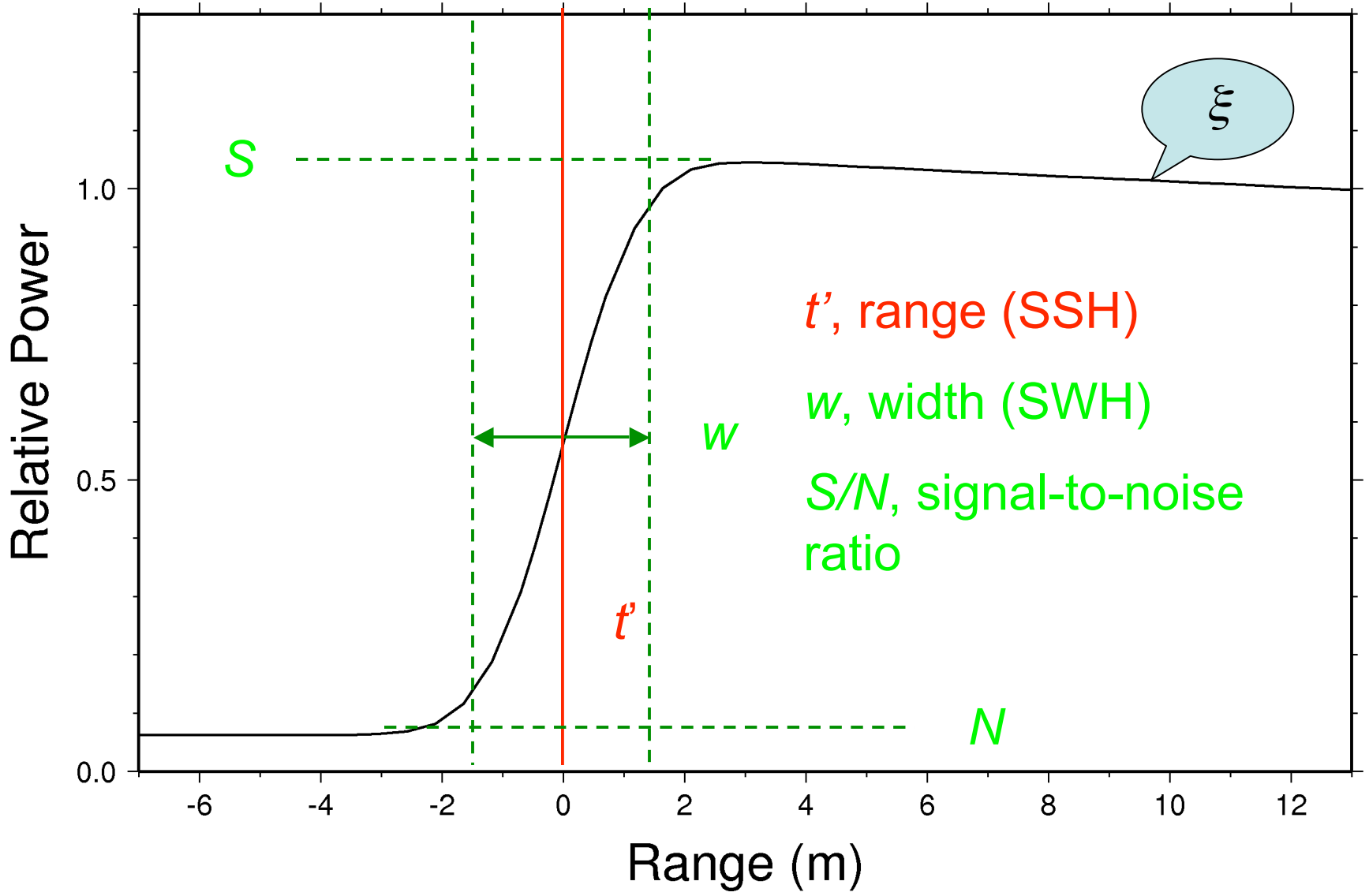
Monte Carlo demonstrations of a sea state bias induced during altimeter waveform retracking

