APRL/95/2

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

ATMOSPHERIC PHYSICS AND RADIOPROPAGATION LABORATORY

TROPOSPHERE – IONOSPHERE INTERACTION DURING TROPOSPHERIC MCC EVENTS

J.R. Manzano

S.M. Radicella

M.M. Zossi de Artigas

A.N. Filippi de Manzano

and

A.H. Cosio de Ragone

INTERNATIONAL ATOMIC ENERGY AGENCY

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

MIRAMARE-TRIESTE

APRL/95/2

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

ATMOSPHERIC PHYSICS AND RADIOPROPAGATION LABORATORY

TROPOSPHERE – IONOSPHERE INTERACTION DURING TROPOSPHERIC MCC EVENTS

J.R. Manzano
Laboratorio de Ionosfera, Instituto de Física,
Universidad Nacional de Tucumán, Argentina
and
Consejo Nacional de Investigaciones Científicas y Técnicas,
Buenos Aires, Argentina,

S.M. Radicella
International Centre for Theoretical Physics, Trieste, Italy
and
Consejo Nacional de Investigaciones Científicas y Técnicas,
Buenos Aires, Argentina,

M.M. Zossi de Artigas
Laboratorio de Ionosfera, Instituto de Física,
Universidad Nacional de Tucumán, Argentina
and
Consejo Nacional de Investigaciones Científicas y Técnicas,
Buenos Aires, Argentina,

A.N. Filippi de Manzano and A.H. Cosio de Ragone
Laboratorio de Ionosfera, Instituto de Física,
Universidad Nacional de Tucumán, Argentina
and
Facultad de Agronomia y Zootecnica, Cátedra de Física,
Universidad Nacional de Tucumán, Argentina.

MIRAMARE TRIESTE
September 1995

PREFACE

The ICTP-APRL reports consist of preprints relevant to research and development work done at the Atmospheric Physics and Radiopropagation Laboratory of the International Centre for Theoretical Physics with the participation of visiting scientists.

More information can be obtained by contacting:

Prof. Sandro M. Radicella
Atmospheric Physics and Radiopropagation Laboratory
P.O. Box 586
34100 Trieste
Italy
Phone: +39 40 2240331
FAX: +39 40 224604
E-mail: rsandro@ictp.trieste.it

INTRODUCTION

Several indications of the signature of meteorological processes on the ionosphere have been reported in the literature (Gherzi, 1950; Bauer, 1957 and 1958; Arendt and Frisby, 1968; Shresta, 1971a,b; Kersley and Rees, 1982; Goldberg, 1991; Chen,1992; YI and Chen,1993;, and others). Some of the effects mentioned are:1.-descent of ionosphere reflection height with advance of the direction of movement of a hurricane, 2.-increase of critical frequencies with hurricane approach, 3.- variation of sporadic layer parameters with passage of fronts, 4.- planetary and gravity waves launched by weather fronts and other sources in the troposphere or stratosphere, capable of propagating into the F2 region where their energy is dissipated through the action of viscosity, 5.- modulation of the intensity of the annual variation of the day to day variability of the equatorial ionization by the QBO of the low equatorial stratosphere, 6.- incidence of lightning on the lower ionosphere, 7.- medium scale atmospheric waves generated from tropospheric sources and propagated into the ionosphere and termosphere.

The present paper describes the investigation of possible effects of the type of large meteorological events known as Mesoscale Convective Complexes (MCC)on the F-region of the ionosphere over Argentina. These warm-season weather systems of uge size are present in the United States (Maddox, 1980) and in South America (Velasco and Fritsch, 1987).Their extension can be as large as 1 300 000 Km2 and they tend to move in different directions over the earth surface. It is expected that these meteorological events should leave its signature in of the upper region of the atmosphere.

METHOD AND RESULTS

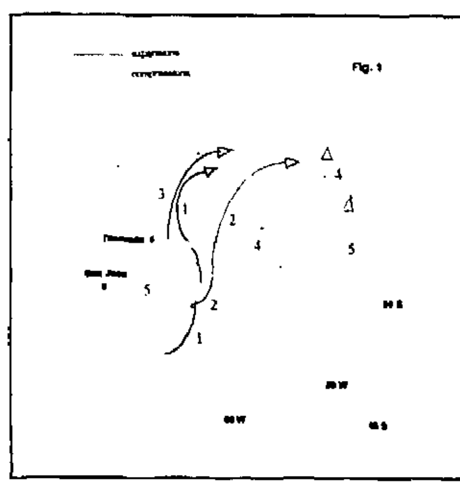
Five events have been studied, three of them corresponding to MCC's with strong northward component, and two with a prominent eastward component of their movement.

The MCC's chosen for this study correspond to events with good availability of ionospheric data obtained at Tucuman (26.9°S, 65.4° W) and San Juan (31.5°S, 65.6° W). Another reason for the particular choise of the events presented here was that those MCC's that were generated during periods of geomagnetic storms have been discarded. However, some of the processes studied have occurred during magnetic activity around -50 nT. In order to know if this activity could introduce significant changes in the ionosphere, a 12 days period distributed from November 1982 to March 1983, with no MCC activity but with Dst ≈ -50 nT, has been analyzed. Such a magnetic activity does not appear to influence the diurnal behaviour of foF2.

