Recent Ocean Activities within the S2S context (Subseasonal-to-Seasonal)

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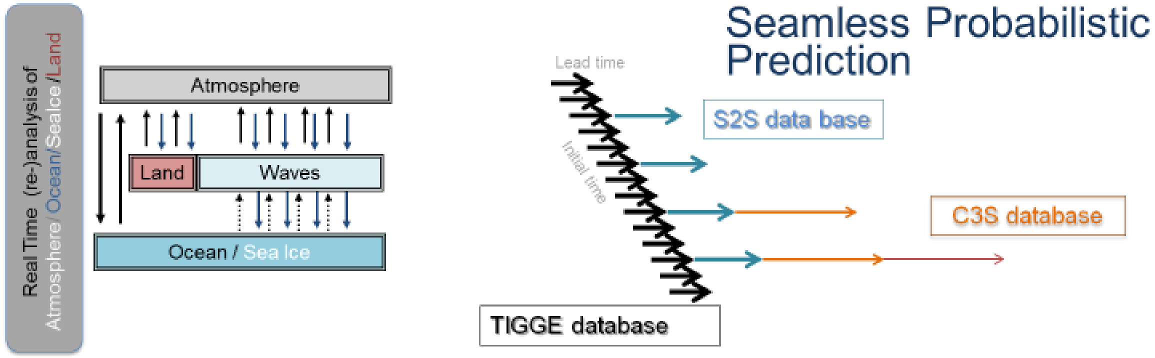
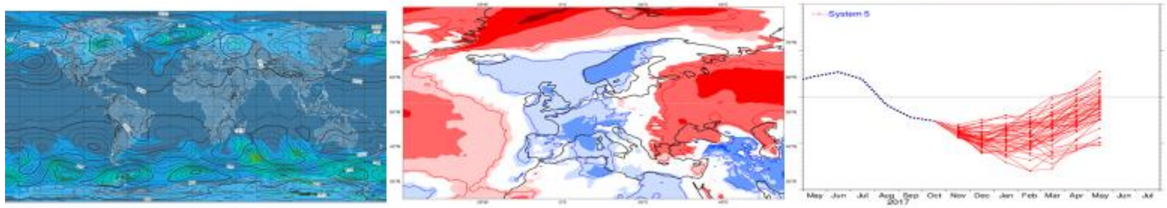


In-Situ Ocean Observing System Impact of S2S

Reanalyses and Seasonal Forecasts of OHC

Medium range prediction | Extended range –monthly- prediction | Long range –seasonal- prediction



High resolution mean sea level pressure and ensemble spread
Forecast range: several days ahead

Weekly anomaly – 2m temperature over Europe
Forecast range weeks 3-4

El Nino 3.4 SST anomaly plume – 1 November 2017

Up to 6-12 months

https://www.ecmwf.int/en/forecasts

Calibration and Skill assessment of seamless probabilistic predictions need Earth System Reanalyses

Part I: Impact of Ocean Observations on S2S forecasts

Experimental design

ORA: provision of initial conditions

FC: Ensemble of coupled forecasts

Period: 1993-2015, 5 ens members
As ORAS5 except for :
lower resolution(~1^o, 42 levels)
No Altimeter - No bias correction
All ORA have strong SST constrain

Reforecasts Period: 1993-2015
Model: as operations at low resolution ocean (1^o , 42 levels)
Seasonal: May and November starts, 15 ens. Members.
Low resolution atmosphere (Tco199)
Subseasonal: Starts every month, 5 ens. members (Tco399)

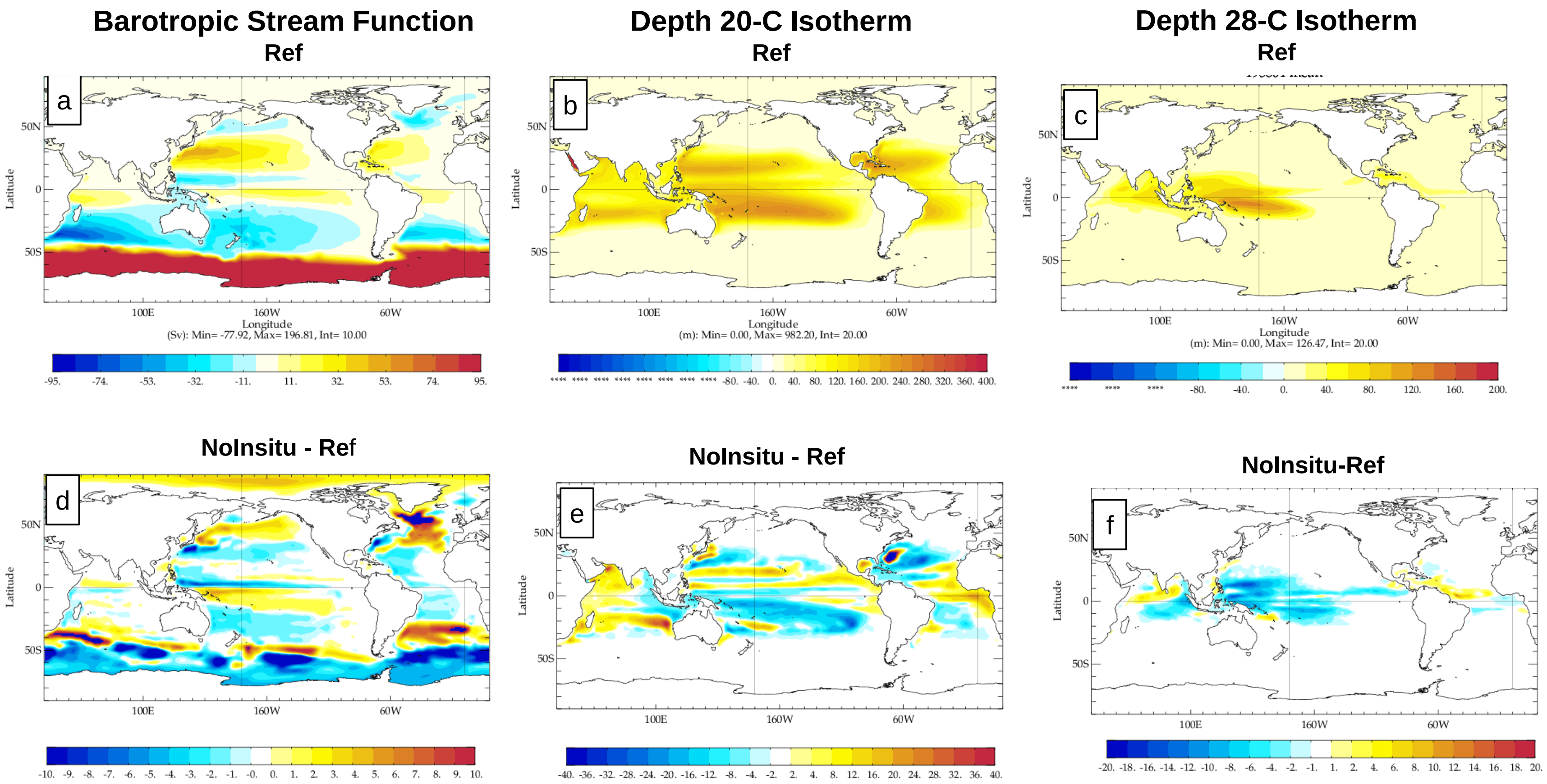
Experiments
REF: SST, all Insitu
NoArgo: As REF, No Argo
NoInsitu: As REF, No Insitu
NoInsituAtl: As REF, but No Insitu in Atlantic

