Global Cal/Val of CryoSat-2 LRM and SAR Data over Oceans

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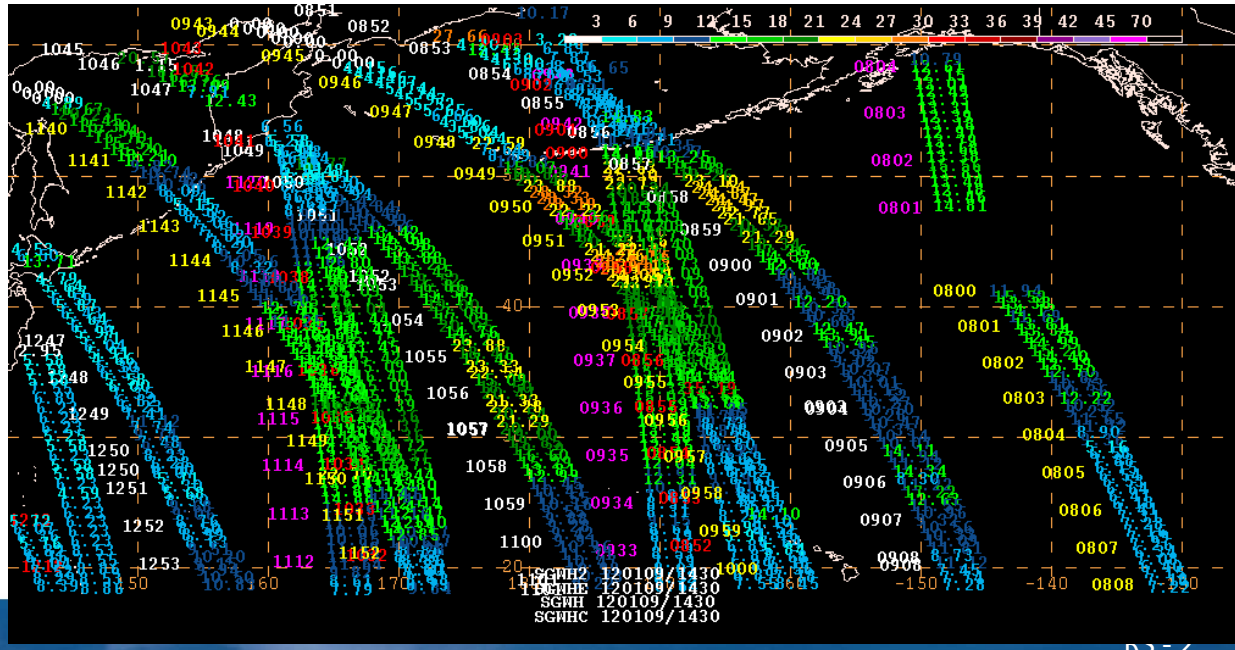
CryoSat-2 Refresher

- NOAA's involvement in CryoSat-2
  - NOAA wanted to compute near-realtime winds and waves from CryoSat-2 for 2011 Hurricane season.
  - Existing ESA Fast-Delivery Level 2 product had vastly incorrect backscatter and SWH estimates. *Fixed since Feb 2012.*
  - At NOAA we built our own retracker for Level 1B waveform data.
  - We are now delivering winds and waves every half hour to the National Hurricane Center.

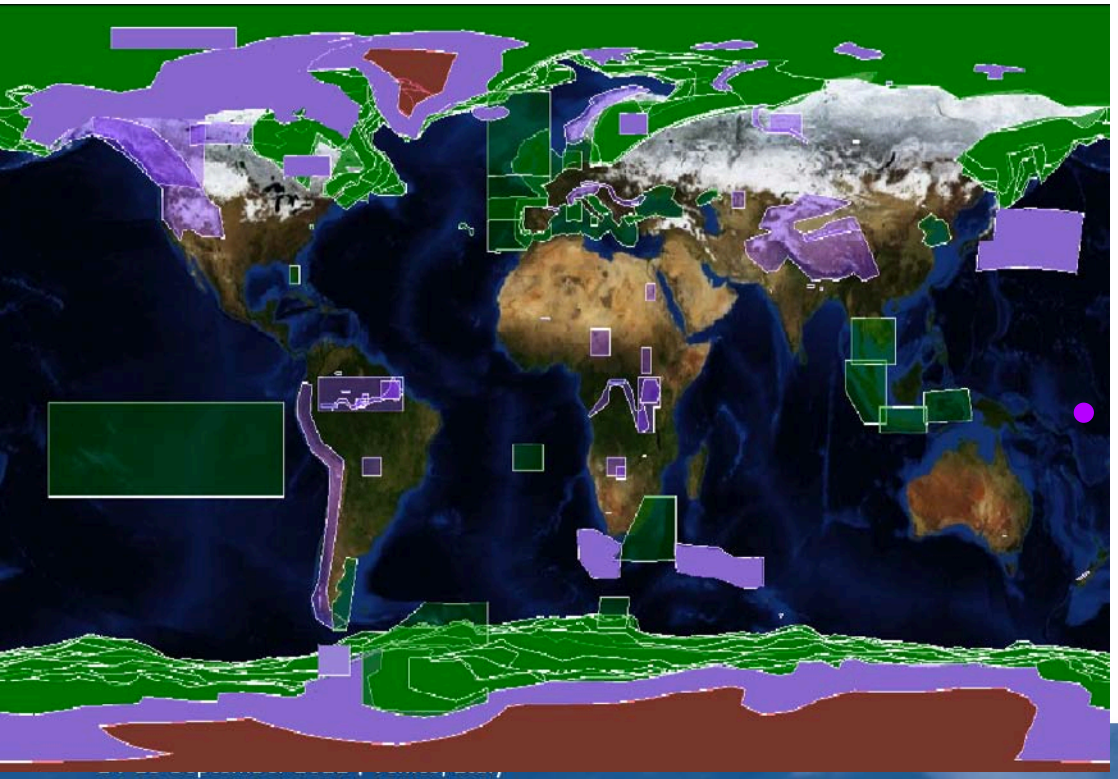
Scatterometers showing on the NAWIPS display

Altimeter SWH in feet (9 Jan 2012)



CryoSat-2 Operating modes

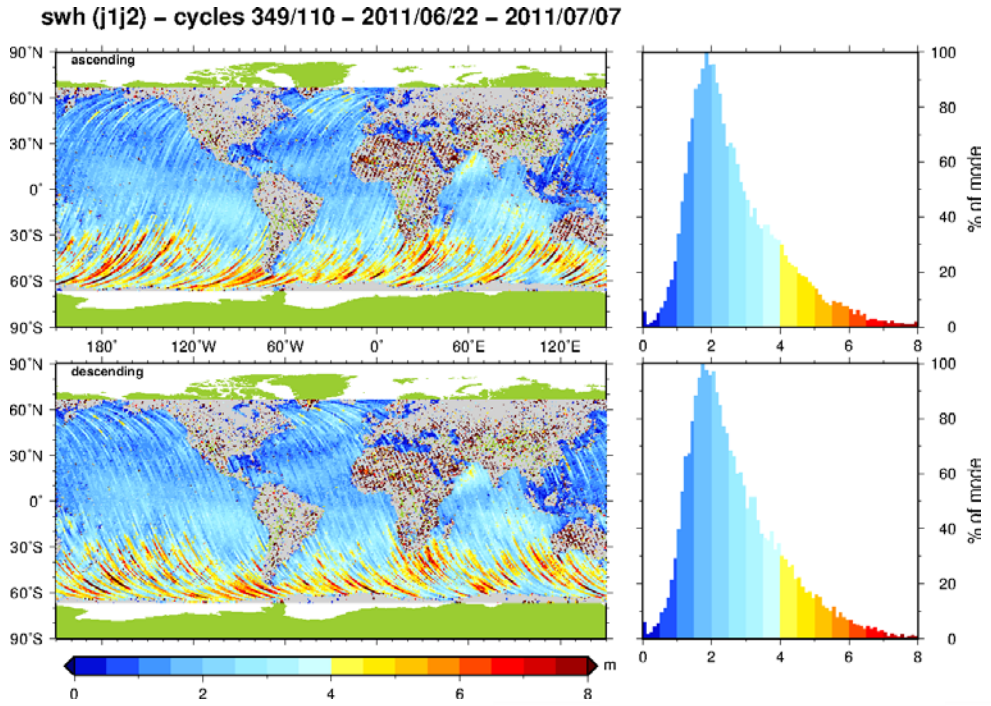
- **LRM**
  - "Conventional Altimetry"
  - Fast-delivery (**FDM**) or delay-time (30-day) (**LRM**) products



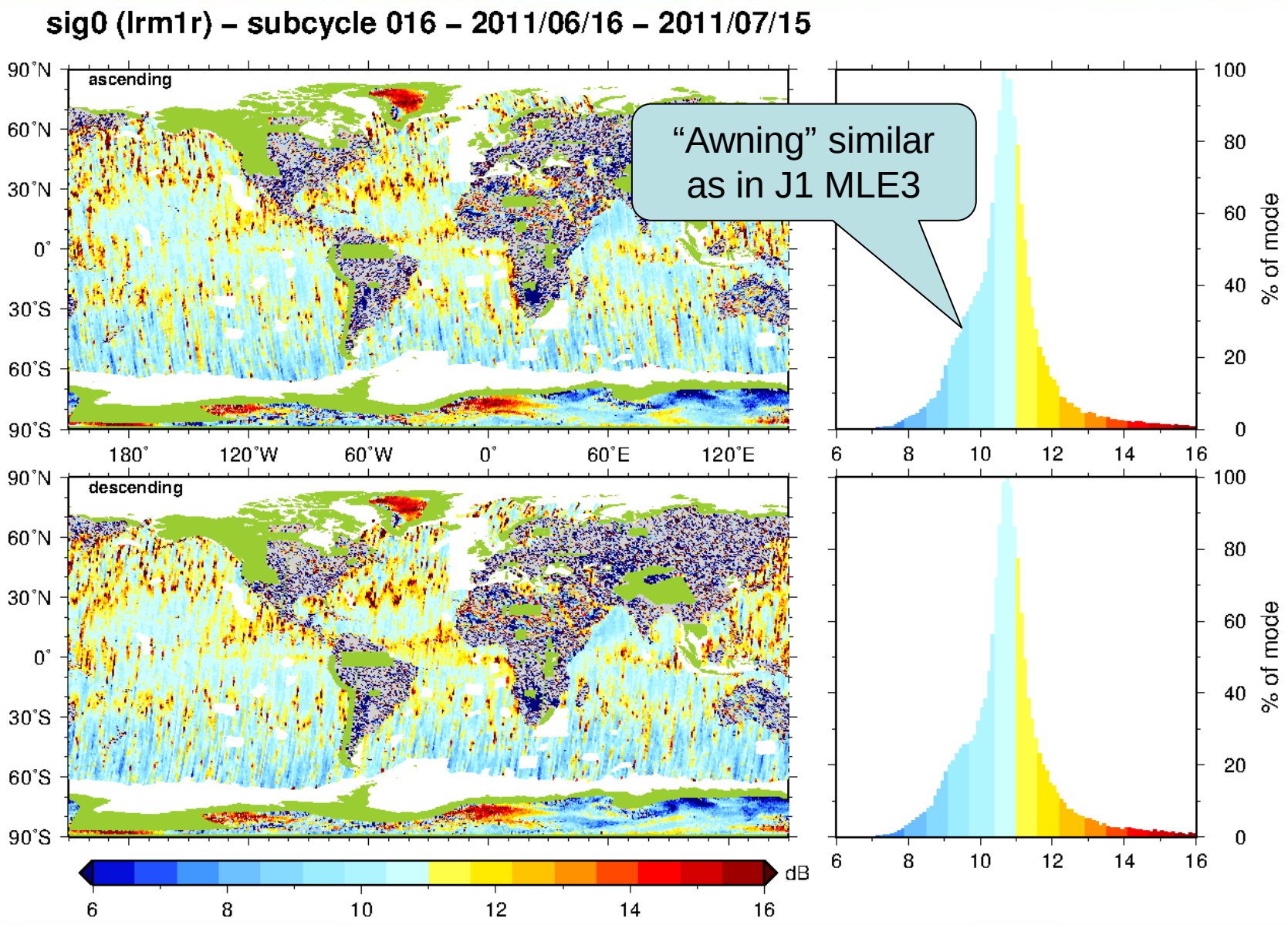
- **SAR**
  - "Synthetic Aperture"
  - Increased along-track resolution.
  - Quite different from "conventional altimetry"
  - Echoes can be *"reduced"* to LRM mode from **FBR** product
- **SARIN**
  - As SAR, but including cross-track resolution
  - Not yet investigated

