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Equatorial night-time *F*-region events: a survey of 6300 Å airglow intensity maps at Arecibo

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Abstract—6300 Å nightglow intensities have been mapped along an arc following the emission layer. The resulting time vs zenith angle airglow maps show significant structure which is classified into three main types: meridional intensity gradients (MIG), *F*-region southward propagating waves, and short wavelength (about 100 km) events. Interpretation of winter MIG data suggests that the equatorial midnight pressure bulge is in the northern hemisphere in winter and in the southern hemisphere in summer.

1. INTRODUCTION

The 6300 Å nightglow intensity is representative of thermospheric behavior in the neighborhood of 300 km altitude. If the intensity distribution is mapped along an arc following the emission layer, a spatial structure is often observed whose motion can be studied by examining a time sequence of the intensity distribution maps.

In this paper we present some airglow maps which show the occurrence of a number of phenomena that have been observed with significant frequency in the years 1976–1978. We have made a survey of the data and have found that the most significant events can be classified into three groups: (a) MIG's (meridional intensity gradients), (b) *F*-region waves propagation southward, and (c) short wavelength waves (50–100 km) or single pulse events.

The most significant of these, the MIG, is now well understood, and will be discussed briefly below. New data on MIG's occurring during the winter are presented, and we discuss their significance with regard to the location of the center of the midnight pressure bulge in winter. The *F*-region waves are shown to be similar to the gravity waves detected with incoherent scatter radar, and their interaction with the MIG is illustrated. The small scale (about 100 km wavelength) events are presented and discussed.

2. EXPERIMENTAL METHOD

The airglow intensity distributions were obtained with a tilting filter photometer whose field of view was scanned in an arc through the zenith. The actual scanning was accomplished with a single-axis rotating mirror system. The zenith angle was scanned to ±70° on most experiments, and the zenith arc could be oriented along any azimuth as desired. On some nights north–south maps were obtained, on others east–west. Figure 1 shows a group of successive north–south scans for the night of 3–4 May 1978. The scans occurring between 0026 and 0051 LT are typical of a layer with nearly uniform brightness. This short sequence shows the expected Van Rhijn effect for large zenith angles. The anomalous drop in the north intensity in the time intervals 0116–0206 LT show the meridional intensity gradient (MIG), which is one of the pheonomena discussed below. After the Van Rhijn effect is corrected, consecutive scans can be mapped in a zenith-angle vs time map to generate maps like that of Fig. 2. For a more detailed discussion of the experimental method see HERRERO and MERIWETHER (1980).

3. RESULTS

Figure 2 is a meridional map for the night of 3–4 May 1978. It has been chosen because it illustrates the first two phenomena indicated above. The seven shades of grey range from 13 to 102 rayleighs. The MIG is the sharp gradient in intensity which appears in the north between 70 and 50° and between 2105 and 0000 LT and again between 0230 and 0330 LT. The *F*-region wave is clearly seen by the three maxima in the map in the time interval 0020–0050 LT, 0130–0230, and 0200–0330. The three maxima propagate southward with a speed between 500 and 600 m/s, and they are seperated in time by roughly 140 min. These parameters give a wavelength of 4000–5000 km. This event is representative of anomalous MIG, and will be discussed further below.

