Cone metrics: a new tool for scatterometer intercalibration

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Scirocco PM#2

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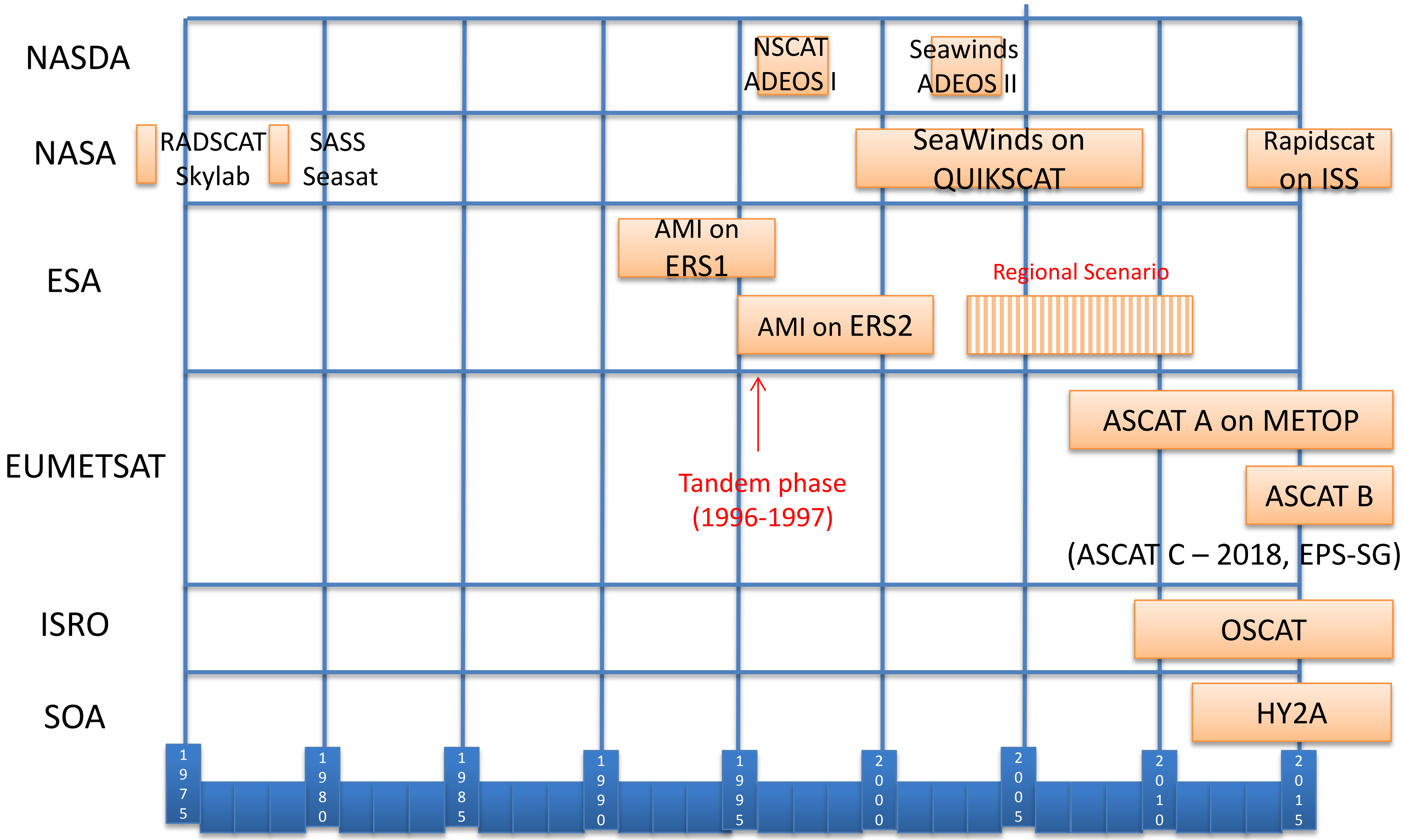
Outline

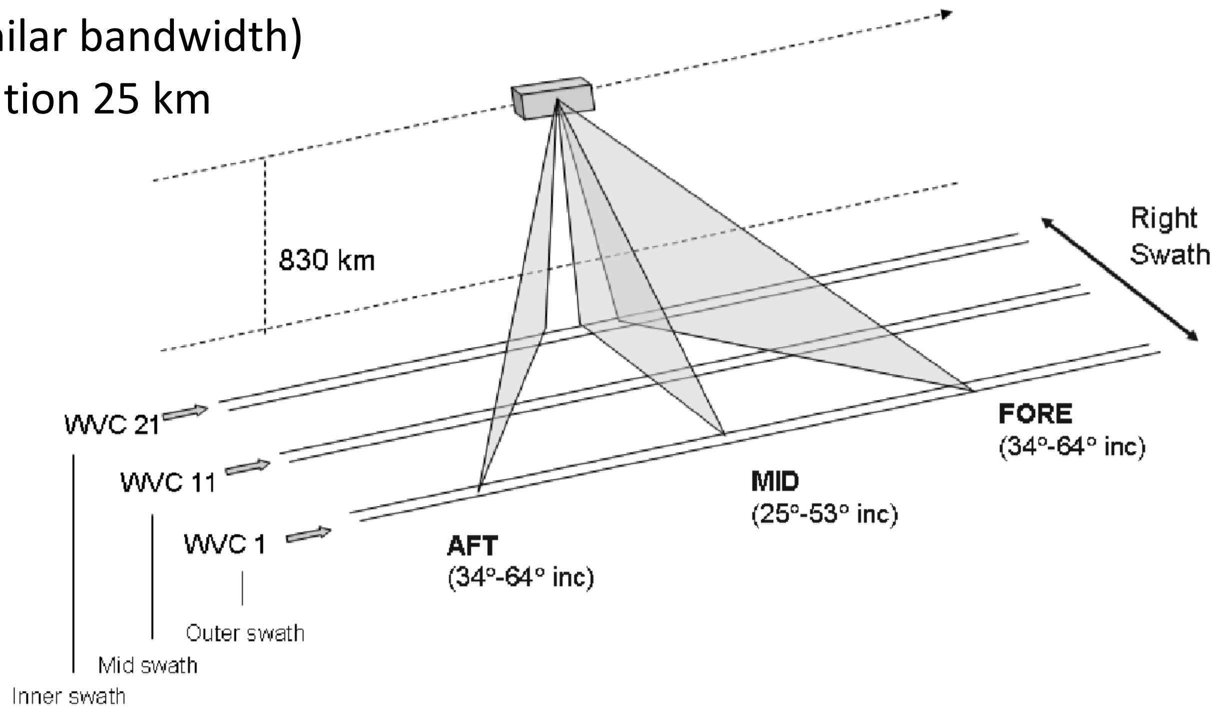
- Motivation:
  – Scatterometer CDR for ERS and ASCAT
- NWP ocean calibration (NOC)
  – Standard method
  – Limitations
- Calibration via cone metrics
  – Novel method
  – Application in the context of the reprocessing activities for ERS-1 and ERS-2 (SCIROCCO)

Satellite scatterometers



ERS & ASCAT

C-band VV (similar bandwidth)
Nominal resolution 25 km



Main differences:	ERS1/ERS2	ASCAT
- local time	10:30 (DES) / 22:30 (ASC)	9:30 (DES) / 21:30 (ASC)
- Incidence	18-40 deg (M) / 27-58 deg (F/A)	25-53 deg (M) / 34-64 deg (F/A)
- Noise	ASCAT has better noise properties	

Introduction

- SCIROCCO (ESA) inter-calibration efforts

Rain forest (ERS2 tandem phase, 1997) NOC

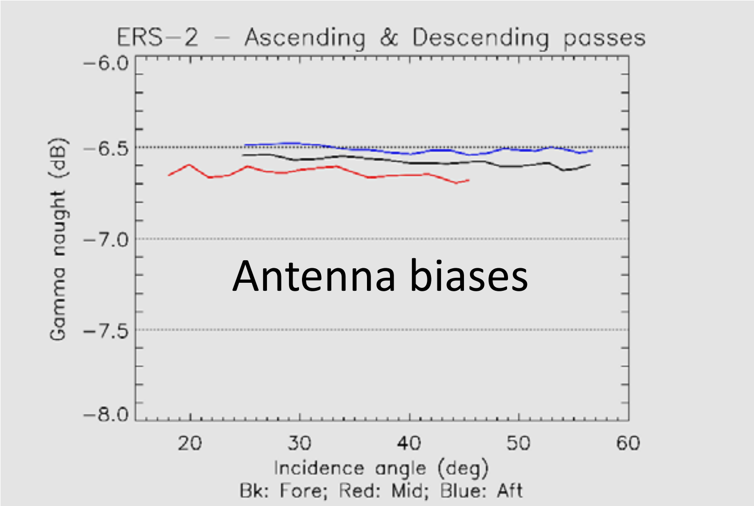


Figure 3.5: Gamma nought

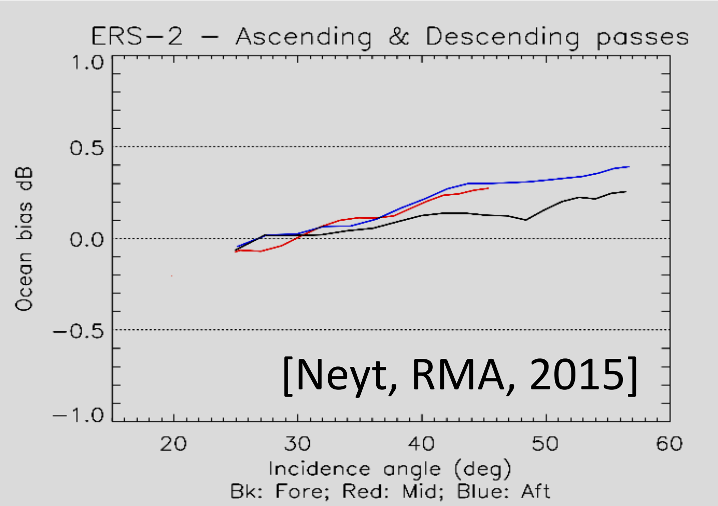


Figure 3.7: Model bias relative to CMOD6

+ linearity and stability in backscatter: cone analyses

http://scirocco.sp.serco.eu/

GCOS WCRP ECV requirement: 0.5 m/s accuracy, 0.1 m/s stability per decade → 0.1 dB

NWP Ocean Calibration (NOC)

(beam,node)

$$<\sigma^o{}_{obs}> \longleftrightarrow <\sigma^o{}_{sim}> \left\{ \begin{array}{l} \text{GMF} \\ \text{NWP winds} \end{array} \right.$$

Averaging over all wind states:

$$< \ldots > = \int (\ldots) N(v, \phi) dv\, d\phi \qquad N_{true} \neq N_{nwp}$$

