Report no. 2

Project Title: Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective (SnowBall)

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1. GENERALE OBJECTIVE

Overall project objective:

Explore and develop methodology supporting the vision of developing a future service providing national authorities with hind-cast and real-time snow and avalanche information retrieved from earth observation data.

SnowBall is aiming at providing and demonstrating the methods required for a snow service to deliver geospatial products on the seasonal snow cover derived from satellite data, to the scientific community in Romania, policy makers, users of snow information and the public.

To meet its overall objective, SnowBall has identified 6 key project objectives. These key objectives and the related sub-objectives are directly mapped onto the tasks undertaken in each of the work packages.

Project objectives:

- Improve the spatial and temporal resolution of in-situ snowpack parameters measurements (WP2).
- Development of algorithms and implementation of a prototype snow monitoring system combining Sentinel-1/-3 satellite data, weather station data, and hydrological modelling for snowpack parameters estimation (WP3).
- Assess the impact of climate change on the snow-related resources and hazards (WP4).
- Define and test a reliable methodology for the snowmelt infiltration component of the hydrogeological cycle (WP5).
- Develop and implement a data assimilation procedure for adjusting the snowpack related state parameters within the snow models module of the hydrological forecasting models (WP6).
- Develop methods for avalanche detection, modelling, and hazard assessment (WP7).

2. OBJECTIVES of the 2015 reporting period

WP1 Management
Activity 1.1. Project Management

WP2 In-situ snow parameters measurements
Activity 2.1. Design and implementation of new snow measuring devices and equipment (completition degree 100%);
Activity 2.2. Snowpack parameters observation and measurements (completition degree 40%);
Activity 2.3. Create and set-up of a spatial database managed by GIS software (completition degree 100%);
Activity 2.4. Elaboration of spatial products using the spatial database (completition degree 40%).

WP3 Satellite remote sensing, data fusion and modelling of snow parameters
Activity 3.1. Single sensor algorithm porting to Sentinel (completition degree 100%);
Activity 3.2. MWS algorithm and product (completition degree 35%);
Activity 3.3. New multilayer snow model module in NOAH (completition degree 55%).

WP4 Climate change impact on snow-related hazards
Activity 4.1. Snow-related climate variability and change and associated impact (completition degree 55%);
Activity 4.2. Variability and change in flash floods with snow melt contribution (completition degree 40%);
Activity 4.3. Variability and change in avalanche statistics (completition degree 55%).

WP5 Aquifer replenishment modelling from snowmelt infiltration

Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone (completition degree 95%);
Activity 5.2. Aquifer modelling (completition degree 95%).

WP6 Assimilation of snowpack parameters in the National Flood Forecasting and Warning System

Activity 6.1. Update the LC/LU map for the study area using high spatial resolution satellite images (completition degree 100%);
Activity 6.2. Design of the algorithms and methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models (completition degree 100%);
Activity 6.3. Implementation of the methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models (completition degree 55%).

WP7 Avalanche inventory, release and hazard mapping

Activity 7.1. Develop avalanche detection algorithms (completition degree 100%);
Activity 7.2. Change-detection algorithm for Sentinel-1 and Sentinel-2 (completition degree 25%);
Activity 7.3. Avalanche simulation (completition degree 40%).

WP8 Promotion and Dissemination

Activity 8.1. Project website (completition degree 55%);
Activity 8.2. Dissemination strategy (completition degree 100%);
Activity 8.3. Dissemination and training actions (completition degree 45%).

3. SUMMARY

WP1 Management
Activity 1.1. Project Management

Quality ensuring, decision-making and project management were performed through taking the following measures: work meetings via Skype, meetings of the work groups, inter-partner communications via Internet.

The 19 SEE/30 June 2014 SnowBall annual Project Meeting took place at the Timişoara West University from 26 to 28 October 2015. The meeting encompassed the conference of the Steering Committee which analysed the project implementation stage, in accordance with the activity plan and those issues were discussed that may affect the fulfilment of the project's objectives (annex A). The project's management plan was verified and updated and the latest instructions received from the contracting authority were discussed regarding the verification of the expenses borne at project level and the achievement of the indicators within the annual Scientific and Technical Report for 2015.

As project promoter, the Romanian National Meteorological Administration continued to ensure throughout 2015 a tangible, efficient project management which comprised administrative and financial issues together with issues concerning the communication with the competent ministry and regarding the exploitation of the obtained results.

WP2 In-situ snow parameters measurements
Activity 2.1. Design and implementation of new snow measuring devices and equipment

Version 2 of the prototype data logger has been assembled and laboratory tested, working according to the specs. The main characteristics are:

- high autonomy (energy – solar pannel and communications – 3G mobile network);
- modular (works with any combination of the probes used in the project);
- scalable (works with 8 or 32 bits microcontrollers).

The mobile stations built arround the prototype data logger have been thoroughly tested outdoor at the NMA's Băneasa experimental meteorological platform. The operation of the stations as a whole and of each of the individual components (including all the sensor types), in „real life" conditions has been thus analysed and some fine tuning has been applied in the software.

The equipements have been installed at the cal/val sites Joseni and Târgu Secuiesc, inside the perimeter of the weather stations. There are 2 data loggers at each site, each connected to a different set of sensors: snow profile temperature (5 sensors), snow wetness (2 sensors), snow depth (1 sensor); ground temperature profile (6 sensors), snow surface temperature (1 sensor), air temperature (1 sensor), snow depth (1 sensor).

Data received so far from the 4 data loggers confirm the soundness of the design and the rightness of the choice of the components and the quality of assembly and testing. The equipements to be installed at the selected locations in the test zone will be configured slightly different, sensor wise.

Activity 2.2. Snowpack parameters observation and measurements

Satellite data derived snowpack parameters require proper calibration/ validation with in-situ data measured during intensive data collection campaigns. As an example, determination of snow wetness from remote sensed images (how much liquid water is contained in the snowpack) implies knowledge of the snow pack optical spectra in the visible and infrared domain. This type of information can only be obtained in-situ from portable spectrometers measuring the reflected light in the visible spectrum and infrared emission of the snow. Several snow measurement campaigns have been foreseen during the project. In March 2015, the first data collection campaign took place in Sinaia (Vârful cu Dor – Cota 1500), Babele and Poiana Brașov. Snow depth, moisture, temperature, density, water equivalent and snow spectra in the visisble and infrared have been measured during the 3 days expedition. Both NMA and NR have made measurements of the snow spectra, using the FieldSpec Pro (ASD Inc.) and respectively the DSR (StellarNet) portable spectrometers. During the winter season 2016-2017, the spectral measurements of the snow pack will resume at the same locations and the data gathered will be used for the calibaration/ validation of the snowpack properties retrieval algorithms in the optical domain.

Activity 2.3. Create and set-up of a spatial database managed by GIS software

The following tasks were carried out during the geospatial database design and implementation:

- Review of existing geospatial data and databases in terms of type, structure, data format, etc;
- Analysis of the project needs in terms of data flow and information;
- Selection of the geospatial data to be included in the geoportal;
- Analysis of the attribute data type;
- Review of the existing spatializing procedures for missing data;
- Review of the procedures for data correction / validation;
- Complience check with the INSPIRE directives;

The geospatial database contain both historic and recent data. When not available in digital format, aerial photographs and maps have been digitised. Data and databases originating from the following sources have been used to populate the geospatial database: government institutions, freely available data (internet based), national projects, and data from the SnowBall consortium members – either existing or produced for the project needs (topographical map, orthophotomap, satelite imagery vectorisation or GPS data collection).

The data have been obtained in ESRI Shapfile, ESRI Geodatabase and CAD, format with variable spatial domains. Pre-processing for attribute homogenization, geometric and topologic correction, new layer derivation or combining information on the same layer, relationship definition between tables and layers and centralising data has been applied to the entire dataset.

Activity 2.4. Elaboration of spatial products using the spatial database

Daily gridded data sets have been produced at a spatial resolution of 1000 x 1000 m for the period 1st October 2005 – 30 April 2015 for the following parameters : air temperature (minima, average and maximum) ; precipitations ; snow depth (SD) and snow water equivalent (SWE).

The main steps in the spatial interpolation of the weather station data are:

- multianual averages for each month (2005-2015) at a spatial resolution of 1000 x 1000 m;
- spatial interpolation of the daily/ pentadic computed deviation;
- the spatio-temporal datasets have been obtained by joining the surfaces obtained in the previous steps.

For the air temperaure, the anomalies have been calculated as the differences between the hourly values and the multianual averages, while for the precipitation and the snow depth and snow water equivalent, the ratio of the hourly values and climatological values has been used.

The maps of the multianual normals have been produced by „Regression Kriging" (RK). For the selection of the optimal method for spatialising the deviations, the following interpolation procedures have been evaluated: multi-quadratic (MQ), kriging normal (OK) and inverse distance (IDW).

WP3 Satellite remote sensing, data fusion and modelling of snow parameters

Activity 3.1. Single sensor algorithm porting to Sentinel

This work represents the single-sensor algorithm development and validation in the test sites in Norway and Romania for the 2015 season. The validation was limited to comparison with air temperature as this was what was available for the 2015 season, but will be extended with comparison with in-situ snow liquid water measurements when these become available for the 2016 season.

The optical wet snow (OWS) maps were generated from a time series of Terra MODIS data, while the SAR wet snow (SWS) maps were generated from a time series of Sentinel-1data. All data were acquired in the period from 1st of January until 30th of June 2015 for the test sites in Jotunheimen in Norway and the upper parts of the Arges and Ialomita Rivers Catchments in Romania.

The wet snow maps are consistent in the way that the content usually follows the topography and local climate very well and without being noisy. The temporal transitions are similar in the way that increasing temperature gives increasing wetness, also within the same day (for the cases when we had more than one snow map from the same day). Increasing temperature during the day at lower altitudes also consistently brings wet snow to higher altitudes. Also, the classes follow the topography logically (canonically) with wettest snow at lower altitudes and reduced wetness with altitude.

The optical-based (OWS) maps were in general quite consistent with the air temperatures. In most cases retrieval results of dry snow corresponded with air temperatures below freezing point, and retrieval results of one of the wet-snow classes with air temperatures above freezing point. The highest temperatures usually gave the wettest snow classes. When inconsistencies were identified, most could be well explained with transitions from cold and dry conditions during the night to wet snow at some time during the day. If air temperatures above 0°C have lasted for a short time (up to 2-3 hours), the snow surface has not necessarily become wet. What happens when the air temperature is above freezing point depends very much on the wind. The melting intensity strongly increases with wind speed for air temperatures above 0°C.

By comparing SAR wet snow (SWS) maps with the temperature profiles at the weather stations, we conclude that Sentinel-1 is suitable for mapping wet snow in mountain regions. The use of SAR flattening gamma terrain correction reduces the terrain effects substantially, and we may therefore create daily mosaics by combing ascending and descending satellite passes. However, for mapping of wet snow, this may not be desirable since the snow wetness varies between night and day due to varying temperatures.

Activity 3.2. MWS algorithm and product

The multi-sensor/multi-temporal algorithm validation results for the test sites in Norway and Romania for the 2015 season have been presented. The validation was limited to comparison with air temperature as this was what was available for the 2015 season, but will be extended with comparison with in situ snow liquid water measurements when these become available for the 2016 season.

The multi-sensor/multi-temporal wet snow (MWS) algorithm have been developed by fusing optical and SAR data to map the wet snow area. Multi-temporal observations of wet snow with optical and SAR are fused in a novel model simulating states of surface properties to generate reliable wet snow maps. The algorithm is based on NR's experience of combining data from multiple sensors using Hidden Markov Model (HMM) approaches. The snow map includes the thematic classes dry snow, moist snow, wet snow, very wet snow and soaked snow, in addition to partial snow cover, bare ground and clouds.

The Multi-sensor/multi-temporal Wet Snow (MWS) algorithm combines multi-temporal observations of STS (surface temperature), SGS (snow grain size) and SWS (SAR wet snow) in a fusion model to generate significantly improved coverage in space and time than possible with the single-sensor approaches. The basic idea of the approach is to simulate the states the snow surface goes through during the snow season with a state model. The states are not directly observable, but the remote sensing observations give data describing the snow conditions, which are related to the snow states. HMM is building on statistical theory making it possible to establish a sound probabilistic model derived from observational data. The HMM model is applied per pixel, so each pixel's history through the snow season is modelled.

The MWS maps showed many of the same properties as the optical, as one might suspect as the optical observations were much more frequent that the SAR observations for the winter 2015. The overall structure of the maps is the same as the optical with the degree of wetness following the topography quite much, as one would expect under conditions without very strong wind. There is, however, more thematic information in the MWS maps as they include two more classes than optical.

The main added value with the MWS maps is certainly that there is a new map every day, independent of observations that day. Sharp weather shifts would certainly not be included without any observations, but otherwise the approach seems to produce useful estimates of the current conditions.

Activity 3.3. New multilayer snow model module in NOAH

During this phase, was designed the methodology for estimationg the snow water equivalent, by data fusion approach, using the distributed model NOAH simulations, ground observations and satellite products. Within the methodology, the diferrent type of data and information are analyzed and compared, using a series of automatic cross-validation algorithms, and then the snow water equivalent is estimated in grid format, at spatial resolution of 1 km, by multiple succesive steps of interpolations and adjustments, depending on the degree of uncertainty associated with different type of data.

Main processing steps within the data fusion methodology:

a) Automatic quality check of all the input data:

- Point observations and grid cell values from model simulation or satellite products.
- As output of this step, all the available data will be categorized on 3 classes, based on the results from automatic quality checks: very good, good, acceptable, and all the values not passing the tests will be set to missing.
- The quality check algorithms will be applied not only on the the last values but also for the relative variation compared with the values from the previous day.

b) General processing phase, having as objective the estimation of the most probable values, by iterative analyses of the groups of cells associated to previous established different quality categories:

- Analyse the cells with at least one data source in the category "very good";
- Interpolate the values estimated at previous step, for the entire grid;
- Validate and adjust the interpolation results using the cells with at least one data source in the category "good data";
- Validate and adjust the interpolation results using the cells with at least one data source in the category "acceptable data".

WP4 Climate change impact on snow-related hazards

Activity 4.1. Snow-related climate variability and change and associated impact

The team from the National Meteorological Administration completed the analyses of changes in snow depth, snow amount and melted snow amount during October-April, in Romania, under the RCP 4.5 and RCP 8.5 scenarios for the timeframes 2021-2050 and 2070-2099. The reference interval considered is 1971-2000. In the analyses, the team from the National Meteorological Administration have used the results of numerical experiments with five regional climate models from the EURO-

CORDEX program. Under more intense radiative forcing (RCP 8.5 scenario) the decrease of the snow depth, the amount of snow, and the increase of the amount of melted snow in mountainous areas are higher in the analysed intervals. These changes will become stronger at the end of the XXI century, especially under the RCP 8.5 scenario.

The National Meteorological Administration team built the input data for hydrological model, starting from numerical experiments under climate change conditions (RCP 2.6 and RCP 8.5) with the regional model RCA4 driven by the global model ICHEC-EC-EARTH. The simulated data from the regional model (at a resolution of 12.5 km) have been disaggregated at a spatial resolution of 1 km, using geostatistical methods. This has been done for the basins of interest to better fit the input data to the needed spatial scales and to add corrections due to the differences between the model orography and the real one. The downscaled data have been also analysed from the perspective of climate change in the regions of interest.

Activity 4.2. Variability and change in flash floods with snow melt contribution

A hydrological model calibration was performed by simulating the snow accumulation and melting processes in the upper part of the Arges and Ialomita river basins. To simulate the flow in the upper part of the Argeş and Ialomiţa river basins the conceptual hydrological model Consul was used, model developed within the NIHWM. The main rainfall-runoff processes considered by the hydrological model are: accumulation and melting of the snow cover, precipitation interception, water storing in depressions, evapotranspiration, infiltration, percolation, surface runoff, hypodermic runoff and basic runoff.

Calibration of Consul hydrological model parameters was performed by simulating the most important events rainfall-runoff selected particularly during the transition from winter to spring, from the calibration period considered, 2001 to 2005.

The results of flow simulation with the Consul model in the analysed river basins showed that the model gives the best results, in particular in the case of floods generated by precipitation evenly distributed in space. Deviations between discharge hydrographs simulated by Consul and observed are due to both model errors and insufficient meteorological and hydrological data. The main error is caused by the uncertainty related to the determination of mean precipitation on the river basin and its variable spatial and temporal distribution.

Activity 4.3. Variability and change in avalanche statistics

The previous analyses have continued in order to develop the empirical model that links the atmospheric circulation characteristics to avalanches indices. Thus, a list with the dates of avalanches was drawn up, starting from 1928 to the present. Related information are also available (e.g., location, number of persons affected, toll death and the source of information) for these events which have taken place in the Ceahlău, Făgăraş, Bucegi, Lotru, Rodna, Retezat, Piatra Craiului, Căpăţânii, Gutîi, Postăvaru, Ţarcu, Vâlcan, and Baiului mountains. The most frequent avalanches are recorded in the Făgăraş and Bucegi mountains.

WP5 Aquifer replenishment modelling from snowmelt infiltration

Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone

The assessment of the existing infiltration methods based on energetic equilibrium and on the temperature index revealed the advantages and disadvantages of both methods. The models based on the temperature index are easy to apply and have reasonable results, bur sensitive to weather conditions, especially wind speed and solar radiation. In order to improve these methods and to raise the accuracy of the results it recommended using the parameters concerning the wind and the humidity. The energetic equilibrium models are sensitive to data input estimation errors (wind, solar radiation and albedo). Thus, a better parameterization of the albedo factor, the wind function and a better estimation of the meteorological conditions could increase the accuracy of the results.

In-situ measurements were performed to determine the infiltration from snowmelt. Based on these measurements a mathematical simulation model for water flow into the unsaturated zone was developed.

Activity 5.2. Aquifer modelling

Three representative study areas were chosen for the project. For each of them the geological, hydrogeological and climatic settings were described in detailed. The three study areas are: 1. Bolboci – Vf. Omu (Upper basin of Ialomita river), 2. Prahova-Teleajen Aluvial Cone and 3. Colentina Site (Bucharest City).

The aquifer recharge process was considered for each of the hydro structures: fissured mountain aquifer, were the North – East slopes of the Bucegi mountain was chosen, regional alluvial aquifers is represented by Prahova – Teleajen Aluvial Cone and the las type of aquifer, small size shallow aquifers, is represented by the Colentina Site (Complex Laboratoare Colentina, București).

Processes of water infiltration trough frozen soil can be modeled, but additional studies needs to be performed in order to enhance the precision and prediction of the results.

The predictions of water infiltration trough frozen soils can be used to assess the risks and damages caused by climate chance especially in mountain region and regions with permafrost.

WP6 Assimilation of snowpack parameters in the National Flood Forecasting and Warning System

Activity 6.1. Update the LC/LU map for the study area using high spatial resolution satellite images

It was elaborated the methodology, in order to obtain the updated land use/land cover map of the Romanian study area from Romania, within the Activity 6.1. The methodology consists in data fusion of satellite data in order to achieve classifications, followed by classifications using three sources of thematic information: the 2012 version of the Corine Land Cover database, the LPIS identification system (Land Parcel Identification System) and Landsat 8 unsupervised classifications.

Accessing and comparing of recent information relating to land cover / land use lead in updating and improving the quality of existing databases. Within a GIS system, through integration with orthophotos and / or satellite images can be achieved a better management and monitoring of agricultural and non-agricultural land in a territory.

The updated land use / land cover map over the study area, represented by Arges and Ialomita river basins, is necessary for the implementation of the distributed hydrological model NOAH-R, developed into the work package WP3.

Activity 6.2. Design of the algorithms and methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models

The methodology for data assimilation of snowpack parameters in the hydrologic model NWSRFS and in the system for estimation of flash floods occurence risk in Romania – ROFFG, was designed.

The hydrological forecasting systems NWSRFS and ROFFG are using the same conceptual snow model SNW-17, for simulation of the snowpack evolution, and the optimal values of the snow water equivalent resulted after the application of the data fusion procedure will be assimilated in a specific way within this model, for adjusting the state parameters.

An important aspect that was taken into consideration is related to the fact that at the time when the water equivalent value simulated by the SNOW-17 model is changed, in an automatic way it is also changed accordingly within the NWSRFS systems the percent of snow cover at the hydrographic basin level. This internal adjusting procedure difference take into consideration the fact that we could encounter significant variations of the snowpack depletion curve from one year to another, respectively the fact that the model use a depletion curve resulted from the calibration process, and which could be significantly different comparing to the real situation at a certain moment within the basin, even if the snowpack mean water equivalent value is close to the real value.

Activity 6.3. Implementation of the methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models

Was done the inventory and selection process for the software systems, modules and utilities that are needed for implementing the methodology of snowpack parameters assimilation in the operational hydrological forecasting models.

Using the selected software applications was started the implementation of scripts and programs for handling the export-import operations for the data flow, and for the specific processing steps for assimilating the snowpack parameters into the operational hidrological models NWSRFS and ROFFG. Within the data assimilation process for these operational hydrological models the dirrect method approach will be used for assimilating the snow water equivalents values.

WP7 Avalanche inventory, release and hazard mapping
Activity 7.1. Develop avalanche detection algorithms

A database of time and location of avalanches in Făgăraș Mountains was completed, and first avalanche inventory based on GeoEye-1 images was conducted. These data are very useful for an objective evaluation of the location, magnitude and frequency of the snow avalanches in the Carpathians. These results are also an important input for snow avalanche hazard and risk evaluation and provide information over large areas, as compared to those provided by in-situ observations. This inventory for Făgăraș Mountains represents the first example for the use of GeoEye-1 images for mapping and analysis of avalanches. The results showed that the number of snow avalanches occurring in the Carpathians are higher than previous estimates, and satellite images have a key role for an objective development and update of a spatial database of avalanches for the entire mountain areas in Romania.

An automated detection algorithm for snow avalanches in optical images has been developed and validated using HR and VHR satellite images. The algorithm for avalanche detection is based on so-called texton-approach (a texton is a prototype of tiny surface patches with associated local texture properties). The key part of this detection algorithm involves texture analysis, seeking to distinguish avalanche snow from other relevant terrain cover types, such as smooth snow, rugged snow, trees and rock. The texture characteristics of the avalanche-affected snow were extracted by convolving the image with a set of 12 multi-scale multi-directional filters. Six of the filters are oriented in the same direction as the terrain aspect, which is estimated from a digital elevation model, and six filters are oriented in the vertical direction. The reason for using vertical filters was that early experiments indicated that they provided useful features for distinguishing sparse forest from avalanches. Further, the pixels from the filtered images are classified into a texton-representation and then classified as avalanche/non-avalanche.

The algorithm has correctly identified many of the avalanches in the test areas (up to 87% from the total number of avalanches). Detection errors were generated by the variability in terrain and snow characteristics. To compensate these effects, is possible to increase the number of filters. Also, delineation of areas with high probability in avalanche occurrence in GIS environment with multicriteria analysis of standardized factors using fuzzy functions may provide a thematic layer that can be integrated in the detection algorithm in order to reduce the overestimation errors.

The algorithm has been tested on VHR satellite images with 40-60 cm spatial resolution (QuickBird, WorldView-1 and GeoEye-1).

