SCAT calibration approach @ TU-Wien

Presentation to

SCIRoCCO project team
ESA

scirocco
scatterometer instrument
competence centre

Presented by

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Vienna University of Technology

Outline

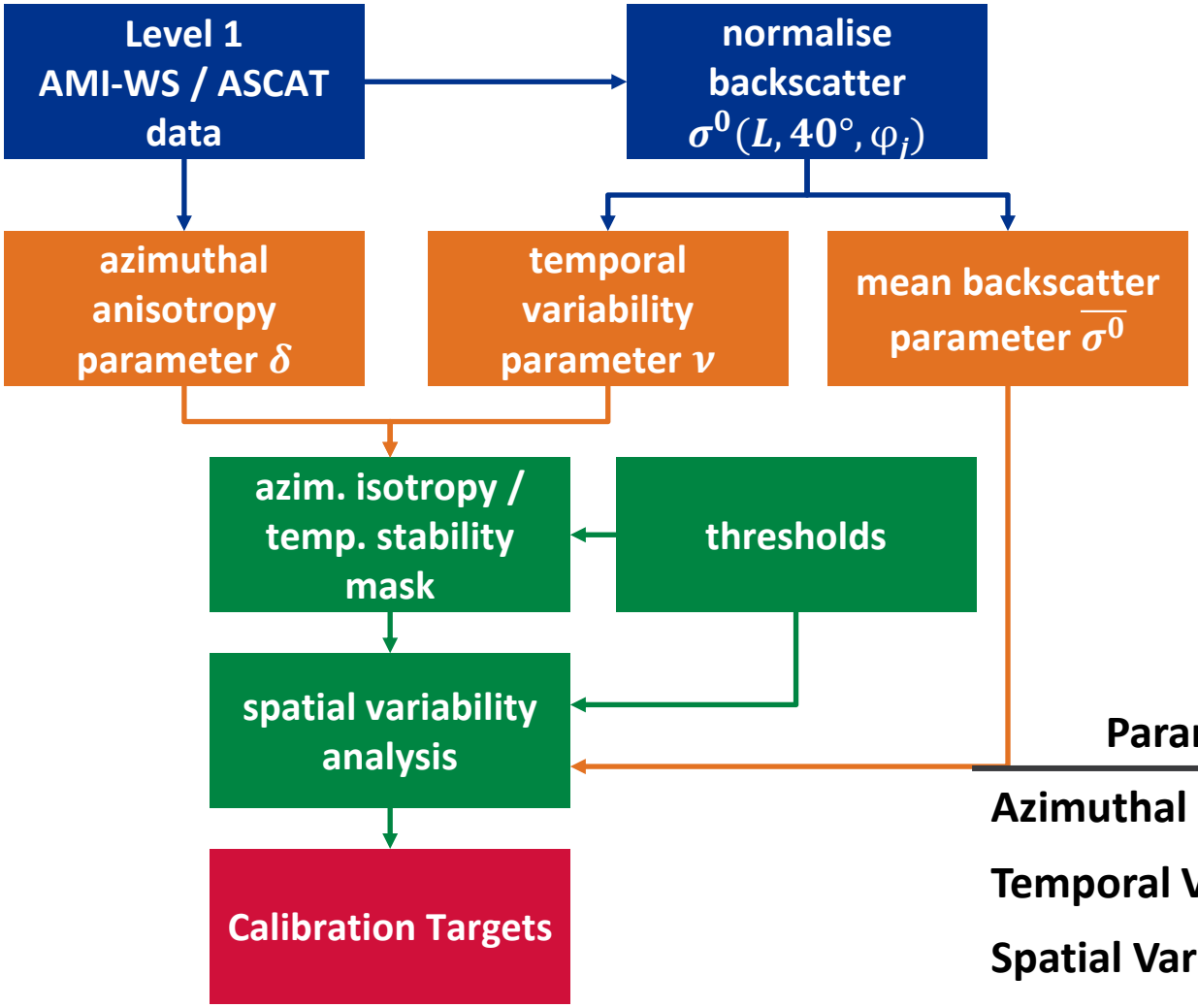
- Calibration methodology
  - intra-calibration / inter-calibration
- Sensor “intra-calibration”
  - Theoretical framework
  - Results / Verification
    - ERS-2 SCAT and
    - MetOp-A ASCAT
- Sensor “inter-calibration”
  - Theoretical framework
  - Results / Verification
    - ERS-2 SCAT → MetOp-A ASCAT
- (MetOp-B ASCAT calibration)

Calibration methodology

- Stepwise relative calibration strategy
  - Sensor “intra-calibration”
    - Detect and correct for temporal inconsistencies of an individual mission
  - Sensor “inter-calibration”
    - Detect and correct for biases between SCAT missions
  - Utilising a “set of natural calibration targets” over land
- Level 1 scatterometer data

Instrument	Spatial Resolution	Temporal Coverage	Spatial Coverage
ERS- 2 SCAT	25 km	May 1997 – Feb. 2003	Global
MetOp-A ASCAT	25 km	Jan. 2007 – Nov. 2012	Global

