Small September semidiurnal tidal amplitudes over Collm in 2002

Christoph Jacobi and Dierk Kürschner

Summary

The mesopause region monthly mean winds and semidiurnal tidal amplitudes and phases over Central Europe in the height range between 85-105 km have been measured at Collm Observatory continuously since September 1982. The regular annual cycle of the semidiurnal tidal amplitudes show in all cases maximum values during late August and September. In contrast to that, in autumn 2002 no enhancement of the tidal amplitudes was measured, while the autumn tidal phase transition occurred unusually early. The unexpected behaviour of the semidiurnal tides seems to be connected with a very early autumn transition of the zonal prevailing winds. This suggests that in 2002 the zonal mean winds influence the tidal propagation in a different way than usual.

Zusammenfassung

Die monatlich gemittelten Grundwinde und halbtägigen Gezeiten werden am Collm seit September 1982 im Höhenbereich zwischen 85-105 km gemessen. Der normale Jahresgang der halbtägigen Gezeiten zeigt maximale Amplituden im Winter und vor allem im Spätsommer/Herbst. Dieses Maximum ist im Jahre 2002 nicht zu verzeichnen. Dies ist begleitet von einer ungewöhnlich frühen Phasenänderung von der Sommer- zur Winterposition. Das Verhalten der Gezeiten scheint mit einer sehr frühen Änderung des zonalen Grundwindes vom Sommer- zum Winterregime verbunden zu sein, so dass die Anomalie der mittleren Zirkulation für die Gezeitenanomalie verantwortlich zu sein scheint.

Introduction

The seasonal behaviour of the semidiurnal tide in the mesosphere/lower thermosphere (MLT) region around 80-100 km has been measured using ground-based and space-based measurements (Manson et al., 1989; Lysenko et al., 1992; Burrage et al., 1995; Jacobi et al., 1999). Also, modelling of the seasonal variation has been performed using modified classical theory (Greisiger, 1975) and numerical models (Hagan et al. 1999; Manson et al, 1999). The authors concordantly report that the semidiurnal tidal amplitudes at higher midlatitudes (50-55°) are small in winter and late autumn, but larger in winter and above all in late August and September. The phase of the semidiurnal tide generally has different positions in winter and summer, with the latter around 95 km being about 2 hours earlier than the former. The vertical wavelength of the semidiurnal tide in winter is about 60 km, while it is much larger or even indefinite in summer. The transition from summer to winter phase generally occurs very regularly during the second half of October.

During September usually the mean summer mesospheric midlatitude easterly winds below 90 km change to the winter westerlies, resulting in comparatively low mesospheric winds during this month. On average, the MLT winds at higher midlatitudes are still eastward and increasing with height (e.g. Portnyagin and Solovjova, 2000), which is typical for summer, but with smaller absolute values, and especially in the mesosphere rapidly changing to westerly winds, i.e. to winter conditions.

At Collm Observatory mean winds and semidiurnal tides near 95 km have been measured since 4 decades. Vertical profiles of those parameters in the height range 85-105 km are available since September 1982, so that a 21-year dataset is available. Here we focus on the unusual behaviour of the semidiurnal tides in September 2002.

Measurements at Collm

At Collm Observatory, LF (low frequency) radio wind measurements are carried out on 177, 225, and 270 kHz with differing measuring paths, applying the spaced antenna method and the similar-fade method for analysis. The LF measurements use the reflected sky wave at oblique incidence from commercial amplitude modulated radio transmitters with reflection levels in the MLT between 85 to 105 km and the centre of the triangle of the three reflection points at 52°N and 15°E. The individual measurements on each frequency are combined to half-hourly means, each representing an average over 30 – 60 data points depending on local time and LF propagation and reflection conditions.

The reference heights are obtained using the amplitude modulation in the frequency range near 1.8 kHz by measuring the travel time differences between corresponding modulation bursts in the sky wave and in the ground wave. Because of the intensive absorption of the sky waves during daytime the measurements in the summer months are restricted to nighttimes and twilight conditions.

The obtained half-hour means of the measured zonal and meridional wind components and the reference height are analysed using a multiple regression analysis with height-dependent coefficients. The measurements have been described by Kürschner (1975, 1991) and Kürschner and Schminder (1980), while data analysis procedures have been described by Kürschner and Schminder (1986), Kürschner (1991), and Jacobi et al. (1997). The method of height determination was described by Kürschner (1981) and Kürschner et al. (1987). Monthly reports of the wind measurements are available on the internet under http://www.uni-leipzig.de/~jacobi/collm/reports.

