Wavenumber spectrum of estimated uncertainty in Jason-2 sea surface height measurement

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Why do we care about along-track SLA error spectrum?

→ Quantification of errors in any diagnostic based on Altimetry
→ Specification of error covariance matrix for along-track data assimilation

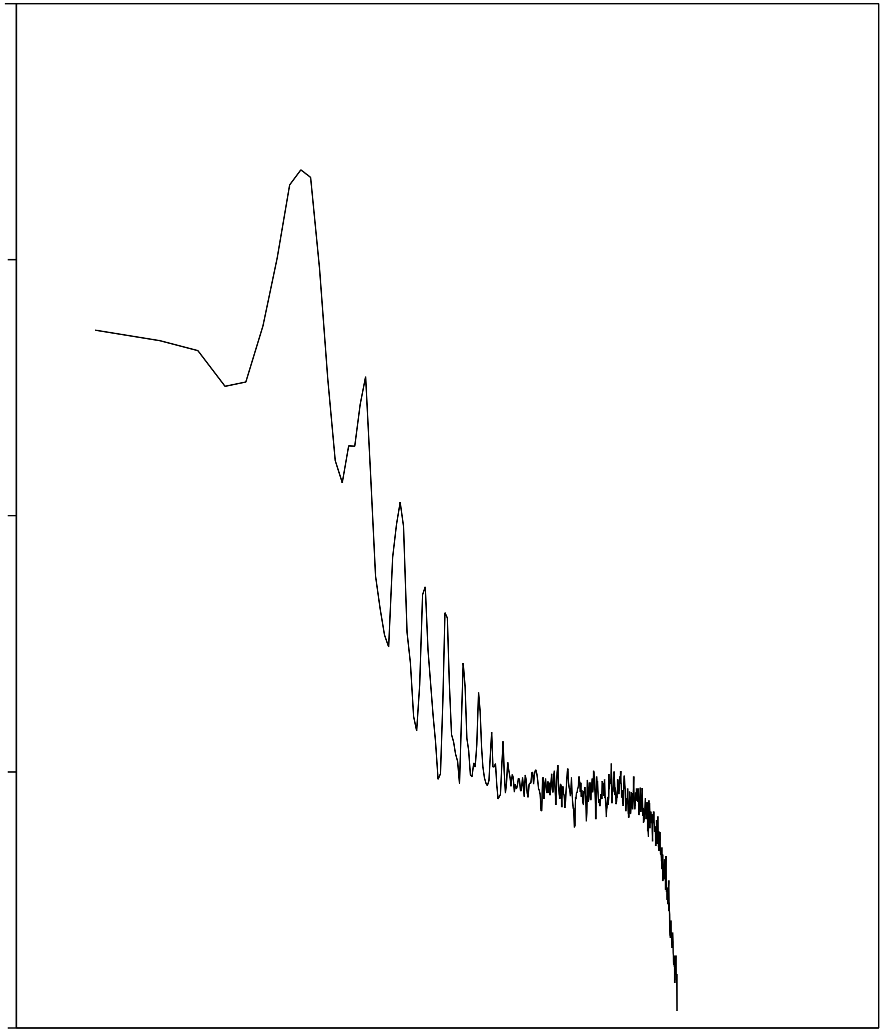
Integrated error budget

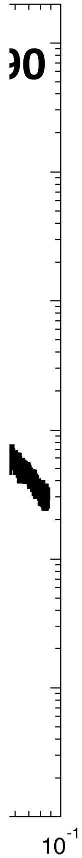
(Lambin et al., 2010)

Parameter	OGDR 3 hours	IGDR 1 to 1.5 days	GDR 40 days	Goals
Altimeter noise[1]	1.7	1.7	1.7	1.5
Ionosphere[2]	1	0.5	0.5	0.5
Sea state bias[3]	3.5	2	2	1
Dry troposphere	1	0.7	0.7	0.7
Wet troposphere	1.2	1.2	1.2	1
Altimeter range RSS	**5**	**3**	**3**	**2.25**
RMS orbit (radial component)	10[(4)]	2.5	1.5	1
Total RSS sea surface height	**11.2**	**3.9**	**3.4**	**2.5**
Significant wave height (SWH)[5]	10% or 0.5 m	10% or 0.4 m	10% or 0.4 m	5% or 0.25 m
Wind speed	1.6 m/s	1.5 m/s	1.5 m/s	1.5 m/s
Sigma naught (absolute)	0.7 dB	0.7 dB	0.7 dB	0.5 dB
System drift				1mm/year[6]

- **How are these errors distributed in wavelength ?**
- The corrections have geophysical causes → errors should have medium to long wavelength.

