Impact of loss of the 35-day altimeter repeat tracks on estimates of the mean sea level evolution

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Contact agps@SKYMAT.co.uk

European Space Agency

Andrew G. P. Shaw(1), Paolo Cipollini(2), Francisco Mir Calafat (2), Jérôme Benveniste (3)

(1) SKYMAT Ltd, Southampton, United Kingdom, (2) National Oceanography Centre, United Kingdom, (3) European Space Agency, ESRIN, Frascati, Italy

ABSTRACT

The 18-year time series of altimetry on the ERS-1/2 and ENVISAT 35-day orbit repeat tracks were discontinued in October 2010 when ENVISAT orbit changed into a 30-day repeat cycle. Eighteen months later, on 8th April 2012, ENVISAT ceased operations. This investigation, carried out within the ESA Sea Level Climate Change Initiative (SL_cci), addresses the impact of the loss of sea surface height (SSH) measurements on the 35-day tracks with respect to the mean sea level (MSL) Essential Climate Variables (ECV) indicators.

We report the results of a sensitivity study to estimate to what extent does the sea level trend need to increase within the polar region (where only the 35-day orbit observations are available) in order for the global trend to be statistically different at the 95 % confidence interval.

Methodology

We assessed the impact of the temporal gap in the 35-day orbit by flying a satellite along the 10-day reference mission and 35-day tracks, over real altimetric gridded SSH anomaly field for the period between 1993 and 2013, to obtain the SSH observations and compute the ECV indicators, which are then compared with the CCI ECVs v1.1 indicators (Ablain, et al. 2015) . We then sample the sea surface according to four 'scenarios'.The first three scenarios are designed to provide a validation check and to assess the sensitivity of the ECV indicators with respect to the SL_cci ECVs indicators. The fourth scenario reproduces the loss of 35-day mission from ENVISAT and its resumption in March 2013 with Altika. The ECVs were calculated from a model containing a constant; trend and sinusoidal terms using the traditional standard least squares method. Scenarios (S1 to S4) are listed below:

- S1) Resampled along 10-day orbital track only (Jason-2 track).
- S2) Resampled along 35-day orbital track only (ENVISAT track).
- S3) Resampled along 10-day + 35-day orbital tracks.
- S4) Resampled along 10-day and 35-day orbital tracks, with the 35-day orbits missing for the period between November 2010 and February 2013.

Data preparation

We created a realistic dataset of SSHA observations by flying satellites over real altimetric SSHA data and extracting these observations along known satellites tracks (i.e, Jason-2 and ENVISAT) at a one second interval. The daily two satellite global mean sea level anomaly AVISO ¼ degree resolution product is used for this study for the period 1st January 1993 to 31st December 2013.

Software from the Fine Scale Altimetry ESA contract (No. 4000101341) called Error Program Prediction for Altimetry (EPPA) is used to create the Jason-2 and ENVISAT orbits. Thus, one "exact" Jason 2 ten day repeat cycle and the ENVISAT 35 day repeat cycle were created using daily two line element (TLE) updates and then duplicated such that they spanned the period from January 1st 1993 to 31st December 2013. The Jason-2 (10 day repeat) and the ENVISAT (35 day repeat) single orbit were verified using the Radar Altimeter Database System (RADS). The SSHA one second data are then sampled for the period 1993 to 2013 along both Jason-2 and ENVISAT and then gridded into monthly composites with a one degree resolution.

