Sea state bias in altimetry measurements using new parametric model

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1. OUTLINE

Sea state bias (SSB) in radar altimeter measurements is one of the most complex sources of the ranging errors. Being of the order of a few percents of significant wave height it is the largest remaining error in mean sea level estimates (Gommenginger et al., 2018).

Three main effects are assumed to be responsible for SSB:

(1) Electromagnetic bias (EB): Different reflectivity of wave crests and troughs -> mean scattering level is shifted towards the wave troughs
(2) Skewness bias (SB): The inherently nonlinear dynamics, asymmetric profiles with flat troughs and sharp crests leads to the SSB overestimation.
(3) Tracker bias (TB): Numerous instrumental and retracking effects.

SSB is usually parameterized as a function of the altimeter-derived dimensional variables: wave height (H_s) and wind speed (U_{10}).

We propose to solve the problem in terms of dimensionless altimeter derived quantities: pseudo-wave age $\xi=gH_s/U_{10}^2$ and wave steepness $\mu=<ak_p>$. Wave steepness is estimated from along-track measurements as [Badulin, 2014]

$$\mu=0.598|dH_s/ds|^{1/5}. \quad (1)$$

Similarity approach allows for developing a physical model and discriminating contributions of different physical effects into SSB. The model of a random weakly nonlinear sea surface (Srokosz, 1986) predicts

$$SSB=\frac{1}{8}\left(\lambda_0/3+\lambda_1\right)H_s$$

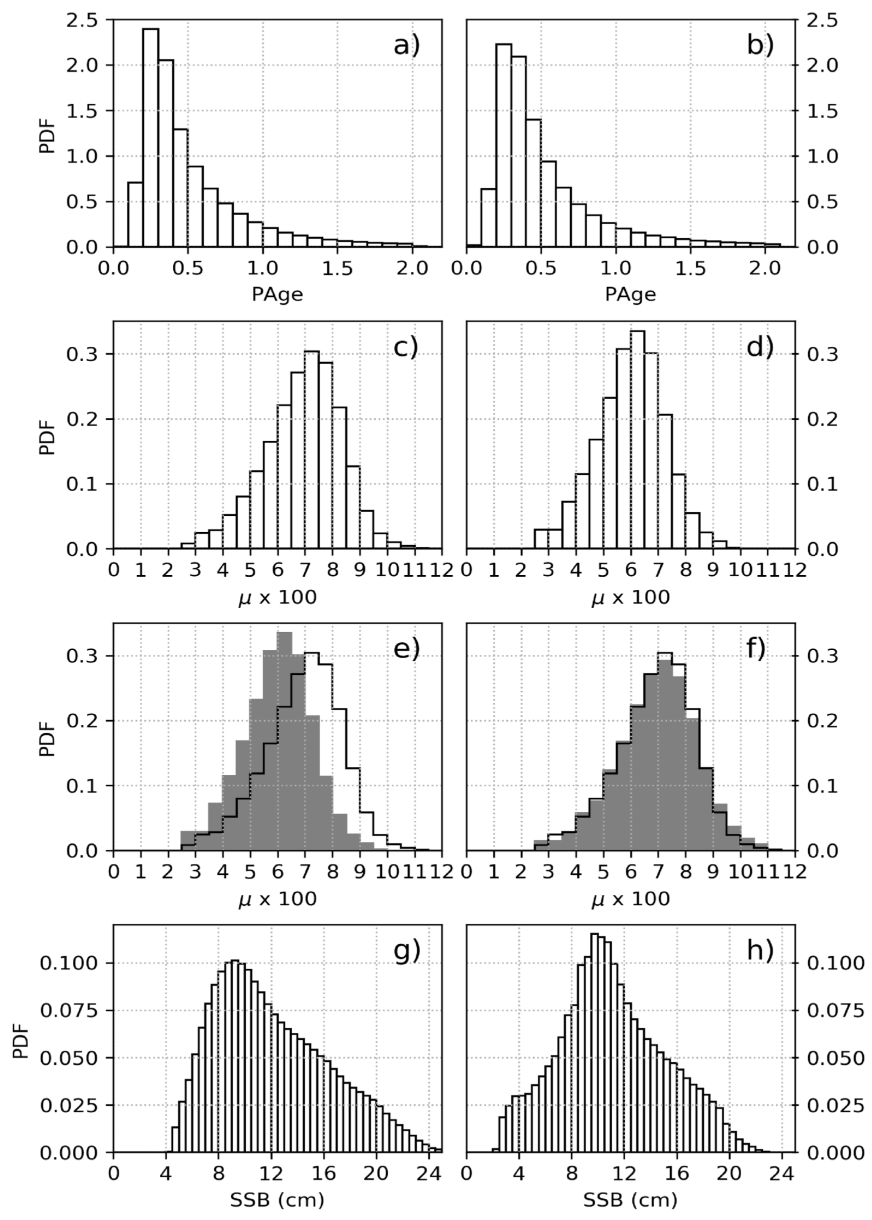
and, after additional assumptions,

$$SSB=C(\xi)\mu H_s \qquad (2)$$

as the skewness bias fraction of SSB.

