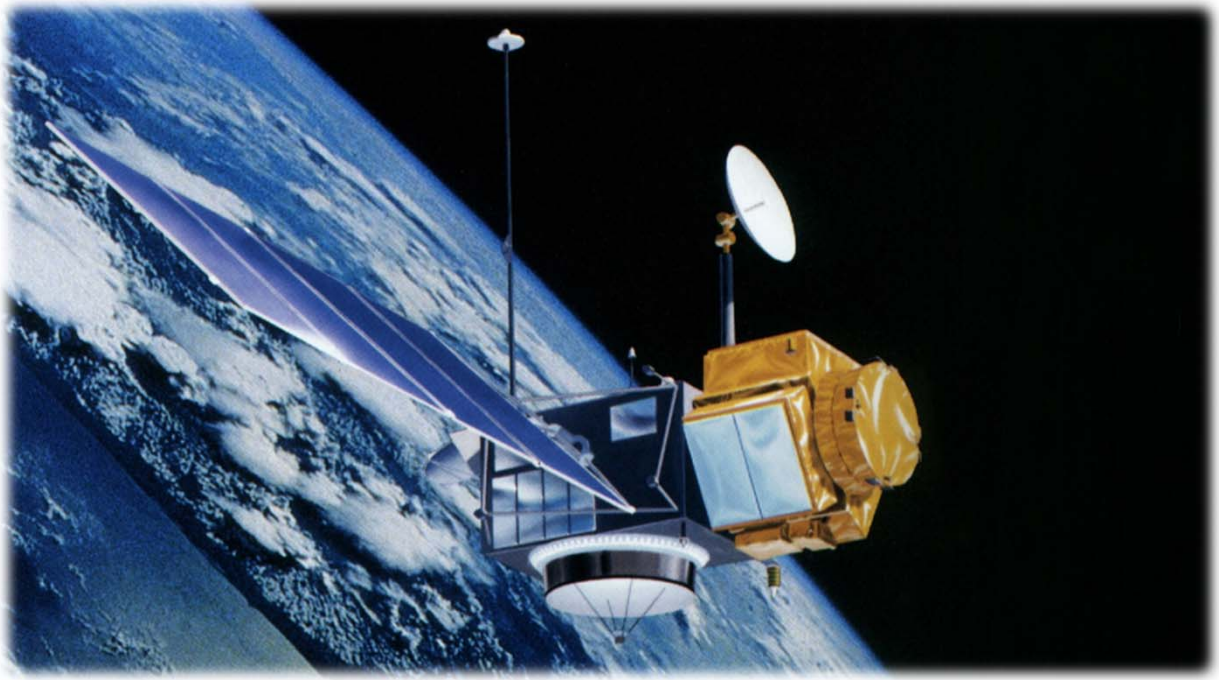
Jet Propulsion Laboratory
California Institute of Technology

A Numerical Retracking Approach for TOPEX Data Reprocessing



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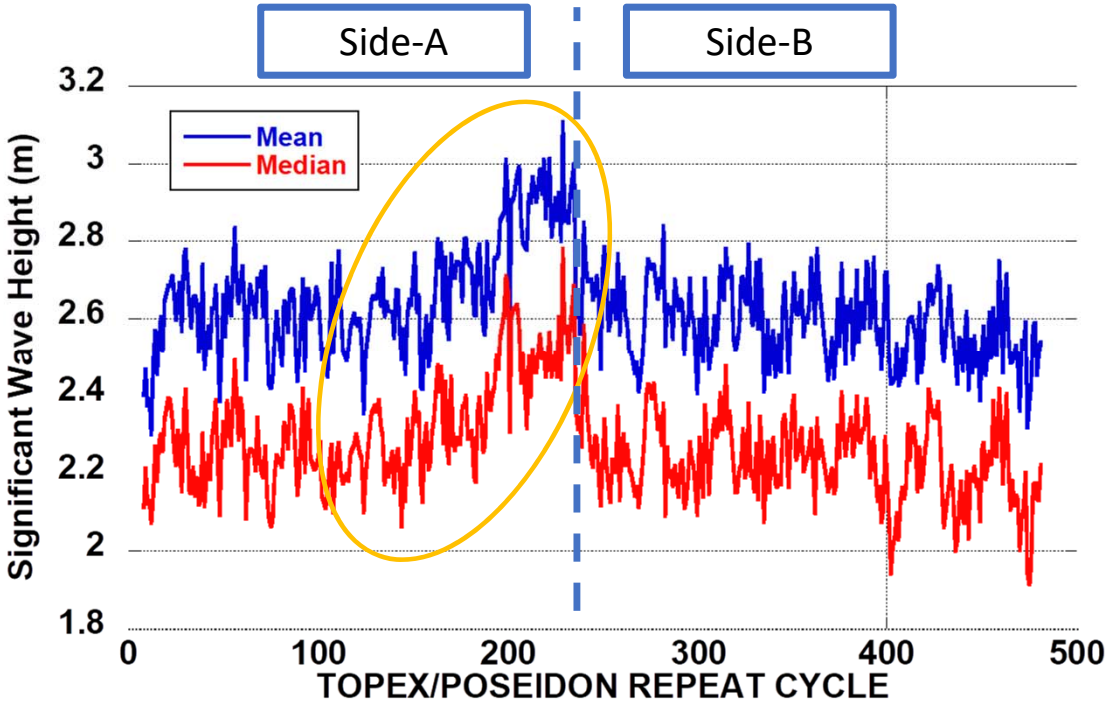
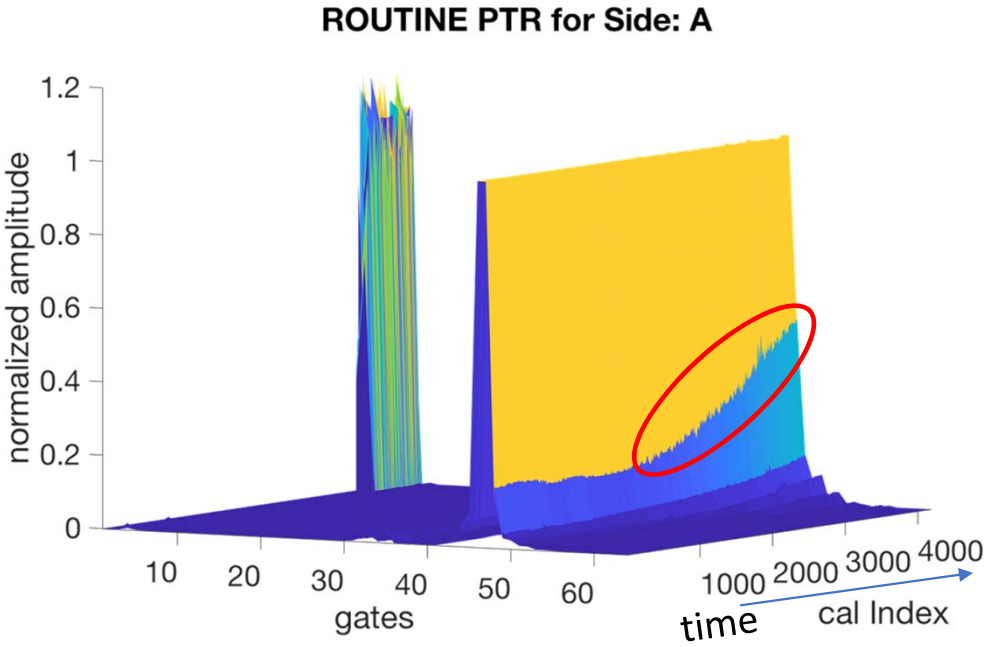
OSTST Chicago, 2019

Motivations for TOPEX Reprocessing

1. Historical TOPEX MGDR and GDR Products based upon on-board estimates for range, SWH and Sigma0 -> some limitations.
2. Side-A altimeter suffered major degradation inducing an increase of about 40cm for the estimated Significant Wave Height following a quadratic evolution



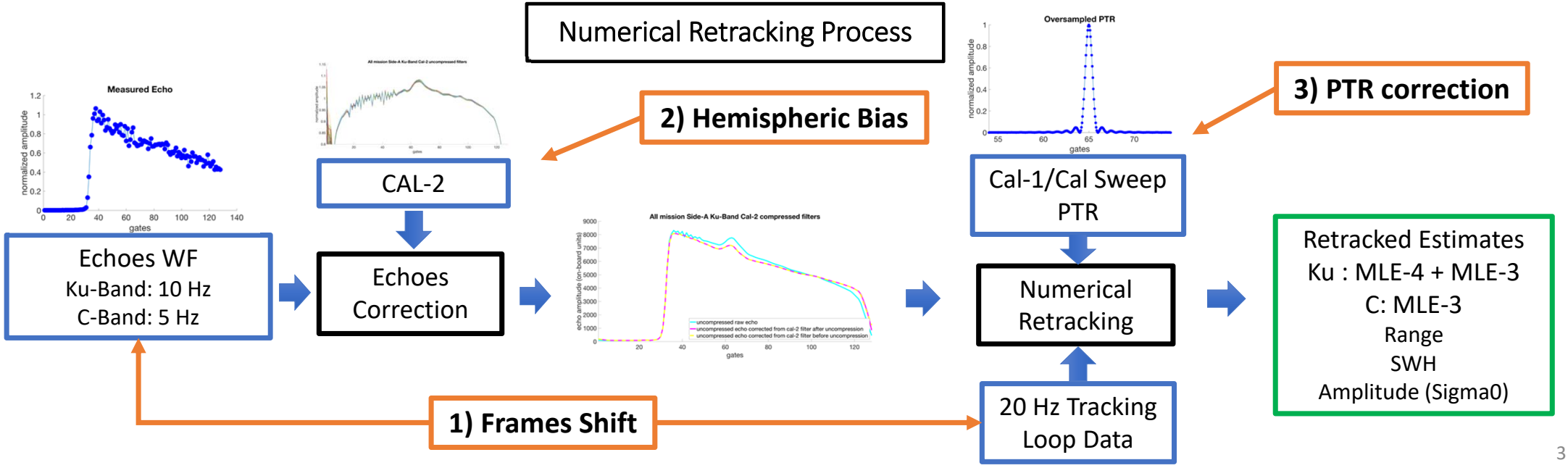
TOPEX Significant Wave Height evolution



Side-A Point Target Response
Increase of secondary lobes amplitude

Main Results

1. **Frames shift: improve performance** (See back-up and OSTST 2018 CalVal poster)
2. **Hemispheric Bias:** new Cal-2 filter correction of echoes resulting in a strong reduction of the ascending vs descending hemispheric differences
3. **PTR corrections:** How Cal-1 PTR are impacting the altimeter estimations
   a) Explains Wallops Range Correction... and more
   b) Reduces side-A SWH evolution
   c) Provides direct correction for Sigma0

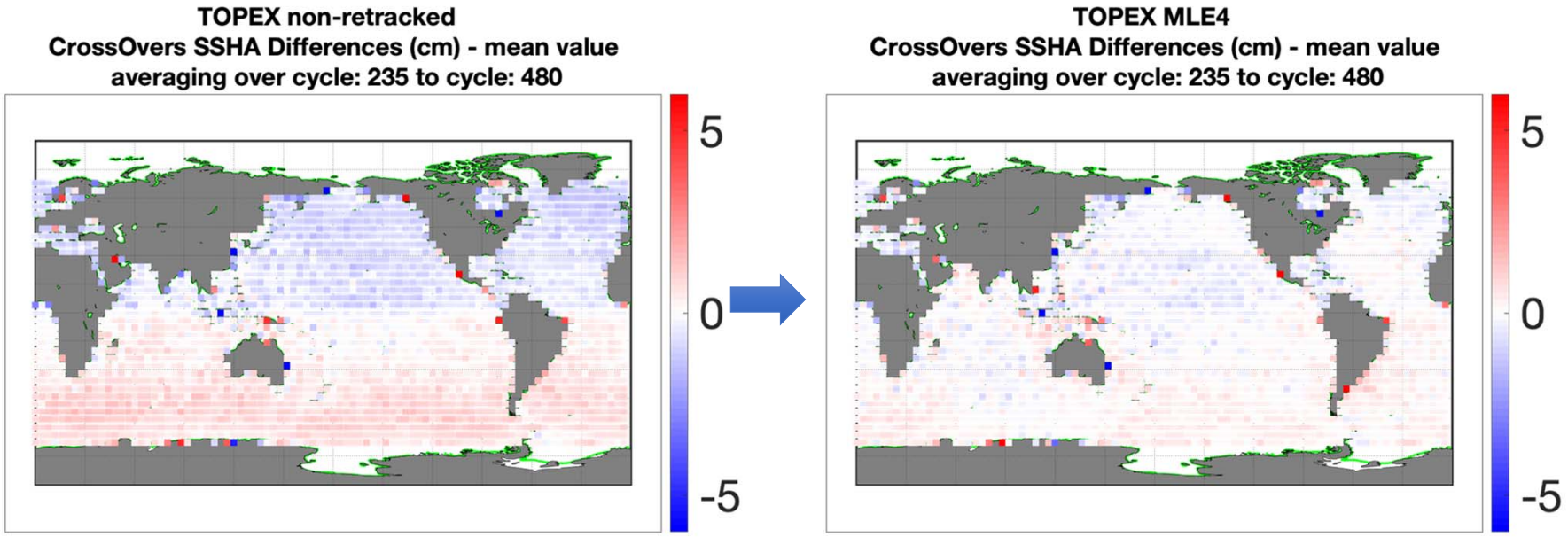


2. Hemispheric Bias

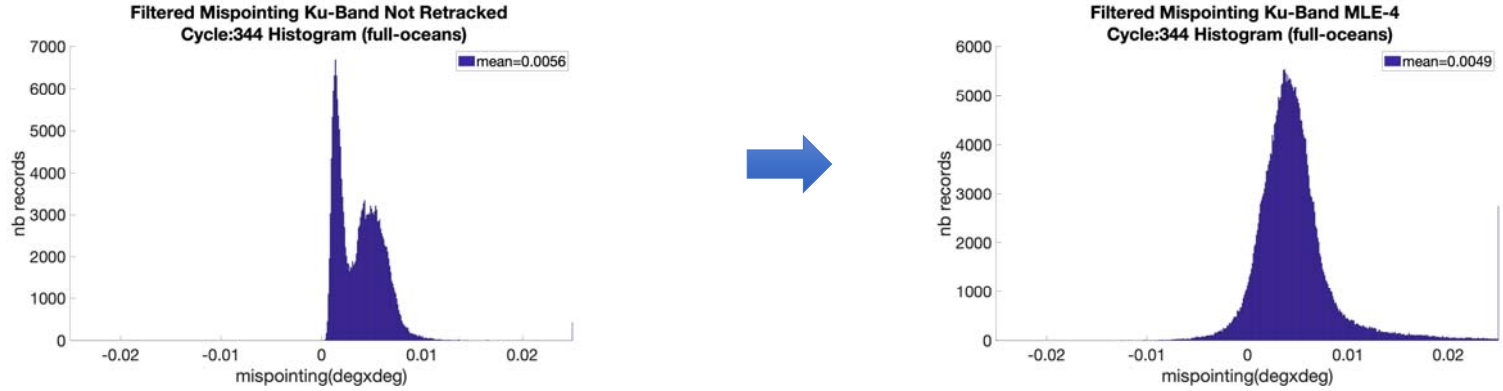
Hemispheric signal observed in TOPEX M/GDR Data

MLE4 Retracking Results

SSH Crossovers North/South signal



Non-homogeneity in Mispointing estimates



New Cal-2 correction

Why?

