On the Connection Between Stratospheric Water Vapour Changes and Widespread Severe Denitrification in the Arctic

F. Khosrawi[1], J. Urban[2], S. Lossow[3], K. Weigel[4], G. Stiller[3], D. Murtagh[2]

[1]MISU, Stockholm University, Stockholm, Sweden
[2]Department Earth and Space Science, Chalmers University of Technology, Gothenburg, Sweden
[3]IMK, Karlsruhe Institute of Technology, Karlsruhe, Germany
[4] IUP, University Bremen, Germany

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Motivation

- Severe denitrification observed in the two recent Arctic winters 2009/2010 and 2010/2011
- Formation of an Arctic "ozone hole" in 2010/2011

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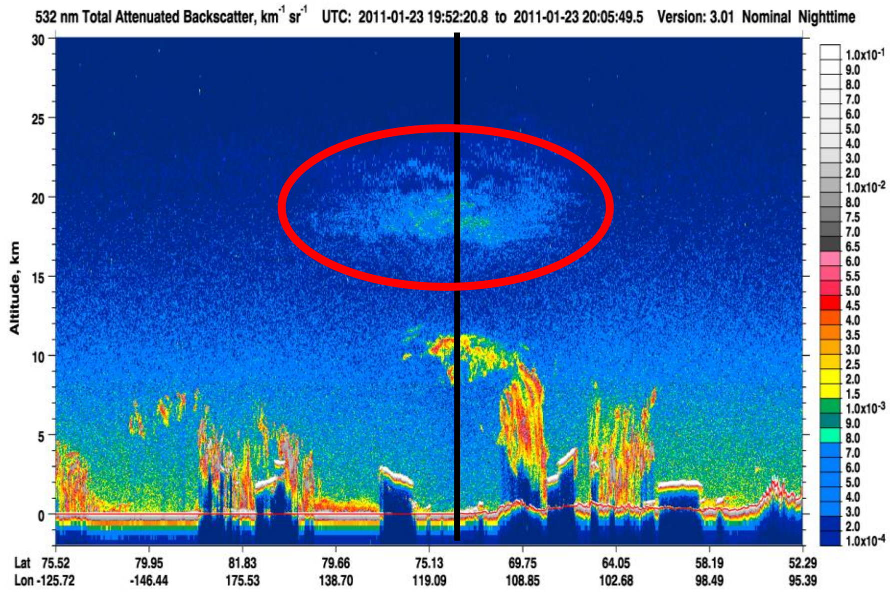
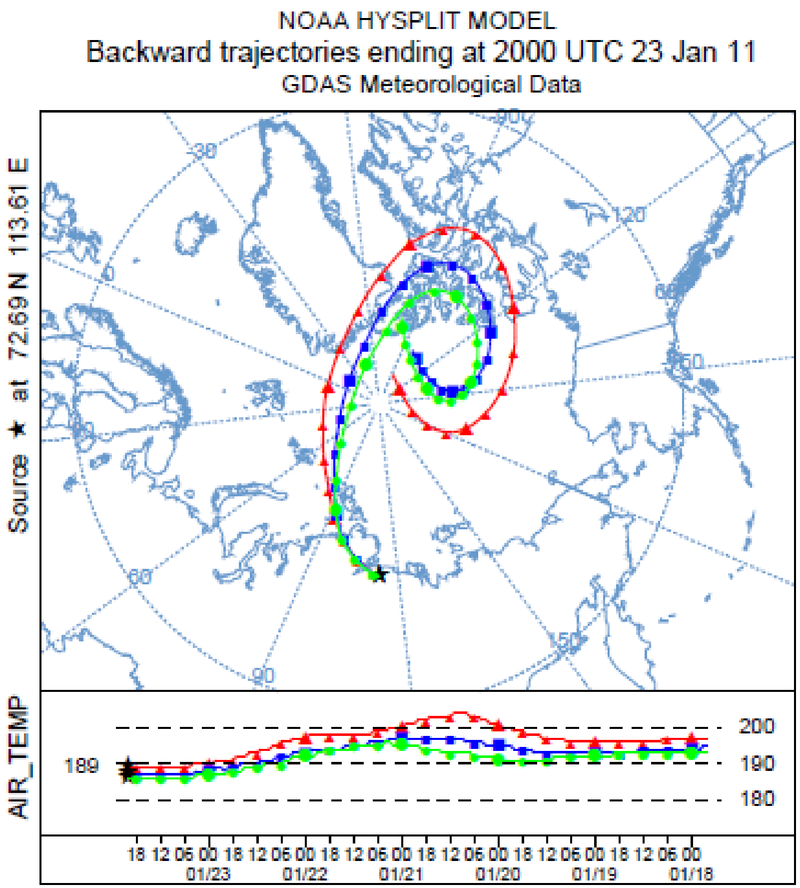
→ repeat of this likely or was this just an exceptional Arctic winter?

Does a 1 ppmv increase in water vapour or a cooling of 1 K matter?

CALIPSO PSC on 23 January 2011





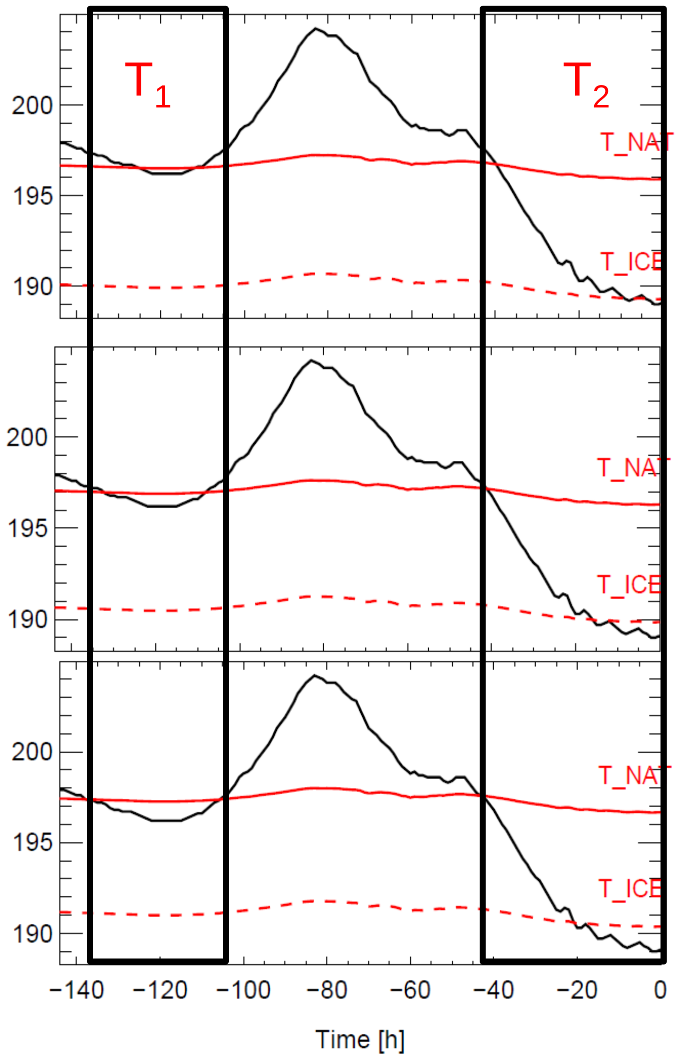
Trajectories calculated 6 days backward at 20 UTC at 18, 20, 22 km

