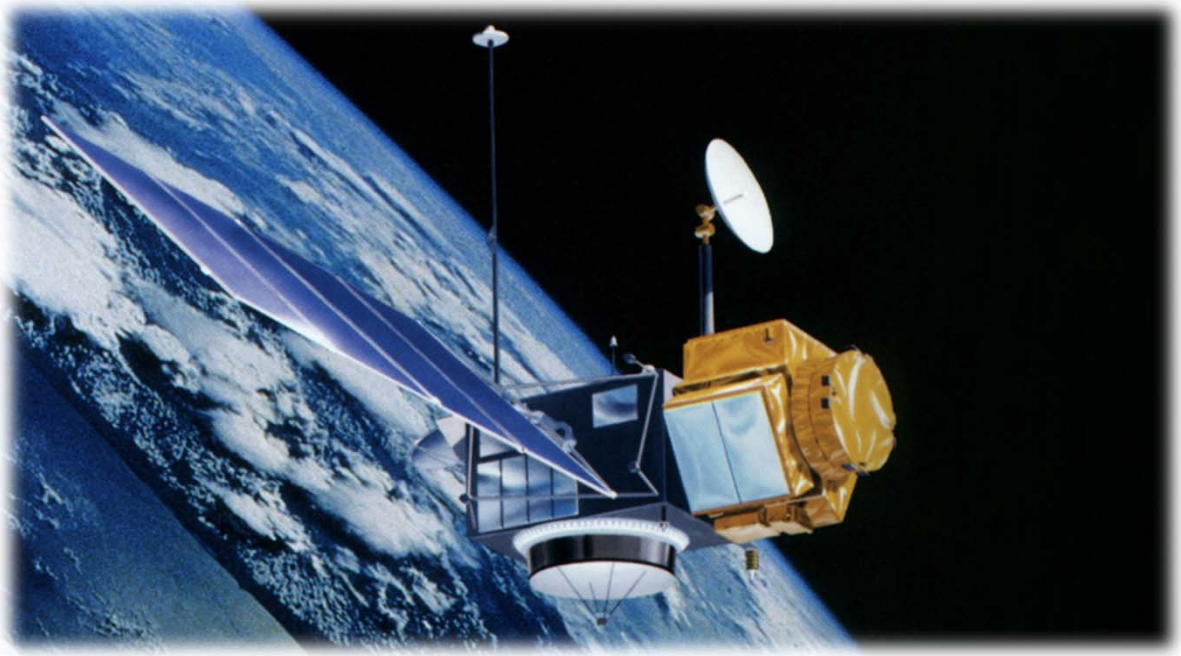
A Numerical Retracking Approach for TOPEX Data Reprocessing



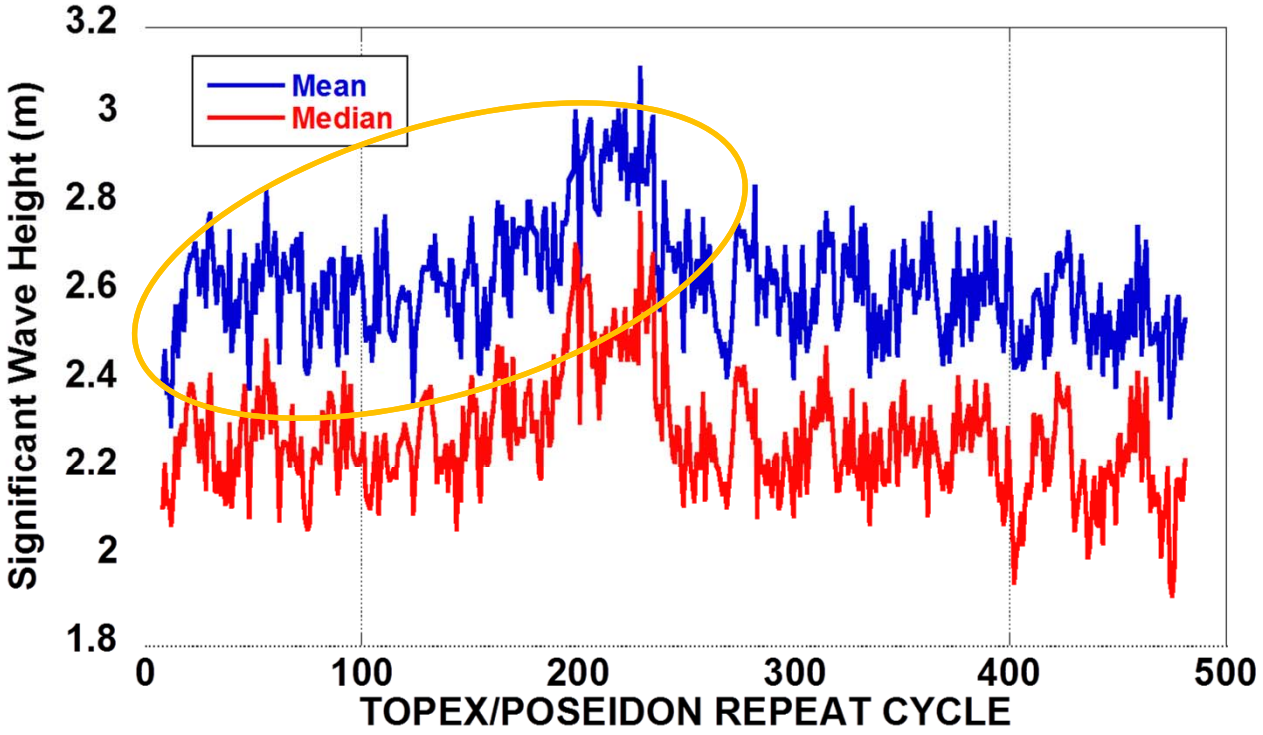
Jean-Damien Desjonquères, Philip Callahan, Matthieu Talpe, Shailen Desai

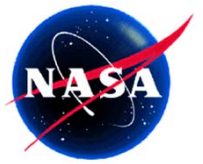
Jet Propulsion Laboratory, California Institute of Technology

September 27, 2018

Motivations for TOPEX Reprocessing

- TOPEX Current GDR Product is based on on-board estimations for range , SWH and Sigma0.
- Side-A altimeter suffered major degradation inducing an increase of about 40-50 cm for the estimated Significant Wave Height following a quadratic evolution





TOPEX Calibrations

TOPEX Point Target Response Calibrations

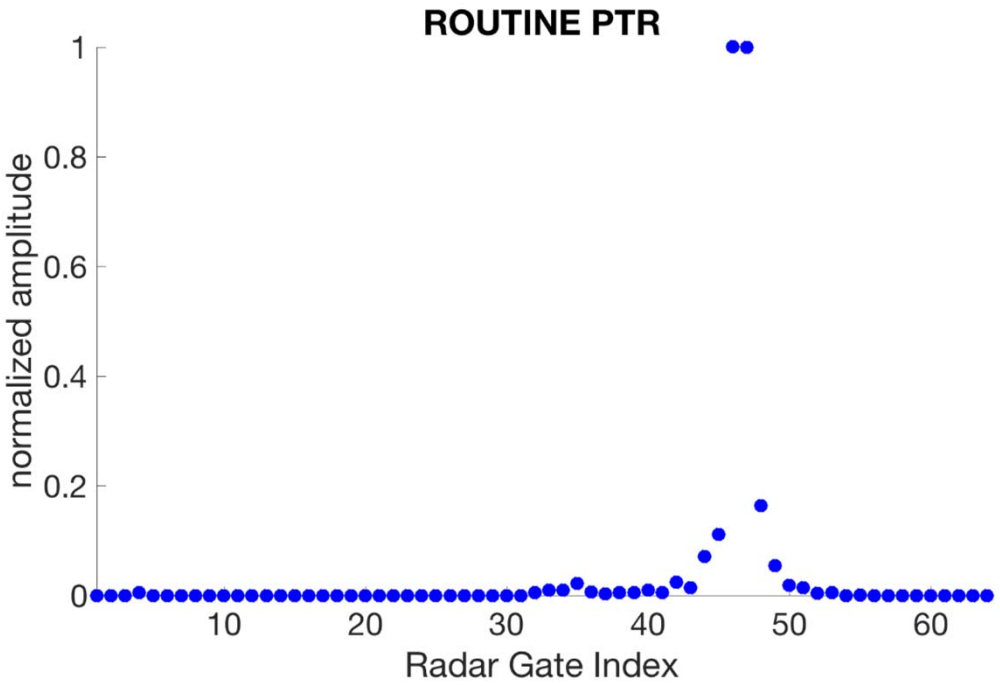
Topex altimeter was routinely calibrated twice a day

Calibration-1 mode measures the altimeter Point Target Response

The PTR is the fingerprint of the altimeter.

