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ABSTRACT

Measurements of OI 7774 Å and 6300 Å tropical nightglow emissions were made with a grille spectrometer and a tilting-filter photometer, respectively, during March-September, 1972 at Mt. Agulhas Negras, Brazil. The temporal and spatial enhancements observed are studied in terms of F-region electron density and height changes, sometimes associated with magnetic storms. The observed time variations of intensities in the zenith are compared with model calculations using electron density profiles obtained from an ionosonde operating at São José dos Campos. There is a good agreement between the calculated and observed intensities, with the major contribution for OI 7774 Å and 6300 Å emissions coming from radiative recombination and dissociative recombination processes, respectively.

Preliminary results of OI 6300 Å emission measurements obtained during January-February, 1973 at Natal, Brazil, near the magnetic dip equator are presented.

INTRODUCTION

Tropical nightglow has been characterised by large enhancements in OI 6300 Å emission unrelated to magnetic activity (Barbier, 1958, 1959). These enhancements are closely related to the equatorial anomaly in the F-regio of the ionosphere and have been recently reviewed by several investigators (e.g.,Weill, 1967; VanZandt and Peterson, 1968; King, 1968; Thomas, 1969). The ultraviolet spectrometer on OGO-4 observed OI 1306 Å and 1356 Å in the nighttime tropical region between 12^{o} - 15^{o} on either side of the magnetic equator in positions completely circling the earth (Hicks and Chubb, 1970). The observed ultraviolet arcs coincide closely, in position, with the regions of equatorial anomaly and seem to be correlated with the position and local time variation of OI 6300 Å intertropical arcs. Chandra et al., (1972,Fig.1) have observed longitudinal asymmetry in OI 6300 Å and UV emission enhancements from OGO-4 observation in the southern hemisphere, but in the Brazilian sector these emissions seem to be well correlated.

The UV emissions are also accompanied by permitted OI lines 4368 Å and 7774 Å . Therefore, a correlative study of OI 6300 Å and 7774 Å emissions observed at Mt.Agulhas Negras, Brazil (22.4°S; 44.1°W; altitude 2.4 km) was carried out. Both these emissions emanate from F-region heights but are controlled by different processes and hence simultaneons observations reveal valuable information regarding F-region morphology.

In a recent publication, Tinsley et.al., (1973) discussed excitation of OI 7774 Å emission observed from Mt.Agulhas Negras. The expected emission rates due to radiative recombination (Hanson, 1969) and ion-ion recombination (Knudsen, 1970) were calculated and agreed reasonably well with the observed intensities. It was concluded that the major source for tropical oxygen permitted line emission is radiative recombination with a small contribution from ion-ion recombination.

In March 1972 nightglow observations of OI 5577 Å and 6300 Å emissions with a tilting-filter photometer were started at Mt.Agulhas Negras, which is approximately under the Appleton Anomaly at night. The temporal and spatial enhancements observed in the OI 6300Å emission are studied in terms of F-region electron density and height changes. The observed time variations of intensities in the zenith are compared with model calculations using electron density profiles obtained from an ionosonde operating at São José dos Campos (23.2°S, 45.9°W), 140 km southwest of Mt. Agulhas Negras. The effec of magnetic disturbances on the observed OI 6300 Å emission are also discussed

During the period March-September, 1972, the grille spectrometer (Tinsley, 1966) was also in operation at the same site which permitted simultaneous measurements of tropical F-region permitted line OI 7774 Å and forbidden line OI 6300 Å nightglow emissions. Salient features of this simultaneous study are presented.

The tilting-filter photometer was operated at Natal, Brazil (5.9°S, 35.2°W) near the magnetic dip equator during January-February, 1973. The observed temporal variations of OI 6300 Å emission are discussed.

OBSERVATIONS

Measurements of OI 7774 Å emission were made with the grille spectrometer (Tinsley, 1966). The spectrometer was operated at Agulhas Negras during November 1970-September 1972 in a cooperative project between the University of Texas at Dallas, U.S.A. and the Instituto de Pesquisas Espaciais (INPE), Brazil. The measurements were made by observing at a zenith angle of 60° and at azimuths of 0°, 90°, 180° and 270° (North, East, etc.). The reduction of the observed spectra has been described in Tinsley et al., (1973). No extinction or Van Rhijn corrections have been made in the data presented.

The OI 6300 Å emission was measured with a tilting-filter type photometer. The interference filter (bandwidth 11 Å) was rocked between two positions to give the on-line and background intensities. The photomultiplier used was an EMI-9558 with S-20 type photo-cathode. Analog signals were recorded on a Kipp and Zonen micrograph recorder. The sky scans were made with azimuthal sweeps at zenith angles of 75°, 70°, 60°, 40° and 0° with filter in on-line and background positions.

The photometer was calibrated with a Kr 85 excited phosphor light source (American Atomic Corporation, U.S.A.). The source was earlier calibrated at Fritz Peak Observatory, NOAA, Boulder, U.S.A. Absolute intensities in rayleighs of OI 6300 Å emissions were calculated using tilting filter (Yano, 1966) and calibration (Kulkarni and Sanders, 1964) techniques. The absolute calibration is estimated as ± 10%. As a narrow band filter is used, the OH contamination at 6300 Å has been considered to be negligible.

CALCULATION OF EXPECTED OI 6300 Å EMISSION RATE

Dissociative recombination of photoionization products, created during daytime by solar radiation, is considered to be the major sourc of excited atomic oxygen giving this nightglow emission. Now it is well established that this emission is ionospherically controlled (Noxon, 1971). The "Barbier Formula" (Barbier, 1959) which relates OI 6300 Å emission intensity to the ionospheric F-region parameters has been considered to be of only limited applicability (Peterson et al., 1966; Noxon and Johanson, 1970). A more recent approach (Peterson and Steiger, 1966; Peterson and VanZandt, 1969; Forbes, 1970; Noxon and Johanson, 1970; and Chandra et al., 1972) has been to use the theory developed by Peterson et al., (1966) to estimate the OI 6300 Å emission rate. The volume emission rate of OI 6300 Å due to dissociative recombination of O_2^+ (Peterson et al., 1966) is:

$$\epsilon_{6300}(z) = \frac{A_{6300}}{A_D} \cdot \frac{1}{1+\frac{d_D}{A_D}} \cdot K_D \cdot \frac{\gamma_1 [O_2] \quad [Ne]}{1 + \left[\frac{\gamma_1 [O_2]}{\alpha_1 [Ne]} + \frac{\gamma_2 [N_2]}{\alpha_2 [Ne]}\right]} \quad \ldots\ldots(1)$$

where A_{6300} = 0.0069 sec^{-1}-Einstein coefficient for the $^1D_2$ - $^3P_2$ transition of atomic oxygen

A_D = 0.0091sec^{-1}-Einstein coefficient for all transitions from the $^1D_2$ state of atomic oxygen

d_D = quenching frequency and is given by S_D ($^n2$) $[N_2]$ (Forbes, 1970)

$S_D(N_2)$ = rate coefficient for quenching of $O(^1D)$ by N_2

K_D = number of excitations of $O(^1D)$ per recombination of O_2^+ (including ^1S - ^1D cascade effect)

γ_1, γ_2 = rate coefficient for charge transfer reactions $O^+ + O_2$ and $O^+ + N_2$, respectively

α_1, α_2 = rate coefficient for dissociative recombination of O_2^+ and NO^+ molecular ions, respectively,

$[X]$ = number density of constituent X

and z = height.

The integrated volume emission rate is, in rayleighs,

$$J_{6300} = 10^{-6} \int \epsilon_{6300}(z) \quad dz \qquad \ldots.(2)$$

or

$$J_{6300} = 10^{-6} \int \frac{A_{6300} \; K_D}{A_D + S_D \; [N]} \cdot \frac{\gamma_1 \; [O_2][Ne] \quad dz}{1 + \left[\frac{\gamma_1 [O_2]}{\alpha_1 [Ne]} + \frac{\gamma_2 [N_2]}{\alpha_2 [Ne]}\right]} \qquad \ldots(3)$$

Since the terms in the paranthesis of the Eq.3 are of minor importance (Peterson and VanZandt, 1969) above the height of about 200 km, Eq.3 can be written as

$$J_{6300} = 10^{-6} \int \frac{A_{6300} \;\; K_D \; \gamma_1 \;\; [O_2][Ne] \quad dz}{A_D + S_D \; (N_2)[N_2]} \qquad \ldots.(4)$$

The values of K_D, γ_1, and $S_D(N_2)$used by different workers to estimate the integrated volume emission rate is given in Table I. There seems to be general agreement for the value ($\sim$ 7 x10^{-11} cm^3 sec^{-1}) of $S_D(N_2)$. Considerable uncertainty in the estimate of K_D exists. Noxon and Johanson (1970) and Chandra et al., (1972) adopted $K_D \sim 1$ from laboratory work of Zipf (1970). Recent estimates of γ_1, for F-region are 1.5 x 10^{-11} cm^3 sec^{-1} (Noxon,1971) and 1 x 10^{-11} cm^3 sec^{-1} (Hanson, 1972; Rishbeth et al., 1972) for the temperature dependent rate coefficient (Ferguson, 1969).

The expected volume emission rate due to dissociative recombination was calculated by using exospheric temperature and density profiles (Jacchia, 1971) and electron density profiles obtained from ionosonde data (Tinsley et.al.,1973). The computations were carried out on a Burroughs 6700 computer at INPE. Numerical integration of Eq.3 was carried out from 90 km to 900 km. The rate coefficient used were: $\gamma_1 = 1 \times 10^{-11} cm^3$ sec^{-1} (Rishbeth et al., 1972), $\gamma_2 = 7 \times 10^{-13}$ cm^3 sec^{-1} (Noxon, 1971), $S_D(N_2) = 9 \times 10^{-11} cm^3$ sec^{-1} (Noxon, 1970), $\alpha_1 - \alpha_2 = 1 \times 10^{-7} cm^3$ sec^{-1} (Biondi, 1969), and $K_D = 0.9$ (Zipf, 1970). Changes in the rate coefficients with temperature were neglected.

In the absence of any conjugate effects (Cole, 1965) observed in the OI 6300 Å emission, there appears to be no evidence for any significant number of photoelectrons to exist locally during the nighttime. The contributio to the OI 6300 Å emission from ion-ion recombination process is very small (Olson et al.,1971) compared to the contribution from dissociative recombination and can be neglected.

TABLE I

RATE COEFFICIENTS OF K_D, γ_1; and $S_D(N_2)$ USED BY DIFFERENT WORKERS TO ESTIMATE OI 6300 Å EMISSION RATE.

