# Early look at SARAL/AltiKa data

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# SARAL Processing by RADS (1)

## Starting with SARAL GDRs, IGDRs and OGDRs

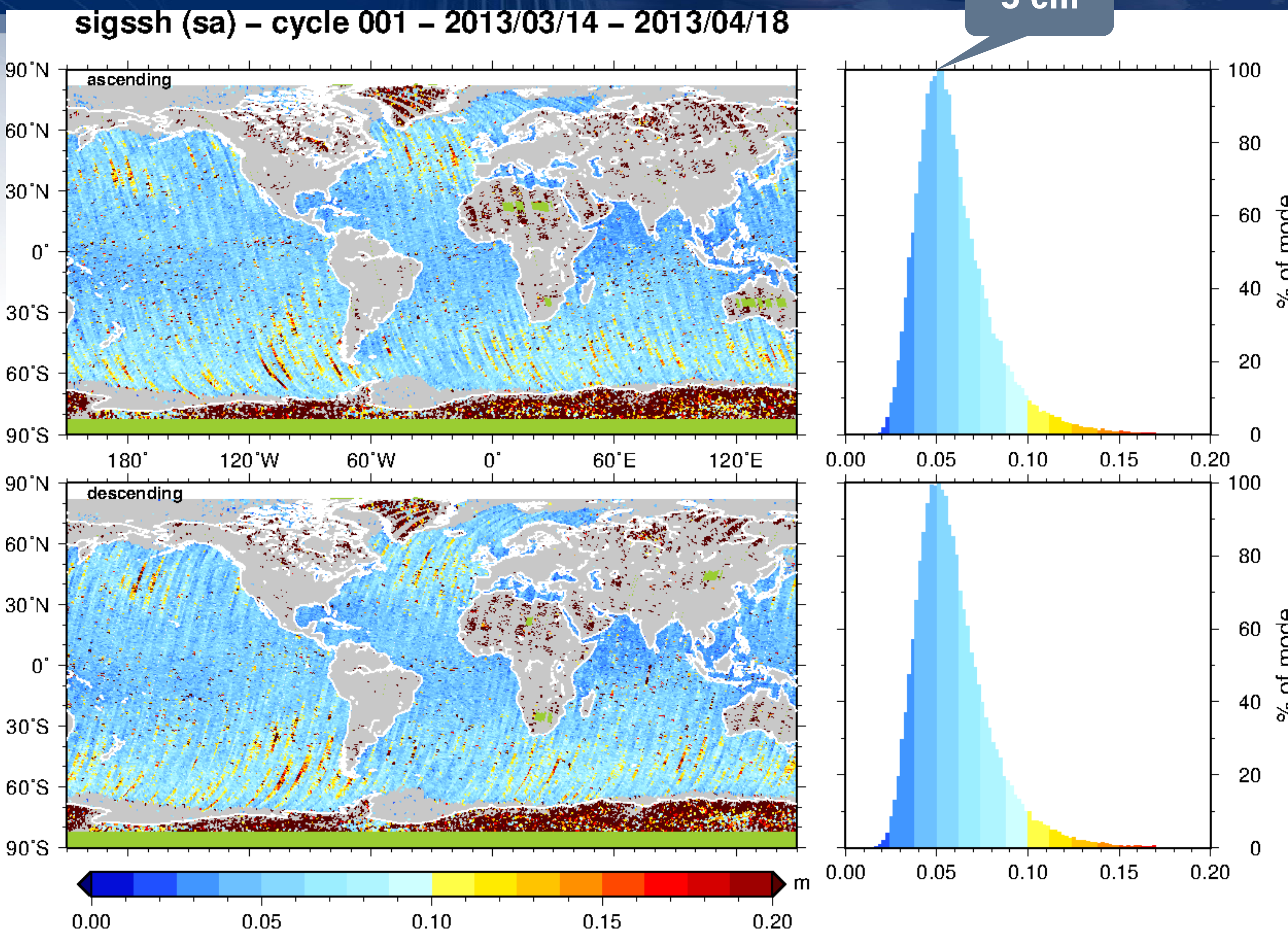
- Twice-daily download of IGDRs and OGDRs
- OGDRs produced at EUMETSAT
- Use all measurements *as is,* including radiometer wet
- 6.0 cm added to SLA to compensate for intermission range biases
- Standard RADS processing replaces most geophysical models
    - This will be topic of later analyses
    - Current focus is on measurement and orbit quality only
- Data available in RADS since June

# SARAL Processing by RADS (2)

## Further enhancements

- Introduce sigma0 attenuation correction based on theory
  International Telecommunication Union (ITU)
- Corrected sigma0
- Computed sea state bias
- Tailored wind model based on Saleh Abdalla’s for Envisat
- Added NOAA Global Forecasting System (GFS) wet and dry tropospheric corrections (not used here)

# SARAL – Std Dev of 40-Hz SLA



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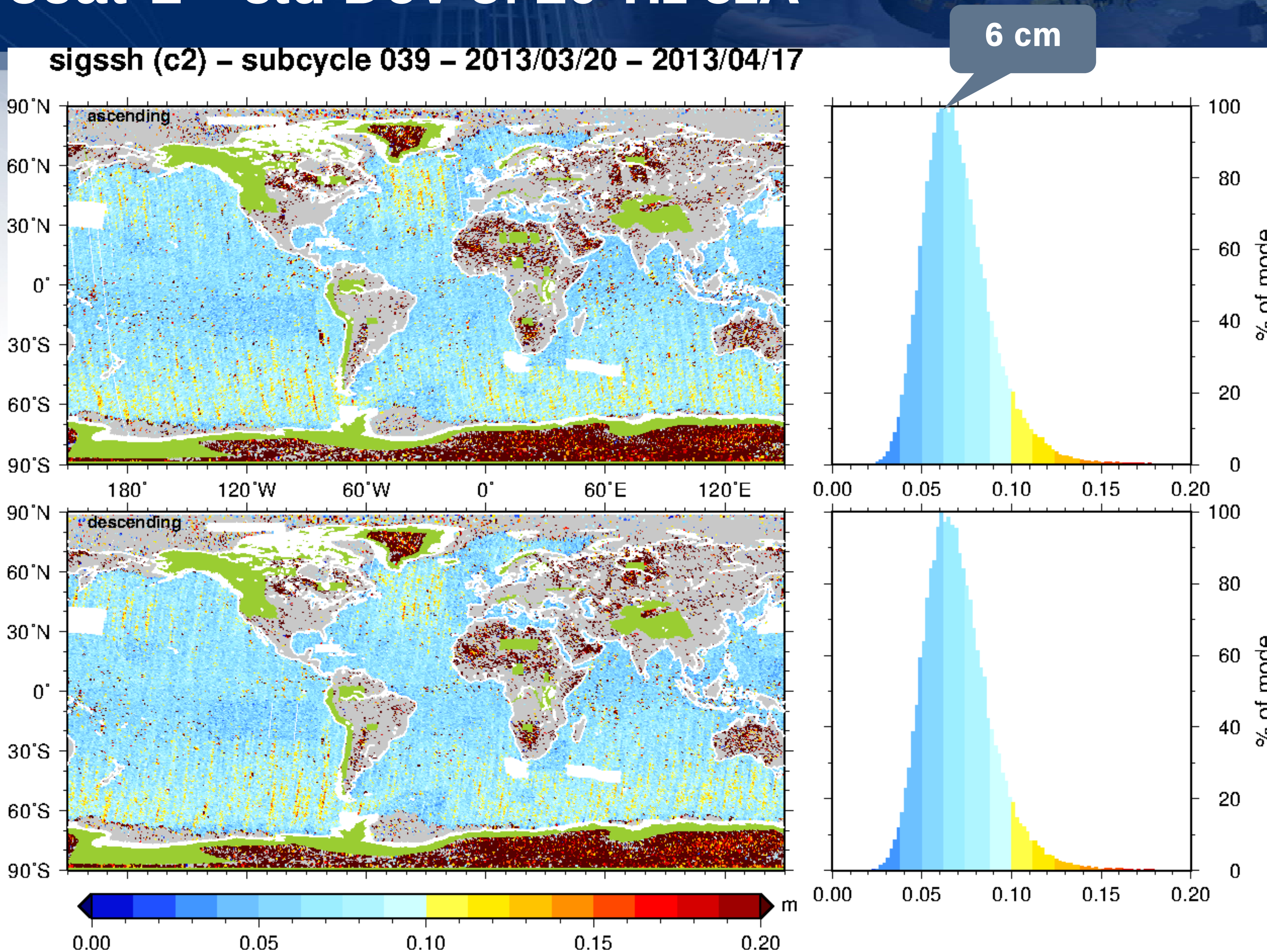
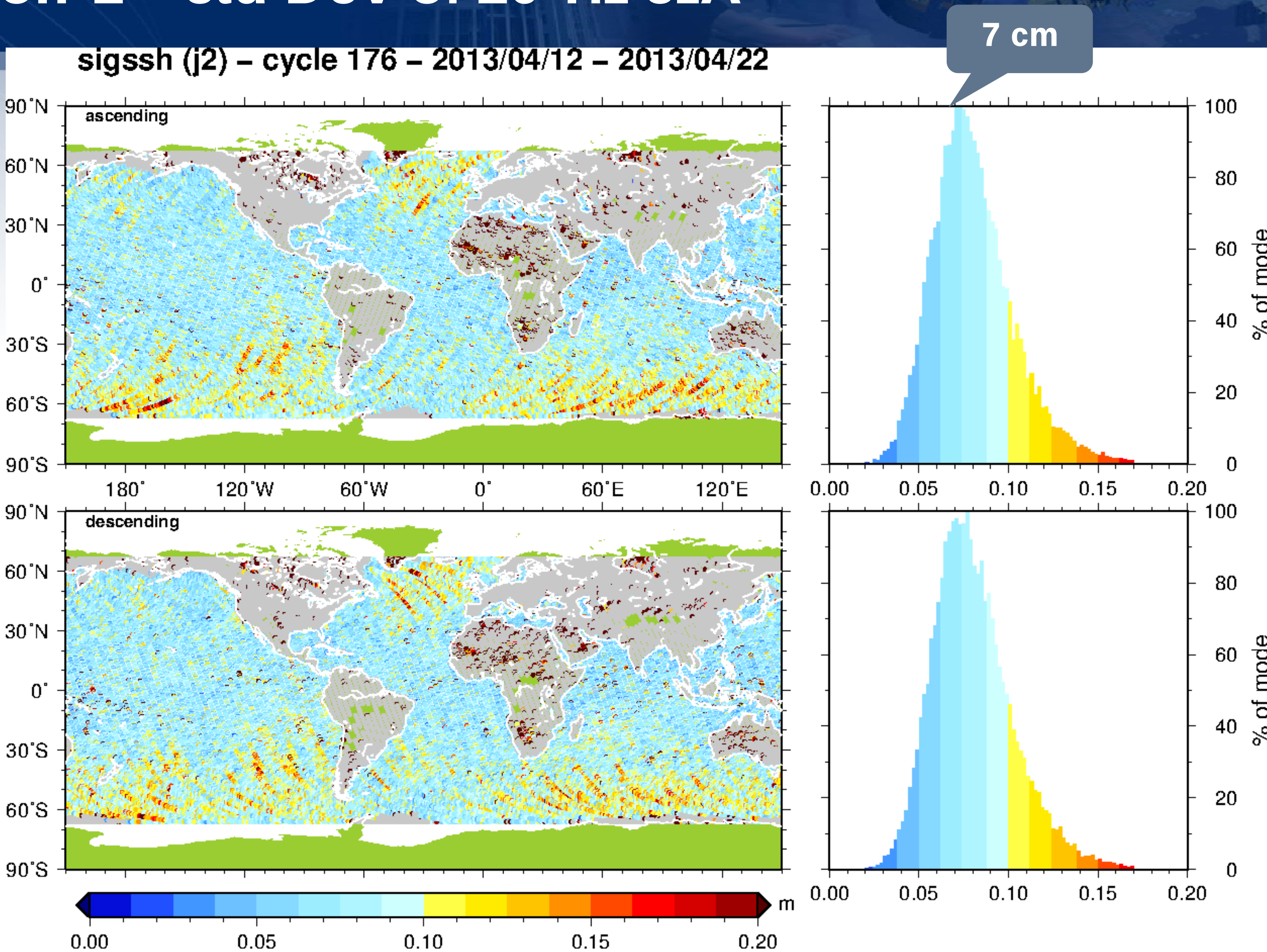
# CryoSat-2 – Std Dev of 20-Hz SLA



