Project: **1198**

Project title: **Aerosol-circulation interactions**

Principal investigator: **Stephanie Fiedler**

Report period: **2021-11-01 to 2022-10-31**

The resources for bb1198 were instrumental for our research. We summarise the output enabled by DKRZ resources in the following.

1. Performing and exploiting own simulations

1.1 - WRF experiments

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 performed high-resolution experiments with Weather Research and Forecasting Model (WRF) over the Atacama Desert for different climate states of the past. The simulations covered the domain marked in Figure 1 with a horizontal resolution of 10 km. We used PMIP4/CMIP6 data at the lateral boundaries of the model for simulating the climate in the Atacama Desert during the mid-Pliocene and for present-day conditions. To the best of our knowledge, this is the first time a global climate model experiment for the mid-Pliocene has been downscaled to a resolution that is more suitable to study rainfall events. The results from these experiments were analysed to understand why the desert was less arid in the mid-Pliocene compared to present-day. To that end, we employed machine learning techniques to identify different weather patterns. The combination of techniques allowed us to understand the atmospheric dynamics that led to extreme rainfall over the desert in the geological past. Interestingly these are similar, but not identical compared to the weather for extreme rainfall under present-day conditions. The results have been presented at the EMS Annual Meeting 2022 and are now available as preprint under review for Climate of the Past (Reyers et al., 2022). Further output from our ensemble of WRF experiments over the Atacama Desert is currently analysed for interdisciplinary research questions in collaboration with biology and geology in CRC1211.

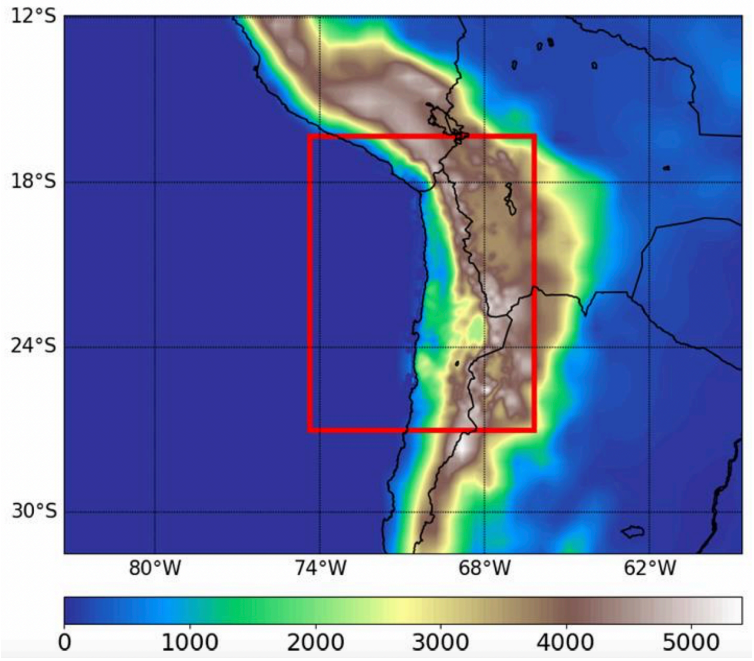

Figure 1: *Model domain for the WRF experiments over the Atacama Desert for geological time periods. The orographic height [m] is shaded. Figure from Reyers et al. (2022).*

1.2 - WRF-CHEM experiments

PhD student Robert Scheele performed high-resolution WRF-CHEM experiments to assess a continental-scale dust outbreak from North Africa towards the Americas in June 2019. He performed several parallel experiments with different dust aerosol parameterization schemes.

The large experiment domain covers North Africa, the North Atlantic, and parts of America with a horizontal resolution of 10 km, shown in Fig. 2. A smaller domain nested into that simulation has

a horizontal resolution of 2 km and is centred over Northwest Africa. The 10 km experiments are performed with three different dust parameterization schemes, namely GOCART, AFWA and UoC. The results are compared against the CAMS reanalysis from ECMWF, and retrievals from AeroNet sun photometers and satellite data. Figure 1 points to similar large-scale patterns of the dust outbreak, but magnitudes strongly depend on the model and parameterization scheme used. Averages in dust concentrations can regionally vary by as much as a factor ten. He is currently performing the last experiments that are needed for his research and shared first analyses of the model output at the retreat of the research group this summer. The analysis of the output will include an assessment of radiative effects and meso-scale dynamics involved in the dust-plume development.

