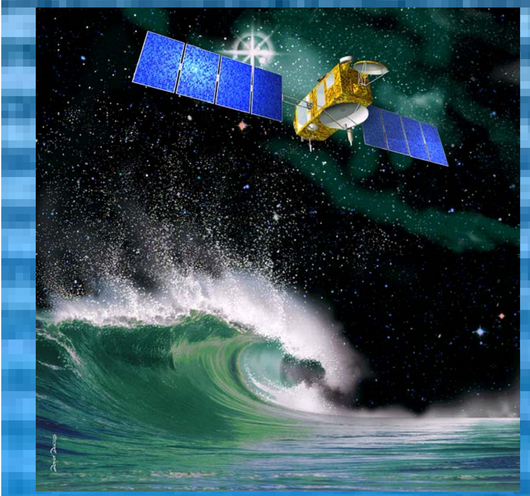
# Operational Assimilation of Altimeter Wind/Wave Data



## A. ABSTRACT

Since July 2003, Meteo-France has been putting wind/wave JASON/OSDR products on the WMO World Meteorological Organisation) Global Transmitting System, making them available in near real-time to the international meteorological community. Since May 2004, these data have been introduced in addition to ERS/FDP products (Which should be replaced by ENVISAT/FDMAR products) into Meteo-France's sea-state forecasting systems. A data quality control has been set up in order to eliminate spurious wind/wave data (about 10-15% of Jason/OSDR products over oceans). Independent data sets from moored buoys and Geosat Follow-On satellite (US Navy Satellite) have been used to assess the benefit of using these new data in addition to ERS2 ones (or ENVISAT ones) for numerical wave analyses and forecasts, both in terms of significant wave height and mean wave period. A regional analysis of the results is also presented.

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Florida,USA
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## B. DATA QUALITY CONTROL FOR DATA ASSIMILATION

The data quality control procedure used for OSDR products is the following:

1. Perform basic quality control on the raw data.

A record is rejected if:

- RMS_Ku_SWH > 1.34 m
- 0.01 m < Ku-Band SWH > 12.6 m
- observation is on land or over ice

2. Perform consistency checks on the remaining data.

Observations are grouped in sequences of several observations enclosed in the wave model grid box. A sequence is rejected if:

- there is less than 4 observations in a box
- it is too noisy

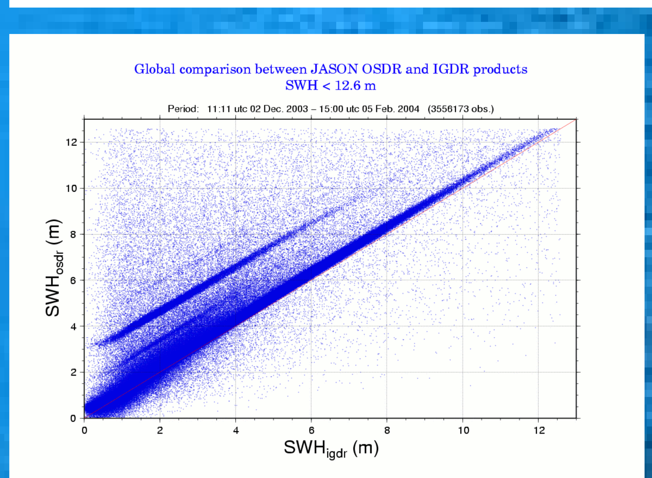


**Figure B.1 Scatter plot of OSDR versus IGDR SWH (no quality control but SWH <12.6 m)**

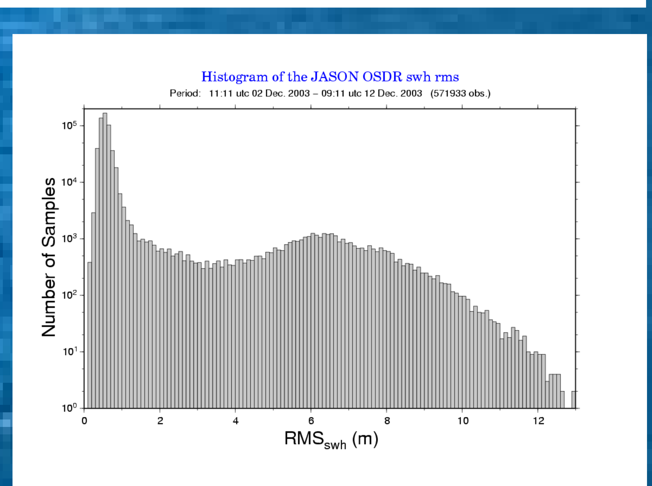


**Figure B.2 Jason rms_SWH histogram**

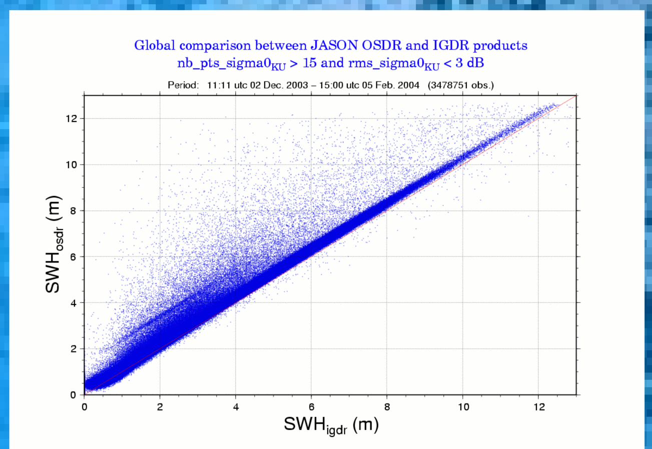


**Figure B.3 Scatter plot of OSDR versus IGDR SWH for RMS_SWH_KU < 3 dB.**

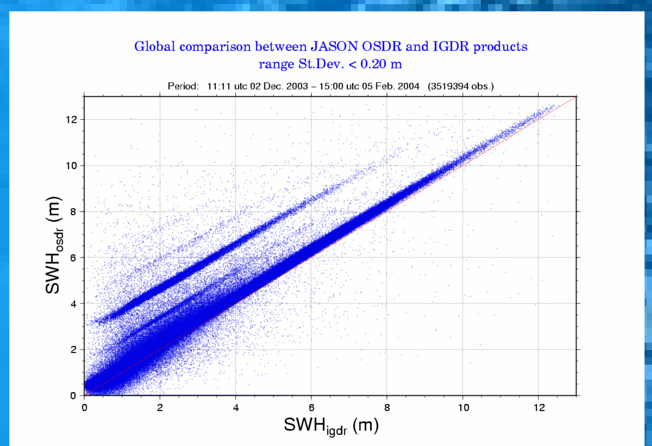


**Figure B.4 Scatter plot of OSDR versus IGDR SWH For RMS_Range_Ku < 0.20 m.**

•Scatter plots of Jason OSDR versus IGDR SWH indicates multimodal distributions of their differences (Figure B.1).

•The distribution of the RMS of the 20 Hz Jason data has also multiple modes for OSDR (Figure B.2) unlike for IGDR (not shown) due to some anomalous OSDR measurements (about 1% of the data).

• However, the criteria (RMS_sigma0_KU<3 dB) suggested in Desai and Vincent (Marine Geodesy, 2003, Vol 26) is not sufficient to remove all extra modes (Figure B.3).

•The RMS of the 20 Hz measurements of range does not appear as a good parameter to avoid the multimodal distribution for SWH differences, as shown on figure B.4.

•Unimodal distribution of OSDR measurements (Figure B.5) can be obtained by removing about 10% of the data over ocean (Figure B.6) by selecting data with a small RMS of the 20 Hz Ku measurements of SWH (RMS_SWH_Ku < 1.3 m).