Sensitivity to H_2O increases

5 ppmv

5.5 ppmv

6 ppmv



$T_2 < T_{NAT}$ Δt=40

$T_1 < T_{NAT}$ Δt=41
$T_2 < T_{NAT}$ Δt=25

$T_2 < T_{ice}$ Δt=15

$T_1 < T_{NAT}$ Δt=44
$T_2 < T_{NAT}$ Δt=30

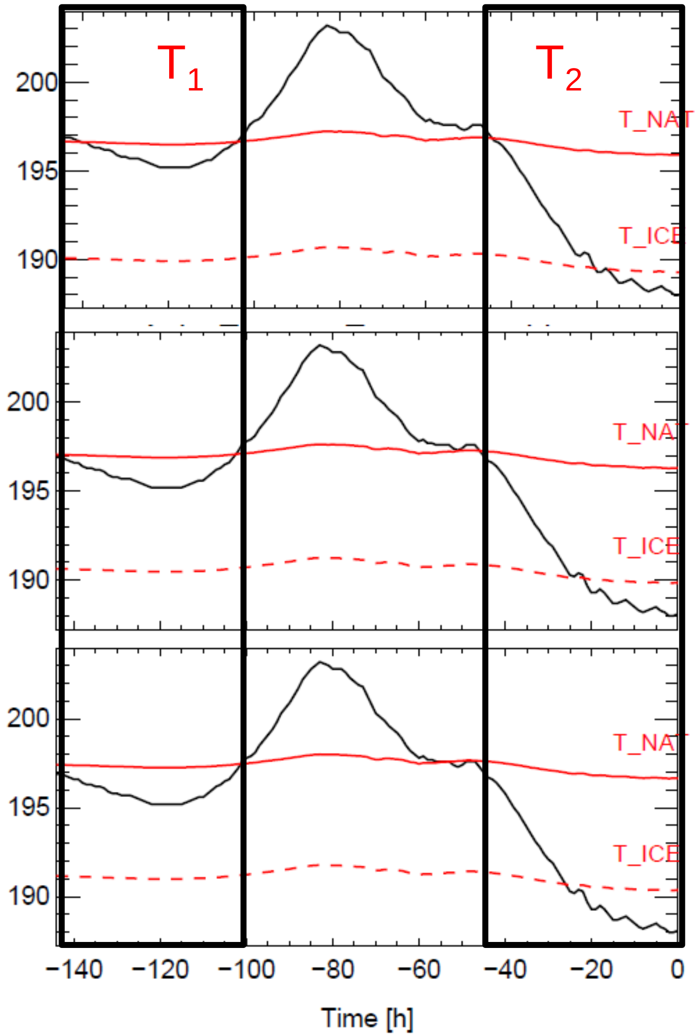
$T_2 < T_{ice}$ Δt=20

Sensitivity to H_2O and T changes

5 ppmv
T-1K

5.5 ppmv
T-1K

6 ppmv
T-1K



$T_1 < T_{NAT}$ Δt=45
$T_2 < T_{NAT}$ Δt=35

$T_2 < T_{ice}$ Δt=20

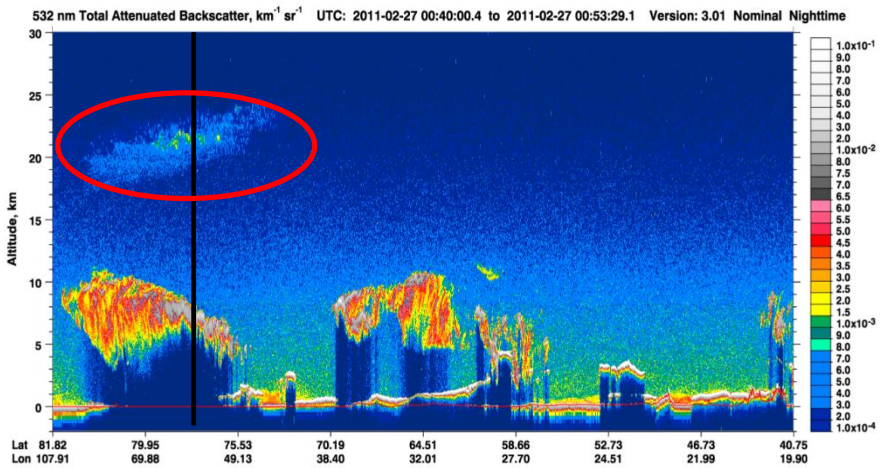
$T_1 < T_{NAT}$ Δt=45
$T_2 < T_{NAT}$ Δt=42

