Impacts of the increased horizontal resolution on the predictability of the tropical Pacific variability

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Background

Seasonal to Decadal climate prediction (S2DCP) 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*).

However, one major limitation common to current S2D systems is the little skill that they present over the continents, which appears to be connected to an incorrect representation of the teleconnection mechanisms that, mediated via the atmosphere, connect the ocean with the neighbouring continents.

There are several indications that the current generation of models at standard resolution misrepresents those key teleconnections, and that **higher resolution** versions might improve them, 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*).

We want to assess **how the predictive skills change when the horizontal resolution is increased** and how these changes are related to the simulation of physical processes. The comparison of **two different Climate models** allow to better understand how the development of model-specific biases can impact predictive skills.

Initial conditions of the predictions

Atmospheric forcing (assimilation scheme)
Applied to the ocean-sea ice surface
Variables: t10, u10, v10, precip., q10, qlw, qsw

Ocean surface restoring (ORAS5)
Applied to the surface with fixed strength
Variables: temperature and salinity

Sub-surface 3D-nudging (EN4v4.2)
Applied to the sub-surface with varying strength in depth and weak nudging in the equatorial band
Variables: temperature and salinity

FIG. 1. Schematic summarizing our protocol to produce in-houses ocean reconstruction, used as initial conditions for the prediction systems. Courtesy Alba Santos Espeso.

		Atmospheric initial cond.	Ocean initial cond.
CNRM-CM6.1	SR	ERA-interim	Glorys 2v4
	HR	ERA5	Glorys 12v1
EC-Earth3.3	SR	ERA5 interpolated to the corresponding IFS grid	In-house reconstruction using NEMO with the corresponding grid
	HR		

TAB. 1. Atmospheric and ocean initial conditions used for each corresponding prediction system.

Experimental approach

We used two different models, EC-Earth3 (*Döscher el al., 2021*) and CNRM-CM6.1 (*Voldoire et al., 2019*), in their Atmosphere-Ocean configuration. We compare their configuration at two different resolutions, standard (SR) and high (HR) resolution. We performed two sets of seasonal retrospective hindcasts with each resolution configuration of the two models.

		Atmospheric component	Oceanic-sea ice component
CNRM-CM6.1	Model	ARPEGE v6	NEMO3.6 - GELATO v6
	Standard resolution	~130 km (TL127)	~100 km (eORCA1)
	High resolution	~50 km (TL359)	~25 km (eORCA025)
EC-Earth3.3	Model	IFS cy36r4	NEMO3.6-LIM3
	Standard resolution	~80 km (TL255)	~100 km (ORCA1)
	High resolution	~40 km (TL511)	~25 km (ORCA025)

TAB. 2. Model components and corresponding grid and resolution for the two models used, CNRM-CM6.1 and EC-Earth3.

