Consortium Members

ESA Sea Level CCI

SL-CCI Phase I: synthesis of additional activities

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1.2	2014-12-17	Improvement to take into account the ESA review	M. Ablain
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List of tables and figures

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Applicable documents

AD 1 Sea level CCI project Management Plan
CLS-DOS-NT-10-013

Reference documents

RD 1 SL-CCI CCN Additional Activities
CLS-DOS-PR-12-005-SLCCIAditionnalActivities_versionFinale

List of Acronyms	
SL-CCI	Sea Level –Climate Change Initiative
ECV	Essential Climate Variables
MSL	Mean Sea Level
GSFC	Goddard Space Flight Center
GFZ	GeoForschungZentrum
GPD	GNSS Path Delay

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1. Overview

The Algorithms Selection meeting (2-4th may, 2012) that has been held in Toulouse has been an important step of the Sea Level – Climate Change Initiative (SL-CCI) project where the algorithms that have been used for the Sea Level Essential Climate Variable (ECV) production generation were identified. During this meeting, very interesting results exhibiting significant improvements were shown in various domains: instrumental corrections for Envisat, new orbit solutions for ERS-1/2, ENVISAT and Jason-1, new atmospheric corrections for all the missions, etc… A synthesis of the algorithm selection recommendations and summary of the discussion about open issues is provided within the Product Validation and Assessment Report (PVSAR). The next step has consisted in the generation of the SL ECV product.

This has demonstrated our capacity to generate long time homogeneous time series dedicated for climate applications. However, as mentioned during the Sea level Selection meeting but also during the previous CCI Integration meetings, generation of ECV products is more a continuous evolution in operation activity than a one shot production. Outcomes of the algorithm selection meeting are in line with the statement. That's why it has been proposed to perform an additional round-robin exercise (WP2100) and to generate a new version of the sea level ECV product (WP 2200 & WP 2300). This new round-robin exercise will permit to take into account the algorithms that have been available after the selection process due to several reasons as delays in its development or delays in the reprocessing project that should be delivered them.

In the framework of the CCN (see the proposal document RD1: CLS-DOS-PR-12-005-SLCCIAditionnalActivities_versionFinale), only algorithms for which maturity and impact is ensured have been identified. This includes the already existing Jason-2 and Envisat reprocessing altimeter products. In addition, new algorithms have been developed and evaluated which are uniform wet tropospheric correction for all satellites and new improved GFZ orbit solutions for Jason-1, Jason-2 and TOPEX/Poseidon. Then a new V1.1 altimeter SL-CCI product has been generated and validated.

This document synthesizes the analyses of the new algorithms and their selection and also describes the SL-CCI V1.1 production and validation.

2. New algorithms and selection

The new algorithms which have been developed and evaluated consist in a new improved GFZ orbit solutions for Jason-1, Jason-2 and TOPEX/Poseidon and a uniform wet tropospheric correction for all satellites.

2.1. GFZ Orbit solutions

The purpose of this task was to generate new improved GFZ orbit solutions computed in the ITRF2008 Terrestrial Reference Frame using the models that were defined in the document "Definition of common standards for ERS-1, ERS-2, Envisat, TOPEX/Poseidon, Jason-1 and Jason-2 precise orbit determination (May 16, 2011" by S. Rudenko and T. Schoene). The results are based on the use of improved geopotential models and improved attitude modelling of the satellites.

The RRDP analyses (Round Robin Data Package) performed for the quality assessment of these orbit solutions are:

1. Envisat orbit comparison: GFZ (CCI) versus GDR-D
2. TOPEX/Poseidon orbit comparison : GFZ (CCI) versus GSFC (STD09)

The conclusions of these analyses are the following:

Envisat orbit comparison: GFZ (CCI) versus GDR-D :

- Concerning the estimation of the global Mean Sea Level (MSL) evolution:

⇒ No impact for the global MSL trend (0,02 mm/yr over 8 years) and annual and semi-annual signal

- Concerning the estimation of the global MSL inter annual signals, we observe that GFZ orbit gets closer to Grace 10 days orbit solution (which is considered as a reference) so this orbit seems to be better than the GDR-D orbit solution at these spatial and temporal scales.
- Concerning the regional MSL evolution, the results are more balanced :

  ⇒ (+) Comparison between GFZ orbit solution and Grace 10 days orbit highlights an evolution toward Grace 10 days (which is considered as a reference) for years 2003, 2004, 2008, 2009, 2010 and for the regional MSL trend.

  ⇒ (-) But for years 2005, 2006, 2007 and on the mean over all cycles, we see a strong north/south effect which we don't explain.

Thus, the GFZ orbit solution is found to provide equivalent performances of Envisat sea level estimations as the one already provided by the CNES GDR-D orbit solution. However, some differences are detected concerning the regional trends of the MSL. As we did not manage to assess which orbit is better, a conservative point of view has been adopted and the already used GDR-D orbit solution has been kept for the computation of the V1.1 SL-CCI product.

TOPEX/Poseidon orbit comparison : GFZ (CCI) versus GSFC (STD09) :

- GFZ orbit solution provides deteriorated performances than GSFC orbit solution at crossovers (-1 cm^2 on average)
- Concerning the estimation of the MSL evolution:

⇒ Low impact for the global MSL (0.14 mm/yr over 13 years)

⇒ Significant impact for the regional MSL trends (+/- 0.8 m/yr): East/West and North/South MSL trend differences have been displayed: it's not possible to determine which orbit is the best one.

⇒ Strong 58.77 signals are observed between GSFC and GFZ: using GOT or FES models, the impacts are not the same on the SLA. This requires more investigations.

Thus, the GFZ orbit solution is not selected and the GSFC orbit solution is kept for TOPEX measurements of the sea level.

Detailed descriptions of the results of these RRDP are presented in annex:

Annex 1: Envisat orbit comparison: GFZ (CCI) versus GDR-D

Annex 2: TOPEX/Poseidon orbit comparison: GFZ (CCI) versus GSFC (STD09)

They are also available on the sea-level CCI ftp server.

2.2. Wet troposphere correction (Univ. Of Porto)

In the framework of the SL-CCI phase 1 project, a new wet troposphere correction of the altimeter sea level estimations have been developed for the Envisat mission. It is based on the GNSS Path

Delay (GPD) estimations (related with GPS network) and it aims at improving the correction in coastal areas where the usual radiometer correction is deteriorated.

In the context of the CCN additional work, this correction has been uniformly developed and validated for all satellites. In practice, the GPS based wet troposphere correction has been completed for the whole Envisat mission, and has been computed for the Jason-1, Jason-2, T/P, ERS-1 and ERS-2. The bug identified during the selection meeting has also been corrected. These corrections are computed globally. The development has been performed by the University of Porto (FCUP).

Concerning the Envisat mission, the already used GPD correction in the V1.0 SL-CCI product will be used in the SL-CCI V1.1 product.

The RRDP analyses (Round Robin Data Package) performed for the quality assessment of these corrections consist in the comparison of the new GPD wet troposphere correction with the AVISO reference correction for the following missions:

1. TOPEX/Poseidon
2. ERS-1
3. ERS-2
4. Jason-1
5. Jason-2

The conclusions of these analyses are the following:

Comparison of GPD and AVISO wet troposphere corrections for TOPEX mission:

- GPD correction is better than the reference one used in AVISO products:

⇒ Better performances at crossovers and improvement of the regional MSL trends particularly in Indian Ocean

⇒ However spurious measurements are probably remaining in GPD correction for a few cycles and missing measurements have also been detected for a few cycles

- Anomalies concerning the tape recorder occurred from cycle 370 of TOPEX mission. They produced missing measurements especially in the Indian Ocean. A second effect has been also observed on the TOPEX radiometer wet troposphere correction which is deteriorated close to data gaps (due to interpolation anomaly).

⇒ The new correction (GPD) allows us to take into account these interpolation problems using the ECMWF model instead of the radiometer data.

The GPD wet troposphere correction is selected for the computation of TOPEX/Poseidon sea level estimations in the V1.1 SL-CCI products.

Comparison of GPD and AVISO wet troposphere corrections for ERS-1 mission:

- The GPD wet troposphere correction is better than the reference one used in AVISO products:

⇒ Better performances at crossovers are clearly observed near coasts and over some large areas in the open ocean. However, performances are deteriorated at crossovers for 3 isolated cycles: it is probably due to spurious GPD correction as observed for TOPEX mission (but not demonstrated in this study).

⇒ A significant impact on the regional MSL trends is observed in coastal areas. This is likely to be an improvement due to the reduction of SSH variance at crossovers in these coastal areas. Caution should be paid to analyze these results because the period considered is rather short (only 4 years of ERS-1 data).

⇒ At last, the analysis of the sea level variance differences versus the coastal distance confirms the strong improvement provided with the GPD correction near coasts but only for coastal distances less than 50 km. For coastal distances between 50 km and 100 km, the reference one used in AVISO products is very slightly better.

The GPD wet troposphere correction is selected for the computation of ERS-1 sea level estimations in the V1.1 SL-CCI products.

Comparison of GPD and AVISO wet troposphere corrections for ERS-2 mission:

- The GPD correction is better than the reference one used in AVISO products:

⇒ Better performances at crossovers and improvement of the regional MSL trends

The GPD wet troposphere correction is selected for the computation of ERS-2 sea level estimations in the V1.1 SL-CCI products.

Comparison of GPD and AVISO wet troposphere corrections for Jason-1 mission:

- The GPD correction is better than the reference one used in AVISO products particularly near coasts:

⇒ Improvement of the regional MSL trends

⇒ However spurious measurements are probably remaining in GPD correction for a few cycles

⇒ Note that a specific signal observed in 2008-2009 (see details in annex) highlights the improvement of the Jason-1 enhancement products used in the GPD correction (in RADS) and not used in CCI Wet Troposphere Correction (release 1). This signal is not directly associated with the GPD correction.

The GPD wet troposphere correction is selected for the computation of Jason-1 sea level estimations in the V1.1 SL-CCI products.

Comparison of GPD and AVISO wet troposphere corrections for Jason-2 mission:

- The GPD correction is equivalent to the reference one used in AVISO products:

⇒ Few better performances at crossovers particularly in Indonesia area

⇒ However spurious measurements are probably remaining in GPD correction for a few cycles and missing measurements have also been detected for a few cycles.

The GPD wet troposphere correction is selected for the computation of Jason-2 sea level estimations in the V1.1 SL-CCI products.

Detailed descriptions of the results of these RRDP are presented in annexes:

Annex 3: Comparison of GPD and AVISO wet troposphere corrections for TOPEX mission

Annex 4: Comparison of GPD and AVISO wet troposphere corrections for ERS-1 mission

Annex 5: Comparison of GPD and AVISO wet troposphere corrections for ERS-2 mission

Annex 6: Comparison of GPD and AVISO wet troposphere corrections for Jason-1 mission

Annex 7: Comparison of GPD and AVISO wet troposphere corrections for Jason-2 mission

They are also available on the sea-level CCI ftp server.

2.3. Envisat reprocessing

After the production of the SL-CCI product, the whole time series of the Envisat sea level measurements have been reprocessed and made available (V2.1). Details of this reprocessing are available online:

http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/EN/EnvisatReprocessingReport.pdf

This new dataset has been used for the computation of the updated V1.1 SL-CCI product.

2.4. Jason-2 reprocessing

After the production of the SL-CCI product, the whole time series of the Jason-2 sea level measurements have been reprocessed and made available (GDR-D version). Details of this reprocessing are available online:

http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/J2/Jason2ReprocessingReport-v2.1.pdf

This new dataset has been used for the computation of the updated V1.1 SL-CCI product.

3. SL-CCI V1.1 production and validation

3.1. Production

The V1.1 SL-CCI product is provided in the framework of the additional activities of the phase 1 of the SL-CCI project. It is an update of the original product and consists in a set of grids of sea level anomalies combining all altimetric satellite measurements, with a regular spatial resolution of 0.25°x0.25°, with monthly temporal resolution from 1993 to 2010. It includes new algorithms and datasets described in the former section:

- The GPD wet troposphere correction of the sea level estimations for TOPEX/Poseidon, ERS-1, ERS-2, Jason-1 and Jason-2 missions,
- The V2.1 Envisat reprocessed time series,
- The GDR-D Jason-2 reprocessed time series

This product is now available on the ESA SL-CCI ftp server.

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3.2. Internal validation

The validation of the new V1.1 SL-CCI product can be performed with different approaches, distinguishing level 3 processing (processing of each altimeter mission) and level 4 processing (maps of gridded merged altimeter products

3.2.1. Inter mission biases (level 3)

The biases observed between all altimeter missions are taken into account (level 3 processing) before the computation of the gridded maps of sea level anomalies (level 4 processing). The analysis of the effect of this bias reduction contributes to the quality assessment of the time series.

Because of the technical differences between the altimeter missions, global as well as regional biases can be found between the missions. The figure below shows the global mean sea level for all altimeter missions before (left) and after (right) the reduction of global biases. It illustrates the impact of the biases reduction. This step is fundamental before the computation of merged altimeter maps.

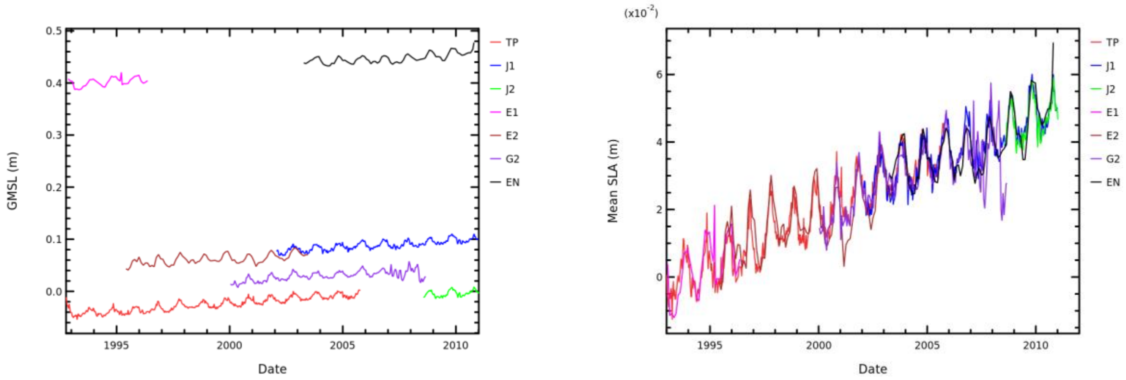

Figure 1: Global mean sea level for all altimeter missions before (left) and after (right) the reduction of global and regional biases.

The principle of the reduction of the regional biases between the principal altimeter missions (TOPEX/Poseidon versus Jason-1 and Jason-1 versus Jason-2) is based on a polynomial adjustment of the sea level differences between both missions function of the latitudes. The details of the method are described in the validation report available on SL_cci website (http://www.esa-sealevel-cci.org/webfm_send/182). In summary, the polynomial function to adjust he TOPEX SSH on the Jason-1 SSH is the following:

$$SSH_{TP\_AdjustedOnJ1} = SSH_{TP} - p(lat)$$

For ascending passes:

$$p(lat)=\begin{cases} -9.06 + 1.11e^{-2} * lat + 6.22e^{-4} * lat^2 + 3.62e^{-4} * lat^3 + 3.92e^{-7} * lat^4 \; \mathit{if} \; lat < -1.5° \\ -9.36 - 0.245 * lat + 0.143 * lat^2 + 0.119 * lat^3 \; \mathit{if} \; -1.5° \leq lat < 0.2° \\ -9.43 + 0.128 * lat + 0.0672 * lat^2 - 0.0137 * lat^3 \; \mathit{if} \; 0.2° \leq lat < 4° \\ -8.72 - 2.05e^{-3} * lat + 2.51e^{-4} * lat^2 - 8.04e^{-6} * lat^3 + 8.34e^{-8} * lat^4 \; \mathit{if} \; lat \geq 4° \end{cases}$$

And for descending passes:

$$p(\mathrm{lat}) = \begin{cases} -8.80 + 0.0141 * \mathrm{lat} + 2.15e^{-4} * \mathrm{lat}^2 - 3.21e^{-6} * \mathrm{lat}^3 - 7.77e^{-8} * \mathrm{lat}^4 \ \mathit{if} \ \mathrm{lat} < -1.5° \\ -9.00 - 0.259 * \mathrm{lat} - 0.0951 * \mathrm{lat}^2 \ \mathit{if} \ -1.5° \leq \mathrm{lat} < 1.3° \\ -9.56 - 0.00128 * \mathrm{lat} + 0.0347 * \mathrm{lat}^2 - 0.0137 * \mathrm{lat}^3 \ \mathit{if} \ 1.3° \leq \mathrm{lat} < 4° \\ -9.04 + 6.95e^{-3} * \mathrm{lat} + 3.51e^{-4} * \mathrm{lat}^2 - 2.72e^{-5} * \mathrm{lat}^3 + 2.82e^{-7} * \mathrm{lat}^4 \ \mathit{if} \ \mathrm{lat} \geq 4° \end{cases}$$

Note that this empirical correction strongly depends on the altimetry standards used on the Jason-1 or TOPEX MSL calculation. If one of them is modified, especially with respect to the orbit calculation, the coefficient of the polynomial function should be revisited.

The following figures show the estimated polynomial functions for the TOPEX and Jason-1 bias and the regional mean differences before and after the polynomial adjustment. It provides an estimation of the regional bias to be used as a correction between these missions and the corrected regional sea level differences are shown. The hemispheric East/West mean differences observed before the bias correction is now removed.

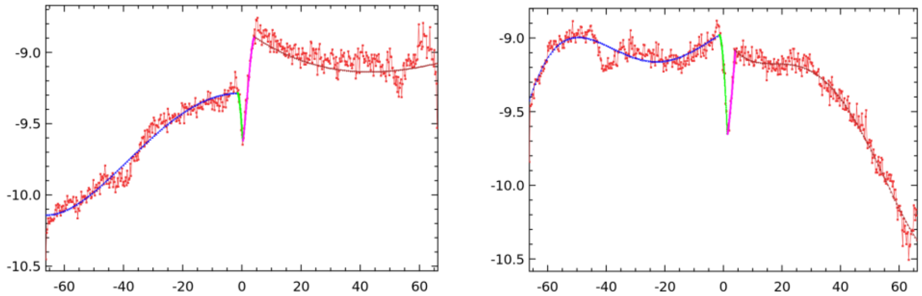

Figure 2: Polynomial adjustment of the sea level differences between Jason-1 and TOPEX according to the latitudes, separating ascending (left) and descending (right) tracks.

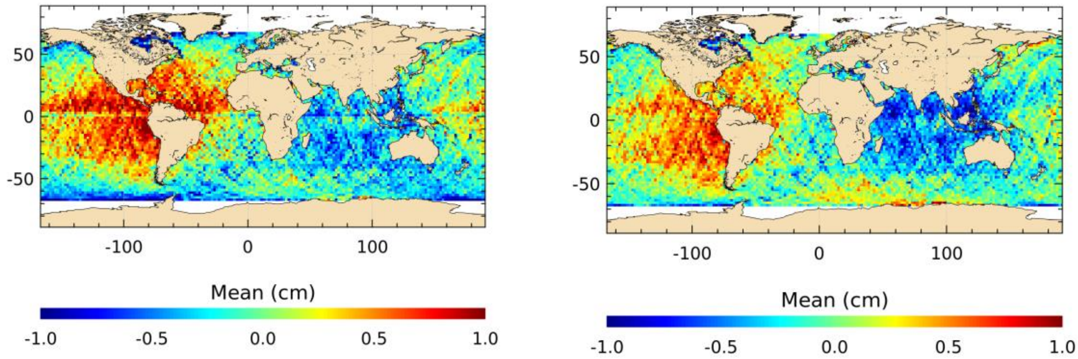

Figure 3: Regional mean sea level differences between Jason-1 and TOPEX before (left) and after (right) the polynomial adjustment.

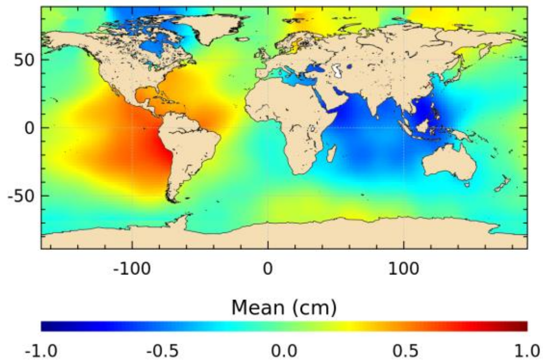

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Figure 4: Regional bias to be used as a correction between TOPEX and Jason-1 sea level measurements

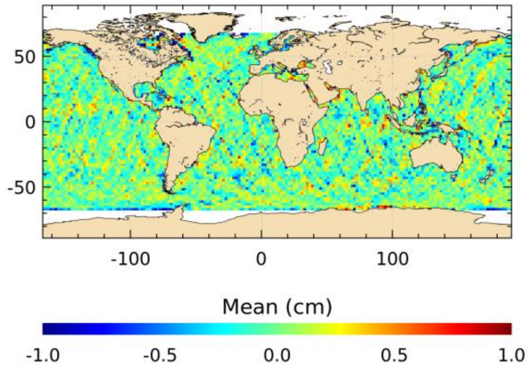

Figure 5: Mean regional sea level differences between TOPEX and Jason-1 after the correction of the regional bias

Similar adjustment is performed to reduce the regional bias between Jason-1 and Jason-2 missions. The following figures show the estimated polynomial functions for the Jason-1 and Jason-2 bias and the regional mean differences before and after the polynomial adjustment. It provides an estimation of the regional bias to be used as a correction between these missions and the corrected regional sea level differences are shown. The remaining regional differences observed before the bias correction is now removed.

Note that the bias between TOPEX and Jason-2 is the sum of the biases between TOPEX and Jason-1 and between Jason-1 and Jason-2.

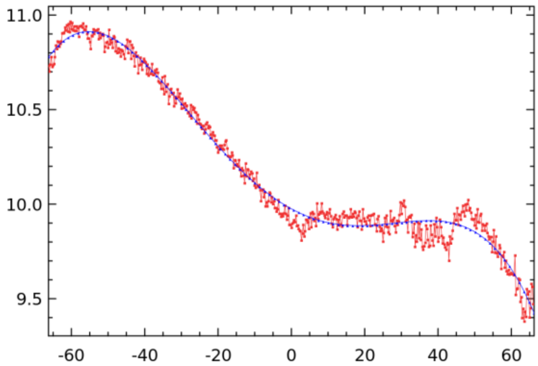

Figure 6: Polynomial adjustment of the sea level differences between Jason-2 and Jason-1 according to the latitudes.

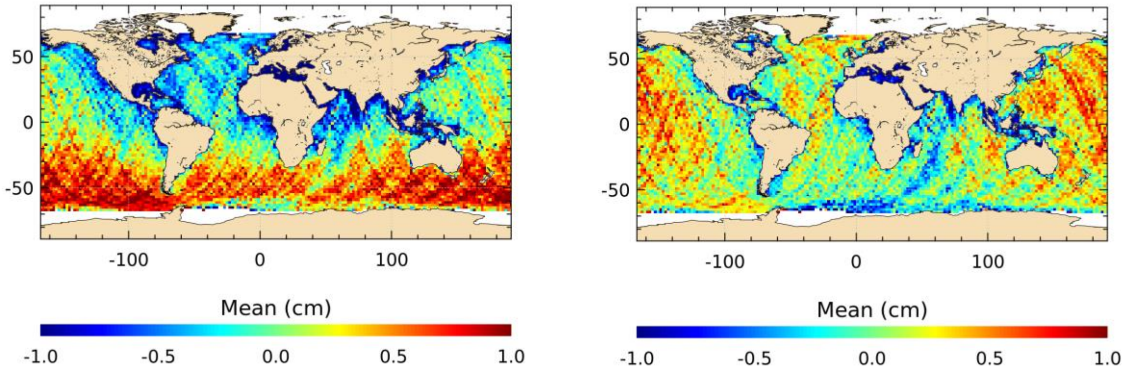

Figure 7: Regional mean sea level differences between Jason-2 and Jason-1 before (left) and after (right) the polynomial adjustment.