# Jason-2 – Std Dev of 20-Hz SLA



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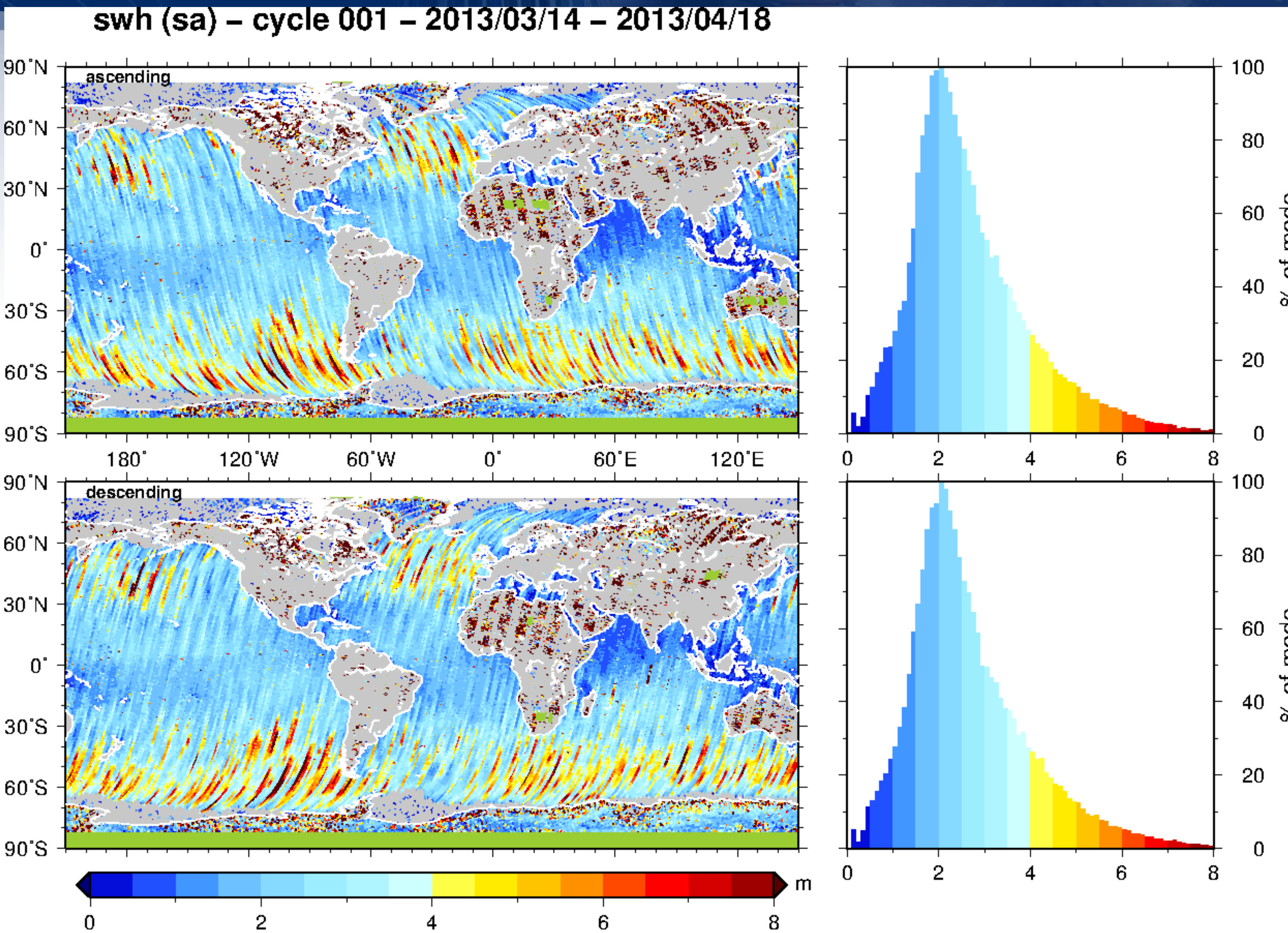
# SARAL – Significant Wave Height



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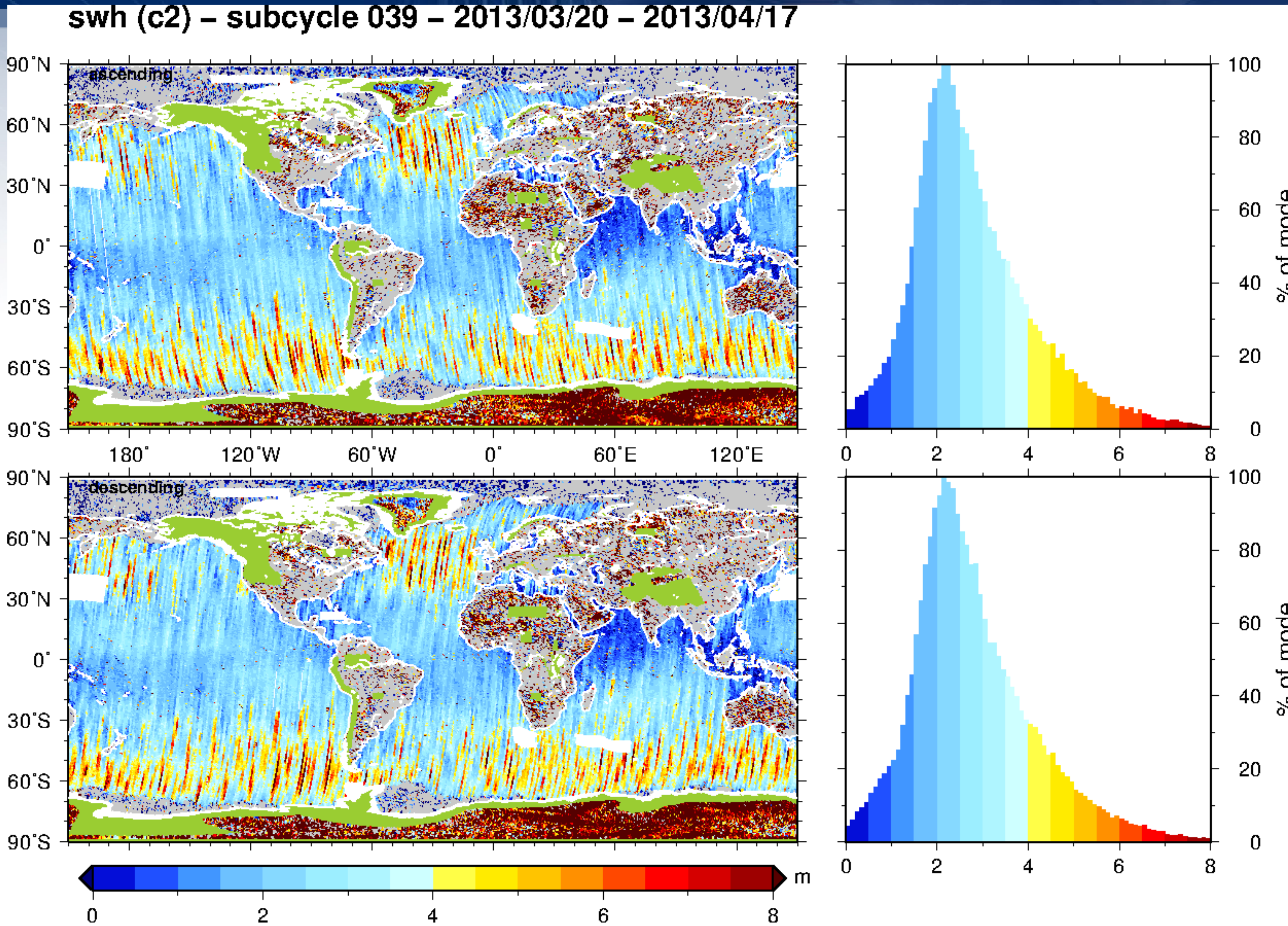




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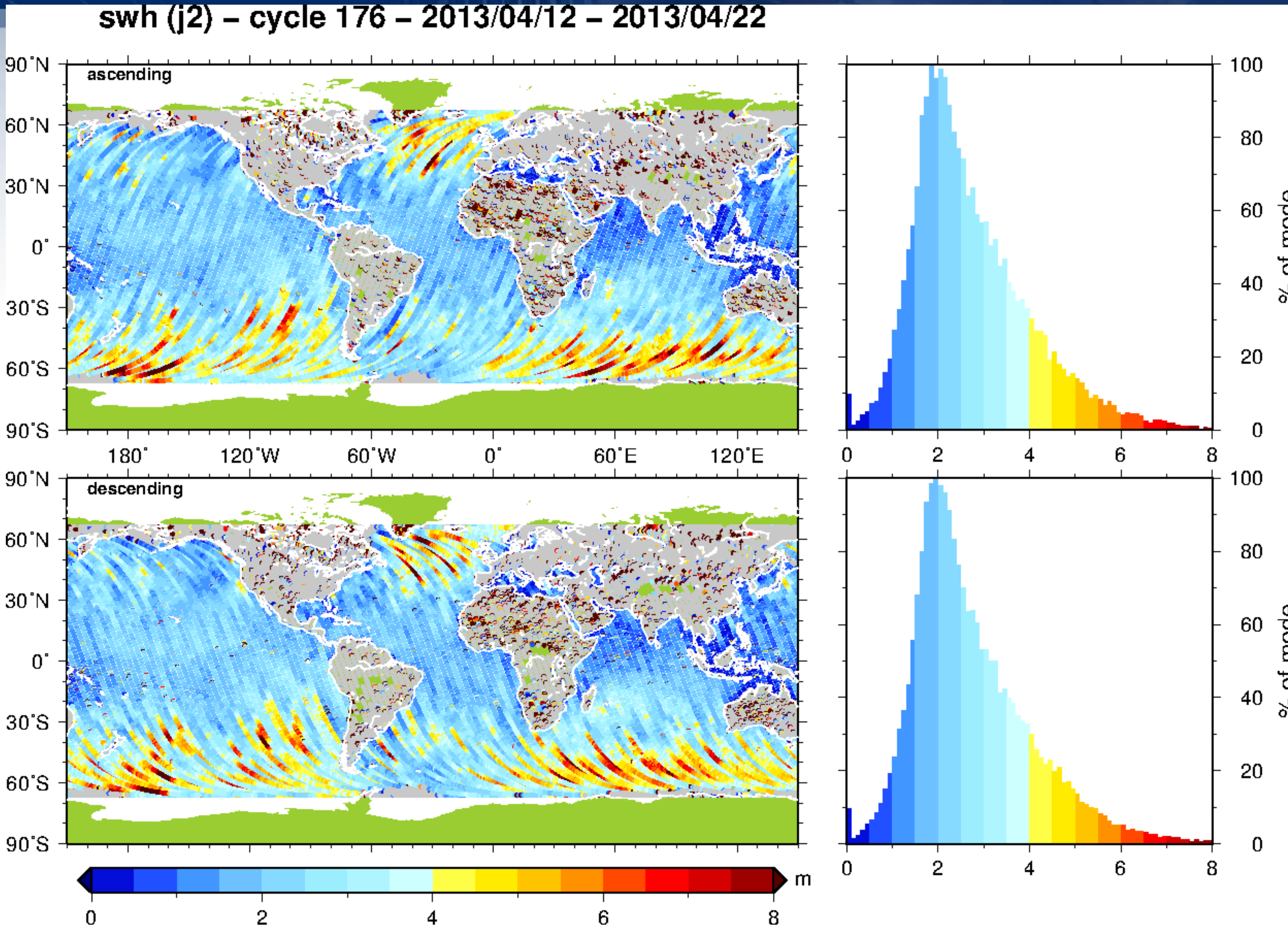
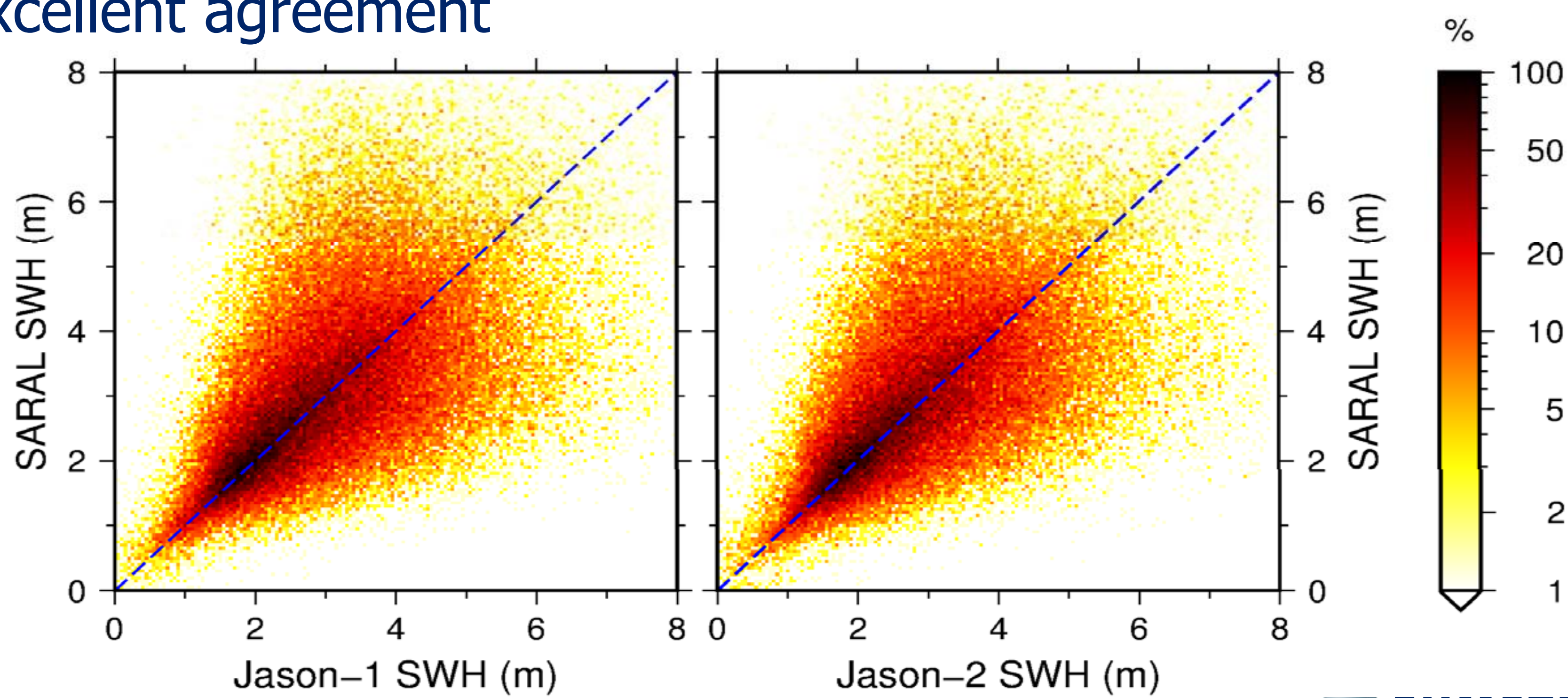
# Jason-2 – Significant Wave Height



