Project: **1238**

Project title: **Middle atmosphere localized gravity wave forcing: Formation, impact and long-term evolution**

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We utilize the ICON version 2.6.3 with upper-atmosphere extension (UA-ICON) as distributed by the German weather service (DWD). So far, we have conducted a set of 30-year long (excluding the spin-up periods) time-slice experiments with the UA-ICON model by employing repeated annual cycles of SST, SIC, and greenhouse gases of the year 1985. This year is appointed as both the El-Nino Southern Oscillation and the Pacific Decadal Oscillation were in their neutral phase and no major volcano eruption has occurred, hence conditions in this year can serve as a useful proxy for the multi-year mean conditions and an estimate of their internal variability. First, a control (CTL) run is carried out where both the sub-grid scale orography (SSO) scheme and non-orographic GW scheme are used and two sensitivity tests where a) the SSO scheme is disabled (noSSO) and b) the non-orographic gravity wave (GW) scheme is disabled (noGWD).

We have studied the interaction between the resolved waves and parameterized gravity wave drag in the UA-ICON model [1]. The stratospheric polar vortex accelerates, cools and shifts poleward in both sensitivity runs. The frequency of sudden stratospheric warmings in the CTL simulation is 5.7 events per decade and drops to 1.7 and 4 events per decade in the noSSO and noGWD, respectively. In both sensitivity runs (particularly in noGWD), an enhancement in the resolved wave amplitude is found in the high latitude stratosphere and in the mesosphere and lower thermosphere (MLT) region in all latitudes. The magnitudes of the resolved waves responses are generally larger for noGWD than noSSO. Our results confirm the compensation mechanism in the UA-ICON model, whereby the perturbed forcings in the GW parameterization drag are often cancelled or compensated by a resolved large-scale wave driving of opposite sign.

In addition, we have studied the climatology of the stratopause height and temperature in the UA-ICON model and have examined them by comparing to a 11-year Microwave Limb Sounder (MLS) climatology. In addition, the elevated stratopause (ES) events occurrence, their main characteristics, and driving mechanisms in the UA-ICON model are examined in the above-mentioned sensitivity runs [2]. Our modelling results suggest that the contributions of both gravity waves and resolved waves are important in explaining the enhanced residual circulation following ES events compared to the SSW-only events but their contributions vary through the lifetime of ES events. We emphasize the role of the resolved wave drag in the ES formation: when the non-orographic GW drag is absent, the anomalously enhanced resolved wave forcing in the mesosphere gives rise to the formation of the elevated stratopause at about 85 km.

We also studied the teleconnection between the quasi-biennial oscillation and the Arctic stratospheric polar vortex, or the Holton–Tan (HT) relationship, that, according to simulations, weakens in a warmer climate or one with stratospheric aerosol intervention and compared them with the present-day climate [3] using large datasets such as NCAR's GLENS simulations. The weakening of the HT relationship under the RCP8.5 scenario is likely due to the weaker QBO wind amplitudes at the equator. In general, the changes in the HT relationship cannot be explained by changes to the critical line. The changes in the residual circulation (particularly due to the gravity wave contributions) are important in explaining the changes in the HT relationship. The allocated resources is also used to study the impact of climate change and stratospheric aerosol injection on the polar vortex morphology using GLENS and ARISE simulations [4].

References:

[1]: Karami, K., Mehrdad, S., and Jacobi, Ch. (2022), Response of the resolved planetary wave activity and amplitude to turned off gravity waves in the UA-ICON general circulation model, J. Atmos. Sol-.Terr. Phys., 241, 10596, https://doi.org/10.1016/j.jastp.2022.105967.

[2]: Karami, K., Borchert, S., Eichinger, R., Jacobi, Ch., Kuchar, A., Mehrdad, S., Pisoft, P., and Sacha, P. (2023), The climatology of elevated stratopause events in the UA-ICON model and the contribution of gravity waves, J. Geophys. Res.: Atmospheres, 128, e2022JD037907. https://doi.org/10.1029/2022JD037907.

[3]: Karami, K., Garcia, R., Jacobi, Ch., Richter, J. H., and Tilmes, S. (2023), The Holton–Tan mechanism under stratospheric aerosol intervention, Atmos. Chem. Phys., 23, 3799–3818, https://doi.org/10.5194/acp-23-3799-2023.

[4]: Karami, K. and Jacobi, Ch. (2023), The morphology of the stratospheric polar vortex under Stratospheric Aerosol Intervention scenarios, submitted to the international journal of climatology.