Results for September 2002

Figure 1 shows time series of the semidiurnal tidal phases and amplitudes, together with the meridional and zonal mean wind during summer and autumn 2000, 2001, and 2002. The daily data has been calculated using regression analyses with quadratically height-dependent coefficients that include the mean winds and the oscillations with periods 12h, 48h, 10d and 30d. Each analysis was performed on a basis of 25 days and the result was attributed to the centre of the time interval. It has therefore to be taken into account that this analysis includes a strong smoothing. However, the determination of the time of autumn tidal phase transition is not affected. The results are shown for an altitude of 93 km, which is the height of maximum measuring density during September 2002.

It can be seen from Figure 1 that the semidiurnal amplitudes and phases in early summer 2002 do not strongly differ from those during other years. However, the increase in semidiurnal tidal amplitude that is regularly starting in early August is not visible in the curve for 2002. The tidal amplitudes remain near 10 m/s during the whole August and part of September, while during the second half of September, when during other years a strong maximum is found, even a tendency towards a minimum is visible.

The unusual behaviour of the tidal amplitudes in 2002 is accompanied by a very early change of the tidal phases from their summer value (about 6 UT near 93 km) to the winter value (about 9 LT near 93 km). In all years, this change is starting in a narrow time interval in the

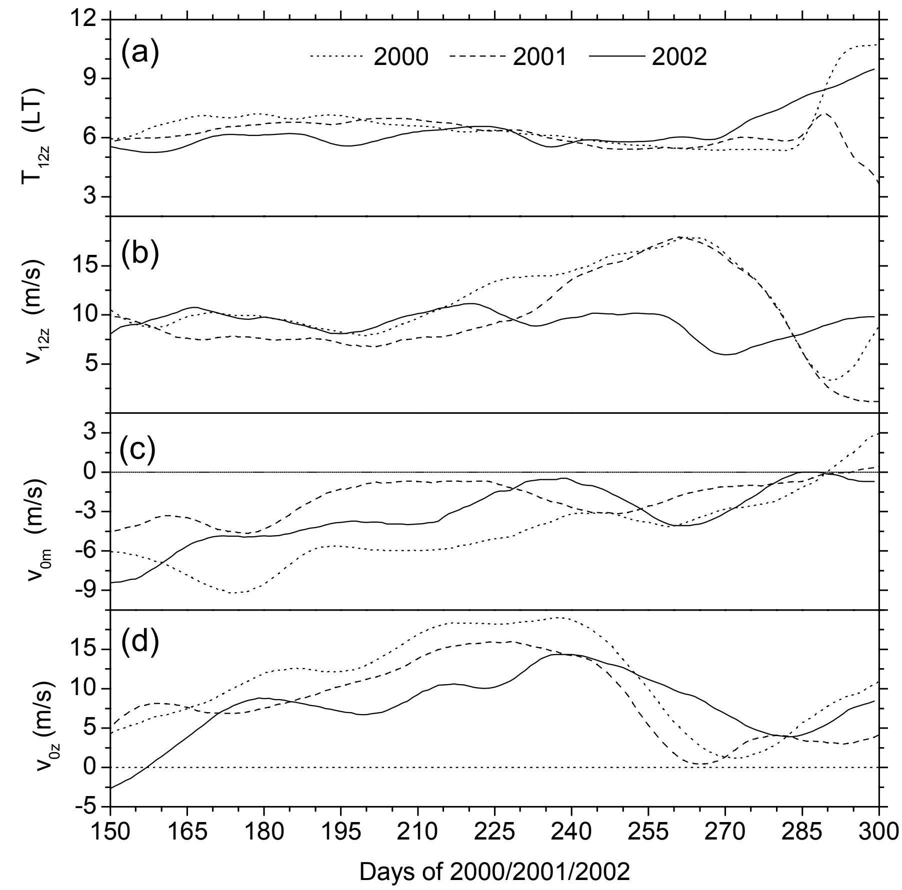

Figure 1: *Time series of (a) semidiurnal tidal phases T_{12z}, defined as the time of eastward wind maximum, (b) semidiurnal tidal amplitudes (v_{12z}), (c) meridional prevailing winds (v_{om}) and (d) zonal prevailing winds (v_{oz}) at 93 km over Collm in summer and autumn 2000, 2001, and 2002.*

second half of October, in the course of which this transition may occur in different ways: either it consists of a sharp phase jump (as in 2000), or of a more moderate progression or also regression of the phase is found (as in 2001). In 2000 and 2001 the phase transition did not start before mid October. In contrast to that, the phase transition in 2002 starts about two weeks earlier.