# SWH: Comparison with Jason-1/2

## Crossover data

- SARAL vs Jason-1 and -2
- Maximum 5-day time interval
- Excellent agreement



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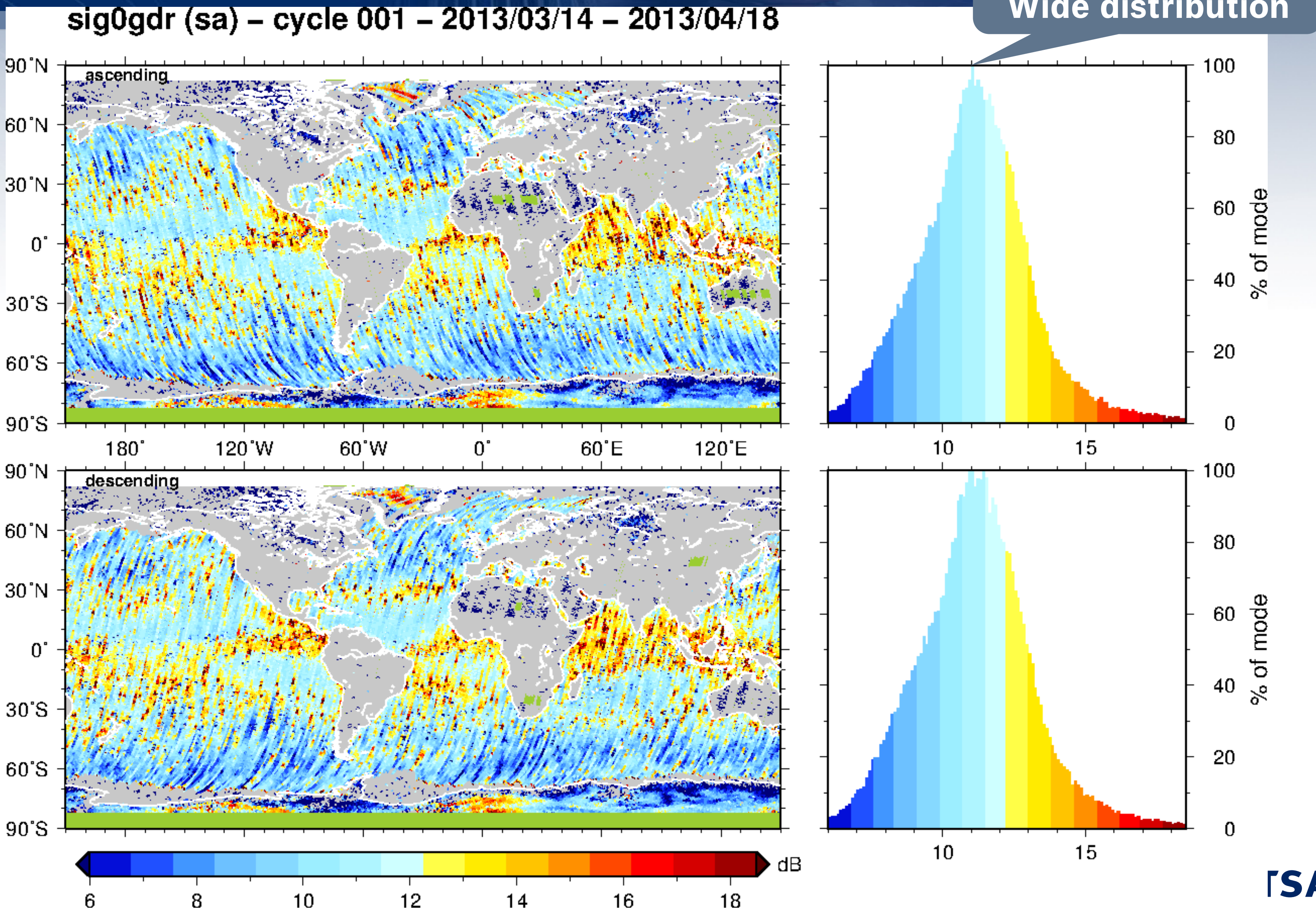
# SARAL – Backscatter Coefficient



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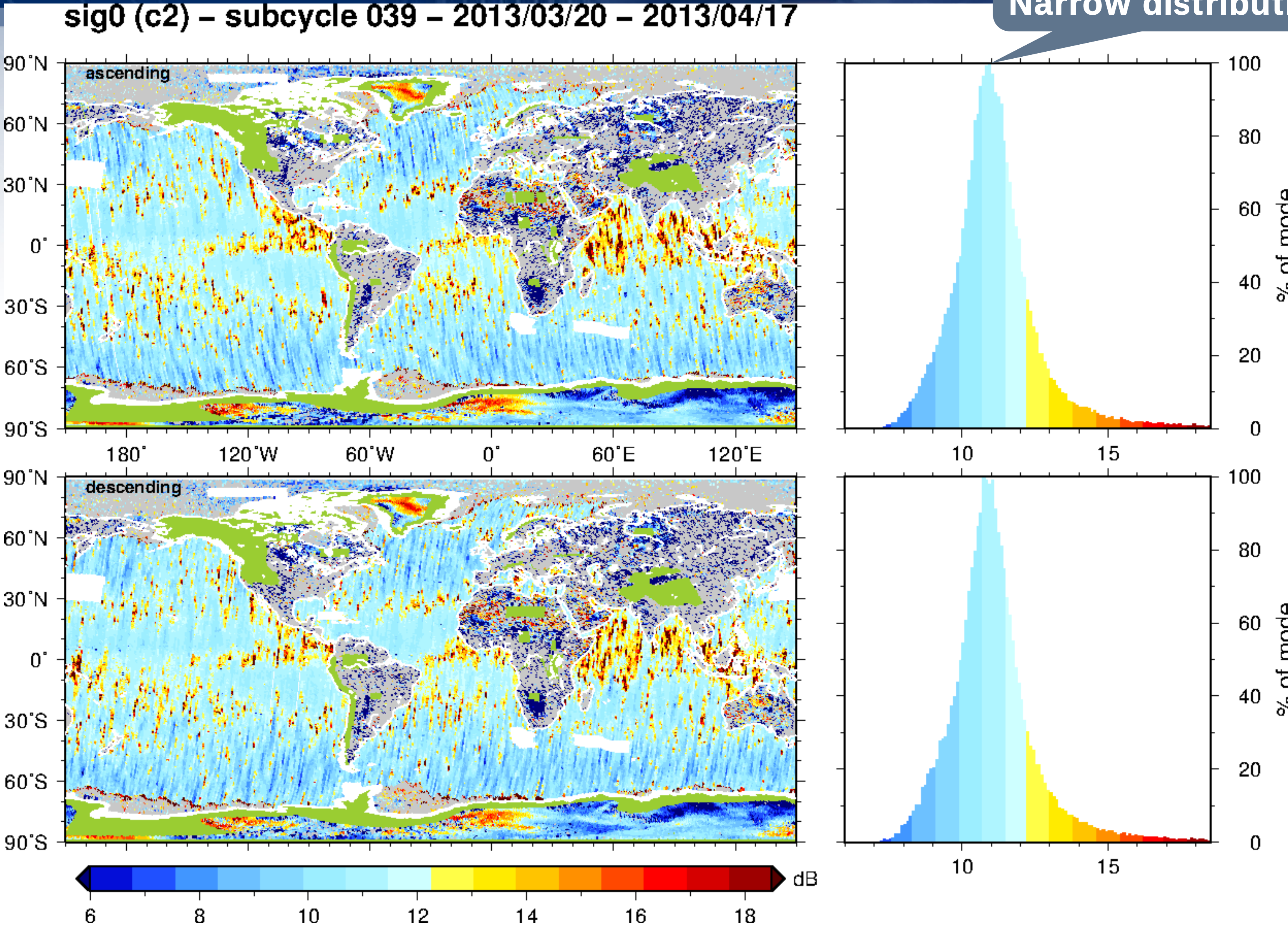




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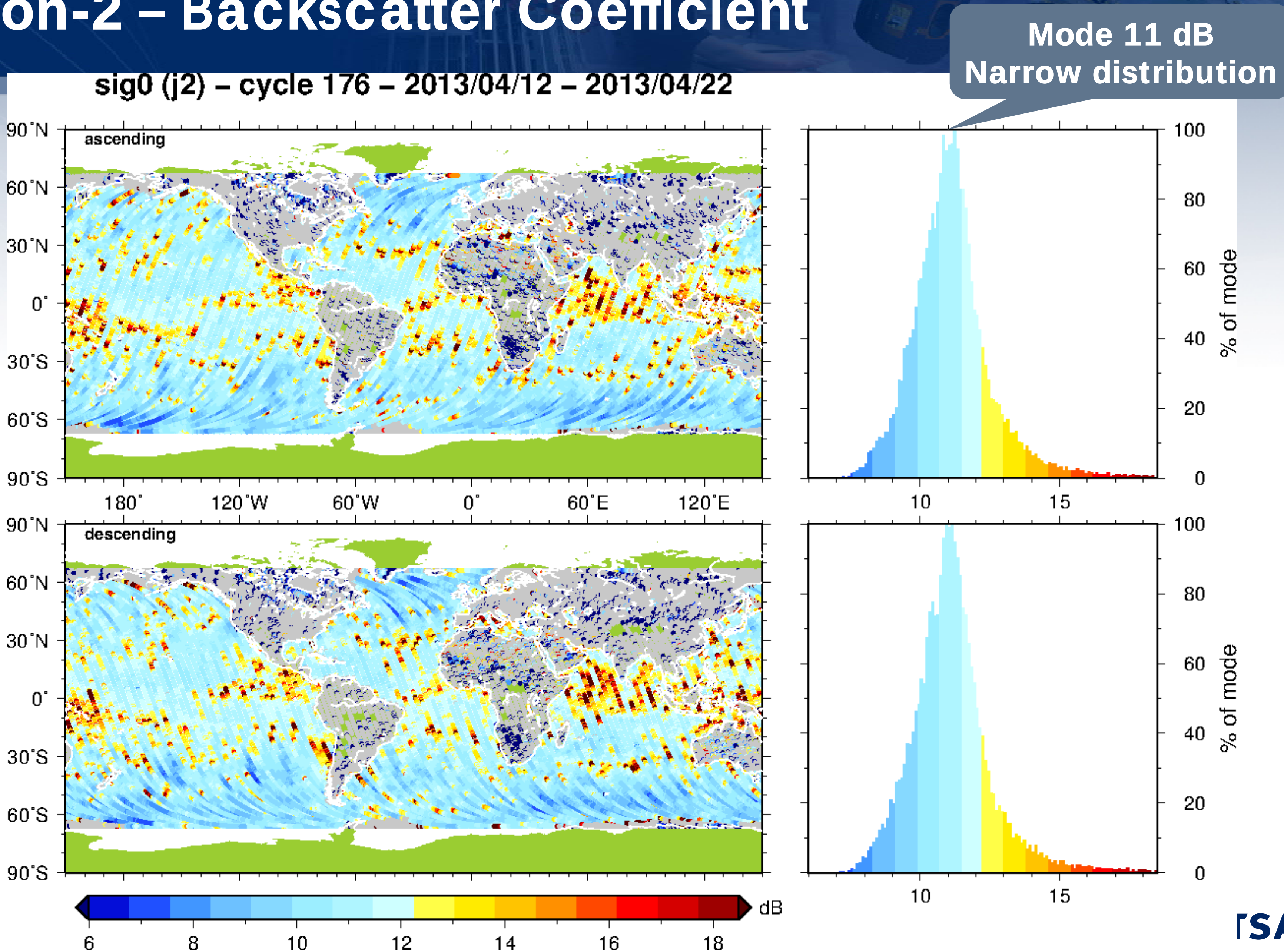
# Jason-2 – Backscatter Coefficient



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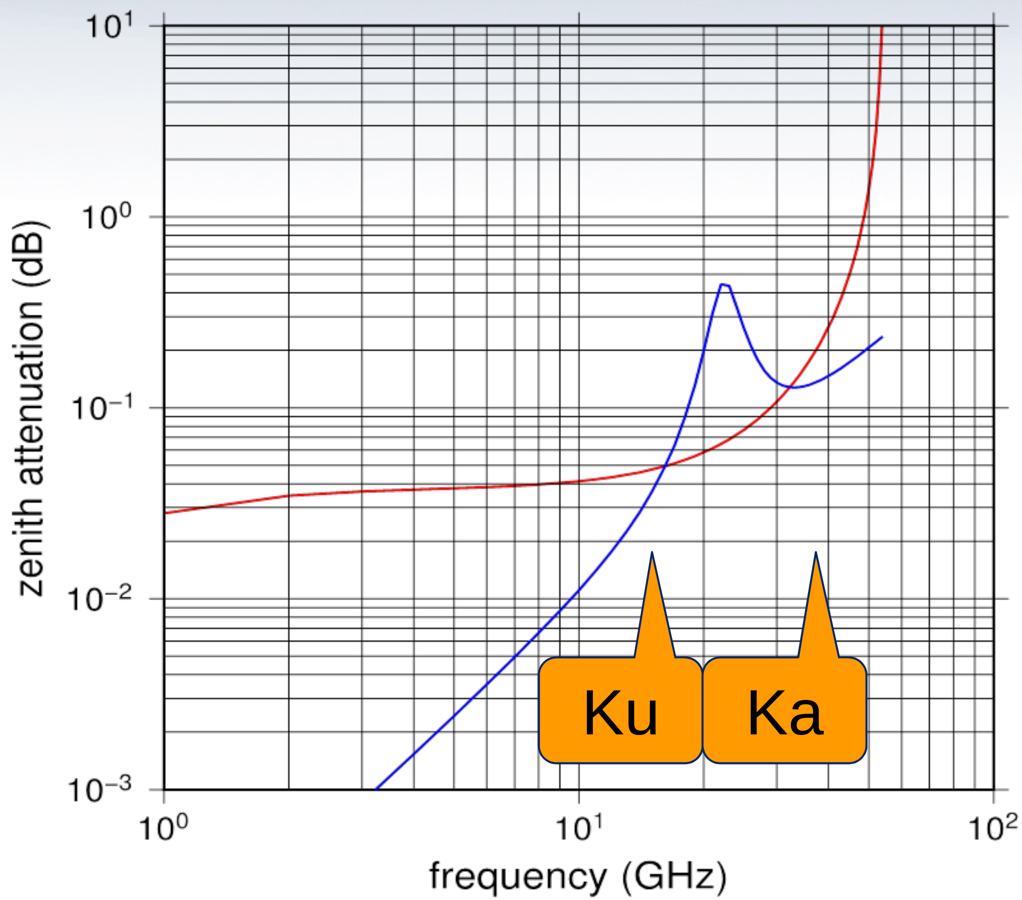
# Backscatter Correction — General

SARAL backscatter originally not corrected for attenuation

- Yet, this is much larger in Ka- than in Ku-band
- Based on radar propagation theory (ITU reports)
- Now backscatter attenuation based on radiometer
- However, not optimal



