Radiometric analysis of GPM Ku- and Ka-band near-nadir data over sea ice

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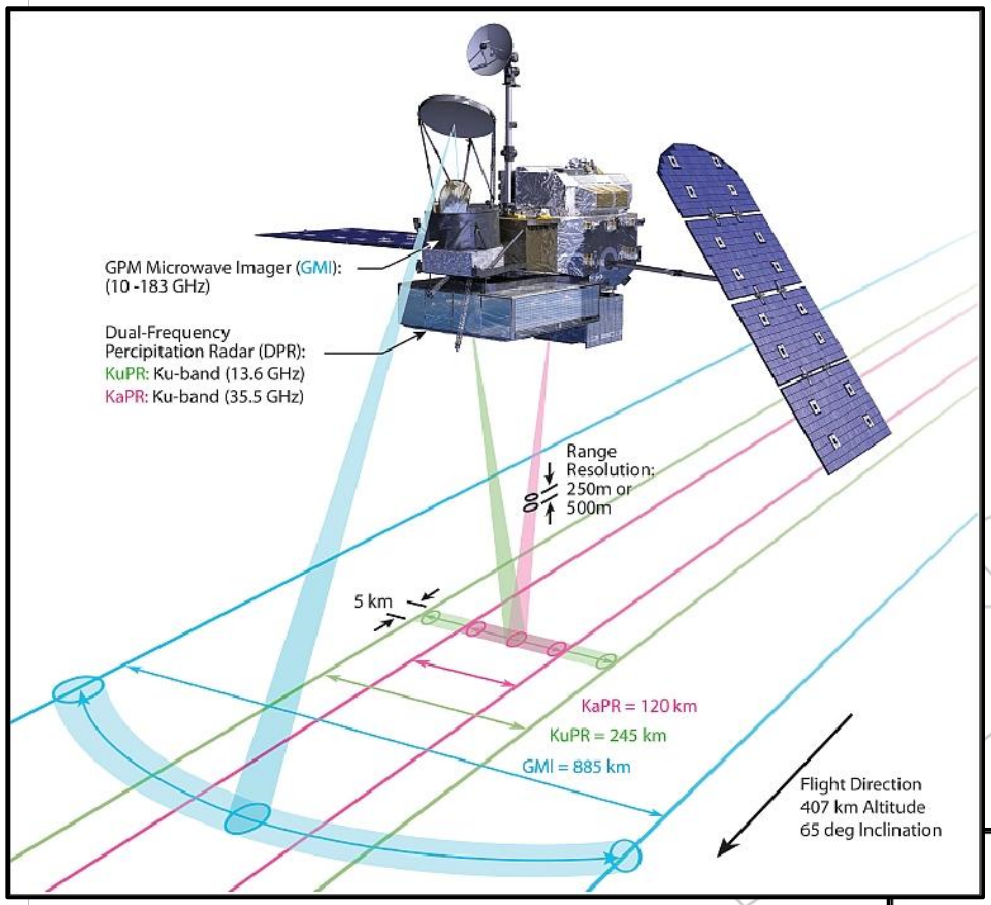
Plan

- **Short presentation of GPM mission**
- **Some analyses over sea surface and sea ice: separability ?**
- **Sea ice flagging with Ku- and Ka- band GPM data**
- **Toward sea ice characterization ….**

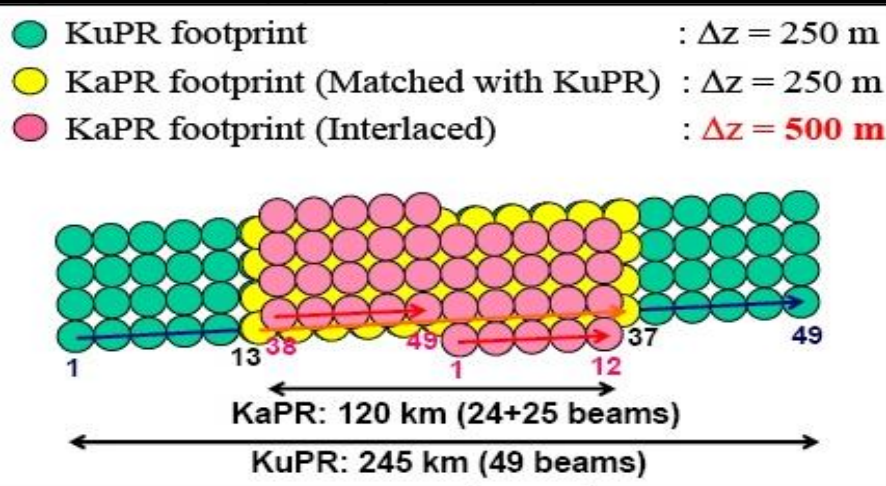
Short presentation of GPM mission



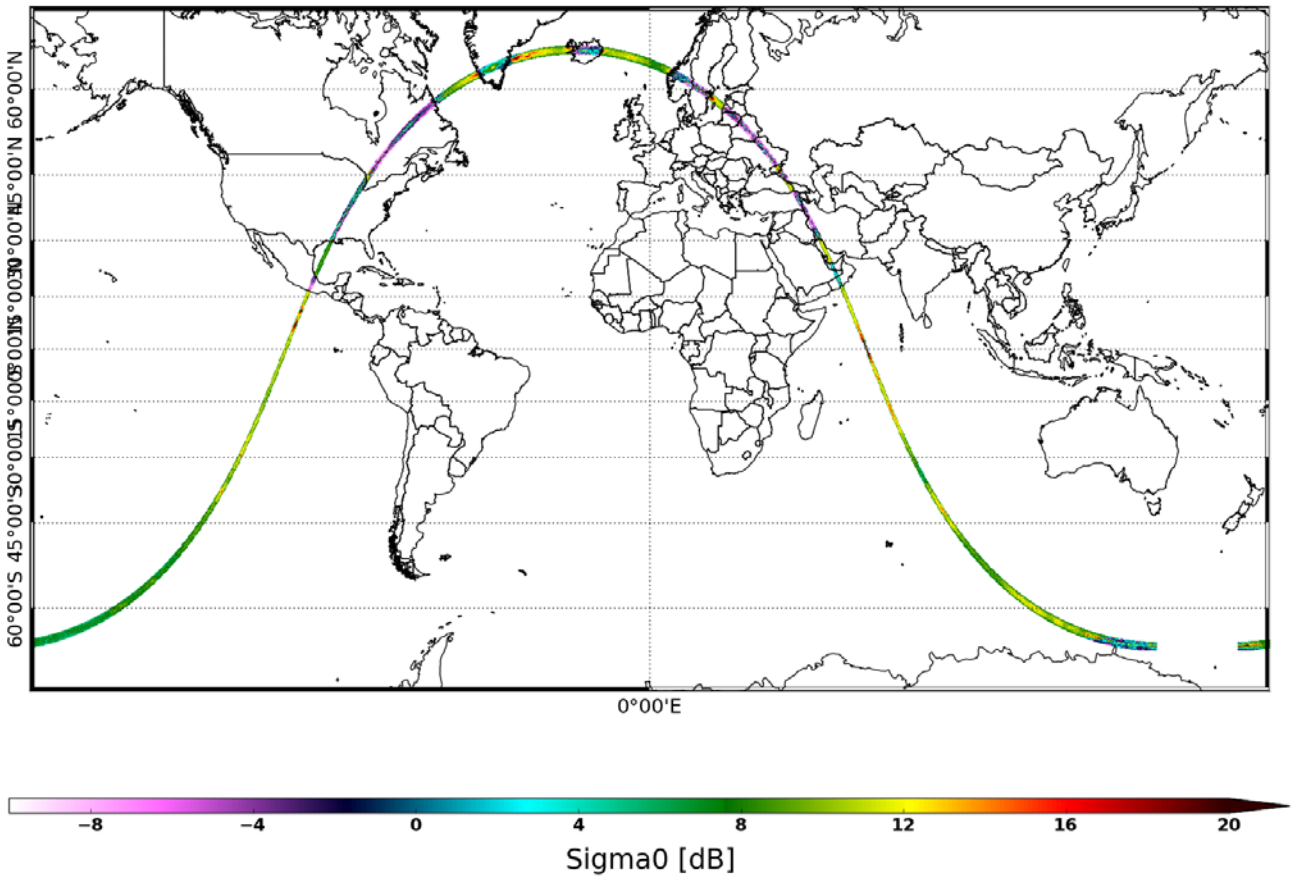
Quasi-simultaneaous observations are available from both KaPR and KuPR in the quasi-specular domain :

