POSEIDON-1 and POSEIDON-2 Noise analysis

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Abstract :

Through the past years and more recently, several studies on the noise determination of the radar altimeters have been carried out. These studies at first were motivated to understand the discrepancy between TOPEX and POSEIDON-1. This point has been elucidated as shown in the poster “Preliminary comparison of the TOPEX and POSEIDON-2 Radar Altimeters”.

Today the motivation for such studies is to fully characterize and understand the features of this noise and also to evaluate the impact of the more and more precise editing parameters and methods.

Two types of method for computing the altimetric parameters noise are presented :

- Spectral analysis
- High frequency analysis

Both methods have been applied on the high frequency (10 and 20 Hz) POSEIDON-1 and POSEIDON-2 radar altimeters data. The estimations of the altimetric range noise level are presented and it is shown that these methods are equivalent and yield the same results.

Furthermore, the impact of different data editing is analysed in terms of HF Signal variance. Significant reduction is obtained at local scale for Jason after collocation with Topex. Consistent features are found for Poseidon-1 and Poseidon-2.

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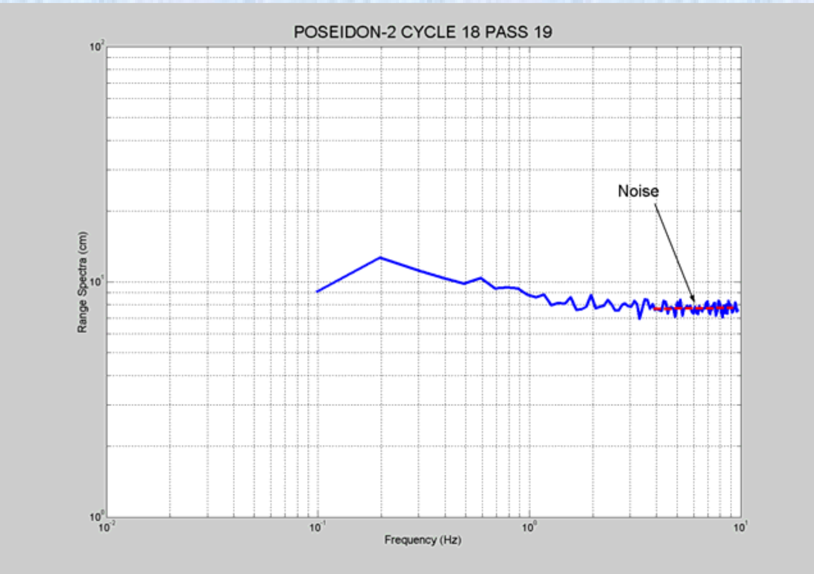
1 Spectral analysis (1/3)

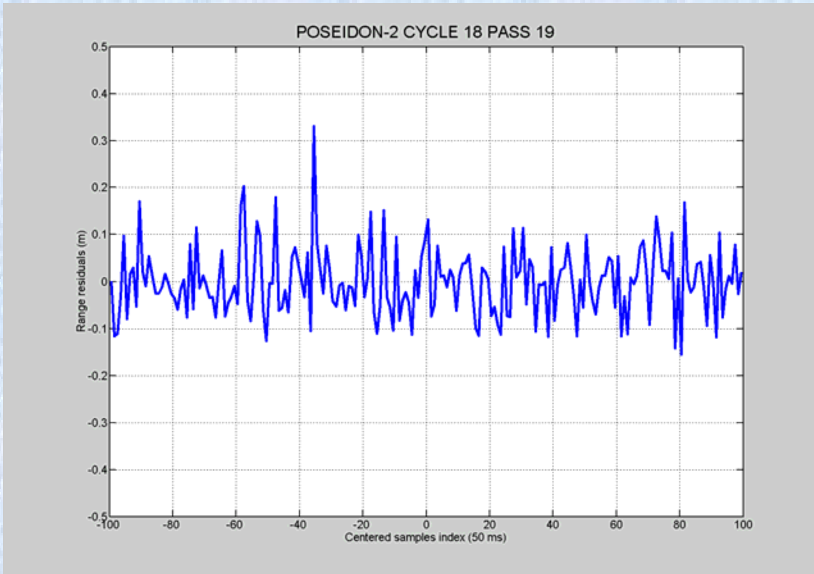
The standard periodogram method and the more sophisticated Welch method have been used to estimate the "noise" of the altimetric range. Both IGDR and independent retracked products for both Jason-1 and Poseidon have been used. The signal studied was the raw Sea Surface Height (SSH_raw = Orbit – Range) using 10 Hz and 20 Hz data.

