Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management

Adapted Bayesian Sea Ice Detection with CFOSAT Scatterometer[1]

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Outline

- Bayesian sea ice detection: *Algorithm*
  Sea ice GMF (Geophysical Model Function)
  Sea ice detection result and validation
- Summary

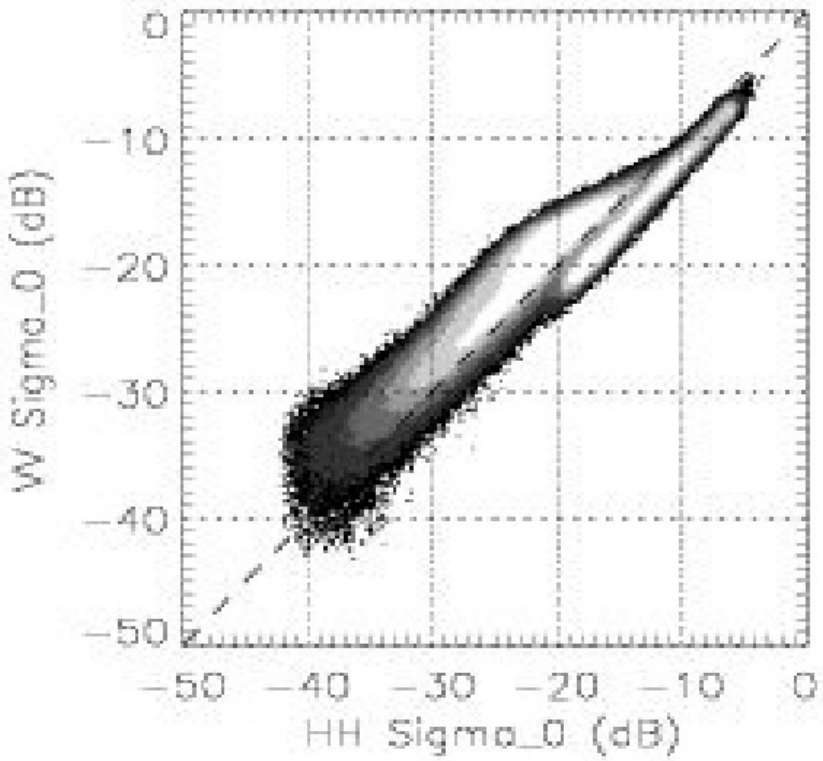
Note: this work has been published recently:

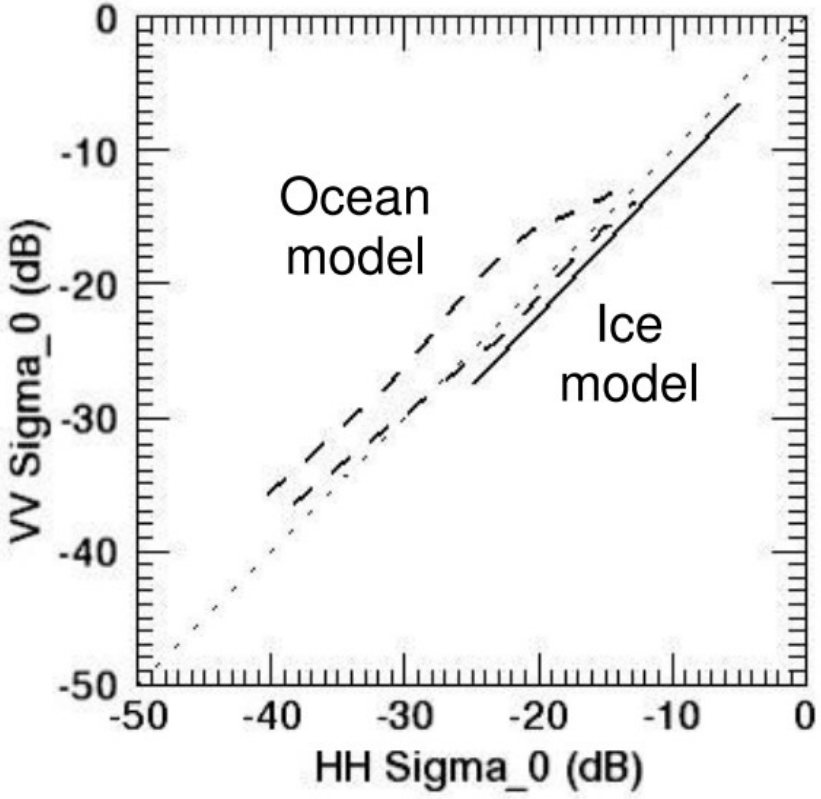
Li, Z.; Verhoef, A.; Stoffelen, A. Bayesian Sea Ice Detection Algorithm for CFOSAT. Remote Sens. 2022,14, 3569. https://doi.org/10.3390/rs14153569

Bayesian Sea ice detection Algorithm

- Ocean surface wind speed and wind direction retrieval is the prime purpose for scatterometers. However, they have also been used to detect and characterize sea ice.

- The sea ice detection method we propose here is an adapted version of the existing algorithm developed for pencil-beam scatterometers such as QuikSCAT.





Rivas et al., 2009

is the conditional probability of given ice (in the case we would measure over ice), i.e., following the typical ice distribution around the sea ice GMF in measurement space.

$$p(ice|\sigma^\circ) = \frac{p(\sigma^\circ|ice)\,p_0(ice)}{p(\sigma^\circ|ice)\,p_0(ice) + p(\sigma^\circ|wind)\,p_0(wind)}$$

