CHAPTER - 5

DATA ANALYSIS

5.1 Optical, Ionospheric and Magnetic Data

In this section we present the correlation between optical data, ionospheric data and geomagnetic data.

5.1.1 Optical Data

Airglow observations were made from the terrace of Physics Department, Shivaji University, Kolhapur, a low latitude station (16.8° N; 74.2° E; 10.6° N dip lat) fig.5.1.

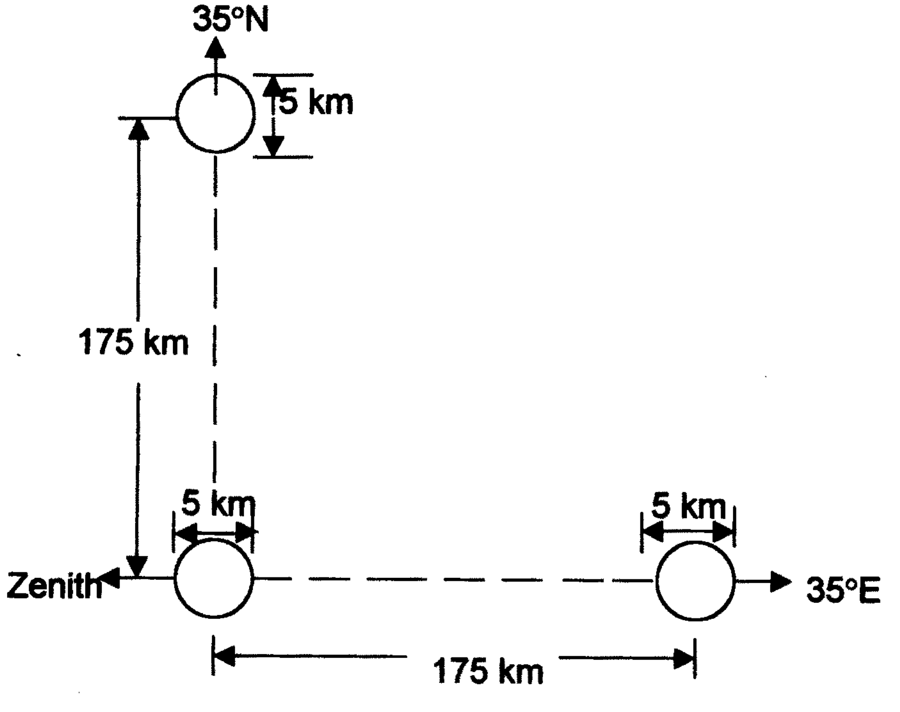


Fig 5.2

(Cross-section of three ionospheric volumes as viewed by three photometers at 250 km height)

Three tilting photometers are installed at terrace of the

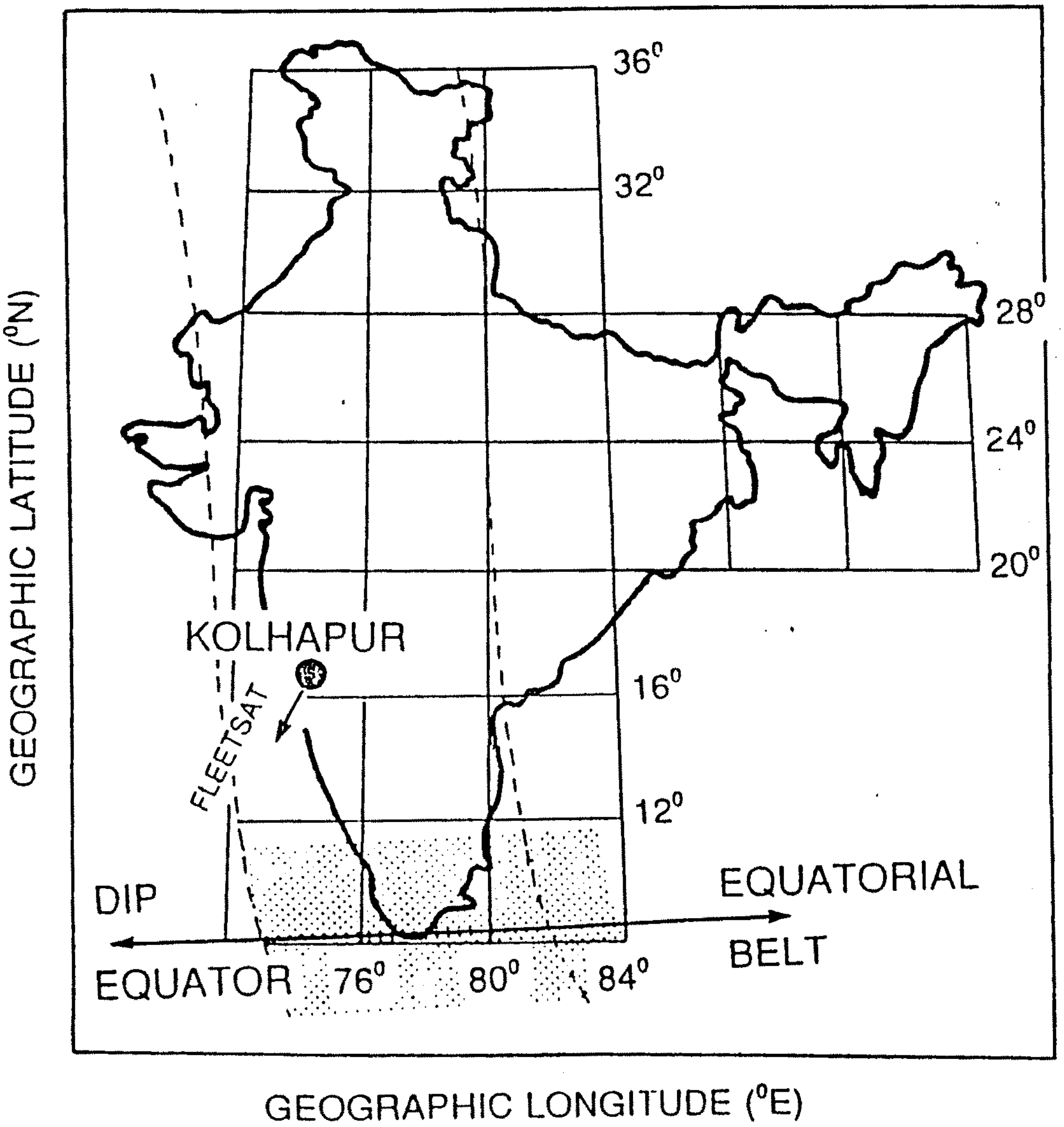


Fig. 5.1. Geographic longitude and latitude of Kolhapur

Physics Department, Shivaji University, by Indian Institute of Geomagnetism (IIG), Mumbai.

The ultimate form of overall photometer was such that, not only could it be used to monitor three different small (about 5 km in diameter at 250 km height) volumes of ionosphere (Fig.5.2) above.

Simultaneously, but also the separation of three ionospheric volumes being monitored could be made variable in accordance with the corresponding research objectives. The photometers were positioned in the direction of Zenith, 35° East and 35° North.

5.1.2. Ionosonde Data

The ionospheric parameters (critical frequency) of the F2 layer (f_0F_2) and the virtual F-layer height (h'F) of the ionosphere have been used from Ahmedabad (geog. lat., 23.02° N, long. 72.6° E) station to know ionospheric conditions during the time of airglow observation. The square of (f_0F_2) critical frequency of F-layer is proportional to electron density at the peak of the F_2-layer [1].

5.1.3 Geomagnetic Indices

The magnetic data is obtained from the set of magnetic observations all over India maintained by IIG.

(1) Indices

K is the 3-hours index designed to measure the irregular variations on the standard magnetograms. It is a measure of solar corpuscular radiation based upon the intensity of geomagnetic activity caused by the electric currents produced in the upper atmosphere by such radiation. Each observatory assigns an integer from 0 to 9 each of the 3-hours intervals starting at 00:00 to 21:00 UT. A permanent scale is adopted for each observatory. This scale defines 'K' index by giving limits for amplitude ranges 'R', K has assigned values from 0 to 9. But, during a storm, the effect may be different at different places and that would prevent us from having a uniform value of 'R' globally. In order to counter this, different frequency ranges were allotted to different stations basing on 1938 data. However since K-index is based on a single station it includes regional conditions.

(2) K_p and K_s Index

K_p index is a 3-hourly one, designed to measure planetary variations in geomagnetic activity. The indices are first translated into standard indices K_s. These K_s indices are freed from local variations. K_p indices are then based upon the K_s.

(3) Ap Indices

The K_p indices are converted into linear scale corresponding amplitudes is known as A_p. We will get 8 three-hourly values for A_p, when these eight A_p values are averaged we get the A_p values for the day. It serves as a daily index.

5.2. Description of Photometer Data

We use for analysis the photometer data obtained at Kolhapur during clear moonless nights. Three tilting photometers were pointed to the North (35°), East (35°) and Zenith directions.

Each photometer consists of a filter with tilting mechanism, normal position gives the signal and background reading, the second filter position gives only the background reading.

The difference between two readings gives the signal of distant 630.0 nm airglow variations. This was repeated throughout the night to get the airglow intensities during the night at two-minute interval.

For knowing the condition of ionosphere, we also use ionosonde data of Ahmedabad (geog. lat., 23.02° N, long. 72.6° E). The parameter h'F, the virtual height of the height F-layer and foF2, the critical frequency of the F2 layer have been used here. 630.0 nm intensity is proportional to electron density below the peak of the F2 layer. The square the parameter (foF2) gives the electron density values. Also, if the F-layer height decreases, the enhancement in 630.0 nm intensity takes place at the ground due to presence of more O_2 molecules at the lower altitudes at a given place. On the other hand, the layer may be stationary, but electron density within the layer may change which can produce change in 630.0 nm airglow.

Table 5.1 outlines the data of geomagnetic activity index A_p and solar flux F10.7 cm during period of study.