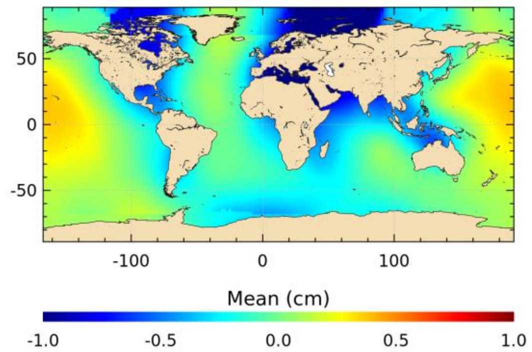

Figure 8: Regional bias to be used as a correction between Jason-1 and Jason-2 sea level measurements

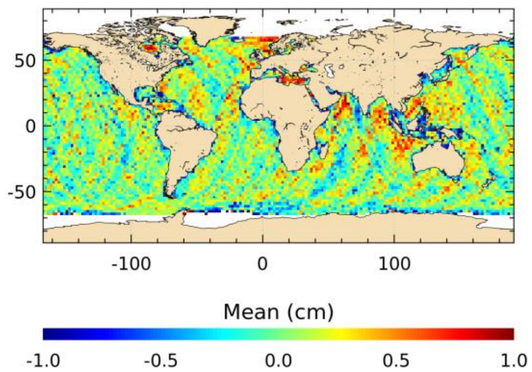

Figure 9: Mean regional sea level differences between Jason-1 and Jason-2 after the correction of the regional bias

The analysis of the impact of this bias reduction contributes to the quality assessment of the time series.

3.2.2. Gridded products comparison (level 4)

This part aims at summarizing the validation results of the comparison between the new V1.1 SL-CCI maps and the first SL-CCI time series. The goal here is to certify the end-to-end quality of the ECV and analyze the total contribution of the improvements mentioned in the first part of this report. The internal consistency of the sea level ECV V1.1 is estimated by the analysis of:

- The global and regional MSL trend differences (between ECV-V1.1 and V1.0),
- Periodic signals and inter-annual signal over all the altimeter period
- The sea level variance evolution.

This list of potential analyses is not exhaustive but it allows us to give an overview of the diagnoses that will be used to validate and promote sea level ECVs.

3.2.2.1. Global mean sea level evolution

Figure 10 shows the evolution of the global mean sea level trend for SL-CCI V1.1 and V1.0. The trend is not changed. No mean bias is observed between both products over the altimeter period (1993-2010).

The difference between both time series highlights differences at the mm level. In particular, a -2 mm difference is observed at the end of year 2008. This is related with the reprocessing of the Jason-1 radiometer wet troposphere correction over the last 15 cycles of the mission. Indeed, an error occurred in the processing of the radiometer correction over this period. Thus, the -2 mm difference observed on Figure 10 is associated with an improvement of the new CCI V1.1 product.

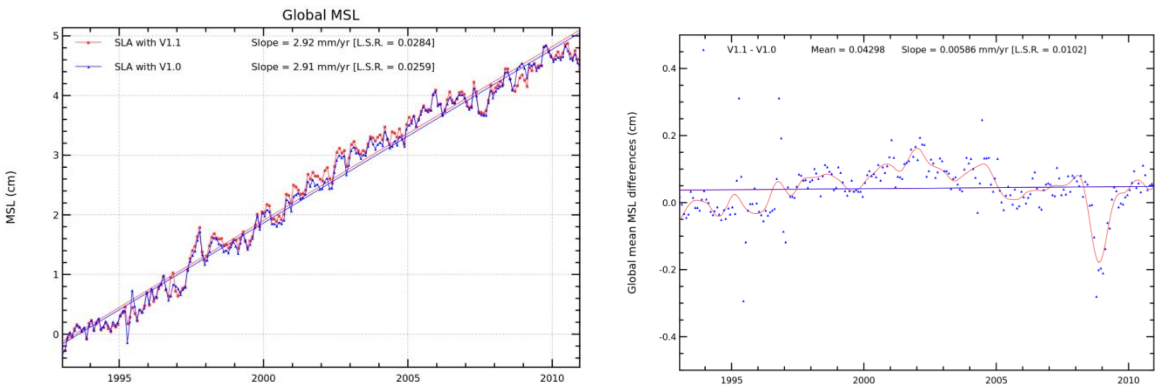

Figure 10: MSL trend of SL-CCI V1.0 and V1.1 (left) and associated differences (right)

3.2.2.2. Regional mean sea level evolution

Figure 11 shows the map of regional MSL trend over 1993-2010 obtained with the SL-CCI V1.1 maps as well as the difference with V1.0. A ±0.5 mm/yr East/West hemispheric bias is observed. This is associated with the GDR-D orbit solution available in the Jason-2 and Envisat reprocessed datasets which have been used in the V1.1 maps. Initially, preliminary GDR-D orbit solution has been already used in the SL-CCI V1.0 maps. Thus, the remaining ±0.5 mm/yr hemispheric sea level trend bias observed here is the residual difference between the preliminary version (CCI V1.0) and the final version (CCI V1.1) of the GDR-D orbit solution. Internal quality assessment performed with the Jason-2 mission has demonstrated that this leads to improved sea level estimation.

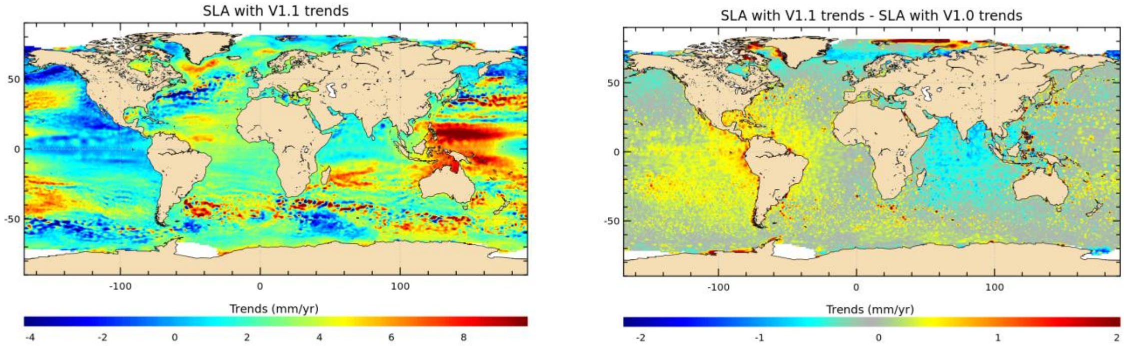

Figure 11: Regional MSL trends derived from CCI V1.1 maps (left) and differences with V1.0 (right)

3.2.2.3. Annual signal

Figure 12 displays the map of the differences between the amplitude and phase of the annual signal in the V1.1 and V1.0 products estimated over the 1993-2010 period. Almost no difference is observed in amplitude and the phase of the annual signal is slightly different. This may be related with the new Envisat and Jason-2 altimeter standards.

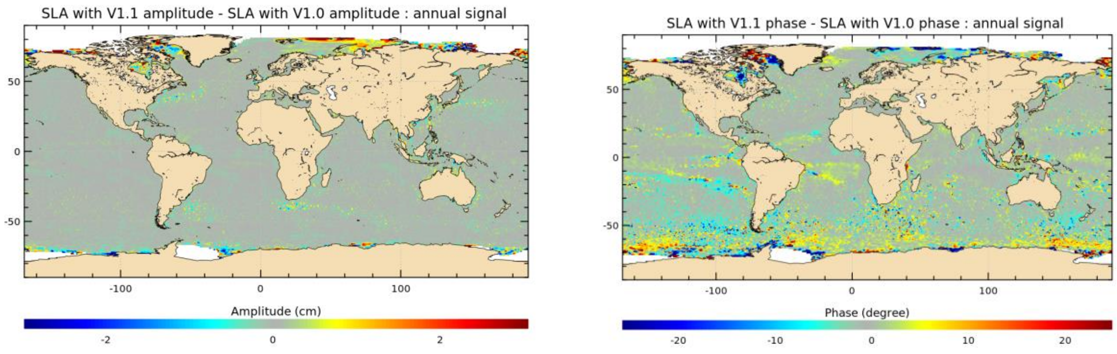

Figure 12: Annual signal differences in amplitude (left) and phase (right)

3.2.2.4. Evolution of the sea level variance

The evolution of the variance of the sea level indicates in which extent the geophysical corrections applied to the altimeter range provide an improvement of the sea level estimation compared with the mean sea surface.

Figure 13 displays the spatial distribution of the temporal variance differences between SL-CCI V1.1 and V1.0 maps. No variance difference is observed in large parts of the global ocean. Differences are located in areas of high ocean variability. The filtering of the maps indicates that this variance evolution is only observed at high frequencies (<1yr). This is associated with the evolution of altimeter standards in the Envisat and Jason-2 reprocessed datasets included in the V1.1 maps.

In addition, a reduced sea level variance is observed in the Indian Ocean with the V1.1 time series. The separation in frequency bands indicates that this evolution only affects low frequencies (>3yr). This is associated with the new GPD wet troposphere correction whose impact is particularly significant in this region for the TOPEX-Poseidon mission. The comparison with in-situ independent measurements demonstrates the improvement of the sea level estimation: Figure 15 shows a better consistency in terms variance differences with V1.rather than V1.0 with a variance reduction of 4 cm^2 with tide gauges data and 1 cm^2 with Argo profiles.

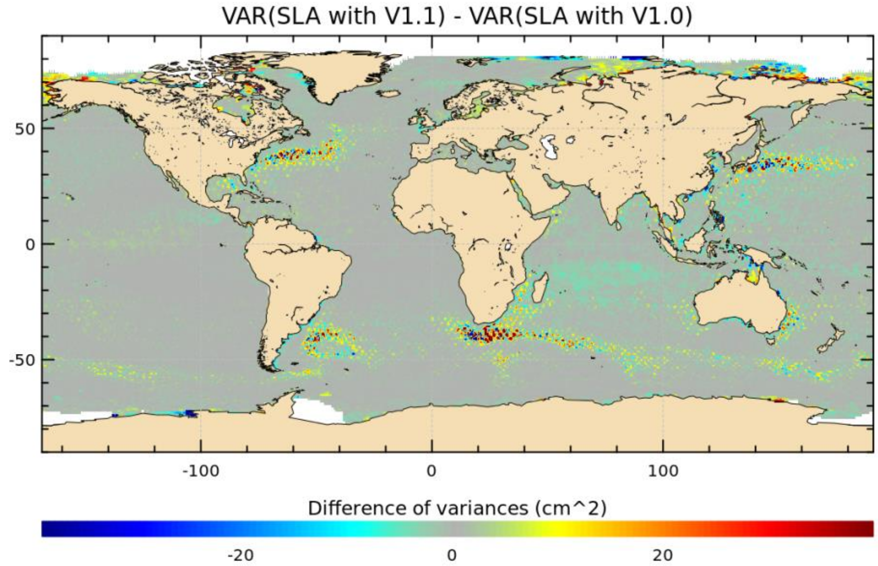

Figure 13: Spatial distribution of temporal variance differences between SL-CCI V1.1 and V1.0.

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Figure 14 shows the temporal evolution of the spatial variance. The V1.1 sea level variance is globally smaller than the variance of the V1.0 sea level by 1.7 cm^2 over the total period. This results from the cumulative effects of the new GPD wet troposphere correction and of the reprocessed Envisat and Jason-2 altimeter sea level measurements.

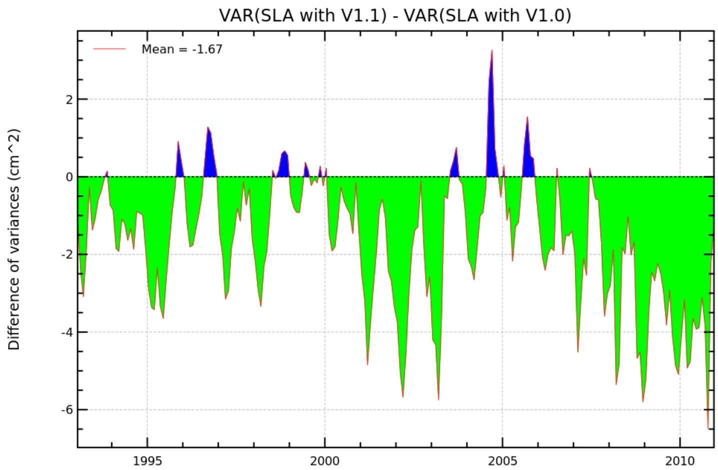

Figure 14: Temporal evolution of the spatial sea level variance differences between SL-CCI V1.1 and V1.0 with the green colour implying it is an improvement of the solution.

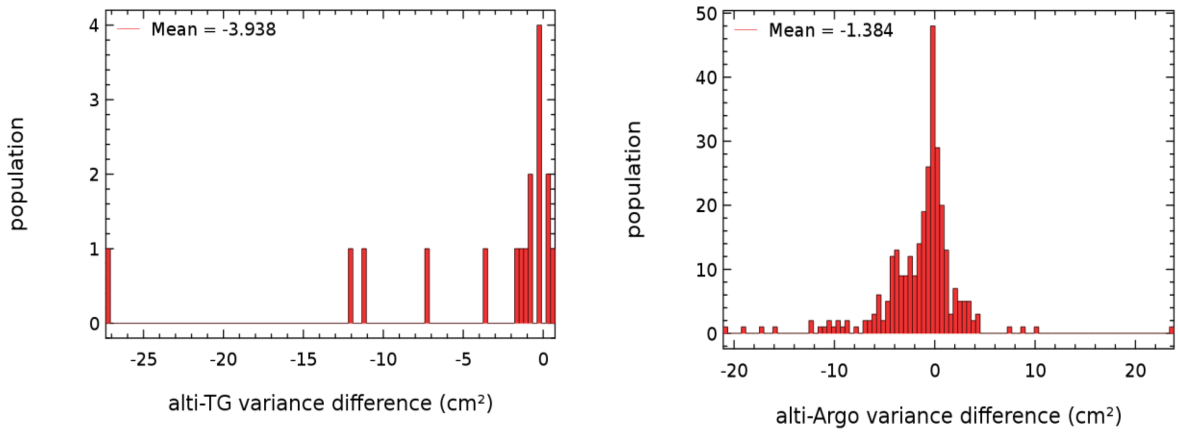

Figure 15: Differences of the altimetry – insitu variance between SL-CCI V1.1 and V1.0 for tide gauges (on left) and for Argo profiles (on right)

4. Conclusion

The SL-CCI product has been reprocessed over the period 1993-2010 including evolution in the altimeter level 2 measurements. The GPD wet troposphere correction (already used for Envisat measurements) has been included for the computation of the sea level concerning all altimeter missions. The V2 reprocessed Envisat measurements and the GDR-D reprocessed Jason-2 measurements have been used for the computation of the new SL-CCI V1.1 maps series.

Global and regional biases between the different altimeter missions have been taken into account and the analysis of the residual differences shows a good internal consistency and provides a first quality assessment of the reprocessed dataset.

The comparison of the reprocessed and the original level 4 CCI sea level maps show that the evolution is relatively small: the global mean sea level trend is unchanged and at regional scales, a ±0.5 mm/yr East/West hemispheric bias is observed. It is directly associated with the final GDR-D orbit solution included in the Envisat and Jason-2 reprocessed time series. Notice that a jump of about 2 mm was corrected in 2008 thanks to the new wet troposphere correction. However this improvement is not directly due to the new GPD correction, but by the enhancement products provided by JPL (the GPD correction is now based on the enhancement product).

In terms of sea level variance, the reprocessed V1.1 SL-CCI time series displays a slightly reduced variance compared with the original dataset, traducing the choice of improved level 2 sea level geophysical corrections (the wet troposphere correction for instance).

5. Annex 1: Envisat orbit comparison: GFZ (CCI) versus GDR-D

ENVISAT orbit comparison : GFZ (CCI) versus GDRD

Antoine Edwell, Michaël Ablain (CLS)

Envisat orbit comparison : GFZ_CCI versus POE_GDRD

Introduction:

• We will observe and analyse the impact of the GFZ_CCI orbit Envisat for climate applications (see following table)

• We will compare this orbit with the reference orbit used in Envisat CNES GDRD product noticed Ref. in this presentation

Climate Applications	Temporal Scales	Definition of the indicator value		
		Significant impact	Low impact	No impact detected
Global Mean Sea Level	Long-term evolution (trend)	Trend >0.15 mm/yr	Trend> 0.05 mm/yr	Trend< 0.05 mm/yr
	Inter annual signals (> 1 year)	Amplitude> 0.5 mm	Amplitude> 0.2 mm	Amplitude< 0.2 mm
	Annual and semi-annual Signals	Amplitude> 1 mm	Amplitude> 0.2 mm	Amplitude< 0.2 mm
Regional Mean Sea Level	Long-term evolution (trend)	Trend > 0.5 mm/yr	Trend> 0.1 mm/yr	Trend< 0.1 mm/yr
	Annual and semi-annual Signals	Amplitude> 5 mm	Amplitude> 0.5 mm	Amplitude< 0.5 mm
Mesoscale	Signals < 2 months	Crossovers Variance differences > 1 cm²	Crossovers Variance differences > 0.2 cm²	Crossovers Variance differences < 0.2 cm²

This table summarizes the thresholds to determine the impact of a new orbit in terms of climate applications and temporal scales :
- **Significant impact**
- **Low impact**
- **No impact detected**

Moreover, we will try in this study to indicate for each impact detected if it's a positive **(+)** or a negative **(-)** impact.

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Global Mean Sea Level

Envisat		
		Round Robin Data Package (RRDP)
Climate Applications	Temporal Scales	GFZ_CCI Versus Ref.
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

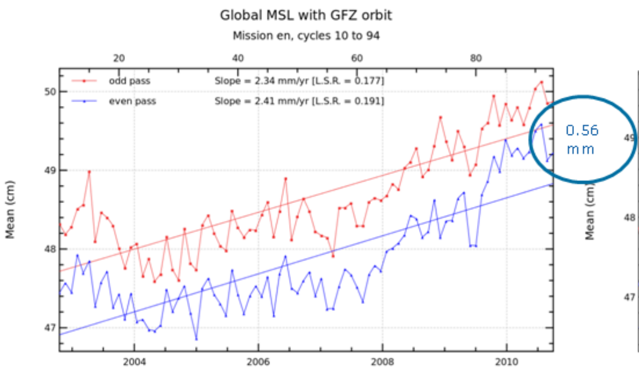
Impact of the orbit solutions on global MSL trends for Envisat		
Altimetry missions	GFZ_CCI	Ref.
Envisat	2.37 mm/yr	2.35 mm/yr

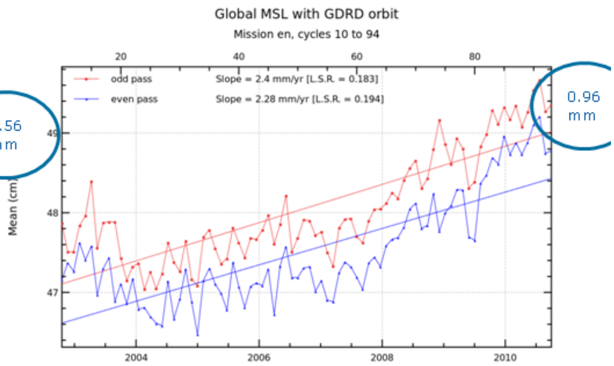
⇒ 0.02 mm/yr on the Global MSL is low (see figure on next slide)

Global Mean Sea Level

⇒ Low impact between odd and even pass : GFZ_CCI orbit is a little bit more homogeneous than Ref orbit ; approximately 0.05 mm/yr
⇒ The MSL trend differences between odd and even pass have been calculated and displayed in the following table from graphics below.

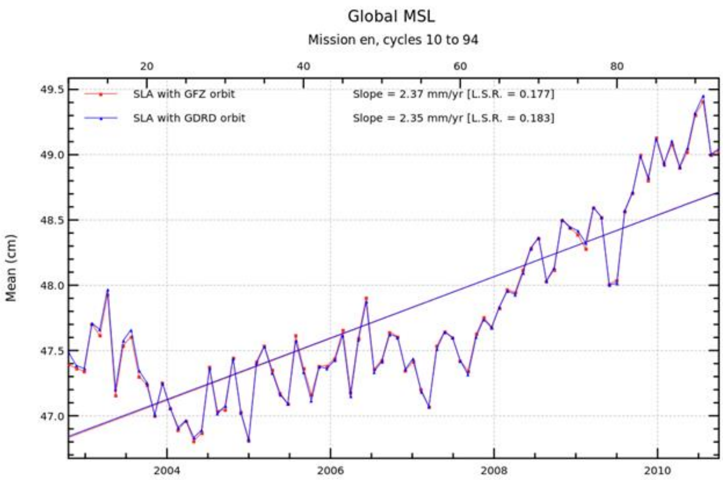
MSL trend differences between Odd and Even pass for the two orbit solutions		
Altimetry missions	GFZ_CCI	Ref.
Envisat	Δ=0.07 mm/yr	Δ=0.12 mm/yr





Global Mean Sea Level

This figure shows the temporal evolution of SLA mean calculated globally.

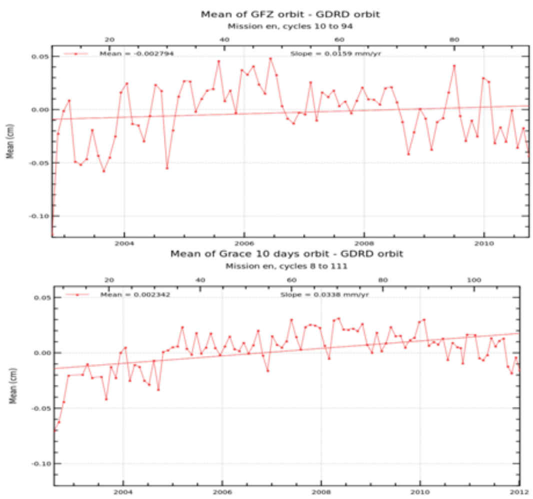


Global Mean Sea Level

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	+ ? To be discussed
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Significant impact detected on Inter annual Signals

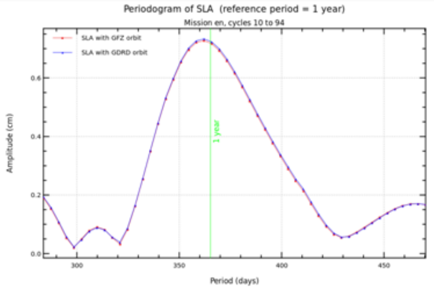
We can see on this comparison between means of GFZ orbit – GDRD CNES orbit and Grace 10 days orbit (which is considered as reference) – GDRD CNES orbit that GFZ orbit seems to get closer to Grace 10 days orbit.