1.1 Method

$$Noise\ (cm) = \sqrt{\frac{Noise\ (m^2/Hz)*10^4}{2*\Delta\tau}}$$

The spectra are obtained by performing the Fourier Transform of the polynomial raw SSH residuals over a segment of 10 or 50 seconds duration. Data are separated by 50 or 100 ms ($\Delta\tau$) in each segment.





Both methods are using a cut-off frequency of 3 Hz in computing the variance

Simple periodogram method

Data are splitted into segments of 10 continuous second. For each segment, raw SSH residuals are computed by fitting a polynome. The Power Spectrum Density (PSD) of each individual segment is computed and a variance of the range is deduced. The average value of SWH and Sigma0 are also computed. Then the variances are binned by classes of SWH and the noise is deduced from the average of the variance in each class.

Welch periodogram method

Data are splitted into segments of 90 continuous seconds. Gap filling is performed by interpolation. Sub-segment are selected using an overlapping moving window. For each segment, raw SSH residuals are computed by fitting a polynome. The PSD of each individual sub-segment is computed and an average is performed for the segment. The average value of SWH and Sigma0 are also computed for the segment. Then the PSD are binned by classes of SWH and Sigma0 and an average is performed. The variance is then deduced from the averaged PSD and consequently the noise.

1 Spectral analysis (2/3)

1.2 Data and Editing criteria

Simple periodiogram method

• POSEIDON-1
20 Hz data
pass 13 and 19 of cycle 361
10 seconds per segment
residuals obtained by fitting a 2nd order polynome
Editing : - number of valid data = 20
- SWH_Ku between 0 and 8 m
- Sigma0_Ku between 7 and 15 dB

• POSEIDON-2 (JASON-1)
20 Hz data retracked by the POSEIDON-1 retracker*
pass 13 and 19 of cycle 18
10 seconds per segment
residuals obtained by fitting a 2nd order polynome
Editing : - number of valid data = 20
- SWH_Ku between 0 and 8 m
- Sigma0_Ku between 7 and 15 dB

Welch periodiogram method

• POSEIDON-1
GDR 10 Hz data
all pass of cycle 90
20 seconds per segment
residuals obtained by fitting a 2nd order polynome
Editing : - number of valid data >= 19
- 20 Hz standard deviation <= 150 mm
- SWH_Ku between 0 and 11 m
- Sigma0_Ku between 7 and 30 dB

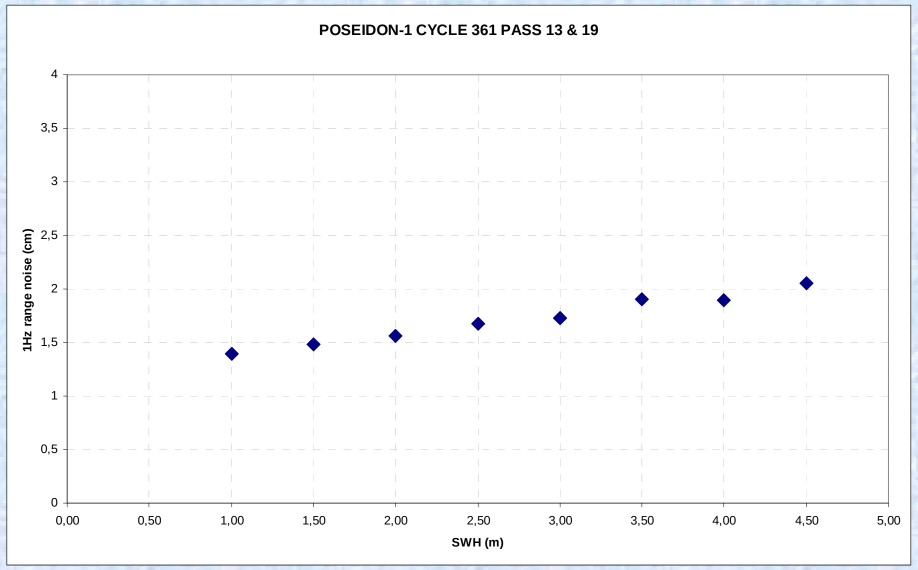
• POSEIDON-2 (JASON-1)
SGDR 20 Hz data
all passes of cycle 11
50 seconds per segment
residuals obtained by fitting a 8th order polynome
Editing : - number of valid data >= 18
- 20 Hz standard deviation <= 150 mm
- SWH_Ku between 0 and 12 m
- Sigma0_Ku between 7 and 16 dB

