Journal of Atmospheric and Solar-Terrestrial Physics 71 (2009) 1540–1546

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Midlatitude mesopause region winds and waves and comparison with stratospheric variability

Ch. Jacobi [a,*], P. Hoffmann [a], R.Q. Liu [a], P. Križan [b], J. Laštovička [b], E.G. Merzlyakov [c], T.V. Solovjova [c], Yu.I. Portnyagin [c]

[a] University of Leipzig Institute for Meteorology, Stephanstr. 3, 04103 Leipzig, Germany
[b] Institute of Atmospheric Physics of ASCR, Bocni II, 14131 Prague, Czech Republic
[c] Scientific and Production Association "Typhoon", Institute of Experimental Meteorology, Lenin Street 82, 249038 Obninsk, Russia

ARTICLE INFO

Article history:
Accepted 6 May 2009
Available online 10 May 2009

Keywords:
Middle atmosphere
Stratospheric ozone
Planetary waves
Long-term trends

ABSTRACT

We present time series of January–May mean mesosphere/lower thermosphere (MLT) mean winds and planetary wave (PW) proxies over Europe together with stratospheric stationary planetary waves (SPW) at 50°N and time series of European ozone laminae occurrence. The MLT winds are connected with stratospheric PW and laminae at time scales of several years to decades. There is a tendency for increased wave activity after 1990, together with more ozone laminae and stronger MLT zonal winds. However, possible coupling processes are not straightforward. While mean MLT winds before the 1990s show similar interannual variations than stratospheric PW at 100 hPa, later a tendency towards a connection of the MLT with the middle stratosphere SPW is registered. There is also a tendency for a change in the correlation between lower and middle stratosphere SPW, indicating that coupling processes involving the European middle atmosphere from the lower stratosphere to the mesopause region have changed.

1. Introduction

Recently, a relatively consistent picture of middle and upper atmosphere temperature trends have been presented, showing cooling in the stratosphere/mesosphere, weak trends around the mesopause and cooling in the thermosphere (e.g. Laštovička et al., 2008). However, when dynamical parameters in the middle and upper atmosphere are considered, a much less clear picture is found. Several authors have noted long-term changes of mesosphere/lower thermosphere (MLT) prevailing winds (Portnyagin et al., 1993; Bremer et al., 1997; Jacobi and Kürschner, 2006) or planetary wave (PW) proxies (Jacobi et al., 2008). However, now available MLT wind time series of more than two decades indicated that these trends may be intermittent, or change direction (Portnyagin et al., 2006; Merzlyakov et al., 2009). Portnyagin et al. (2006) have presented mean MLT winds at Northern Hemisphere (NH) midlatitude stations and found that there is indeed a trend change in MLT wind parameters (prevailing winds and semidiurnal tidal amplitudes) around 1990. This raises the question, whether these possible changes of trends may be connected with other atmospheric parameters.

Laštovička and Križan (2006) showed a change of trend in the total ozone content and ozone laminae, the latter being frequently interpreted as the signature of ozone streamers in the vertical, and thus it may be an indication for PW or PW breaking in the lower stratosphere. Baumgaertner et al. (2005), their Fig. 16 showed PW 1 amplitudes at 78° (averages of 78°N and 78°S) together with amplitudes of the semidiurnal tide (SDT) over Scott Base, Antarctica, which showed a change around 1990, however, they do not report convincing evidence for mean wind long-term trends over Scott Base.

Earlier studies (Sprenger and Schminder, 1969; Bremer et al., 1997; Baumgaertner et al., 2005; Jacobi and Kürschner, 2006; and many more) have shown that there is a possible solar cycle effect on MLT mean winds, which may be connected with the solar cycle influence on the stratosphere/mesosphere. When long-term changes are sought, such decadal variations have to be taken into account.

In this study, we consider MLT prevailing winds and wind variability over Europe in connection with stratospheric wave activity. For analysing the latter, we use NCEP/NCAR reanalyses at 50°N and ozone laminae that to a certain degree may be considered as a PW proxy. The MLT and ozone laminae data used have been updated from Križan and Laštovička (2005); Jacobi and Kürschner (2006); Jacobi et al. (2008) and Portnyagin et al. (2006). The main purpose here is to present the search for possible similarities of stratospheric and MLT variability over Europe. A more detailed investigation of exact times of trend breaks in MLT winds and possible connection with tropospheric changes will be presented in a companion paper (Merzlyakov et al., 2009).

* Corresponding author. Tel.: +49 341 9732876; fax: +49 341 9732899.
E-mail address: jacobi@uni-leipzig.de (Ch. Jacobi).

1364-6826/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jastp.2009.05.004

2. Datasets and methods used

2.1. Mesosphere–lower thermosphere wind measurements

Wind measurements over Obninsk (55°N, 37°E) have been carried out using the meteor radar (MR) technique on 33.3 MHz since 1964. The radar transmitting system consists of four antennas pointing in the directions N, E, S and W. For the present investigation focusing on monthly and seasonal means, the mean values of the N, S and W, E beams, respectively, are considered to improve the statistical significance. The wind values are combined to hourly means. Height finding over Obninsk is not available and the results are ascribed to a height of about 90 km, where most of the meteor echoes are found (e.g. Lysenko et al., 1994; Mitchell et al., 1996).

