

# Sea State Bias: 3D vs 2D

Study variable	<b>3D SSB</b>
Reference variable	<b>2D SSB</b>
Missions	Envisat ( <i>en</i> )
Period	[19259, 21890]

Creation date : 2011/09/03

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## Study overview

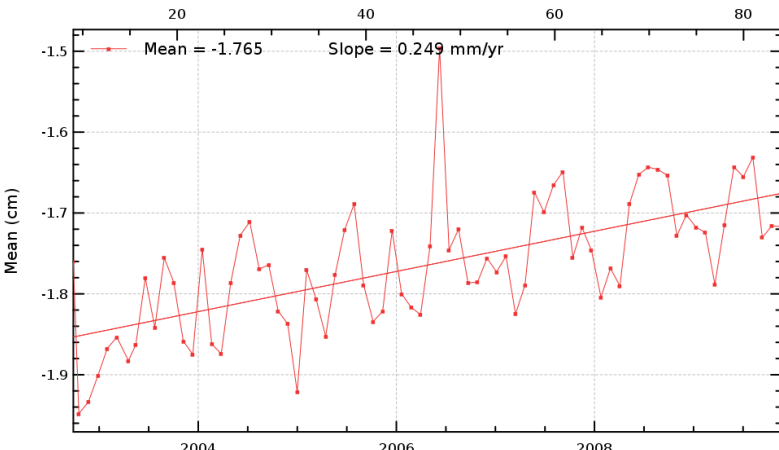
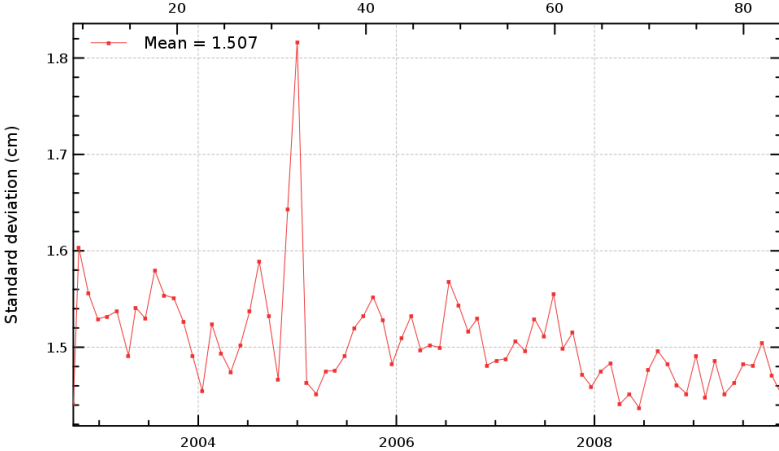
In this study, a new sea state bias correction is compared with the non parametric sea state bias correction used in CNES AVISO products for ENVISAT mission. Note that this reference SSB is not homogeneous over the whole Envisat mission.

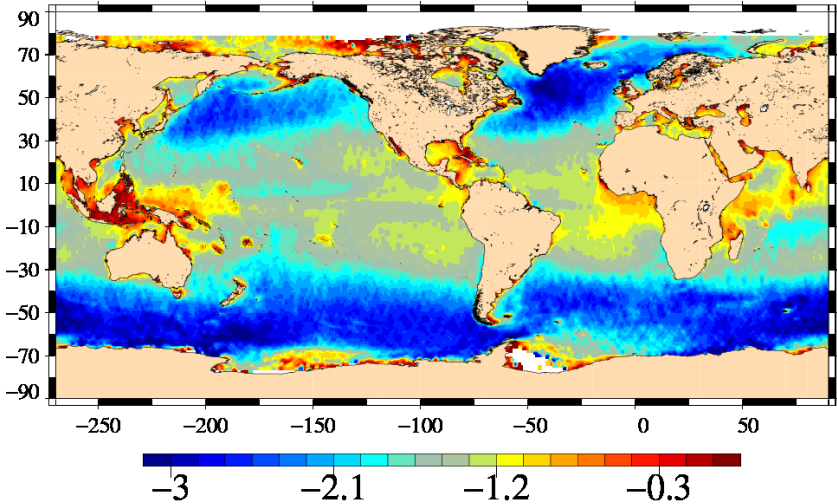
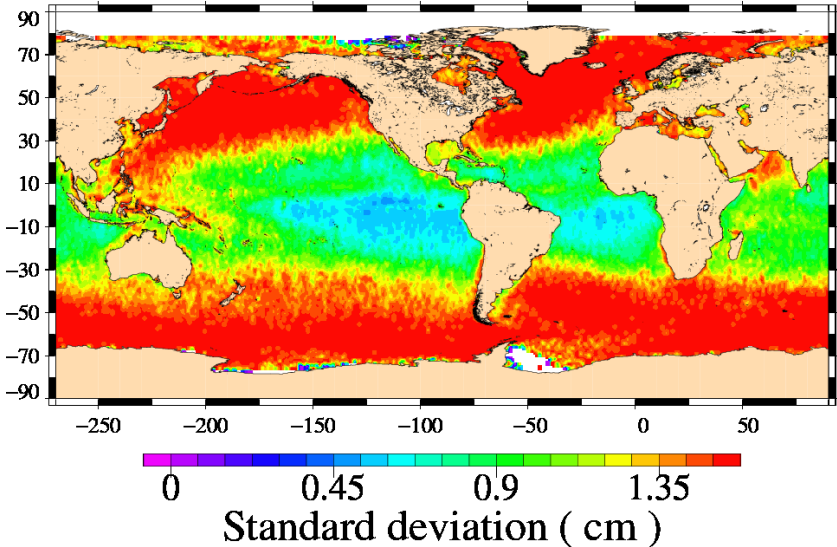
The impact of using these both sea state bias corrections on the SSH computation has been analyzed for Envisat mission from September 2002 (cycle 9) to December 2009 (Cycle 84).

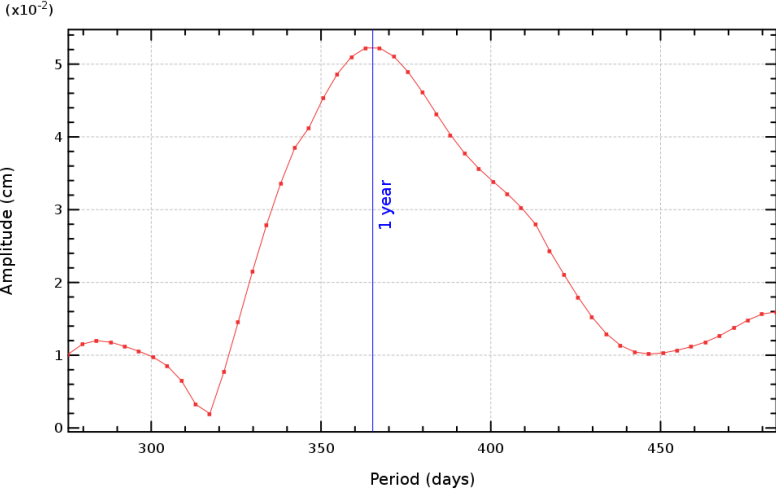
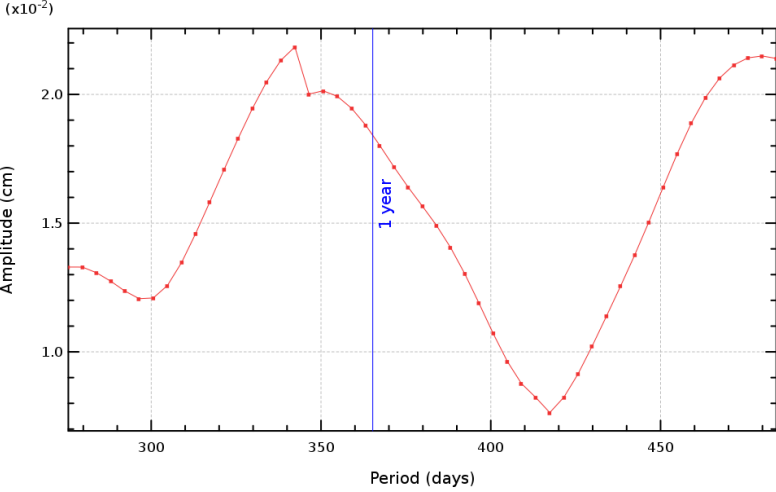
The studied correction results from the development of a new non parametric SSB model adapted for Envisat mission which takes into account a third parameter, the mean wave period ( $T_m$ ) or the swell height ( $shs$ ), from a numerical wave model (WaveWatch3) forced by ECMWF wind fields. Such 3D models have been developed for the Jason missions and have shown some improvement in term of SSH variance reduction when compared to that from the application of the standard 2D SSB model. See Tran 2010, CLS-DOS-NT-10-287, RA2 Ocean and MWR measurement long-term monitoring - Annual report for WP3, Task 2: "SSB estimation for RA2 altimeter".

The reference correction for Envisat is the non parametric 2-D sea state bias: Labroue S., 2007: "RA2 ocean and MWR measurement long term monitoring", Technical Report CLS- DOS-NT-07-198, ESA Contract n 17293/03/I-OL.

All the validation diagnostics displayed in this report has been performed in agreement with the Sea-Level CCI Product Validation Plan (PVP).

Diagnostic A001 (mission en)	
Name : Temporal evolution of differences between both altimetric components	
Input data : Along-track altimetric components	
Description : The temporal evolution of global statistics (mean, variance, slope) of differences between 2 different standards of a same altimetric component (sea surface height correction, altimeter parameter, orbit) are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) . These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.	
<div><div><div>Mean of 3D SSB - 2D SSB Mission en, cycles 9 to 83</div><div><div><div>Mean = -1.765</div><div>Slope = 0.249 mm/yr</div></div></div><div><div>Standard deviation of 3D SSB - 2D SSB Mission en, cycles 9 to 83</div><div><div>Mean = 1.507</div></div></div></div></div>	

Diagnostic A002 (mission en)	
Name : Map of differences between both altimetric components over all the period	
Input data : Along-track altimetric components	
Description : The map of global statistics (mean, standard deviation) of differences between 2 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 statically results. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.	
<div>Mean of 3D SSB – 2D SSB Mission en, cycles 9 to 83</div>  <div>Mean ( cm ) Standard deviation of 3D SSB – 2D SSB Mission en, cycles 9 to 83</div> 	

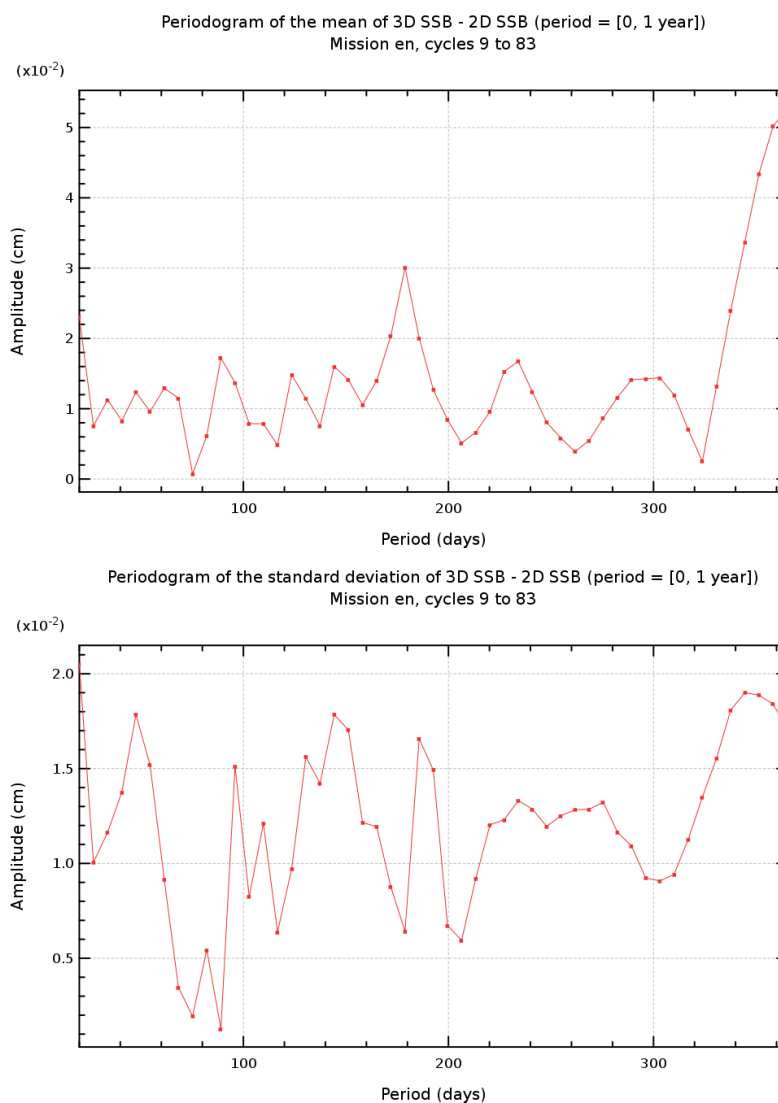
Diagnostic A003_a (mission en)	
Name : Periodogram derived from temporal evolution of altimetric component differences	
Input data : Along-track altimetric components	
<p>Description : The periodogram derived from temporal and global altimetric component differences is calculated from cycle by cycle monitoring of altimetric component differences (derived from diagnostic A001). It is calculated from the mean or the variance differences. The Periodogram can be calculated for all the periods, but it can be focused on a dedicated period.</p>	
<div><p>Periodogram of the mean of 3D SSB - 2D SSB (reference period = 1 year) Mission en, cycles 9 to 83</p><p>Periodogram of the standard deviation of 3D SSB - 2D SSB (reference period = 1 year) Mission en, cycles 9 to 83</p></div>	

