Polar Space Task Group
SAR Coordination Working Group Meeting 5

SAR Coordination for Snow Products

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Observational requirements for satellite-based **snow extent products** for operational hydrology and climate research (*IGOS Cryosphere Theme Report*):

- Spatial resolution: **100 m**
- Revisit time: **1 day**

Product type of the current satellite-based C-band SAR Systems:

- **Extent of snow melt area** based on backscatter sensitivity to wet snow. C-band SAR is not suitable for operational monitoring of **dry snow areas** very limited sensitivity to dry snow.
Science Requirements: Snow

R1: Use wide-swath modes to enable wide area monitoring with high temporal resolution (i.e. RSAT2 SCN or SCW, Sentinel-1 IW or EW, TSX “SC Wide” & CSK “Huge Region” ScanSAR modes).

R2: Build combined ascending/descending coverage by default into acquisition plans covering mountainous regions. Favour asc./desc. acquisition sets acquired within a tight time window (1-3 days) to allow a narrow time-attribution to composites generated from these sets.

R3: Concentrate snowmelt acquisitions on the seasonal window when the majority of snow melting occurs (Feb. 15 through May 30 at temperate northern latitudes). The highest temporal resolution possible is requested during this critical melting period. Although some further acquisitions are also requested outside of this seasonal window, lower temporal resolution at these less critical times is acceptable.

R4: Standardise dual-pol. mode acquisitions on VV/VH combination: a cross-platform consistent polarisation simplifies combination of datasets from multiple providers (e.g. S1/RSAT2/RCM or TSX/CSK). HH/HV in Arctic for ice.

R5: Harmonise acquisition plans of satellites with compatible calibrated backscatter values (e.g. S1/RSAT2/RCM or TSX/CSK). Utilise the available diversity of orbits to achieve the desired diversity of tracks – e.g. to achieve the fullest possible ascending/descending coverage.

R6: Assure full coverage over land also in coastal regions when other modes are by default programmed over ocean (e.g. favour Sentinel-1 IW or EW over WV).

R7: Maintain a regular observation plan also during the winter to assure frequent observations of other important snow parameters, and other phenomena related to the winter period such as avalanches and rain on snow events. Adding a shoulder season ramp-up/down is foreseeable.


Required Data from SAR Missions

• Reminder of coverage plans from SAR missions
  – C-band Sentinel-1 coverage of
    • European Alps IW: VV/VH
    • British Columbia, Canada: VV/VH
    • Ellesmere Island, Canada: EW HH/HV being acquired
  – C-band Radarsat-2 coverage of
    • European Alps in VV/VH when possible (SCNB?)
SAR Data Used

- SAR data used since the last meeting:
  - Sentinel-1A
    - IW: European Alps 2014-2016: VV/VH
    - IW: Vancouver, BC, Canada 2014-2016: VV
    - EW: Ellesmere Island, Canada 2015: HH & HV
  - Radarsat-2
    - SCN & SCW beams: Switzerland 2015: VV & VH
    - SCWA: Ellesmere Island, Canada 2015: HH & HV
Progress since Last Meeting

• Extended Sentinel-1A based backscatter composite generation
• Wet snow mapping algorithm improved, integrated with MODIS products
• Automated Radarsat-2 radiometric terrain correction in Alps
• Applied radiometric terrain correction and backscatter compositing to available Radarsat-2 SCWA coverage of Ellesmere Island
Terrain-flattened Gamma Nought

Interlaken, Switzerland
Sentinel-1A IW GRDH VH-pol.
May 26, 2015

Normalise $\beta^0$: divide by simulated image

\[
\frac{\gamma_T^0}{\gamma_T} = \frac{A_\gamma/A_\beta}{\beta^0}
\]


Contains modified Copernicus Sentinel data (2015)
Radiometric Terrain Correction in Alps with Radarsat-2 SCN & SCW

- Automatic RS2 RTC generation in Swiss Alps
  - Geometric calibration tests with corner reflectors might help reduce residual DEM vs. radar image mis-registration

2015.04.17 Asc. SCNB VH 2015.04.18 Desc. SCWB VH

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Backscatter Composites

Combine asc. & desc. observations to generate **composite** with improved local resolution

• Less shadow than single RTC, lower noise

Interlaken, Switzerland
S1A Alps Backscatter Mosaic

Contains modified Copernicus Sentinel data (2015)

S1A IW VH & VV-pol. processed Oct. 2014 – Aug. 2016: 12d & 16d windows
Jan.-Aug. 2016 VH 16d shown here

S1A Alps Wet Snow Maps

Contains modified Copernicus Sentinel data (2015)

S1A IW 2015 VH & VV-pol.