- Can we find the incomplete (the 2nd type) self-similarity in altimetry data?
- Does the new model reflect physical effects (1), (2), (3) ?
- Is it able to provide relevant quantitative modeling of the SSB in altimetry within the approach?

2. FEATURES OF (ξ , μ) and SSB



Our dimensionless variables are mission- (mostly ξ) and orbit-dependent (mostly μ, see eq.1 because of track and wave directions mismatch).

PDFs of ξ for J3 and SA are quite close (Fig.1a,b) while their counterparts for μ are different in magnitudes and locations of peaks (Fig.1c,d). Simple transformation

$$\mu_{SA}=1.159\mu_{J3} \qquad (3)$$

makes the distributions almost identical (Fig.e,f). Thus, the pair (ξ,μ) looks relevant to the problem discussed with μ corrected.

PDFs of the SSB for two missions shows possible flaws of SSB parameterizations (Fig.1g,h).

Fig.1: PDFs of altimeter-derived values for Jason-3 (left column) and SARAL/AltiKa (right column) for the year 2018. *a,b)* -pseudo-age $\xi=gH_s/U_{10}^2$; *c,d)* - steepness μ; e,f) - comparison of the J3 and SA (3) PDFs of steepness; *g,h)* - SSB. Broken distribution for SA implies problems.

