

Airborne EM Sea Ice Thickness Sounding

Forward Modelling & Hardware Developments



S. Hendricks¹, C. Haas^{1,2}, L. Rabenstein¹, J. Lobach³

- 1) Sea Ice Physics / Alfred-Wegener Institute
- 2) Geosciences Department / University of Alberta, Canada
- 3) Ferra Dynamics, Mississauga, Canada



Relevance

Surface Energy Balance

Momentum Transfer

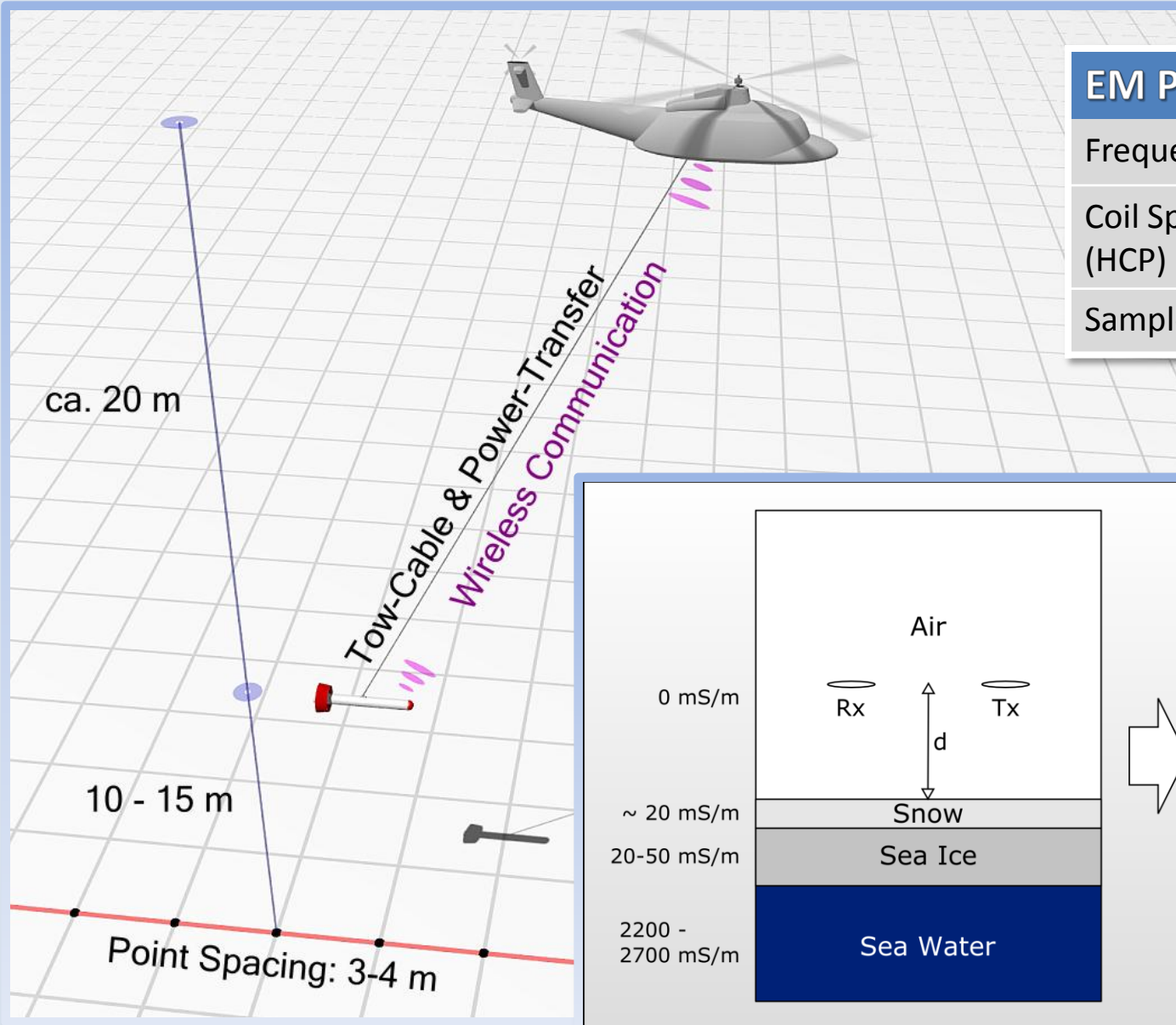
Salinity Distribution

Habitat

Shipping & Offshore Operations

