Reduced SAR Techniques for CryoSat

Remko Scharroo
Altimetrics LLC

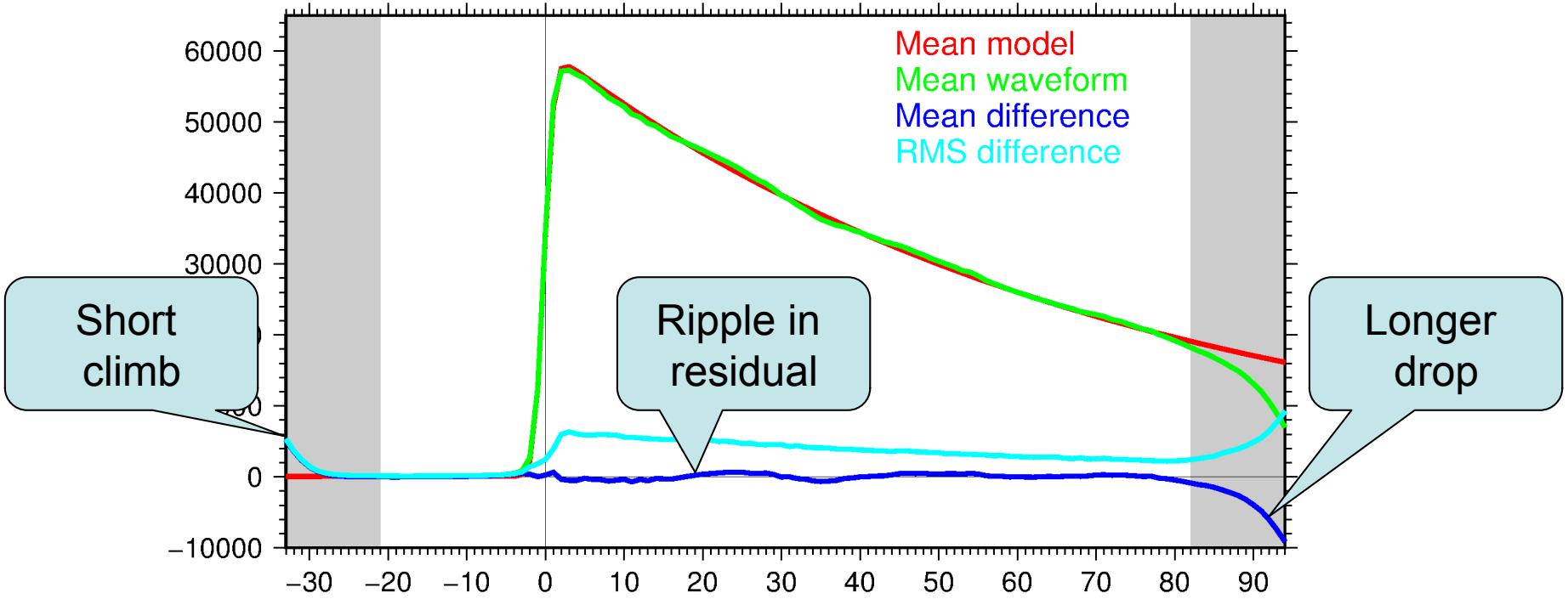
Walter Smith, Eric Leuliette, John Lillibridge
NOAA / Laboratory for Satellite Altimetry

Retracking LRM L1B

- Retrack LRM Level 1B waveforms
  - Daily download FDM and LRM L1B data from ESA
  - Retrack waveforms to compute our own wave height, backscatter, range (MLE3-type retracker)
  - Merge data files (few to tens of minutes normally) into passes and subcycles of 29 days (à la GDR) in **RADS**
- Update in RADS
  - Use additional geophysical corrections from L1B
  - Overwrite and add common RADS geophysical corrections
    - **SSB** (that we determined ourselves)
    - Latest MSS models (DTU10, CNES-CLS11), EGM2008 geoid
    - Tides (FES2004, GOT4.8)
    - ECMWF and NCEP meteo, GPS and NIC09 iono, MOG2D IB
    - Off-line orbits from Delft, ESOC, CNES
  - Compute wind speed from backscatter (Abdalla)

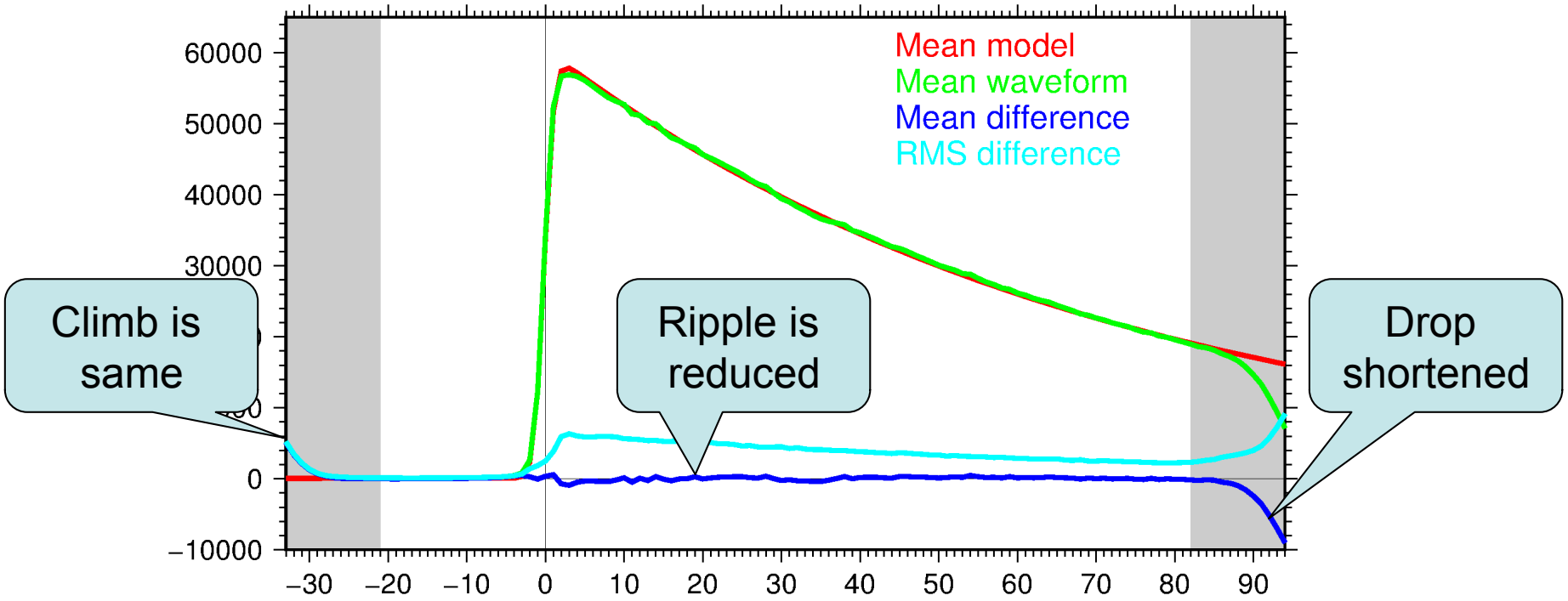
Average Waveform (LRM)

- LRM, open ocean, 116 second average
  - Waveform fitted only in middle part; tracking point at gate 33
  - Drop-off in tail is much wider than climb in front
    - Suggests the waveform is shifted to the left
  - A ripple (wavelength 20 gates) is evident in the residual
    - Suggests that the LPF filter correction is incorrectly applied



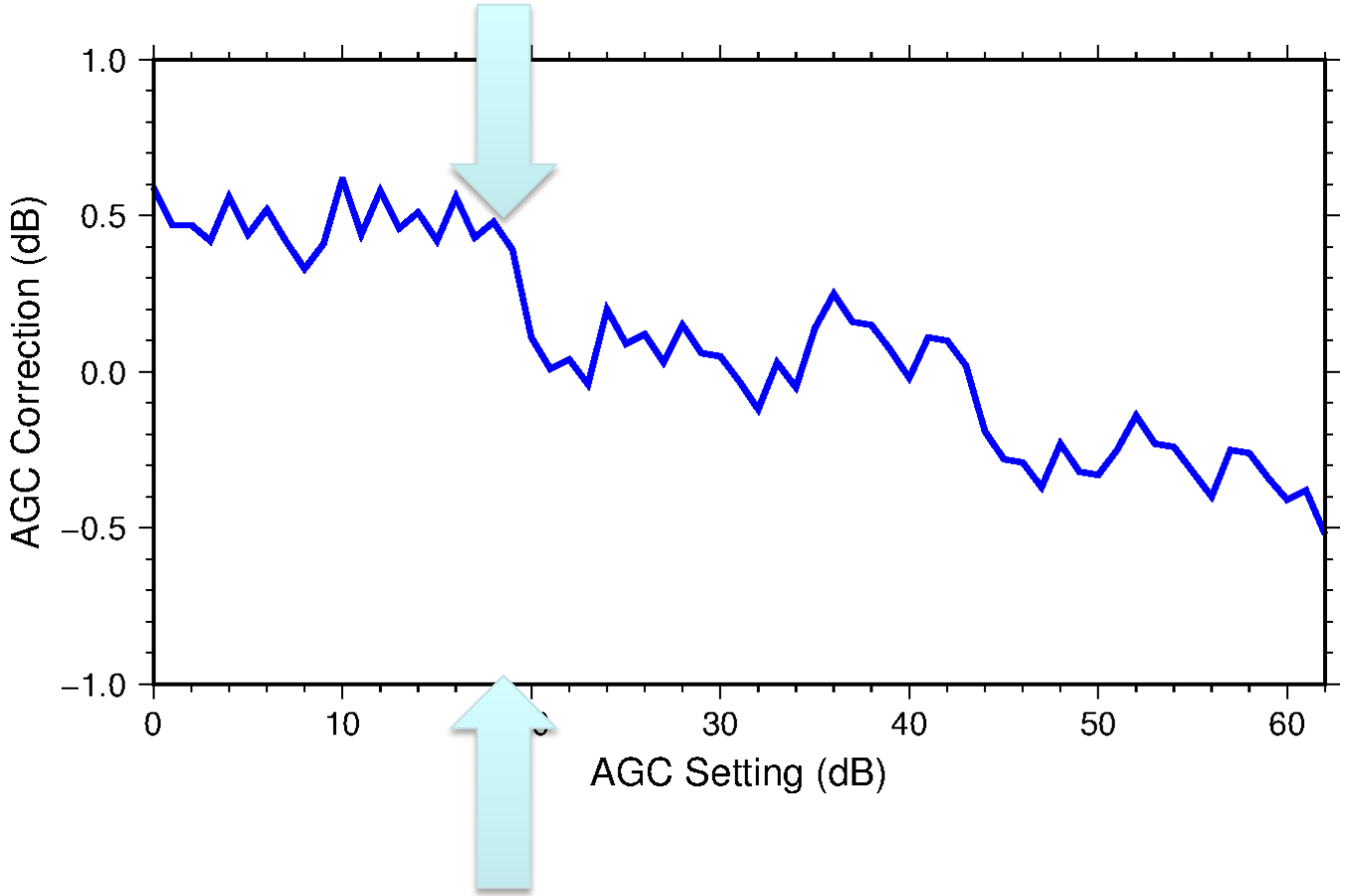
Average Waveform (LRM)

- LPF filter correction now also shifted left by one gate
  - Ripple in residual significantly reduced
  - Drop-off in the tail has shortened by several gates
  - Still, drop-off in tail is ~8 gates, while toe front is ~6 gates
    - This shows waveform is shifted left by one gate



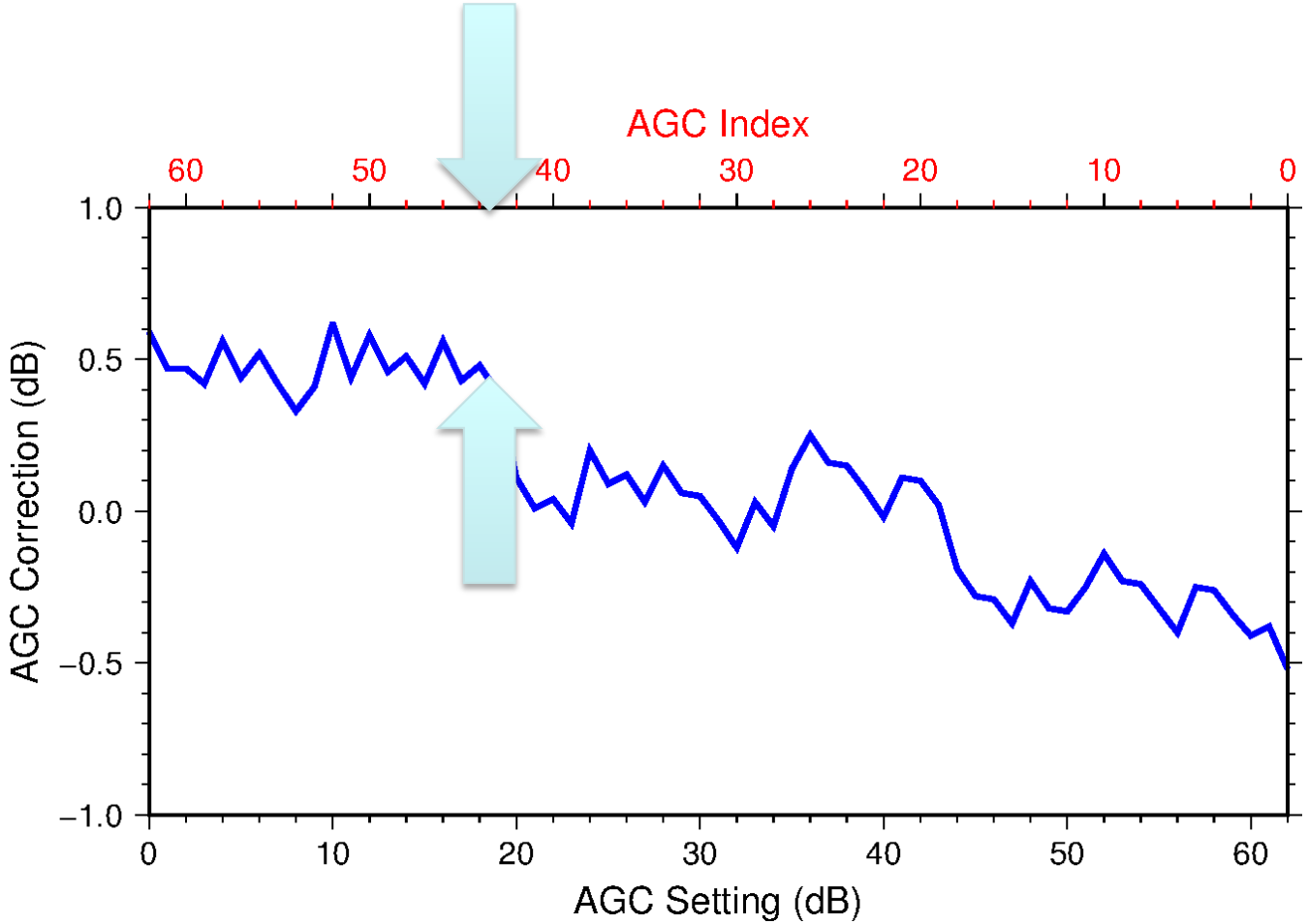
Backscatter “Issues”

- From AGC setting to AGC: Add correction
  - Example: AGC = 18 + 0.48 = 18.48 dB
  - If it would only be so simple …



