Global Precipitation Mission
An opportunity for Ocean surface Remote sensing

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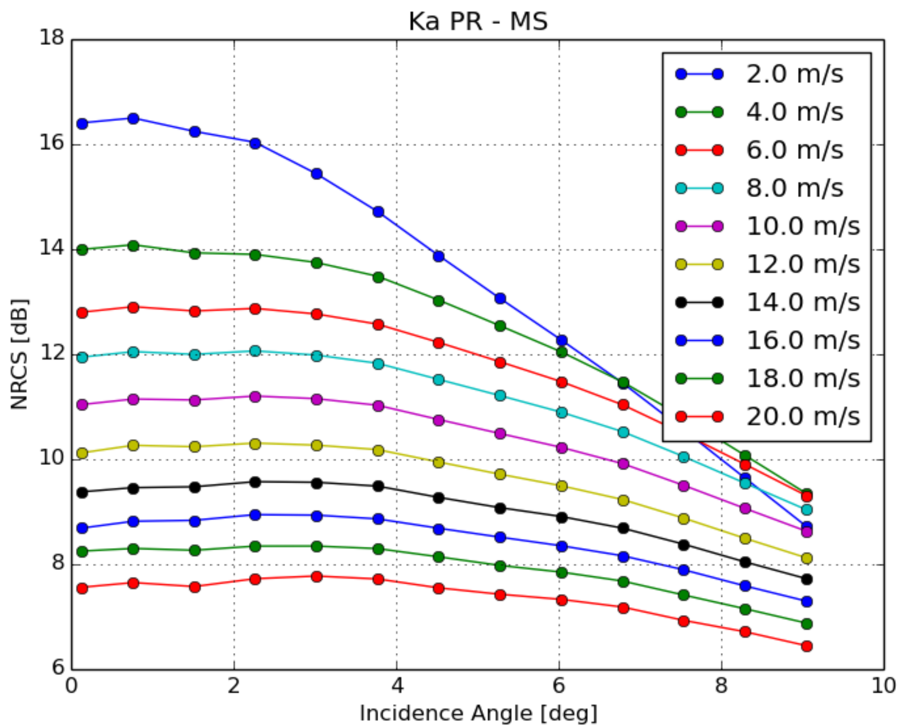
Outline

- GPM, Data & Colocation
- Ku & Ka Data analysis
- Conclusions

Motivations for CFOSAT



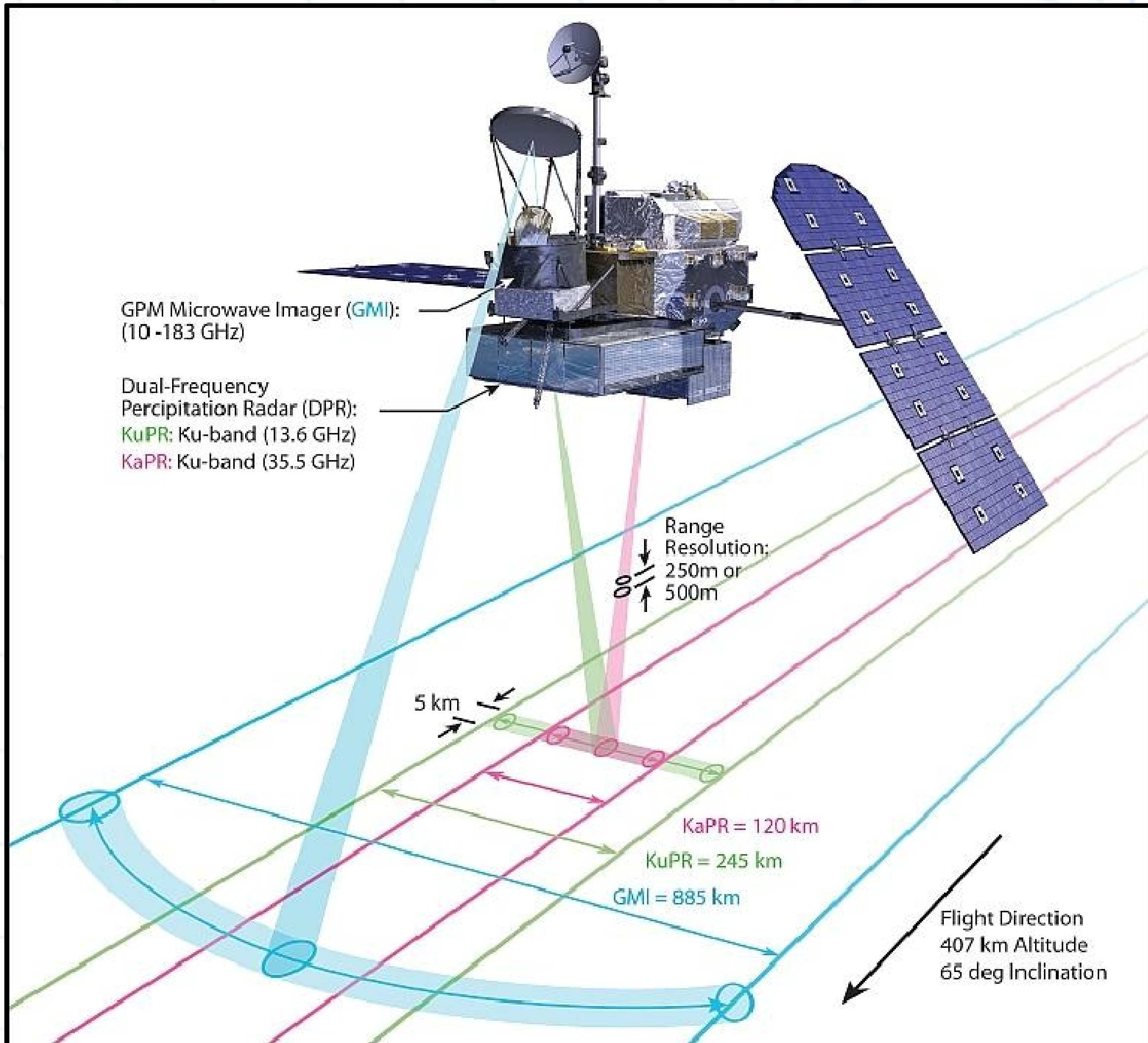
$$\sigma^0_{PO} = \frac{|R|^2}{mss_s} \sec^4(\theta) \exp\left(-\frac{\tan^2(\theta)}{mss_s}\right)$$

- Effective Mean Square Slope
- Small scale dependent (wind)
- Related to unresolved scales !
- Frequency dependent

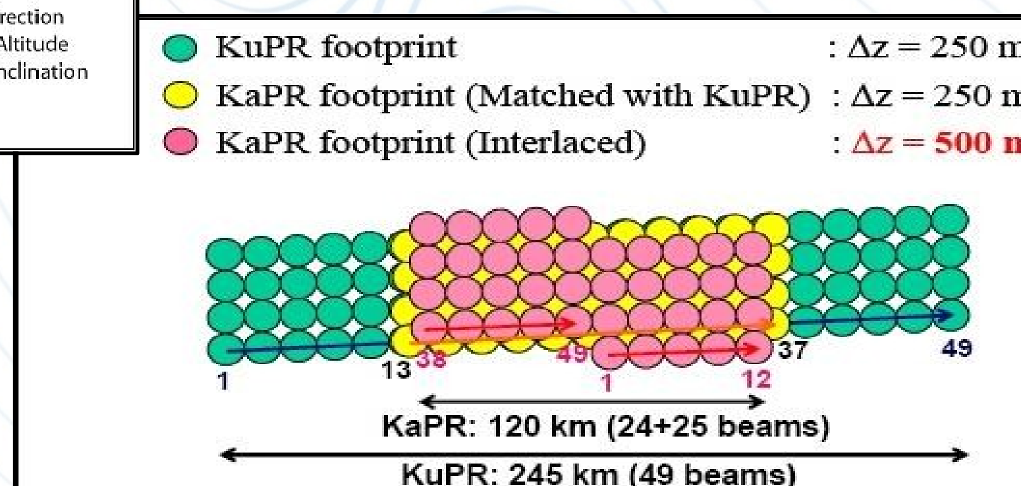
$$\frac{\Delta\sigma^0_{PO}}{\Delta\theta} = f(mss_s)$$

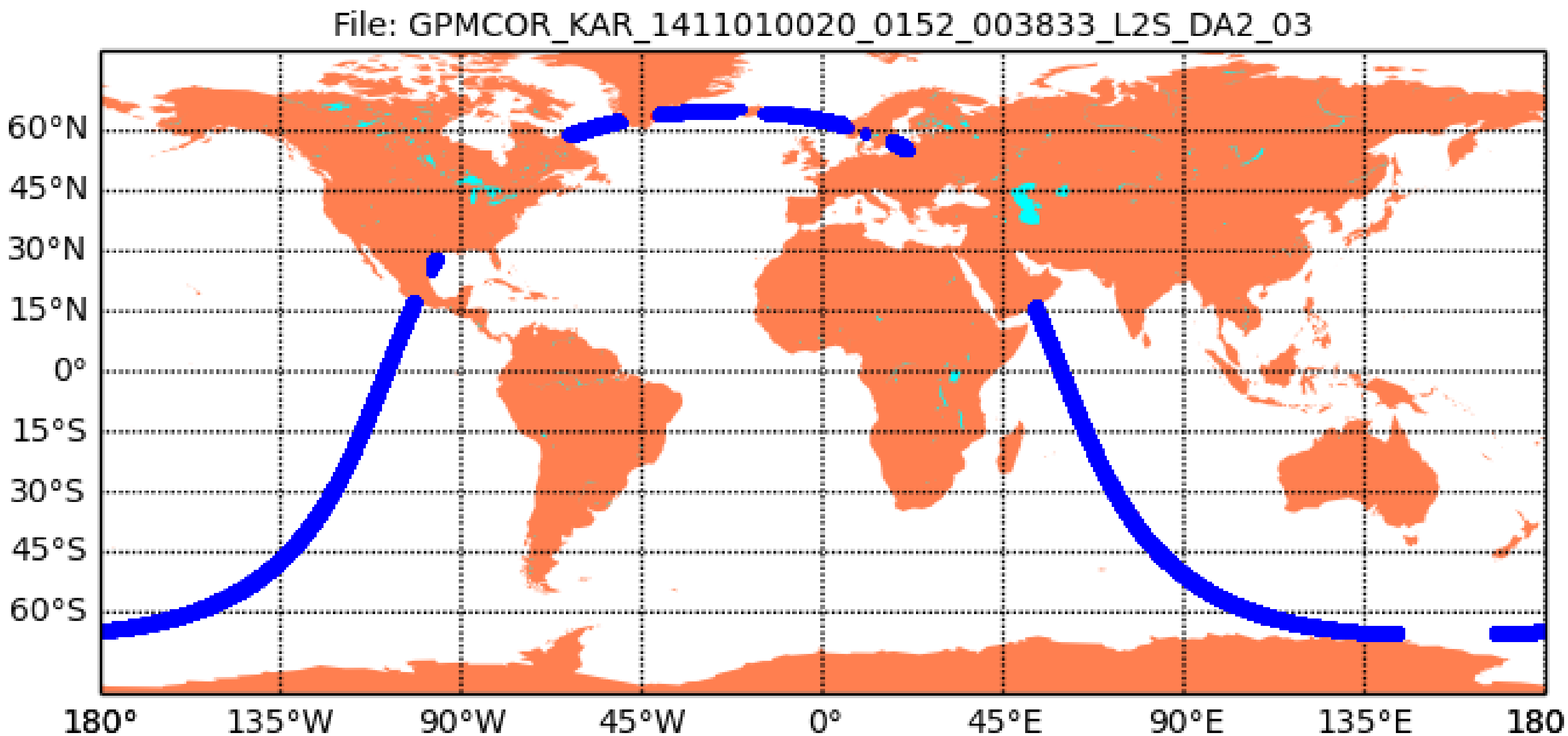
- Inversion of NRCS modulation in terms of local incident angles (wave slopes & spectrum) is conditioned by the knowledge of the effective mss.

GPM, Data & Colocation



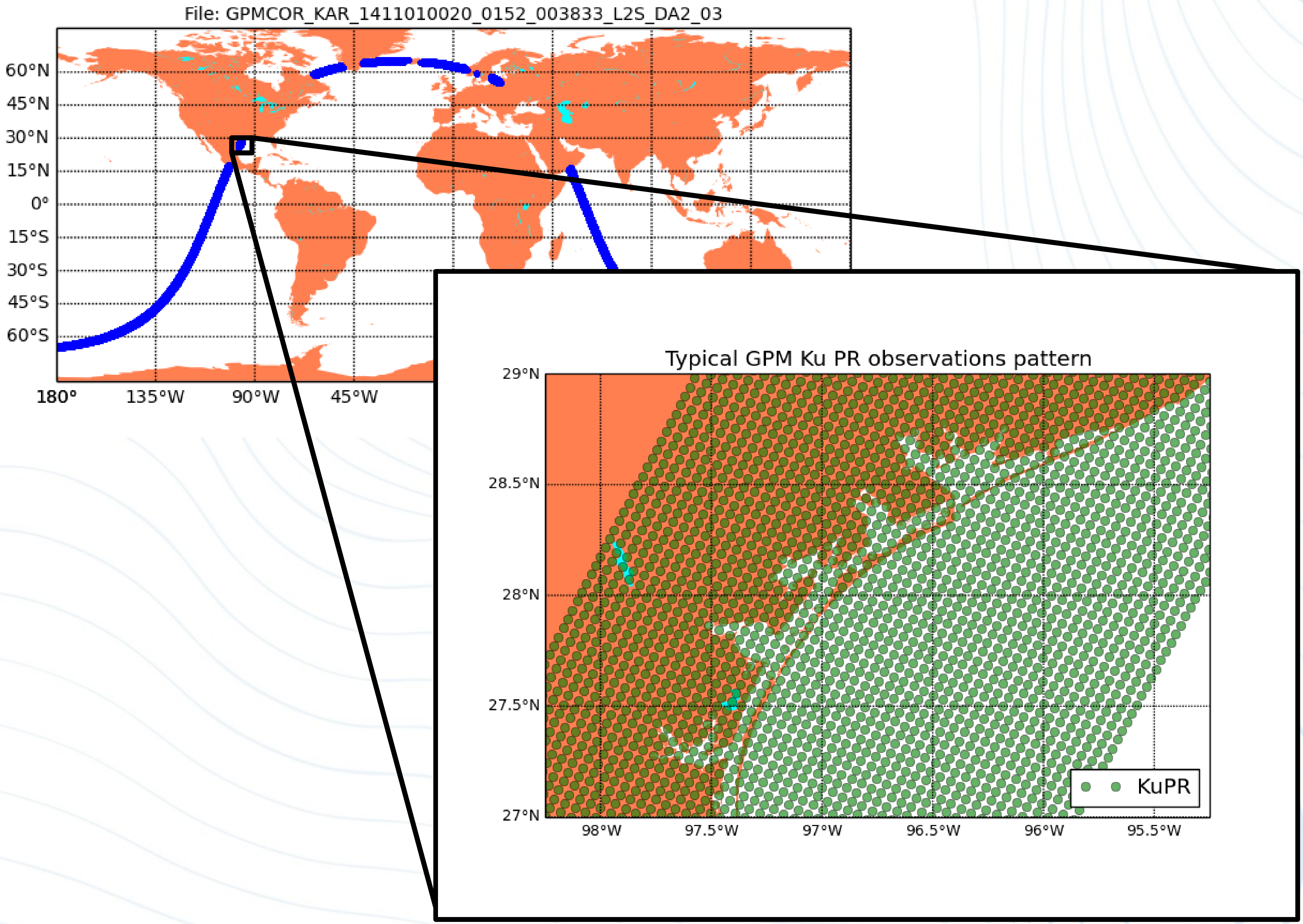
Quasi-simultaneaous observations are available from both KaPR and KuPR in the quasi-specular domain :
inc ϵ [-18,18] Ku PR
inc ϵ [-9, 9] Ka PR





Orbit has changed since TRMM. Latitudes larger than 30°N and 30°S are now observed by PR. Acquisitions up to 66° north and south are available.