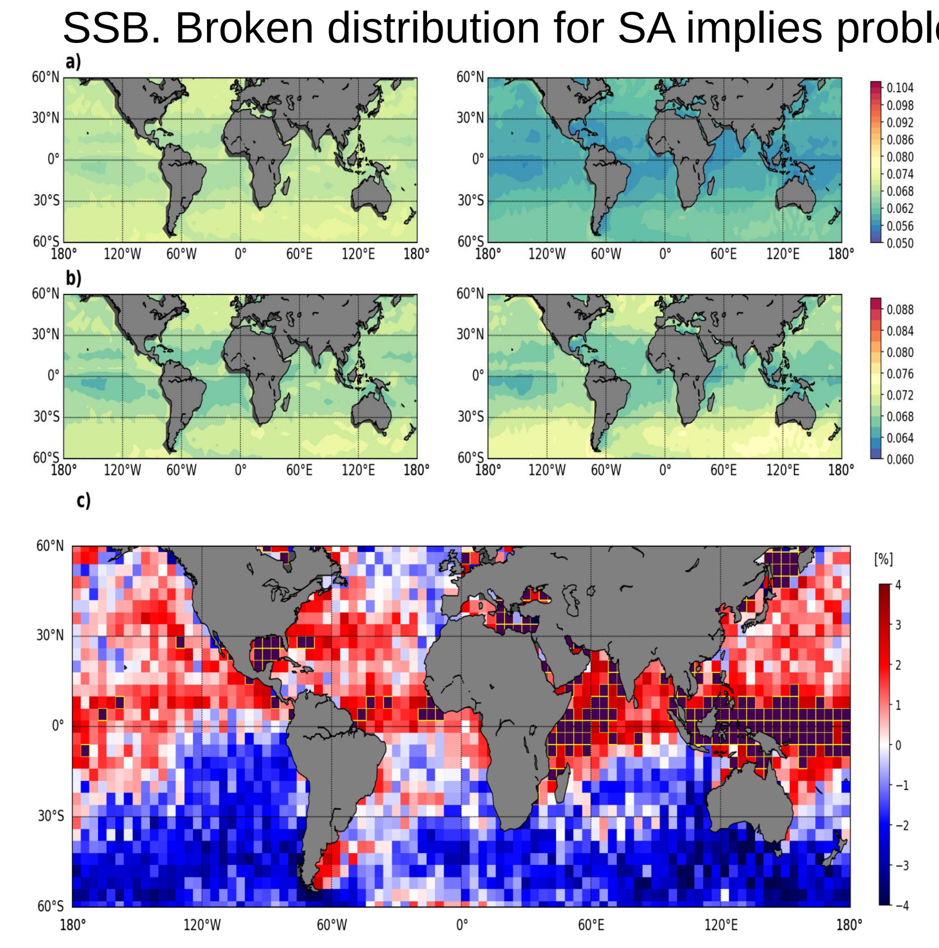


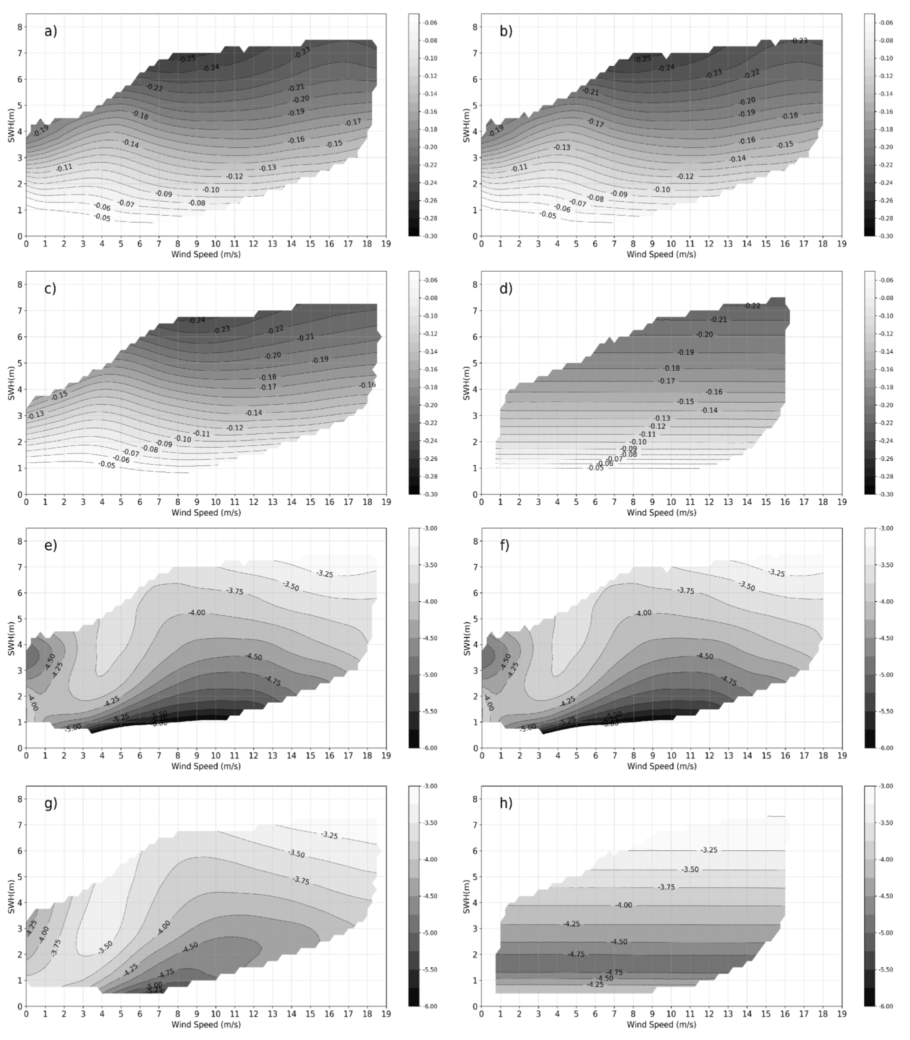
Fig.2: a) - global distribution of wave steepness mean over 4x4° coordinate boxes - J3 (left col.) and SA (right). b) - the same for SA re-scaled by factor 1.159. c) - normalized difference of wave steepness of J3 and re-scaled SA

$$\Delta\mu=100\times\frac{\mu_{J3}-\mu_{SA}}{\mu_{SA}}$$

The outliers exceeding 4% are shown in violet.

Small dissimilarity of hemispheres in $\Delta\mu$ can be explained by features of wind and wave fields with mostly zonal directions.

3. RE-MAPPING SSB DATA ONTO (ξ,μ)



The data used here has been retrieved from Sensor Geophysical Data Records (SGDR, L2 product) with 1-Hz sampling from (https://www.aviso.altimetry.fr).

It should be stressed, that the SSB series cannot be considered as `an ultimate truth'. The corresponding parametric models provide the best fit in space of dimensional H_s and U_{10} but, in general case, do not guarantee a reasonable result in space of dimensionless pair (ξ,μ).