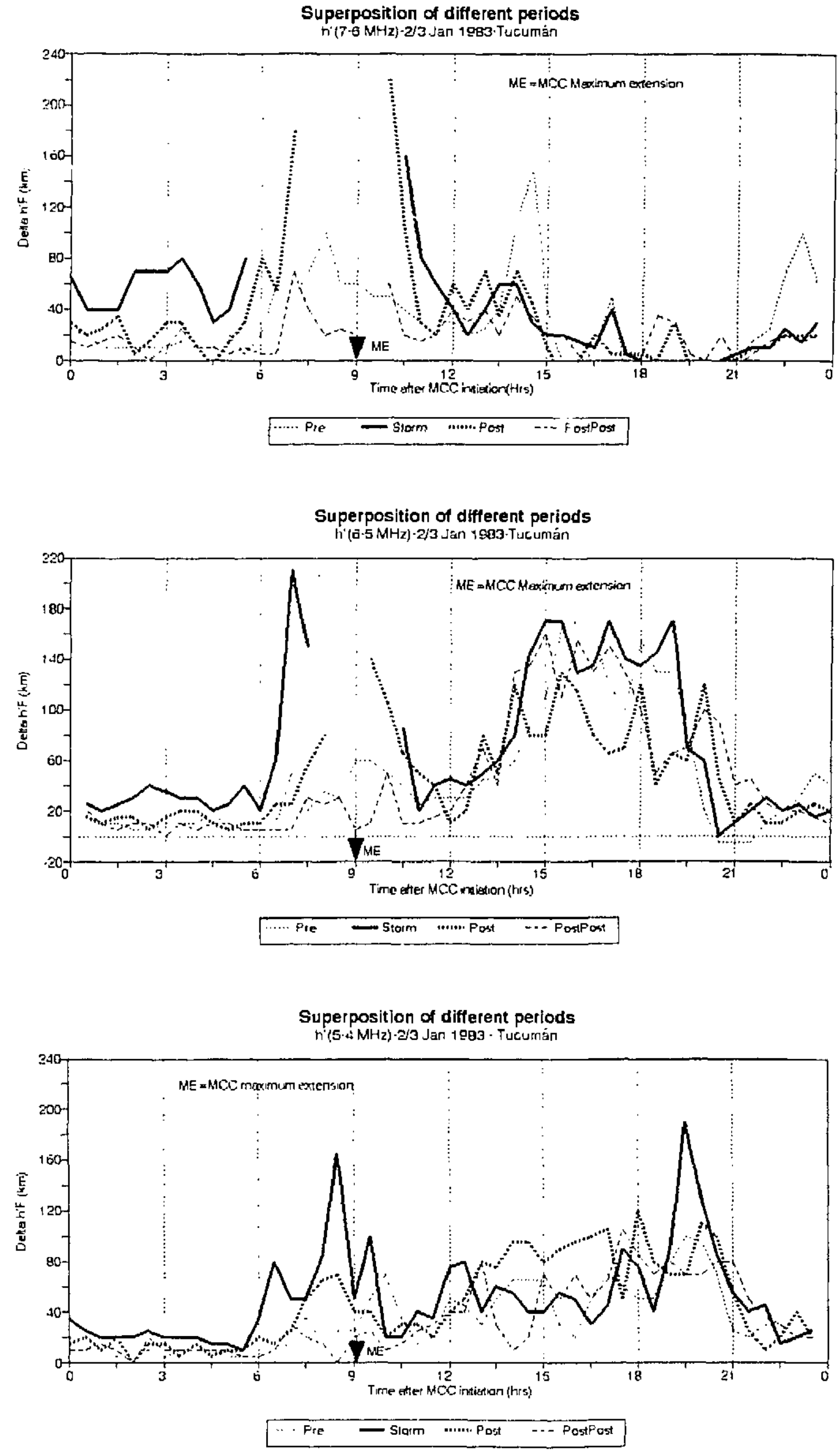
F-region critical frequency, foF2, and ionogram virtual heights of reflection at fixed frequencies, are used to study the behaviour of the ionosphere during the selected MCCs. The differences between the reflection virtual heights for 7 and 6 Mhz, 6 and 5 Mhz, and 5 and 4 Mhz were taken as indicators of F-region thickness before, during and after the presence of the MCC events. Spectra, made with FFT and autocorrelations methods, were obtained to study possible modifications of the F-region quasi-periodical oscillations of medium or large scale.

Table I

N° Date	Time, LST				Area x 10^3 km^2		
	First Storms	Initiation	Maximun Extent	End	T_{BB} -40°C	T_{BB} -62°C	
Expansions 1 2/3 Jan 1983	----	20 00	05 00	12.00	660	250	16
2 23/24 Jan 1983	07.00	10.00	02.00	18.00	950	300	32
3 11/12 Feb 1983	16 00	19 00	07 00	10 00	460	220	15
Compressions 4 27/28 Nov 1981	18.00	21.00	03.00	10 00	750	370	13
5 18/19 Nov 1982	11 00	17 00	02 00	11 00	1,300	450	18

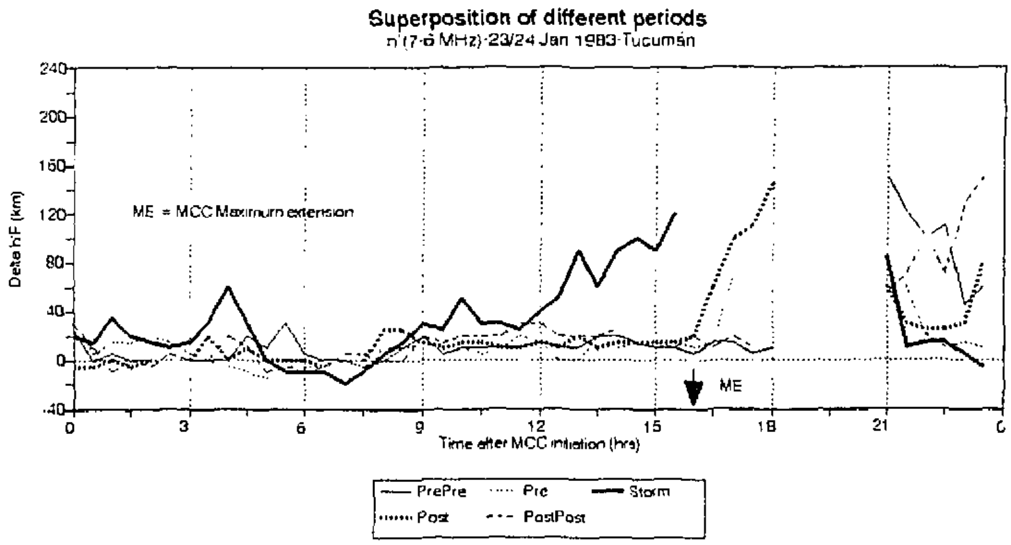


North-ward Trajectories: Data analysis shows the existence of expansions of the F-region during MCC events with trajectories having a strong component south-north (Fig.1). Main features of the MCCs are shown in Table 1. The processes on: 2-3 Jan (Fig. 2), 23-24 Jan (Fig.3), and 11-12 Feb (Fig.4), 1983, show a strong effect with the disappearence of the ionogram echo at 7, 6, 5 and even 4 Mhz (ME in the figure indicates the moment of the maximum extension of the MCC). Arising from the fact that during summer months (January - February), the diurnal minimum of the F-region at Tucumán rarely falls below 7 Mhz (only during winter foF2 is as low as 5 or even 4MHz) it can be assumed that this behaviour corresponds to a strong expansion of the F-region.



Superposition of different periods
h'(7·6 MHz)·2/3 Jan 1983·Tucumán
Delta h'F (km)
ME =MCC Maximum extension
ME
Time after MCC initiation(Hrs)
Pre
Storm
Post
PostPost
Superposition of different periods
h'(6·5 MHz)·2/3 Jan 1983·Tucumán
Delta h'F (km)
ME =MCC Maximum extension
ME
Time after MCC initiation (hrs)
Pre
Storm
Post
PostPost
Superposition of different periods
h'(5·4 MHz)·2/3 Jan 1983 · Tucumán
Delta h'F (km)
ME =MCC maximum extension
ME
Time after MCC initiation (hrs)
Pre
Storm
Post
PostPost

Fig.2


Superposition of different periods
h'(7-6 MHz)-23/24 Jan 1983-Tucumán
Delta h'F (km)
ME = MCC Maximum extension
ME
Time after MCC initiation (hrs)
PrePre
Pre
Storm
Post
PostPost