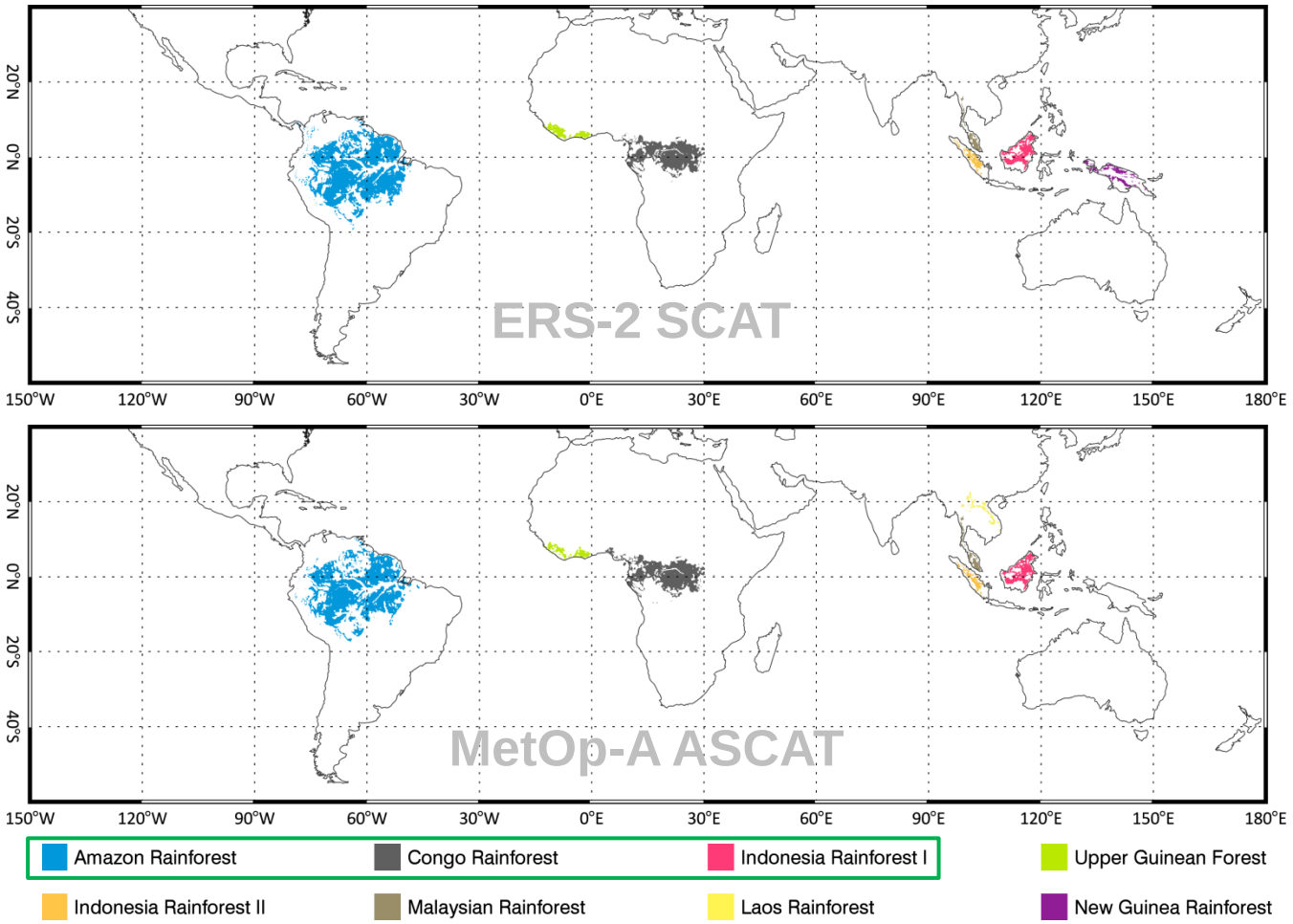
Selection of calibration targets



Parameter	Threshold AMI	Threshold ASCAT
Azimuthal Anisotropy	0.3 dB	0.2 dB
Temporal Variability	0.4 dB	
Spatial Variability	0.25 dB	

Selected calibration targets

- Selection based on global backscatter analysis
  - Azimuthal modulations
  - Temporal variability
- Calibration Tar.
- Verification Tar.



Sensor “intra-calibration”

Measurement Model:

$$\underbrace{\sigma^0(L_T, t_i, \theta, \phi_j)}_{\text{meas. RCS}} = \underbrace{\widetilde{\sigma^0}\,(L_T, \theta)}_{\text{true RCS}} + \underbrace{\tilde{C}_{intra}(L_T, t_i, \theta, \phi_j)}_{\text{calibration coeff.}} + \epsilon$$

Estimate of $\widetilde{\sigma^0}\,(L_T, \theta)$ → Calibration Reference $\overline{\sigma^0}(L_T, \theta)$:

$$\underbrace{\overline{\sigma^0}(L_T, \theta)}_{\text{Cal. Ref.}} = \frac{1}{n_{obs} * n_{ac}} \sum_{i=1}^{n_{obs}} \sum_{j=1}^{n_{ac}} \underbrace{\sigma^0(L_T, t_i, \theta, \phi_j)}_{\text{meas. RCS}}$$

$$\underbrace{\tilde{C}_{intra}(L_T, t_i, \theta, \phi_j) = 0}_{\text{Perfectly calibrated}}$$

Solve for calibration coefficient: $\tilde{C}_{intra}(L_T, t_i, \theta, \phi_j) + \epsilon = \sigma^0(L_T, t_i, \theta, \phi_j) - \overline{\sigma^0}(L_T, \theta)$

Estimate calibration coefficient:

$$\underbrace{\overline{C}_{intra}(t_i, \theta, \phi_j)}_{\text{Intra-Cal. Coeff.}} = \frac{1}{n_{tar}} \sum_{T=1}^{n_{tar}} (\tilde{C}_{intra}(L_T, t_i, \theta, \phi_j) + \epsilon)$$

Sensor “intra-calibration”:

$$\underbrace{\sigma^0_{intra}(L, t_i, \theta, \phi_j)}_{\text{calibrated RCS}} = \underbrace{\sigma^0(L, t_i, \theta, \phi_j)}_{\text{meas. RCS}} - \underbrace{\overline{C}_{intra}(t_i, \theta, \phi_j)}_{\text{Intra-Cal. Coeff.}}$$

Calibration reference

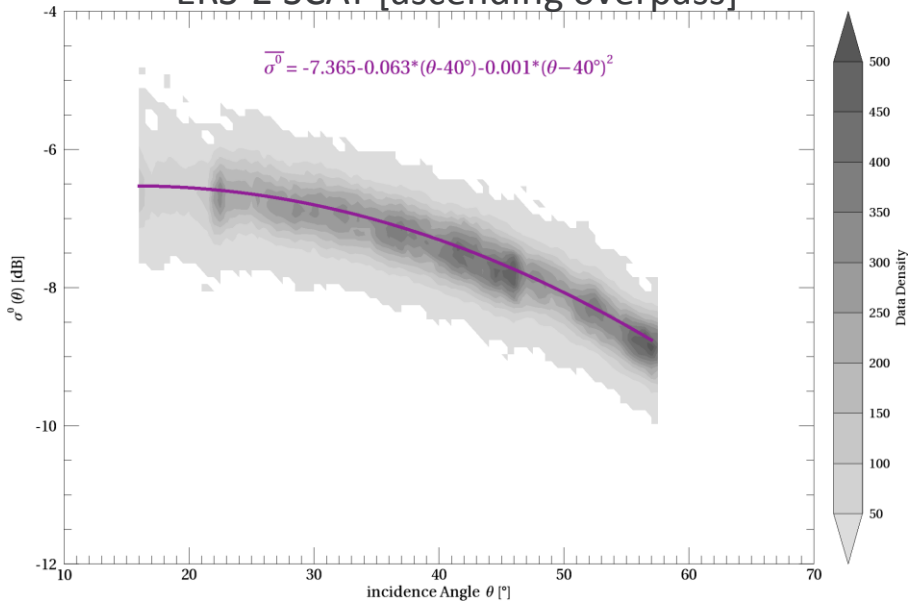
$$\overline{\sigma^0}(L_T,\theta) = \frac{1}{n_{obs}} \sum_{i=0}^{n_{obs}} \sigma^0(L_T, t_i, \theta, \phi_j) = B_0(L_T, 40^\circ) + \sum_{p=1}^{n_{poly}=2} B_p(L_T, 40^\circ) * (\theta - 40^\circ)^p$$