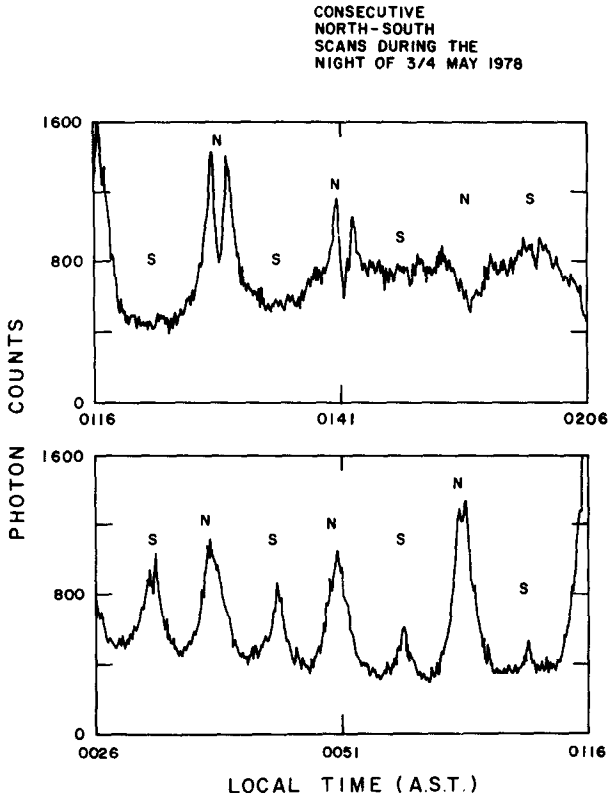

Fig. 1. Successive north–south scans for the night of 3–4 May 1978. The Van Rhijn effect gives rise to the enhanced intensities at the ends of each scan between 0026 and 0050 LT. The anomalous intensity reduction which begins after 0050 LT becomes a meridional intensity gradient (MIG) after 0116 LT, as shown in the upper frame.

3.1 *The MIG*

A normal MIG gives rise to a map with a single intensity maximum. Figure 3 shows an example for the night of 2–3 June 1978. On the basis of these data a MIG has been defined as an airglow meridional intensity gradient larger than about 0.1 rayleighs/km (HERRERO and MERIWETHER, 1980). The high intensity levels in the MIG generally propagate from the south in contrast to the levels of the *F*-region wave which propagate to the south.

The MIG has been interpreted in terms of the velocity gradient that must be developed when the midnight pressure bulge winds encounter the southward meridional winds. The strong southward wind to the north of the MIG lifts the ionosphere along the magnetic field lines, thereby decreasing the airglow intensity to the north of the MIG. To the south of the MIG the northward wind, driven by the midnight pressure bulge, pushes the ionization down along the field lines to produce the observed enhancement in the intensity, and thereby the MIG. A simple calculation based on the integration of the equation of continuity as done by RISHBETH *et al.*, (1978) showed that with typical southward winds of about 100 m/s (HARPER, 1972) one obtains a northward component of about 40 m/s for the wind velocity south of the MIG (HERRERO and MERIWETHER, 1980). Satellite measurements show velocities of about 40 m/s in the midnight temperature maximum (SPENCER *et al.*, 1979), and our recent neutral wind measurements with the Fabry–Perot interferometer confirm directly our earlier interpretation of the MIG (BURNSIDE *et al.* 1980).

3.2. *Southward propagating airglow waves*

The *F*-region wave shown in Fig. 2 is one example of several with periods ranging from 70 to 140 min. The periods and velocities that can be obtained from these maps are comparable to those of the gravity wave observed by HARPER (1972), and the one studied by ROBLE *et al.* (1978).

Figure 4 shows more anomalous MIG occurring between 0240 and 0400 LT (dashed curve). The map shows southward propagating maxima. The enhanced airglow after about 0130 LT is quite remarkable, and must be due to downward ion diffu-

