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Effect of the lower atmosphere gravity wave regional distribution on the middle atmospheric circulation in a global numerical model

F. Lilienthal[1], P. Šácha[2], Ch. Jacobi[1]

[1]Institute for Meteorology, University of Leipzig, Stephanstr. 3, 04103 Leipzig, Germany, friederike.lilienthal@uni-Leipzig.de

[2]Department of Atmospheric Physics, Faculty of Mathematics and Physics, Charles University Prague, Czech Republic

Summary: We analyse the effect of lower atmosphere gravity wave (GW) regional distributions in the Middle and Upper Atmosphere Model (MUAM). To this end, we compare an artificial GW distribution with more realistic ones obtained from GPS RO measurements as zonal means and horizontal 2D fields. Model results are:

- larger differences between the reference run and each of the two GPS based runs than among the GPS based runs
- dynamical changes are largest where GW weightings differ strongest
- enhanced polar vortex
- lowered mesospheric jet
- stronger planetary wave activity with enhanced poleward propagation.

Middle and Upper Atmosphere Model

Numerical aspects:

- Primitive equation 3D grid point model
- horizontal resolution: 5°x5.625° (36 latitudes, 64 longitudes)
- Vertical domain: logarithmic pressure height
  $z = -H \ln(p/p_0)$ with $H=7$km, $p_0=1000$hPa
- 56 vertical layers (1.421km-160km, Δz=2.842km)
- Time step is 225s (Matsuno integration scheme)

Physical aspects:

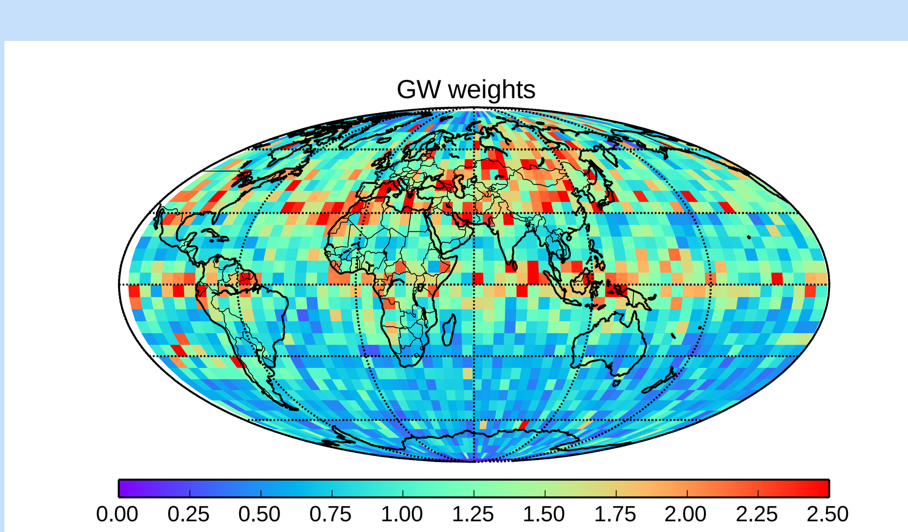
- Nudging of ERA-Interim zonal mean temperature below 30km
- Forcing of ERA-Interim stationary planetary waves of wavenumber 1-3 from temperature and geopotential fields at 1000hPa
- GW parameterization: linear scheme with multiple breaking levels
- GW initialized at 10km (0.01m/s vertical velocity perturbation), meridional weighting functions (standard: hyperbolic tangent)

Gravity Wave Regional Distribution

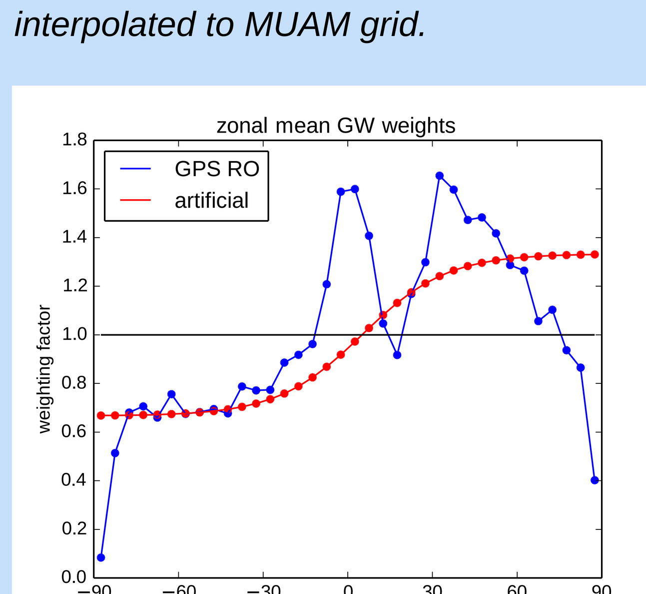
Replaced artificial weighting of the hyperbolic tangent by a distribution based on GPS radio occultation (RO) data.

