Project: **1235**
Project title: **NextGEMS**
Principal investigator: **Daniel Klocke**
Report period: **2021-11-01 to 2022-10-31**

NextGEMS cycle 2 with ICON and preparation for cycle 3

We performed the cycle 2 simulations for the nextGEMS project with the coupled ICON model at 5 km and 2.5 km horizontal resolution and for the first time were able to run the coupled ICON model at 1.2 km resolution for a few days[1]. A lot of the compute resources went into the preparation and debugging of the model for the cycle 2 simulations and were used for the preparation of the cycle 3 simulations. For the cycle 2 simulations, the model configuration was ported to Levante, the ocean vertical coordinate was updated, new ocean spin-ups were done, we implemented a new radiation scheme, land initialisation was changed and the treatment of river runoff was adapted to work for high-resolution.

All simulations where analysed by about 100 scientists from all over Europe in the NextGEMS hackathon in Vienna[2]. A focus of this hackathon was a Knowledge Coproduction component focused on wind energy production online diagnostics. Diagnostics for example wind power production were implemented, and output verified against real world power production.

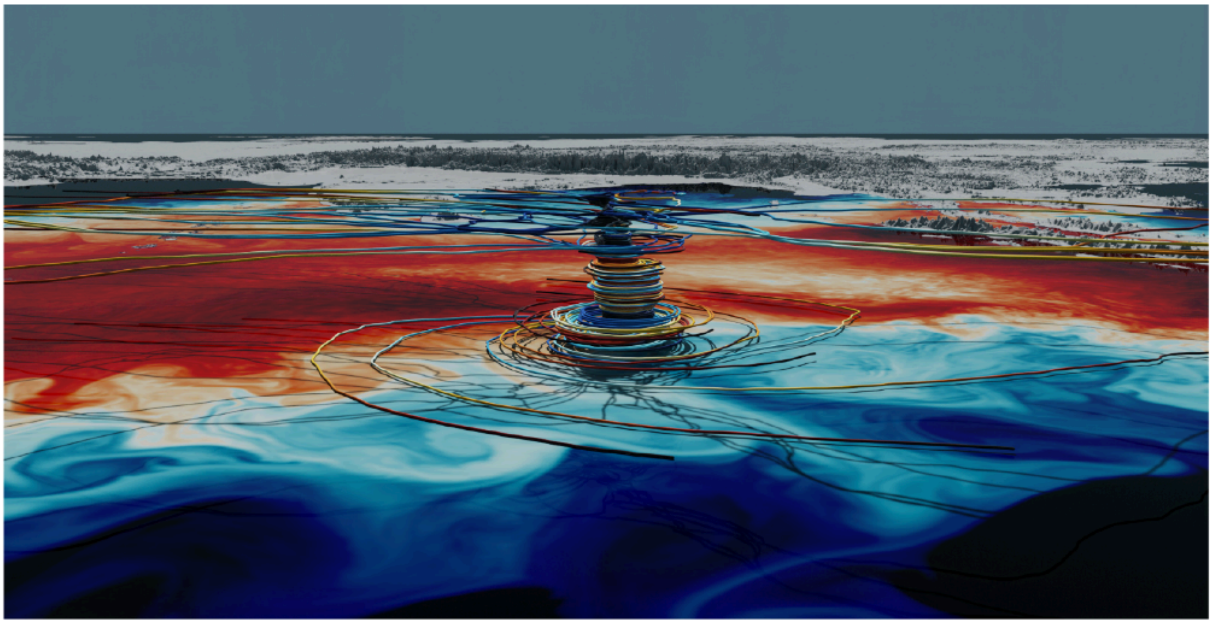

Figure 1: A low pressure system in the Southern Ocean from the 2.5 km coupled NextGEMS run: Wind (streamlines) and surface temperature (shading) are shown (Hohenegger et al. 2022)

The performance of the simulations performed in this project are summarised in the table below and compared to performance on Mistral (published in Hohenegger et al. 2022) and numbers will serve as basis for the renewed compute time application

[1] on MPI-M news site:
https://mpimet.mpg.de/kommunikation/im-fokus/die-zukunft-der-klimamodellierung-die-kilometerskala
https://mpimet.mpg.de/kommunikation/aktuelles/single-news/technischer-meilenstein-erreicht-globale-erdsystem-simulationen-mit-12-km-aufloesung

[2] https://nextgems-h2020.eu/

Grid spacing	Machine	Nodes	SDPD
5 km	Mistral	420 (300 A, 120 O)	17
"	Levante	600, 24A:8O	126
"	Levante	420, 24A:8O	96
"	Levante	400, 24A:8O	90
"	Levante	200, 24A:8O	48
"	Levante	100, 24A:8O	24
2.5 km	Levante	600, 24A:8O	20
1.25 km	Levante	900, 24A:8O	2.5
1.25 km (A)	Levante	908	4
1.25 km (O)	Levante	1024	97
"	Levante	2048	179

Mirrored NextGEMS runs at 10 km resolution for multiple decades

Long integrations with a reduced resolution at 10 km for atmosphere and ocean were partly (20 years) performed as part of this compute project and are also contributing to NextGEMS. These relative long integrations were possible, as a throughput of more than 1 Simulated Year per node was possible with 400 nodes of Levante. For further details also refer to bu1213 (CliCCS A6), where also compute resources were used for these simulations.

