Interannual Variability in Contemporaneous Measurements of Arctic Snow and Sea Ice Thickness

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NOAA/CICS-MD Sea Ice Research Group - Activities
Measurement techniques – utility of altimetry to derive sea ice thickness
Brief overview of Operation IceBridge and sea ice data products
Arctic sea ice fieldwork in 2014
Review of Arctic wintertime sea ice conditions
Arctic Sea Ice Thickness Observations: 2009-2014
  - Assessing interannual variability of first-year and multi-year sea ice
Summary and future work
NOAA Federal Sponsor:
Dr. Laury Miller, Chief, Laboratory for Satellite Altimetry (LSA)

NOAA Sea Ice Team Lead: Dr. Larry Connor

Collaborations with:
• NASA GSFC/Cryospheric Sciences Branch
• US Army Cold Regions Research and Engineering Laboratory (CRREL)
• US Naval Research Laboratory (NRL)
• European Space Agency (ESA)
• Office of Naval Research (ONR)
• Oregon State University, University of Washington
• University College London, University of Reading, York University
Research Activities

- Assessment of **decadal time-series of Arctic sea ice thickness** from satellite altimeters (ICESat, Envisat, and CryoSat-2) and related parameters incl. reanalysis data, satellite imagery, sea ice drift datasets
- **Data synthesis** to improve seasonal-to-decadal predictions of Arctic sea ice
- **Validation of airborne altimeter measurements** using *in-situ* field data sets, assigning accuracy estimates with respect to sea ice type
- **Validation of satellite altimeter data** via coincident airborne campaigns
- Deliver key observational datasets for **model validation / initialization**
- Derive novel, high-resolution sea ice parameters (ice type and morphology) for input to next-generation sea ice models (**model parameterizations**)  
- **Team Members** of IceBridge and ICESat-2 science teams: mission support and planning, algorithm development, support Early Adopter Scheme
**Measurement Technique**

**Sea Ice Thickness from Airborne and Satellite Altimetry**

*An inferred measurement*

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- **Radar Altimeter:**
  - Ice Surface
  - Measure surface elevation
  - Discriminate leads from floes
  - Open water required for calibration
  - Derive freeboard
- **LiDAR Altimeter:**
  - Snow surface
  - Assuming hydrostacy:
    - Infer ice thickness, which is a function of:
      - Snow, ice and water density
      - Snow depth
      - Ice freeboard
  - Ice thickness uncertainty influenced by errors freeboard and snow depth
  - Uncertainty of 11 cm in snow depth => contributes ~ 50 cm to the total ice thickness unc. from laser altimeter system

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**Sinéad Louise Farrell**

2nd Annual CICS-MD Science Meeting, 12-13 Nov. 2014
Sea Ice Thickness from Airborne and Satellite Altimetry

*An inferred measurement*

**Measurements**
- Lead locations
- Lead Elevation (A) => sea surface height
- Floe Elevation (B) => sea-ice surface topography and roughness
- Snow Depth (C)

**Derived Products**
- Mean Freeboard (& uncertainty) (D = B-A)
- Snow Depth (& uncertainty) (C)
- Ice Thickness (& uncertainty) (f (C, D))

Examples of missions employing this technique: ERS-1, -2; Envisat; ICESat; IceBridge; CryoSat-2; ICESat-2

Photo Credit: Andrew Roberts, SEDNA 2007
NASA Operation IceBridge

Airborne mission with a suite of remote sensing instruments, launched in March 2009 to bridge gap between ICESat and ICESat-2

**Instruments for snow depth and sea ice thickness:**

- ATM Laser Altimeter (lead / floe elevation, surface topography, freeboard)
- FMCW Snow Radar (snow depth)
- High resolution digital camera (lead locations)
- Gravimeter (gravity field)
- KT19 Thermal imager (surface temp)

**More info at:**
- icebridge.gsfc.nasa.gov
- nsidc.org/data/icebridge/
- nasa.gov/mission_pages/icebridge/
- @NASA_ICE

Sea ice conditions
Southern Weddell Sea
Oct 20th 2014!

Photo Credit: J. Yungel, NASA IceBridge
**Goal:** Characterize snow depth on Arctic sea ice in a range of locations and varying snow conditions. Multiple field teams validate a suite of airborne radar and laser sensors.

**Background:** ASCAT backscatter data indicates surface conditions, delineating FYI and MYI.

Credit: NASA Scatterometer Climate Record Pathfinder (SCP) Project (www scp.byu.edu)

From: Richter-Menge et al. (2014, in prep)
Tom Newman participated in the **NRL “DISTANCE” airborne project**, 13-27 March 2014. NRL aircraft conducted surveys above field teams and underflights of CryoSat-2.

Alek Petty participated in the **JOIS/Beaufort Gyre Exploration Project research cruise** in the Beaufort Sea on board the CCGS Louis S. St Laurent, Sept/Oct 2014.
Multi-year ice

First year ice

- EUMETSAT Ocean and Sea Ice – Satellite Application Facilities (OSI-SAF) sea ice type product (http://saf.met.no/p/ice/)
- Maslanik et al. [2011] reported that MY ice extent in the Arctic Ocean reached record minimum in March 2008.
- Loss of MY ice was particularly dramatic in the western Arctic, including the Beaufort Sea and the Canada Basin
Sea Ice Thickness in Western Arctic: 2009 – 2014

Updated From: Richter-Menge and Farrell (2013)

Sinéad Louise Farrell

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Regional Variability in Arctic Sea Ice Thickness

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Updated From: Richter-Menge and Farrell (2013)
Variability in Multi-year/First-year Ice Thickness

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Updated From: Richter-Menge and Farrell (2013)
Sea Ice Thickness in western Arctic has remained generally consistent over last six yrs, after dramatic drop in winter 2007/08 (Kwok et al. 2009; Giles et al., 2009)

Mean thickness decreased slightly in winter 2013, after record min. in Sept 2012:

~ -0.26 m (MYI) and ~ -0.33 m (FYI)

Central Arctic: Dominant multiyear ice (MYI) zone: 90% +

Beaufort /Chukchi Sea (BC) Region: Mix of MYI and first-year ice: ~ 25 %: 75 %

Persistent MYI tongue in Beaufort and Chukchi Seas in winter 2014

Slight rebound in ice thickness after winter 2013

Snow depth estimates from IceBridge now available for western Arctic

- Snow on multi-year ice consistent with snow climatology of Warren et al. (1999)
- Snow on first-year ice ~60 % of snow climatology
- See Tom Newman’s presentation later today!

A look ahead – NASA’s ICESat-2 due for launch in late 2017 with coverage to 88°N/S