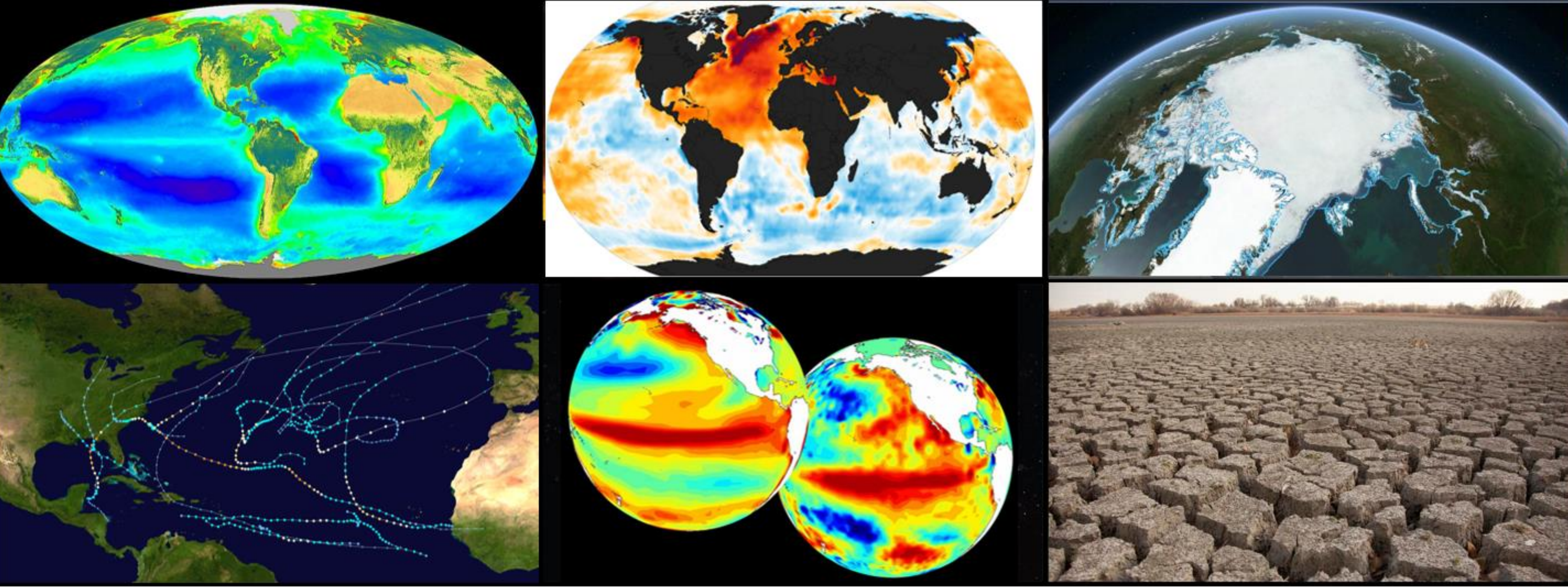


WGSIP Prediction Capabilities Project: Ocean prediction

Johanna Baehr and Bill Merryfield

WGSIP 22

October 29, 2020 (online)

World Meteorological Organization
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
International Science Council
WCRP World Climate Research Programme

Objectives

- Systematically evaluate prediction capabilities for ocean variables other than SST across time scales and for multiple climate prediction systems
- Assess performance of individual prediction systems in relation to their initialization, resolution, etc.
- Assess multi-model performance gains
- Assess properties and suitability of different verification datasets, utility of multi-product verification
- Assess sources of predictability and ability of models to represent them
- Facilitate useful real-time forecasting of ocean properties having societal impacts

Mixed-layer depth (MLD)

Importance

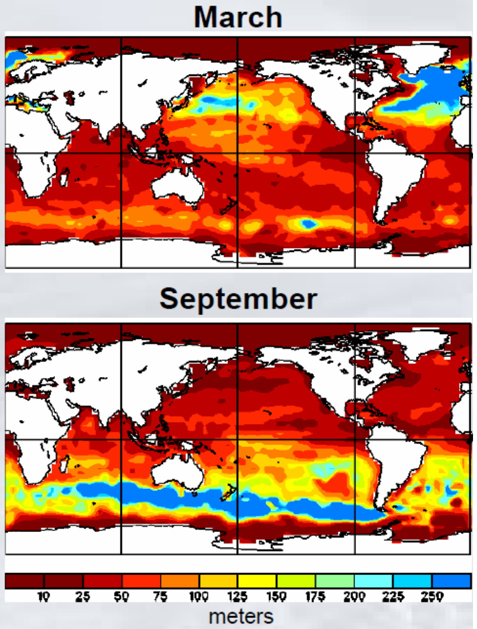
- MLD determines the volume of ocean in ~instantaneous contact with the atmosphere → influences air-sea coupling
- MLD in part governs nutrient supply → impacts ecosystems

Available hindcast data

- 5 CHFP + 2 NMME seasonal hindcasts
- S2S (daily, became available in 2020)
- C3S (daily, in progress)

Available verification data*:

- In situ: EN3v2a, ARMOR3D (CMEMS)
- Ocean reanalyses (S2S uses ORAS5)



Climatological MLD from World Ocean Atlas

* cf. Toyoda et al. *Clim. Dyn.* (2017) https://doi.org/10.1007/s00382-015-2637-7

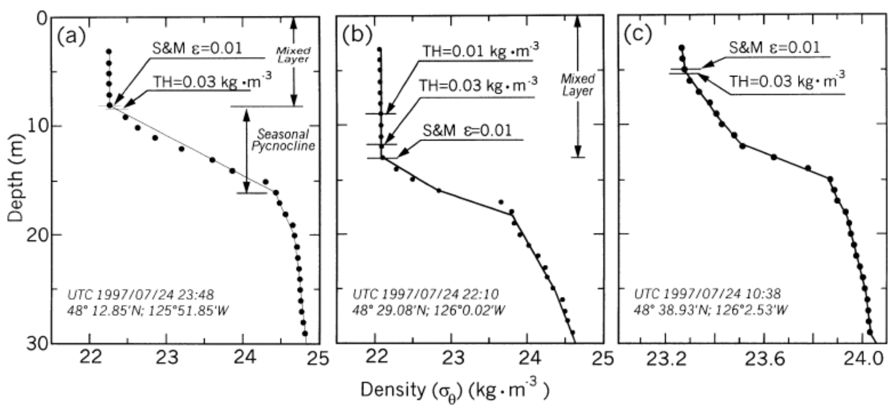
Challenges (+ Opportunities)

- Sufficient in situ data to define global interannual variability only in Argo era (~2001-present)
- Many MLD definitions, dependent on vertical resolution…

  → S2S & C3S use MLD determined by 0.01kg/m^3 density threshold (good in tropics)

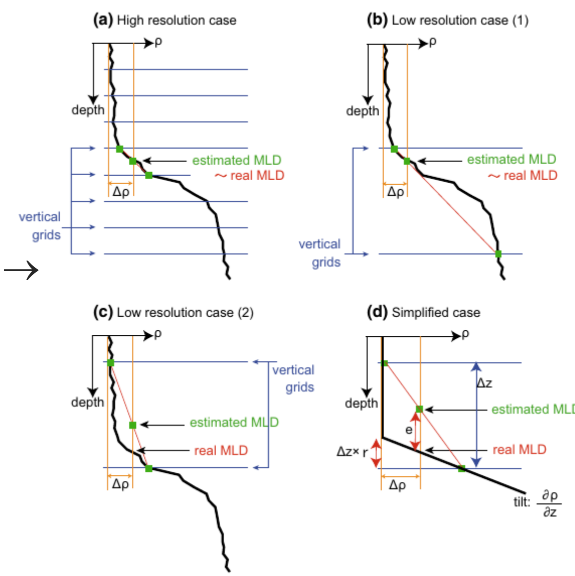
  → CMIP6 uses “ 0.03kg/m^3

  → + others based on different ΔT and density criteria



Thomson & Fine ← *JAOT* (2003)

Toyoda et al. (2017) →



- Approach: accept differences as contributing to biases, focus on anomalies
- **Opportunity**: MLD prediction capabilities have so far barely been examined!

Sea-surface height (SSH)

Importance

- Interannual SSH variability can significantly modulate coastal flooding frequency & severity
- SSH known to be relatively predictable

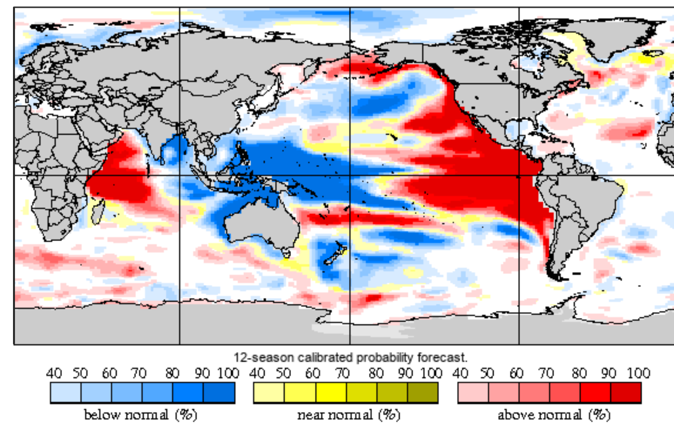
Available hindcast data

- 5 CHFP + 2 NMME seasonal hindcasts
- S2S (daily, became available in 2020)
- C3S (daily, in progress)

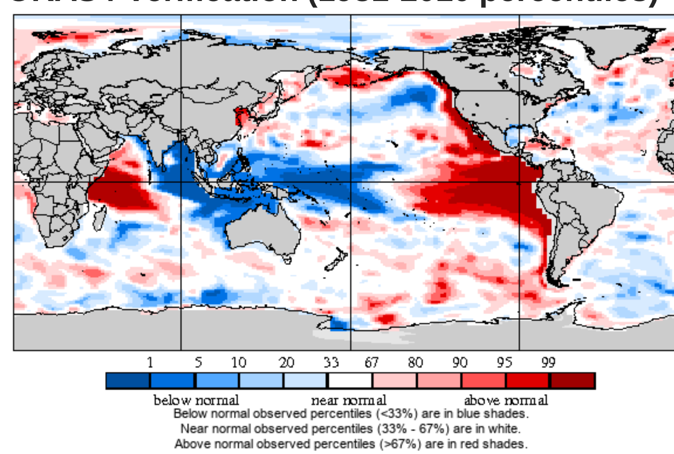
Available verification data*:

- Altimetry, e.g. AVISO (since ~1993)
- Ocean reanalyses

ECCC DJF 1997-8 from Nov (tercile probs)

