EARTH´S MIDDLE ATMOSPHERE RESPONSE TO VARIOUS FORMS OF SOLAR ACTIVITY

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ABSTRACT. Possible solar (including solar wind) variabilities influencing the Earth´s middle atmosphere (h $\approx$ 10-100 km) are summarized. Some new results presented at the 5th Scientific Assembly of IAGA (Prague, August 1985), which concern solar UV variability and periodic as well as sporadic event forcing of the middle atmosphere, are reported and discussed.

ОТКЛИК СРЕДНЕЙ АТМОСФЕРЫ ЗЕМЛИ НА РАЗНЫЕ ПРОЯВЛЕНИЯ СОЛНЕЧНОЙ АКТИВНОСТИ. Описиваются возможные изменчивости солнечной активности (включая солнечный ветер), влияющие на среднюю атмосферу Земли ($h \approx$ 10-100 км). Приводятся некоторые новые результаты, появившиеся на 5-ой Научной ассамблеи МАГА (Прага, август 1985), которые касаются вариаций солнечного ультрафиолетового излучения и периодических и спорадических воздействий на среднюю атмосферу.

REAKCE STŘEDNÍ ATMOSFÉRY ZEMĚ NA RŮZNÉ PROJEVY SLUNEČNÍ AKTIVITY. Jsou shrnuty možné změny sluneční aktivity (včetně slunečního větru), ovlivňující střední atmosféru Země (h $\approx$ 10-100 km). Uvádějí se některé nové výsledky, přednesené na 5. Vědeckém shromáždění IAGA (Praha, srpen 1985), které se týkají variability slunečního ultrafialového záření a periodických i sporadických vlivů na střední atmosféru.

1. INTRODUCTION

The Earth´s middle atmosphere (about 10-100 km above surface) is influenced by many factors of external origin. Some of them come from below. These factors include atmospheric waves of tropospheric origin, mainly internal gravity waves (periods approximately between 10 minutes and a few hours), tides and planetary waves (periods of several days), volcanic eruptions contaminating the middle atmosphere with dust particles, aerosols and various minor constituents, and man-made pollution. Perhaps the best known man-made pollutant is freon with its possible negative effect on the ozone layer, which prevents the dangerous part of the solar ultraviolet spectrum in reaching the Earth´s surface.

Another group of factors (or agents) enters the middle atmosphere from above. These factors are directly or indirectly of solar origin. There are two basic types of solar forcing of the middle atmosphere:

1. Periodic variations, like the 11-year solar cycle, 27-day and 13.5-day variations caused by solar rotation, and some other periodicities. Physically, this represents the variability of solar ultraviolet forcing of the middle atmosphere.
2. Sporadic or quasi-sporadic forcing by events like solar flares (SIDs in the lower ionosphere), geomagnetic storms, variability of galactic cosmic ray flux (e.g. Forbush decreases), relativistic electron precipitation and solar cosmic ray events, variability of the interplanetary magnetic field (IMF) magnitude or components, IMF sector boundary crossings, solar wind speed variability, high speed streams in solar wind, interaction regions - mainly solar wind phenomena associated with high-energy particle precipitation.

The purpose of this paper is to show and discuss some new results presented at the 5th Scientific Assembly of IAGA (Prague, August 1985), which concern the variability of the solar ultraviolet flux of interest for the middle atmosphere, influences of solar ultraviolet variability on the middle atmosphere, and effects of some solar wind phenomena on the middle atmosphere. The papers referred to below were presented in sessions 8.1 "UV Radiances, Cross Sections, Photochemical Modelling", 8.2 "Solar-terrestrial Forcing of the Middle Atmosphere" and 11.10 "Downward Penetration of Solar Activity Effects into the Middle Atmosphere".

2. VARIABILITY OF SOLAR ULTRAVIOLET RADIATION

The 160-410 nm solar UV flux measured by Nimbus-7 exhibits solar rotation variations (27 and 13.5 day periods), increases and decreases on a time scale of months, and a solar cycle variation on the time scale of years. Photospheric emissions contain much more of the 13.5-day component than chromospheric emissions. 27-day and 13.5-day amplitudes display considerably different long-term variations (Heath, 1985).

The ratio of amplitudes of the 11-year variation to the 27- or 13.5-day variations for chromospheric EUV emissions agrees with ground-based measurements of the solar infrared He I absorption line at 1083 nm, but is larger than this ratio for $F_{10.7}$, R and Ca-plages. Fe 28.4 and 33.5 nm coronal lines agree fairly well with $F_{10.7}$ in episodes (time scale of several months) and solar rotation variations. The 13.5-day periodicity is weak for coronal EUV lines, considerably stronger for chromospheric lines H Lyman-beta, 58.4 and 30.4 nm (helium), and for 0.1-1 nm X-rays (here ~180° out of phase), and again considerably stronger for the photospheric line of 205 nm. The 13.5-day periodicity is not simply a second harmonic of the 27-day periodicity, because some episodes of activity are dominated by the 13.5-day periodicity with very weak 27-day periodicity, while other episodes are dominated by the 27-day periodicity with weak 13.5-day periods (Donnelly et al., 1985).

