

# Long-term trends in ozone laminae and stratospheric dynamics at middle latitudes in relation to upper atmosphere trends

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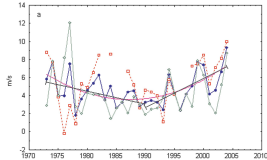
**Abstract.** Laminae in ozone profiles at northern middle latitudes display a principal change in long-term trends in the mid-1990s like the total ozone does; laminae are no more reduced. This change is believed to be of predominantly dynamical origin. We present behaviour of trends of laminae of different thickness. This is compared with intensity and direction of stratospheric winds at 100 and 10 hPa level. Another comparison is done with mesospheric winds, which in the MLT region display a change of trend earlier, around 1990, as it is supported also by change of trend in ionospheric parameter foE (critical frequency corresponding to maximum electron density of the E layer, heights around 105-110 km).

## Data

Ozone laminae derived from European ozone sonde ozone profiles from Toronto database: <http://www.msc-smc.eo.gc.ca/woudc>.  
Velocity and direction of stratospheric winds from ERA-40, 1960-2002.  
Mesopause region winds as measured at Collm (Germany) and Obninsk near Moscow (Russia).  
Ionospheric parameters measured by ionondes at Juliusruh and Slough/Chilton from RAL database: [http://www.ukssdc.ac.uk/wdc1/wdc\\_menu.htm](http://www.ukssdc.ac.uk/wdc1/wdc_menu.htm)

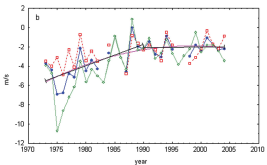
Observations at Scott Base, Antarctica reveal a positive trend since the late 1980s (Baumgaertner et al., 2005).  
Semidiurnal tide time series show that the negative trend seems to cease after the mid 1980s (Portnyagin et al., 2006), or may even reverse.  
Jarvis (2005) used Northern Hemisphere magnetometer measurements to analyse the changes since the early 20th century. He found a decrease of tidal amplitudes at mid-latitudes and a tendency for smaller/reversed changes at the end of the century.  
The total ozone and ozone laminae trend patterns indicate a corresponding change in the sign of trends in the mid-1990s, its origin being mainly changes in trends in dynamics, maybe in NAO (e.g., Križan and Laštovička, 2006).

? Did trends in dynamics change in the 1990s in the whole middle atmosphere?

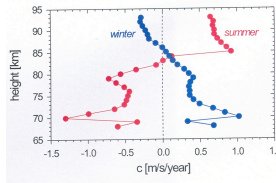


MLT annual mean prevailing zonal winds over Obninsk (55N, 37E) and Collm (52N, 15E), red: Obninsk, green: Collm, blue: mean values. **Change of trend in early 1990s.** (Laštovička et al., 2008, Ann. Geophysicae, 1255-1268).

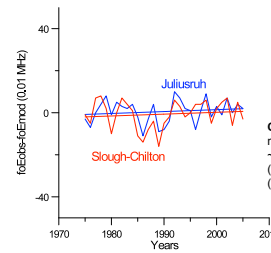
## Winds in mesopause region (~90-95 km)



MLT annual mean prevailing meridional winds over Obninsk (55N, 37E) and Collm (52N, 15E), red: Obninsk, green: Collm, blue: mean values. **Change of trend around 1990.** (Laštovička et al., 2008, Ann. Geophysicae, 1255-1268).



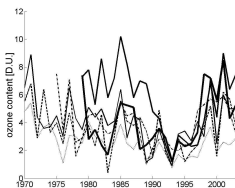
Keuer et al. (2007, Ann. Geophysicae, 1779-1790) – MF radar winds, Juliusruh (northernmost Germany), 65-95 km, 1990-2005: Trends in winds are both positive and negative depending on height and season. The semidiurnal tidal amplitude displays a general positive trend, which means change of trend compared to the 1970s and 1980s.



