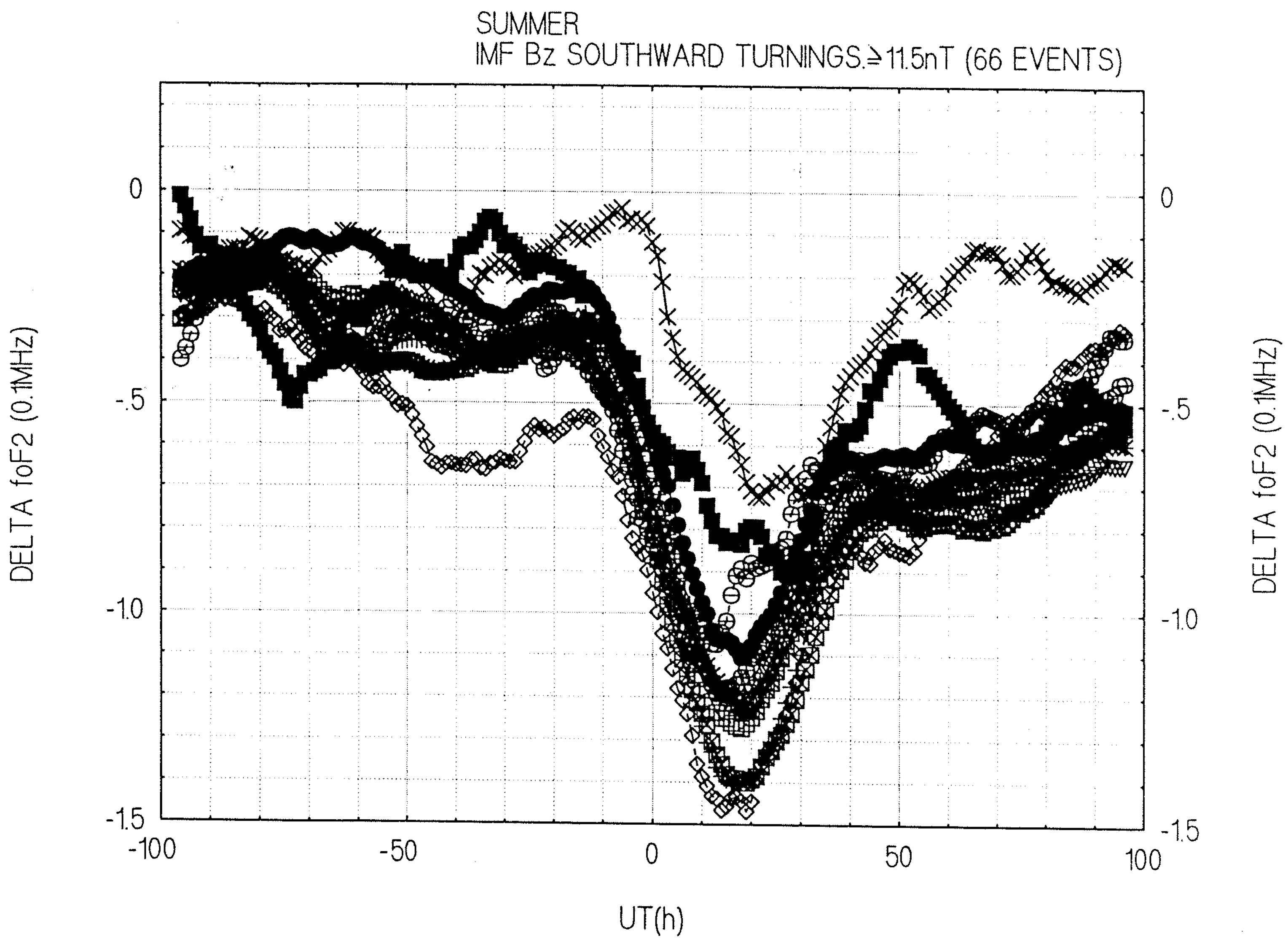
1994 may
A.1


ANNUAL
IMF Bz SOUTHWARD TURNINGS ≥ 11.5nT (125 EVENTS)
DELTA fOF2(0.1MHz)
0
-.5
-1.0
-1.5
-100
-50
0
50
100
HOUR
1994 may
AA2.OUT

WINTER
IMF Bz SOUTHWARD TURNINGS $\geq$11.5nT (59 EVENTS)



1994 may
WINSLER


SUMMER
IMF Bz SOUTHWARD TURNINGS.≥11.5nT (66 EVENTS)
DELTA foF2 (0.1MHz)
0
-.5
-1.0
-1.5
-100
-50
0
50
100
UT(h)

192

To Model the Possible Effects of the IMF on the Mid-Latitude Ionosphere: IV

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The major southward polarity changes in IMF Bz were considered. The possible effects of these events on the ionospheric δfoF2 data obtained at several PRIME stations were investigated in detail for summer and winter (Tulunay, 1994). The figures 5 (a, b, and c) of Tulunay (1994) exhibited that, the superposed epoch analysis of the ionospheric δfoF2, as the IMF Bz southward turnings with $\Delta Bz \geq 11.5nT$ taken as key dates, there had been clear minima in the average δfoF2 during the day after the southward IMF Bz turnings. On the average, the percent peak deviation seemed to be larger in the winter results than those of the summer results with respect to the values obtained before the event. This time , how δfoF2 showed a response around the 0 (zero) hour - that is the Southward turning of the IMF Bz is modeled. To achieve this, a typical response of the δfoF2 to a southward turning is sketched as shown in Figure 1.

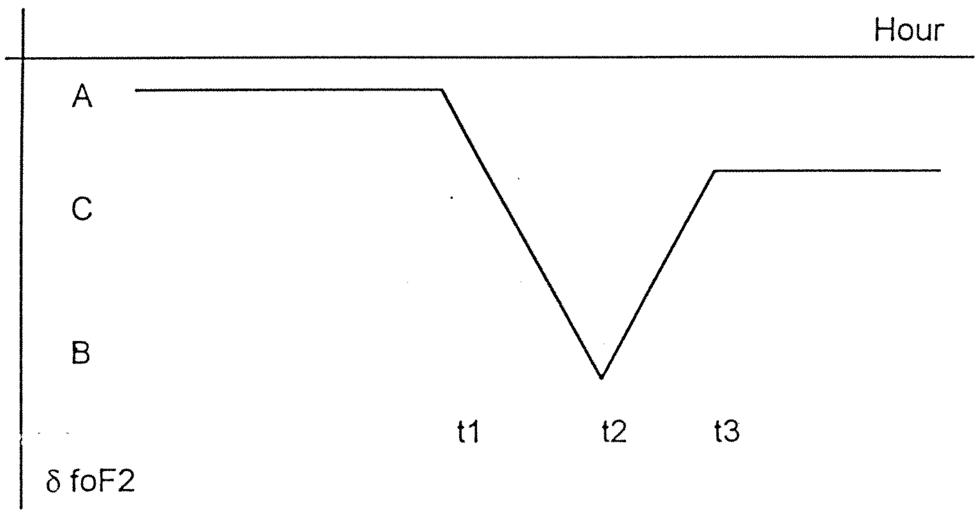

Figure 1 : A typical sketch of the response of the δfoF2 to IMF Bz southward turnings. A: prestorm mean of δfoF2 at t1 hour; B: the minimum δfoF2 achieved due to the IMF turning at t2 hour; C: the post storm mean of δfoF2 at t3 hour.

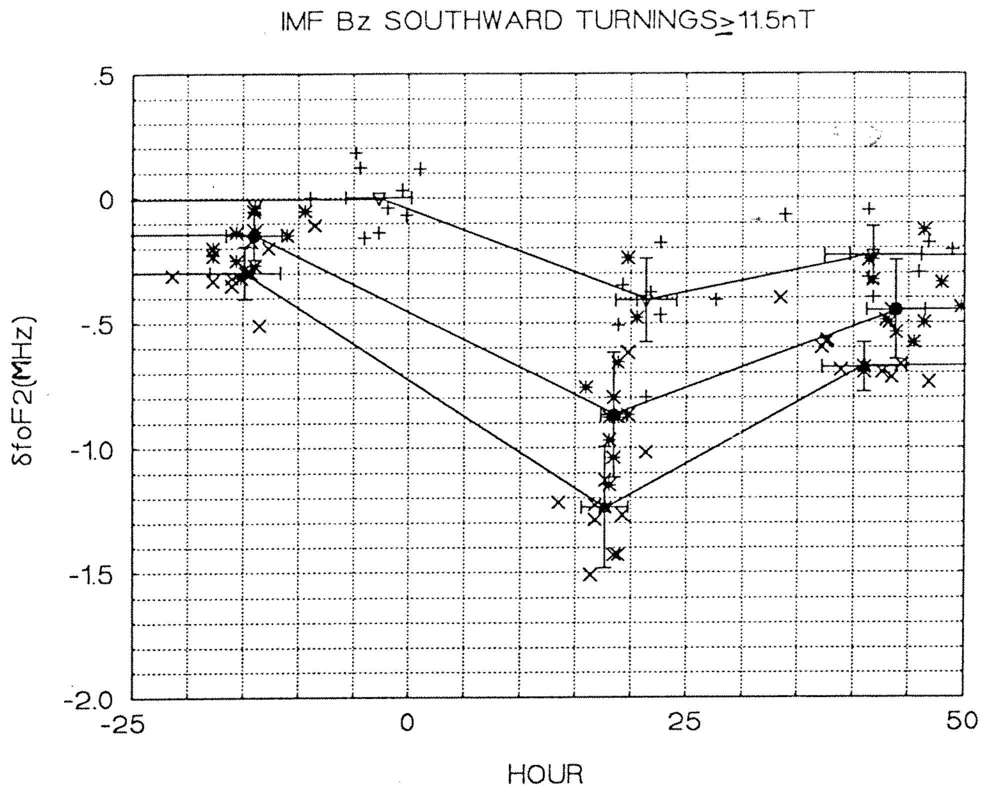

Figure 2 : For 11 PRIME stations the response of the IMF Bz southward turnings and the superimposed are the models constructed by using the appropriate median values.

for all stations,
+ winter, ∇ median
× summer, Δ median
∗ annual, • median

Figure 2 exhibited the overall response of the δfoF2 values to the IMF Bz southward turnings. The results of the superposed expoch analysis (SPE) are grouped into winter and summer. The data input to whole exercise was from the ionosonde measurements at Lannion, Slough, Poitiers, Dourbes, Rome, Juliusrud, Pruhonice, Uppsala, Kalingrad, Miedzeszyn, Kiev between 1963 and 1986. Some of the winter data at some stations were extremely noisy therefore, their SPE analysis did not reveal a clear cut , nice shape as sketched in Figure 1. Therefore, there appeared only 9 stations to consider for the case of winter cases. Then , the δfoF2 values corresponding to A, B, C are considered for each season. The median value of such each group was marked with error bars on. In its simplest form, the model representing the response of the δfoF2 values to the IMF Bz turnings was obtained by joining straight lines between A and B; B and C for each season. Results revealed that the slope in ΔδfoF2 versus Δ hour is greater for the summer results than that of the winter ones. It is also interesting to note that δfoF2 values start to decrease earlier than those of the winter ones and before the zero hour. The findings are summarized in Tables 1, 2, and 3. In these tables the seasonal and the median δfoF2 values and the corresponding time durations after the southward turnings of the IMF Bz for Lannion, Slough, Poitiers, Dourbes, Rome, Juliusrud, Pruhonice, Uppsala, Kalingrad, Miedzeszyn, Kiev between 1963 and 1986 are exhibited in several forms.

Table 1: The differences between A-B and B-C values of the δfoF2.

	Median Annual	Median Winter	Median Summer
Δ(δfoF2) A-B (MHz) (the storm effect)	0.72	0.41	0.94
Δ(δfoF2) B-C (MHz) (the recovery)	0.42	0.18	0.56

Table 2: The differences between t1-t2 (Δt1) and t2-t3 (Δt2) values of the δfoF2.

	Median Annual	Median Winter	Median Summer
Δt1 (h)	32.5	24.1	32.5
Δt2 (h)	25.4	20.4	23.3

Table 3: The slope in ΔδfoF2 versus Δ hour.

Slopes	Median Annual	Median Winter	Median Summer
Slope of A-B (the storm effect) (deg)	12.5°	9.7°	32.5°
Slope of B-C (the recovery) (deg)	9.4°	5°	23.3°

Reference

Tulunay, Y., Interplanetary magnetic field (IMF) and its possible effects on the mid-latitude ionosphere III, Scientific Rep. COST Document COST 238 TD (94) 010, Eindhoven 1994, 137-151.

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30th COSPAR MEETING - HAMBURG

TEMPORAL AND SPATIAL VARIABILITY OF THE IONOSPHERIC foF2 OVER THE HIGH LATITUDE COST 238: PRIME AREA

Yurdanur Tulunay (The METU/ODTÜ, Dept. of Aeronautical Engineering 06531 Ankara, TÜRKİYE)

Since understanding the morphology of the ionosphere is an essential prerequisite for its successful use as a communications medium it is intended to seek further how the ionospheric critical frequencies foF2 exhibits a variability during the interplanetary magnetic field (IMF) Bz turnings, particularly at high latitudes. At a given time-of-year and phase in the solar cycle, the ionosphere exhibits regular, seasonal variations at mid-latitudes as plasma co-rotates with the Earth. In order to study the day-to-day variability of the foF2 about these regular diurnal variations, some form of "quite-time" diurnal variation must be substracted from the variations observed. In order to achieve this, for each hourly value of foF2 all quite time soundings with 15 days of the sounding in question were idendified; quite-time values were identified as when the simultaneous magnetic Ap index was less than 6. The mean quite-time value at the same UT was then subtracted from the value actually observed; the resulting value is here termed δfoF2. The same method of analysis has been employed in order to facilitate a simultaneous comparative examination of the PRIME ionosphere with emphasize on high latitudes. This time a larger set of the IMF turnings were used, and the analysis is being extended to several PRIME stations over the European area over 50oN in both geographic and dipole latitudes and bounded between 10o W and 30o E geographically.

Accepted for oral presentation in session C.4
Wednesday, 20 July 1994
in Lecture Room CCH.7.
(30th COSPAR Scientific Assembly and Associated Events, Hamburg, Germany 11- 21 July 1994.

(gidemedim !!)

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YEŞİLYURT-İSTANBUL

Yurdanur Tulunay
ODTÜ Havacılık Mühendisliği Bölümü
06531, Ankara

ÖZET

Çağımızda, sivil ve askeri havacılık haberleşme dizgelerinin eriştikleri düzey, bu dizgelerin tasarımında işletiminde, kullanılan frekansların denetlenmesini, anında düzeltilmesini gerektirmektedir. Havacılıkta haberleşme, radyo dalgalarının yere yakın uzayda yayılmalarıyla doğrudan ilişkilidir. Örneğin, 1. şekilde görülebileceği gibi, kritik frekans verileri (foF2), İstanbul'da oldukça fazla bir değişkenlik (variability) göstermektedir. Bu değişkenlik, gün-be-gün ve günün değişik saatlerinde farklıdır. Bu değişimlerin büyük bir bölümünü önceden kestirmek olası değildir. Bu nedenle, "ortamla" ilgili model çalışmaları sürekli yapılmaktadır. "Modeller"in çağın teknolojik gelişmesiyle durmadan yenilenmesi gerekmektedir. Bu bildiriyle, bu tür bir model çalışması tanıtılacaktır. Şöyleki, gezegenlerarası manyetik alanın (IMF) yön değiştirmelerinin, iyonosfersel kritik frekanslar üzerinde oluşturabileceği olası değişkenlik sergilenecektir. Bu bildiri, yazarın, Türkiye'de yürütücülüğünü yaptığı bir "Avrupa Topluluğu Projesinin - COST 238:PRIME (Prediction Retrospective Ionospheric Modelling Over Europe" - özgün sonuçlarını içermektedir.