Activity 7.2. Change-detection algorithm for Sentinel-1 and Sentinel-2

Methodology and stages of development have been established for the change-detection algorithm in avalanche affected areas. The proposed algorithm is also based on multi-date SAR images. The underlying principle is a pixel-wise comparison of the backscatter intensities of two SAR images, an event image (the one with avalanches) and a reference image, and assumes that both the event image and the reference image are acquired in the same beam mode, pass direction and from the same repeat cycle. The satellite images were selected from archive and corrections have been made. The avalanche detection algorithm was tested on several Sentinel-1 and Radarsat-2 images in mountain areas from Norway. The performance metric of the results indicates that the algorithm does not agree completely with the manual identifications. Most of the avalanches were detected, with few false detections, but the outline of the features was not always as delineated by the experts.

Activity 7.3. Avalanche simulation

Snow avalanche simulation has been tested and calibrated using RAMMS software. DEMs at various spatial resolutions have been used with different global and snow friction parameter settings. Calculation and classification of friction parameters is based on DEM derived data (altitudine, slope, curvature), forest cover and global parameters (volume and return period). For the estimation of the return period of avalanches in the test areas, data from dendrochronologic reconstructions from other studies have been used. Trajectories simulation have been tested on several high impact past avalanches identified in statistics. The avalanche trajectories (Figure 7.3), depth, velocity, pressure and spatial extent of the snow deposits were simulated for the glacier valley of Bâlea. The results were similar with the data found in the events descriptions. This activity will continue and avalanche hazard maps will be generated for the test areas.

WP8 Promotion and Dissemination
Activity 8.1. Project website

The project website (http://snowball.meteoromania.ro) was updated on a continuous base.

Activity 8.2. Dissemination strategy

The dissemination strategy aims at defining a series of activities suited to an efficient promotion of SnowBall project results both during its development and after finalizing it, to facilitate interaction with similar projects implemented at national or international level. The dissemination strategy also targets the identification of the communication tools suitable for creating links between the project consortium and the final users. The main objectives of the dissemination strategy are:

- Raising community awareness regarding the opportunities supplied by SnowBall project ;
- Communicating results obtained within the project;
- Facilitating cooperation and information exchange within the consortium (internal dissemination);
- Creating the frame necessary for the final users to efficiently use technologies developed within the project;
- Preparing support materials for the products created within the project (e.g. documentation);
- Creating a network of potential beneficiaries for the technologies and knowledge resulted from project implementation;
- Ensuring project visibility at national and international level;

When designing the communication strategy the following were taken into account:

- Identification of the target users group;
- Creating adequate messages to draw the attention of the target audience group;
- Selecting communication channels through which messages are delivered to the target group.

A series of products were made for the project's promotion and visibility: leaflets in Romanian and in English, the project's brochure in Romanian and in English, posters and placards, according to recommendations from the guide to communication and design supplied by National Authority for Scientific Research and Innovation (ANCSI).

Activity 8.3. Dissemination and education activities

Results obtained within the project were presented in national and international conferences and symposia like: 3-rd International Conference on Remote Sensing and Geoinformation of Environment – RSCY2015, Cyprus, 16-19 March 2015; International Conference Water and Air – Environmental Components, Cluj-Napoca, 20-22 March 2015; International Conference "Methodological challenges în geography", 15-16 May 2015, Timișoara; 31st National Symposium on Geomorphology, 21-24 May 2015, Sf. Gheorghe Deltă; ESA Sentinel-3 for Science Workshop, Venice, 2-5 June 2015; EAWS Conference – European Avalanche Warning Services, Rome, 4-6 June 2015; "Geobalcanica-Connects all geographers" Conference, Skopje, 5-7 June 2015; 26-th General Assembly of the International Union of Geodesy and Geophysics-IUGG 2015, Prague, 22 June - 2 July 2015; 33-rd International Conference on Alpine Meteorology – ICAM, Innsbruck, 31 August - 4 September 2015; EUMETSAT Meteorological Satellite Conference 2015, Toulouse, 21-25 September 2015; Annual; Scientific Conference of the National Institute of Hydrology and Water Management, Bucharest, 2-3 November 2015; Annual session of scientific papers of the National Meteorological Administration, Bucharest, 19-20 November 2015.

During the "Achievements and future steps" International Conference organized by ANCSI in the frame of RO-14 Program – "Research Within Priority Sectors", EEA 2009-2014 Financial Mechanism which took place in Bucharest on 10 December 2015 there were presented results obtained during the first half of the project implementation period.

4. SCIENTIFIC AND TECHNICAL DESCRIPTION

4.1. WP1 Management

*4.1.1. **Activity 1.1** Project Management*

During 2015, Romanian National Meteorological Administration, as project promoter, continued to provide a concrete and effective management of the project that covered administrative and financial issues, communication with the ministry and operating results. The Steering Committee of the Project (SCP), composed of officials from partner institutions (P1 - Norsk Regnesentral, Norway, P2 - Technical University of Civil Engineering Bucharest, P3 - National Institute of Hydrology and Water Management, Bucharest and P4 - West University of Timisoara) and led by the project manager is the body that decides on important issues related to project management.

Quality assurance, decision making process and project management were achieved by the following measures: working meetings via Skype, working group meetings, Internet communications between partners.

Thus, on 01.13.2015 held a working meeting with all partners, via Skype, the main subject being the analysis and discussion of the Activity Plan for 2015. The agenda included:

- Presentation of the participant partners;
- The current situation of the project after the first period completed in 2014;
- Presentation of the implementation stage of the project objectives;
- Work Packages (WPs) description and the presentation of the related activities planned for 2015;
- Aspects related to the technical and administrative organization of the project: indicators, scientifical/technical and financial reports and deliverables planned for 2015;
- Organizing shared field campaigns to measure snow parameters;
- Planning work meetings, conferences and scientific papers to be presented in 2015.

In the table 4.1.1 are listed the participants from the project meeting.

Table 4.1.1: List of particpants to the SnowBall meeting, 13.01.2015

Nume	Institution	E-mail
Gheorghe Stăncălie	NMA	gheorghe.stancalie@meteoromania.ro
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Dragos Găitanăru	UTCB - CCIAS	dragos.gaitanaru@gmail.com
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Mircea Voiculescu	WUT	mircea.voiculescu@e-uvt.ro
Florina Ardelean	WUT	florina.ardelean@e-uvt.ro

During the meeting have been established the teams and the person responsible for each activitiy to achieve the project objectives. Also were nominated the responsible of each deliverable for the reported period.

On February 3, 2015 was held a working meeting via Skype devoted to discussing in detail the activities planned under WP 3 - " **Satellite remote sensing, data fusion and modelling of snow parameters** ", relating to calibration / validation methods of snow satellite products (especially those associated with snow humidity) with in-situ data.

The agenda of the meeting included:

- Discussions related to Activity 3.1 (Single sensor algorithm porting to Sentinel) and Activity 3.2 (MWS algorithm and product) related to the validation methods / procedures and in-situ necessary data.
- Suggestions and discussions for shared field campaigns (with the participation of a team from Norway): period, description of test areas, measuring instruments used, correlation between field measurements and satellite passages, logistics problems.

The list of participants is presented in the table 4.1.2.

Table 4.1.2: List of particpants to the SnowBall meeting, 03.02.2015

Name	Institution	E-mail
Gheorghe Stăncălie	NMA – Project director	gheorghe.stancalie@meteoromania.ro
Andrei Diamandi	NMA	diamandi@meteoromania.ro
Narcisa Milian	NMA	narcisa.milian@gmail.com
Vasile Crăciunescu	NMA	vasile.craciunescu@meteoromania.ro
Anişoara Irimescu	NMA	anisoara.irimescu@meteoromania.ro
Denis Mihăilescu	NMA	denis.mihailescu@meteoromania.ro
Oana Nicola	NMA	oana.nicola@meteoromania.ro
Rune Solberg	NR	rune.solberg@nr.no
Arnt-Borre Salberg	NR	arnt-borre.salberg@nr.ro

The annual meeting of the Project 19 / 06.30.2014 SnowBall was held at West University of Timisoara, during 26 to 28 October 2015. The agenda is presented in Appendix 1.

The meeting was attended by researchers from all five institutions involved in the project: National Meteorological Administration, Norwegian Computing Center (Department of Earth Observing) from Oslo, Technical University of Bucharest, the National Institute of Hydrology and Water Management from Bucharest and West University of Timisoara, Department of Geography. Mr. Vice Rector Prof. dr. Viorel Negru, addressed a welcome message to the participants and highlighted the support of WUT in this project, and the availability of institution for future collaborations. The list of participants are presented in Table 4.1.3.

Table 4.1.3: List of particpants to the SnowBall meeting, 26-28.10.2015

Name	Institution	E-mail
Gheorghe Stăncălie	NMA – Project director	gheorghe.stancalie@meteoromania.ro
Prof. Dr. Viorel Negru	WUT – Pro-rector	
Andrei Diamandi	NMA	diamandi@meteoromania.ro
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Marcel Török-Oance	WUT	marcel.torok@e-uvt.ro

During the meeting was held also the meeting of the Project Steering Committee that analysed the implementation stage of the project according to the activities plan and was discussed issues that can affect project objectives. It was checked and updated the project Management Plan and was discussed the latest instructions received from the contracting authority regarding the verification of project expenditure and achievement the indicators from annual scientific and technical report for 2015.

The discussions are focused on preparing the annual scientific and technical report as well as the progress and the final financial report of 2015. It was highlighted the compliance with elaboration of the documents according to the guidelines and instructions of the contracting authority.

Has been analysed the promotion and dissemination of project results and have been established concrete actions to be carried out such as organizing a workshop with potential users of the project benefits.

To prepare the monitoring visit from November 2, 2015 the Steering Committee and Project manager, verified and analysed the documents requested by the program operator, related to the reporting from 2014, according with the "Guide for checking the expenditure of the projects financed by the European financial mechanism 2009-2014 and the Norwegian financial mechanism 2009-2014".

The objectives of the monitoring mission consisted in verifying the project implementation in accordance with MFSEE implementation regulations, contract financing and corresponding agreements. They were verified the purchased goods and their exploitation according to the grant funding rules and the purpose for which they were acquired. It was also evaluated the degree of achievement the project objectives and indicators.

The monitoring team has found that technical progress is in agreement with financial progress report and that the situation described in the scientific, technical and financial reports, sent to the contracting authority matches the reality on the ground.

There were prepared the financial documents related to project activities for the period 01.12.2015 - 10.31.2015 and was elaborated the Interim Financial Report from November 9, 2015 required by the contracting authority.

Representatives of the project promoter participated in the work meeting RO-14 "Research in Priority domains", organized by ANCSI at its headquarter in Bucharest, on 26/11/2015. The agenda of the meeting included:

- Prepare the reporting set for 2015;
- Prepare the addendum of the contract;
- The outcomes of te monitoring visits until the current meeting;
- Publication and promotion of the project results;
- Information about the conference “Achievements and future steps” from Bucharest, December 10, 2015.

The information presented and discussed at the working meeting were forwarded to all partners together with the presentations provided by ANCSI.

There were summarized the results obtained in the first half of the implementation period of the Snowball project, in order to prepare the presentation for the conference "Achievements and future steps" Program RO14- "Research in Priority Sectors" EEA Financial Mechanism 2009-2014, which took held in Bucharest on 10 December 2015.

Those responsible for activities have been established their teams to achieve the proposed objectives. Also have been nominated the responsible for deliverables for the reported period (Table 4.1.4).

Table 4.1.4: List of Deliverables for 2015

LIST of DELIVERABLES - 2015					
Del. no.	**Deliverable Name**	**WP no.**	**WP Leader**	**Delivery date**	**Responsable**
1	D1.2. Annual project reports	1	CO	Each year	Gheorghe Stăncălie
2	D2.2 Laboratory tested prototype for snow temperature profile – Version 2	2	CO	6	Cătălin Dumitrache
3	D2.3 SD and SWE data sets (from AWS) – Version 1	2	CO	9	Vasile Crăciunescu
4	D2.5 Reflectance spectral data sets of the snow – Version 1	2	CO	8	Andrei Diamandi
5	D2.9 Snowpack parameters data sets – Version 1	2	CO	9	Vasile Crăciunescu
6	D2.11 Prototype of the spatial database for snow related parameters	2	CO	6	Vasile Crăciunescu
7	D2.12 Spatial database over the test zone, in a GIS environment	2	CO	10	Vasile Crăciunescu
8	D2.13 Snow related in-situ data sets and historical meteorological and hydrological data – Version 1	2	CO	9	Vasile Crăciunescu

9	D2.15 Mapping products derived from the spatial database – Version 1	2	CO	10	Alexandru Dumitrescu
10	D3.1 Validated optical and SWS retrieval algorithms	3	P1	9	Rune Solberg
11	D3.2 Validated MWS retrieval algorithm	3	P1	15	Rune Solberg
12	D3.3 MWS prototype products for flood and avalanche warnings – Version 1	3	P1	16	Rune Solberg
13	D3.5 Data fusion methodology for estimating the SWE, using distributed snow model simulations, ground observations and satellite products	3	P3	15	Marius Mătreaţă
14	D4.1 Present (1981-2010) and future (2021-2050) assessment of snow-related parameters from CMIP5 archive downscaled for selected hazard and resource analysis over the area of interest	4	CO	12	Roxana Bojariu
15	D4.2. Hydrological model of snow accumulation and snow melt capabilities calibrated in the upper part of Arges-Ialomita river basins	4	P3	18	Ciprian Corbuş
16	D5.1 Sites description and conceptual models	5	P2	12	Gogu Radu
17	D6.1 Updated LC/LU map for the study area	6	CO	18	Simona Catană
18	D6.2 Design of the methodology for snowpack parameter assimilation in the operational hydrological forecasting models	6	P3	18	Marius Mătreaţă
19	D7.1 Validated algorithm for detection of avalanches in optical HR and VHR satellite images	7	P4	18	Mircea Voiculescu
20	D8.2. Dissemination strategy	8	CO	6	Gheorghe Stăncălie
21	D8.3. Project brochure - Version 1	8	CO	16	Denis Mihăilescu
22	D8.6. Visibility products (banners, posters etc.)	8	CO	Each dissemination session	Denis Mihăilescu
23	D8.7. Conference project presentation package	8	CO	Each dissemination session	Vasile Crăciunescu
24	D8.8. Dissemination action report	8	CO	Each year	Oana Nicola
25	D8.9. Project newsletter (e-zine) - digital form	8	CO	Each year	Vasile Crăciunescu

4.2. WP2 In-situ snow parameters measurements

*4.2.1. **Activity 2.1.** Design and implementation of new snow measuring devices and equipment*

For snow measurements it was decided to develop devices and automated equipment to measure continuous in the perimeter of the automatic or existing manual weather stations, or for limited periods of time (winter) in various areas of interest outside the perimeter of the weather stations.

For this purpose, two types of sensors were selected to measure the snow height. The measurement principle is based on the reflection of ultrasonic acoustic waves encountering solid obstructions. Both types of sensors can be interfaced with the automatic weather stations dataloggers.

The main technical characteristics of the sensor for measuring the snow height SR50 (Figure 4.2.1) are:

- measuring time: < 1 s
- type of interface: SDI-12, RS-232, RS-485 (configurable)
- power supply: 9..18 V cc
- consumption: 250 mA (measuring)
  < 1 mA (idle)
- measuring range: 0,5..10 m
- rezolution: 0,25 mm
- accuracy: ± 1 cm or 0,4 % of measured value
- temperature range: - 45° C..+ 50° C

Figure 4.2.1: SR50A sensor

The main technical characteristics of the sensor for measuring the snow height IRU-9429 (Figure 4.2.2) are:

- measuring time: > 45 ms
- type of interface: RS-232
- power supply: 12..28 V cc
- consumption: 60 mA (measuring)
- measuring range: 0,15..10,67 m
- rezolution: 2,5 mm
- accuracy: ± 0,25 % of measured value
- temperature range: - 40° C..+ 60° C

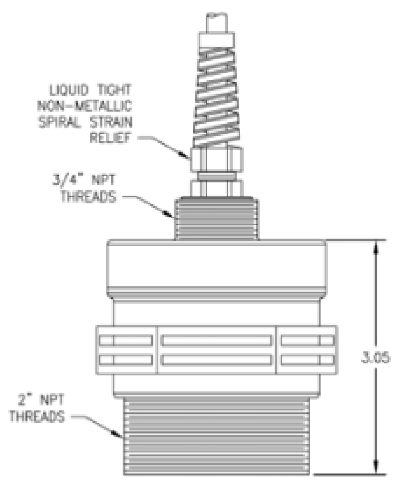


Figure 4.2.2: IRU-9429S sensor

To achieve the snow temperature profiles a sealed sensor was selected (Figure 4.2.3), based on an integrated circuit DS18B20. The main technical characteristics of the sensor for measuring the snow temperature:

- measuring range: - 55° C..+ 125° C
- accuracy: ± 0,5° C

Figure 4.2.3: Sensor for snow temperature

To measure the snow volumetric moisture (liquid water content of snow) a capacitive sensor was selected (Figure 4.2.4), which measures humidity indirectly via measurements of the dielectric permittivity of the environment. In addition to moisture, the sensor measures the ambient temperature. The main technical features of the volumetric moisture sensor are:

- power supply 3,6..15 V cc
- temperature range - 40° C..+ 50° C
- accuracy ± 0,03 m^3/m^3
- type of interface SDI-12

Figure 4.2.4: Sensor for volumetric moisture 5TM

During the project, it became necessary to measure new parameters involved in the evolution of the snow (snow surface temperature, the temperature profile in the soil) and to install measuring points with a sensors structure specific to the area where to install.

In addition to the sensors presented was selected the MLX90614 sensor, IR thermometer (Figure 4.2.5) in TO-39 capsule. The main technical characteristics are:

- rezolution 0.02 °C
- accuracy 0.5 °C
- temperature range - 40...+ 85 °C
- interface SMBus (I2C)

To achieve portable systems it was decided to use "open source" development platforms based on microcontroller's 8 or 32-bits. The choice of "open source" systems was motivated by the availability of resources both "hardware" and of the "software" and from previous experience. They were selected two 32-bit platforms, one based on Freescale Kinetis microcontroller KL25Z and the other on a platform PIC32MX440F256H Microchip 8-bit 328 Olimex.

Described components were purchased for developing the specified equipment at the beginning of the chapter. Were acquired and the necessary power supply components (Pb sealed batteries, solar panels) and the ones needed in order to achieve mechanical prototype (IP 65 boxes, prestupe, bolts, nuts, spacers).

Figure 4.2.5: IR Thermometer

In accordance with the new identified requirements two "reference" stations were made with different sensor configuration.

One reference station (Figure 4.2.6) is measuring the soil temperature profile (6 levels equidistance), snow surface temperature and snow height.

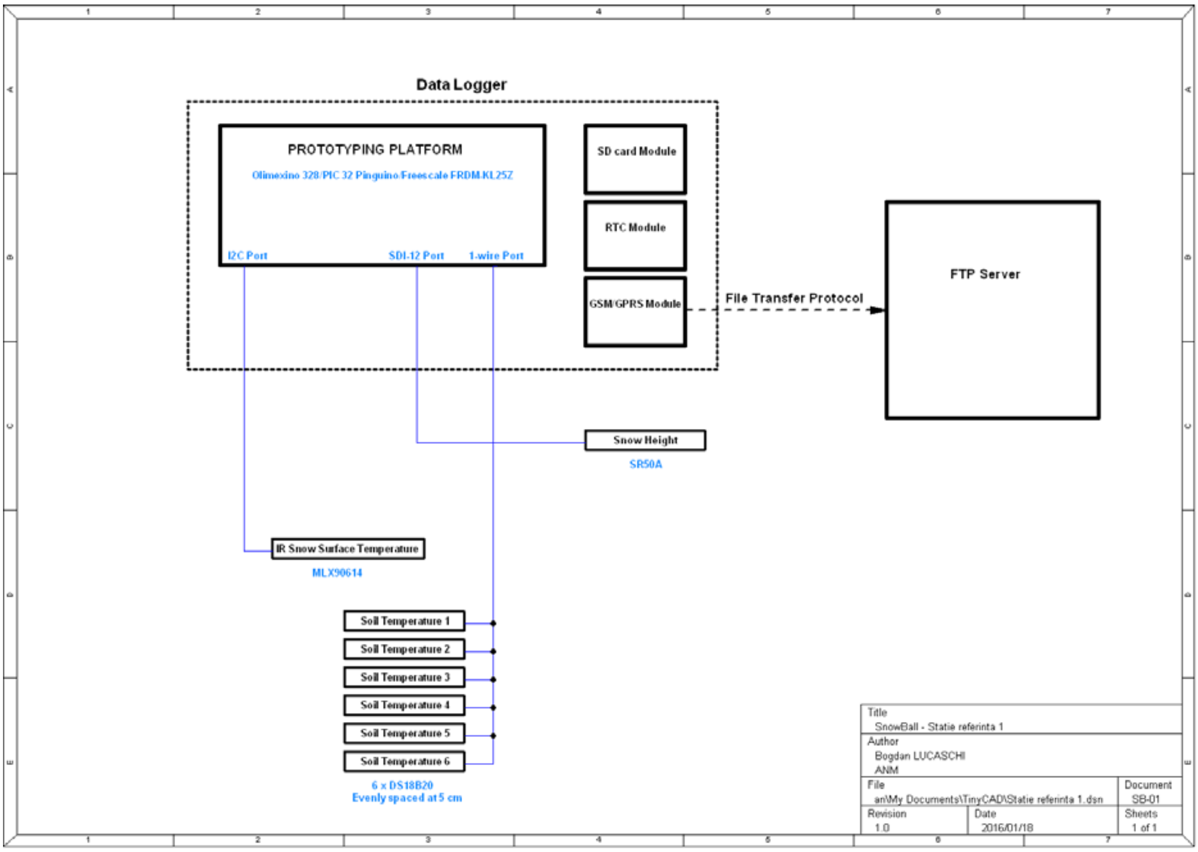


Figure 4.2.6: Reference Station 1

Reference Station 2 (Figure 4.2.7) is measuring the snow temperature profile (5 levels equidistance), volumetric moisture snow (2 levels) and snow height.