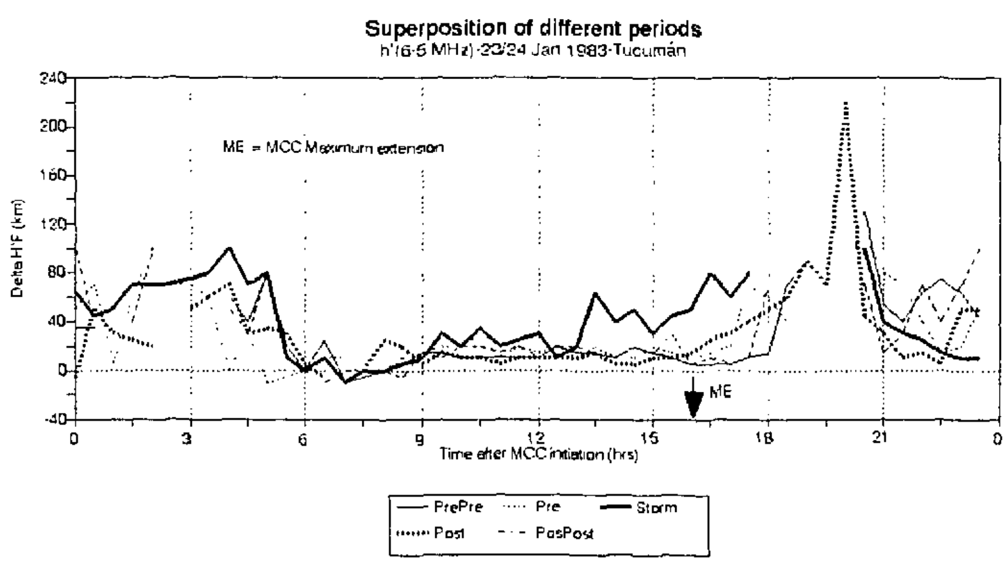

Superposition of different periods
h'(6-5 MHz)-23/24 Jan 1983-Tucumán
Delta H'F (km)
ME = MCC Maximum extension
ME
Time after MCC initiation (hrs)
PrePre
Pre
Storm
Post
PosPost

Fig.3

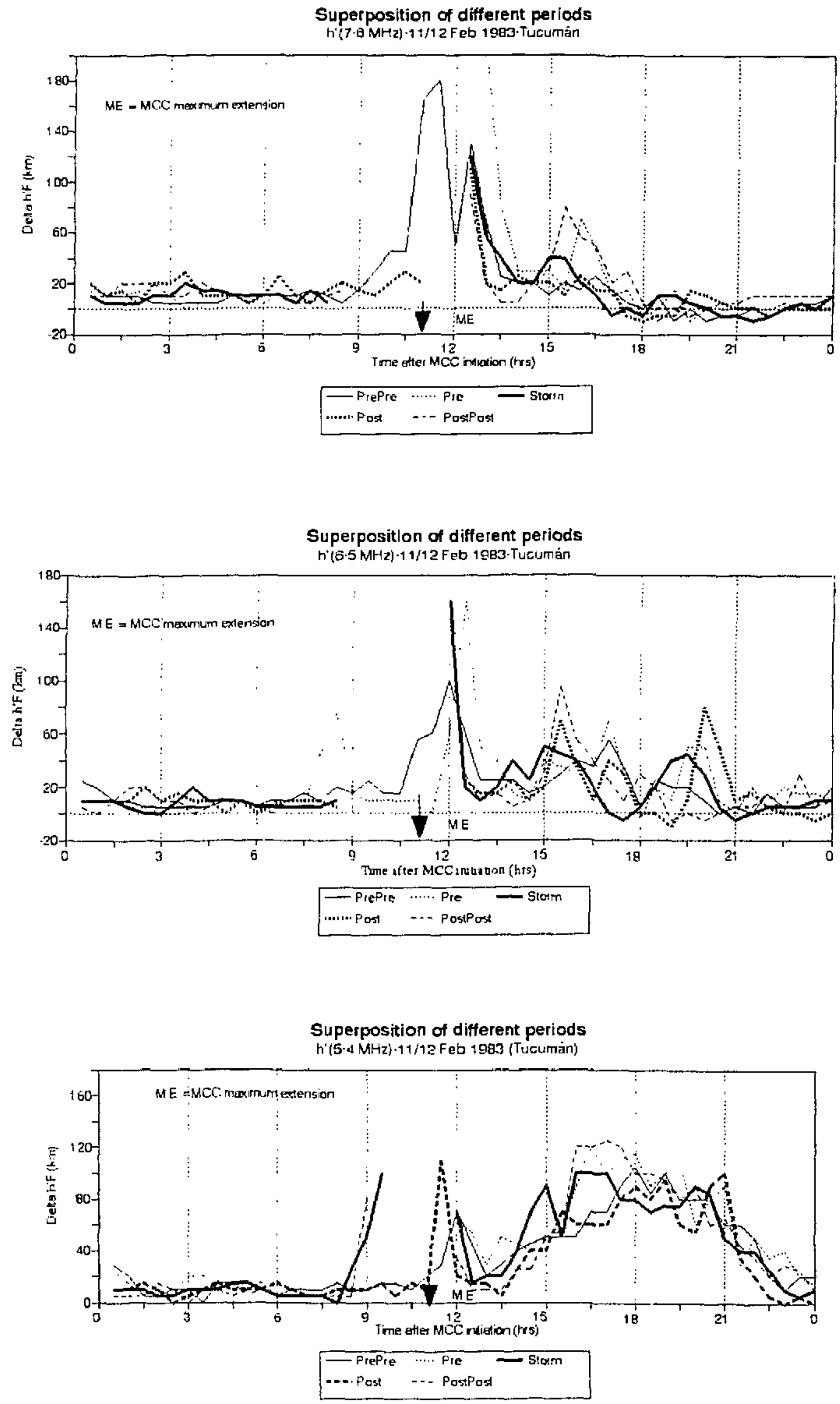

Superposition of different periods
h'(7-6 MHz)-11/12 Feb 1983-Tucumán
ME = MCC maximum extension
Delta h'F (km)
Time after MCC initiation (hrs)
ME
PrePre
Pre
Storm
Post
PostPost
Superposition of different periods
h'(6-5 MHz)-11/12 Feb 1983-Tucumán
M E = MCC maximum extension
Delta h'F (km)
Time after MCC initiation (hrs)
M E
PrePre
Pre
Storm
Post
PostPost
Superposition of different periods
h'(5-4 MHz)-11/12 Feb 1983 (Tucumán)
M E =MCC maximum extension
Delta h'F (km)
Time after MCC initiation (hrs)
M E
PrePre
Pre
Storm
Post
PostPost

Fig.4

Fig. 4 shows the disappearance of ionogram echo at 7, 6 and 5 Mhz one day before the MCC maximum extension. It could be attributed to the fact that the generation of the MCC for that ocassion has been in the same geographical region of Tucumán (Fig. 1) and the energy that is being accumulated during the generation of the process could be propagated in the vertical direction before the event is fully developed and it starts moving to the north.