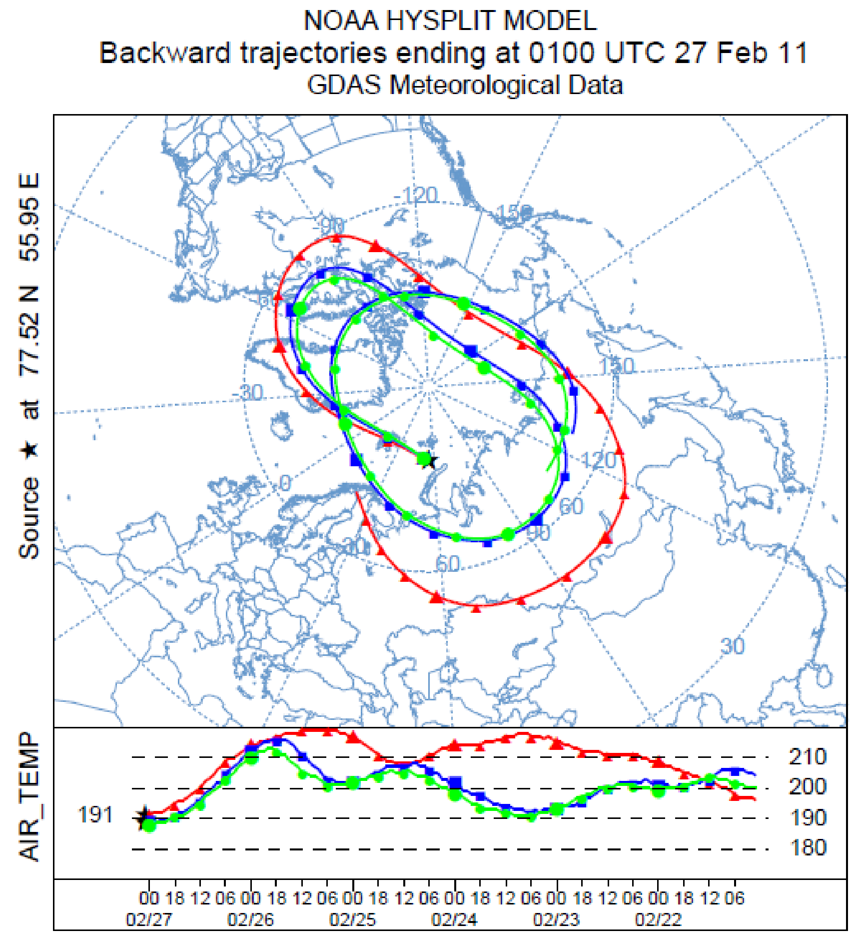
$T_2 < T_{ice}$ Δt=22

$T_1 < T_{NAT}$ Δt>45
$T_2 < T_{NAT}$ Δt=47

$T_2 < T_{ice}$ Δt=25

CALIPSO PSC on 27 February 2011





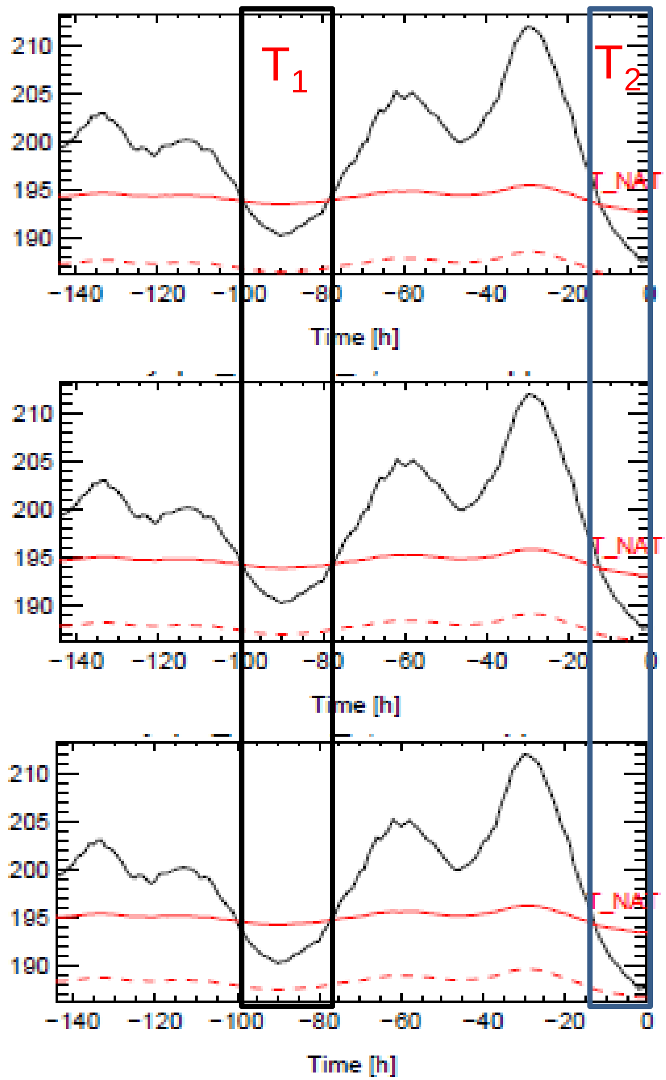
Trajectories calculated 6 days backward at 01 UTC at 19, 21, 22 km

Sensitivity to H_2O and T changes

5 ppmv
T-1K

5.5 ppmv
T-1K

6 ppmv
T-1K



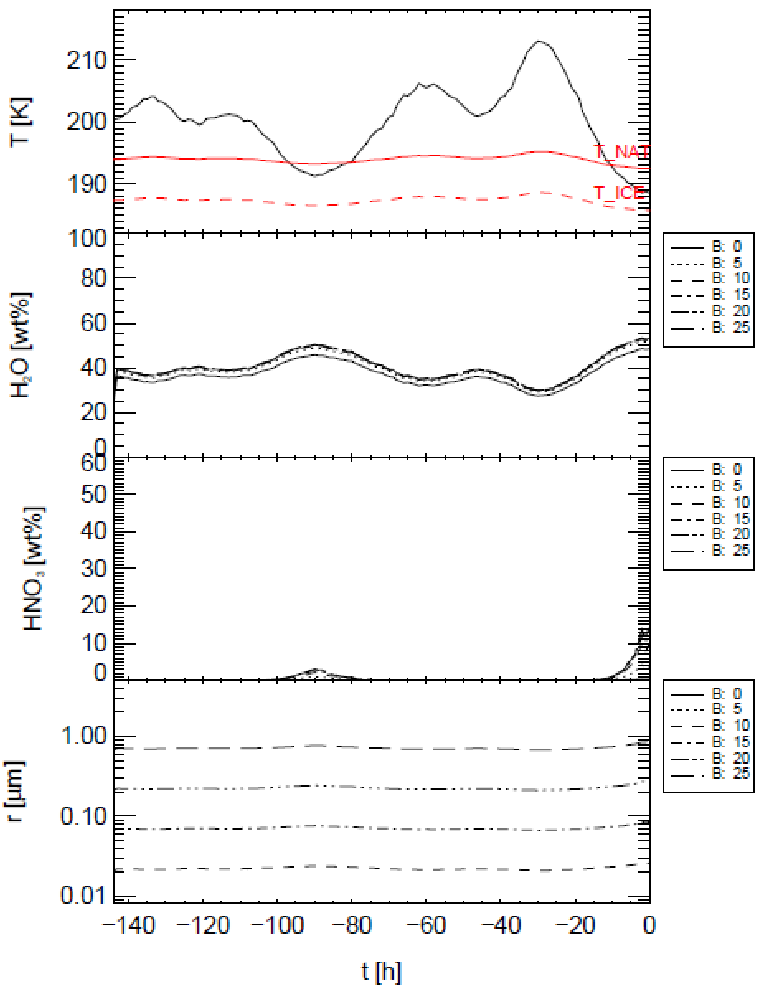
$T_1 < T_{NAT}$ Δt=21
$T_2 < T_{NAT}$ Δt=12

$T_1 < T_{NAT}$ Δt=22
$T_2 < T_{NAT}$ Δt=12

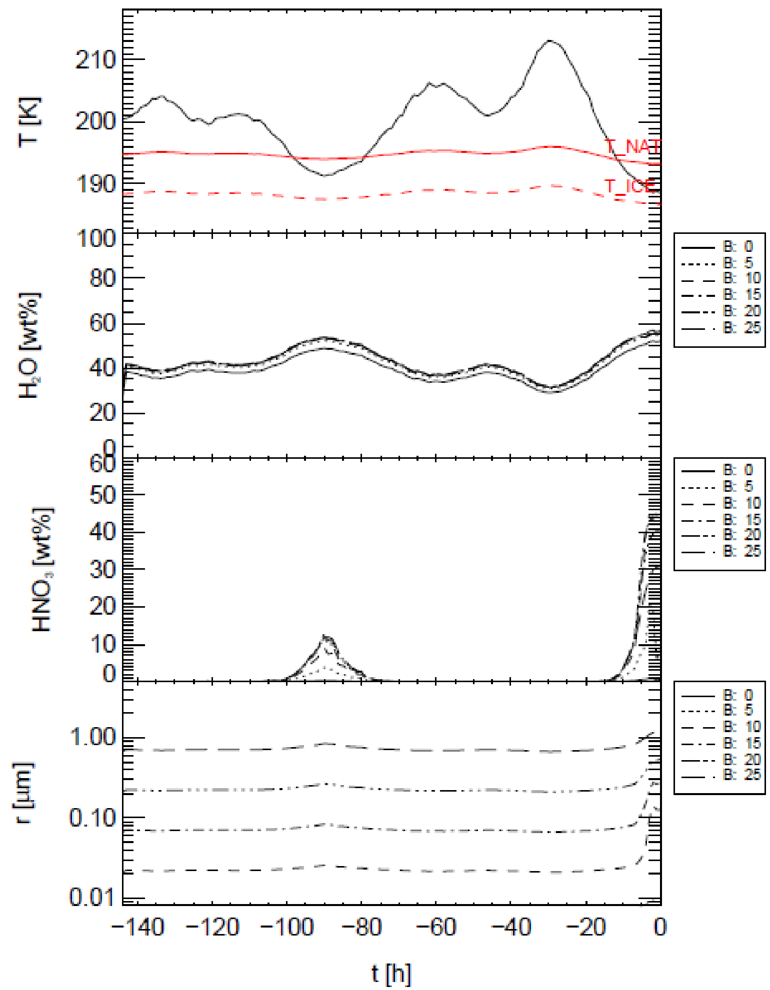
$T_1 < T_{NAT}$ Δt=23
$T_2 < T_{NAT}$ Δt=12