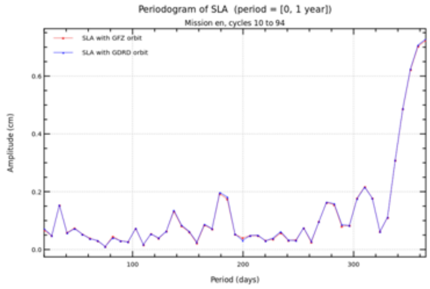


Global Mean Sea Level

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals





Regional Mean Sea Level

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+ - ? To be discussed
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Significant impact detected on Regional Mean Sea Level

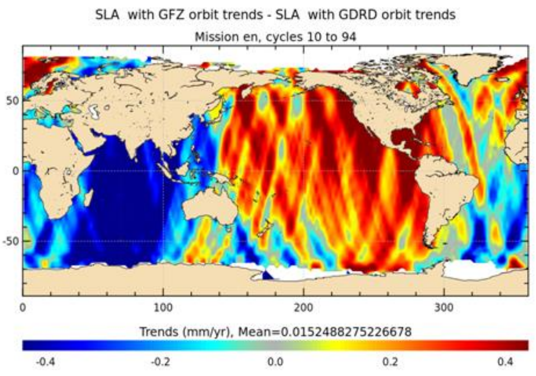
⇒ The GFZ_CCI orbit displays East-West differences between ± 1 mm/yr (see next slide) in comparison with Ref. orbit

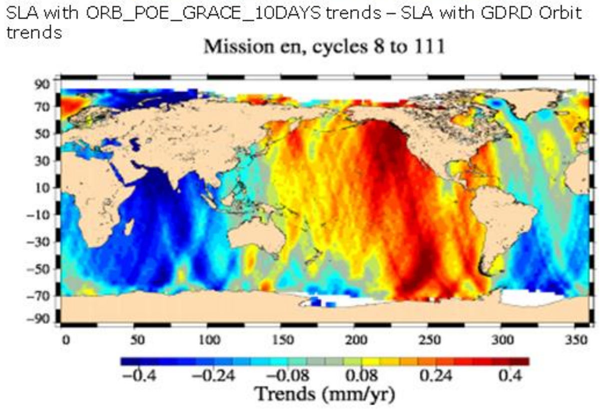
Regional Mean Sea Level

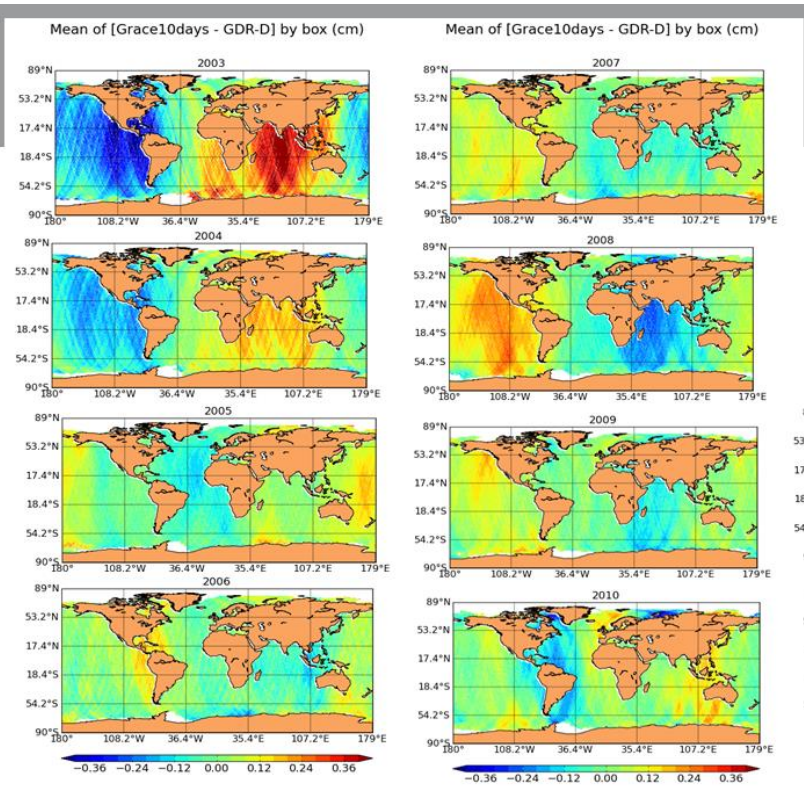
⇒ Map of Sea Level Anomaly differences between **GFZ_CCI** orbit and **Ref.** and **Grace 10 days** orbit and **Ref.** (ALL PERIOD)

⇒ **GFZ** orbit gets closer to **Grace 10 days** orbit (which is considered as reference) so GFZ orbit seems to be better than GDRD orbit for long term evolution of regional mean sea level (to be confirmed by CNES (L.Cerri))..

Extract of OSTST presentation

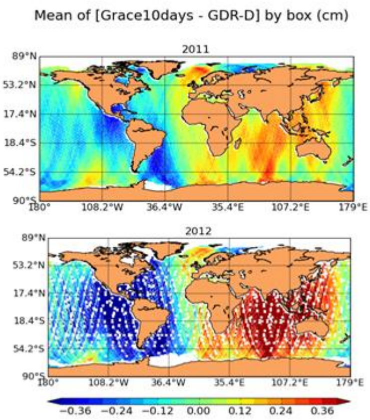


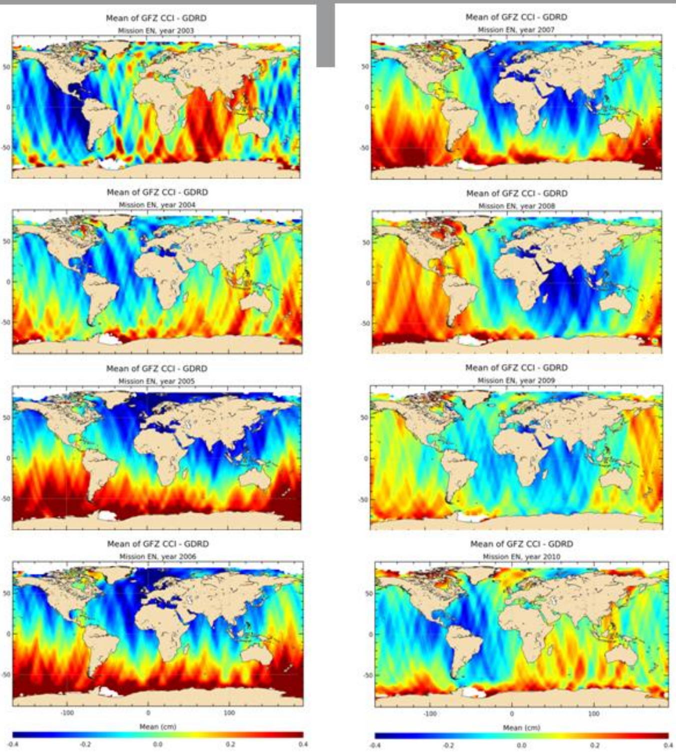




Differences year by year

Extract of OSTST presentation

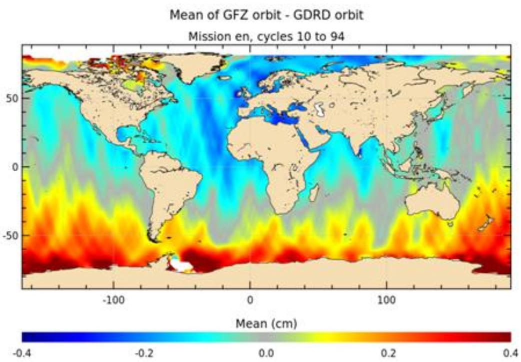




- Comparison between mean of difference by year between GFZ orbit and GDRD CNES orbit and mean of difference by year between Grace 10 days orbit (which is considered as reference) and GDRD CNES orbit highlight an evolution of GFZ orbit toward Grace 10 days orbit for years 2003, 2004, 2008, 2009, 2010.

- But for years 2005, 2006, 2007 we see a big north/south effect which we don't explain.

Envisat orbit comparison : GFZ_CCI versus GDRD



⇒ Map of Mean differences between **GFZ_CCI** orbit and **Ref orbit** (ALL PERIOD)
On this map we observe the north/South effect between the two orbits.

Regional Mean Sea Level

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

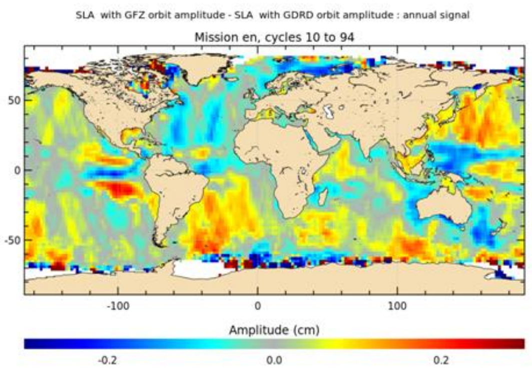
⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

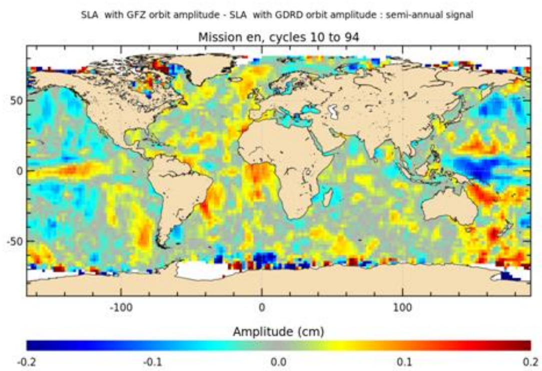
⇒ It's not possible to determine which orbit is the best one for theses scales

Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**





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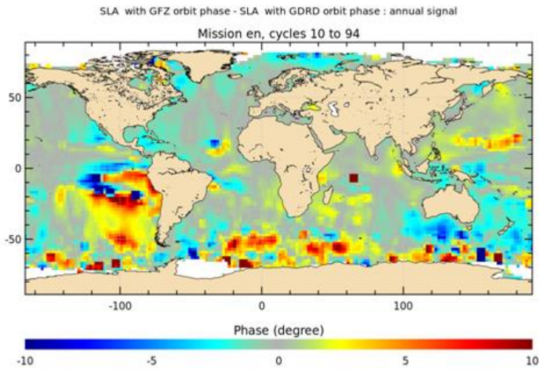
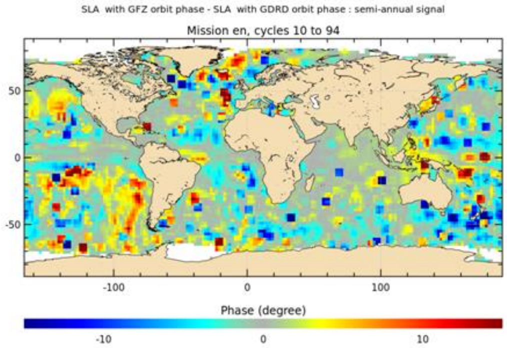
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month





Mesoscale

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on a short temporal scale (signals < 2 months):

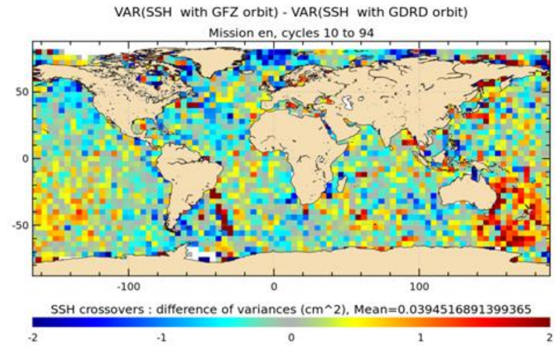
SSH crossovers are the differences between ascending and descending passes for time difference between both passes lower than 10 days (in order to reduce the effect of the oceanic variability)

⇒ Mean of Crossovers Variance Differences < 1 cm² (see figures on next slide) so the impact detected on a short temporal scale is low.

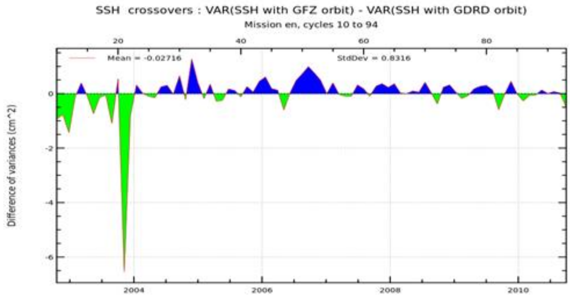
⇒ The two maps of SSH mean at crossovers (see figures on next slide) highlight a better SSH consistency with GFZ_CCI orbit than with Ref orbit near the coast but bader in average (mean ~ 0.04).

Mesoscale

⇒ Map of Variance differences of Sea Surface Height at crossovers between **GFZ_CCI** orbit and **Ref.** (ALL PERIOD)



⇒ Monitoring of Variance differences of Sea Surface Height at crossovers between **GFZ_CCI** orbit and **Ref.** : (TEMPORAL EVOLUTION)

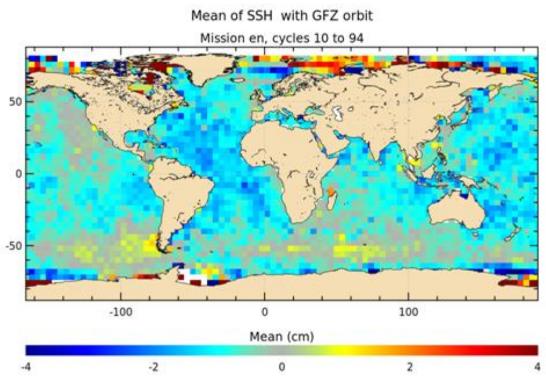


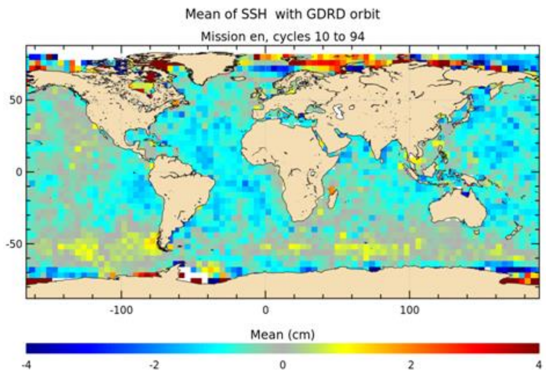
Mesoscale

⇒ Map of Mean of Sea Surface Height at crossovers with the **GFZ_CCI orbit**

AND

⇒ Map of Mean of Sea Surface Height at crossovers with the **Ref. orbit**





Conclusions

Conclusions:

• Concerning the MSL evolution:
⇒ No impact for the global MSL trend (0,02 mm/yr over 8 years) and annual and semi-annual signal

• Concerning the Global MSL inter annual signal we observe that GFZ orbit gets closer to Grace 10 days orbit (which is considered as reference) so this orbit seems to be better than GDRD orbit.

• Concerning the regional MSL evolution, the results are more balanced :
⇒ (+) Comparison between GFZ orbit and Grace 10 days orbit highlight an evolution toward Grace 10 days (which is considered as a reference) for years 2003, 2004, 2008, 2009, 2010 and for the regional MSL trend.
⇒ (-) But for years 2005, 2006, 2007 and on the mean over all cycles, we see a strong north/south effect which we don't explain.

Envisat		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) GFZ_CCI Versus Ref.
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	+ ? To be discussed
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+ - ? To be discussed
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

6. Annex 2: TOPEX/Poseidon orbit comparison: GFZ (CCI) versus GSFC (STD09)

TOPEX/Poseidon orbit comparison : GFZ (CCI) versus GSFC (STD09)

Antoine Edwell, Michaël Ablain (CLS)

Topex/Poseidon orbit comparison : GFZ_CCI versus POE_GSFC

Introduction:

• We will observe and analyse the impact of the GFZ_CCI orbit Topex/Poseidon for climate applications (see following table)

• We will compare this orbit with the reference orbit used in Topex/Poseidon POE_GSFC product noticed Ref. in this presentation

Climate Applications	Temporal Scales	Definition of the indicator value		
		Significant impact	Low impact	No impact detected
Global Mean Sea Level	Long-term evolution (trend)	Trend >0.15 mm/yr	Trend> 0.05 mm/yr	Trend< 0.05 mm/yr
	Inter annual signals (> 1 year)	Amplitude> 0.5 mm	Amplitude> 0.2 mm	Amplitude< 0.2 mm
	Annual and semi-annual Signals	Amplitude> 1 mm	Amplitude> 0.2 mm	Amplitude< 0.2 mm
Regional Mean Sea Level	Long-term evolution (trend)	Trend > 0.5 mm/yr	Trend> 0.1 mm/yr	Trend< 0.1 mm/yr
	Annual and semi-annual Signals	Amplitude> 5 mm	Amplitude> 0.5 mm	Amplitude< 0.5 mm
Mesoscale	Signals < 2 months	Crossovers Variance differences > 1 cm²	Crossovers Variance differences > 0.2 cm²	Crossovers Variance differences < 0.2 cm²

This table summarizes the thresholds to determine the impact of a new orbit in terms of climate applications and temporal scales :
- **Significant impact**
- **Low impact**
- **No impact detected**

Moreover, we will try in this study to indicate for each impact detected if it's a positive **(+)** or a negative **(-)** impact.

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Global Mean Sea Level

Climate Applications	Temporal Scales	Topex/Poseidon – Round Robin Data Package (RRDP): GFZ_CCI Versus Ref. (GSFC)
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Global Mean Sea Level trend

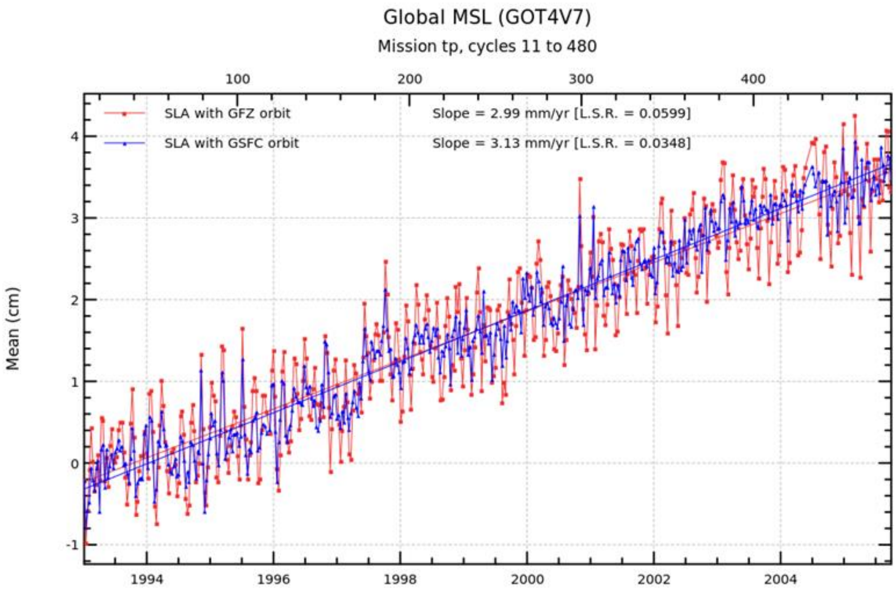
Impact of the orbit solutions on global MSL (with GOT4V7 tide correction) trends for Topex/Poseidon		
Altimetry missions	GFZ_CCI	Ref.
Topex/Poseidon	2.99 mm/yr	3.13 mm/yr

⇒ 0.14 mm/yr on the Global MSL is low (see figure on next slide)

To be noted that ascending/descending MSL are homogeneous with both orbit solutions.

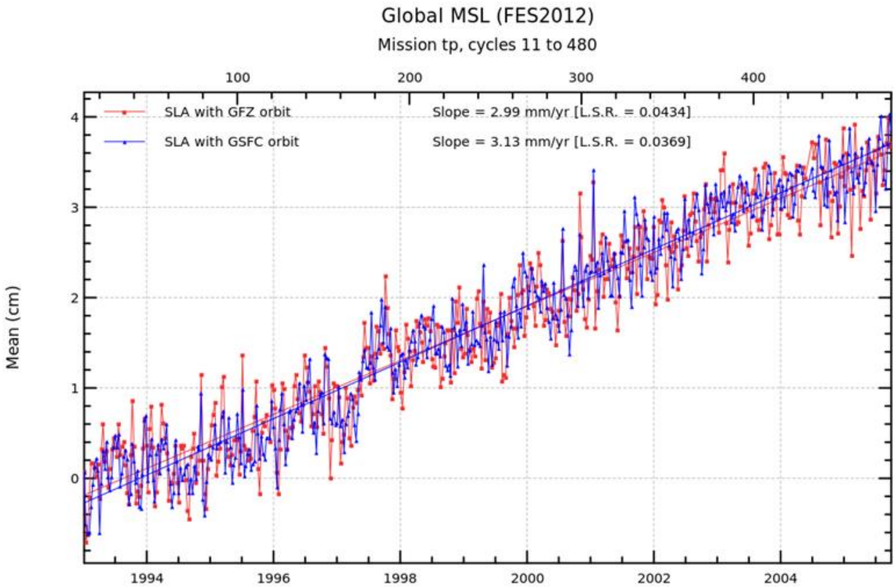
Global Mean Sea Level

This figure shows the temporal evolution of SLA (with GOT4V7 tide correction) mean calculated globally.



Global Mean Sea Level

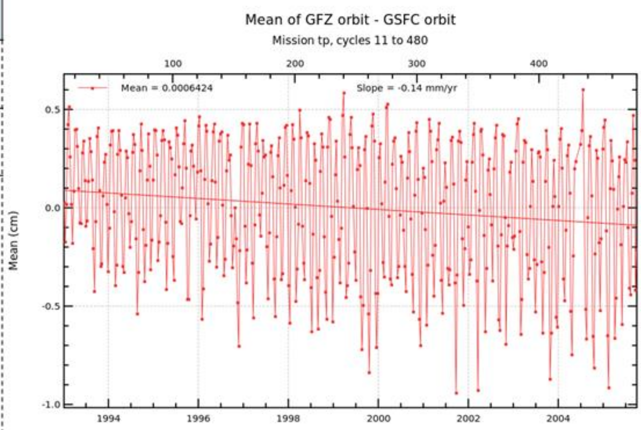
This figure shows the temporal evolution of SLA (with FES2012 tide correction) mean calculated globally. We observed smaller amplitude.



Global Mean Sea Level

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.(GSFC)**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

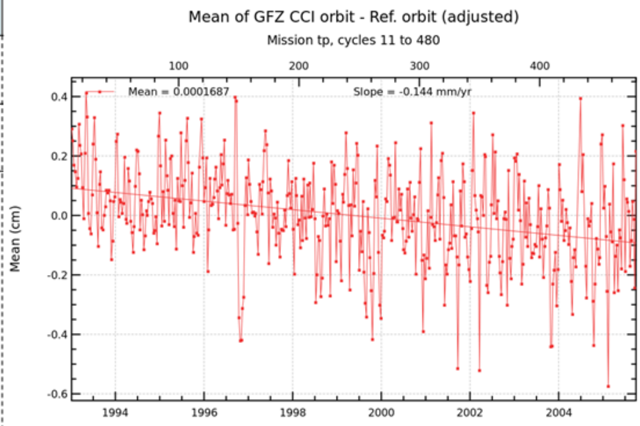
Impact detected on Inter annual Signals



Global Mean Sea Level

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.(GSFC)**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

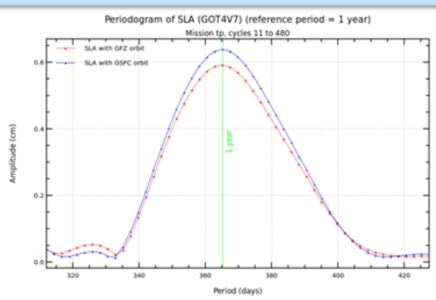
Impact detected on Inter annual Signals

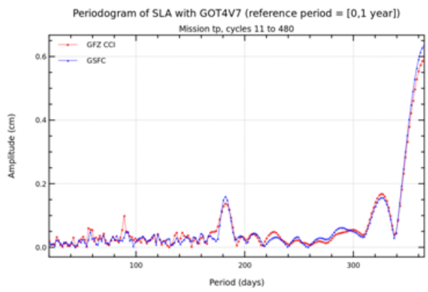


Global Mean Sea Level

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.(GSFC)**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-annual Signals

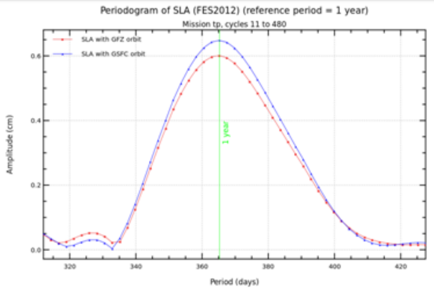




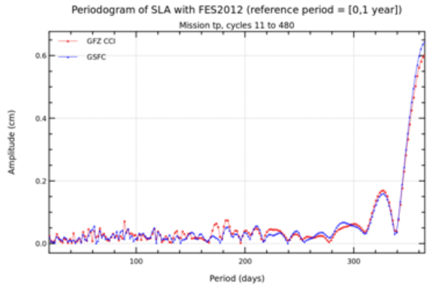
Global Mean Sea Level

Topex/Poseidon		
		Round Robin Data Package (RRDP)
Climate Applications	Temporal Scales	GFZ_CCI Versus Ref.(GSFC)
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-annual Signals



We observed a bigger 60 days signal for GSFC orbit.



