Impact of the initialization with different ocean reanalysis on forecast bias

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1. Motivation and open questions

Introduction: Strong systematic SST biases in Tropical Atlantic commonly develop in seasonal forecasts among most GCMs[1,2]. In EC-Earth3, a strong warm surface temperature bias develops in less than a month in boreal winter or summer over Angola-Benguela Area (ABA), and a cold surface temperature bias develops in ATL3 (Fig 1).

Research questions: What are the mechanisms responsible for the error growth in Tropical Atlantic? What is the impact of the initialization with different ocean reanalysis (ORAS4 and GLORYS) on the forecast bias?

Model: EC-Earth3.0.1, T255L91-ORCA1L46

Simulations: Initialized every 1st May and November between 1993-2009, 4 month forecasts, 10 ensemble members. Atmosphere and land initialized from ERA-interim. Two sets of experiments:

- EXP-ORAS4: Ocean initialized from ORAS4, sea ice initialized from GLORYS2V1
- EXP-GLORYS: Ocean and sea-ice initialized from GLORYS2V1 (interpolated to ORCA1L46 configuration)
- We exclude years 1997, 2001, 2002 because of strong surface and subsurface temperature biases in GLORYS dataset over the equator.

2. Biases in sea surface temperature

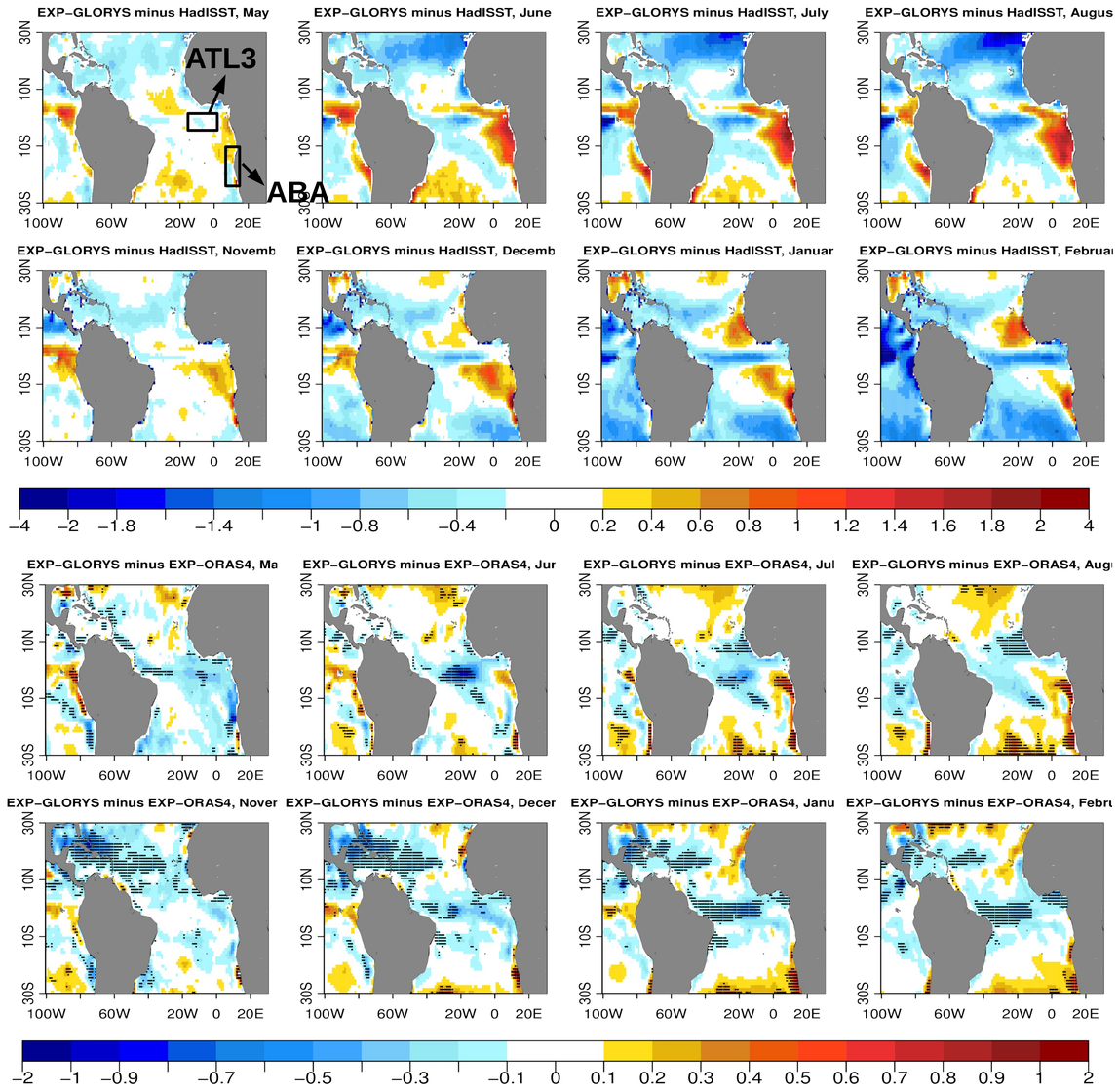

Fig 1: SST bias for EXP-GLORYS (two top rows) with respect to HadISST[3] and difference between EXP-GLORYS and EXP-ORAS4 (two bottom rows). The dotted areas indicate regions where the EXP-ORAS4 has significantly smaller bias (at a 90% significance level). The boxes denote the two regions Angola-Benguela Area (ABA) and ATL3.

