Sea ice detection using Ku-band radar onboard GPM satellite

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Introduction

Microwave spaceborne measurements for sea ice cover monitoring:

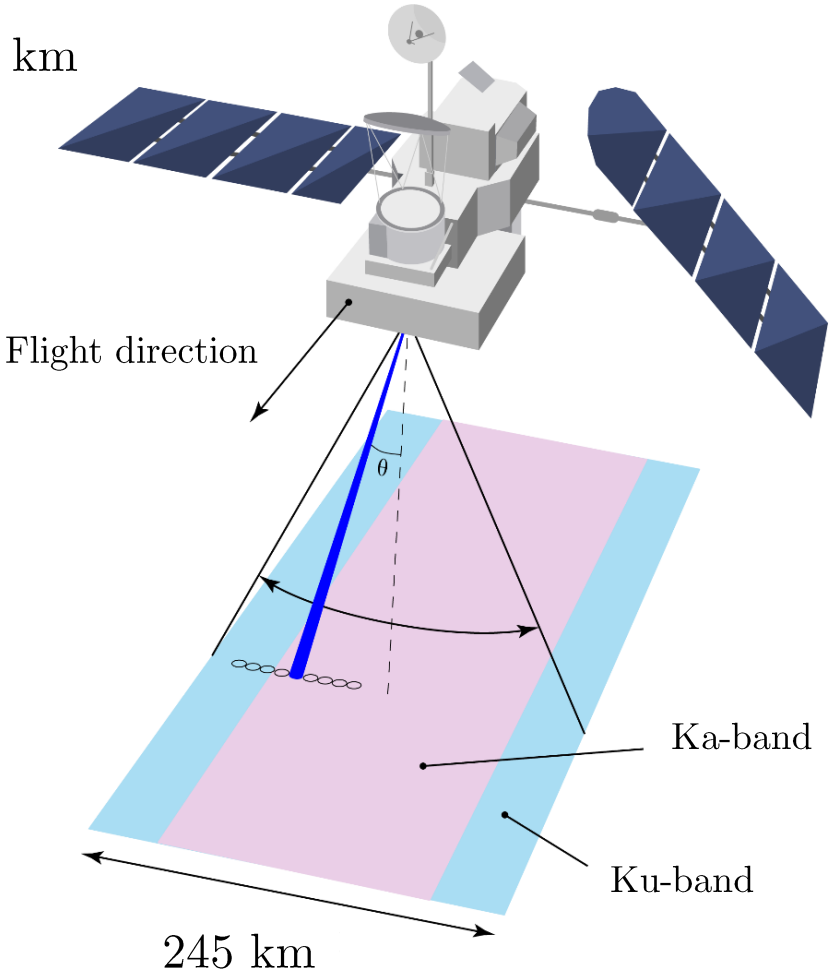
- radiometers (sea ice concentration)
- altimeters (ice thickness)
- high resolution SAR images

But manifestations of sea ice in microwave signal are not studied for incidence angles between 0 and 18 degrees.

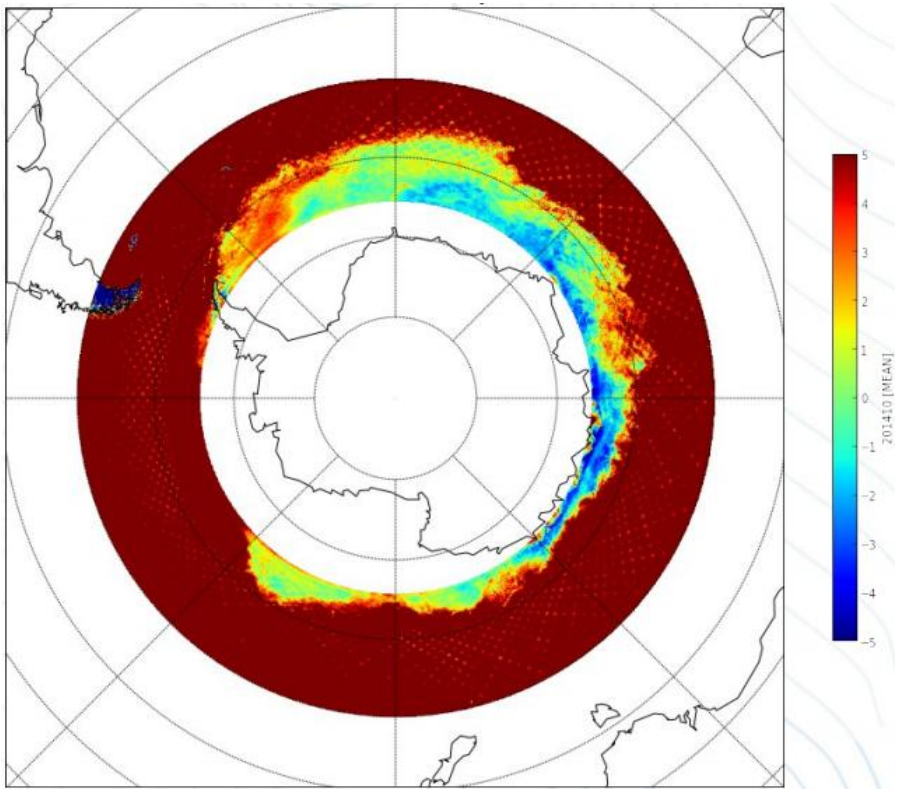
Instruments: SWIM and Dual Frequency Precipitation Radar (DPR) on GPM satellite

