

Ionospheric models comparison: NIC09 versus GIM

Study variable	NIC09 model
Reference variable	Bent model for cycles 1-36 GIM model for cycles 37-85
Missions	ERS-2 (<i>e2</i>)
Period	[16570, 19541]

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Study overview

The aim of this study is to compare the ionospheric correction NIC09 model to GIM model. To do so, the NIC09 model is compared to a correction using the combination of Bent and GIM models to calculate ERS-2 sea-level height (SSH).

The study has been performed on ERS-2 data from cycle 1 to 85 (May 1995 to June 2003).

The studied correction derived from NIC09 model is described in Scharroo R., W. H. F. Smith, 2010, "A GPS-based climatology for the total electron content in the ionosphere", *Journal of Geophysical Research*, VOL 115, doi:10.1029/2009JA0014719.

NIC09 correction is compared to the correction given by:

- Bent model for cycles 1 to 36 (May 1995 to October 1998) described in Llewellyn, S.K. and R.B. Bent, 1973: "Documentation and Description of the Bent ionospheric model", AFCRL-TR-73-0657.
- GIM model for cycles 37 to 85 (October 1998 to June 2003) described in <http://iono.jpl.nasa.gov/gim.html>

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

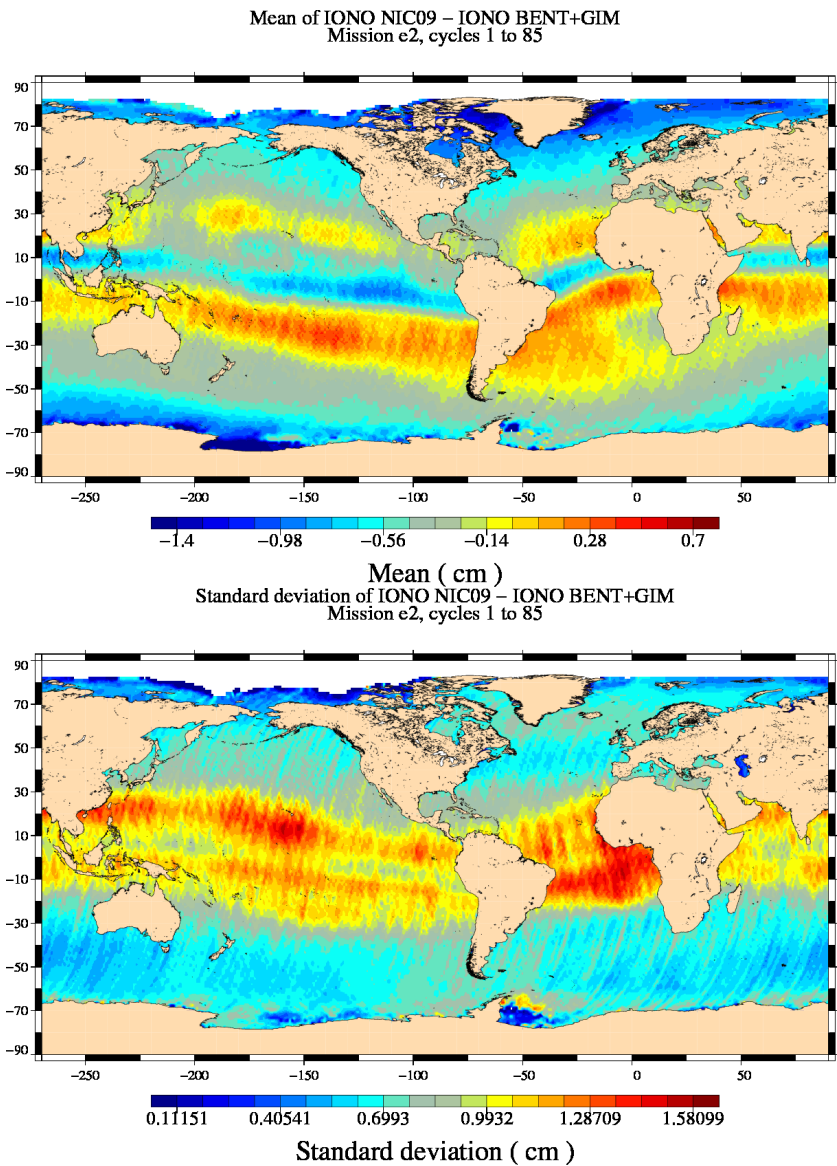
Diagnostic A001 (mission e2)	
Name : Temporal evolution of differences between both altimetric components	
Input data : Along-track altimetric components	
<p>Description : The temporal evolution of global statistics (mean, variance, slope) of differences between 2 different standards of a same altimetric 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.</p>	
<div><div><div>Mean of IONO NIC09 - IONO BENT+GIM</div><div>Mission e2, cycles 1 to 85</div><div><div>1996</div><div>1998</div><div>2000</div><div>2002</div></div><div><div>Mean = -0.2855</div><div>Slope = -0.00139</div></div><div><div>Mean (cm)</div><div>0.2</div><div>0.0</div><div>-0.2</div><div>-0.4</div><div>-0.6</div></div><div><div>BENT</div><div>GIM</div></div><div><div>Cycles</div><div>20</div><div>40</div><div>60</div><div>80</div></div></div><div><div>Standard deviation of IONO NIC09 - IONO BENT+GIM</div><div>Mission e2, cycles 1 to 85</div><div><div>1996</div><div>1998</div><div>2000</div><div>2002</div></div><div><div>Mean = 0.903</div></div><div><div>Standard deviation (cm)</div><div>1.6</div><div>1.4</div><div>1.2</div><div>1.0</div><div>0.8</div><div>0.6</div></div><div><div>BENT</div><div>GIM</div></div><div><div>Cycles</div><div>20</div><div>40</div><div>60</div><div>80</div></div></div></div>	

Diagnostic A002 (mission e2)

