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14. Abstract/Notes

Ionospheric investigations at INPE are mainly concerned with the problems of equatorial and tropical ionospheres and their electrodynamic coupling with the high latitude ionosphere. Present research objectives include investigations in the following specific areas: equatorial ionospheric plasma dynamics; plasma irregularity generation and morphology, and effects on space borne radar operations; ionospheric response to disturbance dynamo and magnetospheric electric fields; aeronomic effects of charged particle precipitation in the magnetic anomaly, etc. These problems are being investigated using experimental data collected from ionospheric diagnostic instruments being operated at different locations in Brazil. These instruments are: ionosondes, VHF electronic polarimeters, L-band scintillation receivers, airglow photometers, riometers and VLF receivers. A brief summary of the research activities and some recent results will be presented.

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IONOSPHERIC RESEARCH AT INPE

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ABSTRACT

Ionospheric investigations at INPE are mainly concerned with the problems of equatorial and tropical ionospheres and their electrodynamic coupling with the high latitude ionosphere. Present research objectives include investigations in the following specific areas: equatorial ionospheric plasma dynamics; plasma irregularity generation and morphology, and effects on space borne radar operations; ionospheric response to disturbance dynamo and magnetospheric electric fields; aeronomic effects of charged particle precipitation in the magnetic anomaly, etc. These problems are being investigated using experimental data collected from ionospheric diagnostic instruments being operated at different locations in Brazil. These instruments are: ionosondes, VHF electronic polarimeters, L-band scintillation receivers, airglow photometers, riometers and VLF receivers. A brief summary of the research activities and some recent results will be presented.

INTRODUCTION Ionospheric research at INPE had its beginning in 1963, starting with the reception of VHF radio beacon from polar orbiting satellites measuring the total electron content in the earth-satellite propagation path. These early measurements were soon extended to other ionospheric parameters using different ground based techniques, such as VLF phase track receivers to monitor lower ionospheric properties and riometers to measure the integrated ionospheric absorption of Cosmic Radio Waves. Regular ionospheric vertical soundings were started at Cachoeira Paulista in 1973 and at the magnetic equatorial station Fortaleza in 1975. In recent years significant progress has been made in developing and building, or in acquiring, new diagnostic techniques for experimental investigations of the ionosphere.

These investigations have the general objective to gain new insights into the physical, dynamical and chemical processes of the different height regions of the ionosphere over Brazil in relation to other geographical regions of the earth, with special attention given to the role of the ionosphere in practical areas of the space activity. Identification of specific investigation areas is naturally influenced by local geomagnetic and geographic considerations peculiar to Brazil, as well as by considerations on global electrodynamic coupling processes. Those considerations necessarily call for coordinated experimental campaign efforts involving participation of international scientific groups. In recent years a few of such collaborative campaigns have been conducted. The areas of investigation currently being pursued are among those that have direct impact on ionospheric and transionospheric communication system considerations, as well as those that concern the wider areas of space plasma and upper atmospheric processes. A brief discussion of those investigation areas, approach of the investigation and a brief summary of some recent and important results are presented in this paper.

PRINCIPAL PROBLEM AREAS UNDER INVESTIGATION Presently ionospheric investigations are being carried out in the following areas: 1) (a) Equatorial ionospheric electrodynamics: Plasma instability mechanisms; generation, morphology and latitudinal and longitudinal distribution of plasma irregularities; Ionospheric irregularity effects on transionospheric radio propagation. (b) E and F region electrical coupling: Dynamo electric fields; Ionization drifts and neutral winds, etc. 2) Ionospheric irregularity effects on the quality and integrity of space borne radar image processing and information extraction at L-band frequencies (SIR-B). 3) Aeronomic effects of charged particle precipitation in the South Atlantic Geomagnetic Anomaly: Sporadic E-layer formation and morphology in the anomaly; VLF radio wave propagation in the lower ionosphere over the anomaly. 4) Global electrodynamic coupling processes and ionospheric disturbances: Low latitude ionospheric response to magnetospheric and auroral disturbances; Magnetospheric electric field penetration to low latitude; Ionospheric response to large scale atmospheric gravity waves (TID's). 5) Ionospheric modelling: Numerical modelling of the E and F region electrodynamic coupling; Modelling of tropical ionosphere ion densities during quiet and disturbed conditions; Comparative study of ionospheric propagation prediction models with observational data for the Brazilian stations; Lower ionosphere chemistry and role of important minor neutral constituents in the lower ionospheric density and composition.