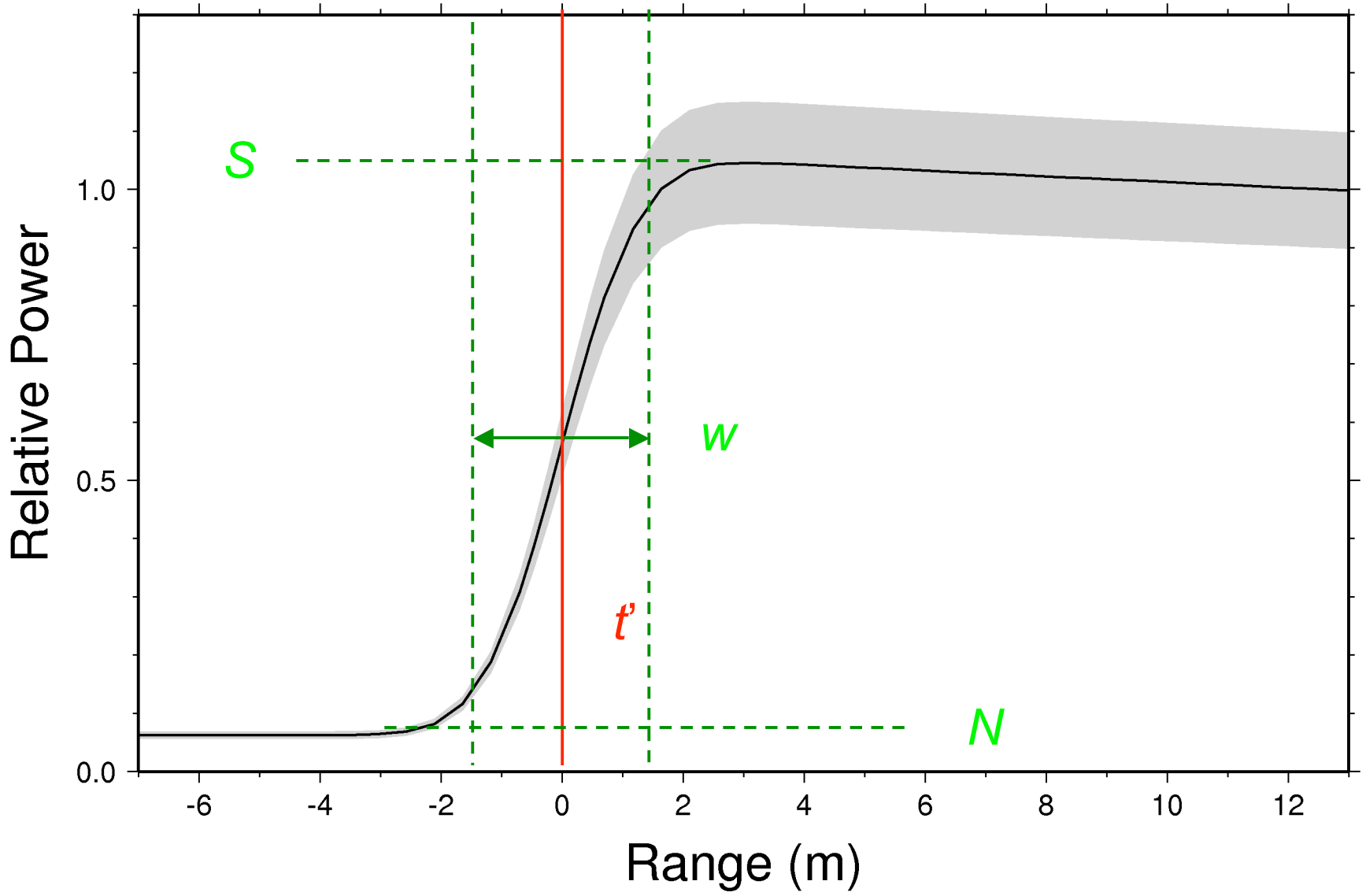
Walter H. F. Smith

NOAA Lab for Satellite Altimetry

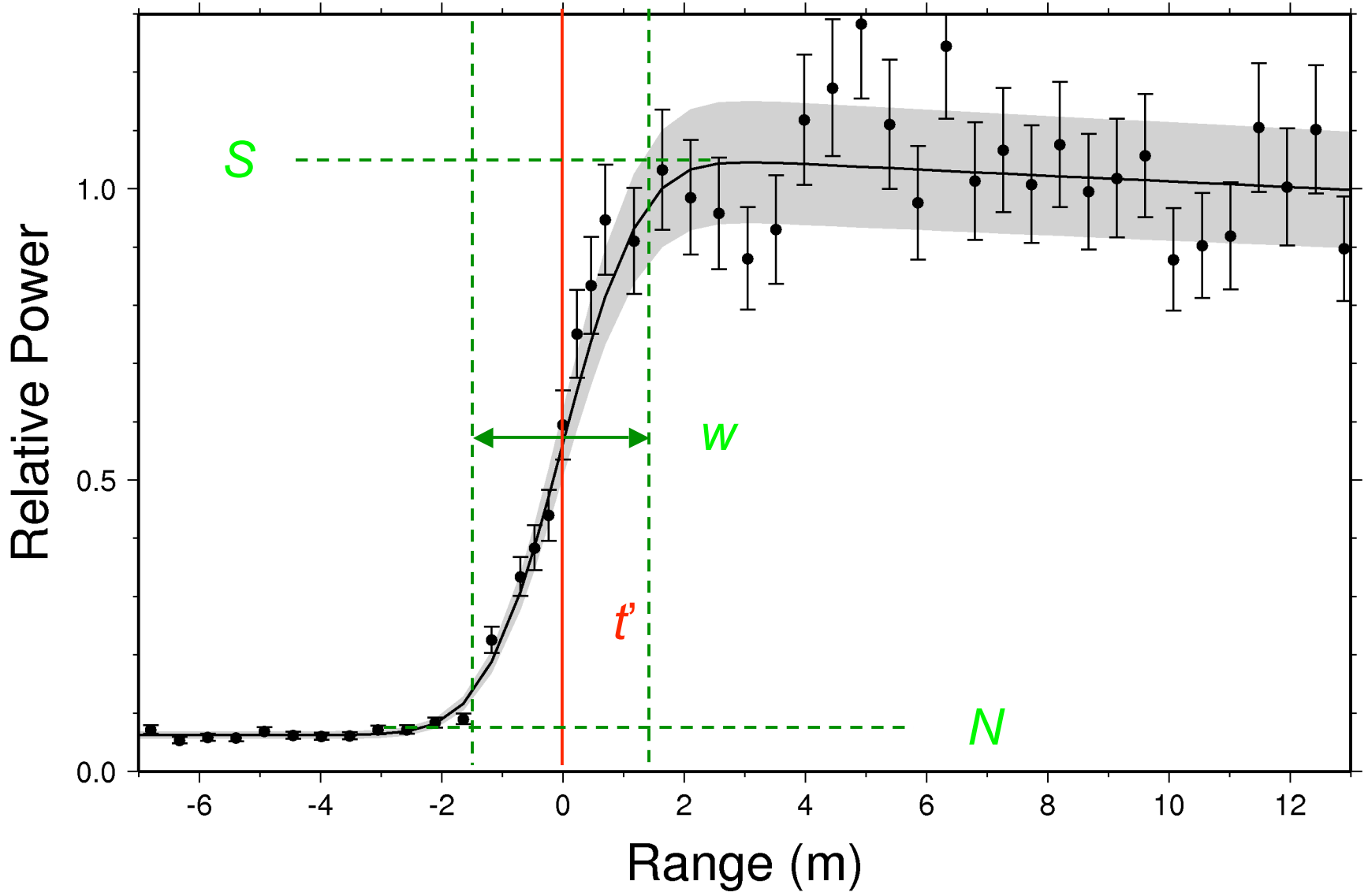
Expected waveform power



Expected waveform error



Waveform realization



