The Lower Arctic Stratosphere in Winter since 1952: an Update

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Four years ago we published a table with monthly mean temperatures (°C) at 30 hPa over the North Pole ([Labitzke and Naujokat, 2000], hereafter LN). These data started with the winter 1955/56, *i.e.* 45 winters were available. One point of interest in the paper was the fact that there was a period of 7 winters without Major Warmings: Northern Hemisphere winter 1991/92 to 1997/1998. We pointed out that during low solar activity the winters in the west phase of the Quasi-Biennial Oscillation (QBO) tended to be cold and stable (Labitzke and van Loon, 2000) and this combination existed during 4 out of the 7 winters.

Here, we would like to give a follow up on the North Pole temperatures and on the characteristics of the last four Arctic winters by supplementing **Table 1** of LN. After the extremely cold winter of 1999/2000 (LN), we observed four highly disturbed winters with a total of five Major Warmings (Table 1). Two of the recent winters belong to the winters in the west phase of the QBO and high solar activity, and they are expected to be connected with Major Warmings.

Particularly interesting was the winter of 2001/2002 when two Major Warmings occurred in December and in February (Naujokat *et al*., 2000). This has been observed only once before, during the winter of 1998/99.

Compared with our earlier results (Table 1 in LN) the overall trend has not changed much during early and mid-winter. The trend over the Arctic lower stratosphere is clearly negative in November and practically zero from December till February.

Major Midwinter Warmings are connected with the breakdown of the polar vortex, much reduced activity of planetary waves, and weak transport of energy. This leads often in late winter to the re-establishment of a persistent cold polar vortex and to the so-called late winter cooling, which is clearly visible in the Arctic temperatures during March and April, especially in the 2003/04 winter

MONTHLY MEAN 30 hPa NORTH POLE TEMPERATURES (°C)

YEAR	*RJ*	*Nov*	*Dec*	*Jan*	*QBO*	*Feb*	*Mar*	*Apr*	*FW*
2000/01	95	-65CW	-70	-79C	w/e	-50*	-57	-58C	Late
2001/02	114	-73C	-71*	-59	east	-57*	-62C	-55C	Late
2002/03	80	-77C	-80C	-65*	west	-64	-57	-50	Late
2003/04	37	-75C	-72	-53*	east	-62	-71C	-63C	Late
(T) n=49		-69.8	-74.0	-71.5		-65.5	-57.8	-48.1	
sigma		3.8	61	9.0		9.8	7.8	5.7	
Trend	K/dec	-1.2	-0.1	-0.2		-0.0	-0.4	-0.7	
Conf.	%	99	13	18		3	41	80	
C		≤-70	≤-77	≤-75		≤-70	≤-60	≤-51	

Table 1. ***RJ*** *is the monthly mean of the sunspot numbers in January; in the column marked* ***QBO*** *the phase of the QBO is given (determined using the equatorial winds between 50 and 40 hPa in January-February);* ***FW*** *gives an indication of the timing of the Final Warmings which are the transitions from the winter to the summer circulation.* ***CW*** *stands for Canadian Warmings and * indicates the occurrence of a Major Mid-Winter Warming. The long-term mean and the standard deviation are based on the period 1955/56 to 2003/04. The values of the linear trend are for the full data set, n=49 years.* ***C*** *stands for a cold monthly mean (about half a standard deviation or more below the long term average; see discussion in LN). [Data: Free University Berlin (FUB) until 2000/01, ECMWF afterwards]*

