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

Airborne sea ice thickness sounding

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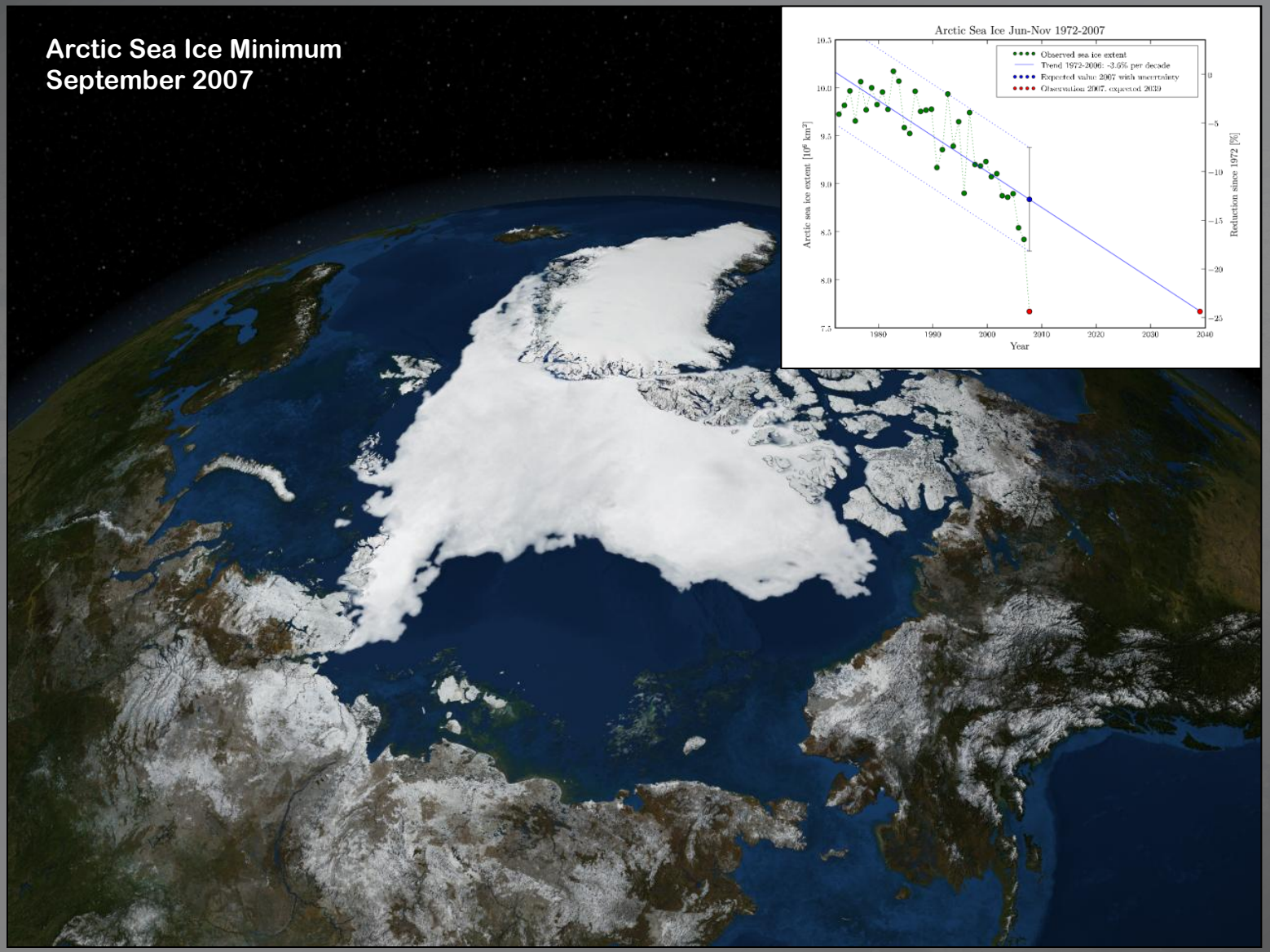
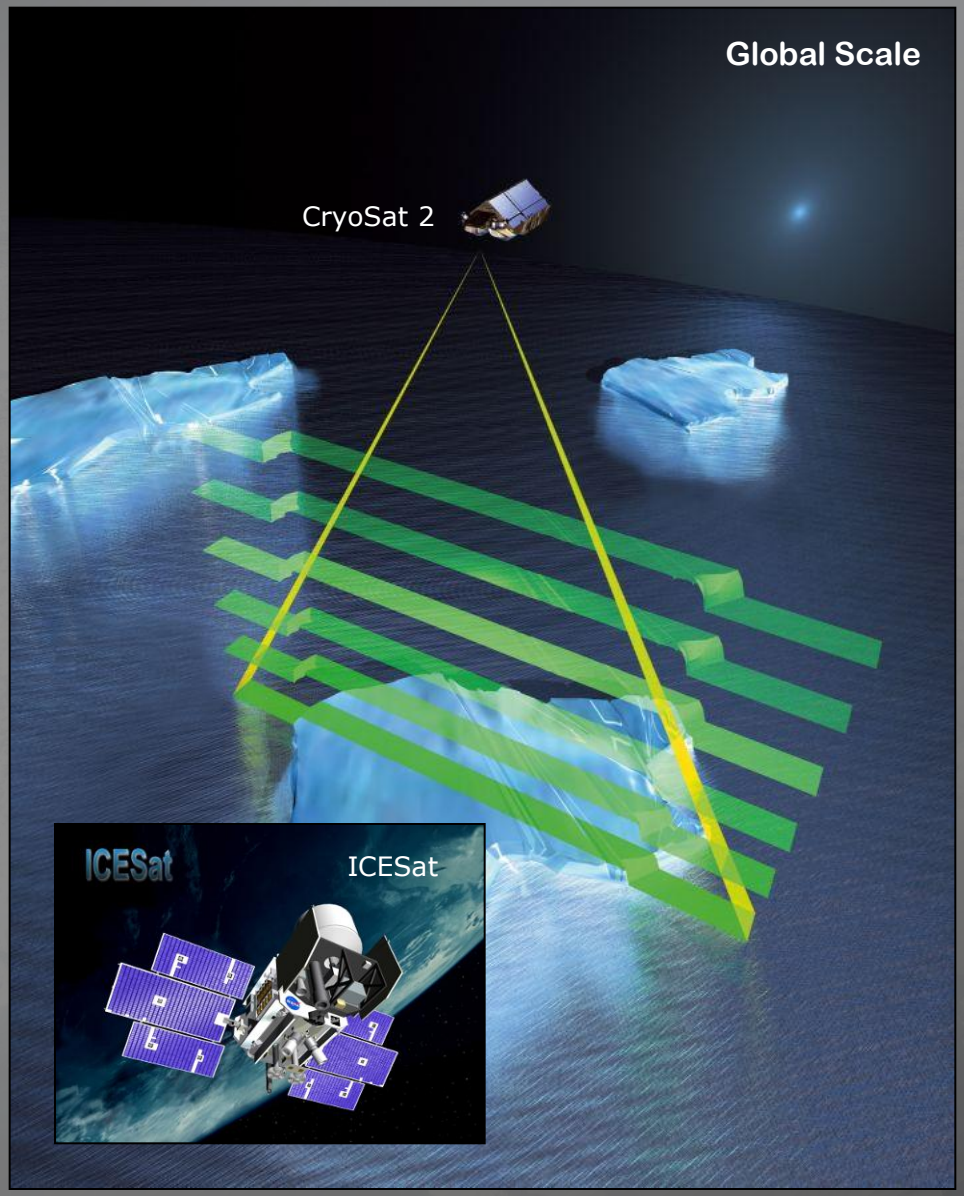
2. University of Alberta, Canada
3. Ferra Dynamics Inc., Canada