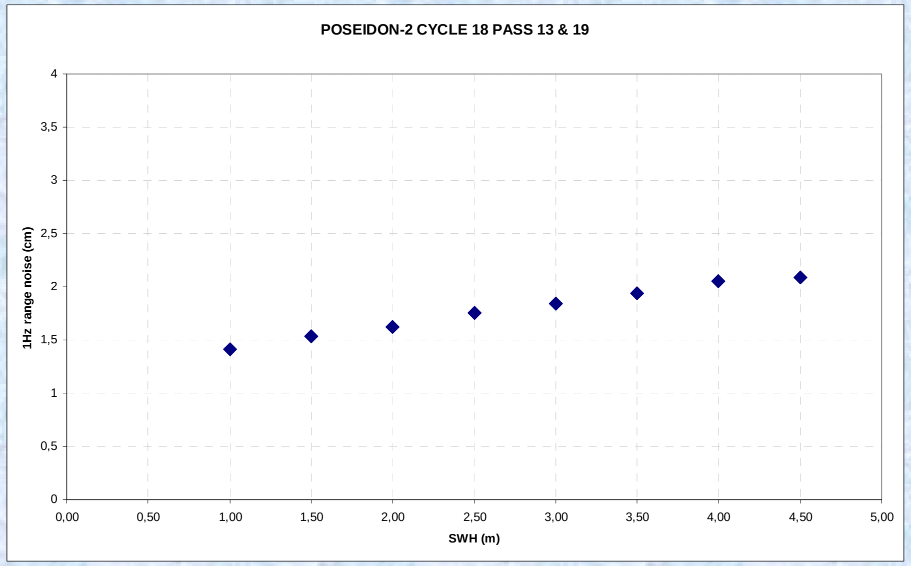
* For details on the POSEIDON-1 retracker* see poster 'Preliminary comparison of the TOPEX and POSEIDON-2 Radar Altimeters'

