Supplement of Atmos. Chem. Phys., 16, 101–121, 2016
http://www.atmos-chem-phys.net/16/101/2016/
doi:10.5194/acp-16-101-2016-supplement

Supplement of

Sensitivity of polar stratospheric cloud formation to changes in water vapour and temperature

F. Khosrawi et al.

Correspondence to: F. Khosrawi (farahnaz.khosrawi@kit.edu)

Result of the trajectory ensemble statistic for T_{NAT}:

Table 1: Total time where the temperature along the back trajectory is below the NAT existence threshold temperature (sum over all 738 back trajectories) for a stratospheric H_2O mixing ratios of 4.75, 5.0, 5.25, 5.5 and 6.0 ppmv. The calculation was performed assuming an HNO_3 mixing ratio of 3, 5 and 7 ppbv. Note: The total trajectory ensemble time is 107 010 h (738 trajectories × 145 h)

		T	T−0.5	T−1
HNO_3 (ppbv)	H_2O (ppmv)	$T<T_{NAT}$ (h)	$T<T_{NAT}$ (h)	$T<T_{NAT}$ (h)
3	4.75	32960	36776	40584
3	5	34486	38301	42171
3	5.25	36024	39782	43779
3	5.5	37476	41310	45210
3	5.75	38802	42709	46533
3	6	40128	44080	47869
5	4.75	38275	42133	45951
5	5	39824	43810	47568
5	5.25	41430	45319	49051
5	5.5	42893	46711	50560
5	5.75	44331	48126	51994
5	6	45667	49460	53447
7	4.75	41849	45746	49513
7	5	43512	47312	51179
7	5.25	45062	48811	52750
7	5.5	46463	50298	54262
7	5.75	47870	51735	55580
7	6	49196	53180	56787

Table 2: Increase in time where the temperature along the back trajectory is below the threshold temperature (sum over all 738 back trajectories) for a stratospheric H_2O increase of 0.25, 0.5, 0.75 and 1.0 ppmv, respectively, and for a stratospheric H_2O decrease of 0.25 ppmv. The calculation was performed assuming an HNO_3 mixing ratio of 3, 5 and 7 ppbv.

		T	T−0.5	T−1
HNO_3 (ppbv)	H_2O increase (ppmv)	Δt for $T<T_{NAT}$ (h)	Δt for $T<T_{NAT}$ (h)	Δt for $T<T_{NAT}$ (h)
3	-0.25	-1526	2290	6098
3	0.25	1538	5296	9293
3	0.5	2990	6824	10727
3	0.75	4136	8223	12047
3	1.0	5642	9594	13383
5	-0.25	-1459	2309	6127
5	0.25	1606	5495	9227
5	0.5	3069	6887	10736
5	0.75	4507	8302	12170
5	1.0	5843	9326	13623
7	-0.25	-1663	2234	6001
7	0.25	1550	5299	9238
7	0.5	2951	6786	10750
7	0.75	4358	8223	12068
7	1.0	5684	9668	13275

Result of the trajectory ensemble statistic for T_{ice}:

Table 3: Total time where the temperature along the back trajectory is below the ice formation threshold temperature (sum over all 738 back trajectories) for a stratospheric H_2O increase of 4.75, 5.0, 5.25, 5.5, 5.75 and 6.0 ppmv. Note: The total trajectory ensemble time is 107 010 h (738 trajectories × 145 h).

	T	T−0.5	T−1
H_2O (ppmv)	$T<T_{ice}$ (h)	$T<T_{ice}$ (h)	$T<T_{ice}$ (h)
4.75	340	771	1530
5	571	1159	2152
5.25	870	1685	3030
5.5	1240	2286	4270
5.75	1738	3133	5523
6	2299	4296	6789

Table 4: Increase in time where the temperature along the back trajectory is below the ice formation threshold temperature (sum over all 738 back trajectories) for a stratospheric H_2O increase of 0.25, 0.5, 0.75 and 1.0 ppmv, respectively, and for a stratospheric H_2O decrease of 0.25 ppmv.

	T	T−0.5	T−1
H_2O increase (ppmv)	Δt for $T<T_{ice}$ (h)	Δt for $T<T_{ice}$ (h)	Δt for $T<T_{ice}$ (h)
-0.25	-231	200	959
0.25	299	1114	2459
0.5	669	1715	3699
0.75	1167	2562	4952
1	1728	3725	6218

Correlation of water vapour and temperature (525-825 K): Correlations of temperature and water vapour anomalies were derived for different time scales (all seasons, specific season, single months). The time series are based on data within 70° and 90°N equivalent latitude. A large majority of these calculations indicate an anti-correlation between these two parameters in the altitude range between 475 and 525 K (see main paper). The correlations are strong in winter and very weak in summer. The figures below show some examples for different data sets for the potential temperature range 525-825 K: (top) T, H2O: Envisat/MIPAS and (bottom) T, H2O: Aura/MLS (Figure 1). The data are averaged over the months January, February and March. The derivation of the anomalies considers the entire time series. The correlation is not as strong as at 475-525 K, but still negative. The weak correlation in the Envisat/MIPAS data is caused by a positive correlation at the begin of the time period considered.