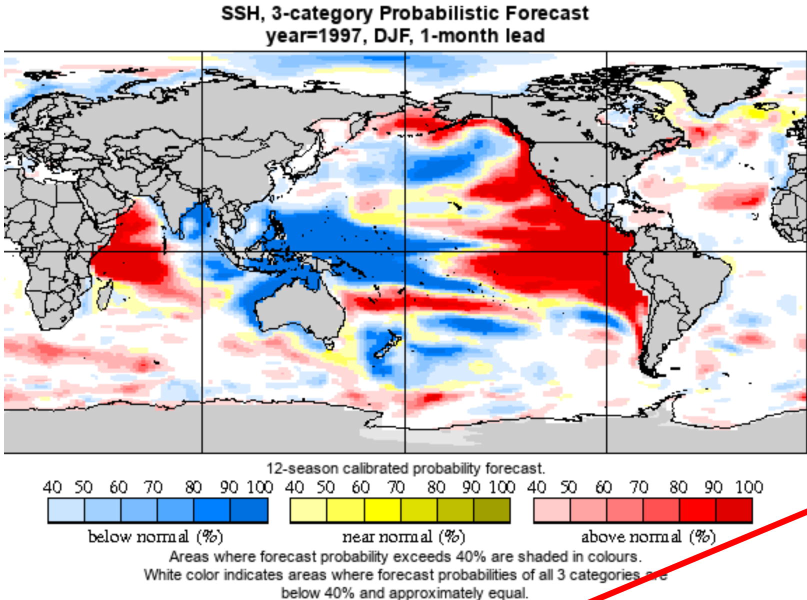


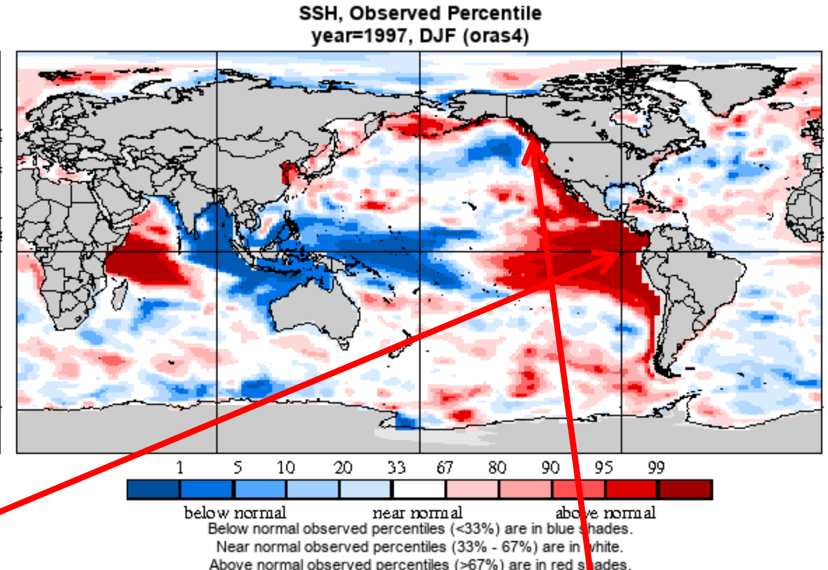
ORAS4 Verification (1981-2010 percentiles)

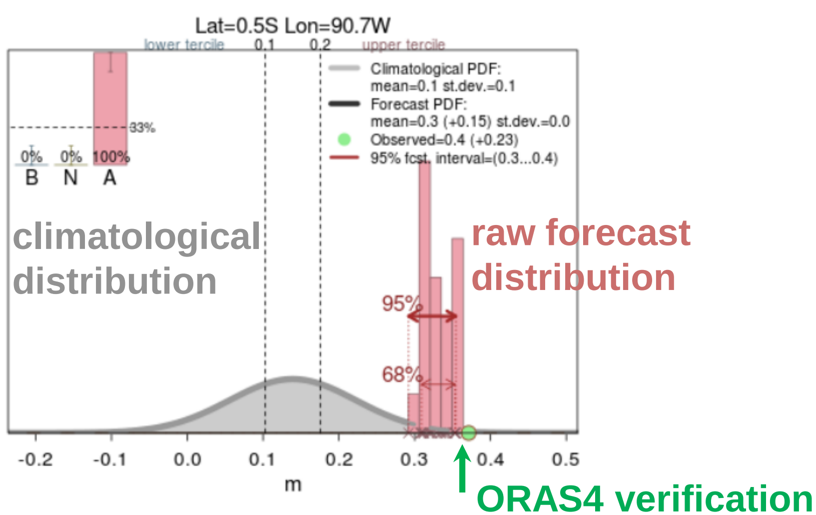


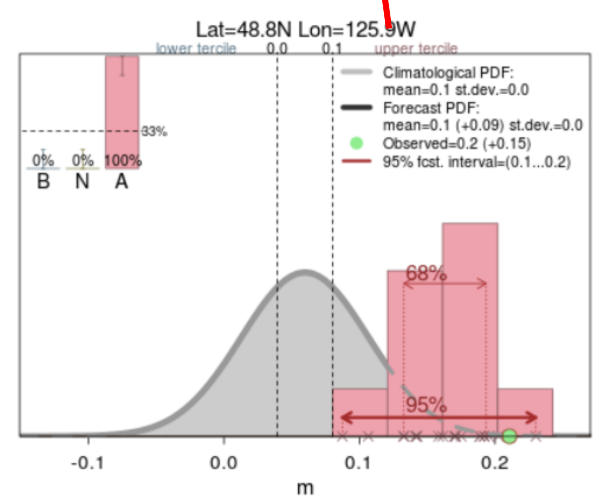
Magnitude of anomalies

DJF 1997-8 lead 1 month

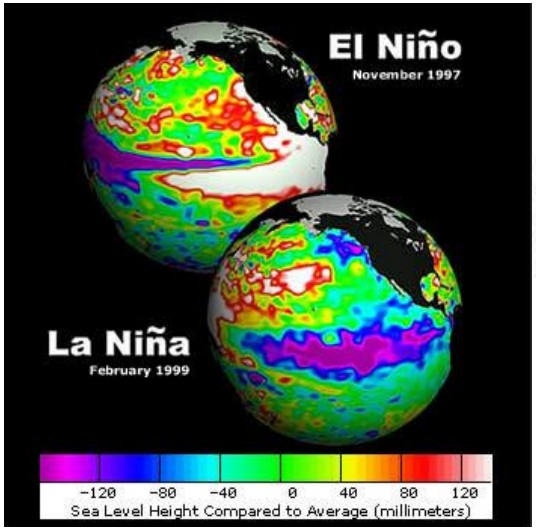


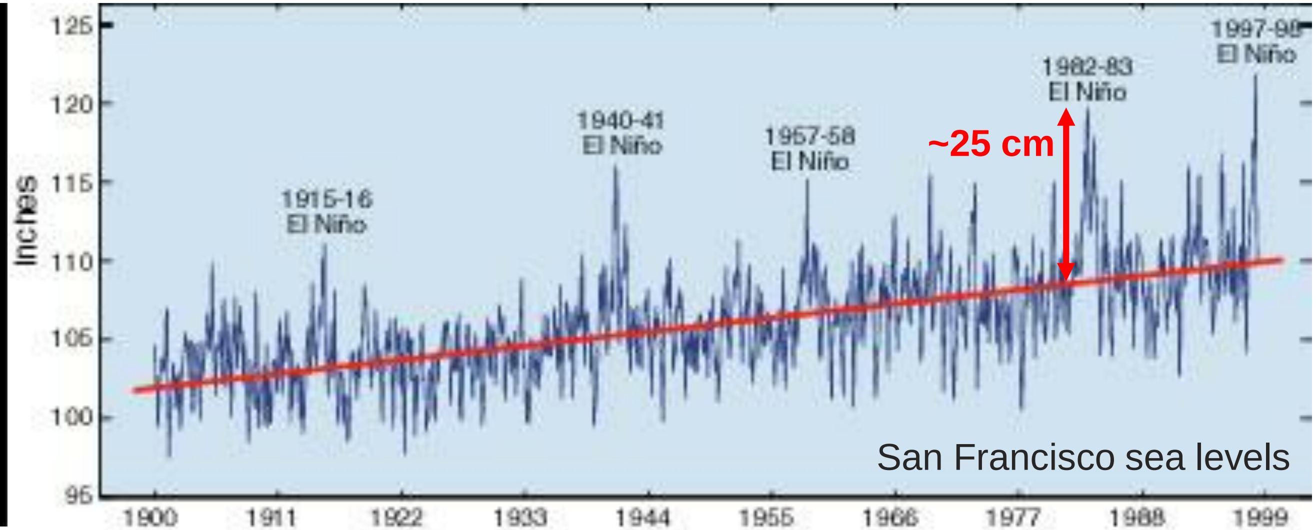






ENSO SSH Impacts





<u>Positive SSHA</u>

- Coastal "nuisance" flooding, worsened storm surges
- Accelerated coastal erosion
- Saltwater intrusion

<u>Negative SSHA</u>

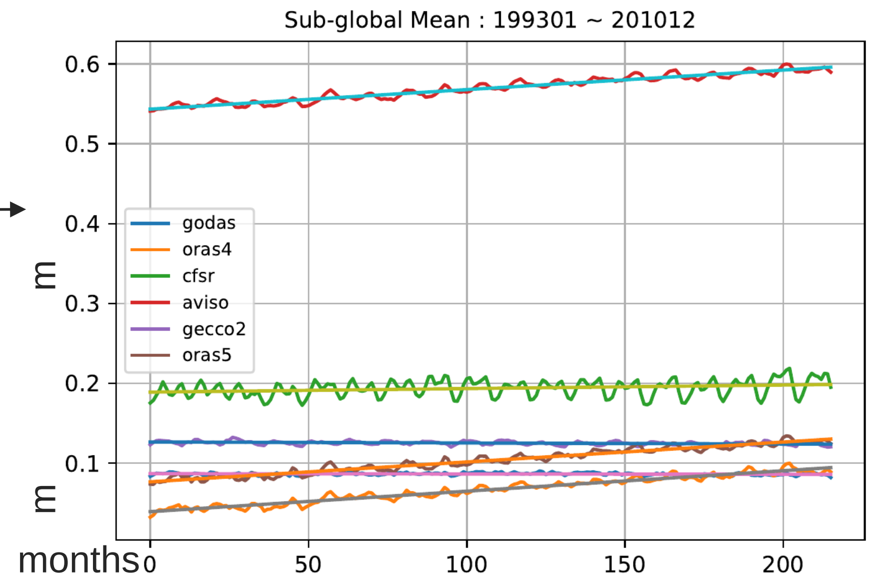
- Exposed shallow reefs
  → coral, fish die-off

