



## **Causal Modes in the Low-frequency variability of Mediterranean and Middle-Eastern climates**

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In the last three decades, the Mediterranean and the Middle East experienced a phase of warming larger than the one that could be expected from global warming, and largely ascribable to natural (e.g. internal) climate variability. To better understand this process we explore here the presence of causal relationships among the diverse modes of variability of the climate system, focusing in particular on inter-annual and decadal scales of variability, influencing the climate of Mediterranean and Middle-Eastern regions. Causality measures used in this study include time and frequency-domain Granger causality (GC) and the phase slope index ( $\Psi$ ), a directional coupling statistic developed by Nolte et. al. in 2007. GC metrics are applied to signals before and after the filtering of high frequency (inter-annual) components, while  $\Psi$  is designed to discern between low-frequency causal flow and higher frequency components. To assure the necessary sample size, the analysis is based on the preindustrial runs of the Fifth Coupled Model Intercomparison Project (CMIP5), which are free from external perturbation and last some hundred years. We selected the runs based on ENSO stationarity – to ensure that the simulations reached the equilibrium – and the consistent representation of the Atlantic Multidecadal Oscillation (AMO), which is considered one of the main drivers for the low-frequency (decadal) climate variability of the Mediterranean and the Middle East in summer. Finally, we discuss the potential of causality metrics for the predictability of future decadal variability in these regions.