## Diagnostic A003\_b (mission en)

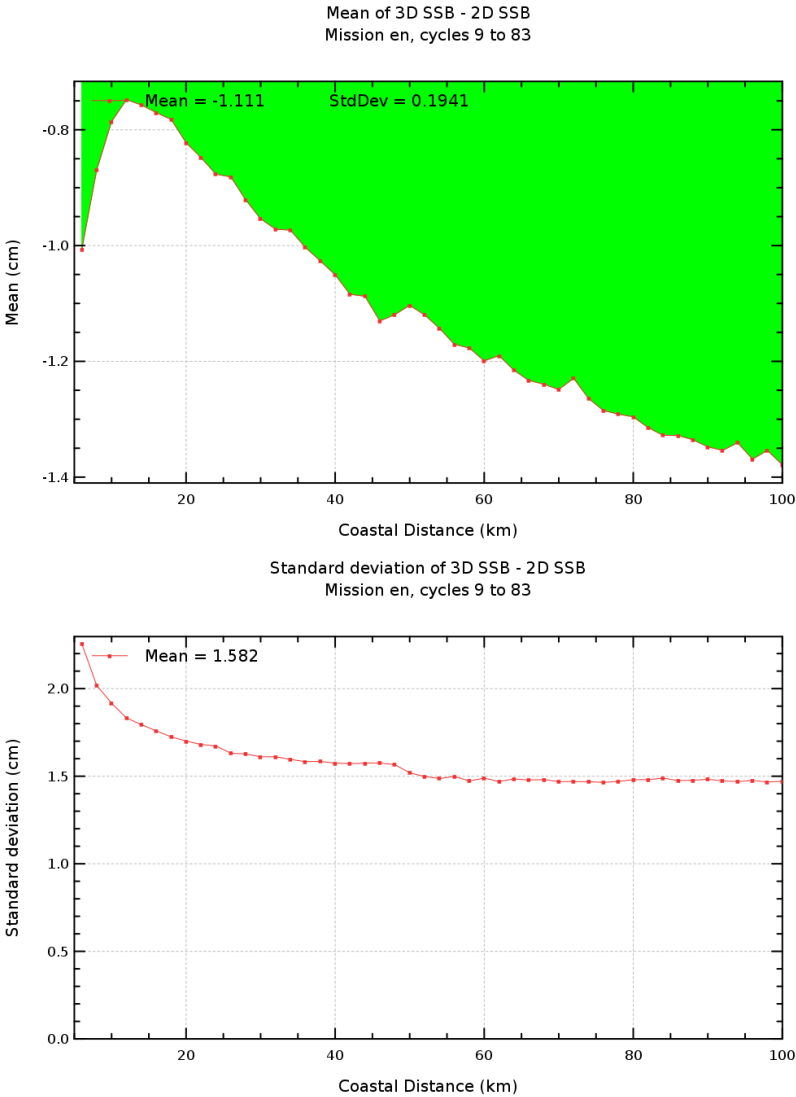
**Name :** Periodogram derived from temporal evolution of altimetric component differences

**Input data :** Along-track altimetric components

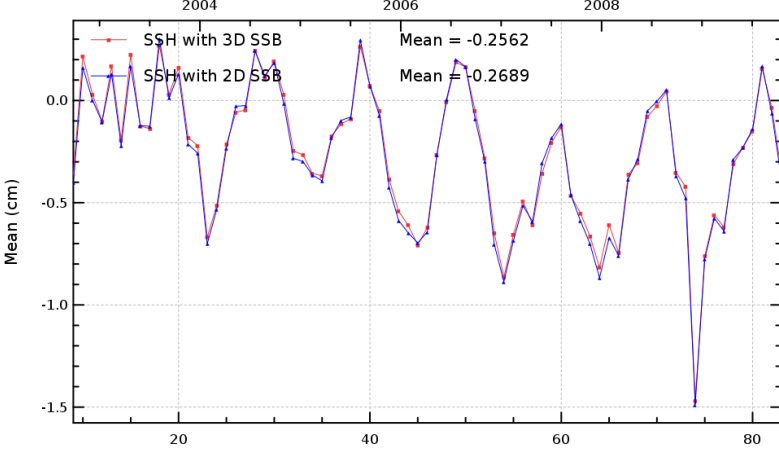
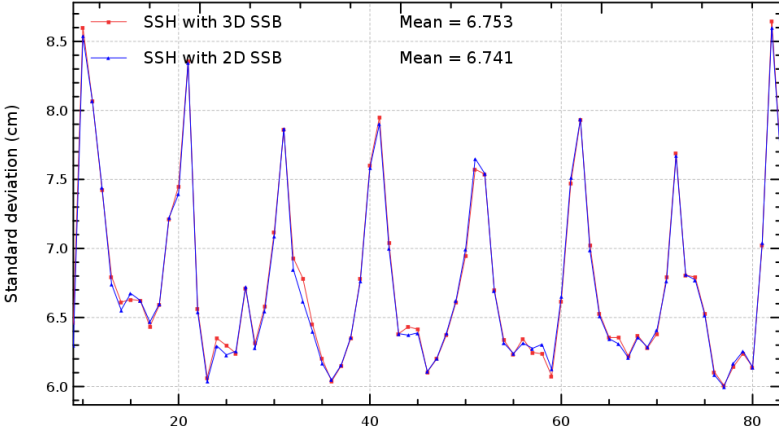
**Description :** The periodogram derived from temporal and global altimetric component differences is calculated from cycle by cycle monitoring of altimetric component differences (derived from diagnostic A001). It is calculated from the mean or the variance differences. The Periodogram can be calculated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



Diagnostic A004 (mission en)	
Name : Altimetric component differences versus coastal distances	
Input data : Along-track altimetric components	
Description : Mean and standard deviation of the differences between 2 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.	





Diagnostic A101 (mission en)	
Name : Temporal evolution of SSH crossovers	
Input data : Sea Surface Height (SSH) crossovers	
<p><b>Description :</b> The temporal evolution of global statistics (mean, standard deviation) 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).</p>	
<div><div><div>Mean of SSH crossovers Mission en, cycles 9 to 83</div><div></div></div><div><div>Standard deviations of SSH crossovers Mission en, cycles 9 to 83</div><div></div></div></div>	

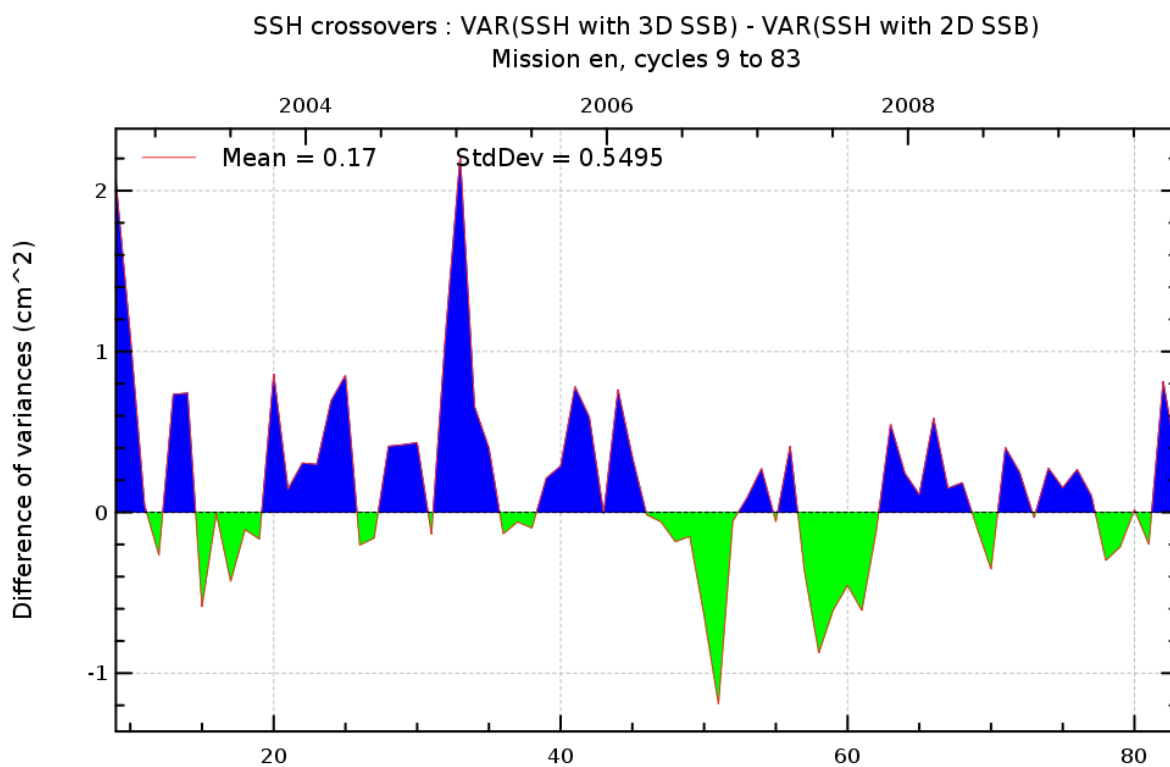
## Diagnostic A102 (mission en)

**Name :** Differences between temporal evolution of SSH crossovers

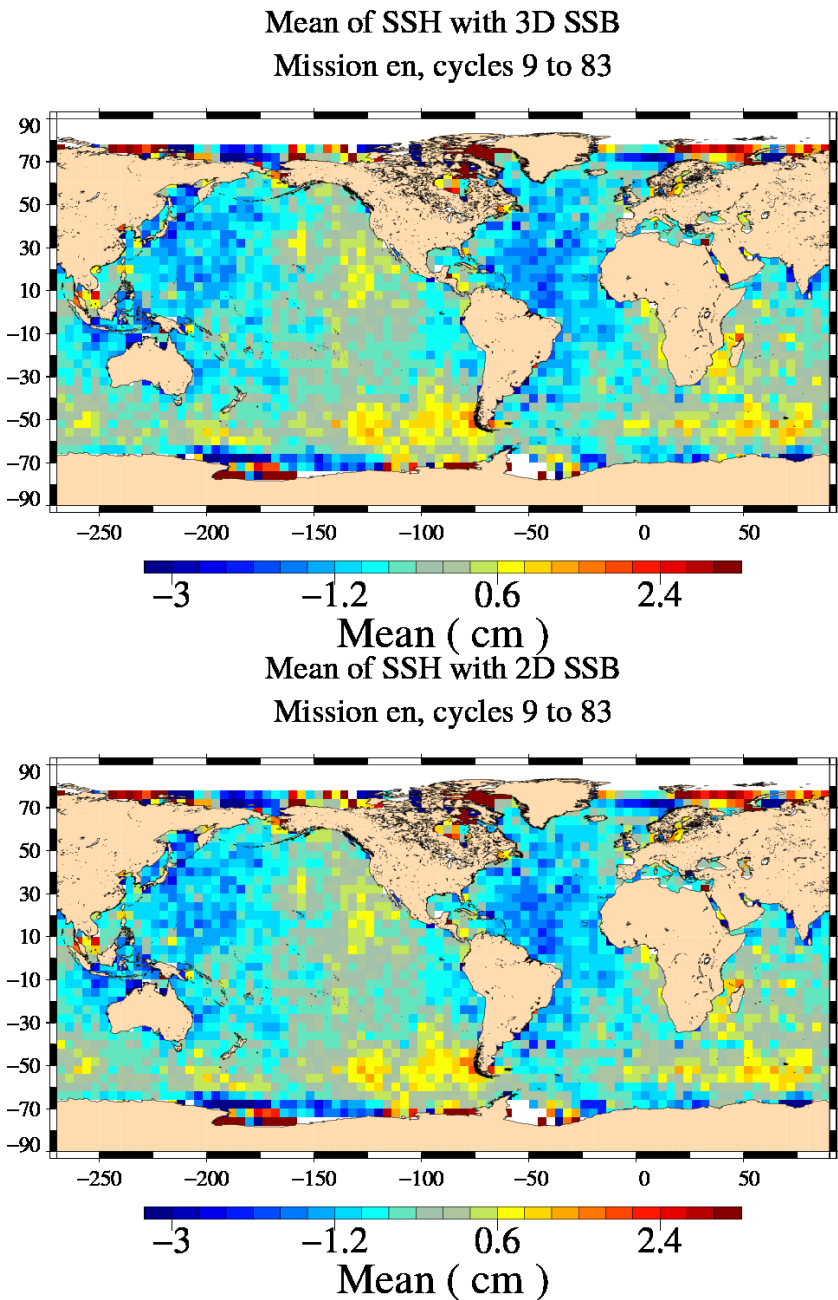
**Input data :** Sea Surface Height (SSH) crossovers