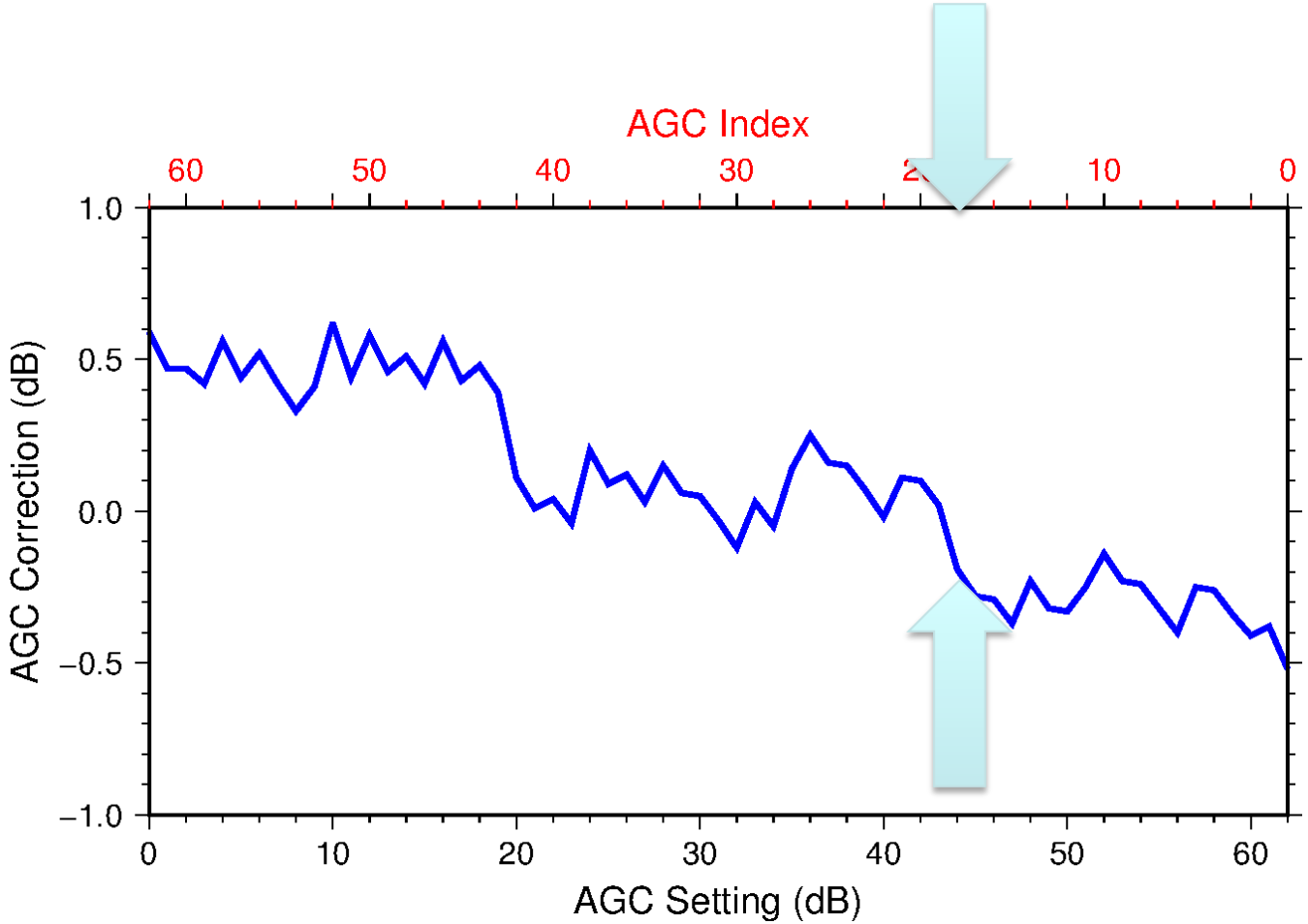
Backscatter “Issues”

- Baseline A: Added correction to **index**
  - Example: AGC = 44 + 0.48 = 44.48 dB



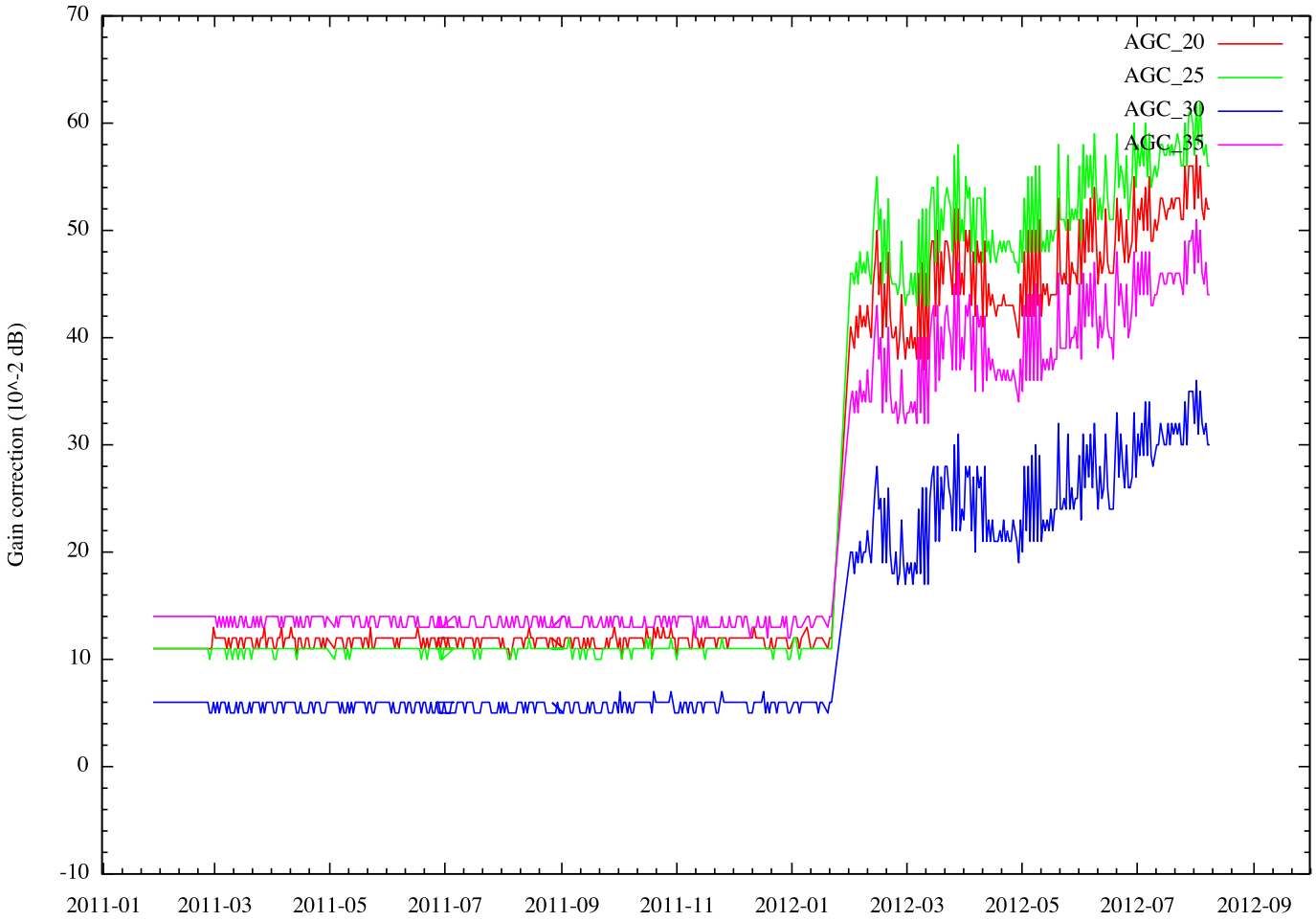
Backscatter “Issues”

- Baseline B: Added wrong correction
  - Example: AGC = 18 + (-0.19) = 17.81 dB

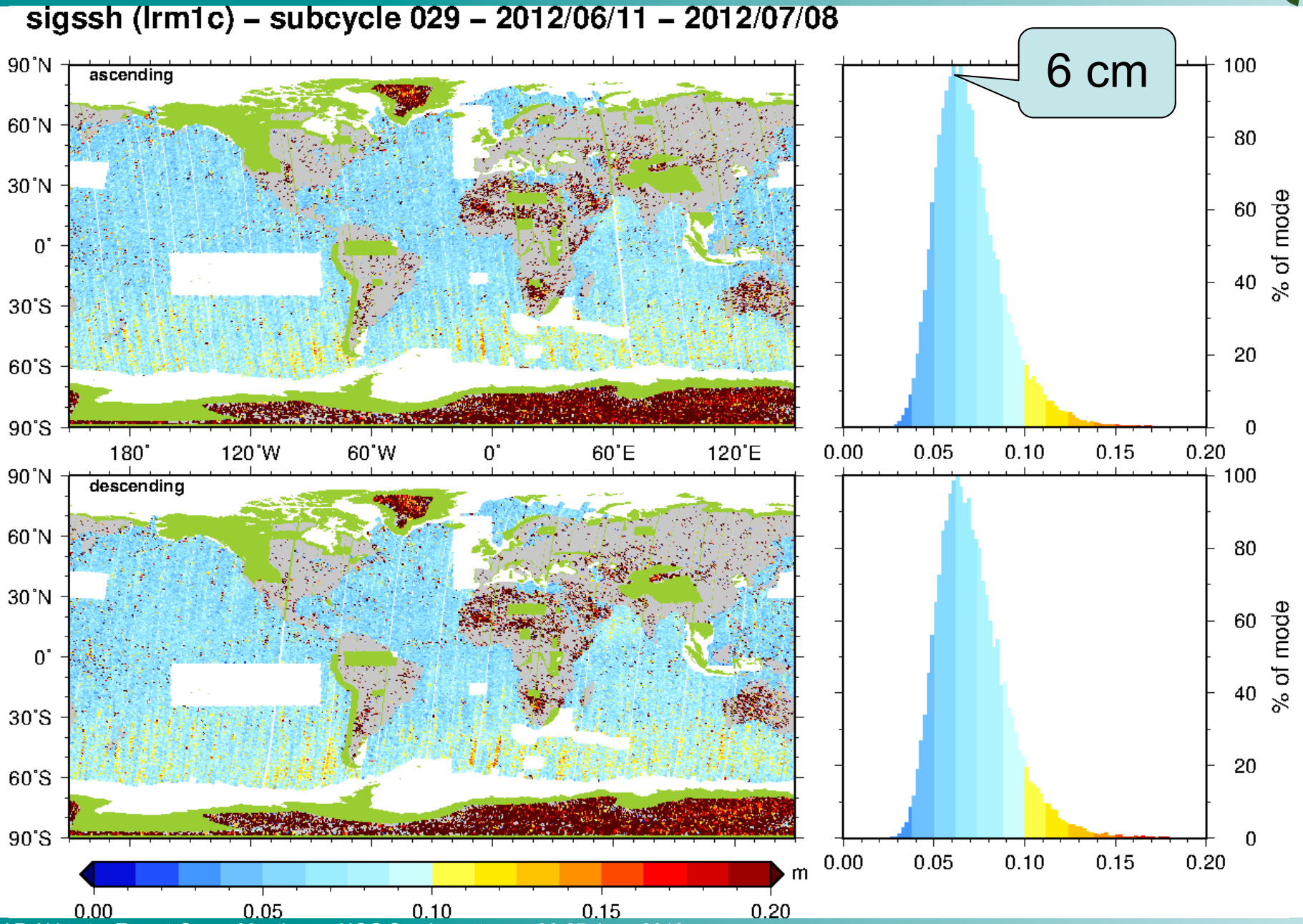


Backscatter “Issues”

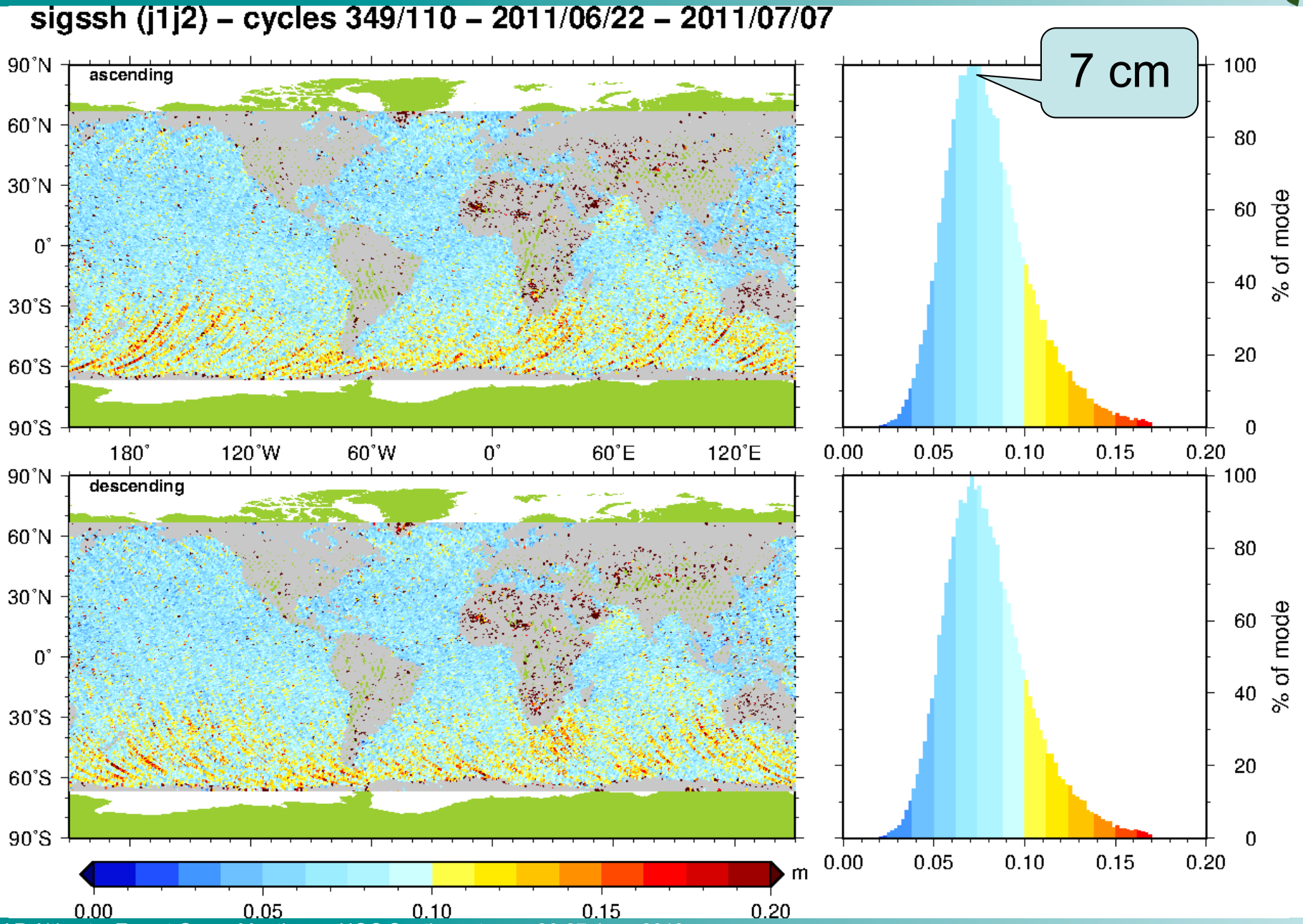
- Baseline B: Added trend wrong way around