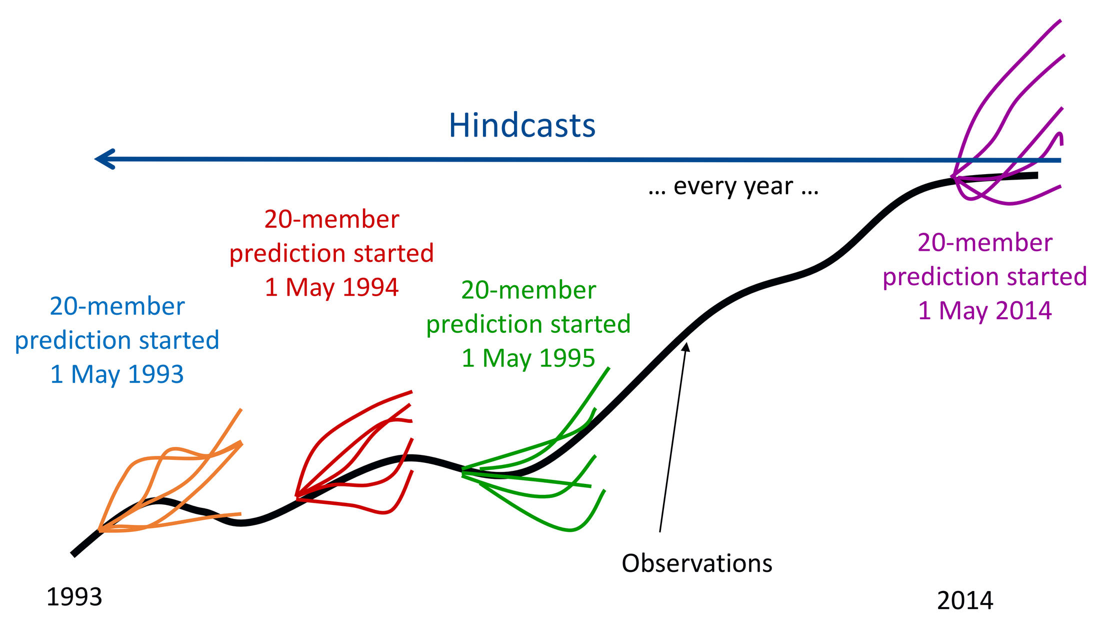

FIG. 2. Schematic of a prediction system simulation structure.

hindcast systems

EC-Earth3	CNRM-CM6.1
1990-2015	1993-2014
Twice a year May and November	Twice a year May and November
20 members	30 members
8 forecasted months	6 forecasted months
TOTAL: 693 eq. years	TOTAL: 660 eq. years