- More chances to get extreme situations such as extra-tropical storms in high latitudes, with high winds and severe sea state.
- Area with strong ocean surface current such as Gulf Stream, Kuroshio or Agulhas current will be better covered.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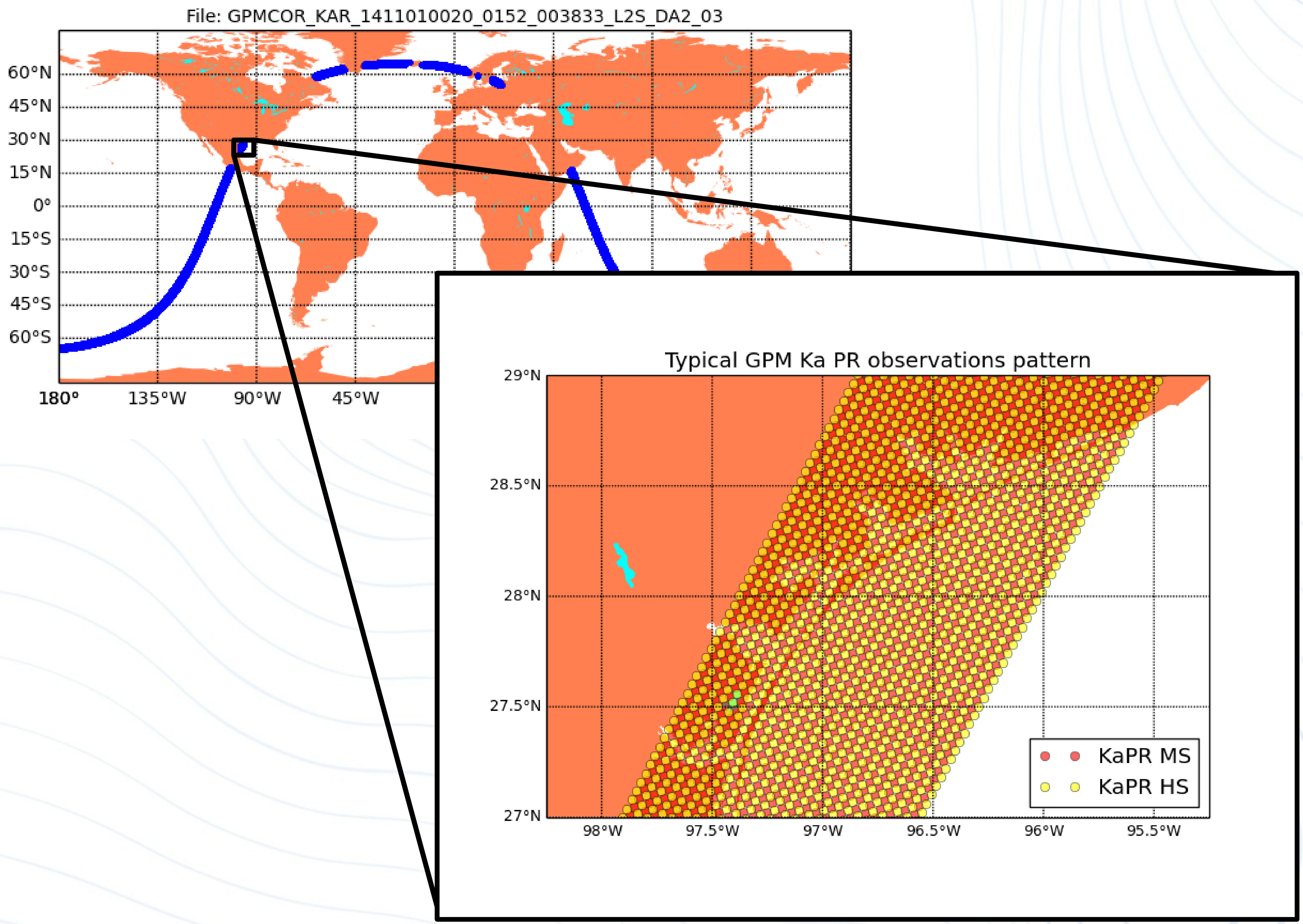
60°N
45°N
30°N
15°N
0°
15°S
30°S
45°S
60°S
180°
135°W
90°W
45°W
Typical GPM Ku PR observations pattern
29°N
28.5°N
28°N
27.5°N
27°N
98°W
97.5°W
97°W
96.5°W
96°W
95.5°W
KuPR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60°N
45°N
30°N
15°N
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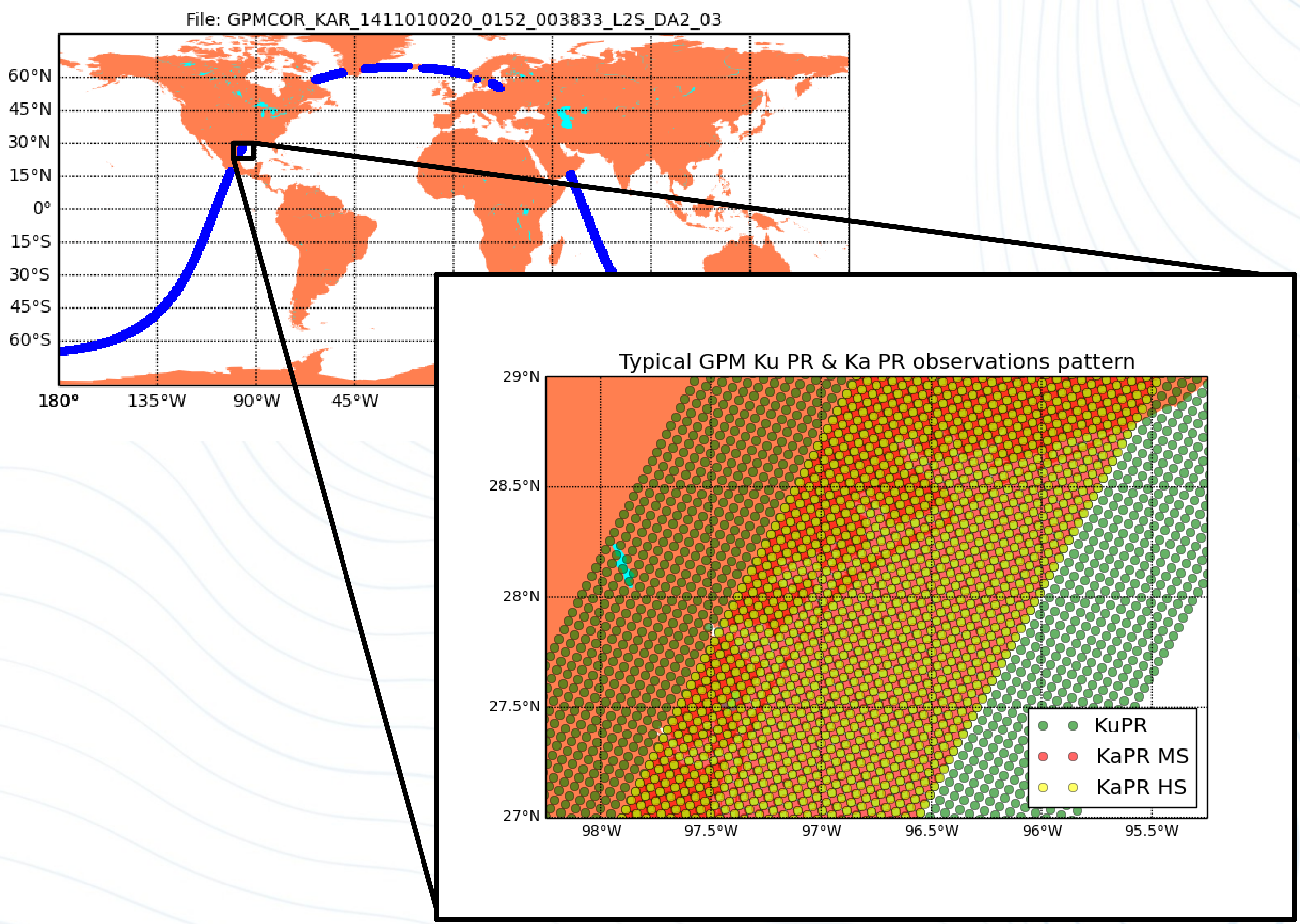
15°S
30°S
45°S
60°S
180°
135°W
90°W
45°W
Typical GPM Ka PR observations pattern
29°N
28.5°N
28°N
27.5°N
27°N
98°W
97.5°W
97°W
96.5°W
96°W
95.5°W
KaPR MS
KaPR HS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60°N
45°N
30°N
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0°
15°S
30°S
45°S
60°S
180°
135°W
90°W
45°W
Typical GPM Ku PR & Ka PR observations pattern
29°N
28.5°N
28°N
27.5°N
27°N
98°W
97.5°W
97°W
96.5°W
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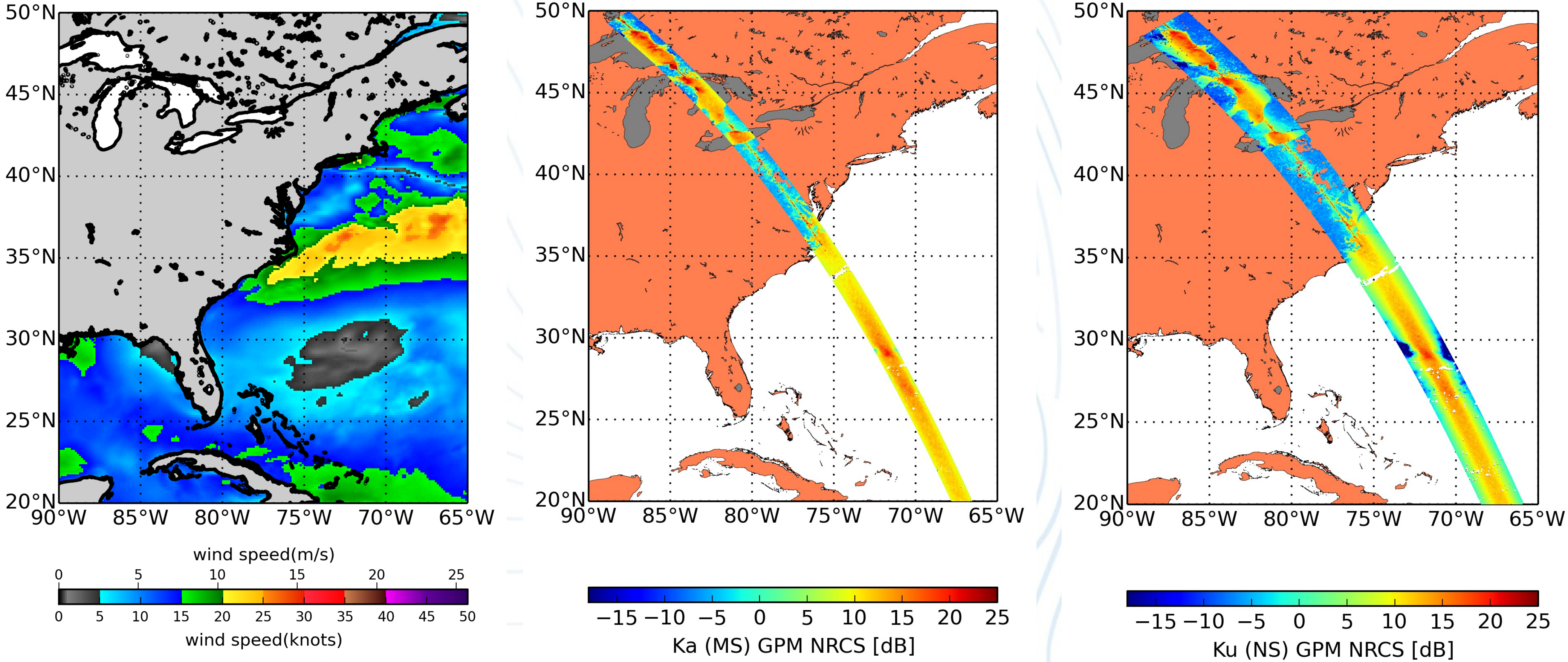
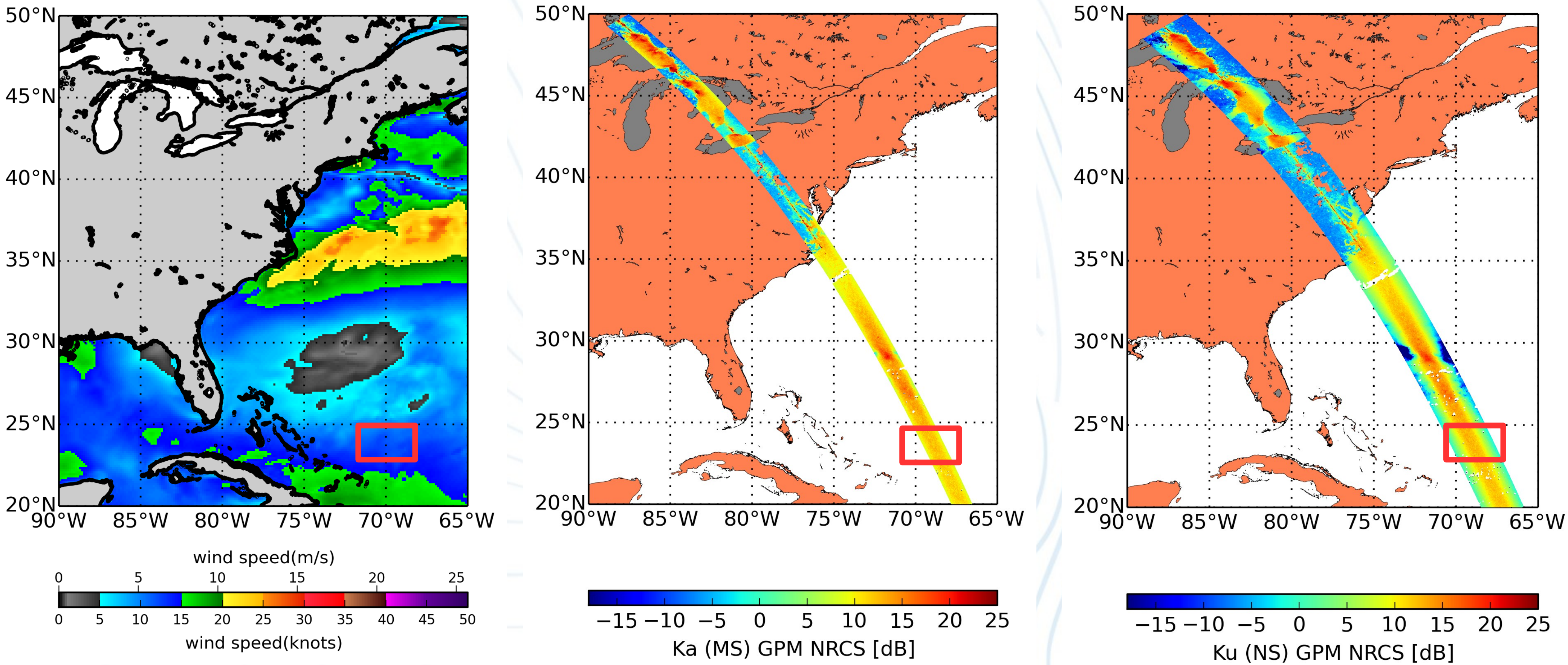
KuPR
KaPR MS
KaPR HS