The altimeter range command has 2 different components

1. The Coarse Range Command
2. The Fine Height Range Command (processing)

TOPEX altimeter (simplified) behavior

- For Altitude Rate > 0 : tracker selects Fine Height in lower range
- For Altitude Rate < 0 : tracker selects Fine Height in higher range

Solution:

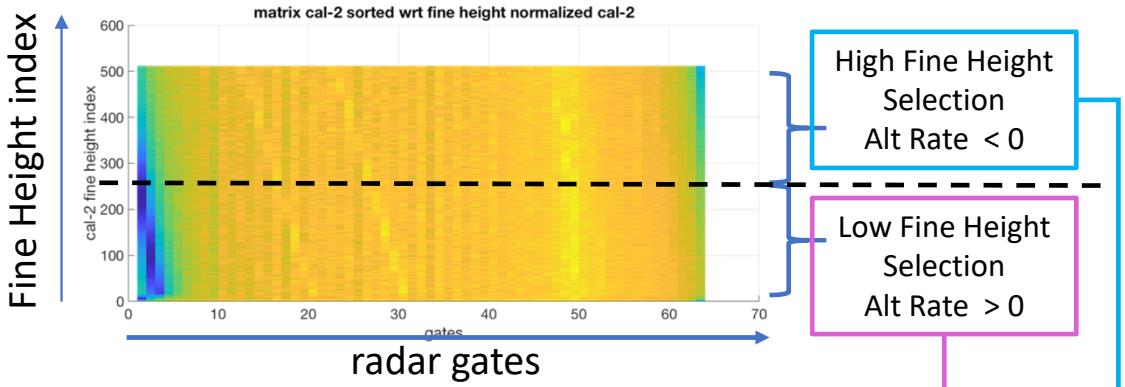
The echoes must be corrected accordingly to this using the "good" CAL-2

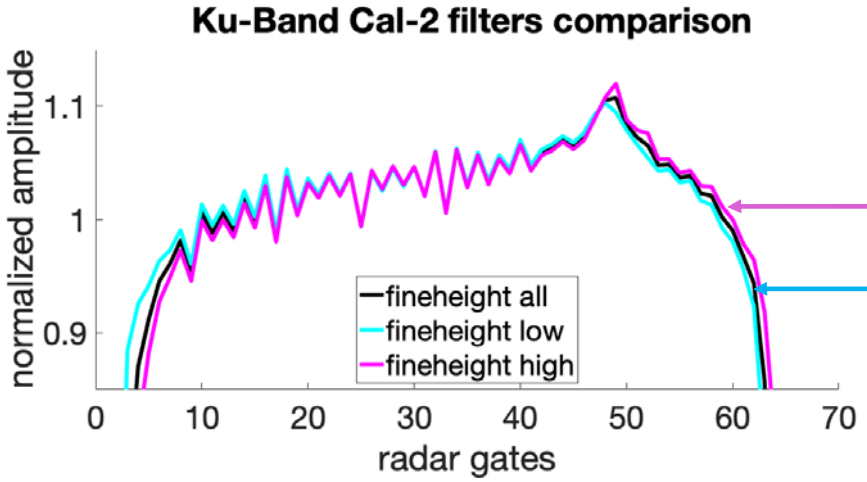
(different solutions tested, use of a simple one)

For a 1 Hz packet, if altitude rate (derived from altimeter) is:

- > 0 apply CAL-2 corresponding to FineHeight lower range
- < 0 apply CAL-2 corresponding to FineHeight higher range
- ~ 0 apply averaged CAL-2

In CAL-2 mode, the filter is measured along Fine Height range





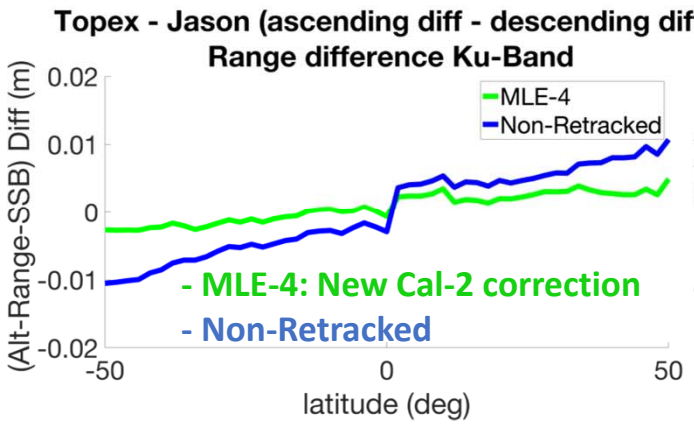
Assessment using TOPEX vs Jason-1 Tandem Phase comparison

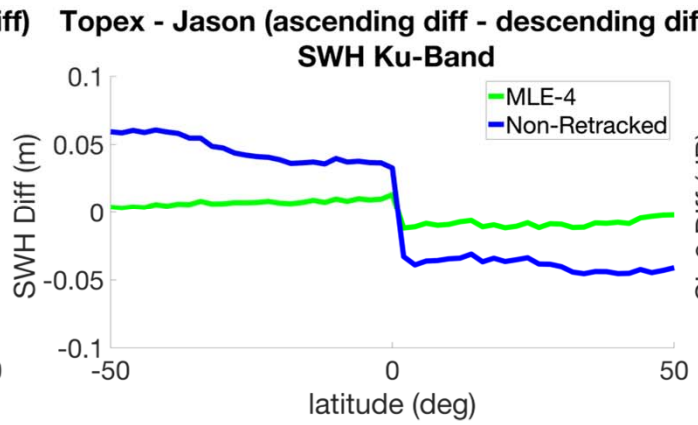
(TOPEX-Jason)^{Ascending} - (TOPEX-Jason)^{Descending} averaged differences vs latitude

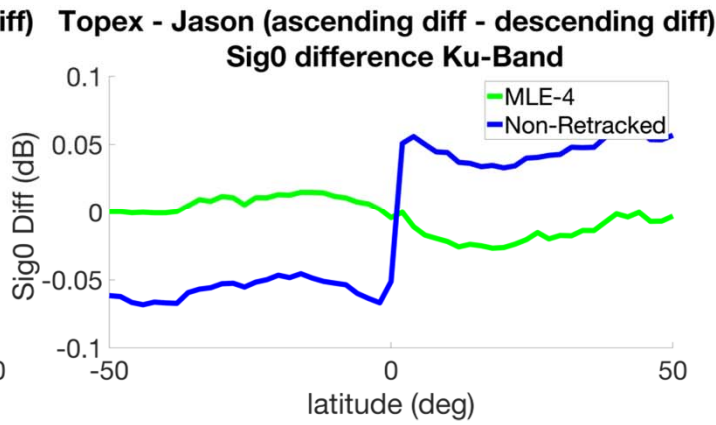
The North / South difference is almost removed

Range difference | SWH difference | Sigma0 difference

Ku







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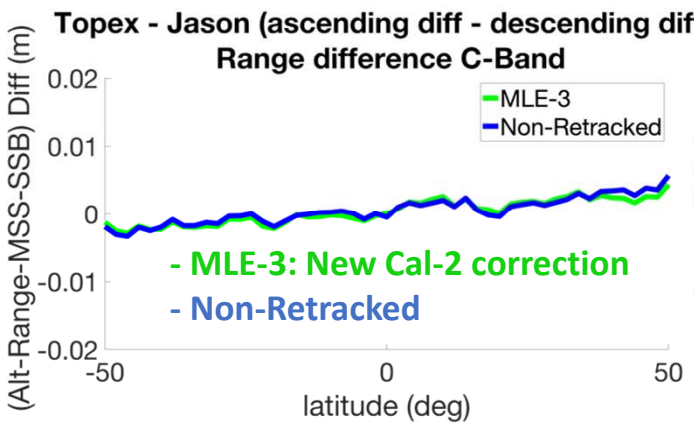
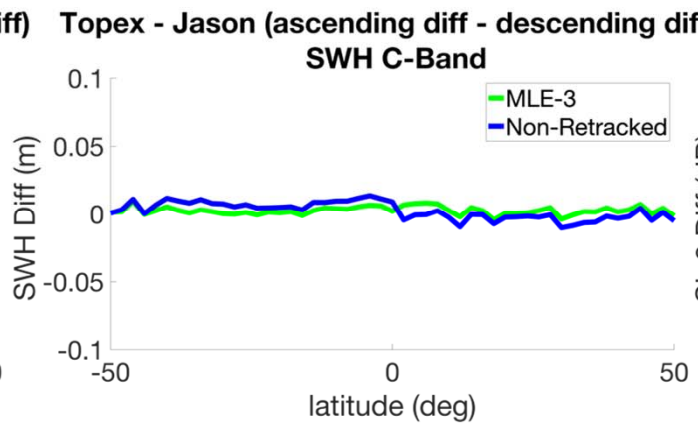
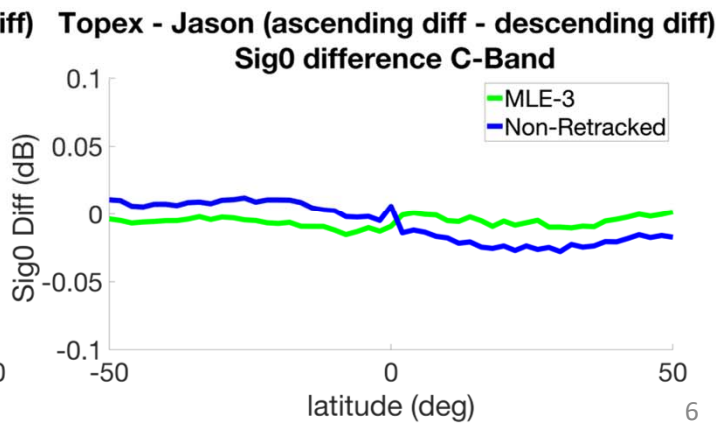




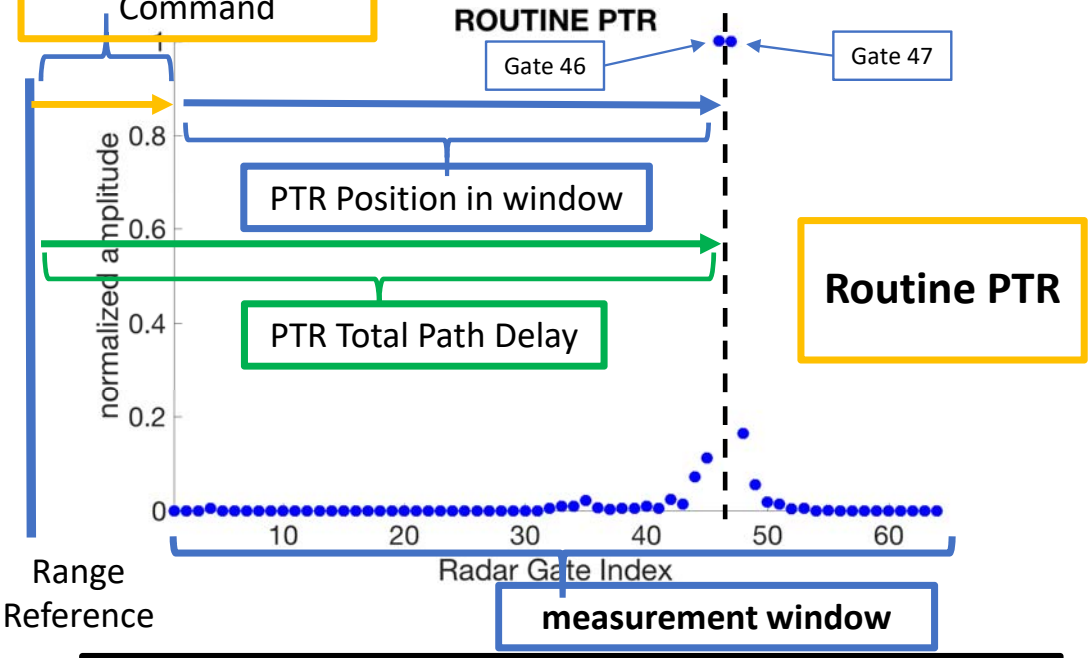


3. PTR corrections

Understanding Wallops Range Correction

Side-A : use of "reconstructed sweep PTR" derived from "routine PTR"