Author	K_D	$\gamma_1 (cm^3 sec^{-1})$	$S_D(N_2) cm^3 sec^{-1}$	Remarks
Peterson and VanZandt (1969)	0.2	4×10^{-11}	5×10^{-11}	K_D= 0.2 was usec but calculated emission rate was normalized t observed,which i equivalent to using another value of K_D.
Forbes (1970)	0.06-0.10	2×10^{-11}	7×10^{-11}	
Noxon and Johanson(1970)	~1	1.4×10^{-11}	7×10^{-11}	They have used $K_D \gamma_1 = 1.4 \times 10^{-11}$. $T_\infty = 1000^o k$
Chandra et al., (1972)	0.9	$3.4 \times 10^{-10} T^{-1/2}$	7×10^{-11}	$T_\infty = 1300^o k$
Present work	0.9	1×10^{-11}	7×10^{-11}	T_∞ variation calculated using Jacchia, (1971).

RESULTS AND DISCUSSION

THE OI 6300 Å EMISSION:

Fig.1 shows a comparison between observed OI 6300 Å intensities from the Mt. Agulhas Negras on April 20-21 and September 19-20, 1972, and calculated from dissociative recombination. The optical observations were made at 25^{o} zenith distance, 235^{o} azimuth to view through the intersection of the ionosonde beam operating at São José dos Campos at about 300 km height level. These are the two nights for which complete ionograms are available. The observed intensities have been corrected to the zenith. The zenith intensity variation for April 20-21, shows an enhancement around 2000 hours and thereafter continues to show fluctuations till 0200 hours before decreasing to a low value. This is a magnetically disturbed night ($K_p \geq 4$,00-06 UT) and intensity variations are discussed later. Data for September 19-20, shows prominent post-twilight decay and enhancement around midnight.

Considering the uncertainties, the calculated OI 6300 Å intensities are in reasonable agreement with the observed intensities as well as time variations. The critical reflection frequency and height of maximum electron density obtained for April 20-21, 1972 are shown in Fig.2. The calculated exospheric temperature variation for this night is presented in Fig.3. The calculated volume emission rates and zenith intensities as a function of height are given in Fig.4 for several different hours, the emitting layer being located between 200 and 300 km. It is observed from

Fig.2 that OI 6300 Å emission due to dissociative recombination depends very much on the height of F_2-layer as suggested earlier by VanZandt and Peterson (1968).

THE OI 7774 Å EMISSION:

As mentioned earlier Tinsley et al.,(1973) have discussed the OI 7774 Å emission observed from Mt. Agulhas Negras and compared it with the model calculation using radiative and ion-ion recombination processes. It was concluded that time variations and absolute intensity of the calculated and observed intensities agree reasonably well and that radiative recombination is the major source of the tropical oxygen permitted line emission. It may be noted that the radiative recombination mechanism does not depend on the height of the F_2-layer , wheres the dissociative recombination does.

TROPICAL NIGHTGLOW ENHANCEMENTS:

The isophote maps of OI 6300 Å emission observed from Mt. Agulhas Negras are typical of the tropical region (Steiger et al., 1966; VanZandt and Peterson, 1968) and show large enhancements of different forms e.g., patchiness, east-west arc, north-south ridges corresponding to sunset and sunrise direction, field aligned structure etc. The tropical arc is seen on most of the nights either overhead (Fig.5) or in the south and moves northwards. This is consistent with movement of the equatorial ionospheric anomaly (King, 1968). The zenith intensity variations show post-twilight decay and enhancements around midnight, which is also typical of the tropical region (Ciner and Smith, 1973).

Figs. 6 to 9 show data from simultaneous measurements of OI 6300 Å and 7774 Å emissions. All the nights are magnetically quiet ($K_p \leq 3$). Fig.6 shows the zenith intensity (azimuth 235°, zenith 25°) variation for March 16-17, 1972. Fig.7 shows two meridian scans, which also coincide with the time of zenith intensity enhancements. The OI 6300 Å emission shows large enhancements, first at about 20:15 hours and then again at about 02:15 hours. Large post-midnight enhancement has also been observed by VanZandt and Peterson (1968, Fig.7). The OI 7774 Å emission also shows enhancements twice, but the peaks preceed the OI 6300 Å peaks and the second enhancement is much smaller than the first one. Presumably, the layer came shown during the second enhancement and decayed by dissociative recombination giving a large enhancement in the observed OI 6300 Å emission. The evening and morning meridian scans have been corrected for van Rhijn factor. The evening scan shows that the arc was 40° south from zenith for OI 6300 Å emission, while it was overhead for OI 7774 Å emission. This separation is to be expected where electron density enhancement is field aligned (Tinsley et al., 1973). The morning scan shows that the OI 6300 Å emission peak was situated at about 50° north while the OI 7774 Å emission showed a broad peak around 30° north. Perhaps due to large spatial gradients in the height of the F_2-layer, the OI 6300 Å emission was maximixing at a larger zenith di-tance.

Figs.8 and 9 show the observed intensities of OI 6300 Å and 7774 Å emissions for the nights of September 8-9 and September 19-20, 1972 at 60^o zenith distance. Assuming that the emission region is near 300 km, the observations at 60^o look at areas separated by 975 km in opposite and 690 km in adjacent quadrants of azimuth. Significant spatial gradients are observed in both the emissions for the night of September 19-20, while spatial gradients are much less for the night of September 8-9 and monotonic decrease of the intensity of both the emissions continued throughout the night. it may be noted that both the emissions show in general much larger values on September 19-20 as compared to September 8-9. Data for September 19-20, show more activity in airglow. It can be seen from Fig.9 that a region of enhanced ionization was situated around 60^o north during the late evening hours and moved southwards during the later part of night as evident from the zenith intensity variations shown in Fig.1 for São José dos Campos, 25^o southwest.

It is observed that normally both the emissions show simultaneous temporal and spatial enhancements but OI 7774 Å enhancements are followed by OI 6300 Å enhancements. As discussed earlier (Tinsley et al., 1973) enhancement from radiative recombination would maximise at the F_2 peak, whereas enhancements from dissociative recombination would maximise in the regions of increasing O_2 abundance. Therefore, the present observations indicate that enhancement in the F_2 peak is normally followed by lowering of the height of F_2 peak as well. VanZandt and Peterson (1968) have also observed that the maxima of $f_o F_2$ preceded by about an hour the maximum lowering of h'F. They also proposed that OI 6300 Å enhancements are a result of increased recombination due to downward motions of the F_2 layer, which are caused by downward electromagnetic drifts which in turn are caused by westward electric fields in the F_2 region.

THE OI 6300 Å EMISSION DURING MAGNETIC DISTURBANCE:

Recent discussions of low-latitude airglow during enhanced magnetic activity by Akasofu (1970) on the basis of the observations of Steiger (1967) dispels earlier thought that low-latitude airglow is uncorrelated with the polar auroras. Weill et al., (1968) observed large OI 6300 Å emission enhancements when K_p reached 7_o at Debrezeit, Ethiopia near the magnetic dip equator. They also observed that the time variations are greatly modified during magnetic disturbances. Akasofu (1970) points out that the low-latitude ionosphere undergoes considerable height shifts during and after magnetospheric substorm but the reaction of the low-latitude ionosphere to an impulsive magnetospheric storm is slow . Delays of few hous after start of substorm, before ionospheric height changes occur have been observed (Ruster, 1965).

The OI 6300 Å emission observation from Agulhas Negras was also affected by enhanced magnetic activity. Fig.10 shows the zenith intensity variation for May 15-16, 1972, a magnetically disturbed night ($K_p \geq 7$). A sudden commencement magnetic storm started at about 1600 hours local time on May 15, 1972. The corresponding magnetogram from Vassouras Observatory State of Rio de Janeiro, Brazil is also presented in Fig. 10. The observed airglow intensity shows a peak enhancement of about 1.3 Krayleighs at 21:15 hours and then decays to a very small value within a short time. Similar enhancement and decay has been observed by Weill et al., (1968) at Debrezeit and the time delay in peak enhancement after sudden commencement is consistent with Ruster (1965). The zenith intensity variations for May 17-18, 1972, a quiet night ($K_p \leq 3$), are also presented in Fig. 10, which shows a smaller premidnight enhancement normally associated with movement of the tropical arc. The isophote maps and meridian scans for the night of May 15-16, 1972 are also presented in Figs. 11 and 12, respectively. The isophote maps show broad E-W band of enhancement at 30^{o} south at the begining of the observations The isophotes continue to be more or less field aligned throughout the night except in the early morning when the sunrise effect is evident. This indicates geomagnetic control, as isophotes tend to be aligned with the isoclines. The meridian scans show the movement of the ionization crest during the course of the night. Owing to electrical power failure at São José dos Campos we have only one ionogram available during the time of peak airglow enhancement. The calculated value of OI 6300 Å emission from dissociative recombination is shown in Fig. 10.

Fig. 13 shows data from March 15-16, 1972, a magnetically disturbed night ($\bar{K}_p \geq 5$, 00-03 UT). Apart from enhancement during the time when K_p is high, large intensity variations are observed. The observed OI 7774 Å emission was about 200 rayleighs in the zenith at 2030 (Tinsley et al., 1973), which was fairly high as compared to the values observed on the following night. On the night of April 20-21, 1972, Fig.1, which was also magnetically distrubed night ($K_p \geq 4$, 00-06 UT), intensity fluctuations are observed and on the basis of reasonable agreement between observed and calculated intensities, these fluctuations can be explained by concomitant F-layer changes during enhanced magnetic activity. Weill and Glaume (1967) observed that form and intensity of OI 6300Å emission at Tamanrasset were strongly pertubed during enhanced magnetic activity although close relation with F_2-layer was maintained.

It is therefore, evident that tropical nightglow emission undergoes considerable temporary changes duing enhanced magnetic activity. It will be interesting to compare observed and calculated OI 6300 Å intensities with dissociative recombination during the main phase of magnetic storms to see whether enhanced particle precipitation (Zmuda, 1966) in this region of South Atlantic Geomagnetic Anomaly, can give a particle excitation component in the observed intensity. Weill and Glaume (1967) have observed such an effect for Haute Provence, a mid-latitude station in the northern hemisphere during the main phase of magnetic storms.