Evaluation methodology:
- Differences in the mean state of atmospheric and ocean forecast variables
- Impact on bias and errors

First time that we look at impact of ocean observations on atmospheric variables

First a look at the mean differences on ocean initial conditions

2005-2015 mean



In-situ observations have an impact on:

- The global circulation (BSF) –large memory-potential to impact multiyear forecasts
- Thermocline depth (D20)- potential to impact seasonal forecasts (several months adjustment time)
- Warm pool (D28) and mixed layer (not shown)- potential to impact monthly forecasts

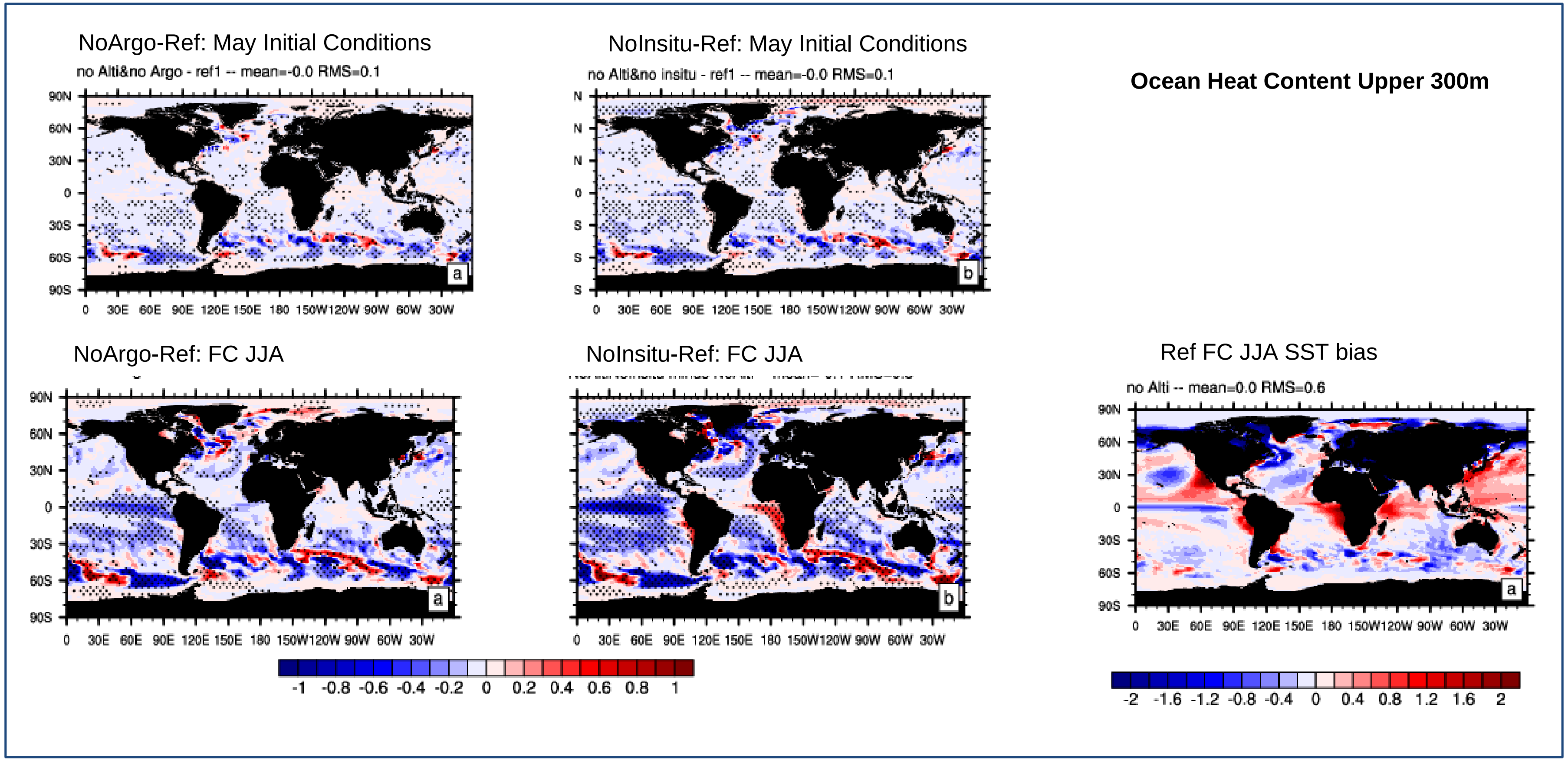
ECMWF

From Initial condition differences to Seasonal Forecast differences: Sea Surface Temperature