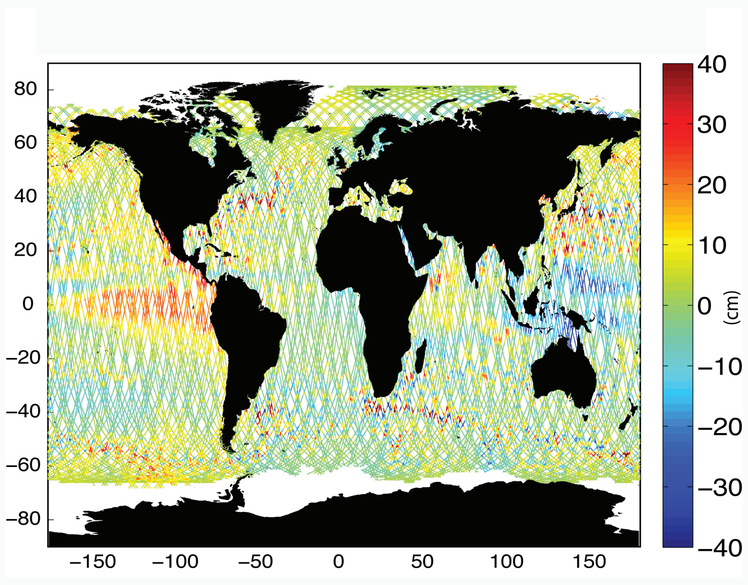

Figure 1 An example of SSHA AVISO daily product resampled on Jason 2 and ENVISAT tracks for one week starting on the 1st August 1997 using EPPA software.

Results : Global

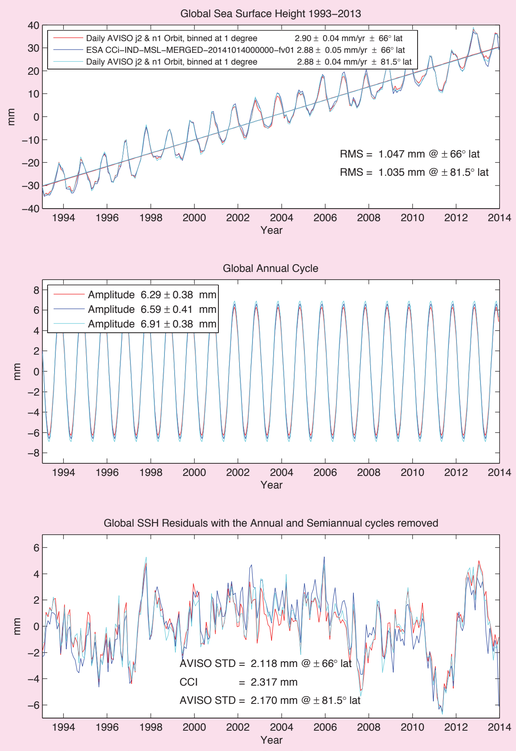

Figure 2 Scenario 3 (S3) for the global sea level trends, annual cycle and residual from and the daily AVISO product resampled along the ENVISAT tracks and the SL_cci product.

Table 1 The comparison of the SL_cci global ECV's and the four the scenarios that were used in this study.

		ESA CCI ± 66°	Daily AVISO @ ± 66° Scenarios S1 to S4 (see Methodology section)			
			[S1] Jason-2 orbit (j2)	[S2] ENVISAT orbit (n1)	[S3] j2 & n1 orbit	[S4] j2 & n1 ** orbit
Trend	(mm/yy)	2.88±0.05	2.87±0.04	2.91±0.04	2.90±0.04	2.89±0.05
Amplitude Annual	(mm)	6.59±0.42	6.59±0.38	6.27±0.38	6.29±0.38	6.33±0.39
Phase Annual	(days)	307.4±3.6	305.5±3.4	304.4±3.5	304.4±3.5	304.2±3.6
Amplitude Semiannual	(mm)	1.48±0.42	1.11±0.38	1.39±0.38	1.41±0.38	1.39±0.38
Phase Semiannual	(days)	124.7±8.2	122.2±10.1	124.4±8.0	124.6±7.8	124.2±8.1
Residuals * STD	(mm)	2.317	2.145	2.130	2.118	2.152
RMS (mm) Daily AVISO minus ESACCI			0.983	1.054	1.047	1.025
			Daily AVISO @ ± 81.5°			
Trend	(mm/yy)			2.88±0.05	2.88±0.05	2.87±0.05
Amplitude Annual	(mm)			6.90±0.39	6.91±0.39	6.88±0.39
Phase Annual	(days)			304.2±3.3	304.1±3.3	304.3±3.2
Amplitude Semiannual	(mm)			1.20±0.39	1.22±0.39	1.20±0.39
Phase Semiannual	(days)			124.2±9.5	124.3±9.3	124.4±9.4
Residuals * STD	(mm)			2.182	2.170	2.160
RMS (mm) Daily AVISO minus ESACCI				1.036	1.035	1.019
* Trend & Annual and Semiannual cycles removed ** 28 months missing from the ENVISAT (n1) orbit						

