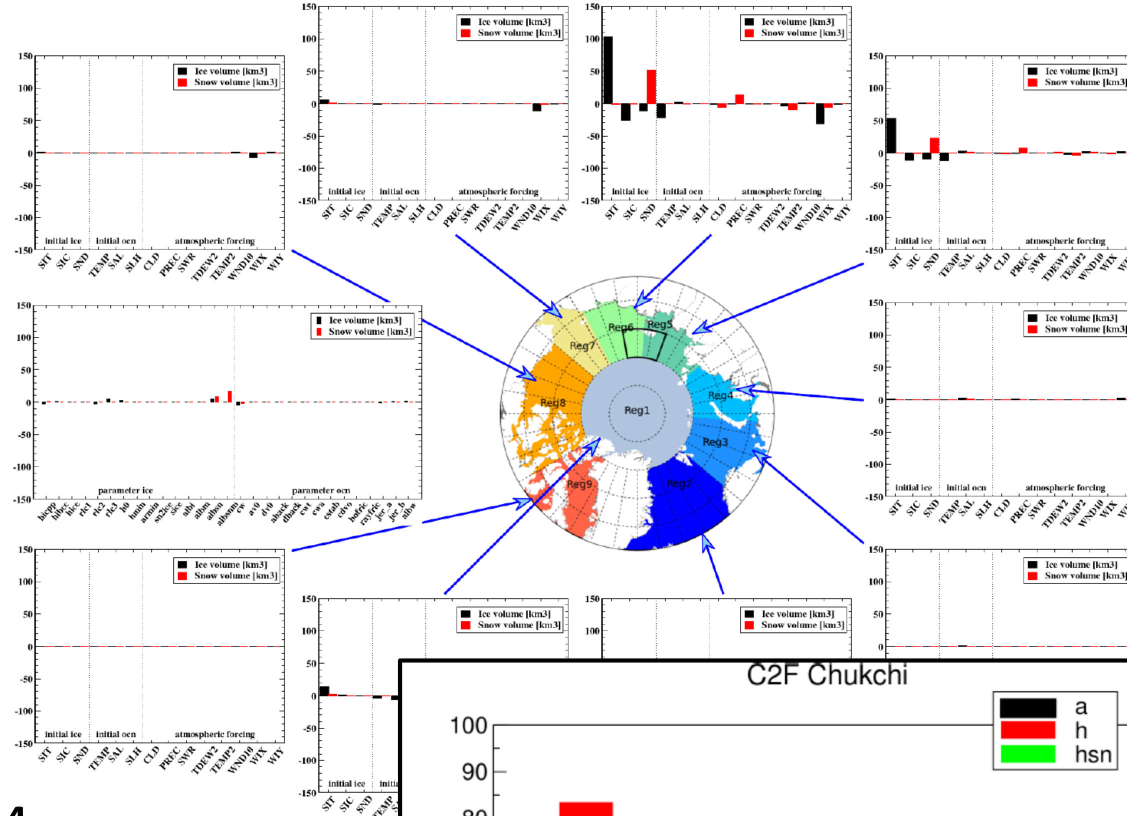
In-situ and airborne sea ice observations for better sea ice prediction and climate analysis

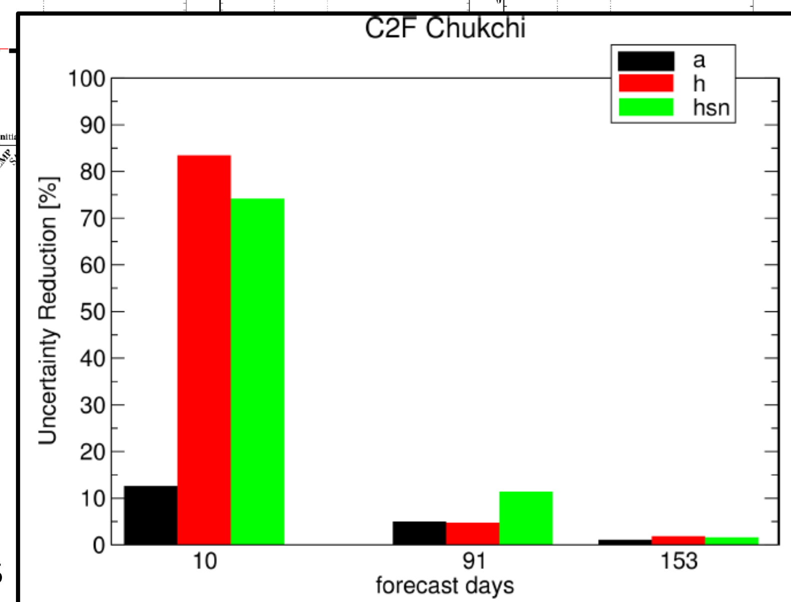
Christian Haas

Data assimilation improves sea ice forecasts

- Most important parameters are:
  - Concentration (SIC),
  - Thickness (SIT),
  - Snow depth (SND)
- Initial ocean condition and atm. Forcing also important
- See e.g.
  - Lindsay et al., GRL 2014;
  - Kaminski et al., TC 2015&2017

