Project: **1053**

Project title: **CRC 1211 - A03: Statistical-dynamical modelling of Aeolian processes in the Atacama Desert over geological time scales and their implications to life at the dry limit**

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Report period: **2022-05-01 to 2023-04-30**

In the second phase of the Collaborative Research Centre 1211 (CRC1211 “Earth – Evolution at the dry limit”; funding period 2020-07-01 to 2024-06-30) we focus on paleo-climate simulations with the regional climate model WRF in the sub-project A03, using PMIP4-CMIP6 global climate model output as boundary conditions. The findings from this research on the mid-Pliocene have been presented at the EMS Annual Meeting by Reyers et al. (2022) and published in Climate of the Past by Reyers et al., (2023). A summary of this work is provided below.

Geomorphic and sedimentologic data indicate that the climate of today's hyper-arid Atacama Desert (northern Chile) was more humid during the mid-Pliocene to Late Pliocene. The processes, however, leading to increased rainfall in this period are largely unknown. To uncover these processes we use both global and regional kilometre-scale model experiments for the mid-Pliocene (3.2 Ma). We found that the PMIP4–CMIP6 (Paleoclimate Modelling Intercomparison Project–Coupled Model Intercomparison Project) model CESM2 (Community Earth System Model 2) and the regional model WRF (Weather Research and Forecasting) used in our study simulate more rainfall in the Atacama Desert for the mid-Pliocene in accordance with proxy data, mainly due to stronger extreme rainfall events in winter (Fig. 1). Case studies reveal that these extreme winter rainfall events during the mid-Pliocene are associated with strong moisture conveyor belts (MCBs) originating in the tropical eastern Pacific. For present-day conditions, in contrast, our simulations suggest that the moisture fluxes rather arise from the subtropical Pacific region and are much weaker. A clustering approach reveals systematic differences between the moisture fluxes in the present-day and mid-Pliocene climates, both in strength and origins. Figures 2 and 3 illustrate that the two mid-Pliocene clusters (4 and 6) representing tropical MCBs and occurring less than 1 d annually on average produce more rainfall in the hyper-arid core of the Atacama Desert south of 20° S than what is simulated for the entire present-day period. We thus conclude that MCBs are mainly responsible for enhanced rainfall during the mid-Pliocene. As seen in Fig. 4, there is also a strong sea-surface temperature (SST) increase in the tropical eastern Pacific and along the Atacama coast for the mid-Pliocene. It suggests that a warmer ocean in combination with stronger mid-tropospheric troughs is beneficial for the development of MCBs leading to more extreme rainfall in a +3 ° C warmer world like in the mid-Pliocene.

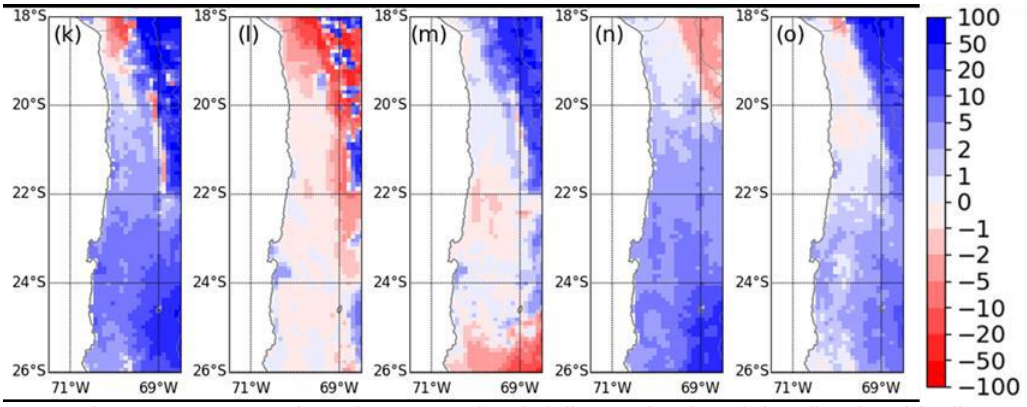

Fig. 1. Present-day mean annual and seasonal rainfall as simulated by (k–o) mid-Pliocene changes (WRFmP minus WRFhist) in the mean annual and seasonal rainfall. Values for (k) the whole year, (l) DJF (winter), (m) MAM (spring), (n) JJA (summer) and (o) SON (autumn).