Arctic Sea Ice

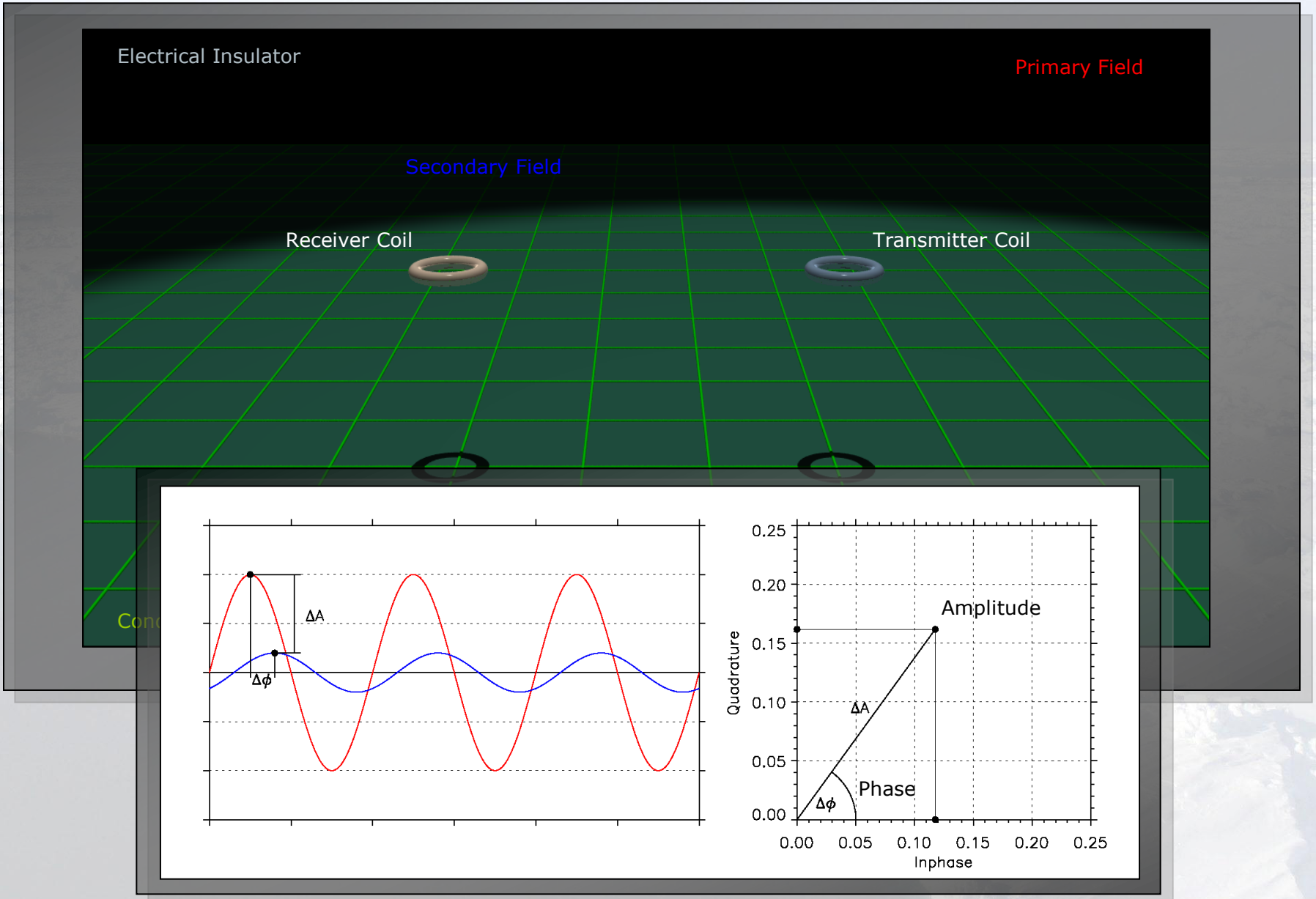


Sea Ice Thickness Retrieval

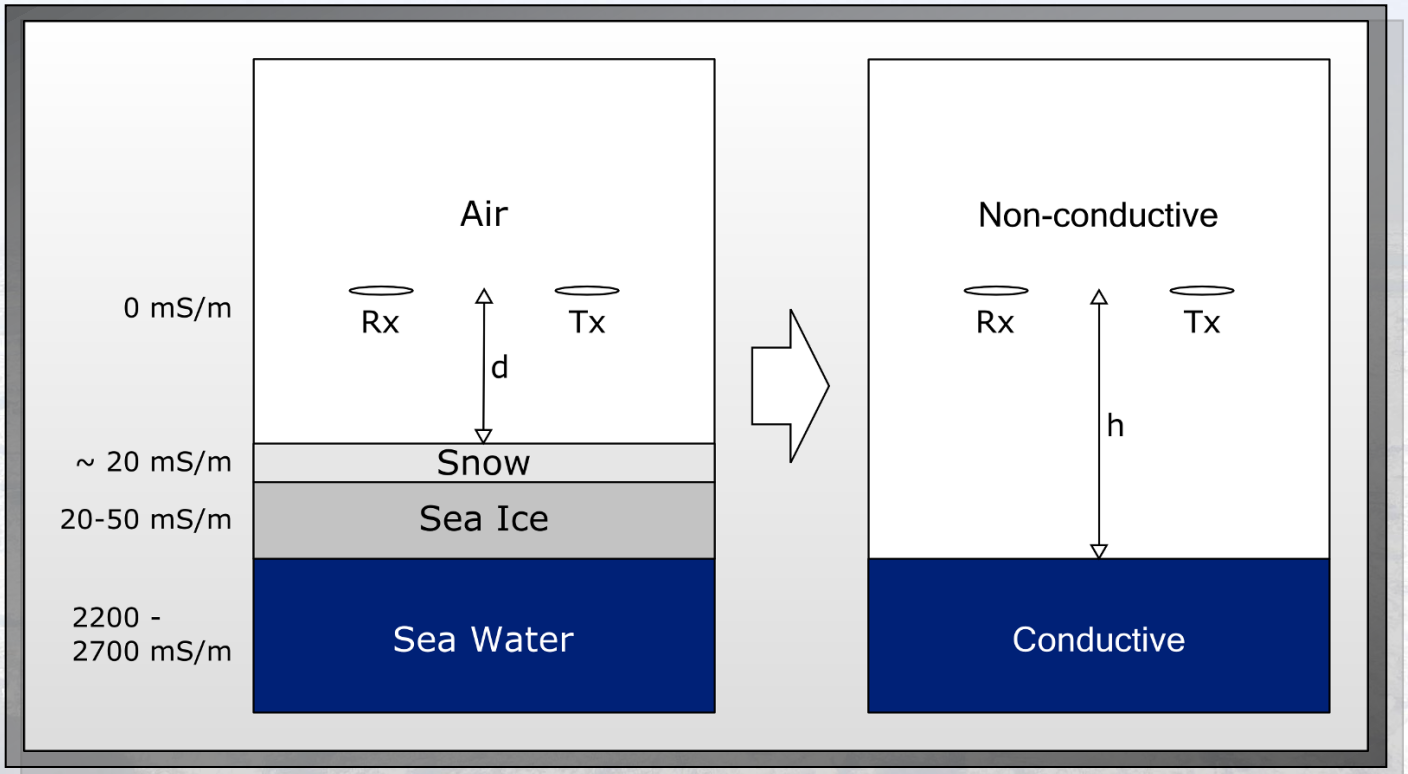
Sea Ice Physics
Stefan Hendricks
AWI



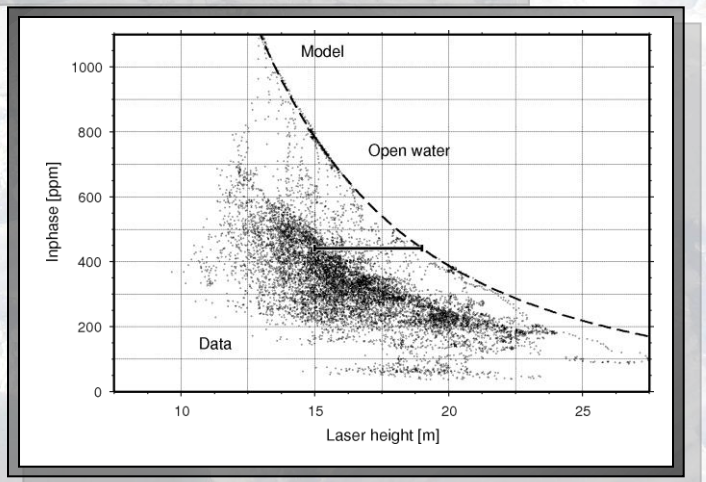
Principle: Frequency EM



EM: Application on Sea Ice



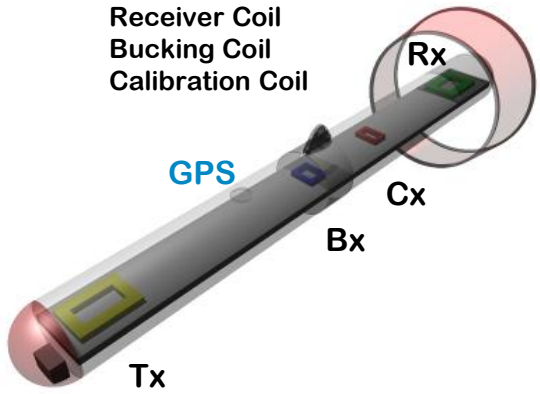
- **High conductivity contrast between sea water & other media**
- **Conductivity in sea ice anisotropic (brine channels)**
- **Assumption even valid for areas with low salinity (e.g. Baltic Sea)**



