CFOSAT and WindRad simulation

IOVWST Meeting

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02-05-2017

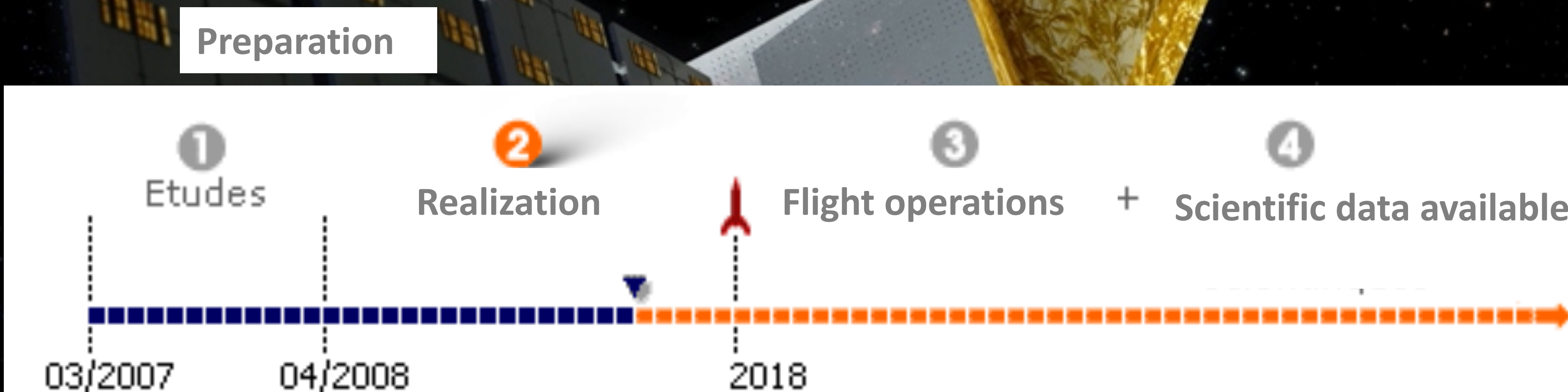
Outline

- CFOSAT – Rotating Fan-beam concept
- FY-3E WindRad dual frequency Ku/C-band
- L1B simulation result
- Beam Weighting method
- Trade-off choice
- CFOSAT-WindRad comparison

CFOSAT concept

Orbit:
- Sun synchronous
- Local time at descending node
  7 am
- Cycle duration
  13 days