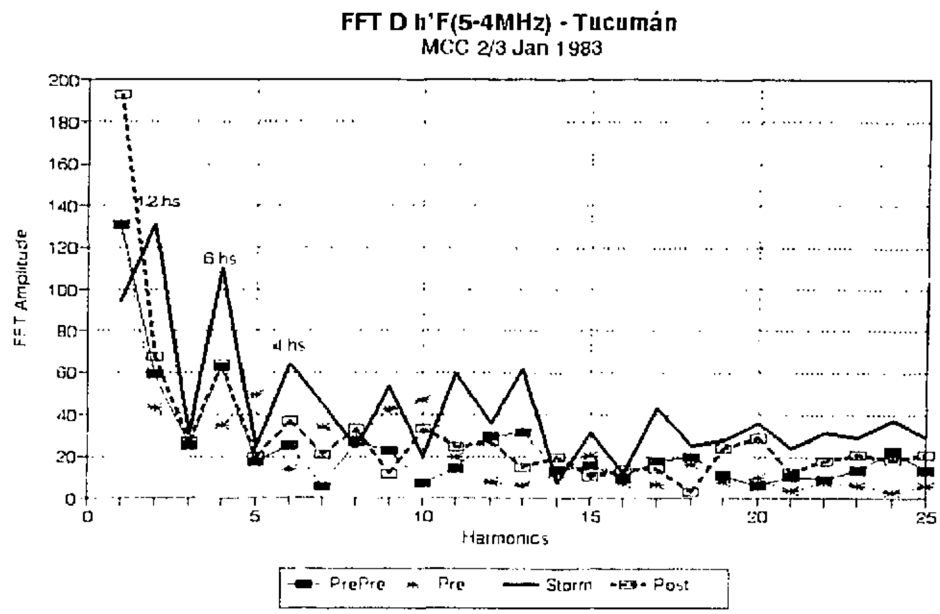


Fig. 5

Fig.5 shows the FFT harmonic analysis for the difference between the reflection heights for 5 and 4 Mhz, for the MCC of 2-3 January 1983 . The noticeable presence of harmonics with relatively large amplitude for the MCC storm period, not seen before or after this period could be due to the existence of a less dense ionosphere (expansion) with less capacity for damping the waves because of the increased collision mean free path . It also indicates the presence of a larger dynamic activity of the F region at the time of MCC.

East-ward Trajectories: For the MCCs with east-ward direction of their motion (Fig. 1) ionospheric data from Tucuman and San Juan have been used. Fig. 6 and 7 show the differences of virtual heights of reflection of 7-6 and 6-5 Mhz for the event of 27-28 November 1981 as observed in Tucuman and San Juan ionograms. The period of 06 Local Storm Time (LsT) or 03 Local Time (LT) corresponds to the diurnal minimum of electron density (equivalent to foF2) and a large thickness of the F-region. During the day of the tropospheric event the virtual height difference is lower than before and after such event and foF2 is increased as seen in Figure 8. This behaviour indicates that for eastward movements of the MCC the ionospheric effect is apparent compression of the F-region. The effect is more pronounced for Tucuman than San Juan. The reason of this difference of behaviour could be due to the fact that the MCC was generated over Tucuman and its extension was of 750 000 km2 equivalent to a radius of 500-600 km touching San Juan located 700 km south of Tucuman.

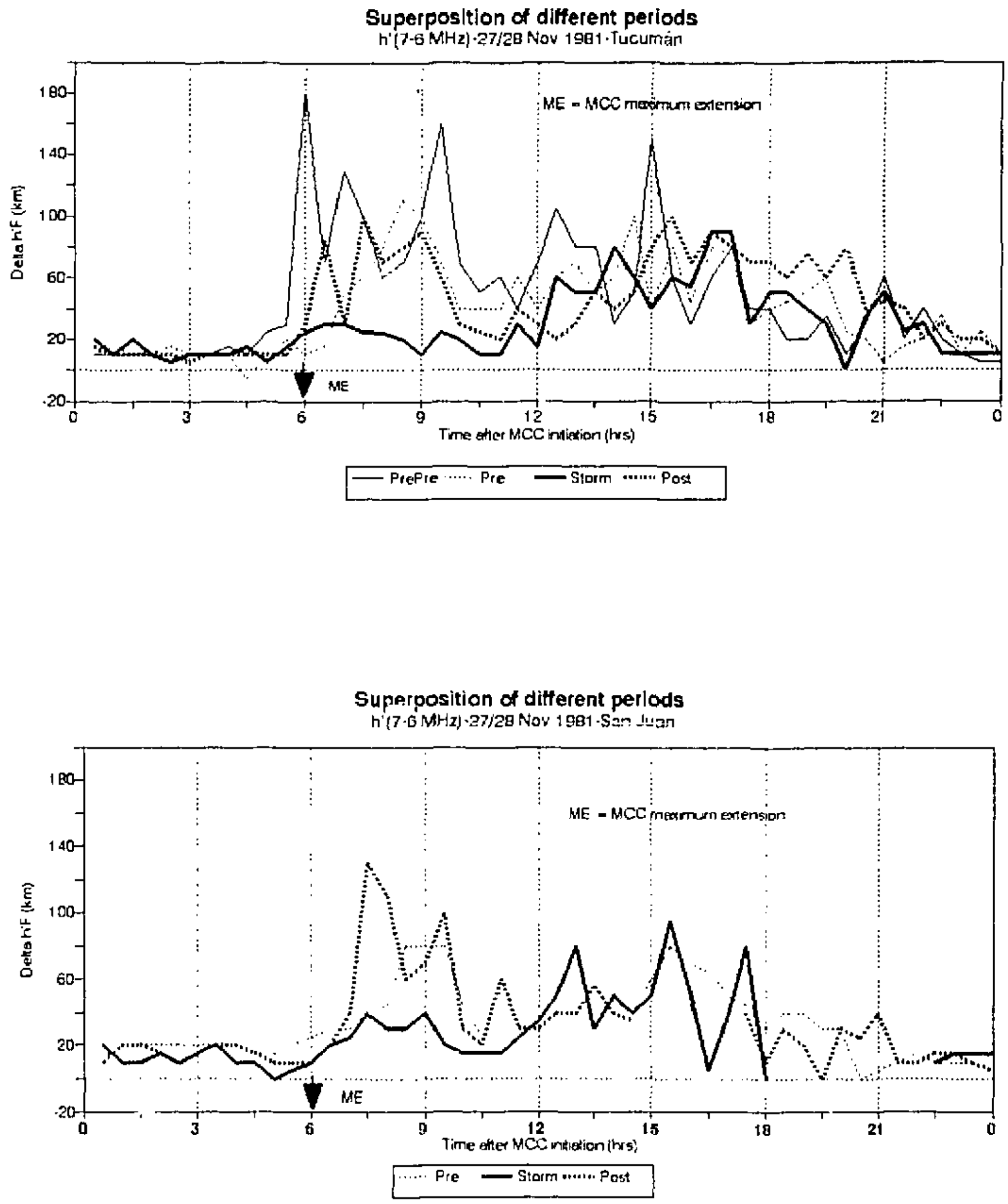
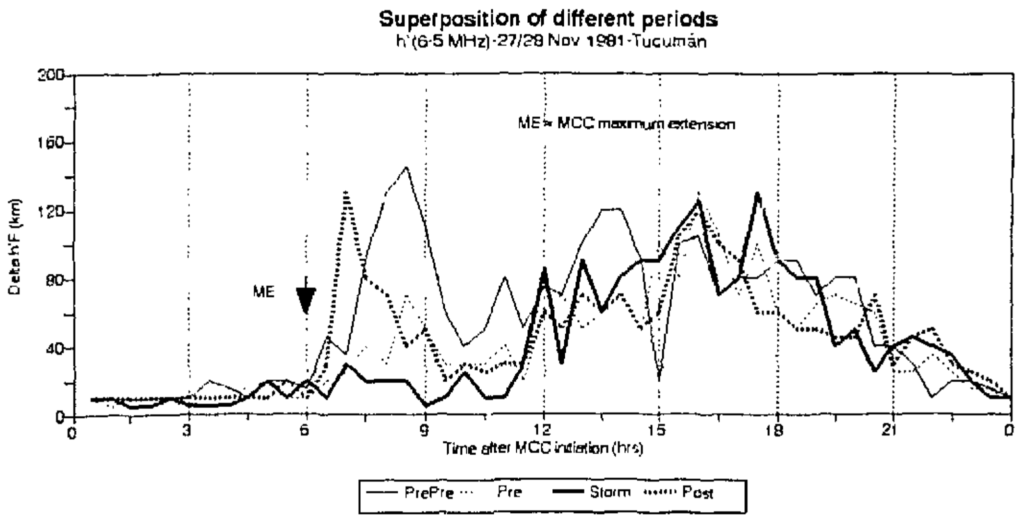

