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Modelling Microwave Scattering from Rough Sea Ice Surfaces

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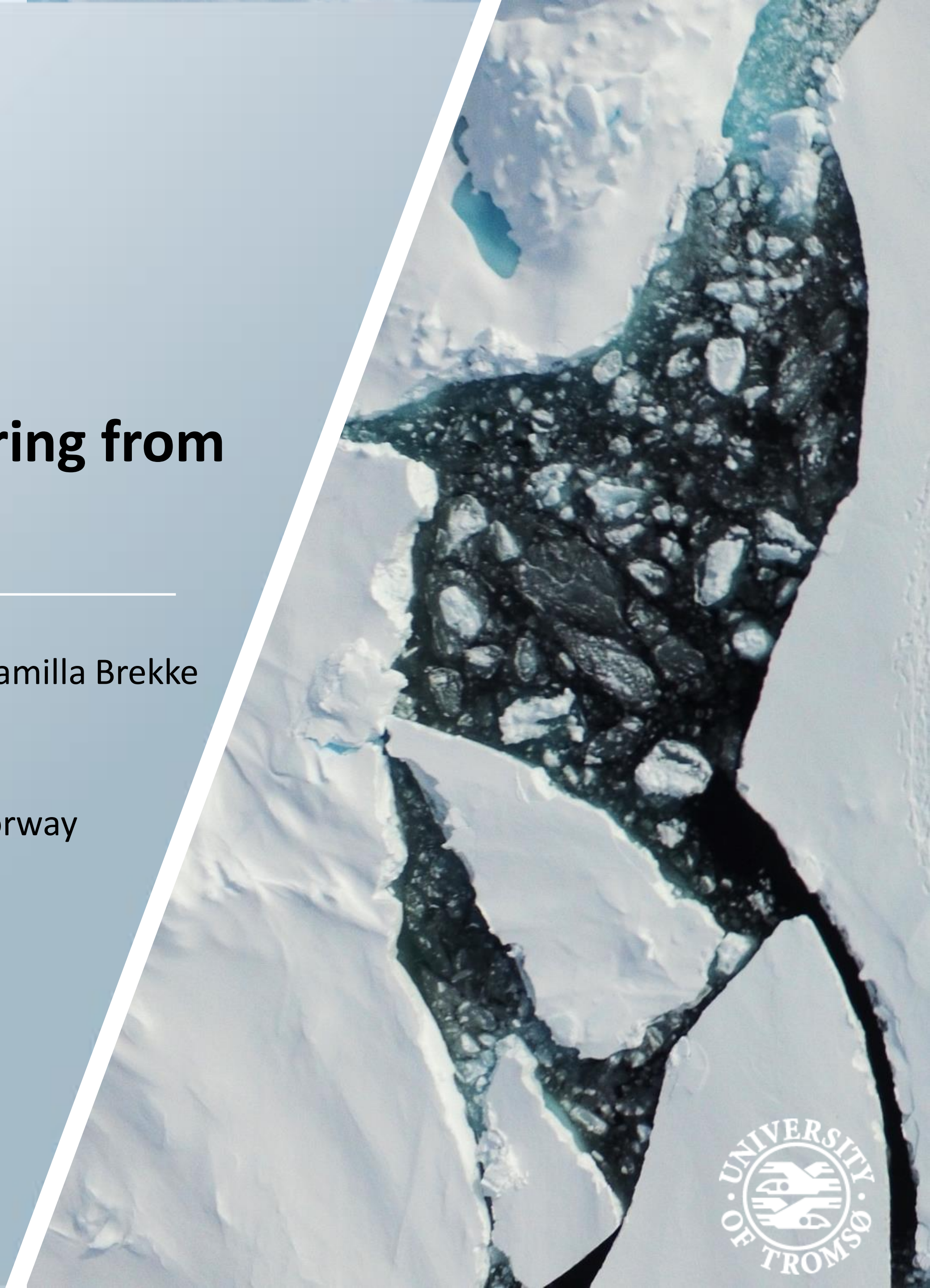


Outline

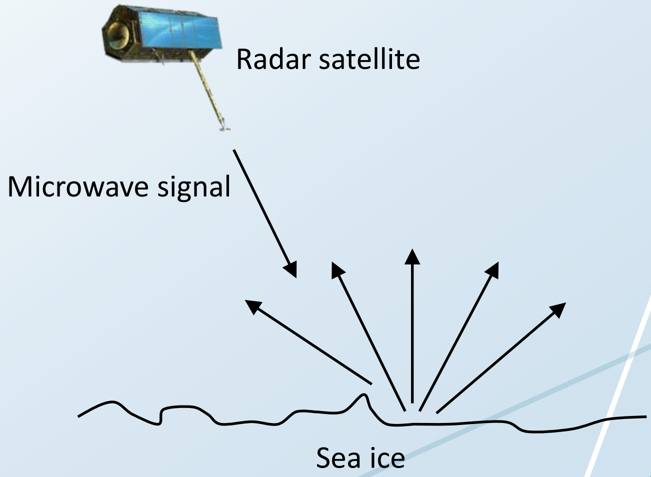
- Background and Motivation
- Sea Ice Simulation
- Nonperiodic Model
- Periodic Model
- Simulation Results
- Conclusions

Background and Motivation

- Sea ice
  - It is a critical component of the earth and an indicator for global climatic changes. Reliable and constant monitoring of sea ice is important.

