ESA SnowLab —
Microwave and Structural Measurements of Alpine Snow

Andreas Wiesmann, Rafael Caduff, Othmar Frey
Gamma Remote Sensing AG, Switzerland

Martin Schneebeli, Matthias Jaggi
SLF-WSL Davos, Switzerland

Thorsten Fehr
ESA ESTEC, Netherlands
Aim of the project

The aim of the project is to provide a comprehensive
- multi-frequency
- multi-polarisation
- multi-temporal
dataset of active and passive microwave measurements over snow-covered grounds to investigate the relationship between effective snow- and ground parameters and the resultant signals detected by microwave radars and radiometers.
Approach and expected Output

Combine a number of active and passive microwave instruments for the investigation of Alpine snow in Switzerland:

- SnowScat (ESA 9-18 GHz polarimetric, coherent scatterometer)
- ELBARA (L-Band Radiometer)
- GPS

Microstructural characterisation by repeated SnowMicroPen and selected micro-CT measurements.

**Study objectives:**

- Effects of snow accumulation (SWE) and temporal evolution of snow morphology on multi-frequency and polarimetric backscatter signatures
- Effect of environmental conditions
- Tomography
- Contribution of microwave observations to the description and understanding of the snow-ground compartment.
Approach and expected Output cont.

- Database (microwave measurements and in-situ data)
- Reports
- Software Tools for tomography
Team / Roles

ESA SnowLab (GAMMA, SLF)
- Andreas Wiesmann Project Management WP0100
- Rafael Caduff Site Setup and Operations WP1000/WP2100
- Othmar Frey Data Processing and Tomo Tools WP3000
- Martin Schneebeli Snow Physics/Characterisation WP2200
- Matthias Jaggi Snow Characterisation
- Charles Werner Hardware/Contact workshops

MicroVegSnow (SLF) → Th. 10:30 Schwank et al, MicroVegSnow Project
- Mike Schwank WSL, PI
- Reza Naderpour WLS, PhD student

Others
- Prof. Alain Geiger / Ladina Steiner ETHZ, GNSS
- Yves Bühler SLF, Drone photogrammetry → Tu. 9:20
Test Site 2016/16 Gerstenegg

Gerstenegg 1706 m

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign 2015/16

- October 2015 – Mai 2016
- On-Site instrumentation:
  - *SnowScat Tomo Mode*
  - *Automatic Weather Station*
  - 5 Surveillance cameras
  - *GNSS*
- **Main Objective: Snow Tomography**
- Validation Campaigns
  - *Snow μ-Pen (6x)*
  - *Snow Pit Profiles (5x)*
  - *Micro CT-Sample (1x)*
  - *Snow Water Equivalent SWE (3x)*
Data Availability and Incidences 2015/2016

SnowScat
- Tomographic scan
- Nominal scan
- Sphere Scan
- Vertical Scan
- Polarmetric calibration

Weather Data
- Sensorscope: HS
- Sensorscope: RSWR, TSS
- Sensorscope: T, H, W
- IMOS OBS2: HS, T, W, RH, RSWR
- IMOS GT2: HS, T, W, RH, RSWR
- Snowfall (Webcam Observation)
- Rain (Webcam Observation)

Cameras
- Canon PowerShot
- D-Link DCS_1 (Metstat)
- D-Link DCS_2 (SnowScat)
- D-Link DCS_3 (Cetar)
- Digitus (Snow Sample Site)

Snow Characterisation
- Snow Micro Pen (SMP)
- Pit Profile
- Micro CT Sample
- Snow Water Equivalent (SWE)
- Spatial Distribution of Snow Surface

Events
- Digitus Camera Power Supply Failure
- Wireless Communication Failure to Canon Camera
- SnowScat Quickset Anomaly
- Installation of Metro Station
- Installation of D-Link DSC_3
- Canon Camera forgot to Power up
- Power Supply of Digitus Replaced
- Rotation of Wind Sensor Pointing to North (previously 310°)
- Flattening of the Snow Surface underneath SRS5a: Leveling to surrounding snow cover
- Digitus Camera Power Supply Failure
- Nikon D500 Replacement
- Digitus Camera Power Supply Failure
- Nikon D500 Replacement
- Exchange of SRS5a and Metal Branch
- Installation of Solar Shield for SRS5a Temperature Sensor
- D-Link DSC_3 was moved away from Digitus
- SnowScat Motherboard Failure
- SnowScat Replaced
- Sensorscope Module 125 was replaced with new module (1266)
- SnowScat Tomo-Motor Failure
Lessons Learned from 2015/16 Campaign

- **Keep spare parts** for critical systems ready or use off the shelf components (Quick-Set; SnowScat parts; Communication modules; Cameras etc.)

- **Automated system-checks** with automated push-notification (e.g. e-mail, SMS) should be improved to minimise reaction-times during system failures.

- Immediate and **automated processing of reference sphere plots and tomo plots** give immediate information on the quality of the measurements. Processing and data-distribution of the results must be implemented in the campaign plan.

- The sampling strategy of the **snow-characterisation** and validation measurements (SMP, profiling) should preferably have **better temporal resolution**.