The analysis the global comparison between that the four scenarios (Table 1 and an example of scenario 3, Figure 2) revealed that there is no statistical significance (@ 95% CI) between them, indicating that the loss of the ENVISAT data for 28 months made no impact into measuring the ECV's.

Regional

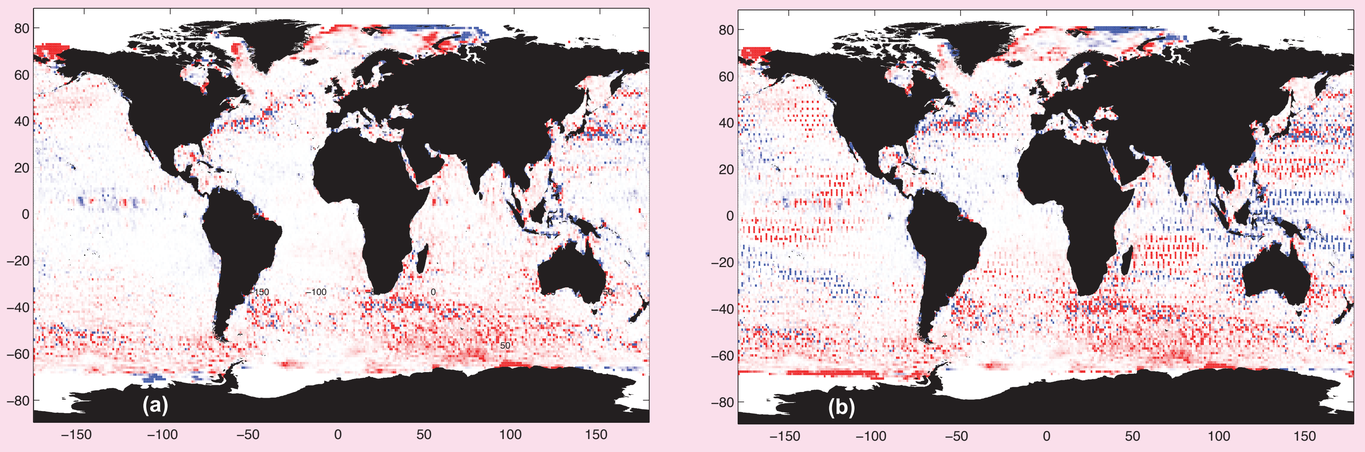

Figure 3 Difference between the SL trend from the AVISO daily product resampled along the Jason-2 and ENVISAT tracks and the SL_cci trend (a). The difference between the SL trend from the AVISO daily product resampled along the Jason-2 and ENVISAT tracks with 28 month ENVISATdata missing and the SL_cci trend (b).

Although there are trend differences in (Figure 3), they were not statistical significance at the 95% confidence interval. Figure 4 shows that the only difference between (a) and (b) not the resampling along the Jason and ENVISAT tracks and not due to the loss of ENVISAT data spanning 28 months.