Incidence angle:
- Ku PR: [-18°,18°]
- Ka PR: [-9°, 9°]

- Low spatial resolution: 5 km

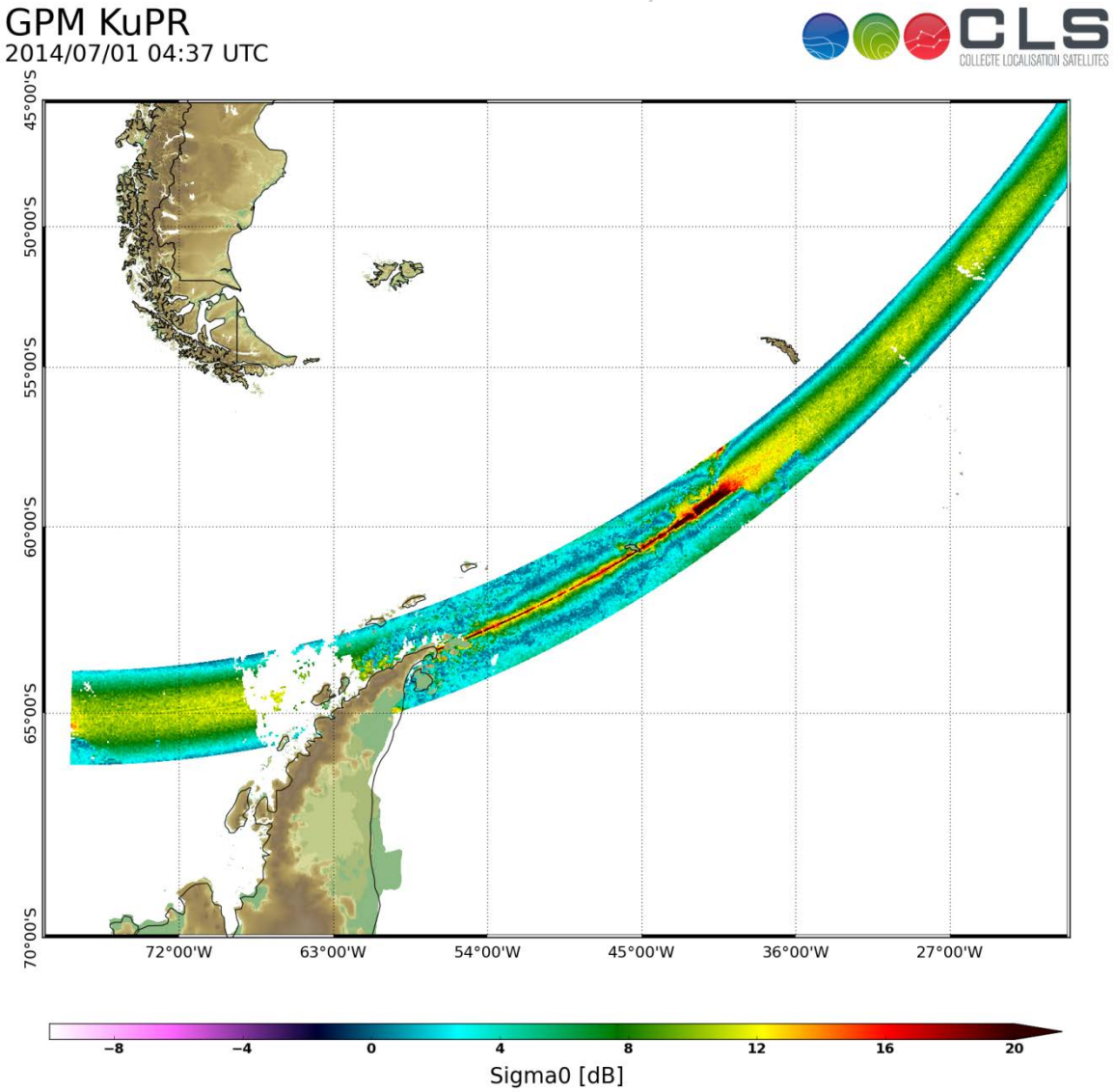


GPM Ka PR
2014/05/15 01:49 UTC



Monitor up to +65°N and 65°S (asset wrt TRMM mission focusing on tropical belt): boreal forest, arctic and antarctica sea ice, greenland ….

And over sea ice when no rain in the atmosphere …



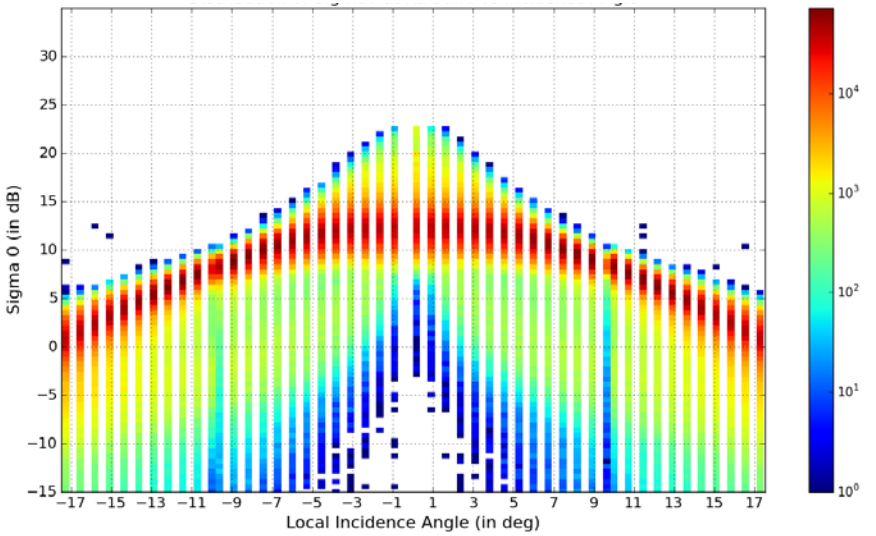
Some analyses over sea surface and sea ice: separability ?