Impact on the Tropical Pacific prediction skill

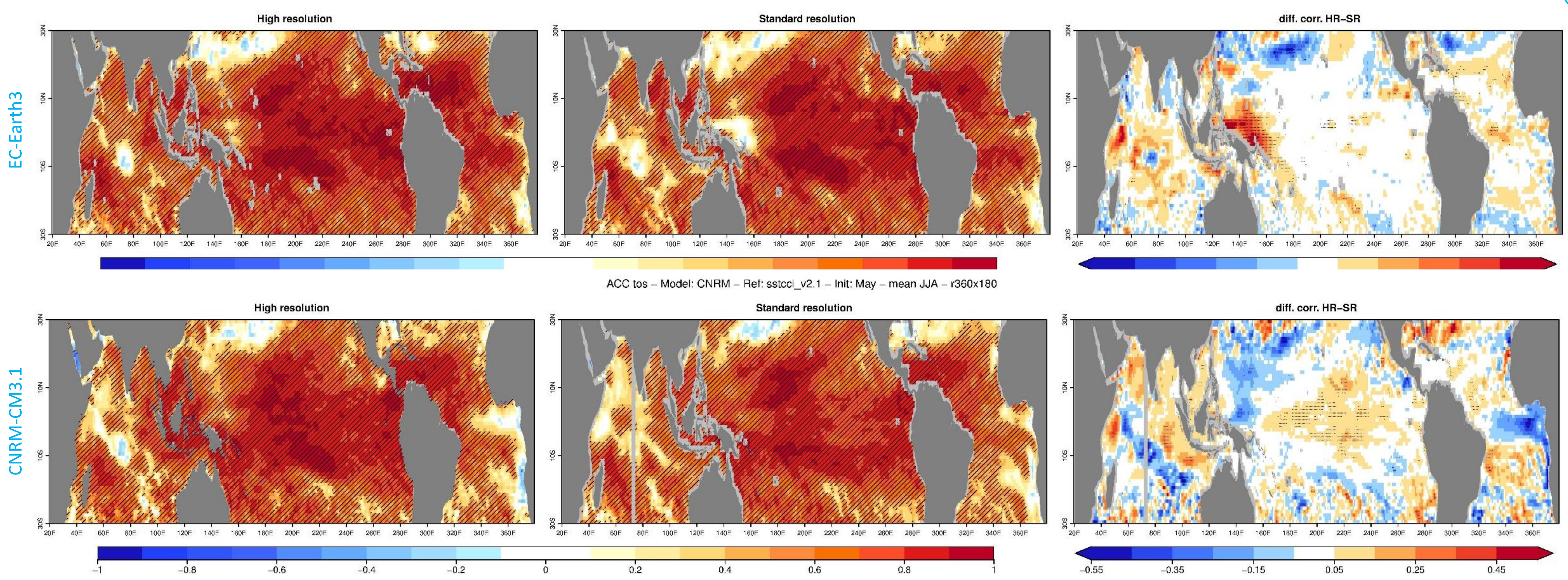

FIG.3. Maps of Anomaly Correlation Coefficient (ACC) for the first forecasted season (June-July-August) of sea surface temperatures (SST) for (top) EC-Earth3 and (bottom) CNRM-CM6.1 forecast system initialised in May. The left column corresponds to the HR version of each model, the middle one to the SR version and the right column shows the difference in correlation between HR and SR. In this right column, red indicates an improvement in the skill with increased resolution, blue indicates a degradation of the skill. The reference dataset is the ESA SST CCI dataset. The ACC has been computed over the 1993-2014 period for each individual grid point. All the models and reference dataset have been interpolated to a regular grid of 1º of resolution before computing the ACC. Dashes indicate that the values are statistically significant at the 95% level.

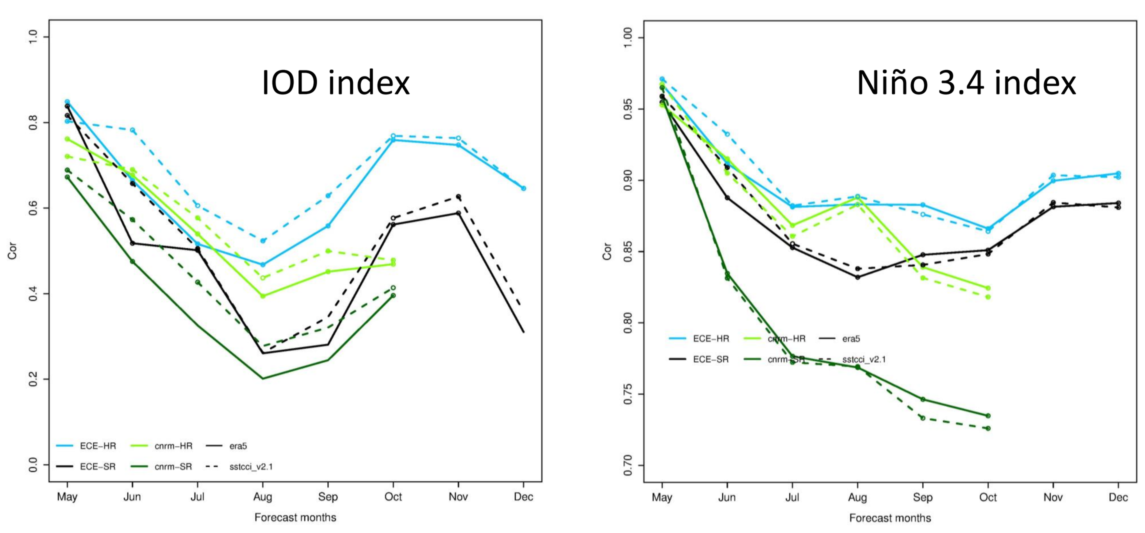

FIG.4. ACC skill scores for the (left) Indian Ocean dipole (IOD) and (right) Niño3.4 SST indexes a function of forecasted month for (black) EC-Earth3-SR, (blue) EC-Earth3-HR, (dark green) CNRM-CM6.1-SR and (light green) CNRM-CM6.1-HR forecast systems initialised in May. The reference datasets are the ESA SST CCI dataset and ERA5 reanalysis.

Both models show an overall **increase in their predictive skill of the tropical Pacific band** sea surface temperature (SST) (Fig.3) and air surface temperature (not shown) with increased horizontal resolution.

The increase in the skill is confirmed when assessing integrated value over specific regions, such as the Indian Ocean and equatorial regions associated with the El Niño-Southern Oscillation (ENSO), such as Niño3.4 (Fig. 4).

Next steps

- Analysis of the physical processes in the tropical band that can explain this increase in skill:
  - Surface winds
  - Thermocline dynamics
  - Bjerknes Feedback
  - Equatorial Atlantic teleconnections
  - Indian Ocean teleconnections
- Analysis of the differences in the mean bias and their change with resolution for each model
- Investigate the November initialised forecast system
- Extension of the EC-Earth3 forecast system over a longer hindcast period (1960-2021) and for a longer forecasted length (up to 3 years) to evaluate how the increased resolution impacts the skill in the tropical Pacific: prediction of ENSO beyond the Spring predictability barrier, prediction of double-dip La Niña (*Wu et al., 2021*), etc.

References

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