Box Model Simulation (STS)

H_2O=5ppmv



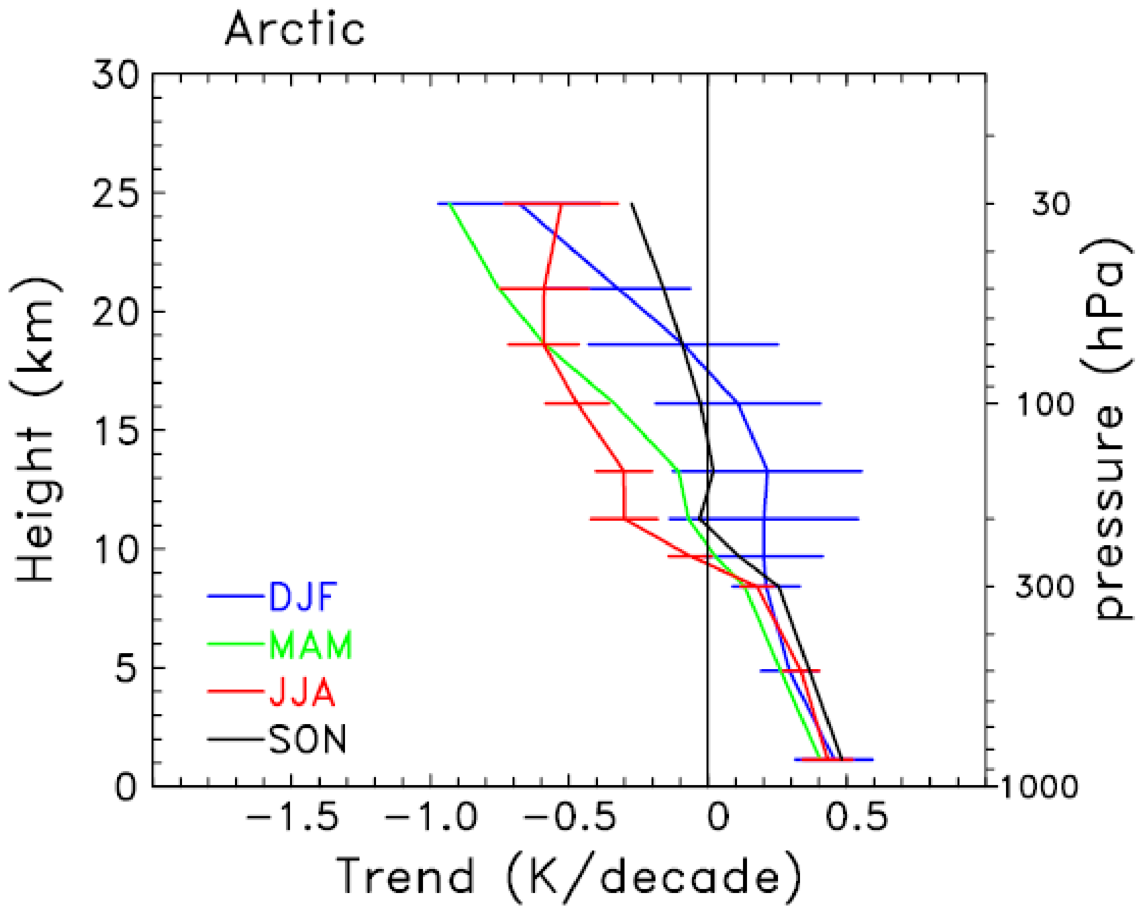
H_2O=6ppmv, T-1K



Is there an H_2O trend or cooling observed in the polar stratosphere?

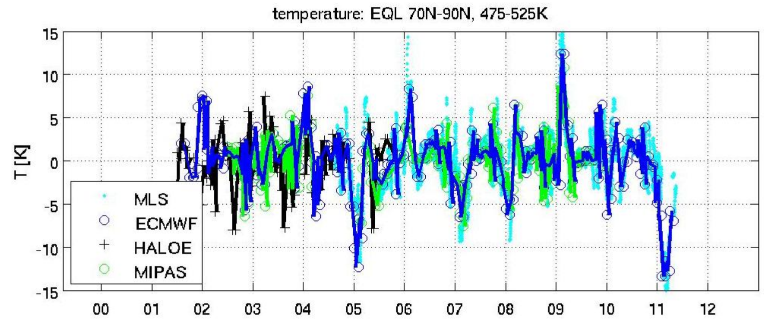
Stratospheric Temperature Trend (1997-2007)

Randel et al., JGR, 2009



H_2O and Temperature Anomalies (2001-2011)

T 475-525 K
(18-22 km)



HALOE
Odin 488.9 GHz
MLS
MIPAS
ACE

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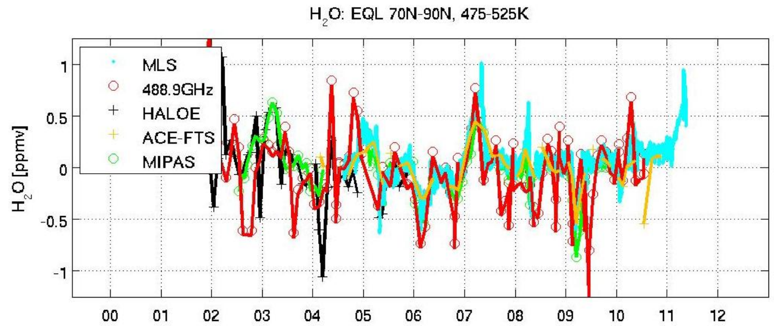
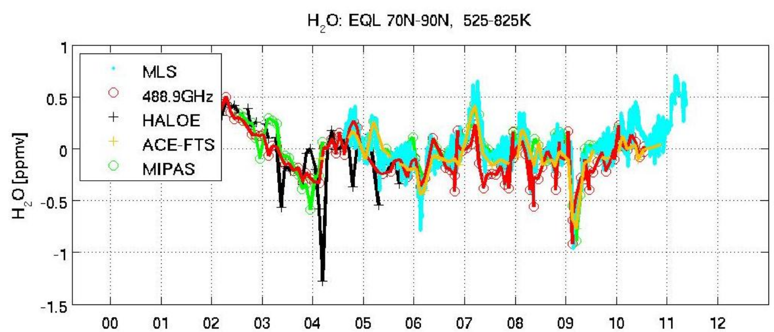


