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Progress in Retracking TOPEX Data for the Climate Data Record

OSTST October 2014

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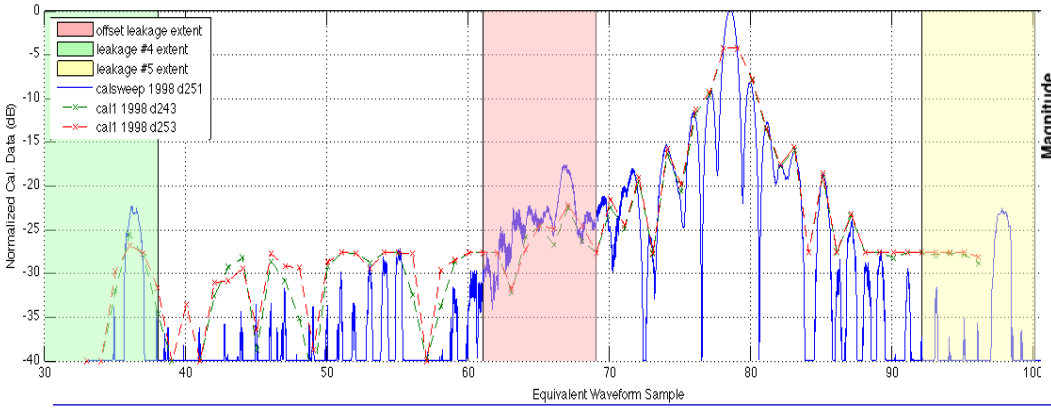
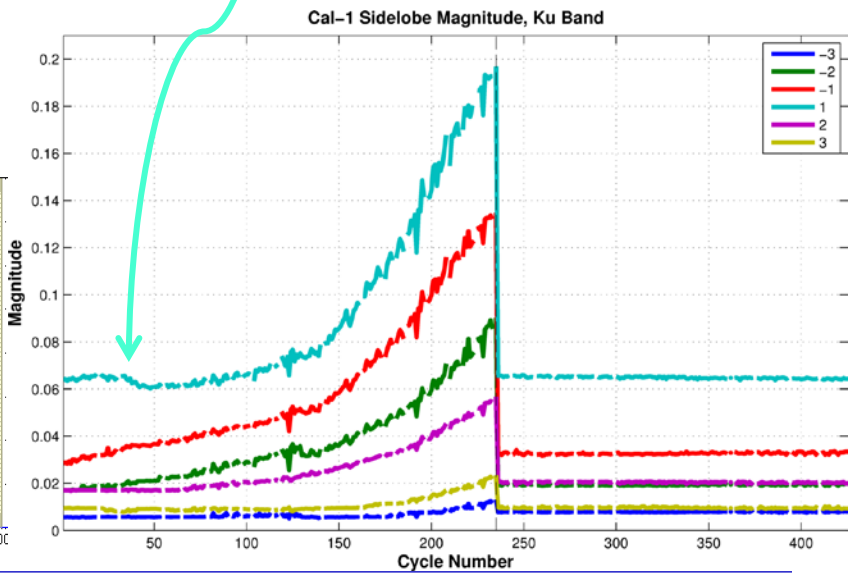
TOPEX Retracking Overview / History

- 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
- Previous versions of retracking in 2007, 2009
  - 2007 used original WFF waveform (WF) weights/gains, hand fit PTRs to some, especially late Alt-A, Cal-1 data
  - 2009 used refit WF weights, systematically fit PTRs to Cal-1 data to 10 lobes
  - Analysis by Labroue '09 showed that 2007 agree with MSL trend and improved agreement with Jason-1, while 2009 cased negative MSL trend and SSB was similar to original MGDR and rather different than that for Jason-1

Retracking Processing (1)

- Revisited Cal data based on review of leakage transfer through signal path. Cal-1 data are just Nyquist sampled.
  - Data in colored areas (left) are contaminated, should not be used in PTR – can only use lobes +/-6 from Cal-1 data
  - Changes in sidelobes near cycle 50: Side lobe +1 drop; 7-10 are below noise before (not shown)
- Developed method to extend PTR to ~ +/-30 lobes consistent with PTR changes (increase in sidelobes, missing lobes with increasing phase imbalance)





Retracking Processing (2)

- Obtained computer that can process TOPEX cycles 20 – 364 in about 1 week
- Updated scripts so no passes are lost
- Updated code so can fix skewness
  - Decided from parameter correlation analysis that solving for skewness to absorb leakages was not the best approach
- Tested various PTR fitting methods and various skewness values
- Ran full data sets for PTRs from +/-6 Cal-1 lobes extended to +/-30 lobes
  - Fixed Skewness = 0, 0.1
  - Fitting Skewness (as in 2007, 09 versions)
- Did run with PTR from +/-3 Cal-1 lobes extended to +/-30 lobes
  - Very similar to 6/30 run
- Have done initial comparisons to MGDR and Jason-1 during overlap period
  - Generally similar to previous results, but many variations that need additional analysis

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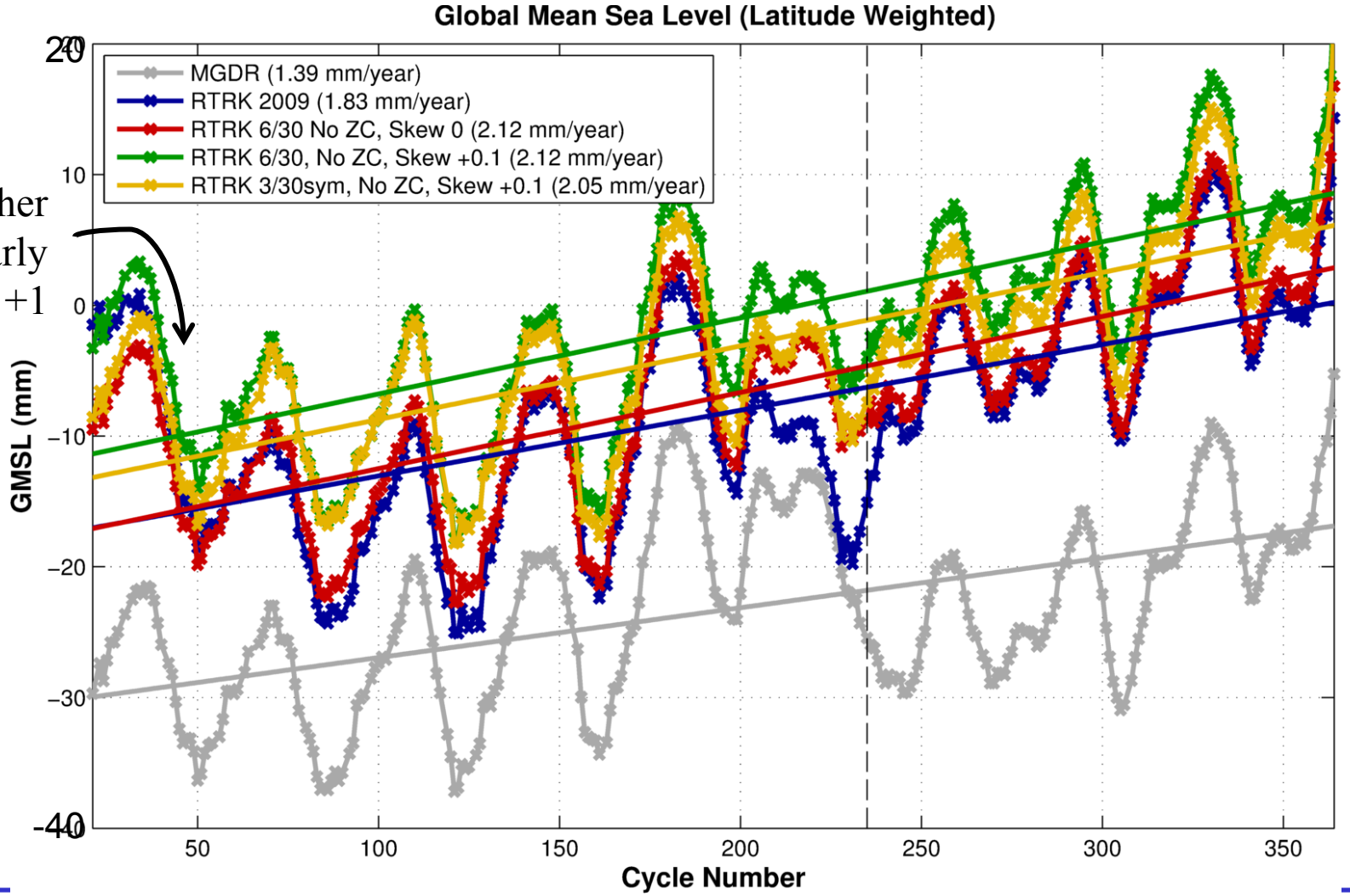
Analysis: GMSL Trend

- Latest retracking corrects for GMSL depression near the end of Alt-A in 2009 release
  - Eliminates discontinuity between Alt-A and Alt-B

From higher early sidelobe +1



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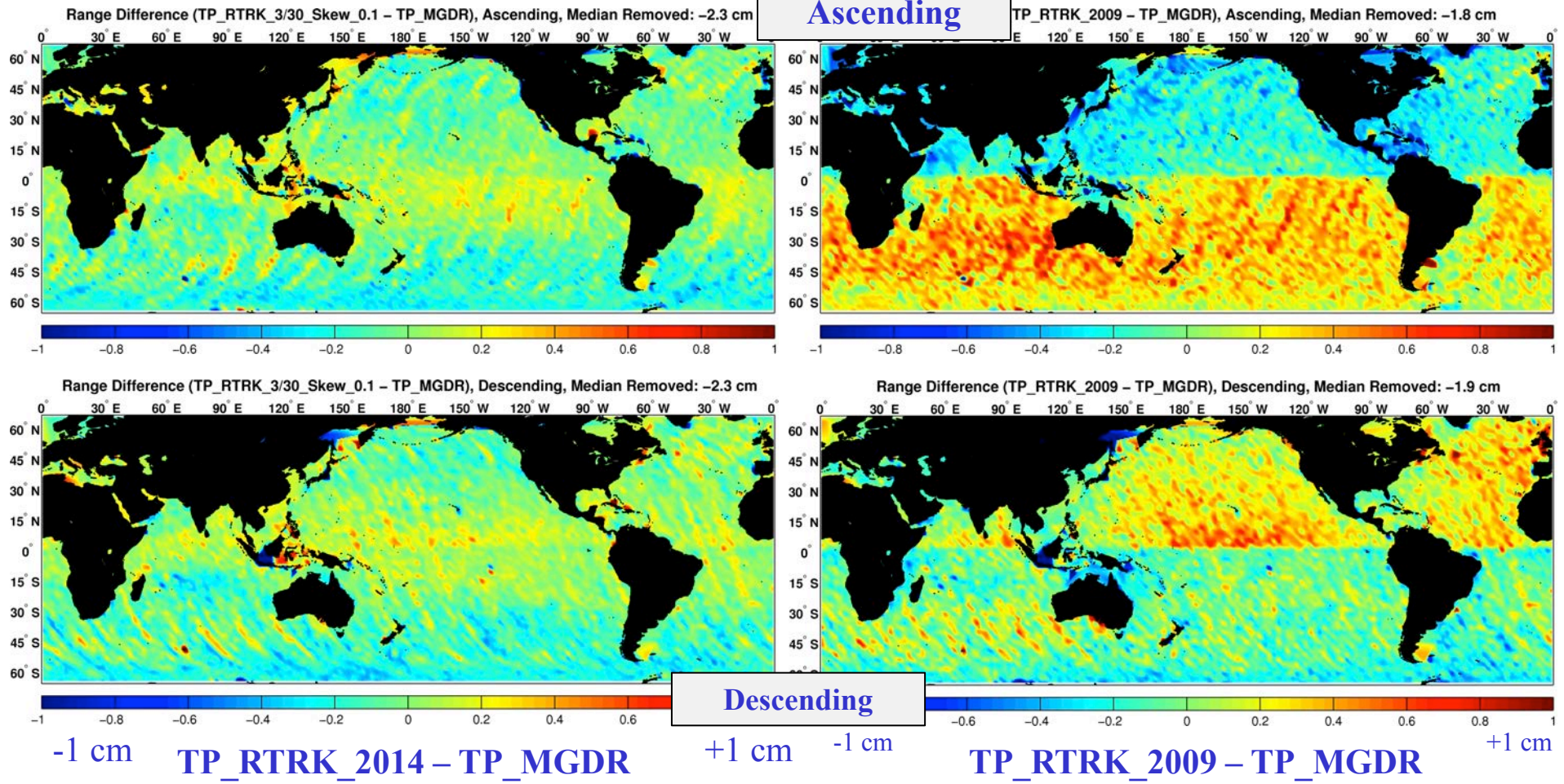
TOPEX RGDR/MGDR Range Comparison

Skewness =0.1



The latest retracking is much closer to the original MGDR SSB model. Differences are less correlated with quadrant.

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

Near-Term TOPEX Climate Data Records Plan

- Make new TOPEX RGDR available as soon as possible for evaluation
  - **Work to do this by end of November**
  - Need to determine distribution method
  - Use netCDF similar to Jason as 2009 RGDR with copy of original GDR
  - Retracking values for range, SWH, attitude for 3 sets: Skewness = 0, 0.1, Fit
  - New GSFC orbits (coming by end of November)
  - Reprocessed TMR data (Shannon Brown: improved calibration, coastal resolution, flagging)
  - New tide models GOT4.10 (J1 & J2). And FES2014?
  - Improved long period non-equilibrium tides
  - Updated MSS CLS 2011
  - Additional Possibilities if available on this short time scale
    - New dry tropo correction and associated MOG2D values (from CNES)
    - Newer MSS, Geoid
- For eventual product will need SSB fitted on Retracked Data (probably with quadrant corrections
  - Doug Vandemark has agreed to use his SSB process on new data
- Plan to have initial evaluations and new SSB done by ~April

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Backup Material

Details

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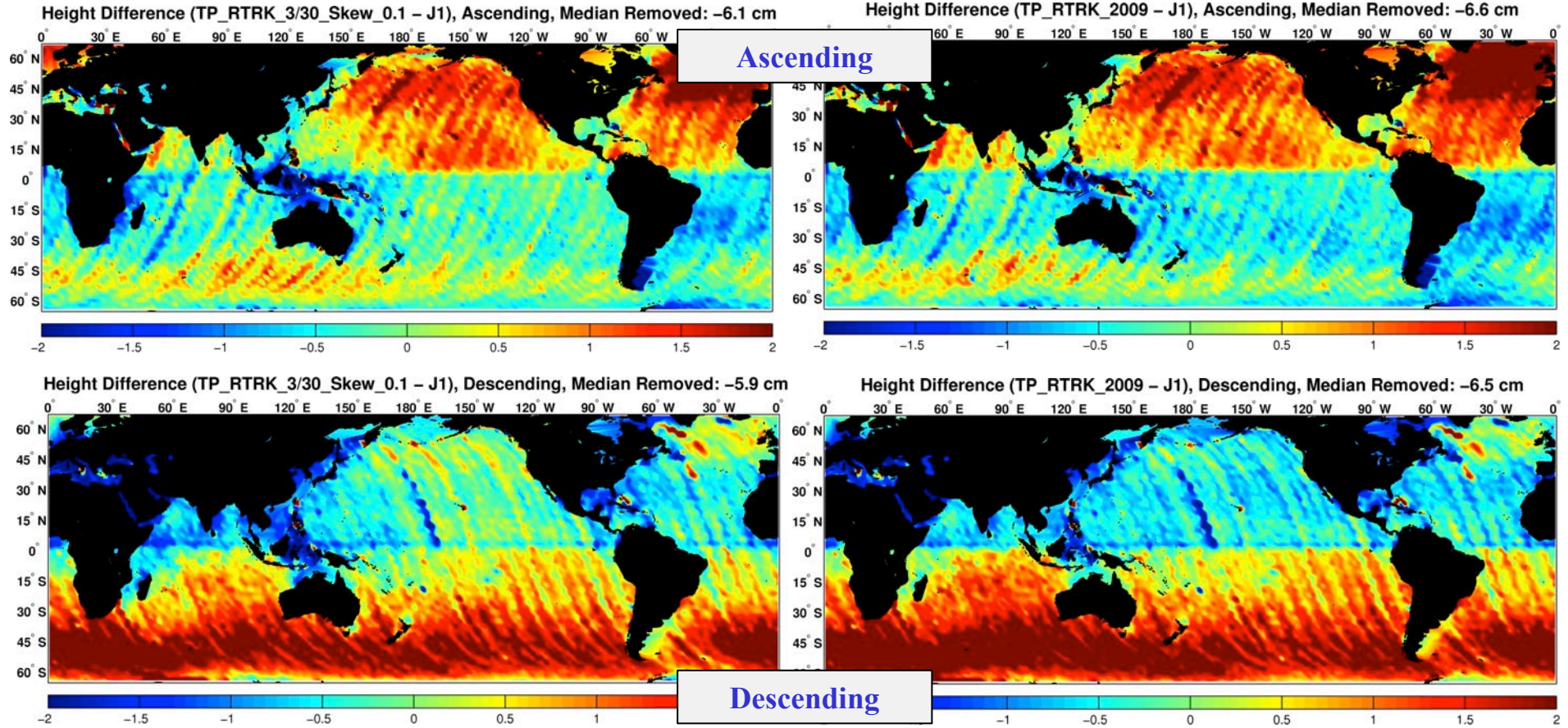
TOPEX - Jason-1 SSH Cross Calibration Skewness = 0.1



Quadrant analysis confirms sea state correlation between J1 and latest retracking, indicating different SSB model is still necessary.

