Preliminary Jason-3 SSB solutions and alternate 3D SSB models based on collinear data

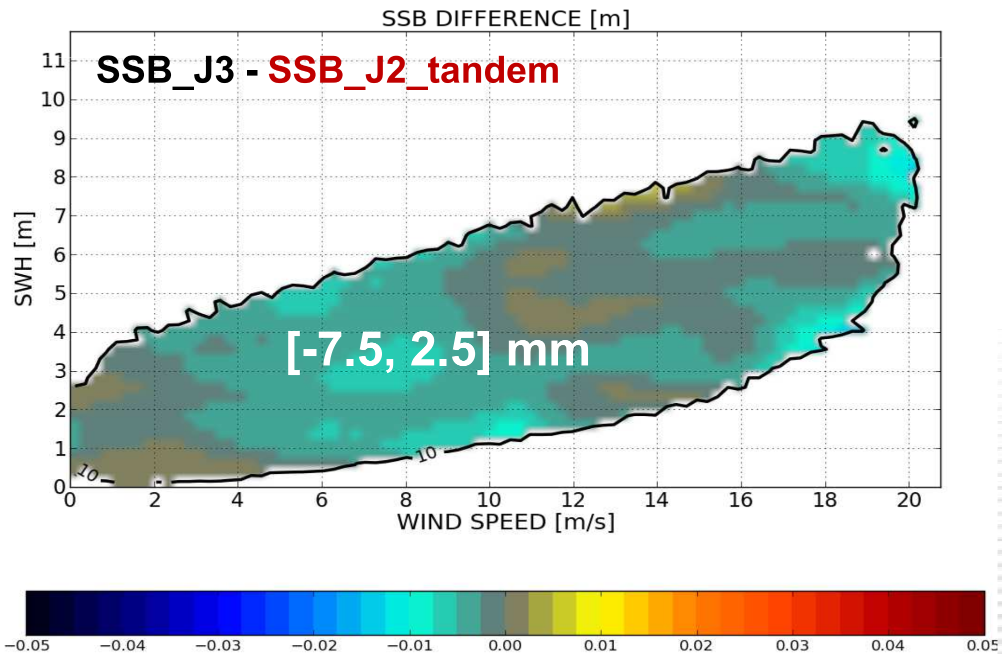
N. Tran, A. Ollivier (CLS)
D. Vandemark, H. Feng (UNH)
S. Le Gac, J.-D. Desjonqueres, N. Picot (CNES)

Outline

- Preliminary Jason-3 2D SSB model
- Jason-3 wind speed calibration
- Preliminary Jason-3 3D SSB model
- Jason-2 SSB models (2D and 3D) comparison
- High frequency content in SSH and SSB estimates

Preliminary Jason-3 2D SSB

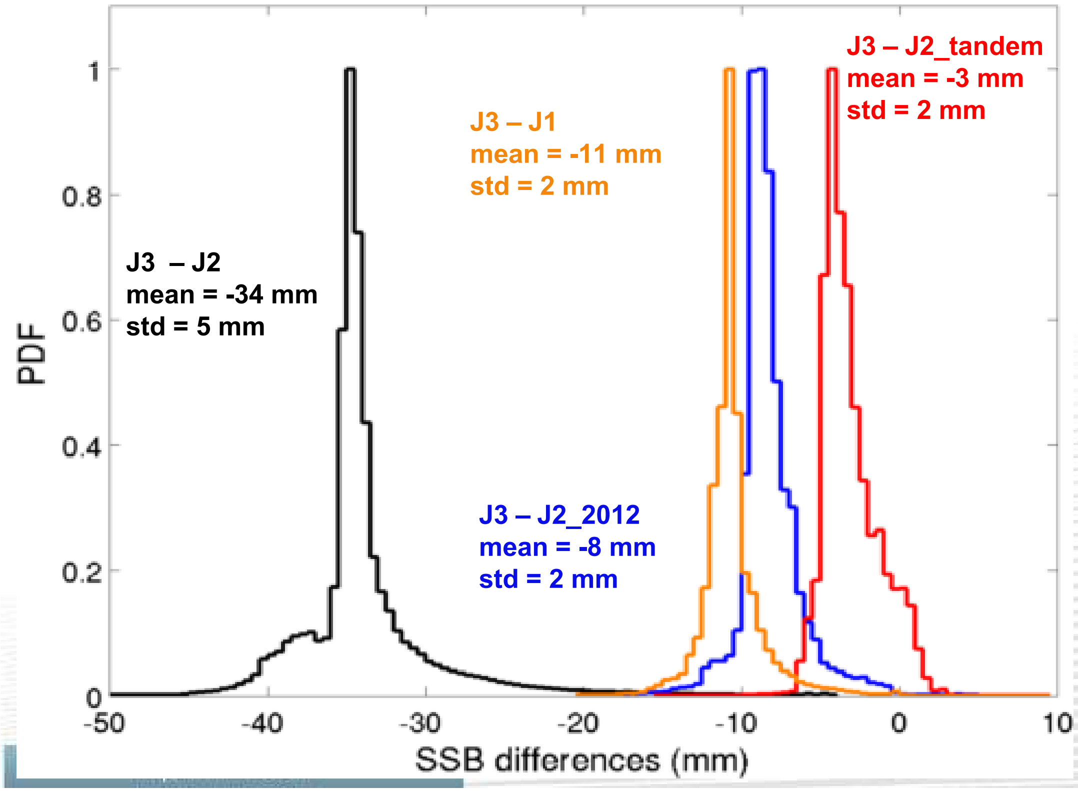
Model name	Period (year)	Cycles	method	Data source	Reference
SSB_J3	half-year	4-20	2D collinear	GDR_T	2016
SSB_J2_tandem	half-year	282-298	2D collinear	GDR_D	2016



- Jason-3 and Jason-2 SSB models derived from tandem period are very similar
  - differences @ mm level (bias of -3 mm and std of 2 mm)
  - 1-year solution will be computed when enough data will be available, mainly a shifted bias is expected due to seasonal variations