- Affects the measured waveforms
- Variations of the PTR can change the estimations for:
  - the range (SSH)
  - the Significant Wave Height
  - the sigma0 (windspeed)

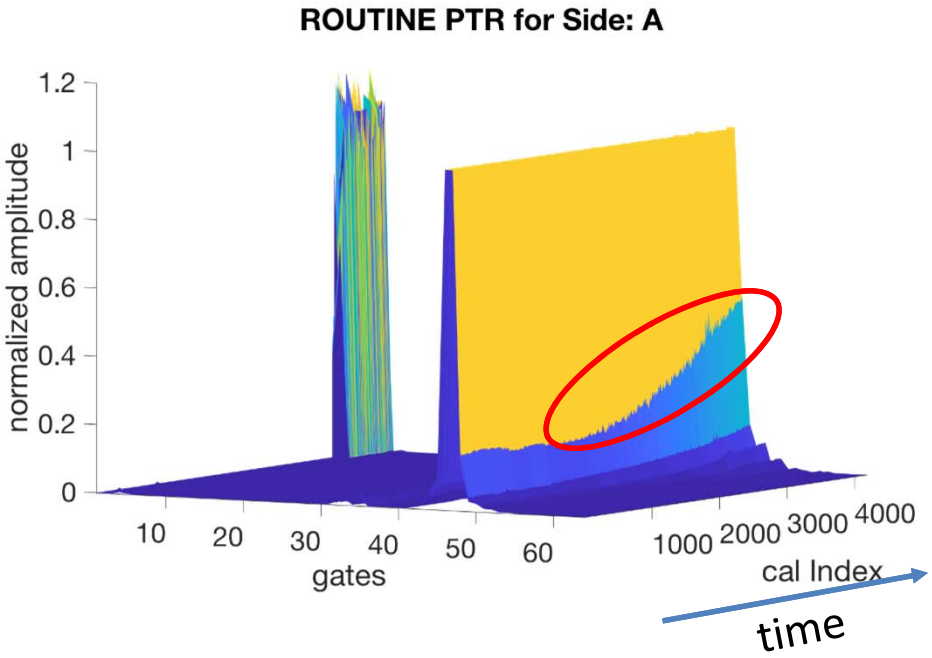
-> WE WANT THE PTR TO BE STABLE

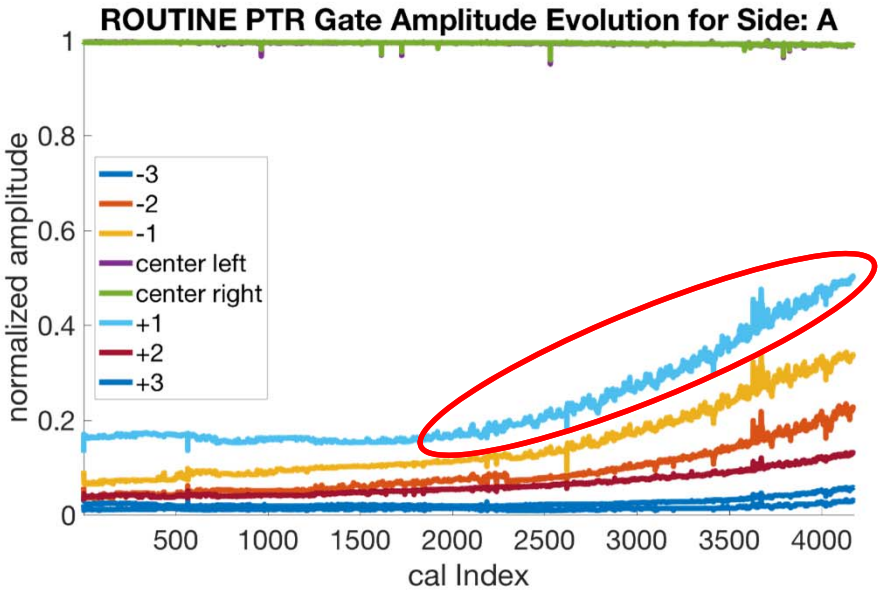


The routine PTR are not oversampled
(1 point per radar gate)

TOPEX Routine PTR Calibrations

The Side-A evolution is also noticeable in the radar PTR

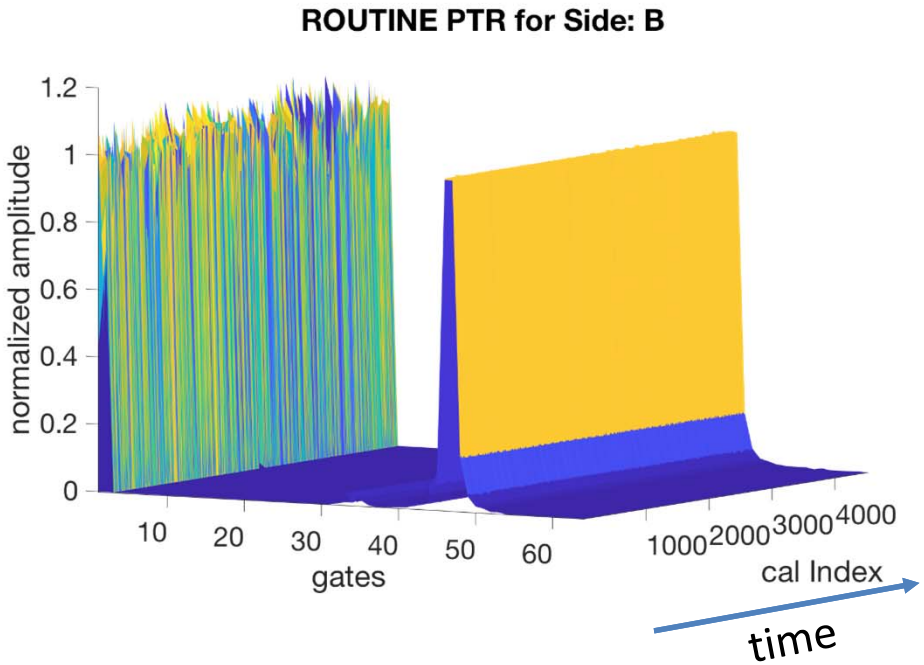


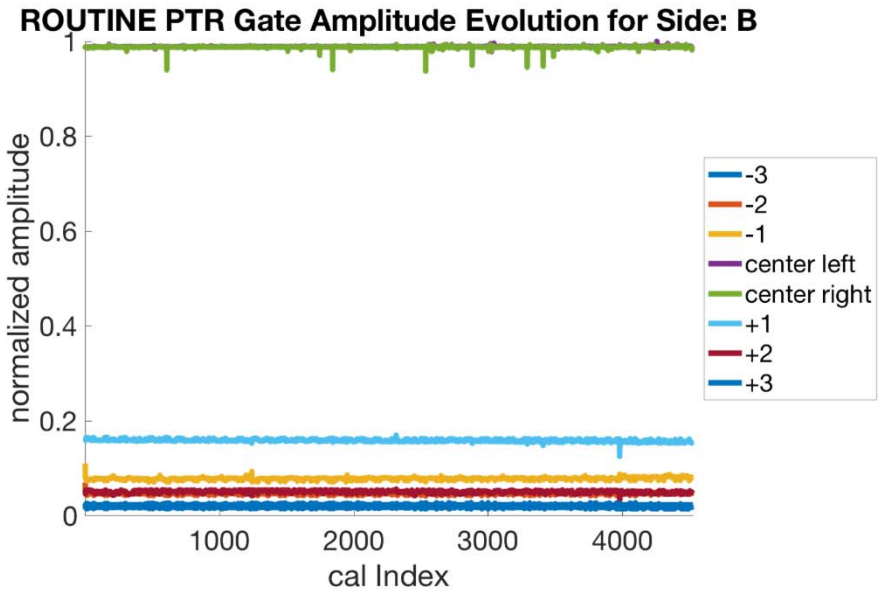


Increase of secondary lobes amplitude

Follow a quadratic evolution as for SWH evolution

In comparison the Side-B PTR is much more stable





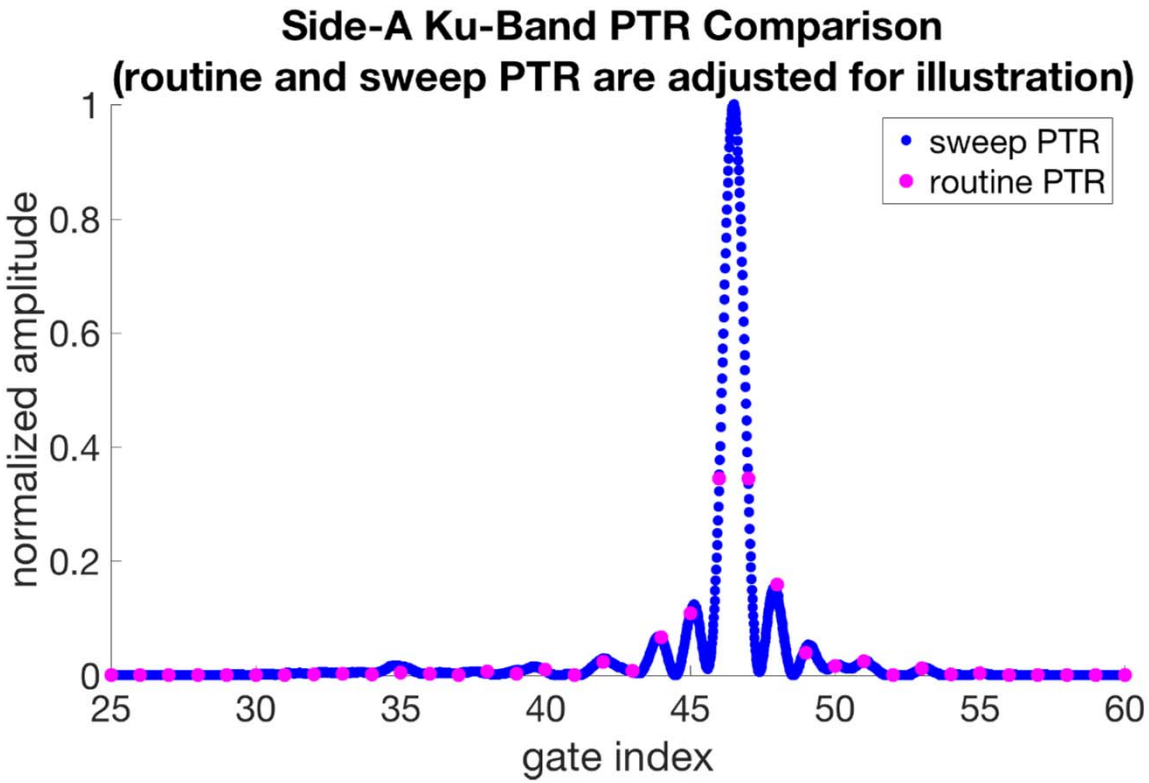
secondary lobes level is stable

Sweep Calibrations Mode

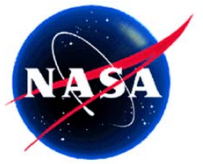
SWEEP Calibrations provide oversampled PTR: 64 points per radar gate