Results and Validation

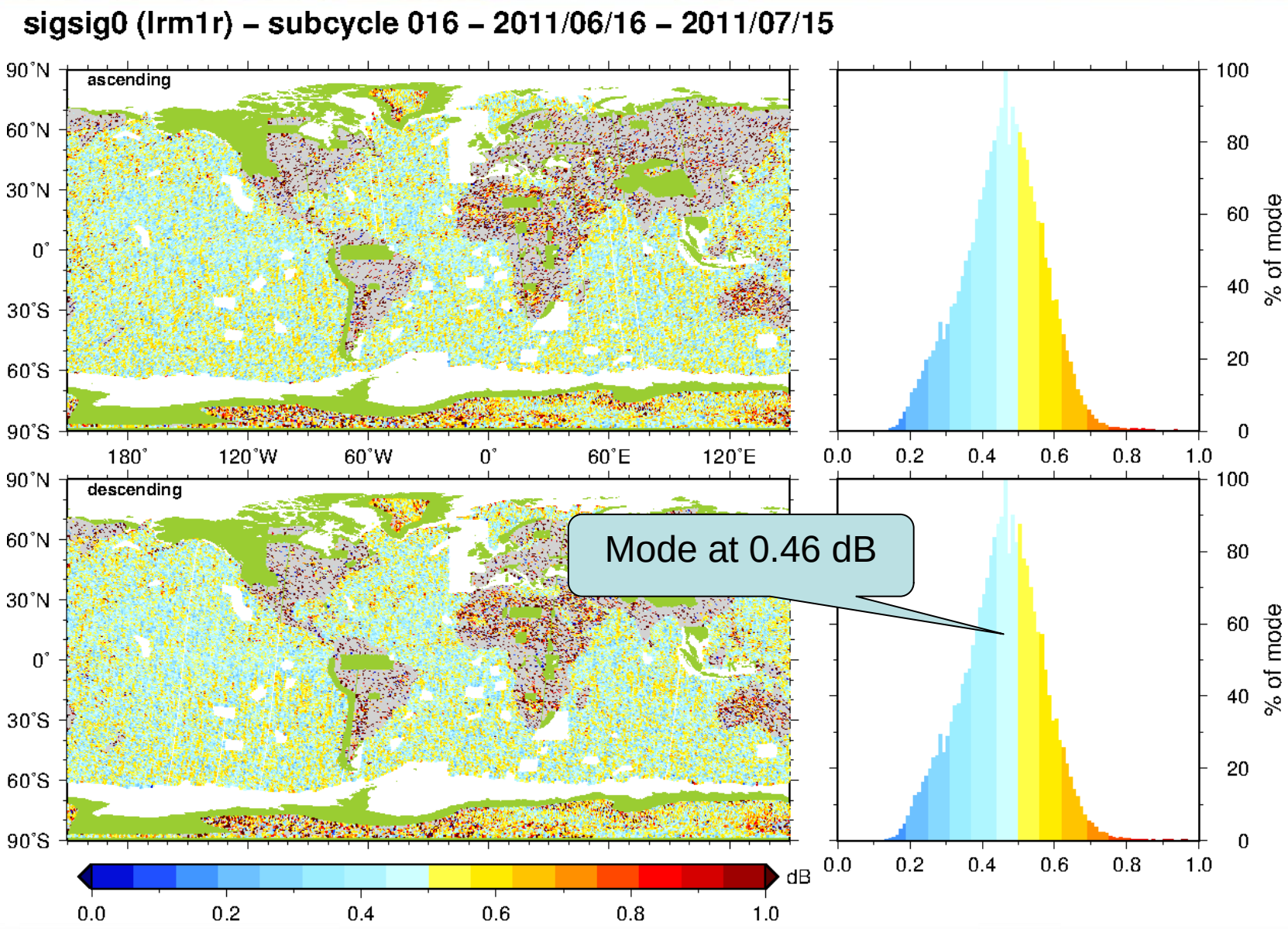
- Cycle maps
  - All data (ocean and land)
  - Ascending and descending separately
  - Two overlapping cycles of Jason-1 and -2 (15 days total)
  - One subcycle of CryoSat (29 days)
- Histograms
  - “Good” ocean data only
  - Normalised by mode