TABLE 5.1

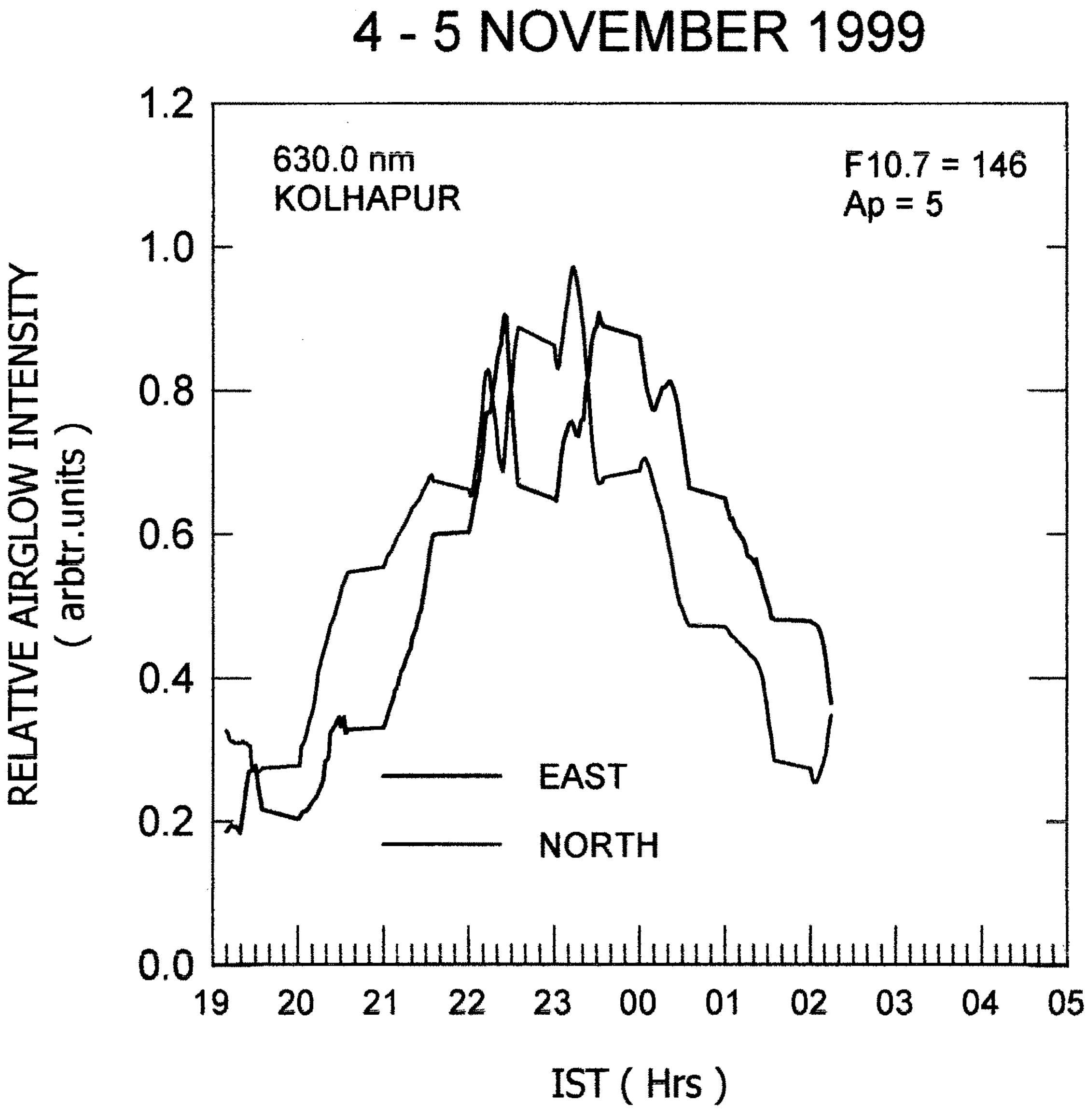
GEOMAGNETIC ACTIVITY Ap AND SOLAR FLUX (10.7 cm)

DATE	AP	SOLAR FLUX
4-5 NOV 1999	5	146
1-2 DEC 1999	5	160
3-4 DEC 1999	16	143
4-5 DEC 1999	30	143
5-6 DEC 1999	20	139
6-7 DEC 1999	19	143
8-9 DEC 1999	14	146
30-31DEC 1999	11	131
31 DEC 99-1 JAN 00	36	128
2-3 JAN 00	16	129
6-7 JAN 00	19	140
7-8 JAN 00	10	144
28-29 JAN 00	32	122
30-31 JAN 00	15	125
31 JAN – 1 FEB 00	10	135
2-3 FEB 00	8	140
6-7 FEB 00	34	173

5.2.1 Observations on 4-5 November, 1999

The Fig.5.3 shows the 630.0 nm intensity variations at Kolhapur by two photometers observed on the night of 4-5 November 1999. The geomagnetic activity index A_p value and solar F10.7 cm flux were also shown in Figure.

It is observed that 630.0 nm intensity peaked around 23:00 hrs in the North direction. In the same night, the East looking photometer showed a dip in intensity in 630.0 nm around 23:00 midnight with two



4 - 5 NOVEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 146
Ap = 5
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
EAST
NORTH
IST (Hrs)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19
20
21
22
23
00
01
02
03
04
05

Fig.5.3

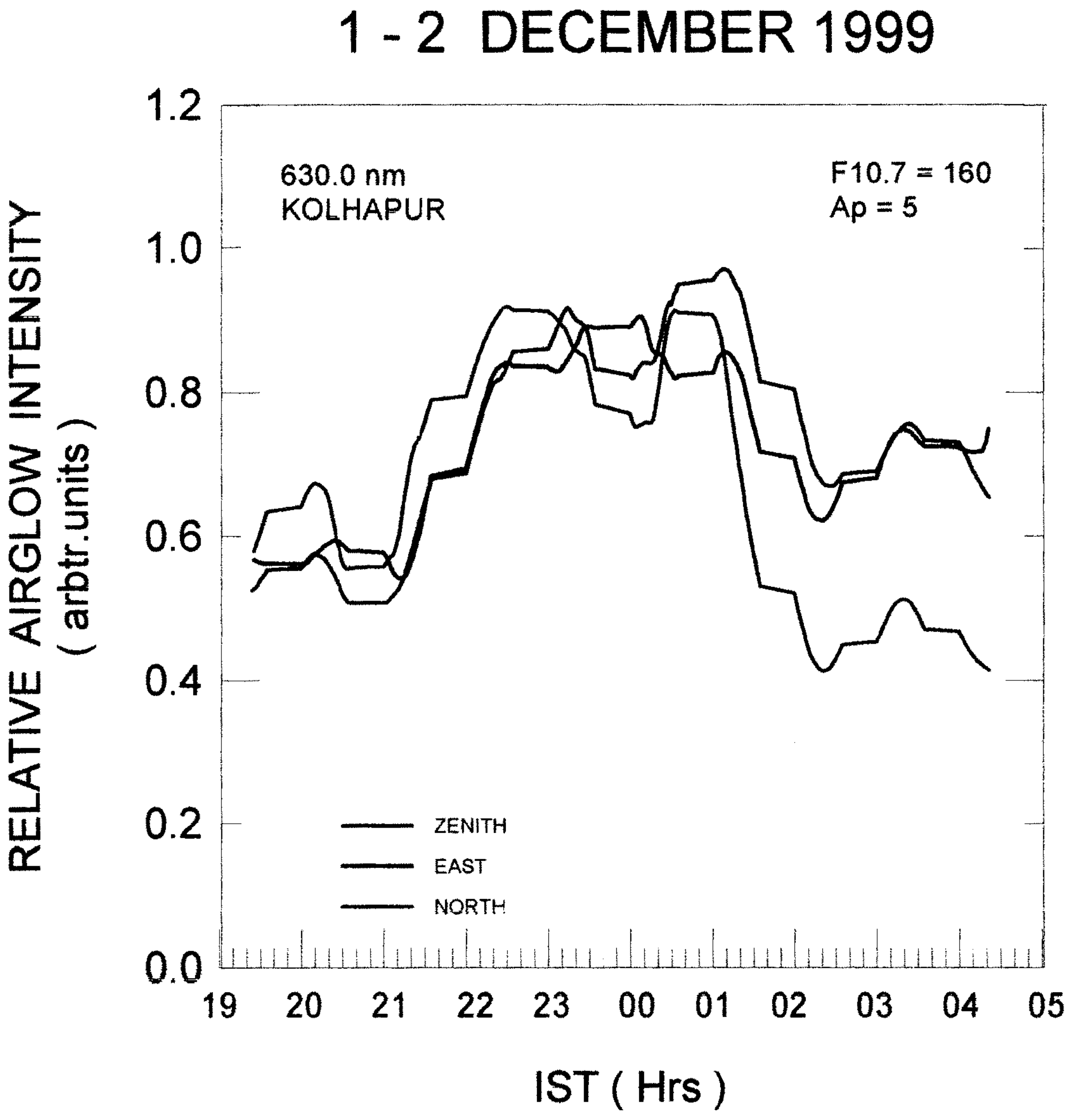
maxima occurring at 22:00 hours and midnight.

5.2.2 Observations for 1-2 December, 1999

The fig.5.4 shows graph for 1-2 December.The average solar flux (F10.7 cm) for the day was 160 units and magnetic activity index Ap was 5. It was typically a magnetically quiet period with moderate solar activity. The average 630.0 nm intensity was more between 22:00 hrs and 01:00 hrs at night than at other periods. Though the intensity fluctuation was in the same phase around 22:00 hrs and 01:00 hrs in Zenith and 35^0 North direction, the fluctuation showed the peak value at 23:30 hrs in the East. The intensities were minimum around 02:00 hrs, which were observed by three photometers.

5.2.3 Observations on 3-4 December, 1999

The magnetic activity index Ap was 16 and the solar flux F10.7 cm was143 units. The fig.5.5 shows the nightglow variations of 630.0 nm intensity during the night as observed by three photometers looking at 35^0 N, 35^0 E and at Zenith directions. It is clearly seen that there are two intensity peaks observed by the photometers around 22:30 hrs and 02:00 hrs at night. The second peak is larger in intensity than the first. The Zenith photometer and the North looking photometer display the 630.0 nm intensity at the same phase and at 02:00 hrs but the East photometer shows the peak earlier compared to other photometers.



1 - 2 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 160
Ap = 5
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ZENITH
EAST
NORTH
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.4

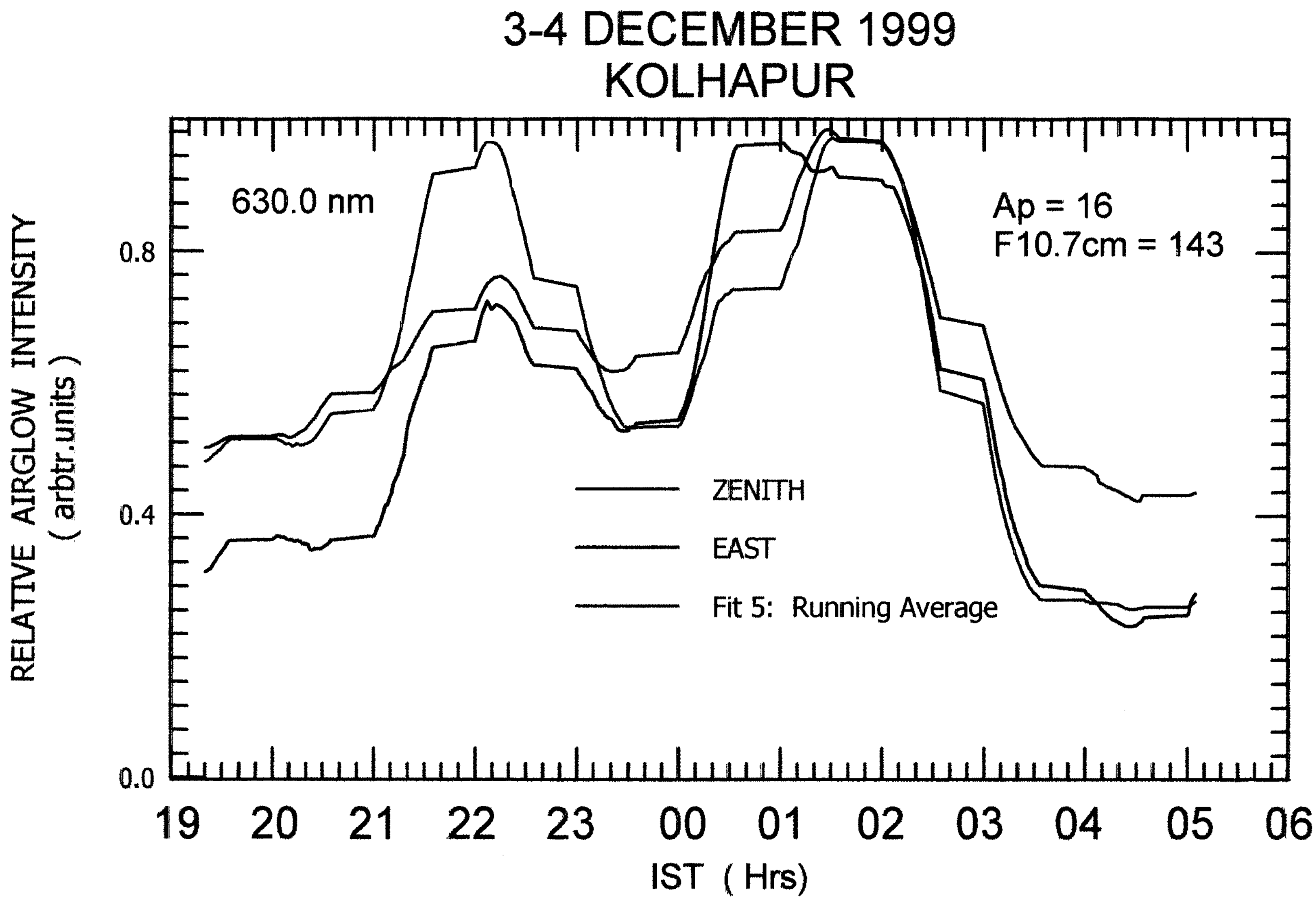

3-4 DECEMBER 1999
KOLHAPUR
630.0 nm
Ap = 16
F10.7cm = 143
ZENITH
EAST
Fit 5: Running Average
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
0.0
0.4
0.8
19
20
21
22
23
00
01
02
03
04
05
06
IST (Hrs)