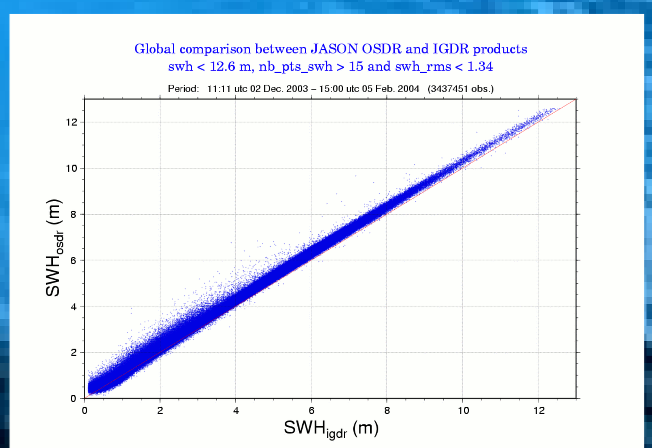


**Figure B.5 Scatter plot of OSDR versus IGDR SWH after quality control on raw data.**

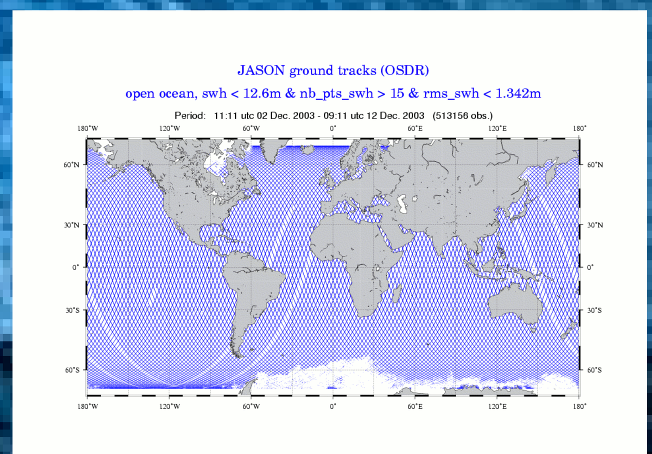


**Figure B.6 Jason Ground tracks (OSDR after quality control on raw data).**

## C. DATA ASSIMILATION : GLOBAL IMPACT

In order to assess the impact of using several altimeters in a wave analysis/prediction system several experiments have been carried out. A first run has been performed without any assimilation (referred to as « noassi »). Then, assimilation runs have been performed using 1, 2 and 3 altimeters. In a first period of 19 days, referred to as « the analysis period », data have been assimilated in a global version of the WAM model. After 19 days, the assimilation was stopped in order to evaluate the duration of the impact in the « forecast period ».

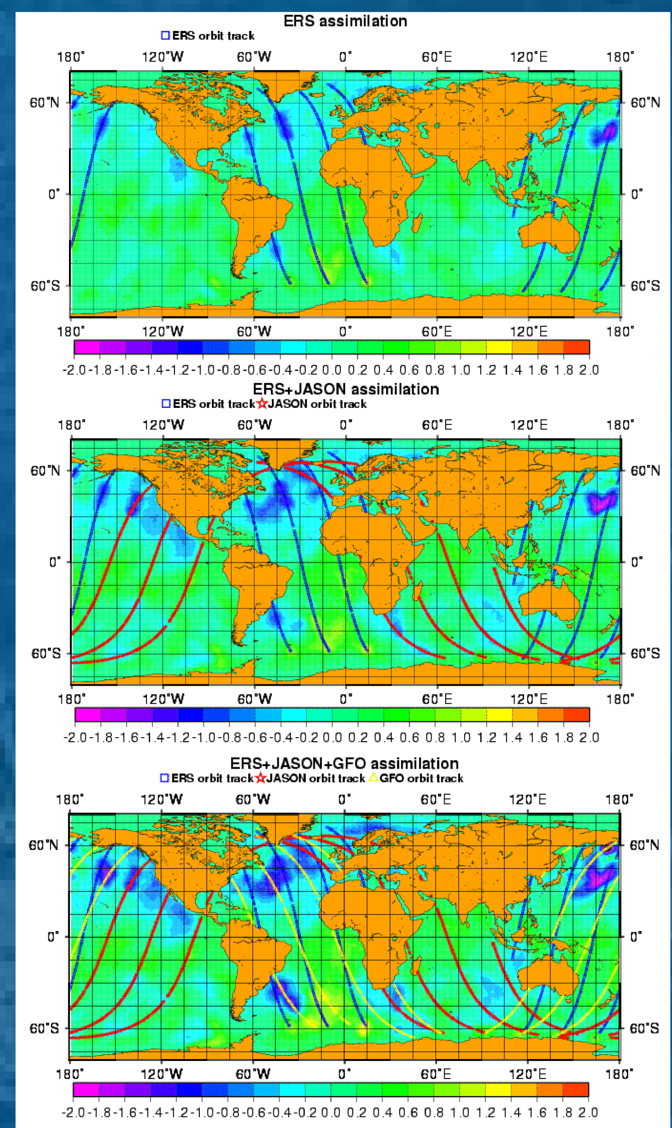
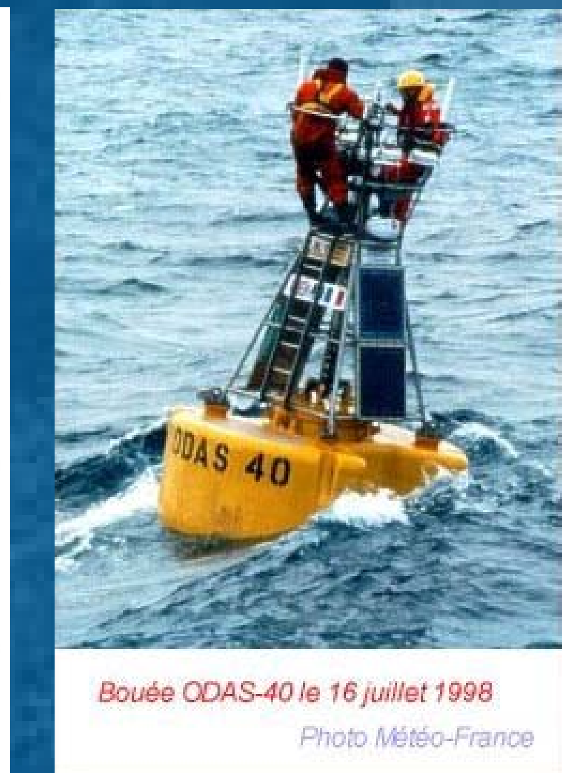




