Effect of rain on
Ku band fan beam Scatterometer

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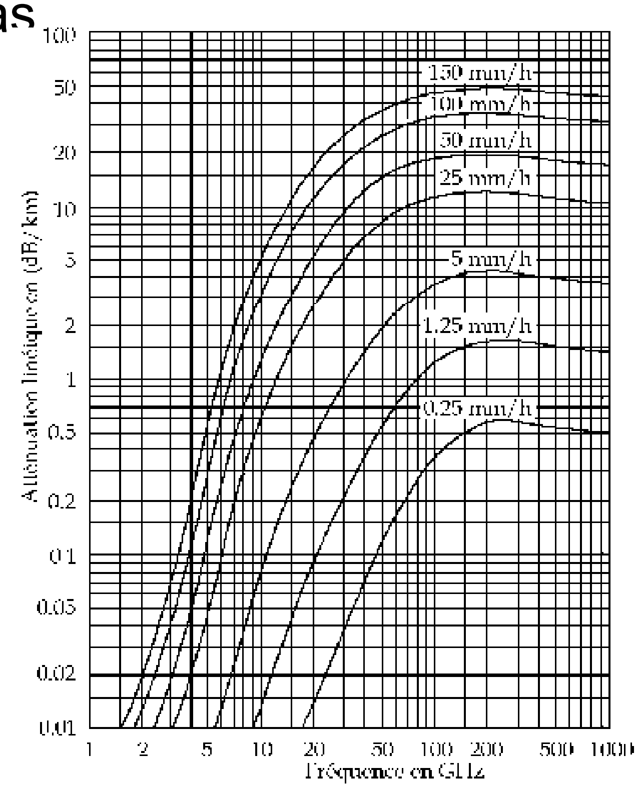
Problem/Drawback of the use of Ku-Band for radar

- SCAT on the future CFOSAT satellite as well as the SWIM instrument (wave spectrum measurement): real aperture radars (RAR) operating in Ku-band (13.255 GHz)
- At Ku band : atmospheric liquid water (rain, cloud droplets) can strongly attenuate the radar signal, for example 10 mm/hr 5 km height rain= ~4dB attenuation
- Necessity of analyzing the impact of rain/clouds SCAT signals
- Experience with NSCAT and SEAWINDS (*Tournadre & Quilfen, 2003 and 2005*)



