Project: **1198**

Project title: **Aerosol-circulation interactions**

Principal investigator: **Stephanie Fiedler**

Report period: **2020-11-01 to 2021-08-31**

The resources for bb1198 were instrumental for our research, summarised in the following.

1) Atacama Desert

The project A03 of the CRC1211 "Earth – Evolution at the dry limit" aims to improve our knowledge of past climate shifts in the hyper-arid Atacama Desert and of the key drivers for these shifts.

PostDoc Mark Reyers has worked on the analysis of different paleo-climate experiments of the CMIP6/ PMIP4 data base in the report period. He used the PMIP4 data copy on mistral and computational resources of the DKRZ for the analysis. We found that the majority of the global climate models (GCMs) contributing to CMIP6/PMIP4 simulate the hyper-aridity of the present climate, while a few GCMs clearly overestimate the rainfall in the Atacama Desert. For the Last Glacial Maximum (LGM), we identified three out of four GCMs with more rainfall than for the present (historical, Figure 1), consistent with observational records obtained by other CRC1211 projects (e.g., Diederich et al., 2020).

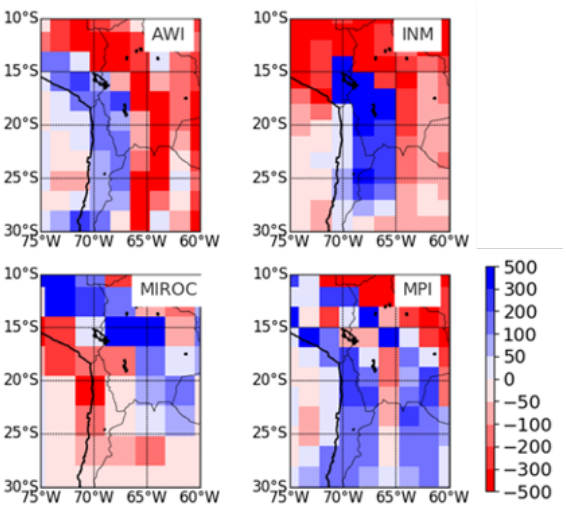

Figure 1: *LGM minus historical for mean annual rainfall in mm yr^{-1} in four CMIP6/ PMIP4 models that show the expected change from paleo records.*

The complex terrain at high altitudes requires dynamical downscaling of the global climate model output to understand the mechanisms that control the rainfall decrease between the LGM and today. In project A03 of CRC1211, we use the established Weather Research and Forecasting Model (WRF) for our research interests. Since the start of bb1198 in January 2021, we have simulated 25-year time slices for the historical (WRF_{hist}) and the LGM (WRF_{LGM}), using MPI-ESM1.2 output for creating the initial and lateral boundary conditions. Our WRF simulations reveal a dipole in rainfall for the LGM compared to today. That is more rainfall in the hyper-arid core of the Atacama Desert and less rainfall in the Northeast during the LGM relative to today (Figure 2). The strongest signals are seen for southern hemisphere winter (JJA, Figure 2). The ongoing investigation of the key drivers of the rainfall pattern indicates that the rainfall increase is related to more frequent and stronger low-pressure systems over the subtropical Southeast Pacific in the LGM (not shown). Similar WRF experiments are planned for other PMIP4 experiments (mid-Holocene, lig127k, midPliocene-eoi400). A WRF simulation for the mid-Pliocene has already been set up and started, using output of CESM2 from NCAR to generate initial and lateral boundary conditions of the WRF experiment. The model run is expected to be completed in September 2021. Results of the WRF simulations have been presented at EGU 2021 and are in preparation for publication (Reyers et al., in prep.).

