Real-time Ocean Reanalyses Intercomparison for Quantifying Uncertainties in Ocean Reanalyses and Monitoring Climate Variability

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GSOP and pan-CLIVAR meeting on July 14-18, 2014, Hague, Netherlands
CLIVAR-GSOP/GODAE OceanView
Ocean Reanalysis Intercomparison
(ORA-IP, 2013-2014)

- Reanalysis production is an on-going activity
- New vintages are produced approximately every 5 years
  - Improved quality controlled observations (XBT corrections, Argo corrections and black lists)
  - Improved and extended forcing fluxes
  - Improved models and methods
- We need to assess uncertainties among ocean reanalyses (through intercomparison and validation with independent data)
- We need to facilitate the use of ocean reanalyses by other communities
- We need to prepare for quasi-real time monitoring of the ocean

Balmaseda et al., GODAE OceanView Symposium, Baltimore, MD
Climate Observation Division
Historical TAO reporting + ship resourcing

TAO Array Data Return
January 2003 - July 2013

ship days

Number of Buoys Reporting Data

KA taken off-line
Tropical Pacific Observing System (TPOS) 2020 Workshop
(January 27-30, 2014, La Jolla, CA)

- Highlight the impacts of the tropical Pacific observing system on information/services of societal relevance – ENSO monitoring and prediction

- Evaluate existing and potential requirements for sustained observations of ocean variables in tropical Pacific Ocean – uncertainties in ocean estimation in tropical Pacific

- Evaluate the adequacy of existing observing strategies

- Recommend revisions and/or adjustments to enhance resilience, efficiency, integration.

- Evaluate logistical requirements for implementation of the recommended Tropical Pacific Observing System.

- Assess readiness of new technologies, their potential impact and feasibility in addressing requirements, and/or lowering costs per observation.
## Operational Ocean Reanalyses

<table>
<thead>
<tr>
<th>Name</th>
<th>Method &amp; Forcings</th>
<th>In Situ Data</th>
<th>Altimetry Data</th>
<th>Resolution</th>
<th>Period</th>
<th>Vintage</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN3.v2a</td>
<td>Analysis Correction Scheme</td>
<td>No XBT</td>
<td>No</td>
<td>1°x 1°, 42 Levels Monthly Temp.</td>
<td>1950-2009</td>
<td>2009</td>
<td>Ingleby and Huddleston (2007)</td>
</tr>
<tr>
<td>NODC</td>
<td>Objective Analysis</td>
<td>No XBT</td>
<td>No</td>
<td>1°x 1°, 16 Levels, 0 to 700m Seasonal Temp.</td>
<td>1955-2010</td>
<td>2010</td>
<td>Levitus et al. (2009)</td>
</tr>
<tr>
<td>GODAS</td>
<td>3D-VAR</td>
<td>No XBT</td>
<td>NO (Yes in real time)</td>
<td>1°x 1° (1/3° near Eq), 40 Levels Pentad, Monthly</td>
<td>1979-2003</td>
<td>2003</td>
<td>Behringer and Xue (2004)</td>
</tr>
<tr>
<td>ECMWF (S3)</td>
<td>OI</td>
<td>No XBT</td>
<td>Yes</td>
<td>1°x1° (1/3° near Eq), 29 Levels Daily, Monthly</td>
<td>1959-2007</td>
<td>2007</td>
<td>Balmaseda et al. (2008)</td>
</tr>
<tr>
<td>JMA</td>
<td>3D-VAR</td>
<td>No XBT</td>
<td>Yes</td>
<td>1°x1° (1/3° near Eq), 50 Levels Pentad, Monthly</td>
<td>1979-2009</td>
<td>2009</td>
<td>Usui et al. (2006)</td>
</tr>
<tr>
<td>CFSR</td>
<td>3D-VAR Partially coupled</td>
<td>No XBT</td>
<td>No (Yes in real time)</td>
<td>1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Pentad, Monthly</td>
<td>1979-2010</td>
<td>2010</td>
<td>Xue et al. (2010)</td>
</tr>
<tr>
<td>GFDL</td>
<td>EnKF Fully coupled</td>
<td>XBT</td>
<td>Yes</td>
<td>1°x 1° (1/3° near Eq), 50 Levels Daily, Pentad, Monthly</td>
<td>1970-2010</td>
<td>2010</td>
<td>Zhang et al. (2009)</td>
</tr>
<tr>
<td>GMAO</td>
<td>EnOI Fully coupled</td>
<td>XBT</td>
<td>No</td>
<td>1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Monthly</td>
<td>1980-2011</td>
<td>2011</td>
<td>Rienecker et al. (2011)</td>
</tr>
<tr>
<td>MERCATOR (PSY2G2)</td>
<td>KF-SEEK</td>
<td>No XBT</td>
<td>Yes</td>
<td>2°x 2° (1/2° near Eq), 31 Levels Daily, Pentad, Monthly</td>
<td>1979-2007</td>
<td>2007</td>
<td>Dréville et al. (2008)</td>
</tr>
</tbody>
</table>

Xue et al. 2012, J. Climate
Real-Time Ocean Renalyses Intercomparison

- Extend CLIVAR-GSOP/GODAE OceanView Ocean Reanalyses Intercomparison Project (ORA-IP) into real time

