Early- and late-winter ENSO teleconnections to the Euro-Atlantic region in state-of-the-art seasonal forecasting systems

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Objectives and methodology

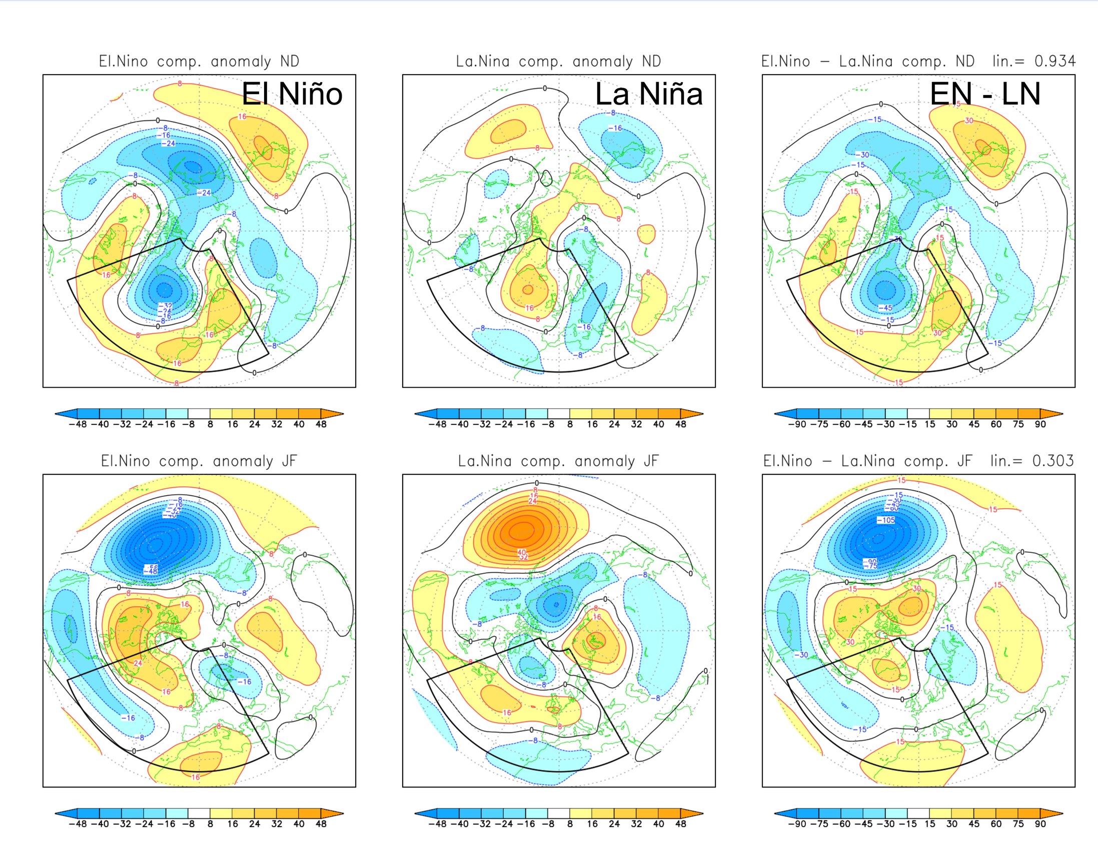
- Several recent studies have noted differences in the observed response to ENSO in the North Atlantic /European (NAE) region between the early and the late part of the boreal cold season. In particular, the projection of the NAE response on the NAO pattern changes sign between November-December (ND) and January-February (JF), with a significant projection onto the Eastern Atlantic pattern in the ND response.
- The goal of this study is to assess the ability of models contributing to the **Copernicus Climate Change Service (C3S) seasonal multi-model ensemble** (MME) to reproduce the differences between the ND and JF response in the NAE region in initialised ensembles. In order to compare the responses at the same fc. time, data are taken from re-forecasts initialised (nominally) on 1 Sep. to compute the ND response, and from re-forecasts initialised on 1 Nov. to compute the JF response (i.e. fc. months 3 and 4 for both periods).
- Regression and composite maps are computed separately from El Niño and La Niña winters which fall in the lower and upper tercile of the distribution of Nino3.4 SST in the 1980/81 to 2019/20 period covered by ERA5. This selection includes 13 winter in each category for ERA-5, with 8 El Niño years and 9 La Niña years included in the 1993-to-2016 period covered by the MME re-forecasts.
- For both El Niño and La Niña years, composite anomalies are defined by: $C(\underline{x}) = \mu_{3.4}\, R(\underline{x})$, where $\mu_{3.4}$ *is* the average of the Niño3.4 anomaly $s_{3.4}$ (over all years and ens. members) and $R(\underline{x})$ is the regression pattern.
- The fidelity of the model simulation is quantified by the spatial correlation of the ERA-5 and model composites, and the ratio of their r.m.s. amplitudes in a spatial domain *D;* here we focus on the Euro-Atlantic region (70W-30E, 25N-80N).