50°N
45°N
40°N
35°N
30°N
25°N
20°N
90°W 85°W 80°W 75°W 70°W 65°W
wind speed(m/s)
0 5 10 15 20 25
0 5 10 15 20 25 30 35 40 45 50
wind speed(knots)
−15 −10 −5 0 5 10 15 20 25
Ka (MS) GPM NRCS [dB]
−15 −10 −5 0 5 10 15 20 25
Ku (NS) GPM NRCS [dB]


50°N
45°N
40°N
35°N
30°N
25°N
20°N
90°W 85°W 80°W 75°W 70°W 65°W
wind speed(m/s)
0 5 10 15 20 25
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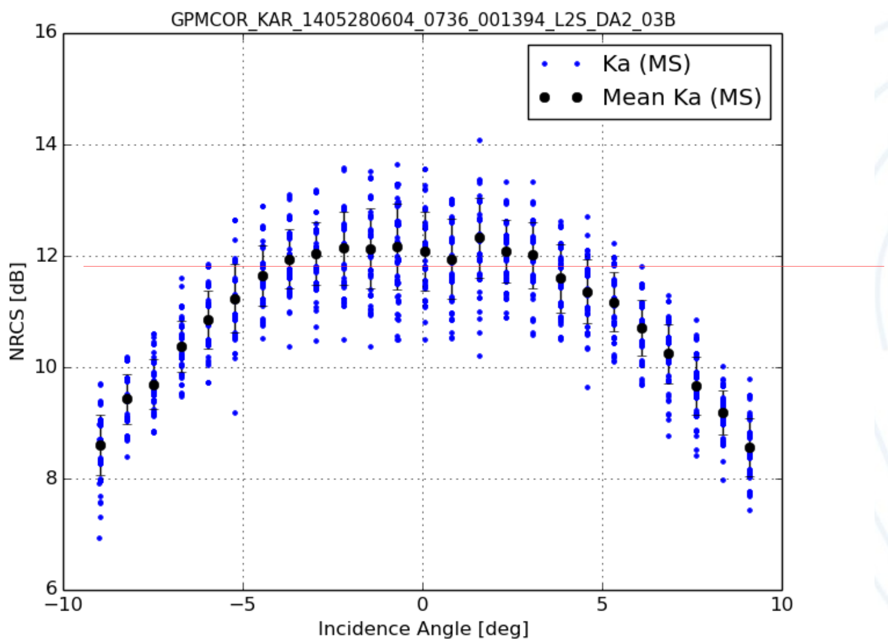
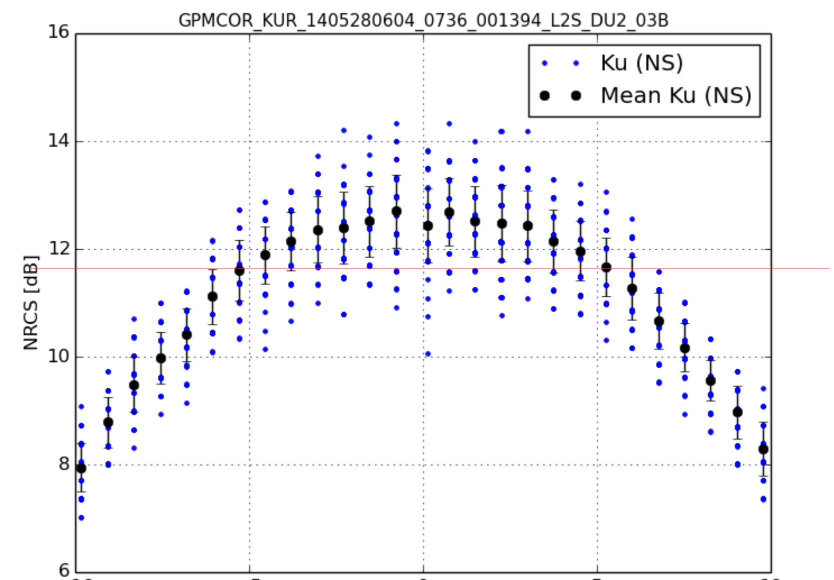
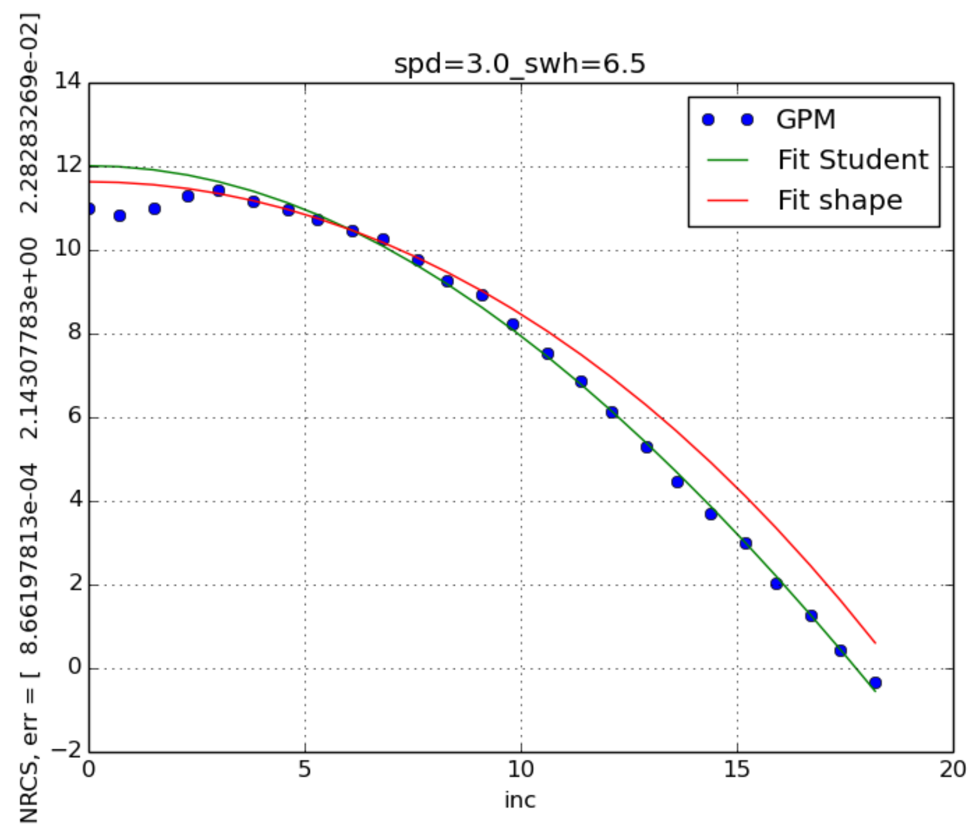






Angular mean

- No skewness effect !

- GPM data from Ku PR and Ka PR have been archived at IFREMER from 2014/03 up to now.

- All GPM PR data
  - acquired over ocean,
  - with rain flag at 0,
  - quality flag OK,
  - colocated with Wave Watch 3 wave model analysis outputs. Resolution grid is :
  - 0.5 degrees,
  - 1 hour.

- WW3 gives :
  - wind speed and direction,
  - significant wave height,
  - peak frequency & direction.

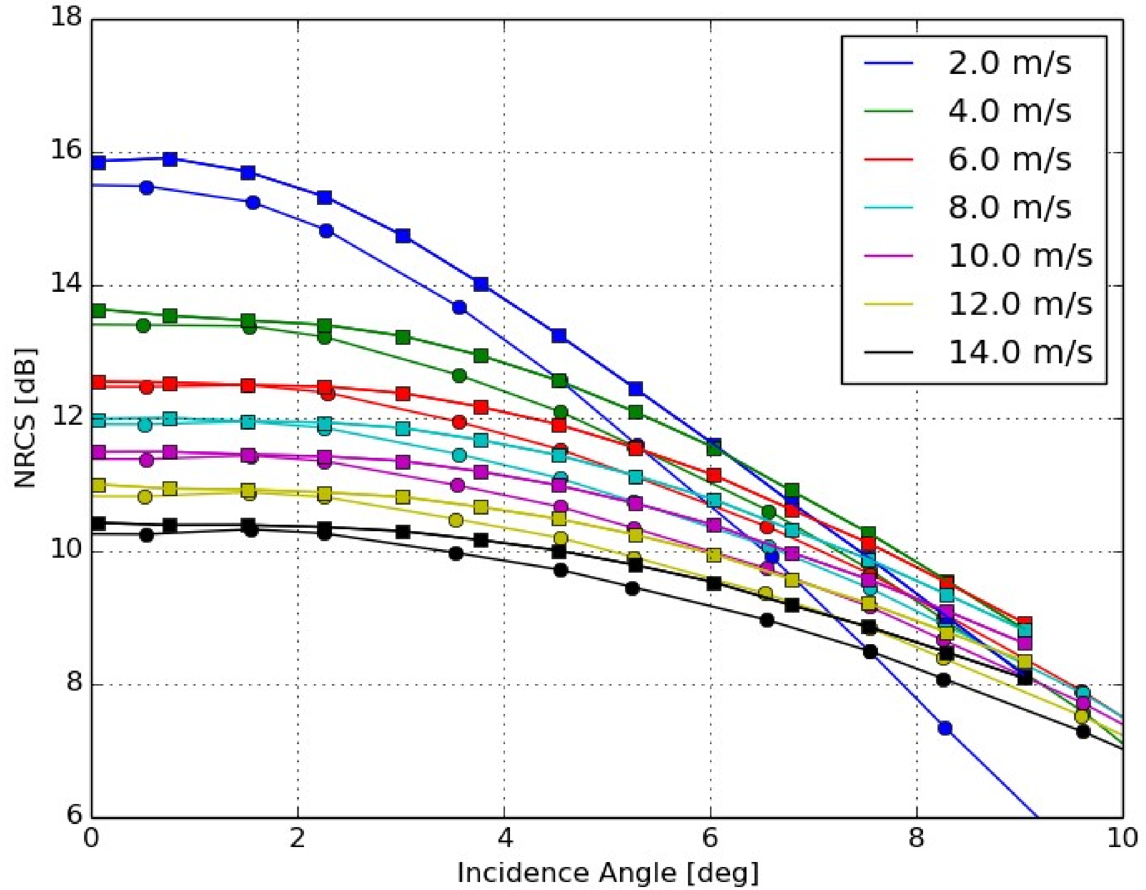
- GPM gives :
  - NRCS
  - Incidence angle

- We end up with more than 8000 colocated orbits for Ka PR (MS and HS) and 4000 for Ku PR.