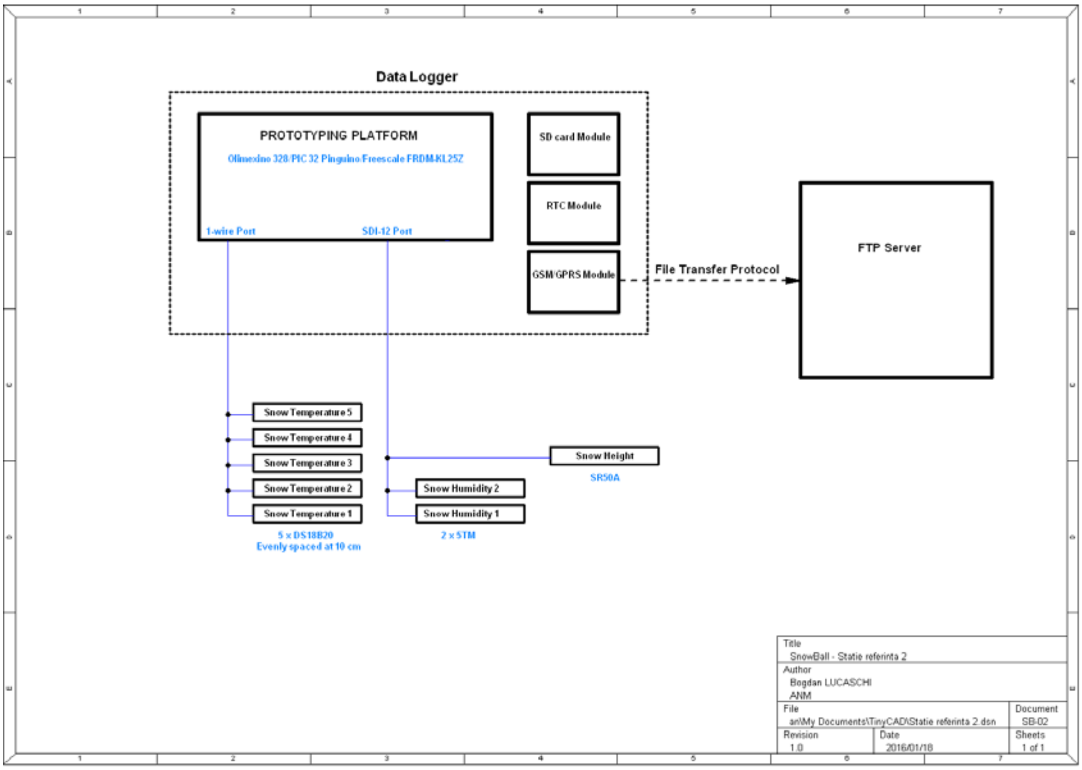


Figure 4.2.7: Reference Station 2

The prototype allows to connect, as required, one or more of the following sensors:

- SR50 (Campbell Scientific) for measuring the snow height;
- 5TM (Decagon Instruments) to measure snow moisture;
- MLX90614 (Melexis) for measuring the snow surface temperature in IR;
- DS18B20 (Dallas Semiconductor) for measuring the temperature profile of soil or of snow in many ways.

Operating mode (short):

- the sensors are connected to a specific port (SDI-12, I2C, 1-wire);
- under the control software installed in the microcontroller flash memory snow parameters are measured and stored on an SD card along with a timestamp;
- a periodic (once per day) measured data are transmitted via FTP protocol to NMA servers;
- a real-time clock is synchronized with the GSM / GPRS system clock;
- a system is powered from the battery Pb, which is charged from a solar panel, under program control.

The layout of the sensors for the two reference stations is given in Figure 4.2.8.

The project itself (electrical scheme) is given in the deliverable D2.2. The prototype was developed and tested in the laboratory; operation complies with the specifications. Two measuring points are installed in the field.

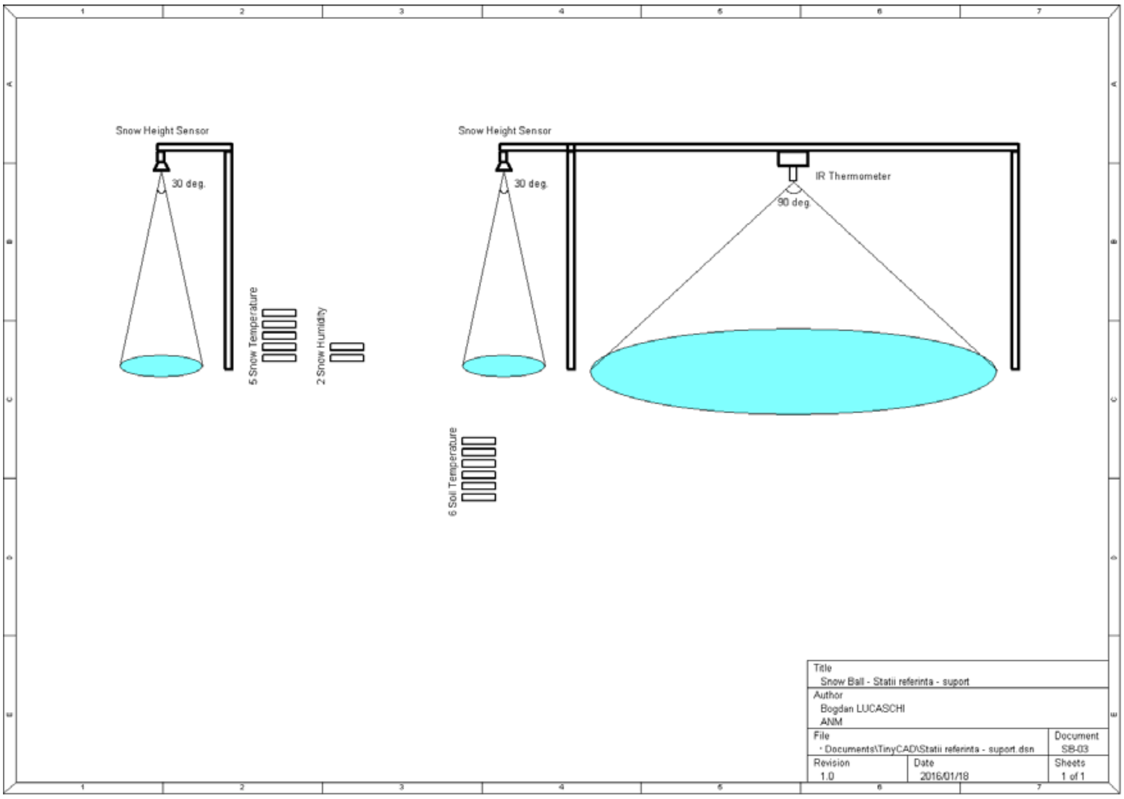


Figura 4.2.8: Sensors placement

4.2.2. ***Activity 2.2.*** *Snowpack parameters observation and measurements*

Understanding absorption, transmission and reflection of light by the snow is important for two main categories of applications. The first one is to calculate the radiation budget of the snow and planetary radiation budget of the land covered with snow. This is important both for hydrology - since radiation is the main component of the energy budget of the snow surface, and for global climate modeling. A second application is used in the planning of remote measurement of the snow properties with high spectral resolution. In recent years, considerable progress has been achieved in terms of understanding the optical properties of snow in solar and infrared spectrum.

Using remote sensing to determine the snow parameters - such as the amount of liquid water - requires calibration / validation of satellite data with in situ data obtained during measurements campaigns of the snow optical properties in the visible and infrared spectrum. To this end, it has been used portable spectrometers that can measure both reflected light in the solar spectrum and the emission in the infrared spectrum snow.

In the SnowBall Snowball there were established several snow measurements campaigns of the snow properties, including measurements of the snow optical properties in solar and infrared spectrum. In March 2015 there was the first measurement campaign that took place in Sinaia (Vârful cu Dor - Cota 1500), Babele and Poiana Brasov (Figure 4.2.9). Measurements were conducted by both NMA and NR, using DSR (StellarNet) and Pro FR FieldSpec spectrometers (ASD Inc.).

In winter 2016-2017, spectral measurements of snow will continue in the same locations in the test area and the data obtained will be used in the calibration / validation algorithms for calculating the snow properties from optical satellite data.

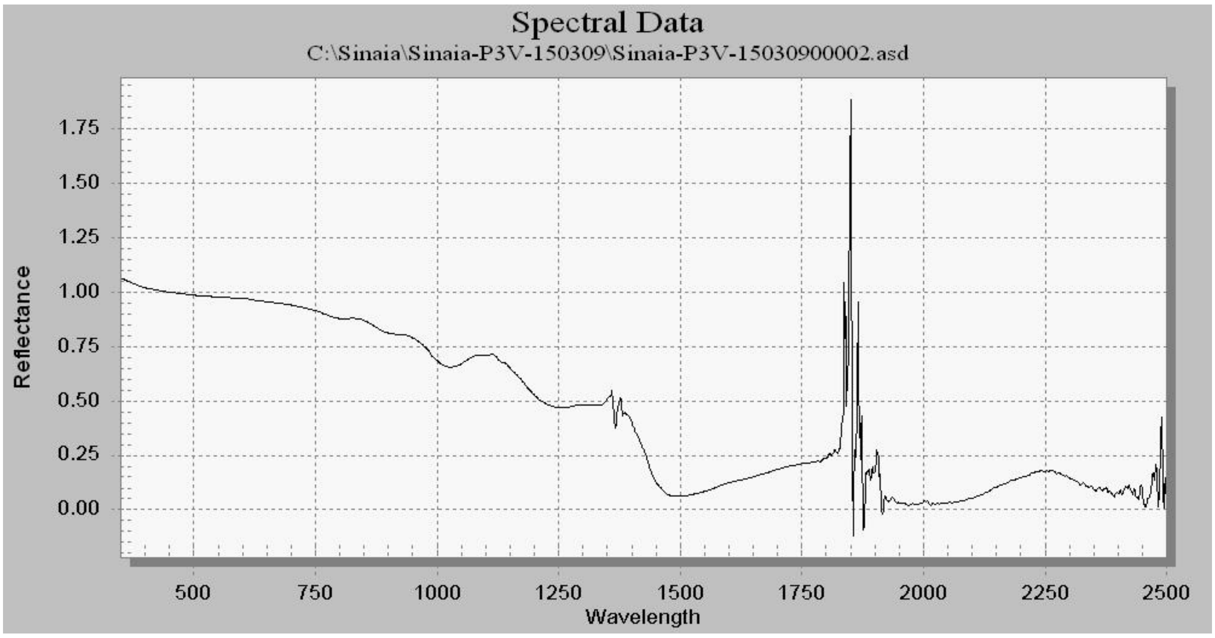


Figure 4.2.9: Solar spectrum, Sinaia Varful cu Dor – Cota 1500, measurement point "S3", 09/03/2015

Also, in this activity it has been established, together with Norwegian partner, the execution methodology of the observations and measurements of snow. Thus, we developed two types of measurements: in-situ surface measurements (Table 4.2.1) and in-situ snow depth measurements (Table 4.2.2).

In-situ snow surface measurements include the following parameters:

- air temperature;
- temperature of snow (2 cm below the surface, with digital thermometer);
- snow crystals (type and diameter with snow booklet and magnifying glass);
- snow density (with an aluminum tube and a dynamometer);
- snow thickness (with a nivological graduated probe);
- humidity of snow (determined empirically or with the hygrometer);
- inclination of the slope (with the inclinometer).

In-situ snow depth measurements (stratigraphic profile and snow resistance) aimed at measuring the following parameters:

- snow resistance to immersion probe (survey by hitting);
- snow surface temperature;
- snow temperature: in the first 20 cm at every 5 cm, and then from 10 to 10 cm;
- number of internal layers of snow. For each of these are identified:
  - crystals type;
  - average diameter of dominant crystal;
  - snow humidity;
  - snow hardness;
  - snow density.

Tabelul 4.2.1: NMA's template for in-situ snow surfacemeasurements

Observer: ……………………………… Data:………………….. Hour: 06.00 UTC		
Group	**Observation**	**Value**
iii	Station (site) indicative	….
H VV	Low cloud base height above station (h) Visibility (VV)	…. ….
N Dd ff	total cloudiness wind - direction (dd) - speed (ff) (m/s)	…. …. ….
$\pm$ TTT	Air temperature ($0\ ^0C$)	….
ww W_1 W_2	present weather (ww) past weather (W_1) past weather (W_2)	…. …. ….
N_h C_L C_M C_H	Low cloudiness low clouds type medium clouds type high clouds type	…. …. …. ….
$\pm T_xT_xT_x$	Maximum air temperature during last 24 hours (^0C)	….
$\pm T_nT_nT_n$	Minimum air temperature during last 24 hours (^0C)	….
sss	Snow depth (cm)	….
RRRR	Precipitations during last 24 hours (mm)	….
s's'	Fresh snow height during last 24 hours (cm)	….
$-T_sT_sT_s$	Snow temperature below snow surface (^0C)	….
E_n P_sP_s N_V C_n	Snow type at surface (E_n) Sonde penetration (P_s) (cm) Valley clouds (N_V) Drifted snow (C_n)	…. …. …. ….
L_1 L_2 L_3 L_4 L_5	Observed avalanches: - number of observed avalanches (L_1) - avalanche type (L_2) - triggering altitude (L_3) - avalanche slope exposure (L_4) - local avalanche risk estimation (L_5)	…. …. …. …. ….
2 dd ff	Wind on altitudine: - Direction (dd) - speed (ff) (m/s)	…. ….
sss s's'	Snow on altitudine: - snow depth (sss) - fresh snow depth (s's')	…. ….
3 UU T_LT_L	Relative air humidity (UU) - în % snow water content (T_LT_L – în %) (if $T_sT_sT_s \approx 0\ ^0C$)	…. ….
4 F_1 (dominant crystal type) F_2 (second crystal type) D_m D_m	Snow crystal type on surface (F_1; F_2) 1: + fresh snow | 6: ○ snowmelt 2: **λ** decomposed snow | 7: ▬ ice crust 3: ● round snow | 8: V surface hoar 4: □ faceted snow | 9: * graupel 5: ^ depth hoar Medium diameter of dominant snow crystals on surface (mm)	…. …. ….
5 i $M_vM_vM_v$	Snow surface homogenity indicator **i = (0-1-2)** Volumique mass $M_vM_vM_v$ (kg/m^3)	…. ….

Tabelul 4.2.2: NMA’s template for in-situ snow depth measurements

Station (or site): ……………… **Data**: …………………………………… **Hour (local)**: ……………………….. **Observer**: ……………………… **Location**: ………………. ……….. **Altitude**: ……………………..	**PROFIL STRATIGRAFIC No:** **Exposure**: …………………… **Slope inclination (grades)**: …………………. **Weather**: …………………………………. **Air temperature (at 2 m)**: ………………………..

Snow temperature		**H**	**F1 F2**	**Dm**	**d**	**U**	**MV**	**TEL**	**CISA**		**(h)**	**H – snow height (cm)**
H (cm)	°C	cm	symbol	mm			kg/m^3	%	ø	C	cm	For the temperature: H indicates the level where the measurement is made. For stratigraphy: H indicates the levels between snow crystals are examined.
												F1 F2 - crystal shape 1. + fresh snow 2. λ decomposed snow 3. ● round snow 4. □ faceted snow 5. ∧ depth hoar 6. o snowmelt 7. **–** ice crust 8.∨ surface hoar 9. * graupel
												Dm - dominant snow crystals medium diameter (tenth of mm. ex.: 0.5/1.0)
												d – snow hardness 1. fist: very soft 2. 4 fingers : soft 3. 1 finger : hard 4. pen : very hard 5. knife blade: compact
												U – snow wetness **1**. dry (T≤ -1°C, or cannot make snowballs) **T≥ -1°C** ; can easily make snowballs: **2**. slightly wet (glove stays dry) **3**. wet (glove is wet) **4**. soaked (water flows when clenching the fist) **5**. very soaked (water and snow mixture)
												MV - volumique mass (kg/m3) MV = net weight x 2 (weight in grams) (measured with a 500 cm^3 cylinder)

The survey by hitting was done using the graduated nivological probe, thus obtaining the snow resistance profile. Stratigraphic profile implies measuring the snow layer temperature, from 10 to 10 cm (the first 20 cm and then from 5 to 5 cm), determination of each inner layer and its characteristics (such as the crystal diameter of the dominant crystals, hardness, moisture and density). The data are then entered in the Gelin V 3.3.2 software, CEN Météo France.

The purpose of the survey and of the stratigraphic profile is to study the resistance and structure of snow layers deposited in time, which together form the snow total layer, in order to determine areas that may underlie instability that cause avalanches. Their execution requires the presence of at least two people: one to work with the probe and the other to record data in specific forms. It has been used specific tools: snow probe, electronic thermometer for measuring the temperature in the layer (Figure 4.2.10), snow booklet (Figure 4.2.11), magnifying glass (to determine the types of granular snow), sampling tube, dynamometer, avalanche shovel (with high resistance and short tail).

Figura 4.2.10: Instrumentation used for nivologiceal observations

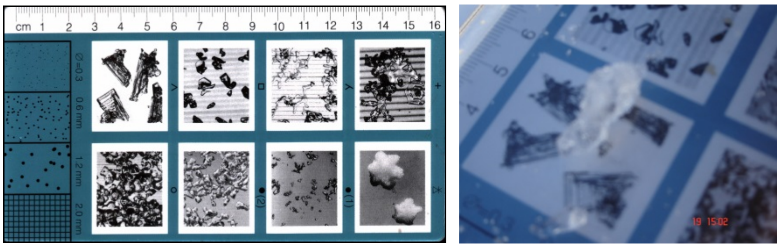


Figura 4.2.11: Snow booklet to determine the types of granular snow

The measurement campaign included:

- Bâlea-Lac, in 2015.02.19:
  - In 3 locations. Nivological measurements were conducted: survey by hitting and stratigraphic profile.
- Sinaia , in 2015.03.09 :
  - In 3 locations. There were conducted measurements in 5 places of temperature, humidity, stratigraphy and density, according to the Norwegian methodology; nivological measurements: the survey by hitting and stratigraphic profile.
- Poiana Braşov and Postăvaru, in 2015.03.09:
  - In 3 locations. There were conducted measurements in 5 places of temperature, humidity, stratigraphy and density, according to the Norwegian methodology; nivological measurements: the survey by hitting and stratigraphic profile.
- Bâlea-Lac, în 2015.04.16:
  - In 3 locations. There were conducted measurements in 5 places of temperature, humidity, stratigraphy and density, according to the Norwegian methodology; nivological measurements: the survey by hitting and stratigraphic profile.

At Balea Lac-meteorological station, were made measurements of temperature, humidity, stratigraphy and density, according to the methodology agreed, in 5 places, correlated with the passage of the satellite:

- 2015.04.04: grain type, temperature, density and water equivalent in 5 points
- 2015.05.05
- 2015.05.16
- 2015.05.23

At Sinaia, Predeal, Omu (Ialomita basin) and Balea-Lac (Arges basin) weather stations, were made nivological measurements (daily observations and weekly survey by hitting and stratigraphic profile) throughout the winter season.

Permanent processing of data from nivological measurements - including snow surface temperature, humidity (empirically), type and size of crystals and internal stratigraphy - Regional Weather Service Forecast in Sibiu.

Figure 4.2.12 shows an example of resistance profile, temperature and stratigraphy on 16/04/2015 at the meteorological station Balea-Lac.

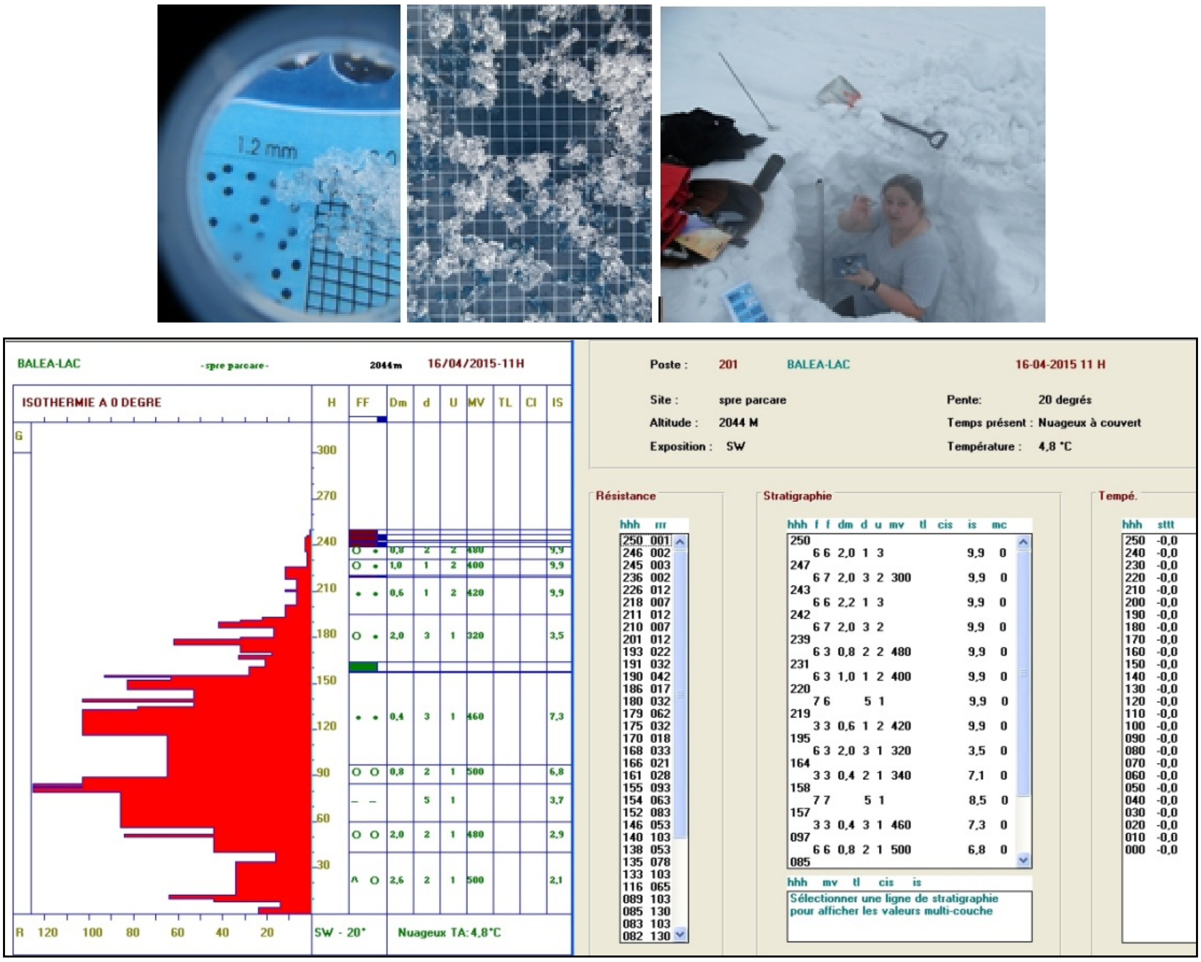


Figure 4.2.12: Type of granular from the stratigraphic profile (round and big, top)
resistance, temperature and stratigraphic charts obtained by introducing measured data in the Gelin software (below)

Figure 4.2.13 shows an example of resistance profile, temperature and stratigraphy on 09/03/2015 at Sinaia, along the Drumul de Vara slope in undeveloped areas.

