Sea state bias correction in coastal waters

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Overview of group consensus and steps for forward progress

1) ssb review
2) Some questions
3) New work & points for discussion

Sea State Bias - an altimeter time/range bias attributed to ocean gravity wave dynamics (1-25 cm, 1-5% SWH)

SSB Components:

- Range Tracking bias - altimeter uses a median tracker while mean is desired measure
- Elevation skewness bias - physical, *F*(SWH)
- Radar scattering (EM) bias - measured in field
- Retracking - all Brown model fit parameters impact empirical SSB determination (range,SWH,sigma0,skewness, point_angle)

SSB model formulation

ε (m) = β * SWH

β = 0.03 1st generation, 3%

β = F(SWH, U_{10}) 2nd generation

U_{10} = wind speed

β = F(SWH, U_{10} , *) 3rd generation

* - use of past theory/field/satellite work + wave model data to include wave age information.

Global SSB modeling issues

- on-orbit determination: forced to use the range data itself to estimate the range error
- time/space scale of wind wave dynamics is hours and 10-200 km, thus need high-res. data (SWH,U_{10} alt)
- interplay of tracking factors -> platform specific algorithms (T/P, Jason work showing convergence)
- net result is that these models are empirical & custom

SSB On-orbit Model Methods

Crossover/Collinear: use time difference of SSH, SWH and U10 (3-10 days) to cancel out all but the SSB residual

Direct long-term SLA averaging: use conditional average over dependent variables and assume all other factors, including dynamic topography, tend to zero.

The coastal questions

Are the open-ocean altimeter SSB corrections accurate in coastal regions?

If not, how large is the error and what are strategies to handle it?

What are the options for developing and validating coastal SSB algorithms?

Further List of questions: Coastal SSB

1. Do we need to clarify understanding of EM bias, the skewness bias, and the instrument bias with the overall SSB models?
2. What empirical and parametric models are available?
3. Is there reason to believe that the global open-ocean correction will be inaccurate in coastal regions?
4. Which correction is best for coastal applications?
5. What is the accuracy and coastal correlation length scales of SWH and wind speed and hence of potential variability in the SSB correction?
6. What is our group recommendation regarding an SSB correction approach that bridges multiple altimeter missions?
7. Why not use altimeter NRCS rather than wind speed in the empirical SSB model developments?

Do we need to clarify understanding of EM bias, the skewness bias, and the instrument bias within the overall sea state bias models?
AND
Do we need custom SSB models for each satellite?

Consensus is no for first and yes for the second.

From Victor “As Remko and SYlvie clearly showed, even for the same instrument after retracking one needs to change the SSB (and the overall bias, of course). Heck, TOPEX side A needed a different SSB in the last year of its life (1998) as its point target response kept deteriorating than in its first year (say 2003).That is because, as you all know, SSB is part EM and skewness bias which have nothing to do with instrument electronics, and part TRACKER bias which has everything to do with instrument and retracking. Sadly, despite the n altimeters we have had, we have an n+1 unknown problem, so we not have enough info to separate the two . It would be really nice to compute the instrument-specific component from open water data, where there are plenty of samples.”

What empirical SSB models are available/ in use?

Jason-2 - (will have better tracking….and Jason-1 retracking) NP collinear
Jason-1 _ LaBroue (latest is NP Collinear with MLE-4, into next GDR)
Topex - Gaspar & Ogor 94 (but best/final will likely be with final retracked NP collinear by LaBroue)
Poseidon - new correction coming from LaBroue, RADS has a patch now.
Enivasat RA2 – LaBroue, crossover NP, reference below
ERS - Gaspar & Ogor, 94b
GFO - Hybrid SSB method /Scharroo-Lilllibridge, reference below
Geosat - "" ""

Gaspar, P., Ogor F., P.Y. Le Traon, and O.Z. Zanife, 1994, Joint estimation of the Topex and Poséidon sea-state biases, J. Geophys. Res., 99, 24981-24994.
Gaspar, P., and F. Ogor, 1994, Estimation and analysis of the sea state bias of the ERS-1 altimeter. Technical Report. Ifremer/CLS contract n° 94/2426016/C
Labroue S., 2007: RA2 ocean and MWR measurement long term monitoring. Technical Report, CLS-DOS-NT-07-198 ESA Contract n。17293/03/I-OL."
Scharroo, R., and J. L. Lillibridge (2005), Non-parametric sea-state bias models and their relevance to sea levelchange studies, in Proceedings of the 2004 Envisat & ERS Symposium, Eur. Space Agency Spec. Publ., ESASP-572, edited by H. Lacoste and L. Ouwehand, April 2005..

Is there reason to believe that the global open-ocean SSB correction will be inaccurate in coastal regions?