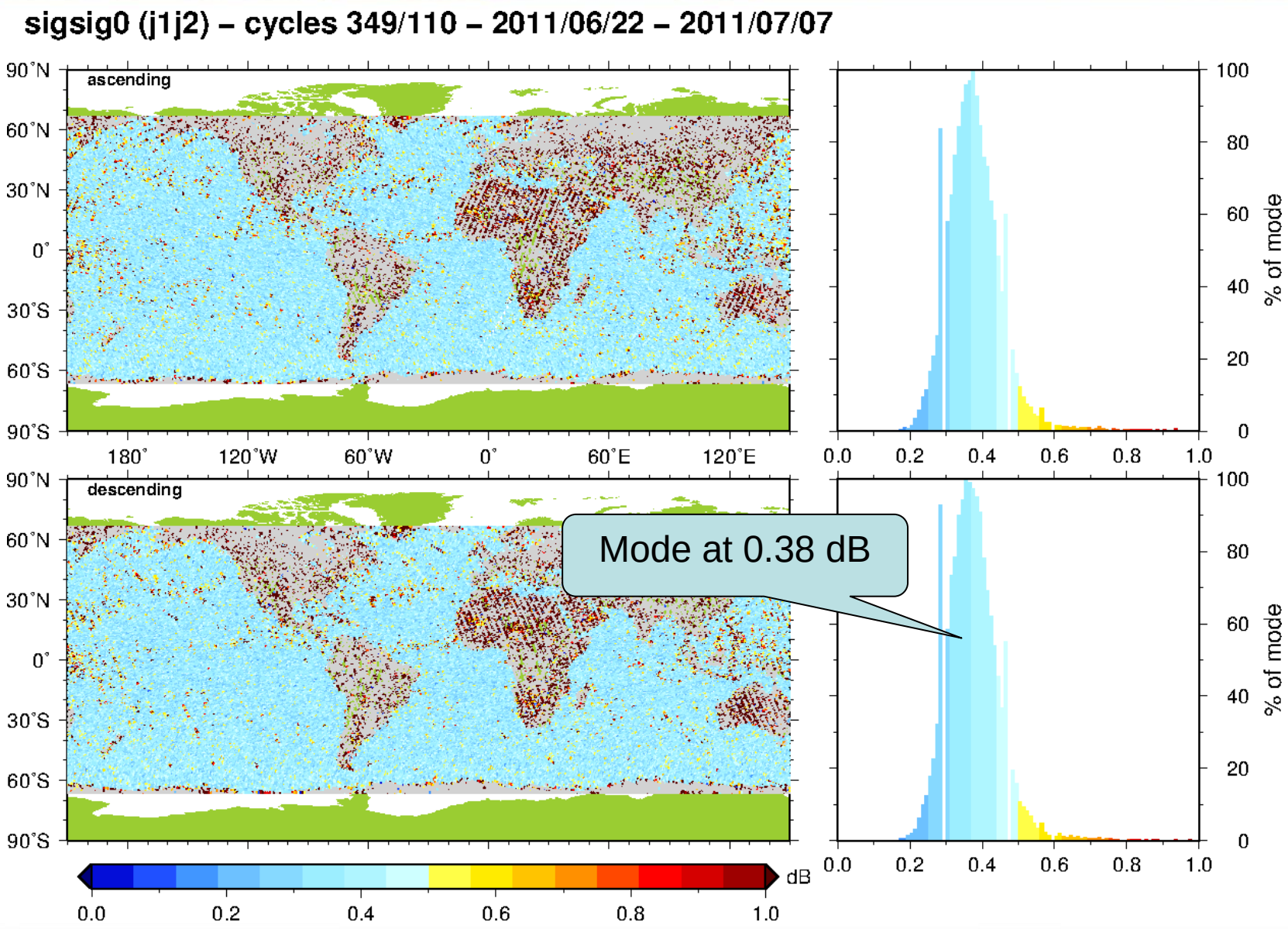
CryoSat L1B – Backscatter



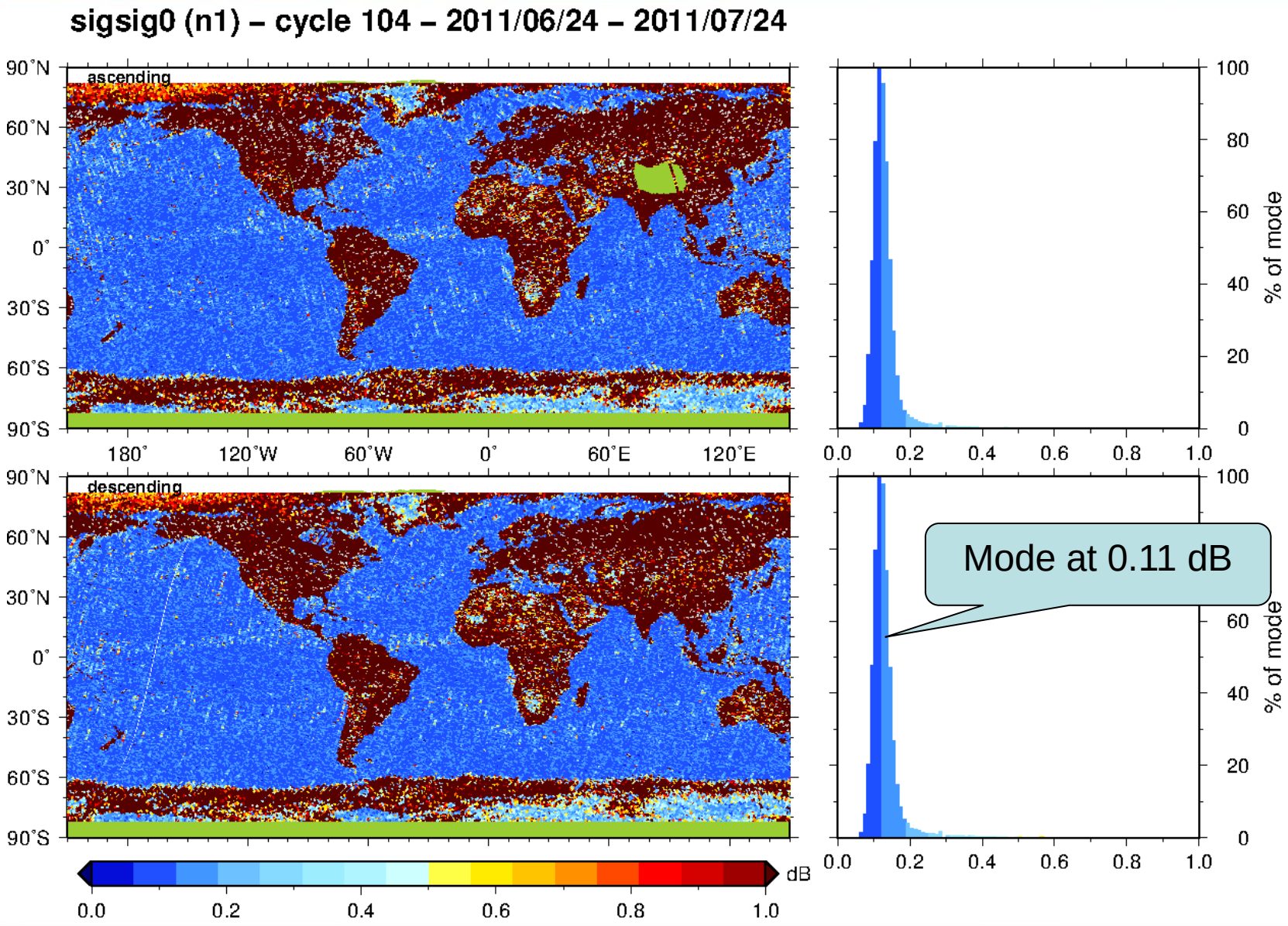
CryoSat L1B – Std Dev of Backscatter



Jason – Std Dev of Backscatter



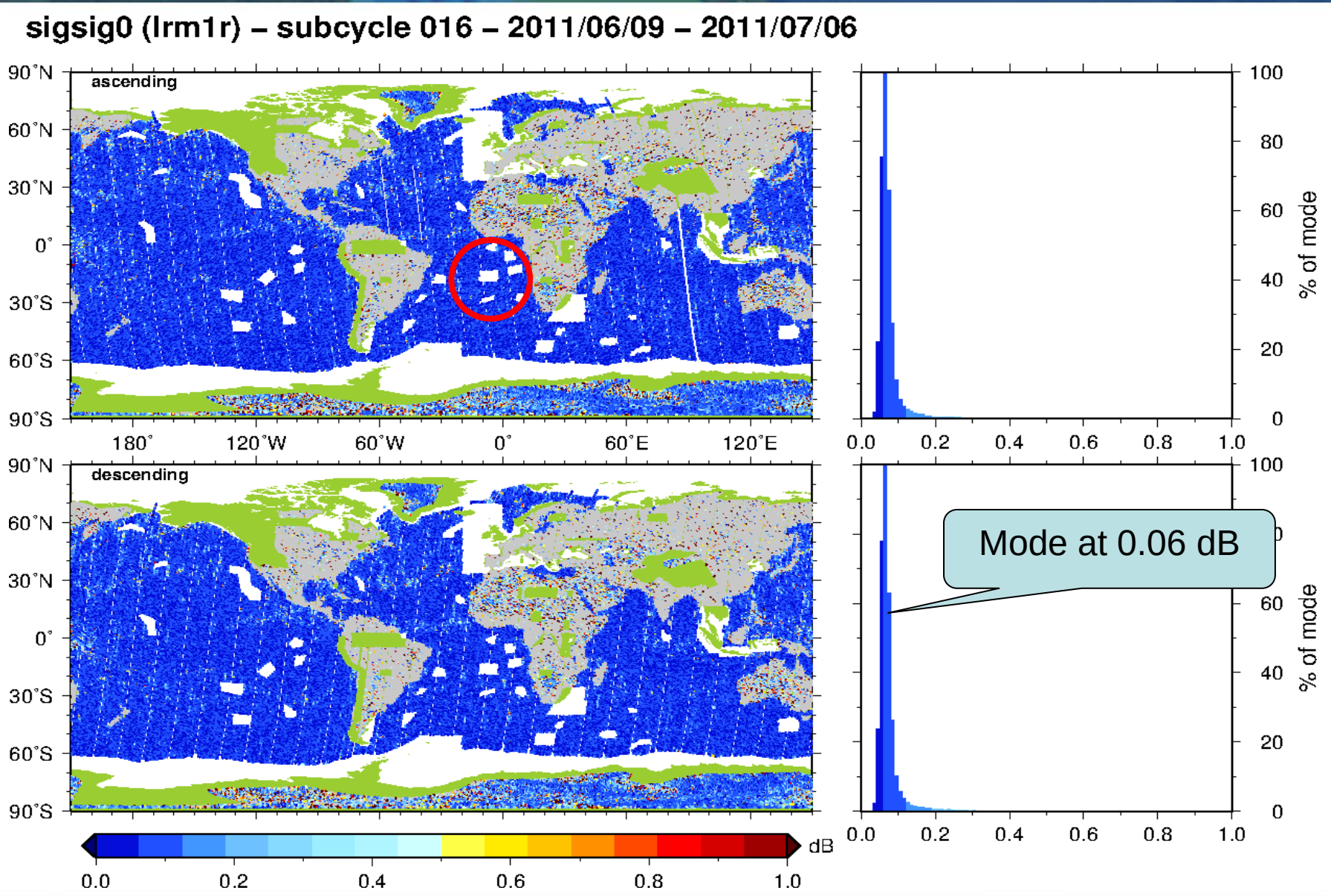
Envisat – Std Dev of Backscatter



CryoSat 1B – Backscatter fixes

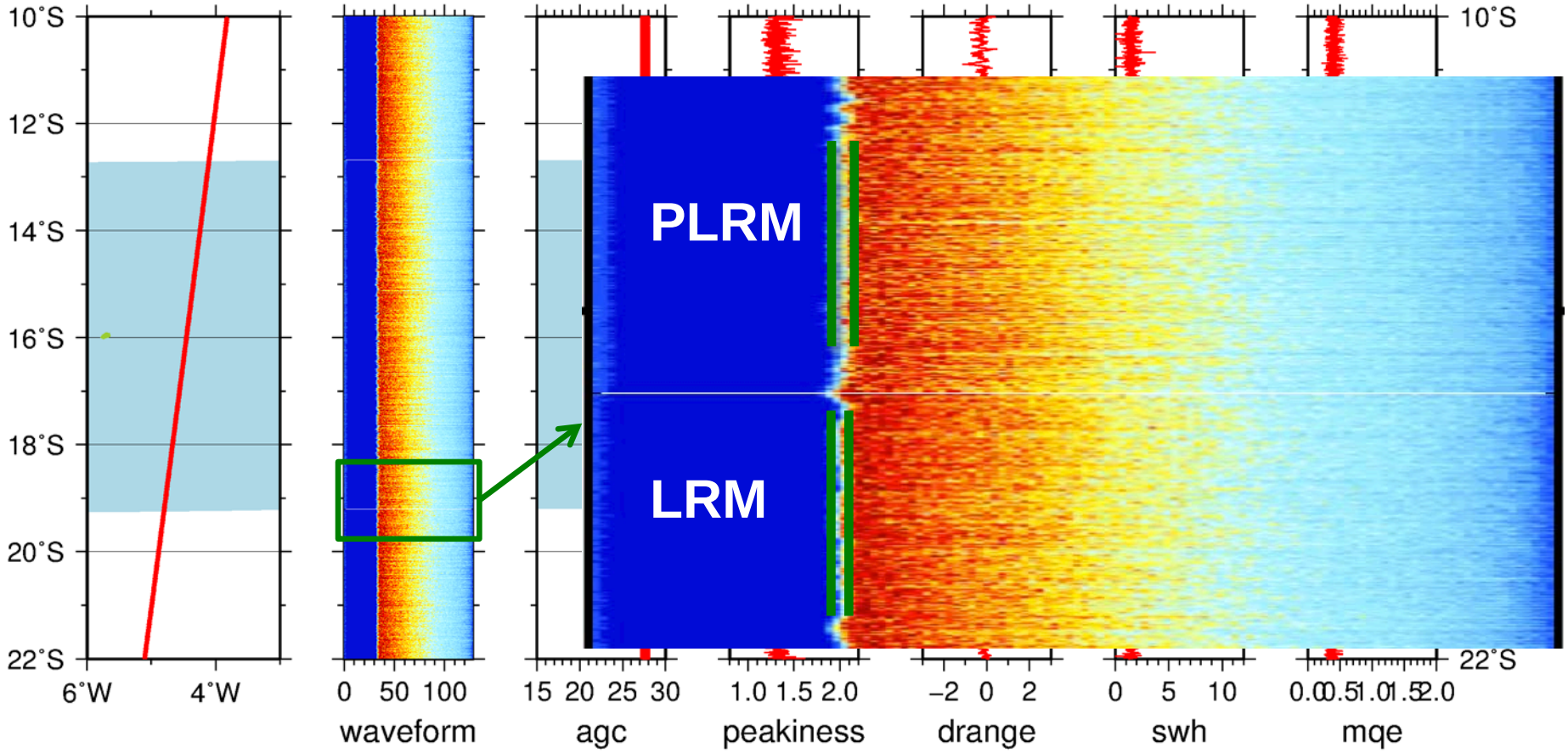
- "Misinterpretation" on ESA side
  - Wrong implementation of corrections to Automatic Gain Control
    - Either applied backwards (e.g. 0.25 dB instead of -0.25 dB)
    - Or applied to the wrong values (e.g. correction for 32 dB applied to 30 dB and vice versa)
    - Drift correction of ~0.03 dB/month applied with the wrong sign (decreasing instead of increasing the backscatter)
    - Or combination of those
  - Caused "lopsided" distribution
- "Misinterpretation" on NOAA side
  - Did not account for scaling of waveform in Analogue-Digital Converter
    - Hence increased noise of 20-Hz values

CryoSat L1B – Std Dev of Backscatter



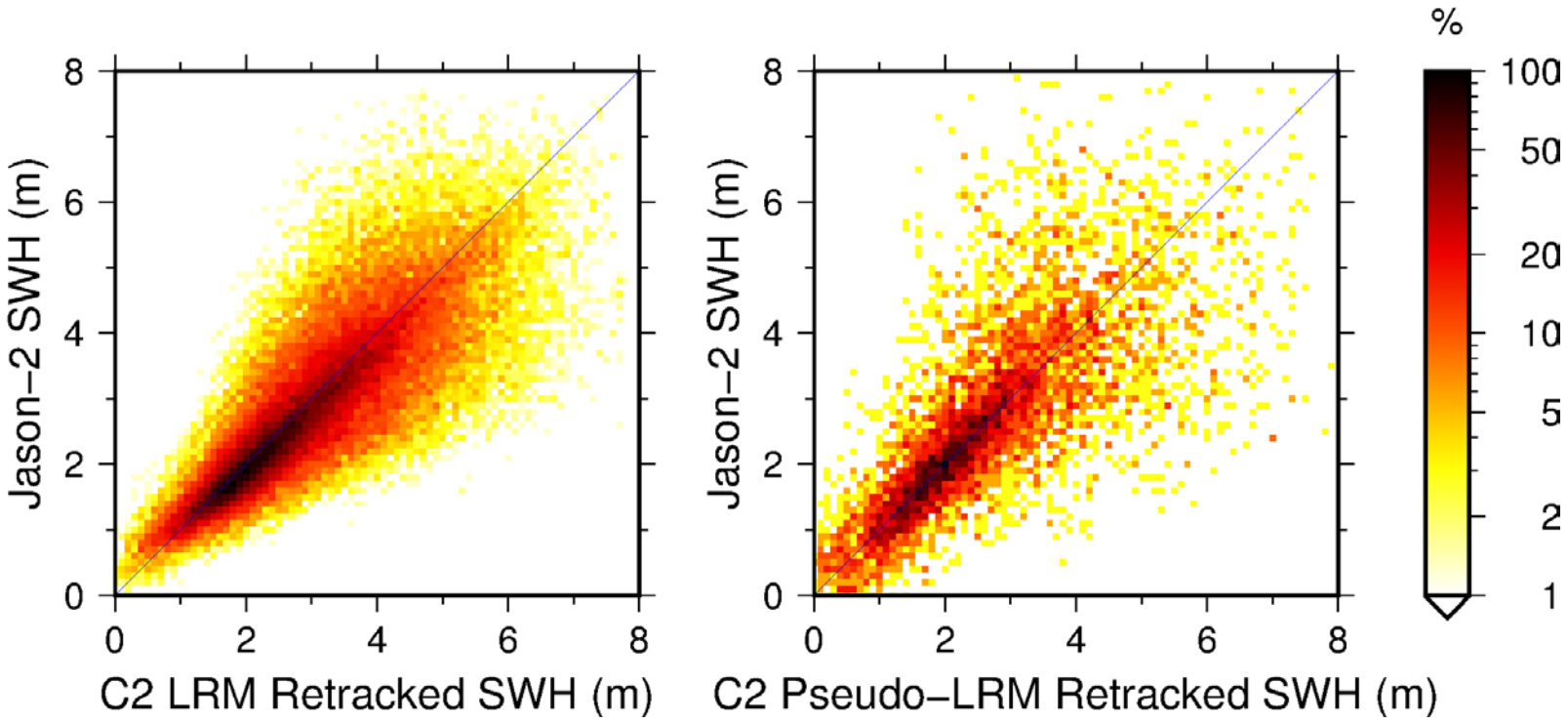
Retracking over St Helena box

- AGC is 1 dB lower during SAR mode. Why?
- Leading edge of waveform somewhat more blurry during PLRM