Least-squares fit (MLE)

Minimize

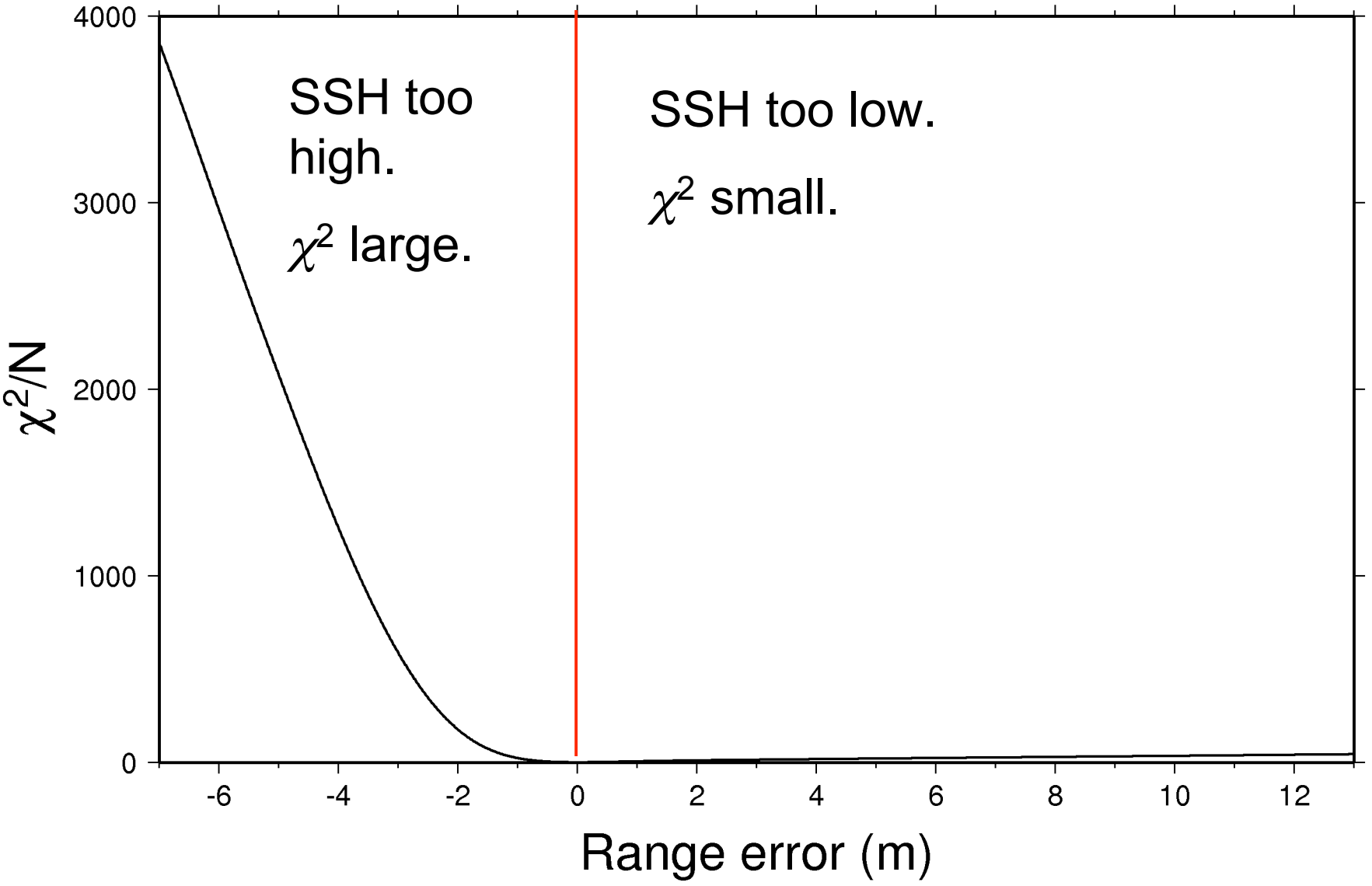
$$\chi^2 = \sum_{gates} \left[\frac{p_i - \mathrm{model}\left(\mathrm{t_i}, t'_{est}, S, N, w, \xi\right)}{e_i} \right]^2$$