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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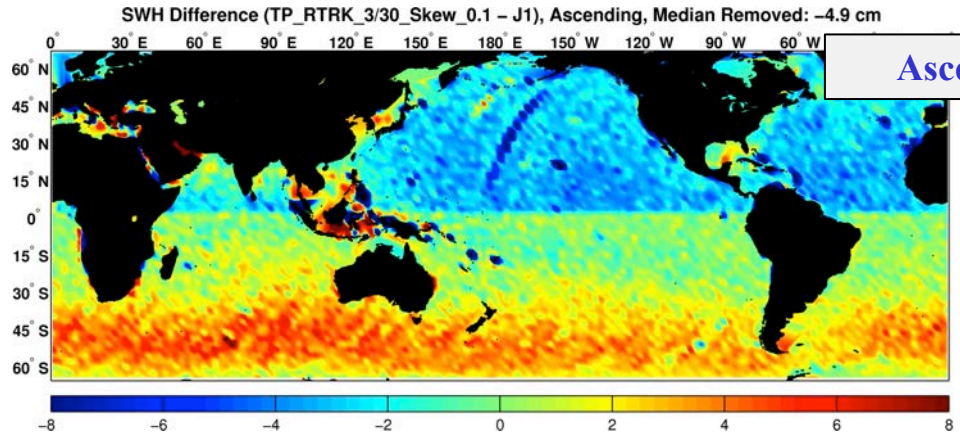
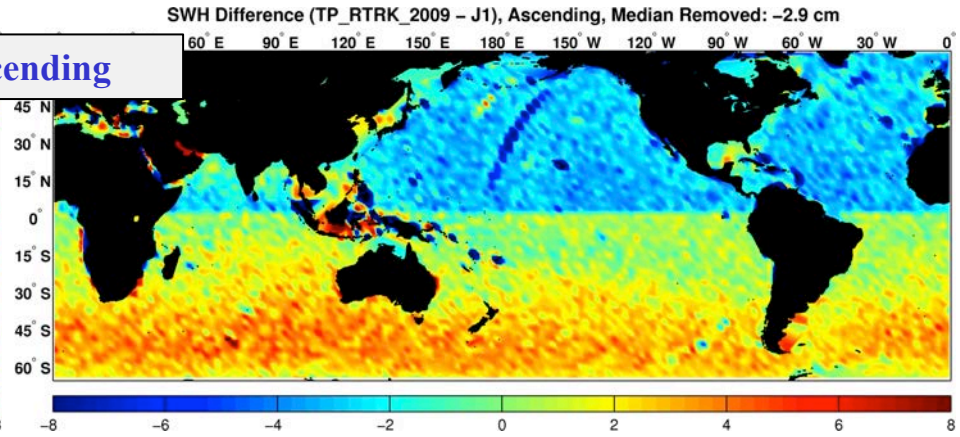
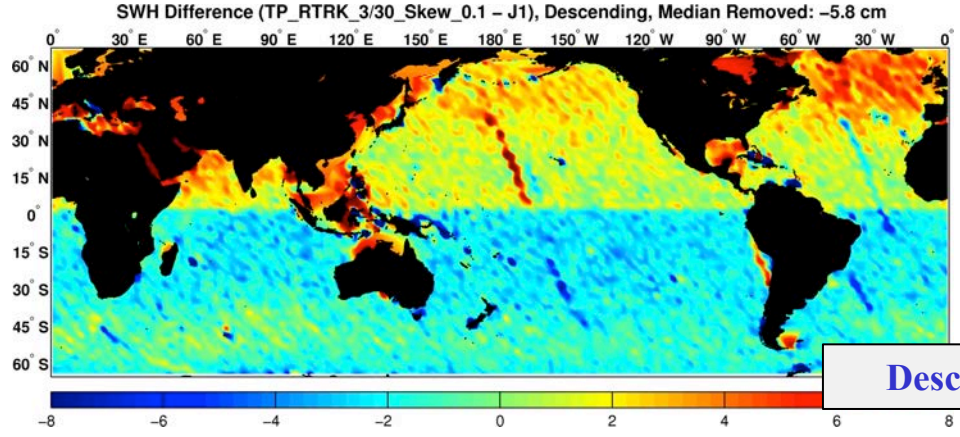
TOPEX - Jason-1 SWH Cross Calibration

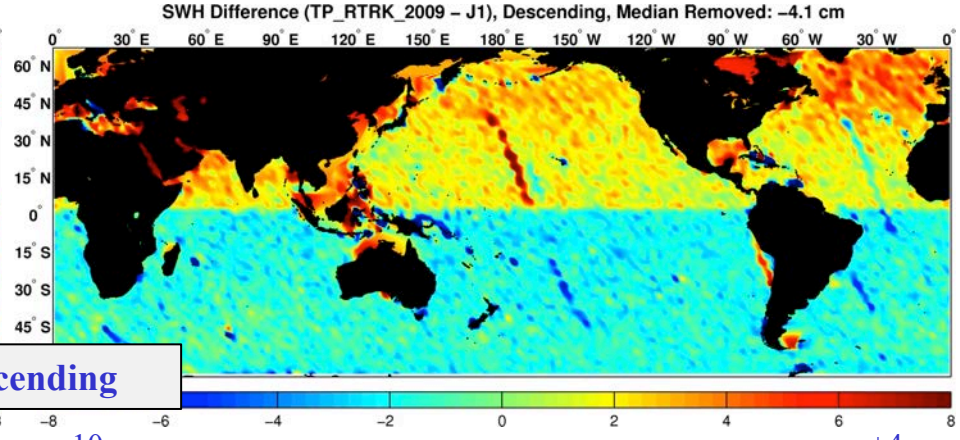
Skewness = 0.1





Ascending





Descending

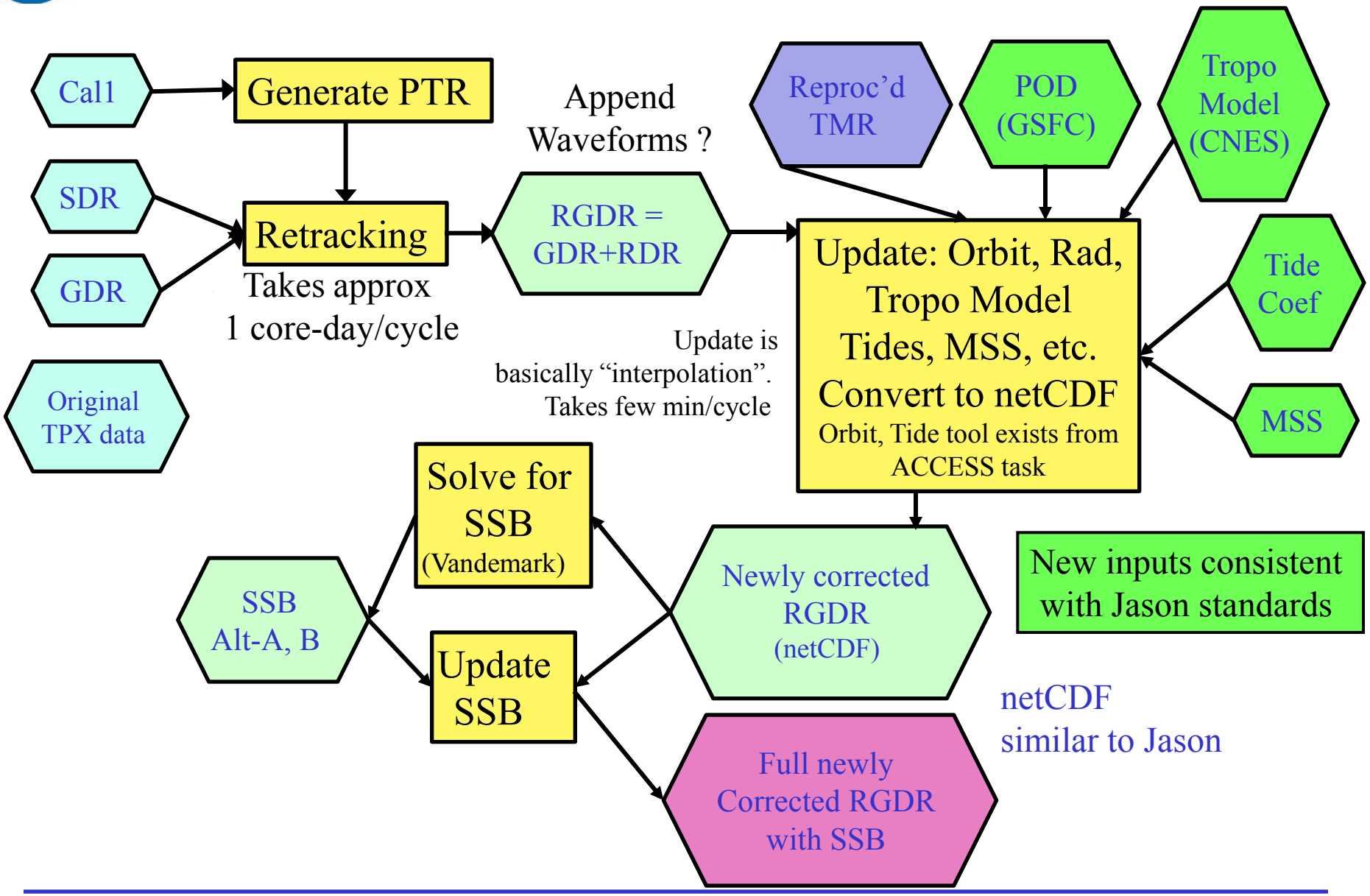
-10 cm TP_RTRK_2014 – J1 +4 cm

-10 cm TP_RTRK_2009 – J1 +4 cm

Quadrant analysis shows that latest retracking behaves similarly to 2009 release with respect to SWH differences.

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

TOPEX CDR Processing Flow

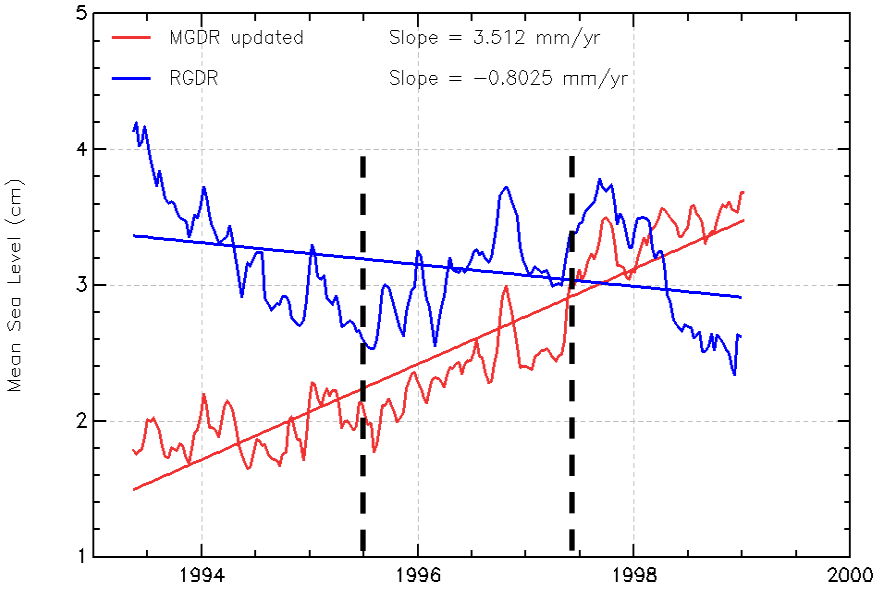


Outline / Overview

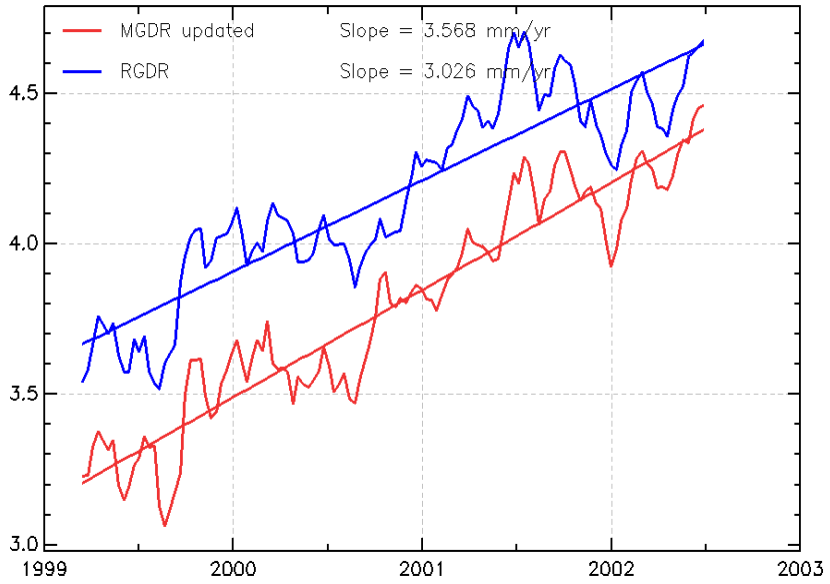
- Work funded by TOPEX/Jason-1 Project and NOAA Climate Data Records program task: “Generation of Altimeter Climate Data Records Using Retracking and Updated Corrections”
- TOPEX Retracking Overview, History
- New Results on Alt-A PTR Changes and Cal Data
- Recent Retracking Results
- GDR Update Plan

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.

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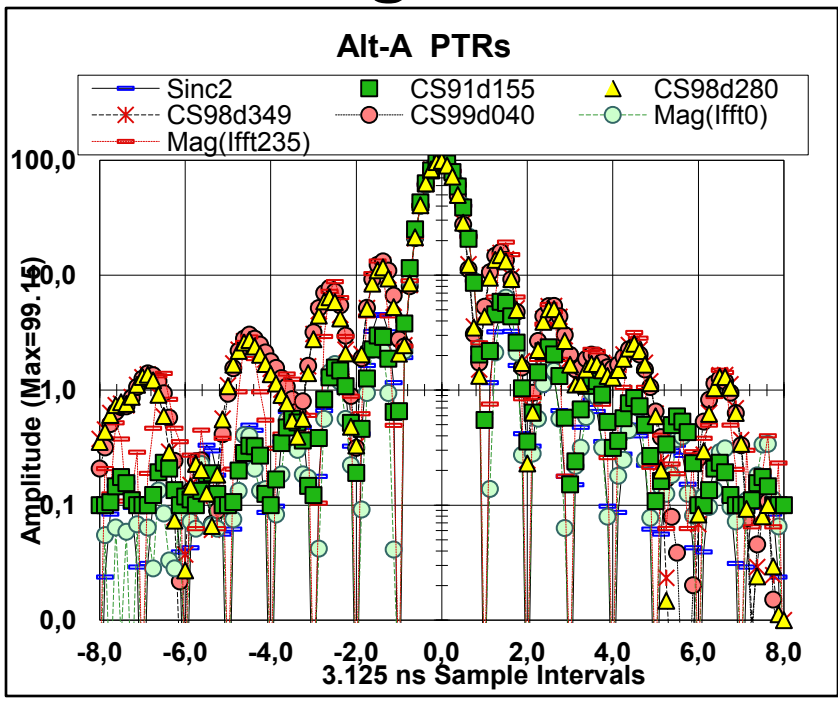
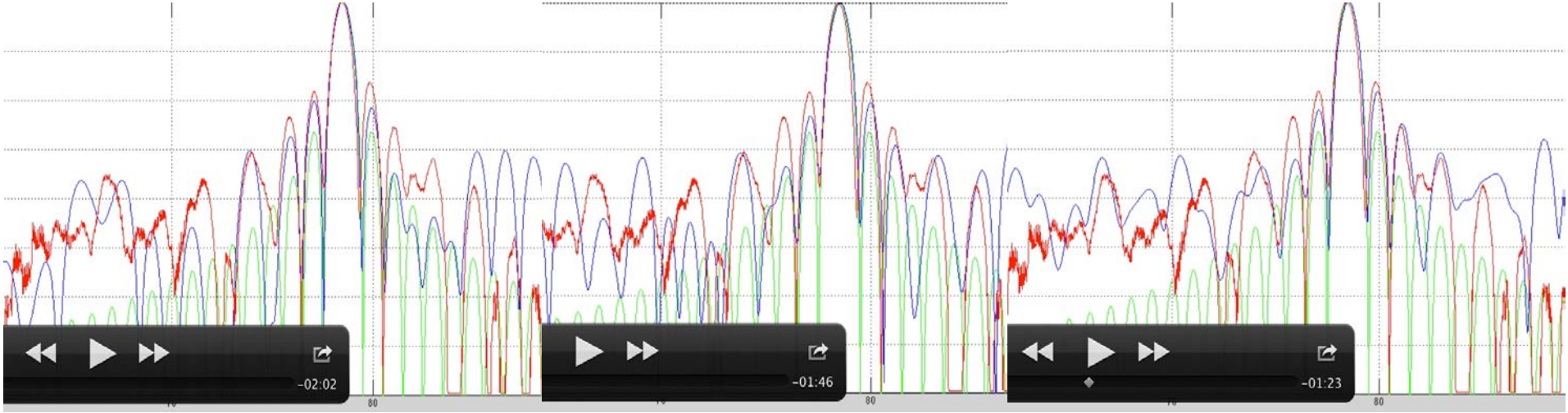
TOPEX Alt-A PTR Changes

- 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.
  - Effect depends on center location. Figures below shows I/Q phase diff 18 deg, 3 different center locations
  - 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.