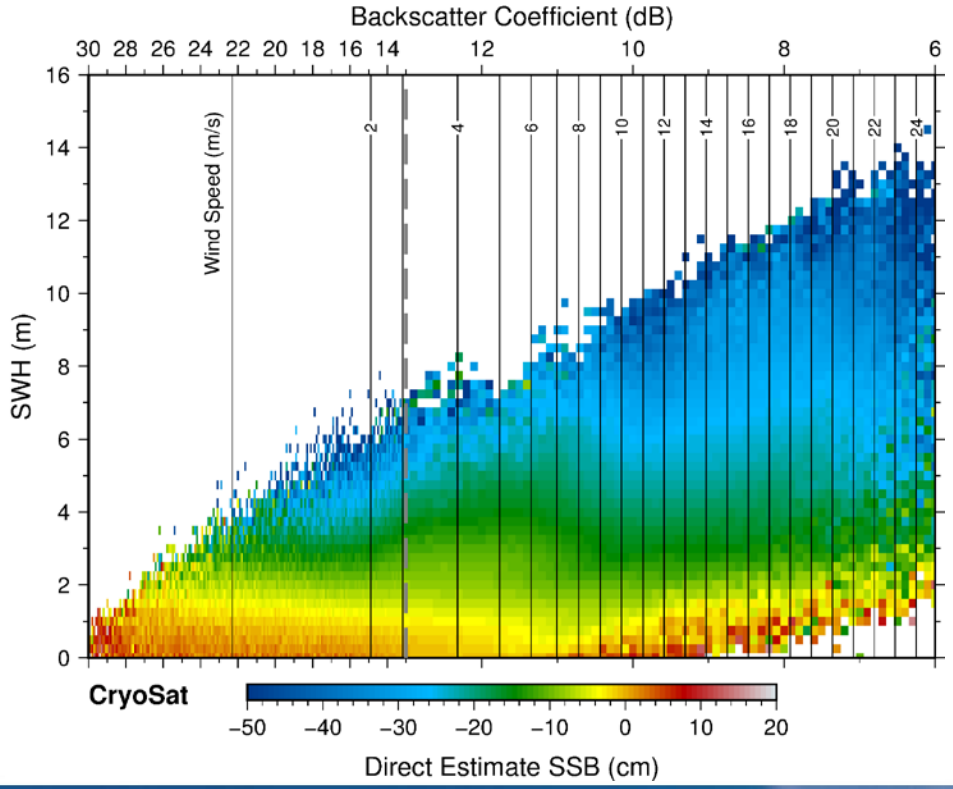
SWH Comparison with Jason-2

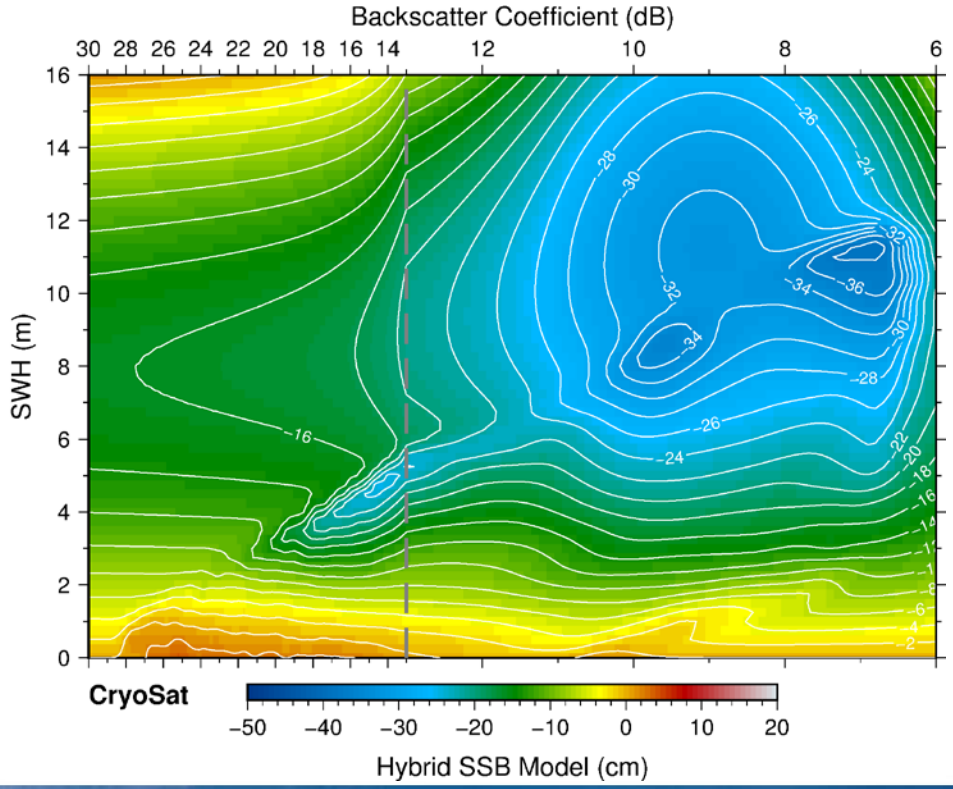
- Crossover data
  - CryoSat-2 vs Jason-2
  - Maximum 2-day time interval
  - Too few crossovers between LRM and Pseudo-LRM



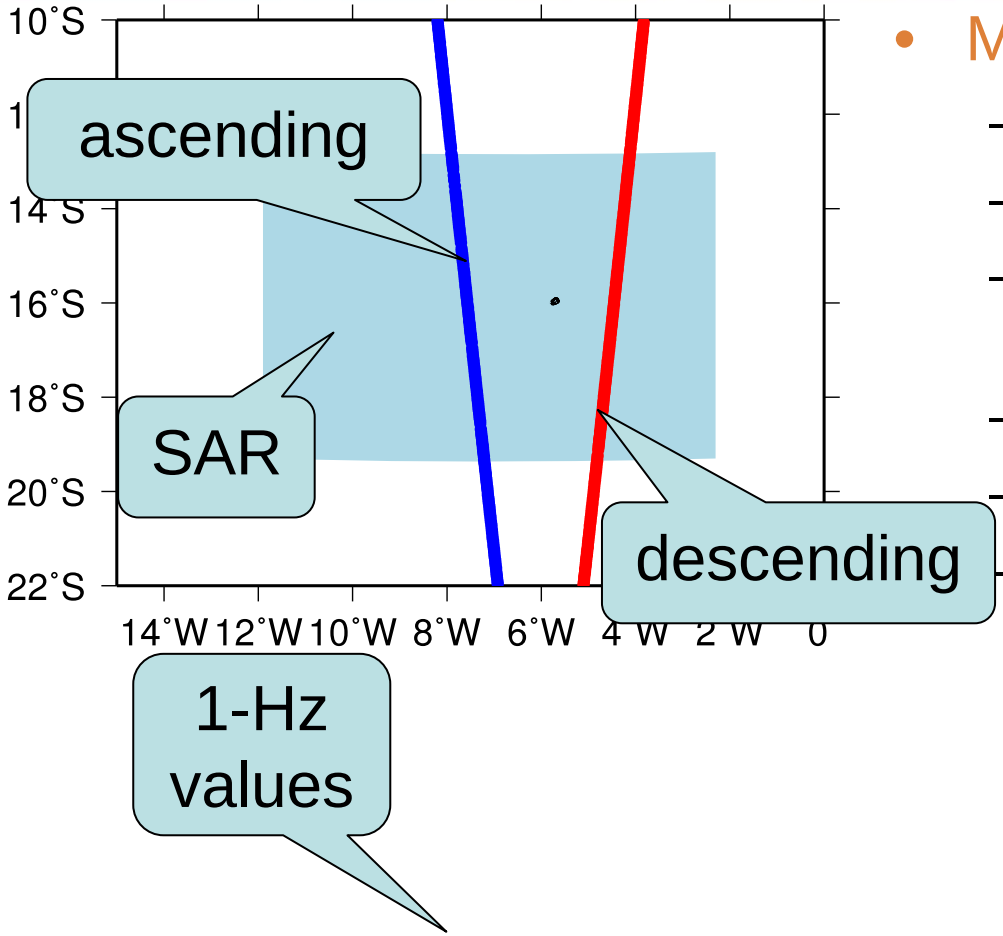
Hybrid Sea State Bias Model

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





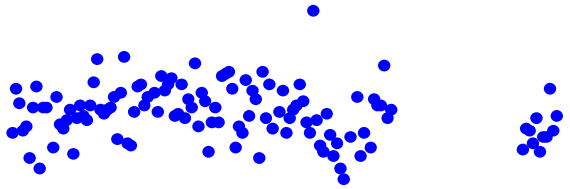
Merging LRM and PLRM (1)



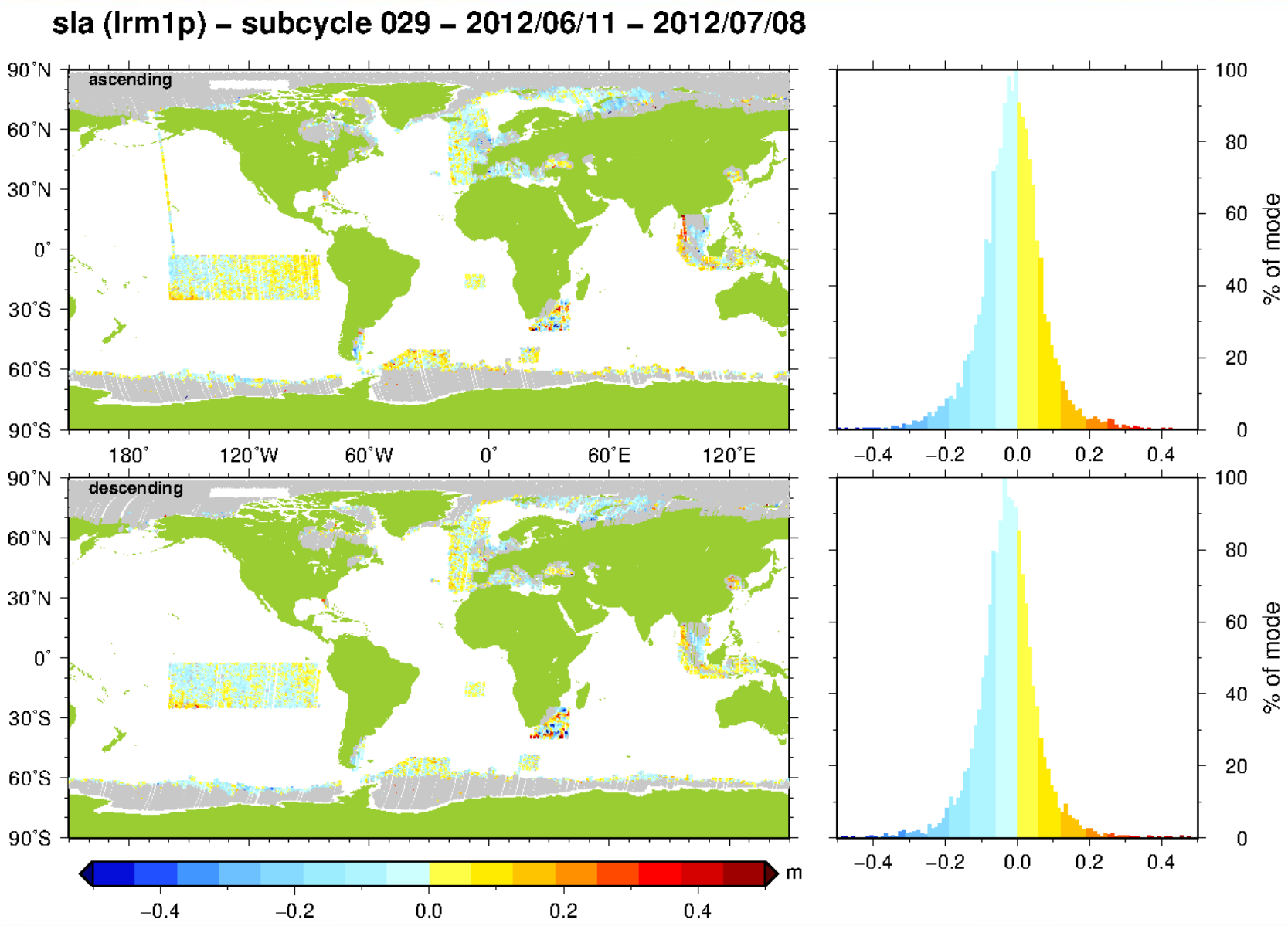
- Matching SLA
  - LRM: Timing error
  - LRM: One wave gate offset
  - PLRM: Internal calibration and Doppler range correction
  - PLRM: Adjusted SWH
  - Improved backscatter
  - New SSB model from LRM

20-Hz Std Dev

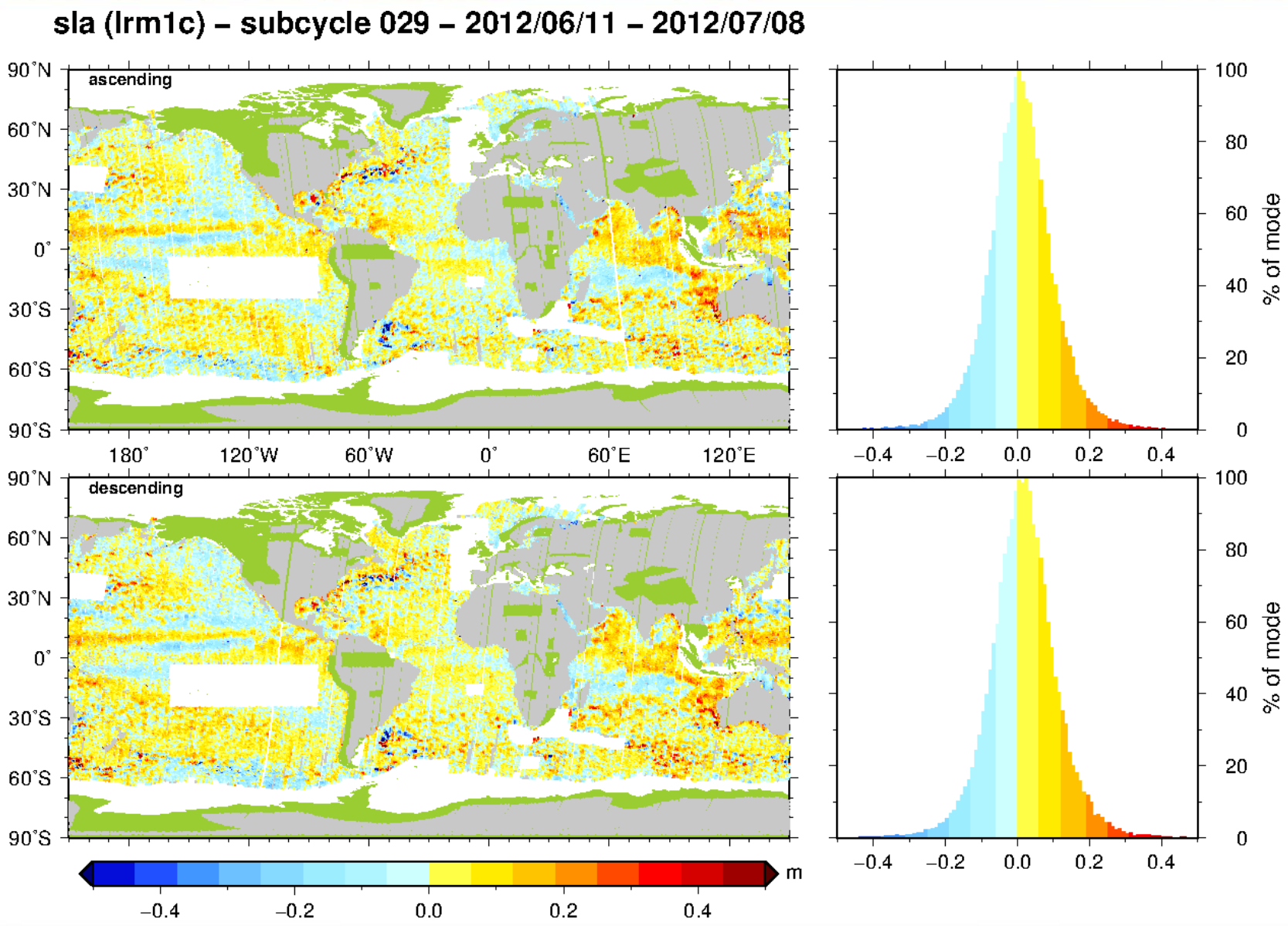
Merging LRM and PLRM (2)



