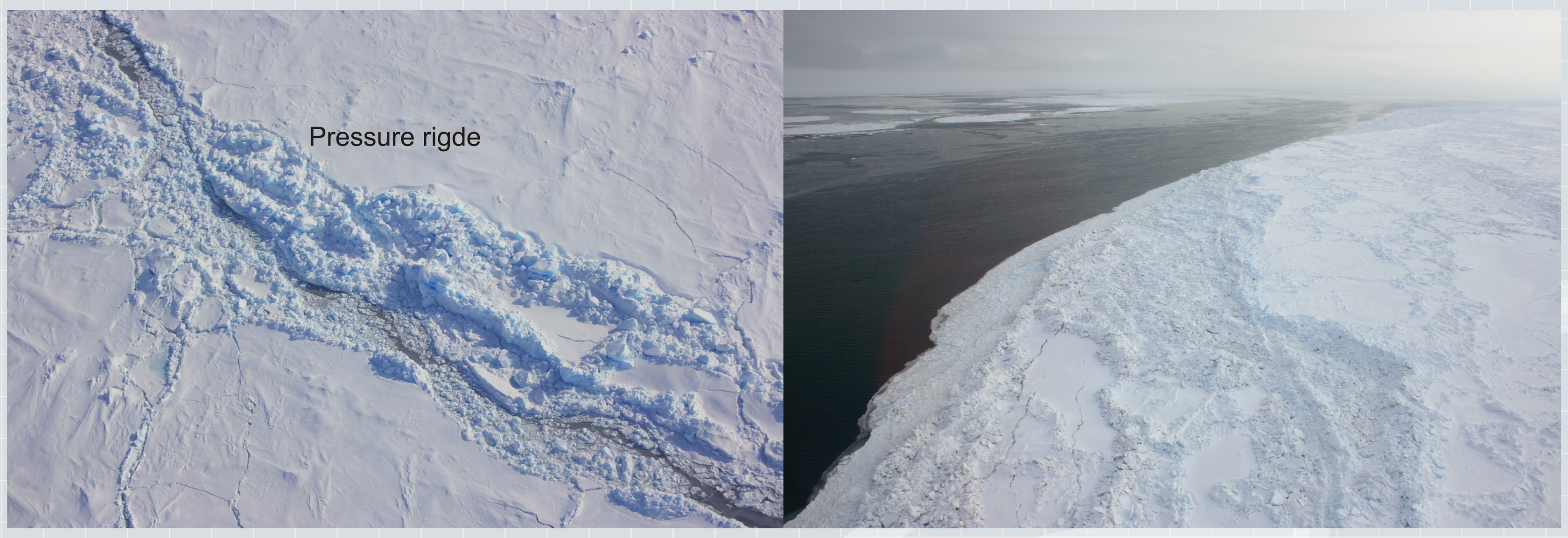
Alfred Wegener Institute for Polar and Marine Research
Sea Ice Physics Group

Stefan Hendricks, Christian Haas, Lasse Rabenstein

Implications of 3D Structures in the Sea Ice on Helicopter-EM Ice Thickness Estimates