PTR **Tracked** Range Command



Routine PTR

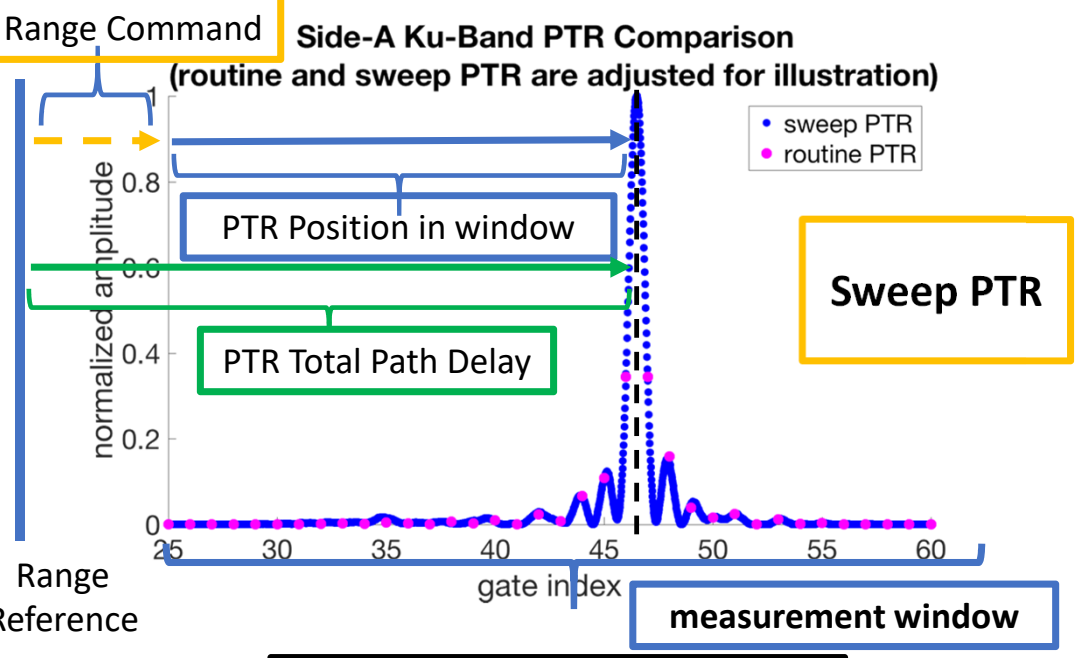
Range Reference

measurement window

PTR Total path delay evolution
= Range Command evolution + In Window Position evolution

Side-B : use of measured "sweep PTR"

PTR **Fixed** Range Command



Sweep PTR

Range Reference

measurement window

PTR Total path delay evolution
= In Window Position evolution

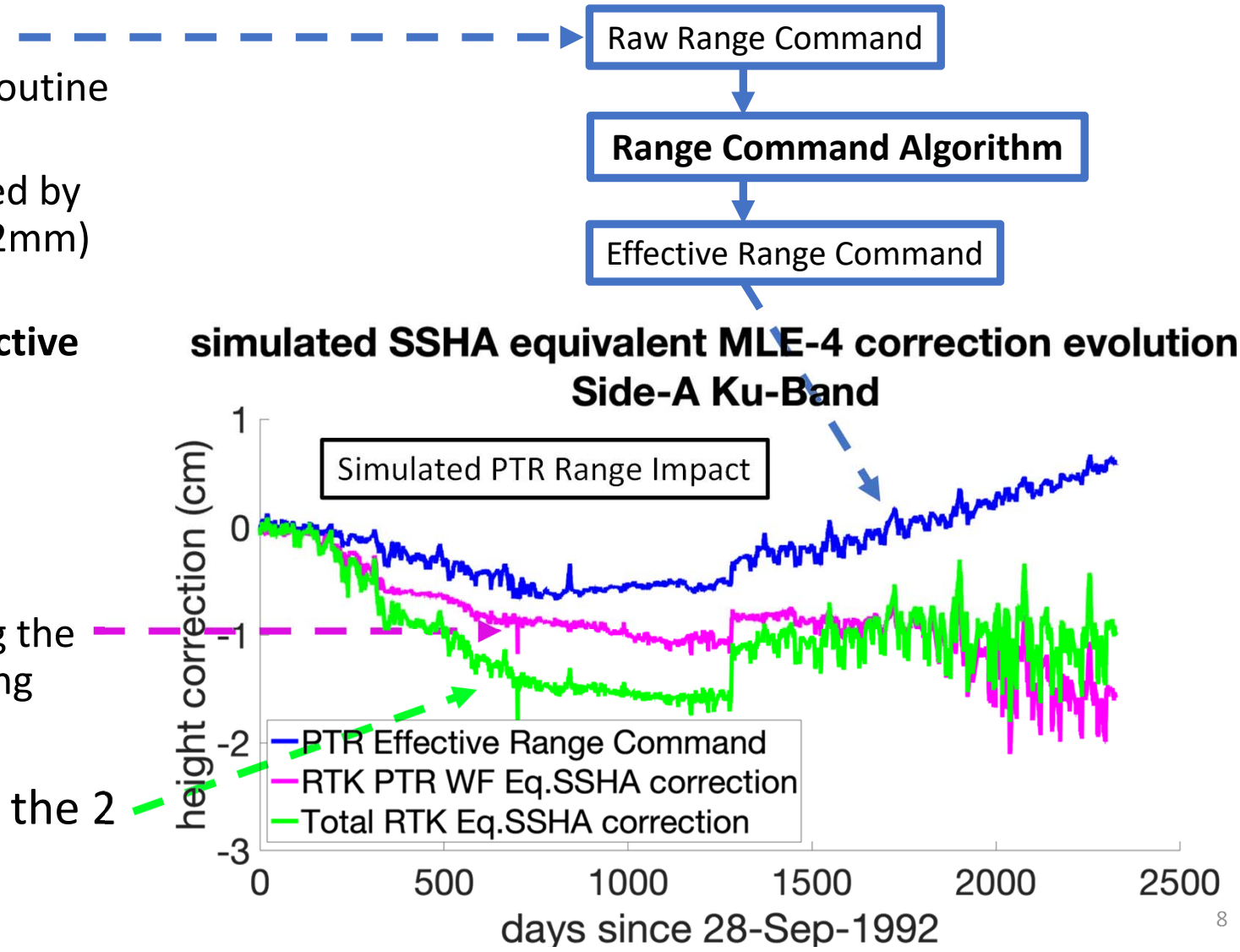
The numerical retracking is inherently accounting for any change affecting the shape of the PTR waveform.
It includes variations of the Position and of the Amplitude in the measurement window

Side-A range processing deals with two PTR components

- The PTR range command
  - **is necessary** when using the routine PTR for retracking.
  - PTR range command is affected by quantization (1/64th gate ~ 7.2mm)
  - requires development of an algorithm to compute an **effective range command**

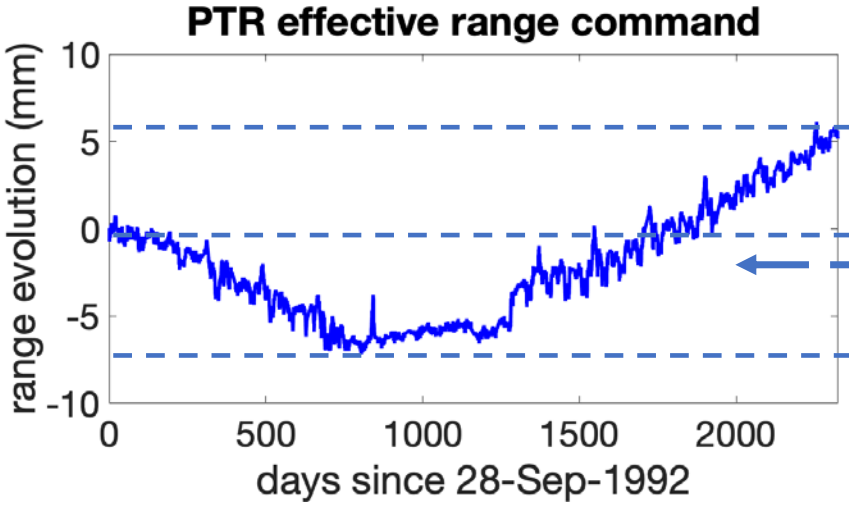
- PTR waveform shape in the measurement window.
  - direct estimation: introducing the PTR Waveform in the retracking

- The total effect is the sum of the 2 components

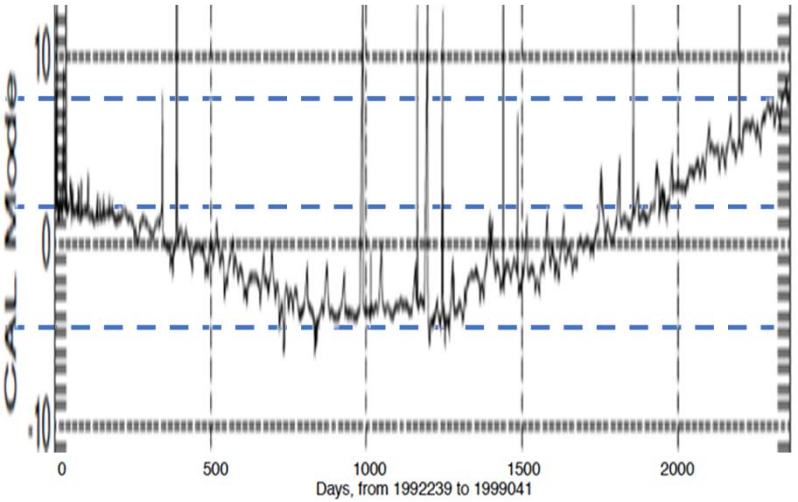


Wallops Range Correction is explained

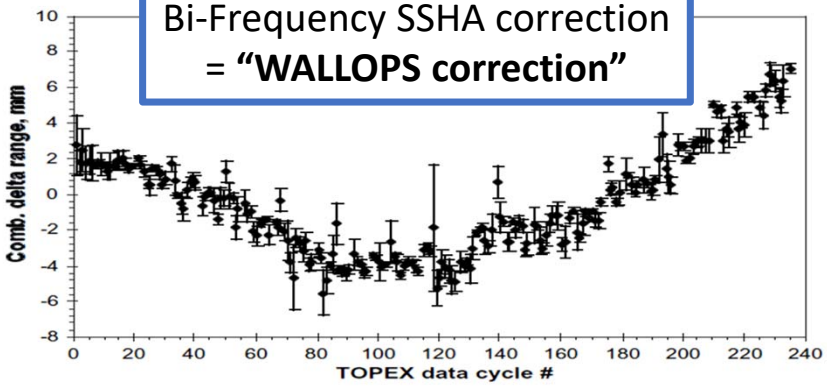
Processed Ku PTR range command (for Att=5)
from new algorithm



Reported Ku PTR range command (for Att=5)
from TOPEX Radar Altimeter Engineering Assessment Report



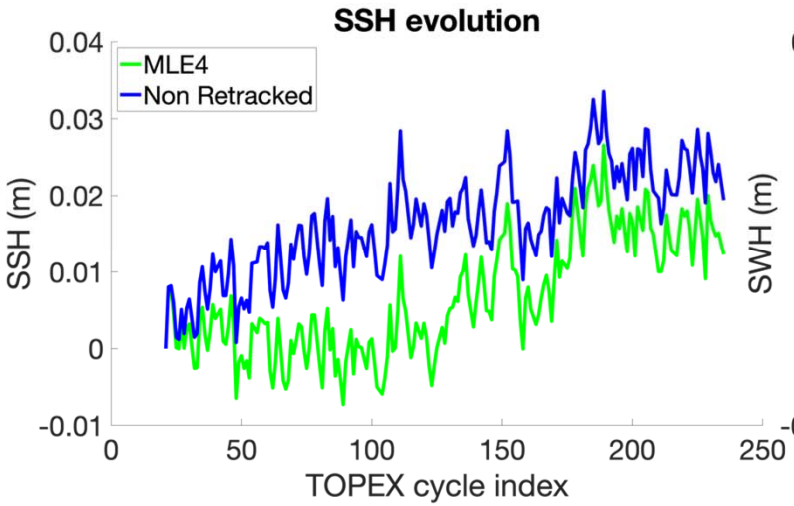
Bi-Frequency SSHA correction
= **"WALLOPS correction"**