May starts 2005-2015   JJA verification

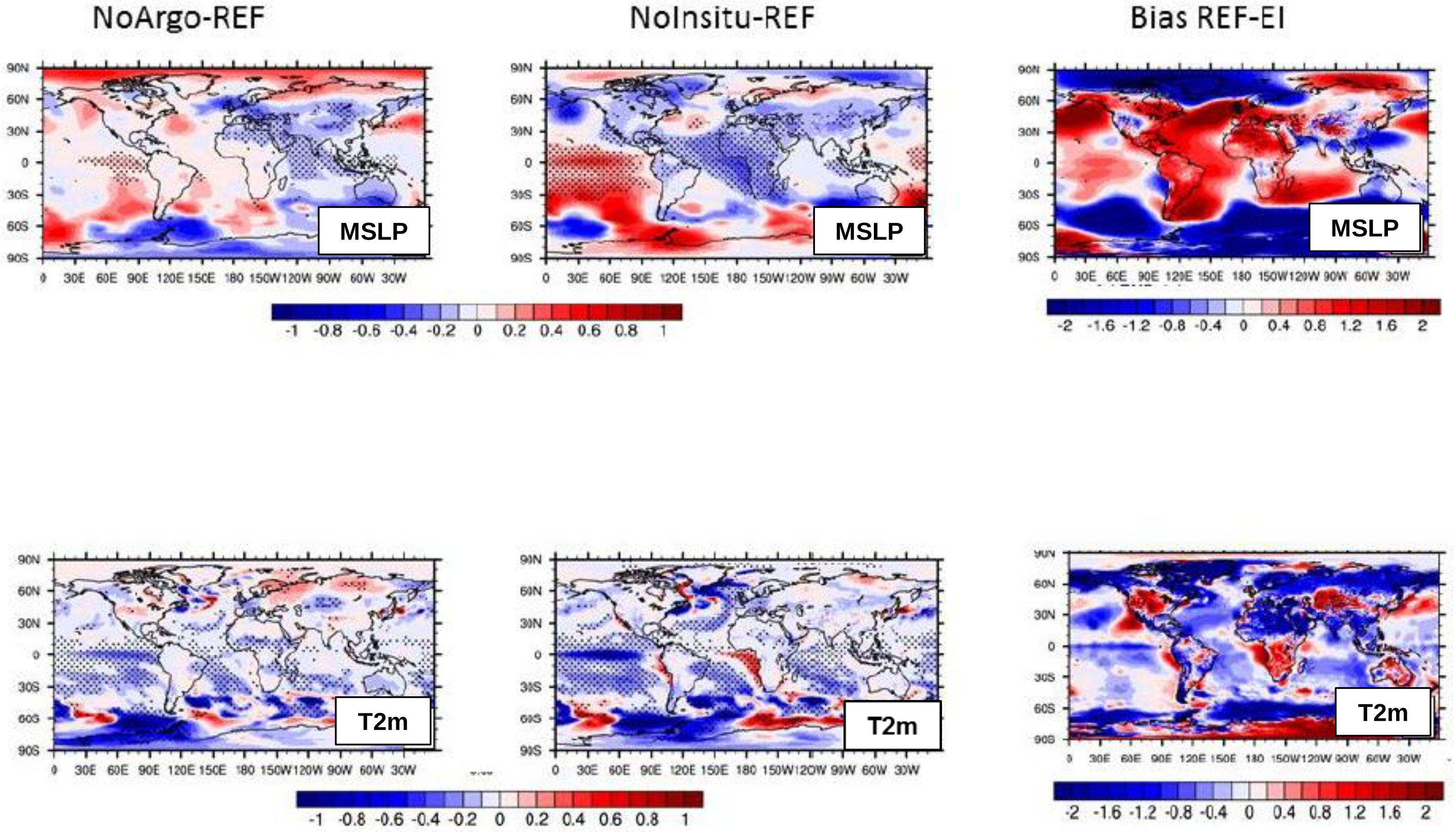
Mean difference on Ocean Initial Condition

Mean difference on seasonal forecasts



- Impact of observations visible in SST initial condition. Impact small but significant.
- **Fast**: Removing observations induces overall cooling in forecasts (likely Mixed layer processes. Note different sign of impact between SST and OHC in Indian Ocean)
- **Medium** : Strong dynamical cooling (warming) in Pacific(Atlantic) cold tongue by removing observations.
- **Slow:** In Extratropics and gyres, impact on SST Forecast resembles the impact on OHC initial conditions

Impact of Ocean Observations impact Seasonal Forecast atmospheric mean state



May starts 2005-2015
JJA verification

Top panels: Mean sea level pressure (MSLP)

- Tropical Pacific: increased MSLP over Cold Tongue Area, La Nina-like conditions, associated dryness in precip
- Tropical Indo-Atlantic: decrease in MSLP likely due to large scale SST gradients
- Extratropics: Likely due to teleconnections though some local impact due to Gulf Stream and subpolar gyre.

Bottom panels:

- T2m changes compatible with overall cooling in sea surface temperature
- NoInsitu impact is largely similar to NoArgo

Balmaseda et al. (in prep)

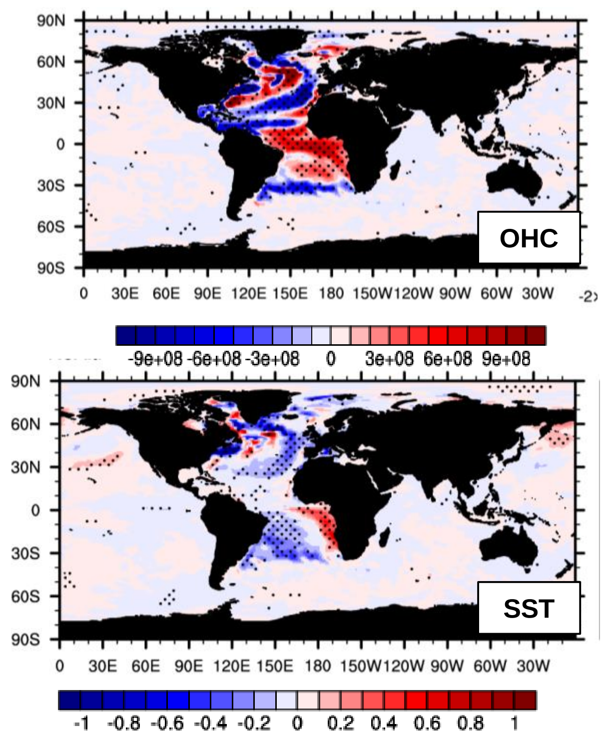
Note that while the amplitude of observation impact may be comparable to the forecast bias, the structure is not a 1-1 match.

In the Equatorial Pacific, removing observations enhances the cold bias and the high MSLP.

But over the Atlantic, removing the in-situ seems to improve the forecast bias in MLSP

