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Influence of the spatial distribution of gravity wave activity on the middle atmospheric circulation and transport.

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Summary:

With a mechanistic circulation model for the middle atmosphere we performed experimental runs to study the effect of a localized gravity wave (GW) breaking region above the Eastern Asia/North-western Pacific (EA/NP) region on the large-scale circulation and transport. Our results demonstrate an important role of the spatial distribution of GW activity for the formation of planetary waves (PW). We show that PW created by such a localized forcing can have consequences for the polar vortex stability and the stratosphere-troposphere exchange in the tropical region of South-East Asia.

The 3D residual circulation gives insight into the role of the GW hotspots in forcing longitudinal variability of the Brewer-Dobson Circulation (BDC), e.g. an enhanced downwelling branch in the EA/NP region.

Middle and Upper Atmosphere Model (MUAM)

- Primitive equation 3D grid point model
- horizontal resolution: 5°x5.625°
- Upper boundary: 160km (log-p); Δz=2.842 km
- Time step: 225s (Matsuno integration scheme)
- Nudging of ERA-Interim zonal mean temperature below 30km
- GW parameterization: linear scheme with multiple breaking levels
- GW initialized at 10km (0.01m/s vertical velocity perturbation)

See also: Pogoreltsev et al. (2007)

Gravity Wave Regional Distribution

We use GPS radio occultations to initialize the horizontal field of GW activity in the model (at an altitude of 10 km):

- Potential energy (E_p) from FORMOTSAT3/COSMIC density
- Average between tropopause (8-17km) and 35km altitude
- no filtering of Kelvin waves
- At each grid point: E_p normalized with global mean E_p

See also: Šacha et al. (2014)

Experimental Setup

Background:

- Šacha et al. (2015) discovered a localized area of enhanced GW activity and breaking in the lower stratosphere of EA/NP region
- Convective and dynamical instability indicators suggest robust and persistent wave breaking at anomalously low levels (around 25 km altitude)

Model runs:

- After spin-up of the model we artificially enhanced GW drag in the GW parameterization output for the period of the simulation (30 model days)
- Two configurations for the local enhancement:

box (EA/NP):	z=18-30 km,	x=112-169°E,	y=37.5-62.5°N
zonally uniform:	z=18-30km,		y=37.5-62.5°N

Values for the enhanced parameters:

- Zonal acceleration:	gcu =	-0.5 m/s/d	and	-10 m/s/d
- Meridional acceleration:	gcv =	-0.1 m/s/d	and	+0.1 m/s/d
- Heating:	gt =		0.05 K/d	

Related Articles:

Šácha, P., U. Foelsche and P. Pišoft: Analysis of internal gravity waves with GPS RO density profiles, Atm. Meas. Tech., 7, 4123-4132, doi:10.5194/amt-7-4123-2014, 2014.

Šácha, P., Kuchar, A., Jacobi, C., and Pišoft, P.: Enhanced internal gravity wave activity and breaking over the northeastern Pacific/eastern Asian region, Atmos. Chem. Phys., 15, 13097-13112, doi:10.5194/acp-15-13097-2015, 2015.

Pogoreltsev, A.I., Vlasov, A.A., Fröhlich, K., and Jacobi, Ch.: Planetary waves in coupling the lower and upper atmosphere, J. Atmos. Sol.-Terr. Phys., 69, 2083–2101, doi:10.1016/j.jastp.2007.05.014, 2007.