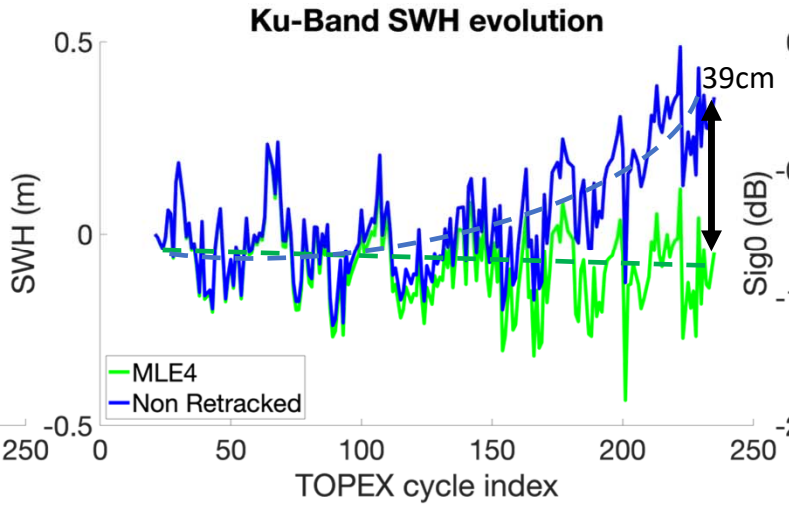


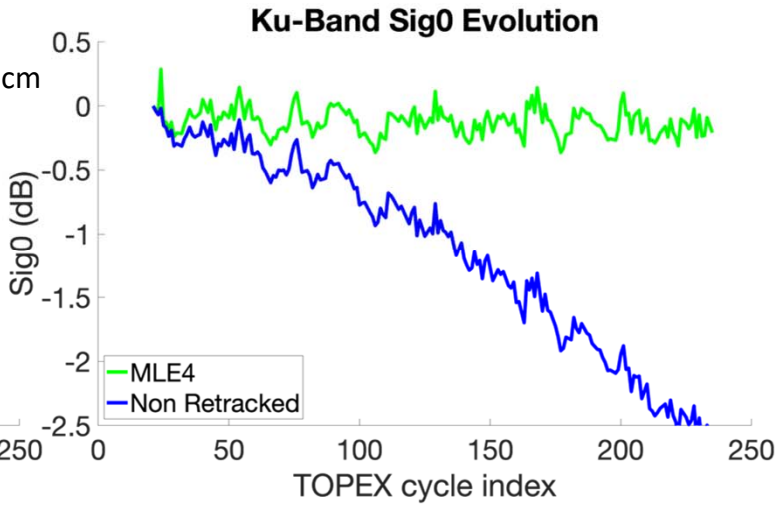
1. New algorithm is able to reproduce the range command as reported in the TOPEX Radar Altimeter Engineering Assessment Report (February 10, 1999)

2. The derived bi-frequency range correction is the so-called "Wallops Range Correction"

SSHA, SWH & Sigma0 resulting evolution comparison between Retracked and Non-Retracked estimates







The resulting trend in SSH is lower for MLE-4 than for Non-Retracked

The drift of the SWH is significantly reduced

The Sigma0 and therefore the windspeed show good stability

TOPEX side-A estimates long term evolution
Using GDR-F standard with Retracked and Non-Retracked altimeter data

Note: the Sigma0 in the original GDR product is corrected using a Wallops climatological correction

TOPEX side-B long-term evolution of retracked and non-retracked are similar (see backup slides)

Conclusion

TOPEX side-A and side-B

- A frame shift has been identified and corrected in the generation of the GDR-F products
- **The hemispheric bias** affecting TOPEX has been **explained** by the altimeter behavior **and corrected.** The new algorithm introducing different cal-2 filters depending on the altitude rate provides a noticeable improvement of the data.
- **The retracking offers better overall performance** and better agreement with Jason-1.
  - Refer to Topex Side-B Cal/Val Presentations (Talpe et al; Roinard et al.).
- The stability of the altimeter parameter for side-B is similar to the M/GDR dataset (see Cal/Val).

TOPEX side-A

- **The WALLOPS range correction:**
  1. **Is understood and has been reproduced.**
  2. Corresponds to only one component (range command) of the range evolution. The second component is the evolution of waveform shape.
  3. **Numerical retracking accounts for both components of total evolution.**
- **The SWH evolution is significantly improved.**
- **The Sigma0 is now corrected using altimeter calibrations and presents a good stability.**
- The range / SSH evolution uncertainty related to the PTR processing is work in progress.
  - Poseidon Retracking will provide beneficial validation metric.
- Global Cal/Val by the JPL and CNES projects is work in progress.

Back-up slides

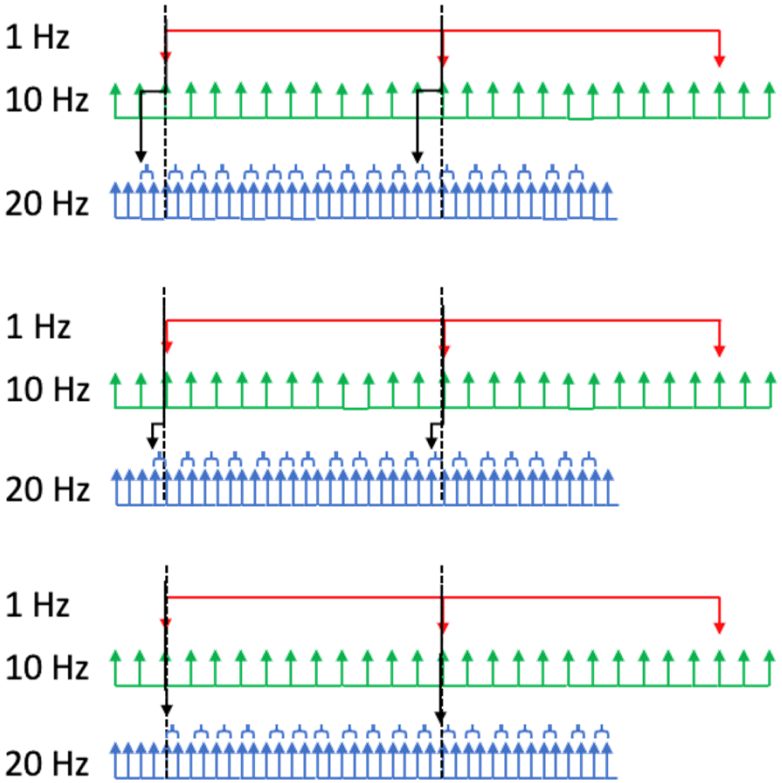
1. Frames Shift

A discrepancy in the synchronization of high frequency data (20 Hz vs 10/5Hz) has been identified

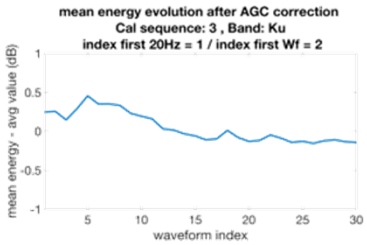
-> **this shift impacts all calibrations and oceans measurements**

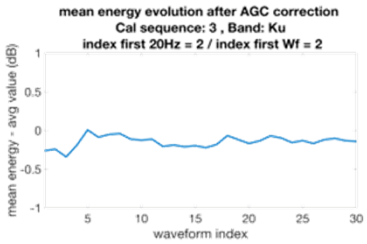
New configuration

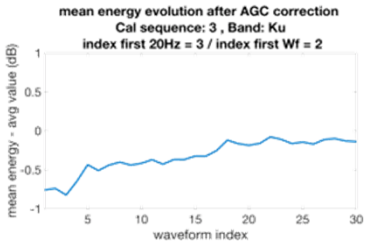
Previous configuration



Cal-2 sequence energy stability

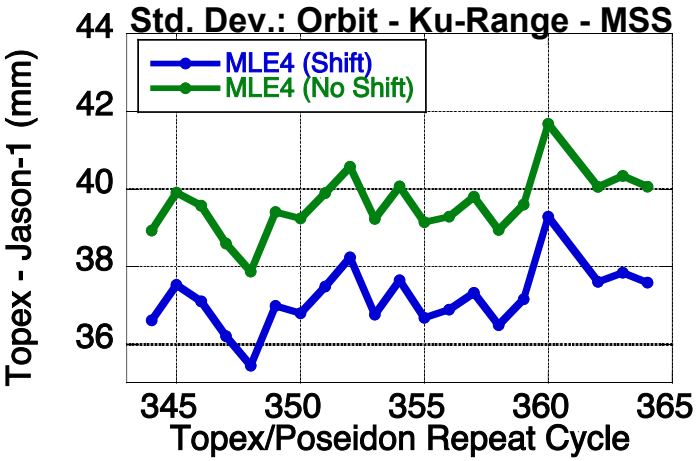


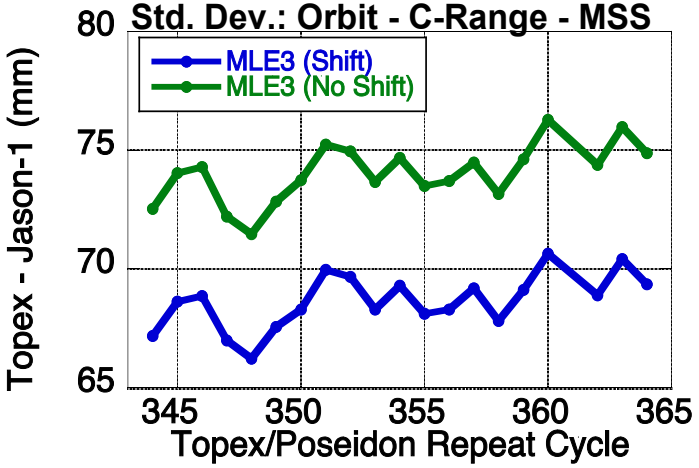


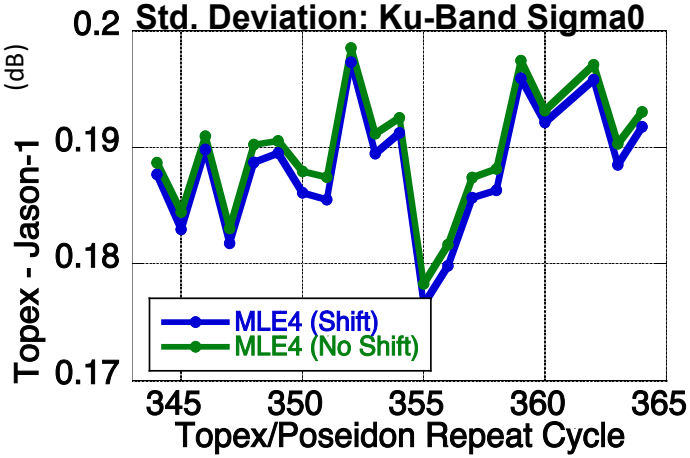


Shifting Waveform by 1 Index Improves Consistency with Jason-1

Lower standard deviation of the difference of 1Hz measurements.







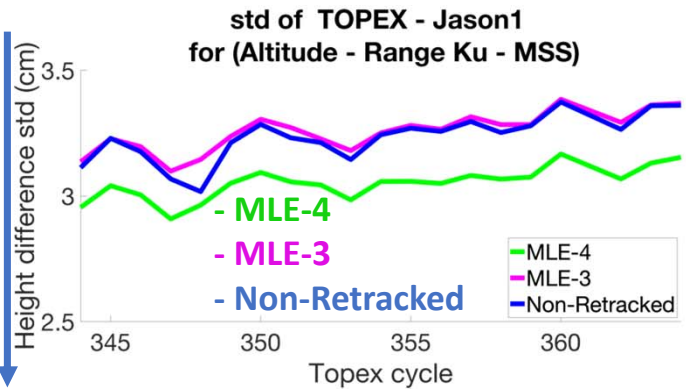
1.+2. : Global Performances when compared to Jason-1 are better for all parameters using Numerical Retracking

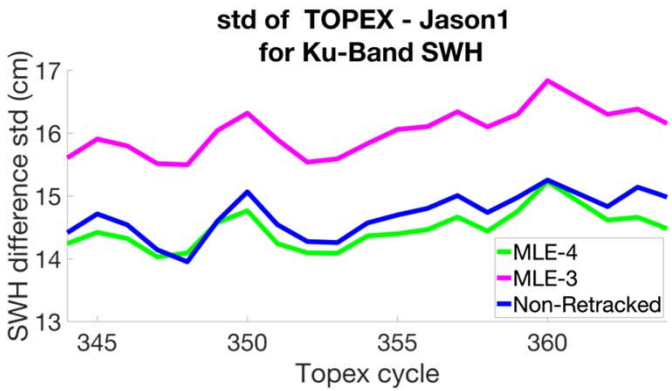
Height std of (TOPEX – Jason-1)

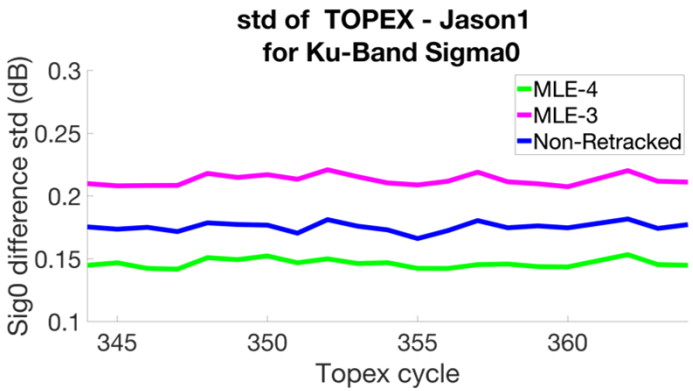
SWH std of (TOPEX – Jason-1)

Sigma0 std of (TOPEX – Jason-1)

