Review and analysis of the relationship between the Sea State Bias correction and the high frequency content in the Sea Surface Height data

N. Tran (1), A. Ollivier (1), P. Thibaut (1), D. Vandemark (2), J.-D. Desjonqueres (3), N. Picot (3)

(1) Collecte Localisation Satellite (CLS), Toulouse, France
(2) University of New Hampshire (UNH), Durham, United States
(3) Centre National d'Etudes Spatiales (CNES), Toulouse, France

OVERVIEW

During the past decade, several studies have focused on the high frequency content of the sea-surface height (SSH) and its dependence to significant wave height (SWH) signal at wavelengths shorter than 100 km. These results altogether point out that the Sea State Bias correction is a major contributor to the high frequency content of the SSH data and that removing the correlation between range measurement noise and SWH measurement noise related to the waveform retracker decreases the noise floor of along-track SSH spectra.

Standard empirical SSB correction encompasses then right physical (e.g., electromagnetic bias and skewness bias) causes of SWH and SSH correlation but also some retracker-related noise directly linked to the SWH noise. This poster reviews these past studies and provides some insight on separate quantification of low-frequency and high-frequency SSB signals to design global empirical SSB correction.

Review of past studies

- Low-pass filtering the SSB values applied on SSH increases the noise floor of the along-track spectrum when one compares to standard SSB correction application [Ollivier et al, 2009] while 3D SSB solution based on smoothed sigma0, smoothed SWH and the SWH smoothing residual achieves significant variance reduction of Jason-1 sea level anomalies with respect to standard operational correction [DeCarvalho et al, 2011]. They obtained respectively:
    - -2.1 cm² for along-track variance reduction
    - -4.1 cm² for collinear variance reduction
    - -0.3 cm² for crossover variance reduction
- Zaron and DeCarvalho [2016] used the observed correlation between the measurement errors of SSH and SWH to correct the SSH data by removing the noise correlated with the SWH noise. They obtained a variance reduction of ~2 cm² from crossovers dataset and reductions of 20% to 30% in the noise floor of along-track spectra (Fig 1).

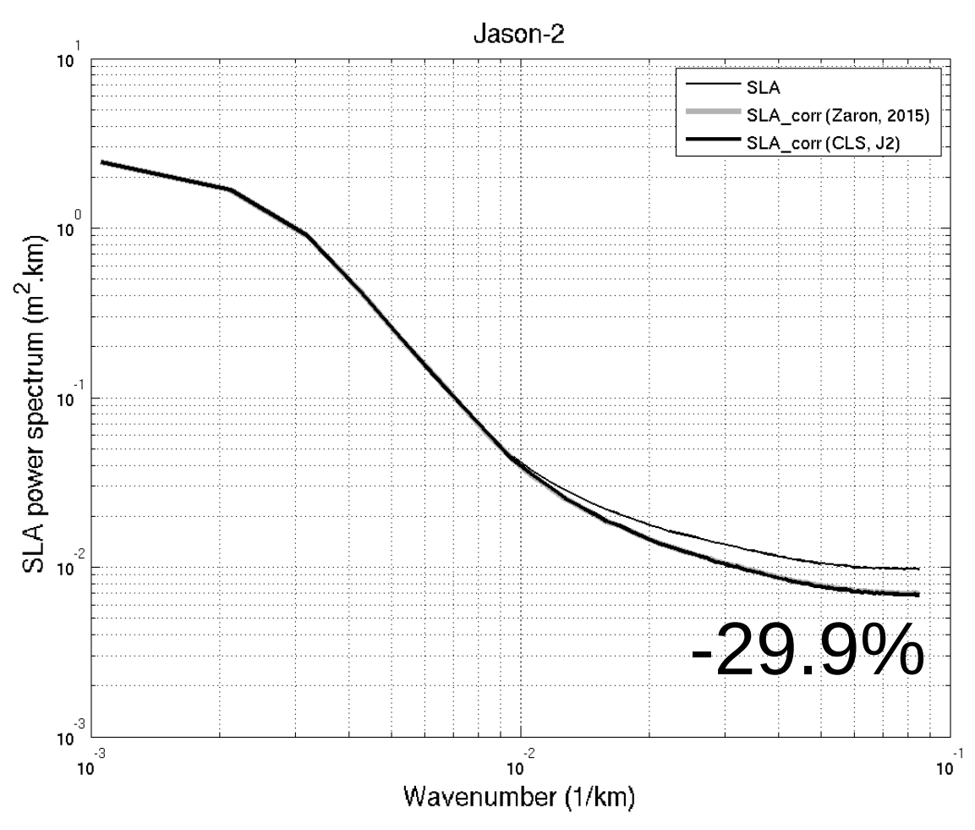

Fig 1: Reproduction of Zaron and DeCarvalho's [2016] approach and application of this emprical correction to Jason-2 SSH data (cycles 1 to 20) from global ocean. SLA power spectra computed without and with this correction are shown in this figure.