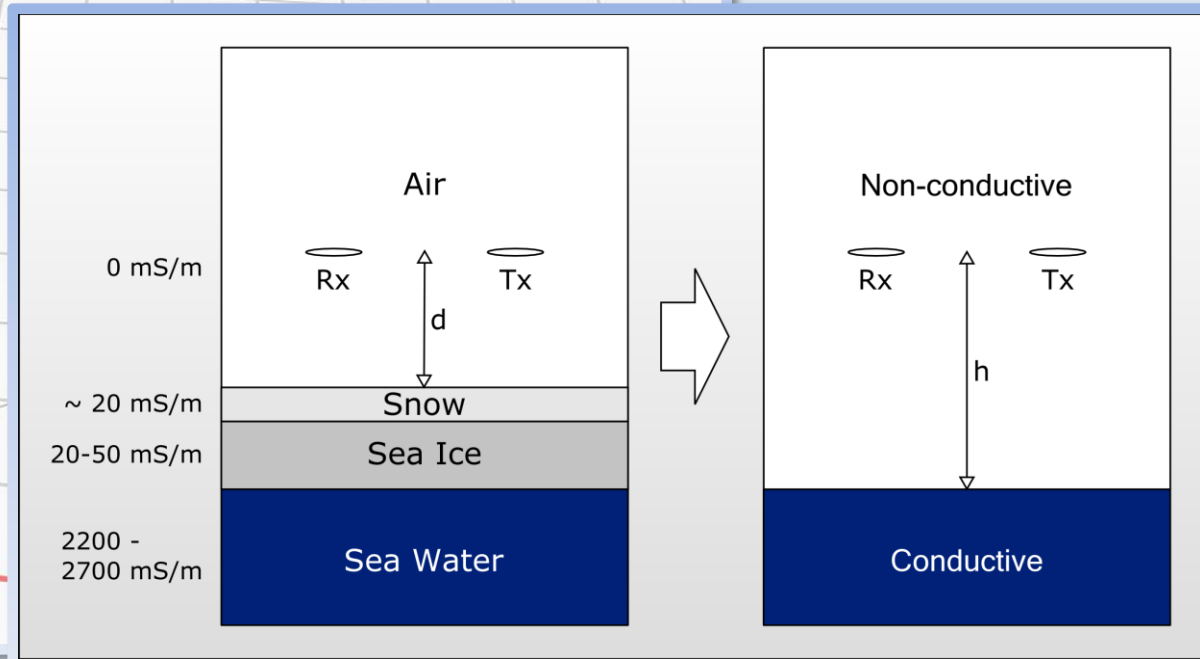
Airborne Sea Ice Thickness Sounding

Introduction
3D Forward Model



EM Parameter

Frequency	4.09	kHz
Coil Spacing (HCP)	2.77	m
Sample Interval	10	Hz



1D Assumption

Layers of sea ice and snow can be described as level plates

Sea ice is a non-conductive medium

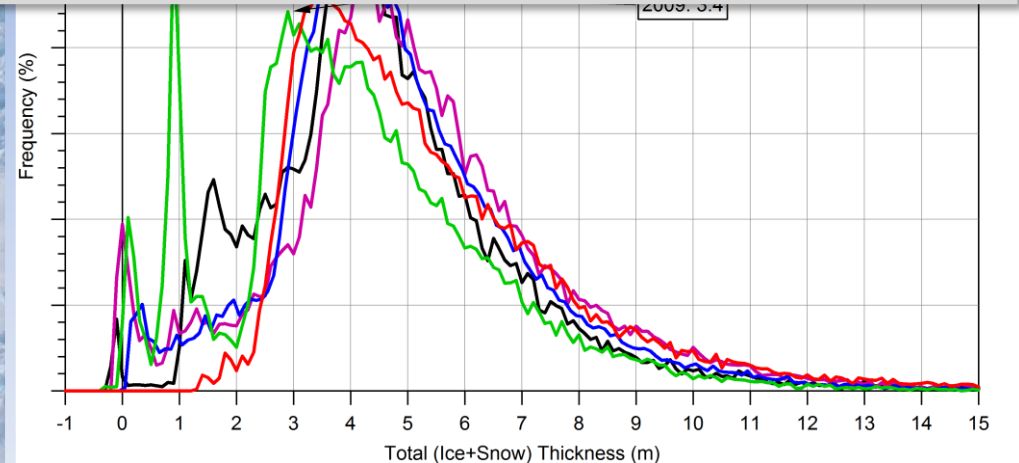
Reality

Common ice deformation zones show high ice thickness variability on sub-footprint scale