Regional Mean Sea Level

Topex/Poseidon		
		Round Robin Data Package (RRDP)
Climate Applications	Temporal Scales	GFZ_CCI Versus Ref.(GSFC)
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Regional Mean Sea Level

⇒ The GFZ_CCI orbit displays East-West differences between ± 0.8 mm/yr (see next slide) in comparison with Ref. orbit (GSFC)

⇒ In order to know which orbit solution is the best one, we have also analyzed the temporal evolution of SLA mean separating North/South hemispheres, separating East/West areas and separating [-280°,-100°]/[-100°,80°] areas. Hereafter, we can observe (see figures on next slides) for these two diagnoses that GFZ_CCI orbit provide more homogeneous MSL trends than the GSFC.

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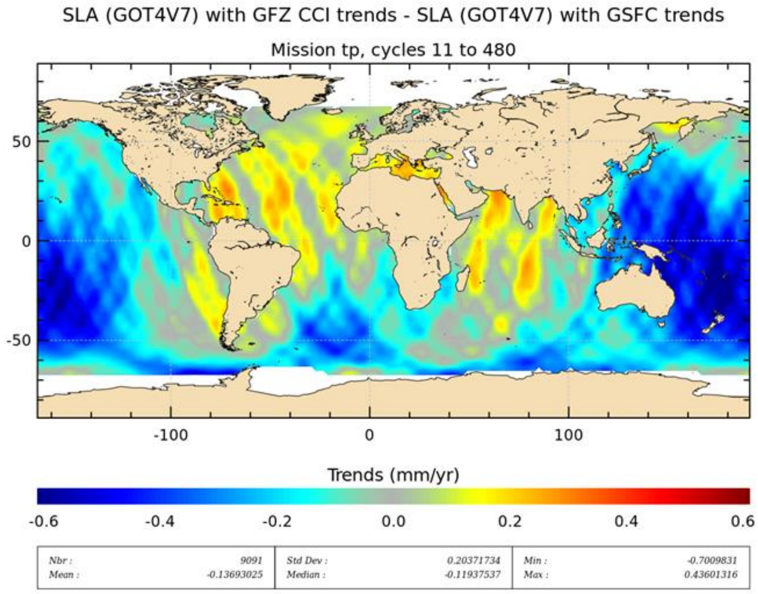
Regional Mean Sea Level

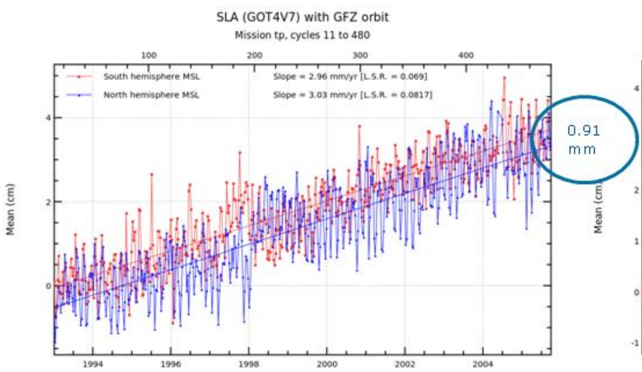
⇒ Map of Sea Level Anomaly differences between **GFZ_CCI** orbit and **Ref.(GSFC)** (ALL PERIOD)

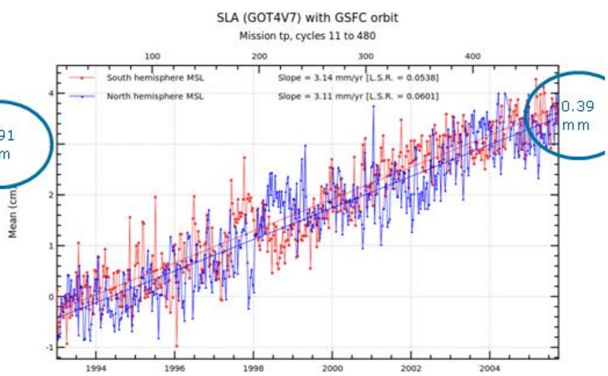


Regional Mean Sea Level

⇒ No impact between North and South : GFZ_CCI orbit is less homogeneous than GSFC ; approximately 0.04 mm/yr
⇒ The MSL trend differences between South and North hemispheres have been calculated and displayed in the following table from graphics below.

Hemispheric MSL trend differences between South and North hemispheres for the two orbit solutions		
Altimetry missions	GFZ_CCI	Ref.(GSFC)
Topex/Poseidon	Δ= 0.07 mm/yr	Δ= 0.03 mm/yr





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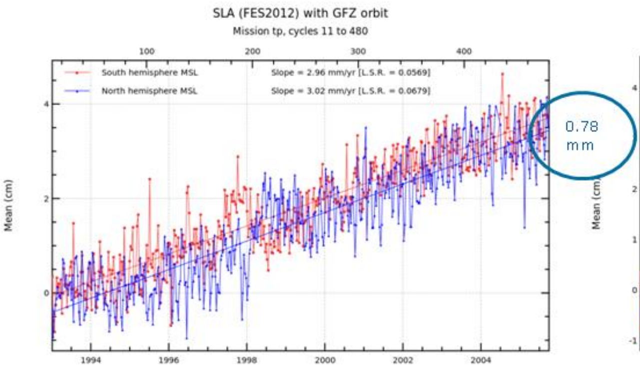
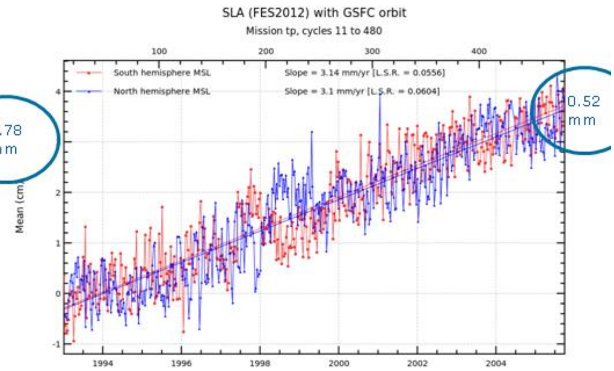
Regional Mean Sea Level

⇒ No impact between North and South : GFZ_CCI orbit is less homogeneous than GSFC ; approximately 0.04 mm/yr
⇒ The MSL trend differences between South and North hemispheres have been calculated and displayed in the following table from graphics below.

Hemispheric MSL trend differences between South and North hemispheres for the two orbit solutions		
Altimetry missions	GFZ_CCI	Ref. (GSFC)
Topex/Poseidon	Δ= 0.06 mm/yr	Δ= 0.04 mm/yr

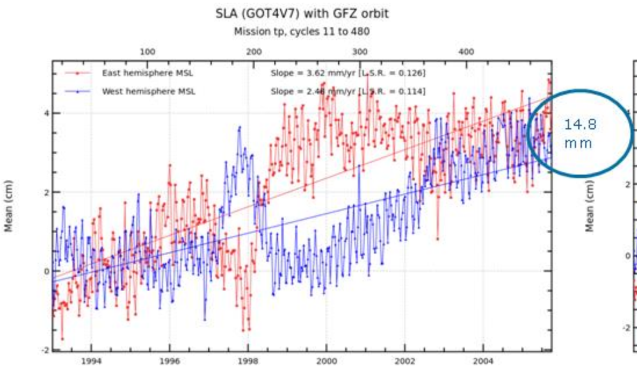


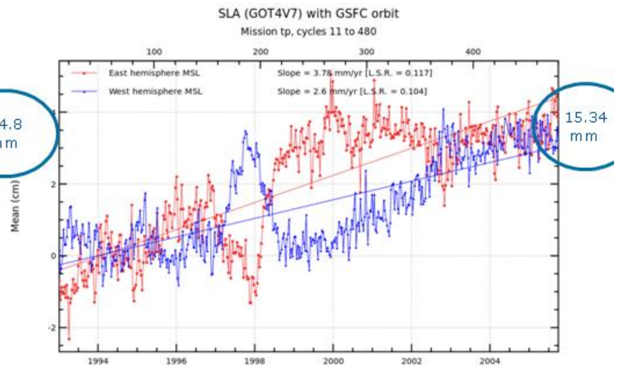


Regional Mean Sea Level

⇒ No significant impact between East and West
⇒ The MSL trend differences between East and West areas have been calculated and displayed in the following table from graphics below.

Area MSL trend differences between East and West areas for the two orbit solutions		
Altimetry missions	GFZ_CCI	GSFC
Topex/Poseidon	Δ= 1.14 mm/yr	Δ= 1.18 mm/yr





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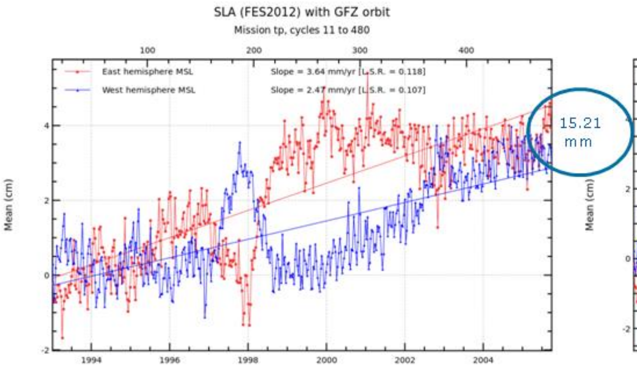
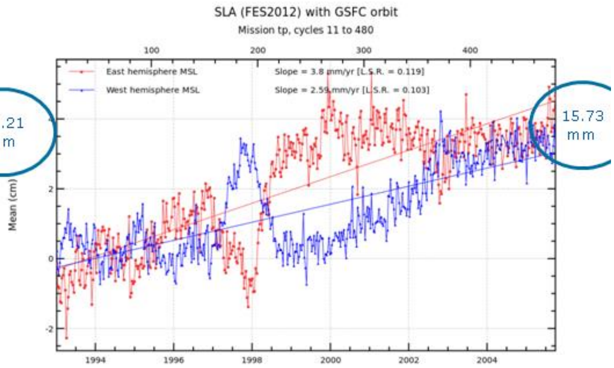
Regional Mean Sea Level

⇒ No significant impact between East and West
⇒ The MSL trend differences between East and West areas have been calculated and displayed in the following table from graphics below.

Area MSL trend differences between East and West areas for the two orbit solutions		
Altimetry missions	GFZ_CCI	GSFC
Topex/Poseidon	Δ= 1.17 mm/yr	Δ= 1.21 mm/yr

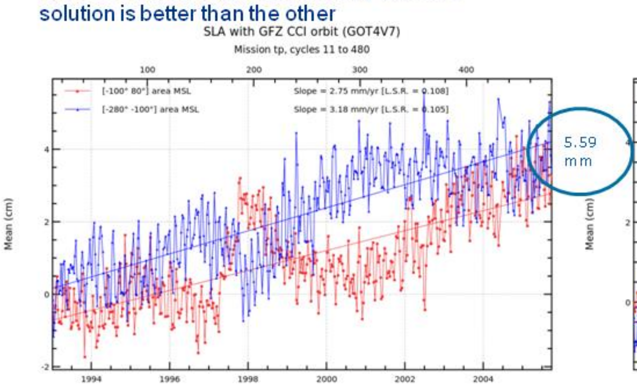


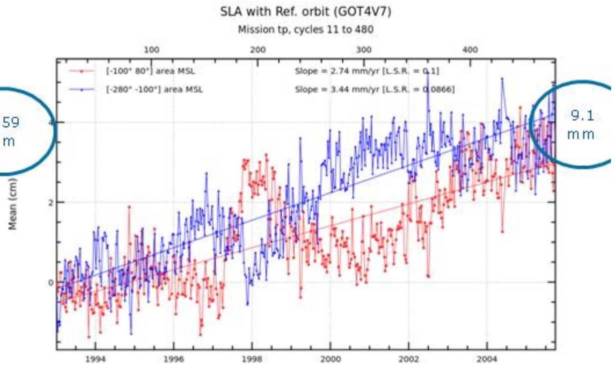


Regional Mean Sea Level

⇒ Low impact between [-100°,80°] and [-280°,-100°] longitude boxes : GFZ_CCI orbit is more homogeneous than GSFC : approximately 0.3 mm/yr
⇒ The MSL trend differences between new areas have been calculated and displayed in the following table from graphics below.
⇒ Due to strong interannual signals (related to ENSO oscillations), we can not say that one solution is better than the other

Area MSL trend differences between [-280°,-100°] and [-100°,80°] areas for the two orbit solutions		
Altimetry missions	GFZ_CCI	GSFC
Topex/Poseidon	Δ= 0.4 mm/yr	Δ= 0.7 mm/yr





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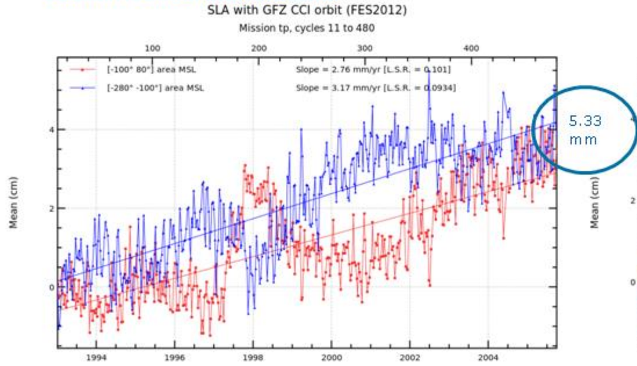
Regional Mean Sea Level

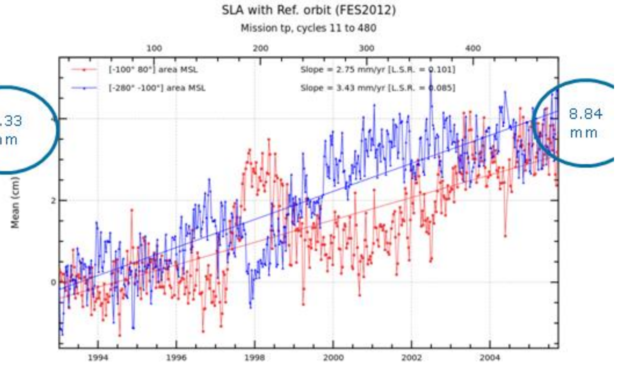
⇒ Low impact between [-100°,80°] and [-280°,-100°] longitude boxes : GFZ_CCI orbit is more homogeneous than GSFC : approximately 0.3 mm/yr

⇒ The MSL trend differences between new areas have been calculated and displayed in the following table from graphics below.

⇒ Due to strong interannual signals (related to ENSO oscillations), we can not say that one solution is better than the other

Area MSL trend differences between [-280°,-100°] and [-100°,80°] areas for the two orbit solutions		
Altimetry missions	GFZ_CCI	GSFC
Topex/Poseidon	Δ=0.41 mm/yr	Δ=0.68 mm/yr





Regional Mean Sea Level

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.(GSFC)**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

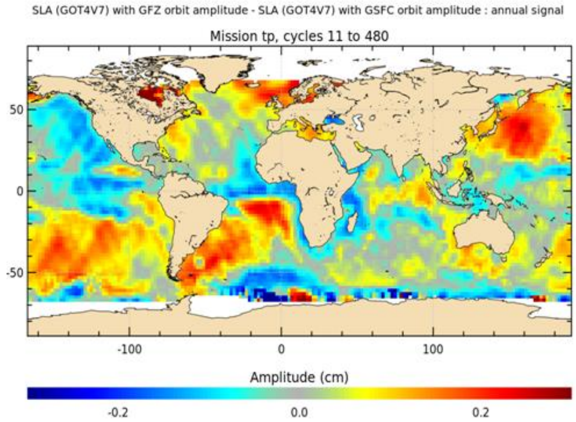
⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

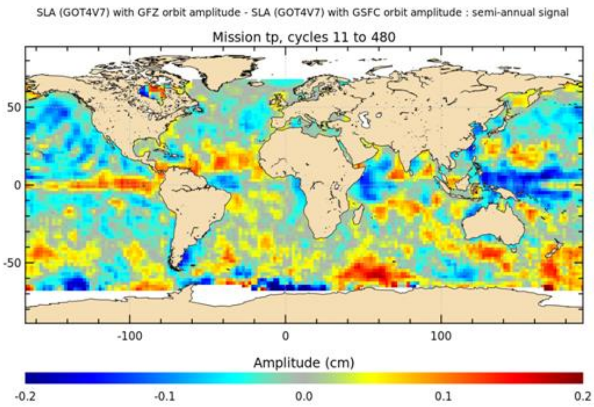
⇒ It's not possible to determine which orbit is the best one for theses scales

Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

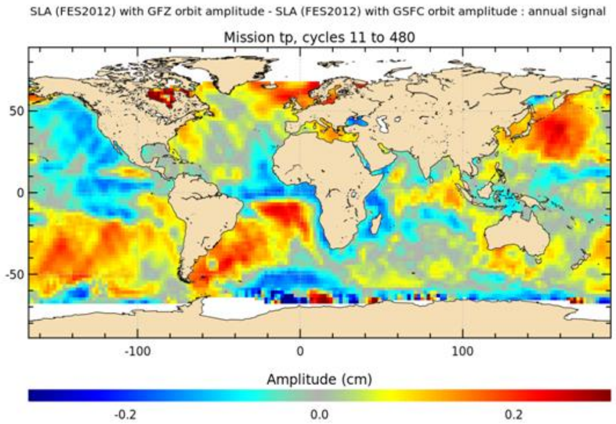


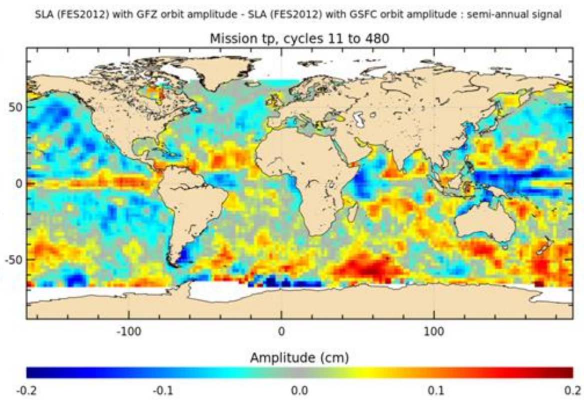


Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**



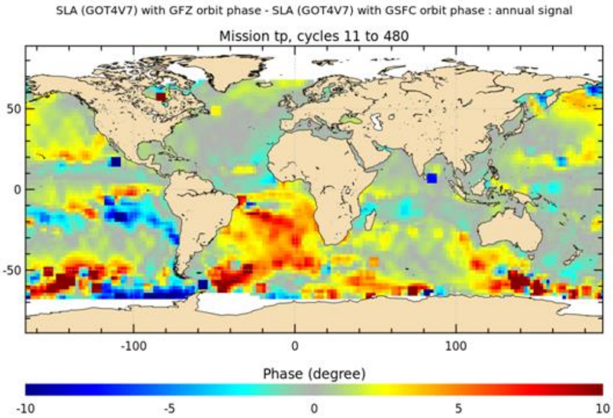


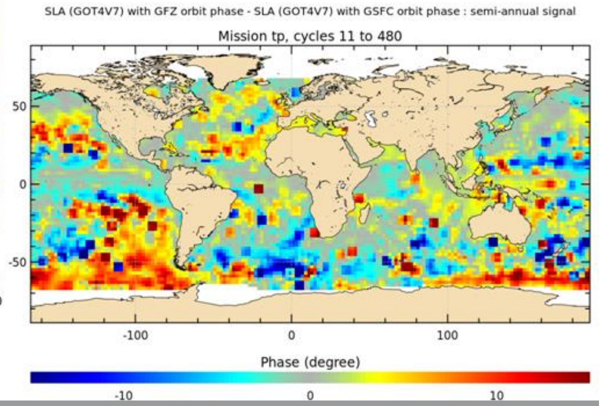
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month



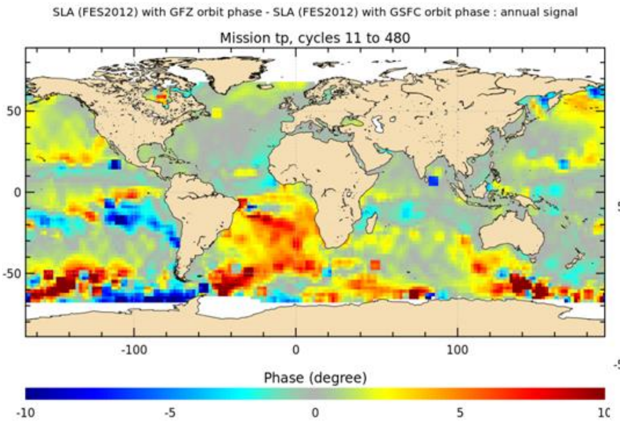


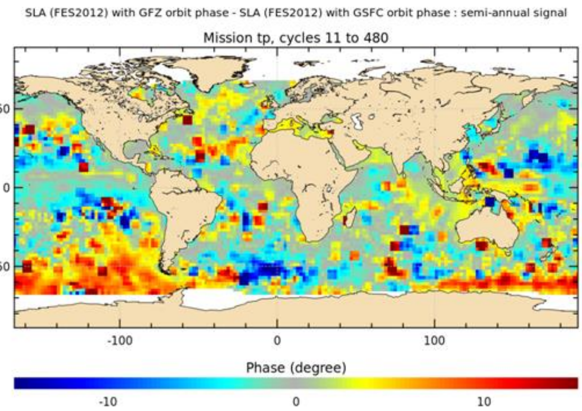
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month





Mesoscale

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **GFZ_CCI Versus Ref.(GSFC)**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	-

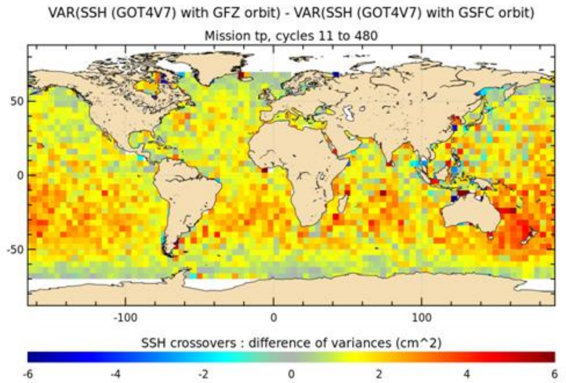
Significant impact detected on a short temporal scale (signals < 2 months):

SSH crossovers are the differences between ascending and descending passes for time difference between both passes lower than 10 days (in order to reduce the effect of the oceanic variability)

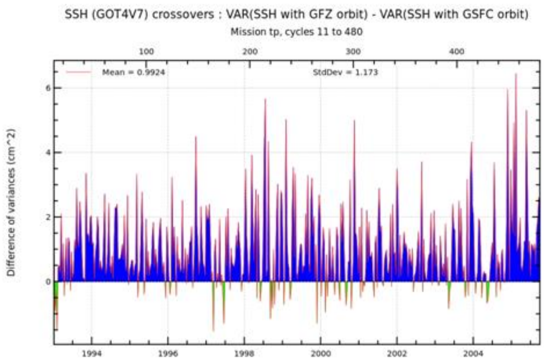
⇒ Crossovers Variance Differences = [-2,6] cm²
(see figures on next slide) so the impact detected on a short temporal scale is significant to determine which orbit solution is the best one.

⇒ The two maps of SSH mean at crossovers (see figures on next slide) highlight clearly a bader SSH consistency with GFZ_CCI orbit than with GSFC.

