

Sea State Bias: 3D vs 2D

Study variable	3D SSB
Reference variable	2D SSB
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 of the AVISO products which has been updated so that it is homogeneous over the whole Envisat mission. It is thus not exactly the SSB used in AVISO products.

The impact of using these both sea state bias corrections on the SSH calculation 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. It has been updated so that it is homogeneous over the Envisat period.

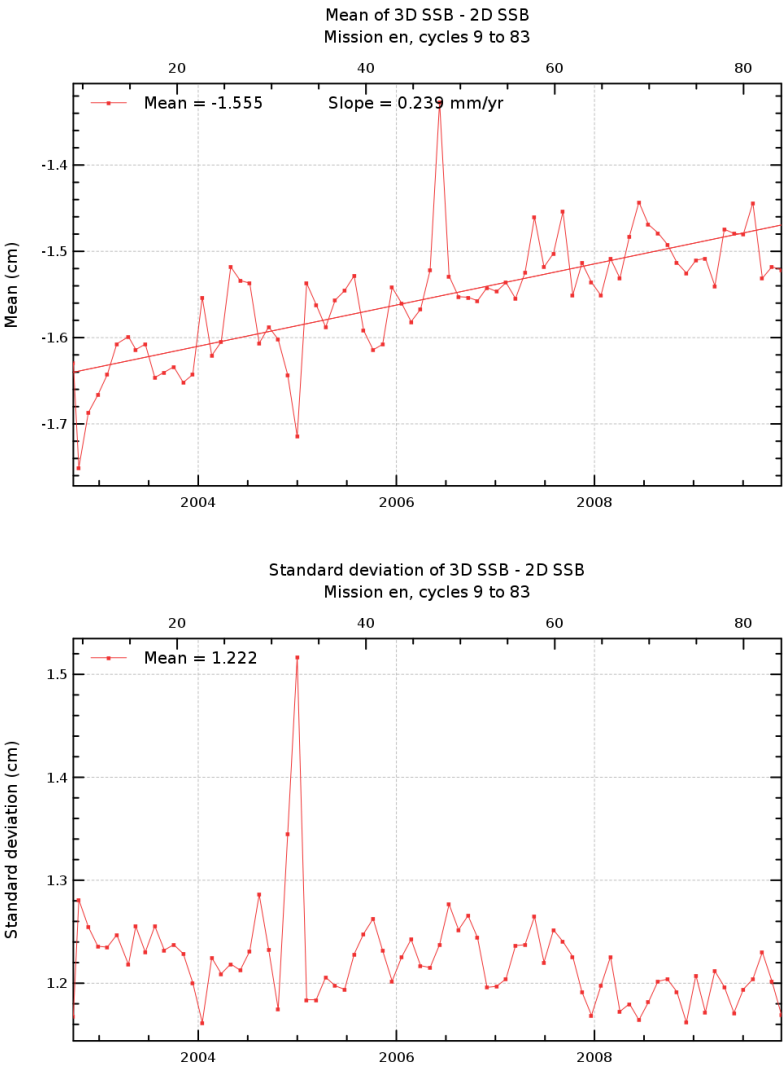
All the validation diagnostics displayed in this report has been performed in agreement with the Sea-Level CCI Product Validation Plan (PVP).

Diagnostic A001 (mission en)

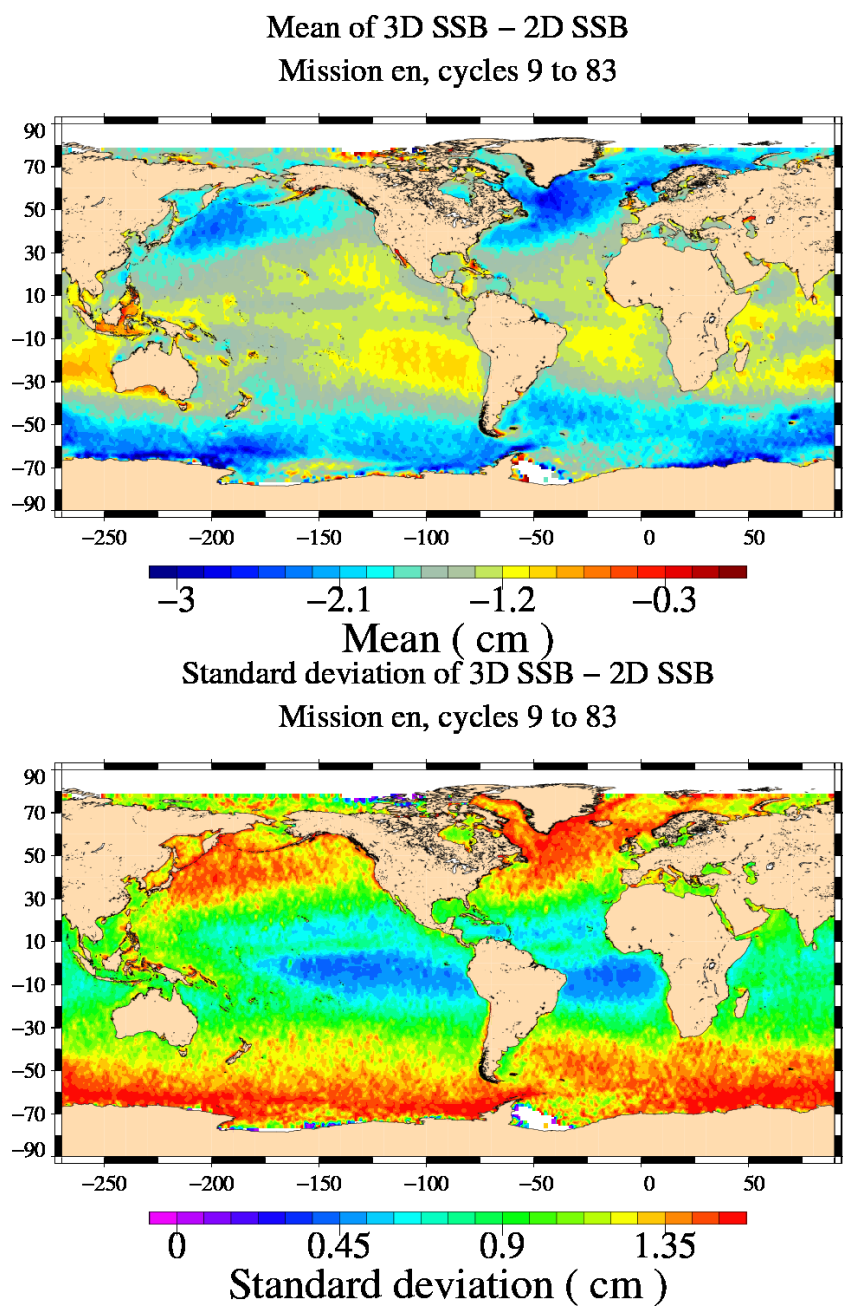
Name : Temporal evolution of differences between both altimetric components

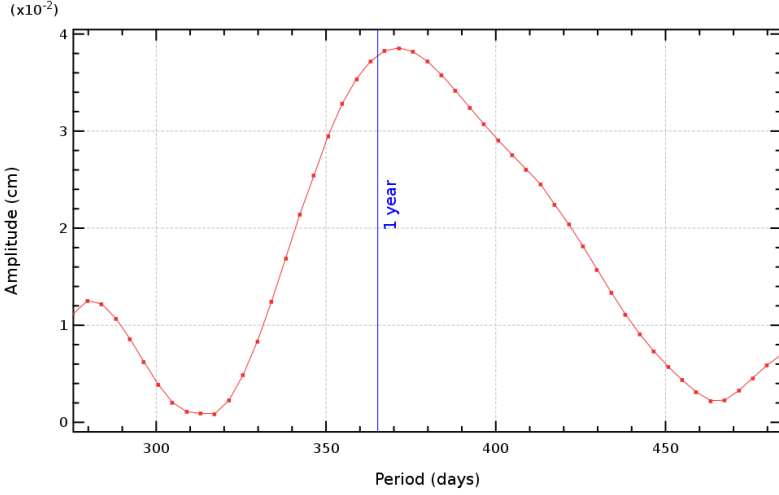
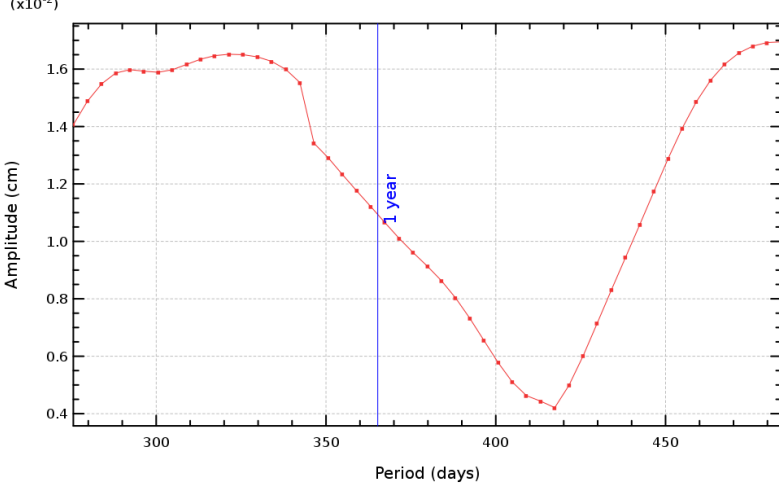
Input data : Along-track altimetric components

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.



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.



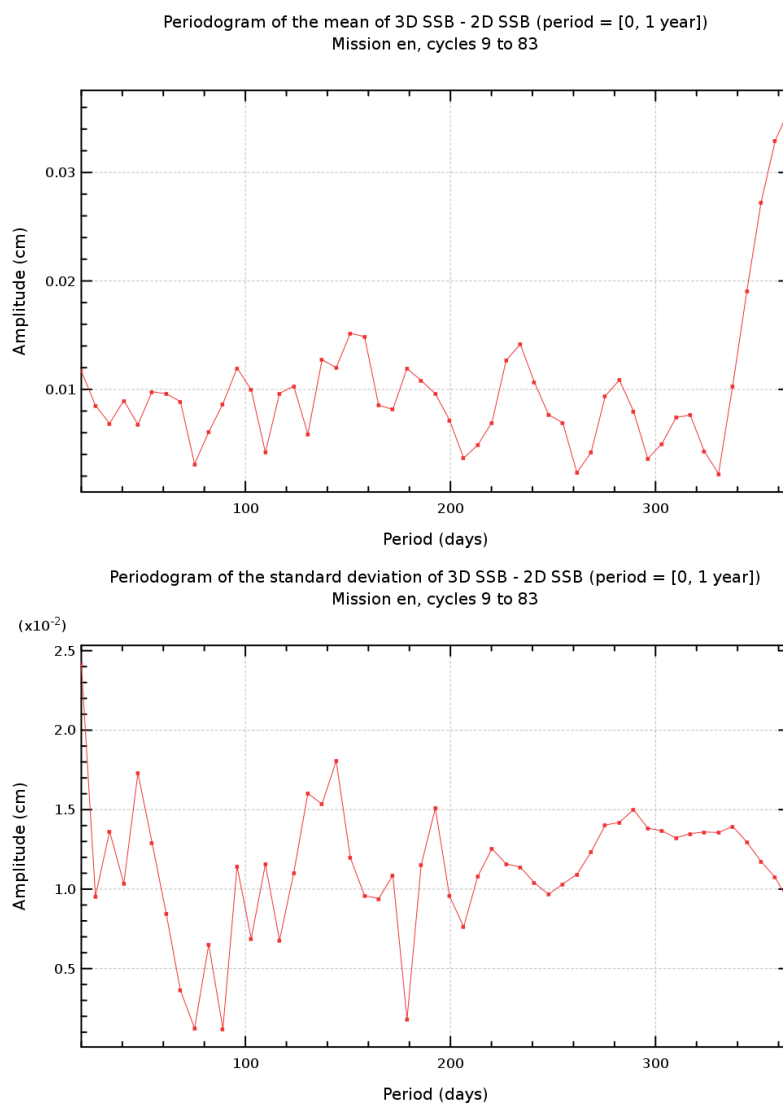
Diagnostic A003_a (mission en)	
Name : Periodogram derived from temporal evolution of altimetric component differences	
Input data : Along-track altimetric components	
<p>Description : The periodogram derived from temporal and global altimetric component differences is calculated from cycle by cycle 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)