Groundbased EM

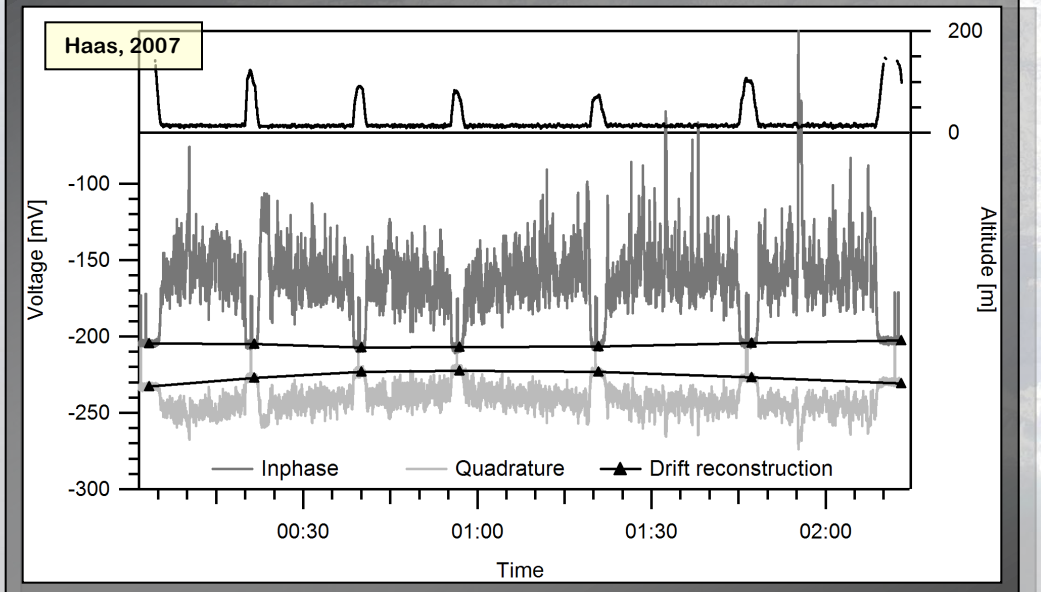
- **Standard instrument: Geonics EM31**

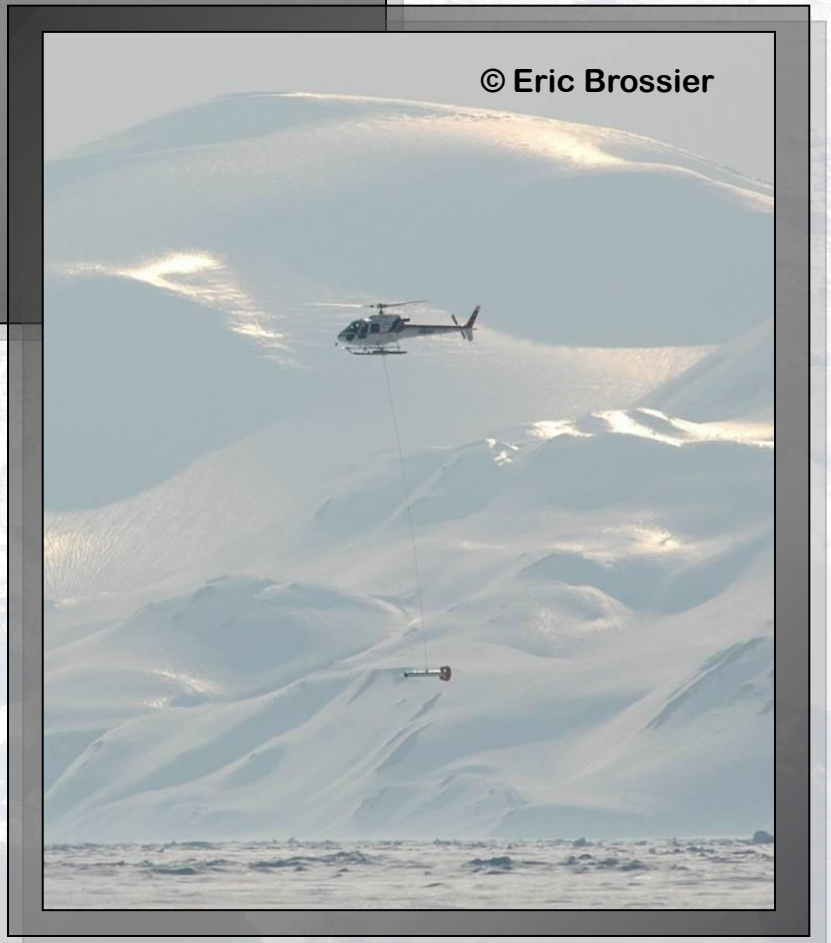
Tx Transmitter Coil
Rx Receiver Coil
Bx Bucking Coil
Cx Calibration Coil



Laseraltimeter

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





EM – Bird: Operations

Land Based

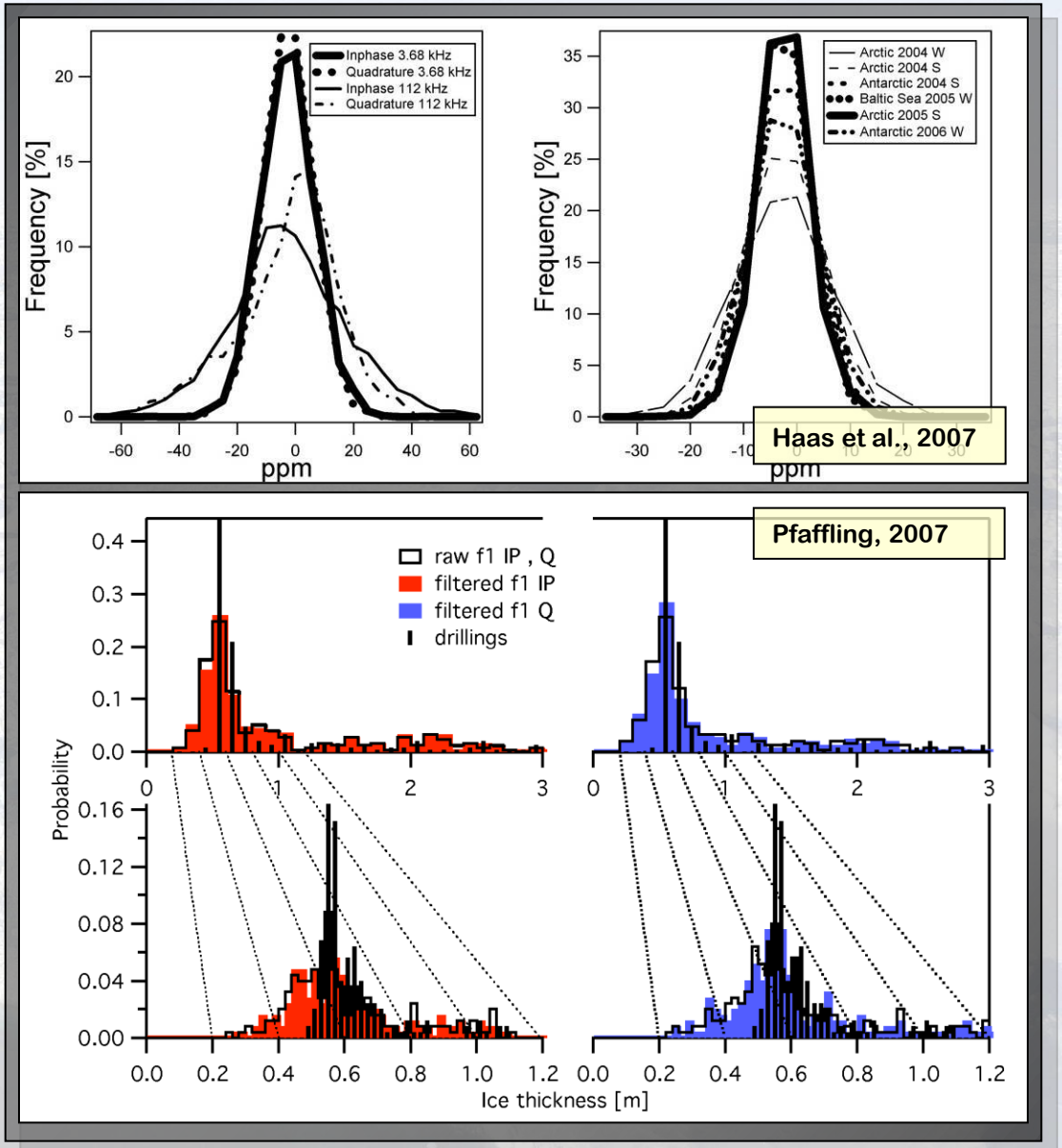
Various types of helicopters

Ship Based

Ice Camp

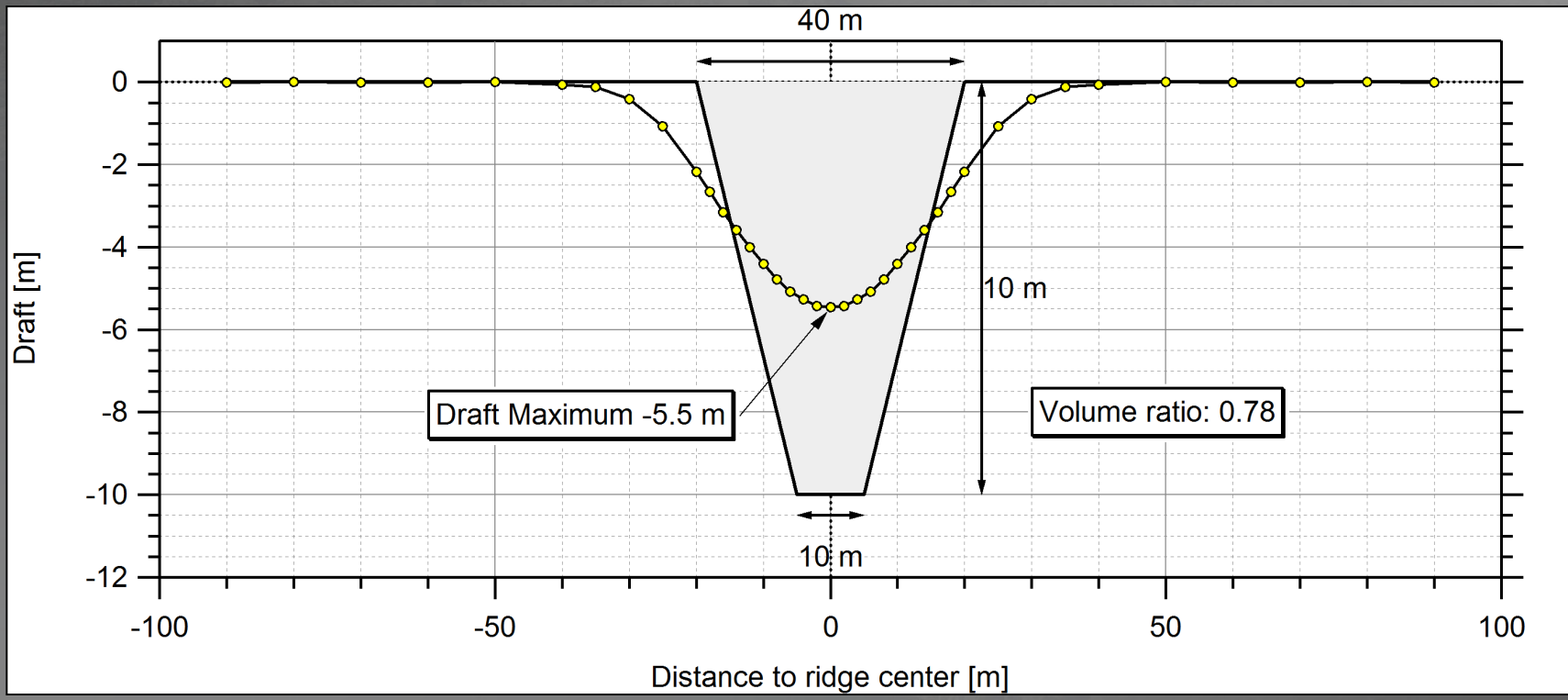
EM Bird – Accuracy

- **Instrument errors**
  - Noise
  - Temperature changes
  - Pitch & Roll
- **Other error sources**
  - Conductivity Variations (bottom melting)
  - Sea Ice Porosity
- **Over Level Ice**
  - Noise ± 5 cm
  - Accuracy ± 10 cm



