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Progress in Retracking TOPEX Data for the Climate Data Record

OSTST October 2013

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Outline / Overview

- NOAA Climate Data Records program task: “Generation of Altimeter Climate Data Records Using Retracking and Updated Corrections”
- TOPEX Overview, History
- New Results on Alt-A PTR Changes and Cal Data
- TOPEX Climate Data Records Plan

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TOPEX Overview / History

- TOPEX standard processing did not include retracking
  - Quantities were estimated onboard with “adaptive gate” (SWH dependent) tracker using sums of power in waveform gates
  - Ground processing corrections for pointing angle and SWH from simulations
- Alt-A had changes in Point Target Response (PTR) beginning about Cycle 140 (mid-1996)
  - Changes became clear in 1997 as apparent increase in SWH
  - Switch to Alt-B in Feb 1999 (Cyc 236). No apparent changes in Alt-B

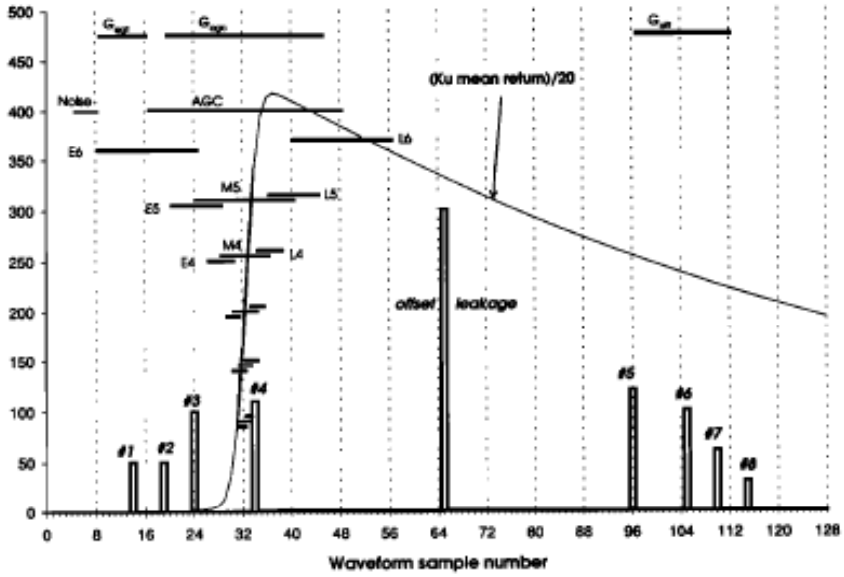

Figure 6. TOPEX Ku altimeter gates, mean return, and center locations of waveform leakage spikes.

- Leakages (x20) in the TOPEX Alt-A waveform from Hayne et al., 1994, JGR, ***99,*** 24,941.
- Need correction in processing via masking or “weights” on WF gates
- Move with range rate giving North/South Ascending/Descending (“toward” / “away” Eq) differences
- Onboard gates used to estimate the same parameters obtained from retracking shown as bars