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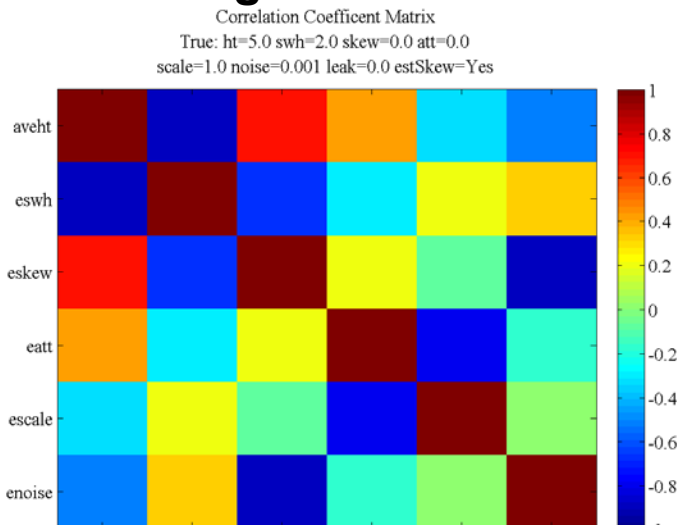
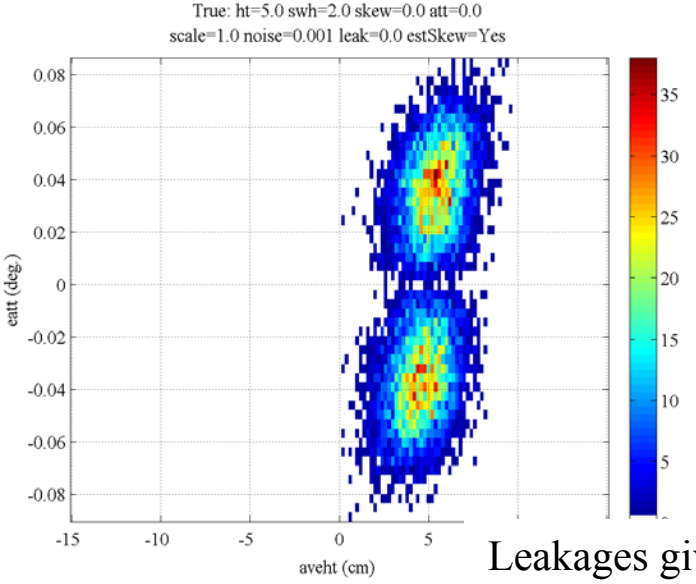
Simulation Results

Parameter Correlation Solving for Skewness





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

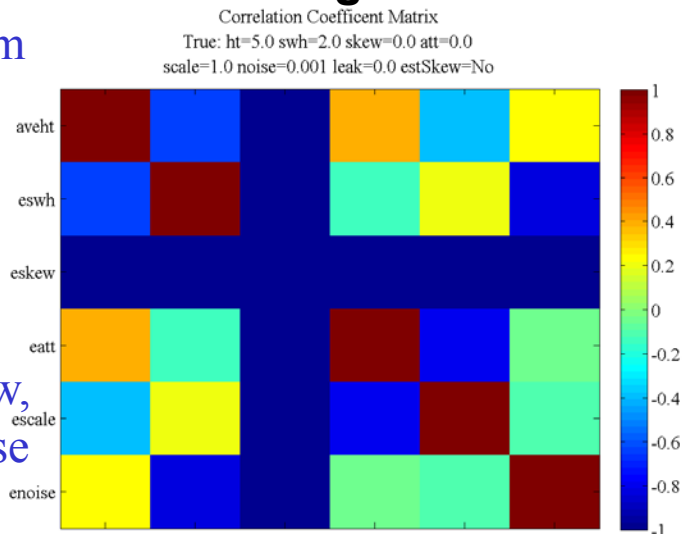
Parameters:
dH, SWH, Skew,
Att, Scale, Noise

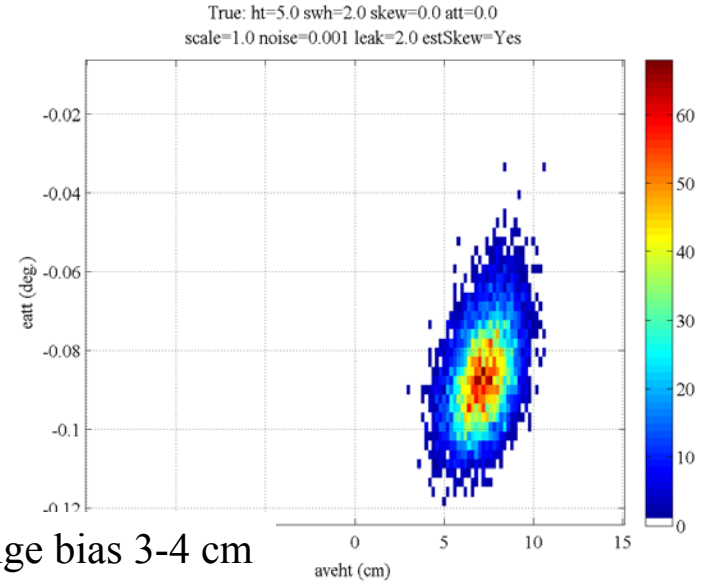
← Leakage = 0

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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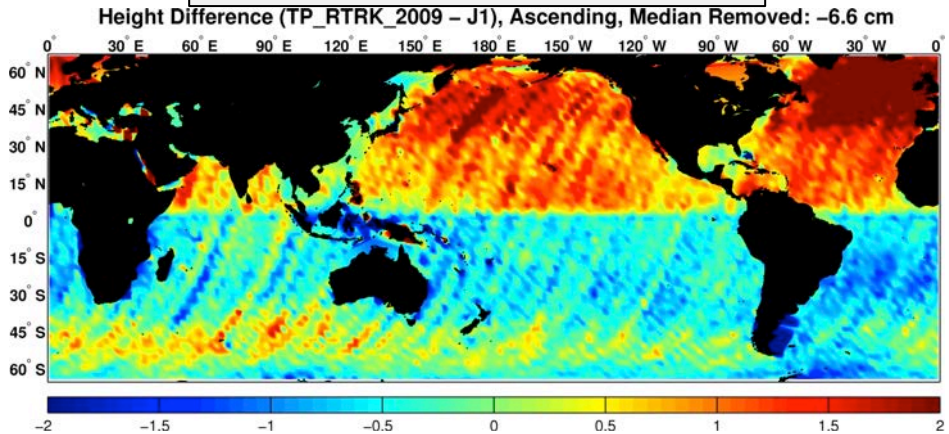
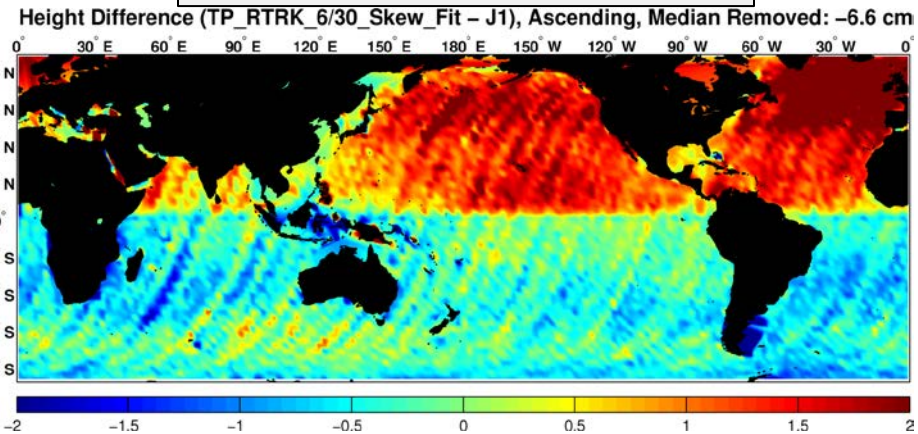
TOPEX – Jason-1 SSH Comparison – Asc

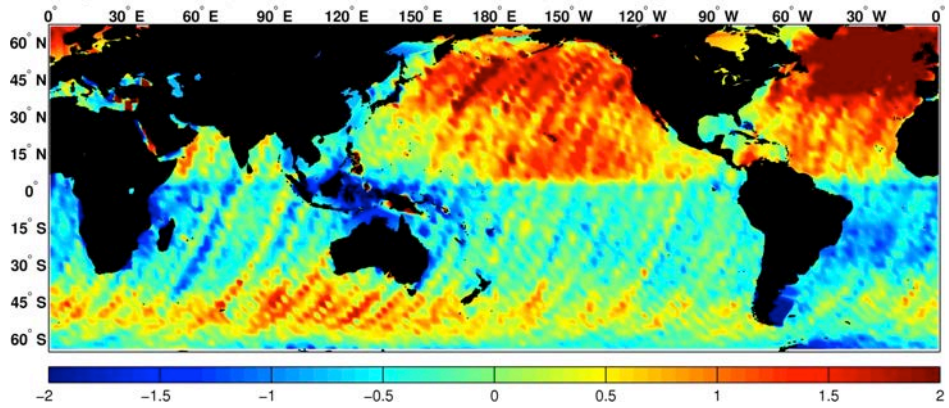
Retrk09 Skew Fit – J1



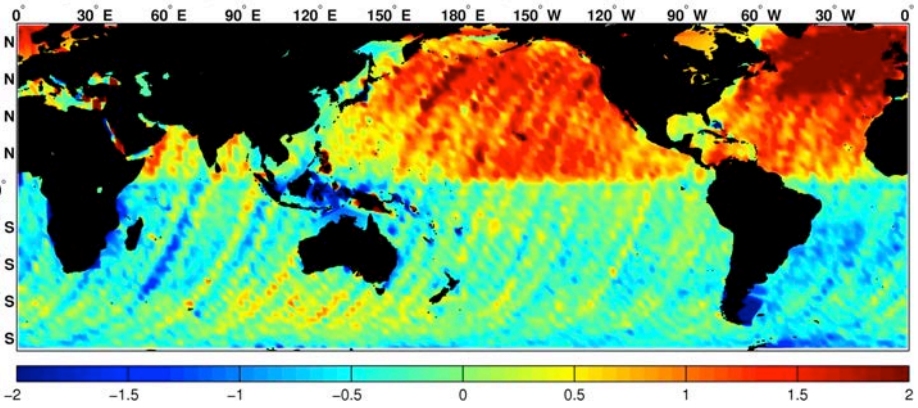
Retrk14 6/30 Skew Fit – J1



Retrk14 6/30 Skew = 0.1 – J1



Retrk14 6/30 Skew = 0 – J1



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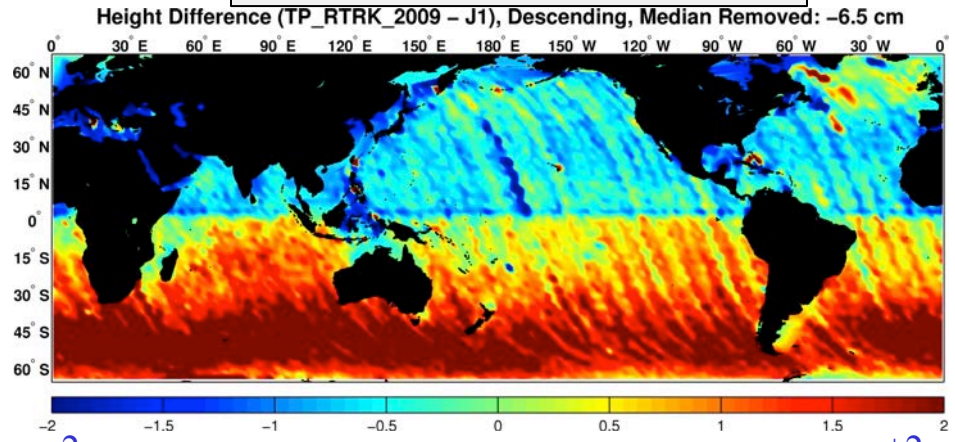
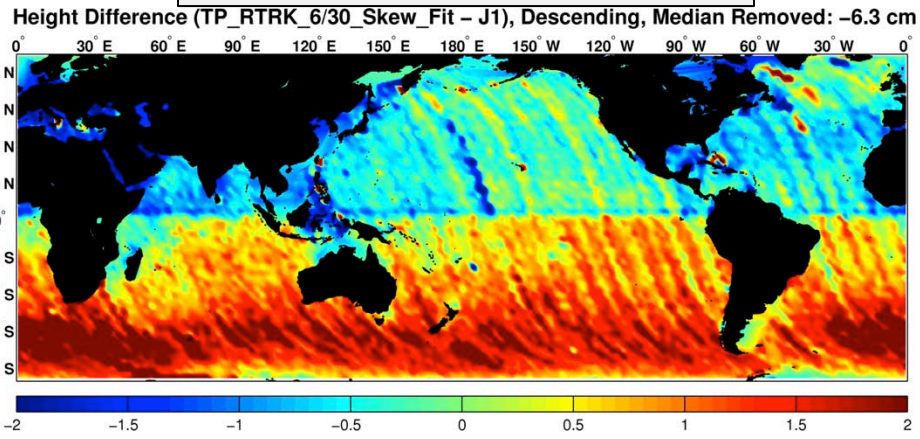
TOPEX – Jason-1 SSH Comparison – Des

Retrk09 Skew Fit – J1



Retrk14 6/30 Skew Fit – J1



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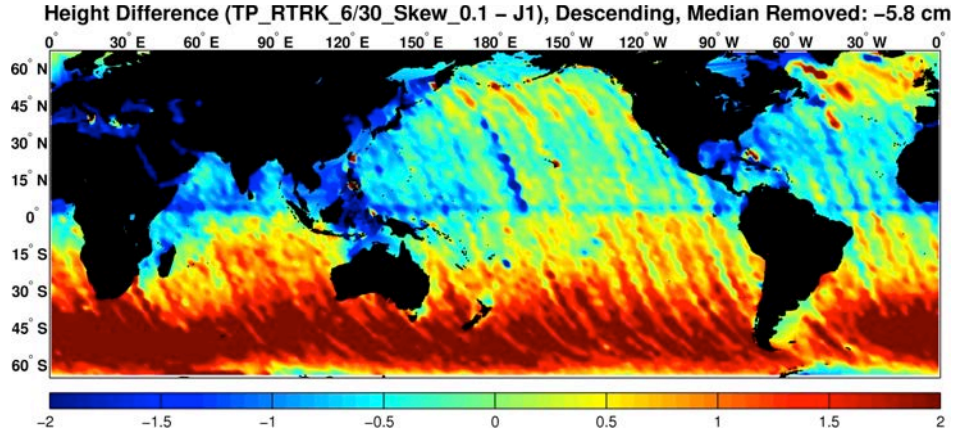

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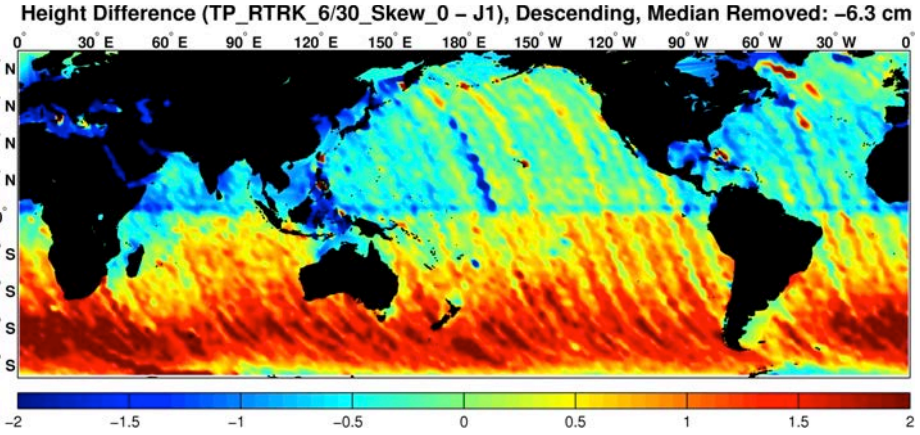