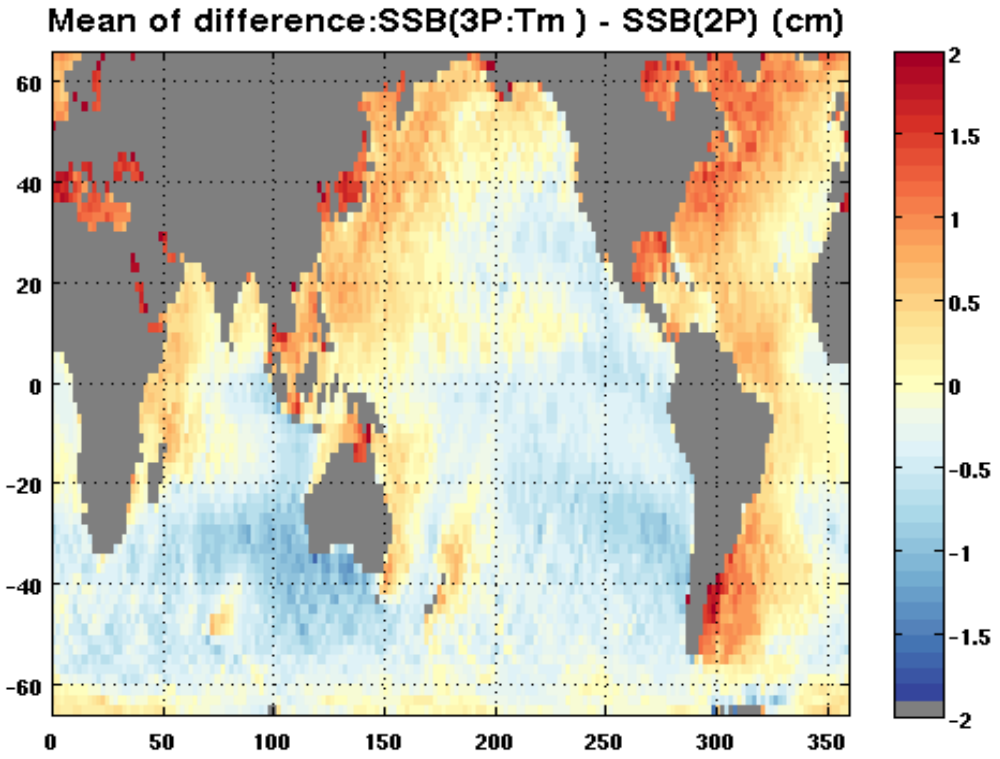
Consensus is yes - with at least two recent lines of evidence and a clear tie back to many EM bias studies illustrating that our two parameters [SWH,U] do not explain all the variance. Coastal zones can be wave age specific with swell on the eastern edge of basins and lack of it in the western edges.

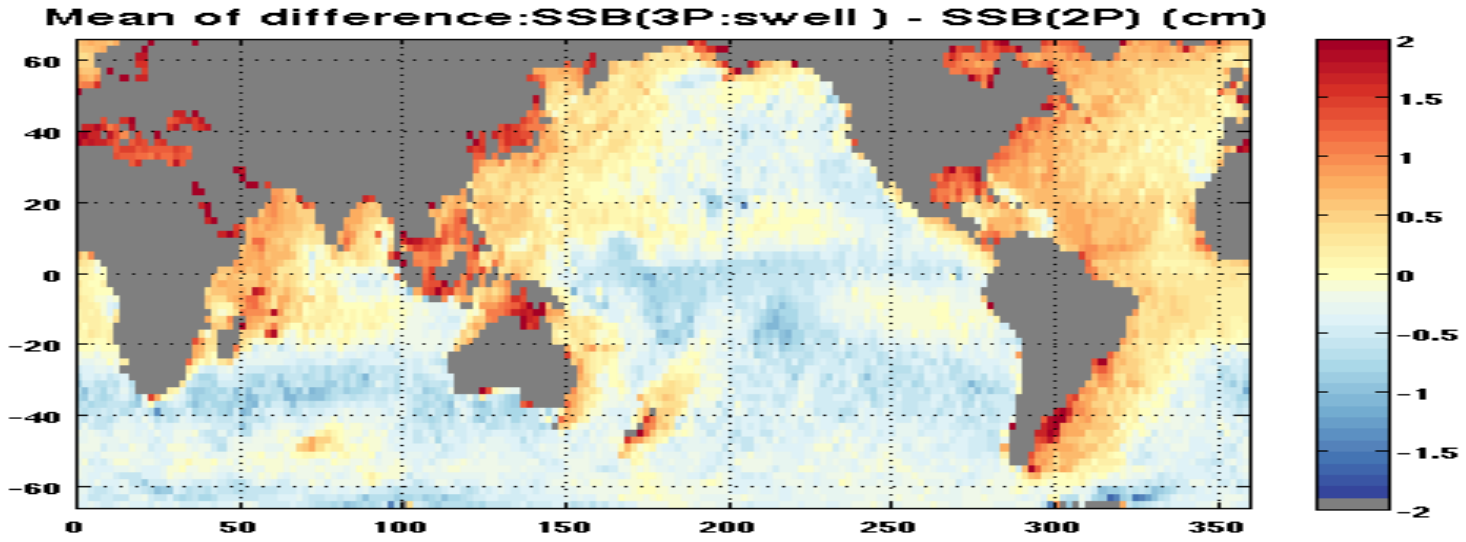
One line of evidence:

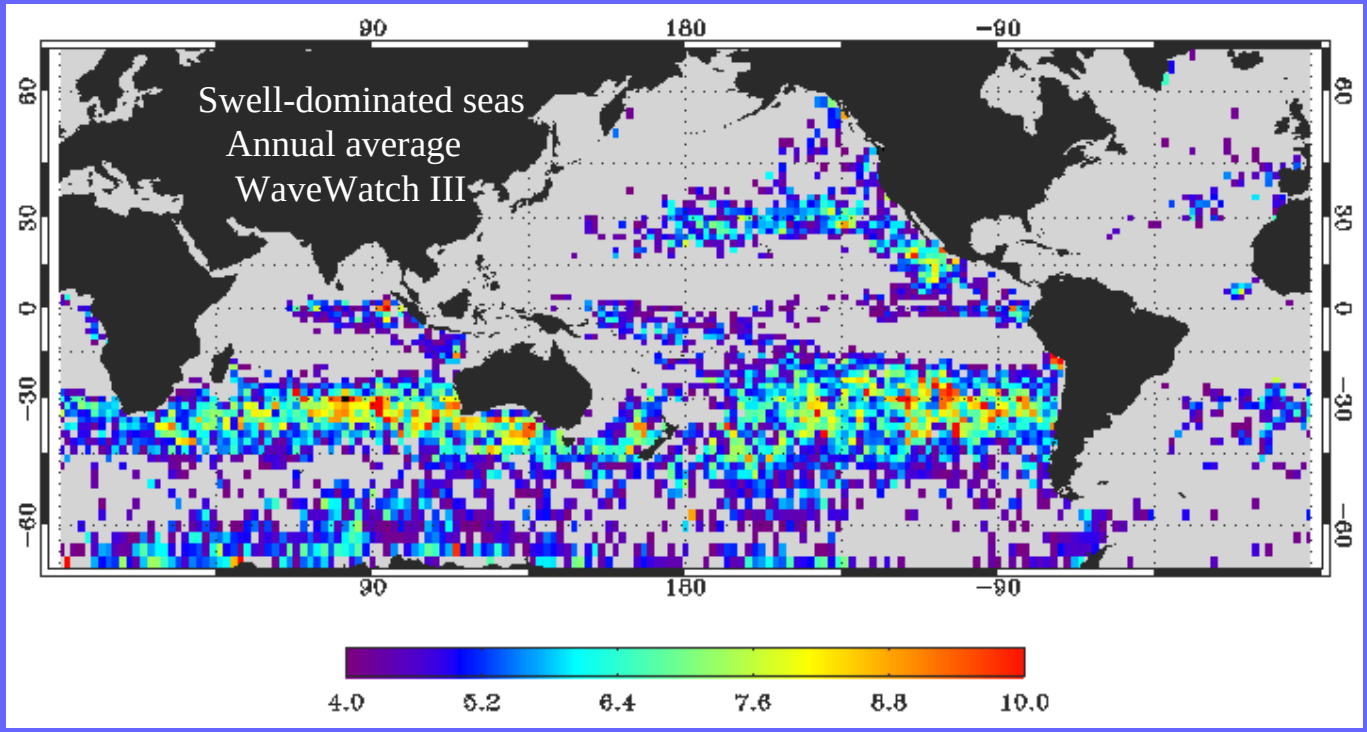
3 parameter NP Jason SSB model developed with help from WaveWatch3