Global Precipitation Measurement satellite (GPM): Dual Frequency Precipitation Radar (DPR)

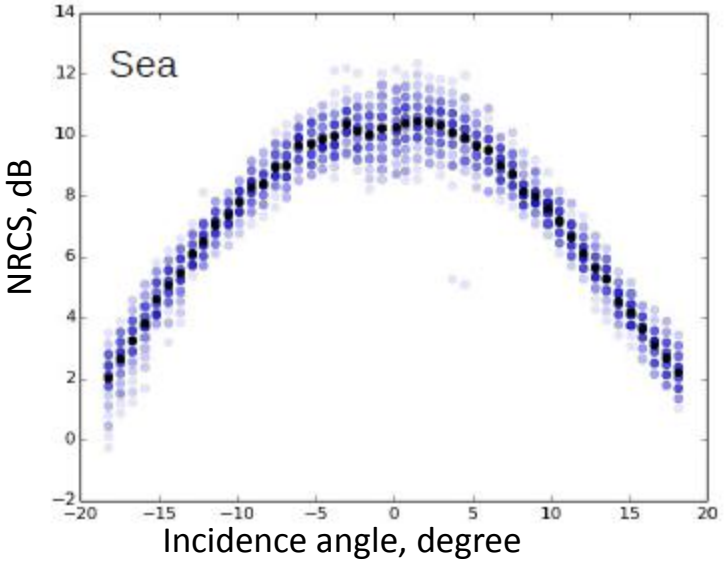
- Ku-band - 13.6 GHz, Ka-band – 35 GHz
- Ku-band radar scans perpendicularly to the flight direction [-18°,18°].
- The swath 245 for Ku-band
- Antenna footprint 5 km

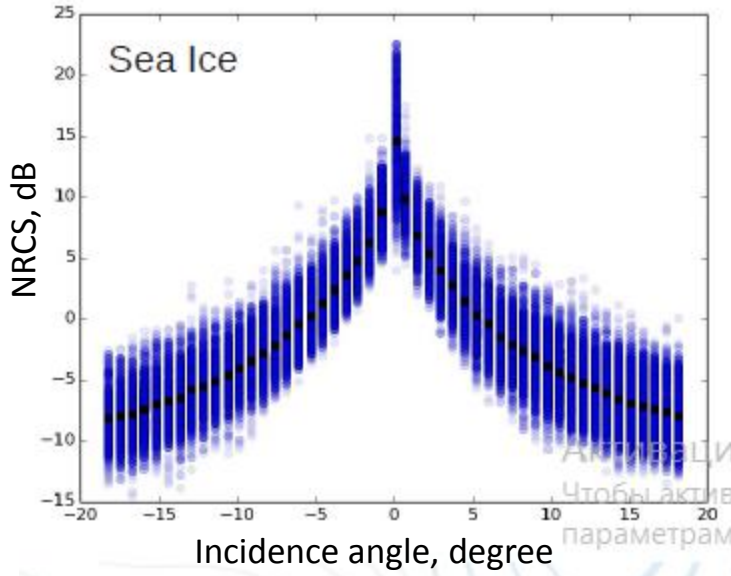


Introduction



Monthly map of averaged NRCS as obtained in Ku-Band for September 2014
DPR radar data