THE OI 6300 Å EMISSION OBSERVED NEAR THE MAGNETIC EQUATOR:

Fig. 14 shows data for zenith intensity variation observed at Natal, on four nights viz., January 31-February 1, February 1-2, 13-14, and 14-15, 1973. All the nights are magnetically quiet ($K_p \leq 3$). Enhancements around midnight were observed on all the nights while Feb. 1-2 and 13-14 show much stronger enhancements. Small enhancements around 04:00 hours have also been observed on most of the nights. Midnight enhancement near the magnetic equator appears to be a common feature and have been observed at Thum (Kulkarni and Rao, 1972), Huancayo (Silverman and Casaverde, 1961), Liwro (Delsemme and Delsemme, 1960). Midnight enhancements are presumably caused by downward drift of F-region plasma which brings ionization along the field lines towards magnetic equator from higher latitudes described as the 'inverse fountain effect' by Hanson and Moffett (1966).

Although the nocturnal variations are similar, the observed intensities at Natal is much higher than those reported for Huancayo during the period May-August, 1958 and Thumba during March 1970 and March-April 1971. A detailed analysis of the observed intensities and behaviour of OI 6300 Å emission on the basis of dissociative recombination and F-region dynamics at Natal will be presented later.

CONCLUSIONS

The isphote maps and zenith intensity variations of OI 6300 Å emission observed in the Brazilian Sector are typical of the tropical region. A correlative study of OI 6300 Å emission and ionospheric measurements indicate that intensity variations can be explained by concomitant F-Layer changes with dissociative recombination being the dominant mechanism for the tropical emission. The OI 6300 Å emission is also affected by enhanced magnetic activity and undergoes considerable temporary changes.

The observed OI 7774 Å intensities are what one would expect from the recombination processes with the major contribution coming from radiative recombination. Simultaneous temporal and spatial enhancements of OI 6300 Å and 7774 Å emissions are observed. This seems to be consistent with OGO-4 data presented by Chandra et al., (1972) for this region.

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FIGURE CAPTIONS

Fig.1 Comparison of observed and calculated OI 6300 Å intensities.

Fig 2 Ionospheric data obtained from ionograms taken at São José dos Campos.

Fig.3 Exospheric temperature variation calculated using static model (Jacchia, 1971) of thermosphere and exosphere.

Fig.4 Volume emission rate and zenith intensity calculated by dissociative recombination.

Fig.5 OI 6300 Å emission isophote map showing tropical arc overhead at Mt. Agulhas Negras.

Fig.6 Observed OI 6300 Å and 7774 Å zenith intensities for azimuth 235^{o}, elevation 65^{o} on March 16-17, 1972 from Mt. Agulhas Negras.

Fig.7 Meridian scans of OI 6300 Å and 7774 Å emissions on March 16-17, 1972.

Fig.8 Observed OI 6300 Å and 7774 Å intensities at 60^{o} zenith distances on Spetember 8-9, 1972.

Fig.9 Observed OI 6300 Å and 7774 Å intensities at 60^{o} zenith distances on September 19-20, 1972.

Fig.10 Observed OI 6300 Å zenith intensities on May 15-16, 1972 (magnetically disturbed) and May 17-18, 1972 (quiet) at Mt.Agulhas Negras along with magnetogram for May 15-16 from Vassouras, Brazil. Calculated OI 6300 Å intensity using dissociative recombinations for May 15-16 is also shown.

Fig.11 OI 6300 Å emission isophote maps for May 15-16, 1972 showing spatial and temporal variations.

Fig.12 Meridian scans of OI 6300 Å emission for May 15-16, 1972.

Fig.13 Observed OI 6300 Å zenith intensity on March 15-16, 1972.

Fig.14 Observed OI 6300 Å zenith intensities at Natal for Jan 31-Feb 1. Feb 1-2, 13-14, 14-15, 1973.

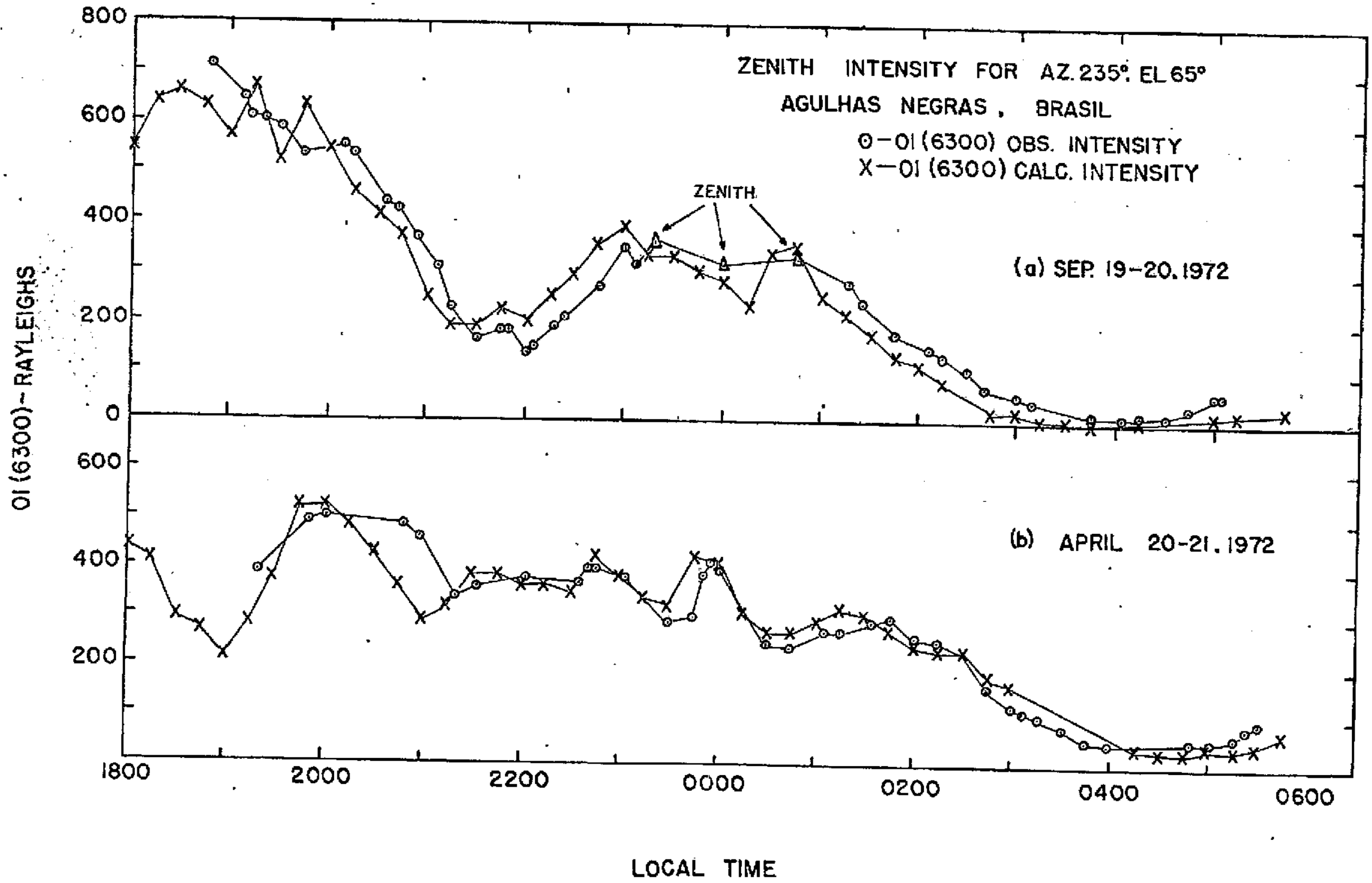
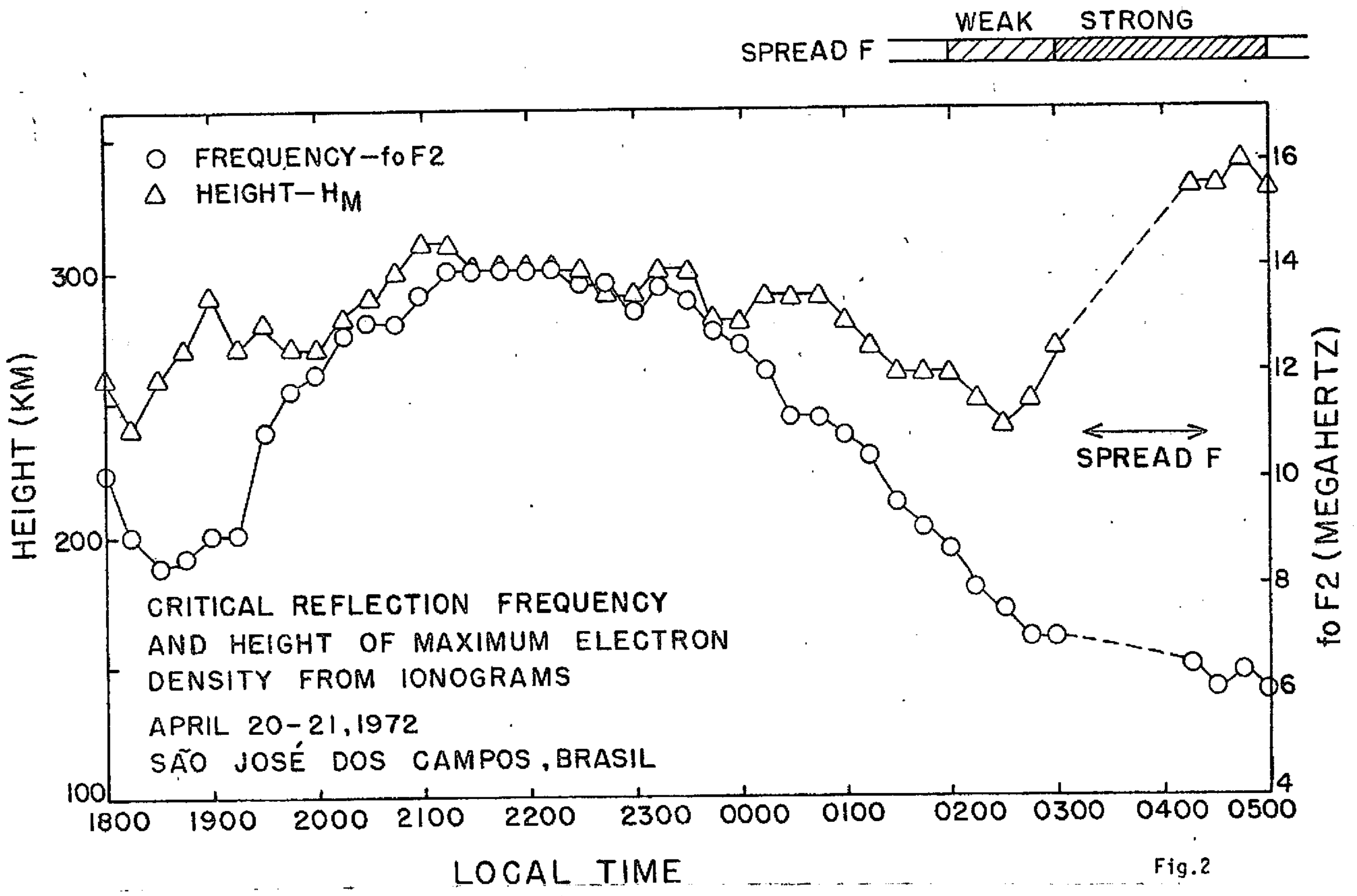