- **ESCAT data of year 1998**
- **ASCAT data of year 2007**

Δ overpasses ≈ 0.1 – 0.2 dB [asc - desc]
→ Calibration reference per overpass

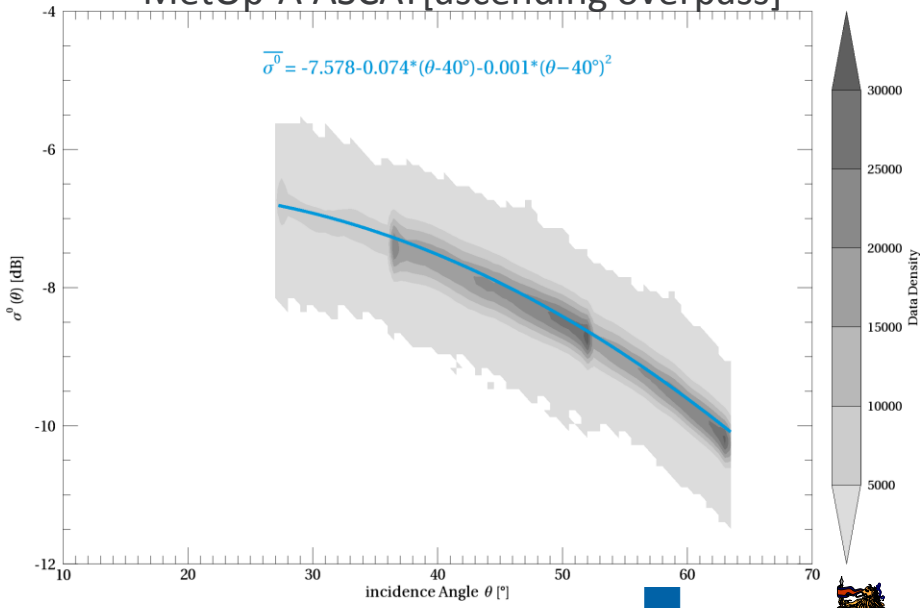
New Guinea Rainforest

ERS-2 SCAT [ascending overpass]



Amazon Rainforest

MetOp-A ASCAT[ascending overpass]



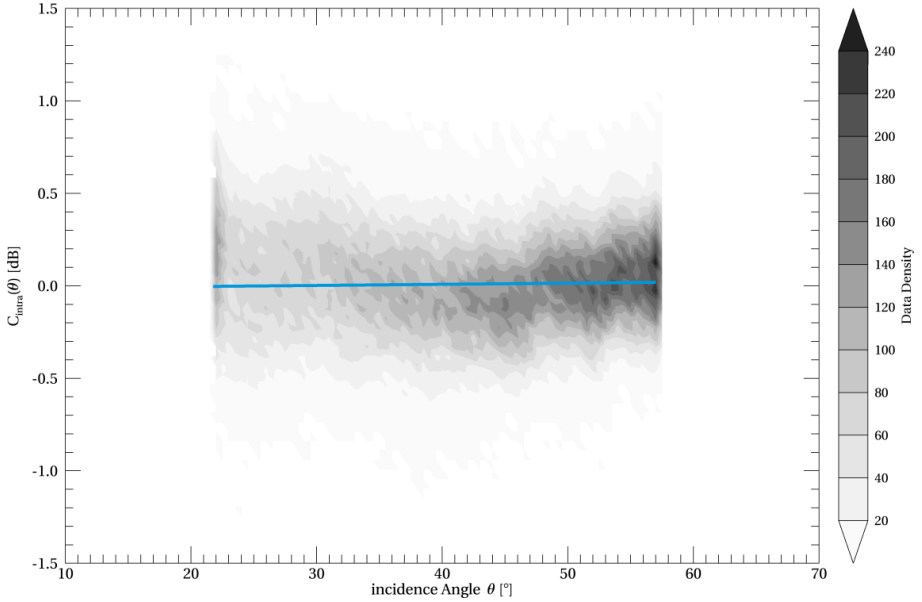
Estimation of intra-calibration coeff.

$$\overline{C}_{intra}(L_T, t_i, \theta, \phi_j) = \sigma^0(L_T, t_i, \theta, \phi_j) - \overline{\sigma^0}(L_T, \theta)$$

$\overline{C}_{intra}(L_T, t_i, \theta, \phi_j)$ modelled as 1-order polynomial centred at 40° per month

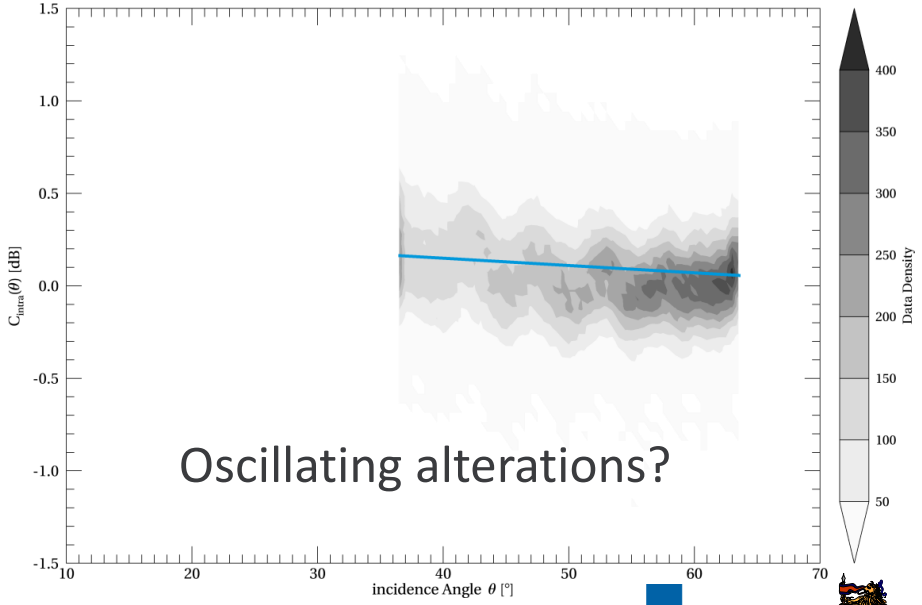
Amazon Rainforest July 1999

ESCAT [Fore-beam / Right Swath]