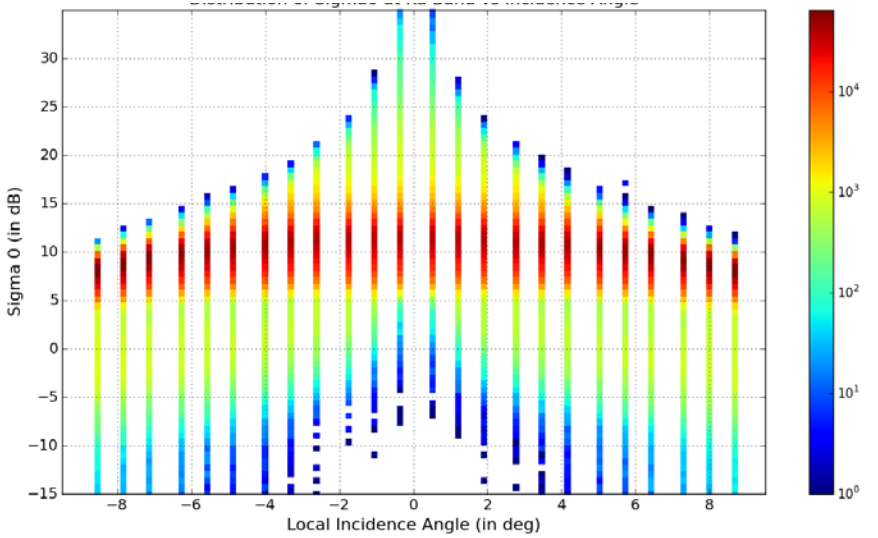
Water vs Sea ice automatic flagging

Distribution of Sigma0 at Ku-band

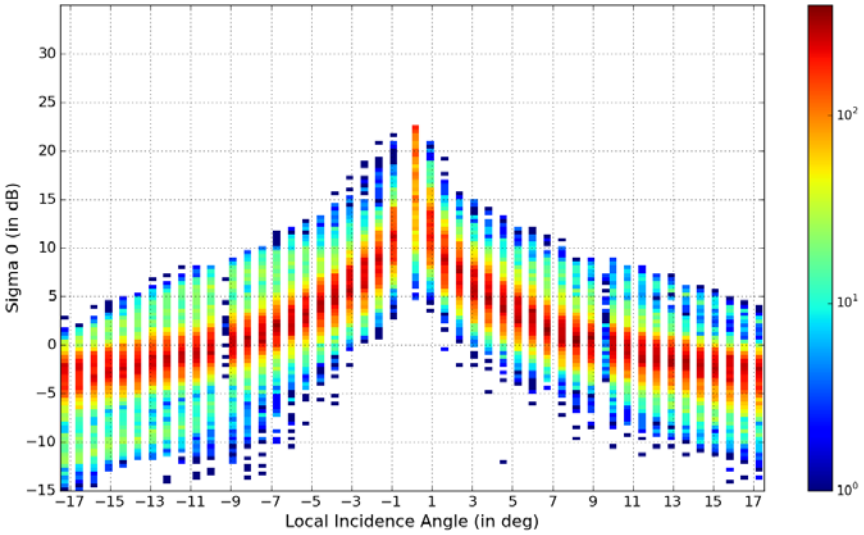
Distribution of Sigma0 at Ka-band

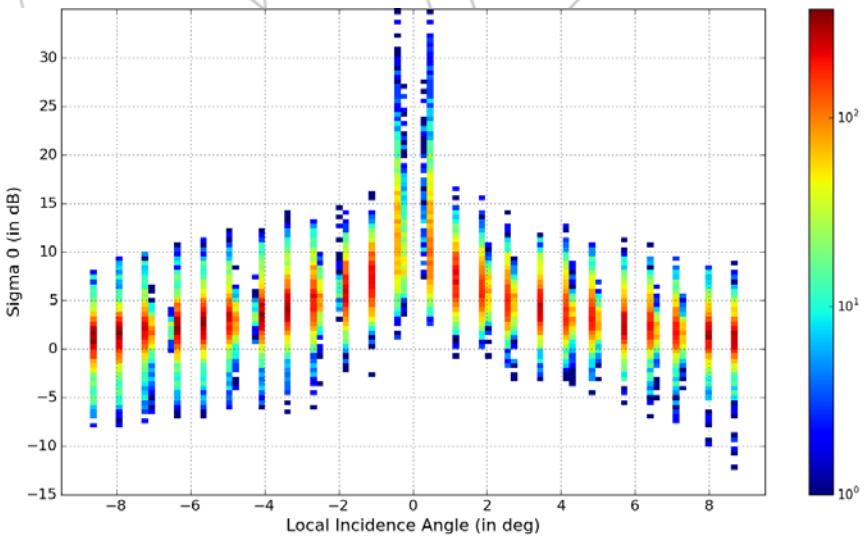
Open water





Sea ice (no specific season)