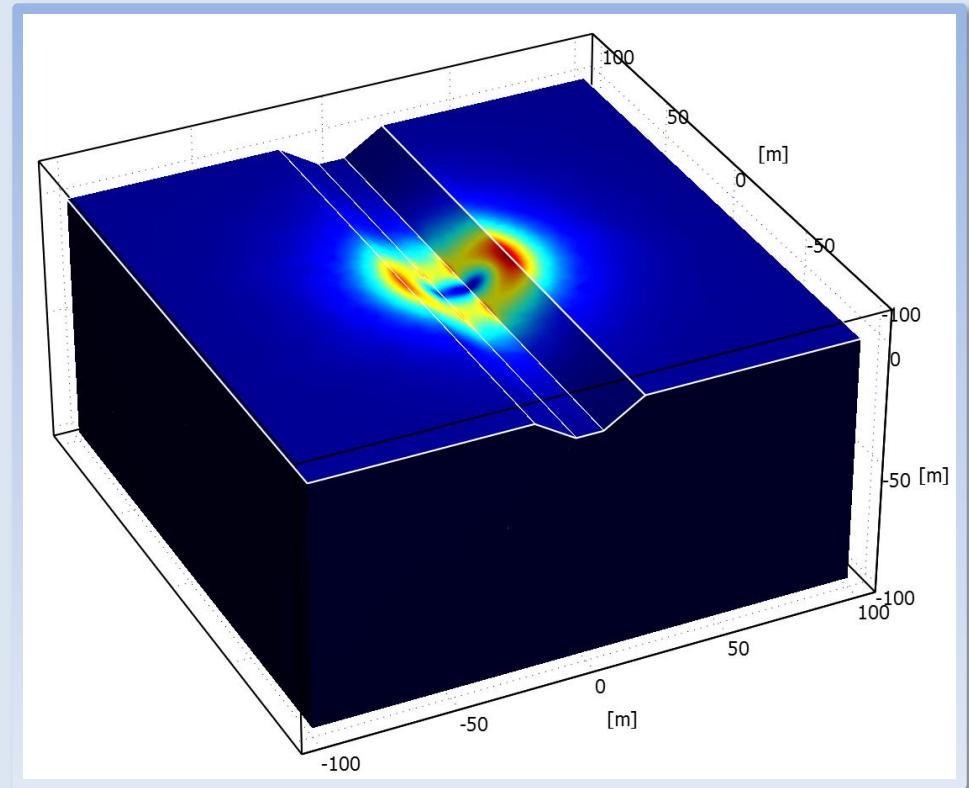
Young Pressure ridges consists of blocky structures with significant brine inclusion

Objectives

1. Estimate misinterpretation of local 1D ice thickness
2. Bias of mean sea ice thickness on longer profiles



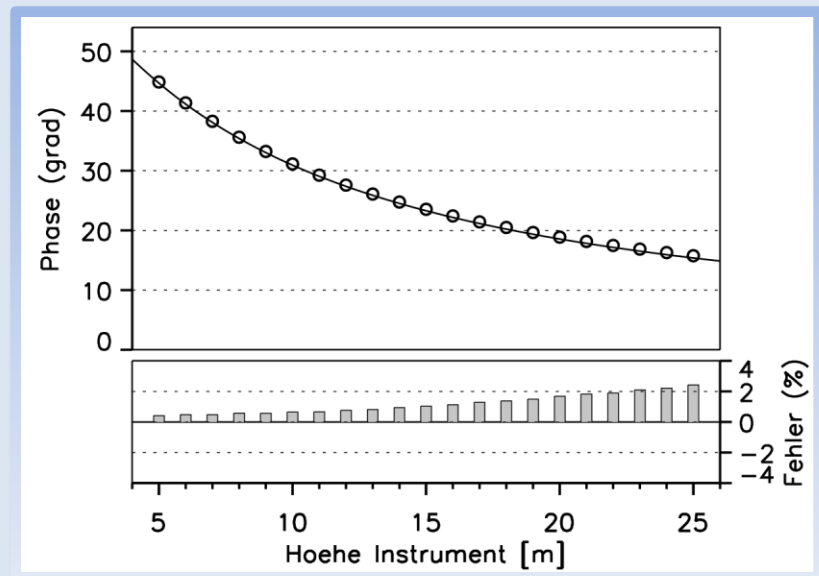
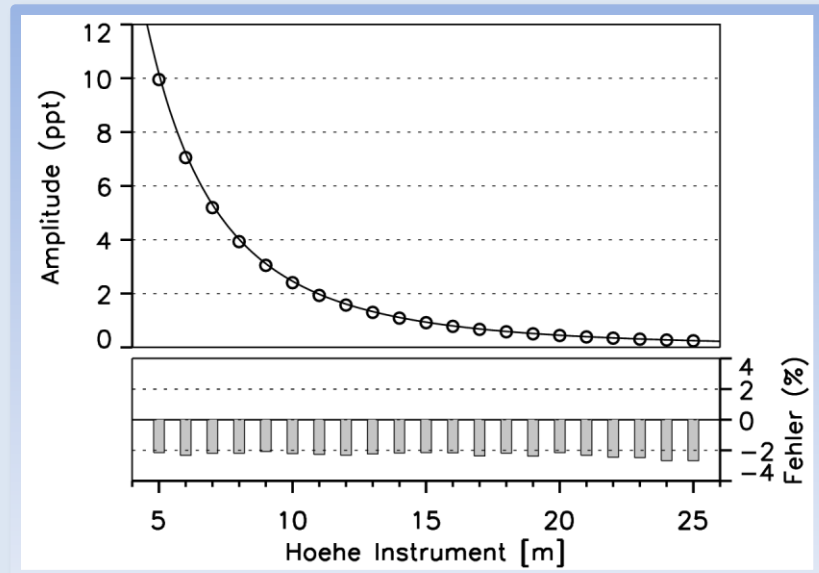
- Comsol Multiphysics
 - Finite Elements
- Forward Modelling of Inphase/Quadrature
- Interpretation with 1D Approach
 - ▶ Apparent 1D ice thickness vs. specified (true) ice thickness