Superposition of different periods
h'(7-6 MHz)-27/28 Nov 1981-Tucumán
ME = MCC maximum extension
ME
Delta h'F (km)
Time after MCC initiation (hrs)
PrePre
Pre
Storm
Post
Superposition of different periods
h'(7-6 MHz)-27/28 Nov 1981-San Juan
ME = MCC maximum extension
ME
Delta h'F (km)
Time after MCC initiation (hrs)
Pre
Storm
Post

Fig.6


Superposition of different periods
h'(6·5 MHz)·27/28 Nov 1981·Tucumán
ME = MCC maximum extension
ME
Delta h'F (km)
Time after MCC initiation (hrs)
PrePre
Pre
Storm
Post

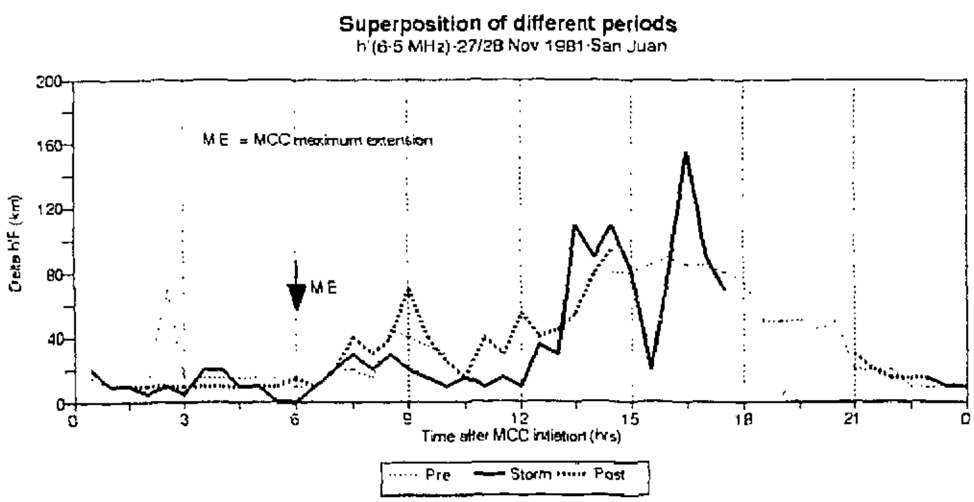
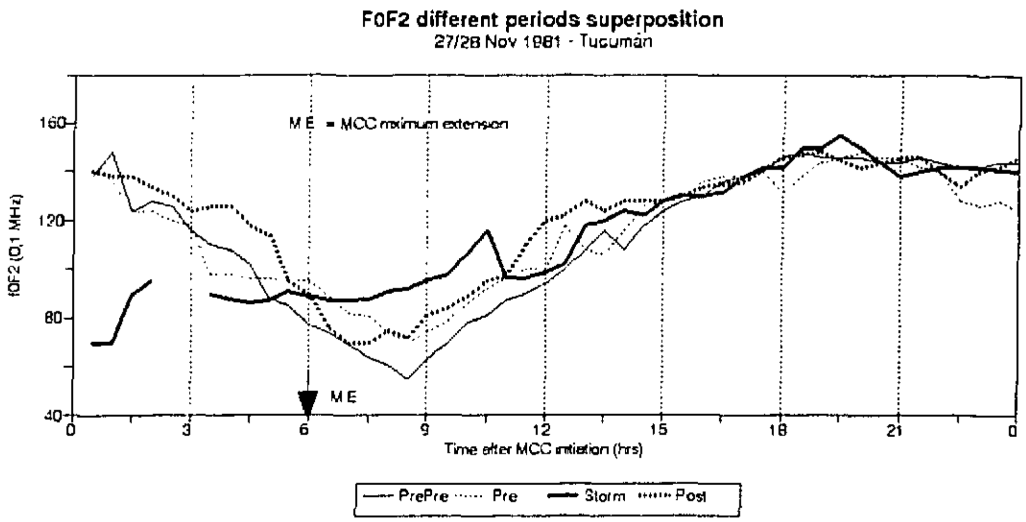

Superposition of different periods
h'(6·5 MHz)·27/28 Nov 1981·San Juan
M E = MCC maximum extension
M E
Delta h'F (km)
Time after MCC initiation (hrs)
Pre
Storm
Post

Fig.7


FOF2 different periods superposition
27/28 Nov 1981 - Tucuman
M E = MCC maximum extension
M E
fOF2 (0.1 MHz)
Time after MCC initiation (hrs)
PrePre
Pre
Storm
Post

