Performance and quality assessment of the global ocean eddy-permitting physical reanalysis GLORYS2V4.


Mercator Ocean, ¹CLS (Toulouse)

EGU General Assembly
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Outlines

1. Objectives
2. The New GLORYS system
3. Validation Protocol/Results
4. Summary/Prospectives
Objectives

• Reproduction of climatic signals on altimeter periods (from 1993 until present), with interannual variability and trend (essential variables, heat content, mass, sea ice, biogeochemistry…).

• A reference database for the description of the global ocean (Ocean State Report/CMEMS).

• As close as possible to Near Real Time in order to be a reference for real time application (Copernicus Marine Environment Monitoring service/CMEMS).

• Deliver boundaries conditions for coastal and regional applications (CMEMS).

• Deliver initial conditions to coupled predictions (seasonal, climatic scenario).

• All available observations are assimilated.
The core of the actual GLORYS System

**Model/Configuration**
- **NEMO**3.1 (TKE, ...) at $1/4$°, 75 z-levels.
- LIM2: thermodynamic-Dynamic (2+1 Semtner-like) sea ice model
- Atmospheric forcing: **ERA-Interim** (3H) – Bulk Formulation.
- Bathymetry: ETOPO+GEBCO
- Runoffs: seasonal climatology (120 rivers).

**Assimilation**
- SAM2 (Singular Evolutive Extended **Kalman filter**) / 3D-FGAT innovation (First Guess at Appropriate Time) / IAU (Incremental Analysis Update)/ Local 2D Technic.
- **3D-VAR** Large Scale Biases Correction
- Assimilation of sea ice concentration

**Observations**
- **SST** (1/4°) from AVHRR+AMSRE
- **Altimetry** (T/P, Jason, Cryosat2, ...)
- **In situ** (T,S) (Argo) from CORA (CMEMS*) data base
- Hybrid Mean Dynamical Topography (**MDT**)

CMEMS* = Copernicus Marine Environment Monitoring Service
# Changes since last release

<table>
<thead>
<tr>
<th>GLORYS2V3</th>
<th>GLORYS2V4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EmP=0 (Mass surface budget)</td>
<td>Idem + Mass surface budget =+1.74mm/yr</td>
</tr>
<tr>
<td>Initial conditions (T,S) from Levitus (1998)</td>
<td>Global mean of steric* increment=0</td>
</tr>
<tr>
<td>3D (T,S) damping south. 60°S and below 2000m depth. <strong>No SSS restoring.</strong></td>
<td>Initial conditions (T,S) from <strong>EN4</strong> (90’s)</td>
</tr>
<tr>
<td>Large scale correction of rainfalls and radiative fluxes towards resp. GPCPV2.2 &amp; GEWEX SRB3.0.</td>
<td>Idem + damping in Gibraltar and Bab-El-Mandeb straits.</td>
</tr>
<tr>
<td>Hybrid MDT CNES-CLS 09</td>
<td>Idem but Large scale correction of rainfalls towards PMWC</td>
</tr>
<tr>
<td>CORA3.3 in situ data base</td>
<td>Hybrid MDT CNES-CLS 13</td>
</tr>
<tr>
<td>Assimilation of sea ice CERSAT</td>
<td>CORA4.1 in situ data base</td>
</tr>
<tr>
<td></td>
<td>Idem.</td>
</tr>
</tbody>
</table>

steric* = volume changes due to density changes
Current quality control: Assessment of the reliability of the reanalysis on average, and at basin scale

- Model physics
  - Water masses, Currents and transports, Variability, Mesoscale, Waves, high frequencies, tides
- Data assimilation performance, error tunings
- Stability over time (need for long hindcast)
- Intercomparisons between reanalysis products (GOV/CLIVAR/GSOP ORA IP)
- QC on assimilated data → feedback to observation data centers
- Non regression with respect to previous versions
- Summary of results.

