Consortium Members

ESA Sea Level CCI

D2.1 Product Validation Plan (PVP)

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Applicable documents

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

Reference documents

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1. OVERVIEW

The objective of this document is to define the Product Validation Plan (PVP) in order to perform the round-robin intercomparison (WP2800) but also the final validation and user assessment (WP4000) of ECV data products. Concretely, we describe the protocol to benchmark the outputs from the new or improved algorithms against existing satellite observations (FCDR and ECV products).

The validation protocol described in this document concerns:

- The definition and the description of the validation diagnoses necessary for the round-robin intercomparison and the final validation: they are based on intrinsic altimetry comparisons and intercomparison between all the missions (defined in this document), but also using external data as in-situ measurements (tide gauges, ARGO data). The main idea is to define the same diagnoses for all the algorithms proposed in the project in order to estimate their impact in the same way (same statistics).
- The Round-Robin Data Package description, content and structure (RRDP) which will be available for all the participants. The length of validation period is also defined.
- The description of algorithm selection process.

This validation protocol has been defined in agreement with all the participants of the consortium. Consequently, we consulted each algorithm developer in order to check if the protocol proposed will allow us to estimate correctly the quality of new algorithms. We also iterated with the scientific expert team on the relevance of the diagnoses proposed in the frame of climate change studies.

In order to develop the PVP, we have taken into account that the validation protocol developed in the frame of this project will be available for any user and that scientific peer reviewed journal publication is a great objective.

2. Definition of validation diagnoses

2.1. Overview

The validation diagnoses are defined in order to respond to 2 different objectives:

- To assess the impact of the new algorithms on the round-robin procedure (see next section) and finally to select the best ones to calculate the altimeter sea surface height (WP2000).
- To assess the final FCDR and ECV products generated during the project (WP4100).

A main principle of validation phases including round-robin and final validation is to use a common set of validation diagnoses for all the algorithms or products (FCDRs and ECVS) which will be developed in the project. This strong principle allows us to compare the impact of different algorithm categories together with comparable statistics. This will be also a rigorous approach to characterize the sea-level altimetry errors better.

The objective of this section is then to define these common validation diagnoses taking into account that the main objective of the CCI project is to generate a climate data record, so the improvement of long scales (trend, inter-annual signals,...) are more important than the error reduction at very short scales (white noise, ...). Therefore more attention is paid to diagnoses concerning long temporal scales.

2.2. Type of validation diagnoses

The validation diagnoses are composed in distinct types which allow us to check altimetry data with complementary objectives. These categories depend on the altimetry levels considered. For levels 1 and 2, there are 3 types:

- **Intrinsic altimetry comparisons for 1 dedicated altimetry mission (A):** objective is to ensure the internal consistency of new proposed algorithms compared to standard or reference and to measure the global system performances improvements. *This family is noted "Global internal analyses"* further in the document.
- **Intercomparison between at least 2 missions and all the missions when possible (B):** objective is to measure the sea-level consistency improvements between different altimetry missions using the new algorithms. This family is noted "*Global multi-mission comparisons*" further in the document.
- **External data comparison using in-situ measurements (C):** objective is to use independent data to measure the impact of new algorithms on the sea-level calculation derived from altimetry missions. This family is noted "*Global altimetry and In-situ data comparison*" further in the document.

Concerning altimetry levels 3 and 4, there are 2 types:

- **Internal analyses of L3/L4 products (A)**: it is the equivalent of the "*Global internal analyses"* concerning level 1 and 2, but for L3/L4 altimetry products.
- **External L3/L4 products data comparison using in-situ measurements (C):** it is the equivalent of the "*Global altimetry and In-situ data comparison*" concerning level 1 and 2, but for combined altimetry products.

2.3. Input data for validation diagnoses

Inside a validation diagnosis type, there are different diagnoses groups based on the same input data. This input data can be directly derived from altimetry measurements or corresponds to the external data used:

- **Along-track altimetric components:** values of the altimetric corrections (used in the sea-level calculation) or altimetric parameters (range, SWH…) or orbit calculation along the ground track of the satellite at 1 Hz and for valid measurements.
- **Along-track Sea Level Anomaly (SLA):** Sea level anomalies (sea surface height minus the mean sea surface) along the ground track of the satellite at 1 Hz and for valid measurements.
- **Along theoretical track SLA:** SLA along the theoretical ground track of the satellite at 1 Hz and for valid measurements (the sampling of the theoretical ground track is the same for each ground track allowing precise temporal analyses).
- **Gridded map of SLA combined from several missions:** SLA grids are derived from along-track SLA missions combining and interpolating in time and space several altimetric missions.
- **SSH Crossovers:** SSH differences between ascending and descending passes for time differences between both passes lower than 10 days (in order to reduce the effect of the oceanic variability).
- **Tide gauges:** global tide gauges network (GLOSS/Clivar, PMSL) covering all the altimetric period.
- **Temperature/Salinity profiles:** global network derived from ARGO data (from 2002 onwards)

2.4. Validation diagnoses

The basic principle of validation diagnosis is to compare the new algorithms or the new product with the reference ones. The reference algorithms or products are the state of the art at the beginning of the project.

2.4.1. Common validation diagnoses

Therefore, for each new algorithm or new product, a set of common validation diagnoses will be systematically performed in order to evaluate its quality and its potential improvement in comparison with the reference one. The diagnoses generated will be concatenated in a report available for all the round robin-participant (see dedicated section further).

The list of these common validation diagnoses are defined in annexe of this document using a standardized format file. The diagnoses are classified by type (intrinsic, intercomparison, external) and declined for each kind of input data. A short description and objective is given for each of them to illustrate their role and their interest.

Thanks to this synthesized files, all the round-robin participant could understand the role and objective of each diagnosis, and therefore bring their own expertise to choice the best algorithms or to analyse/describe the final sea-level ECV products.

Diagnosis number	Diagnoses name
A001	Temporal evolution of differences between both altimetric components
A002	Map of differences between both altimetric components over all the period
A003	Periodogram derived from temporal evolution of altimetric component differences
A004	Temporal evolution of SSH crossovers
A101	Differences between temporal evolution of SSH crossovers
A102	Map of SSH crossovers
A103	Differences between maps of SSH crossovers
A201	Temporal evolution of SLA
A202	Differences of SLA temporal evolution
A203	Map of SLA over all the period
A204	Differences between maps of SLA
A205	Periodogram derived from temporal SLA evolution
A206	SLA differences versus coastal distances between 0 and 300 km
B001	Temporal evolution of SLA for 2 missions over the same period
B002	Differences between maps of SLA for 2 missions over the same period
C001	Temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period
C002	Differences of temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period
C003	Periodogram derived from temporal evolution of SSH differences between tide gauges

	and altimetry data over all the altimetry period
C004	Difference of histograms between tide gauges and altimeter SSH differences
C101	Temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period: global, north/south, east/west
C102	Differences of temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period
C103	Periodogram derived from temporal evolution SSH differences between T/S profiles and altimetry data over all the altimetry period

Table 1: List of validation diagnoses

2.4.2. Specific and external validation diagnoses

Although, the main idea is to use a common set of validation diagnoses as already explained, it could be justified for some of them to use dedicated analyses only applicable for a specific algorithm. It could be for instance the case for algorithms concerning high latitude issues where global analyses are not adapted. In this case it could be necessary to adapt the global diagnosis to regional areas.

In addition, if external diagnoses provided by external participants seem to be relevant for the selection of the best algorithms, it is of course recommended to add them in the RRDP report.

3. Round Robin data package (RRDP) description

3.1. RRDP content

Just before describing the RRDP content, it’s important to mention that the RRDP will be available for all the round-robin participant in a dedicated area on the sea-level-CCI website (http://www.esa-sealevel-cci.org/).

The RRDP will contain all the validation diagnoses as defined in the previous section. A clear link between each validation diagnosis and the validation diagnosis file (described in annex) will allow each of the round-robin participant to understand the role and objective of each diagnosis, and therefore to bring their own expertise to choice the best algorithms.

3.2. RRDP structure

3.2.1. Overview

As the number of new algorithms is very high in the sea-level CCI project, the organisation of the validation diagnosis has to be clearly described. Indeed, we have planned to test about 50 new algorithms (for all altimetry levels). For each new algorithm, there are approximately 20 validation diagnoses for each given mission (considering altimetry levels 1 and 2). Finally, the total number could reach about 5000 validation diagnoses.

First, all the validation diagnoses linked to the evaluation of the same new algorithms will be classified in the same directory with a sub-directory division by missions (considering altimetry levels 1 and 2). As the evaluation could be done by comparison with several algorithms of reference, this directory will be duplicated. Second, the or these directories will depend on a main directory for all the algorithms being part of the same category as orbit calculation, wet troposphere correction, the altimeter instrumental processing... These categories correspond to WP2100 to WP2600. Finally, round-robin validation reports will be performed for each algorithm category (see next section).

In order to give a concrete approach, the following sub-sections describe the organisation of the RRDP for each algorithm category (WP2100 to 2600).

3.2.2. RRDP structure for WP2100: Altimeter instrumental processing

The altimeter instrumental processing improvements planned in WP2100 are dedicated to ENVISAT and ERS missions. They concern the improvements of the PTR (Point Target Response) correction and the USO (Ultra Stable Oscillator). Dedicated comparisons with SWH (Significant Wave Height) and wind speed derived from altimeter (Sigma0, SWH) will also be performed in addition with common validation diagnosis dataset already defined, in order to better characterize the impact of these new algorithms on sea level.

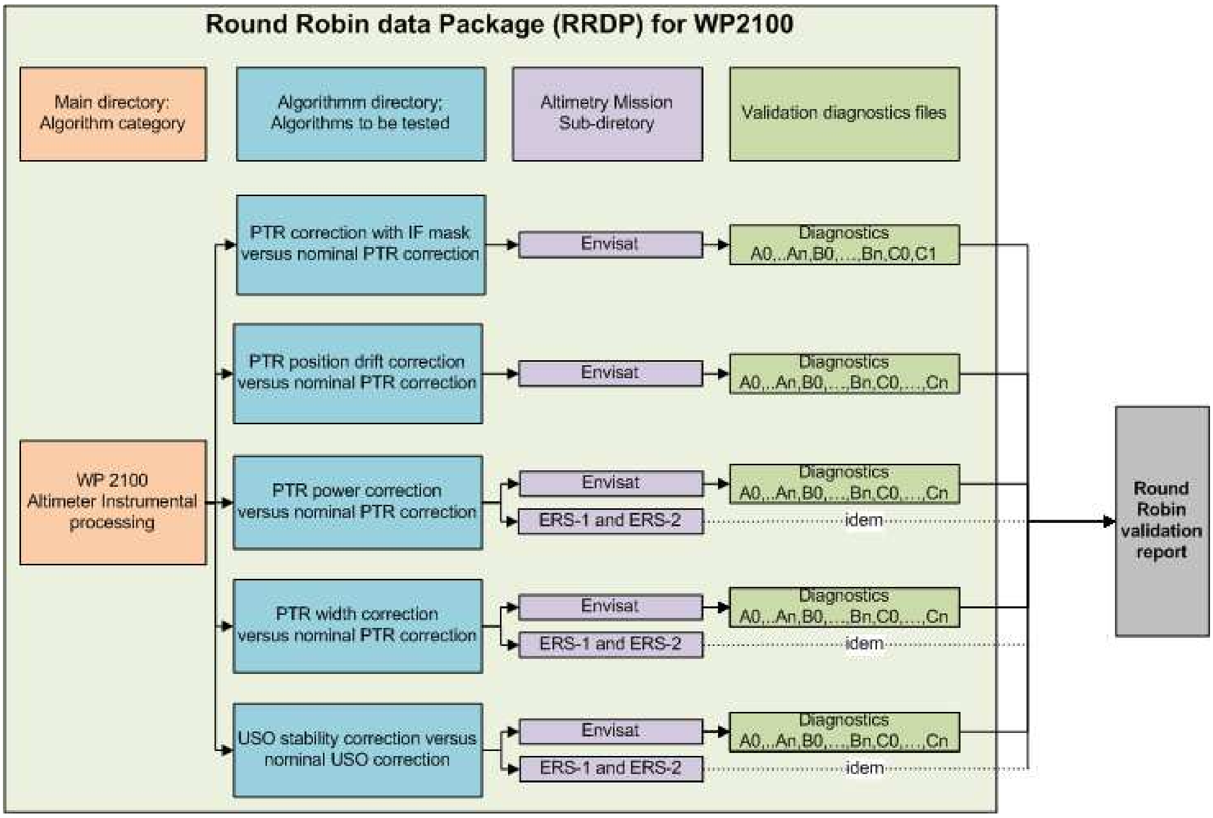


Figure 1: Round Robin data package for WP2100

3.2.3. RRDP structure for WP2200: Orbit calculation and terrestrial frame

Concerning the orbit calculation, new GFZ's orbits for all the missions correspond to the new algorithms to be tested in the RRDP. It is planned to assess these new orbits, comparing them with 4 orbit datasets from CNES, ESA, GFSC and JPL, and for all the altimetric missions as plotted on the following schema. Concerning Jason-1, Jason-2 and Envisat, the reference orbits are included in GDR products (it is CNES's orbit corresponding to the GDR-C release). For TOPEX/Poseidon, the reference orbit is provided by GSFC (std0809) which is not included in the M-GDR product. For ERS-1 and ERS-2, the references orbits have yet to be defined: it could be the orbits included in the level-2 products or reprocessed orbits provided by the REAPER project.