IONOSPHERIC OBSERVATIONAL NETWORK OPERATED BY INPE In Figure 1 we have presented the geographic distribution of the different ground based instruments used for routine monitoring of the ionosphere parameters at different locations in Brazil. Two vertical sounding ionosondes are now being operated by INPE: one (type C-4) at the magnetic equatorial station Fortaleza (4°S, 38°W, dip latitude 1.8°S) and another (type Magnetic AB) at the low latitude station Cachoeira Paulista (23°S, 45°W, dip latitude 14°S). The ionograms, taken at quarter hourly intervals, provide data on the critical frequencies and virtual heights of the different layers, presences of spread F irregularities, sporadic E-layers etc. The F-layer height variation could provide measure of F-region zonal electric field over the equator under favourable conditions. The ionograms are also used for true height analyses. An additional ionosonde is being proposed to be installed at the magnetic equatorial location Conceição do Araguaia.

Two elevation scanning 6300Å airglow photometers are operated at Cachoeira Paulista in east-west and meridional scan modes, to investigate the dynamics of the tropical ionosphere.

VHF electronic polarimeters are being operated at Cachoeira Paulista and São José dos Campos for monitoring the total electron content (TEC) in the geostationary satellite propagation path, by measuring the Faraday rotation angle of VHF signals transmitted by the satellites. Simultaneous recordings of TEC at the two sites provide also the zonal drift velocities of plasma bubble structures and scintillation irregularity patches. Two more polarimeters are being planned to be installed at Brasília and Goiânia in the immediate future. Further expansion of the polarimeter network is planned by including three more locations, namely, Fortaleza, Vassouras and Blumenau.

One L-band scintillation receiver is being operated at São José dos Campos. This will shortly be operated in a spaced reception mode by adding a second receiving system at a point magnetically westward of the present one.

One VLF phase track receiver is used at São José dos Campos to record the amplitude and phase of omega transmission from Argentina.

Three riometers are operated at Cachoeira Paulista with their antennas directed in different directions to measure the cosmic noise absorption and its spatial and temporal variations in the D and F regions of the ionosphere.

<u>IONOSPHERIC INSTRUMENTS UNDER DEVELOPMENT</u> As part of an ongoing program for development of new ionospheric diagnostic techniques, the ionospheric division is developing a backscatter coherent radar. This radar will be capable of measuring 3 m irregularity distribution and dynamics in the equatorial electrojet and in the F-region. This is a pulsed monostatic radar working with a peak transmitter power of 120KW (Janardhanan, 1983). After its completion, expected to be in 1985, this radar will be installed and operated at the magnetic equatorial station in Fortaleza.

The ionospheric division is also developing rocket payloads for in situ measurements of ionospheric properties. These payloads will be launched on soundings rockets provided by the Instituto de Atividades Espaciais (IAE), São José dos Campos. The different payloads will be measuring the ionospheric electron densities, temperatures, plasma irregularity distribution spectra and nitric oxide concentrations.