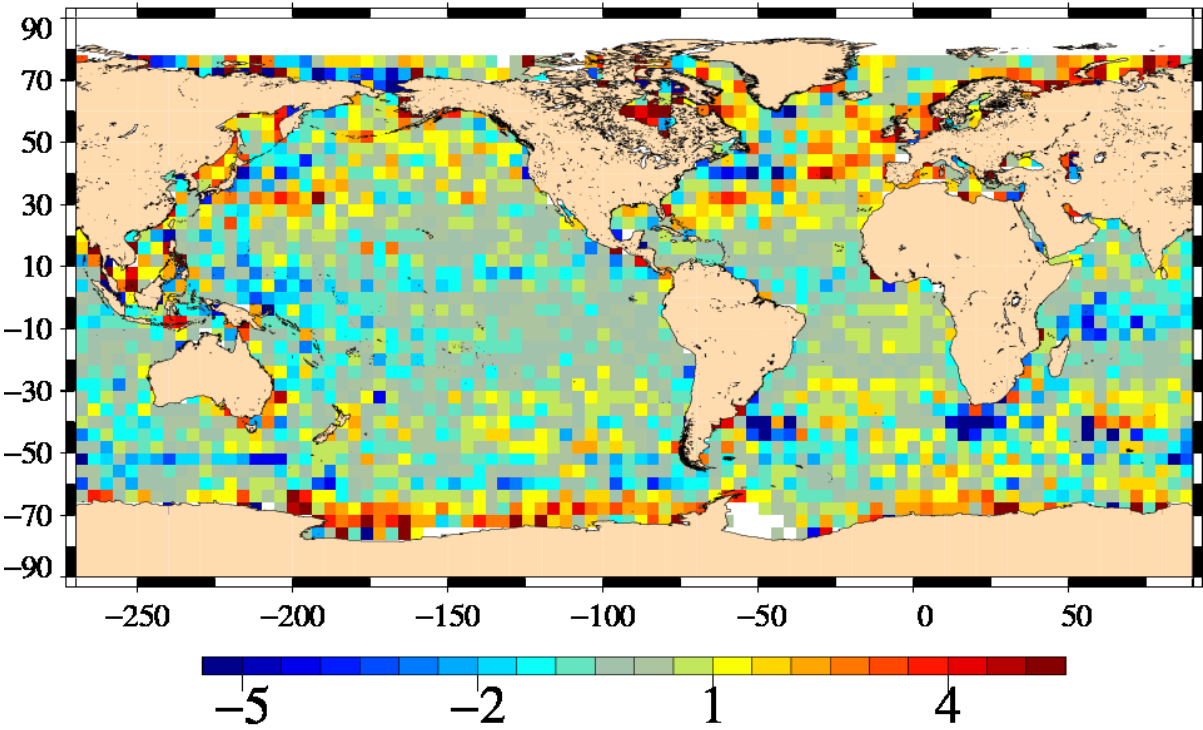
**Description :** The difference of temporal evolution between the global statistics (mean, standard deviation) of SSH differences are calculated using successively both altimetric components in the SSH calculation. SSH crossovers are the differences between ascending and descending passes for time differences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

Diagnostic type : Global internal analyses



Diagnostic A103 (mission en)	
Name :	Map of SSH crossovers
Input data :	Sea Surface Height (SSH) crossovers
Description :	The differences between maps of SSH crossovers differences (mean, variance) 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).



Diagnostic type : Global internal analyses	Diagnostic A104 (mission en)	
	Name : Differences between maps of SSH crossovers	
	Input data : Sea Surface Height (SSH) crossovers	
	Description : The differences between maps of SSH crossovers (derived from diagnostic A103) are calculated from the SSH crossover differences (mean, standard deviation) 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).	
	<div>VAR(SSH with 3D SSB) – VAR(SSH with 2D SSB)</div> <div>Mission en, cycles 9 to 83</div>  <div>SSH crossovers : difference of variances ( cm^2 )</div>	

Diagnostic type : Global internal analyses	Diagnostic A201 a (mission en)																					
	Name : Temporal evolution of Sea Level Anomaly (SLA)																					
	Input data : Along track SLA																					
	<p>Description : The temporal evolution of SLA statistics (mean, standard deviation) 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.</p>																					
	<div>Global MSL Mission en, cycles 9 to 83</div> <p>The graph displays two data series: 'SLA with 3D SSB' (red line) and 'SLA with 2D SSB' (blue line). The y-axis represents 'Mean (cm)' ranging from 49 to 51. The x-axis represents 'Mission en, cycles 9 to 83' with major ticks at 20, 40, 60, and 80. Below the x-axis, the years 2004, 2006, and 2008 are marked. Both series show a general upward trend with significant fluctuations. The red line starts around 50.3 cm and ends near 50.7 cm, while the blue line starts around 48.8 cm and ends near 49.2 cm. Linear regression lines are shown for both series with their respective slopes and L.S.R. values.</p> <table border="1"><thead><tr><th>Mission Cycle</th><th>SLA with 3D SSB (cm)</th><th>SLA with 2D SSB (cm)</th></tr></thead><tbody><tr><td>9</td><td>~50.3</td><td>~48.8</td></tr><tr><td>20</td><td>~50.4</td><td>~48.9</td></tr><tr><td>40</td><td>~50.5</td><td>~49.0</td></tr><tr><td>60</td><td>~50.6</td><td>~49.1</td></tr><tr><td>80</td><td>~50.7</td><td>~49.2</td></tr><tr><td>83</td><td>~50.8</td><td>~49.3</td></tr></tbody></table>		Mission Cycle	SLA with 3D SSB (cm)	SLA with 2D SSB (cm)	9	~50.3	~48.8	20	~50.4	~48.9	40	~50.5	~49.0	60	~50.6	~49.1	80	~50.7	~49.2	83	~50.8
Mission Cycle	SLA with 3D SSB (cm)	SLA with 2D SSB (cm)																				
9	~50.3	~48.8																				
20	~50.4	~48.9																				
40	~50.5	~49.0																				
60	~50.6	~49.1																				
80	~50.7	~49.2																				
83	~50.8	~49.3																				

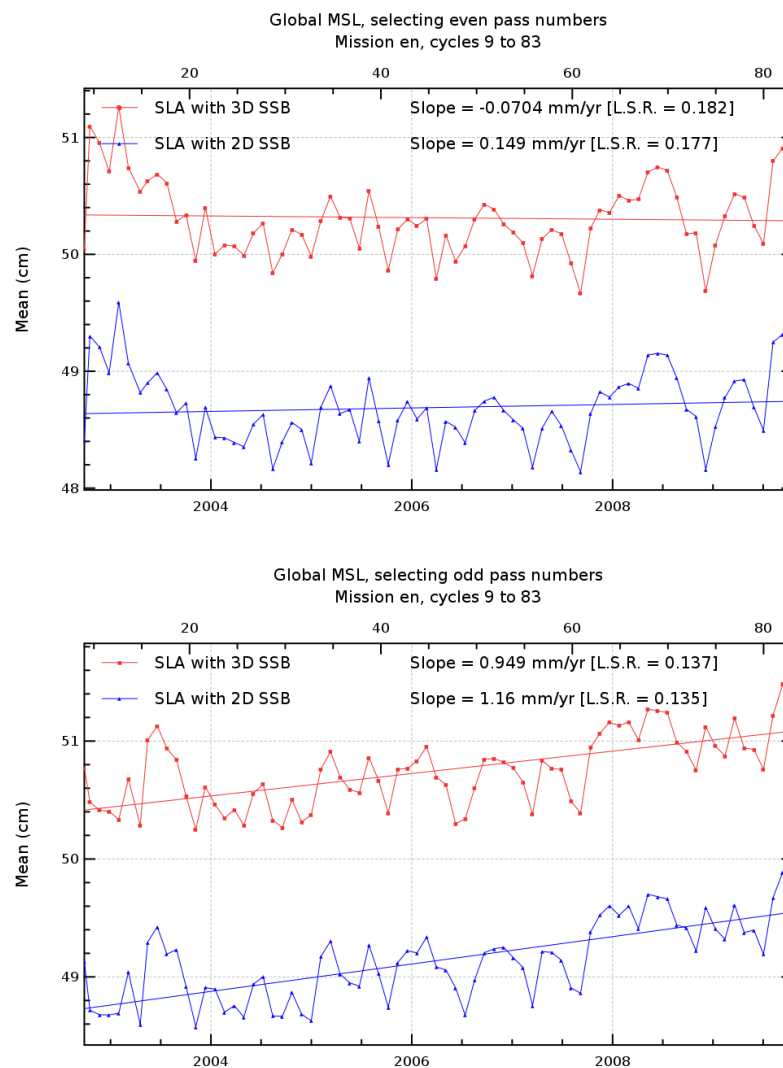
## Diagnostic A201\_b (mission en)

**Name :** Temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

**Description :** The temporal evolution of SLA statistics (mean, standard deviation) 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.

Diagnostic type : Global internal analyses



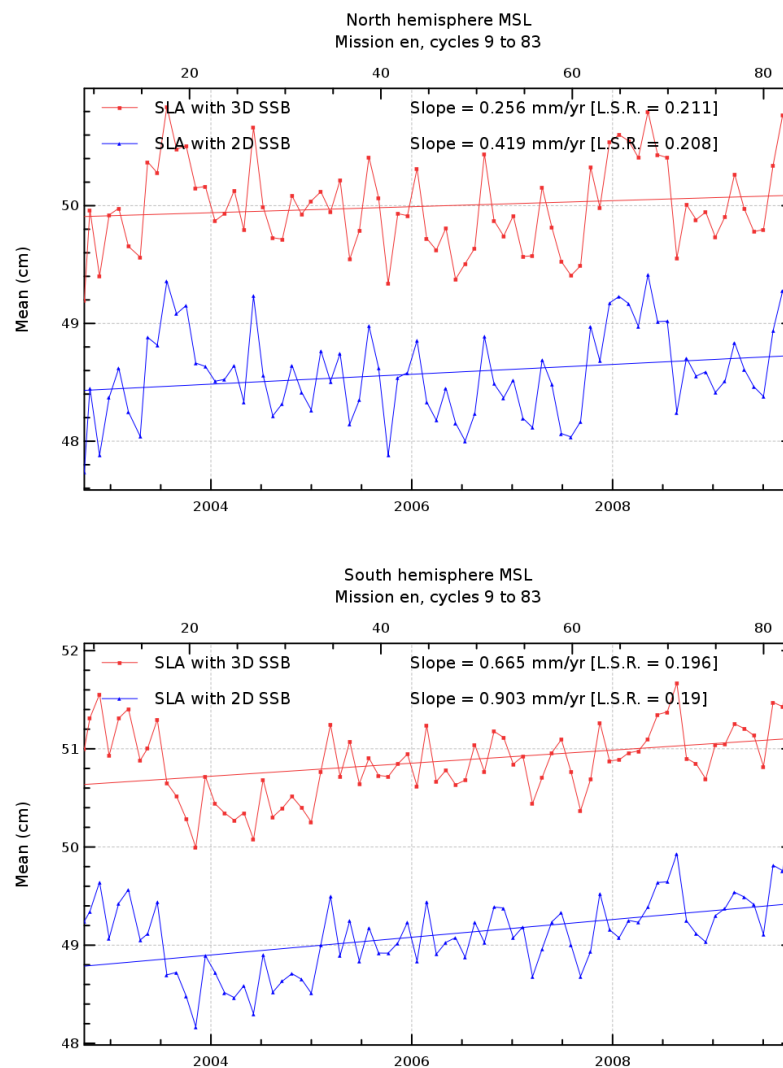
## Diagnostic A201\_c (mission en)

**Name :** Temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

**Description :** The temporal evolution of SLA statistics (mean, standard deviation) 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.