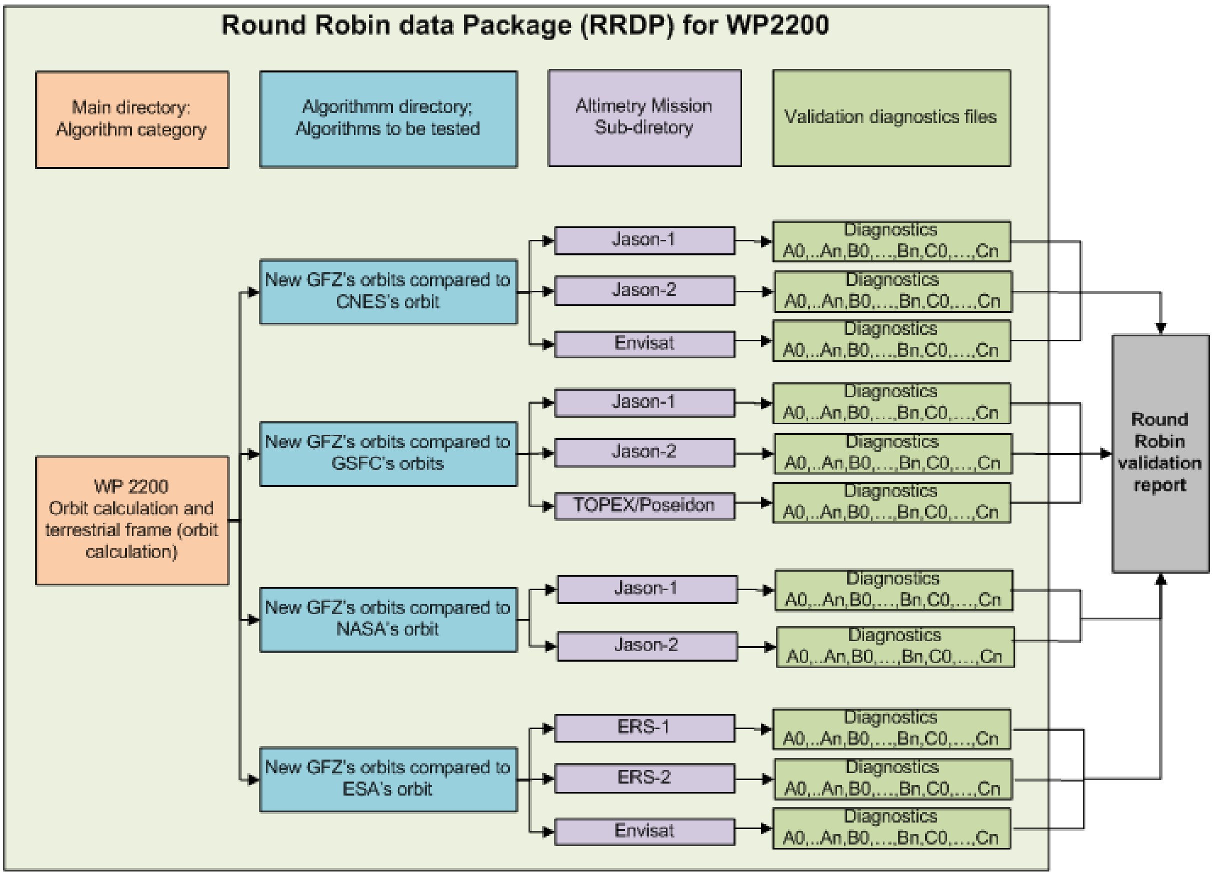


Figure 2: Round Robin data package for WP2200

RRDP structure for WP2300: Wet troposphere correction

The new algorithms proposed for the wet troposphere correction are on the first hand derived from radiometers (for all the altimetry missions) with expected long-term stability improvements and on the other hand derived directly from the models (NCEP reanalysis and ERA-interim). In the round robin, we proposed to compare the radiometer algorithm and models together, but also with the radiometer wet troposphere corrections already existing in the level-2 products (GDR) for all the altimetric missions.

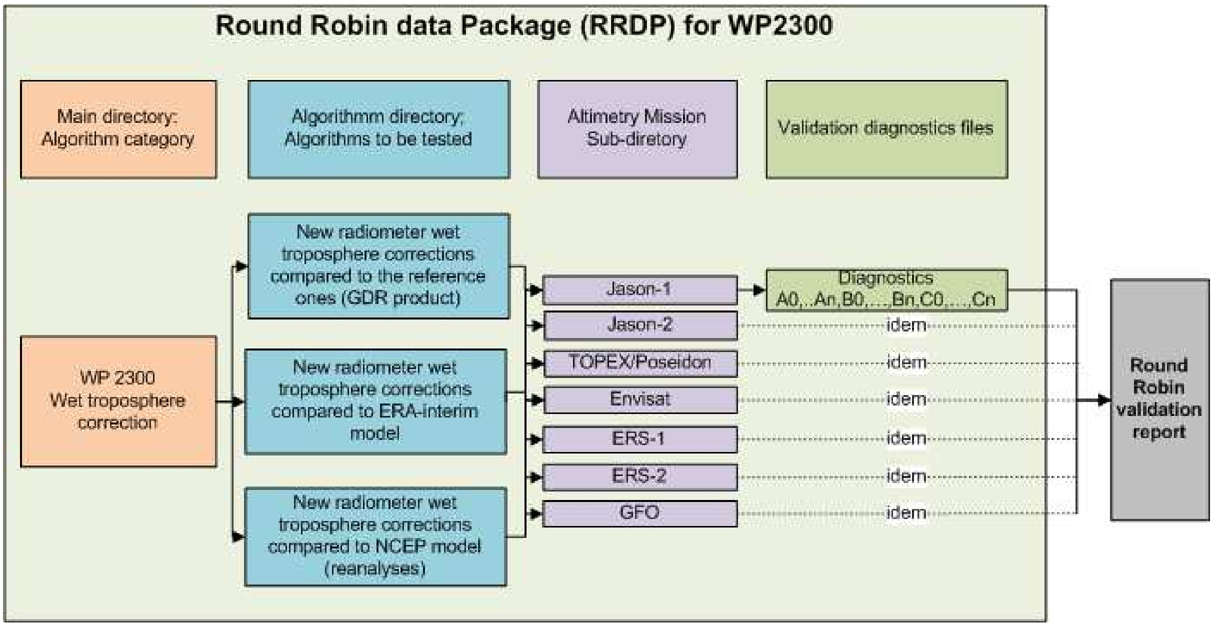


Figure 3: Round Robin data package for WP2300

3.2.4. RRDP structure for WP2400: Other SSH corrections

This WP is characterized by a collection of new algorithms dedicated to altimetry level 2 but not necessarily linked together. They have been selected since their impacts are minimal in terms of long term stability, but they might affect the sea-level at shorter scales. These new algorithms are the Sea Sate Bias (SSB), the ionosphere, the dry troposphere, the inverse barometer and the dynamical atmospheric correction. The new algorithms developed and the round-robin phase proposed is defined in the following table.

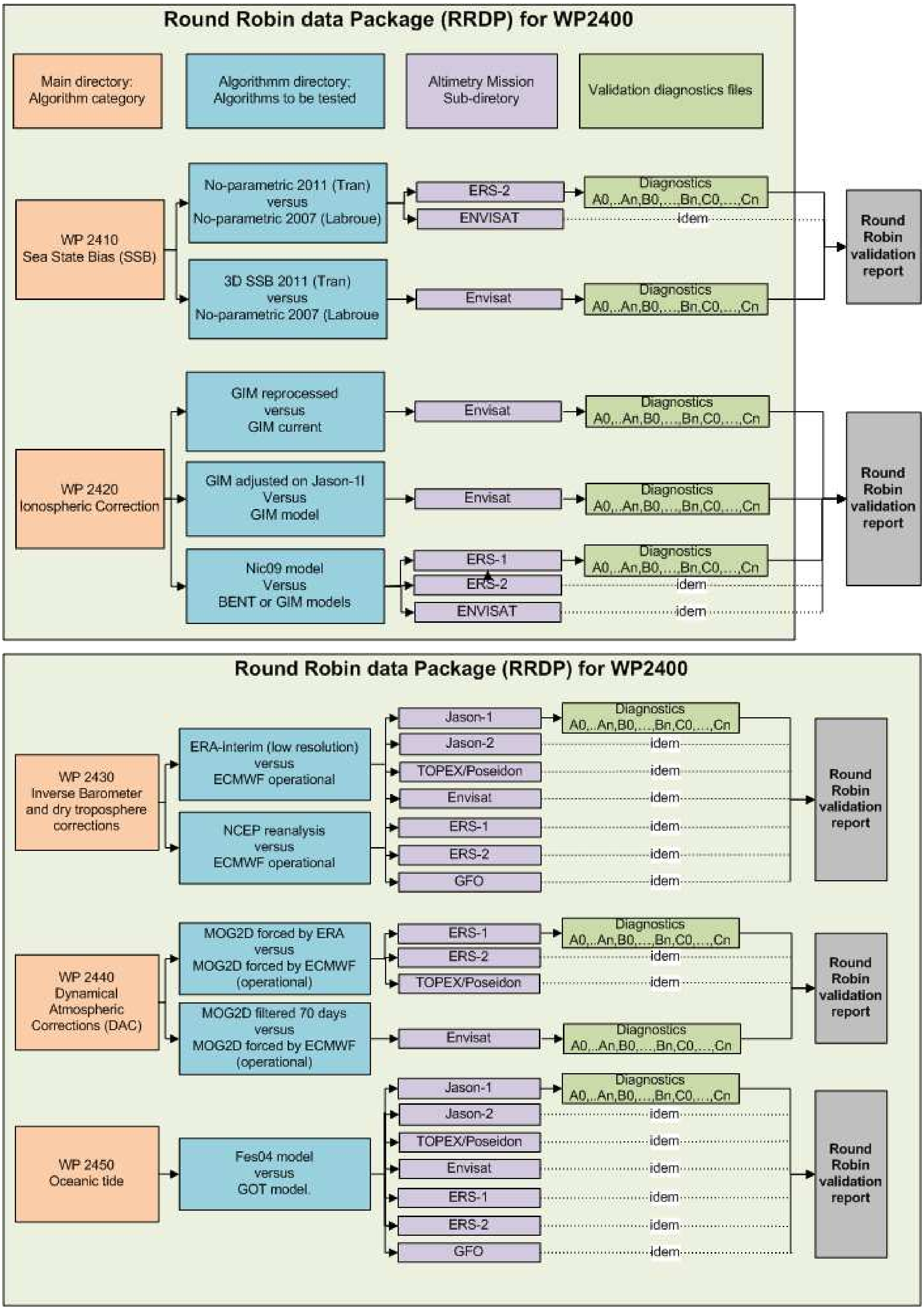


Figure 4: Round Robin data package for WP2400

3.2.5. RRDP structure for WP2600: High latitudes issues

The goal of this WP is to develop new algorithms concerning sea-level calculation improvements in high latitudes.

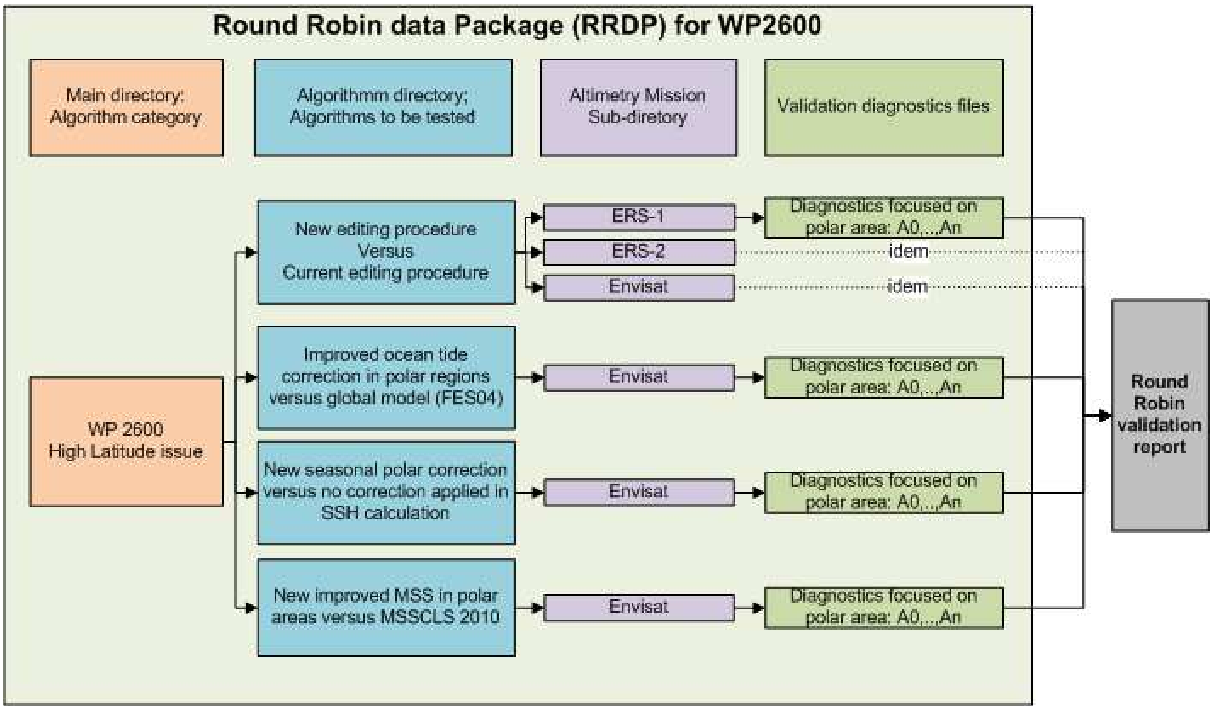


Figure 5: Round Robin data package for WP2600

3.2.6. RRDP structure for WP2500: Multi-mission merged products

The new algorithms of multi-mission merged products will not be developed inside the sea-level CCI project but rather in the frame of SALP project supported by CNES. On the other hand, it is already planned to test them in round-robin phase and select the best ones.

4. Applicability of validation diagnoses in RRDP

It is expected that not all the diagnoses will be applicable at each validation phase. In the following section we describe their applicability by separating the round-robin (WP2000) into 2 phases for levels 1 and 2, and levels 3 and 4. We also define their applicability for the final validation (WP4000).

