Application of Sentinel-1 SAR for monitoring surface velocity of Greenland outlet glaciers

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OUTLINE

• Ice Surface Velocity from S1 TOPS data
• Intercomparison of Ice velocity S1 with TSX
• Examples for speed change of outlet glaciers 2007 – 2015
• 12 Days coherence and INSAR
• Ice velocity Map
• Summary and Conclusions
Ice Surface Velocity from SAR TOPS mode data

**CO-REGISTRATION:**
- Geometric Co-registration of Master and Slave Bursts: DEM, Precise Orbits
  - 1st Refinement of Azimuth Shifts: Incoherent OT all Bursts
  - 2nd Refinement of Azimuth Shifts: ESD in Overlaps of adjacent Bursts
- Master and Slave Burst by Burst Co-registration

**OFFSET TRACKING:**
- DAY = 10
- DAY = 11
- Azimuth offset (y)
- Range offset (x)
### Characteristics of Sensors and Data sets

<table>
<thead>
<tr>
<th>SAR Platform</th>
<th>Sentinel-1</th>
<th>TerraSAR-X / TDX</th>
<th>ALOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>C-band SAR</td>
<td>X-band SAR</td>
<td>PALSAR / band</td>
</tr>
<tr>
<td>Mode / Product</td>
<td>IWS / SLC</td>
<td>Stripmap / SLC</td>
<td>Fine Beam / SLC</td>
</tr>
<tr>
<td>Resolution</td>
<td>3 x 22m</td>
<td>1.2 x 3.3m</td>
<td>4 x 3 m</td>
</tr>
<tr>
<td>Repeat cycle</td>
<td>12d</td>
<td>11d</td>
<td>46d</td>
</tr>
<tr>
<td>Swath width</td>
<td>250km</td>
<td>30 km</td>
<td>70 km</td>
</tr>
</tbody>
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**TerraSAR-X STRIPMAP**
- Dec 2014
- Jan/Feb 2015

**Sentinel-1 IWS**
- Oct 2014 to Mar 2015
Sentinel 1 Ice Surface Velocity & Comparison to TSX and PALSAR

Sentinel 1
3-15 Jan 2015

TerraSAR-X
Dec-Feb 2015
11 days image pairs

PALSAR
Dec 2009

PALSAR
Sept 2008
Horizontal Ice Surface Velocity
Sentinel-1 versus TSX

**SENTINEL-1**  

**TerraSAR-X**  
(9 - 20 Dec 2014)

Ice Velocity S1-TSX:  
Mean Difference = -0.02 m/d  
Std: 0.36 m/d

Difference Map: S1-TSX
Iterative Offset Tracking of Fast Glaciers

**Iterative Procedure:**

- Calculate shifts with a coarse sampling and without sub-pixel matching
- Where no matching found: Estimate shifts based on neighbours from previous run and apply coarse offset matching, until no improvement is observed
- Use coarse resolution offset map for final matching with small matching windows and sub-pixel matching

Image sequence of the iterative calculation of a very fast glacier (e.g. Jakobshavn glacier; ca. 30 m/d)
Intercomparison of Sentinel-1 and TSX

Sentinel 1  Jan 2015

TerraSAR-X  Feb 2015
Length-Profiles S1 versus TSX & PALSAR

Jakobshavn/SK

Distance [km]

Velocity [m/d]

S1 Jan 2015
TSX Feb 2015
PALSAR Dec 2009
PALSAR Sep 2008

IASC Workshop on the dynamics and mass budget of Arctic glaciers | Obergurgl | 23-25 March 2015 | Jan Wuite
Sermeq Silarleq – Increase of Speed 2008-2015

Velocity Increase

Velocity (S1 Jan 2015)

Sermeq Silarleq

Distance [km]

Velocity [m/d]
Length-Profiles S1 versus TSX & PALSAR

**Store Gl./SK**

- **S1 Jan 2015**
- **TSX Feb 2015**
- **PALSAR Dec 2009**
- **PALSAR Sep 2008**

**Umiammaku Isbræ/US**

- **S1 Jan 2015**
- **TSX Feb 2015**
- **PALSAR Dec 2009**
- **PALSAR Sep 2008**
X-Profiles S1 versus TSX & PALSAR

### SK-KS

- **Distance (km):**
  - SK
  - KS
  - S1 Jan 2015
  - TSX Dec 2014
  - PALSAR Dec 2009
  - PALSAR Sep 2008

### Rink Isbræ/KS

- **Distance (km):**
  - Rink Isbræ
  - Kanglennata Sermia
  - S1 Jan 2015
  - TSX Feb 2015
  - PALSAR Dec 2009
  - PALSAR Sep 2008
12 days Coherence over GIS

Sentinel 1 IWS SLC
Period: Jan-Mar 2015
(some scenes Oct-Dec 2014)

S1 Track 83
8 Feb – 20 Feb 2015
Examples for 12 days Interferograms

Track 133 30.1 – 11/2/2015

Track 25 19/10 – 31/10 2014

Coregistration:
- Geometric
- Precise orbits

Ice sheet:
- Fringes well developed over some regions
- Significant phase jumps at burst and swath interfaces might occur:
  - Azimuth motion
  - Different LOS direction at burst interfaces

- Further developments needed to use this information
Greenland Ice Sheet

Sentinel-1
Ice Surface
Velocity Map \( v_h \)

Sentinel 1 IWS SLC
Period: Jan-Mar 2015
(some scenes Oct-Dec 2014)
~700 Scenes
~19,000 bursts
Summary and Conclusions

- Sentinel-1 IWS has excellent capabilities for regular repeat mapping of ice sheets velocities.
- Ice velocity maps from Sentinel-1 IWS agree very well with TerraSAR-X data acquired at the same period. Main differences are observed in shear zones, where higher resolution provides better results.
- SAR TOPS Interferometry: during winter coherence over 12 days is suitable for generating interferograms. Further developments are needed to retrieve velocity from TOPS InSAR to compensate for variable LOS direction within bursts and phase jumps at burst interfaces due to azimuth motion.
- 1st Sentinel-1 velocity map of Greenland has been generated using data from January to March acquisitions (3 repeat acquisitions for most tracks). We recommend to acquire at least 2 independent repeat image pairs per campaign.