Project: bb1152 ClimXtreme
Project title: ClimXtreme: Climate Change and Extremes (ClimXtreme)
Project leader: A. Hense, C. Kottmeier, J. Pinto, U. Ulbrich, F. Kaspar
Project Funding: BMBF
Allocation period: 1.1.2020 - 31.12.2020

Used Resources at DKRZ in 2020 (by Oct. 30th 2020)

	Work space	Computation time
Granted for 2020	144050 (GiB)	411432 Nh
Used by end-October 2020	120785 (GiB)	327760 Nh
Remaining	23265 (GiB)	83672 Nh

In 2020 resources were granted to four subprojects A1, A3, A6 and A9 of ClimXtreme Module A for the full twelve month period Jan-Dec. and to subproject Module B1.3 for the six month period Jul. - Dec. Those reports are given below. As indicated by the accumulated resource shown in the above table, the use of those was well in plan.

Scientific activities conducted during the report time 2020 in Module A

<u>A1 SEVERE</u>

The aim of SEVERE is to derive robust estimates for precipitation events in present and future climate with return periods beyond the range, which can be derived from observations (e.g. < 100 years). For these event set the changes and variability of the relevant small-scale (e.g. convection conditions, heat and moisture fluxes, etc.) and large-scale processes (weather- and teleconnection pattern, as well as large scale moisture advection) are analysed. To derive robust estimates and classifications, a sufficient number of events is needed. Within MiKlip a unique large ensemble of consistent regional climate simulations with COSMO-CLM have been calculated. They cover about 13.000 simulation years for the period 1900 - 2030 (called LAERTES-EU, Ehmele et al., 2020) with a horizontal resolution of 25 km. For the core period, 1960 - 2020, each calendar year is sampled up to 200 times by the ensemble simulations, allowing for a robust estimation of the trends and variability of high-return-period events. But, For a sufficient representation of the regional and local scale processes, simulations on the convection permitting scale (~3km resolution) are required. To achieve the goals, the tasks are divided in three phases.

1. Event set for extreme precipitation events based on observations and re-analysis driven simulations including long-term high-resolution events. Following steps have been performed: i) an index covering amount, intensity, duration and affected areas of precipitation has been applied to observations from E-OBS and HYRAS as well as to ERA40/ERAInterim driven simulations at 25 km resolution from the LAERTES-EU ensemble as well as a further downscaling simulation, down to 3 km resolution, performed within the CORDEX FPS Convection. ii) an evaluation and categorization of the most extreme events for the period 2000 - 2016 has been performed, which provides suitable criteria to determine extreme episodes from the LAERTES-EU ensemble (cf. Figure 2; publication in preparation).

2. The LAERTES-EU ensemble has been evaluated that it is able to reproduce statistical properties of extreme precipitation events, including intensity distributions as well as the variability and trends on various time-scales. The results are published in Ehmele et al., 2020. Figure 1 depicts the long-term trend and variability of the 99th precipitation percentile in Mid-Europe. Within this project the LAERTES-EU ensemble has been updated and supplemented by ten regional decadal prediction simulation for the period 2020 - 2030 (~5000 nh).

3. Based on the results from phase 1 and 2 the methods are applied to LAERTES-EU to detect the strongest precipitation events. For this event set an episodic downscaling to convection permitting scales is performed, to assess the contributions from local scale processes. These episodic simulations just for the most extreme events reduces the required resources to a low and manageable level. Phase 1 has been mostly finished. We currently consolidate the results for a publication. Phase 2 is finished as well (Ehmele et al., 2020). We currently prepare the third phase, which is expected to start in the 4th quarter of 2020. Then the requested downscaling simulations will be performed. The requested downscaling of the ERA5 simulations were delayed due to conversion errors detected (This work was done outside the project). Meanwhile, other groups outside ClimXtreme currently produce the intended simulation.