H_2O 525-825 K
(22-28 km)



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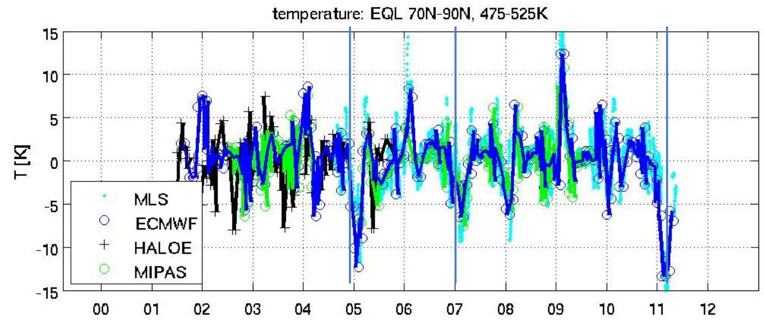

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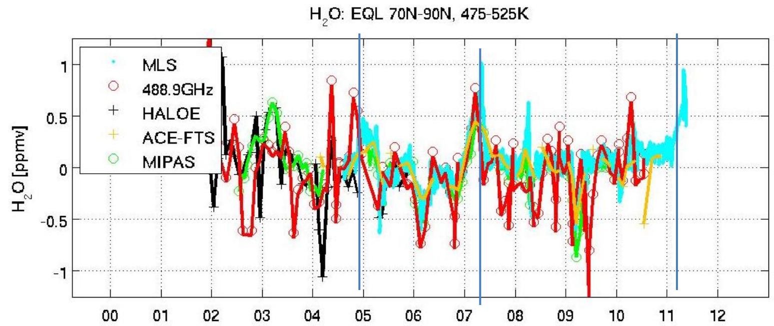

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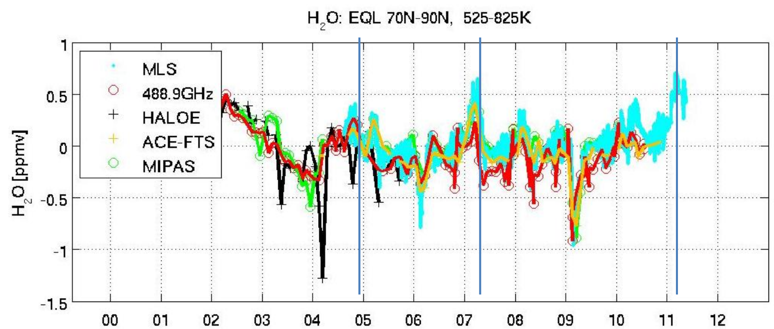


What caused the severe denitrification in 2010/2011?

Is there a connection to stratospheric water vapour increases?

Possible Causes for Strong Denitrification

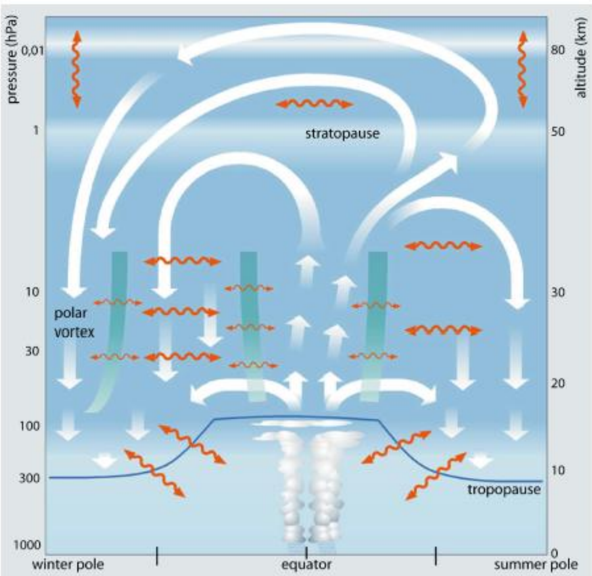
Possible causes for the strong denitrification in 2009/2010 and 2010/2011 are:

- H_2O trend and cooling in the polar regions

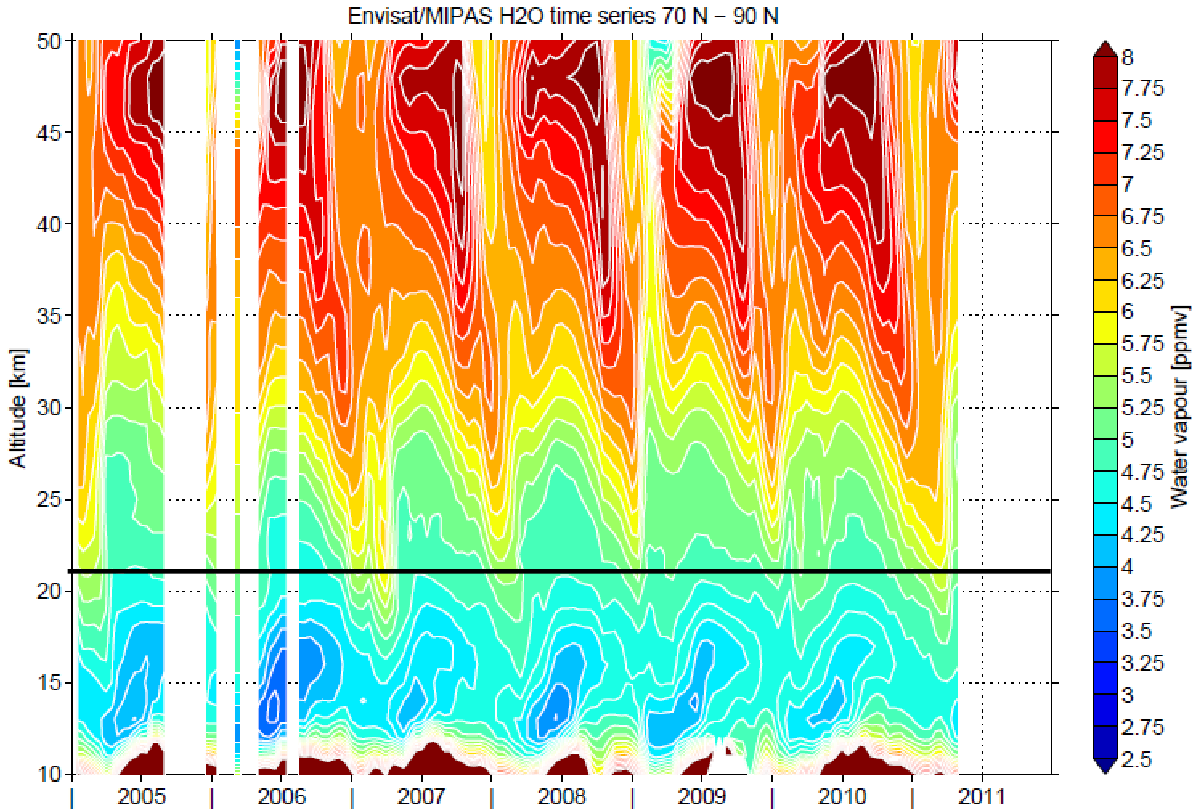
And/or:

