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9. Authorship *C.J. Zamlutti*

Responsible author

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14. Abstract/Notes

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# TID's COMPRISED WITHIN A GLOBAL UPPER ATMOSPHERE DYNAMICS SYSTEM

C. J. Zamlutti

Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
12200 São José dos Campos, S.P., Brasil

Abstract

This paper suggests a simple mechanism as an alternative approach in the study of TID's. These phenomena are interpreted as resulting from the "response" of the global upper atmosphere dynamics system whenever energy differences tend to break its internal equilibrium. Seasonal characteristics are discussed as one of such differences.

## 1 - Introduction

The first routine observation of TID's was carried out by Munro (1948). Since then, these phenomena received considerable observational interest (e.g., Toman, 1955; Thomas, 1959; Valverde, 1958). The theoretical understanding, however, started after the introduction of the gravity wave theory by Hines (1960). Comparisons showing TID's as resulting from gravity waves were successfull (e.g., Thome, 1968; Testud and Vasseur, 1969; Klostermeyer, 1972). Classification of TID's is attributed to Georges (1968), who grouped them as large-scale waves (horizontal speed greater than the sound speed) or medium-scale waves (horizontal speed smaller than the sound speed).

Large-scale TID's find reasonable grounds on the existing theories and their sources are related to the auroral behavior during magnetic storms. Medium-scale oscillations are also known to propagate from the winter polar region, but the atributed trigger mechanisms do not present the required energy to drive the oscillations. A detailed review on the matter was given by Francis (1975).

The present approach is based on a diagnostic type balance of energy to account for the generation of TID's in the winter auroral zone.

## 2 - The upper atmosphere system

A detailed description of the upper atmosphere system is extremely lengthy and involves a whole book (e.g., Rishbeth and Garriott, 1969; Whitten and Poppoff, 1971). A brief outline of its behavior, as far as energy balance is concerned, will be presented next. The approach follows closely that of Volland (1969). Unidimensional models are not effective for global scale phenomena, thus,a bidimensional pattern will be assumed. Only differential characteristics, necessary to account for summer-winter differences relative to average equinoctial behavior, will be considered for the system dynamics. Therefore, a bidimensional dynamics approach will suffice.

The upper atmosphere can be thought of as a system composed of particles and fields. Under external "action" the particles either undergo transformations or are put into motion controlled by the existing fields. These features are called the "response" of the system.

Two of the external actions need to be emphasized: (1) the solar radiation (which is the heating source for the lower thermosphere) and (2) the solar corpuscular bombardment (which goes to the auroral zone by the geomagnetic field transport).

The solar radiation contributes with an energy density of 30 $mWm^{-2}$ (Rishbeth and Garriott, 1969) in the range 1026-1750 Å. This energy is mainly distributed in the lower thermosphere below the most ionized ionospheric layers (E and F). A smaller contribution, whose density amounts to 3 $mWm^{-2}$, comes from the solar ultraviolet radiation shorter than 1026 Å (Hinteregger, 1965). This energy goes to the production of ionization of the E and F layers.

The solar corpuscular bombardment brings additionally an energy density of the order of 0.6 $mWm^{-2}$ (see Volland and Mayr, 1972a). Almost all of this energy is transferred to the auroral region by geomagnetic transport.

For the purpose of a global energy balance we will split the upper atmosphere in three regions:

a) Lower atmosphere-including the troposphere, stratosphere, mesosphere and the ionized D layer of the ionosphere.

b) Thermosphere-comprising the bulk of available ionization (E, $F_1$ and most of $F_2$ layer).

c) Exosphere - constituted by the protonosphere region.

The lower atmosphere receives the largest part of the energy input. In the lower thermosphere photodissociation generates energetic particles which, by means of collisions, transfer energy to the neutral gas. This is the main heating source in the lower atmosphere, for nonauroral regions.