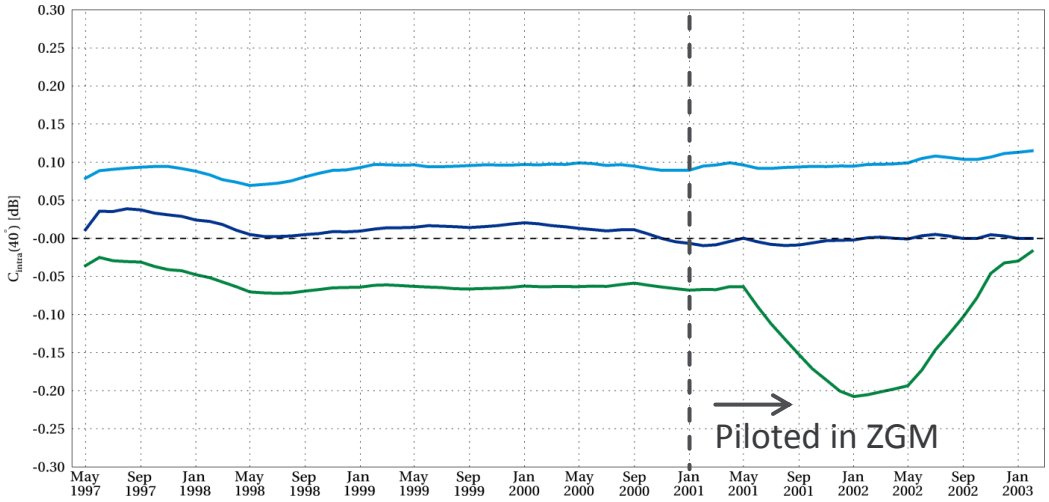
Amazon Rainforest July 2010

ASCAT [Fore-beam / Right Swath]



Oscillating alterations?

Intra-Calibration anomalies



ERS-2 SCAT

Right Swath:
Fore-/**Mid-**/**Aft-**beam

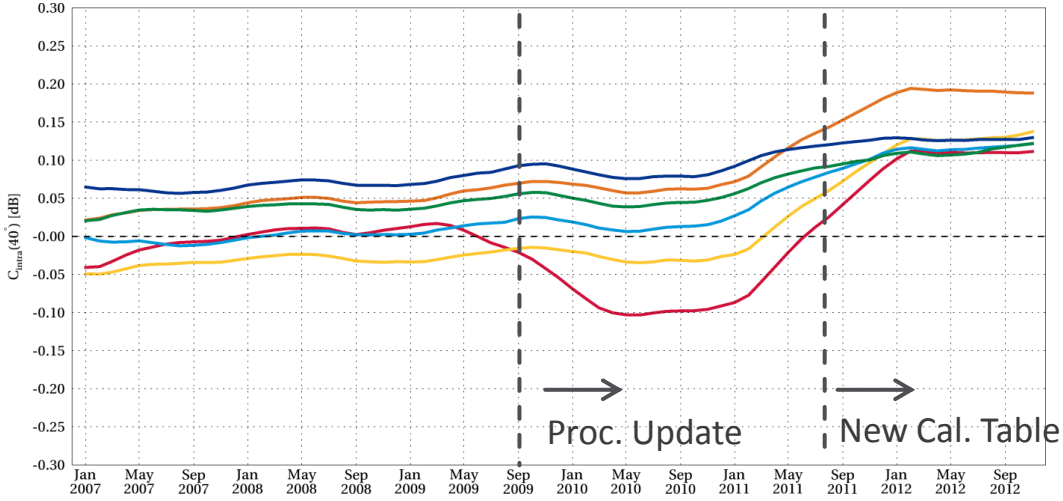
Mean over Calibration Targets

$$\overline{C}_{intra}(t_i, 40°, \phi_j)$$

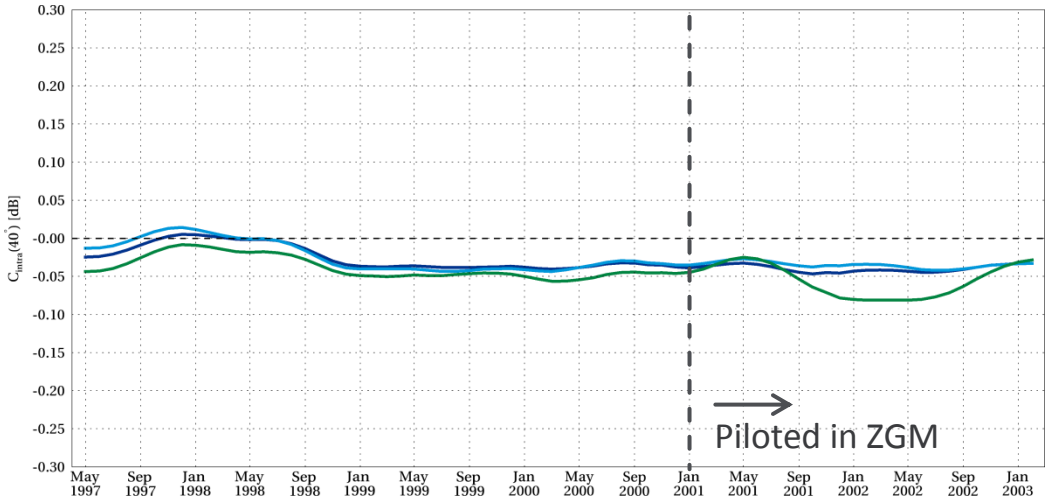
MetOp-A ASCAT

Right Swath:
Fore-/**Mid-**/**Aft-**beam

Left Swath:
Fore-/**Mid-**/**Aft-**beam



Intra-Calibration verification



ERS-2 SCAT

Right Swath:
Fore-/**Mid-**/**Aft-**beam

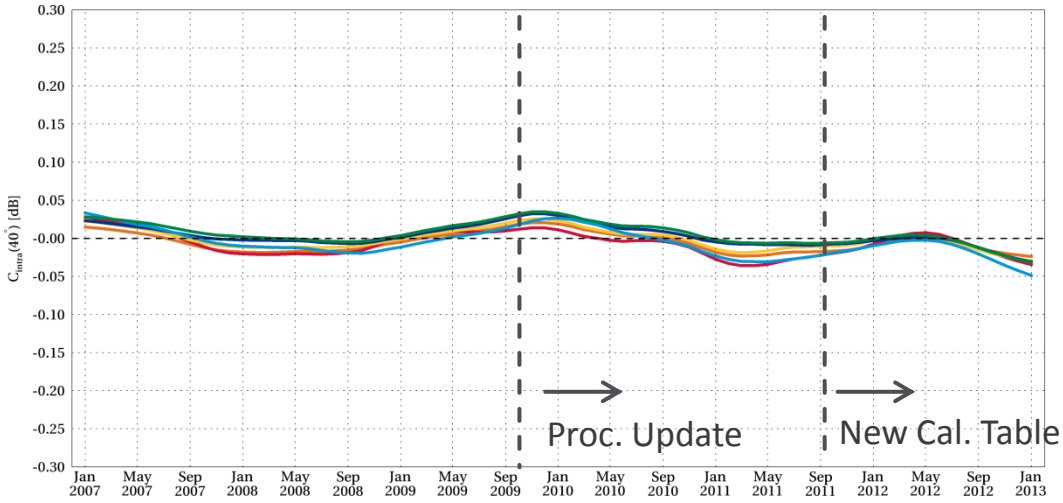
Mean over Verification Targets

$\overline{C}_{intra}(t_i, 40°, \phi_j)$

MetOp-A ASCAT

Right Swath:
Fore-/**Mid-**/**Aft-**beam

Left Swath:
Fore-/**Mid-**/**Aft-**beam



Sensor “inter-calibration”