With the error in the ith waveform gate sample weighted proportional to the sampled power

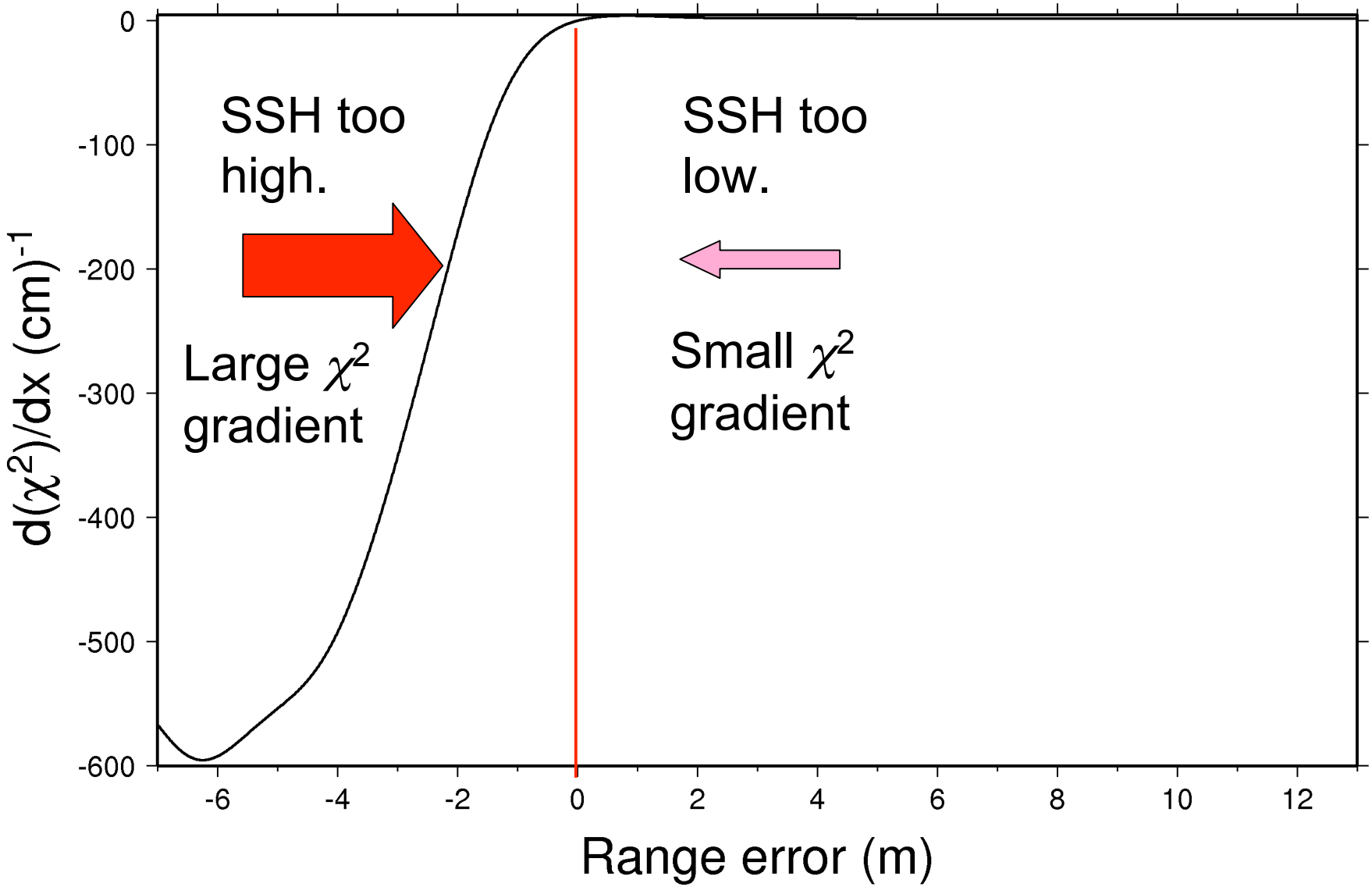
$$e_i = p_i \Big/ \sqrt{\#\,\mathrm{waveforms}}$$

This gives most of the weight to the pre-arrival part of the waveform.

