Monitoring mountain environment with COSMO-SkyMed imagery

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Introduction

Our aim: to generate tailored EO products to improve the understanding of processes in mountain areas

Our challenge: the effect of topography and the land cover heterogeneity have to be taken into account in the algorithm development

Our products: dealing with

- Water resources -> soil moisture and snow;
- Ground movements -> rock glaciers and landslide.

All the results shown in the following derived from international and national projects that involved several partners. For more details, you can refer to the mentioned projects and to the publications reported in the slides.
The main aim is the exploitation of C and X band images collected from Radarsat2 (RS2) and COSMO-SkyMed (CSK) on Mazia Valley test area in South Tyrol (Italy), to estimate soil moisture.

Images availabe were: CSK HIMAGE HH, RS2 standard HH+HV

A retrieval approach based on the Support Vector Regression (SVR) methodology is used with adaptation to mountain areas, considering as input topographic features (DEM, slope and aspect) and land cover information. The best performances were reached thanks to the synergy of X- and C-band.

The RADARSAT-2 images and COSMO-SkyMed were acquired in the framework of the project ASI-SOAR-PI2880/5225 entitled «SARWeCan».
Study area, Mazia Valley: an experimental elevation transect
Retrieval based on SVR

Aim: to define the mapping between the input features and the target biophysical variable

- Support Vector Regression (SVR) technique trained on Field Reference Samples
- Multi-objective Model Selection Approach

SVR performance analysis

(a) RS2 July 18, (b) CSK July 21, (c) CSK July 22

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<th>a+b</th>
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<td>RMSE (%)</td>
<td>R²</td>
<td>MAE (%)</td>
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<td>R²</td>
<td>MAE (%)</td>
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<td>3.11</td>
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The retrieval with only RS2 seems to provide the best $R^2$.

The combination of RS2+CSK provides the lowest MAE & MSE.

CSK data alone provide results comparable to the one of RS2.

The main aim is to assess the capability of X-band CSK images to monitor snow cover and related changes.

Images Available: CSK PP VV-VH

Different indices were investigated such as: Wet Snow Ratio ($\frac{\sigma_{\text{VV-SC}}^0}{\sigma_{\text{VV-REF}}^0}$), Cross-Pol. ratio ($\frac{\sigma_{\text{VH-SC}}^0}{\sigma_{\text{VH-REF}}^0}$), and depolarization factor ($\frac{\sigma_{\text{VH-SC}}^0}{\sigma_{\text{VH-REF}}^0}$). Both these ratios depend on different factors such as: land cover, the choice of the reference images. A combination of all different ratios has been proposed. As a result, an improvement is found when VV and VH are both used to determine the SCA. A further improvement is found when also the depolarization factor is added.

The activities were carried out in the framework of the SNOX project (2010-2012) financed by the Italian Space Agency.
Detecting snow cover area with CSK images

**Wet snow and snow extension**

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<th>Snow Extension [%]</th>
<th>Layover/Shadowing [%]</th>
<th>No-Snow [%]</th>
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The main aim is to investigate the capability of interferometric techniques to detect rock glacier movements. Rock glaciers are alpine periglacial landform composed of a debris/ice mixture that slowly creep downslope (0.1-1 m/year) due to the deformation of the inner ice-core/ice-supersaturated debris.

Rock glaciers are geomorphological evidences of the presence of permafrost, which changes are strongly related to climate change. Monitoring of rock glacier deformations is also relevant for the management of the natural hazards related to these phenomena, especially when infrastructures (e.g. roads, cable cars, dams, etc.) are involved.

Images available: CSK HIMAGE HH, RS2 standard HH+HV

COSMO-SkyMed and RADARSAT-2 images have been provided thanks to the COSMO-SkyMed/RADARSAT-2 Joint AO Project “ALARM: Alpine and Arctic cryosphere changes monitoring using X- and C-band SAR” (ID 2925)
How to construct the best interferometric stack with our dataset, considering:

- Loss of coherence even for C-band during winter (due to snow)
- Loss of coherence between two consecutive snow-free period both at C- and X-band (fast movement)

6 COSMO SkyMed images from 1st of August 2014 to 20th of October 2014 each 16 days

Limited number of images in the interferometric stack

Need of high redundancy

Small Baseline Subset (SBAS)
SBAS results

Geocoded velocity map obtained with the SBAS algorithm

Total station – SBAS comparison

Displacement time series obtained with SBAS
The main aim is to investigate the feasibility of SAR Multi Temporal Interferometry (MTI) for monitoring ground deformations over mountain areas.

The case study is the Corvara landslide that is located uphill of Corvara in Badia, flows from 2000m to 1500m a.s.l., has an area of more than 2.5 km², with an instable mass of 30 Mm³ and movements rate from few cm to tens of m per year.

CSK images: Stripmap, Descending mode, HIMAGE H4-17 (off-nadir angle ≈ 45°)

Methods: SBAS (IREA), PSI (TRE and SARscape)

The activities were carried out in several projects such as: SloMOVE financed in the Interreg program Italy-Switzerland, LAWINA financed by the Italian Space Agency and PSI Feasibility project.
CRs visibility

- Installed 17 Corner Reflectors designed for X-band (56 cm)
Detected displacements

- The displacement rate for the points: 6, 11, 13, 49 and 53 show a good behaviour.
- Trend almost linear and/or in some case of small entity of the displacement

Point 6
- GPS LOS
- EURAC PS

(CSK images acquired during PSI feasibility project and processed with SARscape)
Detected displacements

- The points: 4, 28, 57, 58 has a strong non-linear behaviour. For these points, the PS time series displacement shows a large deviation respect to the GPS measurements.

Point 57
- GPS LOS
- EURAC PS

(CSK images acquired during PSI feasibility project and processed with SARscape)
Detected displacements

Lessons Learned 1/2

• **CSK imagery can provide useful information** related to the monitoring of mountain areas. Main advantages are related to the frequent revisiting time and high ground resolution.

• The **topography** can reduce the observable areas, however in case of possibility to plan the acquisitions we can request specific incidence angles in order to reduce the areas of layover-shadow.

• For soil moisture monitoring, the main problem is related to the **limited penetration capability of the X-band**. In this case a combination with a lower frequency is highly desirable (CSK-SAOCOM). Moreover, to understand the impact of the vegetation, a cross-polarization would be helpful. A fully polarimetric sensor can be of great advantage.
Lessons Learned 2/2

• For wet snow monitoring, CSK images need to be available on a higher temporal frequency as the snow processes can be very fast, especially during melting season.
• As proved in the SNOX project, a virtual constellation of C and X-band data can reduce the time gaps. Moreover, the use of the optical data (S2) are needed to detect the full snow cover extent.
• In mountain areas, X band quite sensible to the decorrelation due to snow and vegetation, strongly non linear movements are not well described by PS sw used.
• Principal advantages: in X band smaller CRs are needed (maintenance easier, lower cost, less deformation problems); higher sensibility for X band useful in case of small deformation rate
• For movement detection, the MIT needs to be integrated with other techniques such as off-set tracking.
Thank you for your attention!