Fig. 3: a,b,c,d) - isolines for the global SSB (m) from bin-averaging into boxes 0.25 m/s by 0.25 m over the (H_s,U_{10}) domain. a) - J3, cycles 70-105, b) - J2, cycles 18-55; c) - J-1, cycles 257-294; d) - SA cycles 116-124 (cf. Vandemark et al., 2002, Fig.1); e,f,g,h) - isolines for normalized value $SSB=H_s$ (in percents) over the (H_s,U_{10}) domain for the same data.

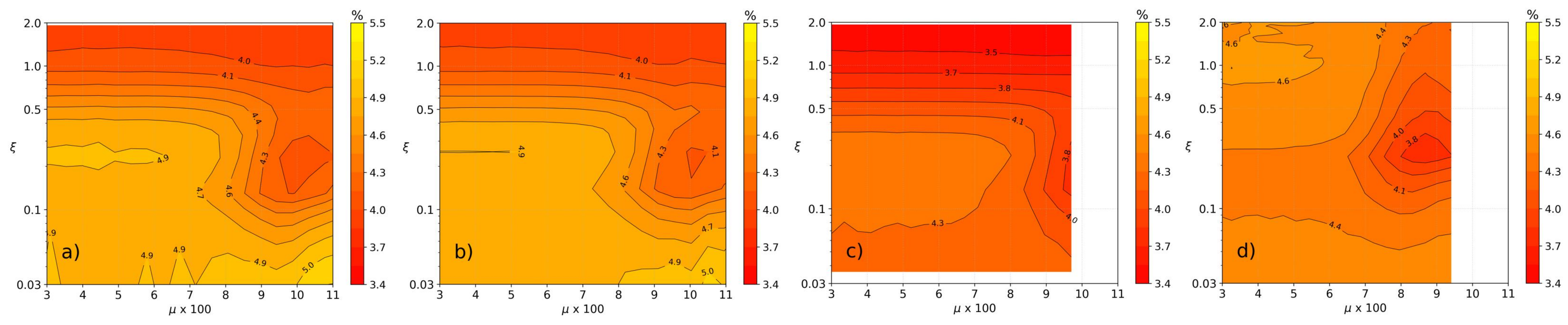


Fig.4: Isolines for the global normalized value SSB/H_s (in percents) obtained from bin-averaging into boxes $\Delta\xi$=1.1 by $\Delta\mu$=0.002. a) - J3, cycles 70-105, b) - J2, cycles 18-55; c) - J1, cycles 257-294; d) - SA, cycles 116-124.

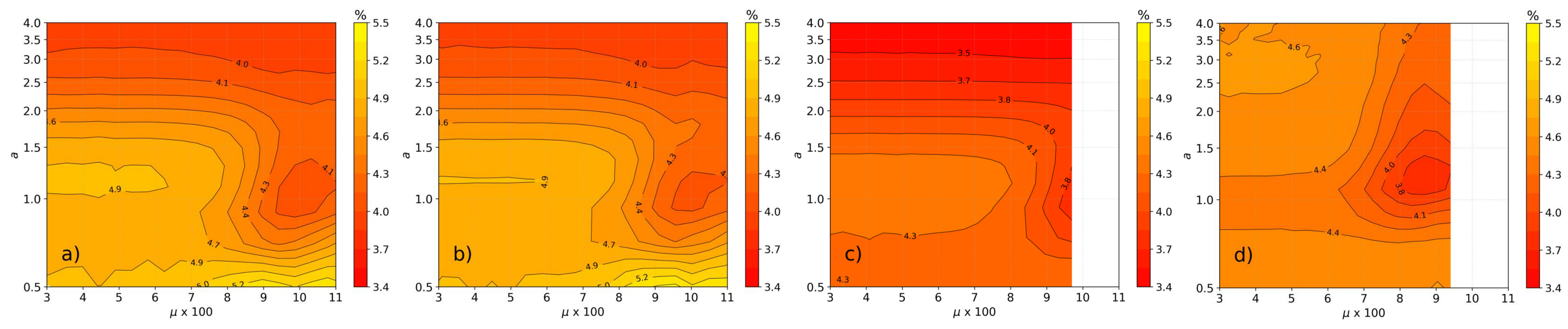


Fig.5: Same as previous for wave age $a=gT_p/(2\pi U_{10})$

4. CONCLUSIONS

1. The similarity approach is applied to the problem of sea state bias (SSB) in altimetry measurements;
2. A comprehensive analysis of SSB data is performed within dimensionless wave characteristics (wave steepness and pseudo-age)
3. Similarity of global distributions of SSB within the new approach is demonstrated for altimeters with different operational bands of Jasons' and SARAL/AltiKa missions.

SSB should be re-tracked for employing the new approach in altimetry

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