July 1998: because of Side-A degradation, TOPEX on-board **software has been updated to perform in-flight** so-called **sweep calibrations**

A few SWEEP Cal PTR have been collected before TOPEX Side-A has been switched off (cycle 236)

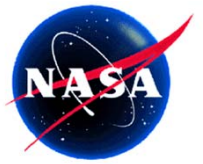


SWEEP calibrations are coherent wrt routine calibrations
-> confirmed the strong evolution of the PTR



TOPEX Waveforms Retracking

Long Time Idea: use the PTR for waveforms retracking



- In GDR, measurements are derived from on-board waveforms parameters estimations

- Ku-Band and C-Band Waveforms were transmitted to ground
  -> allows waveforms expertise and retracking (see “Calibration Data for Retracking TOPEX Data” poster)

- Previous approach: PTR Gaussian decomposition (E.Rodriguez et Al.)
  - Every side lobes are considered individually as gaussians
  - Routine PTR are used as an input to derive lobes parameters
  - The associated retracking remains analytical

  + Efficient in term of computing time

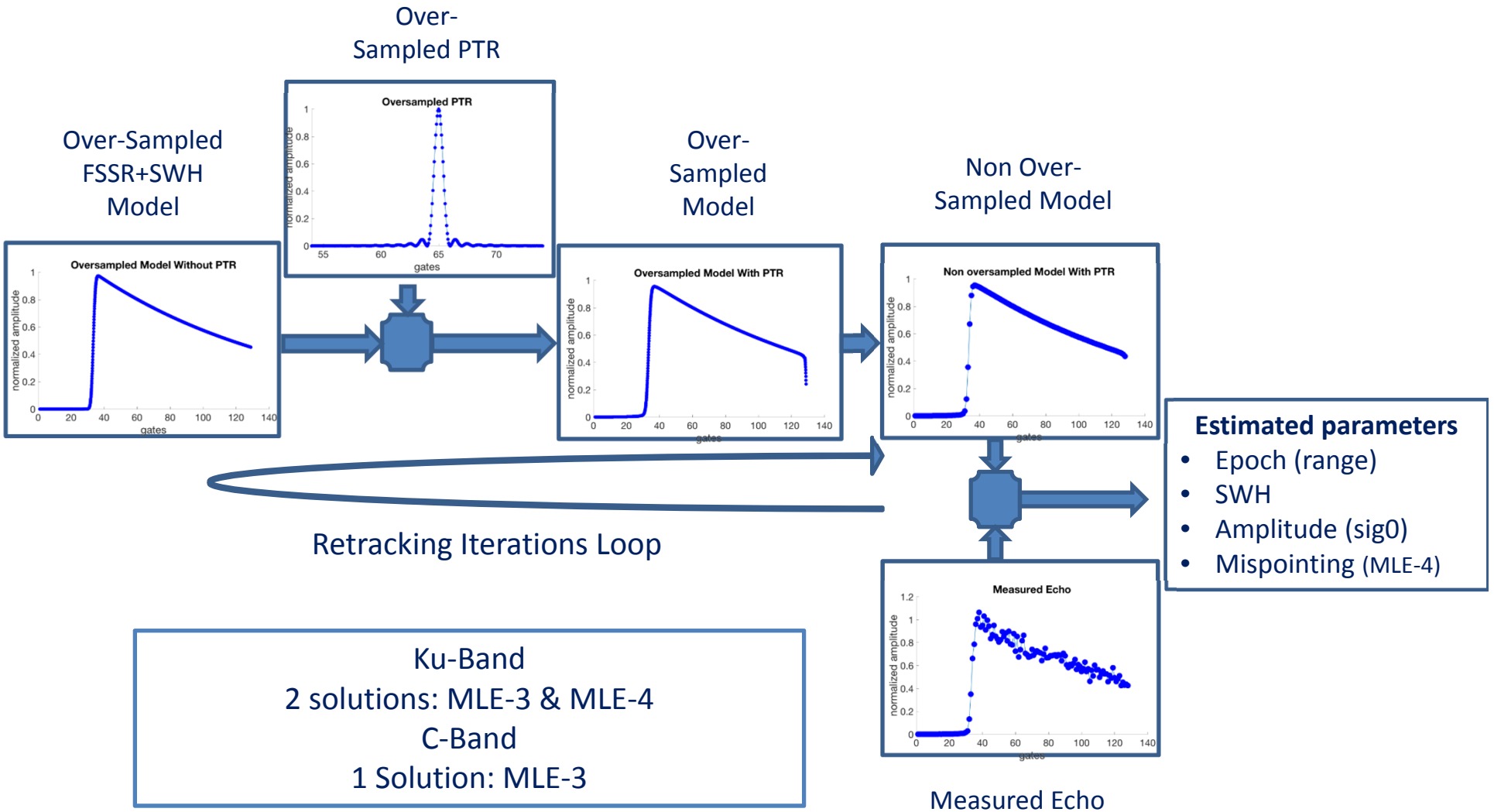
  + Huge improvement compared to classical single gaussian PTR approach (which is unable to take into account secondary lobes amplitude variation)

  – Can not take into account lobes shape change (in particular main lobe)

  – Assumes that lobes are centered on routine PTR measured gates

- $\Longrightarrow$ New approach: **numerical retracking**
  - Based on the uses of oversampled PTR
  - Takes benefit of improved computing capability

Numerical Retracking
-> introducing over-sampled measured PTR



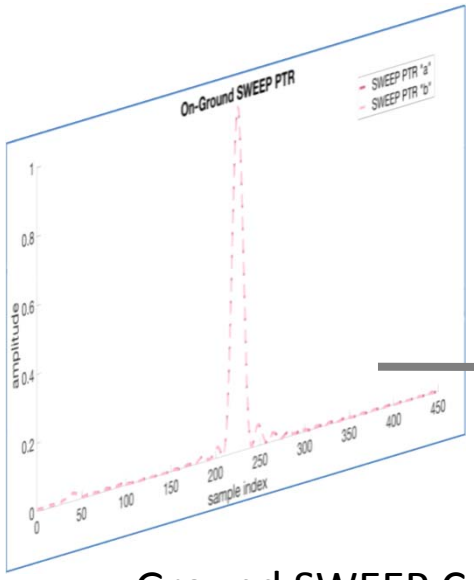
Oversampled PTR available?

numerical approach -> requires to use an oversampled PTR

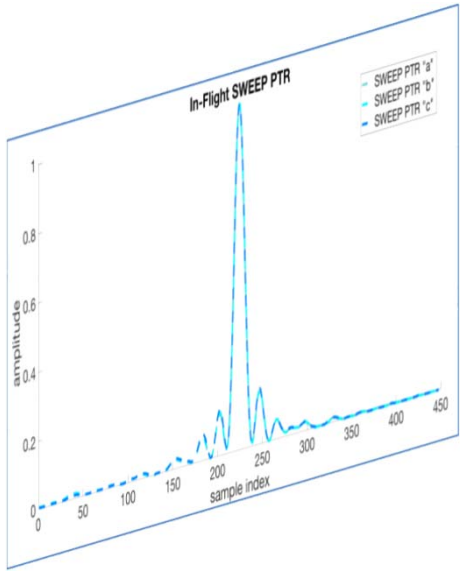
- Side-B : -> OK
  - In-flight sweep calibrations have been performed periodically (1 per month during half of the Side-B missions, 1 per cycle later)
  - In total 148 sweep calibrations available

- Side-A : -> NOK
  - Only 3 usable sweep calibrations at the end of Side-A mission are available
  - A couple of sweep calibrations have been performed on-ground

Goal: Generate missing sweep PTRs



?