SCAT-Ku on CFOSAT

New concept

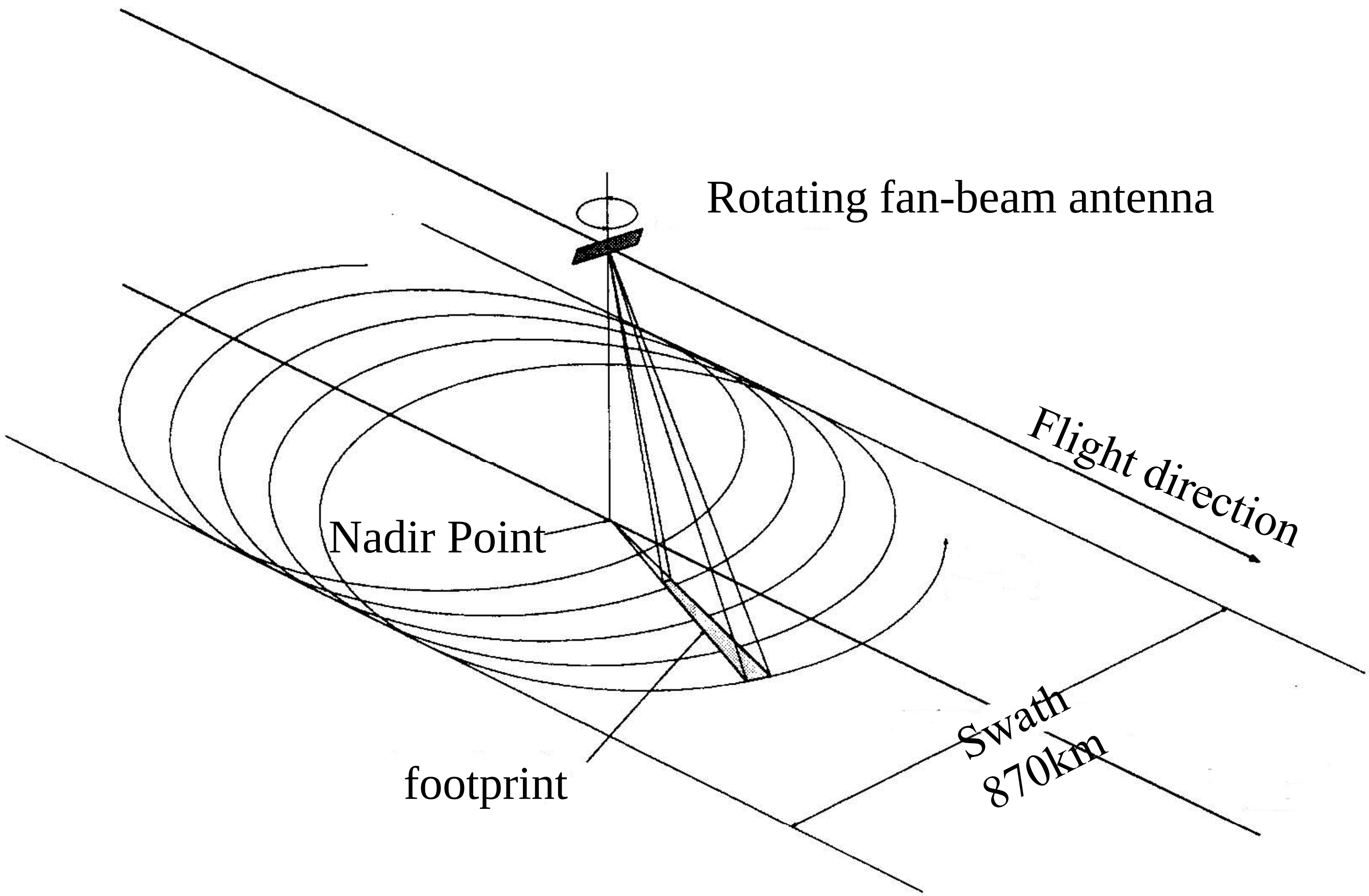
Ku band 13.255 GHz

Fan beam incidence between 18 and 55 deg

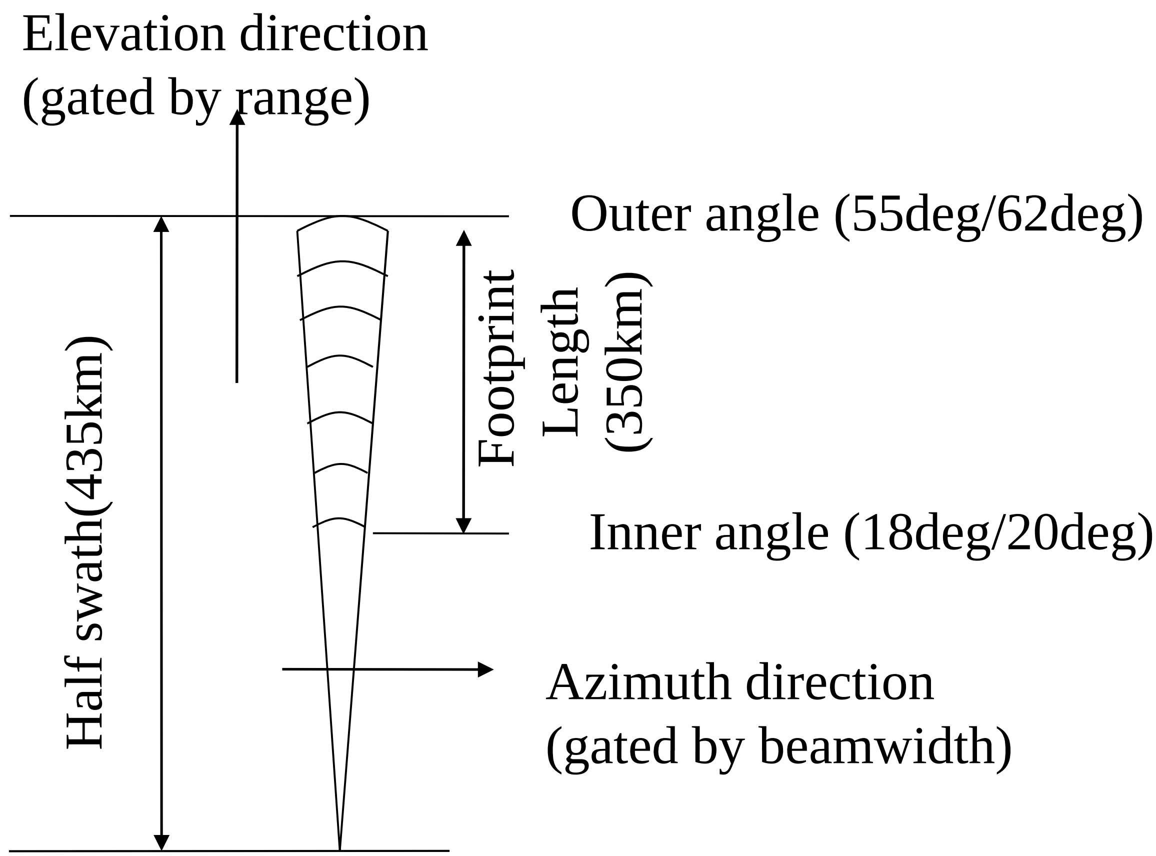
Rotating antenna at 3.245 rpm

HH and VV polarizations

Observation Geometry



Surface Resolution Cell



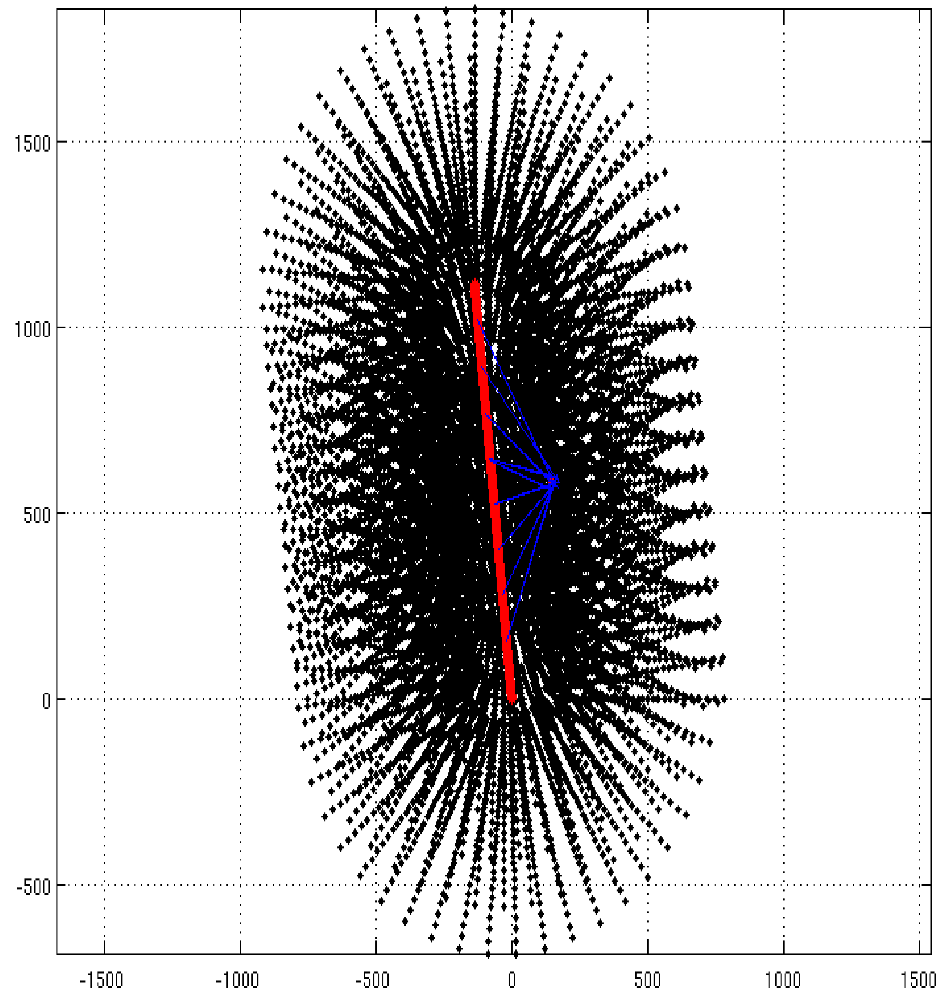
2. Performance Specifications and Key Engineering Parameters