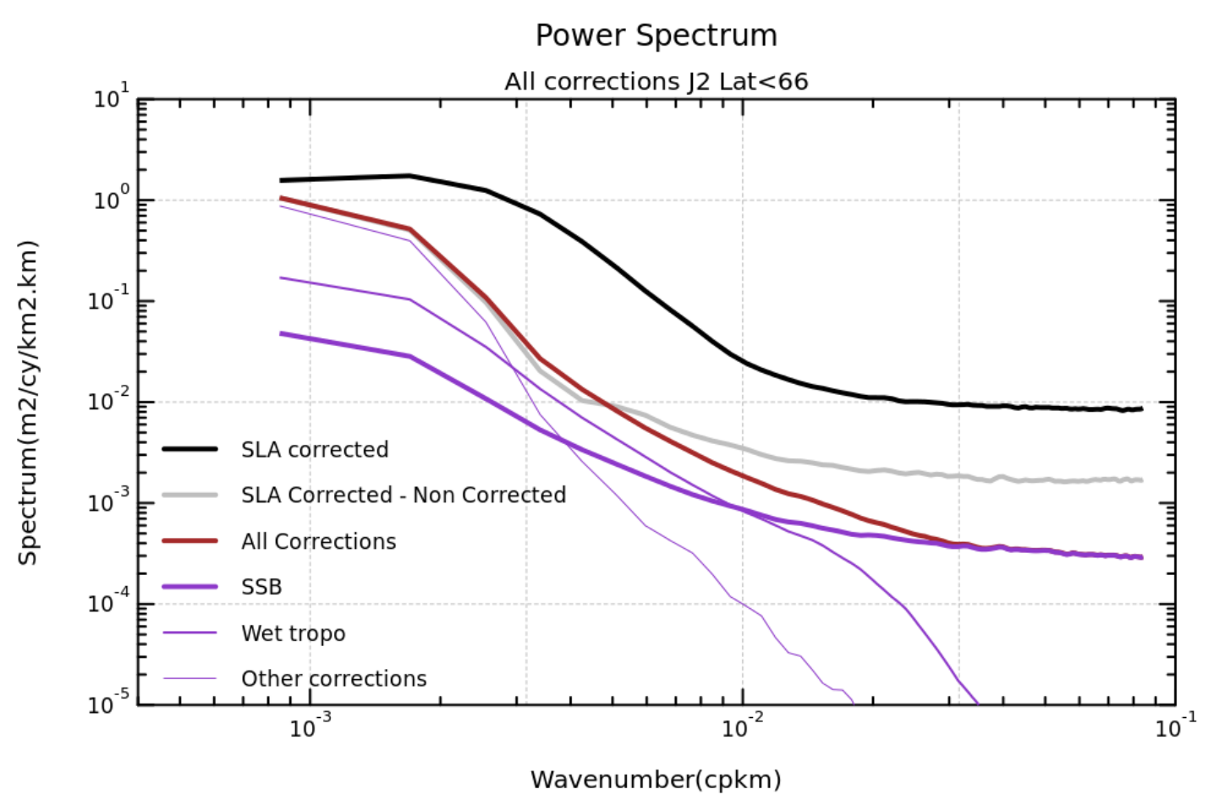

Fig 2: Spectral analysis of Jason-2 SLA and corrections [Ollivier et al, 2016]. Below 50 km, the high frequency content is due to range measurement and SSB correction.

- Spectral analysis of Jason-2 corrections to the range measurements showed that the SSB correction is a large signal for wavelength below 100 km and is the only contributor for wavelength below 50 km [Ollivier et al, 2016] as one can see in Fig 2.

Zaron's empirical correction

- It describes the error correlation between SSH and SWH and is defined by the (α, β) pair.
- The corrected SSH is expressed as :

  SSH_corr = SSH – (α + β SWH_FILT) * (SWH – SWH_FILT)
  where SWH_FILT corresponds to low-pass filtered SWH
- This correction represents **~0.1% of SWH** when the SSB correction is **~3% of SWH**

J2	Slope (β)	Intercept (α)
SSH vs SWH_MLE4	-0.006	-0.076
(ORBIT – RANGE_MLE4) vs SWH_MLE4	-0.003	-0.114
(ORBIT – RANGE_MLE4 – SSB_MLE4) vs SWH_MLE4	-0.0061	-0.0749

Table 1: Values of (α, b) when the SSH is not computed with all geophysical corrections.

