Post-K&C – First Report

**InSAR based Ice Velocity and Grounding line Measurements in Antarctica**

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With Funding from NASA MEaSUREs & Cryosphere Science Programs

Post-KC Science Team meeting #1  
Tokyo, Japan, January 20-24, 2020
Motivation for this work
Ice sheets are acknowledged by WMO and UNFCCC as Essential Climate Variable (ECV) needed to make significant progress in the generation of global climate products and derived information.

Background
The Polar Space Task Group (PSTG) coordinates acquisitions in Polar regions in support of scientific exploitation.

Information Requirements
- Surface Elevation & Elevation Change
- Ice Velocity
- Grounding Line Location
- Calving Front Location
- Bed Elevation

→ Ice Sheet Mass Balance
Key Question: Are the ice sheets in Antarctica and Greenland loosing mass?

Three independent methods are available to measure mass balance:
• Input – Output
• Gravimetry
• Altimetry

Shepherd et al. 2012. Science (47 authors)

A Reconciled Estimate of Ice-Sheet Mass Balance

IMBIE.org

Fig. 3. Intercomparison of mass balance estimates of the GrIS, APIS, EAIS, WAIS, AIS, and the AIS plus GrIS, derived from the four independent geodetic techniques of RA (cyan), IOM (red), LA (green), and gravimetry (blue) over the period 2003 to 2008. Also shown is the reconciled result (gray).
Mass Balance of the Antarctic Ice Sheet

The IMBIE Team.
Mass Balance of the Antarctic Ice Sheet

Using the Input/Output method to analyze data acquired over four decades.

Total mass change of major basins for 1979–2017 (blue:gain, red:loss); circle proportional to the absolute mass balance

Takeaway message: Mass loss is dominated by enhanced glacier flow in areas closest to warm, salty, subsurface circumpolar deep water, including East Antarctica.

Rignot et al. PNAS 2019;116:4:1095-1103
Mapping ice motion from image cross-correlation

- Correlation of small image chips between 2 consecutive images.
- Ice velocity mapping precision around tens of meter per year.
- Composite maps can reach 2-5 m/yr precision.

Mouginot et al. 2017
Rignot et al. 2011
https://nsidc.org/data/NSIDC-0484/versions/2
Earth Science Data Records

Products:
http://nsidc.org/data/measures/data_summaries

Ice Velocity Maps:
https://nsidc.org/data/NSIDC-0754
https://nsidc.org/data/NSIDC-0484
https://nsidc.org/data/NSIDC-0720
https://nsidc.org/data/NSIDC-0545
https://nsidc.org/data/NSIDC-0525

Grounding Line:
https://nsidc.org/data/NSIDC-0498

Boundaries
https://nsidc.org/data/NSIDC-0709
Objective: Maximize coverage while limiting the observation period.
Mapping ice motion from image cross-correlation

About 60% of the Antarctic ice sheet is flowing slower than 10 m/yr.

Tracking-based ice velocity maps based on tracking are not precise enough to properly describe the ice flow.

Precision is suitable for calculating ice volume fluxes along the periphery, where ice speed ranges from 400 to 4,000 m/yr (Rignot et al., 2019).
Using the InSAR Phase

Theoretical precision of ice motion mapping from a single combination of ascending and descending phases is typically 0.15-1.79 m/yr.

Difficult in fast flow = aliasing (two many fringes)

Need observations with different geometry, typically asc/des

<table>
<thead>
<tr>
<th></th>
<th>Wavelength (cm)</th>
<th>Period (data processed)</th>
<th>Nominal Repeat Cycle (day)</th>
<th>Mapping precision (m/yr)</th>
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<td>ERS</td>
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<td>1992-1996</td>
<td>1 (3)</td>
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</table>
Ionosphere correction for L-band

Used a split spectrum based correction (Liao et al. 2018)
Applied the method on 546 ALOS/PALSAR tracks
Phase noise is reduced by 90%, dropping from 1 m/yr to 10 cm/yr

Average ice velocity and its standard error:
Red line and shading: non-ionosphere-corrected
Blue line and shading: ionosphere-corrected
Gray: tracking-based reference ice velocity
Unwrapped phases for more than 2400 tracks
Stripmap mode data used only

- **ALOS/ASAR**
  - 319 unwrapped tracks
  - ESA

- **ALOS/PALSAR**
  - 559 unwrapped tracks
  - JAXA

- **ERS & RADARSAT-1**
  - 341 unwrapped tracks

- **RADARSAT-2**
  - 1196 unwrapped tracks
  - CSA, MDA

**Flag Legend**
- **ESA**
- **JAXA**
- **CSA**
- **MDA**
InSAR
Phase-based
Ice Velocity

Phase-based map covers 71% of Antarctica

Limitation:
the interferometric phase is aliased in areas of fast flow

Mouginot et al. 2019
Speed Error

Error of composite map is on average about 2-5 m/yr from the tracking map versus 15-20 cm/yr with the phase data, or about 10x more precise

Mouginot et al. 2019
Error in flow direction with phase data is less than 1 degree over 25% of Antarctica and less than 7 degrees over 80% vs. less than 25% from tracking data.

Mouginot et al. 2019
Ice Velocity and Grounding Line in Antarctica Measured from Space

Rignot E., Mouginot J., Scheuchl B.

Data Sources:
Copernicus Sentinel-1, ERS-1 & ERS-2, ENVISAT-ASAR, RADARSAT-1 & -2, COSMO SkyMED, ALOS PALSAR, ALOS-2 PALSAR-2, TerraSAR-X & TanDEM-X, Landsat-8

PSTG is acknowledged for its role in coordinating the data acquisition plans.

These data sets are available at NSIDC
https://nsidc.org/data/NSIDC-0754
https://nsidc.org/data/NSIDC-0498
Grounding Line

Require 2 interferograms for a single measurement.

Now looking at multiple grounding line measurements per year – ongoing acquisition:

Tidal influence observed for some glaciers → define a grounding zone
Comments to JAXA

- We use all data available to us and generate a series of composite multi-sensor geophysical products for Antarctica.
- JAXA L-band data are a valuable resource for ice sheet mapping in Antarctica (and Greenland).
- Interferometric data is required for ice velocity (speckle tracking & InSAR phase), multiple interferograms are required for grounding line measurements.
- The ALOS-2 quota restriction reduces the impact of ALOS-2 for continent-wide product generation.
- Data suitable for ice sheet monitoring should still be collected – in case future wide releases become an option.