- Wind speed:
  - 2m/s (or 10% which is bigger) @4-24m/s
- Wind direction:
  - ±20°@360°
- Spatial resolution:
  - Nominal: 50km;
  - Experimental: 25km.
- Frequency:
  - Ku-band: 13.256GHz

(TBD by EMC considerations with SWIM)
- Bandwidth:
  - 3MHz
- Coverage Swath:
  - >800km
- Spatial Resolution:
  - Nominal: 50km
  - Experimental: 25km
- Scanning rate:
  - 3.24rpm

Complex sampling patterns

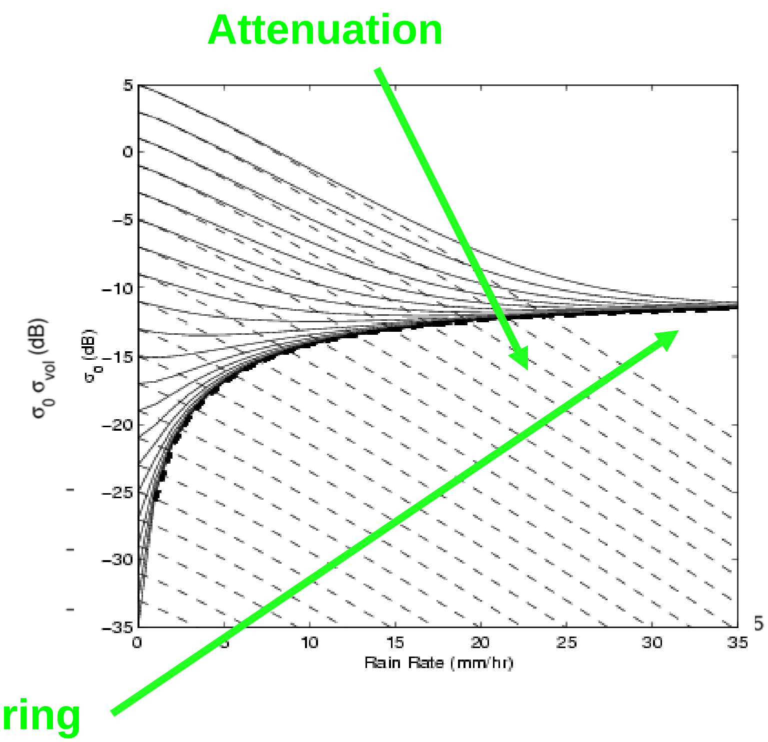
- Fan bean rotating antenna: this implies a complex sampling pattern
- Rain cell will affect several/all incidences
- Previous studies showed that rain variaibility within the ifov is as important as the mean rain



Modeling liquid water effect

Atmospheric liquid Water has 3 main effects on radar signal

- Attenuation (several dB for medium rain)
- Volume scattering (important for SCAT)
- Roughness modification (difficult to model but could be important)



Liquid water/radar interaction

For an active sensor the radiative transfer equation for a completely filled beam written as follows:

$$\sigma_0' = \sigma_0 e^{-2kf} + \eta e^{-2kf}$$

$\sigma 0$ radar cross-section of the sea surface, $\sigma' 0$: rain-affected cross-section measurements, κ: attenuation coefficient of rain, η volume backscattering by rain, *f* : rain optical thickness

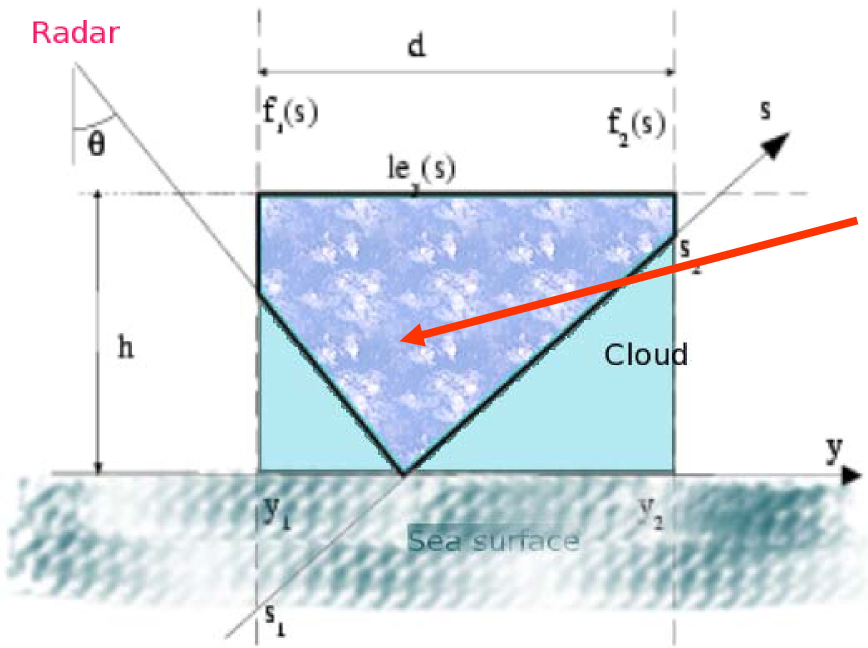
Attenuation by rain, related to rain rate, *R*, by Marshall-Palmer relation