**Figure C.1 Plots of the SWH difference (in meters) between runs with assimilation of one, two and three altimeters and without assimilation for December 19 at 00 UTC. Altimeter ground track are reported for ERS , Jason and GFO.**





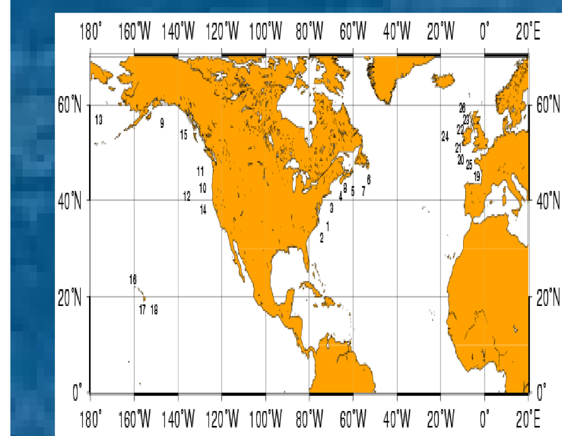


**Figure C.2 Buoy (see Table 1) locations.**

**TABLE 1: buoy information**

| | | | |
|---|---|---|---|
| 1 | 41001 US East Coast, E Hatteras ECNA | 14 | 46059 US West Coast, California WCNA |
| 2 | 41002 US South-East Coast, S Hatteras ECNA | 15 | 46184 Canada West Coast, North Nomad WCNA |
| 3 | 44004 US North-East Coast, Hotel ECNA | 16 | 51001 Hawaii North-West HW |
| 4 | 44011 US North-East Coast, Georges Bank ECNA | 17 | 51002 Hawaii South-West HW |
| 5 | 44137 Newfoundland, East Scotia slope ECNA | 18 | 51004 Hawaii South-East HW |
| 6 | 44138 Newfoundland, SW Grand Bank ECNA | 19 | 62001 Gulf of Biscay, Gascogne WCE |
| 7 | 44141 Newfoundland, Laurentian Fan ECNA | 20 | 62029 UK Celtic Sea shelf break (K1) WCE |
| 8 | 44142 Nova Scotia, Lahave Bank ECNA | 21 | 62081 UK East Atlantic (K2) WCE |
| 9 | 46001 Gulf of Alaska WCNA | 22 | 62105 UK East Atlantic (K4) WCE |
| 10 | 46002 US West Coast, Oregon WCNA | 23 | 62106 UK North-East Atlantic RARH WCE |
| 11 | 46005 US North-West Coast, Washington WCNA | 24 | 62108 UK East Atlantic (K3) WCE |
| 12 | 46006 US West Coast, SE Papa WCNA | 25 | 62163 UK Celtic Sea shelf break (Britany) WCE |
| 13 | 46035 Bering Sea WCNA | 26 | 62045 UK North-East Atlantic WCE |

