It is maximum in summer (~20°K) and minimum in winter (~7°K). It is about 12°K in spring and autumn. The ratio between the summer and winter amplitudes is about 3. Making use of these values, theoretical calculations of the amplitude of the lunar tide in the upper atmosphere indicate that there are the seasonal variations of the altitude of the hydroxyl emission layer. It would be desirable to make the comparison with the available data of the rocket measurements of the OH altitude. Unfortunately the rocket data are meagre and are related to the spring and autumn periods. Nevertheless, they showed the tendency of lunar-time variations near 90 km level. It is evident that OH altitude measurements by rocket are very essential during winter and summer.

The author expresses his gratitude to Prof. V. I. Krassovsky for advice and attention to this work.

References

Relation between Disturbed Variations of Hydroxyl Emission & Radio Wave Absorption in D Region

Z. Ts. Rapoport

Institute of Terrestrial Magnetism, Ionosphere & Radio Wave Propagation, USSR Academy of Sciences, Moscow

&

N. N. Shefov

Institute of the Physics of the Atmosphere, USSR Academy of Sciences, Moscow

Received 15 May 1973; accepted 28 May 1974

The variations of hydroxyl emission and radio wave absorption after geomagnetic storms in middle latitudes are observed to be similar. A correlation between these values is noted.

The influence of geomagnetic storms on the upper atmospheric conditions manifests itself not only during a storm, but also after it. For instance, in a few days after a storm typical oscillating variations in the intensity and rotational temperatures of hydroxyl emission are observed at middle latitudes, as well as variations in some other emissions, such as the atmospheric system of molecular oxygen at 8645 Å, helium at 10830 Å, hydrogen at 6562 Å (Ref. 3,4) and oxygen green emission at 5577 Å (Ref. 5). The duration of such disturbed variations of the emission intensities lasts 3 to 4 weeks, depending on the magnitude of a magnetic storm.

The analysis of the behaviour of upper atmospheric emissions shows that the phenomena observed stem from the transfer of activated masses of air from high latitude regions towards the equator at an average speed of about 10 m/sec. The stored energy of the dissociation of molecular oxygen ensures a considerable enhancement of hydroxyl emission for a long period of time. However, this additional energy release in hydroxyl emission decreases with a decrease of latitude. The subsidence time is about 2 days.

However, besides variations in atmospheric emission, the after-effect is revealed in some of its other characteristics, including radio wave absorption. According to some workers, at stations in middle latitudes 2 or 3 days after a storm a systematic increase of absorption was observed. Although rather
small periods after magnetic storms were studied, it is possible to trace the evident similarity of variations in emissions of the upper atmosphere and the ionization of the ionosphere from radio wave absorption.

Therefore, it is of interest to compare data of simultaneous measurements of atmospheric emission and ionospheric parameters. However, there are some peculiarities here. Data on hydroxyl emission appearing at altitudes of about 90 km have been obtained in the nighttime. Ionospheric parameters under measurement, such as $f_{\text{min}}$ characterizing the ionosphere for the same altitude region, were most effectively determined in the daytime.

It is well known that the intensity and rotational temperature of hydroxyl emission and especially the magnitude $f_{\text{min}}$ have substantial variations during a day. However, these specific features are not obstacles to their comparison. As an indicator of the radio wave absorption the $\Delta f_{\text{min}}$ values are used, which are determined as differences between $f_{\text{min}}$ (mean values for the period from 09 00 to 15 00 hrs Moscow time) and $f_{\text{min-med}}$ (mean value of the monthly median for the same hours). As shown by the result of the comparison, the hydroxyl emission intensities average for a night and value of $\Delta f_{\text{min}}$ average for a day have similar variations after geomagnetic disturbances. For this purpose, use was made of the data of observations on hydroxyl emission at the Zvenigorod Geophysical Observatory and at the Krasnaya Pakhra ionospheric station* lying in the vicinity of Moscow. As an example, periods close to strong magnetic storms were chosen for which there was the greatest number of nights of observations on hydroxyl emission: February 2-3, 1957; March 27-28, 1957; March 31 - April 1, 1960; April 30 - May 1, 1960; May 8-9, 1960; March 23-24, 1969.