Chi-square


SSH too high.
χ^2 large.
SSH too low.
χ^2 small.
χ^2/N
4000
3000
2000
1000
0
-6
-4
-2
0
2
4
6
8
10
12
Range error (m)

∂(Chi-square)/∂(range)



Monte Carlo Experiment

Generate a mean waveform with $t' = 0$ and all other parameters (S, N, w, ξ) fixed to known values.

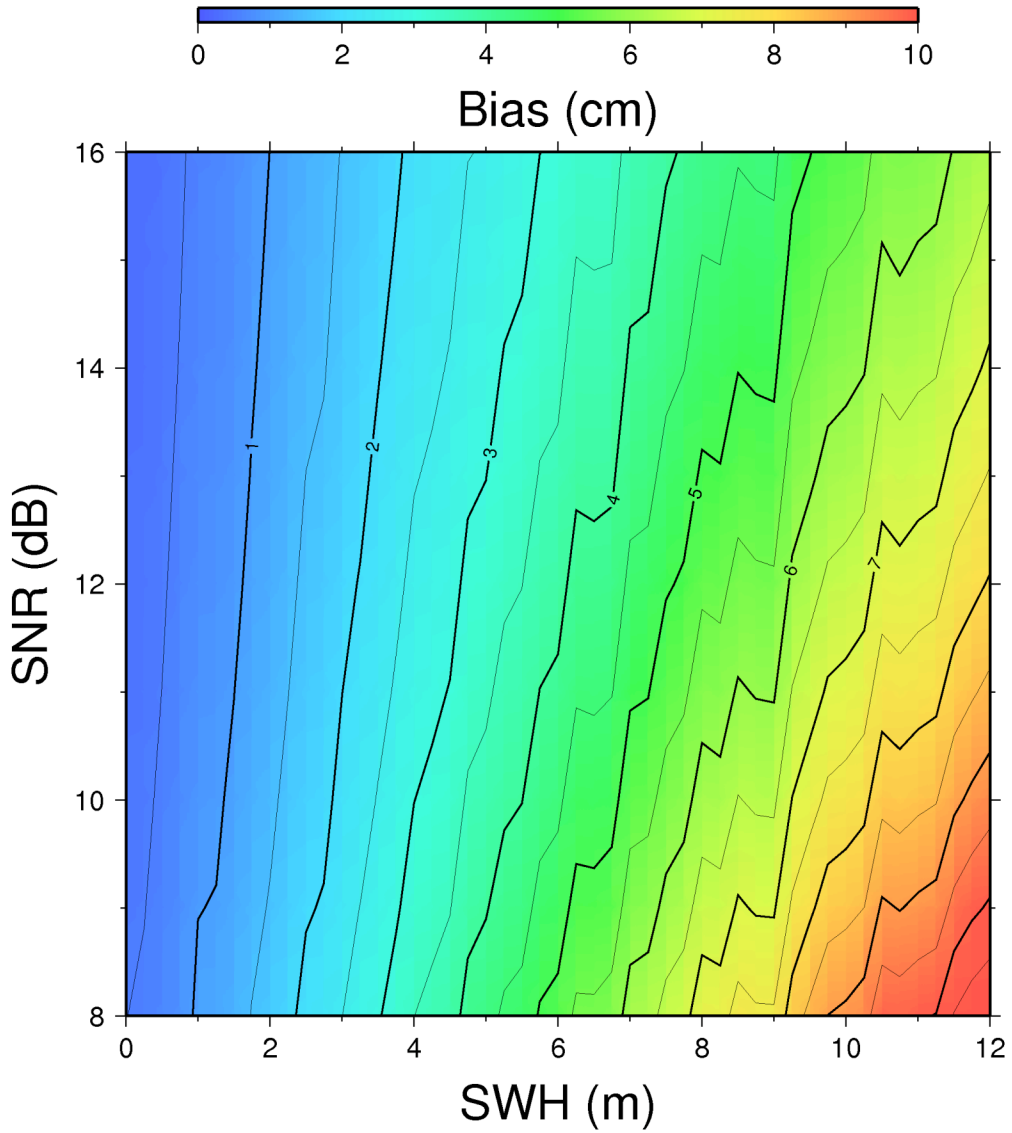
Generate many random realizations of this waveform, adding random error proportional to power / $\sqrt{}$#.

Retrack each realization, holding S, N, w, ξ fixed to the correct values and solving for t'_{est} that minimizes χ^2.

The mean of all such t'_{est} is the SSB for that particular choice of waveform parameters.

I repeat this experiment for different values of w (SWH) and Signal-to-Noise-Ratio, SNR = S/N.