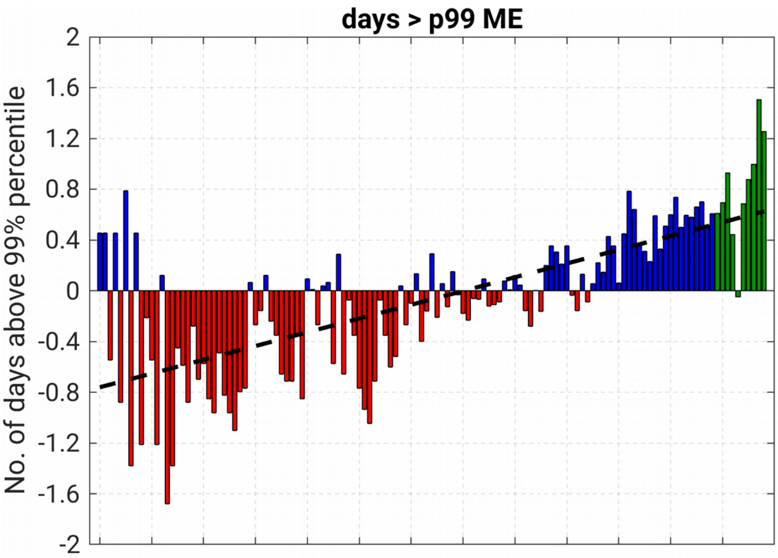

Figure 1: Deviation of the ensemble mean for the large LAERTES-EU RCM ensemble (12500 simulation years) of the yearly number of days above the 99th percentile (wet days only) of daily spatial mean precipitation compared to the climatological mean 1961 - 1990 for Mid-Europe. Red bars indicate negative anomalies (less days); blue bars indicate positive anomalies (more days). The predictions (2018 - 2028) are given in green. The black dashed line indicates a linear regression. From Ehmele et al. (2020).

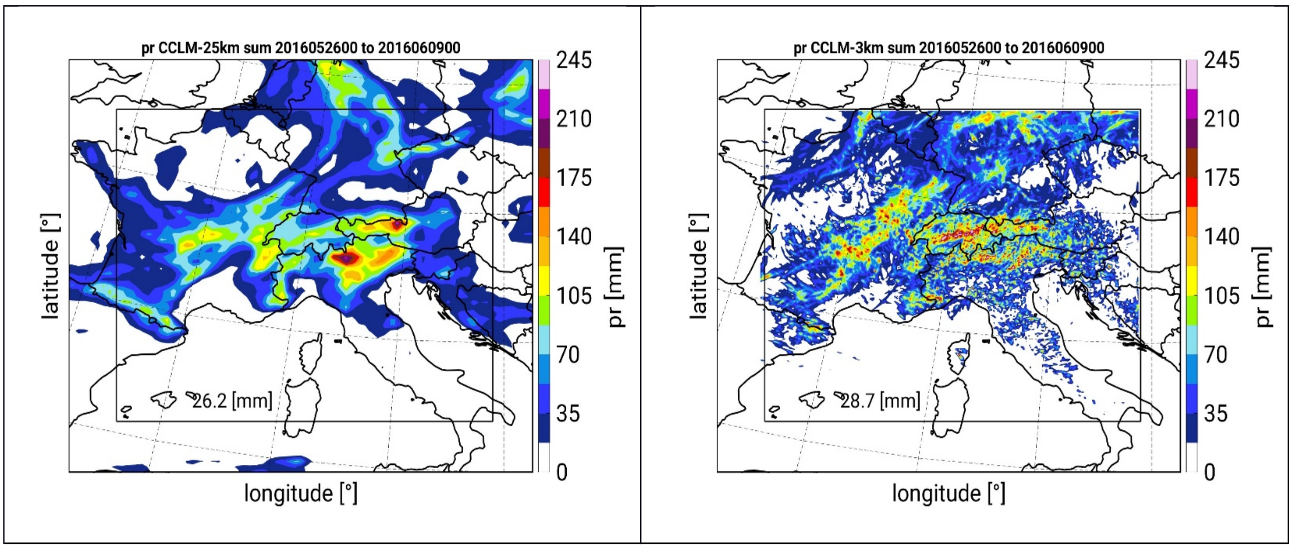

Figure 2: Extreme precipitation episode 26 May - 9 June 2016. Comparison of two CCLM simulations with boundary conditions from ERAInterim. Upper left: 25km horizontal resolution, upper right at 3 km resolution.