Orb

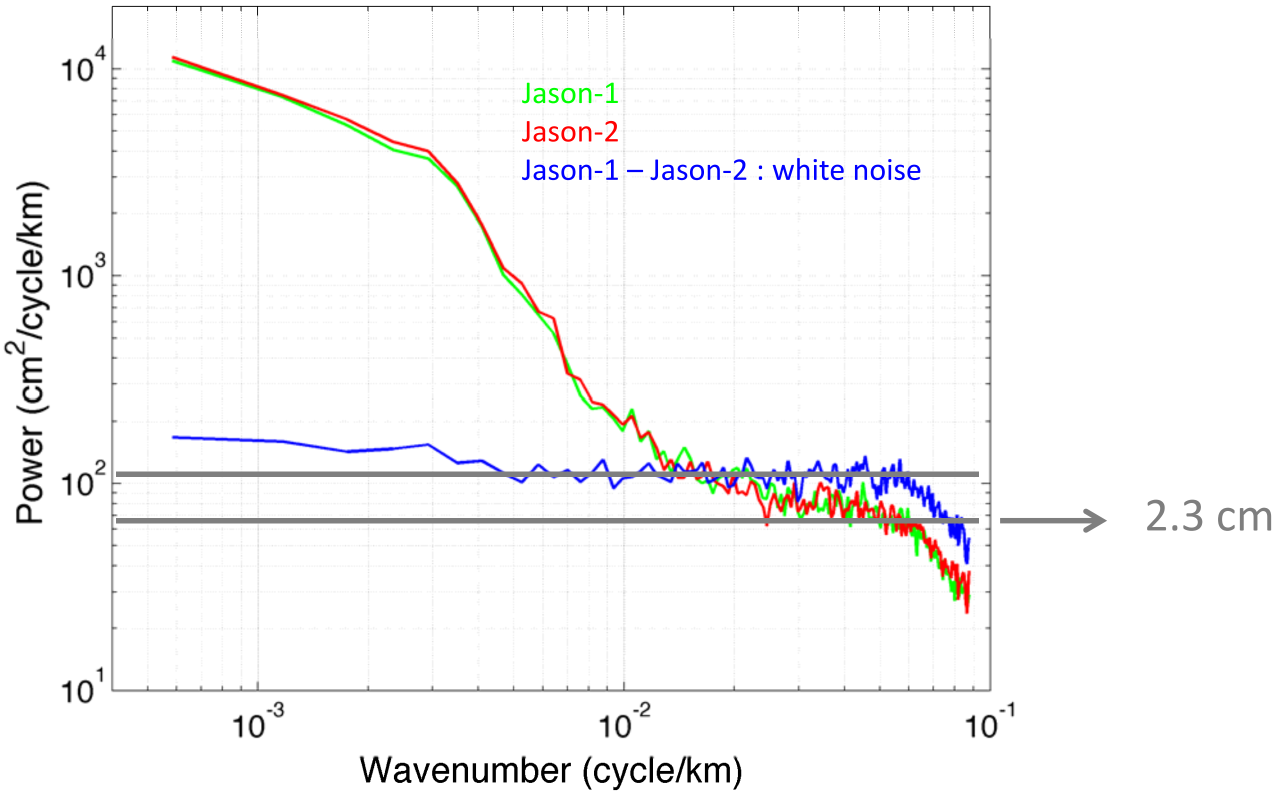




- Ratio signal/noise >100 even at basin scales. Not a concern for SLA along-track variability

Altimeter noise

From Jason-1 / Jason-2 tandem mission (20 cycles)



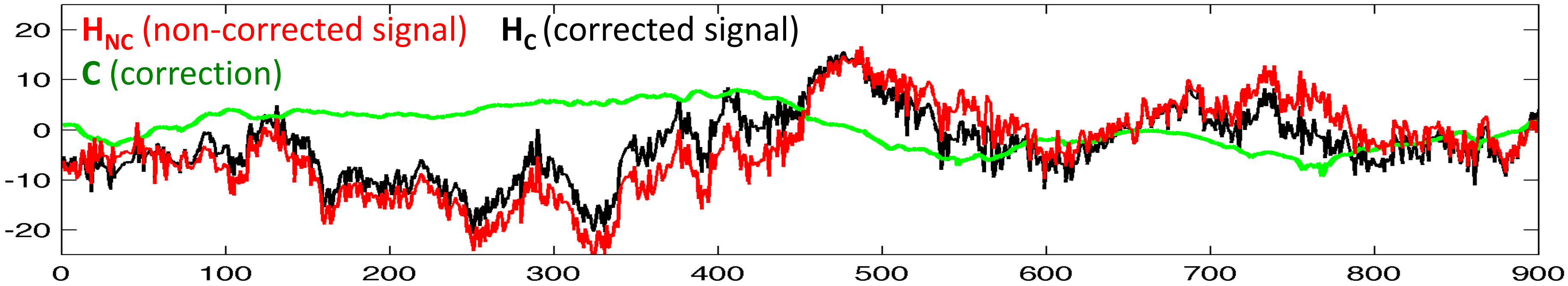
- Only instrumental noise should differ between J1 and J2

- Very white noise at all wavelengths : 2.3cm (half the (J1 – J2) noise).