Introduction

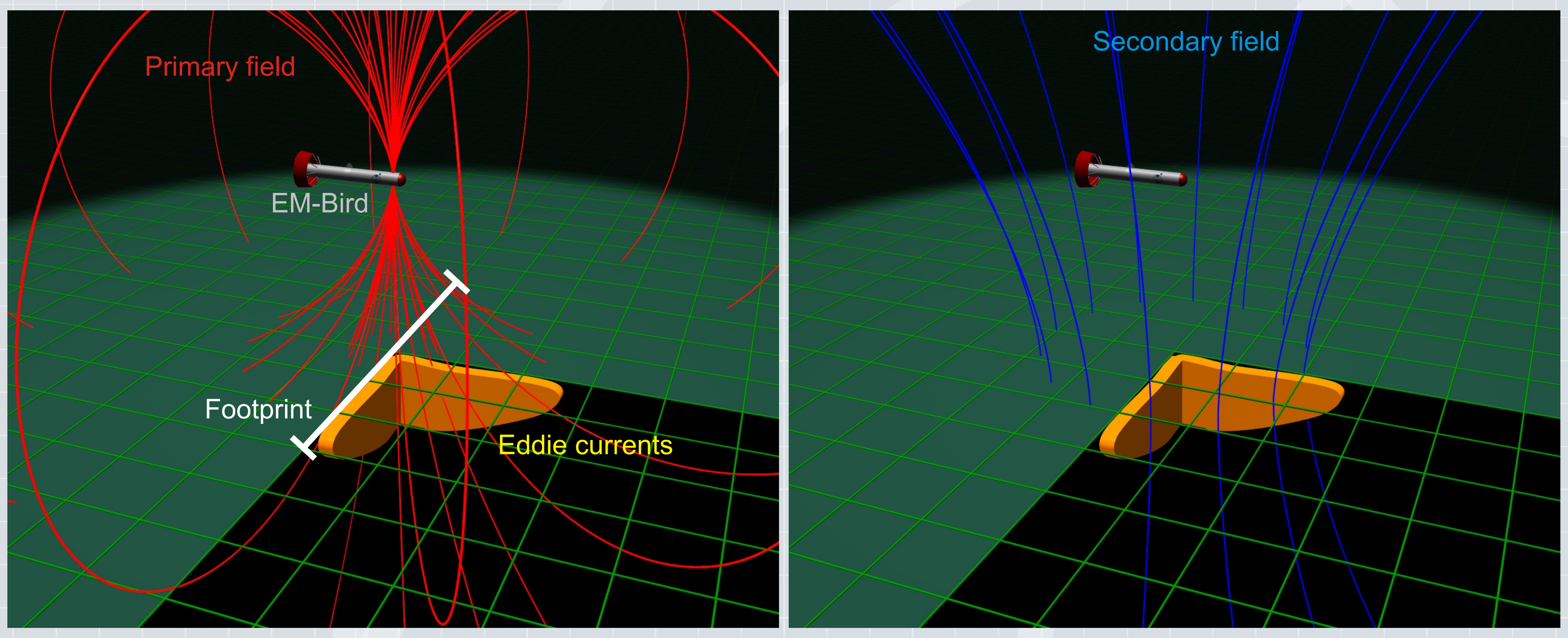
The global sea ice thickness distribution is yet a barely measured quantity in the estimation of the arctic and antarctic sea ice volume. While ice concentration and extend can be easily monitored from space, the development of a dedicated sea ice thickness satellite mission (CryoSat II, ESA) still needs ground truthing for the development of data processing algorithms. Sea ice thickness has been measured for decades by military submarines using upward looking sonars (ULS). In the recent years helicopter electro-magnetics (EM), a method of exploration geophysics, has been used more systematically to survey sea ice thickness from land and from ice breakers.
The standard processing of the EM data is based on a 1D representation of the sea ice and can lead to a significant misinterpretation of the actual thickness of deformed ice. Since the volume stored in deformed sea ice is not neglible a more enhanced data processing algorithm is nedeed to provide a data basis for the validation of space-borne sea ice thickness monitoring.



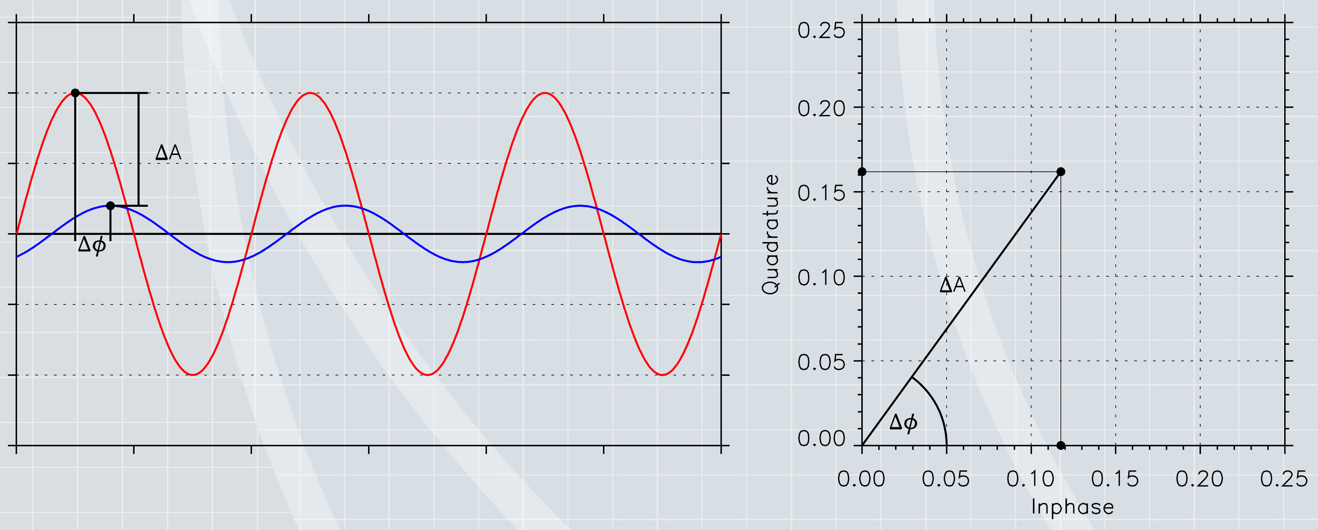
Figures: *Typical sea ice deformation features*