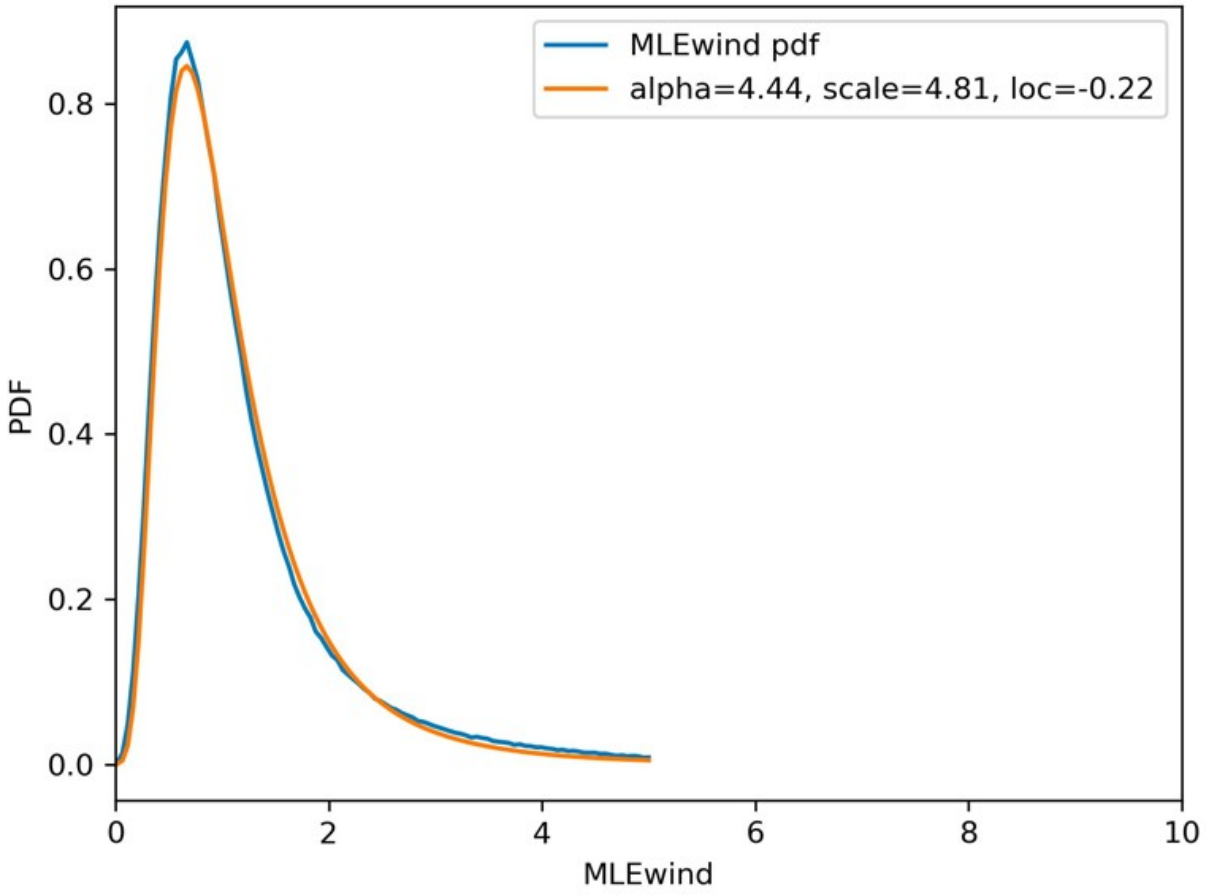
is the conditional probability of s given wind (in the case we would measure wind over open sea), i.e., following the wind distribution around the ocean GMF.

Probability distribution of sigma0 given wind is: $p(\sigma^\circ|wind) = p(MLE_{wind})$

$$MLE_{wind} = \sum_{i=1}^{N} \frac{(\sigma^\circ{}_i - \sigma^\circ{}_{wind,i})^2}{var[\sigma^\circ{}_{wind,i}]}$$

$$p(\sigma^\circ|wind) = \frac{x^{-\alpha-1}}{\Gamma(\alpha)} e^{-\frac{1}{x}} \frac{1}{scale}$$

where $x = (MLE_{wind} - loc)/scale$, $loc = -0.22$, $\alpha = 4.44$, $scale = 4.81$.



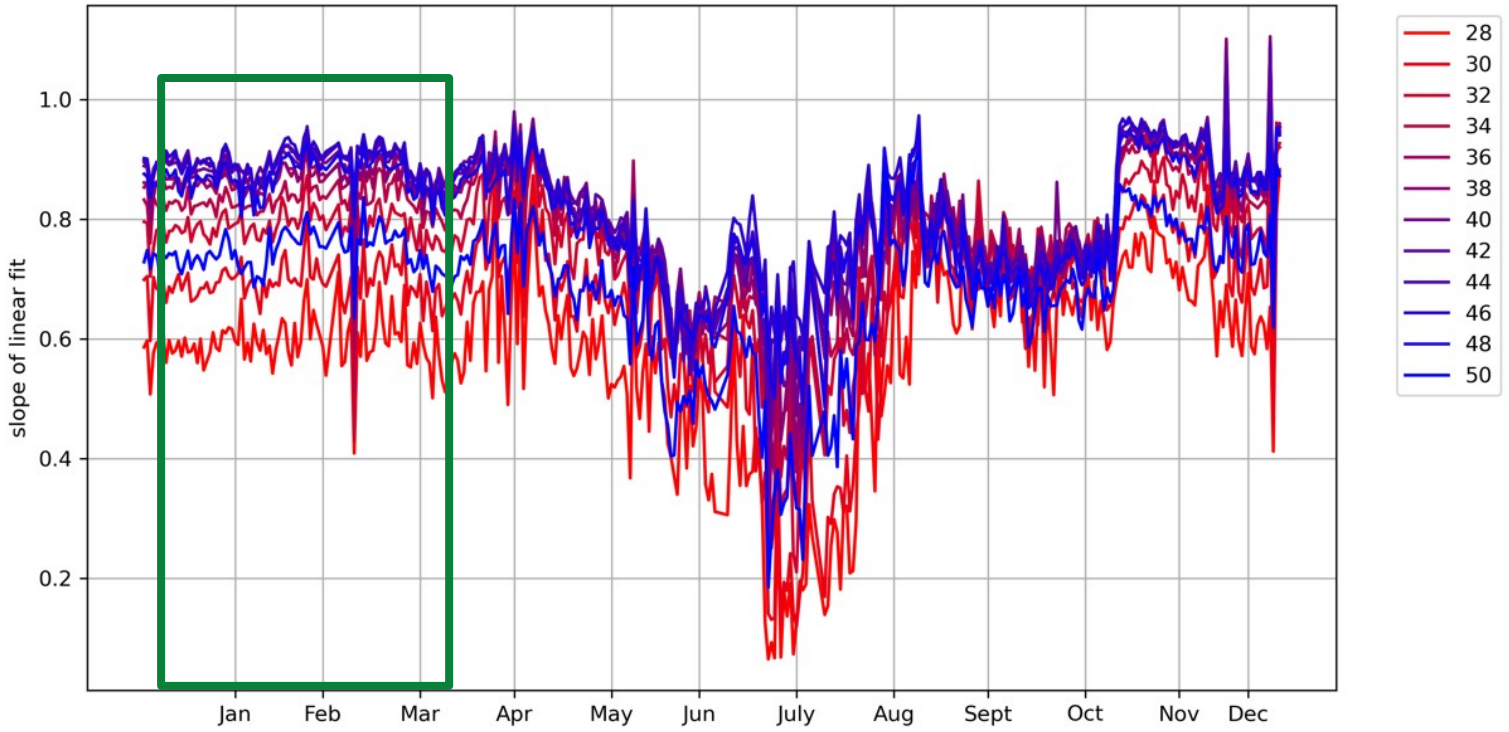
Probability distribution of sigma0 given ice is: $p(\sigma^\circ|ice) = p(MLE_{ice})$