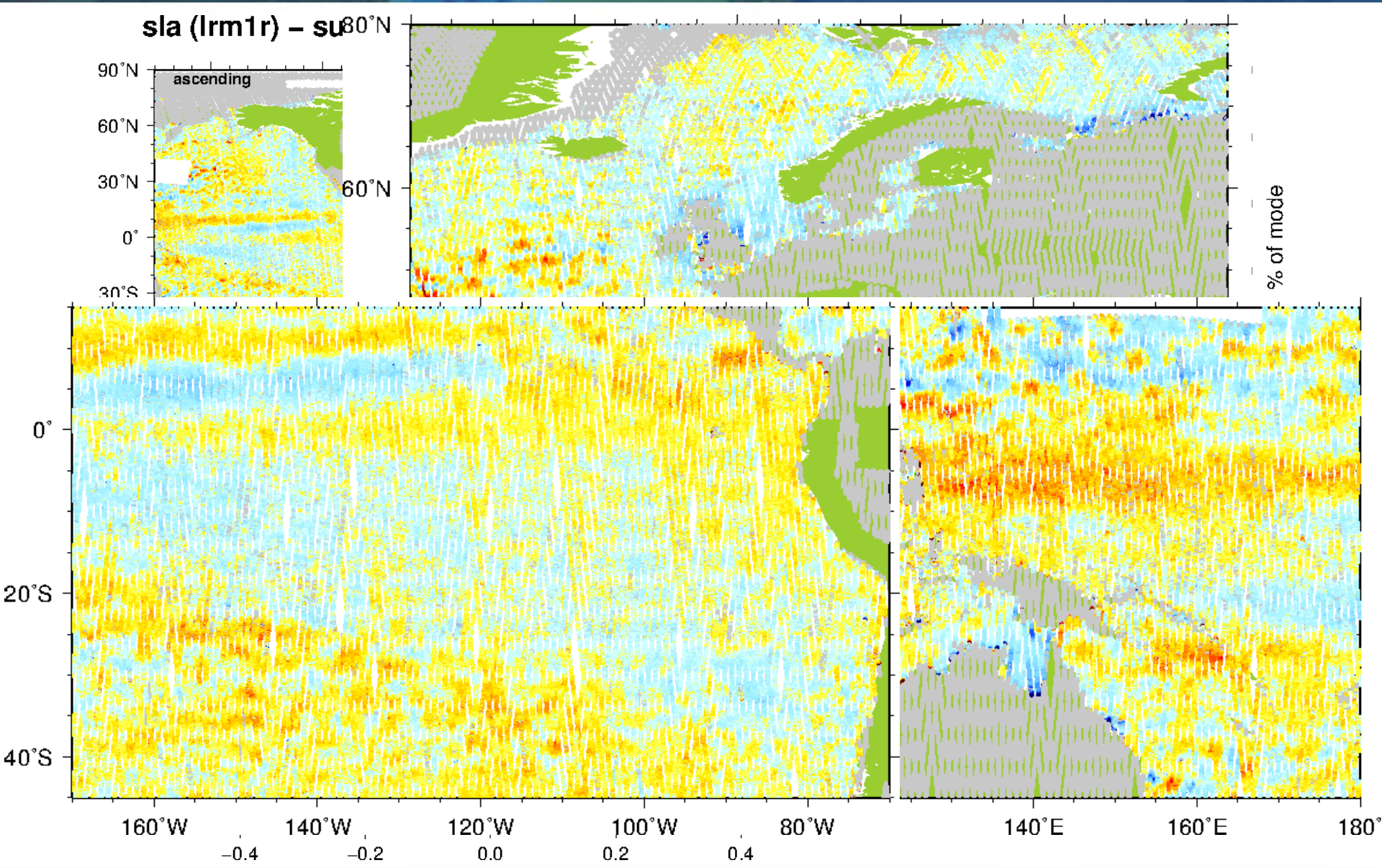
PLRM – Sea Level Anomaly



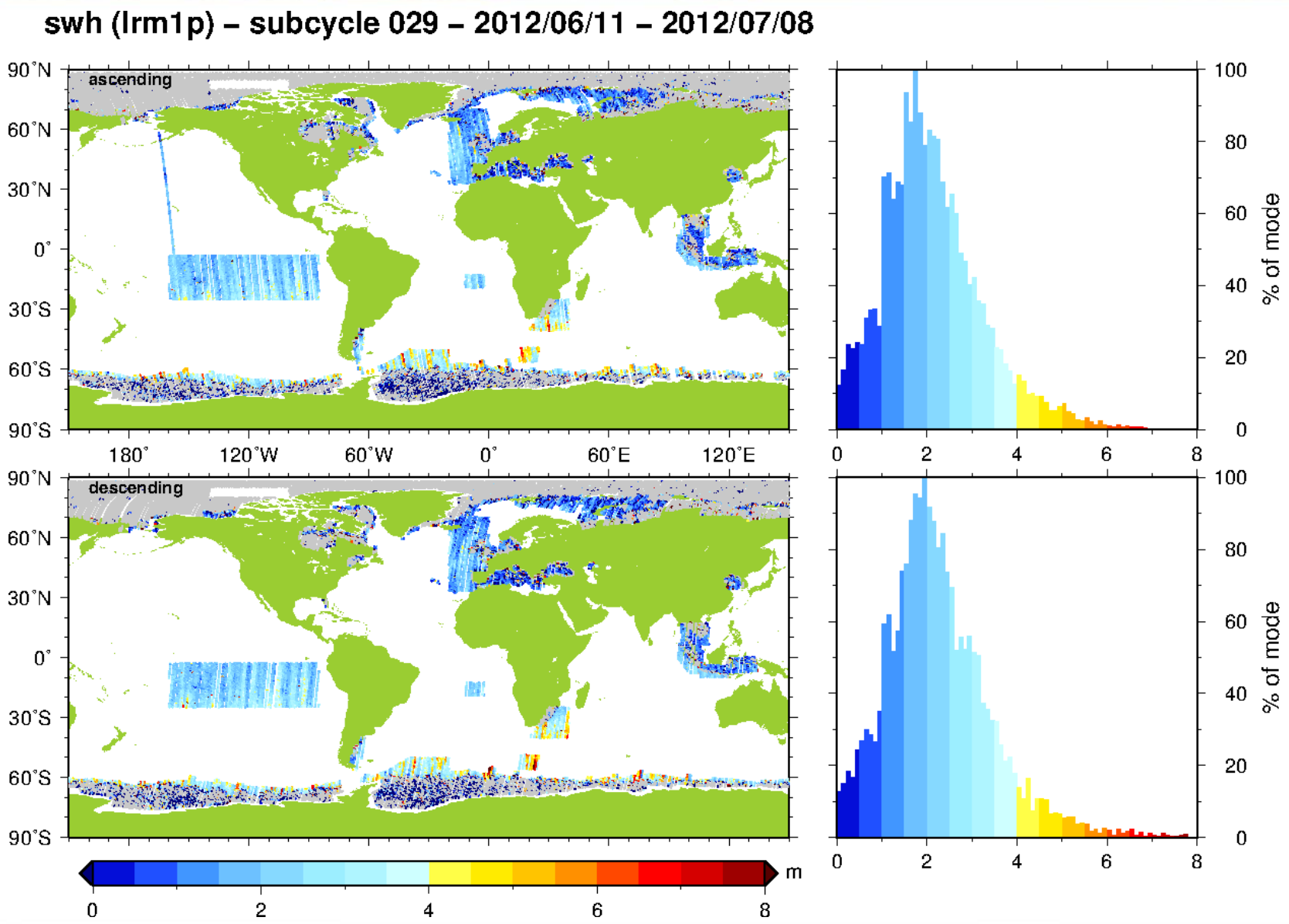
LRM – Sea Level Anomaly



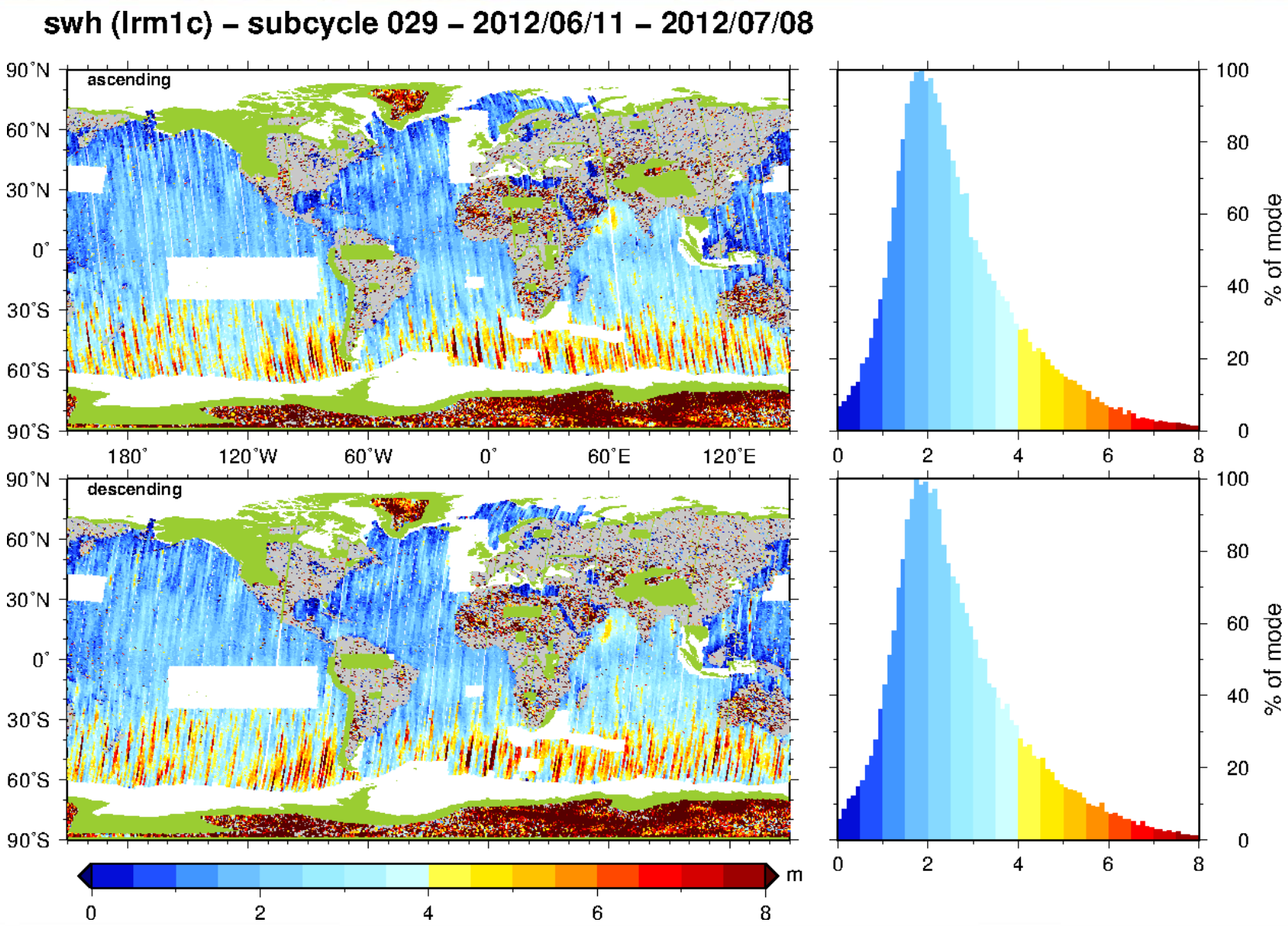
LRM+PLRM – Sea Level Anomaly



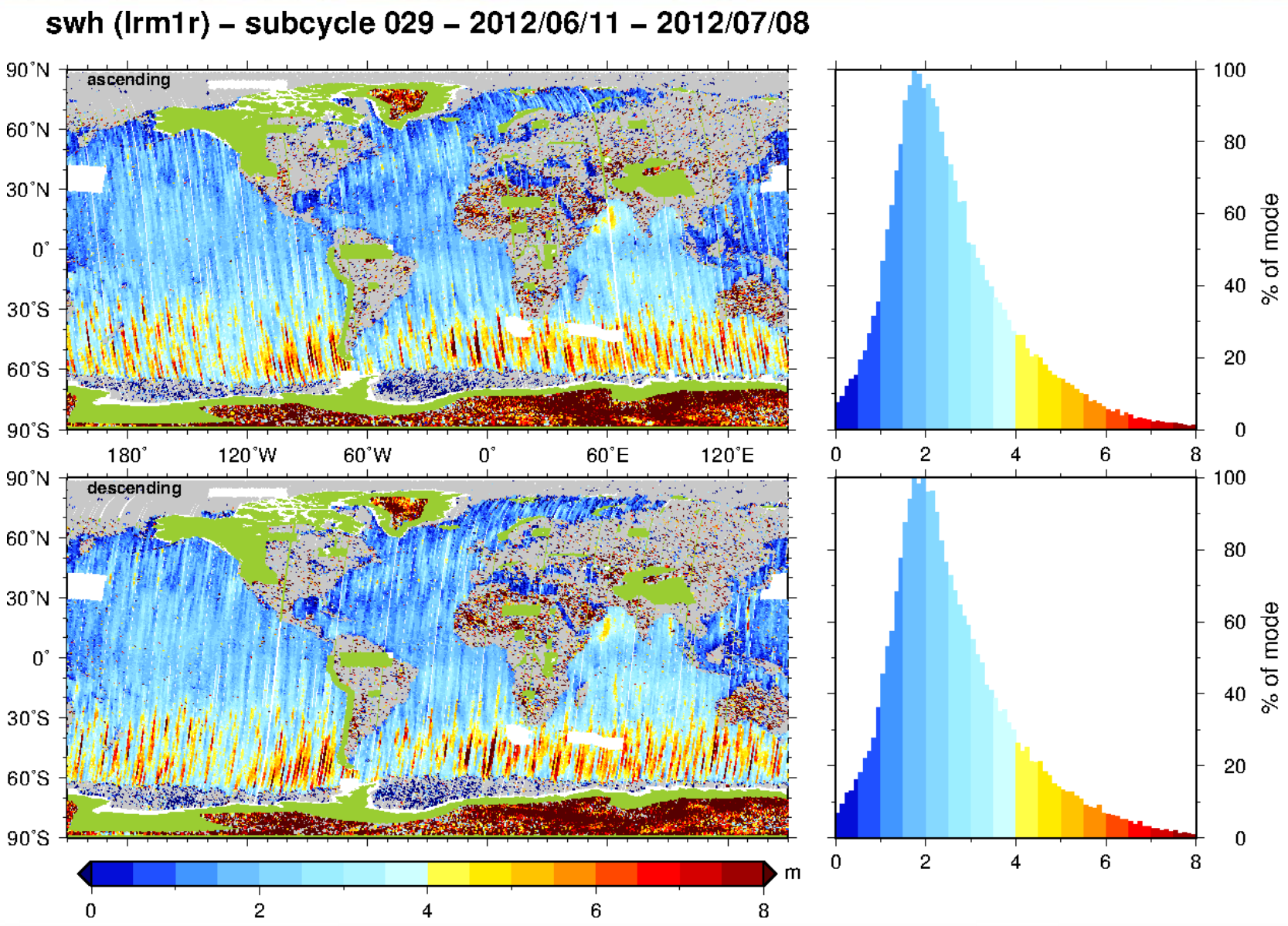
PLRM – Significant Wave Height



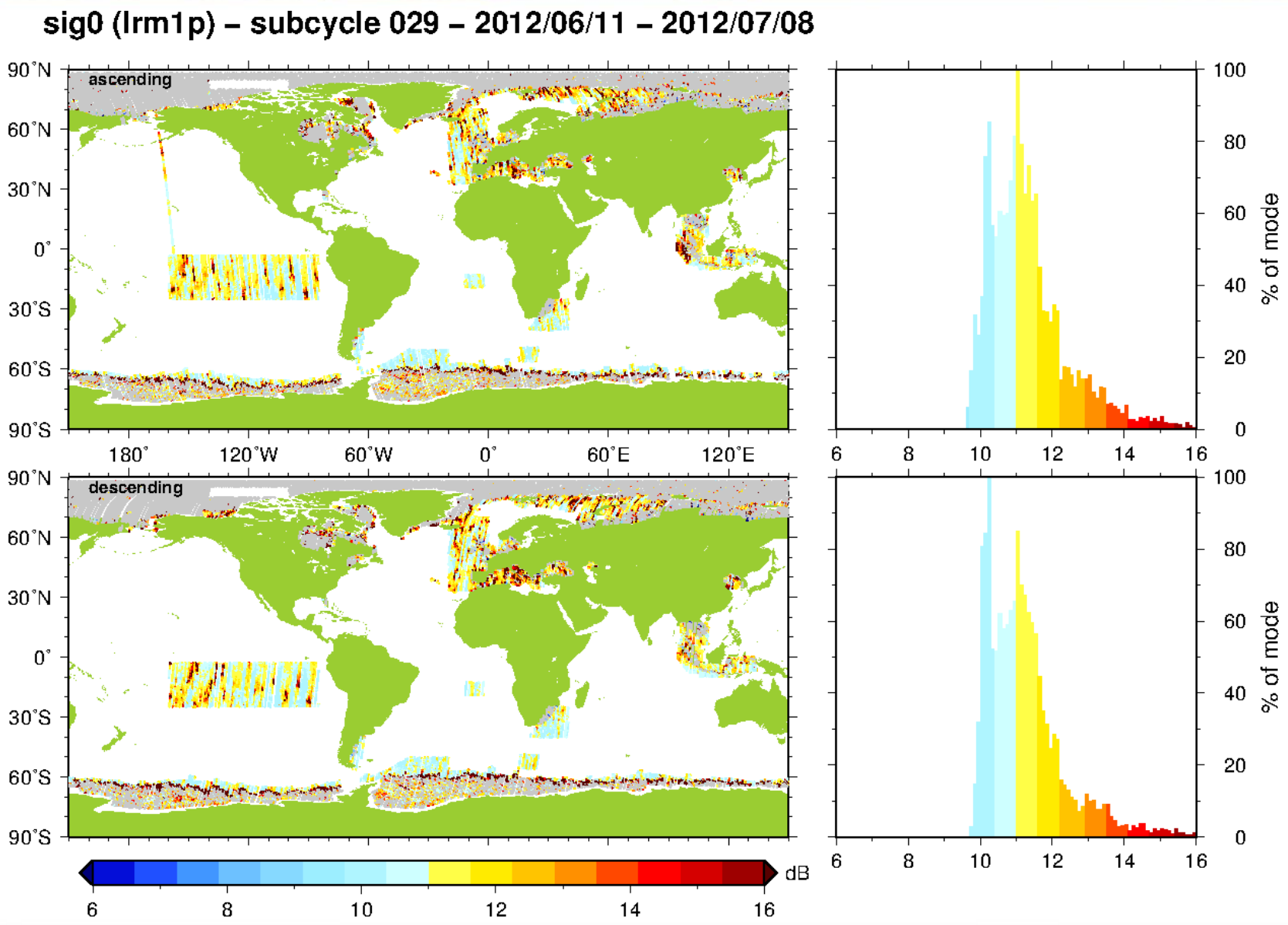
LRM – Significant Wave Height



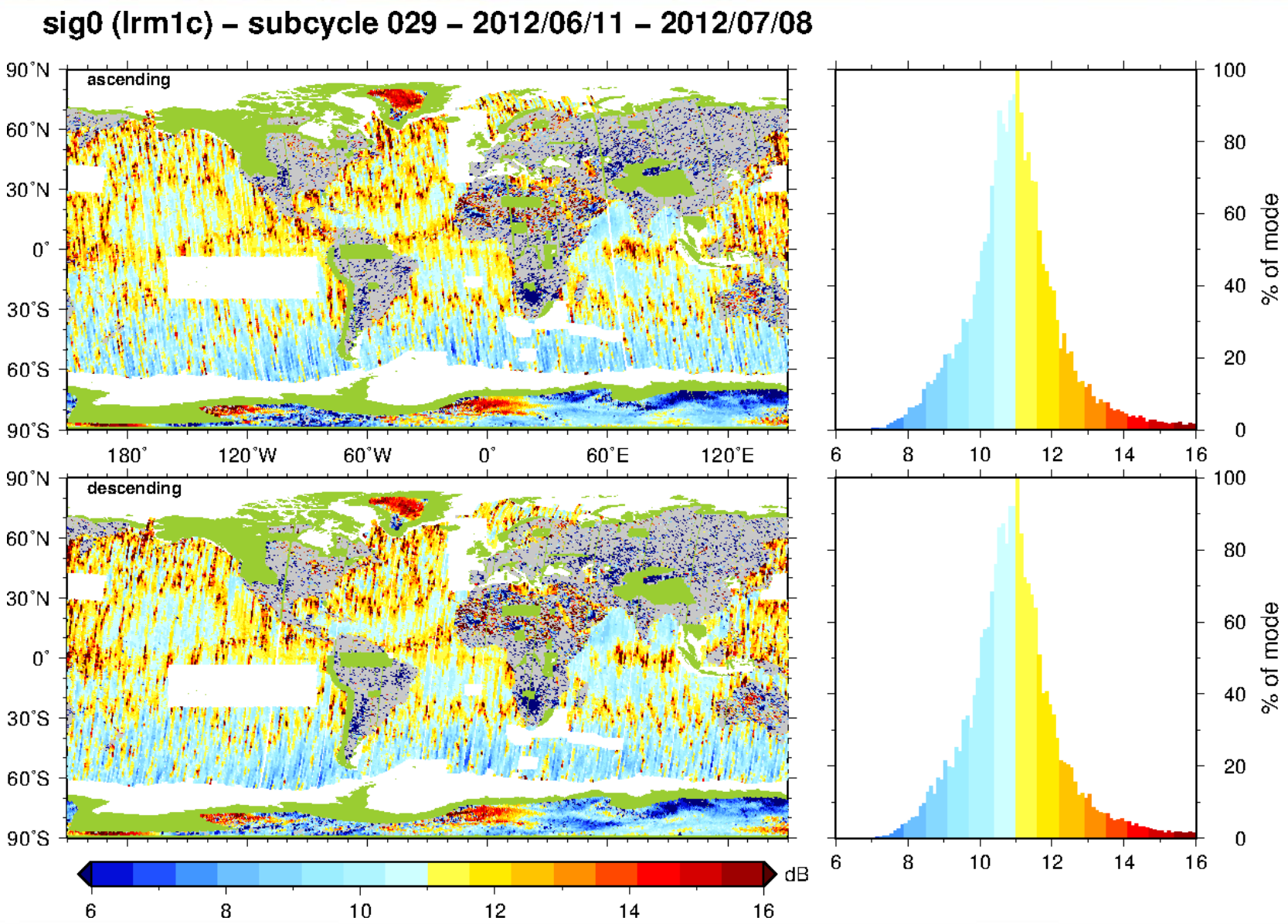
LRM+PLRM – Significant Wave Height



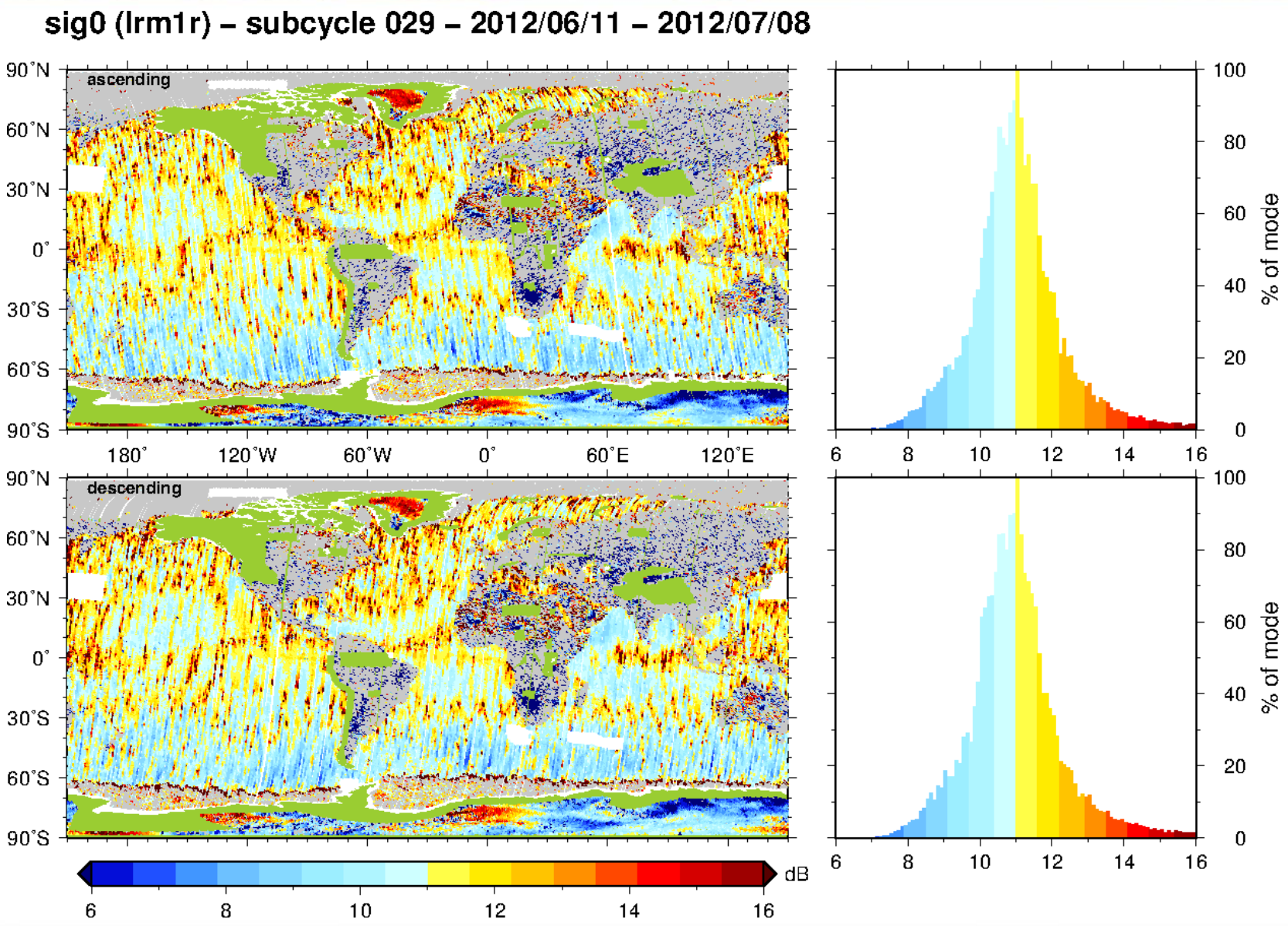
PLRM – Backscatter



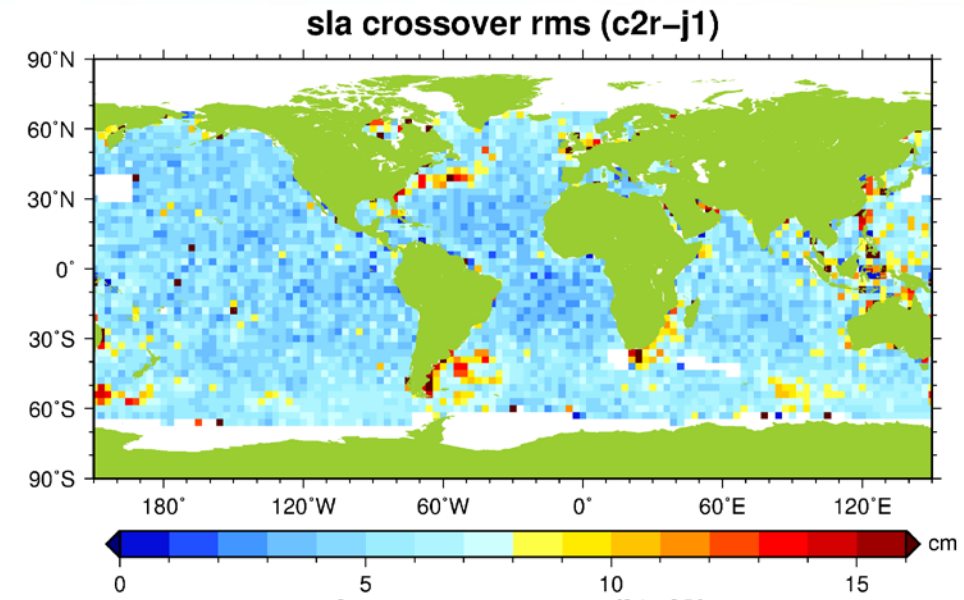