Mesoscale

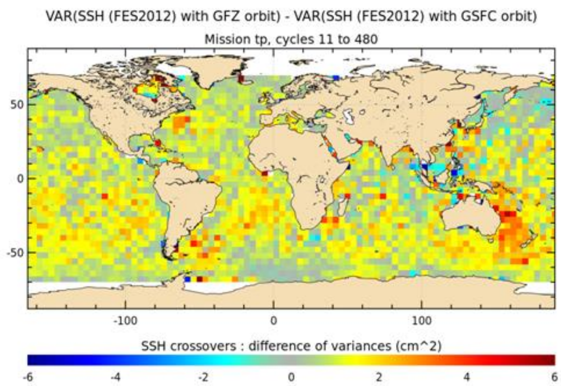


⇒ Map of Variance differences of Sea Surface Height (with GOT4V7 tide correction) at crossovers between **GFZ_CCI** orbit and Ref. : **GSFC** (ALL PERIOD)

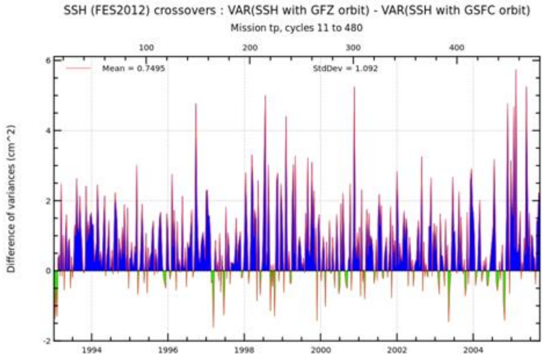


⇒ Monitoring of Variance differences of Sea Surface Height (with GOT4V7 tide correction) at crossovers between **GFZ_CCI** orbit and Ref. : **GSFC** (TEMPORAL EVOLUTION)

Mesoscale



⇒ Map of Variance differences of Sea Surface Height at crossovers between **GFZ_CCI** orbit and Ref. : **GSFC** (ALL PERIOD)



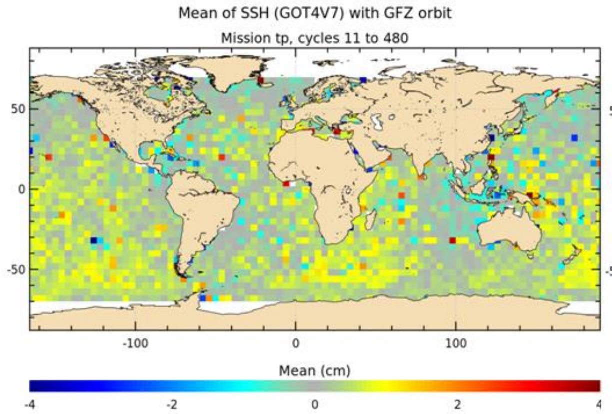
⇒ Monitoring of Variance differences of Sea Surface Height at crossovers between **GFZ_CCI** orbit and Ref. : **GSFC**(TEMPORAL EVOLUTION)

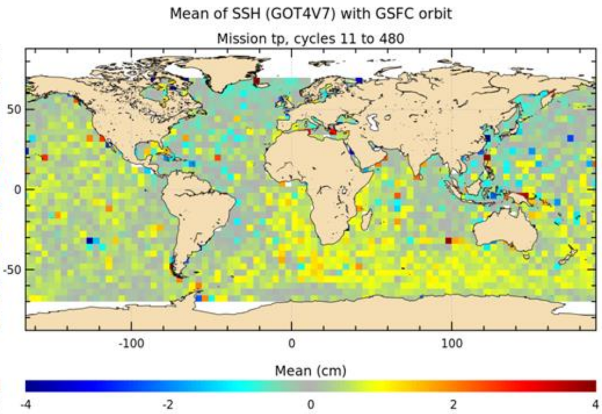
Mesoscale

⇒ Map of Mean of Sea Surface Height at crossovers with the **GFZ_CCI orbit**

AND

⇒ Map of Mean of Sea Surface Height at crossovers with the Ref. : **GSFC orbit**



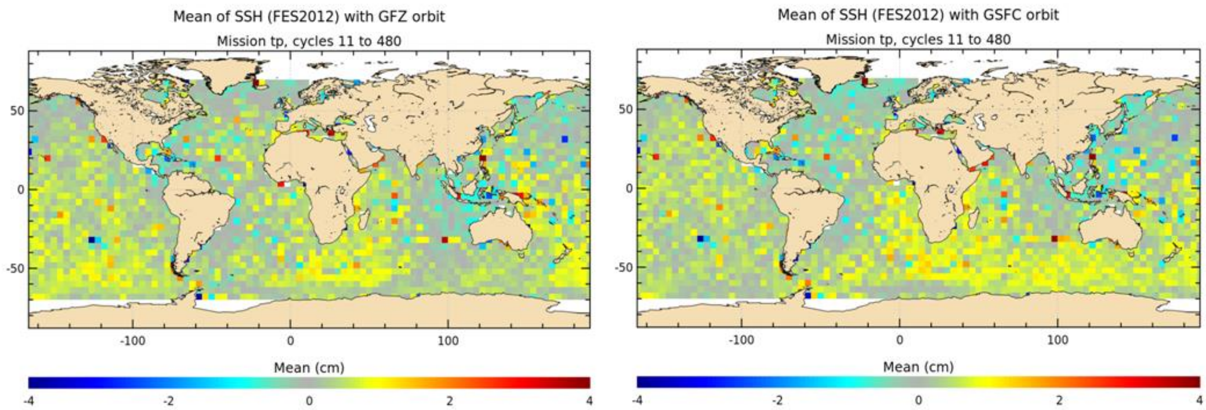


Mesoscale

⇒ Map of Mean of Sea Surface Height at crossovers with the **GFZ_CCI orbit**

AND

⇒ Map of Mean of Sea Surface Height at crossovers with the Ref. : **GSFC orbit**



Conclusions

Conclusions:

• GFZ orbit is bader than GSFC orbit at crossovers (-1 cm² on average)

• Concerning the MSL evolution:
⇒ Low impact for the global MSL (0.14 mm/yr over 13 years)
⇒ Significant impact for the regional MSL trends (+/- 0.8 m/yr) : East/West and North/South MSL trend differences have been displayed : it's not possible to determine which orbit is the best one.
⇒ Strong 58.77 signals are observed between GSFC and GFZ : using GOT or FES models, impact is not the same on the SLA ... more investigations are needed

• From CLS point of view, GFZ orbit solution can note replace GSFC for TOPEX

Topex/Poseidon		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP)
		GFZ_CCI Versus Ref. (GSFC)
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	-

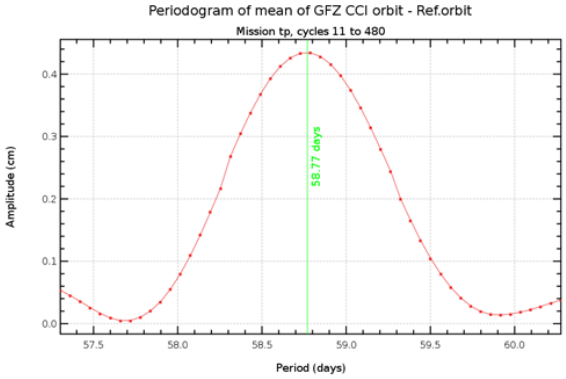
Topex/Poseidon orbit comparison : GFZ_CCI versus GSFC

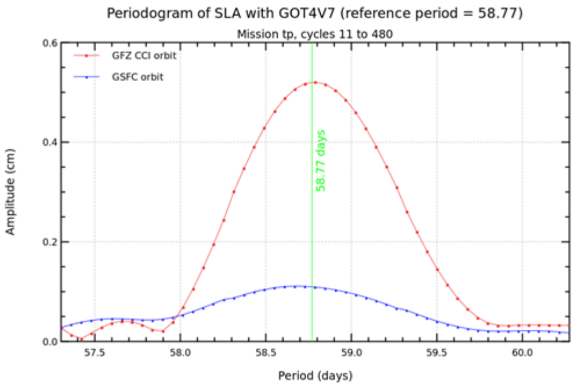
APPENDICES : some additional plots…

Investigations on 58.77-day signal

-We observed a strong 60-day signal in differences between global mean of GFZ CCI and GSFC orbit variations
=> this signal is due to the semi-diurnal aliasing with TOPEX orbit's repetitiveness: it is in fact a 58.77-day signal.

- Calculating the periodogramm of SLA using successively both orbits, we clearly observe a strong signal at 58.77 days with the GFZ orbit (5mm instead of 1 mm with GSFC ones)
⇒This results suggest there is an error on GFZ orbit at these scales : this means for semi-diurnal signal





Investigations on 58.77-day signal

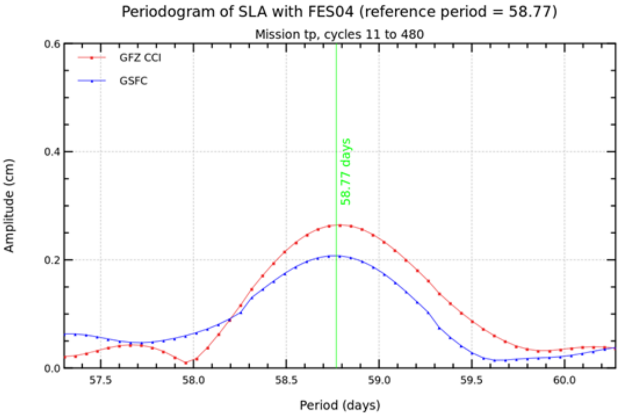
- According to Ablain's study (Lisbon 2010, OSTST), the 58.77-day signal observed on altimetric missions depends on the oceanic tide model applied : GOT or FES
=> it has been demonstrated that a 58.77-day error (not yet well understood) is present on TOPEX data and has been assimilitated by stochastical tide model as GOT

- Calculating now the same SLA periodogram using FES04 instead of GO4.7, we obtained a very diffrent result that in previuos slide :

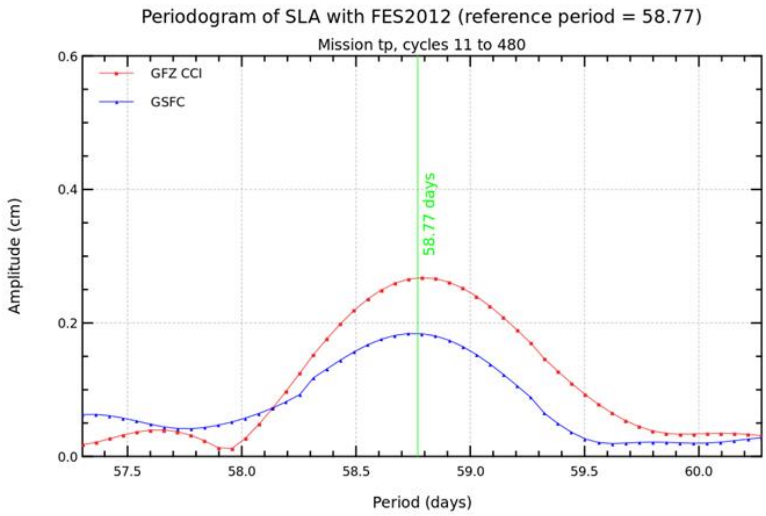
⇒ We observe a 58.77 signal with GFZ CCI orbit decreases strongly while signal with GSFC increases : close to 2 mm in both cases

⇒ This means that the 58.77-day signal observed between GFZ and GFSC orbits is complex differences: we can not determine which orbit is the best one.

⇒ We're making other analyses with other oceanic tide (as FES2012 and GOT08) …



Investigations on 58.77-day signal



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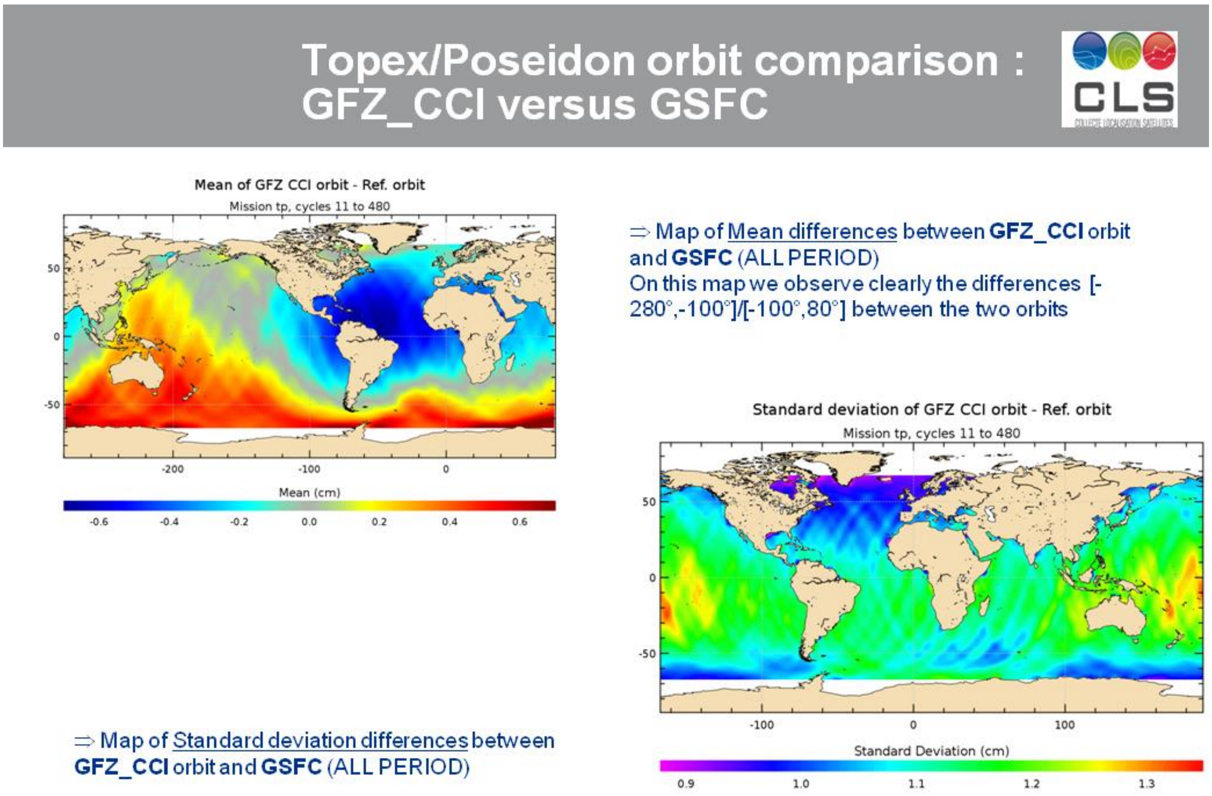

Topex/Poseidon orbit comparison :
GFZ_CCI versus GSFC
CLS
Mean of GFZ CCI orbit - Ref. orbit
Mission tp, cycles 11 to 480
Mean (cm)
⇒ Map of Mean differences between GFZ_CCI orbit and GSFC (ALL PERIOD)
On this map we observe clearly the differences [-280°,-100°]/[-100°,80°] between the two orbits
Standard deviation of GFZ CCI orbit - Ref. orbit
Mission tp, cycles 11 to 480
Standard Deviation (cm)
⇒ Map of Standard deviation differences between GFZ_CCI orbit and GSFC (ALL PERIOD)

7. Annex 3: Comparison of GPD and AVISO wet troposphere corrections for TOPEX mission

Wet tropospheric correction comparison for TOPEX mission between GPD (FCUP) and reference (AVISO) correction

The GPD correction is called : COAST_WET_TRO in the following study
The Reference correction is called :TRO_HUM_COMPOSITE (it corresponds to the correction used in AVISO products)

David Alexandre, Michael Ablain (CLS)

Wet tropospheric correction comparison for TOPEX mission

Introduction:

• We will observe and analyse the impact of the GPD (COAST_WET_TRO) wet tropospheric correction TOPEX from FCUP for climate applications

• We will compare this correction with the reference wet tropospheric correction used in AVISO products noticed TRO_HUM_COMPOSITE in this presentation

• In order to determine the impact of the new wet tropospheric correction in terms of climate applications and temporal scales, we will try in this study to indicate for each impact detected if it's a positive (+) or a negative (-) impact :

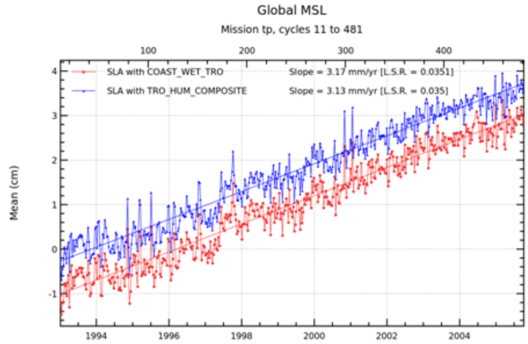
Low impact
Significant impact
No impact detected

Global Mean Sea Level

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

⇒ 0.04 mm/yr on the Global MSL is very low (especially over a 12-year period).
(see figure on next slide)



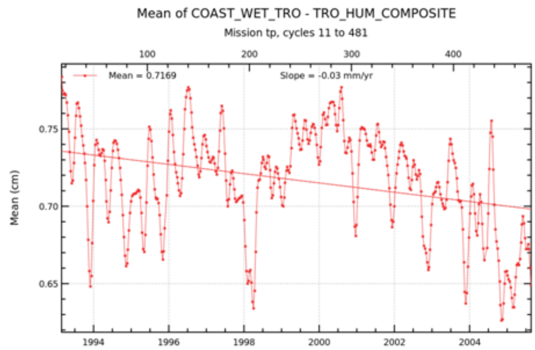
Temporal evolution of SLA mean calculated globally.

Global Mean Sea Level

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Inter annual Signals

⇒ The figure below shows the mean difference between the two corrections calculated globally by cycle.
⇒ We observed inter annual signals slightly marked.



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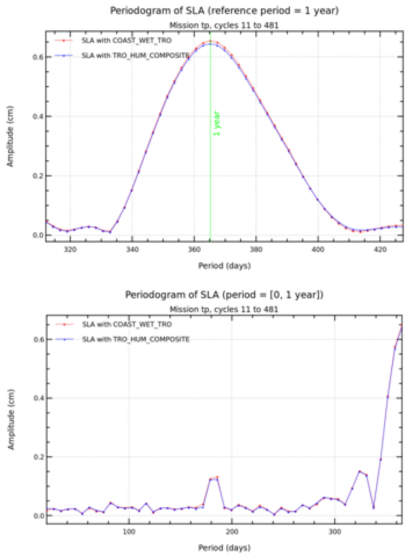
Global Mean Sea Level

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals



Mesoscale

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

Significant impact detected on a short temporal scale (signals < 2 months):

⇒ Crossovers Variance Differences are generally negative (see figures on next slide) between 0 and -2 cm² : this means that the new GDP correction is better than the reference one. Few isolated values are positive : it might corresponds to spurious GPD correction (see annex).

⇒ Improvement is especially observed at the end of the period (related to TOPEX recorder anomalies)

⇒ The map of SSH crossovers Variance Differences shows that these improvement is especially in Indian ocean (related to TOPEX recorder anomalies)

⇒ The map of SLA variance differences (see figure on next slide) confirms a better SSH consistency with GPD than with reference one in the same areas. To be noted also a light degradation near equator line not observed on SSH analyses.

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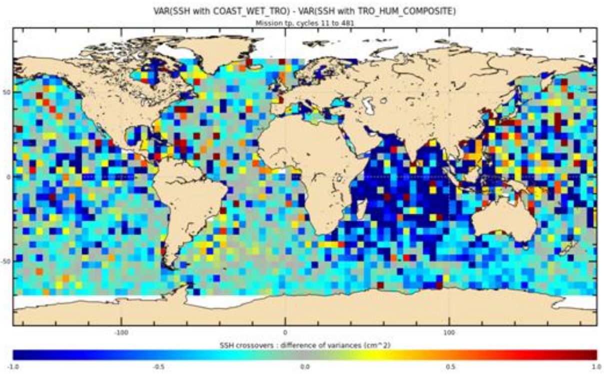
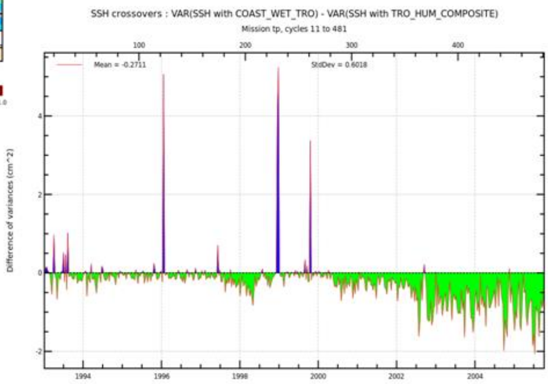
Mesoscale



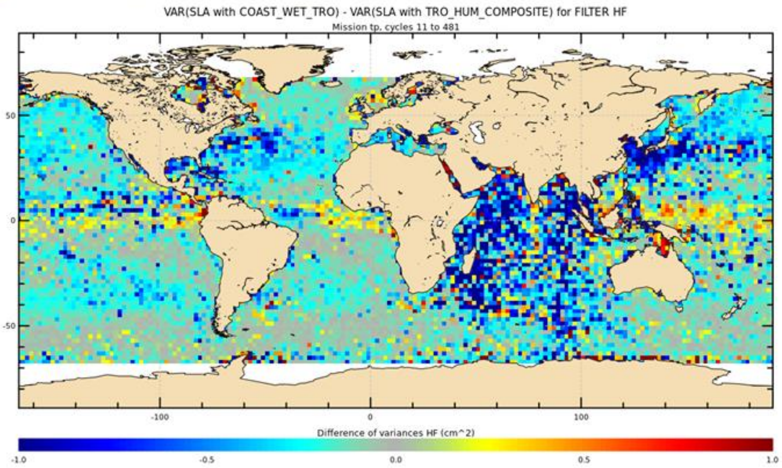
⇒ Map of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE (over all the period):
- Significant improvement in Indian Ocean



⇒ Temporal evolution of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE:
-Stronger improvement at the end of the period
- GPD is worse in few isolated cycles

Mesoscale

⇒ Map of SLA variance differences between the two corrections selecting temporal signal lower than 2 months:
- Strong improvement in Indian ocean (between 1 and 2 cm²)
- Small degradation in equator band not expected



Regional Mean Sea Level

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Significant impact detected on Regional Mean Sea Level

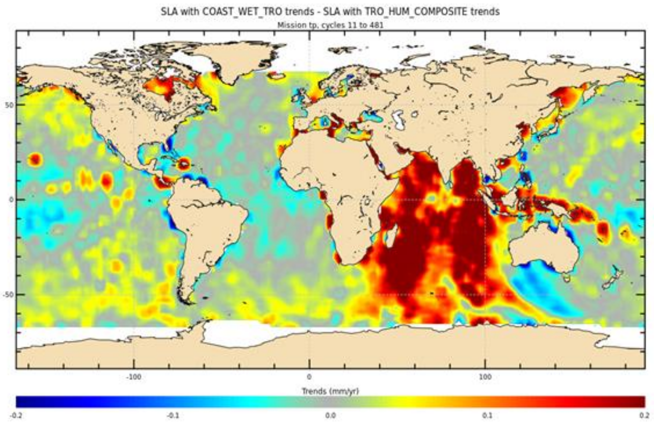
⇒ We observe a strong impact (between 0.2 and 1 mm/yr) on the regional trends in Indian ocean

⇒ it's likely an improvement of the regional trends because the SSH crossovers analyses clearly highlight a strong improvement of the SSH in this area.