SWIM
- Wave scatterometer: ku-band

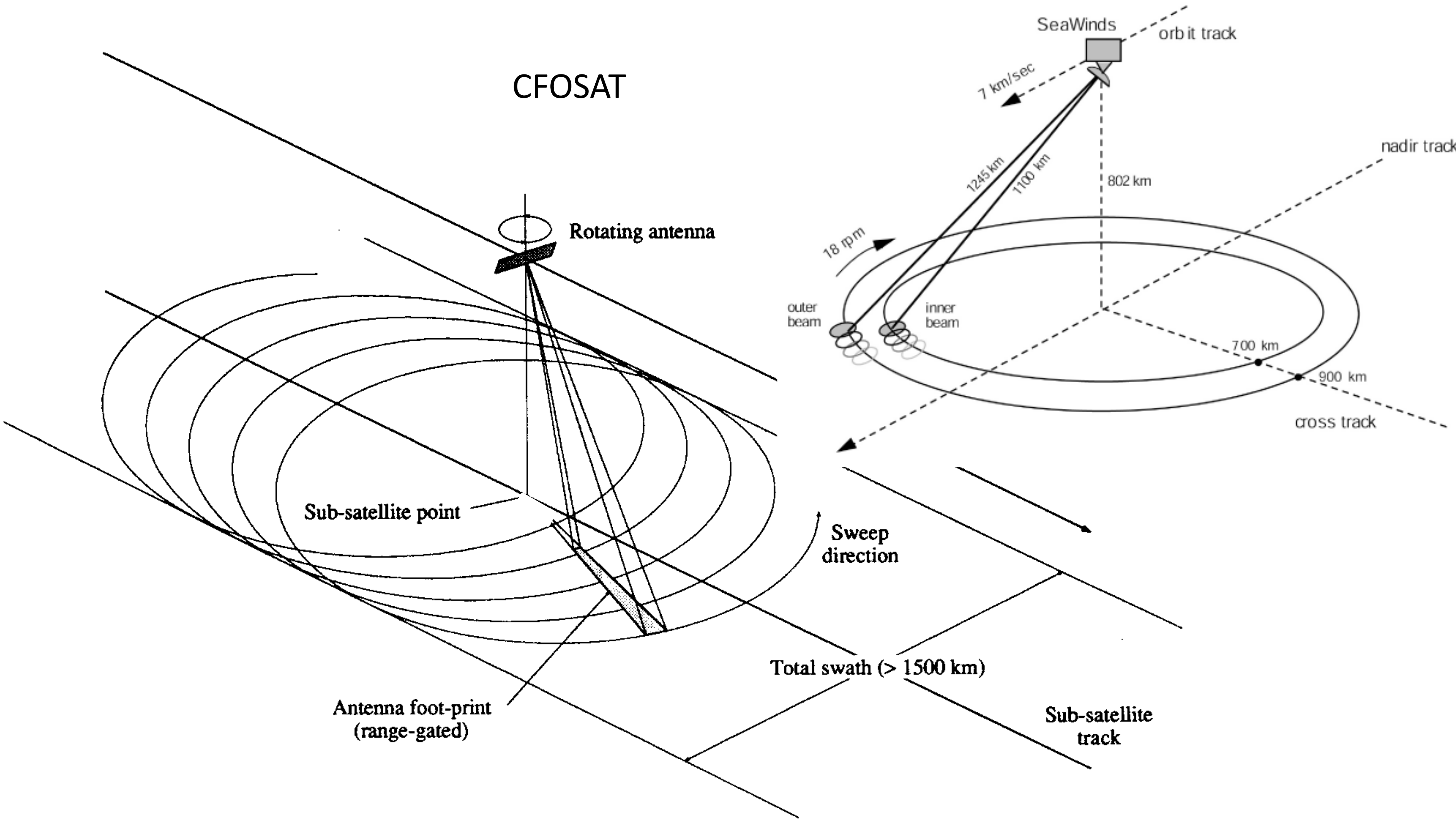


RFSCAT
- Rotating Fan-beam wind scatterometer at ku-band

https://cfosat.cnes.fr/

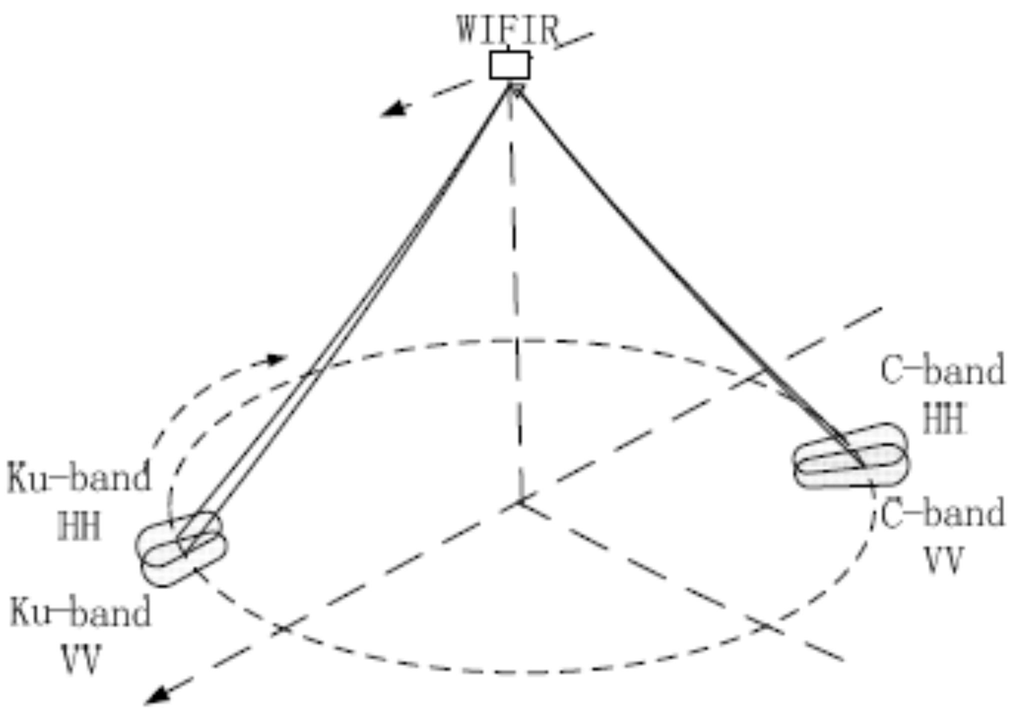
Rotating Fan Beam

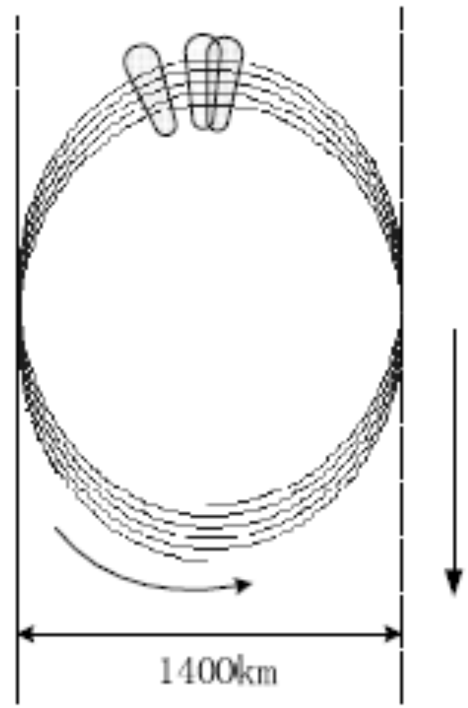
CFOSAT



Lin et al., 2000 projects.knmi.nl/scatterometer/rfscat/

WindRad





Dou, et. al 2014

Parameters Comparison between CFOSAT and WindRad

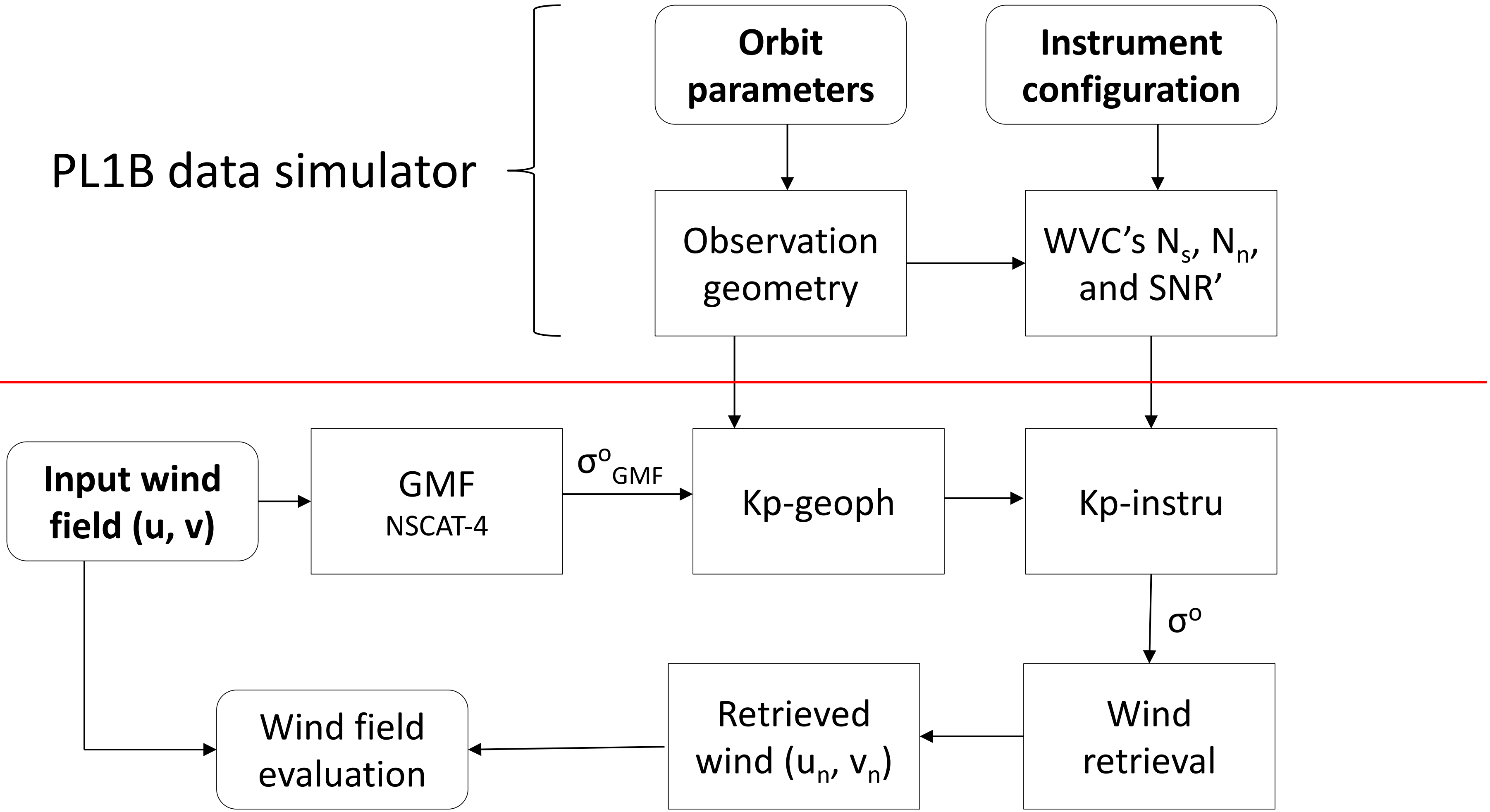
Specification	Value
Frequency	Ku band
Bandwidth	0.5 MHz
Polarization	VV and HH
Swath width	1000 km
Orbit height	514 km
Incidence angles	25 – 47.6 degree
Rotation rate	3.5 rpm
Transmit power at HPA	120 W
Pulse repetition frequency (PRF)	75 Hz

CFOSAT

Specification	Value
Frequency	Ku and C band
Bandwidth	0.6 MHz
Polarization	VV and HH
Swath width	1400 km
Orbit height	836km
Incidence angles	34.9 – 44.9 degree
Rotation rate	3.03 rpm
Transmit power at HPA	120 W (ku band) 100 W (C band)
Pulse repetition frequency (PRF)	104 Hz (Ku band) 208 Hz (C band)