<u>SOME RECENT INVESTIGATIONS AND RESULTS</u> An international campaign called the Brazilian Ionospheric Modification Experiment (BIME) was conducted in September 1982 from Natal region to study the equatorial F-region dynamics and possible plasma irregularity generation mechanisms. The campaign was organized by the AFGL

(USA) and Max Plank Institute (Germany) in collaboration with IAE and INPE and with participation of a number of research groups in USA. A perspective schematic of the campaign is shown in Figure 2. As part of the experiment two SONDA III rockets were used to perturb the ambient ionospheric plasma by explosive releases of water vapour creating water holes in the bottom side F-region, in an attempt to initiate irregularity generation. The development and decay and the dynamics of the water hole as well as the irregularity generation resulting from the perturbations were monitored using ground based on airborne digisondes and airglow imaging cameras, VHF electronic polarimeters and radars. The ionosonde and polarimeter operated by INPE and IAE at Fernando de Noronha, some 400km eastward of the launch site, detected the plasma irregularities produced by the water release experiments. In a second phase of the campaign, denominated "Coloured Bubble", Barium and Europium vapour clouds were released at different heights in the bottomside F-region to determine wind shears, as well as to initiate irregularity generation at the bottomside F-region electron density gradient region based on the Rayleigh--Taylor instability criterion. Following this experiment also irregularity developments from the vapour cloud releases were detected by the ionosonde and polarimeter at Fernando de Noronha. For the first time an ionosonde was used to track ionized Barium vapour trails and associated irregularity drifts to great distances (~500km) from the point of their releases. Figure 3 presents some results obtained from one of the two Coloured Bubble experiments. (See Abdu et al., 1983a, 1984a).

Transequatorial plasma bubble vertical rise velocities were deduced from analysis of ionogram data obtained from latitudinally spaced ionosondes. In this analysis range spread F onsets over

Fortaleza were compared with those over Cachoeira Paulista and the systematic difference in these onset times were interpreted as caused by vertical rise velocities of the flux tube aligned plasma bubbles. These velocities showed good correlation with the evening F-region zonal electric field variations. Figure 4 shows an example of these results (Abdu et al. 1983b, c).

The VHF satellite signal amplitude scintillation data recorded at Natal and range spread F events observed at Fortaleza were analysed and the yearly statistical occurrence patterns were compared between them and with such irregularity occurrences statistics available for Huancayo, Peru. The corresponding F-region dynamo electric field developments at the Brazilian and Peruvian locations were also compared. These results provided, for the first time, important clues on the role of magnetic declination control (through the conjugate E-layer conductivity gradients) in the seasonal behaviour of the equatorial ionospheric irregularity occurrences. (Abdu et al., 1981; Medeiros et al., 1983).

Polarimeters recordings of TEC simultaneously at two stations, Cachoeira Paulista and São José dos Campos, having a magnetic east-west separation of 110km,have permitted determination of zonal velocities of plasma bubble structures. These velocities showed exactly similar local time variation as that of the zonal bulk plasma velocities measured by Jicamarca radar, and that of the irregularity drift detected from other techniques near the equator. However, our measurements at low latitude region presented significantly higher velocities compared to the radar measurements (Figure 3). These results suggested the possibility of a latitudinal gradient in the zonal plasma motion, in agreement with the known features of the vertical velocity shears in the plasma flow over the equator (Abdu et al., 1984b). Studies of the zonal plasma bubble velocities during magnetospheric disturbances showed that the bubble irregularity events occurrences that are usually limited to local times near and before the local midnight extends to morning hours, and the zonal flow at these hours (near 03-04 LT and after) reverses to westward direction (Abdu et al., 1984b).

Zonal velocities of plasma bubbles were also measured by east-west scanning 6300Å airglow photometers operated at Cachoeira Paulista. Data from two years of measurements were analysed to determine average local time dependence of these velocities. Part of the data showed good agreement with the polarimeter results, while significant departure from the "normal" pattern was observed in the remaining set of data. Possible causes for these differences are now being investigated (Sobral et al., 1984).