- Radar Remote Sensing
  - The radar emits a microwave that interacts with the sea ice and receives the scattered microwave that carries the information of the sea ice.
  - Independence of light and cloud

- Electromagnetic Scattering Model
  - Build the relation between the received radar signal and sea ice properties.

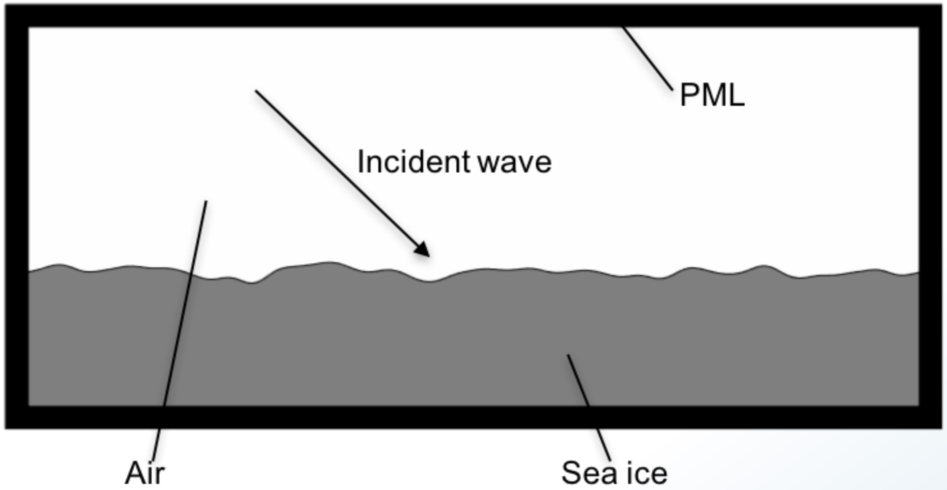


Sea Ice Simulation

- Geometry -- random rough surface
  - A Gaussian distributed rough surface. It involves two parameters: the root mean square (rms) height and correlation length.
  - Generated in MATLAB® and imported into COMSOL

- Permittivity
  - the Polder-van Santen-de Loor mixture model

Nonperiodic model



Geometry of the model

- Air domain
  - RF module -- Electromagnetic Waves, Frequency Domain physics interface
  - Scattered field formulation
- Sea ice domain
  - RF module -- Electromagnetic Waves, Frequency Domain physics interface
  - Total field formulation
- Air/Sea ice interface
  - Add continuity boundary condition

Tapered incident wave

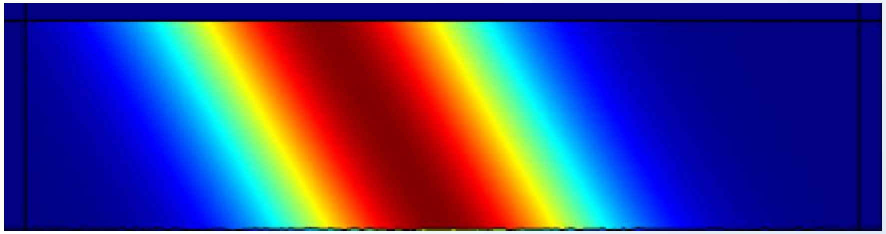
- TE

$$\vec{E}_{inc} = E_b \vec{z}$$

- TM

$$\vec{E}_{inc} = E_b \cos\theta_i \vec{x} + E_b \sin\theta_i \vec{y}.$$

$$E_b = \exp\left\{ -jk_0(x sin\theta_i - y cos\theta_i) \left[1 + \frac{\left(\frac{2(x+y tan\theta_i)^2}{g^2} - 1 \right)}{(k_0 g cos\theta_i)^2} \right] - \frac{(x+y tan\theta_i)^2}{g^2} \right\}.$$



An example of tapered incident wave

Calculation of Radar Cross Section

- Near-to-Far-Field transformation based on the Stratton-Chu formulation

- Monte Carlo method
  - A number of different random rough surfaces with the same roughness parameters are generated. Take the ensemble average of scattered field for every surface
  - Achieved by using the LiveLink™ for MATLAB®. Parallel computing can be used to accelerate the simulation.