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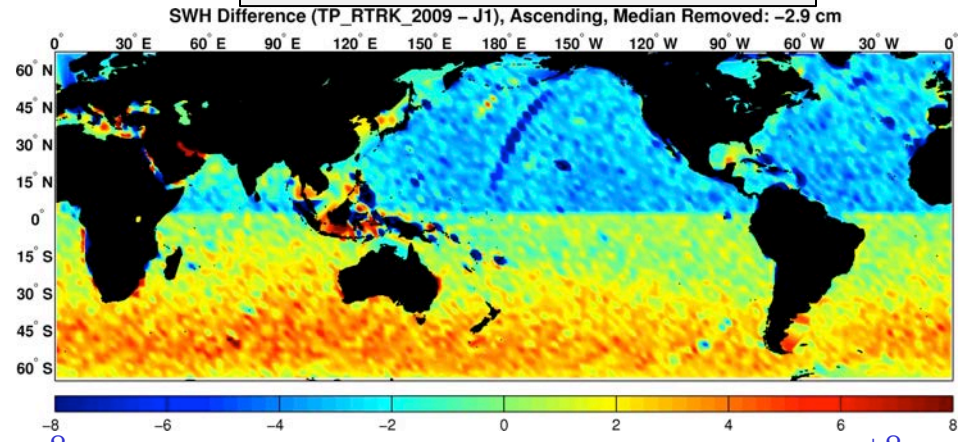
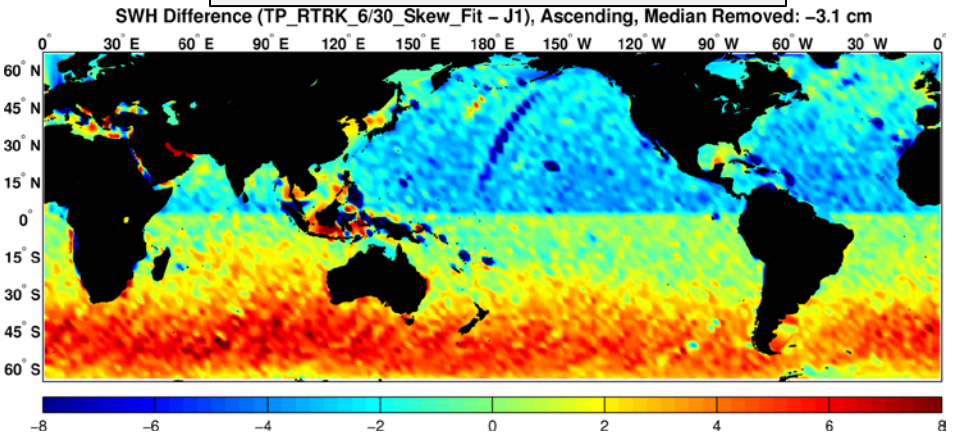
TOPEX – Jason-1 SWH Comparison – Asc

Retrk09 Skew Fit – J1



-8 cm +8 cm

Retrk14 6/30 Skew Fit – J1



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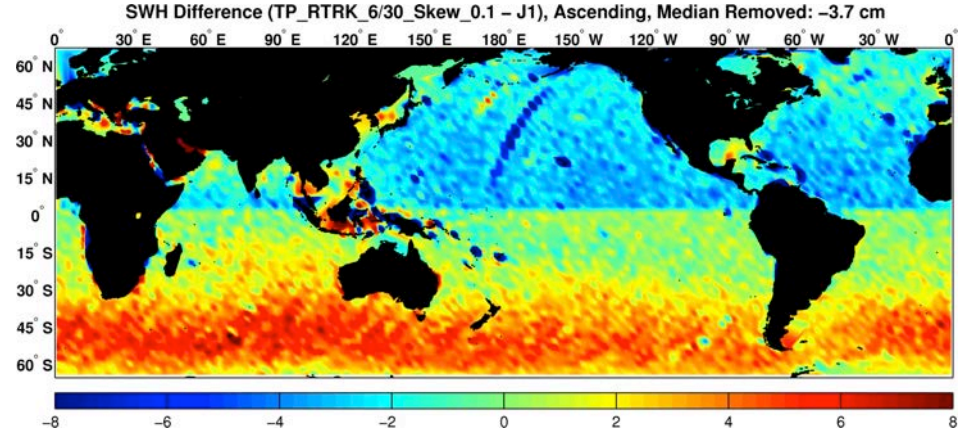

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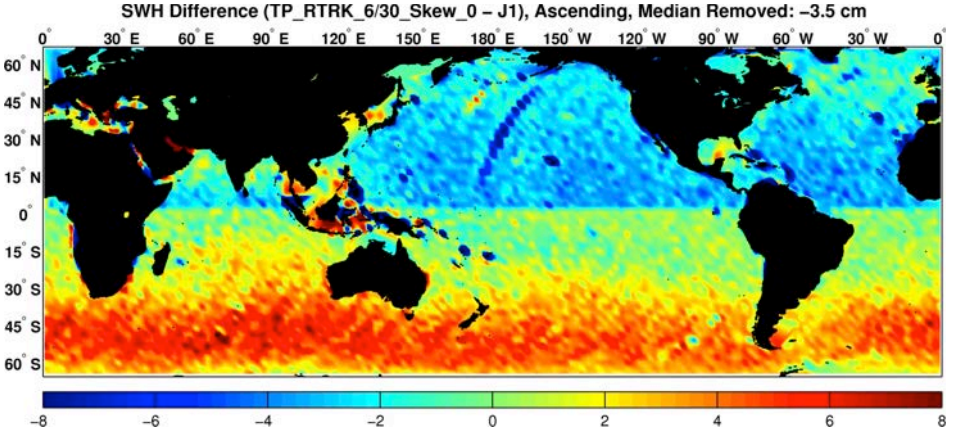

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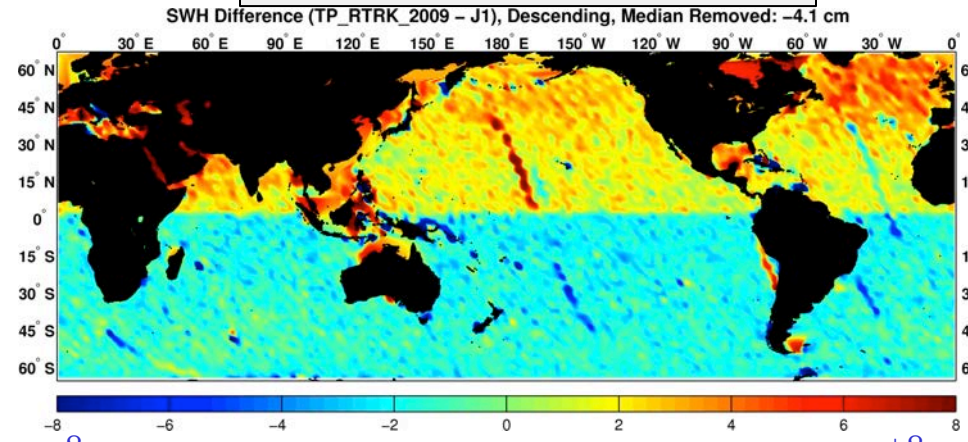
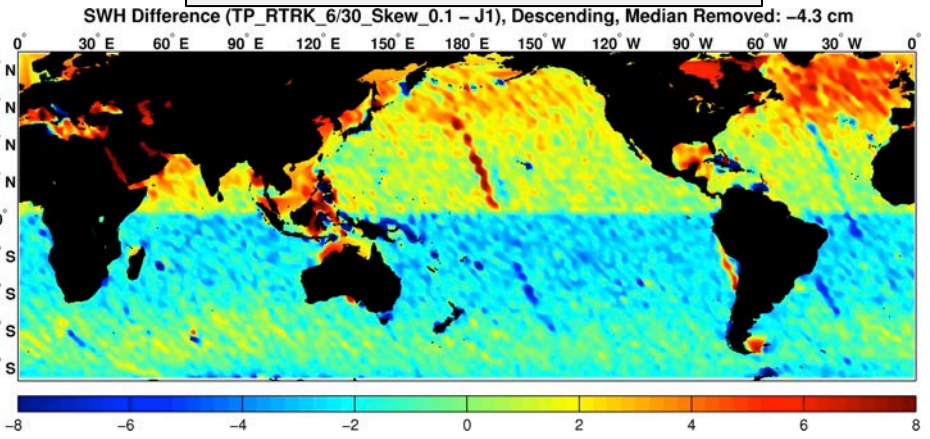
TOPEX – Jason-1 SWH Comparison – Des

Retrk09 Skew Fit – J1



-8 cm

Retrk14 6/30 Skew Fit – J1



+8 cm

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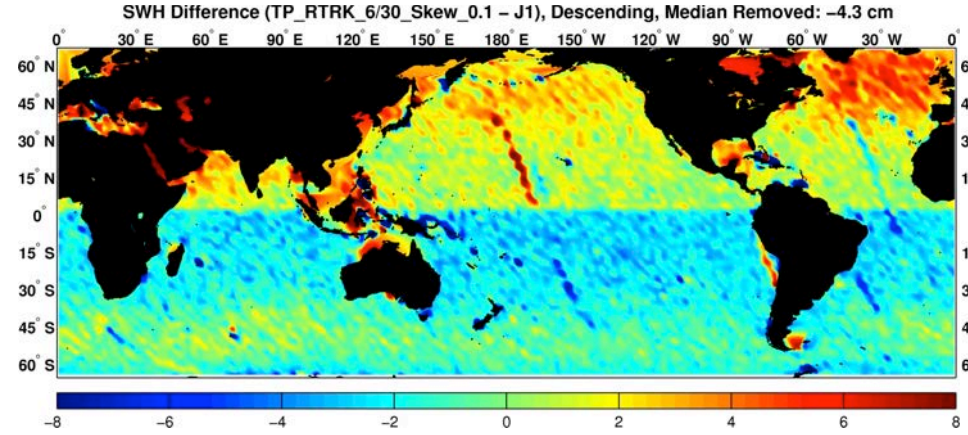
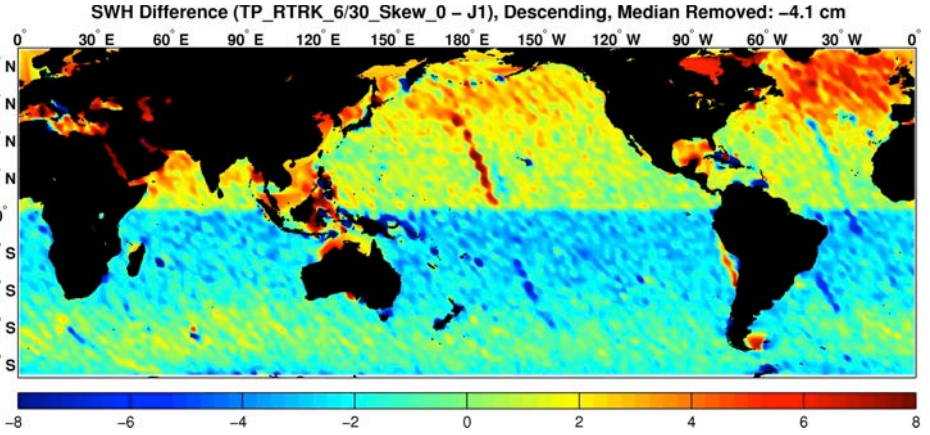


Retrk14 6/30 Skew = 0 – J1



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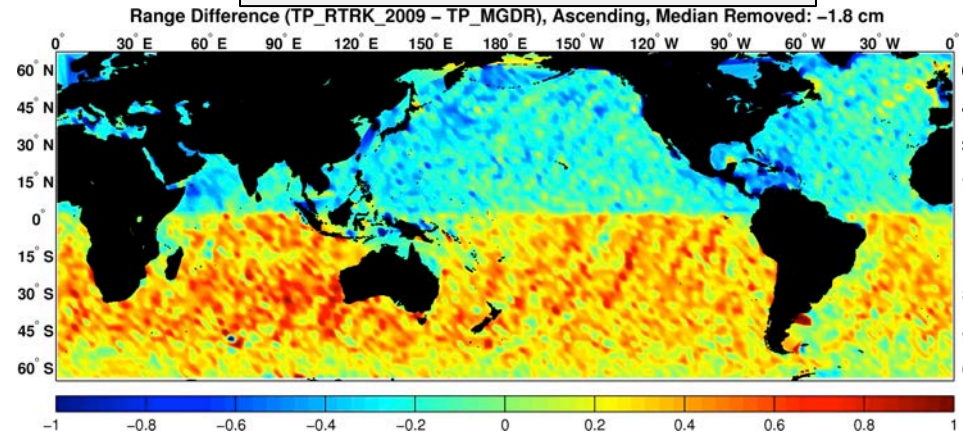
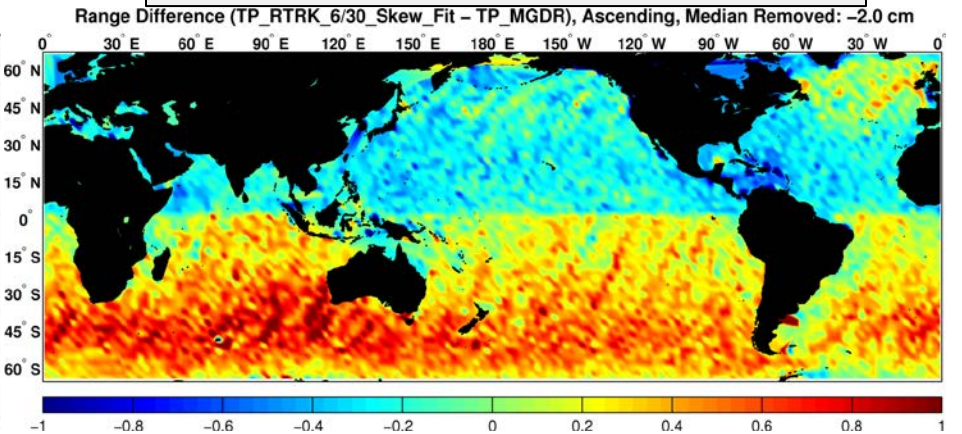
TOPEX – MGDR SSH Comparison – Asc

