# Trends in low-frequency radio wave reflection heights and lower E-region drifts over Collm, Germany – an update including the years 1979-2007

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Lower E region low-frequency measurements using commercial radio broadcasting stations have been used to indirectly measure mesospheric temperature variability via changes of the radio wave reflection height (Bremer and Berger, 2002, Kürschner and Jacobi, 2003). They have shown a general shrinking of the mesosphere due to middle atmosphere cooling, which is in correspondence with other measurements (see, e.g., the reviews by Beig et al., 2003; Beig, 2006; Laštovička et al., 2007). Recent analyses, however, have shown that the temperature decrease is obviously not linear, but ceases during the last decade. Collm measurements of reflection heights on 177 kHz, referring to a reflection point at 52.1°N, 13.2°E are shown in *Figure 1*. Owing to group retardation, these virtual heights are about 5 km too high compared with the real ones. Until about 2000, as has been presented by Kürschner and Jacobi (2003), the reflection heights decrease, but after that time the lower E region heights remain at a similar level.

Low-frequency measurements can are also used to analyze E region drifts at the reflection point (e.g. Jacobi and Kürschner, 2006, and references therein). These drifts can be interpreted as neutral winds at about 90 km altitude. Analyses of long-term trends have revealed possible long-term trends in some parameters (Bremer at al., 1997, Jacobi et al., 2006), generally thought to be in connection with middle atmosphere changes. Semidiurnal

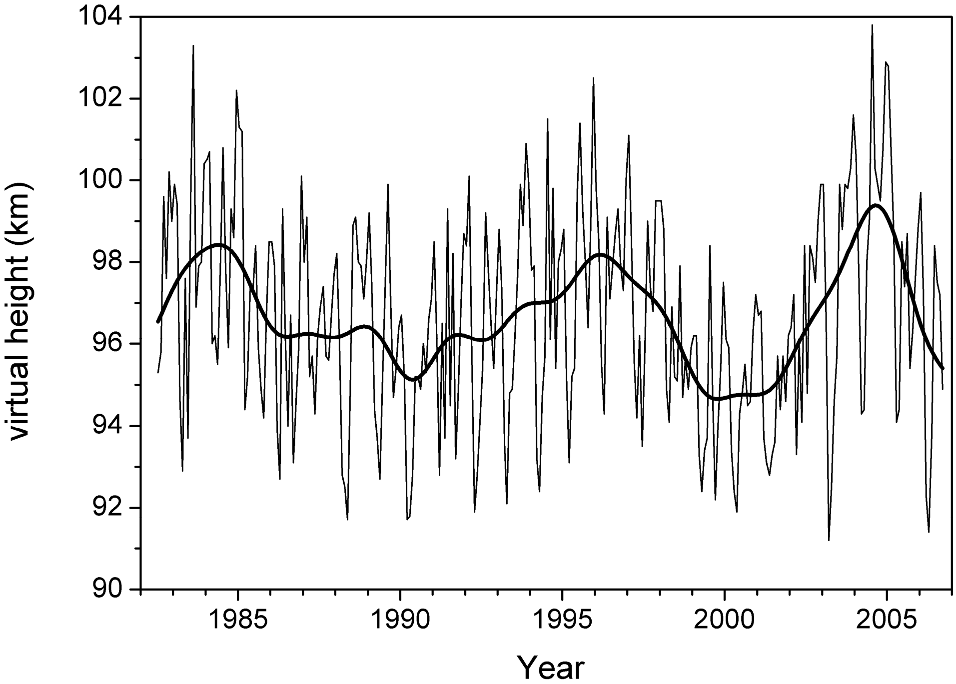

*Figure 1:* Collm monthly mean 21-1 UT nighttime virtual reflection heights on 177 kHz (transmitter Zehlendorf, reflection point at 52.1°N, 13.2°E). The thick solid line shows 12 pt FFT-filter smoothed data.