Mean difference with open-ocean NP SSB model for one year =>

(work of Tran, Vandemark in collaboration with support from CNES and JPL)




Mean of difference:SSB(3P:swell) - SSB(2P) (cm)
60
40
20
0
−20
−40
−60
0
50
100
150
200
250
300
350
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2

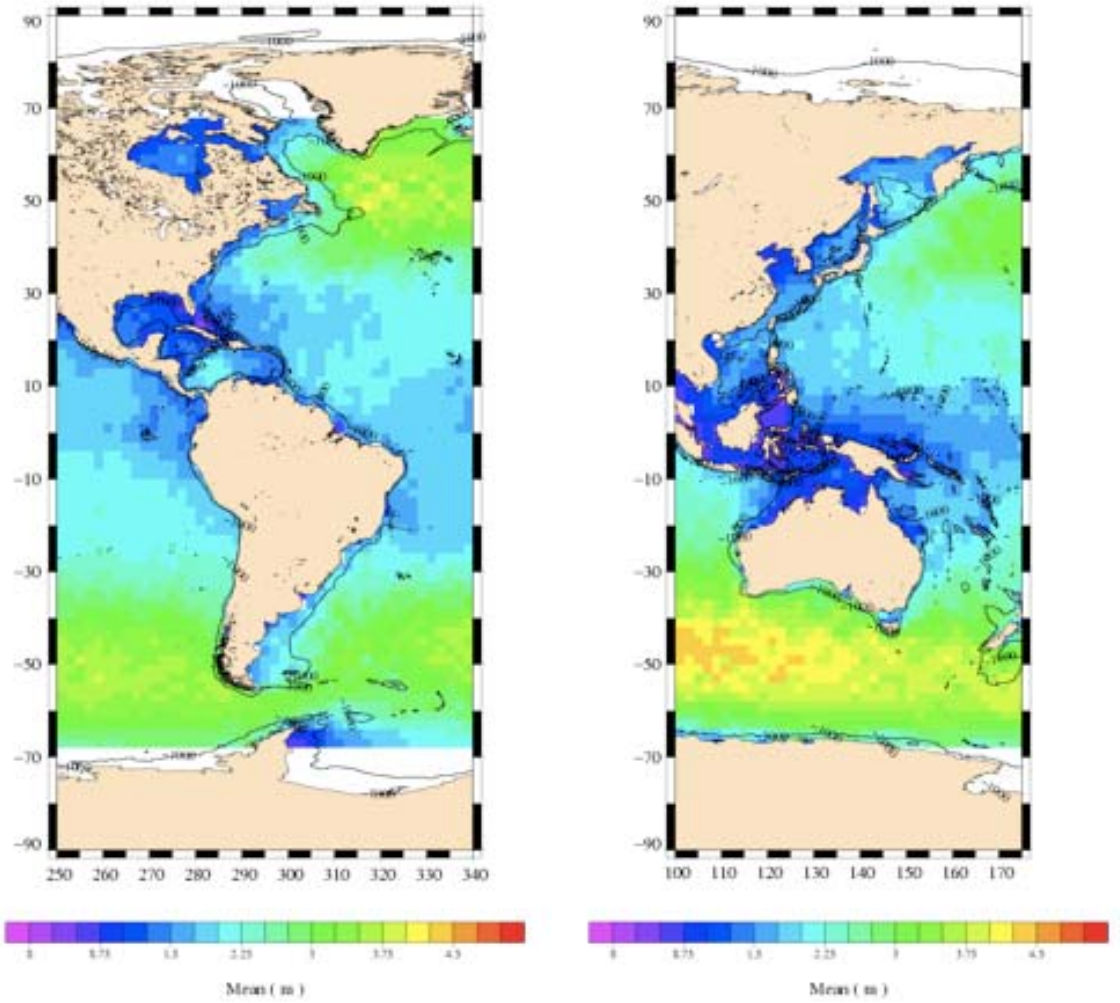

Swell-dominated seas
Annual average
WaveWatch III
90
180
−90
60
30
0
−30
−60
4.0
5.2
6.4
7.6
8.8
10.0

Is there reason to believe that the global open-ocean SSB correction will be inaccurate in coastal regions?

Second line of evidence:

S. Labroue: the global ocean crossover SSB models differ depending on the inclusion of exclusion of data for depths shallower than 1000 m. 2 cm difference at SWH < 1.5 m

…..More coming from CNES PISTACH study



Some relevant work in progress

- PISTACH Coastal SSB Study (Labroue et al)- initial draft report here for discussion
- SSB models using WaveWatch3
- Other….