In the thermosphere, photoionization is the dominant process that uses the incoming energy. However, the energized particles maintain their energy much longer, since collisions with the neutral gas are less frequent in this range of altitudes. Charge transfer chemical reactions become then an important additional heating source for the neutral atmosphere at these heigths.

For the exosphere,photoionization is also the process that uses the incoming solar radiated energy. The heating source, for the neutral atmosphere, comes from charge transfer chemical reactions.

Whenever excess energy is present in each of the three regions mentioned above, a redistribution process takes places. The amplitude of the solar energy deposition increases downward, therefore excess energy is more likely to flow upwards, when present. However, horizontal redistribution process may eventually precede the upward flowing if large horizontal gradients appear.

The excess energy in the bottom region generates atmospheric waves (gravity waves, tidal waves and planetary waves). After horizontal redistribution these perturbations penetrate the ionized regions where they undergo collisions and chemical reactions, manifesting sometimes as TID's. Surplus energy in the thermosphere after horizontal averaging is transferred upwards to the protonosphere by chemical charge transfer reactions. The protonosphere looses its excess energy by transport along the magnetic field lines. This last energy will be released at the magnetic conjugated point. This process is responsible for driving corpuscular energy to the auroral zone.

When the upper atmosphere above a given location is energy depleted it acts as an energy sink. Transported energy from the magnetic conjugated point should then flow downwards.

The important chemical reactions, that provide neutral atmosphere heat input in the middle and top regions, can be found summarized in Szuszczewicz (1978).

Atmospheric waves dissipation, in the thermosphere, provides a heat input energy equivalent to 50% of the solar radiation energy in the same range (see Rishbeth and Garriott, 1969).

## 3 - The Model

The heating-cooling alternation, resulting from diurnal variation (day to night) or seasonal variations (winter to summer), constitutes the driving mechanism for the regular effects observed in the thermosphere (Volland, 1969). These effects are manifested as tidal or seasonal waves, as an example. We are interested here in finding a seasonal energy input difference, for the auroral zones, that would help the TID trigger mechanisms to generate these phenomena.

The axis of revolution of the earth is tilted with respect to the normal to the orbital plane. This tilting is partially responsible for the seasonal differences. As a matter of fact, the receiving cross section of the summer hemisphere, for the energy input from the Sun, can be larger than that of the winter hemisphere by as much as 27%. This excess heating, as pointed out before, should be redistributed in a global scale. Another 10% difference exists when comparing Sorthern Hemisphere summer (winter) with Nouthern Hemisphere summer (winter). This difference results from the eccentricity of the earth's orbit around the Sun and must be taken into account in a quantitative model.

Taking into account the characteristics of the upper atmosphere system presented in Section 2, we propose that any excess energy present in the upper atmosphere above a given location would be removed, partly, to its magnetic conjugated location. The equinoctial diurnal average of the upper atmosphere is taken as reference, i.e., the response of the system to the average (or unperturbed) input of energy. With this assumption, the upper atmosphere system can be treated by a bidimensional differential, oversimplified, model. This model is only useful to account for peculiar summer-winter characteristics of the upper atmosphere. We will discuss next some observed phenomena which seem to confirm this model.

The so called winter anomaly, in the noon $N_mF_2$, can be qualitatively explained by our model. In fact, excess energy in the summer hemisphere will be removed along the magnetic field lines to the winter, energy depleted, hemisphere. The energetic particles entering in the protonosphere will increase the $H^+$ density. A consequent donwnward diffusion of $O^+$ ions will follow, resulting from an increase in the reaction rate of:

$$H^+ + O \rightarrow O^+ + H$$

which depends on the square root of the ion temperature (Fehsenfeld and Fergunson, 1972). This temperature is enhanced by the incoming extra energy, from the opposite hemisphere. Since electrons are constrained, by electrostatic forces, to follow the ion motion, the diffusion of $O^+$ ions implies an electron flow into the $F_2$ region. This additional ionization will increase $N_mF_2$. This proposed mechanism is quite similar to that used by Evans (1965) and Carlson (1966) to explain the maintainance of the nighttime $F_2$ layer and follows the indication of Whitten and Poppoff (1971). Another problem which may be explained by the above mechanism is that of the persistence of F region ionization during the polar winter.

