Alfred-Wegener-Institut
für Polar- und Meeresforschung
in der Helmholtz-Gemeinschaft

Airborne sea ice thickness measurements in 2007 and 2008

Stefan Hendricks[1], Christian Haas[2], Lasse Rabenstein[1], Torge Martin[3]

1. Alfred Wegener Institute for Polar and Marine Research, Germany
2. University of Alberta, Canada
3. National Oceanic and Atmospheric Administration, USA

1. Sea Ice Thickness Results
   - Sedna Ice Camp — April 2007
   - SIZONet — April 2008
   - IPY Polarstern Cruise — August – September 2007

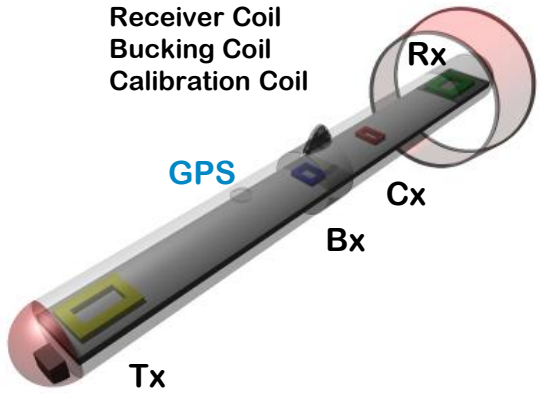
2. EM-Bird measurements over deformed sea ice
   - 1D assumption: EM bird data processing
   - 3D forward model: Effects of footprint and sea ice geometry

Part I

Sea Ice Thickness Results

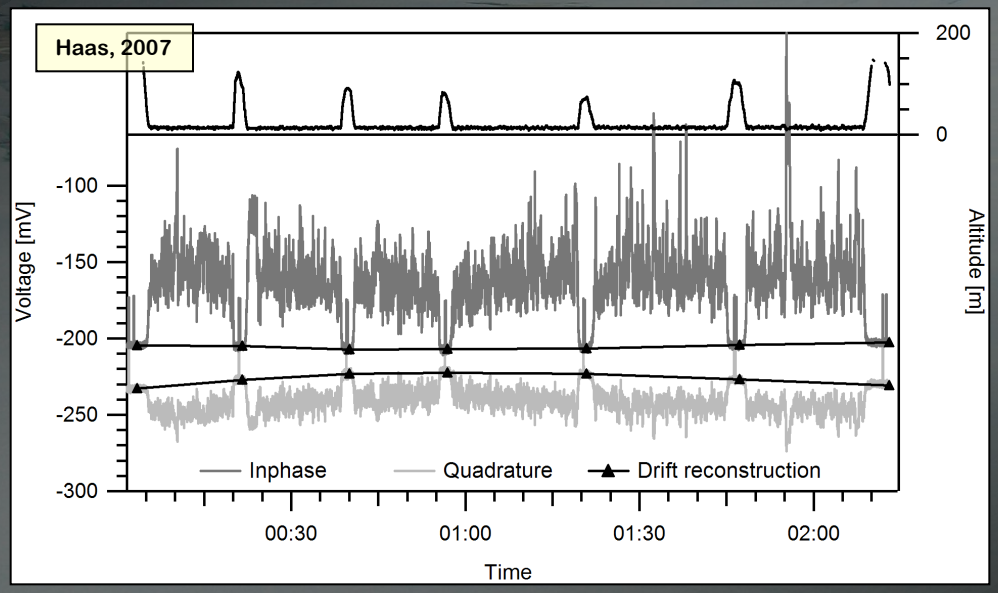
EM Bird

Tx Transmitter Coil
Rx Receiver Coil
Bx Bucking Coil
Cx Calibration Coil

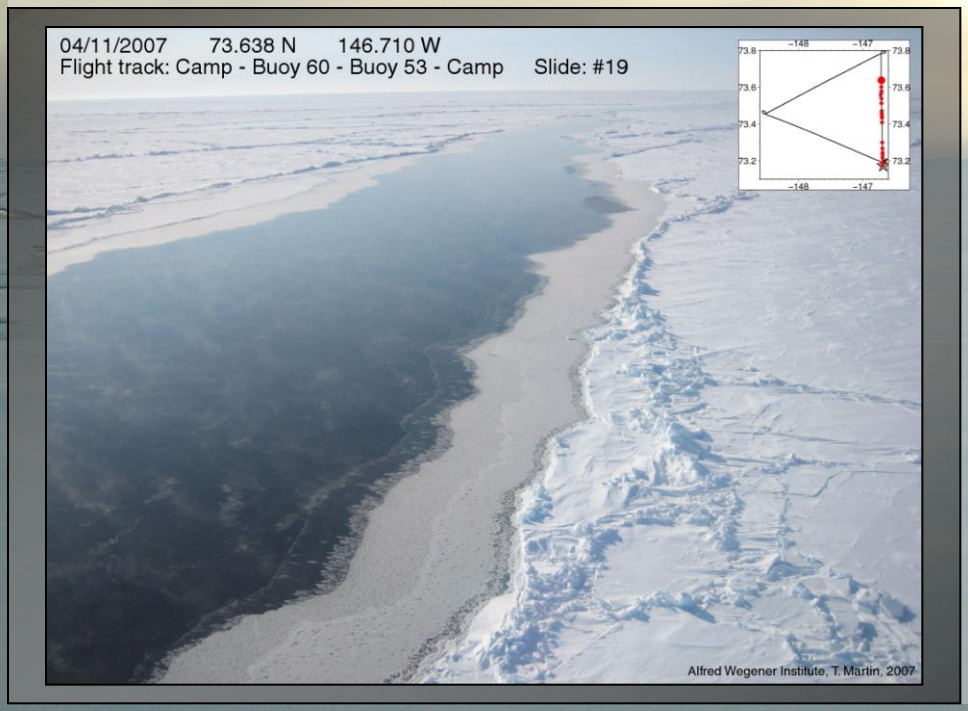


Laseraltimeter

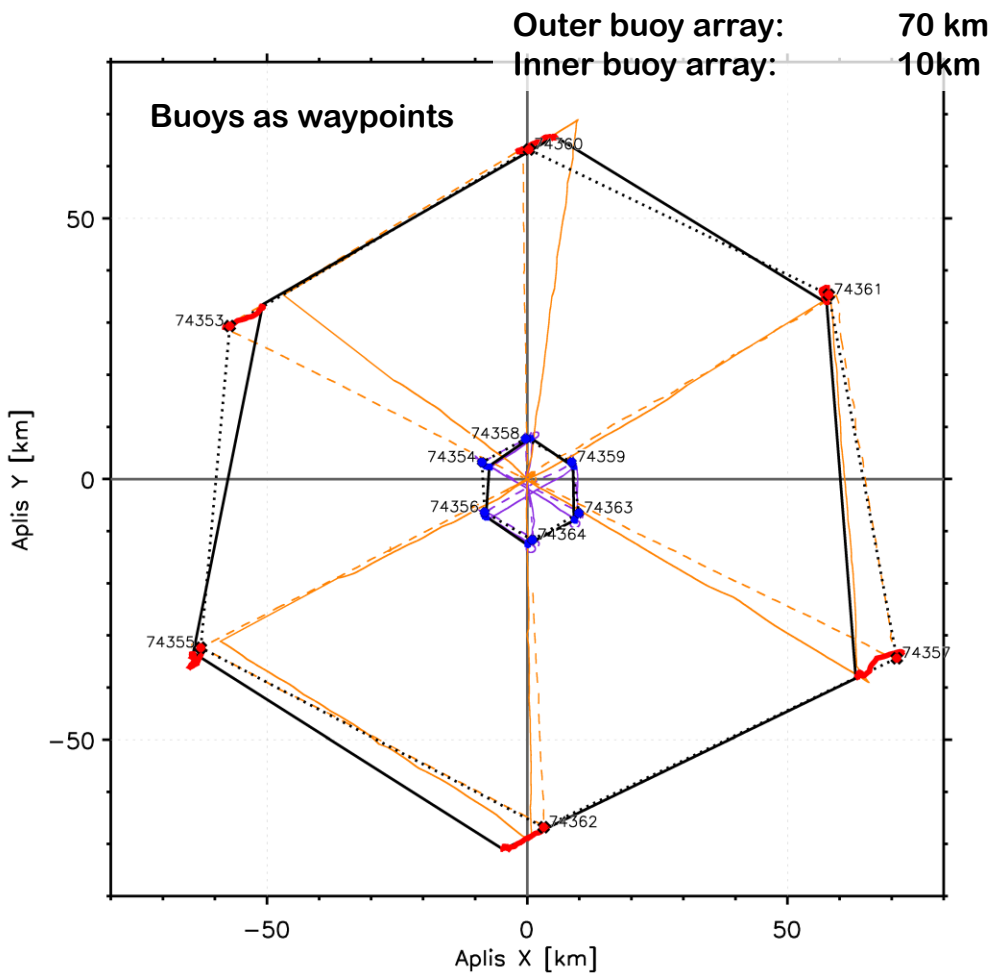
Length	: 3.4m
Weight	: 100 kg
Coil Separation	: 2.7 m
Frequency	: 3.68 (4.06) kHz
Recording Frequency	: 10 Hz ≡ 3 – 4m
Operation Height	: 10 – 15 m
Footprint	: 40 – 50 m



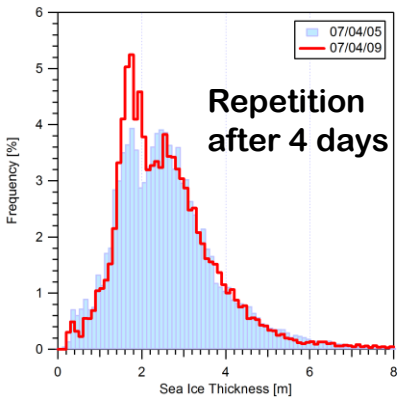
- **Facts**
  - 11 flights
  - ~2150 km of profile data
  - Sea ice thickness + areal photography