The LAERTES-EU data set is valuable and necessary not only for the SEVERE project, but also for other projects within ClimXtreme and beyond. It is therefore, important to save the core data of this ensemble in the HPSS archive at DKRZ beyond the lifetime of the archive space MiKlip computing-time project bb0849, which ends at the end of this year. This would require assigning these data from bb0849 to the ClimXtreme computing-time project bb1152. The core amount ~ 1.6 PB, essential to maintain the ability to do episodic downscaling.

A3 ArcClimEx

First steps within the ArcClimEx project included the identification of Euro-Atlantic atmospheric circulation regimes and the identification of potential links to Arctic Sea Ice. All analyses were done on the DKRZ server Mistral. This also guaranties direct access to a variety of model data, especially to the project internal X-CES database and plugins. Using ERA5 reanalysis (1979-2018) and assuming 5 Regimes, significant changes in the occurrence probabilities of winter regimes can be observed in response to Arctic Sea Ice changes (see Figure 3). However, when isolating the Sea Ice forcing effect by investigating e.g. coordinated sea ice sensitivity experiments from the CMIP6-subproject PAMIP, significant differences in occurrence probabilities between low and high ice simulations are absent (see Figure 4). These PAMIP ECHAM6 T127 simulations were forced with different combinations of future, present day and preindustrial sea ice and SST forcing. As these forcings partly differ significantly from the ERA5 period, they are not well suited when comparing different model simulations with results from the ERA5 data analysis. This also applies for the upcoming analysis in the context of climate extremes.

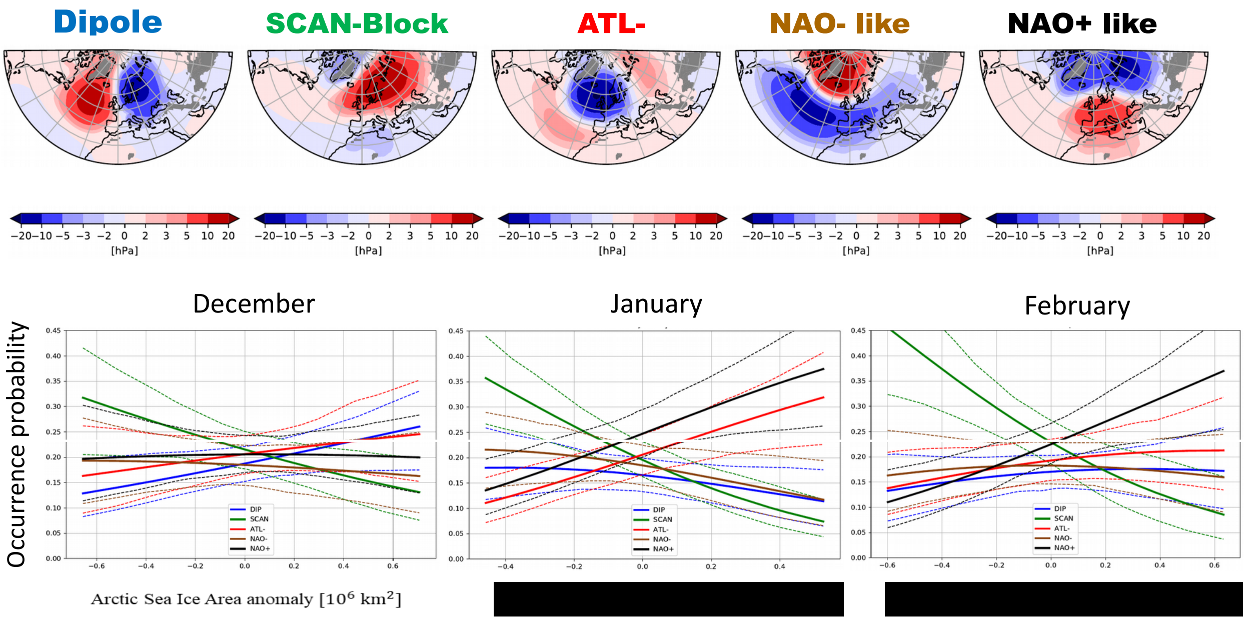

Figure 3: Five circulation regimes identified by kmeans applied to ERA5 SLP data for winter months (DJF, above). ERA5 occurrence probability of each regime in dependence on Arctic Sea Ice Area anomalies for each month of winter season (below). Significant changes in occurrence probabilities are especially pronounced for SCAN and the NAO+ pattern in January and February.