ABSTRACT

Using critical frequencies, foF2 from the Lannion, Slough, Poitiers, Garchy, Dourbes, Rome, Juliusrud, Gibilmanna, Pruhonice, Uppsala, Kaliningrad, Miedzeszyn, Sofia, Atheries, Kiev ionosonda stations, the possible effects of the orientation of the IMF on mid-latitude ionosphere are further investigated. This time, the southward

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were considered only. The same method of analysis were employed in order to facilitate a comparison between the recent results presented here with those of appeared in the preceeding papers in the series. That is, the regular diurnal, seasonal and solar cycle variations in the foF2 data were removed by subtracting the mean of the foF2 for the same UT on all magnetically quite days (AP<6) within 15 days around the IMF B_Z turnings [1]. The regular variability which may be observed in the foF2 is illustrated at the foF2 measured at the COST 238 International campaign whose one of the experimental site was the B.Ü. Kandilli Observatory [2]

GİRİŞ

Geniş bir frekans aralığını kaplayan radyo dalgaları (VLF - HF ; ~3 kHz -30 MHz) iyonosfer aracılığıyla çok uzun mesafelere kadar yayılabilirler. F- bölgesi iyonosfersel elektron yoğunluklarında doğal olarak var olan günlük değişimler, HF dalgalarının yayılma karakteristiklerini oldukça fazla etkiler. foF2'nun günlük değişimleri, sürdürülmekte olan bir sürü bilimsel araştırmaya karşın şu anda da önceden kestirilememektedir. Bu, önceden kestirilemeyen değişkenlik, HF radyo dalgalarında çalışan iletişim, radar ve "navigation" dizgelerinin işletim verimini çok fazla sınırlamaktadır.

Bu bildirinin amacı, gezegenlerarası manyetik alanın (IMF) Bz bileşeninin, Bz, güneye döndüğünde (IMF southward turning), orta enlem iyonosfersel kritik frekansları (foF2) üzerinde yaratacağı olası etkiyi sergilemektedir. Güneş rüzgarından yer manyetosferine enerji, kütle ve momentum aktarılmasında en etkin bilinen mekanizma; güney doğrultusundaki IMF Bz ile kuzeye doğru olan yer manyetik alanının birleşmesidir. Bu nedenle, yalnız Bz bileşenindeki dönme ile ilgilenilmektedir.

IMF verileri, ABD "NSSDC"dan, foF2 verileriyse COST 238:PRIME veri bankasından alınmıştır. Veri çözümlemesi 1967 ve 1984 yılları arasındaki dönemi kapsamıştır.

Güneş ... merkezli dönerken, iyonosfer, günlük düzgün değişmeler sergilemektedir. İyonosfersel yoğunlukların bu, düzgün günlük değişmeler etrafındaki gün-be-gün değişkenliklerini incelemek için bir tür "sakin-zaman" (denetim-"control") değerinin, gözlenen değişimlerden çıkarılması düşünülmüştür. Bunun için, IMF Bz'nin güneye döndüğü tarih etrafındaki 15 günlük sürede, aynı tarihe ait manyetik Ap indisinin 6'dan daha küçük olduğu tarihlere karşılık gelen foF2 verileri dikkate alındı. Bu tür hazırlanan tüm "denetim" (control) foF2 verilerinin ortalama değerleri, o an için gözlenmiş olan foF2 verisinden çıkarıldı. Bu şekilde elde edilen ve periyodik günlük değişkenliği taşımadığı varsayılan değer δfoF2 olarak tanımlandı.

Şekil 2 tipik bir örneği sergilemektedir. Bu şekilde görülebileceği gibi, "control" foF2 verilerinin, Slough, iyonosfer istasyonunda mevsimlere göre değişimi mevsimsel anormalliği göstermektedir. Şöyleki, gündüz saatlerinde kış verileri (∇, ve wins) yaz (□ ve, sums) ve ortalama (o, outs) kritik frekans değerlerinden büyüktür. Diğer saatlerde beklenen değişim vardır. Şöyleki, en küçük frekanslar kışın erken ve geç saatlerde gözlenmiştir.

Şekil 3 (a-c), IMF Bz güneye döndüğünde, bu tarihler-"IMF southward turnings" verileri-anahtar veri olarak alınırsa, bu dönmelerin δfoF2 verisi üzerindeki olası etkilerinin ne olacağını sergilemektedir. Bu etki "superposed epoch analysis" yöntemiyle araştırılmıştır. IMF Bz'nin güneye dönmesi olarak tanınan bir olay sırasında, herhangi bir olayın anahtar veri olabilmesi için, $|\Delta Bz| \geq 2nT$ ve dönmenin bir saat içinde olması ölçütlerine uyulmuştur. Şekil 3(a) yılın tüm sonuçlarını, 3(b) kış verisi sonuçlarını 3(c) ise aynı çözümlemenin yaz verisi için olan sonuçlarını içermektedir. Her şekilde, x eksenindeki 0 saat, IMF Bz bileşeninin güneye döndüğü saati göstermektedir. y ekseni ise ortalama δfoF2 değerlerini vermektedir. Tüm şekillerde ortalama δfoF2 değerleri, IMF Bz'nin güneye dönmesinden sonraki gün en küçük değere ulaşmaktadır.

Bu en küçük değerler:

Kış (winter) verisinde -0.6 *MHz*

Yaz (summer) verisinde -1.22 *MHz*

Böyle bir çözümlemede anahtar verisinin simgelediği olaydan önce beklenen, δfoF2 değerlerinin sıfır olmasıydı. Şekil 3 (a, b, c)'de gözlenen durum, IMF Bz dönmesinden önce birçok "manyetik-sakin" olmayan günün olduğunu düşündürtmektedir.

IMF Bz'nin dönmesiyle ilişkilendirilebilecek olan δfoF2'nun yaklaşık doruk değişimi, böylece,

Yıllık (annual) veride -0.57 *MHz*

Kış (winter) verisinde -0.51 *MHz*

Yaz (summer) verisinde -1.93 *MHz*

olarak saptanabilir. Ortalamada, anahtar veriyi oluşturan olaydan önce gözlenen δfoF2 değerlerine göre doruk değişim % olarak ifade edilirse, ortalamada en büyük değişikliğin kış verisinde olduğu ortaya çıkacaktır. Tulunay (1994) [3]'de foF2, kritik frekanslarının ortalamada, 0.1 MHz ile 17.0 MHz arasında değiştiğini göstermiştir. foF2 değerlerinin bu ölçüde değişebilmesi, beklenen günlük, mevsimsel, yıllık periyodik değişimlerle birlikte, diğer nedenlerden kaynaklanan ve "gün-be-gün değişikliği" olarak tanımlanan değişikliklerdir. Bu çalışmayla, IMF Bz'nin güneye dönmesinin, tek başına, 0.51 MHz ile 1.93 MHz arasında bir değişme oluşturabileceği gösterilmiş oldu. Ayrıca, bu tür bir değişiklik mevsime de bağımlılık göstermektedir.

SONUÇ

Çeşitli, COST 238: PRIME istasyonlarında ölçülmüş olan foF2 kritik frekans verilerinin incelenmesi, iyonosferin "gün-be-gün" değişiminde IMF Bz'nin güneye dönmesinin de katkısı olacağını ve bu katkının kış mevsiminde daha fazla olduğunu ortaya çıkarmıştır.

TEŞEKKÜR: Bu çalışma TUBİTAK ve COST 238 projesi tarafından desteklenmiştir. Yazar, veri çözümlemesinde katkısı olan Y.Gülbahar Yiğit'e, çizimleri oluşturan Ş.Baykal'a ve bilgisayarda bildiriyi yazan G. Cangül'e özellikle teşekkür eder.

KAYNAKLAR

[1] Tulunay, Y., Interplanetary Magnetic Field (IMF) and Its Possible Effects on the Mid-Latitude Ionosphere: III, COST 238/ PRIME Workshop on Numerical Mapping and Modelling and Their Applications to PRIME (16 - 18 / 5 / 1994) Eindhoven, Netherlands.

[2] Tulunay, Y., Özgüç, A., Ataç, T., Altaş, L., Barlas, O., The Preliminary Results From The Kandilli foF2 Data in 1993, COST 238: PRIME WG:3 REPORT, 1994 March, Warsaw.

[3] Tulunay, Y., Interplanetary Magnetic Field and Its Possible Effects on The Mid-Latitude Ionosphere: II, 1994. Annali Di Geofisica (basım aşamasında)

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4 May, 1994

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Dear Dr Tulunay

International Beacon Satellite Symposium 1994

Thank you very much for submitting the abstract of the following paper for the Beacon Satellite Symposium.

Temporal and Spatial Variability of the Ionospheric foF2 Over the COST 238: Prime Area

Y K Tulunay

On behalf of the Programme Committee I am pleased to announce acceptance of your paper for presentation.

The response to the Call for Papers has been excellent. To accommodate all of the papers in the limited time available it will be necessary to restrict the duration of individual oral presentations to 15 minutes, including questions. It is essential that authors prepare their presentations to ensure that the main points are covered within this time limit.

A full programme will be drawn up, giving a date and time for the paper, once further information about registered participants is known. However, it should be noted that it may be necessary to restrict oral presentation to two papers per participating author, with additional papers being given as posters.

We look forward to seeing you at the Symposium.

Yours sincerely,

L Kersley.

Dr. L. Kersley,
(on behalf of Programme Committee BSS94)

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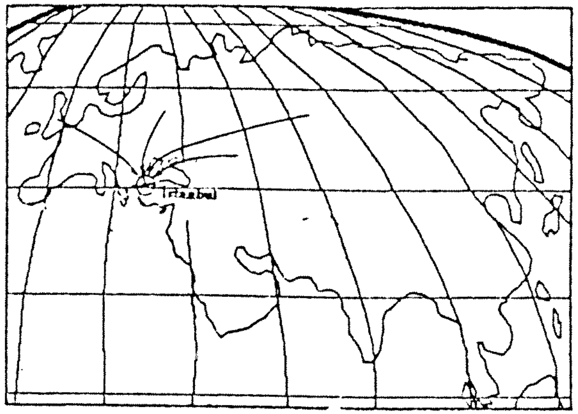

October 25 - 27, 1993

Turkish Scientific and Technical Research Council
Marmara Research Center - Gebze, Kocaeli

SESSION 5A
IONOSPHERE / INSTRUMENTATION
(October 27, 1993 Wednesday)

Chairmen: G.F. Tulinov, O.Palamutçuoğlu
Presentations:

14.00 - 14.20 **"Solar Energy and Its Interaction With Earth's Atmosphere: Some Results of Interplanetary Magnetic Field and Its Possible Effects on the Mid-Lattitude Ionosphere"**
Y. Tulunay
Middle East Technical University, Turkey

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Solar Energy and Its Interaction with Earth's Atmosphere: Some Results of Interplanetary Magnetic Field and Its Possible Effects on the Mid-Latitude Ionosphere

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Received 14.1.1994

Abstract

The Sun is responsible for many of the phenomena on Earth, including the maintenance of life. In addition, magnetic storms capable of disrupting radio communication and auroral displays are associated with solar events. Man-made electrical, satellite, and communication systems are affected strongly by the near-Earth space environments. The purpose of this paper is to review briefly the interaction of solar activity with the near-Earth environment. These processes can be studied by examining two sets of interactions. That is the interaction of the solar electromagnetic output with the Earth's neutral atmosphere, and the solar corpuscular output with the geomagnetic field. In order to understand the types of interactions, one needs to know more details of the interacting components. Therefore, the near-Earth environments which comprise neutral atmospheric, ionospheric and magnetospheric regions will be discussed in relation to the direct and indirect influences of solar activity.

1. Introduction

Since the beginning of this century there has evolved a picture of two separate types of solar energy; one is the electromagnetic energy which is almost constant and photoionize the Earth's upper atmosphere over the whole dayside of the Earth; whereas, the other is the corpuscular energy which is emitted from the sun and interacts with the Earth via the geomagnetic field by day and night, but only around the high latitudes does it produce the aurorae. The corpuscular radiation contains energetic particles, solar wind plasma etc... In order to understand the interaction of solar activity with the near-Earth environment, one needs to know more about the interacting components. Figure 1

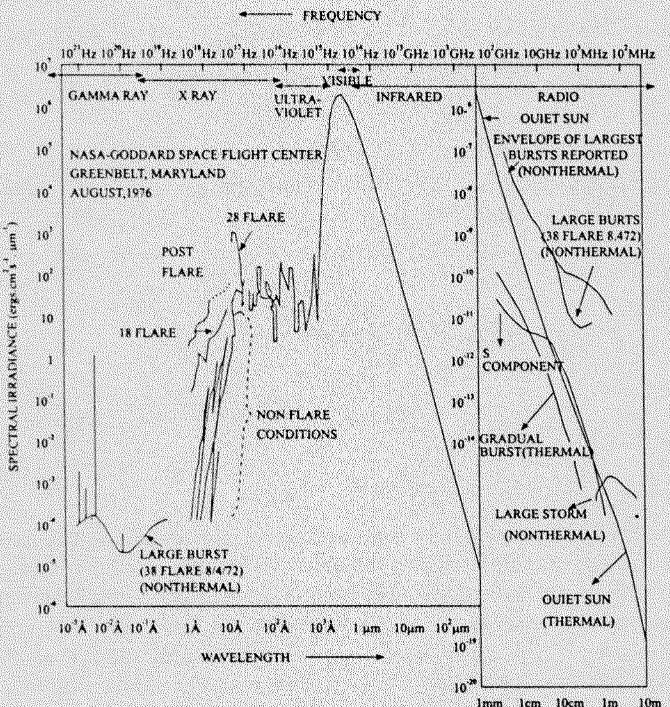

Figure 1. Spectral distribution of solar electromagnetic radiation (or energy) (from [1])

shows the spectral distribution of solar energy. It covers the frequencies and wavelengths between 1020 Hz, or $10^{-3} \mathring{A}$, and hundreds of MHz or tens of meters. A total of 70 % of the solar energy lies between near ultraviolet, visible, and near infrared, corresponding wavelengths of 0.32 μ m to 1 μm. Another 2 % of the solar energy appears at ultraviolet and X-ray wavelenths shorter than 0. 32 μm. The remainder of the solar energy appears at infrared and radio wavelengths longer than 1.0 μ. The solar energy corresponding to wavelengths shorter than 0.32 μm is strongly absorbed in the upper atmoshere where it drives several important photochemical reactions including ozone production. Much of the energy corresponding to wavelengths longer than 0.32 μm is strongly absorbed by atmospheric water vapor and carbon dioxide and thus contributes to the energy budget

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of the lower atmosphere. The height to which solar radiation with different wavelengths penetrates before being attenuated by a factor (exp)-1 is illustrated in Figure 2. It is evident that at altitudes greater than about 100 km, most of the energetic radiation is absorbed, resulting in photoionization to form atomic oxygen. The neutral temperature increases up to 1500K or 2000K depending on the solar cycle. Between about 50 km and 100 km there is little radiation absorbed. At altitudes less than 50 km, very little energetic solar radiation can be absorbed and the ozone formation is the most important event at those altitudes. The layer warms up at around 50 km altitude. The next figure (Figure 3) represents a more complete picture of the different sources which contribute to the ionization of the upper atmosphere [2]. At higher altitudes (> 200 km) where molecular species become less and less in number concentration, photochemical reactions become less probable. For example, diffusion of plasma, electromagnetic drifts, neutral winds, etc. can be named as the major transport processes. At altitudes where photoionization competes with transport phenomena there forms a peak in ionization between 200-450 km altitude.

Figure 4 is the height profile of electron density at the ionosphere. The ionosphere is the region of the Earth's atmosphere where the propagation of radio waves can be affected by the presence of free electrons. The ionosphere can be viewed as a variable shell of plasma surrounding the Earth's [2]. To facilitate a comparison, the neutral gas profile is also illustrated by a dashed line in Figure 4. Below the main peak there often appear density maxima, sometimes distinct enough to form secondary peaks. Historically, the earliest radar measurements detected reflections from around 100 km.