$$\kappa = aR^b$$

Volume scattering, η (in 1/m),

$$\eta = \frac{\pi^5}{\lambda_0} |K_0|^2 Z$$

Partially filled ifov



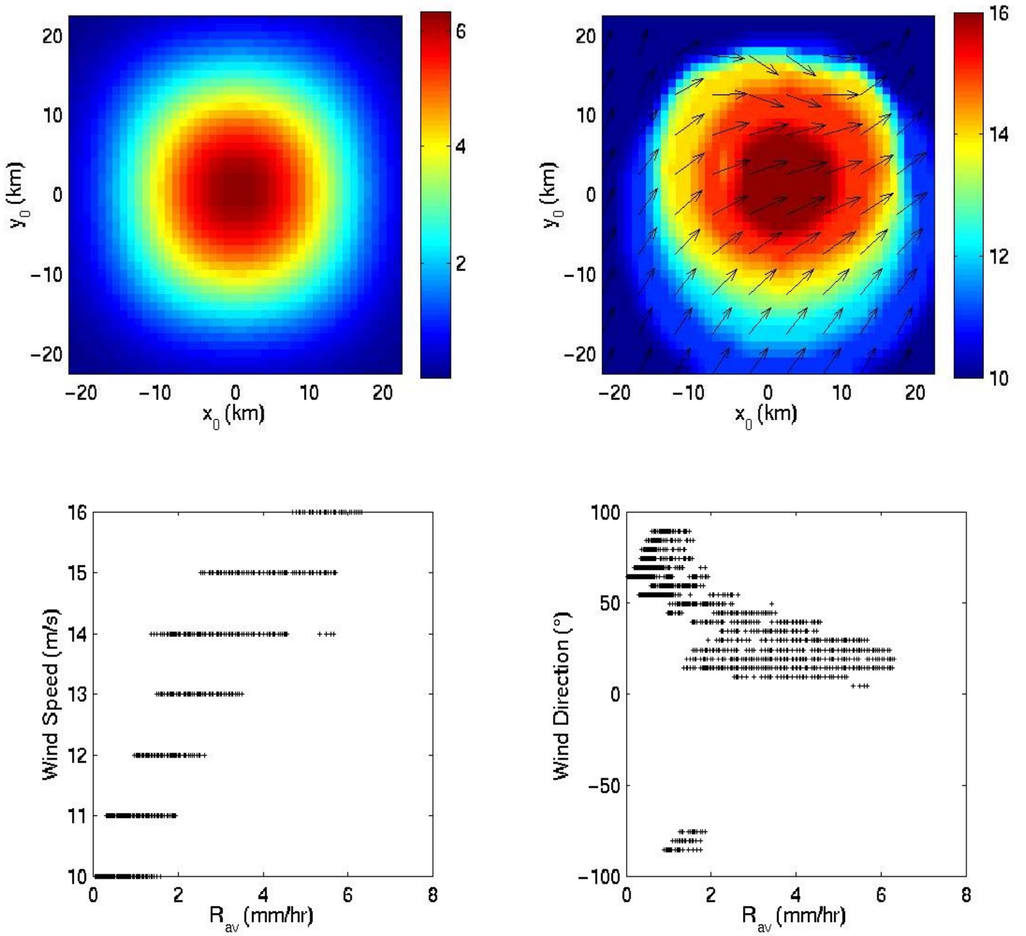
Attenuation and emission by rain drops

$$\sigma_0'(y) = \sigma_0(y) e^{-2k(y)f(y)} + \int_0^{l(y)} \eta(y) e^{-2k(s)f_y(s)} ds$$