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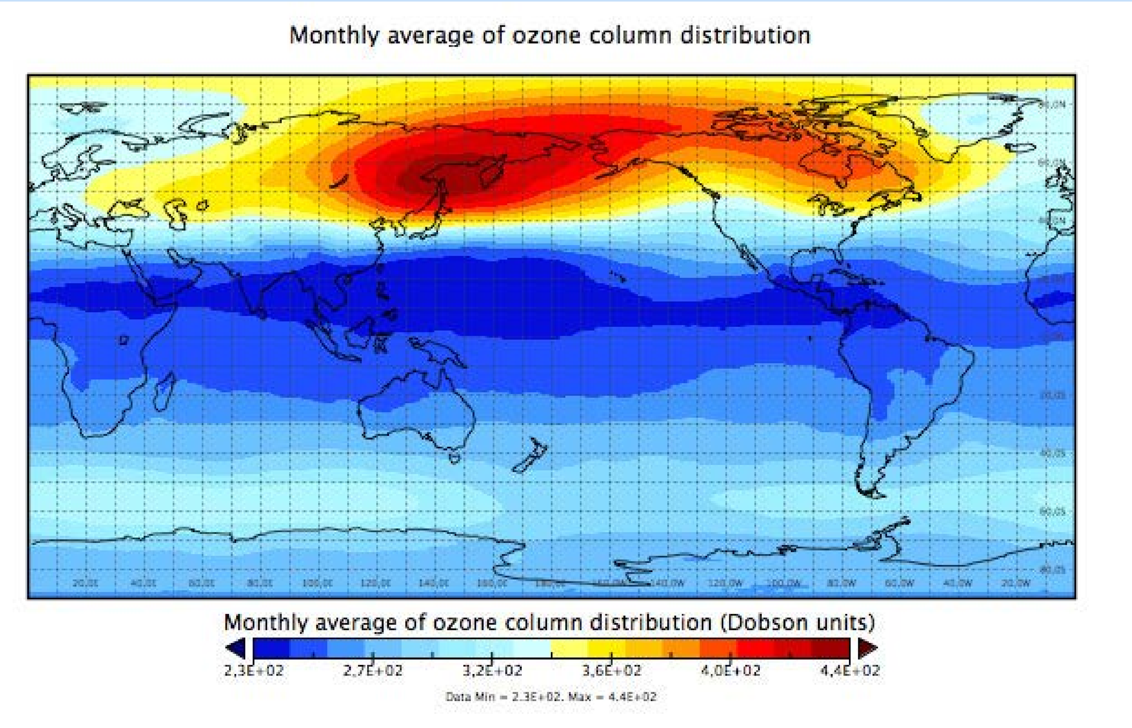
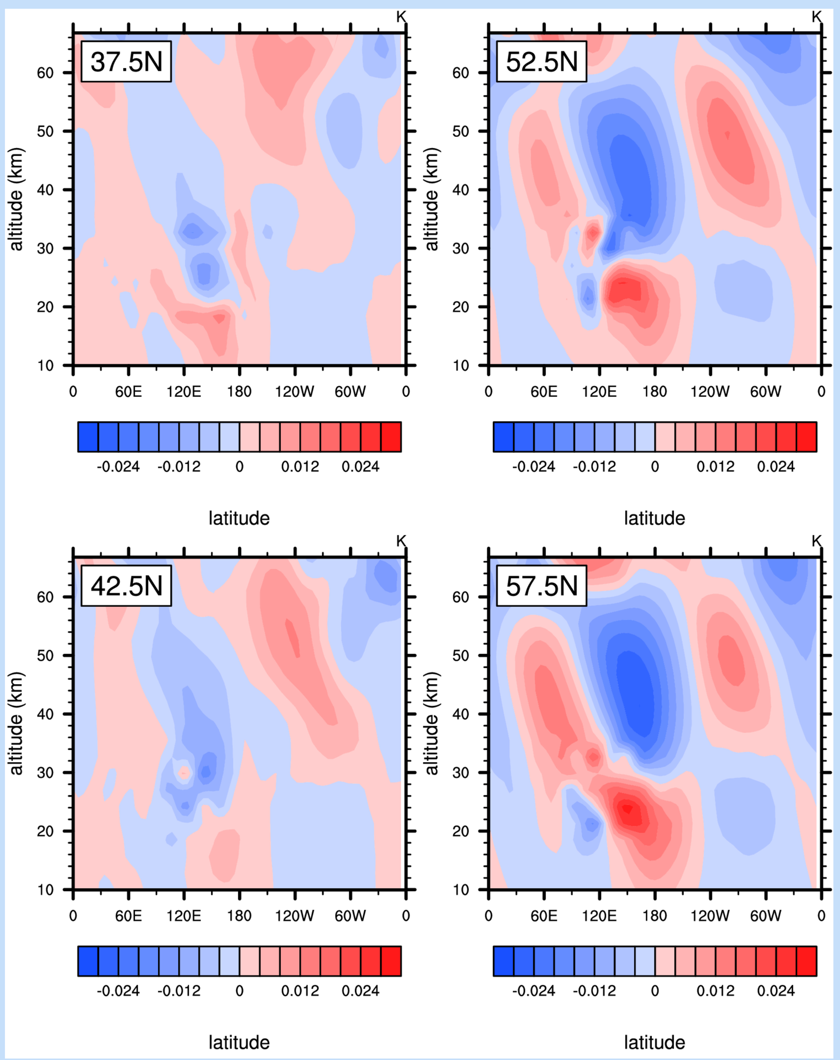
Implications on the Brewer-Dobson Circulation

