climate change initiative

→ SEA LEVEL NEWSLETTER

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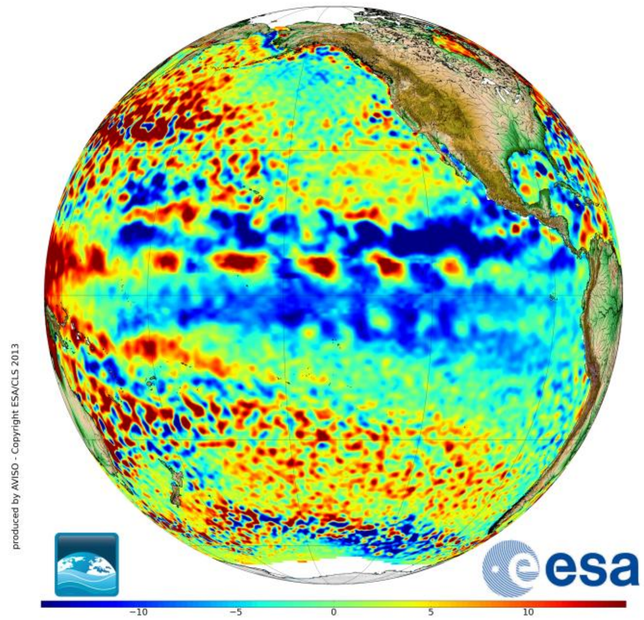

The Pacific sea level anomalies in December 2010 during the 2010-2011 La Niña.

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A new homogeneous and accurate Sea Level ECV under construction…

The objective of the Sea Level Climate Change Initiative project is to provide stable, long-term satellite-based Sea Level products for climate applications. During phase I of the project (2011-2013), the climate research community has been involved and the user requirements have been refined for climate applications, providing more requirements on regional scale and inter annual variability.

New algorithms were developed to improve the altimeter data and a formal validation protocol was used for the estimation and the validation of their performances. The best algorithms for climate applications have been selected by an international panel of experts. More than 50 years of cumulated altimeter data were processed, leading to the production of a recently extended time series of sea level maps (together with climate indicators), which now covers 1993-2013. The climate modelling group contributed to the assessment of the products (see dedicated article on page 3) through assimilation and comparison with models and sea level closure budget studies.

The work performed contributed to homogenise radar altimetry time series (from TOPEX/Poseidon, Jason-1, Jason-2, ERS-1, ERS-2 and Envisat) in terms of sea level trends and to better characterise and reduce altimetry errors at climate scales.

However, the user requirements have not been reached at all temporal and regional scales and many ideas for improvement remain to be explored. During phase II (2014-2016), the work focused on improving the radar altimetry standards that should contribute most effectively to increase the ECV homogeneity and to reduce the altimetry errors. In addition, significant work is performed to improve the sea level estimation in the Arctic Ocean (see dedicated article on page 2) and in the coastal areas.

As required for climate studies, the Sea Level ECV will be extended up to 2014 by the end of the year and a full v2 reprocessing of the product will be delivered in 2016, including the best algorithms developed during phase II and using new altimeter missions (CryoSat-2 and SARAL-AltiKa).

Access to products and more info:

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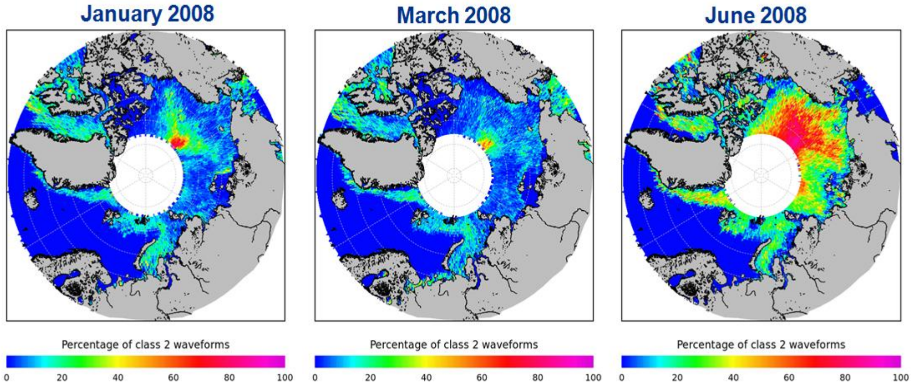
Improvement of the Sea Level measurement over sea ice regions