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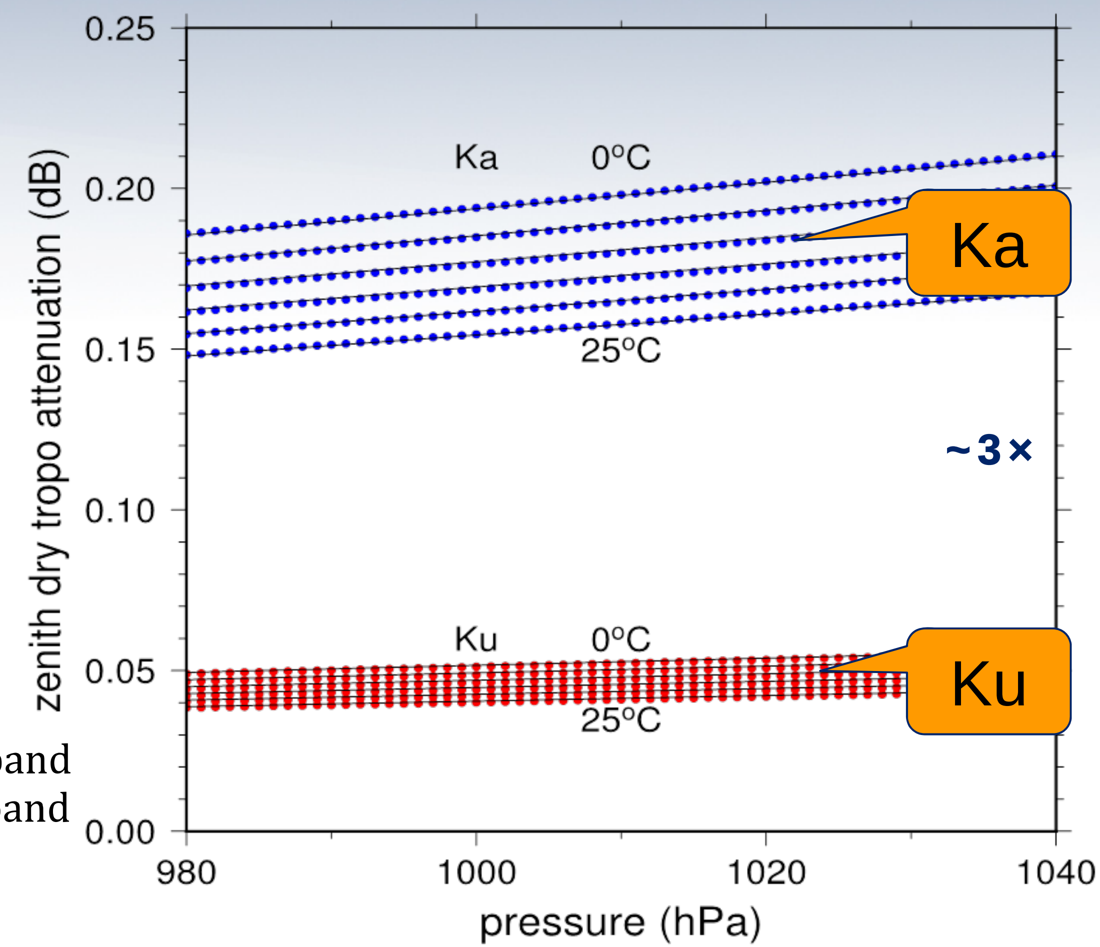
# Backscatter Correction — Dry

## Dry troposphere attenuation

- Jason-2: constant
- In fact, is linear function in pressure and air temperature

$$\Delta\,\sigma^{o}_{\mathrm{dry}} = \begin{cases} 0.094 - 0.177\,p' - 0.145\,t' + 0.274\,p't' & \text{for Ku-band} \\ 0.310 - 0.593\,p' - 0.499\,t' + 0.956\,p't' & \text{for Ka-band} \end{cases}$$

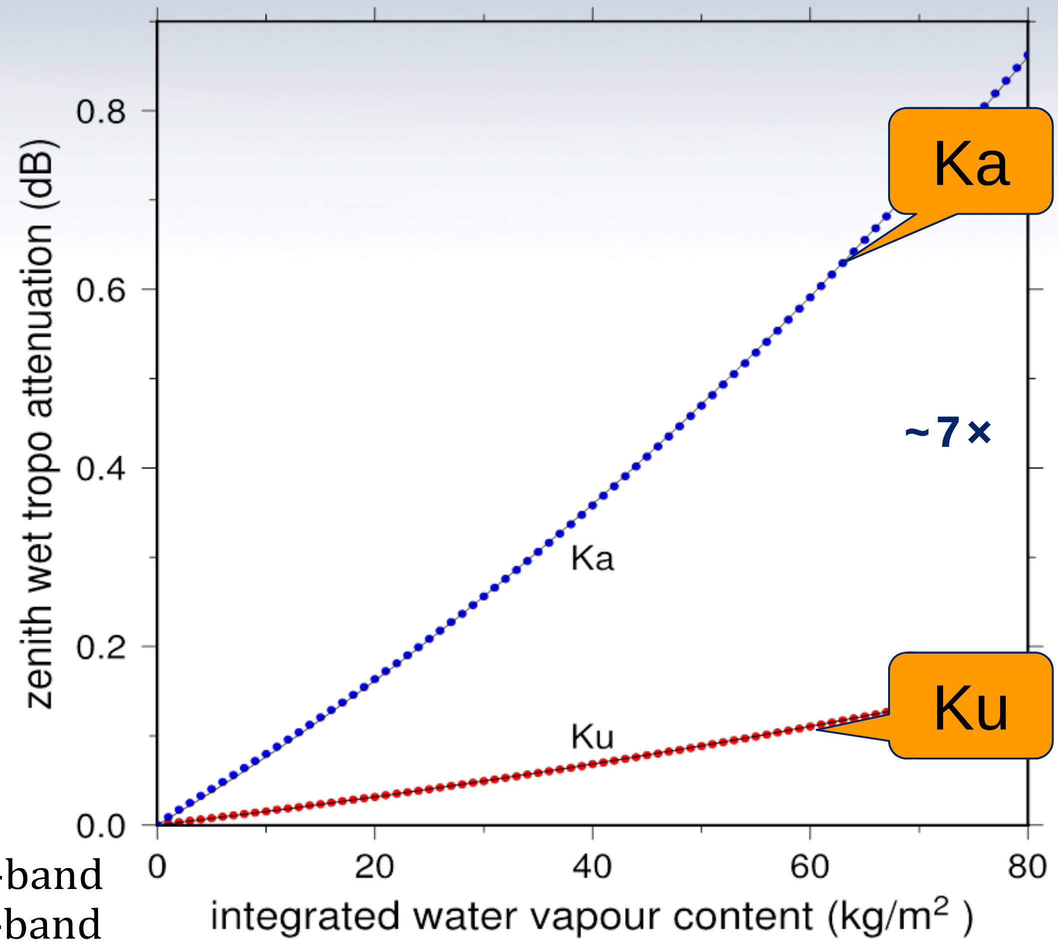
$$p' = p/1013 \qquad p = \text{ pressure in hPa}$$
$$t' = 288.15/t \qquad t = \text{temperature in K}$$



# Backscatter Correction — Wet

Wet troposphere attenuation

- Jason-2: proportional to the wet tropo path delay
- In fact, is quadratic function of water vapour content




$$\Delta\,\sigma^{o}_{\text{wet}} = \begin{cases} 1.45\times10^{-3}\, w + 0.66\times10^{-5}\, w^{2} & \text{for Ku-band} \\ 7.21\times10^{-3}\, w + 4.43\times10^{-5}\, w^{2} & \text{for Ka-band} \end{cases}$$



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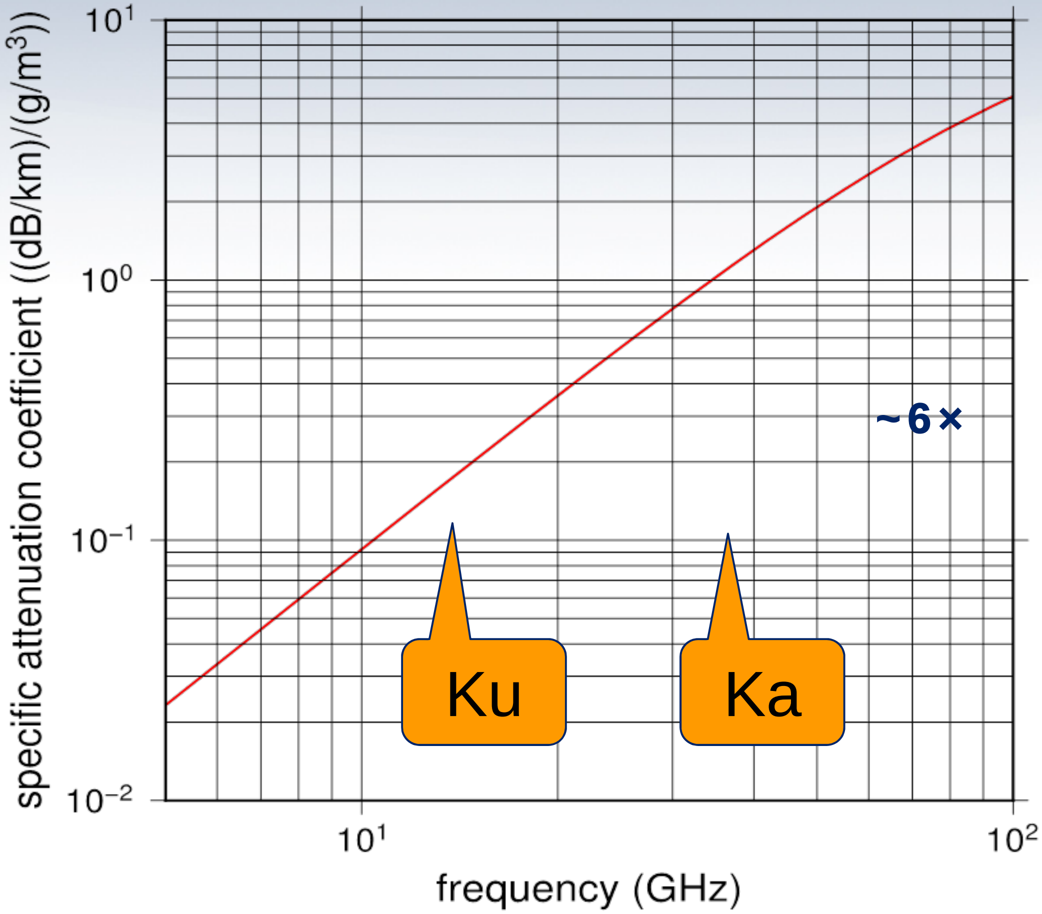
# Backscatter Correction — Liquid Water

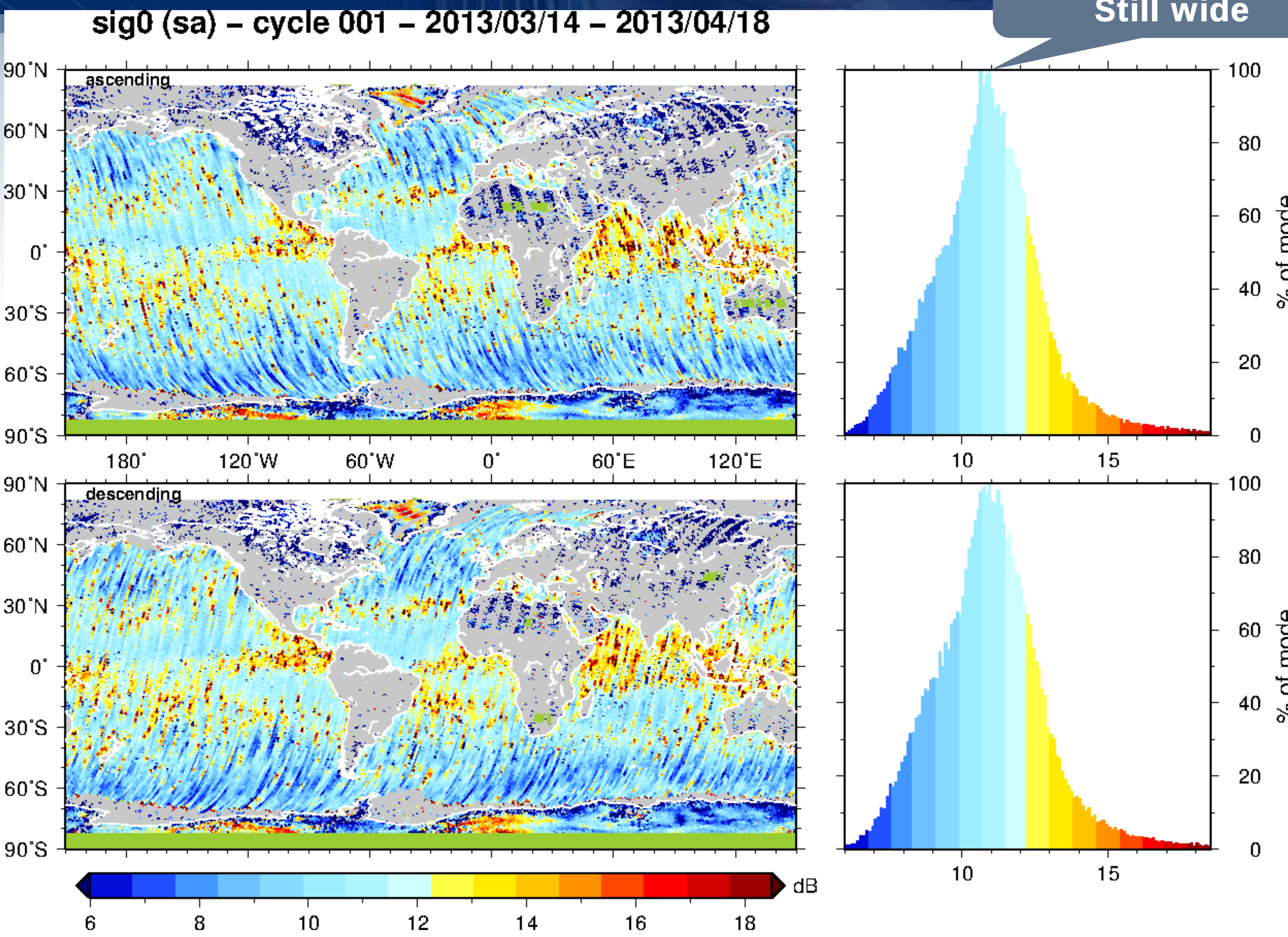
## Liquid water attenuation

- Jason-2: proportional to liquid water content
- That is also what theory says

$$\Delta\,\sigma^o_{\text{rain}} = \begin{cases} 0.169\,L & \text{for Ku-band} \\ 1.070\,L & \text{for Ka-band} \end{cases}$$