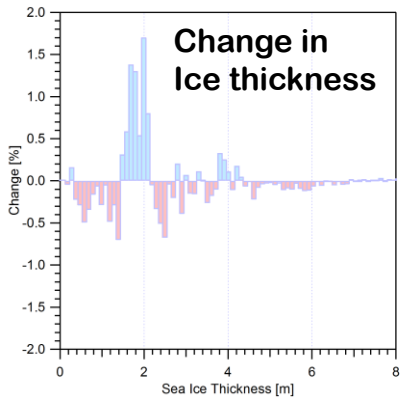


Buoy Array

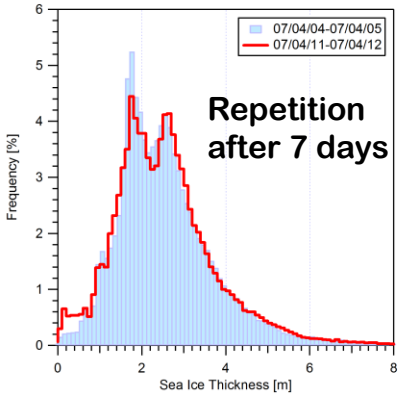


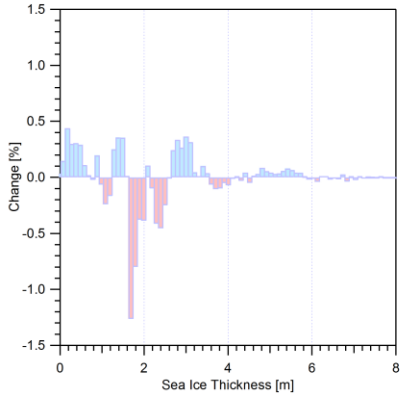
Inner Buoy Array



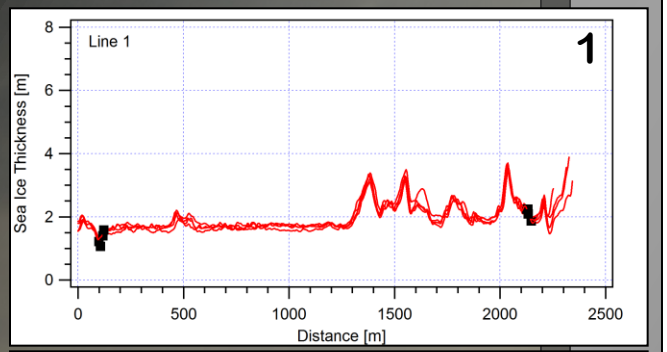


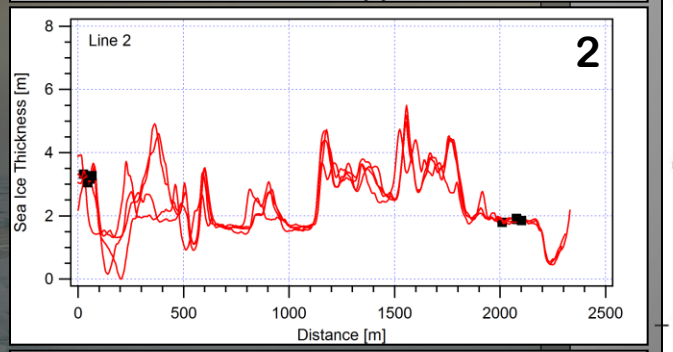
Outer Buoy Array

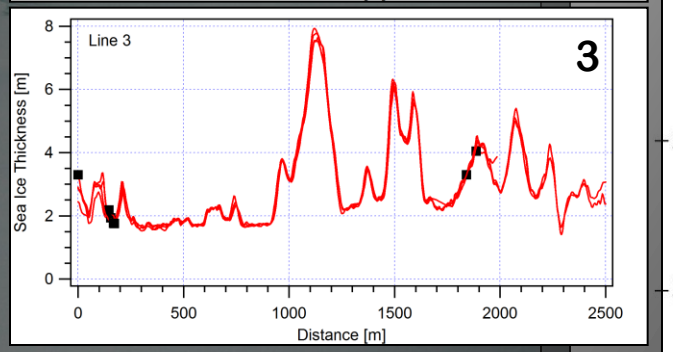


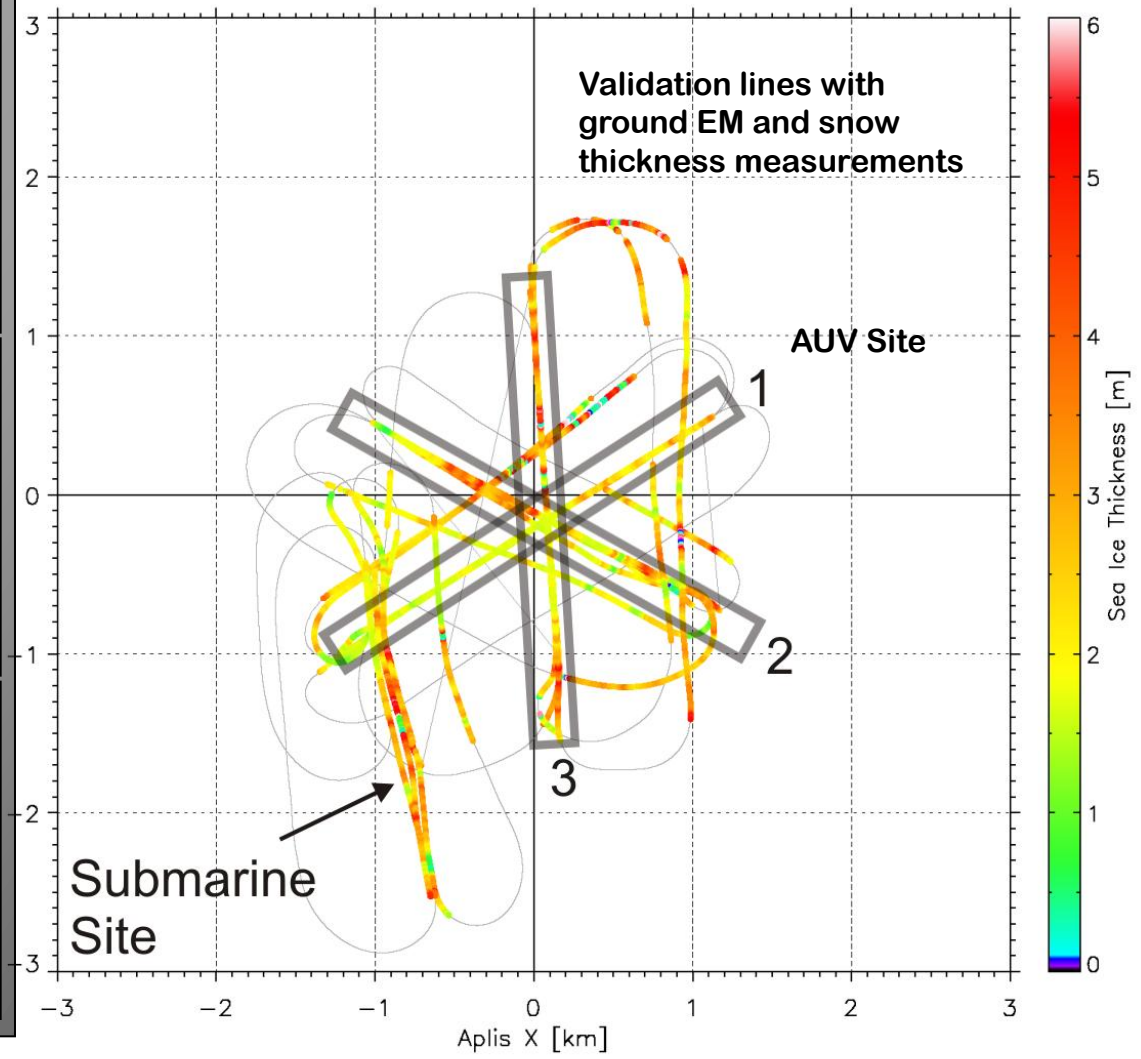


Validation Lines

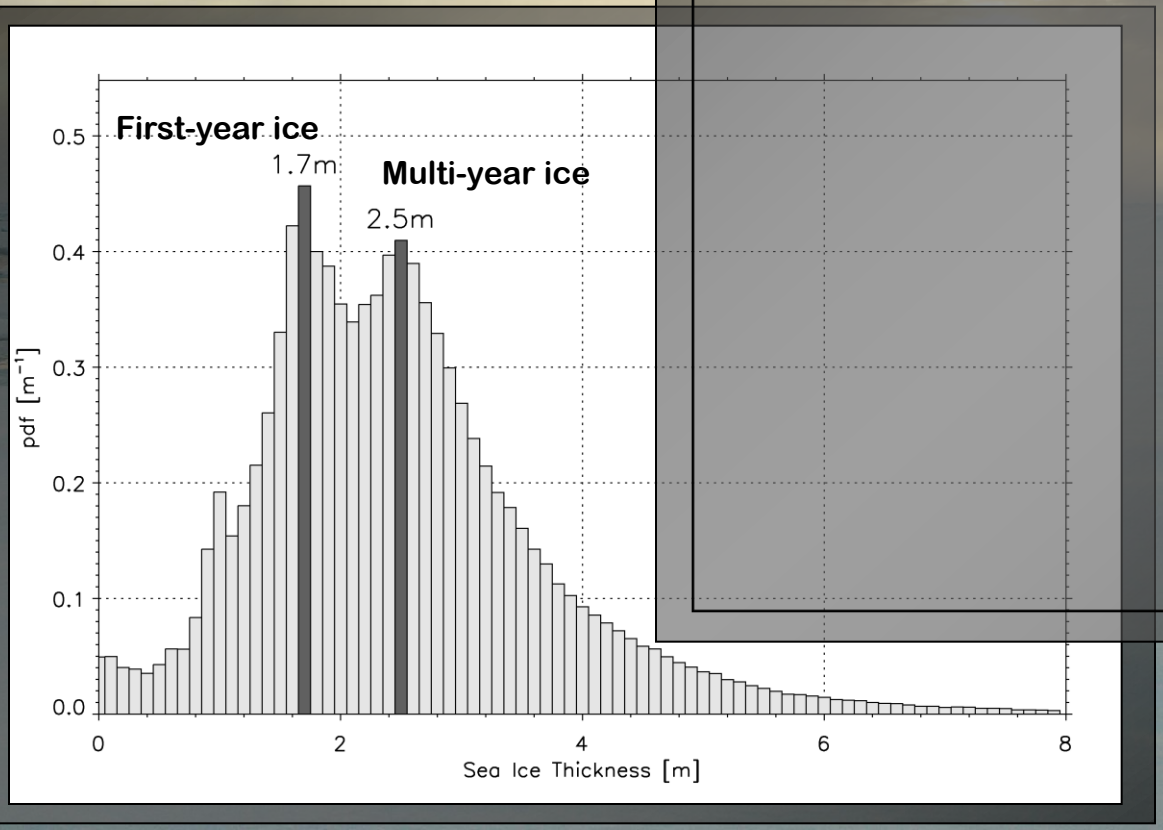


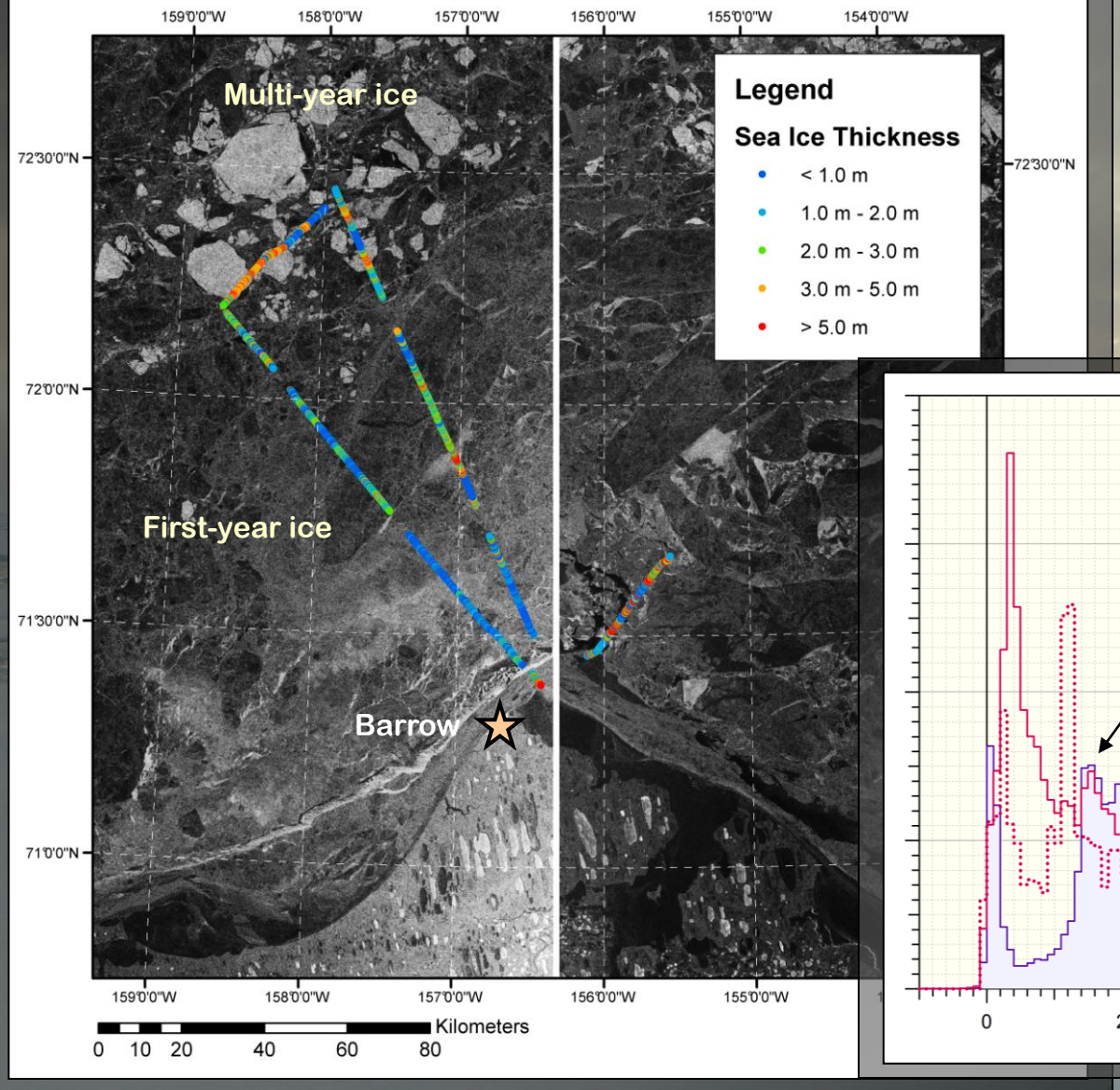


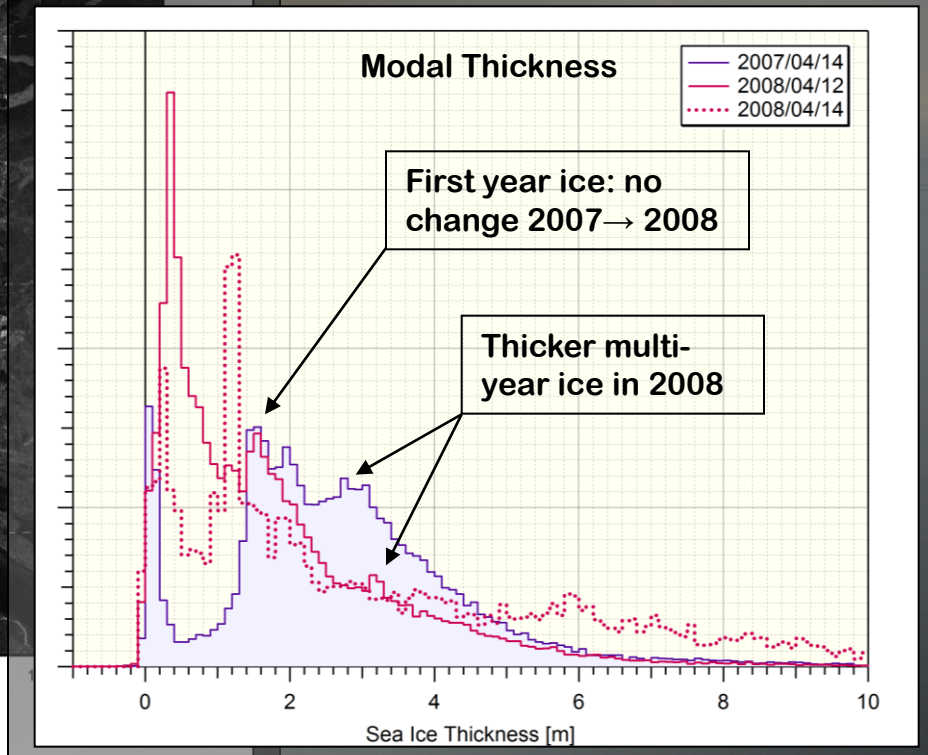