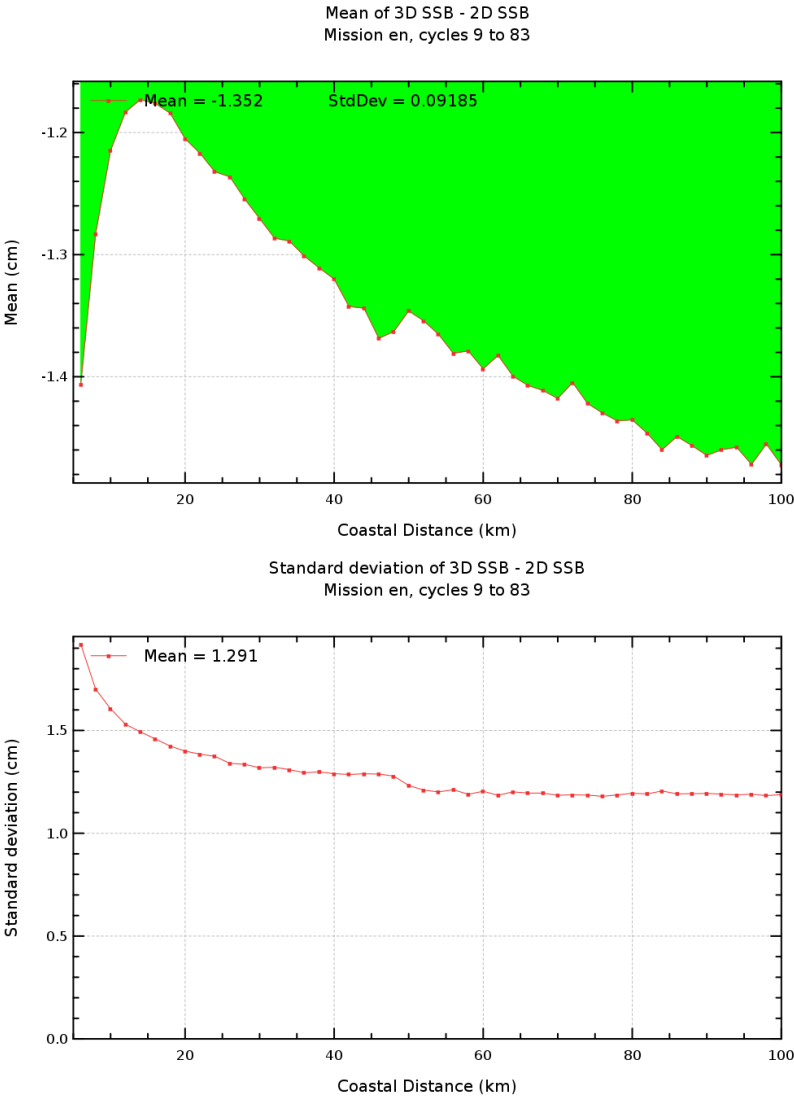
Name : Periodogram derived from temporal evolution of altimetric component differences

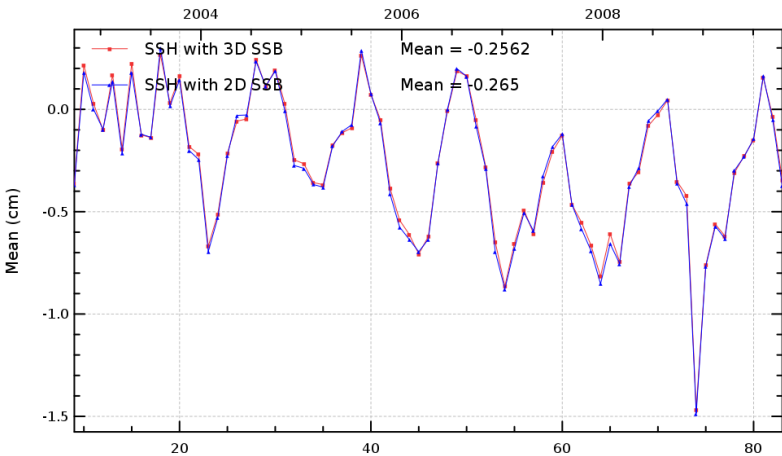
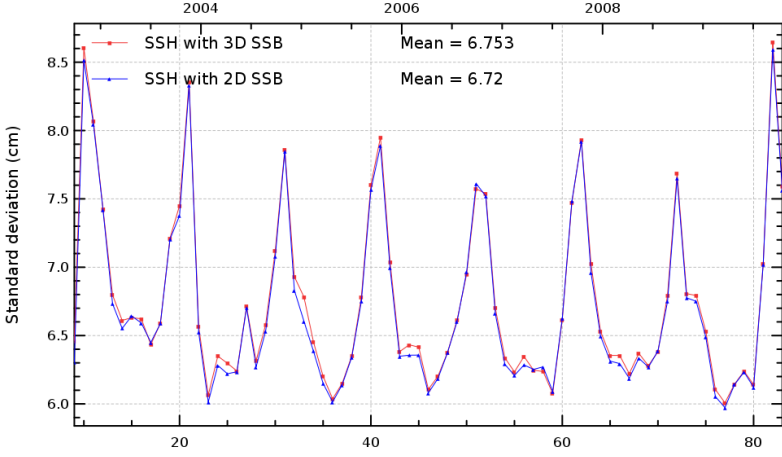
Input data : Along-track altimetric components

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>Description : 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>	

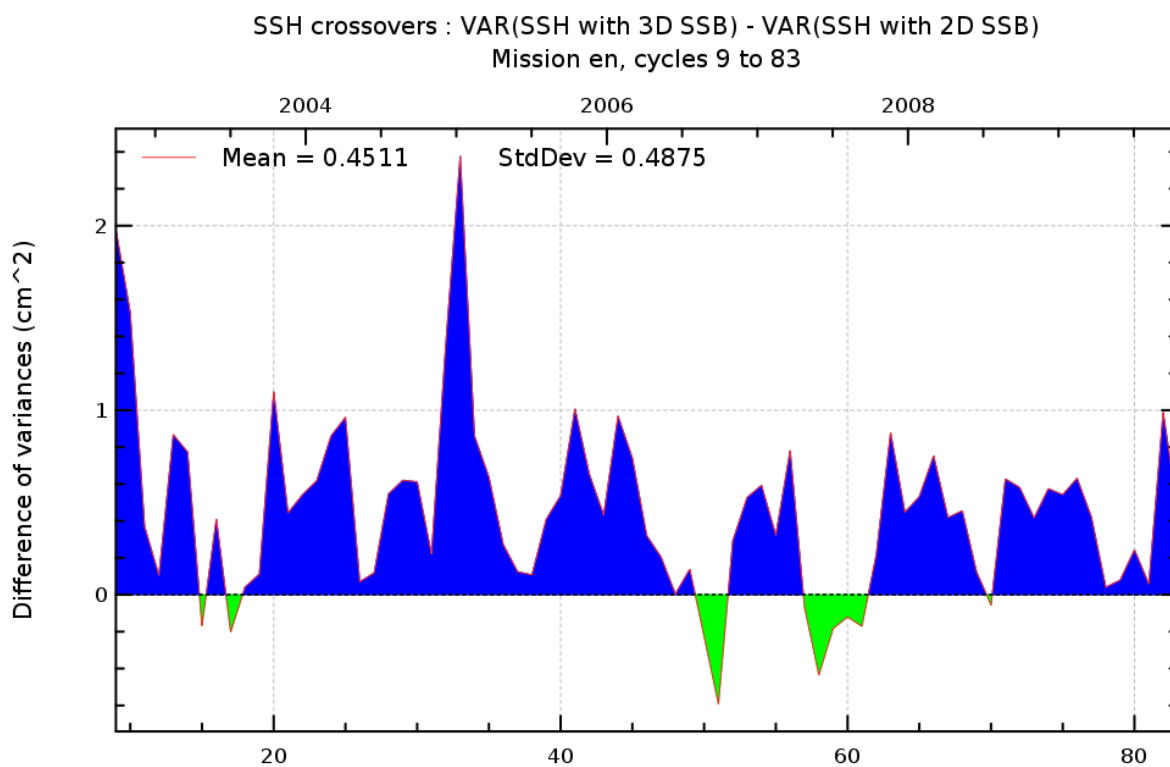
Diagnostic A102 (mission en)

Name : Differences between temporal evolution of SSH crossovers

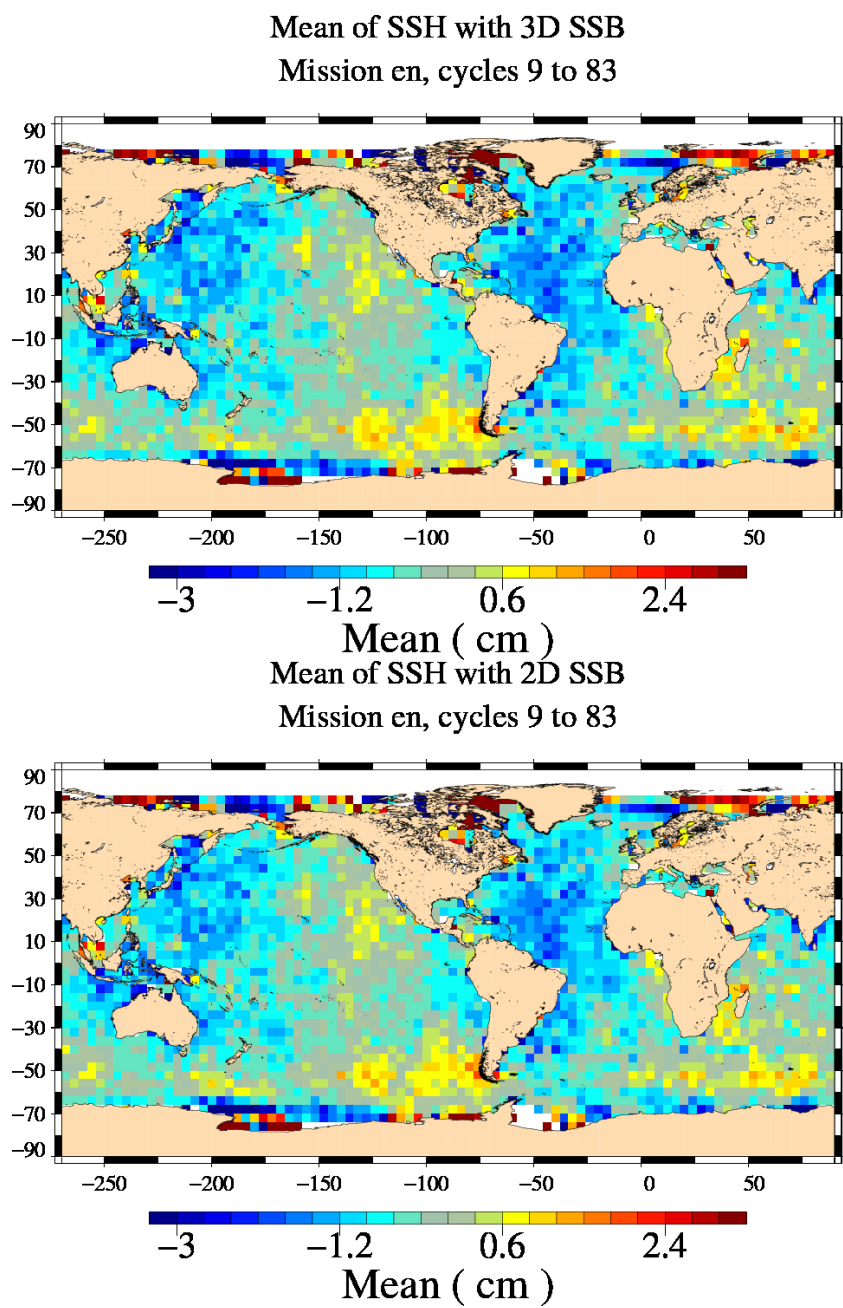
Input data : Sea Surface Height (SSH) crossovers