Fig.5.5

5.2.4 Observations on 4-5 December, 1999

Fig.5.6 shows the night time variation of 630.0 nm intensity on the night of 4-5 December 1999. The solar flux (F10.7 cm) and the magnetic activity index Ap are also shown in the figure. It was a magnetically disturbed night with moderate solar activity. It is seen that there are two prominent peaks (630.0 nm) as observed by the three photometers occurring around 22:30 hrs, the maximum in 630.0 nm intensity at 22:00 hrs may be close to the passage of reverse ionization anomaly at the station. Generally the post-midnight enhancement in 630.0 nm at 02:30 hrs may be due to midnight temperature maximum which produces heating of the equatorial F-region at midnight. This induces poleward winds from the equator. The vertical component of the neutral wind pushes the F-layer downwards. Lowering of F-layer gives rise to enhancement in 630.0nm intensity. The magnitude of the 630.0 nm intensity enhancement due to temperature maximum is about half the value due to enhancement in reverse ionization anomaly.

There are cases when the measurements both by ground-based and satellite borne instrumentation, revealed a pronounced increase in the neutral wind temperature around mid-night over the equator, sometimes the value exceeds the afternoon maximum **[2]**. This feature is known as the midnight temperature maximum (MTM), a region of anomalous temperature and density that is generally considered to result from

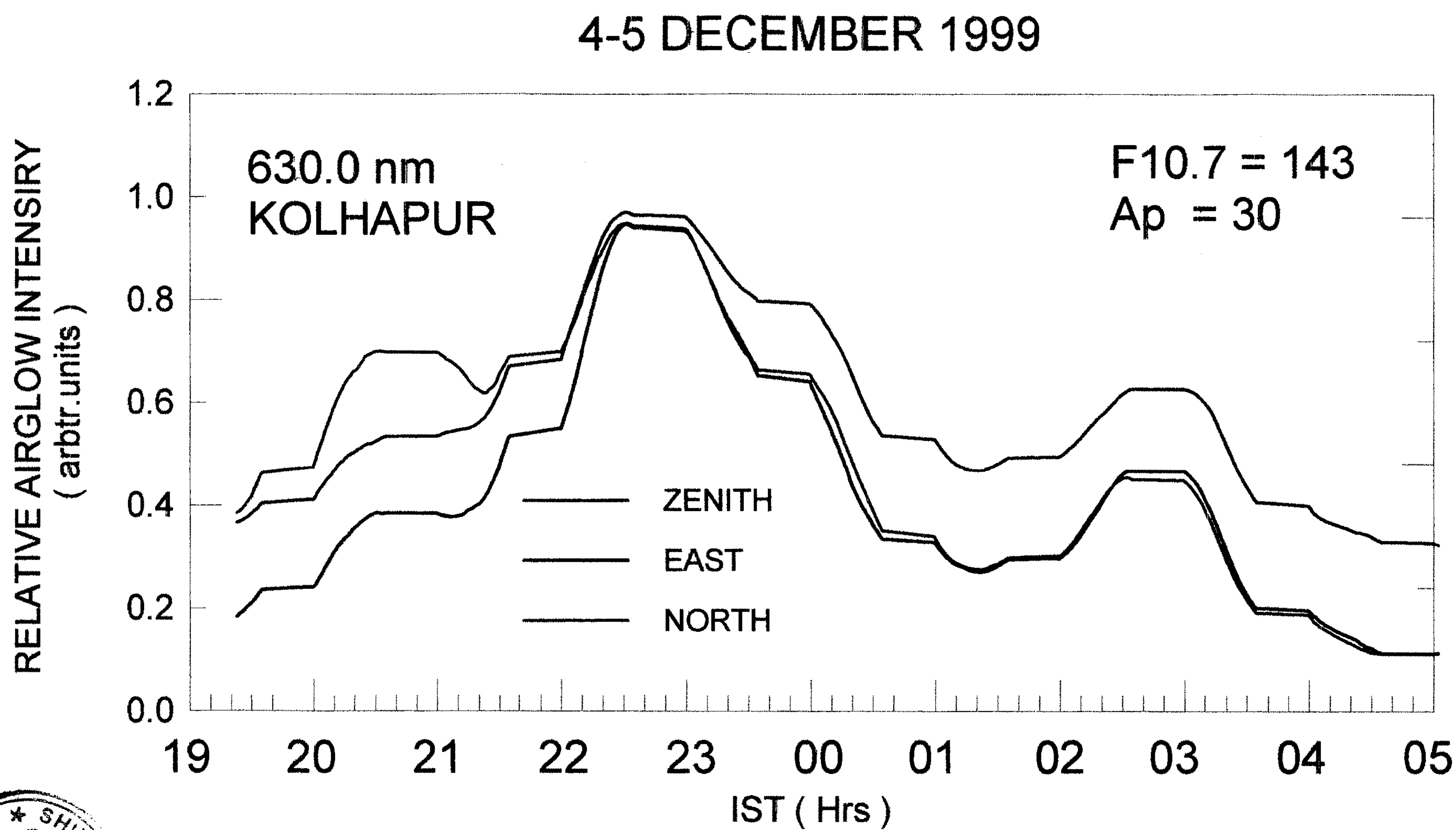

4-5 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 143
Ap = 30
ZENITH
EAST
NORTH
RELATIVE AIRGLOW INTENSIRY
(arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.6

atmospheric tidal interactions. Winds generated due to pressure bulge phenomena propagate northward and its vertical component moves the F-region plasma downward to region of enhanced loss and airglow production. This event is prominent at the stations during the months of March and April around local midnight. An all-sky camera can be used to map the movement of the transient airglow structure (brightness wave) caused due to MTM induced winds propagating across the all-sky field of view from equator to poles.

5.2.5 Observations on 5-6 December, 1999

Fig.5.7 shows the 630 nm intensity variations as a function of IST (hrs) on the night of 5-6 December, 1999. The magnetic activity index Ap and the solar flux (F10.7) values for the day are also shown in the figure. It is observed that there is no clear sharp peak in 630 nm intensity during 21:30 to 00:30 hrs. Fluctuations in 630 nm intensity may be related due to the changes in the heights of F-layer due to magnetic disturbance.

5.2.6 Observations on 6-7 December, 1999

The Fig.5.8 shows the 630 nm variations on a moderately disturbed night at Kolhapur. There were two prominent peaks observed on this night in night airglow data. The first peak occurs at 20:30 hrs and the second enhancement takes place around 23:20 hrs. The time of the two peaks coincides in all three directions. The intensity decreases sharply in these three directions after midnight hours.

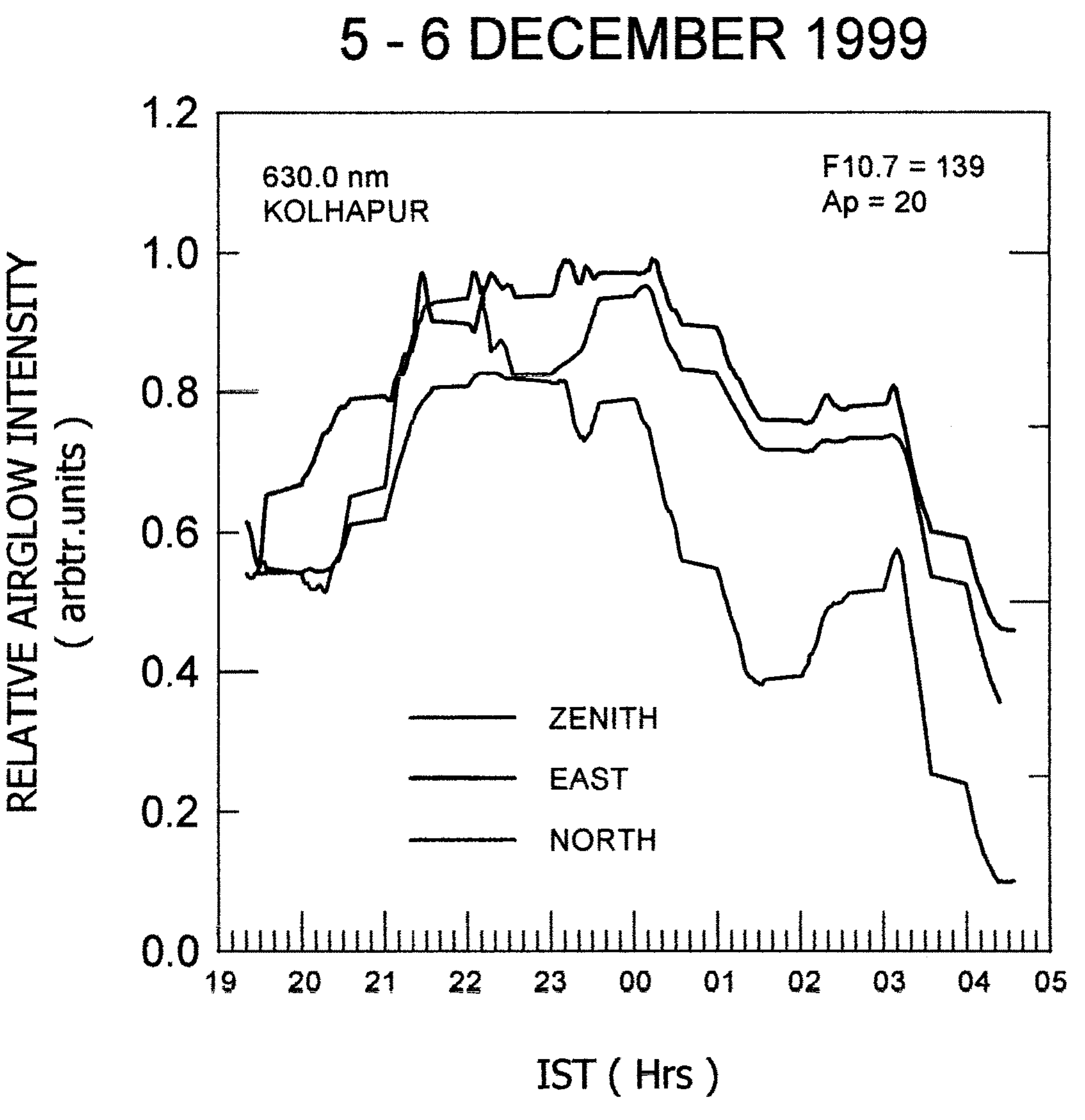

5 - 6 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 139
Ap = 20
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ZENITH
EAST
NORTH
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.7