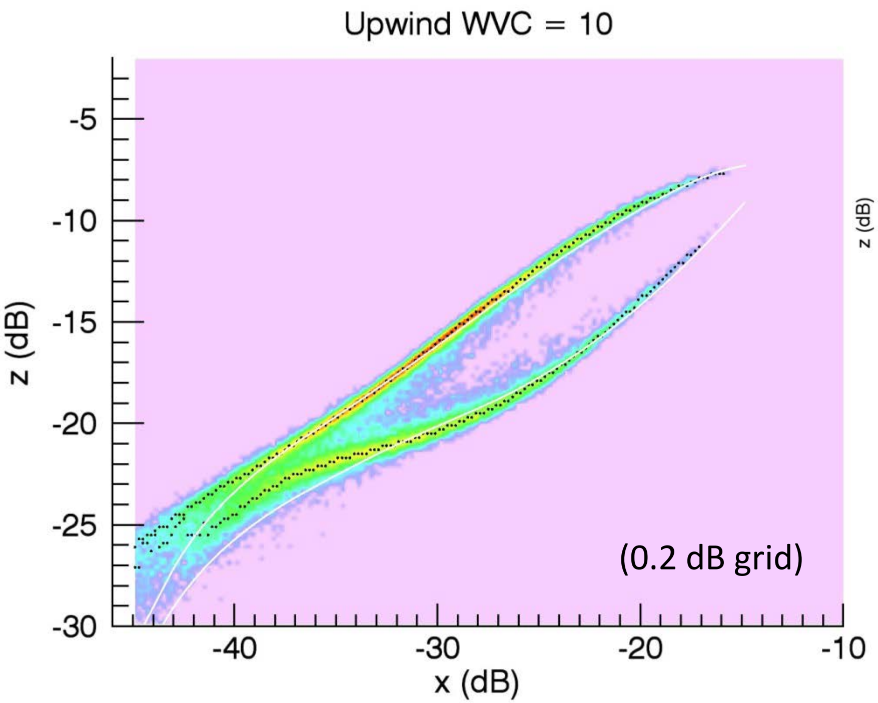
- Sensitivity to NWP wind direction errors ~ 0.1 dB for MID beam
- Sensitivity to NWP wind speed errors ~ 0.1 dB all beams
- Linear calibration offset assumption

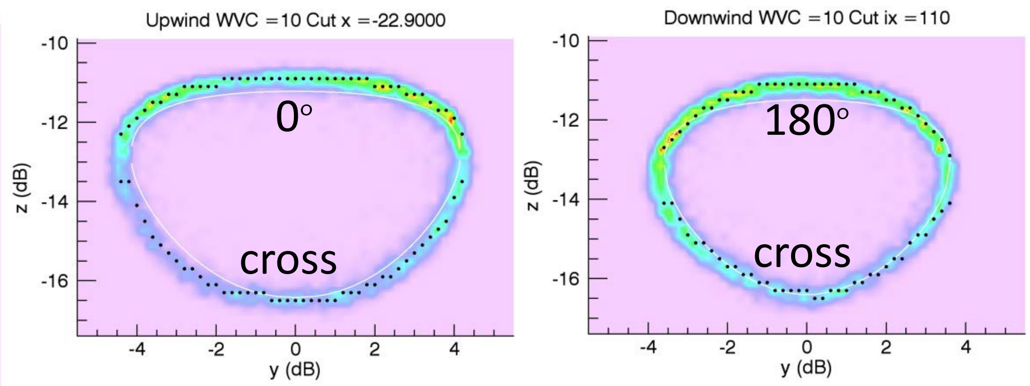
$\Rightarrow$ In line with absolute error from rain forest or transponder calibration ~ 0.1-0.2 dB

Cone analyses

σ^{o}_{obs} → Histograms in {x,y,z} measurement space

For every node and every x section





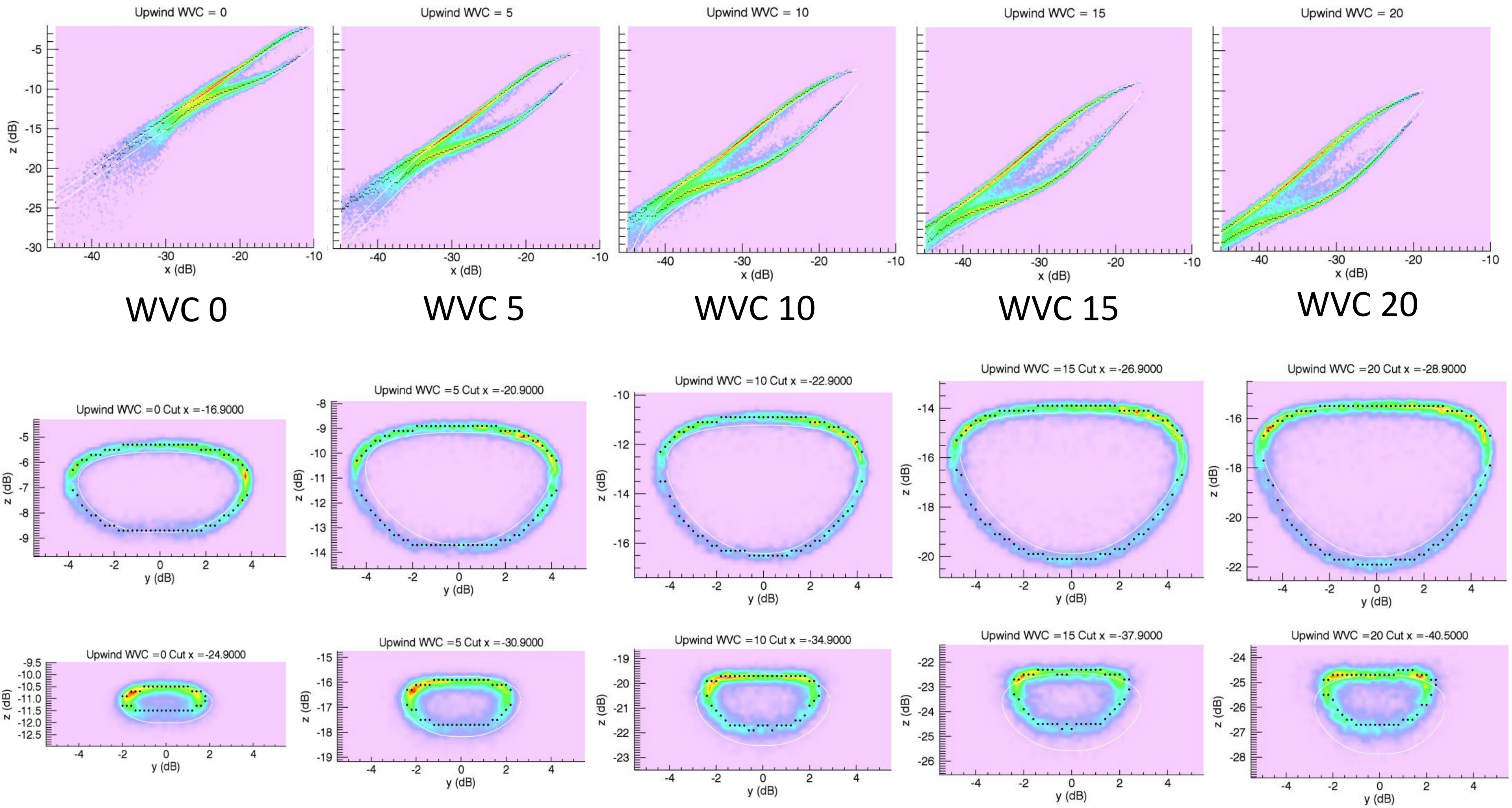
Split upwind/downwind branches

Find maximum density surfaces

Reference period (Oct'07- Sep'08) CMOD6

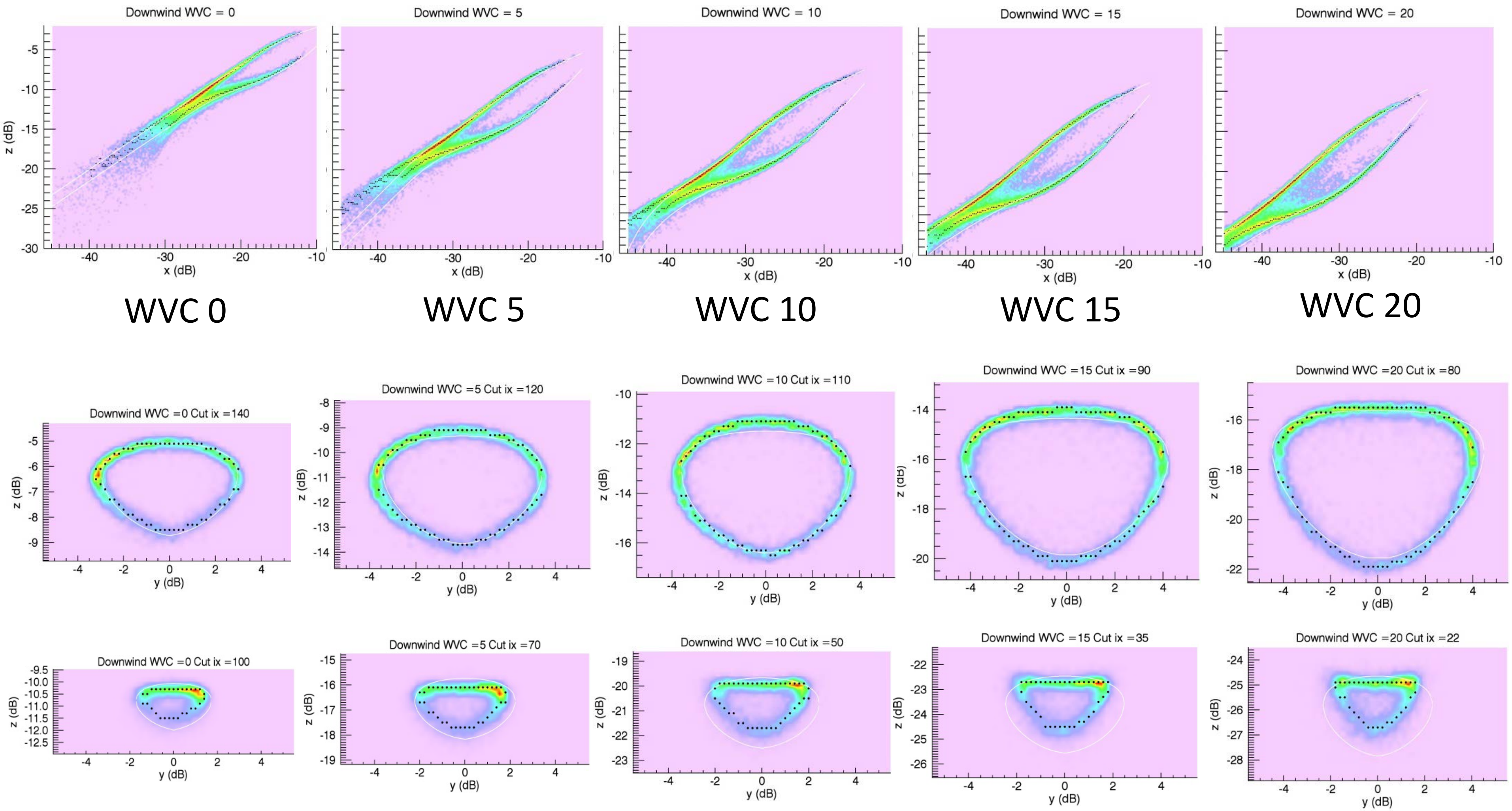
- Tracking changes in maximum density surface
- Independent of wind PDF

ASCAT A (REF 25 km) UPWIND



Max density surfaces invariably well defined above 5 m/s

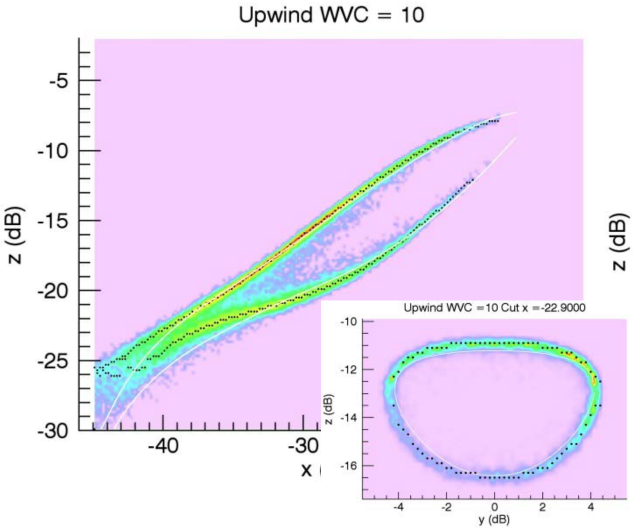
ASCAT A (REF 25 km) DOWNWIND



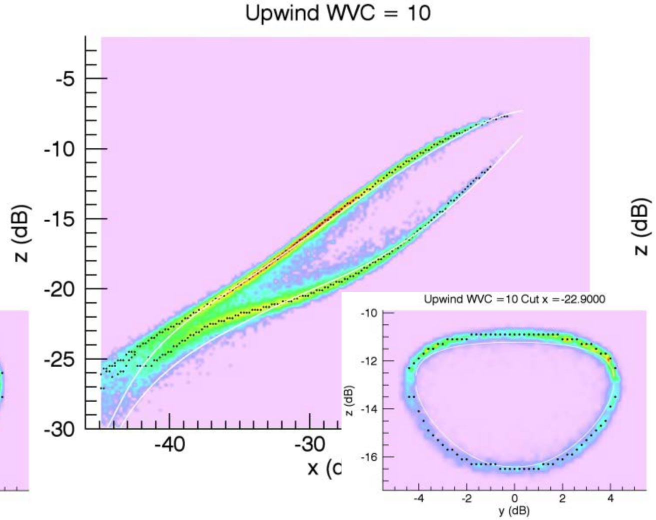
Max density surfaces invariably well defined above 5 m/s

