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

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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
Small scale ice thickness variability

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

**Principle:** \( F = h_{\text{ellip}} - D_{\text{laser}} - h_{\text{geoid}} - \Delta h \)

\( \Delta h \): Ocean dynamic topography

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)

Spatial coverage / representativeness (log)

Uncertainty

Satellite altimetry (ICESat, CryoSat)

IceBridge

Airborne EM

Submarine ULS

Moored ULS

Buoys/IMBs

Drill holes/ Ice cores

<hourly
monthly
yearly
>yearly
Sea Ice Thickness CDR

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

Lindsay & Schweiger 2015
Lindsay, 2010, http://psc.apl.uw.edu/sea_ice_cdr

Number of Observations
- submarines
- moorings
- airborne
- coastal

Count / Year
Year
1980 1990 2000 2010
Buoys

- Drift (& Deformation?)
- Ice growth and temperature
- SNOW
- 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

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

- ROV and buoy measurements of spectral light transmittance;
- Sampling of biomass and primary productivity
A major international research initiative under IASC to improve the representation of Arctic processes in climate & ecosystem models

2019 - 2020
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