### Ionospheric models comparison: NIC09 versus Bent

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Study overview

The aim of this study is to compare the ionospheric correction NIC09 model to Bent model. To do so, a correction using a combination of the NIC09 model and GIM model is compared to a correction using the combination of Bent and GIM models to calculate ERS-1 and ERS-2 sea-level height (SSH).

The impact of using these models on the SSH calculation have been analyzed for ERS-1 and ERS-2 missions:

- for ERS-1: from October 1992 (cycle 15) to June 1996 (Cycle 53)
- for ERS-2: from May 1995 (cycle 1) to June 2003 (Cycle 85)


The studied correction is then:

- NIC09 model for ERS-1 and ERS-2 until cycle 36 ERS-2 (October 1998)
- GIM correction for ERS-2 from cycle 37 (October 1998)

and it is compared to the correction given by:

- GIM model for cycles 37 to 85 (October 1998 to June 2003)

Note that in another RRDP, the comparison between NIC09 for cycles 1 to 85 (contrary to the combined correction NIC09+GIM made here) and BENT+GIM is performed. The interest of using different corrections along all the period is to study the long-term impact of such combinations on the mean sea level.

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 e1)

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.
**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 e1)

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 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.
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 e1)

**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.

![Periodogram](image1)

- Periodogram of the mean of IONO_NIC09 - IONO_BENT+GIM (period = [0, 1 year])
- Mission e1, cycles 16 to 52

![Periodogram](image2)

- Periodogram of the standard deviation of IONO_NIC09 - IONO_BENT+GIM (period = [0, 1 year])
- Mission e1, cycles 16 to 52
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.
**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.
Name: Temporal evolution of SSH crossovers

Input data: Sea Surface Height (SSH) crossovers

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).
Name: Temporal evolution of SSH crossovers

Input data: Sea Surface Height (SSH) crossovers

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).
**Diagnostic A102 (mission e1)**

**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).
**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).
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: 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 A104 (mission e1)**

**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).

**VAR(SSH with IONO NIC09+GIM) – VAR(SSH with IONO BENT+GIM)**

Mission e1, cycles 16 to 52

SSH crossovers: difference of variances (cm^2)
**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).

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**VAR(SSH with IONO NIC09+GIM) – VAR(SSH with IONO BENT+GIM)**

Mission e2, cycles 2 to 84

SSH crossovers: difference of variances (cm^2)
Diagnostic A201_a (mission e1)

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

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

**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.

![Graph showing Global MSL with SLA and IONO measures](image)
Diagnostic A201_b (mission e1)

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

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

**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.

![Graphs showing temporal evolution of SLA](image)
**Diagnostic A201_c (mission e1)**

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

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

**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.

![Graph showing the temporal evolution of MSL for North and South hemispheres](image)

**Diagnostic type**: Global internal analyses
**Diagnostic A201_a (mission e2)**

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

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

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

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

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

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

**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.

![Graphs showing North and South hemisphere MSL](image)

**Diagnostic type:** Global internal analyses
**Diagnostic A202.a (mission e1)**

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

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

**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 A202_b (mission e1)

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

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

**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 A202.a (mission e2)**

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

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

**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.

![Graph](image-url)
**Diagnostic A202.b (mission e2)**

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

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

**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 A203_a (mission e1)**

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

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

**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.

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![SLA map](image1)

**Trends (mm/yr)**

SLA with IONO NIC99+GIM : trends
Mission e1, cycles 16 to 52

![Trends map](image2)

**Trends (mm/yr)**

SLA with IONO BENT+GIM : trends
Mission e1, cycles 16 to 52
Name: Map of Sea Level Anomaly (SLA) over all the period

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

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 A203_c (mission e1)

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

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

**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 A203_a (mission e2)

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

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

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 A203_b (mission e2)

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

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

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 A203_c (mission e2)**

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

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

**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.

![Map of Sea Level Anomaly (SLA)](image)
# Diagnostic A204_a (mission e1)

**Name**: Differences between maps of SLA

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

**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 A204_b (mission e1)

**Name**: Differences between maps of SLA

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

**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 A204_a (mission e2)

Name: Differences between maps of SLA

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

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).

SLA with IONO NIC09+GIM – SLA with IONO BENT+GIM : trends
Mission e2, cycles 2 to 84
**Diagnostic A204_b (mission e2)**

**Name:** Differences between maps of SLA

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

**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 A206.a (mission e1)

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

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

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 e1)

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

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

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.

![Periodogram of SLA differences, north and south hemispheres (reference period = 1 year)](image1)

Periodogram of SLA differences, north and south hemispheres (reference period = 1 year)

Mission e1, cycles 16 to 52

![Periodogram of SLA differences, north and south hemispheres (period = [0, 1 year])](image2)

Periodogram of SLA differences, north and south hemispheres (period = [0, 1 year])

Mission e1, cycles 16 to 52
Diagnostic A206_a (mission e2)

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

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

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 e2)

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

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

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.