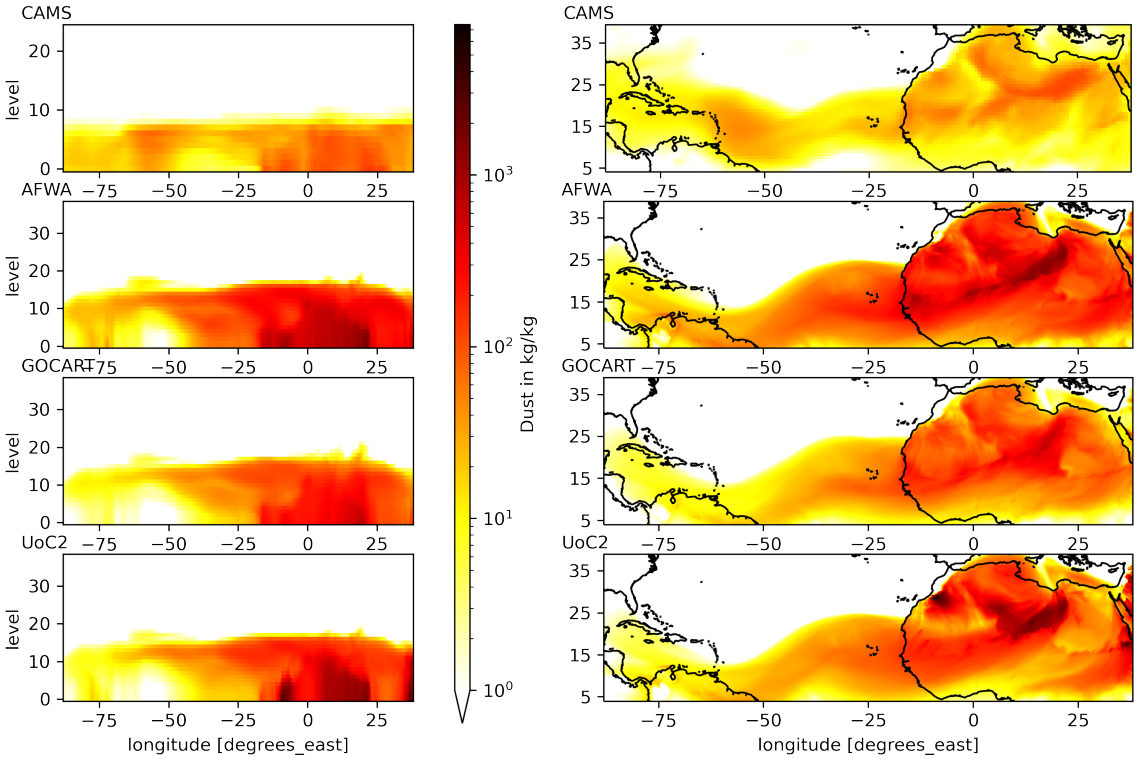

Figure 2: *Mean dust concentration (kg/kg) for 20 June 2019 as (left column) vertical cross section of meridional averages, and (right column) vertical averages for (top to bottom) the CAMS reanalysis, and our WRF-CHEM experiments with the AFWA, GOCART and UoC2 dust parameterization schemes. Note the logarithmic scale. (Figure by Robert Scheele)*

2. Analyses of other big data

Several works have been conducted on bb1198 involving big data analyses on Mistral and Levante, summarised in the following.

2.1 - Exceptional East Asian dust storm

PhD student Feifei Mu worked on the dust emission, transport, and air quality impact of the exceptional dust storm that occurred in East Asia in mid-March 2021. With the help of Mistral and Levante, he compiled climatological analyses based on reanalysis and observational data. Figure 3 shows some of the unusual characteristics of the dust event. It highlights strong

anomalies in the mean sea-level pressure and near-surface winds. These were strong enough for emitting dust aerosols from the Gobi and Taklamakan deserts affecting China via substantially reduced air quality. The results of his work are currently written up in a manuscript that will be submitted in the next few weeks. The work was presented at the EMS Annual Meeting 2022.