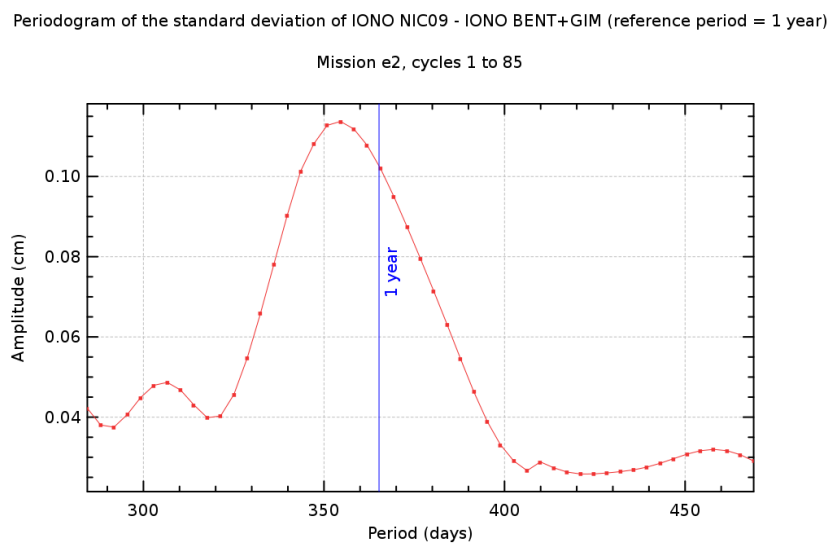
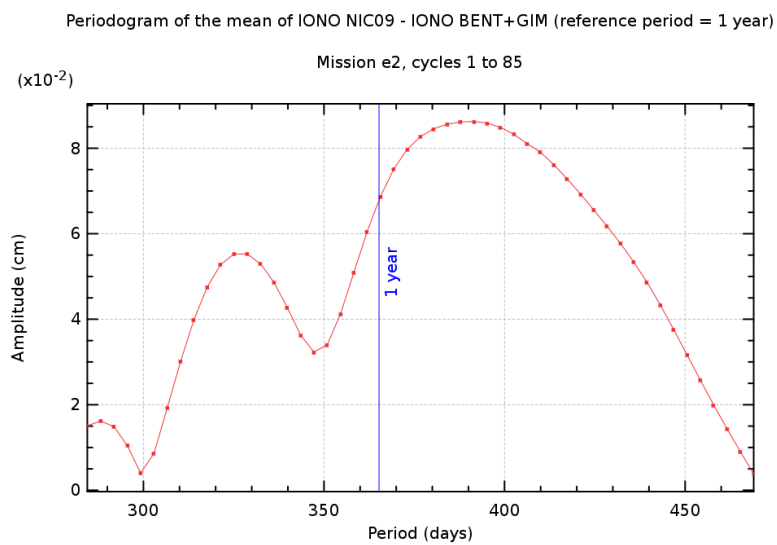
Name : Map of differences between both altimetric components over all the period

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 e2)
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.



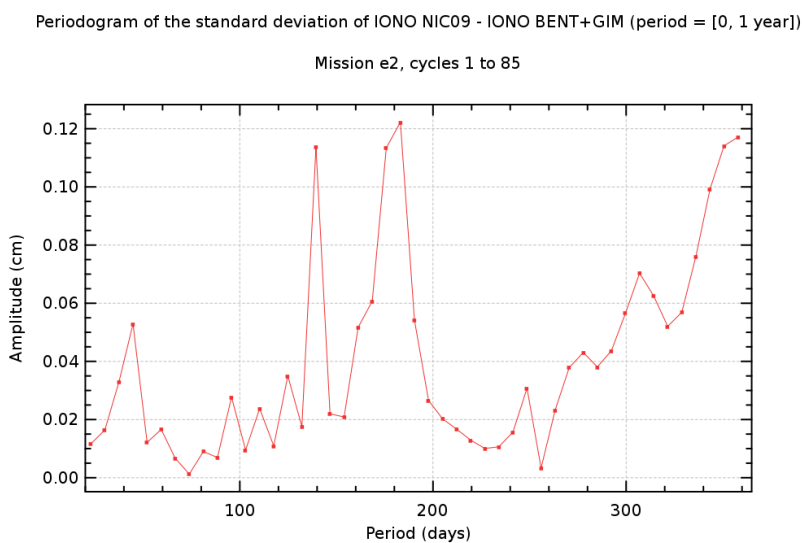
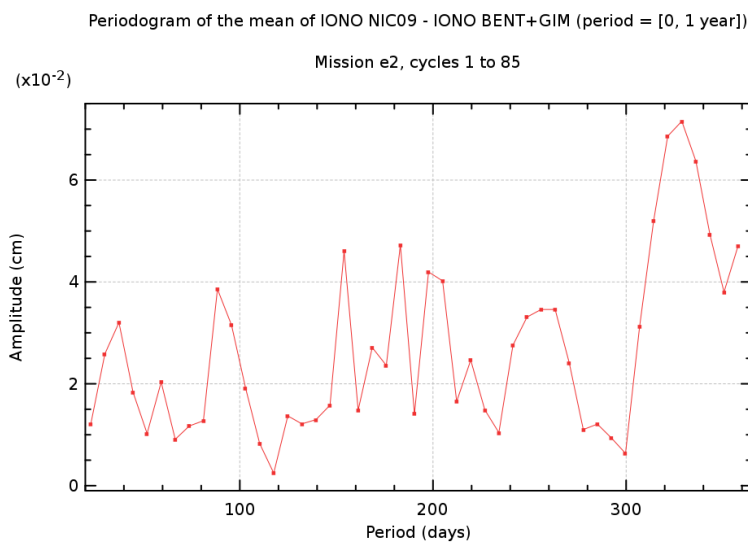
Diagnostic A003_b (mission e2)

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 type : Global internal analyses