Comparing different records

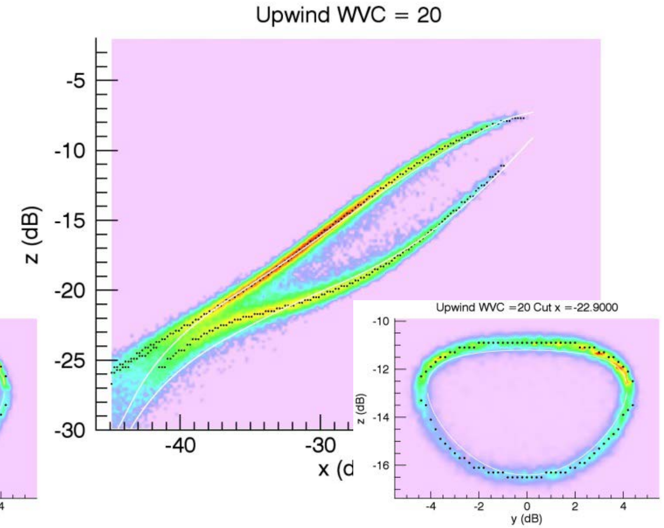
ASCAT A 2014 (25km)



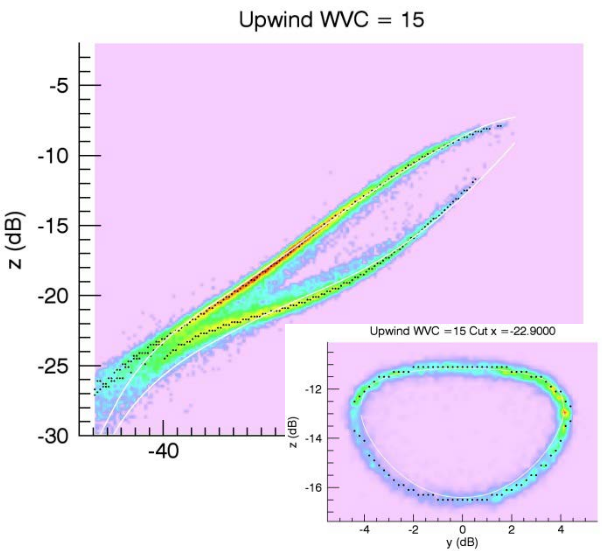
ASCAT A REF (25km)



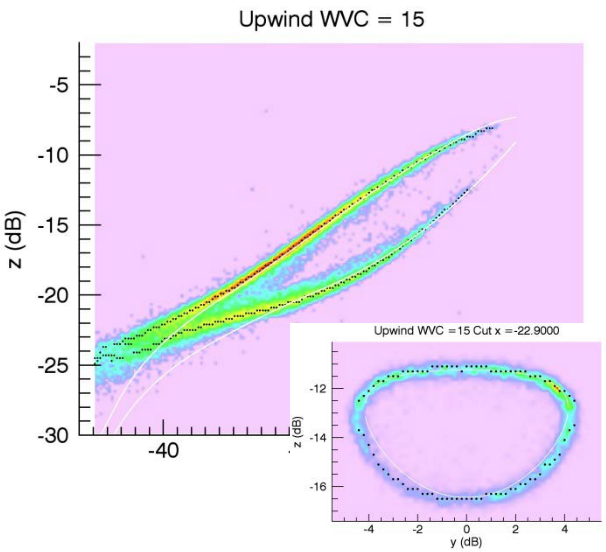
ASCAT A REF (12km)



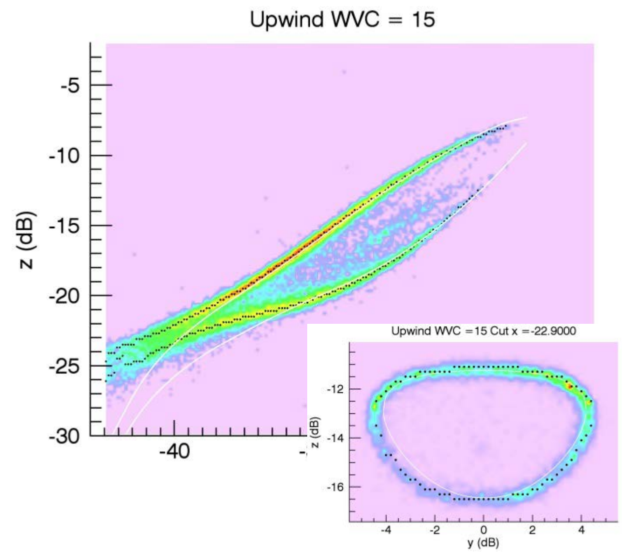
ERS1 KNMI 1995 (25km)



ERS2 KNMI 1997 (25km)

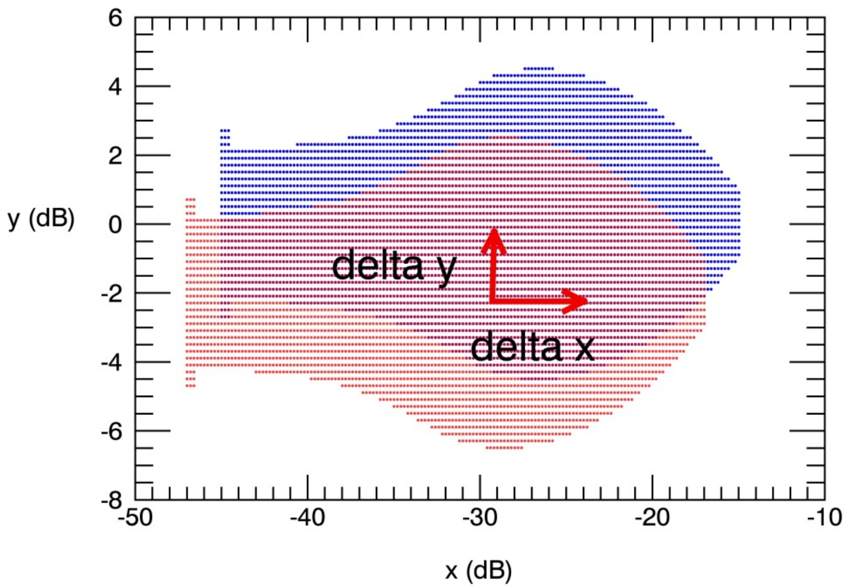


ERS2 ASPS 1997 (25km)

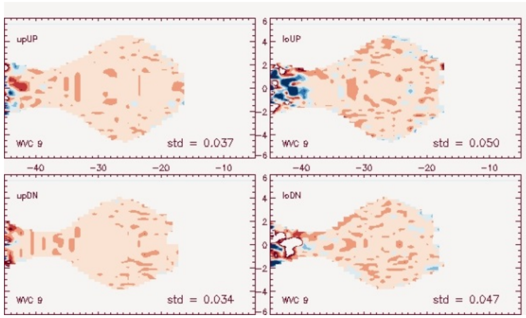


Antenna beam offsets

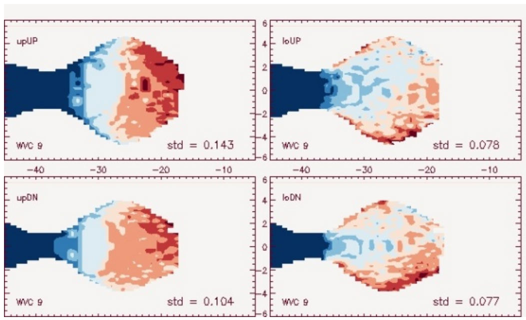
1) Minimize the STD of the cone difference {Δx, Δy, Δz}



ASCAT to ASCAT



residuals: $Z(x + \Delta x, y + \Delta y) - Z_0(x, y)$



ASCAT to ERS2

2) Translate into constant beam offsets:

{Δx, Δy, Δz} →

$$\delta\sigma^0{}_{fore} = (\Delta x + \Delta y)/\sqrt{2}$$
$$\delta\sigma^0{}_{aft} = (\Delta x - \Delta y)/\sqrt{2}$$
$$\delta\sigma^0{}_{mid} = \Delta z$$

Linear calibration offsets: comparable to NOC

- **Cone shifts** translate into constant beam offsets
- **Residuals** inform about more complex calibration relations (non-linearity)

Sensitivity of cone shifts to wind PDF, instrument noise and observation geometry

(simulation based)

Build a clean cone using GMF with flat wind PDF and mean observation angles:

→ change measurement noise (12 km K_p)
→ change input wind PDF (climatology)
→ add realistic distribution of incidence and azimuth angles (std ~ 0.1-0.2°)

CONCLUSIONS:

- Cone offsets are <u>not</u> sensitive to measurement noise
- Cone offsets are <u>not</u> sensitive to wind PDF
- Cone offsets are <u>not</u> sensitive to geometric variability
- Cone offsets are sensitive to changes in incidence angle (~0.1 dB per 0.1°)

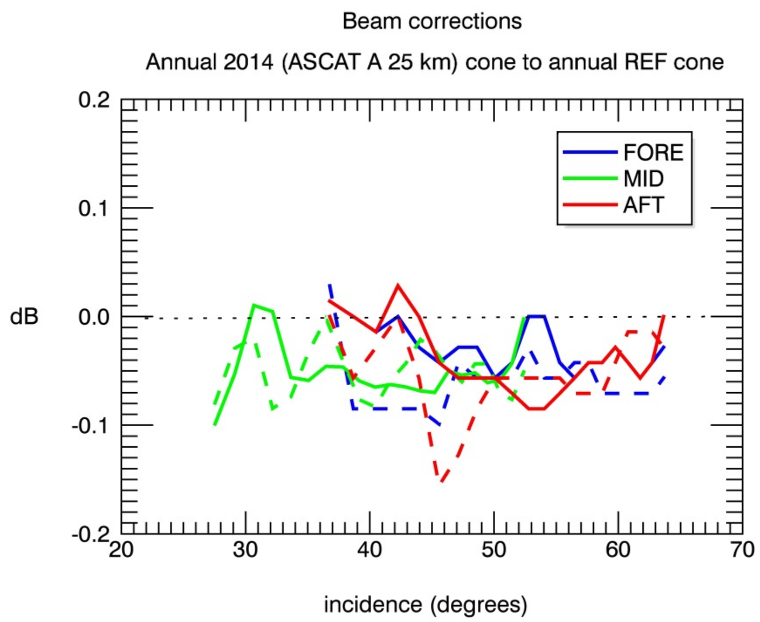
deviations from nominal geometry must be taken into account