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



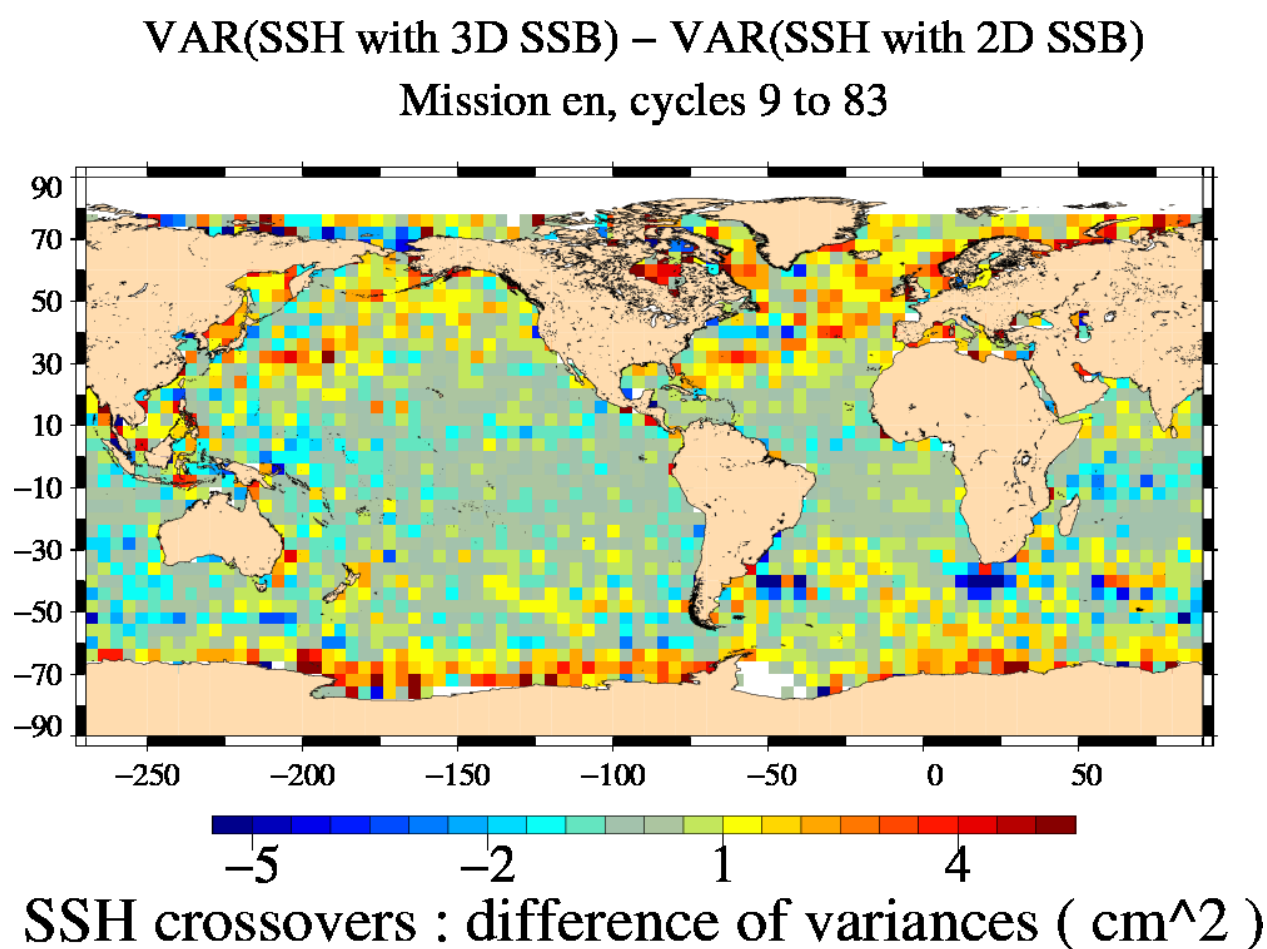
Diagnostic A103 (mission en)	
Name :	Map of SSH crossovers
Input data :	Sea Surface Height (SSH) crossovers
Description :	The differences between maps of SSH crossovers differences (mean, variance) are calculated using successively both altimetric components in the SSH calculation. SSH crossovers are 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).



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).



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 time series of Sea Level Anomaly (SLA) statistics over mission cycles 9 to 83. The y-axis represents the Mean in centimeters, ranging from 49 to 51. The x-axis represents mission cycles, with corresponding years 2004, 2006, and 2008 marked. The red line represents 'SLA with 3D SSB' and the blue line represents 'SLA with 2D SSB'. Both series show significant high-frequency variability. Linear regression lines are fitted to each series, with the 3D SSB series having a slope of 0.487 mm/yr and the 2D SSB series having a slope of 0.691 mm/yr. The legend also provides the L.S.R. (Least Squares Residual) for each series: 0.143 for 3D SSB and 0.139 for 2D SSB.</p> <table><tr><th>Mission Cycle</th><th>Year (approx.)</th><th>SLA with 3D SSB (cm)</th><th>SLA with 2D SSB (cm)</th></tr><tr><td>9</td><td>2002.5</td><td>50.8</td><td>49.2</td></tr><tr><td>20</td><td>2003.5</td><td>50.7</td><td>49.1</td></tr><tr><td>40</td><td>2005.5</td><td>50.7</td><td>49.1</td></tr><tr><td>60</td><td>2007.5</td><td>50.8</td><td>49.2</td></tr><tr><td>80</td><td>2009.5</td><td>50.9</td><td>49.3</td></tr><tr><td>83</td><td>2010.0</td><td>51.0</td><td>49.4</td></tr></table>		Mission Cycle	Year (approx.)	SLA with 3D SSB (cm)	SLA with 2D SSB (cm)	9	2002.5	50.8	49.2	20	2003.5	50.7	49.1	40	2005.5	50.7	49.1	60	2007.5	50.8	49.2	80	2009.5	50.9	49.3	83	2010.0	51.0
Mission Cycle	Year (approx.)	SLA with 3D SSB (cm)	SLA with 2D SSB (cm)																										
9	2002.5	50.8	49.2																										
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60	2007.5	50.8	49.2																										
80	2009.5	50.9	49.3																										
83	2010.0	51.0	49.4																										

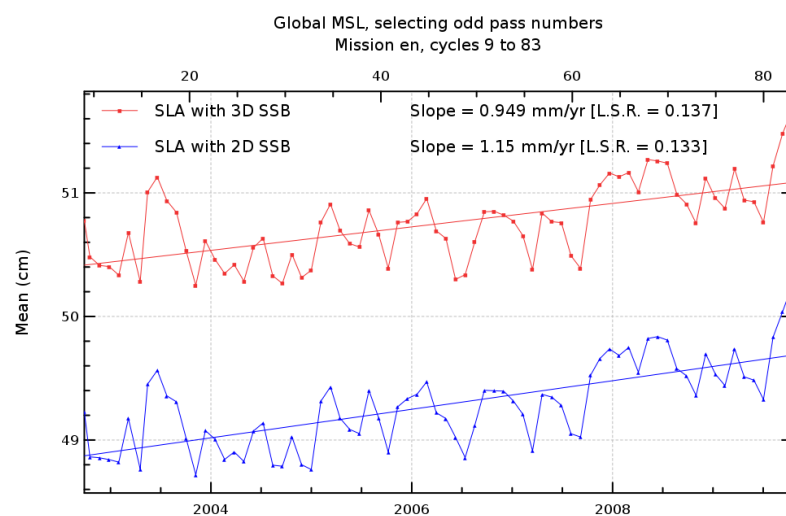
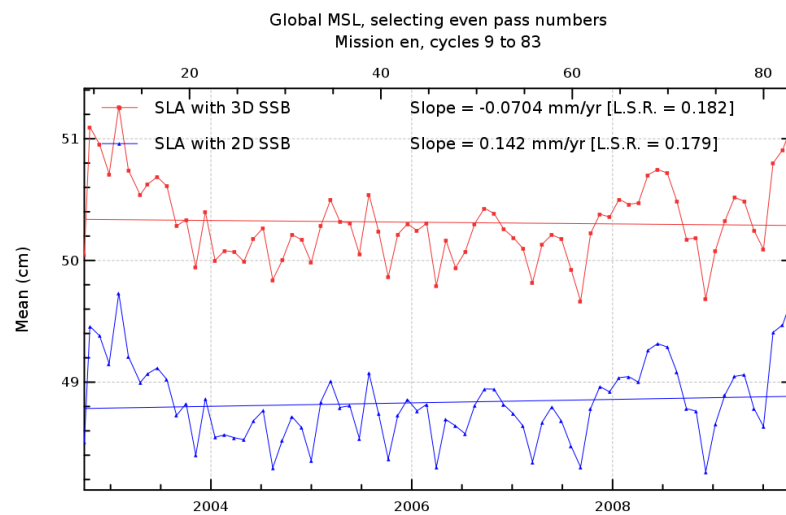
Diagnostic A201_b (mission en)

