Effect of intermittent gravity wave activity on the dynamics in the mesosphere during winter

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Introduction

- Gravity waves (GWs) are the major contributor to vertical coupling of atmospheric layers by distributing energy and momentum throughout the whole atmosphere.
- GWs have horizontal wavelengths of tens to hundreds of kilometers so that GWs are mostly parameterized in global circulation models.
- GW distributions are mainly based on GW source parameterizations, or on specific functions or observed GW fields [Šácha et al., 2016; Lilienthal et al., 2017].
- Effects of different spatial and temporal GW distributions have to be studied to reproduce a more realistic circulation in the middle atmosphere.

MUAM – Middle and Upper Atmosphere Model

- Primitive equation 3D grid point model [Pogoreltsev et al., 2007]
- horizontal resolution: 5°x5.625°
- Upper boundary: 160 km (log-p); Δz=2.842 km
- Nudging of ERA-Interim zonal mean temperature below 30 km
- GW parameterization: linear scheme with multiple breaking levels
- GW initialized at 10 km (1 cm s^{-1} vertical velocity perturbation)

Fig. 1: Horizontal resolution of MUAM.

Model setup: GW distribution

1. Spatial distribution:

- Instead of using the GW distribution based on the observed E_{pot} data we calculated the momentum flux (MF) distribution by applying midfrequency approximation according to Ern et al. [2004]:

$$F_h = 3\rho \frac{f}{N} E_{pot}$$

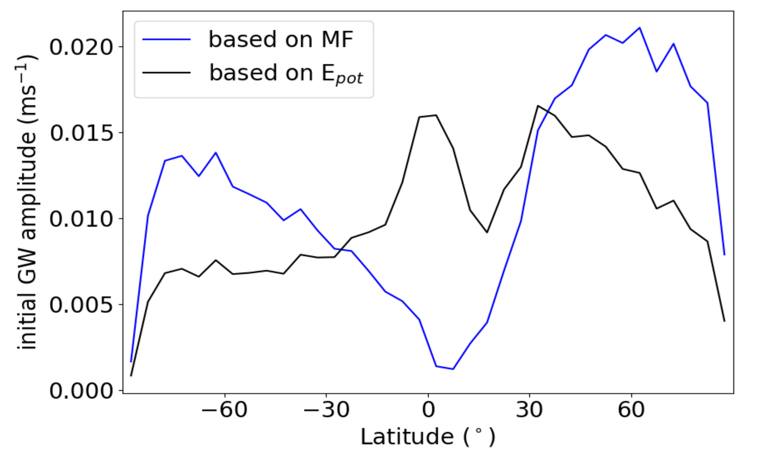

Fig. 2: GW vertical wind amplitudes for the simulation based on the GPS RO E_{pot} (dotted line) and MF (solid line) data for January conditions.

2. Temporal distribution:

- Real GW MF is unevenly distributed [Hertzog et al., 2012]: many GWs with small and only a few ones with large MFs.
- Create temporal variation of GWs by multiplying GW amplitudes with randomly generated numbers with mean values of 1 cm s^{-1}, 0.55 cm s^{-1} and 0.275 cm s^{-1}.
- Distributed linearly and polynomially