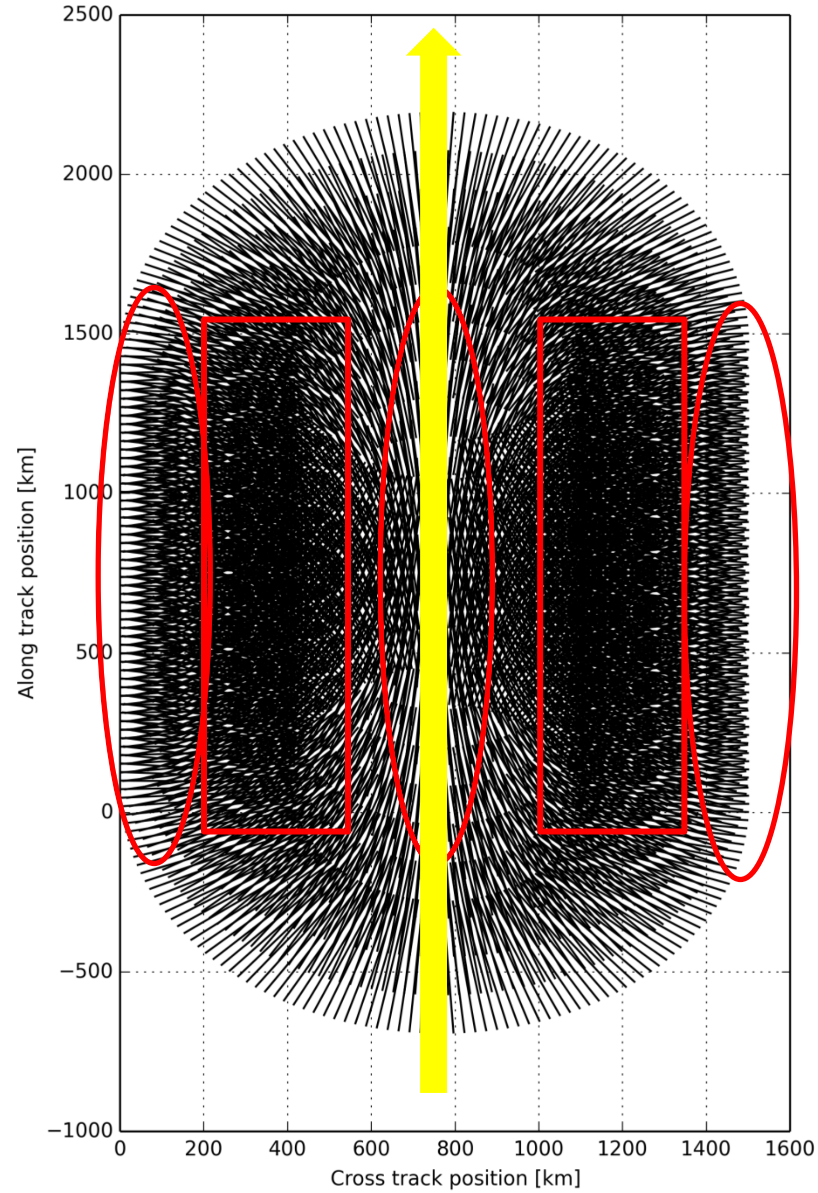
WindRad

RFSCAT end to end simulator

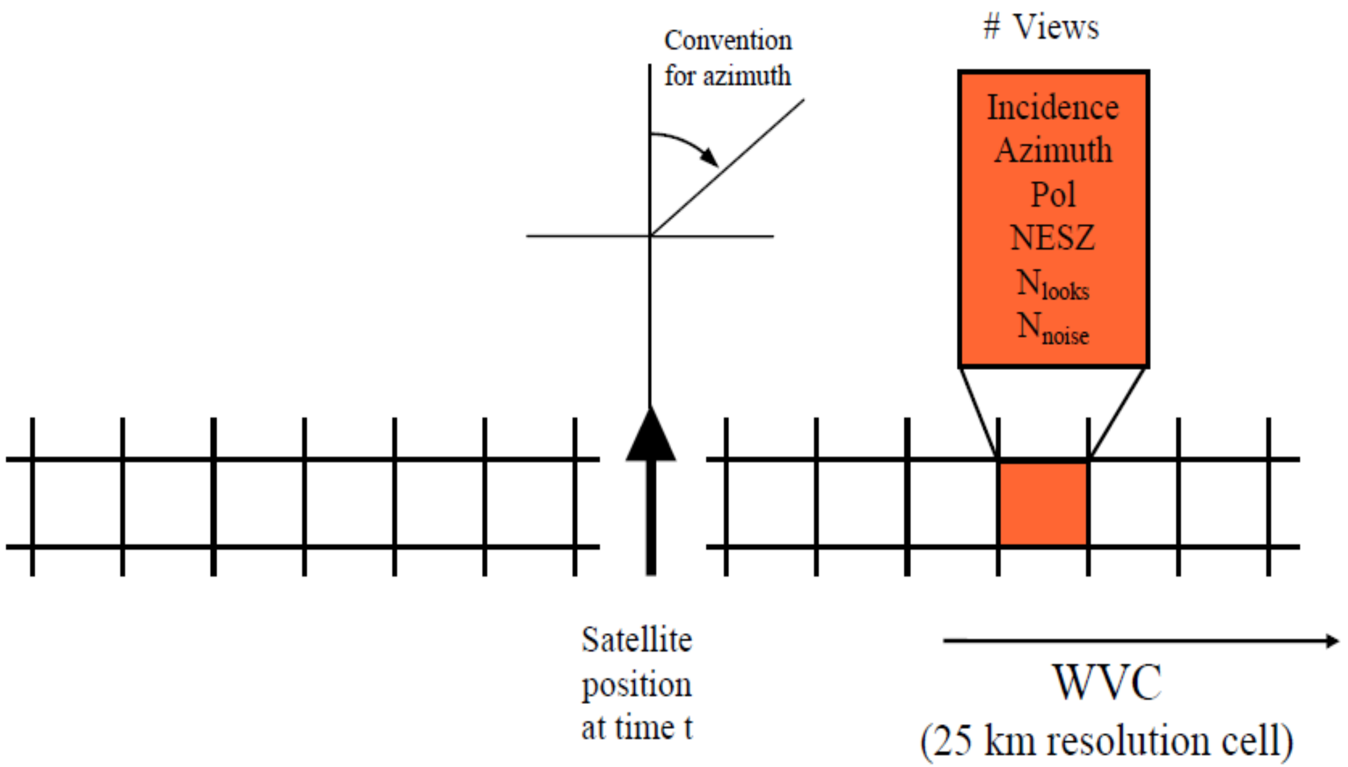


RFSCAT simulator developed by Jos de Kloe

L1B simulation illustration

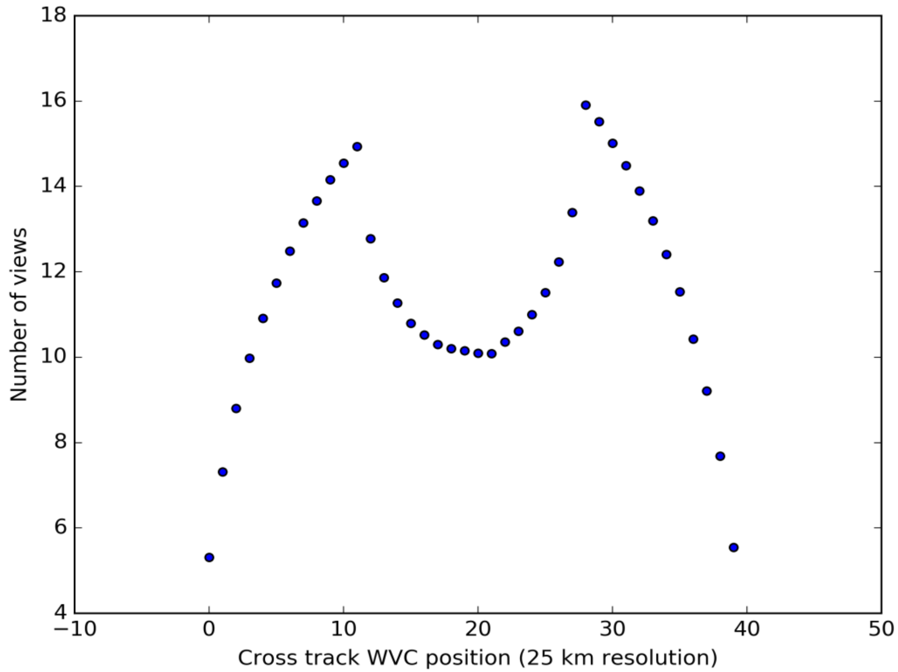


Content of L1B data

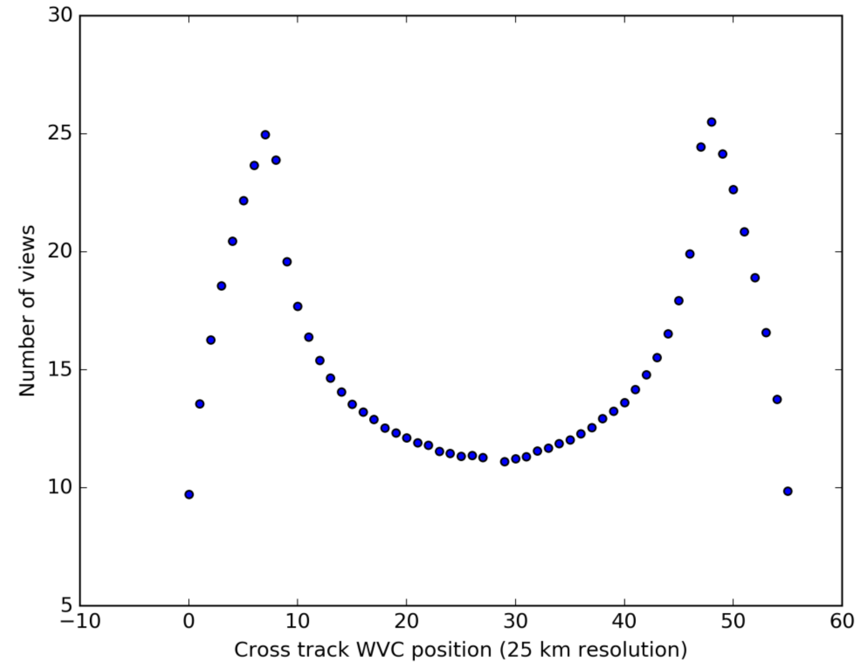


Belmonte et al., 2009

Number of views on the WVCs



CFOSAT

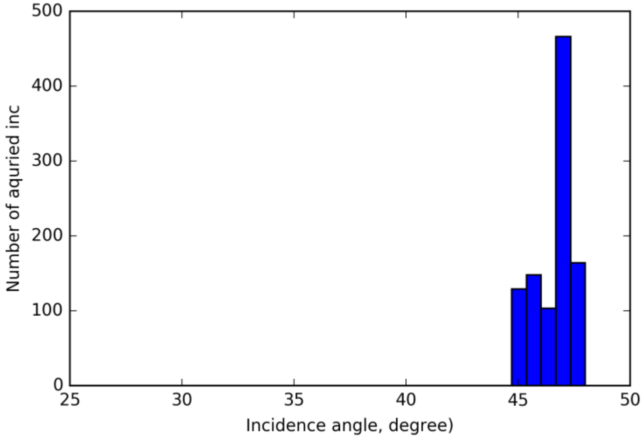


WindRad
(C-band, ku-band)

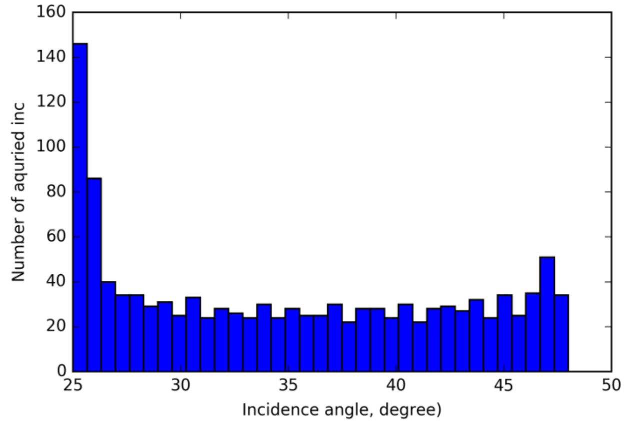
Incidence and azimuth angle distribution