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



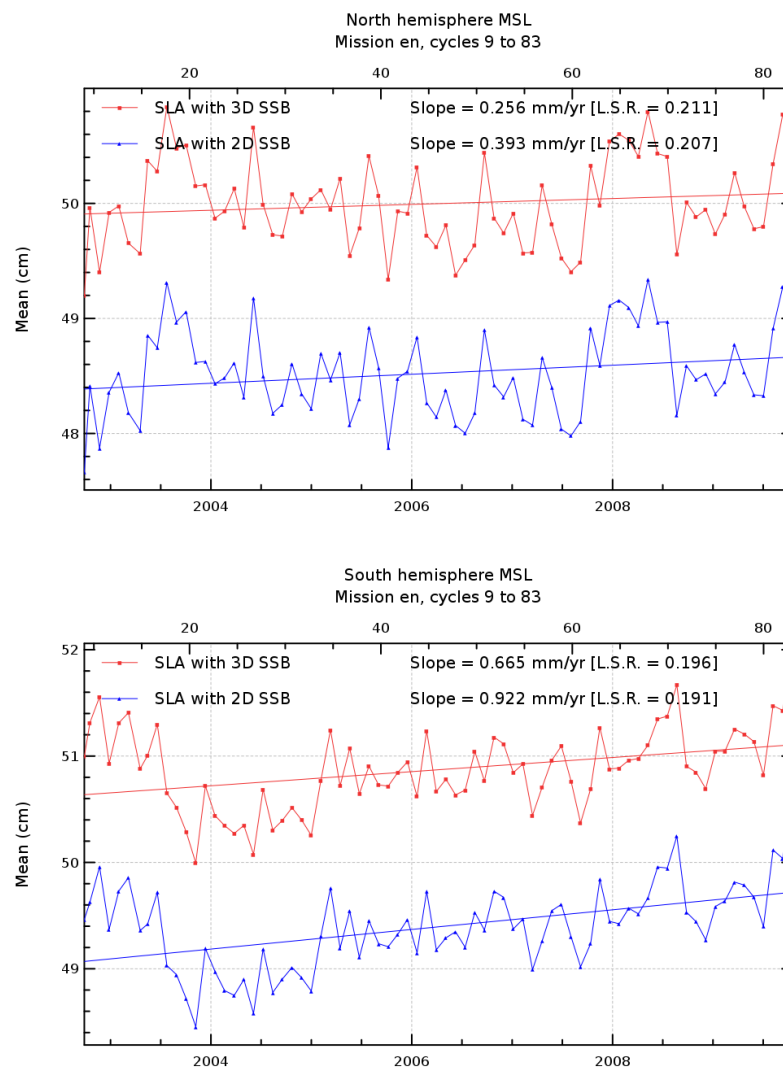
Diagnostic A201_c (mission en)

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)

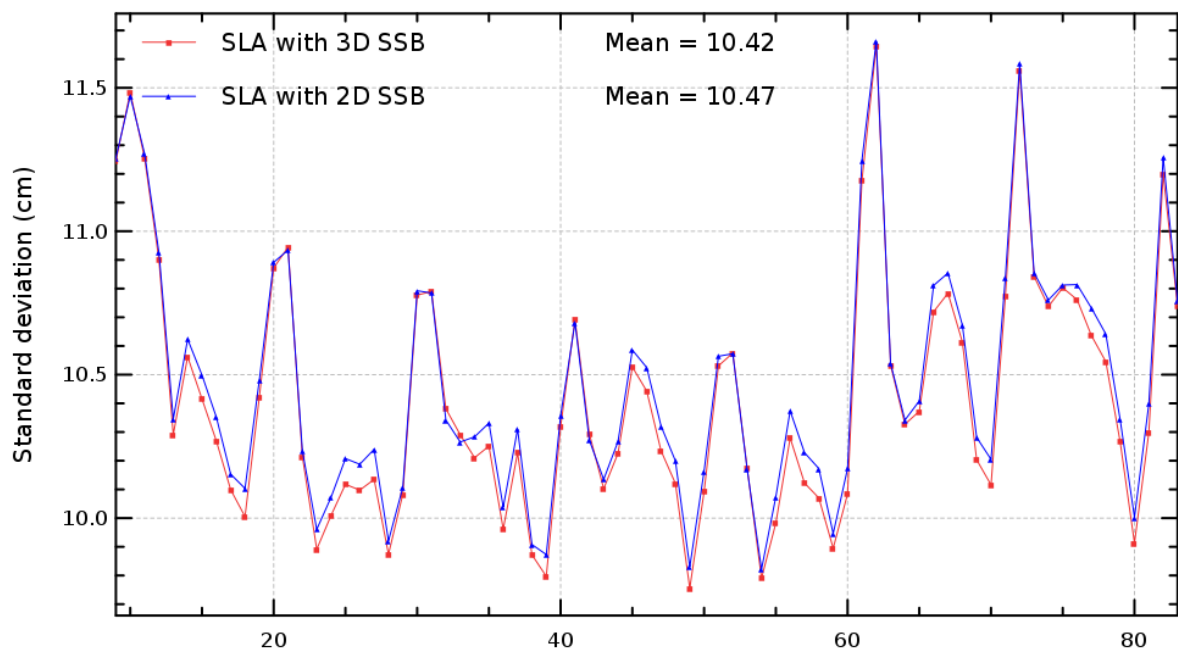
Name : Temporal evolution of Sea Level Anomaly (SLA)

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)

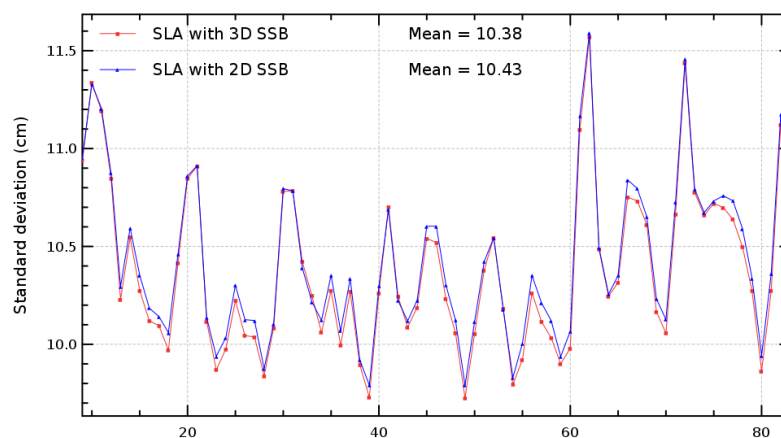
Name : Temporal evolution of Sea Level Anomaly (SLA)

Input data : Along track SLA

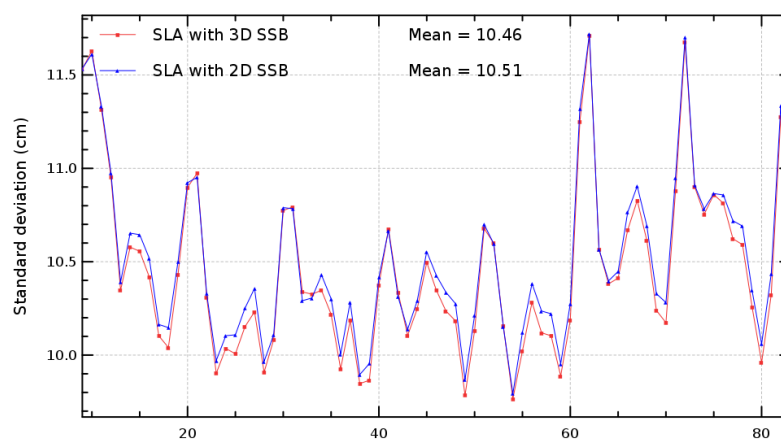
Description : The temporal evolution of SLA statistics (mean, standard deviation) are calculated from a cyclic way (altimeter repetivity, daily, weekly, monthly) using successively both altimetric components in the SLA calculation. These statistics are calculated from 1 Hz altimetric measurements after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

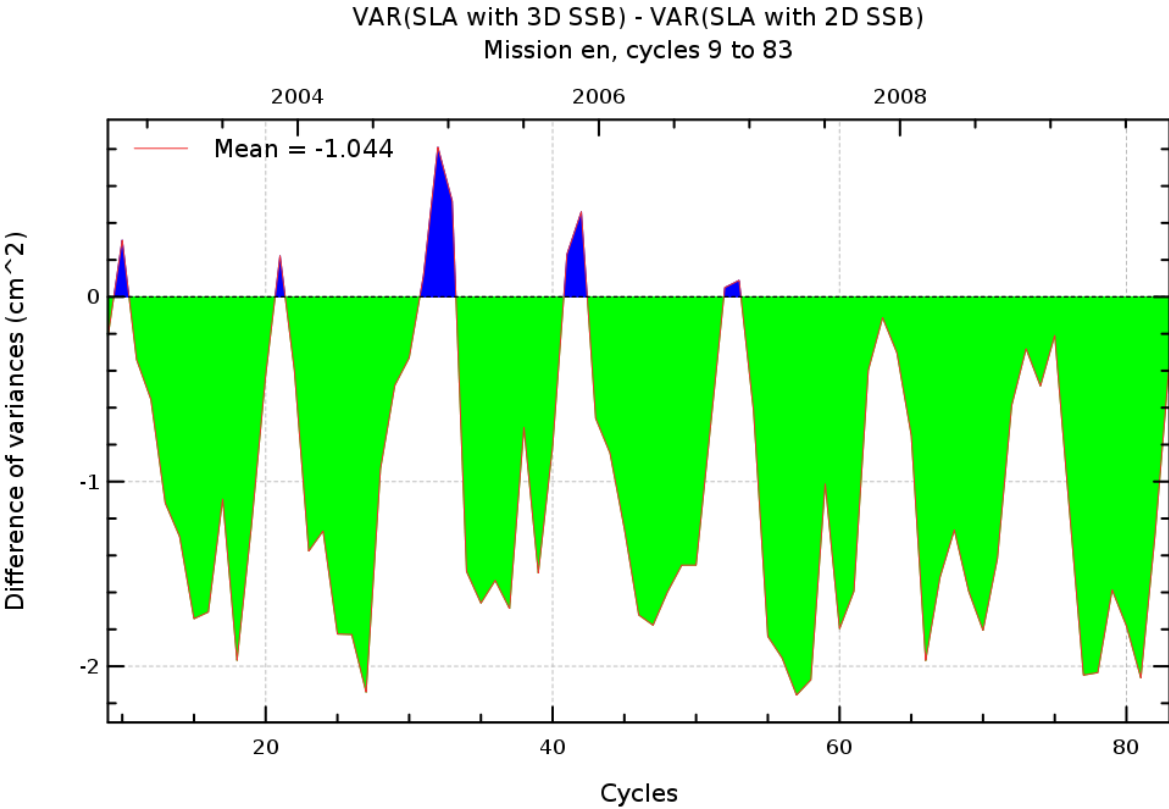
Diagnostic type : Global internal analyses

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	Diagnostic A202_a (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.	
	<div>VAR(SLA with 3D SSB) - VAR(SLA with 2D SSB) Mission en, cycles 9 to 83</div> 	