GW weighting from GPS RO:

- Potential energy (E_p) from FORMOTSAT3/COSMIC density profiles (after Šácha et al., 2014)
- Average between tropopause (8-17km) and 35km altitude
- no filtration of Kelvin waves
- At each grid point: E_p devided by global mean E_p



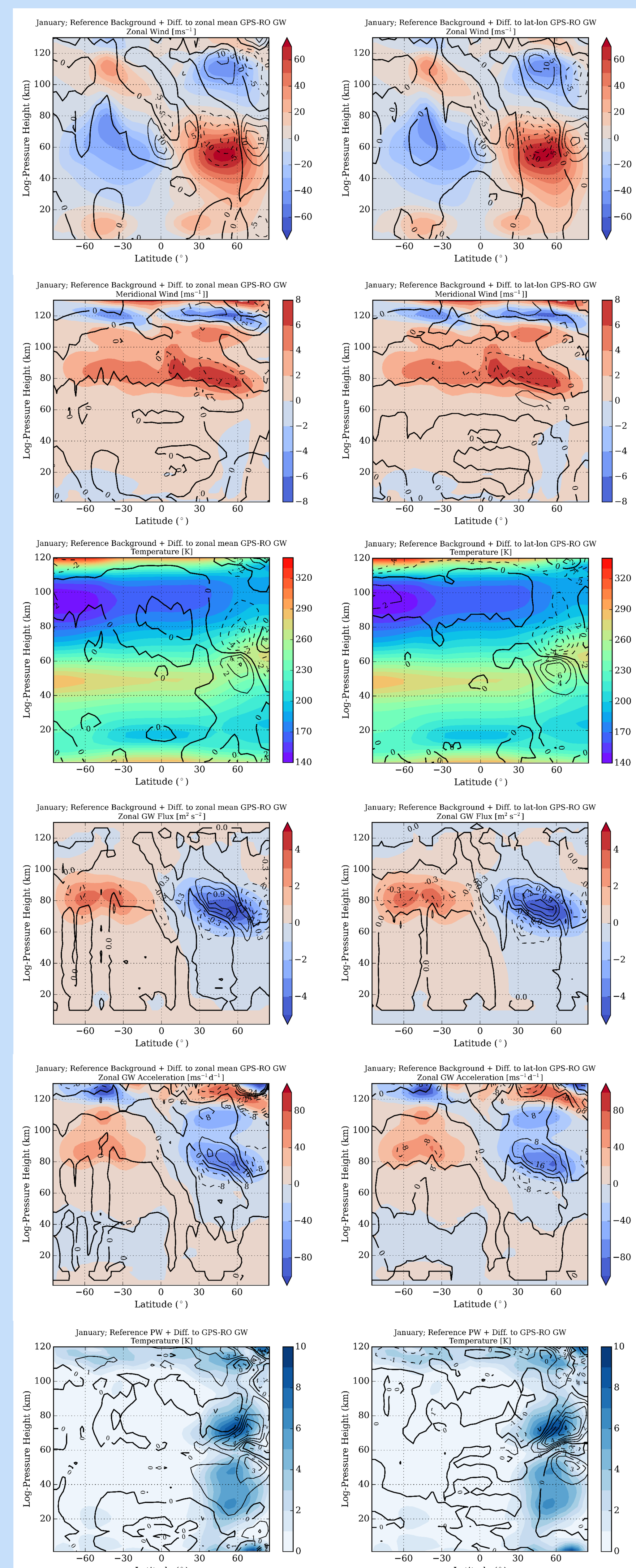
Left: Horizontal 2D distribution of GW weights as introduced in MUAM. Data are based on GPS RO and interpolated to MUAM grid.



Right: Zonal mean GW weights as introduced in MUAM. Artificial hyperbolic tangent (red) and GPS RO based weighting (blue). MUAM grid points are highlighted by dots. GPS RO data strongly exceed the artificial weighting near the equator and at 30-50°N.

Results

Changes between reference run and GPS based runs are much larger than between the GPS based runs mutually. The larges differences to the reference run appear where GW weightings differ most (close to equator and at 30°-50°N).



Zonal wind:
- Mesospheric jet shifted poleward
- Easterly winds in NH pole region appear in zonal mean run

Meridional wind:
- Jet is shifted downward where GW amplitudes are larger (earlier breaking region)