→ **expected accuracy of 0.01-0.02 dB**

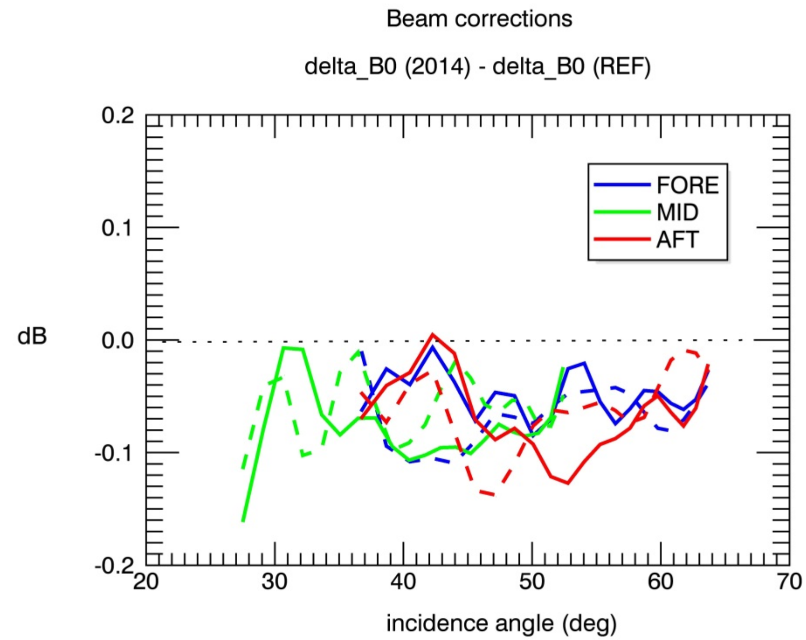
Interannual stability

To see how the max density surface moves from year to year…

- ASCAT A 2014 (25 km) to ASCAT A REF (25 km)



Cone metrics



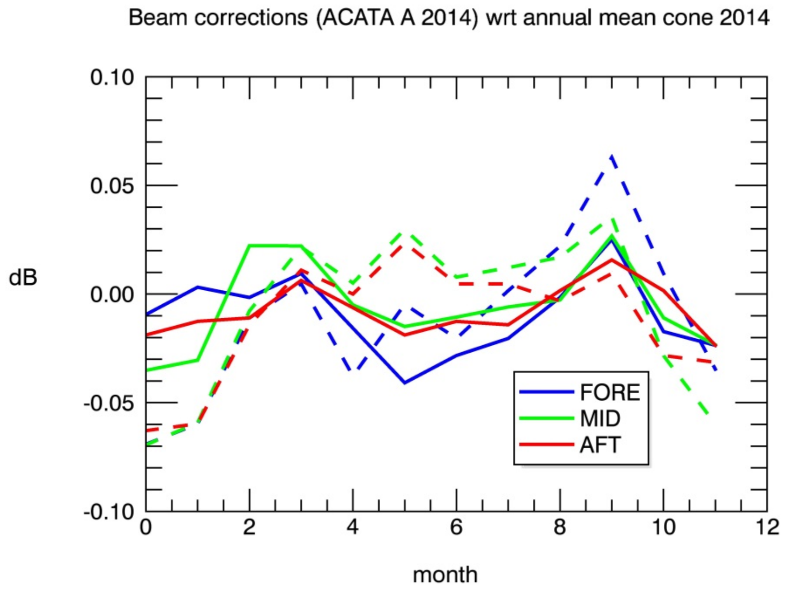
NOC

NOC or cone metrics may be used to monitor backscatter stability over ASCAT period

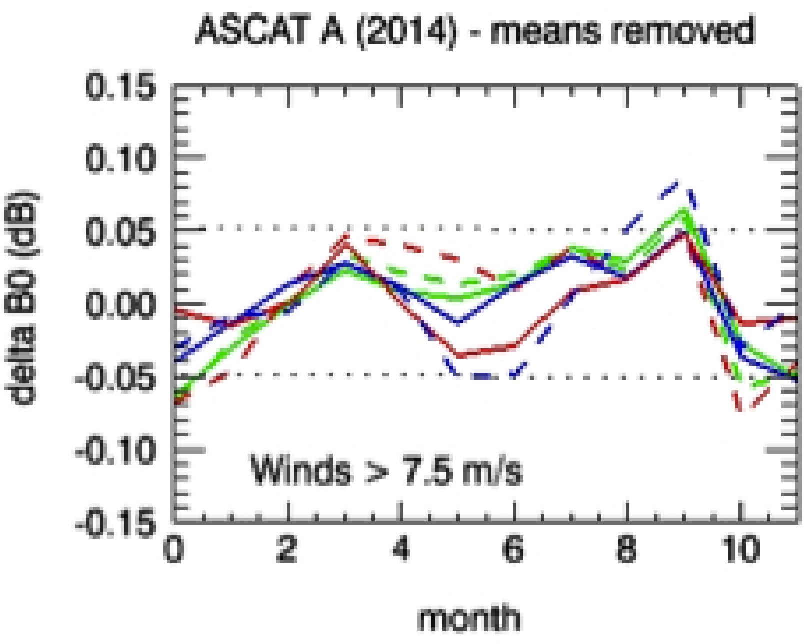
Seasonal stability

- The maximum density surface moves with the seasons…

Cone metrics



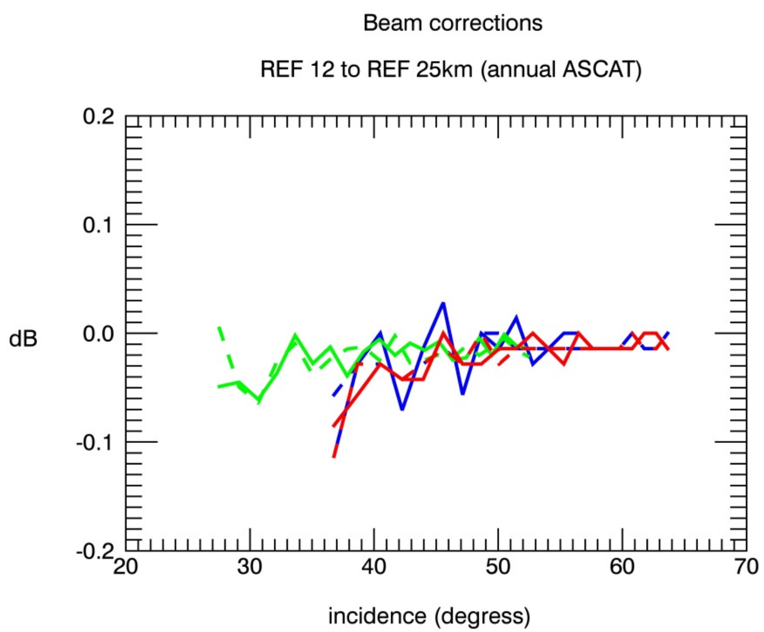
NOC



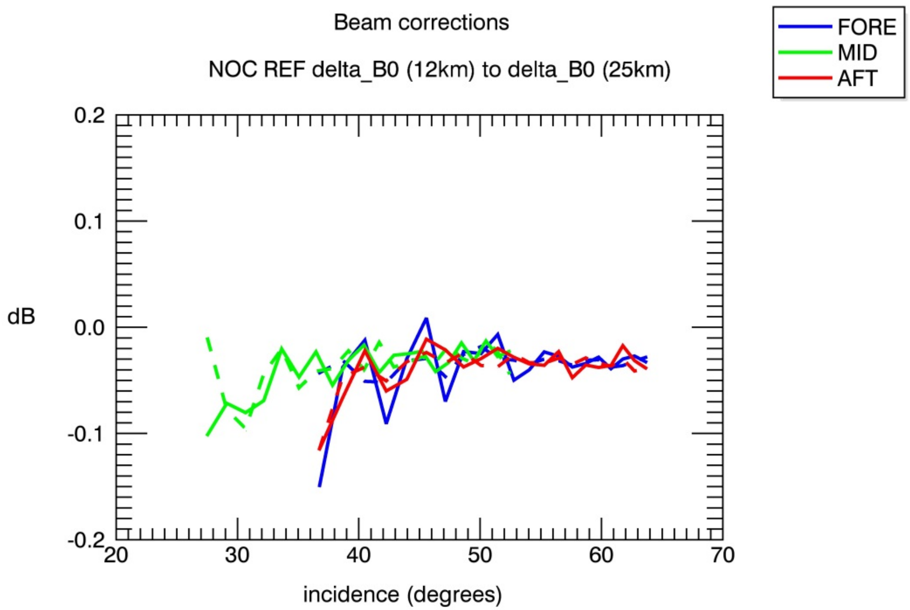
Where does this variability come from? … not a definite answer yet

Spatial resolution

- ASCAT A REF (12 km) to ASCAT A REF (25 km)



Cone metrics

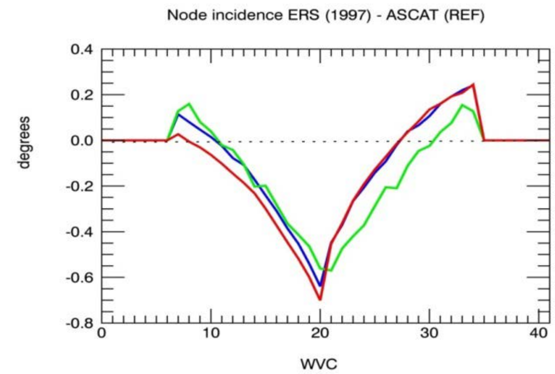


NOC

Where does the difference come from?

… different calibration tables for 12km and 25km processors?

Relating ERS to ASCAT



- ASCAT and ERS node incidences differ slightly → apply a geometric correction:

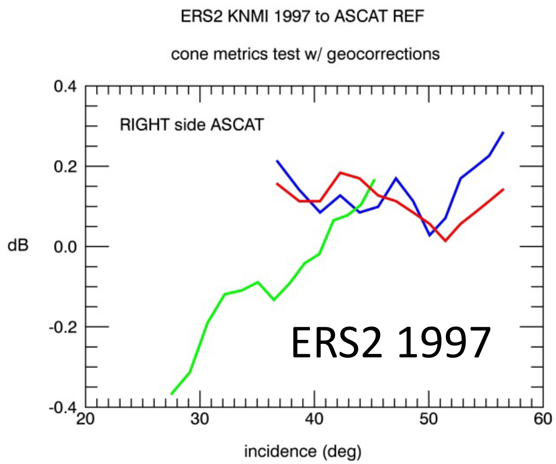
$$\overrightarrow{\sigma^0} = \overrightarrow{\sigma^0} + \overrightarrow{\sigma^0_{sim}}(\vec{v}_{scat}, \theta_0, \phi_0) - \overrightarrow{\sigma^0_{sim}}(\vec{v}_{scat}, \theta, \phi)$$

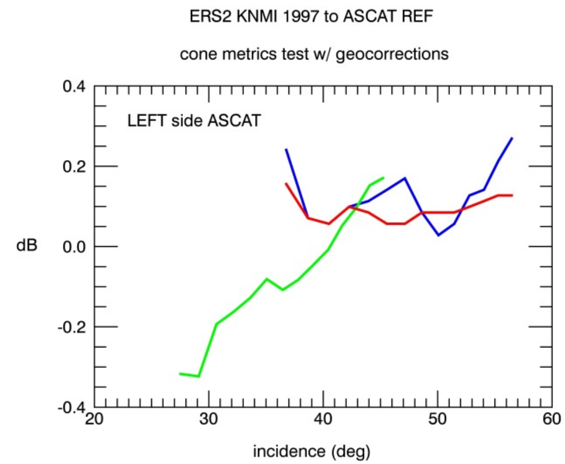
New cone | Old cone | geocorrection

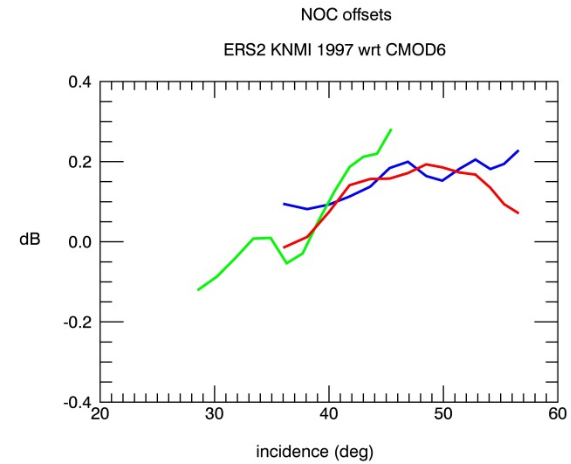
The "geometry correction" is based on CMOD6 and collocated scatterometer winds, using the initial input geometry from ASCAT and the final input geometry from the corresponding ERS node