Sea Ice Thickness Distribution



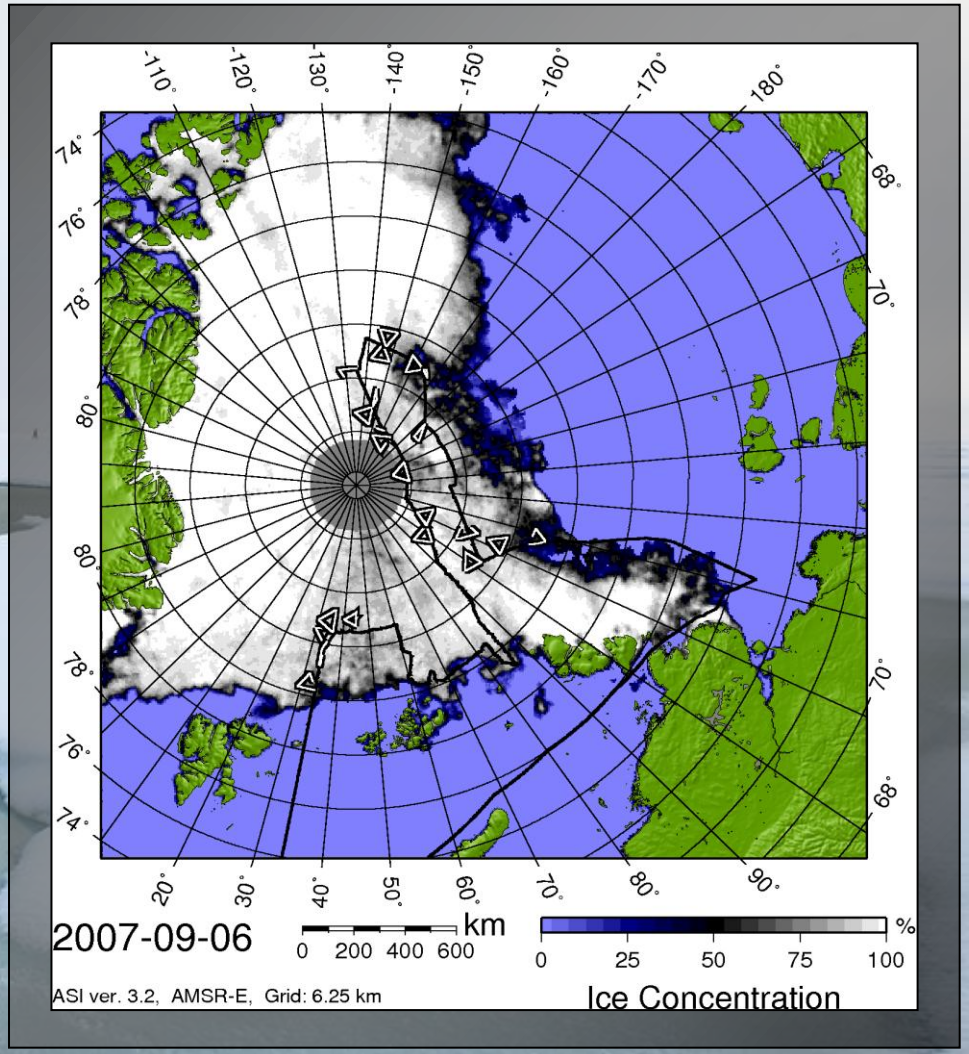

159°0'0"W
158°0'0"W
157°0'0"W
156°0'0"W
155°0'0"W
154°0'0"W
72°30'0"N
72°0'0"N
71°30'0"N
71°0'0"N
Multi-year ice
First-year ice
Barrow
Legend
Sea Ice Thickness
< 1.0 m
1.0 m - 2.0 m
2.0 m - 3.0 m
3.0 m - 5.0 m
> 5.0 m
Kilometers
0 10 20 40 60 80


Modal Thickness
2007/04/14
2008/04/12
2008/04/14
First year ice: no change 2007→ 2008
Thicker multi-year ice in 2008
0
2
4
6
8
10
Sea Ice Thickness [m]