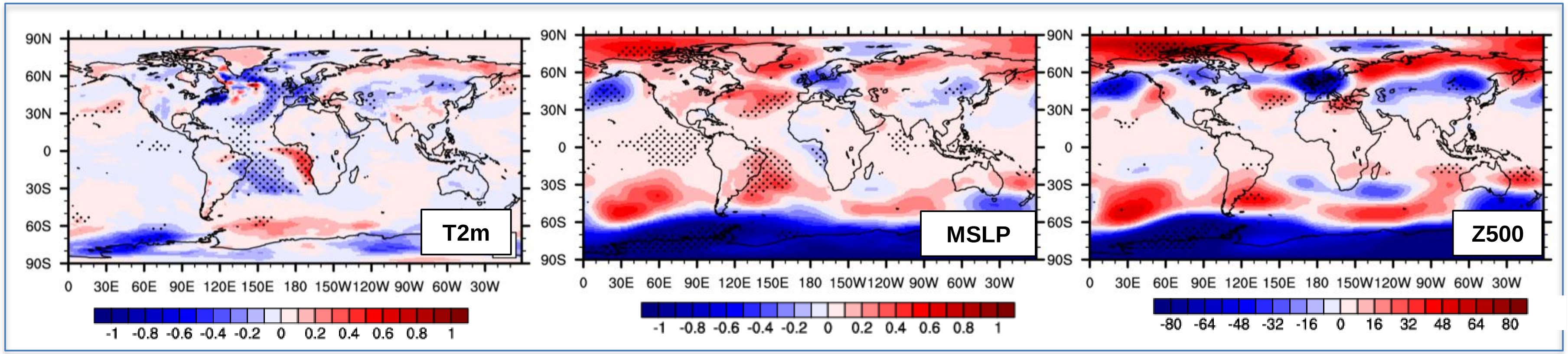
The impact of ocean observations is non-local: atmospheric bridge

May Ocean Initial Conditions



NoInsitu Atlantic - Ref

Seasonal Forecasts verifying in JJA



The atmosphere responds to large scale SST gradients. As a consequence, at seasonal time scales:

A) differences in Atlantic SST are felt by the atmosphere at a global scale:

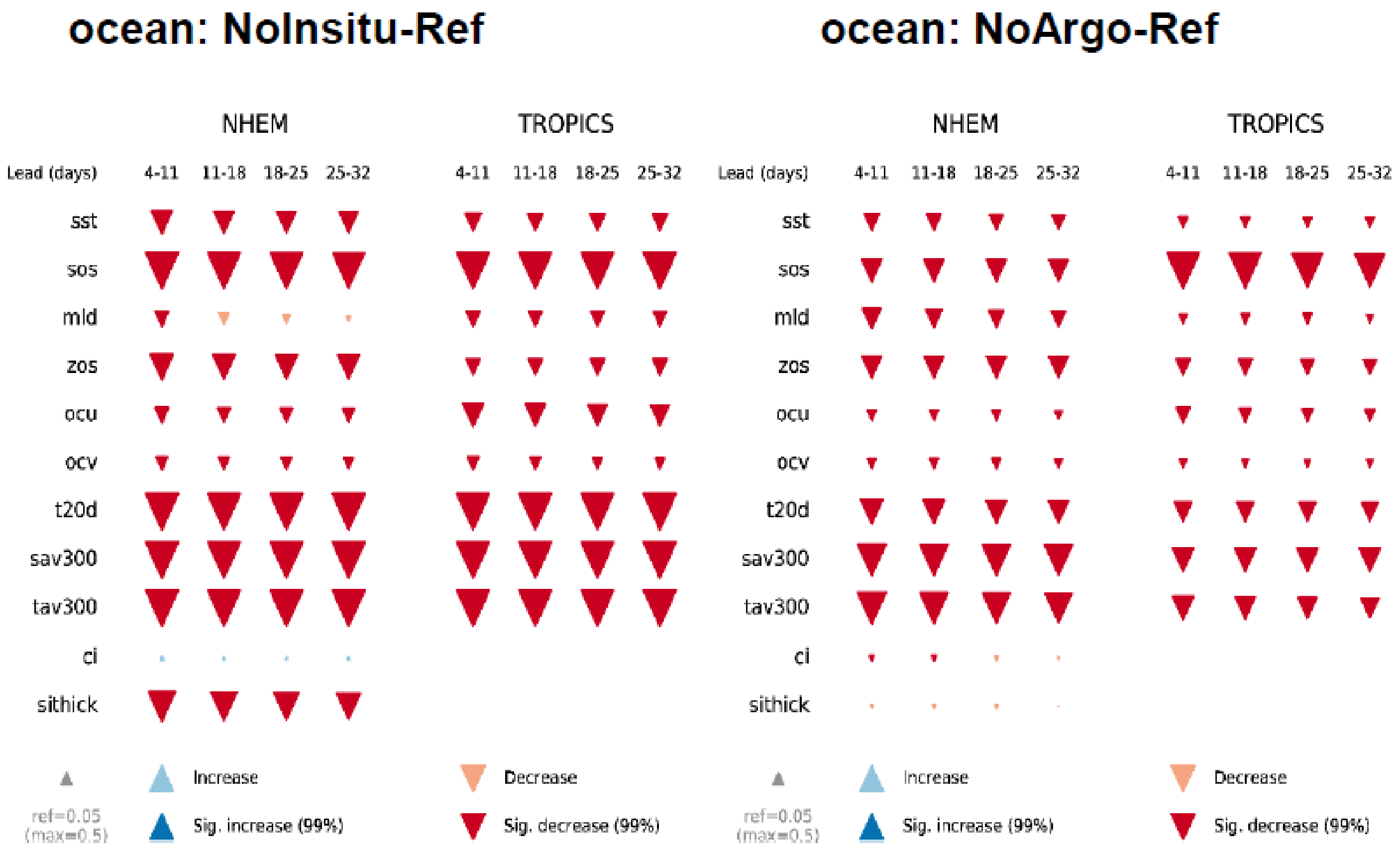
Note the significant impact on MSLP in the Tropical Pacific, the impact on T2m at the Pacific mid-latitudes.

There are also some significant impact on the Southern hemisphere subtropical jet by Australia

B) The response to local SST may be modified by signals from other areas, creating interference:

Note the MSLP response over the tropical Atlantic is very different between NoInsitu-global (previous slide) and NoInsitu-Atlantic

