Ice motion mapping in Antarctica with Envisat ASAR and ALOS PALSAR

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Objectives

• Ice sheet mass balance and changes in ice dynamics.

• Measurements of ice motion, tidal flexure, glacier acceleration, surface drawdown, grounding line migration have been made in Greenland and Antarctica with ERS-1/2 tandem and Radarsat-1 data.

• These data are critical to document ice sheet mass balance and improve our capability to predict their evolution in the next 100 yrs using numerical models.

• What is the potential for Envisat ASAR and ALOS PALSAR for ice sheet studies?
Ice motion with (long-repeat) ASAR and PALSAR

- Speckle tracking with ASAR I2 (35-day) and PALSAR FBS (46-day) because fringes are no longer visible.
- HH polarization (stable) fine beam (baseline) preferred.
- Critical baselines: 500 m for ASAR, 14 km for PALSAR.
- Practical baselines: 0-100 m for ASAR, 2 km for PALSAR.
- L-band signals more stable (SIR-C), greater penetration (AIRSAR), but more sensitive to ionosphere and thermal noise.
- ASAR IPY campaign in May - July 2006.
- PALSAR IPY campaign in fall 2007; test data in May - Aug 2006.
Speckle tracking

- Speckle tracking (Michel and Rignot, 1999; Gray et al., 1999).
- Precision of offsets = 1/128th of a pixel.
- Offsets calculated over 64/128 x 256 windows with 32 x 32 search windows.
- PALSAR: 4.7 m SR (7.1 m GR) x 3.1 m AZ, 41.7° angle, down to 79 South.
- ASAR: 7.9 m SR (20.4 m GR) x 4.0 m AZ, 22.8° angle, down to 81 South.
- Offsets are filtered, plane fitted using zero-motion reference areas, and georeferenced with DEM combining ERS-1 and ICESAT-1 altimetry (Bamber, unpublished).
- Provide 2-dimensional vector displacement with 1 pair, less sensitive to topography than interferometric phase, and less sensitive to ocean tides (best for ice shelves).
PALSAR Speckle Tracking

Radar amplitude  Filtered offsets  Velocity magnitude

(slant-range radar geometry)
• Getz and Abbot Ice Shelves, West Antarctica, decorrelate regardless of baseline and season.
• Fundamental reason for loss of temporal coherence is not volume scattering, thermal noise, melt, or baseline, but surface weathering from wind and precipitation (Hoen and Zebker, 2000).
• Antarctic Peninsula: high decorrelation on ice shelves, 35-days more limiting than 24 days, even in winter.
Low precipitation, correlation can remain high over large areas.
Lambert Glacier, East Antarctica
ENVISAT ASAR

Very low accumulation, ASAR provides excellent mapping
Fringe 2007
Geocoded velocity                   Entire track       Mosaic of 7 tracks
Crosson Ice Shelf
Dotson Ice Shelf
Getz Ice Shelf, West Antarctica, PALSAR
Crosson and Dotson ice shelves, West Antarctica
Getz Ice Shelf, West Antarctica
• High coherence on Lambert Glacier.
• No change in speed since 1996.

• Coherence lost on Law Dome because of SNR.
• Loss of coherence on Totten Ice Shelf (?).
• No change in speed since 1996.
Pine Island Bay, West Antarctica
• PALSAR/RSAT 2006 agree.
• Thwaites Glacier widened by several km.
• Smith Glacier and all tributaries accelerated 85%.
• Discharge from entire glacier system increased from 215 Gt/yr to 261 Gt/yr in 10 yrs.
• Mass loss increased from 38 Gt/yr to 84 Gt/yr or 120%.
ERS-2/ASAR 30 mn InSAR: Kangerdlugssuaq Glacier, Greenland

- Interferometric baseline ~ 2km; temporal baseline 30 mn, Oct. 2, night time.
- Coherence is lost on snow/firn; coherence is preserved on rock.
- ERS-2/ASAR 30 mn InSAR: Kangerdlugssuaq Glacier, Greenland

- Flow
- Along track
- Radar look
- 5 km
ERS-2/ASAR 30 mn InSAR:
Kangerdlugssuaq Glacier, Greenland

• Interferometric baseline ~ 2km; temporal baseline 30 mn, Oct. 2, night time.
• Coherence is lost on snow/firn but reasonable on ice (end of melt season).
• Ice flows at 14 km/yr = 79 cm/30mn = 14 fringes at C-band.
• Requires precise topographic correction (ASTER+ATM). 5-6 m change in elevation = 1 fringe
• Fringes were not visible in ERS-1/2 1-day data on this glacier.
• Provide insights on glacier flow variability on sub-hour time scale (sliding, calving, drawdown, ice quakes, etc.).
Conclusions 1/2

- ERS-1/2, Radarsat-1 and Envisat ASAR mapped the entire coastal regions of Greenland to determine the mass flux and mass balance of the ice sheet.
- Greenland’s mass loss doubled in the last decade from 82 Gt/yr to 202 Gt/yr (Rignot and Kanagaratnam, 2006).

• Same in Antarctica using ERS-1/2, Radarsat-1 and ALOS PALSAR.
- Zero balance in East Antarctica, slight gain in southern parts of West Antarctica, but large losses in northern parts of WAIS and northern tip of AP from glacier speed up (Rignot, et al., Nature Geosc., in press).
- Antarctic mass loss increased from 112 Gt/yr in 1996 to 196 Gt/yr in 2006, entirely from Pine Island Bay and the northern tip of AP.
Conclusions 2/2

- Envisat ASAR IPY 2007 acquired many valuable data with short baselines, but it won't work everywhere. Best results in dry, East Antarctica.

- ALOS PALSAR works exceptionally well, especially in wet coastal basins where Radarsat-1 and Envisat ASAR are limited.

- ERS-2/Envisat ASAR will provide new insights into short-term variability in fast glacier flow.

- Two NASA-funded “MEASure” projects will assemble multi-year velocity maps for Antarctica (Rignot, PI) and Greenland (Joughin, PI) using ERS-1/2, Radarsat-1, Envisat ASAR, and ALOS PALSAR and distribute the products to the community via NSIDC.

- PALSAR and ERS-1/2 showed that the mass loss from Pine Island Bay increased 120% in the last ten years, with potential for > 100 Gt/yr mass loss in the next decade.

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