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Calibration Data for Retracking TOPEX Data

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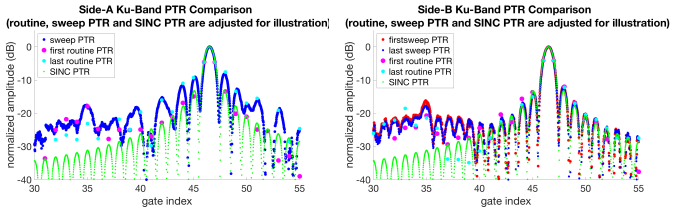
Overview

We summarize the collection of calibration data assembled to support the retracking of TOPEX data for the climate data record. The data include the Cal-1 and Cal-2 data acquired twice each day throughout the mission and "Cal Sweeps" acquired pre-launch, toward the end of Alt-A and during Alt-B operations.
The Cal-1 and Cal Sweeps provide measurements of the altimeter point target response (PTR). As is now well known, the Alt-A PTR changed with time becoming significant after about cycle 140 (July 1996) until turnoff at cycle 235 (February 1999). Alt-B operated for cycles 236 until the end of mission at cycle 481 in October 2005, including the colinear period with Jason-1 for cycles 344-364 and the interleaved orbit from cycle 366. The twice-daily Cal-1 data are averaged by cycle. Unfortunately, the Cal-1 data provide bare Nyquist sampling of the PTR and are centered at a different gate than regular tracking. Nonetheless, the data provide a clear picture of the changing Alt-A PTR and the stability of the Alt-B PTR. The Cal Sweeps provide very detailed information on the PTR by sweeping the Cal-1 data through a range of delays. Cal Sweeps were performed for both Alt-A and Alt-B prelaunch. Unfortunately, Cal Sweeps of Alt-A were then not done until the changes in the PTR had become quite obvious beginning in cycle 220. For Alt-B, Cal Seeps were done approximately monthly. From these data it was determined that separate estimates of the PTR for Ku and C bands should be used.

Point Target Response

The TOPEX PTR was measured onboard by the Cal-1 mode twice a day. Unlike Jason satellites, the TOPEX PTR was measured without oversampling (i.e., 1 point per radar gate) which offers limited information. As Side-A suffered unexpected degradations after a few years in-orbit, the capability to measure in-flight oversampled PTR (named '"sweep calibrations" or calsweep) was uploaded for a better characterization of the altimeter change. For Side-A, only a few sweep calibrations are available at the very end before switching off the instrument. For side-B, sweep calibrations were performed every month and ,even later, every cycles.



Routine and calsweep PTRs show good agreement, including for late Alt-A (left). For late degraded PTR, Alt-A shows much higher sidelobes and "missing" lobes -3 (43) and -5 (41). Alt-B (right) for gates 40-55 is close to the theoretical sinc. The reality of the high level for gates ~30-40 requires additional analysis; it has previously been attributed to "leakages" (below left. Leakages exaggerated x20, from Hayne et al., 1994, JGR, ***99,*** 24,941).

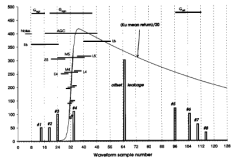
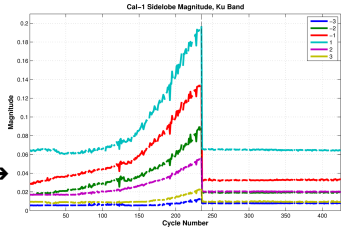
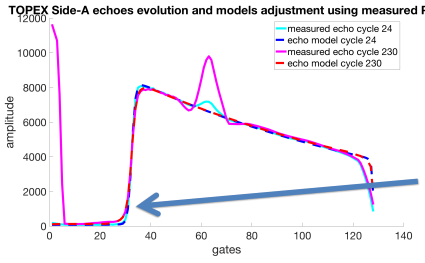


Figure 6. TOPEX Ku altimeter gates, mean return, and center locations of waveform leakage spikes.

Another view of PTR sidelobe evolution from Cal-1 showing Alt-A somewhat anomalous behavior of sidelobe +1 before cycle 50; significant changes after cycle 140; stability of Alt-B.

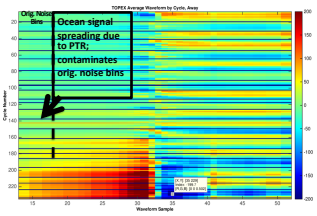


The altimeter PTR has a direct impact on the echo. The change of the PTR shape on Side-A led to a spread echo leading edge and therefore to an overestimation of the Significant Wave Height (SWH). Using a PTR model with actual sidelobes will correct this overestimate. Because parameters are correlated, misestimation of SWH leads to an incorrect estimate of range.