Fig 1: percentage of very reflective signals (identified as class 2) from January 2008 to June 2008



One of the major goals of the Sea Level_cci project is to improve the sea level estimation in the Arctic Ocean. Due to the presence of sea ice and depending on its temporal variability, the sea level data coverage is seasonal and this hampers the use of altimetry for climate studies in these areas. Thus, the estimation process is essential and <u>the first key step</u> consists in distinguishing ice-free regions from sea ice covered regions.

Parallel studies have been conducted by Plymouth Marine Laboratory (PML) and Collecte Localisation Satellite (CLS) with the aim to identify and flag the measurements over open water or over leads in the ice covered regions. Partially-melted sea-ice may have puddles of liquid water on top, producing a smooth isotropic reflecting surface that can generate Brown-like returns, whilst the narrow leads between ice floes contain very calm water and only produce a radar return for irradiation directly orthogonal to the surface, thus producing a waveform that is like an impulse function. CLS has chosen to implement a neural network algorithm for classifying echoes while PML has developed editing criteria based on the characteristics of the waveforms. Three indicators of sea ice are distinguished: pulse peakiness for example which is a measure of how much the waveform deviates from an even power distribution. A second potential indicator of sea-ice is sigma0, as the radar reflectance of water lying on the ice typically results in high values of backscatter. A third sign may be the increased variability in the estimated measures of range, sigma0 or wave height once the surface within the footprint becomes inhomogeneous. The CLS classification identifies more "sea ice" measurements compared to PML but a very good agreement has been found on data classified as "ice floe" by PML. Nearly the same regions are detected with similar proportion of leads measurements.

Figure 1 represents the percentage of very reflective signals (identified as class 2) from January 2008 to June 2008. The percentage of such signals is increasing as the ice melts which opens more and more leads in the ice. Sea level estimates will be mainly based on these open water points.

When plotted over the complete Envisat period (2002-2012) (figure 2, left), the percentage of waveform classes in the Arctic regions provides a clear indicator of the seasonal and long term variability, indicator that has been linked very coherently with sea ice extent indicators provided by OSI-SAF or NSIDC (figure 2, right).

<u>The next step</u> will then consists in defining retracking strategies adapted to the particular shapes of the altimeter waveforms in particular over open water surfaces. The evaluation of these different retrackers and of the sea level estimates resulting from them, will be jointly done by PML and CLS through inter-comparison exercises.