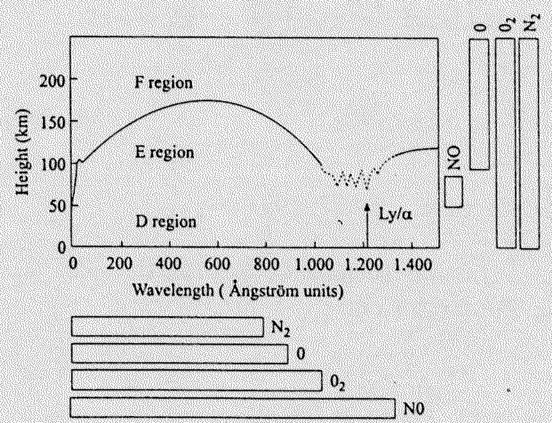


Figure 2. Altitude at which the intensity of solar radiation drops to 1/exp of its value outside the Earth's Atmosphere, for vertical incidence (from [3])

The ionosphere at this height was named the "E Layer" (E for electric). For alphabetical continuity, the ionosphere around the main peak higher up was named the "F Layer". Since a secondary "bump" in the profile sometimes appears in the lower part of the Flayer, this layer is sometimes divided into an "F_1 layer" (the lower "bump"), and an "F_2 layer" (the main peak). Equivalently, we speak of F, F_1 and F_2 "regions" rather than "layers". Below the E region is a highly variable region of lesser electron density called the D region, around 60 to 90 km in altitude. The electron density in all of these regions varies with time of day, altitude, season, strength of solar ionizing radiation, and level of magnetospheric activety. Typical electron densities (or plasma densities) in the ionosphere range from 10^3 to 10^6 cm^{-3} (as compared with neutral gas densities at about 10^7 to 10^{16} cm^{-3}). The ionosphere extends into the protonosphere where the major constituent is the singly ionized hydrogen atoms, H^+. Figures 5 shows how the electron density, Ne, total ion density Ni, H^+ and 0^+ vary in invariant magnetic latitude at two particular altitudes of two satellites, 0G0-4 and Ariel 3. In this figure, the transition between 0^+ (reflecting Ne) and H^+ is also well illustrated [4].

Radio waves are refracted or reflected by the ionospheric plasma. Of particular importance is the peak density of the ionospheric plasma. The largest frequency of a radio wave in which the F-layer reflects back to a vertical incidence sounder is called the "critical frequency". The critical frequency, f_c, is related to the F-region peak, electron density, and N max by

$$fc = 9.0\sqrt{N}\max(electr./m^3).$$

Radio waves of sufficiently high frequency, greater than fc, can pass trough the ionosphere. A vertically transmitted radio wave with a frequency below fc will normally be reflected by the ionosphere. Because of the reflective properties of the ionosphere, radio waves from very low frequency (VLF) to high frequency (HF) (broadly 3 kHz to 30 MHz) can be propagated to great distances. Figure 6 shows vertical profiles of electron density and how radio wave propagation is influenced by the ionosphere. As illustrated in Figure 6, at radio wave propagation is influenced by the ionospher. As illustrated in Figure 6, at sufficiently low radio frequencies, the ionosphere can be used for long-distance communication. In the short-wave band, signals are reflected from the F region or from the dayside E region, while at lower frequencies they are reflected from the D or lower E regions. Waves are partly absorbed by the ionosphere as the vibrated electrons collide with air molecules. Because air is most dense at the lower ionosphere, wave absorption in the D region can be particularly important especially when the electron density increases sharply during solar flares or solar cosmic ray events. In addition to sporadic absorption ionospheric radio proopagation is also degraded by fading and interference caused by temporal and spatial ionospheric variations. Higher- frequency satellite communications overcome most of these problems since they are little affected by ionospheric refraction and absorption, but they nonetheless are subject to signal distortion and modulation due to small- scale ionospheric irregularities [2].

The sun is also the source of the solar wind and energetic particles. The solar wind is a "wind", not a static phenomena. In simple terms, it is the extension of the solar atmosphere into the interplanletary medium. It is electrically highly conducting and a low density (5-10 particles/ cm^3), low energy (10-200 eV) plasma. The solar wind mainly consists of protons, H^+, and electrons with speeds between 250 km/s to 2000 km/s. Near the orbit of Earth, its average density is about 8 ion-electron pairs per cubic centimeter. The dynamic pressure of the solar wind is greater than its magnetic pressure. Therefore, one may envisage that as the solar wind plasma is being ejected from the solar atmosphere, it also imprisons the solar magnetic field and thus the solar wind introduces the interplanetary magnetic field in the interplanetary space. Depending on where it originates on the sun, the solar wind can be a "fast"-"quasi stationary" wind or it can be a "slow", - "transient" wind.

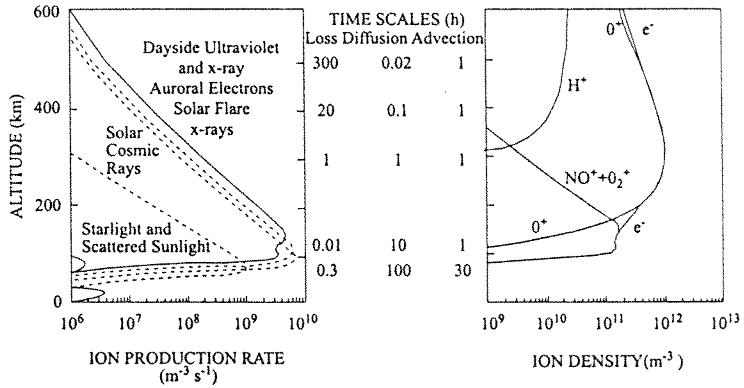


Figure 3. (Left) Different sources contribute to the ionization of the Upper Atmosphere. Solid lines show regular sources. During the day, Direct Solar Extreme Ultraviolet (EUV) light is the main ionization source. At night, EUV scattered from the Geocorona as well as that from stars helps maintain the E-region ionosphere. Other sources are highly variable in time, and are shown with dashed lines: Solar Flare X- rays and EUV (day-side only) and Auroral Electrons and Solar Cosmic Rays (high latitudes only). (Middle) The table of representative time scales for different physical processes effecting the daytime ionosphere shows the relative importance of these processes at various altitudes. The smaller the time scale, the more rapidly that process acts. The shortest time scale at a given altitude therefore points to the dominant process. For example, in the E region ions are lost rapidly so they are influenced little by diffusion and wind transport. In the upper ionosphere, ions diffuse rapidly and tend to approach a state of hydrostatic equilibrium with density falling exponential with altitude. (Right), The height profiles of ion and electron densities are a result of the various processes affecting the ionosphere: production, charge exchange, loss, diffusion, and transport. 0^+ ions are dominant in the F

region, while NO^+ and O_{2+} are dominant in the E region. At very high altitudes, H^+ ions (i.e., protons) eventually dominate [2]

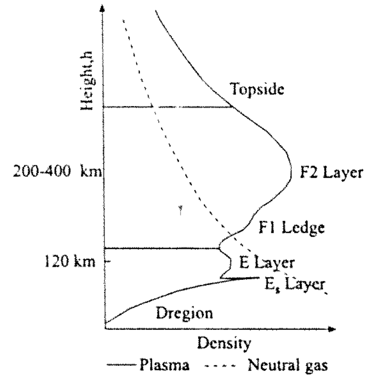


Figure 4. A typical ionospheric electron density height distribution (vertical profile). Different altitude regions of the ionosphere are labeled D,E,F1 and F2. (Diagram: Rutherford Appleton Laboratory)

The fast solar wind originates from the solar coronal holes. From coronal holes single polarity, weak solar magnetic fields open out into the inteplanetary space. The boundary between outgoing field and incoming field is called sector boundary [5]. On the other hand, the slow solar wind originates from the more active regions of the Sun. The slow wind is highly variable [6]. The solar rotational velocity couples with the outward velocity of the solar wind producing the Archimedean spiral pattern in the interplanetary magnetic field (Figure 7); [7]. It is now common knowledge that the key link between the solar atmosphere and the Earth system is the solar wind [8]. Therefore, the solar wind travels in space at supersonic speeds. When the supersonic solar wind encounters an obstacle, a shock wave is produced. Due to the interaction between the interplanetary and geomagnetic fields, the geomagnetic field is pushed into the dayside and swept backwards from the nighside to form a long tail which extends hundreds of Earth radii well beyond lunar orbit [8]. The interaction between the solar wind and the geomagnetic field is maximal when the southward component of the interplanetary magnetic field attracts the northward component of the geomagnetic field [7,9,10]. Such merging forces the solar wind particles into the Earth system [8,11,12]. Thus, as a result of this interaction, the solar wind particles can directly enter, dump their kinetic energy, or trigger the release of different energies which are stored at other places within the magnetosphere. As a consequence, geomagnetic activity may increase. The high latitude ionosphere is strongly linked to the magnetosphere by the geomagnetic field, and the variations that

take place in that region are mainly driven by geomagnetic activity whose origins lie within the magnetosphere. The typical signatures of geomagnietic activity are the geomagnetic storms, visible aurorae, ionospheric disturbances, and others [7].

The shocked solar wind flows around the magnetosphere in the region called the magnetosheath. A small fraction of the solar wind plasma enters the magnetosphere through the polar cusp. Some of this entering plasma forms a boundary layer called the plasma mantle, and some of it drifts to a region of the neutral point where it is accelerated and forms the plasma sheet [11]. It has been estimated that only 1% of the incident solar wind energy flux is ultimately dissipated within the magnetosphere [6].

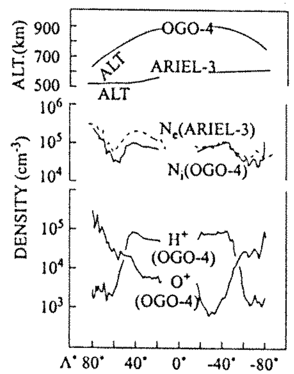


Figure 5. Comparison of ion composition results obtained from 0G0-4 with electron density measurements from Ariel-3, using orbits nearly coincident in local time and season [4]. Sept. 10,1967 -0G0-4 1512-1602UT; ARIEL-3 1357-1441UT

Figure 8 shows a noon-midnight meridian cross section of the magnetosphere and labels its different morphological feautures [11]. The polar cusps are two regions at the interface between the day and night, one north and one south, where the magnetic field lines form a funnel shaped geometry. The solar wind plasma gains entrace to the magnetosphere at the polar cusps. As the solar wind flows downstream to the plasma mantle it is subjected to an ExB drift force which forces it toward a neutral sheet at the mid-plane of the tail where there is no magnetic field since the flowing plasmas carry with them the opposing, frozen-in magnetic fields. The neutral sheet, also called the plasma sheet, is occupied by a current which is made up of ions and electrons.

The magnetic fields on the two sides of this current sheet have opposite directions. The field lines pointing sunward arrive from the north lobe and lines pointing antisunward arrive from the south lobe. A situation of this kind can be unstable and under some circumstances the energy stored in the current sheet can be passed to charged particles.

They can travel along lines of force towards the polar regions of the Earth where they appear as energetic particles. If the energy of the current sheet is passed in the way suggested to energetic particles, the shape of the magnetic field alters. The field lines of opposite direction begin to touch and reconnect across the plasma sheet at about 100 Earth radii downstream from the Earth [13].

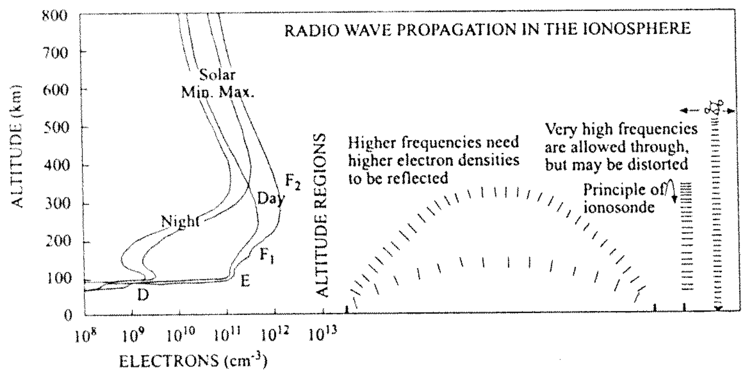


Figure 6. (Left). Typical midlatitude ionospheric electron density profiles for sunspot maximum and minimum, day and night. different altitude regions of the ionosphere are labeled D.E.F1 and F2. (Right). Radio Wave Propagation is influenced by the ionosphere. At frequences below about 30 MHz radio wavelengths longer than 10m waves can be reflected back to Earth. The higher the frequency, the greater the electron density required to reflect the signal. Higher frequencies tend to be reflected from the F region, while lower frequencies are reflected from the E and D regions. Part of the wave energy is absorbed in passing through the ionosphere. Transmissions to and from satellites use much higher frequencies, which are deflected only slightly by the ionosphere. These transmission can nevertheless be distorted by ionospheric irregularities. (from [2], Diagram: Rutherford Appleton Laboratory)

As a result of reconnections, the magnetotail has three types of magnetic field lines. The first consists of the field lines in the lobes. One end of each of these lines is attached to the Earth; the other end extends downstream into the solar wind. Such lines are called open field lines.

The second type is found in the plasma sheet on the earthward side of the magnetic neutral sheet. Here each field line comprises the earthward ends of two lobe field lines that have reconnected. Thus each field line in the plasma sheet on the earthward side of the magnetic neutral line is a loop, both ends of which are attached to the earth. Such lines are called closed field lines.

The third type is found in the plasma sheet downstream from the magnetic neutral

sheet. Here each field line comprises the downstream ends of two of the lobe field lines that have reconnected; thus, they are loops completely free of the Earth. Their ends extend antisunward into interplanetary space. They are known as interplanetary field lines [13,14,15].

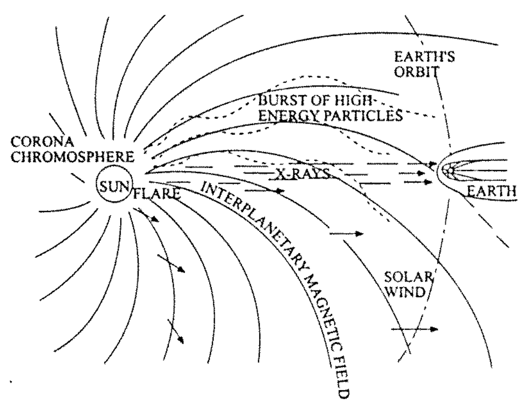


Figure 7. Polar view of interplanetary space in the ecliptic plane, showing the proagation of solar Xrays, solar energetic particles and the solar wind from the Sun to the vicinity of Earth. The sun's rotational velocity coupled with the outward velocity of the solar wind produces the archimedean spiral pattern of the interplanetary magnetic field (From [7]).

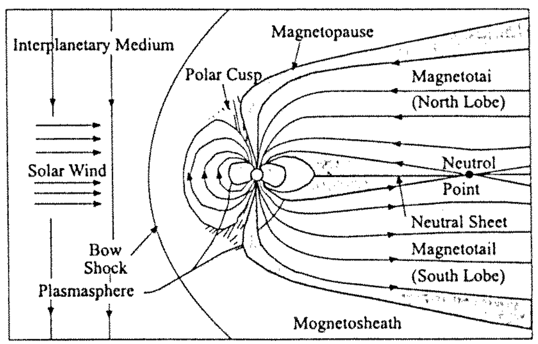


Figure 8. A simplified cross-section of the noon- midnight meridian of the terrestrial magnetosphere showing schematically the interaction of a southward interplanetary magnetic field with the geomagnetic field (from [11])

The magnetic pattern consisting simply of these types of magnetic field lines is disturbed at times when the interaction of the solar wind and the Earth's magnetic field overloads the magnetotail with energy, leading to the phenomenan called a magnetospheric substorm. The substorm is the mechanism by which the magnetosphere intermittently releases large amounts of energy that have been stored in the magnetotail. Some of this energy goes to create the aurorae near the Earth, while the rest is released downstream to the solar wind in the form of a plasmoid. (A substorm which lasts for and hour or so is distinguished from a geomagnetic storm which lasts for a day or more and is caused when a solar flare initiates a shock in the solar wind). A substrom, thus, causes a fourth type of tail magnetic field line which exists only transiently and forms the magnetic structure of a plasmoid [13].