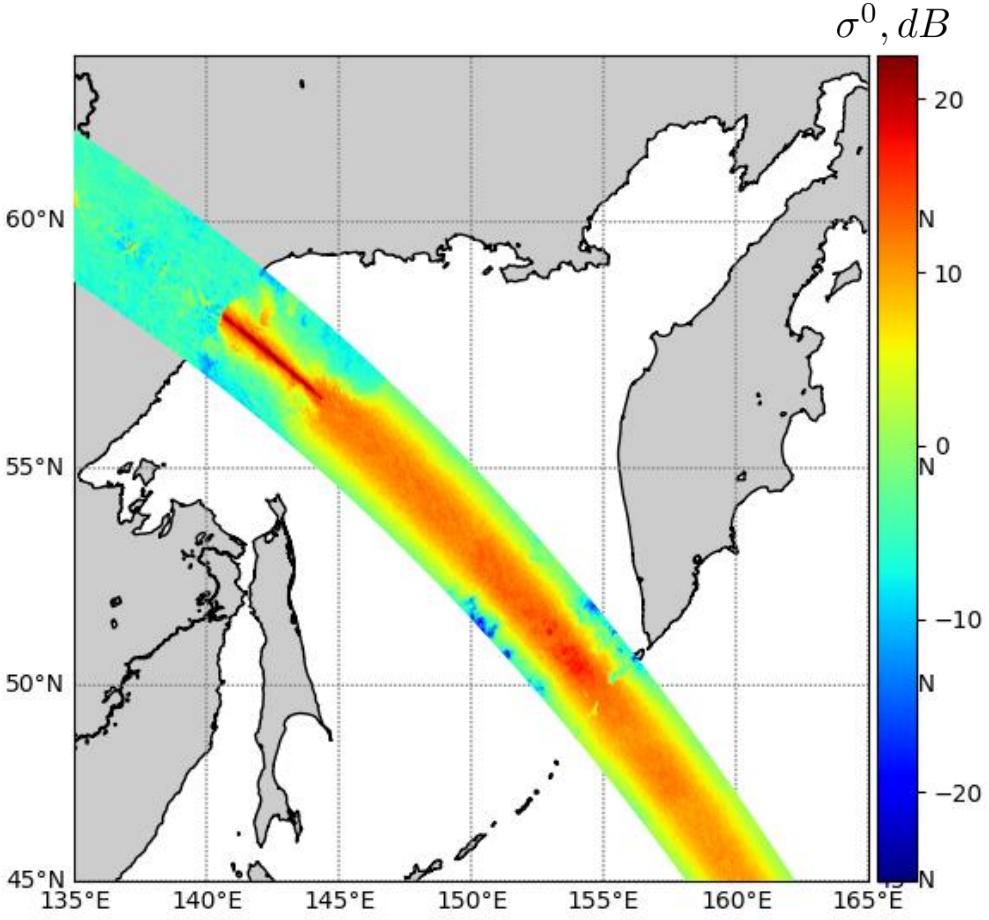




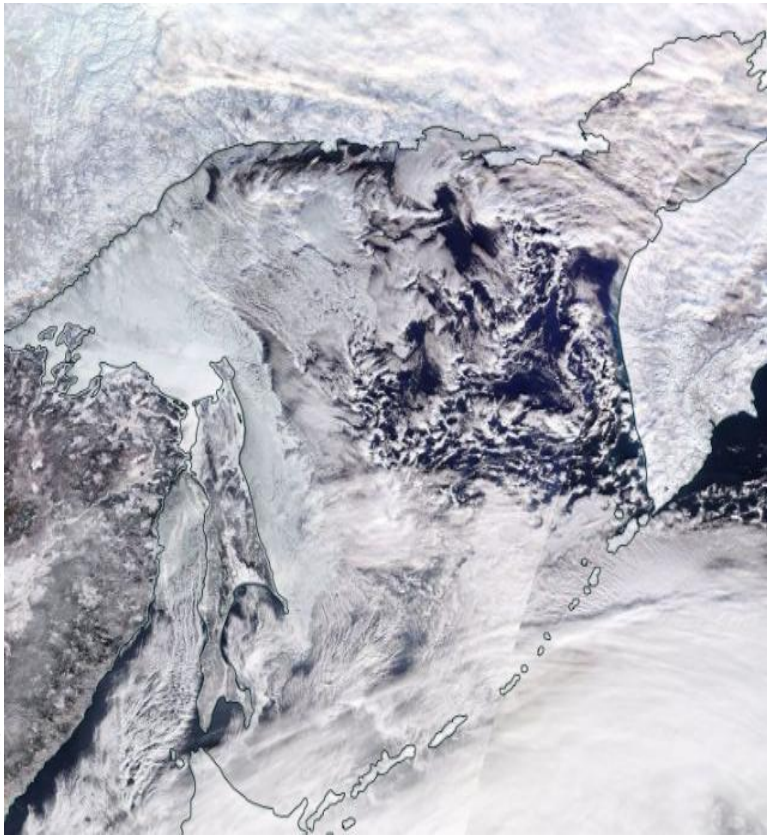
From the seminar at IFREMER
"Global Precipitation Mission
An opportunity for Ocean surface Remote sensing ?
Elements for discussion & Focus on Sea-Ice"

The area of interest is the Sea of Okhotsk

27.12.2016



MODIS image



Introduction

Our goal is to suggest the simple formal method for express-estimate of the ice cover position using DPR data.

a) The dependence of NRCS on incidence angle along scanning direction
b) Analysis of the data using edge detection method along the flight direction