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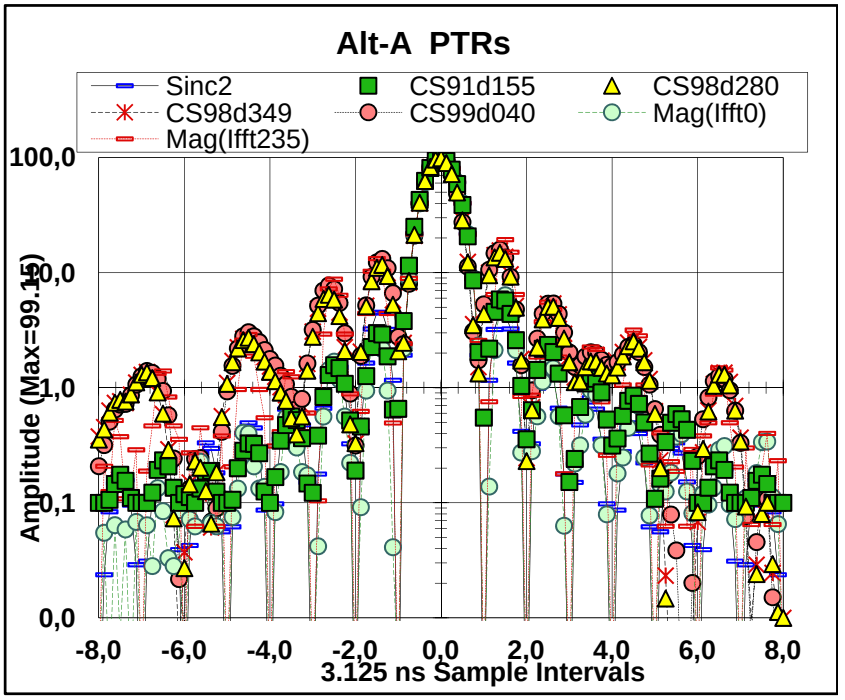
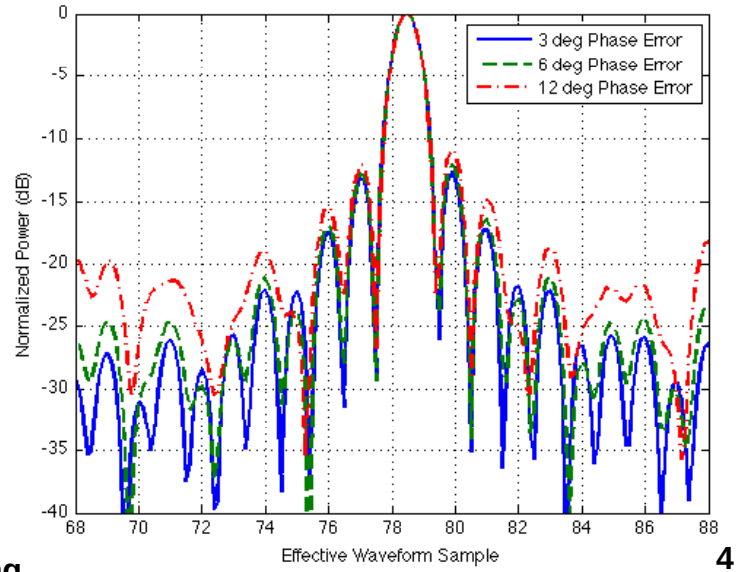
TOPEX Alt-A PTR Changes (1 of 2)

- TOPEX Alt-A PTR degradation – increase and distortion of sidelobes likely caused by I/Q phase difference
  - "Cal Sweeps" done only late in 1998
- Reproduced Jensen analysis
  - Reproduced Jensen analysis. Fig shows I/Q phase diff of 3, 6, 12 deg
  - Effect depends on center location. BUT, observations and previous simulations by G. Hayne indicate that effect is not as large as suggested by model
  - Modeling is not adequate to generate PTRs
- TOPEX Cal1 data contains bare Nyquist sampling of PTR





