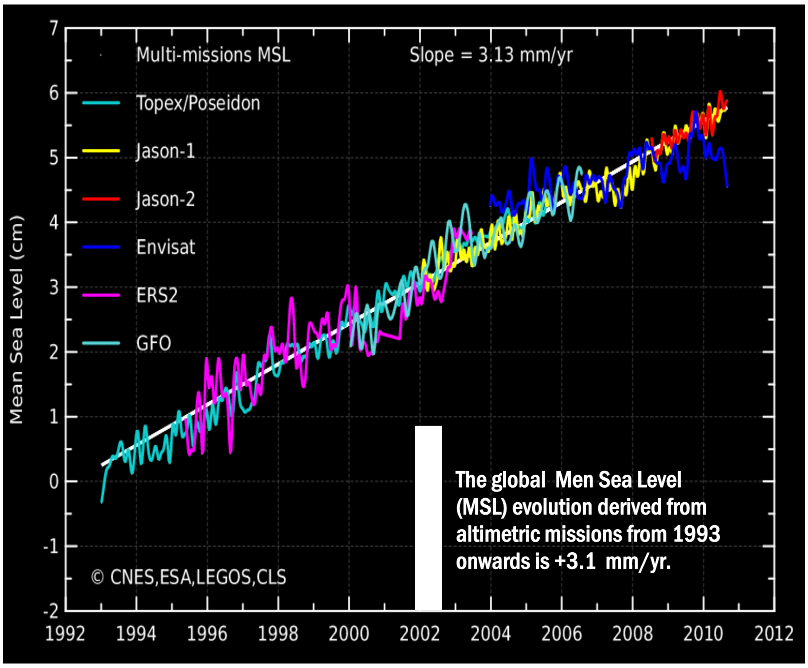
→ CLIMATE CHANGE INITIATIVE

Sea Level CCI Newsletter

Issue 1 | November 2010



In this issue:

The sea level variable

Sea Level is a essential climate variable and an integrating parameter of other ECVs. Change in sea level is a significant parameter in the detection of climate change and an indicator of our ability to model the climate system adequately.

Sea level is a very sensitive index of climate change and variability. As the ocean warms in response to global warming, sea waters expand and, as a result, sea level rises. When mountain glaciers melt in response to increasing air temperature, sea level rises because more freshwater glacial runoff discharges into the oceans. Similarly, ice mass loss from the ice sheets causes sea-level rise. The increase of freshwater flowing into the oceans reduces its salinity, decreasing its density and affecting ocean circulation patterns that in turn affect sea level and its spatial variability. Modification of the land hydrological cycle as a result of climate variability and direct human-induced forcing leads to increased or decreased runoff, and ultimately to sea-level change. As a result, local and regional climate changes may affect sea level globally.

Understanding sea level variability and changes therefore implies in addition to the understanding of the ocean variability the understanding of exchanges between ocean, land, cryosphere, and atmosphere. Sea Level is an integrating parameter of other ECVs. Therefore, this variable needs interdisciplinary coordination to be fully addressed. The CCI gives us a unique opportunity to set up dialogue and cooperation between Earth Observation and Climate Research communities.

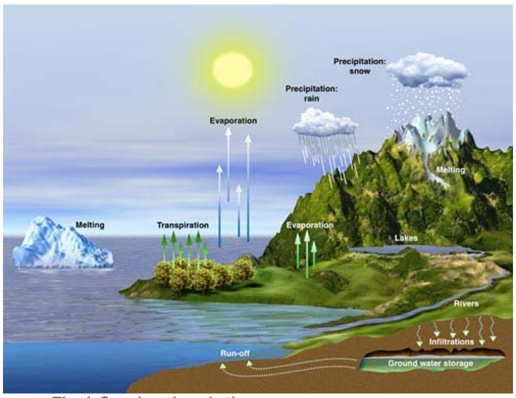


Fig 1 Sea level variations causes

Sea level measured by altimetry

Altimetry satellites basically determine the distance from the satellite to a target surface by measuring the satellite-to-surface round-trip time of a radar pulse. They allow us estimate the sea level over all the ocean

Altimeters emit signals to Earth, and receive the echo from the sea surface, after its reflection. The sea height is represented by the distance satellite-to- surface and the satellite's position relative to an arbitrary reference surface (the reference ellipsoid).