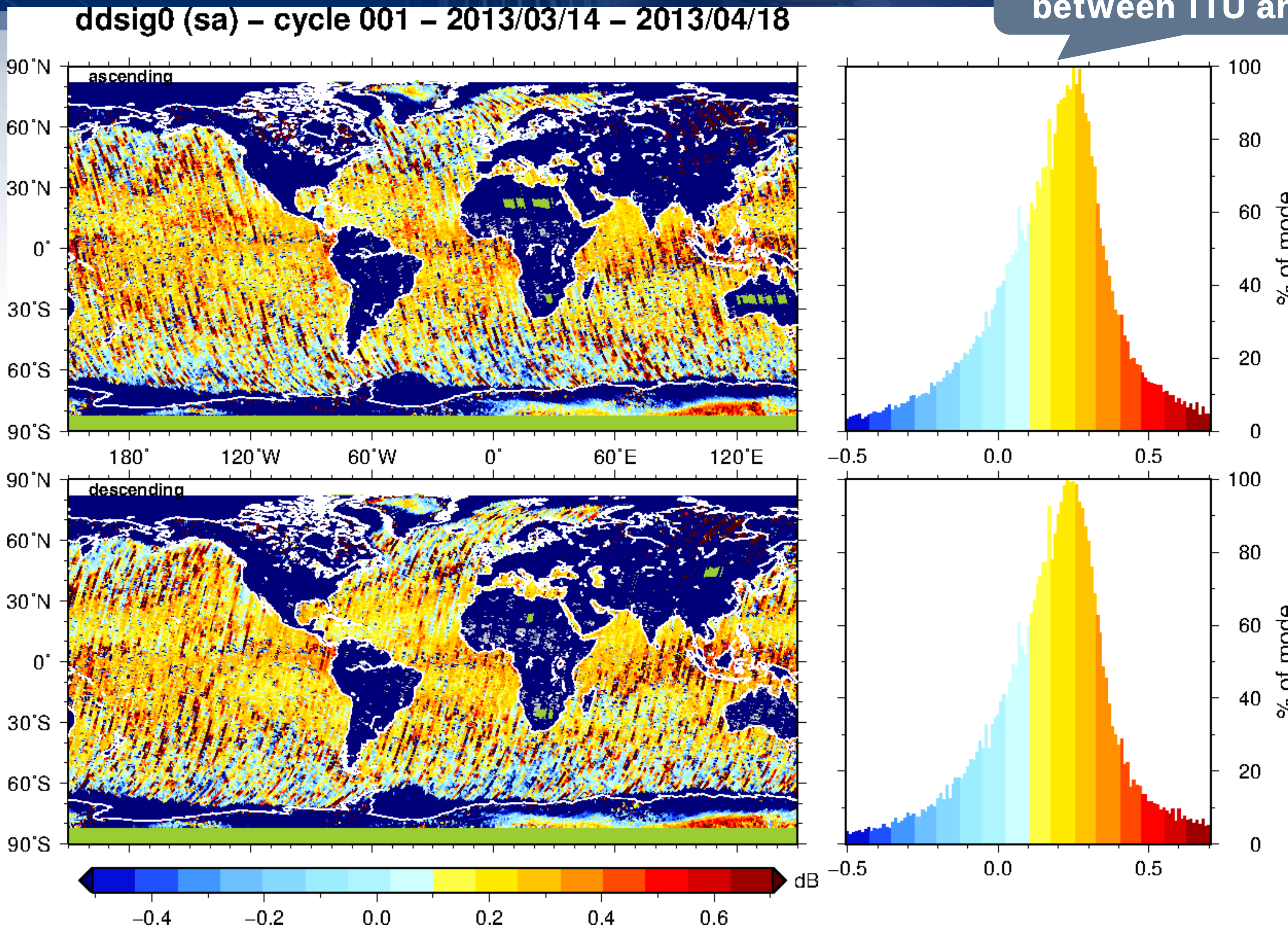


# SARAL – Backscatter Coefficient



# SARAL – Backscatter Coefficient

0.2 dB mean difference between ITU and MWR



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# One-Dimensional Wind Speed Model

## Follow formalism from Abdalla (2007)

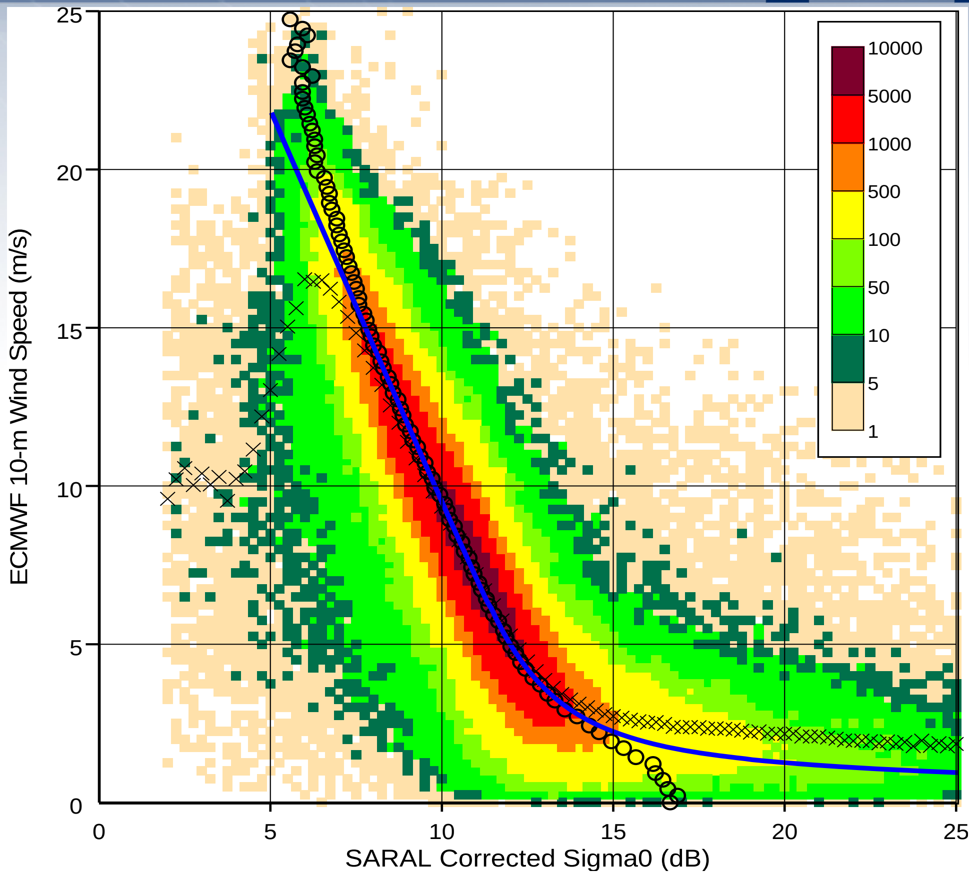
- Originally developed for Envisat's Ku-band altimeter
- Only dependent on backscatter
- Two-branch model: linear (low) + exponential (high)

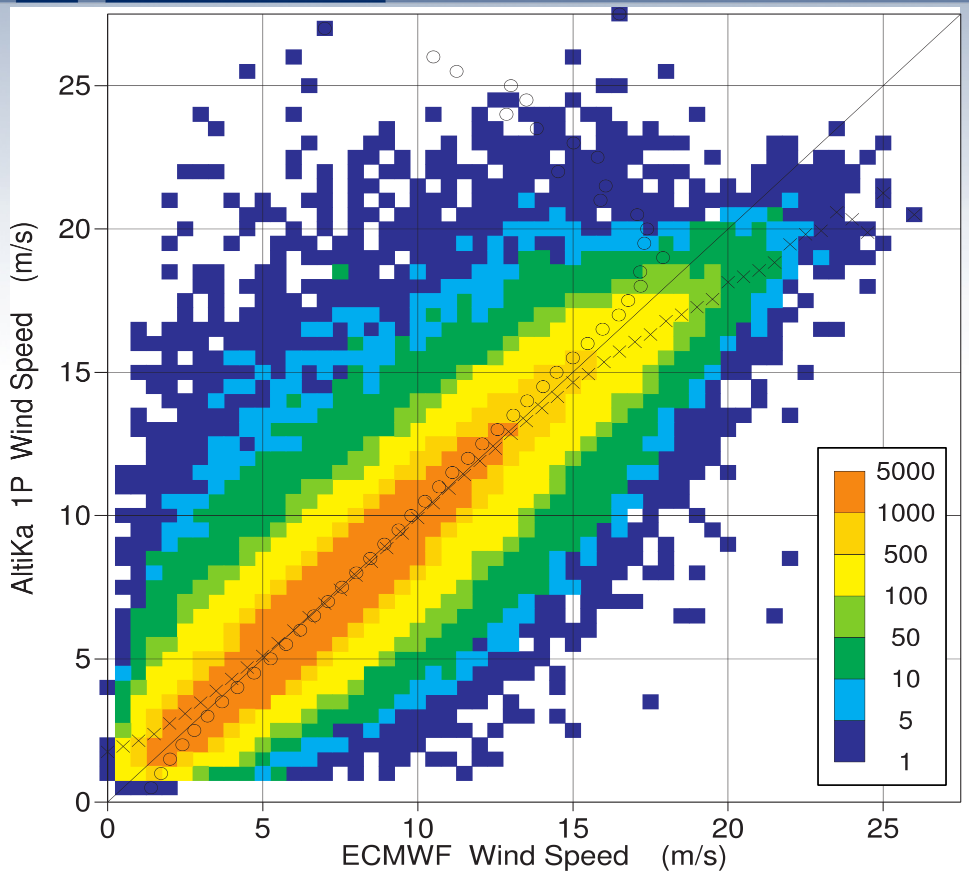
$$U_m = \begin{cases} \alpha - \beta\sigma^o & \text{if } \sigma^o \le \sigma_b \\ \gamma \exp(-\delta\sigma^o) & \text{if } \sigma^o > \sigma_b \end{cases} \qquad U_{10} = U_m + 1.4U_m^{0.096}\exp(-0.32U_m^{1.096})$$

## Correct AltiKa $\sigma^0$ for attenuation first

- Fit model coefficients to ECMWF winds
- Expect different linear slope at Ka vs. Ku

# One-Dimensional Wind Speed Model




$\alpha = 34.2 \quad \beta = 2.48 \quad \sigma_b = 11.409$

$\gamma = 711.6 \quad \delta = 0.42$



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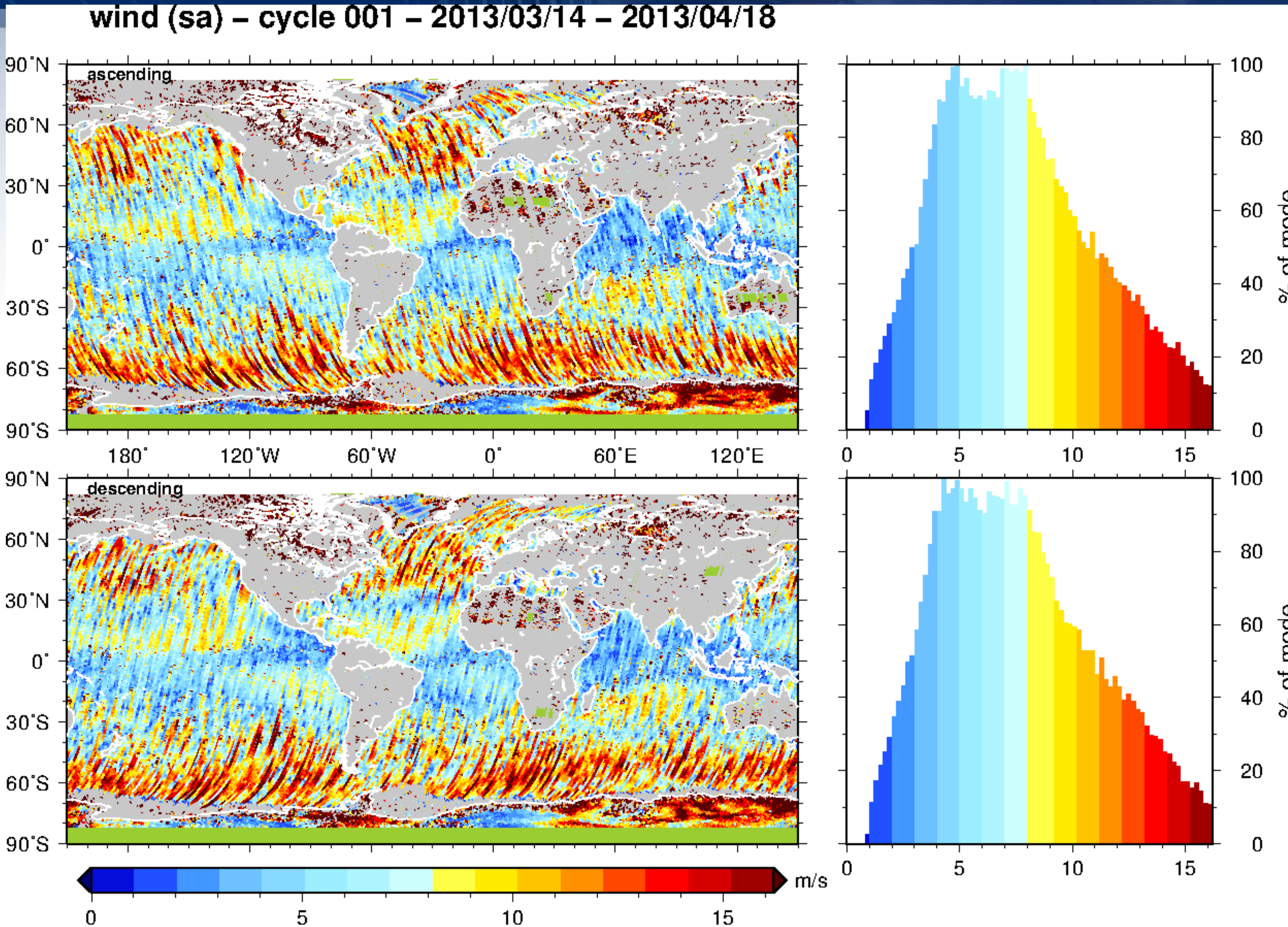
# SARAL – 1-D Wind Speed Model