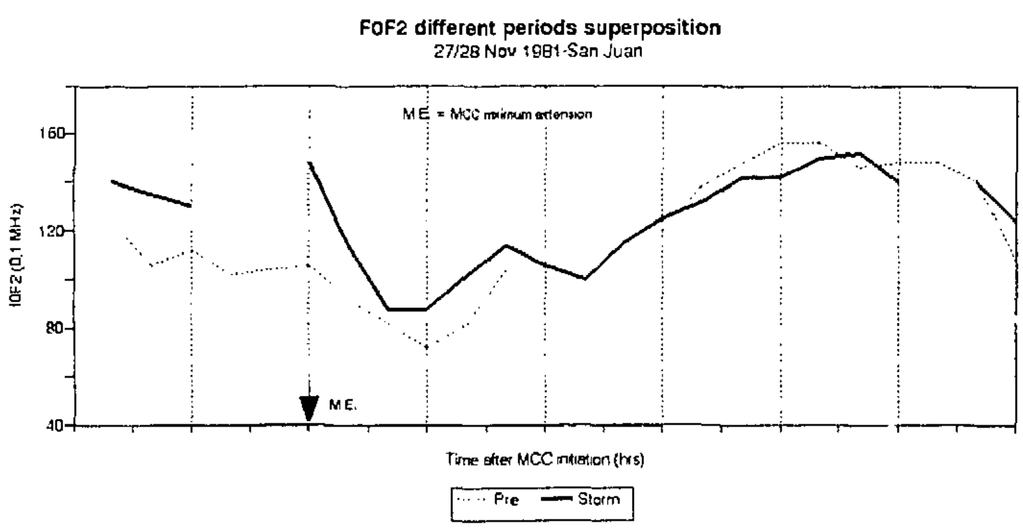

FOF2 different periods superposition
27/28 Nov 1981-San Juan
M E = MCC maximum extension
M E.
fOF2 (0.1 MHz)
Time after MCC initiation (hrs)
Pre
Storm

Fig.8

Fig. 9 corresponds to the FFT analysis fot the virtual height differences 7-6 and 6-5 Mhz. It shows a damping of the waves that corresponds to tidal motions during the storm period. These result could confirm the suggested compression mechanism indicated above through the increase of electron density and the resulting reduction of collision mean free path.

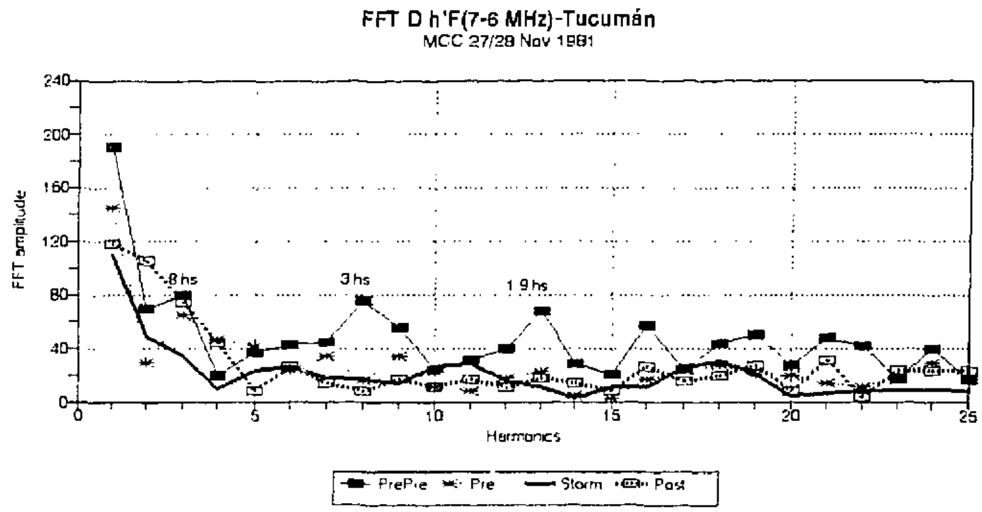


Fig. 9

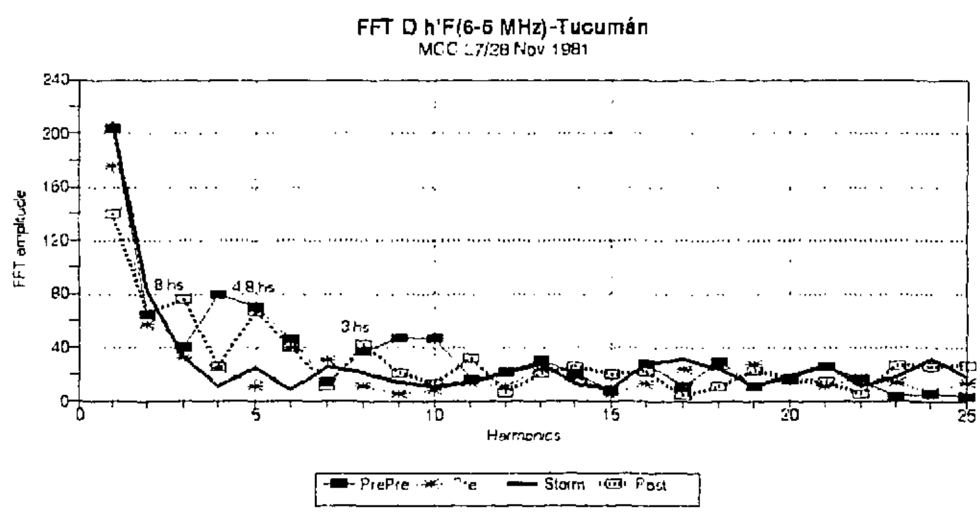
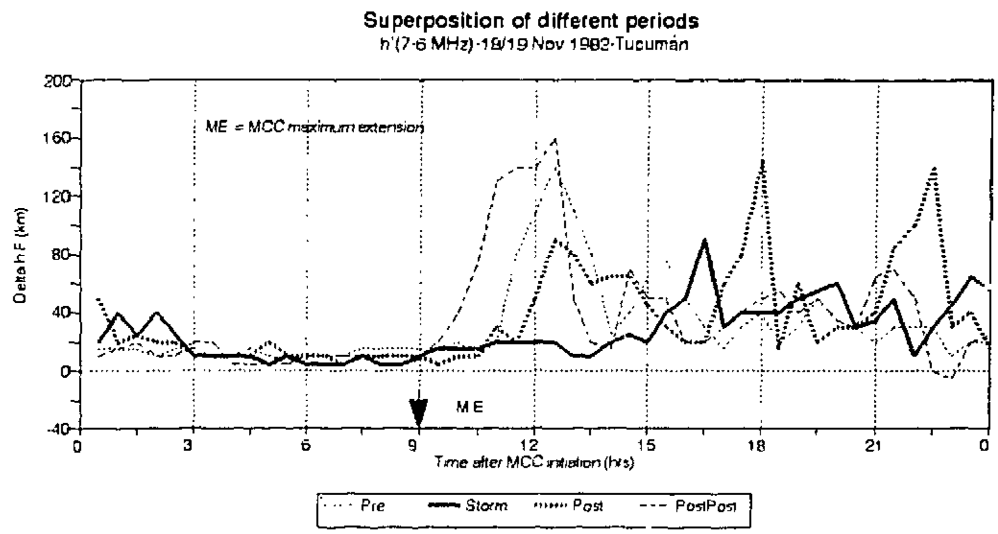


Fig. 10, 11 and 12 show the results of the analysis for the MCC of 18-19 November 1982.The behaviour observed for this case is similar than the one described for the other eastward event.