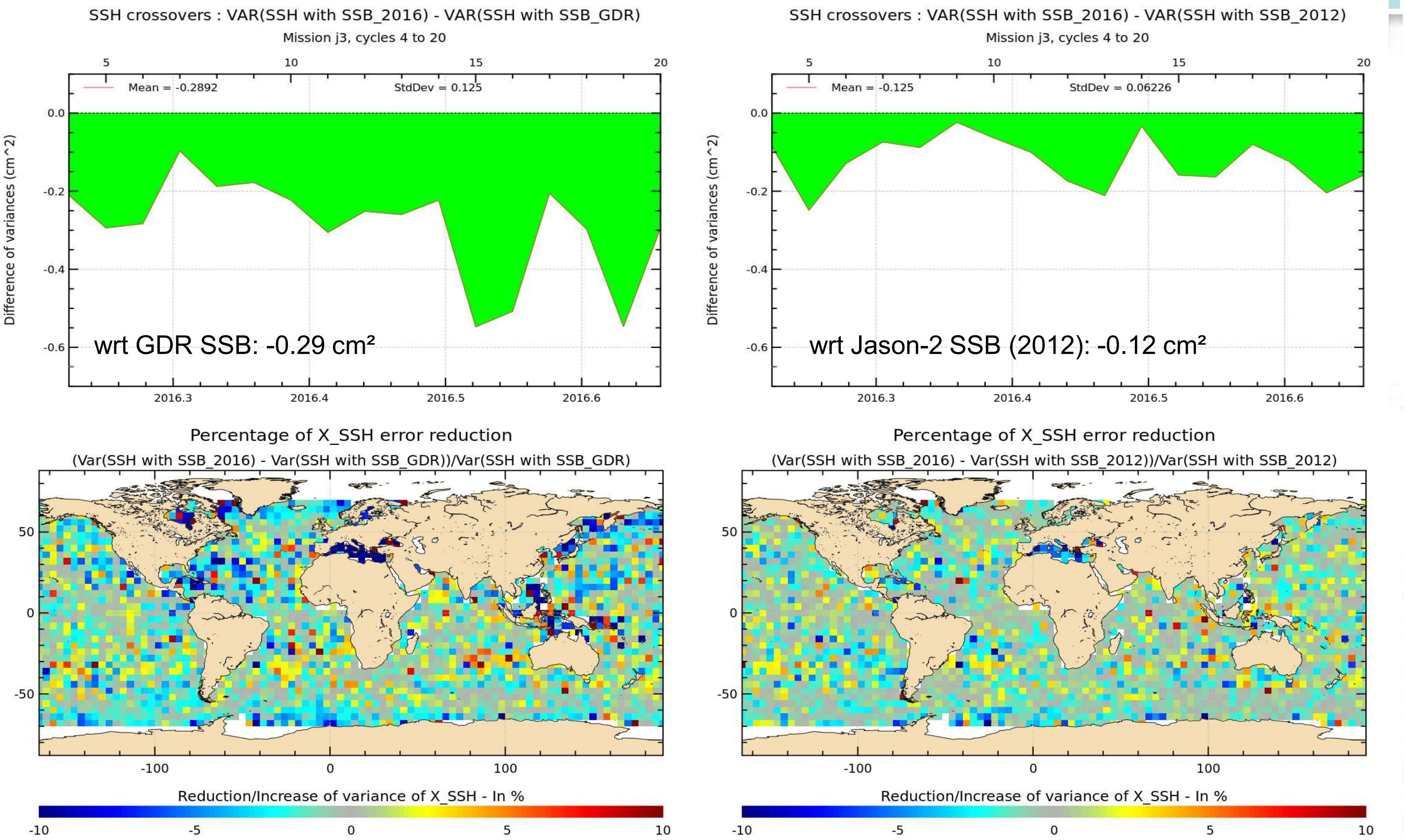
Jason-3 to Jason-1 SSB consistency

Model name	Period (year)	Cycles	method	Data source	Reference
SSB_J2 (official in GDR_D)	1	7-43	2D collinear	GDR_T + CLS updates	2011
SSB_J2_2012	1	1-36	2D collinear	GDR_D	2012
SSB_J1	3	1-111	2D collinear	GDR_E	2015

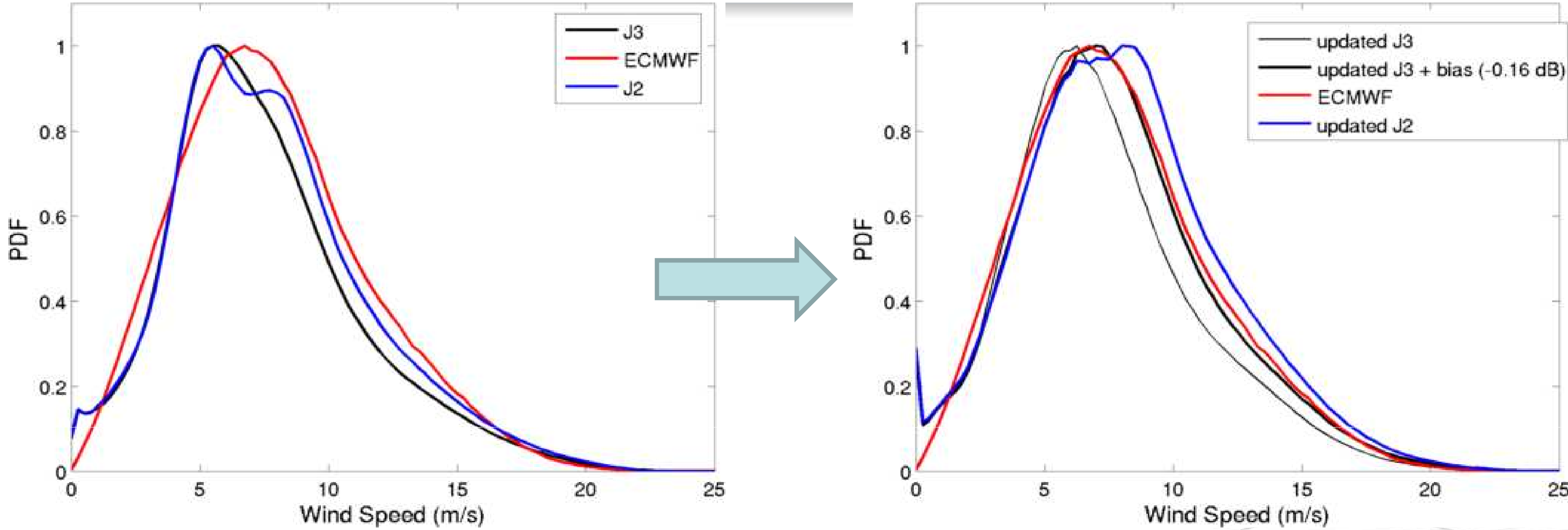


- Very good consistencies between SSB models for the 3 Jason missions are expected when stable version for Jason-3 will be available
  - Jason-1 and Jason-2 models applied on Jason-3 data
  - already low bias and low dispersion of the differences between Jason-3 and Jason-2 (2012 version) SSB models: -8 mm and 2 mm respectively
  - already low bias and low dispersion of the differences between Jason-3 and Jason-1 SSB models: -11 mm and 2 mm respectively

