N85-20464

SEASONAL CHARACTERISTICS OF MESOSPHERIC PLASMA AND THEIR TRANSITIONS

E. A. Lauter

Academy of Sciences of the GDR
Central Institute of Solar-Terrestrial Physics
Observatory of Ionospheric Research
DDR-2565 Kuhlungsborn, GDR

The main seasonal features of the middle atmosphere are arising from the different dynamical basic states in winter and summer. The development of the two controversial circulation systems and the also different peculiarities of transition between them in spring and autumn create the completely dominant seasonal variations in strato- and mesosphere. Even in the plasma structures of the mesospheric D-region the seasonal variation is towering above the amplitudes of extraterrestrial influences. Therefore, the conventional monitoring of the D-region by radio wave propagation methods is still important for the exploration of atmospheric processes in mesosphere and lower thermosphere and the modes of action in the stratosphere. Due to the activities of the IGY and IQSY there are now available long series of such data for Middle Europe (50°-60°N) in Ionospheric Bulletins of the MPI Lindau (FRG), ZISTP-OIF Kuhlungsborn (GDR), de Bilt (Netherlands) and Uppsala (Sweden). From standard ionospheric sounding, from A1 and A3 absorption measurements and from winds in the meteor region we known the existence of significant seasonal D- and E-region effects, adhering to equally significant structure changes in the neutral gas in the height region from 20 to 100 km.

We have summarized results about such typical seasonal features in Figures 1 and 2. Following at first the sectors of representation in Figure 1 we may give the following statements:

(1) In mid-latitudes a pronounced increase of the occurrence probability of the sporadic E-layer exists in summer, lasting from the beginning of May up to the end of August (SPRENGER, 1981) (typical duration time (TDT) of the phenomenon 130 days).

(2) In the meteor-wind region there exists a regime, which can be described by four seasonal periods (SPRENGER et al., 1974; GREGORY et al., 1982): Two west wind periods correspond to the main development of the stratospheric circulation systems. Representing the upper boundary of the uniform circulation from troposphere to mesosphere in winter, rather stable west winds exist in the 90 km region from late October towards March, culminating in intensity around winter solstice (TDT 140 days). A second west wind period from May to September belongs to a fluctuating thermospheric circulation, existing within and above the cold summer mesopause. Two rather significant transition periods are separating these two wind regimes. The most pronounced one is the wind reversal in spring, i.e. east winds from March 15 till May 10, with a maximum around April 10. The second transition period occurs in autumn between early September and late October with disappearing westerlies and calms in the zonal circulation. Both transition periods are reacting, with significant phase changes in the tidal wind components, on the decrease or reversal of the zonal circulation in the mesospheric wind system below.

(3) The most remarkable seasonal feature of the D-region is the ionization enhancement in the height region from 80-100 km, the winter anomaly, lasting in our latitude from very late October up to the first days of March (TDT 130 days). It is best observed on frequencies around 1.8 MHz (Figure 1c and Figure 2), which penetrate the whole D-region, when they are reflected at the bottom of the E-layer. An increased electron density gradient at the bottom of the D-

