Added value of the CCI_SL data for scientific investigations

Final Meeting
ESA-ESRIN, 27-28 February 2017
Why is it important to precisely monitor sea level changes?

1. Global mean sea level rise is an integrator of changes occurring in the climate system
   → provides an integrative view of present-day changes (land ice melt, ocean warming, land waters); one of the best indicators of anthropogenic climate change and natural variability

2. Studying the sea level budget using different observing systems offers constraints on « missing contributions » (e.g. deep ocean warming) or poorly known components (e.g., ground water depletion in aquifers)

3. Observed sea level changes at global and regional scale help validating climate models used for projections and inform on detection/attribution issues

4. Observed sea level variations at the coast provide constraints on models of coastal impacts and shoreline erosion
Question 1: What was the status of the « sea Level » landscape at the start of the CCI programme?

Landscape ➔
- International collaboration
- Developpement of networks
- Cross project activities

……
Responses to question 1

- Satellite altimetry was already a mature technique  
  → high precision altimetry era started in the early 1990s

- International collaboration already well established
  - within Europe (ERS-1/2 & Envisat ESA missions)
  - between USA and Europe (Topex/Poseidon & Jason series)

- Networks of altimetry users & sea level scientists worldwide already existed
  (in particular thanks to the annual working meetings called « OSTST » handled by CNES and NASA)

- However, in spite of continuous progress in altimetry data processing,
  still important differences between « Sea Level » products provided by the main processing groups

- GCOS accuracy requirements not satisfied; no error characterisation  
  → Errors and uncertainties not well described
Detrended Global Mean Sea Level (1993-2016)
Question 2: What is the status of the « Sea Level » landscape at the end of the 6 years of CCI?
Responses to question 2

- **International collaboration reinforced:**
  - the CCI Sea Level project involved 15 European partners that met at least twice a year during the past 6 years
  - an international panel of experts invited to assess the processing activities
  - contributed to the visibility of the CCI project and led to the development of a significant number of scientific collaborations (e.g. between altimetry experts and ocean modelers)

- **Innovative frame work proposed by ESA (i.e. Round Robin exercise):**
  - A formal protocol of validation has been set up, allowing the evaluation of the numerous altimeter standards (corrections) and algorithms
  - Selection of algorithms obtained through a consensus between Earth Observation experts and climate scientists

- **Cross project activities**
  - Very positive synergy
  - Contribution to a European network of expertise
  - Emergence of collaboration between sea level experts and climate modelers (via CMUG)
  - At the origin of a new integrated project (“Sea Level Closure Budget”)
A few examples of science achievements based on the CCI_sea level products
(Quality Assessment Group)
### Current Sea Level Uncertainties

**«ESA Climate Change Initiative/CCI» products**

<table>
<thead>
<tr>
<th>Spatial Scales</th>
<th>Temporal Scales</th>
<th>GCOS Requirements</th>
<th>Errors of CCI products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Mean Sea Level</strong></td>
<td>Long-term trend</td>
<td>&lt;0.3 mm/yr</td>
<td>≤0.5 mm/yr</td>
</tr>
<tr>
<td></td>
<td>Interannual signals</td>
<td>0.5 mm</td>
<td>&lt; 2 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>over 1 year</td>
<td>over 1 year</td>
</tr>
<tr>
<td><strong>Regional Sea Level</strong></td>
<td>Long-term trend</td>
<td>&lt;1 mm/yr</td>
<td>&lt;2 mm/yr</td>
</tr>
<tr>
<td></td>
<td>Interannual signals</td>
<td>Not Defined</td>
<td>(except for western boundary currents)</td>
</tr>
</tbody>
</table>

**GCOS: Global Climate Observing System**

Source: Ablain et al., 2017
Science achievements at NERSC and findings

• The new ESA CCI Sea Level products have provided advanced opportunities for studies of sea level changes at high northern latitudes seas and in the Arctic Ocean with focus on the Beaufort Gyre (BG), the Lofoten Basin (LB) and the Sub-Polar Gyre (SPG).

• In particular comparison and assessment of the SL_CCI products to the in-situ observations, the coupled climate model NorESM fields, and the operational forced ocean model (TOPAZ) reanalyses fields in Copernicus Marine Environmental Monitoring Services (CMEMS).

• Distinct sea level rise are encountered in:
  ✓ BG: around 6 mm/yr
  ✓ LB: around 3-4 mm/yr
  ✓ SPG: around 4-5 mm/yr

• This rise is explained by
  ✓ BG: salinity reduction
  ✓ LB: temperature increase
  ✓ SPG: temperature increase

Johannessen et al., 2017
Science achievements at NERSC and findings (cont.)

• These findings point to an important contribution of the ocean circulation to the SSH changes in the Northeast Atlantic, Nordic Seas and Arctic Ocean.

• Using the coupled NorCMP it is, moreover, clearly revealed that assimilation of SST lead to very good agreement in the representation of the SSH variability and trend. In contrast, the free run with the coupled NorESM is not able to reproduce this evolution at all.

• Assimilation of Argo floats and SSH are highly important for simulation and prediction of the total sea level and steric conditions in the forced operational models.

• Assimilation in coupled climate models is equally highly important to reduce the uncertainty in the model simulations and predictions.
According to the GECCO2 model synthesis, the SL data V1.1 has been improved as compared to SL V0. The SL estimates improved for most parts of the world's oceans of up to 30%.

Assimilating SL V0 or SL V1.1: the model synthesis results G1.1 are in closer agreement to the SL V1.1 data than G0 has been to SL V0.
Data set: improvement of SL V1.1

According to the GECCO2 model synthesis, the SL data V1.1 has been improved as compared to SL V0.

The SL estimates improved for most parts of the world's oceans of up to 30%.