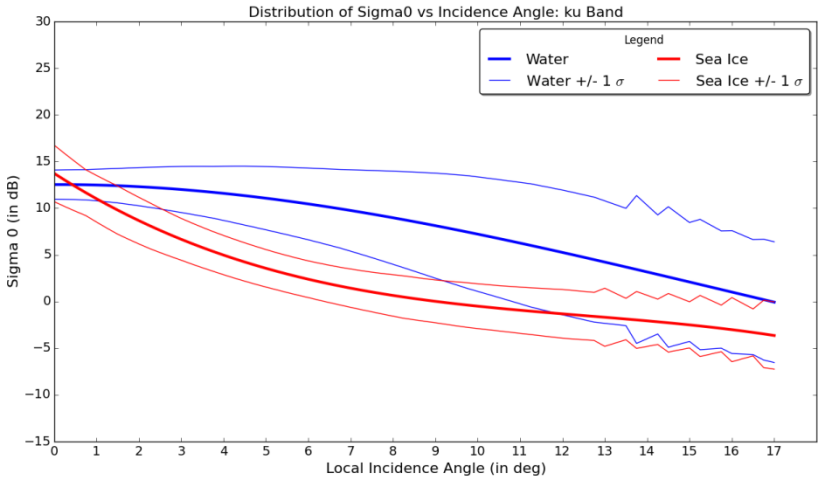


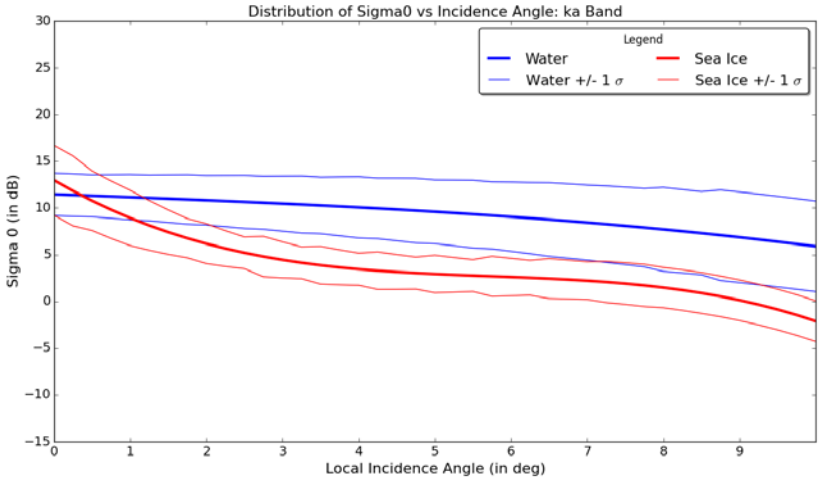


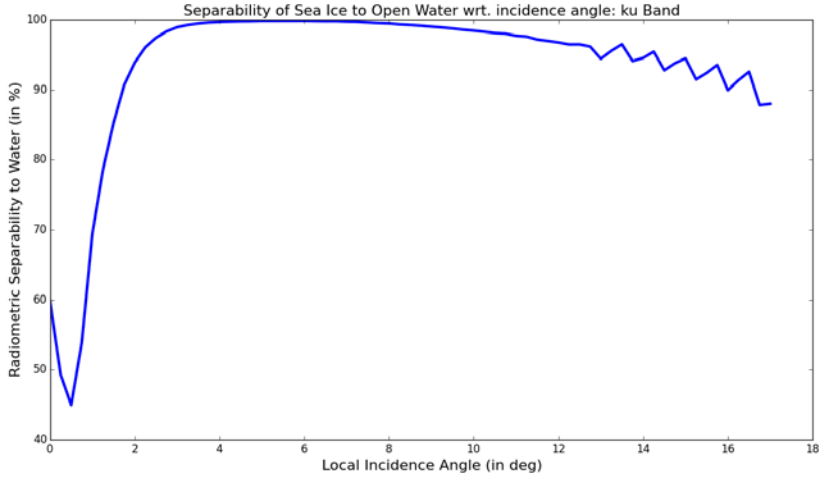
Water vs Sea ice automatic flagging

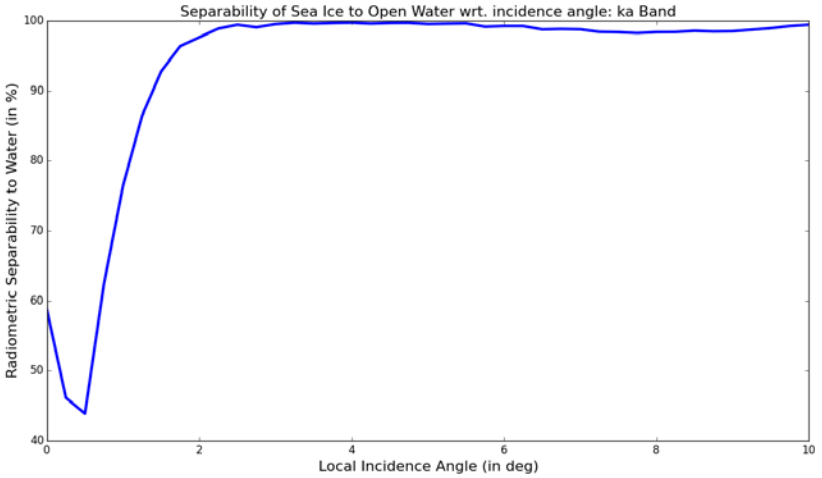
Separability computed from data histogram separation based on simple threshold decision

- Assuming:
  - 50/50 prior probabilities









A first prototype for Ku-band Sea ice flagging

Based on naive Bayesian Classifier

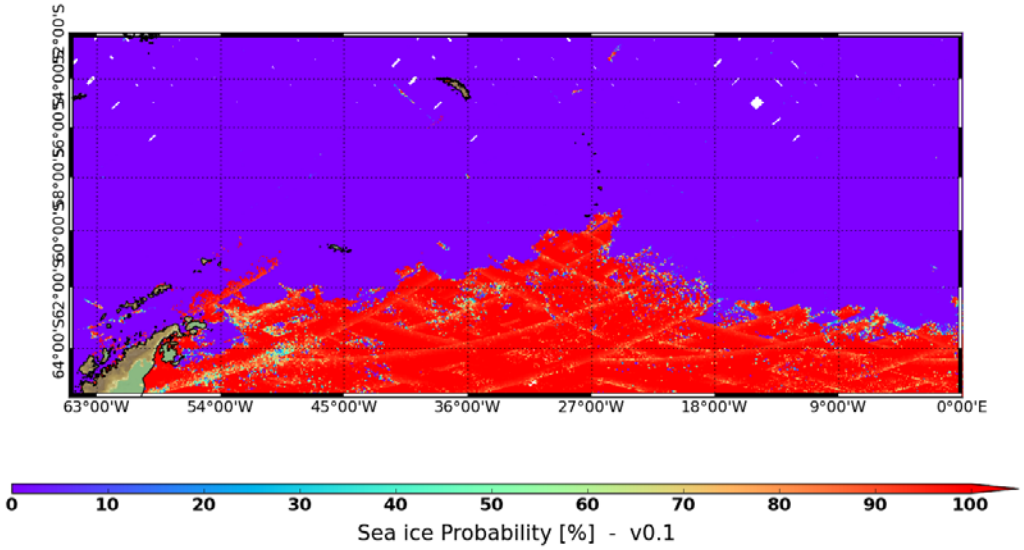
- Data histogram for each class (water and sea ice) are used to estimate sea ice probability

-Multi-track approach over 15 days:

-Reject data with high unreliability -> incidence angle < 3° and > 13°

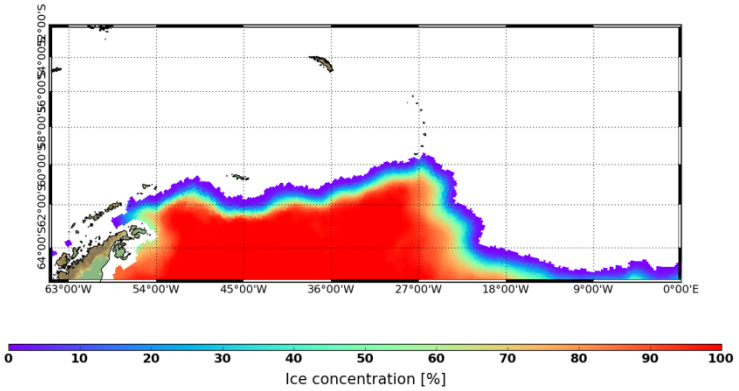
-If same point covered by several dates: keep the more reliable

GPM KU 2014-04-22 - 2014-05-07



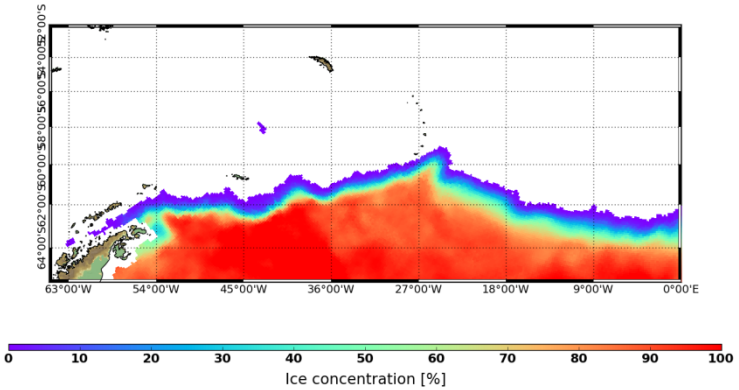
OSI-SAF 2014-04-22

Ice Concentration



OSI-SAF 2014-05-07

Ice Concentration

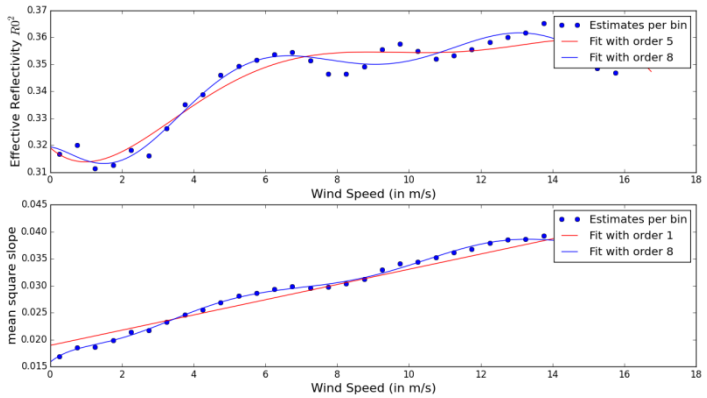


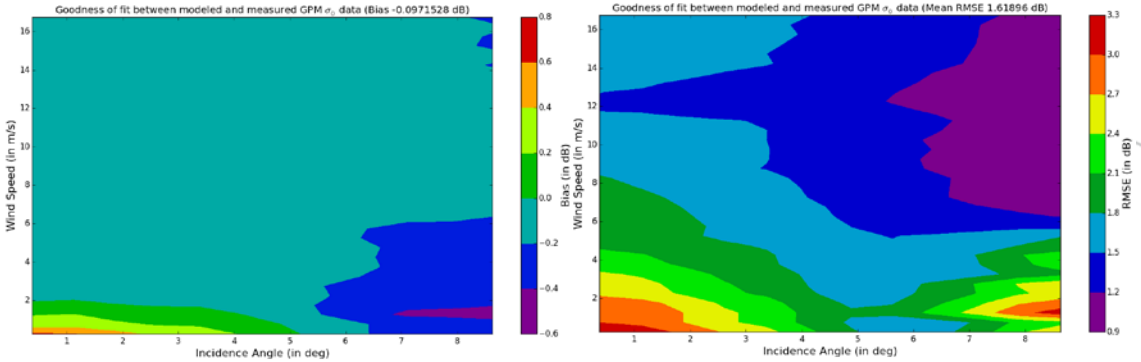
Other prototype needed for Ka-band…

At Ka-band, radiometric ambiguities between ocean and sea ice expected especially in view of SWOT [0-4°] angle range.
-> Need for improving Naive Bayesian Classifier with a priori metocean information (at least wind speed)

Model Ka-band Sigma0 as a function of Incidence Angle and wind speed using Freilich-type model

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





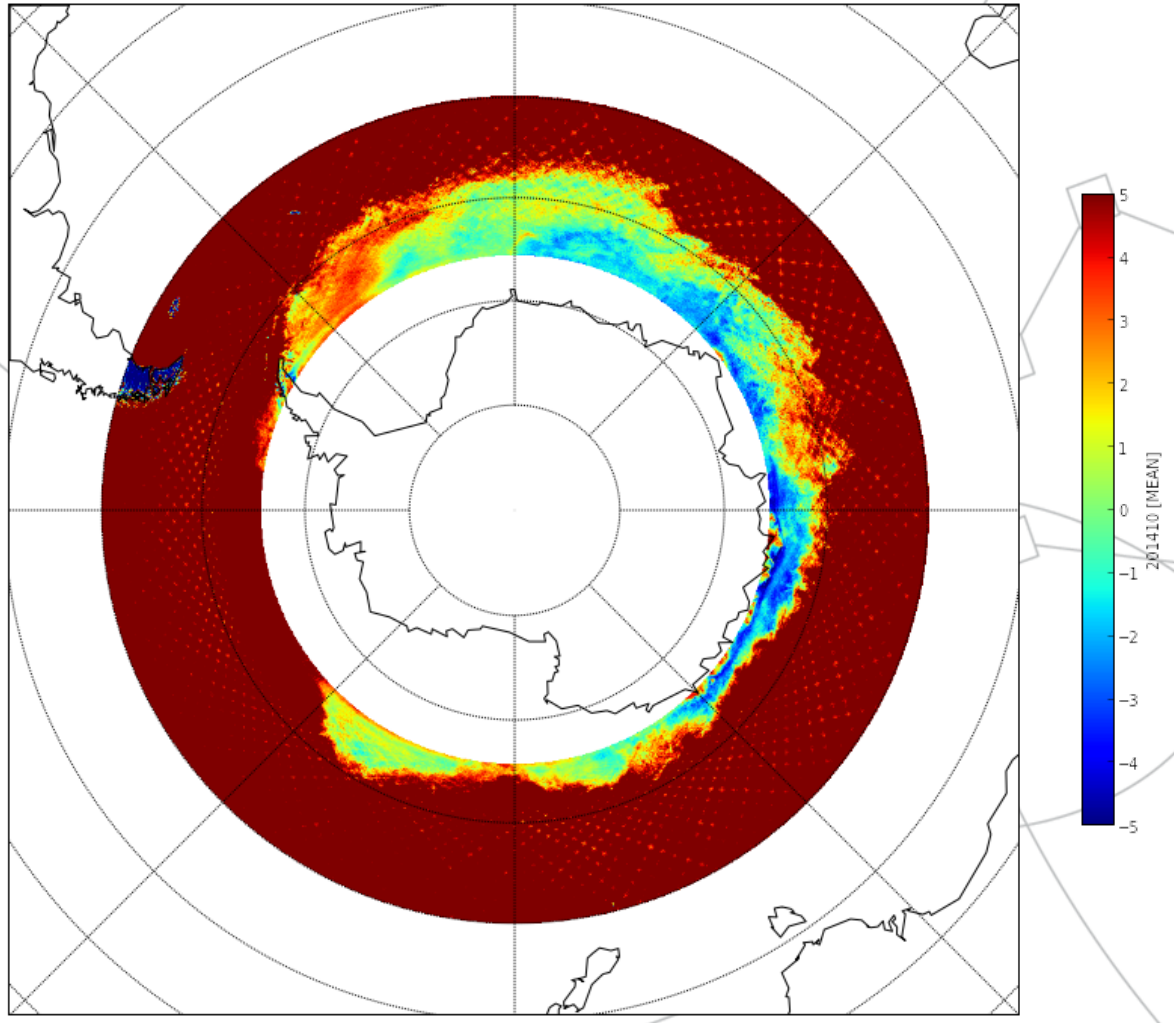
Basic Ocean Ka GMF seems satifactory enough as an a priori input for sea ice flagging