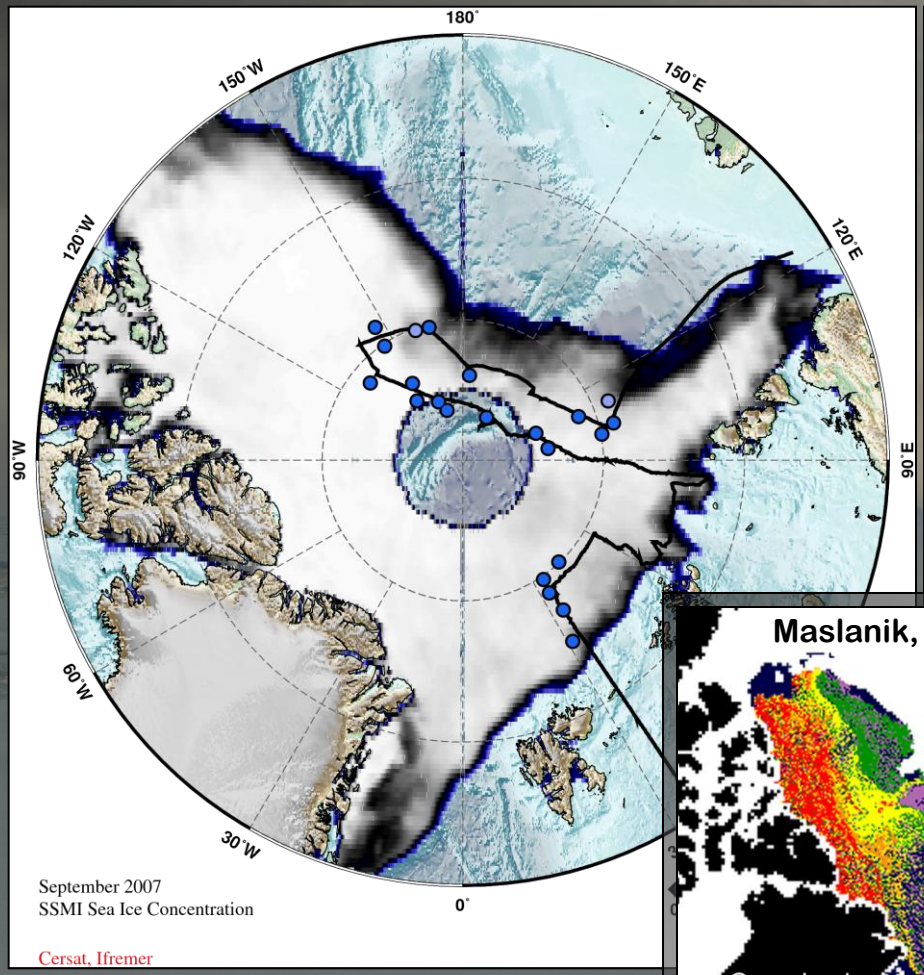
SPACE (Synoptic Pan-Arctic Climate and Enviroment Study)

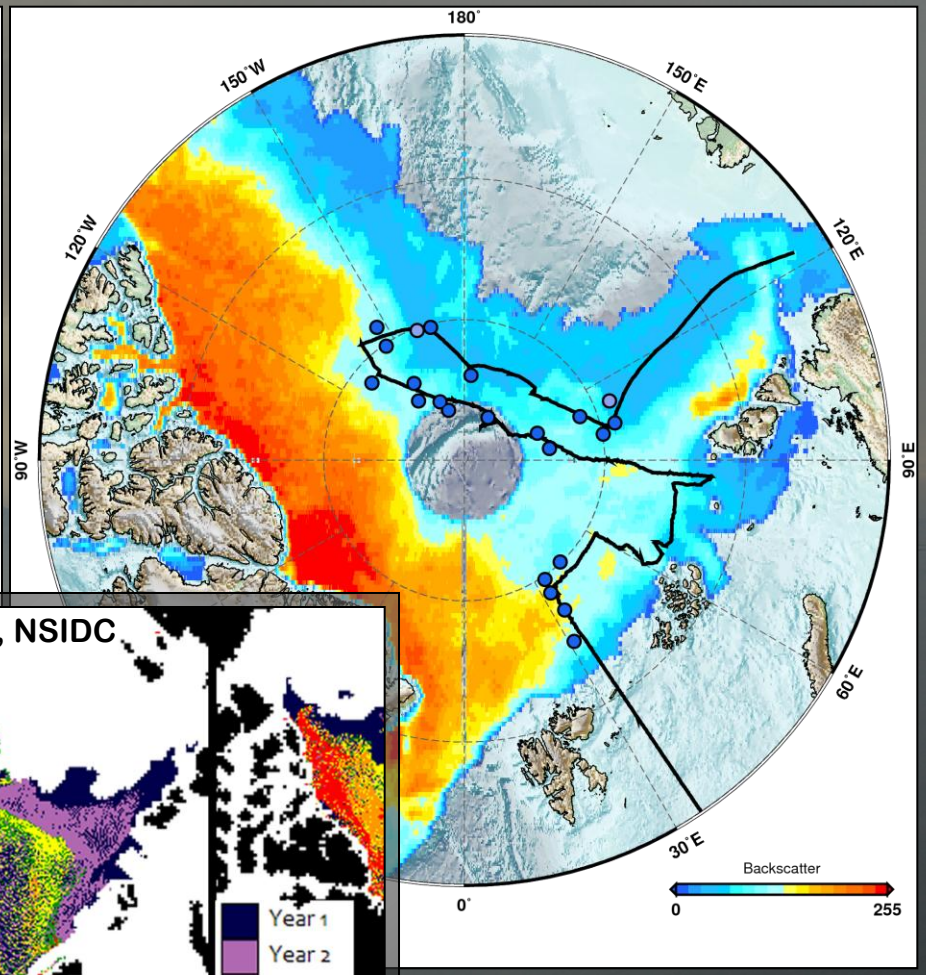
Sea Ice Work

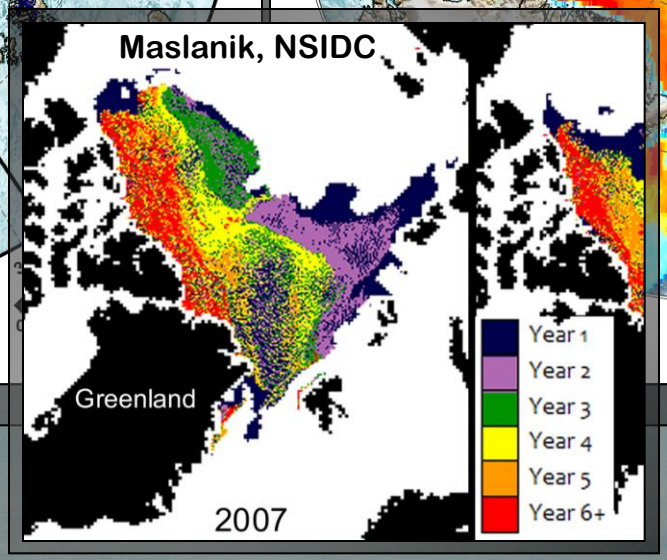
- 22 flights ~ 4000 km
- Ground EM on 12 ice stations
- Drill hole measurements in Russian EEZ