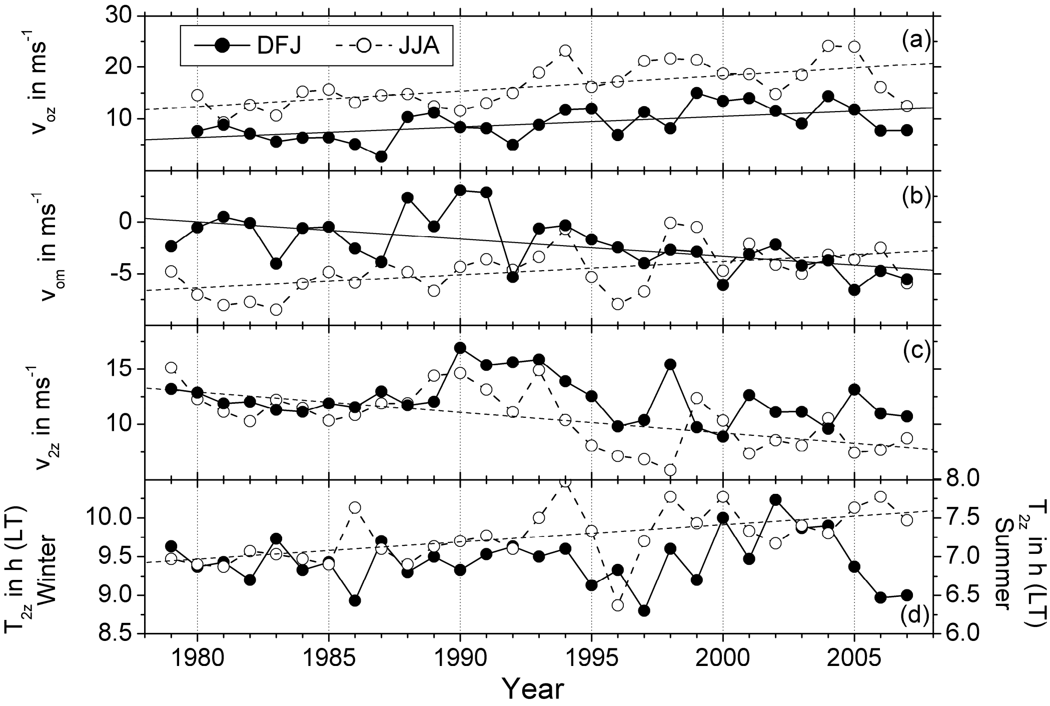

*Figure 2:* Time series of December-February (solid symbols) and June-August (open symbols) mean wind parameters over Collm (a) $v_{oz}$: zonal prevailing wind, positive eastward, (b) $v_{om}$: meridional prevailing wind, positive northward, (c) $v_{2z}$: semidiurnal tidal amplitude and (d) $T_{2z}$: semidiurnal tidal phase, defined as the time of eastward wind maximum. Linear trends from *Table 1* are added if they are significant. Updated from Jacobi and Kürschner (2006).

tidal amplitudes have decreased (see also Jarvis, 2005), possibly in connection with stratospheric ozone decrease. Meridional winds have decreased due to stratospheric cooling, decrease of the mesospheric wind jets and a resulting weaker gravity wave filtering which leads to reduced mesospheric Brewer-Dobson circulation (Jacobi et al., 2003). Changes of tidal phases towards later phase positions may as well be due to middle atmosphere cooling through changes of the vertical wavelength of the tide (Jacobi and Kürschner, 2006). Collm wind parameters are presented in Figure 2. The data represent an update from Jacobi and Kürschner (2006), they are calculated from monthly median half-hourly mean drifts using a least-squares analysis to analyze monthly mean winds and semidiurnal amplitudes and phases. Linear trends are provided in Table 1 and are added as straight lines in Figure 2 if they are statistically significant.