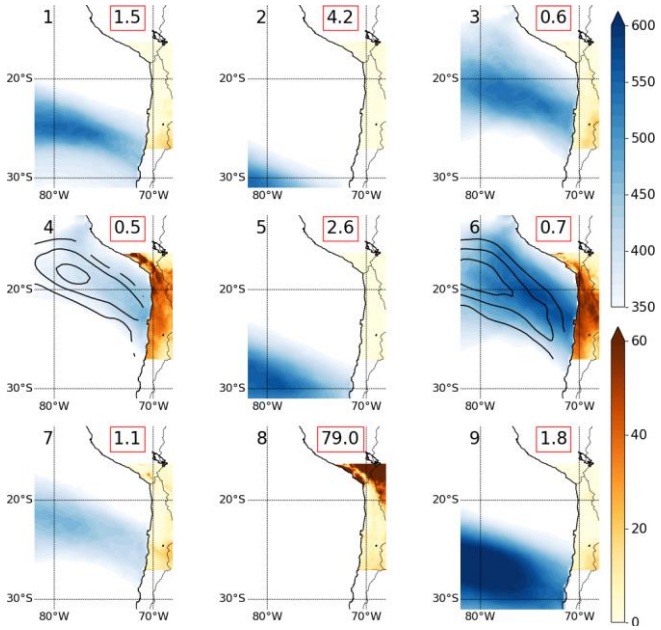

Fig. 2. Final mid-Pliocene wintertime IWVF clusters (yellow–green shading, in kg m^{-1} s^{-1}) as obtained by the combined SOM and k-means clustering for WRFmP (outer model domain with 50 km resolution). The numbers in the red boxes are the frequencies of occurrence of the individual cluster (in days per Southern Hemisphere winter). Red–blue shading shows the fraction (in %) of the rainfall associated with the individual clusters to the total winter rainfall (inner model domain with 10 km resolution). The black contours in clusters 4 and 6 show the composite mean wind speeds at 4000 ma.s.l. (15, 17 and 19 m s^{-1}).

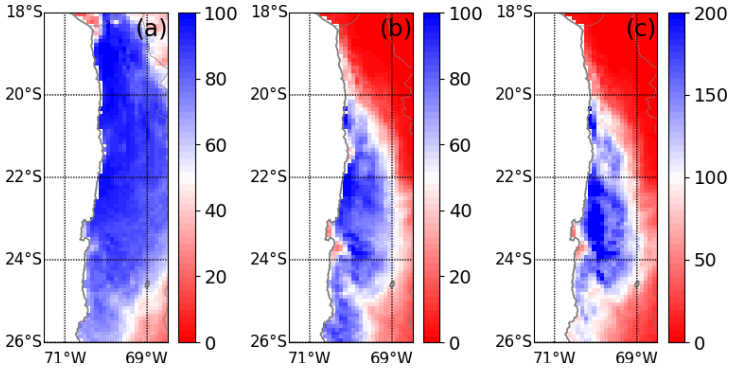

Fig. 3. Fraction (in %) of the rainfall associated with MCB cluster 4 and 6 of WRFmP to (a) total winter rainfall in WRFmP, (b) total annual rainfall in WRFmP and (c) total annual rainfall in WRFhist (inner model domain with 10 km resolution).

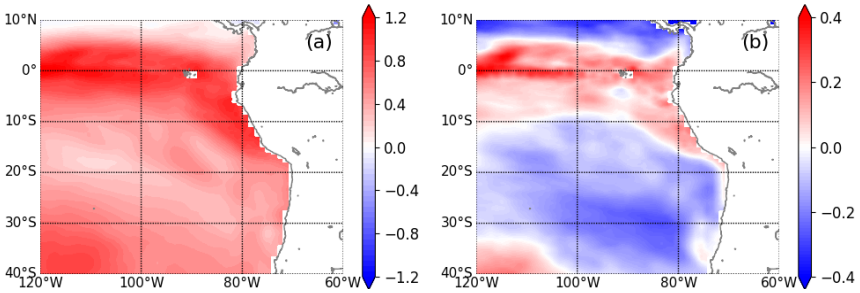

Fig. 4. SST composite mean over all days with MCB cluster 4 and 6 minus the (a) 50th percentile of winter SST and (b) 70th percentile of winter SST in the mid-Pliocene experiment of CESM2.

References:

Reyers, M., Fiedler, S., Ludwig, P., and Shao, Y.: What caused the increased rainfall during the Pliocene in today's hyper-arid Atacama Desert?, EMS Annual Meeting 2022, Bonn, Germany, 5–9 Sep 2022, EMS2022-112, https://doi.org/10.5194/ems2022-112, 2022.

Reyers, M., Fiedler, S., Ludwig, P., Böhm, C., Wennrich, V., & Shao, Y. (2023). On the importance of moisture conveyor belts from the tropical eastern Pacific for wetter conditions in the Atacama Desert during the mid-Pliocene. Climate of the Past, 19(2), 517–532. https://doi.org/10.5194/cp-19-517-2023