Superposition of different periods
h'(7-6 MHz)-18/19 Nov 1982-Tucumán
ME = MCC maximum extension
ME
Delta h'F (km)
Time after MCC initiation (hrs)
Pre
Storm
Post
PostPost

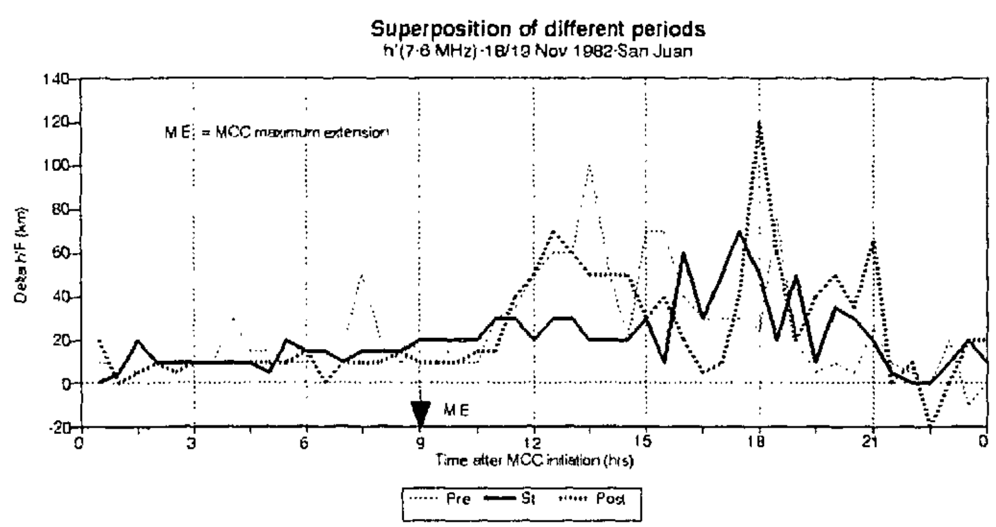
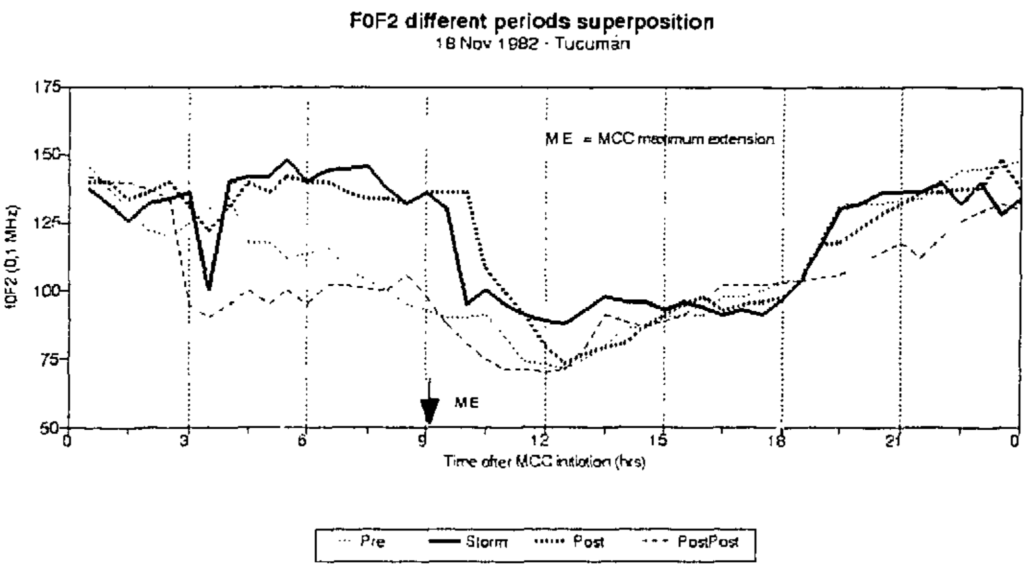

Superposition of different periods
h'(7-6 MHz)-18/19 Nov 1982-San Juan
ME = MCC maximum extension
ME
Delta h'F (km)
Time after MCC initiation (hrs)
Pre
St
Post

Fig.10


F0F2 different periods superposition
18 Nov 1982 - Tucuman
M E = MCC maximum extension
ME
10F2 (0,1 MHz)
Time after MCC initiation (hrs)
Pre
Storm
Post
PostPost

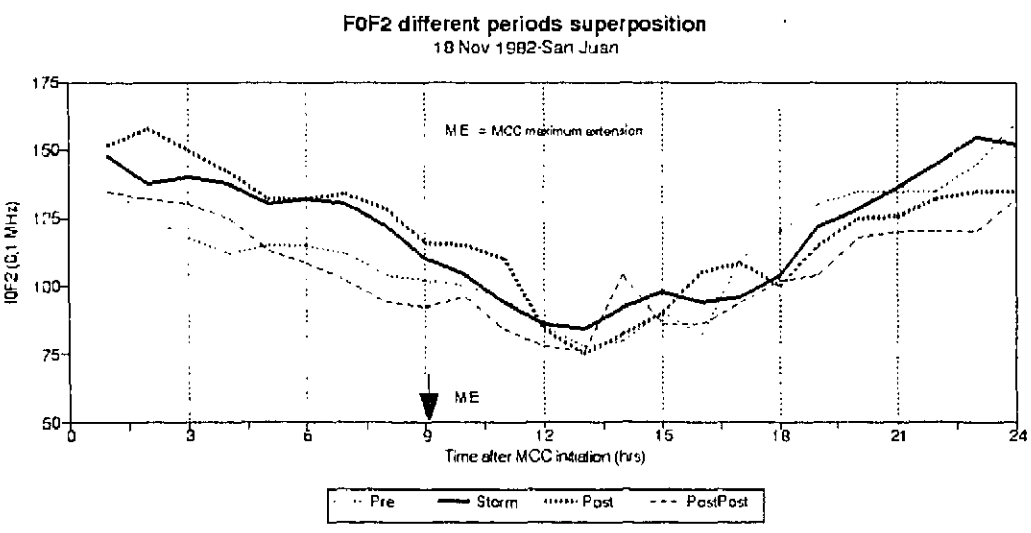

F0F2 different periods superposition
18 Nov 1982-San Juan
M E = MCC maximum extension
ME
10F2 (0,1 MHz)
Time after MCC initiation (hrs)
Pre
Storm
Post
PostPost