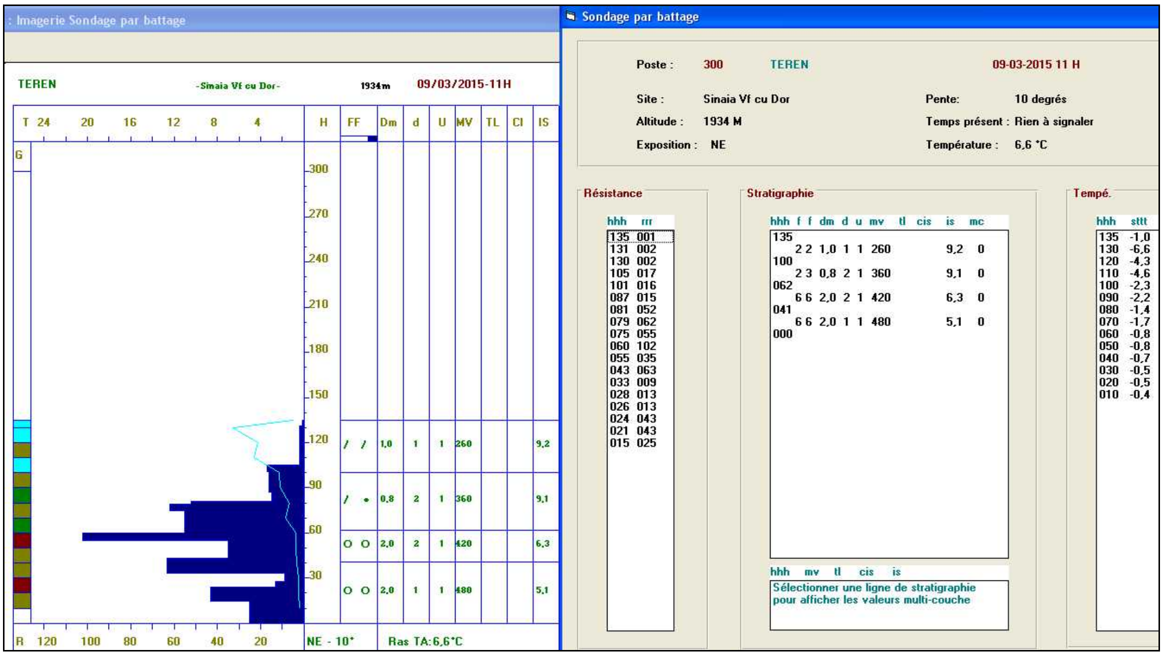


Figura 4.2.13. Resistance profile, temperature, stratigraphy and observation data

4.2.3. *Activity 2.3. Create and set-up of a spatial database managed by GIS software*

The SnowBall spatial database integrated in GIS environment includes: geospatial classical database (maps, satellite images, field measurements) or other types of data (photos, graphics, statistical data, descriptive documents).

The first step was the inventory of all necessary data, design of adequate data models and setting up the procedures for their integration in the GIS database. The following actvities were carried out during the design and creation stage of geospatial database:

- The analysis of the existing spatial data;
- Knowing data and databases: date type, structure, formats, etc.;
- Understanding data flow and necessary information for the project;
- The analysis of required spatial data which will be represented in Geoportal;
- The analysis of attribute data;
- The analysis of the spatialization procedures for missing data;
- The analysis of the procedures for data correction / validation;
- Identification of the required elements according to INSPIRE directive.

4.2.3.1. Data base content

The geospatial database includes both recent and hystorical data. The flowchart from Figure 4.2.14 shows the types of geospatial data stored in the database.

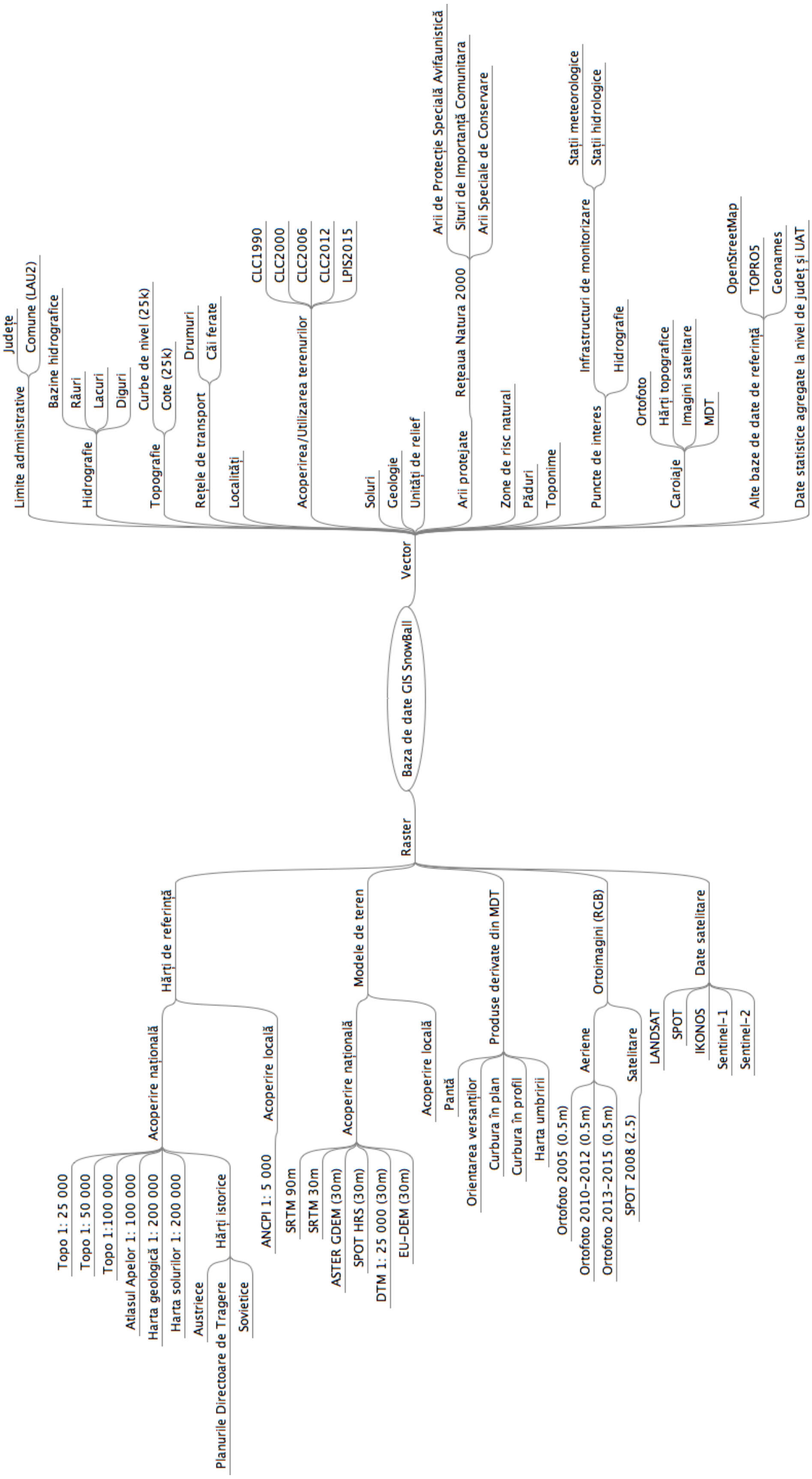


Figure 4.2.14:The content of the SnowBall GIS database

4.2.3.2. Sources of data

The structure described in the previous paragraph implies a very large volume of spatial data. The consortium involved in developing of SnowBall GIS database was relied mostly on existing data sets. If such data has not been identified (especialy in the case where is needed data at very large scale) was proceeded to their extraction using as a support scanned maps, satellite images or aerial photographs. The following sources of data and methods have been used to develop the database:

- Database created by national institutes (e.g. National Agency for Cadastre and Land Registration, Military Topographic Directorate, Agency for Payments and Intervention in Agriculture, National Institute for Research and Development in Forestry, National Institute of Statistics, National Institute of Hydrology and Water Management, Ministry of Environment and Climate Change, etc);
- Data base available on the Internet. From this category is highlighted the archives of satellite imagery and derived products made freely available to the community by space agencies such as NASA (National Aeronautics and Space Administration) ESA (European Space Agency) or JAXA (Japan Aerospace Exploration Agency). As vector data were used data published on geo-spatial.org and OpenStreetMap platforms and environmental data distributed free by EEA (European Environment Agenc). OpenStreetMap (abbreviated OSM) is a collective project, under open source, which aims to build a global geographic database, such as road atlases, using both data input manualy having as background spatial images and data collected from GPS;
- Data produced under national projects to which exist free access to data. One of the best examples of this is the GIS database developed within the project PHARE / 2005 / 017-553.03.03 / 07.02 - "Technical assistance in developing GIS map", having as beneficiary the Ministry of Environment and Forests (current Ministry of Environment and Climate Change);
- Data produced by the members of SnowBall consortium by vectorization topographical maps, orthophotomaps, satellite images or measurements with GPS receivers.

4.2.3.3. Operations applied to existing data

Existing vector data have been obtained in different file formats (Shapfile ESRI, ESRI Geodatabase, CAD) with variable spatial domains, presenting a series of errors at geometric and topological level. There were necessary several processing steps as attributes homogenization, geometric and topological correction, new layers derivation or combination of certain information in the same layer, defining relationships between layers and tables, centralizing data in a database.

4.2.3.3.1. ConverSnowBall Shapefile>PostGIS

Large majority of existing data were stored in ESRI Shapefile format. ConverSnowBall Shapefile> PostGIS was done quite easily due to the similarities between the two formats at a geometric and attribute level. There are still differences, especially in the tabular information (Table 4.2.3).

Table 4.2.3. Correspondence between Shapefile tabular attribute data types (dBASE file) and PostGIS

Field type Shapefile format	Field type PostGIS
data	data
string 1 - 254	text
boolean	boolean
number 1 – 4 (without decimals)	smallinteger
number 5 – 9 (without decimals)	integer
number 10 – 19 (without decimals)	bigint
float 1 - 13	real

float 14 -19	double precision
number 1 – 8 (with decimals)	real
number 9 – 19 (with decimals)	double

In the following is an example of a commands list used to convert roads layer from ESRI Shapefile format into PostgreSQL+PostGIS format:

- Creation of a PostGIS database

```
sudo su postgres
createdb postgistemplate
createlang plpgsql postgistemplate
psql -d postgistemplate -f /usr/share/postgresql-9.3-postgis/lwpostgis.sql
psql -d postgistemplate -f /usr/share/postgresql-9.3-postgis/spatial_ref_sys.sql
createdb -T postgistemplate -O gis romania
```

- Data loading

```
shp2pgsql -I -s 31700 drumuri.shp drumuri > drumuri.sql
psql -d romania -h localhost -U gis -f drumuri.sql
```

- Server result

```
BEGIN
psql:drumuri.sql:4: NOTICE:  CREATE TABLE will create implicit sequence "drumuri_gid_seq" for serial column "drumuri.gid"
psql:drumuri.sql:4: NOTICE:  CREATE TABLE / PRIMARY KEY will create implicit index "drumuri_pkey" for table "drumuri"
CREATE TABLE
          addgeometrycolumn
------------------------------------------------------
drumuri.the_geom SRID:32633 TYPE:POINT DIMS:2
(1 row)
CREATE INDEX
COMMIT
```

Loading sequence was repeated for all vector layers from the database.

4.2.3.3.2. Clip data

Part of the vector data are found in files with national coverage. For this it is necessary the application of clipping operations to o bring them at the desired spatial extend (the project study area). It can be realized using the vector limit of the area of interest as mask (Figure 4.2.15).

Figure 4.2.15: Crop data with national extent using the limit of the area of interest

4.2.3.3.3. Data merge

There have been cases where information of the same type is available in a separate file. The best example is the case of roads separated in two layers: (a) national and county roads; (B) communal roads

For on ptimal access this data will be brought in the same layer, and the separation of categories (national, county, municipal) will be achieved the attributes level (Figure 4.2.16).

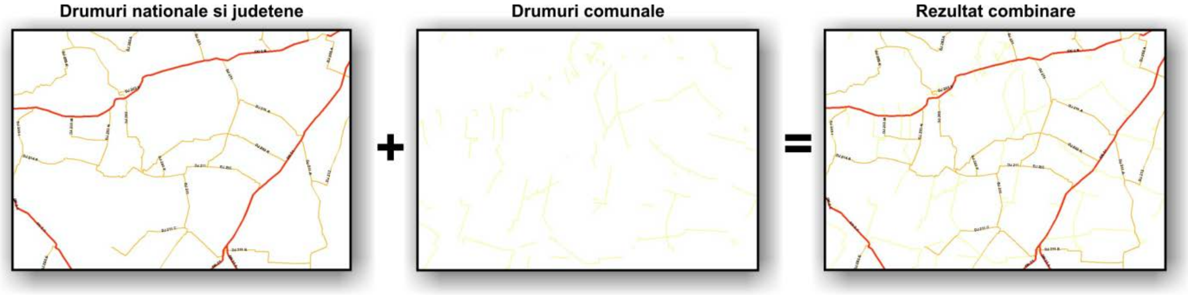


Figure 4.2.16: Data merge

4.2.3.3.4. Topological correction of the data

The topology is the model that describes how the layers of geospatial information share their geometries, functioning as a mechanism that allows definition and keeping the geometric relationships between entities from the same layer or different layers. The relevant topological rules for data stored in the database are: (a) " must not have gaps” and "must not overlap" for polygon data; (b) "must not overlap" and " must not have dangles” for linear data (Figure 4.2.17).

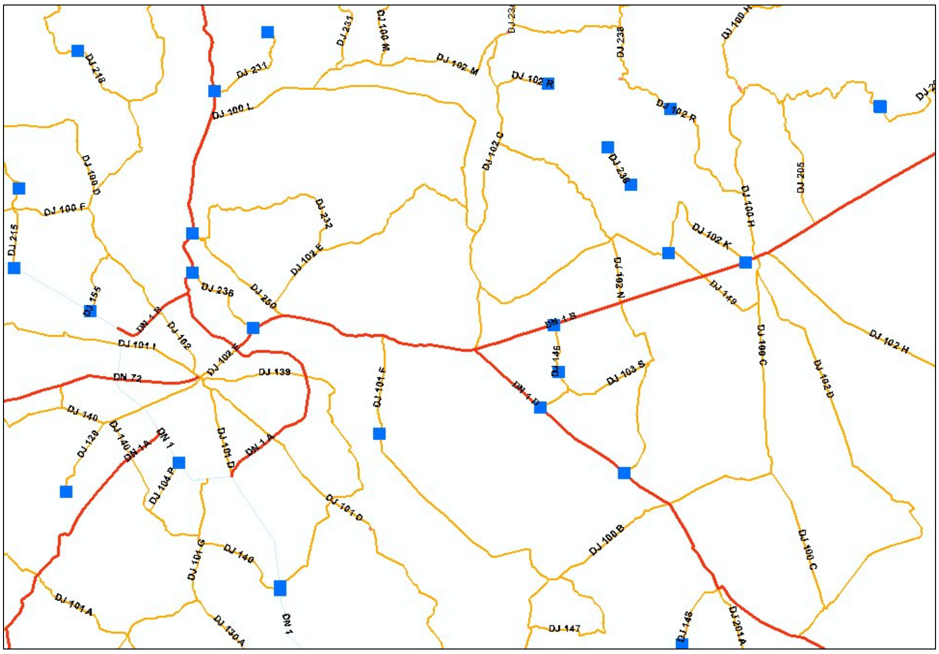


Figure 4.2.17: Highlighting (blue) the topological errors „must not have dangles" for roads layer

4.2.3.3.5. Geometry conversion

Considerations of cartographic representation, certain data structures requires the presence of several types of geometries. Thus, for localities is useful a point geometry for visualization / representation at small scales and a polygon geometry for visualization / representation at large scales (Figure 4.2.18). In a similar way, for the different limits it is necessary the presence of a polygon geometry for interrogation, geoprocessing, calculating perimeters and areas operations, and line geometry for complex cartographic representations.

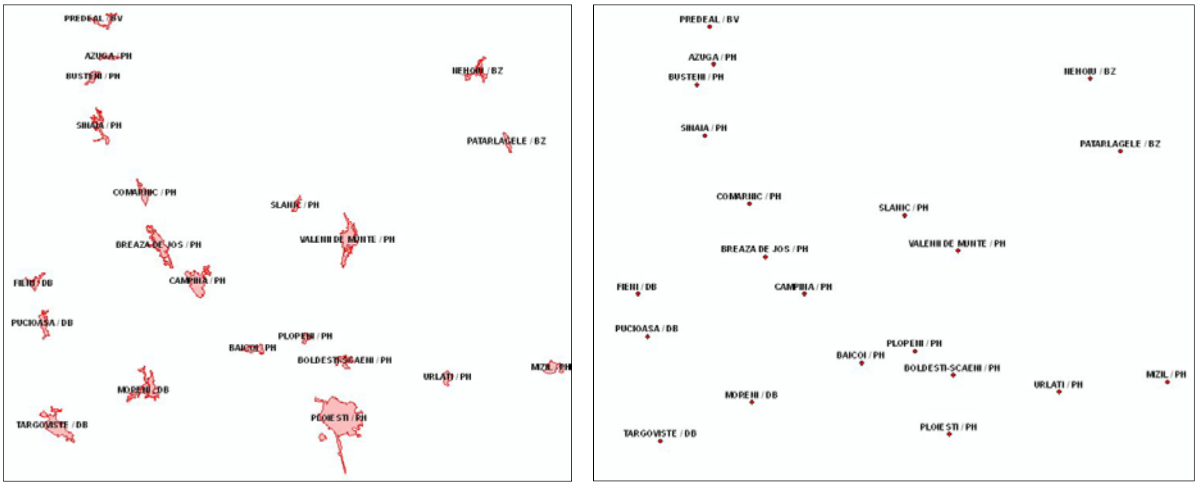


Figure 4.2.18: Example of conversion the geometry polygon into point geometry

4.2.3.4. Coordinate systems and metadata

4.2.3.4.1. Coordinate systems

Each data set has an associated specific reference coordinate system and spatial reference system. The Snowball GIS database stores and manages both information on the native layer coordinate system and information on the spatial extent expressed in degrees, minutes, seconds. Also, it can be done reprojection of data by defining the native reference system and an asked coordinate system. The system uses EPSG Geodetic Parameter Registry for coordinate system definition and transformation. The Snowball has the ability to provide geospatial data in multiple coordinate reference systems.

The default coordinate system used for SnowBall project is Stereo 70, EPSG 31700 code (Figure 4.2.19).

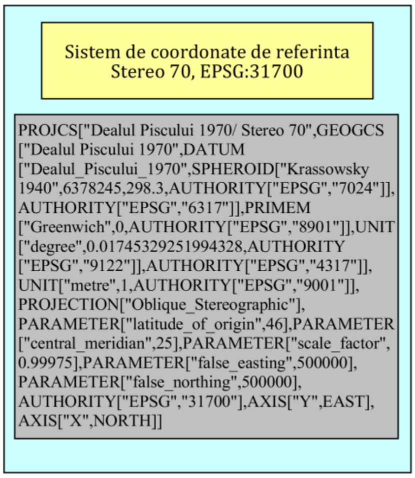


Figure 4.2.19: Reference coordinate system

4.2.3.4.2. Metadata

According to the US Federal Geographic Data Committee a record of metadata is "an information file, usually presented as a XML document that captures the basic features of a data resource or information. It represents the answer on the questions who?, what ?, when ?, where ?, why? and how? regarding that resource information. Geographic metadata are used to document the geographic digital resources, such as files and geographic information systems (GIS), geospatial databases and satellite images. Geographic metadata are used to document the geographic digital resources, such as files and geographic information systems (GIS), geospatial databases and satellite images. A record of geospatial metadata includes elements of cataloguing as title, abstract, and date of publication, geographical elements, such as geographical extent and coordinate system and elements related to the database, such as defining attribute labels or values fields of attributes".

Each layer is defined by a set of metadata internally stored, due to the format nature (raster or vector), or encapsulated in the internal memory of the Snowball system. Another simple way to recover the basic metadata attributes is to analyse each layer name, which most often is self-explicit.

Each data set is stored using known formats that are able to internally save an amount of metadata on that layer information. For most of the layers accessible via the Snowball GIS database, is used GeoTIFF format for data raster or ESRI Shapefile / PostgreSQL format for data vector. An example of metadata internally stored and read using GDAL library is given below:

```
Driver: GTiff/GeoTIFF
Files: mozaic_spot.tif
Size is 300000, 212000
Coordinate System is:
PROJCS["Dealul Piscului 1970/ Stereo 70",
  GEOGCS["Dealul Piscului 1970",
    DATUM["Dealul_Piscului_1970",
      SPHEROID["Krassowsky 1940",6378245,298.2999999999985,
        AUTHORITY["EPSG","7024"]],
      TOWGS84[28,-121,-77,0,0,0,0],
      AUTHORITY["EPSG","6317"]],
    PRIMEM["Greenwich",0],
    UNIT["degree",0.0174532925199433],
    AUTHORITY["EPSG","4317"]],
  PROJECTION["Oblique_Stereographic"],
  PARAMETER["latitude_of_origin",46],
  PARAMETER["central_meridian",25],
  PARAMETER["scale_factor",0.99975],
  PARAMETER["false_easting",500000],
  PARAMETER["false_northing",500000],
  UNIT["metre",1,
    AUTHORITY["EPSG","9001"]],
  AUTHORITY["EPSG","31700"]]
Origin = (130000.000000000000000,760000.000000000000000)
Pixel Size = (2.500000000000000,-2.500000000000000)
Metadata:
 AREA_OR_POINT=Area
Image Structure Metadata:
 COMPRESSION=YCbCr JPEG
 INTERLEAVE=PIXEL
 SOURCE_COLOR_SPACE=YCbCr
Corner Coordinates:
Upper Left  (  130000.000,  760000.000) ( 20d 1' 5.72"E, 48d13'58.18"N)
Lower Left  (  130000.000,  230000.000) ( 20d25'36.72"E, 43d28'35.61"N)
Upper Right (  880000.000,  760000.000) ( 30d 6'57.33"E, 48d13'37.30"N)
Lower Right (  880000.000,  230000.000) ( 29d41'47.01"E, 43d28'17.18"N)
Center      (  505000.000,  495000.000) ( 25d 3'52.23"E, 45d57'17.95"N)
Band 1 Block=256x256 Type=Byte, ColorInterp=Red
 Overviews: 150000x106000, 75000x53000, 37500x26500, 18750x13250, 9375x6625, 4688x3313,
2344x1657, 1172x829, 586x415, 293x208, 147x104
```

Band 2 Block=256x256 Type=Byte, ColorInterp=Green
Overviews: 150000x106000, 75000x53000, 37500x26500, 18750x13250, 9375x6625, 4688x3313, 2344x1657, 1172x829, 586x415, 293x208, 147x104
Band 3 Block=256x256 Type=Byte, ColorInterp=Blue
Overviews: 150000x106000, 75000x53000, 37500x26500, 18750x13250, 9375x6625, 4688x3313, 2344x1657, 1172x829, 586x415, 293x208, 147x104

Information about each layer stored and managed bu SnowBall system include:

- Name
- Title
- Abstract
- Keywords
- Addresses for metadata
- Reference coordinate system
- Layer limits
- Publication options (interpolation method, format, the style applied by default, layer identifiers)

4.2.3.5. The implementation of the INSPIRE network servicies

Geospatial network services operate after principles and communications protocols similar to classic web services (XML-RPC, UDDI, WSDL, SOAP). Their role is particularly important in the current context, when we are witnessing, on the one hand, to a continuous expansion of the sources and quantity of stored geospatial data, and on the other hand, an increasing need to access this data. In the Snowball geoportal was implemented a GIS server with the following network services:

4.2.3.5.1. Visualization service

This service allows to display, navigate, zoom in / out, pan, visual overlapping of spatial data sets and to display legend information and any relevant content of metadata. The service was implemented according to ISO standard 19128 (Geographic information - Web map server interface), also known as WMS (Web Map Service). The implemented service offers three methods:

- GetCapabilities - enables service query to get a list of the type of information that can deliver;
- GetMap - allow request and transfer of a map / data set;
- GetFeatureInfo - allows to obtain the associated attributes to maps / entities.