Ku & Ka Data Analysis

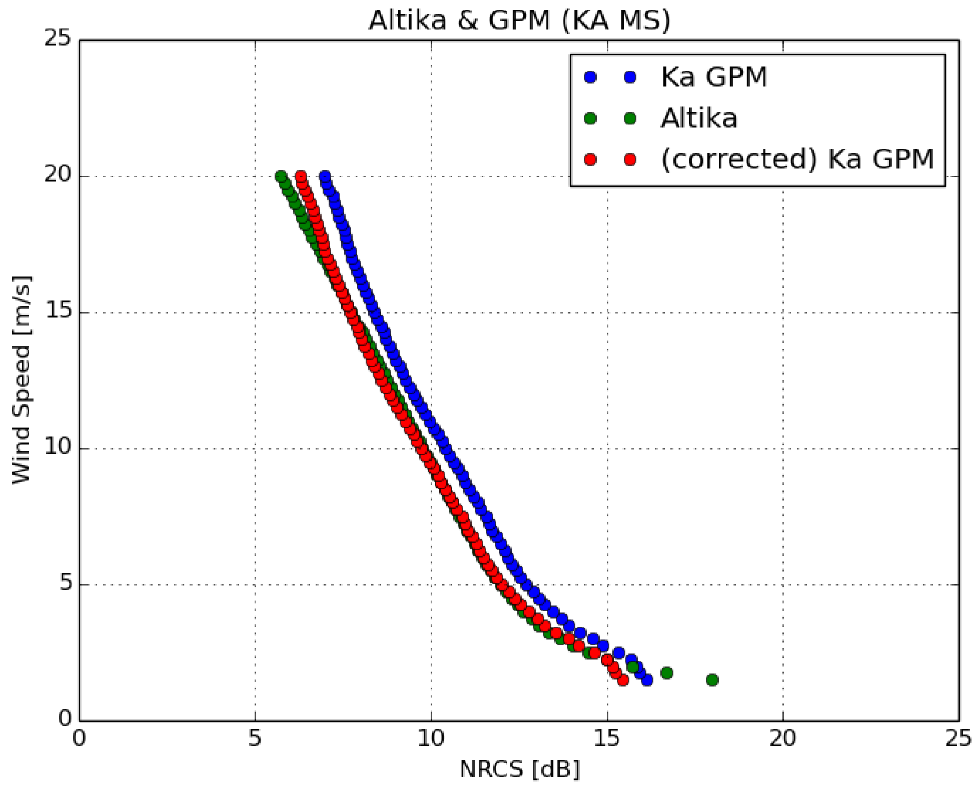
Ku-Band: Comparison between TRMM & GPM

GPM : Squares
TRMM : Circles



- GPM seems to be cross-calibrated on TRMM at nadir
- NRCS dependencies to wind speed are consistent
- NRCS dependencies significant waves height are also consistent (not shown)

Ka-Band: Comparison between Altika & GPM



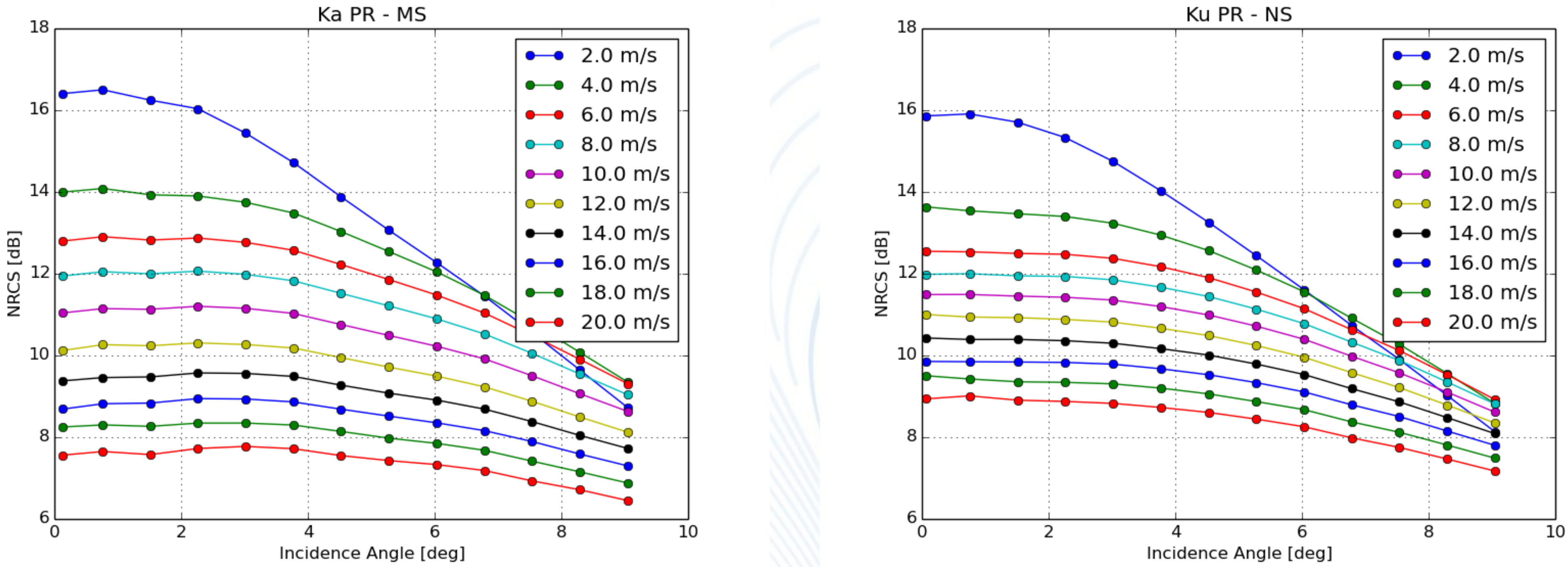
$$U_m = \begin{cases} \alpha - \beta\sigma^o & \text{if} \quad \sigma^o \leq \sigma_b \\ \gamma \exp(-\delta\sigma^o) & \text{if} \quad \sigma^o > \sigma_b \end{cases}$$

$$\alpha = 34.2 \quad \beta = 2.48 \quad \sigma_b = 11.4$$
$$\gamma = 720 \quad \delta = 0.42$$

Lillibridge et al. (2014)

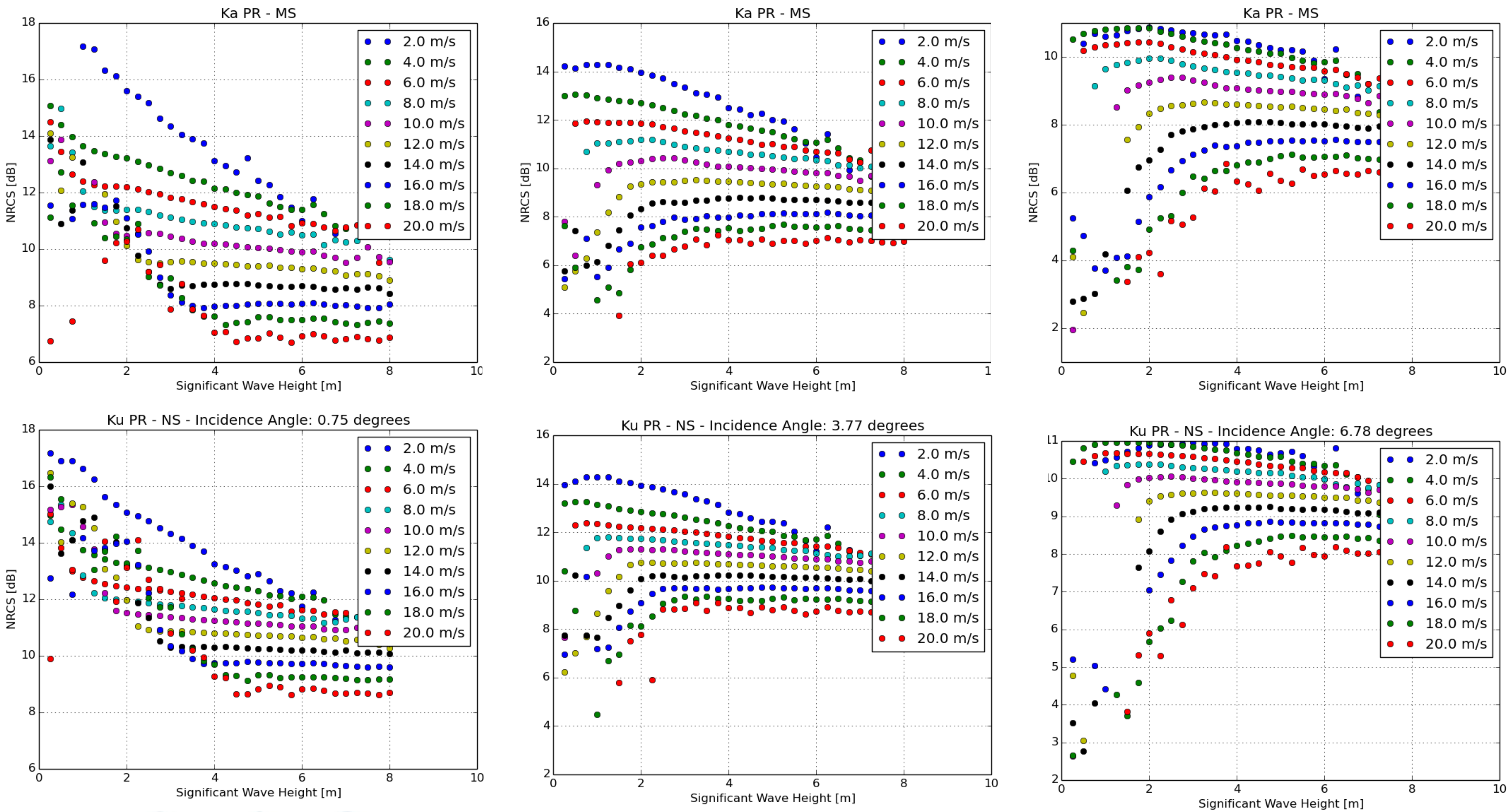
- GPM and Altika are not cross-calibrated
- At nadir NRCS dependencies to wind speed are consistent

Ku/Ka-Band comparisons : Open Ocean



- Mean NRCS versus incidence angle for different wind speeds.
- Here no filtering is done according to waves.
- More dynamic with respect to wind speed is observed at Ka-Band.

Ku & Ka Data Analysis

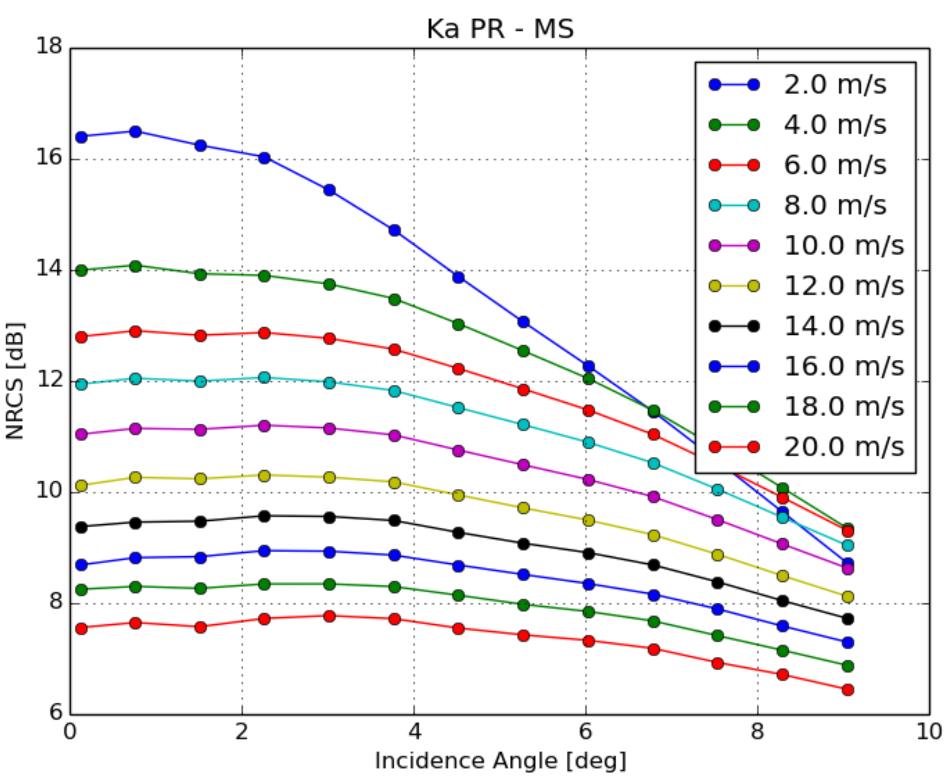


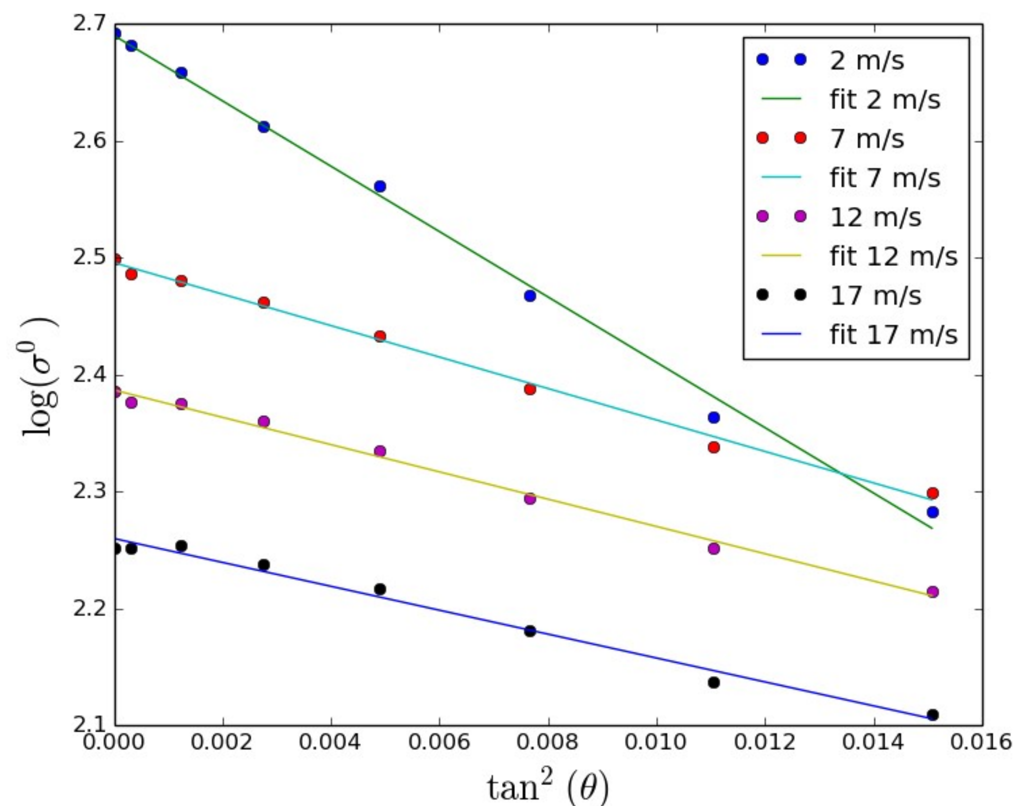
- For a given wind speed and incidence angle, dynamic with respect to significant wave height observed at Ka-Band and Ku-Band seems quite similar.
- Impact of significant wave height decreases when incidence angle and/or wind speed increases

Ku/Ka-Band comparisons : Open Ocean

- Mean Square Slope Shape retrieval method :
  → Fit on incidence

$$\log\left(\cos^4(\theta)\sigma^0_{PO}\right) = \log\left(\frac{|R|^2}{mss_s}\right) - \frac{\tan^2(\theta)}{mss_s}$$