Solar cycle variations in the range spread F occurrences over the equatorial and low latitude locations were analysed together with corresponding variations in the plasma bubble vertical rise velocities and the F-region dynamo induced zonal electric field in the evening hours. While the monthly percentage spread F occurrence over the equator (Fortaleza), in the evening hours, was very high (close to 90-95 percent) in all the phases of the solar activity, that over the low latitude location (Cachoeira Paulista) showed an increase of a factor of ~3 from solar activity minimum (~30%) to solar activity maximum (~90%) epochs. The plasma bubble rise velocity and F-layer zonal electric field also increased by a similar factor, suggesting that the plasma bubble irregularity generations occur primarily over the equator and the vertical rise of the flux tube aligned plasma bubble would account for the occurrences of spread F irregularities over the low latitude locations (Abdu et al., 1984c, d).

CONCLUDING REMARKS A few of the most important results obtained in the last two years have been summarised above. Investigations are continuing in these and other areas of interests mentioned earlier. It is particularly important to mention that studies are being carried out to understand more about the equatorial E and F region electrical coupling processes, and about the response of the tropical ionosphere to magnetospheric disturbances when global electrodynamic coupling and disturbance dynamo effects produce significant modifications in the low latitude regions. These studies are being carried out by using numerical modelling to interpret the observational data. It is hoped that the completion of the coherent radar and developments of different rocket payloads, together with the realization of the proposed extension of the ground based ionospheric diagnostic systems mentioned earlier, will complement greatly to enhance our ability to undertake further important investigations into these and several remaining problems of the equatorial and low latitude ionosphere and neutral atmosphere.

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FIGURE CAPTIONS

Fig. 1 - Ground based ionospheric diagnostic instruments locations in Brazil showing those that are operational as well as the ones proposed for the immediate future. The magnetic dip latitude and magnetic meridian lines are also shown besides the geographic coordinates.

Fig. 2 - A perspective representation of the BIME - Coloured Bubble ionospheric modification experiment campaign of September 1982 conducted from Natal.

Fig. 3 - A plot of the local time versus longitude of two big Barium clouds positions during the Coloured Bubble II experiment, tracked optically from Natal (Δ, ▲) as well as by ionosonde at Fernando de Noronha (0, 0). Scintillation onsets and durations observed, on SIRIO VHF beacon, by the polarimeter at Fernando de Noronha are shown by the vertical patches.

Fig. 4 - Ten-day running means of the vertical bubble rise velocity for January and February 1978, plotted together with the corresponding running means of the amplitudes of the prereversal enhancements in the F-layer vertical rise velocities in the evening hours, $\overline{V}_{zp}$, and with those of the heights of the base of the F-layer, $\overline{h'F}$.

Fig. 5 - Zonal velocities of plasma bubble structures representing the average summer 1982-83 conditions, measured on VHF beacon from SIRIO, marked by open circles. The curve through solid triangles represents the average summer 1981-82 zonal plasma bubble velocities measured on VHF beacon from GOES-3 satellite.

Note that SIRIO was eastward and GOES-3 was westward of the magnetic meridians of São José dos Campos and Cachoeira Paulista. (Eastward is up from zero).

Fig. 6 - Local time variation of eastward velocities of airglow valleys taken as averages within 20-minutes intervals for all the nights of group 1 (broken line) and group 2 (solid line).

