Comparing the seasonal predictability of the Tropical Pacific in EC-Earth3 at two resolutions

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Seasonal climate predictions

Seasonal to Decadal climate prediction is a field of research attracting growing interest beyond the scientific community due to its strong potential to guide decision-making in many sectors (e.g. energy production, agriculture) in the face of the pressing dangers of climate change (*Hermanson et al., 2022*).

There are several indications that **higher resolution** versions of the current generation of climate models might improve key air-sea teleconnections, decreasing common biases of global models and improving the skill to predict certain regions at seasonal scales, e.g. in tropical sea surface temperature (*Prodhomme et al. 2016*). Several studies show that using higher horizontal resolution improves the ocean mean state in the Tropics (*Liu et al., 2022*) which can lead to better predictive skills (*Beverley et al., 2022*).

Using the climate model EC-Earth3, we assess **how the predictive skills change when the horizontal resolution is increased** and how these changes are related to the simulation of physical processes.
We focus on the Tropical Pacific as it is a major source of seasonal predictability thanks to the influence of El Niño-Southern Oscillation (ENSO).

Experimental approach

We use the climate model EC-Earth3 (*Döscher et al., 2021*) in its Atmosphere-Ocean configuration at two different resolutions, **standard (SR) and high (HR) resolutions**. We performed two sets of seasonal retrospective hindcasts (initialised in Nov. and May) with each resolution configuration. Each set covers the hindcast period **1990-2015**, has **20 members** and a forecast length of **8 months**. We focus on the May initialisation.

	Components	Resolution SR	Resolution HR	Atmospheric initialisation	Oceanic initialisation
EC-Earth3	IFS cy36r4	80	40	ERA5	in-house reconstruction (NEMO3.6 based)
	NEMO v3.6, Oasis	100	25		
	LIM3				

TAB. 1. Model components (2nd column) and the corresponding horizontal resolution (3rd column) of EC-Earth3. The respective atmospheric (4th column) and oceanic (5th column) initial conditions used are summarised.

Recent release, made publicly available on esgf, of a multi-year (3 years) climate prediction system with EC-Earth3:

- Nov init.: 1960-2021, SR and HR, 20 and 15 members
- May init.: 1980-2021, SR and HR, 20 and 15 members

Impact of the horizontal resolution on the Tropical Pacific prediction skill

In EC-Earth3-HR, improved predictive skills in the central-to-eastern equatorial Pacific, less degraded skills in the Western Equatorial Pacific (WEP) (Fig. 1).