Diagnostic type : Global internal analyses



## Diagnostic A201\_d (mission en)

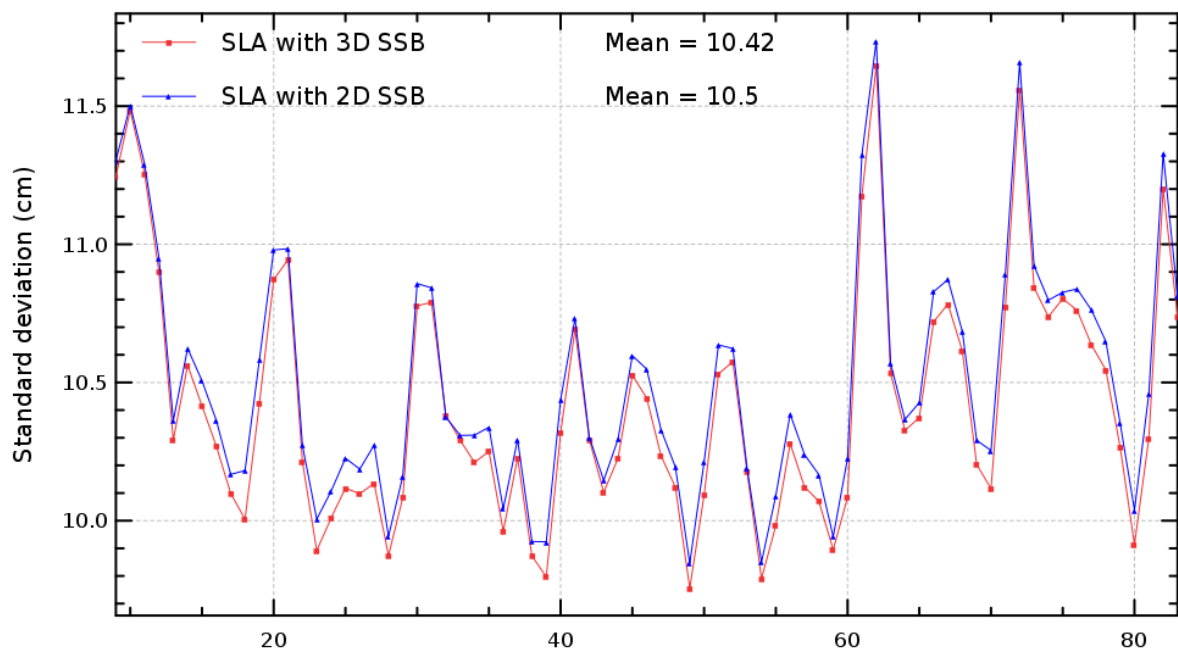
**Name :** Temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

**Description :** The temporal evolution of SLA statistics (mean, standard deviation) 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.

Diagnostic type : Global internal analyses

Global MSL  
Mission en, cycles 9 to 83





## Diagnostic A201\_e (mission en)

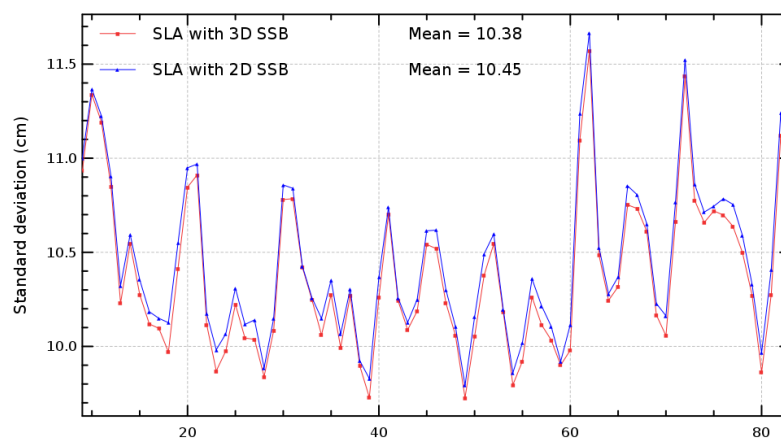
**Name :** Temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

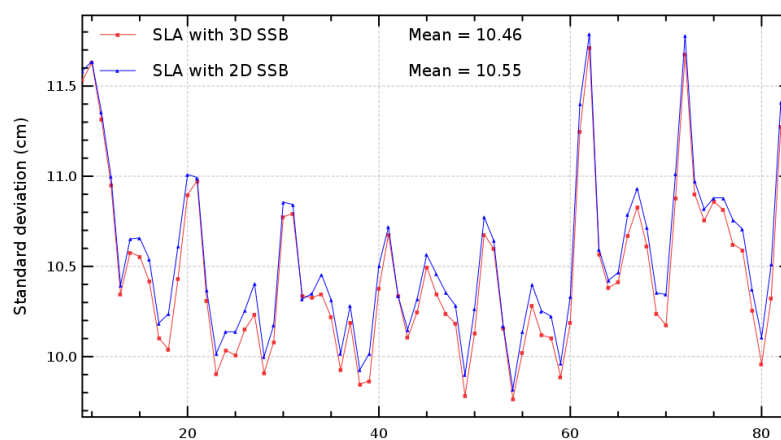
**Description :** The temporal evolution of SLA statistics (mean, standard deviation) are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in the SLA calculation. These statistics are calculated from 1 Hz altimetric measurements 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.

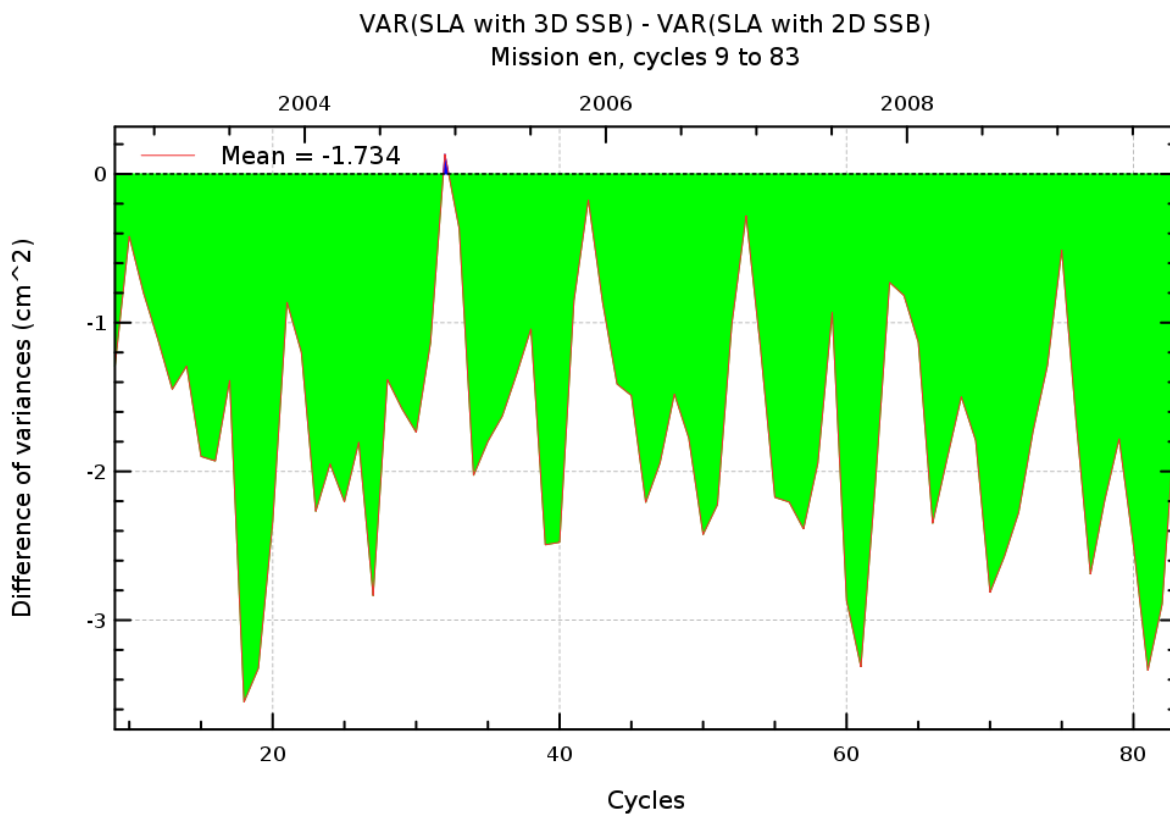
Diagnostic type : Global internal analyses

Global MSL, selecting even pass numbers  
Mission en, cycles 9 to 83



Global MSL, selecting odd pass numbers  
Mission en, cycles 9 to 83



Diagnostic type : Global internal analyses	<b>Diagnostic A202_a (mission en)</b>
	<b>Name :</b> Differences between temporal evolution of Sea Level Anomaly (SLA)
	<b>Input data :</b> Along track SLA
	<b>Description :</b> The differences between temporal evolution of SLA are calculated from statistics derived from diagnostic A201 (mean, variance) using 2 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.
<p>VAR(SLA with 3D SSB) - VAR(SLA with 2D SSB) Mission en, cycles 9 to 83</p>  <p>2004 2006 2008</p> <p>Mean = -1.734</p> <p>0 -1 -2 -3</p> <p>20 40 60 80</p> <p>Cycles</p>	

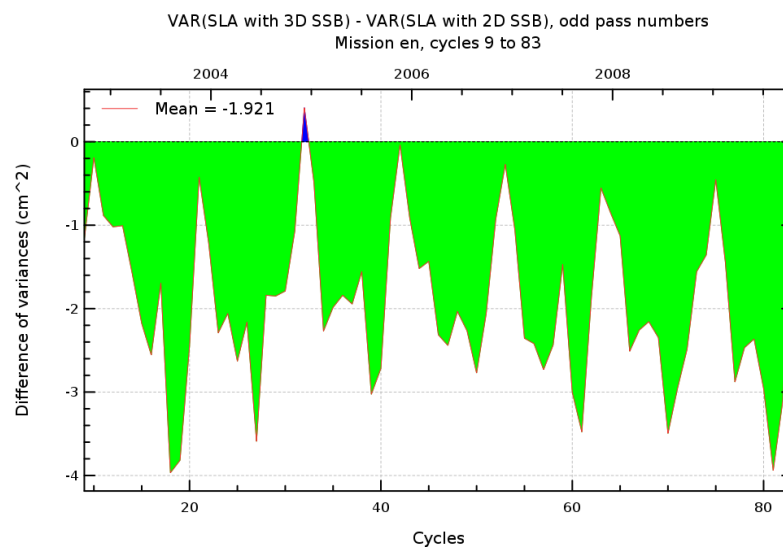
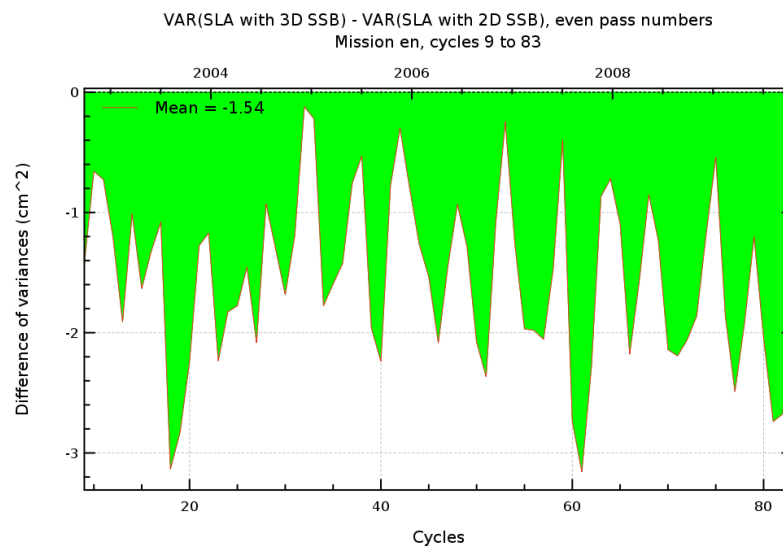
## Diagnostic A202\_b (mission en)