Ku

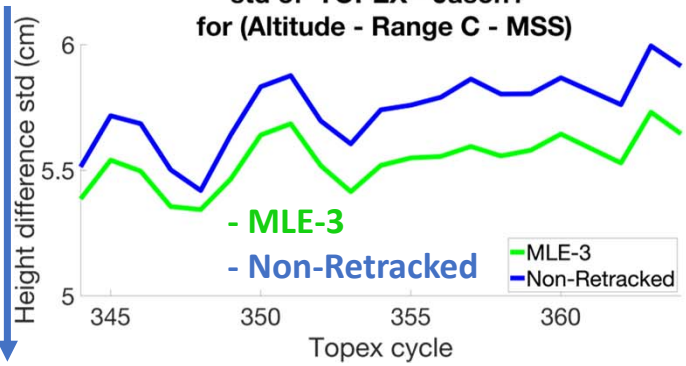


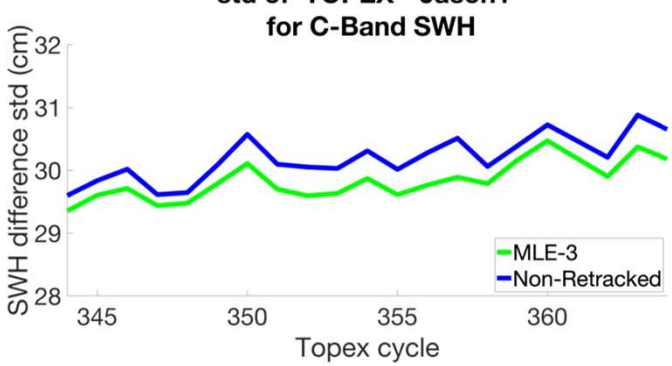


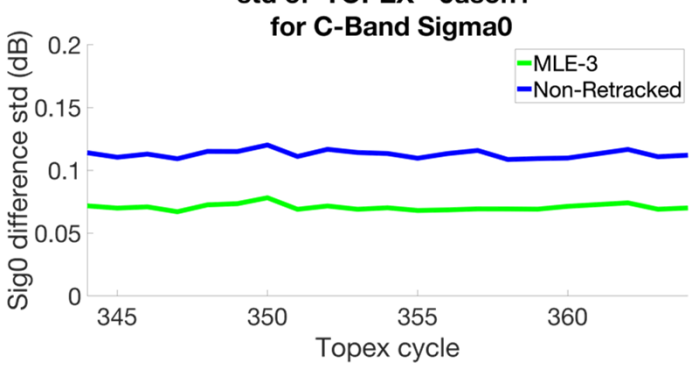


Better agreement

C



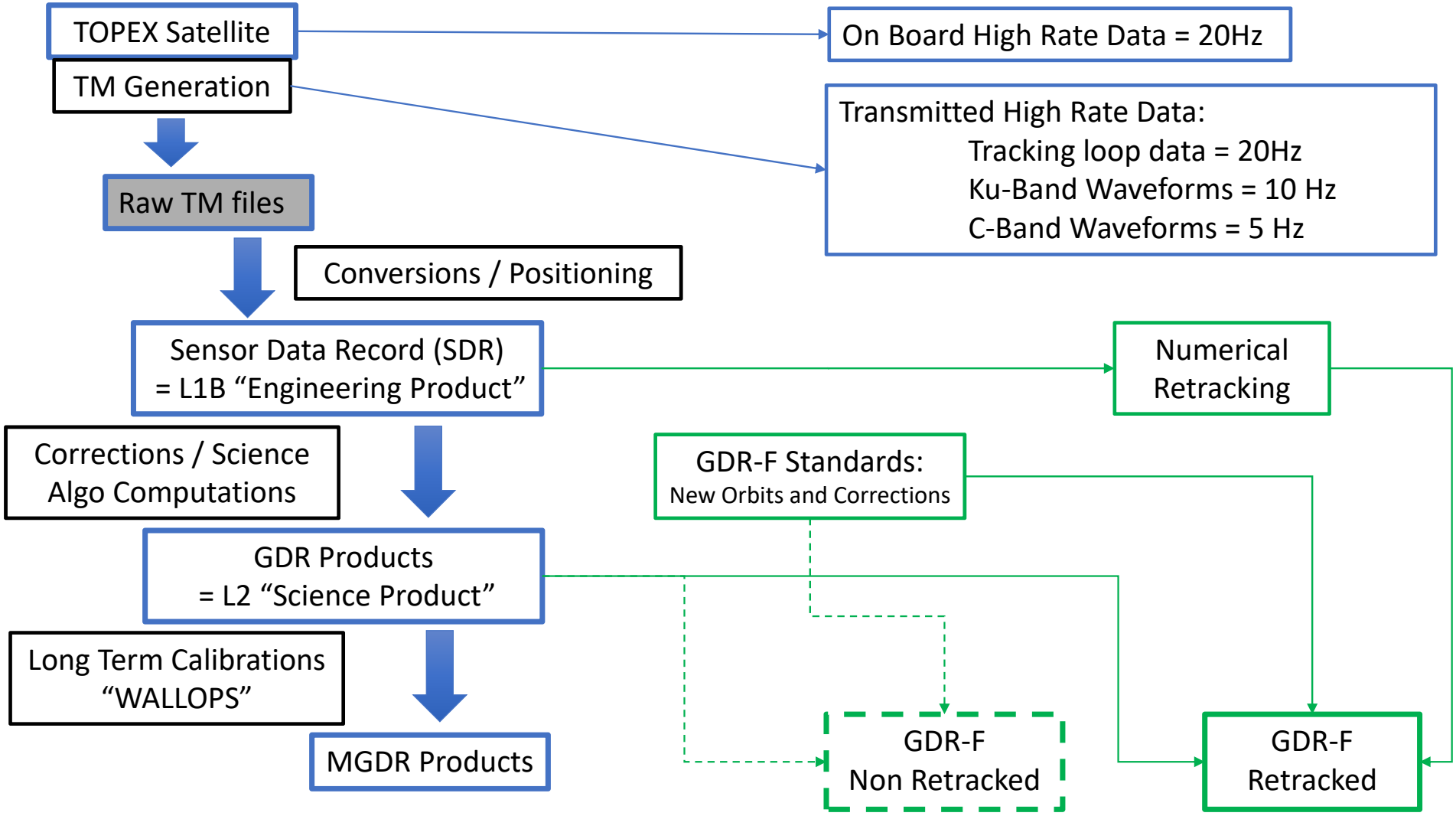




Better agreement

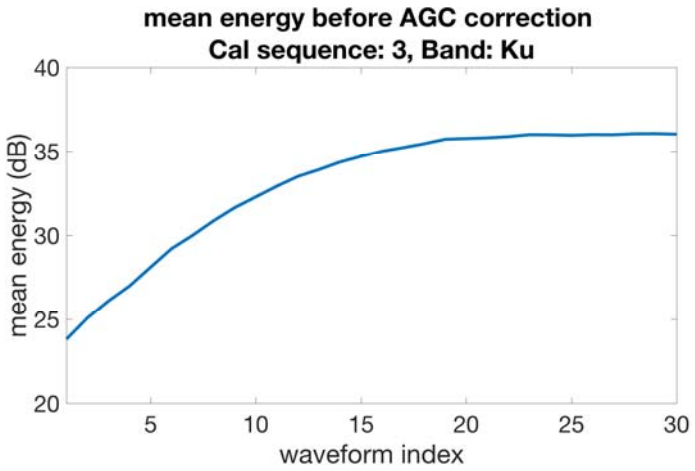
Consistency with Jason-1 is significantly improved with retracked data

TOPEX Data and Products

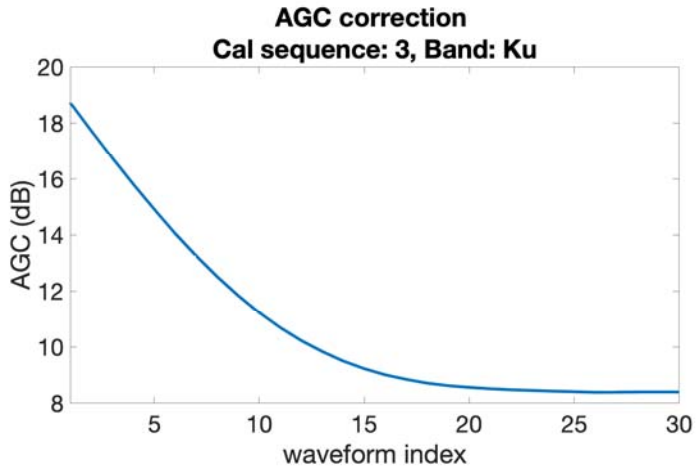


High Rate Data Frames Shift

WaveForms shift illustration with Cal-2



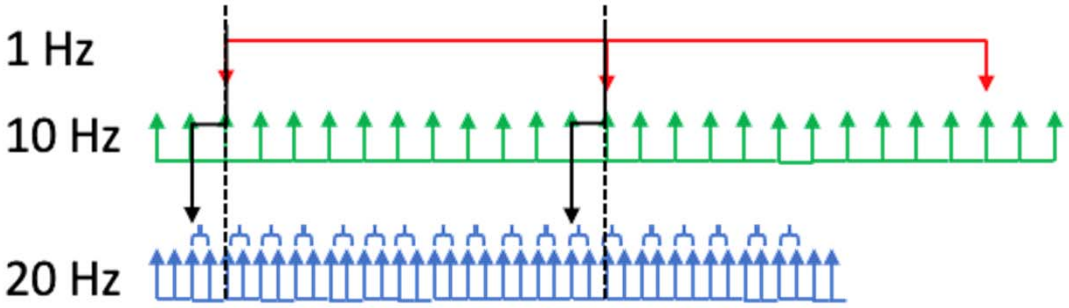
Waveform Energy : 10 Hz



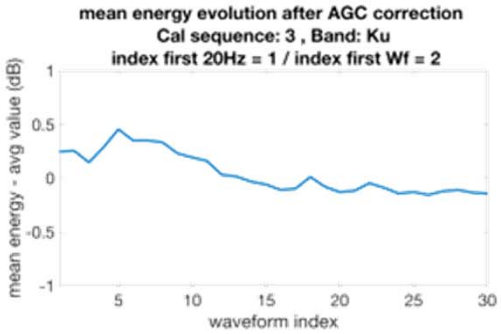
Tracking Loop Attenuation:
20 Hz -> 10Hz

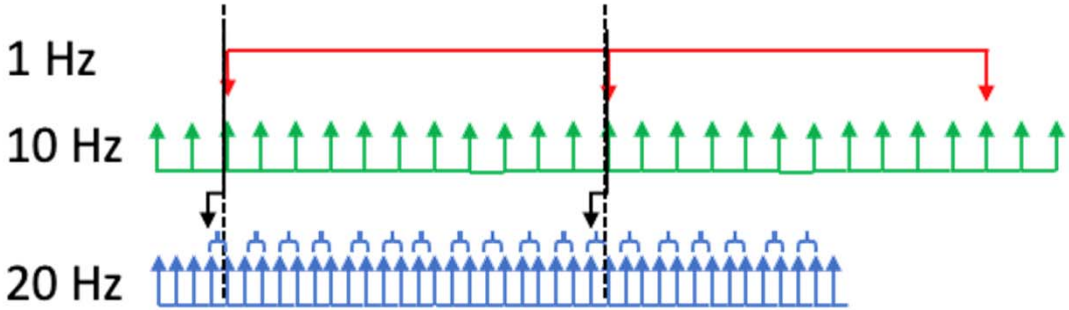
At the very beginning of a calibration sequence the AGC is not yet stabilized - > used for shift test
Hypothesis = the “true” energy from noise measurement should be stable
Select shift that allow better stability of WF energy after corresponding AGC correction

