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Dynamical and Photochemical Couplings in the Middle and Upper Stratosphere during the remarkable 2003-04 Stratospheric Sudden Warming

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Abstract

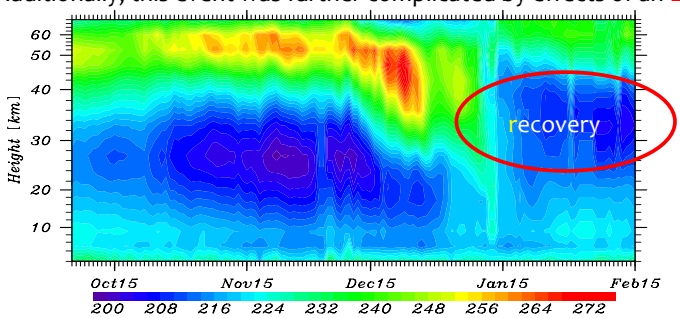
The global 3-D stratospheric/tropospheric chemical transport model MOZART-3 is applied to study the dynamical and photochemical couplings in the middle and upper stratosphere during the 2003-04 remarkable SSW event in boreal winter. Result shows that 1) both the horizontal exchange across the vortex edge and vertical motions inside the polar vortex play important roles in controlling the stratospheric O3 and N2O inside the mid-stratospheric polar vortex. 2) Moreover, shift of the vortex outside the polar-night region disturbed both the catalytic O3 losses and the NOy photochemistry inside the relatively isolated polar vortex. 3) Especially, the prominent descents associated with the rapid recovery of upper stratospheric vortex transported high concentration of NOx downward into the mid-stratospheric vortex and caused enhanced O3 losses inside the vortex.

MOZART-3

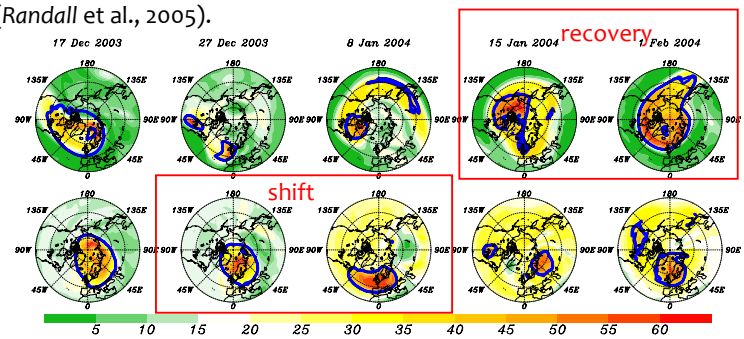
Model for Ozone And Related chemical Tracers ,version 3 (*Kinnison* et al., 2007) accounts for physical and chemical processes from the Earth's surface to the lower thermosphere, including vertical mixing associated with gravity wave breaking in the upper stratosphere and mesosphere, molecular diffusion of constituents above 80 km, photochemical reactions, stratospheric heterogeneous processes and auroral contribution to the chemical budget. Thus it is more suitable for representing chemical/physical processes in stratosphere. In this study, the MOZART-3 is driven with operational ECMWF analysis. In order to take the energetic particle precipitation (EPP) event into account, the NO2 upper boundary value is modified according to MIPAS NO2 observation.

the remarkable 2003-04 SSW

The boreal winter witnessed a remarkable major stratospheric warming in January, 2004 (*Manney* et al., 2005). This event was characterized by an extraordinarily long vortex disruption in the lower and middle stratosphere, with a strong and rapid recovery of the upper stratospheric vortex. Additionally, this event was further complicated by effects of an EPP event (*Randall* et al., 2005).

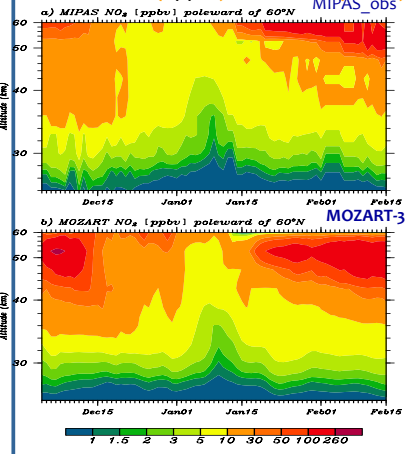


stratospheric temperature poleward of 60°N from MIPAS

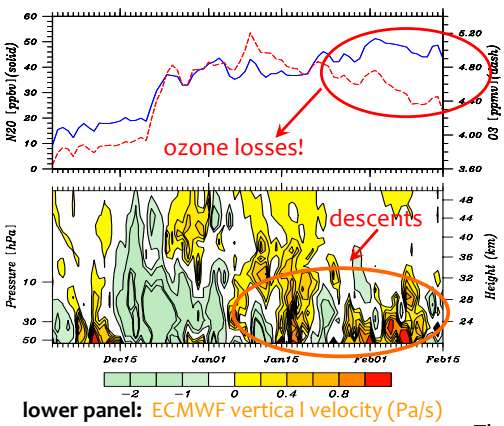


polar vortex on upper (1mb) and middle (10mb) stratosphere

NO2 poleward of 60°N from observation (upper) and model (lower)



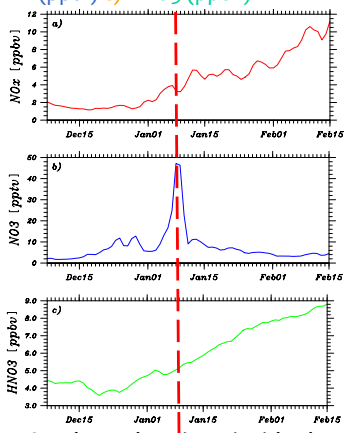
upper panel: N2O (blue) and O3 (red) inside the 10 mb polar vortex



lower panel: ECMWF vertica l velocity (Pa/s) inside the polar vortex

enhanced stratospheric NO2 by strong descents inside the recovered polar vortex

NOy inside the 10 mb polar vortex a) NO2 (ppbv) b) NO3 (pptv) c) HNO3 (ppbv)



NO_x cycle 1

$NO+O_3 \rightarrow NO_2+O_2$

$NO_2+O \rightarrow NO+O_2$

$O_3+O \rightarrow 2O_2$

NO_x cycle 2

$NO+O_3 \rightarrow NO_2+O_2$

$NO_2+O_3 \rightarrow NO_3+O_2$

$NO_3+h\nu \rightarrow NO+O_2$

$O_3+O_3 \rightarrow 3O_2$

$NO2+OH \rightarrow HNO3$

The NOy photochemistry inside the polar vortex is greatly disturbed by the vortex shifting outside the polar-night region and the enhanced NO2 inside it.

References

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Manney et al. (2005), J. Geophys. Res., 110, D04107, doi:10.1029/2004JD005367.
Randall et al. (2005), Geophys. Res. Lett., 32, L05802, doi:10.1029/2004GL022003

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