Diagnostic A101 (mission e2)	
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>Mean of SSH crossovers</div><div>Mission e2, cycles 1 to 85</div><div><div>1996</div><div>1998</div><div>2000</div><div>2002</div></div><div><div>SSH with IONO NIC09</div><div>SSH with IONO BENT+GIM</div></div><div>Mean = -0.3609</div><div>Mean = -0.08766</div><div>BENT</div><div>GIM</div><div>Mean (cm)</div><div>1</div><div>0</div><div>-1</div><div>20</div><div>40</div><div>60</div><div>80</div></div> <div><div>Standard deviations of SSH crossovers</div><div>Mission e2, cycles 1 to 85</div><div><div>1996</div><div>1998</div><div>2000</div><div>2002</div></div><div><div>SSH with IONO NIC09</div><div>SSH with IONO BENT+GIM</div></div><div>Mean = 8.8</div><div>Mean = 8.761</div><div>BENT</div><div>GIM</div><div>Standard deviation (cm)</div><div>14</div><div>12</div><div>10</div><div>8</div><div>20</div><div>40</div><div>60</div><div>80</div></div>	

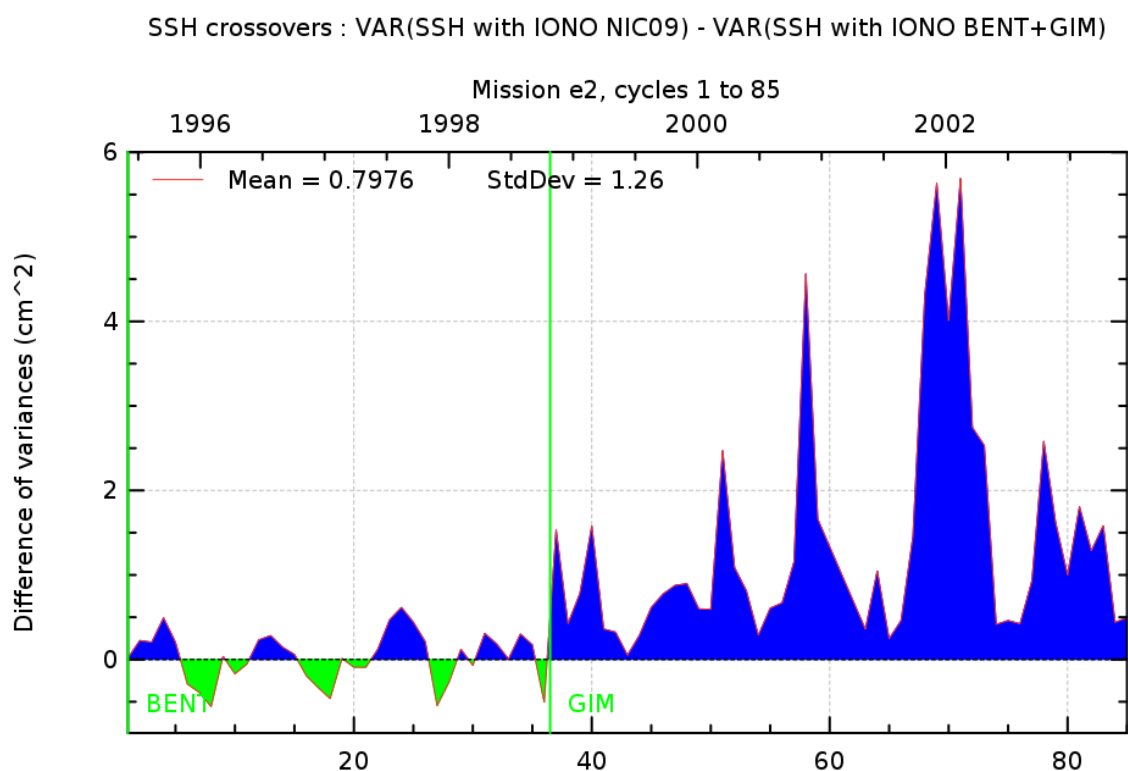
Diagnostic A102 (mission e2)

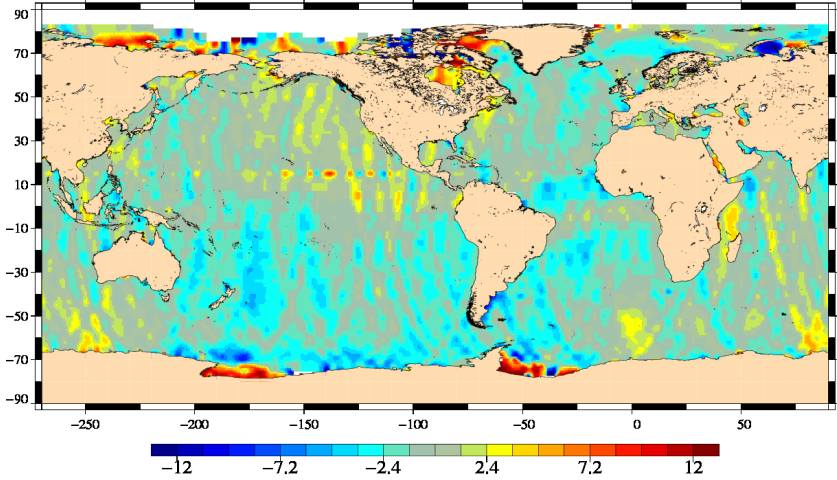
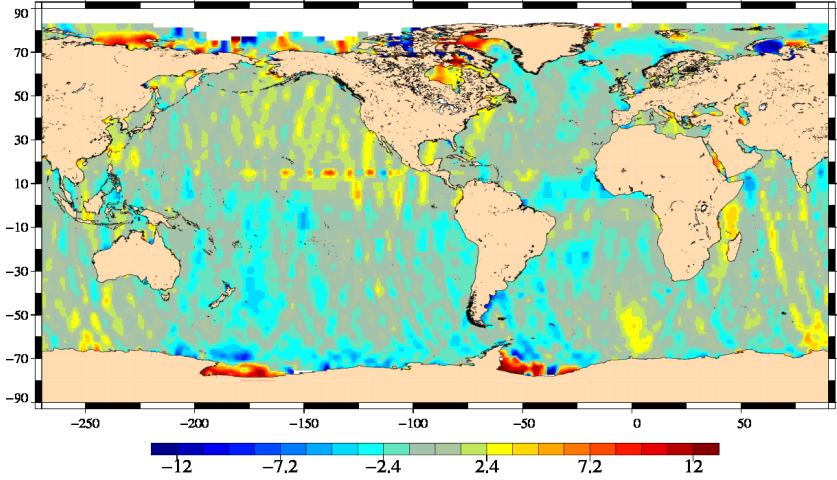
Name : Differences between temporal evolution of SSH crossovers