4.1. Round Robin: Level-1/2

Most of the new algorithms proposed in the sea-level CCI project concern the altimetry level 1 and 2: altimeter and radiometer parameters, geophysical corrections and orbit calculation. Their applicability is defined in the following table. We also describe in the table, the statistics applicable and useful for each diagnosis. There are 3 kinds of elementary statistics:

- The mean using the mean sea level standard calculation: Mean per box of 2°x2° and weighted by cosine of latitude for the global mean.
- The variance (or the standard deviation);
- The slope is a basic linear fitting using a least square method.
- The periodic signals (amplitude, phase) are a poly-sinusoidal fitting using a least square method.

Most of the time, when the statistic is applicable, it is specified on the following table. But sometimes, it is not very relevant or redundant to specify the statistic. For instance the map of the slope differences between both altimetry components over all the period is not specified since it is already specified in diagnosis concerning the slope differences between

Type	**Input Data**	**Validation Diagnosis**	**Statistics**			**Diagnosis file**
			Mean	**Variance**	**Slope or periodic signal**	
Global internal analyses from mono-mission (A)	Along-track altimetric components	Temporal evolution of differences between both altimetric components	x	x	x	A001
		Map of differences between both altimetric components over all the period	x	x		A002
		Periodogram derived from temporal evolution of altimetric component differences: all periods, focus on annual and semi-annual periods	x	x		A003
	SSH Crossover	Temporal evolution of SSH crossovers	x	x		A101
		Differences between temporal evolution of SSH crossovers		x		A102
		Map of SSH crossovers	x	x		A103
		Differences between maps of SSH crossovers		x		A104
	Along-track SLA	Temporal evolution of SLA : global, separating ascending and descending passes, separating North and south hemispheres	x	x	x	A201
		Differences of temporal evolution of SLA : global, separating ascending and descending passes, separating North and South hemispheres		x		A202
		Map of SLA over all the period: global, separating ascending and descending passes, separating North and South hemispheres	x	x	x	A203
		Differences between maps of SLA: global, separating North and South hemispheres	x	x	x	A204
		Periodogram derived from temporal evolution of SLA differences (global and separating North and south hemispheres) : all period, focused on annual and semi-annual periods	x	x		A206
		SLA versus coastal distances between 0 and 100 km	x	x	x	A207
		SLA differences versus coastal distances between 0 and 100 km	x	x	x	A208
Global multi-mission comparisons (B)	Along-track SLA	Temporal evolution of SLA for 2 missions over the same period as longer as possible: global, separating, ascending and descending passes, separating North and south hemispheres	x	x	x	B201
		Differences between maps of SLA for 2 missions over the same period as longer as possible: global, separating ascending and descending passes	x	x	x	B202

Global altimetry and In-situ data comparison from mono-mission (C)	Tide gauges	Temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period	x	x	x	C001
		Differences of temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period		x		C002
		Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period	x	x		C003
		The difference of histograms between tide gauges and altimeter SSH differences	x	x		C004
	Temperature / Salinity profiles	Temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period: global, north/south, east	x	x	x	C101
		Differences of temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period.		x		C102
		Periodogram derived from temporal evolution SSH differences between T/S profiles and altimetry data over all the altimetry period.	x	x		C103

Table 2: Applicability of validation diagnoses for altimetry levels 1 and 2

4.2. Round Robin: Level-3/4

The algorithm for altimetry levels 3 and 4 especially concerns the merging between all the missions in order to build the final altimetry products. Ideally, the selection of new algorithms should be done before the level 3 and 4 round-robin. In practise, this will not be possible due to the schedule. But the more important consideration is to use the same level 1 and 2 reference algorithm in order to test all the new algorithms for levels 3 and 4. The list of applicable diagnoses is limited in comparison with levels 1 and 2. It is defined below.

Type	**Input Data**	**Validation Diagnosis**	**Statistics**			**Diagnosis file**
			Mean	**Variance**	**Slope or periodic signal**	
Global internal analyses from combined missions (A)	Along theoretical ground track SLA	Temporal evolution of SLA : global, separating North and south hemispheres	x	x	x	A101
		Differences of temporal evolution of SLA : global, separating North and South hemispheres	x	x		A102
		Periodogram derived from temporal evolution of SLA differences (global and separating North and south hemispheres) : all period, focused on annual and semi-annual periods	x	x		A103
	SLA Grids combined between all missions	Temporal evolution of SLA : global, separating ascending and descending passes, separating North and south hemispheres	x	x	x	A201
		Differences of temporal evolution of SLA : global, separating ascending and descending passes, separating North and South hemispheres		x		A202
		Map of SLA over all the period: global, separating ascending and descending passes, separating North and South hemispheres	x	x	x	A203
		Differences between maps of SLA: global, separating North and South hemispheres	x	x	x	A204
		Periodogram derived from temporal evolution of SLA differences (global and separating North and south hemispheres) : all period, focused on annual and semi-annual periods	x	x		A206

		SLA versus coastal distances between 0 and 100 km	x	x	x	A207
		SLA differences versus coastal distances between 0 and 100 km	x	x	x	A208
Global altimetry and In-situ data comparison from combined missions (C)	Tide gauges	Temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period	x	x	x	C001
		Differences of temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period		x		C002
		Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period	x	x		C003
		The difference of histograms between tide gauges and altimeter SSH differences	x	x		C004
	Temperature / Salinity profiles	Temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period: global, north/south, east/west	x	x	x	C101
		Differences of temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period		x		C102
		Periodogram derived from temporal evolution SSH differences between T/S profiles and altimetry data over all the altimetry period.	x	x		C103

Table 3: Applicability of validation diagnoses for altimetry levels 3 and 4

4.3. Length of the validation period

As previously mentioned, the validation diagnoses concerning long spatial and time scales are especially relevant in the frame of the sea-level CCI project. Therefore, it is crucial for the project to provide all the new algorithms over the complete altimetric period if they are defined for all the altimetric missions or over the corresponding altimetric mission period if they are defined for dedicated altimetric missions.

The complete altimetric period is defined **from January 1993 to December 2010**. This represents a 18-year period. The altimetric period by mission are defined in the following table.

Altimetric Mission	Period
TOPEX/Poseidon	01/01/1993 to 8/10/2005
Jason-1	15/01/2002 to 31/12/2010
Jason-2	12/07/2008 to 31/12/2010
ERS-1	01/01/1993 to 02/06/1996
ERS-2	01/01/1993 to 02/07/2003
Envisat	24/09/2002 to 31/12/2010
Geosat Follow-On	07/01/2000 to 07/09/2008

Table 4: Altimetric mission periods

5. Algorithm selection

5.1. Overview

The objective of the selection step is to provide recommendations to ESA on the algorithms selection. The recommendations will be provided by an external expert team which will be asked to review the available algorithm, check them against state of the art knowledge and come up with a conclusion about which algorithm should be included for the ECV version-1 data stream.

5.2. Expert team

The list of experts contacted to participate to the selection process is the following one:

- J. Willis
- S. Nerem
- C. K. Shum
- R. Scharroo
- P. Woodworth
- N. Picot
- P.Y. Le Traon
- R. Ponte
- S. Vignudeli

All the people mentioned agree to participate to the selection. They cover a large panel of expertise both in altimetry processing and climate.

5.3. Collection of the intercomparison and validation reports

The final round robin validation reports will be performed for each algorithm category independently. The synthesis of all the validation diagnoses generated in the corresponding RRDP will allow us to describe the performances and the quality of the new algorithms in comparison with the references ones.

There are 2 main final objectives. The first one consists in providing a synthetic description of the advantages or disadvantages of new algorithms (inside each WP) in terms of climate studies in order to help the expert team to select the best ones. Therefore, the description of improvements or degradations should be performed separating the different spatial and temporal scales. Of course, large scales will be more important to choose the best algorithms for climate studies.

The second objective is to provide crucial information for the WP2900 concerning the estimation of sea levels errors. It is a main objective of CCI project. In agreement with the description of the new algorithm performances, the sea level error should also be described at different spatial and temporal scales.

Other reports could be collected from external groups that have used the RRDP to lead their own validation. The announcement of the possibility to use the RRDP to lead validation studies will be advertised and encouraged through the sea-level-CCUI project website.

5.4. Analysis of the reports by the experts' team

The people engaged in the expert team will receive the reports few weeks before a workshop dedicated to the selection of the best algorithms. The Earth Observation (EO) team of the sea-level-CCI consortium will be available to answer any questions from the expert team.

The workshop should gather the Expert team as well as the groups involved in the development of the algorithms, that includes the sea-level-CCI consortium partners but also representative of the external contributions which represents in the case of the project an important sources of algorithms.

The date and the place of the workshop is not yet decided.

6. Final Validation and User Assessment

Work package 4100 is dedicated to the final validation and intercomparison of FCDR and ECV products. Of course all the validation diagnoses defined previously and applied in the round-robin phase could be applied in this task. This allows us to measure the global impact of all the improvements made in WP2000 after selecting the best algorithms concerning altimetry levels 1 to 4 by comparison with the already existing products:

- FCDR product: it is L2P product (level 2 plus), therefore the applicable validation diagnoses are defined in Table 2.
- ECV product: it is L4 product, therefore the applicable validation diagnoses are defined in Table 3.

In this task a more scientific approach is also planned to complete the formal and systematic approach described here. It will be based on thoroughly ocean analysis as the study of the MSL closure budget considering the different components of sea-level elevation.

Appendix A - **List of validation diagnoses**

Diagnostic type: Global internal analyses **(A)**

Diagnostic A001

Name : Temporal evolution of differences between both altimetric components

Input data : Along-track altimetric components

Statistics : mean, variance, slope

Description : The temporal evolution of global statistics of differences between two different standards of a same altimetric component (sea surface height correction, altimeter parameter, orbit) are calculated from a cyclic way (altimeter repetivity) . These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

Objective : This diagnostic allows the assessment of the long-term evolution between both component differences in terms of mean and variance.

Example: The cycle by cycle mean and standard deviation of the oceanic tidal correction differences between two different models (GOT4.8 and GOT4.7) have been calculated and plotted on the following figures.

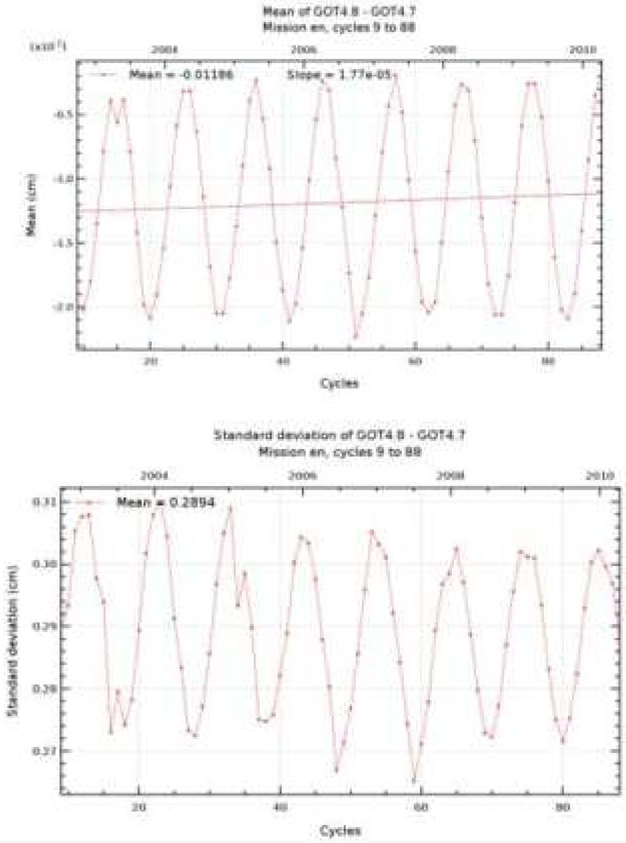


Figure 6 : Temporal evolution of differences between both altimetric components

Diagnostic type: Global internal analyses **(A)**

Diagnostic A002

Name : Map of differences between both altimetric components over all the period

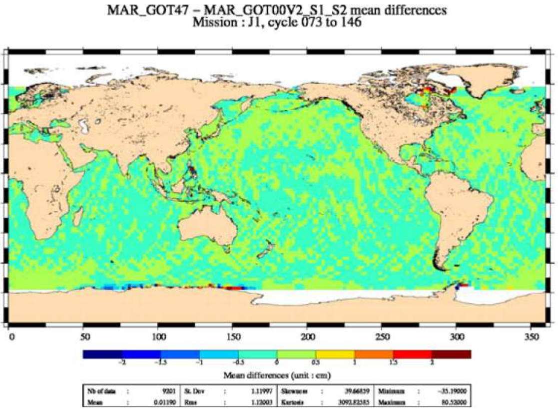
Input data : Along-track altimetric components

Statistics : mean, variance

Description: The map of global statistics of differences between two different standards of a same altimetric component (sea surface height correction, altimeter parameter, orbit) are calculated over a given period which is the longer as possible to have obtain reliable results. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level data.

Objective: This diagnostic allows us to check and analyze the spatial distribution of both component differences in terms of mean or variance.

Example: The map of mean and standard deviation of the oceanic tidal correction differences between two different models (GOT47 and GOT00) have been calculated and plotted on the following figures.