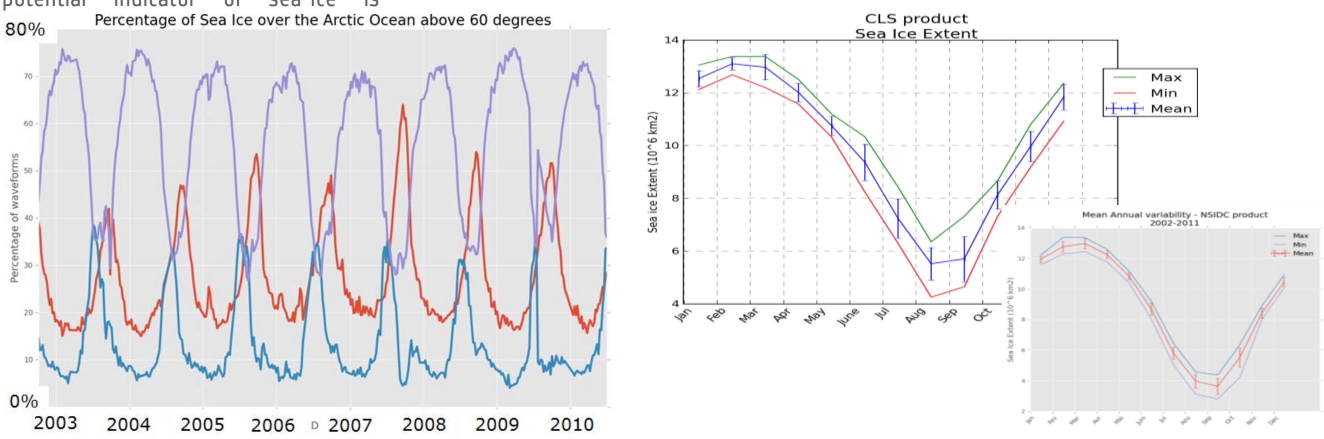


Fig 2: left: percentage of waveform classes in the Arctic regions (sea ice waveforms in purple, ocean waveforms in red and peaky waveforms in blue); right: CLS sea ice extent compared with NSIDC indicator.

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Validation of the SL_cci products

Because it integrates changes and interactions of all components of the climate system (ocean, atmosphere, cryosphere, hydrosphere), sea level is a major indicator of climate change. It varies globally and regionally in response to internal climate variability and external forcing factors including human-induced Greenhouse Gas Emissions. During the first phase of the Sea_Level CCI project, improved and homogeneous reprocessing of satellite altimetry data from ERS-1, ERS-2, Envisat, TOPEX/Poseidon, Jason-1, Jason-2, GeoSat and GFO has been performed using new orbit solutions, improved wet troposphere corrections, tidal corrections and additional up-to-date geophysical corrections of the altimeter measurements. We now have at our disposal an accurate 21-year long (1993-2013) sea level record (global mean and gridded sea level time series) with associated uncertainties.

Since the beginning of the phase II that started one year ago, an important ongoing task involving several project partners consists in validating the sea level products. Three types of assessments are investigated: (1) compare ocean model-based sea level with the CCI satellite products, (2) compare the sea level time series with tide gauge records and (3) study the sea level budget. In (1), different methodologies are developed, e.g., study the sensitivity of an ocean reanalysis (the GECCO general ocean circulation model with data assimilation) to the new CCI sea level data via inclusion of these data in the assimilation procedure; comparison with ocean-only simulation at different resolutions and with existing ocean reanalyses, which assimilate subsurface data; Assessment of sea level changes at high northern latitudes seas and in the Arctic Ocean by comparison of CCI sea level products and simulation runs of the Norwegian Earth System Model (NorESM).

The sea level budget approach consists in computing the sea level components using different observing systems, and comparing their sum to the CCI global mean sea level over the altimetry time span. Focus is currently made on the 2005-2013 time span because of the availability of Argo temperature and salinity data down to 2000 m depth to compute the thermal expansion as well as the data from the space gravimetry mission GRACE to directly estimate the ocean mass change due to land ice melt and land water storage change. Figure 3 shows the CCI sea level time series over 2005-2013 with the sum of the thermal expansion and ocean mass components (estimated from Argo and GRACE data). We note that over this time span, there is a very good agreement between the CCI sea level and sum of components, both in terms of trend and interannual variability. The CCI data lead to quasi-closure of the sea level budget; a significant improvement compared to other sea level products.

