Contribution of Antarctic sea ice thickness observations to understanding of sea ice volume change

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Antarctic sea ice thickness and volume 2003-2008

ICESat sea ice thickness averaged over the 2003-2008 time period from Kurtz and Markus, 2012

Sea ice thickness climatology from ship based observations by Worby et al., 2008.

Spatial structure in reasonable agreement with ship observations from 1981-2005, small differences suggest no large changes in thickness over the time period.
Variability of snow and sea ice densities introduces uncertainty in the ice thickness and volume estimates.

Only trends in the Bellingshausen/Amundsen, Western Weddell, and Indian Ocean regions were large enough to be statistically significant.
Outline of major challenges

- Only small changes seen and short time series available, difficult to separate uncertainties to obtain statistically significant trends
- Satellite observations (e.g. ICESat, ICESat-2, CryoSat-2) are the only available tool to attain basin-wide observations of sea ice thickness over long time scales
- Major uncertainty sources of uncertainty from altimeters:
  - Laser: open water identification, clouds/forward scattering, zero freeboard assumption, snow depth/density, sea ice density
  - Radar: waveform tracking, absorption/penetration, snow and ice backscatter characteristics, off-nadir returns, snow
The way forward: radar altimetry

- Radar altimetry (ERS-1, ERS-2, Envisat, CryoSat-2) offers longest time series (since 1991) but a number of problems need to be solved to get accurate retrievals.

From Giles et al., 2008, “the ERS ice elevation is possibly a measurement of the ice freeboard plus part of the overlying snow, i.e. the radar doesn’t penetrate to the snow/ice interface, but to somewhere between the air/snow and snow/ice interfaces over Antarctic sea ice.”
The way forward: satellite altimetry and other data sets

- Other data sets have great promise in contributing to a better sea ice thickness record: in-situ measurements, undersea sonar (AWI), autonomous underwater vehicles, EM bird, passive microwave record
- Operation IceBridge: novel combination of laser and radar measurements, how to best use limited flight lines?
- Need for validation of remote sensing data sets with in-situ measurements
Model comparisons with satellite retrievals of ice area, thickness, and volume show promising ability to assess Antarctic sea ice trends.

Model results show only a small increase in sea ice thickness and volume since 1992.
Summary and outlook

- Sea ice thickness and volume observations can be used to constrain models, help better constrain physical reasons for observed variability and trends

- Only small changes have been observed in Antarctic sea ice thickness and volume, longer time series and/or more accurate retrievals needed in order to determine statistically significant trends
  - ICESat-2 to be launched in 2017

- Big need to exploit in-situ measurements to quantify spatiotemporal variability of snow and sea ice density

- Validation and improvement of existing satellite data sets possible with other data sets