Retracking-Induced SSB



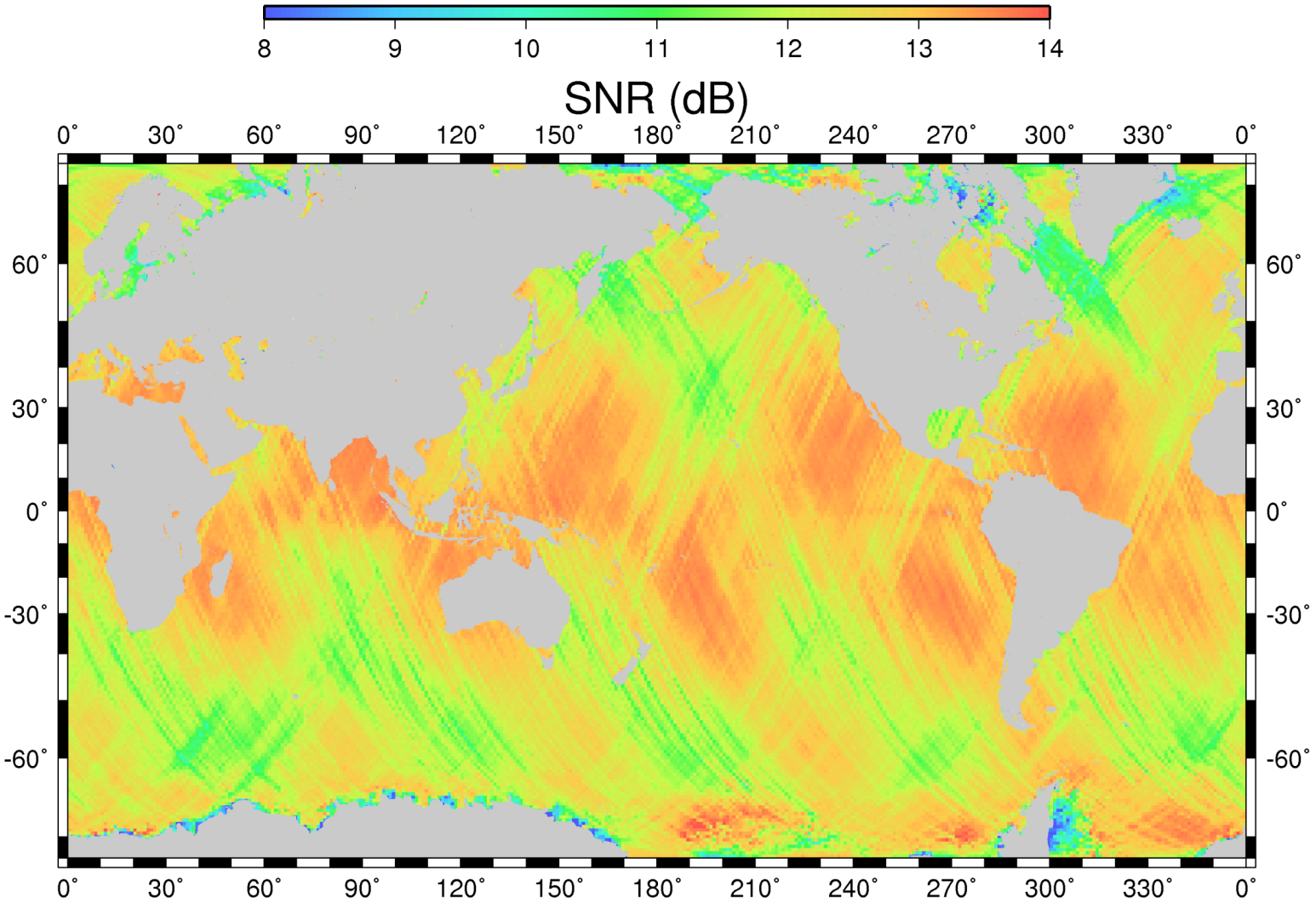
SSB is consistently positive (range too large, sea level too low).

SSB increases with SWH, ~ linearly.