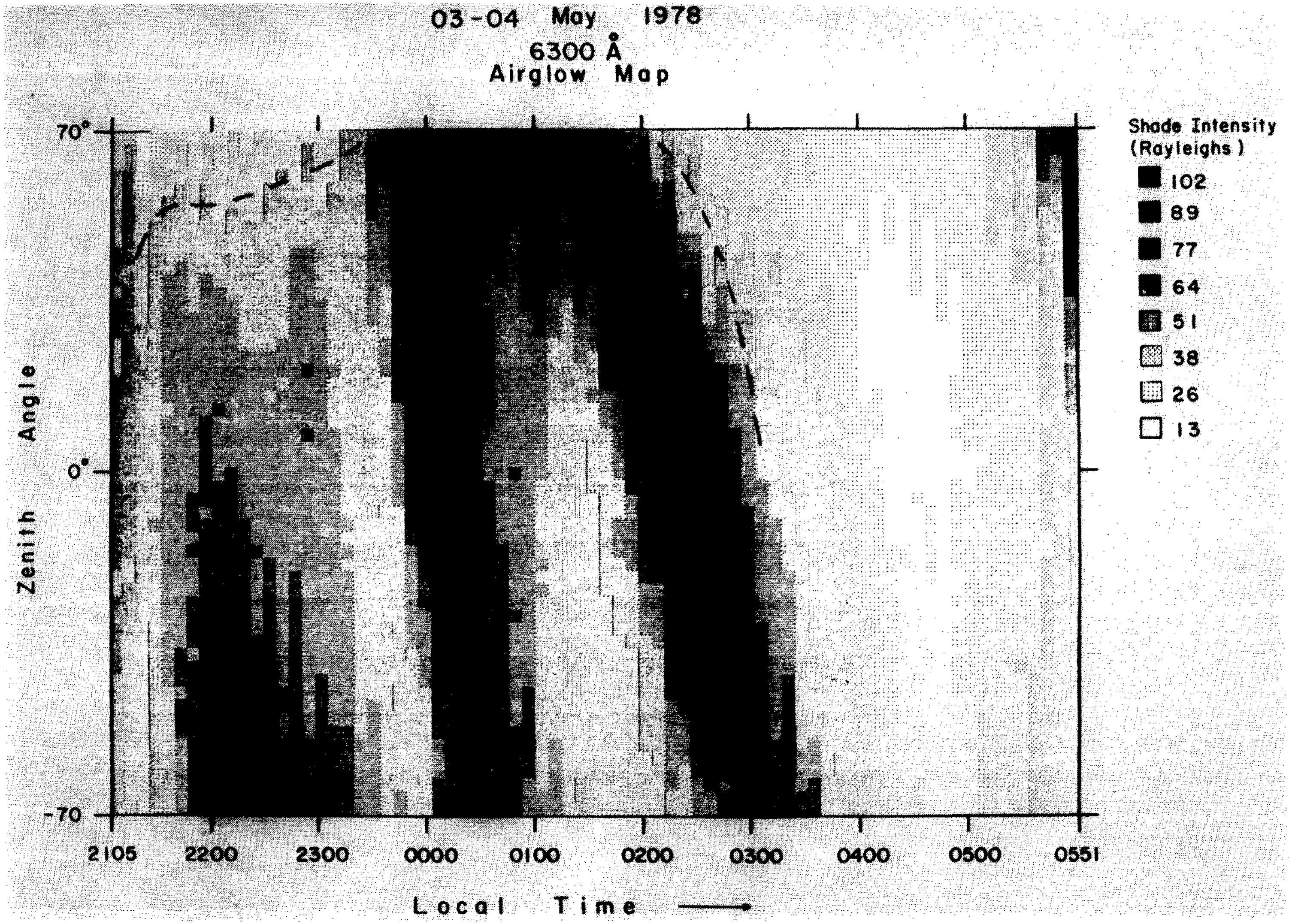

Fig. 2. Map of 6300 Å intensity in time vs zenith angle coordinate. The darkest shade represents an intensity of 102 rayleighs and the lightest appearing in the map represents 13 rayleighs. The MIG is shown by the dashed curve. This event is representative of anomalous MIG in the presence of a southward propagating wave.