Winter 1982-83, Aptos, CA *San Jose Mercury News*

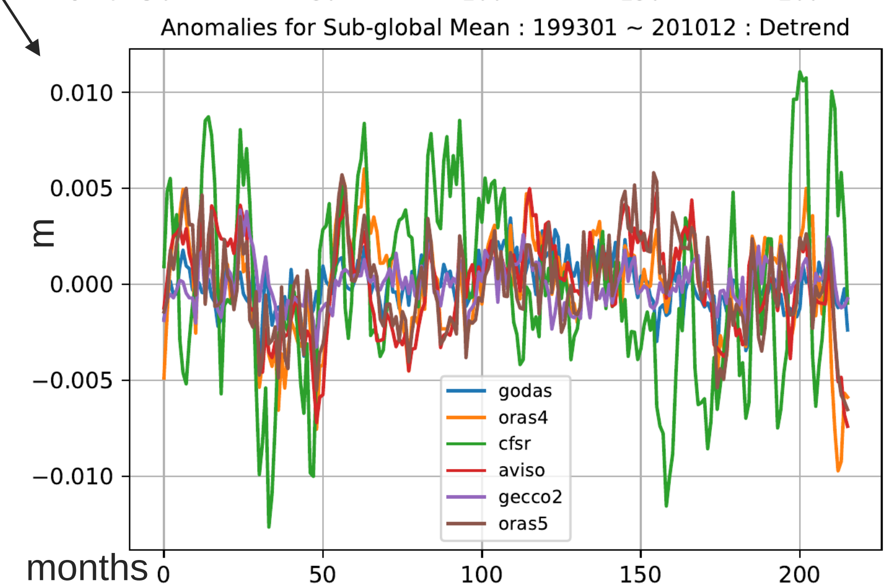
Verification datasets

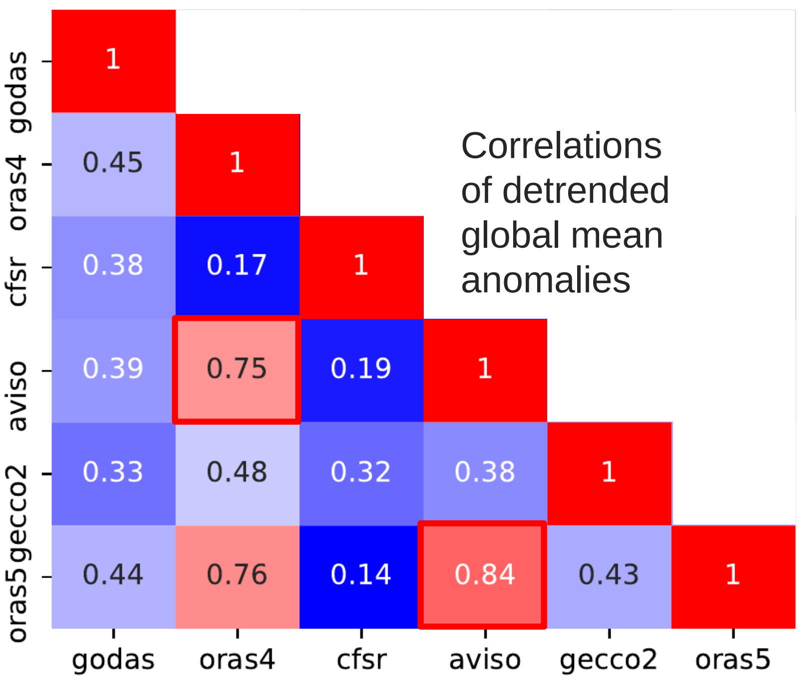
- Compare AVISO vs 5 reanalyses (CFSR, GECCO2, GODAS, ORAS4, ORAS5)
- Consider sub-global averages (60S-60N)

Full global-mean values 1993-2010
→ OASS4, ORAS5: similar trend to AVISO
→ CFSR, GECCO2, GODAS: no trend



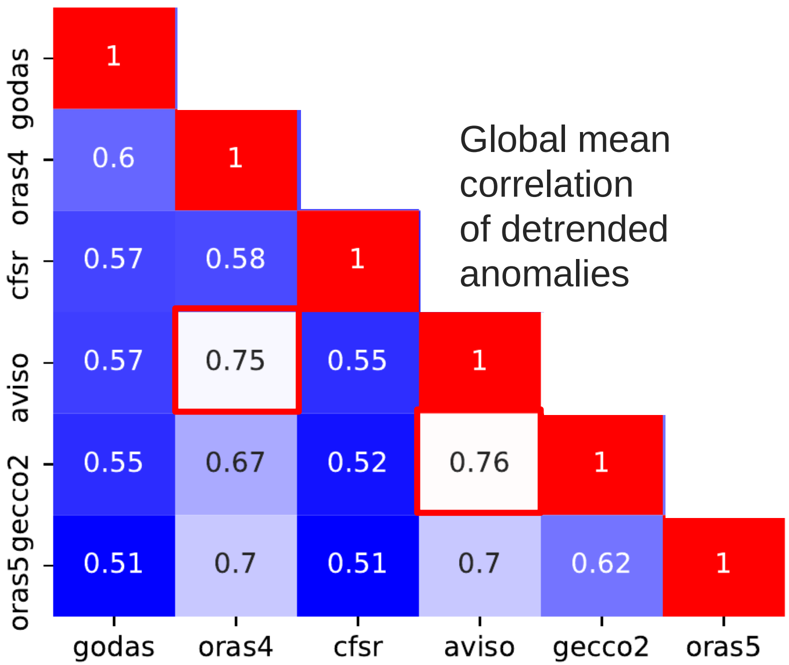
Detrended anomalies

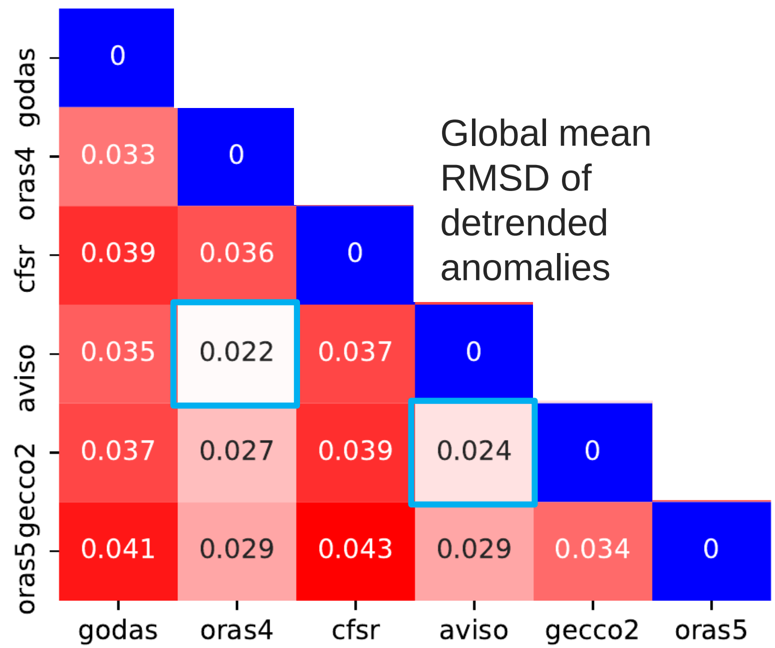




Verification datasets

- Compare AVISO vs 5 reanalyses (CFSR, GECCO2, GODAS, ORAS4, ORAS5)
- Consider sub-global averages (60S-60N) for 2D fields





→ ORAS4 and GECCO2 most similar to AVISO

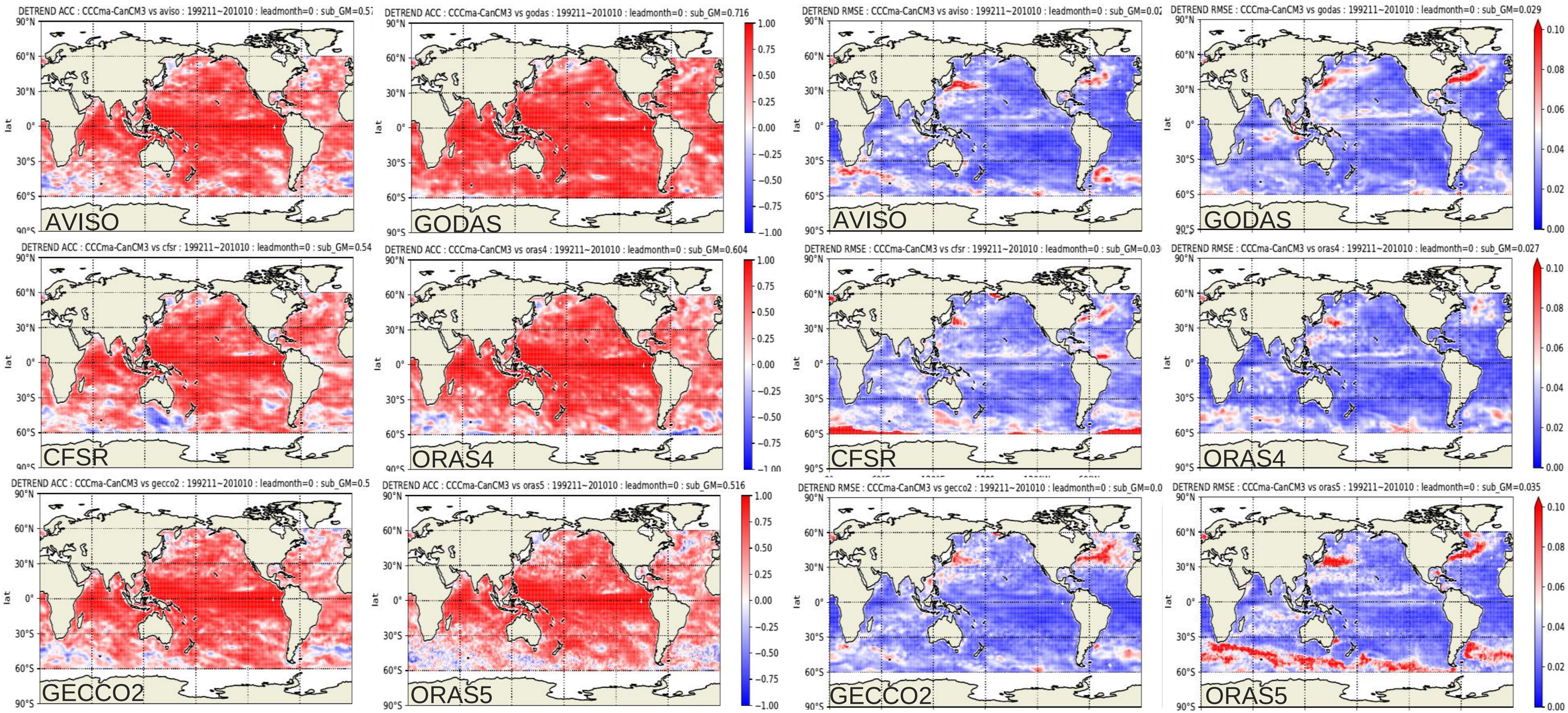
CHFP models

- SSH for 5 CHFP models (CanCM4, CanCM4, CanCM4i, JMAMRI-CGCM1, MIROC5)
- Consider ACC & RMSE for detrended anomalies (60S-60N)
- 1993-2010 hindcast period to enable comparisons with AVISO