→ moves the measurement cloud to some new location dictated by the change in geometry

NOC and Cones differ on ERS period

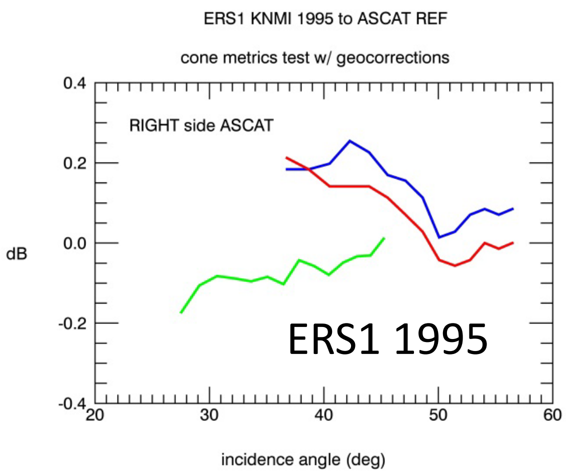


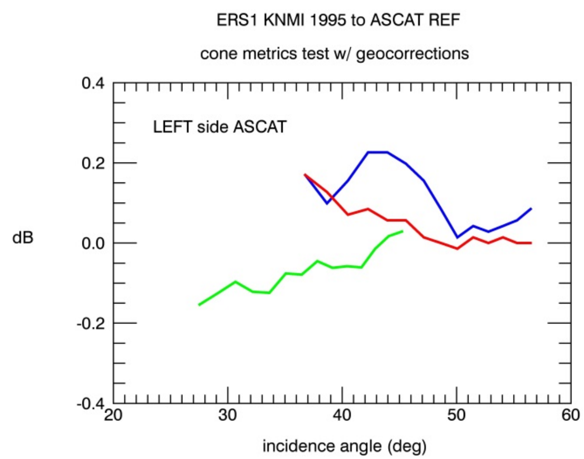


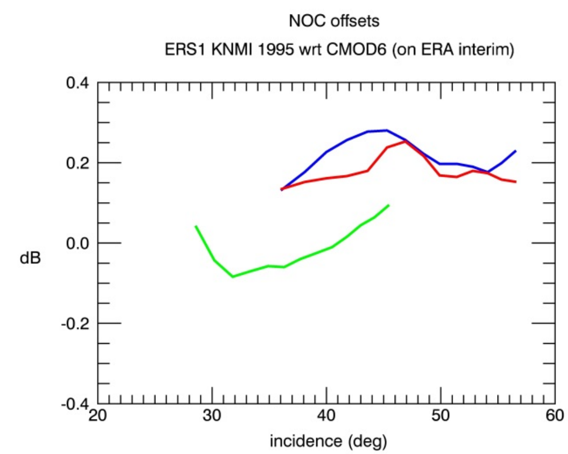


Cone metrics

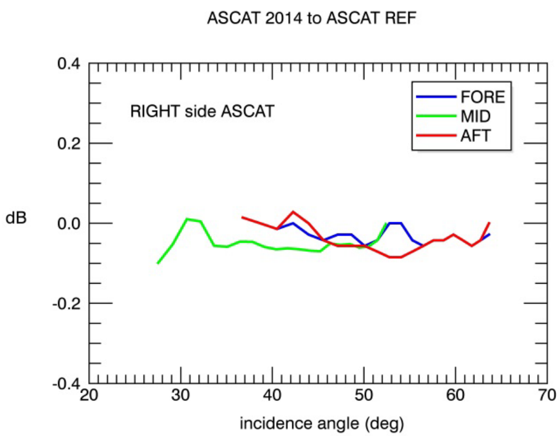
NOC



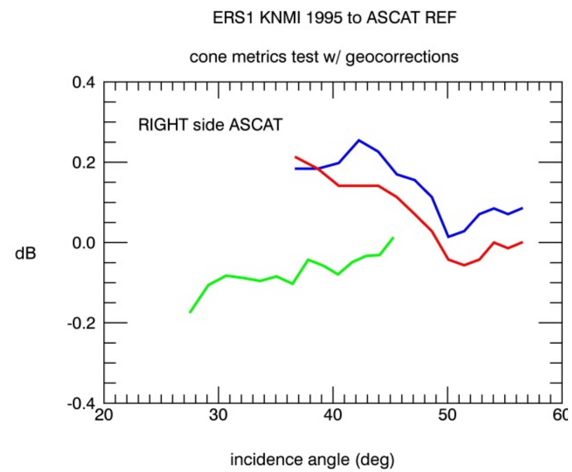




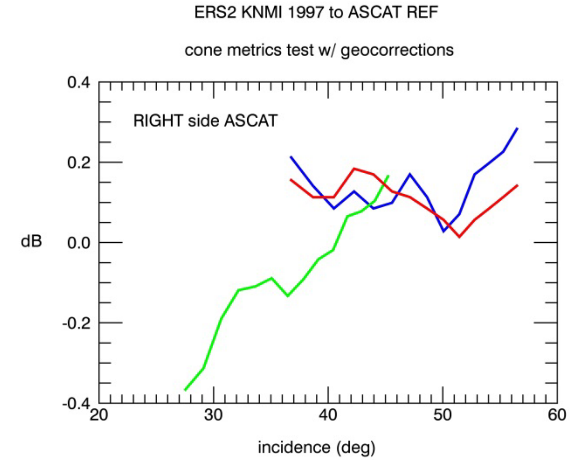
Relating ERS to ASCAT reference



ASCAT 2014

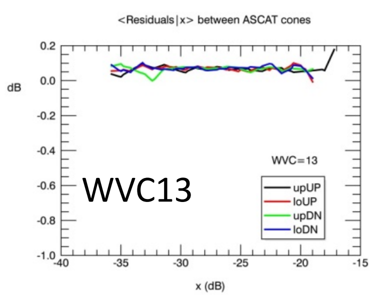


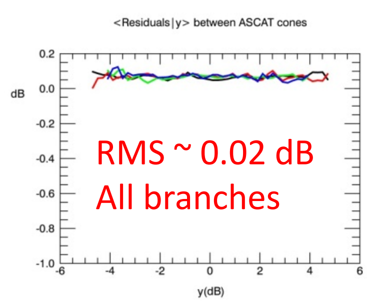
ERS1 1995

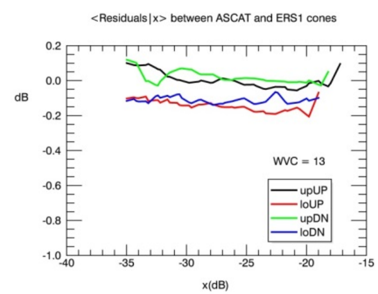


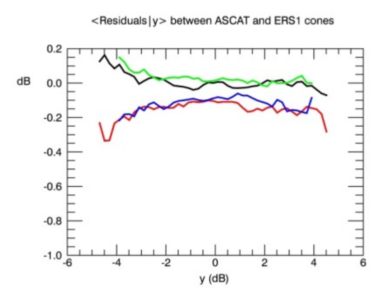
ERS2 1997

RESIDUALS

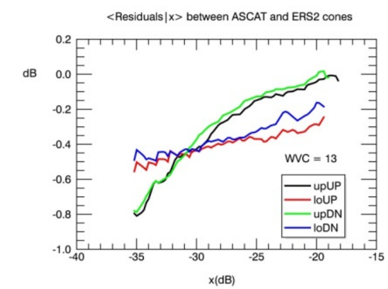


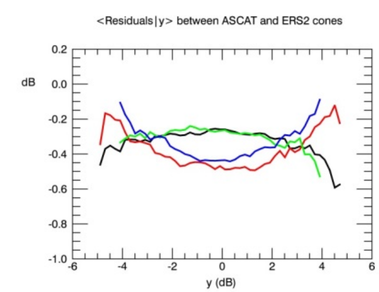