- Radar cross section

$$\sigma(\theta_s) = \lim_{r\to\infty} \frac{2\pi r\left|E_{sf}\right|^2}{g\cos\theta_i\sqrt{\frac{\pi}{2}}\left[1-\frac{1+2\tan^2\theta_i}{2k_0^2 g^2 \sin^2\theta_i}\right]}$$

$$\sigma_{db}(\theta_s) = 10\log_{10}\sigma(\theta_s)$$

Periodic model

- Electromagnetic Waves, Frequency Domain physics interface

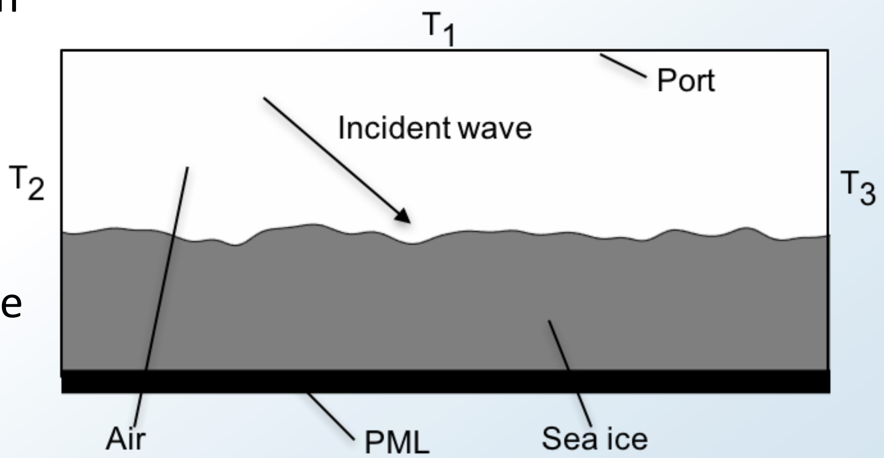
- Floquet periodic boundary conditions on lateral sides

- Ports on top boundary
  - One port —– excite incident wave
  - Several diffraction order ports —– receive scattered waves

$$-\frac{(1+sin\theta_i)d}{\lambda} \leq m \leq \frac{(1-sin\theta_i)d}{\lambda}$$

- Radar cross section

$$\sigma(\theta_s) = dk_0|S_{n1}|^2cos\theta_s$$

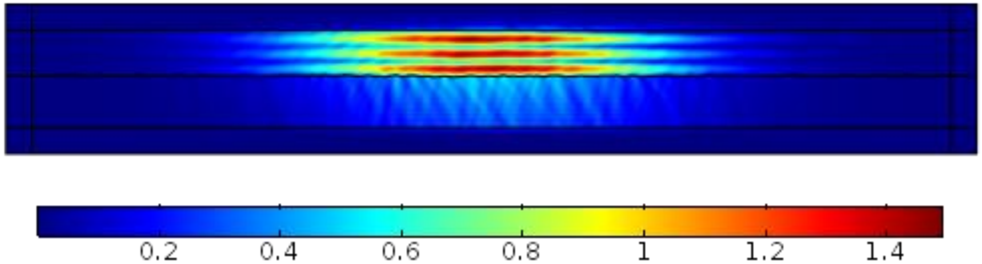


Geometry of the periodic model

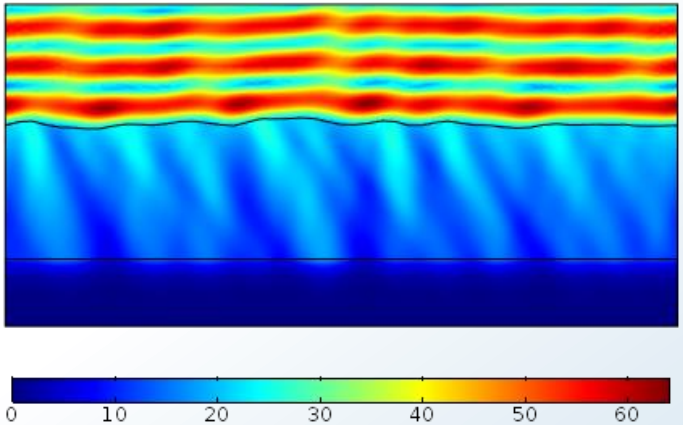
Simulation results

Frequency of incident wave	5.4GHz
Incident angle	30°
Rms height of sea ice surface	0.002m
Correlation length of sea ice surface	0.02m
Permittivity of sea ice	5.5-0.2i
Surface length for nonperiodic model	36λ
Surface length for periodic model	10λ
Number of surfaces	150

