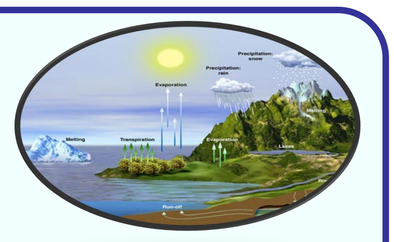
Accurately measuring sea level change from space: an ESA Climate Change Initiative for MSL closure budget studies

G. Larnicol, JF Legeais, M. Ablain (CLS), A. Cazenave (LEGOS), Benoît Meyssignac (LEGOS), D. Stammer (UoH), M. Scharffenberg (UoH), J. Johannessen (NERSC), G. Timms (CGI), S. Rudenko (GFZ), M. Roca (IsardSat), O. Andersen (DTU), P. Cipollini (NOC), M. Balmaseda (ECMWF), J. Fernandes (FCUP), G. Quartly (PML), Luciana-Fenoglio-Marc (TUD), J. Benveniste (ESA), A. Ambrozio (ESA), S. Dinardo (ESA) and T. Guinle (CNES)

I - The sea level Climate Change Initiative (CCI) project overview

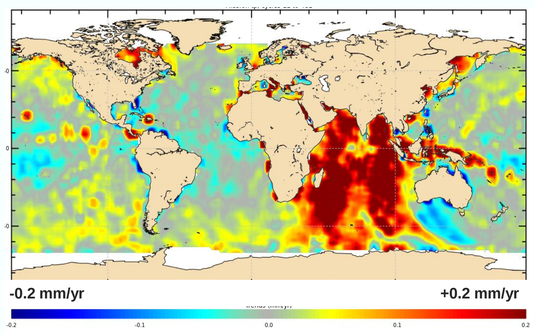
Sea Level (SL) is a very **sensitive index** of **climate change and variability**. It has been selected as an Essential Climate Variables (ECV) by the European Space Agency (**ESA**) which has initiated the **Climate Change Initiative** (CCI) program, including 13 ECV projects. It aims at providing accurate long-term **satellite-based products for climate** applications. It provides a unique opportunity to set up dialogue and cooperation between **Earth Observation** and **Climate Research** communities. The **first version of the Sea Level ECV** has been **produced** during the 1st phase of the project (2011-2013) and the **2nd phase** has started in 2014 for the following 3 years, including a European consortium of 13 partners.



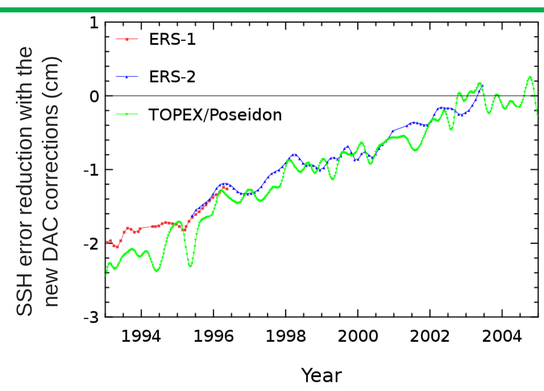
II – Main achievements in the 1st Sea Level CCI release

Many **altimeters corrections** have been developed, tested and applied to **more than 50 years** of cumulated altimeter measurements. A **formal validation protocol** has been developed to select the **best standards for climate applications**. The most important evolutions are associated with:

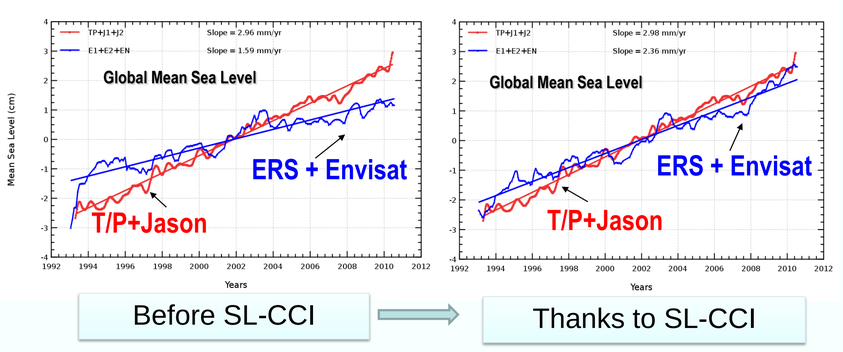
New wet troposphere corrections, based on the GNSS path delays, with a **strong impact on the regional sea level trends** (see figure).