Impact on Extended Range: Ocean Biases



Red : Degraded mean state compared to Reference fc

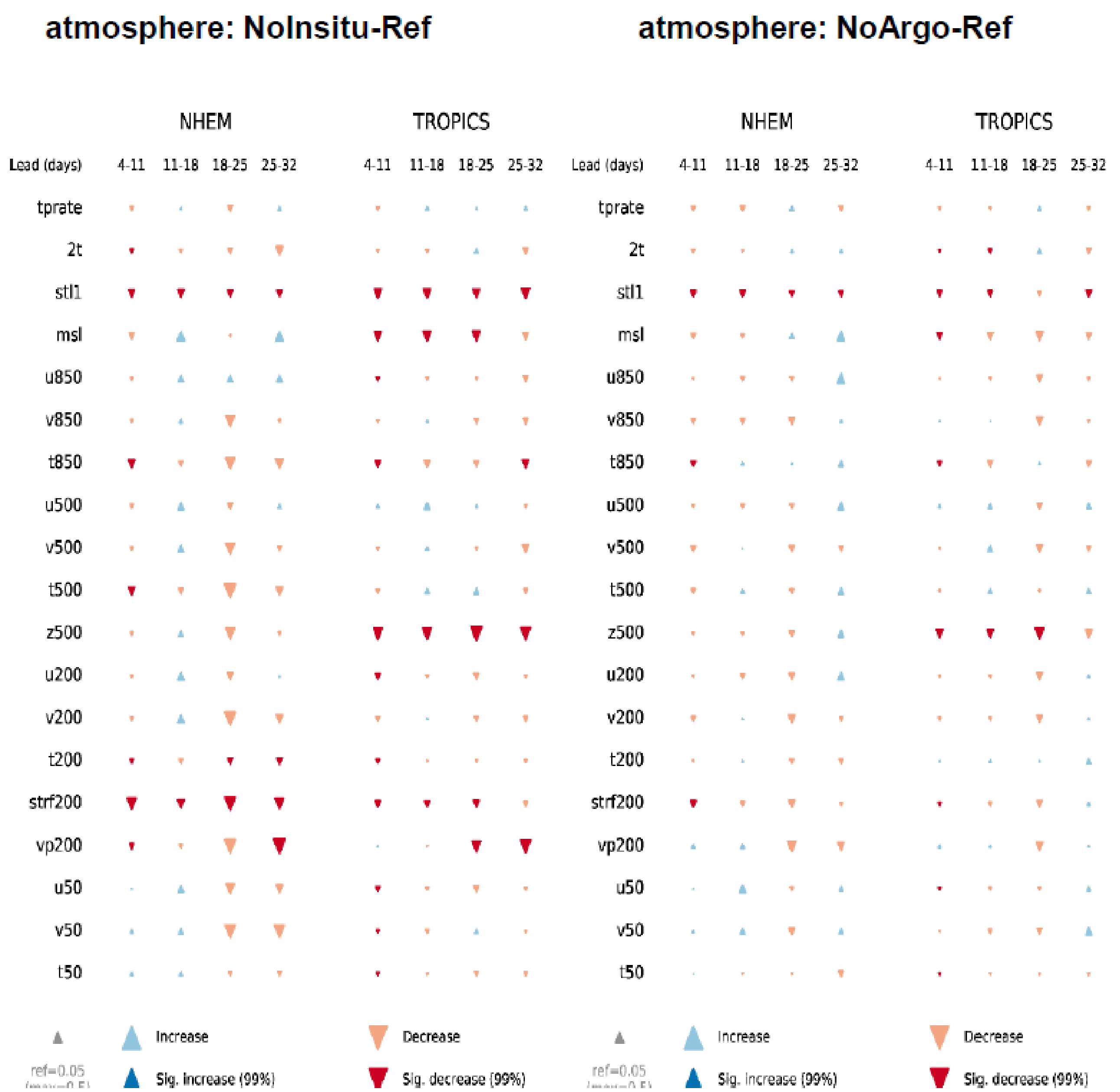
Significant degradation in ocean surface and subsurface variables when removing observations From week 1 to week 4

ECMWF

Impact on Extended Range: Atmospheric biases

Compared to the impact in the ocean biases, the impact on atmospheric biases is comparatively smaller:
-more indirect impact
-biases in atmosphere affected by many other factors.

But still, impact on bias is significant on tropical surface temperature and MSLP. The impact on barotropic stream function on NH is also significant.



Part II: Forecasts of Ocean Variables

- Subseasonal:
  - Substantial progress within the S2S program (not shown here)
  - Selected ocean variables are now part of the public S2S database
  - Progress on defining verification datasets and score cards (previous examples).
  - It will not be covered here any futher.

- Seasonal:
  - Contribution to H2020 EuroSea project
  - C3S seasonal multi-model is preparing to output forecasts of ocean variables