Improvements to crossover variance

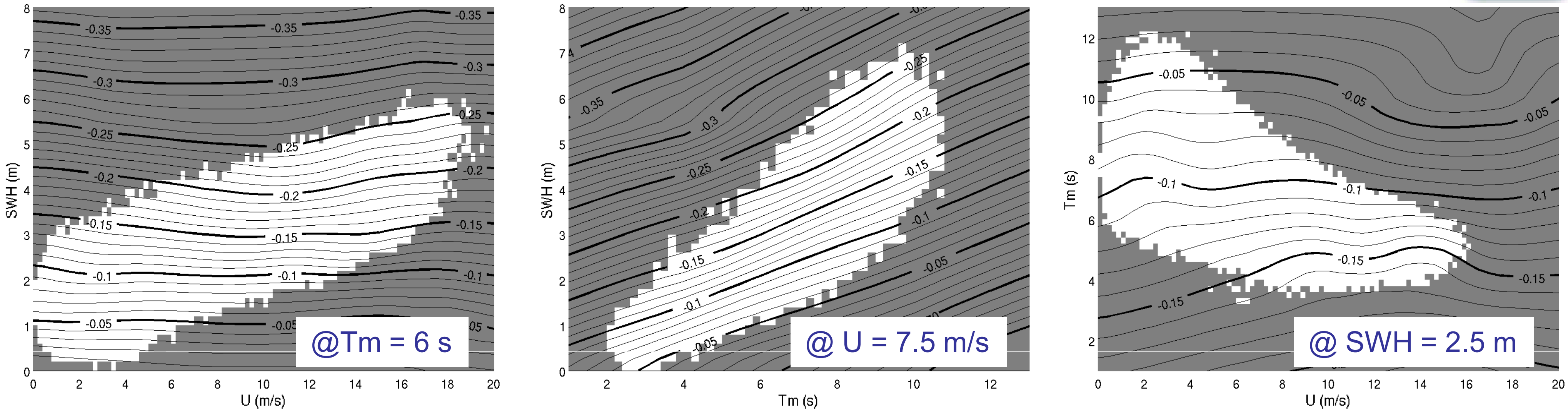


Wind speed calibration



- Jason-3 wind speeds computed with 2015 model fitted on Jason-2 data display an histogram shape closer to ECMWF one (Weibull distribution) with an average @ 7.8 m/s
  - 2015 model presented at 2015 OSTST meeting by D. Vandemark
  - Jason-3 GDR wind speed retrieval based on Collard's model [2005] fitted on Jason-1 data
  - adjustment on backscatter (sigma-0) needed for both models (+0.14 dB wrt Jason-1 model and -0.16 dB wrt Jason-2 one)
  - difficulty to properly adjust the calibration bias because of the Jason-2 sigma0 decrease (-0.095 dB) over the Jason-2 life period (cycles 1 to 299) leading to an increase of Jason-2 wind speed of +0.31 m/s. Some of the sigma-0 decrease is related to changes in CAL1 data that are not taken into account in the processing [Desjonqueres, 2016].

Preliminary Jason-3 3D SSB



- Jason-3 3D SSB model (SWH, U, Tm) developed with the collinear SSH differences approach within the CNES Jason-3 PEACHI project
  - use of mean wave period (Tm) from IFREMER WaveWatch3 products
  - to better model SSB behavior with improved description of the sea state
  - commonly 3D models are derived with the direct method [Vandemark et al, 2002]
  - Jason-3 data from cycles 4 to 7
  - when U and Tm are fixed, the magnitude of the SSB is an increasing function of SWH
  - when SWH is fixed, variations with Tm are larger than those with U
  - crossover variance reduction: -1.54 cm² wrt GDR SSB values (5 times more than with the preliminary Jason-3 2D SSB solution)
  - such model will be consolidated when 1-year of data will be available

Jason-2 2D/3D SSB Comparison

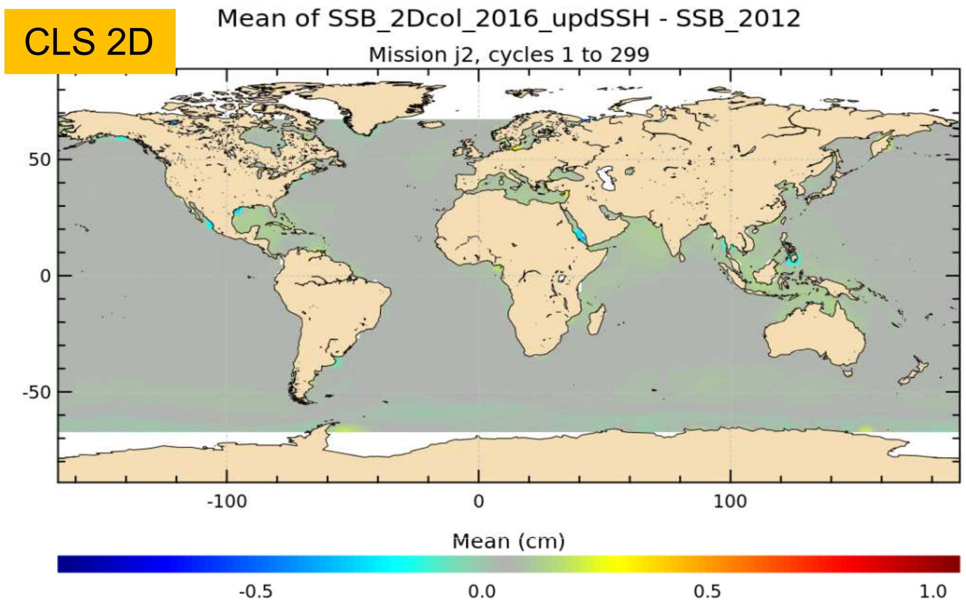
- comparison of 2D/3D SSB models from CLS (collinear differences approach) and UNH (refined direct approach)
- use of the same Tm parameters from IFREMER WaveWatch 3 products with NCEP-CFSR wind forcing to ease use by the altimetry community since they are provided in netcdf files by UNH along with their 2D and 3D SSB estimations:

  http://www.opal.sr.unh.edu/data/sea_state_bias.shtml

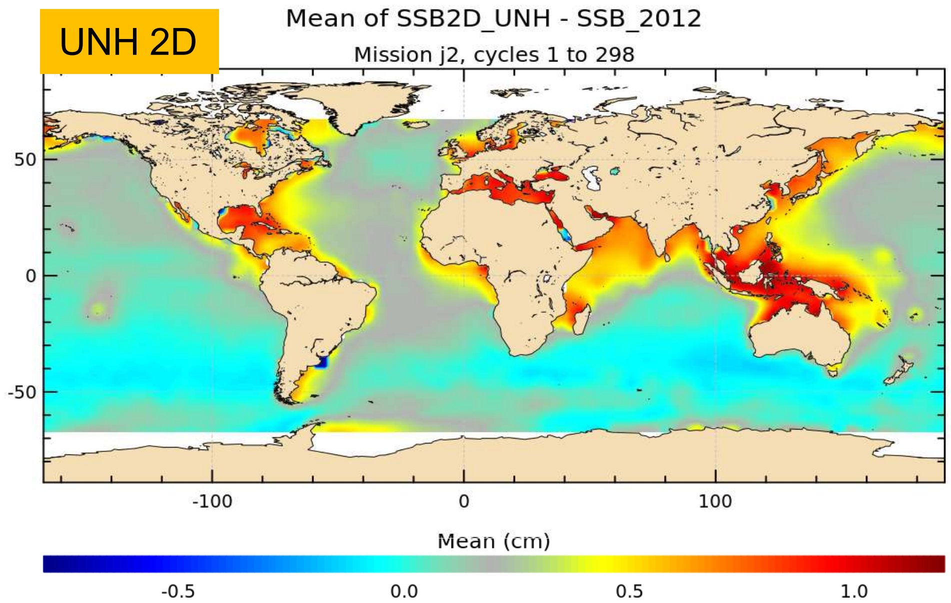
- some CLS models used IFREMER runs with ECMWF wind forcing instead (for instance Jason-3 model)
- for NRT purpose, possibility to switch to Meteo-France WAM operational products for Jason-3 mission in the future
- UNH refined direct approach:
  - Preprocessing of the SLA data by removing the rise trend
  - Computation of multiple-year ensemble SSB model (averaging year-based models)
  - Use of DTU10 MSS product
- CLS collinear SSH differences approach:
  - Standard 2D approach used to develop operational version adapted to handle 3 inputs
  - Some updates made on SSH computation (POE-E Orbits, FES 2014 Ocean Tide, Pole Tide [Desai, 2015])