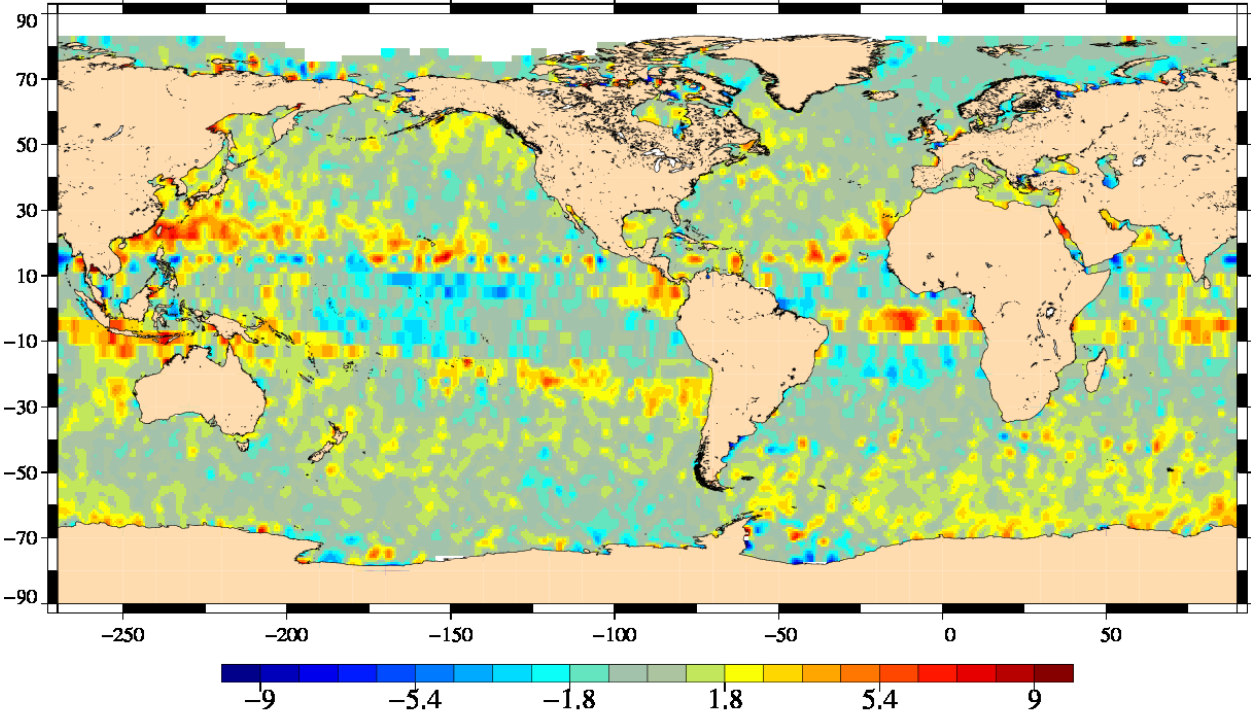
Input data : Sea Surface Height (SSH) crossovers

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 e2)	
Name : Map of SSH crossovers	
Input data : Sea Surface Height (SSH) crossovers	
<p>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).</p>	
<div><div><div>Mean of SSH with IONO NIC09 Mission e2, cycles 1 to 85</div><div>Mean (cm)</div></div><div><div>Mean of SSH with IONO BENT+GIM Mission e2, cycles 1 to 85</div><div>Mean (cm)</div></div></div>	

Diagnostic type : Global internal analyses	Diagnostic A104 (mission e2)	
	Name : Differences between maps of SSH crossovers	
	Input data : Sea Surface Height (SSH) crossovers	
	<p>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).</p>	
	<div>VAR(SSH with IONO NIC09) – VAR(SSH with IONO BENT+GIM) Mission e2, cycles 1 to 85</div>  <p>SSH crossovers : difference of variances (cm^2)</p>	

Diagnostic type : Global internal analyses	Diagnostic A201_a (mission e2)	
	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</div> <div>Mission e2, cycles 1 to 85</div> <div></div>	

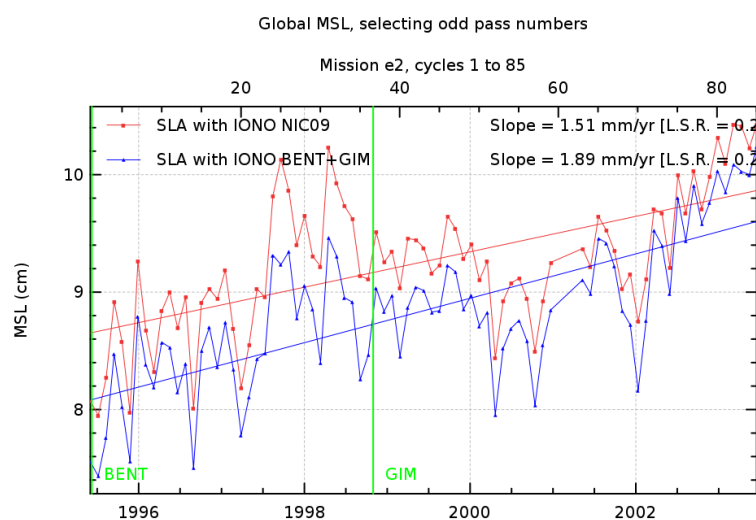
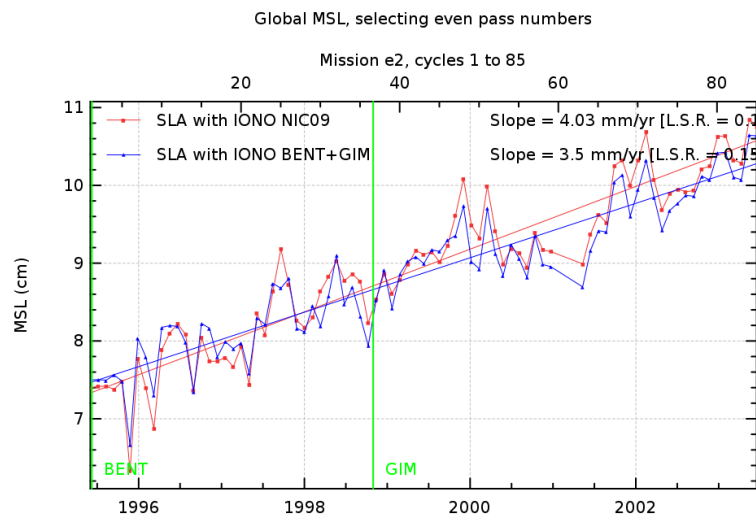
Diagnostic A201_b (mission e2)