MAR_GOT47 – MAR_GOT00V2_S1_S2 mean differences
Mission : J1, cycle 073 to 146

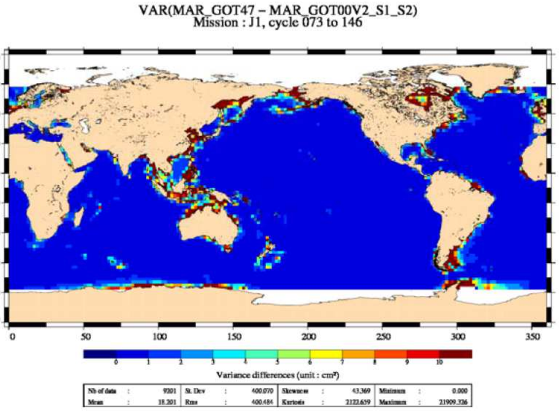
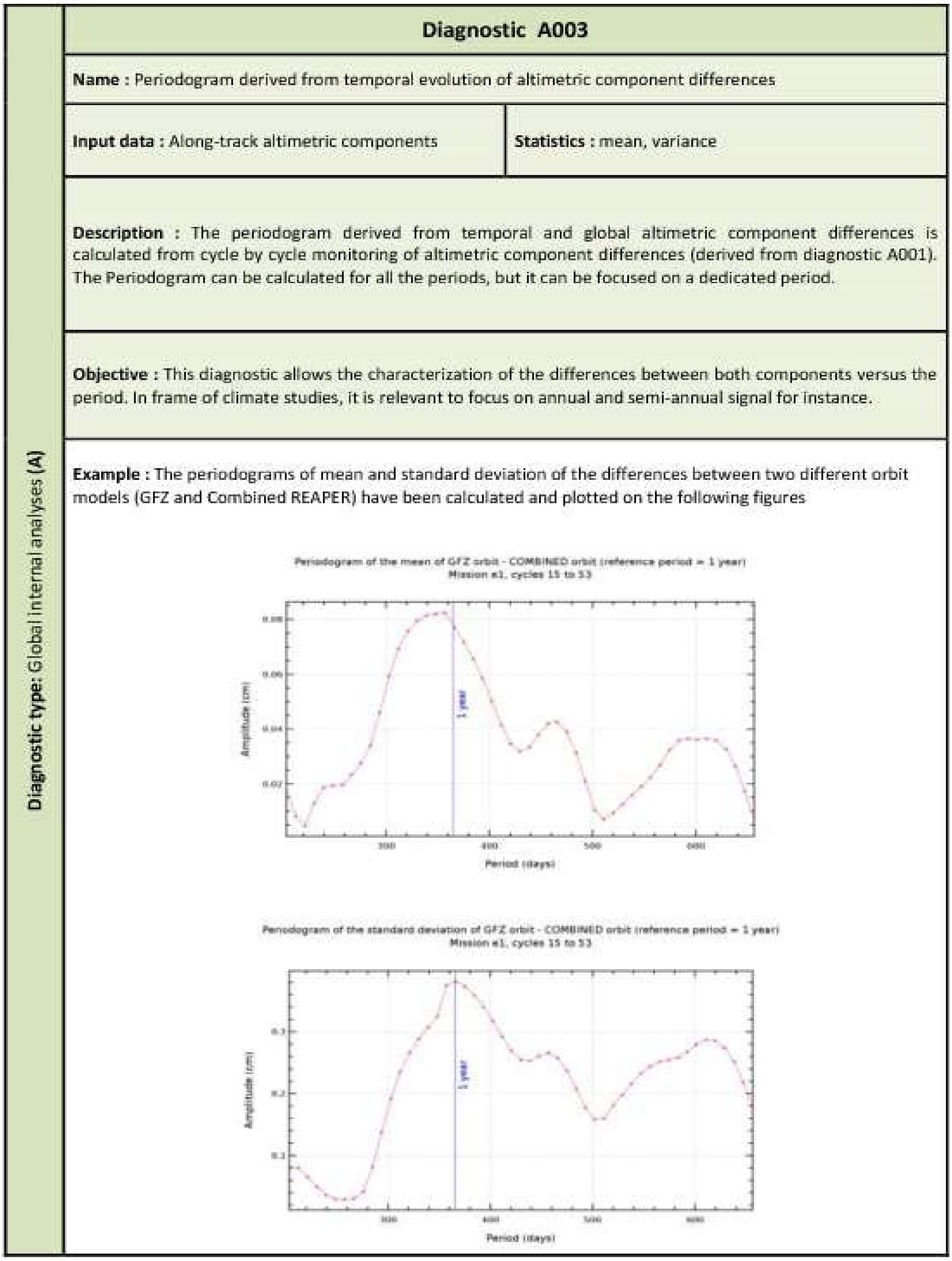

VAR(MAR_GOT47 – MAR_GOT00V2_S1_S2)
Mission : J1, cycle 073 to 146

Figure 7 : Map of differences between both altimetric components over all the period



Diagnostic type: Global internal analyses **(A)**

Diagnostic A003

Name : Periodogram derived from temporal evolution of altimetric component differences

Input data : Along-track altimetric components

Statistics : mean, variance

Description : The periodogram derived from temporal and global altimetric component differences is calculated from cycle by cycle monitoring of altimetric component differences (derived from diagnostic A001). The Periodogram can be calculated for all the periods, but it can be focused on a dedicated period.

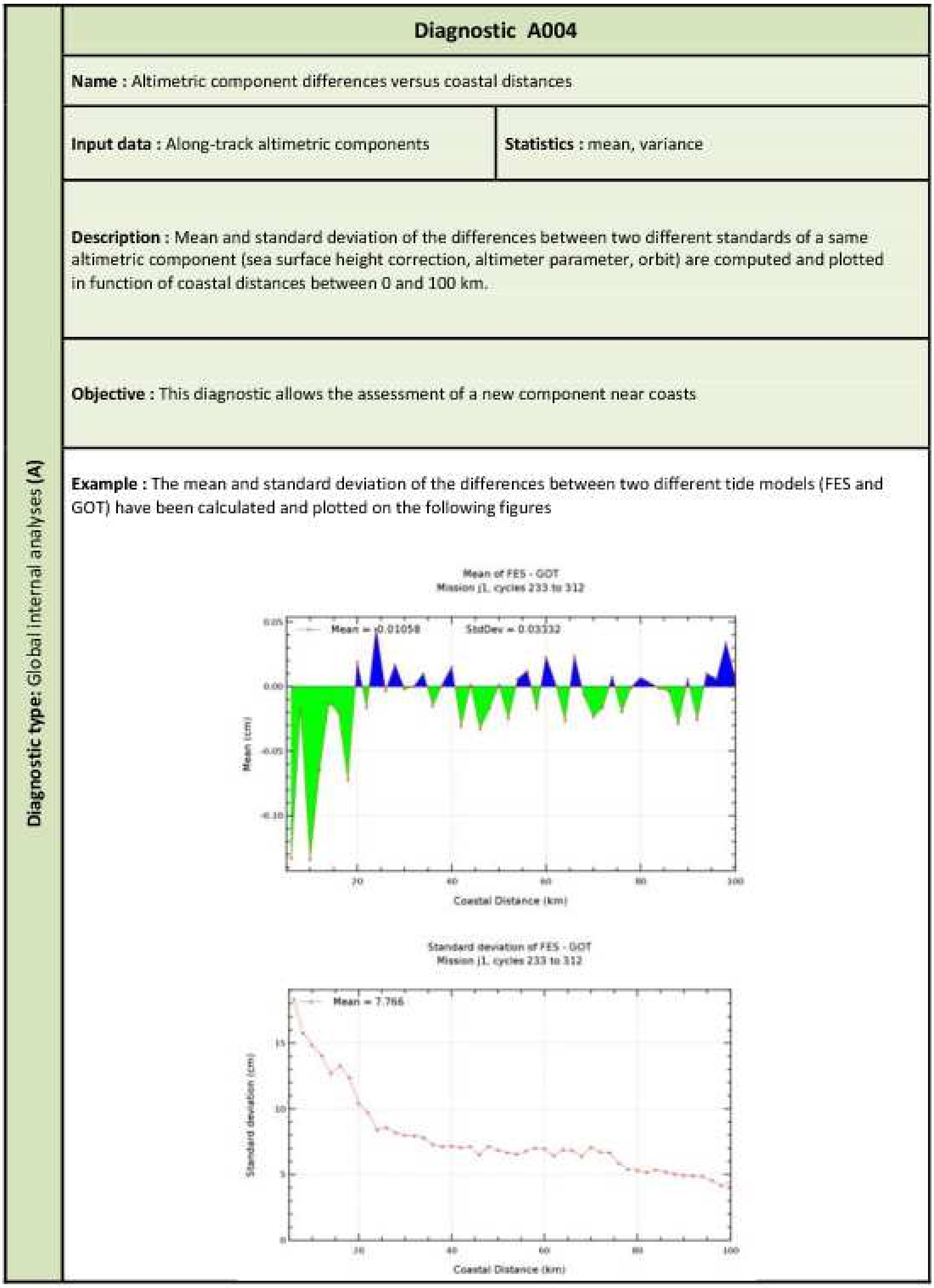
Objective : This diagnostic allows the characterization of the differences between both components versus the period. In frame of climate studies, it is relevant to focus on annual and semi-annual signal for instance.

Example : The periodograms of mean and standard deviation of the differences between two different orbit models (GFZ and Combined REAPER) have been calculated and plotted on the following figures

Periodogram of the mean of GFZ orbit - COMBINED orbit (reference period = 1 year)
Mission e1, cycles 15 to 53

Periodogram of the standard deviation of GFZ orbit - COMBINED orbit (reference period = 1 year)
Mission e1, cycles 15 to 53

Figure 8 : Periodogram derived from temporal evolution of altimetric component differences



Diagnostic type: Global internal analyses **(A)**

Diagnostic A004

Name : Altimetric component differences versus coastal distances

Input data : Along-track altimetric components

Statistics : mean, variance

Description : Mean and standard deviation of the differences between two different standards of a same altimetric component (sea surface height correction, altimeter parameter, orbit) are computed and plotted in function of coastal distances between 0 and 100 km.

Objective : This diagnostic allows the assessment of a new component near coasts

Example : The mean and standard deviation of the differences between two different tide models (FES and GOT) have been calculated and plotted on the following figures

Figure 9 : Altimetric component differences versus coastal distances

Diagnostic type: Global internal analyses **(A)**

Diagnostic A101

Name : Temporal evolution of SSH crossovers

Input data : Sea Surface Height (SSH) crossovers

Statistics : mean, variance

Description : The temporal evolution of global statistics of SSH differences are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in the SSH calculation. SSH crossovers are the differences between ascending and descending passes for time differences between both passes lower than 10 days (in order to reduce the effect of the oceanic variability).

Objective : This diagnostic allows the assessment of the consistency between ascending and descending passes in terms of mean and variance. It is also a good way to measure the performance of the system since SSH crossover differences should be as low as possible assuming the oceanic variability is negligible within a 10-day window.

Example : The cycle by cycle mean and standard deviation of SSH crossovers using successively two different oceanic tidal models (GOT47 and GOT00) have been calculated and plotted on the following figures.

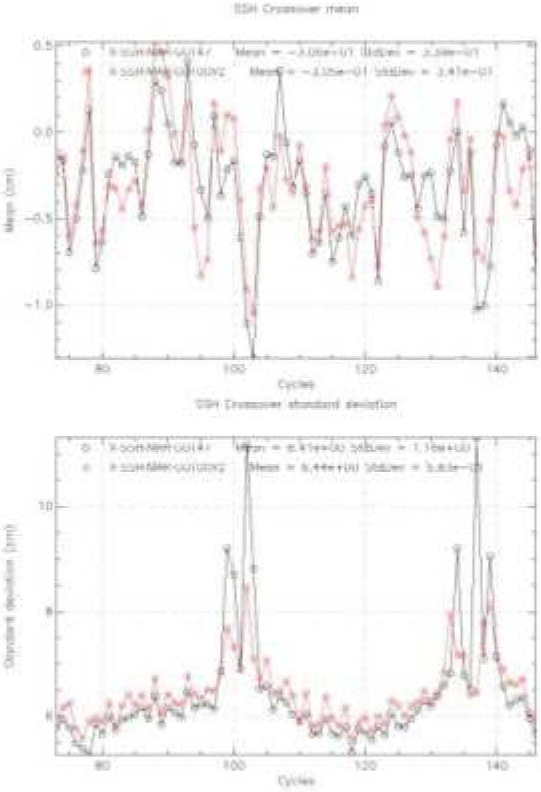


Figure 10 : Temporal evolution of SSH crossovers

Diagnostic type: Global internal analyses (A)

Diagnostic A102

Name : Differences between temporal evolution of SSH crossovers

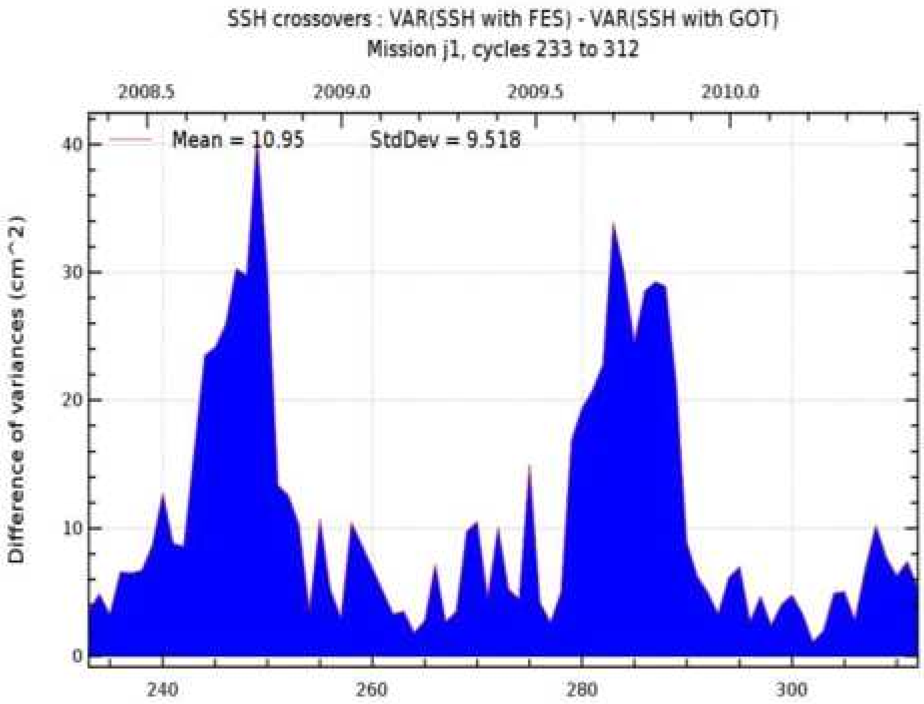
Input data : Sea Surface Height (SSH) crossovers

Statistics : variance

Description : The difference of temporal evolution between the global statistics of SSH differences are calculated using successively both altimetric components in the SSH calculation. SSH crossovers are the differences between ascending and descending passes for time differences between both passes lower than 10 days (in order to reduce the effect of the oceanic variability).