This model was used to study the influence of rain on Quikscat

More complex especially in case of multiple azimuths

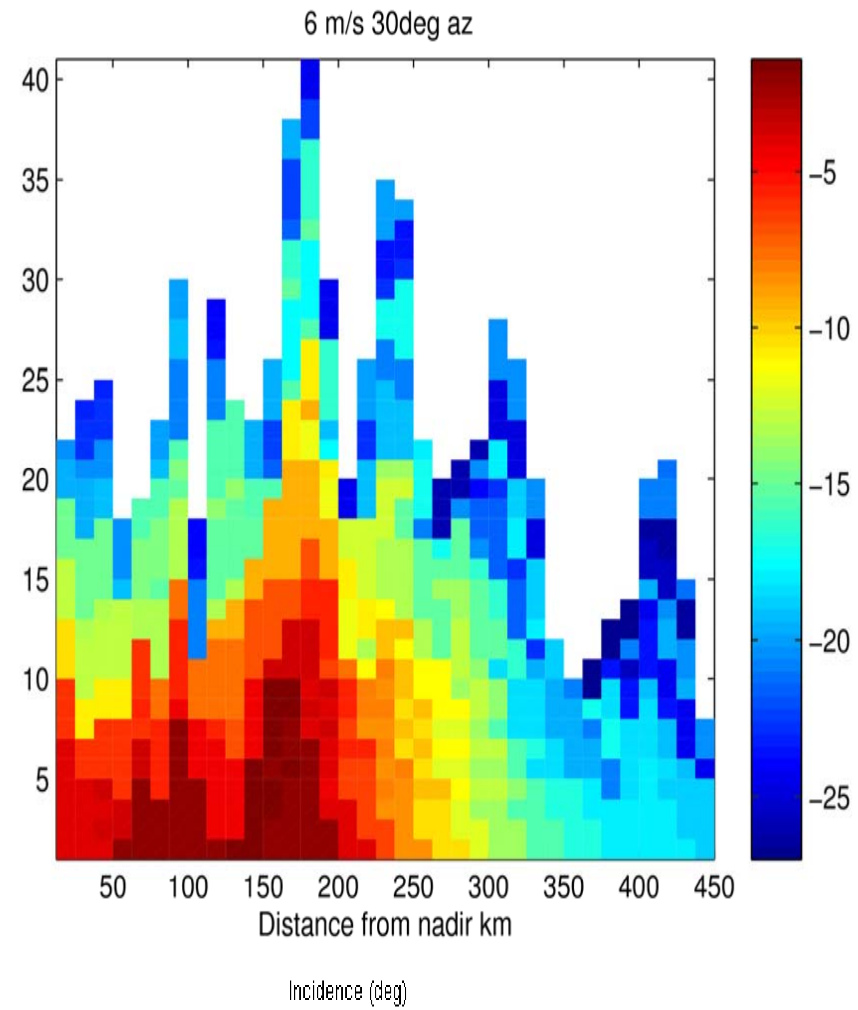
Modeling of rain influence



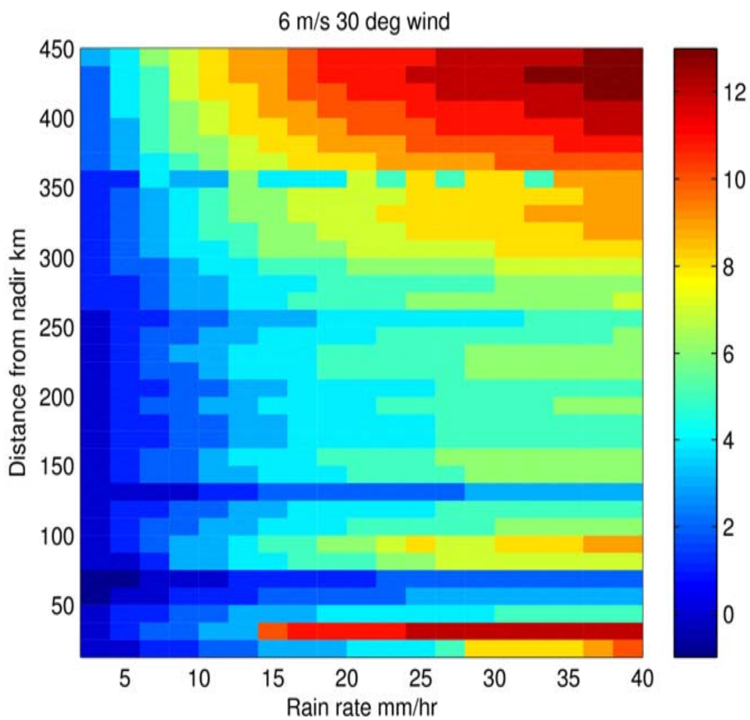
- **Example of rain modification of retrieved winds** by a 15 mm/hr 15 km radius rain cell. Surface wind of 10 m/s , 60° az.
- Dependence on the difference between rain cell center and scatterometer cell
- Dependance on the rain variaibility within the cell

Specificity of rotating fan beam

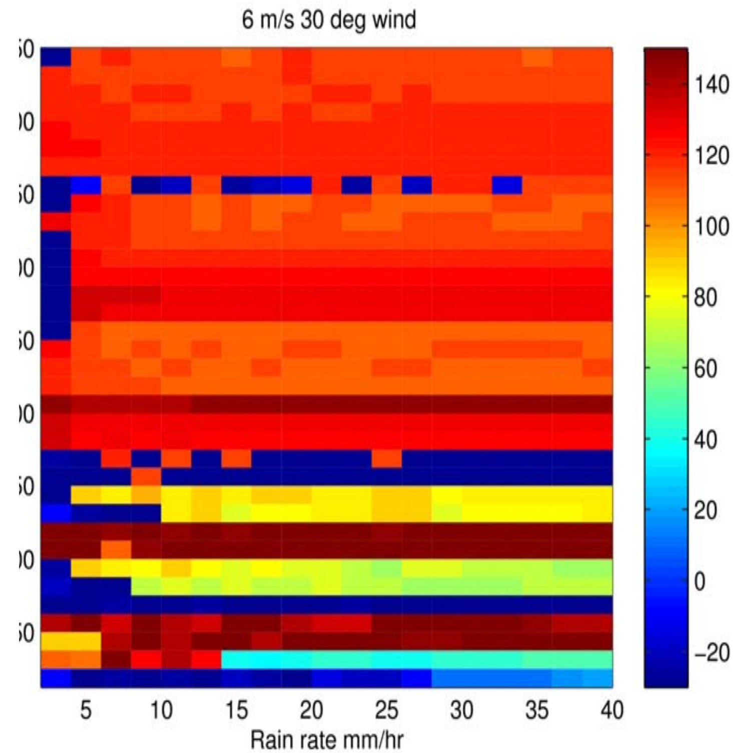
Depending on the distance from nadir
Up to 40 different incidences and azimuths
This implies a wide range of surface backscatter and thus very different rain impact



