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# Relevant Aspects of Medium-Scale Travelling Ionospheric Disturbances (MSTID'S) under different solar activity conditions

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## Abstract

Absorption of MSTID's in the F-layer is analyzed using the theory of magnetohydrodynamic and ground based optical and radio techniques observations. Depending of the solar activity, these disturbances move horizontally at speeds of approximately 50-250 m/s over distances of several thousands of kilometers. It is natural to relate these movements with the propagation of a definite type of wave in the ionosphere. Internal gravity waves can be regarded as waves of this type. If we consider a gravity waves to be primarily a neutral wave phenomenon then its interaction with the ionization in the F-region via ion-neutral collisions can be discussed by the magnetohydrodynamic theory. Using ground-based all-sky imaging systems, measurements of moving MSTID's in the OI 630.0 nm nightglow emission were detected in the tropical region. Estimates of the spatial damping decrements for MSTID's show that the increase in electron concentration in the F-region is the main parameter for the MSTID's absorption. From this point of view we can understand the fact that most moving disturbances covering distances of several thousand of kilometers during low solar activity. In this work, we present and discuss the effect of ionization in the propagation of MSTID's.

## 1 Introduction

The effects imposed on MSTID's by the ionization in the F-region via ion-neutral collisions can be discussed by the magnetohydrodynamic absorption theory. Since the ionospheric F-region is a weakly ionized gas, it is assumed that the propagation of the wave is supported solely by the neutral component of the atmosphere, but that the ionized portion of the atmosphere is set into motion by neutral-ion collisions. These observations offer a unique opportunity to discover important information on the origin and manner of propagation of this type of disturbance in the thermosphere-ionosphere region and to investigate its impact on the nightglow emission chemistry and dynamics.

## 2 Results and Analysis

The ionization effects on the propagation of the MSTID's events is clearly observed by the brightness pattern seen in Figure 1 from 26:00 LT to 27:20 LT. A good parameter to explain the magnetohydrodynamic absorption of these moving disturbances, in the F-region, is the magnitude of the index of absorption. According [1], this index can be written as

$$R_x = G\left[1 + k_x^2/k_z^2 - (\cos\alpha - \cos\gamma/k_z)^2\right] \tag{1}$$

where $G = N_e M \nu_{im} k_x / N_m M_m \omega$, and $cos\alpha$, $cos\beta$ and $cos\gamma$ are the projections, on the $x$, $y$ and $z$ axis, respectively, of the magnetic field direction on a Cartesian coordinate system ($x$ is positive to northward, $y$ to eastward and $z$ to upward). $N_e$ is the electron density, $M$ is the ion mass, $\nu_{im}$ is the ion-molecule collision frequency, ω is the wave angular frequency, $k_x$ and $k_z$ are the horizontal and vertical wavenumbers, $M_m$ is the molecular mass and $N_m$ is the molecule concentration. We can estimate in (1) the value of the factor $G$, that is independent of the orientation of the magnetic field **B**. Table 1 gives the $G$ values (in cm$^{-1}$) for altitudes of 220 km, 250 km and 300 km. In these estimates, we use the phase velocity in the horizontal direction, $V_{Ph} = \omega / k_x = 250 m/s$, obtained by the observations, and the collision frequencies, $\nu_{im}$, for the specified altitudes and data on the electron concentration for nighttime ionosphere. In addition, the molecular concentration was obtained from the MSIS-E-90 model.

On the other hand, the factor in square brackets in Eq. (1) depends on the orientation of the direction of propagation relative to the field **B**. We can compare the R$_x$ values for propagation of MSTID's along the meridian, defined in Eq. (2) as $(R_x)_m$, and in the east-west direction, defined in Eq. (3) as $(R_x)_n$. If we assume that the direction of propagation in the horizontal plane is parallel to the $x$-axis, the direction of the magnetic meridian coincides approximately with the $x$-axis and $cos\beta = 0$. Then, from (1) we have

$$(R_x)_m = G(sin\alpha + k_x \cos\alpha / k_z)^2 \tag{2}$$

and for propagation in the east-west direction, $cos\alpha = 0$ and we obtain

$$(R_x)_n = G(1 + k_x^2 sin^2\gamma / k_z^2) \tag{3}$$

[1] showed that the disturbances, under the condition $\omega^2 / k_x^2 C_0^2 << 1$, have $k_x << k_z$. Then, for very small α (for example in the equatorial region), $(R_x)_m = G k_x^2 / k_z^2$, and for α large (high to mid-latitudes), $(R_x)_m = G sin^2\alpha$. It is evident that $(R_x)_m < (R_x)_n$ and the absorption of the disturbance must be minimal in the north-south direction. It is true that at mid-latitudes $(R_x)_m / (R_x)_n \approx 1$. But, as we approach the equator, α decreases and conditions are possible when $(R_x)_m / (R_x)_n << 1$. Thus, at high and mid-latitudes all the directions of propagation of moving

disturbances are approximately equivalent with respect to magnetohydrodynamic absorption. Consequently $R_x \approx G$. So, using Table 1 and considering that the absorption can be expressed by $\exp - R_x$, we can find the distances