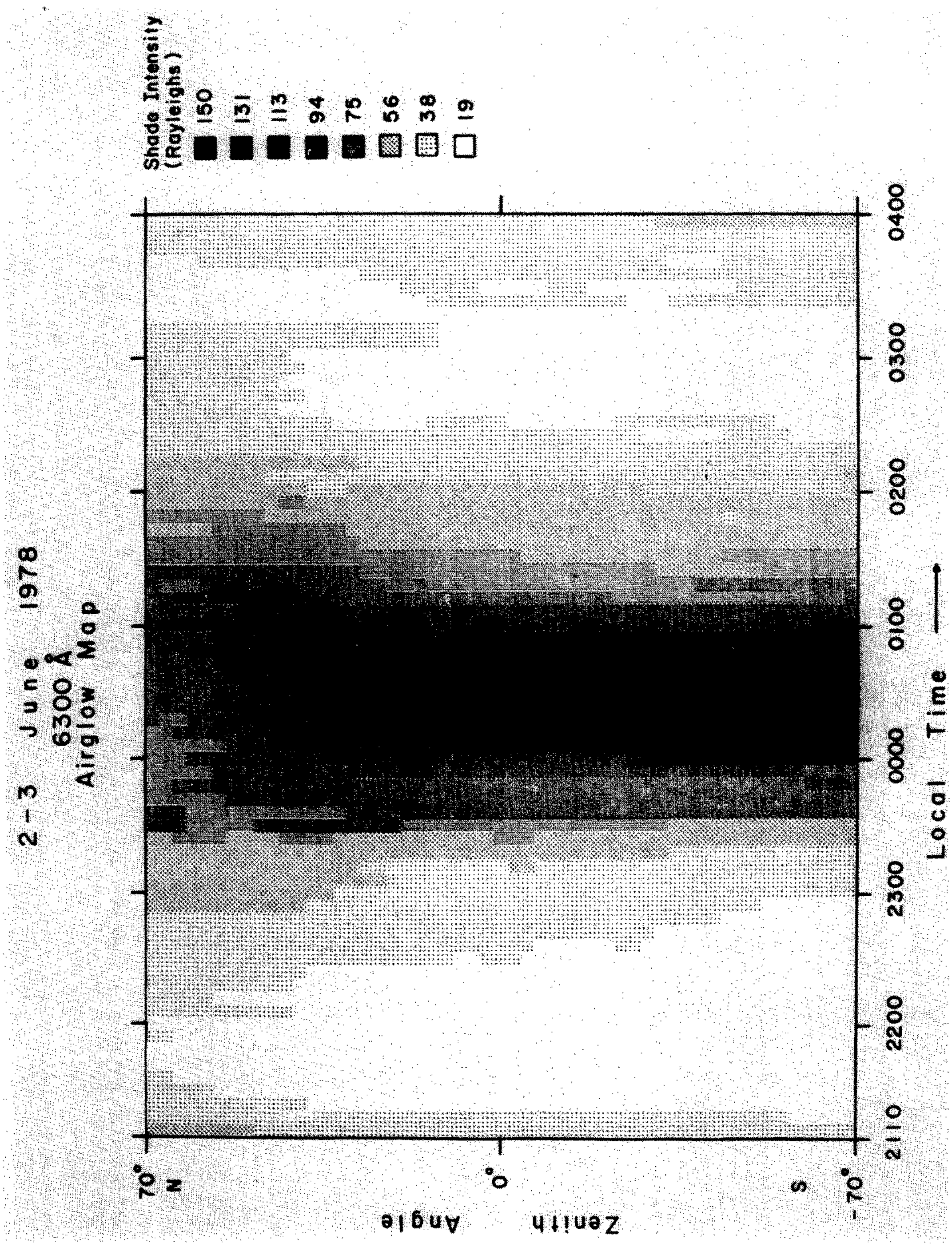

Fig. 3. Normal MIG for the night of 2–3 June 1978.