- High H_2O transported from the tropics to the polar regions

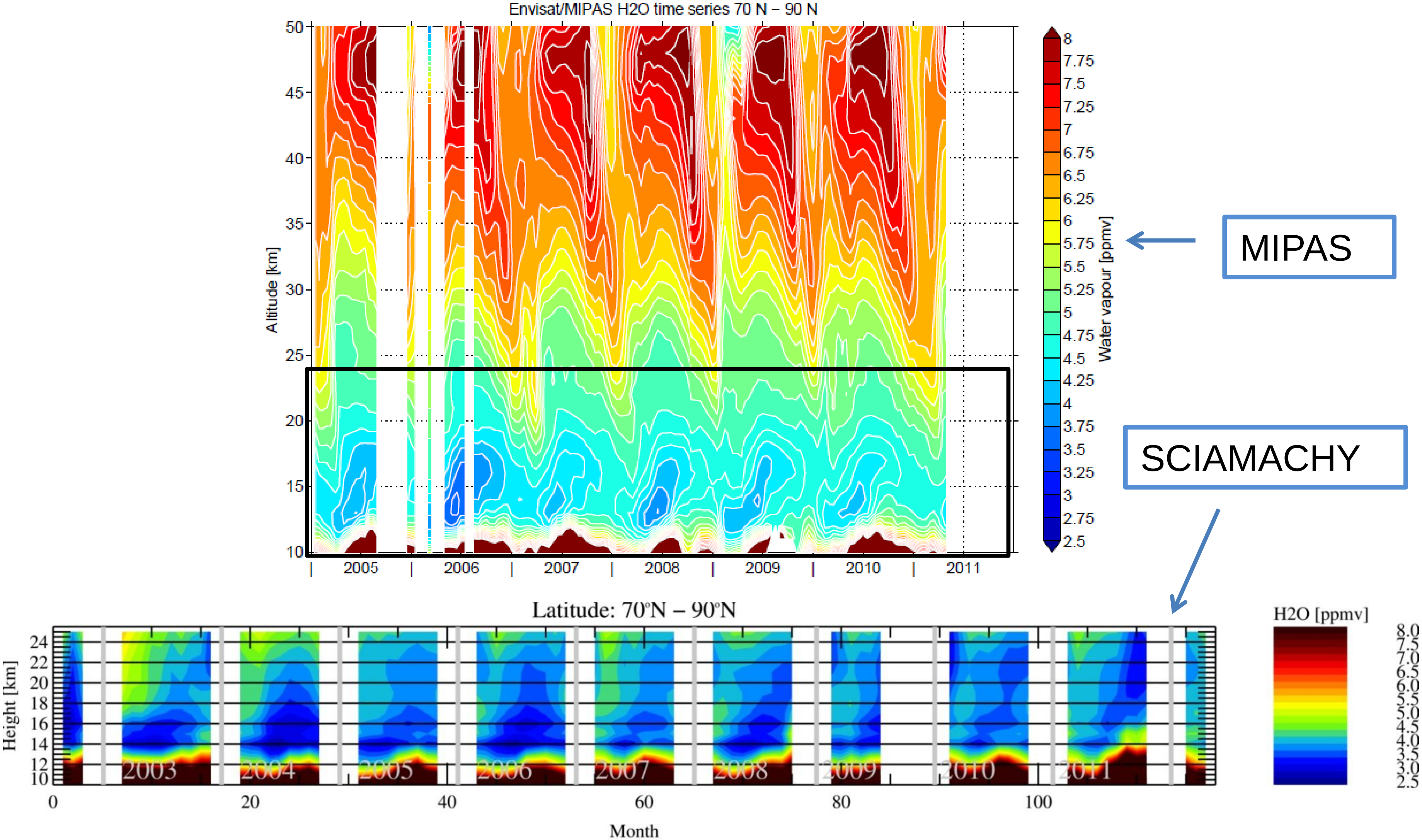
MIPAS H_2O (2005-2011)