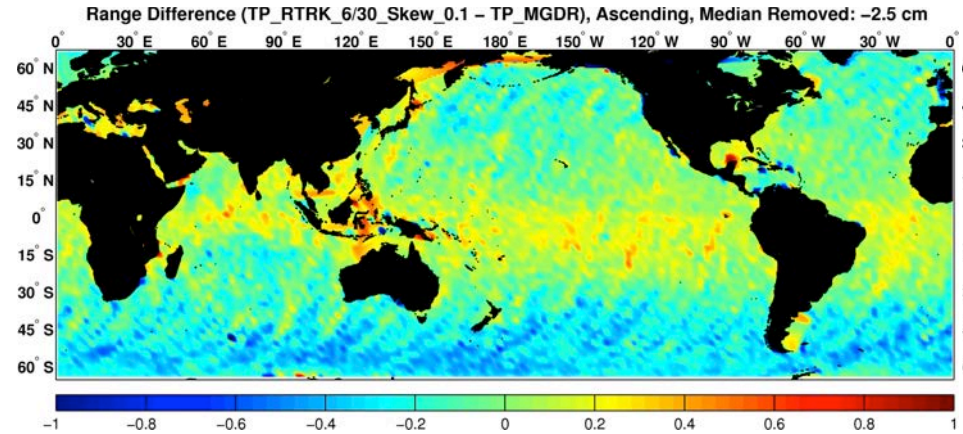
Retrk09 SkewFit – MGDR



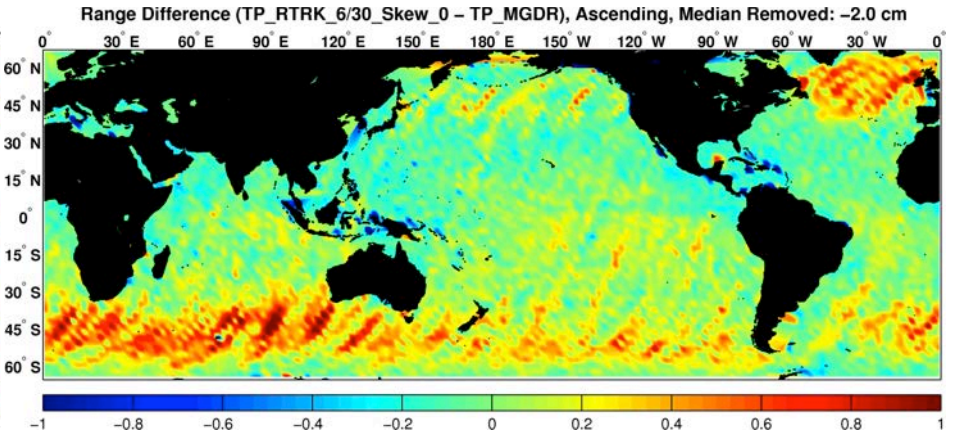
Retrk14 6/30 Skew Fit – MGDR



Retrk14 6/30 Skew = 0.1 – MGDR



Retrk14 6/30 Skew = 0 – MGDR



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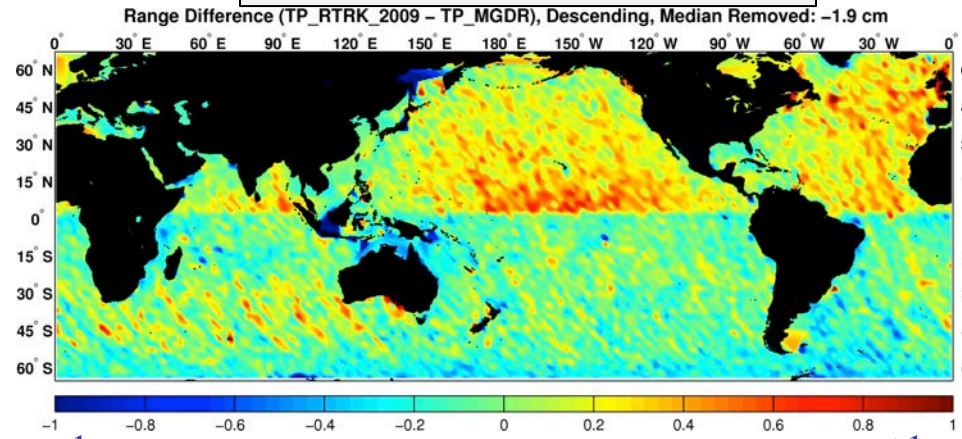
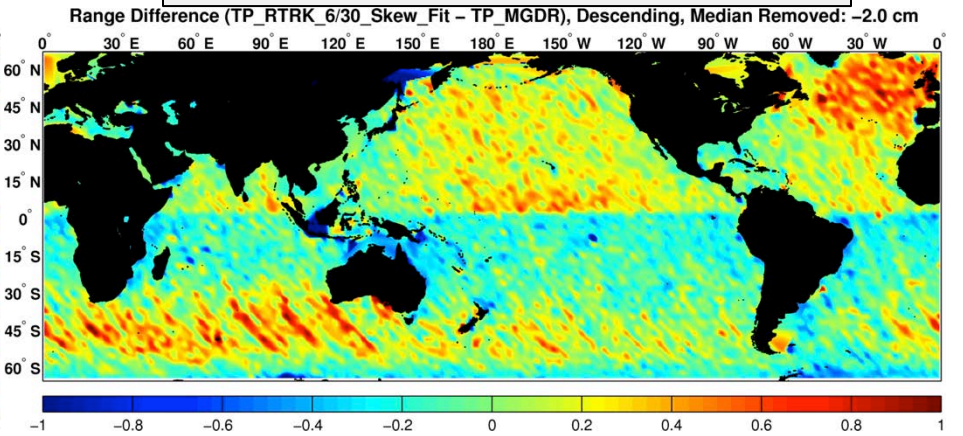
TOPEX – MGDR SSH Comparison – Des

Retrk09 Skew Fit – MGDR



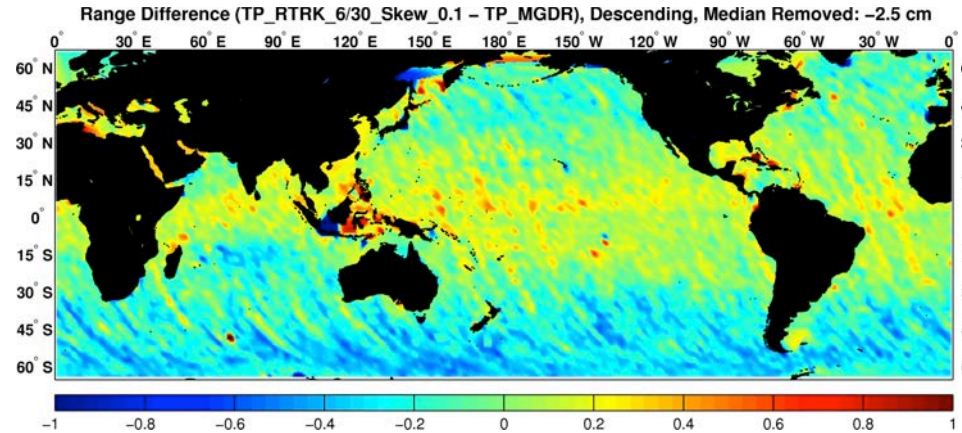
-1 cm

Retrk14 6/30 Skew Fit – MGDR

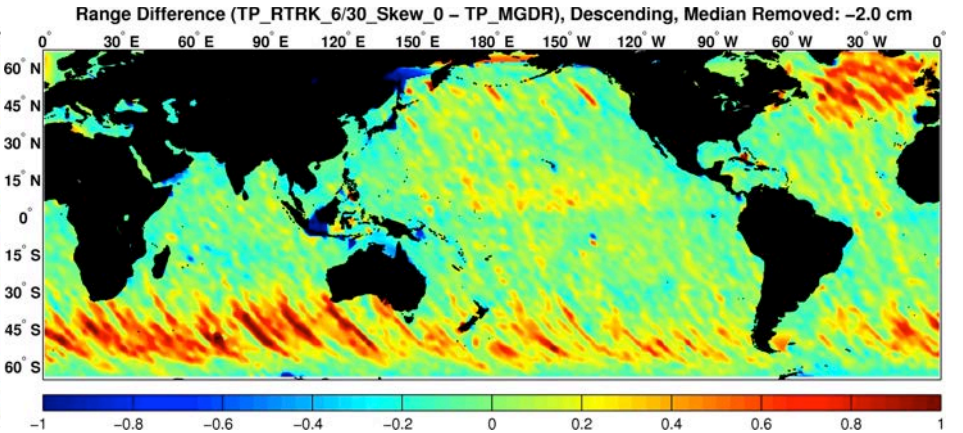


+1 cm

Retrk14 6/30 Skew = 0.1 – MGDR



Retrk14 6/30 Skew = 0 – MGDR



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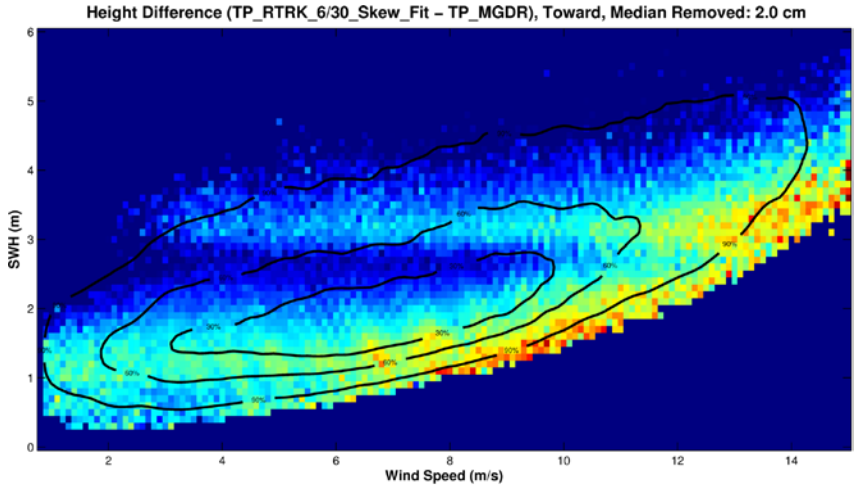
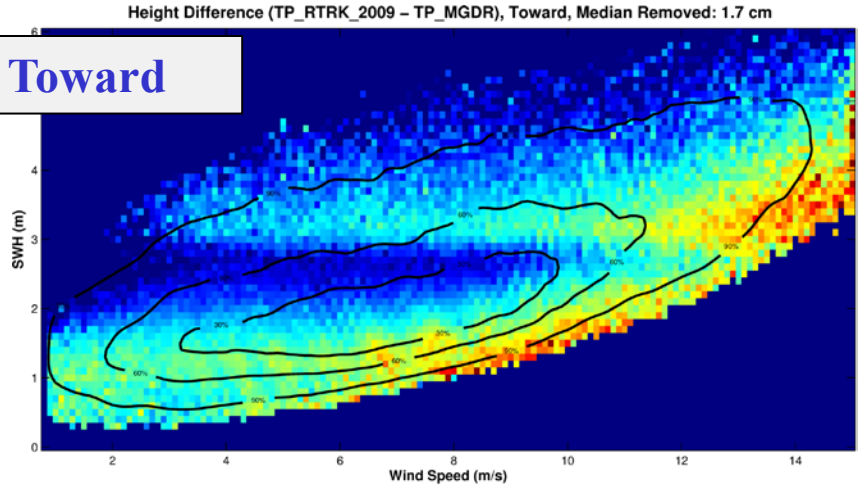
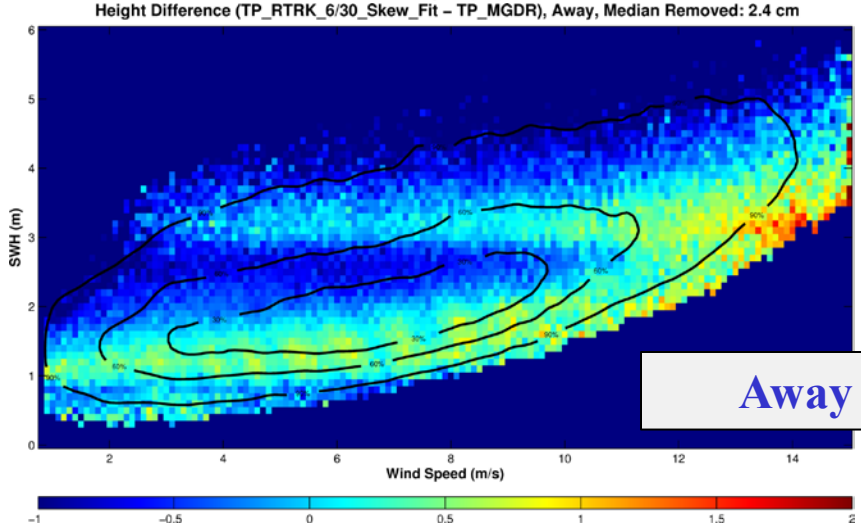
TOPEX Retrack – MGDR SSH Comparison

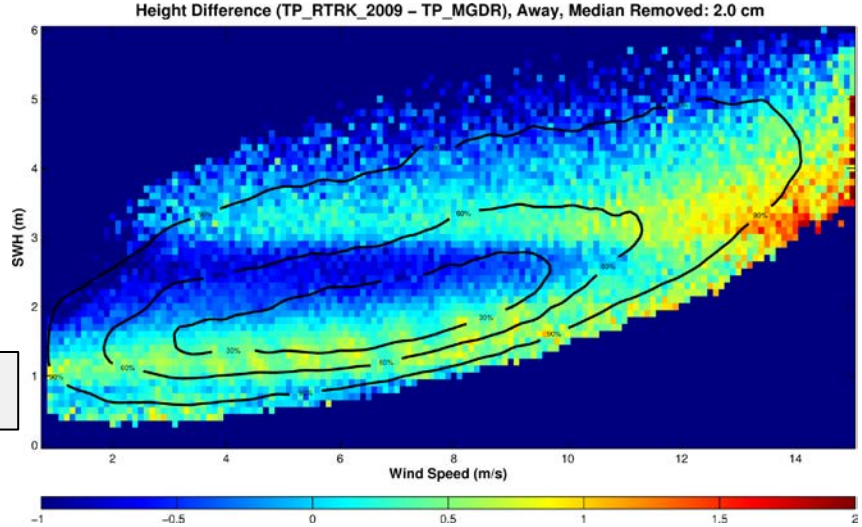
TOPEX Wind Speed





Toward





Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew Fit – TP_MGDR

-1 cm +2 cm

TP_RTRK_2009 – TP_MGDR

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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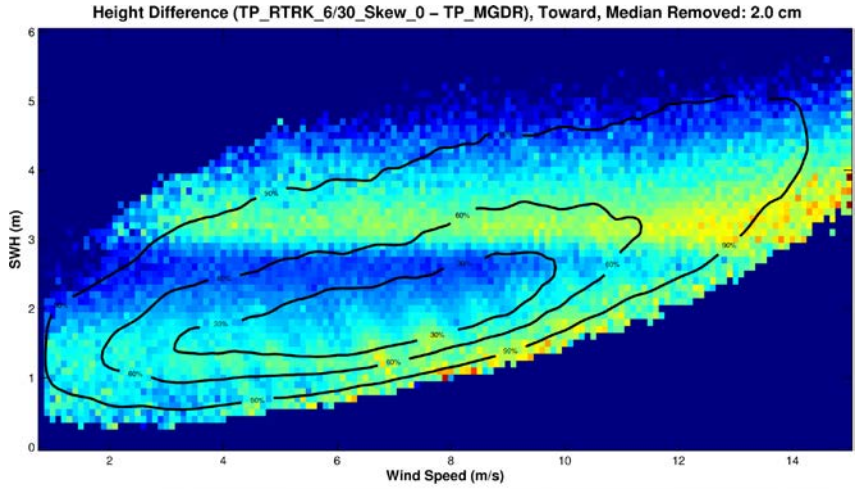
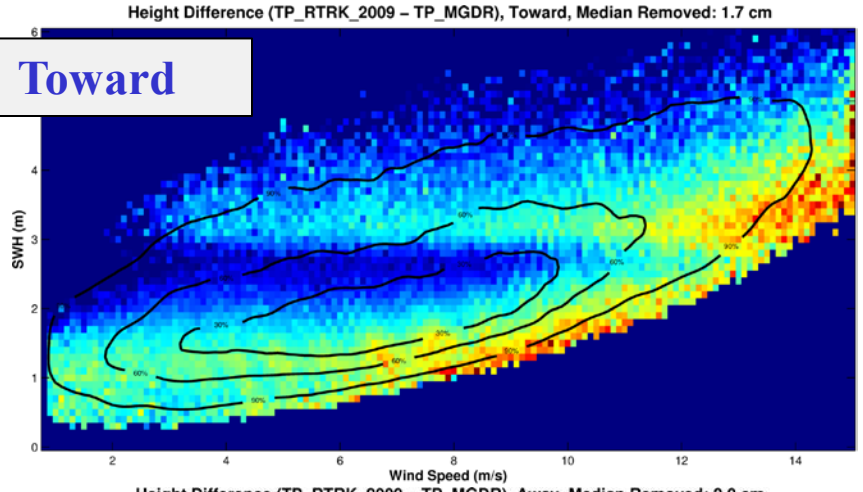
TOPEX Retrack – MGDR SSH Comparison

TOPEX Wind Speed





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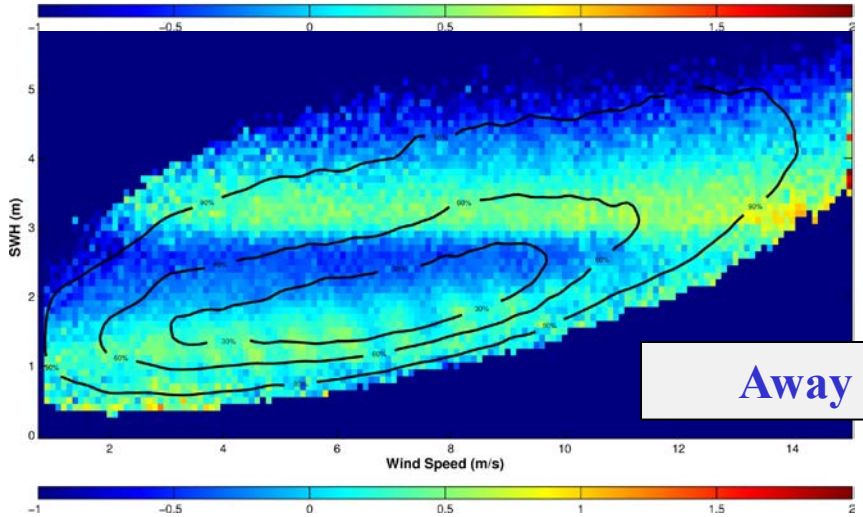
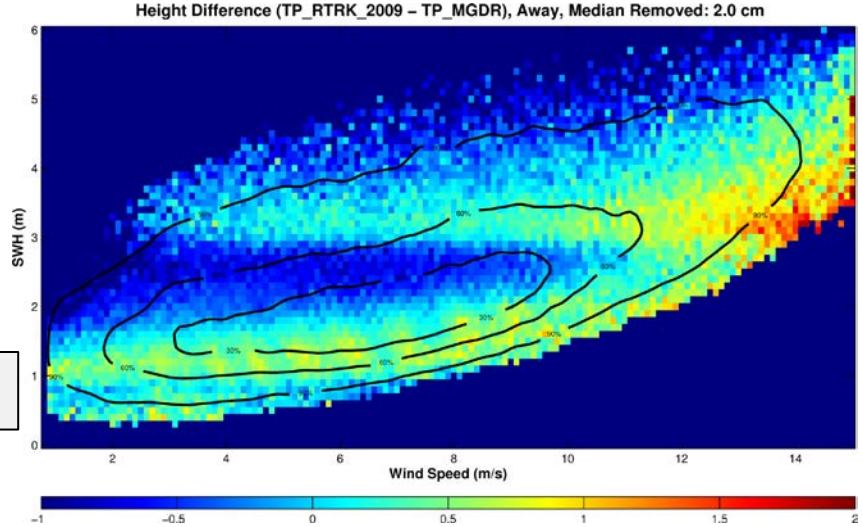