Map of differences

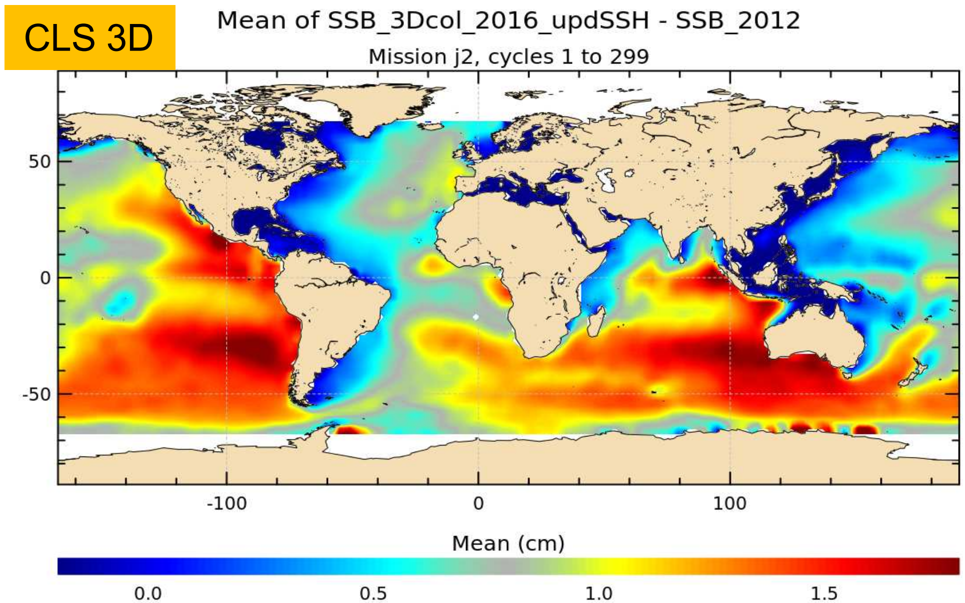
CLS 2D



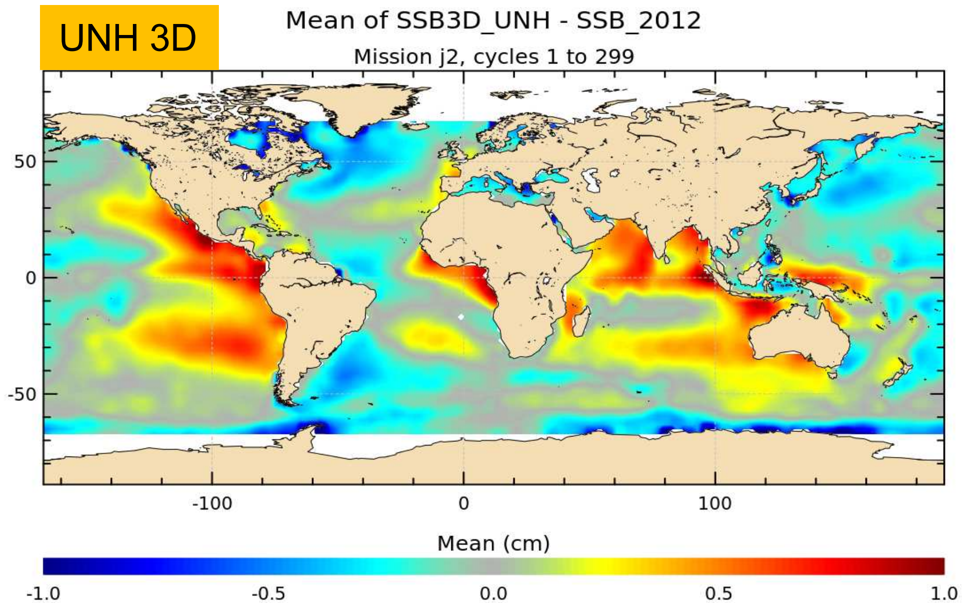
UNH 2D



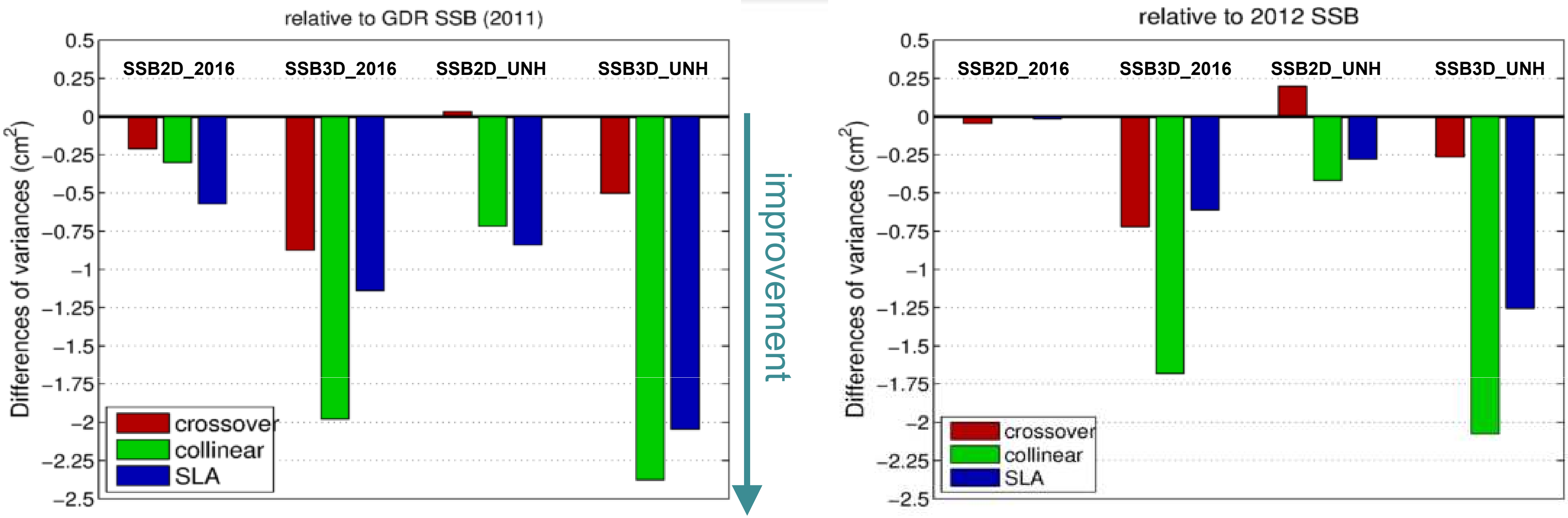
CLS 3D



UNH 3D



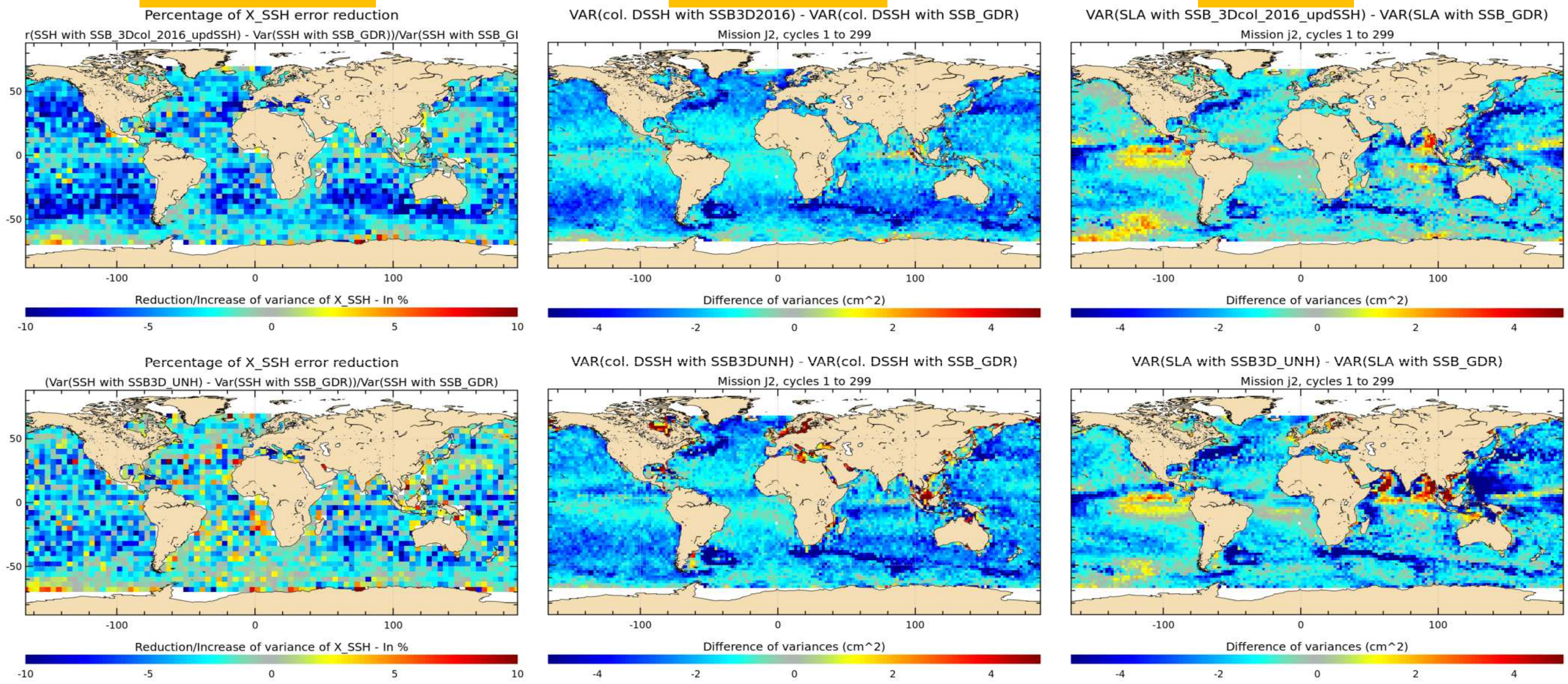
Variance reduction comparison



- Comparison based on 3 possible datasets (crossover and collinear SSH differences, SLA)
  - 3D models perform always better than 2D models and the improvements are the largest when they are used in collinear SSH differences
  - 3D model based on collinear data displays larger improvement on crossover dataset
  - 3D model based on SLA displays larger improvement for both collinear and SLA datasets

Variance reduction maps
(3D models vs model used in GDR)

Crossover Data | Collinear Data | SLA Data



- Mostly same regions are highlighted from each pair of maps but not always with the same magnitude

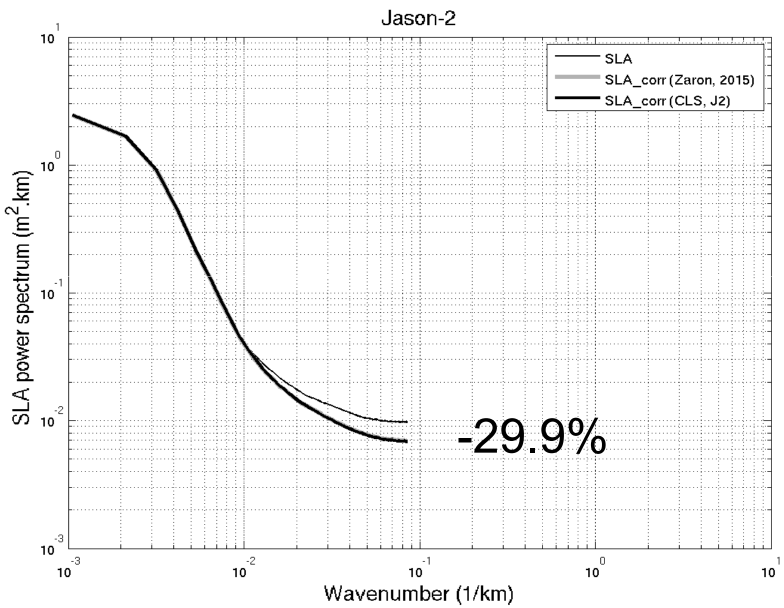
High frequency content in SSH and SSB estimates