LRM – Backscatter

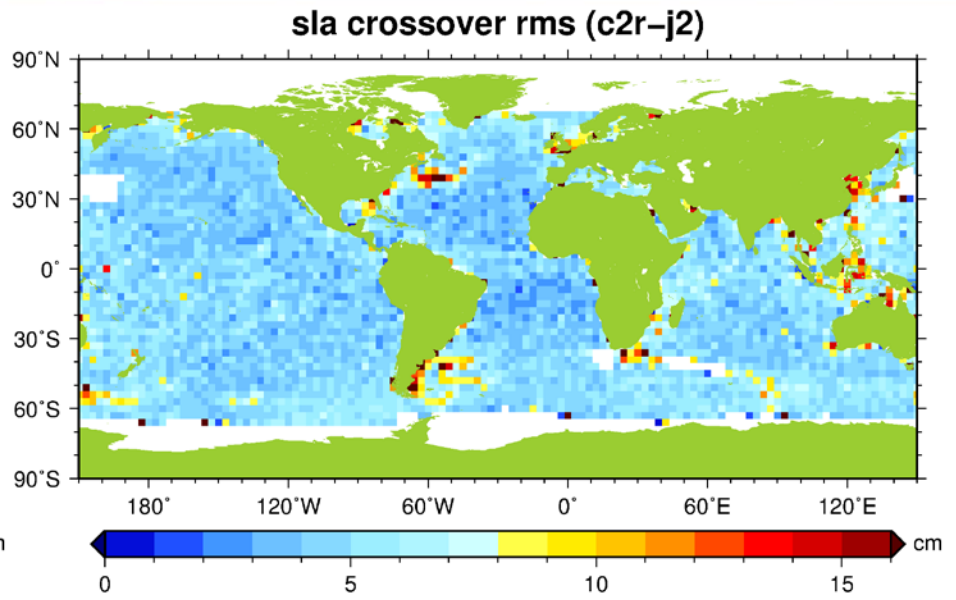


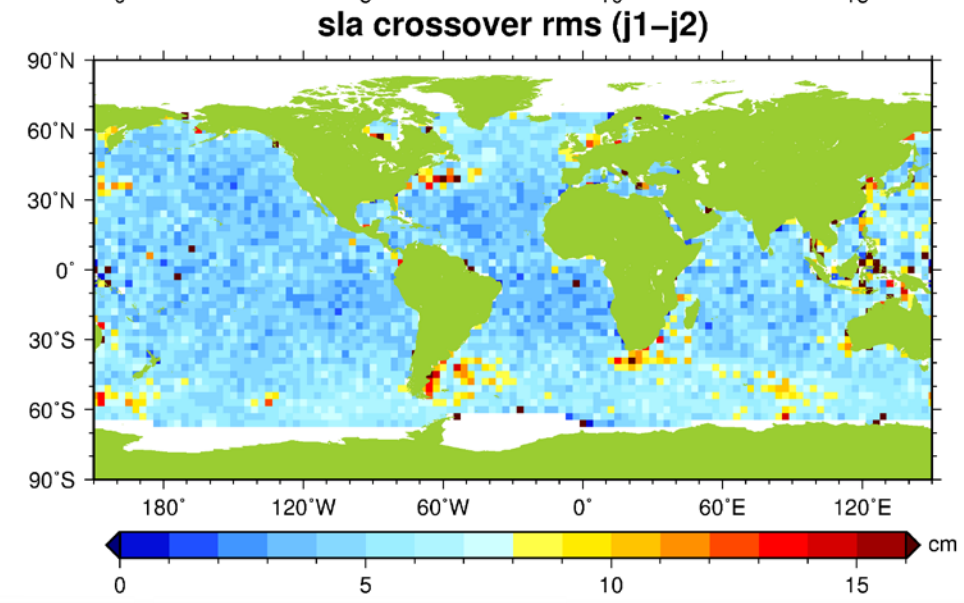
LRM+PLRM – Backscatter



Sea Level (cm) Crossovers

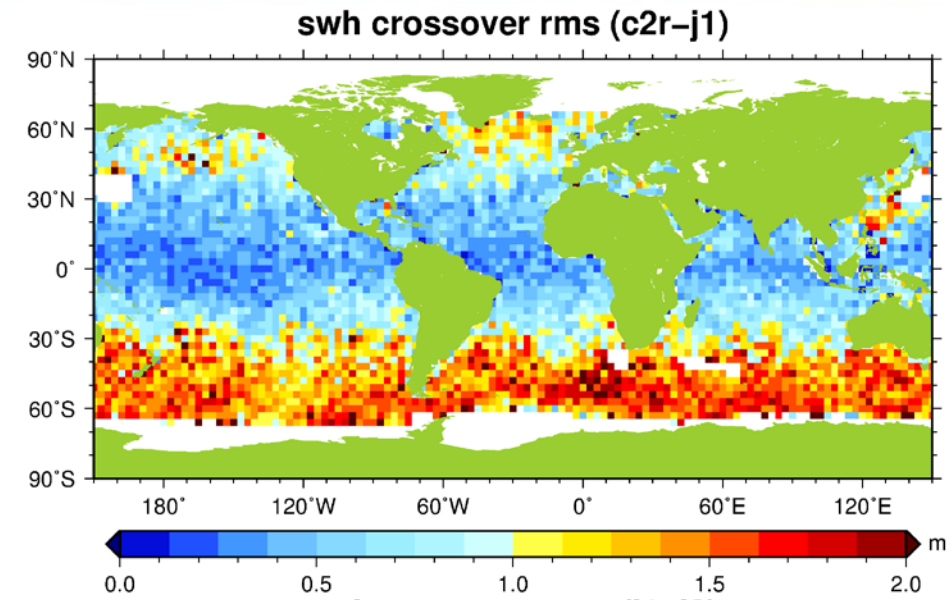


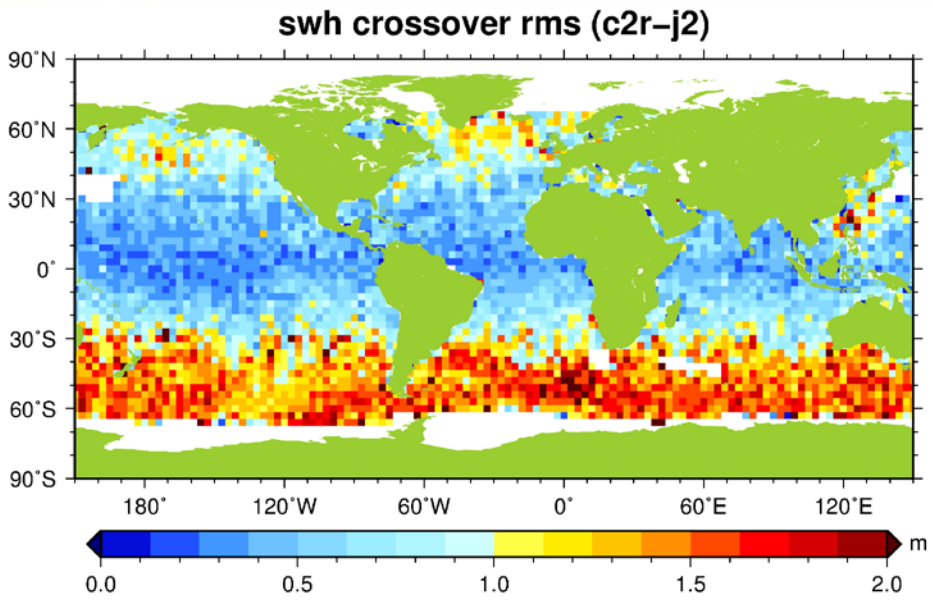


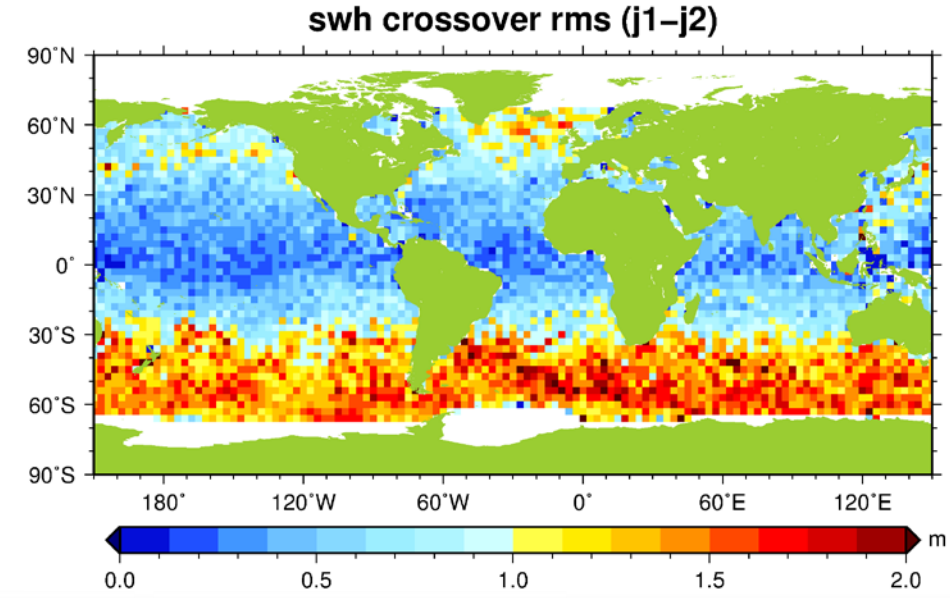


	Mean	Std
LRM – Jason-1	–0.96	6.35
PLRM – Jason-1	–1.73	6.27
LRM – Jason-2	–0.57	5.30
PLRM – Jason-2	–1.46	5.87
Jason-1 – Jason-2	+0.37	6.40

SWH (m) Crossovers

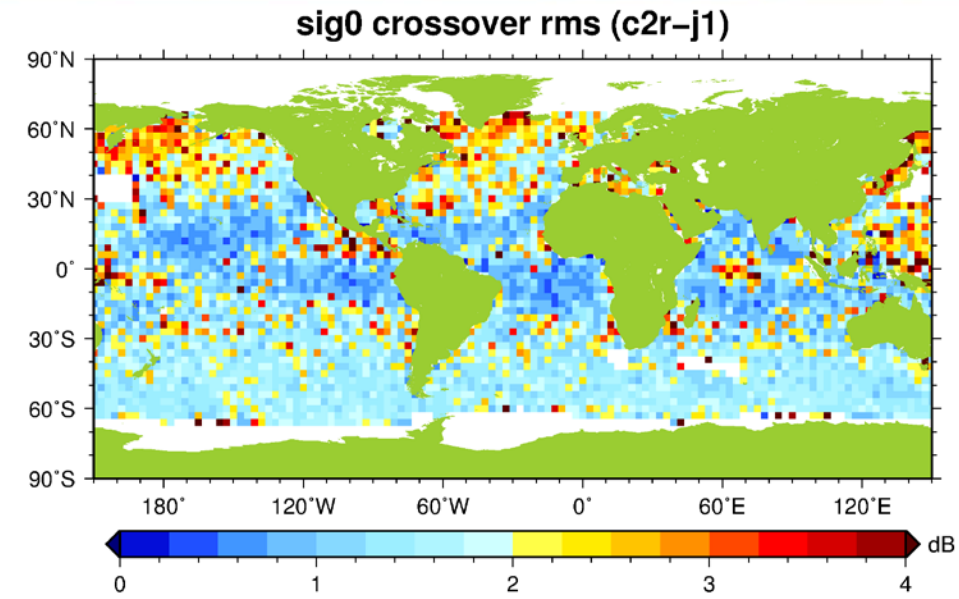


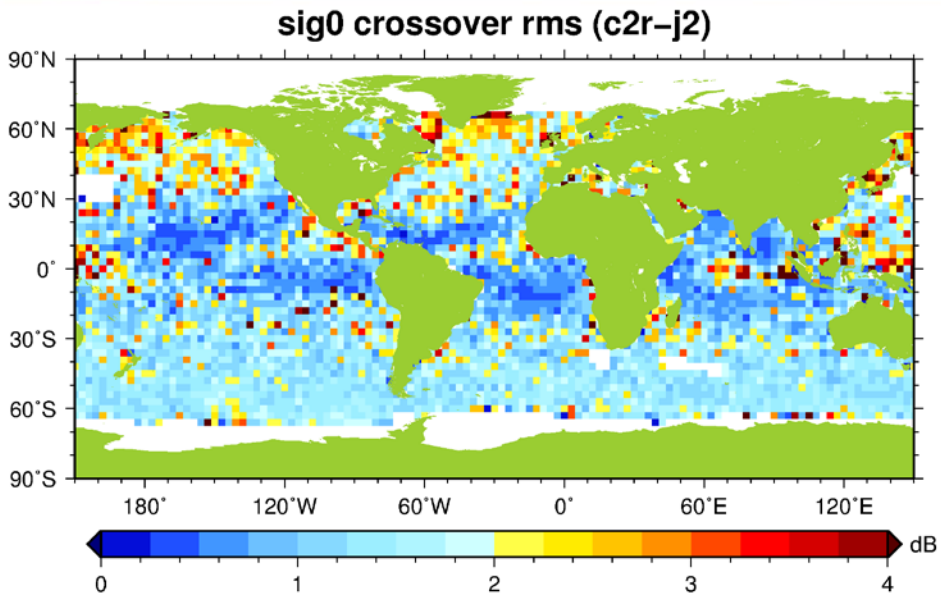


