Does ENSO affect atmospheric river activity in southern Europe? Results from observations and idealized numerical model experiments

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Idealized AGCM experiments have been run to study how AR-counts respond to ENSO

Abstract

While ARs are typically seen as large-scale precursors of local-scale hydrological (extreme) events, here we ask for the precursors of below- or above-normal AR activity. Namely, it is asked whether the El Niño - Southern Oscillation (ENSO), known to be associated with climate anomalies in many regions of the world, influences the number of ARs affecting the west coasts of Europe and northwestern Africa. The focus is put on the October-through-December (OND) season, during which such a relationship has been documented for precipitation in southwestern Europe (Mariotti et al. 2002). To this aim, the ENSO-AR link is first assessed with statistical methods and (quasi) observational reanalysis data. However, due to correlations arising from chance and possible covariability with predictor variables others than ENSO, this commonly applied empirical approach is unable to detect causal relationships when standing alone. Therefore, the proposed links are additionally assessed by means of idealized numerical model experiments run with the Community Atmosphere Model version 3.1, forced with prescribed SSTs varying in the equatorial Pacific only. These experiments are complemented with the six-member ensemble of IPSL-CM5a-LR Earth System Model run under AMIP conditions. The teleconnection patterns found in observations are roughly reproduced by both experimental set-ups, pointing to the fact that they indeed might be causal.

Set-up of the idealized numerical model experiments and applied data

An Atmosphere General Circulation Model (AGCM, Community Atmosphere Model 3.1) has been run with prescribed sea-surface temperatures (SSTs) and sea-ice cover (SIC) from observations (HadISST1) at T85 resolution (~1.4º). To isolate the effect of ENSO, only the *equatorial* Pacific SSTs are allowed to vary within the observed limits of the 1950-2000 period. SSTs in the remaining regions, as well as sea-ice cover, is held constant using the monthly climatological mean value. In this mode, 32 experiments have been run, considering SST anomalies in between -2.8 and +3.6ºC (increasing be +0.2ºC from one experiment to another) at the grid-box of maximum amplitude of the first EOF ("Pacific Warm Pool" pattern, see Figure 1). Thus, La Niña, neutral, and El Niño conditions are mimicked. These 32 experiments are hereafter referred to as a "model run". Using ten distinct initial conditions between the 15th of August and 15th of September of the years 1950-53, and integrating the model to the 31st of December in any case, 10 different model runs have been generated. Each of them represents one possible atmospheric response to the observed range of equatorial Pacific SST variations. Note that only the October-through-December (OND) model data are used for analysis, meaning that at least 16 days are allowed for model spin-up. All experiments were run at the High Performance Computing Cluster of the Santander Meteorology Group. For comparison, the 6-member AMIP-ensemble of IPSL-CM5A-LR's atmosphere component has been retrieved from the CMIP5 / ESGF portals. Unlike the "home-made" CAM 3.1 experiments, these runs are forced with prescribed SSTs and SIC *around the entire globe*. Also, quasi-observational data from the ECWMF ERA-20, NOAA-CIRES 20th century v2 and NCEP/NCAR 1 reanalyses are used. Due to similar results, only ERA-20C is shown here.