- **Assess uncertainties** in temperature analysis of tropical Pacific in support of ENSO monitoring and prediction

- Explore any connections between gaps in ocean observations and spreads among ensemble ORAs

- Articulate needs for sustained ocean observing systems in support of TPOS2020

- **Monitor signal-to-noise ratio** in the global ocean temperature, 300m heat content, depth of 20C isotherm
Real Time Multiple Ocean Reanalysis Intercomparison

(with contributions from: NCEP, ECMWF, JMA, GFDL, NASA, BOM based on 1981-2010 Climatology)

(Background Information)

Tropical Pacific Ocean

• Climate Indices
  - Depth of 20C isotherm anomaly in NINO3: last 4 years  last 15 years  1979-present
  - Depth of 20C isotherm anomaly in NINO4: last 4 years  last 15 years  1979-present
  - Upper 300m heat content anomaly in NINO3: last 4 years  last 15 years  1979-present
  - Upper 300m heat content anomaly in NINO4: last 4 years  last 15 years  1979-present
  - Warm Water Volume: last 4 years  last 15 years  1979-present
  - Warm Water Volume average in last two months ending in:

  Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

• Spatial Maps
  - Temperature anom. at z=5m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. at z=15m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. at z=35m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. at z=55m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. at z=75m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. at z=100m (X-Y section): last month  month before last month  1979-present
  - Temperature anom. in 1S-1N (X-Z section): last month  month before last month  1979-present
  - Temperature anom. in 5N-10N (X-Z section): last month  month before last month  1979-present
  - Temperature anom. in 10S-5S (X-Z section): last month  month before last month  1979-present
  - Temperature anom. in 120W-90W (Y-Z section): last month  month before last month  1979-present
  - Temperature anom. in 150W-120W (Y-Z section): last month  month before last month  1979-present
  - Temperature anom. in 160E-150W (Y-Z section): last month  month before last month  1979-present
  - Temperature anom. in 130E-160E (Y-Z section): last month  month before last month  1979-present
  - Depth of 20C isotherm anomaly: last month  month before last month  1979-present
  - Upper 300m heat content anomaly: last month  month before last month  1979-present
- The ensemble mean (ensemble spread) can be used to measure signal (noise).
- The signal-to-noise (SN) ratio is relatively low in the western (central-eastern) Pacific where negative (positive) anomalies presented.
- The low signal-to-noise ratio may be partially attributed to the sparse observations in those regions.
Upper 300m Heat Content Anomaly

May

Anomalous Upper 300m Heat Content (C): MAY 2014

June

Anomalous Upper 300m Heat Content (C): JUN 2014

GODAS

GODAS

NCEP

JMA

ECMWF

GFDL

NASA

BOM

ENS. Mean

SN Ratio

-2.7 -2.1 -1.5 -1.0 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.5 2.1 2.7

2 4 6 8 12
Influences of ocean observations on spread among ocean reanalyses

(a) Signal

(b) Noise

(c) Signal/Noise
- Warm Water Volume averaged in May-June 2014 is similar to that in May-June of 2009, 2006 and 1991. However, the pattern of subsurface temperature anomaly averaged in 5S-5N in Jun 2014 is mostly similar to Jun 1991.
Upper 300m Heat Content Anomaly Averaged in 5S-5N
Summary

• An ensemble of six operational ORAs has been collected to assess signal (ensemble mean) and noise (ensemble spread) in upper ocean temperature analysis in near real-time.

• Uncertainties in ocean reanalyses seem partially attributed to the declining TAO array:
  
  - The spread of ensemble ORAs decreased abruptly in early 1990s when the TAO array was fully implemented.
  - The spread started to increase since 2010 and reached a peak value in 2013 when the TAO array return rate drops to 40%.

• Although there are uncertainties in ocean reanalysis products, the ensemble mean of multiple ocean reanalyses likely provides the best estimation of the state of ocean and can be used to derive climate indicators. The ensemble spread provides uncertainties in our estimation.

• The ensemble mean of temperature analyses from multiple ORA products has been used in monitoring and prediction for current ENSO conditions.
Future Plan

- Review the experimental web site
  - Are all the plots useful?
  - Are there any new plots need to be developed?
  - Should some of the plots be displayed in a more prominent web site, e.g. OOPC?

- Further explore the linkage between spread and data distribution

- Understand why spread is large in certain areas and what are implications for designing ocean observing systems

- Develop plots for other oceans, how?

- Support TPOS2020?

- Support Climate Indicator Task Team?
Thanks!

Comments and Suggestions?
- Positive D20 anomaly in GODAS has much narrower meridional extend than CFSR between 130W-100W, and negative D20 anomaly near Dateline was stronger than that in CFSR.
- Easterly wind anomaly was stronger in R2 than that in CFSR.
Trade winds in R2 are much stronger than those in CFSR near 170W since 2010.
Consistent to the stronger trade winds in R2, D20 anomaly in GODAS is about 3-6m lower than that in CFSR east of 150W since 2010.
Recent Evolution of Ocean Heat Content Anomaly

Upper 300m Heat Content Anomaly Averaged in 5S–5N (°C)