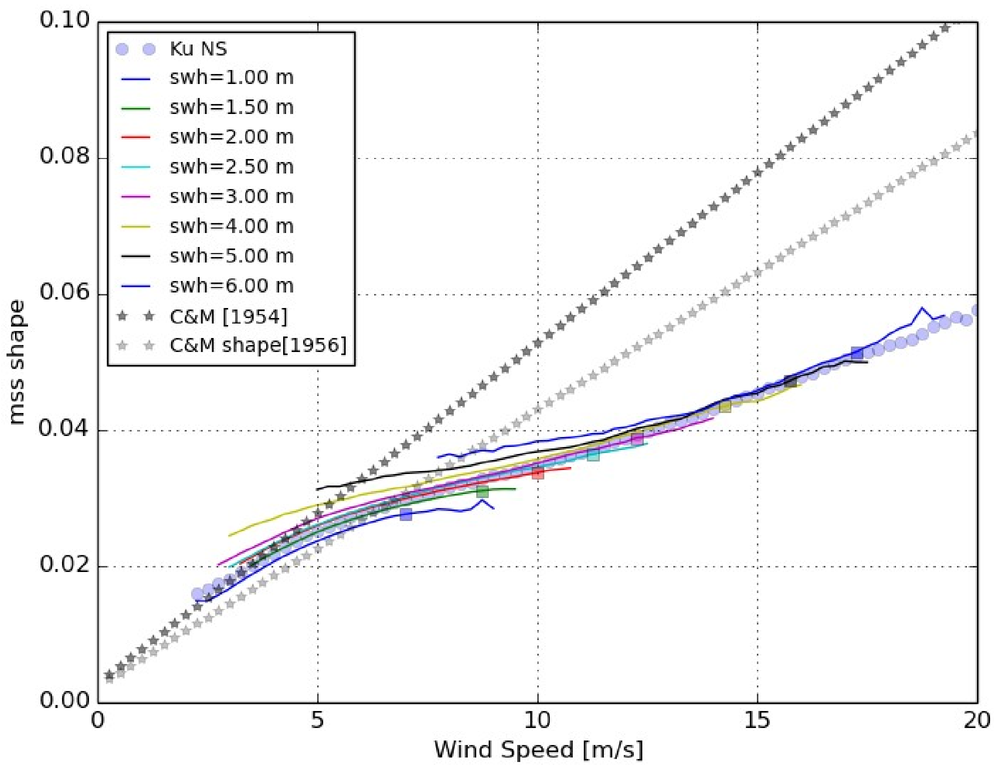




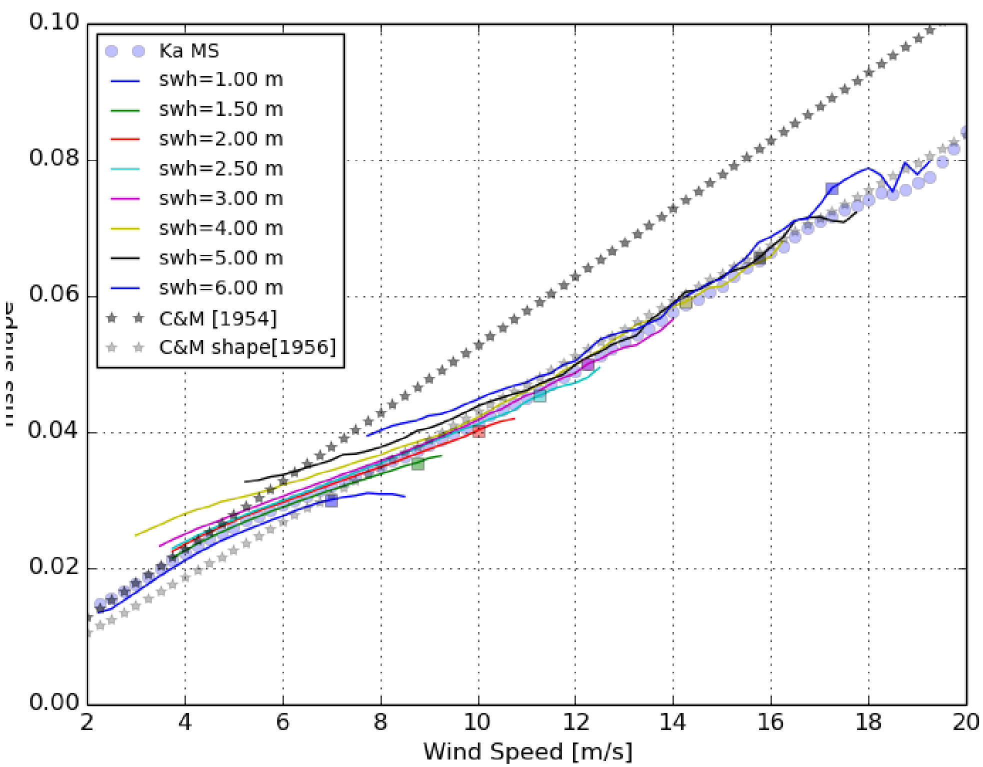
Ku/Ka-Band comparisons : Open Ocean

mss shape

Ku Band



Ka Band



Mss shape Ka = mss shape optical (C&M 56, Chapron 2000)

MSS shape : a curvature correction

$$\sigma^0_{PO} = \frac{|R|^2}{mss} \sec^4(\theta) \exp\left(-\frac{\tan^2(\theta)}{mss}\right) \times \left[1 + \lambda \left(\frac{\tan^4(\theta)}{mss^2} - 4\frac{\tan^2(\theta)}{mss} + 2\right)\right]$$

$$\lambda = \frac{msc}{4Q_z^2 mss^2} + \frac{\lambda_4}{6}$$

- Identification with mss_s

$$mss_s = \frac{mss_T}{1+4\lambda} \sim mss_T(1-4\lambda)$$

- Ka vs Ku

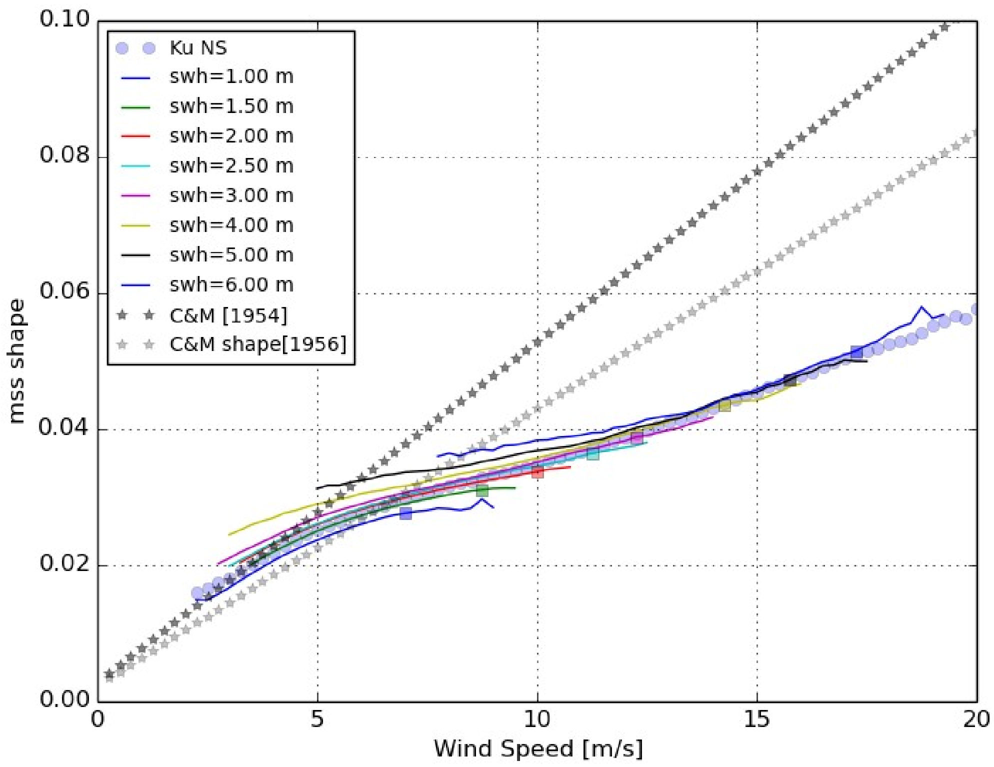
$$mss_s(\mathrm{Ku}) = mss_T(1 - 2\lambda_4/3 - \lambda_c)$$

$$mss_s(\mathrm{Ka}) = mss_T(1 - 2\lambda_4/3)$$

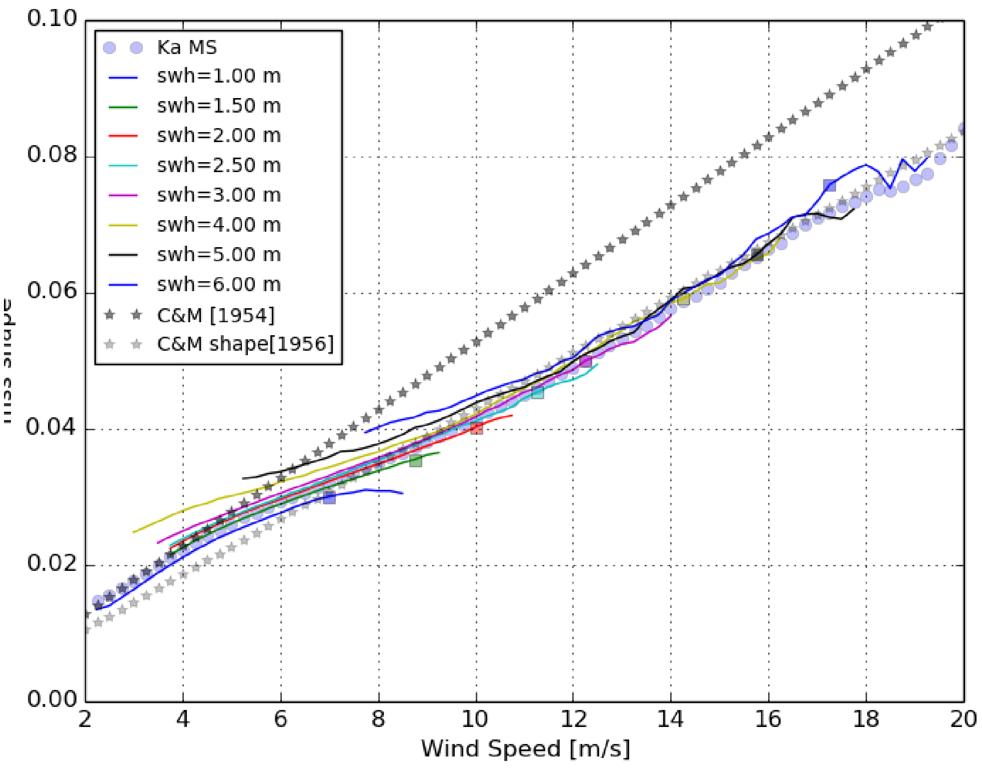
$$\Delta mss_s = \lambda_c \, mss_T$$

Ku/Ka-Band comparisons : Open Ocean

Ku Band



Ka Band



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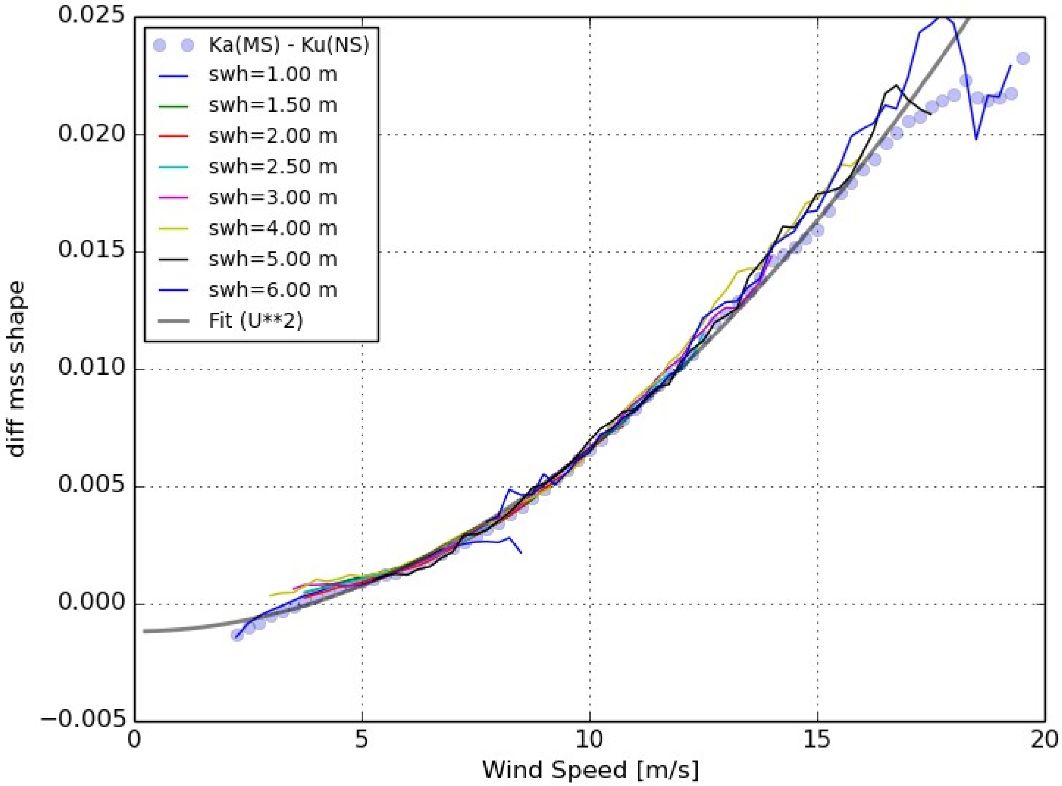
Ku/Ka-Band comparisons : Open Ocean