Example: CanCM3 / Nov initialization / Lead 0 months

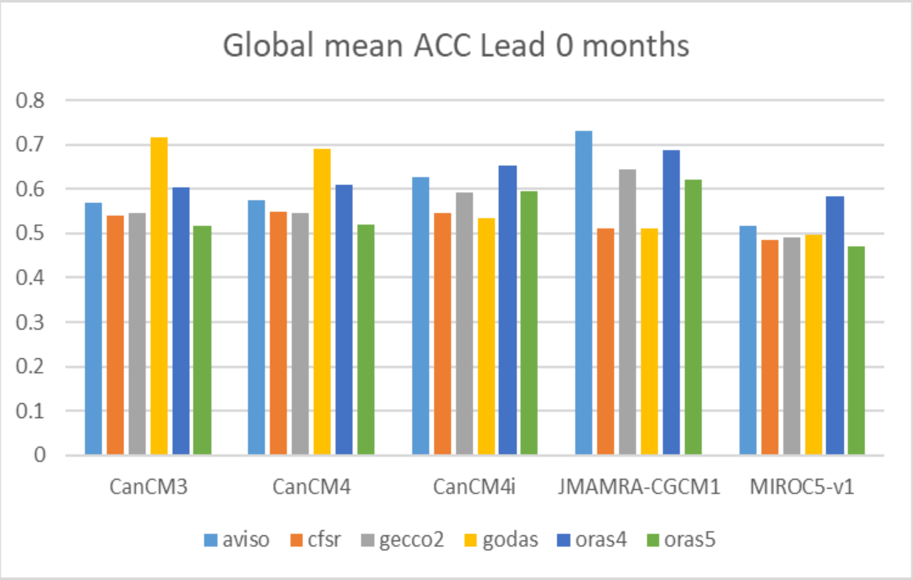
ACC

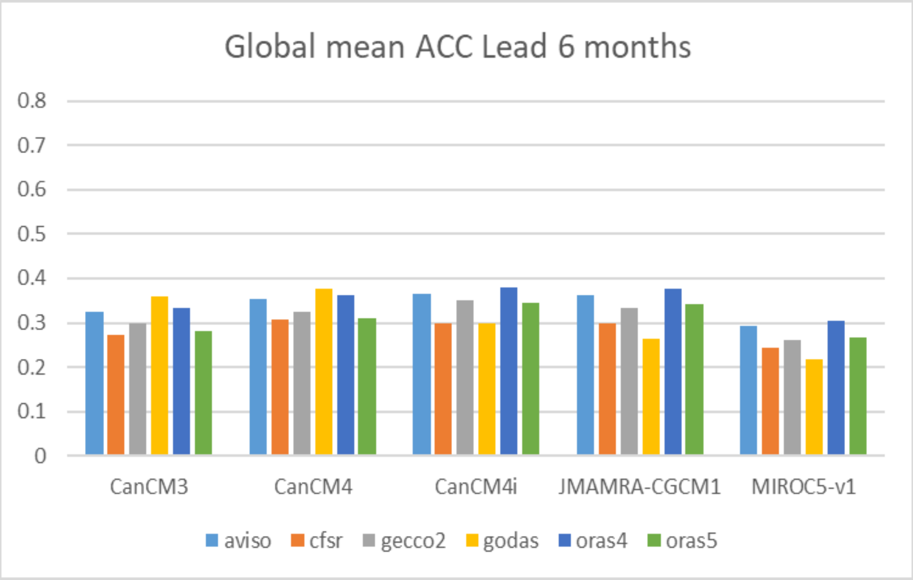
RMSE



ACC vs verification product

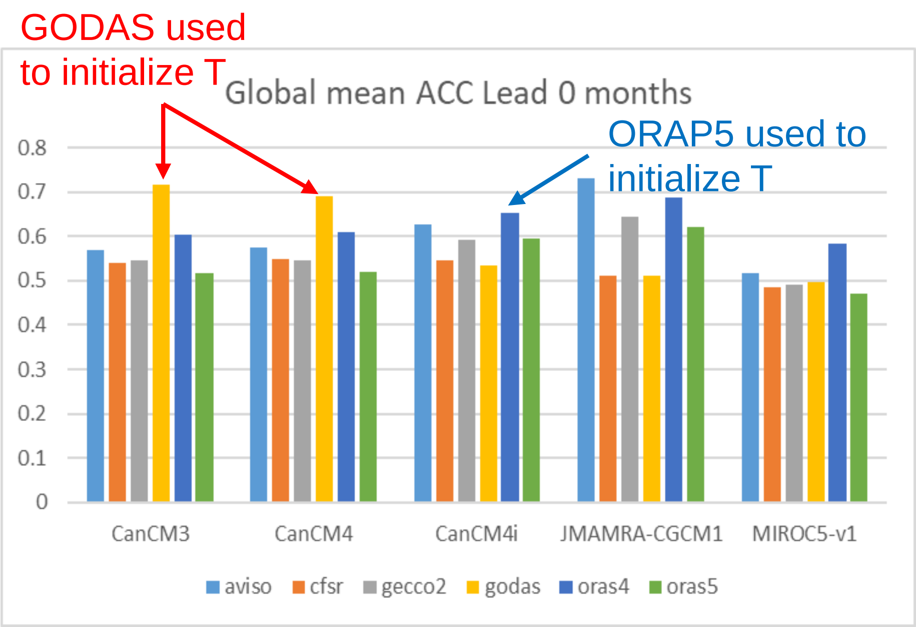
- Global means of ACC for Nov initialization (detrended)
- Skill strongly dependent on verification dataset

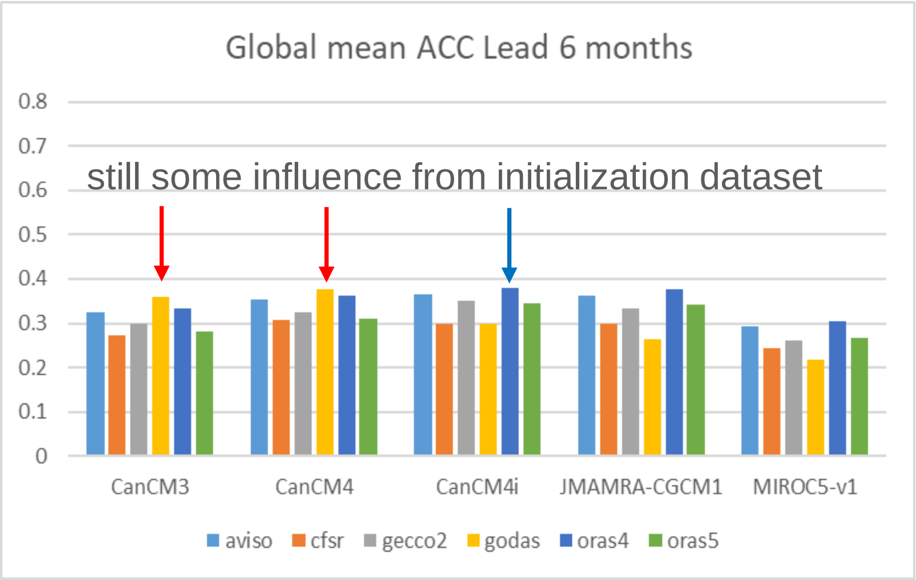




ACC vs verification product

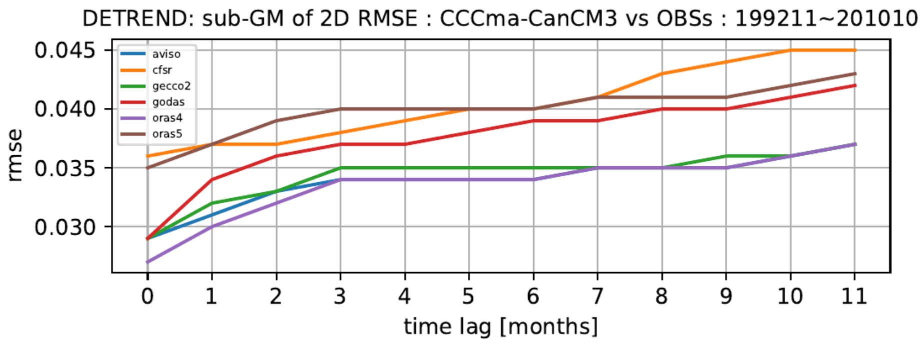
- Global means of ACC for Nov initialization (detrended)
- Skill dependent on verification dataset

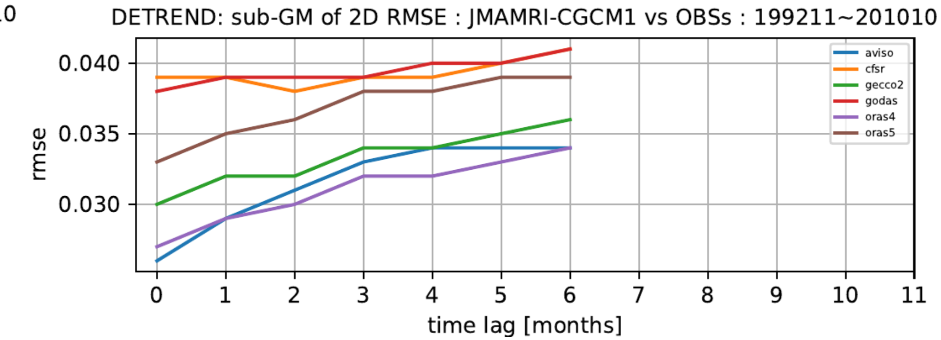


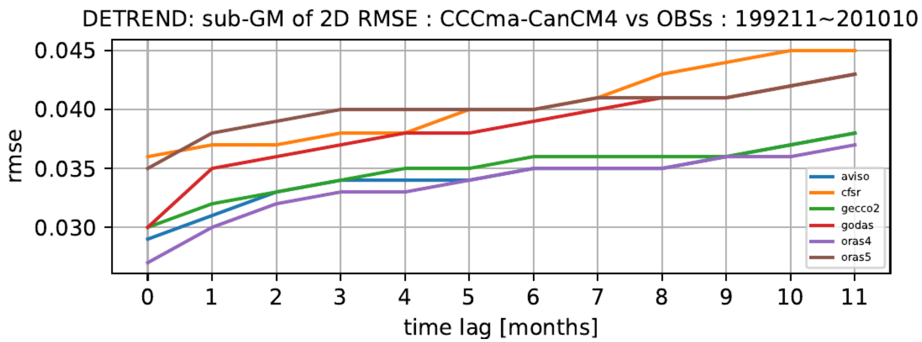


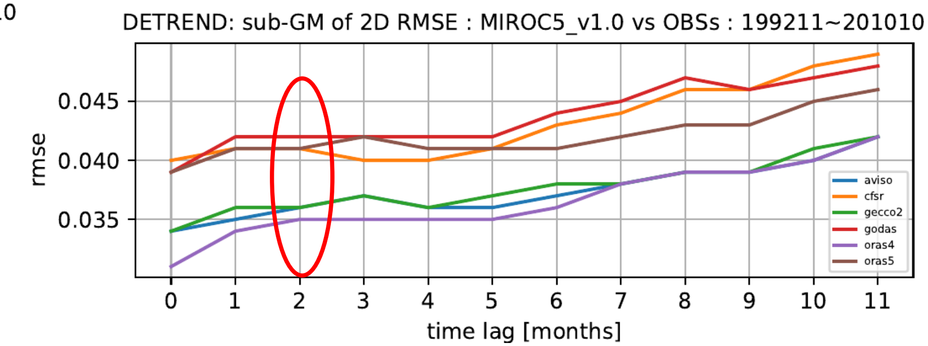
RMSE vs verification product

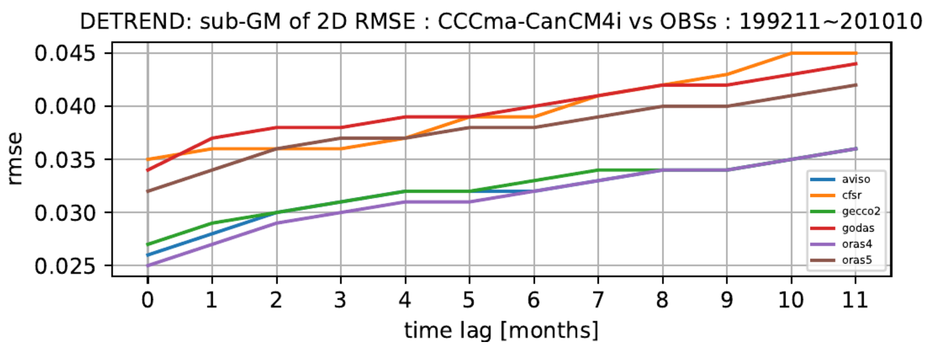
- Global means of RMSE for Nov initialization (detrended)
- Skill dependent on verification dataset