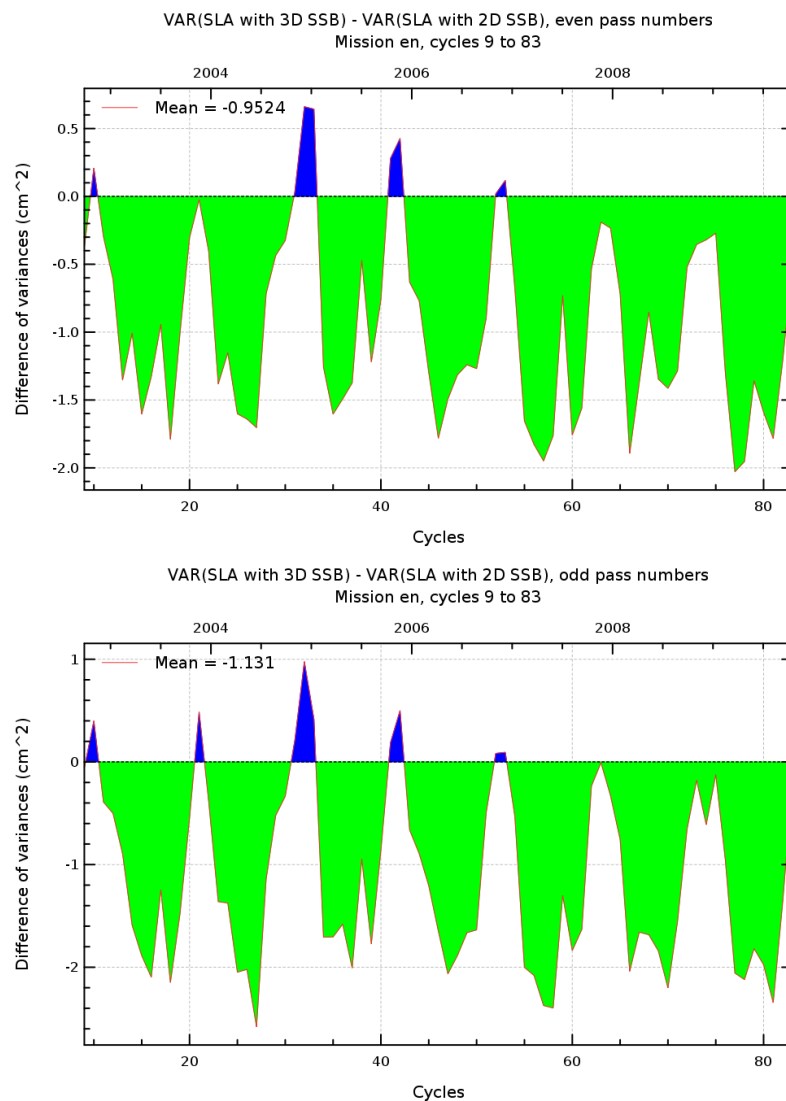
Diagnostic A202_b (mission en)

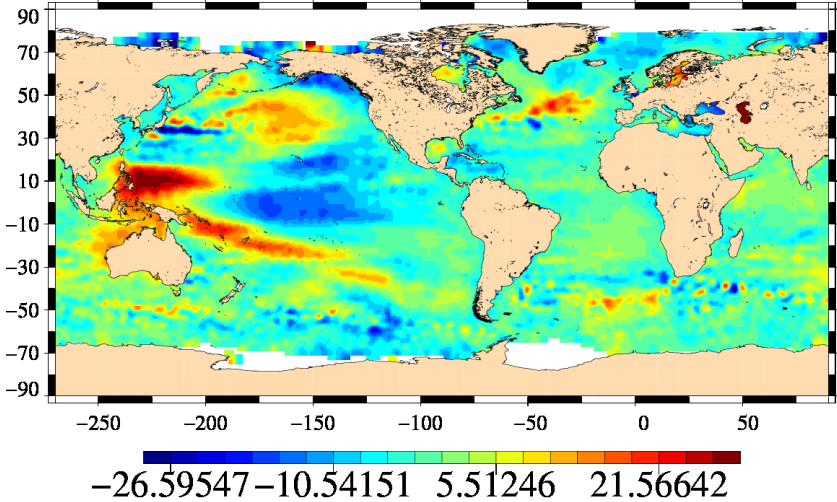
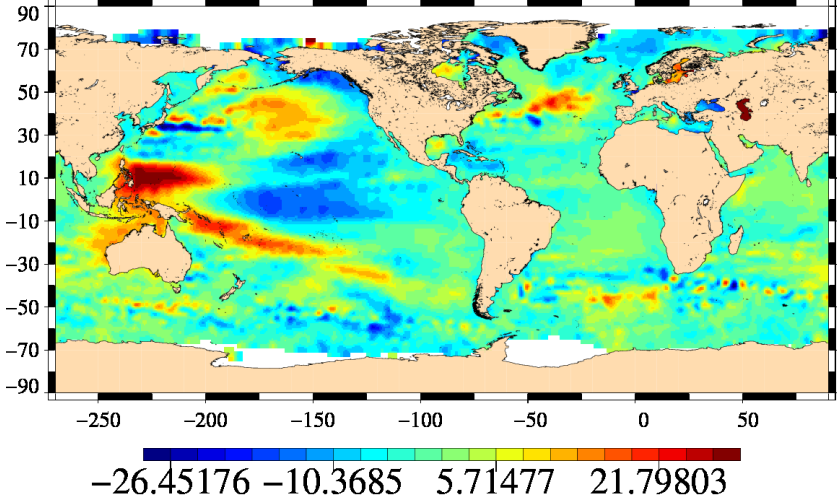
Name : Differences between temporal evolution of Sea Level Anomaly (SLA)

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)

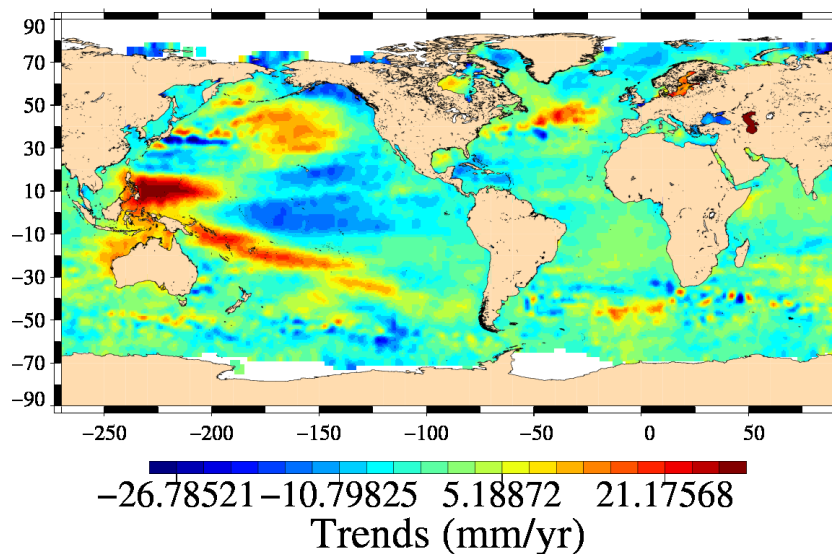
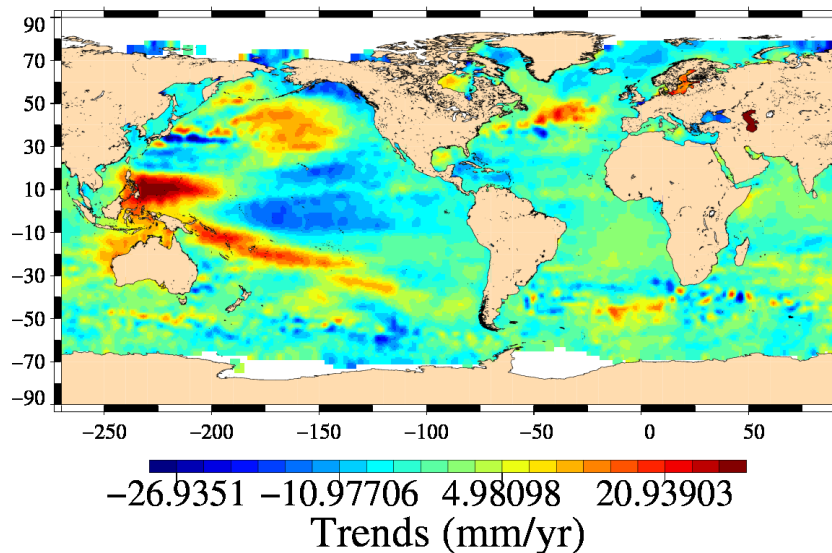
Name : Map of Sea Level Anomaly (SLA) over all the period

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)

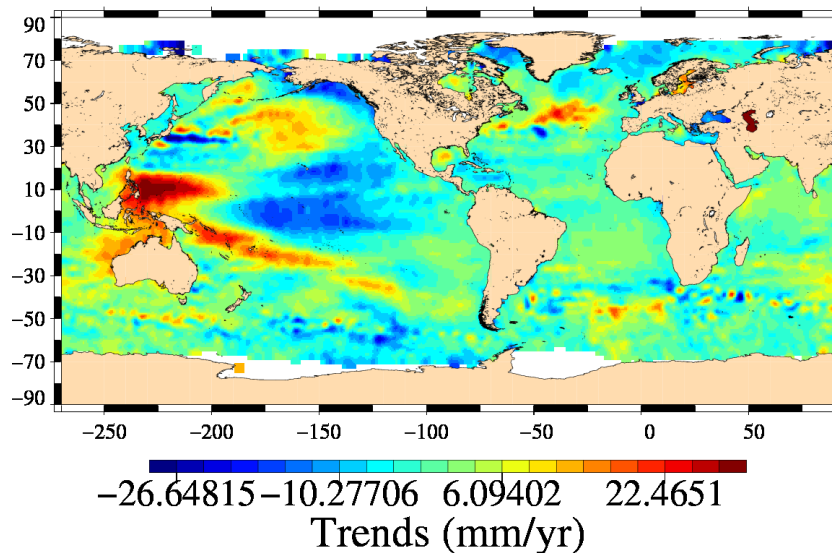
Name : Map of Sea Level Anomaly (SLA) over all the period

Input data : Along track SLA

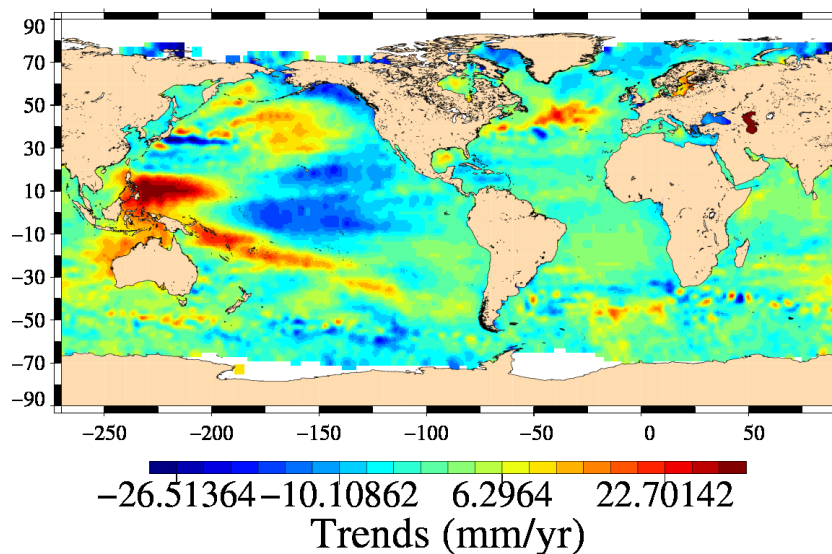
Description : The map of global statistics (mean, standard deviation) of SLA are calculated using successively both altimetric components in the SLA calculation over a large period. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