Helicopter EM

Principle



Figures: *Eddie currents are induced by the harmonic primary field. The eddie currents are the source of a secondary field, which is measured by the bird together with the primary field.*



Figures: *Schematic illustration of* ***Inphase*** *and* ***Quadrature****, which describe the complex ratio of secondary to primary field (****Amplitude*** *and* ***Phase*** *in polar coordinates)*

Inphase and Quadrature are a function of distance to the conductive sea water. Sea ice (+ snow) thickness is obtained by the difference of that distance and the laser range to the top snow cover. The actual height of the instrument above the local sea level is not essential for the standard processing, which bases on two assumptions:

- Within the footprint (40-50m) the problem can be described by a layered halfspace
- The conductivity of sea ice and the snow cover is negligible compared with the sea water

Therefore, the EM problem reduces to homogenous halfspace and the Inphase and Quadrature channels can be used to estimate ice thickness independently.

Challenge

Misinterpretation of the sea ice thickness of deformed ice can be explained by mainly two reasons:

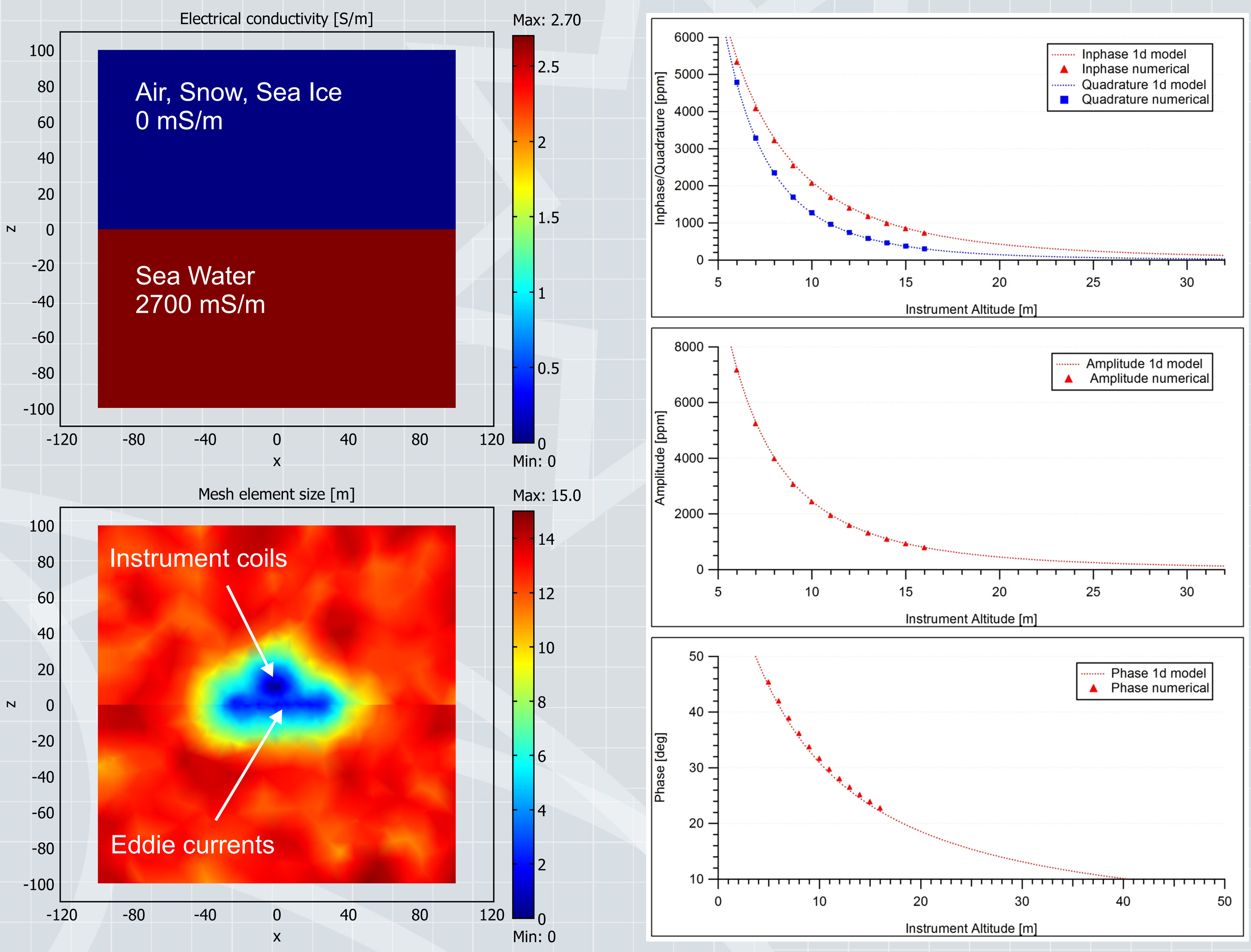
- Structures smaller than the footprint of the system are averaged
- Sea water intrusion in blocky structures change the conductivity of the sea ice layer

