It’s a wet, wet WAIS: Observations of current and historical snow accumulation from the Amundsen Sea sector

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Accumulation is important!

Rignot et al., Nat. Geosci., 2008

Shepherd et al., Science, 2012

Pritchard et al., Nature, 2009

Rignot et al., Nat. Geosci., 2008
Overview

1. Recent
- 1980-2009
- OIB Snow Radar
- Model comparison

2. Historical
- Past 300+ years
- 15 firn cores

3. Firn Compaction
- OIB snow radar
- Model comparison
1. Recent accumulation rates
Annual accumulation from OIB snow radar
Annual accumulation from OIB snow radar

1. Track several internal horizons

Medley et al., *GRL*, 2013
Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced
Annual accumulation from OIB snow radar

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Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced
3. Generate >6,000 30-yr records

Medley et al., GRL, 2013
1. Track several internal horizons
2. Confirm horizons are annually spaced
3. Generate >6,000 30-yr records
4. Evaluate atmospheric models
   - No recent accumulation trend
   - Evaluation of temporal variability in modeled accumulation

Medley et al., GRL, 2013
RACMO 2.3
Van Wessem et al., J. Glac., 2014
mean = 0.440 mwe per year
std = 0.060 mwe per year
\( r_{SR} = 0.68 \)

Snow Radar
mean = 0.457 mwe per year
std = 0.056 mwe per year

RACMO 2.1
(Lenaerts et al., GRL, 2012)
mean = 0.432 mwe per year
std = 0.080 mwe per year
\( r_{SR} = 0.67 \)
Climate model comparison over Thwaites catchment

- **Temporal variability**
  - *REANALYSES are spot on!* $r > 0.9$
  - *RACMO2 underperforms relatively, $r = 0.68$*

- **Spatial variability**
  - *REANALYSES vary based on rez., $r = 0.68$ to $0.75$*  
  - *RACMO2 has finest spatial rez., $r = 0.86$*

- **Magnitude**
  - *REANALYSES underestimate*
  - *RACMO2 is about spot on!*

Provides the ability for user to discriminate between models based on need
2. Historical accumulation rates
Long-term core records

ITASE (2000/2001)
(Kaspari et al., J. Glac., 2004)

WDC05A/Q (2005)
(Banta et al., GRL, 2009)

Stack the records with weights based on their average correlation with ERA-Int $P-E$ for each grid cell within the PIG/THW drainage

Medley et al., TC, 2014
Correlation maps for each core record

Black dot show core location

Note strong decrease in correlation beyond the drainage divides

Find the average $r$ for each core within PIG/THW boundary

Stack the records weighted accordingly
Recent accumulation rates are **above average**, but **not out of the ordinary** during the last 300+ years.
Excellent agreement between radar and firn core records suggests:

(7) We know the temporal variability with high confidence over these basins, and
(8) The records are minimally impacted by local-scale phenomena (they are regional!)
Spatial correlation of the 2010 stack with ERA-Interim $P-E$

Strong correlation over majority of the PIG/THW drainage:
(3) These basins experience similar precipitation regimes, and
(4) The stack is likely representative of variability over both PIG/THW
PIG/THW Accumulation Summary

- **No trend:** 1980-2009
- **Recent rates above average, not unusual**
- **Several sources agree on temporal var.**
- **Signal common to both basins**
- **Minimal noise from local processes**
Measuring firn compaction rates from OIB snow radar

1. Find repeat OIB surveys

Medley et al., *in review*
Measuring firn compaction rates from OIB snow radar

1. Find repeat OIB surveys
2. Calculate compaction rates

Medley et al., *in review*
Measuring firn compaction rates from OIB snow radar

1. Find repeat OIB surveys
2. Calculate compaction rates
3. Evaluate modeled compaction rates

- Unique evaluation: typically assess model ability through comparison with measured density profiles

Ligtenberg et al., *in review*
Summary

• We know the temporal var. in accumulation over the past 3 decades over PIG/THW!
  – Radar, firn cores, climate models ALL agree!
• While above average, the recent decades are not out of the ordinary
  – Combines strength of firn core records & models
• FDM performs well, must have good climate input though.
Thanks!

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Twila Moon
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Travel:
WAIS Workshop
NASA NPP

NASA Postdoctoral Program
NASA
NSF
CReSIS
Center for Remote Sensing of Ice Sheets
Airborne radar

- Ice-sheet surface (strong reflector)
- Internal reflectors - density or chemical (i.e., volcanic) contrasts

Allows us to image internal horizons beneath the ice surface, which are used to estimate accumulation, over large distances.
Annual accumulation from OIB snow radar

1. Track several internal horizons

Medley et al., GRL, 2013
Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced
Stable over past ~30 years

- Airborne OIB snow radar: each point represents a 30-yr accum. record (> 6,000)
- Independent of ice core chronology

Medley et al., GRL, 2013
Comparison of various accumulation records

(1) All agree there is no trend over the past 30 years, and
(2) All are significantly correlated with one another

Medley et al., GRL, 2013
Annual accumulation from OIB snow radar

1. Track several internal horizons
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# Radar Properties

<table>
<thead>
<tr>
<th></th>
<th>Accumulation</th>
<th>Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency spectrum</strong></td>
<td>550 – 900 MHz</td>
<td>2 – 6.5 GHz</td>
</tr>
<tr>
<td><strong>Range resolution (ice)</strong></td>
<td>40 cm</td>
<td>5-10 cm</td>
</tr>
<tr>
<td><strong>Deepest horizon mapped</strong></td>
<td>145 m (425 yrs)</td>
<td>52 m (42 yrs)</td>
</tr>
<tr>
<td><strong>Temporal spacing</strong></td>
<td>Multi-year to decadal</td>
<td>Annual*</td>
</tr>
<tr>
<td><strong>Survey design</strong></td>
<td>Targeted</td>
<td>Operation IceBridge</td>
</tr>
<tr>
<td><strong>Distance flown</strong></td>
<td>9,650 km</td>
<td>16,350 km</td>
</tr>
</tbody>
</table>

Center for Remote Sensing of Ice Sheets (CReSIS; www.cresis.ku.edu)
ASL and WAIS Accumulation

When ASL is deeper, accumulation is...

PIG/THW acc. is NOT significantly correlated

Correlation of the ASL center pressure from XXXXXXXX and ERA-Interim P-E
Correlation of stacked record with ERA-Interim z500 Geopotential Heights

Higher accumulation in PIG/THW when high pressure blocking system exists centered over Drake Passage.

It generates anomalous flow up and into these basins.
Correlation of SEAT cores with ERA-Interim P-E: 1979-2010

SEAT10-1
SEAT10-3
SEAT10-4
SEAT10-5

- - - p-value < 0.05
- - - - p-value < 0.01
Correlation of Snow Radar at SEAT cores with ERA-Interim P-E: 1979-2010