Collm low frequency (LF) D1 wind measurements in the height range 80–100 km have been carried out since 1959 until late 2008. Commercial radio transmitters in the LF range (177, 225 and 270 kHz) have been used, and an automatic algorithmic variant of the similar fade analysis is used for interpretation of the measurements. We calculate half-hourly mean winds, and construct monthly median half-hourly winds as well. The reference height has not been measured before September 1982, so that the results used for long-term variability analysis have been attributed to the mean nighttime height near 90 km. From the early 1970s the analysis has been performed automatically, and since 1979 half-hourly winds from three measuring paths are constructed, referring to a mean reflection point at 52°N, 15°E.

We use a multiple regression analysis based on daily hourly or half-hourly mean winds for daily analysis. This analysis includes the SDT, the diurnal tide (DT) and the mean wind for Obninsk, but only SDT and mean wind for Collm. Monthly means for Obninsk are calculated from these daily means. But for Collm, we use monthly median half-hourly winds to perform the multiple regression and obtain monthly mean wind parameters. Due to D region absorption during daylight hours, regular data gaps are present in the daily LF data especially in summer. In addition, the reference height changes from about 90 km during nighttime to 80 km during daytime. Therefore, we used only nighttime winds during those times of the day when the reflection height is approximately 90 km. Data analysis has been described in detail by Jacobi et al. (1998) and Jacobi et al. (2008). Note that neglecting the DT in the decomposition of the wind field into mean winds and the SDT may lead to errors in mean winds, particularly, in late spring and early summer, when the DT is large. Experiments using Collm meteor radar winds with artificial gaps (not shown here) revealed that the zonal prevailing winds in early summer are slightly more easterly or less westerly, while the meridional northerly prevailing winds are overestimated.

Collm LF winds before 1979 have been analysed on the basis of measurements from one transmitter (270 kHz) only. We expect that the variability of the winds measured before the 1980s is larger. Therefore, we do not use daily mean winds before 1979. Note also, that monthly or seasonal means before 1979 should not be interpreted with respect to interannual changes at time scales shorter than one pentad or so.

The long-term mean Collm and Obninsk prevailing winds are shown in Fig. 1. The winter zonal prevailing winds agree within the limits of the standard deviations. During summer, Collm winds are slightly stronger than Obninsk ones, which indicates that the Collm reference height is slightly higher than the Obninsk one. In addition, as predicted by existing climatologies like HWM93 (Hedin et al., 1996), HWM07 (Drob et al., 2008) or GEWM-I (Portnyagin et al., 2004) the 3° latitudinal difference should lead to about 3–4 m/s weaker zonal winds at Obninsk compared to Collm. The meridional winds over Collm and Obninsk generally also agree well. The comparatively strong southward winds for Collm in spring/early summer may be owing to neglecting the DT in the analysis.

2.2. European ozone laminae

In ozone profiles measured by ozonesondes, one may frequently observe the occurrence of relatively narrow layers of substantially increased or depleted ozone concentration. These layers are called laminae, positive laminae in the former and negative laminae in the latter case. According to Reid and Vaughan (1991), laminae occur most frequently at heights around 14 km, which is consistent with results by Laštovička (2002), who found that more than 40% of the overall ozone content in laminae is located between 100 and 200 hPa.

Various authors use various lamina definitions. Hereafter, we will work with laminae defined in terms of ozone concentration represented by ozone partial pressure, not in terms of ozone mixing ratio. The laminae may to a certain degree be considered as proxies for dynamical processes, such as, at middle to higher latitudes, filamentary structures at the polar vortex edge, i.e., connected with PW (breaking) or disturbances of the vortex. Note, however, that there is no simple correlation between laminae and PW. In particular, the latter (e.g. Kanukhina et al., 2008) show

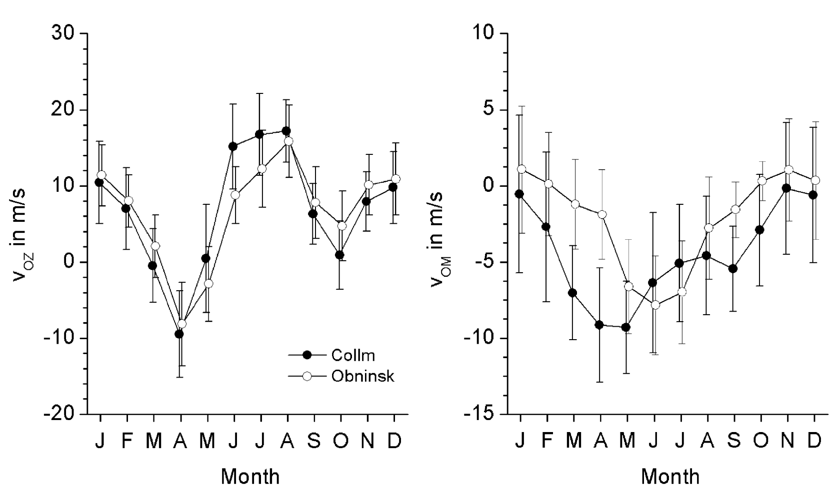

Fig. 1. The 1970–2007 mean monthly mean zonal (v_{OZ}, left panel) and meridional (v_{OM}, right panel) prevailing winds over Collm and Obninsk. Note the different scaling of the ordinates of the two panels.