Some satellite tracking systems like Doris enable to determine the satellite's position with a high accuracy. We have also to take into account the disturbances that affect the radar wave. The measurement of these disturbances (by others instruments, or by using multiple radar frequencies), or their estimation with models, can correct the altimetry measurement.

The sea surface height (SSH), is the vertical distance at a given instant from the sea surface to a reference ellipsoid. Since the sea depth is not known accurately everywhere, this reference provides accurate, homogeneous measurements.

The sea level is simply the difference between the satellite height and the altimeter range.

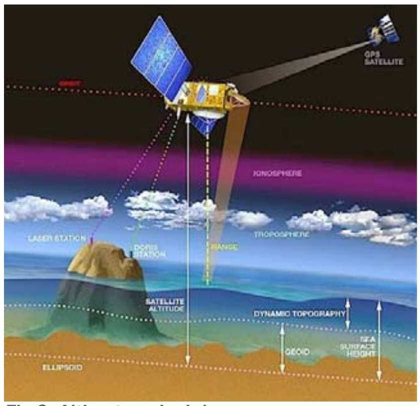


Fig 2: Altimetry principle

Mean Sea Level Elevation

The global mean level of the oceans is one of the most important indicators of climate change. It incorporates the reactions from several different components of the climate system. Precise monitoring of changes in the mean level of the oceans, particularly through the use of altimetry satellites, is crucial for understanding not just the climate but also the socio-economic consequences of any rise in sea level.

With the satellite altimetry missions, the global mean sea level (GMSL) has been calculated on a continual basis since January 1993. 'Verification' phases, during which the satellites follow each other in close succession (Topex/Poseidon and Jason-1, then Jason-1 and Jason-2), help to link up these different missions by precisely determining any bias between them. Envisat, ERS-1 and ERS-2 are also used, after being adjusted on these reference missions, in order to compute Mean Sea Level at high latitudes (higher than 66°N and S), and also to improve spatial resolution by combining all these missions together. In addition, permanent monitoring of quality during the missions (Cal/Val) and studies of the necessary corrections of altimetry data regularly add to our understanding and knowledge.
The reference mean sea level since January 1993 is calculated after removing the annual and semi-annual signals and filtering. By applying the postglacial rebound correction (-0.3 mm/year), the rise in mean sea level has thus been estimated as 3.28 mm/year (mean slope). Analysing the uncertainty of each altimetry correction made for calculating the GMSL, as well as a comparison with tide gauges gives an error in the GMSL slope of approximately 0.6 mm/year with a 90% confidence interval.

Although the global trend indicates a rise in the mean level of the oceans, there are marked regional differences that vary between -12 and 12mm/year. A map of these regional trends (fig. 3) can be obtained using gridded, multi-mission Ssalto/Duacs data since 1993, which enable the local slopes to be estimated with a very high resolution (1/3 of a degree on a Mercator projection). Isolated variations in MSL are thus revealed, mainly in the major ocean currents.

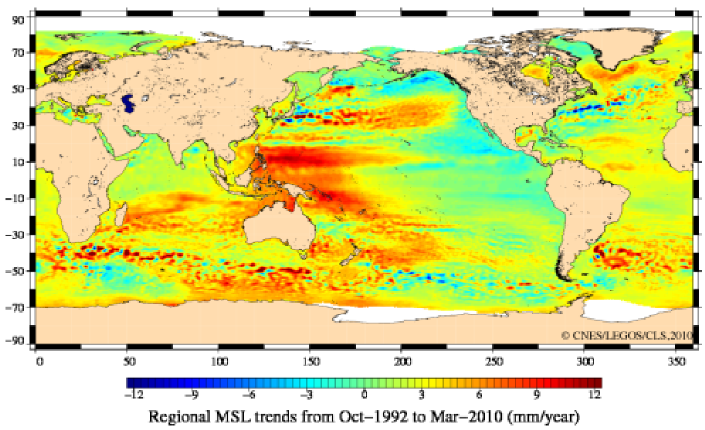


Fig 3: Map of regional mean sea level trends

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Error characterization

When calculating and analysing the evolution of mean Sea level, (MSL) the question legitimately arises as to whether altimeters are reliable enough to measure a rise in MSL of a few millimetres per year over a period of almost 20 years. The question is even more crucial in that there are potentially a lot of possible sources of errors for long-term stability.