- A proxy to the growth rate in short capillary-gravity range

$$\Delta mss_s = \lambda_c \ mss_T \propto U_{10}^2$$

$$\lambda_c \propto U_{10}$$

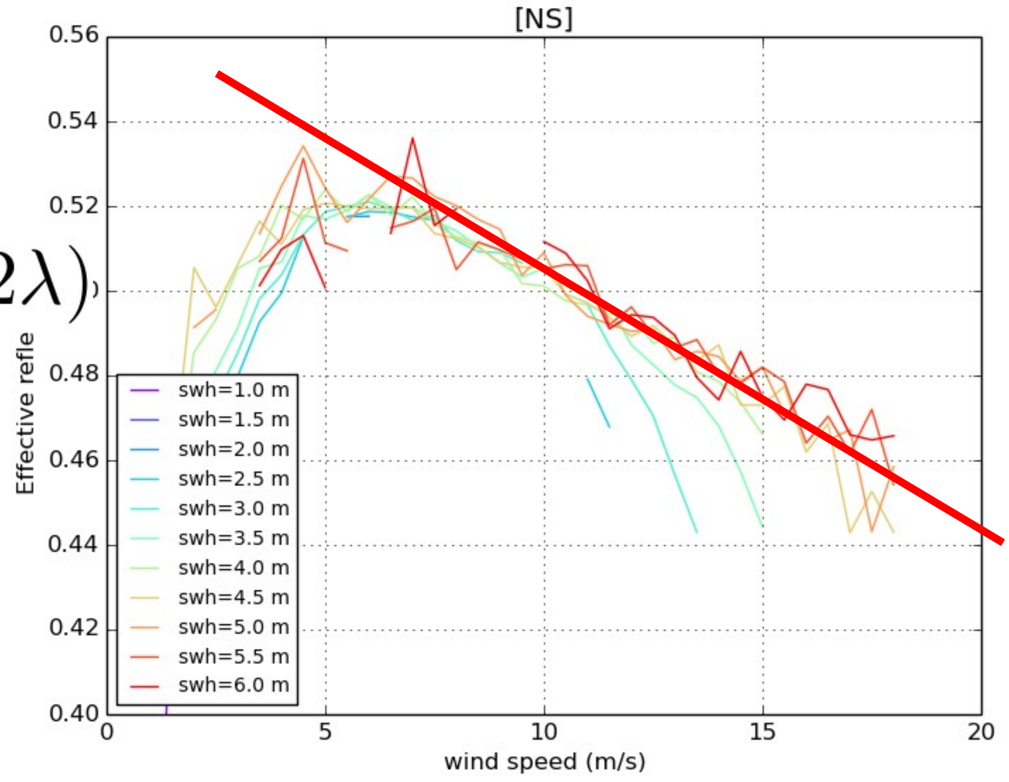
Effective reflectivity (Ku Band)

$$\sigma^0_{PO} = \frac{|R|^2}{mss}\sec^4(\theta)\exp\left(-\frac{\tan^2(\theta)}{mss}\right) \times \left[1 + \lambda\left(\frac{\tan^4(\theta)}{mss^2} - 4\frac{\tan^2(\theta)}{mss} + 2\right)\right]$$

- At nadir : $\sigma^0_{PO}[0] = \frac{|R|^2}{mss_T}(1+2\lambda)$

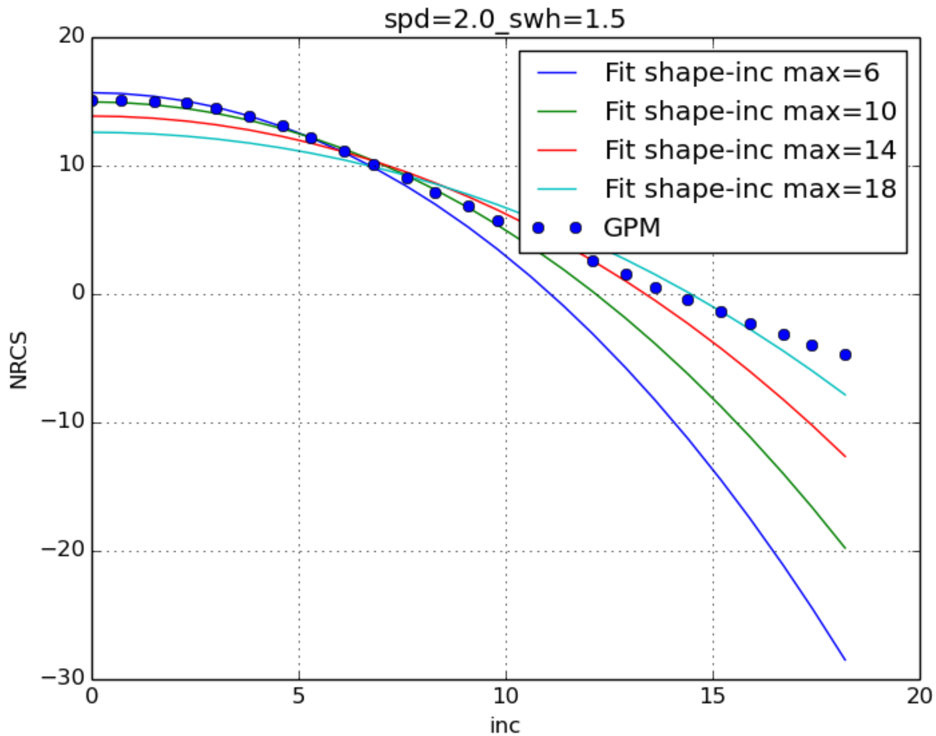
$$mss_s \times \sigma^0_{PO}[0] \sim |R|^2(1-2\lambda)$$

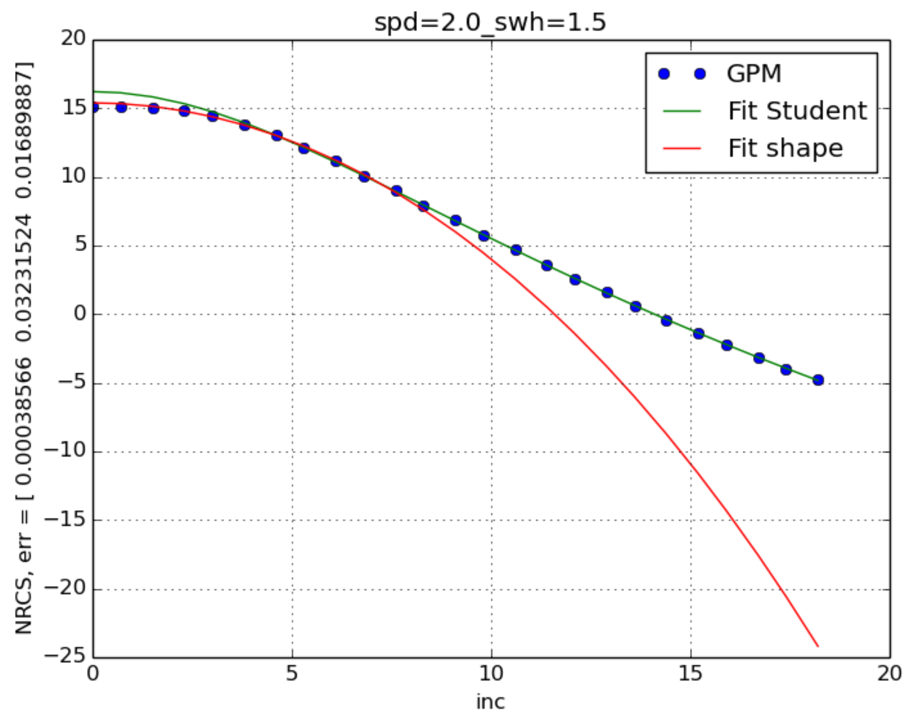
- Elfouhaily et al. (1998)
- Freilich et al. (2002)



Mss shape depends on :

- Curvature (prop. to the EM wavelength squared)
- Kurtosis (intrinsec statistical surface characteristic)
- Considered angular excursion





A more robust inversion ?

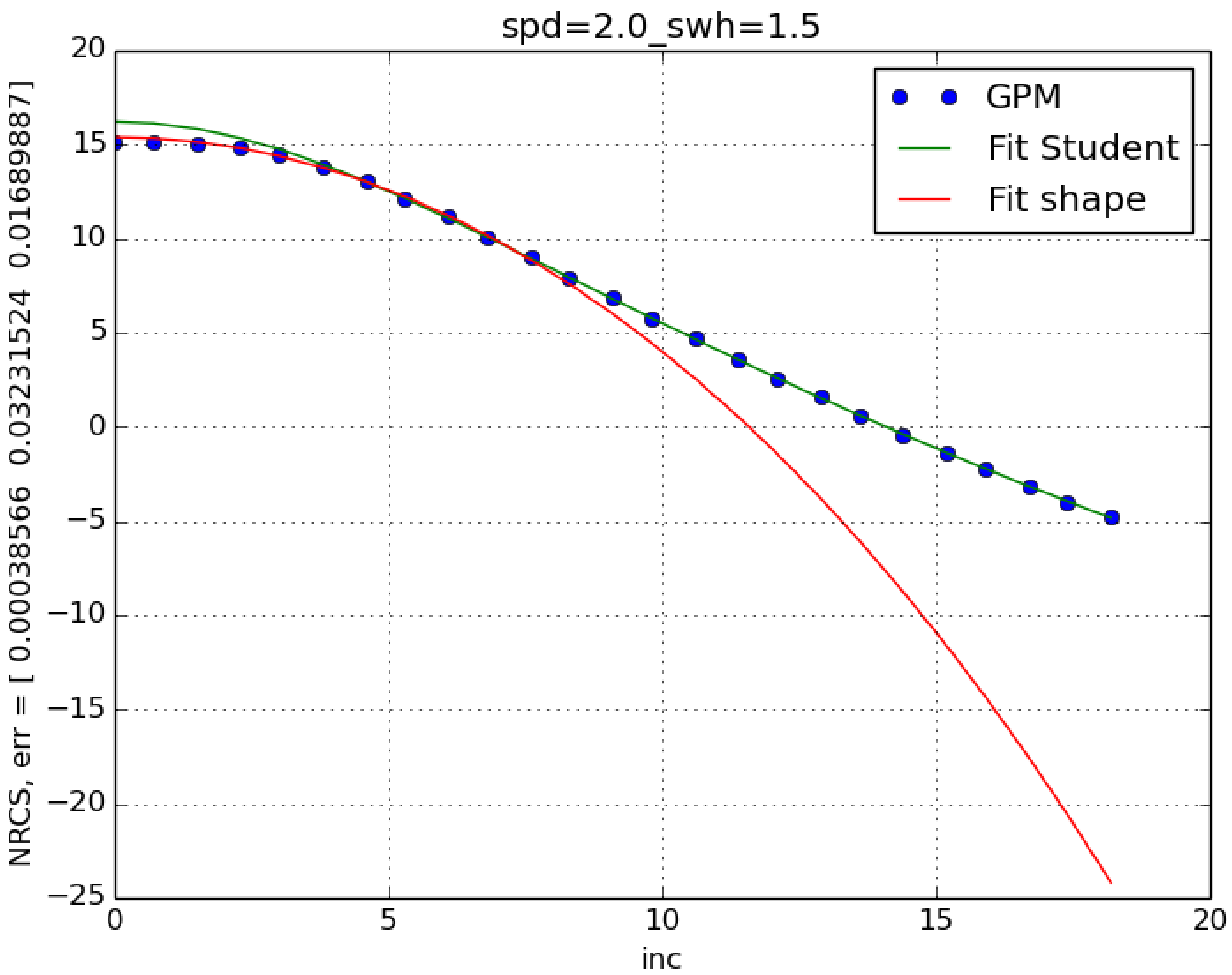
$$\sigma^0_{PO} = |R|^2 \sec^4(\theta) \int e^{i\mathbf{Q_H}\cdot\mathbf{r}} \left\langle e^{iQ_z(\eta_0-\eta_\mathbf{r})} \right\rangle d\mathbf{r}$$

- Fit with a non-divergent distribution with finite moments

  PO : Fourier Transform of a modified caracteristic function (Qz : frequency dependent)

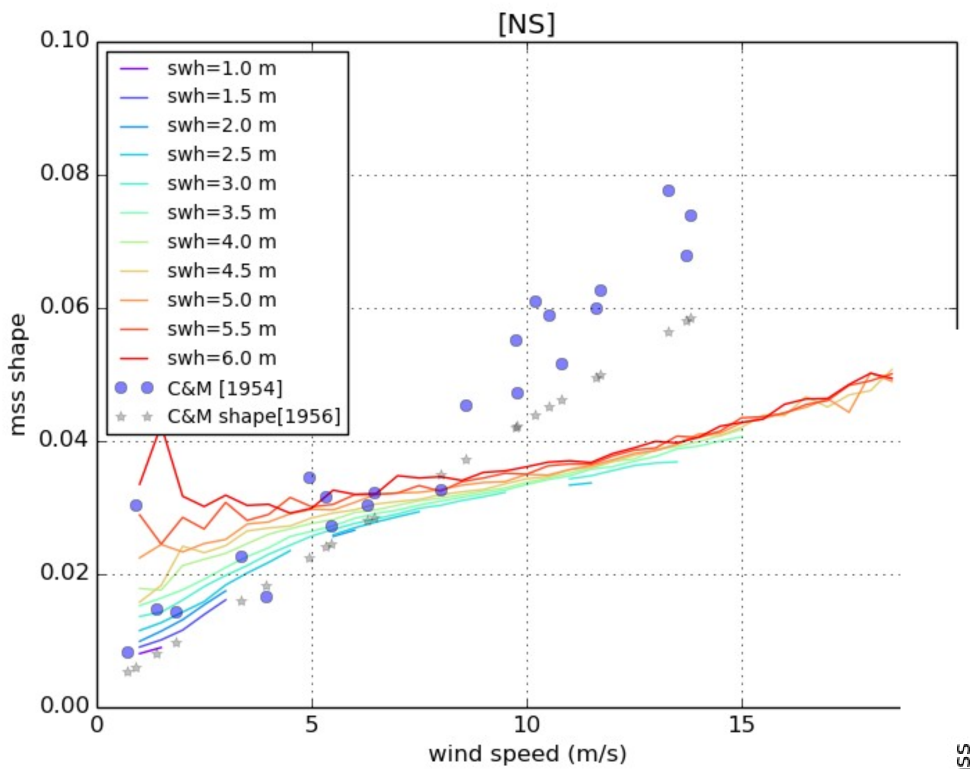
- Identify the distribution moments (variance, skewness, kurtosis) with the surface characteristics

Preliminary tests : Student distribution



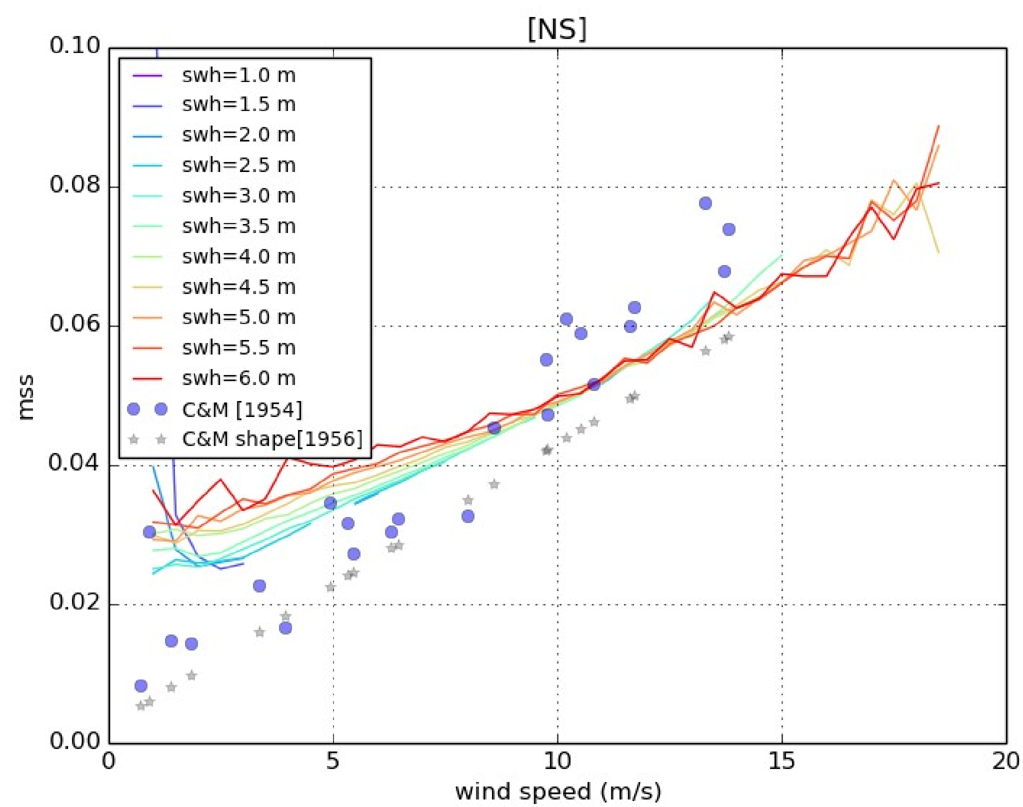
Preliminary tests : Student distribution