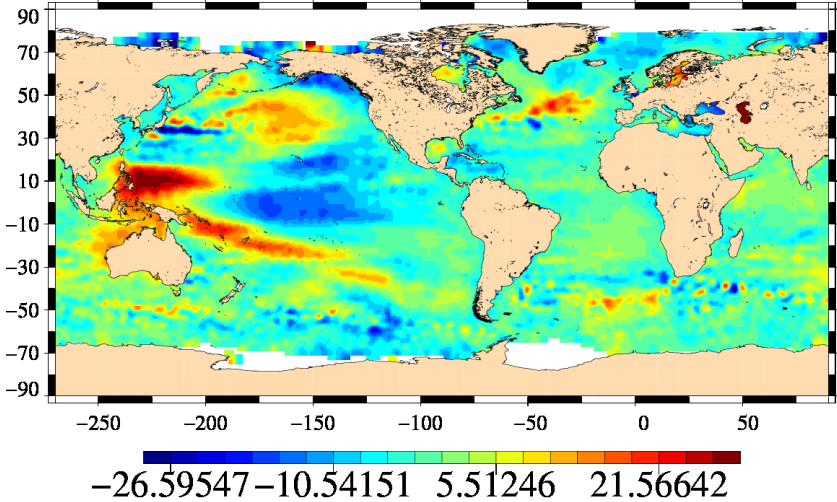
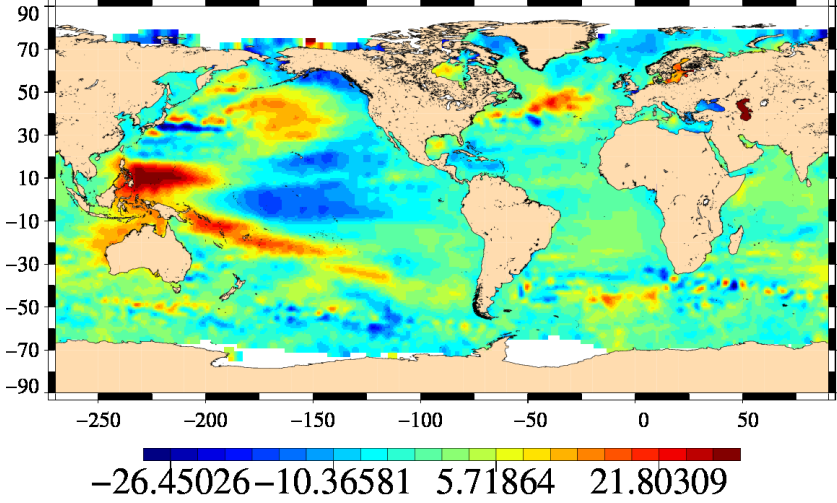
**Name :** Differences between temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

**Description :** The differences between temporal evolution of SLA are calculated from statistics derived from diagnostic A201 (mean, variance) using 2 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.

Diagnostic type : Global internal analyses



Diagnostic type : Global internal analyses	Diagnostic A203_a (mission en)	
	Name : Map of Sea Level Anomaly (SLA) over all the period	
	Input data : Along track SLA	
	Description : The map of global statistics (mean, standard deviation) 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.	
	<div>SLA with 3D SSB trends Mission en, cycles 9 to 83</div>  <div>Trends (mm/yr) SLA with 2D SSB trends Mission en, cycles 9 to 83</div> 	

## Diagnostic A203\_b (mission en)

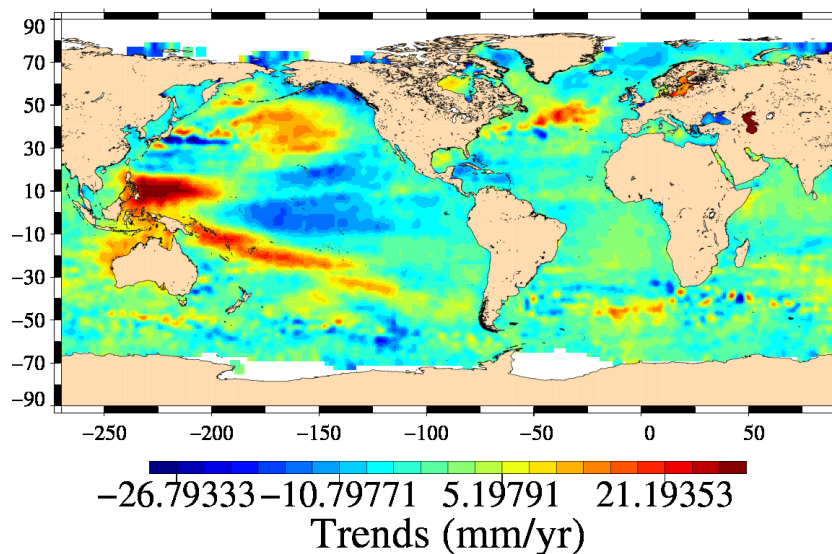
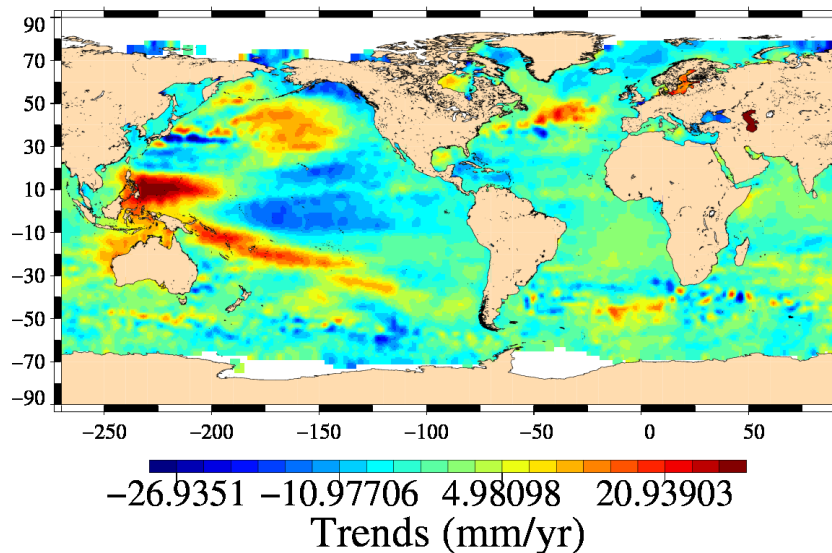
**Name :** Map of Sea Level Anomaly (SLA) over all the period

**Input data :** Along track SLA

**Description :** The map of global statistics (mean, standard deviation) 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.

Diagnostic type : Global internal analyses

SLA with 3D SSB trends : even pass numbers  
Mission en, cycles 9 to 83



## Diagnostic A203\_c (mission en)

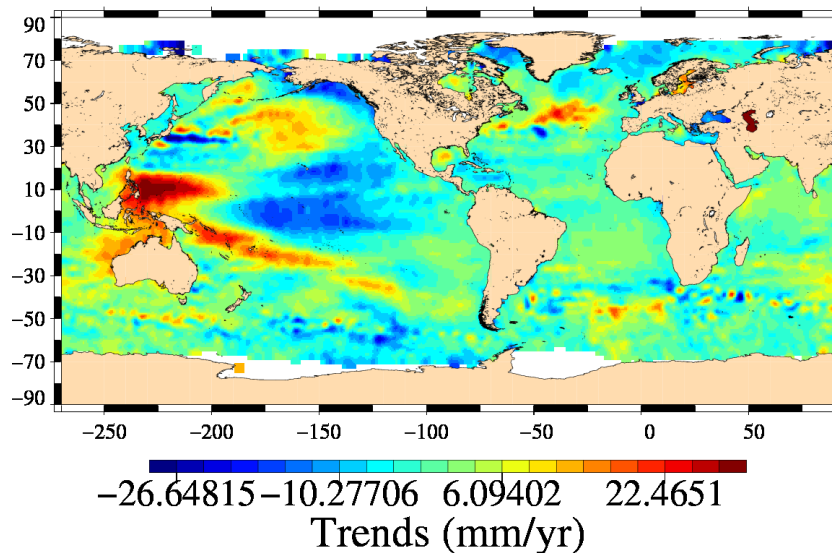
**Name :** Map of Sea Level Anomaly (SLA) over all the period

**Input data :** Along track SLA

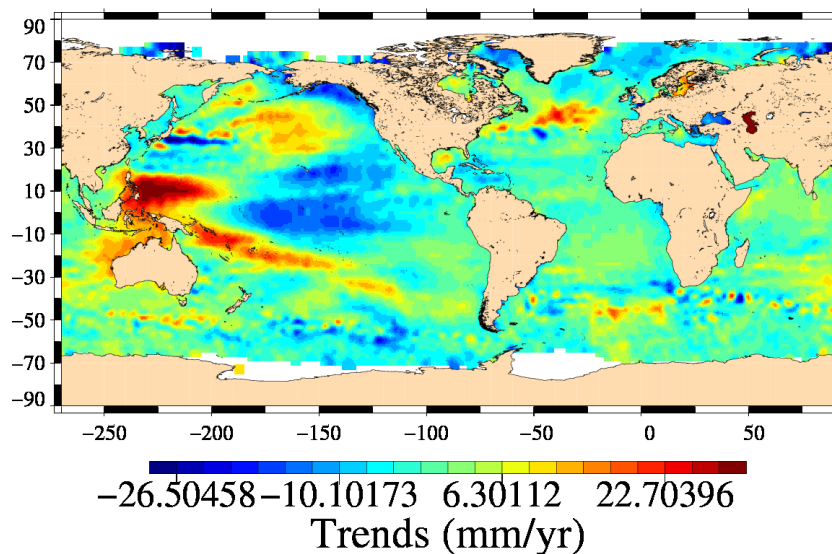
**Description :** The map of global statistics (mean, standard deviation) of SLA are calculated using successively both altimetric components in the SLA calculation over a large period. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

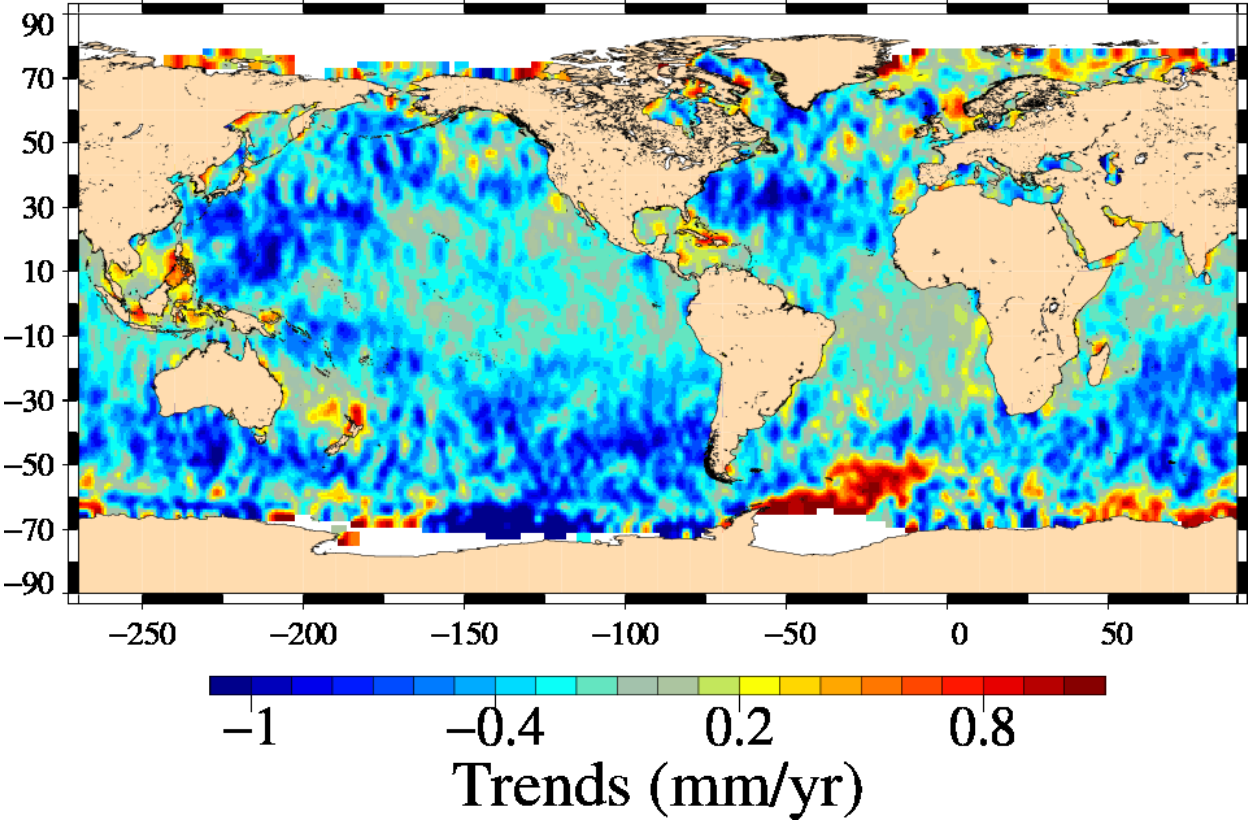
Diagnostic type : Global internal analyses