Sea ice flagging: To be continued with prior sigma0 distribution over ocean surface knowing solely wind speed and inc. Angle (Hs and SST to be added afterward…)

Toward better understanding of Ku-& Ka-band near-nadir backscattering over sea ice …

and sea ice characterization

Monthly sea ice products with Ku-band



Average de-trend function with respect to incidence angle impact is applied

Depend on sea ice concentration, type… ?

Modelling sea ice backscattering ….

Following (Kurtz et al, 2014) (Hagfors et al. 1970), valid if:
- Correlation length larger than Electromagnetic wavelength, $l > \lambda$,
- Radius of curvature of the surface large with respect to the wavelength $\frac{l}{2h\sqrt{\pi/6}} > \lambda$

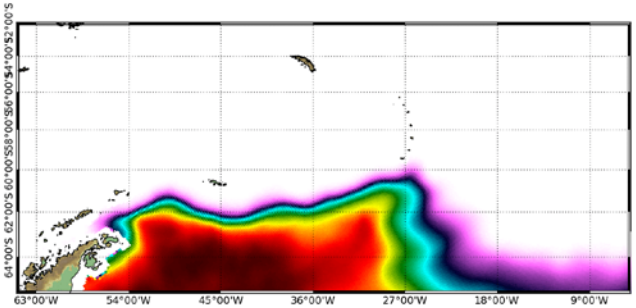
$$\sigma^0(\phi) = \left(\frac{R_0}{2cos^6(\phi)}\left(\frac{l}{2k_0h_m^2}\right)^2\right)\left[1+\left(\frac{l}{2k_0h_m^2}\right)^2\sin^2\phi\right]^{\frac{-3}{2}}$$

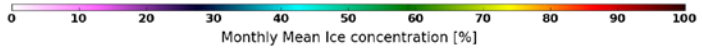
Methodology:
-Over a month, accumulate available (Sigma0 / inc angle) pairs given a geographic grid from all available GPM data
- Over each point of the grid, find optimized R0 and l/h^2 parameters
- Plot these optimized parameters

- Sea ice mask can be derived with threshold on R0 values
  - < 0.4 at Ku but also Ka-band

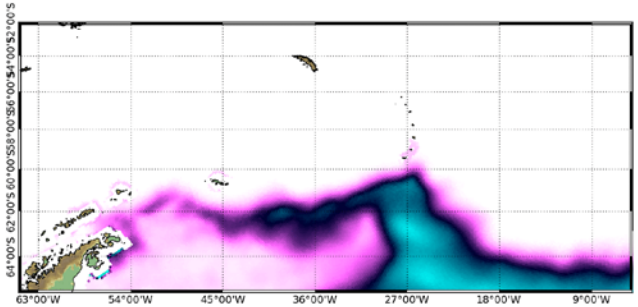
Kurtz et al, «An improved CryoSat-2 sea ice freeboard retrieval algorithm through the use of waveform fitting", The Cryosphere, 8, 1217–1237, 2014