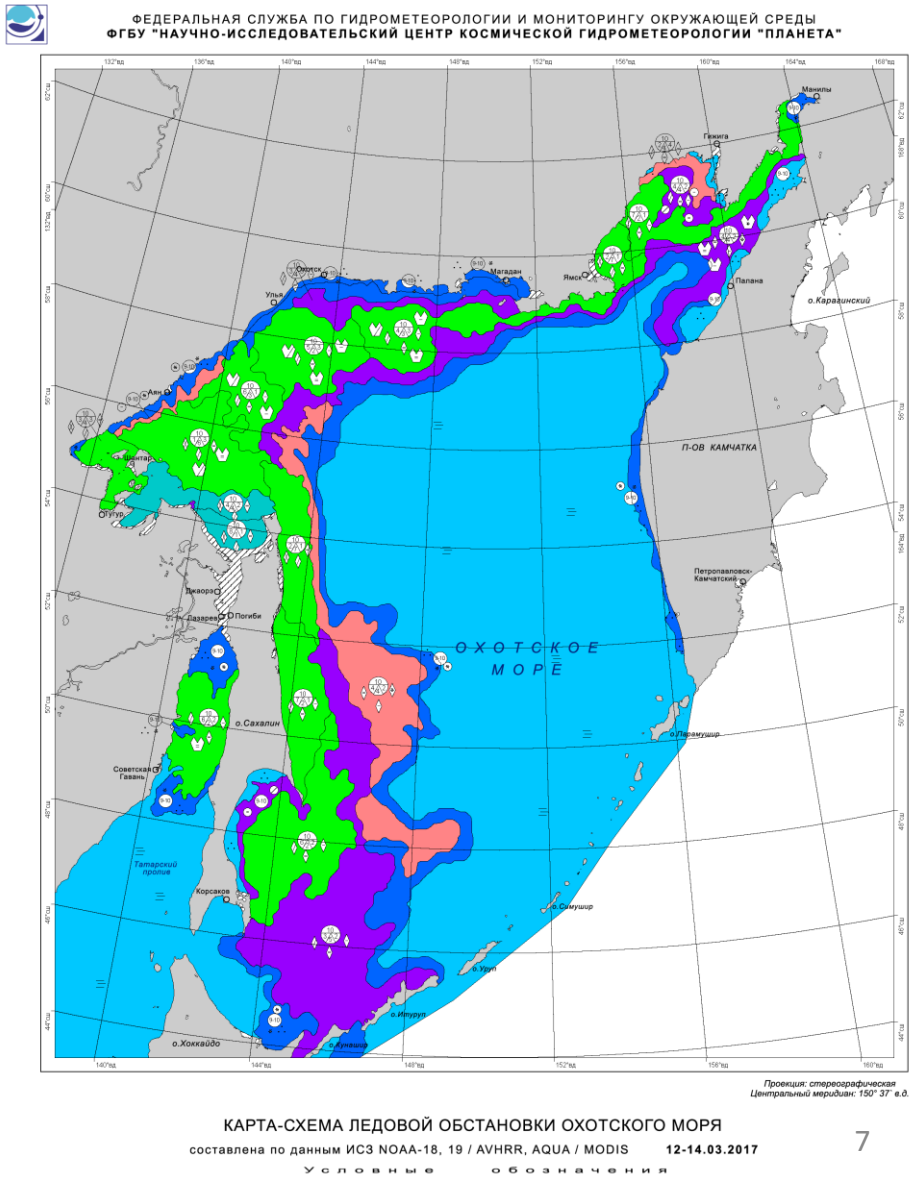
Ice map

State Research Center for Space Hydrometeorology ”Planeta”

12.03.2017 – 14.03.2017

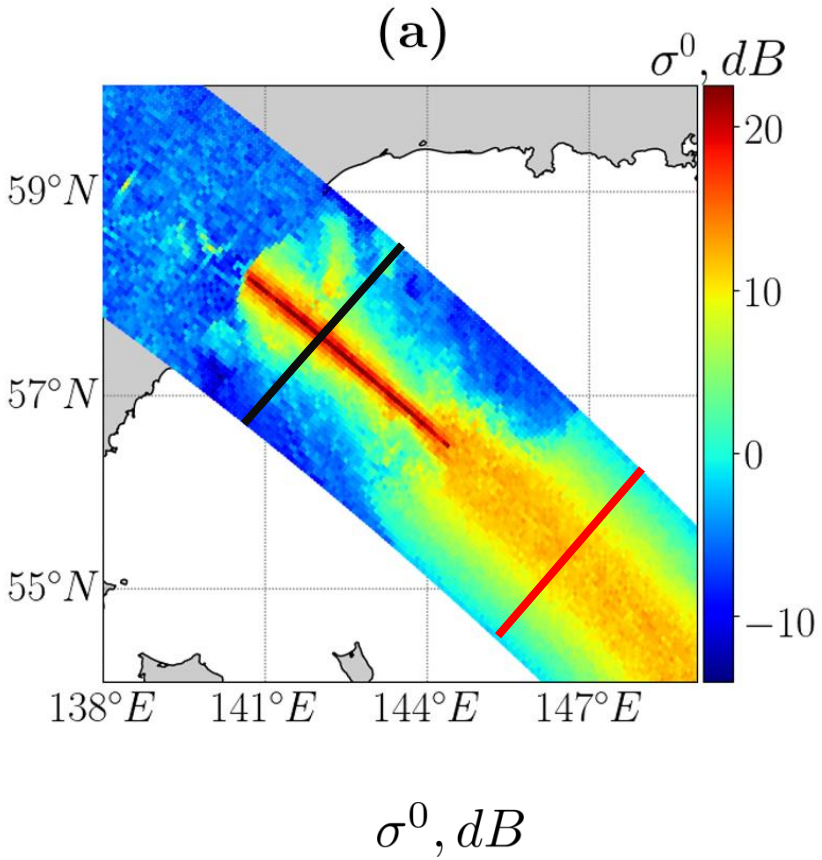
Age and type of ice :