The performance of altimetry missions is analysed in order to determine a precise budget of long-term errors. A study undertaken at CLS and published in 2009 [Ablain et al., 2009 (a)] describes this error budget and the statistical approach used. The biggest uncertainty is due to the correction for the wet troposphere (+/- 0.3 mm/year) for the whole period encompassed by the altimetry.
In order to calculate the total error for the MSL slope, it is possible to sum the absolute value of the errors or to calculate the quadratic sum, which gives total errors respectively of 0.9 mm/year and 0.5 mm/year. But in both cases, this error is not realistic as it does not take into account the correlation of the errors. Consequently, when estimating the MSL slope it is preferable to use an inverse method [Bretherton, 1976] whose mathematical expression can describe the covariance of the errors and deduce a realistic formal adjustment error which can then be expressed as a confidence interval. In this way, the global MSL error deduced for the T/P and Jason-1 missions between 1993 and 2008 was estimated at +/- 0.6 mm/year with a confidence interval of 90%.

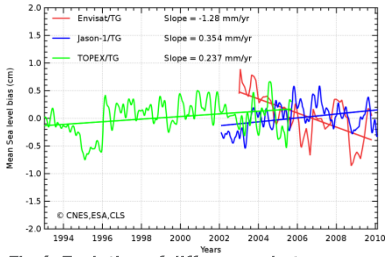


Fig 4: Evolution of differences between altimetry sea surface heights and SSHs from tide gauges for the TOPEX/Poseidon, Jason-1 and Envisat missions after having applied a low-pass filter (two months).

Another approach for describing the *MSL* error consists in comparing the data with in situ data such as tide gauges or ARGO data (temperature and salinity profiles) [Ablain et al., 2009 (a), (b) and (c)]. The stability of the altimetry system can thus be verified by detecting drifts or leaps in the *MSL*. The measurement drifts obtained with the tide gauges (fig. 4) reveal very small drifts for Jason-1 and T/P, respectively close to 0.35 mm/year and -1.28 mm/year with however the possible detection of a leap of a few millimetres in the TOPEX MSL at the end of 1996. On the other hand the drift obtained with the Envisat MSL is more significant, approximately 0.24 mm/year. This is currently being investigated and could possibly be explained by stability problems for the correction of the wet troposphere and instrument corrections.

With respect to local errors of MSL slopes, the same statistical approach was applied in order to describe locally the different sources of uncertainty in altimetry data [Ablain et al., 2009 (d)]. This work revealed the strong local impact of inter-annual variability since it accounts for 80% of the formal adjustment error, which demonstrates that the periods of altimetry data are still too short to estimate slopes locally. The residual errors (20%) due to errors in the altimetry system vary essentially according to latitude between 1 and 2 mm/year due to uncertainties in orbit determination and correction for the wet troposphere respectively at high latitudes and in the tropical band. In this case as well, the description of local errors should be refined to take into account in particular the impact of variable gravity fields for the orbit calculation [Cerri et al., 2010] or again uncertainty in zones close to coasts or to ice due to the degradation of the altimetry measurement.

Sea Level CCI project overview

The main objective of the sea level CCI project is to produce and validate a Sea Level Essential Climate Variable (ECV) product. It represents the first phase of the ESA Climate Change Initiative program that aims at setting up in a second phase an "operational processing capacity of Earth Observation data".

To achieve this global objective, <u>the specific objectives for the Sea Level ECV are:</u>
1) To involve the Climate research community which is the main user of the Sea Level ECV to improve the understanding of their needs and thus ensure a perfect consistency between the need and the future development and improvement of the altimeter processing system.
A clear gap exists between the requirements expressed by the CGOS ([RD-6]) and the current status of the altimeter sea level error budget. Consequently, the user consultation planned at the beginning of this project is an important step to revisit and to precise these requirements in order to find a consensus between the Climate Research and the Earth Observation communities.
2) To develop, test and select the best algorithms and standards in order to produce high quality sea level products for climate applications.
These foreseen activities will allow the altimeter community to work on the development of climate optimized processing algorithms. A large spectrum of algorithms and methods will be assessed during the project and the more relevant for climate applications will be selected. The project will make an extensive use of pre-existing algorithms, software and validation facilities; however, a self-sufficient production prototype will be developed specifically for the generation of the ECV products.
3) To assess and collect information on the quality and error characteristics of the Sea Level ECV product through the involvement of independent climate research groups.