Away



-1 cm +2 cm

TP_RTRK_2014 6/30 Skew 0 – TP_MGDR

-1 cm +2 cm

TP_RTRK_2009 – TP_MGDR

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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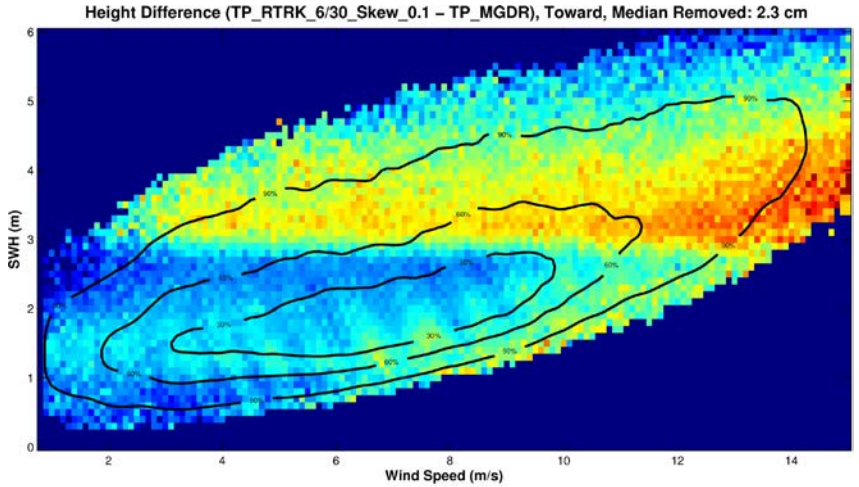
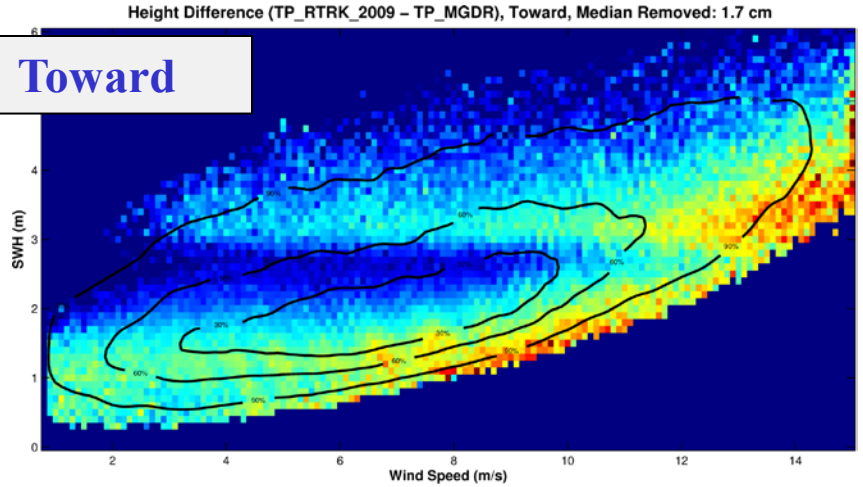
TOPEX Retrack – MGDR SSH Comparison

TOPEX Wind Speed





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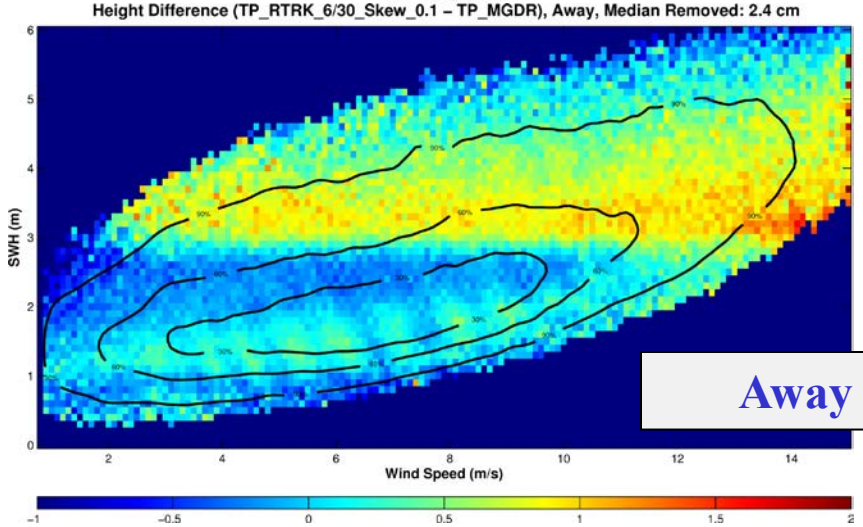

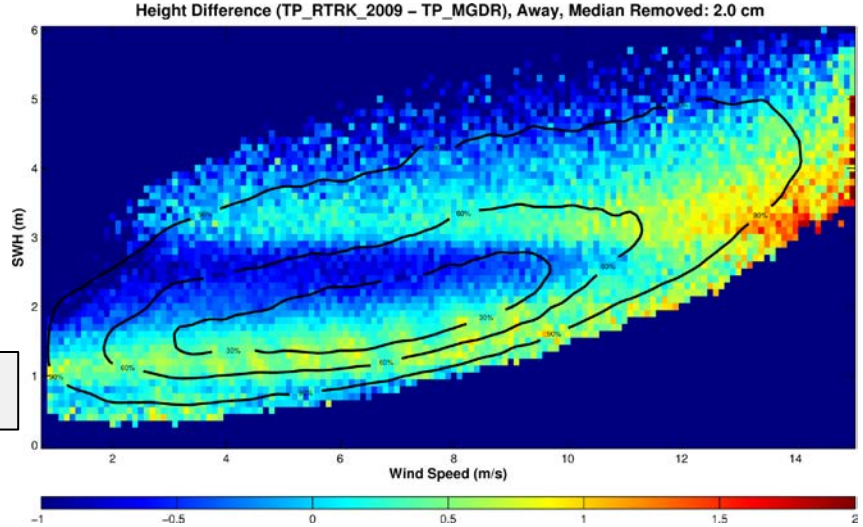

Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew 0.1 – TP_MGDR

-1 cm +2 cm

TP_RTRK_2009 – TP_MGDR

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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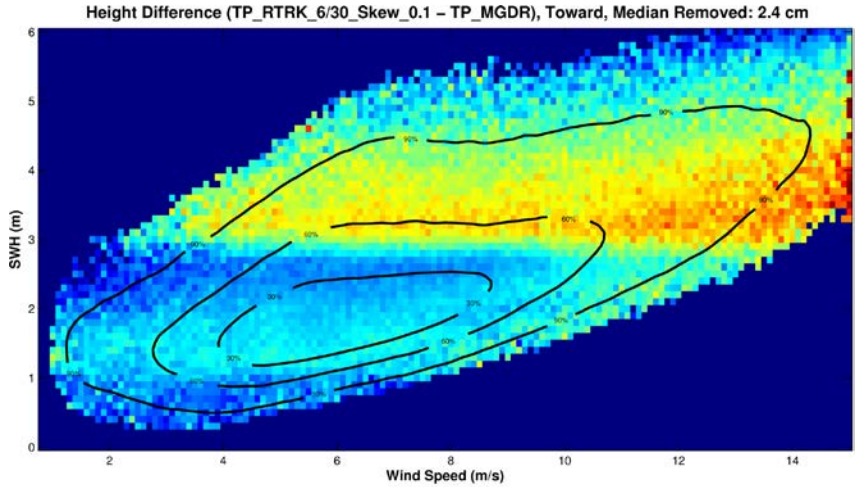
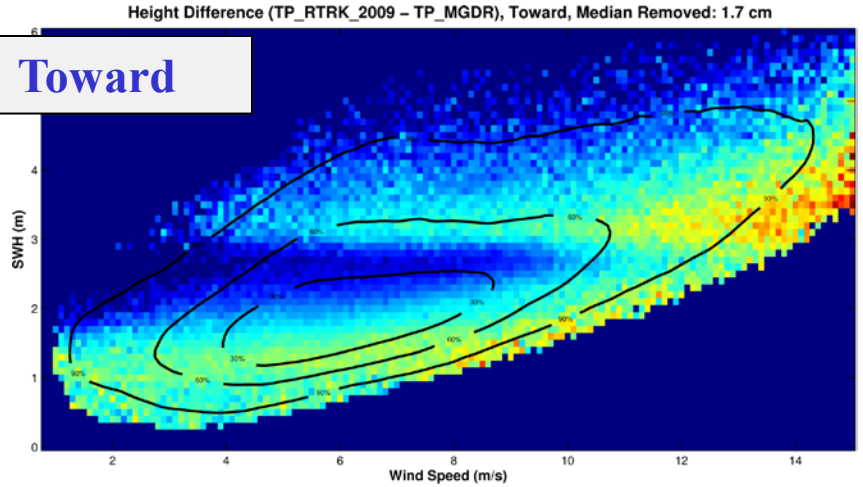
TOPEX Retrack – MGDR SSH Comparison

Jason Wind Speed





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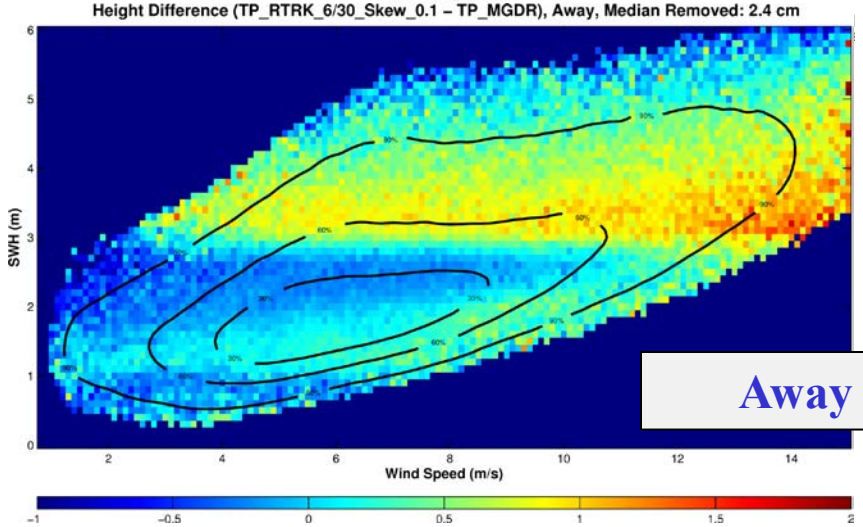

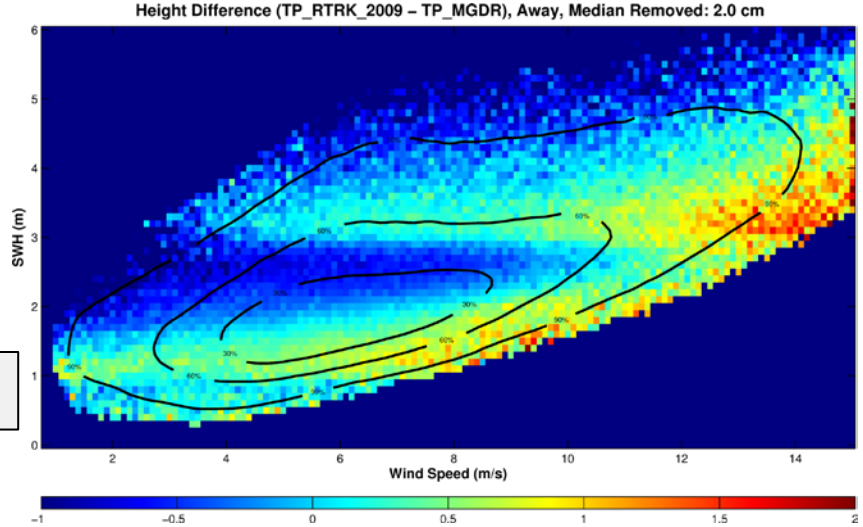

Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew 0.1 – TP_MGDR

-1 cm +2 cm

TP_RTRK_2009 – TP_MGDR

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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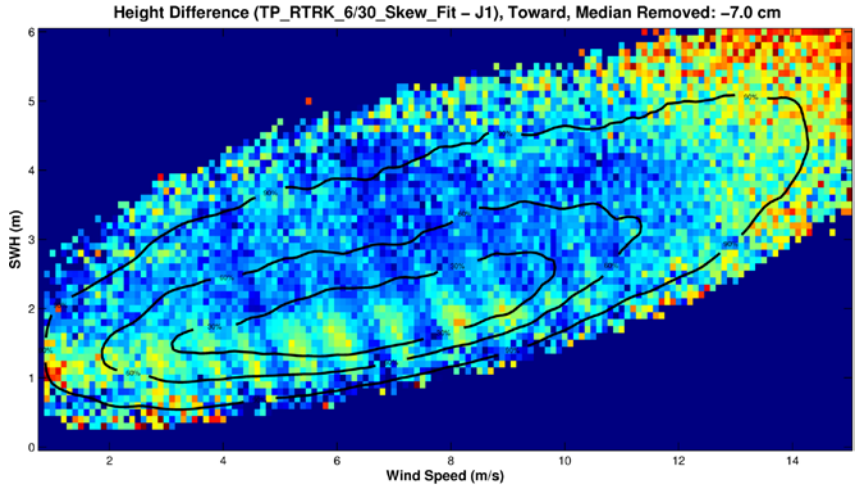
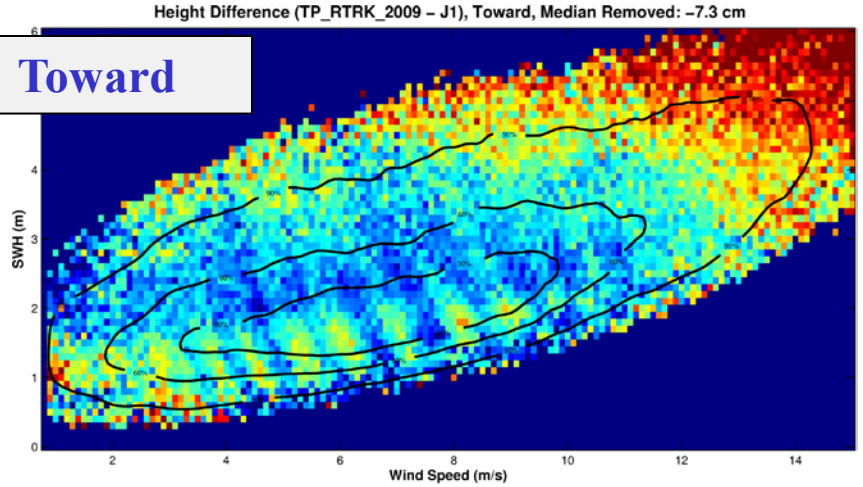
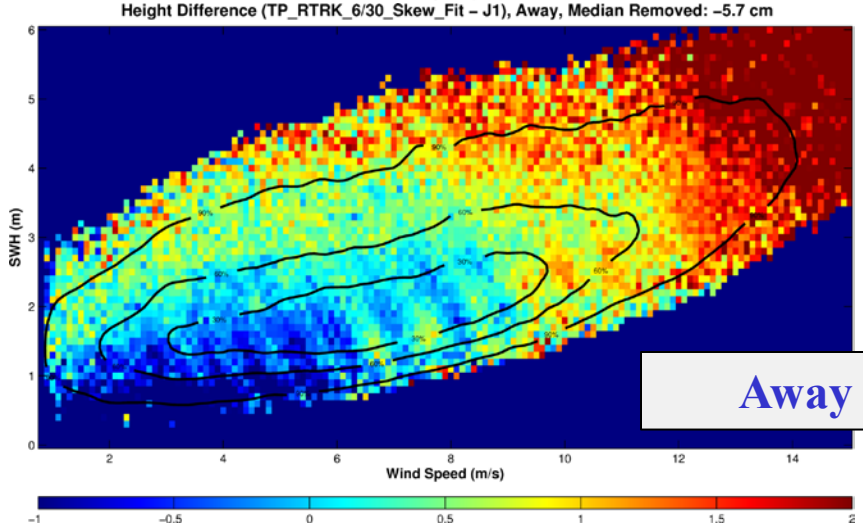
TOPEX Retrack – Jason-1 SSH Comparison