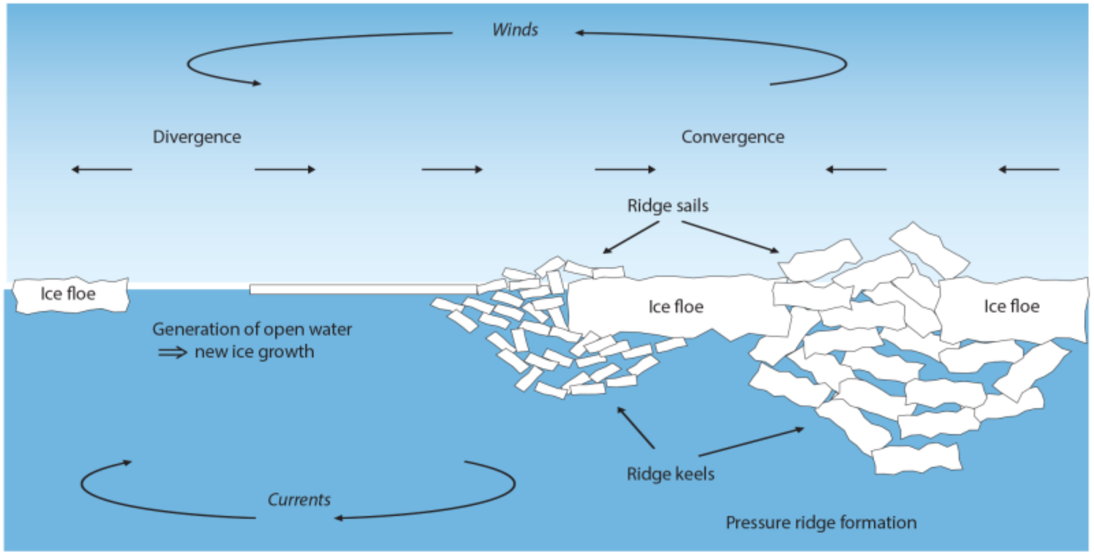


Kaminski et al., TCD 2017

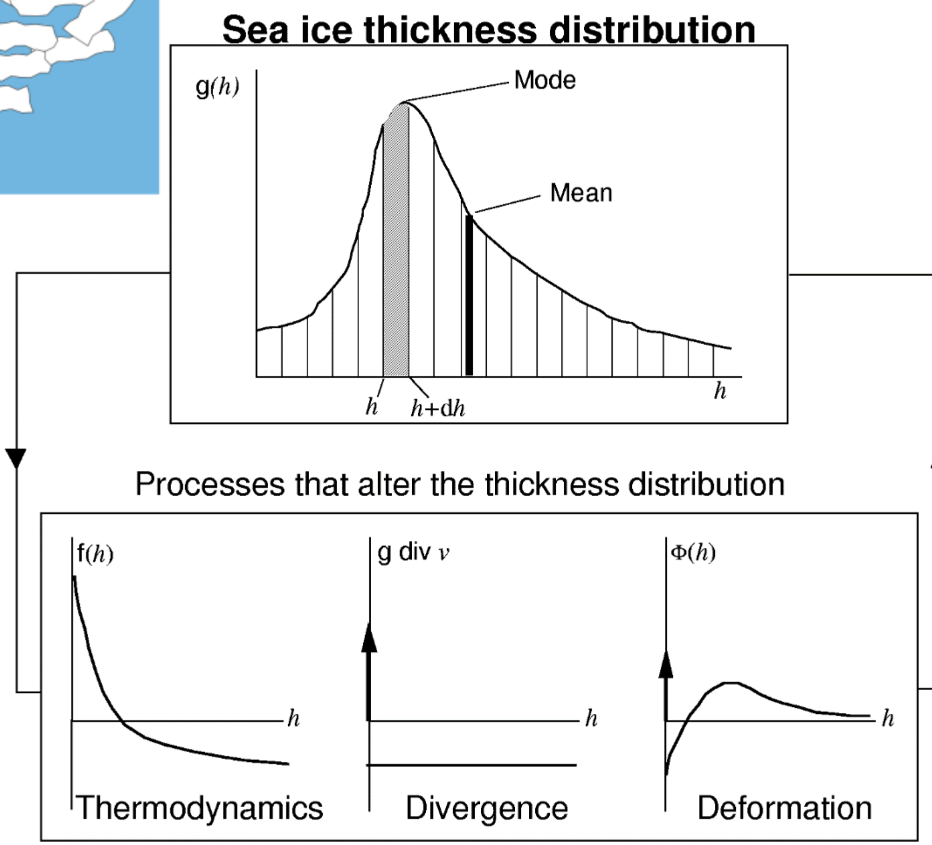


Kaminski et al., TC 2015

Small scale ice thickness variability

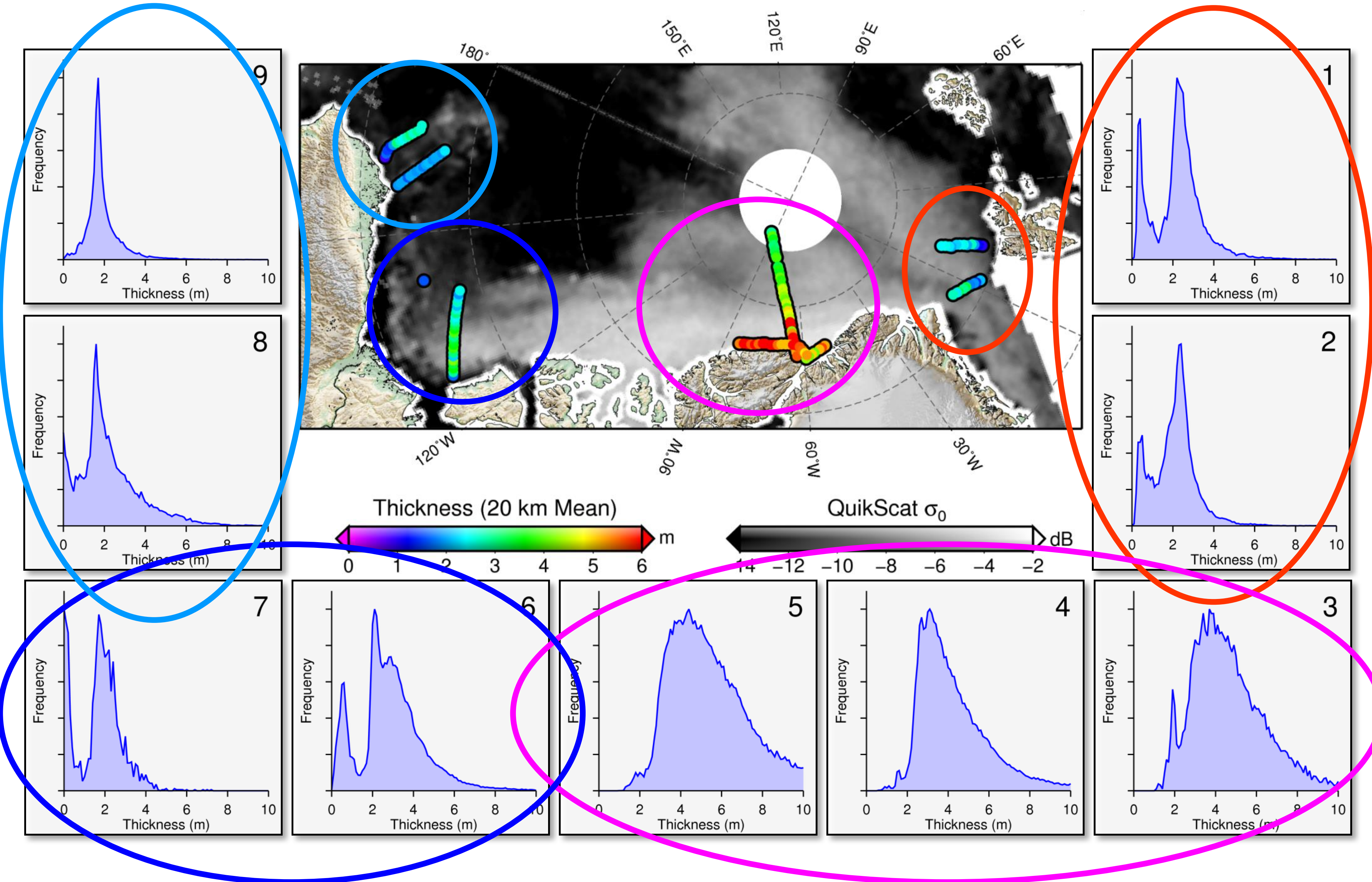


- Non-Gaussian thickness distribution result of different thermodynamic and dynamic processes
- Ice thickness distribution governs ice strength



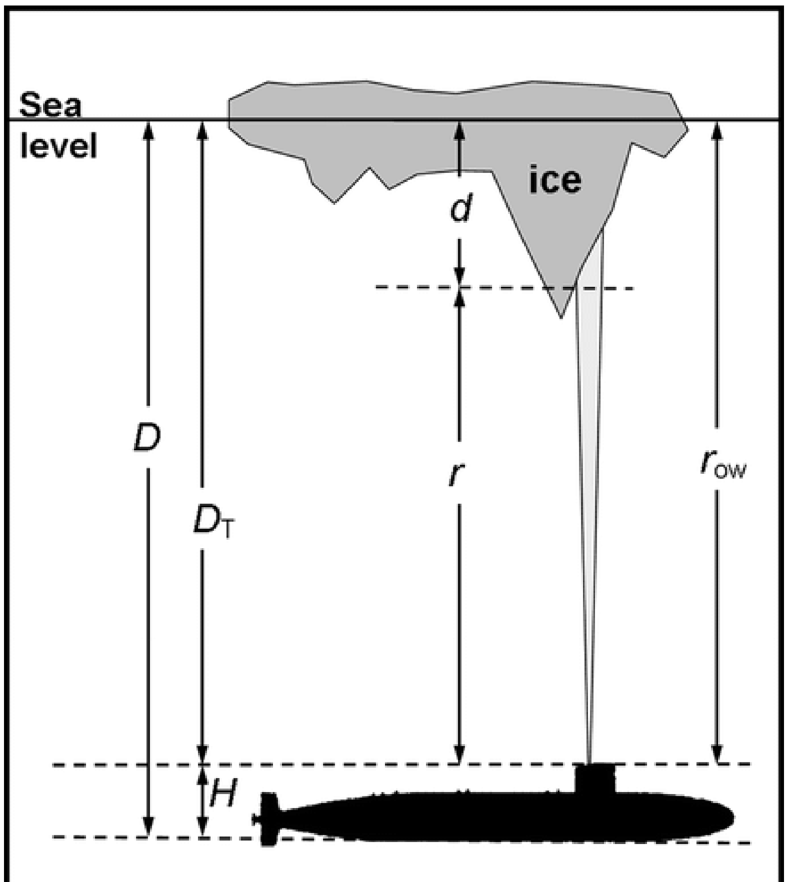
Thorndike et al., 1975; Flato & Hibler, 1995; Hopkins, 1998; etc

Small- and large scale variability

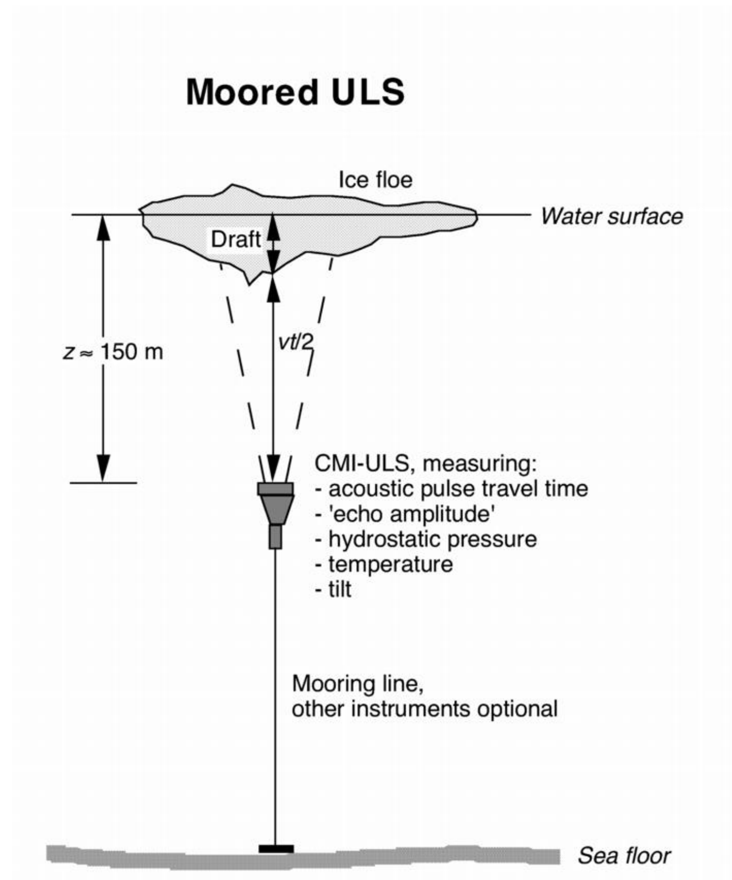


Upward Looking Sonar (ULS)/ Ice Profiling Sonar (IPS)

