Project:	**1376**
Project title:	**IFCES2: Cloud Microphysics Application Case**
Project lead:	**Dr. Fabian Senf (TROPOS)**
Allocation period:	**1.7.2023 - 30.6.2024**

Overview

The compute project bb1376 contributes to the BMBF-funded project IFCES2 in which new algorithms for improved parallelizability and scalability are developed and applied to a complex cloud microphysical scheme concurrently coupled to ICON atmosphere. The application case "cloud microphysics" is symbolic for the potential level of complexity to be gained and flexibility needed for future ESMs. The IFCES2 objective considered here is creating a unique scientific dataset on the development of a tropical storm over the Atlantic Ocean. To achieve this objective, reference simulations of temporal developments of different tropical storms (e.g. Hurricane "Paulette" in 2020) need to be generated with different simulation methods, and evaluated against a multitude of observational data, especially against modern satellite measurements.

Resource Utilization

At the time this report was written, approximately 85% of the granted computing resources were being used by project members, while 15% expired unused. Resources were used by four scientists from three different institutions contributing to cross-institutional collaboration. The largest amount of resources went into the creation of ICON data in limited-area mode.

Scientific Results

ICON-NWP simulations (v2.6.6) have been performed over the Atlantic ocean to simulate the temporal evolution of a tropical hurricane. In the first half of the allocation period we have been experimenting with the ICON setup in terms of domain extent and parameter settings. Finally, we came up with the relative large setup shown in Fig. 1 (upper row) with equivalent horizontal grid spacing of 5 and 2.5 km. The number of vertical levels was set to 70 for the reference run reaching up to 34 km altitude. For this setup, we also implemented the option for time-variable sea-surface temperatures which was not available for limited-area setups with multiple nests. Forward integrations were done for 8 to 10 days which is significantly longer than initially planned. However, hurricane predictions were unexpectedly quite reliable with this setup even for longer periods. Hence, in comparison with the initial cost estimation from the last allocation request an ICON simulation with the described setup takes around 800 nodehours which is around a factor of seven more than initially planned. Storage requirements increased by a similar amount. We like to mention that our modeling activities were severely hampered by the very limited storage space currently available in the project and careful data handling has taken up quite some human resources. Compared to the original request, we shifted order and did sensitivity runs of one selected setup (golden case) first. For the simulation of hurricane

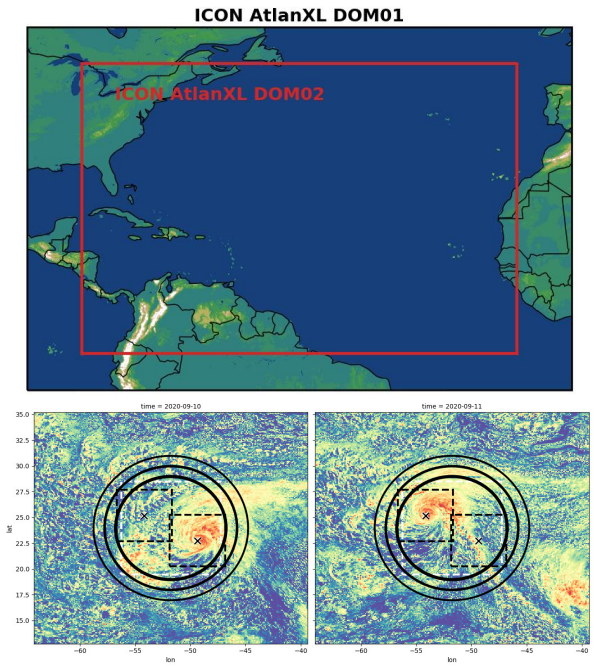

Figure 1: (upper row) One-way coupled ICON setup with two nests covering the tropical part of the Atlantic ocean. The outer domain 1 has a horizontal resolution of R2B9 ($\sim$ 5 km), the inner domain 2 is configured to have R2B10 ($\sim$ 2.5km). (lower row) Visualization of the selection of a hurricane-centric setup. Color shading shows liquid water path. Two time slots, one day apart are shown and the dashed rectangles are located at the hurricane centers at the respective times. The solid circles shows the finally chosen circular one-way coupled ICON setup with three nest refinements with resolutions of R2B11 to R2B13.

Paulette initialized at 7 September 2020 we studied sensitivities to the number of vertical levels (50, 70, 100) and to the number of cloud condensation nuclei. Scientific analysis of these runs is currently ongoing. Moreover, we started to build up a time-lagged ensemble of hurricane simulations, but not with a time lag of one day, but three days. So far this activity has not yet been completed.

Based on the golden case simulation of Paulette, a hurricane-centric ICON setup for further downscaling was designed. Considerations that went into this setup are visualized in Fig 1 (lower row). We have chosen a localized setup of three concentric circles that cover the extent of the hurricane at two different times that are 24 hour apart. We decided for one-way coupling of three limited area nests that go down to $\sim$ 300 m. We successfully implemented the pre-processing chain for this setup with need for later flexibility in mind. After some trouble shooting, first successful six-hour integrations were conducted with this setup just before this writing. We will prioritize the further development of this hurricane-centric simulation type. Some potential improvements will be laid out in the next allocation request.

A significant amount of time was also invested to evaluate the ICON simulations with available observational data. We concentrated on satellite data, considering products from CMSAF and CERES together with original Meteosat data. The project also supported the update of our Synsat interface which is used to input ICON data, to transfer the input to the forward operator RTTOV and finally get synthetic satellite data. This work is also ongoing and may be beneficial for several other ICON-related projects. Finally, the resources in project bb1376 have also been used to support batch analysis of nextGEMS data during the nextGEMS/EERIE/WarmWorld hackathon in Hamburg, March 2024.