Measurement Model: $\sigma^0_{Ma}(L_T, t_i, \theta, \phi_j) = \sigma^0_{Sl}(L_T, t_i, \theta, \phi_j) + \tilde{C}_{inter}(L_T, \theta, \phi_j)$

master RCS | slave RCS | Inter-Cal. Coeff.

Solve for calibration coefficient:

$$\tilde{C}_{inter}(L_T, \theta, \phi_j) + \epsilon = \overline{\sigma^0_{Ma}}(L_T, \theta) - \sigma^0_{Sl}(L_T, t_i, \theta, \phi_j)$$

$$\overline{\sigma^0_{Ma}}(L_T, \theta) = \sigma^0_{Ma}(L_T, t_i, \theta, \phi_j)$$

Calibration Reference

Estimate calibration coefficient:

$$\overline{C}_{inter}(\theta, \phi_j) = \frac{1}{n_{tar}} \sum_{T=1}^{n_{tar}} \left(\tilde{C}_{inter}(L_T, \theta, \phi_j) + \epsilon\right)$$

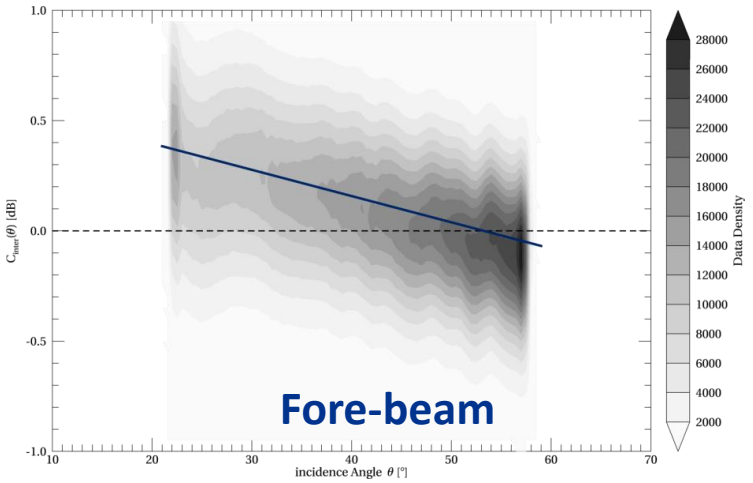
Inter-Cal. Coeff.

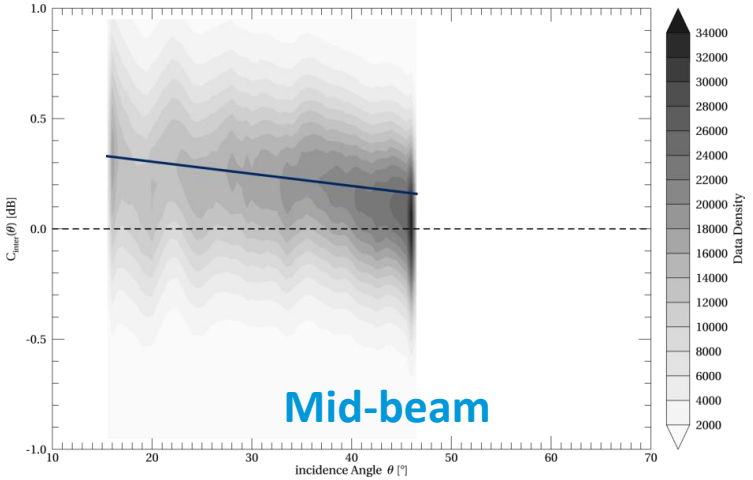
Sensor “intra-calibration”:

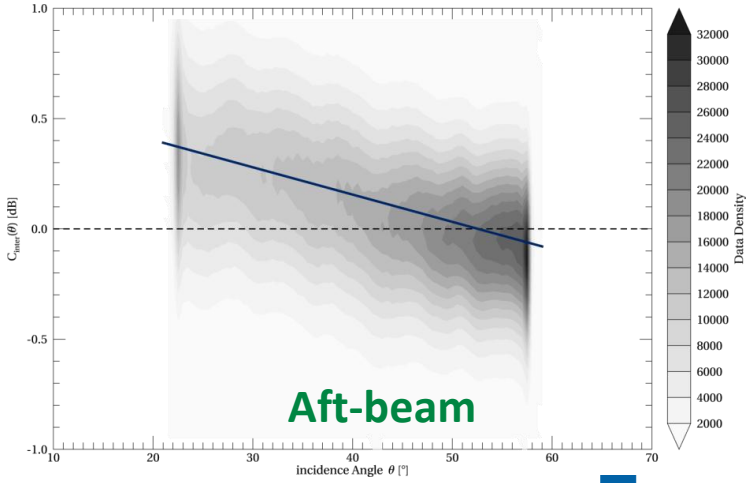
$$\sigma^0_{inter}(L, t_i, \theta, \phi_j) = \sigma^0_{Ma}(L, t_i, \theta, \phi_j) = \sigma^0_{Sl}(L, t_i, \theta, \phi_j) - \overline{C}_{inter}(\theta, \phi_j)$$

calibrated RCS | slave RCS | Inter-Cal. Coeff.