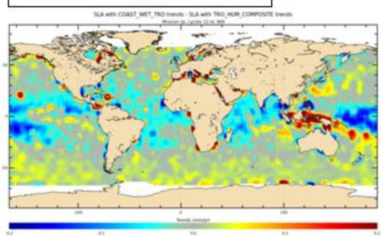
⇒ However it's not a linear signal since separating the period before/after cycle 370, we clearly observe the effect on the trends is only visible on second period (after cycle 370) : it's is also related to the recorder anomalies on TOPEX

Regional Mean Sea Level

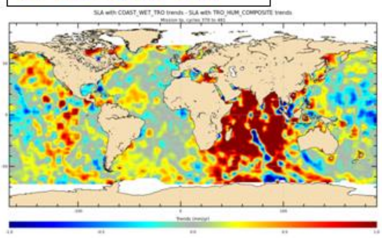
⇒ Map of Sea Level Anomaly differences between GPD and TRO_HUM_COMPOSITE (over all the period)



BEFORE cycle 370 :



AFTER cycle 370:



Regional Mean Sea Level

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO **Versus** TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

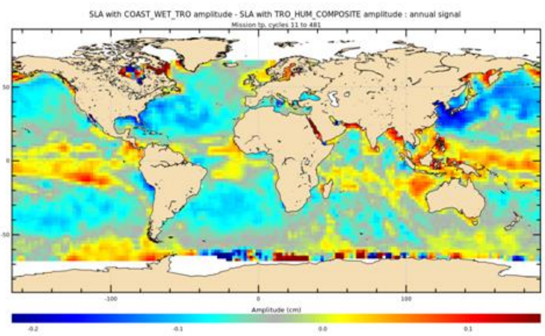
⇒ It's not possible to determine which correction is the best one for theses scales

Regional Mean Sea Level

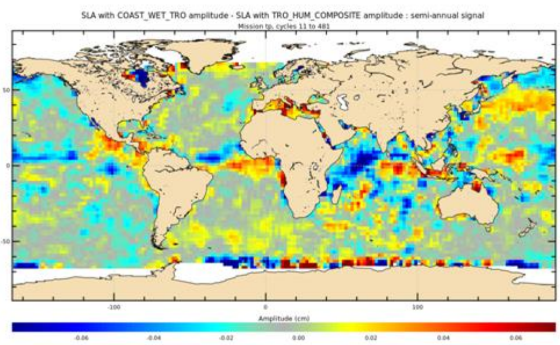
⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : annual signal



SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : semi-annual signal



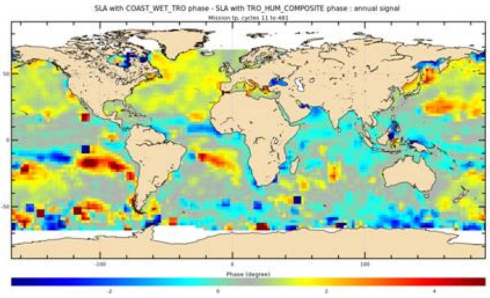
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

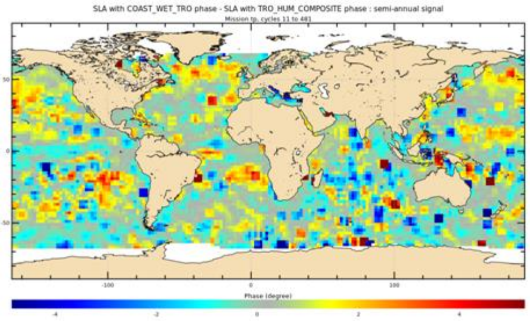
⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month

SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase: annual signal

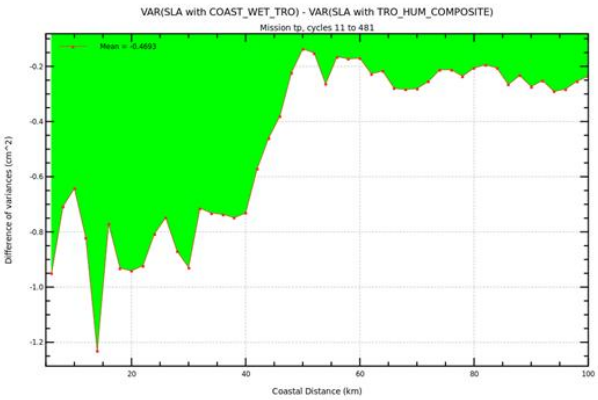


SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase : semi-annual signal



Performances in coastal areas

In terms of SLA variance, GPD correction is better than the reference one in coastal areas :



Variance differences of SLA versus coastal distances between GPD and TRO_HUM_COMPOSITE

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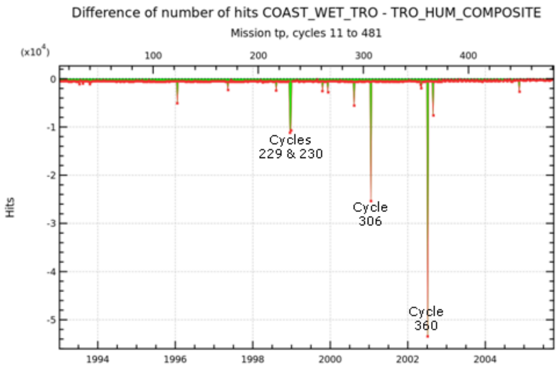
About availability valid measurements…



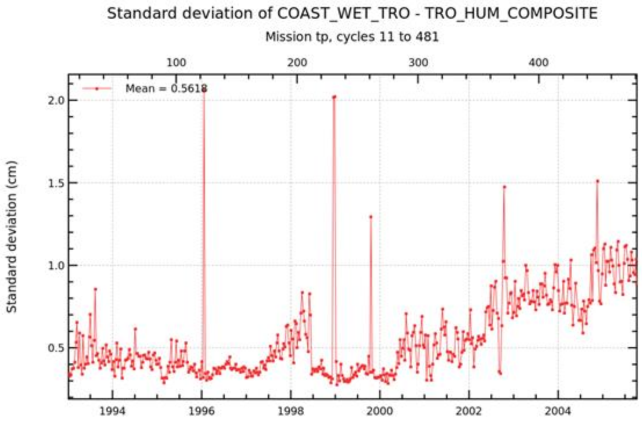
This figure shows the number difference between the two corrections calculated <u>globally</u> by cycle.

Concerning TRO_HUM_COMPOSITE, it's the number of valid measurements with our validity flag

Concerning COAST_WET_TRO, it's the number of valid measurements with our validity flag and validity flag of gpd equal to 0 or 1 :
0 = point for which the radiometer correction (rad_wet_tropo_cor) is valid - for these points wet_GPD=rad_wet_tropo_cor
1 = wet_GPD is a valid estimate

→ For all cycles, the number of measurements is close (slightly less with GPD), but they are missing GPD measurements for cycles 229, 230, 306 and 360 (< 10000 values)

About remaining spurious GPD values



This figure shows the standard deviation difference between the two corrections calculated <u>globally</u> by cycle.
To be noted a strong impact for 5 cycles. The cycle numbers are 123, 231, 261, 371 and 443.

For all cycles and mainly cycles noted above, some values of COAST_WET_TRO are out of threshold (see next slide) :

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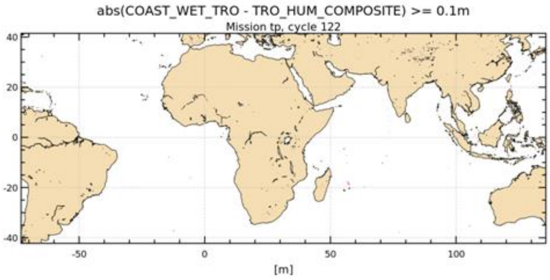
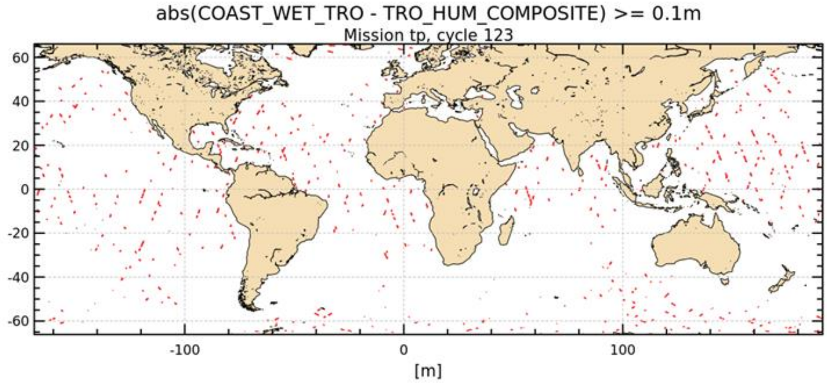
About remaining spurious GPD values



ABS(COAST_WET_TRO - TRO_HUM_COMPOSITE)	Cycle 122	Cycle 123
Values number >= 0.1m	3	2468



Wet tropospheric correction comparison for Topex mission

To conclude:

• GPD correction is better than the reference one used in AVISO products:
⇒ Better performances at crossovers and improvement of the regional MSL trends particularly in Indian Ocean and from cycle
⇒ However spurious measurements are probably remaining in GPD correction for few cycles(see Annex) and missing measurements have also been detected for few cycles

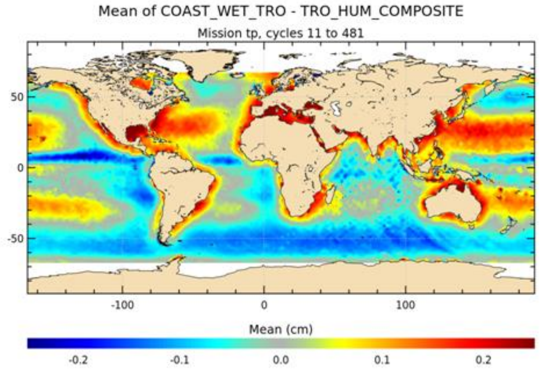
• Anomalies with tape recorder occurred from cycle 370 of TOPEX mission . They produced missing measurements especially in this Indian ocean. A second effect has been also observed on the TOPEX radiometer wet troposphere correction which is degraded close to data gaps (due to interpolation anomaly).
⇒ The new correction (GPD) allows us to take into account these interpolation problem using the ECMWF model instead of the radiometer data.

Topex		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

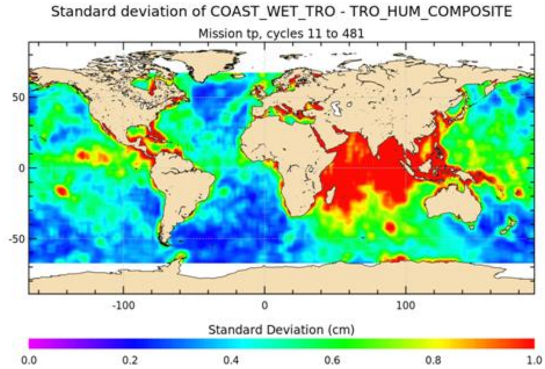
Wet tropospheric correction comparison for Topex mission

APPENDICES : some additional plots…

Few maps of statistic differences…



⇒ Map of <u>Mean differences</u> between **COAST_WET_HUM** and **TRO_HUM_COMPOSITE** (ALL PERIOD)
On this map we observe clearly the differences near coast.



⇒ Map of <u>Standard deviation differences</u> between **COAST_WET_TRO** and **TRO_HUM_COMPOSITE** (ALL PERIOD)
On this map we observe clearly the differences in Indian ocean due to anomalies with tape recorder especially in this region

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8. Annex 4: Comparison of GPD and AVISO wet troposphere corrections for ERS-1 mission

Wet tropospheric correction comparison for ERS-1 mission between GPD (FCUP) and reference (AVISO) correction

The GPD correction is called : COAST_WET_TRO in the following study
The Reference correction is called : TRO_HUM_COMPOSITE (it corresponds to the correction used in AVISO products)

David Alexandre, Michael Ablain (CLS)

Wet tropospheric correction comparison for ERS-1 mission

Introduction:

• We will observe and analyse the impact of the GPD (COAST_WET_TRO) wet tropospheric correction ERS-1 from FCUP for climate applications

• We will compare this correction with the reference wet tropospheric correction used in AVISO products noticed TRO_HUM_COMPOSITE in this presentation

• In order to determine the impact of the new wet tropospheric correction in terms of climate applications and temporal scales, we will try in this study to indicate for each impact detected if it's a positive (+) or a negative (-) impact :

Low impact

Significant impact

No impact detected

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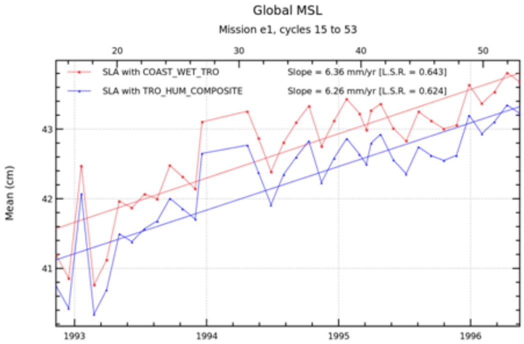
Global Mean Sea Level

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

⇒ 0.1 mm/yr on the Global MSL is very low (especially over a 4-year period).
(see figure below)



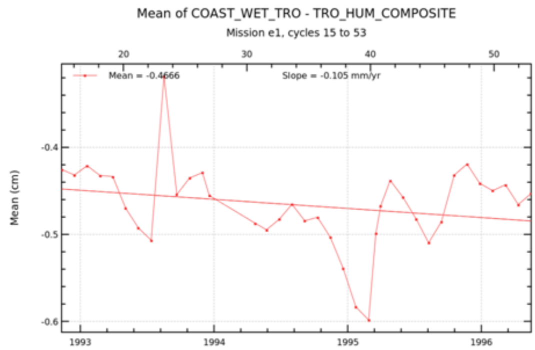
Temporal evolution of SLA mean calculated globally.

Global Mean Sea Level

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Inter annual Signals

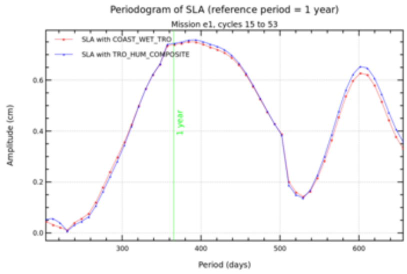
⇒ The figure below shows the mean difference between the two corrections calculated globally by cycle.

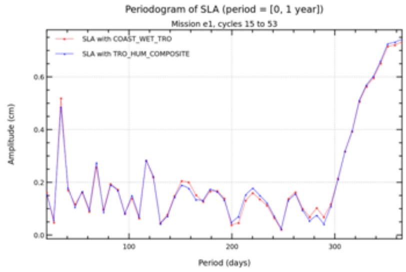


Global Mean Sea Level

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP)
		COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals





Mesoscale

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP)
		COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

Strong impact detected on a short temporal scale (signals < 2 months):

⇒Crossovers Variance Differences are generally negative (see figures on next slide) between 0 and -2 cm² : this means that the new GDP correction is better than the reference one. Few isolated values are positive : it might corresponds probably to spurious GPD correction (like for GPD correction provided for Topex mission).

⇒ The map of SSH crossovers Variance Differences shows that this improvement is especially near coasts but also on large ocean. In fact several blue structures are observed on large ocean.

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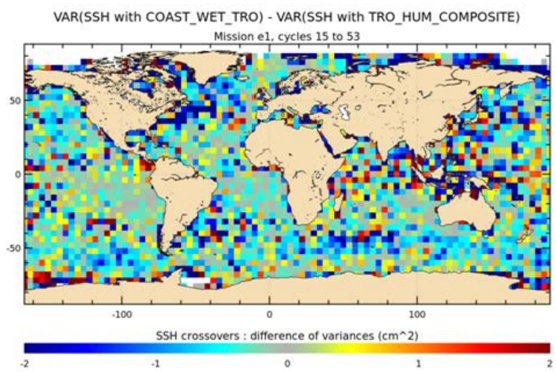
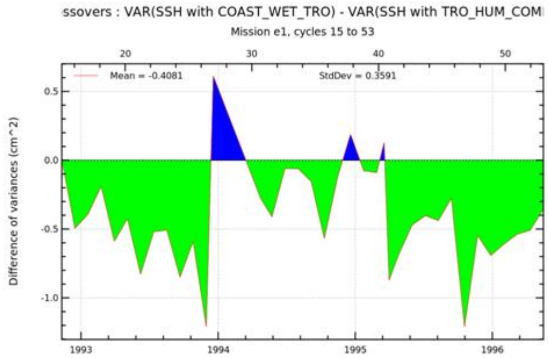
Mesoscale



⇒ Map of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE (over all the period)

⇒ Temporal evolution of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE



Regional Mean Sea Level

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Significant impact detected on Regional Mean Sea Level

⇒ We observe a significant impact (between 0.2 and 1 mm/yr) especially in coast areas but keep in mind the period study is very short : only 4 years !!!

⇒ it's likely an improvement of the regional trends because the SSH crossovers analyses clearly highlight an improvement of the SSH in these coast areas.

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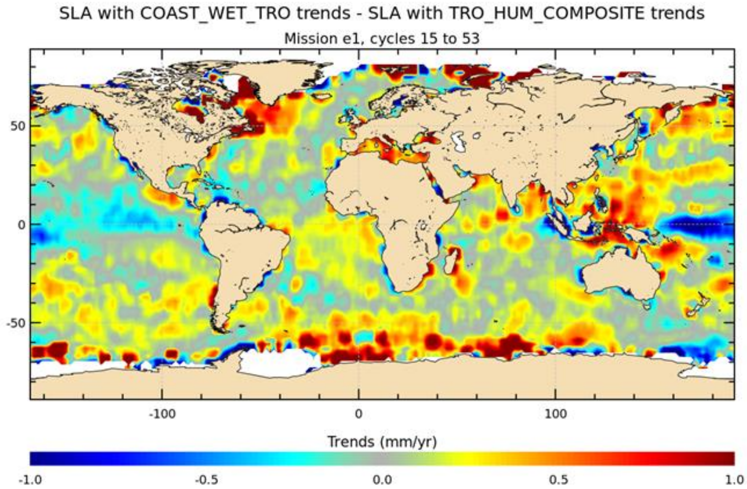
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences between GPD and TRO_HUM_COMPOSITE (over all the period)



Regional Mean Sea Level

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

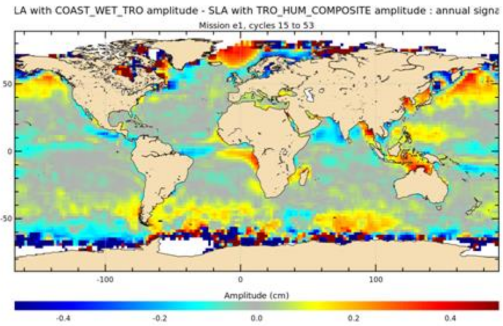
⇒ It's not possible to determine which correction is the best one for theses scales

Regional Mean Sea Level

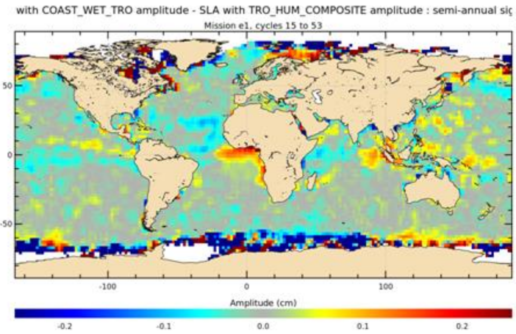
⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : annual signal



SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : semi-annual signal



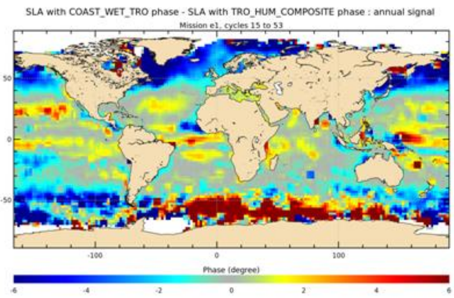
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

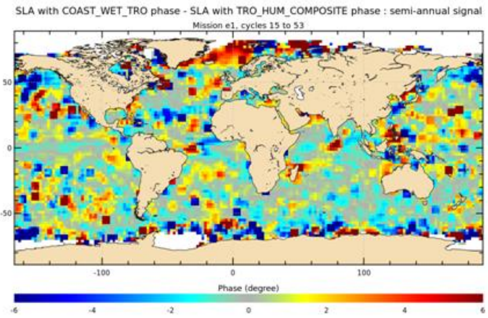
⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month

SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase: annual signal

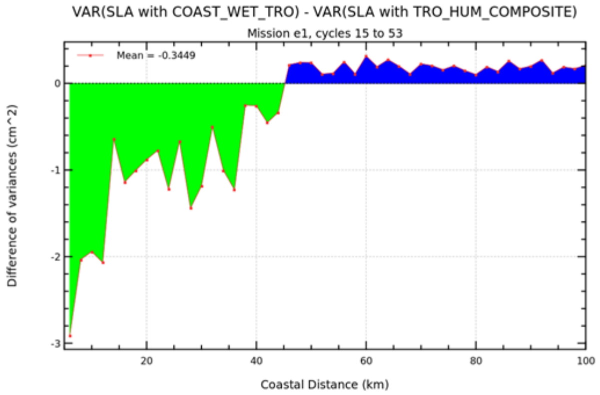


SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase : semi-annual signal



Performances in coastal areas

In terms of SLA variance, GPD correction is better than the reference one in coastal areas :
(to be noted only for coastal distance < 50 km)



Variance differences of SLA versus coastal distances between GPD and TRO_HUM_COMPOSITE

Wet tropospheric correction comparison for ERS-1 mission

To conclude:

• GPD correction is better than the reference one used in AVISO products:

⇒ Better performances at crossovers are clearly observed near coasts and on large ocean in some areas. Caution, performances are degraded at crossovers for 3 isolated cycles : it's probably due to spurious GPD correction as observed for TOPEX mission (but not demonstrated in this study).

⇒ A significant impact on the regional MSL trends in coast areas which is likely ad improvement due the reduction of variance at SSH crossovers in these coast areas. Caution should be exercised to analyse these results because the period is very short : only 4 years of data ERS-1 !

⇒ Finally, the analysis of SLA variance differences versus the coastal distance confirms a strong improvement with GPD correction near coasts but only for coastal distances inferior to 50 km. For coastal distances included between 50 and 100 km, the reference one used in AVISO products is very slightly better.

ERS-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

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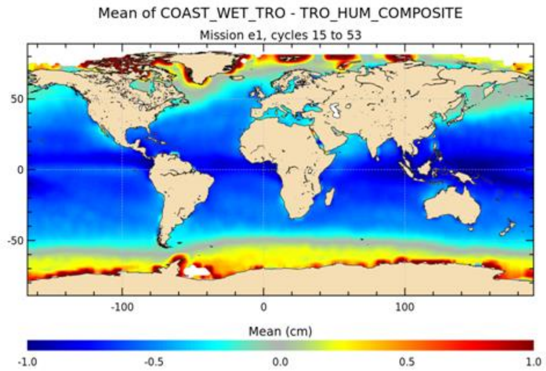
Wet tropospheric correction comparison for ERS-1 mission

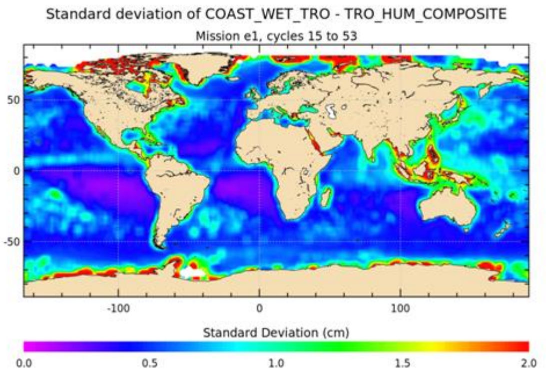
APPENDICES : some additional plots…

Few maps of statistic differences…



⇒ Map of Mean differences between **COAST_WET_HUM** and **TRO_HUM_COMPOSITE** (ALL PERIOD)

⇒ Map of Standard deviation differences between **COAST_WET_TRO** and **TRO_HUM_COMPOSITE** (ALL PERIOD)



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9. Annex 5: Comparison of GPD and AVISO wet troposphere corrections for ERS-2 mission

Wet tropospheric correction comparison for ERS-2 mission between GPD (FCUP) and reference (AVISO) correction

The GPD correction is called : COAST_WET_TRO in the following study
The Reference correction is called : TRO_HUM_COMPOSITE (it corresponds to the correction used in AVISO products)

David Alexandre, Michael Ablain (CLS)

Wet tropospheric correction comparison for ERS-2 mission

Introduction:

• We will observe and analyse the impact of the GPD (COAST_WET_TRO) wet tropospheric correction ERS-2 from FCUP for climate applications

• We will compare this correction with the reference wet tropospheric correction used in AVISO products noticed TRO_HUM_COMPOSITE in this presentation

• In order to determine the impact of the new wet tropospheric correction in terms of climate applications and temporal scales, we will try in this study to indicate for each impact detected if it's a positive (+) or a negative (-) impact :

Low impact

Significant impact

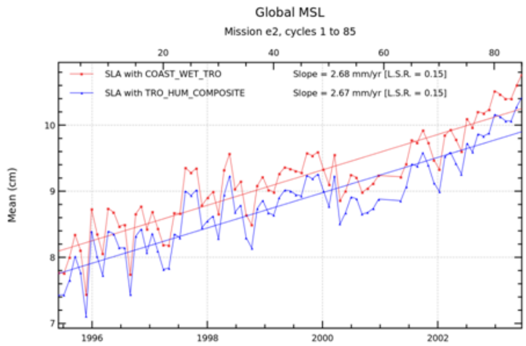
No impact detected

Global Mean Sea Level

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

⇨ 0.01 mm/yr on the Global MSL is very low (especially over a 9-year period).
(see figure below)



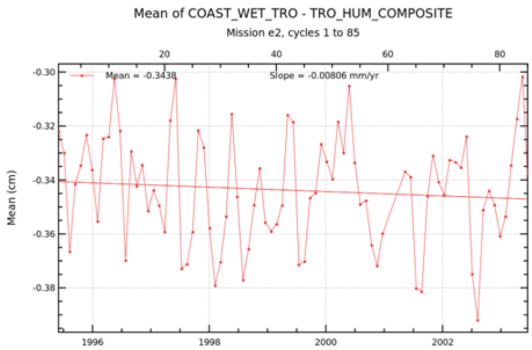
Temporal evolution of SLA mean calculated globally.