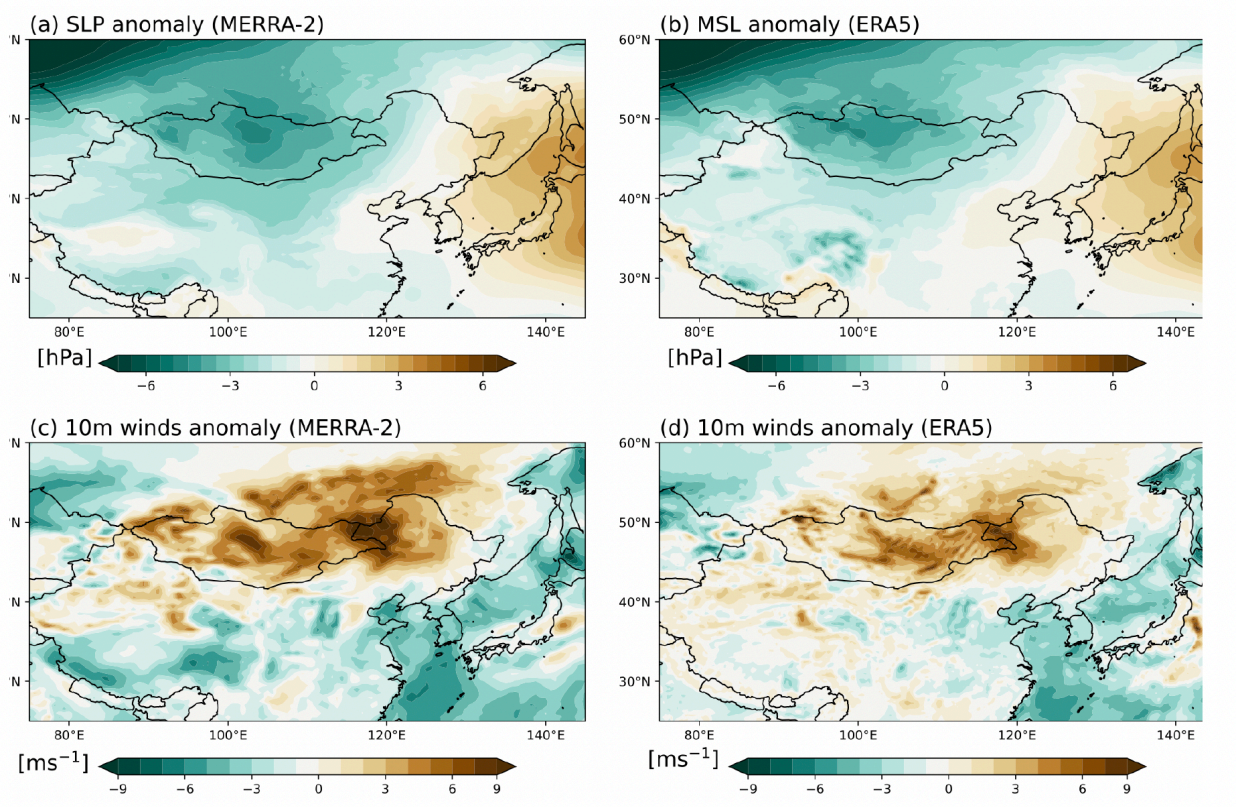

Figure 3: *Unusual characteristics of the dust event in mid-March 2021. Shown are (a-b) sea level pressure anomalies of March 2021 with respect to the March climatology for 1992-2021 from MERRA-2 and ERA5 reanalysis, (c-d) like (a-b) but for the difference between the maximum wind speed in this event and the 99% percentile wind speed for 1992-2021 at 10m a.g.l. (Figure by Feifei Mu)*

2.2 - Nocturnal low-level jets

Eduardo Weide Luiz performed the automated detection of nocturnal low-level jets (NLLJ) in ERA5 re-analysis data, based on contributions from Alejandro Uribe Cortes. We finished the processing of the data for a complete global climatology of NLLJs and began the graphical display of the results. Initial results were included in his presentation at the EMS Annual Meeting 2022.

2.3 - Master thesis

Fiona Paulus compiled a climatology of winds associated with extra-tropical cyclones in Europe using resources of bb1198. She submitted and defended her thesis in the reporting period (Paulus, 2021) and is currently working on preparing her findings for a journal manuscript.

2.4 - Global model data analyses

I used DRKZ resources to analyse RFMIP-SpAer model output for the coordinated RFMIP-SpAer study (Fiedler et al., in prep.) and to generate aerosol optical data for use in CovidMIP (Fiedler et al., 2021). The data intercomparison of aerosol optical depth was published in the

reporting period (Vogel et al., 2022). I also continued analyses of own global climate model experiments for testing a hypothesis (Fiedler and Stevens, in prep.), and analysed together with the new PostDoc Vidya Varma own coupled simulations with MPI-ESM1.2 in the framework of the newly DFG-funded project in CRC1502.

2.5 - Preparations for 2023 allocation period

We also prepared works using GPUs for a new project on dust storm forecasts. The work is undertaken by the PostDoc Franz Kanngiesser who joined the team in 2022. We use false-color satellite images from SEVIRI and machine learning techniques to explore new ways for extracting and combining data for dust plumes. He ran tests for algorithms to be used to estimate necessary computing resources for 2023.

References

- Fiedler, S.; Wyser, K.; Rogelj, J. and van Noije, T., 2021: Radiative effects of reduced aerosol emissions during the COVID-19 pandemic and the future recovery, Atmospheric Research, 264, 105866, https://doi.org/10.1016/j.atmosres.2021.105866.
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Acknowledgement

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