Not 1.7cm ?

Method to estimate the correction errors

When applying the correction, the loss of variance from the total signal to the corrected signal should tell us about the quality of the correction



By definition, $\mathbf{H_C=H_{NC}+C}$

We set $\mathbf{C = C_T + E}$ where $\mathbf{C_T}$ is the true (unknown) correction and **E** the correction error

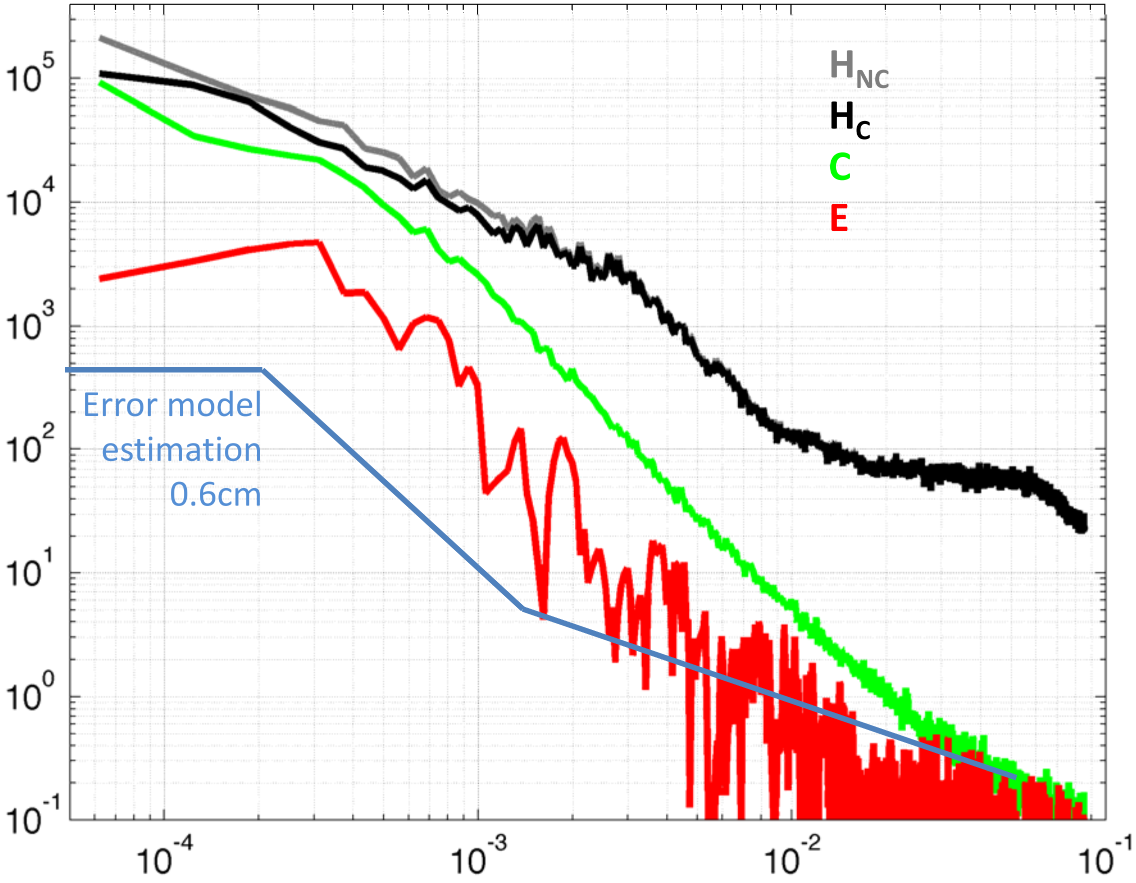
Then $\mathbf{H_C = H_T + E}$ where $\mathbf{H_T}$ is the true (unknown) corrected signal.