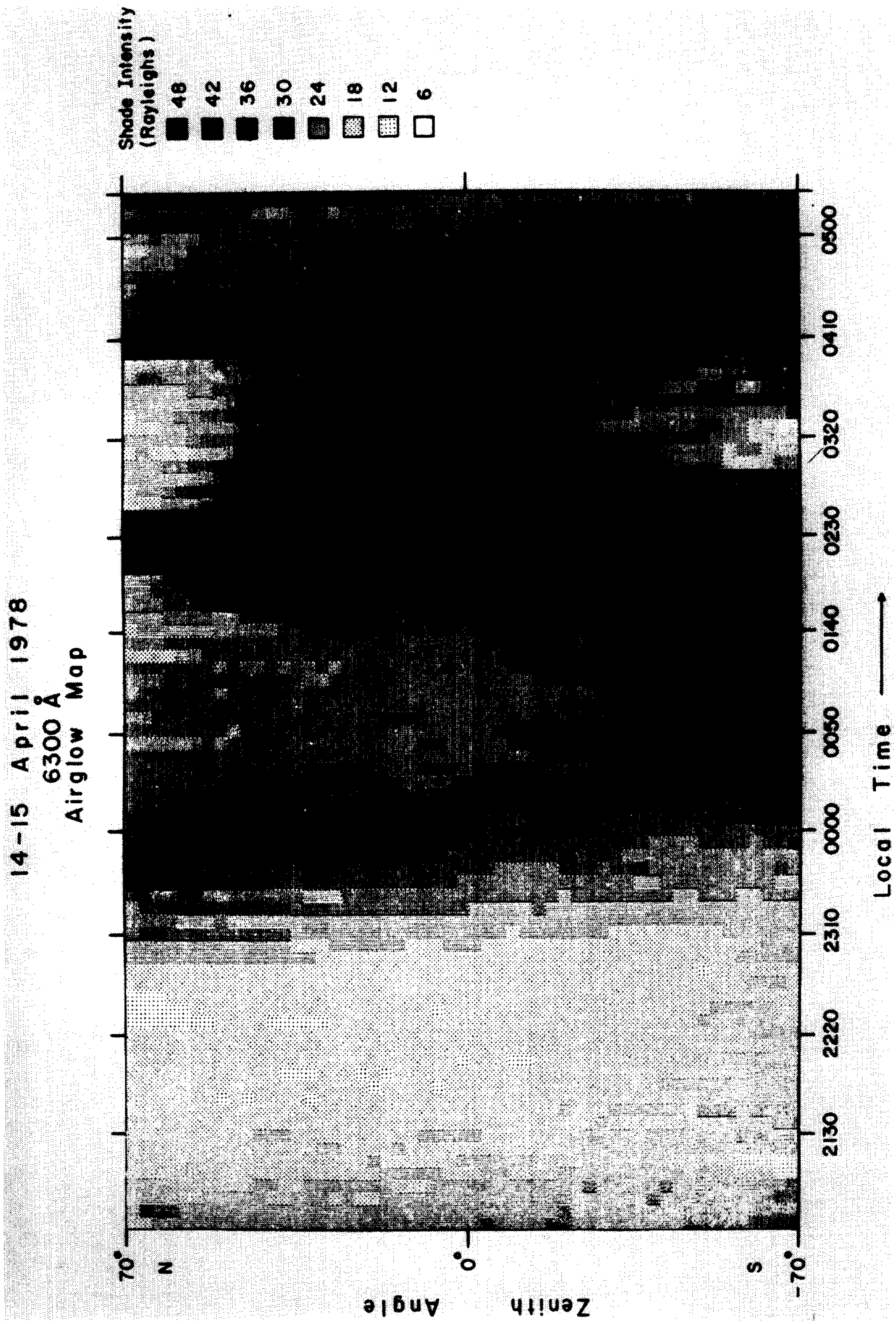

Fig. 4. Anomalous MIG between 0240 and 0400 LT and southward propagating gravity wave. Note enhanced airglow beginning near 0130 LT.