The visualisation service offeres support for two versions of the WMS standard:

- 1.1.1(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wms&version=1.1.1&request=GetCapabilities)
- 1.3.0(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wms&version=1.3.0&request=GetCapabilities).

The Snowball visualization service can produce georeferenced digital maps (raster: PNG, GIF, JPEG or vector: SVG, WebCGM). They can be viewed or interrogated in different contexts. It is possible to combine multiple data sets to generate a single map by using vector and raster formats that support transparency (GIF, PNG). Symbolization mechanism of data is based on the data SLD standard (Styled Layer Descriptor). SLD allows to create an XML file, for each type of geospatial element from the database includes symbolization rules (shape, color, texture, size, etc.). Service testing was done both with desktop (QSIG, uDig, gvSIG) and web (OpenLayers) applications.

4.2.3.5.2. Data download service

It allows downloading of copies of the spatial data sets, or parts of these, and direct access of data. The service was implemented according to ISO 19142 standards for vector data and OGC 07-067 for the raster data. For vector data the service offers the following methods:

- GetCapabilities - allows getting information about operations that the service can execute, data types and associated metadata;
- DescribeFeatureType - enables to provide information about the structure each type of data in the form of XML schema;
- getFeature - allows transferring an element of a data set according to specified spatial and non-spatial criteria (attributes);
- Lock Feature - allows blocking of one or more elements of a spatial data set (eg for spatial editing);
- Spatial Operators and Folders - allows the application of spatial operators or filters for easy access to data or data analysis;
- Transaction - enables the formulation of transactions within which data can be modified by creating, updating or deleting operations.

For raster data, the service offers the following methods:

- GetCapabilities - allows getting information about that the service operations can execute data types and associated metadata;

- Describe Coverage - enables to provide information about each type of data structure in the form of XML schema;

- Get Coverage - enables to transfer a grid data or a subset of it.

Download data service offers support for several WFS and WCS standards:
WFS 1.0.0
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wfs&version=1.0.0&request=GetCapabilities)
WFS 1.1.1
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wfs&version=1.1.0&request=GetCapabilities)
WFS 2.0.0
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wfs&version=2.0.0&request=GetCapabilities)
WCS 1.0.0
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wcs&version=1.0.0&request=GetCapabilities)
WCS 1.1.0
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wcs&version=1.1.0&request=GetCapabilities)
WCS 1.1.1
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wcs&version=1.1.1&request=GetCapabilities)
WCS 1.1
(http://snowball.meteoromania.ro:8080/geoserver/ows?service=wcs&version=1.1&request=GetCapabilities)

The SnowBall data download service can provide data in the following files format: ArcGrid, GeoTiff, Gtopo30, JPEG, PNG, TIFF, GIF for raster data and GML, KML, CSV, TAB, MIF, Shapefile for the vector data. The service was tested using QGIS application.

4.2.3.5.3. Data processing service

Defines how geospatial models and calculations (called processes) can be discovered and executed through a software-based service architectures (SOA), using protocols like HTTP instances exhibited by-GET, HTTP-POST or SOAP. The service was implemented according to standard OGC 05-007, known as the OGC WPS (Web Processing Service). Processing Service of the Snowball portal offers three methods:

- GetCapabilities - lists the processes that the the service they offer;
- Describe Process - full description of processes, including input and output parameters;
- Execute - running command of a process that uses input parameters and returns the processing results.

WPS SnowBall services can use three main data types:

- Complex Data – XML (GML), CSV, Shapefile, GeoTiff, HDF;
- Literal Data – numerical values, text strings;
- Bounding Box Data - coordinates with the geographical extension of an area of interest.

The processing service offers support for the version 1.0.0 of the WPS standard (http://snowball.meteoromania.ro:8080/geoserver/ows?service=wps&version=1.0.0&request=GetCapabilities). The service was tested using QGIS application.

4.2.4. *Activity 2.4. Elaboration of spatial products using the spatial database*

Within this activity gridded daily datasets were constructed at 1000 x 1000 m spatial resolution over 1 October 2005 – 30 April 2015 for the following parameters:

- air temperature (minimum, mean and maximum);
- precipitation;
- snowpack depth (SD) ;
- Snowpack water equivalent.

The spatial interpolation procedure applied to the data measured at weather stations implied completion of the stages below:

a) spatial interpolation at 1000 x 1000m spatial resolution of the mean multiannual values (2005-2015) corresponding to each month, computed from the data extracted from the climatological database;

b) computing the daily / 5-day / yearly deviations over the 2005-20105 interval and spatially interpolating those;

c) obtaining the spatio-temporal datasets was achieved through merging the two surfaces obtained in stages a) and b).

In the case of temperatures, anomalies were considered to be the differences between the hourly values and the multiannual means and in the case of precipitation and snow layer the ratio was used between the hourly values and climatology. To plot the maps with the climatological normals (multiannual means), the Regression Kriging (RK) spatial interpolation method was used. To choose the optimum method applied in spatializing deviations, through applying cross validation, three interpolation methods were tested: Multiquadratic (MQ), Ordinary Kriging (OK) and Inverse Distance Weighting (IDW).

4.2.4.1. Climatological normals (2005-2015)

In this stage (achieving the gridded climatology), there were used as main data the mean monthly multiannual values (1 October 2005-30 April2015) of the parameters of interest. There were also taken for computation in the spatializing procedure the following auxiliary data derived from the Digital Elevation Model: altitude, mean altitude in a 20-km radius, latitude, distance from the Black Sea and distance from the Adriatic Sea.

Maps rendering the climatological normals were obtained with the help of RK method which can take for computation one or more variables with a common distribution in space (numerical altimetric model, satellite images etc.).

Owed to the existence of the collinearity effect (independent correlated variables), predictors derived from the numerical altimetric model were subjected to the filtering process through the analysis of the principal components Filtering the predictors through the principal component analysis (PCA) is performed through transforming the initial variables in a new set of variables, uncorrelated and of a smaller size.

In the first stage there were identified for each month the statistical relationships between the minimum temperature values and the auxiliary variables (PCA predictors). Through applying the retrograde type *stepwise regression* method, statistically significant predictors were selected for each case taken apart (parameter/month).

Through applying RK method, monthly maps were obtained at 1000x1000m spatial resolution, representing the multiannual means of the parameters of interest (Figure 4.2.20).

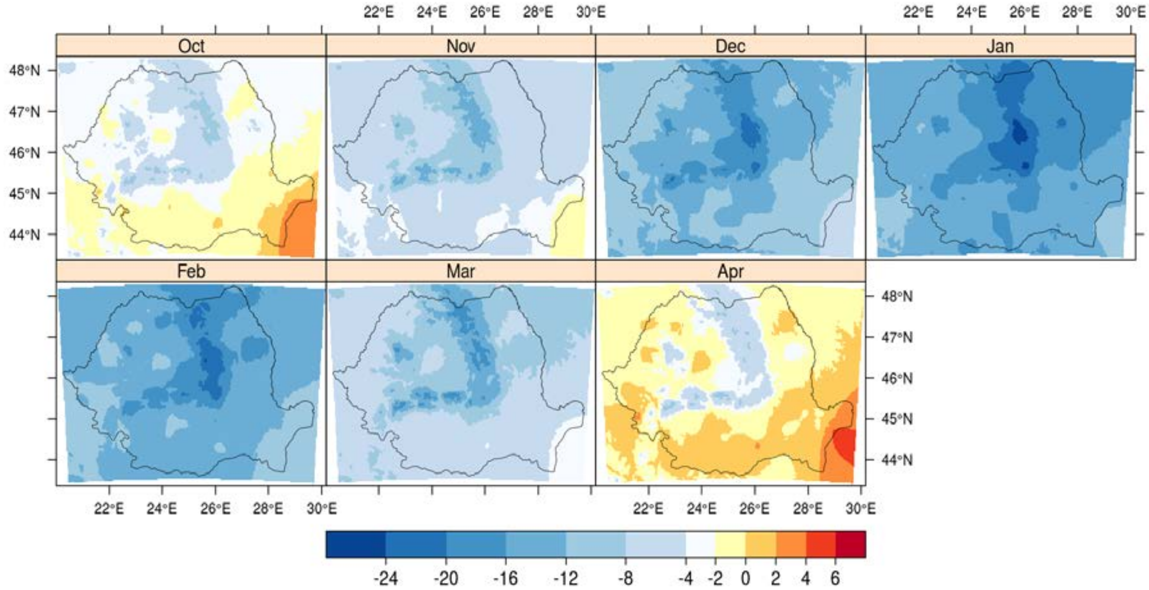


Figure 4.2.20: Mean multiannual minimum temperatures (°C) 2005-2015.

4.2.4.2. Gridded daily data

In this stage the following interpolation methods were tested in order to choose the optimum interpolation method for the daily anomalies against the multiannual means: Inverse Distance Weighted (IDW), Multiquadratic (MQ) and Ordinary Kriging (OK).

To choose the optimum interpolation method for the deviations, the **cross validation** procedure was applied. This implies the elimination of one value in turn from the set of observed values and the determination of the value of the point excluded on the basis of the other observed data. The difference between the estimated $\mathbf{P}$ and the measured $\mathbf{O}$ data represents ε experimental error:

$$\varepsilon_i = \mathbf{P}(s_i) - \mathbf{O}(s_i)$$

Quantification of differences between estimations and observed data was performed with the help of error measuring indicators:

- mean error (ME);
- mean absolute error (MAE);
- root mean square error (RMSE).

Box-plot and Taylor-type diagrams were also used.

In the case of all the analysed parameters, the cross validation procedure was applied to the anomalies computed over the 2005-2015 interval. From analysing results of the cross validation, obtained after applying the three interpolation methods it was noticed that for all the analysed parameters, MQ method succeeds to estimate the values closest to the original dataset, which prompted the decision that this method should be applied in the spatial interpolation of the anomalies. Gridded daily datasets were obtained through merging the maps rendering the anomalies with the maps displaying the climatology.

Using gridded daily data, other parameters can also be computed: number of days with snowpack, first and last day with snowpack, maximum snow depth, maximum precipitation in 24 hours etc. To exemplify, there are further rendered the maps with the monthly maximum snowpack depth computed for each grid point from the daily data series (Figure 4.2.21). The highest values of this parameter correspond to the high mountain areas (more than 200 cm starting from January) and persist until April owed to the negative mean temperatures. A considerable snowpack (deeper than 50 cm) is also to be found in the extra-Carpathian areas, as a consequence of the blizzard episodes specific to January and February.

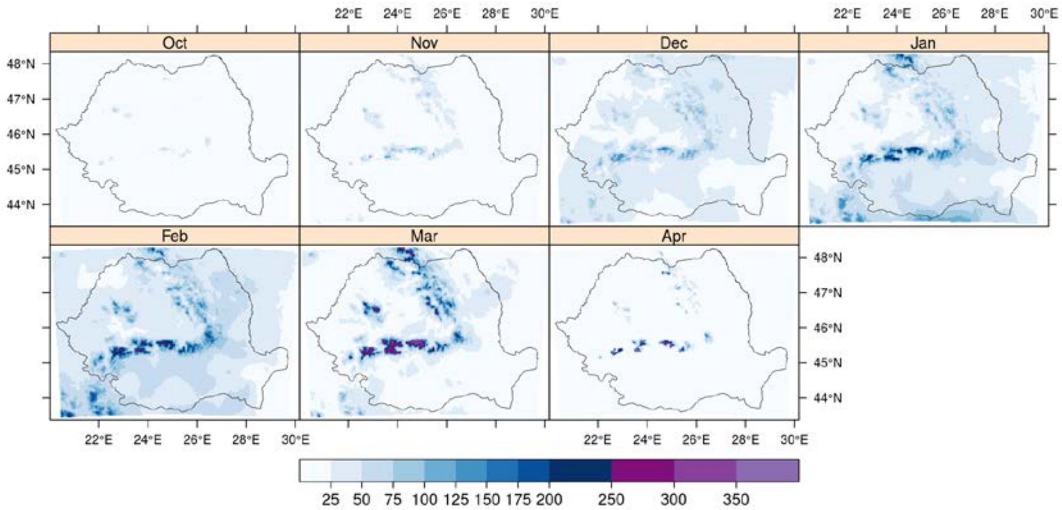


Figure 4.2.21: Maximum snowpack depth (cm) (2005-2015).

Maps obtained within this stage supply an overall picture of the analysed variables but their precision is directly influenced by the scale at which maps were plotted, by the spatial estimation errors specific to the geostatistical method, by the density of the measurement points (stations operated by the National Meteorological Administration). In certain areas, where peculiar climatic conditions are specific and no meteorological measurements are performed, it is recommended to achieve detailed studies on the spatio-temporal variability of the parameters of interest, so as to stress the local character of the spatial and temporal development of meteorological phenomena.

4.3. *WP3 Satellite remote sensing, data fusion and modelling of snow parameters*

4.3.1. Activity 3.1. Single sensor algorithm porting to Sentinel

In the work reported here, the algorithms for wet snow mapping have been adapted and validated. The optical algorithm is based on monitoring of the snow properties fractional snow cover (FSC), surface temperature of snow (STS) and snow grain size (SGS) in addition to cloud masking from the Sentinel-3 optical sensors Ocean Land Colour Instrument (OLCI) and the Sea Land Surface Temperature Radiometer (SLSTR), in combination, leading to the optical snow wetness (OWS) product. The SAR wet snow (SWS) product is based on data from the synthetic aperture radar (SAR) aboard Sentinel-1.

Satellite Data

The primary satellites for the wet snow mapping in the project are Sentinel-3 for optical data and Sentinel-1 for SAR data. Since Sentinel-3 only will deliver data operationally from summer 2016, Terra MODIS data have been used for the algorithm development and validation. Final adaptation and validation for Sentinel-3 will take place as soon as these data are available.

Validation Sites

Validation has taken place with data from winter/spring 2015 in Norway and Romania. Precursor algorithms and products for wet snow have previously been validated in the Jotunheimen validation site by NR, and later demonstrated and applied in the whole country of Norway. The SnowBall algorithms have also been validated in Jotunheimen, and subsequently in the Bucegi Mountain, Sinaia region in Romania.

Validation data will also be collected at the two sites in winter 2016 to make the validation more extensive. For the 2016 winter two new validation sites will be included in Romania, Targu Secuiesc (566 m a.s.l) and Joseni (747 m a.s.l.). These sites include comprehensive meteorological stations and will therefore allow extensive validation with validation data measured on an hourly basis.

Algorithms used for optical satellite data

Experiments with snow wetness algorithms have confirmed that a combination of snow surface temperature and snow grain size, analysed in a time series of observations, can be used to infer wet snow, including giving an early warning of snowmelt start. The temperature observations gave a good indication of where wet snow could be present, but are in themselves not accurate enough to provide sufficiently strong evidence of wet snow. However, if a rapid increase in the effective grain size was observed simultaneously with a snow surface temperature of approximately 0°C, then this was a strong indication of a wet snow surface.

a) The snow surface temperature algorithm

The surface temperature of snow (STS) algorithm is based on the single-view techniques, applied with several sensors of moderate resolution, like MODIS, AVHRR, AATSR and OLCI/SLSTR.

The split-window technique aims at eliminating the atmospheric effects by utilizing the difference between the brightness temperatures in two channels. The surface temperature *T* is estimated as a weighted sum (or difference) of the brightness temperatures observed. The split-window equation utilizes T_{11} measured at 11 µm (MODIS band 31, SLSTR band 7) and T_{12} measured at 12 µm (MODIS band 32, SLSTR band 8):

$$T = b_0 + b_1 T_{11} + b_2 T_{12}$$

The split-window technique is only sensitive to the effect of the atmospheric water vapour, and not to other atmospheric gases or aerosols. The atmospheric influence on the split-window equation depends on the composition of the atmosphere, and the method must therefore be calibrated for different atmospheres.

b) The snow grain size algorithm

For snow grain size (SGS) the normalized grain size index based on MODIS bands 2 and 7 have been used as this index has been shown to be less sensitive to snow impurities.

The ratio approach is a simple method. Signals from two channels are sufficient and information about the terrain is not needed (as it is with several other methods). Published studies do not give a calibrated ratio. One specific ratio value does not give an exact snow grain size value. It is also a problem how to define the grain size. However, the ratio can be used as an index of grain size; the ratio increases with increasing grain size up to the point of saturation.

The grain size index for snow for MODIS data lies typically between 0.7 and 1.0. Bare ground of different kinds gives lower index values. 0.7 is not an exact threshold value for snow. Somewhere around 0.7 the index shows that there is probably some snow on the ground. To be sure that the index represents snow grain size, a fractional snow cover retrieval algorithm have been used in addition to check that the ground is fully snow covered.

c) The snow surface wetness algorithm

The approach is to infer wet snow from a combination of measurements of STS and SGS in a time series of observations materialised when NR analysed in situ and MODIS data for various snow parameters in test sites in Jotunheimen.

The process driving the SGS increase is snowmelt metamorphism. It typically takes place in the spring when snowpack temperatures are close to 0°C. During daytime the air temperature increases to well above 0°C and the snow surface starts to melt. In the late afternoon, evening and nights the temperature falls and the snow surface refreezes. During the melting, smaller grains melt first, and liquid water appears in the upper layer of the snowpack. The bonds between the snow grains are typically destroyed, and the remaining snow grains are covered by a layer of liquid water. When the temperature cools again, the liquid water freezes and the snow grain size of the remaining grains increases due to the liquid water added. From this processes, a melting snowpack typically has an aggregation of rounded grains of 1-2 mm (corn snow). Note that snowmelt metamorphism also might take place due to rain. Liquid water from rain percolates downward in the snowpack and refreezes.

The calculated SGS index did not give the precise physical size of the snow grains, but gave an indication of the grain size. The value of the SGS index increases with increasing grain size. For a pixel totally covered with snow, the SGS index is a good indication of the grain size. Bare ground gives a low value for the SGS index. This means that for a pixel only partly covered with snow, a low SGS index was measured, even for large snow grain sizes. A decreasing value of SGS could mean newly fallen snow or increasing snow-free area.

For STS there was a similar problem. With a snow temperature of 0°C, the snow will start to melt and the temperature will stop increasing. For a pixel only partly covered with snow, the temperature of the snow-free area will create an influence, resulting in measured STS values above 0°C. This would usually mean that the snow is wet, but if the snow-free area is sufficiently large, one can measure an average positive temperature for the pixel even if the snow is cold and dry. Therefore, a good estimate of snow surface wetness (SSW) is valid only for pixels completely covered with snow. An accurate FSC map should be used to restrict the pixels classified. It was assumed that the SSW estimates were reasonably good even if small areas of bare ground were included.

Experiments with the snow wetness algorithm have confirmed that the approach of combining STS and SGS, analysed in a time series of observations, can be used to infer wet snow, including giving an early warning of snowmelt start. Air temperature measurements from meteorological stations confirm the maps produced in general. A potential problem sometimes observed is related to clouds. Non-detected clouds or cloud fractions within a pixel will usually decrease the temperature retrieved. One should be aware of this potential problem with partly cloudy SSW maps.

In the SnowBall project we have defined a revised set of categories based on a physical definition – the volumetric content of free (liquid) water in the snow surface. The snowball optical wet snow (OWS) product provides five wetness classes from dry snow to snow soaked with water, this according to the International classification of seasonal snow on the ground (Fierz, 2009). The algorithm is developed and validated for the use of Terra MODIS and Suomi NPP VIIRS data. The revision is depending on a proper ongoing calibration using accurate in-situ measurements of the liquid water content of the snow surface (2015 and 2016 snowmelt seasons).

Algorithms used for radar satellite data

SAR imaging systems have a potential to measure physical properties of ground features at high resolution. Microwaves allow for imaging through clouds, and because SAR is an active system, day and night imaging is possible. Due to the nature in which microwaves interact with the surface features the information in the backscattered radar signals can be indicative of moisture content, salinity and physical characteristics (shape, size, orientation).

Using SAR to map the snow cover has some limitations. A dry snow pack has minor influence on the SAR signals, and the reflected signals are dominated by the contribution of the snow/ground interface. However, when the snow is wet, the signals cannot penetrate the snow, and the backscattered signal is dominated by the contribution from the air/snow interface. The reflected signal is often lower from areas covered with wet-snow, compared to snow-free or dry snow covered conditions.

The algorithm for mapping wet snow is based on change detection using ratios of wet snow versus snow-free (or dry snow) surfaces.

The steps in wet snow mapping algorithm may be summarized as follows:

i. Conversion of the SAR data (digital numbers) to gamma naught.
ii. Multi-looking to reduce speckle noise. The number of looks we apply depends on the desired output resolution. We have applied 6×6 looks (corresponding to a desired pixel spacing of 50 × 50 m).
iii. Conversion to terrain-corrected gamma naught (flattening gamma) backscatter normalization by following the approach proposed by Small (2011).
iv. Computation of layover and shadow masks.
v. Geocoding using the range-Doppler algorithm.
vi. Construction of daily mosaic images.
vii. Computation of ratio images, i.e. daily mosaic image versus the reference image.
viii. Thresholding of ratio images to detect wet-snow. If the difference is more than 4dB, the pixel is classified as wet-snow.
ix. Masking of layover and shadow areas.

Currently, the algorithm supports Sentinel-1 GRD and Radarsat-2 SCN/SCW/SLC SAR images.

Validation Results

The "Validation plan for remote sensing of snow wetness" has been elaborated in order to complete the validation work in the project, by Nr and NMA (see Annex).

The algorithm validation results are presented for the test sites in Norway and Romania. The validation is here limited to comparison with air temperature for the 2015 winter season, but will be extended with comparison with in situ snow wetness measurements when these become available for the 2016 season.

The optical snow wetness (OWS) maps were generated from a time series of Terra MODIS data acquired in the period 1 January until 30 June 2015. Each acquisition was processed independently of cloud cover. A subset of OWS maps was then selected to show the temporal dynamics and development of the snow surface through the season. The chosen maps have moderate to no cloud cover.

For Norway, the acquisition times of the satellite images are listed in Table 4.3.1 together with retrieval results and air temperature measurements from the weather stations. The temperature measurements shown are from the morning, the measurement closest to the acquisition time of the satellite image and in the early afternoon. The retrieval results are from the 1 km^2 snow map grid cells including the weather stations. The air temperatures in the morning and afternoon are included as to give an indication of the temperature gradient before and around the time of the satellite acquisition.

Table 4.3.1: OSW map retrieval results (W) and corresponding air temperature measurements in the morning (08:00), closest to the acquisition time (Ac) and in the afternoon (14:00) for the five weather stations in Norway. The retrieval results are shown colour coded as well as with letters (D = Dry, M = Moist, W = Wet, V = Very wet and S = Soaked snow). When there is no OSW retrieval result, other classes are shown ('+' = Cloud, '-' = Partly snow-covered ground and '=' = Bare ground (no snow)).

