Project: **1135**

Project title: **3-d cloud-radiative effects on midlatitude cyclones and their predictability**

Principal investigator: **Aiko Voigt**

Report for allocation period **2020-01-01 to 2020-12-31**

Project overview

This project studies the dynamical impact of radiative transfer in numerical weather prediction (NWP) models, with a focus on the impact of 3-dimensional (3-d) cloud-radiative effects. This work is motivated by recent work on the impact of 3-d radiative effects on cloud organization and the current progression towards high- resolution climate modeling where 3-d radiation transfer might become important. The main focus is the dynamical impact of cloud-radiative effects on midlatitude cyclones through idealized baroclinic life cycles simulations. Through baroclinic life cycle simulation with ICON-NWP (40 km horizontal resolution), Schäfer and Voigt (2018) demonstrated that radiation weakens idealized midlatitude cyclones, cutting their maximum strength in half. Cloud-radiative effects were found to substantially contribute to the radiative weakening. However, it has remained unclear which mechanisms underlie this impact, and to what extent model uncertainties in cloud-radiative effects contribute to the dynamical impact. This calls for a more systematic study on the impact of cloud-radiative effects on midlatitude cyclones and their predictability. The project addresses this need by means of ICON simulations of midlatitude cyclones and different treatments of cloud-radiative interactions. The project contributes to project B4 of the SFB/TRR “Waves to Weather” funded by DFG until June 2023 and employs one PhD student at KIT. It also involves colleagues from LMU Munich.

Project progress to date

Due to delays in the visa procedure and further complications related to Covid-19, the PhD student unfortunately could only start on June 15, 2020 (the originally anticipated start date was Feb 1, 2020). This led to a substantial delay of the project and meant that a large part of the allocated for 2020 expired. However, since the start of the PhD student we have made good progress and are confident to get up to full speed soon.

So far, the student has made himself familiar with the ICON model. After this, we have repeated and confirmed the results of the global ICON simulations of type-1 baroclinic lifecycles of Schäfer and Voigt (2018), and we have also repeated these simulations in an extratropical channel setup (meridional width of 60°, center at 45° N) at 20 km resolutions (so higher than in Schäfer and Voigt, 2018). The extratropical channel setup showed general consistency with the global results, although the cloud-radiative impact was found to be smaller (Fig. 1).

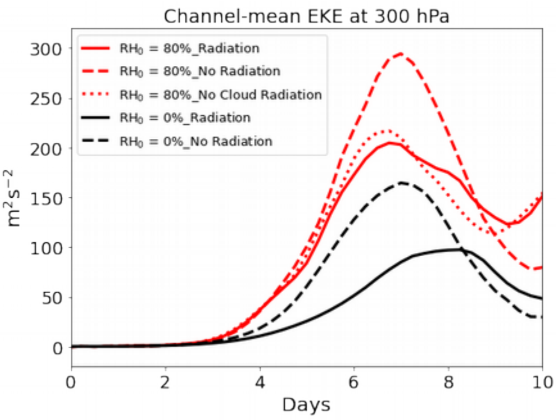

Fig. 1: *Time evolution of the upper level (300 hPa) channel mean eddy kinetic energy in the extratropical channel setup for different treatments of radiation and different levels of initial moisture content.*

However, the extratropical channel used so far spans all longitudes and is too computationally expensive for the envisioned set of ICON-NWP simulatons at 2.5 km horizontal resolution. We are therefore working towards a channel setup that spans only 60 degrees of longitude with zonally-periodic boundary conditions, based on which we can run wave number-6 lifecycles. This setup is so far not available in ICON as we have confirmed with colleagues from MPI-M and DWD. Yet, such as setup appears achievable by building upon the cylinder grid available for the ICON ocean component and the torus grid available for the ICON atmosphere component. This work is ongoing and, upon completion, will provide us with a setup for idealized simulations with a uniform grid and a substantially lower computational cost compared to the “global” channel.

As part of the above process we have also tested the possibility of using a shrinked sphere. While we were able to technically run such simulations, the simulations have led to idealized cyclones that we found difficult to relate to actual cyclones on Earth. We suspect this has to do, at least partly, with the scale change and the fact that the cyclone has less “space” in the extratropical regions of the shrinked sphere. We therefore dropped the idea of a shrinked sphere.

We remain confident to finish the extratropical channel setup before the end of 2020. To do so, we are in contact with colleagues from MPI-M, DWD and W2W. However, in the case that we cannot generate the setup, we will shift to another approach and will simulate baroclinic life cycles through global extratropical channel simulations at 10 km (which is relatively inexpensive) and will nest down to 2.5 km resolution in a subdomain.

As a result of the delay and required development work, only 430 Nh of the total granted 14,000 Nh were used (10,100 Nh expired). Also, we have used less work than anticipated, and likely will not need archive and docu this year. In contrast, our needs for 2021 will be much higher as reflected in the 2021 request.

References

Schäfer, S. A. and A. Voigt (2018): Radiation weakens idealized midlatitude cyclones. Geophys. Res. Lett., 45, 2833-2841, doi: 10.1002/2017GL076726.