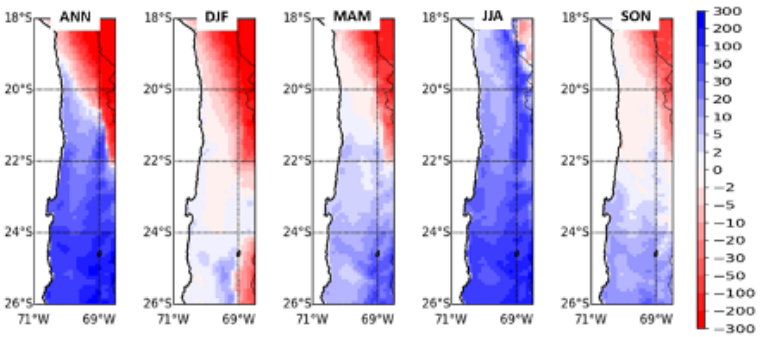

Figure 2: *WRF_{LGM} minus WRF_{hist} for mean annual rainfall in mm yr^{-1}, and for rainfall in summer (DJF), autumn (MAM), winter (JJA), and spring (SON) in mm per season.*

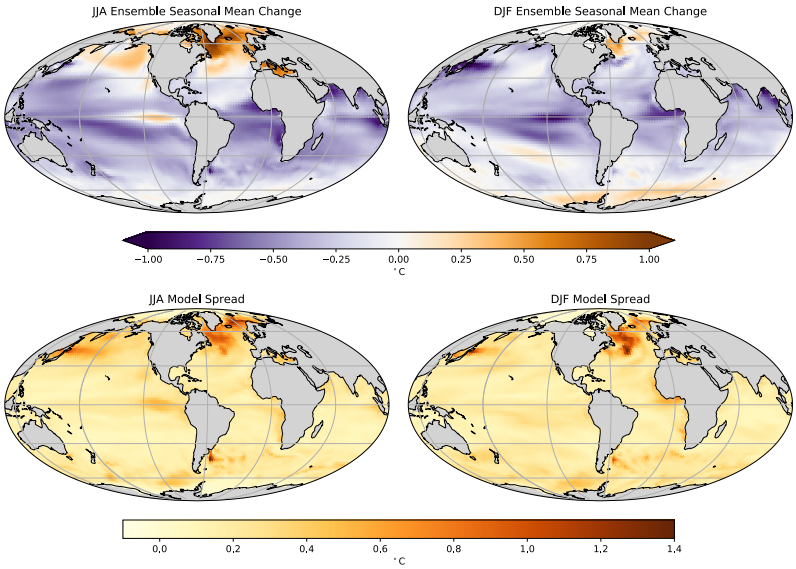

Figure 3: *Seasonal sea-surface temperature changes for midHolocene - pre-industrial in June to August (top-left) and December to February (top-right). The model spread in the mean SST change is measured as the across-ensemble standard deviation and is shown at the bottom.*

Rovina Pinto, PhD student in A03 of CRC1211, has completed an analysis of changes in the sea-surface temperatures from the CMIP6/PMIP4/ScenarioMIP data for the mid-Holocene, pre-industrial, present-day (historical) and future scenarios for the 21st century. An example of her analyses is shown in Figure 3, illustrating the changes in the mean SST patterns for winter and summer next to the calculated model spread.

2) East Asian Deserts

PhD student Feifei Mu, funded by the Chinese Scholarship Council (CSC), used DKRZ resources to perform a meteorological case study on two subsequent dust storms in East Asia during March/April 2021, which had severe impacts on air quality. He used fundamental methods for processing reanalysis data paired with observation data, including the extraction of variables at certain geometric and pressure levels, choosing time steps, and both regions and station locations from the global data sets. His data analysis of the East Asia dust storm included meteorological data for the geopotential height, air temperatures, winds, and humidity on standard pressure levels from ERA5 reanalysis, and aerosol information from CAMS. A part of his meteorological analysis of the storm is shown in Figure 4. He is starting to summarise the analysis in a manuscript (Mu et al., in prep.)