Institution	System no.	Acronym	No. of re-fc. members	Initialisation strategy
European Centre for Medium-range Weather Forecasts	5	ECMWF	25	burst
Météo-France	8	MeteoFr	25	lagged
UK Met Office	600	UKMO	28	lagged
Centro Euro-Mediterraneo per i Cambiamenti Climatici (IT)	35	CMCC	40	burst
Deutscher Wetterdienst	21	DWD	30	burst
National Centers for Environmental Prediction (USA)	2	NCEP	24	lagged
Japan Meteorological Agency	2	JMA	10	lagged
Environment and Climate Change Canada	1	ECCC-1	10	burst
Environment and Climate Change Canada	2	ECCC-2	10	burst

500-hPa height composites: ERA-5

Nov-Dec

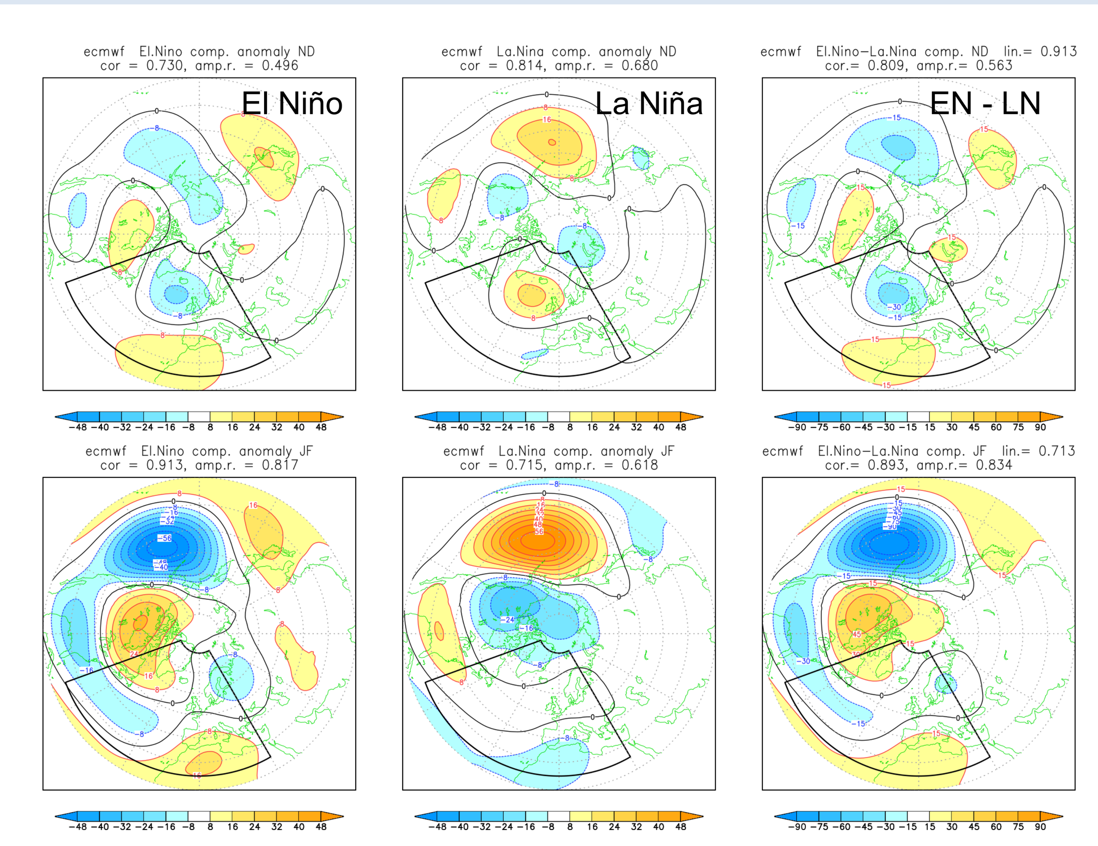
Jan-Feb



500-hPa height composites: ECMWF

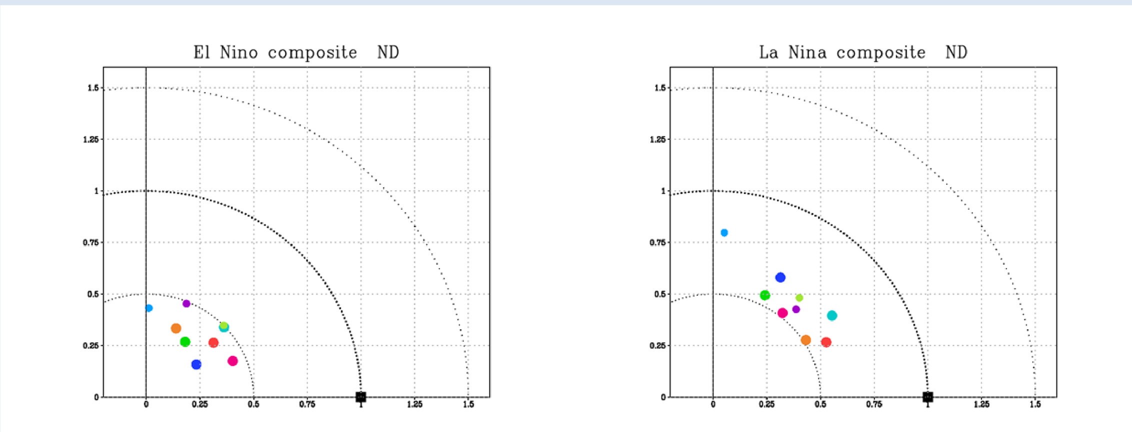
Nov-Dec

Jan-Feb



Taylor diagrams for ENSO composites in the Euro-Atlantic domain

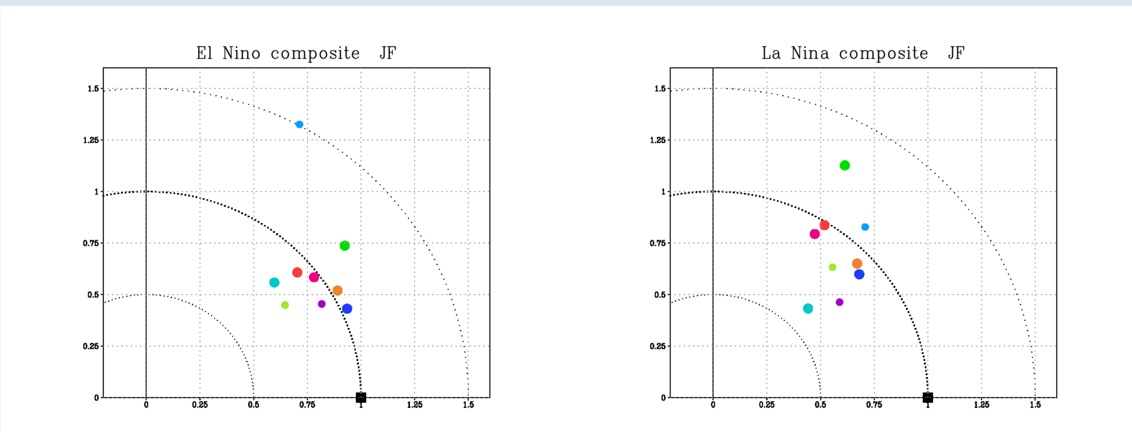
Nov-Dec



- ECMWF
- MeteoFr
- UKMO
- CMCC
- DWD
- NCEP
- JMA
- ECCC-1
- ECCC-2

El Niño La Niña

Jan-Feb



Signal-to-noise ratio for the ENSO regression coefficients in the Euro-Atlantic domain