The main objective here is to obtain relevant feedback from the user community in order to qualify the accuracy and suitability of the ECV products and to define new way of improvements. It is also the opportunity to implement an in-depth dialogue between the Climate research and Earth Observations communities which is fundamental to address climate change issues.

4) To provide a complete specification of the operational production system that should be developed during the phase 2 of the ESA CCI programme.

Thanks to the experience that will be acquired during this project, we aim at providing a complete specification of the future operational production. A key element will be to optimize the architecture of this system to favour close interactions and synergy with elementary mission data production centres, with the modelling groups and with the validation teams. System engineering teams will be involved to perform those activities.

The project team:

The project team is composed of 9 European partners from the Earth Observations community (CLS, GFZ, IsardSat, DTU Space, LEGOS) and partners from the Climate modelling community (UoH, ECMWF, NERSC), all having an internationally acknowledged expertise in their field. The consortium is lead by CLS which is responsible for the overall project management and the technical activities that are related to the development and test of the algorithms as well as the sea level ECV production.

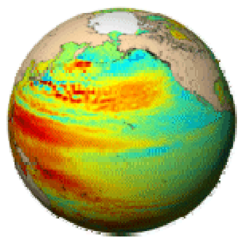
Status of the project: the algorithm development has started.

The initial activities concentrated on the requirements analysis, capture of user feedback via questionnaire and critical gap analysis. Then, preparation activities and work on initial tasks also commenced in the Earth observation Group. The Algorithm Development and integration tasks have started. The main topics and associated challenge are listed below.

- **Altimeter and radiometer processing :** To use a multi mission instrument expertise to enhance all the altimeter and radiometer calibration accuracy.
- **Improved orbits** To have for the first time a similar solution for all mission using most recent standards.
- **Altimeter correction:** To have homogeneous and stable time series using for example most recent reanalysed models.
- **Specific High latitude:** Reduce the altimetry errors at high latitudes, areas of strong strategic interest for climate.
- **Multimission merging (supported by CNES):** It consists in improving the time series continuity, the intermission adjustment and the mapping technique. The objective is to improve the already very mature running system to optimizing the contribution of ESA mission and refine the mapping algorithm for Climate application.

End 2011, the best algorithms for climate applications will be selected. The selection process will be led by Climate Research Group. He will be supported by the Earth Observation team and Climate modeling experts who are not involved in the development of algorithms to ensure the full independency of the selection process: **the Round Robin exercise.**

Links



http://www.esa-sealevel-cci.org The sea level CCI project website (opening November 2011)
http://earth.eo.esa.int/workshops/esa_cci The ESA Climate Change initiative portal
http://www.aviso.oceanobs.com The CNES/CLS altimetry portal
http://www.altimetry.info Radar Altimetry Tutorial

References

a) Ablain, M., A. Cazenave, G. Valladeau, and S. Guinehut. 2009: A new assessment of the error budget of global mean sea level rate estimated by satellite altimetry over 1993-2008. Ocean Sci, 5, 193-201.
(b) Ablain M., 2009: Error estimation of the regional mean sea level trends from altimetry data. Poster presentation in OCEANOBS09, Venice 2009
(c) Ablain M. 2009. Quality assessment of tide gauge and altimeter measurements through SSH comparisons. Oral presentation in OSTST, Seattle 2009.
(d) Ablain M. 2010. Quality assessment of tide gauge and altimeter measurements through SSH comparisons. Oral presentation in ESA Symposium, Bergen 2010.
Cerri L., Berthias J.P., Bertiger W., Haines B., Lemoine F.G., Mercier F., Ries J.C., Willis P., Zelensky N.P., Ziebart M., 2010. Precision Orbit Determination Standards for the Jason Series of Altimeter Missions. Marine Geodesy 2010.