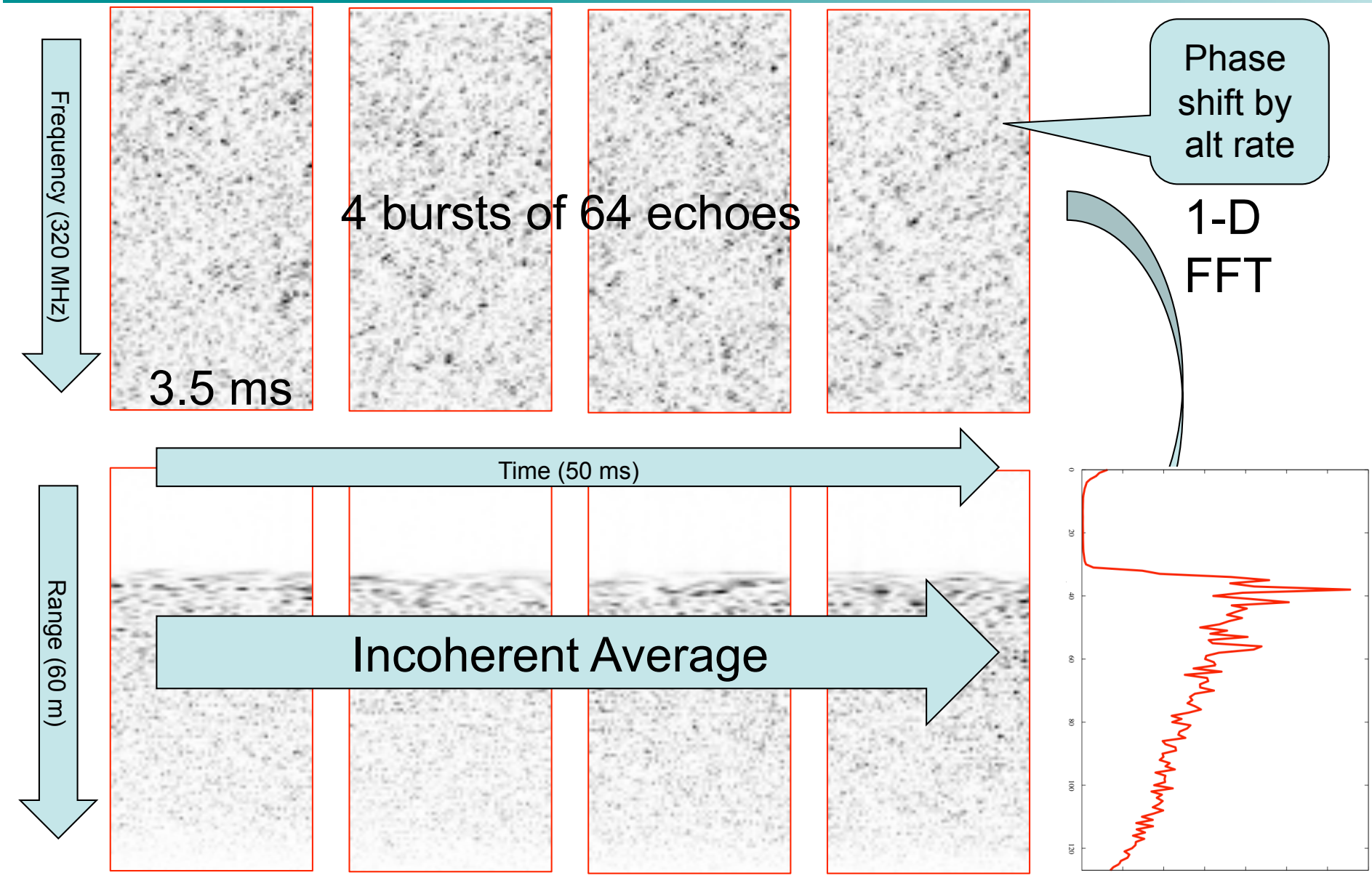
CryoSat LRM – Std Dev of SLA



Jason-1/2 – Std Dev of SLA

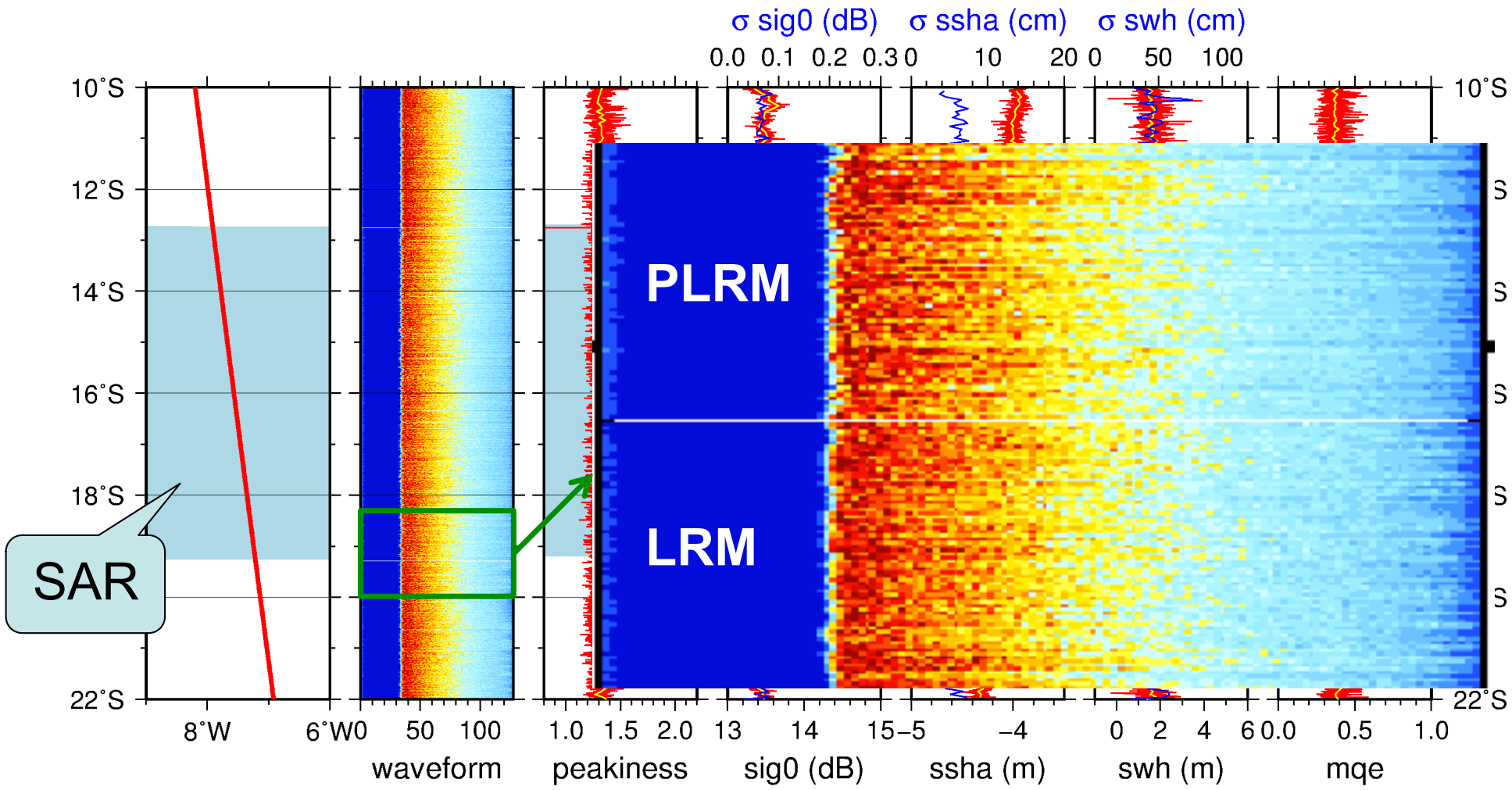


Construct 20-Hz PLRM Waveform



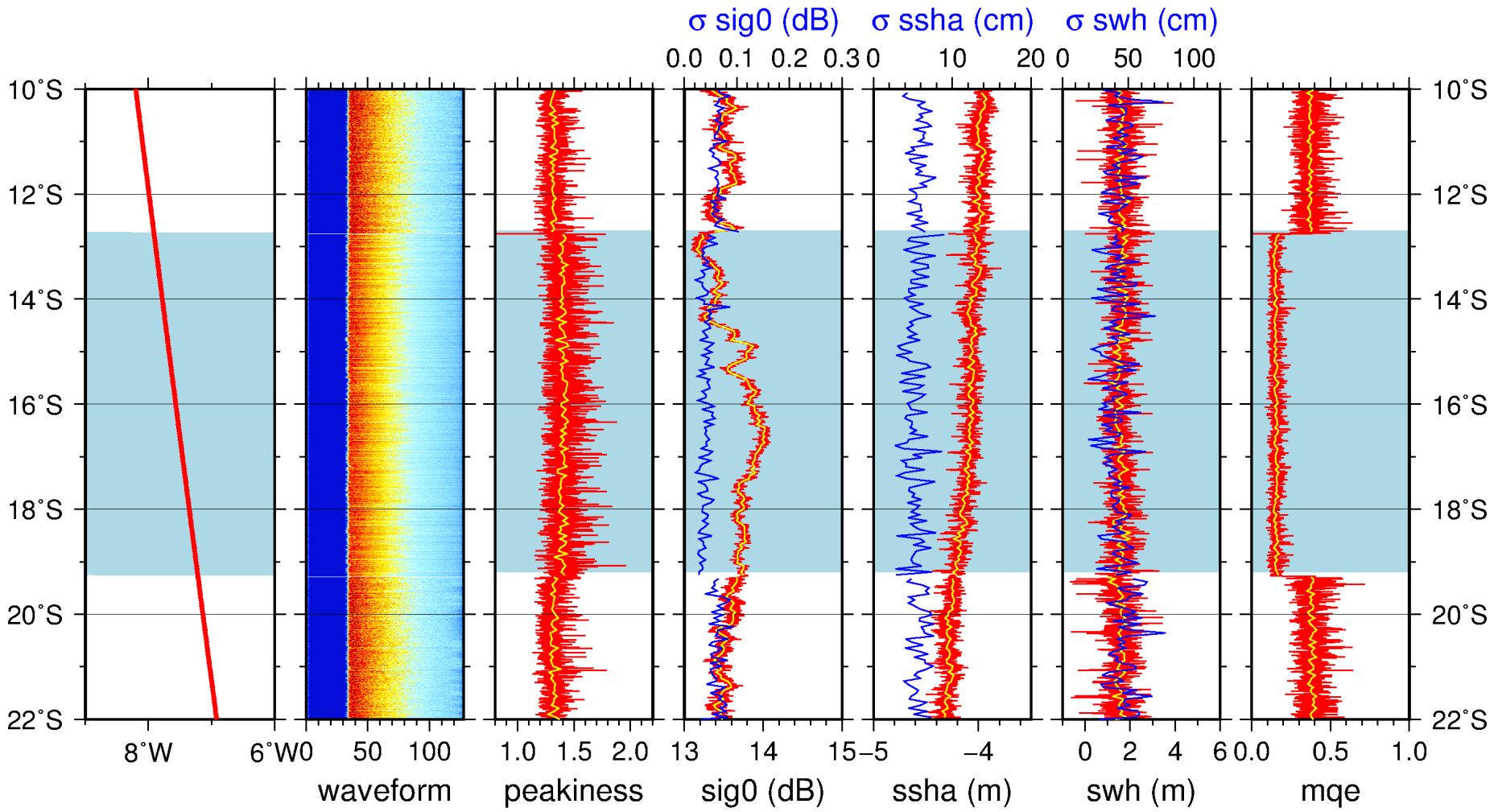
Retracking over St Helena box

- Waveform consistent between LRM and PLRM



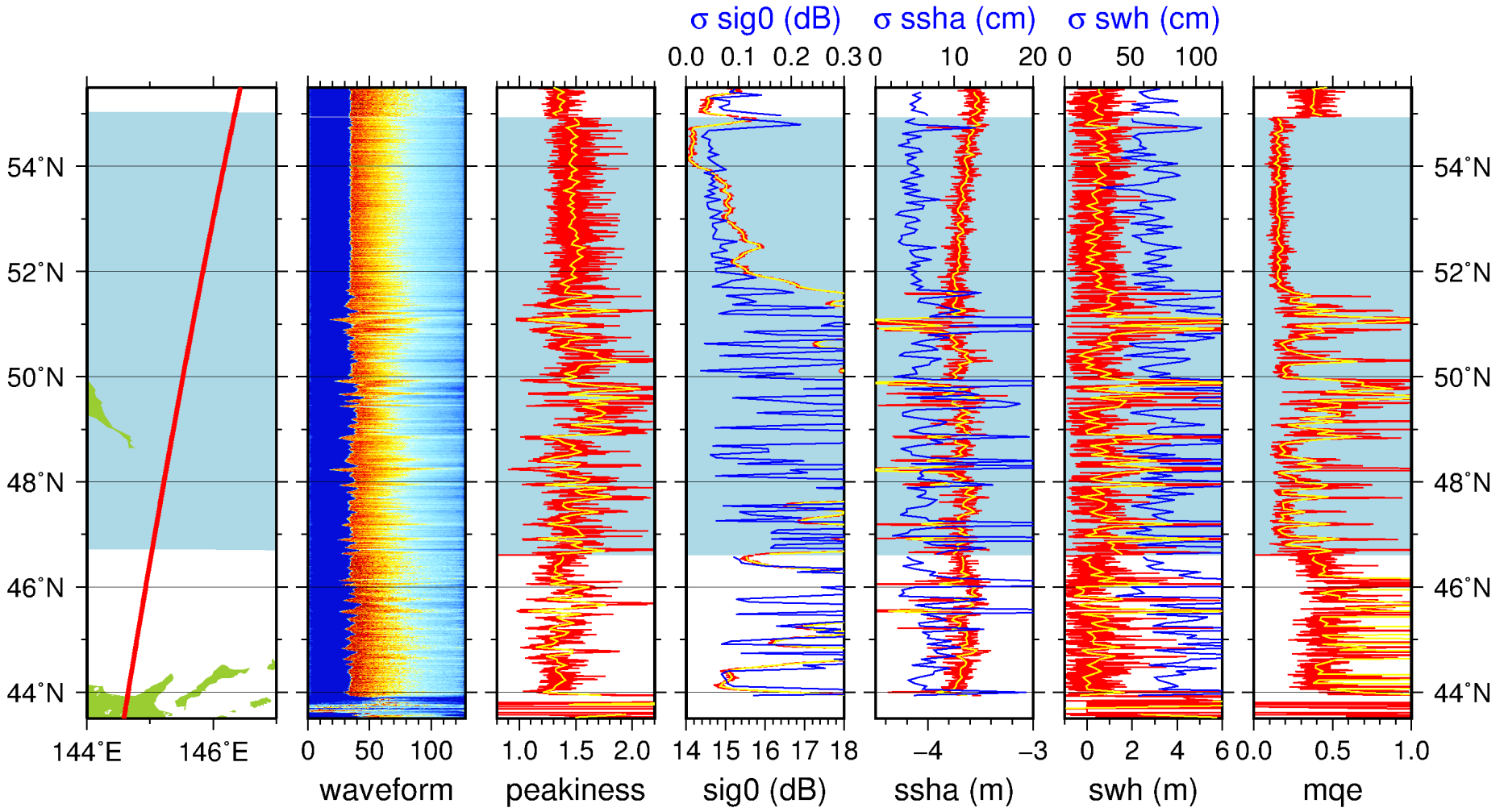
Retracking over St Helena box

- After ¼ + ½ + ¼ smoothing of the PLRM waveform



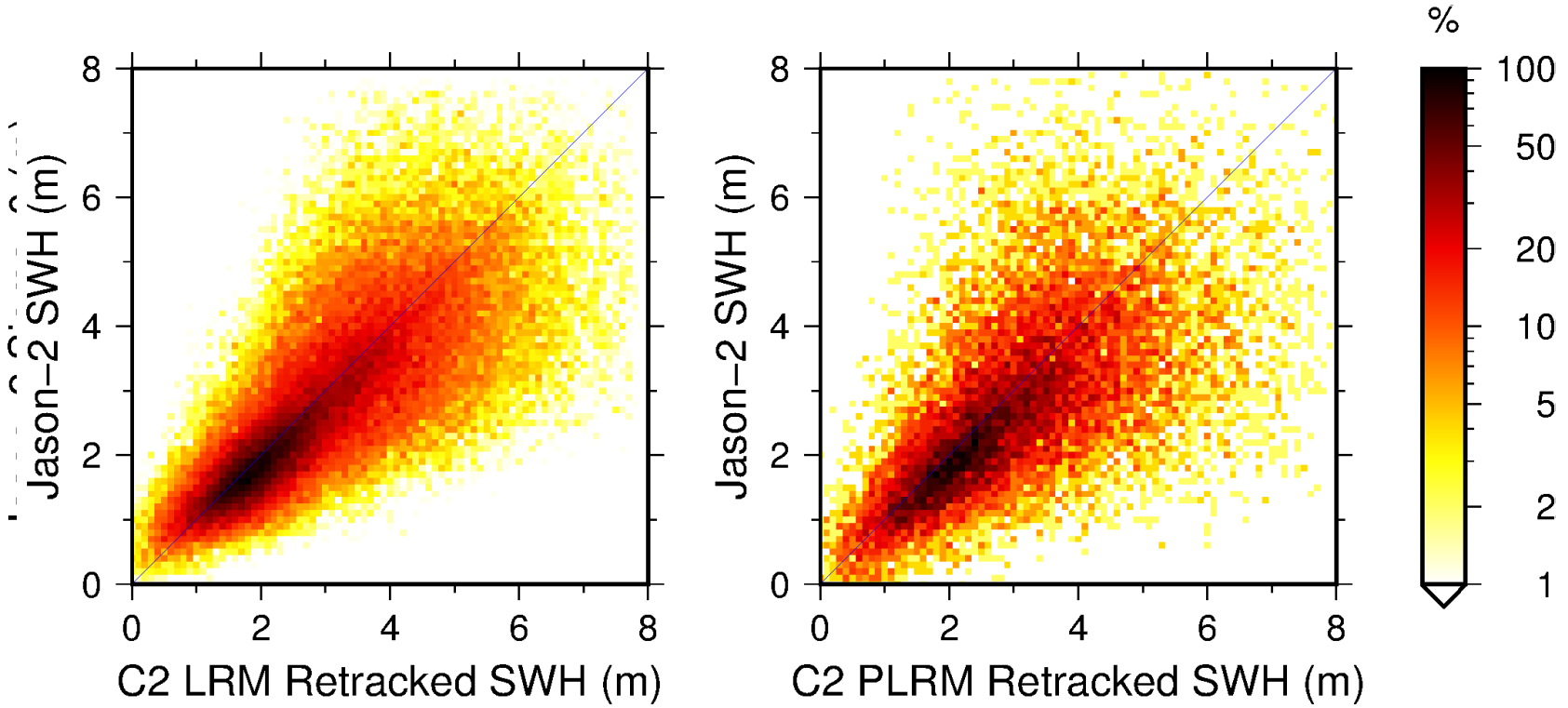
Retracking in the Sea of Okhotsk

