Global Mean Sea Level Budget
January 2003 – December 2014

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Before delivering new data sets to users, these have to be validated.

Validation of the CCI_SL_ECV_V1.1 product

**Two approaches:**

1. Evaluation using a ‘Sea Level Closure Budget’ approach
2. Intercomparison with all GMSL products
Global Mean Sea Level Budget over 2003-2014

→ *Update of the previous presentation*

→ *Addition of year 2014*
Observed Global Mean Sea Level Rise

\[ \Delta M_{\text{ocean}} = -\Delta M_{\text{LI}} - \Delta M_{\text{LW}} - \Delta M_{\text{WV}} - \Delta M_{\text{Snow}} - \ldots \]

\( \Delta = \text{Time variation} \)

\( M = \text{Masse} \)

\( LI = \text{Land Ice (glaciers + ice sheets)} \)

\( LW = \text{Land Waters} \)

\( WV = \text{Water Vapour} \)

\( \text{Snow} \)
Available since ~ 2003, Argo + GRACE → steric sea level (T/S down to 2000m) + ocean mass

**Thermal expansion + salinity of the upper ocean (0-2000 m)**

**Argo**
- 6-12 hours at surface to transmit data to satellite
- Descent to cruising depth (~10 cm/s (~3 hours))
- Salinity & Temperature profile recorded during ascent (~10 cm/s (~5 hours))
- Cruising depth: 2000 km (2000m)
- Total cycle time: 10 days

**3918 Floats 3-Nov-2016**

**GRACE**
- Gravity Recovery And Climate Experiment
- Mass changes

**Ocean mass**

**Glaciers, ice sheets, land waters**
Global Mean Sea Level (GMSL) Budget January 2003 - August 2014
(sea level data from ESA Climate Change Initiative (CCI))

Black: Altimetry-based Global Mean Sea Level
Red: Sum of Thermal Exp.+ Mass

CCI GMSL 3.07 mm/yr
GRACE Ocean Mass + Steric from ARGO (2000m) 2.97 +/- 0.16 mm/yr
Steric from ARGO (2000m) 1.11 +/- 0.12 mm/yr
GRACE Ocean Mass 1.86 +/- 0.1 mm/yr

CCI SL_ECV_1.1:
- good agreement with sum of components in terms of trend (within 0.1-0.2 mm/yr).
- In terms of interannual variability, discrepancies of several mm at some periods

Source: Dieng/legos
Global Mean Sea Level (GMSL) Budget January 2003 - August 2014

Black: Altimetry-based Global Mean Sea Level
Red: Sum of Thermal Exp. + Mass

AVISO GMSL: 3.17 mm/yr
GRACE Ocean Mass + Steric from ARGO (2000m): 2.97 +/- 0.16 mm/yr
Steric from ARGO (2000m): 1.11 +/- 0.12 mm/yr
GRACE Ocean Mass: 1.86 +/- 0.1 mm/yr

Ocean Mass from GRACE

AVISO GMSL:
- Trend agreement within 0.2-0.3 mm/yr
- Interannual larger discrepancies during Jason-1 period

Source: Dieng/legos
Ocean Mass from GRACE

Black: Altimetry-based Global Mean Sea Level
Red: Sum of Thermal Exp. + Mass

CU GMSL: 2.93 mm/yr
GRACE Ocean Mass + Steric from ARGO (2000m) 2.97 +/- 0.16 mm/yr
Steric from ARGO (2000m) 1.11 +/- 0.12 mm/yr
GRACE Ocean Mass 1.86 +/- 0.1 mm/yr

Source: Dieng/legos
Ocean Mass from GRACE

**Mean GMSL (5 products):**
- Trend: same result as with CCI
- Interannual: higher discrepancies than with CCI

Source: Dieng/legos
Residual component from sea level budget

Residual = GMSL – SUM « GRACE Ocean Mass + Steric from ARGO»

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**GMSL Residual**

<table>
<thead>
<tr>
<th></th>
<th>CCI</th>
<th>AVISO</th>
<th>CU</th>
<th>Mean 5 GMSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS (mm)</td>
<td>1.68</td>
<td>1.70</td>
<td>1.68</td>
<td>1.65</td>
</tr>
<tr>
<td>Trend (mm/yr)</td>
<td><strong>0.1 +/- 0.16</strong></td>
<td>0.19 +/- 0.16</td>
<td><strong>-0.04 +/- 0.16</strong></td>
<td><strong>0.1 +/- 0.19</strong></td>
</tr>
</tbody>
</table>

Source: Dieng/legos
With ORAS4:

- Trend: less good than with Argo product
- Interannual: same result as with Argo except during La Nina 2007/08 period
Residual component from sea level budget

Residual = GMSL – SUM « GRACE Ocean Mass + Steric from ORAS4 »

With steric from ORAS4:

In terms of interannual:
- less good than with Argo product
- improvement with CCI during the La Nina periods (2007/08 and 2010/11)

<table>
<thead>
<tr>
<th>GMSL Residual</th>
<th>CCI</th>
<th>AVISO</th>
<th>CU</th>
<th>Mean 5 GMSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS (mm)</td>
<td>1.84</td>
<td>1.99</td>
<td>2.12</td>
<td>1.95</td>
</tr>
<tr>
<td>Trend (mm/yr)</td>
<td>0.16 +/- 0.1</td>
<td>0.22 +/- 0.1</td>
<td>-0.05 +/- 0.1</td>
<td>0.10 +/- 0.14</td>
</tr>
</tbody>
</table>

Source: Dieng/legos
CONCLUSION:

- **Trend**: all products give about similar results, but best closure level budget obtained with CCI SL_ECV_1.1 (with 0.1-0.2 mm/yr). in terms of trend;

  *The sea level budget approach leads to smaller trend uncertainty than the geophysical correction error budget approach developed in Ablain et al., 2015.*

- **Interannual**: Very similar results for all products; Remaining discrepancies of the order of 2 mm RMS.
  - Some products (e.g. mean GMSL) provides better closure of the sea level budget during the 2011 La Nina.
  - Large discrepancy for all products during the 2007-2008 La Nina.
  - Improving the CCI product during 2007-2008 and 2010-2011 La Nina using ORAS4 reanalysis.
Work to do:

- Redo the sea level budget approach using new GRACE products (JPL Mascons, and new LEGOS solution/forward modelling) and different ocean reanalyses for the steric component;
- International comparison of GMSL products computed by different groups (AVISO, CU, NOAA, GSFC, SCIRO and CCI) to better understand the major differences between altimetry-based GMSL products and reduce errors in data processing.
- .....
Thank you!
Still much difference between the different GMSL products in term of trend and in term of interannual variability.

Source: Dieng/legos
Still much difference between the different GMSL products during the La Nina 2010/11 period and between 2005-2007.
Good correlation between the CCI product and Mean of 5 GMSL except during the La Nina 2010/11 period.

Mean GMSL from AVISO, CU, NOAA, GSFC and CSIRO
Trend = 3.09 +/- 0.1 mm/yr

SL_ECV_V1.1 product from CCI
Trend = 3.09 mm/yr

Source: Dieng/legos