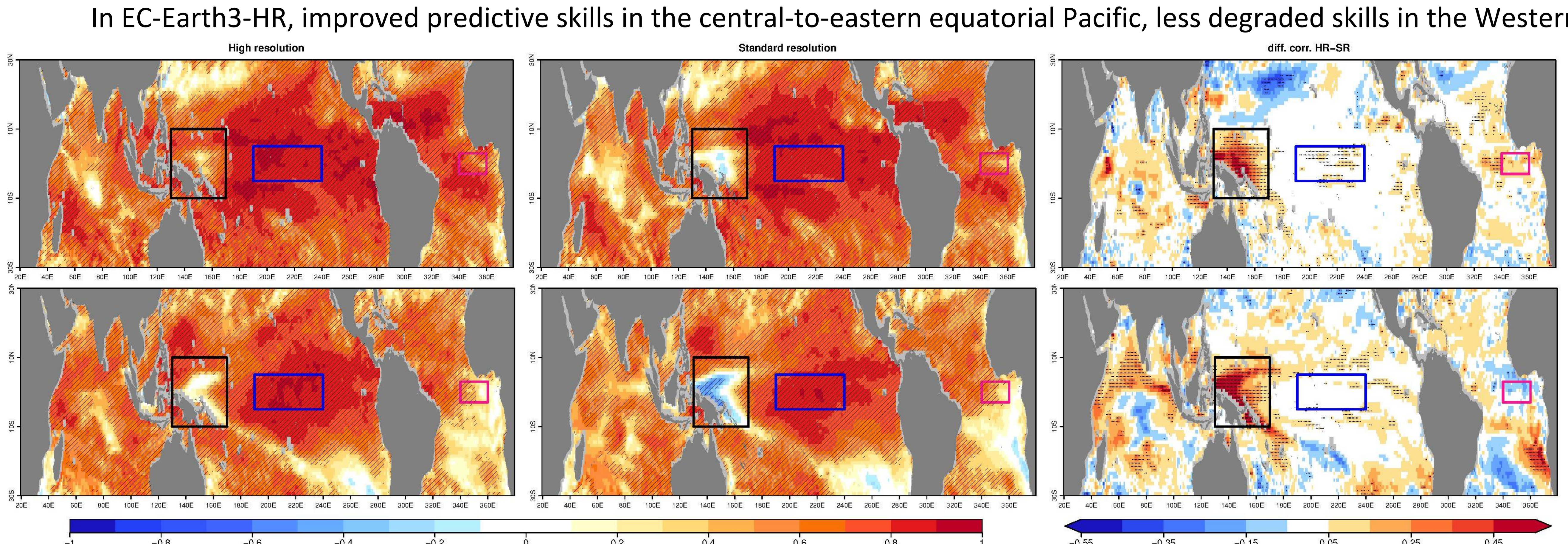

FIG.1. Maps of Anomaly Correlation Coefficient (ACC) for the sea surface temperatures (SST) in the EC-Earth3 forecast systems initialised in May for (top) the summer season (June-July-August) and (bottom) the early winter season (October-November-December). The left column corresponds to the HR configuration, the middle one to the SR configuration and the right column shows the difference in correlation between HR and SR. In the right column, red indicates an improvement in the skill with increased resolution, blue indicates a degradation of the skill. The reference dataset is SSTCCI ESA dataset. The ACC has been computed over the 1990-2015 period for each individual grid point after interpolation to a regular 1º grid. Dashes indicate that the values are statistically significant at the 95% level. The blue box is the Niño 3.4 region, the black box is the Western Equatorial Pacific (WEP) region, the pink box is the Atlantic Niño region.

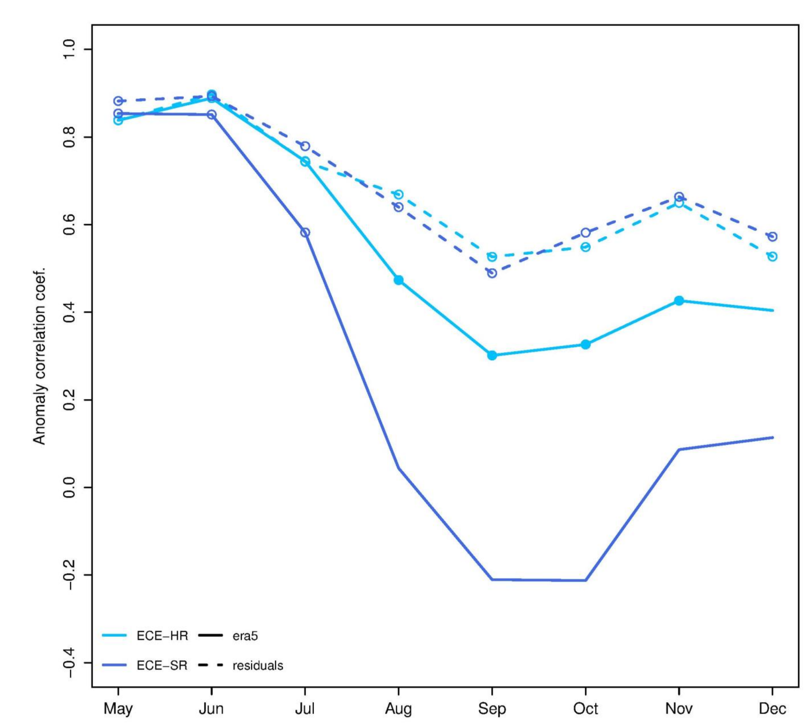

FIG. 2. Anomaly Correlation Coefficient (ACC) skill score in the Western Equatorial Pacific (WEP – 10S10N, 130E-170E) region as a function of forecasted month for (dark blue) EC-Earth3-SR and (light blue) EC-Earth3-HR, compared to ERA5 as a reference. The dashed lines are the correlation coefficients, compared to ERA5, of the residuals of the regression of the WEP onto Niño3.4 SST anomalies.