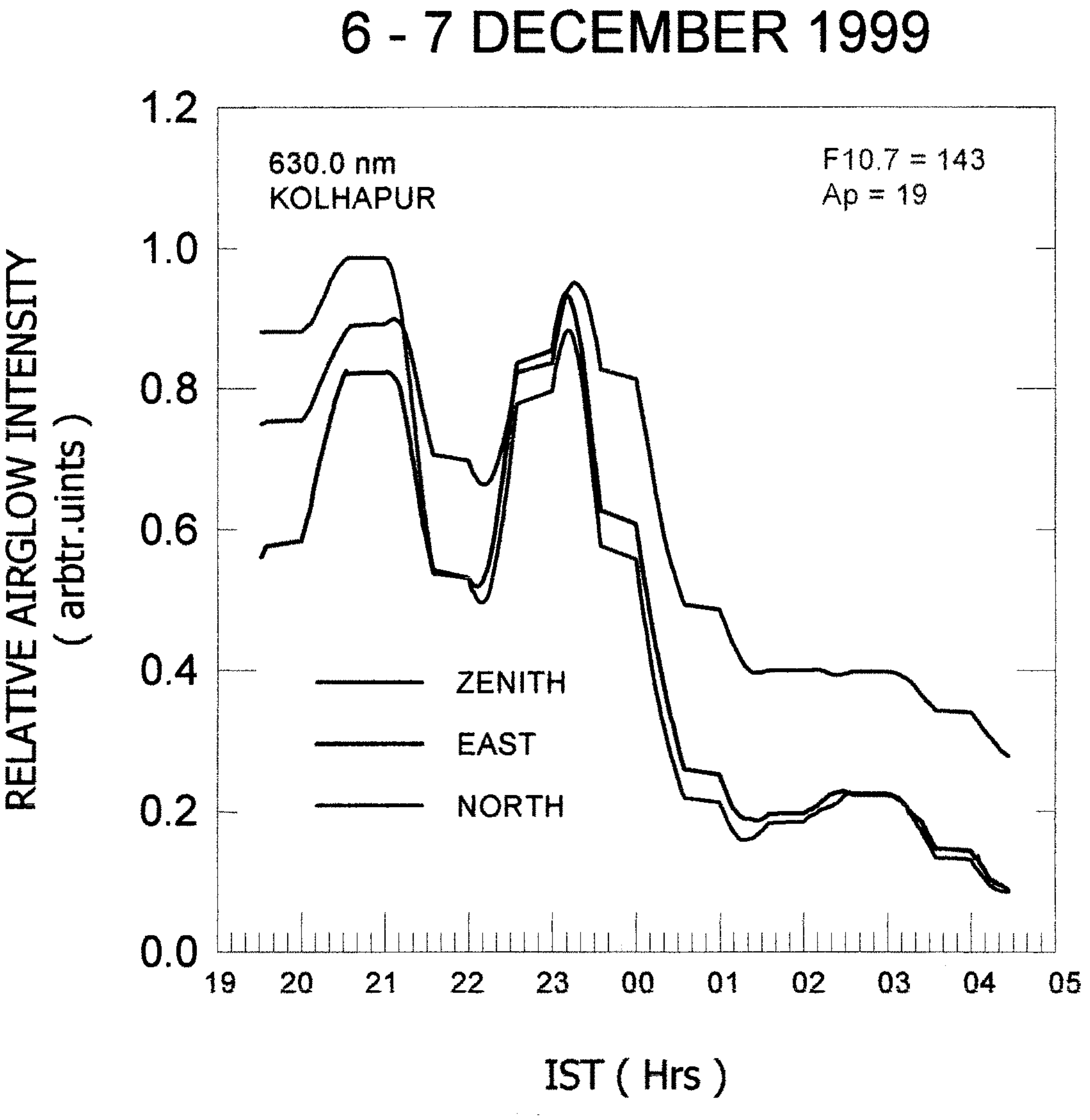

6 - 7 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 143
Ap = 19
RELATIVE AIRGLOW INTENSITY
(arbtr.uints)
ZENITH
EAST
NORTH
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19 20 21 22 23 00 01 02 03 04 05
IST (Hrs)

Fig.5.8

5.2.7 Observations on 8-9 December, 1999

This was a night with moderate activity Ap=14 and solar flux as 146 units. The 630 nm night airglow data shows (fig.5.9) two peaks, one appearing around 22:00 hrs and the second peak around 02:00 hrs at night. It is seen that the peak at North appears first and then it is seen by the Zenith photometer after 20 minutes, this gives rise to drift velocity in meridional direction towards the equator assuming the same structure is moving towards the equator.

We determine the apparent drift speeds simply from the time delay of common features in the data which gave drifts as 97 m/s. It has been tacitly assumed that the maxima progress at a constant speed and at a constant height of 250 km, the shape remaining unchanged. The source of error in this type of calculations may arise due to changes in the constant height (250 km) of the layer assumed in the calculation. A change of 10 km in vertical height during the movement can give rise to an error of 5 m/s in computations of drift speeds. Another source of error could be due to inaccurate estimate of time of occurrence at which airglow fluctuations reach their maxima or minima. As the airglow data used were obtained at a sampling rate of 2 minute, error due to inaccuracy of such time scale in the determination of velocity would be about 1-5 m/sec. We also provide few more examples of thermospheric motion in eastward and northward direction.

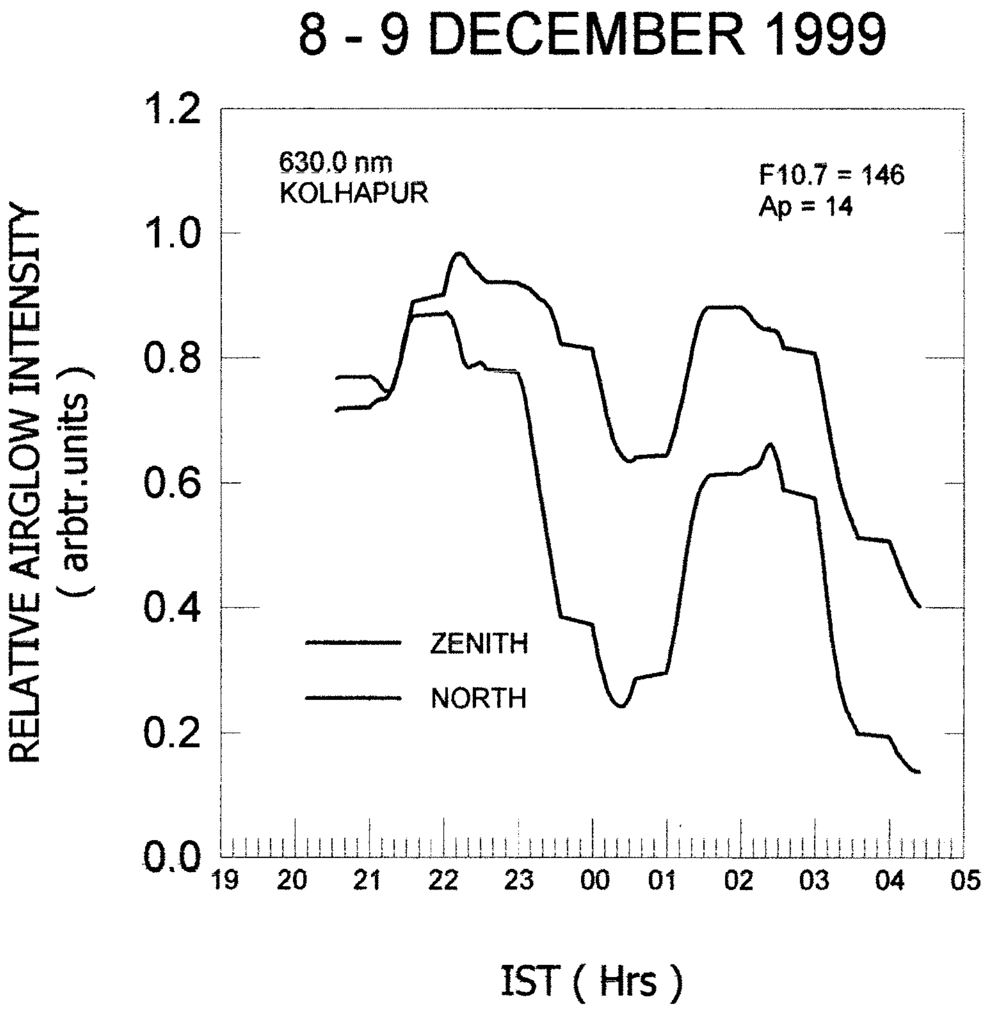

8 - 9 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 146
Ap = 14
ZENITH
NORTH
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19 20 21 22 23 00 01 02 03 04 05
IST (Hrs)

Fig.5.9

5.2.8 Observations on 30-31 December, 1999

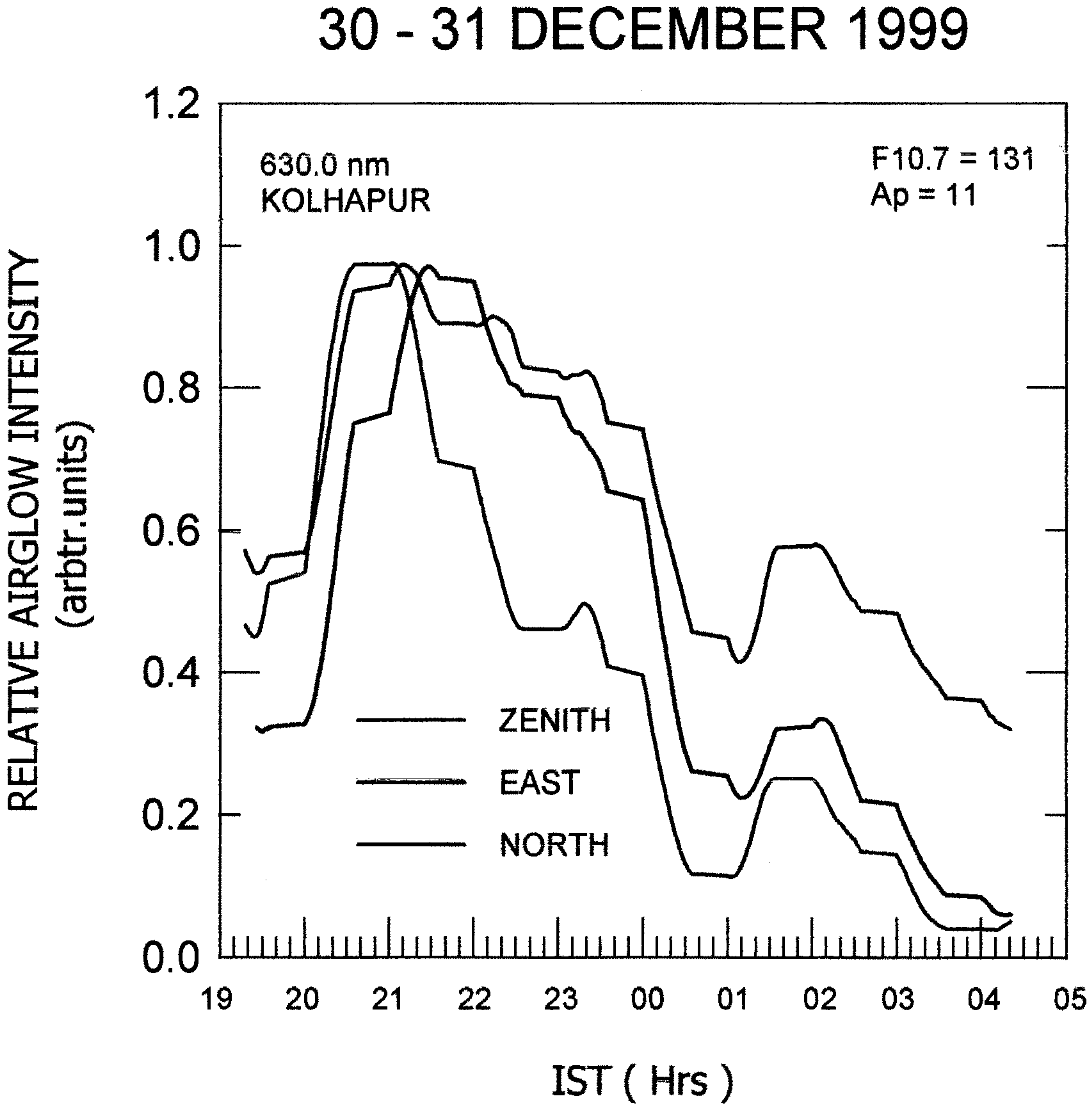
The Fig.5.10 shows the 630 nm intensity variations in Zenith, North and East directions at Kolhapur during the night of 30-31 December, 1999. Though there are two well defined peaks observed in the data around 21:00 hrs and 01:50 hrs, the peaks at 21:00 hrs are stronger than the second one. The first peak could be due to the equatorial ionization anomaly appearing at the station around 21:00 hrs and the second peak could be associated with midnight temperature maximum which causes the heating of the ionosphere and enhancement of 630 nm airglow. Also, it generates poleward wind.