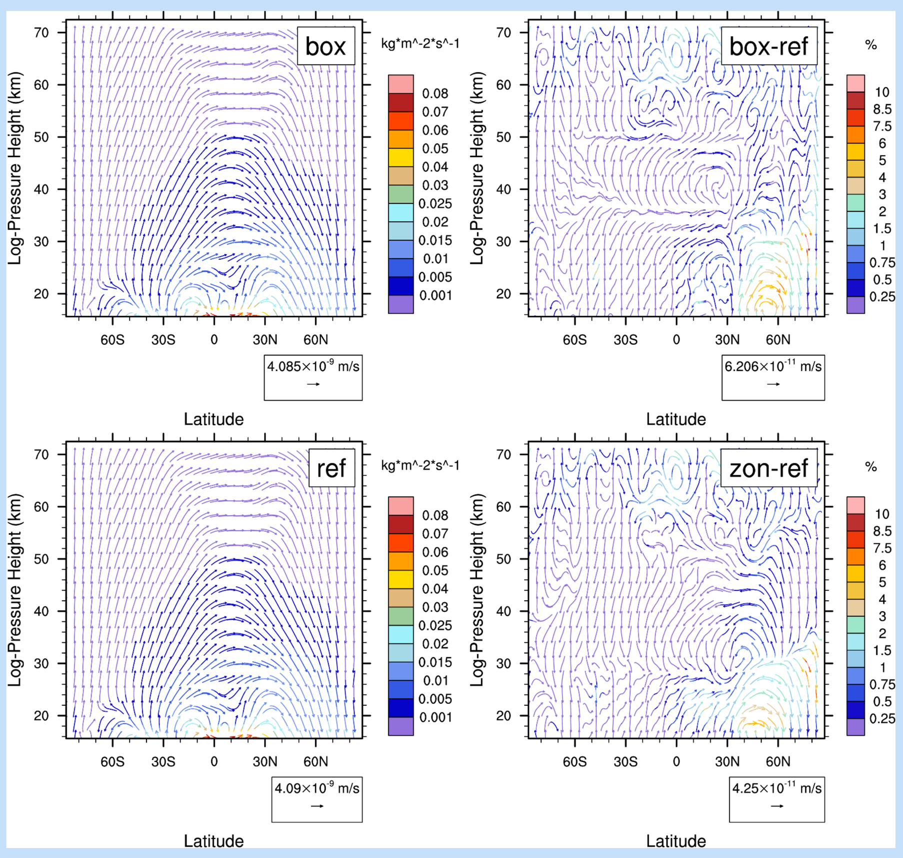
- It is necessary to consider longitudinal variability of GW drag
- Differences between box and zonally uniform run up to 10% (monthly mean)



Left: The 30 year January MSR climatology of total ozone column (DU) proves the location of an enhanced BDC branch in EA/NP region.