Model: improvement due to SL V1.1 assimilation

Assimilating SL V0 or SL V1.1: the model synthesis results G1.1 are in closer agreement to the SL V1.1 data than G0 has been to SL V0.

--> SL and other variables of the ocean synthesis have been improved due to the assimilated SL data and are now in closer agreement with the assimilated data.
Science achievements at LEGOS

• Assessment of the CCI_SL product (V2.0) using the sea level budget closure approach
Global Mean Sea Level (1993-2015)

Mean GMSL (5 products) 3.28 +/- 0.10 mm/yr
CCI v2.0 3.30 mm/yr
Difference time series between individual GMSL products and the ensemble mean

The smallest residual is obtained with the CCI product (V2.0)
CCI GMSL

Argo XBTs

RMS = 1.8 mm; correlation -0.1

RMS = 2.9 mm; correlation 0.7

Residual trend: 0.03 +/- 0.22 mm/yr

Residual trend: 0.03 +/- 0.22 mm/yr
Question 3: What are the activities in CCI that have served to change from status 1 to status 2?
Responses to question 3

- **Annual collocation meetings at ESRIN**
  - development of cross project activities

- **Regular meetings (work meetings, annual meetings, etc.) within the project**
  - Increased group collaborations at the European level

- **Opportunity for increased relationship with international organisations**
  (e.g., GCOS, WCRP, ISSI, IPCC....)
  - Increased visibility of the CCI programme
  - interest for the climate community and other users

- **Innovation in ECV data processing**
  - new protocol of algorithm selection and validation
Question 4: What are the lessons learned from CCI to provide to future projects?
Responses to question 4

- According to the « Sea level » consortium, the CCI project has reached most of its objectives: Sea Level ECV ready for operational production within the Copernicus Climate Change Service /C3S

- Round Robin framework to be used by future CCI+ projects

- Emergence of new projects
  - Closure of the sea level budget
  - CCI-based coastal sea level?
Project objectives

• Investigate in a coherent way the closure of the sea level budget using CCI products. Thereby assess their quality.

• Study and analyze the regional variability of sea level and its steric and mass components. The Arctic Ocean is chosen as study region.

• Prepare the way to more comprehensive and more operational assessments of the global and regional sea level budget.

→ 2-year project to be started next week.
A large fraction of world shorelines currently eroded (~70% of sandy beaches, Bird, 1985)
We don’t know what are the respective contributions of natural phenomena, anthropogenic forcing and sea level rise on present-day shoreline erosion
We don’t know if coastal sea level is rising at the same rate as open ocean sea level

Locally what we need to measure at the coast is the TOTAL RELATIVE SEA LEVEL

Sum of «**GMSL + regional variability + local processes** + vertical land motions»
# Current status of coastal altimetry products

<table>
<thead>
<tr>
<th>ID</th>
<th>Produced by</th>
<th>Missions</th>
<th>Product level</th>
<th>Posting rate</th>
<th>Coverage</th>
<th>Download from</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVISO</td>
<td>CLS, CNES,</td>
<td>e1, tx, e2,</td>
<td>L2, L3, L4,</td>
<td>1 Hz</td>
<td>Global + european</td>
<td>AVISO+</td>
</tr>
<tr>
<td></td>
<td>CNES</td>
<td>en, j1, j2, c2</td>
<td>(LRM/PLRM),</td>
<td></td>
<td>regions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sa</td>
<td>also L4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMEMS</td>
<td>CLS, CNES</td>
<td>e1, tx, e2,</td>
<td>L3</td>
<td>1 Hz</td>
<td>Global + european</td>
<td>marine.copernicus.eu</td>
</tr>
<tr>
<td></td>
<td></td>
<td>en, j1, j2, c2</td>
<td>(LRM/PLRM),</td>
<td></td>
<td>regions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sa</td>
<td>L3 for assim</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>PISTACH</td>
<td>j2</td>
<td>L2</td>
<td>20 Hz</td>
<td>Global</td>
<td>AVISO+</td>
</tr>
<tr>
<td></td>
<td>CLS, CNES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEACHI</td>
<td>CLS, CNES</td>
<td>sa</td>
<td>L2</td>
<td>40 Hz</td>
<td>Global</td>
<td>AVISO+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>XTRACK</td>
<td>tx, j1, j2, gfo, en</td>
<td>L2, L3</td>
<td>1 Hz</td>
<td>23 regions</td>
<td>CTOH, AVISO+</td>
</tr>
<tr>
<td></td>
<td>LEGOS-CTOH</td>
<td></td>
<td></td>
<td>20 Hz</td>
<td>(test)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>RADS</td>
<td>gs, e1, tx, pn, e2, gfo, j1, n1, j2, c2, sa</td>
<td>L2, L3</td>
<td>1 Hz</td>
<td>Global</td>
<td>TUDelft</td>
</tr>
<tr>
<td></td>
<td>EUMETSAT, NOAA, TUDelft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>ALES</td>
<td>j2, n1</td>
<td>L2</td>
<td>20 Hz</td>
<td>Global, &lt;50 km from coast</td>
<td>PODAAC</td>
</tr>
<tr>
<td></td>
<td>NOC</td>
<td>(coming)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>SARvatore</td>
<td>c2 (SAR only)</td>
<td>L2</td>
<td>20 Hz</td>
<td>SAR mode regions</td>
<td>ESA GPOD</td>
</tr>
<tr>
<td></td>
<td>ESA-ESRIN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>^</td>
<td>COP</td>
<td>c2 (LRM/PLRM)</td>
<td>L2</td>
<td>20 Hz</td>
<td>Global</td>
<td>ESA</td>
</tr>
<tr>
<td></td>
<td>ESA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>