Global Mean Sea Level

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Inter annual Signals

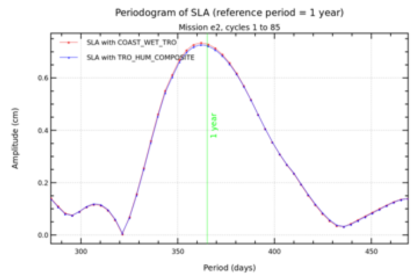
⇨ The figure below shows the mean difference between the two corrections calculated globally by cycle.
⇨ We observed inter annual signals slightly marked.

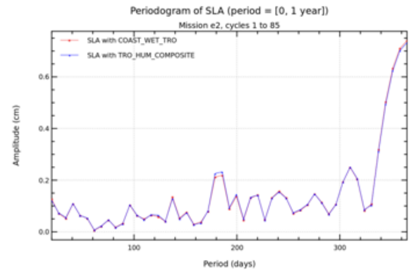


Global Mean Sea Level

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals





Mesoscale

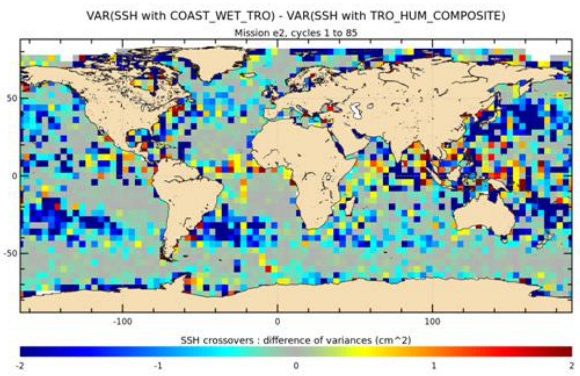
ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

Low impact detected on a short temporal scale (signals < 2 months):

⇒ Crossovers Variance Differences are generally negative (see figures on next slide) between 0 and -2 cm² : this means that the new GDP correction is better than the reference one.

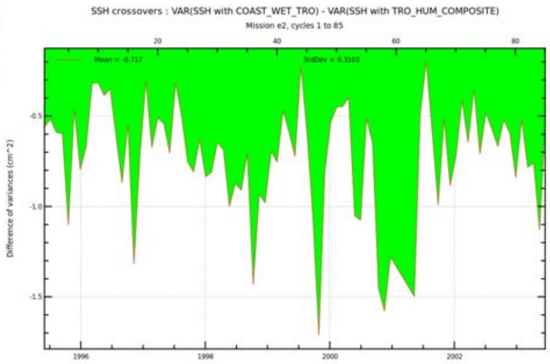
⇒ The map of SSH crossovers Variance Differences shows that these improvement are concentrated in several zones (see blue structures on next slide map)

Mesoscale



⇒ Map of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE (over all the period)

⇒ Temporal evolution of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE



Regional Mean Sea Level

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

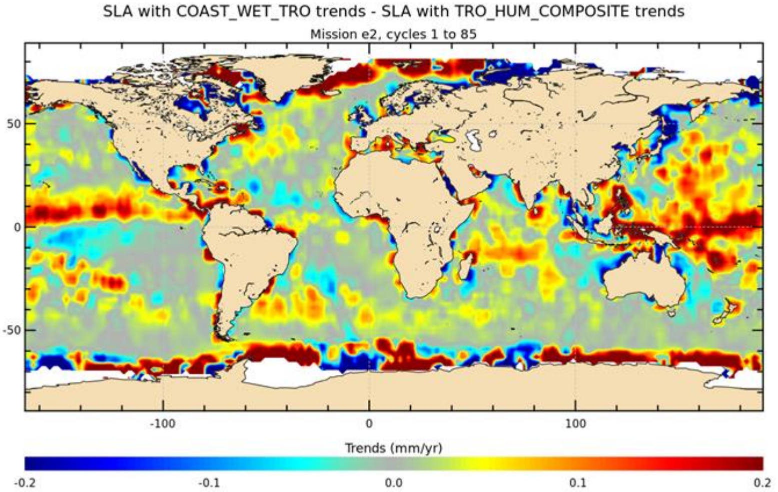
Significant impact detected on Regional Mean Sea Level

⇒We observe a strong impact (between 0.2 and 1 mm/yr) in several areas.

⇒ it's likely an improvement of the regional trends because the SSH crossovers analyses clearly highlight a strong improvement of the SSH in this several areas.

Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences between GPD and TRO_HUM_COMPOSITE (over all the period)



Regional Mean Sea Level

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

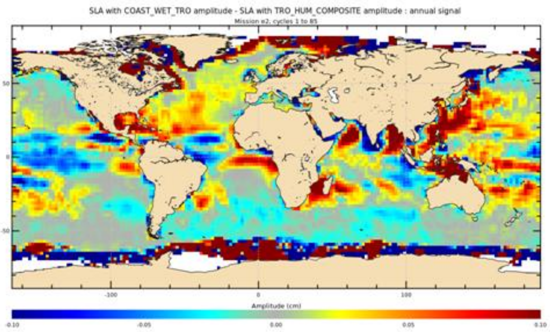
⇒ It's not possible to determine which correction is the best one for theses scales

Regional Mean Sea Level

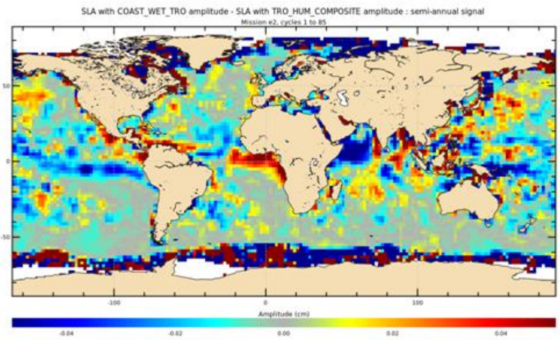
⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : annual signal



SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : semi-annual signal



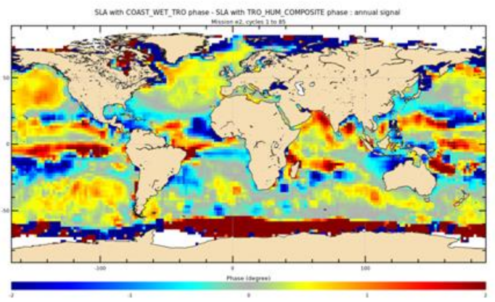
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

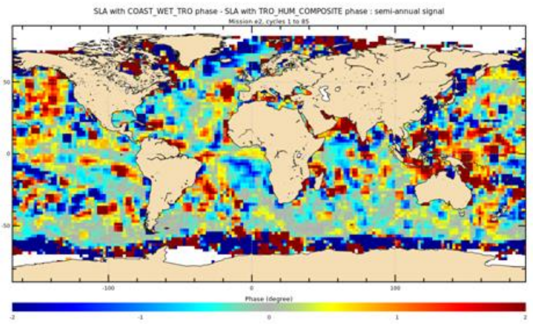
⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month

SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase: annual signal

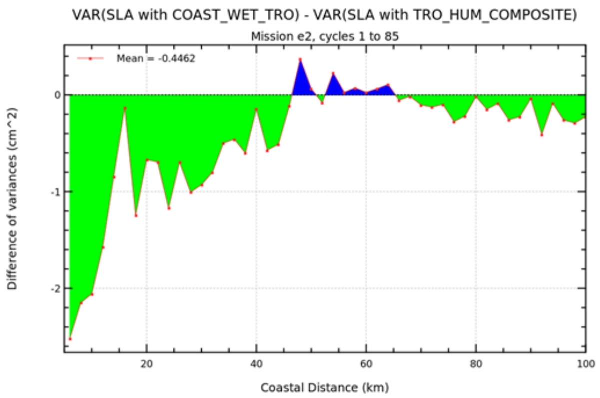


SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase : semi-annual signal



Performances in coastal areas

In terms of SLA variance, GPD correction is generally better than the reference one in coastal areas : (to be noted a strange behavior for coastal distance between 45 and 65 km)



Variance differences of SLA versus coastal distances between GPD and TRO_HUM_COMPOSITE

Wet tropospheric correction comparison for ERS-2 mission

To conclude:

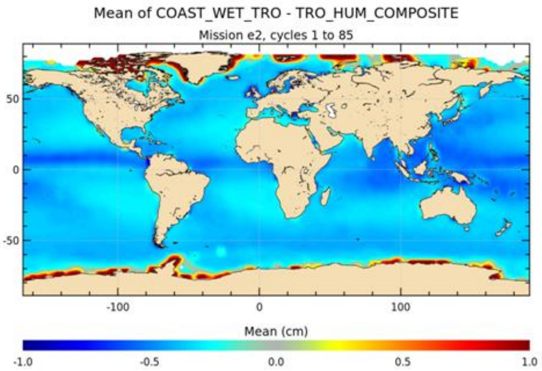
• GPD correction is better than the reference one used in AVISO products:
⇒ Better performances at crossovers and improvement of the regional MSL trends

ERS-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_COMPOSITE**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	+

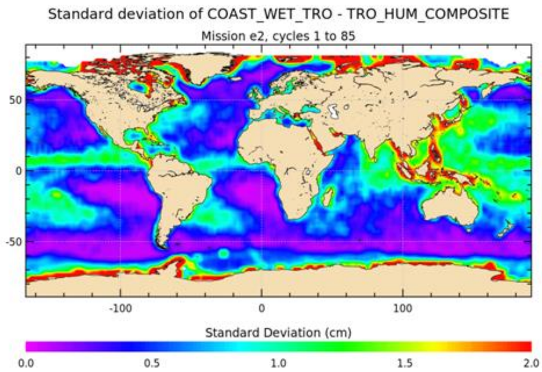
Wet tropospheric correction comparison for ERS-2 mission

APPENDICES : some additional plots…

Few maps of statistic differences…



⇒ Map of Mean differences between **COAST_WET_HUM** and **TRO_HUM_COMPOSITE** (ALL PERIOD)



⇒ Map of Standard deviation differences between **COAST_WET_TRO** and **TRO_HUM_COMPOSITE** (ALL PERIOD)

10. Annex 6: Comparison of GPD and AVISO wet troposphere corrections for Jason-1 mission

Wet tropospheric correction comparison for Jason-1 mission between GPD (FCUP) and reference (AVISO) correction

The GPD correction is called : COAST_WET_TRO in the following study
The Reference correction is called :TRO_HUM_COMPOSITE (it corresponds to the correction used in AVISO products)

David Alexandre, Michael Ablain (CLS)

Wet tropospheric correction comparison for Jason-1 mission

Introduction:

• We will observe and analyse the impact of the GPD (COAST_WET_TRO) wet tropospheric correction Jason-1 from FCUP for climate applications

• We will compare this correction with the reference wet tropospheric correction used in AVISO products noticed TRO_HUM_COMPOSITE in this presentation

• In order to determine the impact of the new wet tropospheric correction in terms of climate applications and temporal scales, we will try in this study to indicate for each impact detected if it's a positive (+) or a negative (-) impact :

Low impact
Significant impact
No impact detected

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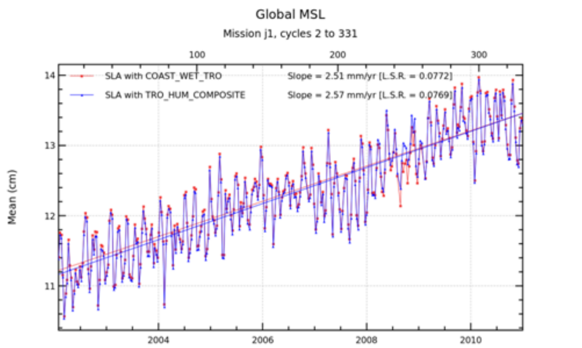
Global Mean Sea Level

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

⇒ 0.06 mm/yr on the Global MSL is very low (especially over a 9-year period).
(see figure below)



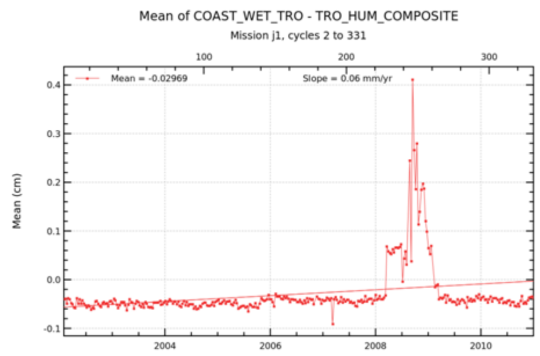
Temporal evolution of SLA mean calculated globally.

Global Mean Sea Level

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Inter annual Signals

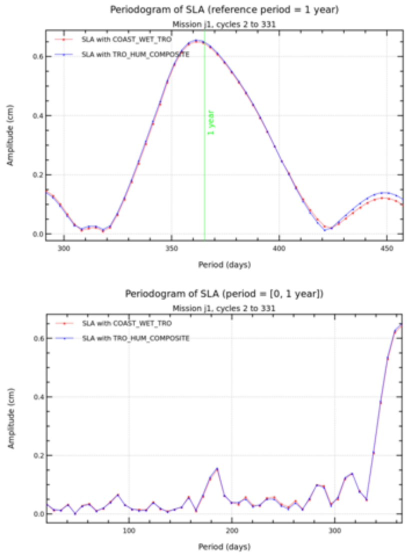
⇒ The figure below shows the mean difference between the two corrections calculated globally by cycle.
⇒ Notice that the signal observed on 2008-2009 highlight the improvement of the Jason-1 enhancement products used in GPD correction (in RADS) and not used in CCI WTC in release1, this signal is not due directly to the GPD correction.



Global Mean Sea Level

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals



Mesoscale

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

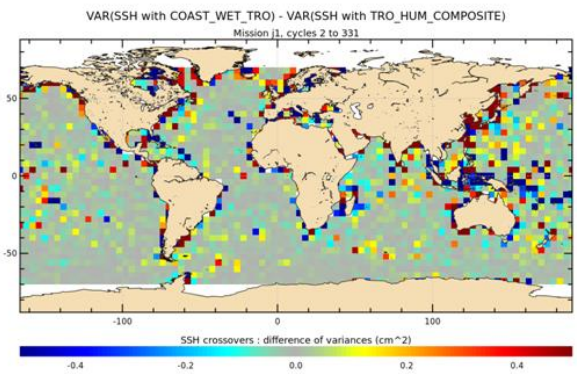
Low impact detected on a short temporal scale (signals < 2 months):

⇒ Crossovers Variance Differences are alternatively negative and positive (see figures on next slide) between 0.5 and -0.5 cm² : this indicator can't help us to determine which solution is the best (see annex).

⇒ The map of SSH crossovers Variance Differences shows that the impact is more stronger near coast but that's also difficult to determine the best solution. The two solutions seems very similar at mesoscale.

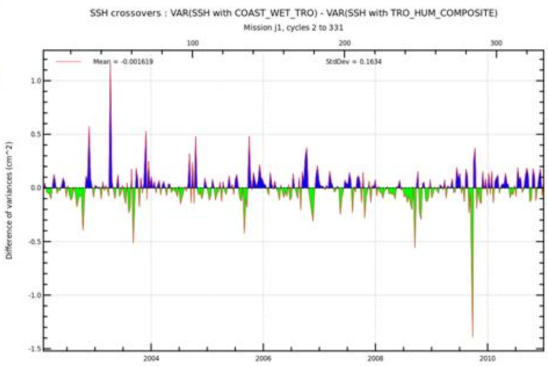
⇒ The map of SLA variance differences (see figure on next slide) shows generally an improvement near coasts particularly in Indonesia and Caribbean regions.

Mesoscale



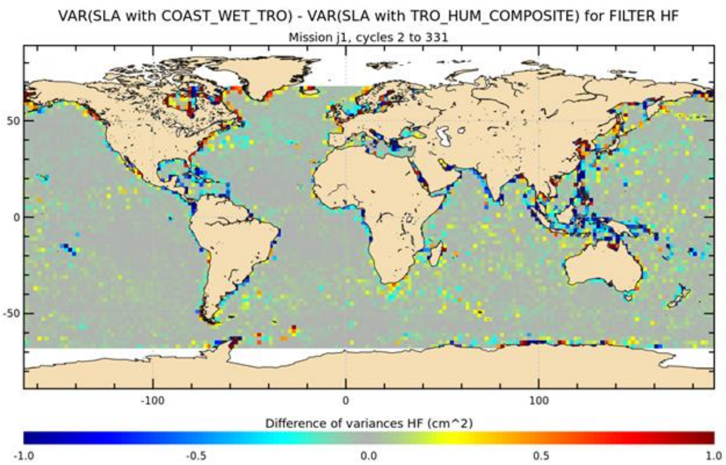
⇒ Map of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE (over all the period)

⇒ Temporal evolution of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_COMPOSITE



Mesoscale

⇒ Map of SLA variance differences between the two corrections selecting temporal signal lower than 2 months:
- Improvement in Indonesia area and in Caribbean sea



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Regional Mean Sea Level

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

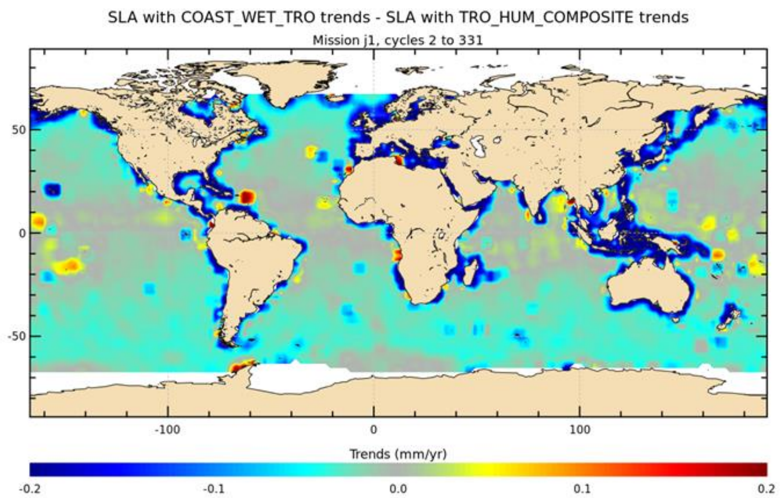
Significant impact detected on Regional Mean Sea Level

⇒ We observe a strong positive impact on the regional trends near coast and a low positive impact in offshore ocean

⇒ To be noted few structures of positive values appear (see next slide)

Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences between GPD and TRO_HUM_COMPOSITE (over all the period)



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Regional Mean Sea Level

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

⇒ Amplitude differences are lower than 0.5 cm for annual signal (see figures on next slide) and 0.25 cm for semi-annual signal.

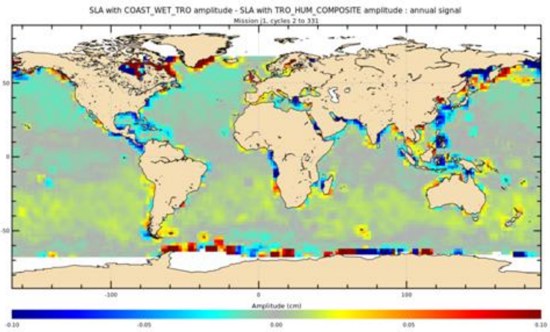
⇒ It's not possible to determine which correction is the best one for theses scales

Regional Mean Sea Level

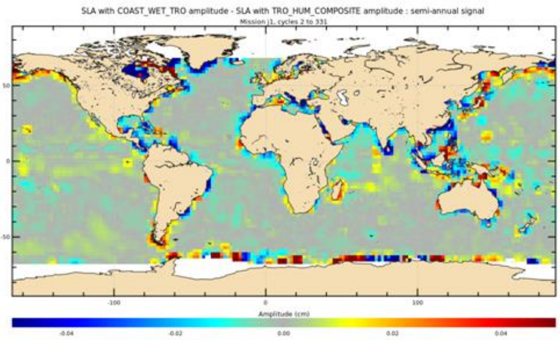
⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : annual signal



SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_COMPOSITE amplitude : semi-annual signal



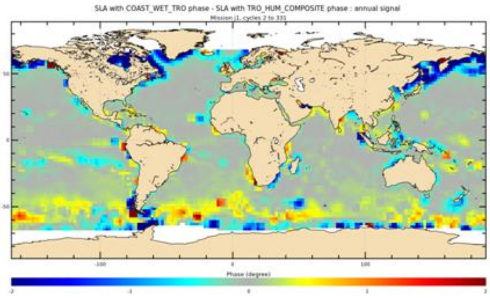
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

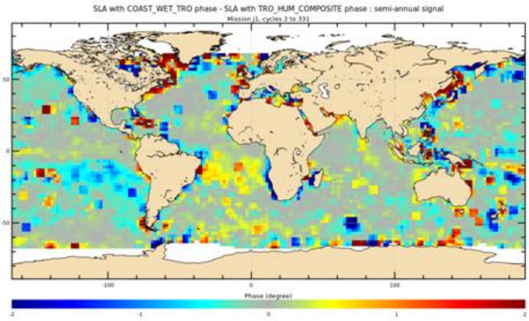
⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month

SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase: annual signal

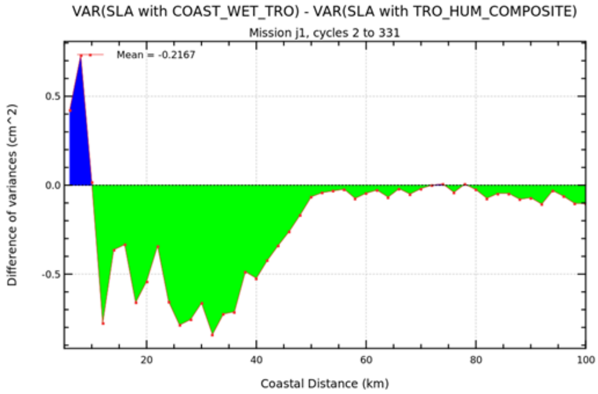


SLA with COAST_WET_TRO phase – SLA with TRO_HUM_COMPOSITE phase : semi-annual signal



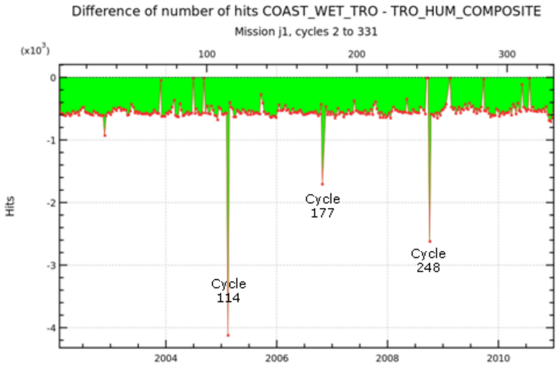
Performances in coastal areas

In terms of SLA variance, GPD correction is better than the reference one in coastal areas :
(to be noted a strange behavior for coastal distance < 10 km)



Variance differences of SLA versus coastal distances between GPD and TRO_HUM_COMPOSITE

About availability valid measurements…



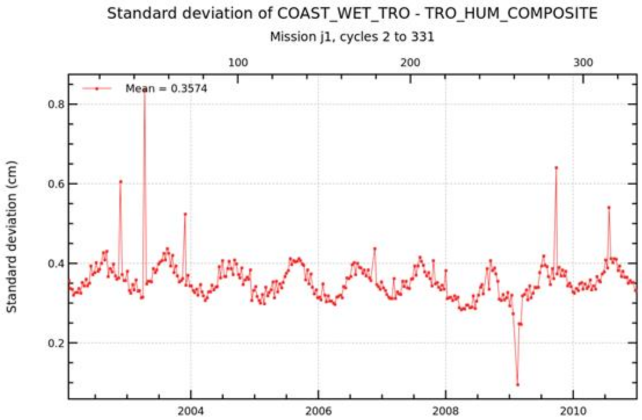
This figure shows the number difference between the two corrections calculated globally by cycle.