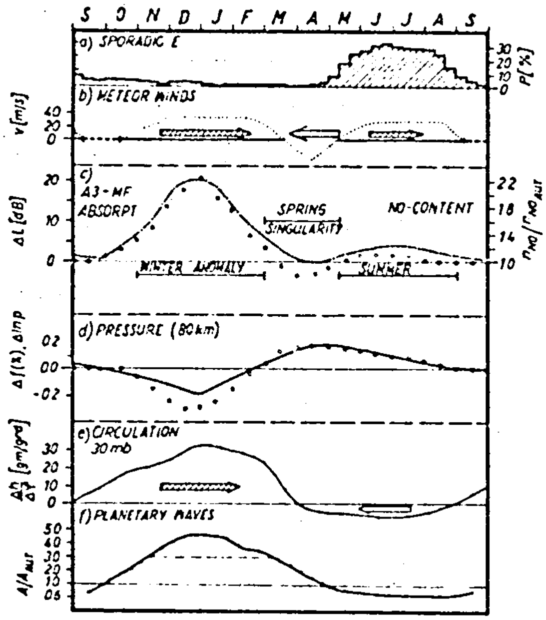

Figure 1. a) Lower thermosphere: probability of E occurrence; b) Meteor winds; c) Upper mesosphere (86 km), high frequency absorption (full line), variation of NO content in respect to Autumn (dots); d) Pressure at 80 km from rockets (full line) and from VLF phase height (dots); e) Circumpolar zonal circulation at 30 mb; f) Planetary wave amplitude at 30 mb.

region accompanies this phenomenon, which is thought to be produced by an enhanced content of nitric oxide in and above the winter-time cyclonic polar vortex. From low frequency phase height analysis we can find an estimation for the seasonal trend of NO increase in 86 km, relative to normal autumn conditions (LAUTER et al., 1983). The dotted trend in Figure 1c informs us that a NO increase by a factor of 2.5 in this height may describe the anomalous ionization around winter solstice. This extreme ionization enhancement in winter is followed by an ionization deficit in spring, when on all frequencies (Figure 2) an absorption minimum occurs.

(4) In mid-latitudes the pressure at 80 km undergoes a rather continuous variation as to be seen from the Volgograd rocket results (Figure 1d). The winter minimum of pressure corresponds to the maximum of the mesospheric circulation. There is a rather fast transition towards a pressure maximum in spring (April), shifting to late March with greater heights. Analyzed for the same height from VLF reflection height observations, the relative pressure variation (dotted trend in Figure 1d) is in remarkable coincidence with the rocket results, demonstrating also the spring maximum and the small but rather steady pressure decrease over the whole summer up to October, when the drop towards winter level becomes sharper.

(5) The change of the basic states of the middle atmosphere is, of course, seen

best in the circumpolar zonal circulation, expressed in Figure 1e in terms of the gradient of the 30 mb level between 50°N and the pole (geopotential meters per degree of latitude). It is easily seen that the westerlies in winter are rather steeply decreasing towards spring, defining a mean reversal date to easterlies of April 2 for the last 25 years. Contrarily, the autumn reversal is much smoother and more precisely at the very end of August. That means that the winter status of the stratosphere has a typical duration time of 215 days in comparison with the summer status of 150 days. The latter is caused mainly by the radiation transfer of the atmospheric ozone layer and defines the decoupling of meso- and stratospheric energetics from the lower atmosphere. The wind reversal dates in spring are widely fluctuating from year to year obviously in connection with the quasi-biennial wave and preceding major stratospheric warmings, which generally retard the spring reversal (ENTZIAN and LAUTER, 1982).

(6) As a further important parameter of the middle atmospheric dynamics we show in Figure 1f for the 30 mb-level the mean annual trend of the planetary wave amplitude (wave number 1 and 2) relative to its spring and autumn values. It can be seen that the duration of strongly enhanced planetary wave amplitudes (amounting to three times the equinox amplitude) is from the beginning of November to the end of February (TDT $\approx$ 120), comparable with the duration of the winter anomaly. This parameter normally increases rather steadily up to mid-winter, but often fluctuates rather heavily afterwards, especially in connection with stratospheric warmings.

Summarizing the results from Figure 1 we may say, that the annual trends of middle atmosphere parameters do inform us about significant seasonal variations from the stratosphere upwards to the lower thermosphere, but the coupling between the presented parameters is not yet well explored. For example, we expect indeed that the occurrence of sporadic E-layer is connected with wind shears, but we have not yet detected a connection between E_s-layer and the meteor winds. In the same way we have no clear connection between the tidal structure of the meteor winds and the thermal regime of the mesosphere. On the other hand we know that a significant coupling exists from middle stratosphere to the mesopause region in winter and spring. The development and intensity of the ionospheric winter anomaly is dependent on the development and intensity of the stratospheric-mesospheric circumpolar cyclonic vortex. The winter anomaly, i.e. the enhanced NO-content, disappears rather suddenly when the reversal of the stratospheric wind system occurs, during a major stratospheric warming event as well as in spring. The coupling of the zonal winds in winter is also well detectable up to the meteor region in winter.