Sea State Bias in the PISTACH project

Context / Assumptions

- Sea state is influenced by several sources: currents, tides, wind speed direction and strength, coast shape…

  => All these parameters are highly variable over continental shelf and slope

  => It defines the zone of interest for the EM bias issue: areas defined over continental shelf and slope, even at regional scales for some basins.
- The physics of the EM bias over these regions is badly known.
- The EM bias behavior will certainly be different from one region to another.
- SSB models for open ocean are calculated with open ocean data sets (bathymetry < -1000 m).
- SSB never really studied over coastal areas.

- PISTACH objective : provide coastal products for Jason-2 mission which means that they need a ‘coastal SSB correction’

Objective

- First look at the SSB issue with several experiments in order to better grasp the problem
- Give the requirements for an improved ‘coastal SSB correction’
- Choice of the best SSB correction for first version of Jason-2 coastal products

Sea State Bias in the PISTACH project

Tasks

- Comparisons of regional SSB models

  => 3 regions chosen because of their different features (presence of tide signal, long or short fetch):

  Mediterranean Sea, Gulf of Maine and Gulf of Gascogne

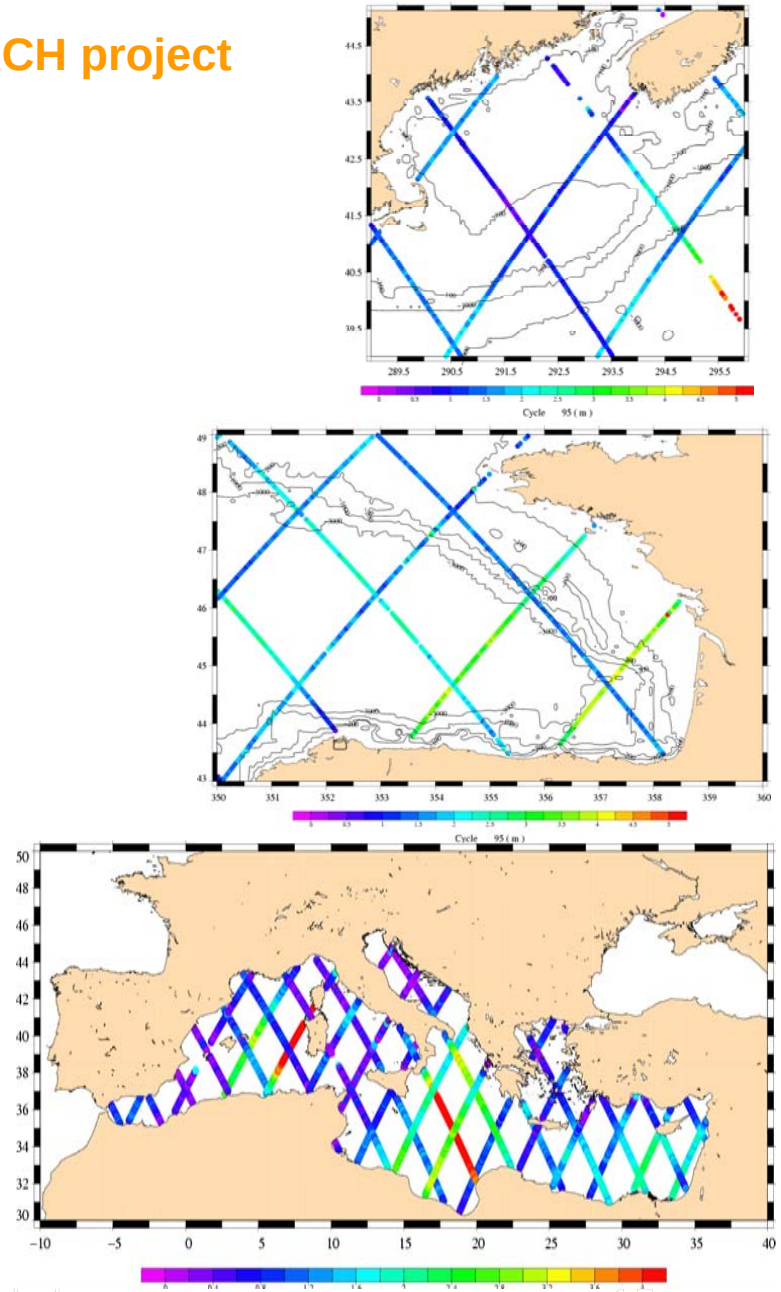
  => Regional SSB is estimated over each region and compared to the open ocean correction (variance gain, validation with in-situ measurements).

- Characterization of the coastal sea states

  => with altimetry data and auxiliary data (Wind speed from IFREMER)

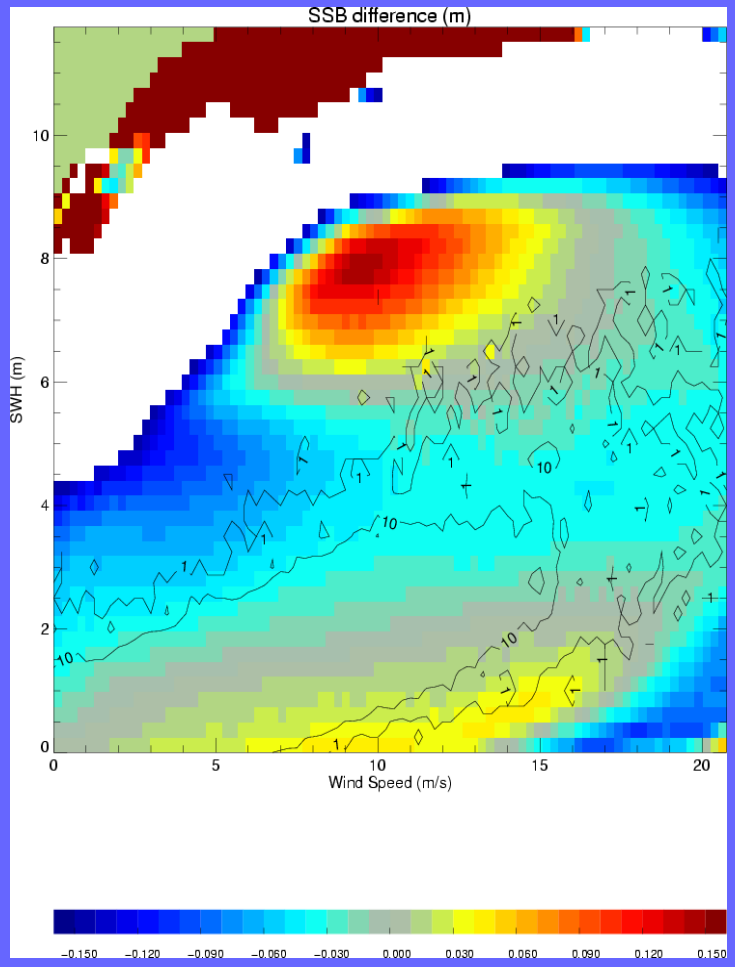
- Influence of the retracking algorithm on the SSB