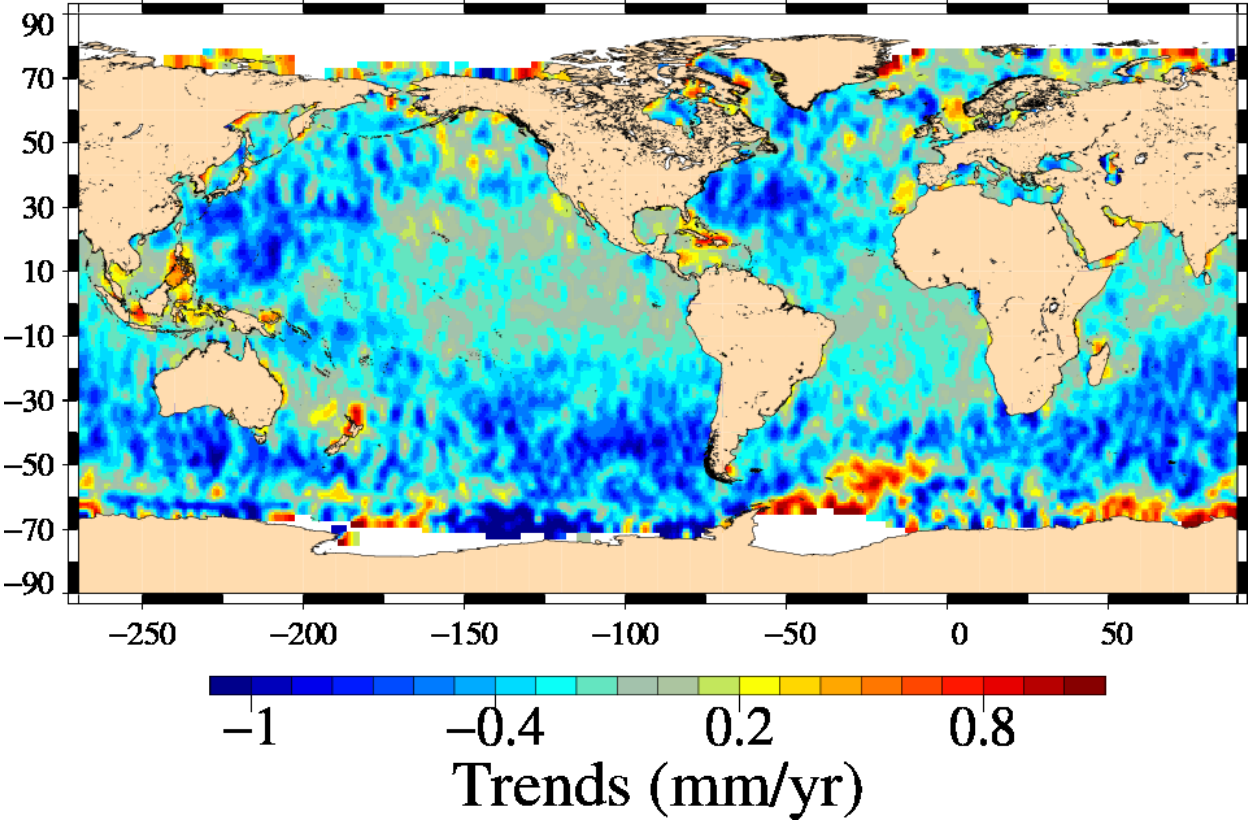
Diagnostic type : Global internal analyses

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)

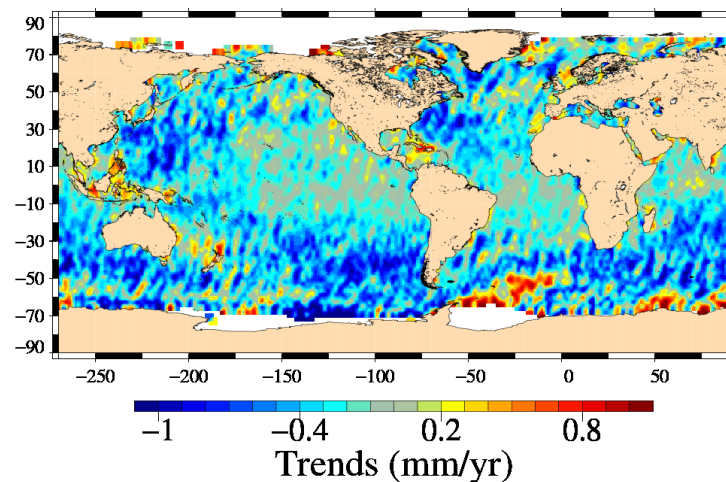
Name : Differences between maps of SLA

Input data : Along track SLA

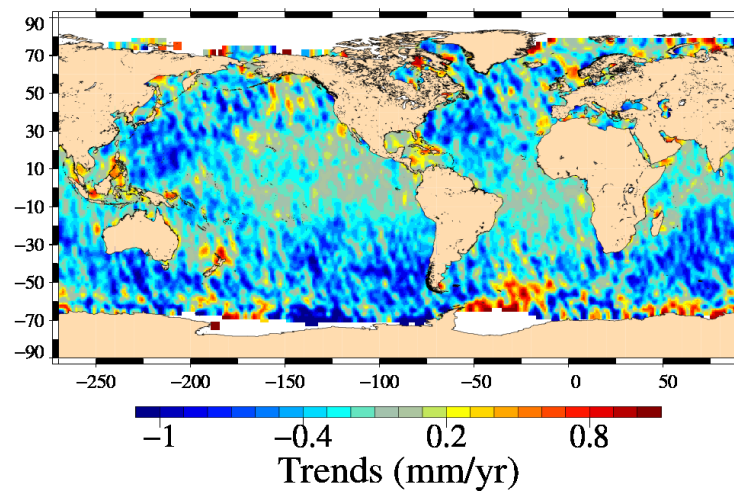
Description : The difference of SLA maps (mean, standard deviation, slope) is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except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

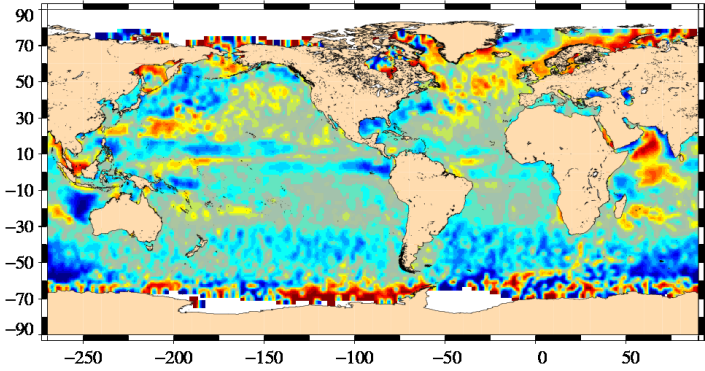
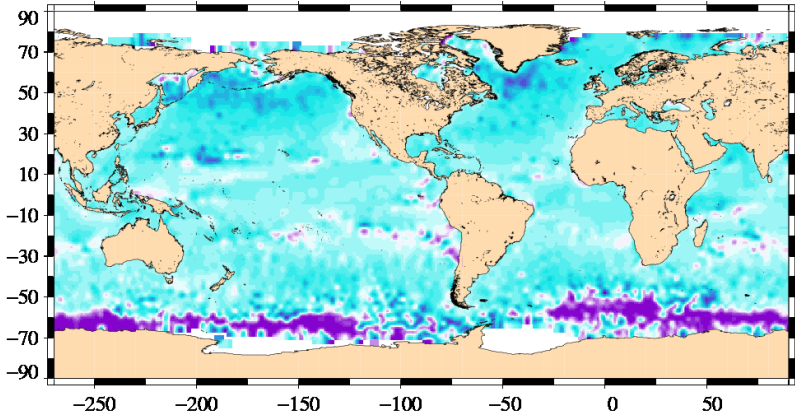
Diagnostic type : Global internal analyses

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>  <p>A global map showing the difference in Sea Level Anomaly (SLA) between 3D and 2D SSB amplitude calculations. The map covers latitudes from -90 to 90 and longitudes from -250 to 50. A color scale at the bottom indicates the amplitude in centimeters, ranging from -0.5 (dark blue) to 0.4 (dark red), with intermediate values at -0.2, 0.1, and 0. The map shows significant spatial variability, with higher positive differences (red/orange) concentrated in the tropical Pacific and Indian Oceans, and negative differences (blue) in the mid-latitude oceans.</p> <div>Amplitude (cm)</div> <div>SLA with 3D SSB phase – SLA with 2D SSB phase : annual signal</div> <div>Mission en, cycles 9 to 83</div>  <p>A global map showing the difference in SLA between 3D and 2D SSB phase calculations. The map covers latitudes from -90 to 90 and longitudes from -250 to 50. A color scale at the bottom indicates the phase difference in degrees, with values -15, -6, 3, and 12. The map shows a mix of positive (green/yellow) and negative (purple) phase differences, with a prominent band of negative differences (purple) along the equator in the Pacific and Indian Oceans.</p> <div>Phase (degree)</div>	

Diagnostic A205_b (mission en)

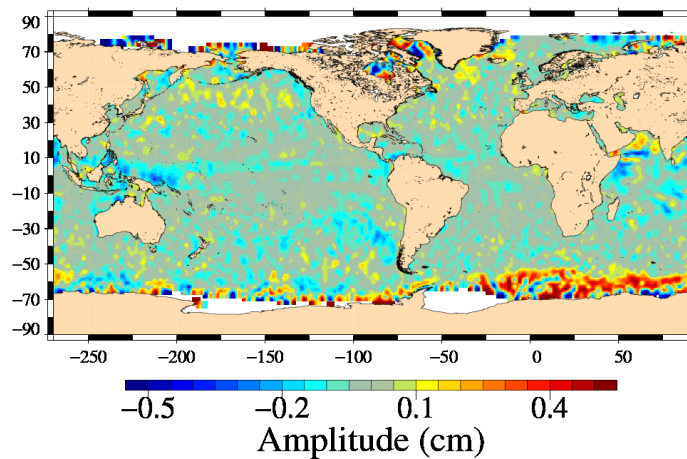
Name : Differences between maps of SLA (2)

Input data : Along track SLA

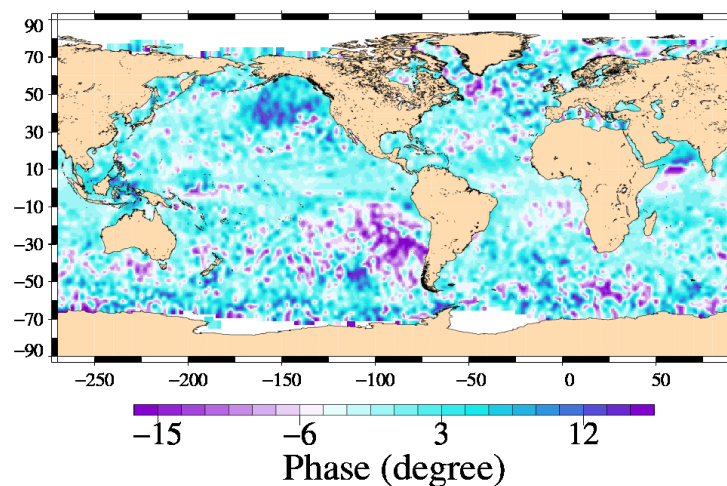
Description : The difference of SLA maps (mean, standard deviation, slope) is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except 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	
<p>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.</p>	
<div><p>Periodogram of SLA (reference period = 1 year) Mission en, cycles 9 to 83</p><p>Periodogram of SLA (period = [0, 1 year]) Mission en, cycles 9 to 83</p></div>	