Seasonal variations, which can be attributed to planetary waves (with probably annual period), have been observed in the lower thermosphere parameters (see Champion, 1967; Waldteufel, 1970; Zamlutti, 1973). For this type of waves, only the latitudinal difference matters (Volland and Mayr, 1972b). Surplus incoming energy, which can be distinguished by an increase in the neutral temperature, was consistent, in summer, for the whole set of data referred above. Differences were observed in the ion neutral collison frequencies, which for the lowest latitudes (Zamlutti, 1973), follow the same behavior as neutral temperature, whereas for middle latitudes (Champion, 1967; Waldtenfel, 1970) have an opposite characteristic, being larger in winter. This last feature was interpreted by Waldteufel (1970) as resulting from an increase of $O^+$ ions in the lower thermosphere during winter. His interpretation is consistent with the mechanism discussed above to explain the winter anomaly. In fact, the downward flow of $O^+$ ions will be redistributed reaching the lower thermosphere where the loss mechanism for these ions takes place by the charge exchange reactions

$$O^+ + N_2 \rightarrow NO^+ + N$$

$$O^+ + O_2 \rightarrow O_2^+ + O$$

The first reaction (Lindinger et al., 1974) is independent of temperature. As far as the second reaction is concerned, its dependence goes with the square root of the inverse electron temperature (Dunkin et al., 1968), thus increasing in winter. This last fact seems to reinforce the consistency of our theoretical model with the results inferred from experimetal data by Waldteufel (1970).

## 4 - Energy Sources for TID's

Georges (1968) suggested auroral sources as responsible for the generation of TID's. These TID's would propagate from (magnetic) pole to pole. This theory encounters some problems concerning the period of oscillations (Francis, 1975). The alternative approach was to assume TID sources elsewhere other than in the polar region. Searches for middle and low-latitude sources present also a number of inconsistent questions (see review by Francis, 1975).

Our proposal here is that Georges suggestion may be correct as far as winter and summer TID's are concerned. Ducting for gravity waves,along the magnetic pole to pole direction, can appear in the winter hemisphere resulting from the increase in the lower thermosphere neutral temperature gradient (see Waldteufel, 1970). For the summer hemisphere the ducted wave approach may not be valid. As a matter of fact using average temperature profiles (equinoctial data) Richmond (1978) has shown that ducting becomes less important. Therefore equinoctial gravity waves and its consequent TID's may be generated, also, elsewhere other than in the polar region.

Computations by Thomas and Ching (1969) and Volland (1969) determined the need of a local heat source in the 100-200 km height range to complete the heat balance in their unidimensional models. The characteristics of this source were specified to have a duration of 4-5 hours and energy input density in the range 0.1-1 $mWm^{-2}$. They employed quasi-static models which, in our opinion, are very limited.Seasonal effects were not properly enphasized too. Klostermeyer (1973) computed the time delay for the exceeding heat, around 250 km, resulting from the viscous dissipation of gravity waves, to reach the lower thermosphere. His calculations used a fixed temperature at 120 km and showed that downward thermal condution is a slow process. Although atmospheric waves dissipate the necessary energy to complete the heat balance, theoretical and experimental support to this hypothesis were still missing. This support was brought by Vidal-Madjar (1979) performing the numerical computation of the heat input, resulting from gravity waves dissipation. He found that, for summer, this energy is deposited in the 120 to 200 km and corresponds to 10% of the solar radiation in the same range. This result agrees with the energy source required by Thomas and Ching (1969) and Volland (1969). It is, however, controversial to the results of Klostermeyer (1973). The basic difference seems to be the horizontal redistribution neglected by Klostermeyer (1973). Anyway, these results confirm our assumption that atmospheric waves constitute an energy balancing mechanism, mainly for the lower thermosphere.