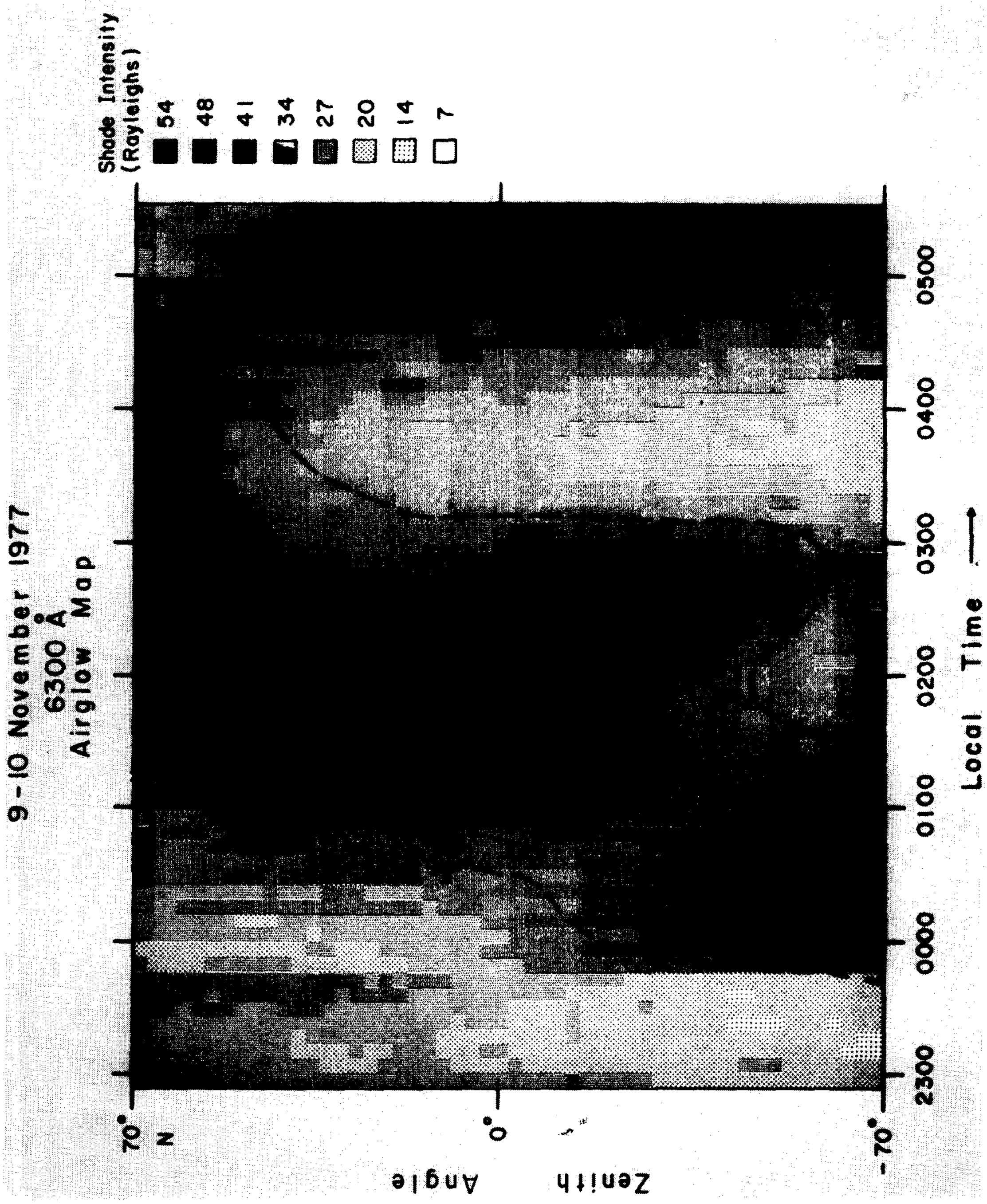

Fig. 5. A southward moving wave produces a gap in the normal MIG in the night of 9–10 November, 1977. See text for details.

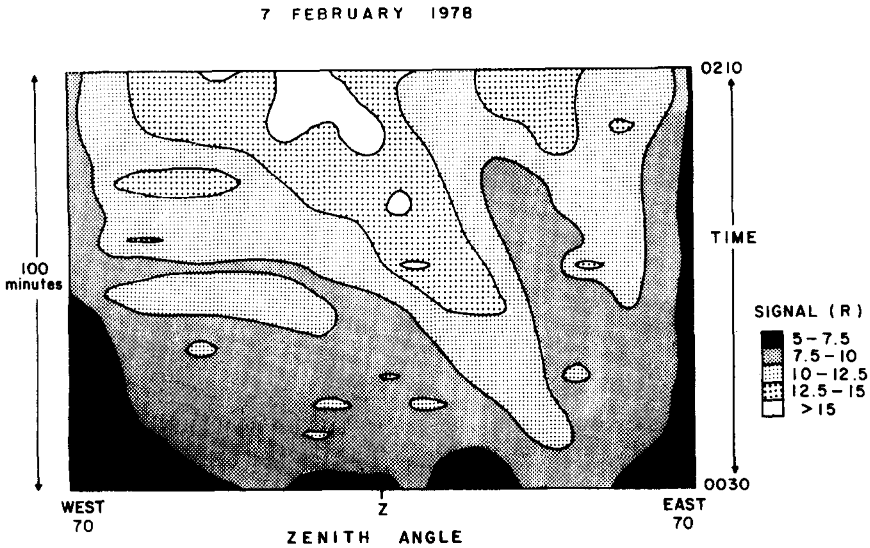

Fig. 6. East–west map of 6300 Å airglow intensity. Note inverted shade levels. Night of 6–7 February 1978.

sion from the plasmasphere modulated by the passage of the gravity wave (HARPER, 1971).

Figure 5 shows a clear example of the interaction between the MIG and a southward propagating wave. This is an example of a typical winter MIG. It begins at 2340 LT and propagates northward (dark intensity trend is indicated with the dashed curves), while the southward propagating wave lifts the ionization making an intensity gap which moves southward across the MIG. The gap begins near 0030 LT and extends initially from about 10°N to 30°S in zenith angle, and disappeared in the south at 0300 LT.