The exact nature of the solar wind-magnetosphere interaction is a difficult problem. Howevery in the models proposed to explain the nature of the interaction, the ambient plasma motion is determined mainly by two electric fields. An electric field due to the rotation of the Earth with its magnetic field and, upon which is superimposed is the convection electic field E directed across the magnetosphere from dawn to dusk. The former field causes the plasma close to the Earth to co-rotate while the dawn-dusk field causes the plasma at greater distances from the Earth to convect towards the magnetopause in the direction of the sun with a convective velocity. The boundary between the region where convection dominates and the region where co-rotation is of major impotance, is the plasmapause. The plasma contained within the plasmapause is in diffusive equilibrium with the ionosphere. Outside the boundary no such equilibrium can be established since the plasma is continously being convected away. A consequence of this is that there is a sharp discontinuty in plasma density as one crosses the plasmapause. Equatorial densities of 100-1000 cm^{-3} can occur within the plasmaphere compared with densities of 0.1-10 cm^{-3} in the outer magnetosphere. Since the rotational flow of the field lines (or plasma) have no radial velocity, while the convective flow has a radial component inward on the night side and outward on the dayside, the flow lines in the combined picture have a minimum geocentric distance at dawn and a maximum geocentric distance at dusk. The ionospheric projection of the plasmapause is the ionospheric electron density trough (see Figure 9, [16])

The convection cycle is completed in about 12-20 hours. Periods of southward interplanetary magnetic field and high solar wind velocities are well correlated with enhancements of magnetospheric convection velocities. The enhanced activity periods result in enhanced fluxes of plasma within the mangetosphere and in enhanced precipitatiton of plasma into the high latitude ionosphere and atmosphere [1].

During geomagnetically quiet conditions, the plasmasphere can extend beyond 5-6 Earth radii. During disturbed conditions due to the enhanced magnetospheric convection, the plasmaphere is eroded considerably. The erosion of the outer plasmasphere during magnetically active peridos can take place within an hour of the onset of enhanced convection, while it can take days for the refilling of the plasmasphere. Thus, the distribution of plasma tends to be quite variable, and the shape of the plasmapause or

trough depends both on the magnitude and time history of geomagnetic activety. Because of infinite conductivity along field lines **ExB**, drifts of flux tubes (or plasma) in the plasmasphere produce changes in the F region of the ionosphere. The convection patterns imposed upon the ionosphere by the coupling of the solar wind to the magnetosphere during periods of northward interplanetary magnetic field are very poorly decribed [12].

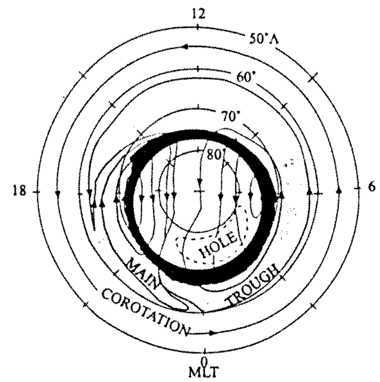


Figure 9. Average locations of the high latitude ionnization "Hole" and the main trough in relation to a representative plasma drift configuration (from [17], see [18] and the quiet-time auoral oval of [19])

Correlations between solar activity and disturbances in the near-Earth magnetosphere, ionosphere, and atmosphere are well documented. Unfortunately, because of the complex and sometimes indirect interactions between the Sun and near-Earth space environment, very few long-term quantitative predictions can be made regarding the effects of an extreme solar maximum on the near-Earth environment or on the complex systems operating in that environment [7,20,21].

The system composed of the Earth's magnetosphere, ionosphere and solar wind responds to a variety of processes on time scales ranging from about $10^{-6}s^{-1}$, the electron gyro-frequency, to $3 \times 10^{8}s^{-1}$, a solar cycle. Feedback between micro-structure of the ionosphere ($< 10km$) and the macro structure of geospace implies that realistic modelling should have very high spatial and temporal resolution on a global scale [12]. Therefore, it is difficult to obtain an exact model which can cope with such a wide range of variation. Currently, the model studies are mainly at the macro-scale state of physical parameters under investigation in terms of temporal and spatial structure. However progress is being made for short- term forecasting of the occurrence of geomagnetic storms based on real-time observations of solar activity, and a number of important qualitative predictions can be made with high confidence [7]; see also [22].

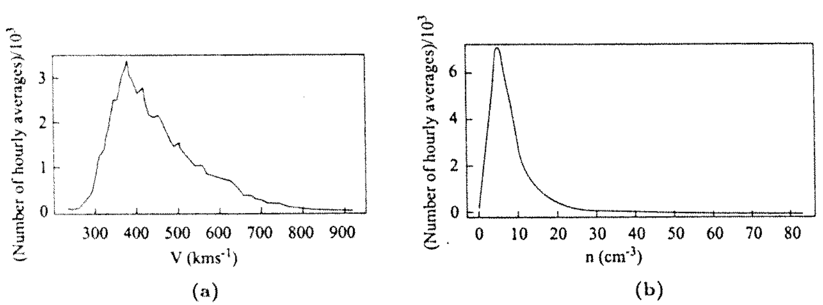
The following section will be composed of some of the findings of a survey based on hourly averages of observations of the interplanetary medium made by satellites at about 1 A. U. in the years 1963-1986, and the possible effects that the inteplanetary magnetic field has on the mid-latitude ionosphere. This section will provide an example of the possible influence of solar activity on the near-Earth space environment directly and also implies, indirectly, some of the expected possible effects of solar activity on systems which operate within that environment.

The Interplanetary Medium at About 1 A.U. and its Possible Influence on the Ionospheric Critical Frequencies

Tulunay [23] and Hapgood et al [24] investigated some of the questions about the variability of both interplanetary magnetic field (IMF) Bz component and the solar wind dynamic pressure using a 24-year sequence of interplanetary observations between 1963 and 1986. Hapgood et al. [24] showed the distribution of the IMF and solar wind values for the whole data set (Figure 10.) The solar cycle variations in out-of-ecliptic component of the IMF and the solar wind are represented in [24], second and third figures (Figure 11 and Figure 12 here). Hapgood et al. [24] concluded that distributions of solar- wind and IMF parameters between 1963 and 1986 are much the same as the corresponding distributions that had been presented from data for all parts of cycle 20 references in [24]). The most notable of the differences they reported between solar-wind density and sunspot numbers as reported previously for cycle 20, is hardly evident at all in cycle 21.

Hapgood et al. [24] quoted Bame et al. [25] in ascribing the increase in the mean and spread of the distrubition of solar-wind speeds in the declining and minimum phase of the solar cycle to increased occurrence of high-speed streams. The solar cycle variation of the averaged magnitude of the IMF-Bz and the the corresponding standard deviations are similar in both solar cycles 20 and 21, and both parameters reflect the larger maximum of the solar cycle 21.

Hapgood et al. [24] investigated the major reversals of the IMF Bz component since these reversals are important events which should cause significant changes in the Earth's



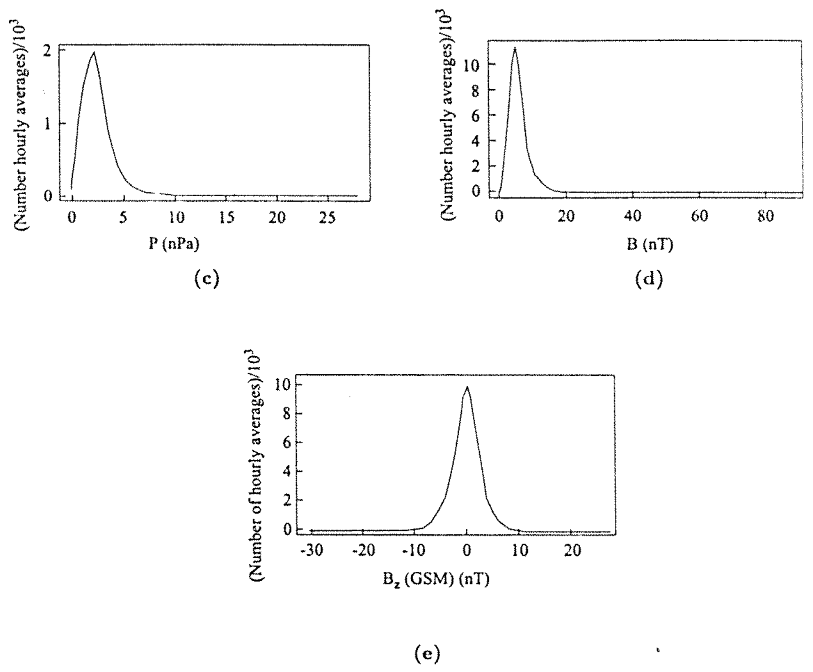


Figure 10. Distributions of IMF and solar-wind values for the complete dataset (a) the solar-wind speed v; (b) the solar- wind density. n: (c) the solar-wind dynamic pressure P; (d) the IMF field strength B; and (e) the northward component of the IMF (GSM coordinate) Bz (From [24])

magnetosphere. They identified "events" as times when there was a reversal of the polarity of Bz between adjacent hourly mean values. As a secondary condition, they required that the magnitude of Bz was greater than 1nT for both hourly values [23]. To estimate the duration of stable IMF conditions, Hapgood et al. [24] determined the interval following each event for which Bz maintained the same polarity (see Figure 4 and 5 in [24]). The distributution of the duration of periods of stable polarity of the IMF-Bz component showed that the Earth's magnetosphere could achieve steady state for only a small fraction of the time and there was some evidence for a solar-cycle variation in this fraction. These authors also found that the polarity changes in the IMF-Bz fall into two classes: one with an associated change in solar wind dynamic pressure, the other without such a change. However, in only 20% of cases does the dynamic pressure change exceed 50%.

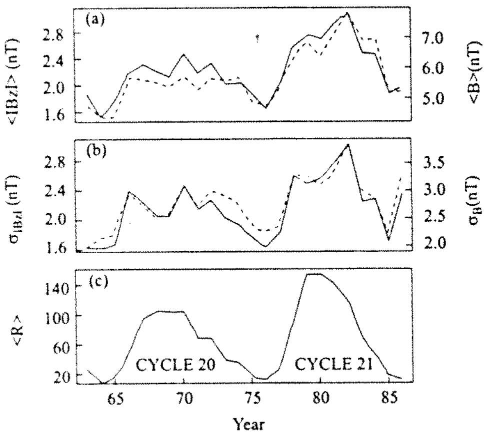


Figure 11. Solar-cycle variations in out-of- ecliptic component of the IMF (GSM coordinates). The solid lines and left- hand scales are for annual values of (a) the mean magnitude of Bz and (b) the standard deviation of the magnitude of Bz. The dashed lines and the right-hand scales are the equivalent variations for the IMF strength, B. The lowest panel (c) gives the mean international sunspot number, R (From [24]

Figure 13 (a,b,c) is taken from a paper by Tulunay [26 ab] in which she searched the possible effects of the orientation of the southward turnings of the IMF on the Slough, Lannion and Dourbes critical frequencies, f_0 F2, in the period 1967 to 1984. Figure 13 (a,b,c) shows the diurnal variations of the critical frequencies after the "quiet-time" diurnal variation was subtracted ($\delta f_0 F2$). Figure 13 (a,b,c) shows clear minima in the average $\delta f_0 F2$ during the day after the southward IMF turnings. These minima are at $\delta f_0 F2$ of - 2.0 MHZ in the Uppsala;- 1.8 MHz in the Lannion and -1.1 MHz in the Dourbes results. The values before the events are, nowever, not always zero, indicating that many non quiet-day values are present. The peak change in $\delta f_0 F2$ which can be attributed to the southward IMF Bz turnings are approximately 1.5 MHz for the Uppsala, 1.4 MHz for the Lannion and 0.7 MHz for the Dourbes results. The mean values before the events are assumed to be -0.5 MHz, -0.4 MHz, and -0.4 MHz for Uppsala, Lannion and Dourbes $\delta f_0 F2$, respectively. Since the magnitude of the changes described here, 0.7 MHz-1. 5 MHz, are a large part of the total variability shown in Figure 2 (a,b,c) of [26 ab] the results imply that the southward turnings of the IMF Bz can contribute in day-to-day variability of the mid-latitute densities.

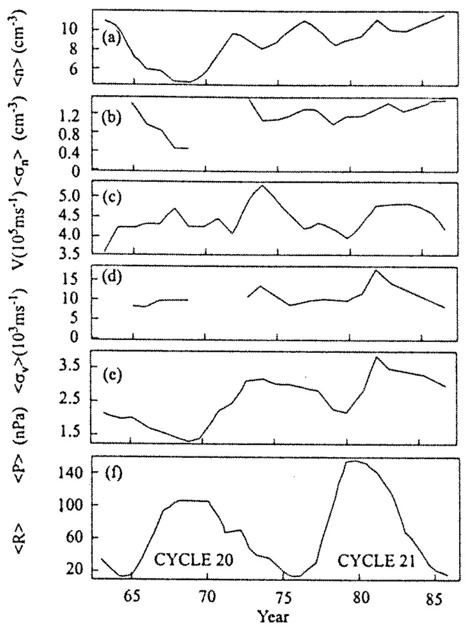


Figure 12. Solar-cycle variations in the solar wind. Annual means of: (a) the solar-wind density, n; (b) the hourly standard deviation of n values, σ_n; (c) the solar-wind speed, v; (d) the hourly standard deviation of v values, σ_v (e) the dynamic pressure, P; and (f) the international sunspot number, R (From [24])

3. Conclusions

The interaction of solar energy with the near-Earth environment has been attracting scientific interest both in its long-term behavior of solar activity and in the physics of such interaction. It has also been attracting considerable interest from the operational point of view concerned with man-made systems. These include, for example, the importance of the STP monitoring program (courtesy of the Space Science Department of the S.E.R.C. Rutherford Appleton Laboratory):

(i) The reliability of worldwide communication, broadcast, navigation and over-the-horizon radar systems depends on the variability of the ionosphere.

(ii) Ionospheric currents cause destructive voltage surges in power lines.

(iii) Ionospheric currents cause corrosion in pipelines.

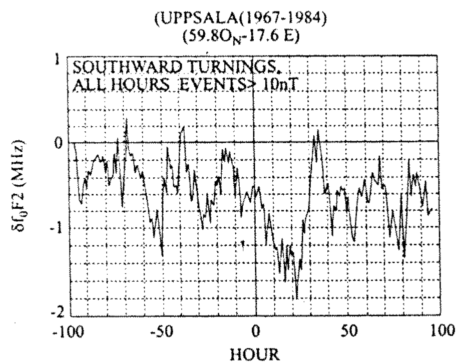
(iv) Upper atmospheric heating causes additional drag on satellites and hence orbital decay and premature reentry. For example, the lifetime of a satellite at an initial altitude of 500 km during quiet solar conditions is about thirty years, although the lifetime of the vehicle is limited to just over two years during active solar conditions [7], see also [27]).

(v) Energetic particles cause temporary faults or permanent damage in electronic systems on satellites.

(vi) Energetic particles represent a radiation hazard to astronauts and high-altitude aeroplane pilots.

In addition, the adverse effects of the solar and geophysical events may be further illustrated with the help of the following examples:

(vii) At altitudes between 500 and 800 km, the highly reactive atomic oxygen concentration can vary over the solar cycle by as much as a factor of one thousand. High concentration of atomic oxygen can react chemically with various surfaces of a satellite or sensor leading to mass losss from external structures and degraded sensor performance ([7], see also [28]).



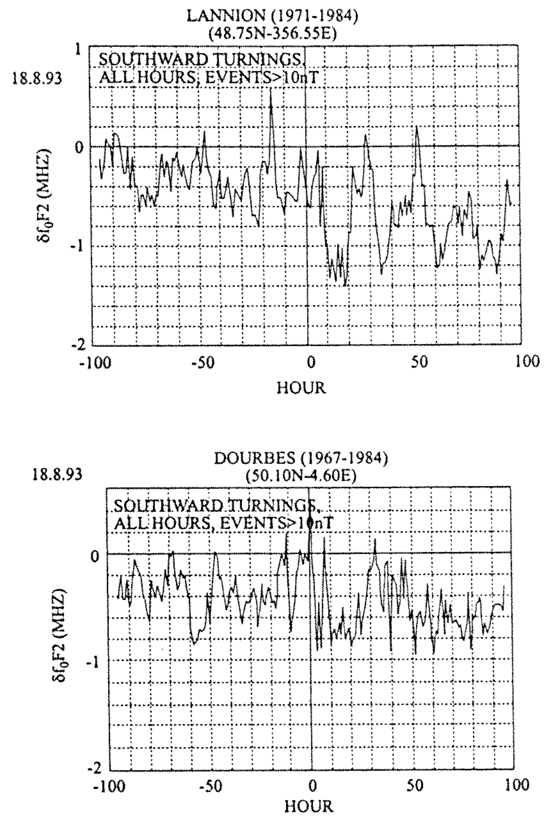


Figure 13. Superposed-epoch plots of mean δf_0F2 as a function of event time. Event time zero is the time of southward turning events of the IMF Bz. (From [26 ab])

(viii) The plasma sheet can cause electrical charging of the surfaces of satellities at about 5-6 Earth radii. The probability of occurrence and the severity of spacecraft changing events are directly correlated with periods of enhanced geomagnetic activity (see [6]).

