Project: **1371**

Project title: **Nested high-resolution UA-ICON simulations for NASA VortEx sounding rockets campaign at ALOMAR**

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Report period: **2023-05-01 to 2024-04-30**

Activity 2023/2024

During the reporting period, we used 14937 Node-hours (~84%) of the requested computing resources for simulations with the upper-atmosphere ICOsahedral Non-hydrostatic (ICON) (Zängl et al., 2015) general circulation model (UA-ICON) (Borchert et al., 2019). This total amount is distributed on preparatory simulations to obtain the adapted settings for the parameters of the non-orographic and orographic gravity wave (GW) parametrizations, and the target simulation covering the period of the NASA VortEx campaign.

We apply UA-ICON with numerical weather prediction (NWP) physics package in a global horizontal resolution of R2B7 (~20 km), with 250 levels up to a top height near 150 km and a vertical resolution of 600 m between ~40 – ~110 km. The non-orographic GW parametrization (Warner and McIntyre, 1996) is applied with the tuneable parameter C*=20 which we identified, after some test simulations, leading to the best atmospheric state in the mesosphere/ lower thermosphere (MLT) region. For the global domain of UA-ICON (DOM01), we specify the dynamics from ECMWF-IFS analyses up to a height of ~50 km. The global R2B7 simulation starts on February 1st 2023 with a model time step of 60 s. The first nest around Andoya Space (DOM02 with R2B8, ~10 km) started on March 21st 2023 and the subsequent nests start at an interval of 6 hours (R2B9, ~5 km; R2B10, ~2.5 km; R2B11, ~1.25 km). The simulation with all five domains active stopped on March 25th 2023 00:00 UTC. In the domain DOM05, the GW parametrizations and the convection parametrization are switched off.

The results of the first year were presented at the European Geophysical Union General Assembly 2024 (EGU24) (Kunze et al., 2024). We compare the results of the nested UA-ICON simulation to the Institute of Atmospheric Physics (IAP) Rayleigh/Mie/Raman (RMR) Lidar (Baumgarten, 2010) and Saura Medium-Frequency (MF) Radar (Renkwitz et al., 2018) measurements taken during the VortEx campaign. Figure 1 shows the time-averaged profiles of temperature, zonal and meridional wind of the five UA-ICON domains for the respective grid points nearest to the ALOMAR observatory in comparison to the RMR-Lidar, Saura MF (only for the winds), and ECMWF-IFS data. The shading around individual mean profiles indicates a range of +/- one standard deviation. The averaged profiles of temperature in all five UA-ICON domains behave very similarly, indicating a strong influence of the global domain on the temperature of the subsequently nested domains. UA-ICON shows a secondary temperature maximum in the mesosphere, not observed in the RMR-Lidar temperature. The profiles of UA-ICON zonal and meridional wind show a less coherent structure in the five domains, but the general shape is still very similar. The zonal wind of DOM05 is in better agreement with Saura MF radar compared to the global domain, although UA-ICON above 70 km shows large deviations from Saura MF, even in DOM05. The meridional wind of UA-ICON shows large deviations from Saura MF and RMR-Lidar measurements, starting above 50 km where the nudging to ECMWF-IFS is levelling off.

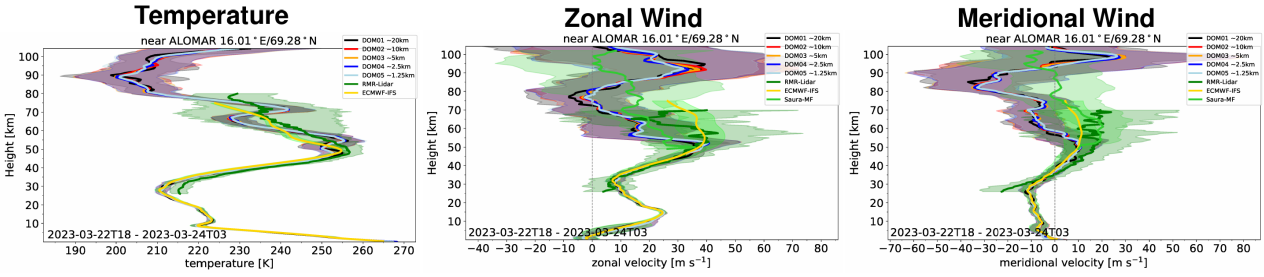

Figure 1: Vertical profiles near ALOMAR of temperature, zonal and meridional wind, averaged from March 22nd 18:00 UTC to March 24th 03:00 UTC for five domains of UA-ICON, RMR-Lidar, Saura MF-Radar (only winds), and ECMWF-IFS data; shading around individual profiles indicates the standard deviation.