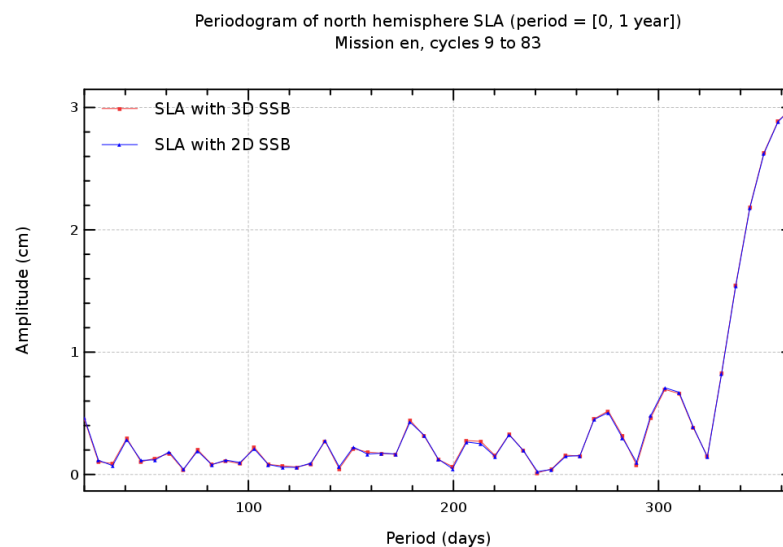
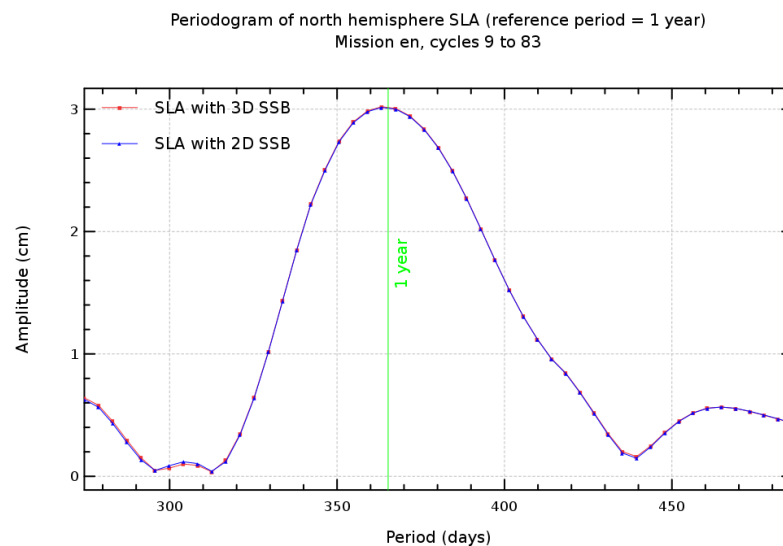
Diagnostic A206_b (mission en)

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



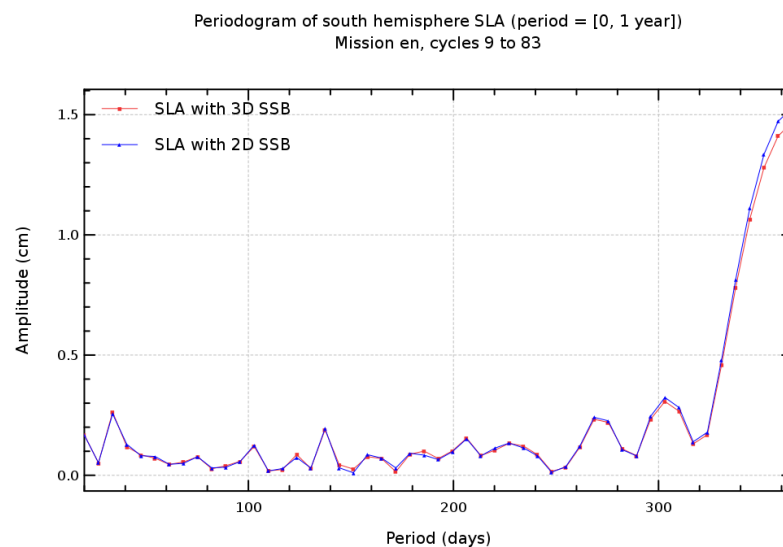
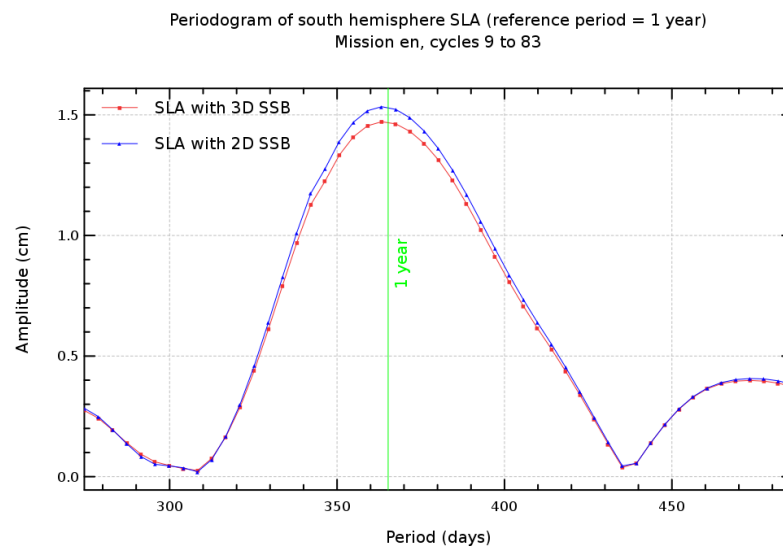
Diagnostic A206_c (mission en)

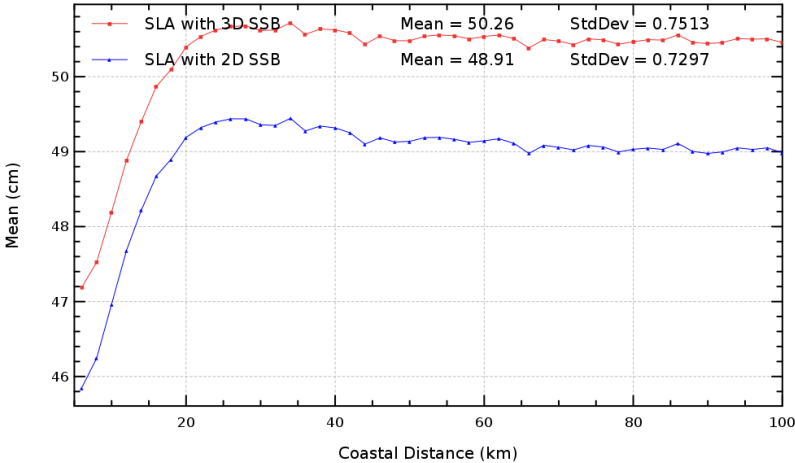
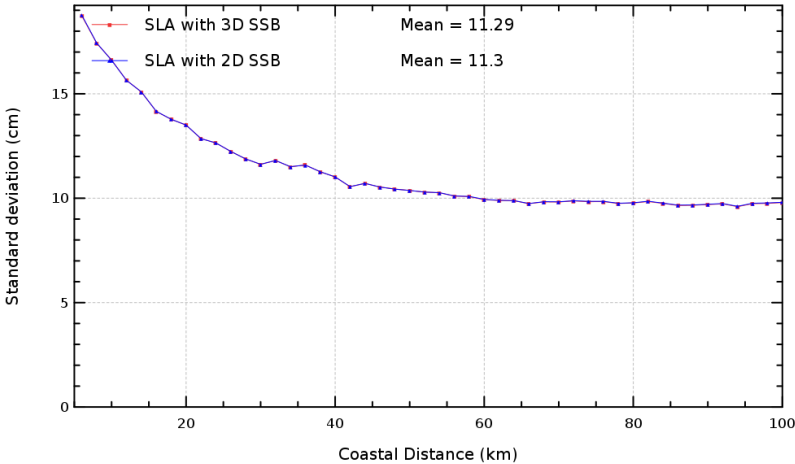
Name : Periodogram derived from temporal evolution of Sea Level Anomaly (SLA)