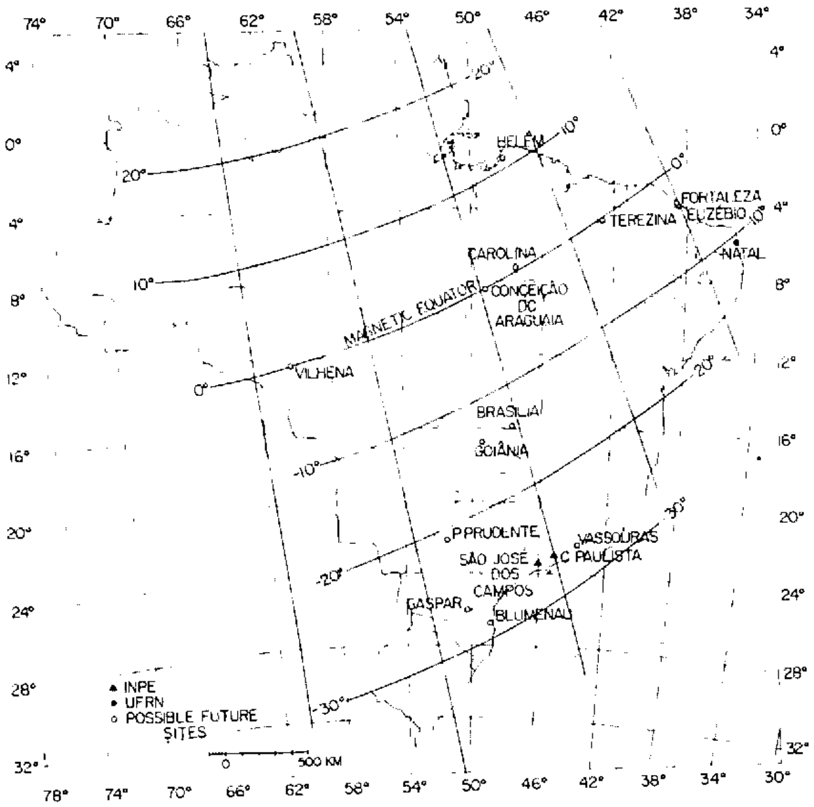
BELÉM
FORTALEZA
EUZÉBIO
TEREZINA
NATAL
CAROLINA
CONCEIÇÃO DO ARAGUAIA
MAGNETIC EQUATOR
VILHENA
BRASILIA
GOIÂNIA
P.PRUDENTE
VASSOURAS
SÃO JOSÉ DOS CAMPOS
C.PAULISTA
GASPAR
BLUMENAU
INPE
UFRN
POSSIBLE FUTURE SITES
0 500 KM

Fig. 1

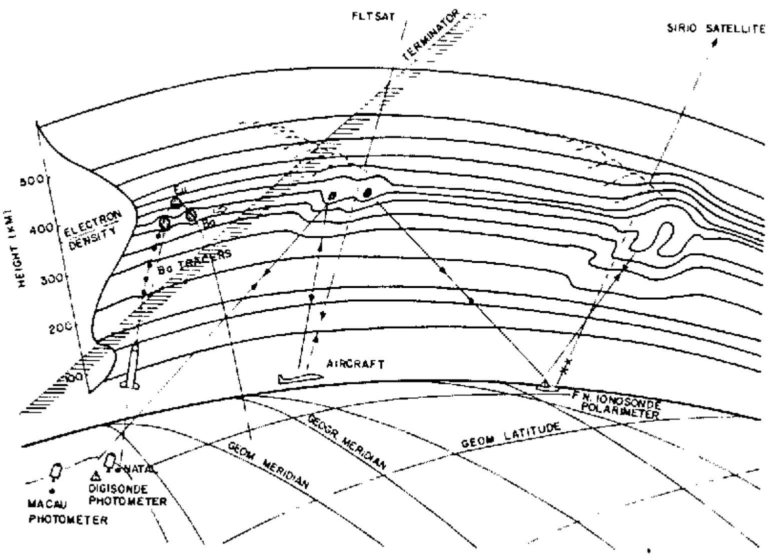
FLTSAT
TERMINATOR
SIRIO SATELLITE
HEIGHT (KM)
ELECTRON DENSITY
TRACERS
AIRCRAFT
F.N. IONOSONDE POLARIMETER
GEOM LATITUDE
GEOGR MERIDIAN
GEOM MERIDIAN
NATAL
DIGISONDE PHOTOMETER
MACAU PHOTOMETER