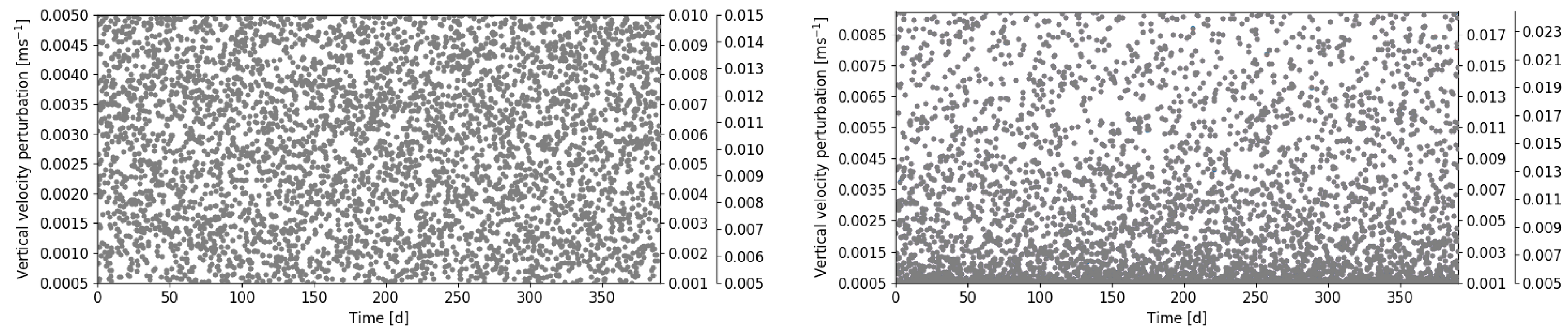

Fig. 3: Linear (left) and x^3 (right) distribution of the random numbers representing the variation of the vertical velocity perturbation with mean values of 1 cm s^{-1}, 0.5 cm s^{-1} and 0.275 cm s^{-1}.

Results: Spatial GW distribution

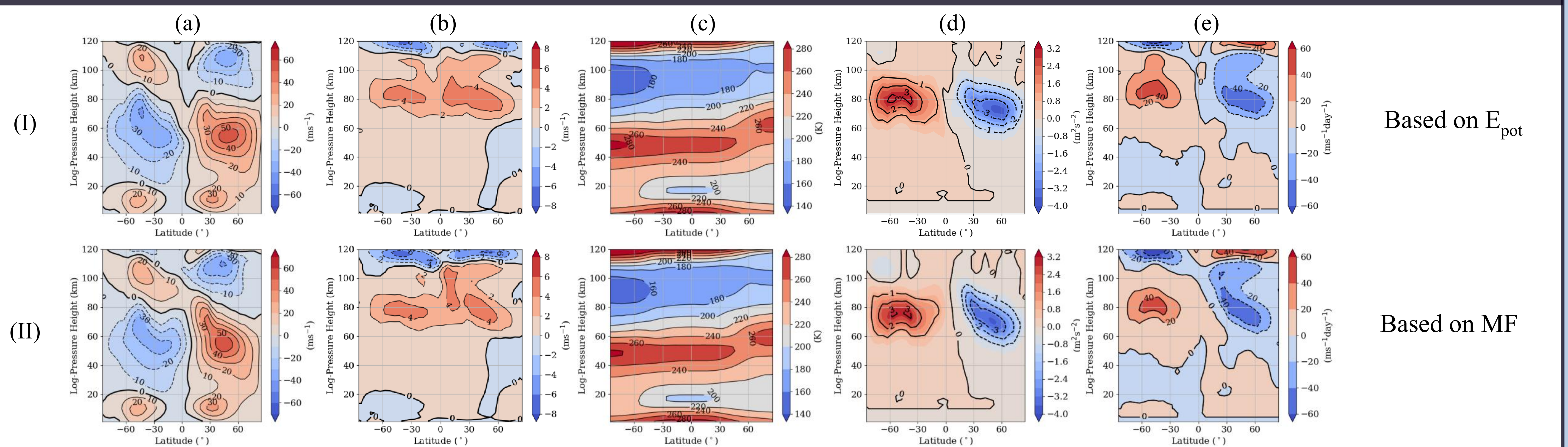

Fig. 4: *January zonal and monthly mean of the (a) zonal wind [ms^{-1}], (b) meridional wind [ms^{-1}], (c) temperature [K], (d) GW fluxes [m^2s^{-2}] and (e) acceleration through breaking GWs [$ms^{-1}day^{-1}$]. GW parameterization is based on E_{pot} (I) and MF (II) data.*

→ Tilt of northern hemispheric mesospheric jet towards lower latitudes with increasing height and of southern hemispheric jet towards the northern hemisphere.

Results: Temporal distribution of GW amplitudes

- Increasing height of the wind reversal with decreasing mean value of vertical velocity perturbation (not depending on temporal GW distribution).
- Decreasing strength of the mesospheric jet with increasing mean value of vertical velocity perturbation (smallest for polynomial distribution).