Beside the dominating winter features in the middle atmosphere parameters, the significant transitions from winter to summer state in this height region have to be considered. We call these remarkable features the "spring singularity" of the middle atmosphere, which includes:

- The final break-down of the cyclonic stratospheric vortex, i.e. the wind reversal to strato- and mesospheric east winds.

- The disappearance of the upward propagation of planetary waves in the middle stratosphere.

- The pressure maximum in lower and middle mesosphere.

- The total disappearance of the winter NO accumulation in the D-region, a significant minimum of ionospheric absorption.

- The well developed temporal reversal of zonal winds in the meteor zone.

These features of the spring singularity are repeated every year between middle of March and end of April, announcing the decoupling of the layers from the middle atmosphere. It is well known that the summer state of the middle atmosphere has also some well developed properties (e.g. opposite winds in mesosphere and lower thermosphere, E_s-layer occurrence). It is much less known that also the D-region has a significant summer status. In Figure 2 we have therefore represented the annual trends of ionospheric absorption on different frequencies. At high frequencies (Figure 2a) the winter maximum dominates, A3 and A1 measurements have the same trend and comparable amplitude. Towards lower frequencies the A3 (245 kHz) semiannual variation is present with maxima in winter and summer and minima in spring and autumn. On low frequencies (f ≈ 200 kHz) a well developed summer maximum of absorption exists, lasting from May to September (TDT ~ 130 days). This enhanced summer absorption is most remarkably developed on low and very low frequencies. This effect of a very low electron density gradient at the bottom of the D-region is already detectable at sunrise conditions and is lasting over the full day. Separated by the spring singularity, the reversal of the frequency dependence of ionospheric absorption is a very significant indicator for the transition from winter to summer season in the D-region.

A further significant seasonal difference in the plasma state of the mesosphere is the fact, that the influence of solar activity upon D-region is much more pronounced in summer than in winter. From 30 years of D-region observation we find correlations with the solar activity of $r \geq 0.9$ in summer and $r \leq 0.6$ in winter months. This gives evidence that the winter D-region structure is much more dependent on the internal atmospheric processes than the summer one.

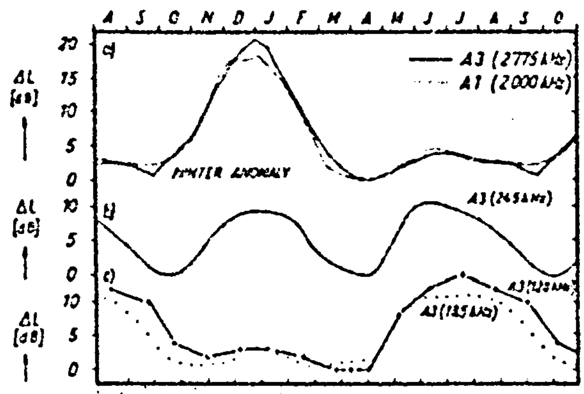

Figure 2. The annual trend of ionospheric absorption on different frequencies.

REFERENCES

Entzian, G. and E. A. Lauter (1982), Z. Meteorol., 32, 209.

Gregory, J. B., C. E. Meek and A. H. Manson (1982), J. Atmos. Terr. Phys., 44, 649.

Lauter, E. A., J. Taubenheim and G. von Cossart (1983), J. Atmos. Terr. Phys., (in press).

Sprenger, K. (1981), Gerlands Beitr. Geophys. Leipzig, 90, 305.

Sprenger, K., R. Schminder K. M. Greisiger, D. Kurschner and B. Schaning (1974), HHI-STP-Report No. 2, Central Institute of Solar-Terrestrial Physics, Berlin, GDR.