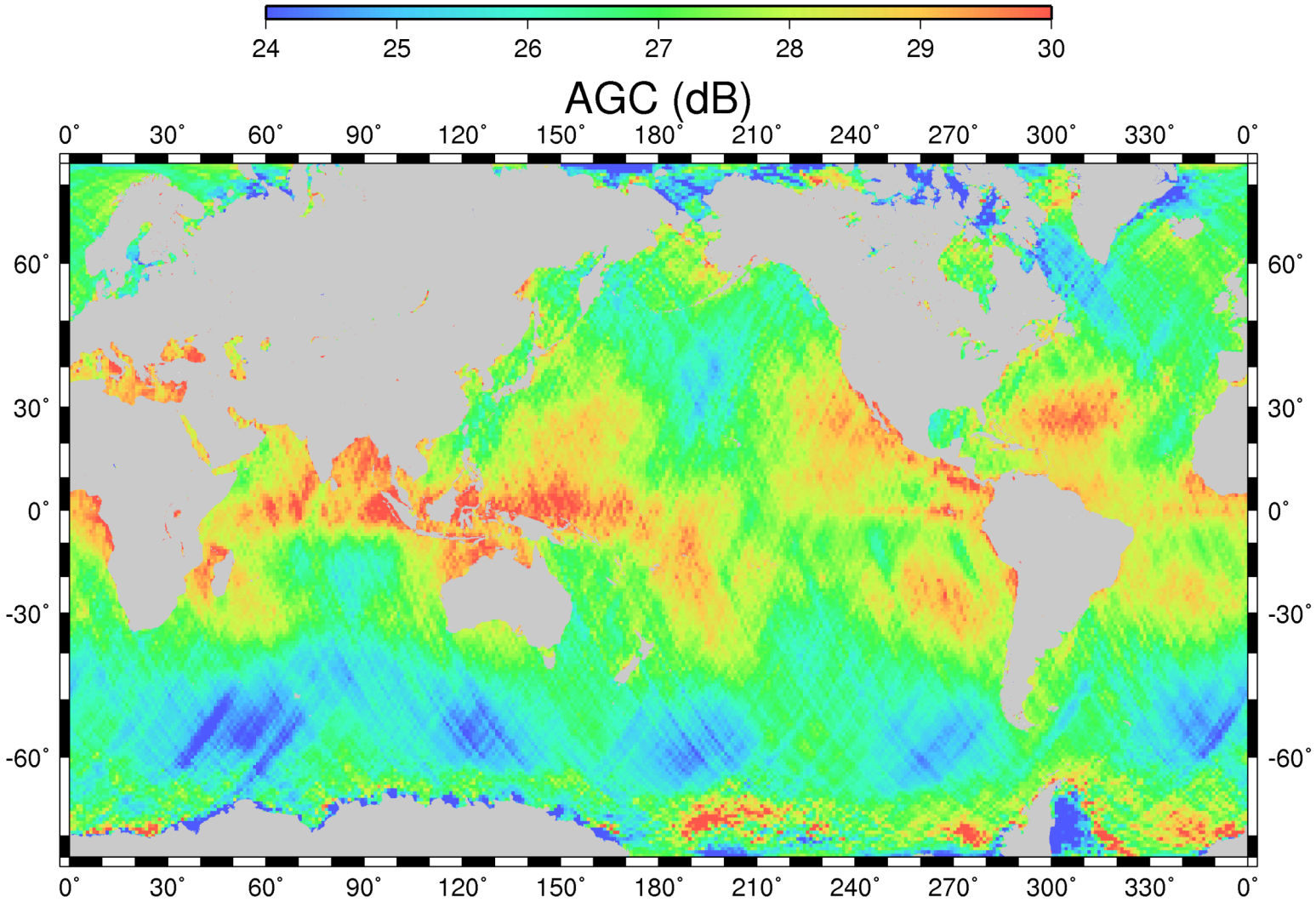
d(SSB)/d(SWH) decreases as SNR increases (decreases as σ_0 increases?).

Results shown are for Geosat.