ZENITH INTENSITY FOR AZ. 235°, EL 65°
AGULHAS NEGRAS , BRASIL
⊙—OI (6300) OBS. INTENSITY
X—OI (6300) CALC. INTENSITY
ZENITH
(a) SEP. 19-20, 1972
(b) APRIL 20-21, 1972
OI (6300)~RAYLEIGHS
800
600
400
200
0
600
400
200
1800
2000
2200
0000
0200
0400
0600
LOCAL TIME

Fig.1



WEAK
STRONG
SPREAD F
FREQUENCY—foF2
HEIGHT—H_M
SPREAD F
HEIGHT (KM)
300
200
100
fo F2 (MEGAHERTZ)
16
14
12
10
8
6
4
CRITICAL REFLECTION FREQUENCY
AND HEIGHT OF MAXIMUM ELECTRON
DENSITY FROM IONOGRAMS
APRIL 20-21, 1972
SÃO JOSÉ DOS CAMPOS, BRASIL
1800
1900
2000
2100
2200
2300
0000
0100
0200
0300
0400
0500
LOCAL TIME

Fig. 2

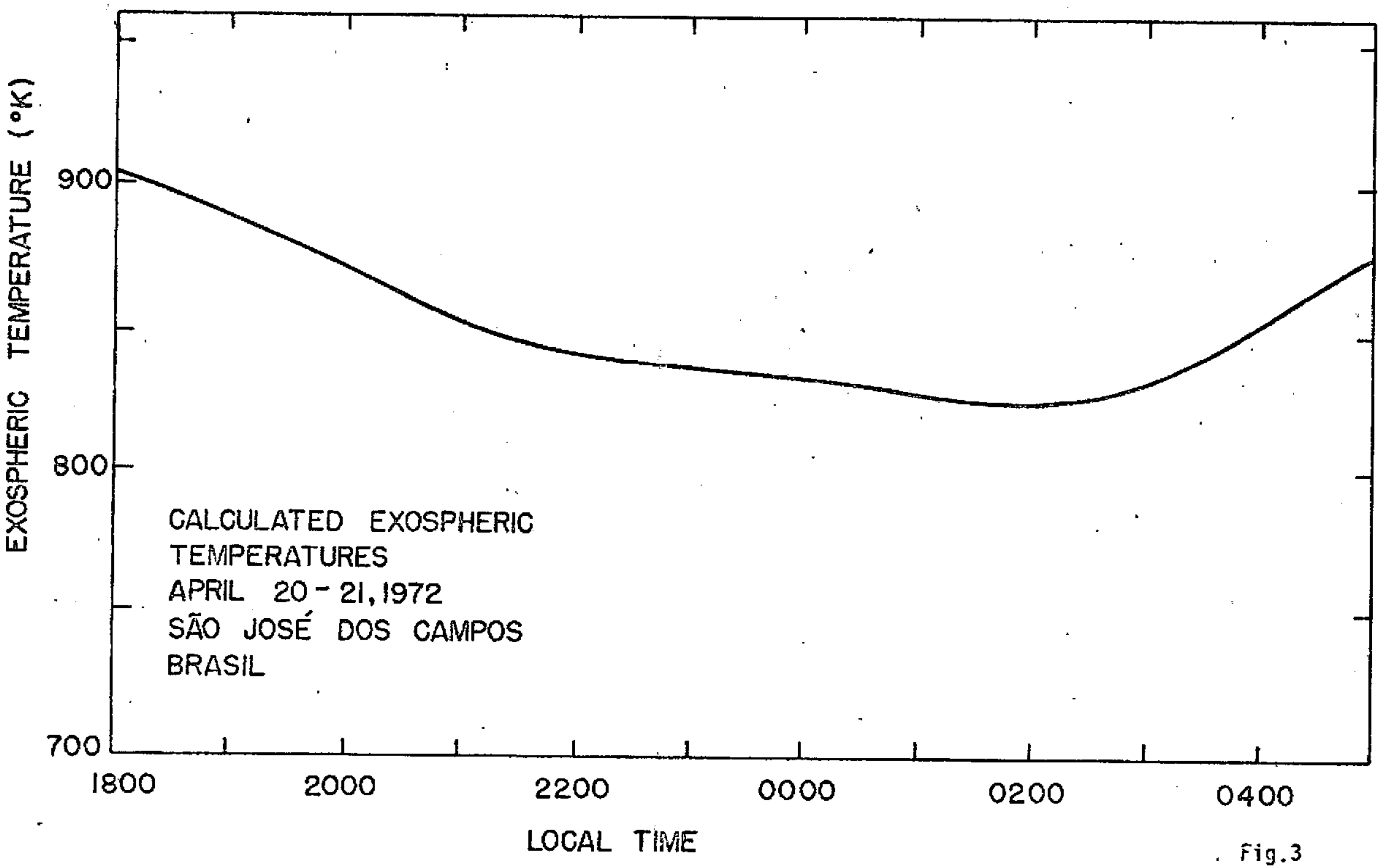
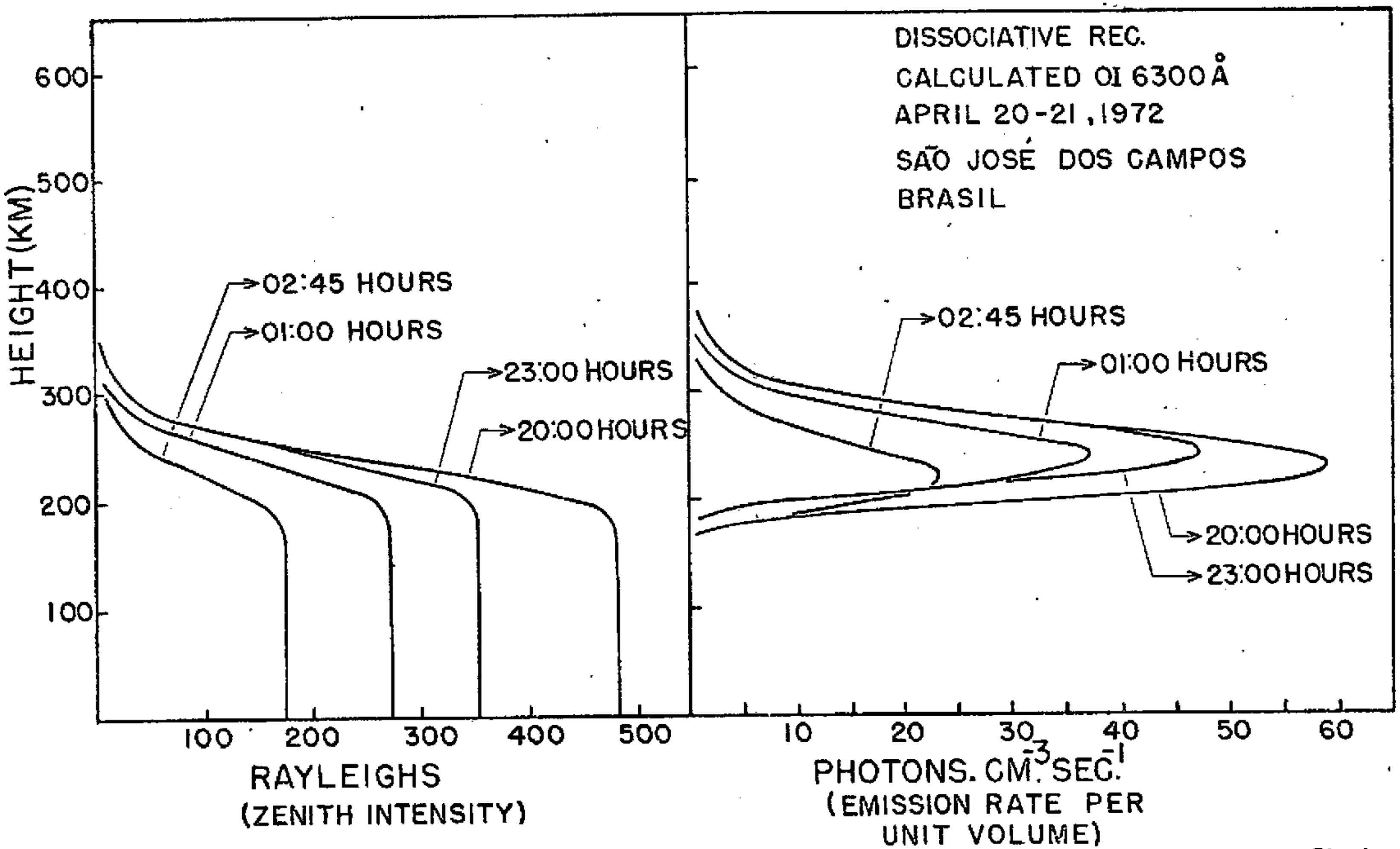
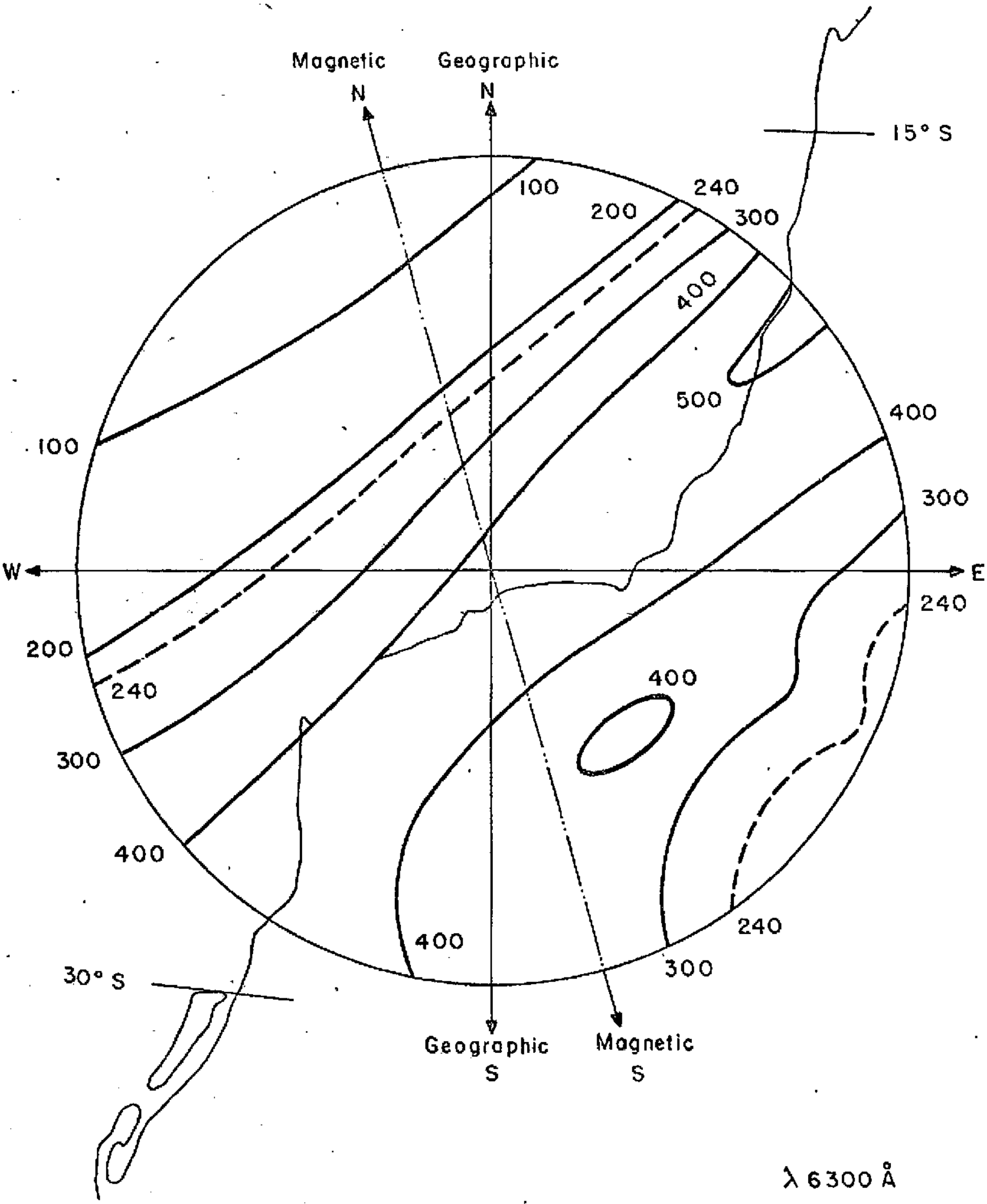