1 Spectral analysis (3/3)

1.3 Results

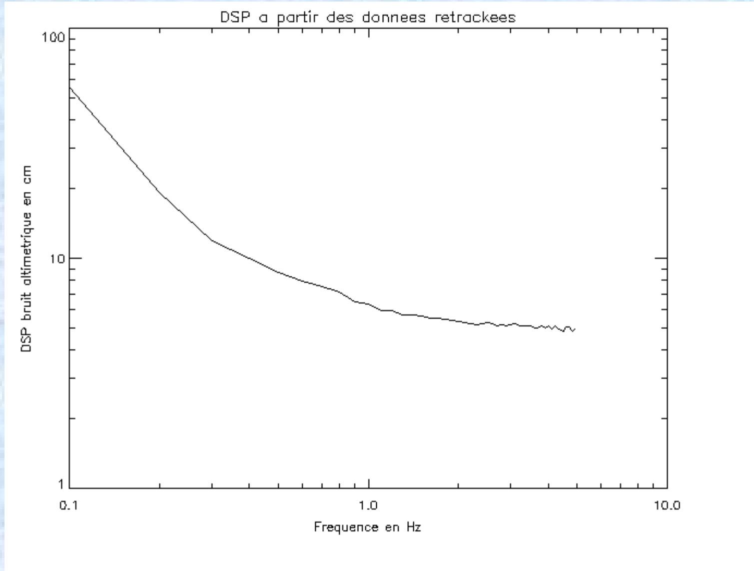
Simple periodiogram method



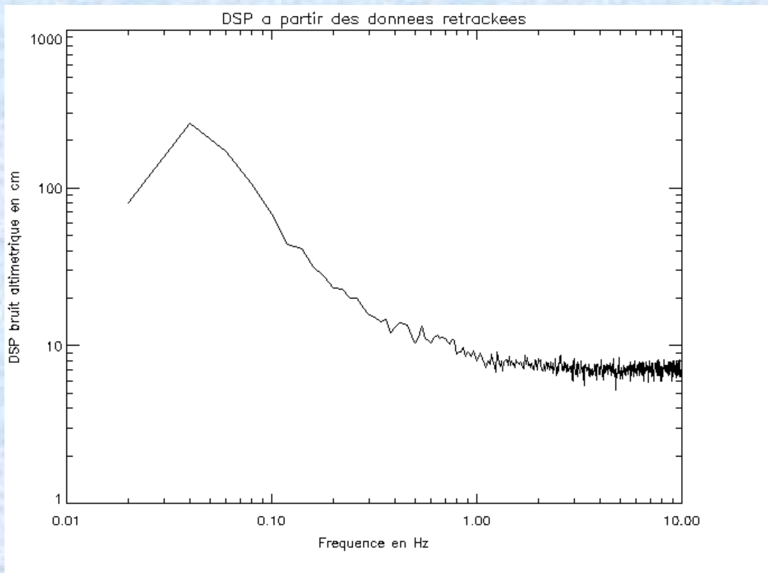


Welch periodiogram method

POSEIDON-1 (10Hz data)



POSEIDON-2 (20 Hz data)



POSEIDON-1 and POSEIDON-2 Spectra for :

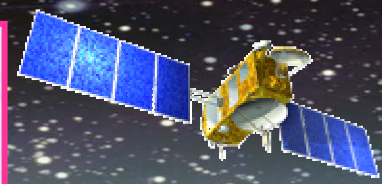
- 2 m SWH
- 11 dB Sigma0

The noises deduced by this method at 1Hz using the decorrelation assumption (division of the 10 or 20 Hz noise by square root 10 or 20) are :

- POSEIDON-1 : 1.59 cm
- POSEIDON-2 : 1.59 cm

Those figures are equivalent with the ones given by the simple periodogram method

2. Noise & High Frequency signal on IGDR Products: method (1/3)



INTRODUCTION: The present study is based on user products and aims at analysing the HF signals (which includes instrumental noise, processing noise, correction noise, residual geophysical signals…). The HF analysis is first compared to spectral analysis and is then applied to Jason-1 and Poseidon-1 data.

Analysis of High Frequency Signals

We use a high-pass filtering technique (Tran et al., 2001) to estimate a HF signal on the Sea Level Anomaly.

SLA relative to a MSS or from repeat-track analysis

Lanczos low-pass filter

Low frequency signal S_{LF}

High frequency signal S_{HF} = SLA - S_{LF}

STD of HF signal integrates:
- instrumental noise
- residual geoid signal
- and possibly HF ocean signals

Spectral Analysis

The power spectrum of ε(t), a pure white noise (i.e a random variable with Gaussian distribution) with standard deviation equal to σ is :

$$S_p(k) = \alpha = 2.\Delta t.\sigma^2$$

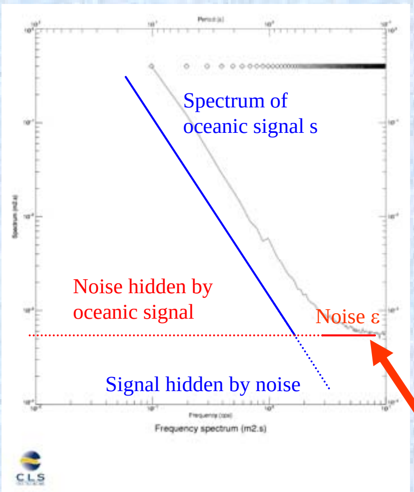
where Δt is the resolution of the signal sample

Therefore, if the signal to analyze is X(t) = s(t) + ε(t) , the power spectrum will be composed of :

• the spectrum of the oceanic signal s

\+

• the spectrum of the noise ε (i.e α)



