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GEOMAGNETIC DISTURBANCES CAUSED BY INTERNAL ATMOSPHERIC DYNAMICS

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INTRODUCTION

It is commonly believed that geomagnetic disturbances are caused by external influences connected with the solar wind. The 27-day recurrence of perturbations seems to be a strong hint for this interaction. But frequently geomagnetic disturbances occur without any relation to sunspot numbers or radiowave fluxes. This was one of the reasons for introducing hypothetical M-regions on the sun and their relation to solar wind activities.

McPHERRON et al. (1982) have reported that only one half of the variance of the geomagnetic AL-index could be related to the solar wind. Therefore they concluded that internal processes of the magnetosphere were responsible for additional geomagnetic activity. This paper discusses arguments, which might lead to the suggestion of geomagnetic disturbances as being caused by internal atmospheric dynamics and tries to establish a rather preliminary scenario of those processes.

STATISTICAL STUDIES

Fig. 1 shows median and arithmetic mean values of the local geomagnetic activity index ΣK_1 of the station Niemegk (GDR) for the October-November period of 41 years. This period obviously exhibits recurring meso-scale variations of remarkable amplitudes. The A_K-index data presented for 26 years show a similar behaviour. Particularly the end of Oct. with a peak about October 28 posesses a distinct activity maximum followed by a pronounced minimum about November 6. The statistical certainty of the ΣK_1-data amounts to 98.5 to 99.9%. Such a distribution of rather strong perturbations is evident also during other periods of the year particularly about and after the equinoxes.

Regarding individual years this statistical finding is not immediately evident, so that it proves only the existence of periods with enhanced probability of disturbed or quiet days, but not an annual recurrence of such events. Solar parameters such as the sunspot number or the 10.7-cm flux gave no hint to explain this phenomenon. Although a period of 2 years very well fits a number of 27 solar rotations, no 2-years' recurrence has been found. This may be seen also on Fig. 2 showing similar variations of the A_K medians during the April/May period, but being out of phase of the 27-day rotation period. Rather strong negative ionospheric disturbances frequently occur approximately between October 25 and November 2. We have called this period the MID-period - period of major ionospheric disturbances (SONNEMANN, 1983). Fig. 3 shows the 11-years mean day-time level of the critical frequency foF2 compared with corresponding values of geomagnetic activity. Clearly visible is the breakdown of the critical frequency after its seasonal peak. A proper ionospheric activity index processed in a special way, shown in the upper part of this figure, exhibits a distinct maximum at the same date.

If we consider other parameters such as radio wave absorption no significant hints for a relation to the D-region parameters can be found. The air pressure mean values show maximum values even before and during the MID-period with a small decrease simultaneously with the decrease of the critical frequency. Also the semiannual exospheric density variation has its maximum about

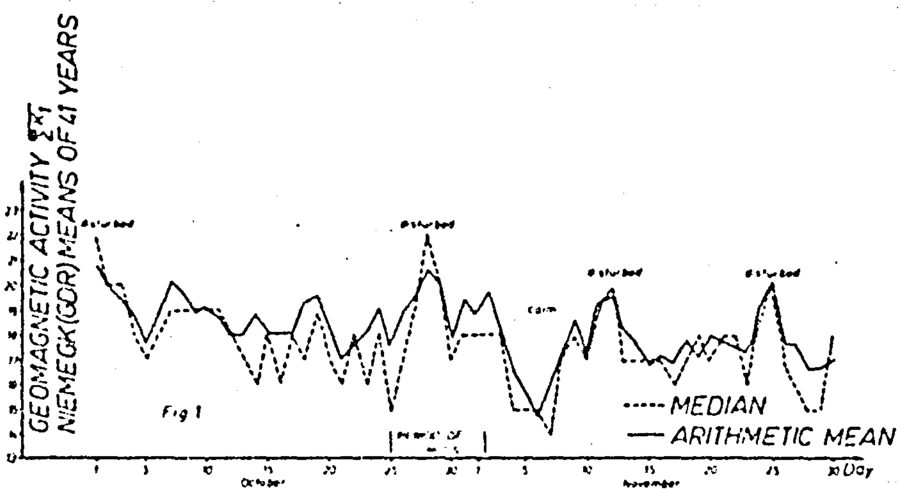

Figure 1.