According to our model, energy must flow in the exosphere from the summer to the winter hemisphere, following the magnetic field lines. This is the natural response of the upper atmosphere system to restore its internal equilibrium (relaxation). Gradients in both composition and temperature reflect the energy difference and the transport mechanism depends on them. Gradients increase with increasing latitude reflecting the behavior of energy difference. Therefore energy flow is maximized into auroral zone. This energy undergoes several process and may end up being converted into atmospheric waves, if some additional trigger mechanism is present. These waves are able to propagate horizontally in ducting modes in the winter hemisphere and constitute another energy equalizer to restore the internal equilibrium of the upper atmosphere system.

Gravity waves, imperfectly ducted (Francis, 1975), generated in the auroral zone, propagate at ionospheric heights in the direction which minimizes ion drag dissipation (Hines, 1968). This direction is the magnetic field orientation and leads a pole to pole path. This is the principle of "least dissipation". It can be used to explain summer and winter TID's. Yet, to be consistent there is the problem of explaining the equinoctial behavior of TID's. Our bidimensional differential approach do not account for that. To extend the model, some caution should be taken.

If we take only the suggestion by Hines (1968) of gravity wave propagation, in the direction that minimizes ion drag dissipation, there is no way to account for the equinoctial behavior of TID's. In the characterization of our upper atmosphere system, we considered atmospheric waves as the system response, to perform the energy balance, whenever excess energy is present in the lower atmosphere. Considered this way, gravity waves should follow, in the lower atmosphere, the path of maximum energy gradient and minimum dissipation, i.e., the path that maximizes the quantity:

$$\Delta E_{net} = \Delta E_{diff} - \Delta E_{diss}$$

where E stands for energy, diff for the difference and diss for dissipation. The agreement with experimental results about TID's requires that the net energy difference maximizes in the North-South direction during summer-winter occurence and in the East-West direction during equinoxes. A final text concerning this aspect is still needed. Evidences, observed in data for altitudes below 105 km in favor of the proposed mechanism, are the amplitude of seasonal waves (30%) as compared to diurnal waves (20%), as inferred from Zamlutti (1973) ion neutral collision frequency results. This suggests, for the lower thermosphere, a net energy difference in the N-S direction for summer winter opposition and in the E-W direction for equinoctial day-night opposition. As a consequence, equinoctial TID's do not necessary have an auroral source.

## 5 - Discussion and Conclusions

A simple bidimensional differential approach was proposed for examining the summer-winter behavior of the upper atmosphere, as compared to an equinoctial dynamical reference. Energy unbalancing of seasonal origin was taken as the driving force, and relaxation as the restoring mechanism. Only a qualitative diagnostic type analysis was presented and examined to the light of evidences. A quantitative analysis will require a continuous monitoring of several observing stations confined to the same magnetic meridian, not available so far.

The proposed method can be extended treating the equinoctial dynamical behavior also by a bidimensional (zonal) differential model, as compared to the same equinoctial diurnal average reference. The driving force, in this case, will result from the energy unbalancing originated by the day-night opposition. Zonal gradient relaxation should be considered as the equilibrium restoring mechanism. The system dynamics is then simplified, the only motion beeing the zonal horizontal gravity waves propagation in the lower atmosphere. This follows as a consequence that for equinoxes the driving force of the meridional bidimensional differential model vanishes.

A qualitative approach including TID's seasonal behavior within an energy unbalancing context was proposed and some evidences examined. It constitutes an attempt to collect together the controversial outcomes about TID's which in our opinion, result from the use of inappropriate thermospheric models. This opinion is based on the fact that the drastic seasonal differences reported for the lower thermosphere have not been fully explored so far in the study of TID's.

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