Fig.11

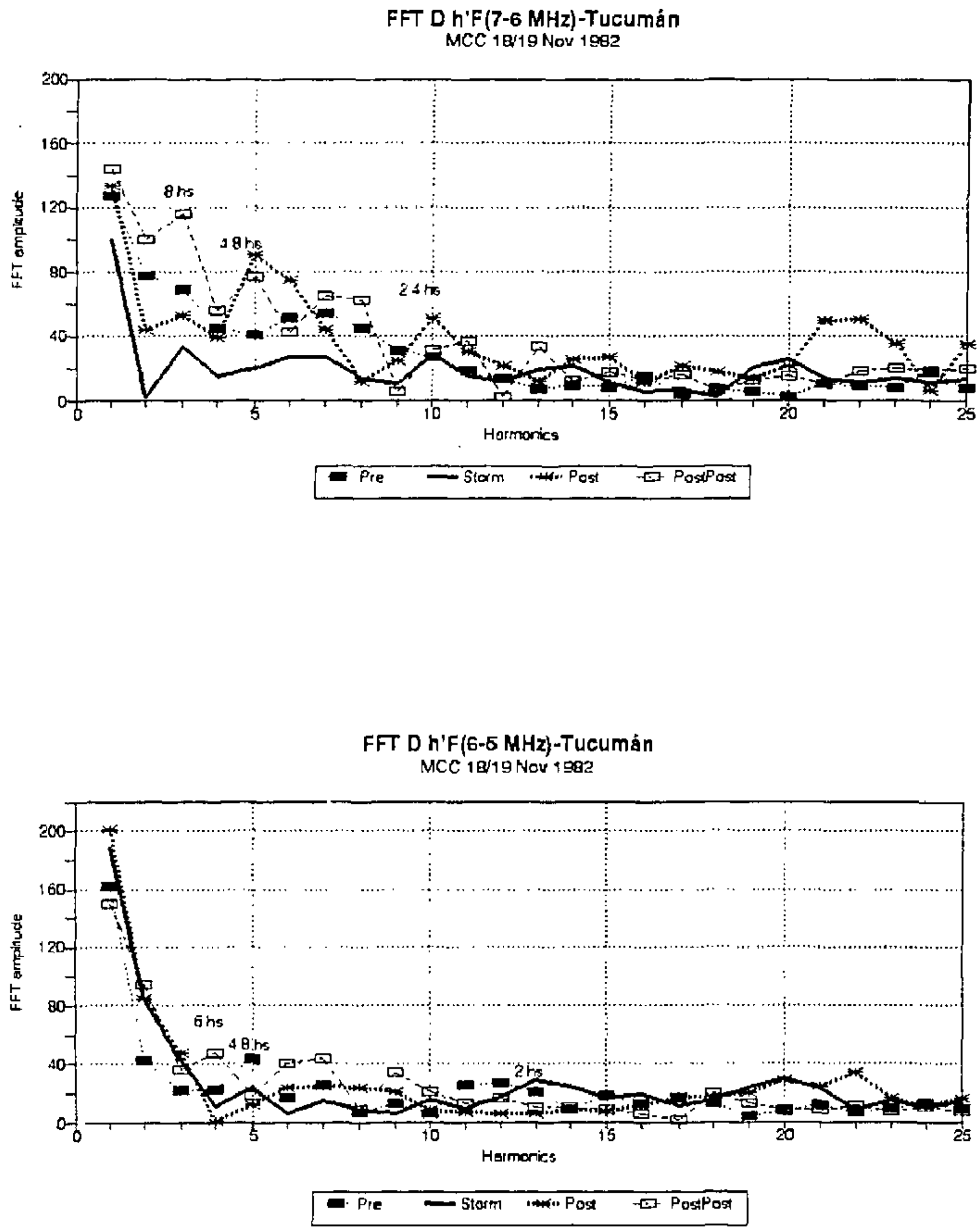

FFT D h'F(7-6 MHz)-Tucumán
MCC 18/19 Nov 1982
FFT amplitude
Harmonics
8 hs
12 hs
24 hs
Pre
Storm
Post
PostPost
FFT D h'F(6-5 MHz)-Tucumán
MCC 18/19 Nov 1982
FFT amplitude
Harmonics
6 hs
4.8 hs
2 hs
Pre
Storm
Post
PostPost

Fig.12

DISCUSSION

As mentioned in the introduction several meteorological phenomena appear to leave their signatures in the behaviour of the ionosphere including the F-region. This paper shows indications that also large warm-season systems like the MCCs can influence the thickness and electron density in the F-region at low latitudes in central South America. However this influence seems to be markedly different according to the direction of the motion of the meteorological system. If such motion is north-ward the apparent effect is an expansion of the ionospheric layer revealed by the increasing of the virtual height differences at fixed frequencies. Such expansion can reach the point where the ionogram echo desappears. When the motion is east-ward the possible effect is reversed and a compression appears in the presence of MCCs as seen by the reduction of the virtual height differences and the increase of foF2.

This apparent contradiction could be explained by the following physical mechanism.

The large meteorological system is such that the energy released can penetrate the tropopause and propagate up to the mesosphere and ionosphere. This energy generates a motion of neutral air and also - by collission processes - of electrons and ions that should follow preferentially the equipotential geomagnetic field lines. This is the case of the north-ward motion of MCCs where the charged particles will be carried along the field lines, with a reasonably large vertical component that helps the up-ward motion. This effect will produce a vertical movement of electrons to a region where they can be easily distributed in height, because of the reduced collision mean free path, producing the expansion seen in the virtual height differences. In the case of east-ward motion of the MCCs the charged particles are forced to cross the geomagnetic field lines by the predominant east-ward horizantal component of the motion. During this crossing the ions suffer the influence of a force $\mathbf{F} = q(\mathbf{v}x\mathbf{B})$ - being q the ions charge, **v** the ions velocity and **B** the geomagnetic field vector - which finally will preclude the vertical movement of electrons forcing them to remain in a region with a shorter collision mean free path. In turn this effect will appear as a compression of the ionospheric layer that will produce a large damping of atmospheric waves.

CONCLUSION

The presence of large warm-season meteorological systems (MCCs) in the troposphere of central South America seems to leave an important signature in the F-region of the ionosphere over that region. The effect appears to be dependent on the direction of the motion of the meteorological system inviolved. North-ward motion will produce an expansion of the layer and an east-ward motion will generate a compression of it. This different behaviour could be explained by the geometry of the geomagnetic field in the area.

Acknowledgements.- Thanks are due to Dr. I. Velasco for stimulating discussions about MCCs. The authors also thank Oscar, Ana María and Sonia Lascano, for the hard task accomplished to process Tucumán ionospheric data for this study.

REFERENCES

ARENDT, P. R. and FRISBY, E. E. M.; NATURE, 219, 475, 1968.

BAUER, S. J.; J. GEOPHYS. RES., 62, 425, 1957.

BAUER, S. J.: J. GEOPHYS. RES., 63, 265, 1958.

CHEN, P. R.; GEOPHYS. RES. LETT., 19, 1089, 1992.

GHERZI, E.; NATURE, 165, 38, 1950.

GOLDBERG, R. A.; External and internal influences on the global electric circuit ; Note presented at the CONFERENCE ON MAJOR SCIENTIFIC PROBLEMS OF THE ATMOSPHERIC SYSTEM AND THE DEVELOPING COUNTRIES, I.C.T.P., Trieste, Italy, November 1991.

KERSLEY, L. and REES, P. R.; J. ATMOS. TERR. PHYS., 44, 147, 1982.

MADDOX, R.A.; BULL. AM. METEOROL SOC., 61, 1374, 1980.

SHRESTA, K. L.; J. ATMOS. TERR. PHYS., 33, 205, 1971.

SHRESTA, K. L.; J. ATMOS. TERR. PHYS., 33, 213, 1971.

VELASCO, I. and FRITSCH, J. M.; J. GEOPHYS. RES., 92, 9591, 1987.

YI, LUO and CHEN, P. R.; J. ATMOS. TERR. PHYS., 55, 1317, 1993.