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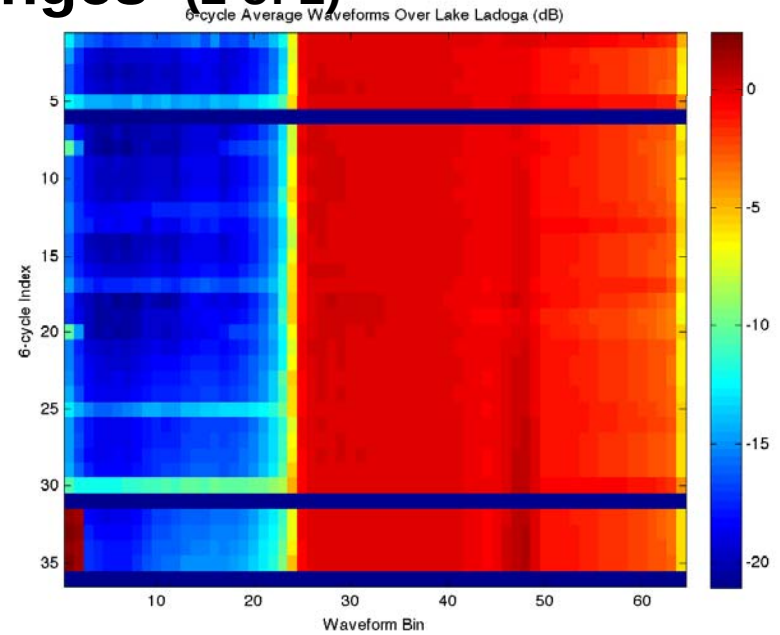
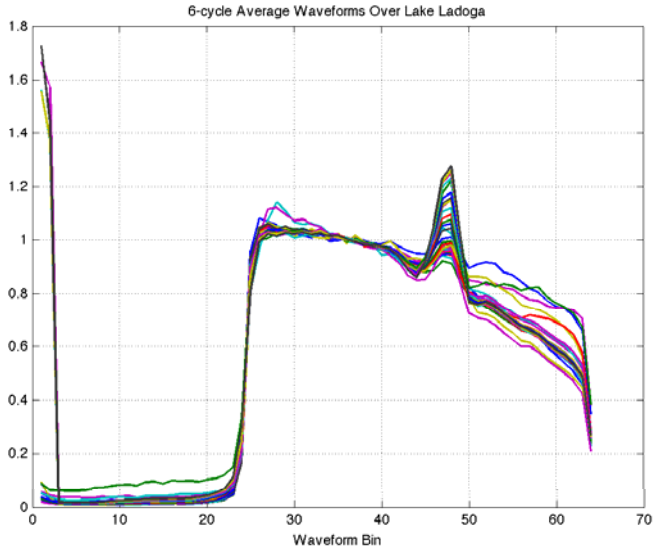
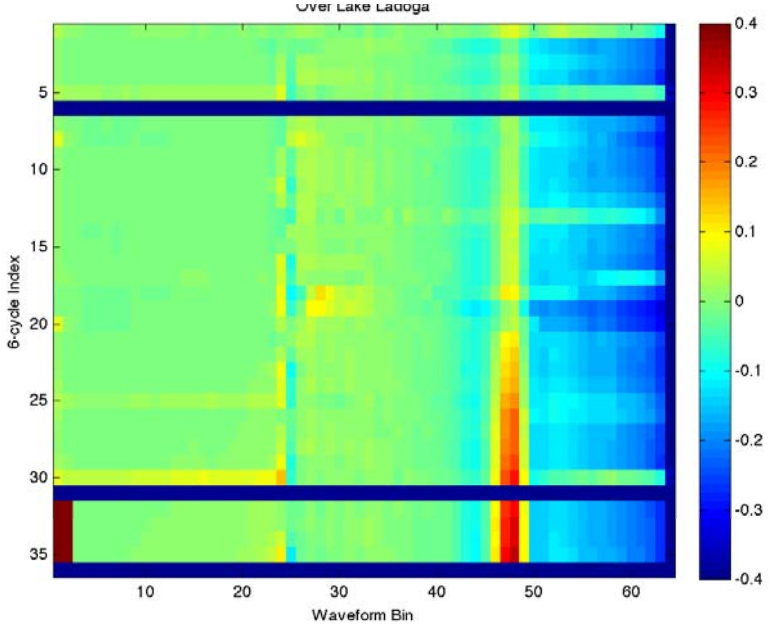
TOPEX Alt-A PTR Changes (2 of 2)

- Investigated changes in the PTR by using data over Lake Ladoga in western Russia. 6 Cycle averages of waveform
  - Below: Line plot – "zero frequency" leakage is prominent
  - Upper Right: Full waveform
  - Lower Right: Difference from first