$$MLE_{ice} = \sum_{i=1}^{N} \frac{(\sigma^\circ{}_i - \sigma^\circ{}_{ice,i})^2}{var[\sigma^\circ{}_{ice,i}]}$$

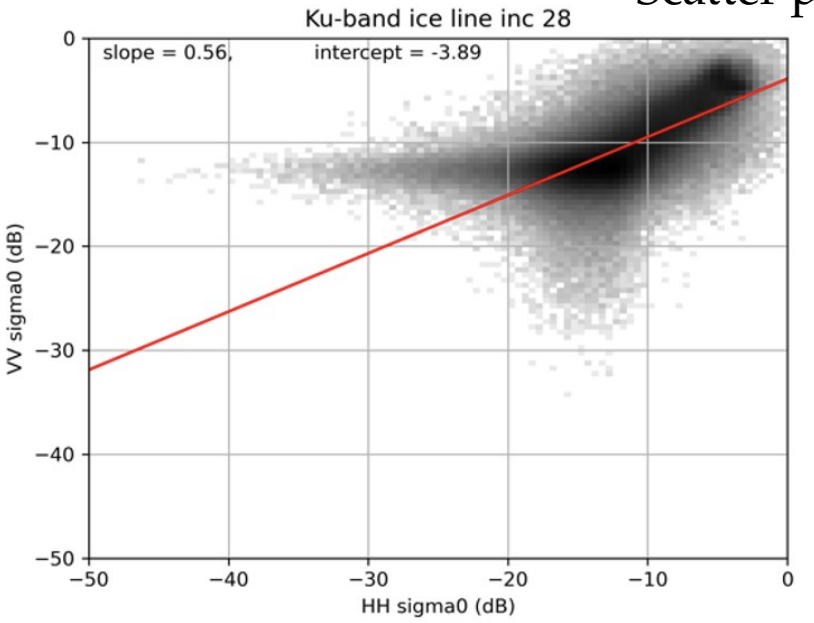
Ice model is azimuth invariance, it is a linear straight line (VV HH measurement space) and incidence angle dependent, which can be defined as following:

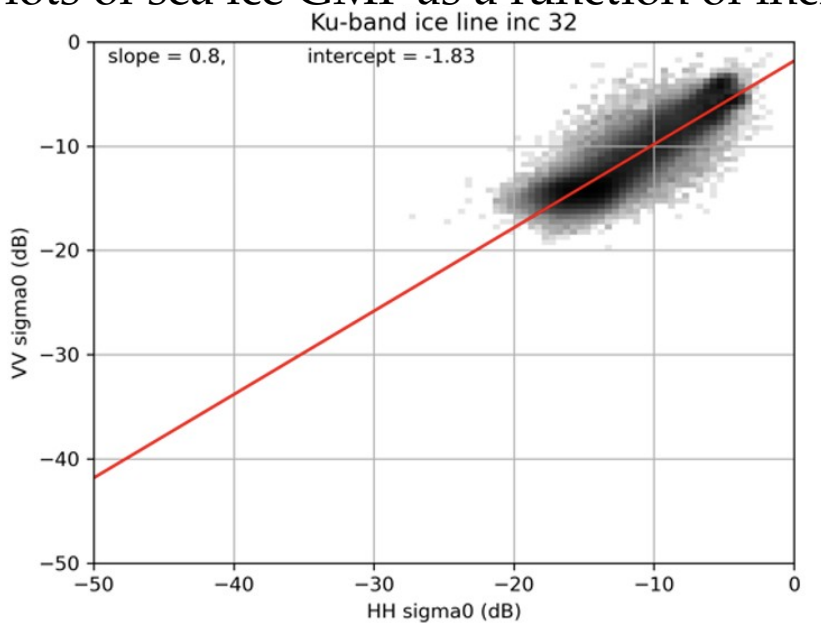
Sea ice GMF: $\sigma^\circ{}_{V,ice} = \sigma^\circ{}_{H,ice} \times slope + offset$

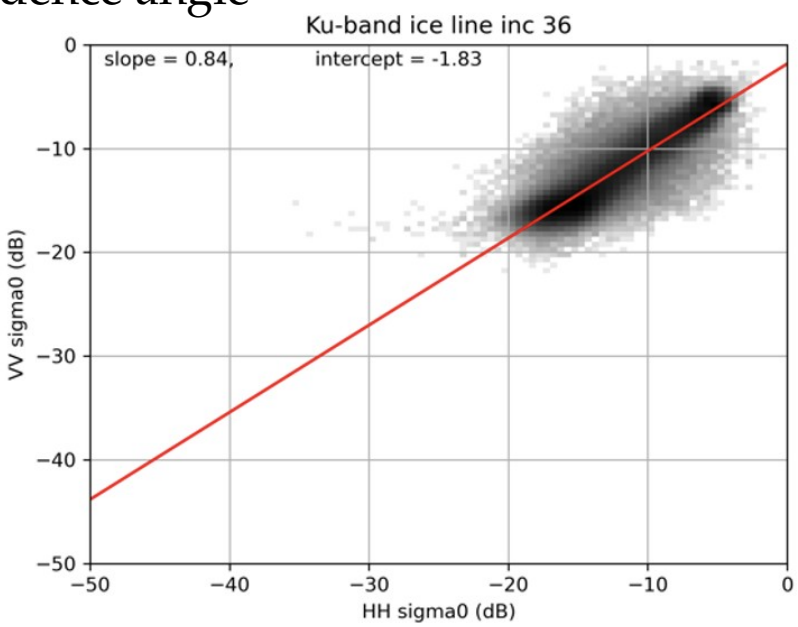
Arctic: daily linear ice model **slope** as a function of incidence angle