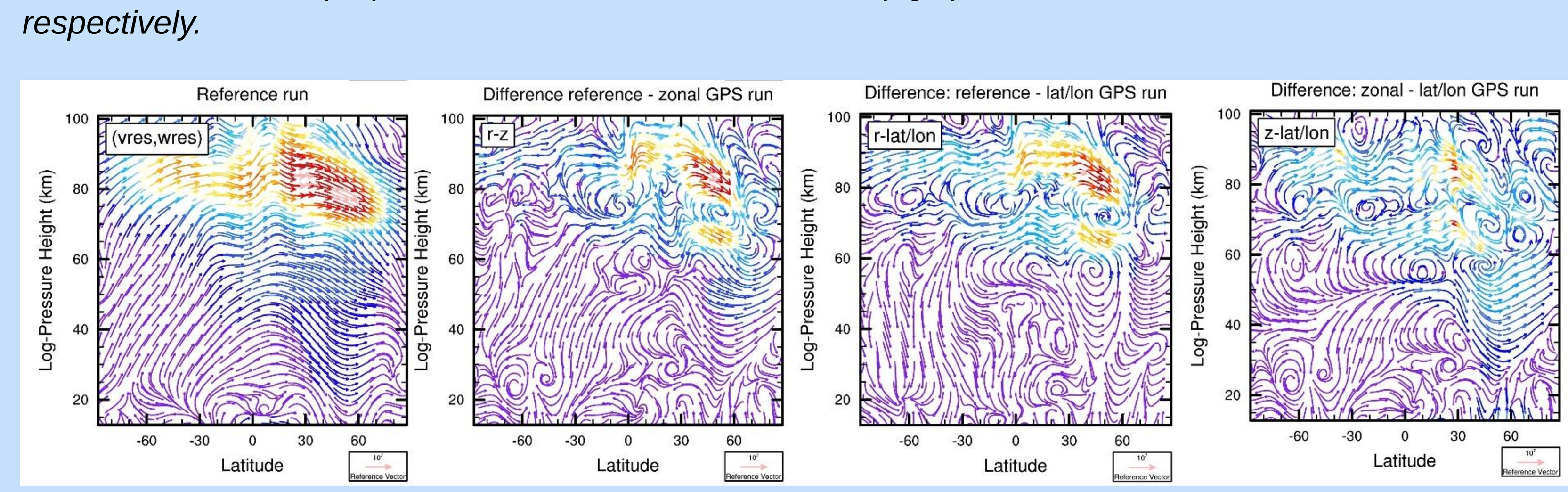
Temperature:
- Quadrupole structure centered at 70km, 70°N
- Reduction of stratopause elevation between polar vortex and surf zone
- Zonal mean run: subsidence at NH polar regions

GW momentum flux:
- NH minimum is reduced in altitude and shifted poleward
- Slight reduction of SH minimum (stronger in 2D GPS RO run)

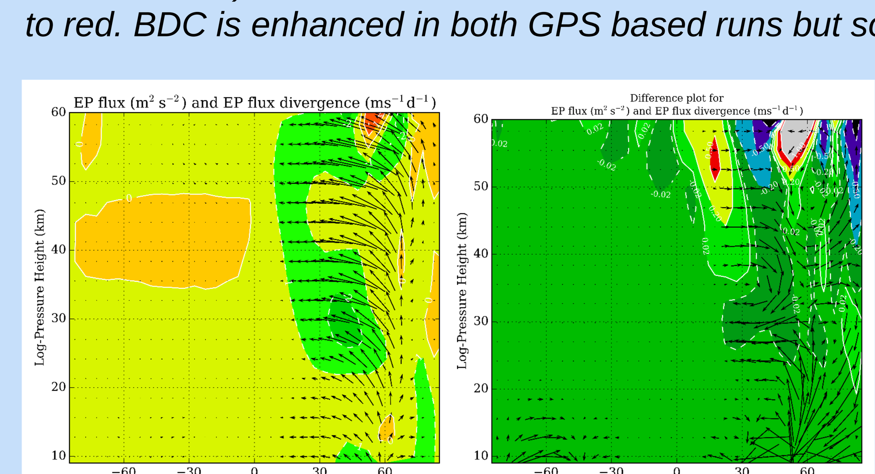
Mean flow acceleration due to GW:
- Acceleration region shifted downward due to earlier breaking

Stationary planetary waves, wavenumber 1 (SPW1):
- Enhanced SPW1 in NH
- Slightly shifted poleward (NH)

Above: Colored areas denote the reference run latitude-altitude cross section as zonal means, isolines show differences to zonal mean GPS RO run (left) and horizontal 2D GPS RO run (right), respectively.



Above (from left to right): Brewer-Dobson circulation (BDC) vectors for a) reference run, b) differences between reference and zonal mean GPS RO run, c) differences between reference and horizontal 2D GPS RO run and d) differences between zonal mean and horizontal 2D GPS RO runs. Intensity grows from blue to red. BDC is enhanced in both GPS based runs but somewhat stronger in the 2D GPS RO run.



Left: Reference Eliassen-Palm flux divergence and Eliassen-Palm flux vectors (left) and difference to the GW distribution from horizontal 2D GPS RO run, scaled by dry air density (right).

In the lower stratosphere, enhanced poleward propagation can be seen at northern midlatitudes.

Related Articles:

Lilienthal, F., P. Šácha and Ch. Jacobi: Gravity wave effects on a modelled mean circulation, Rep. Inst. Meteorol. Univ. Leipzig, 2015, http://home.uni-leipzig.de/jacobi/docs/Lilienthal_2015_LIM_GW.pdf.

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.

printed at Rechenzentrum Leipzig

poster available at http://home.uni-leipzig.de/jacobi/bilder/2015_IUGG_GW.pdf