5.2.9 Observations on 31 December, 1999 – 1 January, 2000

The 630 nm variation during the night of 31 December 1999 – 1 January, 2000 (fig.5.11) observed on a magnetically disturbed night, Ap=36. A sharp peak in 630 nm intensity was observed around 22:30 hrs by both the photometers looking at 35° East and 35° North direction. It is interesting to observe that the peaks are sharp and their occurrence is simultaneous. This is a peculiar behaviour on a very magnetically disturbed night, when the two peaks are not separated.

5.2.10 Observations on 2-3 January, 2000

The fig.5.12 shows the 630 nm intensity variations on the night of 2-3 January, 2000. The 630 nm emission shows short period variations in intensity along with a very large period of 4 hours. The wavy disturbances could be the signature of atmospheric gravity waves. The second



30 - 31 DECEMBER 1999
630.0 nm
KOLHAPUR
F10.7 = 131
Ap = 11
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ZENITH
EAST
NORTH
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.10

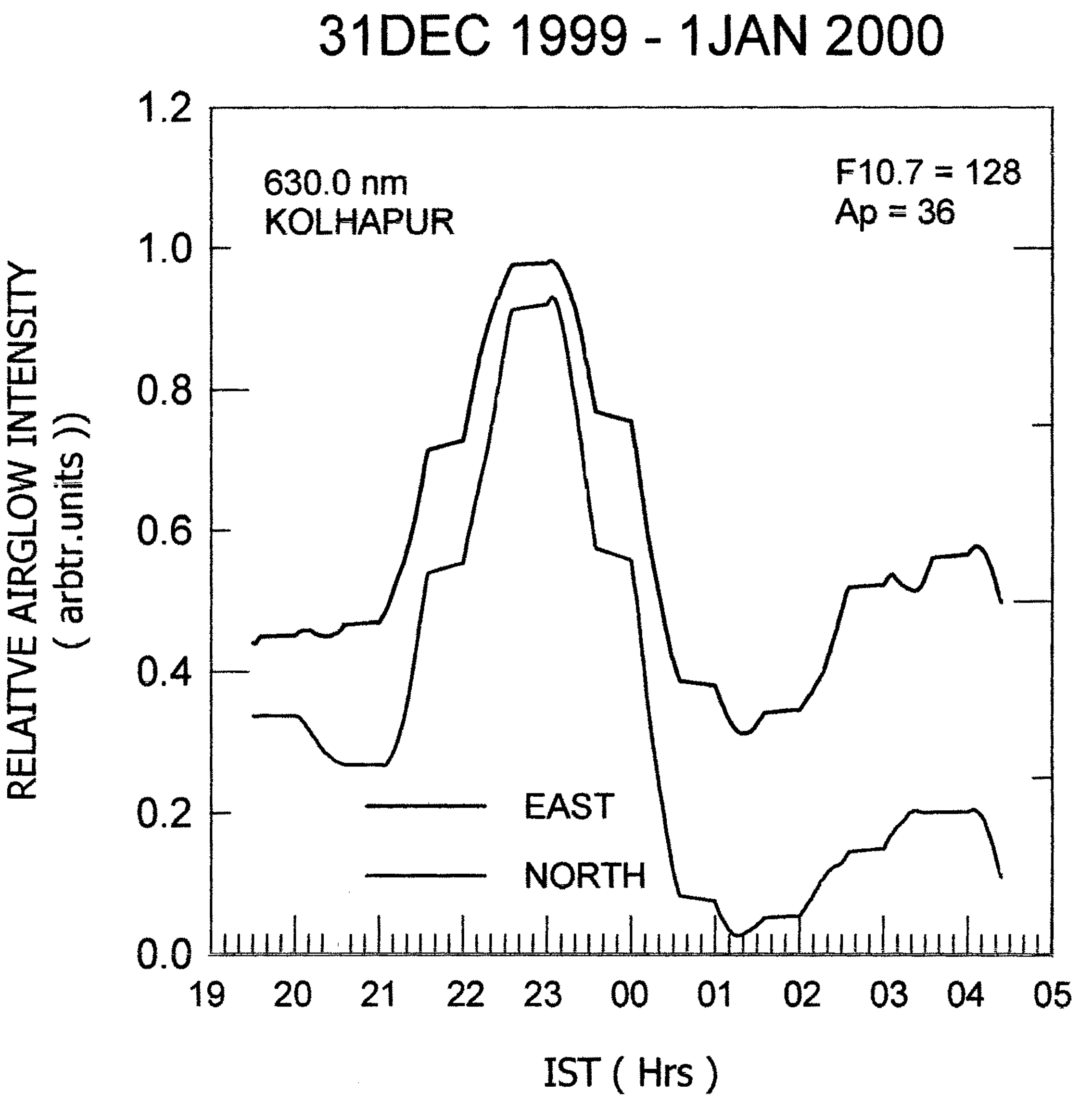

31DEC 1999 - 1JAN 2000
630.0 nm
KOLHAPUR
F10.7 = 128
Ap = 36
EAST
NORTH
RELAITVE AIRGLOW INTENSITY
(arbtr.units))
IST (Hrs)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19
20
21
22
23
00
01
02
03
04
05

Fig.5.11

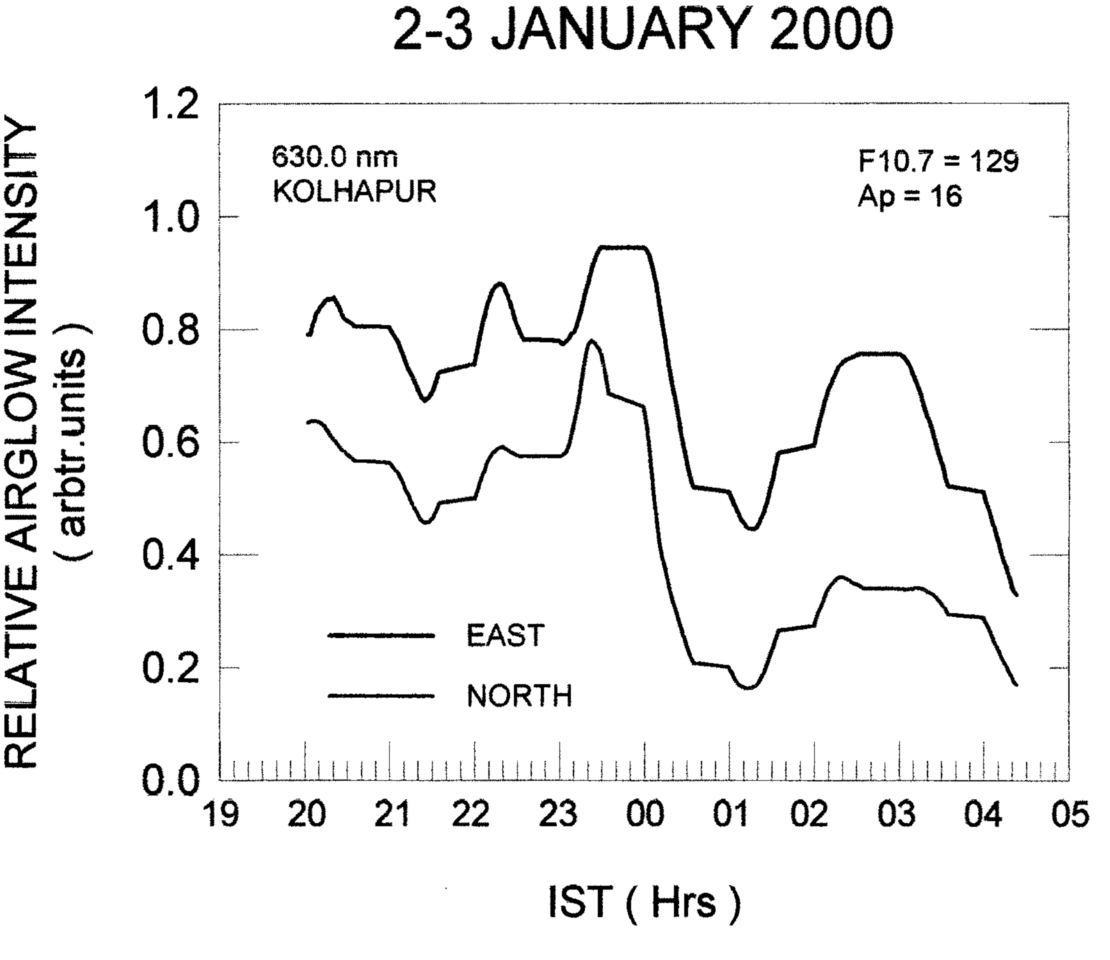

2-3 JANUARY 2000
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
630.0 nm
KOLHAPUR
F10.7 = 129
Ap = 16
EAST
NORTH
1.2
1.0
0.8
0.6
0.4
0.2
0.0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.12

maximum in intensity occurs at about 03:00 hrs.

5.2.11 Observations on 6-7 January, 2000

The upper panel in the fig.5.13 shows the 630.0 nm intensity variations during the night of 6-7 January, 2000, as a function of IST hours. The lower panel shows the variation of ionospheric parameters, $(f_0F_2)^2$ and h'F at Ahmedabad (geog. lat. 23.02° N, long. 72.6° E) during the night.

The 630.0 nm intensity shows monotonic decrease in intensity variation during the night. The maxima in intensity takes place around 22:30 hrs at night. Around the same time h'F is minimum and thereafter h'F keeps on increasing and 630.0 nm shows inverse relationship with height variation. It is also observed that 630.0 nm intensity and $(f_0F_2)^2$ variation shows a good correlation during the night. It is generally seen that 630.0 nm intensity shows good correlation with electron density parameter $[(f_0F_2)^2]$ during quite period.