- **Hindcasts develop a warm bias in ABA in all months and a cold bias in ATL3 in DJF.**
- **Initialized from ORAS4: improvement over ABA during July and August, and improvement over ATL3 during June, January and February.**

3. What are the differences between the two ocean reanalysis?

GLORYS minus ORAS4

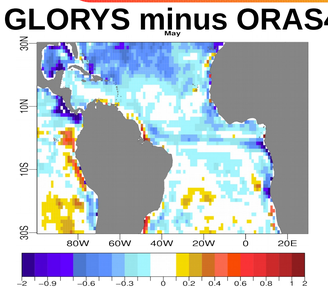

Fig 2: Differences in SST climatology in May (years 1993-2009) between GLORYS and ORAS4.

The GLORYS May climatology is colder than ORAS4, explaining the slower bias development in ABA warming, and the faster development in the ATL3 cooling in EXP-GLORYS.

4. Fast bias development: surface heat fluxes during the first forecast month

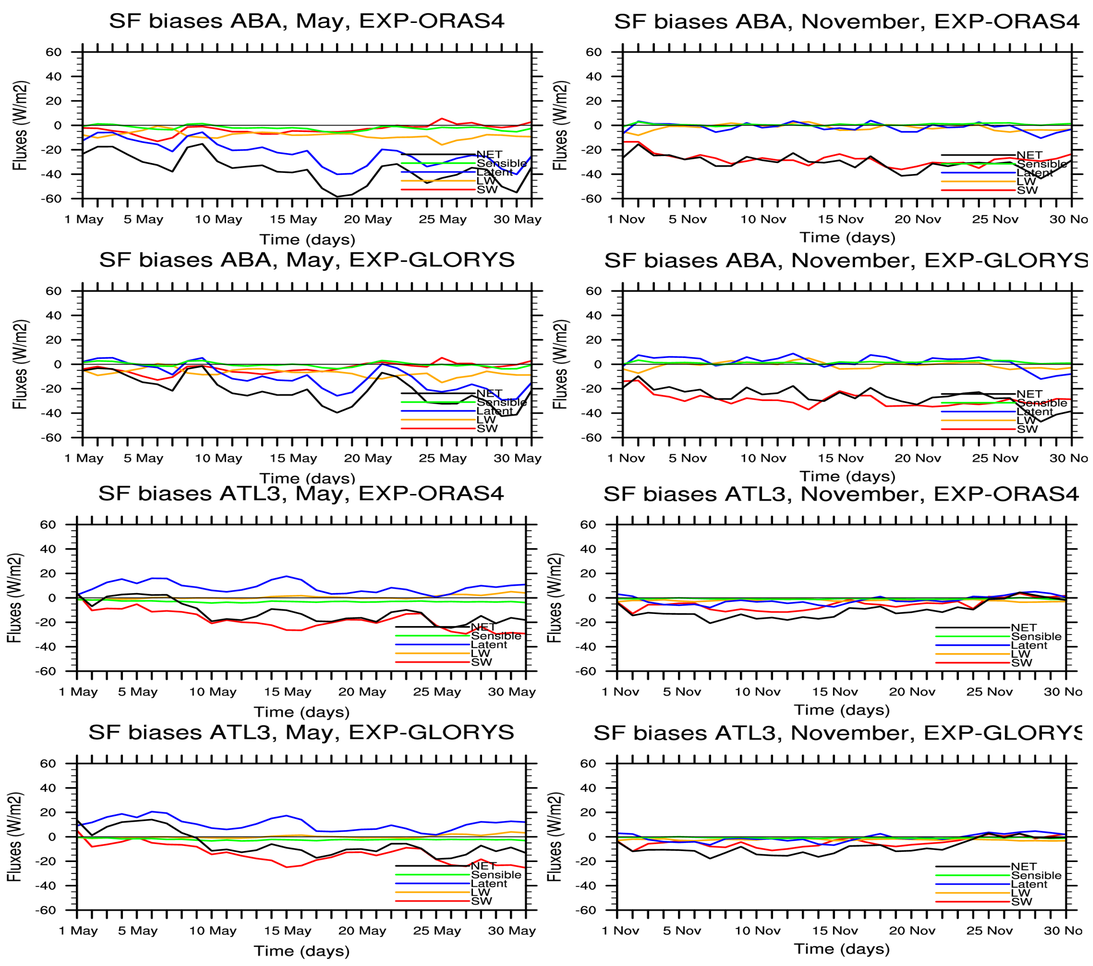

Fig 3: Biases in the four components of the surface heat fluxes with respect to ERAint[4]: sensible (green), latent (blue), longwave (orange), shortwave (red) and net (black), where positive is downwards. The daily climatologies for May (left column) and November (right column), for ABA (top two rows) and ATL3 (bottom two rows) are shown, for EXP-GLORYS and EXP-ORAS4.