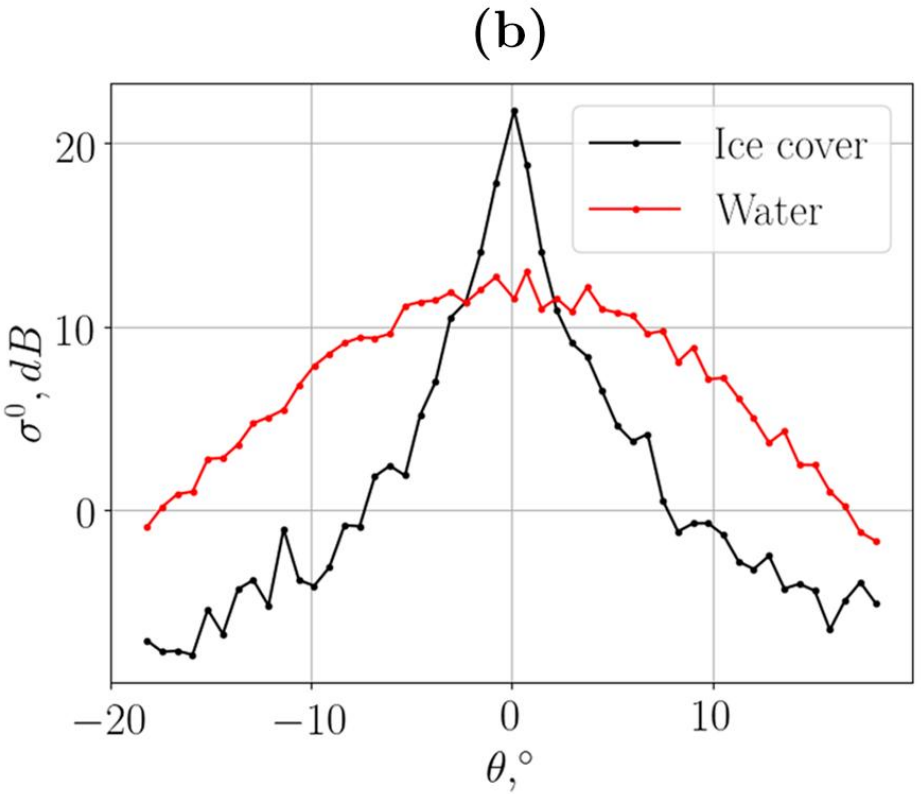
- thin ice (30-70 cm)
- gray-white ice (15-30 cm)
- gray ice (10-15 cm)
- nilas (< 10 cm)
- open water



The sections of the swath in the region of ice and water

27.12.2016





Backscatter at low incidence angles

$$\sigma^0 = A\cos^{-4}(\theta)\cdot P(\tan\theta)$$

NRCS is proportional to the slope probability density function (PDF) along the direction of scanning

For water surface

$$P(\tan\theta) = \frac{1}{2\pi\sigma_x\sigma_y}\cdot\exp(-\frac{\tan^2\theta}{2\sigma_x^2})$$

where $\sigma_{x,y}^2$ are mean square slopes along and across scanning direction respectively

The central statistical moments

$$\mu_k = \int_{-\infty}^{\infty}(z-\overline{z})^k P(z)dz \qquad \overline{z} = \int_{-\infty}^{\infty} zP(z)dz$$

Kurtosis coefficient

$$\gamma_2 = \frac{\mu_4}{\mu_2^2} - 3$$

Kurtosis coefficient

The cumulative distribution function

$$F(+\infty) = \int_{-\infty}^{\infty} P(\tan\theta)d(\tan\theta) = 1$$

$$\int_{\tan(-15^\circ)}^{\tan(+15^\circ)} P(\tan\theta)d(\tan\theta) \approx \sum_{i=1}^{N} P(\tan\theta_i)\Delta(\tan\theta_i) = 1$$