Skill of Seasonal Forecasts of Upper Ocean Heat Content

Fc initialized in May
Verifying MJJ

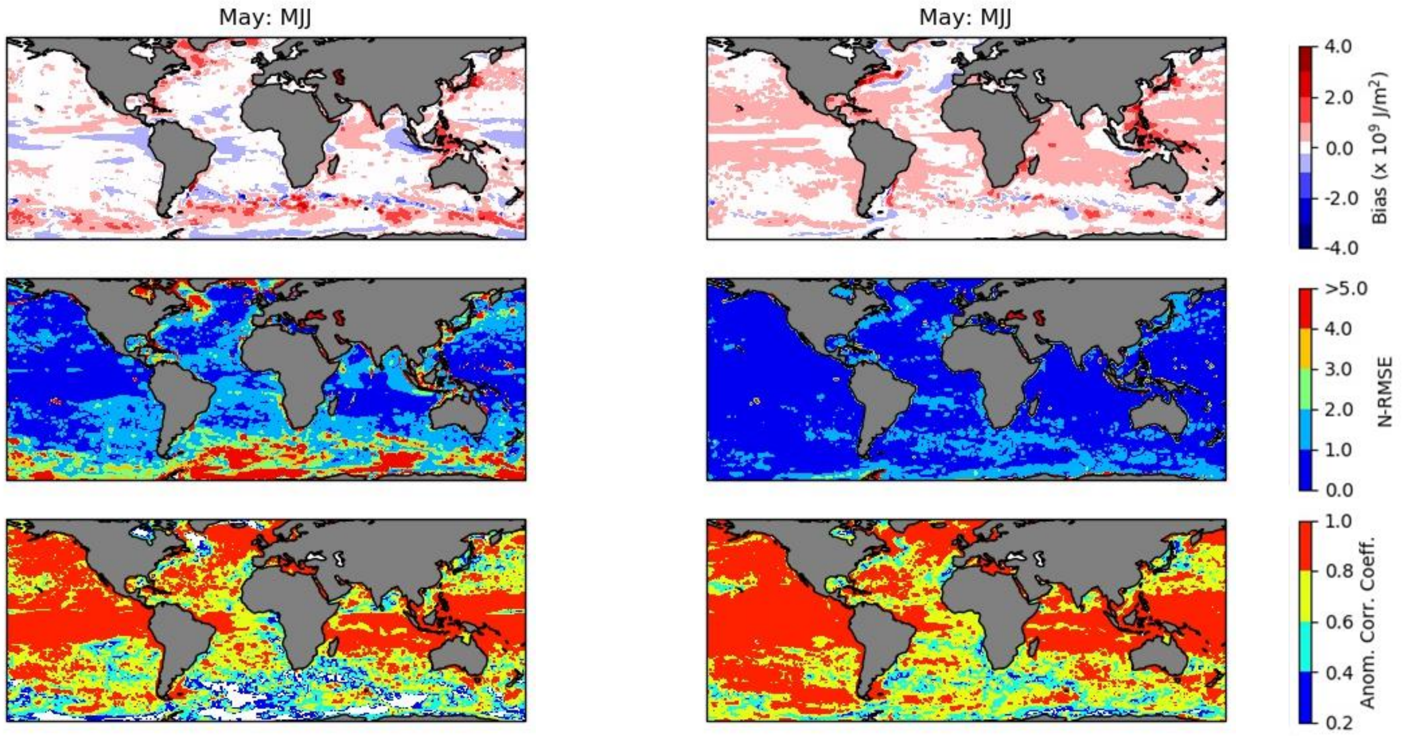
CMCC-SPS

ECMWF SEAS5

Bias

$$NRMSE = \frac{FCRMSE}{CLIM\ RMSE}$$

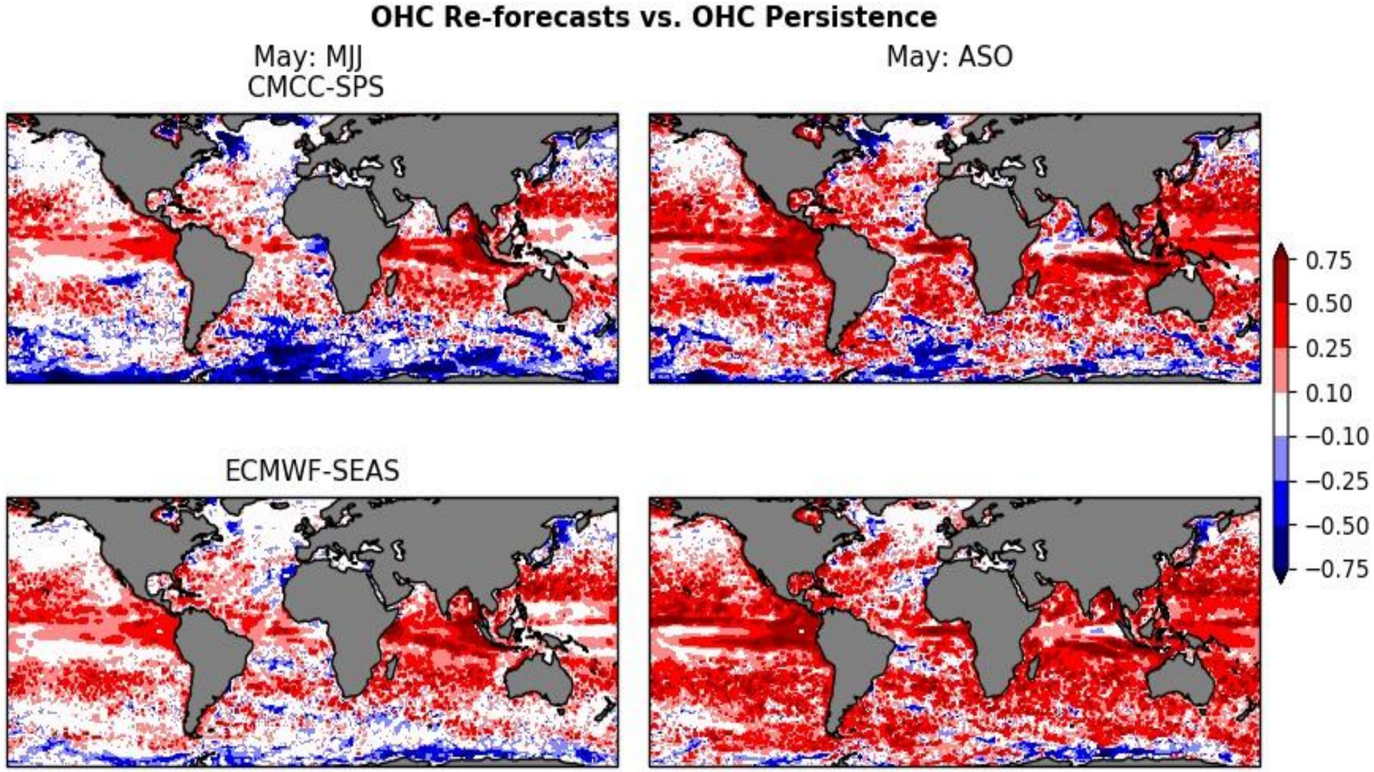
Anomaly Correlation



OHC Skill in Tropical Atlantic less than in other basins

From McAdam et al, 2021, submitted
H2020 EuroSea project

Skill of Seasonal Forecasts of OHC upper 300m: where do dynamical SF beat persistence? Verification against external ECVs



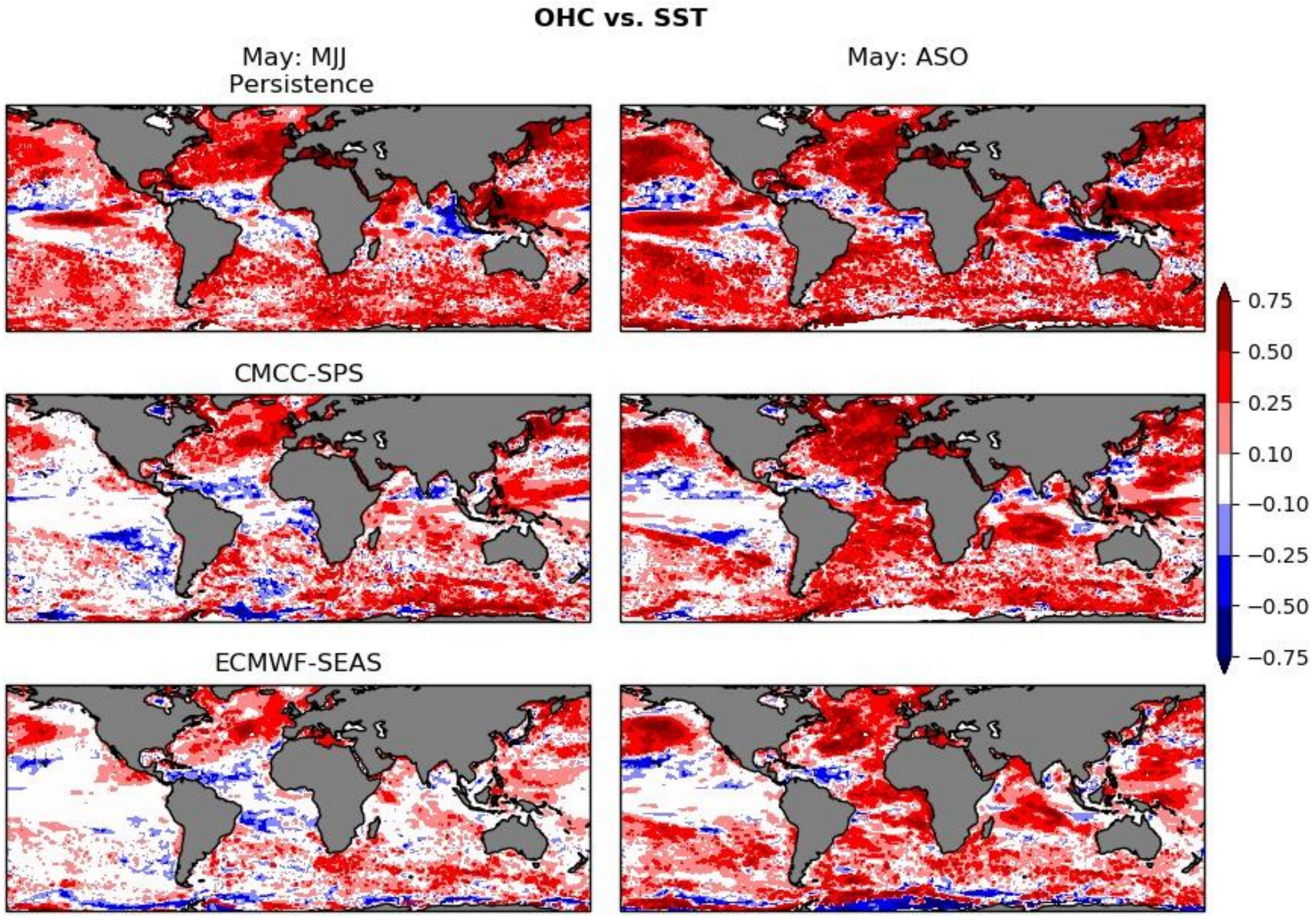
Dynamical SFs of OHC beat persistence in most areas, the Indian Ocean being particularly noticeable.