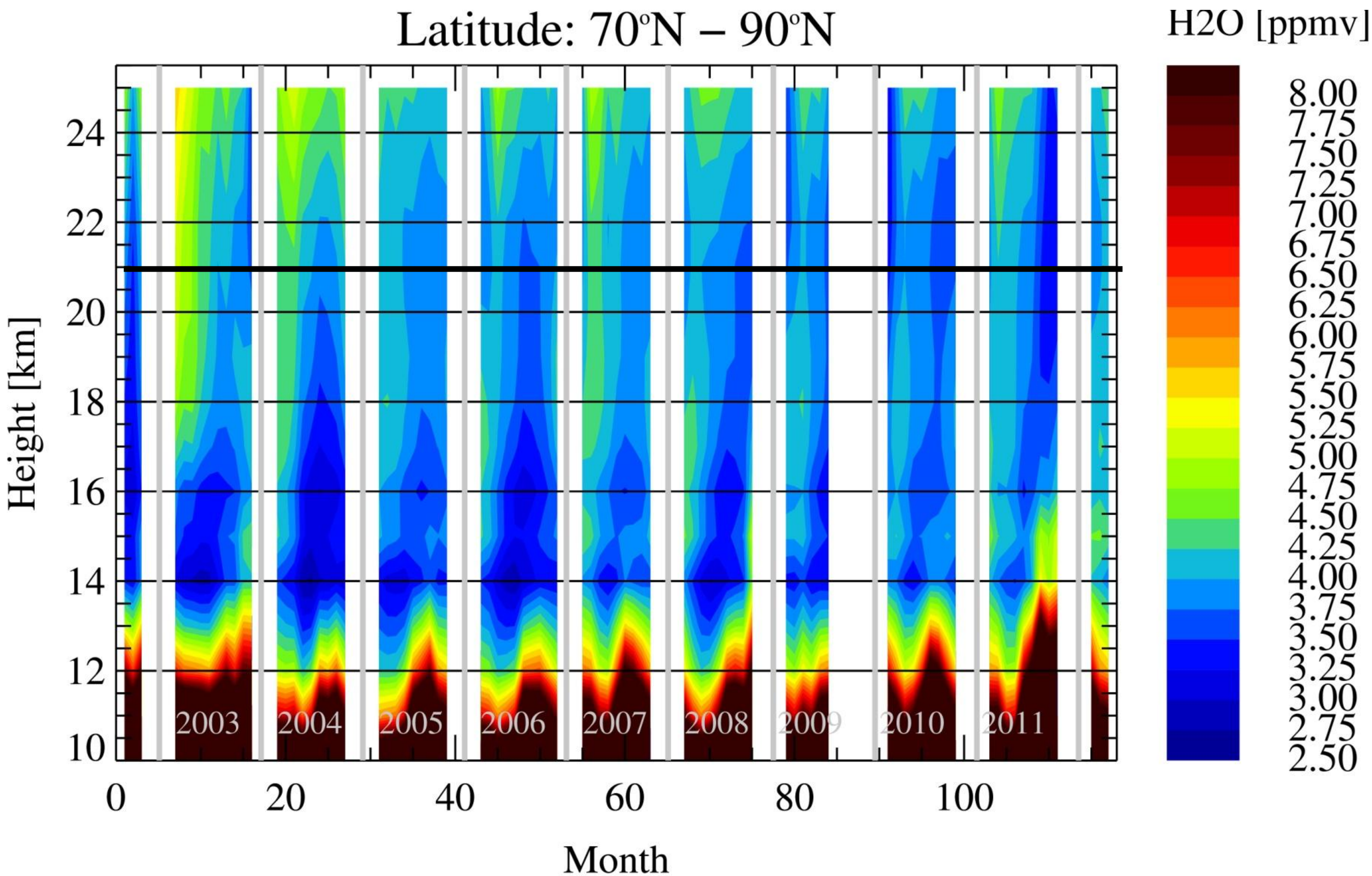
Boenisch et al., ACP, 2011



SCIAMACHY and MIPAS



SCIAMACHY H_2O (2003-2011)



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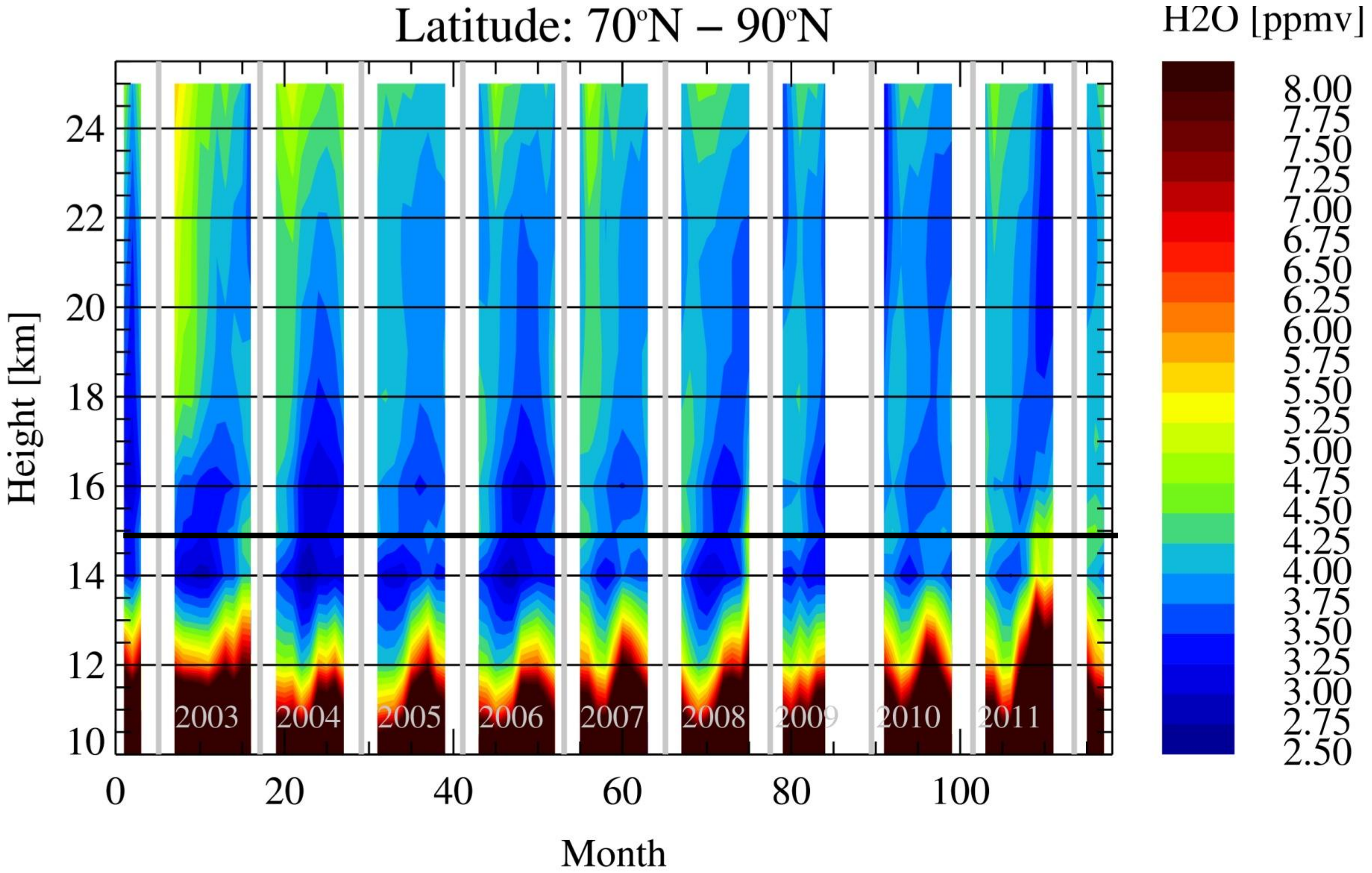
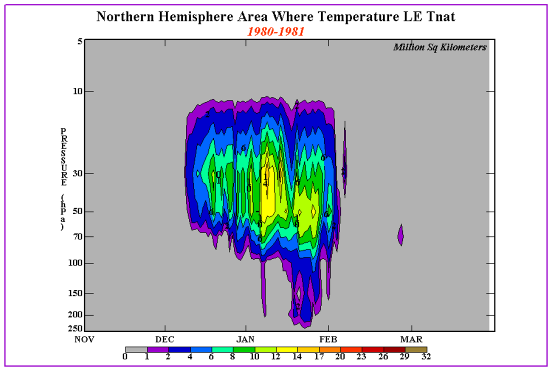
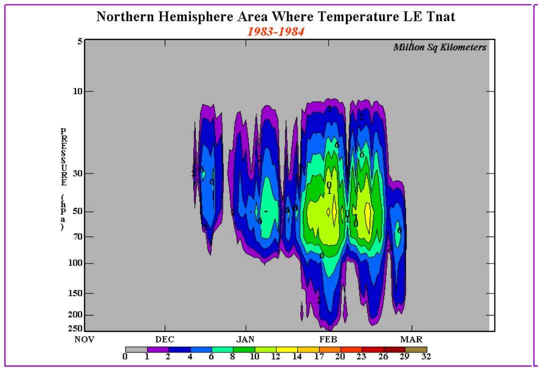


Change in T_{NAT} Area?

