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


Mercator Ocean, \(^1\)CLS (Toulouse)

GMMC
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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.

CMEMS* = Copernicus Marine Environment Monitoring Service
The core of the actual GLORYS system

**Model/Configuration**
- **NEMO** 3.1 (TKE, ...) at $1/4^\circ$, 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** ($1/4^\circ$) from AVHRR+AMSRE
- **Altimetry** (T/P, Jason, Cryosat2, ...)
- **In situ** (T,S) (Argo) from CORA (CMEEMS*) data base
- Hybrid Mean Dynamical Topography (MDT)

CMEEMS* = 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. No SSS restoring.</td>
<td>Initial conditions (T,S) from EN4 (90’s)</td>
</tr>
<tr>
<td>Large scale correction of rainfalls and radiative fluxes towards resp.</td>
<td>Idem + damping in Gibraltar and Bab-El-Mandeb straits.</td>
</tr>
<tr>
<td>GPCPV2.2 &amp; GEWEX SRB3.0.</td>
<td>Idem but Large scale correction of rainfalls towards PMWC</td>
</tr>
<tr>
<td>Hybrid MDT CNES-CLS 09</td>
<td>Hybrid MDT CNES-CLS 13</td>
</tr>
<tr>
<td>CORA3.3 in situ data base</td>
<td>CORA4.1 in situ data base</td>
</tr>
<tr>
<td>Assimilation of sea ice CERSAT</td>
<td>Idem.</td>
</tr>
</tbody>
</table>

steric* = volume changes due to density changes
Sea Surface Height

Bias with satellite data

GLORYS2V4 ≈ 0

GLORYS2V3 ≈ 0

Satellite Data include: ERS, T/P, Jason 1 & 2, Envisat, GFO, Saral/AltiKa, Cryosat2, HY2A.

Root Mean Square Error with satellites

GLORYS2V4 ≈ 6-6.5 cm

GLORYS2V3 ≈ 6-7 cm
In Situ 3D Temperature, Salinity

(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 ¼°
(Warm) Bias in GLORYS2V4 < 0.5°C
(Warm) Bias in GLORYS2V3 < 0.7°C

Diagnostics of interest for seasonal forecast.
Global Ocean Temperature 0-2000m

GLORYS2V4
GLORYS2V3

From Masina et al. (2015)
Steric height

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

Steric signal for 0m-Bottom

<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
Large scale circulation

CLIM GLORYS2V4: Zonal velocity (m s⁻¹)

CLIM 1993–2015 TAC–INSITU CMEMS: Zonal velocity (m s⁻¹)

Mean transport at ACC_Drake_Passage

ORAS5
FOAM
CGLORS
GLORYS2V4

Total Meridional Heat Transport
period: 1993-2015
Sea Ice Extent

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

Arctic Ocean

Antarctica

-76300km²/yr

+44900km²/yr
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
Arctic Sea Ice Volume

Still biases … … but improvements ongoing

From Chevallier et al. (2016)
Summary

- Important improvement with the new release GLORYS2V4: bias & rms, SST, T, S, Heat & Salt content, Steric height (Surface Heat Flux = +0.5 W.M²).
- Validation still ongoing
- 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 OSTIA, sea ice OSI SAF, …)

→ GLORYS12V1 (1/12°) (1993-2016) ongoing run.
Stream function

Averaged over the 1993-2015

ORAS5
MOC Atl (Sv)

GLORYS2V4
MOC Atl (Sv)

GLORYS2V4 – Free run
MOC Atl (Sv)

FOAM
MOC Atl (Sv)

CGLORS
MOC Atl (Sv)

Profiles at 26°N (black RAPID array)
Temperature anomalies in Labrador sea

ORAS5-LAB

GLORYS2V4-LAB

GLORYS2V4runlibre-LAB

FOAM-LAB

CGLORS-LAB

mercator-ocean.eu / marine.copernicus.eu
In Situ Data – Tropical moorings

RMS Temp. < 0.5 °C
RMS Salt < 0.2 PSU

Salinity

Temperature

Global Tropical Moored Buoy Array

RMS: BUOY=GLORYSSV4
In Situ Data – Tropical moorings
Comparisons with independent data

Comparisons with independent Data

Currents measurements (ADCP)

RMS Error with GLORYS2V4

RMS < 0.3 m.s⁻¹
Underestimation of EUC (Equatorial Under Current)
Underestimation of surface currents
Temperature anomalies in Labrador sea

Observations

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