Ground SWEEP Calibrations

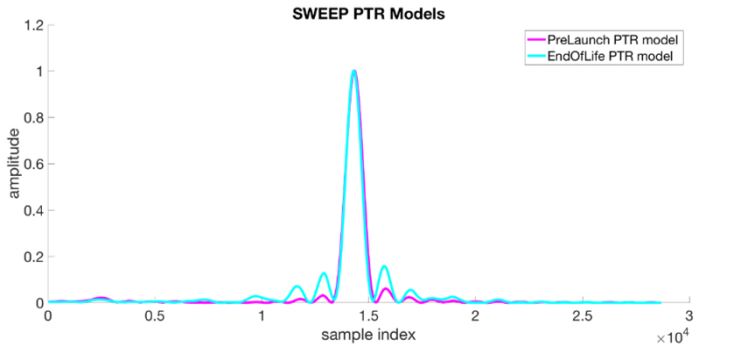
End Of Life SWEEP Calibrations

Evolution of PTR involves more than just amplitude of lobes:

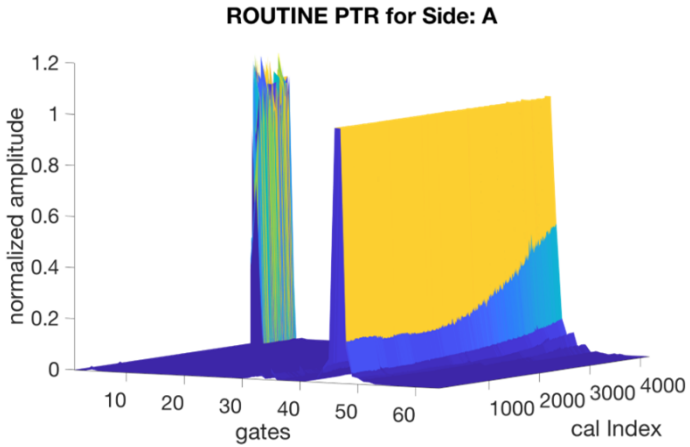
1. Frequency shift of lobes
2. General shape of PTR
3. Width of main lobe

Reconstructing Sweep PTR

averaged on-ground sweep PTR
+ averaged in-flight sweep PTR



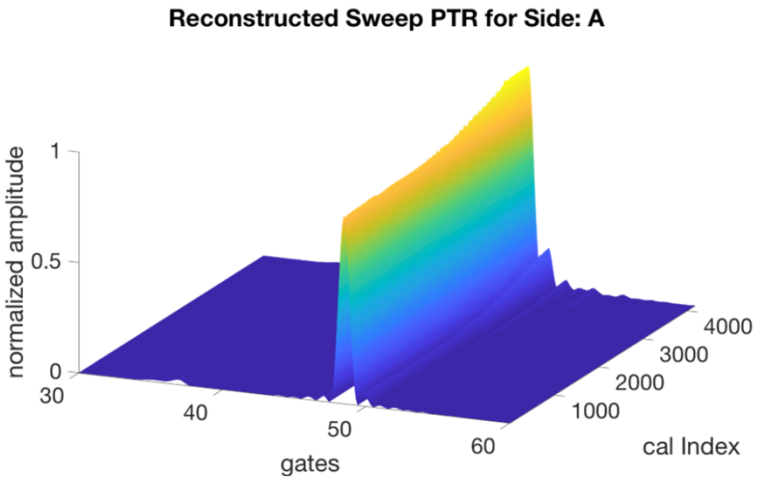
routine PTR time series



Principle

Use of the routine PTR to constrain models morphing derived from the SWEEP PTR

reconstructed sweep PTR time series

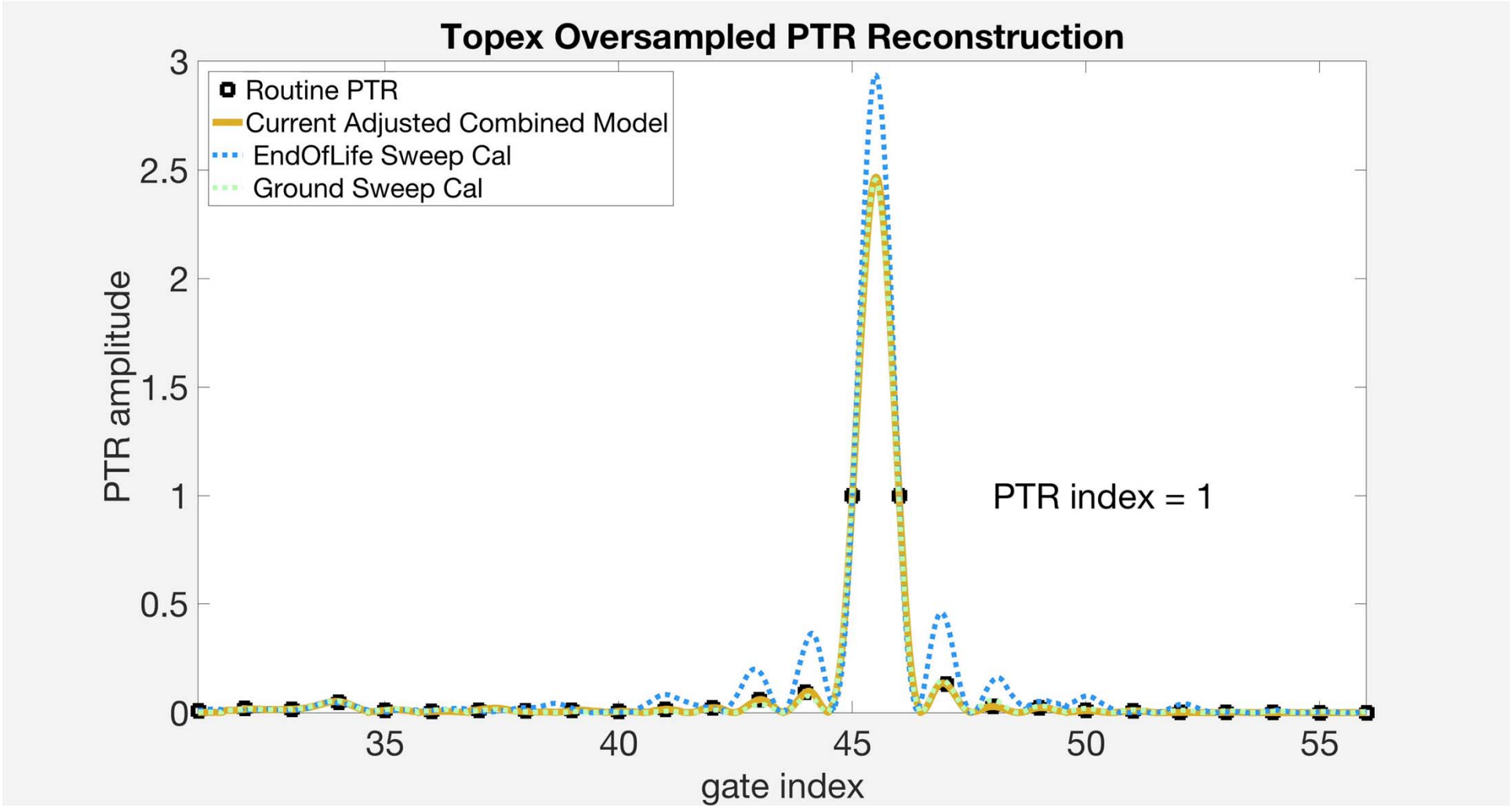


1. Adjusting scheme

Algorithm to shift frequency and amplitude of lobes for each model

2. Weighting scheme

The weighting between the two adjusted models is currently driven by $r = \frac{E_{MainLobe}}{E_{FirstSideLobe}}$, where *E* reflects the energy of a lobe.


Topex Oversampled PTR Reconstruction
Routine PTR
Current Adjusted Combined Model
EndOfLife Sweep Cal
Ground Sweep Cal
PTR index = 1
PTR amplitude
gate index
0
0.5
1
1.5
2
2.5
3
35
40
45
50
55