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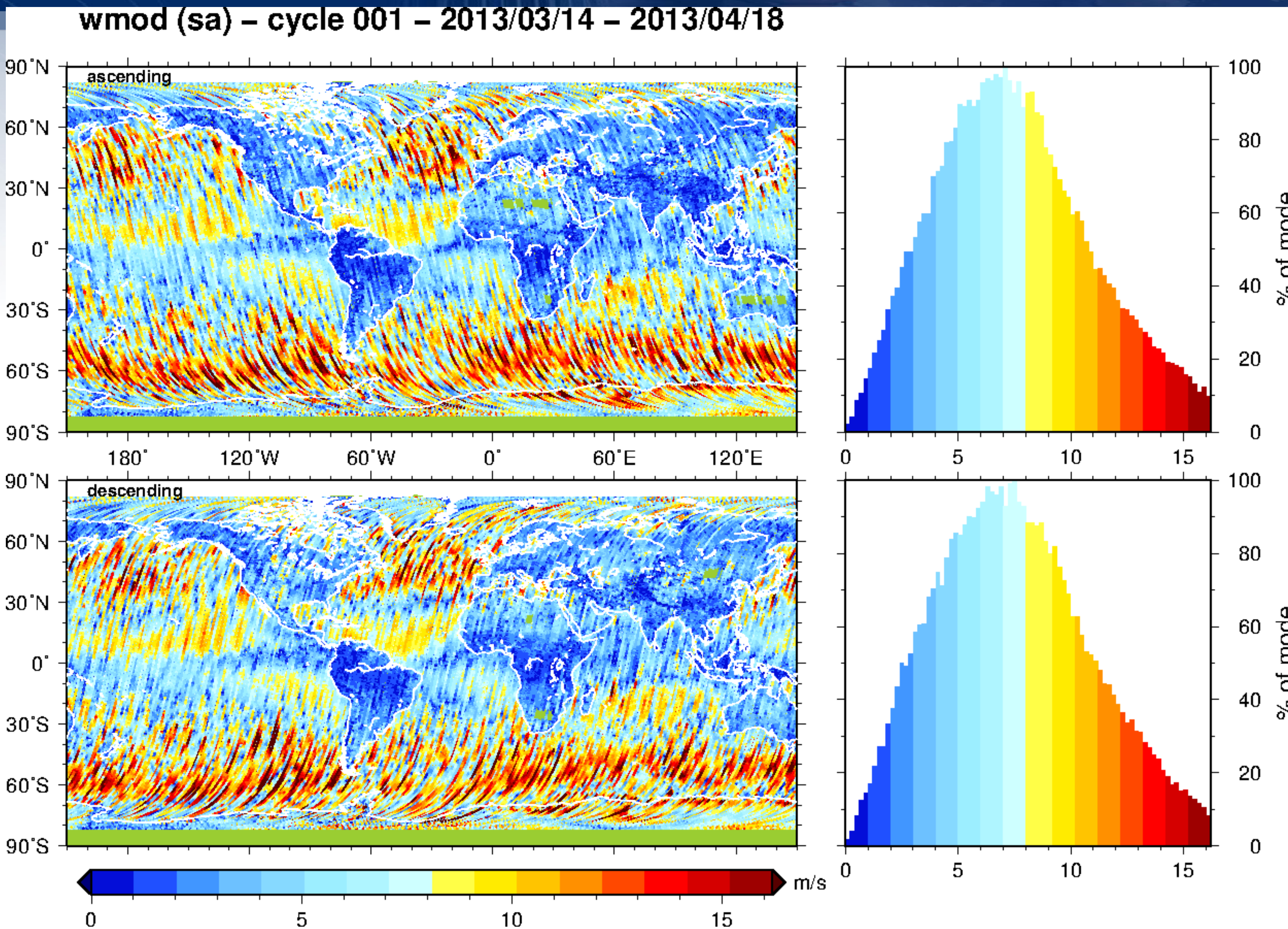
# ECMWF Wind Speed Model





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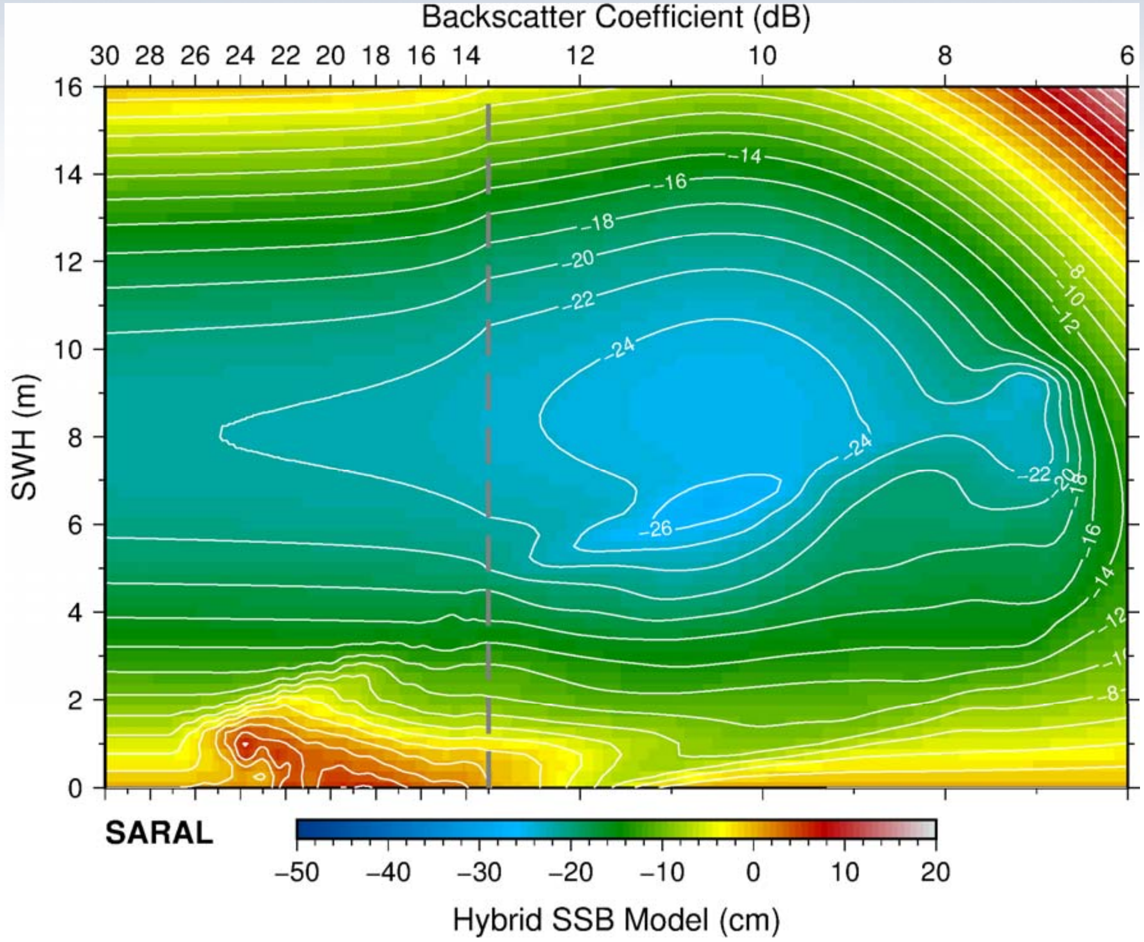
# Hybrid Sea State Bias Model

## Direct method, enhanced

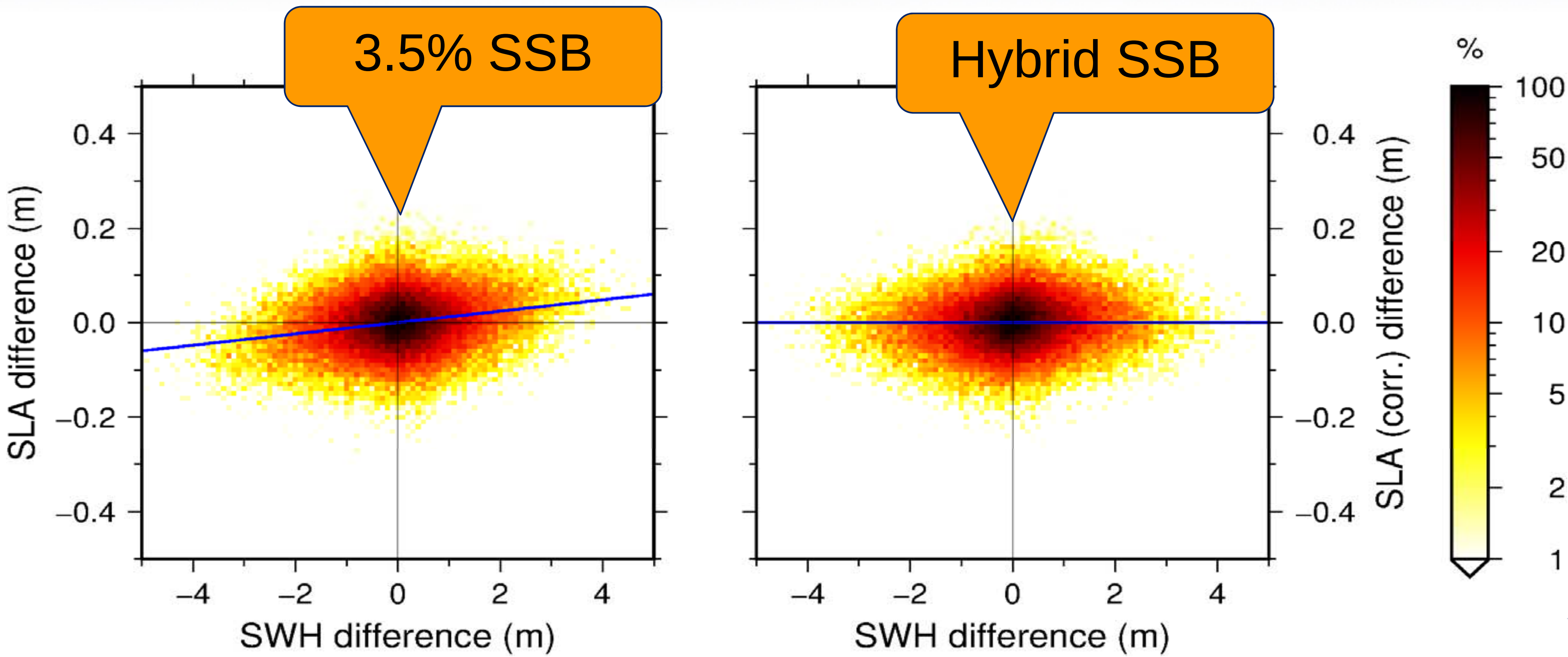
- Sea level anomalies gridded in sigma0-SWH space
- Fit BM4 model
- Blend in residuals
- SSB at higher SWH significantly less than 3.5%



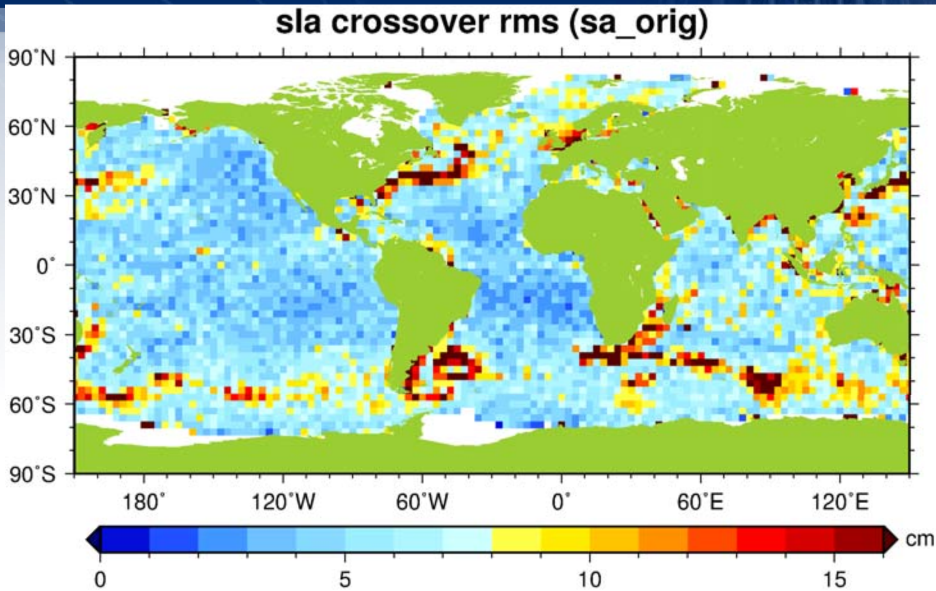
# SSB as seen in crossovers

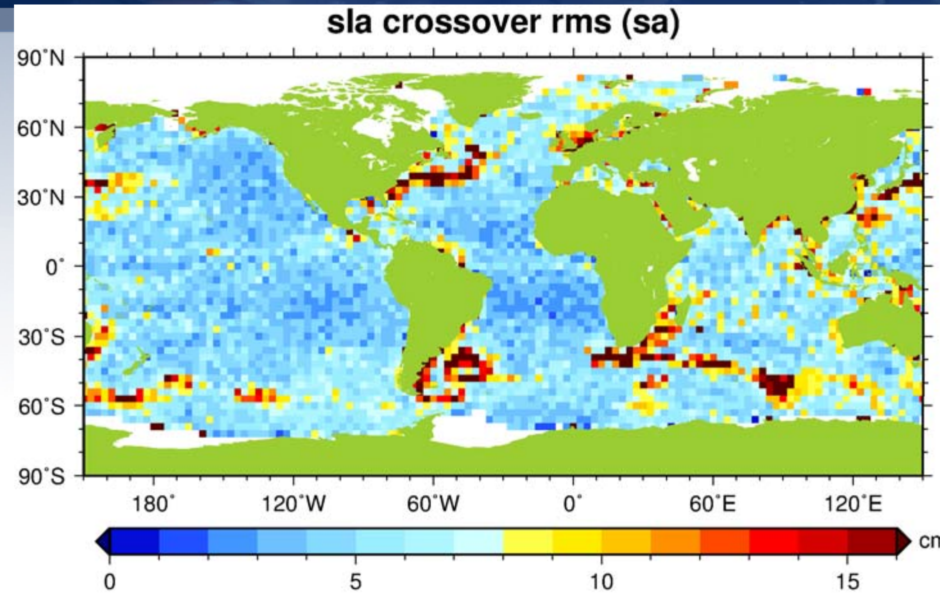
## Single satellite crossovers

- Compare ΔSLA with ΔSWH
- Shows SSB of 3.5% of SWH is too large by ~1%



# Sea Level Anomaly (cm) Crossovers




Single satellite xovers

- Max time difference 17.5 d
- Improvement through SSB
- Insignificant timing bias