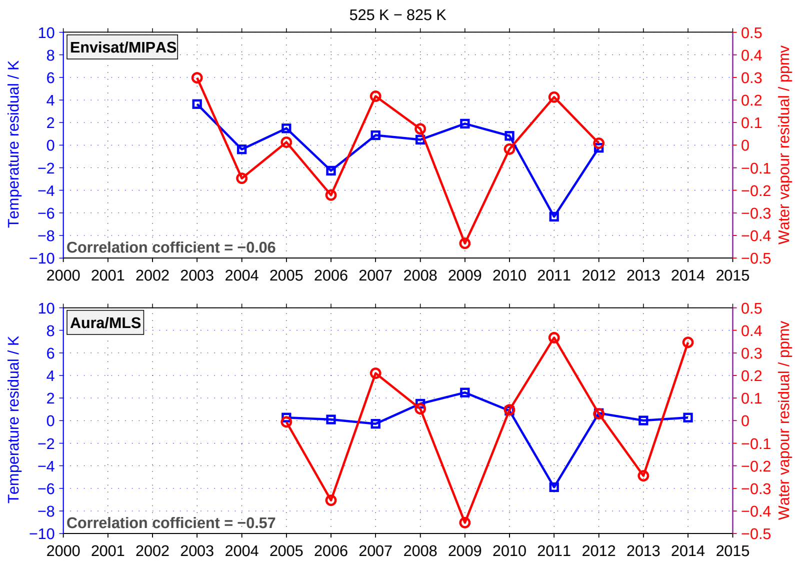

Figure 1: Correlation of temperature (blue) and water vapour (red) anomaly derived from Envisat/MIPAS (top) and Aura/MLS (bottom) for the potential temperature range 525-825 K (3-month average consisting of the months January, February and March; MIPAS: 2002-2012, MLS: 2005-2014).

Linear trend analyses for Winter (DJF):
Linear changes in water vapour are investigated by performing seperately a regression analyses of the Envisat/MIPAS (2002–2012) and the Aura/MLS (2004–2014) time series. From these we derive predominantly positive changes in the altitude range between 350 K to 1000 K potential temperature. The linear changes from Envisat/MIPAS observations are largely insignificant, while those from Aura/MLS are mostly significant. For the temperature neither of the two instruments indicate any significant changes. Considering the linear trend analyses for solely the winter months (DJF) does not change our results (Figure 2). The resulting areas where the changes are positive and significant within the 2σ uncertainty are quite similar to the changes we found when all seasons are considered.

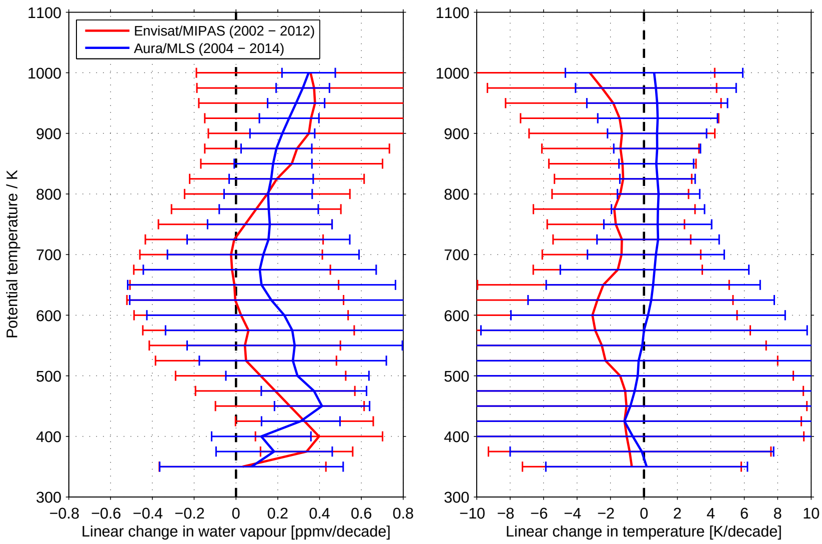

Figure 2: Linear change in water vapour (left) and temperature (right) vs. potential temperature derived from Envisat/MIPAS (2002–2012) and Aura/MLS (2004–2014) for winter (DJF). For the linear change in water vapour derived from Envisat/MIPAS an offset of 0.1 ppmv between the two measurement periods has been considered. As error bars the 2σ uncertainty is given.