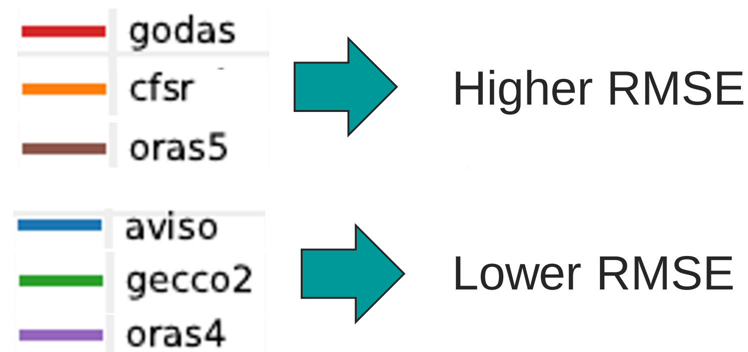










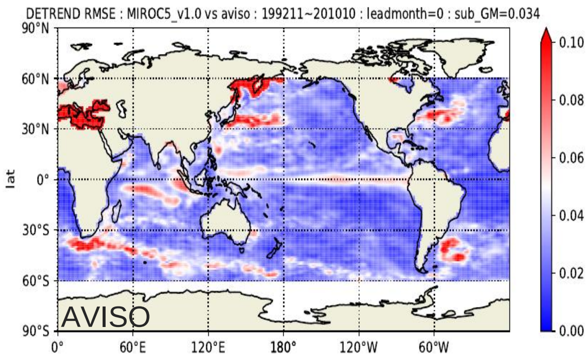


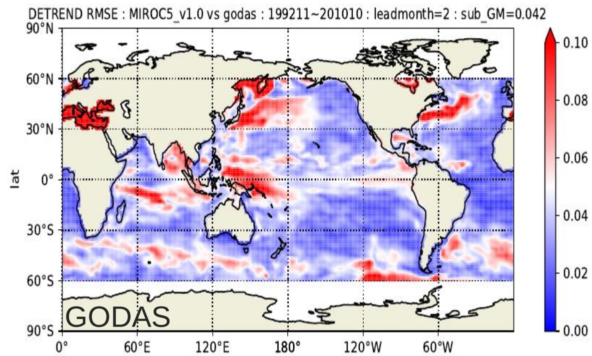
Sources of RMSE differences

MIROC5 / Nov initialization / Lead 2 months

Lower RMSE

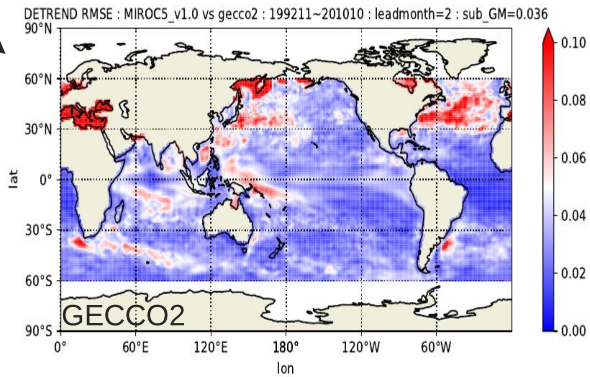
Higher RMSE

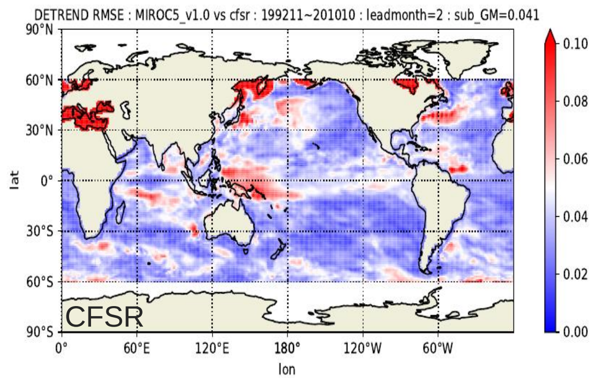




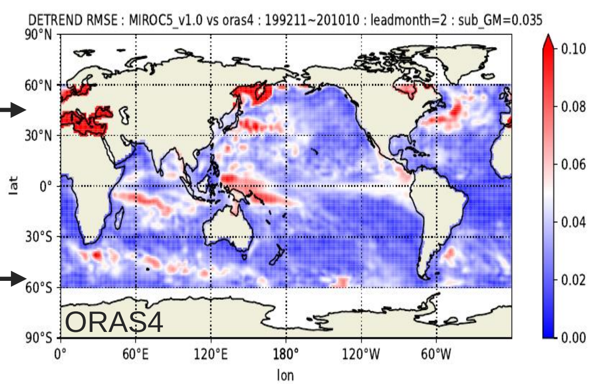
Generally lower RMSE
(Except GECCO2 in N Atl)

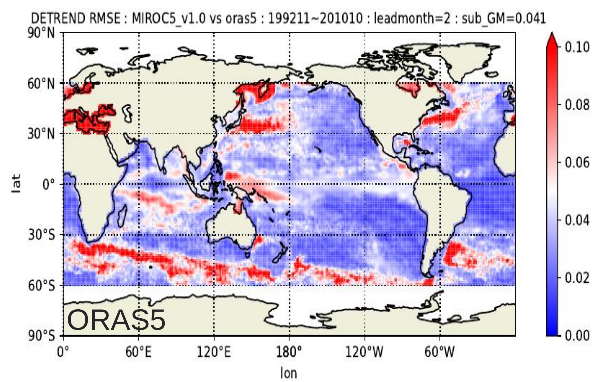
Generally higher RMSE





Low RMSE in eddy-active regions
(1° native resolution)





High RMSE in eddy-active regions
(0.25° native resolution)

Further work & conclusions

Still to do

- Additional models: NMME…
- Probabilistic skill measures
- Multi-model forecasts, multi-product verification → improved skill?
- Non-ENSO sources of skill
- How best to incorporate trend
- Extension to subseasonal and multiannual

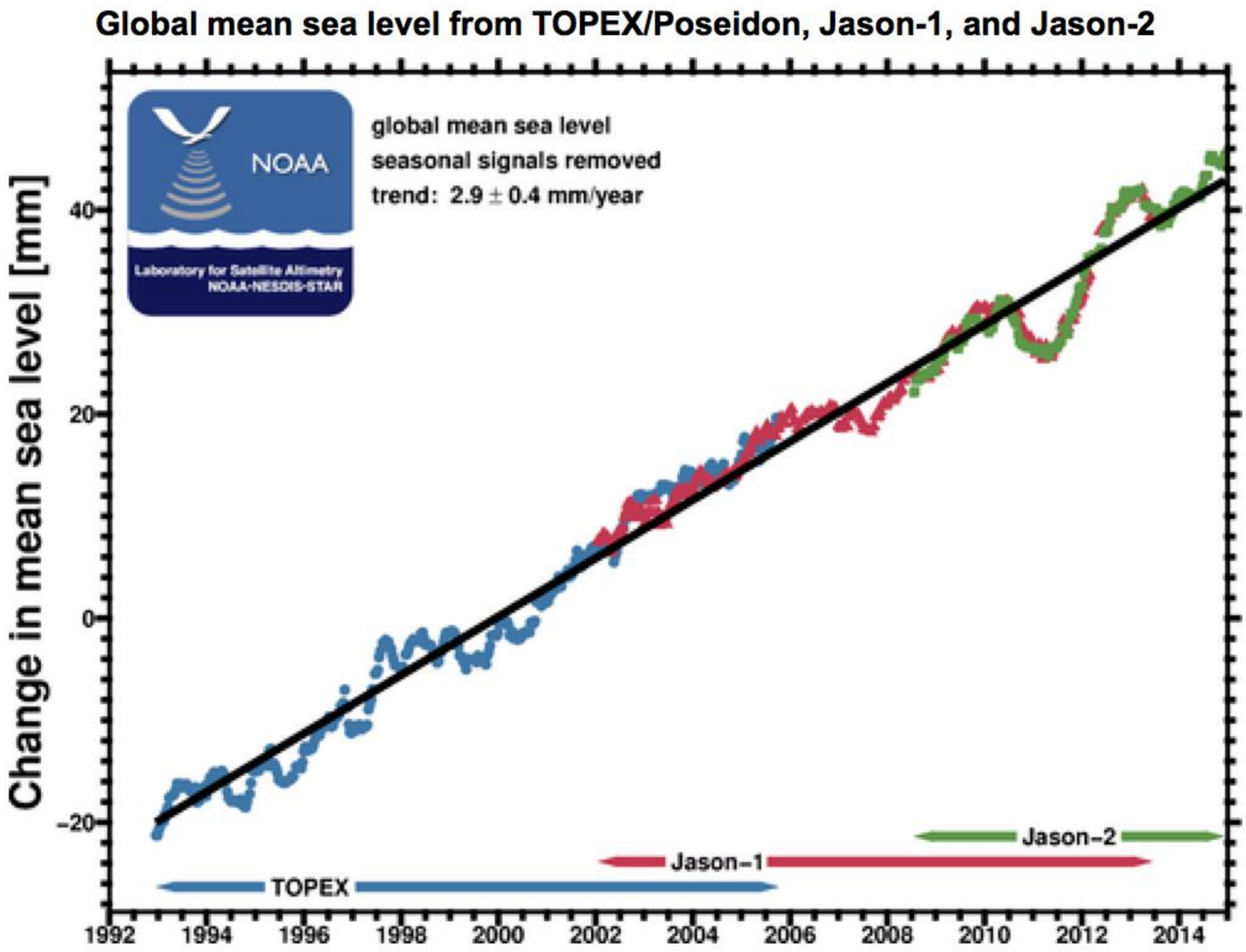
Conclusions

- MLD forecast evaluation & verification is challenging but exciting new territory
- SSH → high societal impacts, considerable skill from ENSO
- Considerable differences between verification datasets: trends, eddy “noise”,...
  → influences skill
- Seek to inform optimal formulation of forecast & verification info