- Several studies have focused on the high frequency content of the SSH and its dependence to SWH signal at wavelengths shorter than 100 km
- Zaron and DeCarvalho [2016] used the observed correlation between the measurement errors of sea-surface height (SSH) and significant wave height (SWH) to correct the SSH data by removing the noise correlated with the SWH noise (variance reduction of ~2 cm^2 obtained)
- Spectral analysis of Jason-2 corrections to the range measurements showed that the SSB correction is the dominating signal for wavelength below 100 km and is the only contributor for wavelength below 50 km [Ollivier et al, 2016].
- 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]
- 3D SSB solution based on smoothed sigma0, smoothed SWH and the SWH smoothing residual achieves significant variance reduction with respect to standard operational correction [DeCarvalho et al, 2011].
- These results altogether point out that some of the observed variance reductions are likely the result of removing correlation between range measurement noise and SWH measurement noise related to the waveform retracker.
- 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.

Zaron's correction vs SSB correction for the high frequency content

$$SSH\_corr = SSH - (\alpha + \beta\ SWH\_FILT) * (SWH - SWH\_FILT)$$

SWH_FILT, low-pass filtered SWH (Lanczos, 40 pts)



→ empirical model to describe the error correlation between SSH and SWH

→ Zaron's correction **~0.1% of SWH** vs SSB correction **~3% of SWH**

J2	Slope (beta)	Intercept (alpha)
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

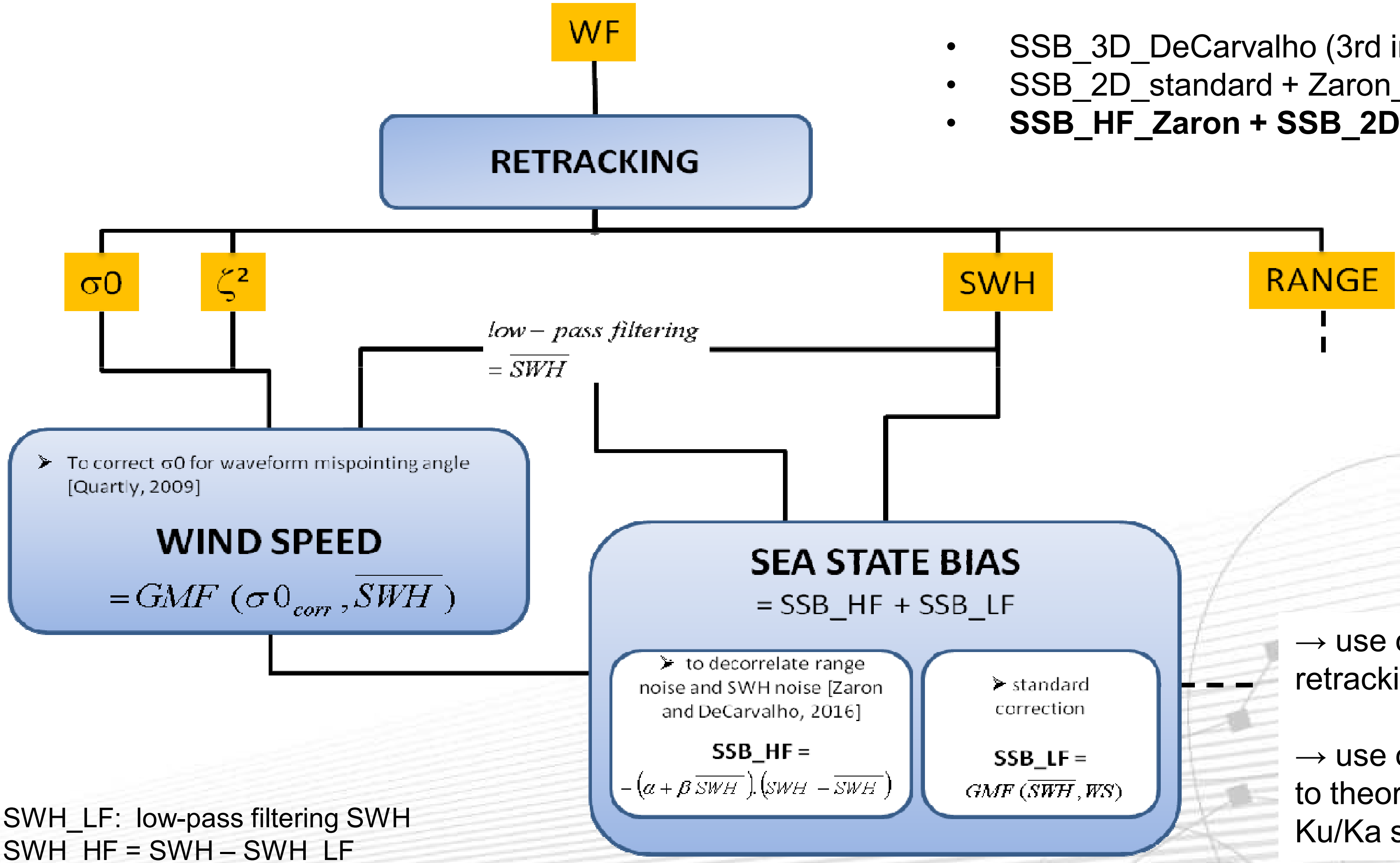
→ range and SSB are the sole sources of SSH high frequency content (in agreement with A. Ollivier et al [2016]) and each contributed in similar proportion

Proposed change in SSB model development

Empirical SSB = Electromagnetic Bias + Skewness Bias + Processing Bias

3 approaches in the same spirit:

- SSB_3D_DeCarvalho (3rd input : SWH_HF)
- SSB_2D_standard + Zaron_correction
- **SSB_HF_Zaron + SSB_2D_filtered**