*Table 1:* 1979-2007 linear trend parameters for circulation parameters over Collm. Statistical significant trends (t-test, 99% level) are highlighted by shading.

| Parameter | Trend/DJF | Correlation coefficient | Trend/JJA | Correlation coefficient |
|---|---|---|---|---|
| $v_{oz}$ | +0.20 $ms^{-1}$/yr | 0.54 | +0.30 $ms^{-1}$/yr | 0.60 |
| $v_{om}$ | -0.17 $ms^{-1}$/yr | 0.56 | +0.13 $ms^{-1}$/yr | 0.49 |
| $v_{2z}$ | -0.06 $ms^{-1}$/yr | 0.25 | -0.19 $ms^{-1}$/yr | 0.61 |
| $T_{2z}$ | +0.003 h/yr | 0.07 | +0.022 h/yr | 0.54 |

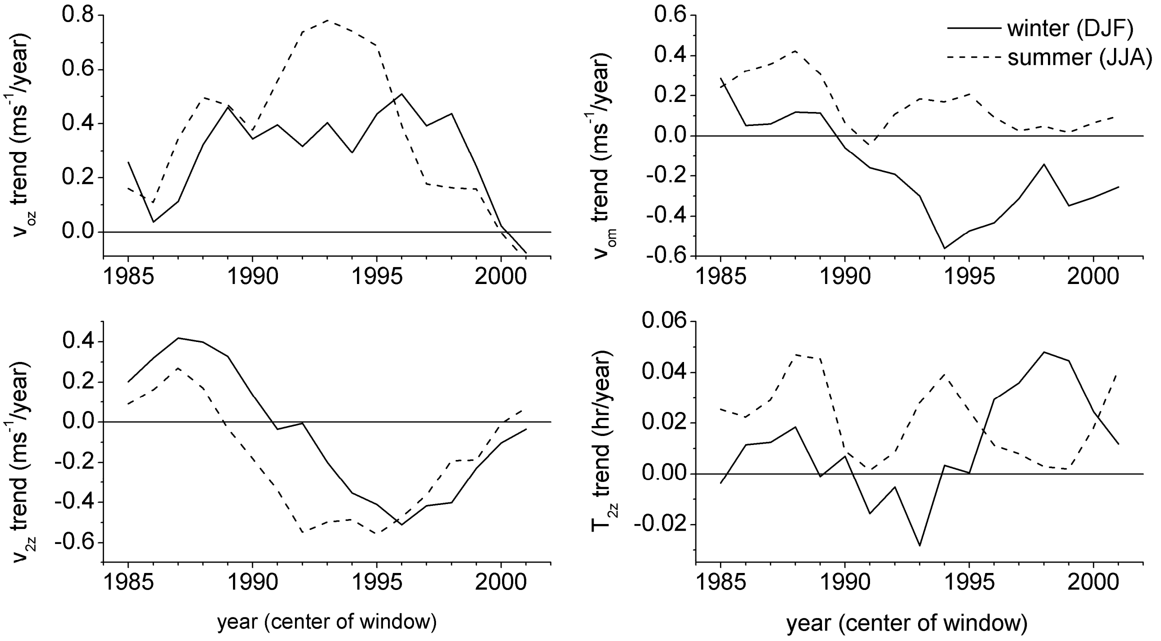

*Figure 3:* Linear trends for winter (DJF) and summer (JJA) mean Collm wind parameters from *Figure 2*, calculated using 13-year running windows centered at the respective years.

Generally, there is an increase of the zonal prevailing wind, a decrease of the meridional wind, which means a positive trend in summer (negative northerly winds) and a negative trend in winter (southerly or weak winds). The trends are not linear, as is shown in Figure 3. The strongest trends are visible in the early 1990s, while before and after that time trends are weak, and, during recent years, even seem to reverse. The meridional winds have decreased, but Figure 3 shows that this decrease changes as well. In particular the summer trend weakens. The semidiurnal tidal amplitudes show a complicated behavior, there are large values in the early 1990s, possibly connected with the 11-year solar cycle. There is an overall tendency for the amplitudes to decrease with time, but no trend is visibly during the last decade. The tidal phases have increased, but the trend is intermittent, and the year-to-year variability is large.

To conclude, the long-term wind and reflection height time series show trends during the last 3 decades, but there seem to be changes of these trends after the 1990s. This is clearly visible in the prevailing winds, and also in temperatures. It is generally thought that middle atmosphere climate change is responsible for at least part of the lower E region changes. This means, that in addition to the continuing $CO_2$ cooling other influences act on the upper middle atmosphere. One candidate is ozone, which has decreased strongly since the 1980s, but had remained at a constant level or even recovered after the mid 1990s.

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