  => Only deals with the last 15 km off/to the coast

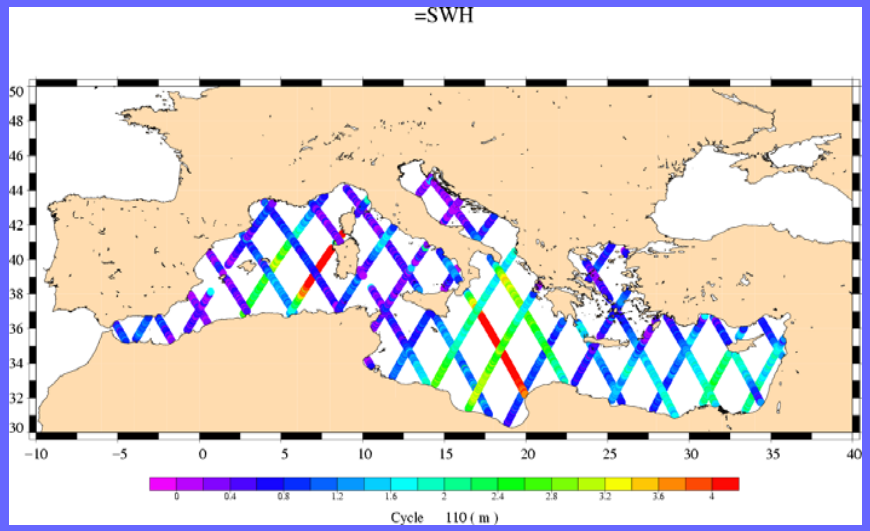


	SSB model	Bathymetry threshold	Number of measurements
All Open Ocean	SSBOCEAN	-1000 m	Close to 14 000 000
Mediterranean Sea	SSBMED	none	94789
Gulf of Lion	SSBLION	none	15327
Gulf of Maine	SSBMAINE	none	15383
Gulf of Gascogne	SSBGASCALL	none	20374
Gulf of Gascogne	SSBGASC	-3000 m	12035
Patagonian shelf	SSBPAT	-1000 m	77458

Mediterranean Sea



SSB difference with respect to open ocean SSB (SWH,U) obtained by direct method with SWH smoothing



Along track SWH for Jason-1, Cycle 110 (Jan. 2005)

Coastal SSB method evaluation collinear vs. direct (crossover has too few points)

Direct method

- Time span for averaging
- Correlation between storm surge, coastal setup and dependent variables
- Mss error
- Will dynamic topo. avergae out in small region
- All missions more feasible

Collinear method

- Time span for averaging
- Sensitivity to other correction errors at 10 day time step (tides, IB, …)
- Coverage of the dependent variable data space

Problems, challenges, questions

- Evaluation of model development methods
- Coastal SSB error characterization (includes metrics) versus what we can do on open-ocean
- Any error in SWH, U10 will directly affect any SSB model - so coastal filtering is clearly needed
- Need to evaluate the tradeoffs between regional altimeter-only SSB models (SWH, U10) versus inclusion of wave model data (coastal wave model data quality?)
- Choice of study regions
- May be wave/current and breaking wave interactions that fall outside analysis capabilities

Extra Material: Coastal SSB

Is there reason to believe that the global open-ocean SSB correction will be inaccurate in coastal regions?

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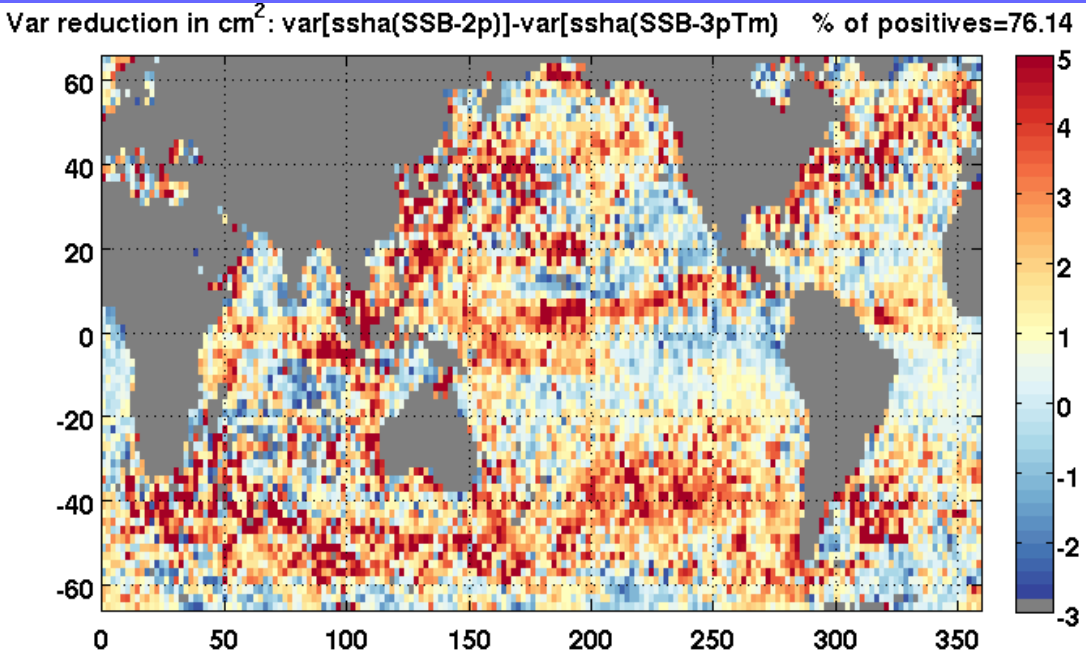

What is the accuracy and coastal correlation length scales of SWH and wind speed and hence of potential variability in the SSB correction?

a) Accuracy issue can be taken up with coastal SWH group and retracking group

b) Length scales - gets to regional wind and wave regimes and wave/current interaction zones….