SLA with 3D SSB trends : odd pass numbers  
Mission en, cycles 9 to 83



SLA with 2D SSB trends : odd pass numbers  
Mission en, cycles 9 to 83



Diagnostic type : Global internal analyses	Diagnostic A204_a (mission en)	
	Name : Differences between maps of SLA	
	Input data : Along track SLA	
	Description : The difference of SLA maps (mean, standard deviation, slope) 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).	
	<div>SLA with 3D SSB trends – SLA with 2D SSB trends</div> <div>Mission en, cycles 9 to 83</div> 	



## Diagnostic A204\_b (mission en)

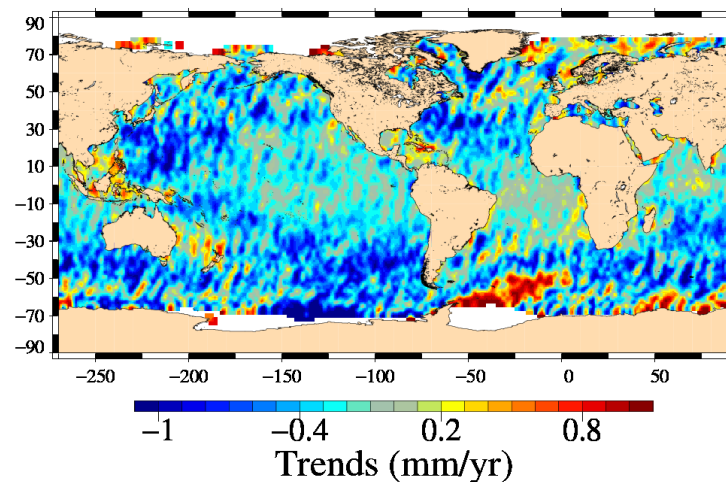
**Name :** Differences between maps of SLA

**Input data :** Along track SLA

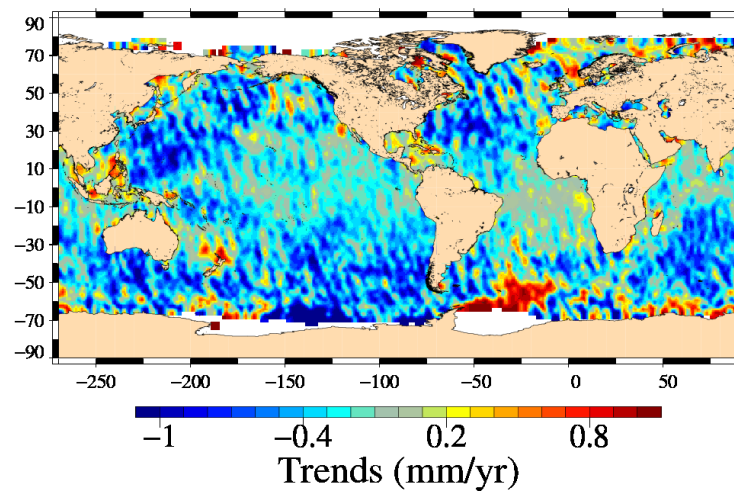
**Description :** The difference of SLA maps (mean, standard deviation, slope) is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except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

Diagnostic type : Global internal analyses

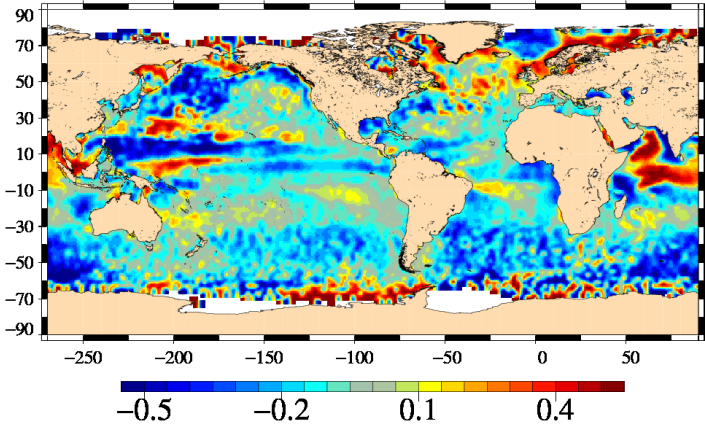
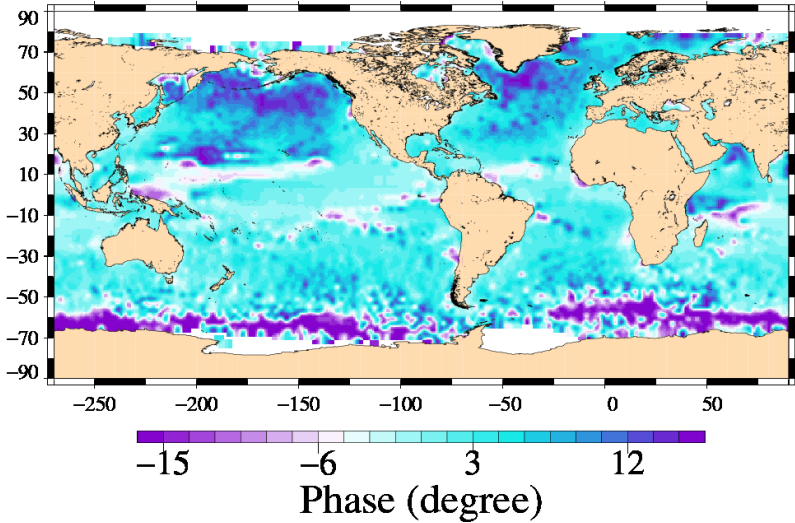
SLA with 3D SSB trends – SLA with 2D SSB trends : even pass numbers  
Mission en, cycles 9 to 83



SLA with 3D SSB trends – SLA with 2D SSB trends : odd pass numbers  
Mission en, cycles 9 to 83





Diagnostic type : Global internal analyses	Diagnostic A205_a (mission en)	
	Name : Differences between maps of SLA (2)	
	Input data : Along track SLA	
	Description : The difference of SLA maps (mean, standard deviation, slope) 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).	
	<div>SLA with 3D SSB amplitude – SLA with 2D SSB amplitude : annual signal</div> <div>Mission en, cycles 9 to 83</div>  <div>SLA with 3D SSB phase – SLA with 2D SSB phase : annual signal</div> <div>Mission en, cycles 9 to 83</div> 	

## Diagnostic A205\_b (mission en)

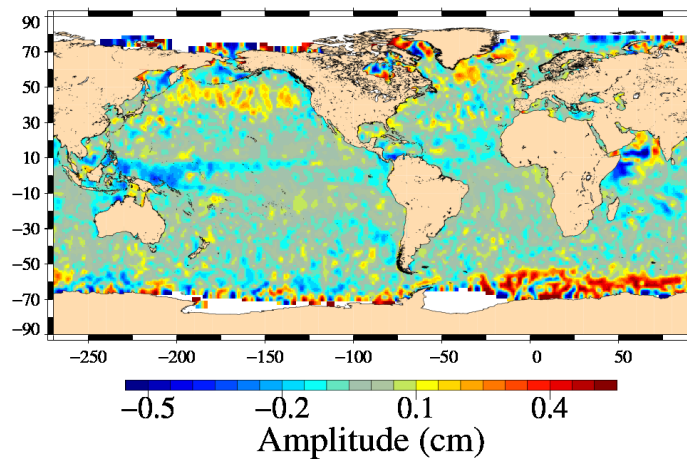
**Name :** Differences between maps of SLA (2)

**Input data :** Along track SLA

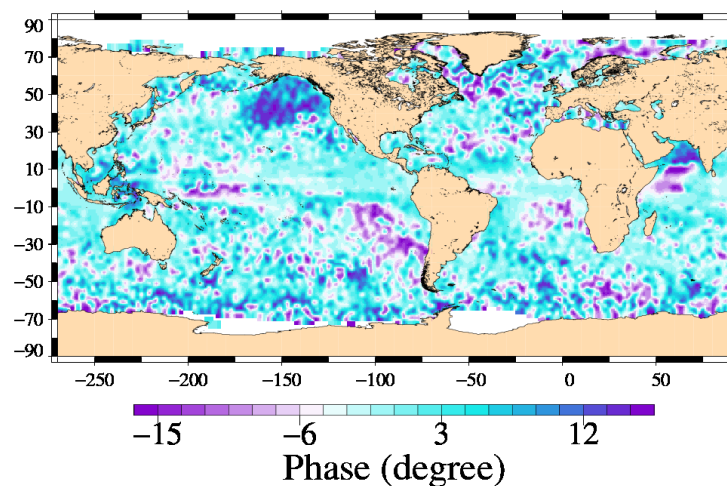
**Description :** The difference of SLA maps (mean, standard deviation, slope) is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except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

Diagnostic type : Global internal analyses

SLA with 3D SSB amplitude – SLA with 2D SSB amplitude : semi-annual signal  
Mission en, cycles 9 to 83



SLA with 3D SSB phase – SLA with 2D SSB phase : semi-annual signal  
Mission en, cycles 9 to 83

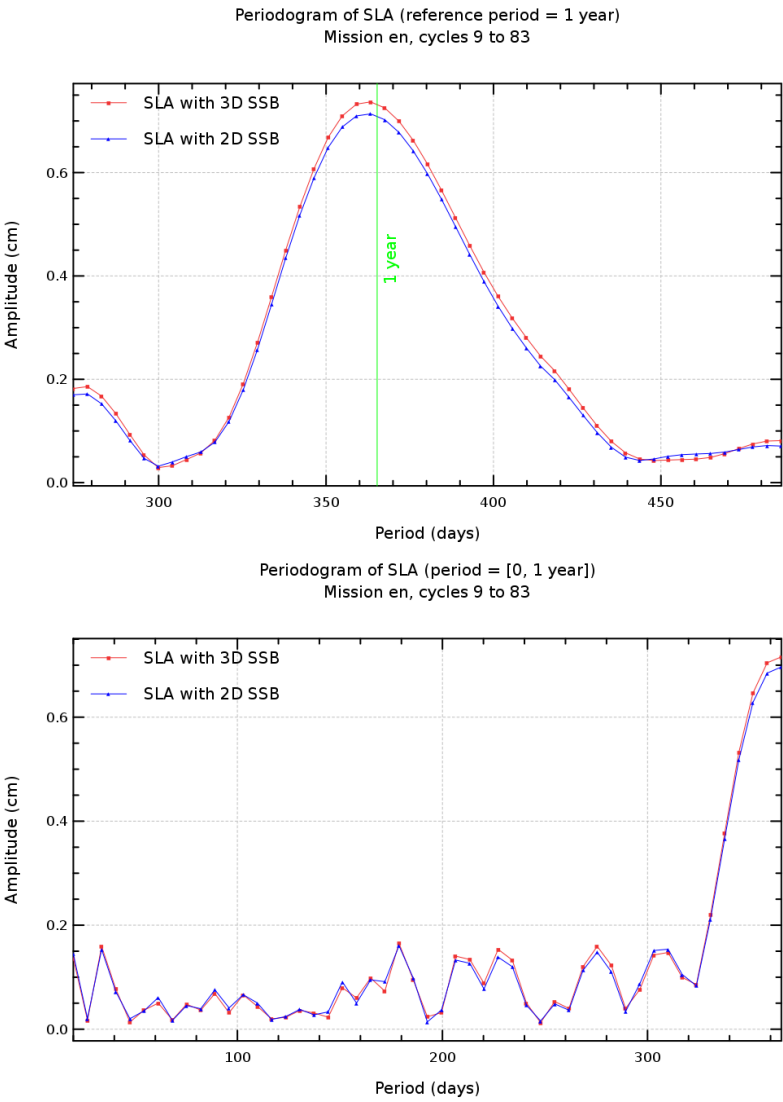


Diagnostic A206\_a (mission en)

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

**Input data :** Along track SLA

**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.



## Diagnostic A206\_b (mission en)

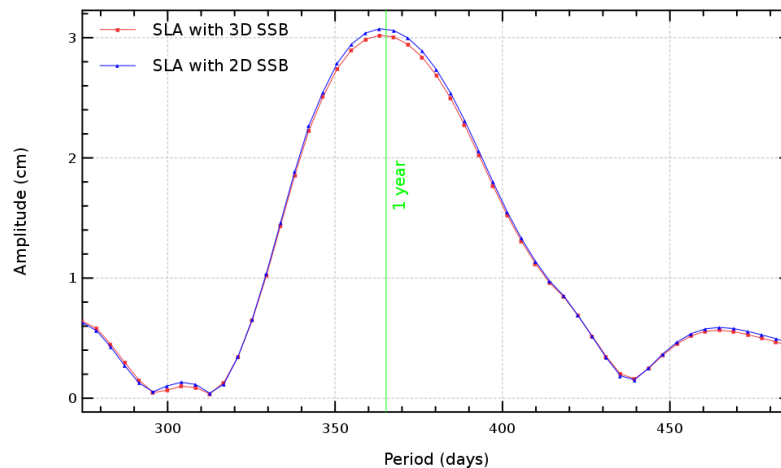
**Name :** Periodogram derived from temporal evolution of Sea Level Anomaly (SLA)