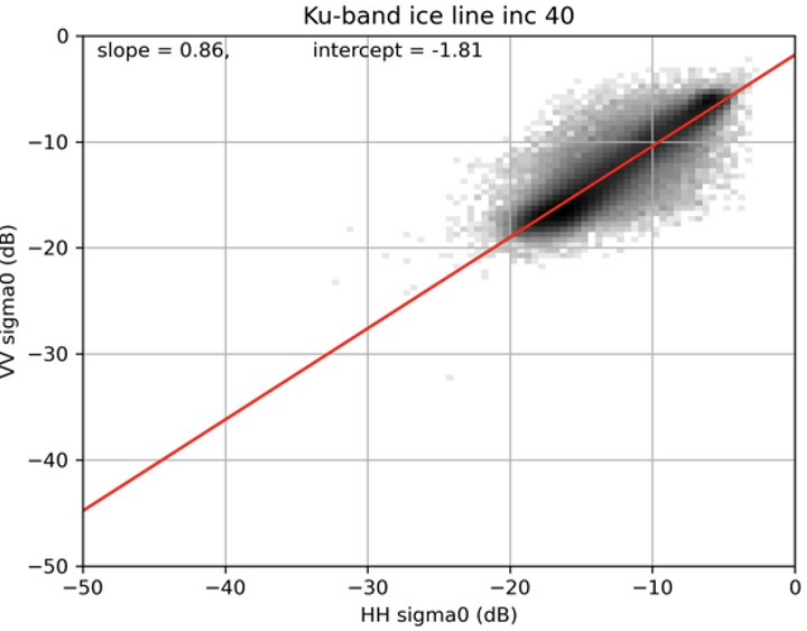


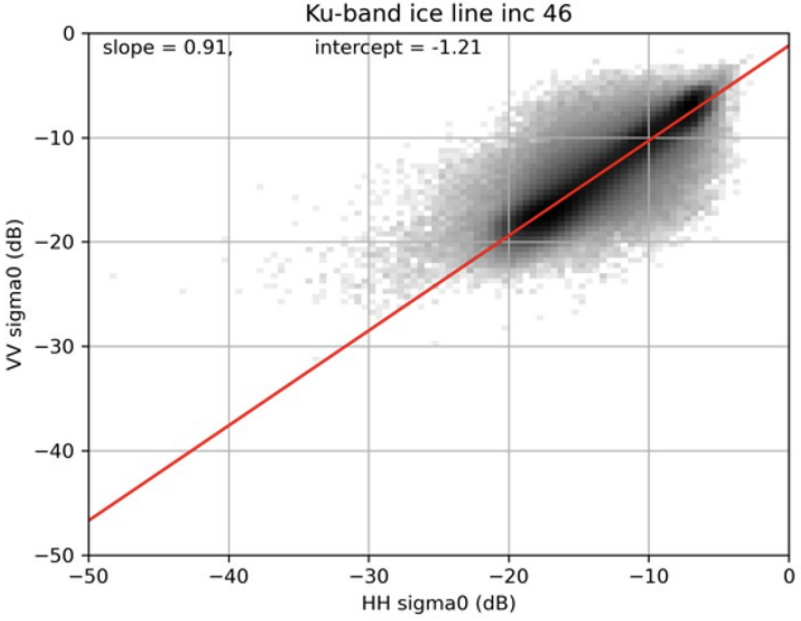
Scatter plots of sea ice GMF as a function of incidence angle