These recently performed analyses support the usefulness of the planned simulations. ECHAM6 standalone T127 time slice simulations forced under high sea ice conditions (average 1979-1983) and low ice scenarios (average 2005-2009) were planned to be performed respectively. To allow for an easy set-up of model simulations, these should be performed with the ESM-tools software. ESM tools is a software product developed and maintained at AWI as part of the HGF-funded ESM project (Advanced Earth System Modelling Capacity) with the aim to provide a common framework for running and organizing coupled or standalone model experiments. As this software is still in an ongoing development and testing process, during set-up phase of the planned simulations several bugs (especially restart problems) have been identified and fixed in close collaboration with the ESM developers. In addition, due to the Corona situation, the training phase to the whole DKRZ system in general and ESM tools in particular of the project scientist J. Riebold took longer than under normal conditions. Due to the above mentioned reasons, the start of the planned simulations has been delayed until the beginning of October. Currently, one of the aforementioned ECHAM6 T127 simulations is running since beginning of October. The second simulation will start subsequently and will be finished until the end of the year. In order to use the granted resources as effectively as possible, we plan to extend these two simulations to 150 years (instead the planned 100 years). This increase of ensemble size will allow a more reliable application of the statistical methods for the detection of signals against the background of the internal variability of the climate system. Additional ensemble simulations with ECHAM6-SWIFT (ECHAM6 coupled to the fast ozone module SWIFT) with T127 resolution were planned in the previous application, since including interactive stratospheric ozone chemistry in ECHAM6 leads to the improvement of changes in the occurrence of atmospheric circulation regimes (and related occurrence of extreme events) related to decreasing Arctic sea ice (Romanowsky et al., 2019). Since the implementation of ECHAM6-SWIFT into the ESM-tools has not been accomplished yet, we postpone the ECHAM6-SWIFT simulations.