Filled ifov 6 m/s 30deg wind

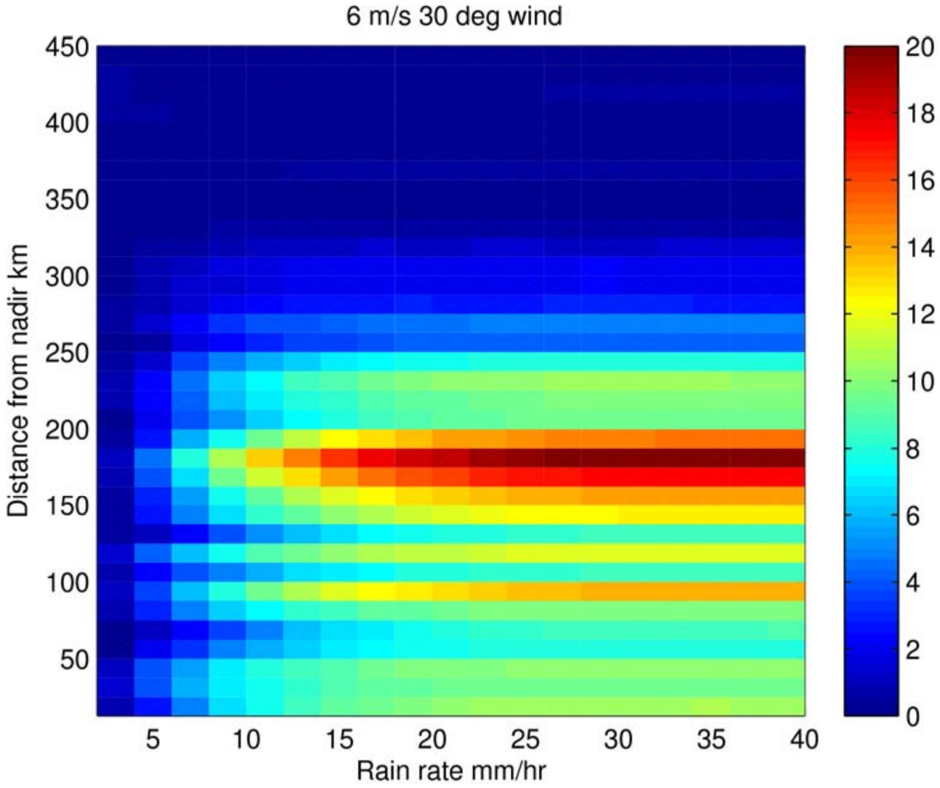


Speed

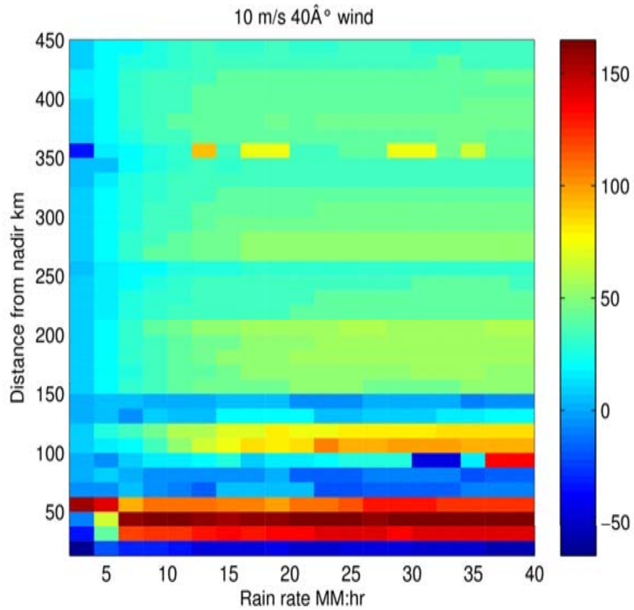


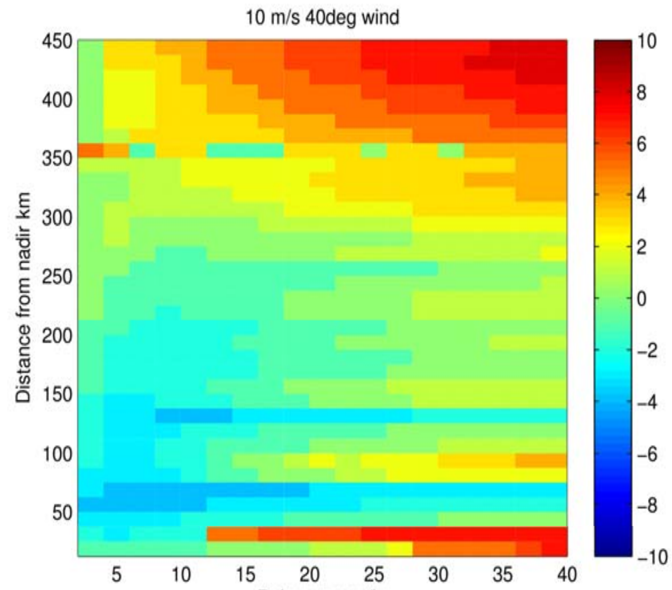
Direction

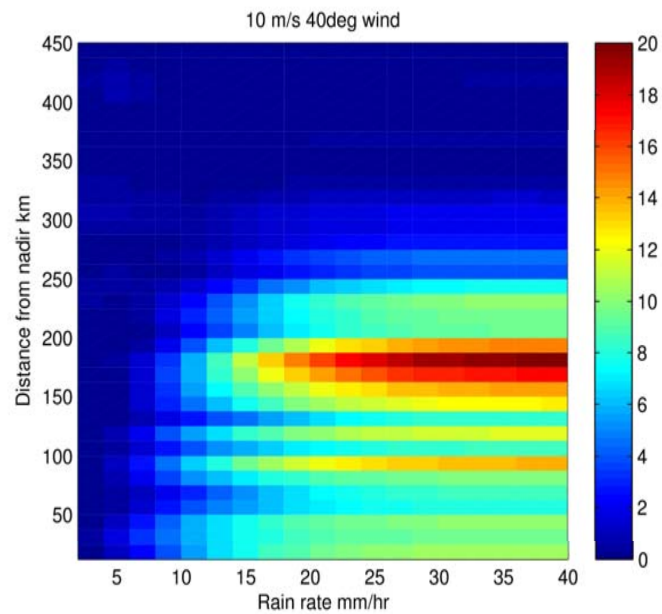
Distance from Kmod



10m/s 40deg







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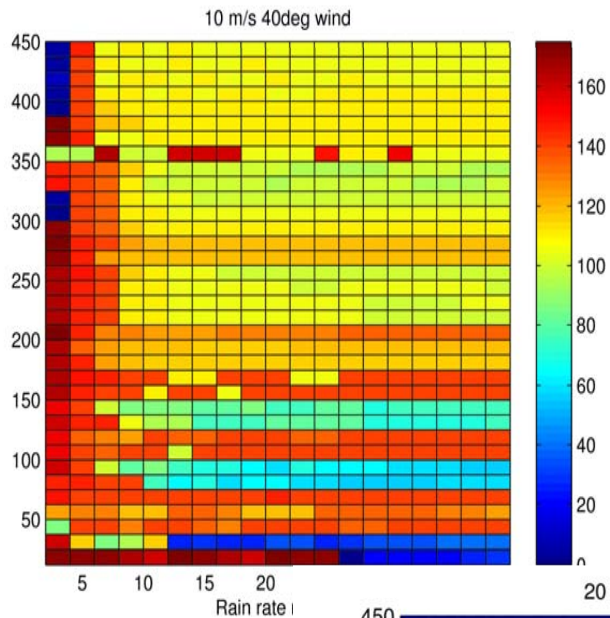
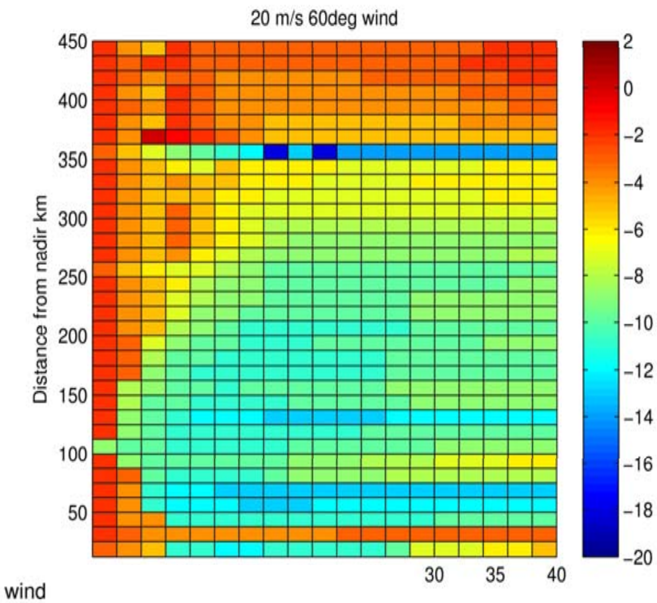
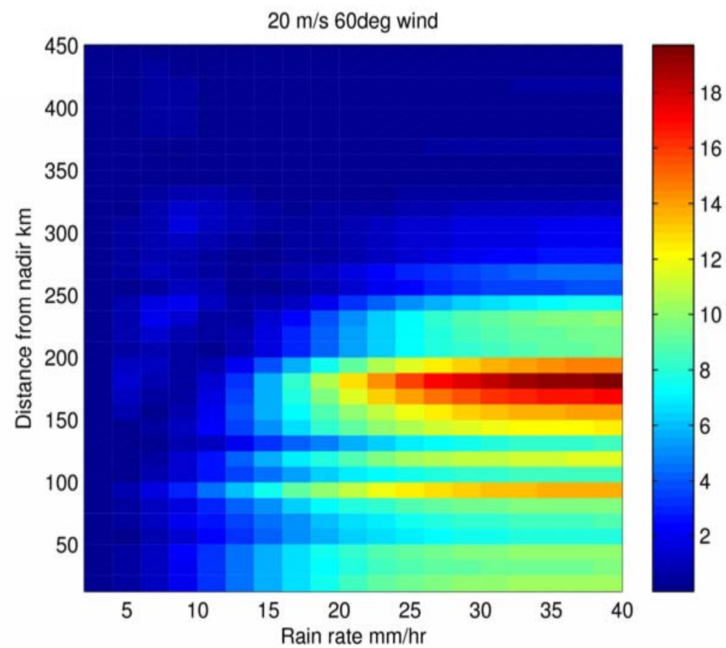

10 m/s 40deg wind
450
400
350
300
250
200
150
100
50
5
10
15
20
Rain rate
160
140
120
100
80
60
40
20


20 m/s 60deg wind
Distance from nadir km
450
400
350
300
250
200
150
100
50
30
35
40
2
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20

20m/s 60deg


20 m/s 60deg wind
Distance from nadir km
450
400
350
300
250
200
150
100
50
5
10
15
20
25
30
35
40
Rain rate mm/hr
18
16
14
12
10
8
6
4
2

Perspective

Tournadre and Quilfen (2003): theoretical modelisation of rain influence on Ku band scatterometer data including attenuation and volume scattering

Analytical rain cells to estimate the mean influence on backscatter and wind retrieval.

Results:

- Overestimation of low winds and underestimation of high winds.
- Strong impact of the distribution of rain within scatterometer cell
- MLE not a good rain indicator. variance might be a candidate for rain flagging
- CFO/SCAT: fan beam like NSCAT rotating like QSCAT
- Model can easily be adapted

