Project: **1097**
Project title: **Multiscale Dynamics of Atmospheric Gravity Waves**
Principal investigator: **Ulrich Achatz**
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The goal of the project is to improve the representation of sub-grid scale gravity wave (GW) effects on the resolved flow in atmospheric models. Using the transient GW parameterization (MS-GWaM: Multi-Scale Gravity Wave Model) that has been successfully implemented to a high-top global model (UA-ICON) in previous years, the main tasks of this year include (1) investigation of the impacts of transient GW dynamics on the intermittency of parameterized GWs as well as on the simulated mean circulations, such as seasonal evolution of stratospheric polar vortex and (2) further extension of MS-GWaM implemented in UA-ICON to allow for lateral propagation of GWs (the latter is on-going and to be continued next year). In addition to these UA-ICON/MS-GWaM based modeling work, (3) the PincFloit model, which has been used for GW-resolving simulations in the project, is further developed in several aspects, e.g., implementation of semi-implicit time integration scheme. Results regarding (1) are reported here, which have been submitted to Journal of the Atmospheric Sciences (Bölöni et al., 2020; Kim et al., 2020).

In the transient GW dynamics, GWs persistently interact with the mean flow during their propagation, being affected by temporal variations of the flow. Such dynamics are not well known in particular when the mean flow varies on long time scales. Performing 8-month simulations of 8 cases initialized on 1 May for the years of 1991–1998 using the R2B4-resolution UA-ICON with MS-GWaM, we observed a signature of interaction between seasonally varying mean flow and parameterized GWs. Figure 1 shows the monthly mean westward GW pseudomomentum flux in June, averaged for the 8 years, in the simulations using the transient GW parameterization (TR; Fig. 1a,c) and using the same parameterization but modified applying the steady-state assumption (ST; Fig. 1b,d) which is a common underlying assumption in all state-of-the-art GW parameterizations. It is found that the monthly mean pseudomomentum flux increases vertically in the lower stratospheric polar vortex in TR (Fig. 1a,b). This is a transient feature which cannot happen under the steady-state assumption and it is somewhat surprising as transient GW dynamics are often considered to average out over long time scales. We confirmed that the flux structure shown in Fig. 1a is associated with the temporal change of GW action density during the month (not shown), which can be explained by seasonal variation of the mean flow. As a result of the westward flux increase with altitude in Fig. 1a, the absolute pseudomomentum flux is ~50% larger in TR, compared to that in ST, at the altitude of 20 km (Fig. 1c,d), which is interesting in the context of the so-called missing drag, i.e., that at 60°S where GCMs as well as high-resolution operational models underestimate GW momentum fluxes by a factor of ~5.

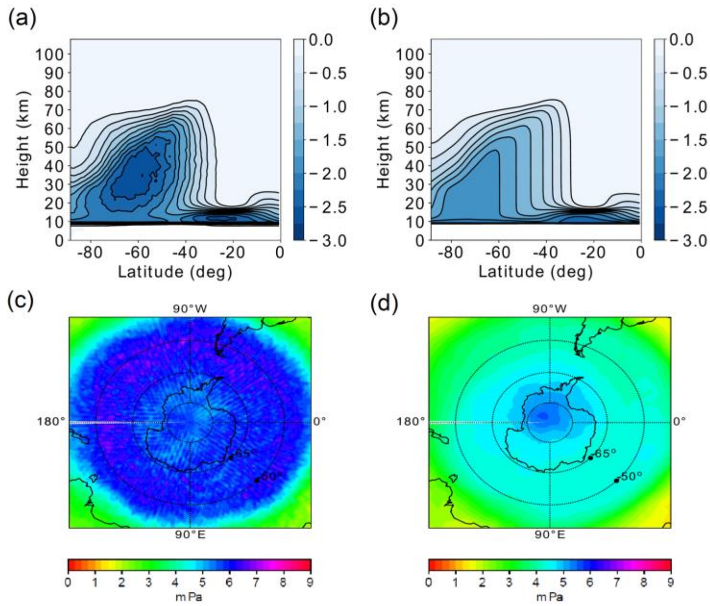

Figure 1. (a,b) Zonal-mean westward GW pseudomomentum fluxes averaged for June in the years of 1991–1998 and (c,d) absolute pseudomomentum fluxes at the altitude of 20 km over the Southern Ocean in (a,c) TR and (b,d) ST simulations.