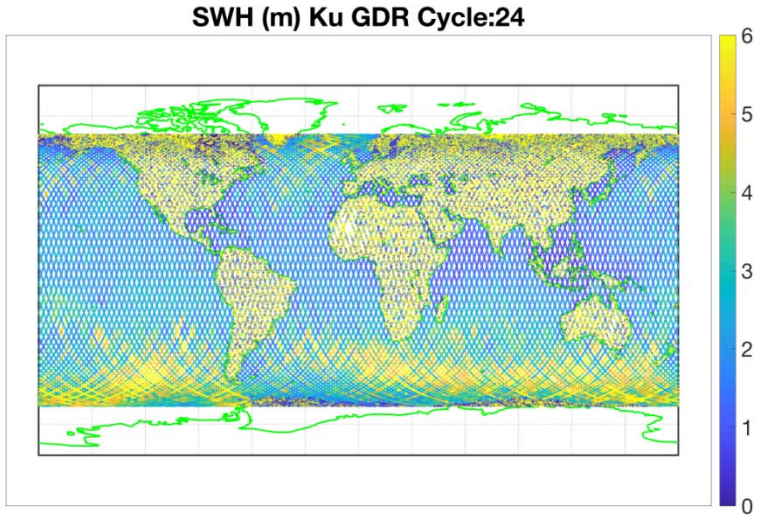
Preliminary Results

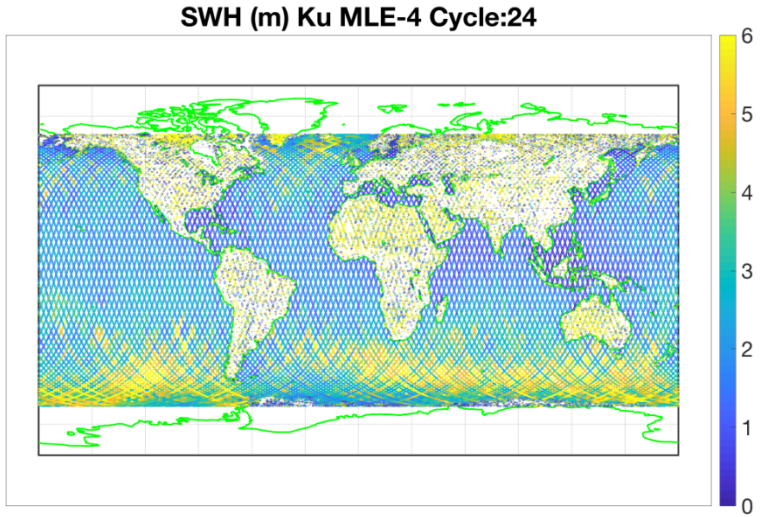
SWH Comparison

GDR

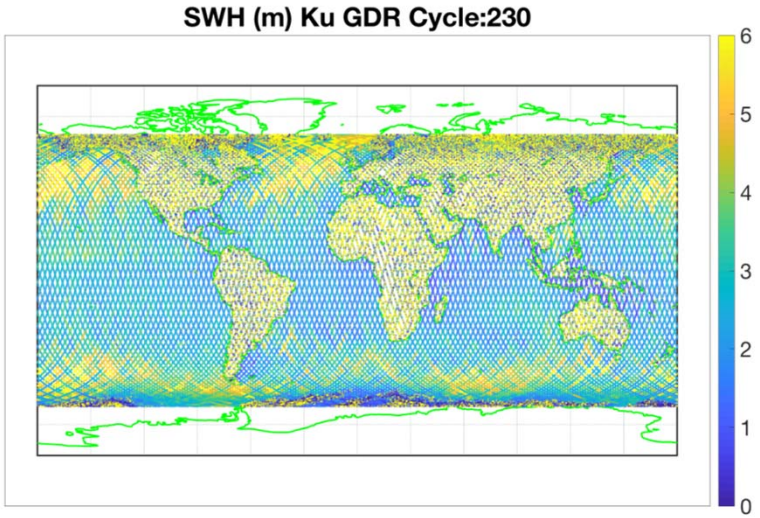
MLE-4

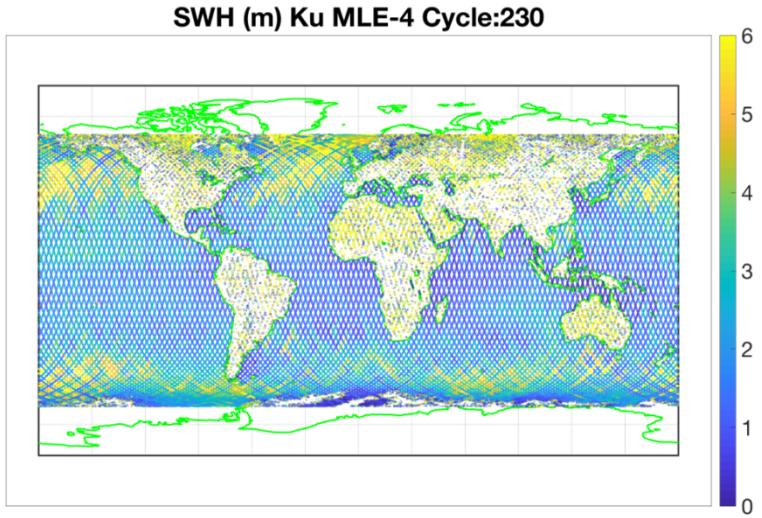
Beginning of side-A mission





End of side-A mission



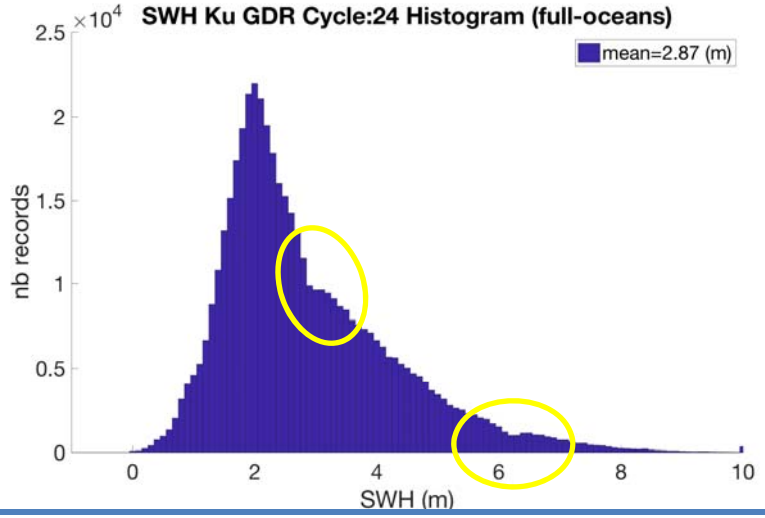


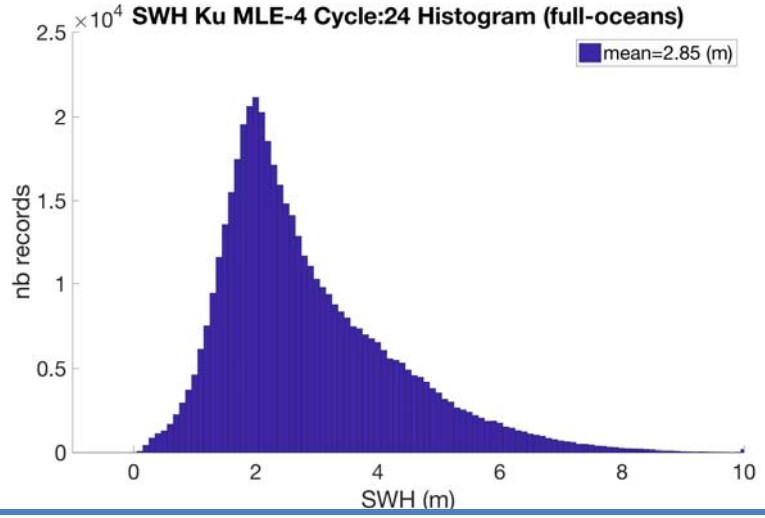
Similar behavior for cycle 24 and 230. For cycle 230 SWH in MLE-4 are lower than for GDR -> expected results