Cal-2 sequence energy stability

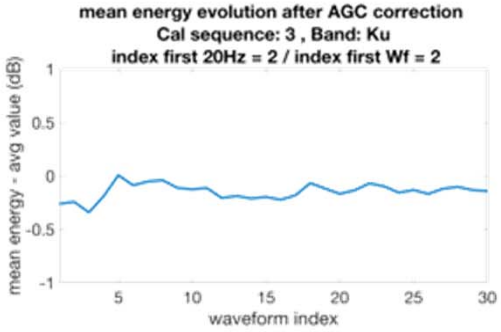


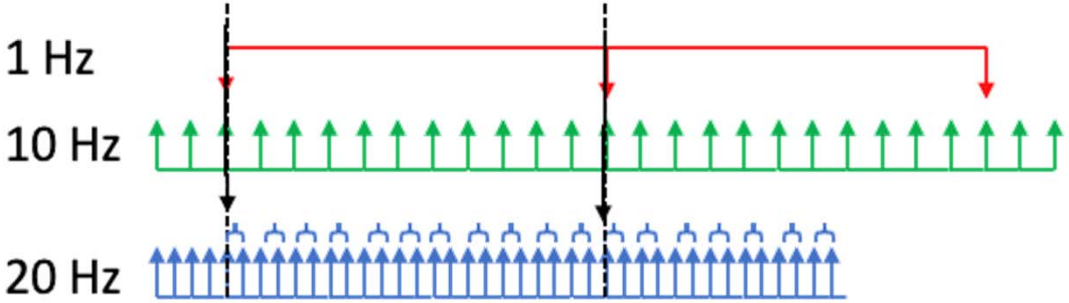
shift=-2



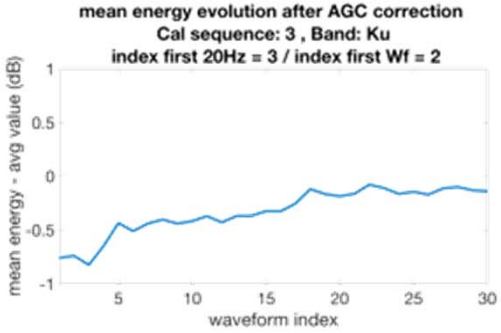


shift=-1



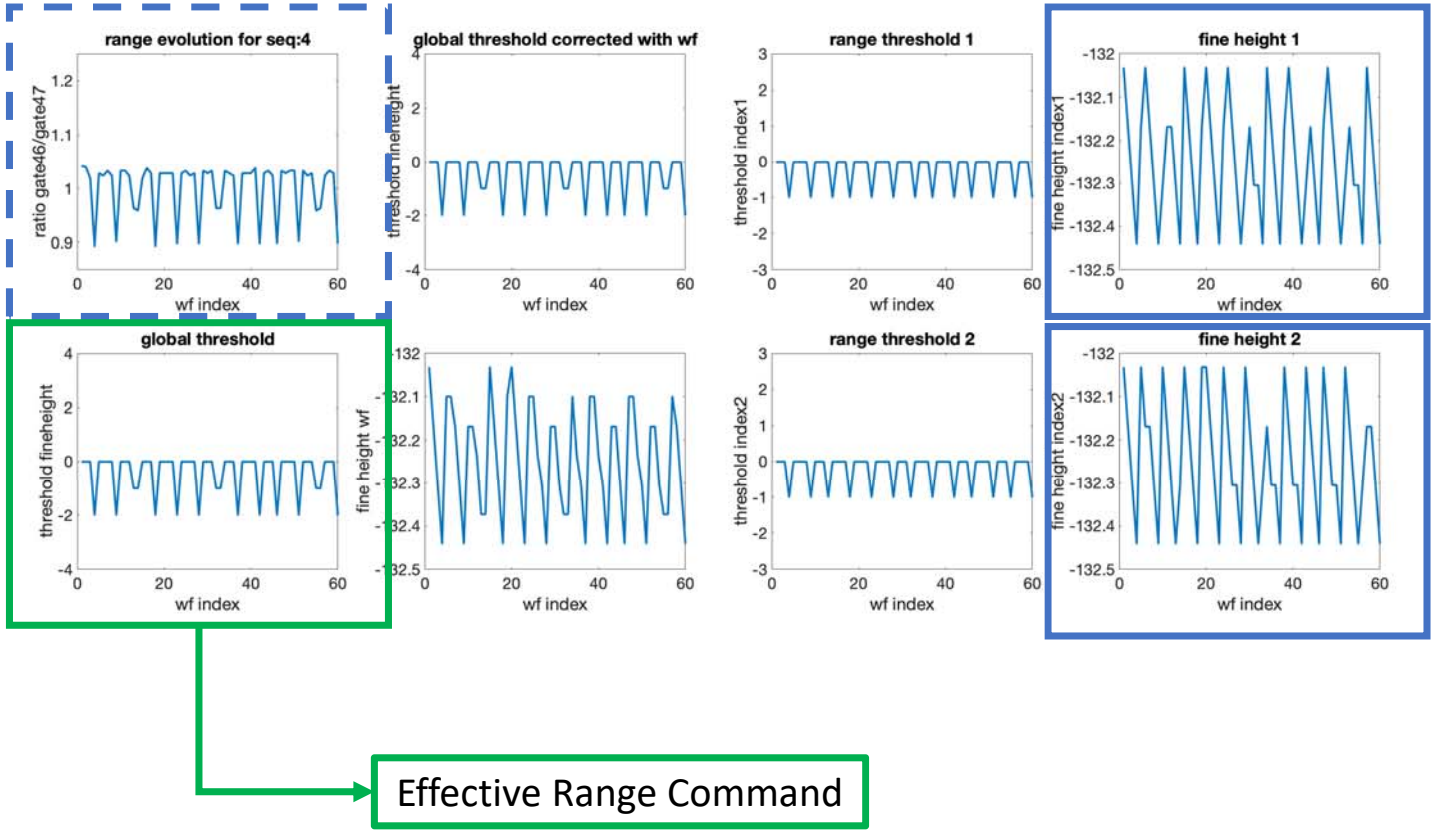


shift=0

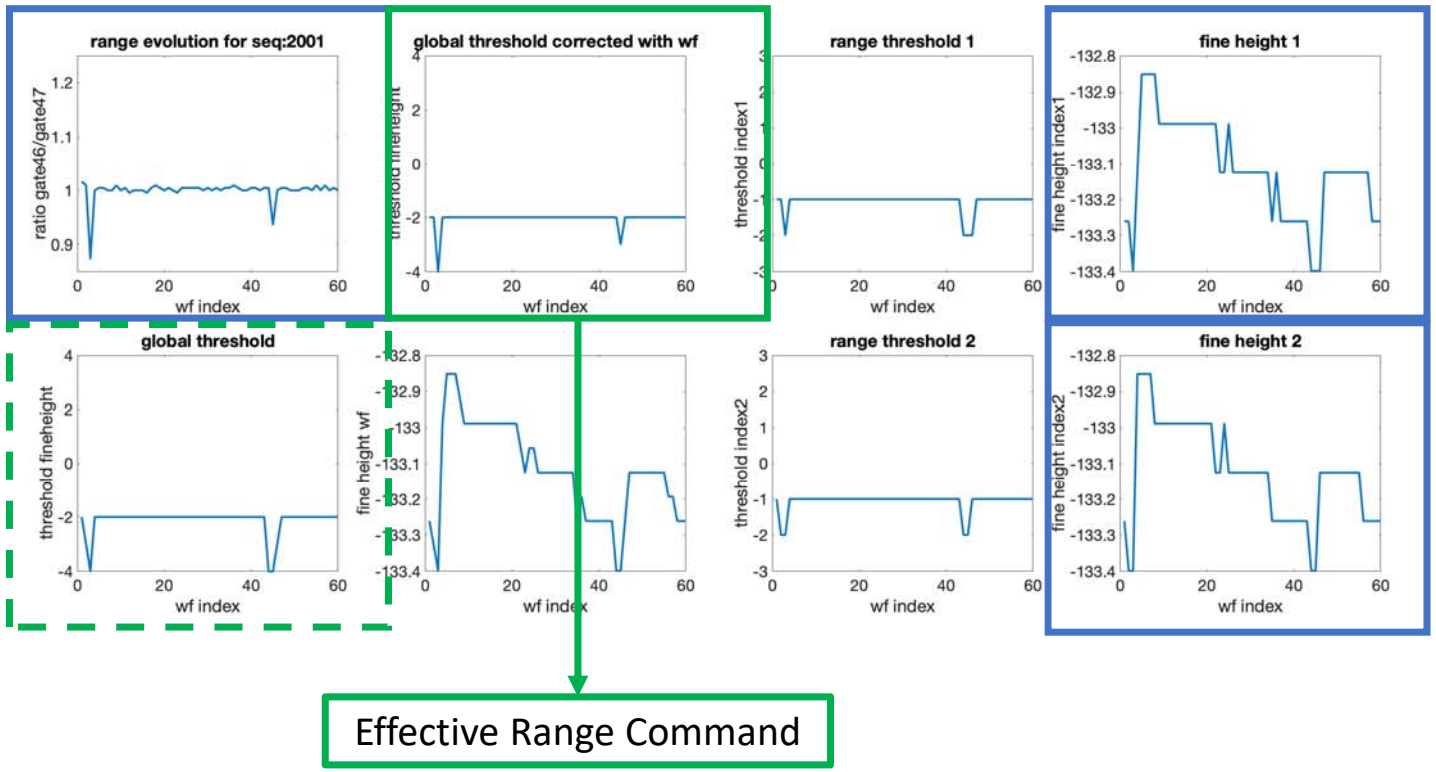


effective range command

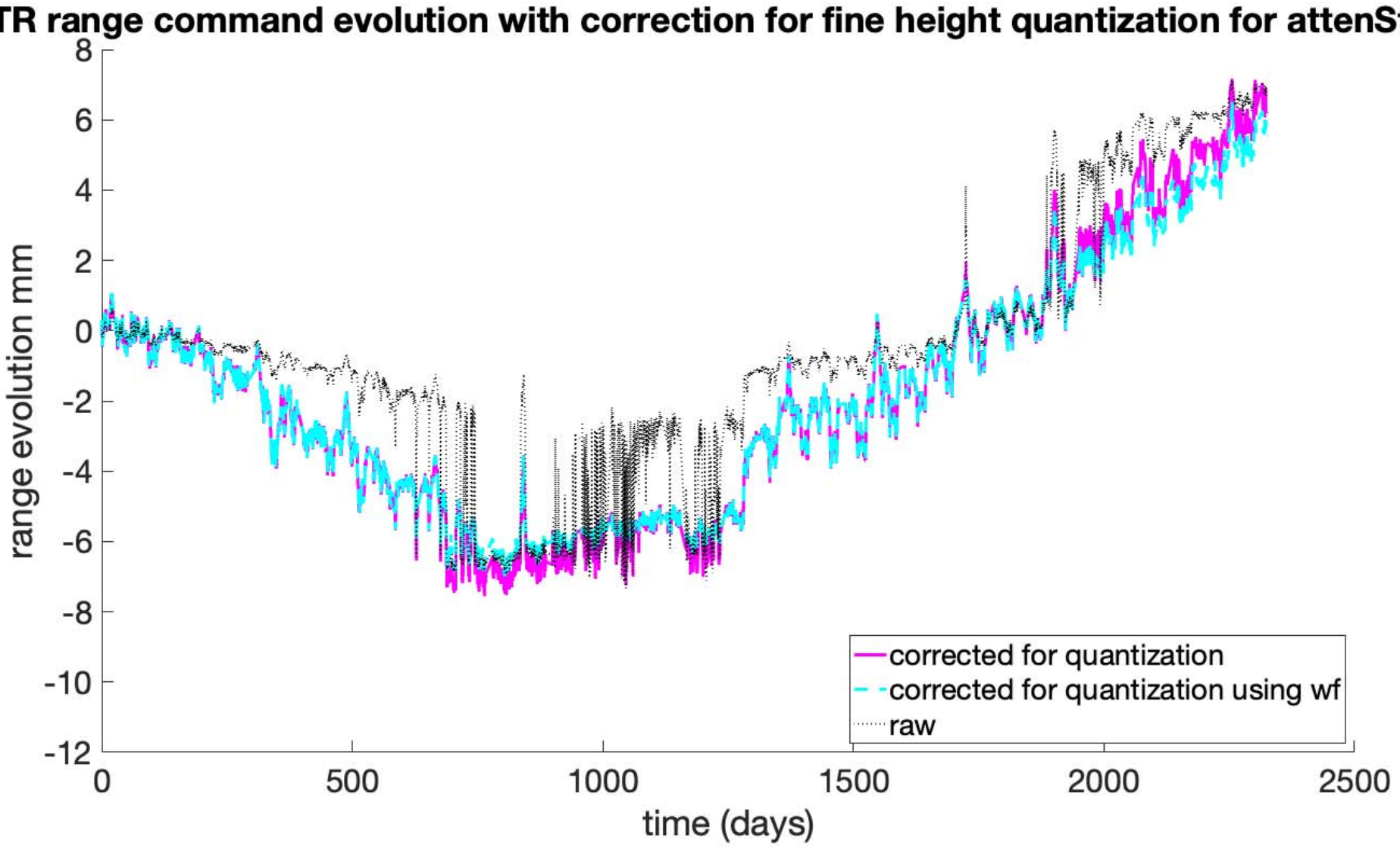
Direct Correction Computation



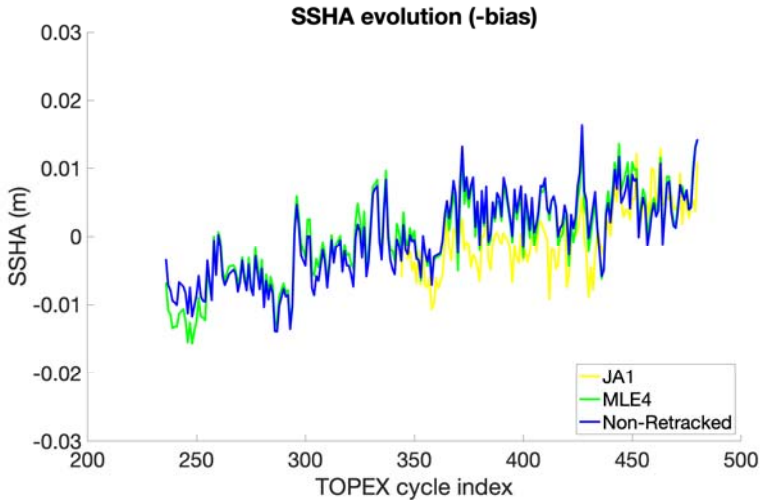
Using waveform for ambiguity correction

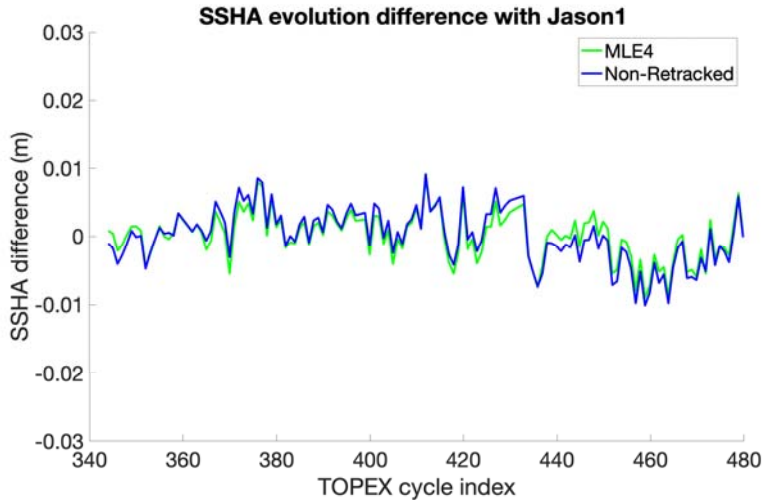


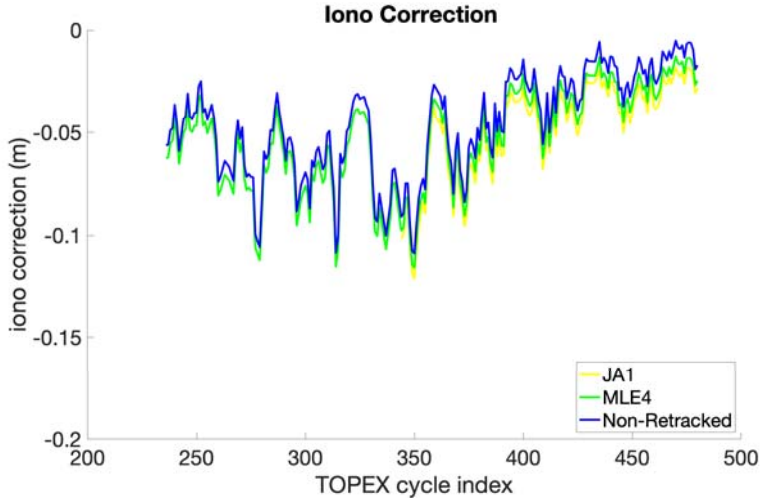
Effective PTR Range Command

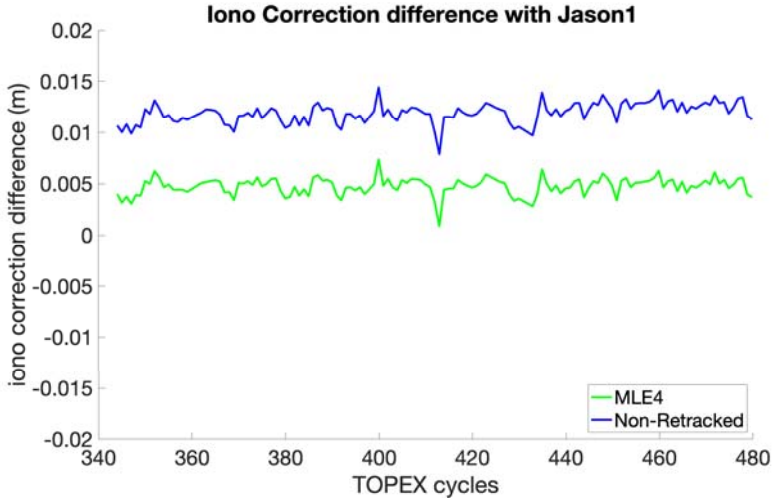