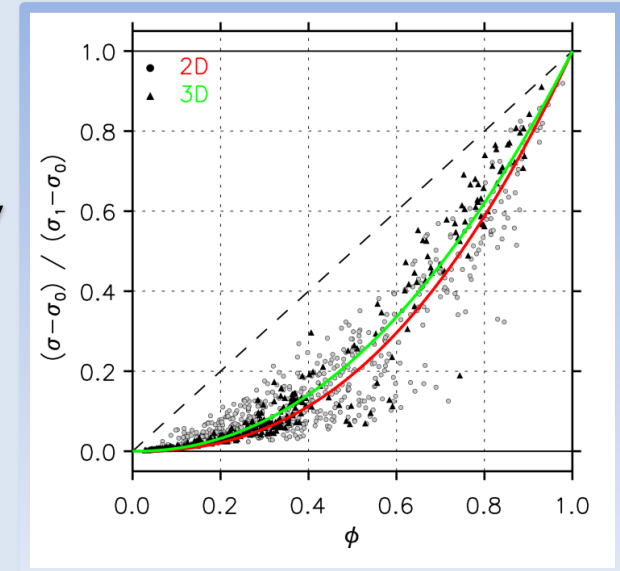
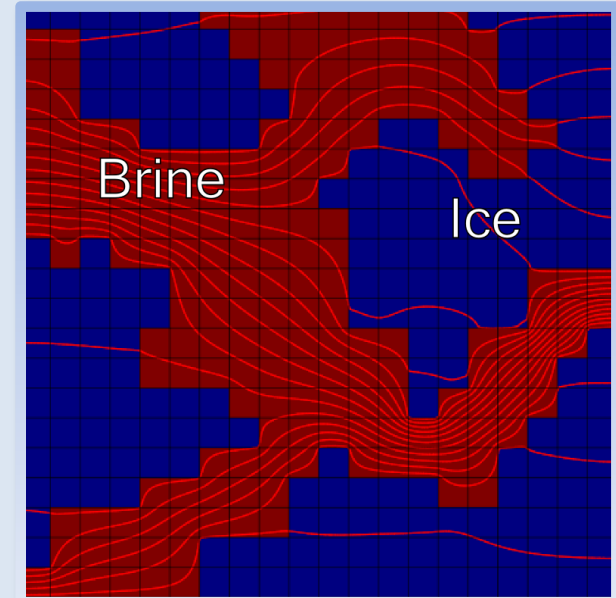
- Numerical 1D Solution vs. 3D Halfspace model
- Variable vertical offset between coil plane and halfspace interface
- ▶ Small systematic bias

$$\frac{H_s}{H_p} = -r^2 \int_0^{\infty} \lambda R_1 \cdot e^{-2\lambda h_0} \cdot f(\lambda r) d\lambda$$