Fig. 1 shows, by way of example, the OH intensity variations for Haute Provence (lat., 43°N) after a storm of February 11, 1958 and relative value of absorption $\Delta L/L_{\text{med}}$ at 2.05 Mc/s for Freiburg (lat., 48°N) and $\overline{\Delta f_{\text{min}}}$ for Juliusruh (Rügen, lat., 54°N), as well as variations in the OH intensity for Zvenigorod (lat., 56°N) after a storm of March 31-April 1, 1960 and $\overline{\Delta f_{\text{min}}}$ for Krasnaya Pakhra (lat., 56°N). These results show that despite diurnal variations of $f_{\text{min}}$ and $I_{\text{OH}}$, the average $\overline{\Delta f_{\text{min}}}$ and $\Delta I/I$ values change simultaneously day in and day out. Apparently this means that the additional intensity of OH emission and the additional ionization of the ionosphere are determined by a common process. Thus, the values $\Delta f_{\text{min}}$ and $\Delta I/I$ under consideration may serve as indicators of the intensity of the agent $\phi$ common for them, which is acting several days after geomagnetic storms, i.e. $\Delta f_{\text{min}} \sim (RWA) \phi$ and $\Delta I \sim (OH) \phi$.

Fig. 1—Examples of variations in the intensity of hydroxyl emission and some ionospheric parameters after geomagnetic storms [(a) February 11, 1958: $\Delta I/I$ are OH emissions on the basis of data of the Haute Provence Observatory (43° N), variations of $\Delta L/L_{\text{med}}$ are the relative absorptions according to data at Freiburg (48°N), $\overline{\Delta f_{\text{min}}}$ for the Juliusruh (54°N). The cases of reflection from sporadic E$_{\text{s}}$ layer are indicated by circles. Therefore, there are the understated value of $\Delta L/L_{\text{med}}$; and (b) March 31, 1961: OH emission on the basis of data for Zvenigorod (56°N), $\overline{\Delta f_{\text{min}}}$ for Krasnaya Pakhra station (56°N). The arrows show that the $\overline{\Delta f_{\text{min}}}$ values are more than 2 Mc/s]
Here functions \( i \) (RWA) and \( r \) (OH) reflect diurnal variations in the ionospheric parameter \( \Delta f_{\text{min}} \) and the hydroxyl emission, respectively. On this basis “interpolation for a night” of values of \( \Delta f_{\text{min}} \) was made to compare them with the nocturnal hydroxyl data - the increments in the intensity \( \Delta I/I \) and the increments of the rotational temperatures \( \Delta T_{\text{rot}} \), i.e. for the same values of \( \phi \). Fig. 2 (a) shows such a comparison. For the sake of comparison, Fig. 2 (b) compares the same values, with the only difference that values \( \Delta f_{\text{min}} \) correspond to days which preceded the nights for which the hydroxyl data were obtained. Although the point dispersion is great, considerable correlations between “simultaneous” values of \( \Delta I/I \) and \( \Delta f_{\text{min}} \) and those of \( \Delta T_{\text{rot}} \) and \( \Delta f_{\text{min}} \), are noted for which correlation coefficients are 0.7 and -0.5, respectively. For the data in Fig. 2 (b) the appropriate correlation coefficients turned out to be 0.4 and -0.2.

It should be noted that despite the proportionality between the parameters of hydroxyl emission and radio wave absorption within the values indicated in Fig. 2, cases of large values of \( \Delta f_{\text{min}} \) (up to 5.5 Mc/s) near storm maxima were observed (shown by arrows in Fig. 1). However, hydroxyl emission data on that time were absent due to the blending by auroral emission. Nevertheless, a considerable (several times) enhancement of hydroxyl emission for these nights should not be expected on the basis of data of measurements conducted for many years. Therefore, this points either to the absence of linear, on the average, proportionality between \( \Delta I/I \) and \( \Delta f_{\text{min}} \), or to other additional causes of the increase in the value of \( \Delta f_{\text{min}} \). It is possible that this is a consequence of the complicated connection between the \( f_{\text{min}} \) value and radio wave absorption in the ionosphere.

Hence, within the considered limits of variations of the intensity and rotational temperature of the hydroxyl emission and radio wave absorption after a geomagnetic storm, the average relationships of the increments of these values are \( \sim 110 \) per cent/Mc/s and \( \sim -25^\circ \) K/Mc/s, respectively.

Such type of variations agree with the data on the increase in the emission intensity and the decrease in the rotational temperature of OH after a storm.

The ratios obtained between different displays of the disturbed state of the atmosphere impose definite conditions on the possible nature of the processes occurring in the mesosphere. The observed hydroxyl emission energetics comprising about \( 10^{28} \) ergs per magnetic storm\(^{1,2} \) and the ionization magnitude of the close altitudinal region contributing to the observed increase of radio wave absorption should be ensured. The authors express their gratitude to Prof. V. I. Krassovsky for advice and attention to this work.

References
6. SHEPOV, N. N., Annls Geophys., 28 (1972), 137.