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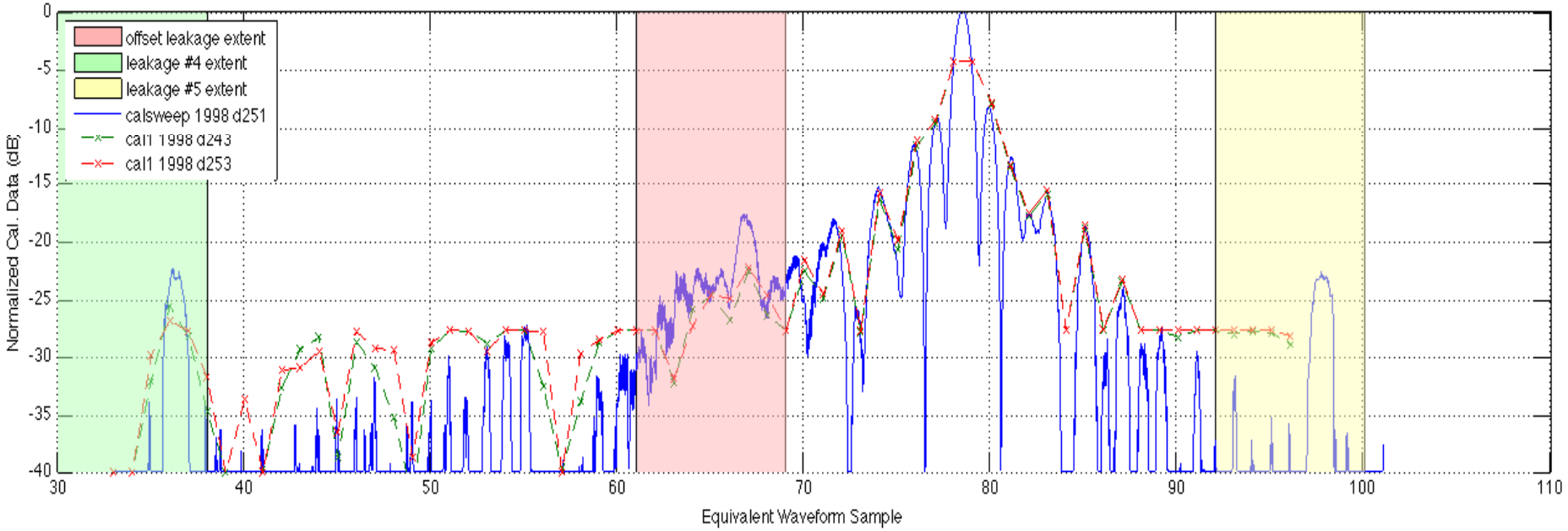
Usable Cal Data

- Revisited Cal data based on review of leakage transfer through Alt signal path
  - Found that data in colored areas are contaminated, should not be used in PTR
  - Limits PTR lobes from Cal data to ~ +/- 7
- Need method to extend PTR to ~ +/-30 lobes consistent with PTR changes (increase in sidelobes, possible missing lobes)
  - Model can guide level change



TOPEX Climate Data Records Plan

- Make new TOPEX RGDR consistent with Jason ver_D (or newer?)
  - Transform format into netCDF similar to Jason. (2009 RGDR available on PODAAC as netCDF)
  - Copy of original GDR
  - Retracking values for range, SWH, attitude (skewness likely to be removed from fits; did not have ocean information)
  - New GSFC orbits
  - New tide models GOT4.7 and ?
  - Improved long period non-equilibrium tides
  - New dry tropo correction and associated MOG2D values
  - Reprocessed TMR data (Shannon Brown: improved calibration, coastal resolution)
  - Updated geophysical fields (MSS, Geoid, etc.)
  - SSB fitted on Retracked Data (with quadrant corrections) – ***Note that this requires making a full RGDR so that SSB does not pick up any orbit, tide, etc. errors***

- Schedule
  - Oct – Dec: Develop systematic PTR generation. Produce sets of test cycles.
  - January 2014 begin bulk Retracking. Collect other data sets.
  - Fall 2014 begin SSB fits - Use Vandemark et als. OSTST set standard for product.
  - Early 2015 products available