EXOSPHERIC TEMPERATURE (°K)
900
800
700
1800
2000
2200
0000
0200
0400
LOCAL TIME
CALCULATED EXOSPHERIC
TEMPERATURES
APRIL 20 - 21, 1972
SÃO JOSÉ DOS CAMPOS
BRASIL

Fig.3



DISSOCIATIVE REC.
CALCULATED OI 6300 Å
APRIL 20-21, 1972
SÃO JOSÉ DOS CAMPOS
BRASIL
HEIGHT (KM)
600
500
400
300
200
100
02:45 HOURS
01:00 HOURS
23:00 HOURS
20:00 HOURS
100
200
300
400
500
RAYLEIGHS
(ZENITH INTENSITY)
10
20
30
40
50
60
PHOTONS. CM^{-3} SEC^{-1}
(EMISSION RATE PER
UNIT VOLUME)

Fig. 4



λ 6300 Å

17–18 May 1972

1900 – 1920 hrs.

Obs:– Mt. Agulhas Negros.

Fig. 5

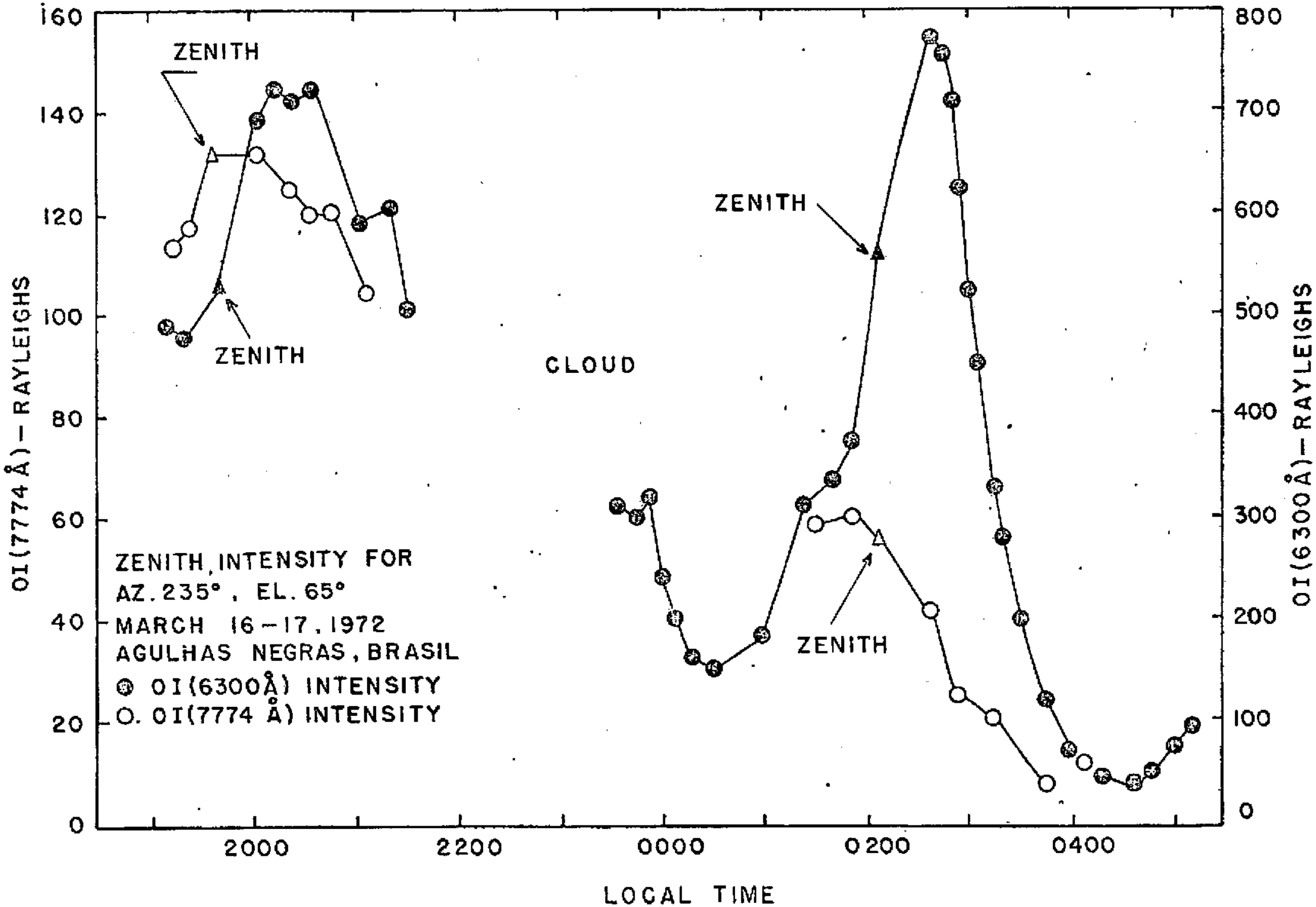

160
140
120
100
80
60
40
20
0
OI(7774 Å) – RAYLEIGHS
800
700
600
500
400
300
200
100
0
OI(6300 Å) – RAYLEIGHS
2000
2200
0000
0200
0400
LOCAL TIME
ZENITH
ZENITH
CLOUD
ZENITH
ZENITH
ZENITH INTENSITY FOR
AZ. 235°, EL. 65°
MARCH 16 – 17, 1972
AGULHAS NEGRAS, BRASIL
OI(6300Å) INTENSITY
O. OI(7774 Å) INTENSITY