Objective : This diagnostic allows especially the analysis of the evolution of the variance reduction at SSH crossovers using successively new and reference components in SSH calculation. This criterion is a good way to measure the improvement brought by the new component in sea level calculation. If the variance is reduced using the new components, this means that the temporal consistency of SSH is improved within a 10-day window.

Example : The cycle by cycle variance differences of SSH crossovers using successively two different oceanic tidal models (FES and GOT) have been calculated and plotted on the following figure. Negative values would highlight an improvement of SSH using FES model, but here only positive values can be observed, which shows a degradation.



SSH crossovers : VAR(SSH with FES) - VAR(SSH with GOT)
Mission j1, cycles 233 to 312

Figure 11 : Differences between temporal evolution of SSH crossovers

Diagnostic type: Global internal analyses **(A)**

Diagnostic A103

Name : Map of SSH crossovers

Input data : Sea Surface Height (SSH) crossovers

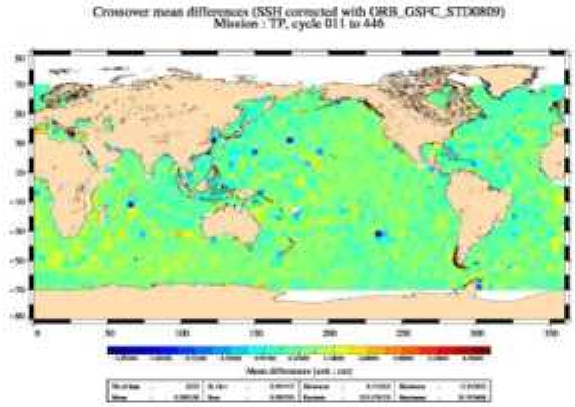
Statistics : mean, variance

Description : The differences between maps of SSH crossovers differences are calculated using successively both altimetric components in the SSH calculation. SSH crossovers are the differences between ascending and descending passes for time differences between both passes lower than 10 days (in order to reduce the effect of the oceanic variability).

(*) A cycle corresponds to the repetivity of the altimetric mission.

Objective : This diagnostic allows especially the assessment of the consistency between ascending and descending passes in terms of mean over a large period. Comparing both maps calculated from new and reference components in SSH, the spatial distribution of SSH crossovers differences can be analyzed to measure the potential improvements brought by the new component.

Example: The map of SSH crossovers mean differences using successively two different orbit solutions (GSFC and NASA) have been calculated over 12 years and plotted on the following figures. The mean of SSH crossovers is significantly improved using the GSFC orbit (top) than with the orbit of reference (bottom).



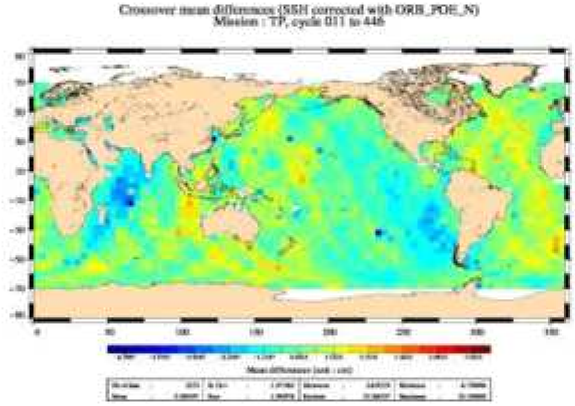


Figure 12 : Map of SSH crossovers

Diagnostic A104

Diagnostic type: Global internal analyses **(A)**

Name: Differences between maps of SSH crossovers

Input data : Sea Surface Height (SSH) crossovers

Statistics : variance

Description: The differences between maps of SSH crossovers (derived from diagnostic A103) are calculated from the SSH crossover differences using successively both altimetric components in the SSH calculation. SSH crossovers are the differences between ascending and descending passes for time differences between both passes lower than 10 days (in order to reduce the effect of the oceanic variability).

Objective: This diagnostic allows especially the analysis of the spatial distribution of the variance reduction at SSH crossovers using successively new and reference components in SSH calculation over a large period. This criterion is a good way to measure the improvement brought by the new component in sea level calculation. If the variance is reduced using the new components, this means that the temporal consistency of SSH is improved within a 10-day window

Example: The differences between variance maps of SSH crossovers differences using successively two different oceanic tidal models (GOT47 and GOT00) have been calculated over two years and plotted on the following figure. Blue areas mean that SSH is improved using the GOT4.7 tidal model in SSH calculation.

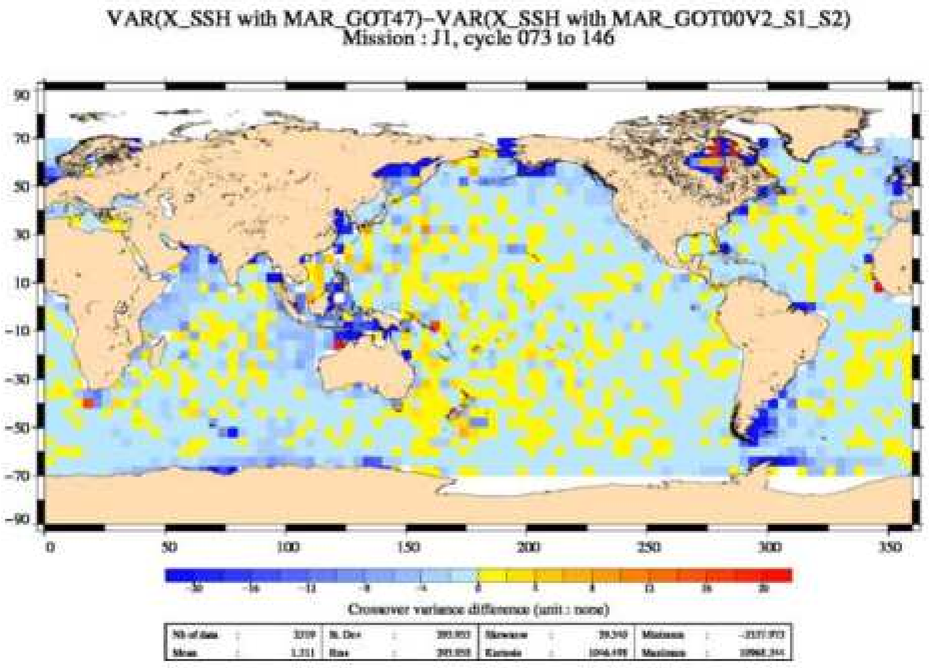


Figure 13 : Differences between maps of SSH crossovers

Diagnostic type: Global internal analyses **(A)**

Diagnostic A201

Name: Temporal evolution of Sea Level Anomaly (SLA)

Input data : Along-track SLA / Along theoretical ground track SLA / SLA Grids combined between all missions	**Statistics :** mean, variance, slope

Description: The temporal evolution of SLA statistics are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in the SLA calculation. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements. They are calculated globally, but also separating ascending and descending passes (except for SLA Grids) , or separating North and South hemispheres.

Objective: This diagnostic is especially useful for the calculation of the global MSL calculation which is a main indicator of the climate change. More information about the MSL calculation from all altimetric missions could found on the AVISO website: http://www.aviso.oceanobs.com/msl/

Example: The global MSL derived from Jason-1 altimeter is plotted on the following figure using successively the radiometer and the model wet troposphere correction in the SLA calculation.

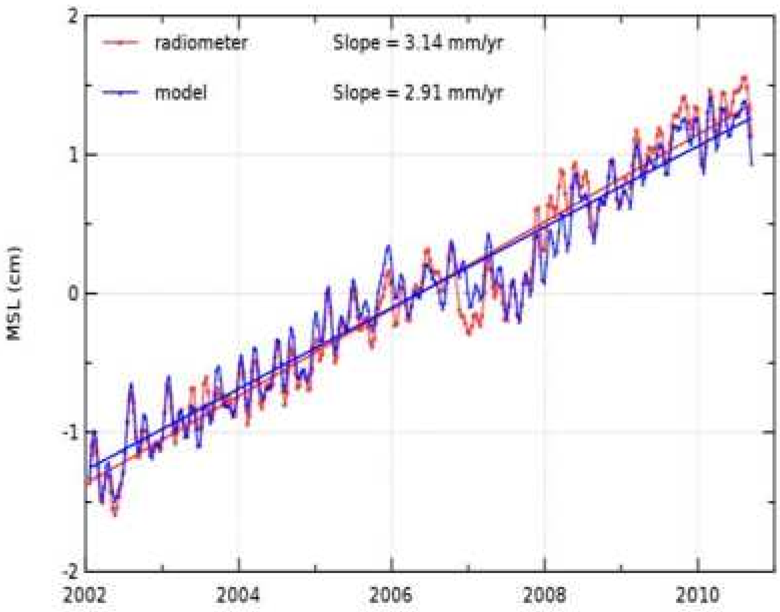


Figure 14 : Temporal evolution of SLA

Diagnostic type: Global internal analyses **(A)**

Diagnostic A202

Name : Differences of temporal evolution of Sea Level Anomaly (SLA)

Input data : Along-track SLA / Along theoretical ground track SLA / SLA Grids combined between all missions

Statistics : variance

Description : The differences between temporal evolution of SLA are calculated from statistics derived from diagnostic A201 using two different components in the SLA calculation. They are calculated globally, but also separating ascending and descending passes (except for SLA Grids) or separating North and South hemispheres.

Objective : The main interest is to calculate the difference of variance between SLA using two different components. As the SLA reduction of variance is considered as a quality criteria (assuming the correlation between a component and the oceanic variability is low), the SLA variance differences give information about the performances of the new component in comparison with the reference one.

Example : The following map shows the temporal evolution of the difference of variance between SLA using two different orbit solutions (COMBINED Reaper and GFZ Reaper) on ERS-1. As the orbit is not or weakly correlated with the oceanic variability, the negative values indicate an amelioration of the SLA calculation thanks to the GFZ orbit.

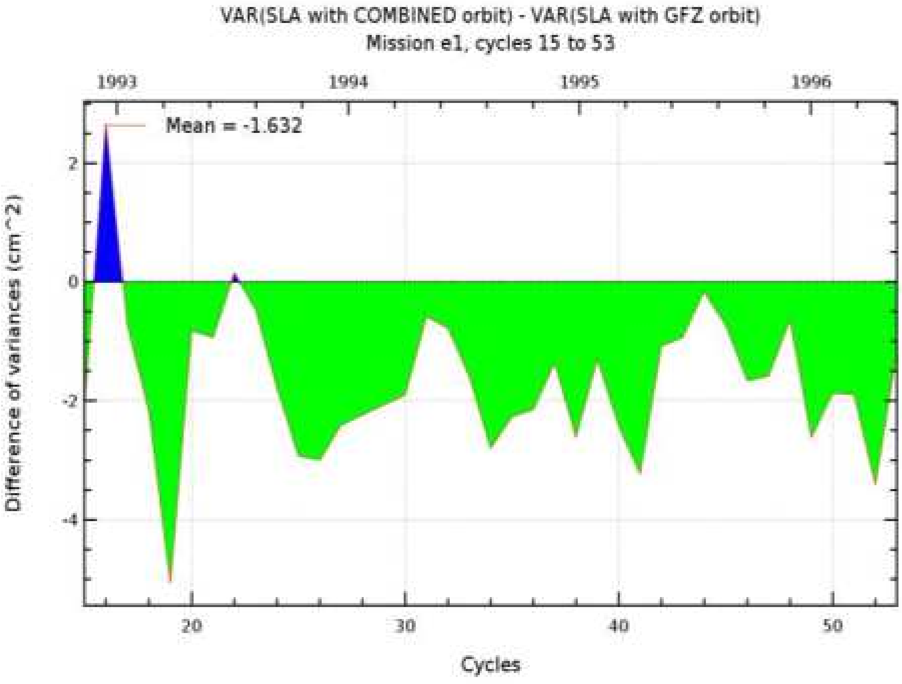


Figure 15 : Differences of SLA temporal evolution

Diagnostic type: Global internal analyses (A)

Diagnostic A203

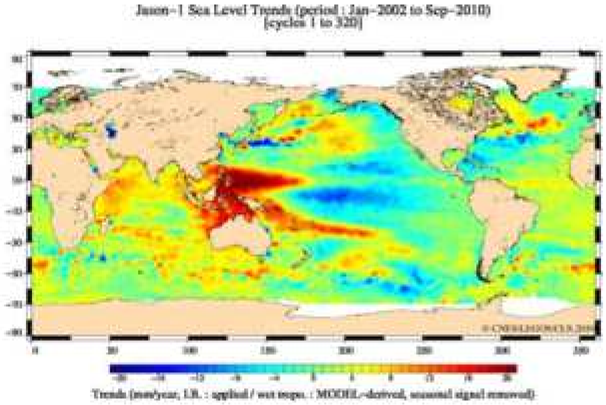
Name : Map of Sea Level Anomaly (SLA) over all the period

Input data : Along-track SLA / SLA Grids combined between all missions	**Statistics :** mean, variance, slope

Description : The map of global statistics of SLA are calculated using successively both altimetric components in the SLA calculation over a large period. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

Objective : This diagnostic is especially useful for the calculation of the map of local MSL trends which is a main indicator of the climate change. More information about the MSL calculation from all altimetric missions could found on the AVISO website : http://www.aviso.oceanobs.com/msl/

Example : The map of local MSL trends derived from Jason-1 altimeter is plotted on the following figures using successively the radiometer (top) and the model (bottom) wet troposphere correction in the SLA calculation.