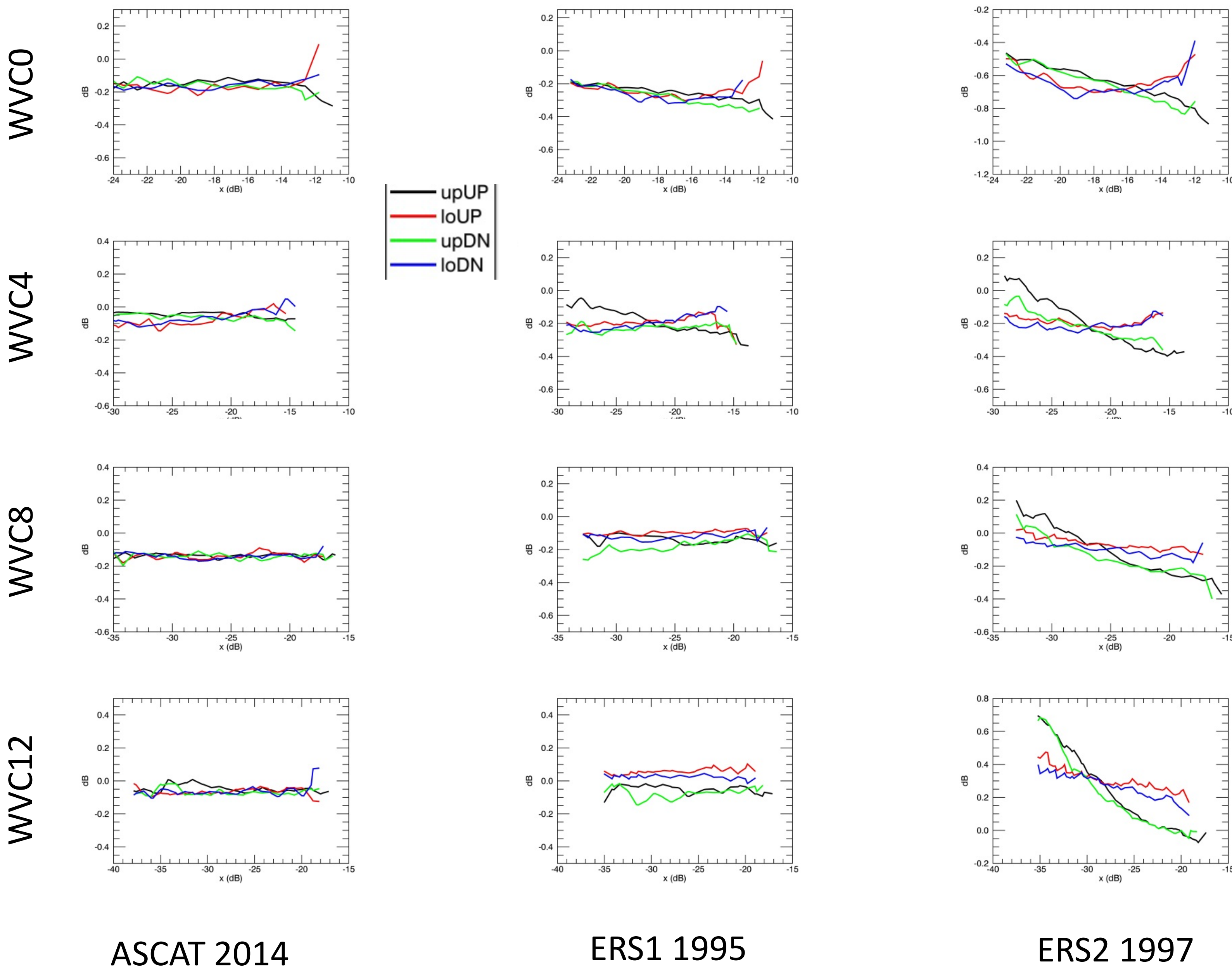


Branch split and structure

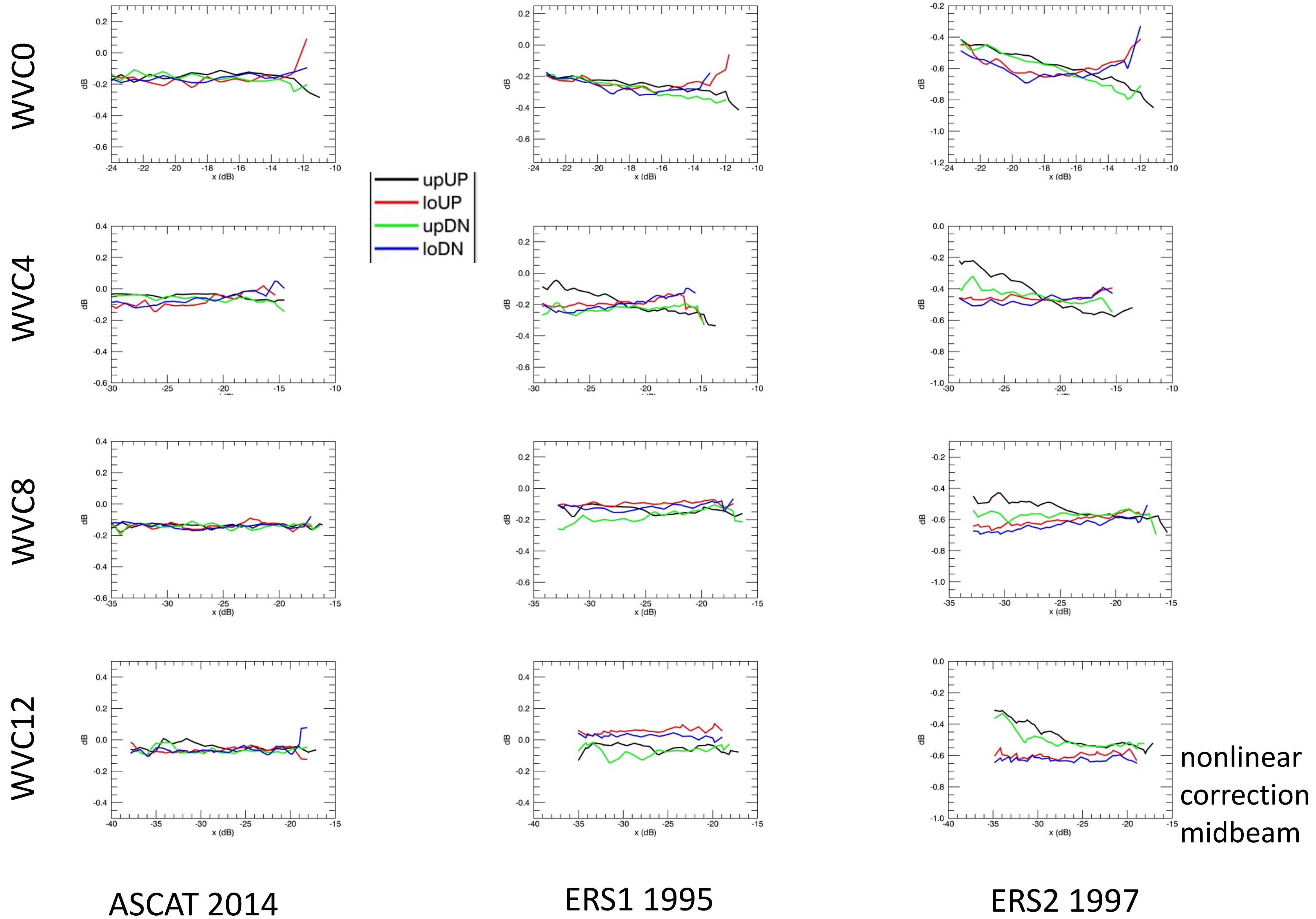




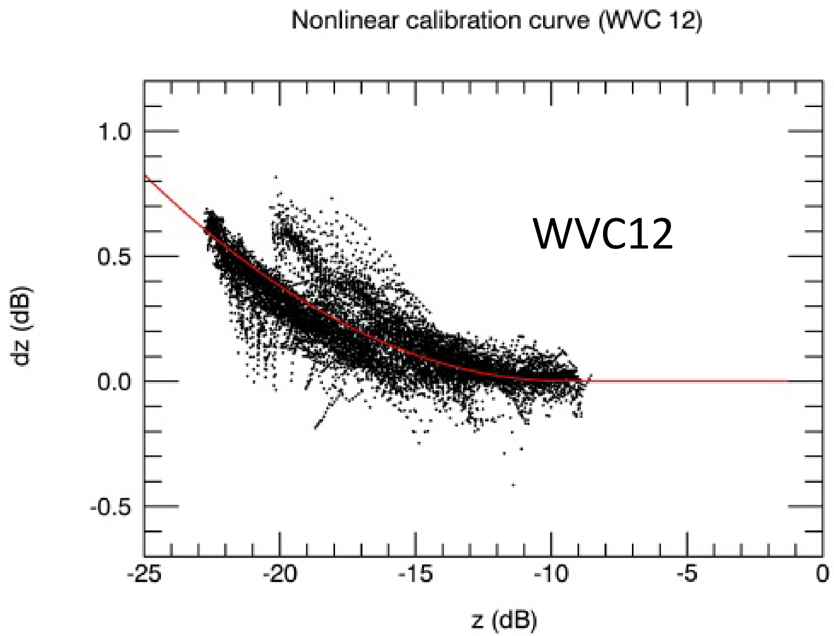
Analyzing residuals to ASCAT REF

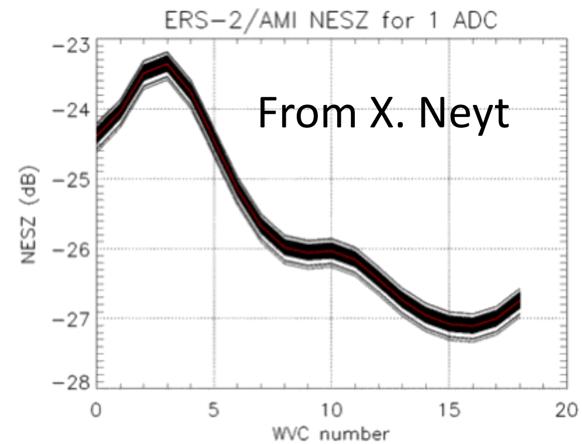


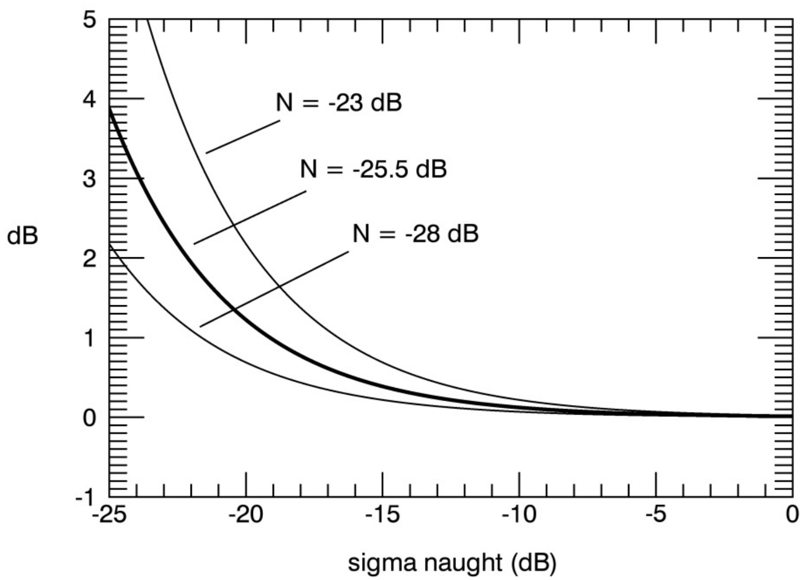
Analyzing residuals to ASCAT REF



Nonlinear correction midbeam ERS2







- Nonlinearity in ERS2 may be related to problems with **noise substraction** in mid beam

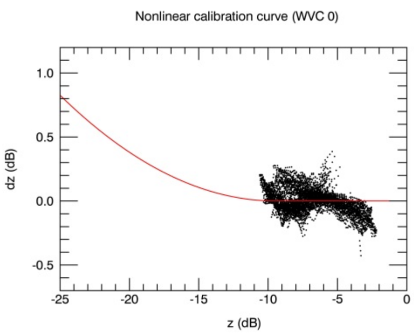
$$\Delta\sigma^0_{dB} = \frac{10}{ln10} 10^{(NESZ_{dB} - \sigma^0_{dB})/10}$$

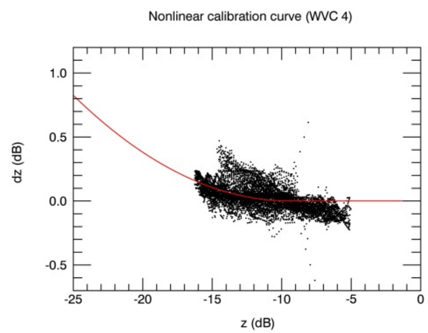
- Structure after non-linear correction indicates problems in **fore and aft** beams as well