Kudos!

| | Mean | Std |
|---|---|---|
| Original (cm) | +0.08 | 7.49 |
| With new SSB (cm) | +0.07 | 7.12 |
| Timing bias (ms) | –0.07 | 0.01 |
| With new SSB (ms) | –0.07 | 0.01 |



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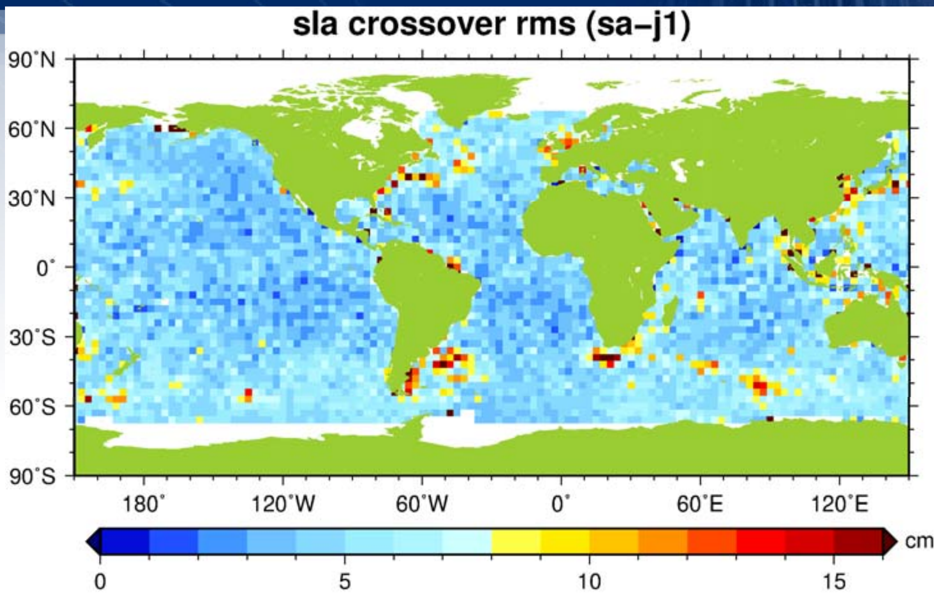
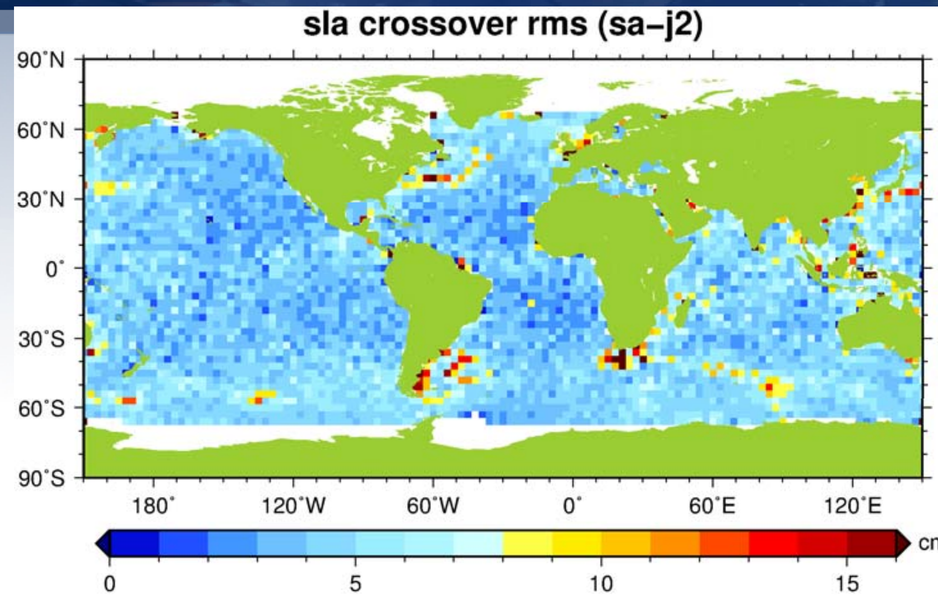
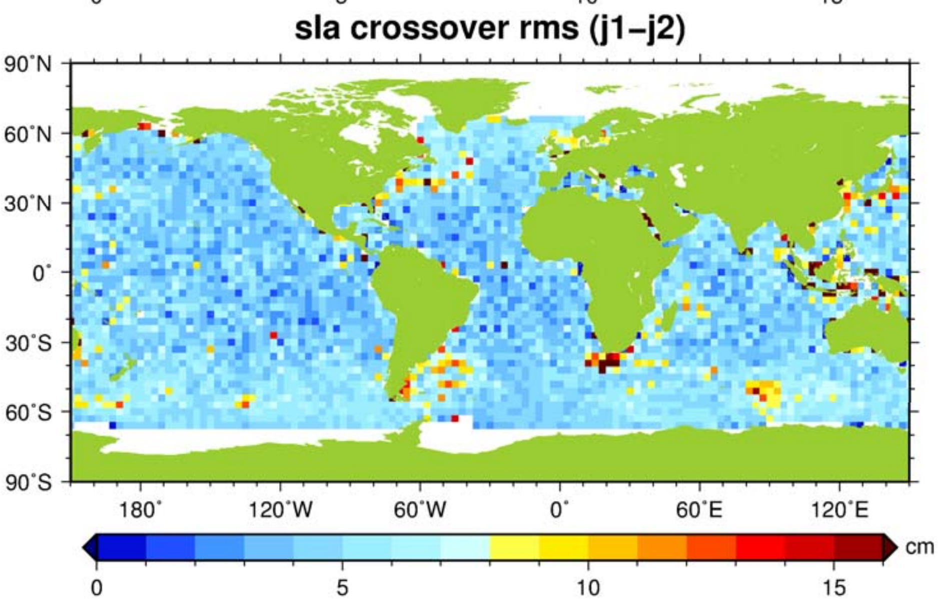
# Sea Level Anomaly (cm) Crossovers

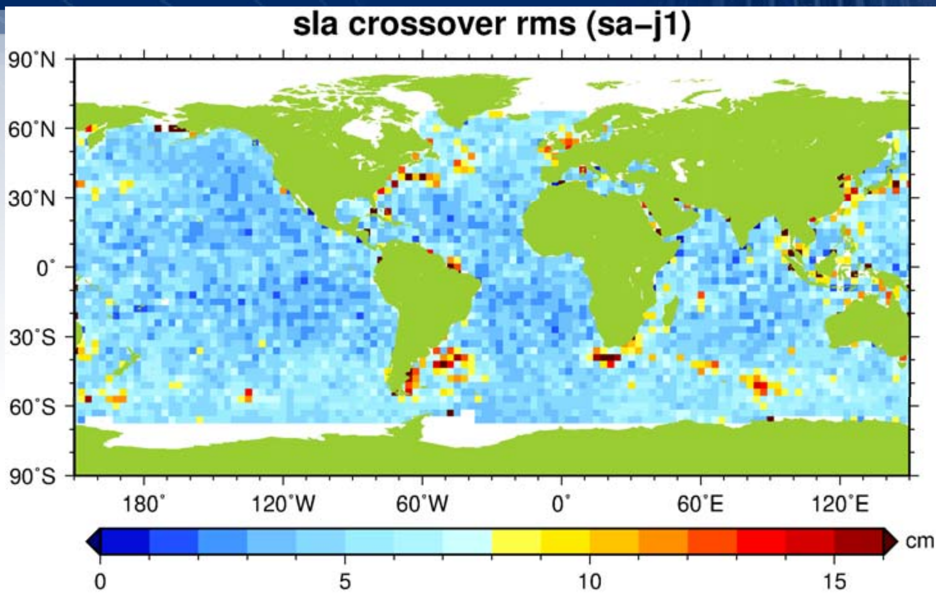


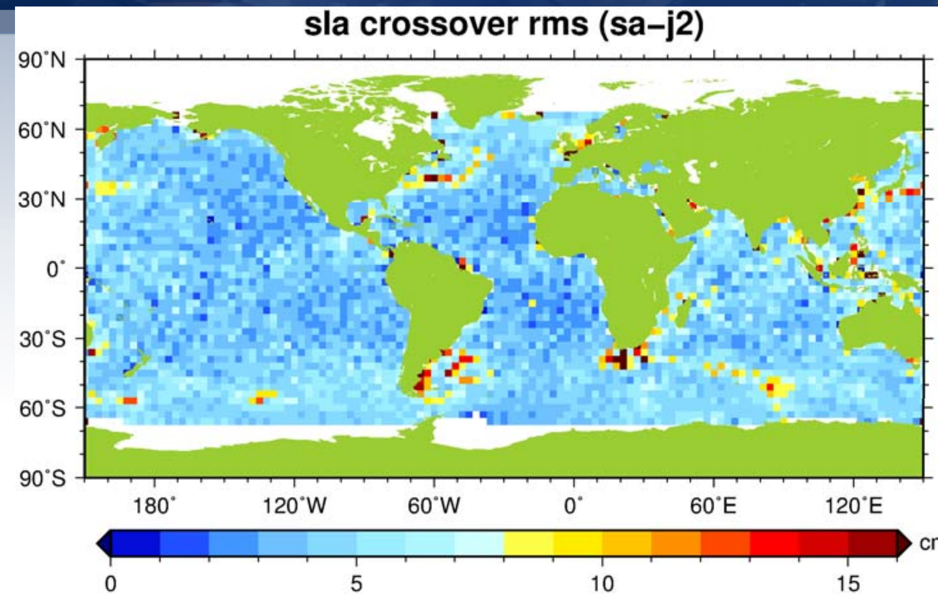



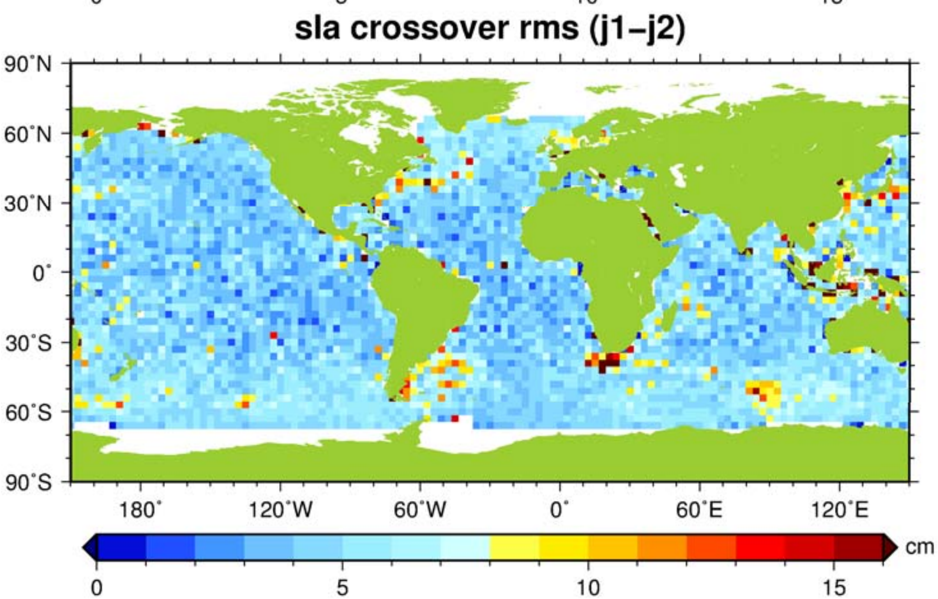




| | Mean | Std |
|---|---|---|
| SARAL – Jason-1 | –0.59 | 5.57 |
| SARAL – Jason-2 | –0.27 | 5.04 |
| Jason-1 – Jason-2 | +0.29 | 5.39 |