Satellite ac.		Valdresflya				Bitihorn				Bygdin				Eidsbugarden				Vinsteren-Bjørnhølen			
Date	Time	W	08:00	Ac	14:00	W	08:00	Ac	14:00	W	08:00	Ac	14:00	W	08:00	Ac	14:00	W	08:00	Ac	14:00
11.03	10:55	D	-9.0	-5.9	-4.1	D	-6.9	-3.2	-1.2	D	-7.3	-3.8	-3.1	D	-9.2	-7.2	-4.9	D	-8.6	-5.6	-3.5
08.04	11:20	D	-3.3	-3.4	-1.3	D	-8.8	-7.8	-6.0	D	-1.8	0.2	0.2	D	-2.5	1.4	0.7	D	-1.5	-0.2	-0.5
17.04	11:10	D	-2,6	-0.9	4.8	D	-5.9	-5.1	-4.6	W	0.1	1.4	3.6	D	-2,7	-0.7	1.5	W	0.4	2.2	3.5
19.04	11:00	W	0.6	5.6	6.1	W	-0.2	2.4	4.1	-	2.9	7.0	8.4	D	-1.5	3.1	5.0	S	3.6	7.9	6,4
20.04	10:10	W	8.3	7.7	6.4	-	4.4	4.8	3.4	-	4.8	6.6	8.9	W	4.2	9.8	8.4	-	-1.0	5.7	5.0
27.04	10:15	D	0.1	1.9	6.5	D	-3.9	-1.2	1.5	-	-5.2	-1.1	3.9	D	-7.6	-3.9	1.9	-	-4.6	-4.2	0.0
14.05	10:55	W	1.6	1.2	2.8	-	-3.4	1.4	0.6	-	2.2	6.8	4.1	W	0.5	2.0	3.8	-	0.4	1.7	2.7
15.05	11:35	D	0.8	8.4	2.6	-	-2.5	5.8	4.9	-	-1.2	1.4	2.4	S	1.6	9.8	6.0	-	-0.9	2.4	3.4
05.06	11:55	W	0.9	5.0	4.5	S	-0.9	4.7	4.2	-	2.4	6.2	6.1	W	3.8	8.1	8.8	-	4.1	6.4	7.7
08.06	10:50	W	3.8	4.4	5.1	-	-2.7	0.3	1.5	-	3.8	5.9	6.2	-	5.5	6.3	6.5	=	4.9	6.7	7.9
13.06	11:05	W	10.4	5.1	5.5	+	-0.1	1.3	2.8	+	4.2	7.1	7.2	-	6.9	7.6	9.6	=	6.7	8.1	9.2
16:06	10:00	D	2.0	4.2	6.2	-	-0.8	1.8	2.7	-	3.4	5.3	7.3	-	6.1	6.9	8.9	=	5.4	8.4	11.1
16.06	11:35	W	2.0	6.6	6.2	-	-0.8	2.1	2.7	-	3.4	5.7	7.3	-	6.1	8.1	8.9	=	5.4	10.2	11.1
20.06	11:15	S	14.2	15.6	9.0	-	7.0	6.1	8.5	=	7.5	10.2	12.2	-	9.7	13.1	12.1	=	9.9	12.0	15.1
27.06	11:20	S	10.4	9.6	12.7	-	4.9	15.6	10.3	=	9.6	14.4	16.0	-	9.2	18.2	15.7	=	9.3	14.7	16.1

The seasonal development of the snow around the weather stations, as shown by the retrieval results, very much follows what is expected for a typical snow season and therefore the local climatology. Valdresflya tends to accumulate very much snow and therefore shows a long snow season. Bitihorn is a mountain peak, so the snow layer is typically shallow and the site is influenced quickly by changing weather. Bygdin is lower than Valdresflya, and usually accumulates much less snow. Eidsbugarden accumulates more snow, and is often influenced by the west-coast weather. Contrary, Vinsteren-Bjørnhølen is dominated by the weather east of the watershed with higher temperatures and less precipitation, and therefore more quickly develops into summer conditions.

Examples of OWS maps for Norway are presented in Figures 4.3.1 and 4.3.2.

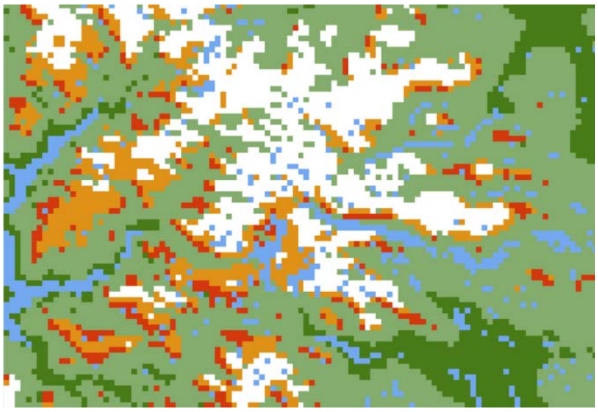


Figure 4.3.1: Optical snow wetness based on MODIS from 15 May 2015 acquired at 11:35 UTC

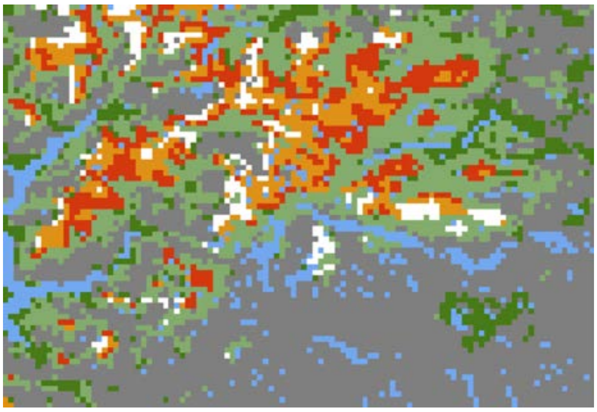


Figure 4.3.2: Optical snow wetness based on MODIS from 13 June 2015 acquired at 11:05 UTC

For Romania, the acquisition times of the satellite images are listed in Table 4.3.2 together with retrieval results and air temperature measurements from the weather stations.

Table 4.3.2: OSW map retrieval results (W) and corresponding air temperature measurements in the morning (08:00), closest to the acquisition time (Ac) and in the afternoon (14:00) for the four weather stations in Romania. All times are given in UTC. The retrieval results are shown colour coded as well as with letters (D = Dry, M = Moist, W = Wet, V = Very wet and S = Soaked snow). When there is no OSW retrieval result, other classes are shown ('+' = Cloud, '-' = Partly snow-covered ground and '=' = Bare ground (no snow)).

Satellite ac.		Vf. Omu				Balea				Sinaia 1500				Fundata			
Date	Time	W	8:00	Ac	14:00	W	8:00	Ac	14:00	W	8:00	Ac	14:00	W	8:00	Ac	14:00
17.01	9:00	-	-0.9	0.6	-1.1	-	2.6	2.5	2.7	=	8.2	10.1	8.5	=	4.8	6.2	7.8
4.02	8:50	+	-13.9	-14.1	-12.7	+	-9.6	-9.7	-9.3	+	-5.6	-3.8	-5.1	-	-5.3	-3.5	-3.0
10.02	9:50	+	-20.8	-19.7	-19.7	+	-15.9	-15.0	-15.3	-	-10.7	-9.8	-9.9	-	-11.5	-9.2	-9.0
11.02	8:55	D	-20.8	-20.6	-20.4	D	-15.6	-14.4	-16.1	-	-12.2	-11.1	-10.2	-	-12.3	-11.4	-9.0
14.02	9:25	D	-8.7	-7.0	-7.0	D	-6.5	-4.4	-4.2	-	2.8	2.8	-0.9	-	2.6	3.7	4.0
21.02	9:30	D	-2.2	-3.1	-3.3	D	-0.6	1.1	-1.2	D	-0.9	2.1	1.7	W	-0.8	0.5	3.2
9.03	9:30	D	-1.7	-0.8	-2.3	-	0.1	1.1	-0.9	D	4.9	5.4	5.2	-	3.5	4.1	6.3
11.03	9:20	+	-4.6	-3.5	-5.2	D	-4.5	-3.0	-4.0	D	-1.6	1.7	4.2	=	-2.1	0.6	3.8
10.04	9:30	D	-9.0	-7.6	-4.9	D	1.3	0.6	6.3	-	3.4	4.9	8.2	S	3.7	5.3	7.7
23.04	9:00	D	-8.9	-7.7	-2.2	D	-0.1	-0.1	2.2	-	4.4	5.9	8.7	=	2.4	5.8	10.2
24.04	9:45	-	-2.0	-0.1	0.8	-	3.9	6.5	7.2	-	10.2	13.7	13.2	=	10.5	12.5	14.0
25.04	8:50	-	0.7	1.3	2.4	-	5.3	6.7	6.7	=	13.0	13.5	11.2	=	13.2	14.0	13.5
20.05	8:40	=	8.1	8.9	6.8	-	11.0	10.6	9.4	=	18.5	19.0	15.5	=	17.2	18.8	16.5
6.06	9:25	=	5.9	8.3	8.5	-	10.3	10.8	12.5	=	15.0	17.8	17.0	=	14.5	15.8	18.5
15.06	9:20	=	7.2	9.6	10.8	+	12.6	14.1	10.9	+	12.6	19.5	18.4	=	16.0	18.3	15.0

For the OWS analysis only Fundata, Sinaia 1500, Bâlea Lac and Vf. Omu weather stations have been taken into consideration because the other stations are within forested and urban areas. The altitude gradient in the melting season is well covered by the four stations. On the other hand, because Fundata and Sinaia 1500 are situated very close to the forest limit, the neighbour pixels in the east of Fundata and west for Sinaia 1500 had to be used. It means that there might be differences due to the slight variation in altitude for air temperatures close to 0°C.

The retrieval results of the seasonal snow around the weather stations follow the altitude profile and the local climatology: Vf. Omu station is situated on a mountain peak (~2500 m a.s.l.), so the snow depth is usually moderate because the snow is often shattered by wind. On the other hand, the snow season lasts longer due to a longer period of air temperature below the freezing point. Opposite at Bâlea Lac, situated in a glacier caldera, the snow layer tends to accumulate very much and therefore shows the longest snow season in the test site. Sinaia 1500, Fundata and Predeal weather stations are situated above 1000 m a.s.l., in the sunny slopes, so the snow conditions are close to Vf. Omu, but the snow season is shorter. Campina weather station is situated around 500 m a.s.l., so the snow depth had a maximum of 25 cm and many interruptions. The snow season is the shortest one in the test site.

Examples of OWS maps for Romania are presented in Figures 4.3.3 and 4.3.4.

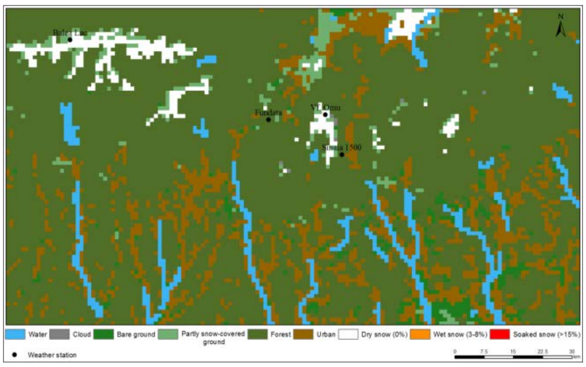


Figure 4.3.3: Optical snow wetness based on MODIS from 14 February 2015 acquired at 09:25 UTC

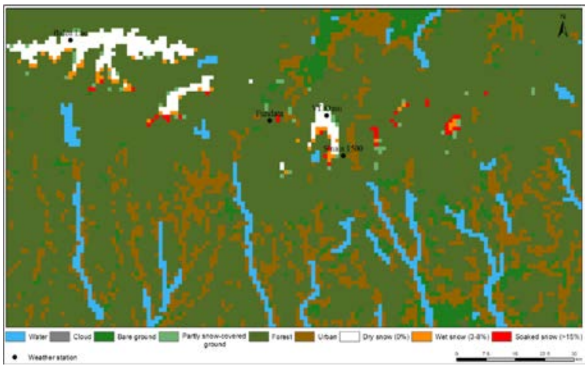


Figure 4.3.4: Optical snow wetness based on MODIS from 10 April 2015 aquired at 09:30 UTC

The SAR wet snow (SWS) maps, for the test sites in Norway and Romania, were generated from a time series of Sentinel-1 data. A subset of SWS maps was selected to show the temporal dynamics and development of the snow surface through the season. The white areas correspond to wet snow, green to dry snow or bare ground, blue areas to water bodies, purple to SAR layover or SAR shadow areas, and black to areas outside the area of interest.

For Norway, the dates April 6, 18, 30, May 12, 24, June 17 and 29, 2015 have been analysed and presented in details in Deliverable D3.1.

For Romania, the dates January 30, February 23, March 19, 31, April 12, 24, May 6 and 18, 2015 have been analysed and presented in details in Deliverable D3.1.

Examples of SWS maps for Norway (Figure 4.3.5) and Romania (Figure 4.3.6) are presented below.

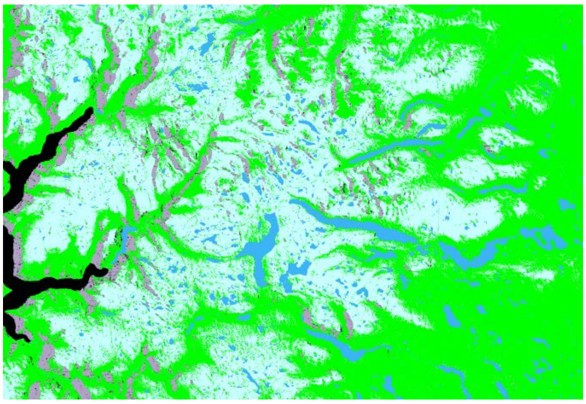


Figure 4.3.5: SAR wet snow map for the test area on June 17, 2015 acquired at 17:02 UTC for Norway

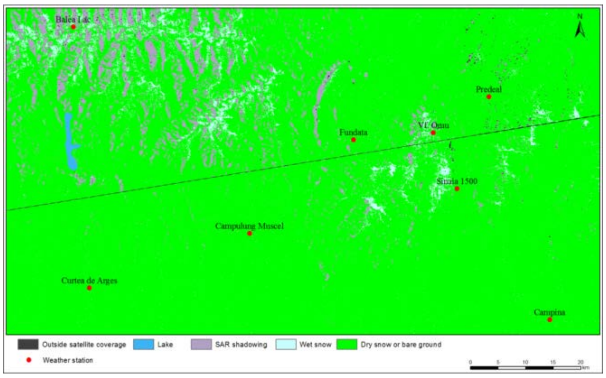


Figure 4.3.6: SAR wet snow map for the validation area on March 31, 2015 for Romania

The validation was limited to comparison with air temperature as this was what was available for the 2015 season, but will be extended with comparison with in situ snow liquid water measurements when these become available for the 2016 season.

Much more details about the OWS and SWS algorithm validation results are presented in Deliverable D3.1: “*Validated optical and SAR snow wetness retrieval algorithms*”.

4.3.2. Activity 3.2. *MWS algorithm and product*

The first prototype version of the multi-sensor/multi-temporal product for wet snow mapping is demonstrate and validate in this report. The optical component of the algorithm is based on monitoring of the snow properties fractional snow cover (FSC), surface temperature of snow (STS) and snow grain size (SGS) in addition to cloud masking leading to the optical snow wetness (OWS) product. The SAR wet snow (SWS) component algorithm is based on data from the synthetic aperture radar (SAR) aboard Sentinel-1.

The multi-sensor/multi-temporal wet snow (MWS) algorithm fuses optical and SAR data to map the wet snow area. Multi-temporal observations of wet snow with optical and SAR are fused in a novel model simulating states of surface properties to generate reliable wet snow maps. The algorithm is based on NR’s experience of combining data from multiple sensors using Hidden Markov Model (HMM) approaches. The snow map includes the thematic classes dry snow, moist snow, wet snow, very wet snow and soaked snow, in addition to partial snow cover, bare ground and clouds.

Satellite Data

The primary satellites for the wet snow mapping in the project are Sentinel-3 for optical data and Sentinel-1 for SAR data. Since Sentinel-3 only will deliver data operationally from summer 2016, Terra MODIS data have been used for the algorithm development and validation. Final adaptation and validation for Sentinel-3 will take place as soon as these data are available.

Validation Sites

Validation has taken place with data from winter/spring 2015 in Norway and Romania. The SnowBall algorithms have been validated in two levels:

- The test sites: Jotunheimen in Norway, and in the Bucegi Mountain, Sinaia region in Romania;
- The country level (nine weather stations in Norway and 14 weather stations in Romania).

Validation data will also be collected at the two sites in winter 2016 to make the validation more extensive.

Multi-sensor/multi-temporal Wet Snow algorithm

The MWS algorithm is novel to this project and fuses optical and SAR data to map the wet-snow area. The idea is to combine multi-temporal observations of STS, SGS and SWS in a fusion model to generate significantly improved coverage in space and time than possible with the single-sensor approaches. The algorithm we have developed fuses the optical and SAR observations using a Hidden Markov Model (HMM) approach.

The HMM approach based on modelling and assimilation (data fusion at the "electromagnetic level" instead of thematic level) was proposed by Solberg et al. (2008) for retrieval of Fractional snow Cover (FSC). The HMM solution represents not only a multi-sensor model but also a multi-temporal model. The sequence of states over time is required to follow certain optimisation criteria. Also, the HMM model is applied per pixel, so each pixel's history through the snow season is modelled.

According to the thematic snow wetness classes applied for the OWS algorithm, five corresponding snow wetness states have been defined in the hidden Markov model (Figure 4.3.7). Additionally, there is a state for *partly snow cover*, depletion (< 100% FSC), and *temporary snow* (thin snow layer making full snow cover for a short period, also named ephemeral snow cover). Allowed transitions between states are shown by arrows.

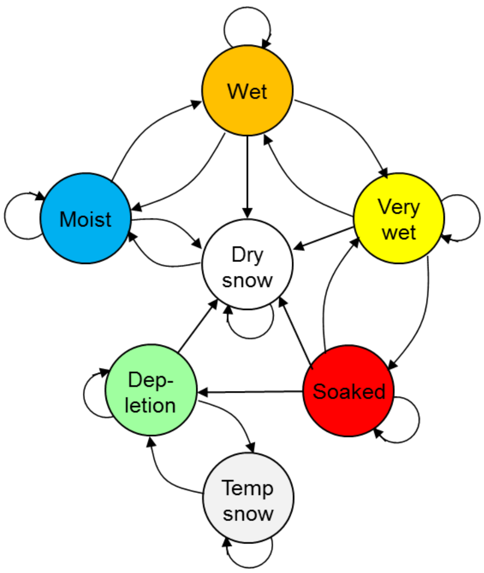


Figure 4.3.7: Hidden Markov model for snow wetness fusing optical and SAR observations.

As the model shows, the wet snow classes are "chained" such that the current state might move up to wetter classes or down to drier classes through its neighbours (in terms of liquid water content). The current state cannot change from, e.g. *dry to very wet* in one step, it has to move through *moist* and *wet*. However, a transition from each wet snow class to dry snow is allowed. This is motivated from the effect a cold, clear night sky might have, also in the melting season.

The restrictions in transitions might seem somewhat artificial. However, if all transitions were allowed, the model would easily become too complex, too challenging to train and too unstable. The chaining is also motivated from in situ observations of the behaviour of a typical seasonal snowpack through the melting season. There might be short-lived situations of all snow wetness classes occurring more or less anytime. However, significant and lasting wetness of a thicker upper snow layer is driven by the seasonal change of the mean air temperature. Higher wetness classes lasting more than as short fluctuations are first occurring when the mean air temperature is above 0°C and lasting for several days. This model inertia is expected too smooth out short-lived fluctuations and better represent the effective snow wetness conditions.

The algorithm takes as input the optical wet snow (OWS) map, containing wet snow class probabilities, and a SAR wet snow (SWS) map containing probabilities of wet snow.

Validation Results

At the test sites level, the situations for March 23, April 9, 11 and 21, May 9 and 17 and June 6, 2015 (for Norway) and February 19 and 23, March 2, 10, 25 and 28, and April 23 and 25, 2015 (for Romania) are detailed in Deliverable D3.2. The wetness state, at the location of the weather stations, is compared with the mean 24 hour air temperature for the same day. But, the 24h mean air temperature is not always an accurate comparison for snow wetness and a potential conflict appeared: the mean air temperature is below 0 and the map indicates wet snow, or vice versa. In these situations deeply investigations have been done by comparing the wetness state with hourly air temperature data.

Examples of MWS maps for Norway (Figure 4.3.8) and Romania (Figure 4.3.9) are presented below.

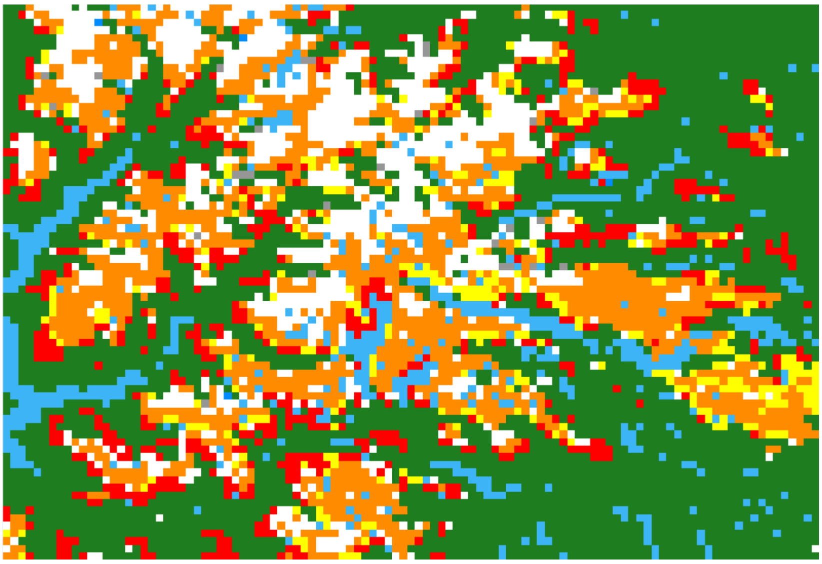


Figure 4.0 Multi-sensor snow wetness map from Jutunheimen, Norway, 21 April 2015

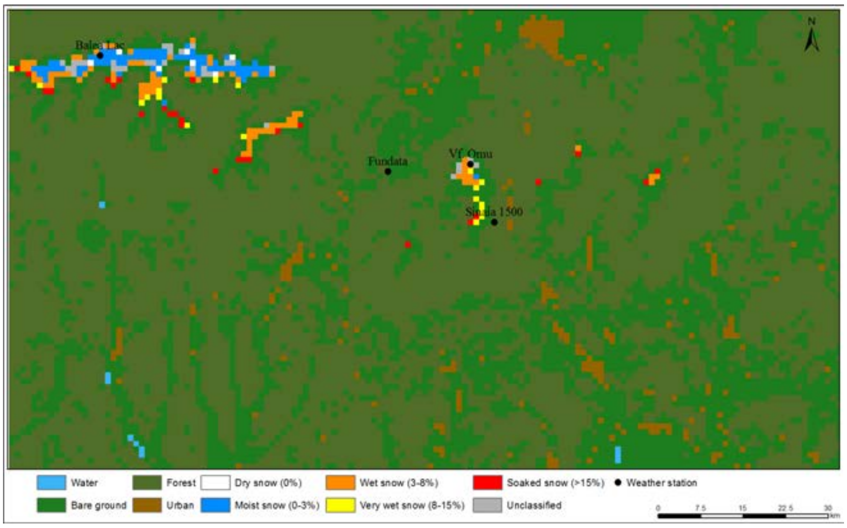


Figure 4.0 Multi-sensor snow wetness product for the test site in Romania, 23.04.2015

Similar analysis has been done at **the country level** for February 27, March 11, April 6, 8, 9, 11, 17, 18, 19, 21, May 11, 15, 23 and June 20, 2015 (for Norway) and for January 23, February 1, 6, 10, 16, 18, 20, 22, March 9, 16, 25, April 24, 26, 2015 (for Romania). Detailes can be read in Deliverable D3.3.