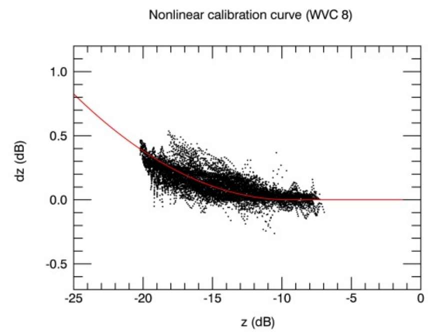
↑ Branch separation

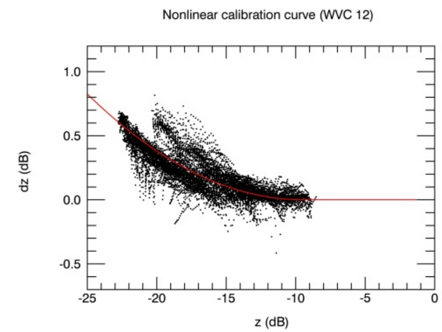
Correcting nonlinearity in ERS2

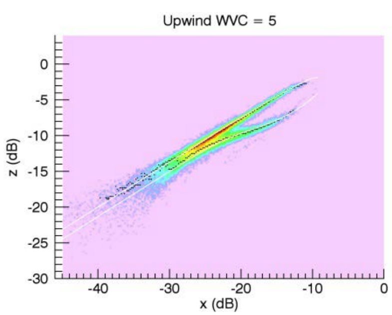
WVC0 WVC4 WVC8 WVC12

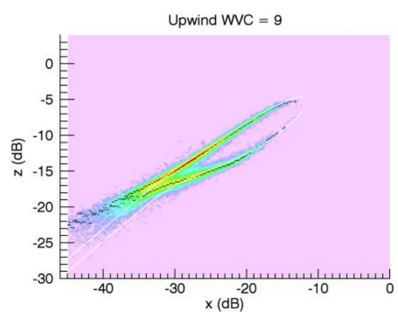


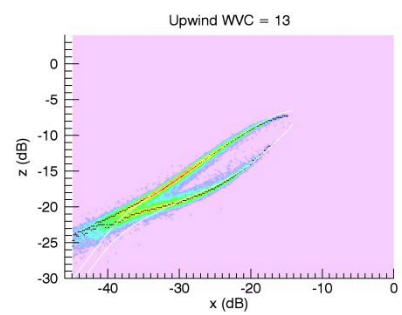


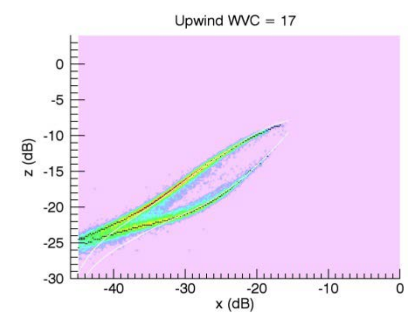








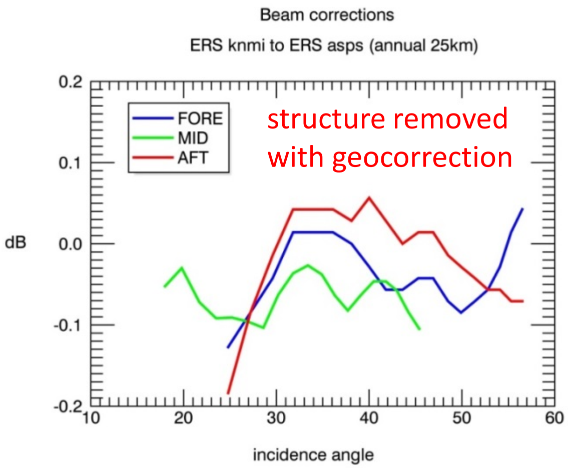




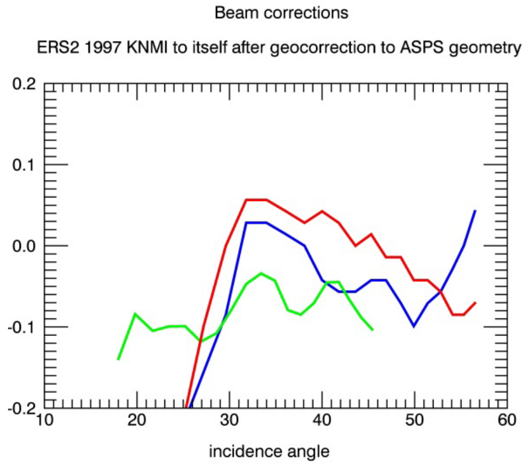
Introduce ERS2 data

- ERS2 **KNMI** 1997 to ERS2 **ASPS** 1997 (25 km)

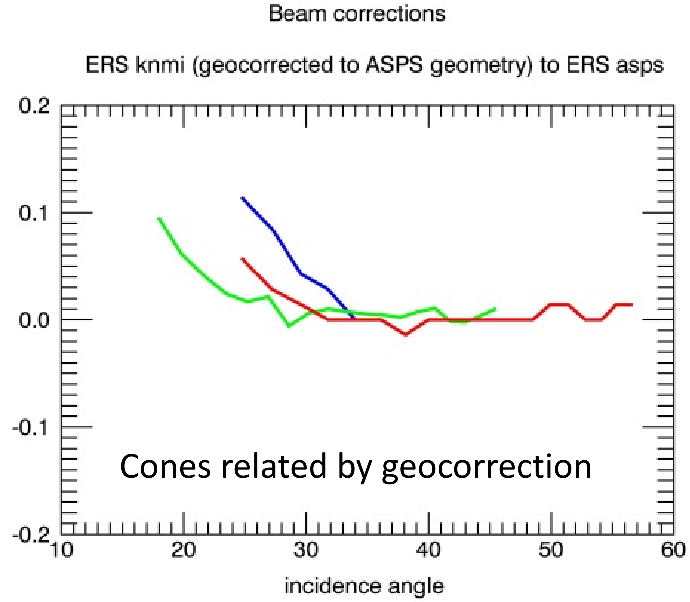
KNMI to ASPS cone offsets:



Raw cone shifts



Geocorrection



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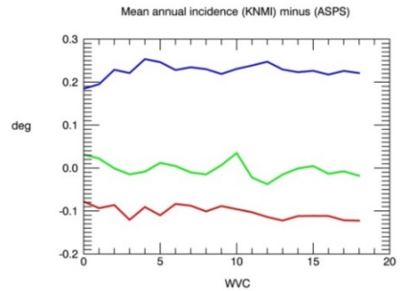
Cone shifts

Must apply a correction to account for changes in observation geometry

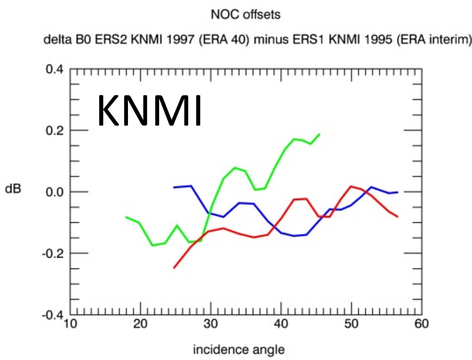
From old ERS (KNMI) to new ERS (ASPS) geometry



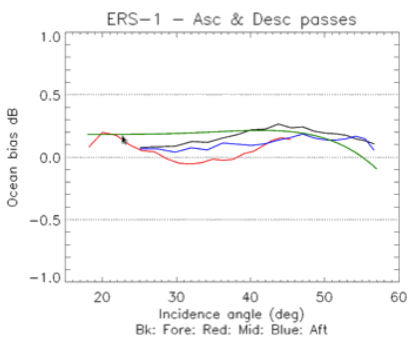
ASPS cone is mostly identical to older KNMI cone shifted by change in observation angles

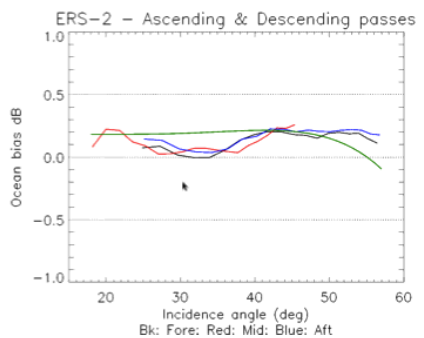
ERS1 to ERS2 cornucopia

From NOC point of view:

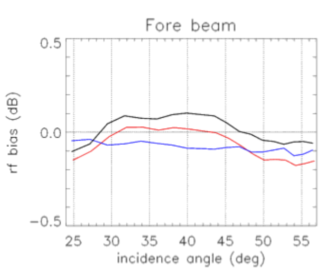


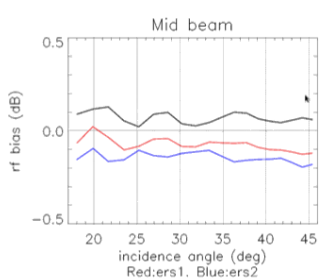
RMA on ERA interim (ERS1 from Ifremer)

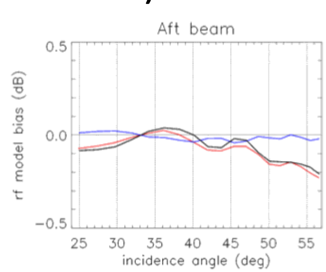




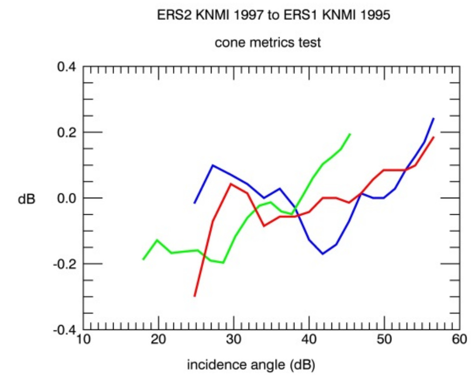
From rain forest (ERS1 – ERS2):



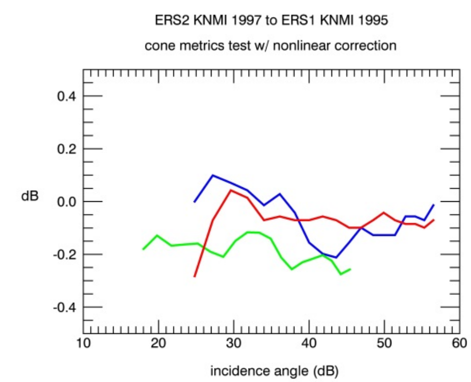




From cone metrics:



ERS2 1997 KNMI
To
ERS1 1995 KNMI
On ERA 40



Same as above
With nonlinear
Correction on
ERS2 midbeam

Did not take geometry change into account

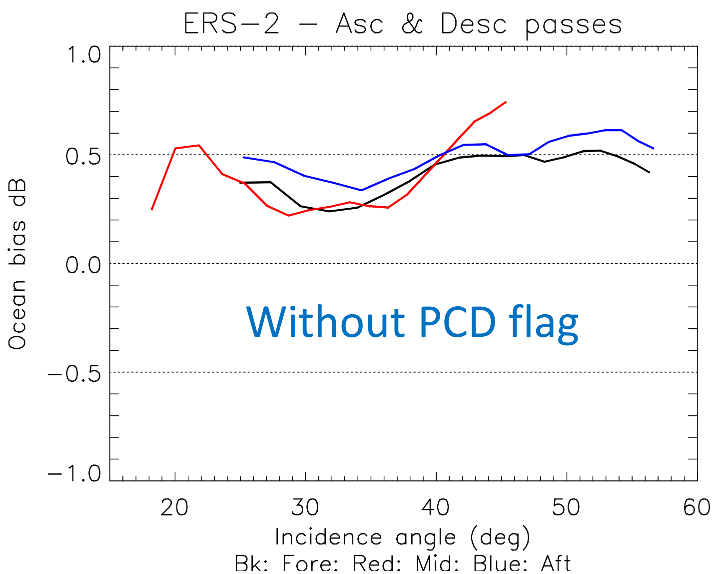
Conclusions

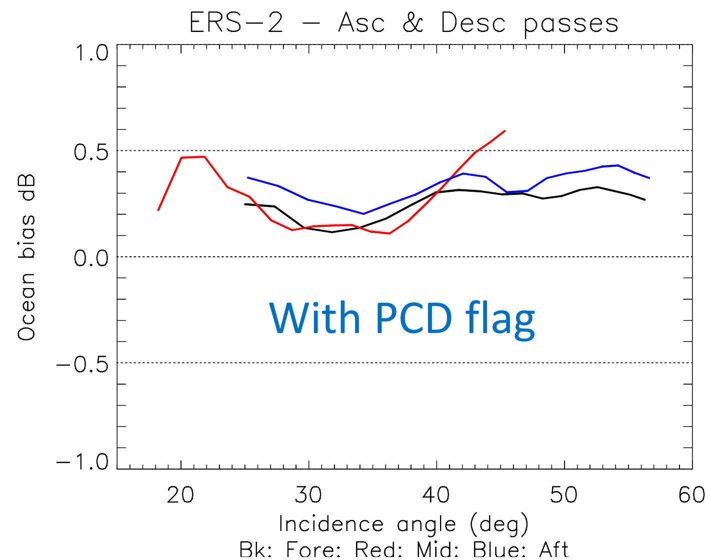
- Solid steps towards ERS/ASCAT intercalibration using a reference cone from the ASCAT period
  - cone metrics validated by NOC over ASCAT record
- Connecting to ERS period is complicated by:
  - Changes in observation geometry (geocorrection)
  - Structured residuals in need for interpretation (beam calibration curves)
    - Non linear correction in ERS2 mid beam
    - Linear correction in ERS1 & ERS2 fore/aft beams
- TO DO:
  - Resolve beam calibration curves for ERS1 and ERS2
  - Reference cone conditioning