The aim of this work is to investigate the influence of different 3D structures in the sea ice to create a probabilistic correction of the ice thickness data processing.

Tool

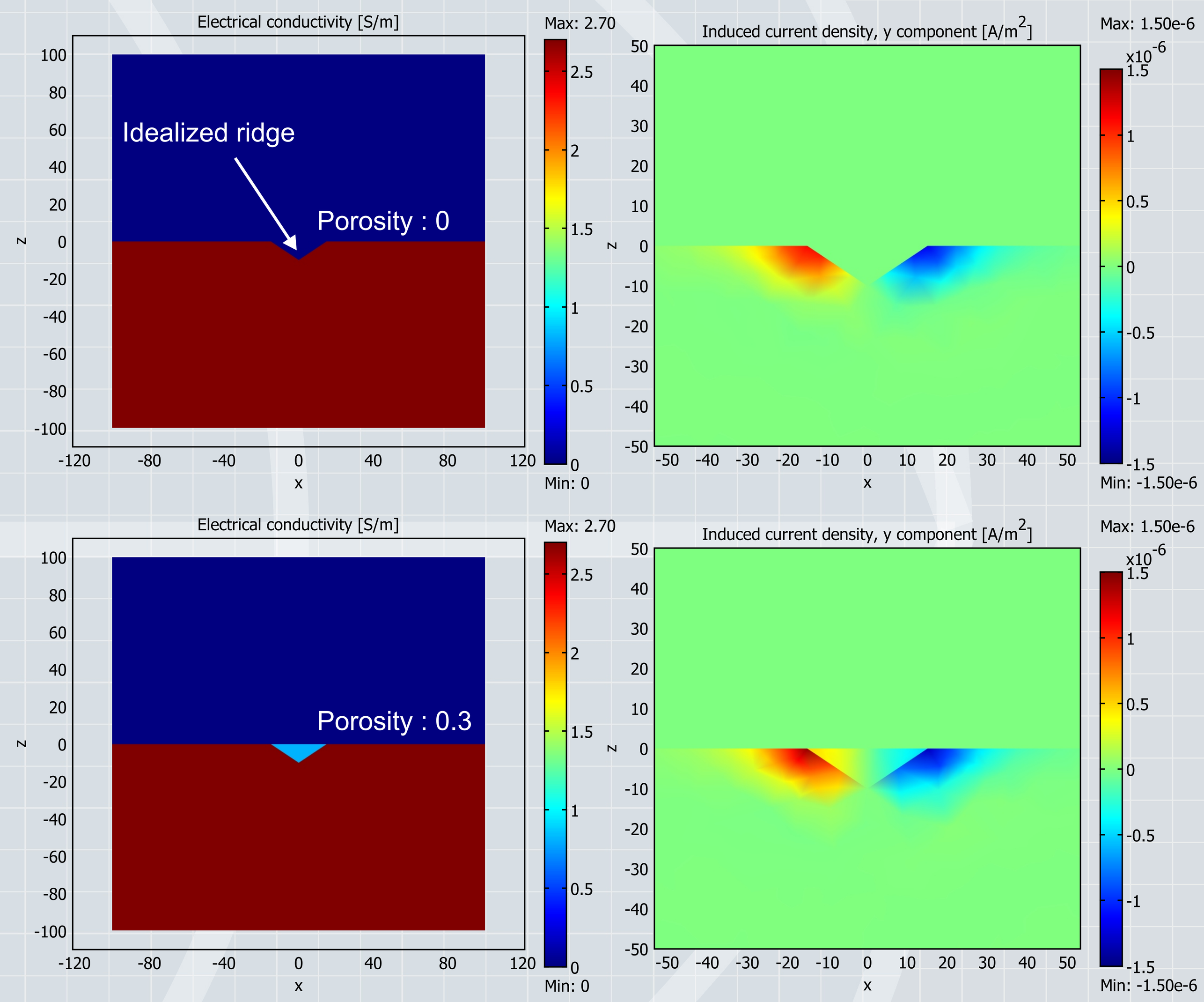
The commercial software **COMSOL Multiphysics** was evaluated for the capability to solve the quasistatic EM PDE's on a finite element grid for the sea ice problem at arbitrary geometries. The test computer was a standard Win XP desktop PC. Limitations of the 32bit memory architecture allowed only coarse model runs.