Inter-calibration anomalies





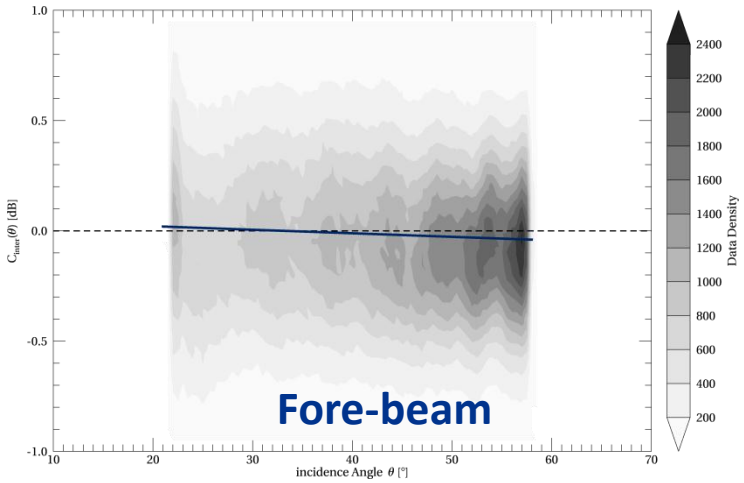


ESCAT is calibrated with respect ASCAT

$\overline{C}_{inter}(\theta, \phi_j)$ 1-order polynomial centred at 40°

Antenna Beam	C_0 [dB]	C_1 [dB/deg]	min(θ) [dB]	max(θ) [dB]
Right Fore	0.158	-0.012	0.384	-0.068
Right Mid	0.194	-0.006	0.332	0.156
Right Aft	0.155	-0.012	0.390	-0.08

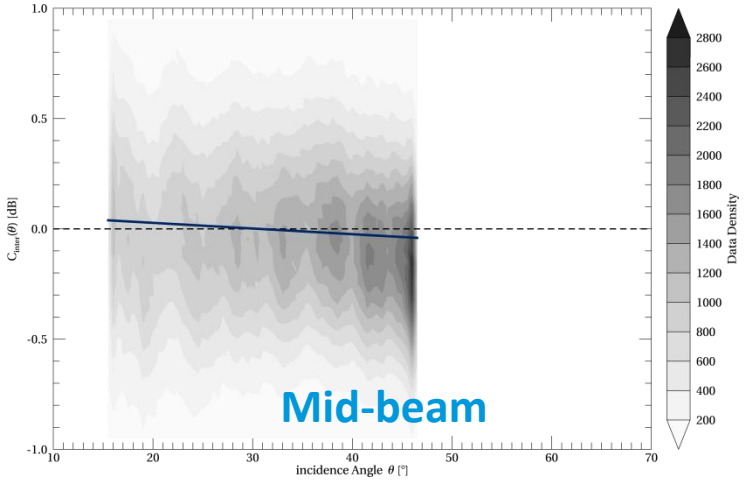
Inter-calibration verification

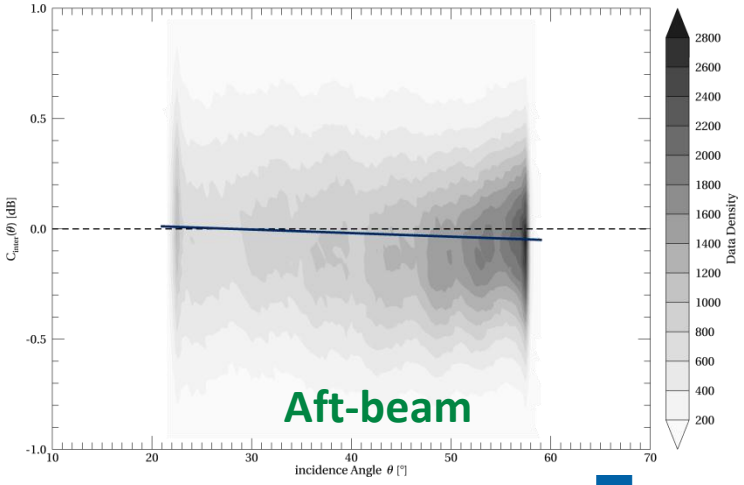


ESCAT is calibrated with respect ASCAT

$\overline{C}_{inter}(\theta, \phi_j)$ 1-order polynomial centred at 40°

Antenna Beam	C_0 [dB]	C_1 [dB/deg]	min(θ) [dB]	max(θ) [dB]
Right Fore	-0.011	-0.002	-0.040	0.019
Right Mid	-0.024	-0.003	-0.042	0.040
Right Aft	-0.019	-0.002	-0.048	0.011





Conclusion

- Simple and obvious SCAT calibration methodology
  - Correct for biases with respect to calibration reference
- Utilising a set of calibration targets
  - A robust estimation of calibration anomalies
- Calibration anomalies correspond to
  - Main mission events
  - On-ground processor updates
- Sensor “inter-calibration”
  - Estimate and correct for biases between SCAT mission
  - Merging of ERS SCAT and MetOp ASCAT

Calibration of MetOp-B ASCAT

MetOp-B calibration

- Objective: derive soil moisture from MetOp-B ASCAT
  - Dedicated MetOp-B ASCAT model parameters not available
    - Too short mission lifetime
  - Current available model parameters are based on MetOp-A ASCAT
- Calibration methodology
  - “intra-calibration” of MetOp-B ASCAT
  - “inter-calibration” of MetOp-B ASCAT utilising MetOp-A ASCAT as calibration reference
- Investigated MetOp-B ASCAT data
  - 06-Nov-2014 to 30-Jun-2014