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



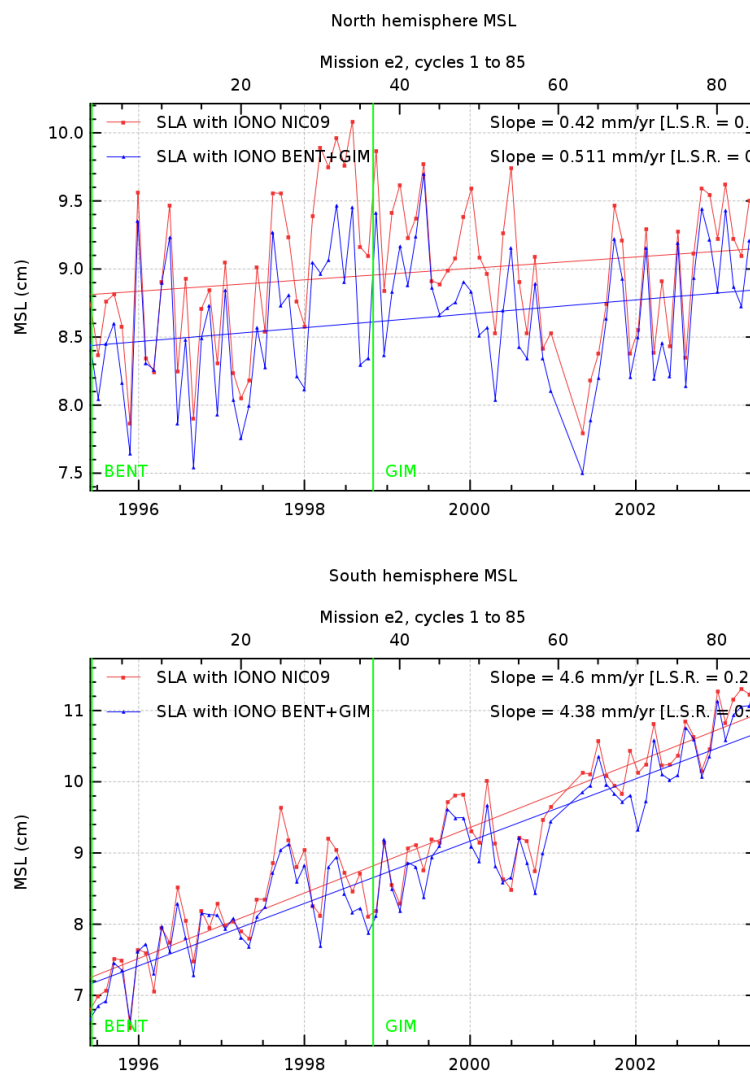
Diagnostic A201_c (mission e2)

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 type : Global internal analyses	Diagnostic A202_a (mission e2)	
	Name : Differences of temporal evolution of Sea Level Anomaly (SLA)	
	Input data : Along track SLA	
	<p>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.</p>	
	<p>VAR(SLA with IONO NIC09) - VAR(SLA with IONO BENT+GIM)</p> <p>Mission e2, cycles 1 to 85</p> <p>1996 1998 2000 2002</p> <p>Mean = 0.2461</p> <p>4 2 0 -2</p> <p>BENT GIM</p> <p>20 40 60 80</p> <p>Cycles</p>	

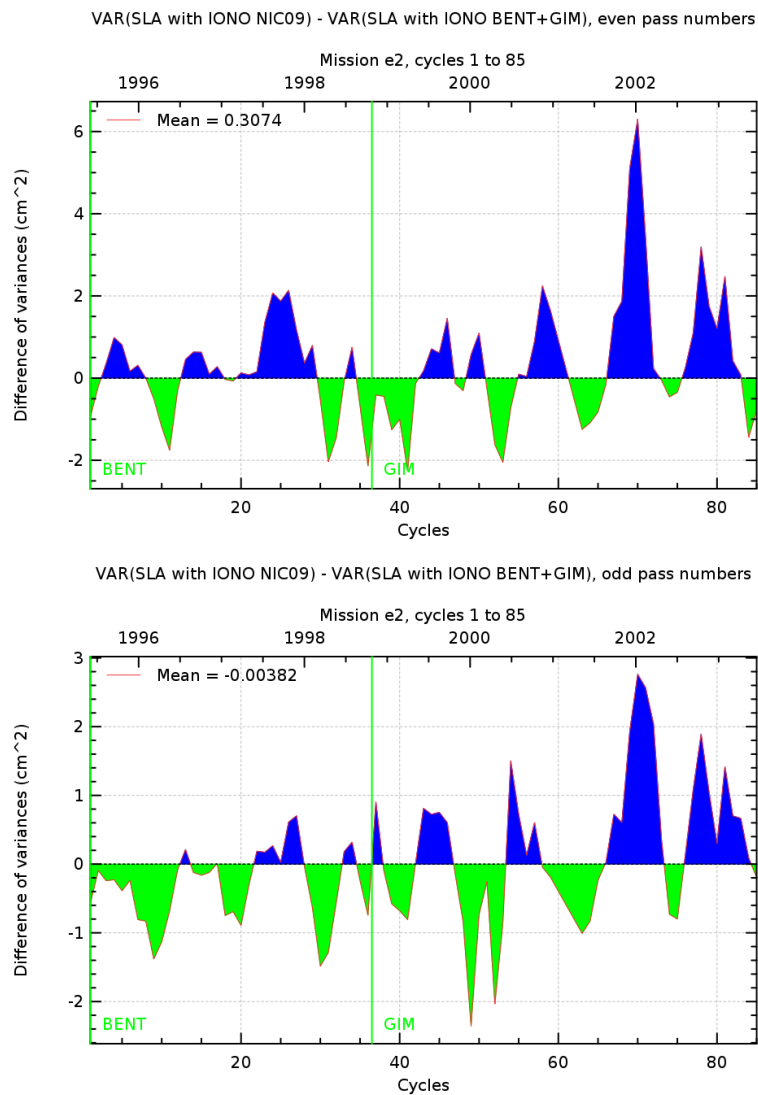
Diagnostic A202_b (mission e2)