- **Both hindcasts have weaker downward heat fluxes than ERAInt in all cases.**
- **Therefore damping the SST warm bias over ABA, rather than generating/enhancing it; but: could contribute to the cold bias over ATL3 in November.**
- **Both hindcasts have less solar fluxes (too much cloud cover) compared to ERAint.**
- **The negative biases in latent heat fluxes over ABA in May imply that the latent heat flux is likely a response, rather than a driver, of the SST warm bias.**
- **The warm bias in ABA seems to have oceanic origin, which can be triggered by a reduction in the upwelling of cold water to the surface.**

5. Biases in surface winds

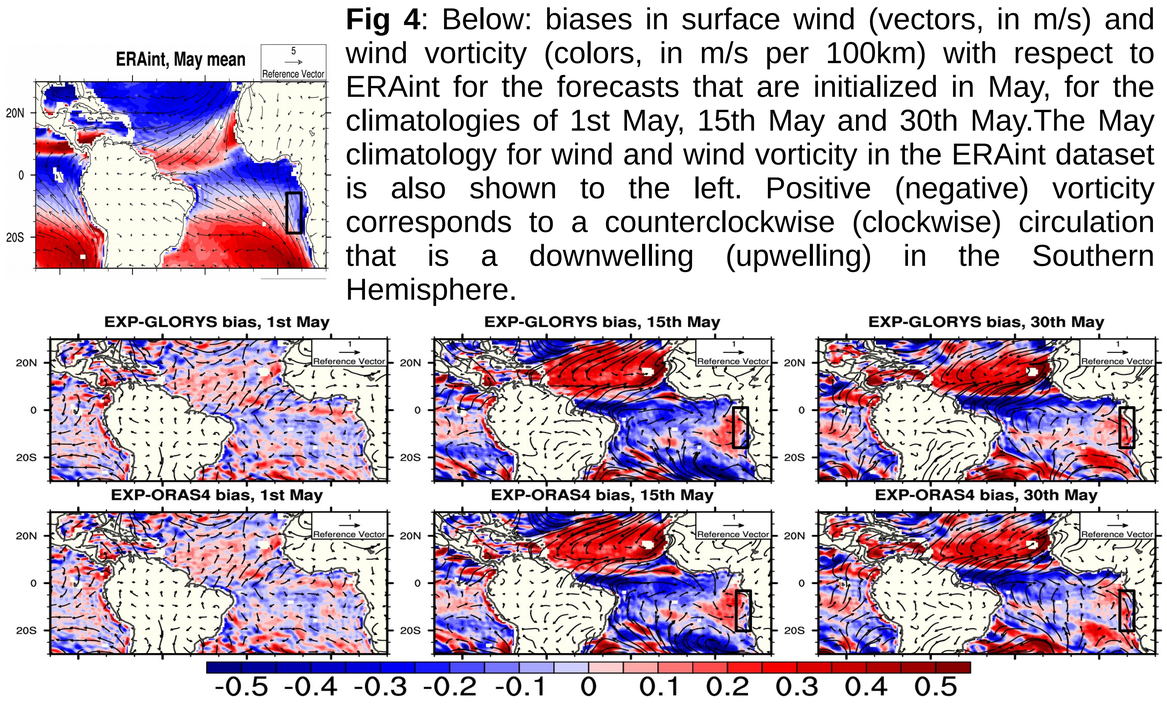

Fig 4: Below: biases in surface wind (vectors, in m/s) and wind vorticity (colors, in m/s per 100km) with respect to ERAint for the forecasts that are initialized in May, for the climatologies of 1st May, 15th May and 30th May.The May climatology for wind and wind vorticity in the ERAint dataset is also shown to the left. Positive (negative) vorticity corresponds to a counterclockwise (clockwise) circulation that is a downwelling (upwelling) in the Southern Hemisphere.

- **Reduction in the (negative) vorticity over ABA (black boxes), present already the 15th day of the forecast, imply reduction of Ekman-induced upwelling of water masses, which can contribute to a warm SST bias.**

Outlook

Investigate possible role of surface fresh water fluxes

Investigate oceanic daily data and compare with oceanic reanalysis data; for example, what are the actual changes in oceanic upwelling?

Investigate possible dynamic connections between ABA and ATL3.

References:
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2. Richter, I. (2015). Climate model biases in the eastern tropical oceans: causes, impacts and ways forward. Wiley Interdisciplinary Reviews: Climate Change, 6(3), 345–358. doi:10.1002/wcc.338
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