5.2.12 Observations on 7-8 January, 2000

The upper panel in the fig.5.14 of 7-8 January, 2000 shows the 630 nm intensity variations observed at the three photometers looking at 35° E, 35° N and Zenith. The geomagnetic activity index Ap=10 and solar ($F_{10.7}$ cm) flux = 144 are also shown. It was a magnetically quiet night. The lower panel shows the variation of ionospheric parameters $(f_0F_2)^2$ and h'F at Ahmedabad during the night. All three photometers 35° E and 35° N and

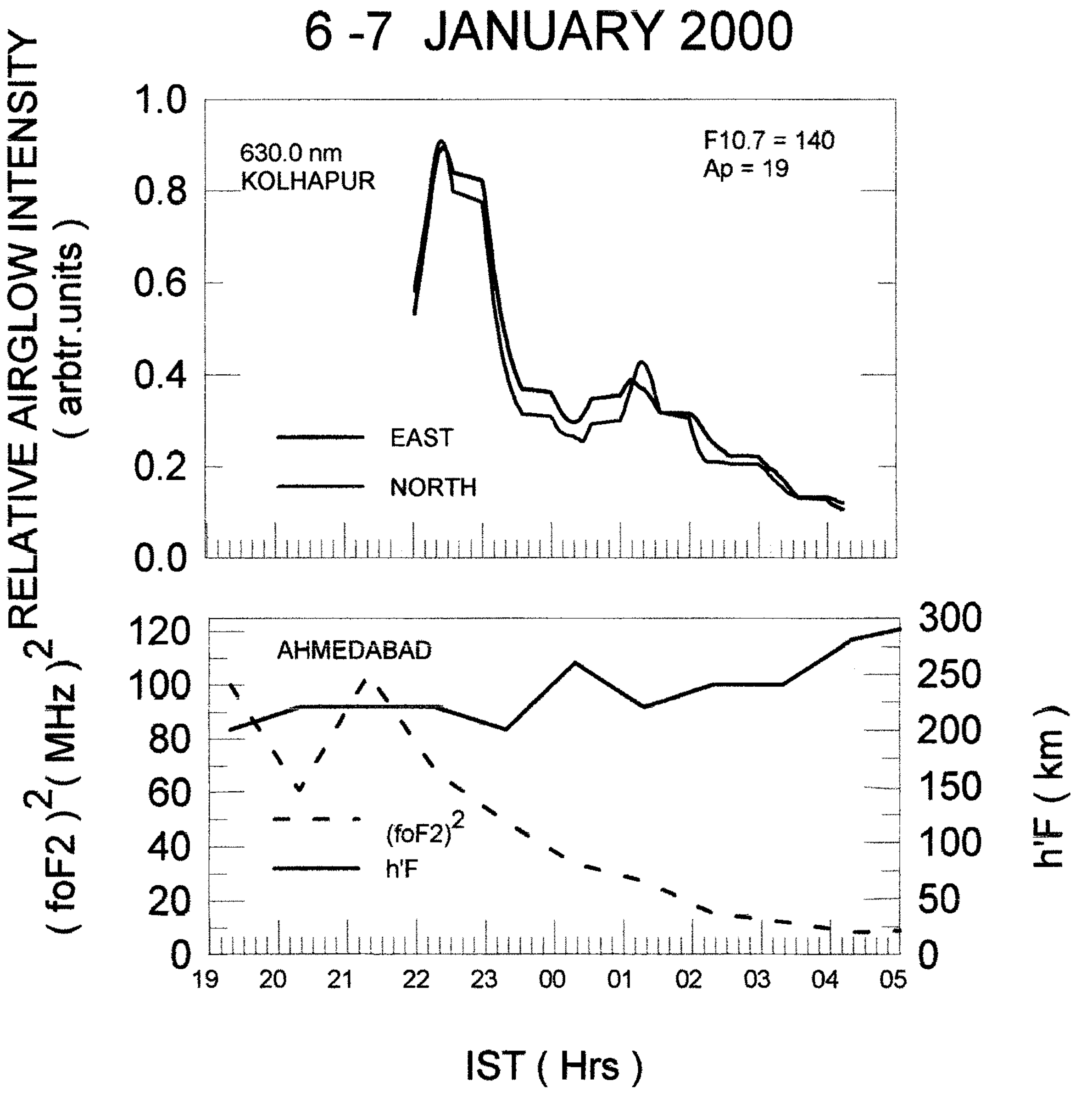

6 -7 JANUARY 2000
RELATIVE AIRGLOW INTENSITY (arbtr.units)
630.0 nm
KOLHAPUR
F10.7 = 140
Ap = 19
EAST
NORTH
1.0
0.8
0.6
0.4
0.2
0.0
AHMEDABAD
(foF2)^2
h'F
(foF2)^2 (MHz)^2
h'F (km)
120
100
80
60
40
20
0
300
250
200
150
100
50
0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.13

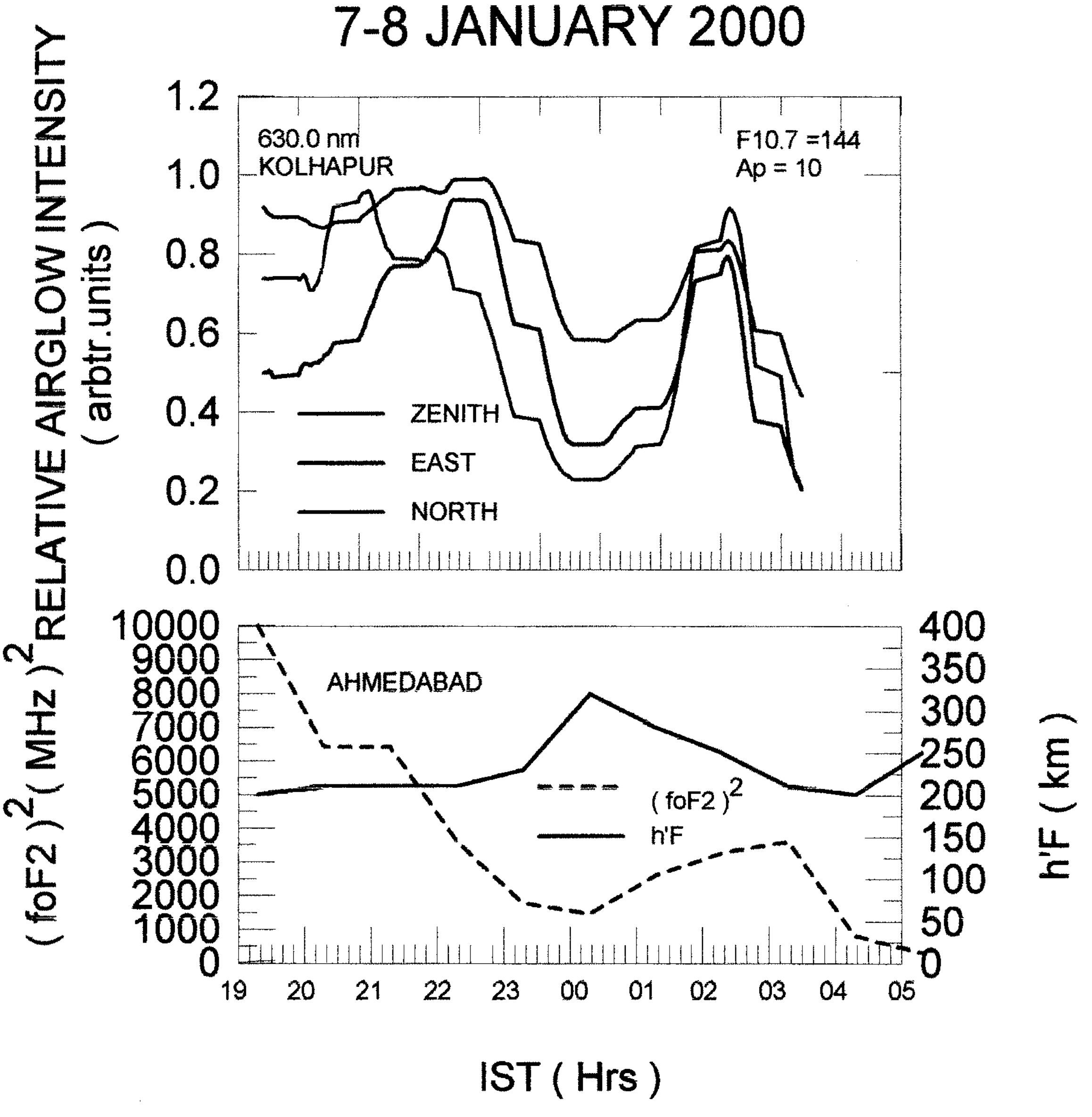

7-8 JANUARY 2000
RELATIVE AIRGLOW INTENSITY (arbtr.units)
630.0 nm
KOLHAPUR
F10.7 =144
Ap = 10
ZENITH
EAST
NORTH
1.2
1.0
0.8
0.6
0.4
0.2
0.0
(foF2)2(MHz)2
AHMEDABAD
(foF2)2
h'F
h'F (km)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
400
350
300
250
200
150
100
50
0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.14

Zenith are showing peaks in 630 nm intensity but their occurrence is not simultaneous. During the first peak the North looking photometer observes maxima at first around 21:50 hrs and the East and Zenith photometers at around 22:20 hrs. There is a time delay of similar structure in the 630 nm data. From this we can compute the drift velocity of airglow structure.

There is velocity propagation from North to South direction. The airglow structure moves with the velocity 97 m/s.

The second peak arrives around 02:20 hrs after midnight. This peak is due to the phenomena of Midnight Temperature Maximum (MTM).

After comparing the ionosonde data with the photometer data it shows that, when the peak arrives the height of the F-layer (h'F) lowers. This reconfirms that low-latitude 630.0 nm airglow is very much coupled to ionospheric parameters $(f_0F_2)^2$ and h'F **[3].**

5.2.13 Observations on 28-29 January, 2000

The 630 nm variation during the night 28-29 January, 2000(fig.5.15) was observed. It was a magnetically disturbed night as the geomagnetic activity index Ap=32 and solar (F10.7 cm) flux=122. It is seen that in the beginning intensity of the airglow is sharply decreasing due to increase in height of F-layer (h'F). After midnight the intensity is increasing and peak comes around 02:25 hrs. After comparing the ionosonde data with the photometer data it is seen that, when the peak occurs, the height of F-layer (h'F) is lowered due to magnetic disturbance.