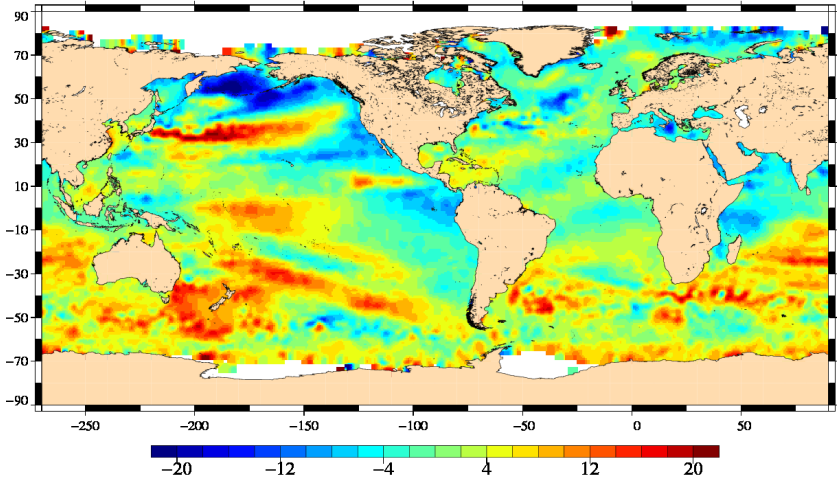
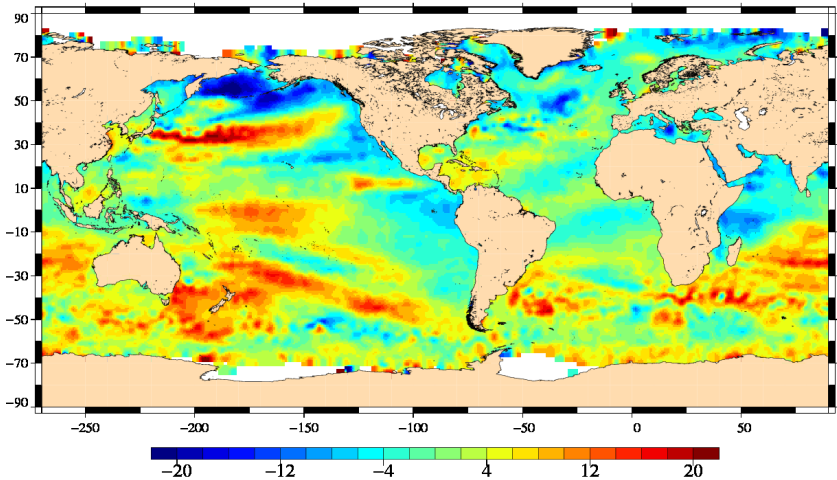
Name : Differences of temporal evolution of Sea Level Anomaly (SLA)

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 e2)	
	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 IONO NIC09 : trends Mission e2, cycles 1 to 85</div>  <div>Trends (mm/yr)</div> <div>SLA with IONO BENT+GIM : trends Mission e2, cycles 1 to 85</div>  <div>Trends (mm/yr)</div>	

Diagnostic A203_b (mission e2)

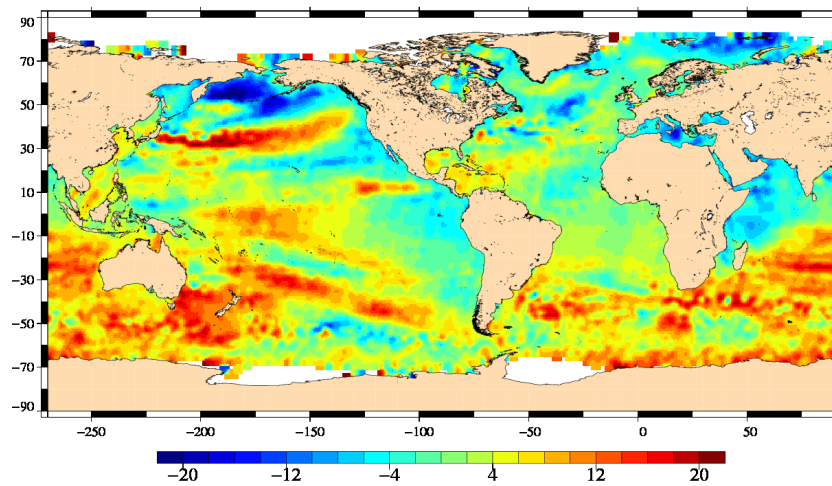
Name : Map of Sea Level Anomaly (SLA) over all the period

Input data : Along track SLA

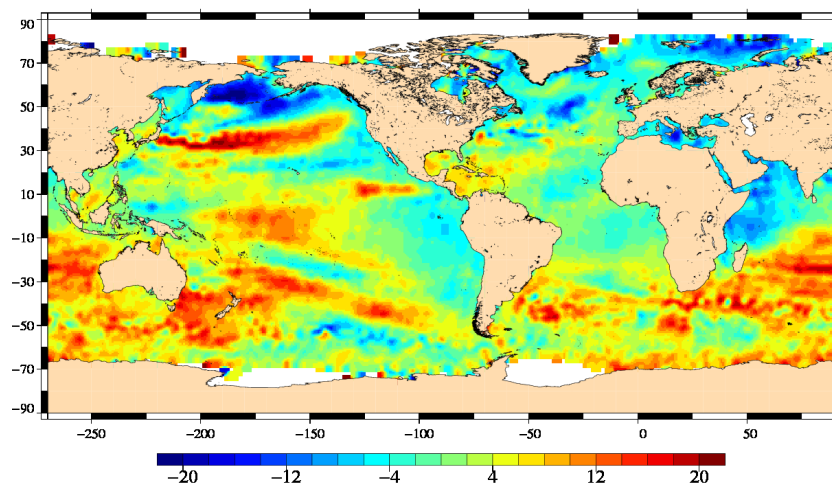
Description : The map of global statistics (mean, standard deviation) of SLA are calculated using successively both altimetric components in the SLA calculation over a large period. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