Jason−1 Sea Level Trends (period : Jan−2002 to Sep−2010)
[cycles 1 to 320]

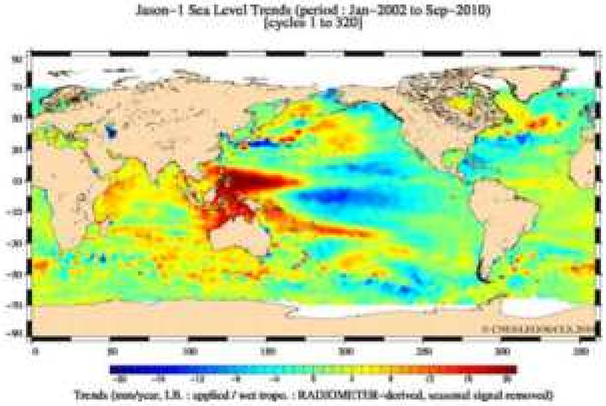

Jason−1 Sea Level Trends (period : Jan−2002 to Sep−2010)
[cycles 1 to 320]

Figure 16 : Map of SLA over all the period

Diagnostic type: Global internal analyses **(A)**

Diagnostic A204

Name : Differences between maps of SLA

Input data : Along-track SLA / SLA Grids combined between all missions

Statistics : mean, variance, slope

Description : The difference of SLA maps is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except for SLA Grids).

Objective : The main interest is to calculate the difference of variance between SLA using two different components in order to characterize the performances of new altimetric component in comparison with the reference one. Thanks to this diagnostic, the slope of SLA differences, giving a relevant information for climate studies.

Example : The map of slope differences between SLA grids derived from two different releases of AVISO products (SLA merged between all the missions) has been computed and plotted below. It highlights regions with slope changes, which in the present case stay in the range of MSL trend errors.

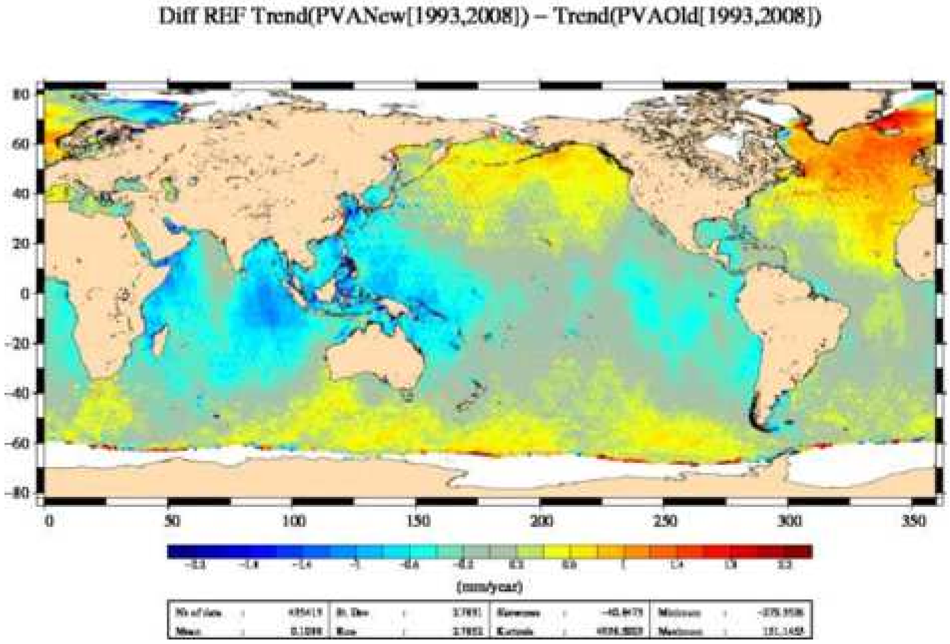


Figure 17 : Differences between maps of SLA

Diagnostic type: Global internal analyses (A)

Diagnostic A206

Name: Periodogram derived from temporal evolution of Sea Level Anomaly (SLA)

Input data : Along-track SLA / Along theoretical ground track SLA / SLA Grids combined between all missions	**Statistics :** mean, variance

Description: The periodogram derived from temporal evolution of SLA (global, northern or southern hemisphere) can be done over all periods or focusing on particular periods, such as annual, semi-annual or 60-day signal. Therefore mean of SLA differences are computed (every day or cycle), and time data series are plotted as a periodogram.

Objective: This diagnostic allows to analyze on which period a new component will have an impact on the SLA calculation. Concerning climate studies, it's particularly interesting to focus on annual and semi-annual signals and to analyze the reduction or increase of such signals.

Example: Global SLA is computed for ERS-1 over several years (mean per cycle) using successively the COMBINED Reaper orbit and the GFZ Reaper orbit. Periodograms of these time series are shown on the figure.

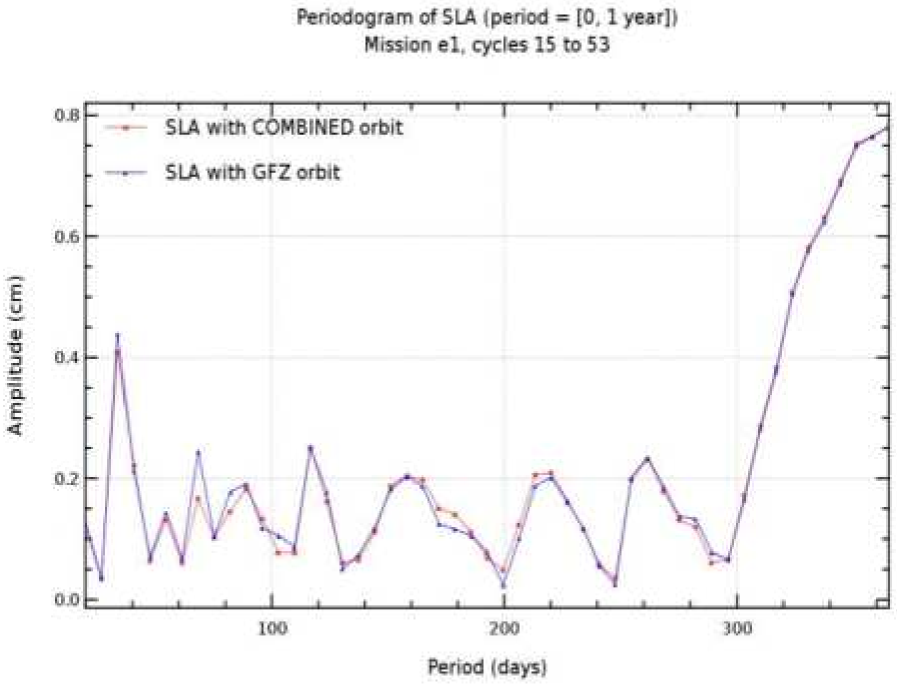


Figure 18 : Periodogram derived from temporal SLA evolution

Diagnostic type: Global internal analyses (A)

Diagnostic A207

Name : Sea Level Anomaly (SLA) versus coastal distances between 0 and 100 km

Input data : Along-track SLA / SLA Grids combined between all missions

Statistics : mean, variance, slope

Description : SLA is computed by using successively both altimetric components. Statistics are plotted in function of coastal distances between 0 and 100 km.

Objective : This diagnostic allows the assessment of the behavior of a new component near coasts.

Example : Mean (top) and standard deviation (bottom) of FES and GOT tide model differences are plotted in function of coastal distance.

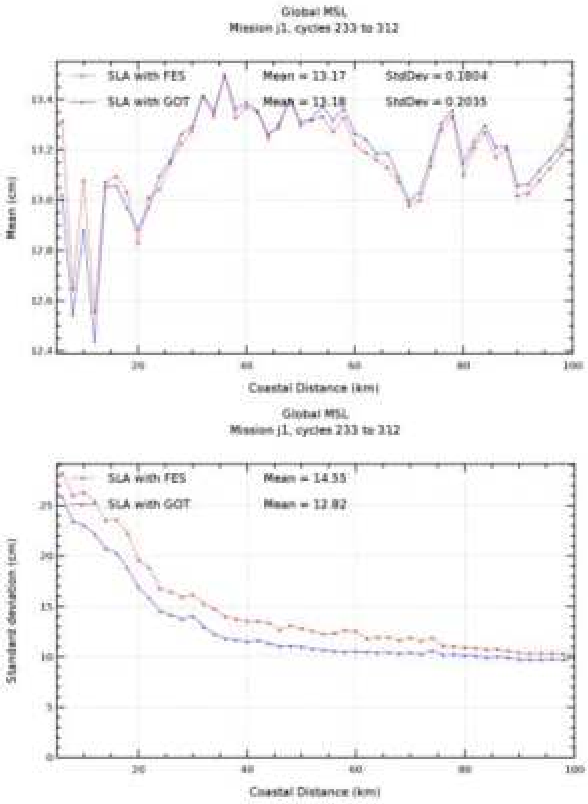


Figure 19 : SLA versus coastal distances between 0 and 100 km

Diagnostic type: Global internal analyses (A)

Diagnostic A208

Name : Sea Level Anomaly (SLA) differences versus coastal distances between 0 and 100 km

Input data : Along-track SLA / SLA Grids combined between all missions

Statistics : mean, variance, slope

Description : SLA is computed by using successively both altimetric components. The difference of variances is plotted in function of coastal distances between 0 and 100 km.

Objective : This diagnostic allows the assessment of the behavior of a new component near coasts.

Example : The difference of variances between FES and GOT tide model differences is plotted in function of coastal distance.

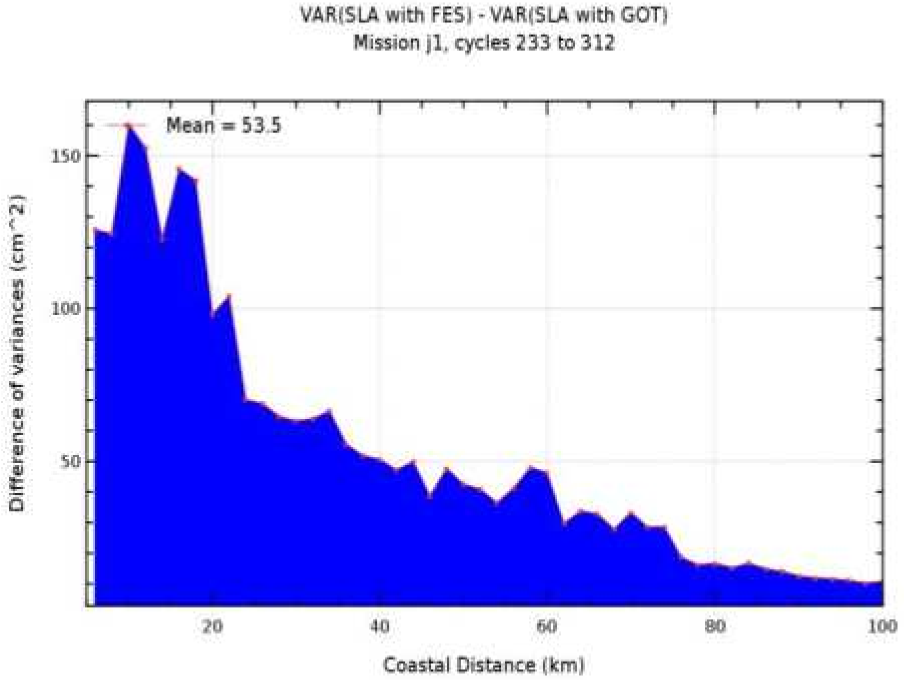


Figure 20 : SLA differences versus coastal distances between 0 and 100 km

Diagnostic type: Global multi-mission comparisons (B)

Diagnostic B201

Name : Temporal evolution of Sea level Anomaly (SLA) for two missions over the same period

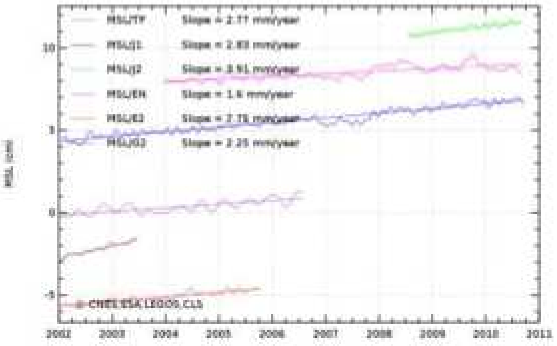
Input data : Along-track SLA

Statistics : mean, variance, slope

Description : Temporal evolution of SLA statistics of two or more missions are computed over the same period as longest as possible using successively both components in the SLA calculation. This can be done globally, or separating in ascending and descending or in northern and southern hemisphere. In order to assure comparability, statistics are computed using sea level standard calculation (mean per box of 2°x2° and weighted by cosine of latitude for the global mean) limited to 66° latitude (even if one mission has a higher inclination).

Objective : This diagnostic allows especially the comparison of MSL between different missions and the analysis of the consistency improvement using the new altimeter component in comparison with the reference one.

Example : The temporal evolution of the global MSL is computed over the Jason-1 period (2002 to 2010) for all the altimetric missions using successively the radiometer and the model wet troposphere corrections.