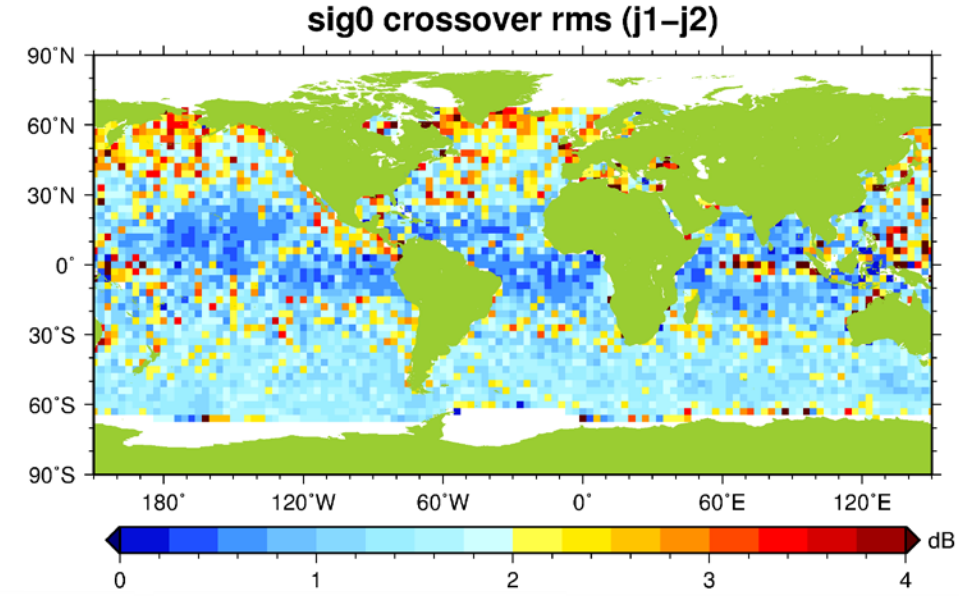


	Mean	Std
LRM – Jason-1	+0.12	1.23
PLRM – Jason-1	–0.04	1.24
LRM – Jason-2	+0.10	1.20
PLRM – Jason-2	–0.03	1.22
Jason-1 – Jason-2	–0.01	1.21

Backscatter (dB) Crossovers





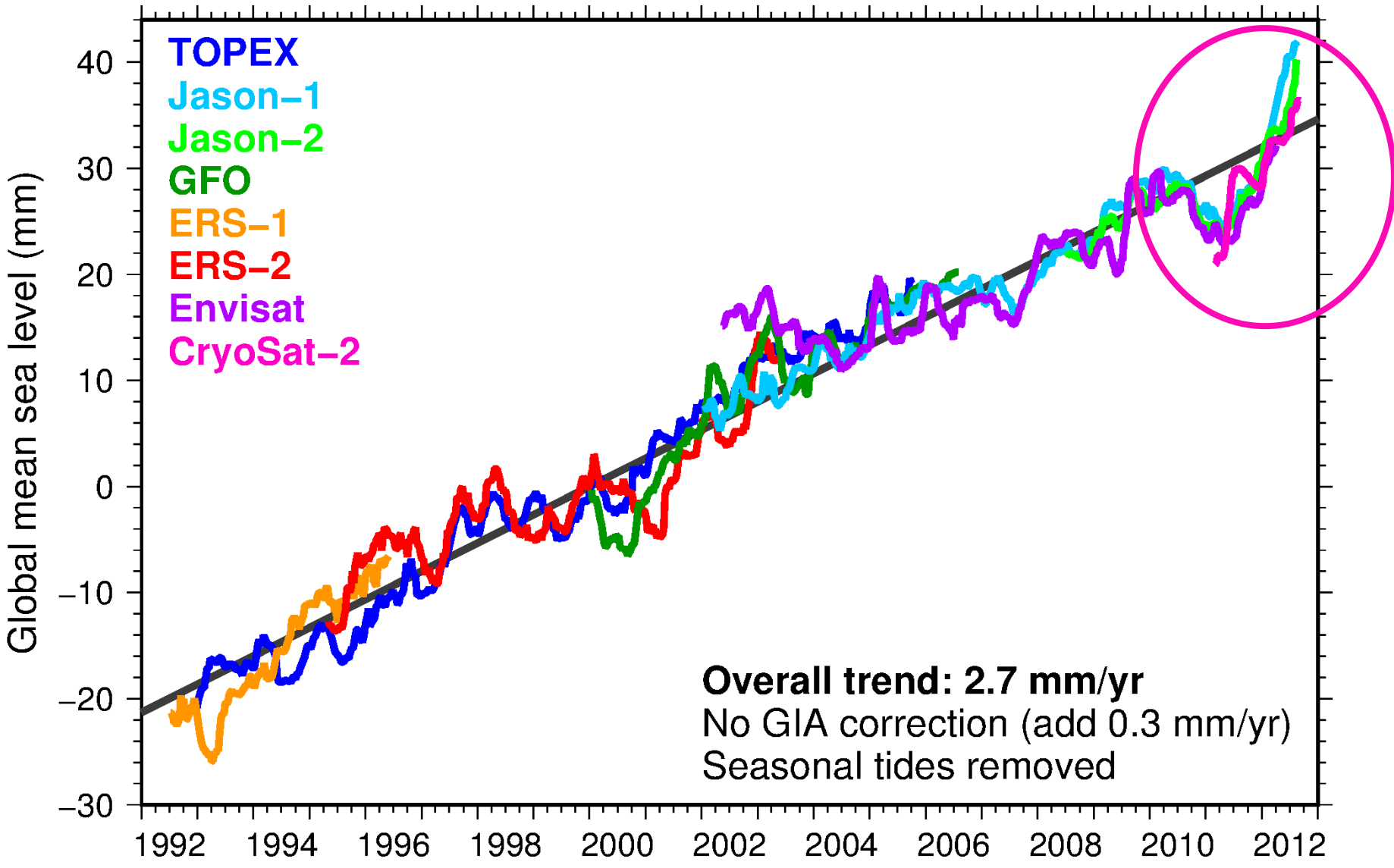


	Mean	Std
LRM – Jason-1	–0.42	1.83
PLRM – Jason-1	+0.13	1.92
LRM – Jason-2	–0.16	1.71
PLRM – Jason-2	+0.33	1.87
Jason-1 – Jason-2	+0.27	1.72

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-2 shows accuracy slightly better than Jason-1, despite lack of radiometer.
- Retracked Pseudo-LRM data
  - After stacking SAR echoes, same retracking.
  - No apparent bias with LRM data.
  - Higher levels of 20-Hz noise, as expected.
  - Still, 1-Hz data quality is comparable to LRM data
- However …
  - Current ESA data policies **do not allow us to release** these valuable PLRM data

Thank You


TOPEX
Jason–1
Jason–2
GFO
ERS–1
ERS–2
Envisat
CryoSat–2
Global mean sea level (mm)
40
30
20
10
0
–10
–20
–30
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Overall trend: 2.7 mm/yr
No GIA correction (add 0.3 mm/yr)
Seasonal tides removed