**Input data :** Along track SLA

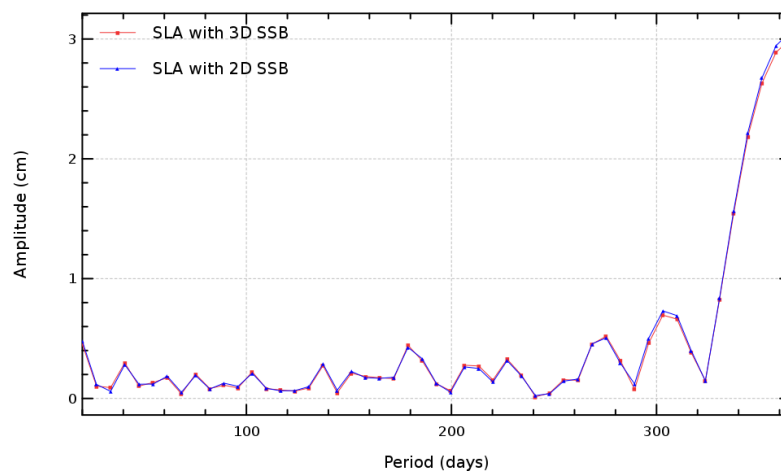
**Description :** The periodogram derived from temporal evolution of SLA (global, northern or southern hemisphere) can be done over all periods or focusing on particular periods, such as annual, semi annual or 60 day signal. Therefore mean of SLA differences are computed (every day or cycle), and time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

Diagnostic type : Global internal analyses

Periodogram of north hemisphere SLA (reference period = 1 year)  
Mission en, cycles 9 to 83



Periodogram of north hemisphere SLA (period = [0, 1 year])  
Mission en, cycles 9 to 83



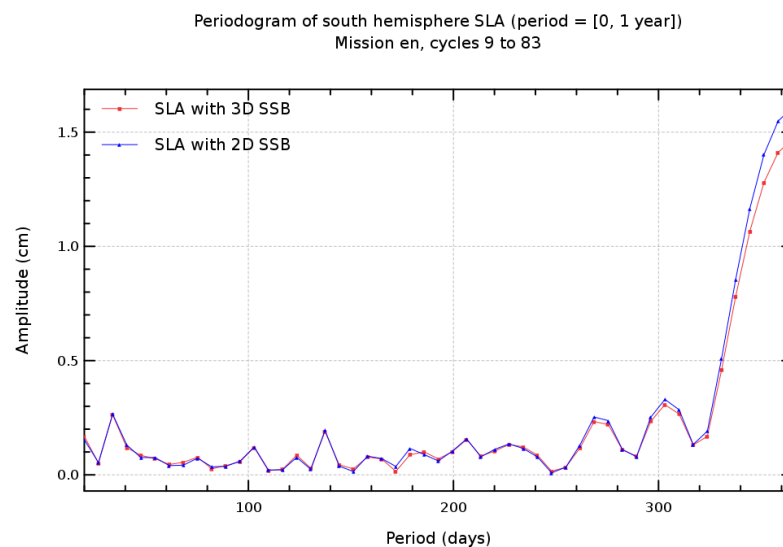
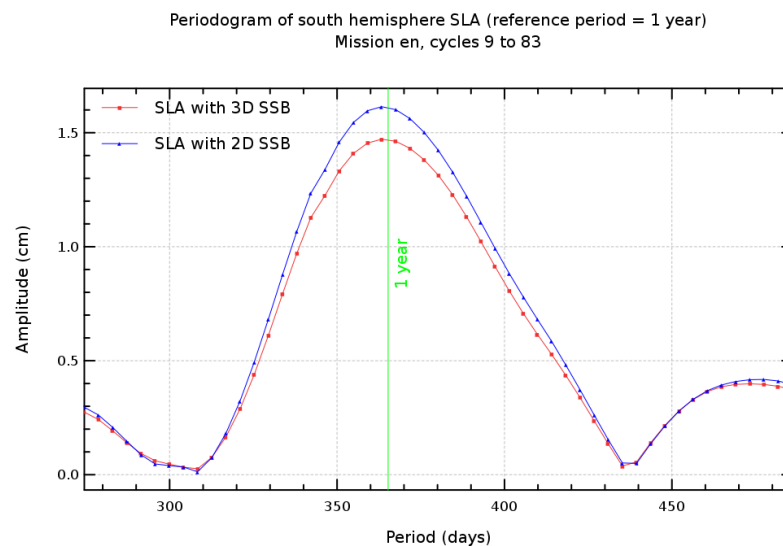
## Diagnostic A206\_c (mission en)

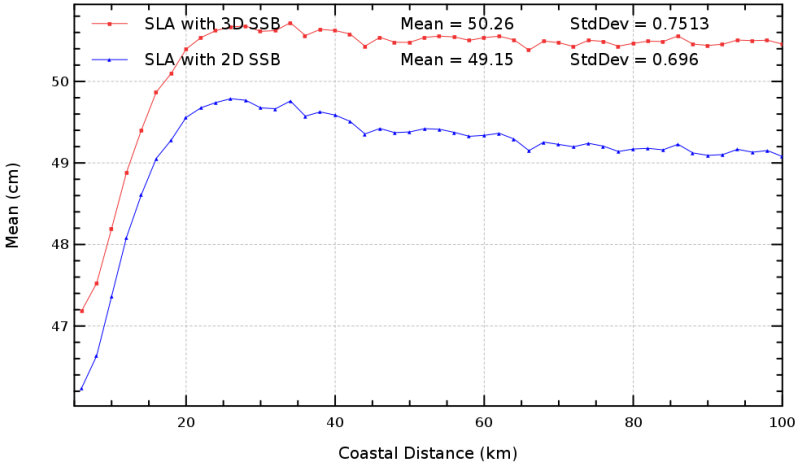
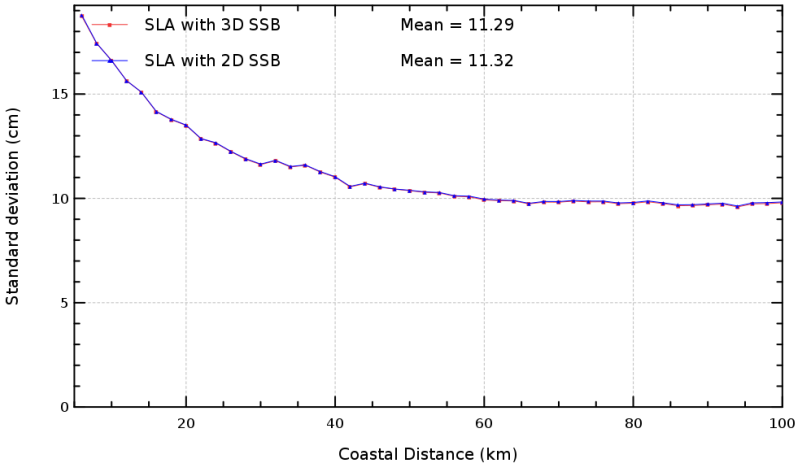
**Name :** Periodogram derived from temporal evolution of Sea Level Anomaly (SLA)

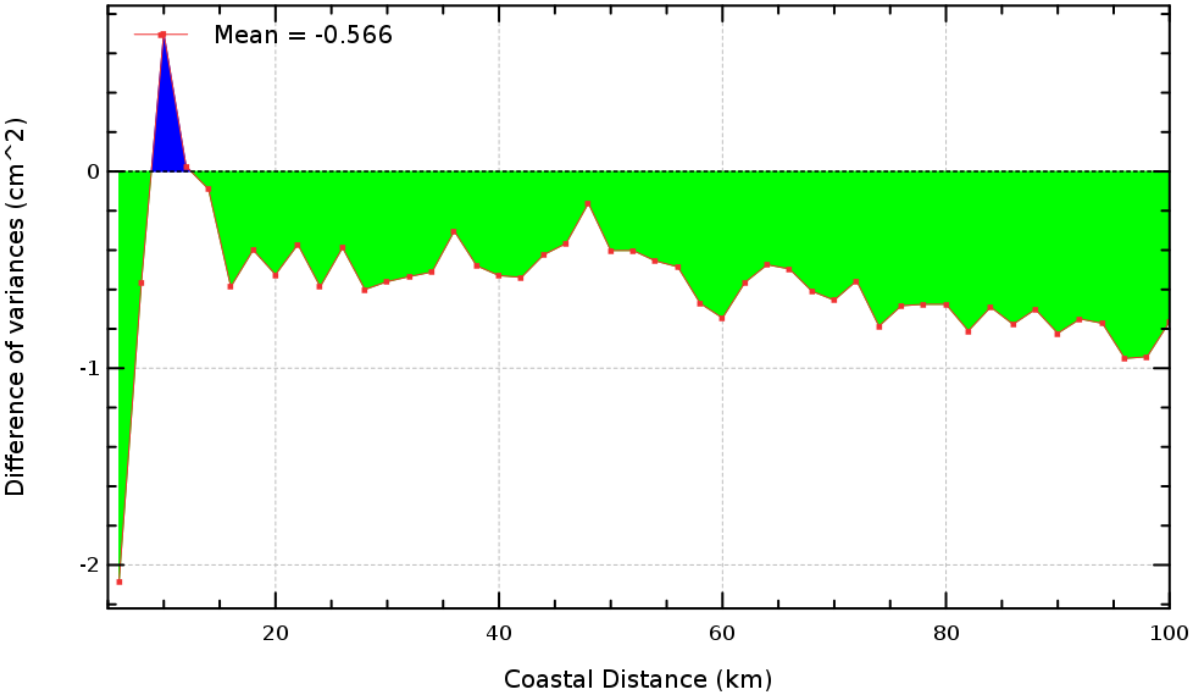
**Input data :** Along track SLA

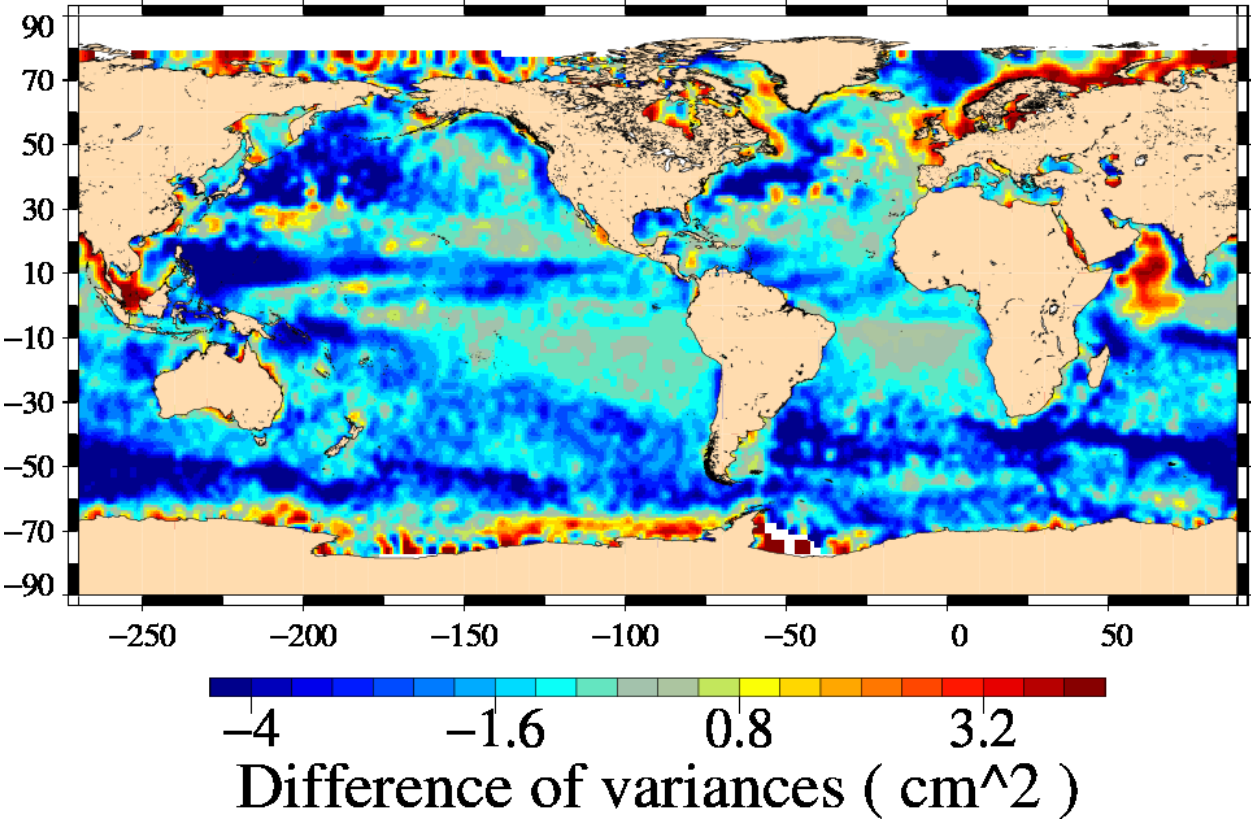
**Description :** The periodogram derived from temporal evolution of SLA (global, northern or southern hemisphere) can be done over all periods or focusing on particular periods, such as annual, semi annual or 60 day signal. Therefore mean of SLA differences are computed (every day or cycle), and time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