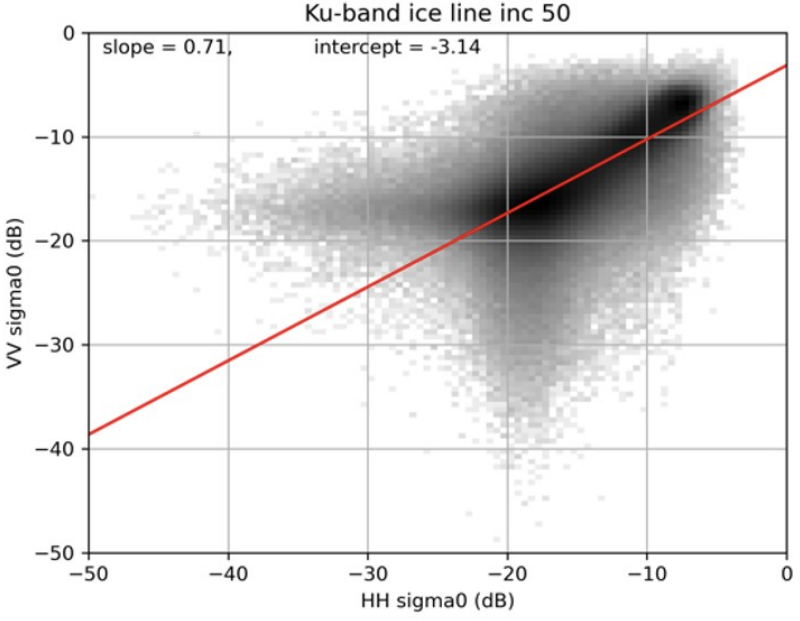


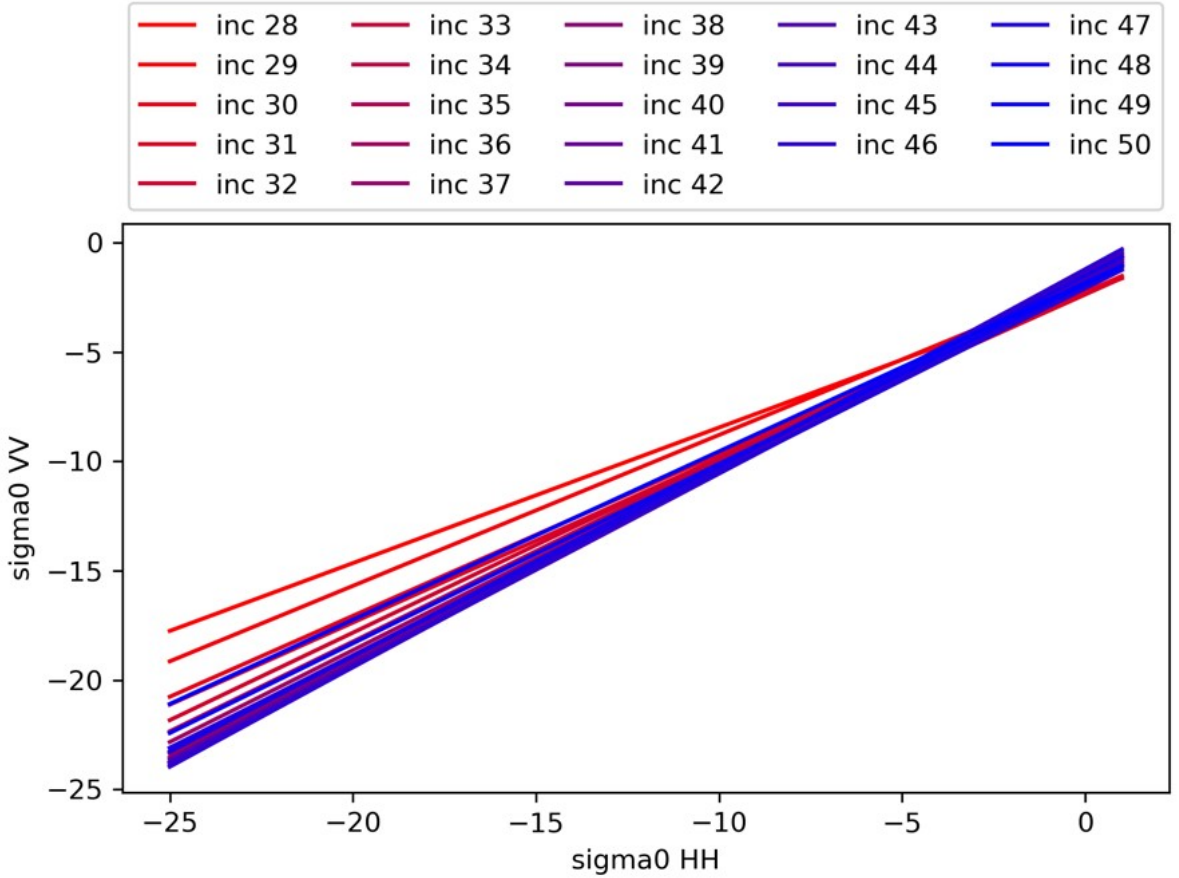




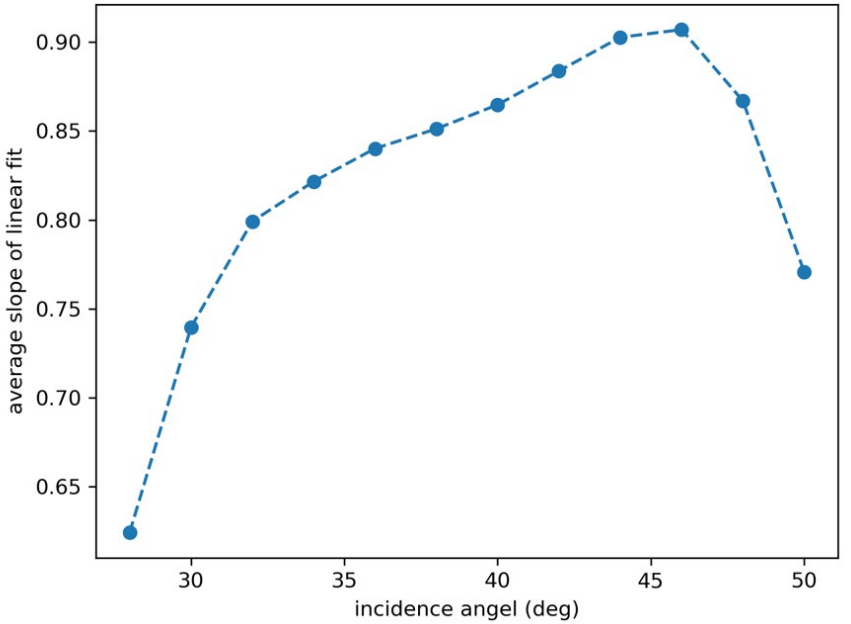




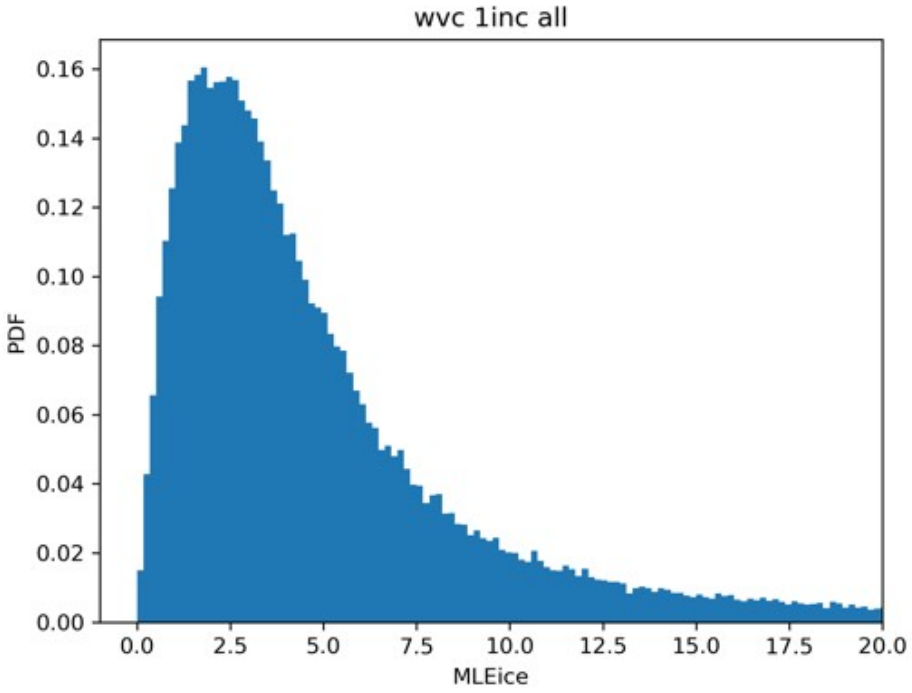


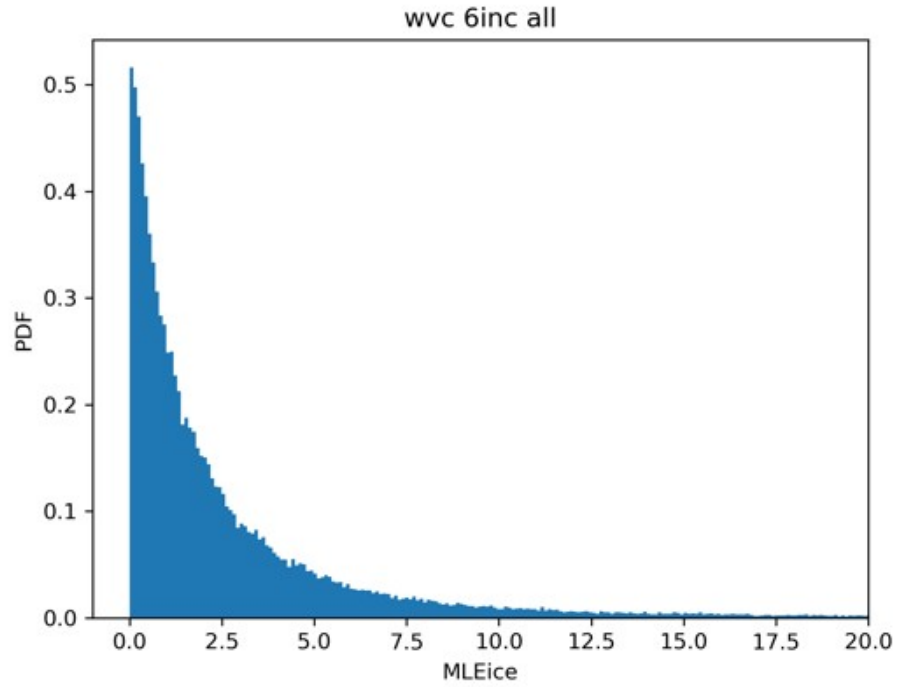


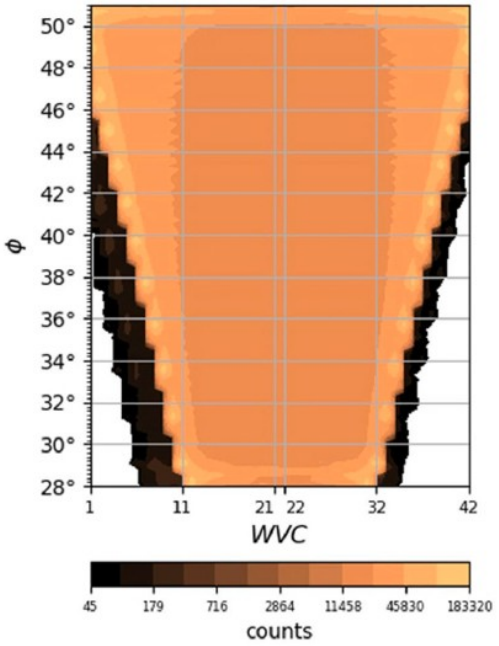
Here are the sea ice GMF as a function of incidence angle in one plot, which shows the GMF changing with the incidence angle.



$$MLE_{ice} = \sum_{i=1}^{N} \frac{(\sigma^\circ{}_i - \sigma^\circ{}_{ice,i})^2}{var[\sigma^\circ{}_{ice,i}]}$$