Side-B SSHA evolution statistics



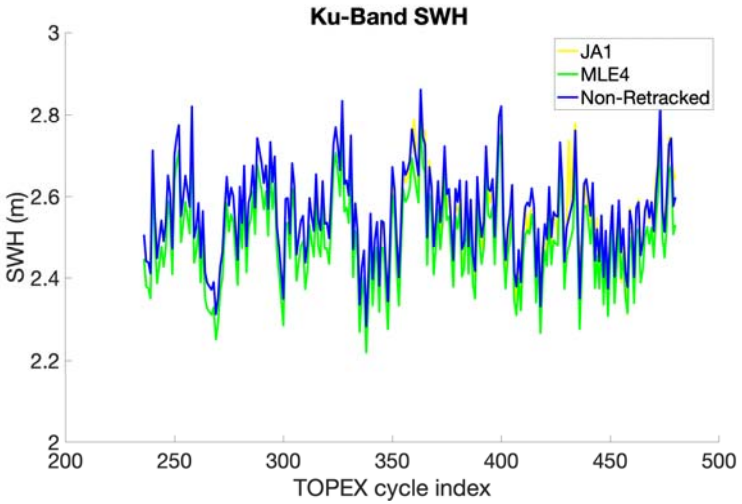


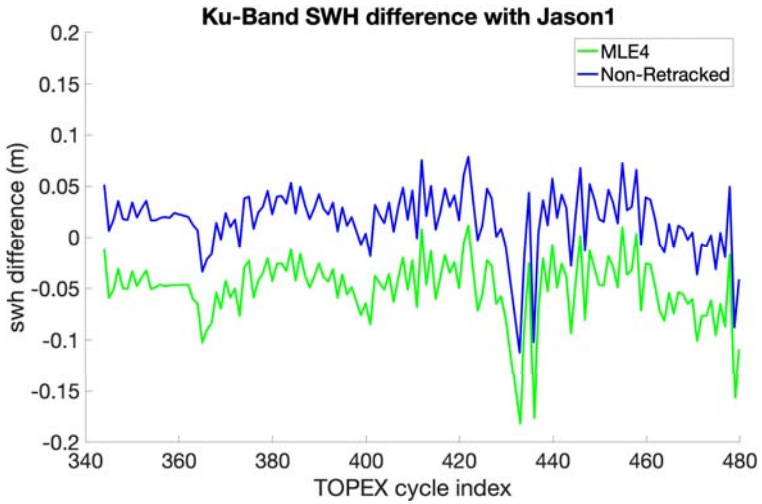


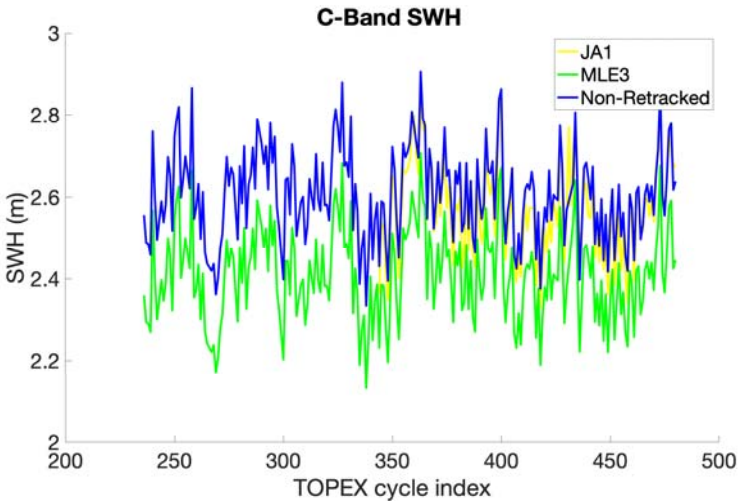


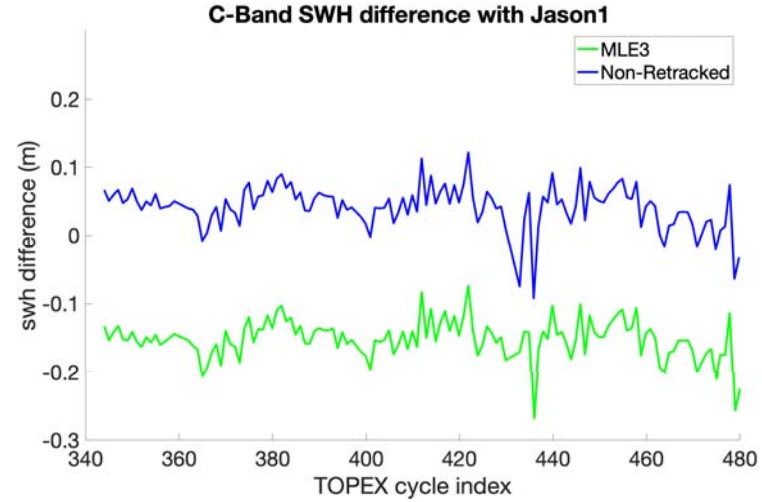
SSHA is very similar for MLE-4 and Non-Retracked data. The consistency with Jason-1 is good for both solutions

Side-B SWH evolution statistics



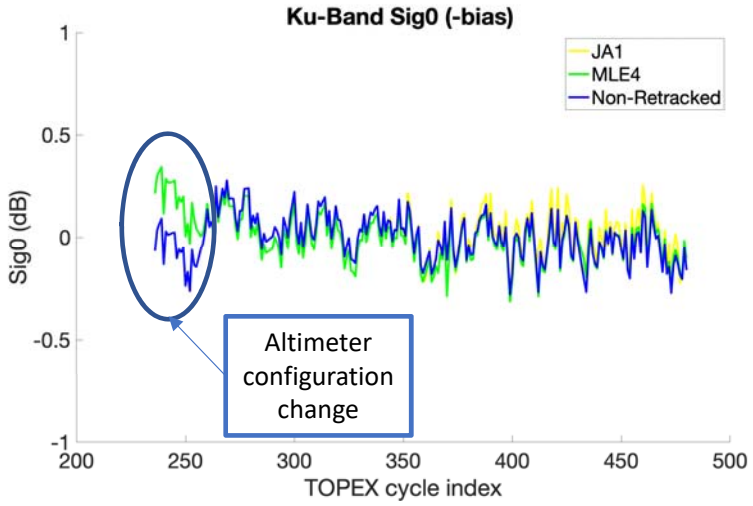


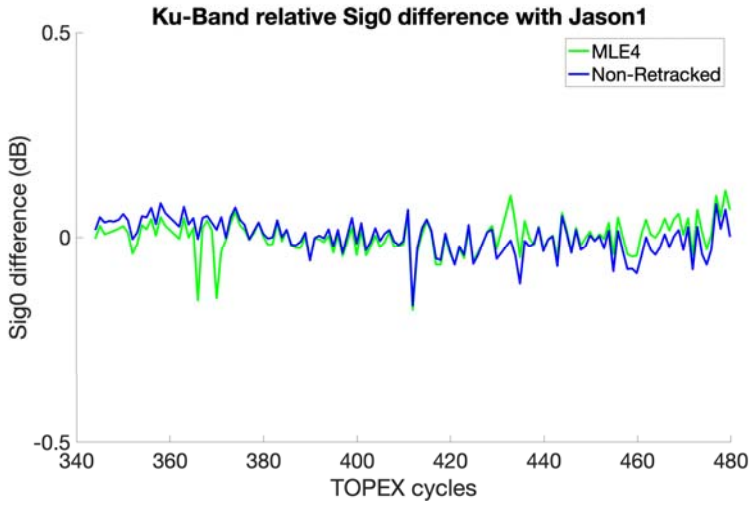


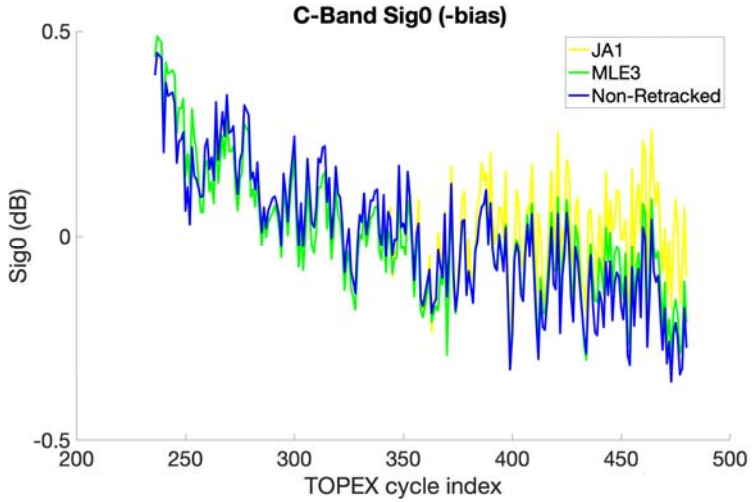


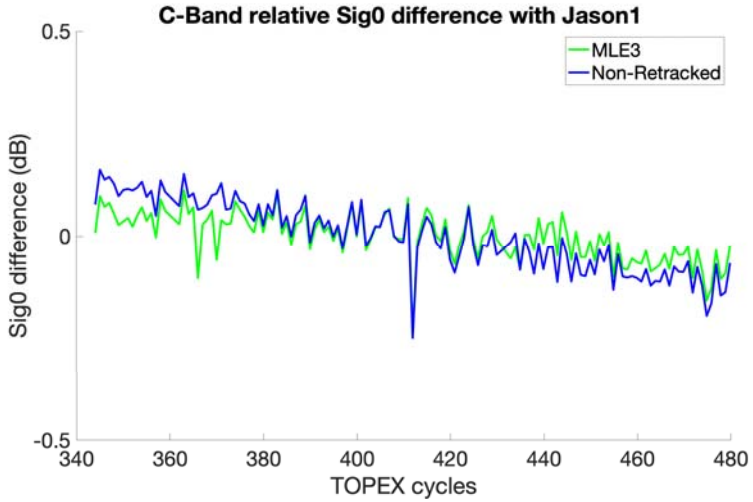
SWH evolution is very similar for MLE-3/4 and Non-Retracked data.
The consistency with Jason-1 is good for both solutions.