- Observation of sea ice draft



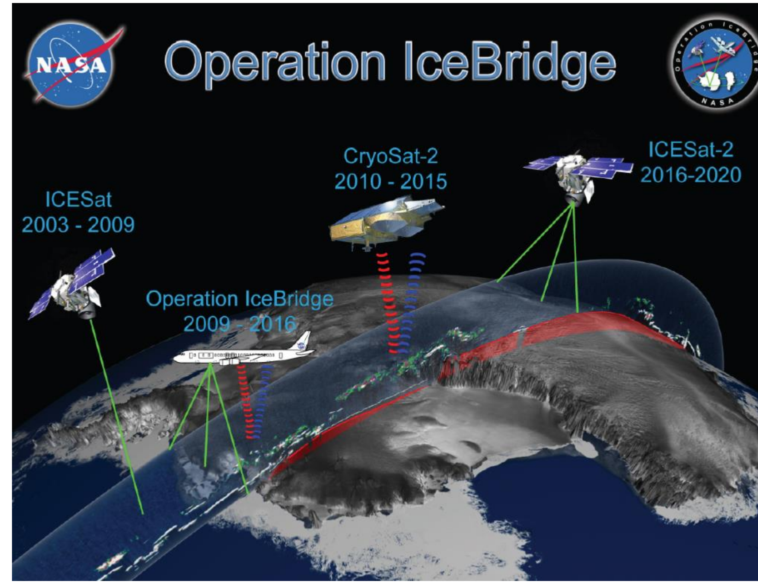
Rothrock & Wensnahan, 2007

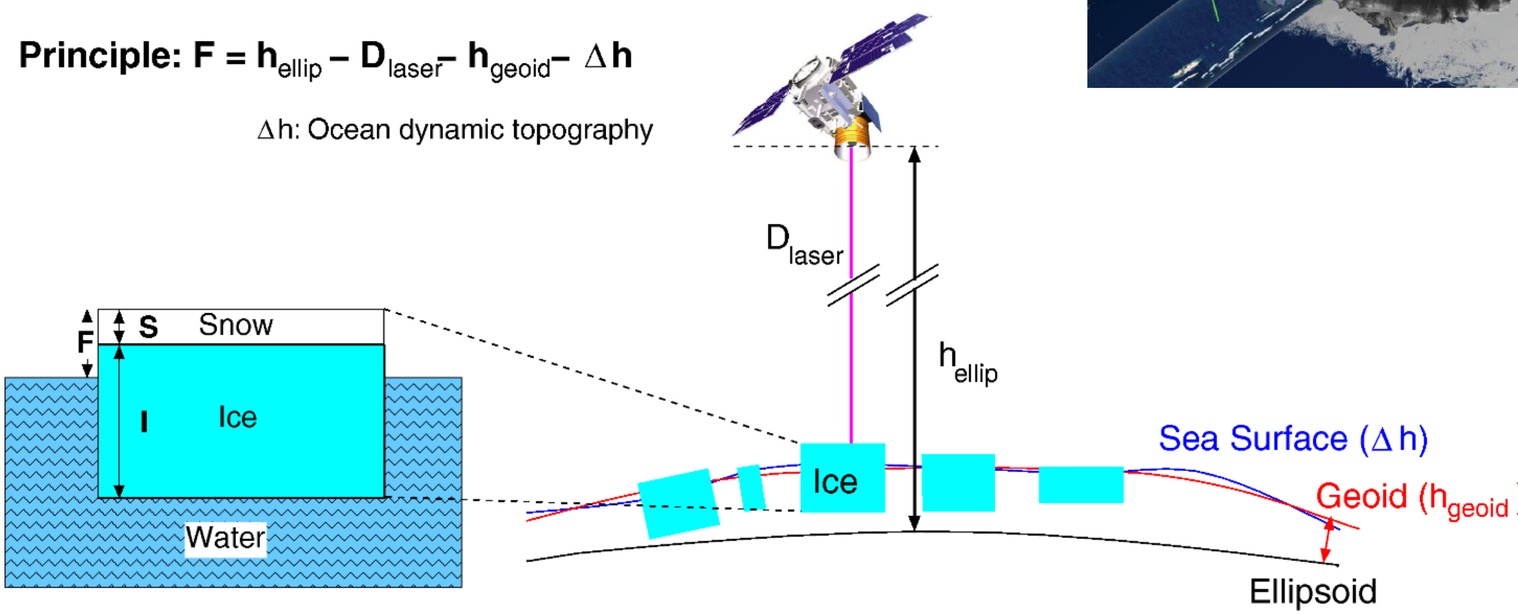


Strass & Fahrbach, 1998

Laser and radar altimetry

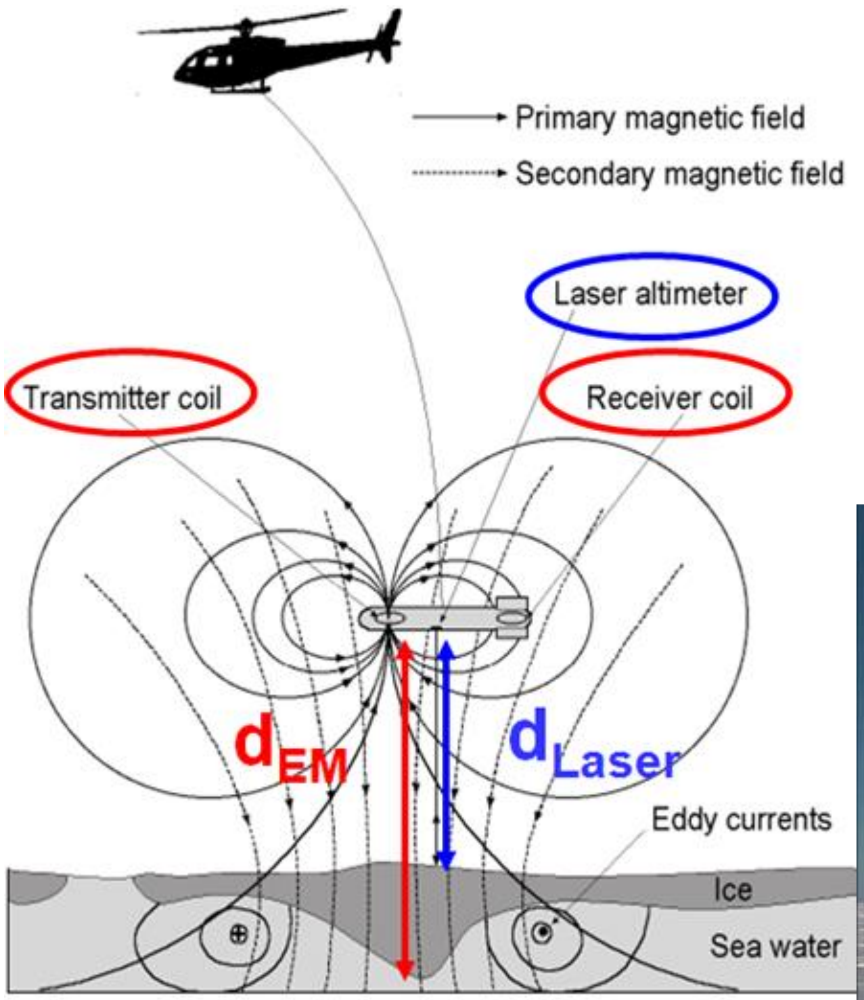
- Observation of sea freeboard





Spreen et al., 2006

EM thickness sounding

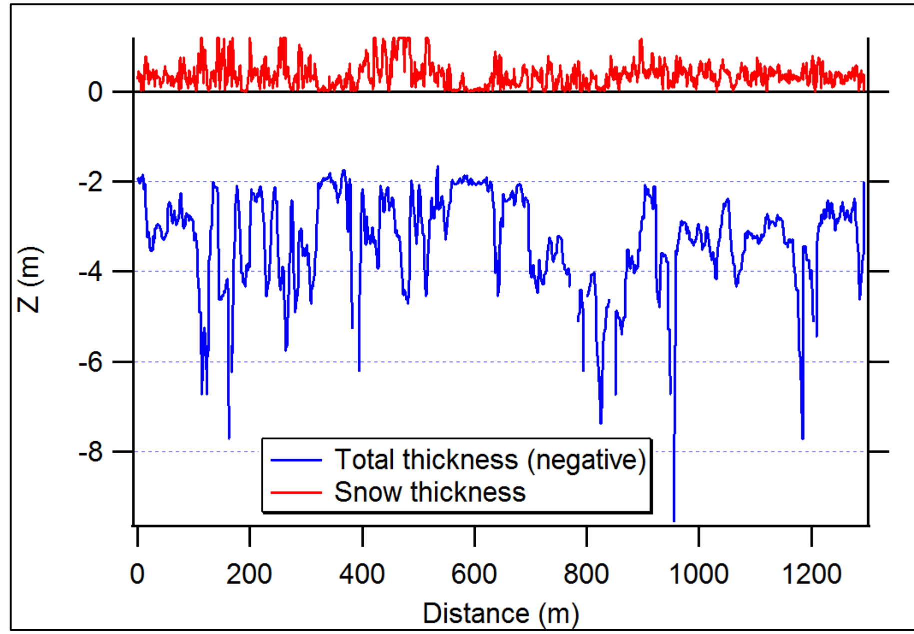


$Z_i = d_{EM} - d_{Laser}$ (snow + ice)

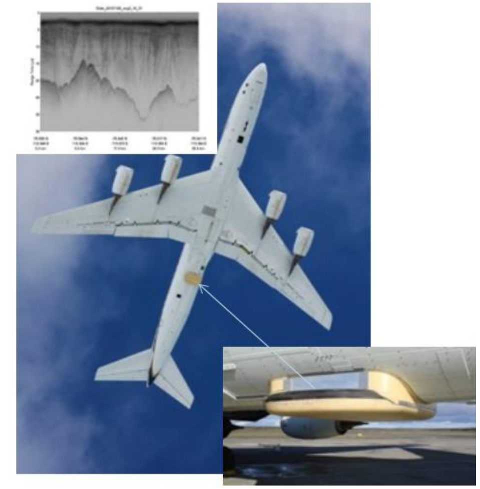
Ground EM and Magnaprobe

- Ice and Snow thickness!

