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Causal drivers of central Amazon precipitation variability during austral summer

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The South American monsoon system is one key component of the regional climate of South America, and its interannual as well as intraseasonal variability is of great relevance for water availability over vast parts of the continent. To further develop advanced prediction systems for hydro-meteorological conditions, a better understanding of the underlying atmospheric as well as coupled ocean-atmosphere and land-atmosphere processes governing the intraseasonal variations of rainfall is of paramount importance.

In this work, we focus on rainfall variability over the central Amazon basin (CAB) as a particularly vulnerable region during the peak season of the monsoon (December to February). In order to identify causal precursors of CAB rainfall variability and their mutual causal interdependence structure, we employ a causal discovery tool called Peter and Clark Momentary Conditional Information (PCMCI) algorithm to monthly average sea surface temperature (SST), mean sea level pressure (MSLP) and precipitation fields from reanalysis data sets for two different time periods, 1950-2020 and 1979-2020. As a first step, anomaly maps and correlation maps are used to identify potential candidate drivers of the precipitation variability in the CAB at lead times of up to three months. The causal effect networks resulting from the subsequent application of the PCMCI algorithm unveil the causal dependencies of different climate phenomena with CAB rainfall variability during austral summer, confirming previous results based on standard correlation analyses and allowing for a quantitative assessment of the different effects.

Among others, we find that SST changes in the tropical Pacific Nino1+2 region close to the South American west coast have a causal effect on CAB precipitation, with lower SSTs promoting more rainfall with a lag of one to two months. Notably, we do not find any similar statistically significant causal impact of SST variations in the Nino3.4 region in the central tropical Pacific, which is commonly most closely associated with the El Niño Southern Oscillation. Additionally, the obtained causal effect networks demonstrate that the Southern Annular Mode (SAM) causally influences the Amundsen Sea Low (ASL), which in turn causally affects the CAB rainfall. Both links are negative,

i.e. a positive SAM mode leads to a deeper ASL with a lag of one month, and a deeper ASL supports higher precipitation in central Amazonia with a lag of three months. Finally, SST variability in the tropical North Atlantic as well the Madden-Julian Oscillation do not show a significant causal relationship with CAB rainfall. Our obtained findings are qualitatively consistent among the two different time periods. However, when analyzing data starting only after 1979, some links increase in strength while generally less causal links show up in the networks.