Validation Protocol
QUID (Quality Information Document/CMEMS)
GLORYS quality control

Sea Surface Height

**Bias with satellite data**

- GLORYS2V4 ≈ 0
- GLORYS2V3 ≈ 0

**Root Mean Square Error with satellites**

- GLORYS2V4 ≈ 6-6.5 cm
- GLORYS2V3 ≈ 6-7 cm

Satellite Data include: ERS, T/P, Jason 1 & 2, Envisat, GFO, Saral/AltiKa, Cryosat2, HY2A.
Validation Protocol
QUID (Quality Information Document/CMEMS)
GLORYS quality control

In Situ Data
(Blue is warmer or saltier.)

• Less biases with ARGO network.
• Less biases in G2V4 in Temperature and surface salinity.
• Salty bias at 100m depth (< 0.05Psu).
Differences relative to SST AVHRR ¾°  
(Warm) Bias in GLORYS2V4 < 0.5°C  
(Warm) Bias in GLORYS2V3 < 0.7°C

Diagnostics of interest for seasonal forecast.
Validation Protocol
QUID (Quality Information Document/CMEMS)
GLORYS quality control

In Situ Data – Tropical Moorings

Salinity

Temperature

RMS Temp. < 0.5 °C
RMS Salt < 0.2 PSU
Validation Protocol
QUID (Quality Information Document/CMEMS)
GLORYS quality control

Mean 3D Temperature

Global Ocean Temperature 0-2000m

From Masina et al. (2015)
Steric height

- Steric signal dominated by thermo-steric.
- GLORYS2V4 in good accordance with recent observed estimations.

<table>
<thead>
<tr>
<th>Trend (mm/yr)</th>
<th>GLORY2V4</th>
<th>Chambers et al. (2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total steric</td>
<td>1.6</td>
<td>1.2 ± 0.23</td>
</tr>
<tr>
<td>Thermo-steric</td>
<td>1.8</td>
<td>1.2 ± 0.23</td>
</tr>
<tr>
<td>Halo-steric</td>
<td>-0.2</td>
<td>~ 0</td>
</tr>
<tr>
<td>Total mass</td>
<td>1.74</td>
<td>1.8 ± 0.46</td>
</tr>
<tr>
<td>Sum of components</td>
<td>3.34</td>
<td>3.0 ± 0.52</td>
</tr>
<tr>
<td>GMSL* (GIA* corrected)</td>
<td>3.56</td>
<td>3.19 ± 0.63</td>
</tr>
</tbody>
</table>

GMSL* = Global Mean Sea Level
GIA* : Glacial Isostatic Adjustment
Arctic Freshwater Content (FWC) Impact of assimilation in sparsely observed areas

Annual mean Arctic FWC anomaly

Trend 1995-2012
GLORYS2V4
677 +/- 50 km³/year⁻¹
FREE RUN
520 +/- 44 km³/year⁻¹

Trend 1992-2012
Rabe et al. (2014)
600 +/- 300 km³/year⁻¹
Sea Ice

Use of different data: CERSAT, NSIDC, OSI SAF (CMEMS) to assess uncertainties.

Arctic Ocean

Antarctica

-76300 km²/yr

+44900 km²/yr
Summary

- Important improvement with the new release GLORYS2V4: bias & rms, SST, T, S, Heat & Salt content, Steric height (Surface Heat Flux = +0.5 W.M$^2$).
- Validation still ongoing (biogeochemistry application, ...)
- Products (T, S, U, V, ...) available in CMEMS catalogue.
- Look forward to users’ feedback!!

Prospectives

- Improvement of Surface mass budget
- Use last updates for assimilation and physics (available in NEMO3.6, time-splitting, Variable Volume, LIM3, ...).
- **Ensemble approach** (stochastic & analysis)
- Assimilation of CMEMS products (SST, sea ice, ...)
- **GLORYS12V1 (1/12°) (1993-2016)** ongoing run.
CMEEMS Ensemble Products:

✓ Multi model (CMCC/ECMWF/Mercator/MetOffice) multi year global ¼° reanalysis product with uncertainty estimates for T, S, U and V and able to derive Ocean Monitoring Indices (Ocean State Report).