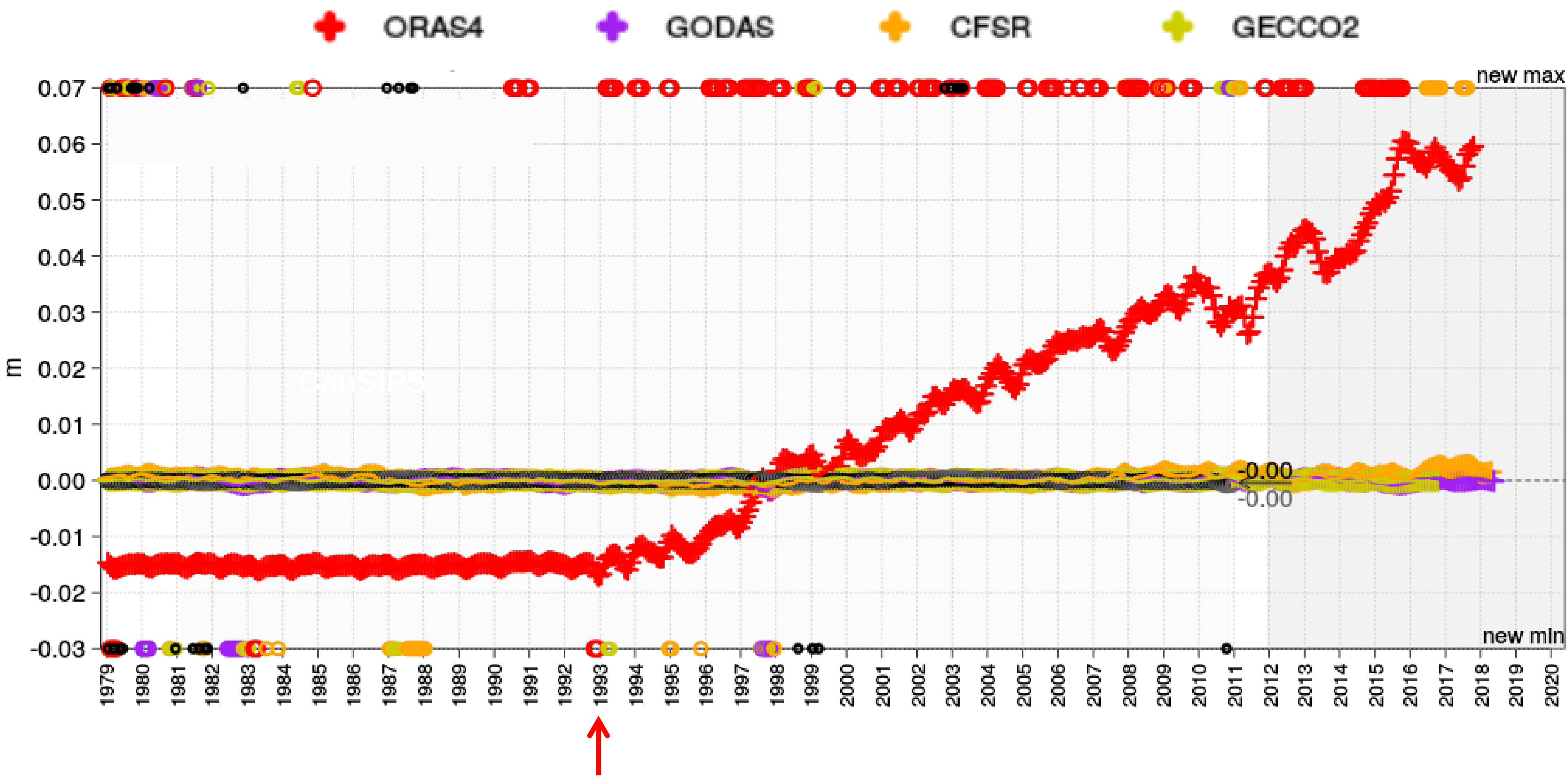
Acknowledgment: Woosung Lee (CCCma) performed most of the data processing and analyses

Extra slides

Global trend from altimetry



Global trends in reanalyses

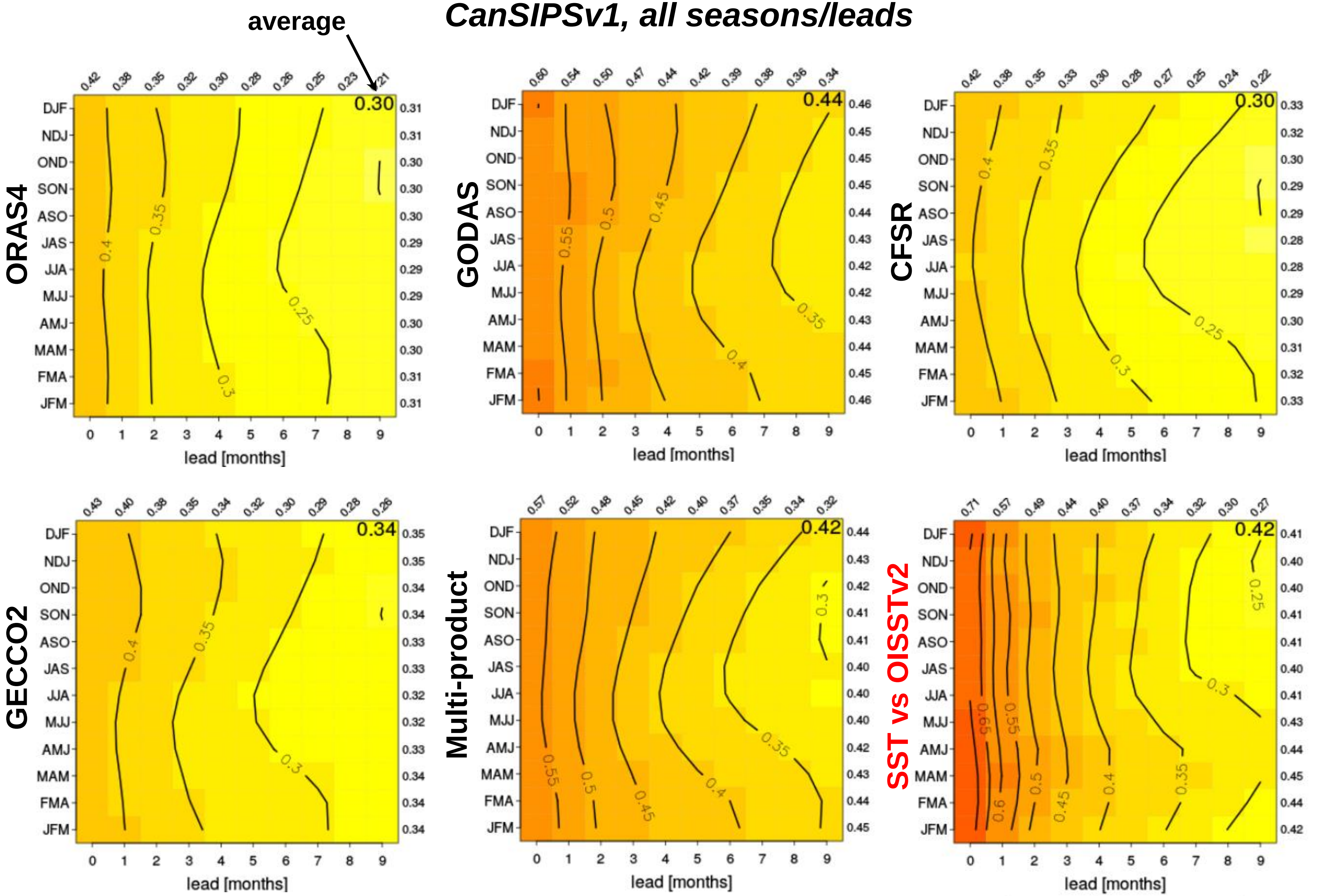


ORAS4 begins assimilating SSH in Nov 1992

No global trend in GODAS, CFSR, GECCO2

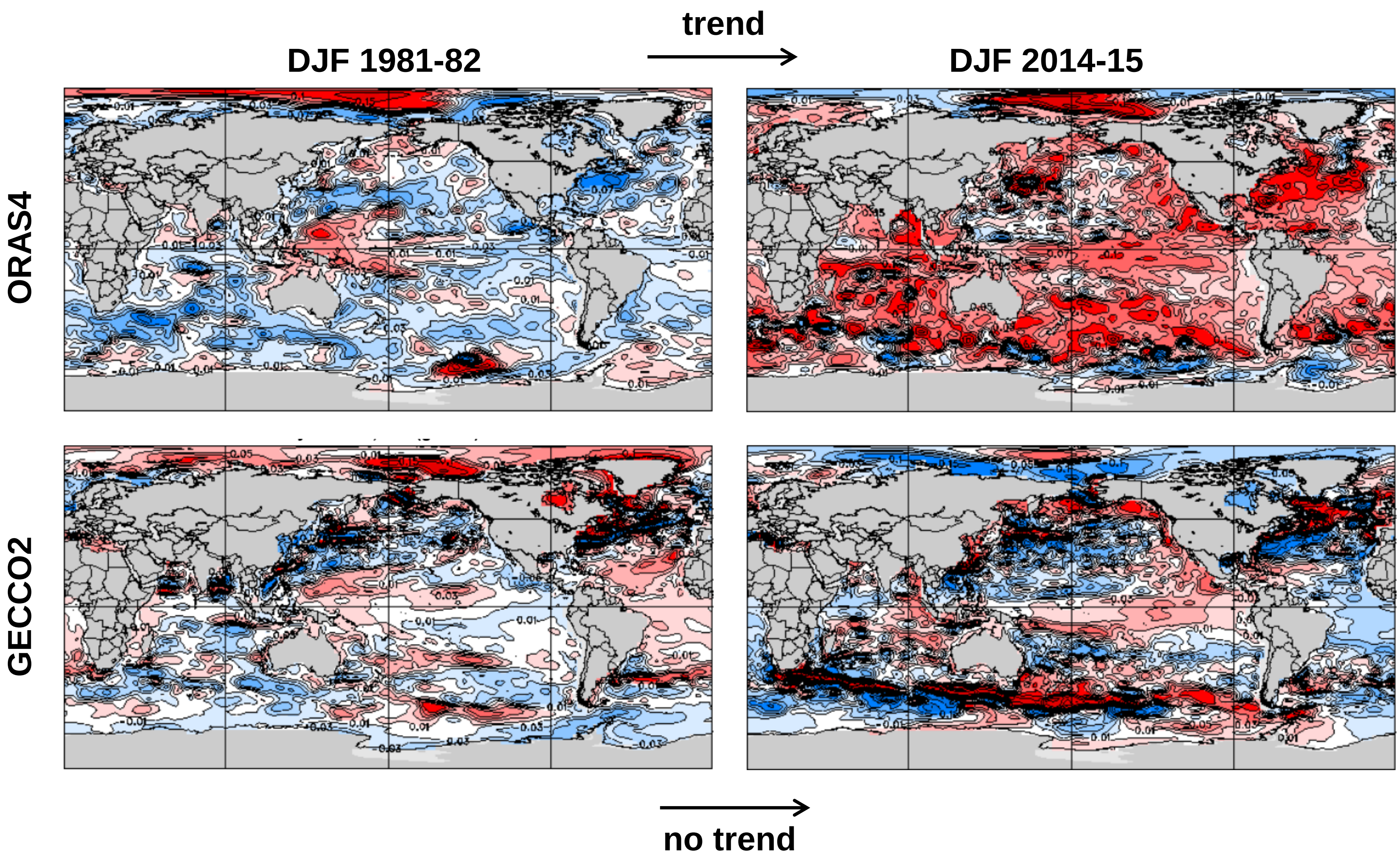
Anomaly correlation skill vs verification dataset

CanSIPSv1, all seasons/leads



What about the SSH trend?