Fig.6

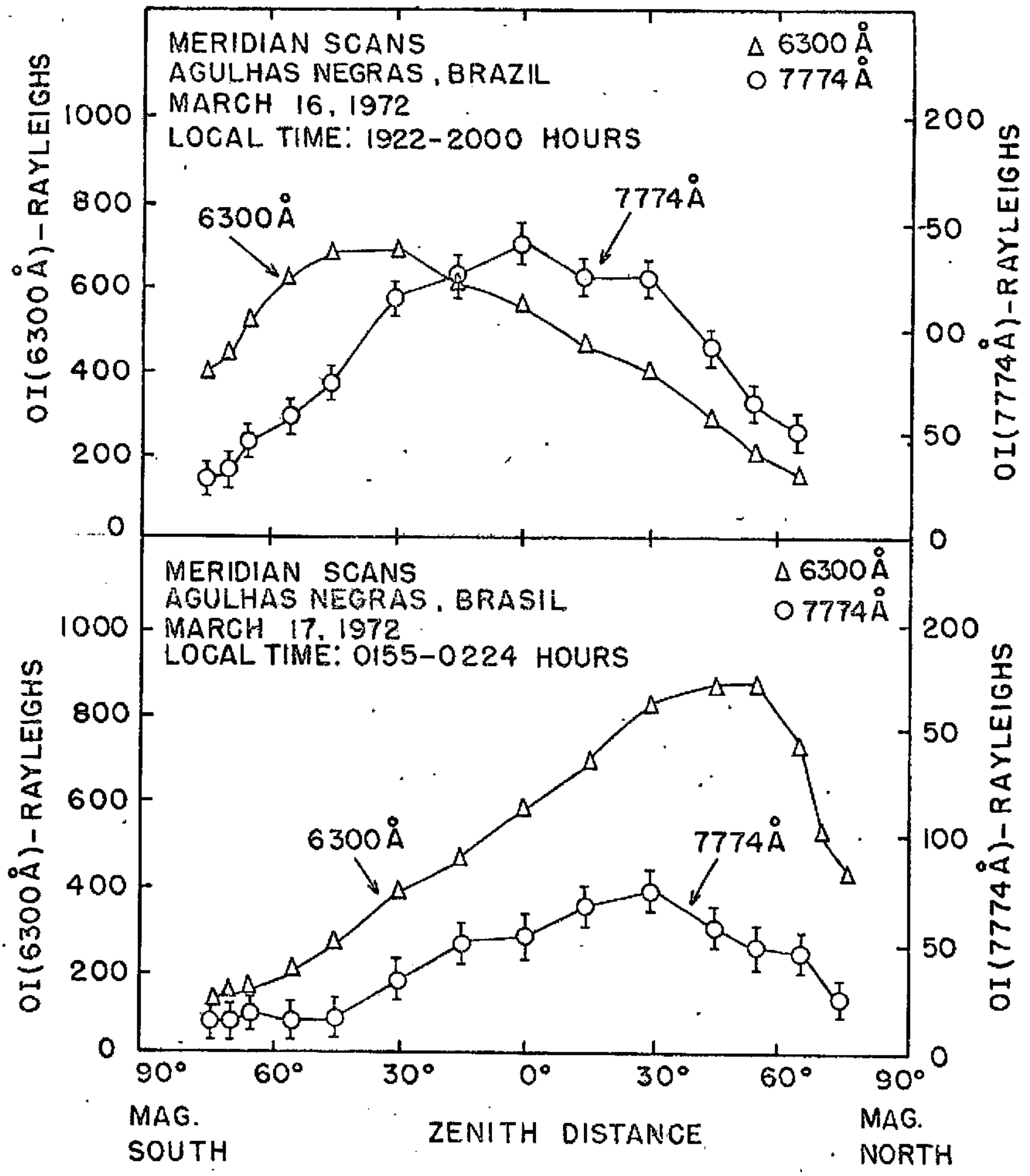

MERIDIAN SCANS
AGULHAS NEGRAS, BRAZIL
MARCH 16, 1972
LOCAL TIME: 1922-2000 HOURS
Δ 6300 Å
○ 7774 Å
6300 Å
7774 Å
OI(6300 Å)-RAYLEIGHS
OI(7774 Å)-RAYLEIGHS
MERIDIAN SCANS
AGULHAS NEGRAS, BRASIL
MARCH 17, 1972
LOCAL TIME: 0155-0224 HOURS
Δ 6300 Å
○ 7774 Å
6300 Å
7774 Å
OI(6300 Å)-RAYLEIGHS
OI(7774 Å)-RAYLEIGHS
90° 60° 30° 0° 30° 60° 90°
MAG. SOUTH
ZENITH DISTANCE
MAG. NORTH

Fig.7

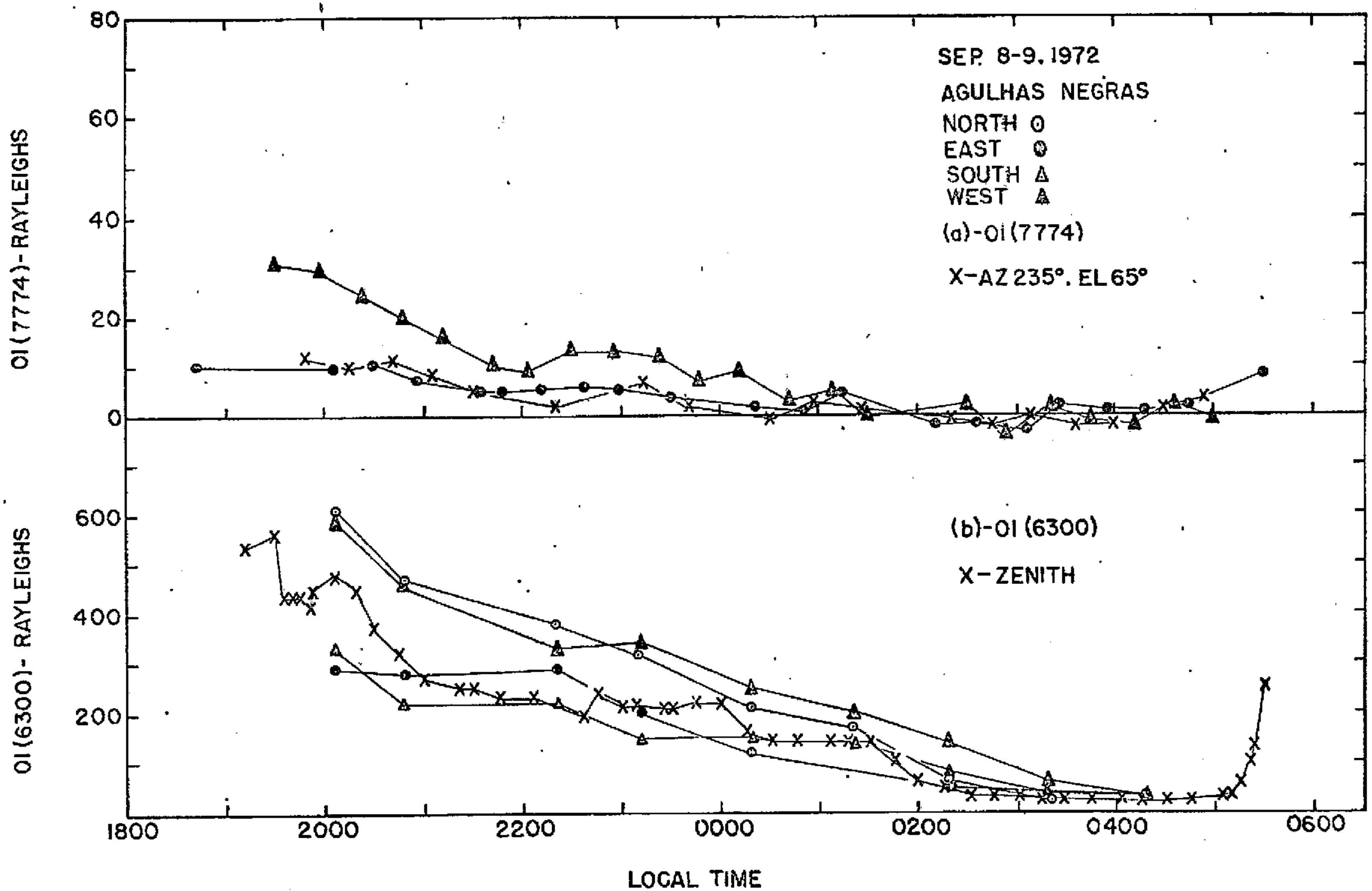
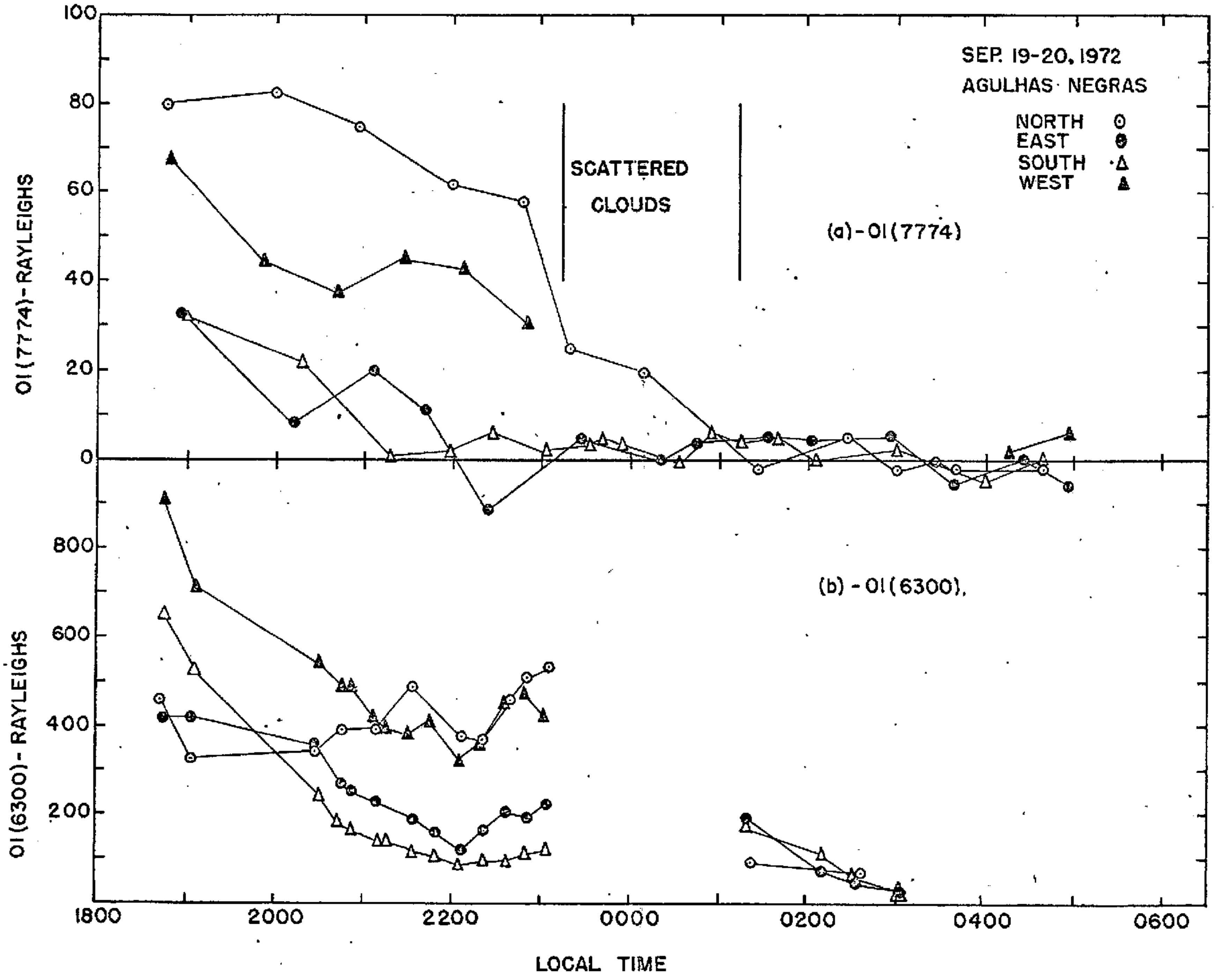
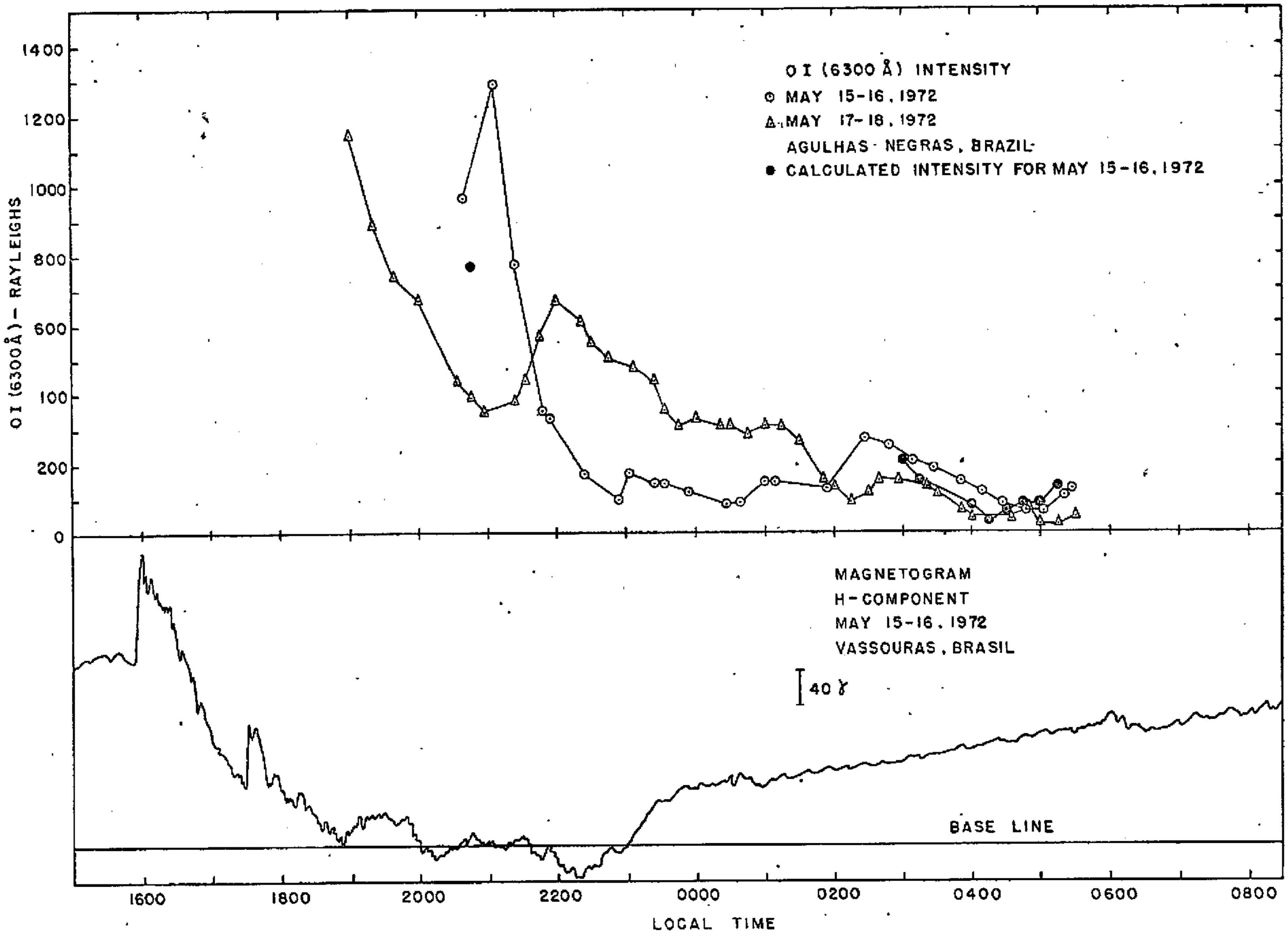