This general review of this very broad and multidisciplinary subject on the physics of solar radiation and its effect on the Earth's atmosphere contitutes only an incomplete introduction to this active research area. Hopefully it will create some interest among the scientist who are working in the related scientific and technological areas.

* Part of this paper appeared in: Biological Effects and Physics of Solar and Galactic Cosmic Radiation. C. E. Swenberg, G. Horneck eds., NATO ASI Series, Plenum Press, N. Y. London (1993).

Acknowledgement

The author would like to record her thanks to Ms. G. Cangül for the typing of this text.

References

[1] R. C. Altrock, D. F. Neiding, H. I. DeMastus, R. R. Radick, J. W. Evans, G. W. Simon, and S. I. Keil, 1985.The Sun, in: "Handbook of Geophysics and the Space Environment", A. S. Jursa ed., National Technica Information Service, Spring field, V. A. U.S.A.

[2] A. D. Richmond, 1987, The ionosphere, in: "The Solar Wind and the Earth", S-I. Akasofu and Y. Kamide, eds., Terra Scientific Publishing Company, Tokyo.

[3] J. A. Ratcllife, 1970 "Sun, Earth and Radio" world University Library, Weidenfeld and Nicolson, London.

[4] H. A. Taylor, and Y. K. Tulunay, 1973, Near-simultaneous measurements of the plasma trough and plasmatail from OGO-4 and Ariel-3, Proc. Chapman memorial Symposium June 18-22, Boulder, USA.

[5] M. Neugebauer, 1991, The quasi-stationary and transient states of the solar wind, Science, 252-405.

[6] M. Dryer, 1987 Solar Wind and Heliosphere, in: "The Solar wind and the Earth", S,-I Akasofu and Y. Kamide, eds., Terra Scientific Publishing Company, Tokyo.

[7] D. J. Gorney, 1990, Solar-cycle effects on the near-Earth space environment. *Rev. Geophys.*, 28:315.

[8] R. Schween 1990, What does the solar wind tell the prediction community?, in: "Solar-Terrestrial Predictions: Proceedings of a Workshop at Leura, Australia, October 16-20, 1989", National Oceanic and Atmospheric Administration Environmental Research Lab. Boulder, Colorado U.S.A.

[9] J. T. A. Ely, 1984, "Cosmic Rays, Solar Activity, Magnetic Coupling, and Lightning Incidence, 1984", NASA Contractor Report 3812, NASA.

[10] W. J. Heikkila, 1990, Magnetic reconnection, merging, and viscous interaction in the magnetosphere, *Space Science Review*, 53-1.

[11] C. T. Russell, 1987, The Magnetosphere, in: "The Solar Wind and the Earth", S.-I Akasofu and Y. Kamide, eds., Terra Scientific Publishing Company, Tokyo.

[12] A. S. Rodger, 1990, Recent progress in understanding the magnetospheric environment, in: "Solar-Terrestrial Predictions: Proceedings of a Workshop at Leura, Australia, October 16-20, 1989", National, Oceanic Boulder, Colorado, U.S.A. and Atmospheric Administration Environmental Research Lab. Boulder, Colorado, U.S.A.

[13] E.W. Hones Jr., 1986, the Earth's Magnetotail, Scientific American (March): 32.

[14] A. Nishida, 1982, Origin of magnetospheric plasma, in: "Magnetospheric Plasma Physics", A. Nishida, ed., D. Reidel Publishing Co, Dordrecht. Boston, London.

[15] G. Haerendel, and G. Paschmann, 1982, Interaction of the solar wind with the dayside magnetosphere, in: "Magnetospheric Plasma Physics". A Nishida, ed., D. Reidel Publishign Co., Dordrecht. Boston, London.

[16] Y. K. Tulunay, and J. M. Grebowsky, 1987, Hemispheric differences in the morphology of the high latitude ionosphere measured at -550 km, Planet. Space Sci., 35-821.

[17] H. C. Brinton, J. M. Grebowsky, and L. H. Brace, 1978, *J. Geophys, Res.*, 83-4767.

[18] J. P. Heppner, 1977, Empirical models of high latitude electric fields, *J. Geophys. Res.*, 82:1115.

[19] Y. T. Feldstein, and G. V. Starkov, 1967, Dynamics of auroral belt and polar geomagnetic distrubances, Planet Space. Sci., 15209.

[20] S. -I. Akasofu, 1981. Energy coupling between the solar wind and the magnetoshere *Space Science Reviews,* 20:121.

[21] N. U. Crooker, and F. L. Siscoe, 1986, the effect of the solar wind on the terrestrial environment, in: "Physics of the Sun", vol. 3, P. A. Sturrock, ed., D. Reidel, Hingham, Mass.

[22] J. Feynman, Y. Y. Gu, 1986, Prediction of geomagnetic activity on time scales of one to ten years, Rev Geophys., 24:650.

[23] Y. K. Tulunay, D. M. Willis, M. A. Hapgood, and M. Lockwood, 1991, Influence of the interplanetary medium on mid-latitude ionospheric variability, "Final Report", NATO Collaborative Research Project, NATO, 0753/87.

[24] M. A. Hapgood, M. Lockwood, G. A. Bowe, D. M. Willis and Y. K. Tulunay, 1991. Variability of the interlanetary medium at 1 a.u. over 24 years 1963-1986, *Planet Space Sci.*, 39:411.

[25] S. J. Bame, J. R. Asbridge, V. C. Feldman, and J. T. Gosling, 1976, Solar cycle evolution of high speed solar wind streams. *Astrophys. J.*, 207-977.

[26] (a) Y. K. Tulunay,1993, Solar Energy and its interaction with atmosphere, in: "Biological Effects and Physics of Solar and Galactic Cosmic Radiation", C. E. Swenberg G. Horneck, eds., NATO ASI Series, Plenum Press, N. Y. London. (b) Y. K. Tulunay, 1993. Interplanetary magnetic field and its possible effects on the mid-latitude ionosphere II, Proc. COST 238 GRAZ Workshop.

[27] R. L. Walterscheid, 1989, Solar cycle effects on the upper atmosphere: Implication for satellite drag, J. Spacecr. Rockets, 26:439.

[28] J. T. Visentine, (Ed.), 1988 "Atomic Oxygen effects measurements for shuttle missions STS-8 and 41-G", NASA Tech. Mermo., TM- 100459, I-III.

THE TROUGH IN THE PRIME AREA

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ABSTRACT
The mid-latitude electron density trough has been investigated at the PRIME latitudes in terms of the ionospheric critical frequencies.

INTRODUCTION
The mid-latitude electron density trough has been investigated by Tulunay extensively since 1968 by using the electron density data returned by the ARIEL 3 and ARIEL 4 Satellites.(e.g. references cited [1] to [13])Tulunay in her related work showed that the trough is the ionospheric projection of the magnetospheric plasma pause. Therefore, the dynamical behavior of the magnetosphere can be investigated at lower altitudes by studying the temporal and spatial behavior of the ionospheric electron densities.Since the electron densities and ionospheric critical frequencies (foF2) are related to each other one may seek the signature of the trough in the foF2 data.

A typical electron density profile obtained from a single tape recorded playback on board the ARIEL 4 satellite can be seen in figure 1 and clearly shows the three important phenomena,namely the equatorial anolmaly,the mid- latitude trough and the auroral peak. Another typical example of an electron density profile as a function of geographic latitude is shown in figure 2.The trough minimum position (MP) is near to 65°N,36°E. The 3h-Kp (3 hour planetary magnetic index) is 1+ indicating that during the observation time interval,a magnetically quiet period had been prevailing . This example represents a nighttime trough over the PRIME area.

Figures 4(a,b,c) show how the trough responded to a very important magnetic storm which took place towards the end of May 1967.A large magnetic storm began on 25 May 1967 following two smaller substorms on the previous days. Both the measured low latitude position (LLP) and MP tended to vary in step with one another,indicating that either point can be used as a general indicator of how the trough position changes with time. The difference between the LLP and MP is not constant,but rather decreases during the peak of the magnetic storm. During that large magnetic storm which occurred in May 1967 the orbital plane lay near dawn and dusk as the satellites crossed the Equator at local times near 05 00 and 17 00[6]. The dusk trough locations show the most pronounced changes with the time as the L coordinate decreases with the onset of substorm activity, only to increase again following the substorms.The dawn trough locations, on the other hand ,show no clear variation with respect to the small storms,although the dawn trough does precipitously decrease to lower L coordinates with the onset of the large storm.The LLP and the MP are illustrated in figure 3 for a typical trough observed on 29 May 1967[6]. It is very interesting to observe the temporal variations of the LLP and MP in terms of the Mc Ilwain L coordinates. With the onset of the magnetic storm the trough positions moved to lower latitudes as shown in figure 4(b) in terms of the L coordinate.

The May 1967 storm is an important one since it is rare for the 3h-Kp index to shoot up to 9. Therefore,it was very tempting to investigate the critical frequencies which are obtained by the ground based vertical ionosondes with the ARIEL 3 and 4 satellite observations. This is the first case inspected. That is the objective of this paper here can be stated as to investigate the period of 22-27 May 1967 day using the critical frequencies obtained at Athenes, Sofia, Kiev, Pruhonice, Miedzeszyn, Kalingrad, Uppsala between 22-27 May 1967. Since the trough is better inspected in magnetic coordinates,the coordinates of the PRIME stations are expressed in magnetic dipole coordinates.

RESULTS

Figures 5(a,b,c,d,e,f,g) show the foF2 values versus local time and days between 22-27 May 1967. In order to facilitate a comparison the monthly median values are also shown in the same figures. The effect of the storm was dramatically felt at all stations. As a result of this on 26 May 1967 the foF2 values were reduced well below their respective median values. Following the storm the ionosphere restored itself gradually back to its mean values on 27 May 1967.

The latitudinal dependence of the foF2 values during the period of interest is presented in figures 6(a,b,c,d,e). The foF2 data for each day were averaged over the 6 hour long local time (LT) groups. The LT groups were centered on 0h, 6h, 12h, 18h. The northern hemisphere mid-latitude trough occur mainly in the 50°-60° geomagnetic latitude region, and as 3h-Kp increases the percentage of troughs occupied at lower latitudes increases (figure 7,[1]). Tulunay and Sayers [1] reported the dependence of trough behavior on local time,as early as 1971 in their paper which included same criteria to identify the mid-latitude troughs by computer analysis of ARIEL 3 electron density data [1]. The statistics presented there in [1] were based on over 1000 troughs. From their results one may expect that as morning approaches the troughs move to lower latitudes in the PRIME region.

The available foF2 data over the PRIME area at present cover only as high dipole latitude as 58°N. Therefore,during magnetically quiet periods, day-time, spring and summer it is not possible to detect the signature of the trough in the ionospheric foF2 values. However one may expect to observe it in the PRIME area (a) during high magnetic activity periods (b) in the local time group of (21-0-2) h.As seen in figure 6(a),the averaged foF2 values over the local time (21-0-2) hours on 22,23,24 May 1967 ranged between,approximately (6.5-8) MHz over the magnetic dipole latitude range of 36° N to 58° N. However, after the onset of the main storm on 25 May and 26 May the averaged foF2 values exhibited a trough like variation in the region interest. In particular, around 51° N the minimum $\overline{\text{foF2}}$ is approximately 2.5MHz which is most likely the signature of the trough as seen in the foF2 values during a storm. On 27 May 1967 the $\overline{\text{foF2}}$ values are recovered and increased over all latitudes to almost back to their pre-storm values.

CONCLUSION

Inside the plasmapause the electron density may be between 10 and 100 times larger than outside. Therefore, the plasmapause presents itself a region in the near Earth-space where particle-wave growth becomes possible due to the instabilities naturally exist. The trough is the ionospheric projection of such a region. The trough moves to lower latitudes with increasing high magnetic activity. Therefore, it would be useful if the COST 238 models included the role that the trough may play in "nowcasting" and forecasting algorithms.

ACKNOWLEDGEMENT: This work is partly supported by the TUBITAK EEEAG. The foF2 data were obtained from the COST 238 data base at CNET. The authors thank to Mr. R. Hanbaba and Mr. H.Sizun for their kind cooperation in making the foF2 data available at a very speedy fashion.

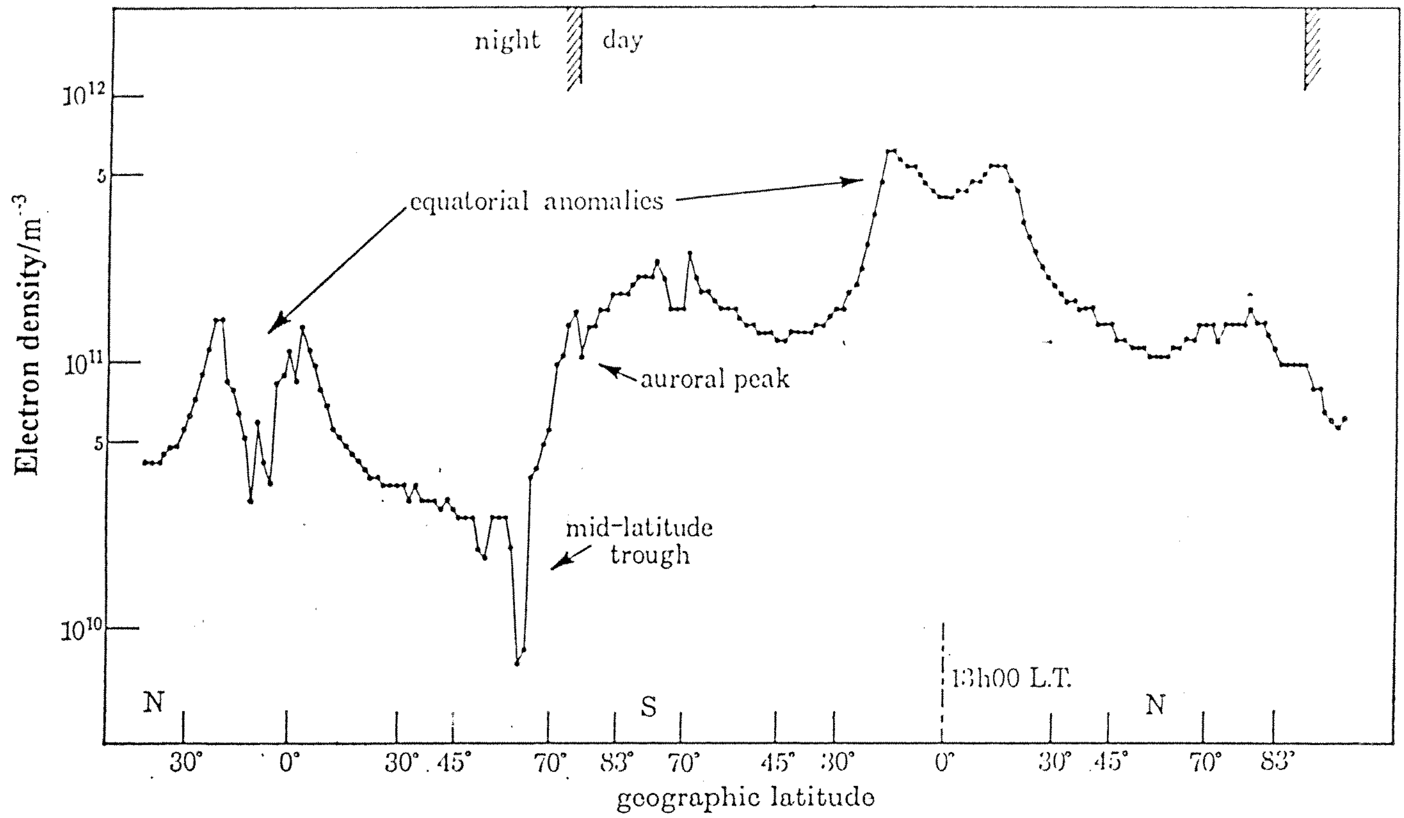


Figure 1. Electron density data from a typical tape-recorder playback. Pass 1437–8, 16 March 1972. [7]