GDR

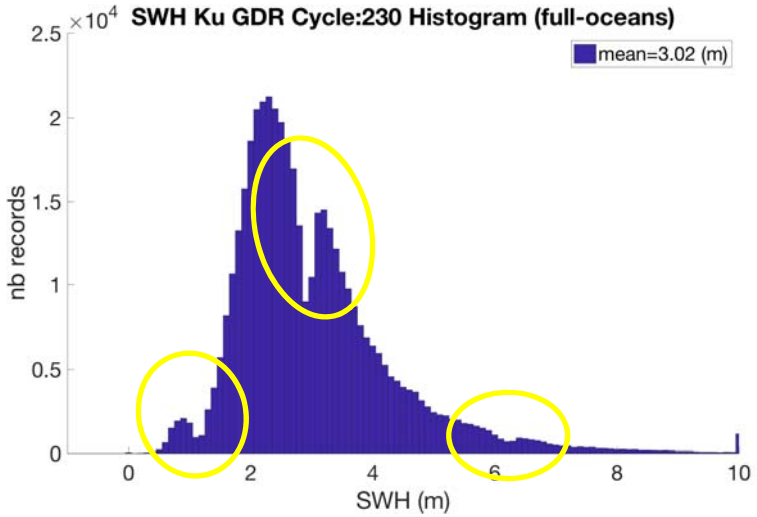
MLE-4

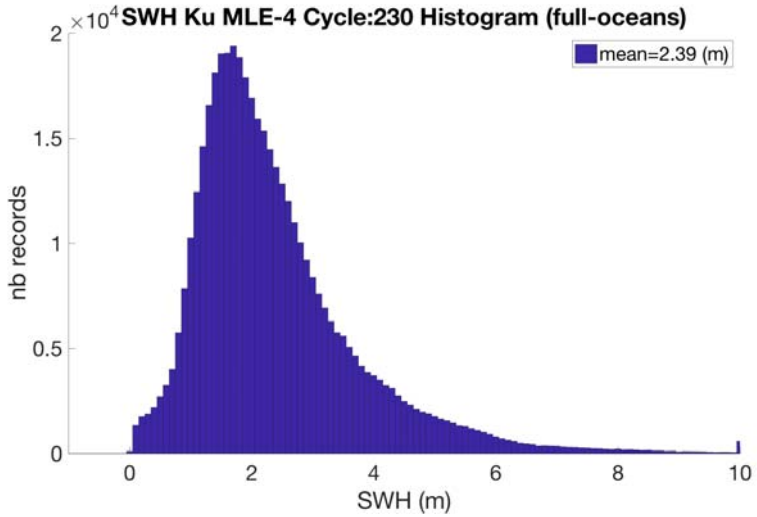
Beginning of side-A mission





End of side-A mission

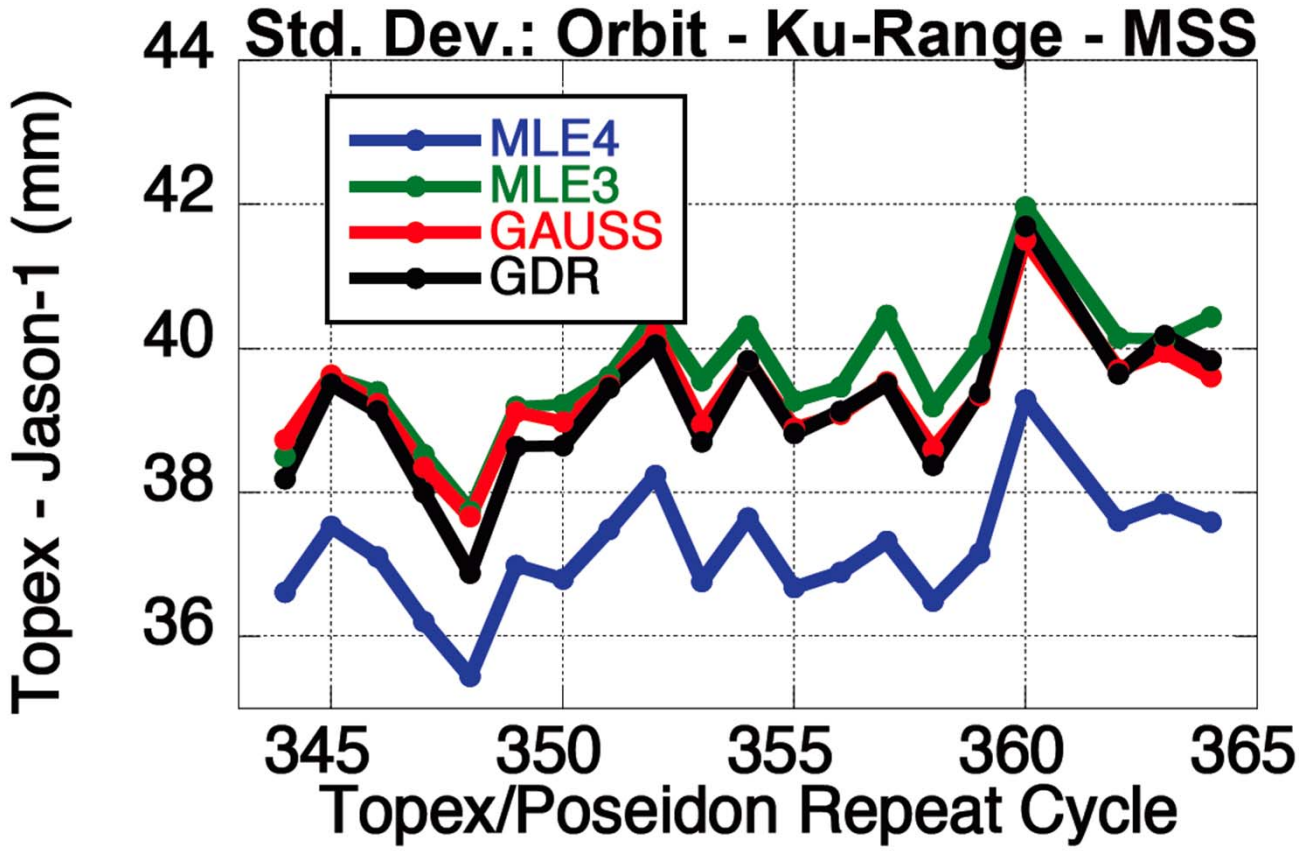




Cleaner distribution thanks to the waveforms retracking especially for cycle 230

The SWH for cycle 230 are lowered by ~60 cm using numerical approach

Standard Deviation of Topex – Jason-1 Differences

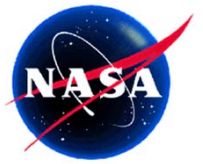


The std of difference wrt Jason-1 is reduced using MLE-4 retracking

For mode results -> see “Calibration and Validation of Reprocessed TOPEX Geophysical Data Records” poster from S. Desai et Al. in CalVal session

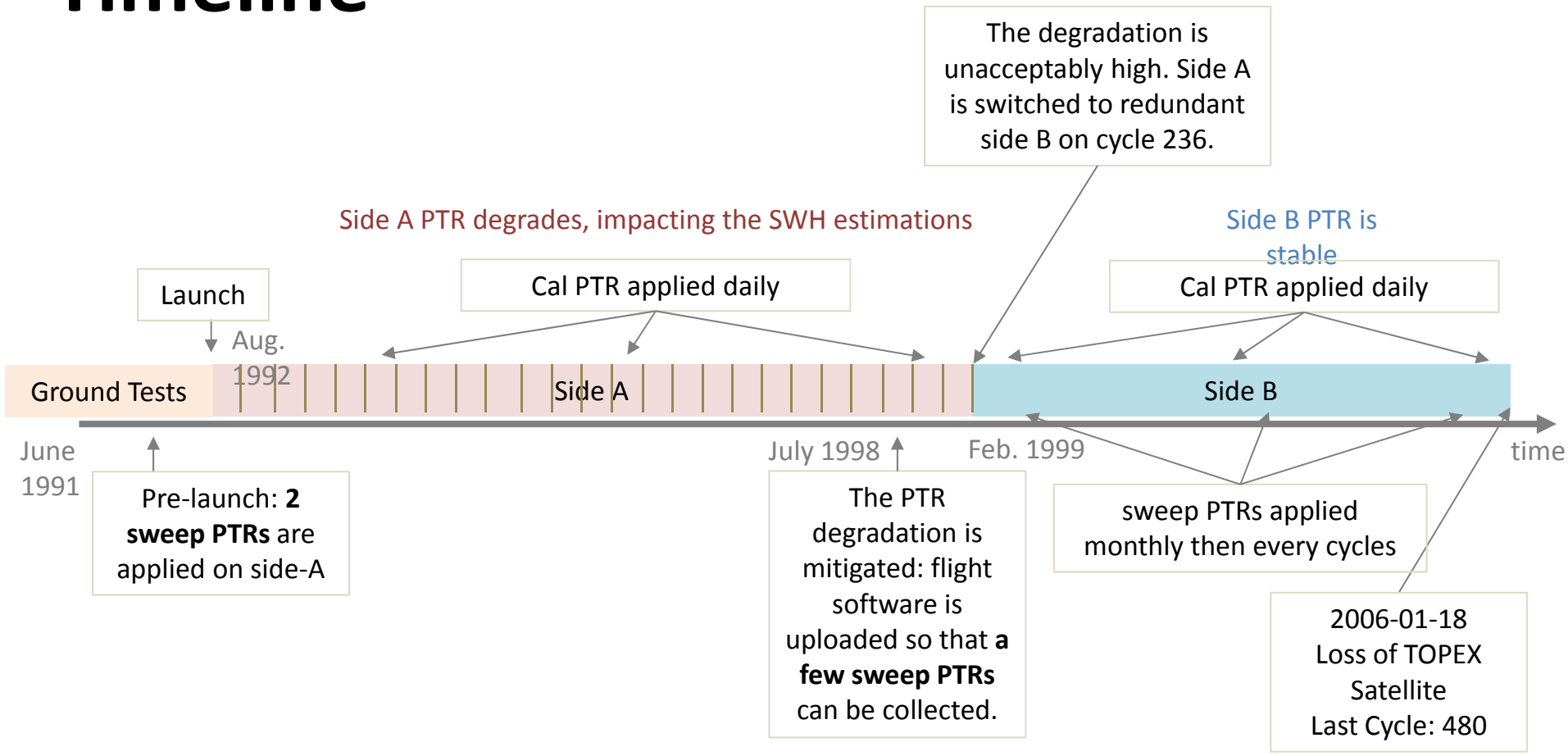
Conclusion

- Method has been fully developed
- First results are promising
- Still some questions about the quality of the TOPEX Calibrations (over compensation of SWH?)
- CalVal on-going
- Work plan:
  - First: Side-B during Jason-1 tandem period
  - Full Side-B mission
  - Full Side-A mission



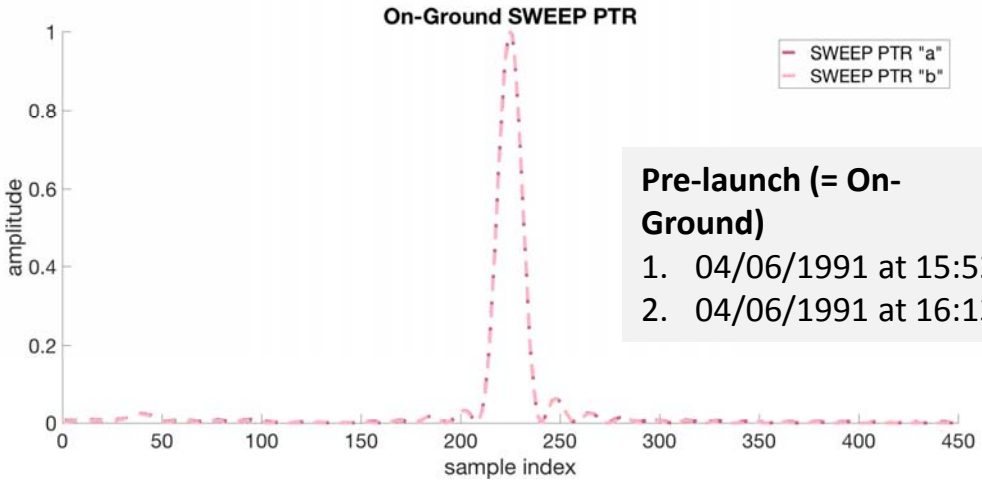
Back-up Slides

Timeline


The degradation is unacceptably high. Side A is switched to redundant side B on cycle 236.
Side A PTR degrades, impacting the SWH estimations
Side B PTR is 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