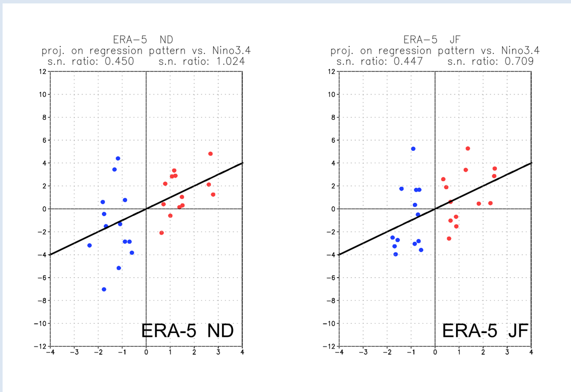
By projecting each anomaly $Z'(\underline{x}, \tau)$ onto the ENSO regression pattern $R(\underline{x})$ in the NAE domain, the following decomposition is obtained:

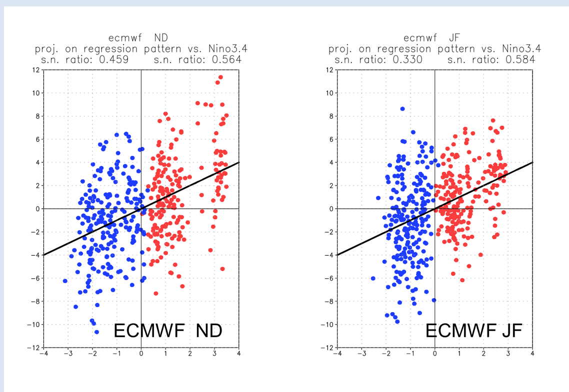
$$\boldsymbol{Z'(\underline{x}, \tau) = b(\tau)\, R(\underline{x}) + O(\underline{x}, \tau) = [s_{3.4}(\tau) + \varepsilon(\tau)]\, R(\underline{x}) + O(\underline{x}, \tau)}$$

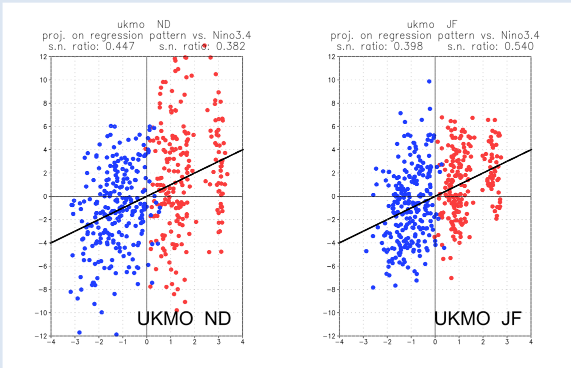
where:

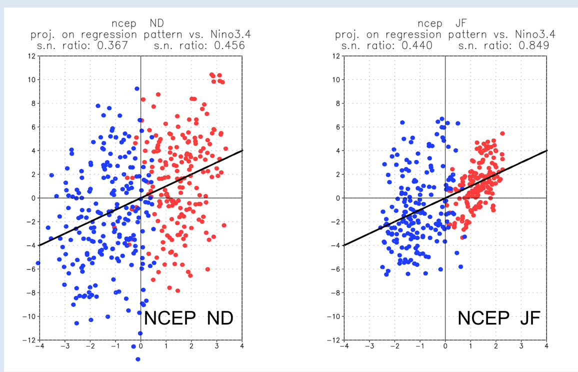
- $\varepsilon(\tau)$ is a time series with zero mean value and zero correlation with the Nino3.4 anomaly $s_{3.4}(\tau)$
- $O(\underline{x}, \tau)$ is a residual pattern which is spatially orthogonal to $R(\underline{x})$ at any time τ
- $b(\tau) = [s_{3.4}(\tau) + \varepsilon(\tau)]$ is the amplitude of the projection of the anomaly $Z'(\underline{x}, \tau)$ onto $R(\underline{x})$