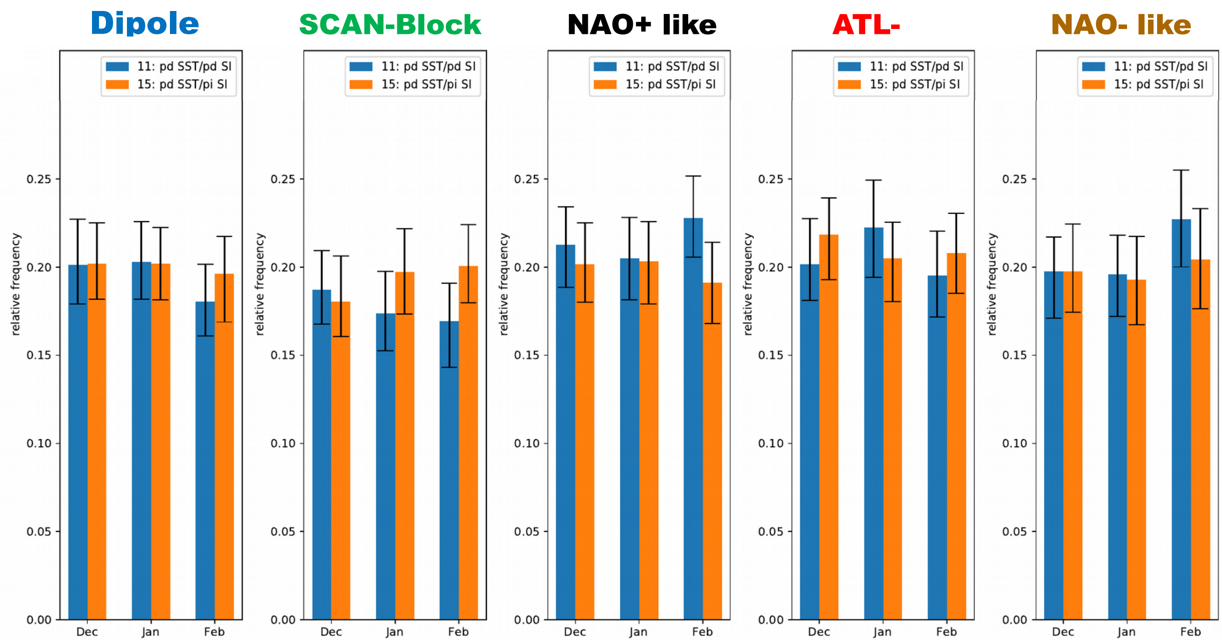

Figure 4: Comparison of relative frequency of regime occurrence between two PAMIP ECHAM6 T127 simulations for the different winter months (see Figure 3 above). Exemplary simulations shown in this plot are: PAMIP setup 1.1 forced with present day SST and Sea Ice (blue bars) and PAMIP setup 1.5 forced with preindustrial Sea Ice and present day SST (orange bars).

<u>Resource utilisation:</u>

Until the 9th October 2020, 2020 Node-h have been consumed from the allocated resources (mostly for test runs in connection with ESM tools). In the beginning of October 2020 one of the two aforementioned 150yr-long ECHAM6 simulations has been started and is running (expected compute time of ~19800 Node-h). The second 150-yr-long ECHAM6 simulation will be directly started afterwards and will be finished until the end of the year (~19800 Node-h). Despite the above mentioned delays, about 73% of the allocated subprojects budget (55950 Node-h) will be finally consumed. The planned ECHAM6-SWIFT simulations have been postponed, since the implementation of ECHAM6-SWIFT into the ESM-tools has not been accomplished yet.

A6 CyclEx

In project A6 the aim is to (1) analyze cyclone statistics and (2) compare the impact of diabatic processes and large-scale environmental processes on extreme cyclones, both for recent and future climate. To this end, several datasets are used: ERA5, CMIP6 historicals, ScenarioMIP, HighresMIP, MPI Grand Ensemble and Miklip. The data should be prepared in order to obtain cyclone tracks using the tool Zykpak in Freva. From all the datasets, the mean sea level pressure is taken and either regridded (in case of a low resolution) according to Pinto et al. (2005) or spectrally interpolated (in case of a high resolution) towards a common grid for relatively fair comparison of the results. After the preparation, the cyclone tracks are obtained with Zykpak in Freva. The impact of diabatic and environmental processes on cyclone dynamics in recent and future climate is evaluated using the pressure tendency equation (PTE, Fink et al., 2012), for datasets where the required variables and enough vertical levels are available (ERA5 and MPI Grand Ensemble). In 2020 the preparation of all the data is the main work for this project, together with first tests for confidence in our tools and data. This is ongoing work until the end of the year. Especially the preparation and computation of the finely resolved vertical data for the PTE analysis is expected to use a large part of the proposed resources (work space and node hours) at the end of the year. The first statistics results are also expected at the end of 2020, with the bulk of the statistic and dynamic (PTE) analysis planned for 2021.

Resource utilisation:

	Work space	Computation time
Proposed for 2020	30 TB	2000 Nh
Used in 2020 (up to Oct 12)	2 TB	69 Nh