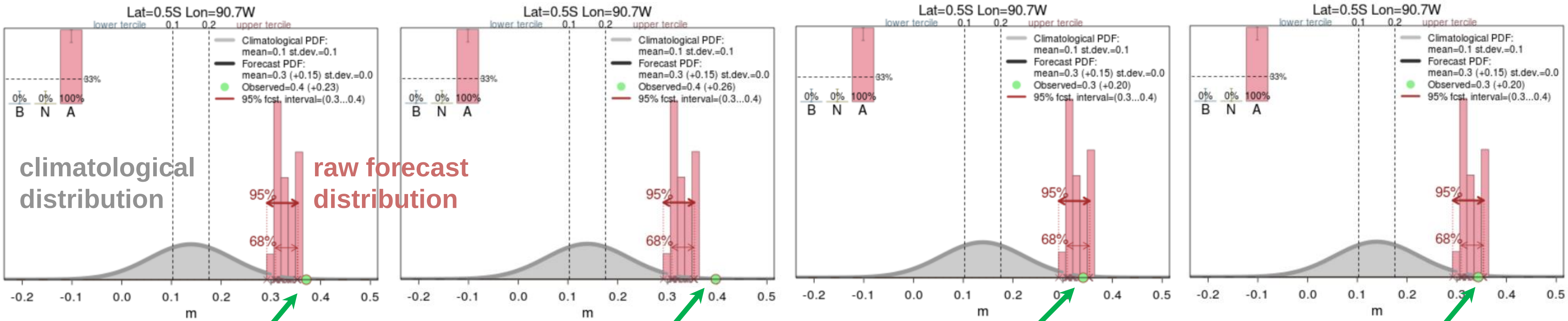
(global sea level rise)



Magnitude of anomalies

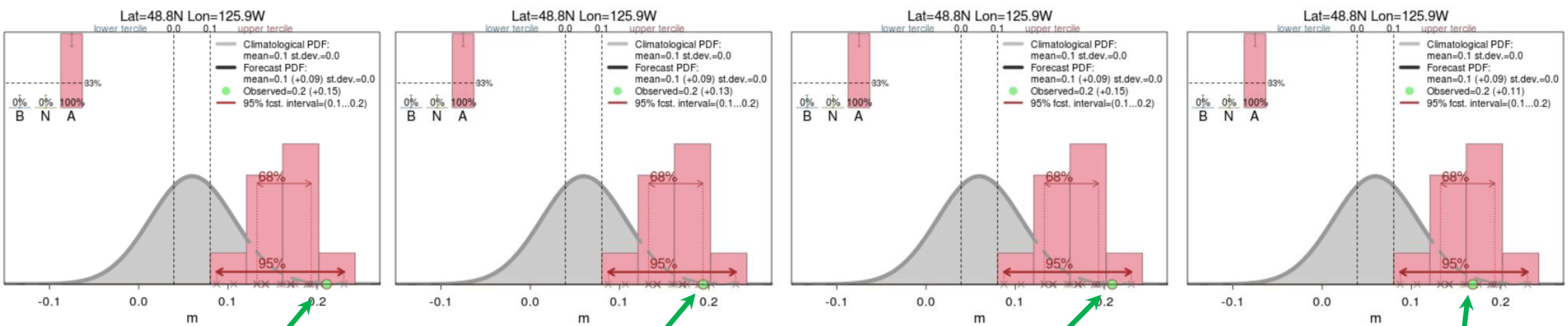
DJF 1997-8 lead 1 month

Galapagos



ORAS4 GODAS CFSR GECCO2

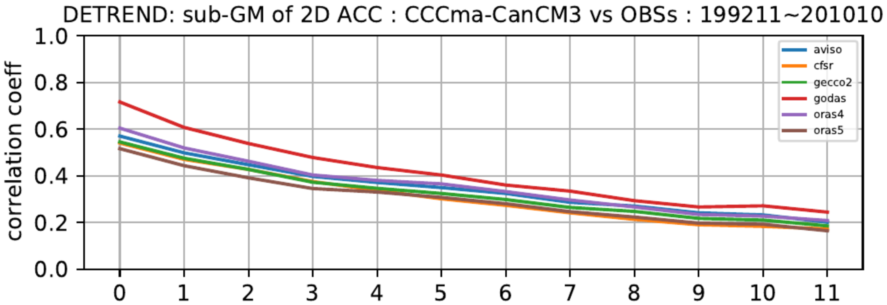
BC Coast

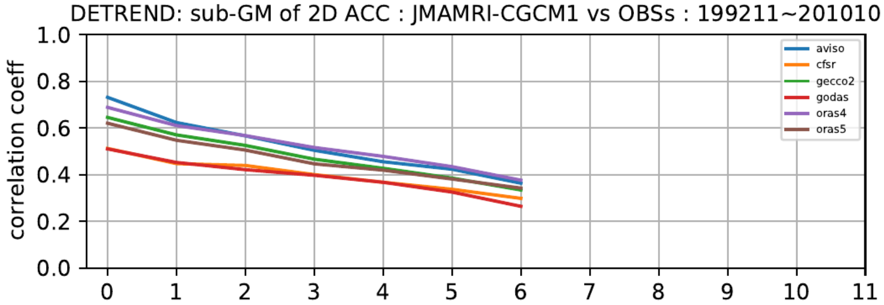


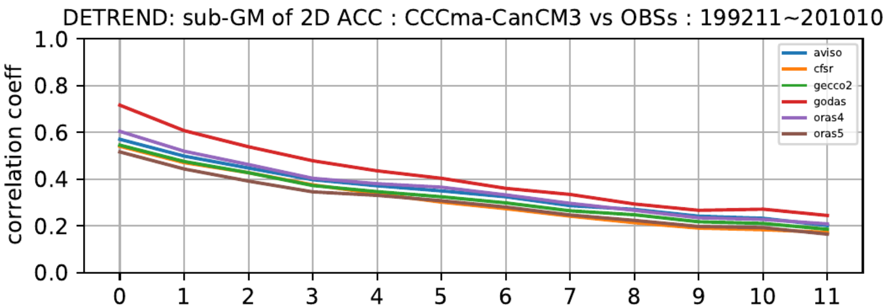
ORAS4 GODAS CFSR GECCO2

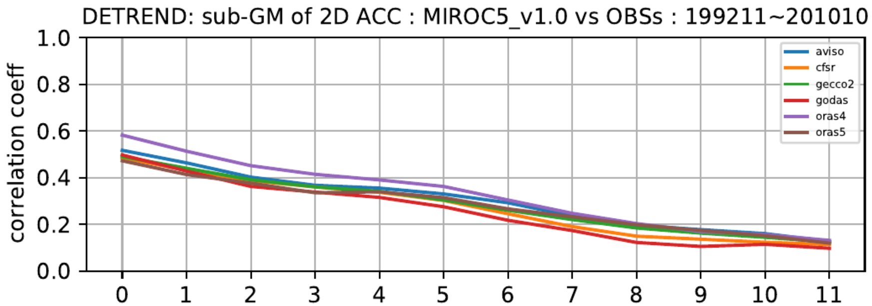
ACC vs verification product

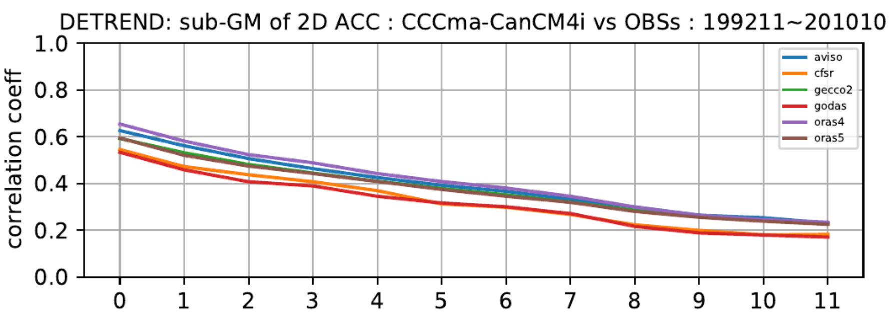
- Global means of ACC for Nov initialization (detrended)
- Skill dependent on verification dataset











How to account for global trend in forecasts & verification?

- Possible approach: remove global mean trends from forecasts and verification products (if any, accounting for piecewise trends)
- As a zeroth-order correction, add observed global mean trend of ≈ 3 mm/year to forecasts and verification products
- At CCCma we are reevaluating skills using this approach (work in progress)
- This does not account for regional differences in forced trends due to circulation changes, etc. →
- However, such deviations from the mean trend should be represented at least partially in forecasts even with volume-conserving ocean