Validation with 1D Analytical Solution

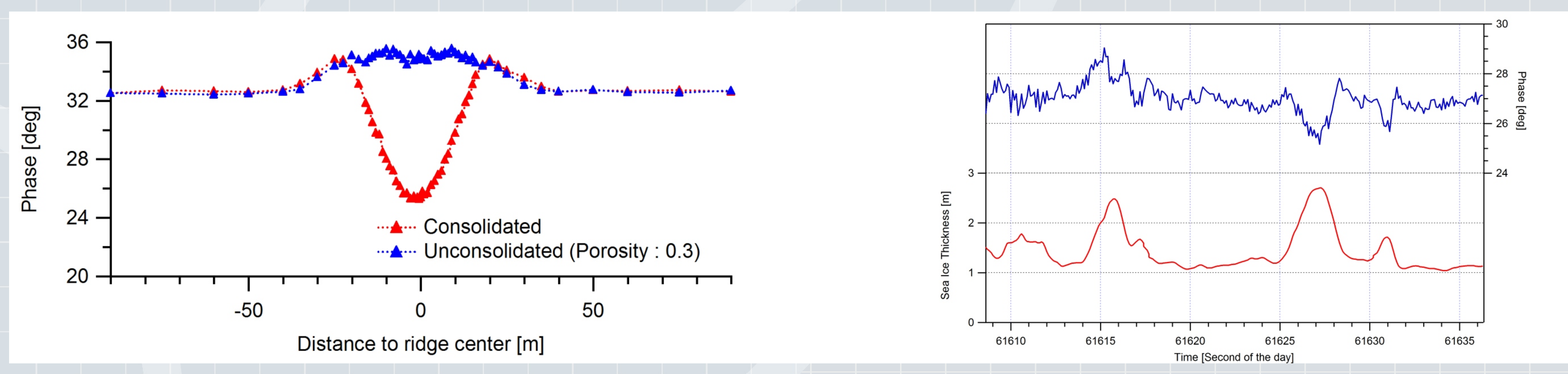


Figures: *[left] Model geometry and mesh size [right] 3D model results (markers) and analytical solution (line) for varying distance between instrument and sea water surface*

First Results : Pressure Ridge (Solid & Porous)



Figures: *[left] Model geometry of an ideal pressure ridge (with/without porosity) [right] model results (y-current density)*



Figures: *Simulated overpass over a ridge (with & without porosity). [left] Phase simulation results [right] Data example of pressure ridges (lower curve) with different phase behaviour (upper curve)*

Conclusions/Outlook

- Precision of 3D modeling is sufficient even on coarse grid (Test PC with trial license)
- First modelling results show a different behaviour between solid and porous pressure rigdes in the phase component
- Effect found in real data
  - DGPS necessary to correct instrument altitude variations
  - Negative phase-thickness relation outweighs the positive case by a factor of ~ 5 in a test data set in the Lincoln Sea
- Higher model resolutions on a 64bit Workstation will allow detailed investigations of 3D structures