A9 ECCES

The planned work was i) to perform global simulations using MPI-ESM-LR for the historical scenario (1950-2005), for the RCP8.5 scenario (2006-2099), and a pre-industrial (PI) control simulation for 1950-2099, each of the first two scenarios with 21 members of an ensemble. Simulation results were not analysed but used as forcing for the next step (MPI-ESM-LR: MPI Earth System Model, coupled global ocean and atmosphere model system); ii) to perform subsequently a regionalization of the same members and the PI control run with the coupled MPIOM-REMO model system with focus on the North Atlantic and the North Sea using the MPI-ESM-LR results for the lateral forcing of REMO and the surface forcing of MPIOM outside the REMO domain (coupling area, EURO-CORDEX22). These data will be analysed essentially with respect to the development of extreme water levels in the German Bight. (MPIOM: global MPI ocean model, REMO: regional atmosphere model on the extended EURO-CORDEX22 domain covering the extended European area). All planned simulations were finished successfully and ahead of schedule, because other ClimXtreme subprojects also wish to analyse the simulation results. Produced simulation results will be made available to the scientific community probably via ESGF of DKRZ: MPI-ESM-LR results as soon as possible, MPIOM and REMO results at a later stage of the project. REMO results will be made available to the ClimXtreme partner projects also as soon as possible. A very preliminary result is presented in Figure 5 showing the return levels of extreme sea levels (yearly maximum) in the nearest neighbour grid cell of Cuxhaven (Germany) tidal gauge position as calculated from the regionalized model results in a non-parametric way: The last thirty years of the 20th and 21st centuries have been merged separately to obtain long-term time series, of which the return periods were calculated for the end of the last and the end of this century. Figure 5 shows the return levels and periods of the single members (up to thirty years, red and blue shading), of the observational data up to 108 years (black line), of the PI control simulation (green line), and of the merged time series for historical and RCP8.5 members up to 150 years (thick red and blue lines, respectively). In general, results agree with recently published return levels (e.g., Lang & Mikolajewicz 2019, 2020). The PI control run corresponds to the lower end of the historical ensemble, while the RCP8.5 members show increased return levels indicating that anthropogenic climate change induces clearly higher storm floods in the German Bight. The curve of the observational data is still under investigation, because other publications display slightly different curves for the same data.