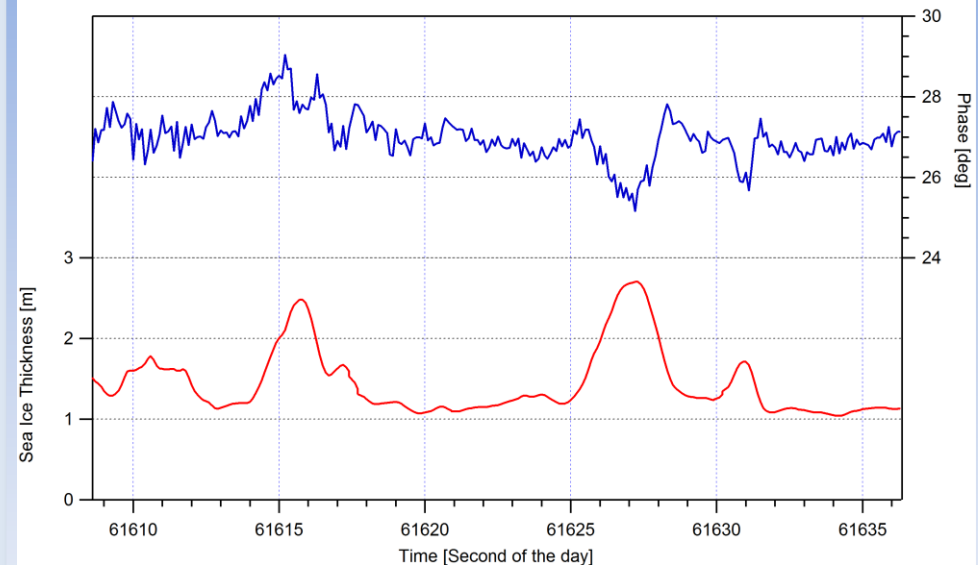
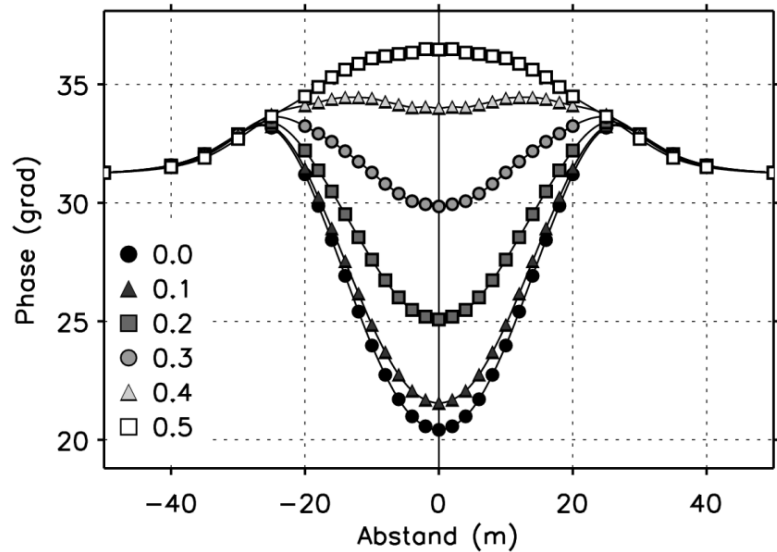
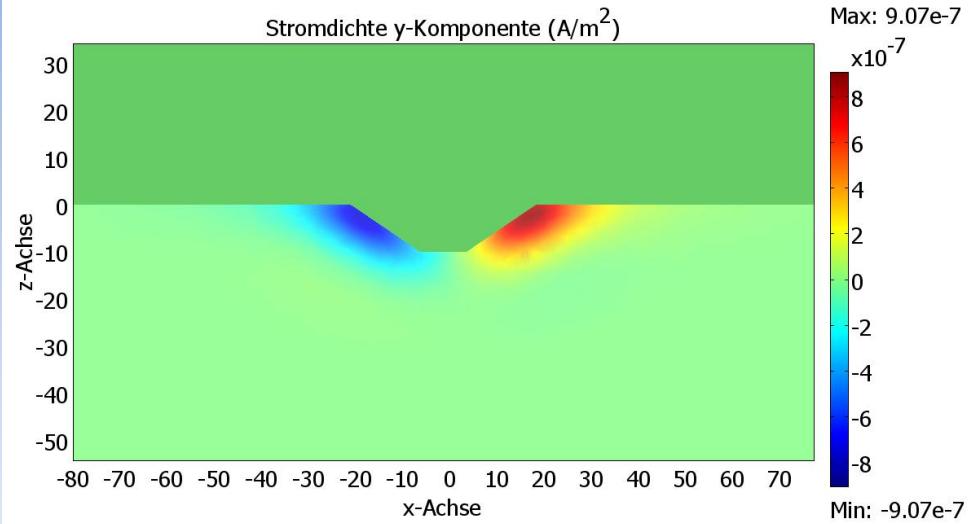
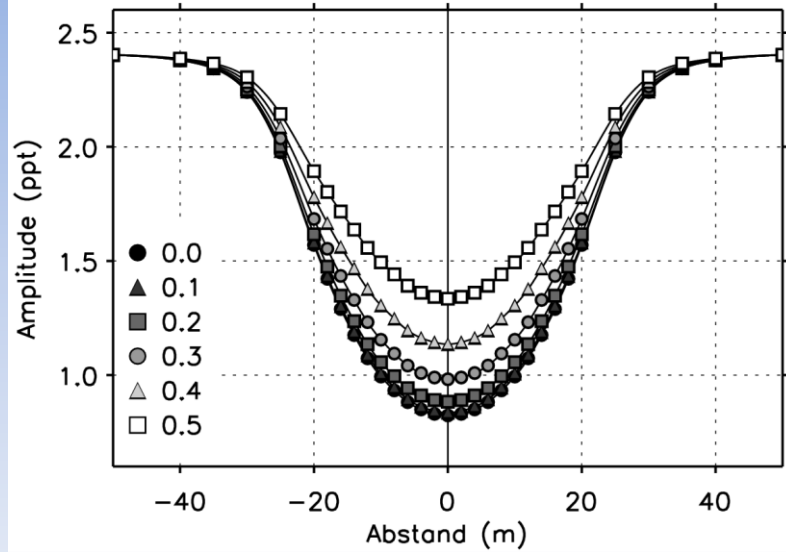
↑
1D Solution