3.3. *Short wavelength events*

East–west maps show a number of features not yet understood. Figure 6 shows an isolated pulse travelling westward beginning just after 0030 LT on the night of 6–7 February 1978. The width of this pulse is less than 100 km at the start, and then it is observed to spread as it travels westward slowly. Figure 7 shows a sequence of scans taken from the same interval to illustrate the appearance of the single pulse event in the individual scans. This type of event, when observed, is accompanied by the midnight pressure bulge or the twilight period. However, more observations are needed to substantiate this correlation.

Short wavelength waves are observed also, and appear to occur most frequently on nights with large intensity variation and some times near the midnight pressure bulge. Figure 8 shows a series of consecutive east–west scans for the night of 17–18 February 1977 near 0330 LT. The maxima near the

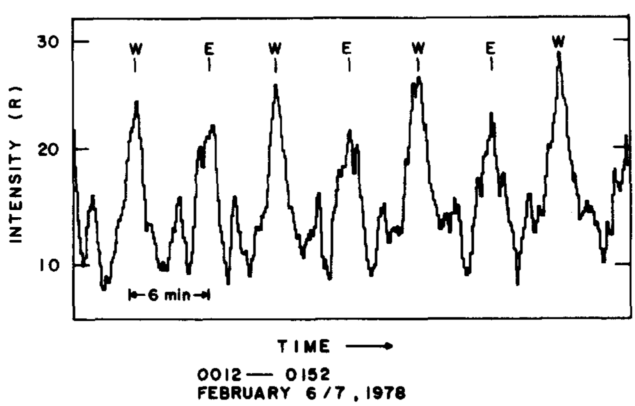

Fig. 7. East–west scans for the same night as Fig. 6 showing the isolated pulse between the scan maxima.

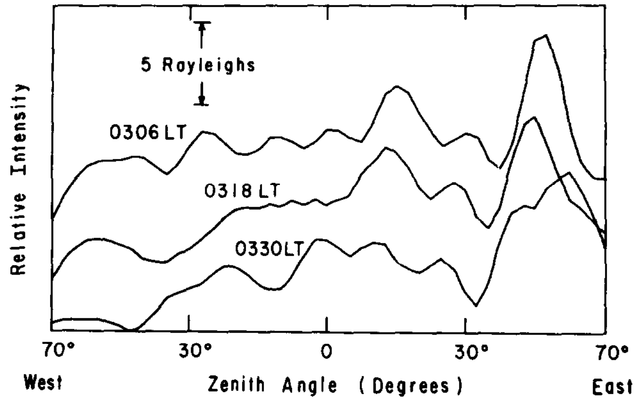

Fig. 8. Three consecutive east–west scans beginning at 0306, 0318 and 0330 LT respectively in the night of 17–18 February 1977. These scans show the short wavelength features associated with large intensity changes. A large, but slow enhancement in the east has been subtracted to illustrate the stability of this event.

zenith show a wavelength of about 80 km. At Cocheira Paulista (23°S, 45°W), Brazil, SOBRAL *et al.* (1980) have observed small scale wavelike disturbances in the meridional intensity distribution of the 6300 Å airglow. That phenomenon propagates from the equator, but is also associated with intervals immediately following the minima in the 6300 Å airglow intensity.

4. SIGNIFICANCE OF THE WINTER MIG

The normal MIG (Fig. 3) is characterized by a northern boundary and occurs predominantly in the summer. This behavior suggests that the northern boundary of the midnight pressure bulge is passing near the observing station. Therefore, the center of the pressure bulge is to the south of the station in the summer (HERRERO and MERIWETHER, 1980). If we assume that the center of the midnight pressure bulge has a tendency to follow the anti-solar point, then we would see that in winter one would expect to observe the MIG propagating well beyond the northern edge of the airglow map. Figure 5 is a good example of the winter behavior of the MIG, and it shows the MIG propagating beyond the northern edge of the map.

The determination of the location of the center of the midnight pressure bulge would surely require simultaneous airglow maps in the southern hemisphere. However, the interpretation of the winter MIG in the light of the data accumulated thus far suggests that the center of the bulge is not fixed to the equator, but rather moves in such a way as to be somewhere north of the geographic equator in winter and south of it in summer.

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