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Backup Material

Details

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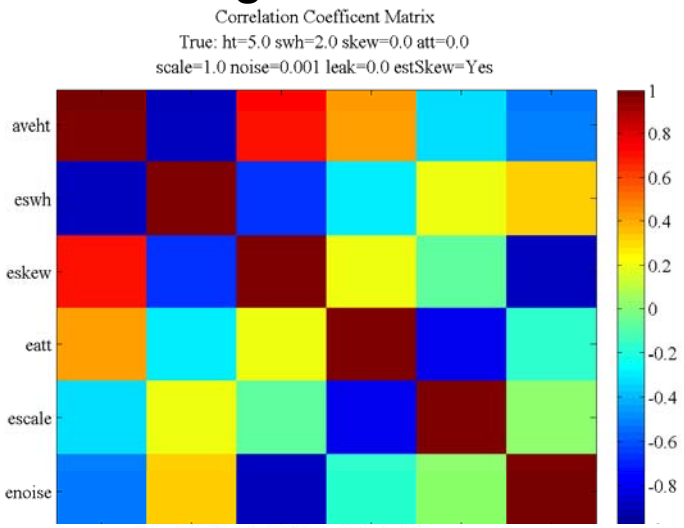
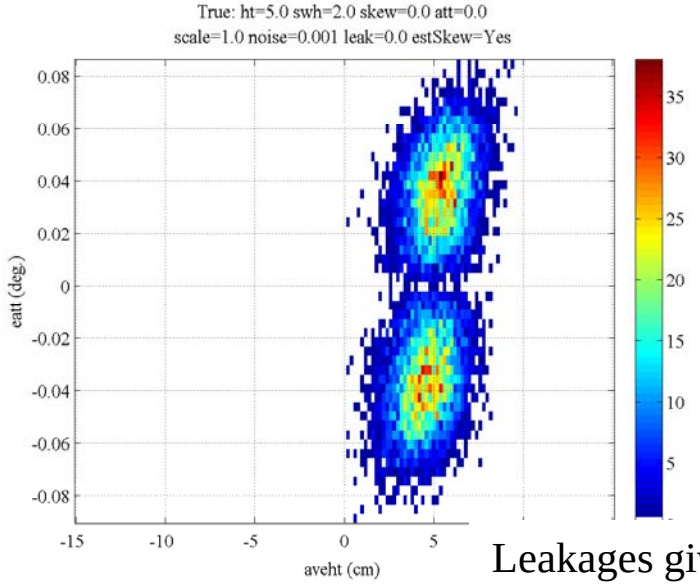
Simulation Results

Parameter Correlation Solving for Skewness





All: SWH = 2 m
Att = 0
Skew = 0
dH = 5 cm

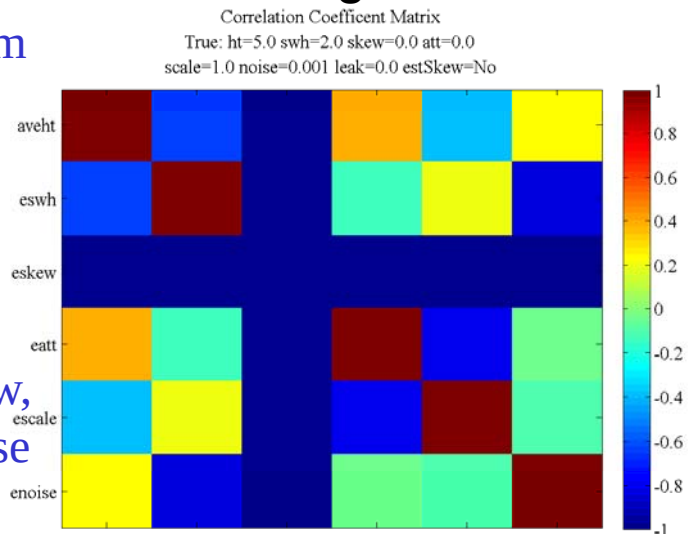
Parameters:
dH, SWH, Skew,
Att, Scale, Noise