The evolution of stratospheric polar vortex during the austral spring is investigated in the same experiment as above but complemented by 6 more cases (for the years of 2010–2015) to increase the sample size. Figure 2 shows the altitudes of polar jet maximum (dashed lines) along with the final warming dates as a function of altitude (solid lines). The former shows that weakening of the polar vortex in this season is slower by about 2 weeks in ST, as compared to the ERA5 reanalysis. This bias is alleviated by ~9 days during Day 280–315 (October–mid-November) in TR. Also, the final warming dates are found to be earlier in TR than in ST during that period, although they are still far late in both experiments, compared to those in ERA5 after Day 290. We note that the final warming dates in ICON can be largely improved by increasing the horizontal resolution from R2B4 (~160 km) to R2B5 (~80 km; not shown). The difference between the TR and ST simulations remains similar in this respect at the resolution of R2B5.

The intermittency of GWs is reproduced realistically by MS-GWaM. Figure 3 presents the Gini index, which is used here as a statistical measure of GW intermittency, along with the monthly mean GW pseudomomentum flux at 20 km in the tropics in TR. It appears that the Gini index is 0.5–0.6 in the convectively active regions where the mean pseudomomentum flux is large. This value is consistent with the previous superpressure-balloon observations at the same altitude in the tropics. In convectively less active regions, the Gini index is larger (GWs are more intermittent) than that in the active regions, due to less frequent occurrences of convections and GWs generated by them. In ST (not shown), the GW intermittency is overestimated in the tropics with the Gini coefficient being 0.7 or larger. The better representation of the intermittency in TR results from the realistic description of GW propagation in MS-GWaM allowing waves to disperse in time and altitude following their actual group velocities.

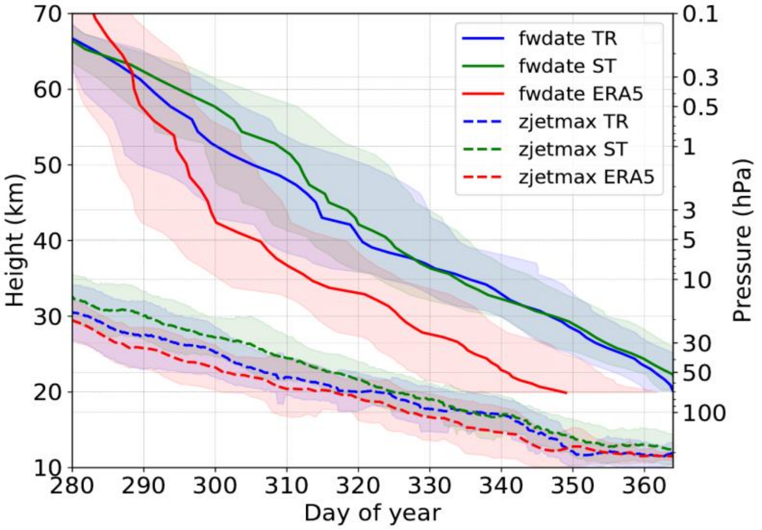

Figure 2. Stratospheric final warming dates as a function of altitude (solid lines), averaged over the years of 1991–1998 and 2010–2015, along with the time evolutions of the height of polar night jet maximum during the same period (dashed lines) in TR (blue) and ST (green) simulations and in ERA5 (red). The shaded bands indicate their variations in one standard deviations around the averages.

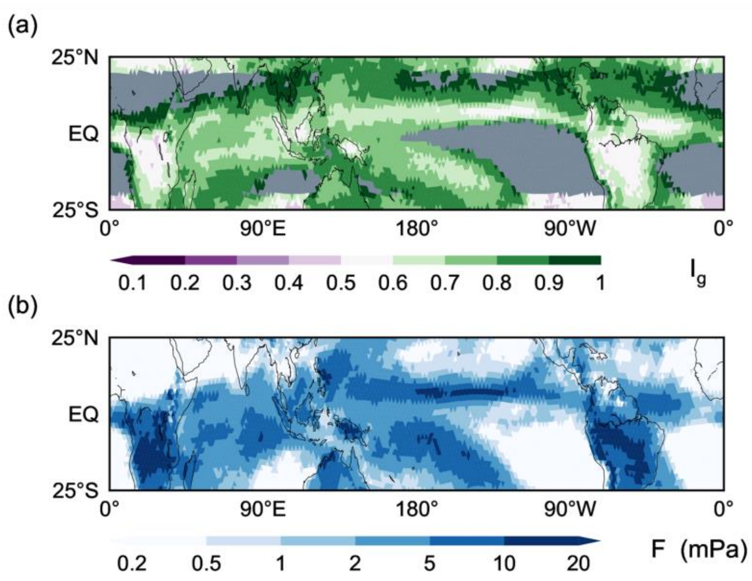

Figure 3. (a) Gini index for the pseudomomentum flux at 20 km in the tropics in December averaged over the 8 simulations (1991–1998) and (b) monthly mean pseudomomentum flux for the same period. Grey shading in (a) indicates the regions where GWs were not generated in any of the simulations.