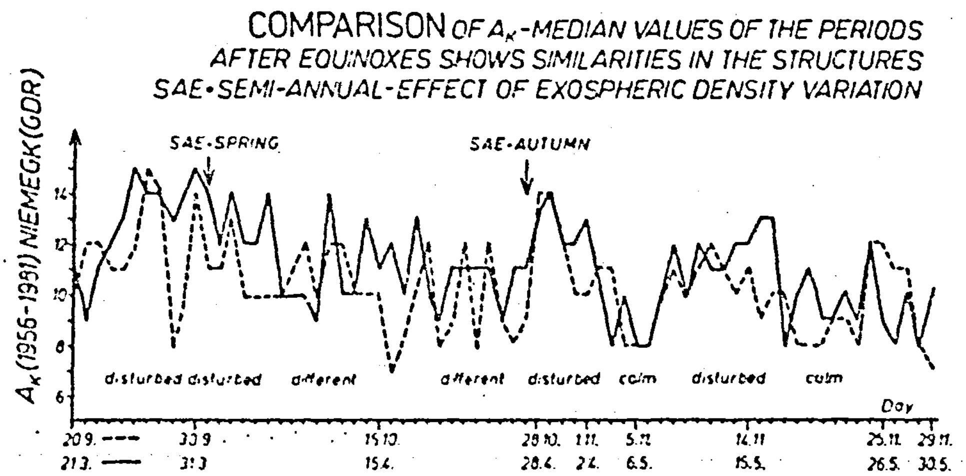

Figure 2.

October 27, indicating an imminent dependence.

SATELLITE OBSERVATIONS

We were able to derive neutral gas profiles of the European sector from occultation measurements of the Solrad-10 satellite for certain ionospheric disturbances related to geomagnetic perturbations. During a major disturbance about October 29, 1971, we derived some results on structural variations of the neutral gas (composition and density) between about 90 and 300 km using Solrad-10 measurements, as shown in Fig. 4. During the positive storm phase the

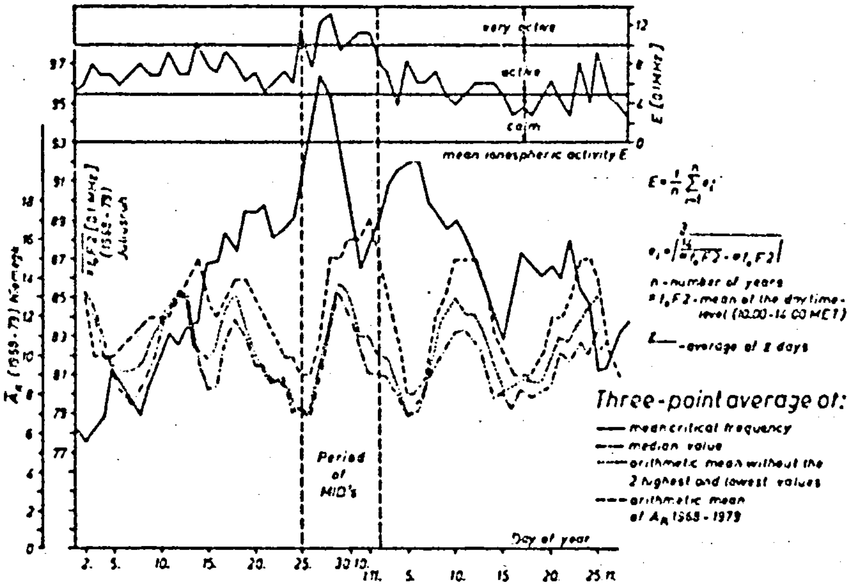

Figure 3.

molecular components decrease and atomic oxygen increases, the profiles are strongly disturbed. The day of negative storm is distinguished by a resonance-like upwelling of the molecular components, while thermospheric atomic oxygen decreases below about 250 km and further increases above 250 km. The mean thermospheric temperature deduced from the density gradient reaches maximum values. The recovery phase starts with a sudden thermospheric cooling, the molecular components decrease but the atomic oxygen density above 250 km attains maximum values.