Intra-Calibration MetOp-B ASCAT

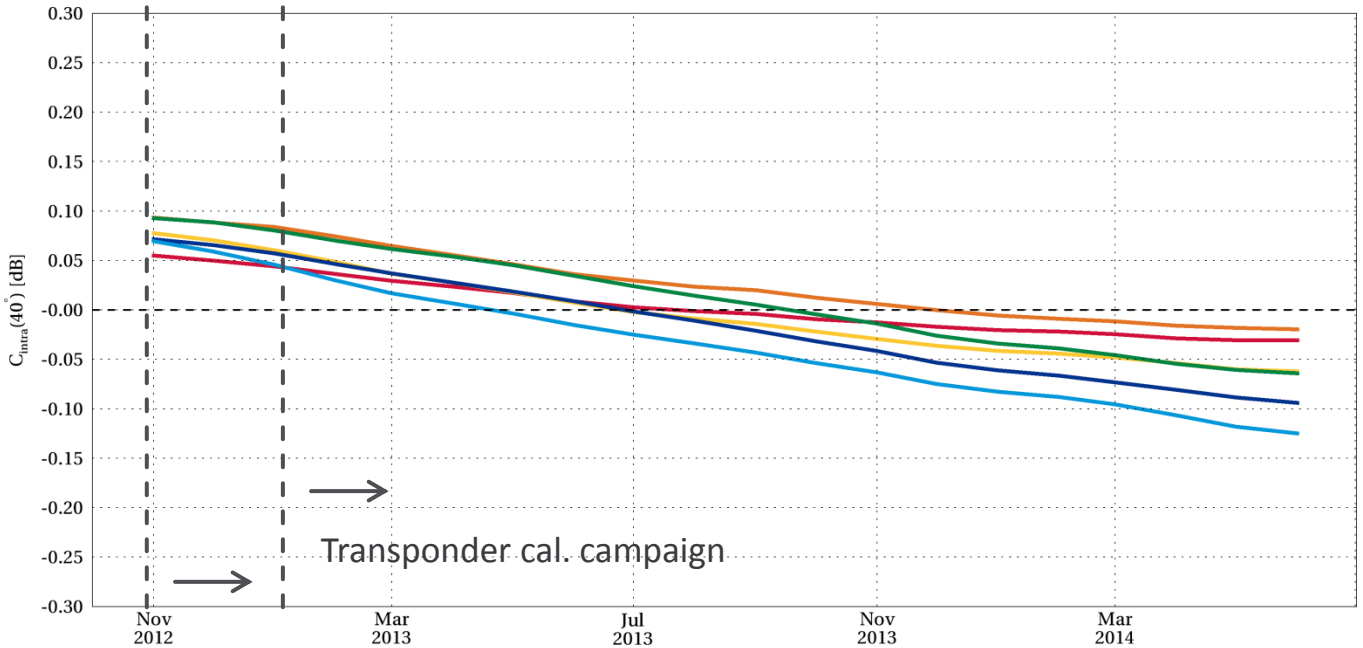
MetOp-B ASCAT

Right Swath: **Fore-**/**Mid-**/**Aft-**beam
Left Swath: **Fore-**/**Mid-**/**Aft-**beam

Calibration Targets:

- Amazon Rainforest,
- Congo Rainforest and
- Indonesia Rainforest I

Year 2013 as Calibration Reference



Rainforest cal. to MetOp-A ASCAT

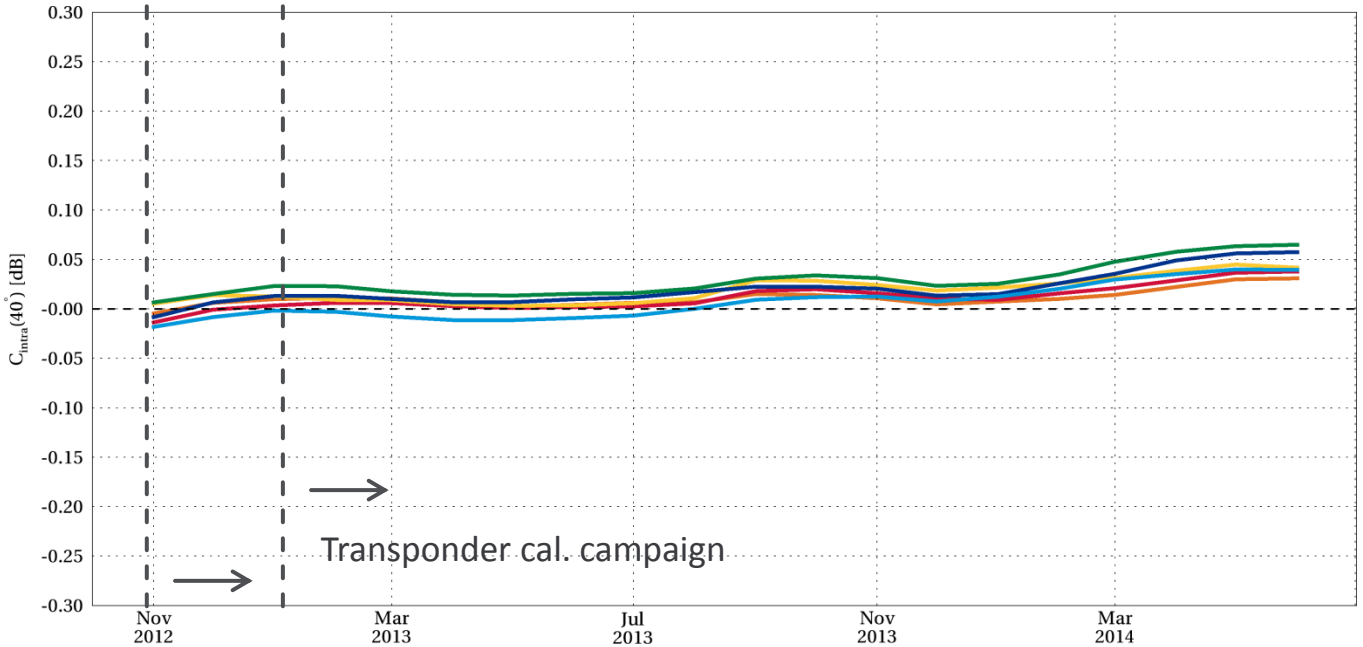
Intra-Calibration MetOp-B ASCAT

MetOp-B ASCAT

Right Swath: **Fore-**/**Mid-**/**Aft-**beam
Left Swath: **Fore-**/**Mid-**/**Aft-**beam

Verification Targets:

- Upper Guinean Forest,
- Indonesia Rainforest II
- Malaysian Rainforest and
- Laos Rainforest



