The influence of zonally asymmetric stratospheric ozone on temperature, planetary wave propagation and atmospheric circulation

Axel Gabriel (1), Dieter Peters (1), Ingo Kirchner (2) and Hans-F. Graf (3)

(1) Leibniz-Institut für Atmosphärenphysik, Kühlungsborn, Germany, (2) Meteorologisches Institut, FU Berlin, Germany, (3) Cambridge University, Cambridge, UK

Introduction

● Zonally asymmetric stratospheric ozone $O_3^*=O_3-[O_3]$ and its long-term variability is analyzed based on assimilated data (ERA-40) and satellite measurements (SAGE, GOME)

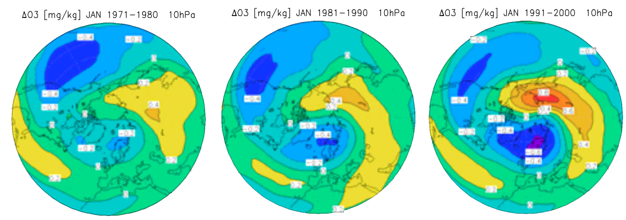
● The influence of O_3^*-induced radiative forcing on temperature, planetary wave propagation and atmospheric circulation is investigated based on the GCM MAECHAM5.

Results

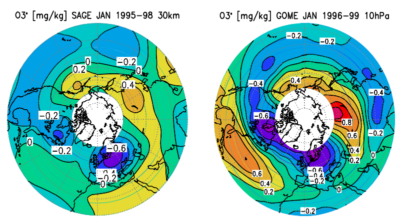
● A pronounced wave one structure in O_3^* increased during the last decades (≈0.2 mg/kg per decade at 10hPa); radiative forcing due to O_3^* during the 1990s is about 0.01-0.1 K day^{-1}

● During NH winter of the 1990s, O_3^* induces temperature changes of ± 2-8 K (increasing with height) due to an increase in amplitude and a westward shift in phase of stratospheric wave one, associated with a shift of vertically propagating wave trains and a change of tropospheric circulation towards negative NAO

(I) Observed changes of zonally asymmetric ozone $O_3^*=O_3-[O_3]$



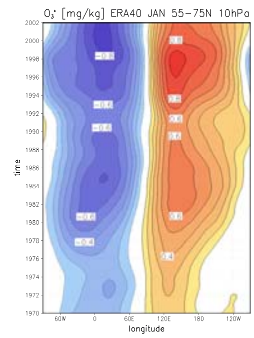
Decadal means of O_3^* at 10 hPa, derived from ECMWF Reanalysis (ERA-40); a wave one structure increased reaching a max. amplitude of 0.8 mg/kg during the 1990s (≈10% of zonal mean ozone)



→

O_3^* derived from SAGE II (left) (max. ≈ 900 profiles per month, sampled on 10°x10° grid boxes)

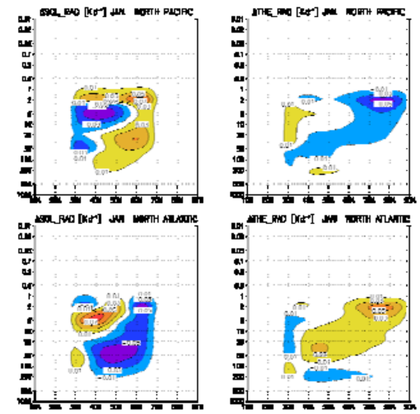
O_3^* derived from GOME (right) (GOME-NNORSY climatology provided on 5x5° grid boxes)



Time series of monthly mean ozone (January), smoothed by a running mean over ±3 months;

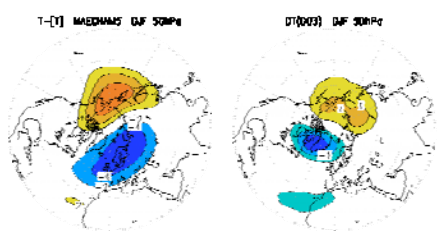
the nearly linear increase of O3* is modified by 11-year solar cycle

(II) Radiative Forcing due to O_3^*

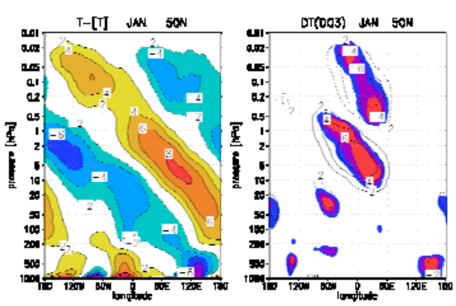


O_3^* -induced (left) solar and (right) thermal radiative heating rates [K day^{-1}] for January, averaged for regions over North Pacific (150°E-150°W) and North-Atlantic (30°W-30°W); UST/LST denotes upper/lower stratosphere