A plateau on a power spectrum can be the signature of a white noise. The STD of its distribution can be obtained by :

$$\sigma = \sqrt{\frac{\alpha}{2.\Delta t}} \quad \textbf{(I)}$$

Plateau α

Two methods for a single result

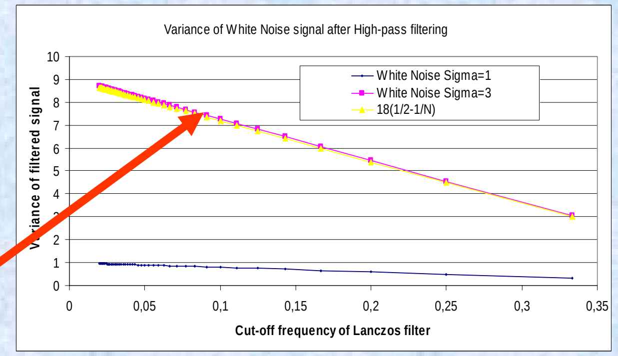
Computing the variance of high frequency filtered signals is equivalent to integrating the power spectrum of the original signal from the cut-off frequency fc to the Shannon frequency fs (highest frequency available on a signal).

If the original signal contains white noise, the high frequency part of the power spectrum is constant (plateau) and equal to α, hence :

$$V(fc) = \int_{fc}^{1/2\Delta x} Sp(f).\delta f \rightarrow V(fc) = \alpha\left(\frac{1}{2\Delta x} - fc\right) \quad \textbf{(II)}$$

The HF method gives the value of V(fc), i.e the energy of HF signal. But, the slope of V(fc) is a direct measurement of the spectral plateau α.

Slope α



Comparing Jason and Poseidon IGDR data sets

The IGDR data of Jason (cycle 18) and Poseidon (cycle 361) can be directly compared even if one is available at a 20 Hz rate and the other at 10 Hz.

$$\left.\begin{array}{l} \sigma_{10Hz} = \dfrac{\sigma_{20Hz}}{\sqrt{2}} \\ \Delta t_{10Hz} = 2\Delta t_{20Hz} \\ \textbf{(I)} \end{array}\right\} \Rightarrow \alpha_{10Hz} = \alpha_{20Hz} \quad \textbf{(III)}$$

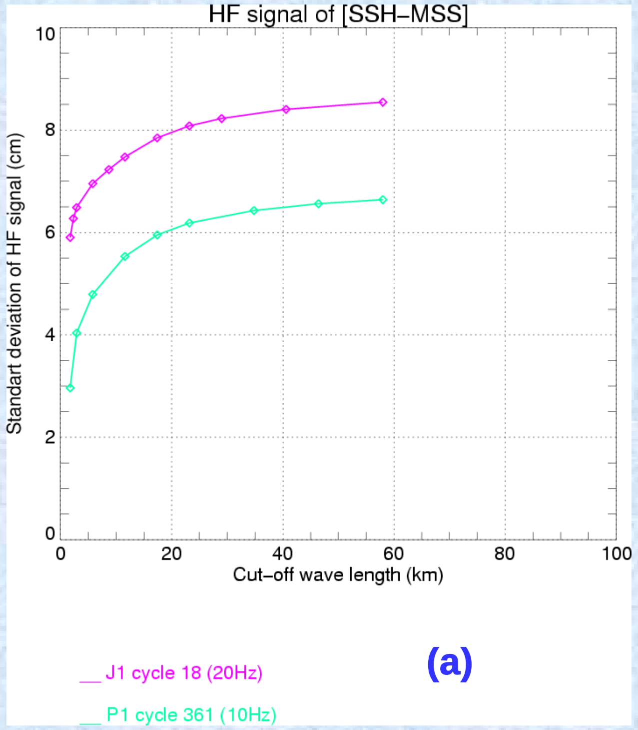
2. Noise & HF signal on IGDR Products: results (2/3)