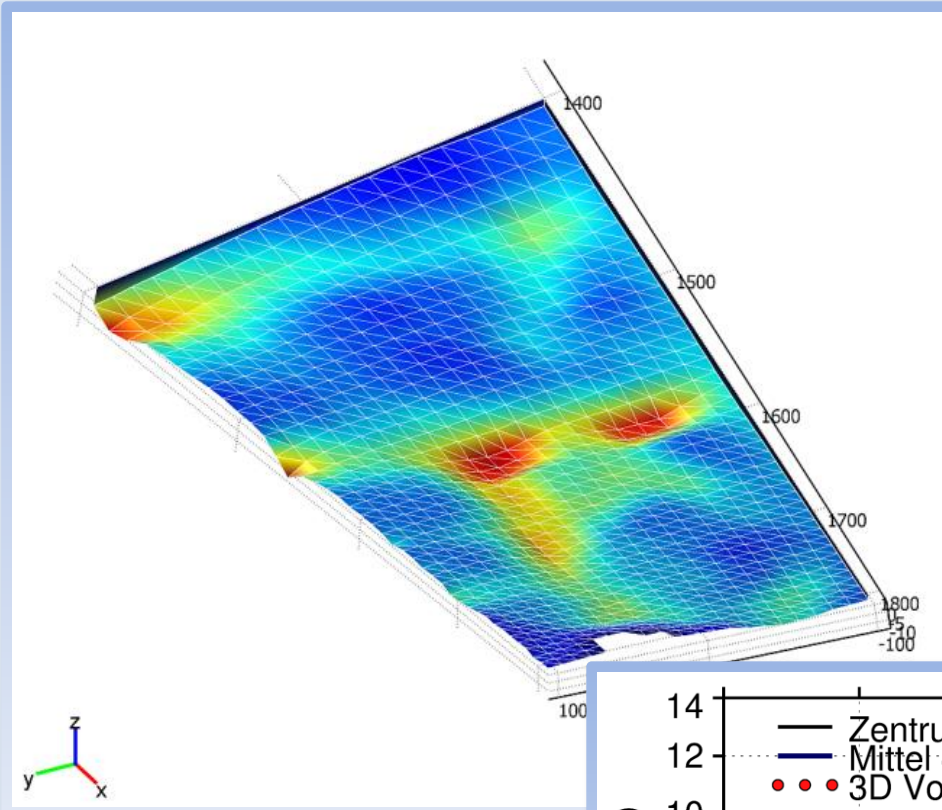
- Relevant parameter for EM
 - DC conductivity
- Ridge parameter: Porosity
 - Blocksize
 - Percolation
- Result of random geometries very close to Archies Law (First-year sea ice)



2D Case : Pressure Ridges



3D Case

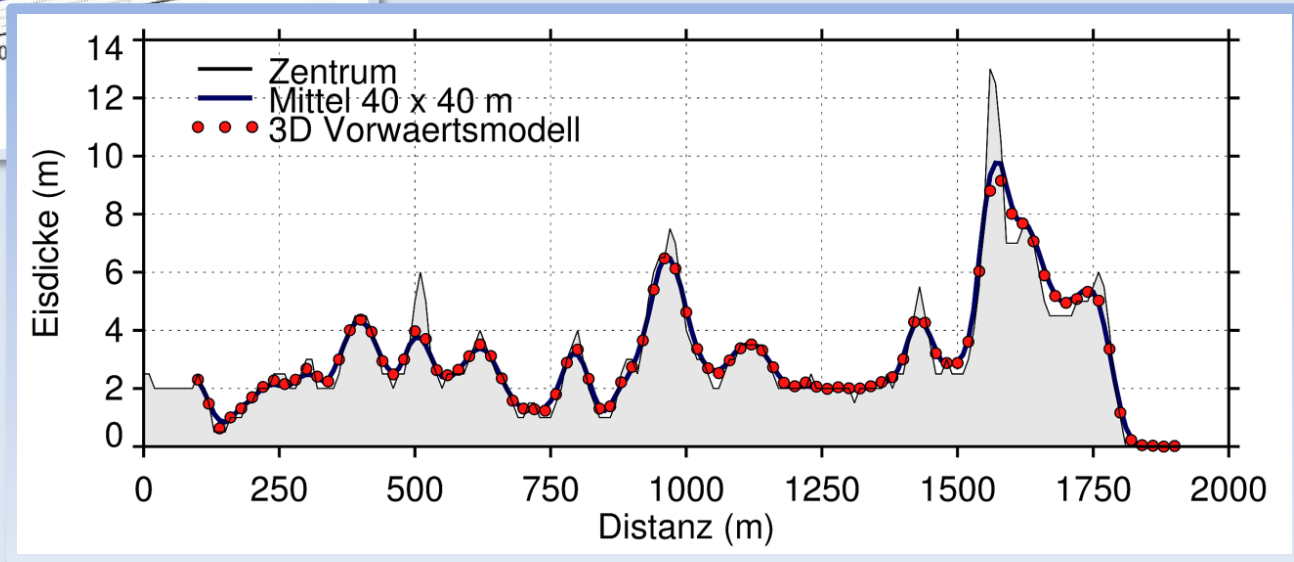


↑
Simulated 3D ice draft

Mean Thickness(m)