**TABLE 2** : SWH statistical comparisons between model data and GFO measurements for analysis and forecast periods. The scatter index is defined as the standard deviation of the difference between model data and GFO data normalized by the GFO data mean value.

| | Analysis | | | | Forecast (two first days) | | | |
|---|---|---|---|---|---|---|---|---|
| | Noassi | ERS | ERS +JASON | ERS+ +JASON +GFO | Noassi | ERS | ERS +JASON | ERS +JASON +GFO |
| Bias (m) | 0.009 | -0.05 | -0.01 | -0.00 | 0.01 | -0.04 | 0.01 | 0.04 |
| StD (m) | 0.56 | 0.44 | 0.39 | 0.17 | 0.53 | 0.47 | 0.43 | 0.36 |
| Rms error (m) | 0.57 | 0.45 | 0.40 | 0.17 | 0.54 | 0.47 | 0.44 | 0.37 |
| Scatter index | 0.20 | 0.16 | 0.14 | 0.06 | 0.19 | 0.17 | 0.16 | 0.13 |
| Assimilation index | | 0.20 | 0.29 | 0.68 | | 0.12 | 0.18 | 0.30 |

**TABLE 3 :** SWH statistical comparisons between model data and buoy data for analysis and forecast periods. The scatter index is defined as the standard deviation of the difference between model and buoy, normalized by the buoy mean value. The symmetric slope refers to the ratio of the sum of squares of the model data with the sum of the squares of the buoy data.

| | Analysis | | | | Forecast (two first days) | | | |
|---|---|---|---|---|---|---|---|---|
| | Noassi | ERS | ERS +JASON | ERS +JASON +GFO | Noassi | ERS | ERS +JASON | ERS +JASON +GFO |
| No. Of entries | 1525 | 1525 | 1525 | 1525 | 242 | 242 | 242 | 242 |
| Buoy mean (m) | 3.40 | 3.40 | 3.40 | 3.40 | 3.72 | 3.72 | 3.72 | 3.72 |
| Bias (m) | -0.30 | -0.20 | -0.10 | -0.08 | -0.30 | -0.27 | -0.20 | -0.15 |
| StD (m) | 0.57 | 0.52 | 0.51 | 0.50 | 0.45 | 0.44 | 0.44 | 0.44 |
| Rms error (m) | 0.66 | 0.57 | 0.54 | 0.51 | 0.56 | 0.52 | 0.50 | 0.48 |
| Scatter index | 0.16 | 0.15 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 |
| Assimilation | | 0.08 | 0.09 | 0.12 | | 0.03 | 0.01 | 0.02 |