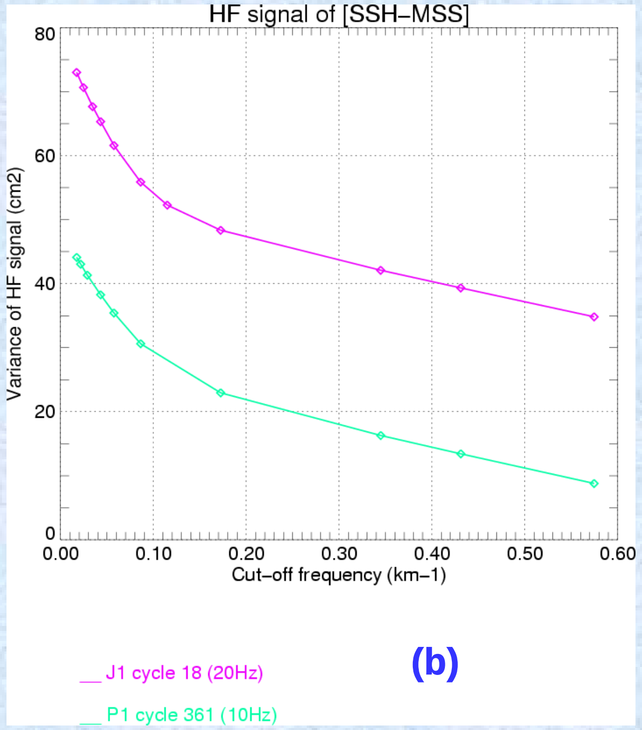
Global results

We plot the variance of the HF Signal for several cut-off frequencies.

STD = f[Cut-off Wave-length]

Variance = f[Cut-off frequency]