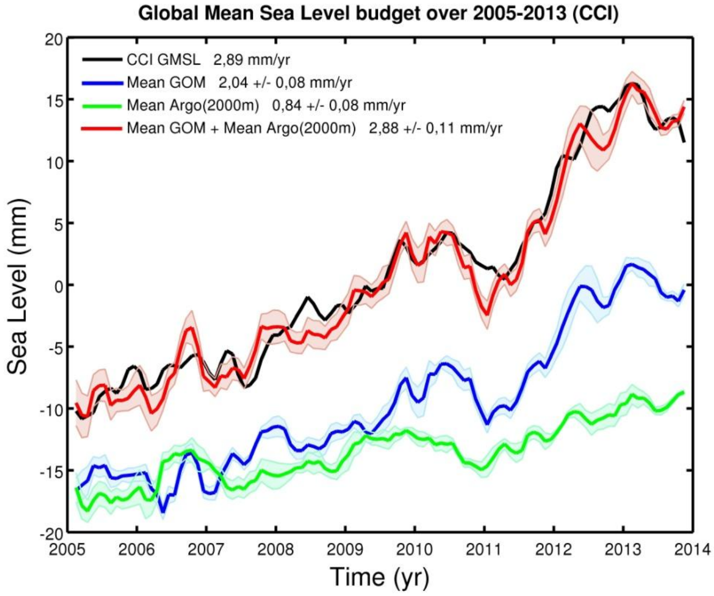
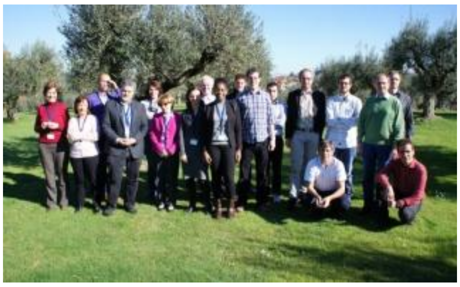


Fig 3: CCI-based global MSL (black); Argo-based steric sea level (green) GRACE-based ocean mass (in equivalent of sea level, blue). The red curve is the sum of the steric and ocean mass components. An arbitrary vertical offset was applied to the green and blue curves for clarity. Adapted from Dieng H., Palanisamy H., Cazenave A., Meyssignac B. and von Schuckmann K.,The sea level budget since 2003: inference on the deep ocean heat content, Surveys in Geophysics, 36, 1, doi:10.1007/s10712-015-9314-6, 2015.

The Sea Level CCI consortium:



The production of SL_cci extensive results has been made possible by the coordinated work of a pan-European organization (the ESA Sea Level CCI project consortium). The project team is composed of 13 European partners from the Earth Observations community (CLS, GFZ, IsardSAT, DTU, LEGOS, FCUP, NOC, PML, TUD and CGI) and partners from the Climate modelling community (LEGOS, UoH, ECMWF, NERSC and CLS), all which hold internationally acknowledged expertise in their respective fields. The consortium is under the scientific leadership of Anny Cazenave (LEGOS) and led by CLS.

Access to products:

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SL_cci team publications

A publication that describes the SL_cci project and the main results of phase I is now available:
Ablain, M., Cazenave, A., Larnicol, G., Balmaseda, M., Cipollini, P., Faugère, Y., Fernandes, M. J., Henry, O., Johannessen, J. A., Knudsen, P., Andersen, O., Legeais, J., Meyssignac, B., Picot, N., Roca, M., Rudenko, S., Scharffenberg, M. G., Stammer, D., Timms, G., and Benveniste, J.. (2015), **Improved sea level record over the satellite altimetry era (1993–2010) from the Climate Change Initiative project**, Ocean Sci., 11, 67-82, doi:10.5194/os-11-67-2015.

Find below some of the peer-reviewed articles recently published by the SL_cci team:

See http://www.esa-sealevel-cci.org/node/177 for a complete list since 2011

- Cazenave A., Dieng H.B., Meyssignac B., von Schuckmann K. Decharme B. and Berthier E., The rate of sea level rise. Nature Climate Change, vol 4, 358-361, DOI: 10.1038/NCLIMATE2159, 2014.
- Couhert A.; L. Cerri; J.-F. Legeais; M. Ablain; N. Zelensky; B. Haines; F. Lemoine; W. Bertiger; S. Desai; M. Otten; Towards the 1 mm/y Stability of the Radial Orbit Error at Regional Scales, Advances in Space Research, 2014.
- Dieng H. B., Hindumathi Palanisamy, Anny Cazenave, Benoit Meyssugnac, Karina von Schuckmann.(2015) The Sea Level Budget Since 2003: Inference on the Deep Ocean Heat Content Survey in Geophysics. DOI 10.1007/s10712-015-9314-6.
- Fenoglio-Marc L., Dinardo S., Scharoo R., Roland A., Dutour Sikiric M., Lucas B., Becker M., Benveniste J., Weiss R. (2015) The German Bight: a validation of CryoSat-2 altimeter data in SAR mode, Advanced Space Research, accepted, doi: 10.1016/j.1sr.2015.02.014.
- Henry O., Ablain M., Meyssignac B., Cazenave A., Masters D., Nerem S., Leuliette E. and Garric G., Investigating and reducing differences between the satellite altimetry-based global mean sea level time series provided by different processing groups, J. of Geodesy, 88:351–361, doi: 10.1007/s00190-013-0687-3, 2014.
- Johannessen J. A., R. P. Raj, J. E. Ø. Nilsen, T. Pripp, P. Knudsen, F. Counillon, D. Stammer, L. Bertino, O. B. Andersen, N. Serra and N. Koldunov (2014) Toward Improved Estimation of the Dynamic Topography and Ocean Circulation in the High Latitude and Arctic Ocean: The Importance of GOCE, Survey in Geophysics, Springer, DOI 10.1007/s10712-013-9270-y.
- Legeais, J.-F., Ablain, M., and Thao, S.: Evaluation of wet troposphere path delays from atmospheric reanalyses and radiometers and their impact on the altimeter sea level, Ocean Sci., 10, 893-905, doi:10.5194/os-10-893-2014, 2014.
- Palanisamy H., Cazenave A., Meyssignac B., Soudarin L., Woppelmann G. and M. Becker, Regional sea level variability, total relative sea level rise and its impacts on islands and coastal zones of Indian Ocean over the last sixty years, Global Planetary Change, 2013,doi: 10.1016/j.gloplacha.2014.02.0001.
- Palanisamy, H. Cazenave A., Delcroix T. and Meyssignac B., Spatial trend patterns in Pacific Ocean sea level during the altimetry era : the contribution of thermocline depth change and internal climate variability, Ocean Dynamics, in revision, 2014.
- Passaro M., P. Cipollini, S. Vignudelli, G. D. Quartly and H. M. Snaith, 2014, ALES: a multi-mission adaptive sub-waveform retracker for coastal and open ocean altimetry, Remote Sens. Env 145, 173-189. DOI: 10.1016/j.rse.2014.02.008
- Rudenko, S., Dettmering, D., Esselborn, S., Schöne, T., Förste, C., Lemoine, J.-M., Ablain, M., Alexandre, D., Neumayer, K.-H. (2014): Influence of time variable geopotential models on precise orbits of altimetry satellites, global and regional mean sea level trends. Advances in Space Research, 54, 1, p. 92-118, doi: 10.1016/j.asr.2014.03.010

Upcoming events

The SL_cci project will be represented at the following colloquia and meetings:

EGU Annual General Assembly, 13–17 April 2015, Vienna, Austria, www.egu2015.eu/

The 5th ESA CCI Climate Modelling User Group (CMUG) meeting, 26–28 May 2015, SMHI, Norrkoping, Sweden, www.esa-cmug-cci.org/

The Sentinel-3 for Science Workshop, 2–5 June 2015, Lido, Venice, Italy, http://seom.esa.int/S3forScience2015/

The 26th IUGG General Assembly, 22 June–2 July 2015, Prague, Czech Republic, www.iugg2015prague.com/

Our Common Future Under Climate Change Conference, 7–10 July 2015, Paris, France, www.commonfuture-paris2015.org/

The EUMETSAT 2015 Meteorological Satellite Conference, 21–25 September 2015, Toulouse, France.
https://www.eumetsat.int/website/home/News/ConferencesandEvents/DAT_2305526.html

The 6th ESA CCI Colocation Meeting, 29 Sept.–1 Oct. 2015, ESA-ESRIN, Frascati, Italy.

Ocean Surface Topography Science Team Meeting, 19–23 October 2015, Washington DC, USA.

The 9th Coastal Altimetry Workshop, held prior to the OSTST meeting, 18–19 October 2015, Washington DC, USA, www.coastalaltimetry.org/

AGU 2015 Fall Meeting 14–18 December 2015, San Francisco, California, USA.

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