When removing ENSO signal from the WEP region, the correlation coefficients are higher and similar in both EC-Earth3 configurations (Fig. 2): **ENSO-related errors degrade skills in this region** → importance of improving the spatial simulation of ENSO for the predictions over the WEP and Maritime-Continent regions.

How the degraded skills in the Western equatorial Pacific is linked to ENSO ?

Amplification of ENSO-related errors

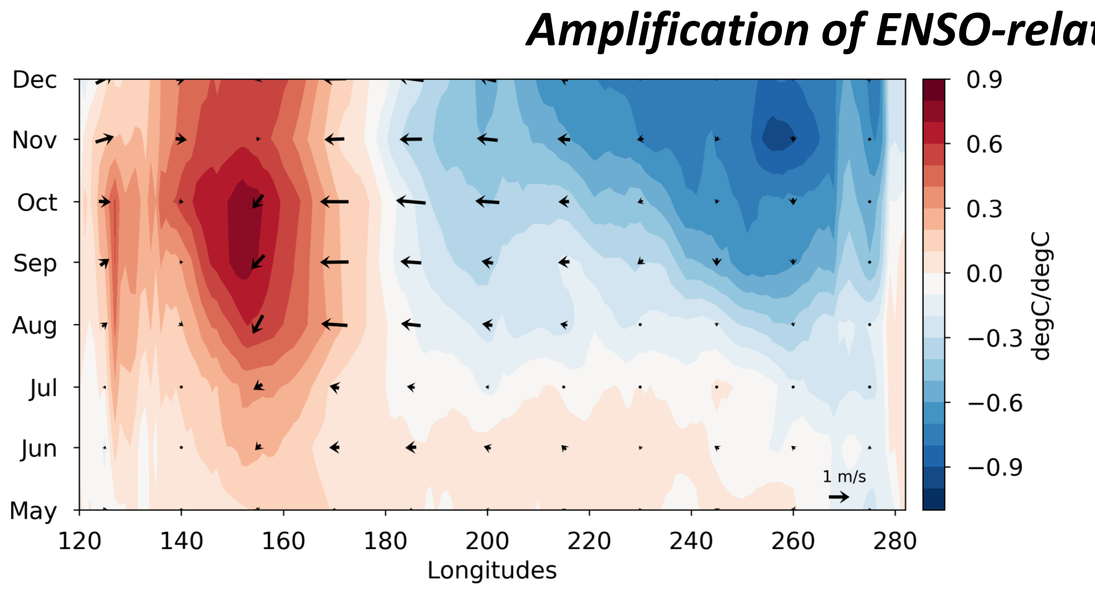

FIG.3. Hovmoller from May to December of the ENSO-related errors for SST (shaded), compared to SSTCCI ESA dataset, and surface winds (arrays), compared to ERA5, in EC-Earth3-SR forecast system. The ENSO-related errors in EC-Earth3-HR are less pronounced.

The degraded predictive skill in the Western Equatorial Pacific (WEP) comes from a common **ENSO-related errors** (Beverley et al., 2022) in climate models, which is a **westward extension** of ENSO-related variability and a cold bias in the central-to-eastern Pacific (Fig. 3) which induces ENSO events of lower amplitude.