CFOSAT

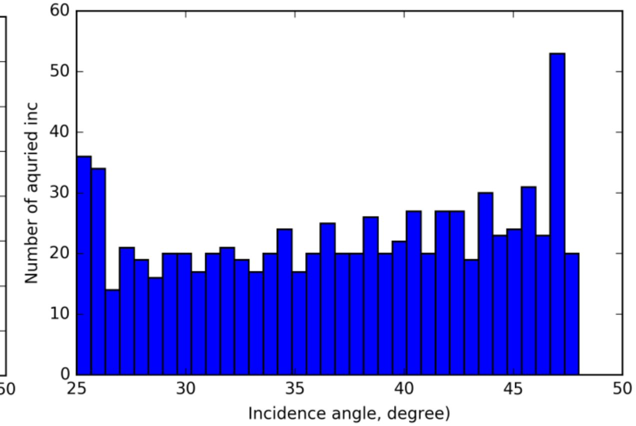
Outer

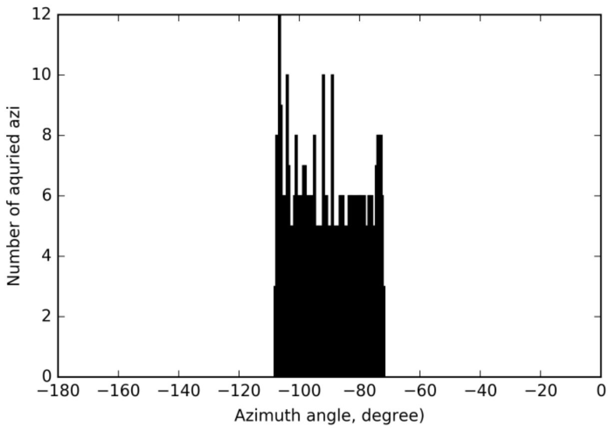


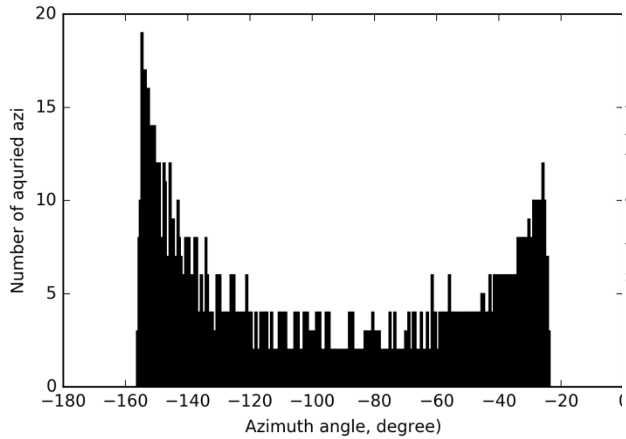
Sweet

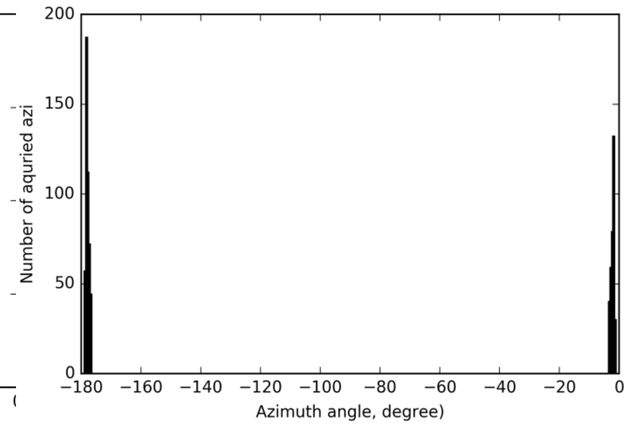


Nadir



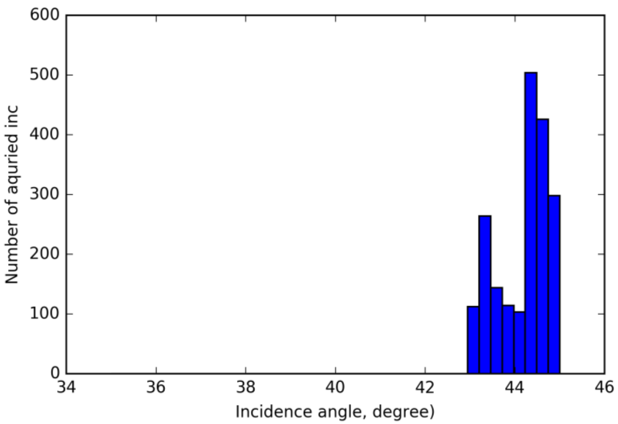


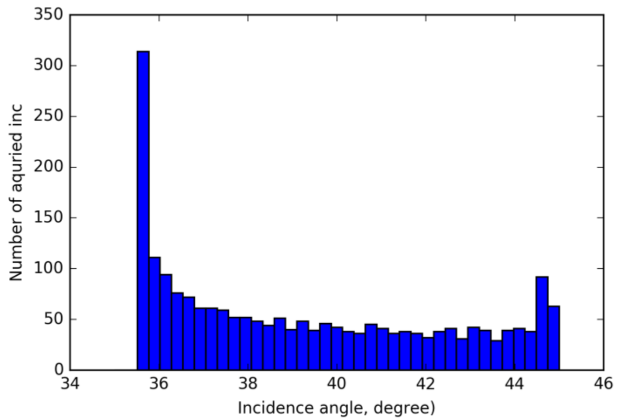


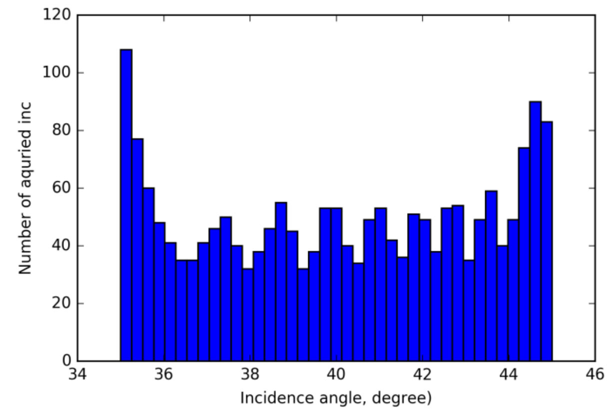


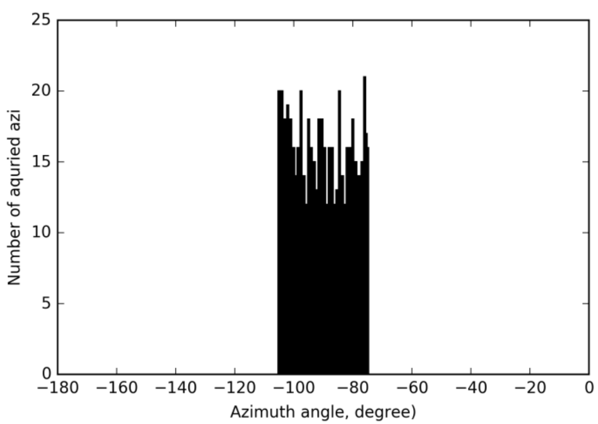
WindRad

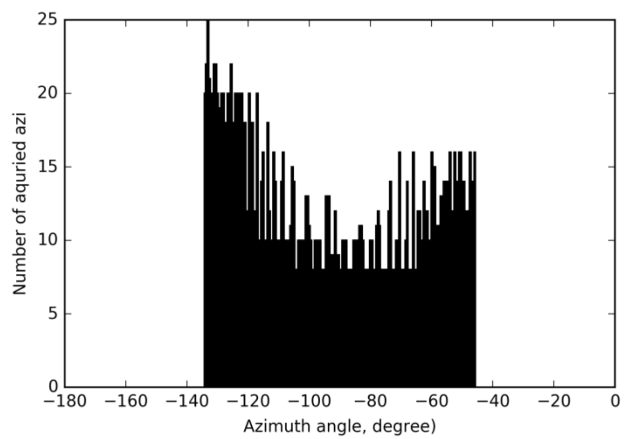
Outer	Sweet	Nadir

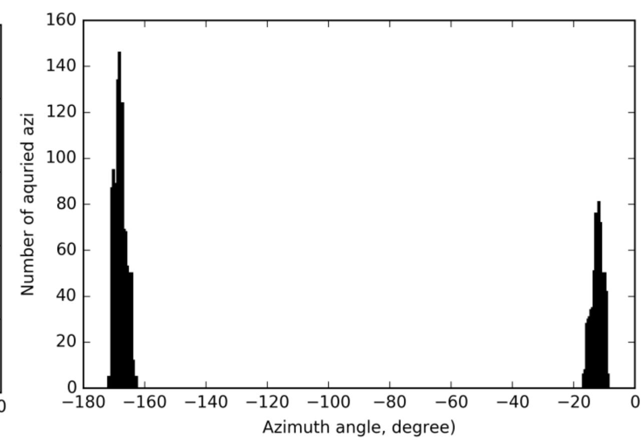






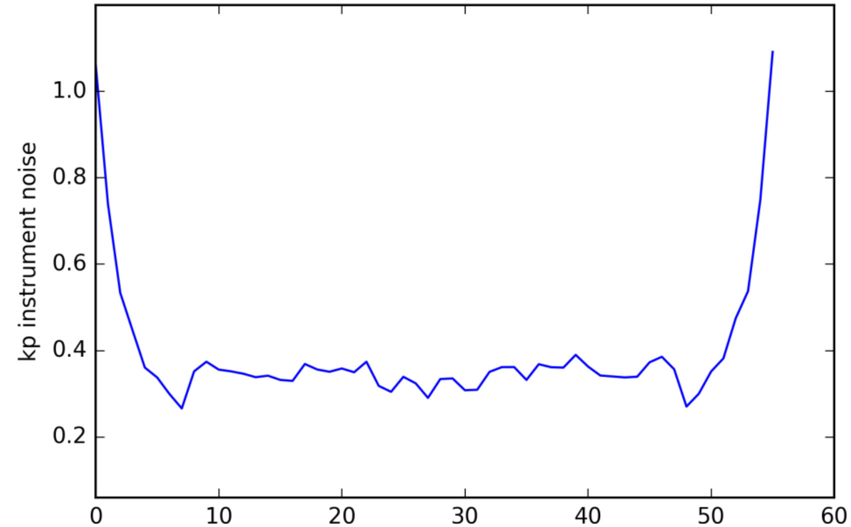


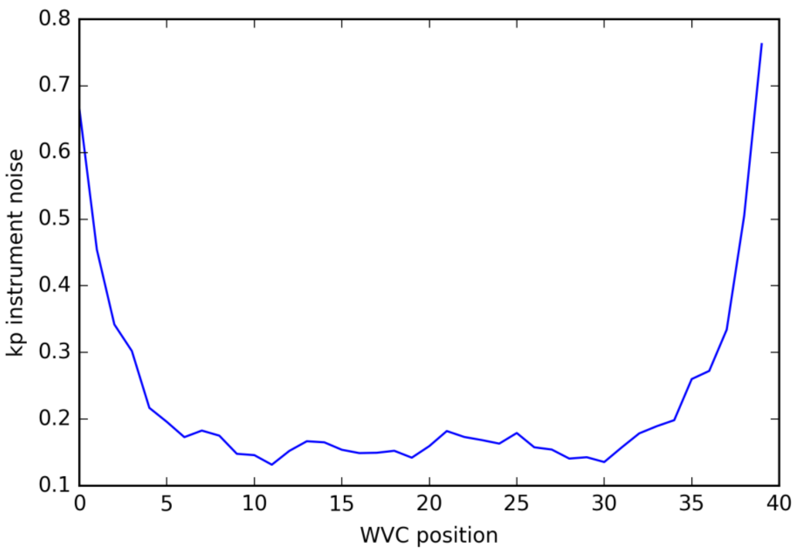




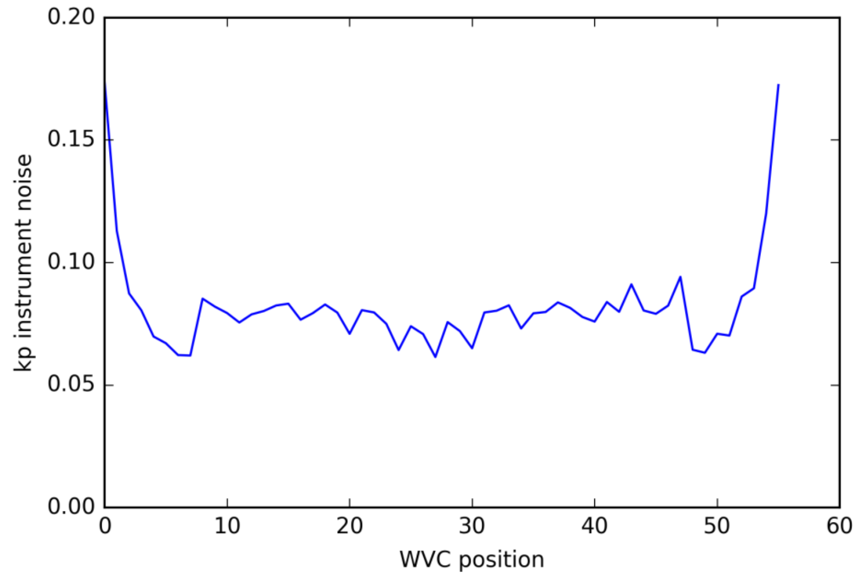
Kp instrument noise distribution

WindRad C-band





CFOSAT

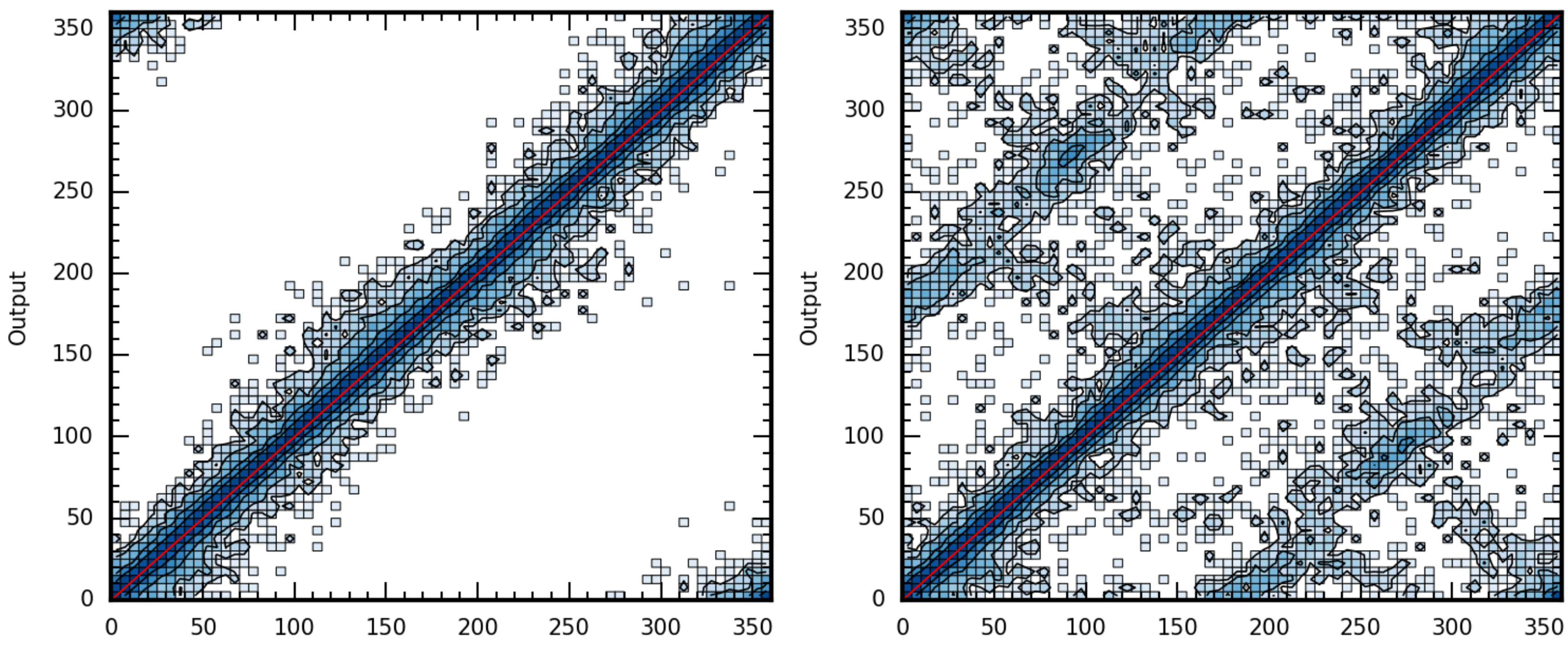


WindRad ku-band

Wind retrieval result with constant wind speed and random wind direction over all the WVCs