$$\langle \mathrm{H_C}, \mathrm{C} \rangle = \langle \mathrm{H}_T + E, \mathrm{C}_T + E \rangle$$

$$= \underbrace{\langle \mathrm{H}_T, \mathrm{C}_T \rangle + \langle \mathrm{H}_T, E \rangle + \langle C_T, E \rangle}_{\text{Assumed zero}} + \sigma^2(E)$$

$$\sigma^2(E) = \langle \mathrm{H}_C, \mathrm{C} \rangle = \frac{1}{2}\left(\sigma^2(C) + \sigma^2(\mathrm{H_C}) - \sigma^2(\mathrm{H}_{NC})\right)$$

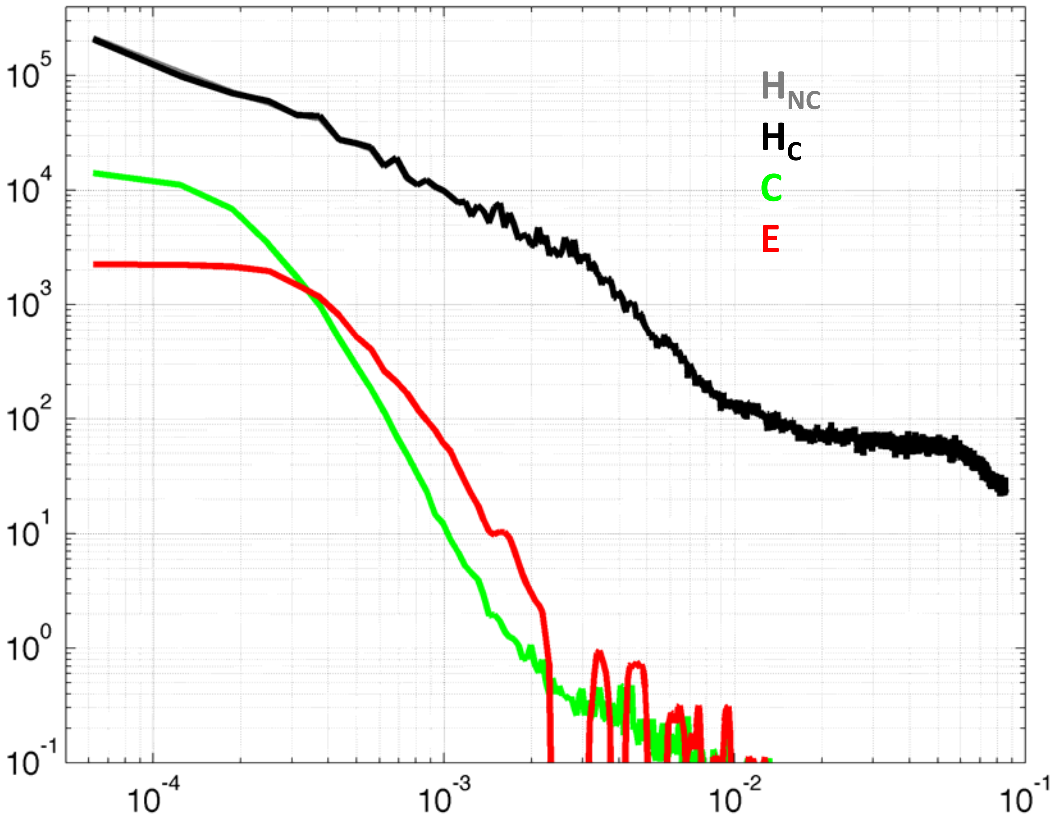
Wet tropo



Integration between 20,000km and 100km: **1.2 cm**

- Less optimistic than the estimation from model error (0.6cm)