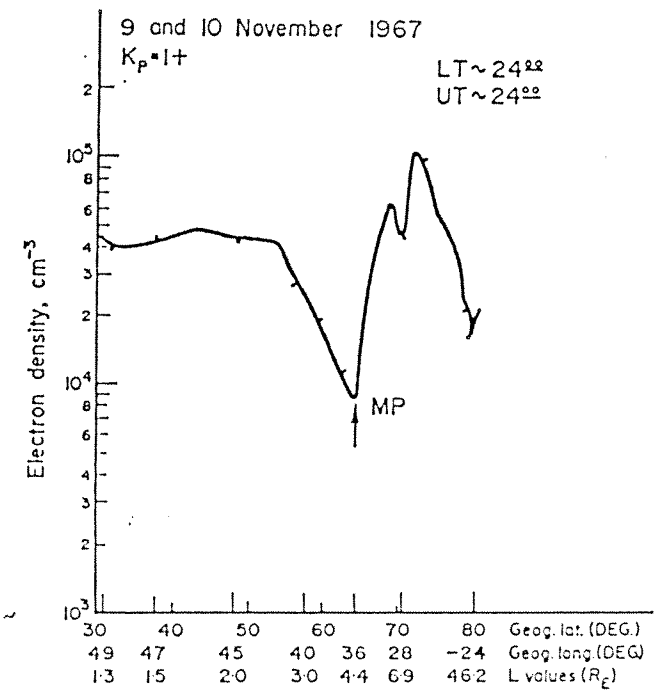


Figure 2 An example of an electron density trough with its position locator MP indicated. [9]

DAWN-DUSK TROUGH

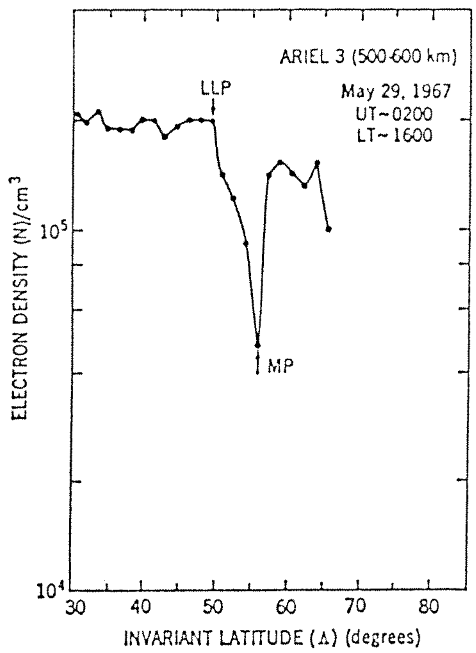


Figure 3. An example of an electron density trough with its position locators MP (minimum point) and LLP (low latitude point) indicated. [9]

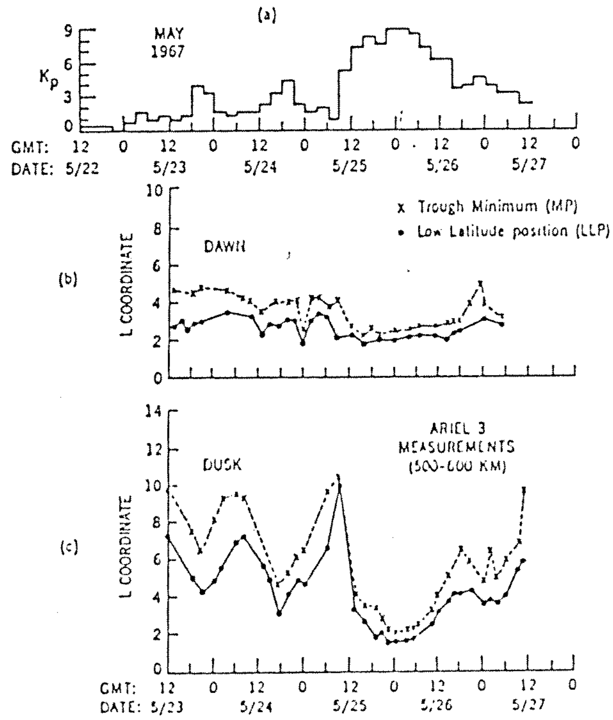
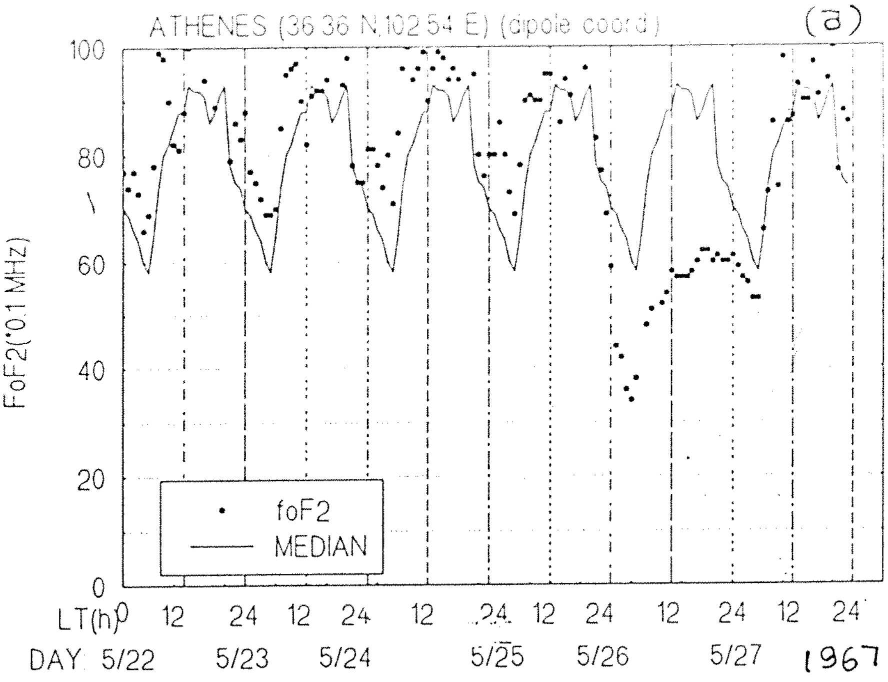
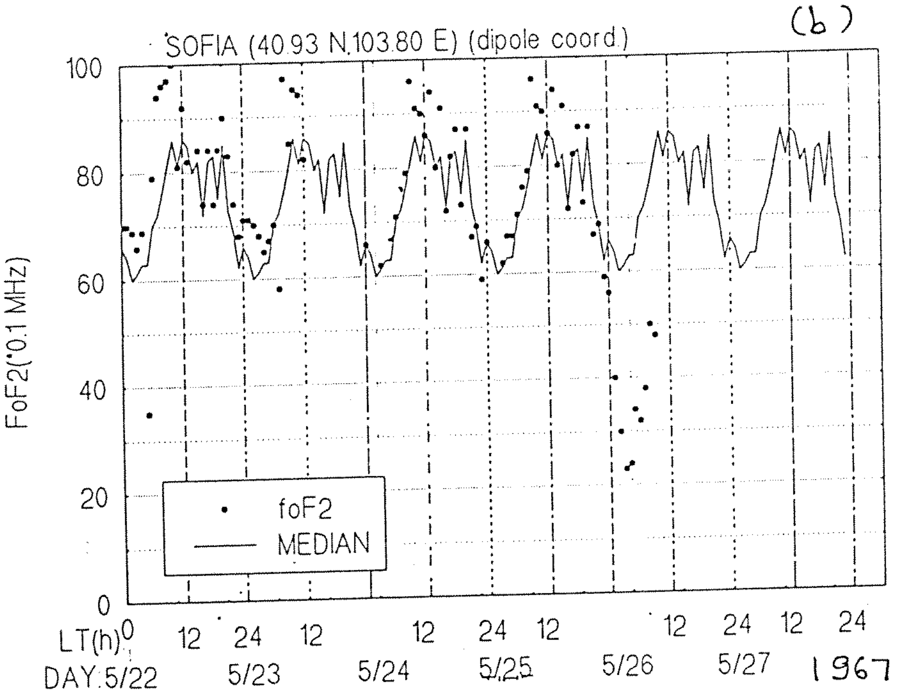
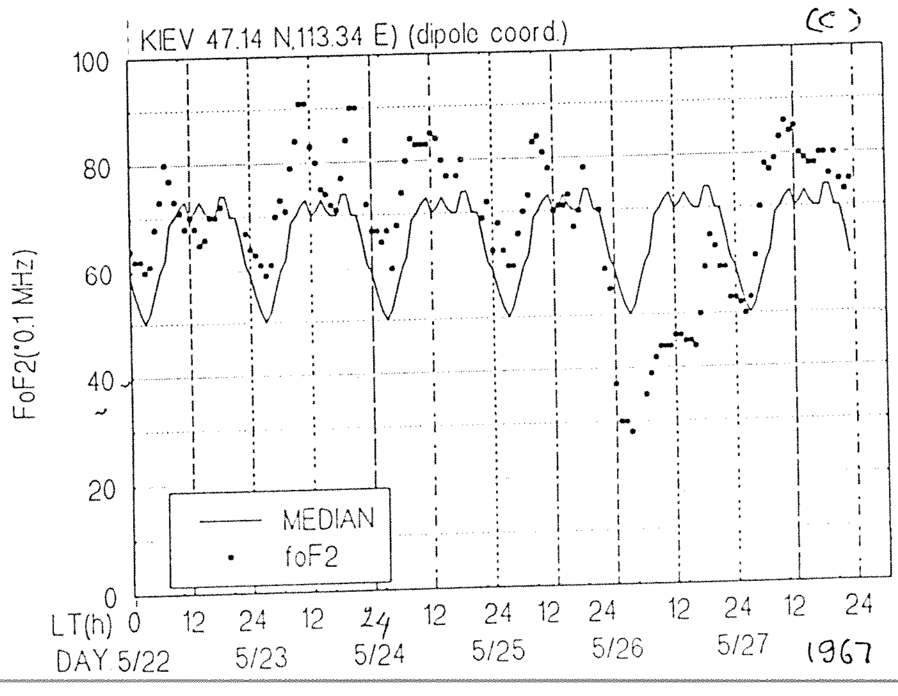
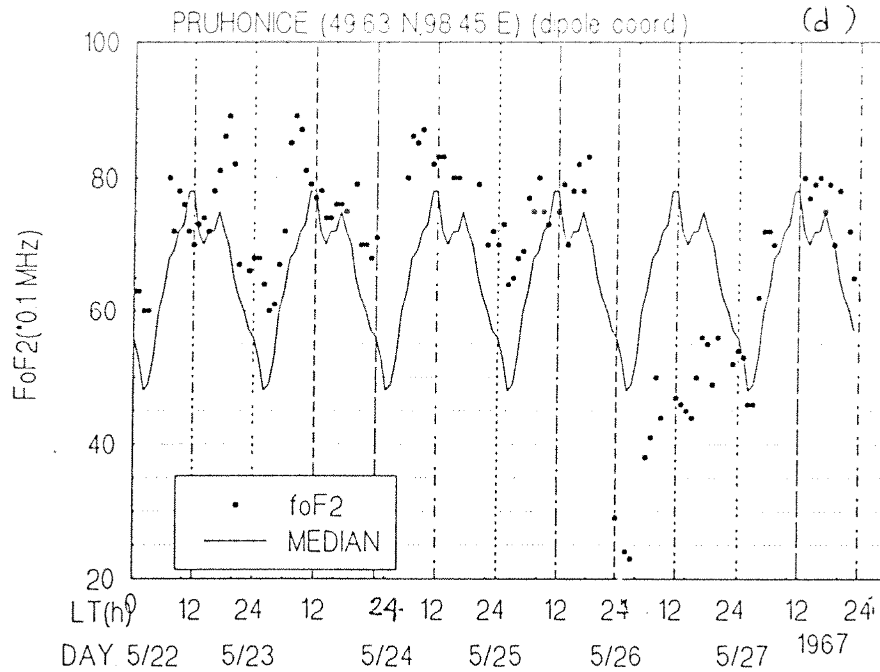


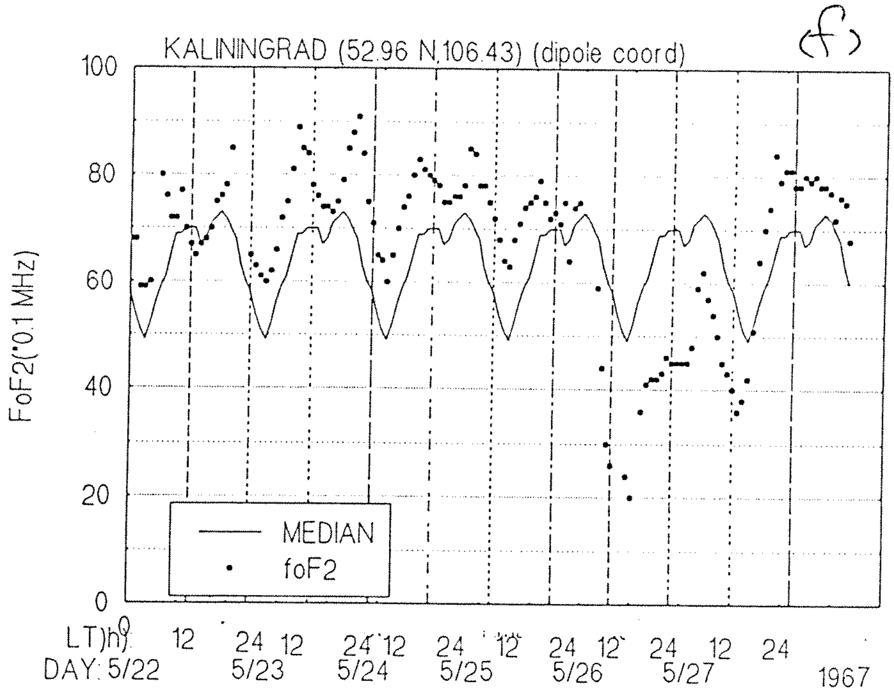
Figure 4. (a) Magnetic K_p index variation for the period of interest. (b) Measured Ariel 3 electron density trough locations at dawn. (c) Measured electron density trough position at dusk. [6]

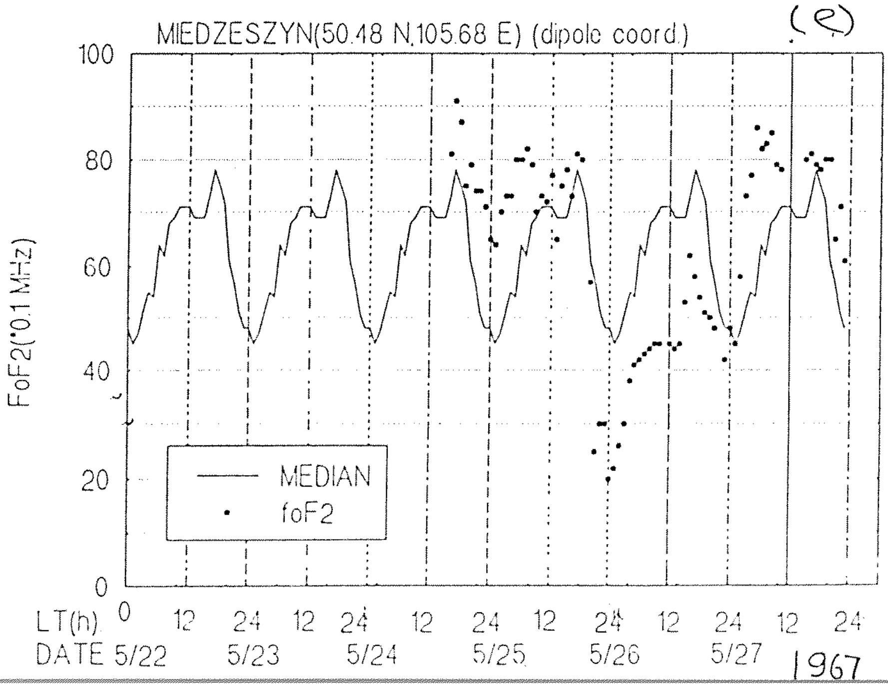

ATHENES (36.36 N,102.54 E) (dipole coord.)
(a)
FoF2(*0.1 MHz)
100
80
60
40
20
0
foF2
MEDIAN
LT(h) 0 12 24 12 24 12 24 12 24 12 24 12 24
DAY 5/22 5/23 5/24 5/25 5/26 5/27 1967