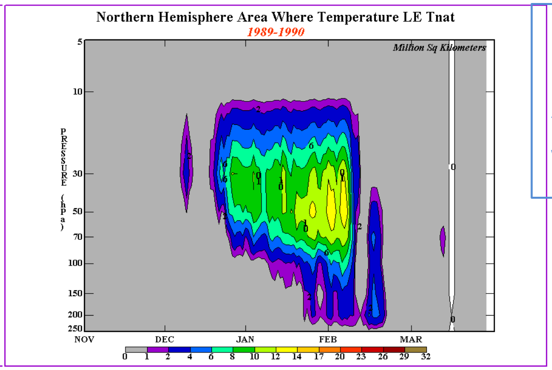
1981/1982



1983/1984

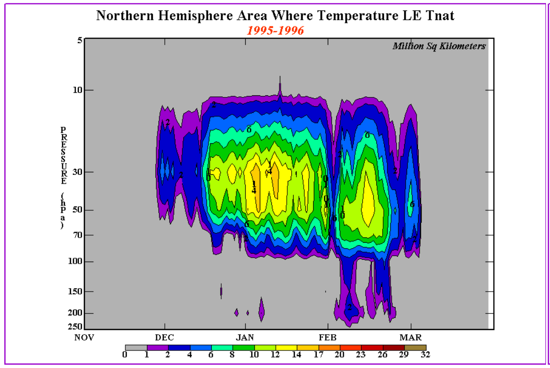


1989/1990

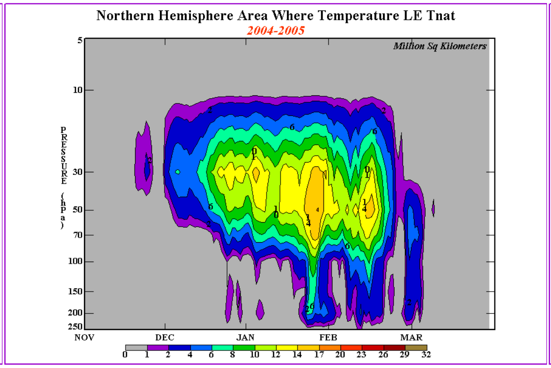


Cold Arctic winters

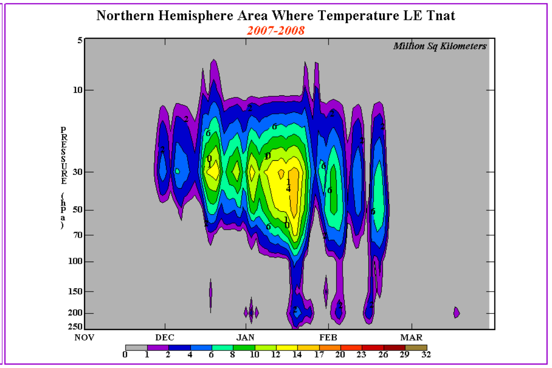
1995/1996



2004/2005



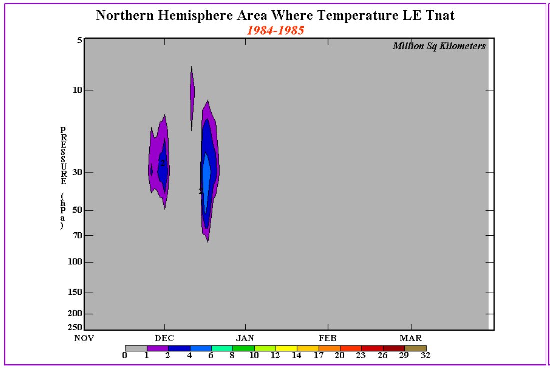
2007/2008



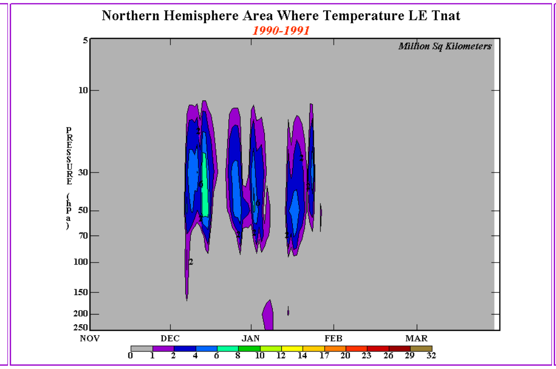
NOAA Climate Prediction center

Change in T_{NAT} Area?

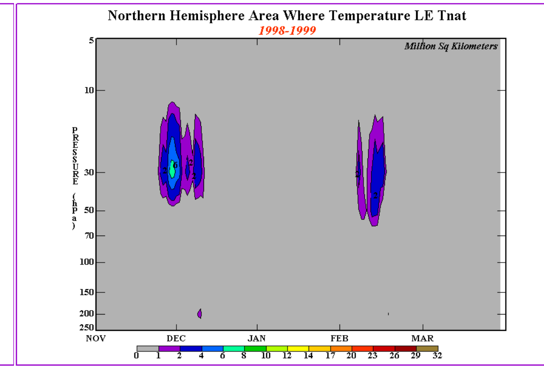
1984/1985



1990/1991

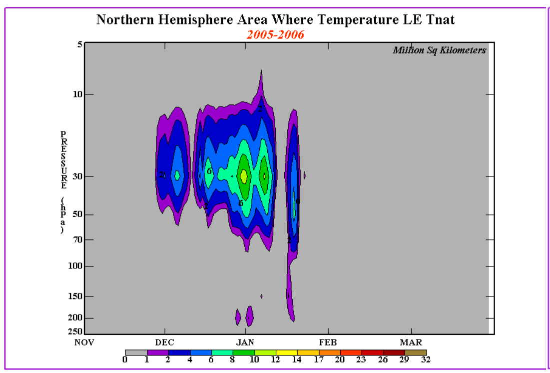


1998/1999

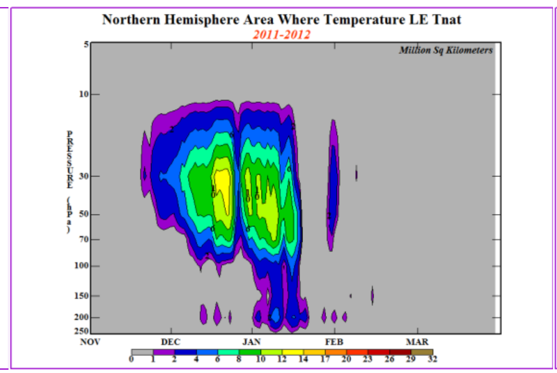


Warm Arctic winters

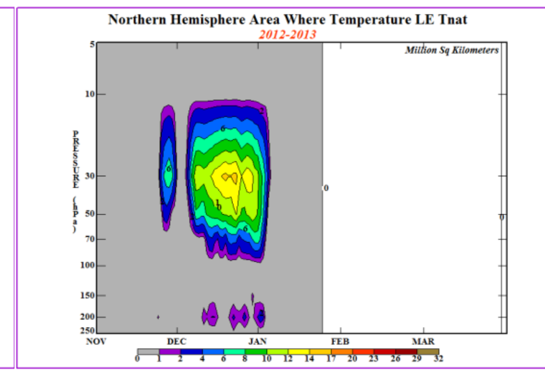
2005/2006



2011/2012



2012/2013



NOAA Climate Prediction center

Conclusions

- PSC formation quite sensititive to H_2O and temperature changes
- Increases in stratospheric H_2O (and cooling of the stratosphere) will increase PSC formation and prolong PSC existence
- Temperature trend is visible in radiosonde time series (1997-2007)
- No significant trend in H_2O visible in the polar regions from satellite measurements (2001-2011)
- Cold winters coincide with higher H_2O, thus transport through Brewer-Dobson Circulation may also play a role
- Further studies are necessary!