The Southern Ocean is notable exceptions

Dynamically active transition regions with thermocline gradients show lower skill in OHC. These are also regions where there is large uncertainty in ocean initial conditions (see later).

From McAdam et al, 2021, submitted
H2020 EuroSea project

Skill of Seasonal Forecasts of OHC upper 300m: where is OHC skill better than SST skill?



Persistence of OHC is higher than SST in most areas. Exceptions are the Tropical Atlantic, frontal areas in Pacific and EEIO.

Possible explanations:

- SST skill due to atmospheric predictability
- Rapid changes in OHC below mixed layer and fronts.

Distinctive features in the OHC/SST Skill in Dynamical Forecasts

In Tropical Pacific, SST skill ~ OHC skill, indicating that dynamical SF benefit from subsurface information

In Tropical Atlantic (1 season ahead) skill of SST larger that OHC. Indication of remote Atmospheric forcing?

Over EEIO: dynamical SF forecasts OHC~SST, different from persistence forecast.

From McAdam et al, 2021, submitted
H2020 EuroSea project

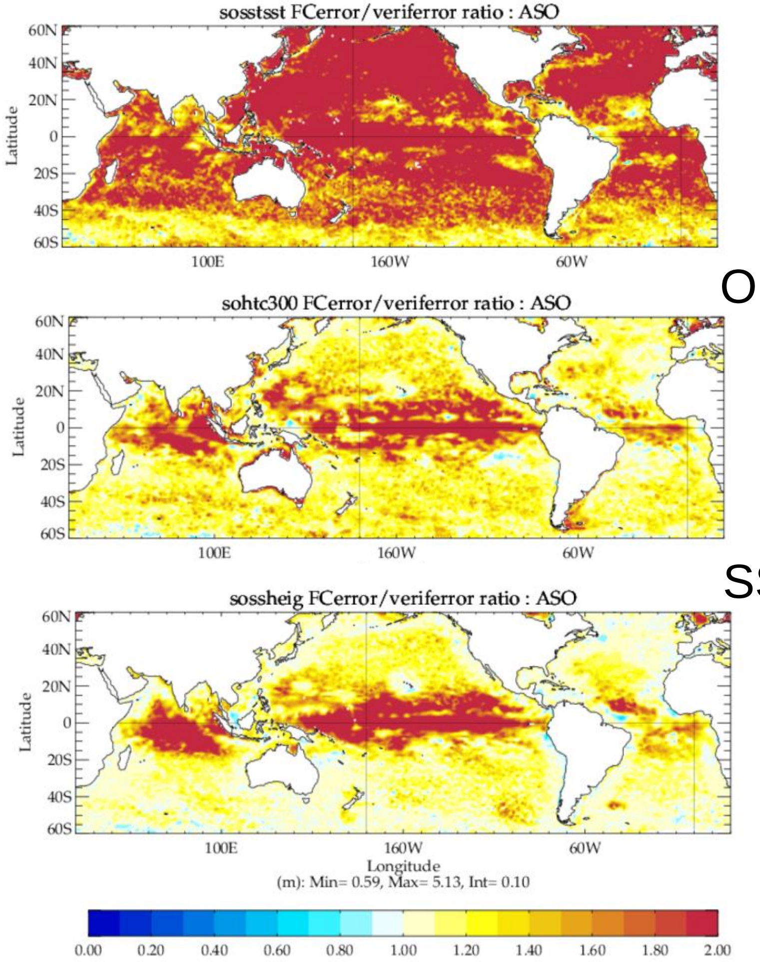
Seasonal Forecast Error versus Ocean Reanalyses Error