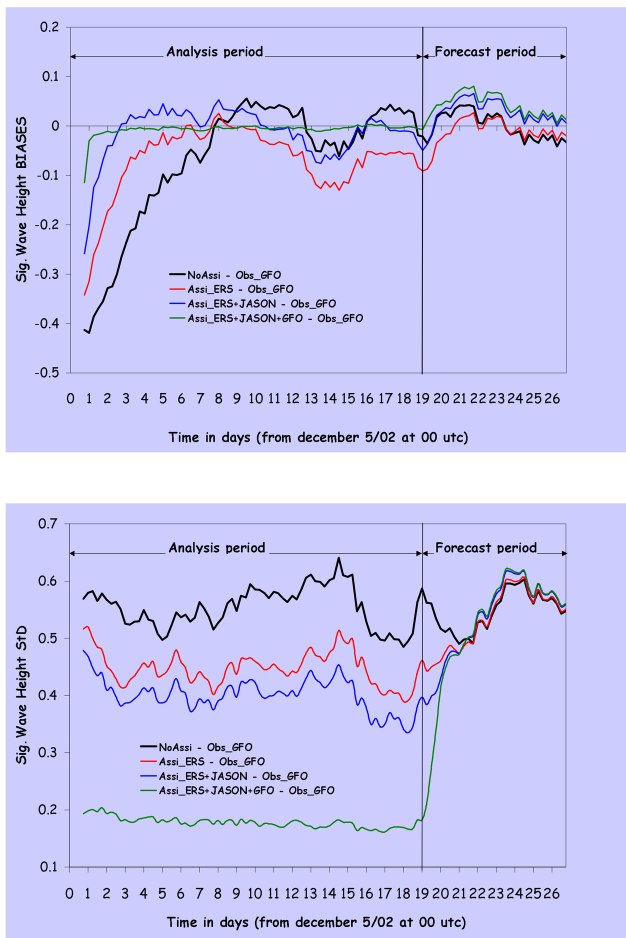


**Figure C.3 Time series of the mean (top panel) and STD differences (bottom panel) between model ouputs SWH and GFO SWH measurements when using 1 (red line), 2 (blue line) and 3 altimeters (green line). The Black line corresponds to no assimilation.**

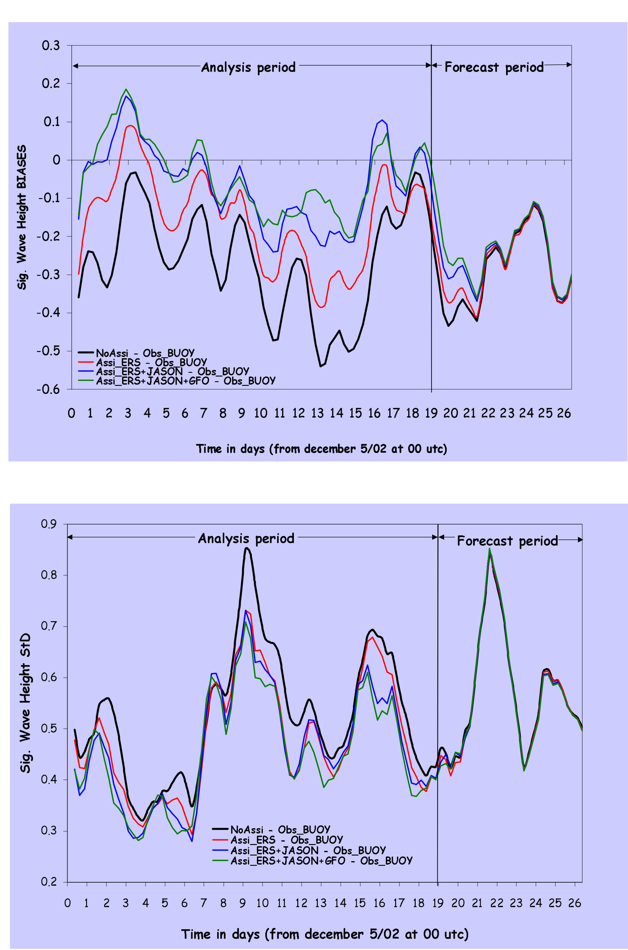


**Figure C.4 Time series of the mean (top panel) and STD differences (bottom panel) between model ouputs SWH and buoy SWH measurements when using 1 (red line), 2 (blue line) and 3 altimeters (green line). The Black line corresponds to no assimilation.**