- Tracker often goes haywire in calm seas
  - Does not matter whether SAR or LRM



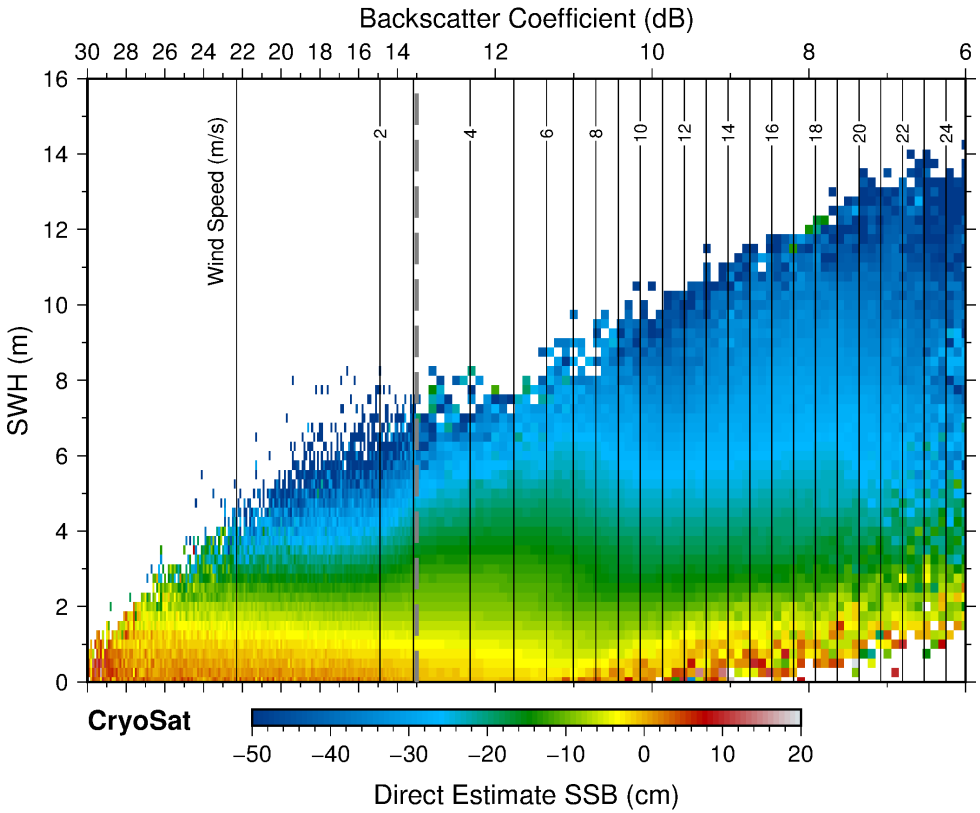
Comparison with Jason-2

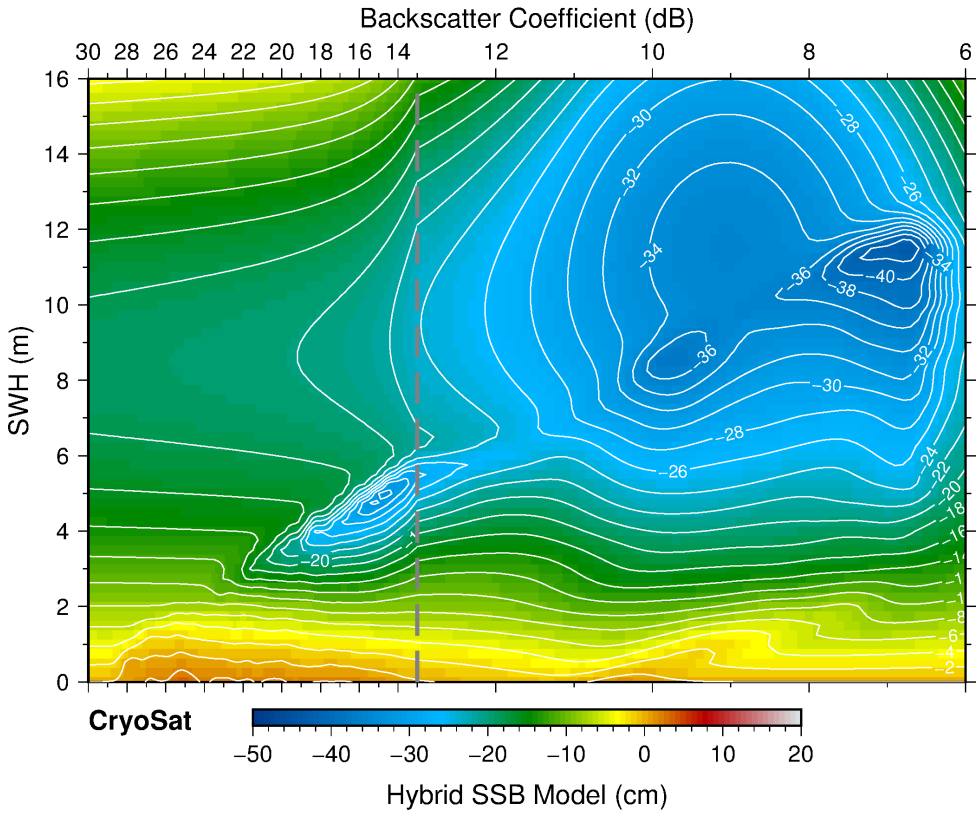
- Crossovers Cryosat-2 vs Jason-2 (dt < 5 days)
  - Too few crossovers between LRM and Pseudo-LRM for direct comparison



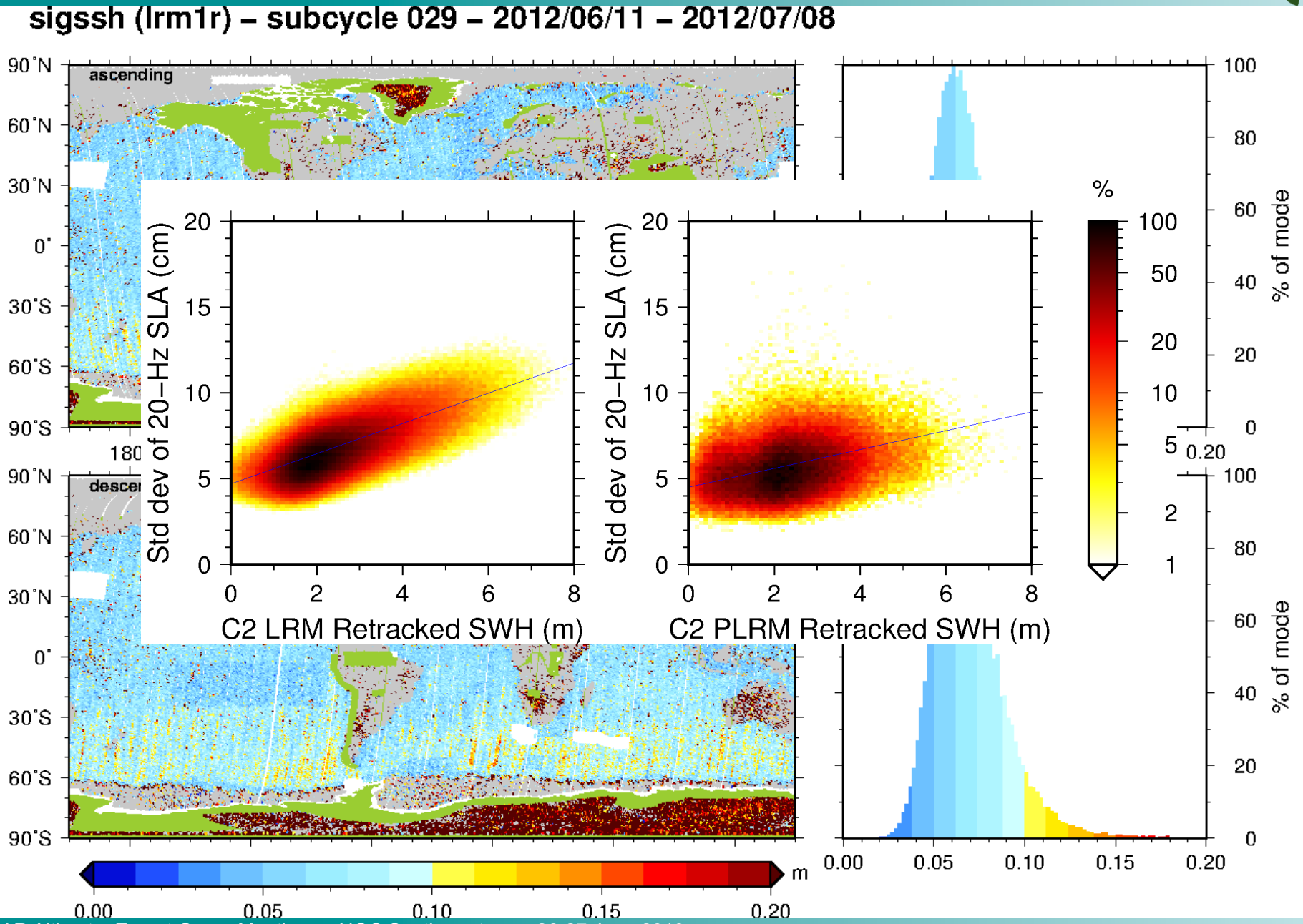
Hybrid Sea State Bias Model

- Direct method, enhanced
  - Sea level anomalies gridded in sigma0-SWH space
  - Fit BM4 model, blend in residuals
  - Approximately –4% SWH