Impact of the new GPD correction on the MSL trends for T/P (1993-2005)



New atmospheric corrections computed with the **ERA-Interim reanalysis** lead to a **strong** SL **error reduction** (see figure) and strong improvement of the regional MSL trends over the early altimetry years.



New instrumental correction for Envisat contributes to make more homogeneous the **global Mean Sea Level** trend and inter annual signals derived from ERS-1 & 2 and Envisat with the signals from other altimeter missions.

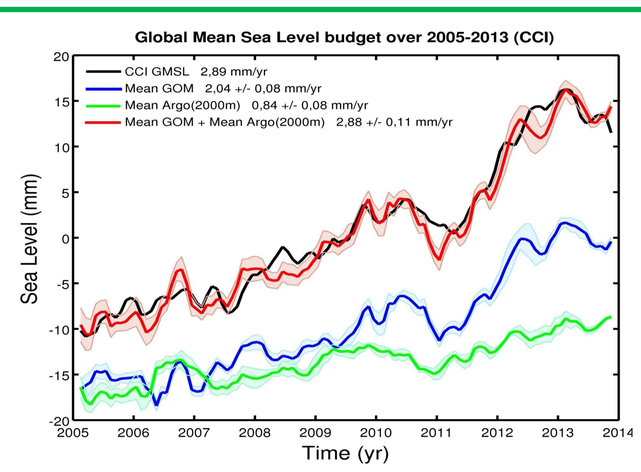
The **validation and user assessment** of the SL-CCI products has been performed through:
- **Internal consistency** check and comparison with **in-situ data**.
- **Comparison** with **ocean model assimilation experiments,** by quantifying changes of the model performances.
- **Sea level closure budget** approach by comparison with the steric (Argo) and mass (GRACE) contributions (see right figure) but also from the glaciers, ice sheets and land waters.

Error Characterization of Sea-Level ECV

The **sea level** ECV products **error budget** has been determined **at climate scales** (see table) through the analysis of **each source of error**. The comparison with the **user requirements** (defined in the CCI project and the last GCOS report) allows us to define the **level of altimetry errors at climate scale**: null, low or strong.

Ablain et al, 2012, OSTST, Venice 2012

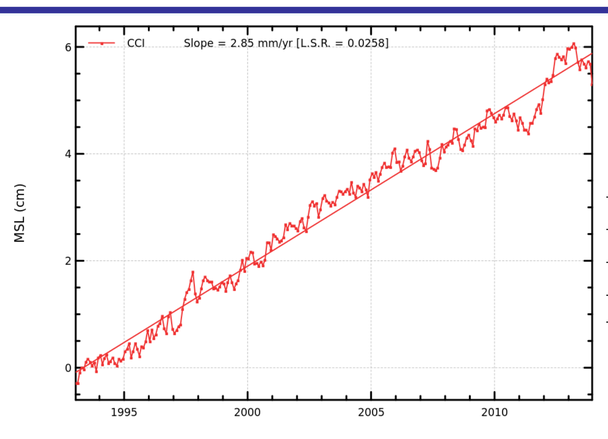
Spatial Scales	Temporal Scales	Altimetry errors	User Requirements
Global Mean Sea Level (10-day averaging)	Long-term evolution (> 10 years)	< 0.5 mm/yr	0.3 mm/yr
	Inter annual signals (< 5 years)	< 2 mm over 1 year	0.5 mm over 1 year
	Periodic signals (Annual, 60-days,...)	Annual < 1 mm 60-day < 5 mm	Not defined
Regional Mean Sea Level (2x2 deg boxes and 10-day averaging)	Long-term evolution (trend)	< 3 mm/yr	1 mm/yr
	Inter annual signals (> 1 year)	Not evaluated	Not Defined
	Periodic signals (Annual, 60-days,...)	Annual < 1mm 60-day < 5 mm	Not Defined