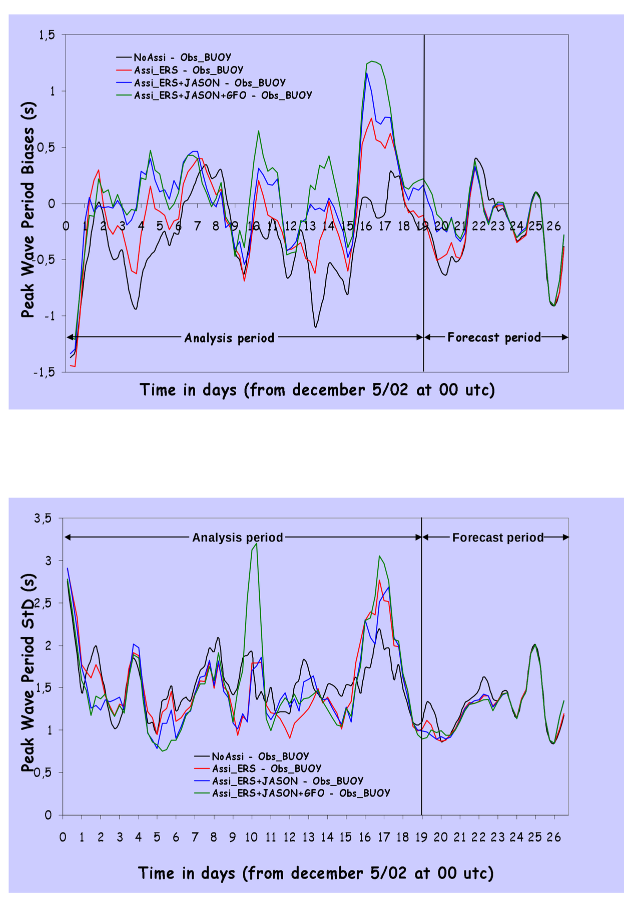


**Figure C.5 Time series of the mean (top panel) and STD differences (bottom panel) between model Peak Periods and buoy peak periods measurements when using 1 (red line), 2 (blue line) and 3 altimeters (green line). The Black line corresponds to no assimilation.**

## D. DATA ASSIMILATION : REGIONAL IMPACTS

In order to evaluate regional impacts of multi-satellite data assimilation in wave model analyses and forecasts, several areas where considered: North and South Hemisphere (extra Tropics) and Tropics.