Wind direction closest result

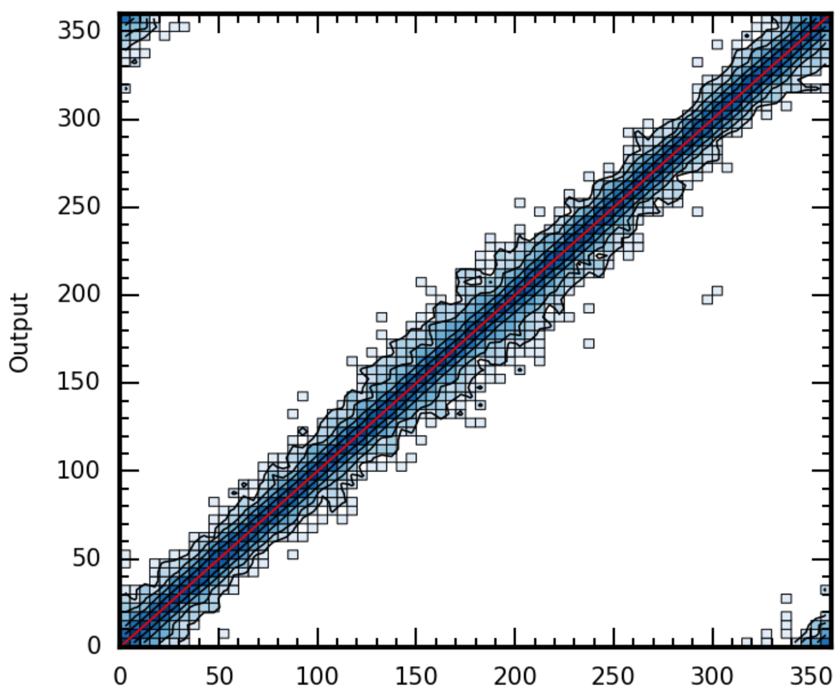
Wind direction first rank result



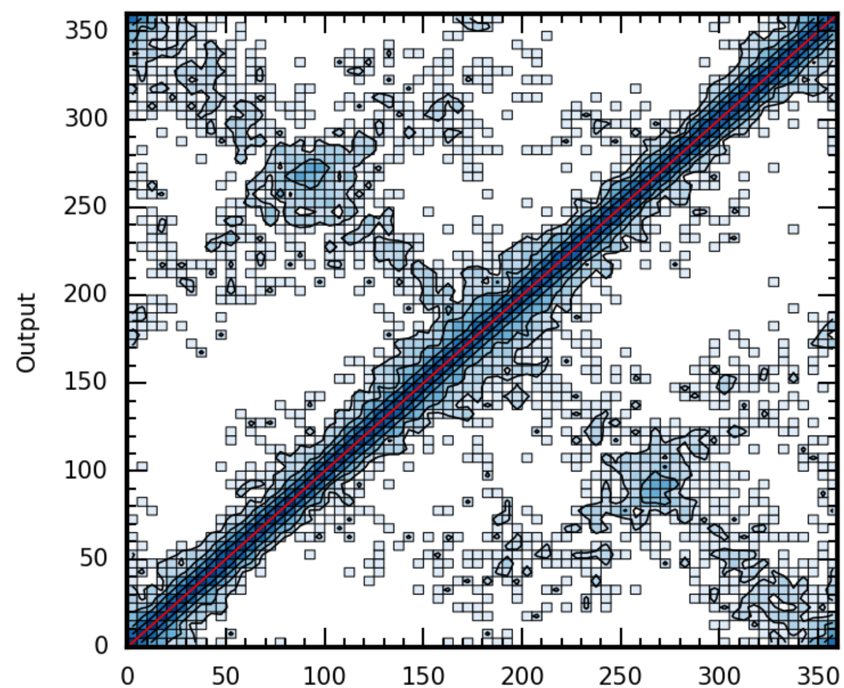
Wind speed = 8 m/s

CFOSAT

Wind direction closest result



Wind direction first rank result



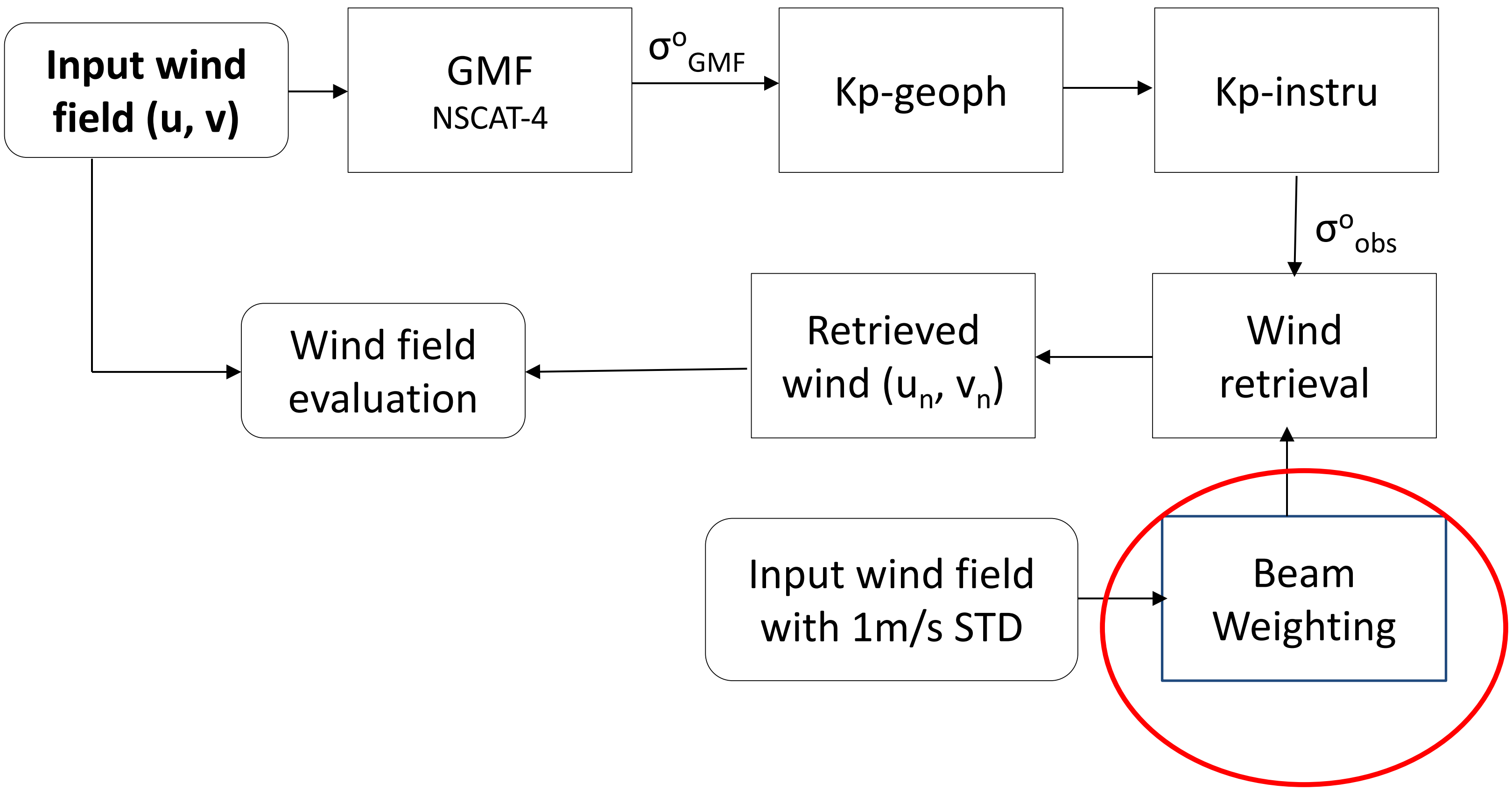
Wind speed = 8 m/s

WindRad

Beam weighting method

- Commonly used MLE has the assumptions: measurement errors are uncorrelated; their errors are Gaussian; The priori probability P($\sigma^{o}{}_{s}$) is constant. The last one is problematic if sensitivity depends on azimuth.
- Z-space transform has been applied on ERS and makes true the assumption of constant P($\sigma^{o}{}_{s}$) (Stoffelen and Anderson, 1997).
- The shape of GMF solution manifold in measurement space is related to the system wind direction sensitivity, and when this sensitivity is uniform, realistic and precise wind direction distributions are retrieved.
- RFSCAT has more than three beams (views), which the transformation could not be derived straightforwardly through visualization of the 3-D measurement space.
- A more generic beam weighting method was applied on ERS and SeaWinds scatterometer. Scaling in the inversion step to get uniform total wind sensitivity (Stoffelen and Portabella, 2006) in order to reduce (un)popular wind directions.

Adapt Beam Weighting Method to RFSCAT



Beam weighting method

Before

Total wind direction sensitivity

Minimization of the sensitivity (cost function)

Coefficients for each view

Wind retrieval

Give coefficients according to the wind field for both $(\sigma^\circ_{oi} - \sigma^\circ_{si})$ in MLE

After

Fourier series fitting

Total wind direction sensitivity

Minimization of the sensitivity (cost function changed)

Coefficients for each view

Iteration of the coefficients in MLE till converged (according to the first solution of previous inversion)

Wind retrieval

$$MLE = \sum_{i=1}^{N} \left[\frac{a_i(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ_{xi})} \right]^2$$