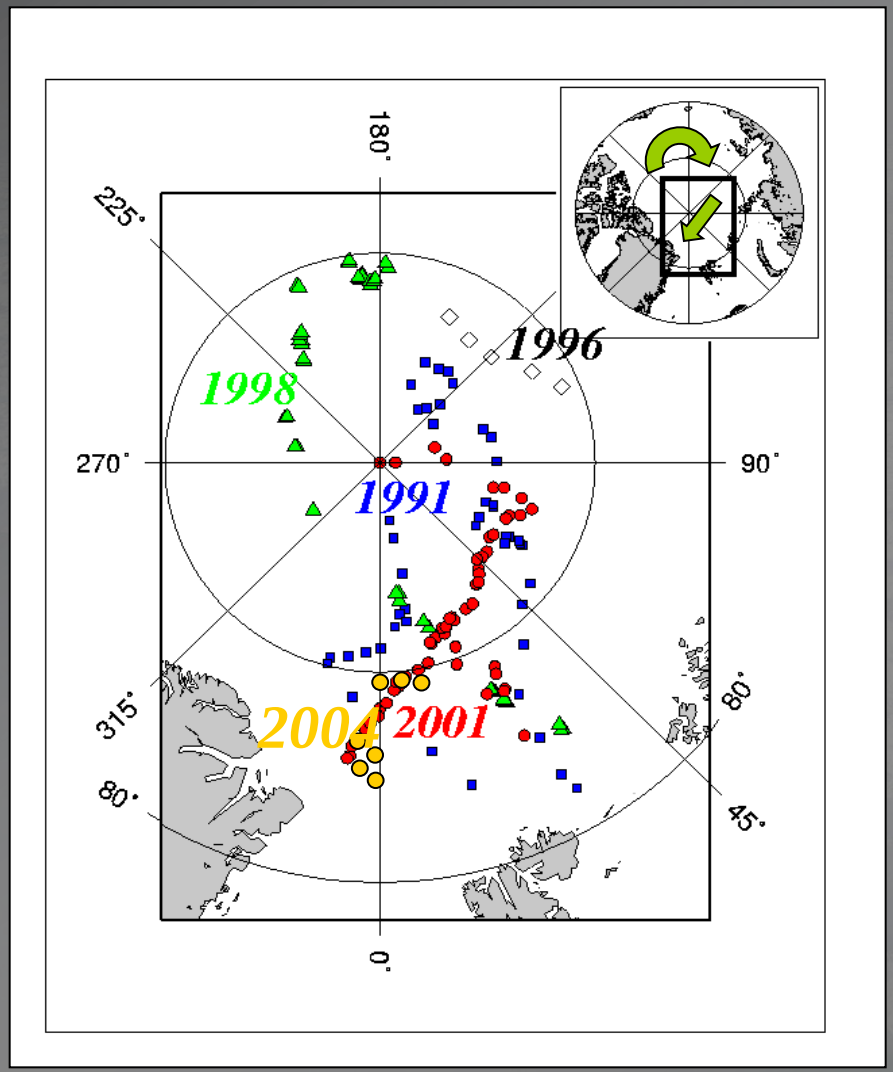
EM Bird – Limitations

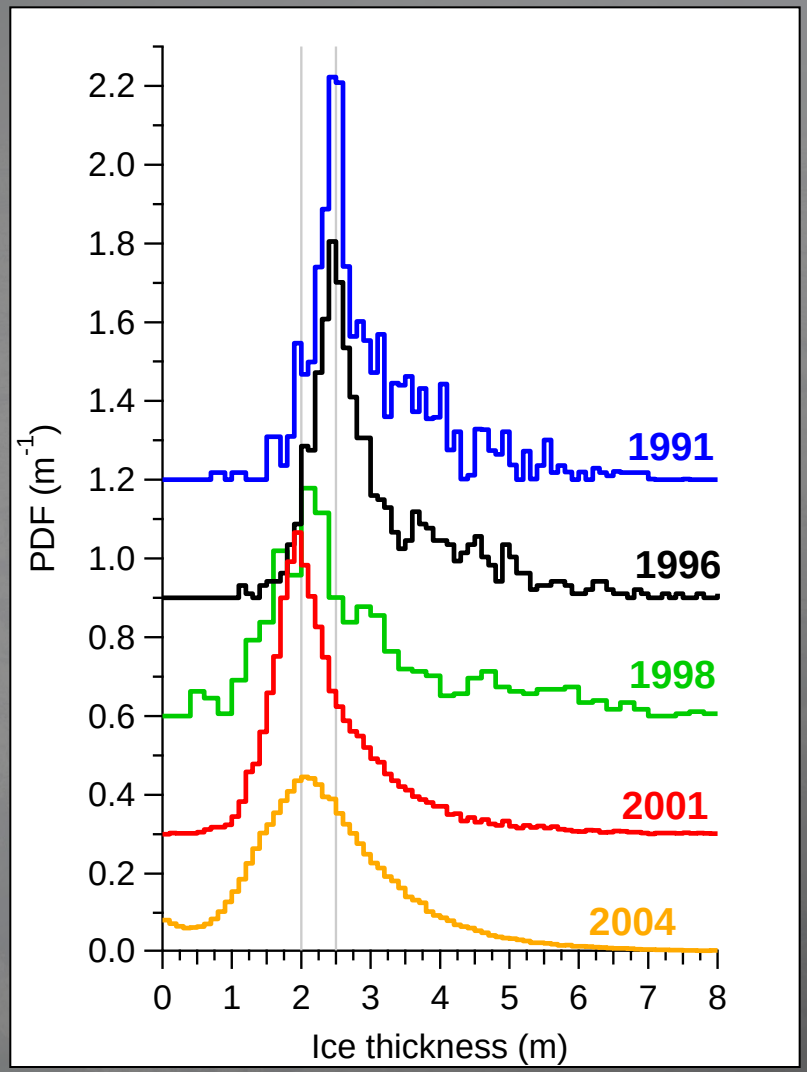
- Footprint ~ 4 × instrument altitude
- Smoothing of underice topography
- Underestimation of pressure ridge thickness ~ 50 %