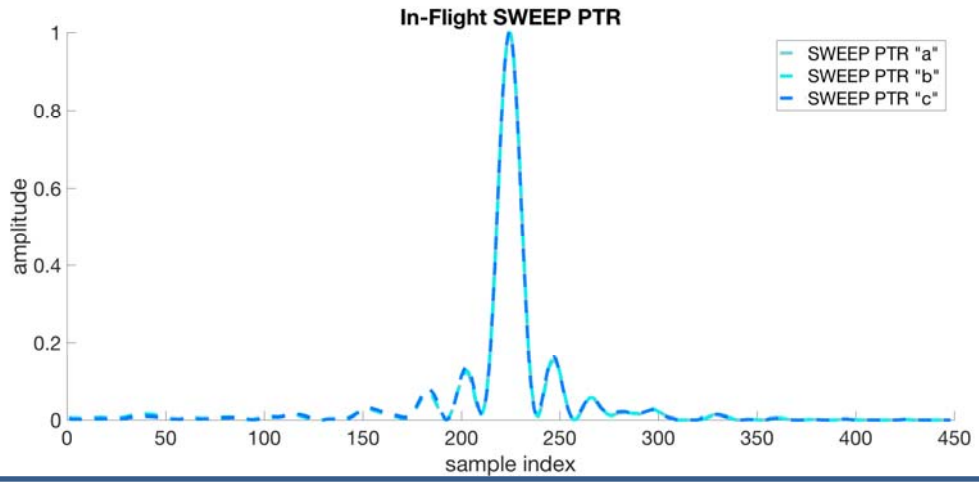
Side-A Sweep PTR

- A few sweep calibrations are available, from which 2 averaged oversampled PTR (pre-launch and post-launch) are derived
- High-resolution: 16 samples/gate for ground calibration and 64 samples/gate for in-flight calibrations (processed from SDR)



Pre-launch (= On-Ground)

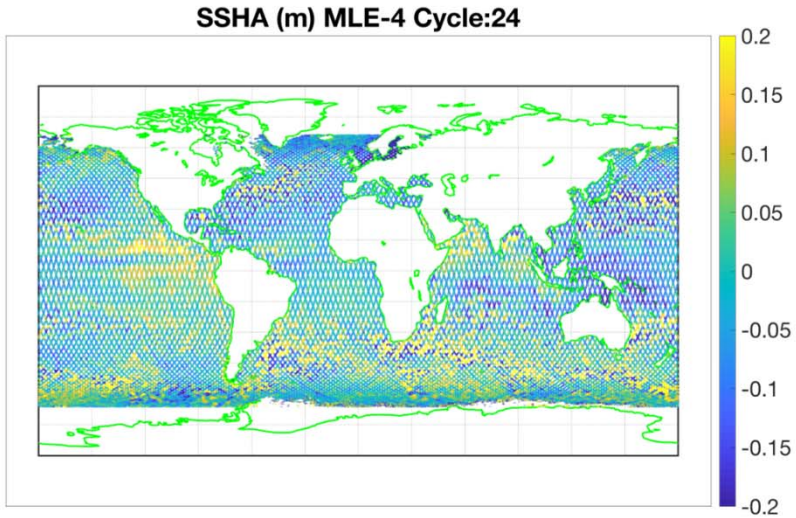
1. 04/06/1991 at 15:52
2. 04/06/1991 at 16:13

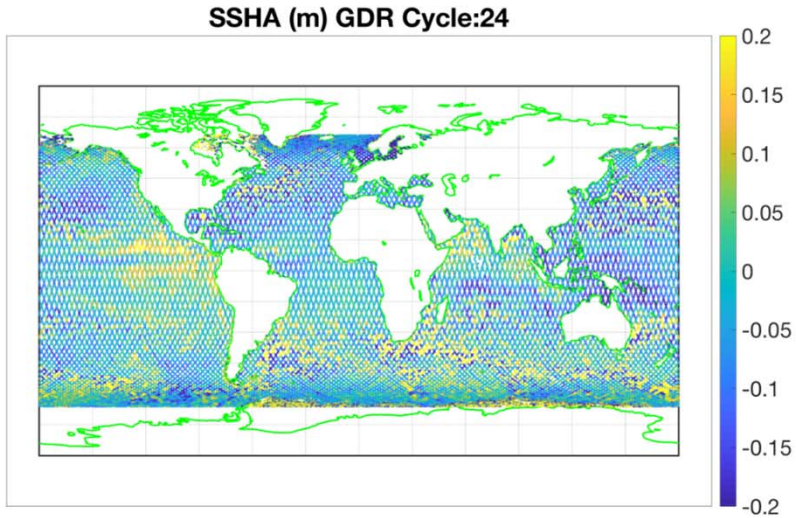


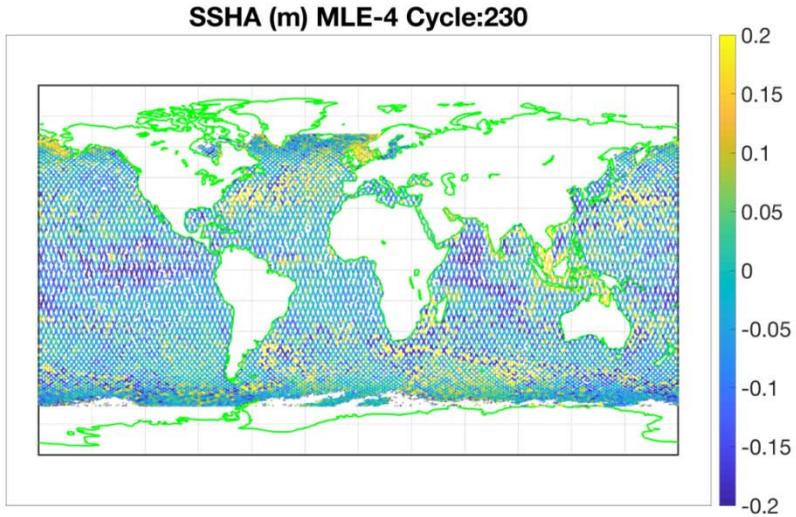
End-Of-Life (= In-Flight)

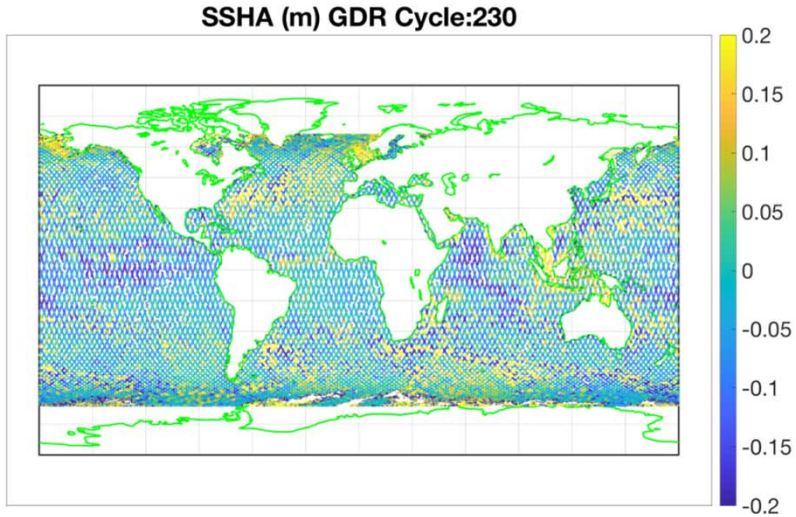
3. 7/10/1998
4. 15/12/1998
5. 09/02/1999

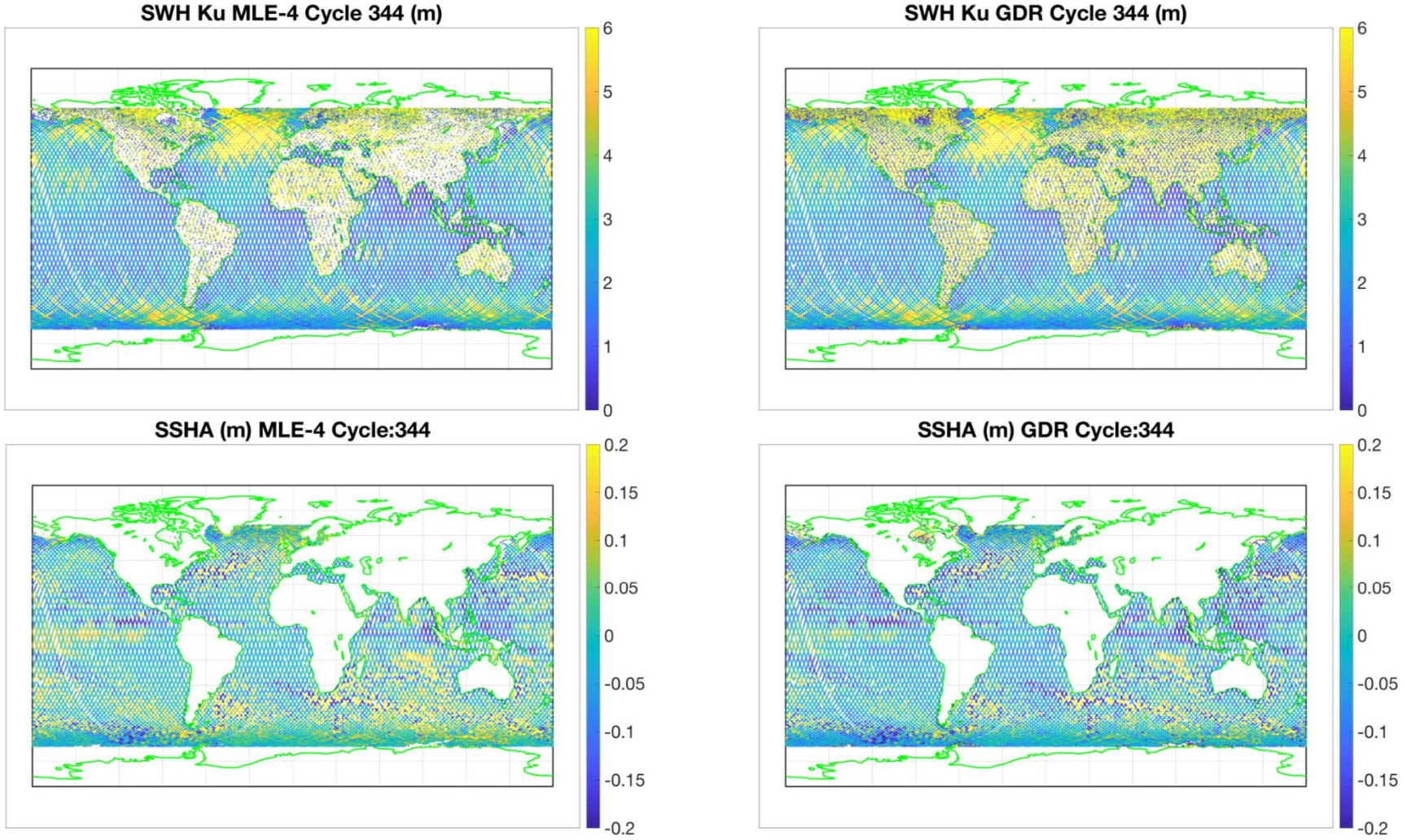
Note: The side-lobes of the in-flight PTRs are larger than the on-ground PTRs. In other words, it confirms the PTRs have strongly evolved between 1991 and 1998.