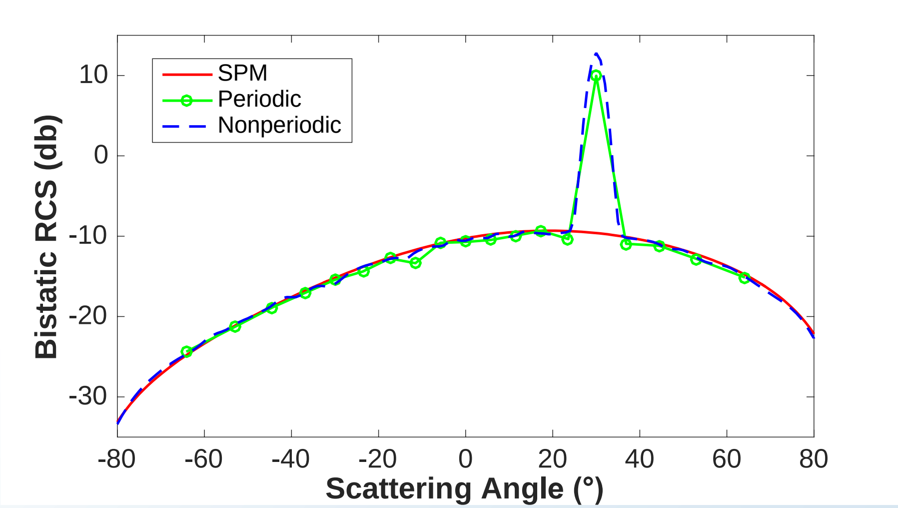
Simulation results



Magnitude of the electric field in the nonperiodic model

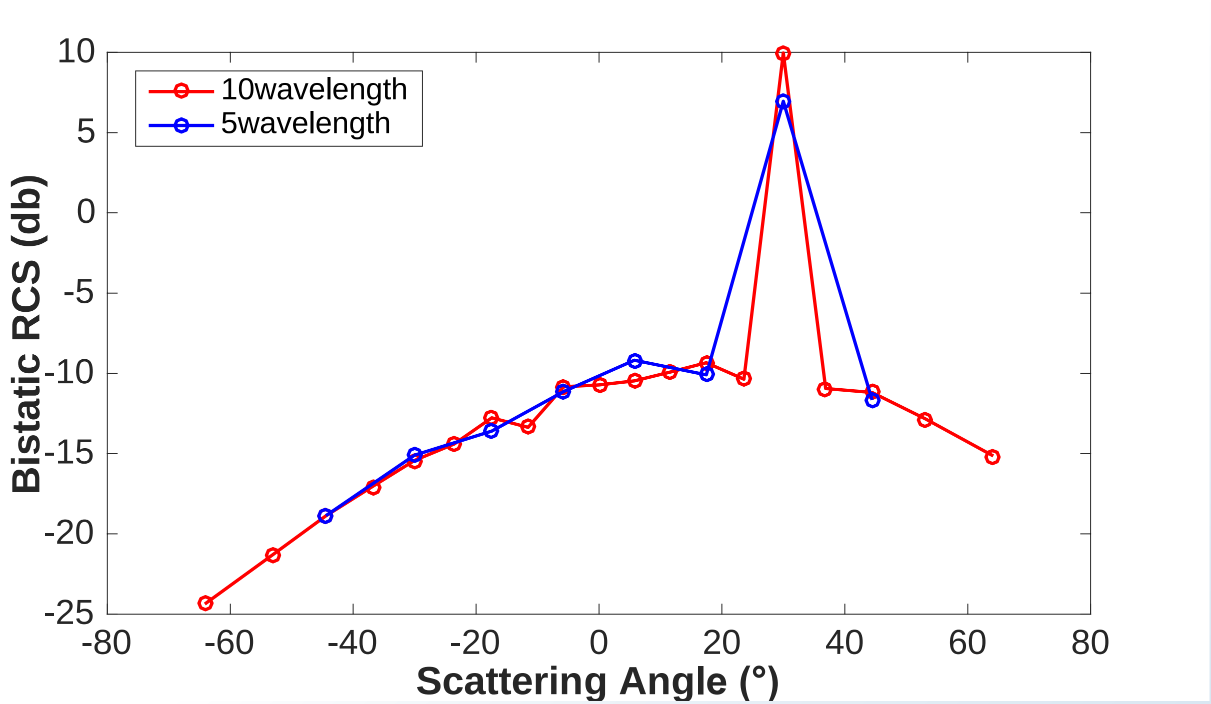


Magnitude of the electric field in the periodic model



RCS simulated by the nonperiodic model, the periodic model and SPM

Simulation results



RCS simulated by the periodic model at different surface sizes

Conclusions

- A nonperiodic model and a periodic model are built to simulate the microwave scattering from the sea ice surface.
- Compared with the SPM, the simulated results of the two models have good agreements.
- The periodic model requires a much smaller computational domain, which is important for the development of a 3-D scattering.

Thank you!