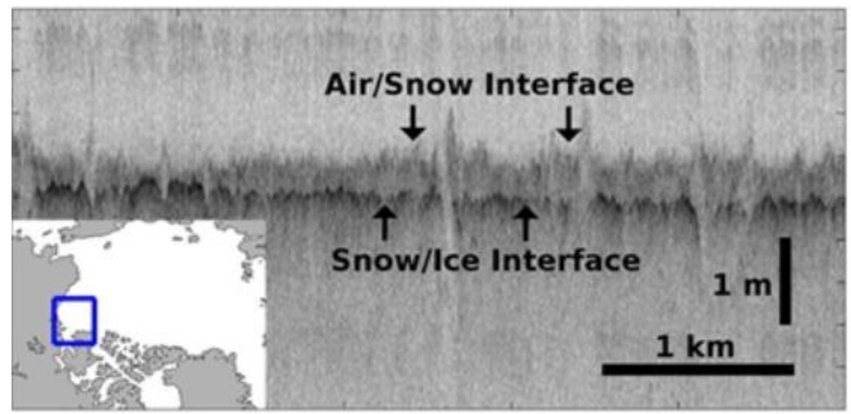
EM31 and Magnaprobe

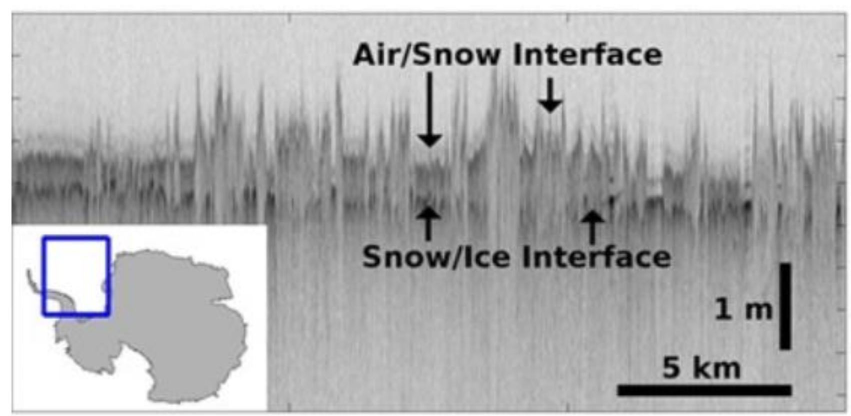


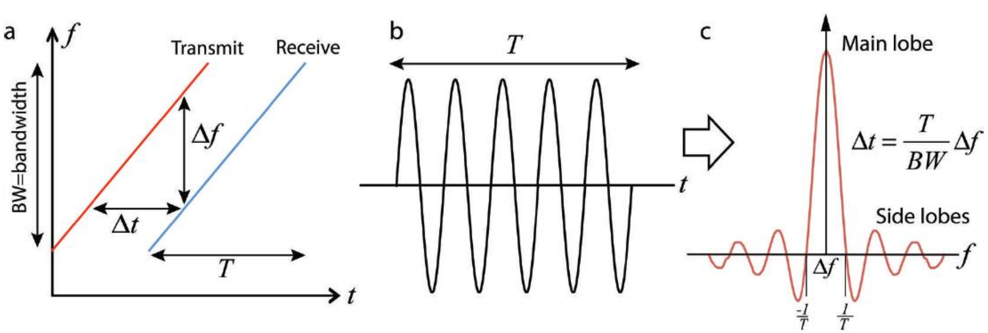
Ultra-wide band FMCW radar



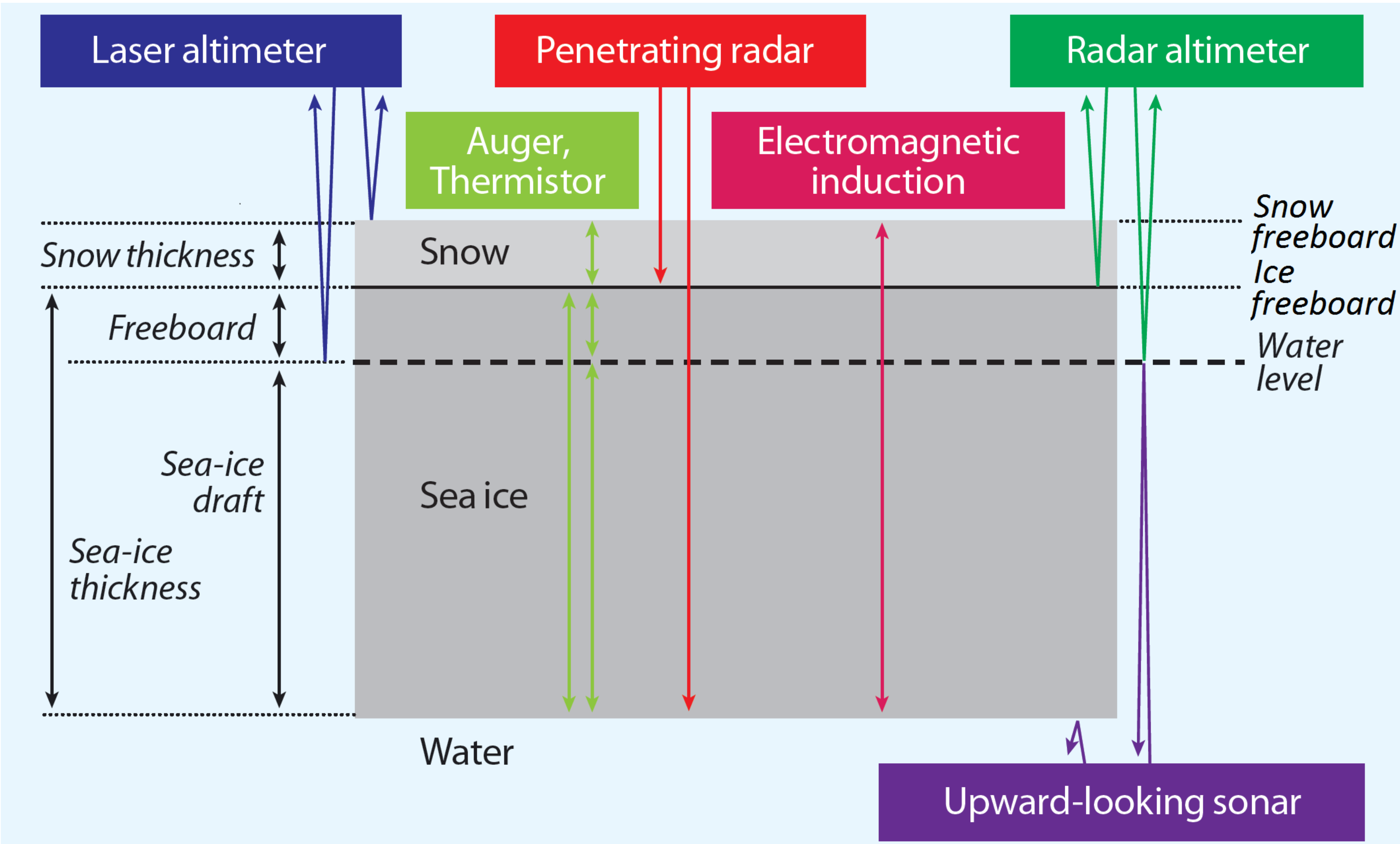
- Frequency-modulated, continuous wave radar (FMCW)
- Detects reflections from top and bottom of snow
- Suffers from data processing (Fourier methods) artefacts (e.g. sidelobes)





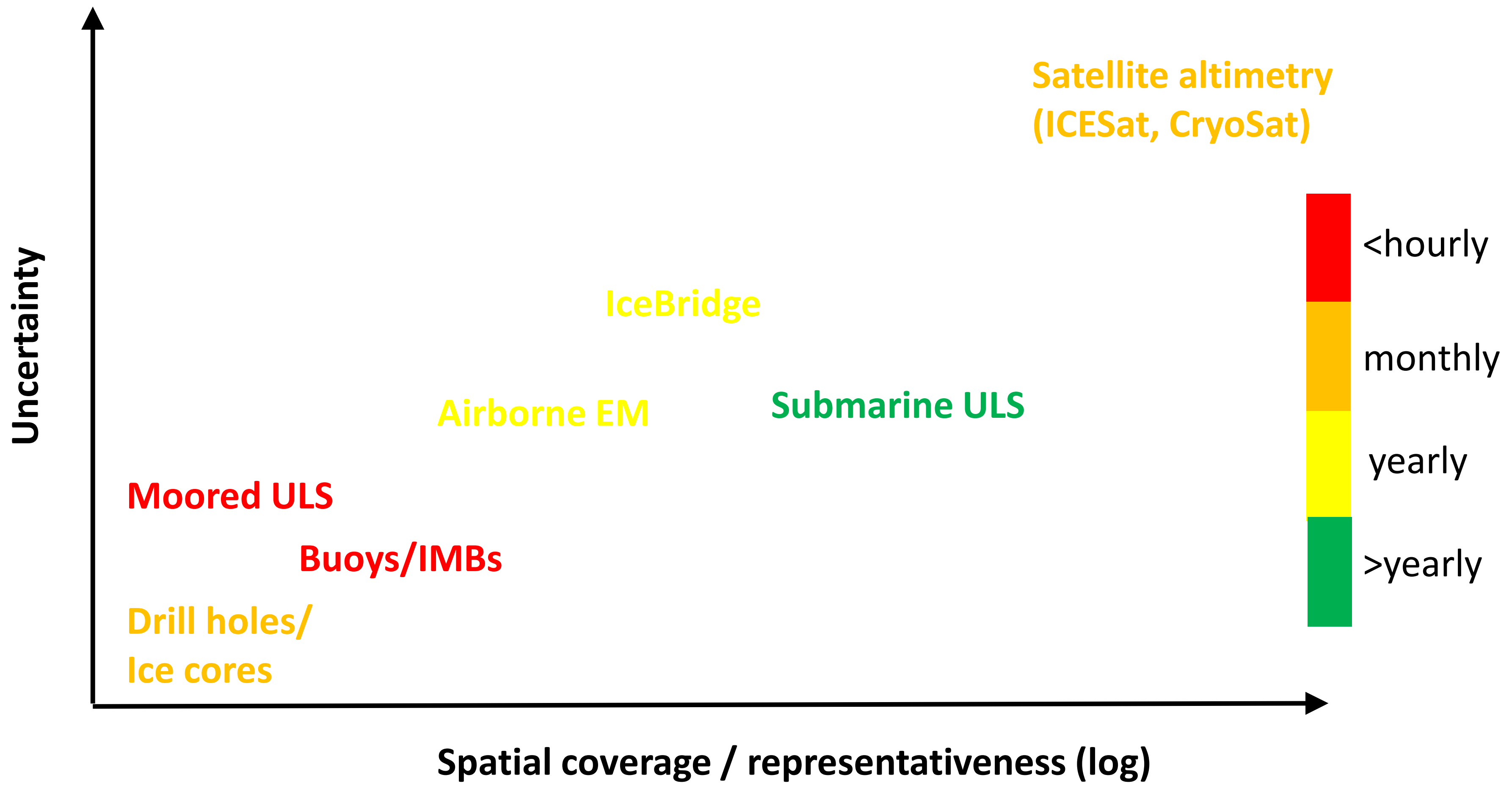


Different in-situ and airborne methods



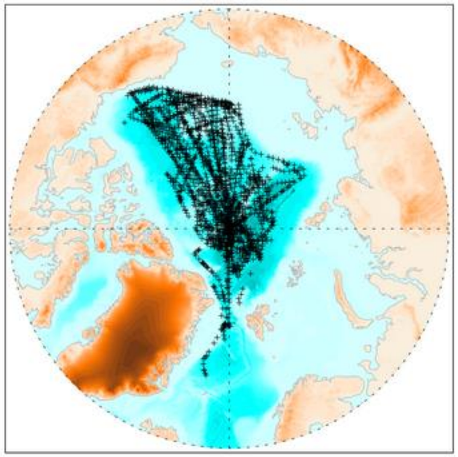
Haas, 2017

Scales and uncertainties (e.g. ice thickness)