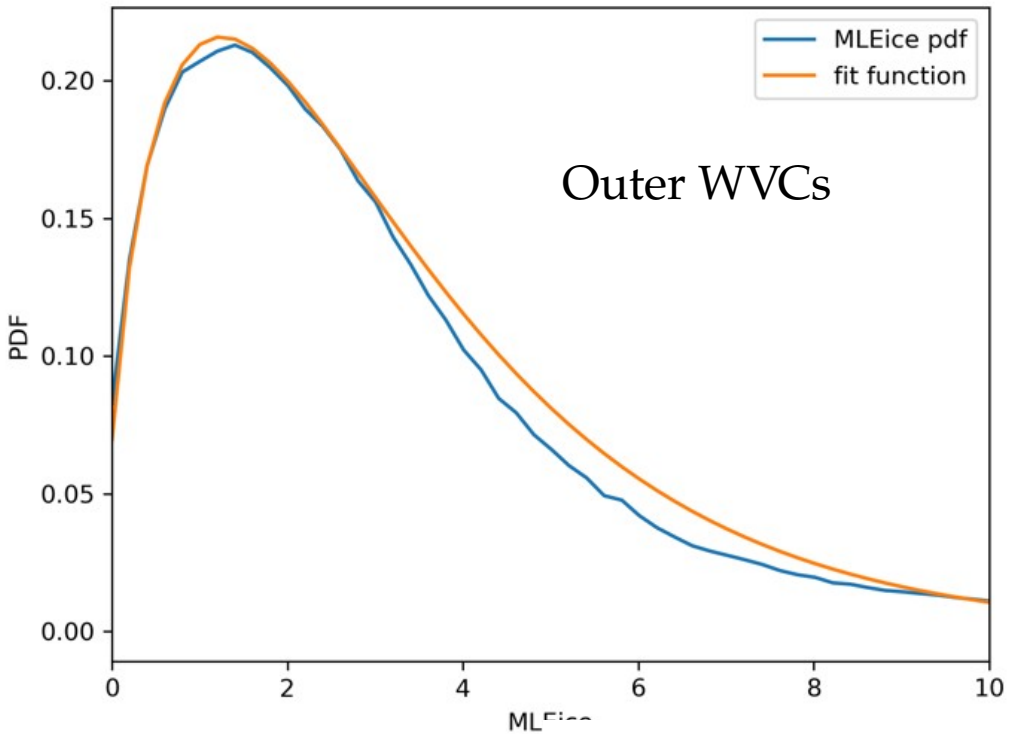


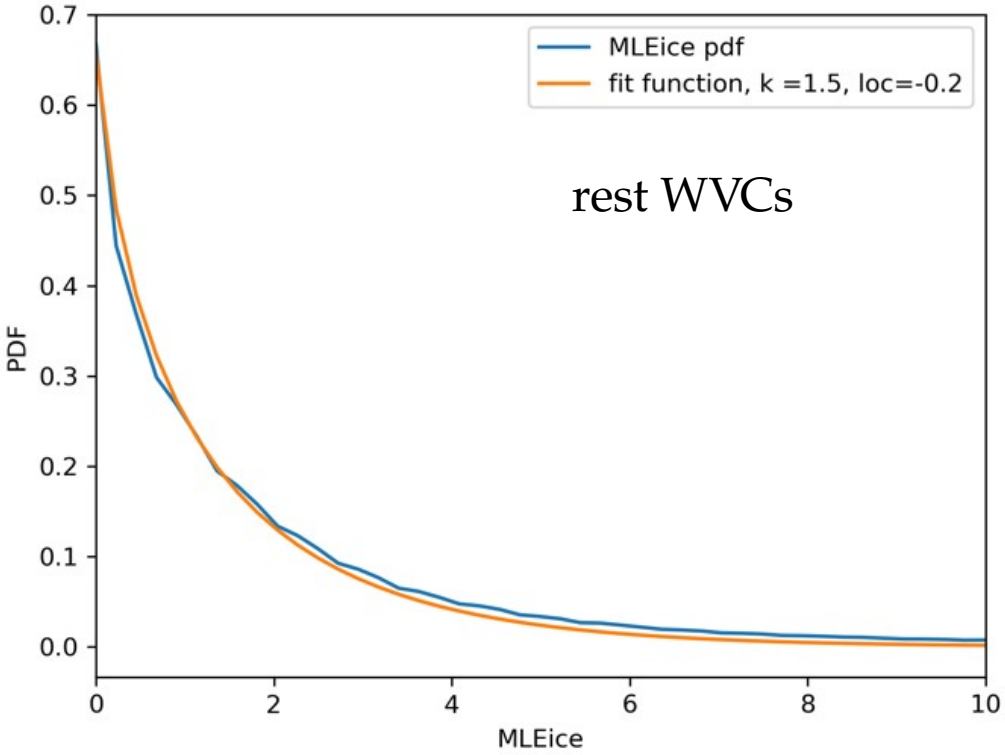


Outer WVCs

rest WVCs

However, the PDF of MLEice is different per WVC groups as shown above, which is caused by the distribution of incidence angle across the swath (plot on the right side), thus two sets of PDF fit are constructed (see next slide).





$$p(\sigma^{\circ}|ice) = \frac{x^{k/2-1}}{2^{\frac{k}{2}}\Gamma(k/2)} e^{-\frac{x}{2}}$$

$$x = MLE_{wind} - loc$$

Up to now, the Bayesian algorithm has been completed.

$$p(ice|\sigma^{\circ}) = \frac{p(\sigma^{\circ}|ice)\,p_0(ice)}{p(\sigma^{\circ}|ice)\,p_0(ice) + p(\sigma^{\circ}|wind)\,p_0(wind)}$$

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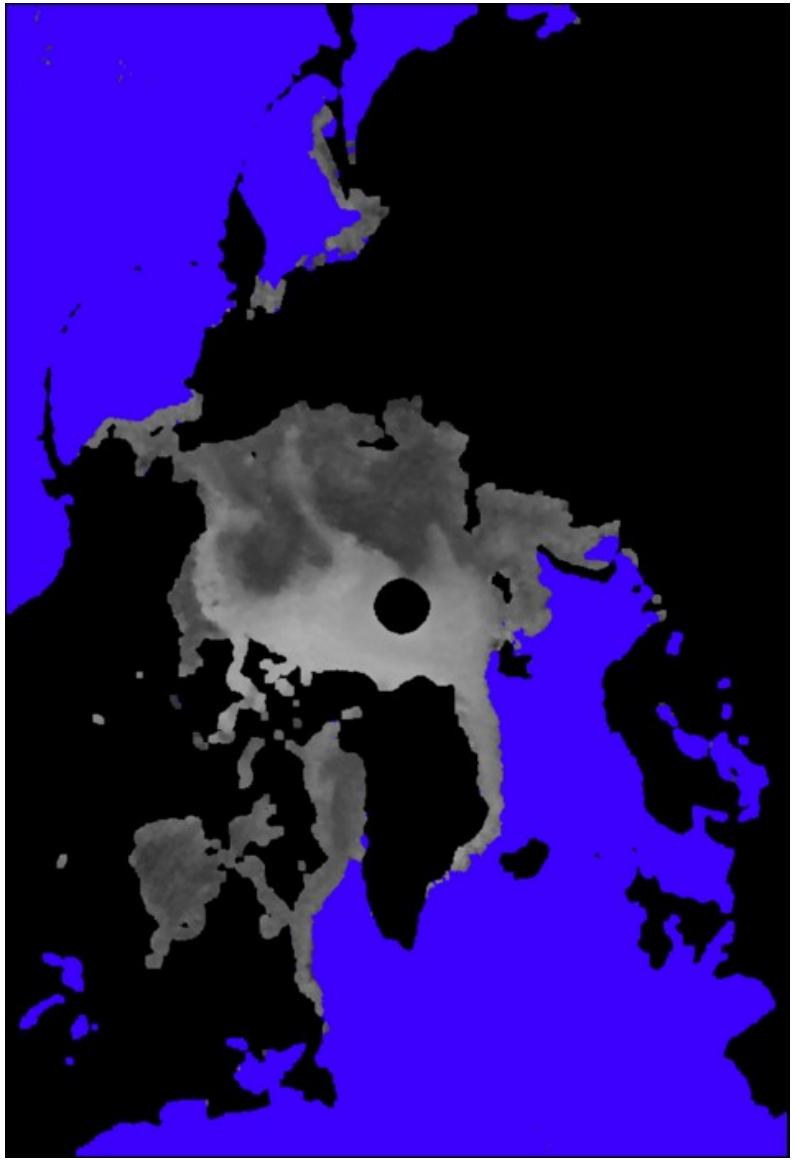
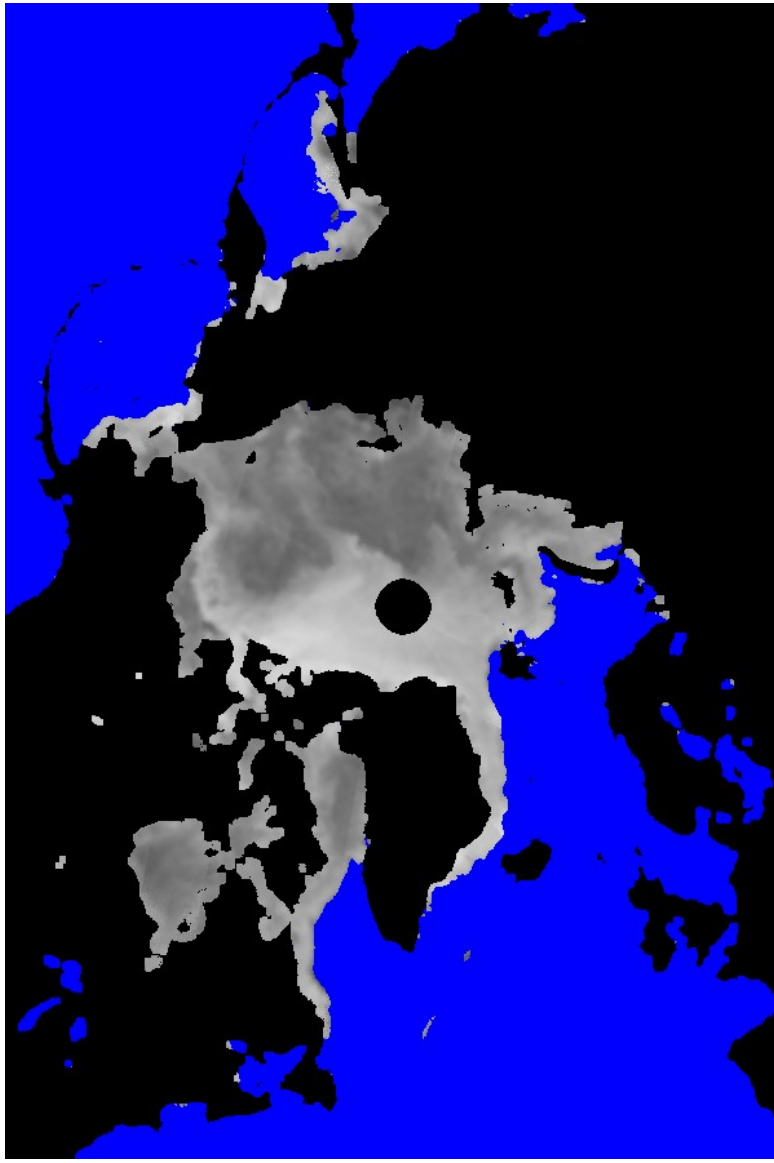
On 10th Jan 2019