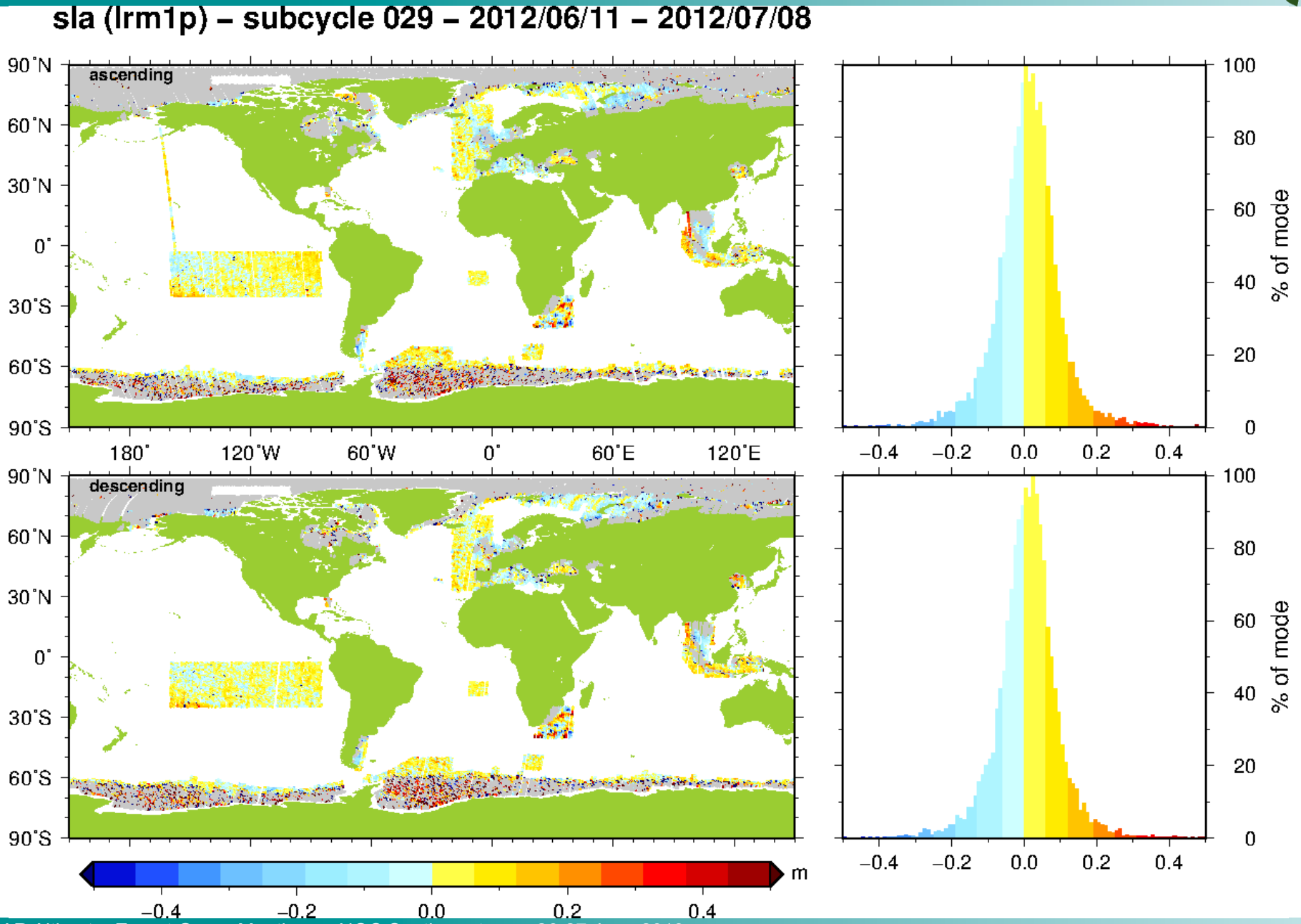




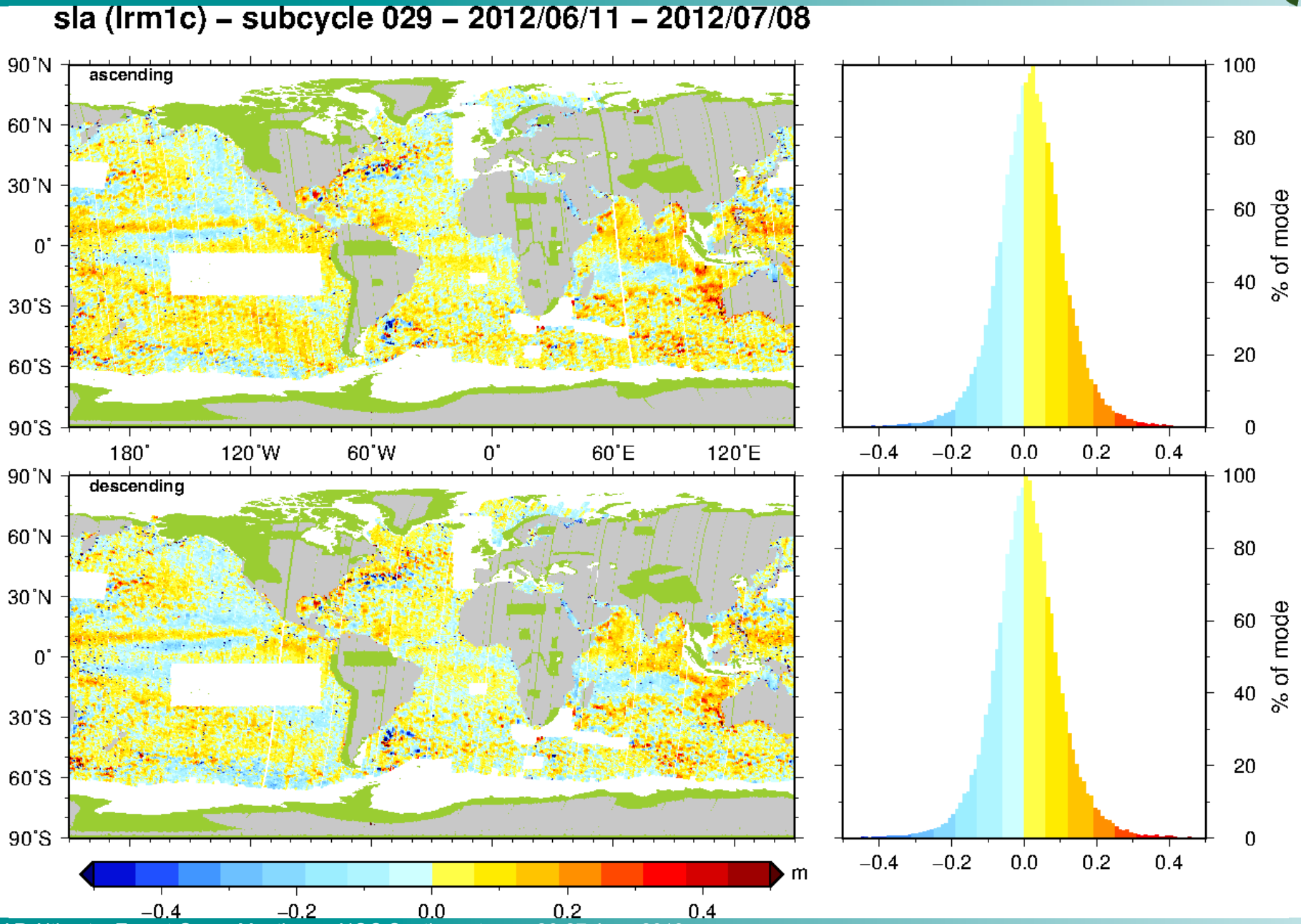
LRM+PLRM – Std Dev Sea Level



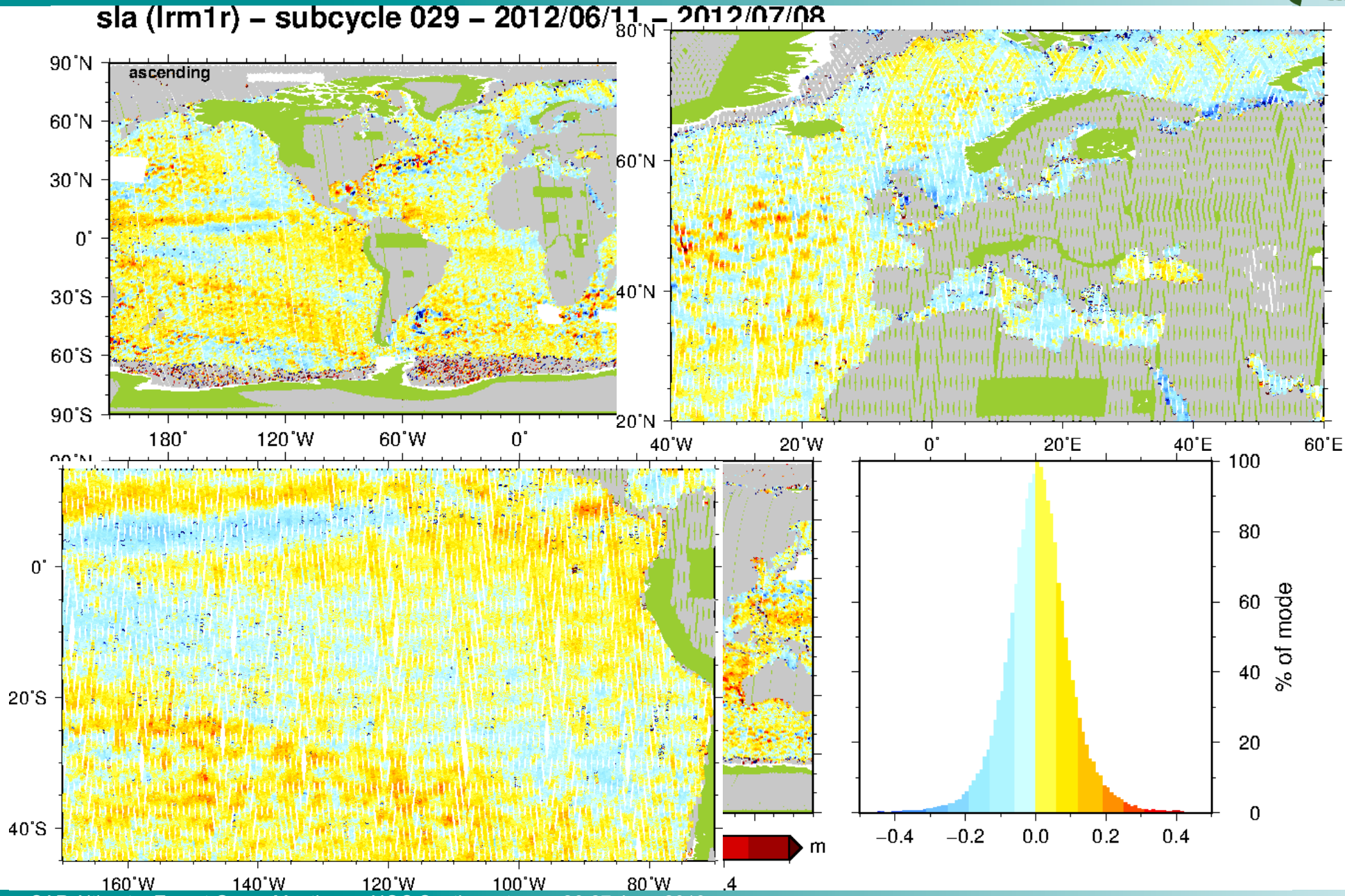
PLRM – Sea Level Anomaly



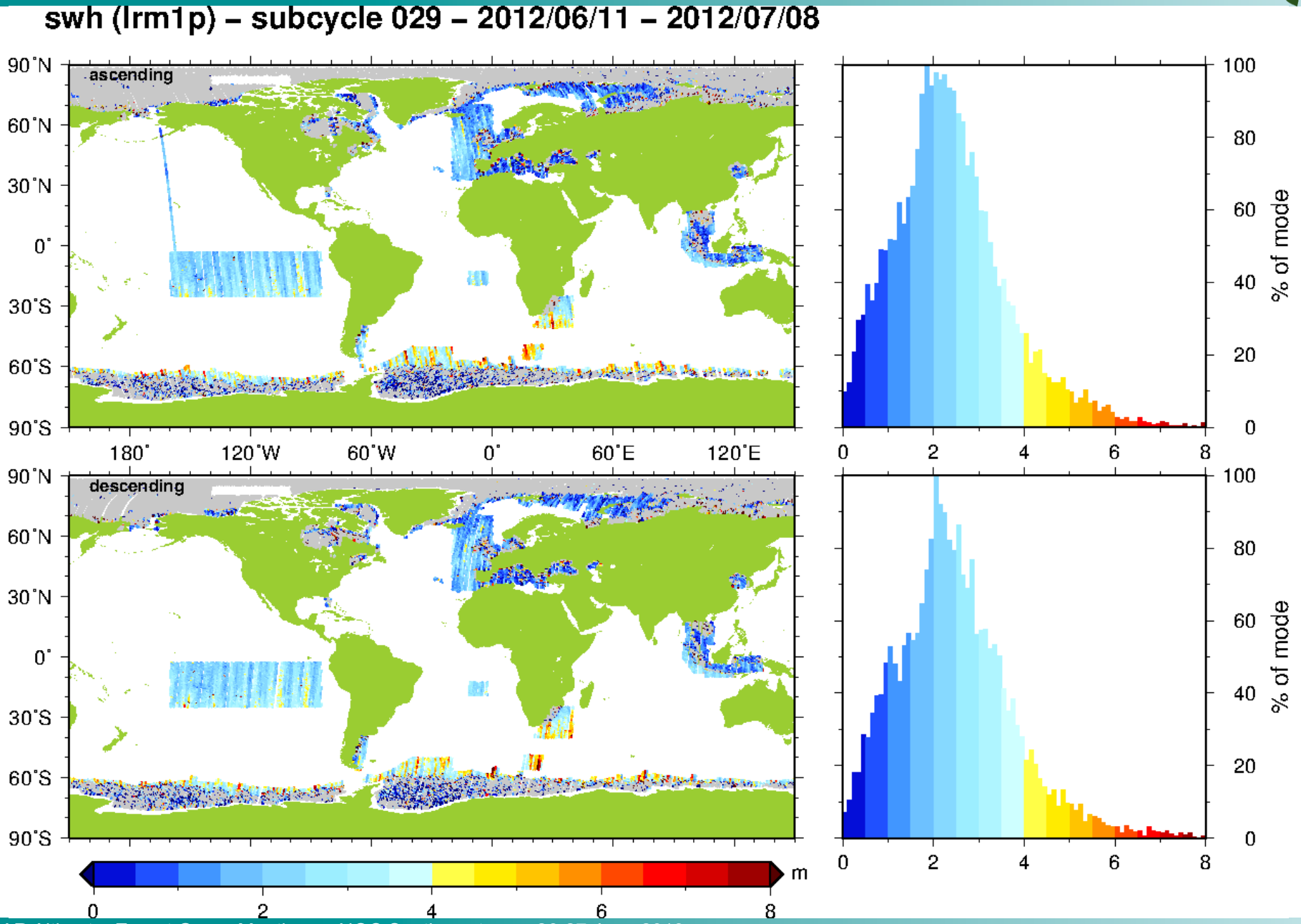
LRM – Sea Level Anomaly



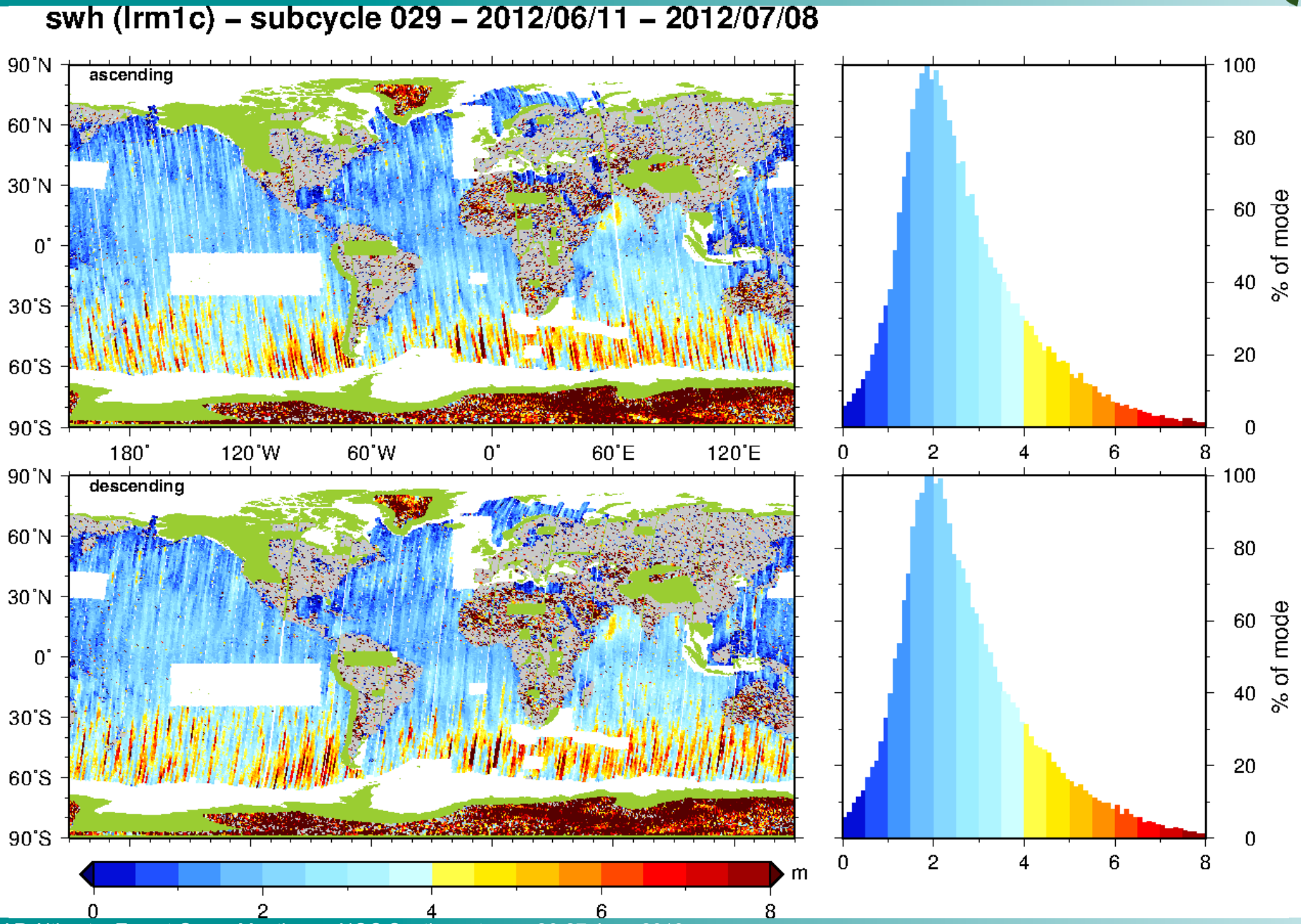
LRM+PLRM – Sea Level Anomaly



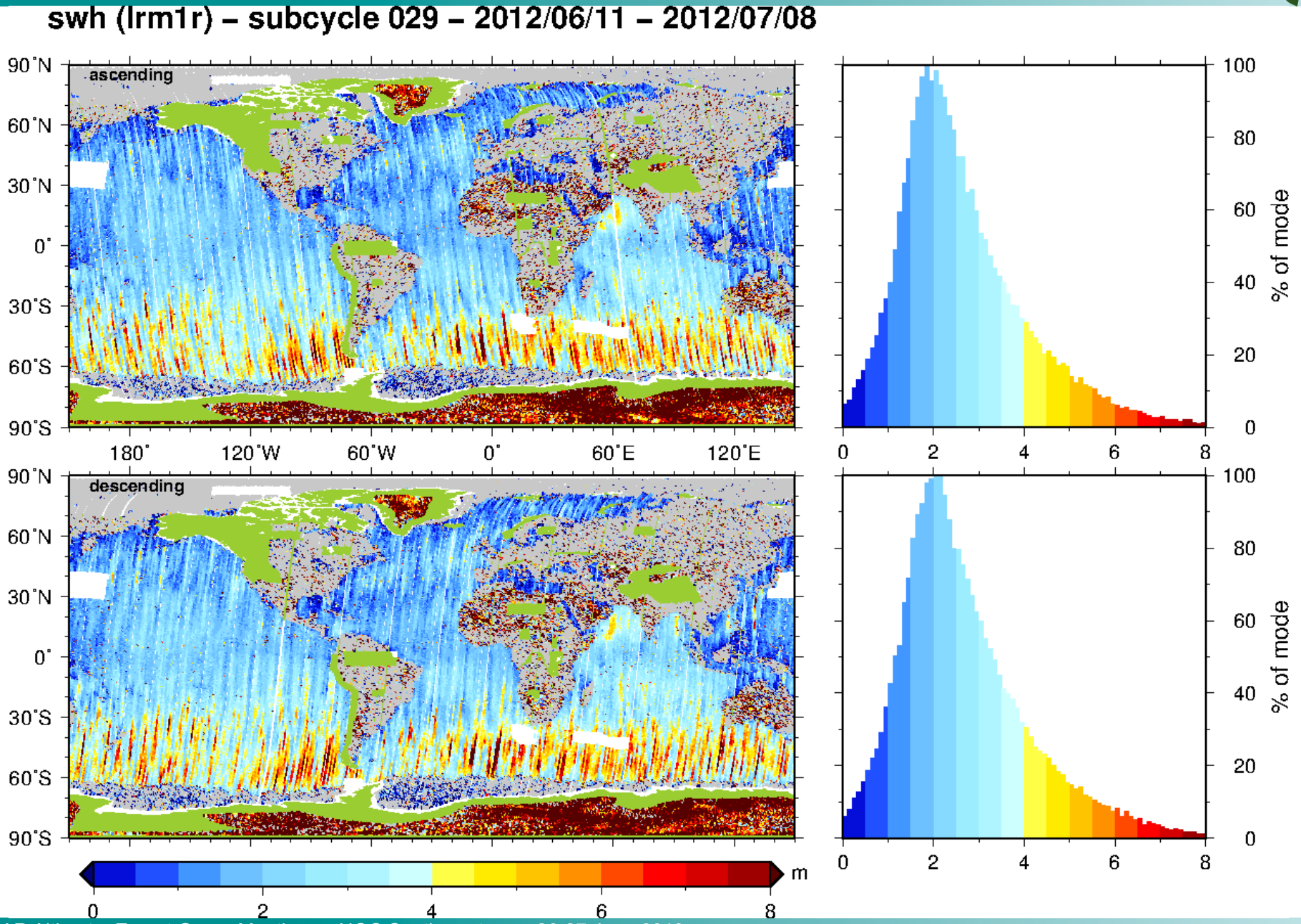
PLRM – Significant Wave Height



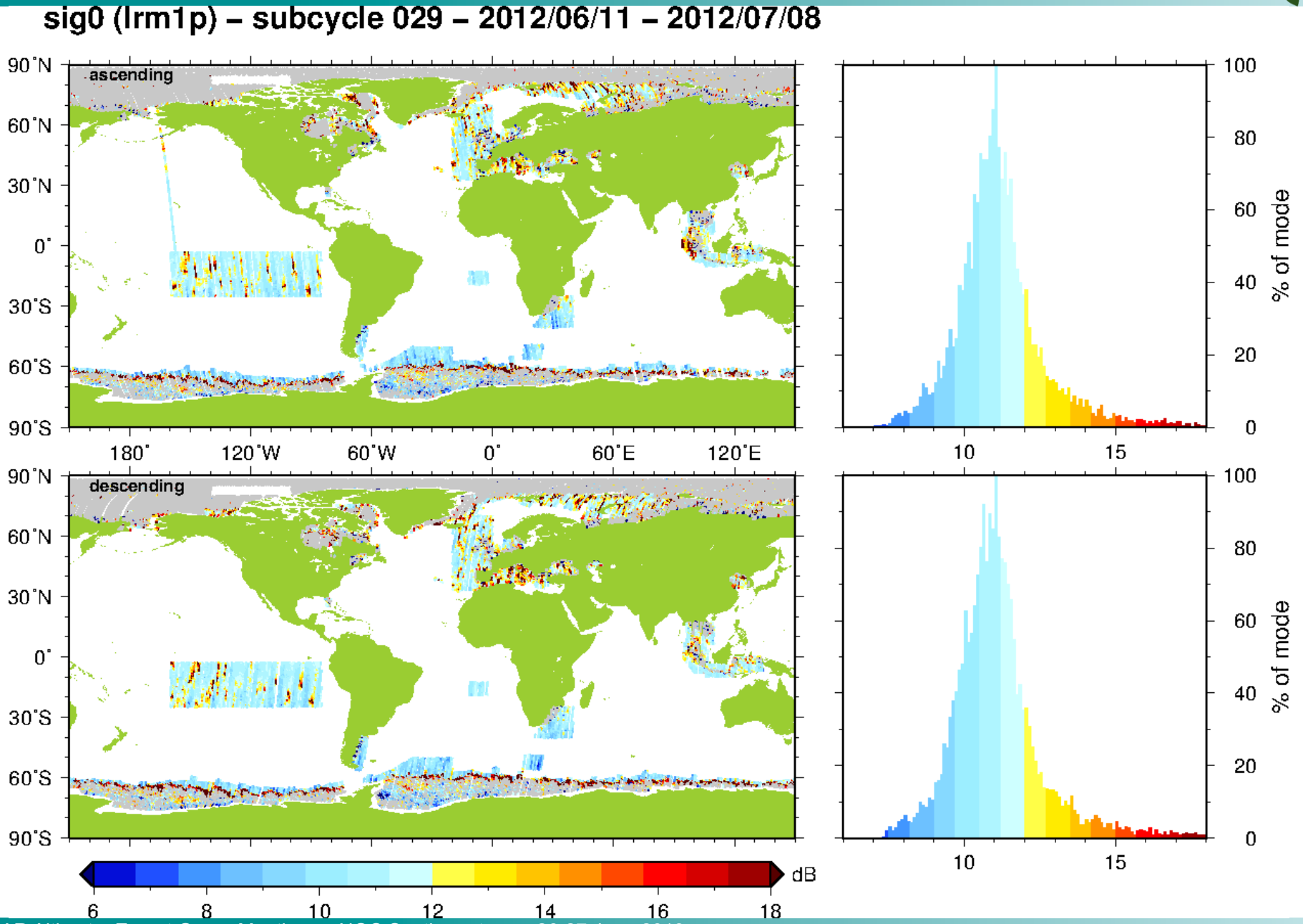
LRM – Significant Wave Height



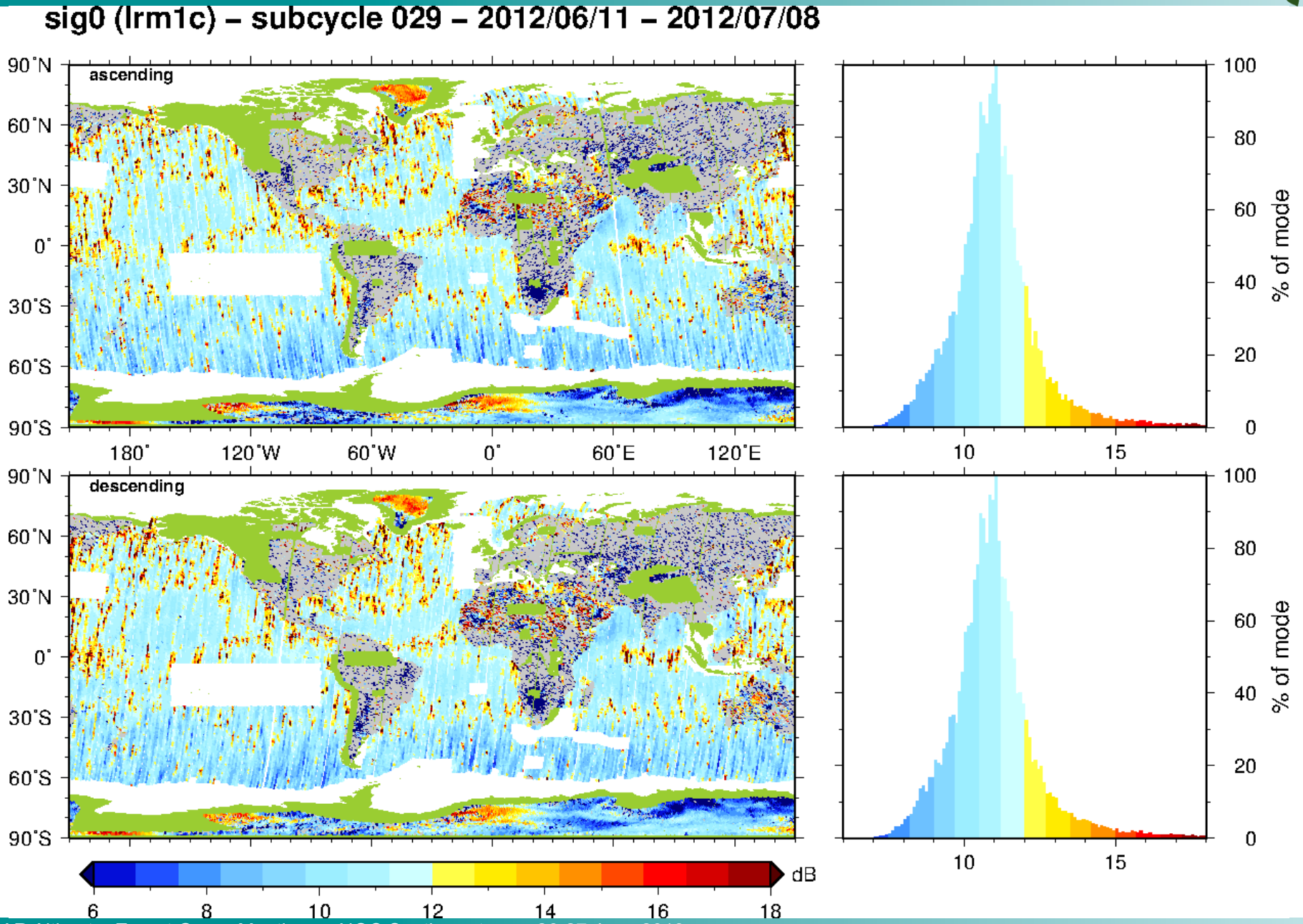
LRM+PLRM – Significant Wave Height