Diagnostic type : Global internal analyses

SLA with IONO NIC09 : trends, even pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)
SLA with IONO BENT+GIM : trends, even pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)

Diagnostic A203_c (mission e2)

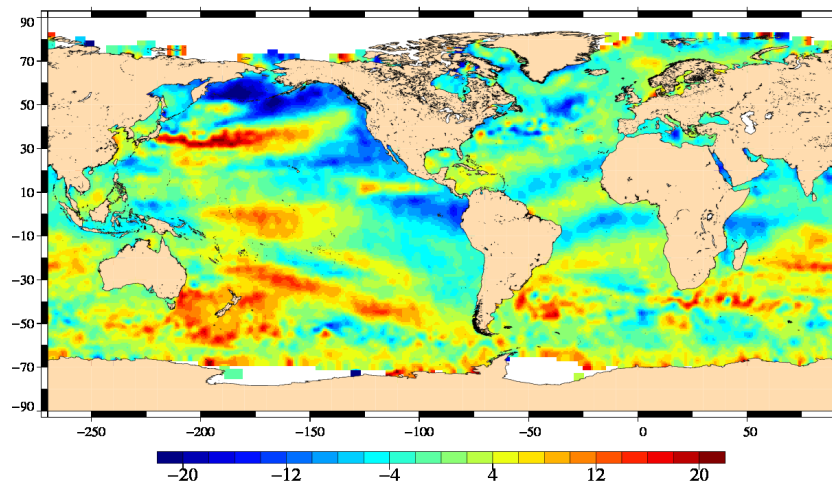
Name : Map of Sea Level Anomaly (SLA) over all the period

Input data : Along track SLA

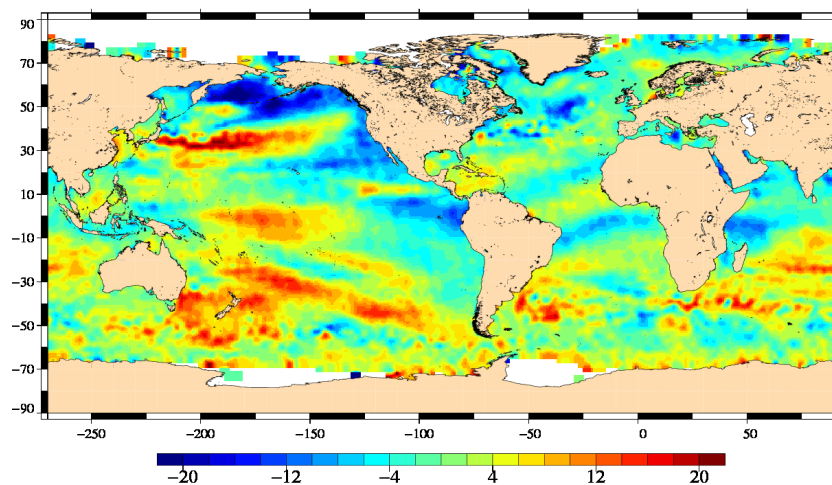
Description : The map of global statistics (mean, standard deviation) of SLA are calculated using successively both altimetric components in the SLA calculation over a large period. These statistics are calculated from 1 Hz altimetric measurements after removing spurious sea level measurements.

Diagnostic type : Global internal analyses

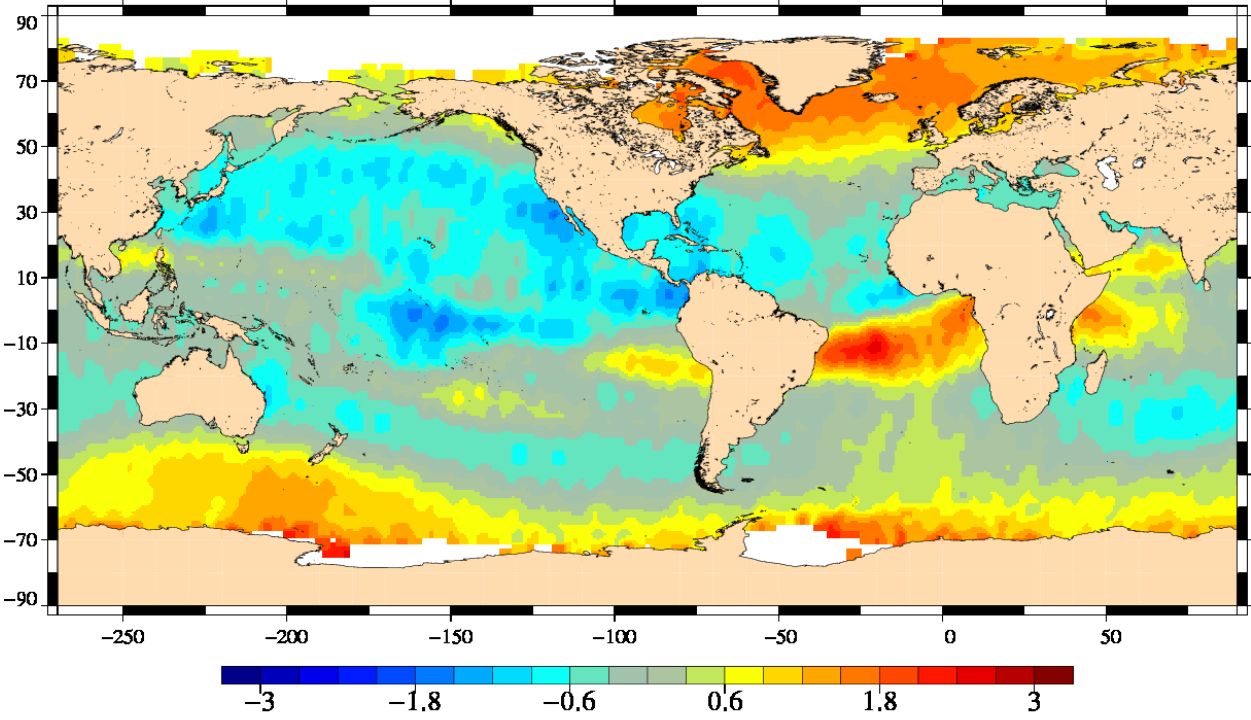
SLA with IONO NIC09 : trends, odd pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)
SLA with IONO BENT+GIM : trends, odd pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)