SSHA (m) MLE-4 Cycle:24
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2

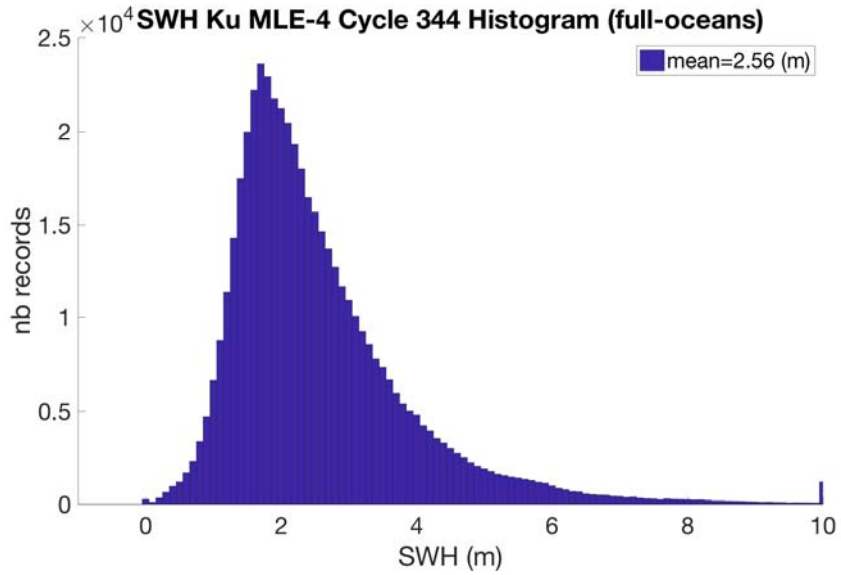

SSHA (m) GDR Cycle:24
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2


SSHA (m) MLE-4 Cycle:230
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2

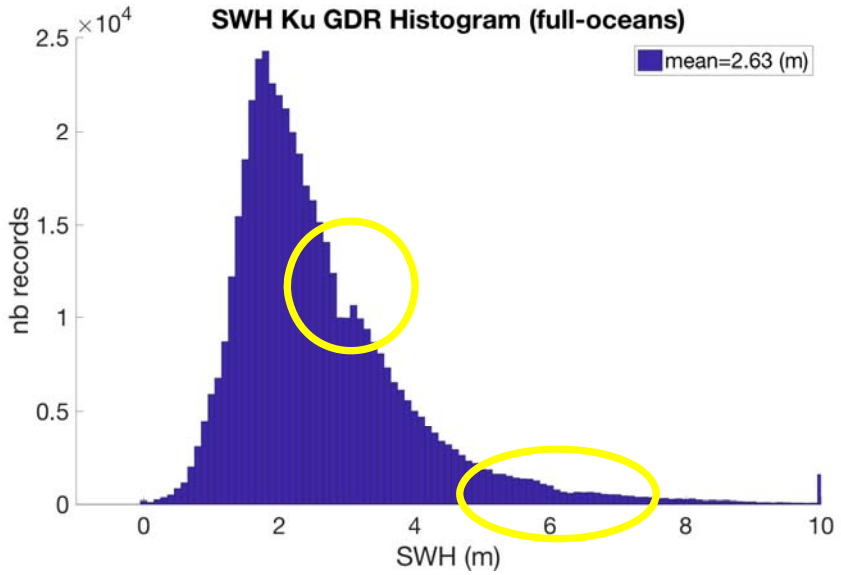

SSHA (m) GDR Cycle:230
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2


SWH Ku MLE-4 Cycle 344 (m)
6
5
4
3
2
1
0
SWH Ku GDR Cycle 344 (m)
6
5
4
3
2
1
0
SSHA (m) MLE-4 Cycle:344
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
SSHA (m) GDR Cycle:344
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2

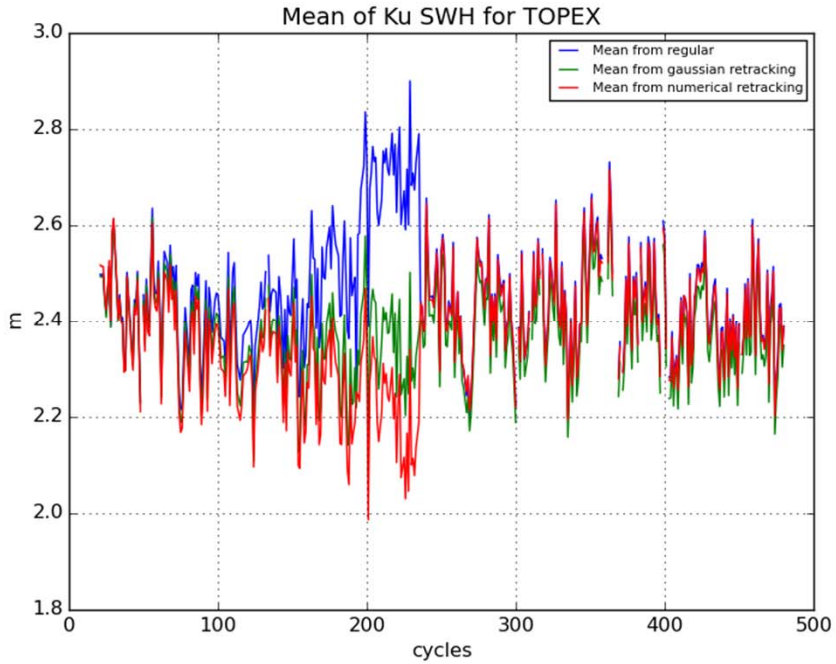
SWH Ku-Band MLE-4

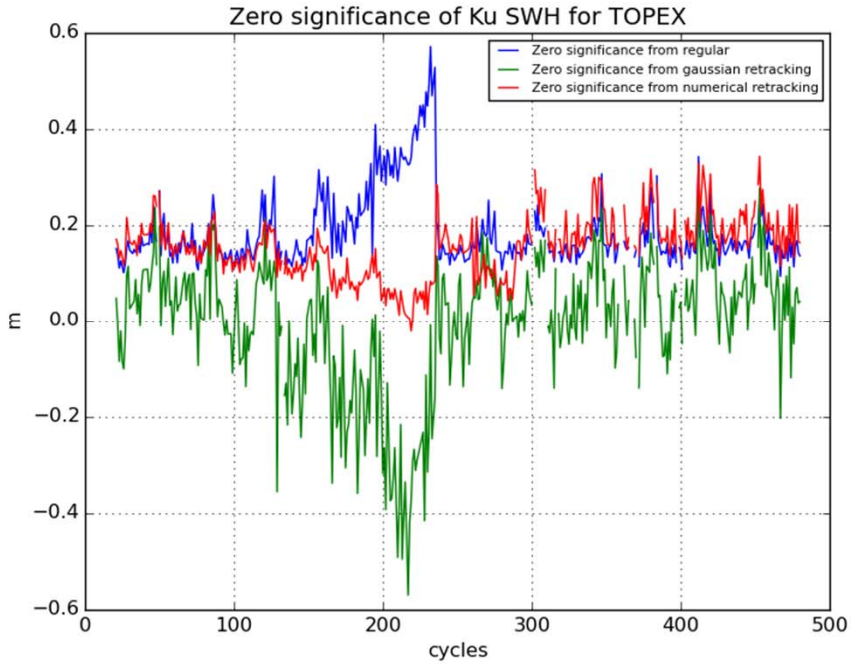


SWH Ku-Band GDR



Cleaner distribution thanks to the waveforms retracking





The drift on SWH is reduced but a little overcompensated (seems to be related to the PTR quality and not processing)

Zero significance highlight has a better behavior for the numerical retracking