SEP. 8-9, 1972
AGULHAS NEGRAS
NORTH
EAST
SOUTH
WEST
(a)-OI(7774)
X-AZ 235°, EL 65°
(b)-OI (6300)
X-ZENITH
OI(7774)-RAYLEIGHS
OI(6300)-RAYLEIGHS
80
60
40
20
0
600
400
200
1800
2000
2200
0000
0200
0400
0600
LOCAL TIME

Fig.8

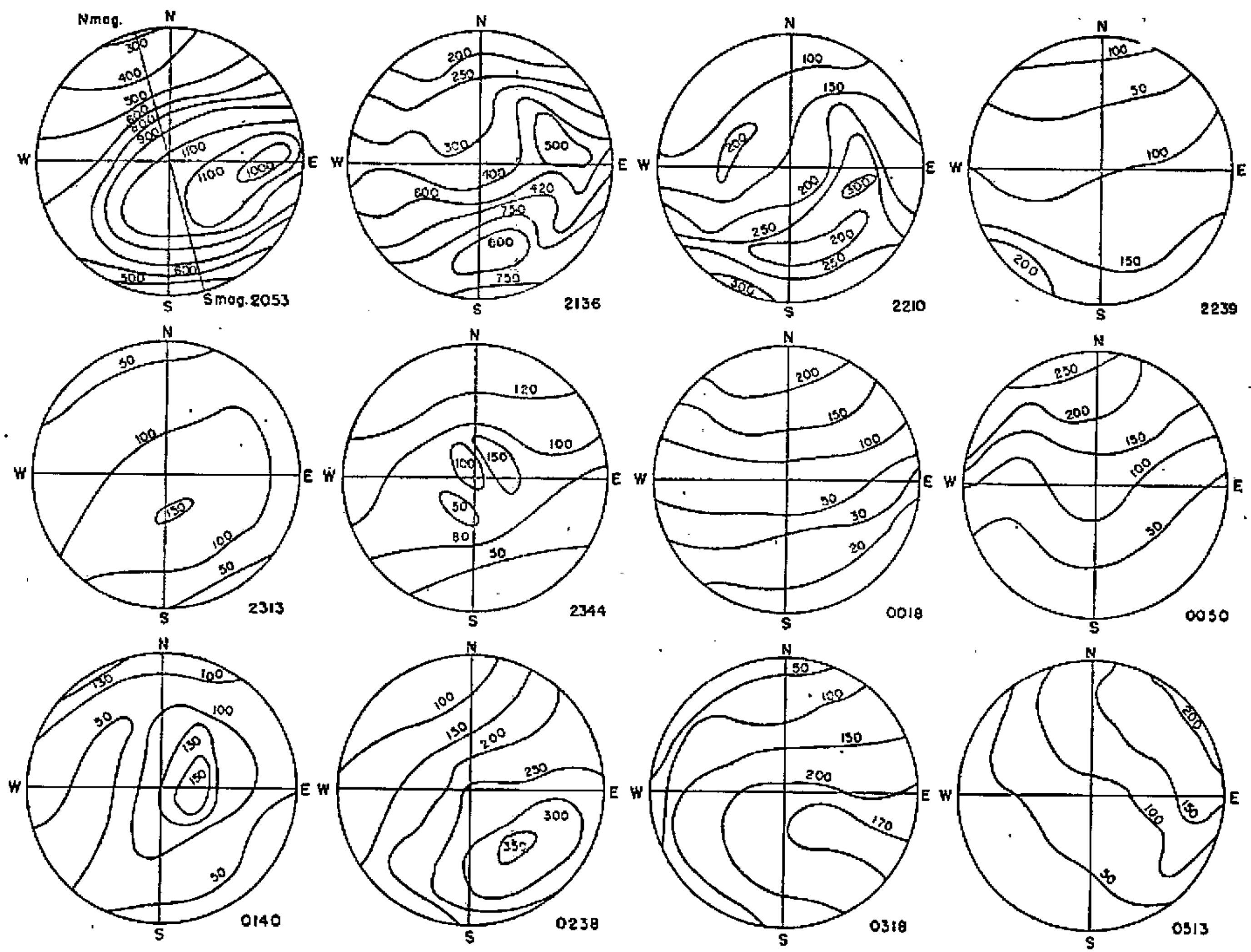

SEP. 19-20, 1972
AGULHAS NEGRAS
NORTH
EAST
SOUTH
WEST
SCATTERED CLOUDS
(a) - OI (7774)
(b) - OI (6300)
OI (7774) - RAYLEIGHS
OI (6300) - RAYLEIGHS
LOCAL TIME
100
80
60
40
20
0
800
600
400
200
1800
2000
2200
0000
0200
0400
0600

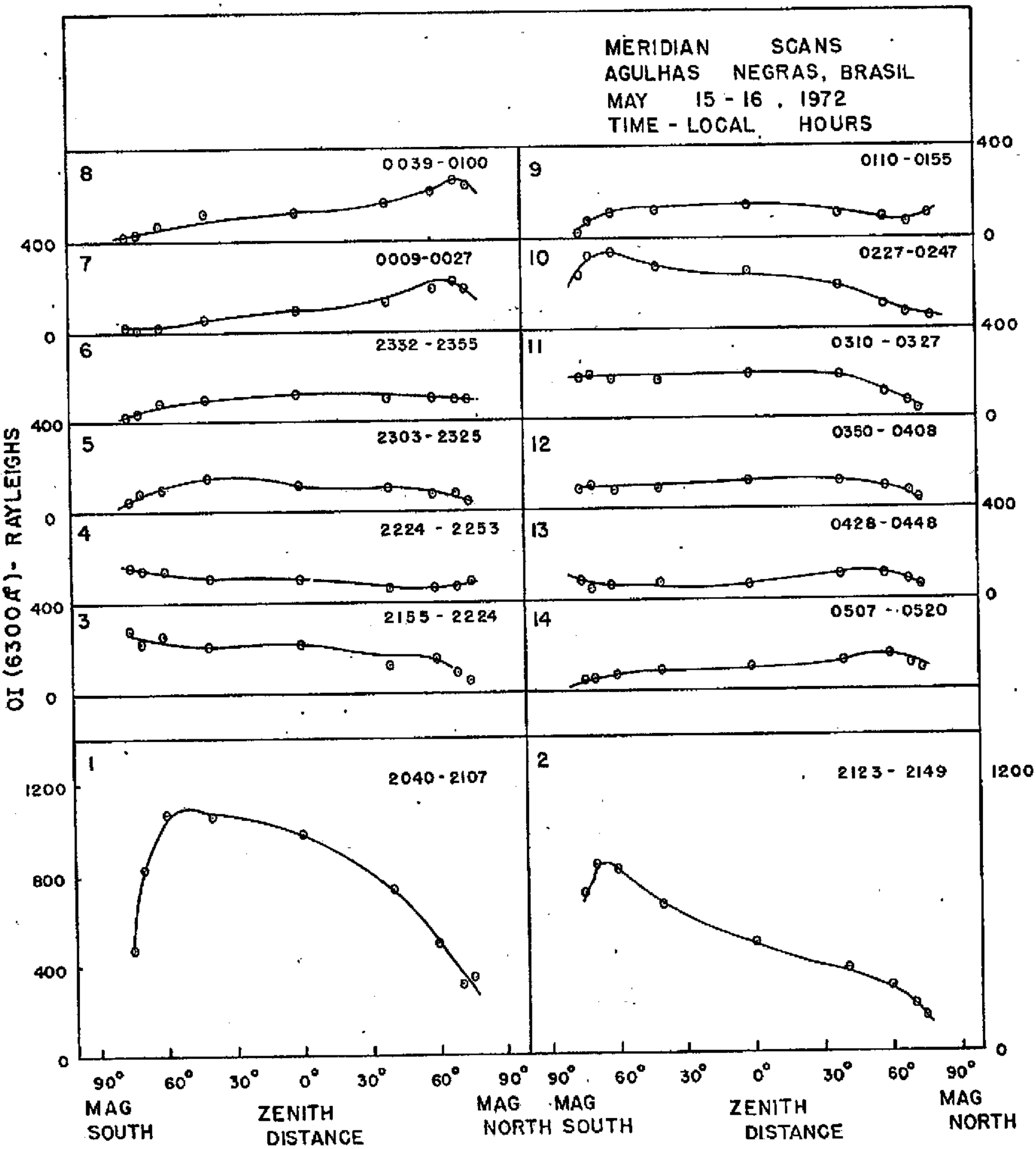

OI (6300 Å) INTENSITY
⊙ MAY 15-16, 1972
△ MAY 17-18, 1972
AGULHAS NEGRAS, BRAZIL
● CALCULATED INTENSITY FOR MAY 15-16, 1972
OI (6300Å) - RAYLEIGHS
1400
1200
1000
800
600
100
200
0
MAGNETOGRAM
H-COMPONENT
MAY 15-16, 1972
VASSOURAS, BRASIL
40 γ
BASE LINE
1600
1800
2000
2200
0000
0200
0400
0600
0800
LOCAL TIME