Adaptation of Beam Weighting Method to RFSCAT

The change of cost function

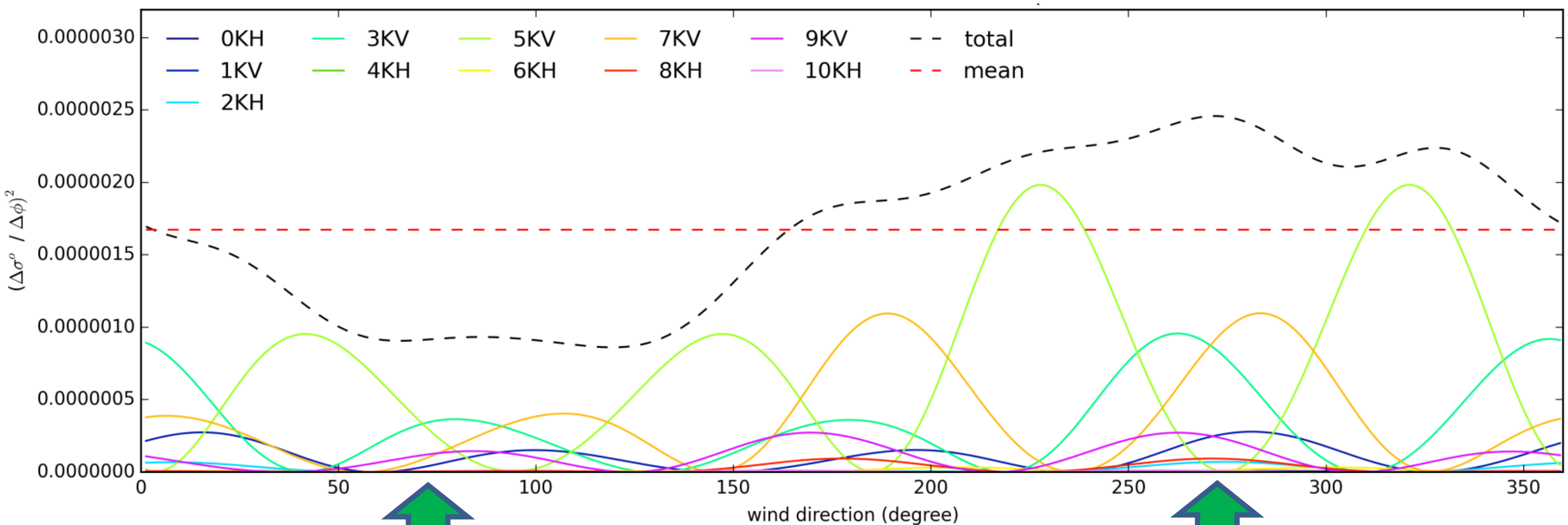
$$\sigma_i^{o'} = a_i \times \sigma_i^{o} \Rightarrow \sum_{i=1}^{N} \left(\frac{\partial \sigma^{o'}{}_i}{\partial \emptyset}\right)^2 \approx \text{constant}$$

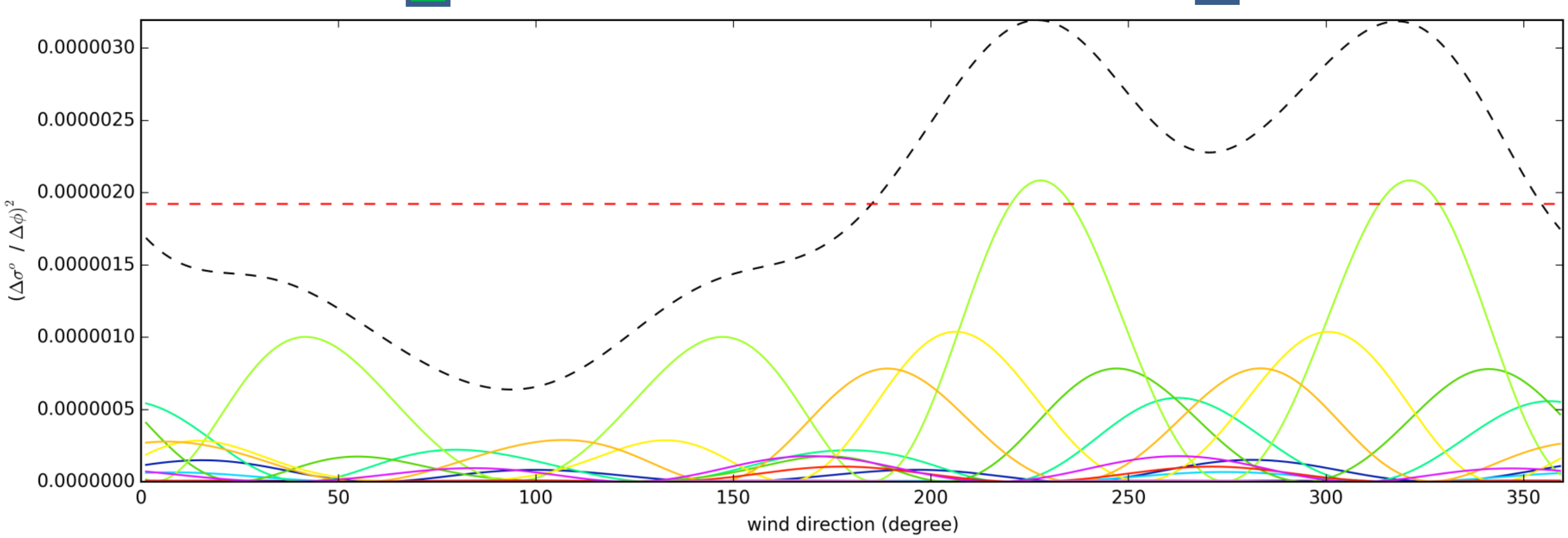
$$J = \frac{1}{M}\sum_{j=1}^{M}\left[\sum_{i=1}^{N}\left(a_i \cdot \frac{\partial \sigma_i^o}{\partial \phi}_{\phi_j}\right)^2 - \text{Mean}\right]^2 \qquad \text{Mean} = \frac{1}{M}\sum_{j=1}^{M}\sum_{i=1}^{N}\left(\frac{\partial \sigma_i^o}{\partial \phi}_{\phi_j}\right)^2$$

$$J_2 = \sum_{j=1}^{M}\sum_{i=1}^{N}\{a_i{}^2 . [\left(\frac{\partial \sigma_i}{\partial \varphi_{i,j+1}}\right)^2 - \left(\frac{\partial \sigma_i}{\partial \varphi_{i,j}}\right)^2]\}^2$$

$J\_new = J + J_2$

Beam weighting method





✓ Reduce sensitivity gradients

Definition of the FoM (Figure of Merit)

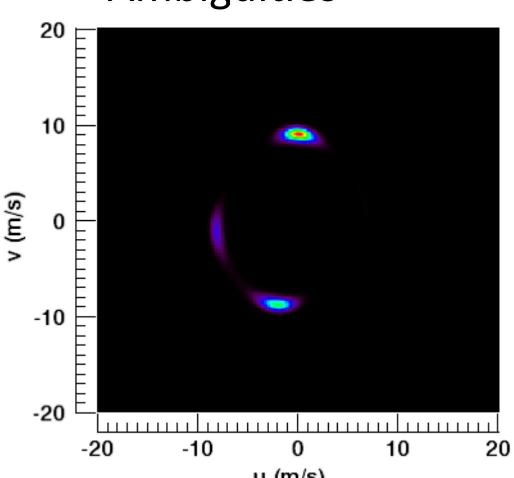
Wind vector RMS error:

It quantifies the total wind retrieval error after ambiguity removal and should be as low as possible

$$FoM = \sqrt{\iint |v_{out} - v_{in}|^2 \cdot P_{obs} \cdot P_{NWP}(v_{out}|v_{in}) d^2 v_{out} \Big/ 2\sigma^2}$$

Belmonte et al., 2009

Ambiguities



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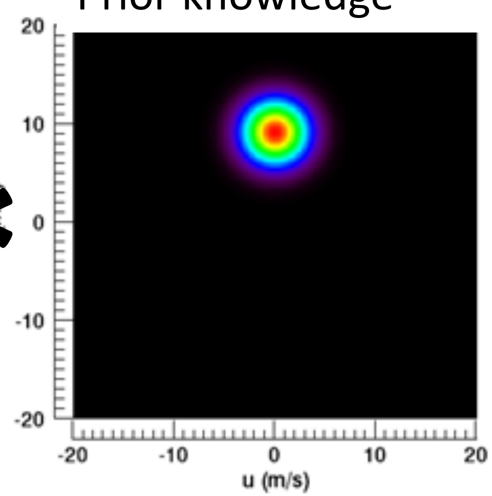
Prior knowledge



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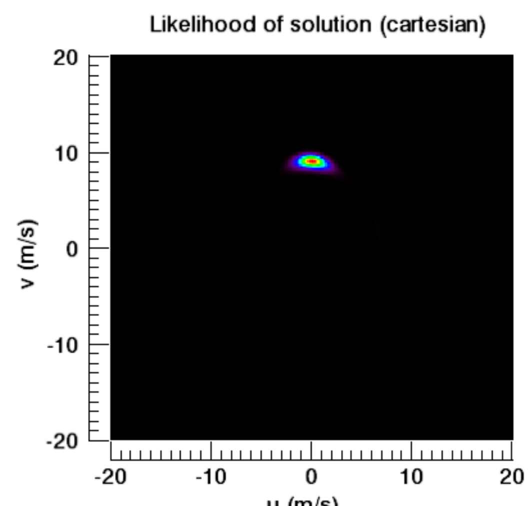
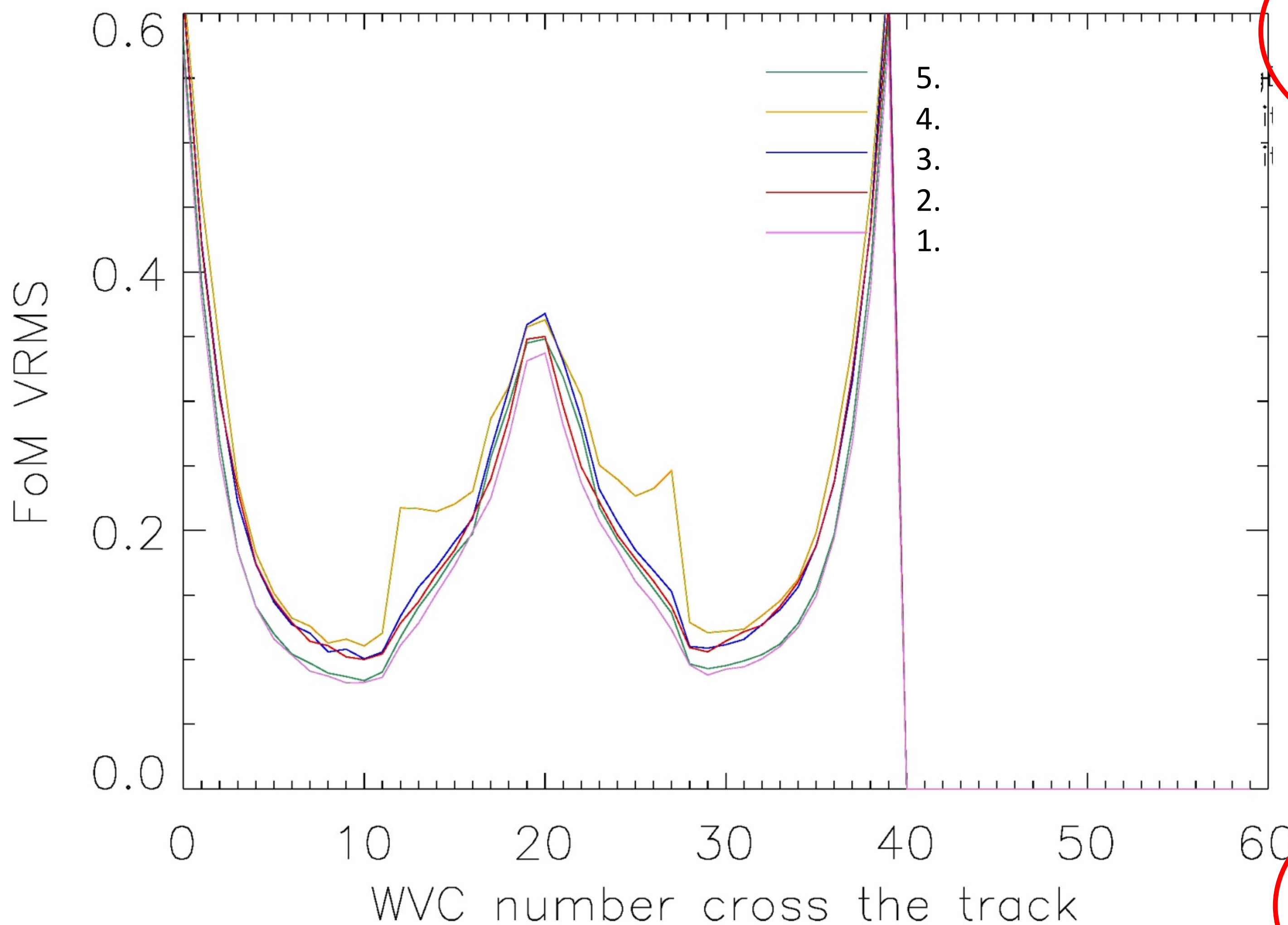