Below: BDC (m/s) and its anomalies (%) of the box enhancement and the zonally uniform enhancement run (gcu=-0.5m/s/d, gcv=-0.1m/s/d) compared to a reference run without artificial enhancements.

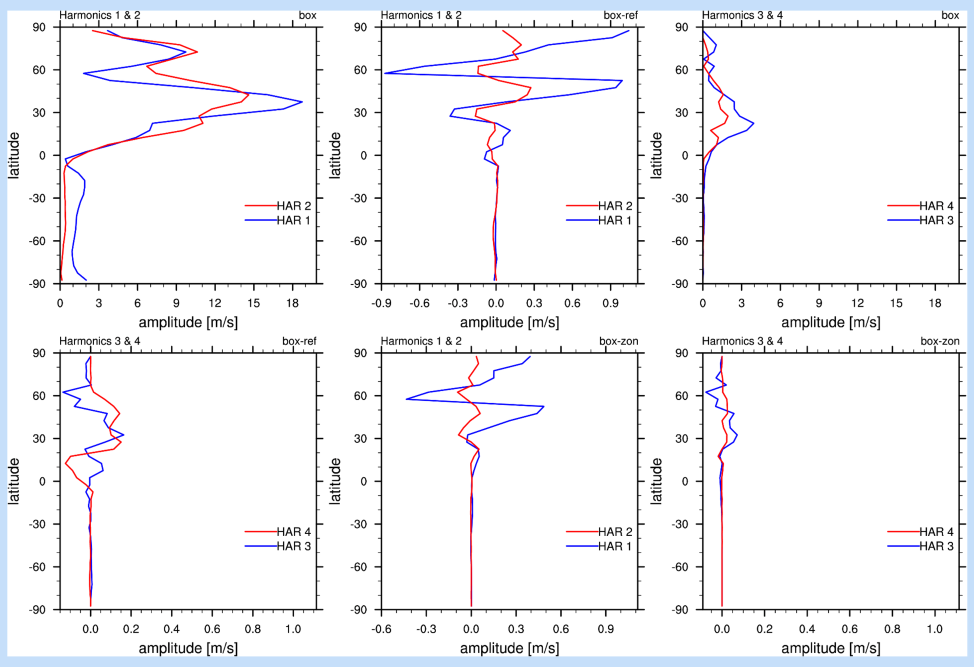


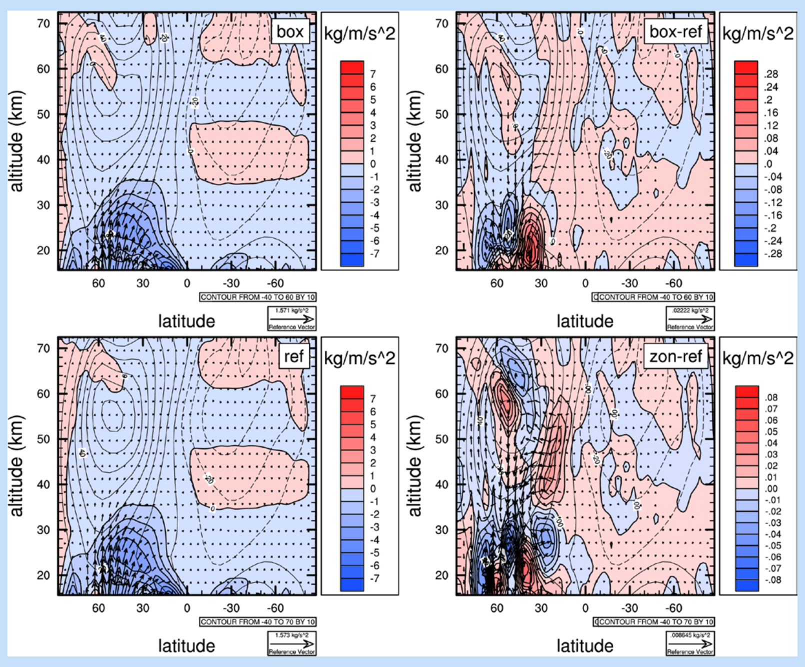


Left: Residual vertical velocity cross sections as induced by the additional GW drag (gcu=-10m/s/d, gcv=-0.1m/s/d).