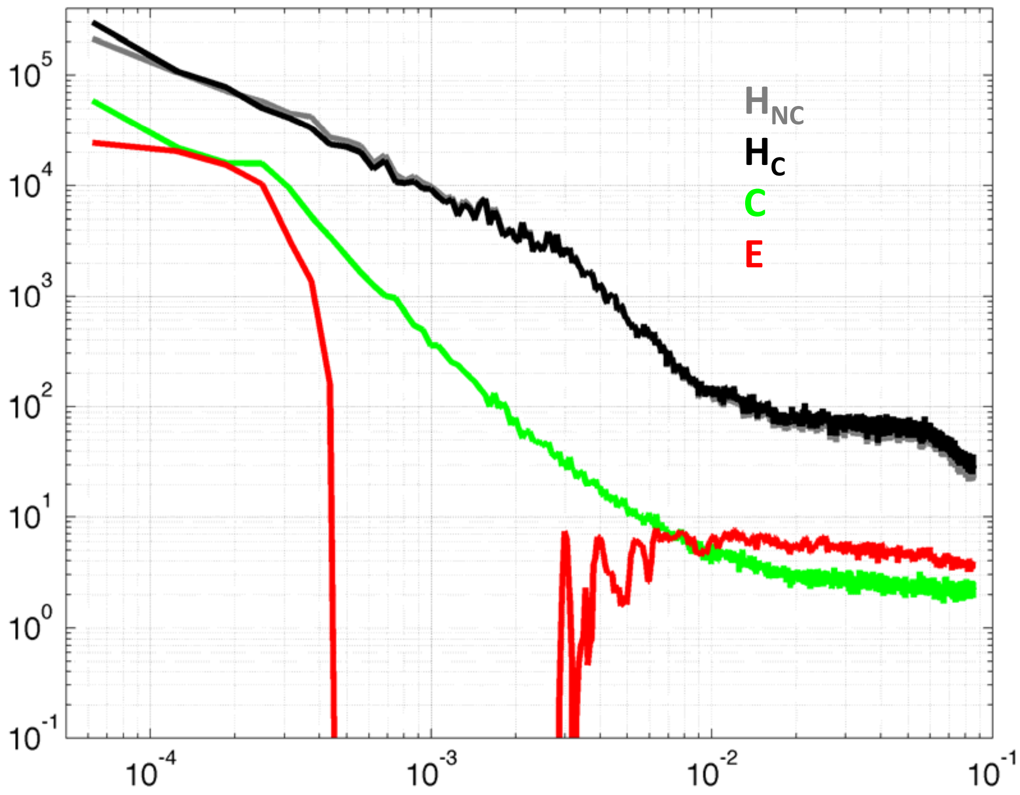
Dry-troposphere



Integration between 20,000km and 100km: **0.9cm**

- Strong reduction of error at the basin scale where the dry-tropo would bother
- Quite consistent with the table (0.9cm against 0.7cm)

Sea State Bias



Integration between 20,000km and 100km: **2.2 cm**

We obtain E<0 !!

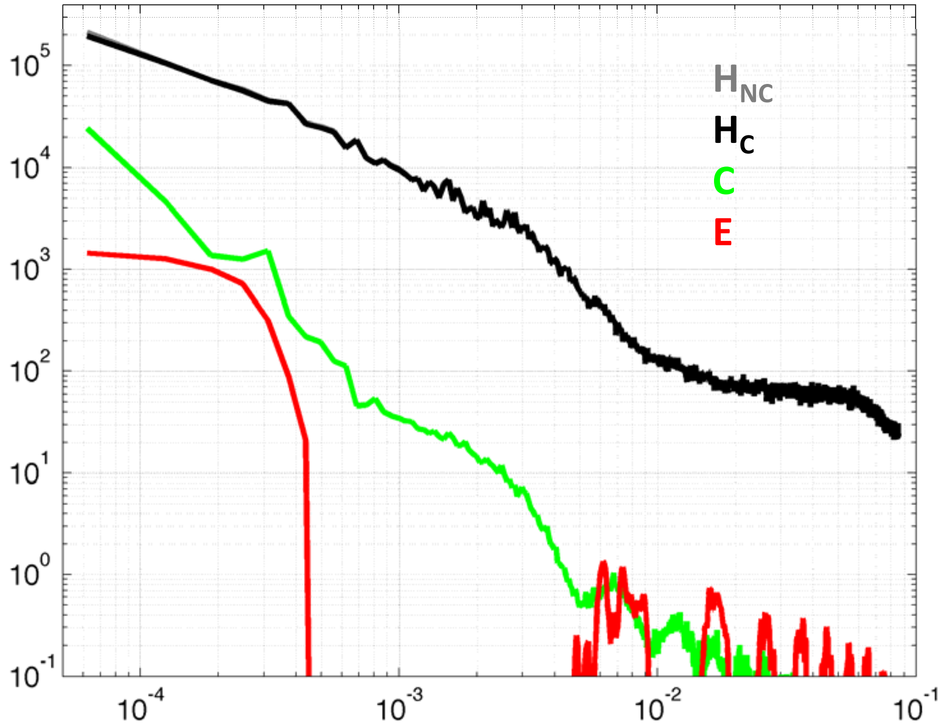
$$\sigma^2(E) = \frac{1}{2}\left(\sigma^2(C) + \sigma^2(\mathrm{H_C}) - \sigma^2(\mathrm{H}_{NC})\right)$$

It means that the reduction of variance (Hnc-Hc) exceeds the correction variance: this happens if **C** is anti-correlated with the sea level signal.

