WGSIP Prediction Capabilities Project: Ocean prediction

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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)

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 $\Delta T$ and density criteria

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

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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
Magnitude of anomalies

DJF 1997-8 lead 1 month

SSH, 3-category Probabilistic Forecast
year=1997, DJF, 1-month lead

SSH, Observed Percentile
year=1997, DJF (oras4)

ORAS4 verification

climatological distribution
raw forecast distribution

Lat=0.5S Lon=90.7W

Lat=48.8N Lon=125.9W

Below normal observed percentiles (<33%) are in blue shades.
Near normal observed percentiles (33% - 67%) are in white.
Above normal observed percentiles (>67%) are in red shades.
Positive SSHA
- Coastal “nuisance” flooding, worsened storm surges
- Accelerated coastal erosion
- Saltwater intrusion

Negative SSHA
- Exposed shallow reefs → coral, fish die-off
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

Correlations of detrended global mean 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 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

GODAS used to initialize T

Global mean ACC Lead 0 months

ORAP5 used to initialize T

Global mean ACC Lead 6 months

still some influence from initialization dataset
RMSE vs verification product

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

Higher RMSE

Lower RMSE
Sources of RMSE differences

MIROC5 / Nov initialization / Lead 2 months

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

Generally lower RMSE (Except GECCO2 in N Atl)

Low RMSE in eddy-active regions (1° native resolution)
Further work & conclusions

Still to do
• Additional models: NMME…
• Probabilistic skill measures
• Multi-model forecasts, multi-product verification $\rightarrow$ 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 $\rightarrow$ high societal impacts, considerable skill from ENSO
• Considerable differences between verification datasets: trends, eddy “noise”,… $\rightarrow$ influences skill
• Seek to inform optimal formulation of forecast & verification info

Acknowledgment: Woosung Lee (CCCma) performed most of the data processing and analyses
Global trend from altimetry

Global mean sea level from TOPEX/Poseidon, Jason-1, and Jason-2

change in mean sea level [mm]


NOAA
Laboratory for Satellite Altimetry
NOAA-NESSI-STAR

global mean sea level seasonal signals removed
trend: 2.9 ± 0.4 mm/year

TOPEX

Jason-1

Jason-2
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

- ORAS4
- GODAS
- CFSR
- GECCO
- Multi-product

SST vs OISSTv2
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 \( \approx 3 \) 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

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**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

*McIntosh et al. GRL (2015)*

**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).
Some previous results

FIG. 2. Observed and simulated sea level anomalies with respect to 1999–2010 climatology from AVISO (1993–2013; black), CFSR (1982–2014; orange), FESODAS (1980–2014; blue), and available tide gauge records (1979–2014; green) around (top) Guam (Apaa Harbor), (middle) Tutuila (Belo), 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.

Widlansky et al. JAMC (2017)