Rainforest cal. to MetOp-A ASCAT

Inter-Calibration ASCAT

Left Swath

Right Swath

Fore-beam

Fore-beam

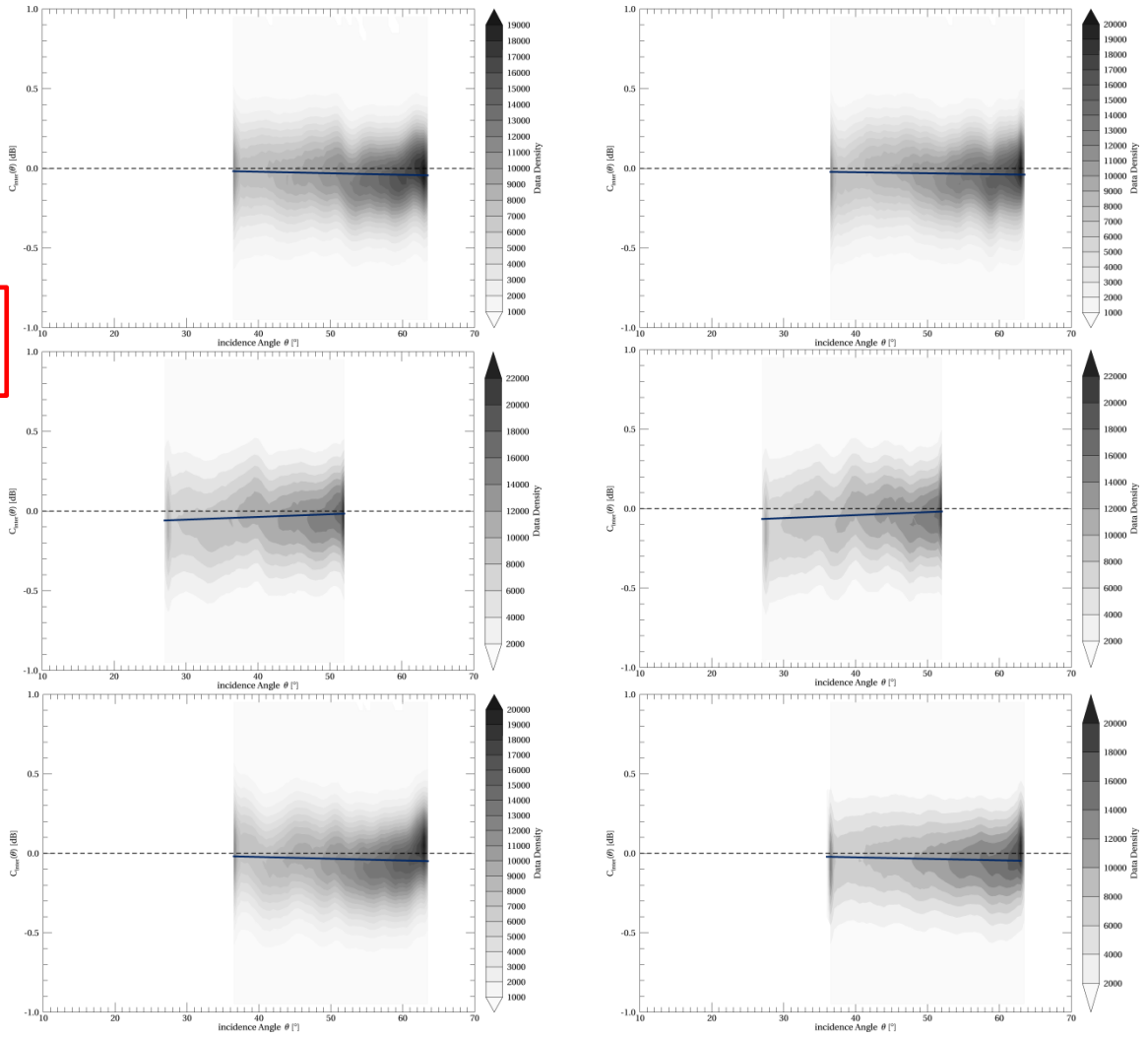
Differences less than 0.1 dB

Mid-beam

Mid-beam

Aft-beam

Aft-beam

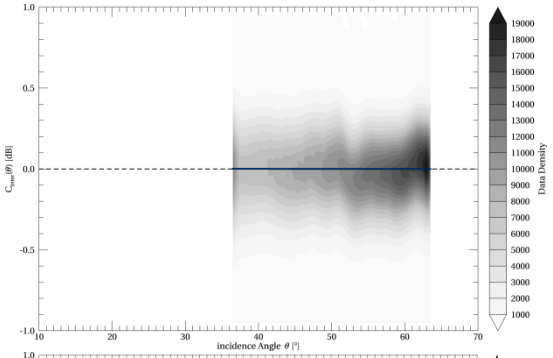


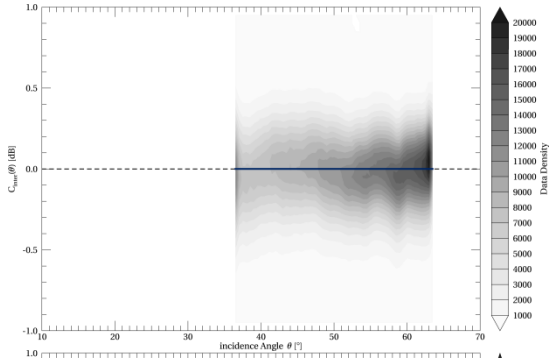
Inter-Calibration ASCAT verification

Left Swath

Right Swath

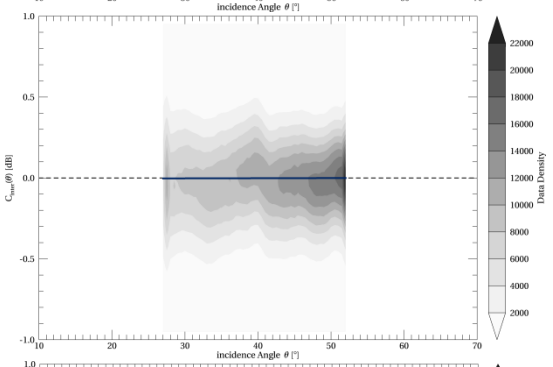
Fore-beam

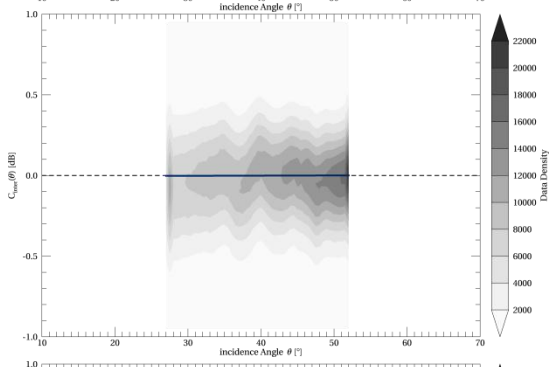




Fore-beam

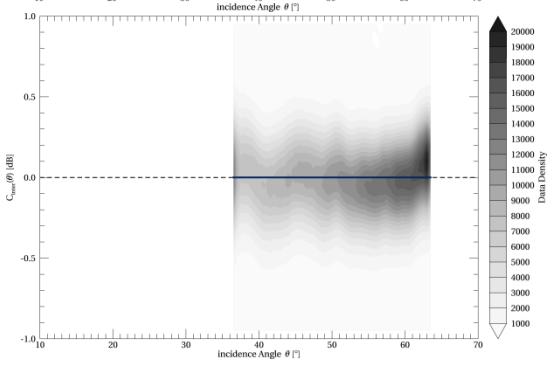
Mid-beam

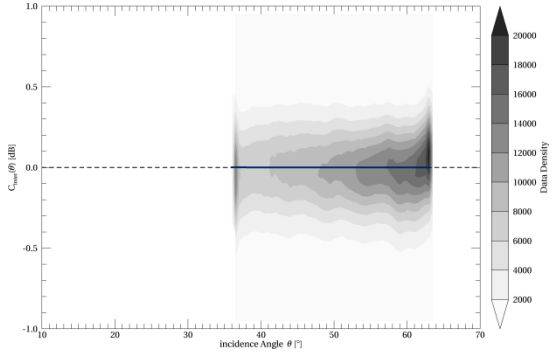




Mid-beam

Aft-beam





Aft-beam

Thank you for your attention

Questions / Comments are welcome