Indeed, sea state bias is empirically adjusted from SWH and roughtness to minimize variance → some oceanic signal is probably removed by C→ C and Ht get anti-correlated

→ <u>our estimation is invalid for sea bias (second hyppothesis wrong)</u>

Ionosphere



Integration between 20,000km and 100km: **0.6 cm**

Same observation for ionosphere.

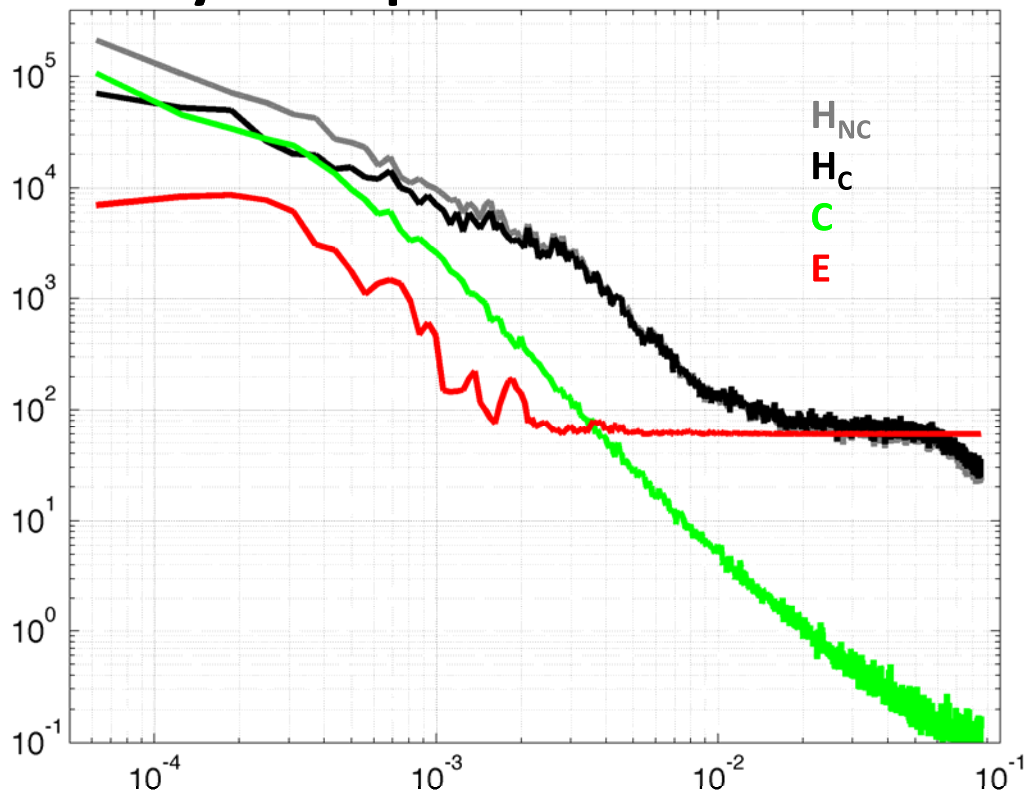
Indeed, ionosphere is a measurement from K-band and C-band:

$$\Delta r_{ion} = \frac{f_c^2}{f_k^2 - f_c^2}(R_C - R_K)$$

→ Δr_{ion} **could be contaminated by the measured ocean signal from K-band**

→ **Our estimation is not valid for Ionosphere**

Wet+dry tropo + altim. noise error budget



Integration between 20,000km and 100km: **1.6 cm**
Integration between 20,000km and 10km (with altimeter noise): **2.9cm**

- Wet and dry tropo are independent measurements (not relying on the altimeter). The assumptions should be valid
- Sea bias and ionosphere not included here