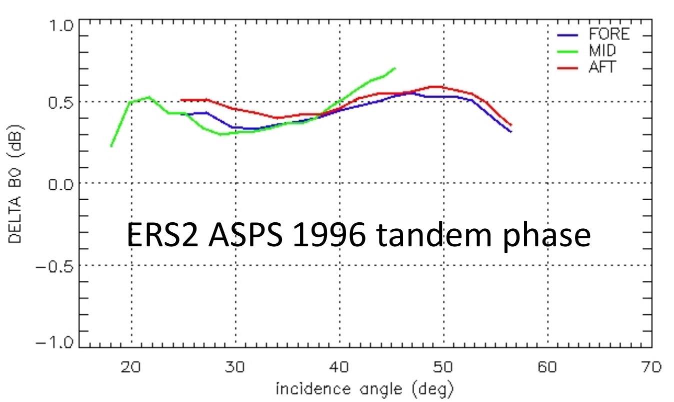
Backup slides

Last interaction with RMA

- Aligning ERS2 tandem phase results with NOC



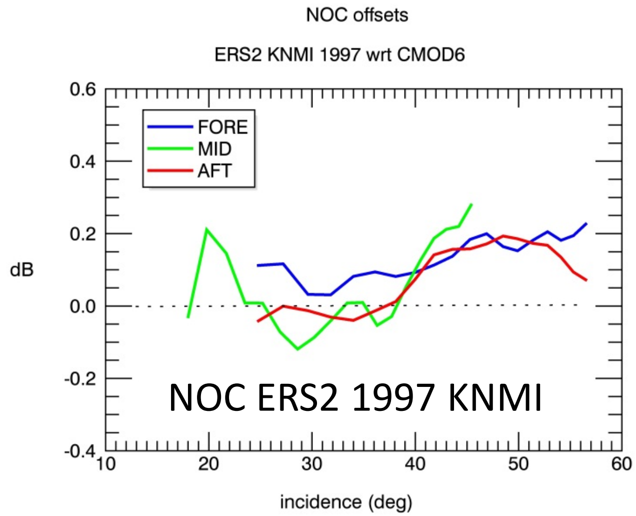


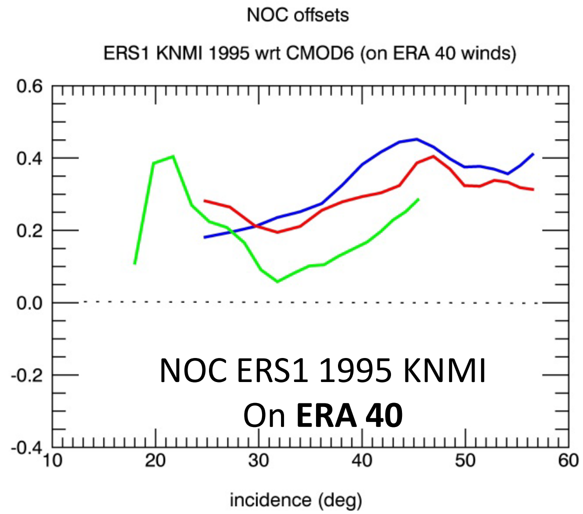


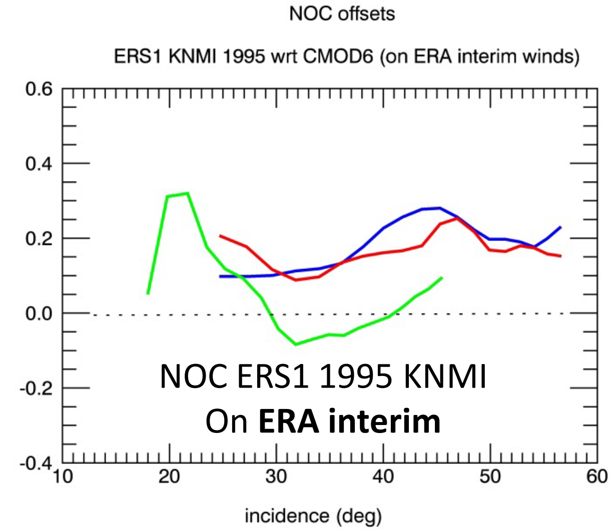
Sensitivity to QC settings:
- Low wind screening should not be applied. Exacerbates NOC errors

To CMOD5n, ERA40 winds (=ASPS winds)

Sensitivity to reference winds: NOC on ERS



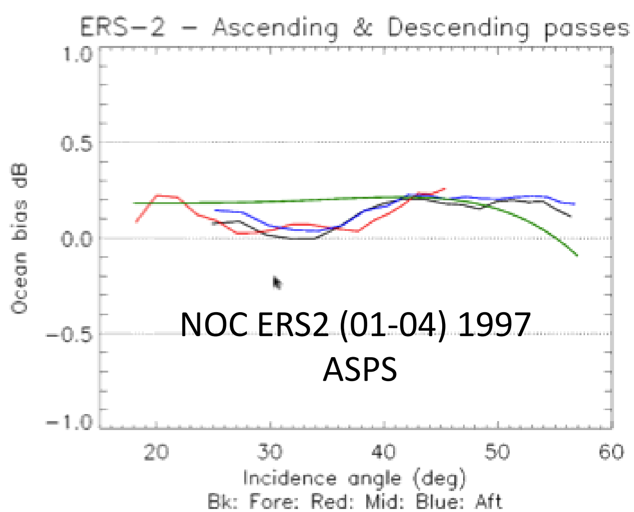


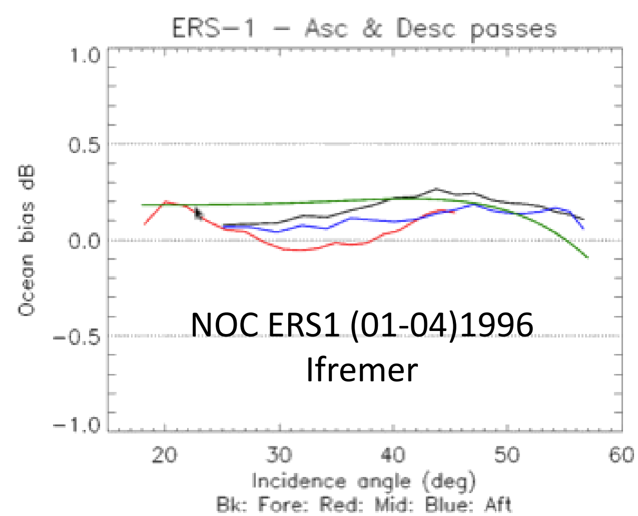


passing from ERA40 to ERA interim is necessary

→ Homogeneity in background reference NWP wind is crucial. ERA 40 seems inadequate.

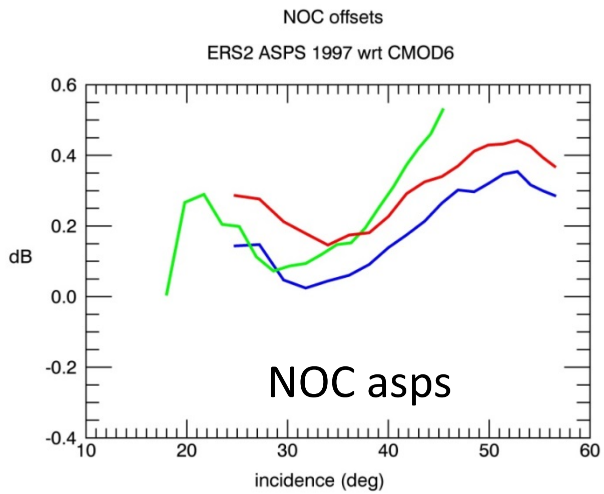
Aim: replicate RMA NOC results (CMOD6 and ERA interim)





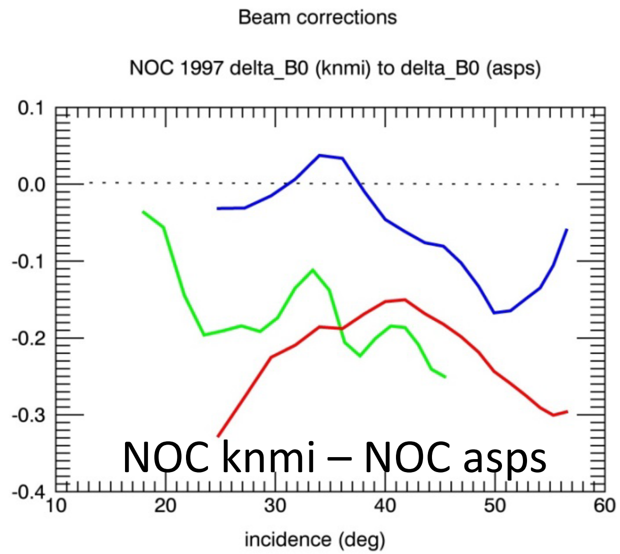
They are different records and may mix seasonality, and nwp errors etc…

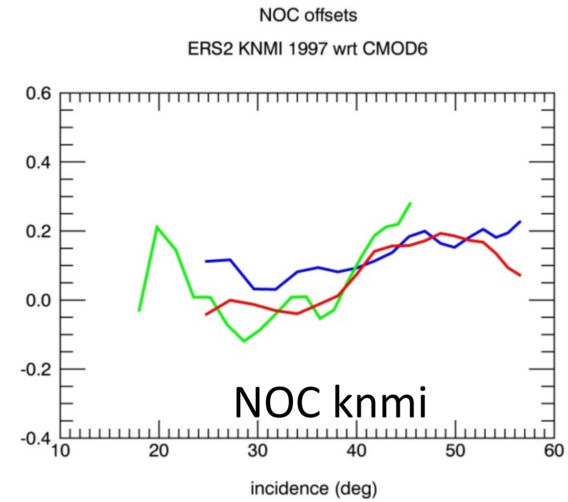
NOC on ASPS and KNMI



Reference winds are ERA40

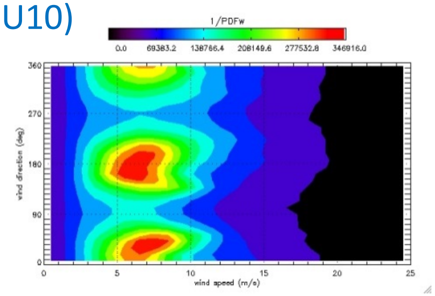
ERS2 1997

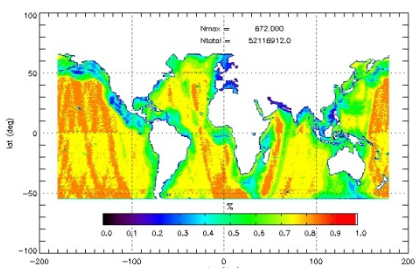


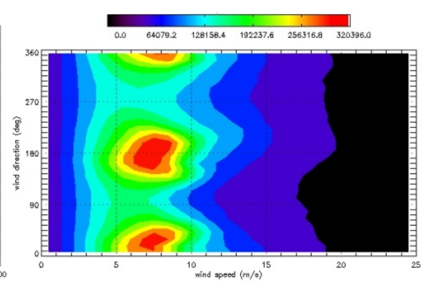


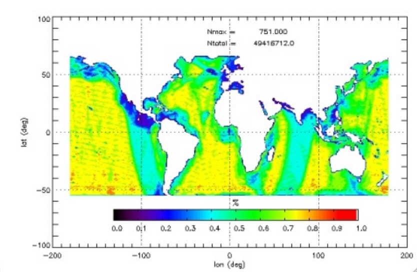
Did we make a mistake in calculating the NWP winds: bias in ASPS file assumed to be selected wind (U10N) minus model wind (U10)

KNMI winds higher than asps…, the reference cone is elevated, and the NOC bias more negative for KNMI than ASPS









The asps mean NWP wind is smaller than the knmi mean NWP wind → larger difference in asps case… but then the F/A beams are switched !!