3) Sahara Desert

Reducing greenhouse gas emissions can be accomplished by a transition to using more renewable energy resources (RES) that depend on the changing weather. Desert-dust aerosols influence the electricity production from photovoltaic power plants. PhD student Robert Scheele estimates the effects of desert-dust aerosols on the yield from PV power from a climatological perspective. To this end, he used the new CMIP6 model simulations to analyse the change of dust-aerosol optical depth (DOD) from now (1985 to 2014) until 2100 and estimated the associated differences in the PV power potential. He used DKRZ resources to compare the DOD in the historical CMIP6 simulations with modern reanalysis. The results show a large model spread for DOD in CMIP6 and a multi-model mean of DOD close to satellite and reanalysis data. The future changes in DOD until 2100 depend on the socio-economic development. For the scenario SSP1-2.6, there is hardly any change in DOD, both in the global mean and in single regions. In the two scenarios with higher CO_2 concentrations (SSP2-4.5, SSP5-8.5), there is a regional increase in DOD over North Africa, the Tropical Atlantic and Australia, but a decrease in DOD over the Taklamakan Desert. He computed the change in the PV power potential using CMIP6 data for the surface irradiance, temperature, and wind speed for the future scenarios against present-day, and estimated the contributions from different components affecting

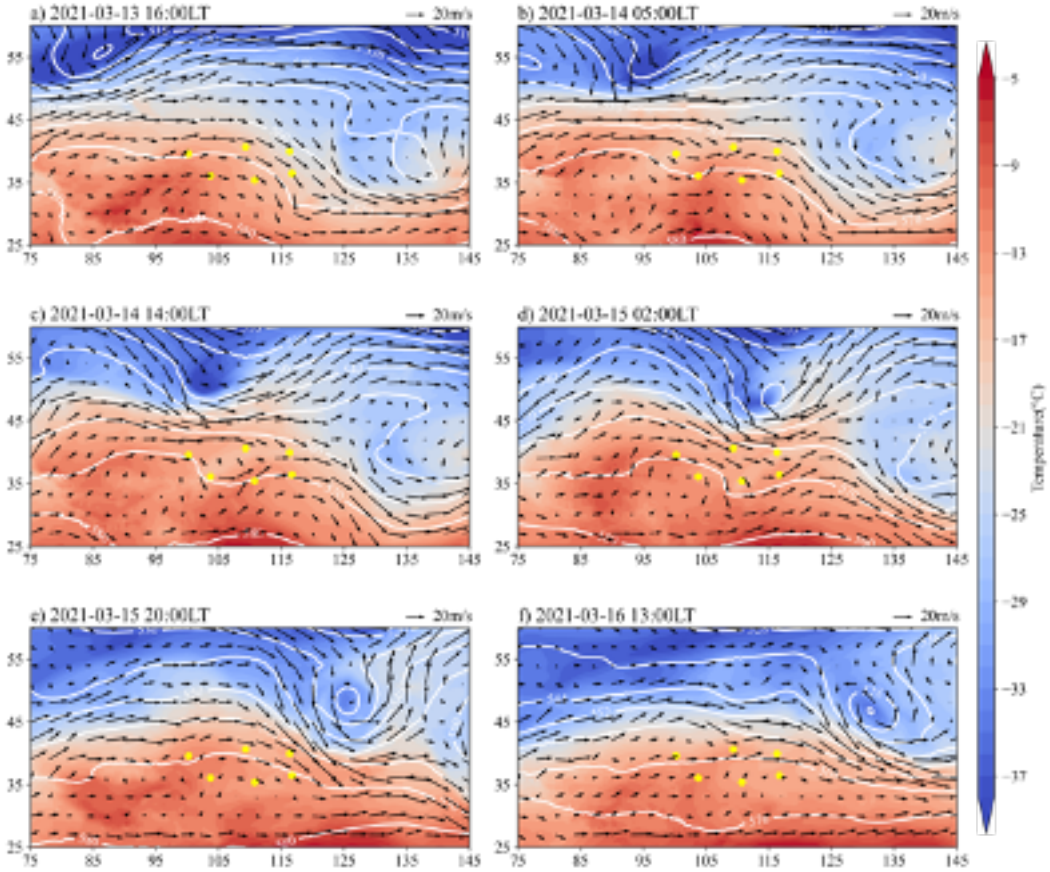

Figure 4. *Meteorological conditions during the severe dust storm affecting East Asia in March 2021. Shown are the geopotential height (white contours), temperature in degree Celsius (shading), and horizontal wind vectors at the 500 hPa level for different times during the storm. Dots mark the array of station observations used.*