- In general **weather-proofing of the installations have to be improved**. Weaknesses in the weather-proofing were discovered in the Winter 2015/16 campaign.
Test Site Laret, Instrument Setup (November 2016)

UAV-Image / Y. Bühler & M. Jaggi
Laret 2017

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Detail Map of Instrument Footprints
# SnowScat Data Acquisition Plan 2016/17

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Schedule</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Scan</td>
<td>4 – 6 times a day</td>
<td>Rail position 100 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reference Target</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth (-45 to +45, inc 5 deg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation (30 to 50, inc 10 deg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reference Target</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backup to NAS</td>
</tr>
<tr>
<td>Tomographic Scan</td>
<td>Daily</td>
<td>Rail 0 to 196 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth 0 deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation 45 deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backup to NAS</td>
</tr>
<tr>
<td>Vertical Scan</td>
<td>Daily</td>
<td>Rail 220 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azimuth 0 deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation -2 to 2, inc 2 deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backup to NAS</td>
</tr>
</tbody>
</table>

![Diagram showing acquisition plan]

**Time [UTC]**

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign Monitor – Gamma Redmine Portal

Latest Camera Images

Latest SnowSat Plots

Time series of nominal target scans (field1 and field2)

Davos - Lanet Field 1 [20 deg]

Davos - Lanet Field 1 [50 deg]

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign Monitor – Nominal Plots

Nominal Plots

Davos - Laret Field 1 [20 deg]

Davos - Laret Field 2 [20 deg]

Davos - Laret Field 1 [50 deg]

Davos - Laret Field 2 [50 deg]
Campaign Monitor – Nominal Plots

Davos - Laret Field 2 [20 deg]

![Graph of data points and lines representing various measurements over time.]

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign Monitor – Calibration Sphere Plots
Campaign Monitor – Calibration Sphere Plots

Target RCS HH

16.01.2017

Target RCS HH

18.01.2017

Target RCS HH

19.01.2017

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign Monitor – Coherence Plots


Dt = 6h
Campaign Monitor – Coherence Plots

HH az: -33.0 inc: 40.0 d1: 20170114 10:25:16.6 d2: 20170114 16:25:17.9

Dt = 6h
Campaign Monitor – Vertical Plots

Last 14 Measurements

Vertical Sounding at HH

[Plot showing measurements with dates from 2017-01-28 to 2017-04-22]

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Campaign Monitor – Tomo Plots

→ Th. 11:30 Frey et al, SnowScats Snow Profiling Mode
## Auxiliary Data Acquisition Plan 2016/17

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Schedule</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image Documentation</td>
<td>10 min</td>
<td>Multiple cameras (&gt;4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check Status of installations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check Status of Snow Cover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Track and document events (Dune Formation, Rain, partial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>snow-melt to ground etc.</td>
</tr>
<tr>
<td>Meteorological Data:</td>
<td>1 – 10 min (local)</td>
<td>In-Situ Data (SnowHeight, TA, TSS, RH, VP, BP, Vwind,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dwind, if possible precipitation)</td>
</tr>
<tr>
<td></td>
<td>30 min (regional)</td>
<td>Regional Data (IMIS and OBS) Stations Nearby</td>
</tr>
<tr>
<td>Snow Characterisation Data</td>
<td>1 SMP/Week</td>
<td>upgrade to 2 SMP/Week if Necessary</td>
</tr>
<tr>
<td></td>
<td>0.5-1 pit profiles/week</td>
<td>Pit Profiles with SWE determination</td>
</tr>
<tr>
<td></td>
<td>1-2 microCT Scans/campaign</td>
<td>CT Scans of Snow Samples: timing, according snow situation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Additionally: Spatial snow depth map from “Structure From Motion”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(if possible 1 surface elevation model before and 1 after a snow-fall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>event) Possible, if automatic acquisition is feasible. Important for</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the documentation of the Spatial Distribution of the snow depth and the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>surface roughness of the snow surface.</td>
</tr>
</tbody>
</table>

---

8th EARSeL workshop on Land Ice and Snow
UniBe, Switzerland, 8.02.2017
Auxiliary Data – Snow Depth Maps

Snow Depth Map 25.01.2017 (Terrestrial Structure from Motion)
Auxiliary Data – Snow Micro Pen

- 4 profile measurements till now
Auxiliary Data – Micro CT

- sample scanning in progress (7 samples x 4500 slices)
- 20 µm effective resolution
- 9 mm x 9 mm cross-section
- full profile depth
## Summary – Data Acquisition

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-02-08</td>
<td>Site Installation</td>
</tr>
<tr>
<td>2017-02-08</td>
<td>SnowScat defective</td>
</tr>
<tr>
<td>2017-02-08</td>
<td>Quickset anomaly</td>
</tr>
<tr>
<td>2017-02-09</td>
<td>All camera connections changed to LAN</td>
</tr>
<tr>
<td>2017-02-09</td>
<td>Re-positioning of cameras</td>
</tr>
<tr>
<td>2017-02-09</td>
<td>W-LAN transmission turned off</td>
</tr>
<tr>
<td>2017-02-10</td>
<td>Permanent snow cover on test site</td>
</tr>
</tbody>
</table>

### SnowScat
- Tomographic scan
- Nominal scan
- Sphere Scan
- Vertical Scan
- Polarimetric calibration

### Weather Data
- Sensorscope: HS
- Sensorscope: RSRW, TSS
- Sensorscope: T, H, W
- SLF Lavet: HS, T, W, RH, RSRW
- Snowfall (Webcam Observation)
- Rain (Webcam Observation)
- Soil cover (Grass, Snow)

### Cameras
- D-Link DCS 2310L_1 (Tower)
- D-Link DCS 2332L_1 (Nadar)
- D-Link DCS 2332L_2 (Tomo Target)
- D-Link DCS 2332L_3 (SnowScat)
- Digilite (Sphere Target + Sample Site)

### Snow Characterisation
- Snow Micro Peri (SMP)
- PR Profile
- Micro CT Sample
- Snow Water Equivalent (SWE)
- 3D SnowSurface (UAV terrestrial)
- 5040
Summary

- Data acquisition is on track
- All system elements perform very well
- System test at -20°C performed
- Snow in test-field since 2.1.2017
- Maximum snow-depth: 70 cm (14.1.2017)