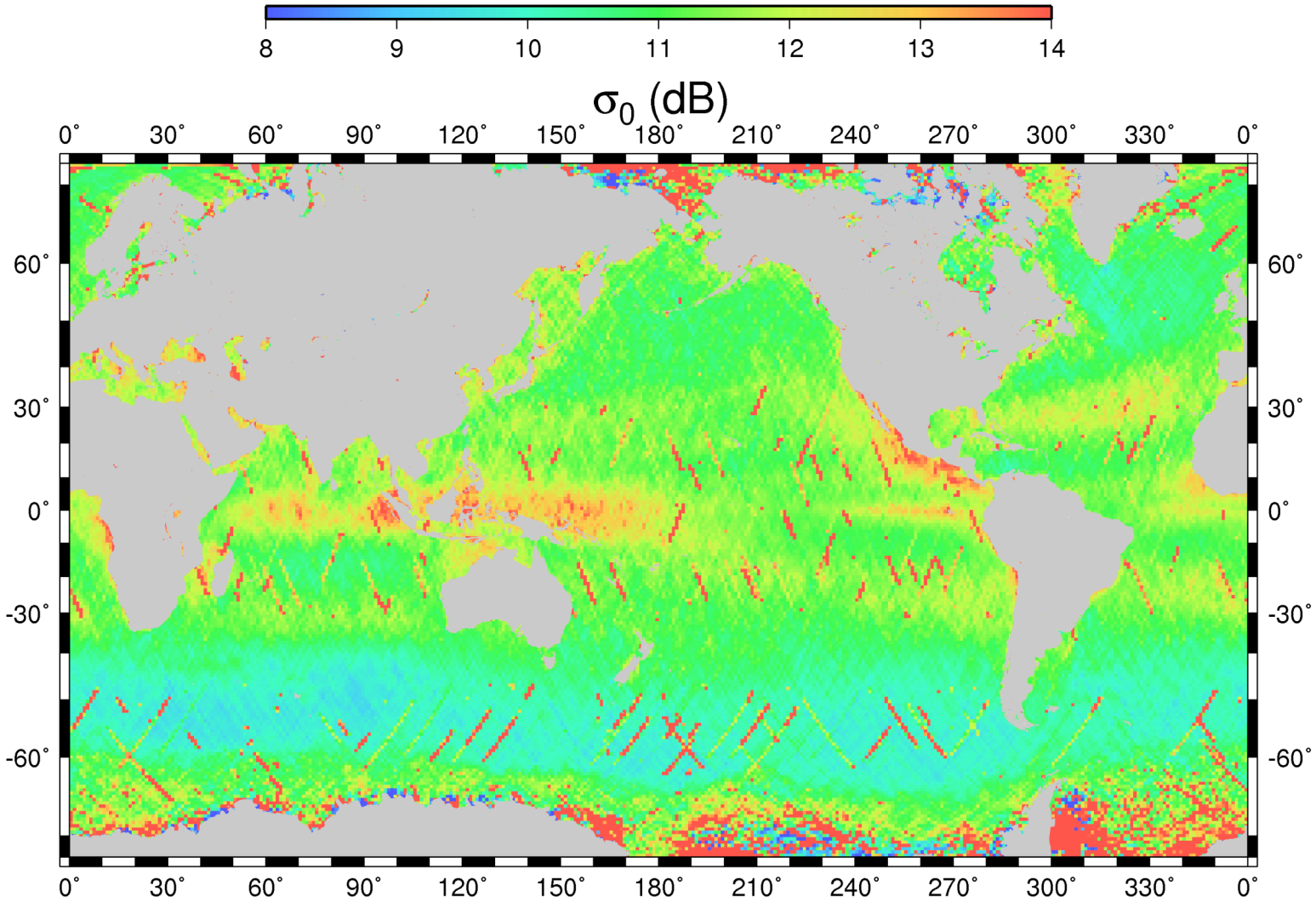
SNR varies geographically



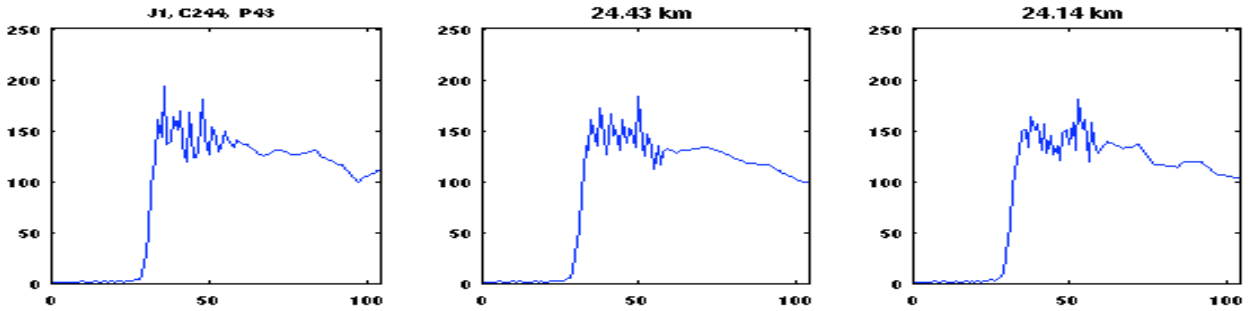
SNR varies with AGC…



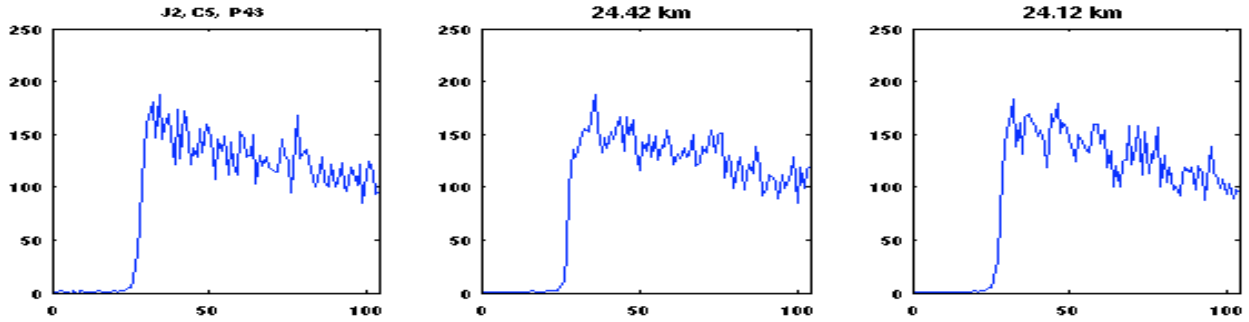
…AGC varies with σ_0



Instrumental features



J1 C244
P43



J2 C005
P43

Chi-square depends on instrumental features: # of gates before/after track point, noise characteristics before/after track point. [Waveforms from Wm Emery.]

Conclusions

Retracking introduces an apparent SSB.

It depends on SWH and may be of order 1% of SWH.

It depends on SNR, and thus is geographically correlated, and also correlated to σ_0.

It should also depend on the algorithm used to minimize the least-squares misfit, and on the weighting used.

It should depend on the error characteristics of each altimeter instrument.

Further Monte Carlo simulations should be done, using the actual retracking algorithm and waveform characteristics of each altimeter.