The meridional mean winds at 93 km in 2002 does not show an unusual behaviour, while the zonal mean winds are different from those during other years in that the autumn decrease of the westerly wind (which, on shorter time scales also includes easterly winds during a short time interval) is not seen in September 2002.

The monthly mean profiles of the semidiurnal tidal phases and amplitudes and the prevailing winds are shown in Figure 2, together with the mean values calculated from all the September data gathered during 1983 – 2002. To determine whether or not the 2002 profiles are outside the range of previously measured winds, the maximum and minimum values between 1982 and 2001 at 95 km are also shown, together with the 1-σ variation during that time interval. It can be seen that both the tidal amplitudes and phases are outside the range of previously measured values. Comparison with literature results (Lysenko et al., 1992; Manson et al., 1999) also show that none of the tidal amplitudes presented are as small as those measured at Collm in 2002. The prevailing winds fall in the range of previously measured wind values,

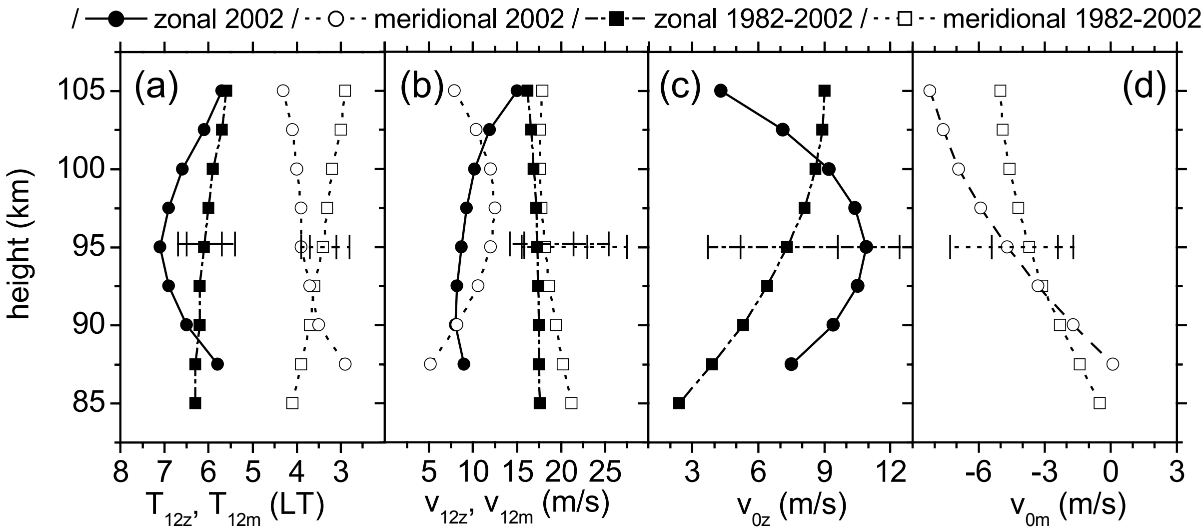

Figure 2: *September 2002 mean profiles of (a) semidiurnal phases (b) semidiurnal tidal amplitudes (c) zonal prevailing winds and (d) meridional prevailing winds over Collm. The circles show the 2002 values, while squares denote the climatological 20-year mean values calculated from all September data between 1982 and 2002. The horizontal bars show the maximum/minimum values (outer vertical bars) recorded between 1982 and 2001, and the 1-σ variation (inner vertical bars) during that time interval.*

but there is an indication that the zonal prevailing winds are more winter-like because they show in the lower height range considered here stronger westerlies than usual, while above 100 km the decrease of westerlies seems to be somewhat stronger. This is an indication for an unusual early transition from summer to winter conditions, i.e. westerlies in the mesosphere and a reversal to easterlies above that layer.