$$D \approx 1/G \qquad (4)$$

at which the wave amplitude decreases by a factor of *e*. At a height h = 220 km, that can represent the F-layer bottomside, we have D = 3000 km and, consequently, the MSTID's take around 3 hours to be completely dissipated (considering the phase velocity $V_{Ph} = \omega / k_x = 250 m/s$). This space-time estimation of the MSTID's lifetime seems to be reasonable and agrees with the MSTID's shown in Figure 2. On the other hand, around the F- layer peak (h = 300 km), we have D = 600 km and, consequently, the MSTID's take around 40 minutes to be completely dissipated. The above absorption estimates indicate that the distance of propagation of DBS does not generally exceed 3000 km. It can be expected (Table 1) that maximum absorption take place in the vicinity of the F-layer maximum. From this point of view we can understand the fact that most moving disturbances covering distances of several thousands of kilometers (for example, the event on August 30-31, 1995) are recorded probably at heights below this maximum. However, our observations sometimes show MSTID's events propagation approximately toward the west direction, thus reinforcing the idea that the effects of the ionization on its propagation in the nighttime ionosphere is more important than the orientation of the direction of propagation relative to the **B** field.

We conjecture that the Perkins instability might be involved in the formation of MSTID's structures. The most notable feature of the structures reported here is their tendency to be aligned from northeast to southwest and drift towards the northwest. Also, [2] showed that the growth rate determined by Perkins is considerably higher during sunspot minimum conditions than during sunspot maximum for comparable altitudes of the ionospheric F layer, and this is consistent with ours observations (ours events were observed during low solar activity and ascending solar activity periods). However, more observations will be useful to further clarify the generation mechanism of the MSTID's.

## 3 Conclusions

Measurements of the two-dimensional MSTID'S in the nighttime thermosphere/ionosphere are presented. The observed features of the MSTID's can be summarized as follows:

1 - The most notable feature of the structures reported here is their tendency to be aligned from northeast to southwest and to drift towards the northwest at an altitude approximately of 220-350 km.

2 - It should be pointed out that these thermospheric events are not related to geomagnetic disturbed conditions.

3 – Estimates of $R_x$ show that the increase in absorption is associated mainly with the increase in electron concentration (for example, the event on July 19, 1998). It can be expected (Table 1) that maximum absorption takes place in the vicinity of the F-layer maximum. From this point of view we can understand the fact that most moving disturbances covering distances of several thousands of kilometers (for example, the events on August 30-31, 1995) are recorded probably at heights below this maximum.

4 - We conjecture that the Perkins instability might be involved in the formation of MSTID's structures. However, more observations will be useful to further clarify the generation mechanism of the MSTID's.

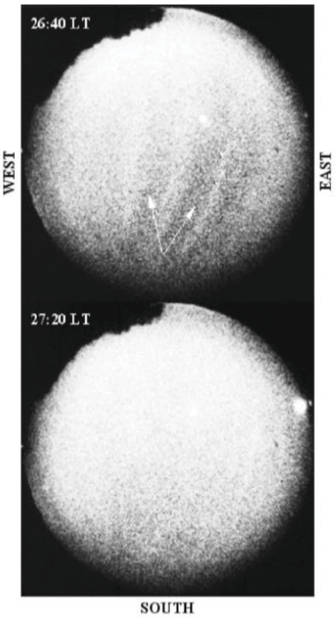

**Figure 1.** MSTID's observed through the airglow OI 630 nm emission on the night July 19, 1998, from 26:40 LT to 27:20 LT at Cachoeira Paulista. Note that the MSTID's was resolved as a series of wave crests ($\lambda_h \cong 98 km$) at 26:40 LT and then, later, was totally dissipated. The white arrows indicate the structures in the all-sky images.

**Table1** – *G* values (in cm$^{-1}$)

| Altitude (km) | $V_{ph}$ = 250 m/s |
|---|---|
| 220 | $3.3 \times 10^{-9}$ |
| 250 | $7.0 \times 10^{-9}$ |
| 300 | $3.2 \times 10^{-8}$ |

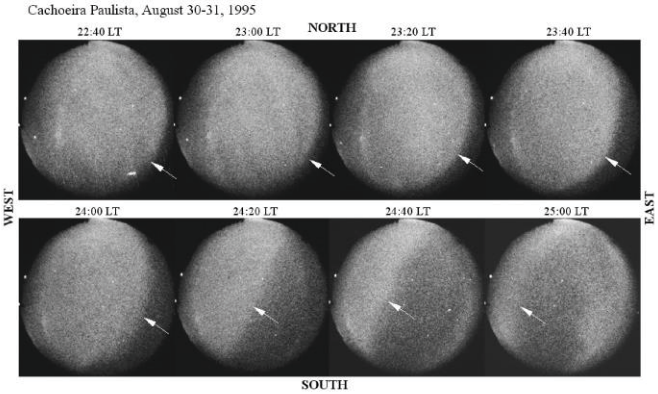

**Figure 3** - All-sky images in the OI 630 nm emission obtained on August 30-31, 1995, from 22:40 to 25:00 LT. In this example, the MSTID's entered from the southeast and moved across the field of view toward northwest, with average speed of about 210 m/s, horizontal wavelength of $\lambda_h \cong 3400\,km$ and period of 4.5-5.0 hours.

## 4 Acknowledgements

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## 5 References

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