Concerning TRO_HUM_COMPOSITE, it's the number of valid measurements with our validity flag

Concerning COAST_WET_TRO, it's the number of valid measurements with our validity flag and validity flag of gpd equal to 0 or 1 :
0 = point for which the radiometer correction (rad_wet_tropo_cor) is valid - for these points wet_GPD=rad_wet_tropo_cor
1 = wet_GPD is a valid estimate

→ For all cycles, the number of measurements is close (slightly less with GPD), but they are missing GPD measurements for cycles 114, 177 and 248 (< 1000 values)

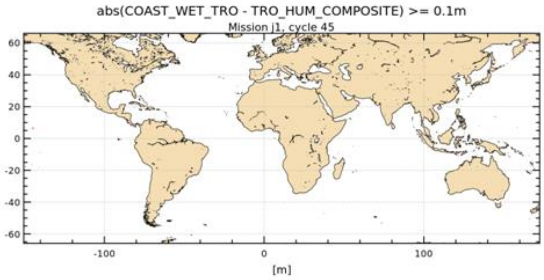
About remaining spurious GPD values



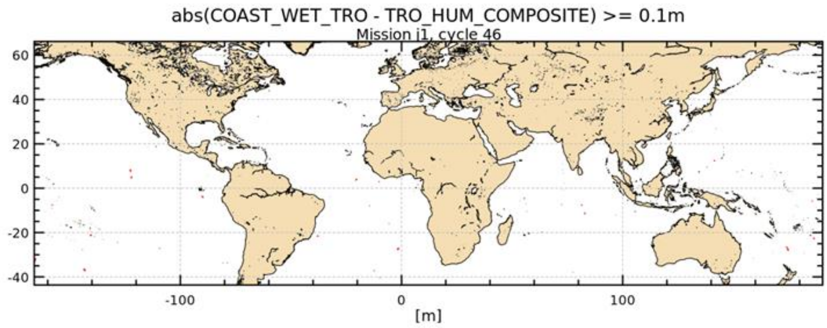
This figure shows the standard deviation difference between the two corrections calculated globally by cycle.
To be noted a strong impact for 6 cycles. The cycle numbers are 32, 46, 69, 262, 284 and 315.

For all cycles and mainly cycles noted above, some values of COAST_WET_TRO are out of threshold (see next slide) :

About remaining spurious GPD values



ABS(COAST_WET_TRO - TRO_HUM_COMPOSITE)	Cycle 45	Cycle 46
Values number >= 0.1m	5	98



Wet tropospheric correction comparison for Jason-1 mission

To conclude:

• GPD correction is better than the reference one used in AVISO products particularly near coasts:
⇒ Improvement of the regional MSL trends
⇒ However spurious measurements are probably remaining in GPD correction for few cycles

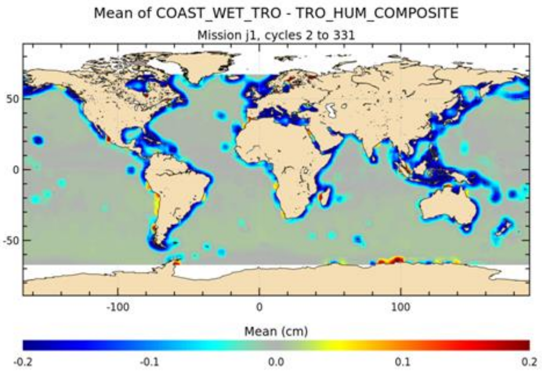
⇒ Notice that the signal observed on 2008-2009 (slide 4) highlight the improvement of the Jason-1 enhancement products used in GPD correction (in RADS) and not used in CCI WTC in release1, this signal is not due directly to the GPD correction.

Jason-1		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_COMPOSITE
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	+
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

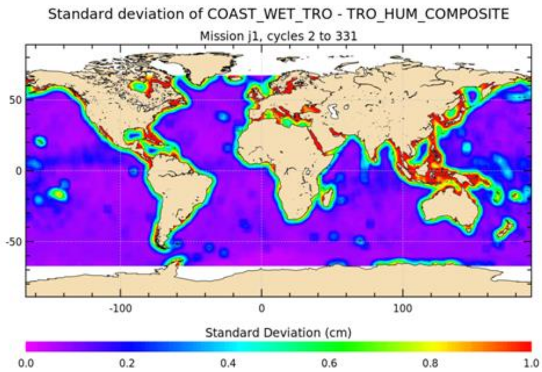
Wet tropospheric correction comparison for Jason-1 mission

APPENDICES : some additional plots…

Few maps of statistic differences…



⇒ Map of Mean differences between **COAST_WET_HUM** and **TRO_HUM_COMPOSITE** (ALL PERIOD)
On this map we observe clearly the differences near coast.



⇒ Map of Standard deviation differences between **COAST_WET_TRO** and **TRO_HUM_COMPOSITE** (ALL PERIOD)
On this map we observe clearly the differences in Indian ocean due to anomalies with tape recorder especially in this region

11. Annex 7: Comparison of GPD and AVISO wet troposphere corrections for Jason-2 mission

Wet tropospheric correction comparison for Jason-2 mission between GPD (FCUP) and reference (AVISO) correction

The GPD correction is called : COAST_WET_TRO in the following study
The Reference correction is called : TRO_HUM_RAD (it corresponds to the correction used in AVISO products)

David Alexandre, Michael Ablain (CLS)

Wet tropospheric correction comparison for Jason-2 mission

Introduction:

• We will observe and analyse the impact of the GPD (COAST_WET_TRO) wet tropospheric correction Jason-2 from FCUP for climate applications

• We will compare this correction with the reference wet tropospheric correction used in AVISO products noticed TRO_HUM_RAD in this presentation

• In order to determine the impact of the new wet tropospheric correction in terms of climate applications and temporal scales, we will try in this study to indicate for each impact detected if it's a positive (+) or a negative (-) impact :

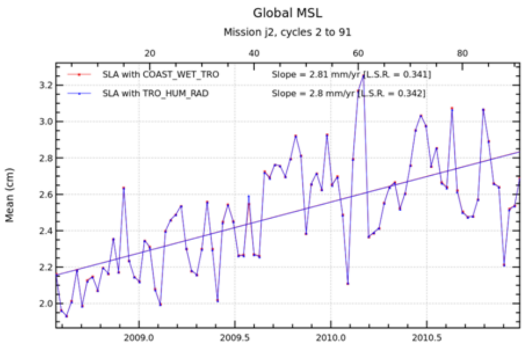
Low impact
Significant impact
No impact detected

Global Mean Sea Level

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_RAD
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Global Mean Sea Level trend

⇒ only 0.01 mm/yr difference on the Global MSL (see figure below)



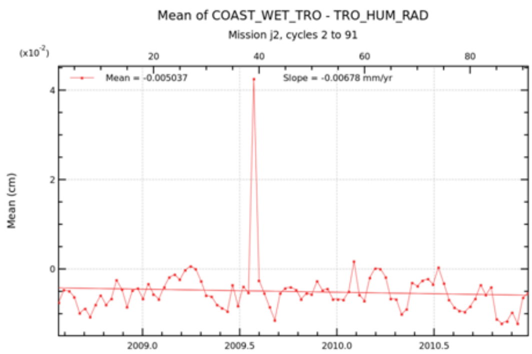
Temporal evolution of SLA mean calculated globally.

Global Mean Sea Level

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_RAD
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Inter annual Signals

⇒ The figure below shows the mean difference between the two corrections calculated globally by cycle.

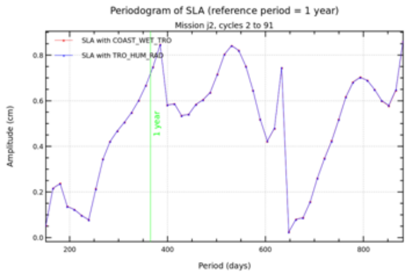


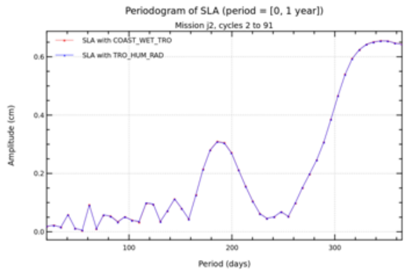
⇒ To be noted a strange behaviour on cycle 39 (see slide about remaining spurious GPD values).

Global Mean Sea Level

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_RAD**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

No impact detected on Annual and Semi-annual Signals





Mesoscale

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_RAD**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

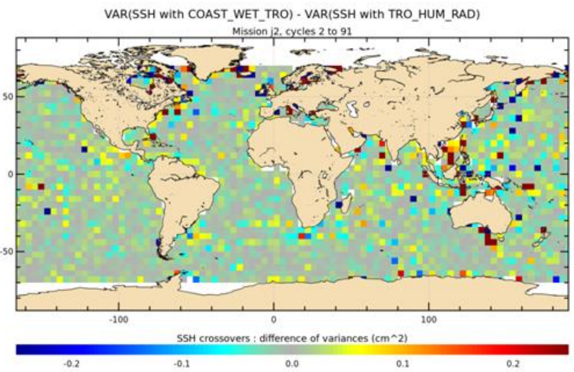
Low impact detected on a short temporal scale (signals < 2 months):

⇒ Crossovers Variance Differences are alternatively negative and positive (see figures on next slide) between 0.2 and -0.2 cm² : this means that the new GDP correction is equivalent to the reference one.

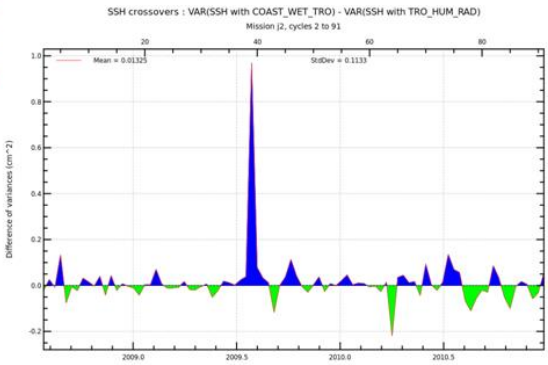
⇒ The map of SSH crossovers Variance Differences shows a light degradation in Indonesia area related to spurious GPD correction (see annex)

⇒ The map of SLA variance differences (see figure on next slide) confirms a light degradation of SSH consistency in the same area but only for one pass.

Mesoscale



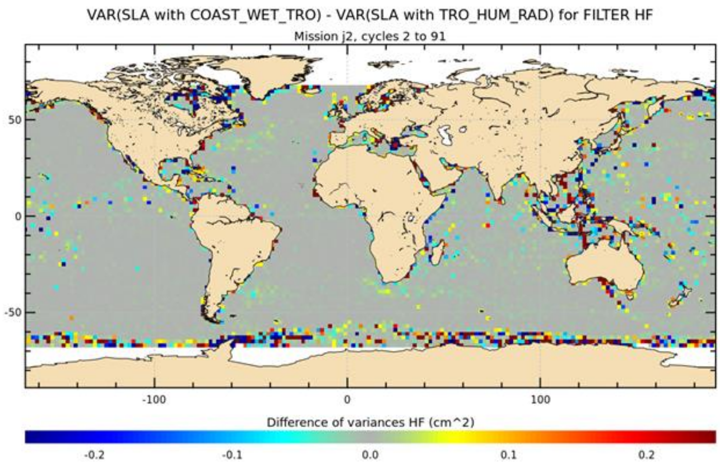
⇒ Map of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_RAD (over all the period):
- A light degradation in Indonesia area



⇒ Temporal evolution of Variance differences of Sea Surface Height at crossovers between GPD and TRO_HUM_RAD:
- No one is better

Mesoscale

⇒ Map of SLA variance differences between the two corrections selecting temporal signal lower than 2 months:
- Improvement in Indonesia area except for a pass



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Regional Mean Sea Level

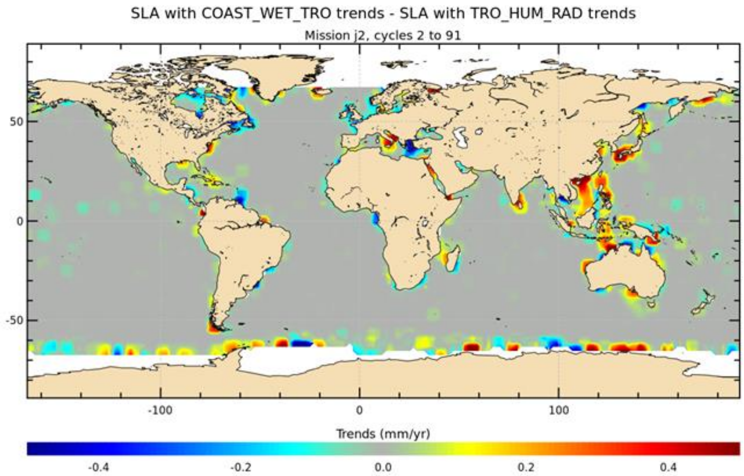
Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_RAD**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	??
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

?? impact detected on Regional Mean Sea Level

⇒ We observe a ?? impact

Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences between GPD and TRO_HUM_RAD (over all the period)



Regional Mean Sea Level

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) **COAST_WET_TRO Versus TRO_HUM_RAD**
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

Low impact detected on Annual and Semi-Annual Signals

⇒ Amplitude differences are lower than 0.10 cm for annual signal (see figures on next slide) and 0.05 cm for semi-annual signal.

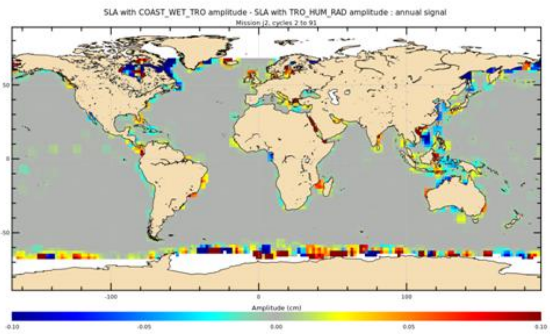
⇒ It's not possible to determine which correction is the best one for theses scales

Regional Mean Sea Level

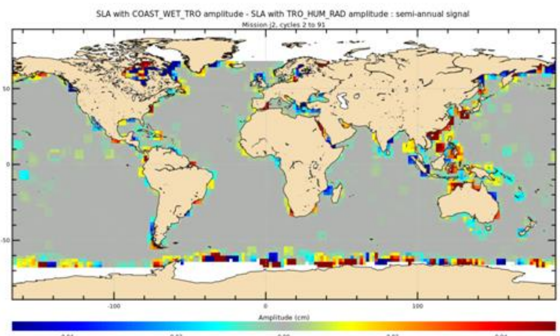
⇒ Map of Sea Level Anomaly differences **amplitude** for **annual signal**

⇒ Map of Sea Level Anomaly differences **amplitude** for **semi-annual signal**

SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_RAD amplitude : annual signal



SLA with COAST_WET_TRO amplitude – SLA with TRO_HUM_RAD amplitude : semi-annual signal



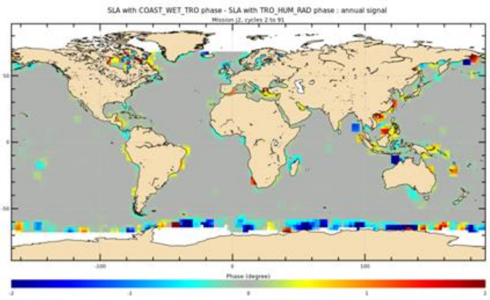
Regional Mean Sea Level

⇒ Map of Sea Level Anomaly differences **phase** for **annual signal**.

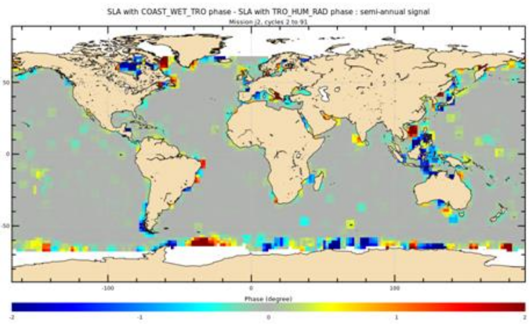
⇒ Map of Sea Level Anomaly differences **phase** for **semi-annual signal**.

To be noted a phase value equal to 30° corresponds to a period of one month

SLA with COAST_WET_TRO phase – SLA with TRO_HUM_RAD phase: annual signal

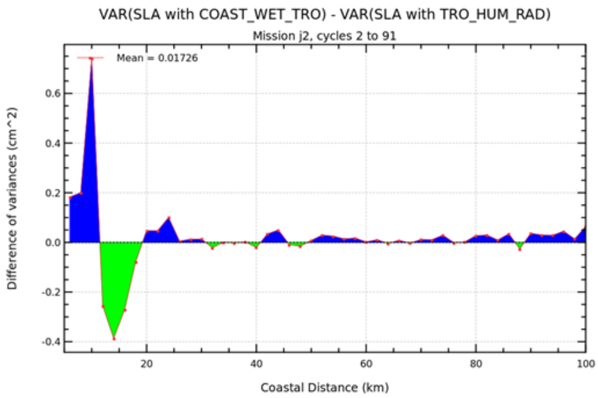


SLA with COAST_WET_TRO phase – SLA with TRO_HUM_RAD phase : semi-annual signal



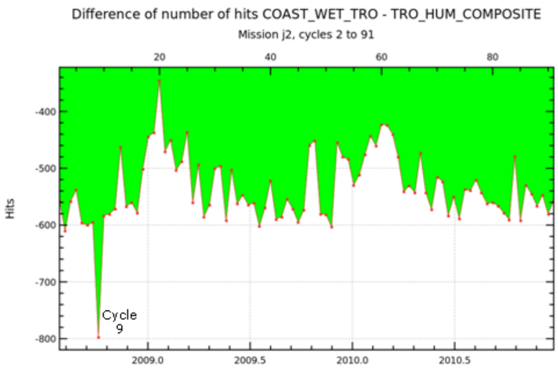
Performances in coastal areas

In terms of SLA variance, GPD correction is clearly better than the reference for coastal distance is inferior to 20 km :



Variance differences of SLA versus coastal distances between GPD and TRO_HUM_RAD

About availability valid measurements…



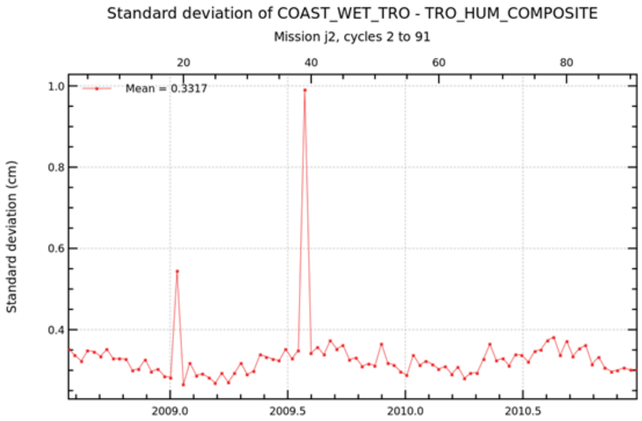
This figure shows the number difference between the two corrections calculated globally by cycle.

Concerning TRO_HUM_COMPOSITE, it's the number of valid measurements with our validity flag

Concerning COAST_WET_TRO, it's the number of valid measurements with our validity flag and validity flag of gpd equal to 0 or 1 :
0 = point for which the radiometer correction (rad_wet_tropo_cor) is valid - for these points wet_GPD=rad_wet_tropo_cor
1 = wet_GPD is a valid estimate

→ For all cycles, the number of measurements is close (slightly less with GPD), but they are missing GPD measurements for cycle 9 (< 600 values)

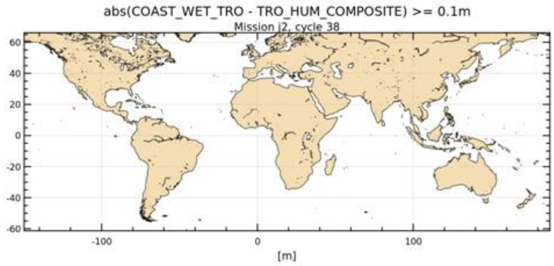
About remaining spurious GPD values



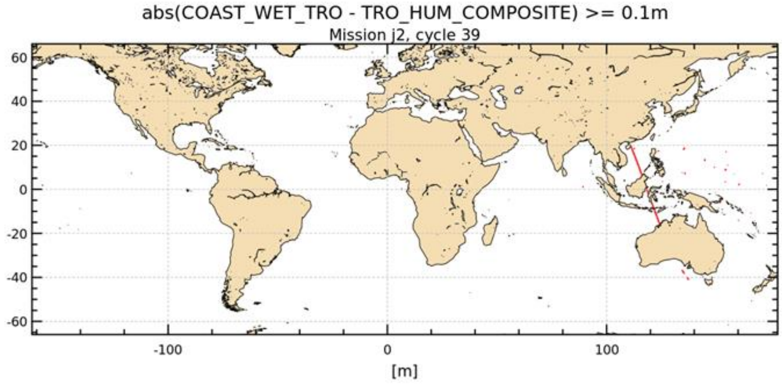
This figure shows the standard deviation difference between the two corrections calculated globally by cycle.
To be noted a strong impact for 2 cycles. The cycle numbers are 19 and 39.

For all cycles and mainly cycles noted above, some values of COAST_WET_TRO are out of threshold (see next slide) :

About remaining spurious GPD values



ABS(COAST_WET_TRO - TRO_HUM_COMPOSITE)	Cycle 38	Cycle 39
Values number >= 0.1m	40	582



Wet tropospheric correction comparison for Jason-2 mission

To conclude:

• GPD correction is equivalent than the reference one used in AVISO products:

⇒ Few better performances at crossovers particularly in Indonesia area

⇒ However spurious measurements are probably remaining in GPD correction for few cycles and missing measurements have also been detected for few cycles

Jason-2		
Climate Applications	Temporal Scales	Round Robin Data Package (RRDP) COAST_WET_TRO Versus TRO_HUM_RAD
Global Mean Sea Level	Long-term evolution (trend)	
	Inter annual signals (> 1 year)	
	Annual and semi-annual Signals	
Regional Mean Sea Level	Long-term evolution (trend)	??
	Annual and semi-annual Signals	
Mesoscale	Signals < 2 months	

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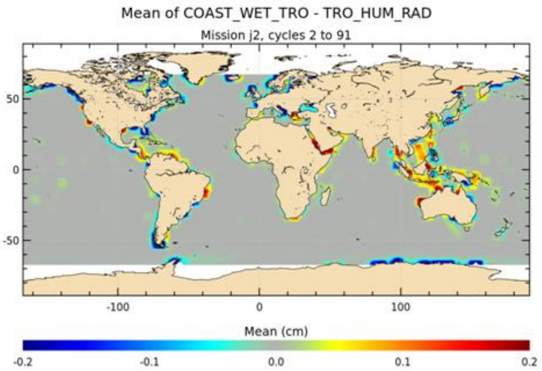
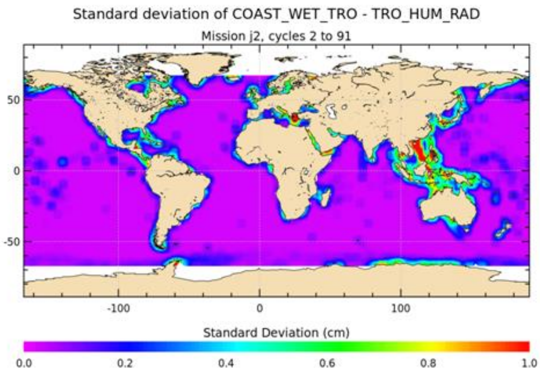
Wet tropospheric correction comparison for Jason-2 mission

APPENDICES : some additional plots...

Few maps of statistic differences...



⇒ Map of Mean differences between **COAST_WET_HUM** and **TRO_HUM_RAD** (ALL PERIOD)
On this map we observe clearly the differences near coast.



⇒ Map of Standard deviation differences between **COAST_WET_TRO** and **TRO_HUM_RAD** (ALL PERIOD)
On this map we observe clearly the differences in Indian ocean due to anomalies with tape recorder especially in this region