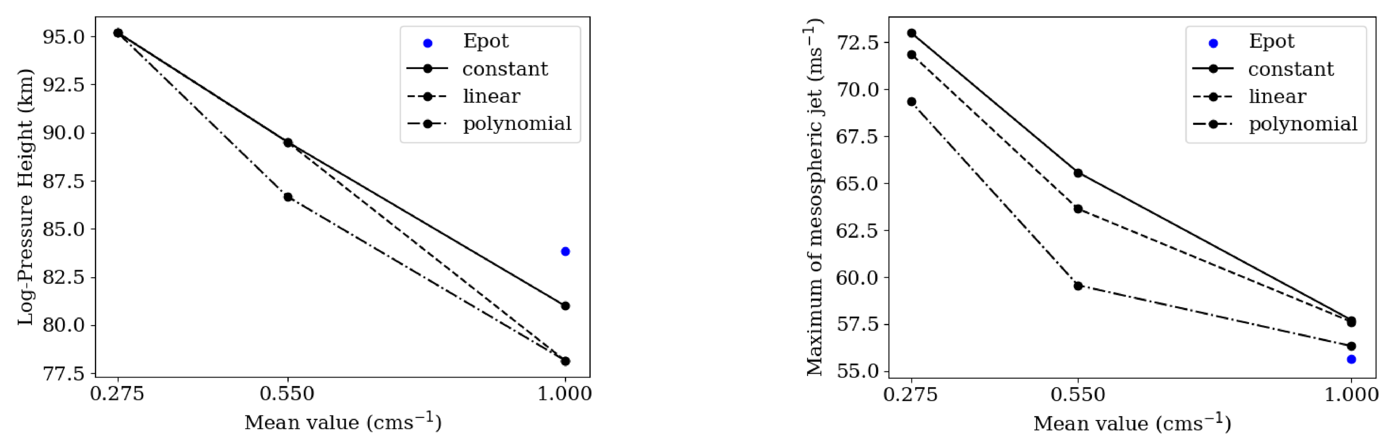

Fig. 5: Overview of the height of the wind reversal at 52.5°N (left) and the strength of the mesospheric jet (right) for each simulation.

Conclusion and outlook

- GW MF distribution leads to a more realistic background field (compare Figs. 4(Ia), 4(IIa) and Fig. 6).
- Further optimization through:
  - a composite of the simulations based on a mean of 1 cm s^{-1} with a minimum of 0.05 cm s^{-1}.
  - adjustment of the phase speed.
  - implementation of a non-linear GW parameterization

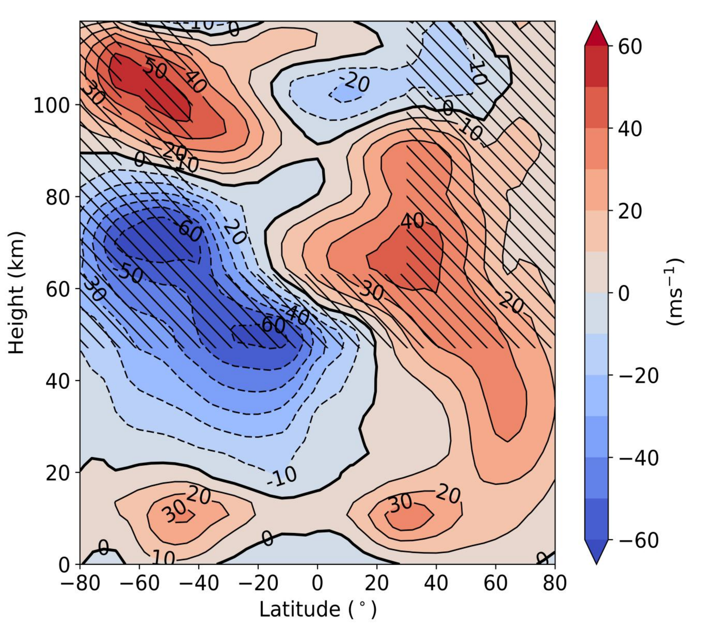

Fig. 6: *URAP latitude-height plot of the zonal wind*

References

Hertzog, A., Alexander, M. J. and Plougonven, R., 2012: On the Intermittency of Gravity Wave Momentum Flux in the Stratosphere. J. Atmos. Sci., 69, 3433–3448, https://doi.org/10.1175/JAS-D-12-09.1.

Lilienthal, F., Jacobi, Ch., Schmidt, T., de la Torre, A. and Alexander, P., 2017: On the influence of zonal gravity wave distributions on the Southern Hemisphere winter circulation, Ann. Geophys., 35, 785-798, https://doi.org/0.5194/angeo-35-785-2017.

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

Šácha, P., F. Lilienthal, Ch. Jacobi, and P. Pišoft, 2016: Influence of the spatial distribution of gravity wave activity on the middle atmospheric circulation and transport, Atmos. Chem. Phys., 16, 15755-15775, https://doi.org/10.5194/acp-16-15755-2016.

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