Diagnostic type : Global internal analyses	Diagnostic A204_a (mission e2)	
	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 IONO NIC09 – SLA with IONO BENT+GIM : trends Mission e2, cycles 1 to 85</div>  <p>Trends (mm/yr)</p>	

Diagnostic A204_b (mission e2)

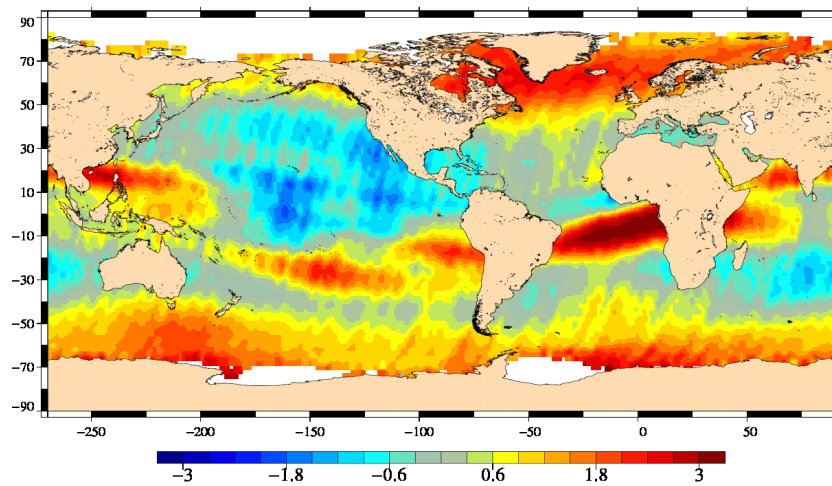
Name : Differences between maps of SLA

Input data : Along track SLA

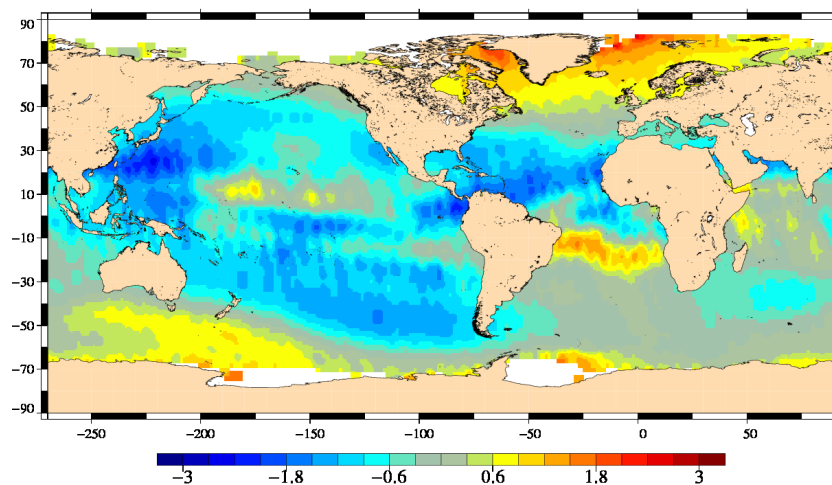
Description : The difference of SLA maps (mean, standard deviation, slope) is calculated from maps derived from diagnostic A203 using successively both altimetric components in the SLA calculation over a given period. This can be done globally, or separating in ascending and descending passes (except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

Diagnostic type : Global internal analyses

SLA with IONO NIC09 – SLA with IONO BENT+GIM : trends, even pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)
SLA with IONO NIC09 – SLA with IONO BENT+GIM : trends, odd pass numbers
Mission e2, cycles 1 to 85



Trends (mm/yr)

Diagnostic A206_a (mission e2)	
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>Periodogram of SLA differences (reference period = 1 year)</div> <div>Mission e2, cycles 1 to 85</div> <p>Amplitude (cm)</p> <p>Period (days)</p> <p>1 year</p> <p>Periodogram of SLA differences (period = [0, 1 year])</p> <div>Mission e2, cycles 1 to 85</div> <p>Amplitude (cm)</p> <p>Period (days)</p> <p>The figure consists of two vertically stacked line plots. The top plot is titled 'Periodogram of SLA differences (reference period = 1 year)' and 'Mission e2, cycles 1 to 85'. The y-axis is labeled 'Amplitude (cm)' and ranges from 0.02 to 0.08. The x-axis is labeled 'Period (days)' and ranges from 300 to 450. A red line with markers shows a curve that starts at approximately 0.02 at 300 days, rises to a local peak of about 0.05 at 330 days, dips slightly, then rises to a global maximum of about 0.085 at 370 days, before gradually declining to about 0.015 at 450 days. A vertical green line is drawn at 365 days, labeled '1 year'. The bottom plot is titled 'Periodogram of SLA differences (period = [0, 1 year])' and 'Mission e2, cycles 1 to 85'. The y-axis is labeled 'Amplitude (cm)' and ranges from 0.02 to 0.06. The x-axis is labeled 'Period (days)' and ranges from 0 to 350. A red line with markers shows a highly oscillatory curve with multiple peaks. Notable peaks occur at approximately 50, 100, 150, 180, 200, 250, and 320 days, with the highest peak reaching about 0.065 at 320 days.</p>	

Diagnostic A206_b (mission e2)

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