OSI-SAF April 2014
Monthly Average Ice Concentration

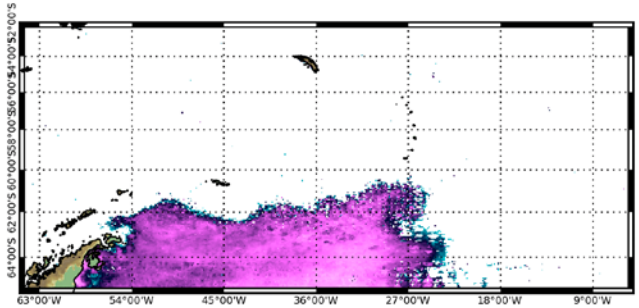




OSI-SAF April 2014
Monthly Standard Deviation Ice Concentration

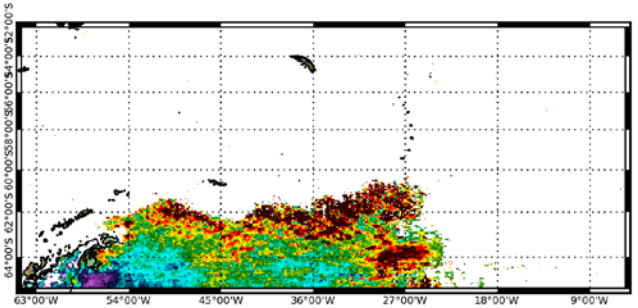


Fresnel reflectivity ku band
April 2014

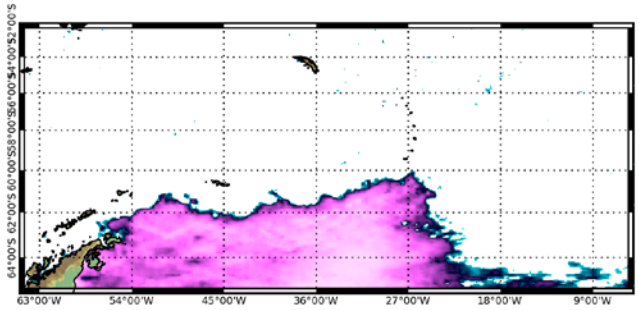


Ice contour derived with R0 < 0.4

Smoothness index ku band
April 2014

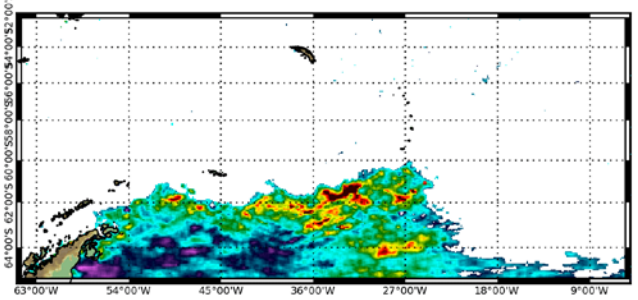


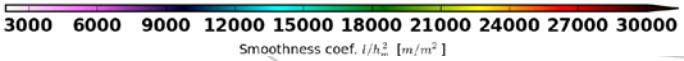
Fresnel reflectivity ka band
April 2014



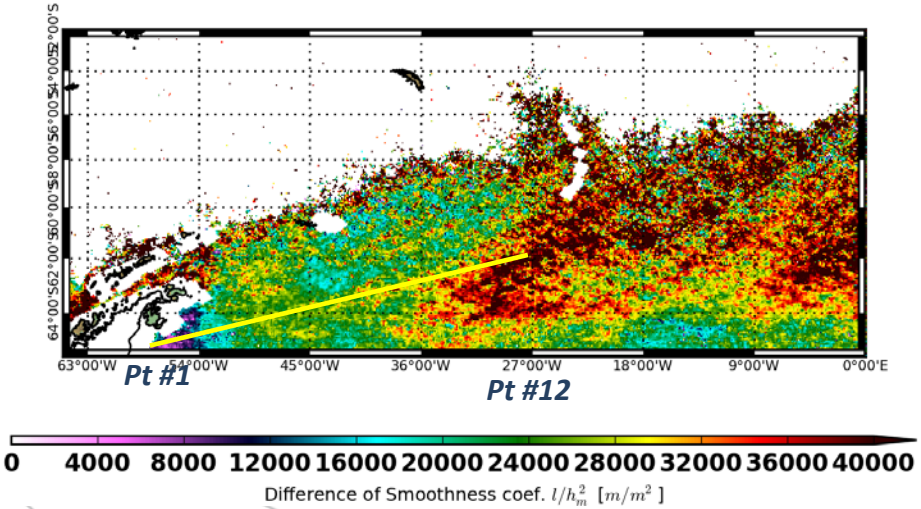
Ice contour derived with R0 < 0.4

Smoothness index ka band
April 2014



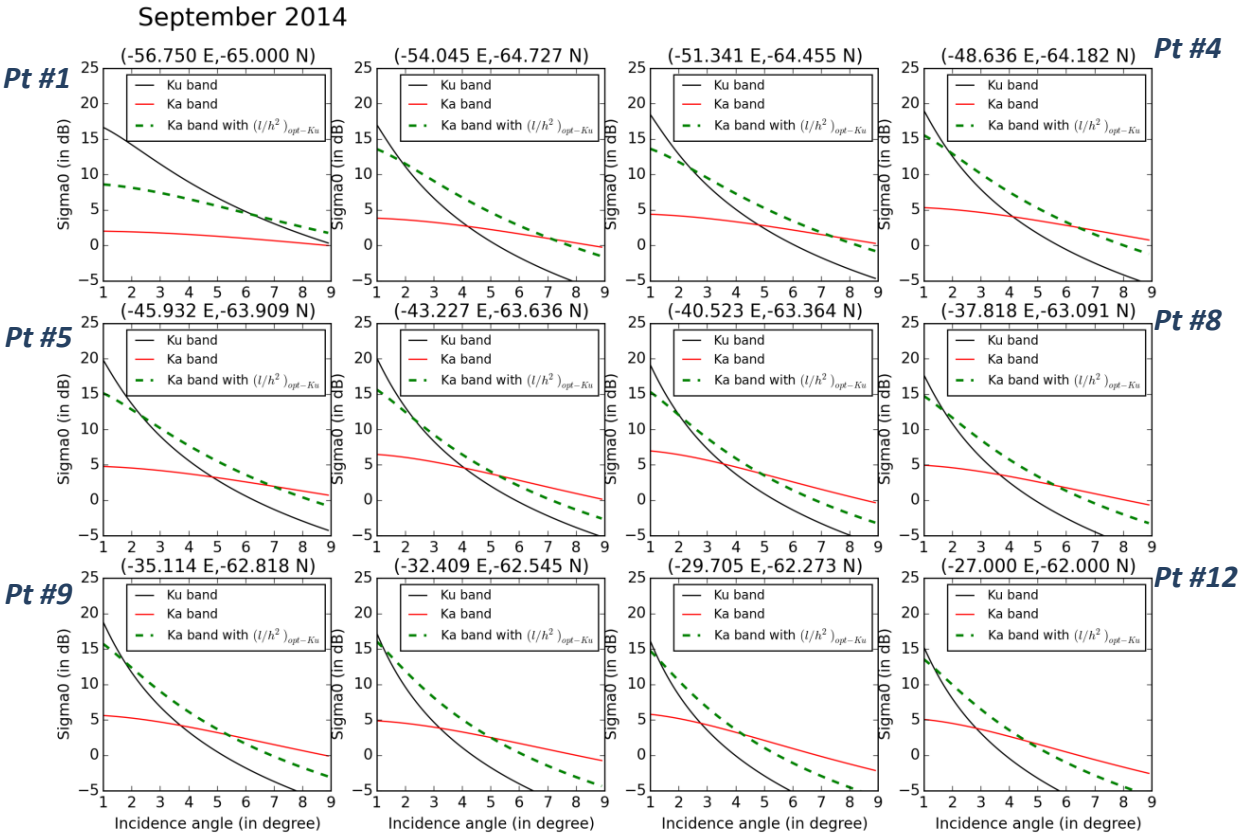


Smoothness index Ku - Ka band
September 2014

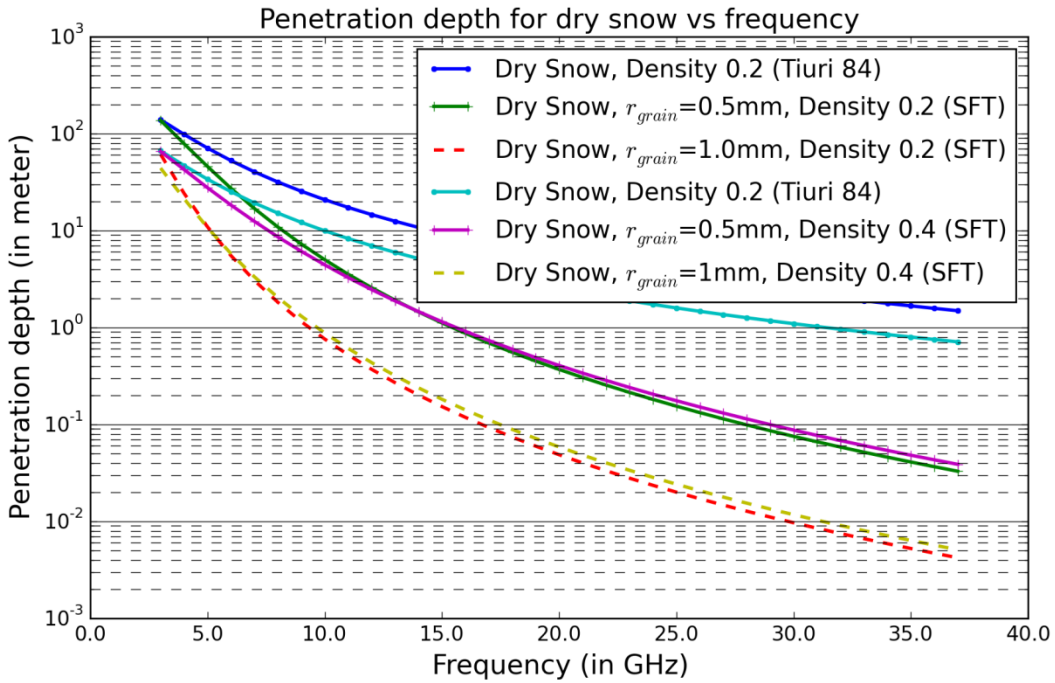


Retrieved smoothness values not consistent between the 2 frequencies
-Due to scale of roughness wrt. wave length ?
-Model non validity at Ka-band ? Impact of dry snow cover at Ka-band (small variation of sigma0 wrt incidence angle…)

Need for adequate modelling for Ka-band:
- volumic contribution from snow pack
-Snow pack attenuation of sea ice roughness contribution
- Contribution from air-snow roughness interface



Modelling snow cover attenuation (preliminary results….)



Penetration depth

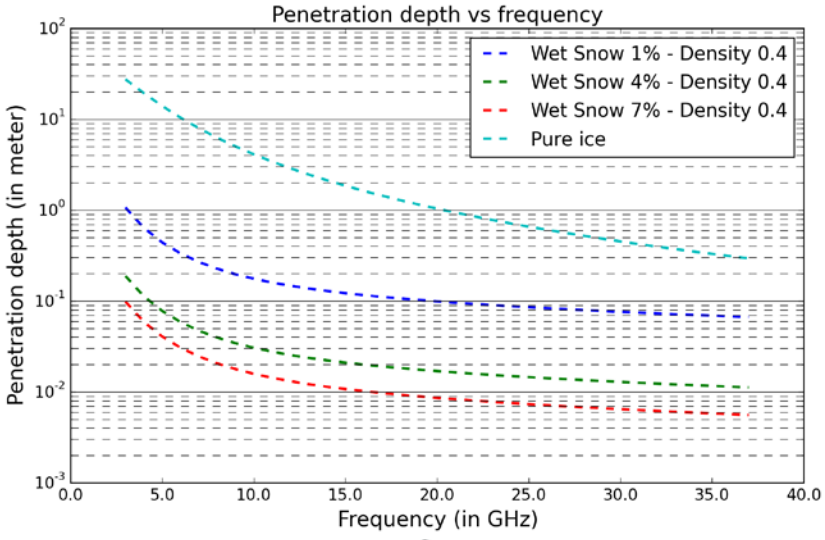
$$P(z) = P(0^-)\exp\left(-\int_0^z \kappa_e(z')dz'\right)$$

$$\frac{P(\delta_p)}{P(0^-)} = \frac{1}{e} \quad \Longrightarrow \quad \delta_p = \kappa_e^{-1}$$

-> Attenuation of exp(-1) -> 4.3 dB every δ_p

At Ku-band: penetration depth in the order of 0.1 to 1m depending mostly on ice grain size
At Ka-band: centimetric penetration