- Range and SSB are the sole sources of SSH high frequency content (in agreement with Ollivier et al [2016]) and each contributed in similar proportion (see Table 1).

Proposed change in SSB model development

- The proposition is to separate high frequency content related to SWH noise due to the retracking algorithm used and low frequency content that is more geophysical. A diagram is presented in Fig 3.

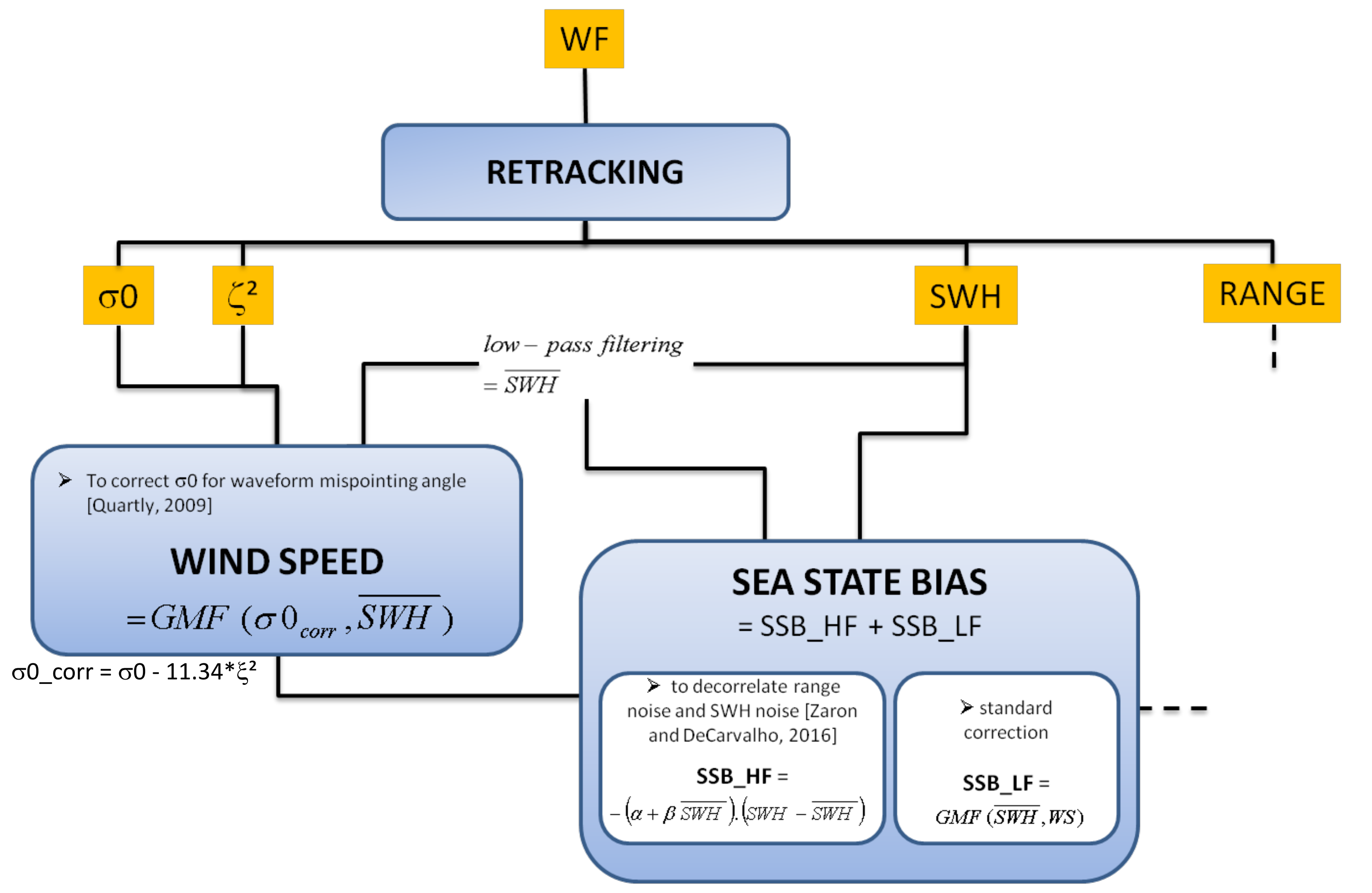

Fig 3: Processing diagram from waveform (WF) to SSB model development. Smoothed wind speed value as SSB_LF input is needed. This can be achieved by using additionally a correction to MLE4 sigma0 developed by G. Quartly [2009] before computing the wind speed.