Such an unexpected behaviour would be connected with comparatively strong westerly zonal prevailing winds, as is visible in Figure 2. Therefore one may assume that there could be a connection between zonal prevailing wind and semidiurnal tidal amplitude. In Figure 3 a scatter plot is shown that depicts the zonal prevailing wind at 93 km vs. the semidiurnal amplitudes. It can be seen that there is a tendency towards larger tidal amplitudes with weaker westerlies. Clearly, this connection, if there is any, is not linear (the correlation coefficients are given in the figure also) and not very strong. However, the tendency as visible in Figure 3 indicates that during those years when the prevailing wind changes earlier to winter conditions (and is therefore already stronger towards the east) the tidal amplitudes are weaker. This indicates that the zonal mean circulation may be responsible for the unusual semidiurnal wave propagation and thus their unexpected amplitudes during September 2002. Weak amplitudes are a regular phenomenon for October, when the prevailing winds are regularly westerly.

Conclusions

At Collm, in September 2002 extremely small semidiurnal tidal amplitudes have been measured. The September mean tides are smaller as those measured at Collm in any year of observation since 1982. The amplitudes are also smaller as those presented by other authors (Lysenko et al., 1992; Mason et al., 1999) for different years or different periods. The small

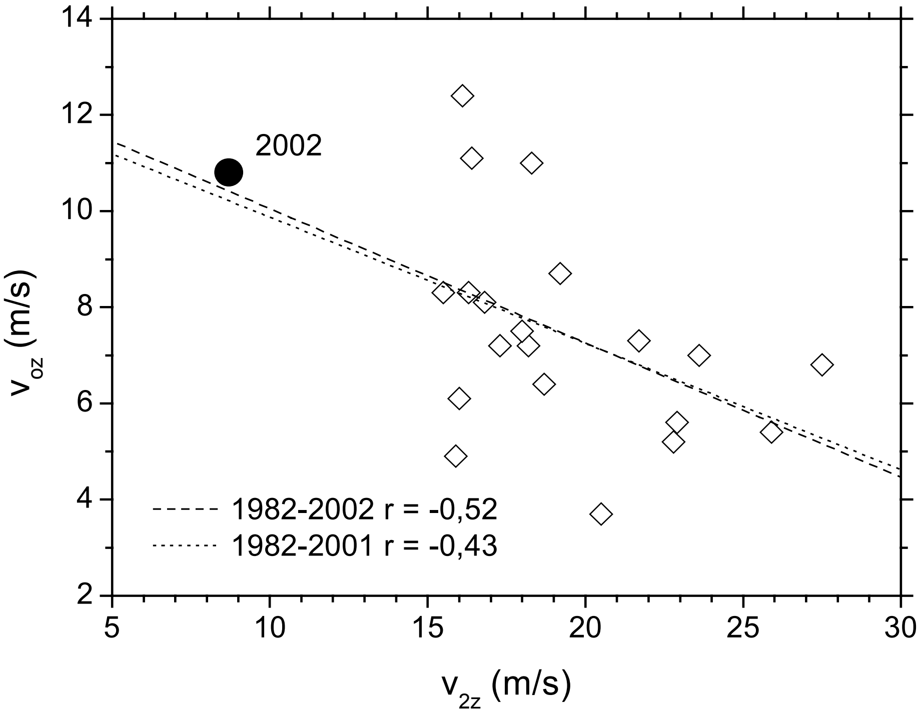

Figure 3: *Scatterplot showing monthly mean September zonal prevailing winds vs. zonal semidiurnal amplitudes at 93 km. The value for 2002 is highlighted. Linear fits are calculated both and disregarding the 2002 data point.*

tidal amplitudes have been accompanied by an unusual early change of the tidal phase from its summer to winter position.

Regarding the mean zonal wind profiles there is some indication that the summer mean circulation in the mesosphere has been shifted to mean winter conditions earlier than during other years, so that it is conceivable that the September tides have been modified by an unexpected behaviour of the mean circulation. This assumption is supported by an analysis of 21 years of September winds and tidal amplitudes. The results indicate that it may be a regular feature that stronger westerlies (i.e. winter conditions) are connected with weaker amplitudes.

Generally, in this connection it is of interest to what degree the mesospheric jets have shown an unexpected behaviour in autumn 2002. The specific situation in the mesosphere, however, cannot be shown by the MLT measurements at Collm. It may, however, be concluded that the seasonal cycle of tidal winds in the MLT is more variable that hitherto assumed.

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Addresses of Authors

Christoph Jacobi, Institut für Meteorologie, Universität Leipzig, Stephanstr. 3, 04103 Leipzig, jacobi@uni-leipzig.de

Dierk Kürschner, Institut für Geophysik und Geologie, Observatorium Collm, 04779 Wermsdorf, kuersch@uni-leipzig.de