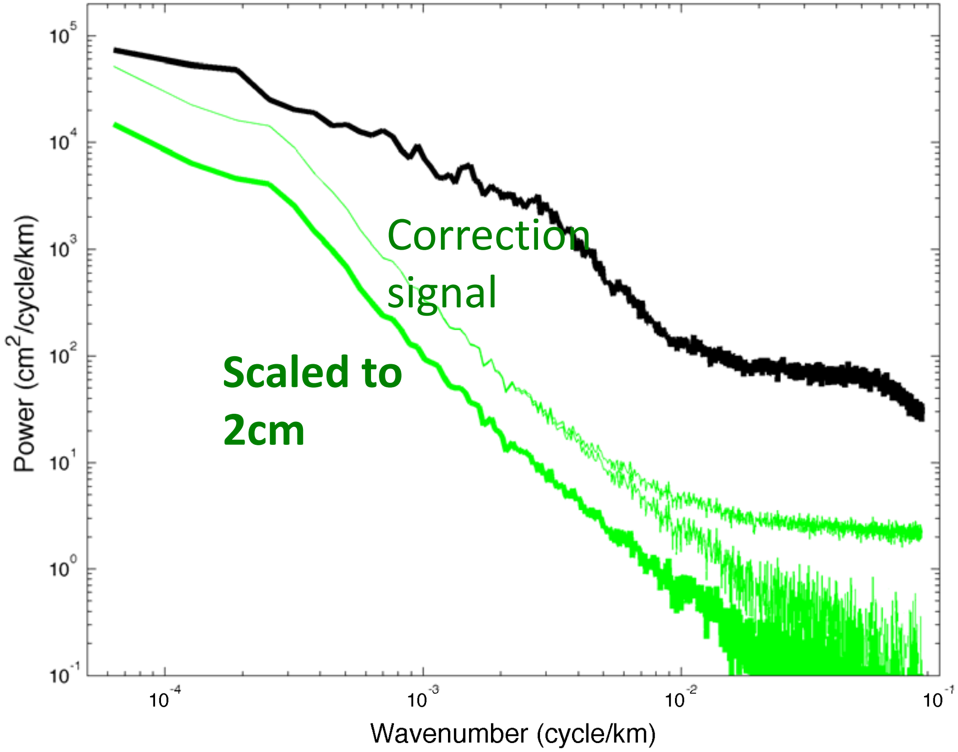
- **The estimated error spectrum is red between 3000km and 500km**
- **Quasi white-noise <500km**
- **The ratio signal/noise would be about 5-10 at the basin scale and >50 at mesoscales**

A second method to estimate the error spectrum

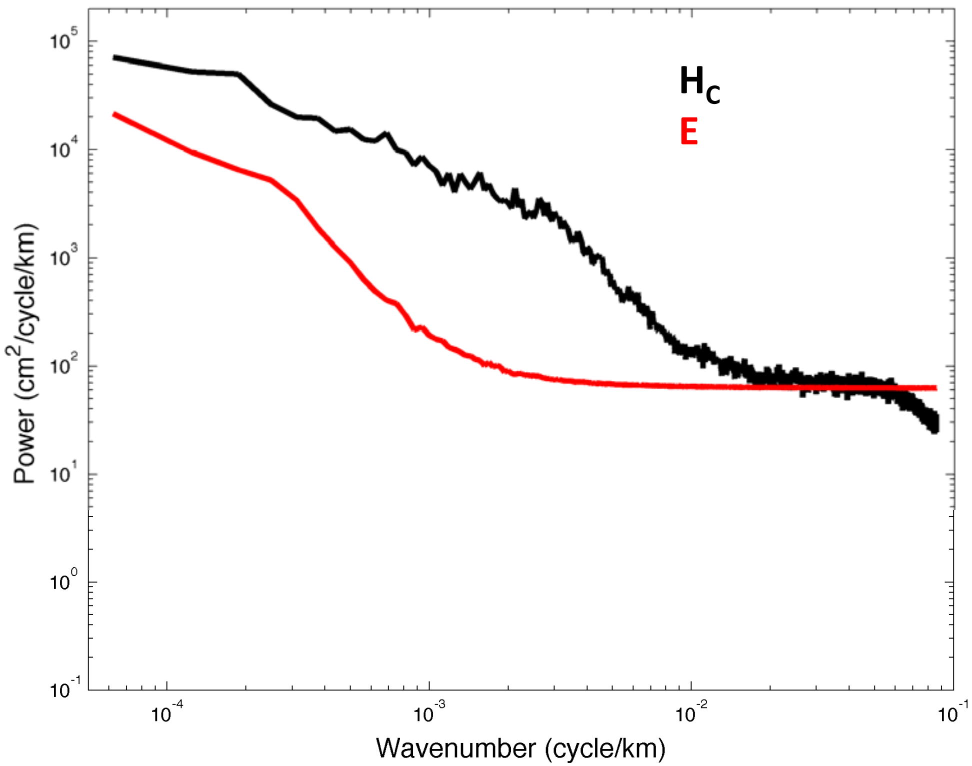
- We rely on the global error budget table for ionosphere, sea bias, dry-troposphere and “scale” the spectra of the correction signal

- We use a separate and more recent estimation for wet-tropo

Example for Sea Bias error estimation:



Results



Integration between 20,000km and 100km: **1.9 cm**

Integration between 20,000km and 10km (with altimeter noise): **3.0 cm**

- **The general shape of the spectrum is the same.**
- **The sea bias accounts for the steeper slope at basin scales**