Examples of MWS maps for Norway and Romania are presented in Figure 4.3.10 and Figure 4.3.11 respectively.

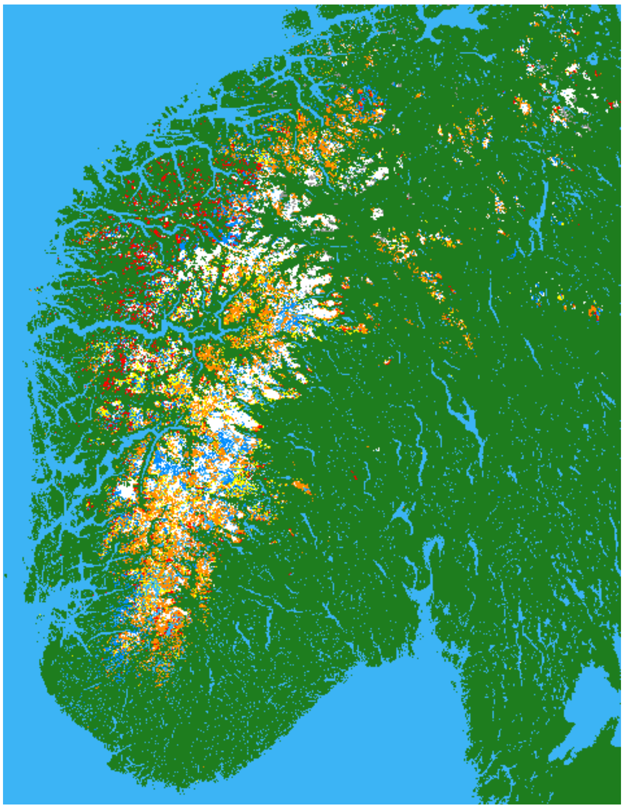


Figure 4.3.10: Multi-sensor snow wetness product for southern Norway, 11 May 2015

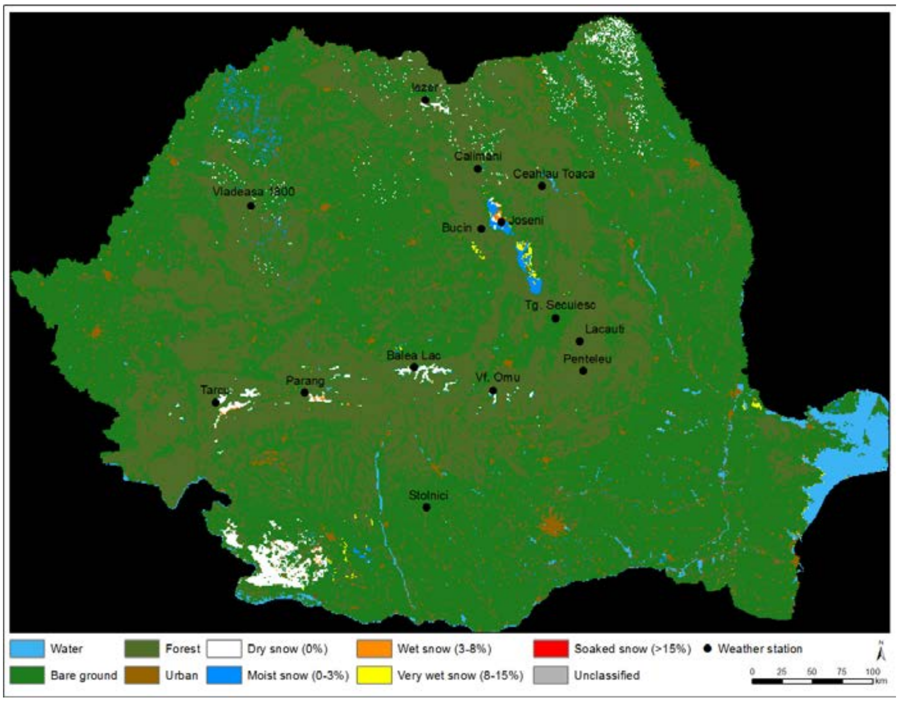


Figure 4.3.11: Multi-sensor snow wetness product for Romania 20.02.2015

4.3.3. Activity 3.3. *New multilayer snow model module in NOAH*

During this phase, was designed the methodology for estimating the snow water equivalent, by data fusion approach, using the distributed model NOAH simulations, ground observations and satellite products (was elaborated the deliverable D3.5.).

Within the methodology, the diferrent type of data and information are analyzed and compared, using a series of automatic cross-validation algorithms, and then the snow water equivalent is estimated in grid format, at spatial resolution of 1 km, by multiple succesive steps of interpolations and adjustments, depending on the degree of uncertainty associated with different type of data.

For the modeling of the snow layer evolution, a multi-layer model with distributed parameters will be used, approach that will significantly improve the distributed simulations of the model regarding SWE evolution and the multi-layer approach will also allow the investigation of benefits of using satellite products for the parameters of snow layer in the methodology for data fusion and testing the implementation of very complex algorithms for adjusting the simulations carried out by model.
The following main input data categories will be used within the data fusion methodology:

- Simulation of SWE evolution made with the new snow multilayer model, grid format (1 km spatial resolution).
- Observations from stations: snow layer depth, water equivalent of snow layer, snow density, daily precipitation amounts, air temperature (daily average and extremes)
- Satellite Products: snow cover, snow layer moisture.
- Detailed observation from pilot areas will be used for testing and validation of data fusion algorithms.

Main processing steps within the data fusion methodology:

I. Automatic quality check of all the input data:
   - Point observations and grid cell values from model simulation or satellite products.
   - As output of this step, all the available data will be categorized on 3 classes, based on the results from automatic quality checks: very good, good, acceptable, and all the values not passing the tests will be set to missing.
   - The quality check algorithms will be applied not only on the the last values but also for the relative variation compared with the values from the previous day.
     - Validate and adjust the interpolation results using the cells with at least one data source in the category “good”, and the other data source values in the same category, “acceptable” category or missing.
     - Validate and adjust the interpolation results using the cells with at least one data source in the category “acceptable”, and the other data source values in the same category or missing.

II. General processing phase, having as objective the estimation of the most probable values, by iterative analyses of the groups of cells associated to previous established different quality categories:
   - Analyse the cells with at least one data source in the category “very good”;
   - Interpolate the values estimated at previous step, for the entire grid;
   - Validate and adjust the interpolation results using the cells with at least one data source in the category “good data”;
   - Validate and adjust the interpolation results using the cells with at least one data source in the category “acceptable data”.

4.4. WP4 *Climate change impact on snow-related hazards*

4.4.1. Activity 4.1. *Snow-related climate variability and change and associated impact*

The team from the National Meteorological Administration completed the analyses of changes in snow depth, snow amount and melted snow amount during October-April, in Romania, under the RCP 4.5 and RCP 8.5 scenarios for the timeframes 2021-2050 and 2070-2099. The reference interval considered is 1971-2000. In the analyses, the team from the National Meteorological Administration have used the results of numerical experiments with five regional climate models from the EURO-CORDEX program. Under more intense radiative forcing (RCP 8.5 scenario) the decrease of the snow depth, the amount of snow, and the increase of the amount of melted snow in mountainous areas are higher in the analysed intervals. These changes will become stronger at the end of the XXI century, especially under the RCP 8.5 scenario (e.g. Figure 4.4.1).

Also, the team from the National Meteorological Administration built the input data for hydrological model, starting from numerical experiments under climate change conditions (RCP 2.6 and RCP 8.5) with the regional model RCA4 driven by the global model ICHEC-EC-EARTH. The simulated data from the regional model (at a resolution of 12.5 km) have been disaggregated at a spatial resolution of 1 km, using geostatistical methods. This has been done for the basins of interest to better fit the input data to the needed spatial scales and to add corrections due to the differences between the model orography and the real one. The downscaled data have been also analysed from the perspective of climate change in the regions of interest.

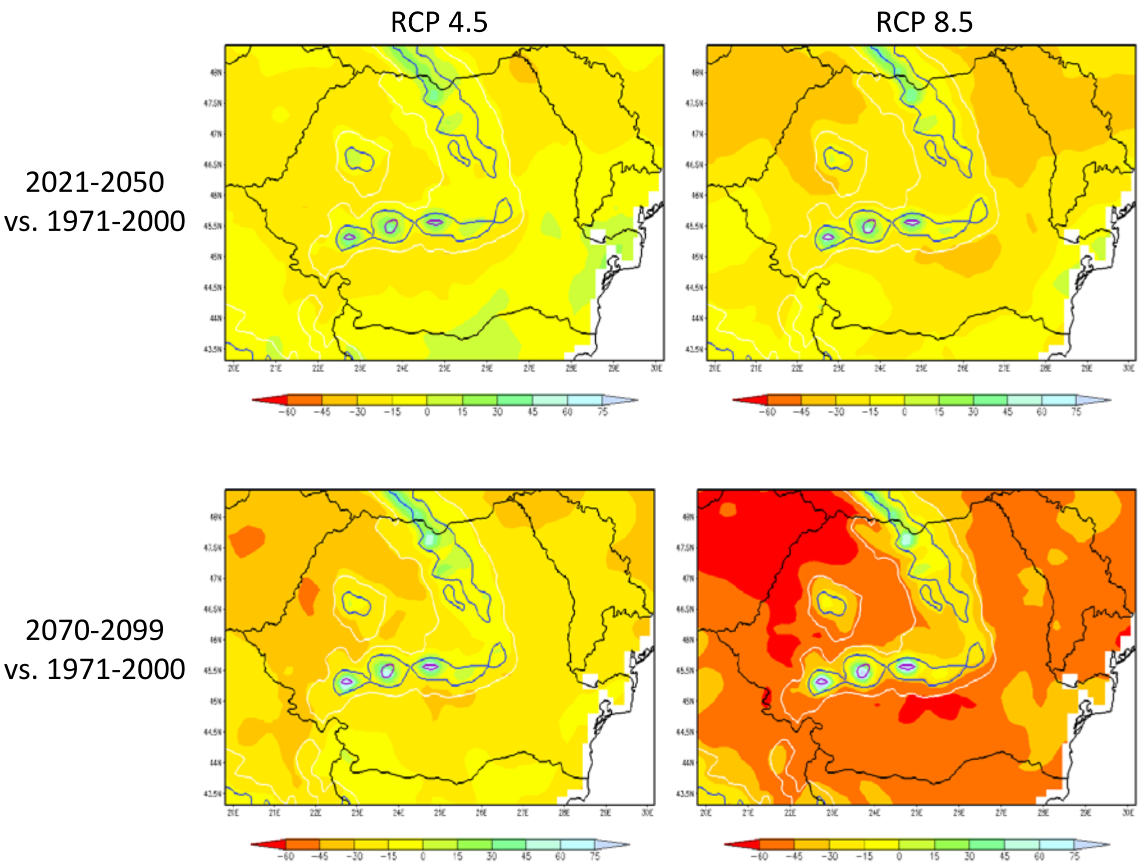


Figure 4.4.1: Changes in the ensemble of mean snow melt amount (in %) in the interval from October to April under the RCP 4.5 and RCP 8.5 scenarios for the periods 2021-2050 and 2070-2099 as compared to the reference period 1971-2000. Contour lines illustre the model topography (white lines – up to 500 m, blue lines – up to 1000 m, magenta lines – up to 1500 m). Five EURO-CORDEX experiments with five regional models have been used here.

4.4.2. **Activity 4.2.** *Variability and change in flash floods with snow melt contribution*

Within this activity was done the calibration of the hydrological model with simulation of the snowpack accumulation and melting for the upper part of the Arges and Ialomita River Basins (more details are presented in the deliverable D4.2.).

The conceptual hydrological model Consul was used for simulating the runoff and flow formation in the upper part of the Argeş and Ialomiţa River Basins, model developed within the N.I.H.W.M..

Consul hydrological model is a conceptual model that allows the simulation of the runoff in a complex hydrographic basin, and the main rainfall-runoff processes considered by this hydrological model are: accumulation and melting of the snow cover, precipitation interception, water storing in depressions, evapotranspiration, infiltration, percolation, surface runoff, hypodermic runoff and basic runoff.

In the hydrological model river basin is divided into sub-basins according to the integrated flow network. For each river sub-basin:

- The degree-day method is used for estimating the water from the snow cover (Chow, 1971);
- The average water inflow is computed by weighting the instrumental values of rainfall and water melting from the snow cover recorded in the network of rain-gauge and meteorological stations (Şerban et al., 1989);
- The net rainfall (runoff) is estimated extracting from the average water inflow the values of infiltration and evapotranspiration using a conceptual reservoir-type model (Şerban et al., 1989);
- Use of the convolution integral having the instantaneous unit hydrograph as the transfer function, for the hydrological system integration of the net rainfall on the slopes and on the first order hydrographic network providing the hydrograph for each sub-basin (Serban, 1984).

The study area on which will be applied the hydrological model is the upper area of the rivers Argeş and Ialomiţa having in downstream closing sections hydrometric stations.

So, the study area consists of five river basins corresponding to the rivers: Argeş up to the hydrometric station Căteasca, Dâmboviţa (left tributary of the Argeş river) up to the hydrometric station Lunguleţu, Ialomiţa up to the hydrometric station Băleni, Prahova (left tributary of the Ialomiţa river) up to the hydrometric station Prahova and Teleajen (left tributary of the Prahova river) up to the hydrometric station Moara Domnească.

Figure 4.4.2. present as example the computation and configuration sketch of the flow routing in the river basin Dâmboviţa up to the section of the hydrometric station Lunguleţu.

Calibration of Consul hydrological model parameters was performed by simulating the most important events rainfall-runoff selected particularly during the transition from winter to spring, from the calibration period considered, 2001 to 2005.

In the Figure 4.4.3. is presented, as example, the comparison of observed and simulated discharge hydrographs with model Consul, for the hydrometric station Bughea de Jos on Bughea River, situated in the upper part of the Argeş River Basin.

The results of flow simulation with the Consul model in the analysed river basins showed that the model gives the best results, in particular in the case of floods generated by precipitation evenly distributed in space.

Deviations between discharge hydrographs simulated by Consul and observed are due to both model errors and insufficient meteorological and hydrological data. The main error is caused by the uncertainty related to the determination of average precipitation on the river basin and its variable spatial and temporal distribution.

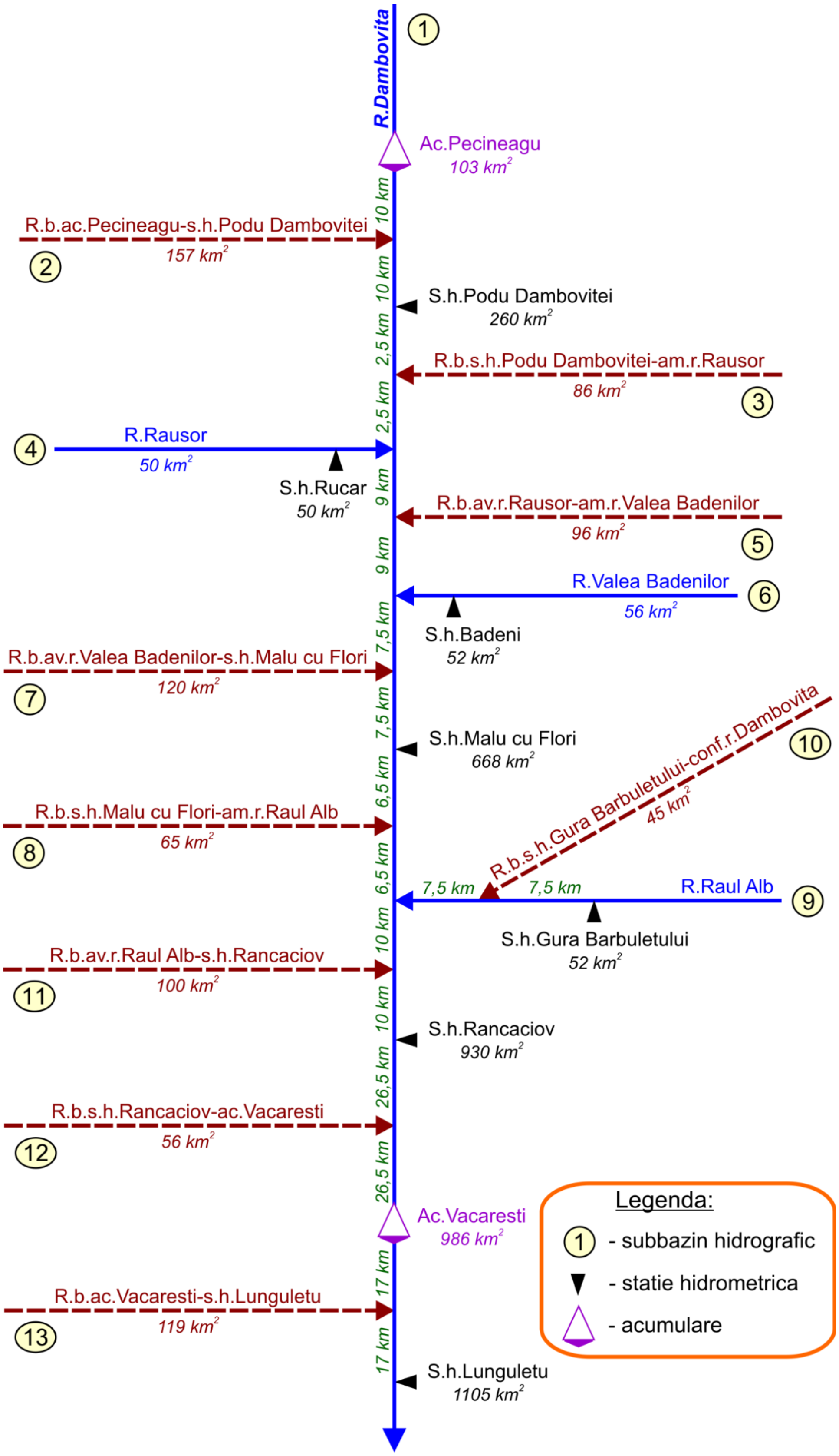


Figure 4.4.2. The computation sketch of the flow routing in the river basin Dâmboviţa up to the section of the hydrometric station Lunguleţu

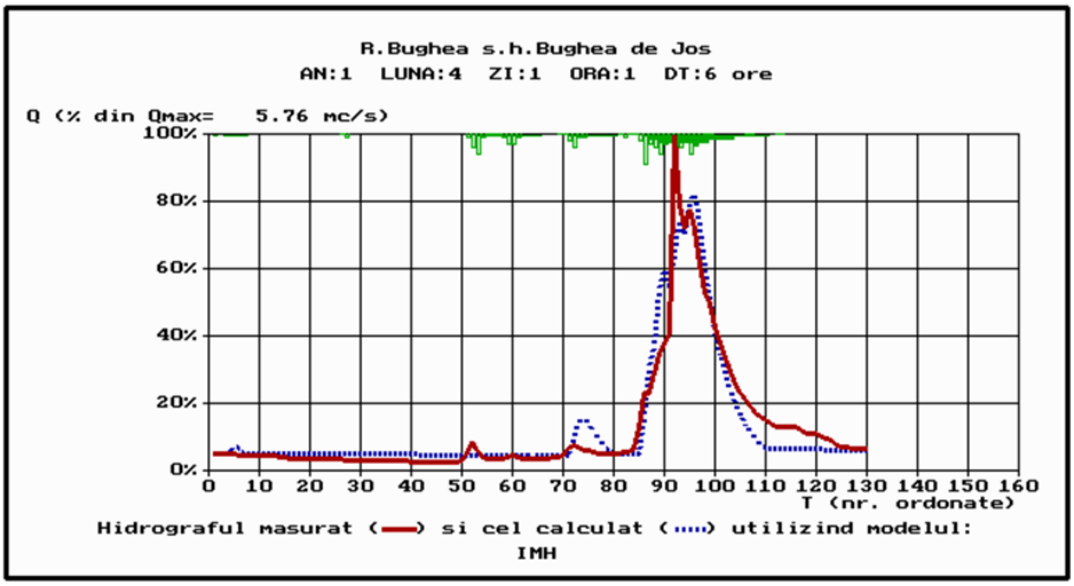


Figure 4.4.3: Recorded and simulated discharges hydrographs for the hydrometrical station Bughea de Jos, Bughea River, for April 2001

4.4.3. Activity 4.3. Variability and change in avalanche statistics

The previous analyses, to develop the empirical model that links the atmospheric circulation characteristics to avalanches indices, have been continued. Thus, a list with the dates of avalanches was drawn up, starting from 1928 to the present. Related information are also available (e.g., location, number of persons affected, toll death and the source of information) for these events which have taken place in the Ceahlău, Făgăraş, Bucegi, Lotru, Rodna, Retezat, Piatra Craiului, Căpăţânii, Gutîi, Postăvaru, Ţarcu, Vâlcan, and Baiului mountains. The most frequent avalanches are recorded in the Făgăraş and Bucegi mountains.

4.5. WP5 *Aquifer replenishment modelling from snowmelt infiltration*

4.5.1. Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone

Advantages or disadvantages of using models for calculating snowmelt infiltrations in unsaturated zone based on the energy balance equation or on the temperature index method have been highlighted within the project.

The temperature index method is easy to apply and provides reasonable results, but is sensitive to weather conditions, especially to wind and solar radiation. To improve these models and increase the accuracy of the results it is recommended to add wind and moisture data.

Models based on the equation for energy balance are prone to estimation errors of data such as wind, solar radiation, albedo factor. Better parameterization of the albedo factor, of the wind function and an improvement of weather conditions estimation may increase the result's accuracy.

During the project stage, measurements were performed to determine snowmelt infiltration and to build the mathematical model for flow simulation in unsaturated area.

Measurements were made during the period 14 -18 April 2015 in Padina, Bucegi. The device used to determine the volumetric water content, temperature and the electric conductivity was the TDR device. Volumetric water content measurements were made on a soil profile of 45 cm. 5 sensors were used at depths of: 0 cm (snow – soil), 5 cm, 10 cm, 15 cm, 30 cm and 44 cm. The recorded data (78 h) can be found in the chart below.

A simulation model for snowmelt infiltration has been prepared for the Padina area. The software Hydrus 1D can be used to estimate the snowmelt infiltration. The software is based on the finite element method. However, the Hydrus 1D does not use the thickness of the snow cover but the snow water equivalent (SWE). It is necessary to have additional data such as air temperature to enable the assessment of snow accumulation layer and to consider the atmospheric condition as boundary conditions. Hydrus 1D is using a flow model based on Richards equation for water rate in saturated – unsaturated area and the heat transfer equation based on convection – dispersion equation.