OI(6300 Å) ISOPHOTES - AGULHAS NEGRAS, BRAZIL

MAY 15-16, 1972

TIME LOCAL HOURS





MERIDIAN SCANS
AGULHAS NEGRAS, BRASIL
MAY 15 - 16 , 1972
TIME - LOCAL HOURS
8
0039-0100
7
0009-0027
6
2332-2355
5
2303-2325
4
2224 - 2253
3
2155 - 2224
9
0110-0155
10
0227-0247
11
0310 - 0327
12
0350 - 0408
13
0428-0448
14
0507 - 0520
1
2040-2107
2
2123 - 2149
OI (6300 Å) - RAYLEIGHS
400
0
1200
800
90° 60° 30° 0° 30° 60° 90°
MAG SOUTH
ZENITH DISTANCE
MAG NORTH

Fig. 12

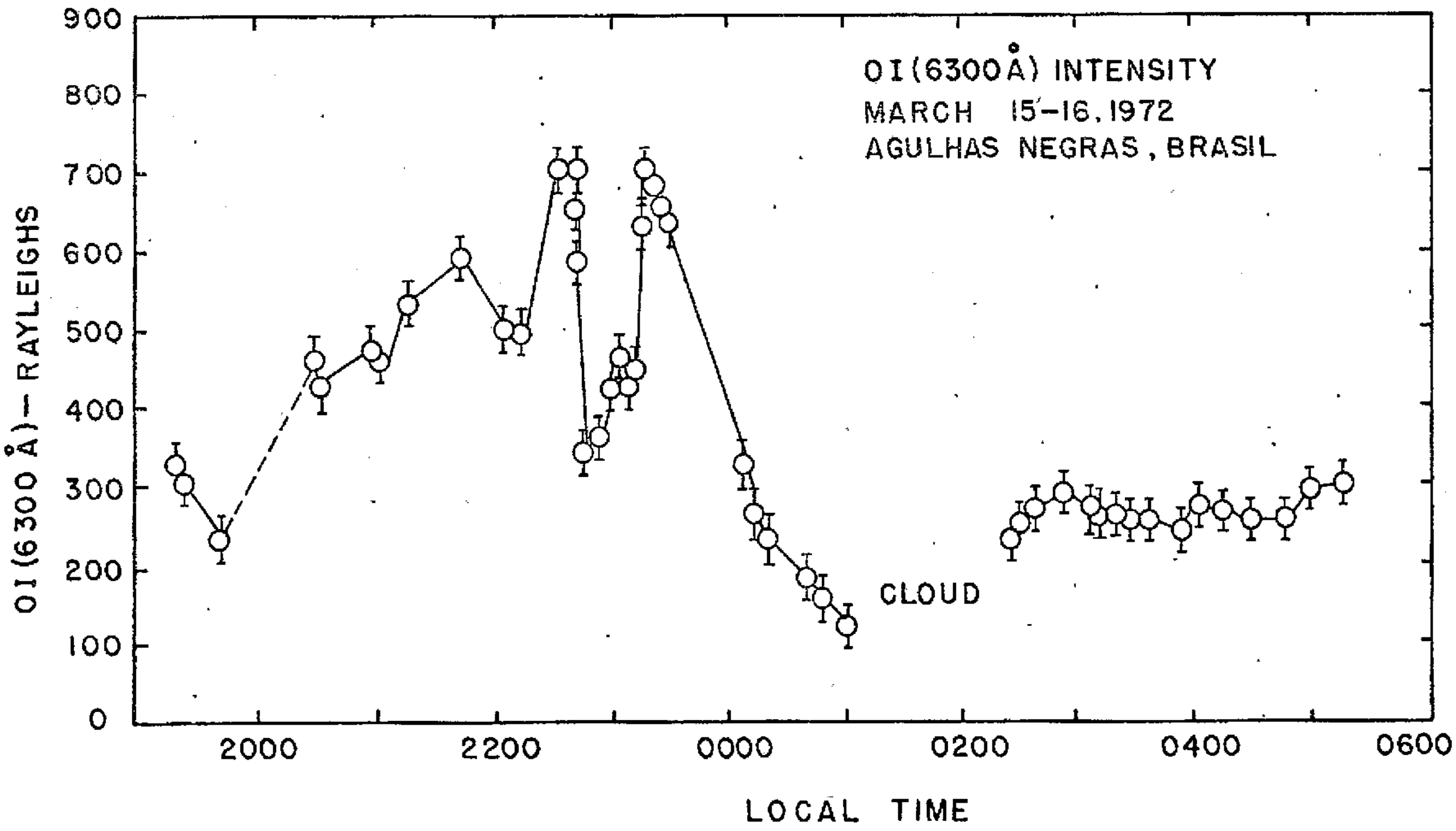

OI (6300 Å) INTENSITY
MARCH 15-16, 1972
AGULHAS NEGRAS, BRASIL
CLOUD
OI (6300 Å) — RAYLEIGHS
900
800
700
600
500
400
300
200
100
0
2000
2200
0000
0200
0400
0600
LOCAL TIME

Fig. 13

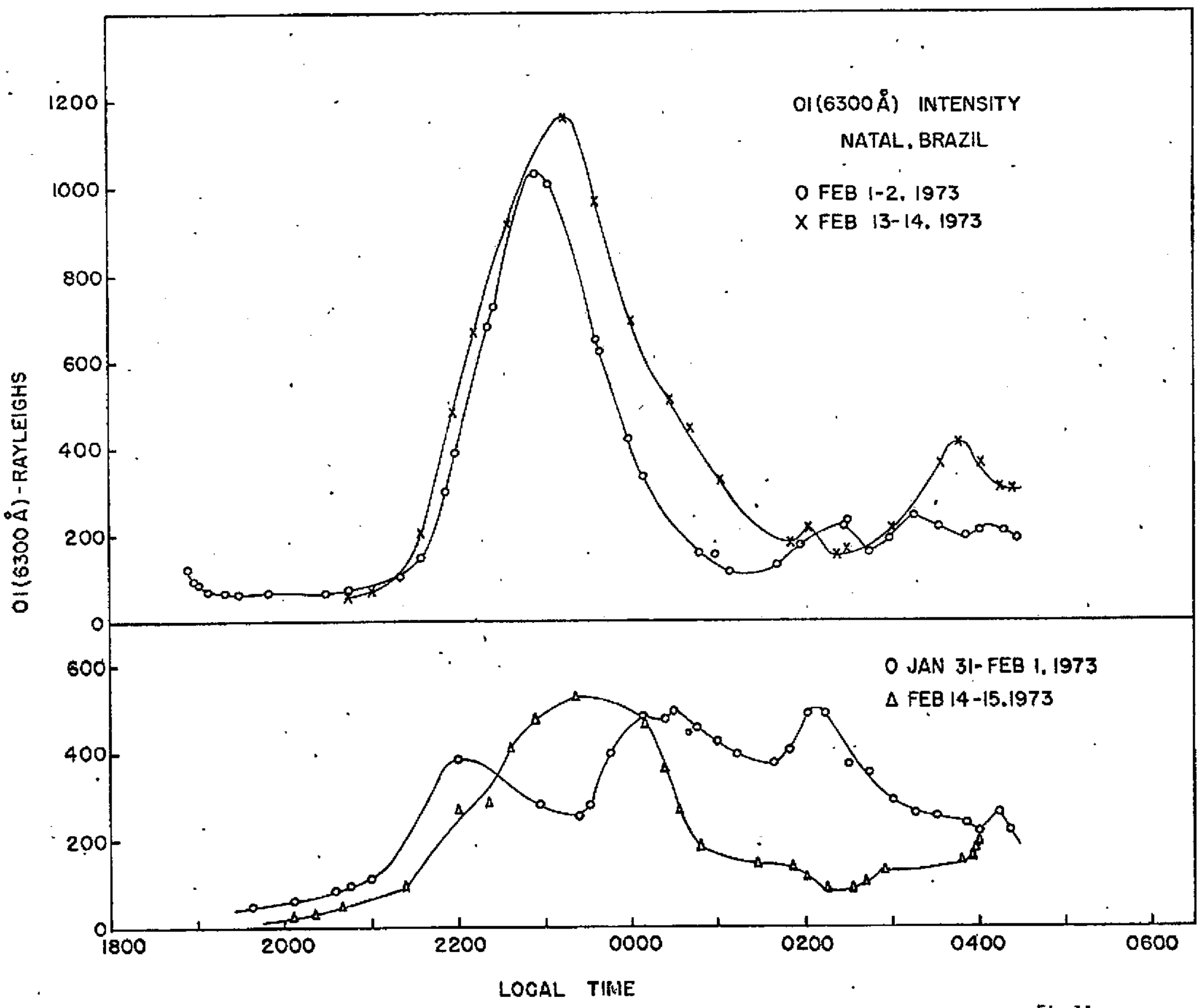

OI(6300 Å) INTENSITY
NATAL, BRAZIL
O FEB 1-2, 1973
X FEB 13-14, 1973
O JAN 31- FEB 1, 1973
Δ FEB 14-15, 1973
OI(6300 Å) - RAYLEIGHS
1200
1000
800
600
400
200
0
600
400
200
0
1800
2000
2200
0000
0200
0400
0600
LOCAL TIME

Fig. 14