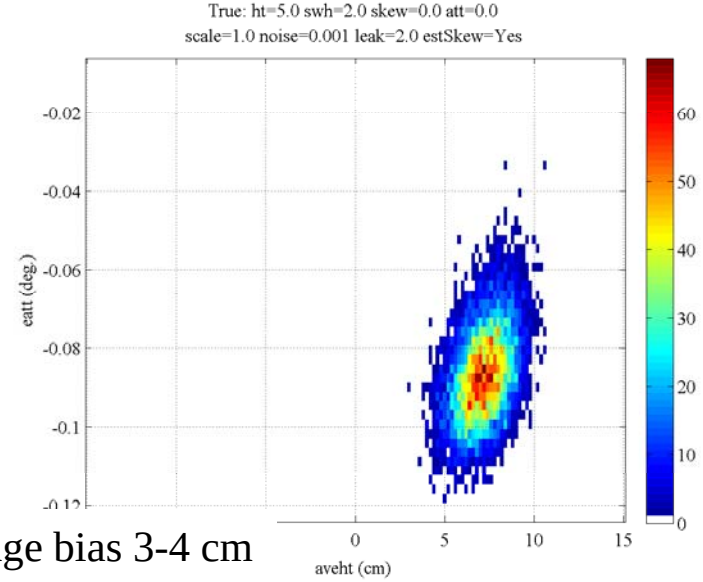
← Leakage = 0

Leakage = 2X →

2D Histogram:
Att / dH

Parameter Correlation Not Solving for Skewness





Leakages give Att2 bias ~ 0.09, Range bias 3-4 cm

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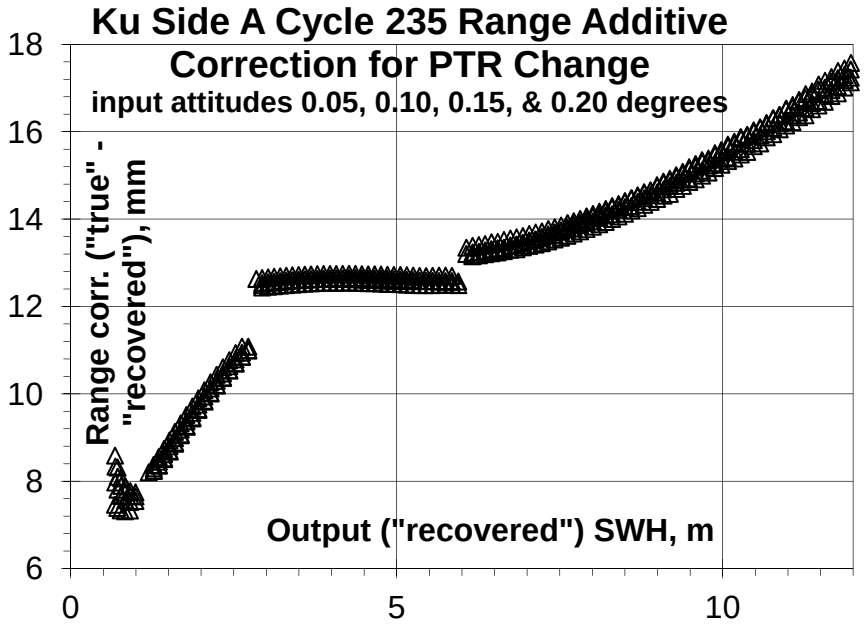
Alt-A PTR Change Simulation