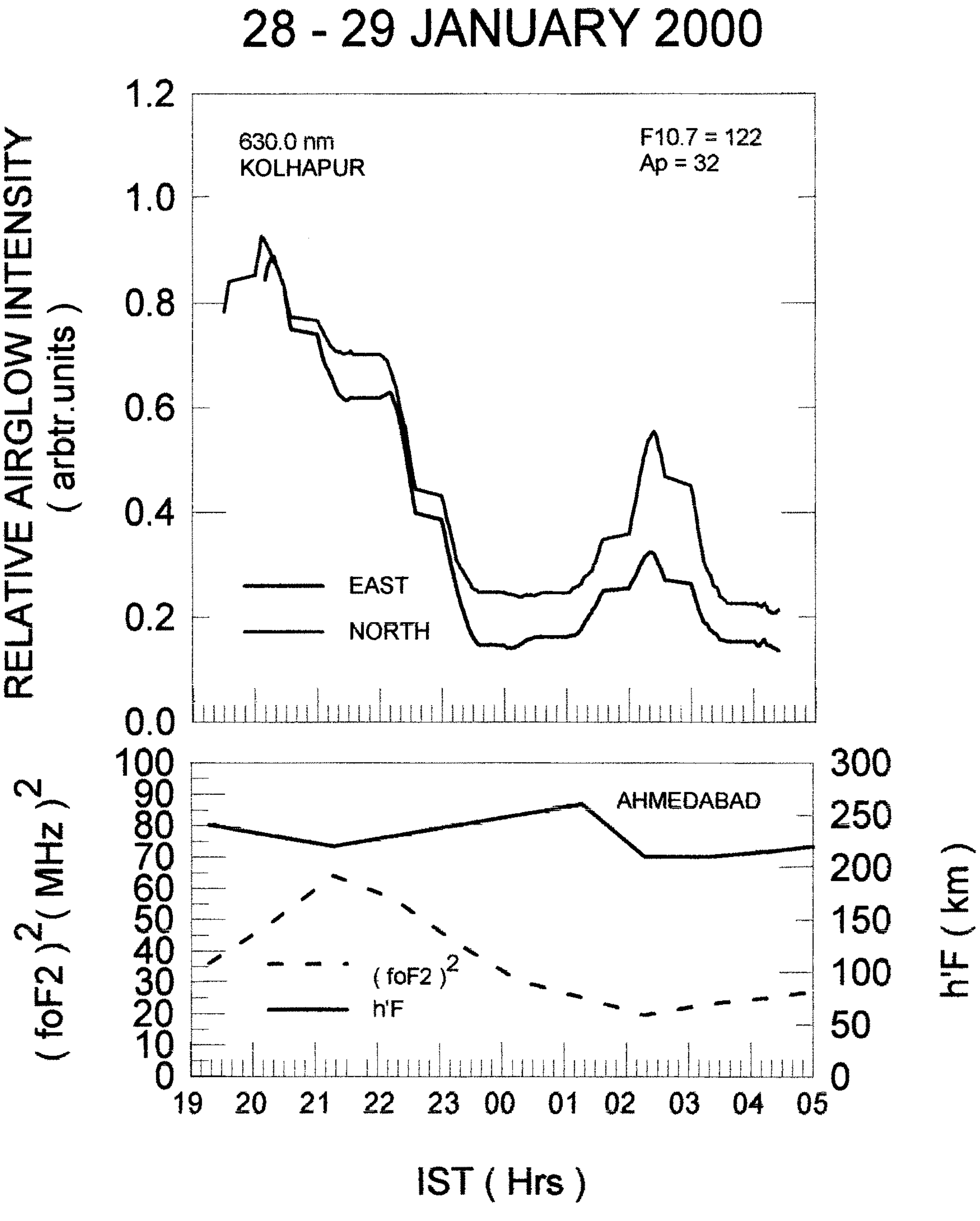

28 - 29 JANUARY 2000
RELATIVE AIRGLOW INTENSITY (arbtr.units)
630.0 nm
KOLHAPUR
F10.7 = 122
Ap = 32
EAST
NORTH
1.2
1.0
0.8
0.6
0.4
0.2
0.0
(foF2)^2 (MHz)^2
AHMEDABAD
(foF2)^2
h'F
h'F (km)
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.15

5.2.14 Observations on 30-31 January, 2000

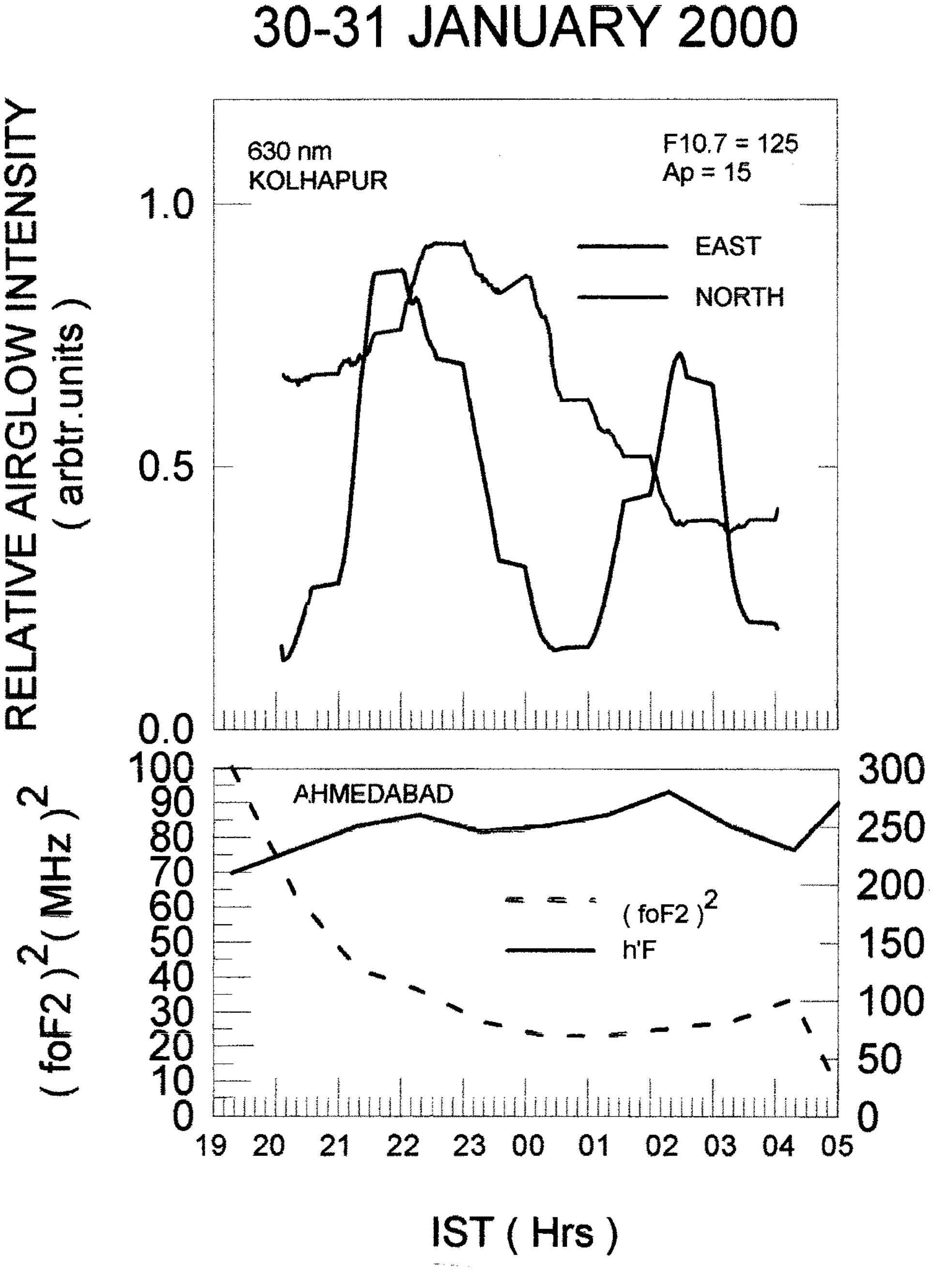
The Fig.5.16 shows the variation of 630 nm intensity during night of 30-31 January, 2000 as a function of IST. Lower panel shows the corresponding ionospheric parameters from Ahmedabad.

Both the photometers looking at 35° E and 35° N are showing peak in the 630 nm intensity but their occurrence is not simultaneous. At the first peak, the East looking photometer observes the maxima at first, around 21:50 hrs and the North looking photometer observes the maxima around 23:00 hrs. There is a time delay of similar structure in the 630 nm data. From this we can compute the drift velocity of airglow structure. There is a velocity propagation from East to North (poleword) direction. The airglow structure moves with velocity 59 m/s.

The second peak of 630 nm is observed by East looking photometer around 02:20 hrs, however, in the North, the intensity is continuously decreasing. This may be due to the airglow structure moving from Zenith to North direction during 2:20 hrs, the enhancement in 630 nm was observed by East looking photometer and not seen by the North looking photometer.

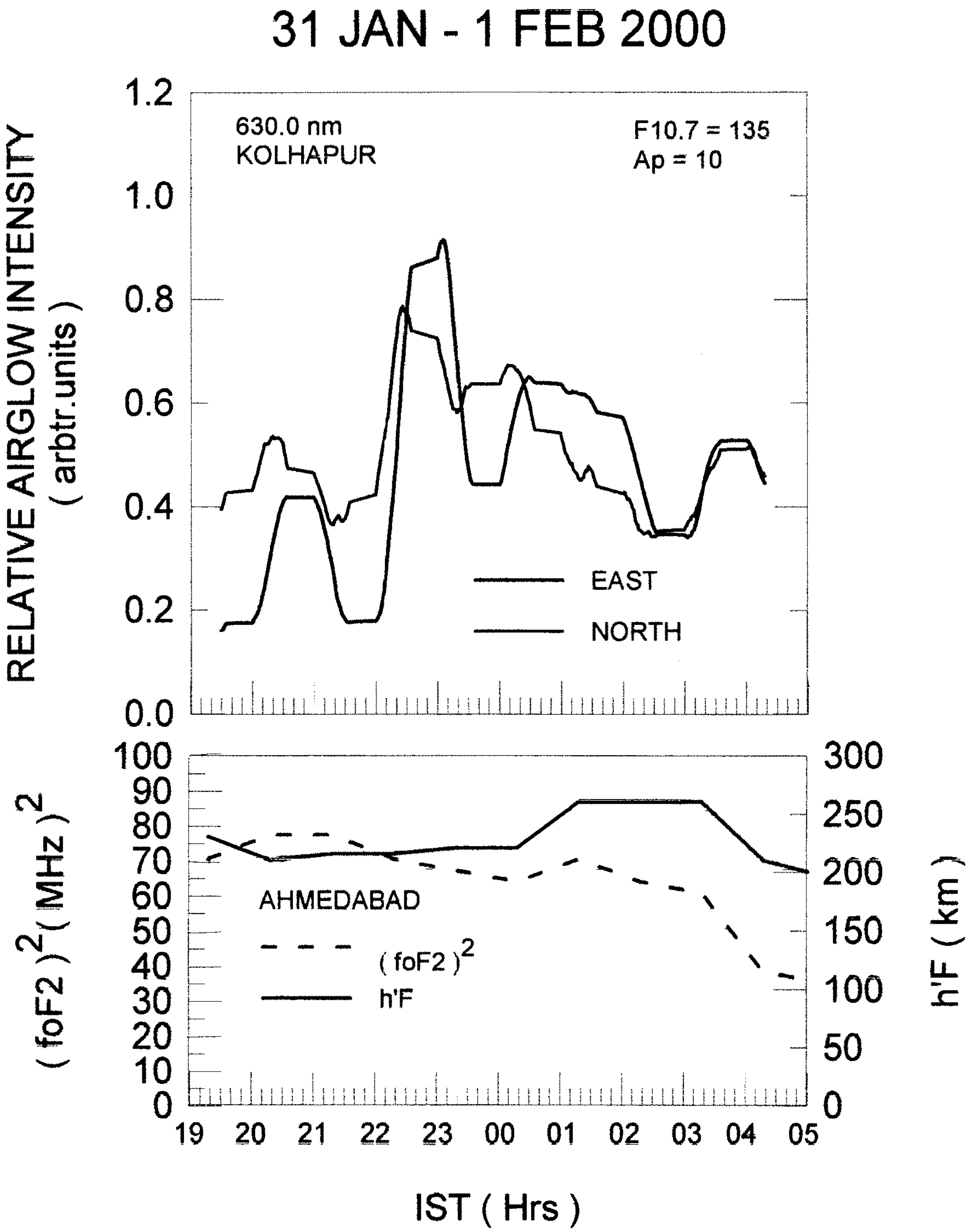
5.2.15 Observations on 31 January-1 February, 2000

The upper panel in the Fig.5.17 of 31 January - 1 February 2000, shows the 630 nm intensity variations observed by the two photometers pointing at 35° N and 35° E. It was a magnetically quite night as A_p value



30-31 JANUARY 2000
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
630 nm
KOLHAPUR
F10.7 = 125
Ap = 15
EAST
NORTH
1.0
0.5
0.0
AHMEDABAD
(foF2)2
h'F
(foF2)2(MHz)2
h'F (km)
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
19 20 21 22 23 00 01 02 03 04 05
IST (Hrs)

Fig.5.16



31 JAN - 1 FEB 2000
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
630.0 nm
KOLHAPUR
F10.7 = 135
Ap = 10
EAST
NORTH
1.2
1.0
0.8
0.6
0.4
0.2
0.0
(foF2)^2(MHz)^2
AHMEDABAD
(foF2)^2
h'F
h'F (km)
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

Fig.5.17

was 10 units. The North photometer observes the peak at first around 22:30 hrs and the East after it. Hence there is velocity propagation from North to East direction. It is also observed that 630 nm intensity shows good correlations with h'F and $(foF2)^2$.