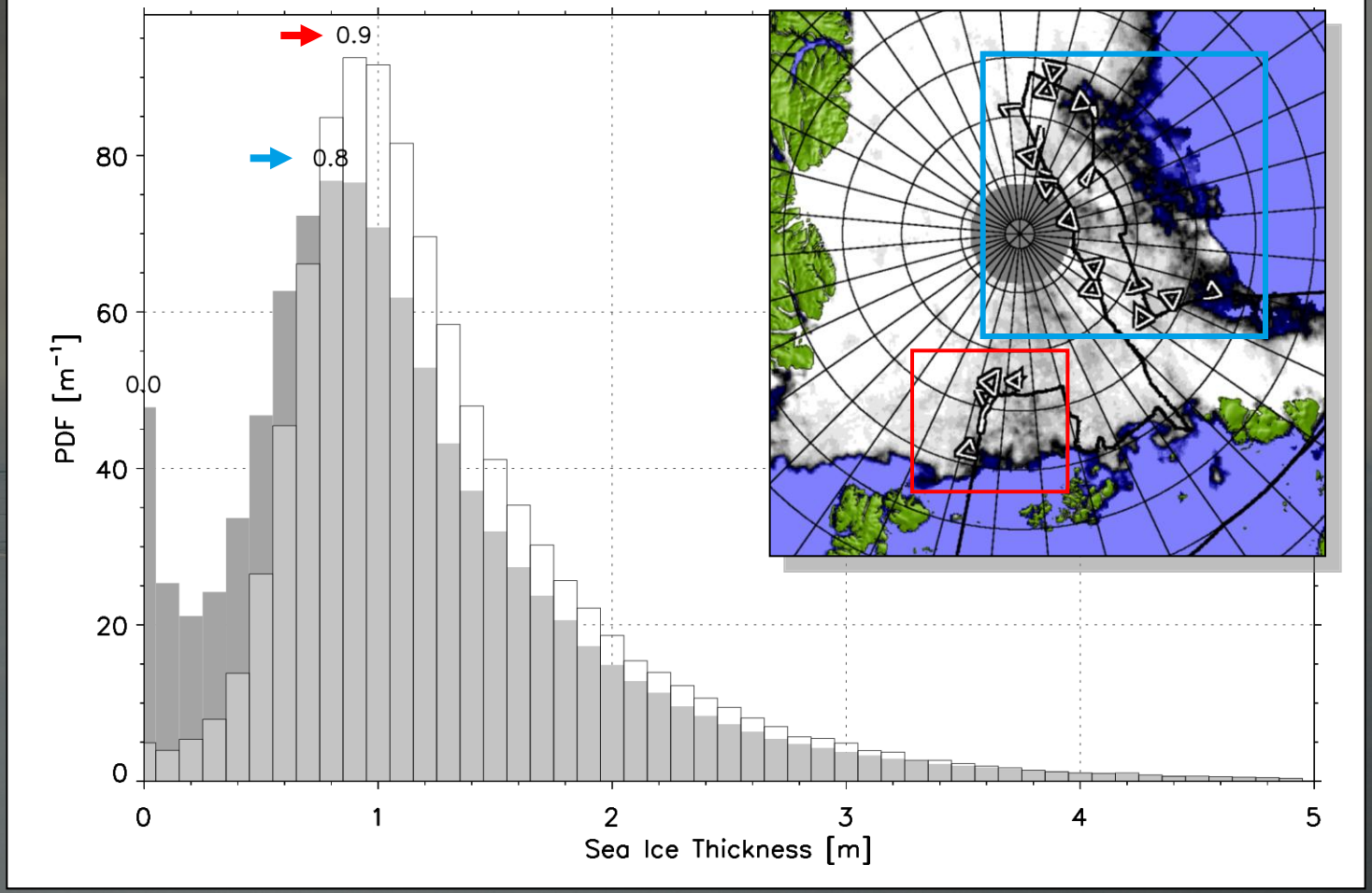
September 2007



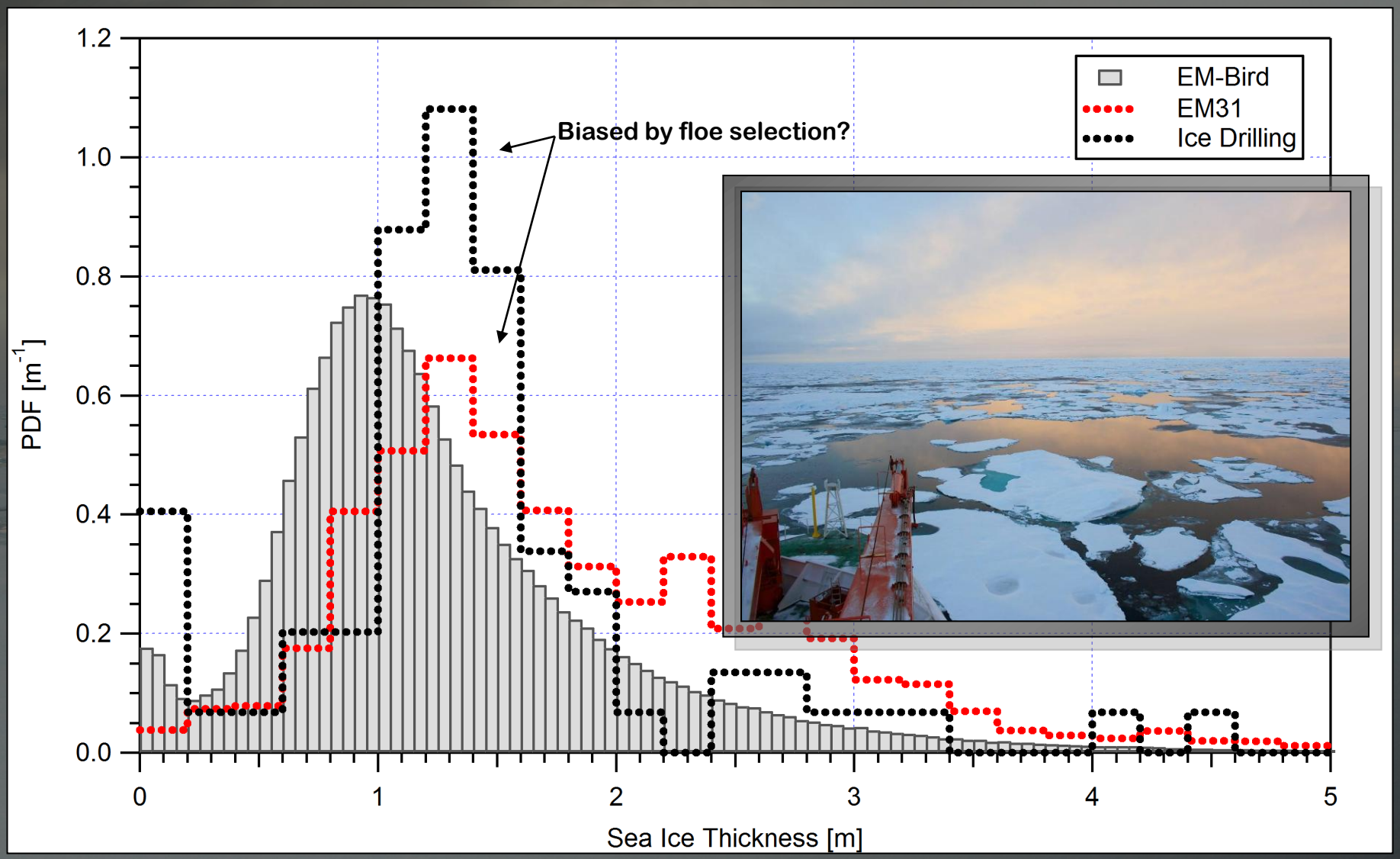




Transpolardrift - Summer 2007

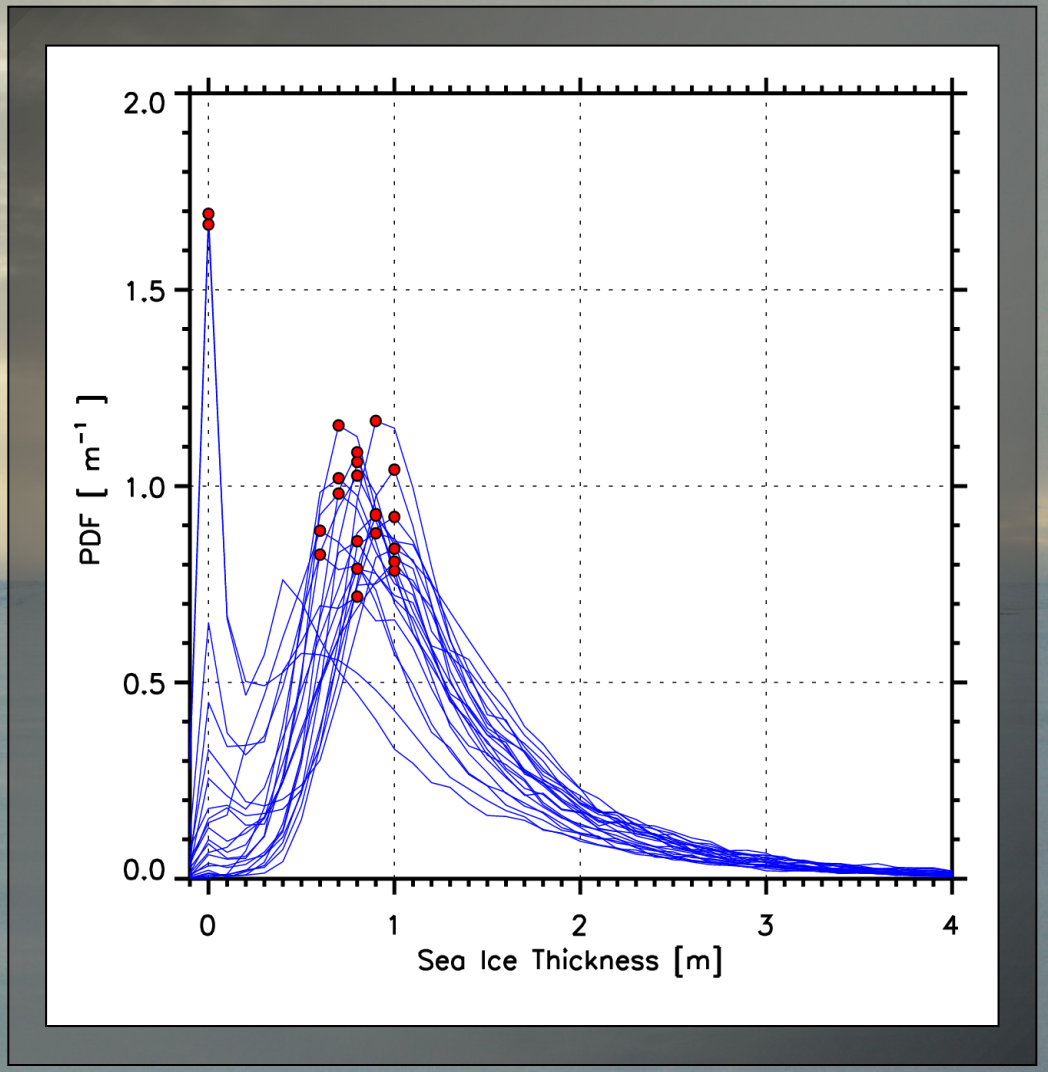


Comparison with Groundbased Methods

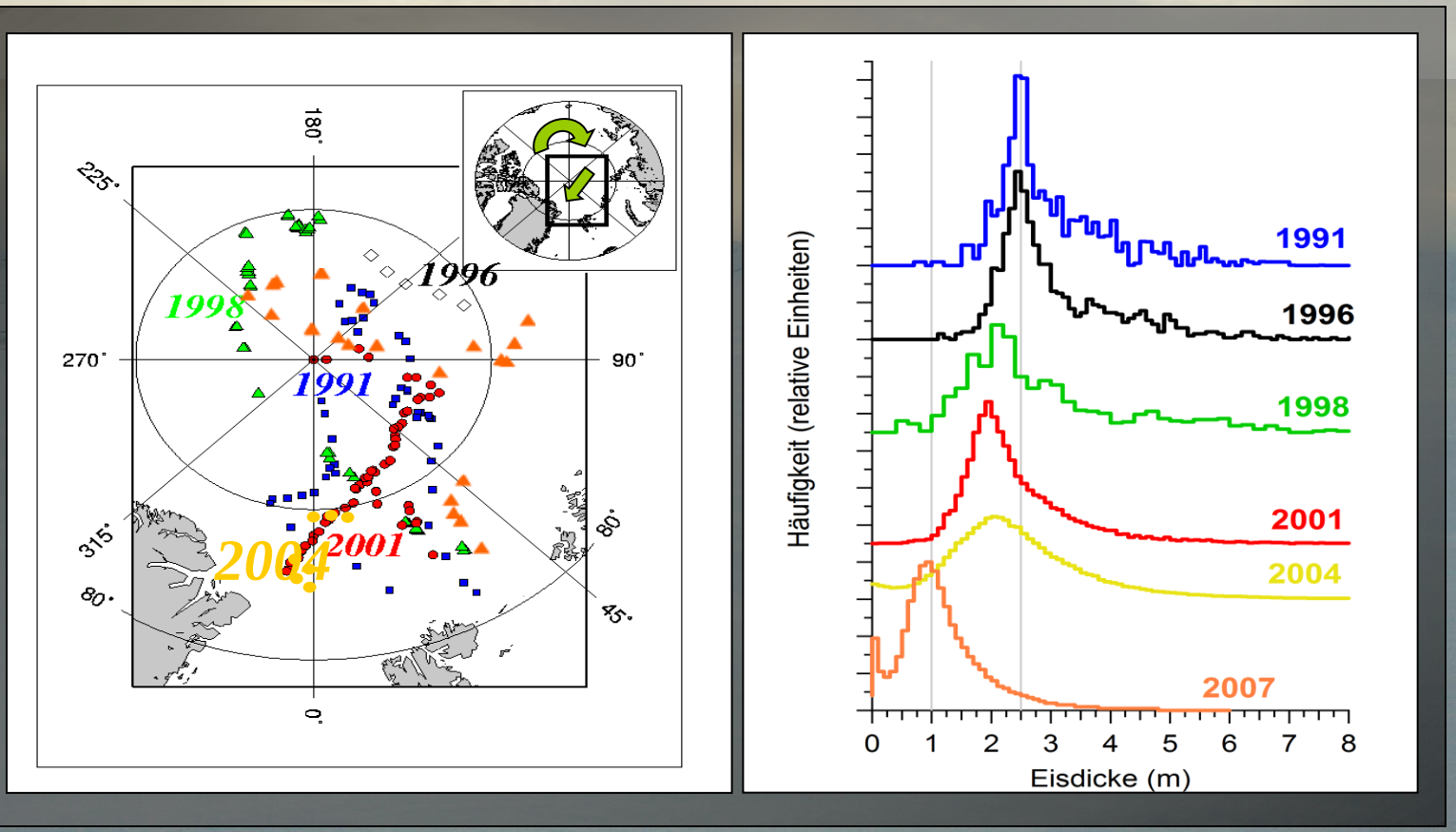


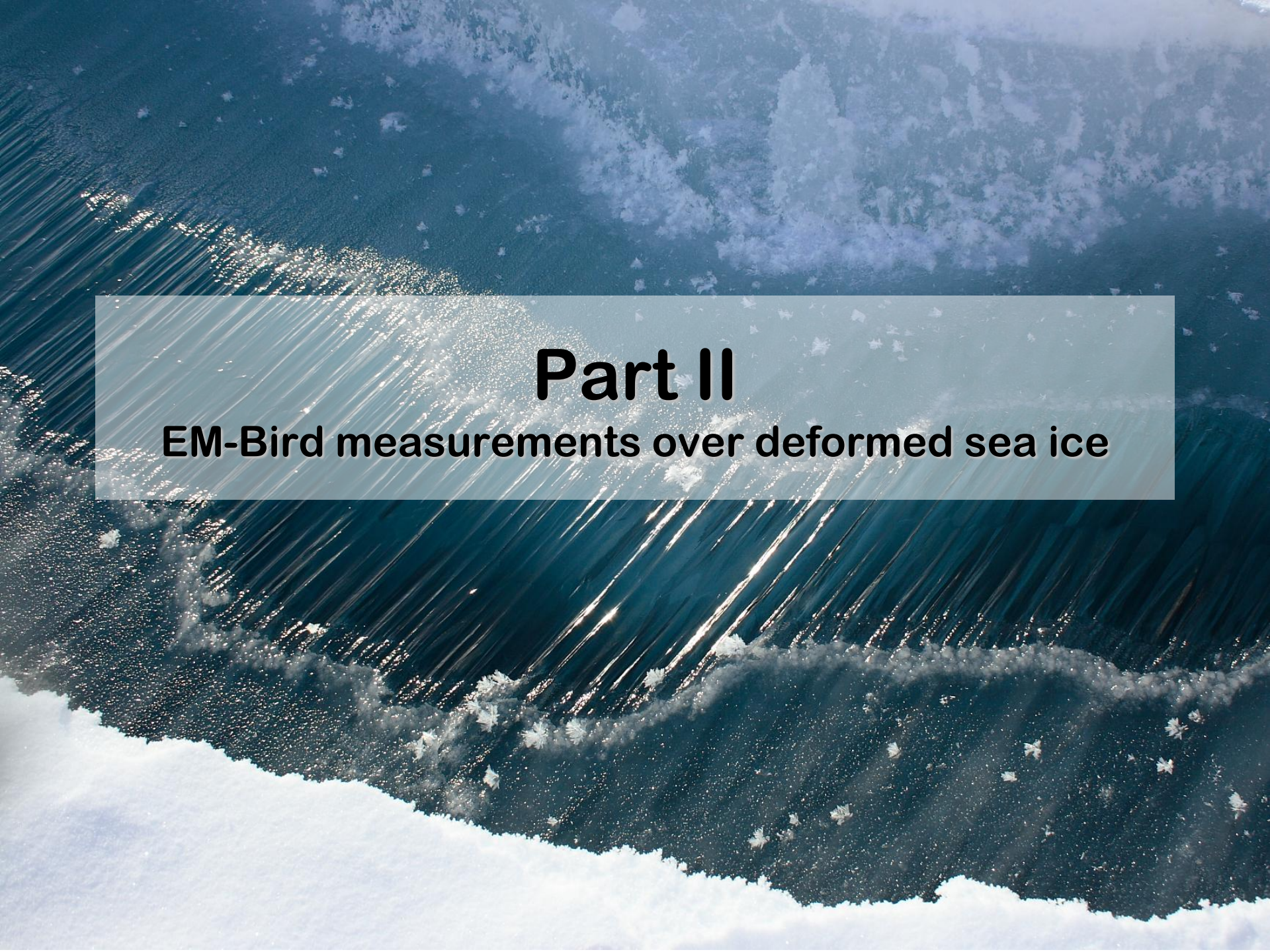
Variability of Thickness Pdf's

- All Modal Thickness values equal or below 1 meter
- 2 profiles at ice edge
- No thick level ice?



- Homogenous ice thickness distribution
  - Modal thickness < 1 m in all profiles
- Decrease of modal thickness from 2.5 m (1991) to 0.9 m (2007) in the Transpolar Drift