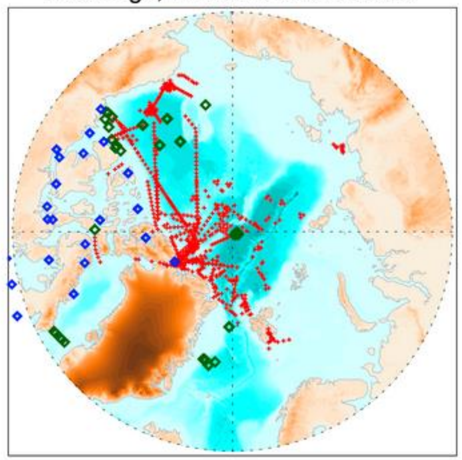


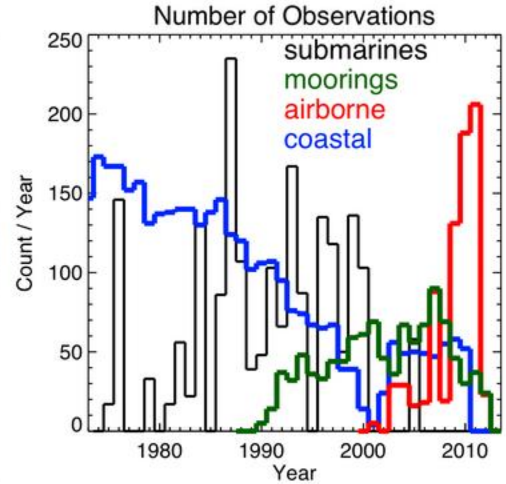
Sea Ice Thickness CDR

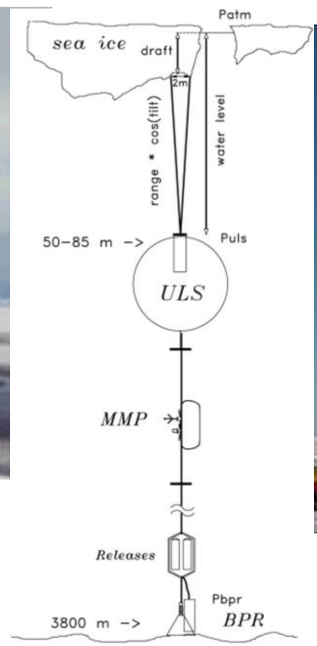
Submarines

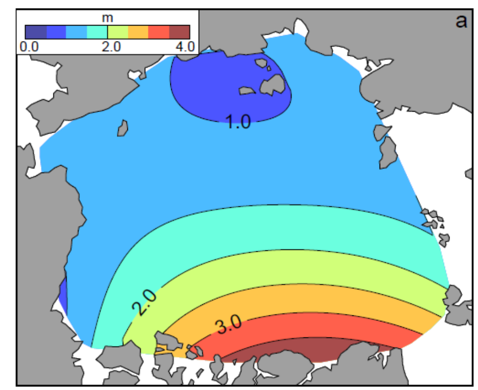


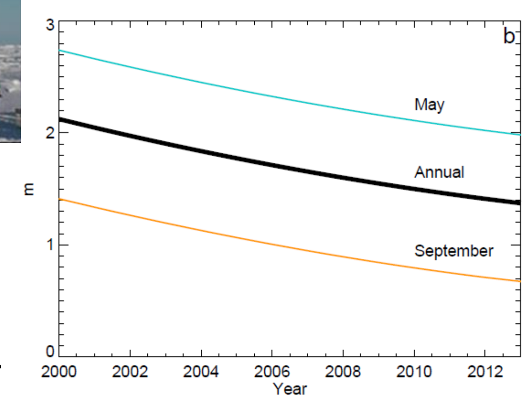
Moorings, Airborne and Coastal











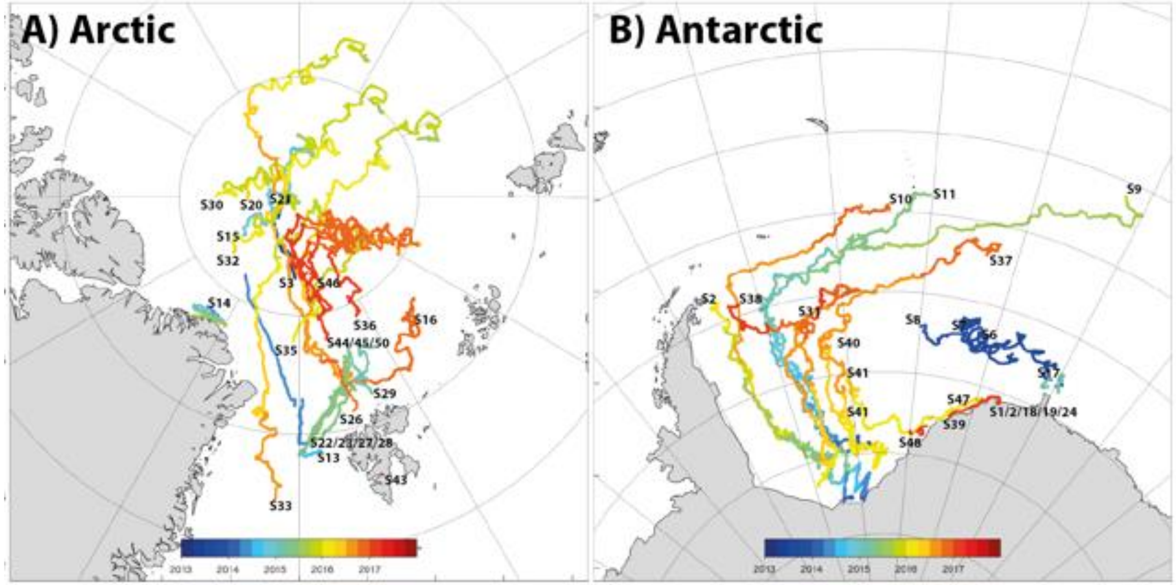
- Mooring arrays:
- IOS
- Beaufort Observatory (WHOI)
- Fram Strait (NPI)

Lindsay & Schweiger 2015

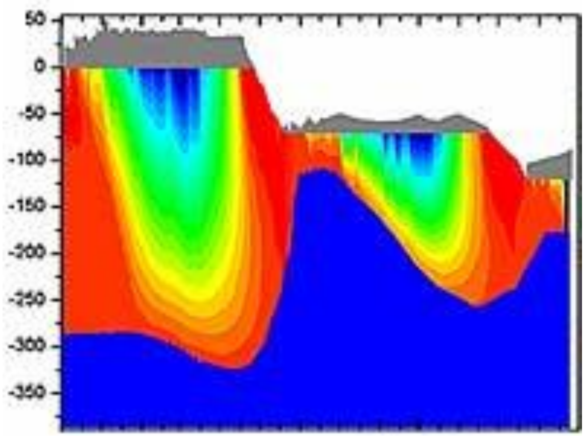
Lindsay, 2010, http://psc.apl.uw.edu/sea_ice_cdr

Buoys

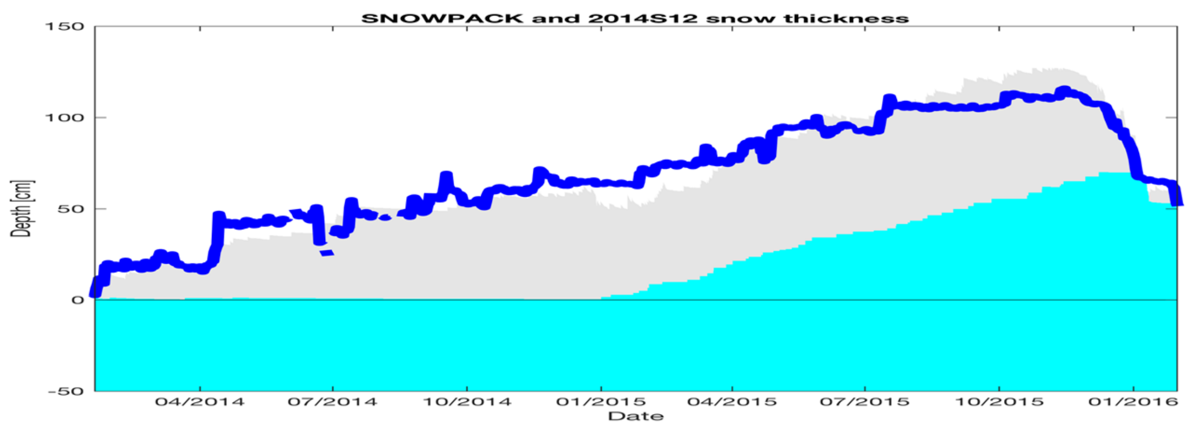
- Drift (& Deformation?)
- Ice growth and temperature
- <u>SNOW</u>
- Arctic and Antarctic Buoy Programs IABP, IPAB
- Data transmitted to GTS