Ku Band



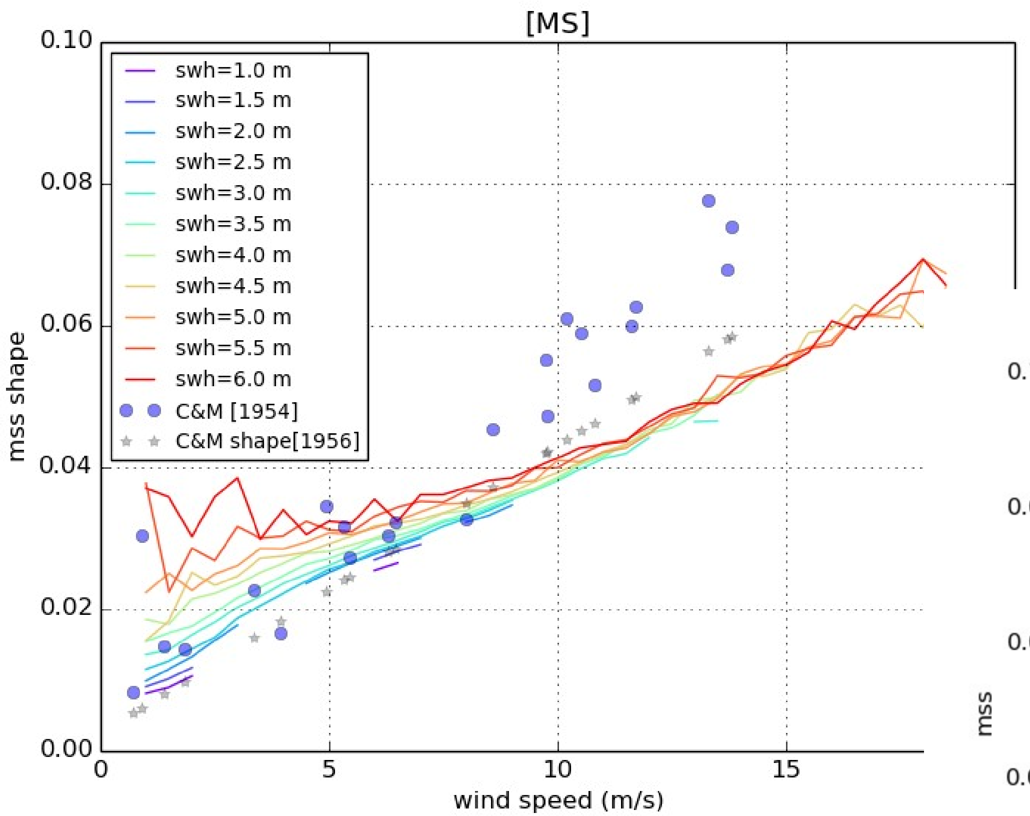
mss shape

“mss total”

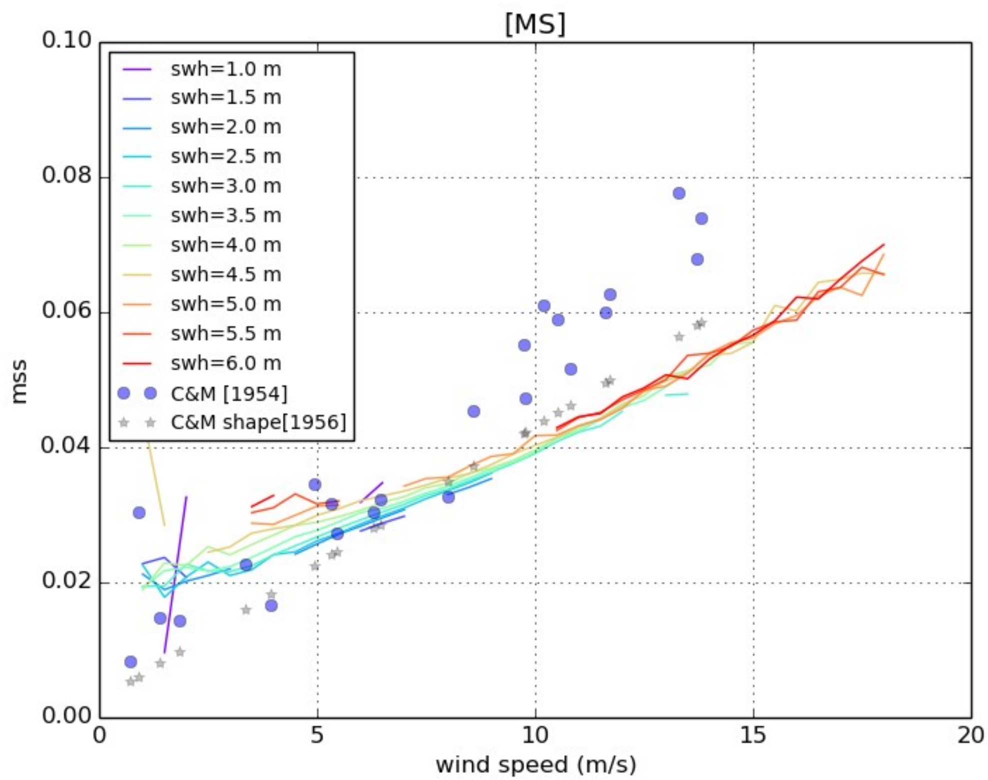


Preliminary tests : Student distribution

Ka Band



mss shape

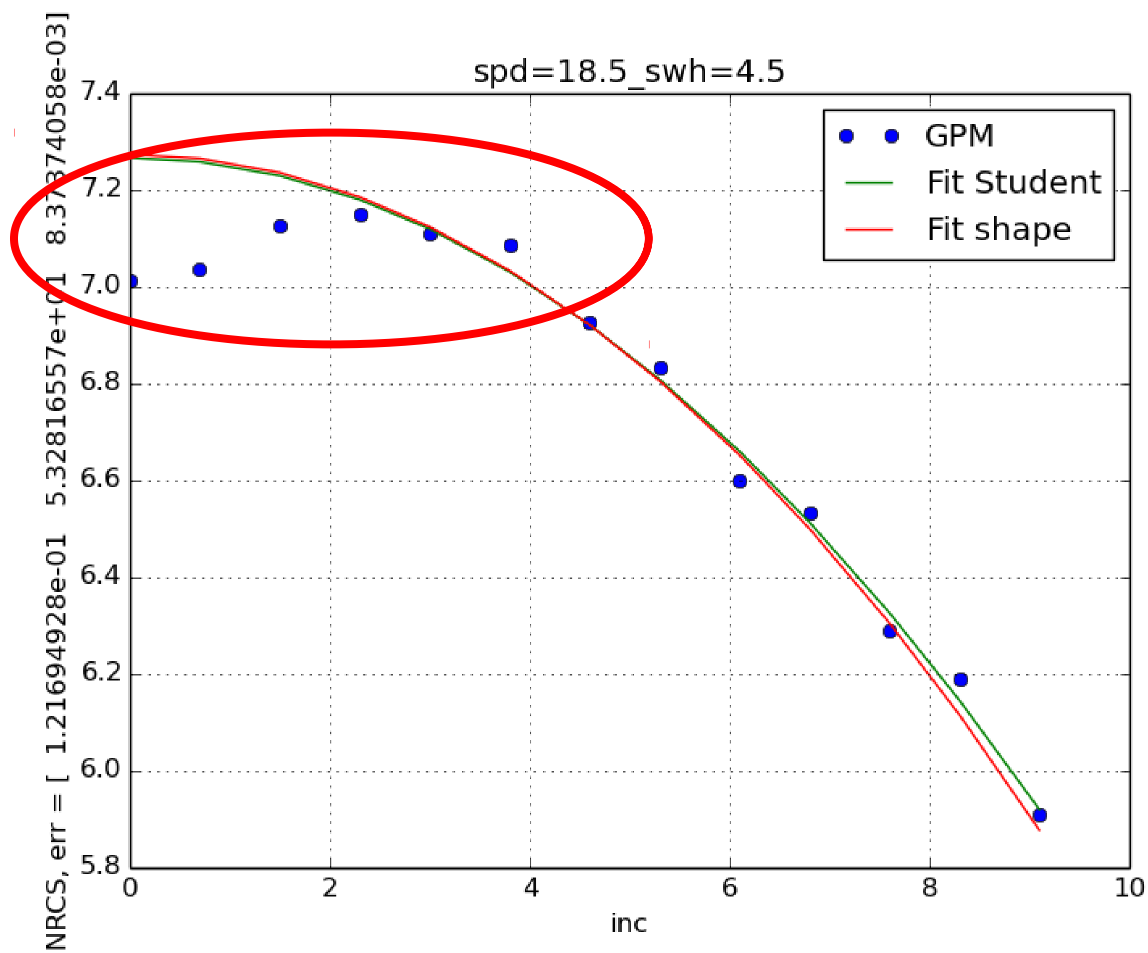


“mss total”

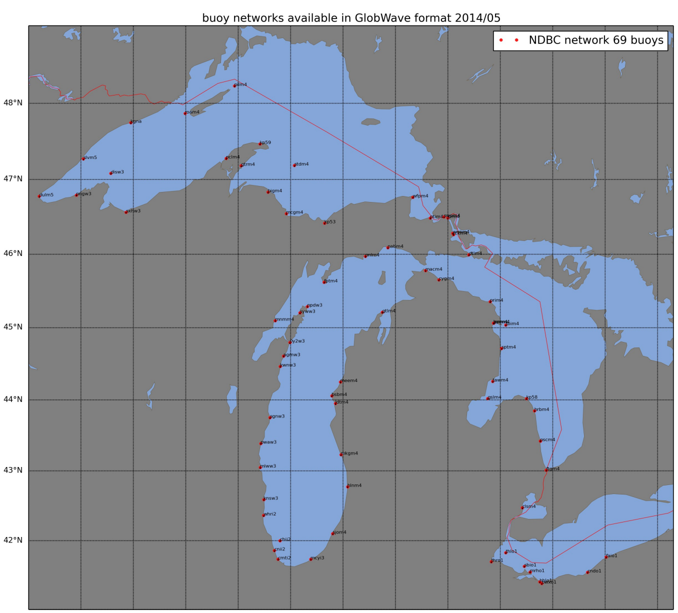
Preliminary tests : Student distribution

Ka Band :

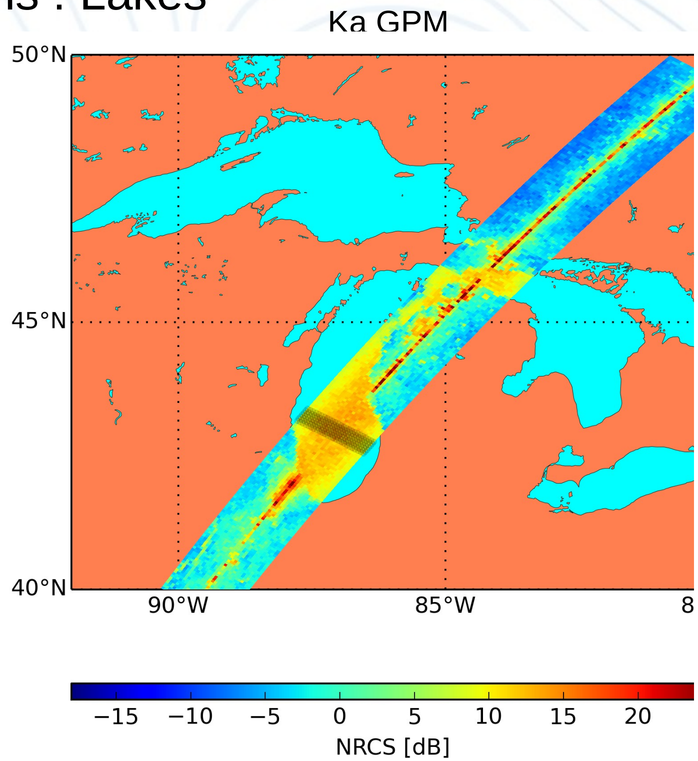
- limited angular excursion (9 degrees)
- Data problems