1. $MLE = \sum_{i=1}^{N} \left[\frac{(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ s_i)} \right]^2$

2. $MLE = \sum_{i=1}^{N} \left[\frac{(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ o_i)} \right]^2$

3. $MLE = \sum_{i=1}^{N} \left[\frac{a_i(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ_{oi})} \right]^2$

With iteration

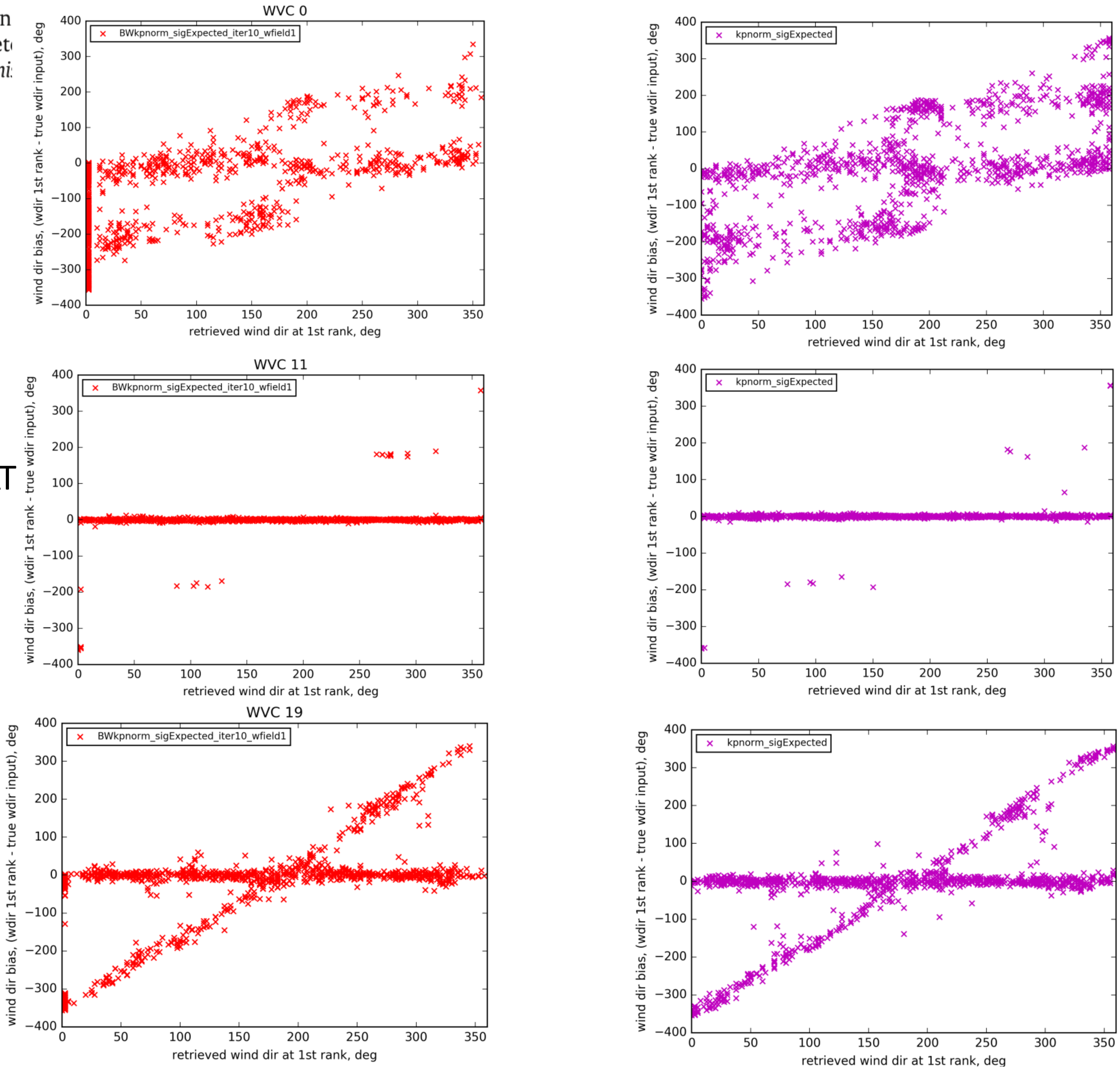
4. $MLE = \sum_{i=1}^{N} \left[\frac{a_i(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ o_i)} \right]^2$

without iteration

5. $MLE = \sum_{i=1}^{N} \left[\frac{a_i(\sigma^\circ_{oi} - \sigma^\circ_{si})}{Kp(\sigma^\circ S_i)} \right]^2$