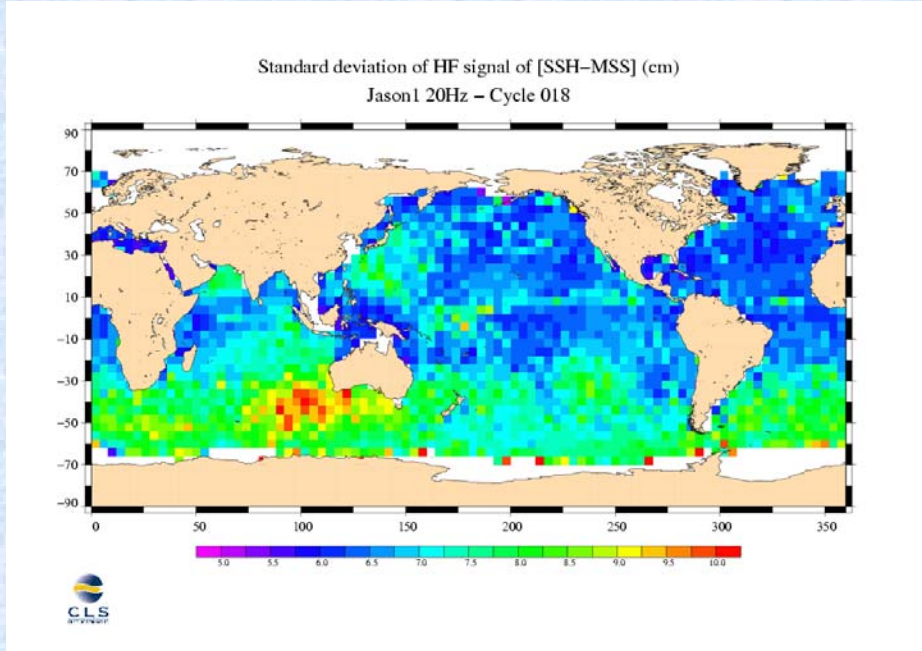




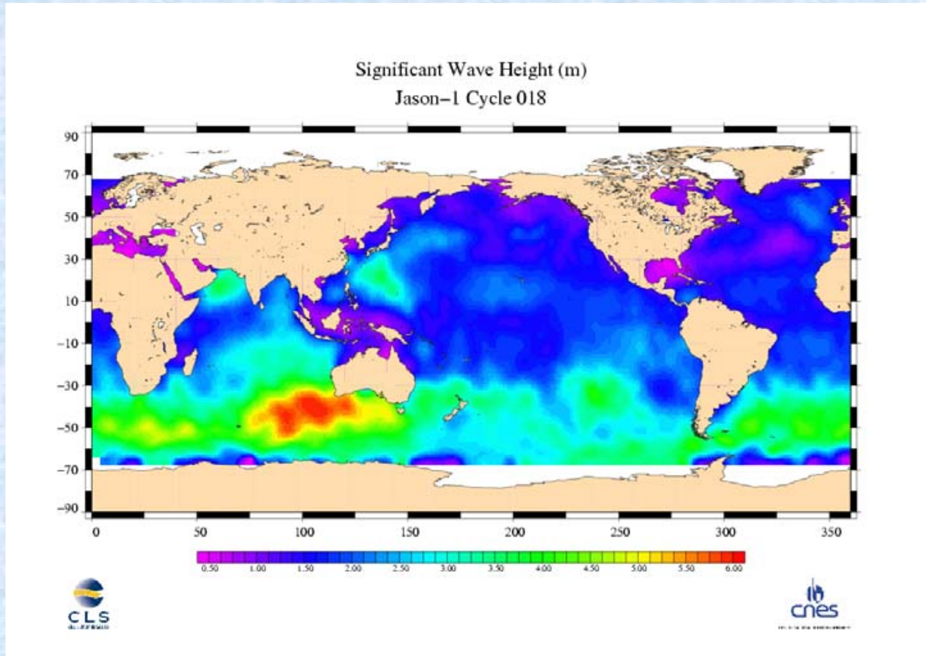
The curve is approximately linear between 0.2 and 0.6 Hz. As described previously (I et II) the white noise is estimated from the slope of this linear part of the curve.

	Jason 20Hz X (X/√20)	Poseidon 10Hz X (X/√10)
Mean of SWH (m)	2.58	2.72
Noise deduced from slope (cm)	7.35 (1.64)	5.30 (1.68)
Noise from spectral analysis (cm)	7.48 (1.67)	5.29 (1.67)

Geographical distribution



The above figure shows the geographical pattern of the HF signal . It is strongly correlated to SWH (bottom figure), but wet areas also appear (rain situations).



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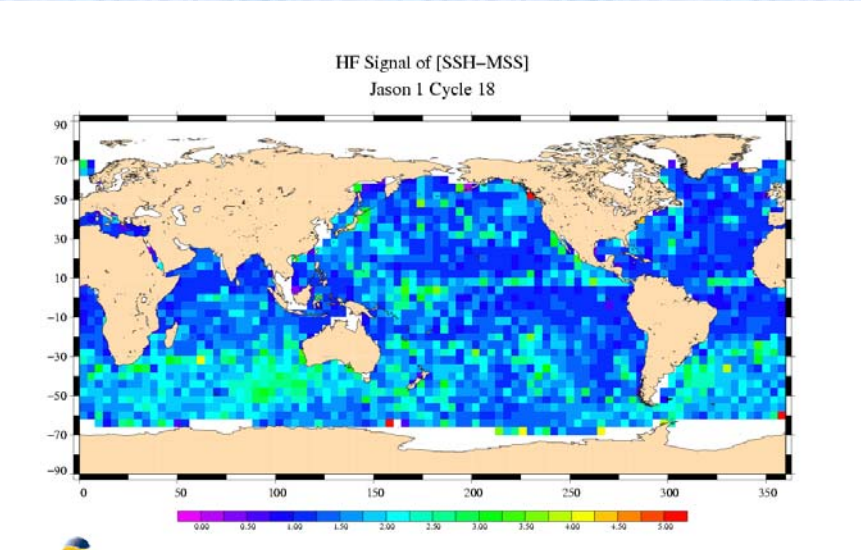
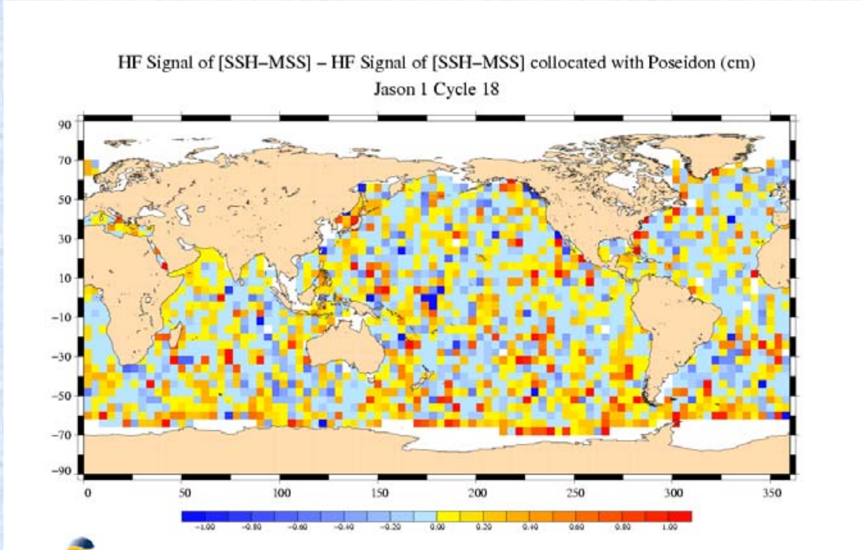
2. Noise & HF signal on IGDR Products: Editing Comparison and conclusion (3/3)