Conclusions

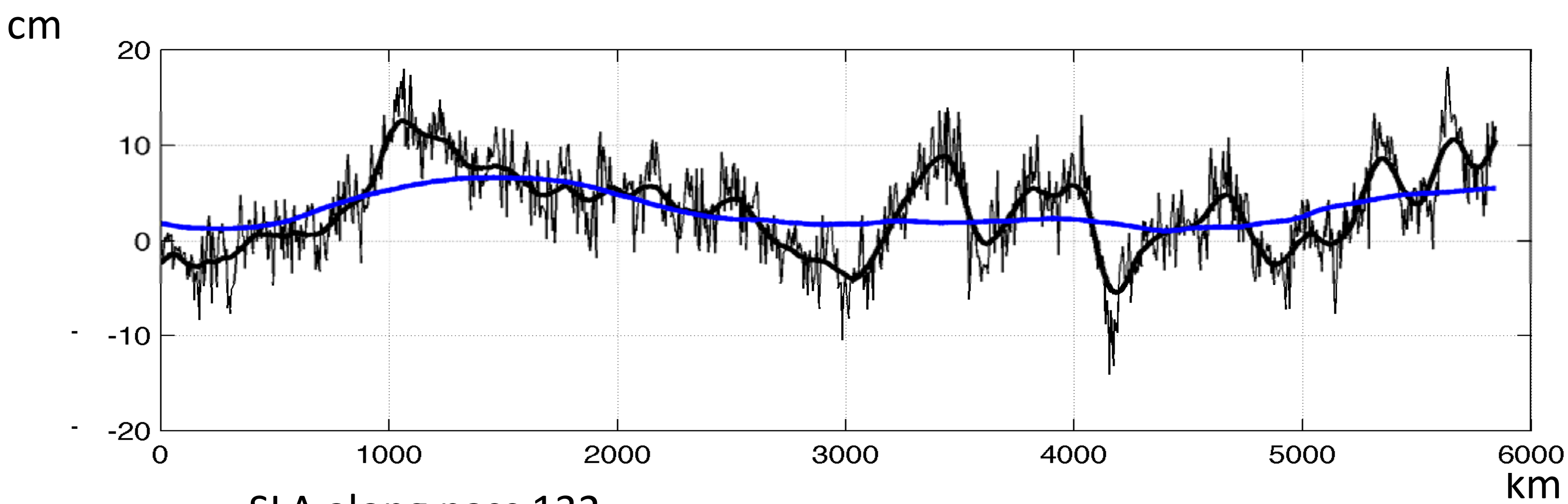
- First attempt …
- The first method is only based on the signal itself. It relies on assumptions that are not valid for sea state bias and ionosphere correction. General agreement with the table. The second method relies on strong assumptions about the error slope and the global budget table
- In both case, the general shape of the estimated error power spectrum is quite similar. The ratio signal/noise is about 5-10 at basin scales and 50 at mesoscales, with white noise until 500km

With the first method:

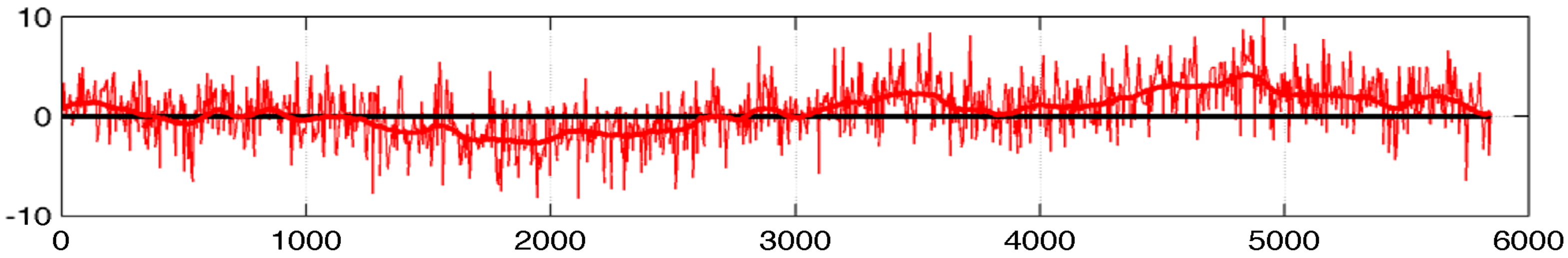
→ The possible contamination of sea state bias by sea level signal needs to be examined

→ Possibilities of doing regional analysis, providing maps of errors, …

Illustration of what signal versus noise may look like along a track



SLA along pass 132



Random signal following the estimated error spectrum

One should be careful when interpreting a large basin-scale 2-3cm pattern …