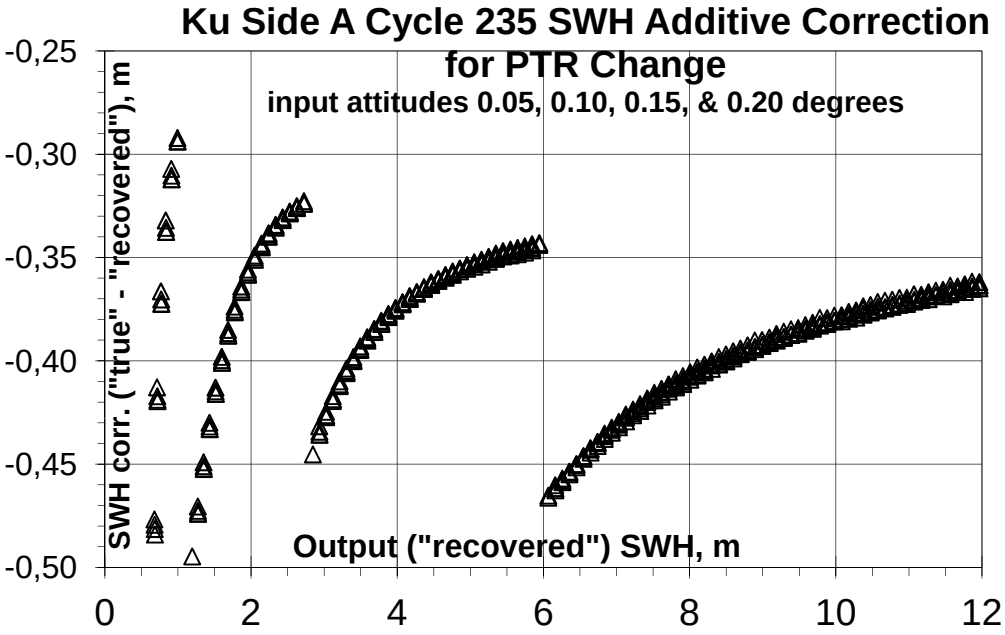
Simulation by G. Hayne (WFF) of change in Range and SWH as a function of SWH for PTR of Cycle 235 (discontinuities reflect internal altimeter function – change in adaptive gate widths).

Left: Range error of ~ 8-13 mm for typical SWH of 1.5 – 6 m.

Right: SWH error of ~ 0.4 m as observed (slide 4).

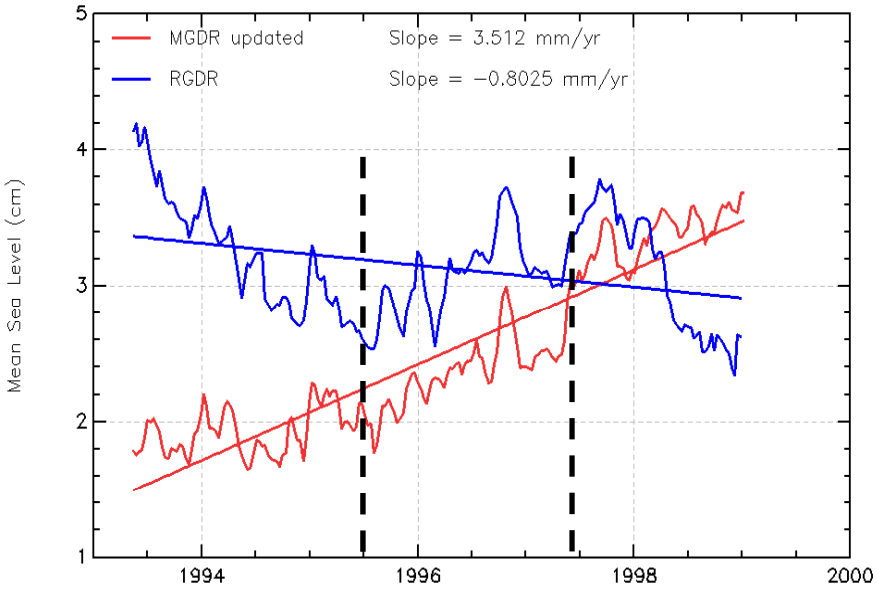
The change in apparent altimeter SWH will also change the calculated Sea State Bias correction.