3D Modelling: Comsol Multiphysics

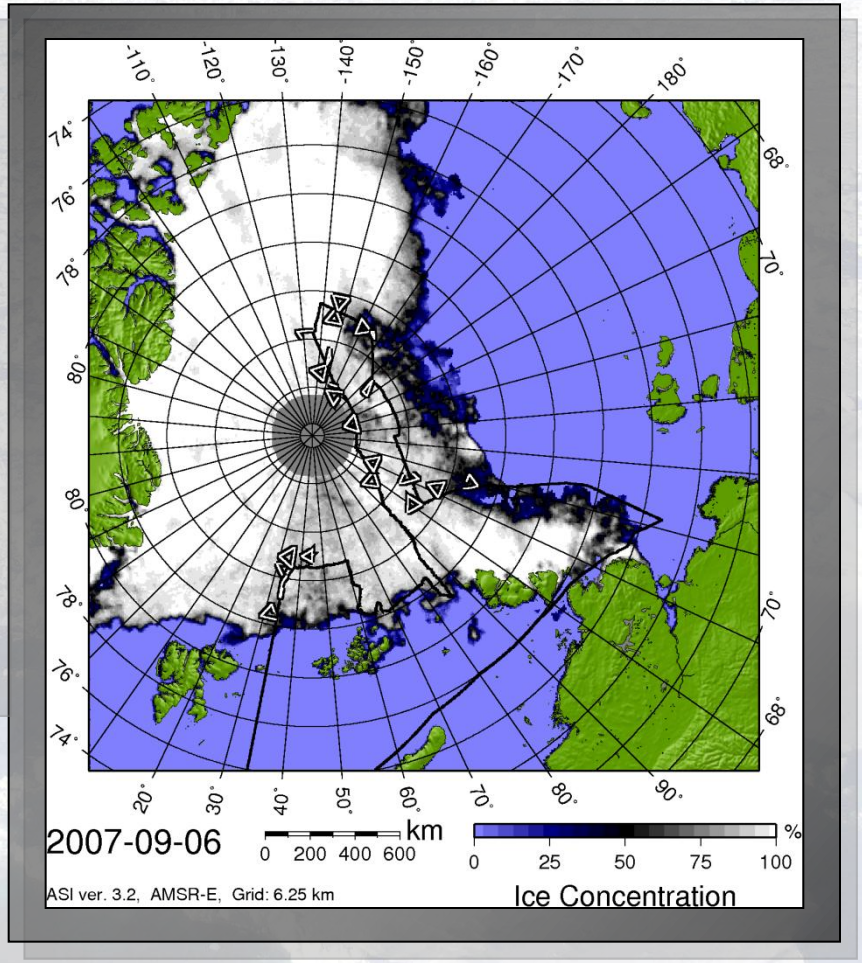
Sea Ice Thickness Transpolardrift

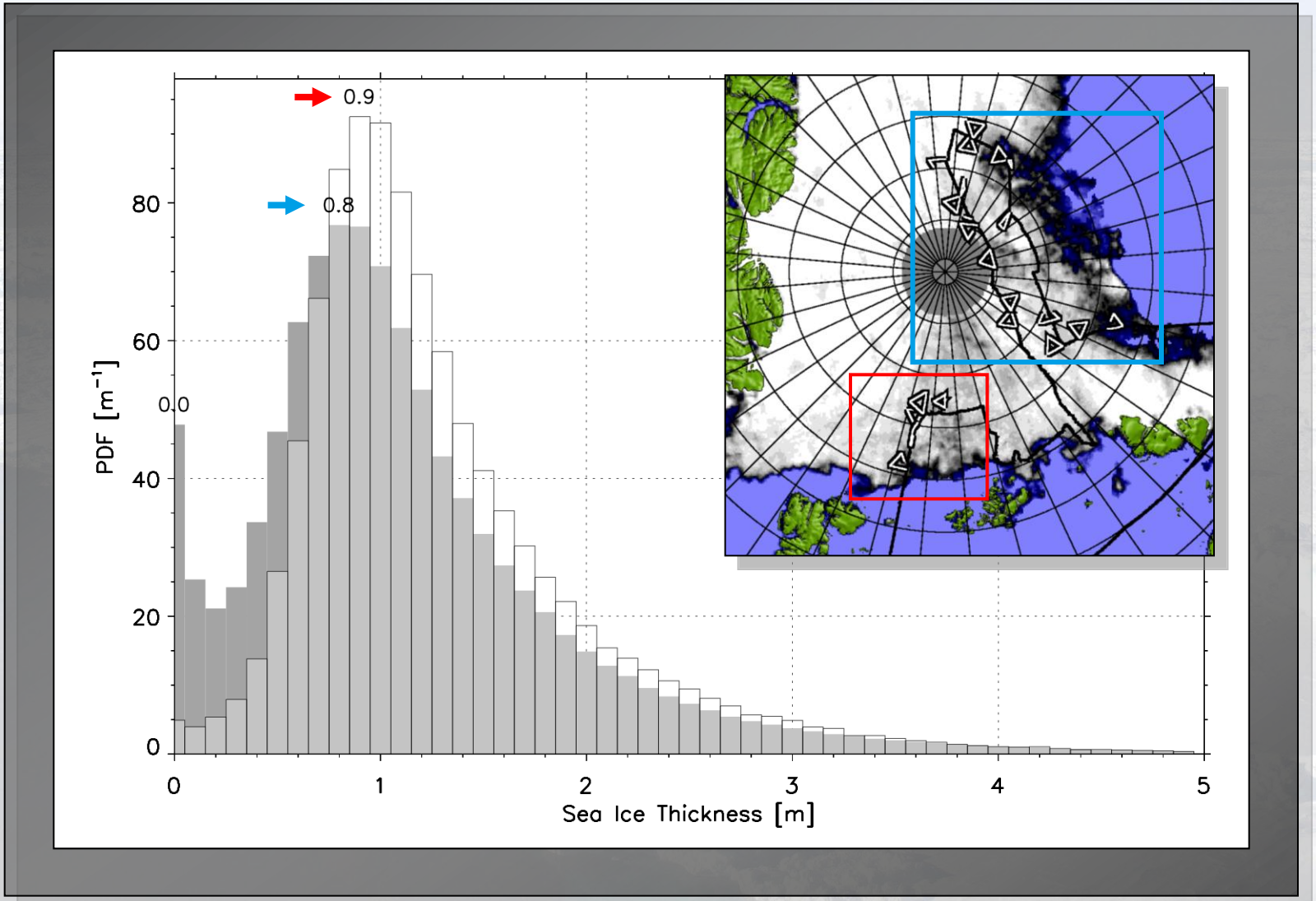




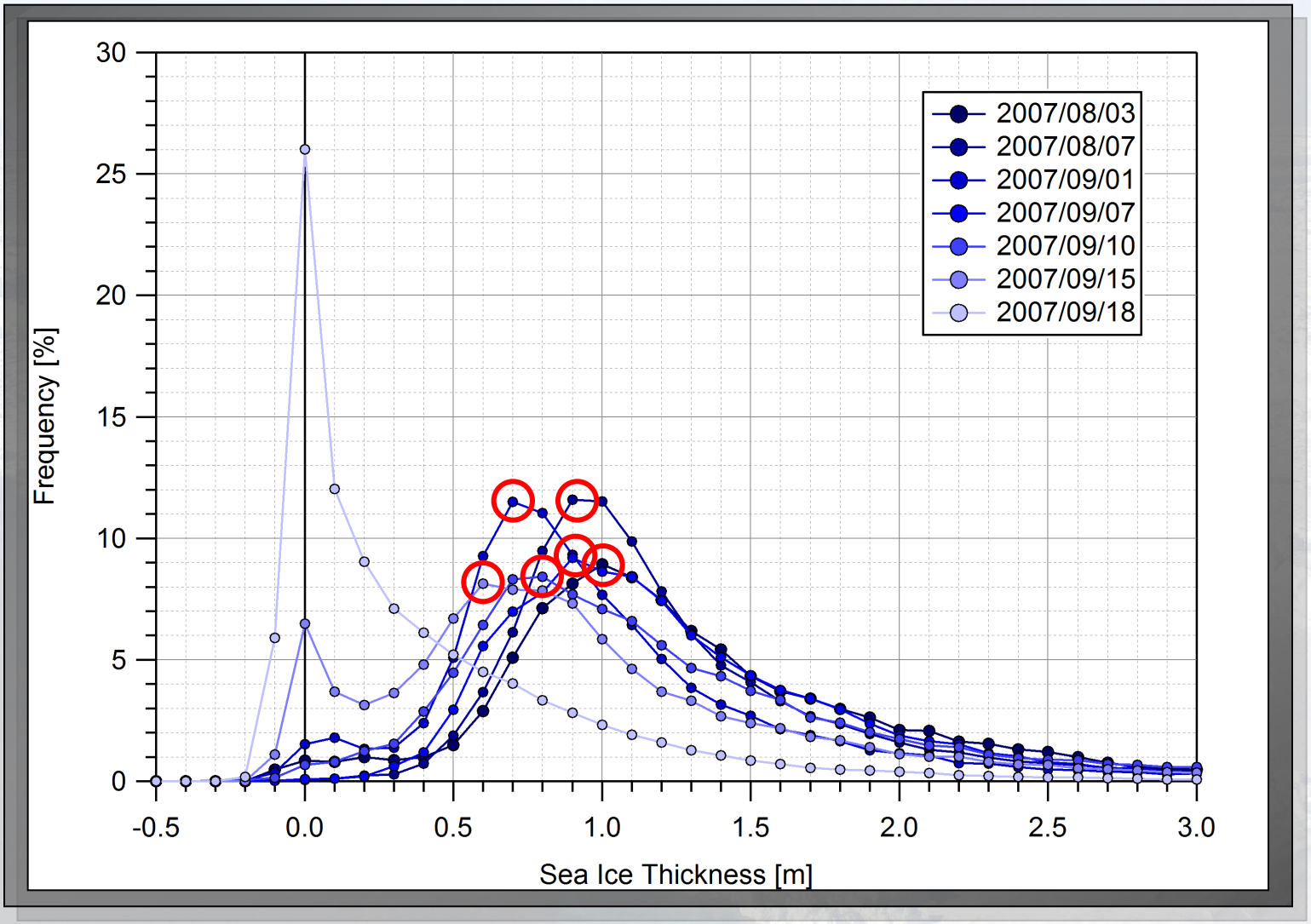
Haas, 2004

- **IPY Polarstern Arctic Cruise Summer 2007**
  SPACE (Synoptic Pan-Arctic Climate and Enviroment Study)



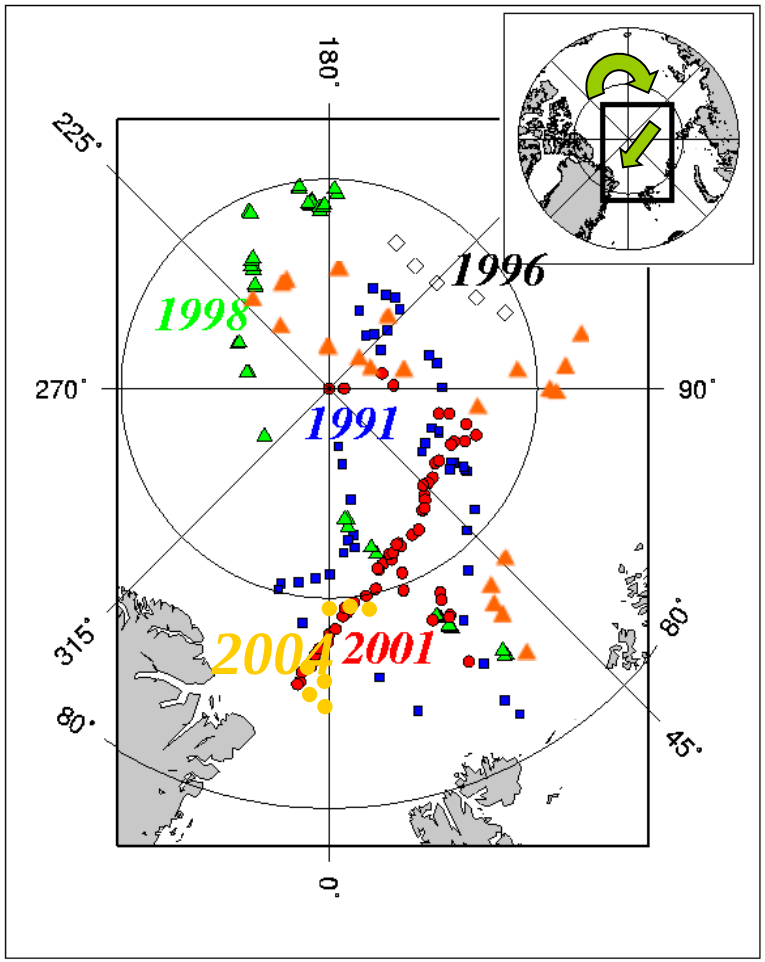

0.9
0.8
0.0
80
60
40
20
0
PDF [m^{-1}]
0
1
2
3
4
5
Sea Ice Thickness [m]

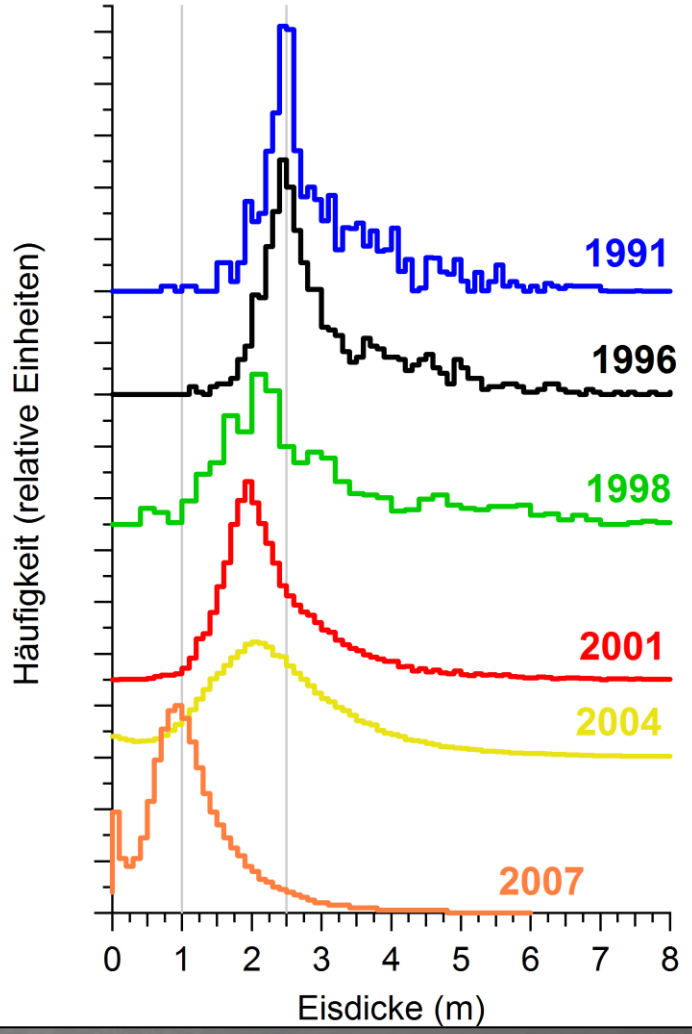
Variability of Thickness Pdf's



Sea Ice Thickness Transpolardrift (incl. 2007)