→ use of SSB_HF to compare retracking algorithms

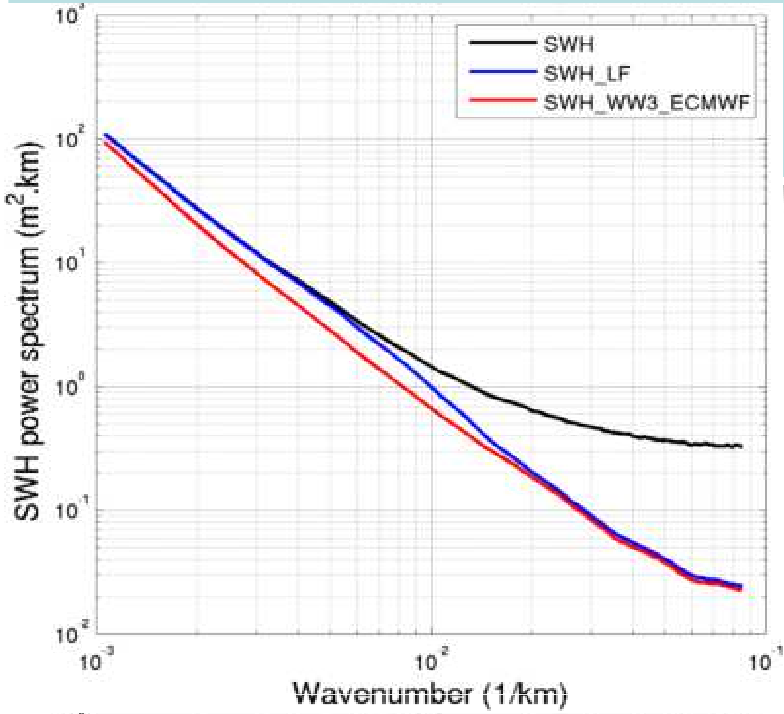
→ use of SSB_LF to compare to theoretical SSB results and Ku/Ka solutions

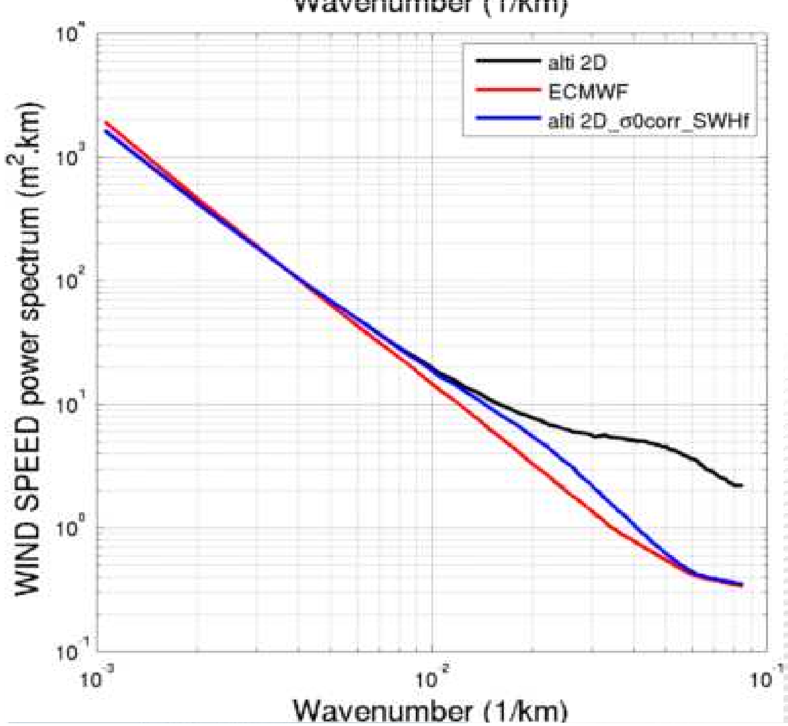
SWH_LF: low-pass filtering SWH

SWH_HF = SWH – SWH_LF

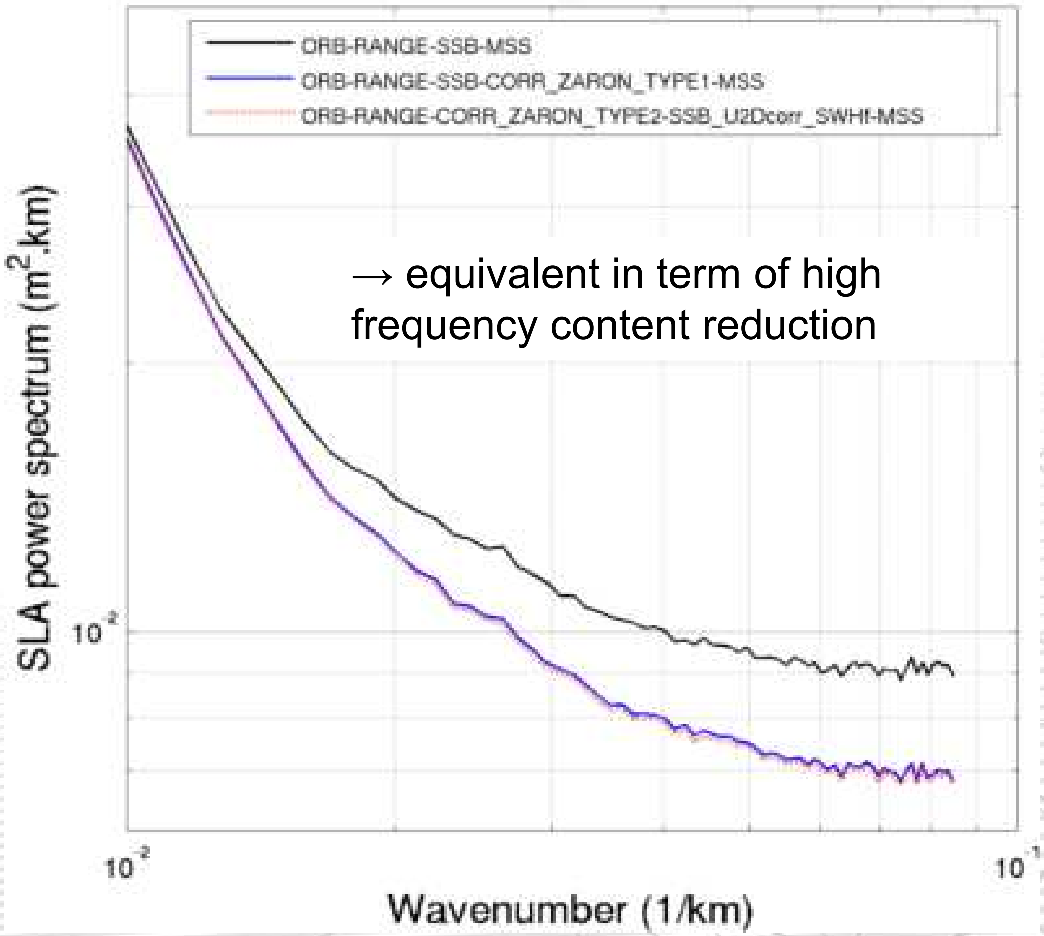
$\sigma0\_corr = \sigma0 - 11.34 * \xi^2$ [Quartly, 2009]