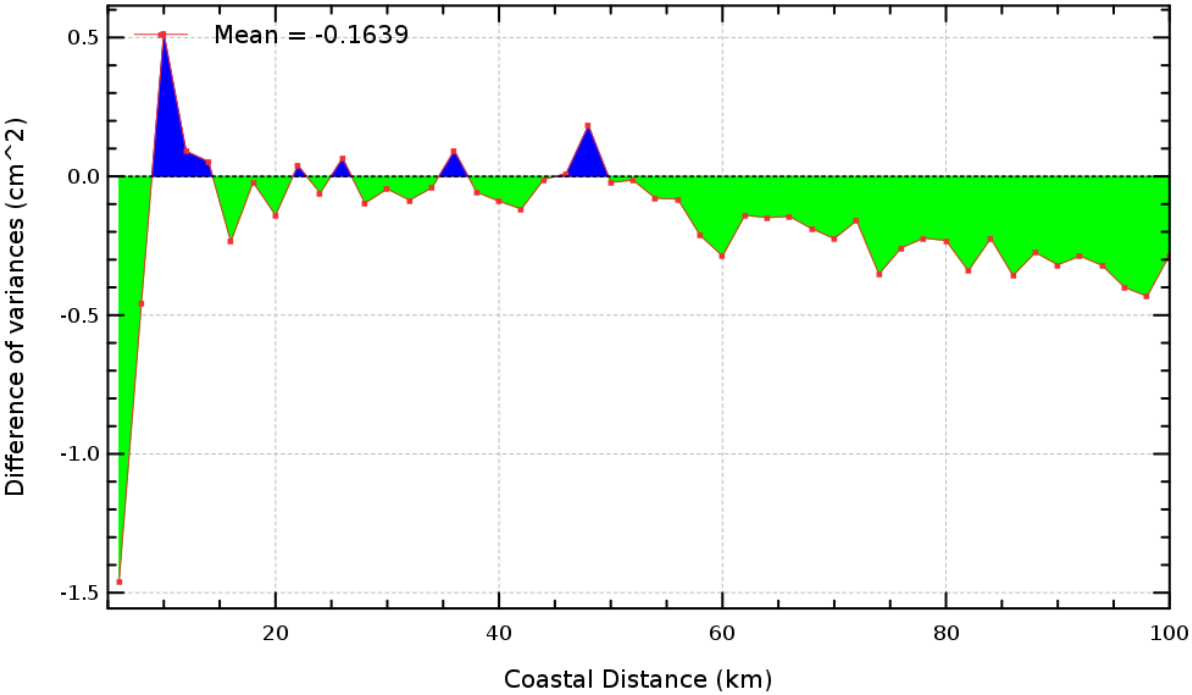
Input data : Along track SLA

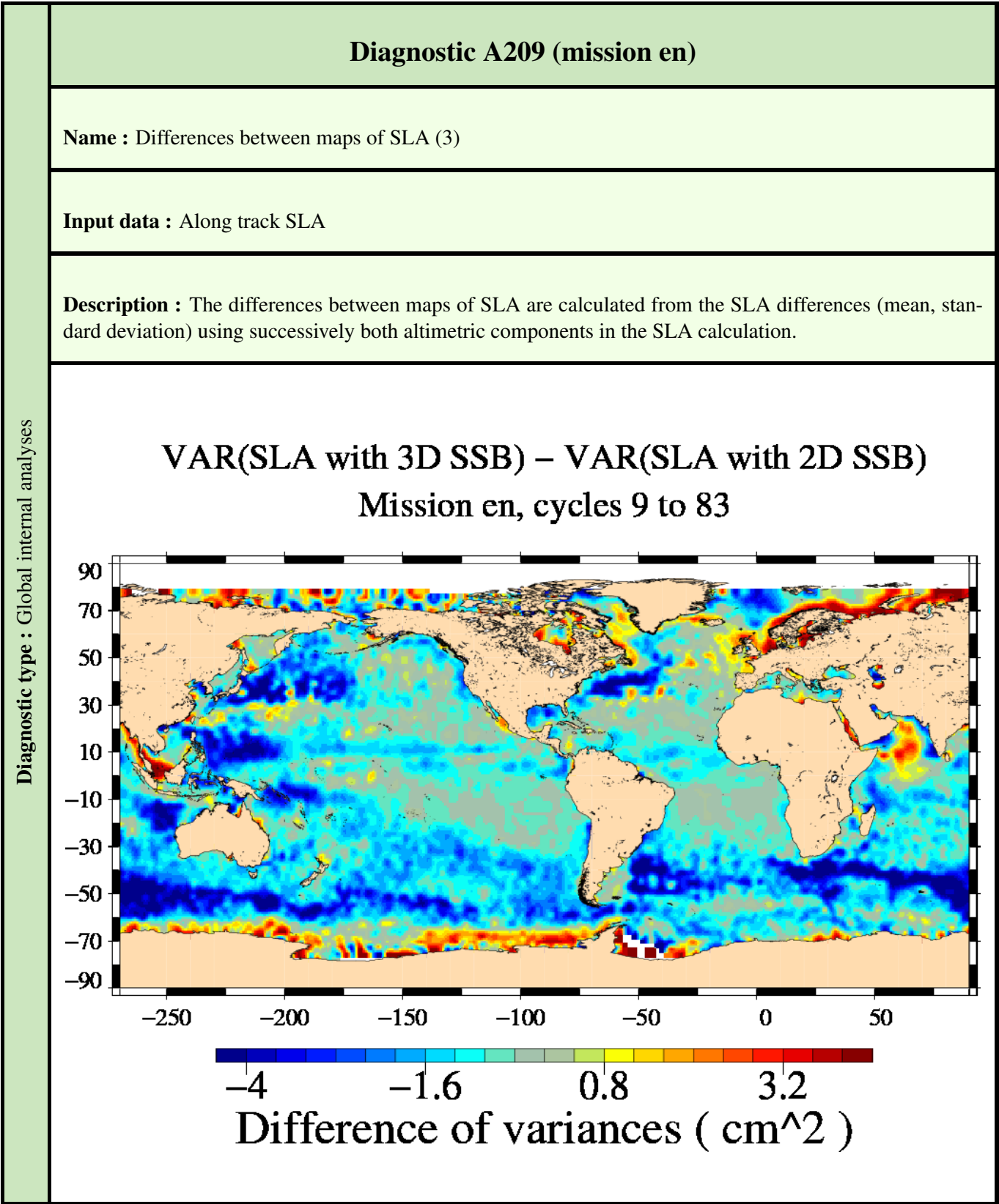
Description : The periodogram derived from temporal evolution of SLA (global, northern or southern hemisphere) can be done over all periods or focusing on particular periods, such as annual, semi annual or 60 day signal. Therefore mean of SLA differences are computed (every day or cycle), and time data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

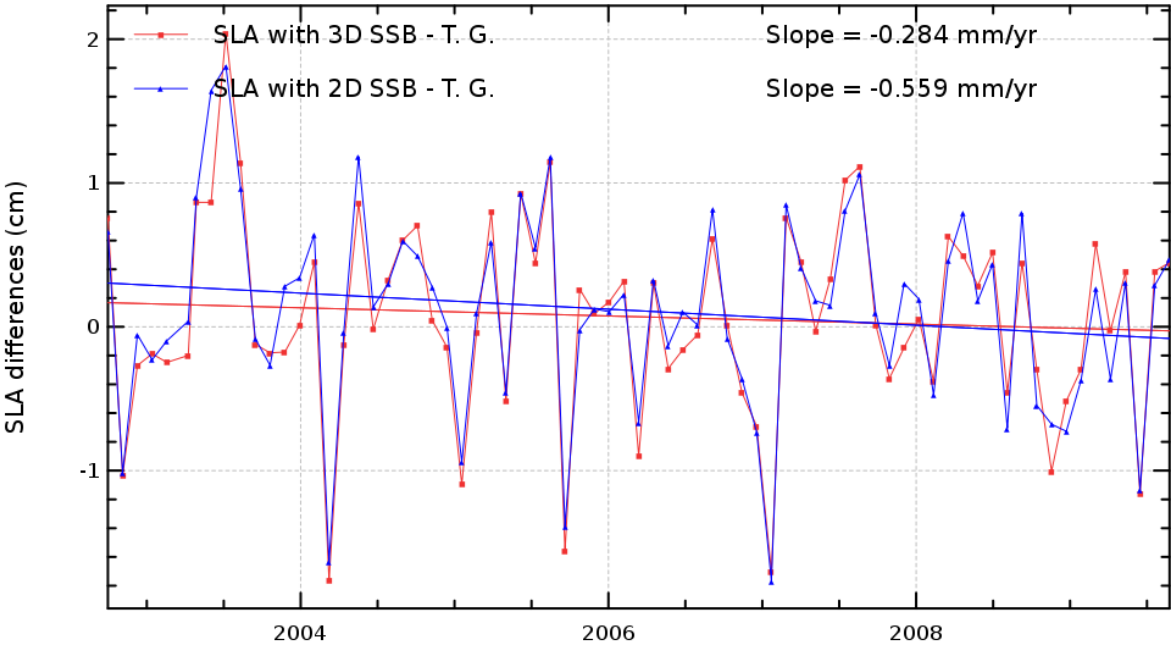
Diagnostic type : Global internal analyses



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>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 = 48.91 StdDev = 0.7297</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 = 11.3</p>	

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 C001 (mission en)							
Name : Temporal evolution of SSH differences between tide gauges and altimetry measurements							
Input data : Tide gauges SSH measurements							
<p>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).</p>							
<div>SLA differences : altimetry measurements - tide gauges Mission en, cycles 9 to 83</div>  <p>The graph displays the temporal evolution of Sea Level Anomaly (SLA) differences between altimetry measurements and tide gauge measurements from 2004 to 2008. The y-axis represents SLA differences in centimeters, ranging from -1 to 2. The x-axis shows years from 2004 to 2008. Two data series are plotted: 'SLA with 3D SSB - T. G.' (red line with square markers) and 'SLA with 2D SSB - T. G.' (blue line with triangle markers). Both series show significant fluctuations but follow a similar downward trend. Linear regression lines are shown for each series, with slopes of -0.284 mm/yr for the 3D SSB series and -0.559 mm/yr for the 2D SSB series.</p> <table border="1"><thead><tr><th>Series</th><th>Slope (mm/yr)</th></tr></thead><tbody><tr><td>SLA with 3D SSB - T. G.</td><td>-0.284</td></tr><tr><td>SLA with 2D SSB - T. G.</td><td>-0.559</td></tr></tbody></table>		Series	Slope (mm/yr)	SLA with 3D SSB - T. G.	-0.284	SLA with 2D SSB - T. G.	-0.559
Series	Slope (mm/yr)						
SLA with 3D SSB - T. G.	-0.284						
SLA with 2D SSB - T. G.	-0.559						

Diagnostic C002 (mission en)

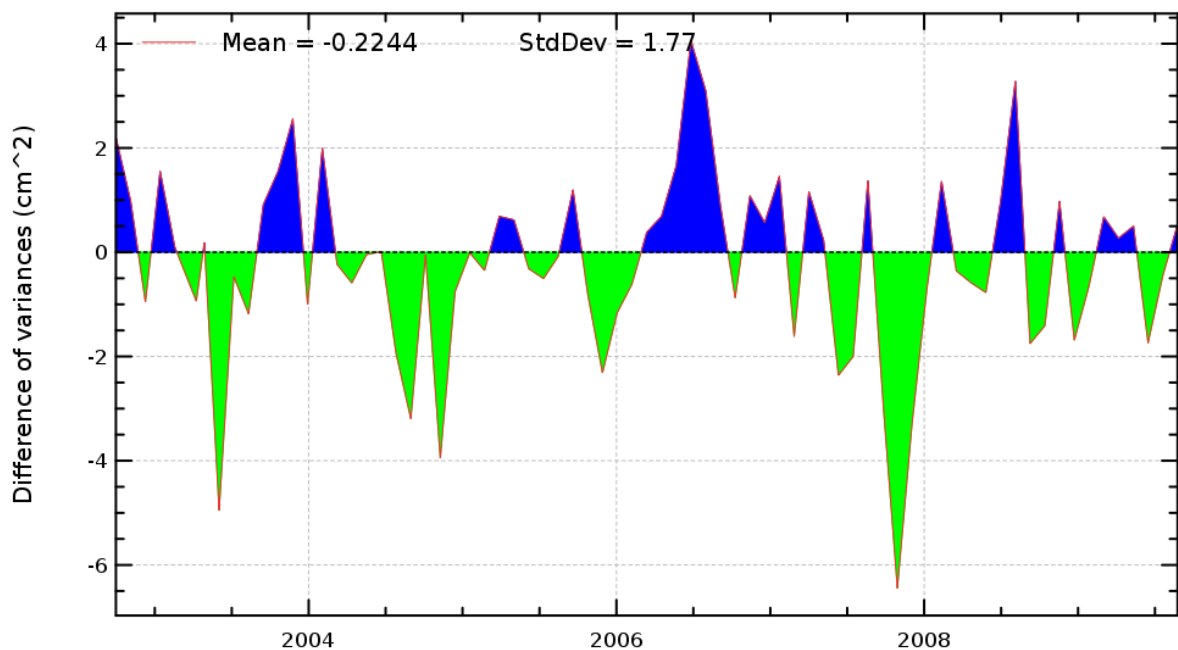
Name : Differences of temporal evolution of SSH differences between tide gauges and altimetry measurements

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

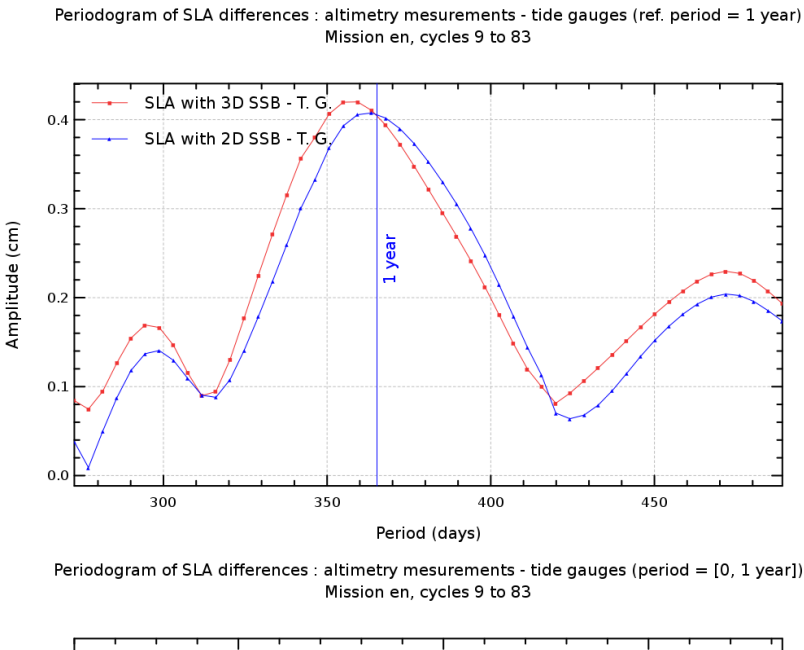


Diagnostic C003 (mission en)

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



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