Sea Ice Physics
Stefan Hendricks
AWI





Comparison with Groundbased Methods

Sea Ice Physics
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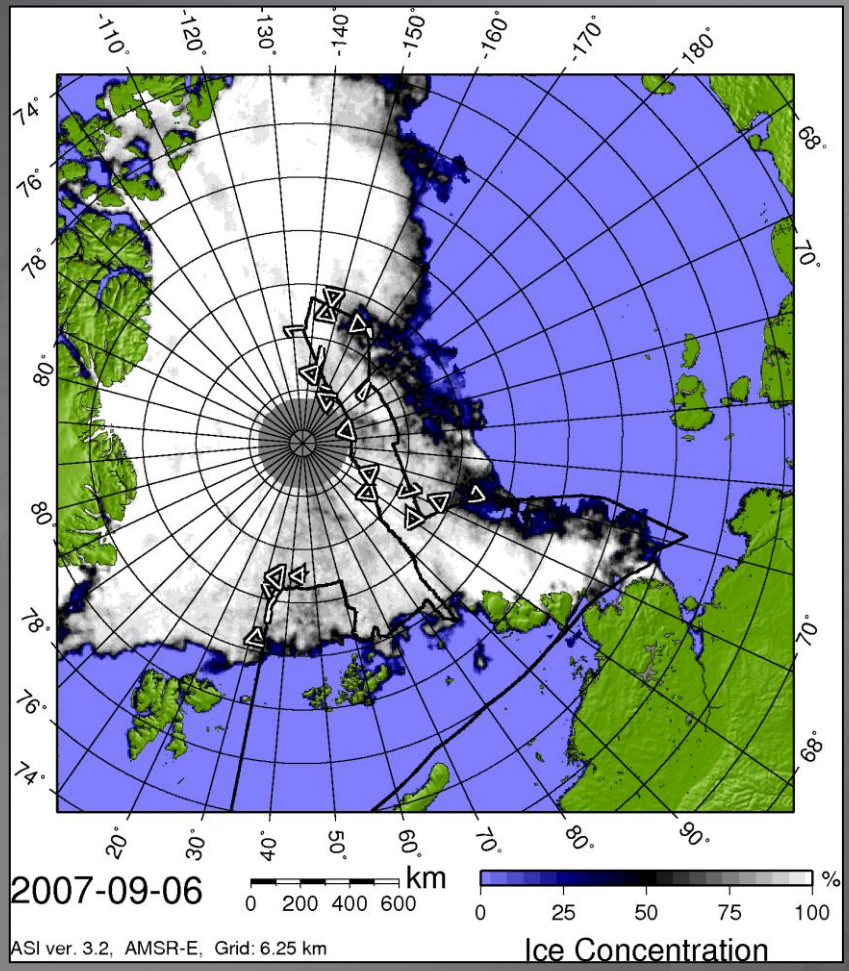
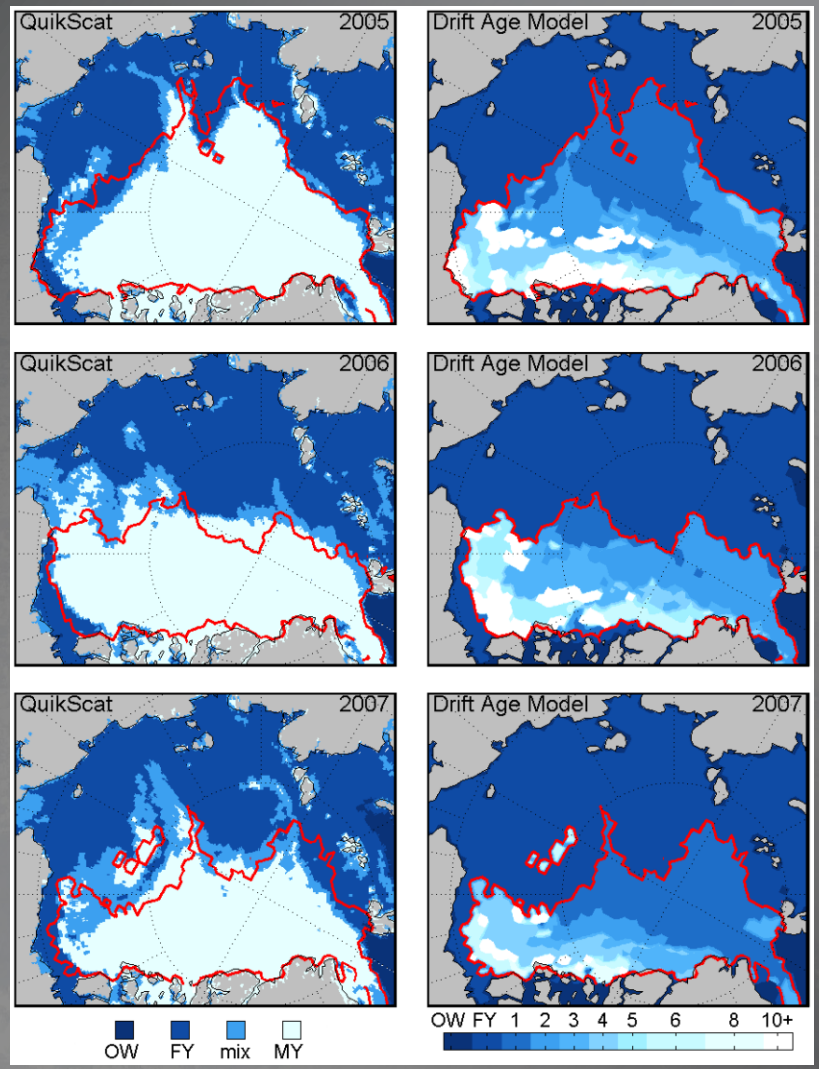
AWI