If we consider the part of the scan -15°<ϑ<15°, *N=41*

$$\sigma^0 = A\cos^{-4}(\theta)\cdot P(\tan\theta)$$

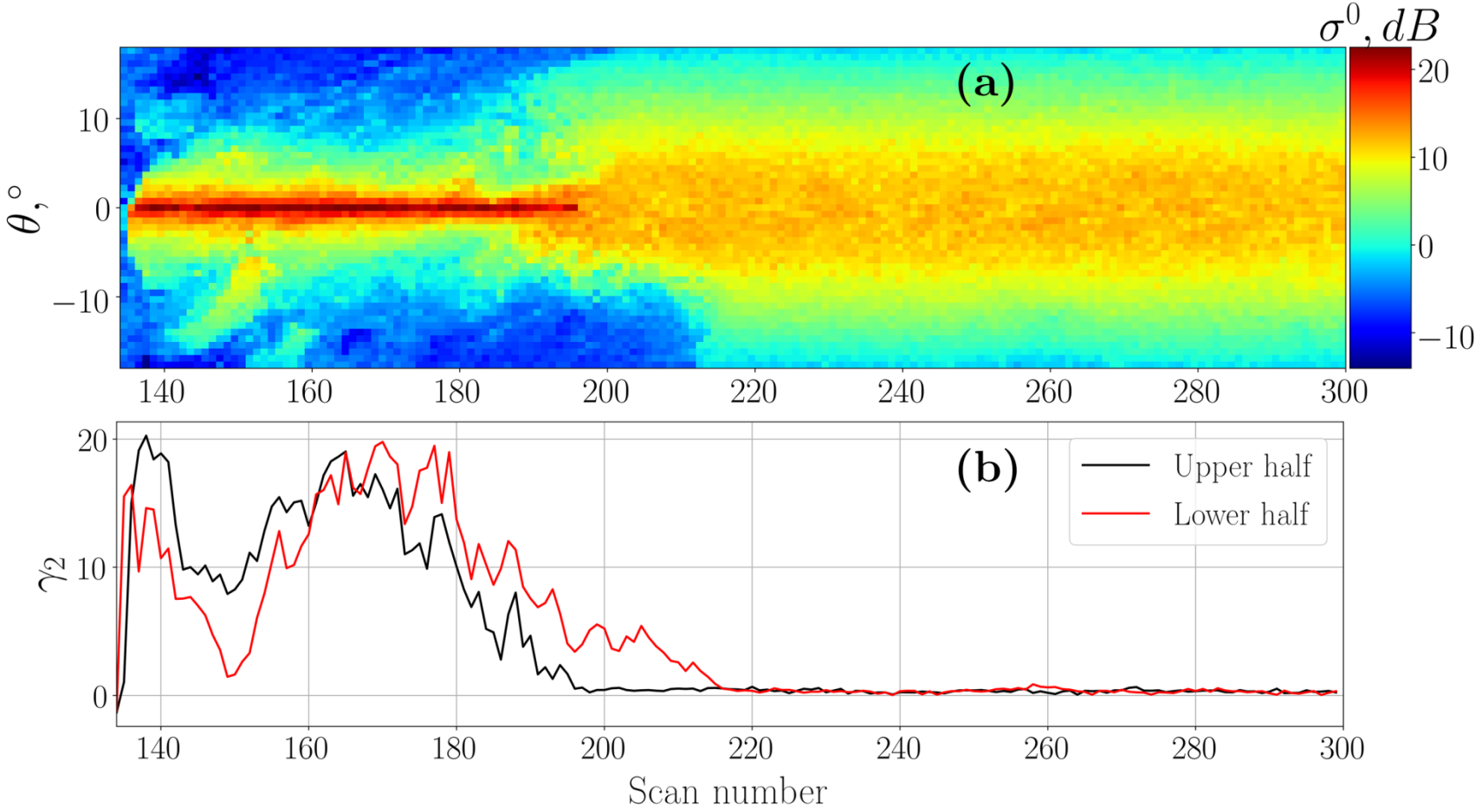
$$P(\tan\theta_i) = \frac{\sigma_i^0 \cos^4(\theta_i)}{A}$$

$$A = \sum_{i=1}^{N} \sigma_i^0 \cos^4(\theta_i)\Delta(\tan\theta_i)$$

$$\mu_k = \sum_{i=1}^{N} (\tan\theta_i - \overline{\tan\theta_i})^k P(\tan\theta_i)\Delta(\tan\theta_i)$$

