# Direct TOPEX Sea State Bias Estimation

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## Abstract

A direct SSB estimation approach is presently described, it takes advantage of the long-term precision of the TOPEX/ Poseidon mission. The SSB estimates are obtained with a simple bin-averaging procedure across the observed (U, SWH) correlatives domain by using global TOPEX sea surface height residuals. Results from a 3-year global average mirror the latest nonparametric model solution from satellite crossover differences [Gaspar et al., 2001]. This validation via intercomparison corroborates these two separate empirical realizations of the TOPEX SSB. It is recognized that this new alternative requires optimization before its full potential can be assessed but it should greatly ease the study of unresolved basin-scale SSB variation and the examination of SSB residual error associated with long wave properties not measured by the altimeter. Solution for the Poseidon-1 altimeter SSB has also been obtained using this method and will be discussed at the splinter session.

## Method and data processing:

The sea state bias (SSB) range correction model used in satellite altimeter sea level estimation is currently determined empirically by an indirect, satellite range measurement differencing approach. A given sea surface height measurement not corrected for the SSB, SSH, contains the geoid signal ($h_g$), the ocean dynamic topography ($h_d$), the SSB, and other measurement and correction noise sources (w):

$$SSH = h_g + h_d + SSB + w \qquad \text{(Eq. 1)}$$

To resolve the small SSB range noise, the dominant marine geoid signal along with the longer-term change in $h_d$ are eliminated from this equation by differencing precise repeat measurements either along collinear tracks [Chelton, 1994] or at crossover points [Gaspar et al., 1994].

Another approach is to solve for SSB directly by imposing a constant known mean sea level at each observation location, thus eliminating the geoid. This method was rejected in past studies due to noise in developing such reference, but the

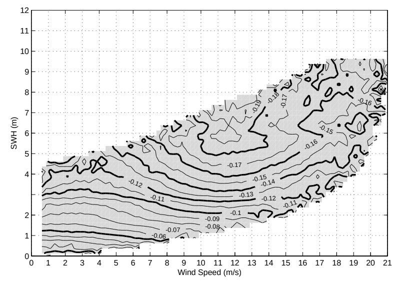



**Fig. 1:** Bin-averaged residual data in the (U, SWH) domain with a bin width of 0.25 m/s in U and 0.25 m in SWH over a 3-year period (cycles 21-131). The extent of the domain is shown by the shaded area and corresponds to the data rich zone. Contours are provided to visualize the features. All SSB values are shifted upward 1.6 cm.

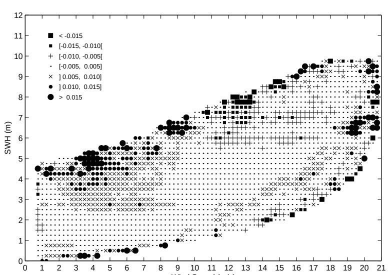
## Method and data processing (cont.)

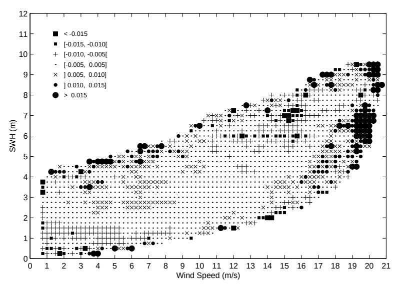
TOPEX/Poseidon mission has now provided 10 years of precise measurements along the same 254 ground tracks across the global ocean. The TOPEX/Poseidon georeferenced altimeter surface height compilation [Koblinski et al., 1998] provides much of the data needed to revisit direct inversion of Eq. 1, including the necessary mean sea surface reference data set along the TOPEX ground track [Wang, 2001].

An individual height residual, $r_h$, from the mean sea surface (MSS) at any referenced location, k, on an altimeter's ground track is:

$$r_{h,k} = SSH_k - MSS_k = SSB(U, SWH)_k + e_{SSB,k} + e_k \qquad \text{(Eq. 2)}$$

where $e_{SSB,k}$ is the mean SSB modeling error carried in the $MSS_k$ estimate. This term is assumed to be a small constant value over much of the (U, SWH) domain. $e_k$ is a composite noise term that carries dynamic sea level variability and other error components (e.g. in sensor range corrections, interpolation errors, orbit, tides, atmospheric terms, etc...) built into the MSS estimate. The method's success depends on randomness in $e_k$.



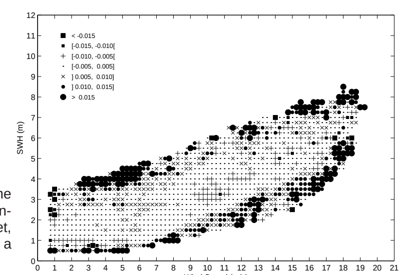




**Fig. 2 :** Difference between the shifted bin-averaged map and the Gaspar et al. [2001] nonparametric model grid (in meters). The bin-averaged estimates were computed by using (left) a 3-year subset, cycles 21-131; (middle) a 1-year subset, cycles 21-57; and (right) a 10-cycle subset, cycles 75-85.

## Results

This is the first reported direct (non-differenced) realization of TOPEX on-orbit sea state bias impacts. Direct comparison with the Gaspar et al. [2001] model (NP) grid shows that the difference between the two methods is less than 1.0 cm for 86% of the SSB estimate bins and 57% of bins differ by less than 5 mm. Both NP and direct methods are obtained over the same 3-year averaging period. This high level of agreement is exceptional and helps to corroborate this recent nonparametric model. Moreover, agreement tends to validate the use of this alternate approach to estimate SSB. The far edges of the comparison domain do exhibit some higher values and these differences are yet to be explored. The method provides stable results in a short period of time as evidenced by the good agreement between the NP result and the direct mapping done over a 100-day (10 cycles) period (Fig. 2, right), especially in the central data-rich zone of the (U, SWH) domain. Our results suggest that there is enough data collected within 100 days to have a first reasonable estimate of the SSB mapping in the very rich zone of the (U, SWH) domain while a 1-year period would provide a complete model.

## Conclusion

It is recognized that this new approach requires optimization before its full potential can be assessed. However, there is no question that the direct method presented here is a much simpler technique to implement. Moreover, one is now working directly with the height residual and its correlatives, rather than the time-dependent differences in each term.These points together suggest the benefit that such direct assessment may have in speeding studies to refine physical insight and empirical models for this sea state effect. For example, direct regression of TOPEX height residuals against global model-derived long wave products, unobtainable using the altimeter, are in progress. It is also shown here that an empirical sense of the SSB over most of the (U, SWH) domain can be obtained with as little as 100 days of data. This same sparse sampling approach can be applied spatially, where basin-scale evaluation of the sea state impacts now becomes more tractable.

## References

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