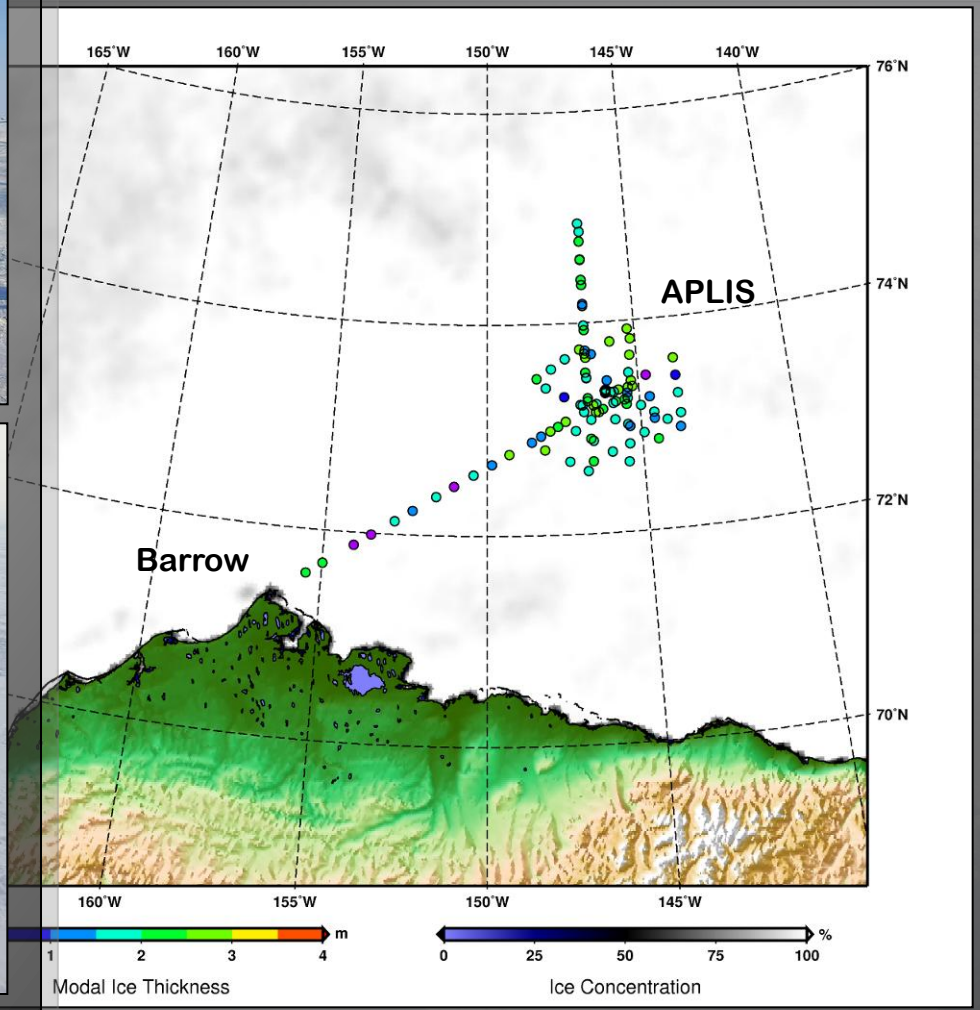
Retreat of Perennial Sea Ice

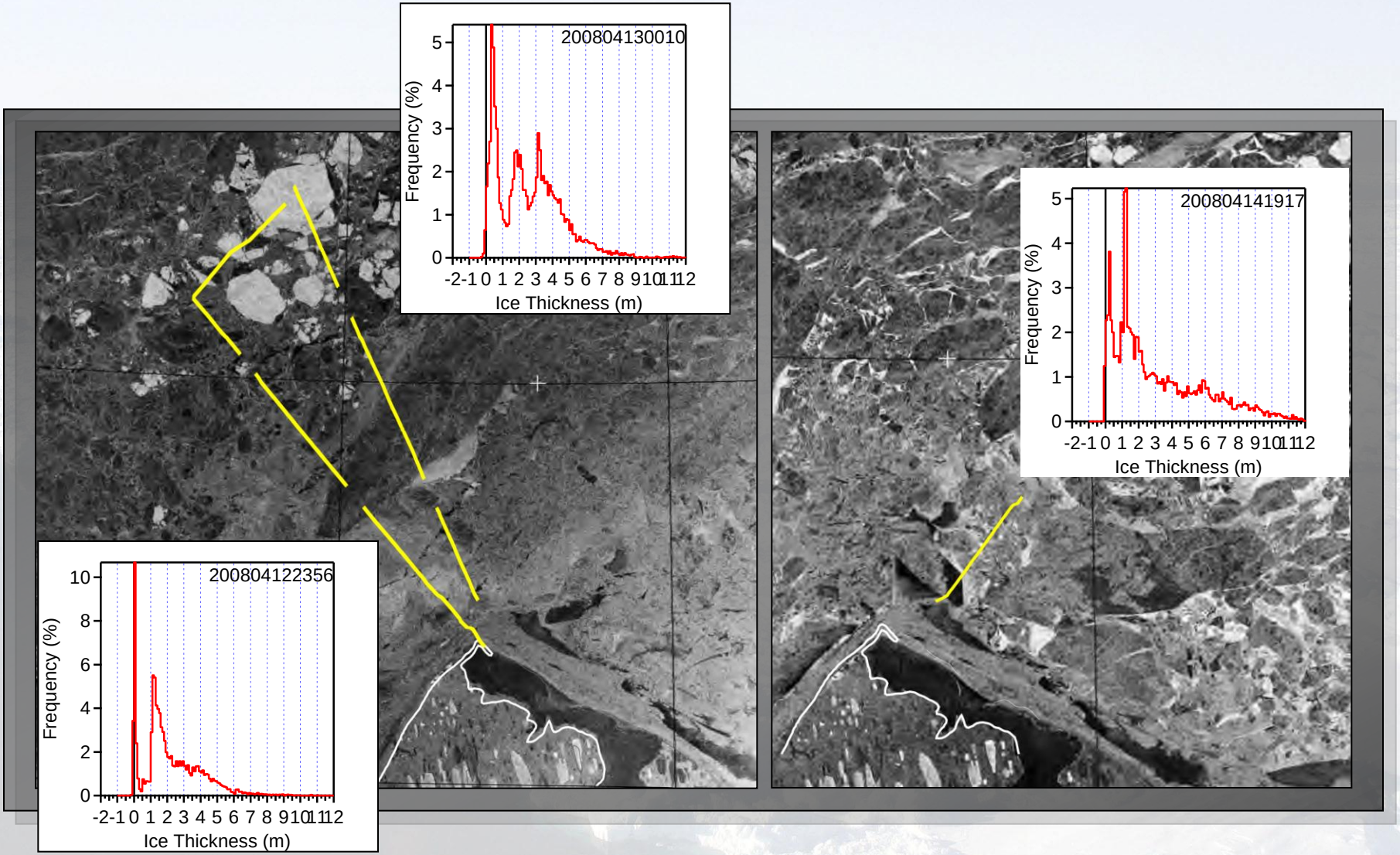


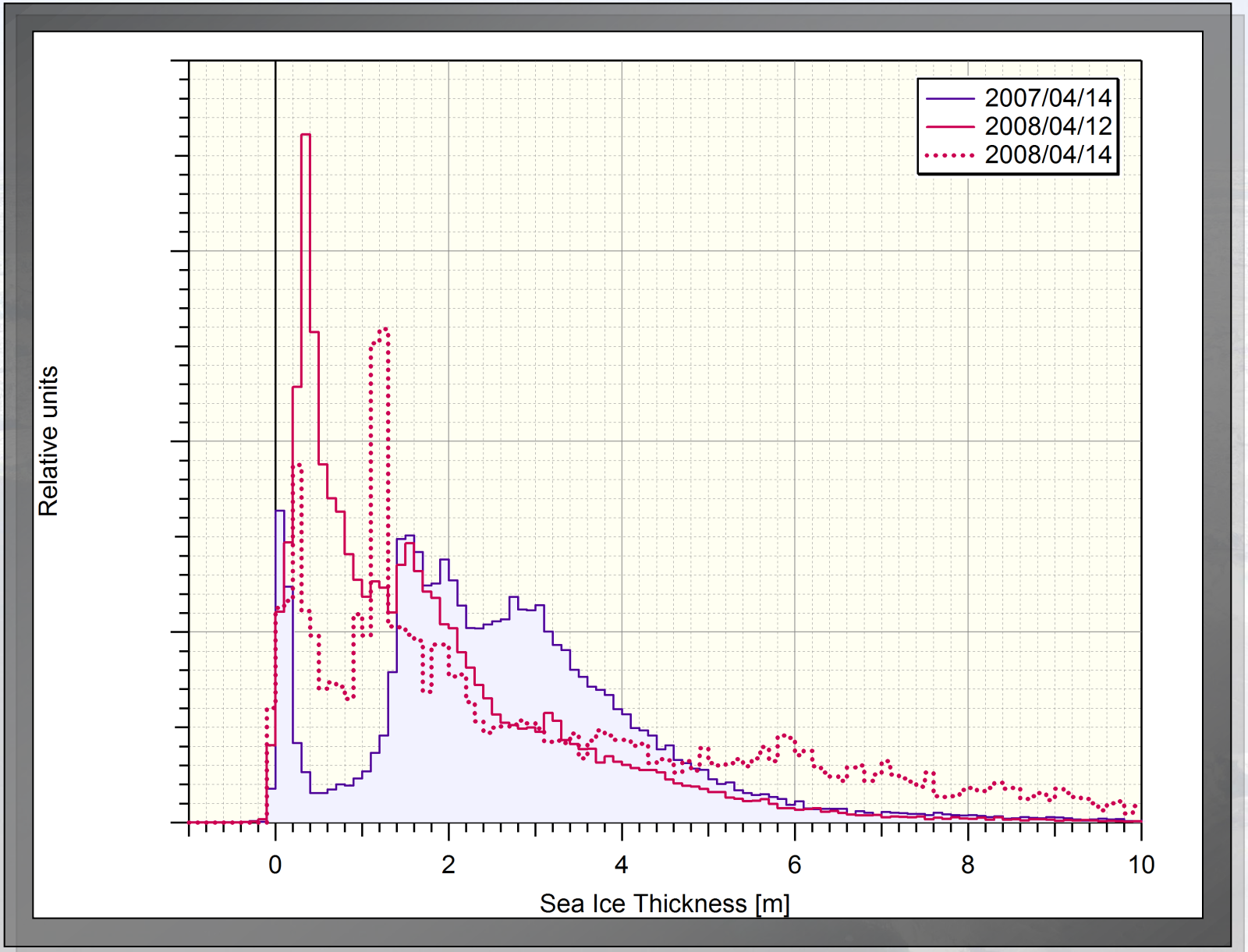


Nghiem, Rigor et al. GRL, 2007

Beaufort Sea

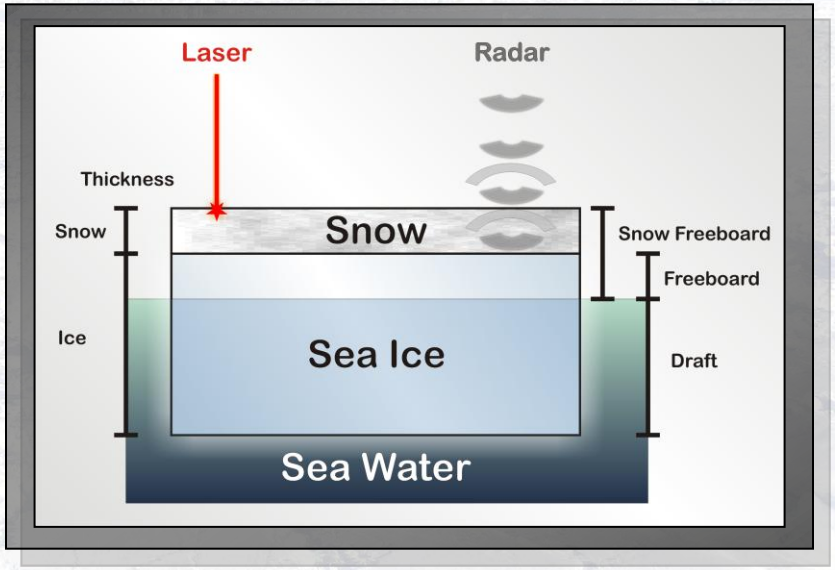



200804130010
Frequency (%)
Ice Thickness (m)
200804141917
Frequency (%)
Ice Thickness (m)
200804122356
Frequency (%)
Ice Thickness (m)


2007/04/14
2008/04/12
2008/04/14
Relative units
0
2
4
6
8
10
Sea Ice Thickness [m]