DISCUSSION

In order to solve the puzzle we shall try to establish a scenario of possible relations. The observed structural variations of the neutral gas are related to perturbations, which are evident even in medium latitudes in the mesosphere, below those altitudes which are sufficiently influenced by precipitating particles caused by external geomagnetic disturbances. This, together with the above statistical results, leads to the suggestion that internal atmospheric dynamics is responsible for perturbations of this type. Geomagnetic variations and perturbations could be connected with wind shears within the dynamo region, particularly at high latitudes. It can be excluded, however, that they are directly and completely caused by the dynamo region currents. More likely, E-fields generated by the dynamo region currents, e.g. the auroral electrojet could be responsible, affecting plasma drifts within the magnetosphere. According to WILLIAMS (1982), only a certain part of the plasma of the ring current originates from the solar wind, while the other part has an ionospheric source. The magnitude of the ring current depends on the balance between injection from the solar wind and decay by charge exchange of ring current plasma with neutrals of the geocorona (DESSLER et al. 1961, TINSLEY 1977). That means that the ring current grows with increasing solar-wind flux (external influence) or with a decrease of the density of neutrals which could be understood by a respiration

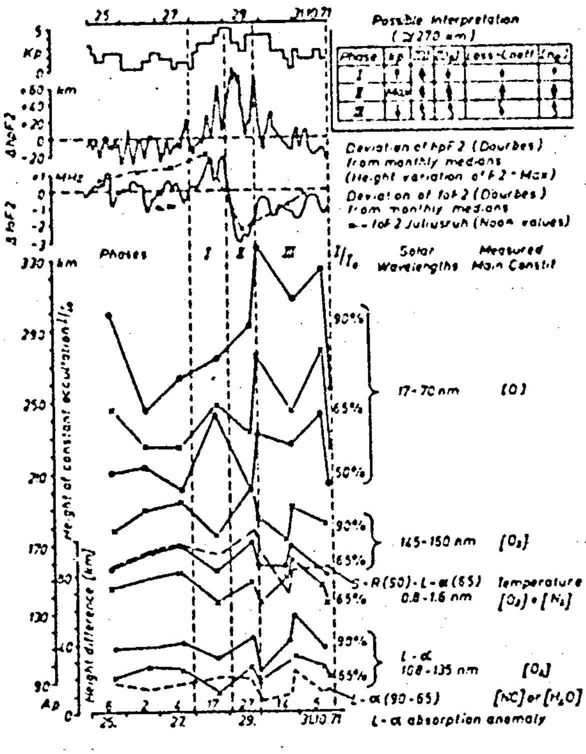

Figure 4.

of the geocorona caused by dynamical processes of the lower atmospheric layers. Due to their short lifetime of about 2 hours, hydrogen ions decay first, followed by a decay of heavier ions such as helium and oxygen with lifetimes 6 times larger. Therefore composition changes of geocoronal neutrals have to be regarded, too. As TINSLEY et al. (1982) pointed out, fast neutrals of several keV energy created by charge exchange cross through the magnetosphere on straight trajectories and precipitate within denser layers, particularly influencing mean and equatorial geomagnetic latitudes. The neutral hydrogen penetrates to an altitude of 200 - 110 km while atomic oxygen precipitating in the second phase reaches only heights of 250 - 300 km. The estimated energy input by fast neutrals amounts to 10% or more related to the EUV-input and may lead to an important enhancement of the nighttime ionisation. This might be deduced from the TEC-data during the night before the negative storm. But the possibility of downward plasma transports caused by equator-to-pole winds and a considerable reduction of the dissociative recombination due to composition change has to be considered. Not regarding other details of the complex process, the neutral influx causes on one hand by its upper thermospheric energy input a positive feedback taking into consideration the upwelling of atomic oxygen and the negative reaction of hydrogen on an enhancement of exospheric temperature. On the other hand, the creation of N_2-ions and of vibrationally excited N_2 could be a source of sufficiently large quantities of NO particularly within equatorial and mean geomagnetic latitudes.

The neutral density of the thermosphere, particularly at medium and higher latitudes of the winter hemisphere, shows variations with planetary time and space scales (SONNEMANN et al. (1982). These variations are connected with plasma variations of the lower E-region (SONNEMANN et al.,1979). As analysed by SATO (1981) SSC-events are followed by excessive absorption simultaneously within a large longitudinal sector explained by sectorwise precipitation of high energetic electrons. From our measurements, however, it follows that the O_2 density changes simultaneously within a large longitudinal sector, linked with O_2-gradient enhancements in the lower thermosphere in phases of low O_2-density and low radio wave absorption and vice versa. This varying gradient may explain the varying absorption of ionising radiation, but a certain influence of precipitating particles cannot be excluded.

The density variations, however, indicate also relations to processes of the lower atmosphere. Particularly, the change from summer to winter circulation patterns could give rise to neutral impact to the thermosphere and geocorona.

External and internal influences do not occur separate from each other but rather combined, including the actual particle and EUV fluxes of the Sun. The internal disturbances can only be understood by considering the whole atmospheric dynamics including meteorological processes and wave phenomena, taking into account various feedbacks.

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