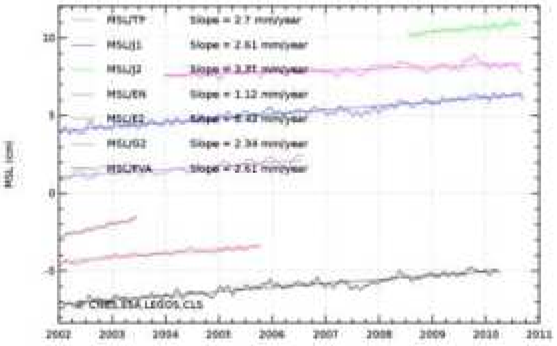
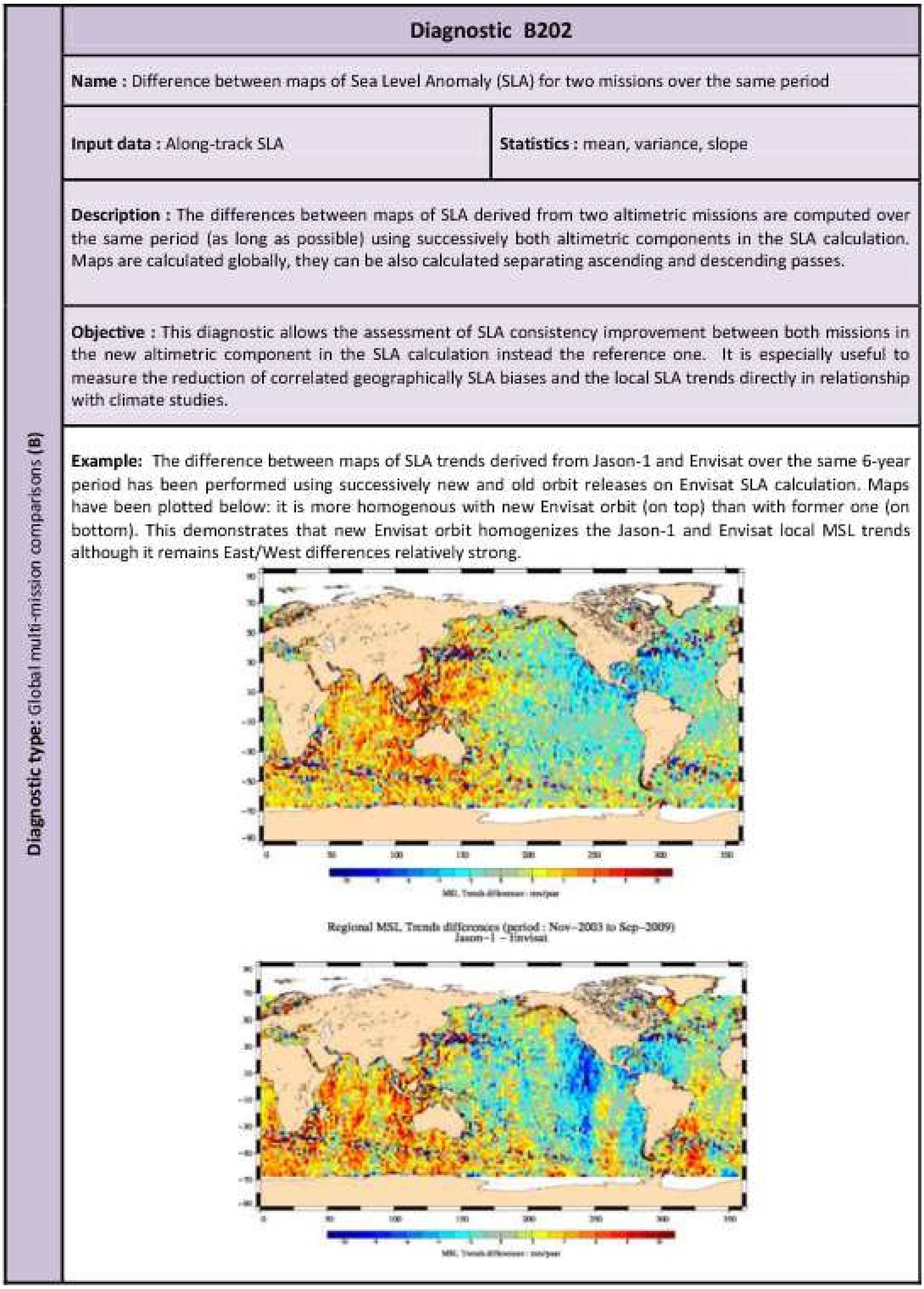


Figure 21 : Temporal evolution of SLA for two missions over the same period



Diagnostic type: Global multi-mission comparisons (B)

Diagnostic B202

Name : Difference between maps of Sea Level Anomaly (SLA) for two missions over the same period

Input data : Along-track SLA

Statistics : mean, variance, slope

Description : The differences between maps of SLA derived from two altimetric missions are computed over the same period (as long as possible) using successively both altimetric components in the SLA calculation. Maps are calculated globally, they can be also calculated separating ascending and descending passes.

Objective : This diagnostic allows the assessment of SLA consistency improvement between both missions in the new altimetric component in the SLA calculation instead the reference one. It is especially useful to measure the reduction of correlated geographically SLA biases and the local SLA trends directly in relationship with climate studies.

Example: The difference between maps of SLA trends derived from Jason-1 and Envisat over the same 6-year period has been performed using successively new and old orbit releases on Envisat SLA calculation. Maps have been plotted below: it is more homogenous with new Envisat orbit (on top) than with former one (on bottom). This demonstrates that new Envisat orbit homogenizes the Jason-1 and Envisat local MSL trends although it remains East/West differences relatively strong.

Figure 22 : Differences between maps of SLA for two missions over the same period.

Diagnostic type: Global altimetry and In-situ data comparison **(C)**

Diagnostic C001

Name : Temporal evolution of Sea Surface Height (SSH) differences between tide gauges and altimetry measurements

Input data : Tide gauge SSH measurements

Statistics : mean, variance, slope

Description : The temporal evolution of global statistics of SSH differences between tide gauges and altimeter measurements are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in altimetric SSH calculation. The altimetric and tide gauges data are collocated with criteria of maximum of correlation, and tide gauges used are derived from global networks as GLOSS/CLIVAR.

Objective : This diagnostic is especially useful to measure the drift of the altimeter MSL thanks to external and independent data. The impact of the new altimetric component can then be evaluated on the MSL drift.

Example : The temporal mean of differences between tide gauge measurements and Envisat altimeter data have been calculated and plotted on the following figure using successively the radiometer and the model wet troposphere corrections in the Envisat SSH calculation.

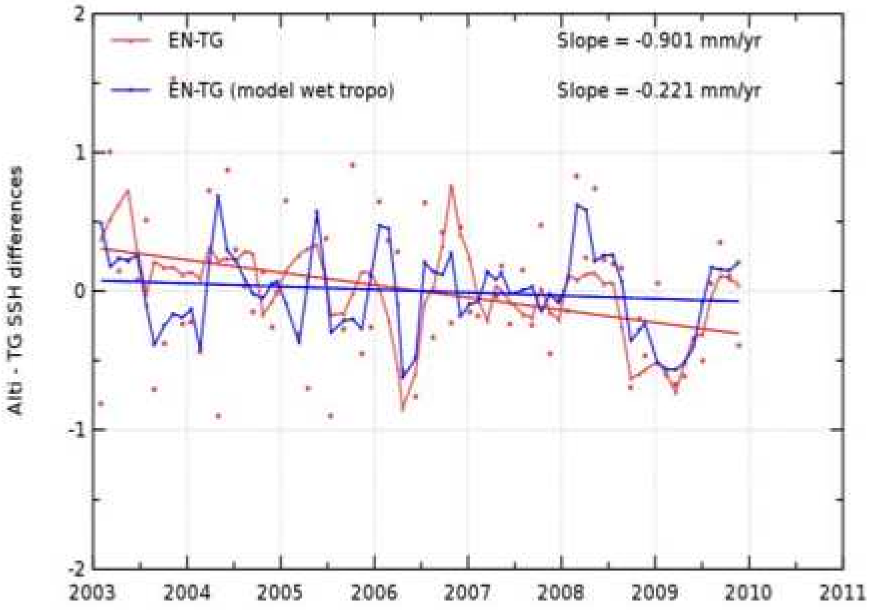
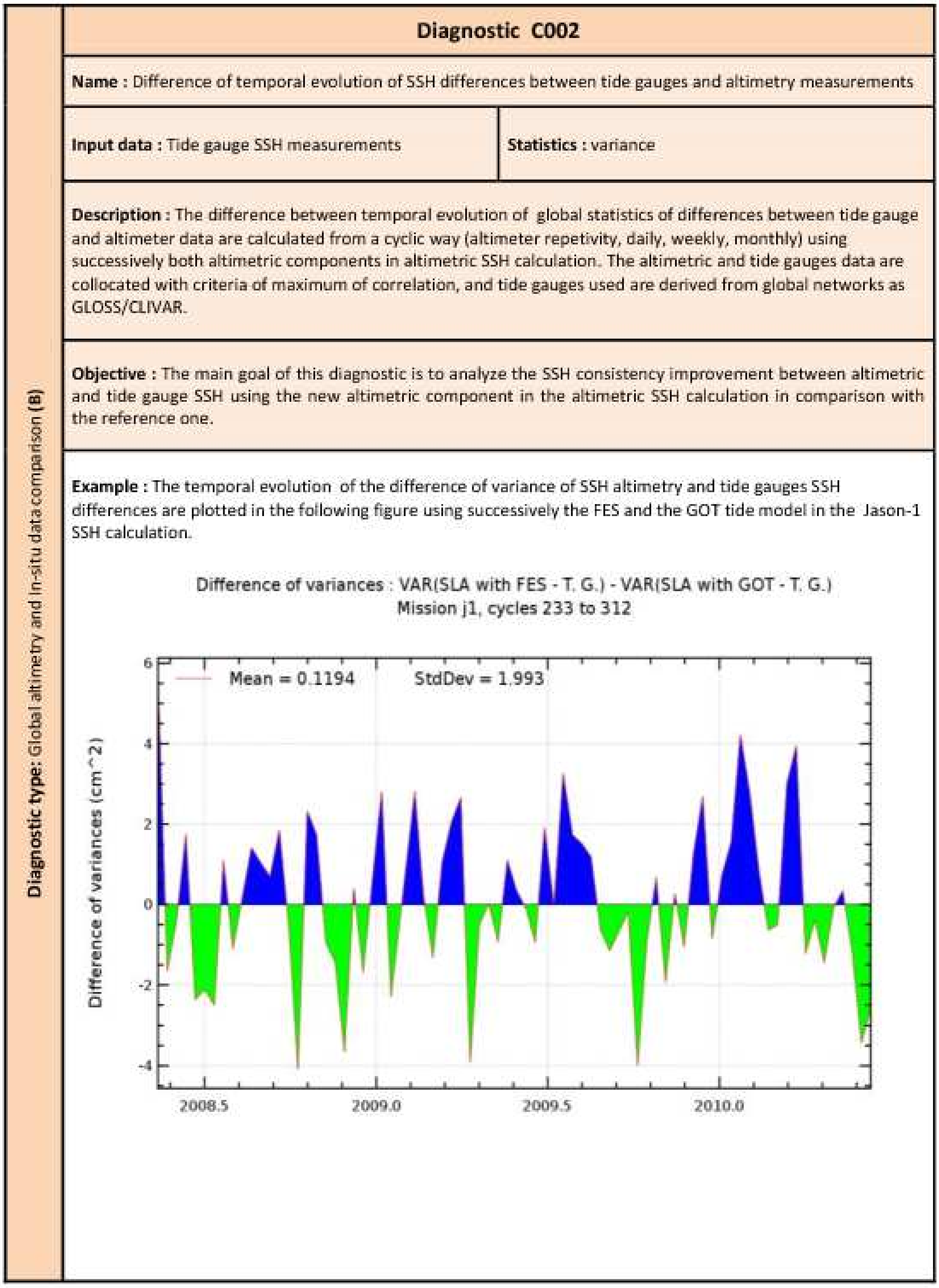


Figure 23 : Temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period



Diagnostic type: Global altimetry and In-situ data comparison (B)

Diagnostic C002

Name : Difference of temporal evolution of SSH differences between tide gauges and altimetry measurements

Input data : Tide gauge SSH measurements

Statistics : variance

Description : The difference between temporal evolution of global statistics of differences between tide gauge and altimeter data are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in altimetric SSH calculation. The altimetric and tide gauges data are collocated with criteria of maximum of correlation, and tide gauges used are derived from global networks as GLOSS/CLIVAR.

Objective : The main goal of this diagnostic is to analyze the SSH consistency improvement between altimetric and tide gauge SSH using the new altimetric component in the altimetric SSH calculation in comparison with the reference one.

Example : The temporal evolution of the difference of variance of SSH altimetry and tide gauges SSH differences are plotted in the following figure using successively the FES and the GOT tide model in the Jason-1 SSH calculation.

Figure 24 : Differences of temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period

Diagnostic type : Global altimetry and in-situ data comparison (C)

Diagnostic C003

Name : Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry

Input data : Tide gauges

Statistics : mean, variance

Description : The periodogram derived from temporal evolution of altimetric and tide gauges SSH differences is calculated using successively both altimetric components in the altimetric SSH. The periodogram is calculated from the mean and it can be displayed for all the whole time period or on a dedicated one.

Objective : This diagnostic allows the characterization of the altimeter and tide gauges SSH differences versus the period. The contribution of the new altimetric component on the SSH can be estimated at relevant scales for climate studies (as annual and semi-annual signals) from an independent way thanks to in-situ measurements.