SOFIA (40.93 N,103.80 E) (dipole coord.)
(b)
FoF2(*0.1 MHz)
100
80
60
40
20
0
foF2
MEDIAN
LT(h) 0 12 24 12 12 24 12 12 24 12 24
DAY 5/22 5/23 5/24 5/25 5/26 5/27 1967


KIEV 47.14 N,113.34 E) (dipole coord.)
(c)
FoF2(*0.1 MHz)
100
80
60
40
20
0
MEDIAN
foF2
LT(h) 0 12 24 12 24 12 24 12 24 12 24 12 24
DAY 5/22 5/23 5/24 5/25 5/26 5/27 1967


PRUHONICE (49.63 N,98.45 E) (dipole coord)
(d)
FoF2(*0.1 MHz)
100
80
60
40
20
foF2
MEDIAN
LT(h) 0 12 24 12 24 12 24 12 24 12 24 12 24
DAY 5/22 5/23 5/24 5/25 5/26 5/27 1967


KALININGRAD (52.96 N,106.43) (dipole coord)
(f)
FoF2(*0.1 MHz)
100
80
60
40
20
0
MEDIAN
foF2
LT)h) 0 12 24 12 24 12 24 12 24 12 24 12 24
DAY 5/22 5/23 5/24 5/25 5/26 5/27 1967


MIEDZESZYN(50.48 N,105.68 E) (dipole coord.)
(e)
FoF2(*0.1 MHz)
100
80
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foF2
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DATE 5/22 5/23 5/24 5/25 5/26 5/27 1967

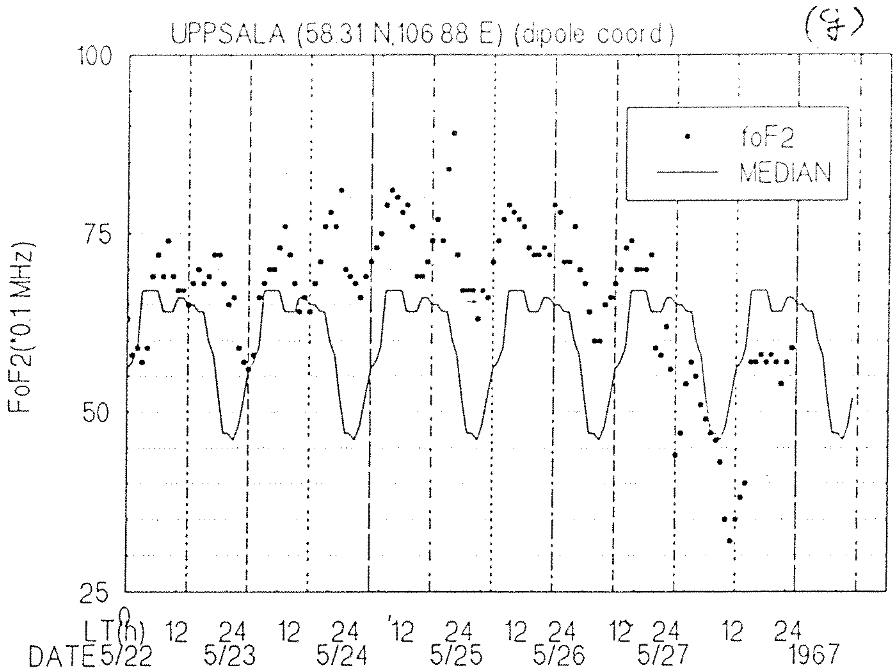


Figure 5. The foF2 values as a function of day numbers between 22 and 28 May 1967 for (a) Athenes , (b) Sofia , (c) Kiev , (d) Pruhonice , (e) Miedzeszyn , (f) Kalingrad , (g) Uppsala.
Superimposed on each data set are the monthly median values of the foF2s.

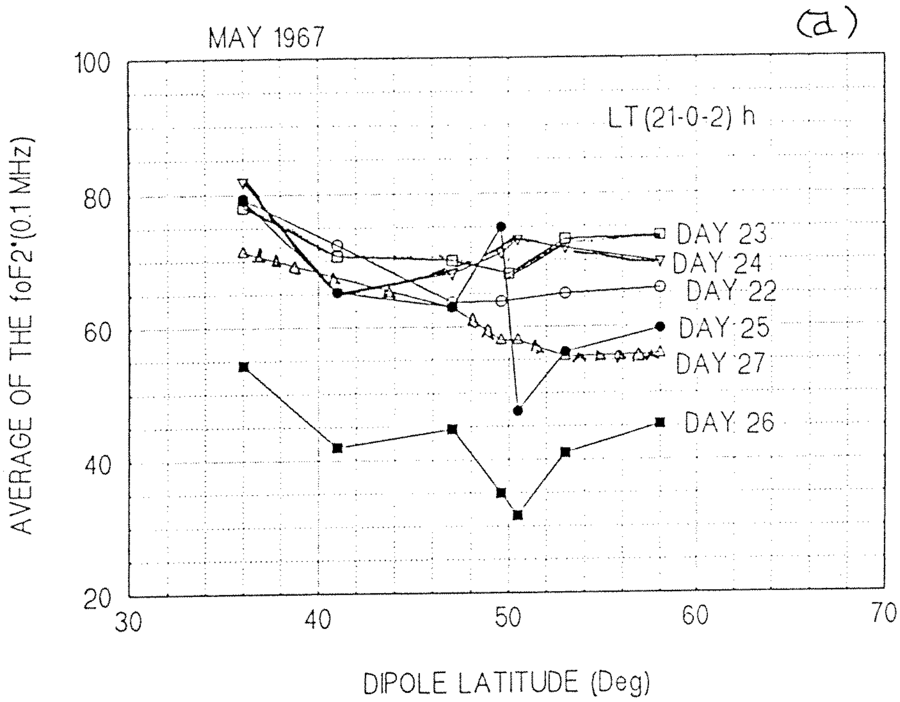
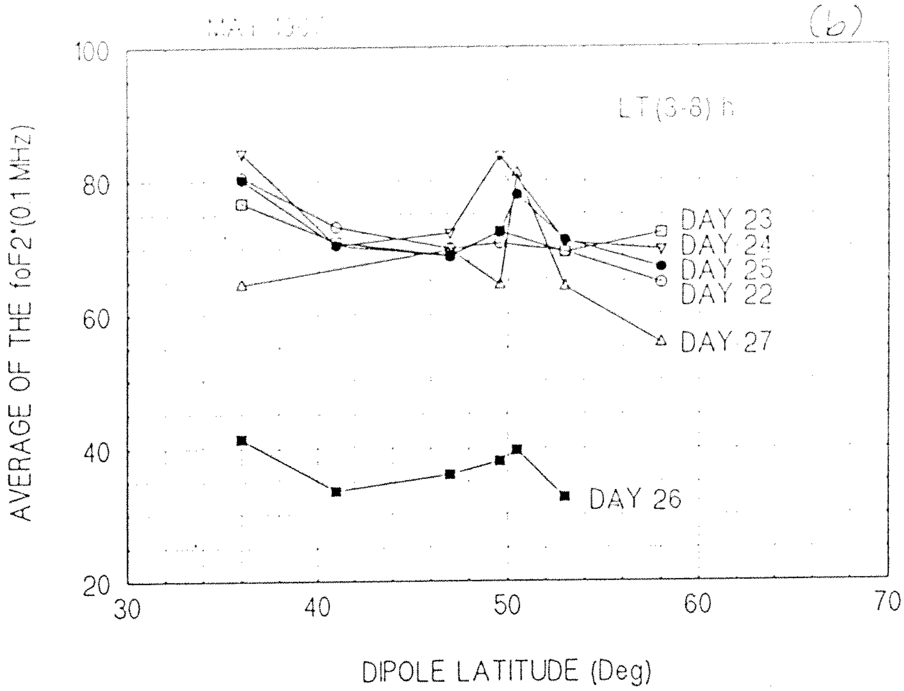
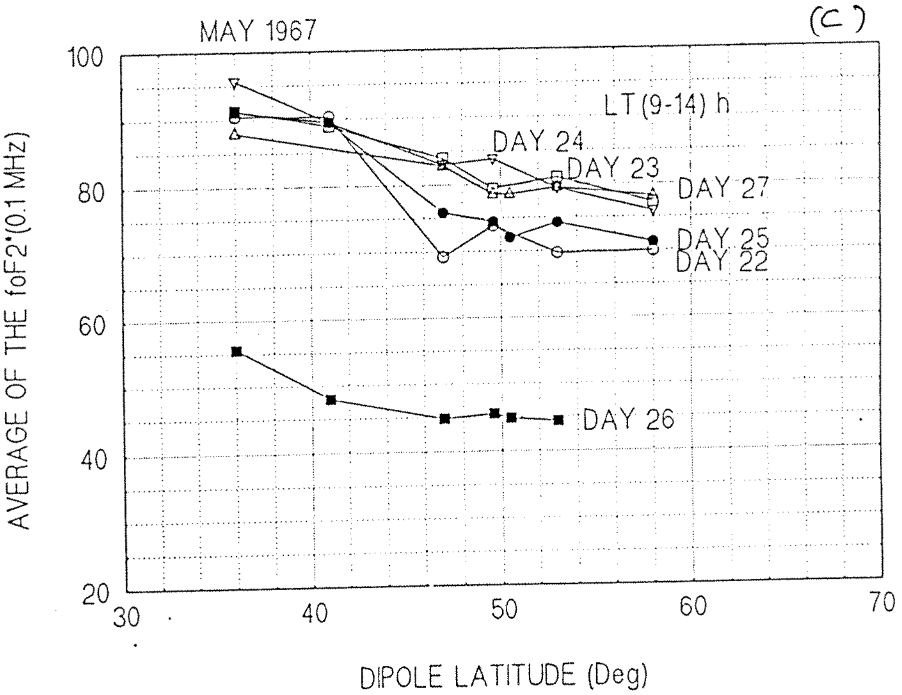


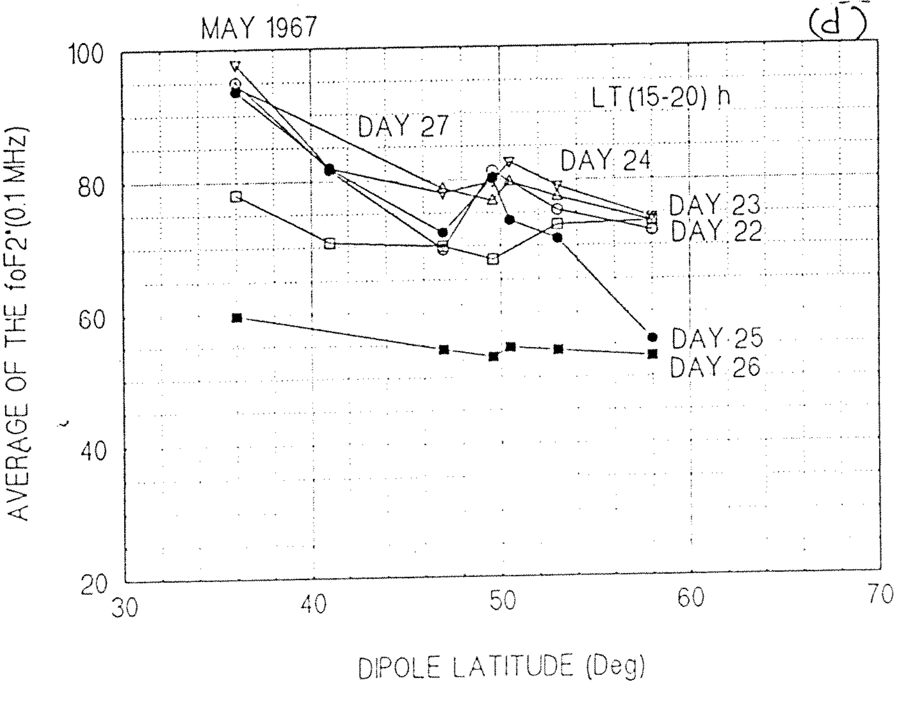
Figure 6. Computer plot of averaged foF2 values versus dipole latitude,
(a) for the local time group of (21-0-2) h
(b) for the local time group of (3-8) h
(c) for the local time group of (9-14) h
(d) for the local time group of (15-20) h , on days 22,23,24, 25,26,27 May 1967.



(b)
LT(3-8) h
DAY 23
DAY 24
DAY 25
DAY 22
DAY 27
DAY 26
AVERAGE OF THE foF2'(0.1 MHz)
DIPOLE LATITUDE (Deg)



MAY 1967
(c)
LT(9-14) h
DAY 24
DAY 23
DAY 27
DAY 25
DAY 22
DAY 26
AVERAGE OF THE foF2'(0.1 MHz)
DIPOLE LATITUDE (Deg)



MAY 1967
(d)
LT(15-20) h
DAY 27
DAY 24
DAY 23
DAY 22
DAY 25
DAY 26
AVERAGE OF THE foF2'(0.1 MHz)
DIPOLE LATITUDE (Deg)

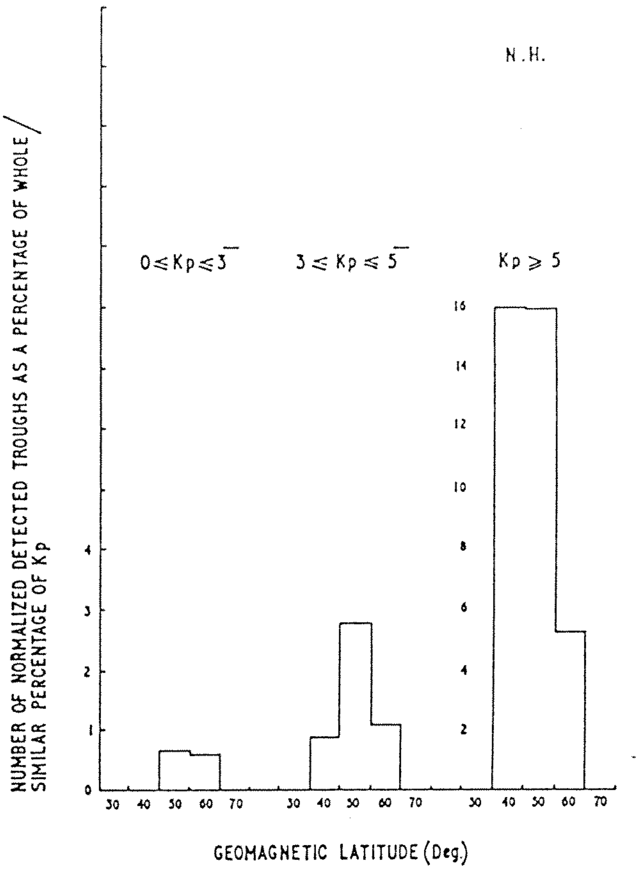


Figure 7.Percentage of normalised troughs divided by the percentage of K_p's in that group as a function of geomagnetic latitude in northern hemisphere (normalised troughs are the number of troughs for each normalised 10° geomagnetic latitude and longitude section) [1].

REFERENCES

1. 1971- Characteristics of mid-latitude trough as determined by the electron density experiments on Ariel-3, *J. Atmosph. Terr. Phys.*, **33**, pp.1737-1761. Y.K.Tulunay and J.Sayers

2. 1972- Topside electron density measurements made by the Ariel-3 satellite during the geomagnetic storm of May 25-27 1967, *Planet. Space Sci.*, **20**, pp. 1299-1307. Y.K.Tulunay.

3. 1972- Magnetically symmetrical detection of the mid-latitude electron density trough by the Ariel-3 satellite, *J. Atmosph. Terr. Phys.*, **34**, pp. 1547-1551. Y.K.Tulunay.