Center profile	3.07
Average Footprint	3.11
3D Model	3.09

Result of forward model



Part II New Developments towards Range Improvements



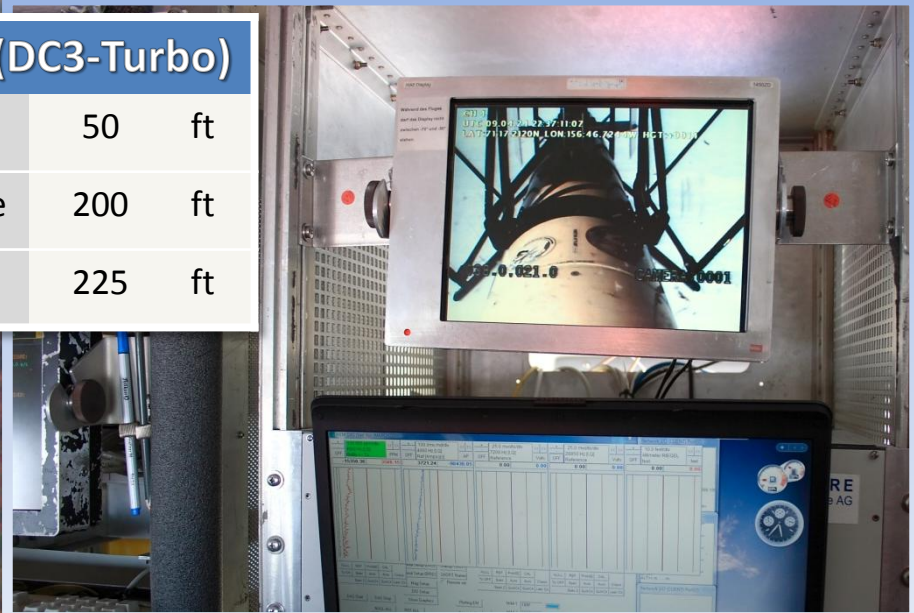
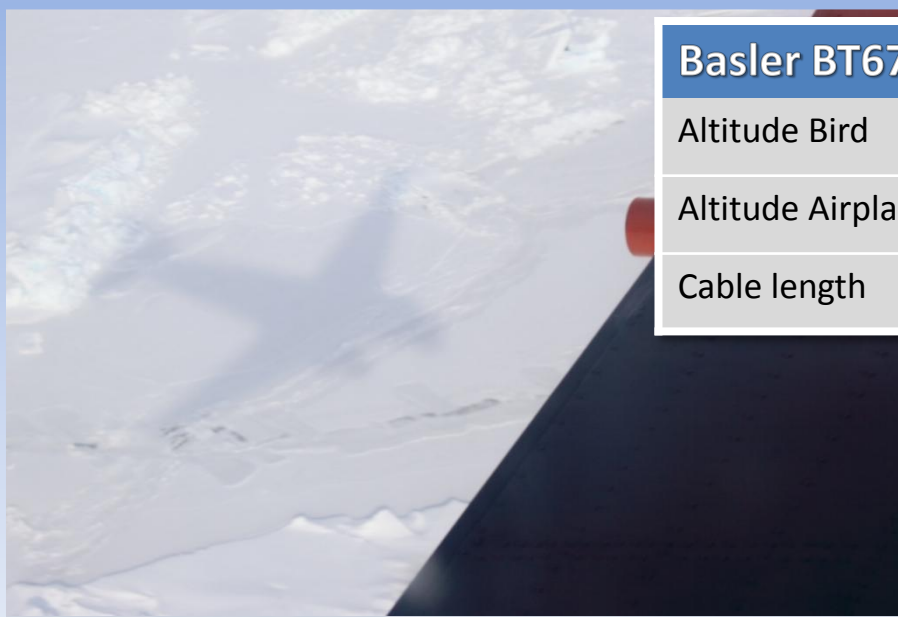
Airplane Utilization