Planetary Wave Forcing and Polar Vortex Stability

We observe increased planetary wave activity in response to the artificial GW drag enhancement:

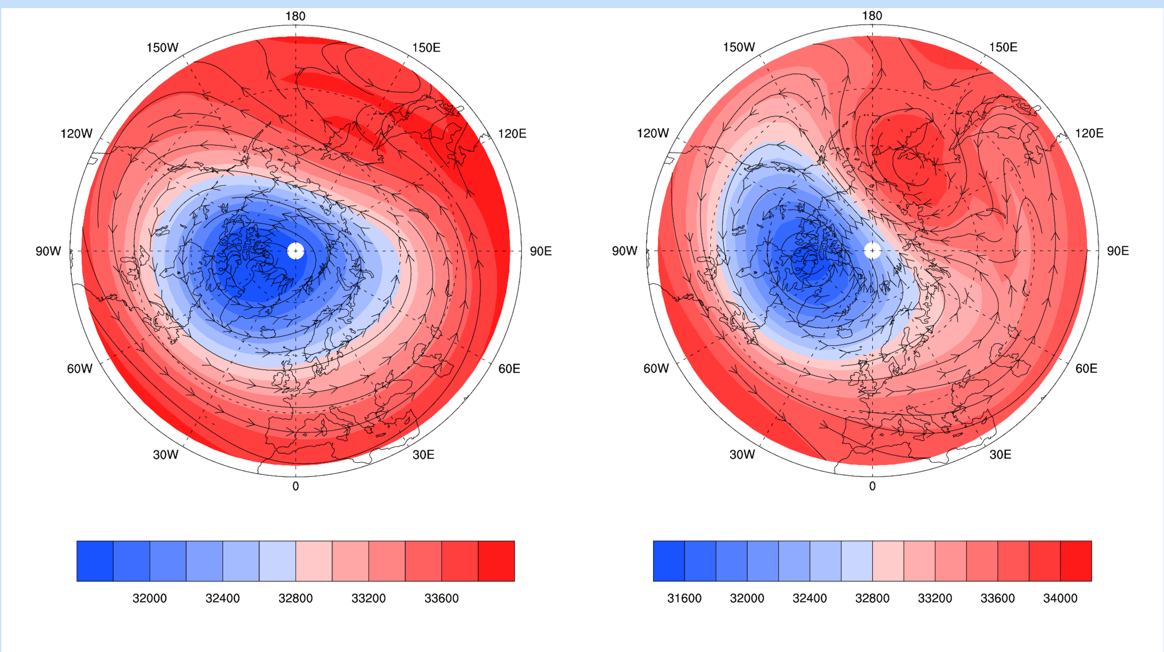




Top left: Zonal wind amplitudes (m/s) of PWs for wavenumbers 1 to 4 for the individual runs and their anomalies, about 8 model days after GWD enhancement (gcu=-0.5m/s/d, gcv=-0.1m/s/d) in 35 km altitude.

Top right: Eliassen-Palm fluxes (arrows) and their divergence (contours) for these runs.

It can be seen that the box run is more efficient in creating PWs than the zonal run. In the subtropics and tropics this can lead to an increased stratosphere-troposphere exchange.



Left: Geopotential (gpm) and horizontal wind velocity (m/s) over the northern polar region, 44hrs after the enhanced GWD injection (gcu=-10m/s/d, gcv=0.1m/s/d) in an altitude of 35km. The displacement of the polar vortex is an implication for a sudden stratospheric warming.

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