4. 1973- Global electron density distributions from the Ariel- 3 satellite at mid-latitudes during quiet magnetic periods, *J.Atmosph. Terr. Phys.*,**35**, pp. 233-254. Y.K.Tulunay

5. 1973- A satellite study of the mid-latitude trough in electron density and VLF radio emissions during the magnetic storm of 25-27 May 1967, *J. Atmosph. Terr. Phys.*, **35**, pp.153-163. Y.K.Tulunay and A.R.W.Hughes.

6. 1974- Temporal variations in the dawn and dusk mid-latitude trough position modelled and measured, *Planet. Space Sci.*, **22**, pp. 1089-1099. J.M.Grebowsky, Y.K.Tulunay and A.J.Chen.

7. 1975- Topside ionosphere electron density measurements, *Proc.R.Soc. Lond. A.*, **343**, pp. 289-206. C.V. Goodall, H.Hopkins, Y.K.Tulunay and R.D'Arcy.

8. 1975- Temporal variations in the dawn and dusk mid-latitude trough position observed by Ariel-3 and Ariel-4, *Ann. Geophys.*, **31**, pp. 29-36. Y.K.Tulunay and J.M. Grebowsky.

9. 1976- A comparison of the relative locations of the mid-latitude electron density trough and the scintillation boundary, *J.Atmosph. Terr. Phys*, **38**, pp. 217-218. Y.K.Tulunay, A.Tauriainen and O.Demir.

10. 1976- Coincident observations of ionospheric troughs and the equatorial plasma-pause, *Planet. Space Sci.*, **24**, pp. 1177-1185. J.M. Grebowsky, N.C. Maynard, Y.K. Tulunay and L.J. Lanzerotti.

11. 1978- The noon and midnight mid-latitude trough as seen by Ariel 4, *J.Atmosph. Terr.Phys.*, **40**, pp.845-855. Y.K. Tulunay and J.M. Grebowsky.

12. 1987- Hemispheric differences in the morphology of the high latitude ionosphere measured at ~500 km, *Planet. Space Sci.*, **35**, pp.821-826. Y.K.Tulunay J.M. Grebowsky.

13. 1990- A further investigation of the time dependence on the Ariel-4 ambient electron densities, J. Geomag. Geoelectr., **42**, pp. 1333-1339. G.Öke and Y.K.Tulunay.

EK (6.3.2)-12

BPU-2

GENERAL CONFERENCE OF THE BALKAN PHYSICAL UNION

12-14 September 1994
Ege University
İZMİR, TURKEY

PROGRAMME

APCP2-The Possible Influence of the Interplanetary Magnetic Field on the Ionospheric Critical Frequencies
Y.Tulunay
Middle East Tecnical University Ankara-Turkey

223

EK (6.4)-1

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
KANDİLLİ RASATHANESİ
VE
DEPREM ARAŞTIRMA ENSTİTÜSÜ MÜDÜRLÜĞÜ

Sayı : 46/01-368

Konu :

20.12.1991

Prof.Dr. Y.Tolunay
O.D.T.Ü.
Mühendislik Fakültesi
Havacılık Mühendisliği Bl.
ANKARA

Sayın Prof.Dr. Tolunay,

21 Kasım 1991 tarihli dilekçenizle Müdürlüğümüze ilettiğiniz PRIME cost-238 no'lu proje incelenmiş ve olumlu bulunmuş, projeye katılmamız Rektörlüğümüzce de uygun görülmüştür.

Bu dört yıllık projeye Müdürlüğümüz iş gücü, alet ve personel olarak katkıda bulunabilir.

Bu projede fiilen çalışacak elemanlar Doç.Dr. Atila Özgüç ve Dr. Tamer Ataç'tır. Projeye katkımız iş gücü olarak;

Doç.Dr.Atila Özgüç %15 çalışma ile yıllık katkısı
360 gün x 50.000.-TL = 18.000.000.-TL
Dr.Tamer Ataç %15 çalışma ile yıllık katkısı
360.gün x 45.000.-TL = 16.200.000.-TL

Araç, gereç kullanımı, teknisyenlik ve haberleşme olarak;
yıllık 16.000.000.-TL

Parasal katkı olarak;
1992 yılı için 50.000.000.-TL
1993 yılı için 50.000.000.-TL
1994 yılı için 50.000.000.-TL
öngörülmüştür.

Bilgilerinizi rica eder, çalışmalarınızda başarılar dilerim.

Saygılarımla,

Prof.Dr. A.Mete IŞIKARA
Müdür

249

81220 Çengelköy - İstanbul Telefon: 332 02 40.41 Telex: 26411 BOUN TR Telefax: 165 03 57

T. C.
ULAŞTIRMA BAKANLIĞI
TELSİZ GENEL MÜDÜRLÜĞÜ

SAYI : 12.1/11665 - 5534 ANKARA

KONU: COST 238 sayılı Proje. 16 ARALIK 1991

TÜRKİYE BİLİMSEL VE TEKNİK ARAŞTIRMA KURUMU
COST Yüksek Düzey Temsilciliği

İLGİ : 03.10.1991 tarih ve 15.COST.1059/5808 sayılı yazınız.

1. ilgi yazı ile Dışişleri Bakanlığı vasıtası ile kurumunuza iletilmiş bulunan COST 238 sayılı "Prediction and Retrospective Ionospheric Modelling Over Europe (PRIME)" konu projeye katılımı ve katılınırsa olabilecek katkısı ile ayrıntılı bilgilerin tarafınıza iletilmesi hususu talep edilmektedir.

2. Görevi, Türkiye dahilindeki telsiz kullanıcılarına (asker/sivil) hizmet etmek olan ve bu hizmeti sırasında frekans spektrumunun en verimli ve etkili bir şekilde kullanımı ve kontrolünü sağlamak olan Genel Müdürlüğümüz aynı zamanda Avrupa nezdinde yapılmakta olan frekans harmonizasyonu çalışmalarına CEPT (Avrupa Posta ve Telekomünikasyon Birliği) dahilinde katılmakta ve böylece Avrupa ile telekomünikasyon alanında olabilecek entegrasyonu kolaylaştıracak şekilde planlamalarını gerçekleştirmektedir.

Bu meyanda COST 238 sayılı PRIME başlıklı projenin uygulamaya konulması halinde;

a. Oluşturulacak "Çalışma Grubunda" Genel Müdürlüğümüz en az bir uzman personelle temsil edilebilecektir.

b. Genel Müdürlüğümüzün üyesi bulunduğu CEPT (Avrupa Posta ve Telekomünikasyon Birliği) ve CCIR (Uluslararası Telsiz Danışma Komitesi) Bünyesinde yürütülmekte olan ve COST 238 sayılı projeye destek olabilecek her türlü araştırma ve çalışma sonucu hakkında elde edilen bilgiler Çalışma Grubuna iletilebilecektir.

c. HF-Kısa dalga frekans bandında yapılacak olan bu projeye yardımcı olacağı düşünülen, halihazırda Genel Müdürlüğümüzce çalıştırıl-

(./..)

T. C.
ULAŞTIRMA BAKANLIĞI
TELSİZ GENEL MÜDÜRLÜĞÜ

SAYI : 121/11665

ANKARA

KONU :

..../..../19....

maktu olan ve HF frekans bandında en uygun frekans bandını ve bu band dahilindeki en uygun nokta frekansları tesbit etmeye yarayan "HF Frekans Analiz Sistemi"ni elde bulunan imkânlar dahilinde proje çalışmalarına tahsis edebilecektir.

d. Finansal açıdan Genel Müdürlük olarak verebileceğimiz destek ise, ancak konu projeye ilişkin olarak mükellefiyetimizin bilinmesinden sonra Bakanlığımızın izinleri çerçevesinde değerlendirilebilecektir.

Konu hususunda bilgi edinilmesini ve gereğini arz ederim.

GENEL MÜDÜR ADINA

H. Alev ERLEVENT
Genel Müdür Teknik Yardımcısı

DAĞITIM :

Gereği :

TÜBİTAK (Cost Yük.Düzey.Temsilciliği)

Bilgi :

Ulaştırma Bakanlığı
(Hab.D.Bşk.lığı

EK (6.4)-3

UİD-1169

T.C

TÜRKİYE RADYO – TELEVİZYON KURUMU
GENEL MÜDÜRLÜĞÜ

SAYI : UTİS/5002-82-0/282

KONU : COST 238 (PRIME) Projesi

17.07.91 08774

17/7/1991

TÜRKİYE BİLİMSEL VE TEKNİK ARAŞTIRMA KURUMU
COST Yüksek Düzey Temsilciliği

İLGİ: a) 8 Kasım 1990 tarih ve 15.COST.1133-6312 sayılı yazınız
b) 26 Kasım 1990 tarih ve UTİS/5002-82-0/522 sayılı yazımız
c) 3 Temmuz 1991 tarih ve 15.COST.419-4302 sayılı yazınız.

COST 238 sayılı "Prediction and Retrospective Ionospheric Modelling over Europe" (PRIME) başlıklı projenin uygulamaya sokulması halinde:

1. Oluşturulacak "Çalışma Grubunda" Kurumumuz en az bir uzman personelle temsil edilecektir.

2. Kurumumuzun üyesi bulunduğu Avrupa Yayın Birliği (EBU) ve Uluslararası Radyo Danışma Komitesi (CCIR) bünyesinde yürütülmekte olan ve COST 238 (PRIME) projesine destek olacak her türlü araştırma ve çalışma sonucu Çalışma Grubu'na transfer edilecektir.

3. Kısa Dalga spektrumuna ilişkin olarak projeye yardımcı olacak her türlü deneme için kısa dalga vericilerinin tahsisi temin edilecektir.

4. Finansal açıdan Kurum olarak verebileceğimiz destek ise ancak mükellefiyetimizin bilinmesinden sonra açıklık kazanacaktır.

Öte yandan, COST 238 (PRIME) projesi kapsamı itibarı ile Telsiz Genel Müdürlüğü ve PTT İşletme Genel Müdürlüğü'nce de ilgi ve destek görebileceğinden adı geçen kuruluşların da bilgilendirilmesi uygun mütalaa edilmektedir.

Bilgilerinize arz ederim.

GENEL MÜDÜR ADINA

A.Akad ÇUKUROVA
Genel Müdür Teknik Yardımcısı

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EK (6.4)-4

T.C.
ULAŞTIRMA BAKANLIĞI
TELSİZ GENEL MÜDÜRLÜĞÜ

ıYI : B.11.1.TGM.0.12.00.01/3228 - 1654

ANKARA

ꞱNU: PRIME Projesi

22 NİSAN 1992

:of.Dr.Yurdanur TULUNAY
:tadoğu Teknik Üniversitesi
ıvacılık Mühendisliği Bölümü

.Gİ : a) 3.10.1991 tarih ve 15.COST.1059/5808 sayılı TÜBİTAK yazısı.
b) 16.12.1991 tarih ve 12.1/11665-5534 sayılı TÜBİTAK'a muhatap yazımız.

1. İlgi (a) yazı ile TÜBİTAK tarafından Avrupa'da COST 238 sayılı ᑊrediction and Retrospective Ionospheric Modelling Over Europe(PRIME)" ıı altında ortak bir projenin planlandığı Genel Müdürlüğümüze iletilmiş .up, sözkonusu projeye Genel Müdürlüğümüzün katılımı halinde yapabileceği ıtkılar ilgi (b) yazı ile TÜBİTAK'a bildirilmiş, proje bünyesinde çalıştı-.lmak üzere Genel Müdürlüğümüzden bir personel görevlendirilmiştir.

2. Bu meyanda yapılan çalışmalar ve incelemeler neticesinde; konu :ojenin gerçekleştirilmesi sırasında kullanılacak olan ve frekans değiştiril-ək suretiyle "pulse" yayma kabiliyetli radar aygıtı olan "iyonosonda" :ihazının; Genel Müdürlüğümüzde kurulu bulunan ve HF frekans bandında en ıygun frekans bandını ve bu band dahilindeki en uygun nokta frekanslarını əsbit etmeye yarayan "HF Frekans Analiz Sisteminden", işlevi bakımından ırklı olduğu anlaşılmıştır. Bununla beraber, konu proje kapsamında yapılacak ıçümlerin teyidi hususunda "HF Frekans Analiz Sisteminin" yardımcı olacağı jşünülmektedir. Ayrıca, sözkonusu iyonosonda cihazının alımının ise; Genel jdürlüğümüzün mevcut yatırım projeleri için ayrılan bütçe gözönüne alındığın-ı ancak uzun vadede, şartlar elverdiği taktirde düşünülebileceği değerlen-irilmektedir.

3. Görevi, Türkiye dahilinde telsiz kullanıcılarına (Asker/Sivil) ızmet etmek olan Genel Müdürlüğümüz bu projenin gerçekleştirilmesi sırasında linde bulunan imkanlar dahilinde, faydalı olabilecek teknik eleman ve :aştırma cihazlarını da belirli sürelerle çalışmalarda faydalanılmak üzere ıhsis edebilecektir.

Bilgi edinilmesini rica ederim.

:NEL MÜDÜR ADINA

Hüseyin GÜLER
Genel Müdür Yardımcısı
(Teknik)

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BİBLİYOGRAFİK BİLGİ FORMU

1- Proje No: COST 238:PRIME (EEEAG)

2- Rapor Tarihi: Mart 1995

3- Projenin Başlangıç ve Bitiş Tarihleri: 1 7 1992 - 1 3 1995

4- Projenin Adı: COST 238 : PRIME
Avrupa Üzerinde İleriye ve Geriye Dönük Öngörü- Kestirim için İyonosfersel Modelleme

5- Proje Yürütücüsü ve Yardımcı Araştırıcılar:
Prof.Dr. Yurdanur Tulunay (Yürütücü)
Doç.Dr. Atila Özgüç
Dr. Tamer Ataç

6- Projenin Yürütüldüğü Kuruluş ve Adresi:
ODTÜ Havacılık Mühendisliği Bölümü
06531 Ankara

7- Destekleyen Kuruluş(ların) Adı ve Adresi:
TÜBİTAK, EEEAG; Ankara
ODTÜ; Ankara
BÜ Kandilli Rasathanesi Çengelköy İstanbul

8- Öz (Abstract):

The objectives of the project, embodied in the agreed Memorandum of Understanding are: 'to develop techniques for using synoptic ionospheric sounding information taken from existing measuring equipments to generate models of the ionosphere needed to estimate ionospheric propogation effects on telecommunication systems' (EK (5.2)). The project was initiated on 7 March 1991 and had duration of four years. The Member States of Germany, Netherlands, Spain and United Kingdom initially signed the MOU. Later Signatories are Belgium (17 October 1991), France (6 February 1992), Greece (24 July 1991), Italy (6 November 1991), Sweden (17 December 1991), and Turkey (17 February 1992).

Following a review of requirements for improved models to those currently available internationally, efforts are being directed towards separate goals concerning: (i) long-term prediction models that can be made available months or years in advance, and so represent 'smoothed' estimators, (ii) short-term forecasting and models for a particular day and hour and (iii) models representative over periods of about 10 minutes on a given day, needed as collateral data to various remote-sensing applications. The work has been structured within five Topic Areas each as follows:

- Working Group 1 (WG1) - Vertical sounding
- Working Group 2 (WG2) - Oblique sounding
- Working Group 3 (WG3) - Instantaneous mapping
- Working Group 4 (WG4) - Forecasting
- Working Group 5 (WG5) - Monthly median mapping and modelling

Anahtar Kelimeler: HF Propagation; Ionospheric Prediction, PRIME,COST 238

Anahtar Kelimeler:

9- Proje ile ilgili Yayın/Tebliğlerle ilgili Bilgiler Bakınız COST 238 Son Rapor EKleri.

10- Bilim Dalı: Uzay Fiziği, Uzay Bilimleri
Doçentlik B. Dalı Kodu: 402 ve 404
ISIC Kodu: ?
Uzmanlık Alanı Kodu: YOK

11- Dağıtım (*) : ☐ Sınırlı ☒ Sınırsız
Genel Kurmay Başkanlığı; PTT; Telsiz Genel Müd.; T.Telekomünikasyon A.Ş. (TURKSAT), Ankara; TRT

12- Raporun Gizlilik Durumu : ☐ Gizli ☒ Gizli Değil

(*) Projenizin Sonuç Raporunun ulaştırılmasını istediğiniz kurum ve kuruluşları ayrıca belirtiniz