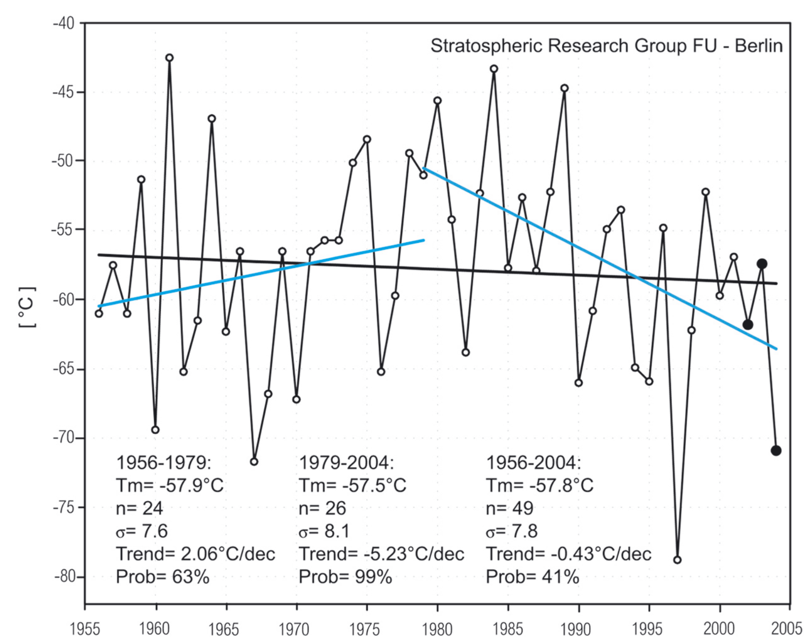

Figure 1. Time series of the monthly mean temperatures (°C) at 30 hPa over the North Pole in March, 1956 to 2004. Linear trends are given for three different periods: 1956-1979, 1979-2004 and 1956-2004 (Labitzke and van Loon, 1999, updated). Data: Free University Berlin (FUB) (open dots), ECMXF (full dots).

(Table 1). In all four winters the Final Warmings were late.

Figure 1 shows the time series of the 30 hPa North Pole temperatures (ºC) for March, an update of Figure 1 in LN. The overall trend for 49 years is weakly negative, but depending on how one divides the data, the trend can be positive, as in the first half of the data set or negative, as in the second half of the data. The change in the sign of the trend between the two different periods is, however, confirmed by the re-analyses of NCEP/NCAR and by the ECMWF-ERA-40 data (Labitzke and Kunze, submitted).

Acknowledgements

FU-Berlin: **http://strat-www.met.fu-berlin.de/products/cdrom**
NCEP/NCAR: **http://wesley.wwb.noaa.gov/reanalysis.html**
ERA40: **http://www.ecmwf.int/research/era**

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The Earth's Protective Ozone Layer still Remains Vulnerable

Report on the Quadrennial Symposium on Atmospheric Ozone, Kos, Greece, 1-8 June 2004

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The XX Quadrennial Symposium on Atmospheric Ozone coincided with the 20th anniversary of the discovery of the springtime Antarctic ozone hole. It also marked two decades of intensified global atmospheric monitoring, and basic research in atmospheric chemistry and physics. The progress in our understanding of the impact of human activities on the chemistry and physics of the global stratosphere since the previous Quadrennial Ozone Symposium was presented among the 690 research papers at the XX Quadrennial Ozone Symposium, which was attended by 450 scientists from 60 countries. For the papers presented and the proceedings of the Symposium see **http://www.QOS2004.gr**.

Among the important topics discussed at the Symposium were recent research on possible ozone recovery, results from an expanded network of satellites and ground-based stations, ozone-climate interactions, modelling and chemistry, results from monitoring of the global composition of the troposphere from satellites, and measurements of UV-B solar radiation reaching ground level, among others.

Evidence was presented that ozone in the past few years has been a little higher than expected from earlier projections based on sensitivity of ozone to influences of aerosols, halogen compounds and the solar cycle. The data may indicate the beginning of a recovery; an issue that is complicated by a number of factors among which is the prominent role played by changes in meteorology, greenhouse gases and in the radiation balance, not excluding the observed recovery of the ozone layer from its perturbation by the volcanic eruption of Pinatubo in the early 90s. The evaluation of future ozone recovery in a changing climate and the effect of ozone on that climate has shown the importance of feedback mechanisms between water vapour content and a warmer planet.

The need for the continuation of well-calibrated instruments and measurements was discussed extensively, and emphasis was given to the use of satellite and ground-based data (*e.g.* NDSC and the Global Ozone Observing System) to evaluate models and ozone loss, and its expected recovery.

Numerous chemistry/climate models were presented at the conference. They addressed the problem of how changes in meteorology or climate interact with changes in the chemistry of ozone. One problem is how changes in meteorology over the last 25 years may have contributed to observed ozone changes and feedback mechanisms. Models can then be used to extrapolate that knowledge to what may happen in the future with the expected increase in methane, nitrous oxide, and carbon dioxide.

Significant new work that combines satellite and *in situ* observations with model calculations was presented at the Symposium, providing an insight into the budget of nitrogen oxides and a range of halogen species, which are indispensable to our understanding of the global carbon and hydrological cycles. Water vapour presents a particularly important challenge. Satellite data shown at the meeting is not consistent with trends from previous ground-based data. Understanding the feedback mechanism between water vapour content, ozone, and polar stratospheric clouds is critical to the evaluation of predictions of ozone in a future warmer global atmosphere.

Important progress was made in monitoring the tropospheric ozone budget with the development of new observational techniques from satellites, combined with models of tropospheric composition. It turns out that the key factors influencing the tropospheric ozone budget (precursors, long-range transport in the troposphere and intrusions from the stratosphere) make the determination and attribution of tropospheric ozone trends difficult.

Long-range transport of tropospheric pollution and its coupling to climate was targeted in a number of studies using climate/chemistry models. Other studies have shown the importance of long-