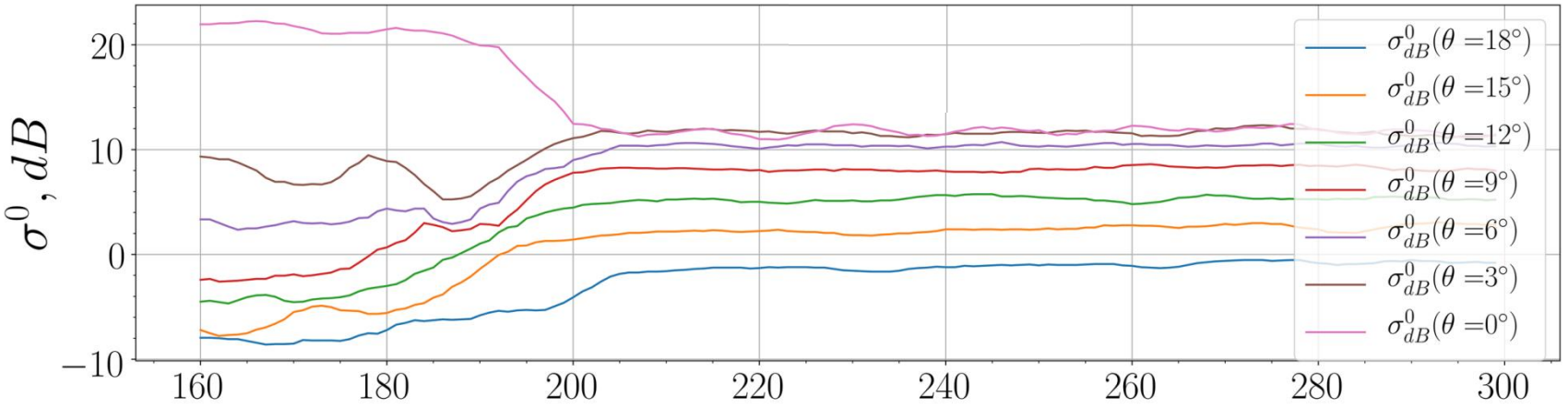
$$\gamma_2 = \frac{\mu_4}{\mu_2^2} - 3$$

Kurtosis coefficient

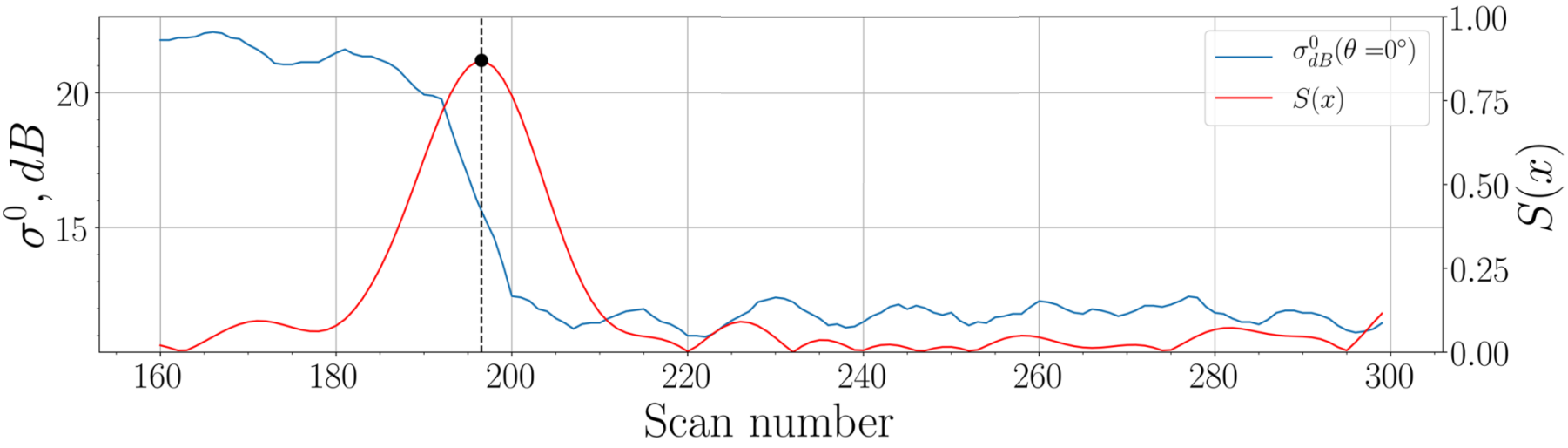


Each half-scan is complemented symmetrically so that $\sigma^0(\theta) = \sigma^0(-\theta)$

The sections along the swath



The sections along the swath



$$S(x_0) = \left| \int_{-W}^{+W} \sigma^0(x_0 - x) f(x) dx \right| \left| \int_{-W}^{+W} \sigma^{0\prime}(x_0 - x) f'(x) dx \right|$$