ASO

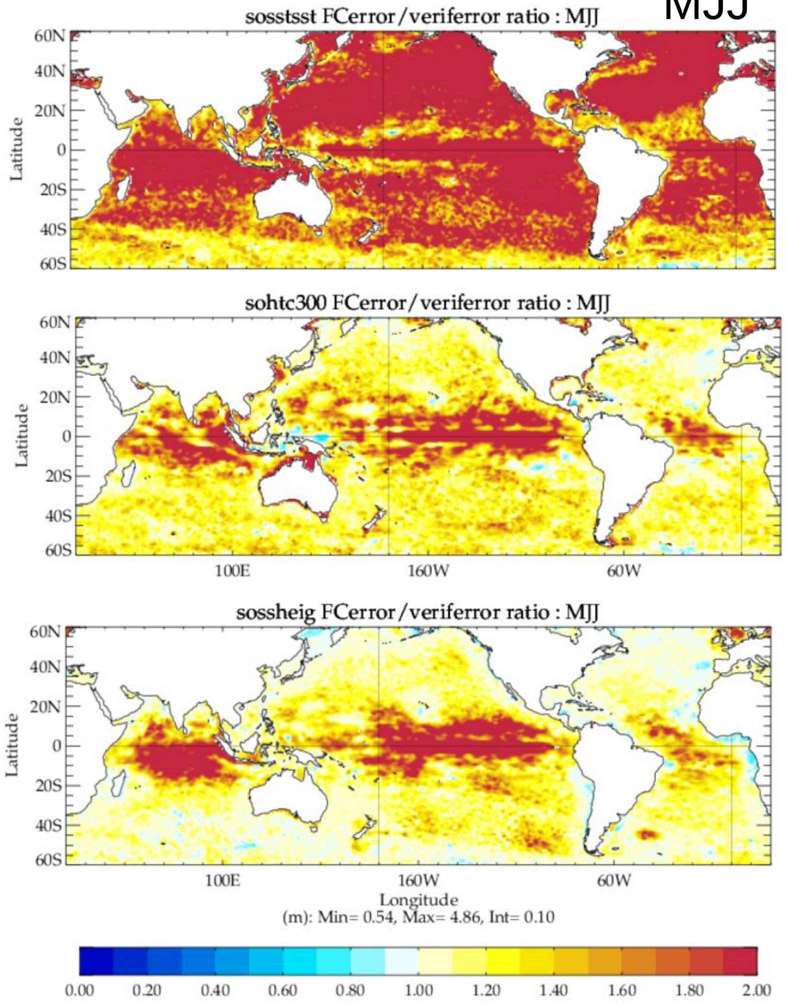
SST

OHC

SSH



MJJ



Ocean Reanalyes:ORAS5
SEAS5 forecasts 1-season ahead

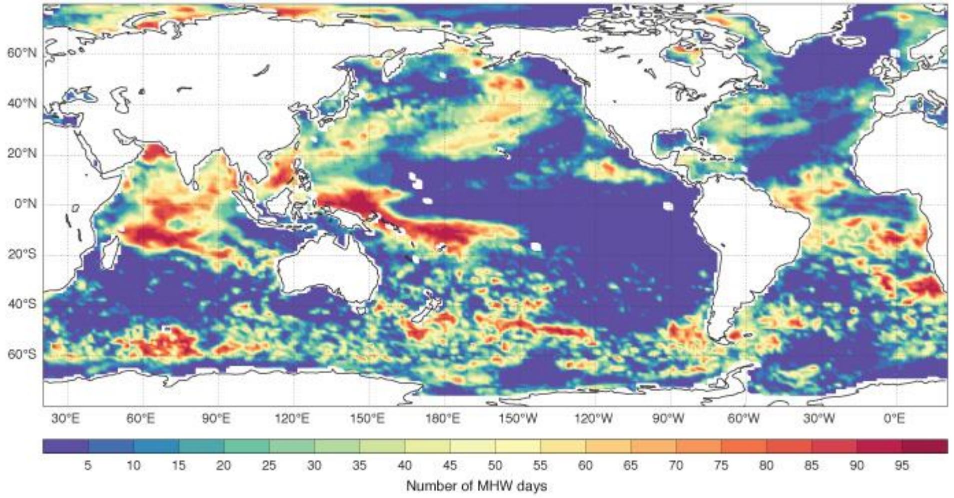
Verification:
SST and SSH: ESA-CCI
OHC: CMEMS GREP

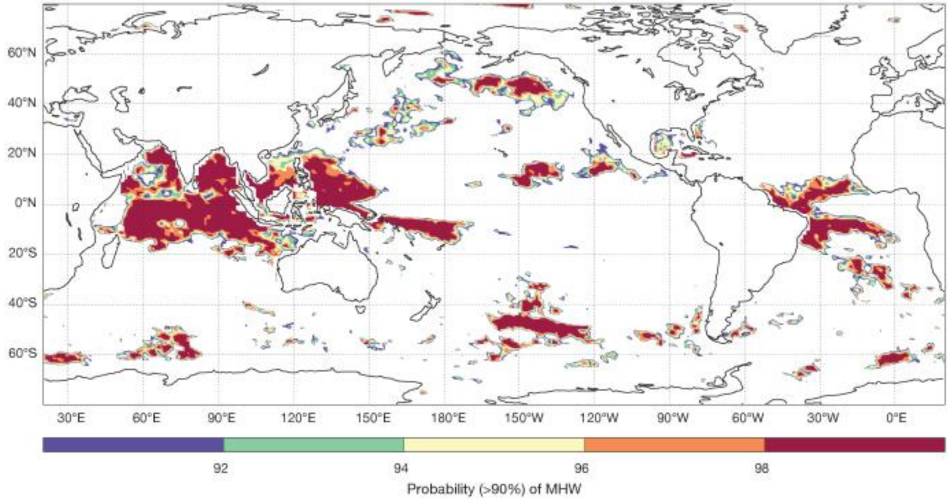
Shown is the Ratio $= \frac{RMSE\ SEAS5}{RMSE\ ORAS5}$

Ocean reanalysis error in OHC/SSH comparable to Seasonal Forecasts errors outside the tropics.

Large SST uncertainty over convective areas and ocean fronts

Detection and Prediction of Marine Heat Waves





Extreme temperature values were widespread and long lasting in summer 2020 (June–July–August), as indicated by the number of marine heatwave days detected by OCEAN5 (left). The extreme nature of the season was captured by the ECMWF seasonal forecasting system SEAS5 in the forecast initialised in May and verifying in June–July–August 2020 (right), which predicted the extreme values in the right areas with more than 90% probability. The reference climatological period is 1993–2006

De Boisseson and Balmaseda, ECMWF Newsletter 2021
See also https://www.ecmwf.int/en/about/media-centre/news/2021/world-meteorological-day-focuses-role-ocean-weather-and-climate

Summary

- We have reported on recent ocean-related activities in the sub-seasonal and seasonal forecasting communities.

- The in-situ ocean observations have a profound and significant impact on the mean state of forecast ocean and atmospheric variables, and can be classified into different categories:

  - Related to local air-sea interaction, a direct consequence of changes in the mixed layer in the ocean initial conditions, and visible in the early stages of the forecasts
  - Related to different ocean dynamical balances, most visible in the Equatorial Pacific at time scales of 3-4 months
  - Resulting from changes in large scale SST gradients; these are non-local, mediated by the atmospheric bridge, and depend on the differential impact of the observing system in different regions.

- Verification of Seasonal Forecasts of upper ocean heat content indicate:

  - OHC is more predictable that SST in most regions
  - OHC forecasts by dynamical models beat the persistence forecasts
  - Indication that dynamical forecasts of SST benefit from the predictability of the OHC
  - The Tropical Atlantic remains difficult to predict and to analyse

- There is potential for subseasonal and seasonal predictions of Marine Heat Waves