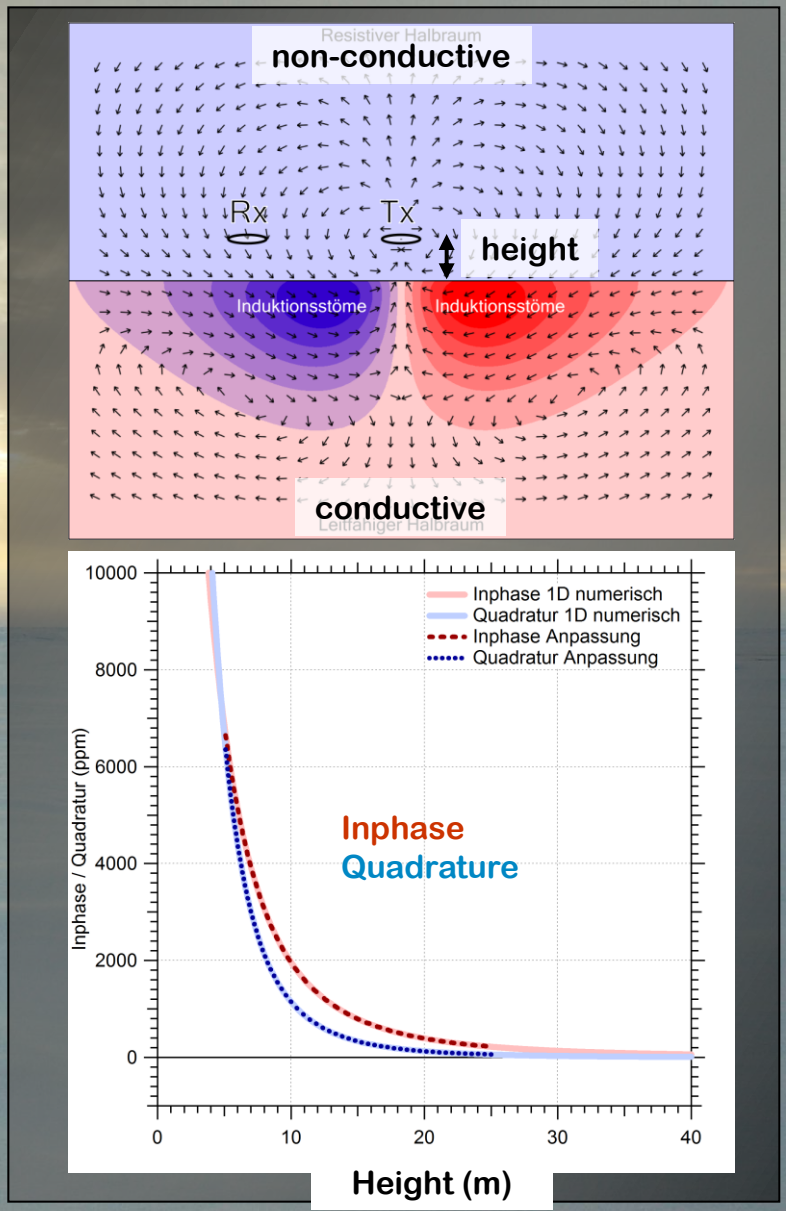


Part II

EM-Bird measurements over deformed sea ice

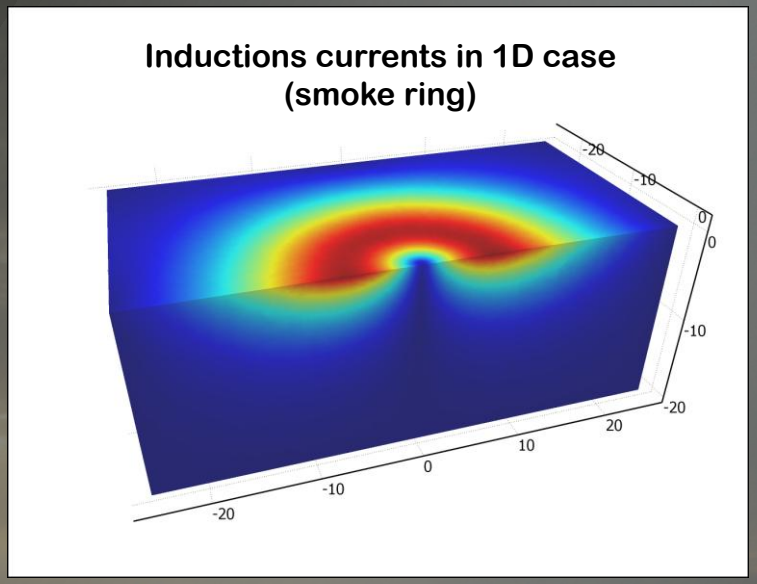
EM Bird data processing

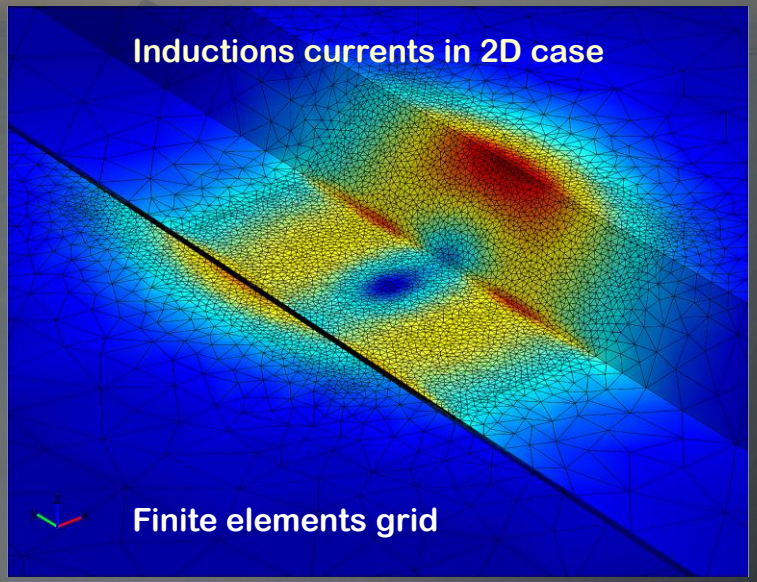
- **Assumptions:**
  - conducticity of sea ice and snow negligible
  - Wide stretched layers: 1D case
- **Complex numerical Solution with Hankel transform**
  - Inphase
  - Quadrature (Apparent conductivity)
- **Direct function of height of instrument with respect to halfspace boundary**
- **Described by double-exponential function**



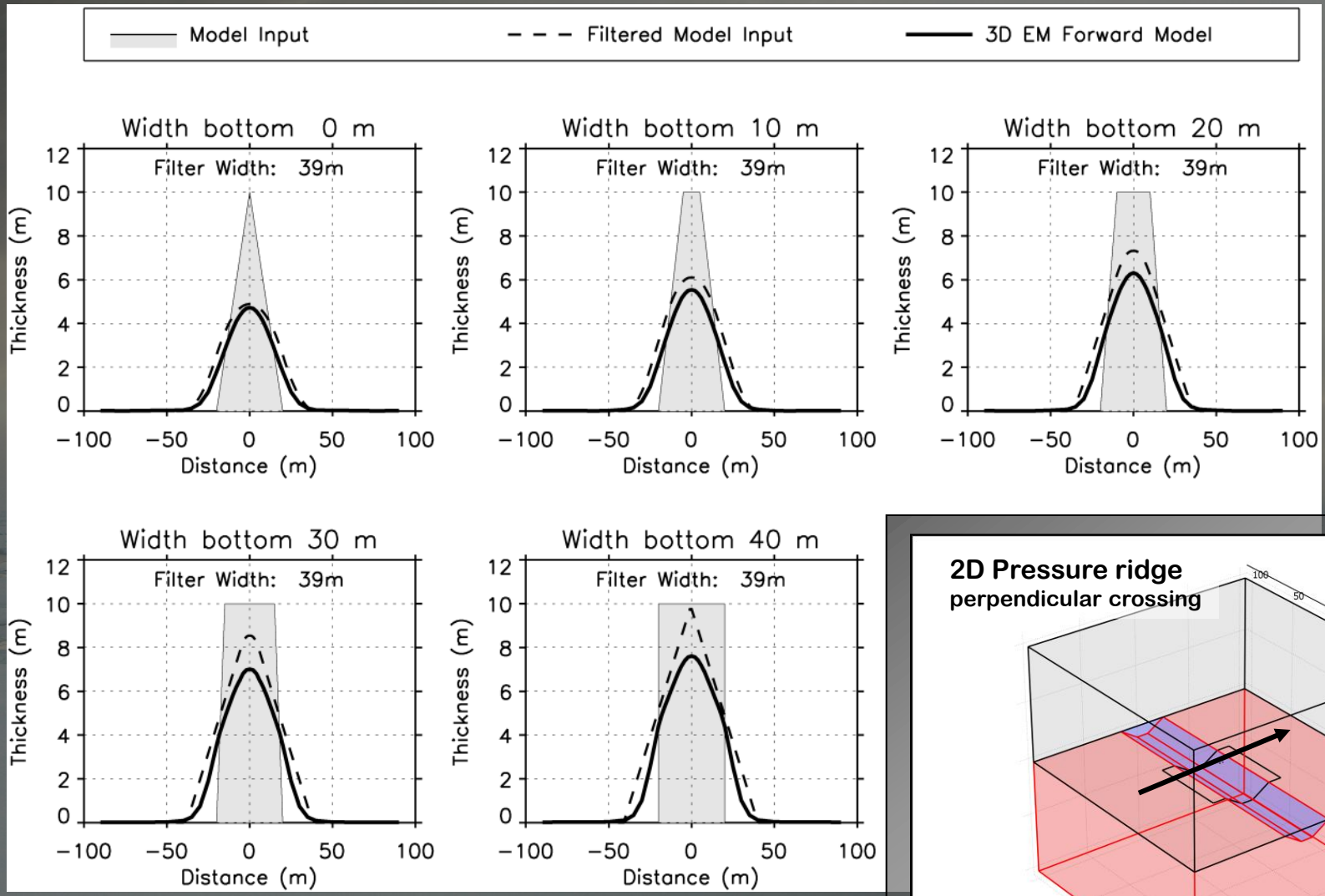
3D EM forward model

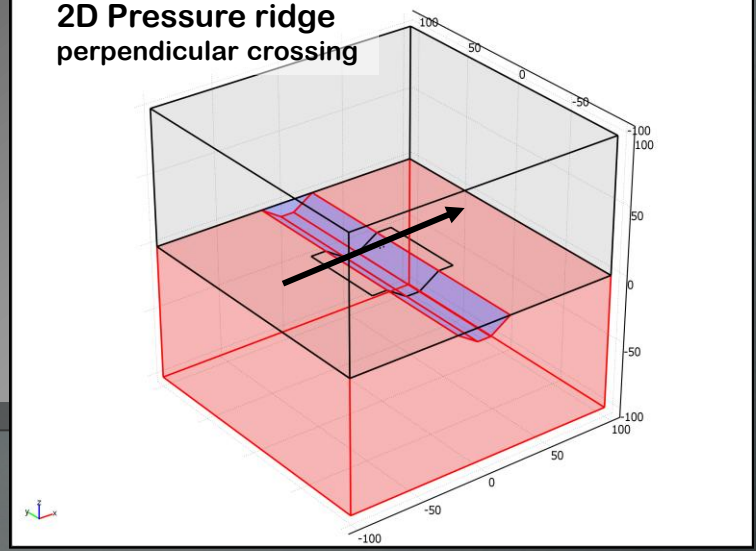
- 1D assumption invalid over deformed
  - Apparent ice thickness
- Error of apparent ice thickness with 3D EM forward model
- *Comsol Multiphysics* commercial software package
  - Magnetostatics, time-harmonic analysis
  - Finite Elements
- Modelling of Inphase and Quadrature component
  - Calculation of ice thickness with 1D approach



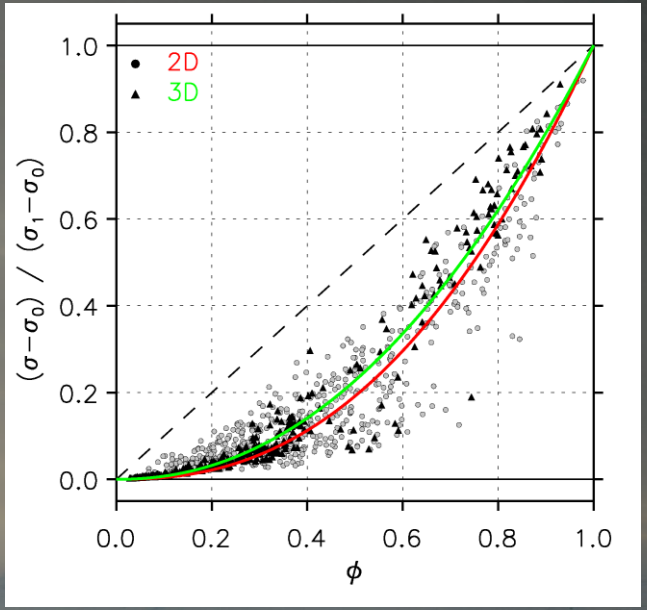


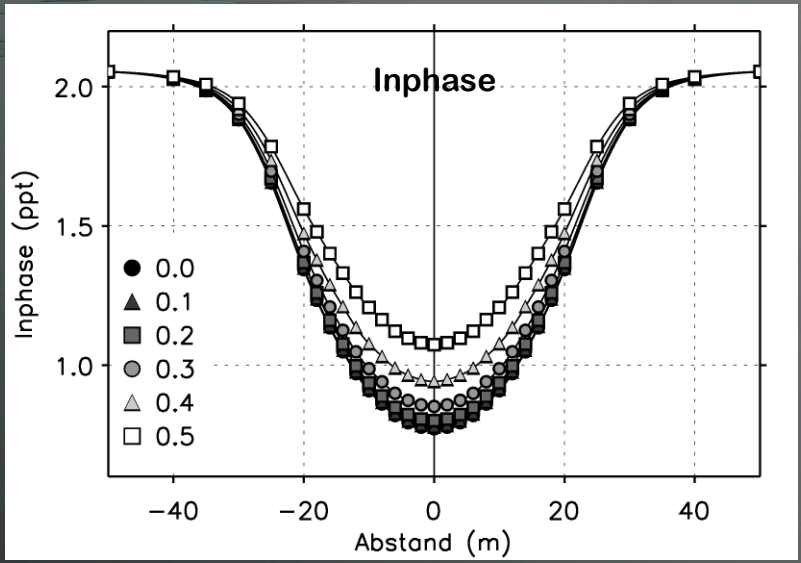
Pressure Ridges: Apparent Sea Ice Thickness