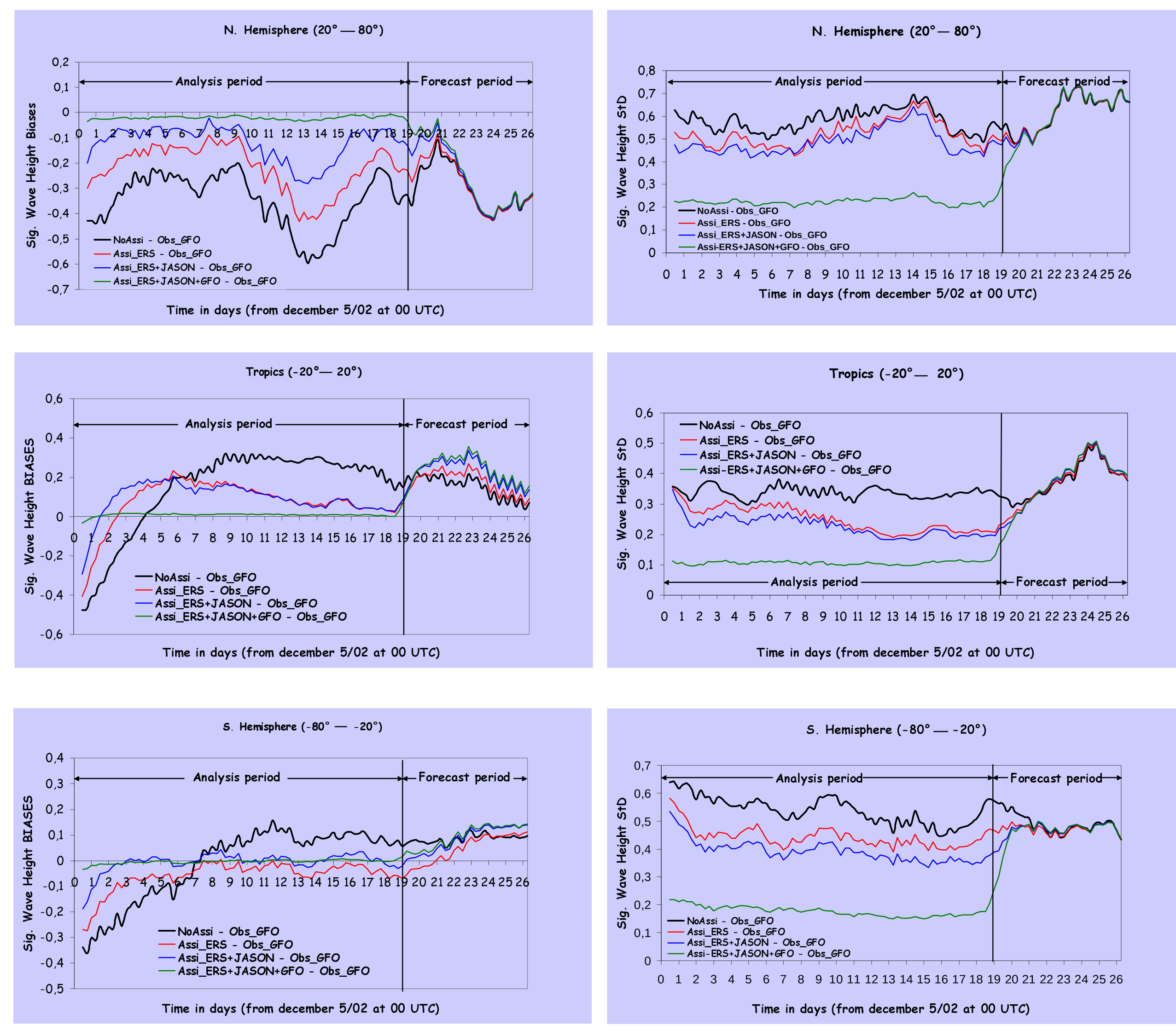


**Figure D.1 Time series of the mean (left panels) and STD differences (right panels) between model SWH and GFO SWH when using 1 (red line), 2 (blue line) and 3 altimeters (green line), for different areas (North Hemisphere in top panels, Tropics in middle panels, South Hemisphere in bottom panels). The black line corresponds to « no assimilation ».**

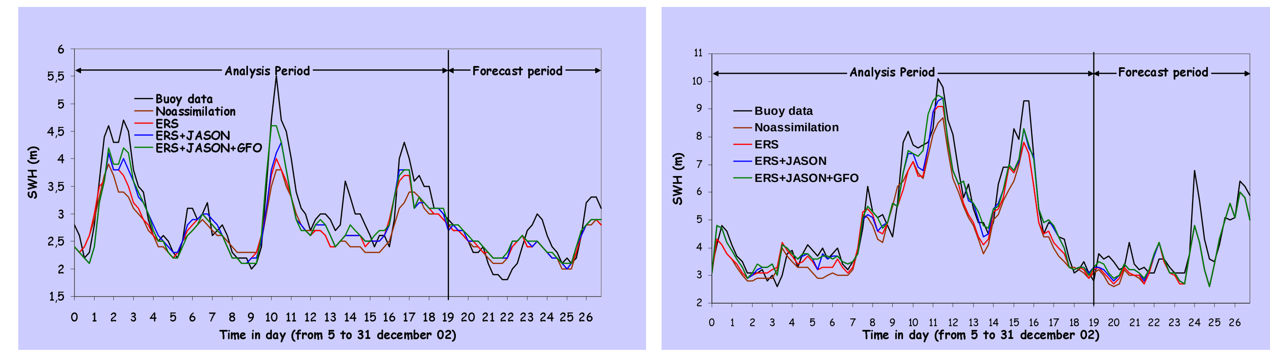


**Figure D.2 Time series of model SWH when using 1 (red line), 2 (blue line), 3 altimeters (green line) at buoy 51001 (left panel) and buoy 46059 (right panel) compared to buoy data (black line) and model SWH without assimilation (brown line).**

## E. RESULTS

Quality control and inter-calibration of altimeters is an important issue for data assimilation purpose in order not to introduce errors in the wave analyse/prediction system.

Assimilation of Jason data in addition to ERS ( or ENVISAT) has positive impact on wave analysis and forecast in term of wave height, not in term of wave periods.

The impact is large in term of bias reduction when comparing model analyses to GFO and buoy data (Figures C.3 and C.4, top panels). It is large in term of STD error reduction only when comparing model analyses to GFO data. The reason for this apparent contradictory result (Figures C.3 and C.4, bottom panels) is related to the geographical distributions of buoys (located in the North Hemisphere) and impact: It is more important in the South Hemisphere in term of STD error reduction (Figure D.1, top and bottom panels), although seasonal effect should have reduced it compared to North Hemisphere.

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