Note : lowest and highest 3 gates and gates around 64 ("zero leakage") are not used for retracking

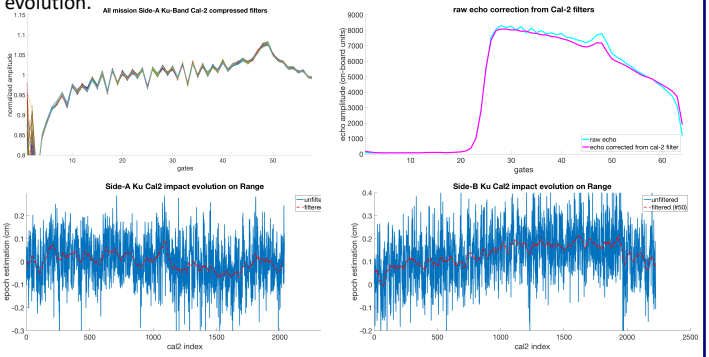
Spread leading edge and sloped noise floor



⇐Further illustration of the spreading of the leading edge and contamination of the noise floor. The image shows the cycle average waveform residual from the overall Alt-A average. In the retracking of 2016 the gates used for estimating the noise were moved from the original 7-12 to 5-7 to reduce the impact of an incorrect noise estimate.

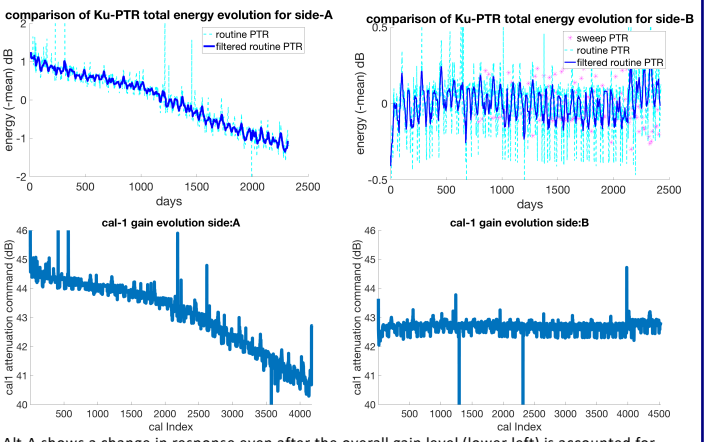
Altimeter Transfer Function (Filter)

The altimeter Transfer Function also called "filter" was measured on-board using the Cal-2 mode. This transfer function affects the measured echoes and must be corrected prior to the retracking step (estimation of the echo parameters).
The Cal-2 data is compressed on-board, averaging gates as done for the echo compression (128→64, non-uniformly, preserves full resolution around leading edge). As a result measured echoes can be directly corrected from the Cal-2.
For both Alt-A and Alt-B, the filters are stable over time (Alt-A shown; Alt-B essentially identical). The visual differences are negligible and simulations demonstrate a low effect on long term trend. Nevertheless for the new retracked product, filtered cal-2 times series have been used to correct echoes instead of a simple averaged filter in order to compensate accurately for filter evolution.



Cal-2 effect on retracked range is at the 1 mm level

The altimeter PTR has a direct impact an the echo. The change of the apparent PTR power may show up in the altimeter AGC which is used to estimate sigma0, hence wind speed and thus Sea State Bias. Two estimates of the PTR power are shown below.



Alt-A shows a change in response even after the overall gain level (lower left) is accounted for. Alt-B is stable to <~0.2 dB.

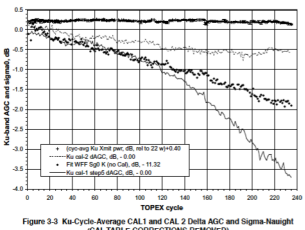


Figure 3-3 Ku-Cycle-Average CAL1 and CAL 2 Delta AGC and Sigma-Nauight (CAL TABLE CORRECTIONS REMOVED)

From WFF Alt-A Engineering Assessment Report: Cal-1 gain (line) agrees with above lower left; but as shown by the * points, this does not reflect the calibration needed to keep the observed sigma0 approximately constant (which was done for GDRs). WFF did not assess the energy of the PTR (upper curves above).