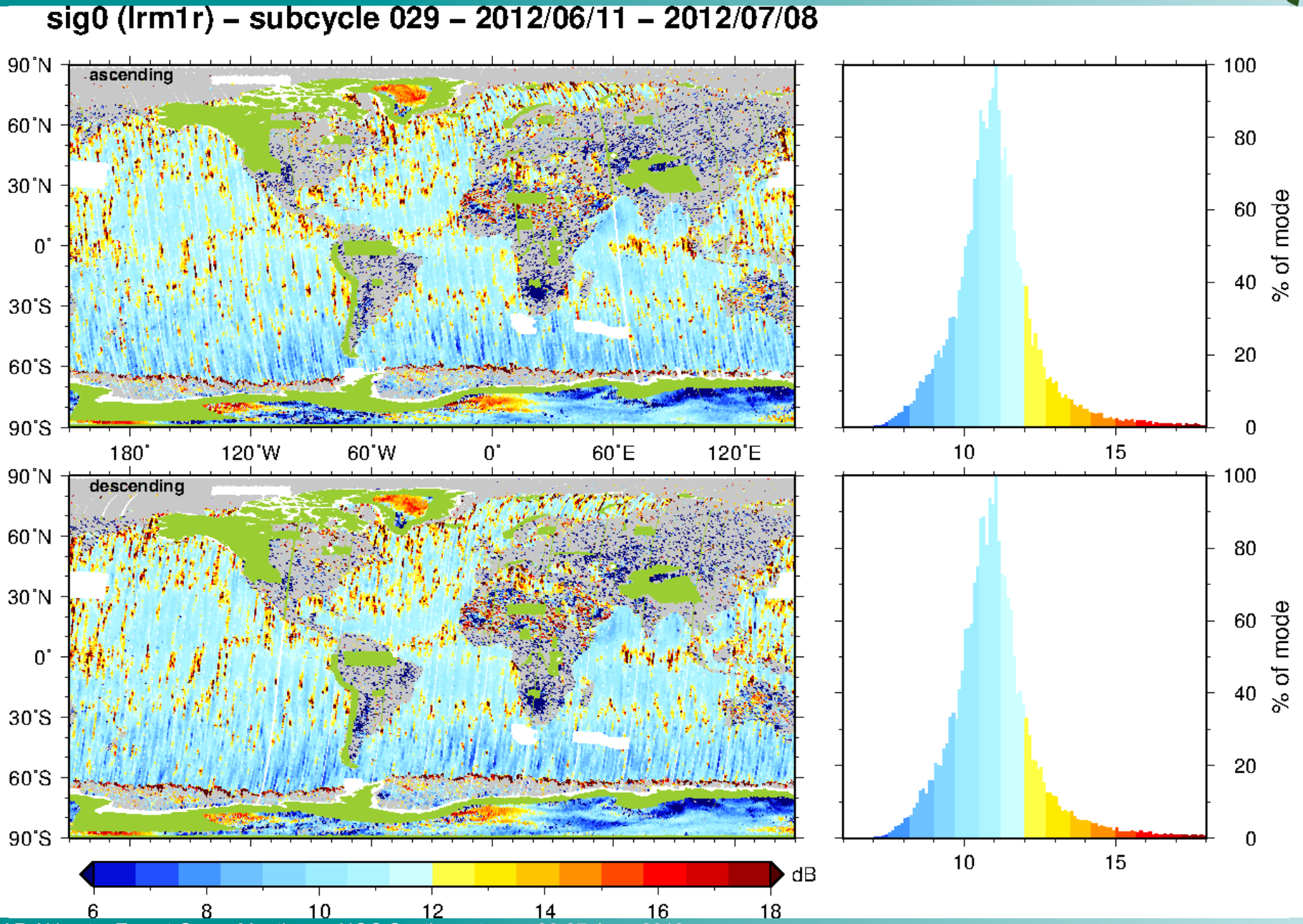
PLRM – Backscatter



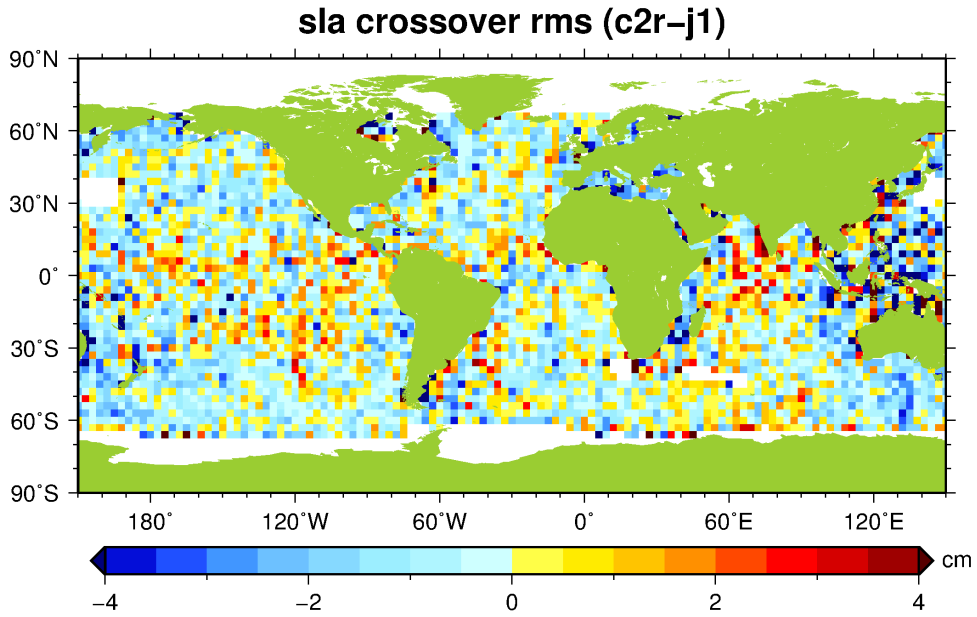
LRM – Backscatter

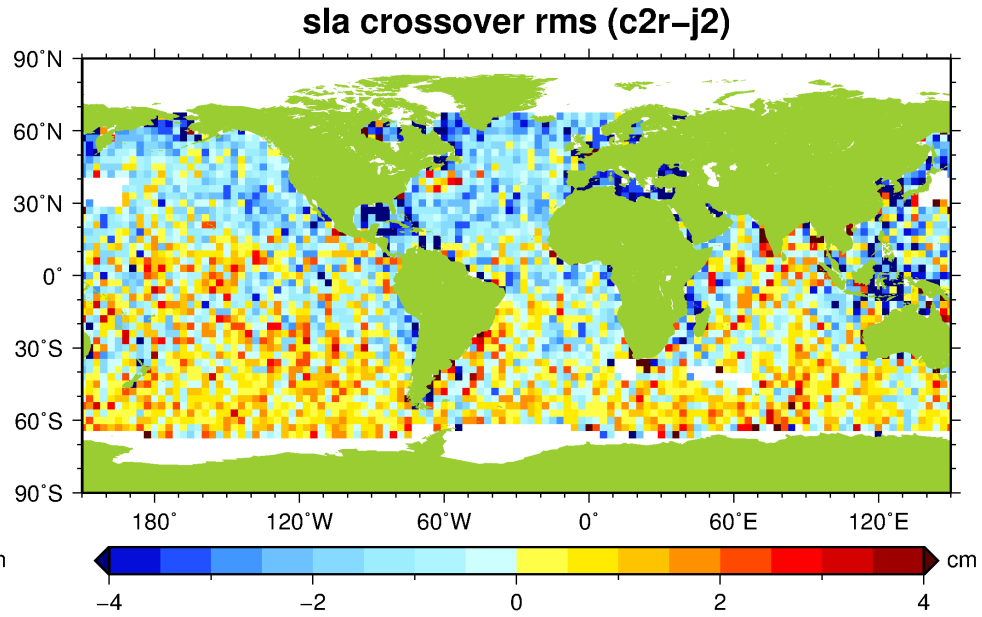


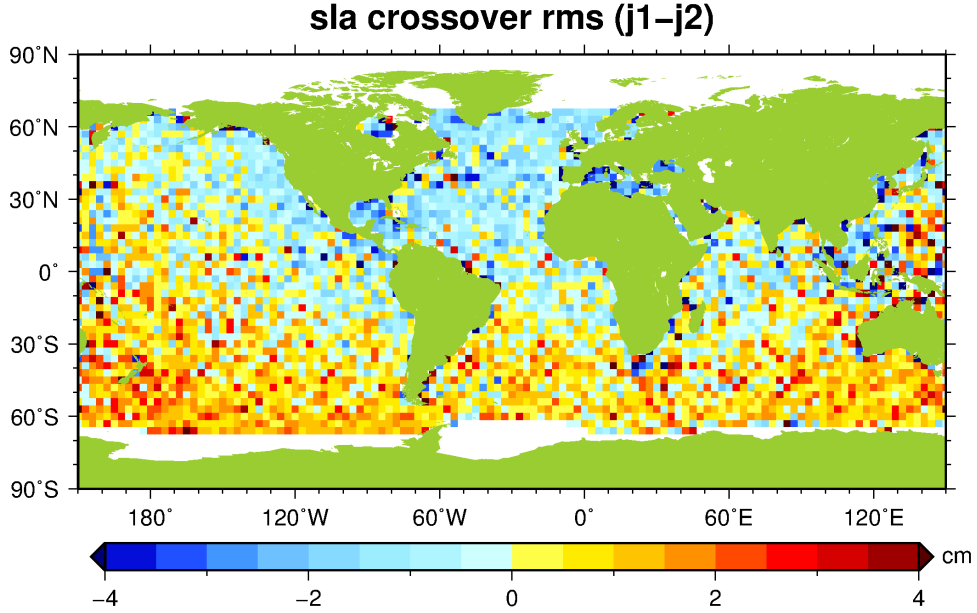
LRM+PLRM – Backscatter



Mean Sea Level (cm) Crossovers

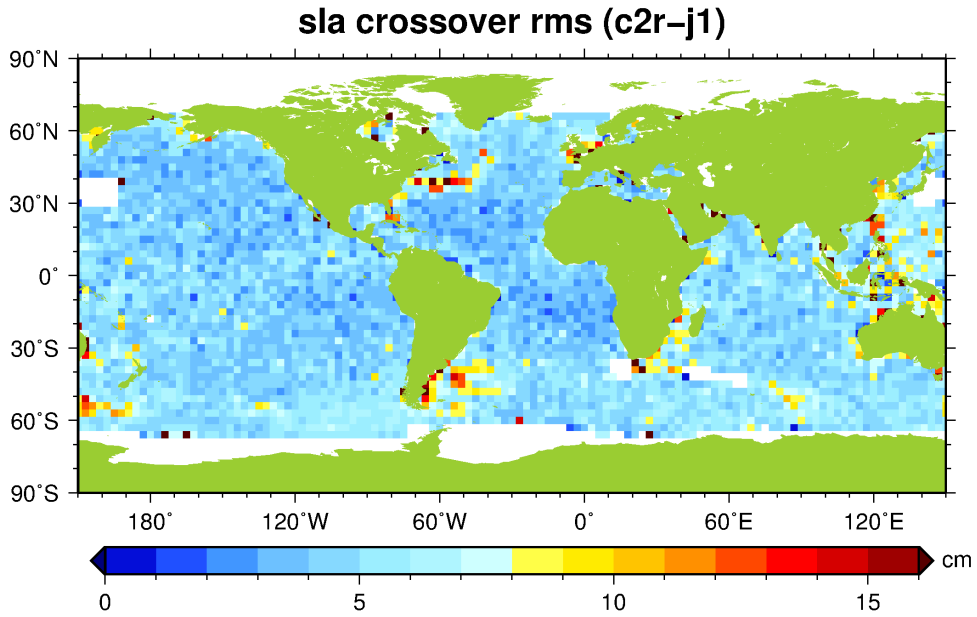


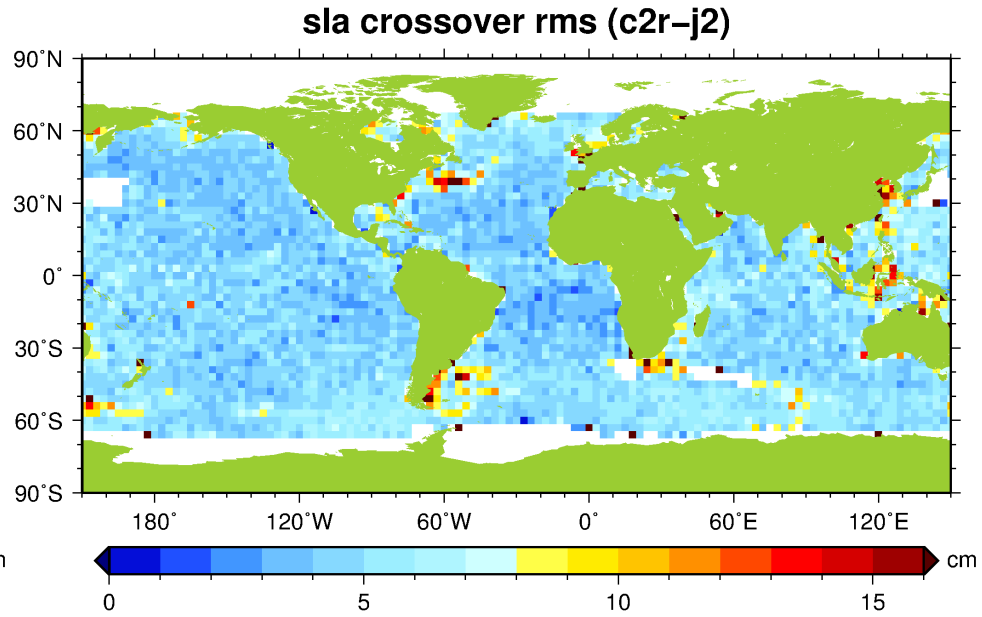


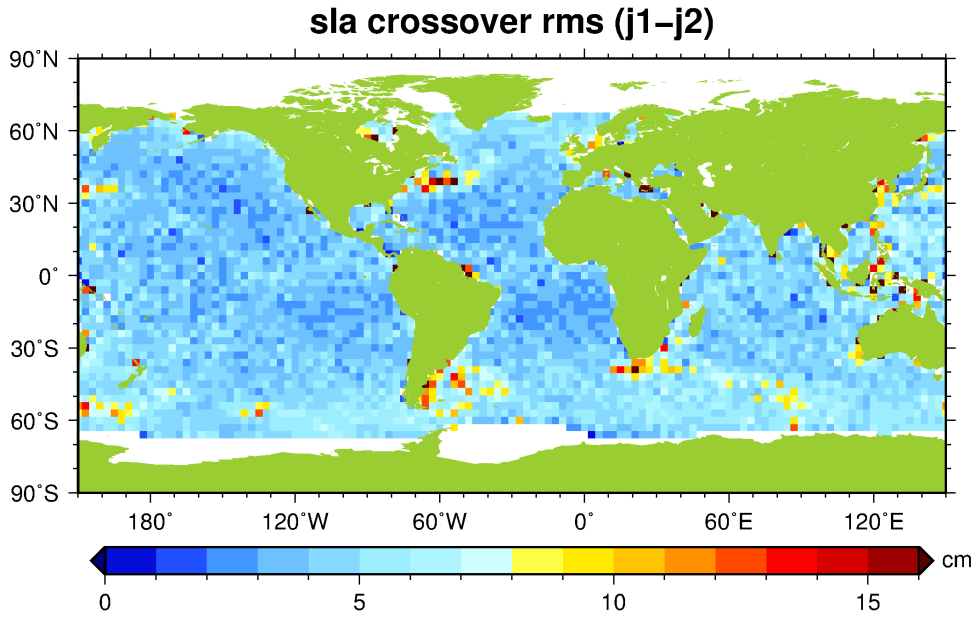


	Mean	Std
LRM – Jason-1	–0.63	
LRM – Jason-2	–0.26	
PLRM – Jason-1	–0.28	
PLRM – Jason-2	–0.15	
Jason-1 – Jason-2	+0.32	

RMS Sea Level (cm) Crossovers