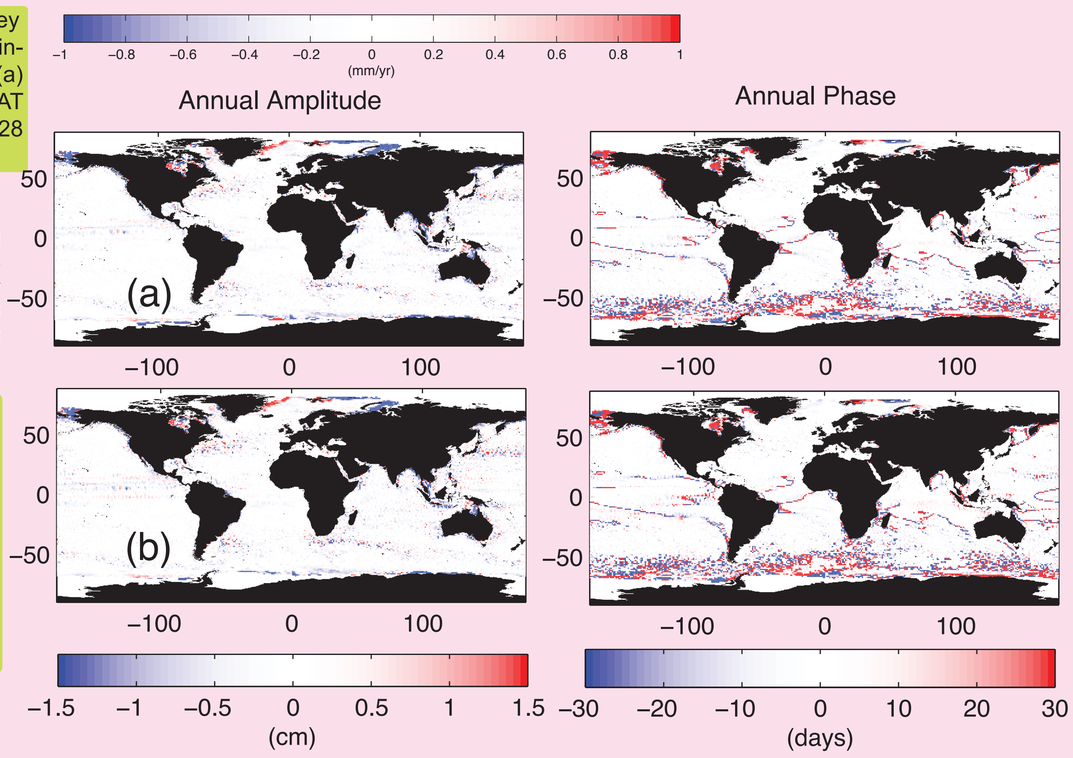

Figure 4 Difference between the annual amplitude and phase from on the AVISO daily product resampled along the Jason-2 and ENVISAT tracks and the SL_cci amplitude and phase (a). The difference between the amplitude and phase from the AVISO daily product resampled along the Jason-2 and ENVISAT tracks with 28 months of the ENVISAT data missing and the SL_cci amplitude and phase (b).

Test to Establish the impact of the Polar Regions

To assess this impact, we replace the polar regions (i.e. 66° to 81.5° and -81.5° to -66°) with simulated sea level data consisting of random noise with the global mean, standard deviation and a specified trend. The results showed that if the average trend over the polar regions were **5.7** mm/yr (or -1.1 mm/yr) then we would see a statistically significant at the 95% confidence interval change in the global mean sea level trend if those regions were included in the weighted global average

Acknowledgments

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References

Ablain, et al. (2015) Improved sea level record over the satellite altimetry era (1993–2010) from the Climate Change Initiative project. Ocean Sci., 11, 67–82, 2015.

AVISO altimeter product, http://www.aviso.altimetry.fr/en/home.html

Radar Altimeter Database System (RADS), http://rads.tudelft.nl/rads/rads.shtml

Sea Level Climate Change Initiative Project, http://www.esa-sealevel-cci.org/

Conclusions

There is no statistical evidence (at the 95% confidence interval) that the loss of the ENVISAT data (i.e. between November 2010 and February 2013 - 28 months) had an impact on the global trend, amplitude and phase.Likewise, there is no statistical evidence that the loss of the ENVISAT data had an impact on the regional trends or on annual and semiannual amplitude and phase values.

Therefore the impact of the loss of data from the ENVISAT mission are minimal as far as the global sea level trend is concerned. But remember that ERS/ENVISAT (and AltiKa) remain **MOST USEFUL** as they sample the polar regions – and to confirm that results over the ±82° band are consistent with those over ±66° band.