IPCC AR5 WG1 report Chap 13

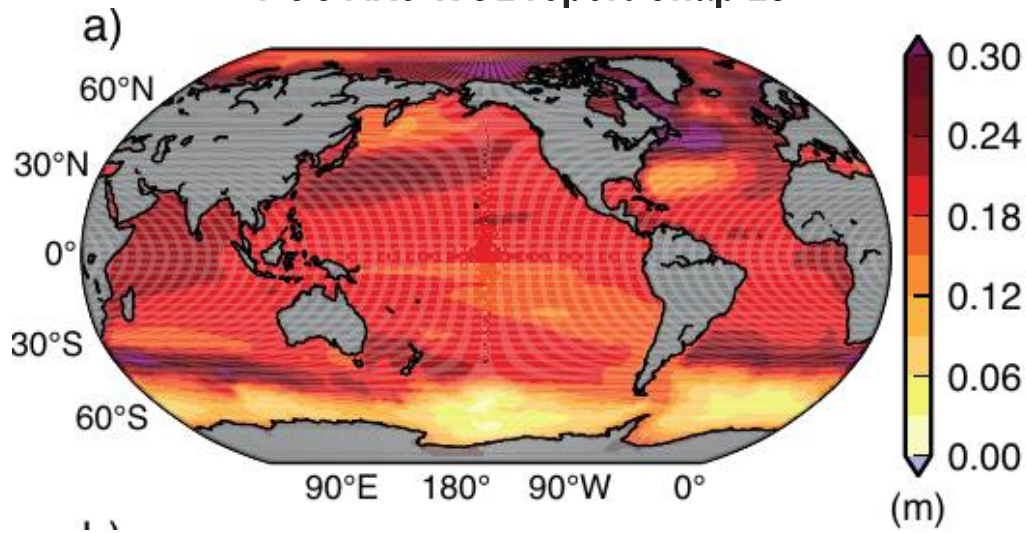
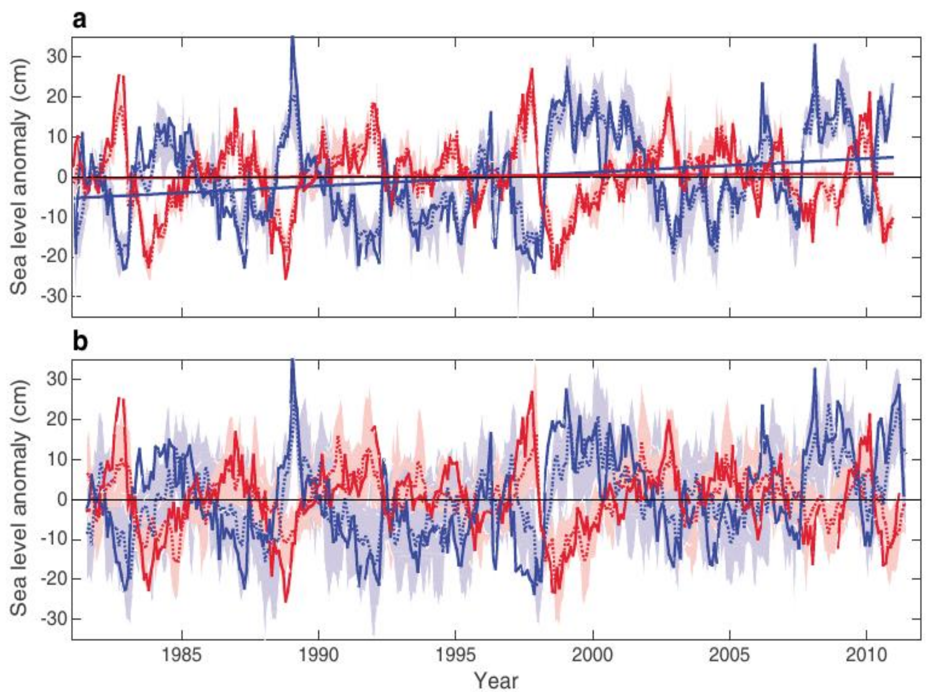


Figure 13.16 | (a) Ensemble mean projection of the time-averaged dynamic and steric sea level changes for the period 2081–2100 relative to the reference period 1986–2005, computed from 21 CMIP5 climate models (in metres), using the RCP4.5 experiment. The figure includes the globally averaged steric sea level increase of 0.18 ± 0.05 m.

Some previous results



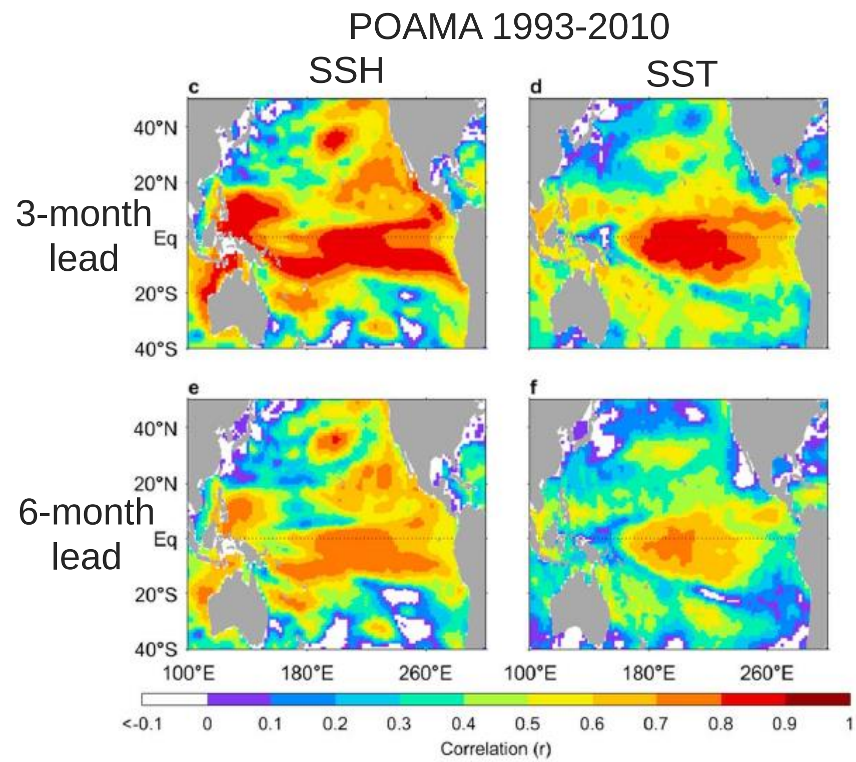


Figure 1. Observed (solid) and forecast (dashed) sea level anomalies at Malakal (blue) and Christmas Island (red) in the Pacific. Forecast lead times are (a) 0 month and (b) 6 months. The seasonal cycle has been removed, but the linear trend over 1981–2010 is retained and is shown in Figure 1a for both sites. The spread of the 33 ensemble members (5th–95th percentiles) is also shown (shading).

McIntosh et al. GRL (2015)

Some previous results

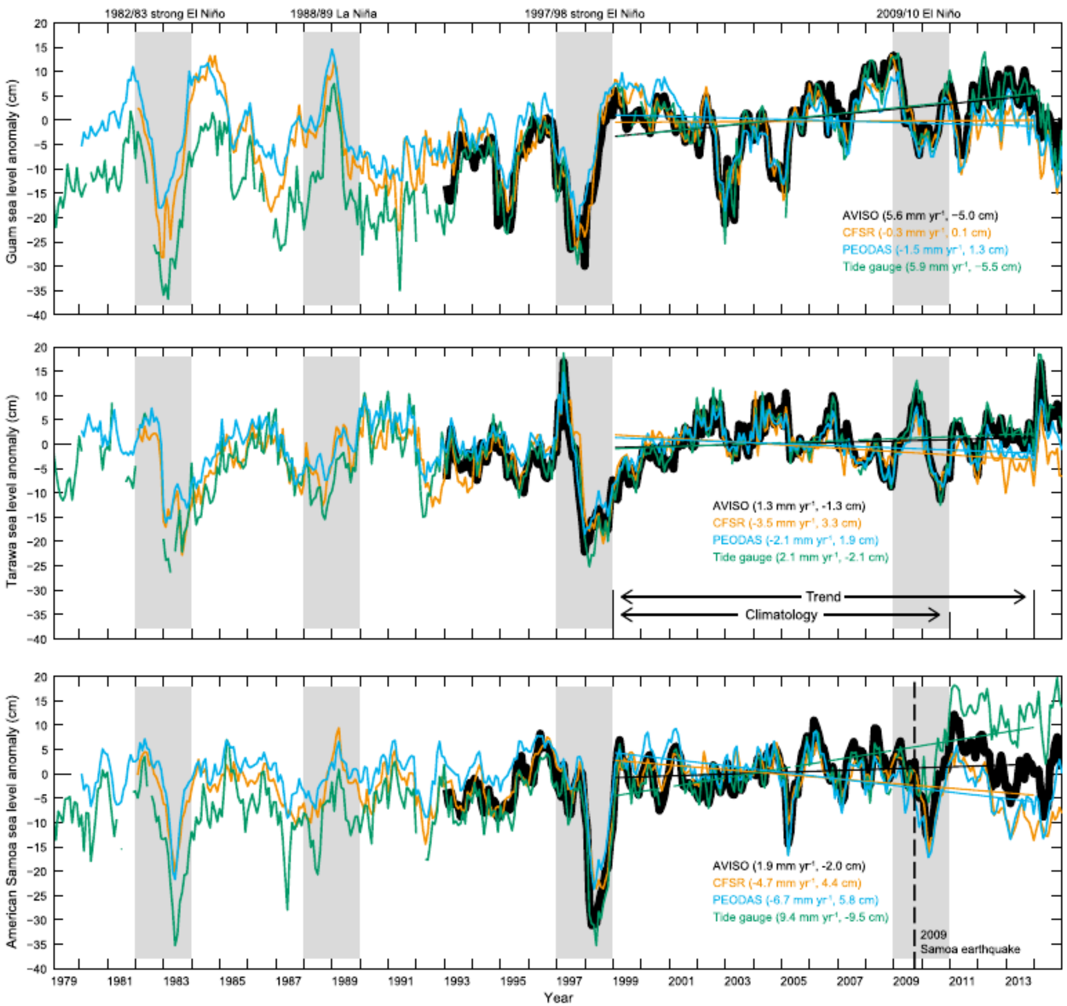


FIG. 2. Observed and simulated sea level anomalies with respect to 1999–2010 climatology from AVISO (1993–2014; black), CFSR (1982–2014; orange), PEODAS (1980–2014; blue), and available tide gauge records (1979–2014; green) around (top) Guam (Apra Harbor), (middle) Tarawa (Betio), and (bottom) American Samoa (Pago Pago). There is close correspondence between sea level products except for differing long-term trends (1999–2013; mm yr^{-1}, see the colored straight lines) for all stations. Trends are especially different around American Samoa since the 2009 earthquake (dashed vertical line in the bottom panel). Trend offsets (cm) added to 2015 real-time forecasts are indicated. El Niño and La Niña events referred to in the text are highlighted.

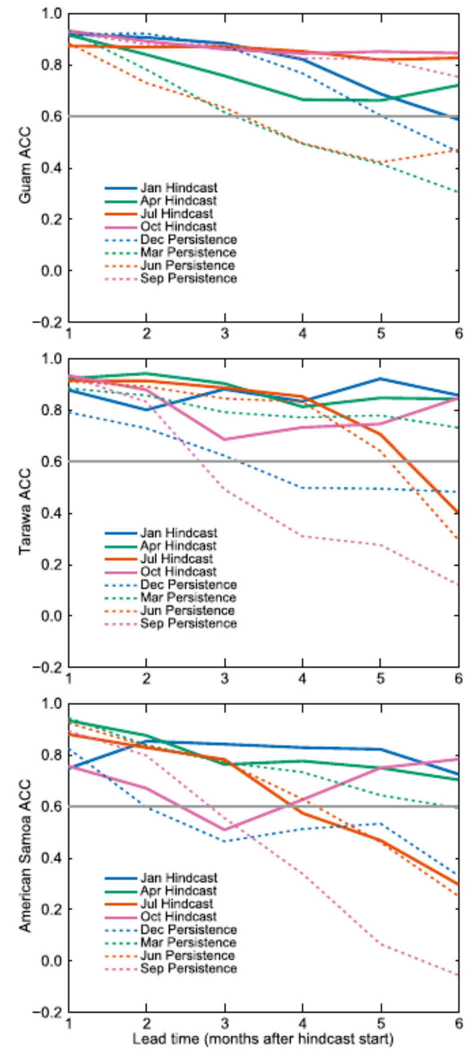


FIG. 4. Retrospective forecast skill of the multimodel ensemble mean measured by ACC for predictions beginning each January (blue), April (green), July (orange), and October (purple) from 1979 to 2014 around (top) Guam, (middle) Tarawa, and (bottom) American Samoa. Corresponding persistence forecasts are indicated by dashed lines. For reference, the gray horizontal line indicates $r = 0.6$ (36% variance explained).

Widlansky et al. JAMC (2017)

Bibliography (chronological)

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