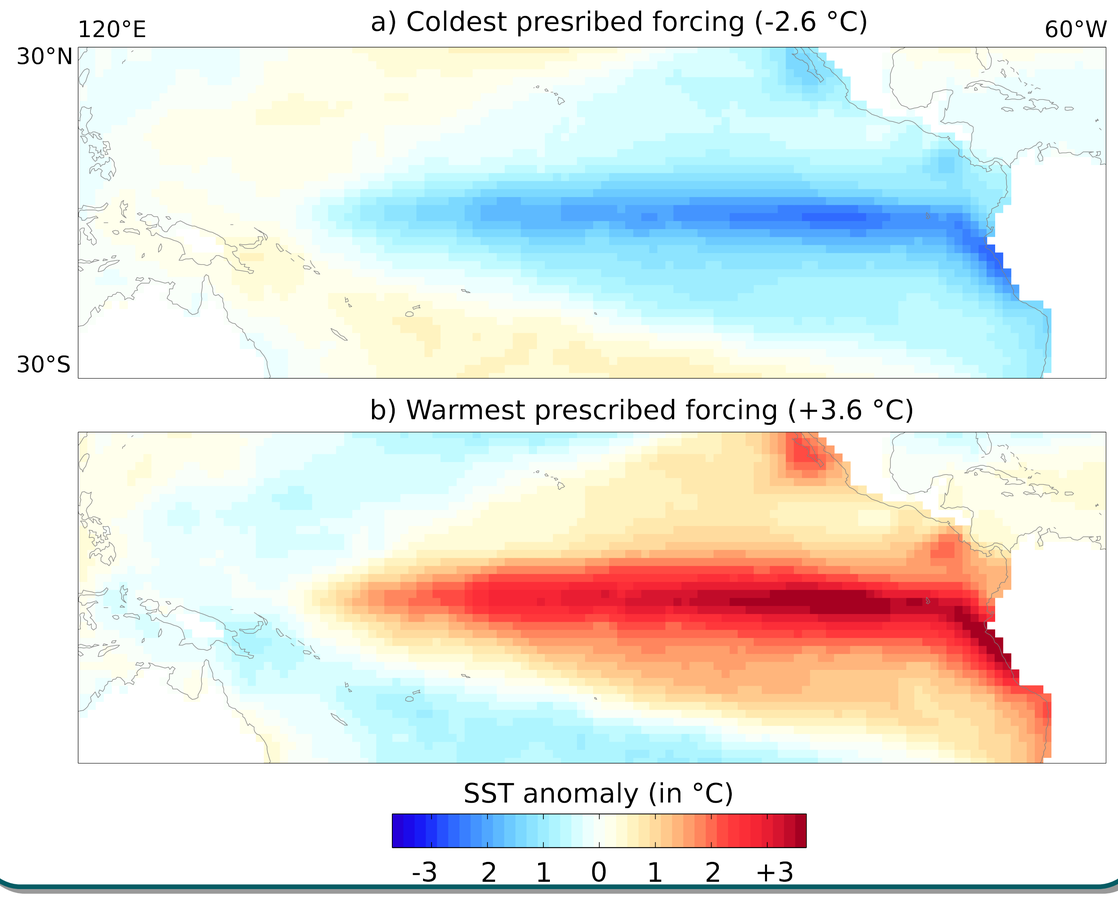
Applied statistical methods

The October-through-December AR-count response to equatorial Pacific SST forcing is measured in terms of ordinary least-squares regression:

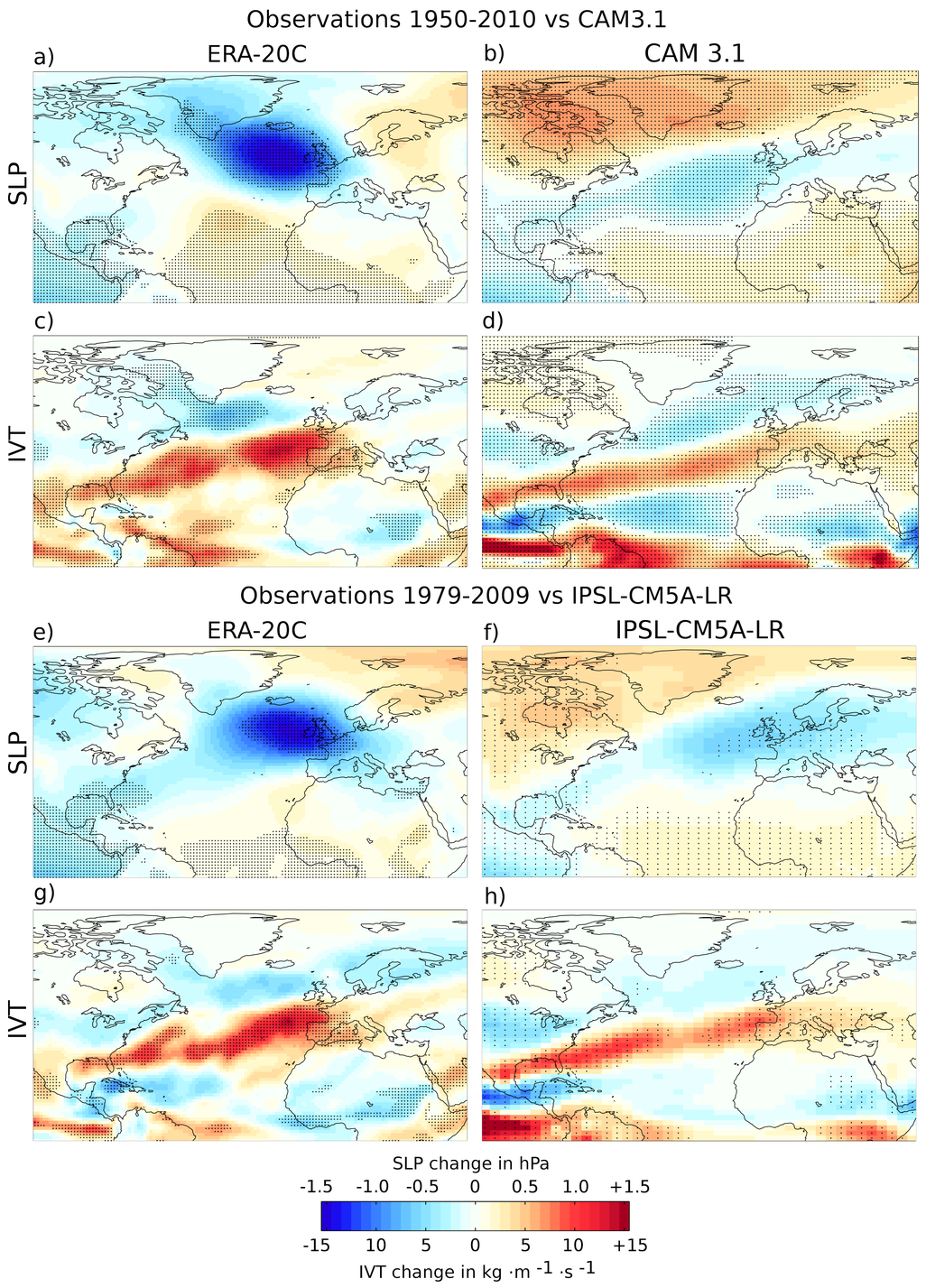
$$y = a + bx + e$$

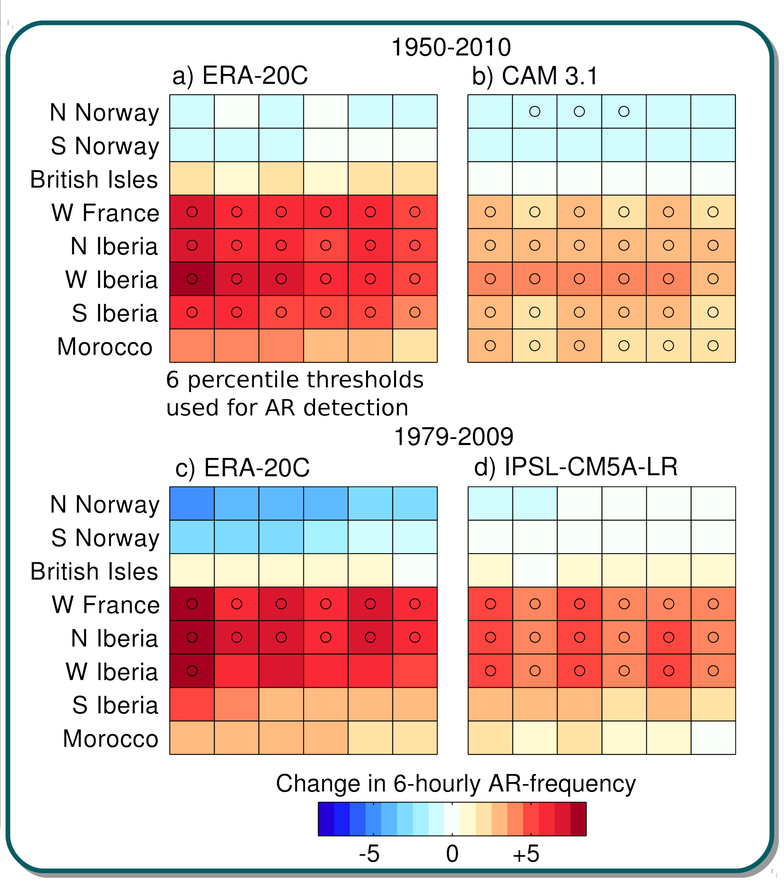
, where **x** is the sample of Pacific Warm Pool index values (in ºC), **y** the sample of modeled or observed AR-counts in OND, **a** the intercept, **b** the AR-count response per unit SST increase and **e** the error term. Note that for the case of the AR-counts from CAM3.1 and IPSL-CM5A-LR, **y** is the multi-model-mean AR-count of the 10 and 6 respective runs. The significance of **b** is obtained with a two-sided f-test conducted at a test-level of 5%. In the figures below, the magnitude and sign of **b** is displayed by the colour shading and significance is indicated by a black dot. A map showing the AR detection regions is provided in poster **P41**.

EOF pattern used to define equatorial Pacific SST forcing



Change in SLP, IVT and AR-counts per unit SST increase





Main Results

- In observations dating from 1950-2010, October-through-December AR-counts over the Iberian Peninsula and western France are related to ENSO.
- In these regions, La Niña / El Niño events favour below / above normal AR-frequencies.
- The observed links are roughly reproduced by idealized numerical model experiments, pointing to the fact that they might indeed be causal.

Reference: Mariotti A et al. (2002) Euro-Meditarranean rainfall and ENSO. A seasonally varying relationship, GRL 29(12),591-594, doi 10.1029/2001GL014248