Air parcel trajectories:

Air parcel trajectories were calculated 6-days backward at dates and times when PSCs were measured by CALIPSO during the Arctic winter 2010/2011. The trajectories were calculated at three different altitudes, corresponding to the bottom, middle and top of the cloud. The following figures show the back trajectories for case 1 and case 2 (started on 26 February 2011 00:00 UTC and 23 January 2011 20:00 UTC).

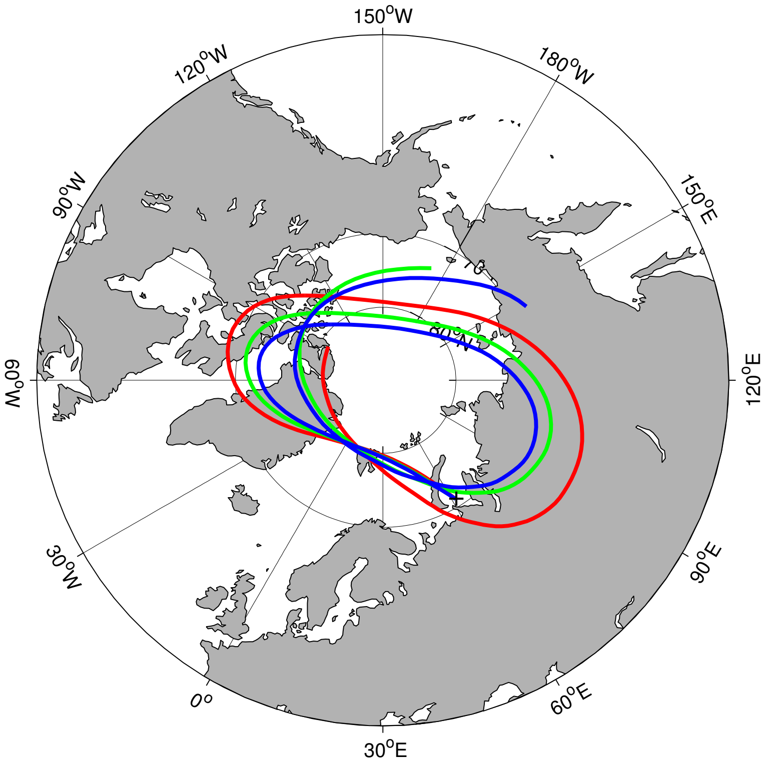

Figure 3: Trajectories calculated 6-days backward with HYSPLIT based on the CALIPSO measurement on 26 February 2011 (76°N, 61°E). The trajectories were started at 00:00 UTC at three different altitudes, 20 km (red), 22 km (green) and 24 km (blue).

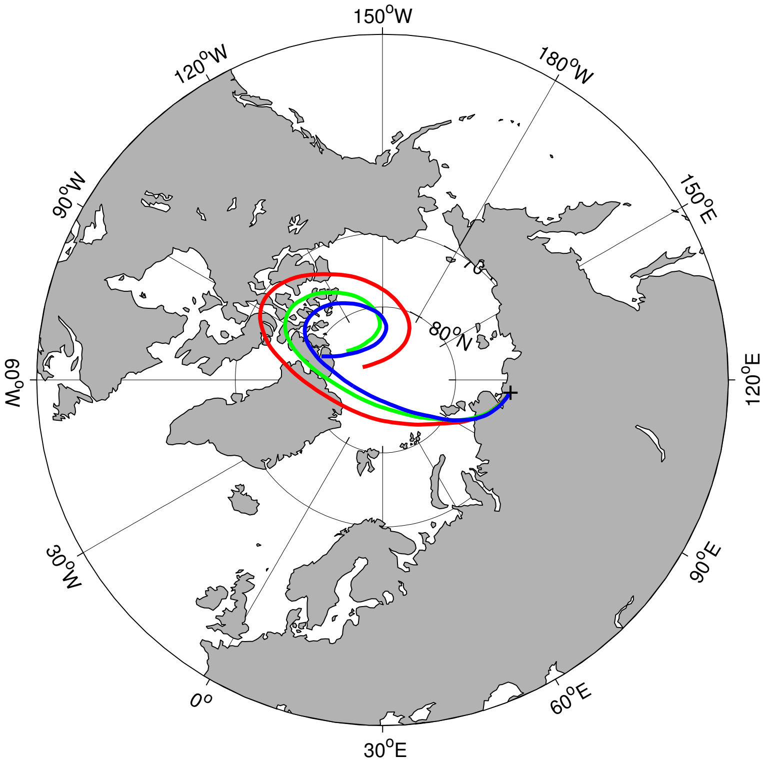

Figure 4: Trajectories calculated 6-days backward with HYSPLIT based on the CALIPSO measurement on 23 January 2011 (72°N, 113°E). The trajectories were started at 20:00 UTC at three different altitudes, 18 km (red), 20 km (green) and 22 km (blue).