Diagnostic type : Global internal analyses



Diagnostic type : Global internal analyses	Diagnostic A207 (mission en)	
	Name : Sea Level Anomaly (SLA) versus coastal distance	
	Input data : Along track SLA	
	Description : Mean and standard deviation of SLA - computed by using successively both altimetric components - are plotted in function of coastal distances between 0 and 100 km.	
	<div><div>Global MSL Mission en, cycles 9 to 83</div><p>Mean (cm)</p><p>Coastal Distance (km)</p><p>SLA with 3D SSB: Mean = 50.26, StdDev = 0.7513</p><p>SLA with 2D SSB: Mean = 49.15, StdDev = 0.696</p><div>Global MSL Mission en, cycles 9 to 83</div><p>Standard deviation (cm)</p><p>Coastal Distance (km)</p><p>SLA with 3D SSB: Mean = 11.29</p><p>SLA with 2D SSB: Mean = 11.32</p></div>	

Diagnostic type : Global internal analyses	Diagnostic A208 (mission en)
	Name : Sea Level Anomaly (SLA) differences versus coastal distance
	Input data : Along track SLA
	Description : The differences of SLA variances - computed by using successively both altimetric components - are plotted in function of coastal distances between 0 and 100 km.
	<div>VAR(SLA with 3D SSB) - VAR(SLA with 2D SSB) Mission en, cycles 9 to 83</div> 

Diagnostic type : Global internal analyses	Diagnostic A209 (mission en)
	Name : Differences between maps of SLA (3)
	Input data : Along track SLA
	Description : The differences between maps of SLA are calculated from the SLA differences (mean, standard deviation) using successively both altimetric components in the SLA calculation.
	<div>VAR(SLA with 3D SSB) – VAR(SLA with 2D SSB) Mission en, cycles 9 to 83</div> 



**Diagnostic C001 (mission en)**

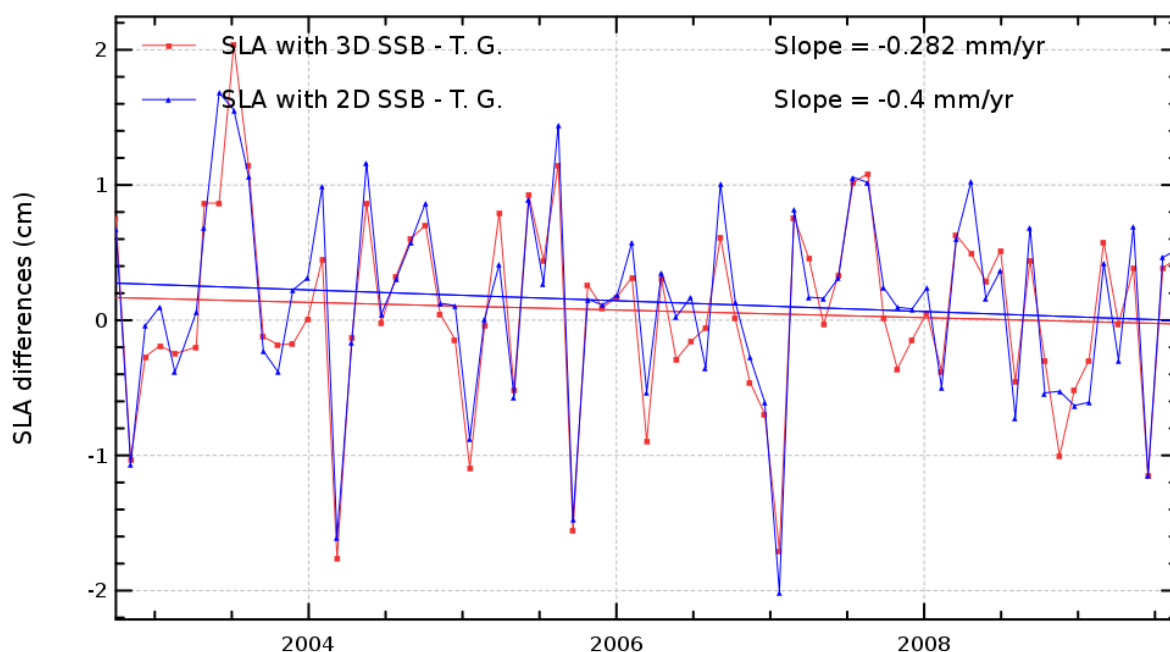
**Name :** Temporal evolution of SSH differences between tide gauges and altimetry measurements

**Input data :** Tide gauges SSH measurements

**Description :** The temporal evolution of global statistics (mean, variance, slope) of SSH differences between tide gauges and altimeter measurements are calculated from a cyclic way (altimeter repetitivity) using successively both altimetric components in SSH calculation. The altimetric and tide gauges data are colocated with criteria of maximum of correlation, and tide gauges used are derived from global networks (GLOSS/CLIVAR, REFMAR).

Diagnostic type : Altimetry and in-situ data comparison

SLA differences : altimetry measurements - tide gauges  
Mission en, cycles 9 to 83



**Diagnostic C002 (mission en)**

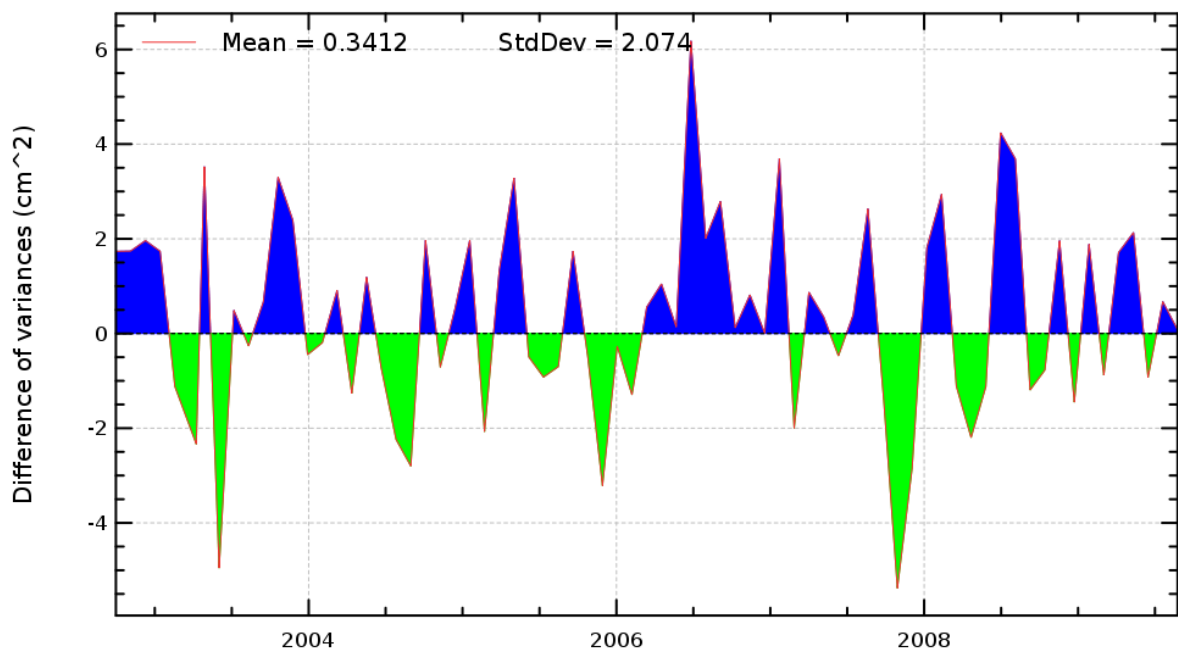
**Name :** Differences of temporal evolution of SSH differences between tide gauges and altimetry measurements

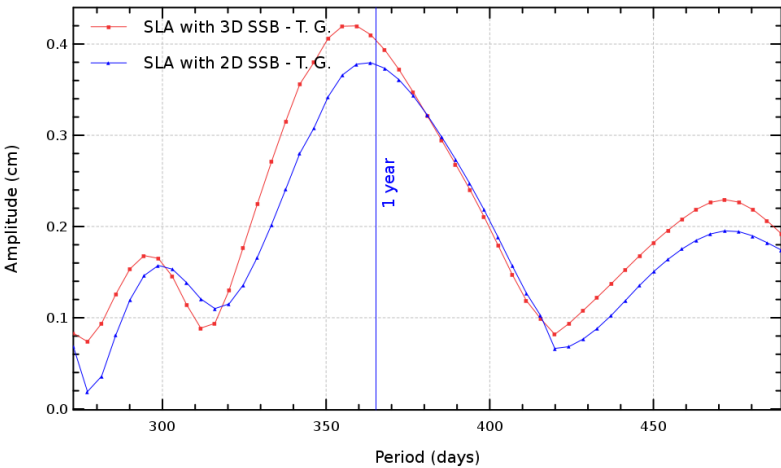
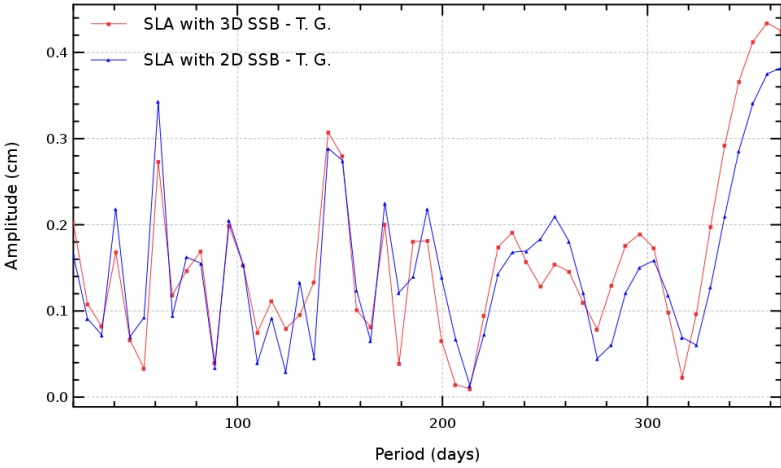
**Input data :** Tide gauges SSH measurements

**Description :** The difference between temporal evolution of global statistics of differences between tide gauge 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 tide gauges data are collocated with criteria of maximum of correlation, and tide gauges used are derived from global networks as GLOSS/CLIVAR.

Diagnostic type : Altimetry and in-situ data comparison

Difference of variances :  $\text{VAR}(\text{SLA with 3D SSB} - \text{T. G.}) - \text{VAR}(\text{SLA with 2D SSB} - \text{T. G.})$   
Mission en, cycles 9 to 83



Diagnostic C003 (mission en)	
Name : Periodogram derived from temporal evolution of SSH differences between tide gauges and altimetry	
Input data : Tide gauges SSH measurements	
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 or variance statistics and it can be displayed for all the whole time period or a dedicated one	
<div>Periodogram of SLA differences : altimetry measurements - tide gauges (ref. period = 1 year) Mission en, cycles 9 to 83</div>  <div>Periodogram of SLA differences : altimetry measurements - tide gauges (period = [0, 1 year]) Mission en, cycles 9 to 83</div> 	

**Diagnostic C004 (mission en)**

**Name :** Histograms of differences between tide gauges and altimeter SSH differences

**Input data :** Tide gauges SSH measurements

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

Diagnostic type : Altimetry and in-situ data comparison

Histogram of the difference of variances :  $\text{VAR}(\text{SLA with 3D SSB} - \text{T. G.}) - \text{VAR}(\text{SLA with 2D SSB} - \text{T. C.})$   
Mission en, cycles 9 to 83