(III) Influence of O_3^* on temperature (MAECHAM5)

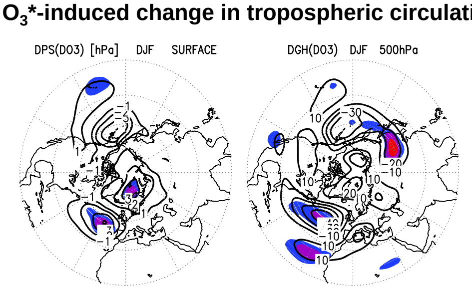


10-year winter means at 50hPa for (left) deviations from zonal mean temperature $T^*=T-[T]$ of the control run without O_3^* and (right) O_3^*-induced differences $DT(O_3^*)$



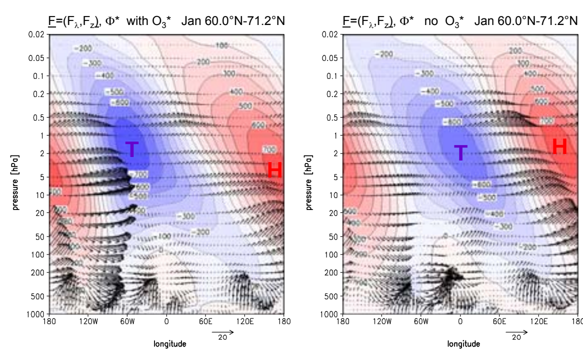
10-year January means at 50°N for (left) deviations $T^*=T-[T]$ of the control run without O_3^* and (right) differences $DT(O_3^*)$ (90%-, 95%-, 99%- significance)

(V) O_3^*-induced change in tropospheric circulation



10-year winter means of O_3^*-induced differences for (left) surface pressure DPS and (right) geopotential height DGH at 500hPa ⇒ change towards negative phase of NAO

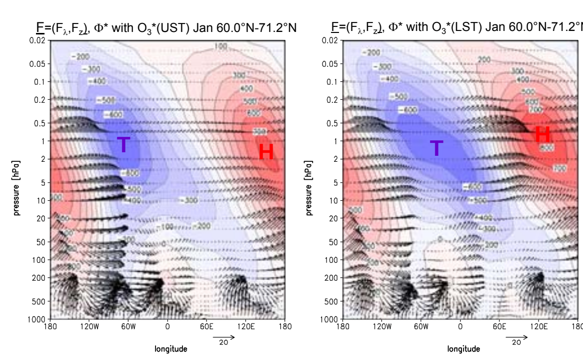
(IV) Influence of O_3^* on quasi-stationary waves for mean January of the 1990s



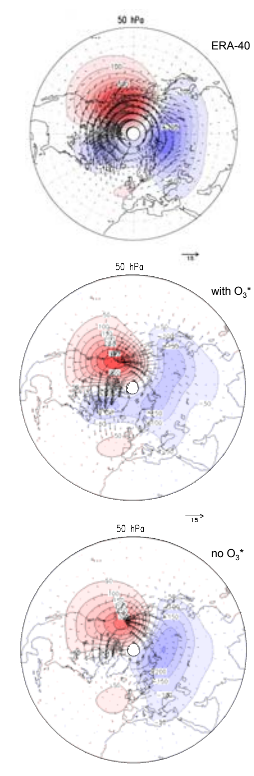
Deviations in geopotential height $\Phi^*=\Phi-[\Phi]$ (isolines in gpm) and wave flux vectors (arrow length at bottom is 20 m^2s^{-2}) for the model run (left) with and (right) without O_3^*.

The wave flux vectors are derived from 3D wave activity equation for quasistationary waves (→Plumb, JAS, 1985) and vertically scaled by $(F_\lambda,F_z) \rightarrow (p/p_0)^{-1/2}\ (F_\lambda, 100*F_z)$.

⇒ O_3^* induce a westward shift of polar low (L) and of pronounced vertically propagating wave trains from the eastern to the western hemisphere.



Same as above, but for left) O_3^* only in upper stratosphere and (right) O_3^* only in lower stratosphere ⇒ the sensitivity study demonstrate the importance of both lower and upper stratospheric O_3^* on position and structure of the polar low.



Deviations $\Phi^*=\Phi-[\Phi]$ (isolines in gpm) and wave flux vectors (arrow length at bottom is 15 m^2s^{-2}) at 50hPa

⇒ in comparison to observations the spatial structure of polar low is better described if O_3^* is included

References

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