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# On the decadal changes of Atlantic-Pacific interactions and the effects of external forcing

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We show the results of a study investigating the predominant role of external forcing in steering Atlantic and Pacific ocean variability during the latter half of the 20th (and early 21$^{st}$) century. By employing the PCMCI+ causal discovery method, we analyze reanalysis data, pacemaker simulations, and a CMIP6 pre-industrial control run. The results reveal a gradual (multi)decadal change in the interactions between major modes of Atlantic and Pacific interannual climate variability from 1950 to 2014. A sliding window analysis identifies a diminishing El Niño-Southern Oscillation (ENSO) effect on the adjacent Atlantic basin through the tropical route, coinciding with the North Atlantic trending toward and maintaining an anomalously warm state after the mid-1980s. In reanalysis, this is accompanied by the prevalence of an extra-tropical pathway connecting ENSO to the tropical Atlantic. Meanwhile, causal networks from reanalysis and pacemaker simulations indicate that increased external forcing might have contributed to strengthening ENSO's opposite sign response to tropical Atlantic variability during the 1990s and early 21$^{st}$ century, where warming tropical Atlantic sea surface temperatures induced La Niña-like easterly winds in the equatorial Pacific. The analysis of the pre-industrial control run underscores that modes of natural climate variability in the Atlantic and Pacific influence each other also without anthropogenic forcing. Modulation of these interactions by the long-term states of both basins is observed. This work demonstrates the potential of causal discovery for a deeper understanding of mechanisms driving changes in regional and global climate variability.

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