with iteration

CFOSAT



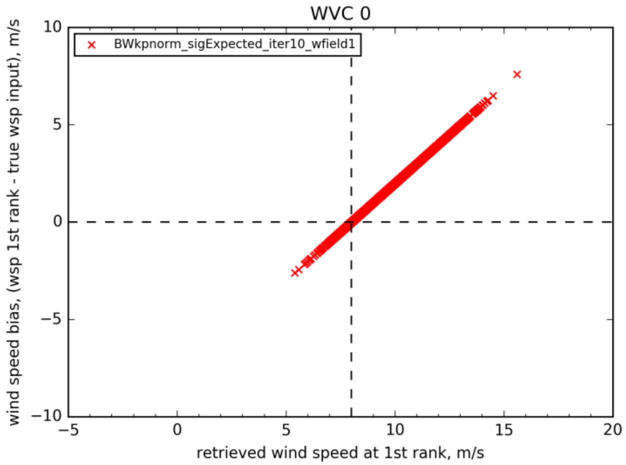
outer

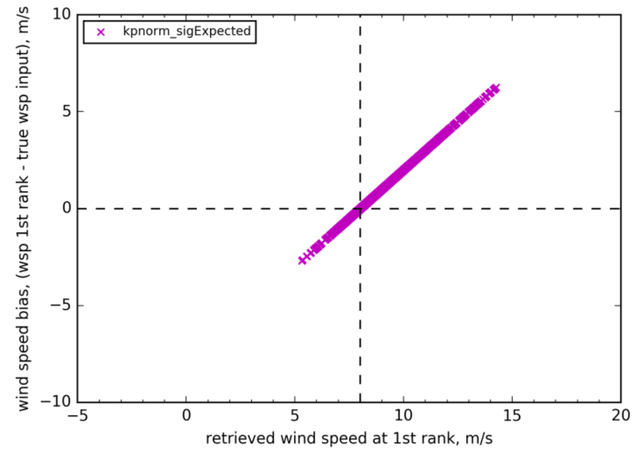
sweet

nadir

Beam Weighting

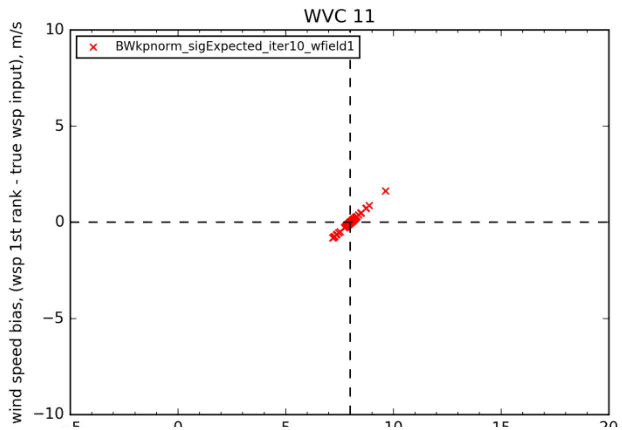
Kp norm

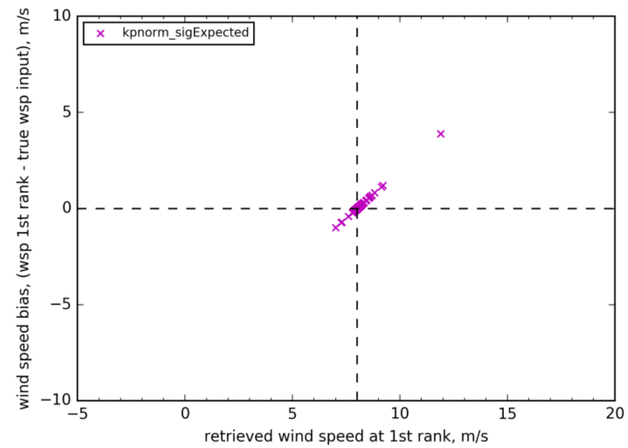




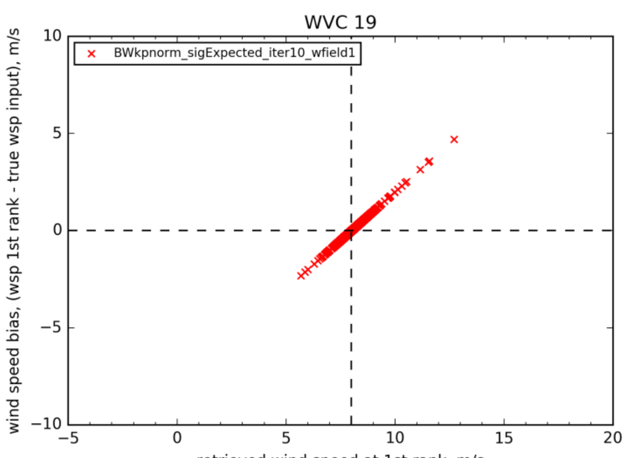
outer

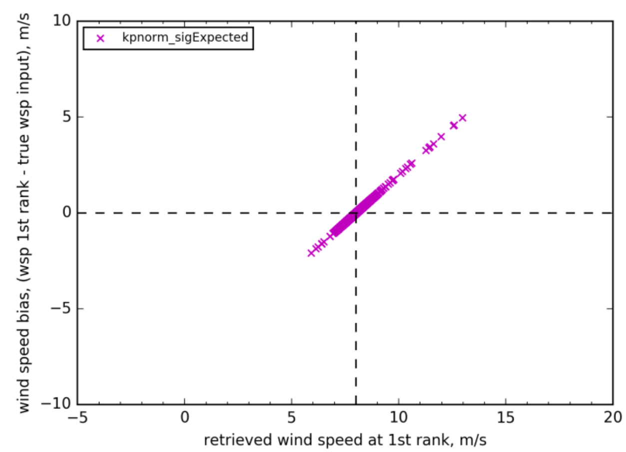
CFOSAT





sweet

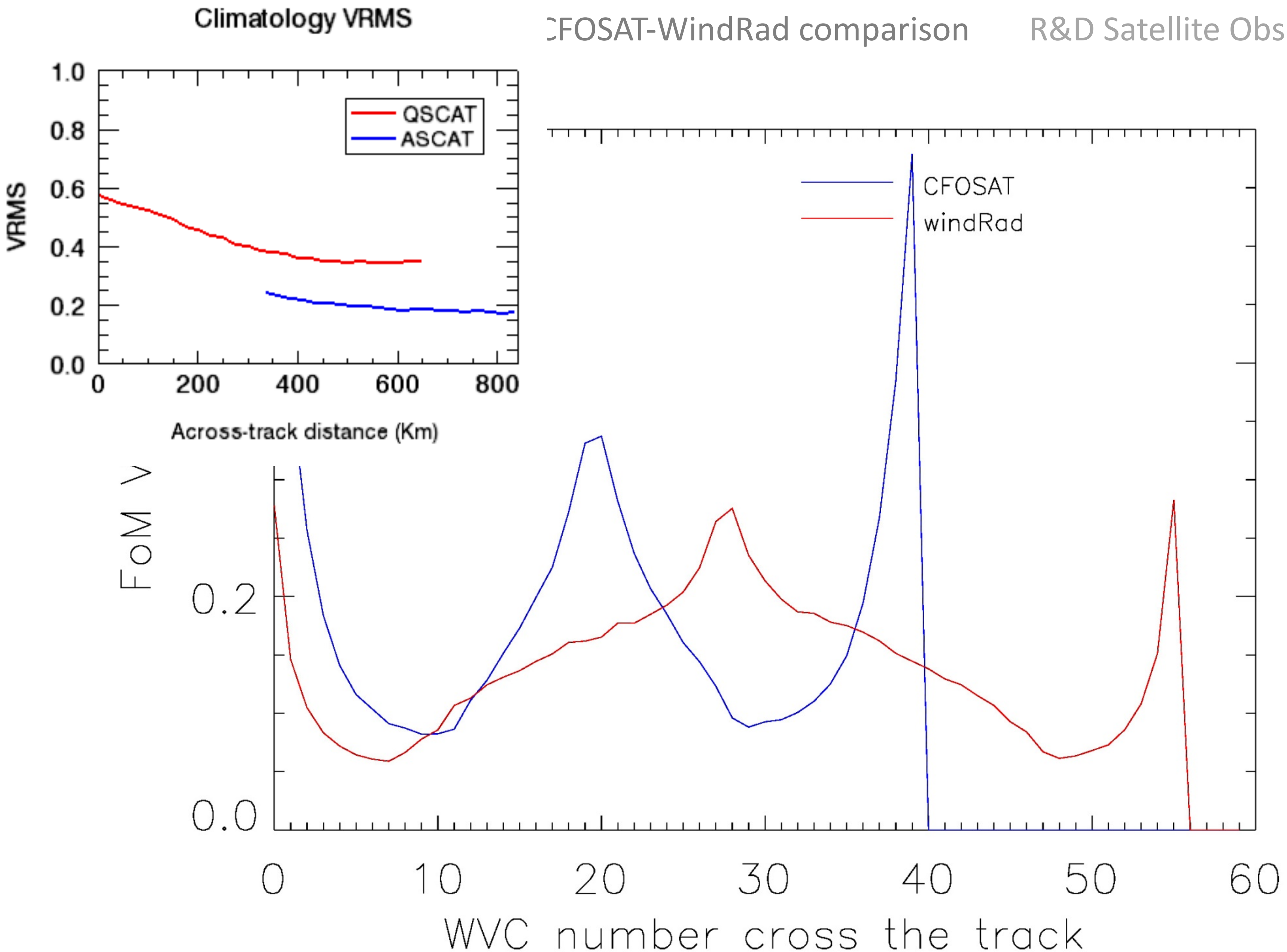




nadir

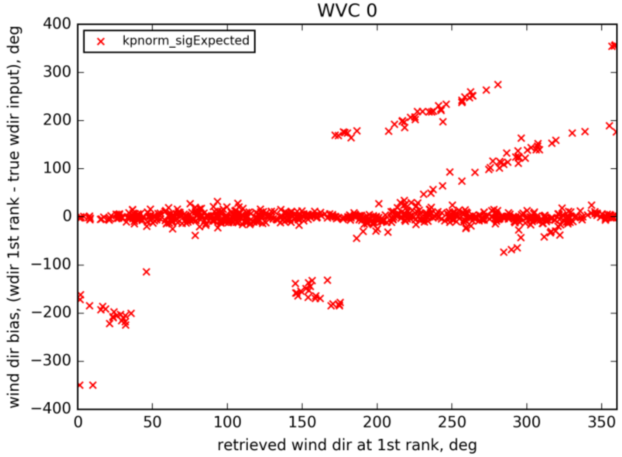
Beam Weighting

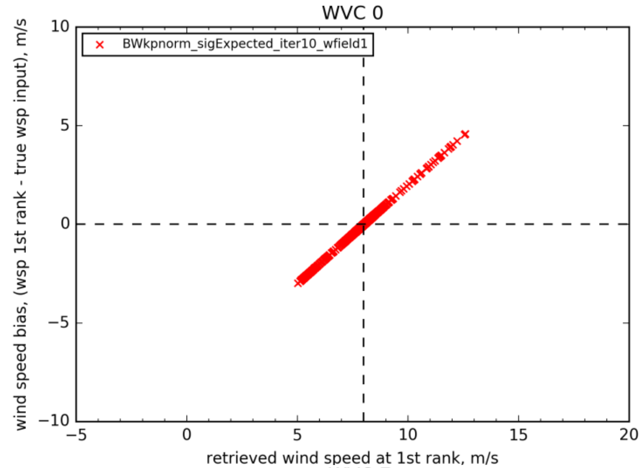
Kp norm


Climatology VRMS
VRMS
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
Across-track distance (Km)
QSCAT
ASCAT
FoM V
0.2
0.0
0
10
20
30
40
50
60
WVC number cross the track
CFOSAT
windRad

Konink
Meteo
Ministe

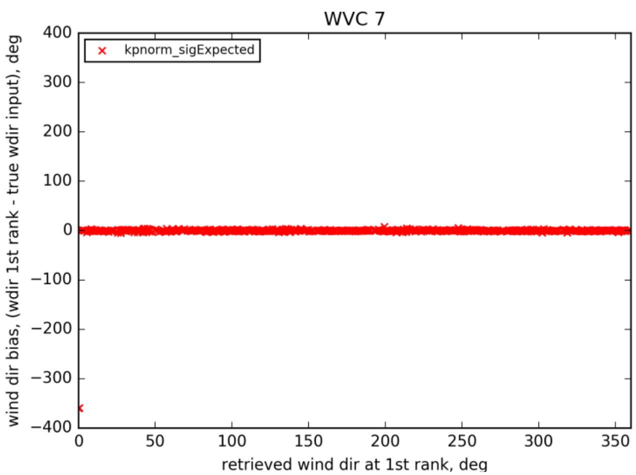
llite Observation

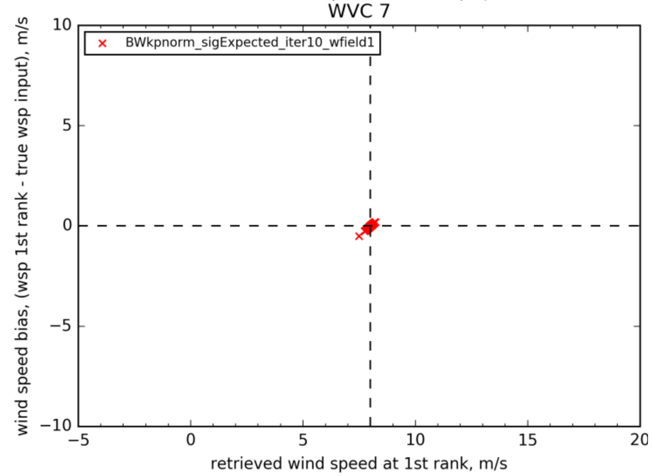




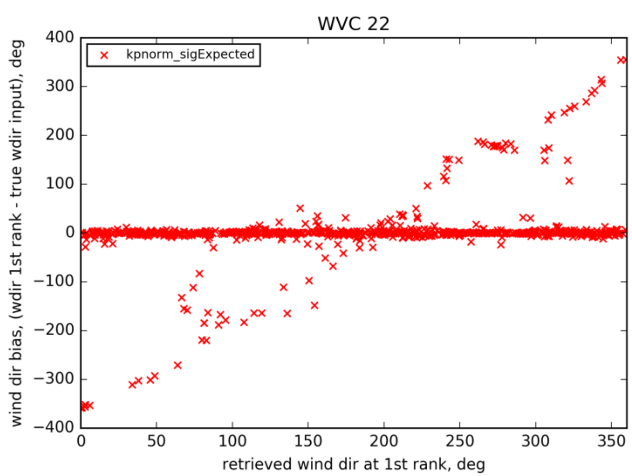
outer

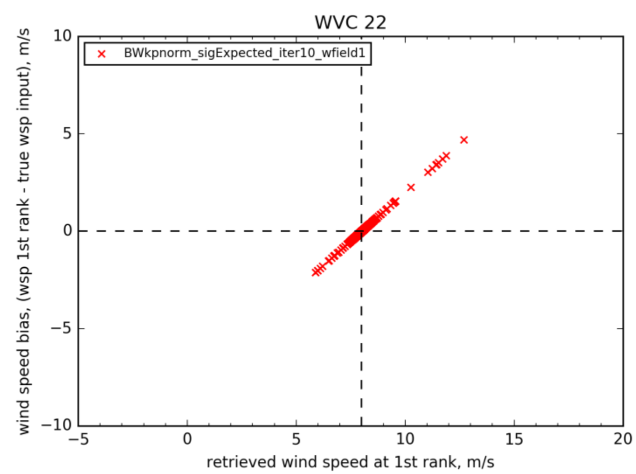
WindRad





sweet





nadir

Summary

- RFSCAT concept gives large swath coverage and significantly improve the wind retrieval quality at the sweet swath.

- Beam Weighting method has been adapted to RFSCAT, it gives similar quality at the sweet swath comparing to the kp normalization with sigma0 simulated, but it also worsens the nadir and outer swath as expected.

- CFOSAT has up to 16 views at sweet swath and shows the ability of good quality retrieval. Near nadir still similar FoM to ASCAT.

- WindRad has double number of views comparing to CFOSAT and its sweet swath (1^{st} rank solution) gives excellent result.

Thank you for your attention.