Aerosols in storm-resolving simulations:

Also as part of the nextGEMS project, the MACv2-SP aerosol plume model, which provides an idealised representation of anthropogenic aerosol radiative properties and the associated change in cloud droplet number was implemented into ICON. Four 40-day global storm-resolving simulations with a horizontal grid-spacing of 5km, capable of explicitly representing deep convection were conducted. A control run using pre-industrial levels of aerosols was run alongside simulations that include anthropogenic aerosols at present-day levels. Two additional simulations were conducted which isolate the impact of aerosol-cloud interactions and aerosol-radiation interactions.

The simulations exhibit a strong sensitivity to aerosol, with robust regional modifications to the diurnal cycle of convection, clouds, radiation and precipitation, consistent with previous work

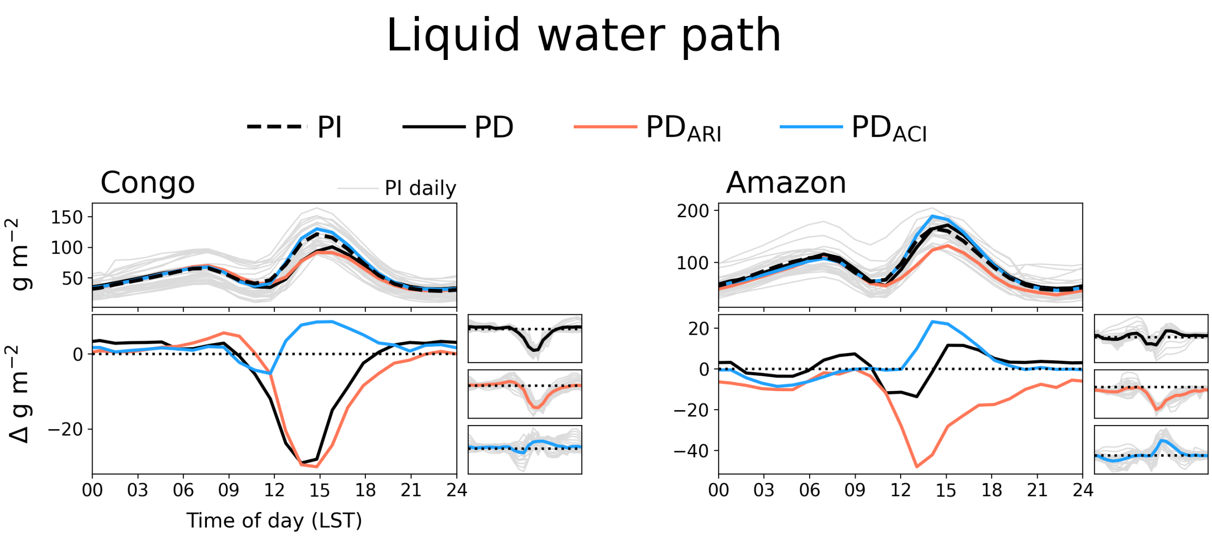

Figure 2.) Simulated mean diurnal cycle of the liquid water path response to anthropogenic aerosol perturbations in two regions dominated by deep convection: the Congo basin in Central Africa and the Amazon rainforest in South America. Lines correspond to the pre-industrial (PI), the present-day (PD), and the PD run separated into the contributions from aerosol-radiation interactions (ARI) and aerosol-cloud interactions (ACI).

using observations and high-resolution, limited-area simulations. In addition to the local response, our simulations are able to capture the effects of buffering or enhancement due to the non-local or large-scale response to the aerosol perturbation. From a global perspective, we demonstrate that anthropogenic aerosol has significant impacts on surface fluxes, cloud liquid water path, cloud coverage, and top-of-atmosphere radiation.

Results were represented at international conferences, publications are planned and this configuration is also planned to be further used in NextGEMS cycle 3, and multi-decade NextGEMS simulations.

Publications:

- Mauritsen, T., Redler, R., Esch, M., Stevens, B., Hohenegger, C., Klocke, D., Brokopf, R., Haak, H., Linardakis, L., Röber, N. and Schnur, R., 2022. *Early Development and Tuning of a Global Coupled Cloud Resolving Model, and its Fast Response to Increasing CO2*. Tellus A: Dynamic Meteorology and Oceanography, 74(1), pp.346–363. http://doi.org/10.16993/tellusa.54
- Hewitt, H., Fox-Kemper, B., Pearson, B., Roberts, M. and Klocke, D., 2022. *The small scales of the ocean may hold the key to surprises*. Nature Climate Change, 12(6), pp.496-499. https://www.nature.com/articles/s41558-022-01386-6
- Hohenegger, C., Korn, P., Linardakis, L., Redler, R., Schnur, R., Adamidis, P., Bao, J., Bastin, S., Behravesh, M., Bergemann, M. and Biercamp, J. et al. 2022. *ICON-Sapphire: simulating the components of the Earth System and their interactions at kilometer and subkilometer scales*. Geoscientific Model Development Discussions, pp.1-42. https://gmd.copernicus.org/preprints/gmd-2022-171/
- Gutjahr, O., Jungclaus, J.H., Brüggemann, N., Haak, H. and Marotzke, J., 2022. *Air-sea interactions and water mass transformation during a katabatic storm in the Irminger Sea*. Journal of Geophysical Research: Oceans, 127. https://doi.org/10.1029/2021JC018075
- Segura, H., C. Hohenegger, C. Wengel, B. Stevens, 2022. *Learning by doing: seasonal and diurnal features of tropical precipitation in a global-coupled storm-resolving model*, submitted to Geophysical Research Letters