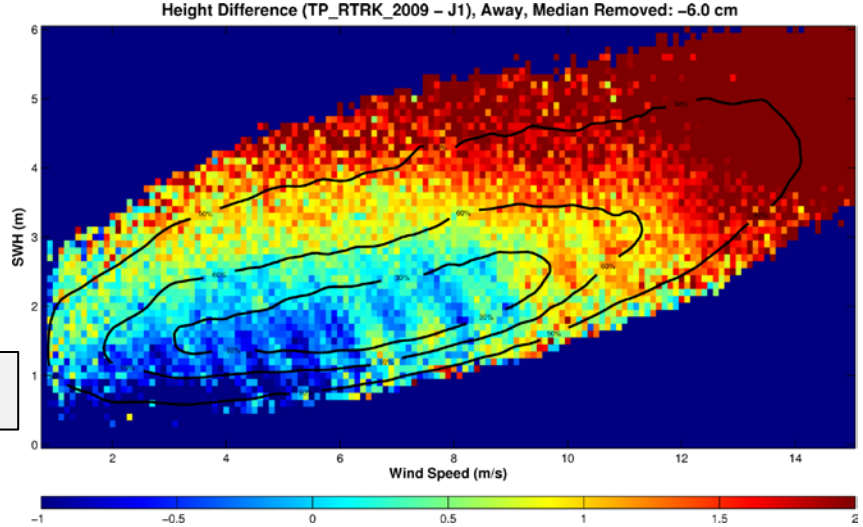
TOPEX Wind Speed





Toward





Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew Fit – J1

-1 cm +2 cm

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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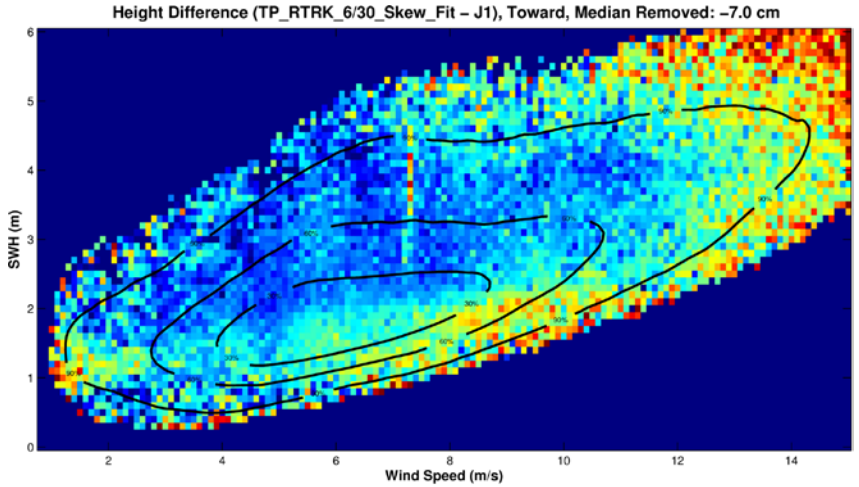
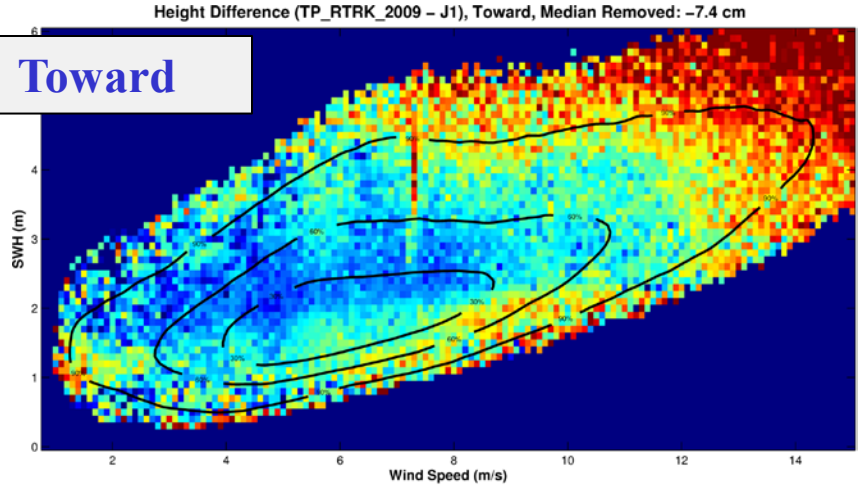
TOPEX Retrack – Jason-1 SSH Comparison

Jason Wind Speed





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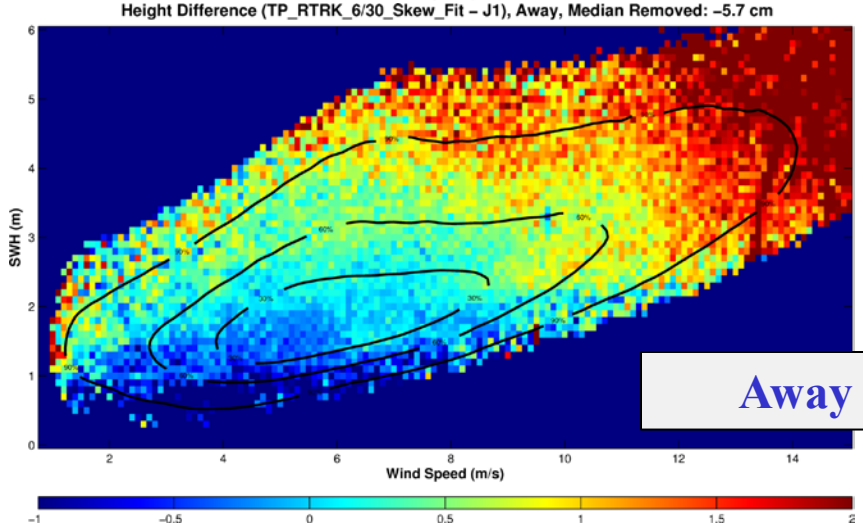

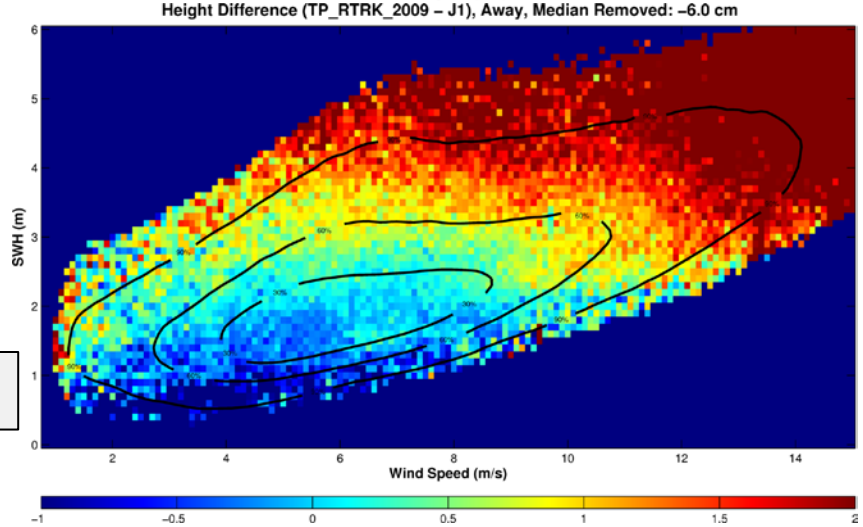

Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew Fit – J1

-1 cm +2 cm

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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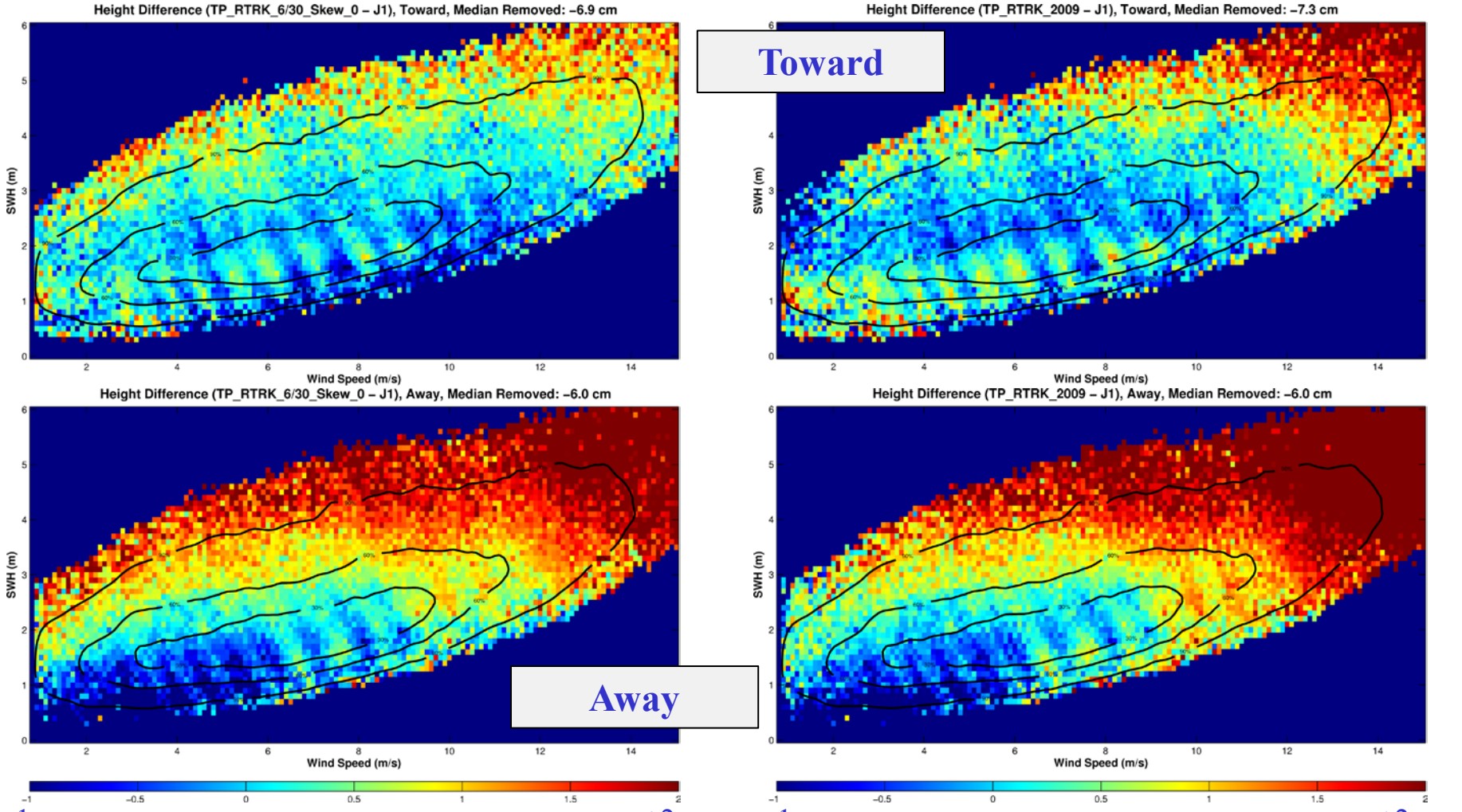
TOPEX Retrack – Jason-1 SSH Comparison

TOPEX Wind Speed



TP_RTRK_2014 6/30 Skew 0 – J1

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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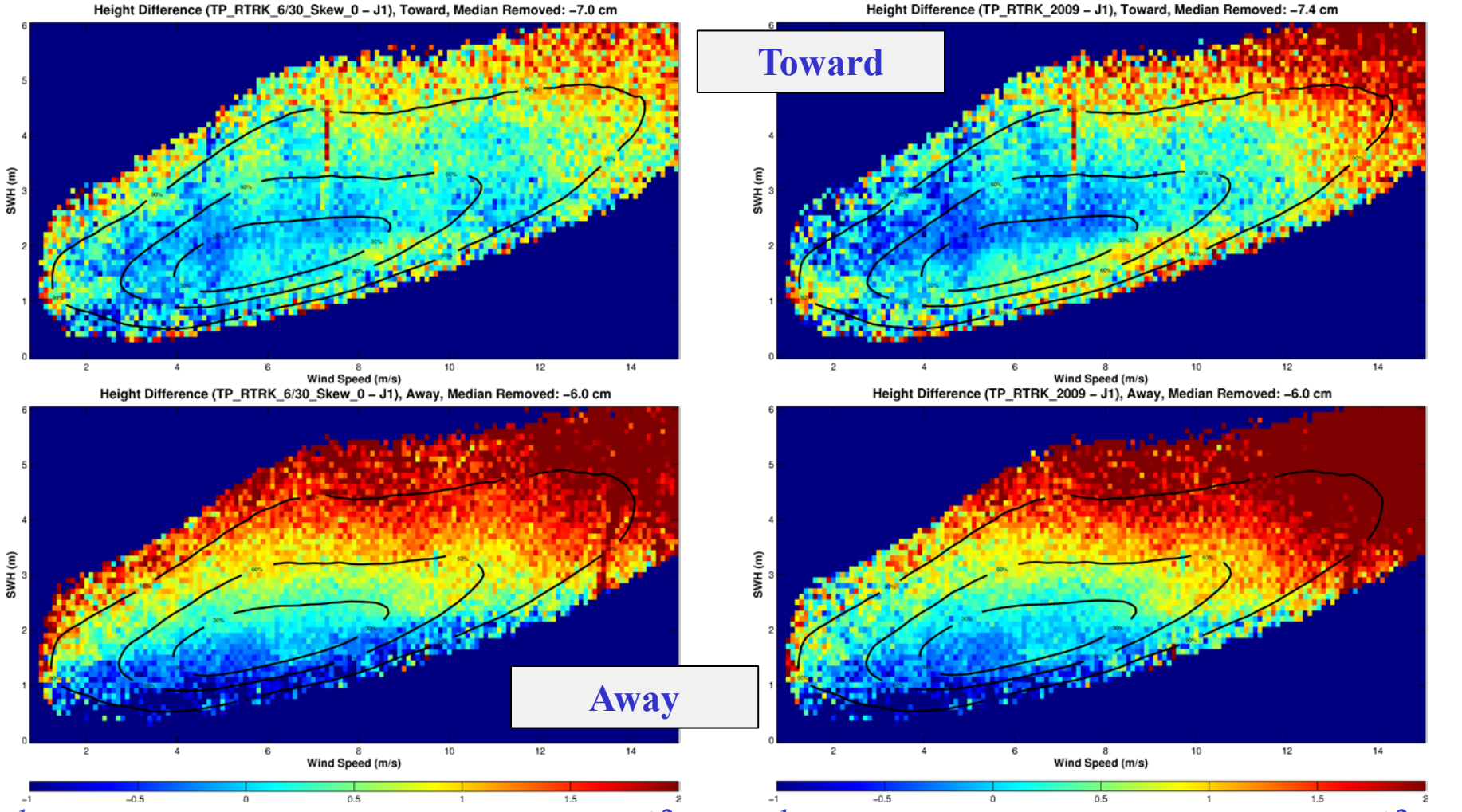
TOPEX Retrack – Jason-1 SSH Comparison

Jason Wind Speed



TP_RTRK_2014 6/30 Skew 0 – J1

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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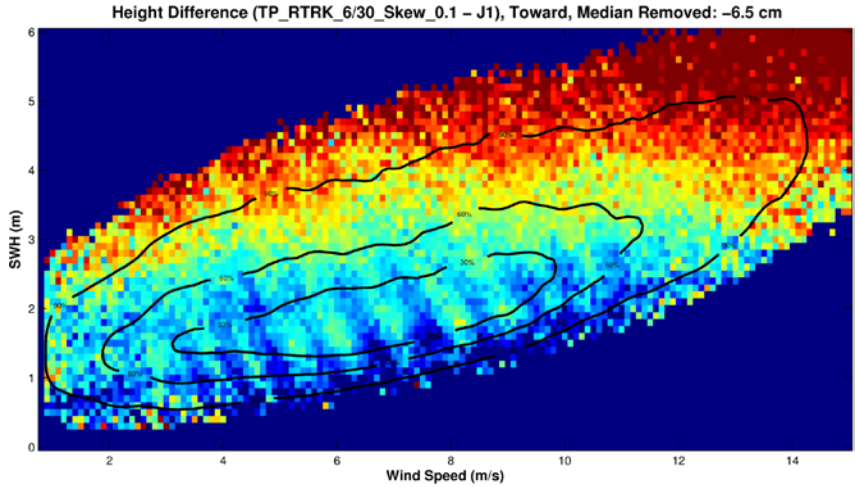
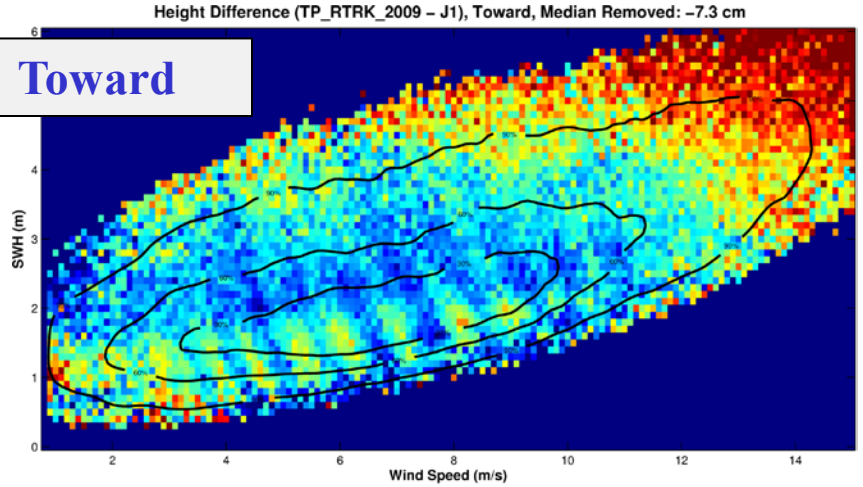
TOPEX Retrack – Jason-1 SSH Comparison