Example : The periodogram of altimeter and tide gauge SSH differences have been calculated for Jason-1 altimeter using successively two different oceanic tidal model corrections : GOT4V7 and FES04

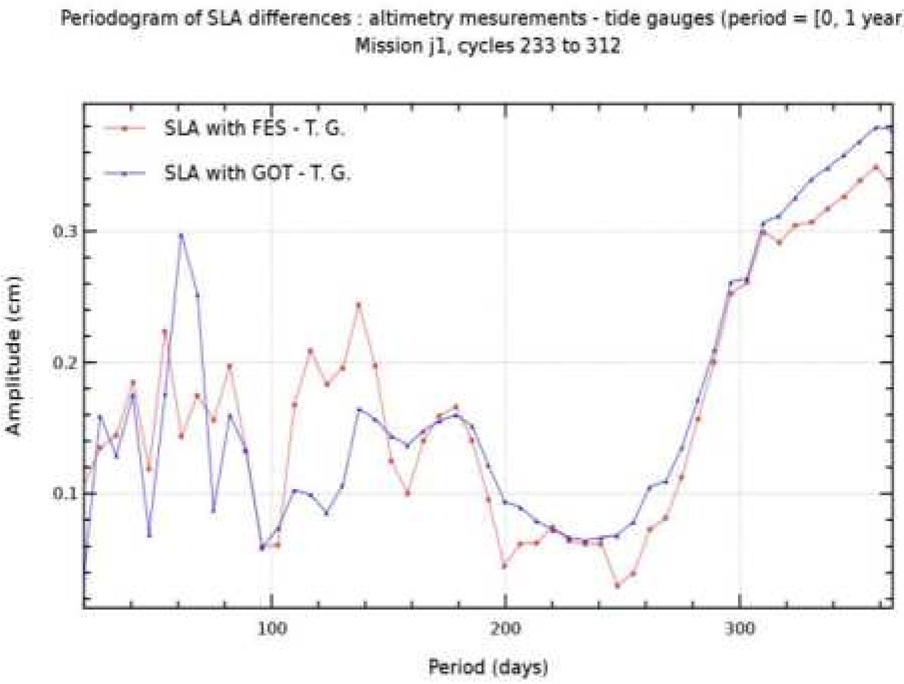


Figure 25 : Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry data over all the altimetry period

Diagnostic type: Global altimetry and In-situ data comparison (C)

Diagnostic C004

Name : Difference of histograms between tide gauges and altimeter SSH differences

Input data : Tide gauge measurements

Statistics : mean, variance

Description : The difference of histograms between altimeter and tide gauge SSH differences is computed from the elementary statistics at each tide gauge using successively both altimetric components in the altimetry SSH.

Objective : This diagnostic allows the estimation of the number of tide gauges where the SSH consistency between altimeter and tide gauges is improved thanks to the new altimetric component in the altimeter SSH calculation.

Example : The differences of histograms between altimeter and tide gauge SSH differences has been computed with Jason-1 using successively two different editing algorithms (in order to remove spurious altimeter SSH measurements better). The positive differences of variance show an improvement of the new editing algorithm for more than 70% of tide gauges.

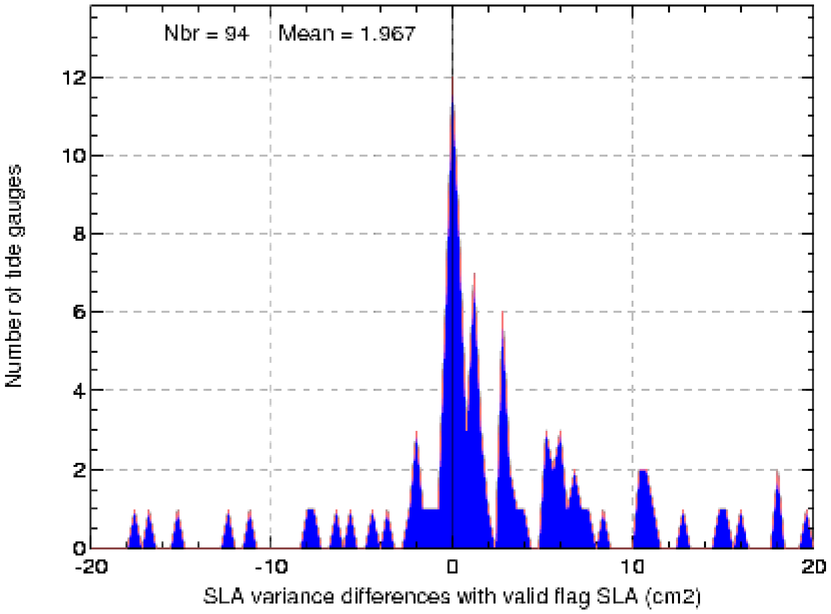


Figure 26 : The difference of histograms between tide gauges and altimeter SSH differences

Diagnostic type: Global altimetry and In-situ data comparison (C)

Diagnostic C101

Name: Temporal evolution of Sea Surface Height (SSH) differences between T/S profiles and altimetry measurements

Input data : Temperature and Salinity (T/S) profiles

Statistics : mean, variance, slope

Description: The temporal evolution of global statistics of SSH differences between T/S profiles and altimeter measurements are calculated from a cyclic way (altimeter repetivity, weekly, monthly) using successively both altimetric components in altimetric SSH calculation. The altimetric and T/S profiles are collocated by a bilinear interpolation each 10 day (approximately) at T/S profile location.

Objective: This diagnostic is especially useful to measure the drift of the altimeter MSL thanks to external and independent data. The impact of the new altimetric component can then be evaluated on the MSL drift.

Example: The temporal mean of differences between T/S measurements and altimeter data have been calculated and plotted on the following figure using successively SSH derived from Jason-1 and SSH derived from multi-mission merged products. Trends are superimposed in order to estimate the drift of the altimeter MSL.

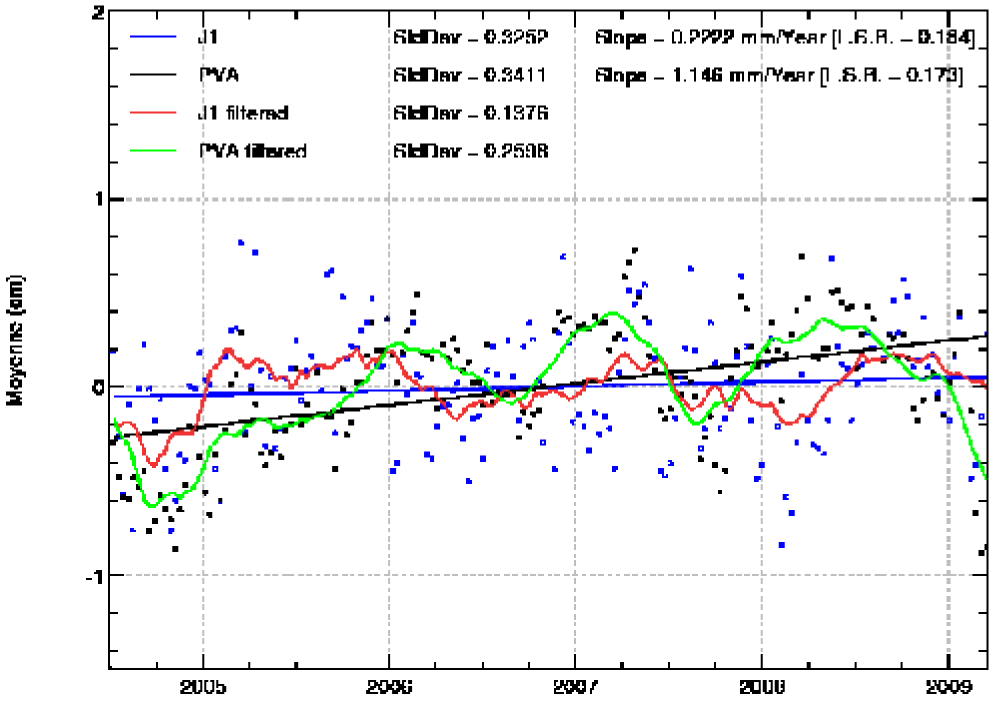


Figure 27 : Temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period: global, north/south, east/west

Diagnostic type: Global altimetry and In-situ data comparison **(B)**

Diagnostic C102

Name : Difference of temporal evolution of SSH differences between T/S profiles and altimetry measurements

Input data : Temperature and Salinity (T/S) profiles

Statistics : variance

Description : The difference between temporal evolution of global statistics of differences between T/S profiles and altimeter data differences are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in altimetric SSH calculation. The altimetric and T/S profiles are collocated by a bilinear interpolation each 10 days (approximately) at T/S profile location.

Objective : The main goal of this diagnostic is to analyze the SSH consistency improvement between altimetric and T/S profile SSH using the new altimetric component in the altimetric SSH calculation in comparison with the reference one.

Example : The temporal evolution of the difference of variance of SSH altimetry and T/S profiles differences are plotted in the following figure for Jason-1 SSH using successively2 CNES's orbit solutions derived from GDR-C and GDR-B releases. The green areas (negative values of difference of variance) indicates a better Jason-1 SSH consistency with T/S profiles using CNES GDR-C orbit.

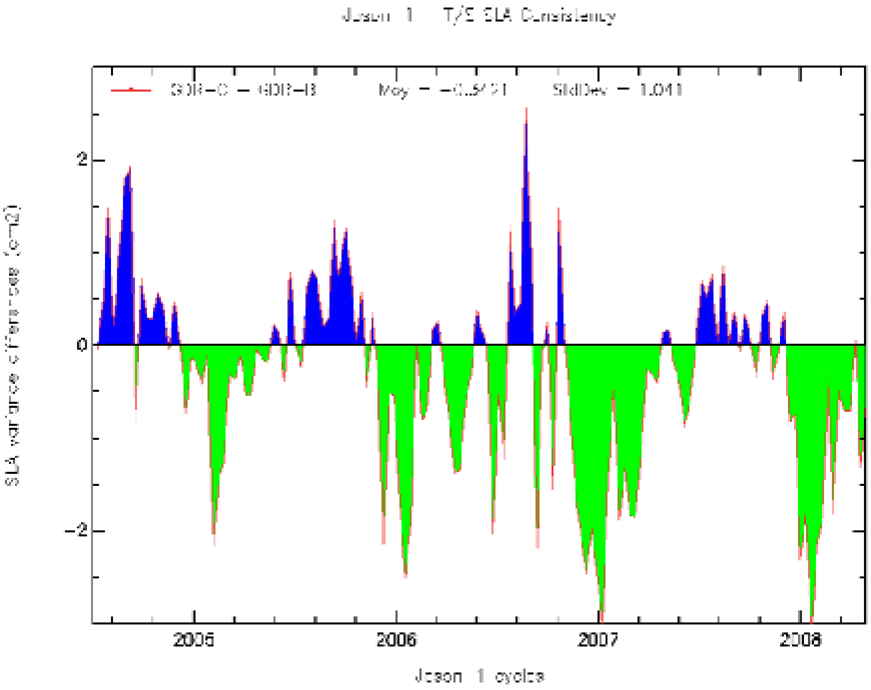


Figure 28 : Differences of temporal evolution of SSH differences between T/S profiles and altimetry data over all the altimetry period

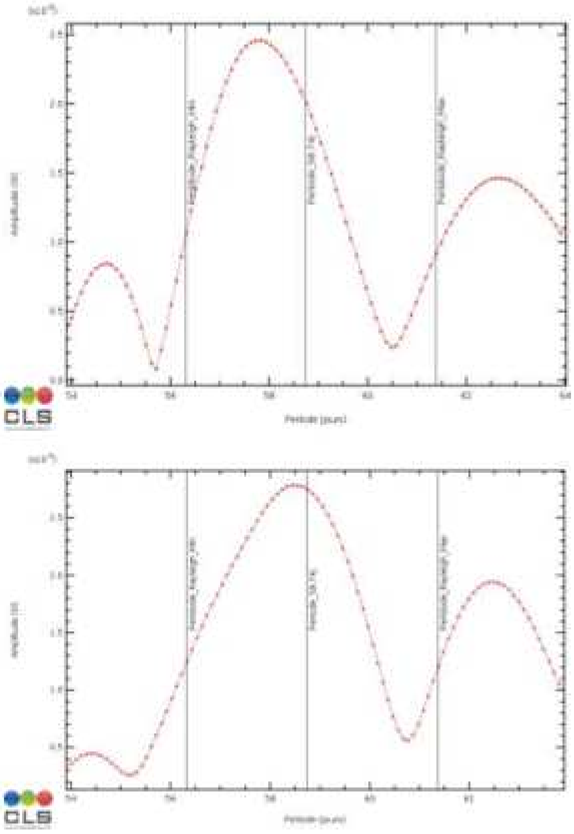
<table>
<tr><td rowspan="6">Diagnostic type: Global altimetry and In-situ data comparison (C)</td><td colspan="2">Diagnostic C103</td></tr>
<tr><td colspan="2">Name: Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry</td></tr>
<tr><td>Input data : Temperature and Salinity (T/S) profiles</td><td>Statistics : mean, variance</td></tr>
<tr><td colspan="2">Description: The periodogram derived from temporal evolution of altimetric and T/S profile SSH differences is calculated using successively both altimetric components in the altimetric SSH. The periodogram is calculated from the mean or variance statistics and it can be displayed for all the whole time period or on a dedicated one.</td></tr>
<tr><td colspan="2">Objective: This diagnostic allows the characterization of the altimeter and T/S profile SSH differences versus the period. The contribution of the new altimetric component on the SSH can be estimated at relevant scales for climate studies (as annual and semi-annual signals) from an independent way thanks to in-situ measurements.</td></tr>
<tr><td colspan="2">Example: The periodogram of altimeter and T/S profile SSH differences have been calculated for TOPEX altimeter focusing on 60-day period and using successively two different oceanic tidal model corrections: GOT4V7 (top) and FES04 (bottom). The 59-day signal is reduces on the SSH differences with GOT4V7 models than with FES04 models indicating a best SSH calculation at this period.

 </td></tr>
</table>

Figure 29 : Periodogram derived from temporal evolution SSH differences between T/S profiles and altimetry data over all the altimetry period.

Appendix B - **List of acronyms**

TBC	To be confirmed
TBD	To be defined
AD	Applicable Document
RD	Reference Document
SSH	Sea Surface Height
SLA	Sea level Anomaly
RRDP	Round Robin Data Package
T/S	Temperature and Salinity profiles
TG	Tide Gauges
MSL	Mean Sea Level
PVP	Product Validation Plan
ECV	Essential Climate Variable
FCDR	Fundamental Climate Data Records