CRREL ice mass balance buoy IMB



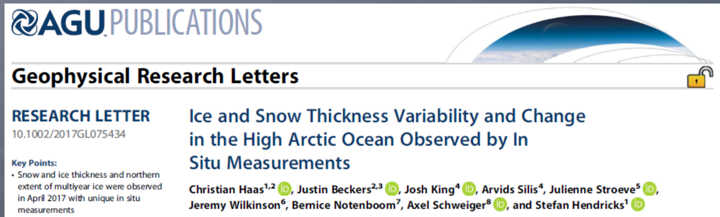
AWI's snow thickness buoy compared to model



http://imb-crrel-dartmouth.org/imb.crrel

http://www.meereisportal.de

Example:
Arctic Ocean sea ice and snow thickness variability and change observed by in-situ measurements


AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL075434

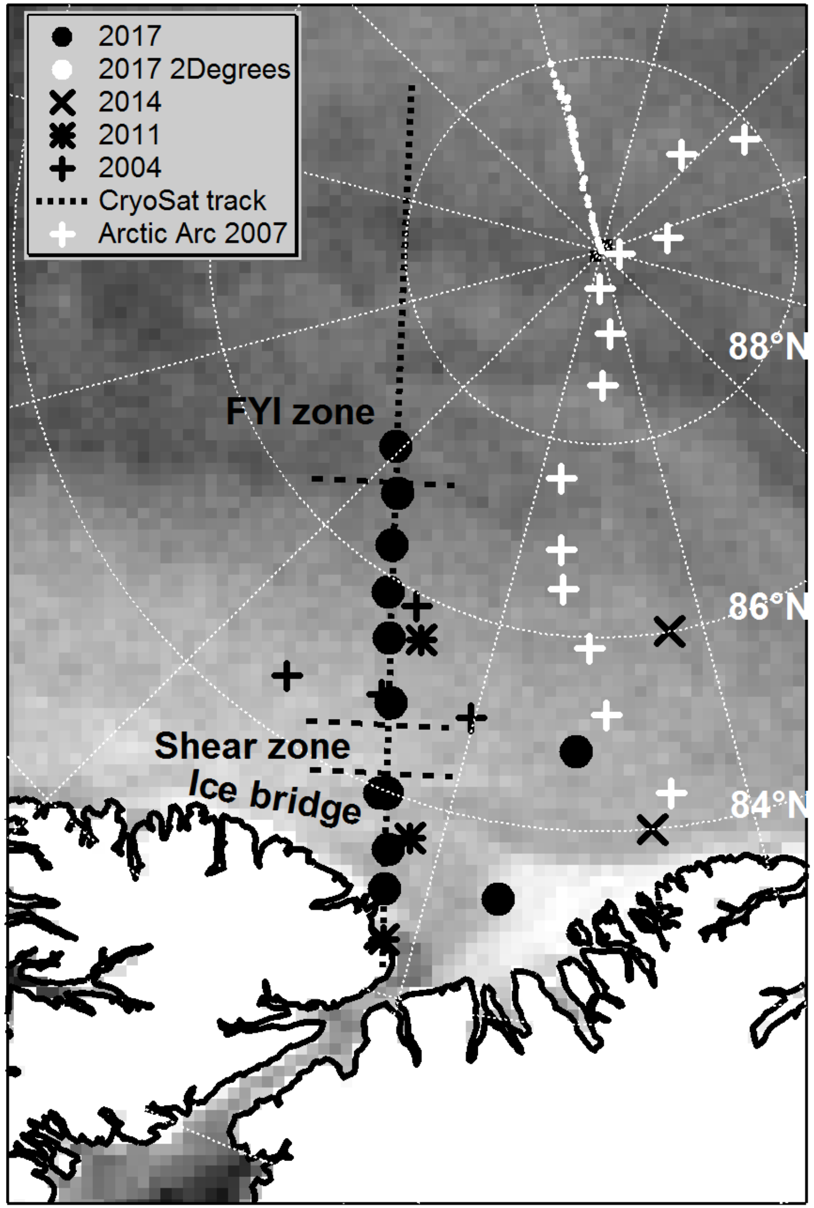
Key Points:
- Snow and ice thickness and northern extent of multiyear ice were observed in April 2017 with unique in situ measurements

Ice and Snow Thickness Variability and Change in the High Arctic Ocean Observed by In Situ Measurements

Christian Haas[1,2], Justin Beckers[2,3], Josh King[4], Arvids Silis[4], Julienne Stroeve[5], Jeremy Wilkinson[6], Bernice Notenboom[7], Axel Schweiger[8], and Stefan Hendricks[1]

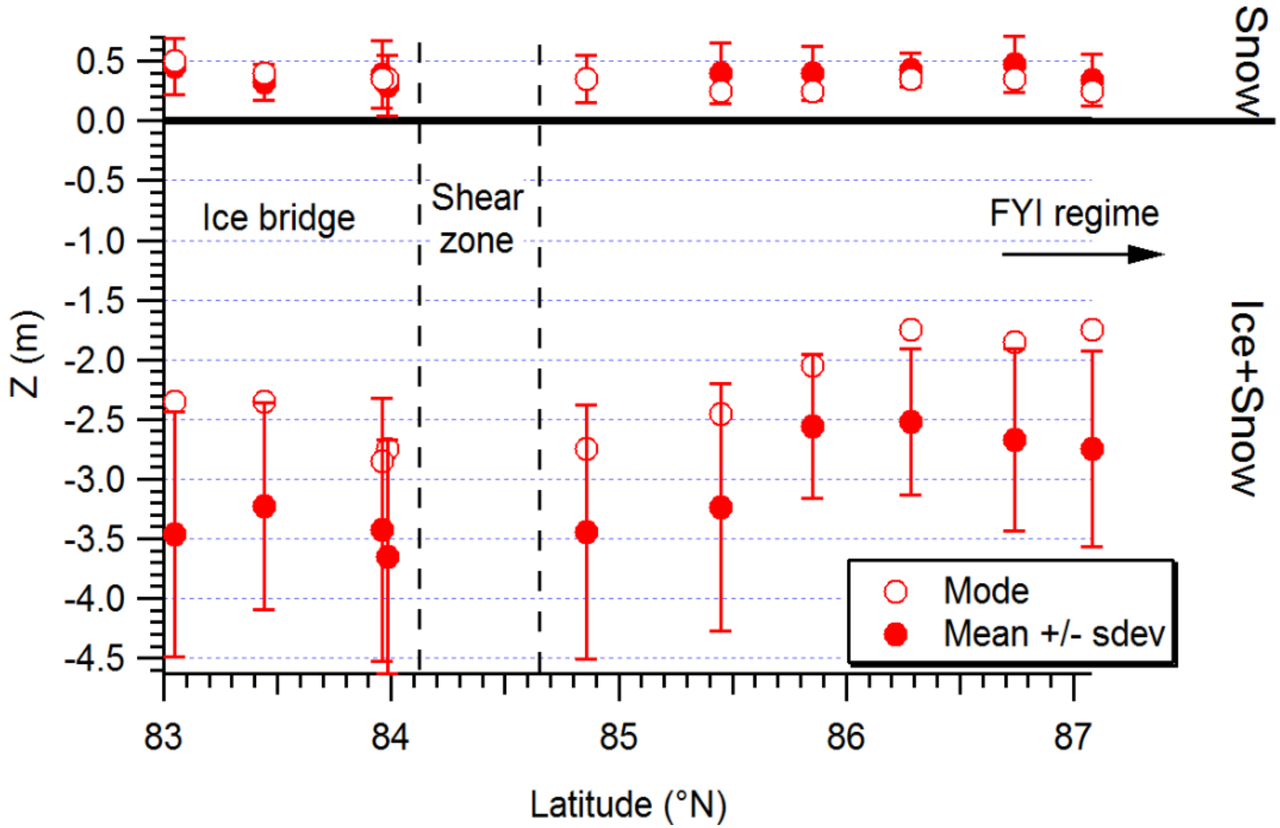
CryoVEx 2017

- Ice and snow thickness measurements at 12 sites visited by Twin Otter
- Complemented by snow thickness data from 2Degrees ski expedition (North Pole)
- Compared to previous CryoVEx data and ski expedition in 2007
- Compared to CryoSat and climatology



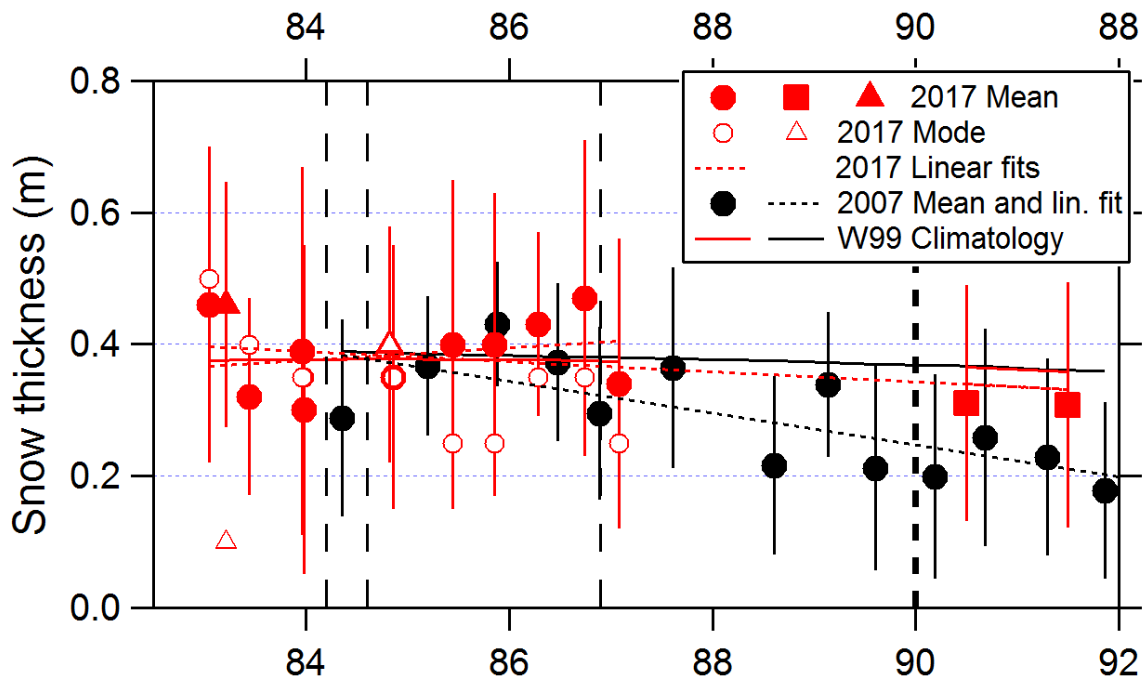
esa

Results (Total, snow+ice thickness)