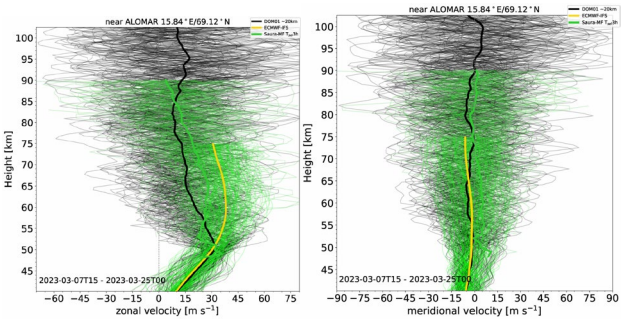

Figure 2: Height section near ALOMAR of zonal (left) and meridional wind (right) for UA-ICON at global resolution (~ 20 km) and Saura MFdata from March 07 15:00 UTC to March 25 00:00 UTC. The MF-Radar data is sub-sampled at 3-hour intervals to match the output interval of the UA-ICON data. Individual profiles (thin lines) and time-averaged data (thick lines) for UA-ICON (black), Saura MF-Radar (green), and ECMWF-IFS (dark yellow).

Comparing Saura MF radar averaged wind profiles for a larger period from March 7th – March 25th 2023 to UA-ICON DOM01 (R2B7, ~20 km) shows a better agreement between model and observations (Figure 2).

Figure 3 shows the time series of the data shown in Fig. 1 for selected height levels between ~60 and ~90 km. The temperature fluctuations of the RMR-Lidar, given at a 5-minutes time resolution, are during daylight much larger than UA-ICON DOM05 output at a time interval of 3 minutes. During the night, the variability of both is in better agreement. The Saura MF zonal and meridional wind data show a tidal signature at ~80 km, which is also visible in the UA-ICON data approximately 10 km higher at ~90 km.

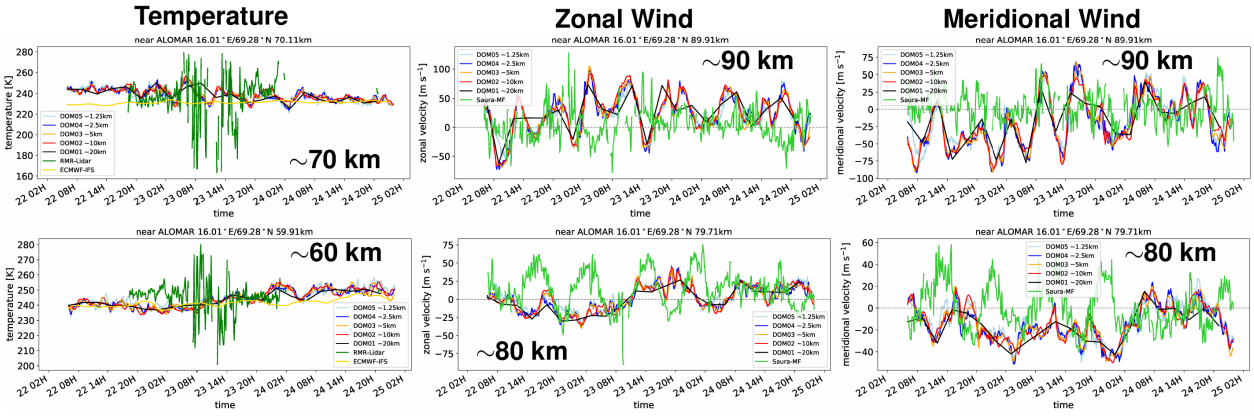

Figure 3: Time-series of the data presented in Figures 1 at selected height levels as indicated.

This first comparison of nested UA-ICON data to IAP observations at ALOMAR shows, to a certain extent, an acceptable agreement with the measurements. However, at some height regions in the upper mesosphere for the shorter period, there are large deviations of the UA-ICON from the measurements, even for the nest with the highest horizontal resolution.

In the next steps, the settings for the non-orographic GW parametrization need fine-tuning for the nests DOM02 to DOM04, to achieve a gradual decrease in parametrized gravity wave flux. In addition to repeating the simulations for the March 2023 period with new settings for the non-orographic GW parametrization, a period in August 2018 during the Northern hemispheric summer, should be simulated as an example of a dynamically less perturbed period.

References

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