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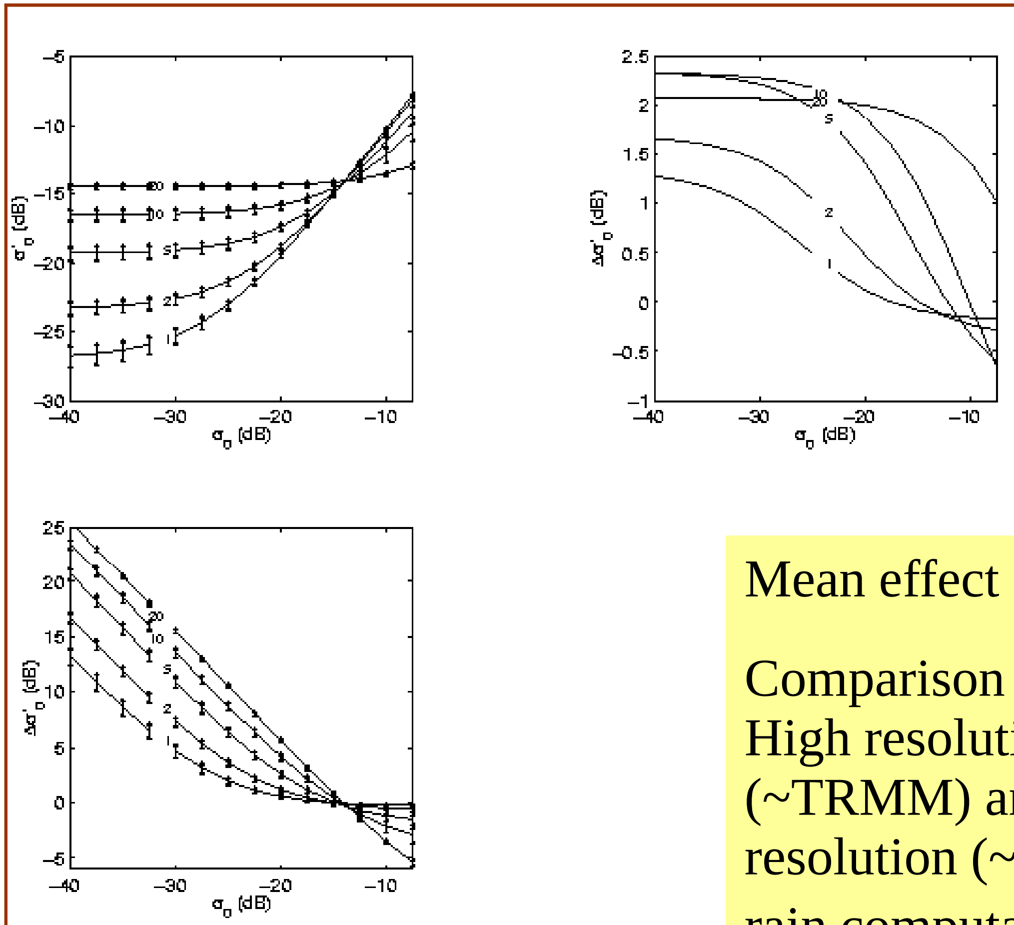
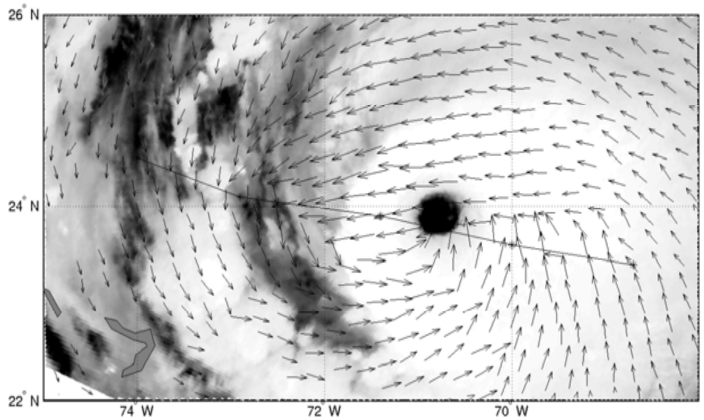
Rain effect modeling



Mean effect on σ0

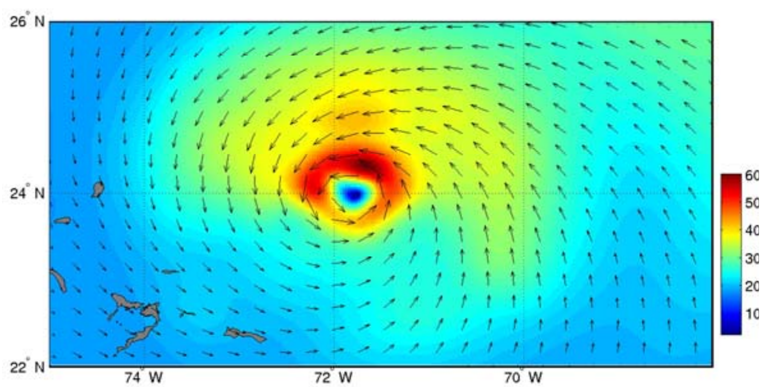
Comparison between High resolution (~TRMM) and low resolution (~to SSMI) rain computation

Tropical cyclone Floyd

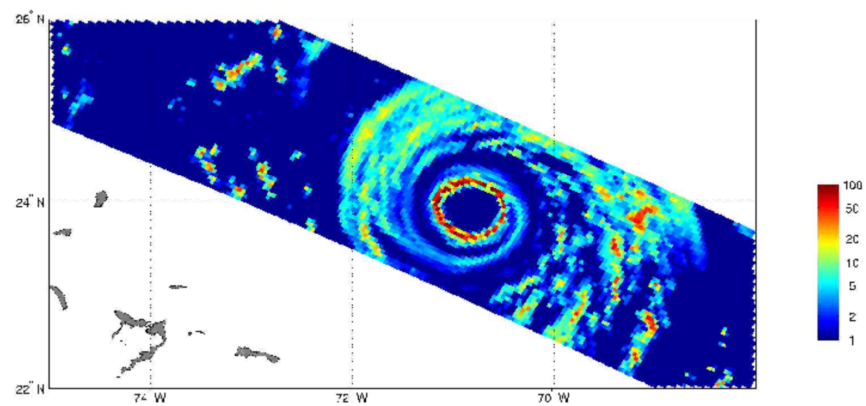


Qscat winds and TRMM visible image (30 min time difference)

- TRMM Precipitation radar data
- High Resolution $\sigma 0$ from BYU (Long)
- NHC surface winds



National Huricane Center surface wind field



TRMM Precipitation Radar rain rate (averaged 0 to 5 km)

Comparison of L2B, NHDC and corrected speed