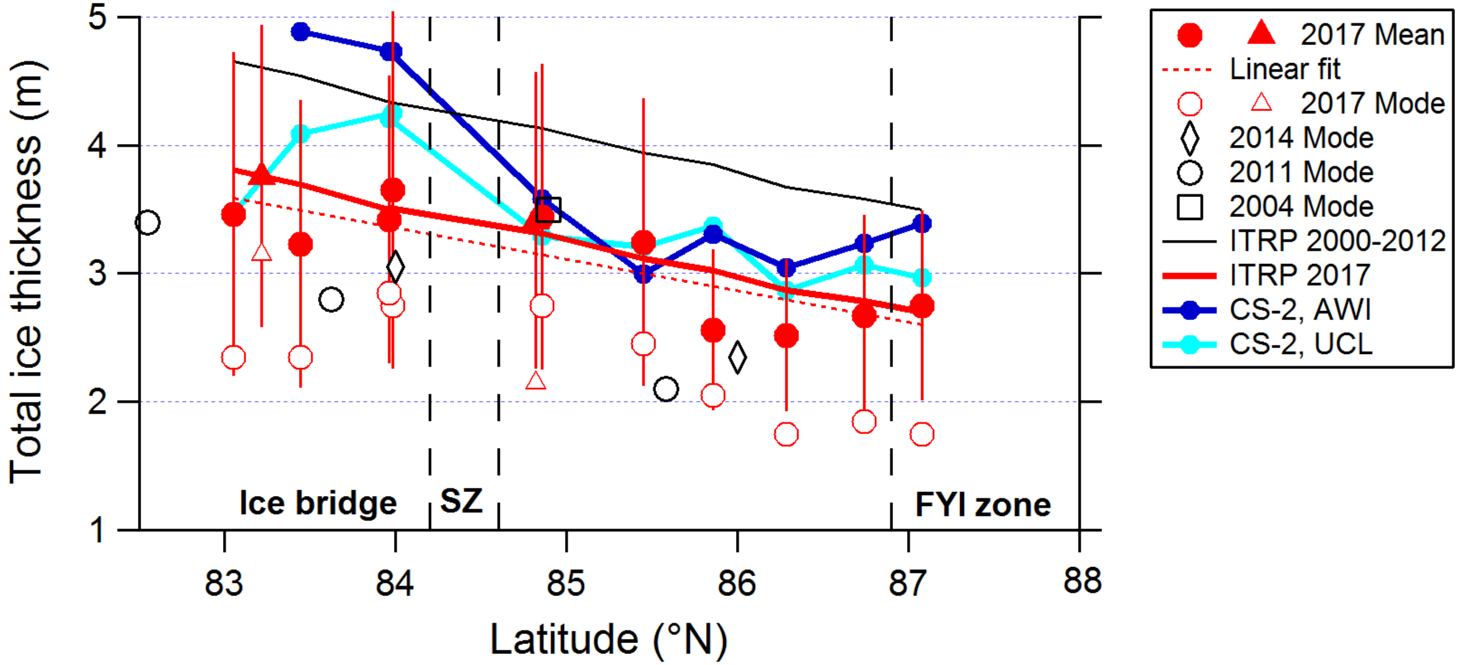
- Old ice zone successfully traversed into FYI in the north
- MYI up to 3.7 (mean) and 2.9 (mode) meters thick
- FYI less than 1.8 m thick (mode)
- Includes 0.39±0.06 m of snow

Snow thickness variability (and change?)



- Large site-to-site variability
- Over MYI: 1 cm agreement with Warren 99 climatology (0.39±0.06 m)
- Thinner snow in 2007

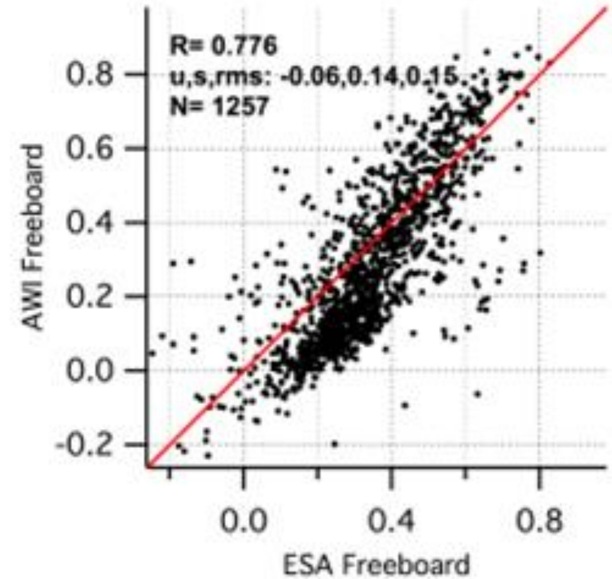
Ice thickness variability and change



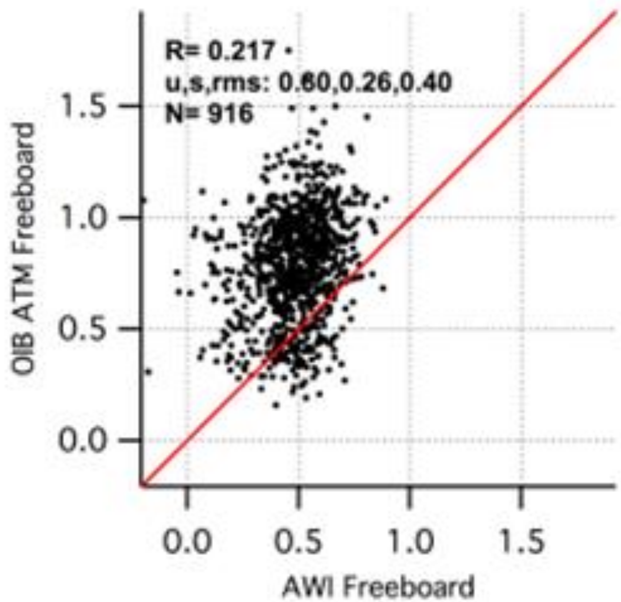
- Modal thickness similar to 2011, 2014;

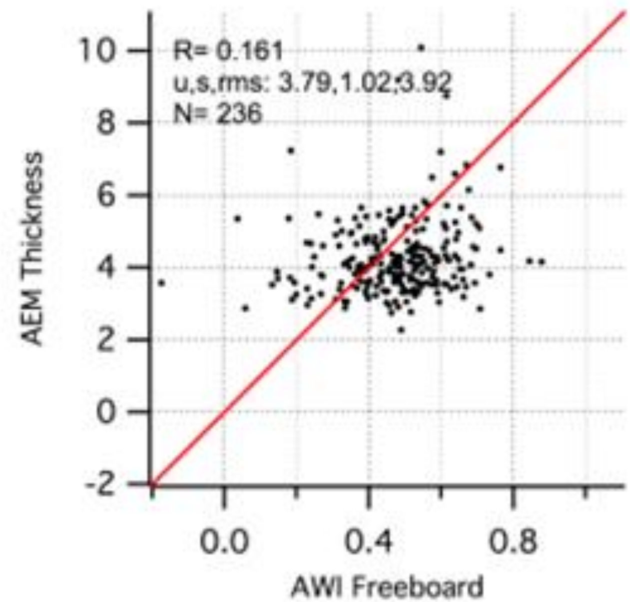
  0.75 m less than in 2004
- Northward gradient similar to Lindsay&Schweiger ITRP
- Good agreement with trend corrected ITPR (-0.58 m/decade)
- Reasonable agreement with gridded NRT CryoSat products

Airborne and satellite freeboard comparison



- ESA CryoVal project
- Large scatter due to small-scale variability and different footprint sizes