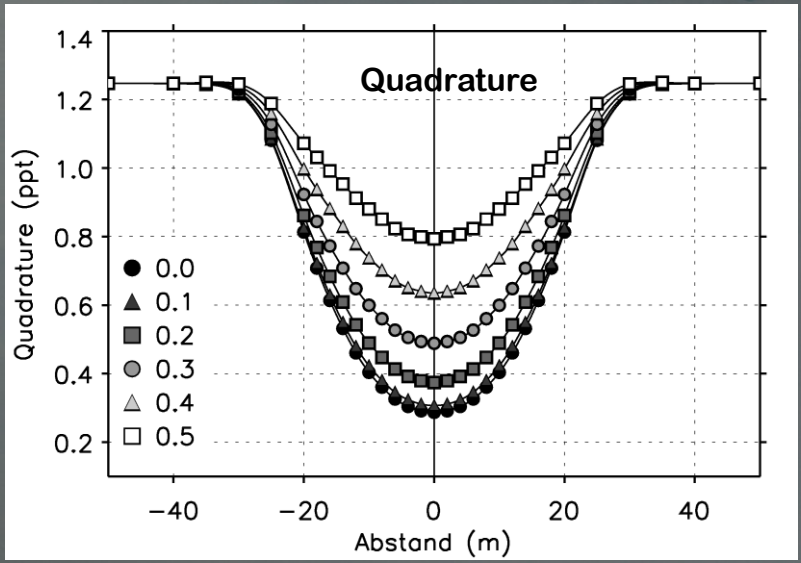




- Porosity – Conductivity Relation
- Inphase less dependent on ridge conductivity than Quadrature

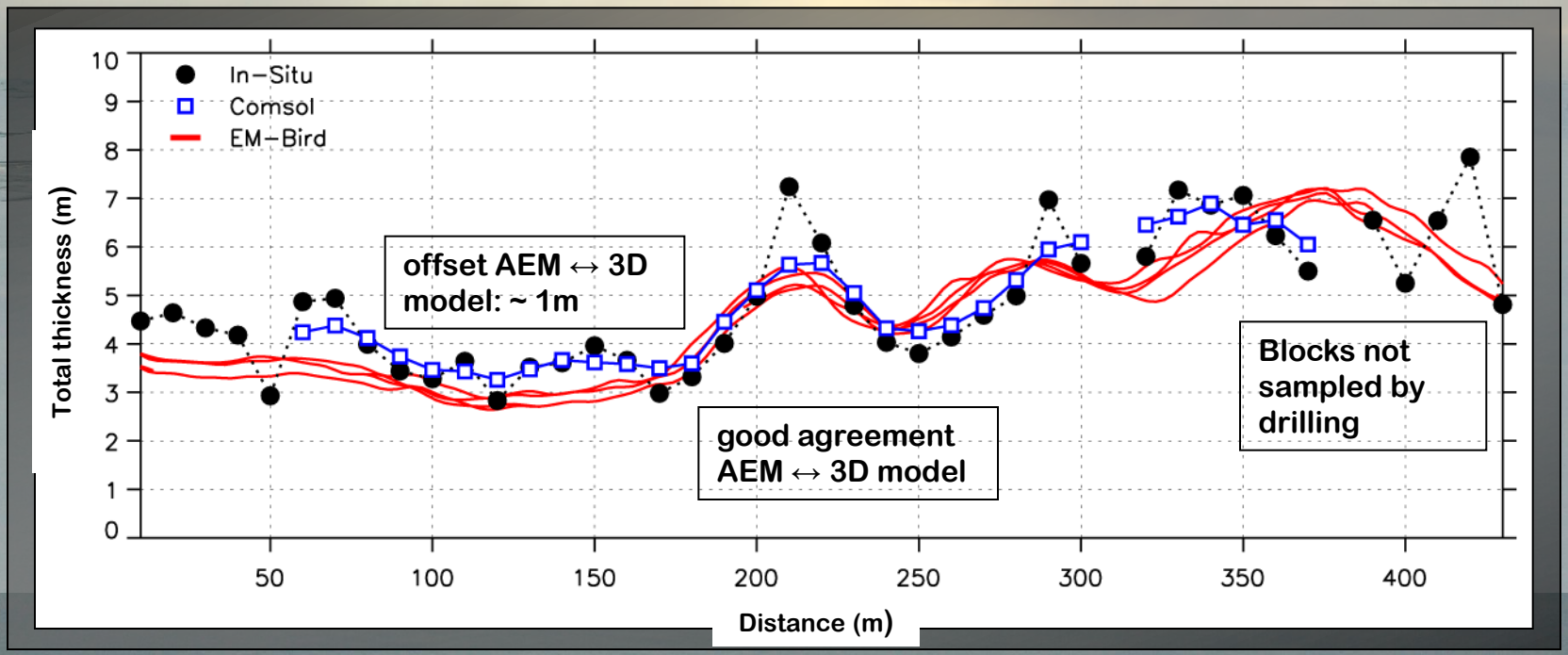






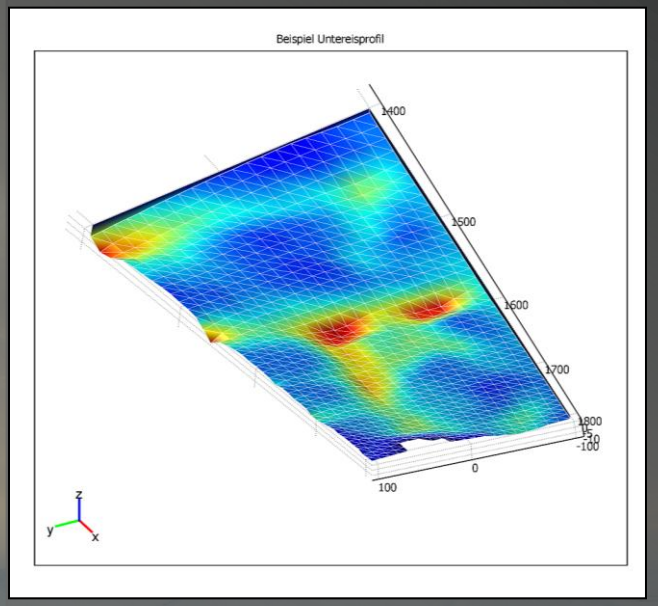
2D Modell from drill profile

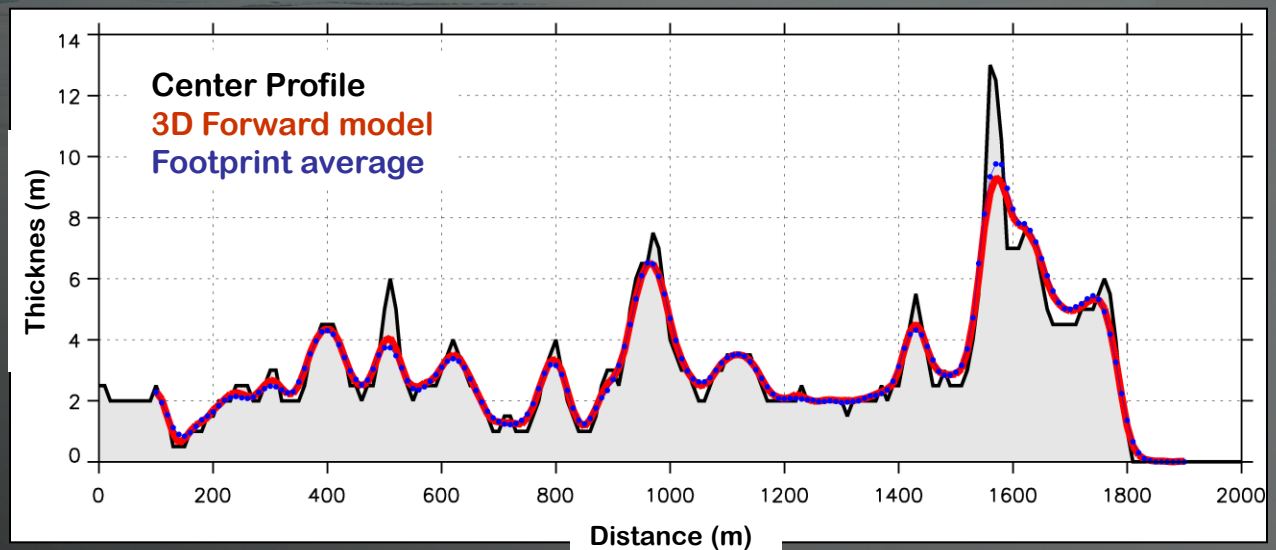
- 3D modell based on drillhole draft profile
- Offset between airborne EM and model data
  - 2D draft profile instead of 3D
  - Non-conductive sea ice
- 3D effects not covered by drillhole line can create a bias of 1 m in airborne data

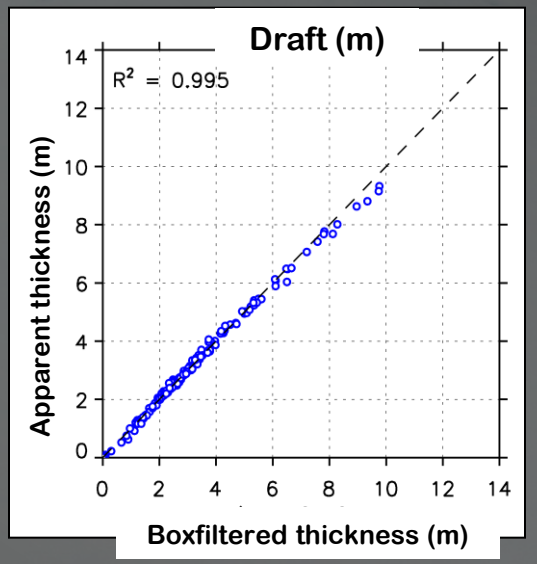


Sea ice draft profile

- Feasibility study of 3D draft profile
- Apparent thickness very well represented by 2D mean over footprint







- Underestimation of maximum ridge thickness due to
  - Footprint smoothing
  - Invalid 1D assumption
- Weighting between both effects depends on geometry
  - footprint dominates for weaker ice thickness gradients
- Mean EM thickness mainly conserved
- Inphase and Quadrature show different sensitivity to ice conductivity

Thank you …