Solar Mesospheric Explorer (SME) measurements of H Lyman-alpha (121.6 nm) flux yielded the relation:

$F_\alpha = 1.7 \times 10^{11} + 4.45 \times 10^{8}\, \bar{F}_{10.7} + 5.55 \times 10^{8}\, F_{10.7}$ (photons/cm^{2}s)

where $\bar{F}_{10.7}$ is yearly (365 day) mean value. This relation agrees well with that based on OSO-5 data. There is good agreement between average values of F_α and $F_{10.7}$, but rather poor relation between individual values. The solar cycle is more smoothed in Lyman-alpha than in $F_{10.7}$. F_α decreases from about 3.7×10^{11} photons/cm^{2}s at the beginning of 1982 to $2.4\text{-}2.5 \times 10^{11}$ in 1985 (Rottman, 1985).

3. SOLAR ULTRAVIOLET VARIABILITY AND THE MIDDLE ATMOSPHERE

The principal "heater" of the stratosphere is ozone. Gille et al. (1985) found only very weak 13.5-day and 27-day variations in ozone at low latitudes in phase with the solar 205 nm flux ($\Delta O_3/\Delta 205$ nm = 0.25-0.5 between 5-0.2 hPa). Chandra (1985) discovered a fairly good correlation of the solar 205 nm flux and stratospheric ozone, but very poor correlation with stratospheric temperature. Hood (1985) found the largest response of daily ozone values to the 205 nm flux variability (1% in 205 nm - 0.5% in O_3) at the 3 hPa level. Keating and Brasseur (1985), correcting for stratospheric temperature effects, reported very high correlations (> 0.8) between detrended ozone and 205 nm radiation. They found the maximum of the solar cycle effect in ozone between 0.2-10 hPa at 5 hPa, about 3-4.5%; total ozone yields only 2%. Heath et al. (1985) compared the effect of solar activity and El Chichon volcanic eruption on stratospheric ozone and found solar effect to be dominant between 0.7-3 hPa, whereas the 5-30 hPa region was dominated by El Chichon eruption.

Many papers have been devoted to the examination of possible influence of solar activity on stratospheric ozone. Considerable progress in this field is expected in the next years because of further analysis of SME data and due to new satellite experiments to be launched in the near future.

Rocket data from Volgograd (von Cossart and Taubenheim, 1985) exhibit an "in-phase" solar cycle variation of temperature. This variation is seen only above 55 km. Its amplitude in the mesosphere is 6 K.

4. EFFECTS OF SOME SOLAR WIND PHENOMENA

The ionization of the lower ionosphere at higher latitudes depends on the flux of precipitating energetic particles. Bremer (1985) demonstrated the dependence of this particle precipitation on regular changes of the geoactive north-south component of the IMF (in terms of seasonal and diurnal variations) by means of ground-based geomagnetic and ionospheric measurements at high and middle latitudes.

Laštovička (1985) reported the existence of two different types of effects of the IMF sector boundary crossing in the ionosphere and atmosphere. He presented the first rough morphological "scenario" of the altitudinal and latitudinal dependences of these effects and showed several factors responsible for variable geoactivity of individual IMF sector boundary crossings.

The tropopause temperature above Berlin was found to be enhanced by 0.5--0.6 K on the day of the IMF sector boundary crossing. The effect of flare--associated high-speed plasma streams on the tropopause temperature and height was stronger than that of IMF sector boundaries, while corotating high-speed streams were followed by no detectable effect (Brown and Gravelle, 1985).

High speed plasma streams can screen the Earth from galactic cosmic rays. This process may decrease the ionization in the lower ionosphere. Bencze and Sátori (1985) found the resulting decrease of atmospheric radio noise at 5 kHz with the use of experimental data from the Panská Ves Observatory, Czechoslovakia. They found evidently stronger effects for flare-associated streams than for corotating streams.

The high-latitude heat source (geomagnetic storms, magnetospheric substorms - particle precipitation, Joule heating from electric currents) intensifies solar driven meridional circulation in the summer hemisphere and acts against it in the winter hemisphere. There is a certain solar cycle variation of prevailing and semidiurnal tidal wind in the mesosphere and lower thermosphere, which is stronger at higher latitudes (probably caused by solar cycle variation of sporadic geomagnetic activity). Individual geomagnetic storms affect the wind system in the upper mesopause region (Kazimirovsky, 1985).

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