Spectra comparison





CORR_ZARON_TYPE1: (α, β) computed from ΔSSH vs ΔSWH
CORR_ZARON_TYPE2: (α, β) computed from Δ(ORBIT-RANGE) vs ΔSWH



Summary and Conclusions

- Preliminary Jason-3 SSB models (2D and 3D) have been computed
- They will be recomputed when 1-year of GDR data will be available and the good consistencies between the SSB models for the 3 Jason missions are expected to be confirmed
- Wind speed calibration is challenging for each new launched mission due to different effects on sigma0 (platform pointing problems for J2/J1 tandem phase, drift on sigma0 measurement for J3/J2 tandem phase)
- The 2D wind speed model developed in 2015 based on Jason-2 data might be a better candidate than the Jason-1 model for Jason-3
- Alternate 3D SSB models derived from collinear SSH differences have been computed and show some differences with standard 3D models derived from SLA data; further comparisons are needed.
- Range estimations and SSB corrections are the two contributors to the high frequency content of the SSH; works performed in the field of retracking algorithms (to decorrelate retracking outputs and/or to develop 2-pass algorithms) could reduce that but meanwhile the application of a correction such the one developed by E. Zaron [2015] is shown to reduce the high frequency content of the SSH and might help to develop an empirical SSB model with more geophysical content than what we get today.

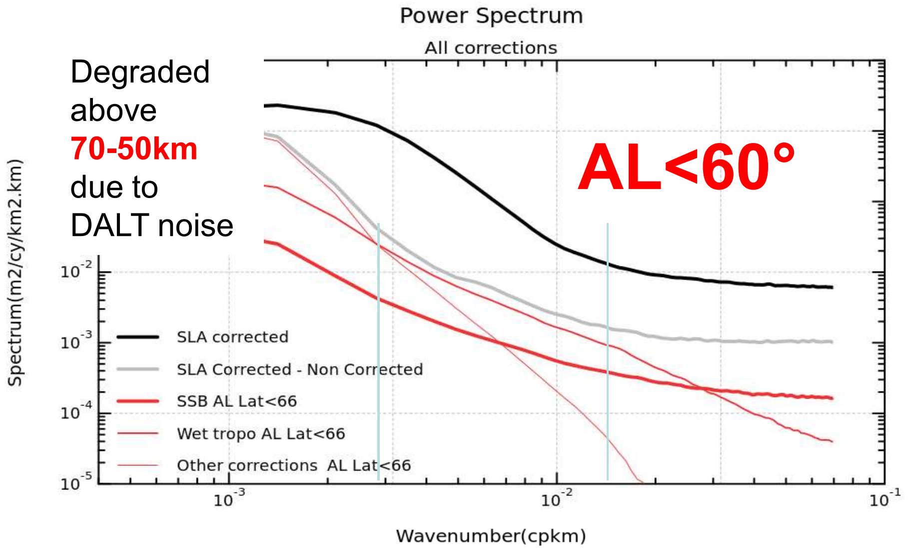
N. B. netcdf files with UNH SSB available for TOPEX, Jason-1, Jason-2 and Jason-3 (soon for Altika)

http://www.opal.sr.unh.edu/data/sea_state_bias.shtml

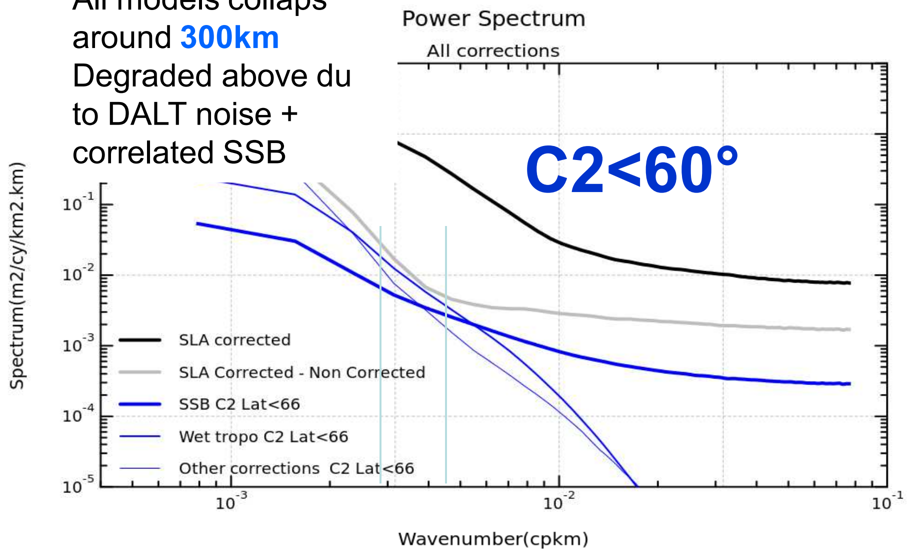
Back-up slides

Ratio of explained variance [Ollivier et al, 2016]

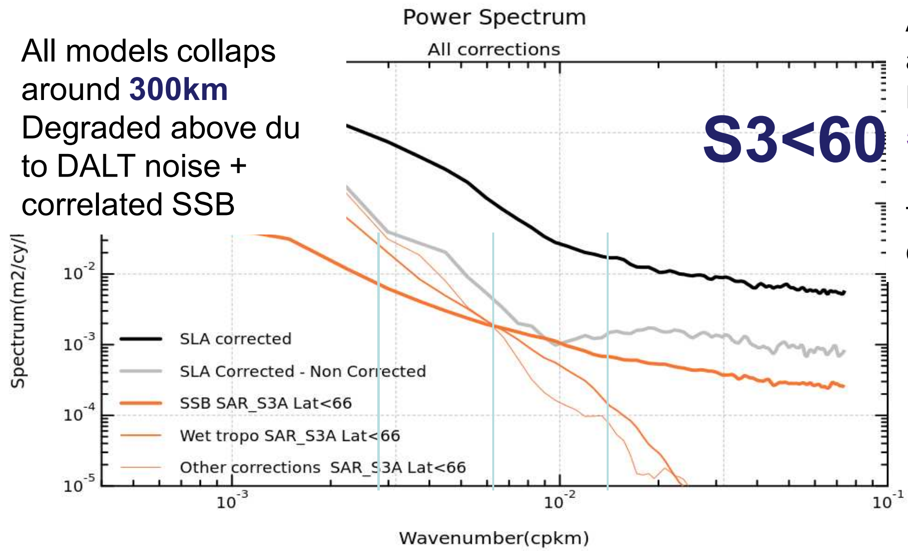
Degraded above **70-50km** due to DALT noise



All models collaps around **300km**
Degraded above du to DALT noise + correlated SSB



All models collaps around **300km**
Degraded above du to DALT noise + correlated SSB



All models collaps around **300km**
But Radiometer up to **50km**
Degraded above du to DALT noise + correlated SSB