# Sea Level Anomaly (cm) Crossovers

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| SARAL – Jason-1 | –0.59 | 5.57 |
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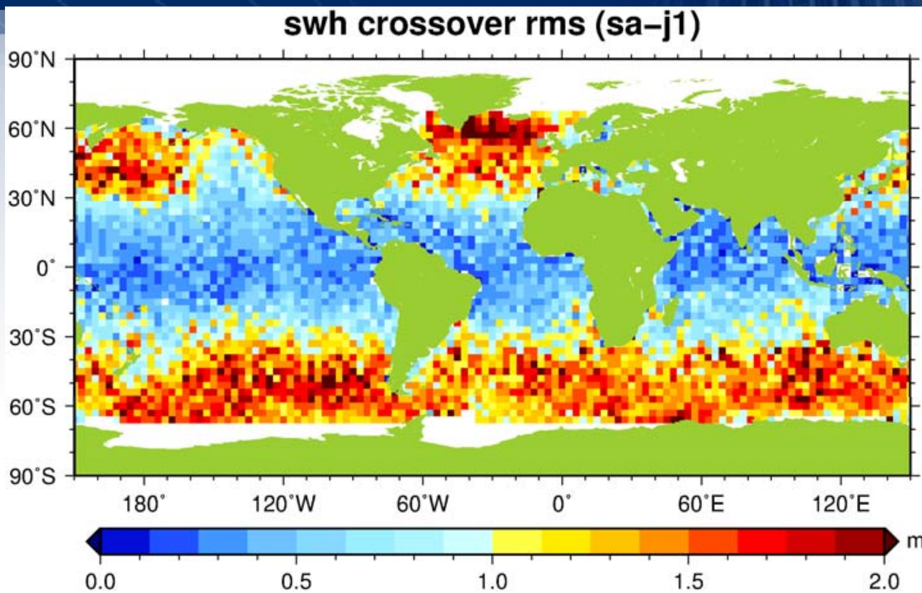
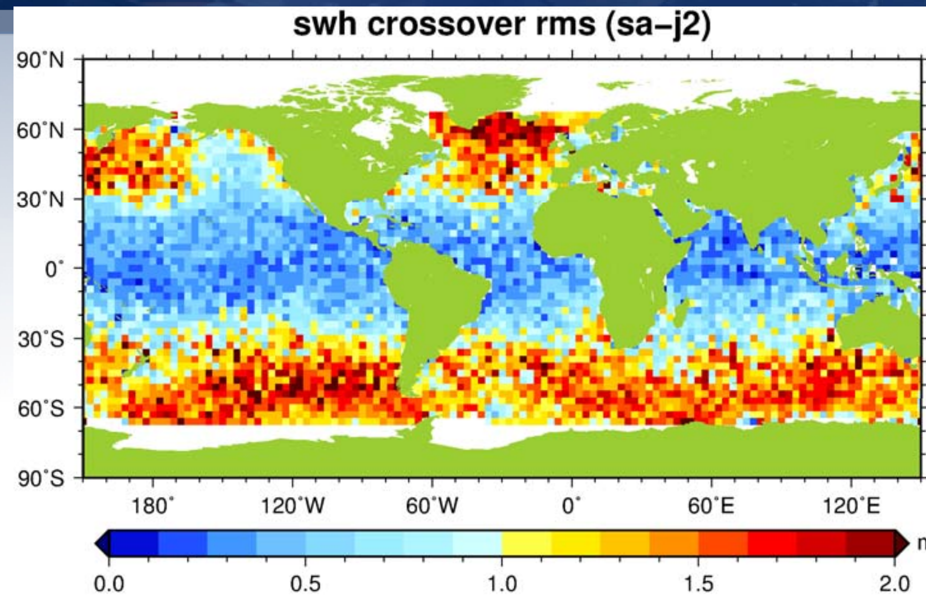
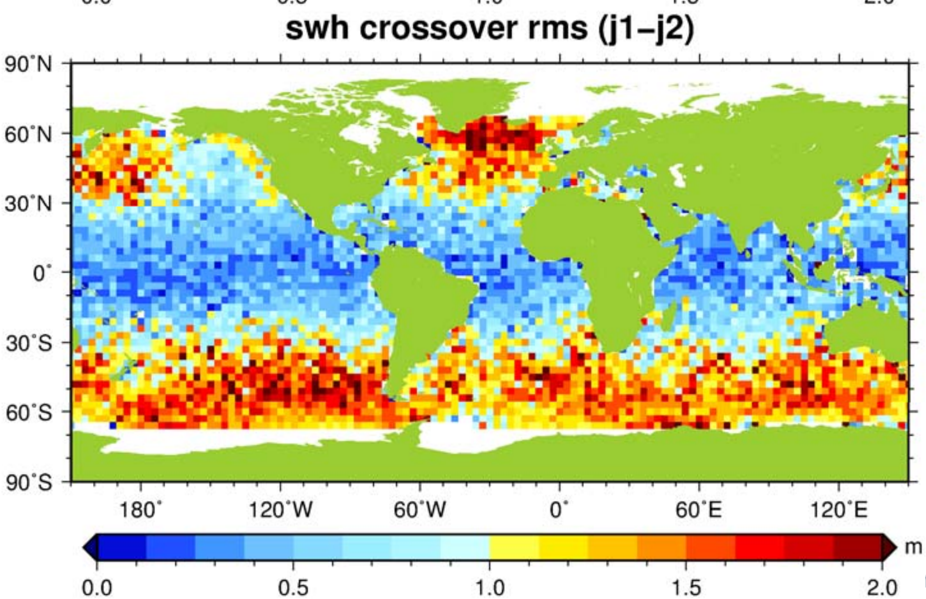
| Jason-1 – Jason-2 | +0.29 | 5.39 |

# Significant Wave Height (m) Crossovers

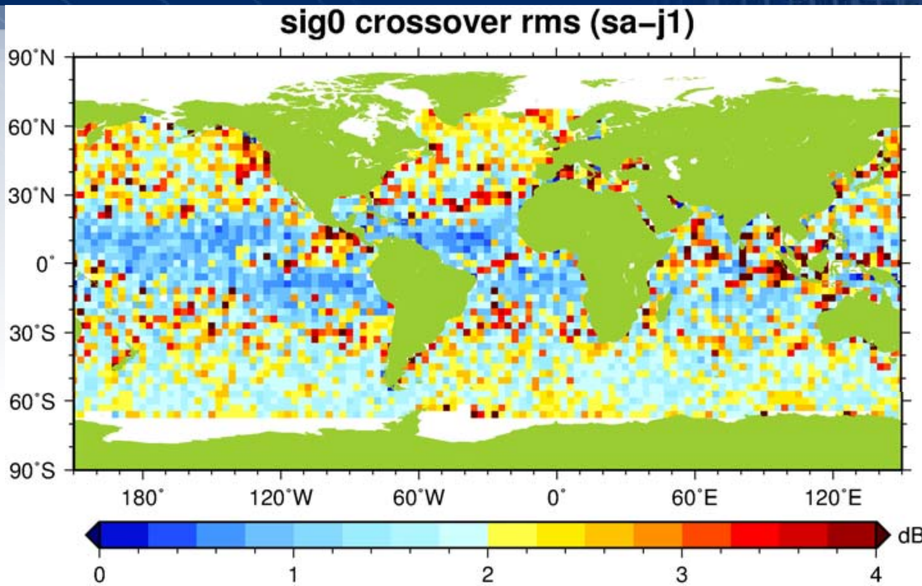


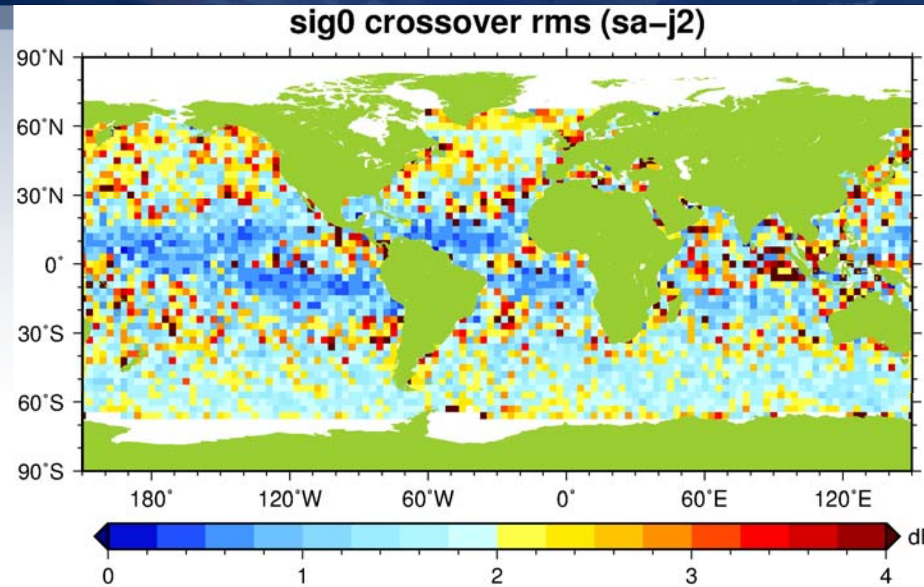



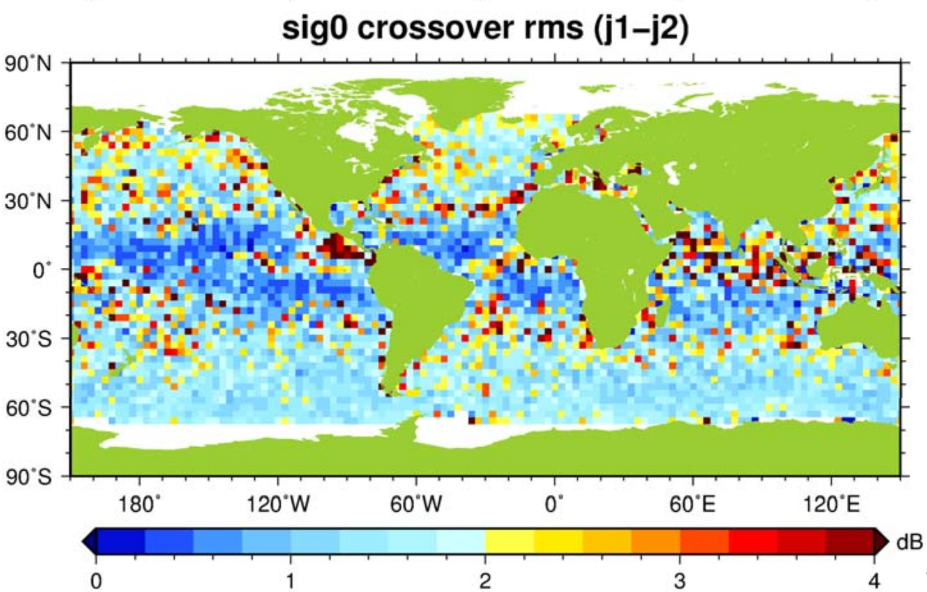




| | Mean | Std |
|---|---|---|
| SARAL – Jason-1 | +0.07 | 1.33 |
| SARAL – Jason-2 | +0.06 | 1.30 |
| Jason-1 – Jason-2 | +0.00 | 1.29 |

# Backscatter Coeffienct (dB) Crossovers




| | Mean | Std |
|---|---|---|
| SARAL – Jason-1 | –0.64 | 1.97 |
| SARAL – Jason-2 | –0.45 | 1.94 |
| Jason-1 – Jason-2 | +0.18 | 1.72 |

# Conclusions (1)

Range

- Performs excellently. Standard deviation of 40-Hz range has a mode at only 5 cm (compare 6 cm for C2, 7 cm for J2)
- Range bias wrt TOPEX with new SSB: long by 6.0 cm.
- Range bias wrt Jason-2 with new SSB: long by 4.2 cm.

SSB

- The current SSB of 3.5% of SWH is too large
- Non-parametric model suggested
- Reduces crossover RMS significantly

# Conclusions (2)

## SWH

- 1:1 relation with Jason-1/2 reference.
- Very small bias with respect to Jason-2.

## Backscatter and wind speed

- Implemented solution for backscatter attenuation
- Proposed new wind speed model

## Wet tropospheric correction

- Radiometer correction not yet fully tuned
- Coastal effect still very large



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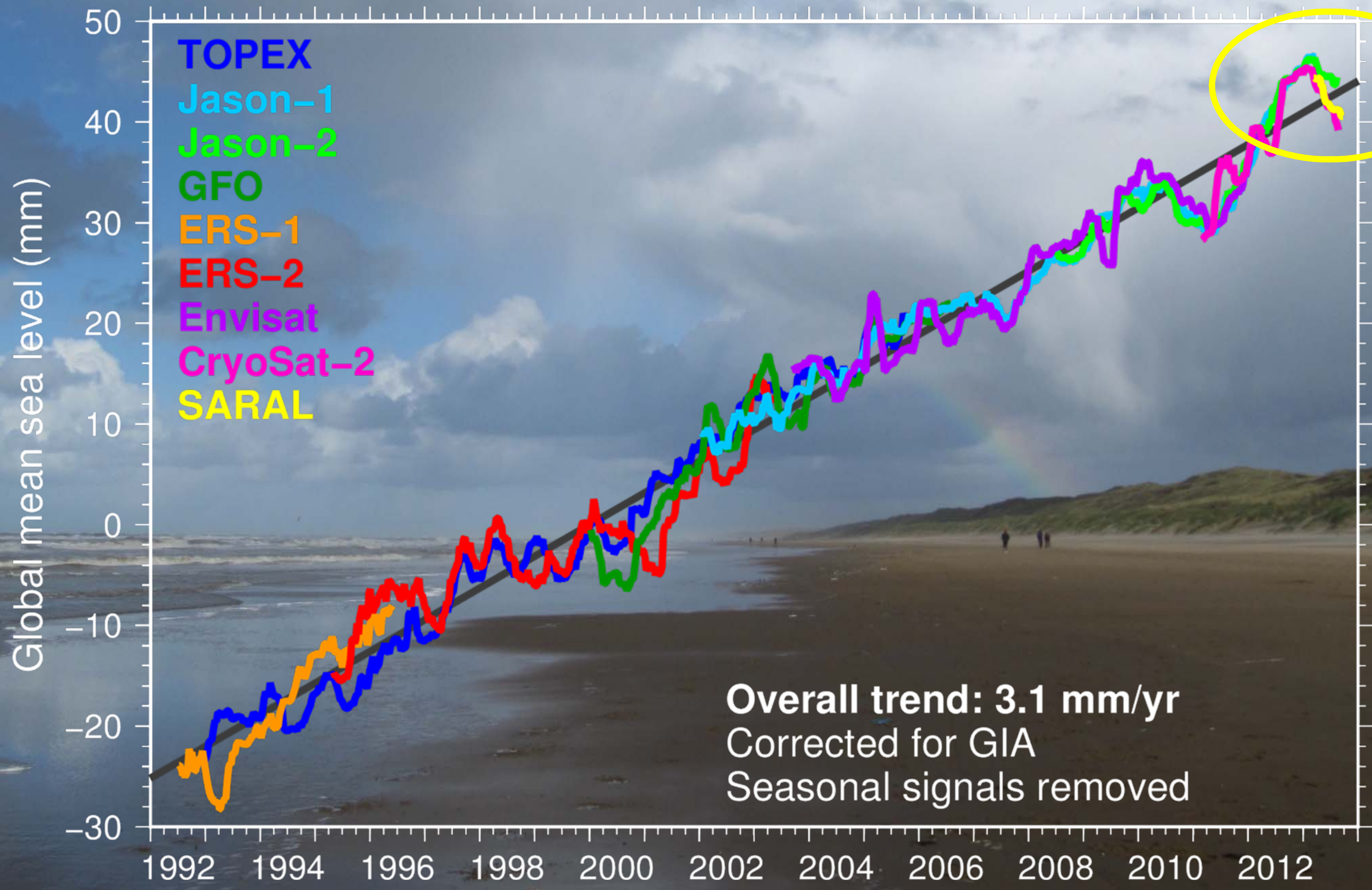
# Thank You



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
TOPEX
Jason−1
Jason−2
GFO
ERS−1
ERS−2
Envisat
CryoSat−2
SARAL
Overall trend: 3.1 mm/yr
Corrected for GIA
Seasonal signals removed