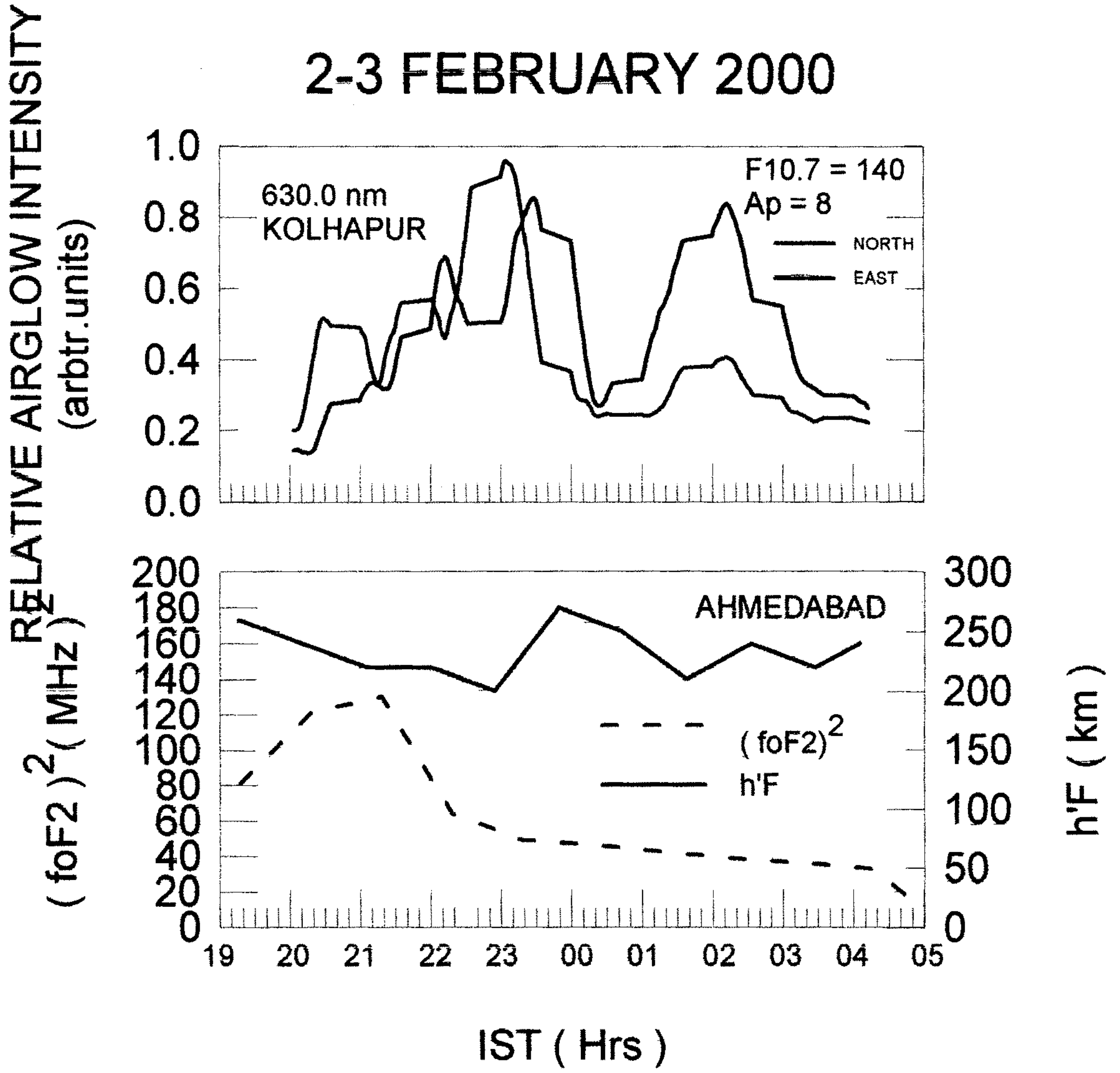
5.2.16 Observations on 2-3 February, 2000

The upper panel in the fig.5.18 of 2-3 February, 2000, shows the [OI] 630 nm intensity variations observed by the two photometers looking at 35° N and 35° E. It was magnetically quite night. The nocturnal variation in [OI] 630 nm shows the presence of pre and post midnight enhancements. The post midnight enhancement in 630 nm could be due to passage of poleward winds caused due to equatorial Midnight Temperature Maximum (MTM) **[4].**

There is velocity propagation from north to south direction. The airglow structure moves with velocity 137 m/s.

5.2.17 Observations on 6-7 February, 2000

The [OI] 630 nm variation during the night of 6-7 February,2000 (fig.5.19) was observed on a magnetically disturbed night (Ap=34). The first sharp peak in 630 nm intensity was observed around 22:10 hrs by all three photometers looking at 35° E, 35° N and Zenith direction. It is interesting to observe that the peaks are sharp and their occurrence is simultaneous. This is a peculiar behaviour on a very magnetically disturbed night, when the three peaks are not seperated.


2-3 FEBRUARY 2000
RELATIVE AIRGLOW INTENSITY
(arbtr.units)
1.0
0.8
0.6
0.4
0.2
0.0
630.0 nm
KOLHAPUR
F10.7 = 140
Ap = 8
NORTH
EAST
(foF2)^2 (MHz)^2
200
180
160
140
120
100
80
60
40
20
0
AHMEDABAD
(foF2)^2
h'F
300
250
200
150
100
50
0
h'F (km)
19
20
21
22
23
00
01
02
03
04
05
IST (Hrs)

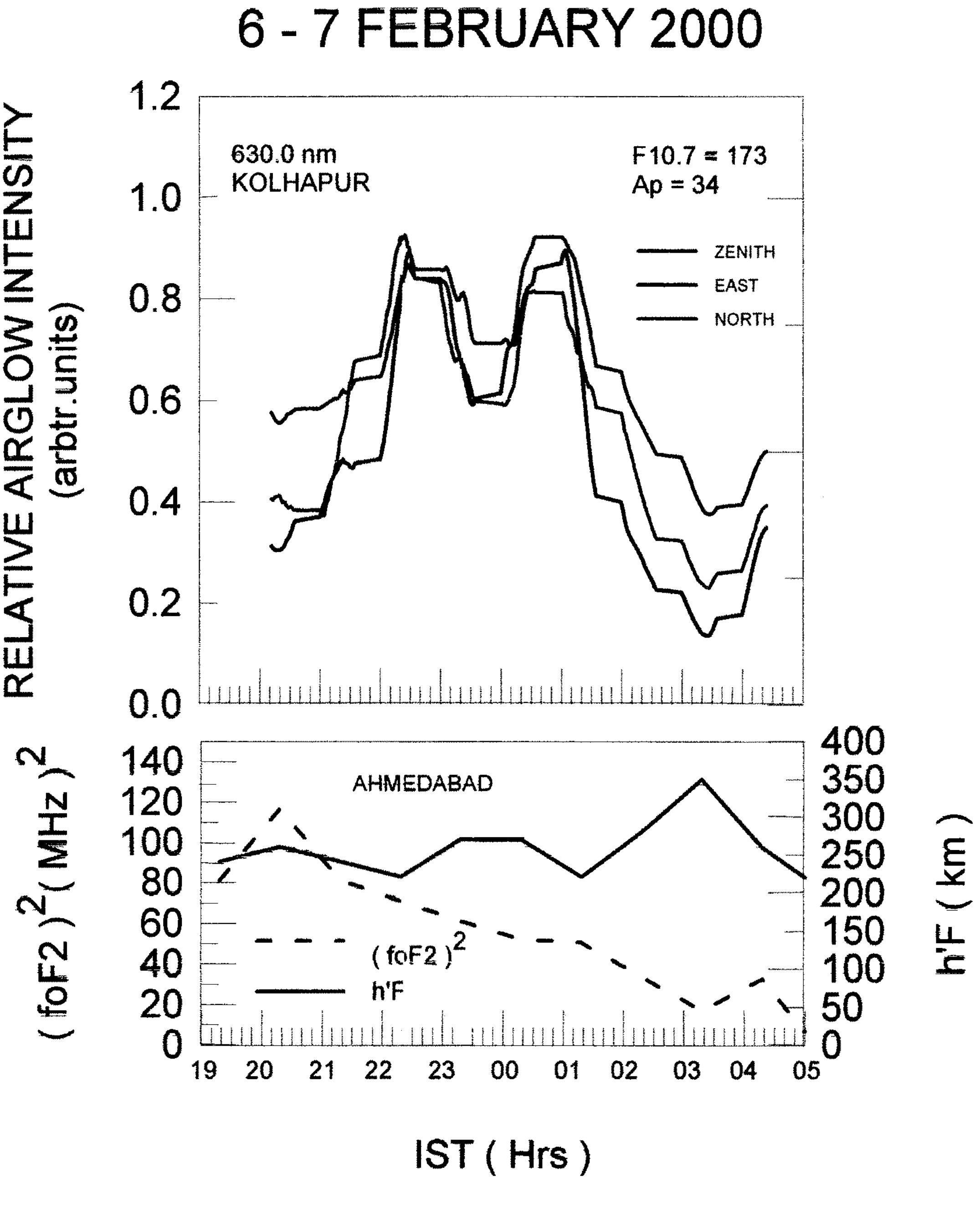

6 - 7 FEBRUARY 2000
RELATIVE AIRGLOW INTENSITY (arbtr.units)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
630.0 nm
KOLHAPUR
F10.7 = 173
Ap = 34
ZENITH
EAST
NORTH
(foF2)^2(MHz)^2
140
120
100
80
60
40
20
0
AHMEDABAD
(foF2)^2
h'F
400
350
300
250
200
150
100
50
0
h'F (km)
19 20 21 22 23 00 01 02 03 04 05
IST (Hrs)

Fig.5.19

After comparing the magnetic and ionosonde data with the photometer data it was seen that when the peak of 630 nm occurs, the height of the F-layer (h'F) changes drastically due to magnetic disturbance.

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