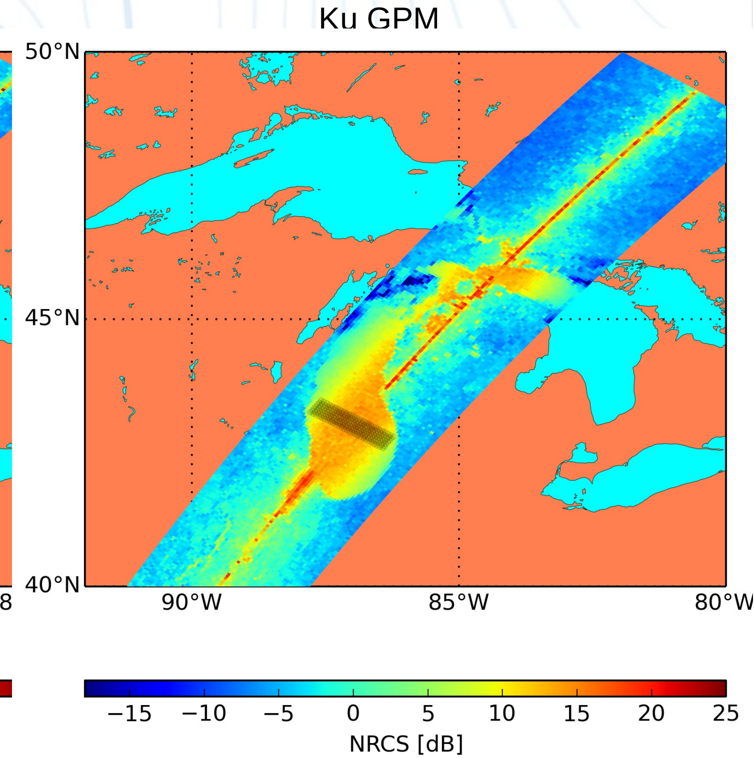


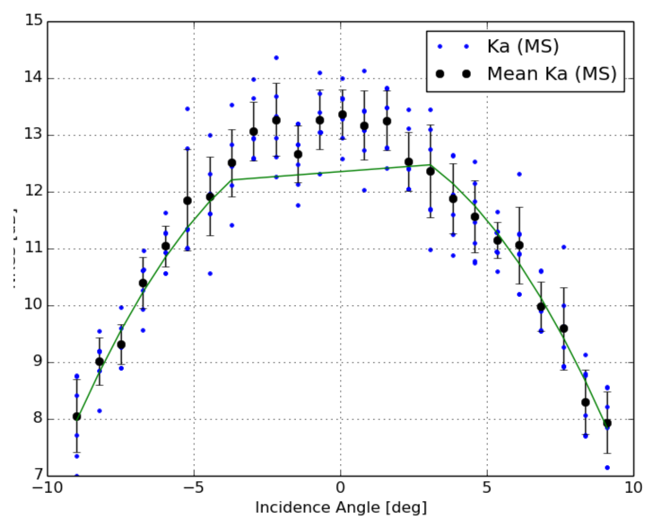
Ku/Ka-Band comparisons : Lakes

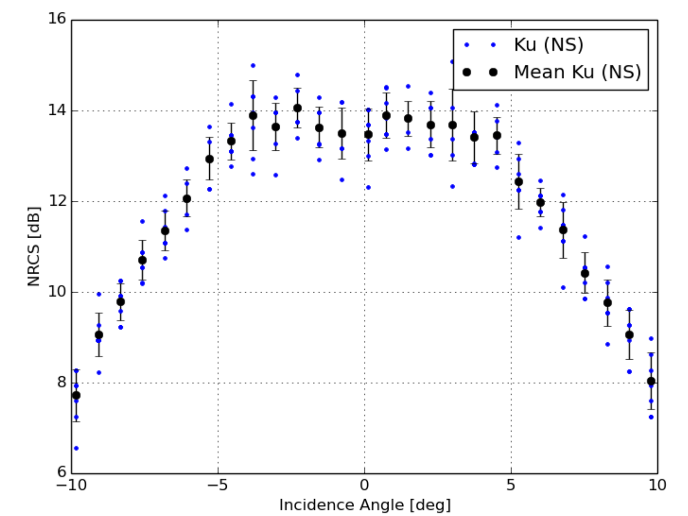


Buoys locations

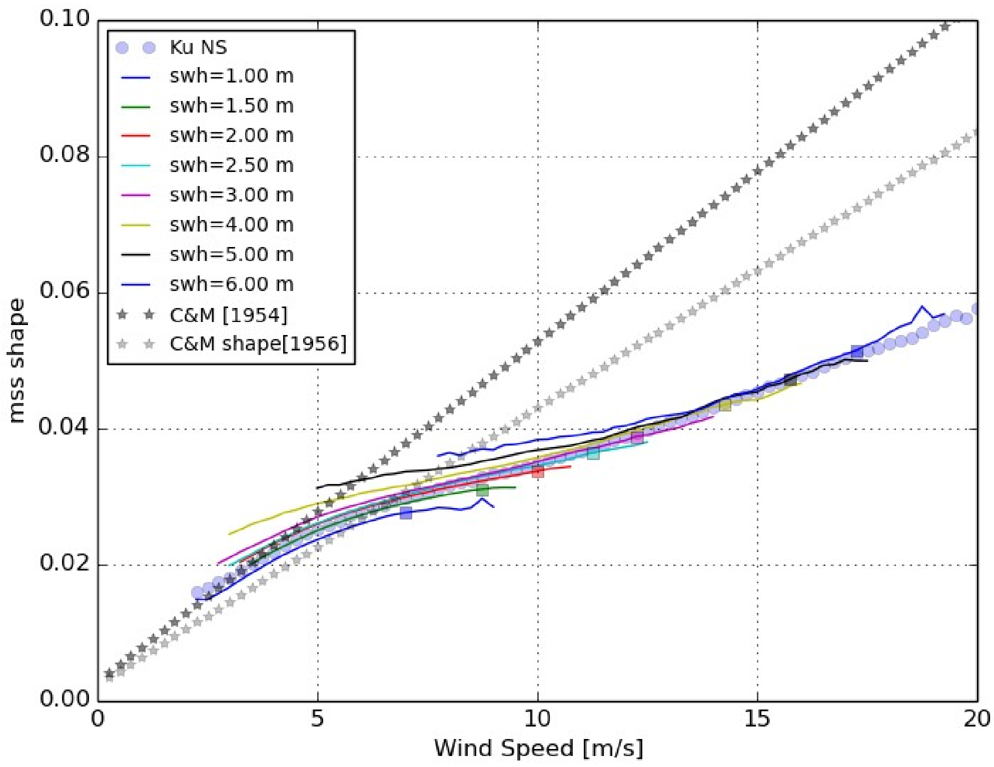


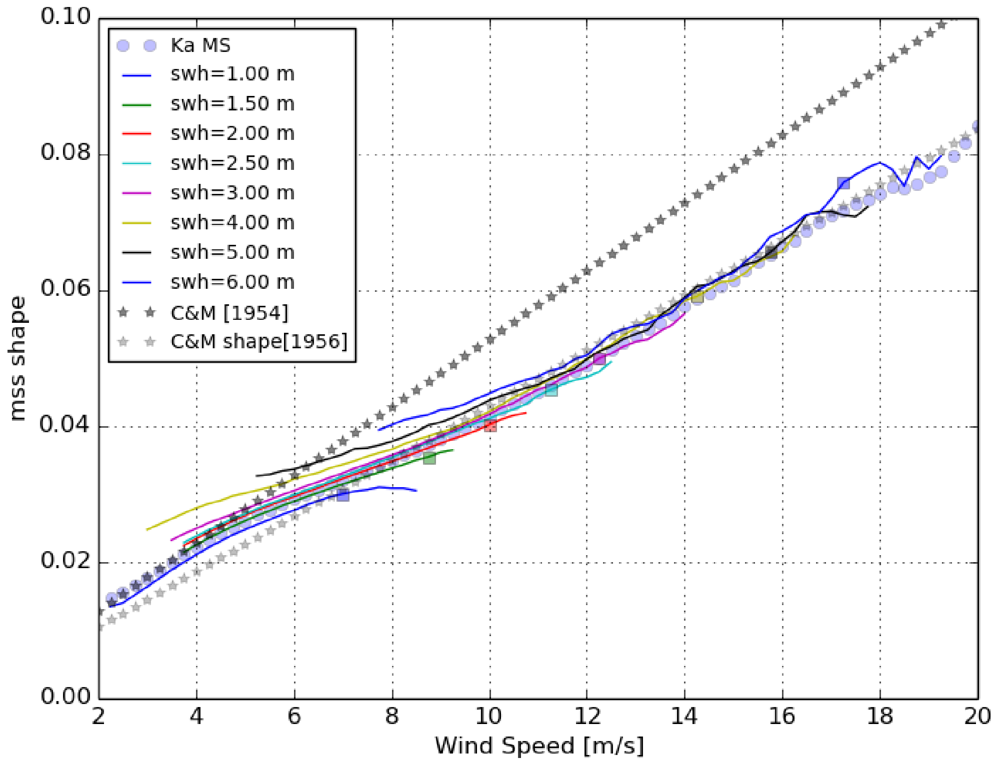






Ku/Ka-Band comparisons : Lakes





Ku/Ka-Band comparisons : Lakes

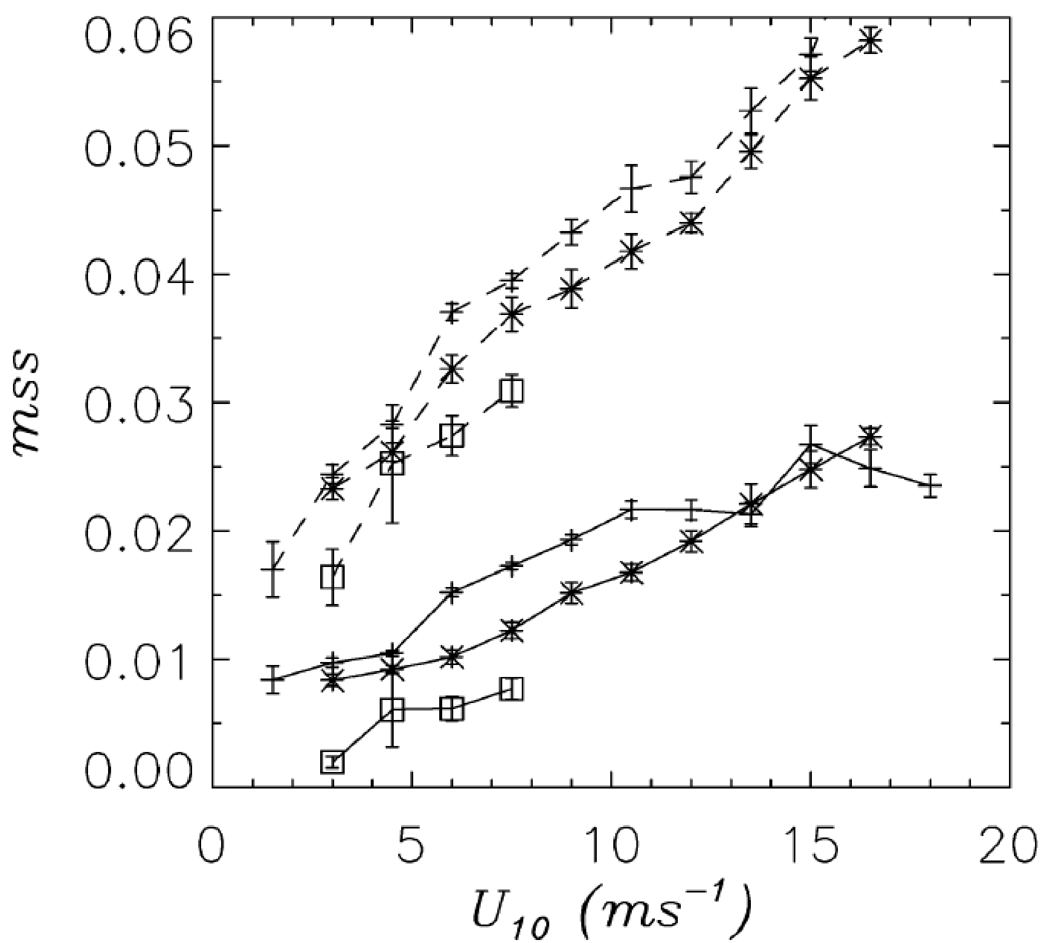
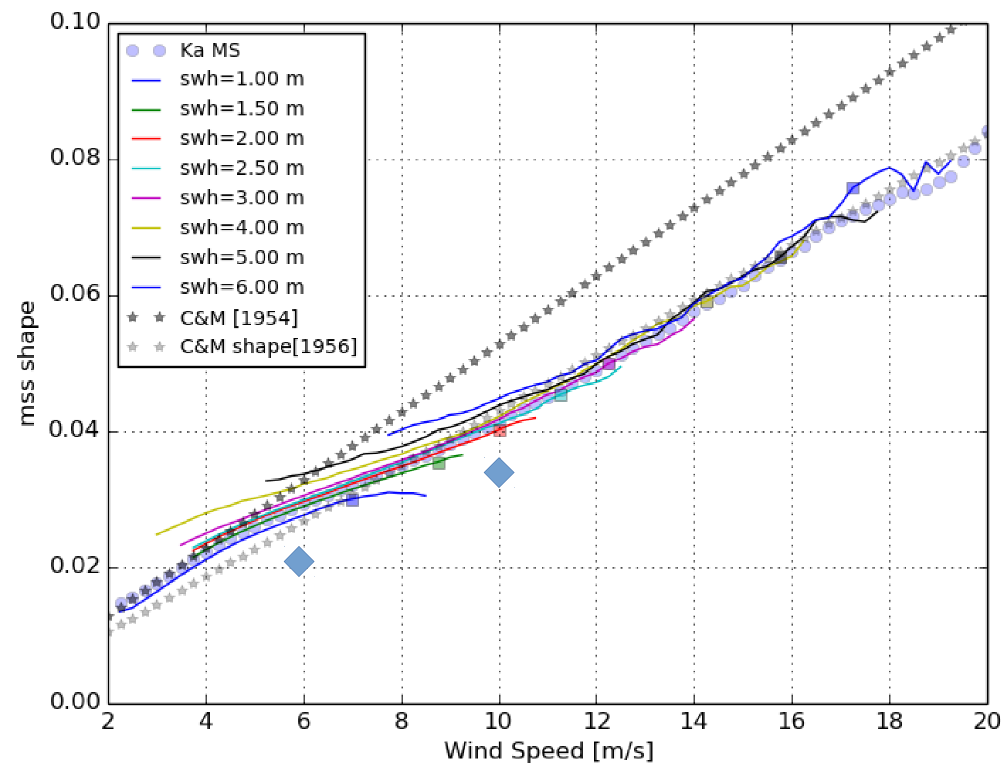


FIG. 9. Laser- and radar-derived mss vs U_{10} for the prescribed inland (□), coastal (*), and open-ocean (+) regions. The lower three curves represent mss_l, the upper curves mss'_{Ka}. Error bars depict b_{err} as defined in text.



Conclusions ...

- High variability of mss as function a of :
  - Wind speed
  - Significant Wave height (especially at low incidence angles and low wind speed)

- Dual frequency measurement let us access to short waves contribution to the mss

- MTF is statistically relevant but each case is peculiar
  - Can we add more physics to mss (mss_S) estimate instead of prescribed MTF ?
  - Could higher statistics parameters (kurtosis) be derived jointly ?

...and perspectives.

- Azimuthal dependency of NRCS
- Enhanced distributions for the characteristic functions
- Wind speed direction - swell direction – azimuth look angle
- Dependency on other relevant quantity (wave steepness, normalized swh, ...)

- Deeper inspection of particular cases (lakes, …)