The impact of data editing on HF signal variance has been analysed. Collocating Jason-1 data with other altimeters (TOPEX) and POSEIDON) should give access to the contribution of different data editing on HF signal estimation.

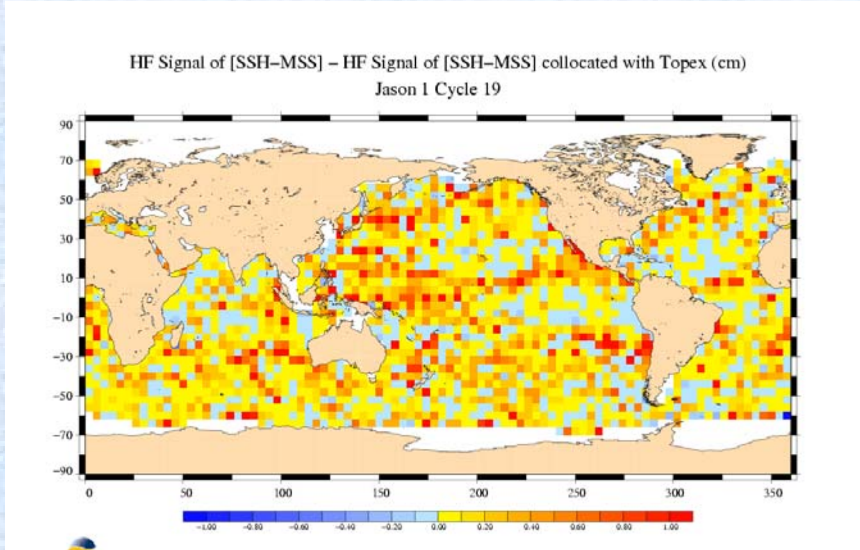
Jason full data set (cycle 18)	Jason collocated on Poseidon –1 (Cycle 361)	Jason collocated on Topex (Cycle 362)
σ_{Full} =STD(HF signal of SSH-MSS)	σ_{Full}- $\sigma_{collocated}$ on Poseidon-1	σ_{Full}- $\sigma_{collocated}$ on Topex



(a)



(b)



(c)

Yellow/red boxes on figures (b) and (c) mean reduction of Jason-1 HF signal after collocation with Poseidon-1 or Topex. Poseidon-1 and Jason (Poseidon-2) data editing are consistent, but collocating Jason-1 with Topex leads to significant HF signal reduction, particulary on wet areas. Note that in these rainy areas a significant amount of Topex data is edited due to the waveform off-nadir angle parameter (not computed).

Conclusion

-There is a good agreement between the noise estimated by spectral analysis and the one deduced from the slope of V(fc) on the 20/10 Hz data
- The performance of Jason-1 and Poseidon 1 are similar (1.6-1.7 cm)
- The editing criteria of Jason is efficient but it can be improved

Conclusions

Several types of methods (spectral analysis, high frequency filtering) have been used to compare the altimetric range noise. The data used were also of different types (standard products and retracked products).

All the computations agree within the uncertainties for both Poseidon-1 and Poseidon-2 and give a standard deviation of **1.6 cm** for a SWH of 2m and a Sigma0 of 11dB.

It should be noticed that the uncertainties for Poseidon-1 are higher than for Poseidon-2 as a lot of Poseidon-1 data do not satisfy the editing criteria.