Which correction is best for coastal applications?

Consensus:

a) we don’t have any to choose from yet - new topic

b) Choice of model estimate method(s) are under discussion - a critical issue

c) Open-ocean model is the present fall back - can we bound the error?

What is our group recommendation regarding an SSB correction approach that bridges multiple altimeter missions?

EARLIER SLIDE - Do we need to clarify understanding of EM bias, the skewness bias, and the instrument bias within the overall sea state bias models?

Do we need custom SSB models for each satellite?

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Why not use altimeter Ku-band σ_o rather than wind speed in the empirical SSB models?

Pros:

removes possibility of spurious correlation between wind speed and SWH in NP SSB models

leaves one with clearer means of comparing one satellite radar GDR product (sigma0) to another and hence the role that variable might play in intersatellite differences

Cons:

SSB model heritage and some aspects of physical modeling of EM bias are tied to wind speed

Recommendation: ?

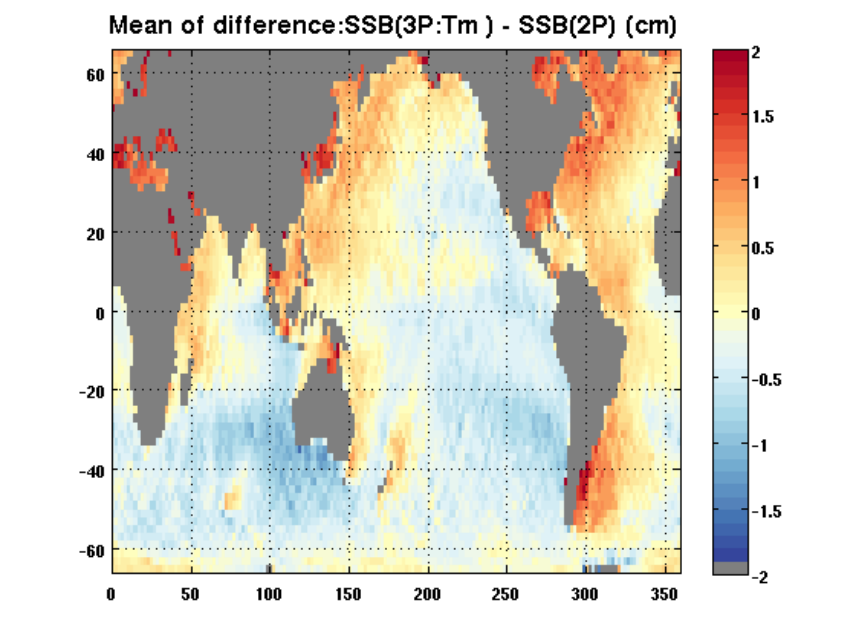
SSB Models developed using WaveWatch 3

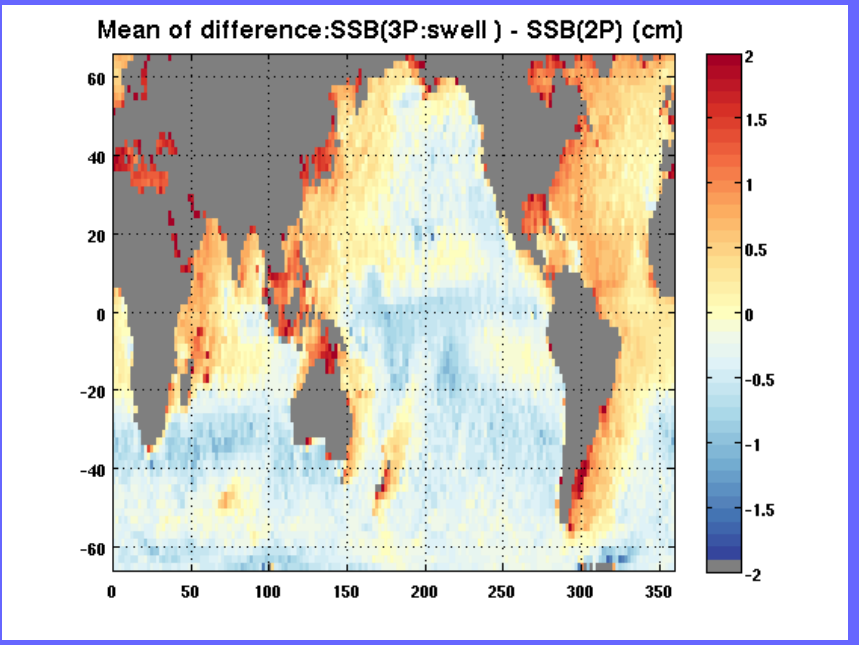
Two models under test (UNH/CLS/CNES collaboration)

SSB_Tm = *F* [SWH, U10, mean_period_WW3]

SSB_Swell = *F* [SWH, U10, H_Swell_WW3]

Both models show improved skill (variance reduction) at all latitudes AND the potential to improve SSB in varying coastal zone wave climates.