irradiance. The results indicate a reduction in the mean potential PV power production by 2 - 4% over North Africa by the end of the 21st century in SSP5-8.5 due to dust aerosols and humidity changes (Figure 5). At global scales, the changes in the potential PV power production is controlled by changes in clouds and air temperature. These results have been presented at EGU 2021 and are now in preparation for publication (Scheele and Fiedler, in prep.).

4) Process-based wind climatologies

A master student in physics from the University of Bonn joined our meteorology research group at the University of Cologne for writing her master thesis to be submitted by the end of October. She used ERA5 data stored at DKRZ for her climatological assessment of winds in Europe.

The application of the nocturnal low-level jet (NLLJ) detection algorithm to global data made progress to the extent of having an automated script for processing the large 4D data and generating output for a larger number of years to allow a more comprehensive quality control of the output. This is a joint work with PhD student Alejandro Uribe Cortes from Stockholm University and the newly appointed PostDoc Eduardo Weide Luiz, funded by the Hans-Ertel-Centre for Weather Research.

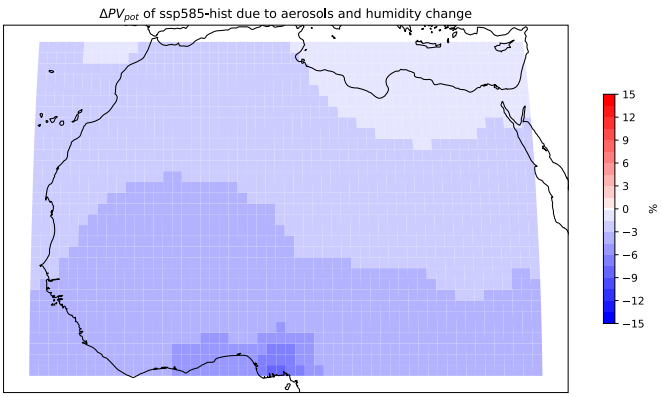

Figure 5: *Change in potential PV power for 2071-2100 in SSP5-8.5 minus 1985-2014 in the historical simulations due to change in aerosols and humidity over North-Africa in %.*

5) Publications

The PI was involved in journal publications, for which data analyses were made with DKRZ resources. One publication is on the climate response for the North Atlantic region to the pattern changes of the anthropogenic aerosol optical depth between the 1970s and 2000s (Fiedler and Putrasahan, 2021). This study was based on fully coupled model simulations with MPI-ESM1.2 that were performed during the PI's time at MPI-M and final analyses in project bb1198. Another example of using DKRZ resources was for the new COVID-19 model inter-comparison project, documented in two joint publications (Jones et al., 2021, Lamboll et al, 2021). The PI used DKRZ resources to create new MACv2-SP input from the COVID-19 emission data (Fiedler et al., in review).

Acknowledgement

We would like to close our report with an acknowledgement of the granted resources from DKRZ. The research projects of the new team at the University of Cologne strongly benefitted from using the DKRZ computing and storage capacities. For working with data as large as CMIP6 and high-resolution model output, the storage space and computational resources of DKRZ have proven very useful. Without it, many of our works could not be done or would not be as easy and quick. Specifically, we benefit from the availability of the CMIP6 and ERA5 data in the DKRZ data pool. Cloud storage makes the data access and processing relatively simple and fast by eliminating the need to download and store data elsewhere. Also jupyterhub at DKRZ makes visualization, batch processing, and sharing code much simpler for the team than otherwise. Last but not least the quick and productive start of the creation of our WRF simulations for CRC1211 was only feasible due to the granted resources.

References

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