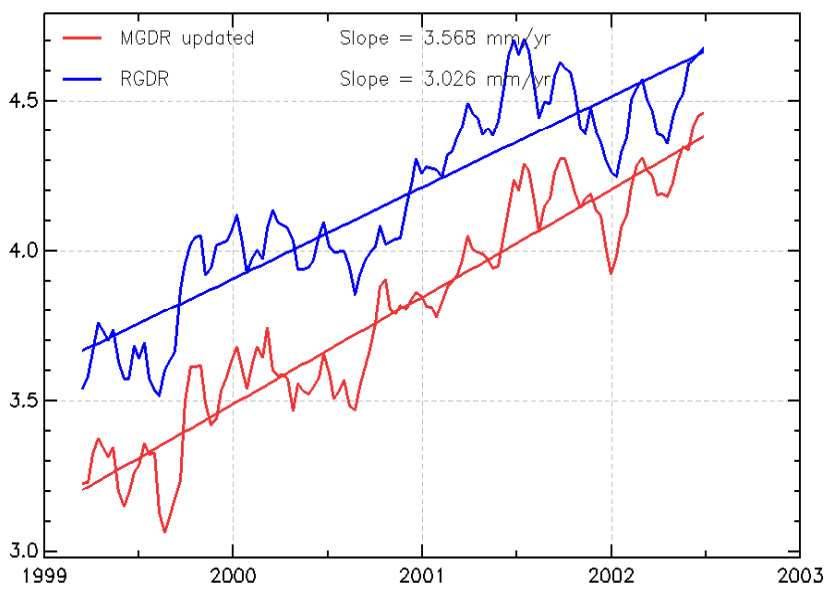


Mean Sea Level Analysis by S. Labroue (CNES) '09 OSTST

Side A MSL



Side B MSL



- Side A MSL with RDGR shows strong discrepancy with respect to MGDR MSL. RGDR exhibits a false curve and trend (-0.8 mm/year!!!!). The main differences appear at the beginning and the end of the time series.
- Side B MSL with RGDR data presents a trend lowered by 0.55 mm/year which is significant for MSL studies. We are more confident in MGDR MSL since side B is very stable (validated against in situ data and Jason-1 data)

Careful assessment of the PTR correction needs to be performed on the SSH (including PTR corrections on range and SWH (through SSB)). A SSB has been estimated on RGDR products for each altimeter.

Three Generations of Retracking

- 1st Generation retracking (Rodriguez and Martin, JGR 94):
  - Decomposition of the PTR into sum of Gaussians
  - Arbitrary attitude angle (expansion to higher order terms)
  - Linearized least squares estimation, including Skewness

  ☙ ➔ 10/frame range, 1/frame other parameters
- 2nd Generation retracking (Callahan and Rodriguez, MG 04)
  - Added iterative estimation of parameters until retracker fully converged
- 3rd Generation retracking: Maximum *a Posteriori* (MAP)
  - 1st and 2nd generation retrackers operated on 1 second frames without constraints
  - Retracker unbiased, but noisy and retrieved parameters could be highly correlated
  - MAP estimation constrains the parameter space for the inversion using *a priori* knowledge (data are still estimated from 1 sec frames)
    - Attitude varies slowly, SWH correlation distance ~100 km and known to better than 60cm, Track Point known to better than 20 cm, |skewness|<1

Retracking Algorithms

Maximum Likelihood Estimator (MLE) Minimizes:

$$-\log(p(x \mid a)) \propto \sum_{i=1}^{Ndata} \frac{\left(x_i - M(a)\right)^2}{\sigma_i^2}$$

Maximum a Posteriori (MAP) Minimizes:

$$-\log(p(x \mid a)p(a)) \propto \sum_{i=1}^{Ndata} \frac{\left(x_i - M(a)\right)^2}{\sigma_i^2} + \sum_{n=1}^{Nparams} \frac{\left(a_n - A_n\right)^2}{\Sigma_n^{\,2}}$$

Where *x* is the data, *a* are the parameters to be estimated, *A* are the parameter a priori values, σ_i are the measurement errors and Σ_n measures the prior confidence level.

Setting the priors and their confidence levels is the trick!

Prior Values: smooth LSE SWH and attitude data over an extent < 80 km relative to center.

Prior Uncertainties: Root Squares Sum residual values in smoothing window with conservative estimate of minimum uncertainty of SWH and attitude variance. Use 1.5 as uncertainty on the skewness, and infinite variances (no priors) on the other parameters, including height.