Fig. 2

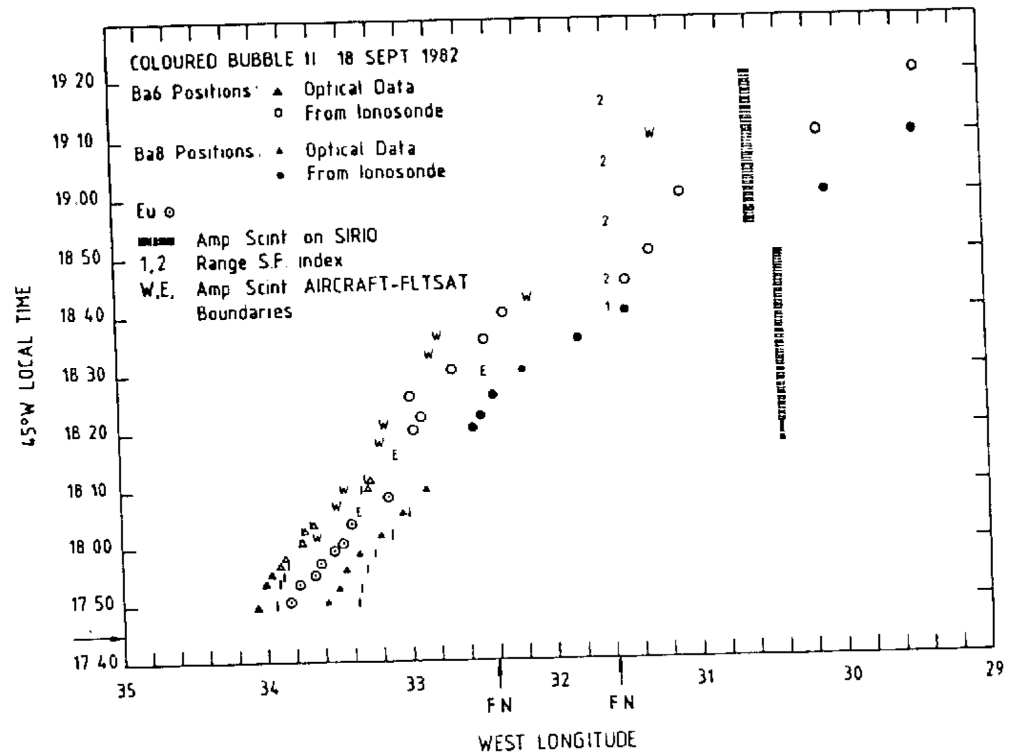
COLOURED BUBBLE II 18 SEPT 1982
Ba6 Positions: ▲ Optical Data
o From Ionosonde
Ba8 Positions: ▲ Optical Data
• From Ionosonde
Eu ⊙
Amp Scint on SIRIO
1,2 Range S.F. index
W,E, Amp Scint AIRCRAFT-FLTSAT Boundaries
45°W LOCAL TIME
WEST LONGITUDE
FN
FN

Fig. 3

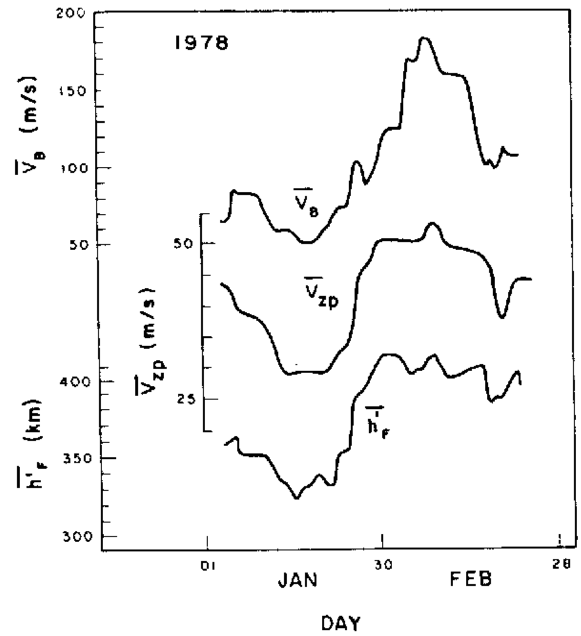
1978
$\overline{V}_B$ (m/s)
$\overline{V}_{zp}$ (m/s)
$\overline{h'}_F$ (km)
JAN
FEB
DAY