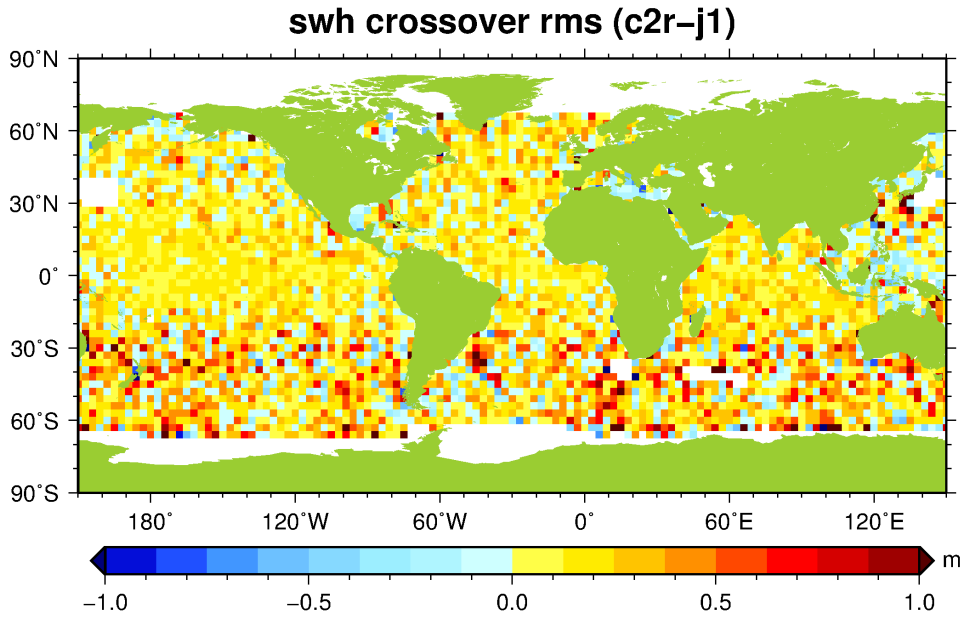


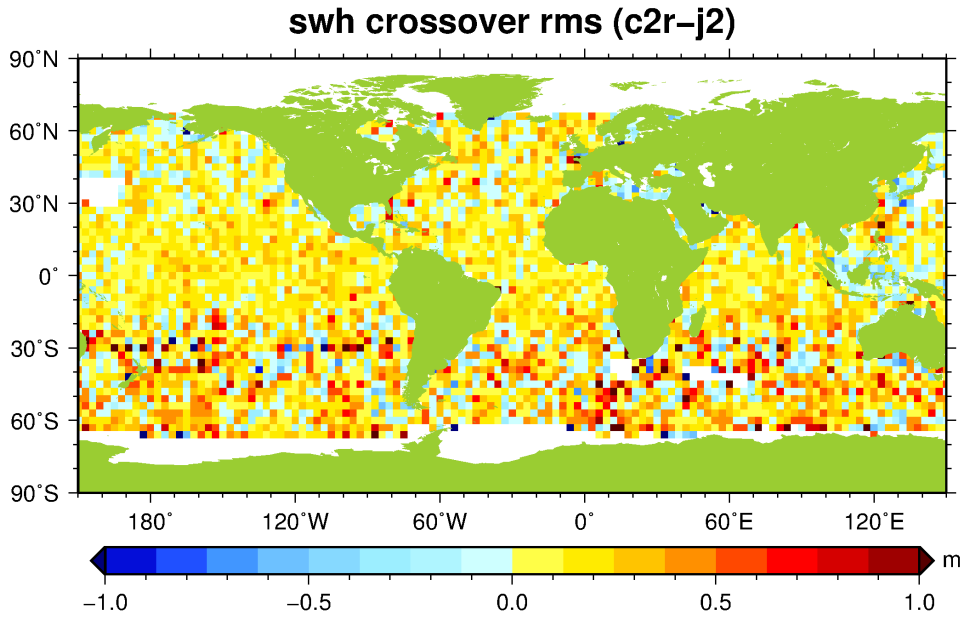


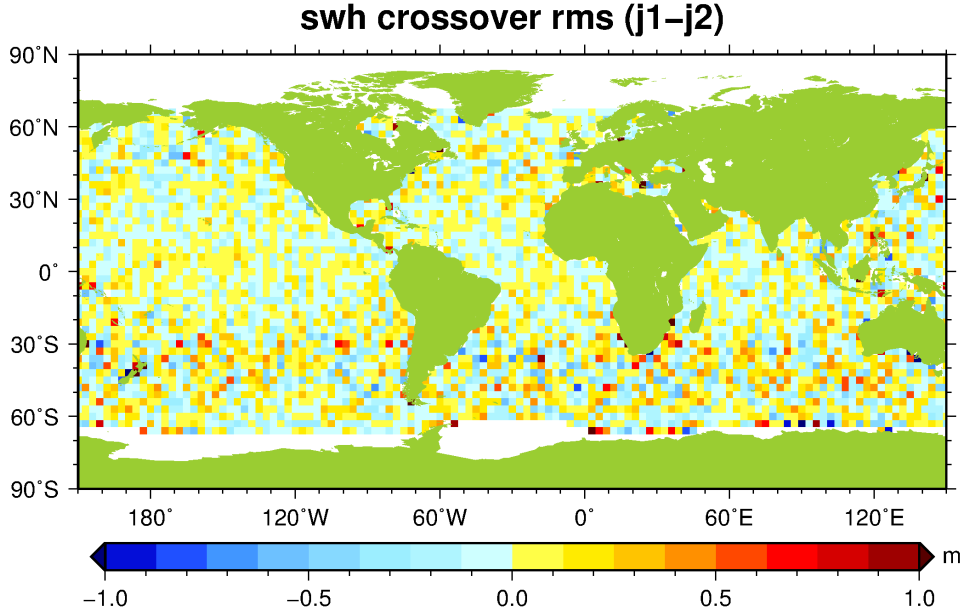


	Mean	Std
LRM – Jason-1	–0.63	5.43 +1.6
LRM – Jason-2	–0.26	5.37 +1.4
PLRM – Jason-1	–0.28	5.55 +2.0
PLRM – Jason-2	–0.15	5.61 +2.1
Jason-1 – Jason-2	+0.32	5.18

Mean SWH (m) Crossovers

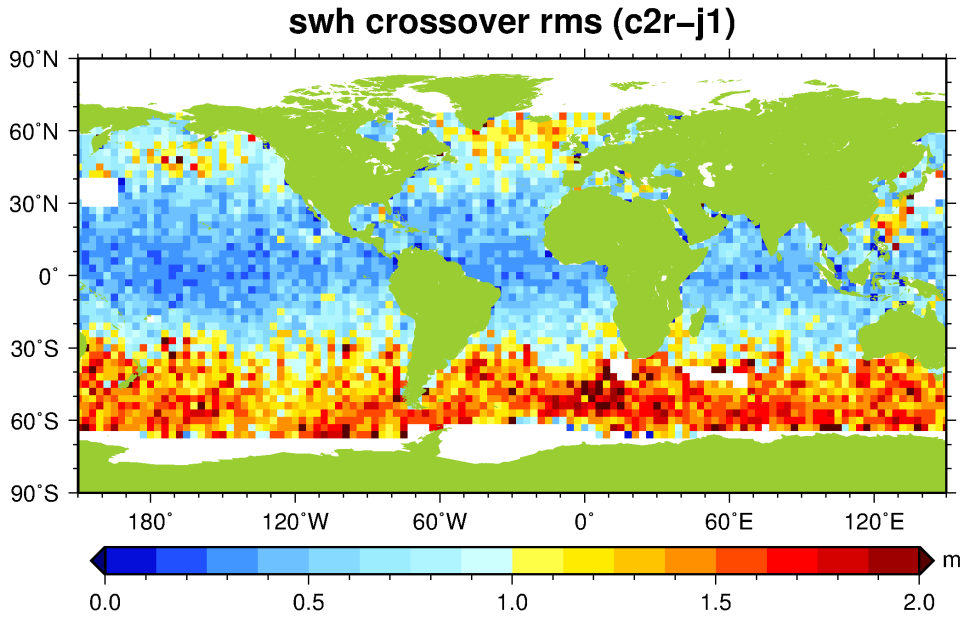


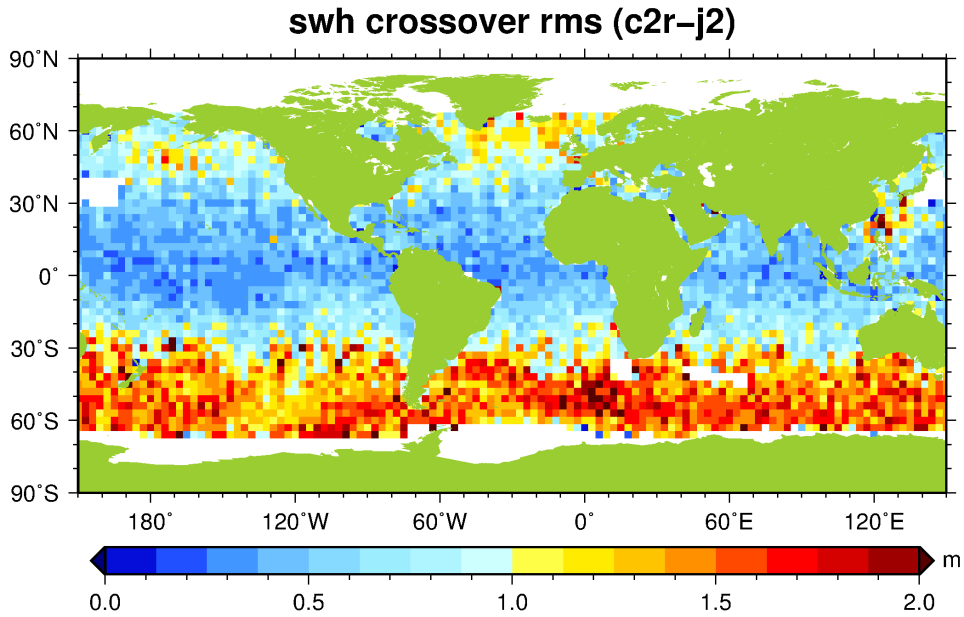


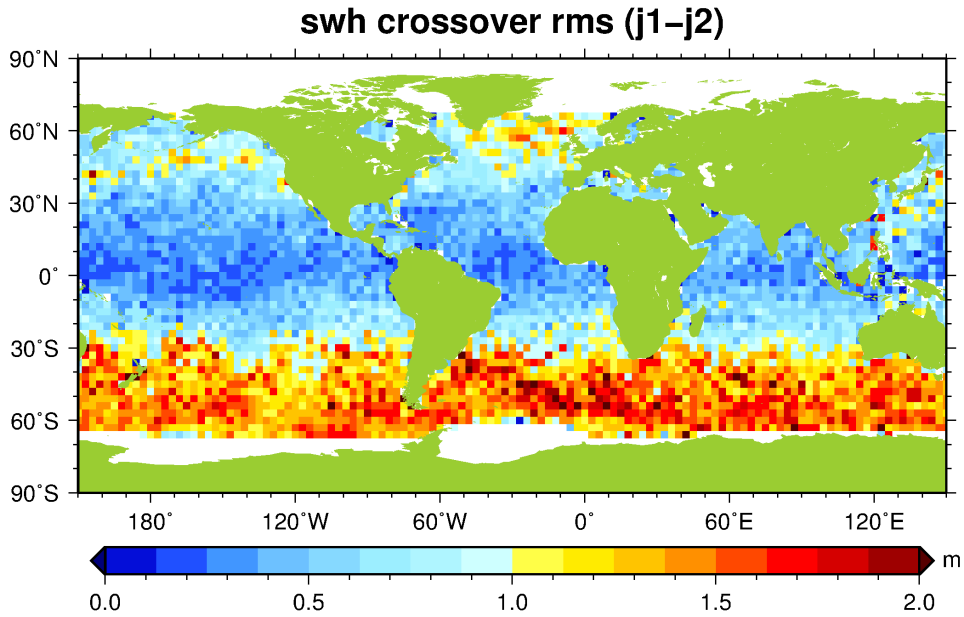


	Mean	Std
LRM – Jason-1	+0.17	
LRM – Jason-2	+0.15	
PLRM – Jason-1	+0.19	
PLRM – Jason-2	+0.17	
Jason-1 – Jason-2	–0.01	