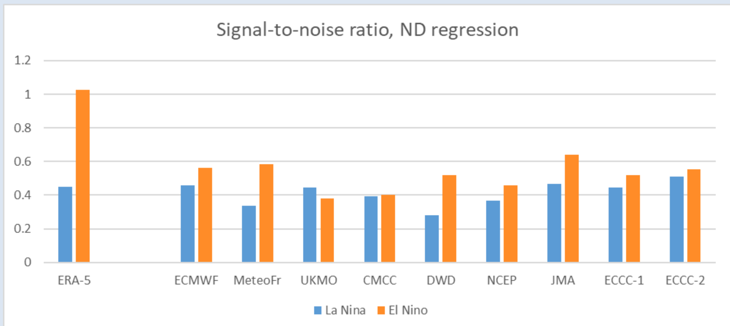
- The signal-to-noise ratio for the projection $b(\tau)$ onto the El Nino or La Nina regression pattern is defined by the ratio between the r.m.s. values of $s_{3.4}(\tau)$ and $\varepsilon(\tau)$, computed over all years and ensemble members.
- Scatter diagrams of $b(\tau)$ against $s_{3.4}(\tau)$ show how well the projection onto the regression pattern $R(x)$ can be approximated by the linear relationship $b(\tau) = s_{3.4}(\tau)$. In the figures below, these are shown in the same plot for El Niño and La Niña years, using red and blue dots respectively.

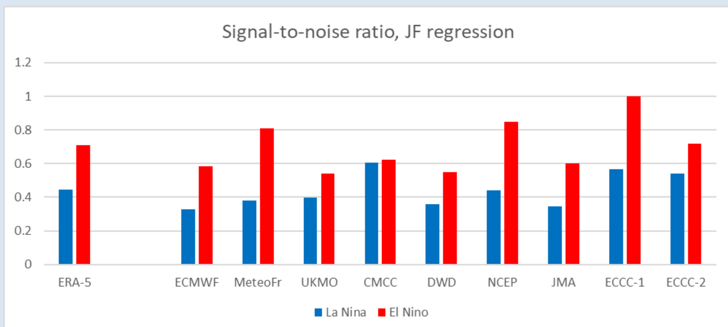


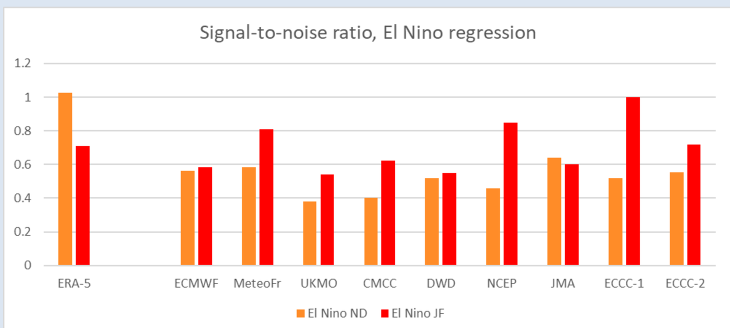












Significance of ERA-5 results estimated by resampling
(10 events out of 13, ~300 samples):

Prob. (s/n El Niño ND > s/n La Niña ND) : **100.%**
Prob. (s/n El Niño JF > s/n La Niña JF) : **100.%**
Prob. (s/n El Niño ND > s/n El Niño JF) : **99.6%**

Summary of results

- **Among the models contributing to the C3S MME, there is a marked difference in the ability of simulating the response to ENSO over the N. Atlantic/European (NAE) domain in November-December (ND) and January-February (JF). While the JF model composites are close to the ERA-5 composite in both spatial correlation and amplitude, the ND composites (especially those for El Niño years) have a much reduced amplitude compared to the ERA-5 counterparts.**
- **Models tend to underestimate the linearity (i.e. spatial anti-correlation) between the El Niño and La Niña composites in ND with respect to ERA-5, while they overestimate it in JF.**
- **The analysis of the signal-to-noise ratio for the projections onto the ENSO regression patterns in the NAE region show that the response is more 'noisy' during La Niña winters than in El Niño winters; this is found in both ERA-5 and almost all model data, for both ND and JF.**
- **However, while the observed s./n. ratios in La Niña winters and in JF El Niño's is within the range of model simulations, the high s./n. ratio observed in ND during El Niño winters is underestimated by all models. Indeed, for El Niño years, almost all models show a larger s./n. ratio in JF than in ND, while the opposite is true in ERA-5 data.**

Climate Change Service