Comparison of power spectra

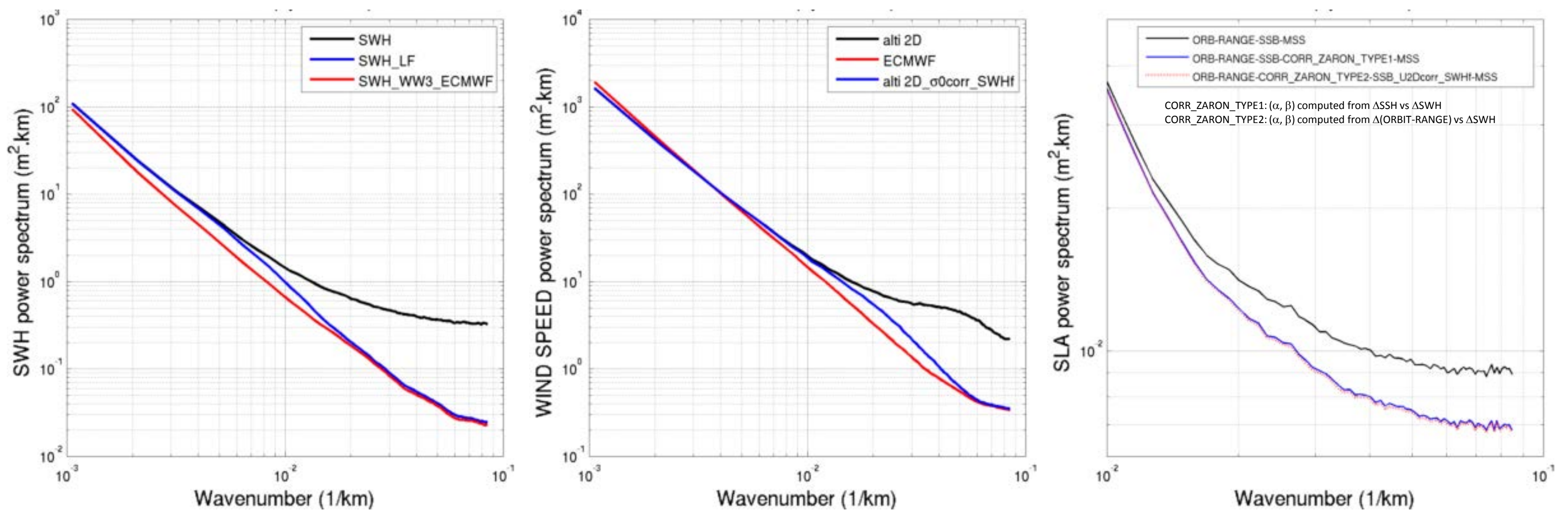

Fig 4: SWH, wind speed and SLA power spectra. Spectra of low-pass filtered SWH and smoothed wind speed are similar to those from model below 50 km.

- Evaluation of the two approaches that are in the same spirit :
    - SSB_2D_standard + Zaron_SSH_correction
    - SSB_HF_Zaron + SSB_2D_filtered

  shows similar result in Fig 4 . They are equivalent in term of high frequency content reduction.

Conclusion

- The Zaron's correction and the SSB correction are both empirical and related to SWH.
- It is proposed to include the small Zaron's correction in the SSB term as the high frequency component while the standard SSB correction is adapted to represent the low frequency component.

REFERENCES

DeCarvalho R., S. Desai, and B. Haines, 2011: A non-parametric sea state bias model based on SWH and Sigma0: extending to three dimensions. OSTST Meeting, San Diego, CA. (available online at http://www.aviso.altimetry.fr/fileadmin/documents/OSTST/2011/poster/Cavalho.pdf)

Ollivier A., J.-D. Desjonqueres, and N. Picot, 2016: Spectral analysis of nadir altimetry corrections. Living Planet Symposium 2016, Prague, Czech Republic.

Ollivier A., 2009: Analysis of the SWH filtering impact on sea state bias, CLS technical report.

Quartly G., 2009: Optimizing σ 0 information from the Jason-2 altimeter, IEEE Geosci. Rem. Sensing Lett., 6 (3), 398-402, DOI: 10.1109/LGRS.2009.2013973.

Zaron E., and R. De Carvalho, 2016: Identification and reduction of retracker-related noise in altimeter-derived sea-surface height measurements. Journal of Atmospheric and Oceanic Technology, 33(1):201-210, doi:10.1175/JTECH-D-15-0164.1