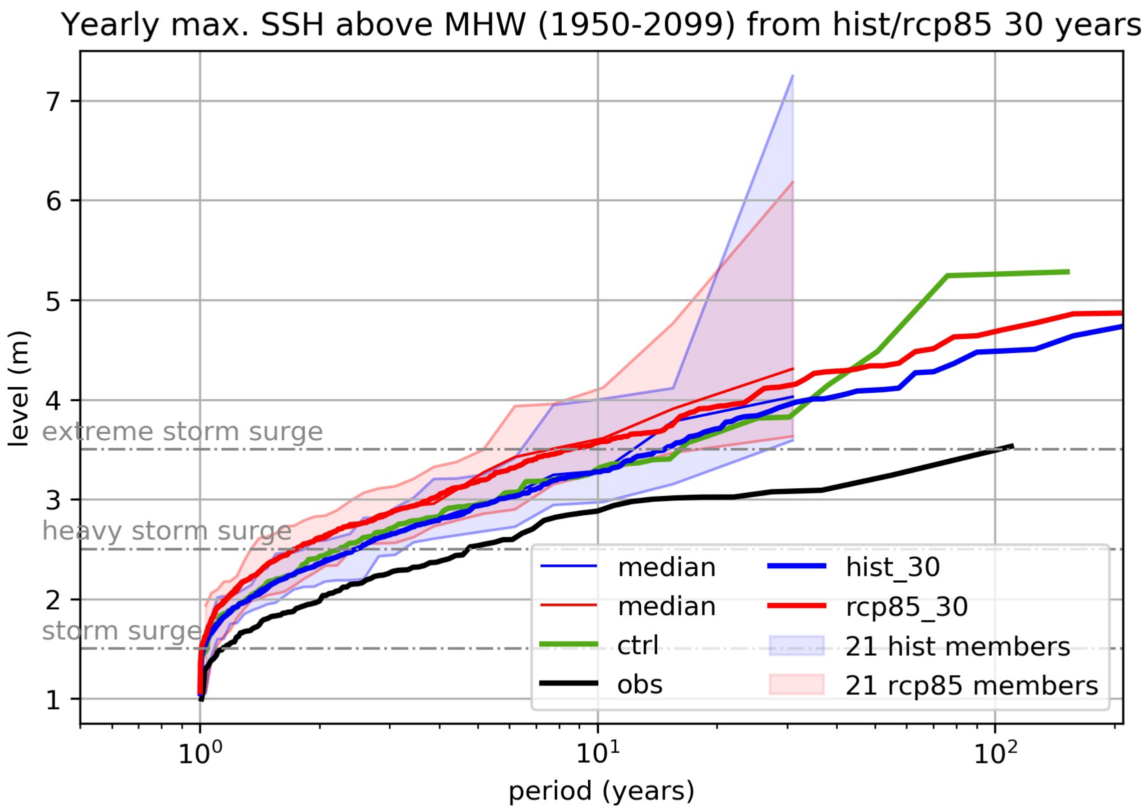

Figure 5: Preliminary return periods and levels of yearly maximum sea levels above mean high water for 1950-2099 at the tidal gauge position Cuxhaven for the PI control simulation (green), observational de-trended time series (black), ranges of 21 members of the historical (blue shading) and RCP8.5 (red shading) periods with thin blue/red lines displaying the median. Bold red and blue lines show the results of the merged last thirty years of 21 hist and 21 rcp85 members, respectively (hist_30, rcp85_30). Note: Validity of this plot, particularly the line of observational data, still needs to be verified.

Resource utilisation:
CPU nh: 174820
Work GB: 80560
Arch GB: 308696

Scientific activities conducted during the report time 2020 in Module B

B1.3 PATTERA

The work conducted in the reporting period (since July 2020) has seen simulations for the Houston case. There were two deviations from the plan: (i) some of the computing time was charged on another (meanwhile finished) DKRZ project so erroneously did not appear in bb1152 (a mistake for which the Leipzig team apologizes); we still report about these here, and (ii) we did not yet work on the Germany case, since the opportunity appeared to still contribute to the model intercomparison project on the Houston case conducted in the framework of the ACPC initiative and led by Sue van den Heever (CSU Fort Collins). Thus the work focused on this case. The setup thus followed the intercomparison set-up and some results are shown in Figure 6: the change in aerosol leads to the expected changes in cloud particle number concentrations. They further imply an increase in cloud water mass in particular in the middle troposphere that is now being analysed in the multi-model context and (in the upcoming phase) the context of radar measurements.

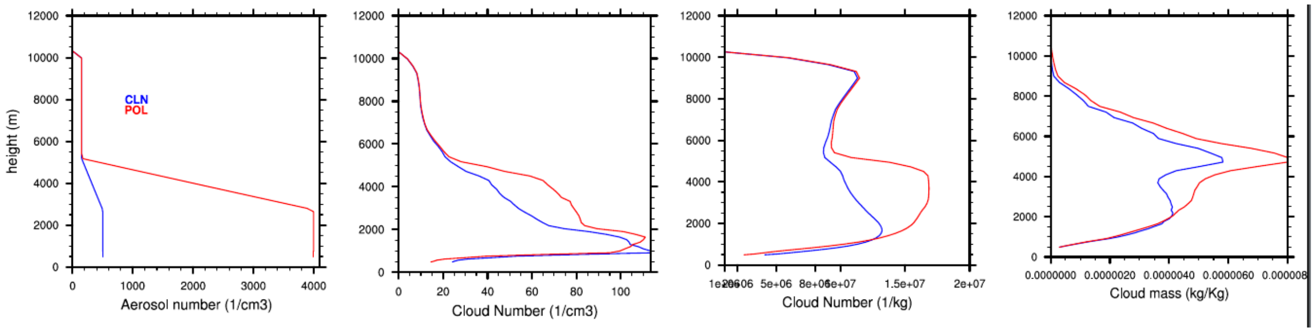

Figure 6: Domain-mean profiles of (left) the prescribed aerosol number for the clean (CLN, blue) and polluted (POL, red) conditions; (middle) the cloud particle number concentration as volume (second) and mass (third) concentrations, and (right) the impact, via rapid adjustments, on cloud water specific masses.

Differences to last years proposal

This was the first proposal.

References:

Ehmele, F., Kautz, L.-A., Feldmann, H., and Pinto, J. G. (2020): Long-term variance of heavy precipitation across central Europe using a large ensemble of regional climate model simulations. Earth System Dynamics, 11 (2), 469–490. doi:10.5194/esd-11-469-2020.

Pinto, J. G., T. Spangehl, U. Ulbrich, and P. Speth (2005): Sensitivities of a cyclone detection and tracking algorithm: individual tracks and climatology. Meteorol. Z. 14:823–838.

Fink, A. H., S. Pohle, J. G. Pinto, and P. Knippertz (2012): Diagnosing the influence of diabatic processes on the explosive deepening of extratropical cyclones, Geophys. Res. Lett., 39, L07803.