J. Canny, "A computational approach to edge detection",1986

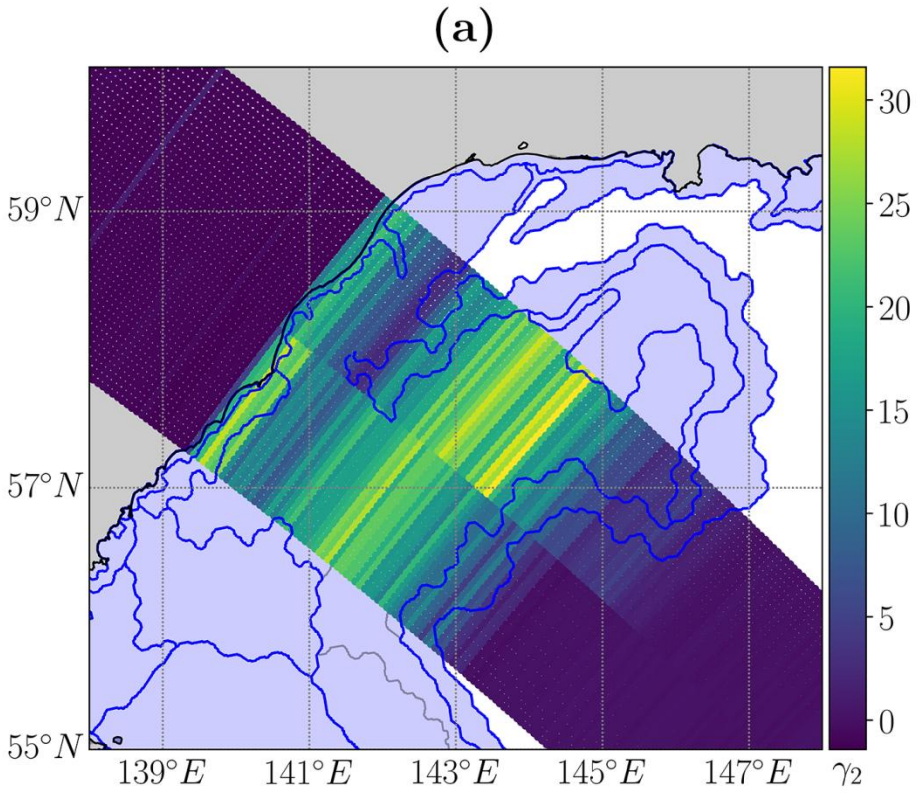
$$f(x) = -x \cdot \exp(-\frac{x^2}{2\sigma_g^2})$$

double-thresholding

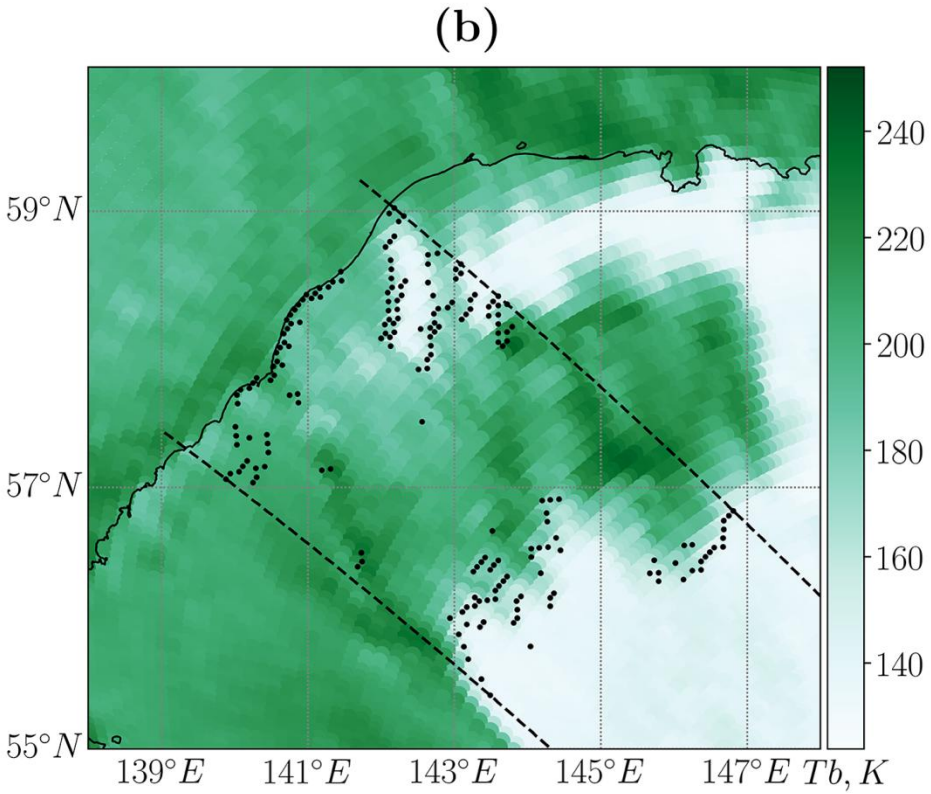
$$S_L = 0.15(S_{max} - S_{min})$$
$$S_H = 0.7(S_{max} - S_{min})$$

Local maxima with $S \geq S_H$ are strong edges; with $S_L \leq S < S_H$ are weak edges

Results



The values of kurtosis for DRP complemented half-scans over the sea ice map (3 days)



Brightness temperature measure by GMI radiometer 36.6 GHz channel, horizontal polarization (color) and the NRCS steps from the DPR data (dots)

Conclusion

- The method for automatic ice detection from DPR data is developed.
- On the first step the kurtosis of the slope PDF is estimated from NRCS for each scan, which can help to obtain the express estimate of ice position from the DPR data.
- On the second step the lengthwise slices of the swath for each incidence angle are studied to obtain the step in NRCS, corresponding to the water-ice boundary.

Further plans

- To obtain sea ice concentration from GMI radiometer data onboard GPM
- To use this data to adjust the parameters in the algorithm
- To study the dependence of NRCS at different incidence angles on sea ice concentration

Thank you for your attention!

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