TOPEX Wind Speed





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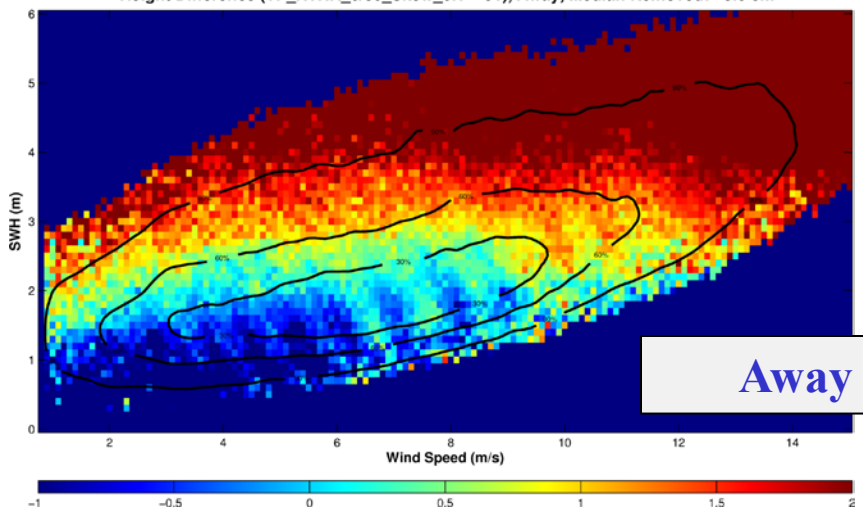

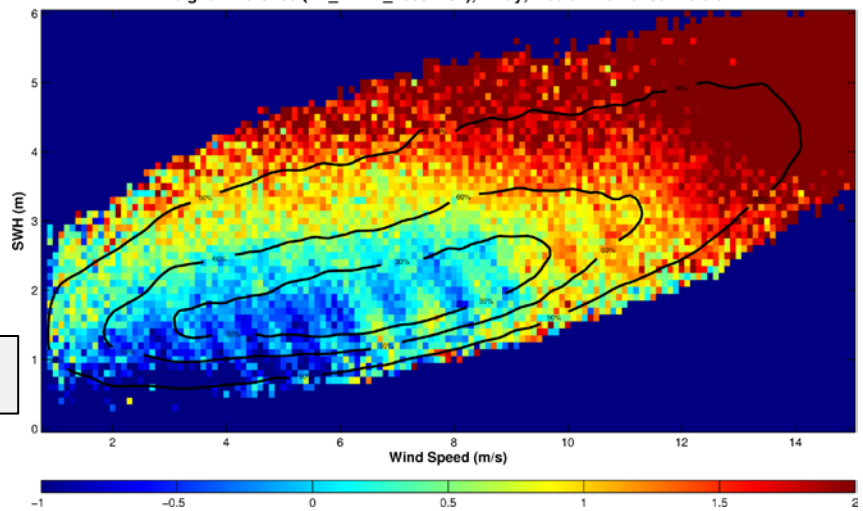

Away

-1 cm +2 cm

TP_RTRK_2014 6/30 Skew 0.1 – J1

-1 cm +2 cm

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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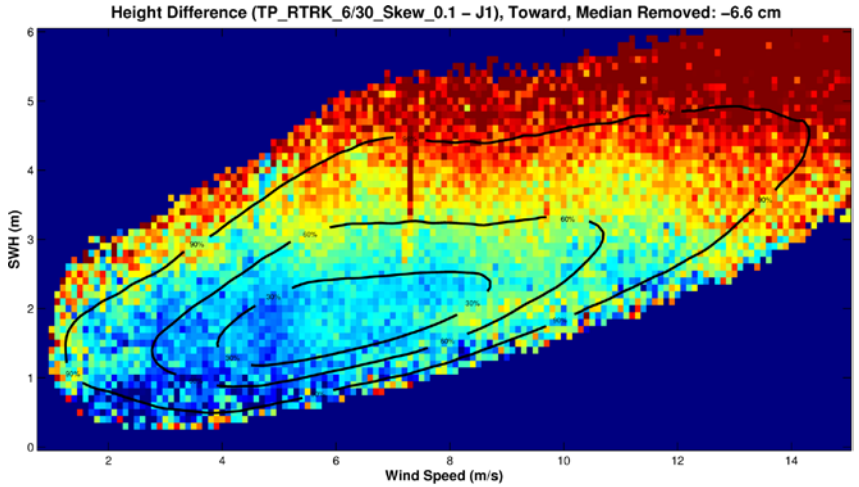
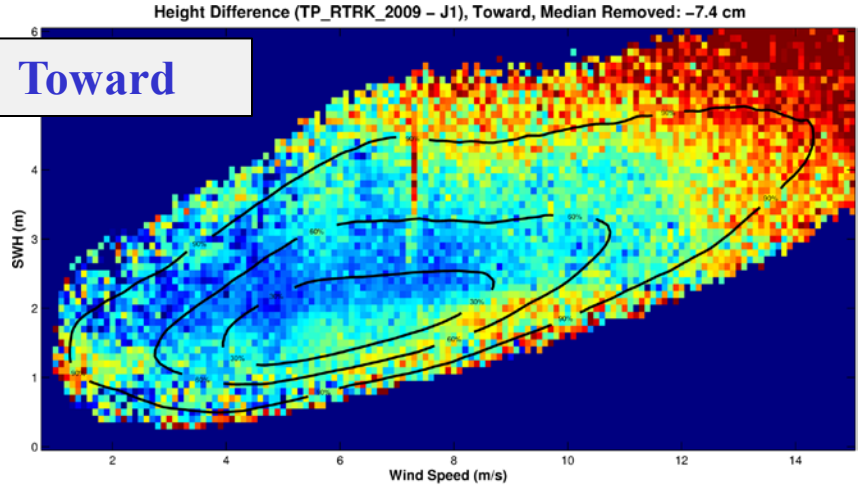
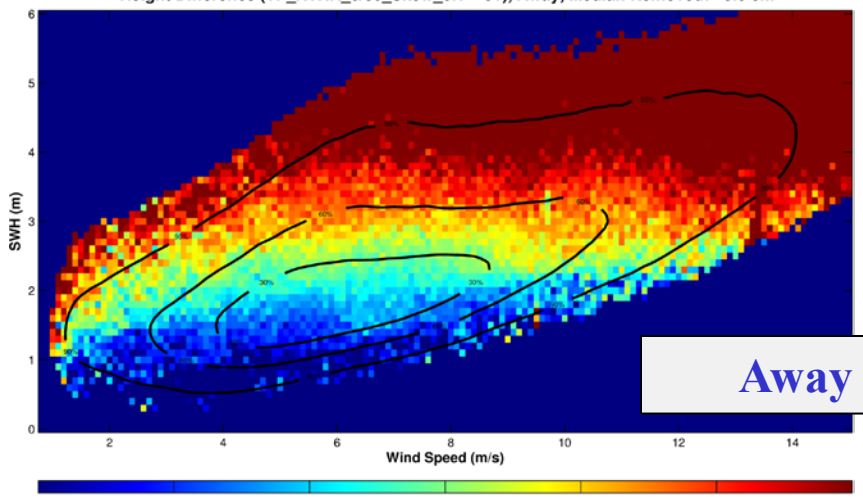
TOPEX Retrack – Jason-1 SSH Comparison

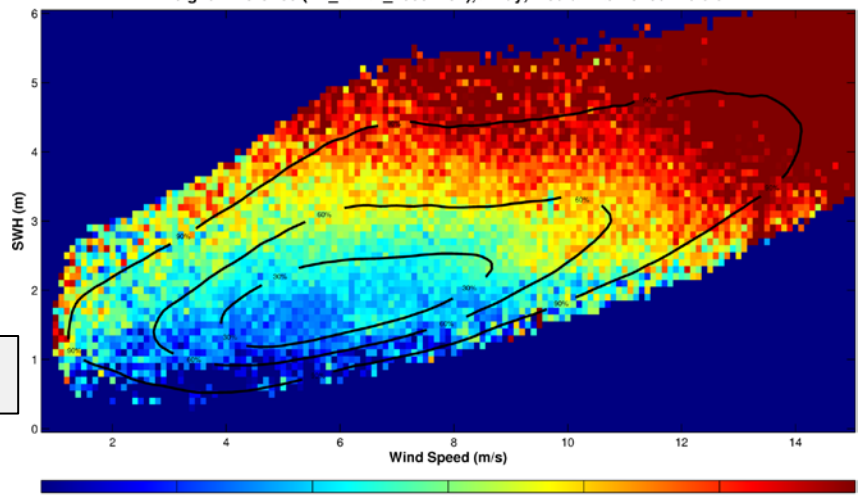
Jason Wind Speed



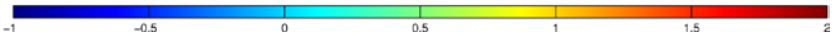


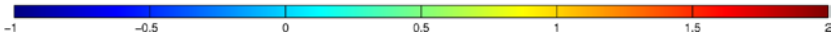
Toward





Away





-1 cm +2 cm

TP_RTRK_2014 6/30 Skew 0.1 – J1

-1 cm +2 cm

TP_RTRK_2009 – J1

MSS: CLS 2011, Orbits: GSFC 2013 (TP) / GDR-C (J1)

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

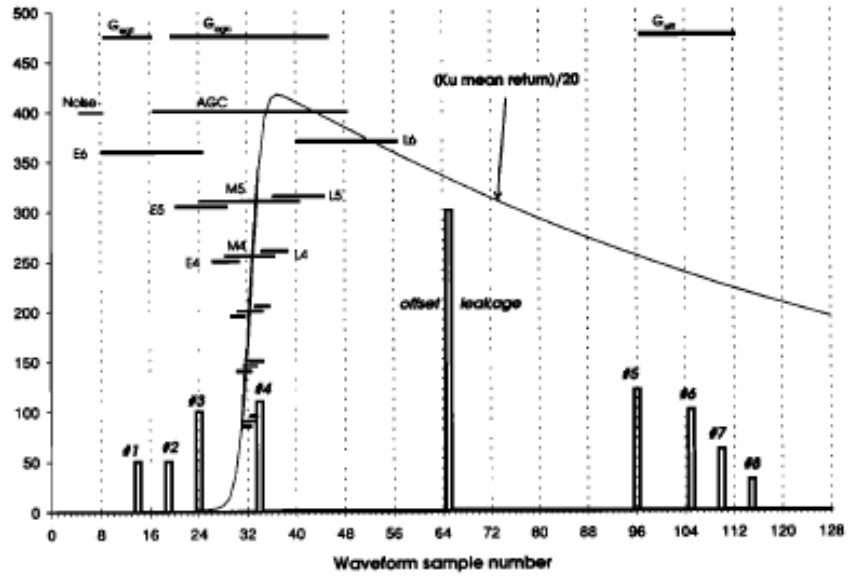
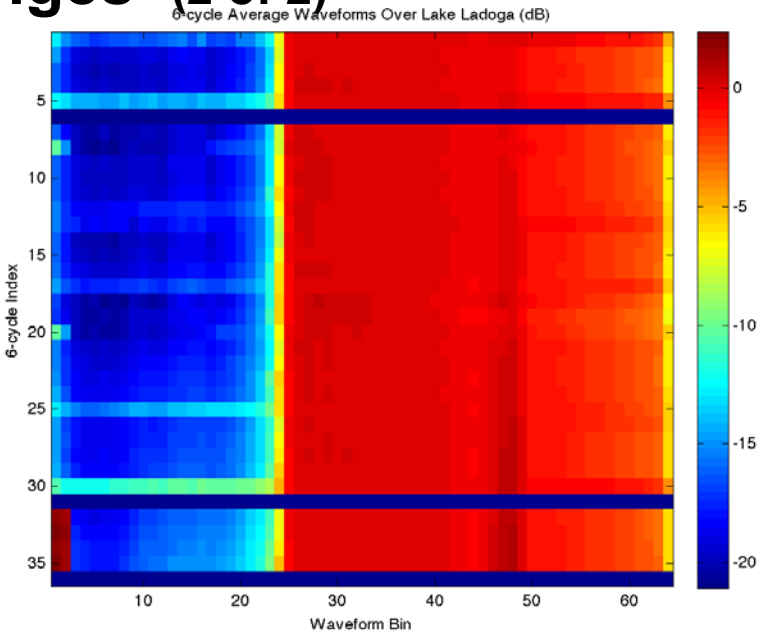


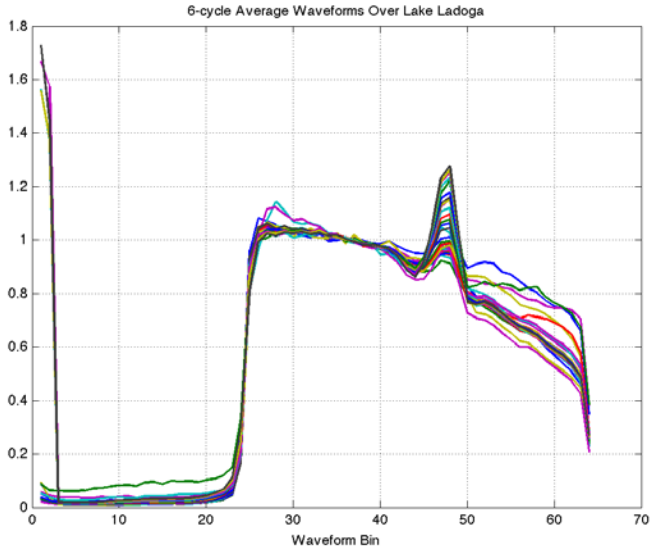
Figure 6. TOPEX Ku altimeter gates, mean return, and center locations of waveform leakage spikes.

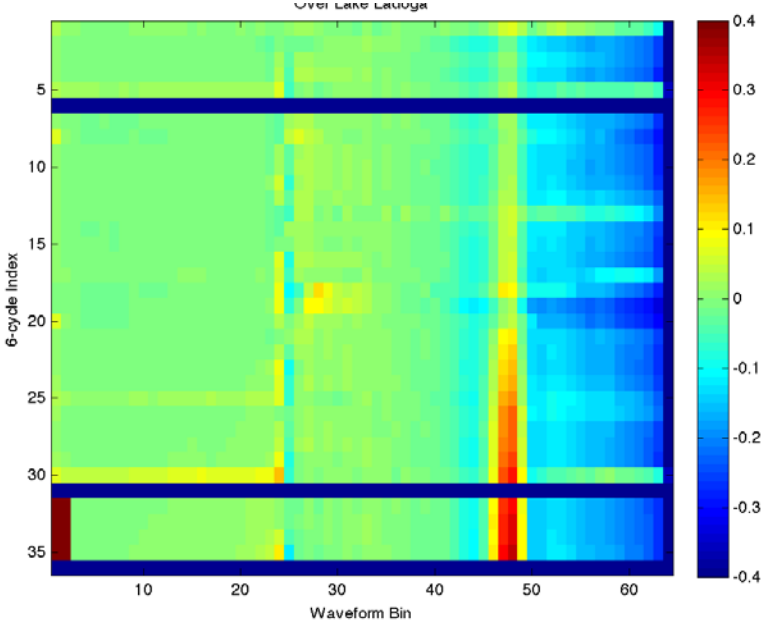
- Leakages (x20) in the TOPEX Alt-A waveform from Hayne et al., 1994, JGR, ***99***, 24,941.
  - Need correction in processing via masking or "weights" on WF gates
  - Move with range rate giving North/South Ascending/Descending ("toward" / "away" Eq) differences
  - Onboard gates used to estimate the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

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







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.