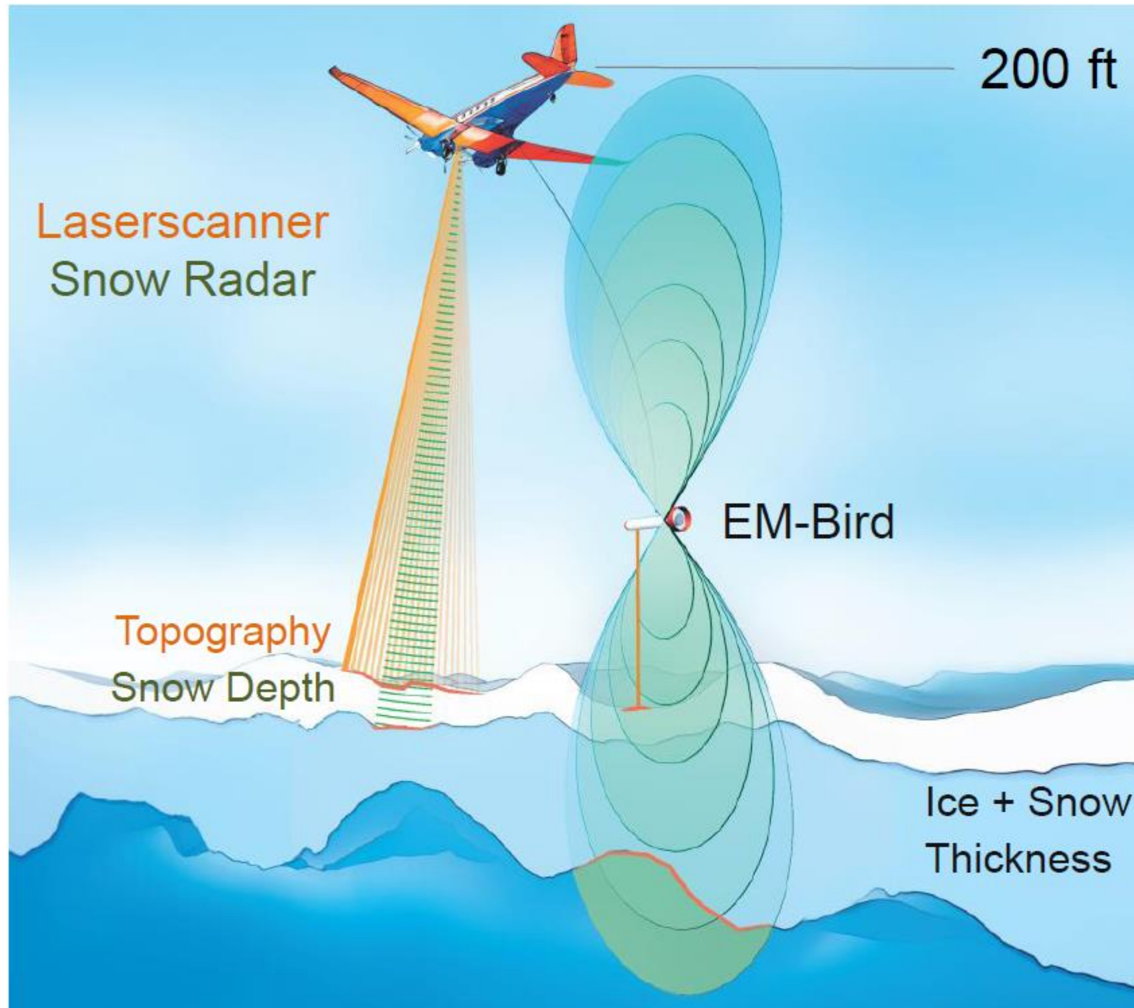




Outlook

Airborne sea ice observatory

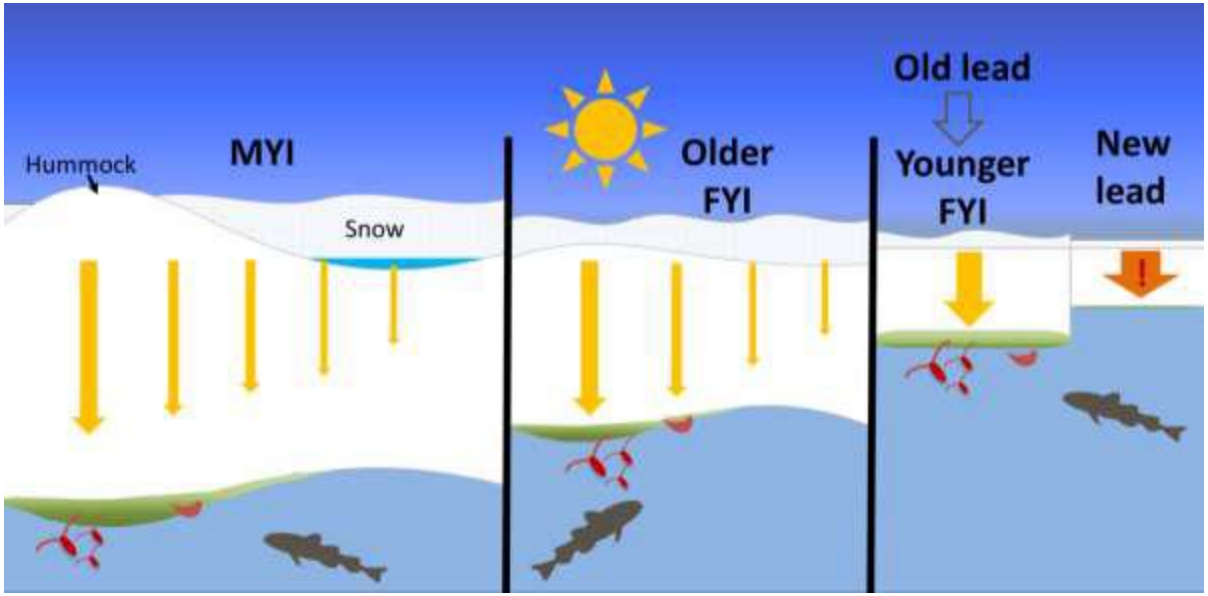
- AEM, laser scanner, and snow radar all on one platform
- Systematic, long-range surveys in key regions of the Arctic

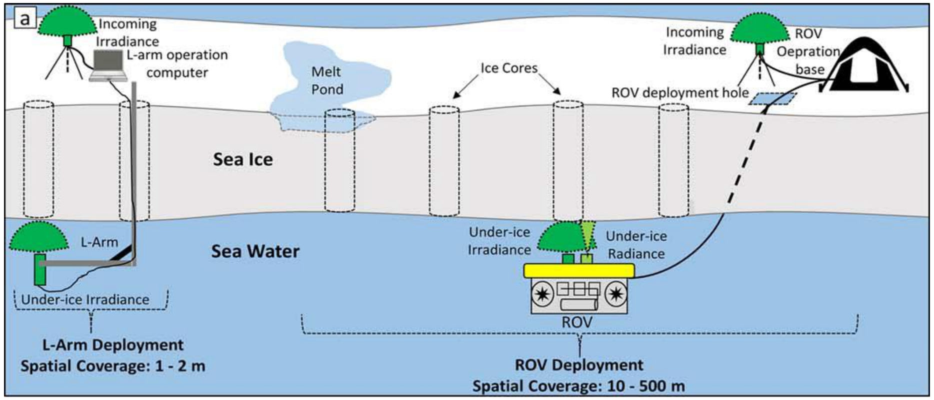


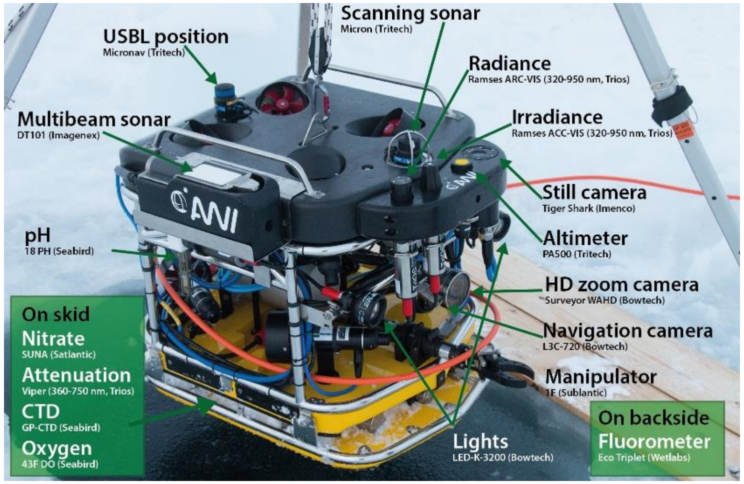
S. Hendricks, AWI

Light and biomass

- ROV and buoy measurements of spectral light transmittance;
- Sampling of biomass and primary productivity

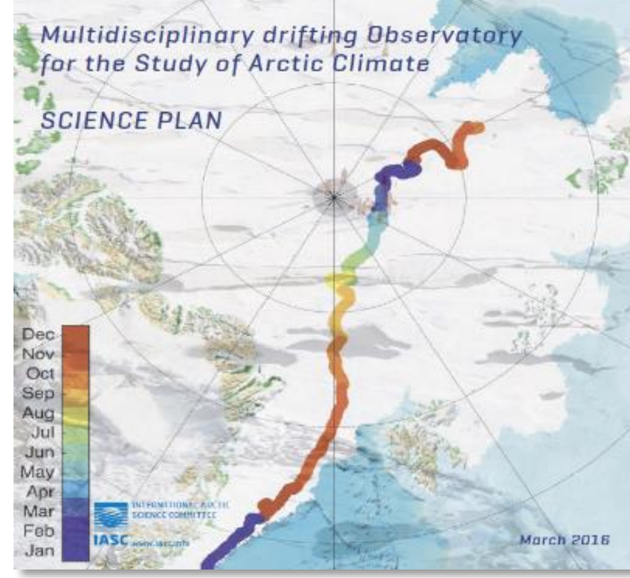






M. Nicolaus, C. Katlein, B. Lange

MOSAiC
The International Arctic Drift Expedition



A major international research initiative under IASC to improve the representation of Arctic processes in climate & ecosystem models

2019 - 2020

Central Observatory
- Ship based
- Sea ice stations
- ➢ Process scale observations

< 5 km

Distributed Network
- Sea ice stations visited by helicopter
- UAV, gliders
- Process & regional model
- ➢ Model grid cell

< 50 km

Large-scale linkages
- Collaborating research vessels (Academic Tryoshnikov, Xue Long, Oden…)
- Aircraft (Polar 5,6)
- Arctic buoys, satellites
- Data assimilation studies
- ➢ Arctic regional & global models

> 1000 km

In-situ and airborne sea ice observations for better sea ice prediction and climate analysis

- A wide range of methods are available
  - Airborne altimetry and EM
  - Upward looking sonar
  - Autonomous drifting buoys
- Key issues are
  - Regional and temporal scope
  - Intercomparability/Representativeness
  - Real-time availability