3D Forward Model
Developments
Conclusion



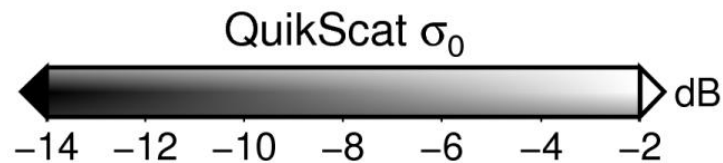
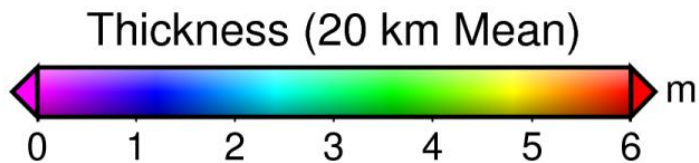
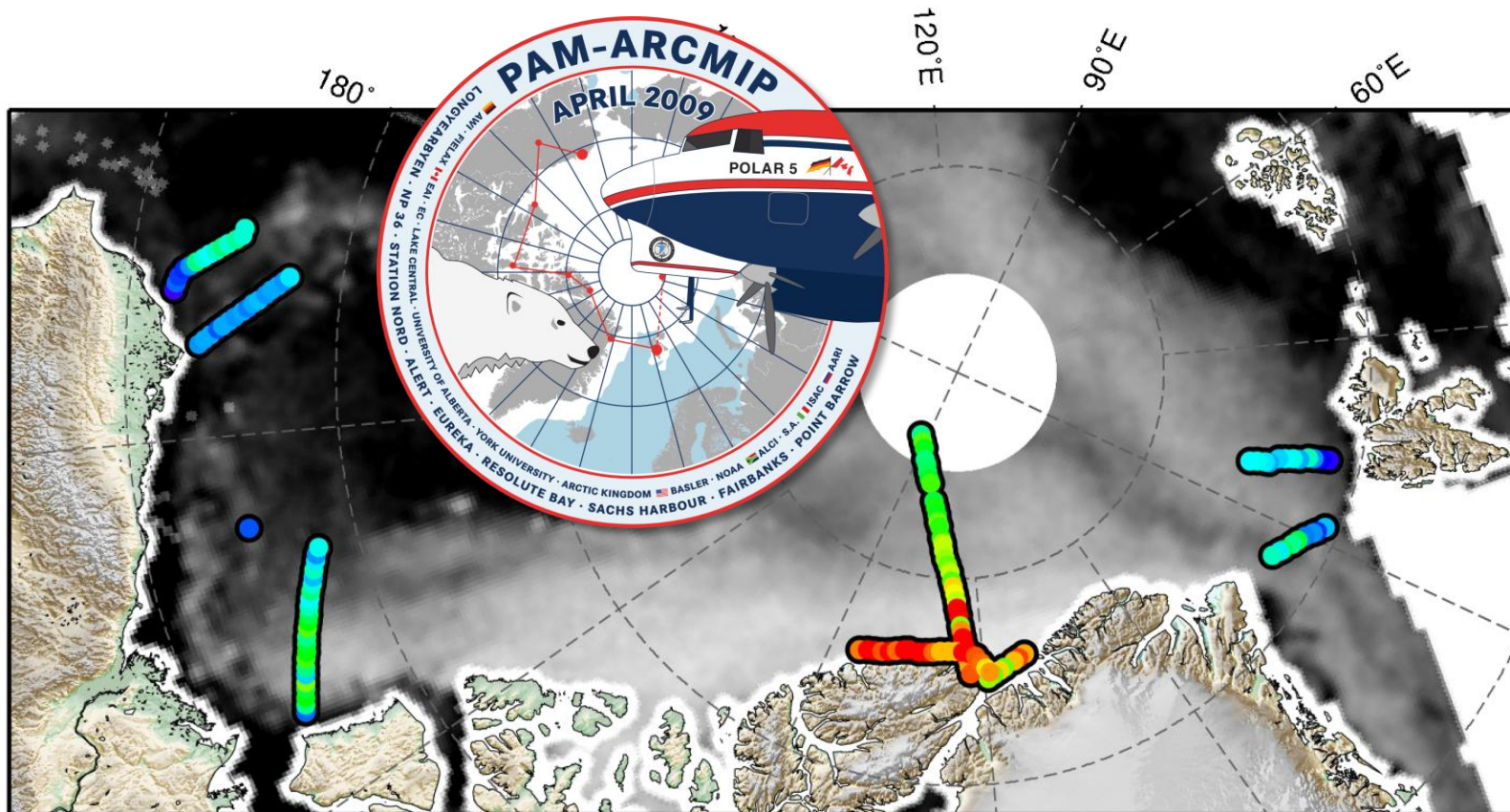
Basler BT67 (DC3-Turbo)

Altitude Bird	50	ft
Altitude Airplane	200	ft
Cable length	225	ft




Airborne EM : Maiden Voyage

3D Forward Model
Developments
Conclusion



- Airborne EM (towed system)
 - State of the Art for regional sea ice thickness surveys
 - Significant range improvements with utilizations of airplanes
- 1D Interpretation
 - Underestimation of maximum sea ice thickness : up to 50%
 - Mean sea ice thickness : Conserved quantity
- Outlook
 - Porosity information of ridges desirable
 - *Ideas for EM parameter changes welcome!*



THANK YOU FOR
YOUR ATTENTION