Westward extension bias in winds and mixed layer depth

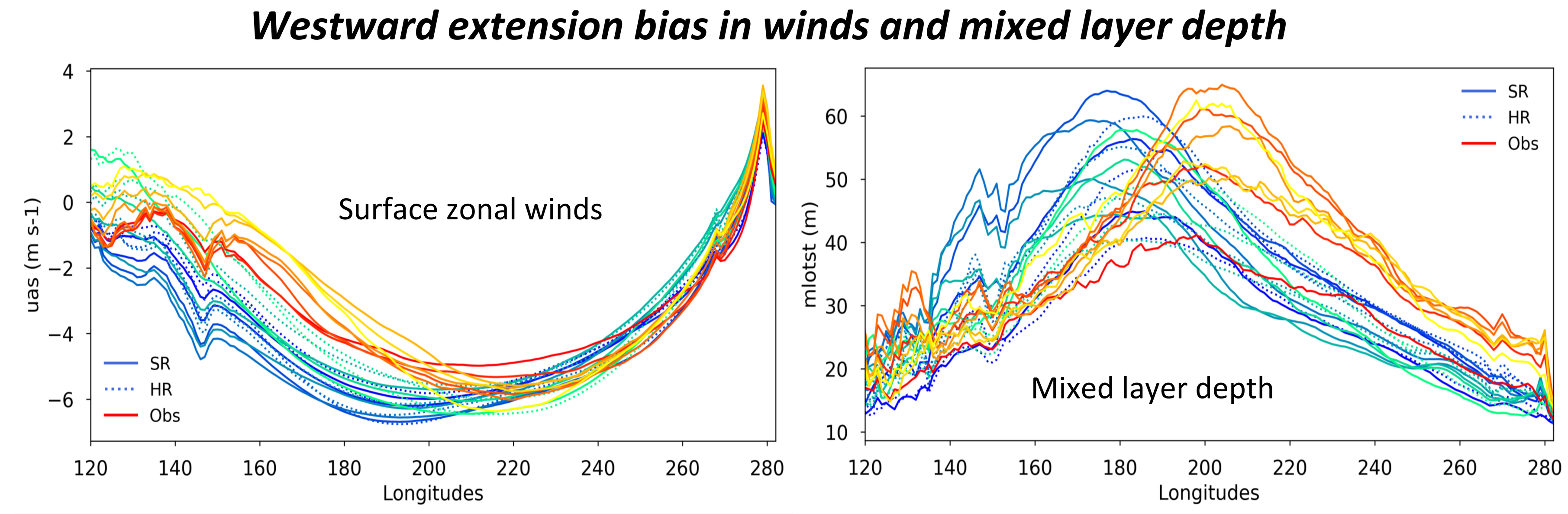

FIG.4. Longitudinal profiles (5S-5N) of the time-evolution of (left) the surface zonal winds and (right) the mixed layer depth, for an observational dataset (ERA5 for the winds, ORAS5 for the mixed layer depth) and the forecast systems EC-Earth3-SR (plain lines) and EC-Earth3-HR (dotted lines). The different colours represent each month along the forecast time, from the first forecast month, May, in red for the observations, in blue for the forecast systems to the eighth forecast month, December, in yellow for the observations, in green for the forecast systems.

The westward extension of the ENSO-related variability is linked to the common biases of climate models in the equatorial Pacific: an overly cold and westward extended cold tongue. In the EC-Earth3 forecast simulations, the westward extension starts in the surface zonal winds and the mixed layer depth (Fig. 4): from the first forecast month, the position of both the mean easterly winds and the deepening of the mixed layer depth shifted westwards by around 20º. The position of the mixed layer too close to the surface in the central-eastern Pacific causes SST to cool through upwelling.