Fig. 4

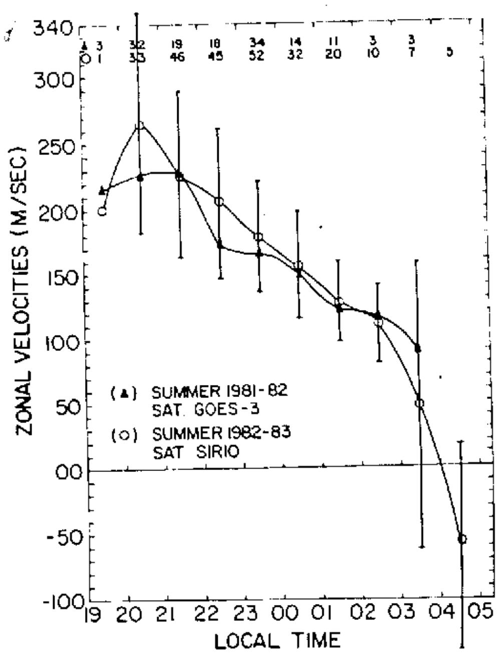
ZONAL VELOCITIES (M/SEC)
LOCAL TIME
(▲) SUMMER 1981-82
SAT. GOES-3
(○) SUMMER 1982-83
SAT SIRIO

Fig. 5

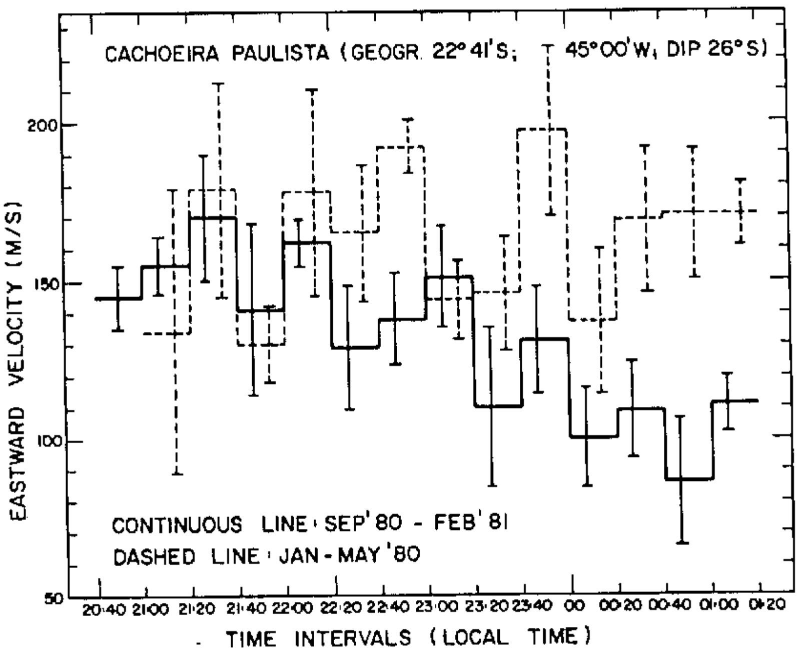
CACHOEIRA PAULISTA (GEOGR. 22°41'S; 45°00'W; DIP 26°S)
EASTWARD VELOCITY (M/S)
CONTINUOUS LINE: SEP'80 - FEB'81
DASHED LINE: JAN - MAY '80
TIME INTERVALS (LOCAL TIME)

Fig. 6