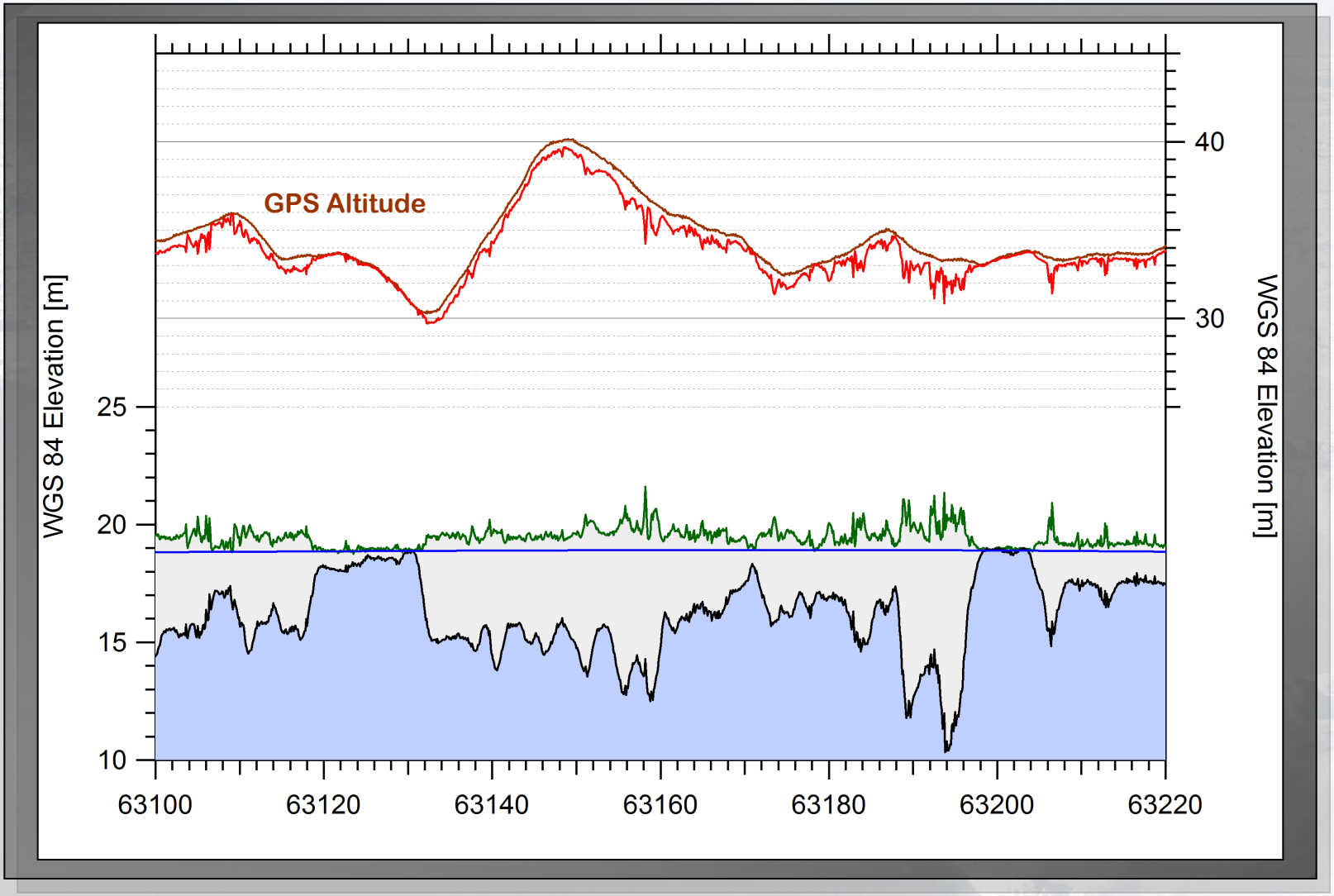
Global Measurements

- Airborne EM applicable on the regional scale
- Limited in spatial & temporal coverage
  - Logistics
  - Weather
- Global measurements only with satellites
- Measurements of freeboard height
  - Laser/Radar
- Requirements
  - Highly accurate elevation
  - Sea surface height
  - Snow thickness

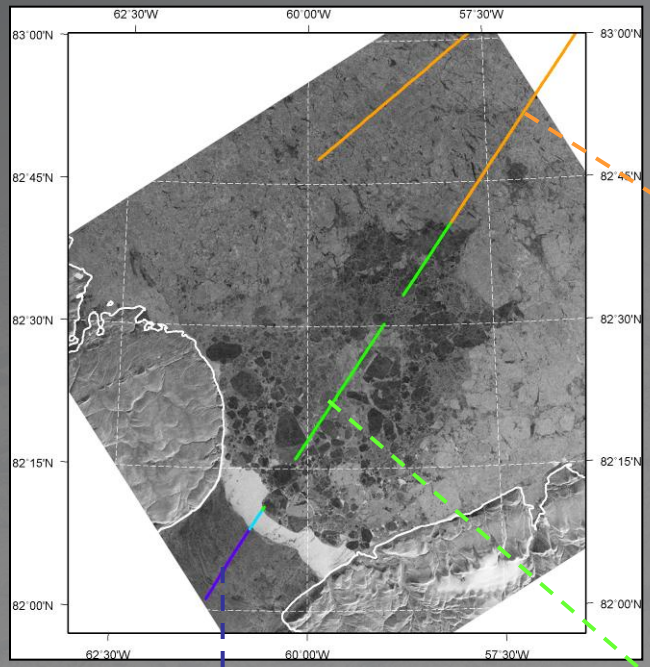


- Airborne EM + DGPS provides validation data

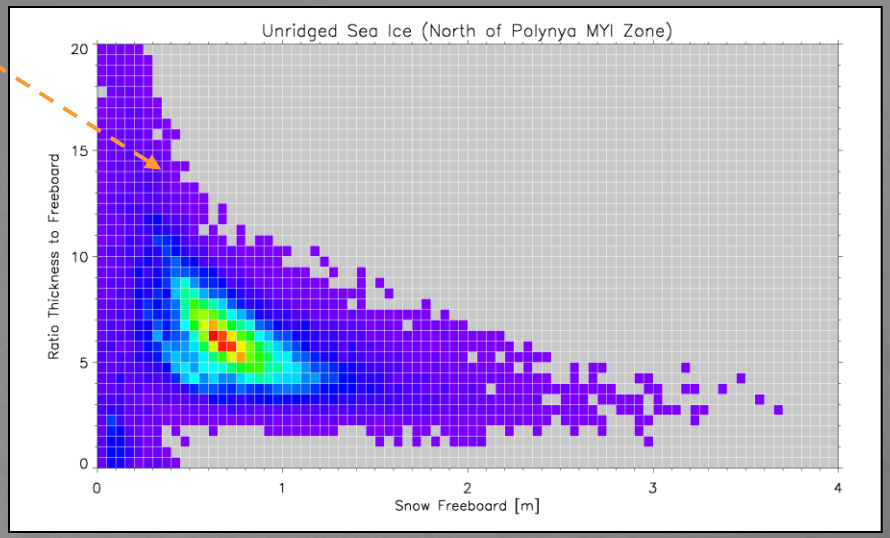
- **Laser range correction with DGPS → Freeboard**

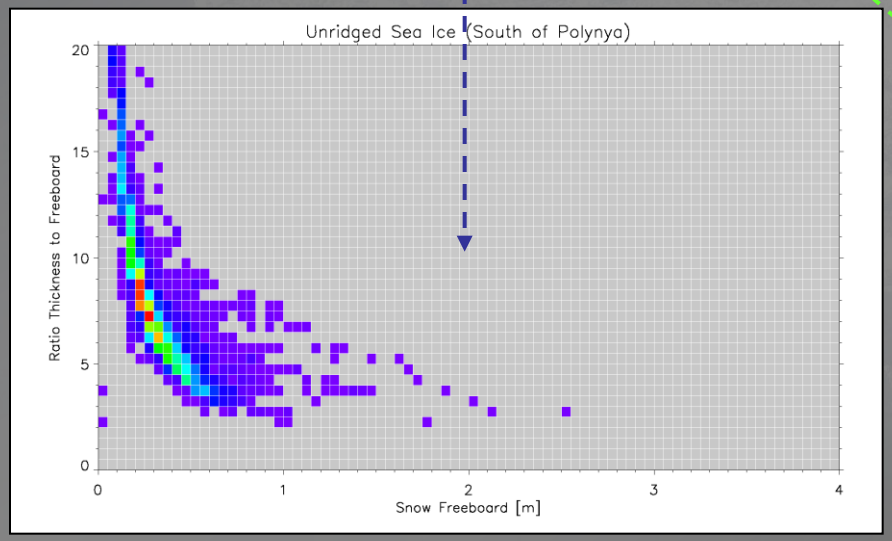


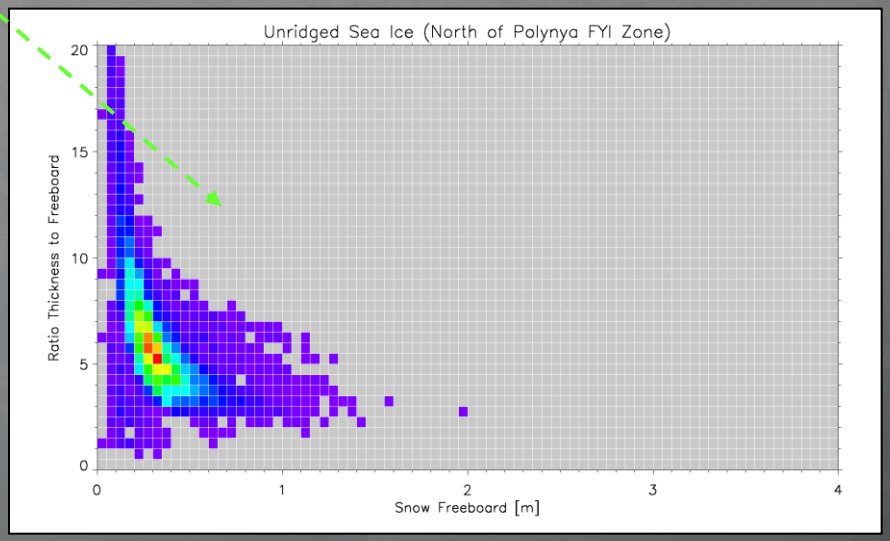
Freeboard Characteristics



Thickness = R × Snow Freeboard





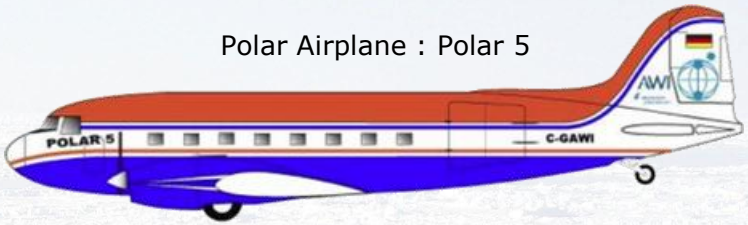


Conclusions

- Airborne EM provides a direct method to estimate sea ice thickness
- Field campaigns in the Arctic and Antarctic since 2001
- Results from the Arctic ocean in late summer 2007 confirms the retreat of thick perennial sea ice in the full thickness pdf
- DGPS data give additional information like laser freeboard
- Upcoming field campaigns this spring
  - Laptev Sea
  - Lincoln Sea

Outlook

Polar Airplane : Polar 5



Fixed Wing EM System

Total Pole Airship