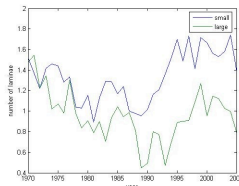
## E-region ionosphere

Change of trend in foE (equivalent to maximum electron density in E-region, ~105-110 km) around 1990 for Juliusruh (northernmost Germany) and Chilton (England) for yearly median values.

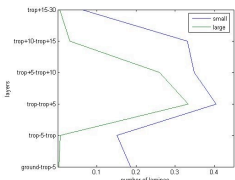
## Trends in Laminae in Ozone Profiles over Europe



The overall ozone content in large positive laminae per profile for European middle latitude stations Hohenpeissenberg (dotted line), Legionovo (heavy full line), Lindenberg (dashed-dotted line), Prague (medium full line), Payerne (thin full line) and Uccle (dashed line), 1970-2003 (Križan and Laštovička, 2005, JGR, D10107). **Change of trend in the mid-1990s.**



Trends in the number of laminae per profile for large (> 40 nbar) and small (< 20 nbar) positive laminae over Europe, middle latitudes. **Change in trends for small laminae around 1990, for large laminae either around 1990, or a few years later.**



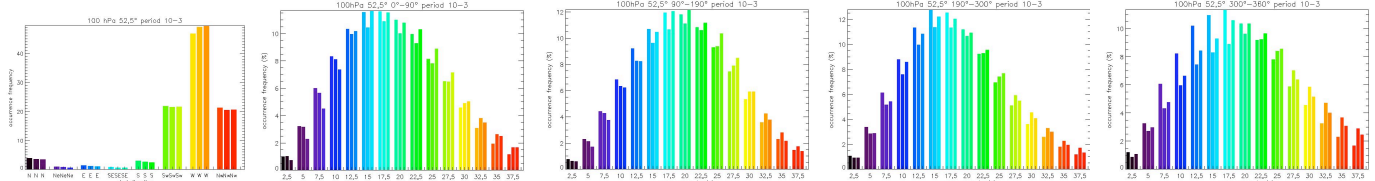
Height distribution of the number of laminae per profile for large (> 40 nbar) and small (< 20 nbar) positive laminae.

## Concluding remarks

1. Horizontal as well as meridional prevailing winds in the mesopause region at northern higher midlatitudes display a change of trend around 1990. A similar change is observed in the European sector in the E-region ionosphere in foE and in number of weak ozone laminae.
2. The total ozone (not shown here) and the overall ozone content in laminae per profile change trends in the mid-1990s, apparently in relation to change of trend in the NAO (not shown here).
3. Number of large laminae in the European sector changes trends in the first half of 1990s.
4. Stratospheric winds at 100 and 10 hPa at 52.5°N display a clear (at least for 100 hPa) tendency to weaker winds before 1980, to stronger winds in 1980-1994 in the period of total ozone reduction, and to medium winds in 1995-2002 in the period of somewhat increasing total ozone at northern midlatitudes.
5. The above changes of trends observed between about 1990-1995 are very probably not caused by the increasing greenhouse concentration; e.g. they are not observed in trends in the height of maximum of the E region, hmE (not shown here). These changes of trends are probably of rather unclear dynamical origin.

## Trends in Stratospheric Wind Velocity and Direction

All data are divided into three columns: 1960-1979 (left), 1980-1994 (middle), 1995-2004 (right), latitude 52.5°N.



Average wind direction - no evident trend.

Wind velocity at 100 hPa reveals evident long-term change – the period 1960-1979 dominates in low velocities, medium velocities are dominated by the period 1995-2002, while the period of rapid decrease of total ozone and the overall ozone content in laminae, 1980-1994, dominates in high velocities. This change is expressed by far best for the Atlantic sector, 300-360°E.

All data for winter half of the year (October-March). Sector 0-90°E

Sector 90-190°E

Sector 190-300°E

Sector 300-360°E

Wind velocity at 10 hPa reveals a similar but less expressed and less regular tendency to long-term change. This change is again developed best for the Atlantic sector, 300-360°E.