S1-based wet snow classifications compared with NASA MODIS snow products
Coastal British Columbia Backscatter Composites

**S1A IW VV**
12 day delta
24 day window

N.B.
*Increased dual-pol VV/VH acquisitions in last months*

Contains modified Copernicus Sentinel data (2015)
Ellesmere Island Backscatter Composites

S1A EW HV
2 day delta
4 day window

N.B.
HH also available
CDEM

May – Sept. 2015
Contains modified Copernicus Sentinel data (2015)
Ellesmere Island Backscatter Composites

RS2 SCWA HV
4 day delta
8 day window

N.B.
8 bit radiometry
CDEM

May – Aug. 2015

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Ellesmere Island Backscatter Composites

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May – Aug. 2015

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Backscatter ratio (median, Mdn, 1st and 3rd quartile) for Sentinel-1 VV- and VH-polarized channels in dependence of the local incidence angle, \( \Theta \), for test area Ötztal.

Relation for merging \( R_{\text{vv}} \) and \( R_{\text{vh}} \) ratios in order to create a combined single channel, \( R_c \):

\[
R_c = W R_{\text{vh}} + (1 - W) R_{\text{vv}}.
\]

With:

\[
\begin{align*}
&IF \ (\Theta < \theta_1) \quad \rightarrow \quad (W = 1.0) \\
&IF \ (\theta_1 \leq \Theta \leq \theta_2) \quad \rightarrow \quad (W = k \left[1 + \frac{(\theta_2 - \Theta)}{(\theta_2 - \theta_1)}\right]) \\
&IF \ (\Theta > \theta_2) \quad \rightarrow \quad (W = k)
\end{align*}
\]

We use

\[ k = 0.5, \ \theta_1 = 20^\circ, \ \theta_2 = 45^\circ, \ \Theta \text{ is the local incidence angle}. \]

Wet snow segmentation rule:

\[ R_c < THR, \quad \text{with} \ \text{THR} = -2 \text{ dB}. \]

Example of S1 Snow Melt and Landsat TM Snow Extent – Tröllaskagi Peninsula, Iceland

Landsat-8, 27 June 2015; Sentinel-1, 26 June 2015;

Confusion matrix for the classes snow (S) and snow-free, for snow classification based on Landsat (LS) and Sentinel-1 (S1) data. S1 results are shown for snow maps based on . — overall agreement rate (\( R_c \)).

<table>
<thead>
<tr>
<th></th>
<th>S1-S</th>
<th>S1-F</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-S</td>
<td>94.6</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>LS-F</td>
<td>0.2</td>
<td>99.8</td>
<td></td>
</tr>
</tbody>
</table>

\( 0.972 \)
Monitoring melting snow using Sentinel-1 SAR

Nagler et al., Remote Sensing, 2016
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| R4 | **Standardise dual-pol. mode acquisitions on VV/VH** combination: a cross-platform **consistent** polarisation simplifies combination of datasets from multiple providers (e.g. S1/RSAT2/RCM or TSX/CSK). **HH/HV** in Arctic for ice. |
| R5? | **Harmonise acquisition plans** of satellites with compatible calibrated backscatter values (e.g. S1/RSAT2/RCM or TSX/CSK). Utilise the available diversity of orbits to achieve the desired diversity of tracks – e.g. to achieve the fullest possible **ascending/descending** coverage. |
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Other Relevant News

- Good news on Sentinel-1B geometric calibration
  - Absolute location error same as Sentinel-1A
- In-Orbit Commissioning review this week at ESTEC
  - After public release of S1B data, soon double the data rate (in comparison to S1A alone) will be the “new normal” (even more with increased use of laser relay)
- Progressive narrowing of time window of backscatter composites will become possible