Side-B Sigma0 evolution statistics



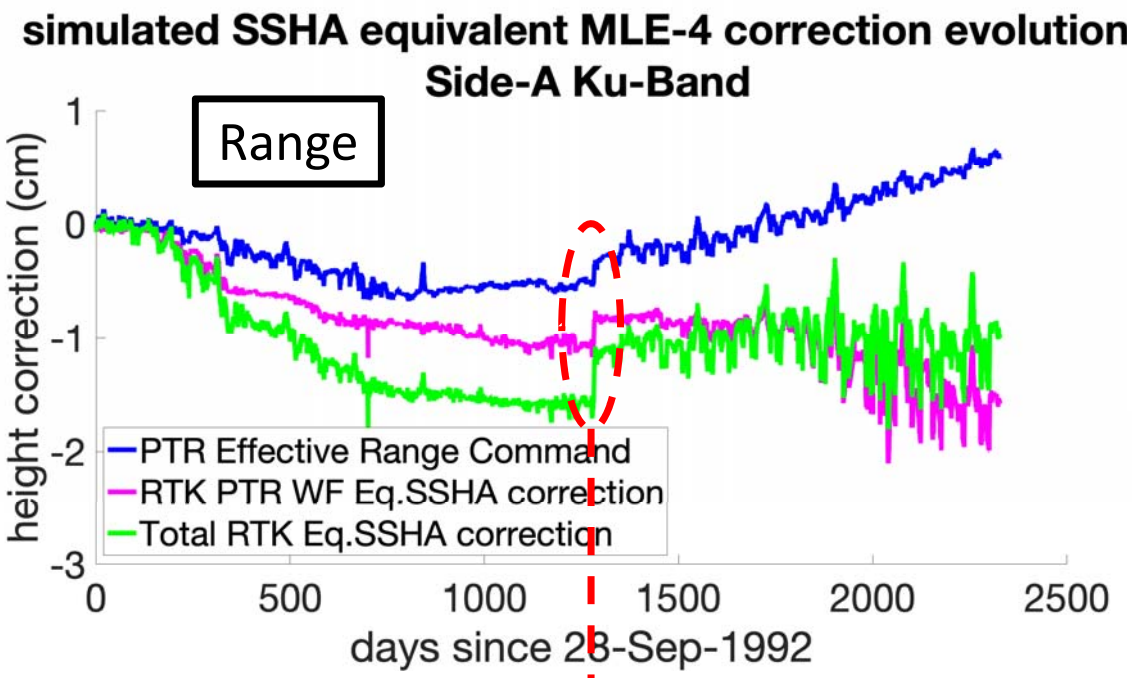




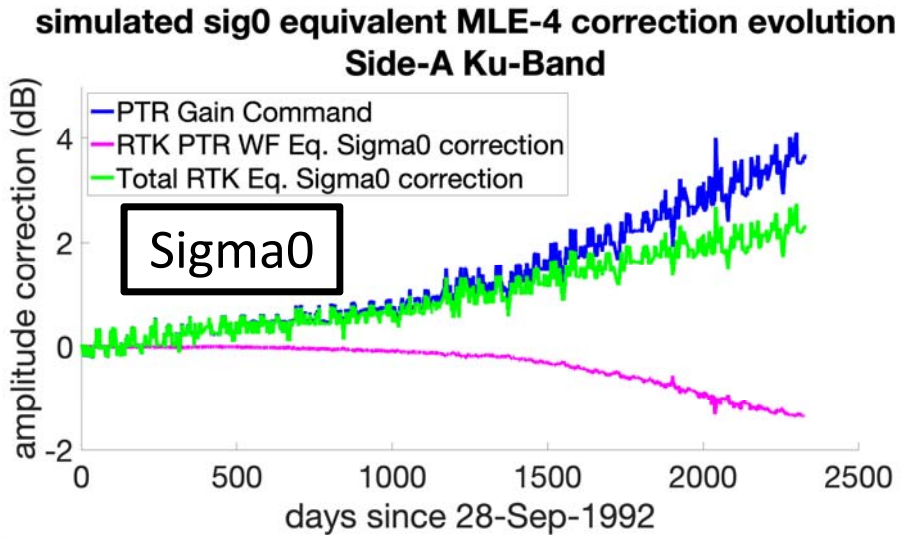


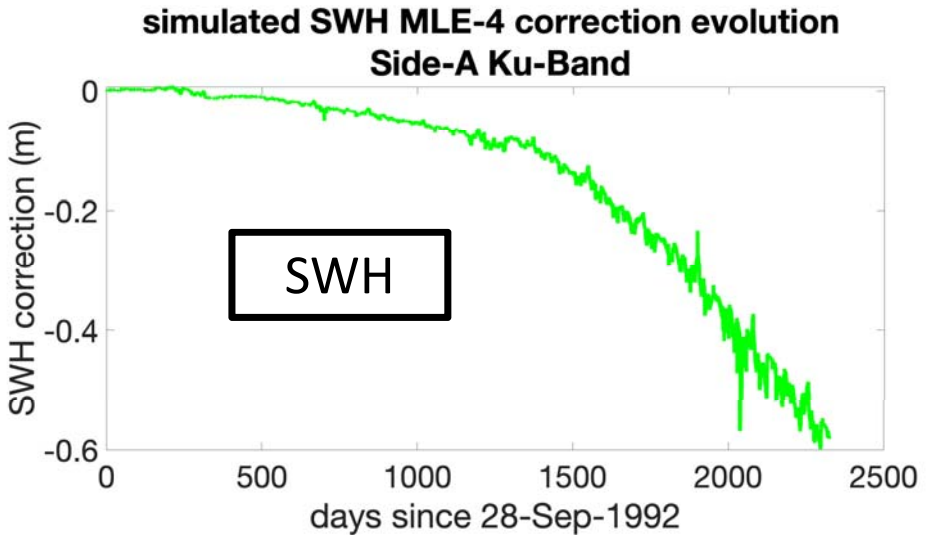
Sigma0 evolution is very similar for MLE-4 and Non-Retracked data excepted at the beginning of the series.
The difference corresponds to an altimeter configuration change.
The consistency with Jason-1 is good for both solutions with a slightly better stability for MLE-3/4.

Simulated Range, SWH and Sigma0 impact of PTR on retracked estimates

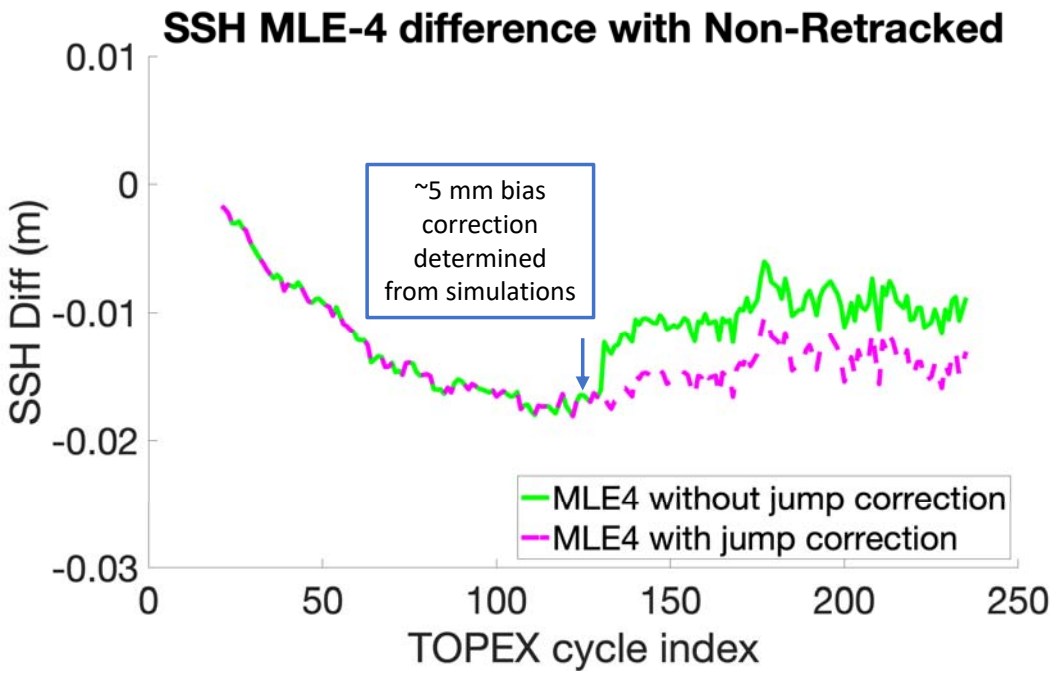


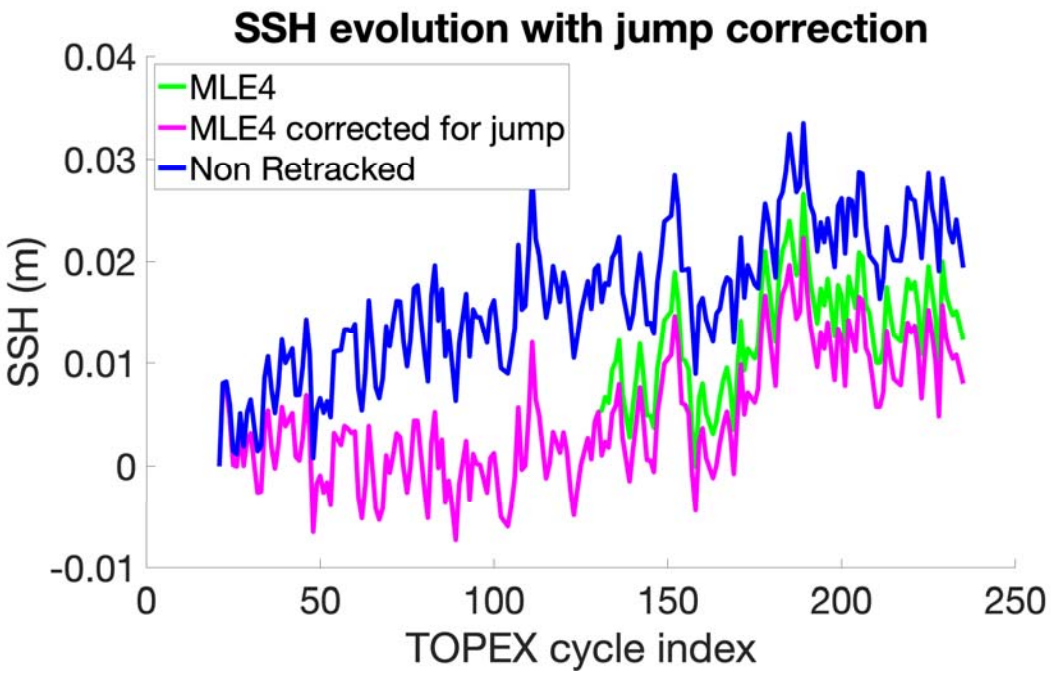
PTR jump occurred during cycle 130
opposite energy change for left/right gates (wrt PTR center)





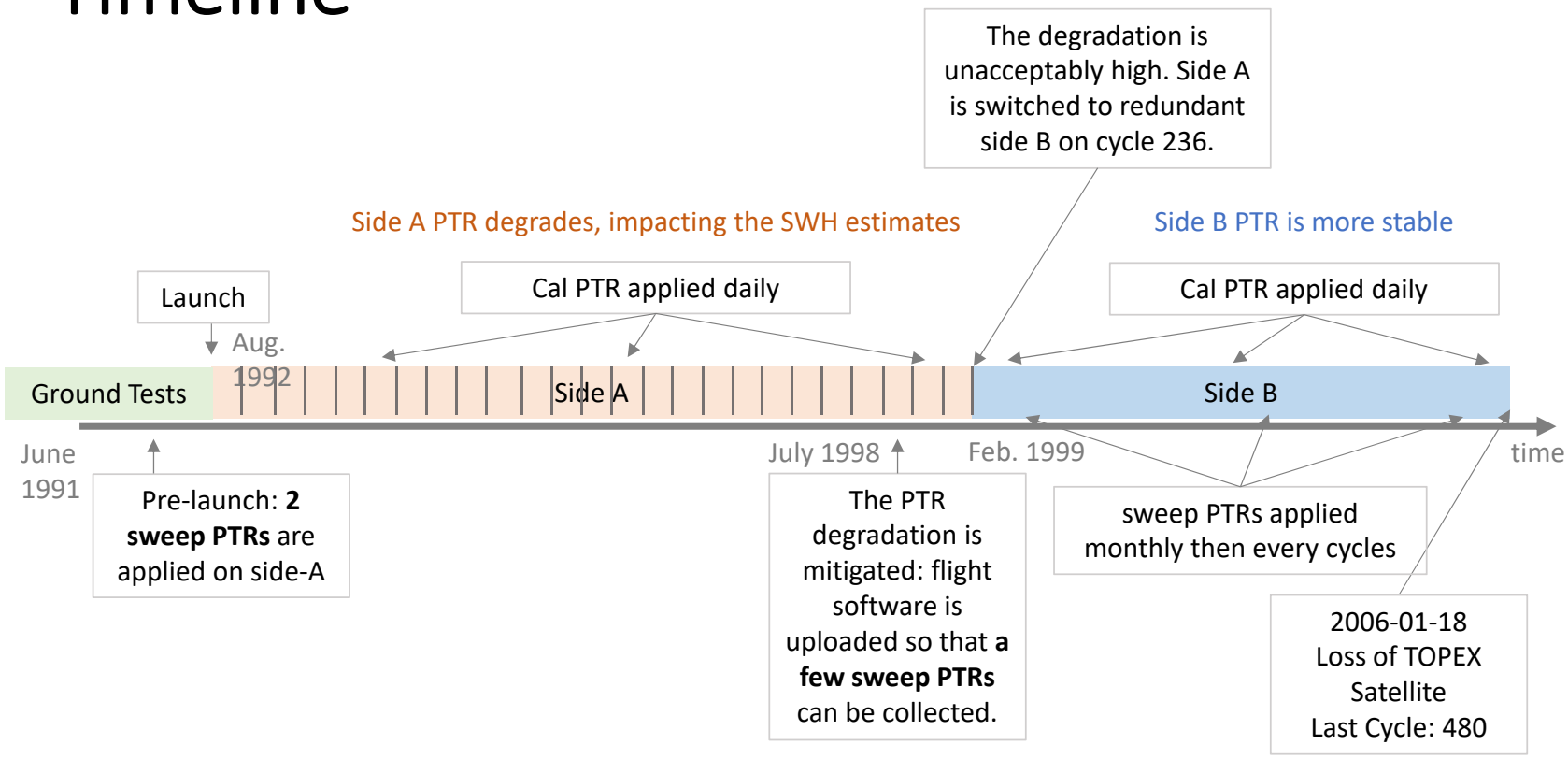
Using Simulations to Correct the PTR Jump at Cycle 130





Correcting the SSHA for the PTR jump lowers the SSH by ~ 5mm
in the second half of Side-A time series

Timeline


The degradation is unacceptably high. Side A is switched to redundant side B on cycle 236.
Side A PTR degrades, impacting the SWH estimates
Side B PTR is more stable
Launch
Aug. 1992
Cal PTR applied daily
Cal PTR applied daily
Ground Tests
Side A
Side B
June 1991
July 1998
Feb. 1999
time
Pre-launch: 2 sweep PTRs are applied on side-A
The PTR degradation is mitigated: flight software is uploaded so that a few sweep PTRs can be collected.
sweep PTRs applied monthly then every cycles
2006-01-18
Loss of TOPEX Satellite
Last Cycle: 480