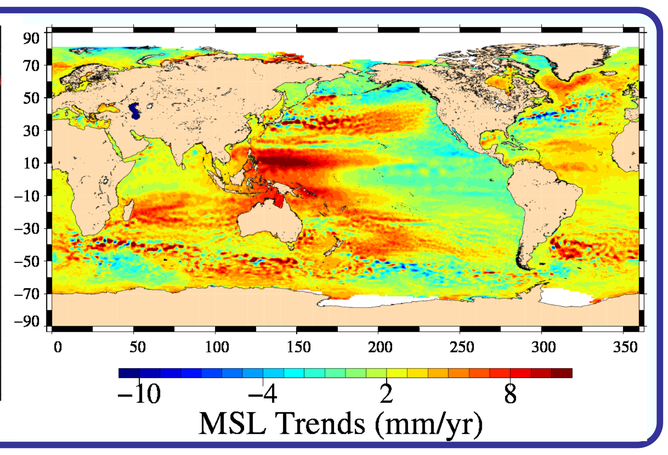


III - The Sea-Level ECV products

The **SL-CCI ECV maps of the sea level** have been generated **from 1993 to 2013** and will be **extended to 2014** by the end of 2015. They are available on request at info-sealevel@esa-sealevel-cci.org. The Product User Guide and Specification Document can be found on the website project: www.esa-sealevel-cci.org

Associated **Climate Sea-Level** indicators are also available for users. They concern:
- The **global mean Sea level evolution** and its **trend** (left figure)
- The **map of regional MSL trends** (right figure)
- The **amplitude and phase** of the **annual cycle** of the sea level

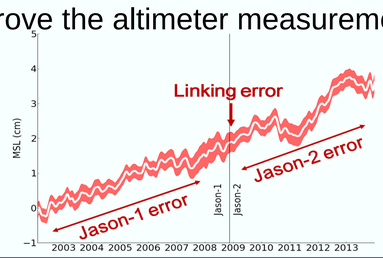




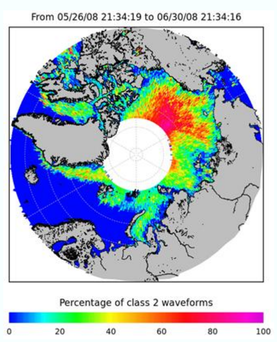
IV – Future plans: phase II of the CCI project

The **phase II** of the SL-CCI program has started in **2014** for the next 3 years. The aim is to better answer the **user requirements** and improve the **altimeter corrections** that most affect the altimeter error budget at climate scales:

- Refine the **altimetry error characterization** (GMSL confidence envelope, see left figure)
- Enhance all the **altimeter** and **radiometer accuracy**
- Provide the best **homogeneous orbit** solutions
- Improve the **atmospheric corrections** with new meteorological reanalyses
- Increase the data quality and coverage in the **Arctic ocean** (see figure)
- Improve the altimeter measurements in **coastal areas**



Estimation of the confidence envelop of the Global Mean Sea Level from Jason-1 & 2



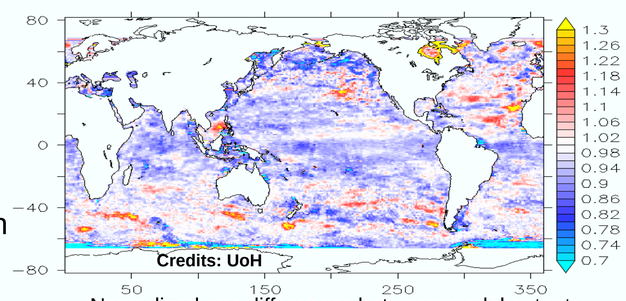
% of leads in 2008/06 (Envisat)

Phase II gives the opportunity to increase the **synergy** between the **altimeter** experts and the **atmosphere and sea ice** communities.

As required for climate studies, the **temporal coverage** of the time series is **extended to present days** with **yearly update** of the sea level ECV.

The ECV products will be **fully reprocessed** in 2016, leading to a v2.0 dataset, covering the **1993-2014** period and **distributed** on request **to users**. It will include the **integration of new altimeter missions** (CryoSat-2, Saral-AltiKa).

In addition of **internal validation** and comparison with **in-situ data**, the **assessment** of the SL ECV will be performed by the **climate research group** with a focus on the **error characterization** and the comparison with datasets from other groups.



Normalized rms differences between model outputs assimilating two different SL products

IV – Contacts

info-sealevel@esa-sealevel-cci.org

Science Leader : A. Cazenave (anny.cazenave@legos.obs-mip.fr)
Project Managers : G. Larnicol (glarnicol@cls.fr , JF Legeais (jlegeais@cls.fr)
Earth Observation group: M. Ablain (mablain@cls.fr)
ESA technical officer: J. Benveniste (Jerome.Benveniste@esa.int)

V – Links

http://www.esa-sealevel-cci.org The Sea Level CCI project website
http://www.esa-cci.org The ESA Climate Change initiative portal
http://www.aviso.altimetry.fr/en The CNES/CLS altimetry portal
http://www.altimetry.info Radar Altimetry Tutorial and Basic Radar Altimetry Toolbox