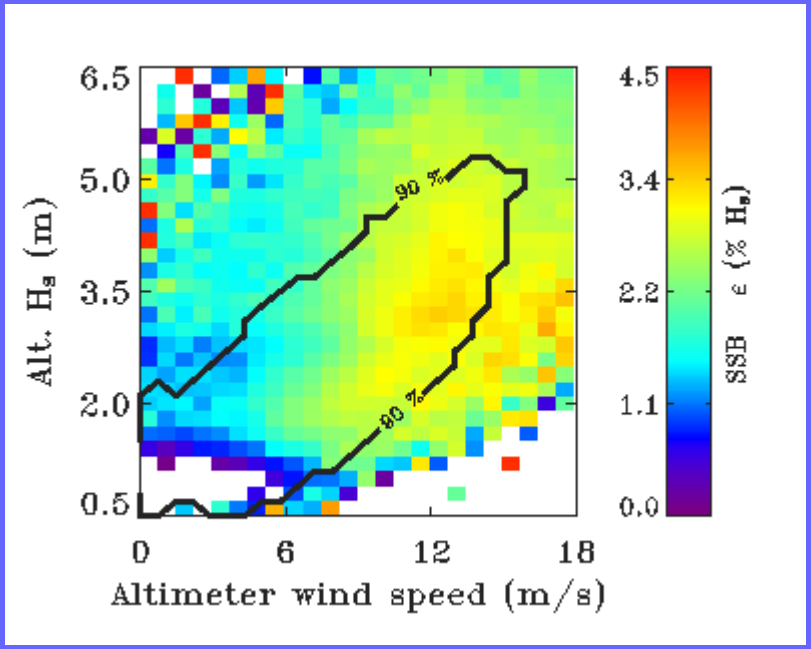


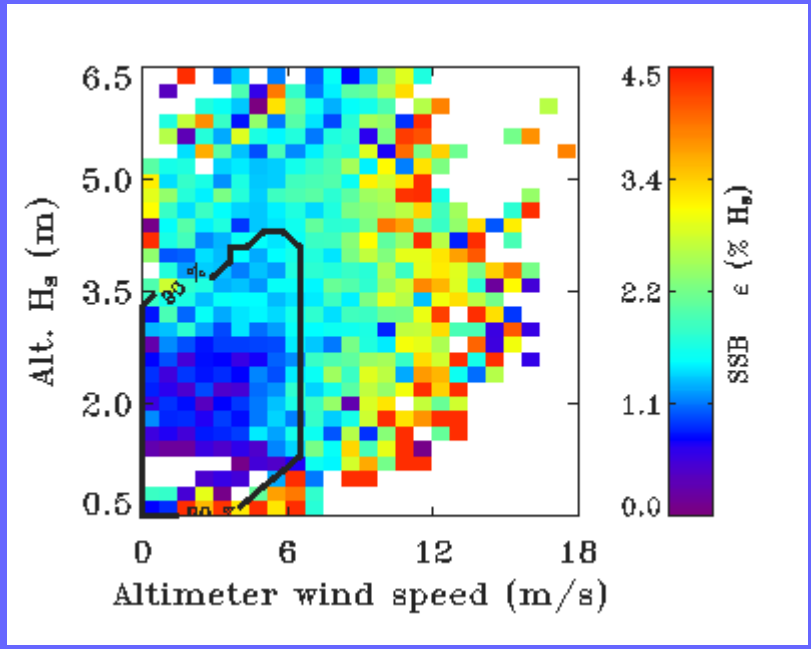
Limiting case – swell dominated

$E_{wind\text{-}sea} / E_{tot} < 0.03$

$E_{wind\text{-}sea}$ from wave model

E_{tot} from altimeter SWH



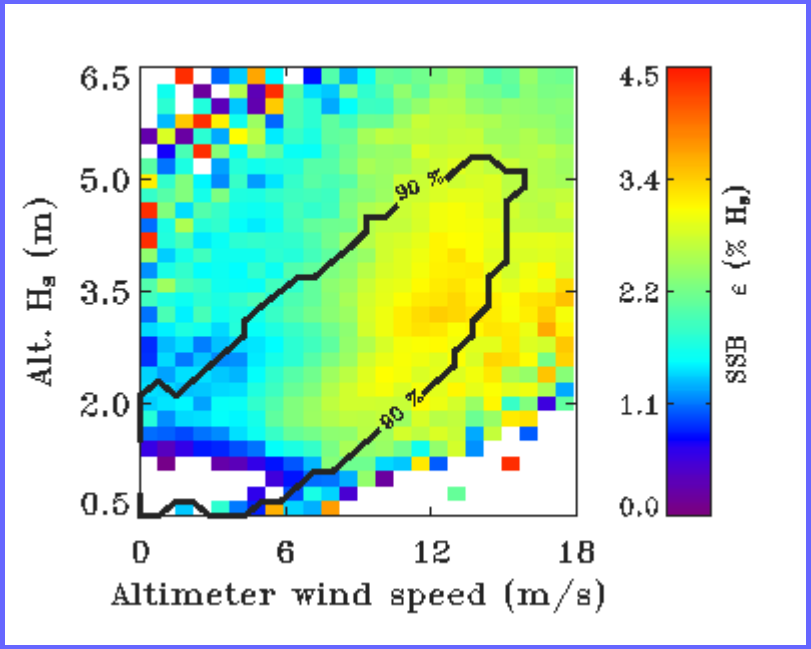


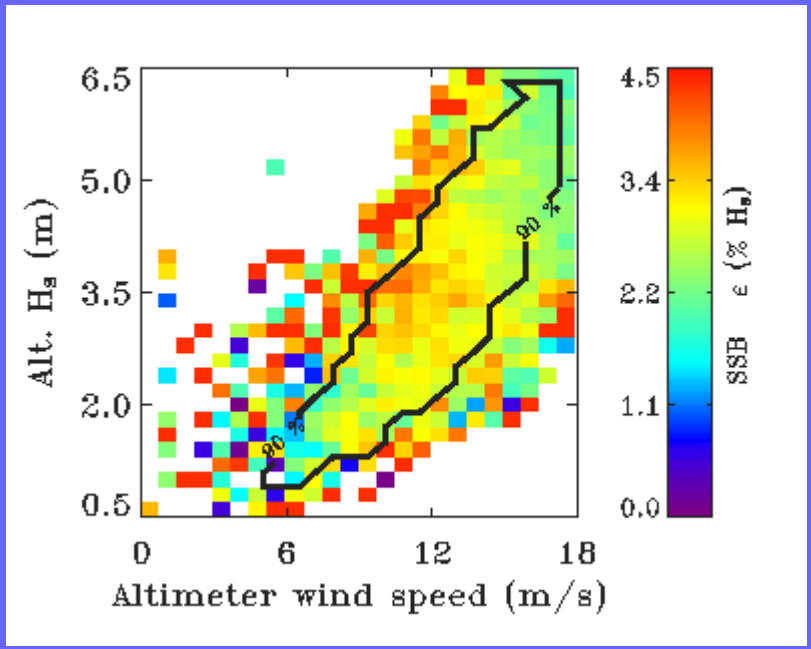
Limiting case – wind sea dominated

$E_{wind\text{-}sea} / E_{tot} \sim 1.0$

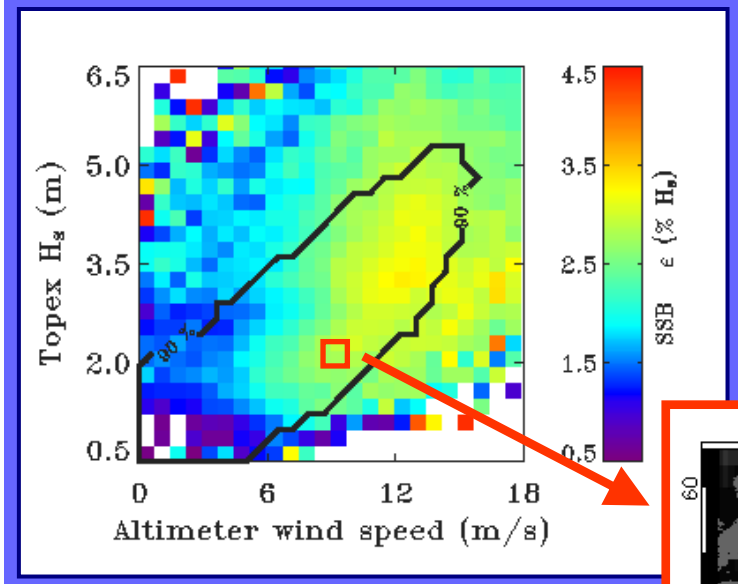
$E_{wind\text{-}sea}$ from wave model

E_{tot} from altimeter SWH

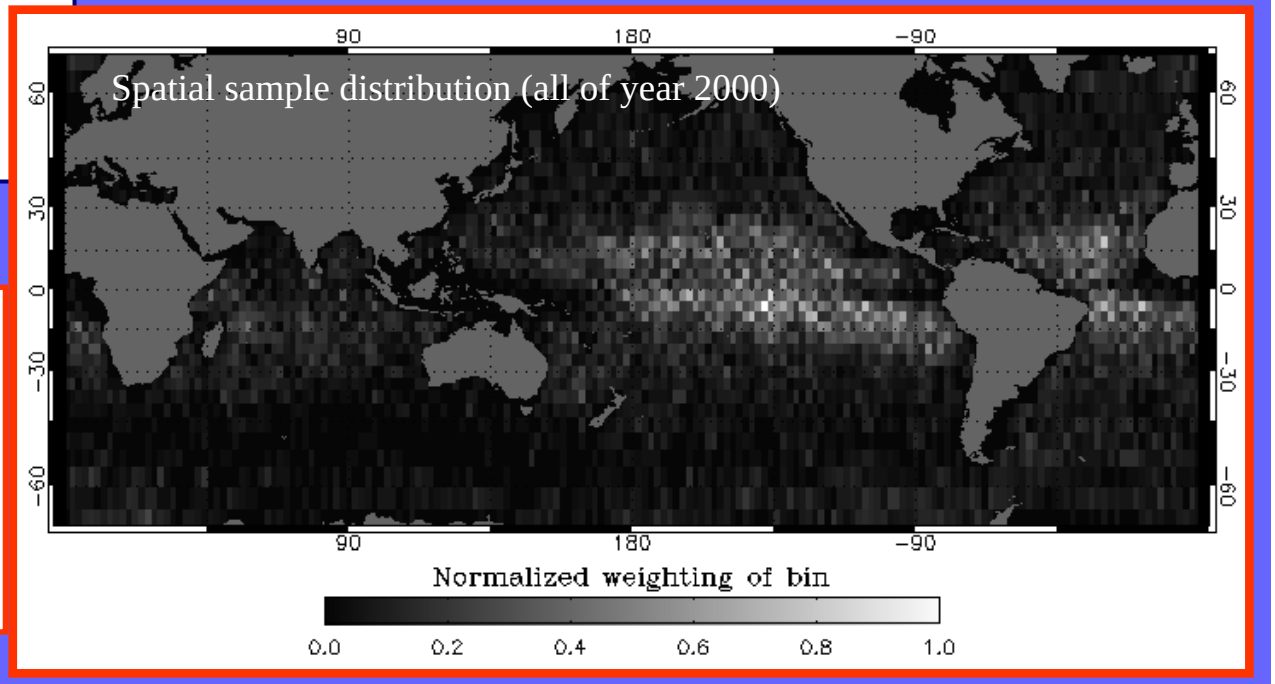




SSB determination using SLA approach : **should consider equalization during averaging!**



Any point in SLA-averaged domain is subject to SSB error (bias) if contributors weighted too strongly to static dyn. topo.



Population dist. for points having:

SWH= 2.0 m

U_10= 8.0 m/s

SSB determination using SLA approach : consider equalization during averaging

Calculated SSB differences

- Spatially-equalized the input data at each SSB domain grid point prior to SLA average

- Difference shown for three different wave heights. Systematic differences are primarily due to coherence between static SLA patterns and (SWH_i, U_10_j) during one year period.