HR and SR configuration differences: from the initialisation of the MLD…

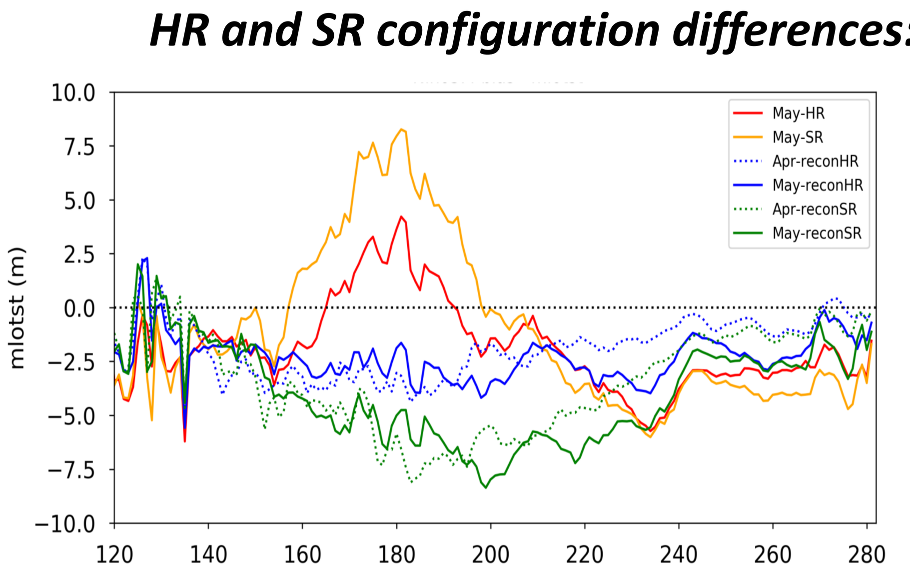

FIG.5. Longitudinal profiles (5S5N) of the mixed layer depth bias (compared to ORAS5) for the first forecast month, May, of EC-Earth3-SR (yellow) and EC-Earth3-HR (red) and for the months of April (dotted lines) and May (plain lines) for the reconstructions used as initial conditions for both resolutions.

The higher ENSO-related errors in EC-Earth3-SR compared to EC-Earth-HR, which induces lower predictive skills in WEP (Fig. 1,2), is enhanced by an initialisation shock in the mixed layer depth (Fig. 5). A shallower mixed layer in the initial conditions leads to a greater deepening in the central Pacific in the first month, May, of the SR forecast system.

… to the low winds variability

The overly westerly positioning of winds seems to be linked in some way to the model's deficiency to produce intense westerlies during ENSO development, a model deficiency that is stronger in EC-Earth3-SR (Fig. 6).

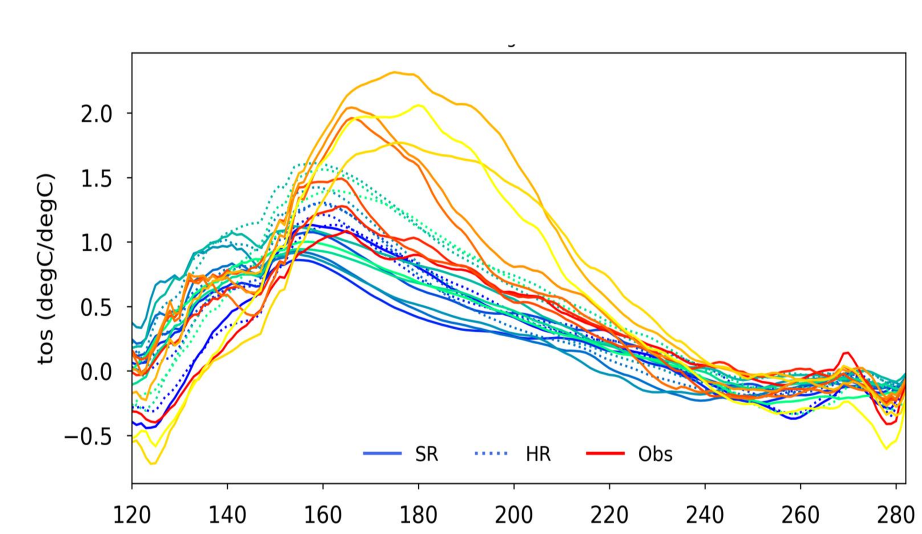

FIG.6. Same as Fig. 4 but for the ENSO-regressed surface zonal winds.

References

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