CFOSAT

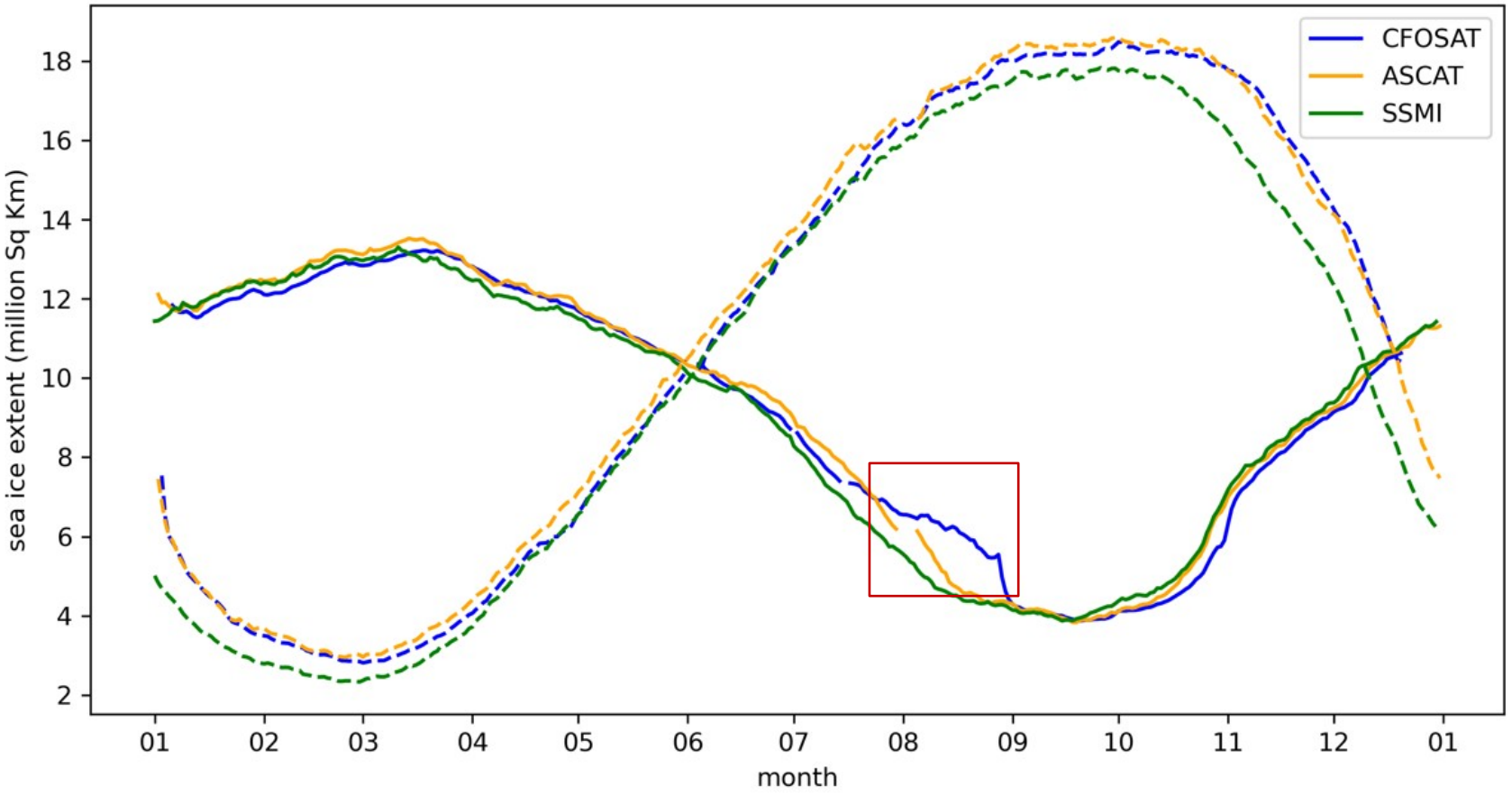
SMMI

ASCAT





Sea ice extend in 2019



The marked area was caused by instrument restart.

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Summary

- Bayesian sea ice detection algorithm is well adapted for CFOSAT.
- The result gives consistent sea ice result with passive microwave instrument and other scatterometer.
- CFOSAT can contribute the sea ice record together with other scatterometers with the same consistent method.
- Ice type classification is possible with this method.