RMS SWH (m) Crossovers

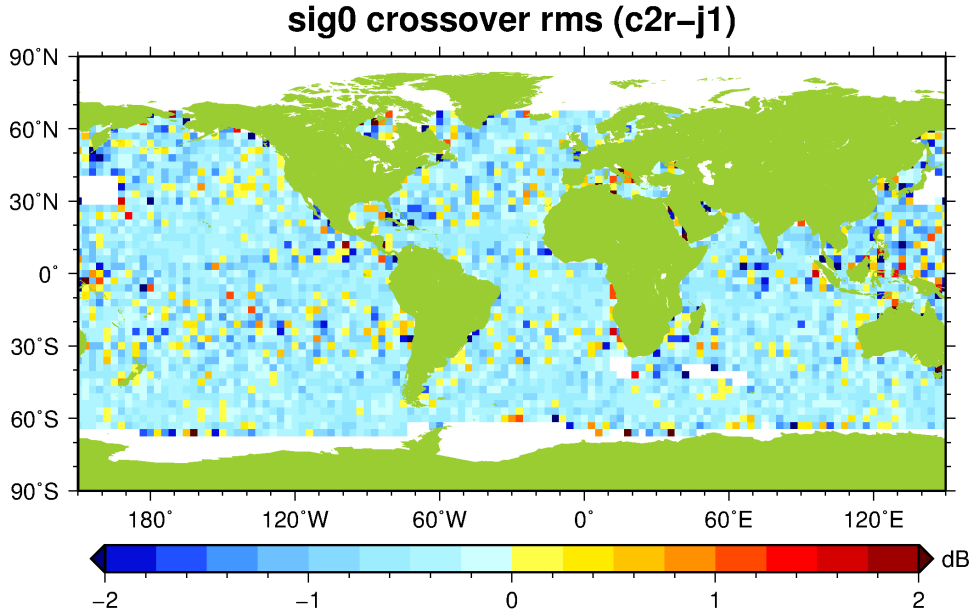


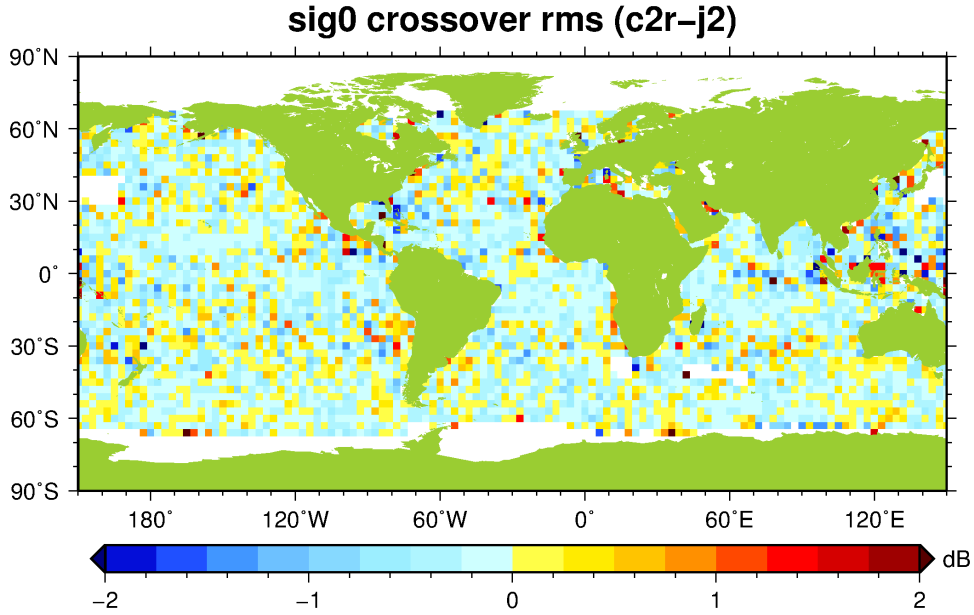


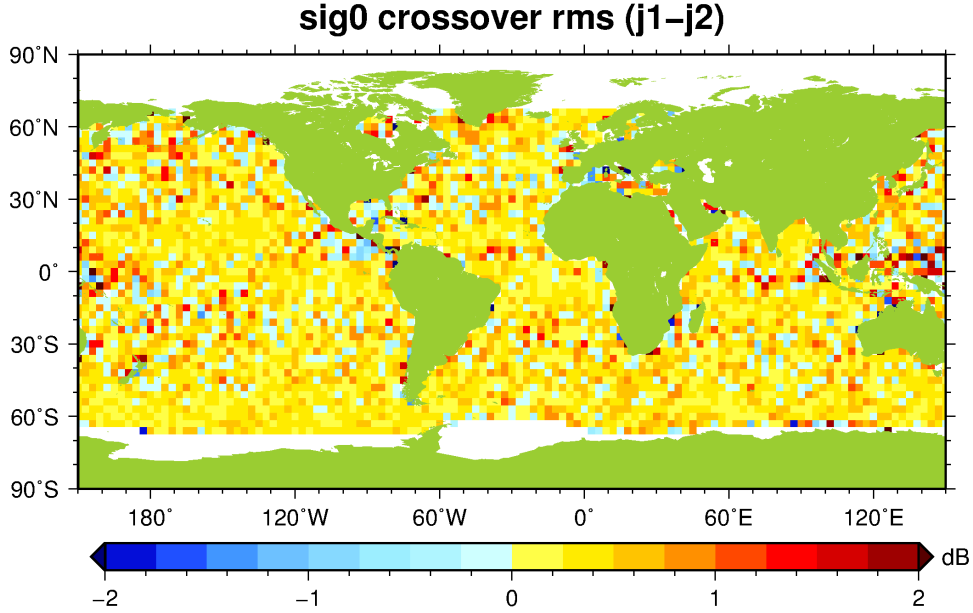


	Mean	Std
LRM – Jason-1	+0.17	1.21
LRM – Jason-2	+0.15	1.20
PLRM – Jason-1	+0.19	1.29
PLRM – Jason-2	+0.17	1.27
Jason-1 – Jason-2	–0.01	1.20

Mean Sigma0 (dB) Crossovers

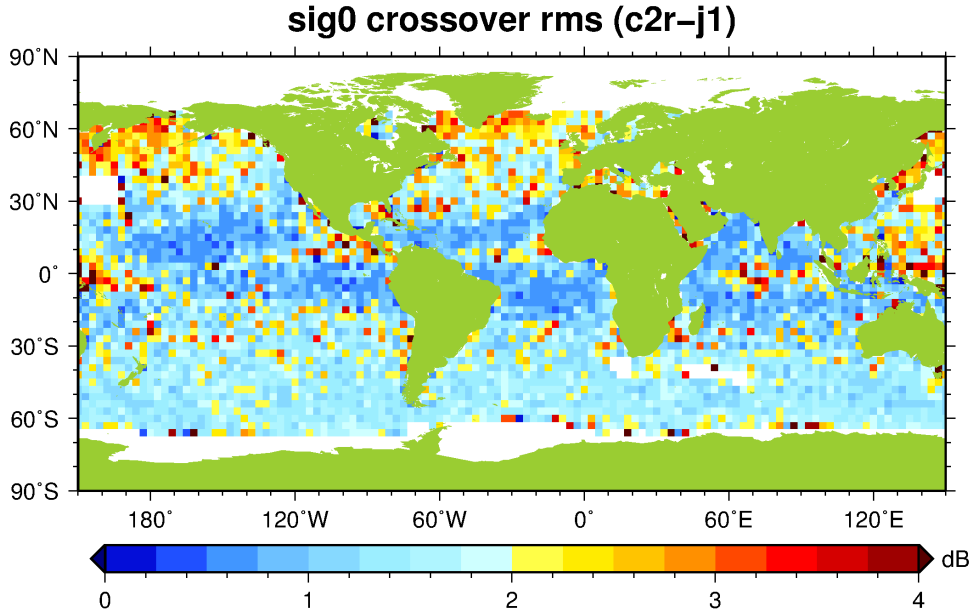


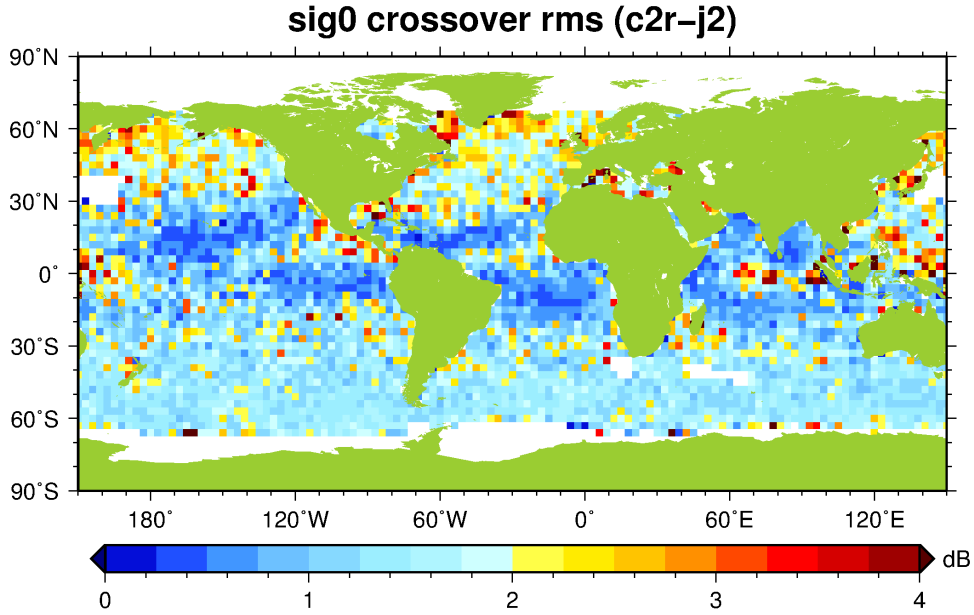


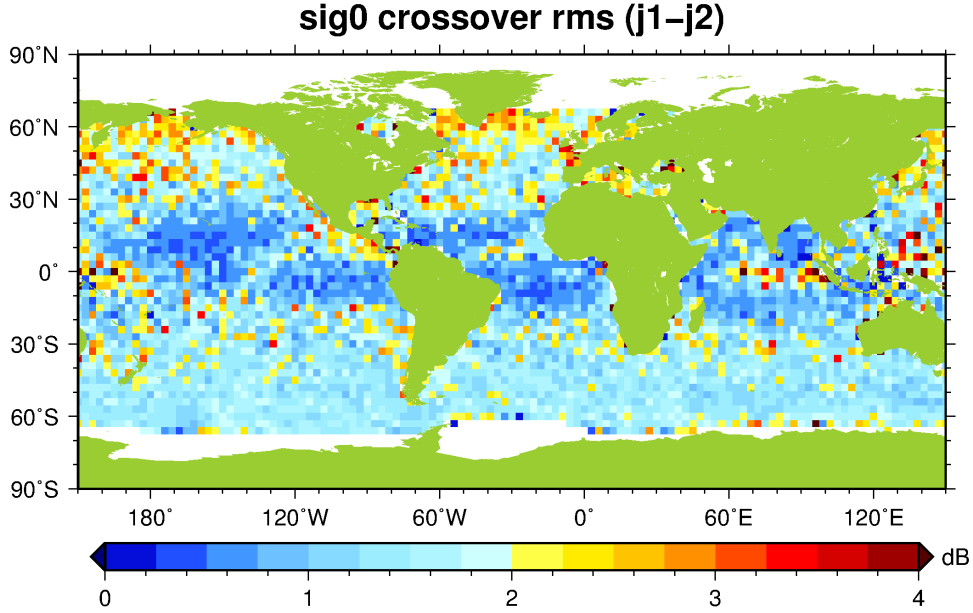


	Mean	Std
LRM – Jason-1	–0.46	
LRM – Jason-2	–0.14	
PLRM – Jason-1	–0.47	
PLRM – Jason-2	–0.15	
Jason-1 – Jason-2	+0.32	

RMS Sigma0 (dB) Crossovers





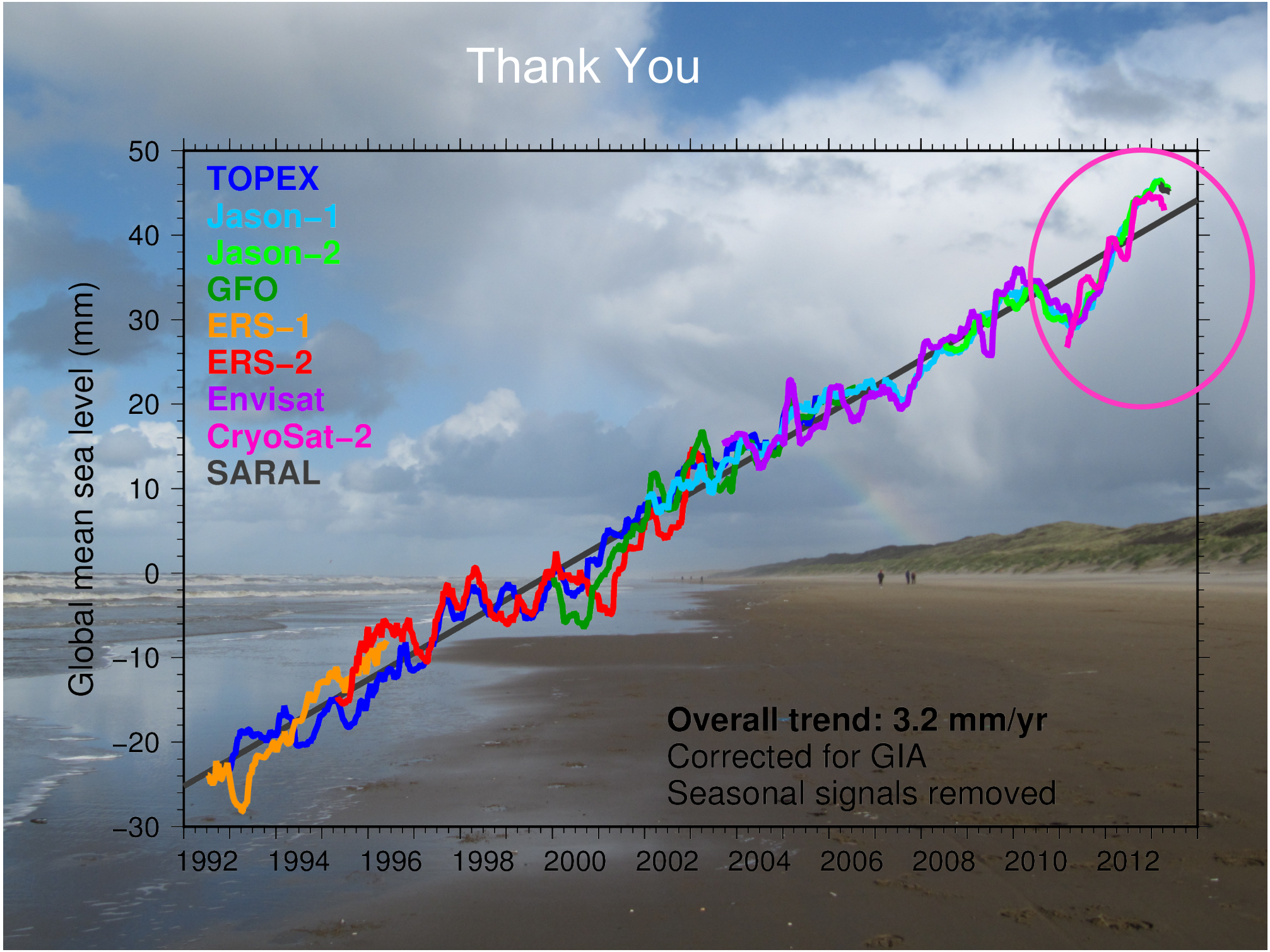


	Mean	Std
LRM – Jason-1	–0.46	1.78
LRM – Jason-2	–0.14	1.76
PLRM – Jason-1	–0.47	1.95
PLRM – Jason-2	–0.15	2.00
Jason-1 – Jason-2	+0.32	1.74

Conclusions

- Retracked LRM L1B data
  - Retracking can be performed with MLE3 with a priori off-nadir angle from star-tracker information.
  - Retracked L1B data shows excellent quality.
  - Crossovers with Jason-1/2 shows sea level variance only slightly higher than Jason-1/2, due to lack of radiometer & dual-frequency.
- Retracked Pseudo-LRM data
  - After stacking SAR echoes, same retracking.
  - No apparent bias with LRM data.
  - Higher levels of 20-Hz noise, as expected.
  - However, data quality is comparable to LRM data.
- RADS
  - Has distributed LRM data since October 2011.
  - Has started distributing PLRM data since October 2012, when ESA data policies were relaxed.

Thank You


TOPEX
Jason–1
Jason–2
GFO
ERS–1
ERS–2
Envisat
CryoSat–2
SARAL
Global mean sea level (mm)
50
40
30
20
10
0
–10
–20
–30
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Overall trend: 3.2 mm/yr
Corrected for GIA
Seasonal signals removed