Liquid water detrimental (even with a limited amount)



Conclusion

Ku- and Ka-band GPM data of high interest to study sea ice phenomenology in view of CFOSAT and SWOT mission

-> Good separability between Ice and open water at Ku-band over SWIM incidence angle range (4°, 6°, 8° and 10°), moderate at 0 and 2°.

-> (Very) Naive Bayesian classifier can be effective for sea ice flagging at Ku-band: To be improved with a priori information on waves and wind in view of SWIM

-> Feasibility of multi angle sea ice flagging (and characterization) demonstrated: Very good adequacy between OSISAF data and retrieved sea ice contour (both at Ku and Ka band)

Need to further investigate retrieved parameters and their links to geophysical parameters -> help also understand altimeter data

-> sea ice status: sea ice type, conconcentration…

-> overlying snow cover: height, density or SWE

Next

-> Analysis with « sea ice egg » over Hudson bay (data from Canadian Ice Service)

-> Study over terrestrial ice and snow (e.g. Greenland)

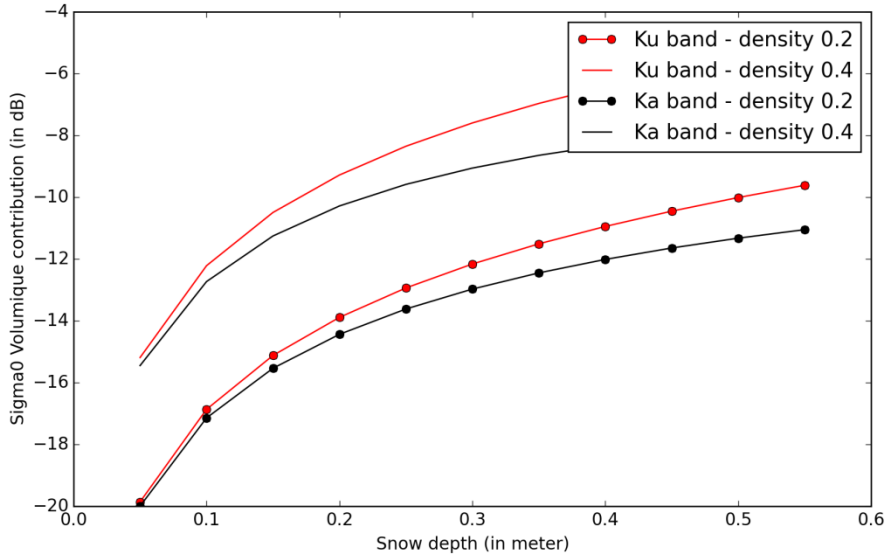
-> Link with Ku and Ka-band Altimeter data using ICENEW and roughness term (so far not conclusive)

-> Apply this study to SWOT or SWIM sea ice flagging and if possible generate sea ice products

This study has been funded to CLS by CNES via the SWOT-ADT project.

IFREMER is funded by CNES as well via the TOSCA program in preparation of the CFOSAT mission

Modelling snow volume backscattering (very preliminary….)



Snow grain size: 0.1 mm
Incidence angle 4° (but no real impact on attenuation or volume contribution -> only modify EM wave path within ice pack

For discussion only