*4.5.2. **Activity 5.2.** Aquifer modelling*

The project includes the description of the geological, hydrological and climatic conditions of the study areas. The Snowball project has three representative study areas. The recharge process of three major hydrostructures was taken into account when selecting the sites: for fissurated mountain aquifers the north eastern part of Bucegi Mts was chosen, for regional aquifers in alluvial area, the alluvial cone Prahova – Teleajen and for small aquifers, the study area chosen was Colentina area (Laboratory Complex Colentina, Bucharest) located in the Romanian Plain.

4.5.2.1. Bolboci – Omu Peak study area (superior basin of Ialomita Valley).

From a geomorphological point of view the study area belongs to the Bucegi Mountains and partly to the Leaota area. From a hydrogeological point of view, it belongs to the Bucegi basin. Lithologically, the deposits are detritic (conglomerates, sandstones) in which a fissurated aquifer is hosted and limestone deposits in which a karst fissurated aquifer is located. Accumulation and groundwater flow is favoured by a developed system of fractures. Bucegi area is characterized by a favourable rainfall regime, both liquid and solid.

4.5.2.2. Prahova – Teleajen alluvial cone study area.

The relief major and detail features of the alluvial cone Prahova – Teleajen can not be understood without a brief overview of the key moments in the paleogeographical evolution. Considering the hydrogeological aspect, complex structure is developing in the area, formed by two complex and relative hydrodynamic independent aquifers:

- The inferior complex, confined, within the Candesti formation;
- The superior complex, unconfined, within the alluvial deposits.

By analysing and interpreting the data from the observation wells of the national monitoring network results that the aquifer is developing between Prahova and Teleajen rivers and it has a complex lithology.

4.5.2.3. Colentina area, Bucharest.

This area was chosen because it meets three essential characteristics, namely: it is a sedimentary aquifer, it is in an urban area and it was well characterized from a hydrogeological point of view. In Colentina, there is an experimental monitoring hydrogeological site consisting of five hydrogeological wells drilled up to 25 m, and a well drilled down to 60 m depth for geophysical logging. In the area, there is the Colentina and Mosiştea aquifer system. The Quaternary sedimentary deposits found are the Colentina Formation and Mosiştea Formation.

The second part of the project deals with the construction of a conceptual model for recharging the aquifers from the melting snow. In order to create the recharging conceptual model based on snowmelt, a diagram of processes and factors involved in determining infiltrations from the soil layer was created. The most important processes that are part of the conceptual model are:

- Atmospheric conditions are defined by meteorological data, such as temperature, wind speed, relative humidity, atmospheric pressure, precipitation, cloud coverage and solar radiation.
- Interception of fallen snow and rain within forest areas, and rain and sublimation and evaporation losses at the interface with the forest;
- Snow status is influenced by the following parameters: temperature, layer thickness and snow density, the Albedo factor, the water equivalent in snow and the water content in snow;

- When frozen ground has fissures, the amount of water from melting snow seeps directly into the unsaturated zone, and when lenses of ice are present, the water drains towards the surface water body;
- Water evaporation;
- Groundwater recharge occurs through percolation into soil layers or directly through macropores into deposits. Part of soil water evaporates, part is consumed by plants through evapotranspiration and part recharges the aquifer.

4.6. WP6 Assimilation of snowpack parameters in the National Flood Forecasting and Warning System

4.6.1. Activity 6.1. Update the LC/LU map for the study area using high spatial resolution satellite images

To continue the activities related to updating the land cover / land use map for the study area, was elaborated a methodology to obtain conclusive results for a good validation from various sources. The methodology assumes the merging of the satellite data in order to make a first classification followed by the classifications themselves, using three sources of thematic information: the 2012 version of the Corine Land Cover database, identification system LPIS (Land Parcel Identification System) and supervised and unsupervised classification of satellite images acquired.

The methodology used to obtain updated map LC / LU
Preparing the satellite images. Selection of Landsat 8 OLI scenes from the years 2013-2014 without significant cloudy coverage on the Arges-Ialomita river basins has led to yield good quality images, with high spatial resolution (15 m) by merging 30 m spectral bands and thereafter by merging multispectral image with band 8 from panchromatic (Figure 4.6.1).

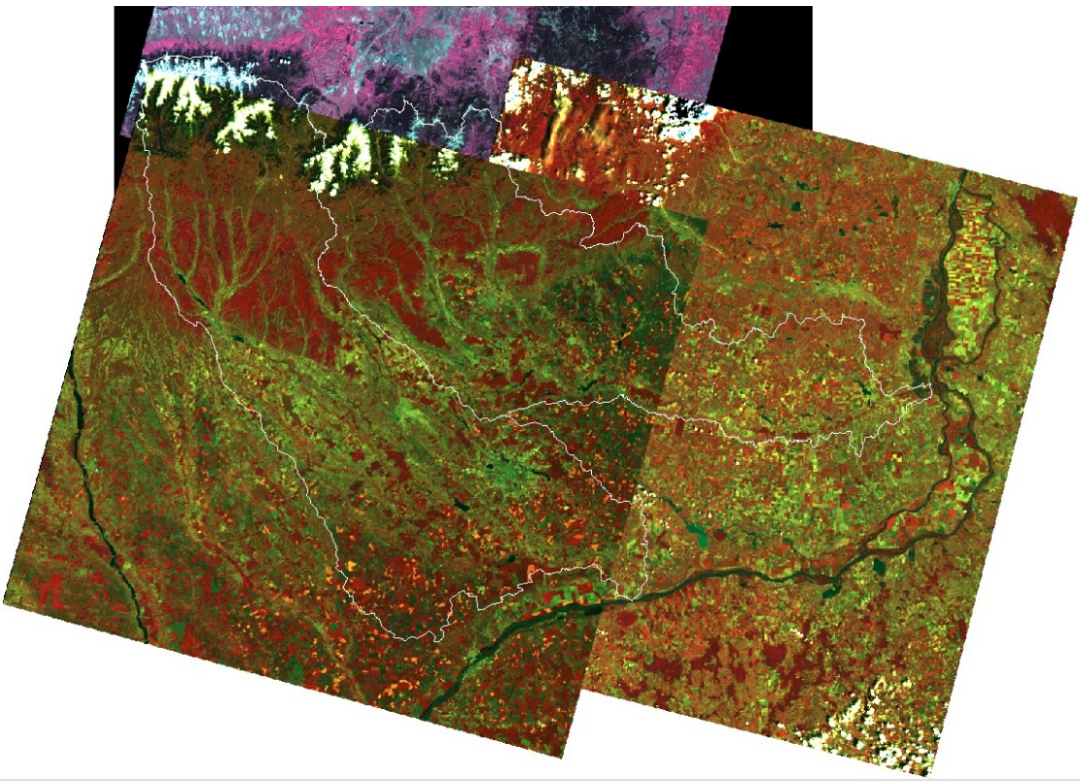


Figura 4.6.1. Mosaicing the merged Landsat 8 OLI images, with overlapping the study area: rivers basins Ages and Ialomita (5-4-2 bands combination)

LC/LU representations for the study area. Differentiation and updating the land use / land cover categories can be achieved by several methods: by accessing the latest version of the Corine Land Cover data base (version 2012), the system for identifying parcels (LPIS - Land Parcel Identification

System), or by processing the Landsat 8 OLI satellite images with supervised and unsupervised classification functions.

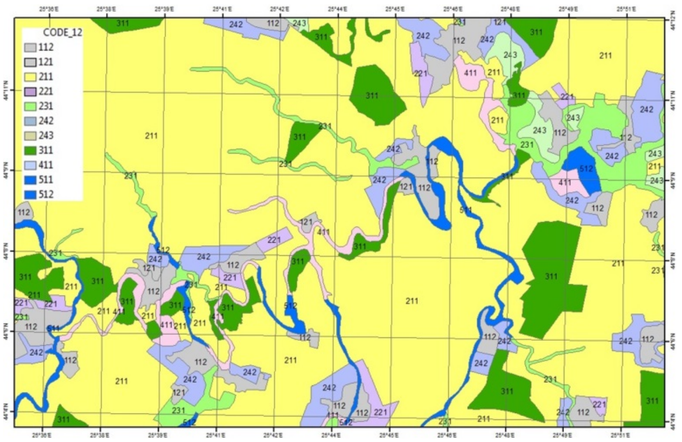
CLC database. From 1990, the CLC database give information about Europe land use and land cover, based on satellite data more and more accurate. This information has led to identification of the landscape changes. For this stage of the study was used the 2012 CLC version. From the 44 classes of the nomenclature CLC the selected categories as representative for the two basins are: arable land, agricultural land (including other crops), orchards, vineyards, forests, grasslands, rivers, bare soil (including artificial areas). These are accompanied by corresponding weights, expressed in km² and percentages.

LPIS (Land Parcel Identification System). For this study were analyzed only the agriculture land use categories, not the areas representing localities, non-agricultural areas (forests, water) and bare soil, over the river basins.

Supervised and unsupervised classifications.

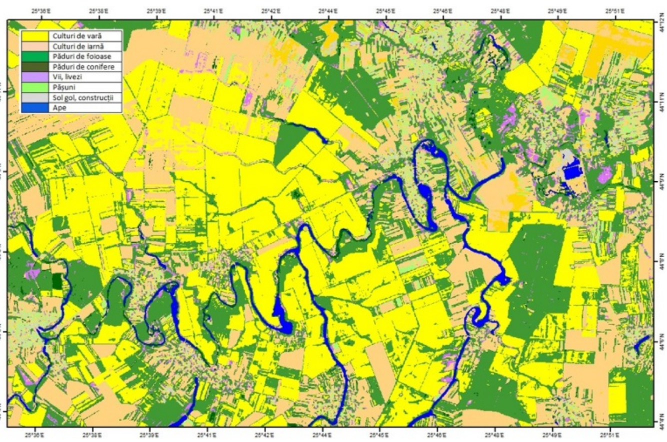
The two classification methods were realized by processing each Landsat 8 OLI satellite image (because of the different spectral signature from acquisition). The final result was satisfactory in terms of connection between different types of land use / land cover.

For a region in the southern part of the study area was performed a comparative analysis between obtained thematic information products. The selected subset includes much of the land use / land cover types over a surface of 294 km^2 in the two watersheds. Were analyzed all the three sources of thematic information: Corine Land Cover (Figure 4.6.1), LPIS (Figura 4.6.3) and the result of the unsupervised classification of the Landsat 8 OLI (from May 2013) (Figura 4.6.4). There are followed updating, validation and an analysis of the data which generate a result more close to the reality.



LC/LU Category	Km^2	%
Arable land	201.8	68.6
Agricultural and other crops	18.35	6.2
Vineyards	4.05	1.4
Forests	26	8.8
Pastures, grasslands	10.5	3.6
Water, wet zone	15.3	5.2
Bare soil, artificial land	18	6.1
	294	**100**

Figure 4.6.2: Land cover / land use map for the study area - CLC 2012 subset; categories and LC / LU percent

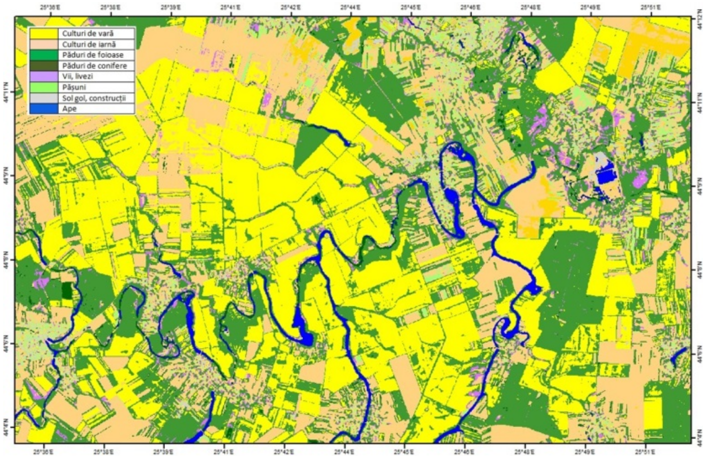


LC/LU Category	Km^2	%
TA – arable land	221.4	94.4
PP – permanent pastures	10.6	4.5
VI - Vineyards	2.1	0.9
CP – permanent crops	0.35	0.1
	234	**100**

Figure 4.6.3: Land cover / land use map for the study area - LPIS subset; categories and LC / LU percent

The remaining 60 km^2 is represented by forest and localities extracted from LPIS database; for this application was taking into account only the mask for the use of the agricultural land.

In the case of unsupervised classification, some of the pixels assigned to the deciduous forests should be included in the category of agricultural land, representing summer crops (due to the similar spectral signature). This explains the higher percentage for forests in the latest classification, comparing with the two other information plans.



LC/LU Category	%
Winter crops	41
Summer crops	30
Vineyards	1.5
Forests	15
Pastures	4.5
Water	5
Bare soil, artificial land	3
	100

Figure 4.6.4: Land cover / land use map for the study area, unsupervised classification subset; categories and LC/LU percent

The results of the comparison of the three information products, containing the weights for each category of land cover / land use are satisfactory and represent a novel approach in analyzing spatial data. Centralize it and bringing them to similar categories of land cover / land use for the three types of classifications can be observed in the table 4.6.1.

Table 4.6.1: The main LC/LU categories and their percentage (%) for the three thematic products

LC/LU Category	CLC_2012 (%)	LPIS (%)	Unsupervised category (%)
Agricultural land	74.8	94.5	71
Vineyards	1.4	0.9	1.5
Forests	8.8	-	13
Pastures	3.6	4.5	4.5
Water	5.2	-	5
Bare soil, artificial zone	6.2	-	5
TOTAL	**100**	**100**	**100**

Accessing and comparing the recent information referring to vegetation cover / use of the soils lead to updating and improving quality of existing databases. Under a GIS system and integrating with ortophotos and/or satellite images, can achieve a better management and monitoring of agricultural and non-agricultural land from a certain region.

4.6.2. Activity 6.2. Design of the algorithms and methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models

Within this activity was designed the methodology for data assimilation of snowpack parameters in the hydrologic model NWSRFS and in the system for estimation of flash floods occurence risk in Romania – ROFFG (details are presented in the deliverable D6.2.).

The National Hydrological Modeling and Forecasting System HFMS-DESWAT is a complex, modular and integrated system, and has hardware and software components for processing and modeling installed at both national level (NIHWM - National Centre for Hydrological Forecasting) and at the level of the Water Basin Administrations (at the Basin Centers for Hydrological Forecasting, Dispatch Services and Hydrological Stations).

The HFMS-DESWAT system consists of specialized components for the simulation and forecasting of hydrological processes at different spatial and temporal scales:

- conceptual hydrological forecasting model with NWSRFS global parameters - for medium and large river basins;
- NOAH-R hydrological forecasting model with distributed parameters for the detailed modeling of hydrological processes with distributed parameters;
- The ROFFG system - for real-time estimation of the flash flood occurrence risk in Romania (Romania - Flash Flood Guidance System) specialized for flash flood issues.

The simulations from the distributed hydrological model NOAH-R will be used as input in the data fusion procedure for estimating the snow water equivalent, and the final adjusted values resulted from the procedure will be assimilated in the operational model, in order to adjust the state parameters related to snowpack.

The other two important hydrological forecasting systems (NWSRFS and ROFFG) are using the same conceptual model SNOW-17 for simulating the snowpack evolution, and the optimal values of snow water equivalent resulted as output from the data fusion procedure will be used for data assimilation, specific to each system, for adjusting the snow model state parameters.

SNOW-17 is a conceptual model, most important physical processes occurring in the snowpack are explicitly included in the model, but only in a simplified form. This model of accumulation and snowmelt was first described by Anderson in 1973, as one of the modeling component of the River Forecasting System of the US Weather Service (Anderson, 1976).

SNOW-17 model is part of the index-type snow models, using air temperature as sole index to determine and characterize the energy exchange processes that occur at the snow-air interface. In addition to data on air temperature, the only supplementary input data necessary for running the model is the precipitation quantities.

Considering the air temperature as representative index for energy exchange processes is based on results obtained in experimental studies that have shown the fact that air temperature is a good indicator for the processes of snowmelt, in fact most operative models on the evolution of snowpack use the degree-day factor to estimate water yield from the snowpack. The measurements of air temperature are also available in real time, being included in the standard program of observations from weather stations and most hydrometric stations, and the interpolation procedures and respectively for estimation of spatial variation of this parameter associated a much lower uncertainty degree than other meteorological parameters, showing the advantage of asignificant dependency with altitude, which allows the extrapolation of the field of air temperature at high altitudes, where the overall density of observation networks is lower, but where simulation of the snowpack is very important for the hydrological regime.

The accuracy of long and medium term forecasts made with meteorological numerical models is also higher for estimations regarding the possible evolution of this parameter (air temperature) than for other meteorological parameters, involved in energy exchange processes from the snowpack-air interface.

The SNOW-17 was designed primarily for use in operative hydrological forecasting activities, respectively to use as necessary input the data which are available in real time, but also data which are available for a necessary representative historical period required for the adequate calibration of model parameters. Even if the model has been used successfully in applications simulating the evolution of the punctual snowpack (eg the location of a weather stations), the model is commonly used at the scale of a river basin, and depending on the altitude variability, the model can be configured in 2 to 3 specific areas, in altitude gaps.

The approach use in the development of the model included two steps, namely a first stage in which they were analyzed and included representations of the physical processes occurring in a snow column, then the structure and configuration of the model has been developed for application at the level of river basin.

Thus, the main processes included in the model for a column of snow are:

- Form of precipitation;
- The accumulation of the snowpack;
- The exchange of energy at the snow-air interface;
- Evolution of the internal condition of snow;
- Transmission of water in the snowpack;
- Heat exchange at the soil - snow interface.

In order to apply the model at the level of a river basin area river, the extension of the snowcovered surface at the level of the entire area is calculated and used to determine the area percentage at the level of the river basin which contributes by releasing water from the snowpack in the formation of runoff.

For the estimation of the partial surfaces in the model, there are estimated the mean values of water equivalent and respectively the thickness of the snowpack. Figure 4.6.4. shows the flow diagram of the SNOW-17 model.

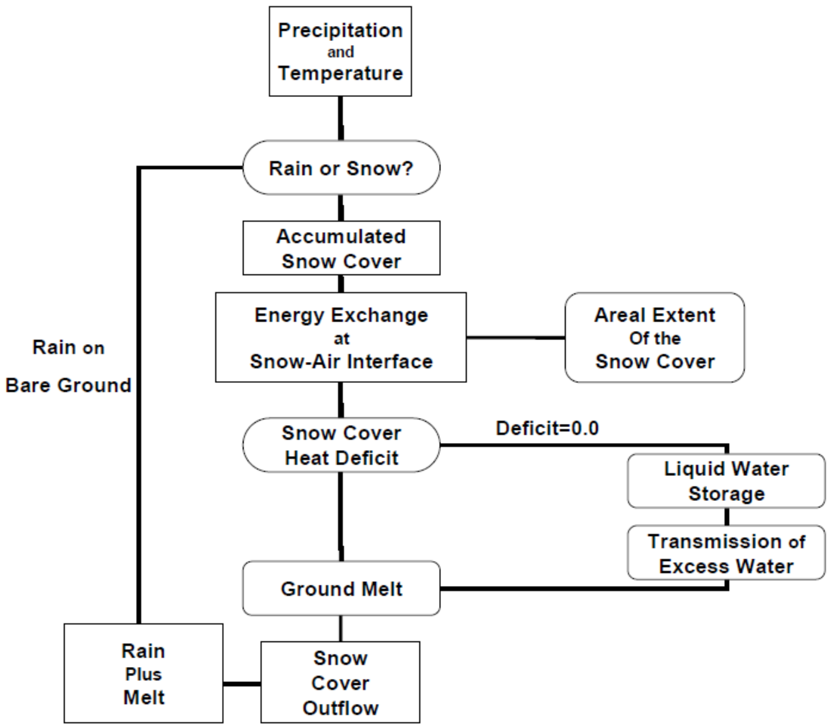


Figure 4.6.4: General data flow diagram for the SNOW-17 model (Anderson, 1976)

During the operational use of the SNOW-17 model, within NWSRFS, we can make a series of adjustments and changes in state variables in order to achieve a better simulation compared to the actual situation, or to try a compensation of model limitations, based on the recorded or forecasted evolution of meteorological parameters.

An important aspect that need to be taken into consideration is related to the fact that at the time when the water equivalent value simulated by the SNOW-17 model is changed, in an automatic way it is also changed accordingly within the NWSRFS systems the percent of snow cover at the hydrographic basin level (excepting the case when this value is maintain at 100%), which is different than the case when the snow extent degree is directly changed, when there is no implicit change in the snow water equivalent (figures 4.6.5 şi 4.6.6).

This difference of internal adjustment procedure takes into account that there may be variations in the snow depletion curve from one year to another, respectively the fact that the model can use an depletion curve resulting from the calibration process that differs significantly from the particular situation at a given time, even if water equivalent of the snowpack has a value close to the real value.

In the case of snow cover percent value modification, at the level of the river basin, only state variables involved in computing the spatial extent of snow are modified, there is no change at the level of the water equivalent of the snowpack, or other state variables of the SNOW-17 model.

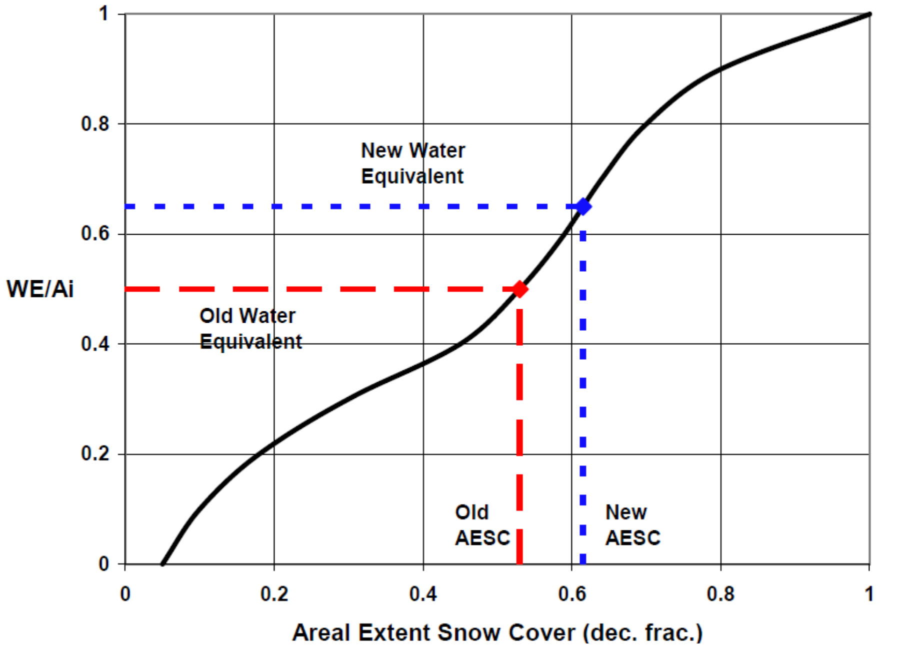


Figure 4.6.5: Effect of changing snow water equivalent on the areal extent of snow cover, during the data assimilation process, on the snow cover extent at the basin level (Anderson, 1976)

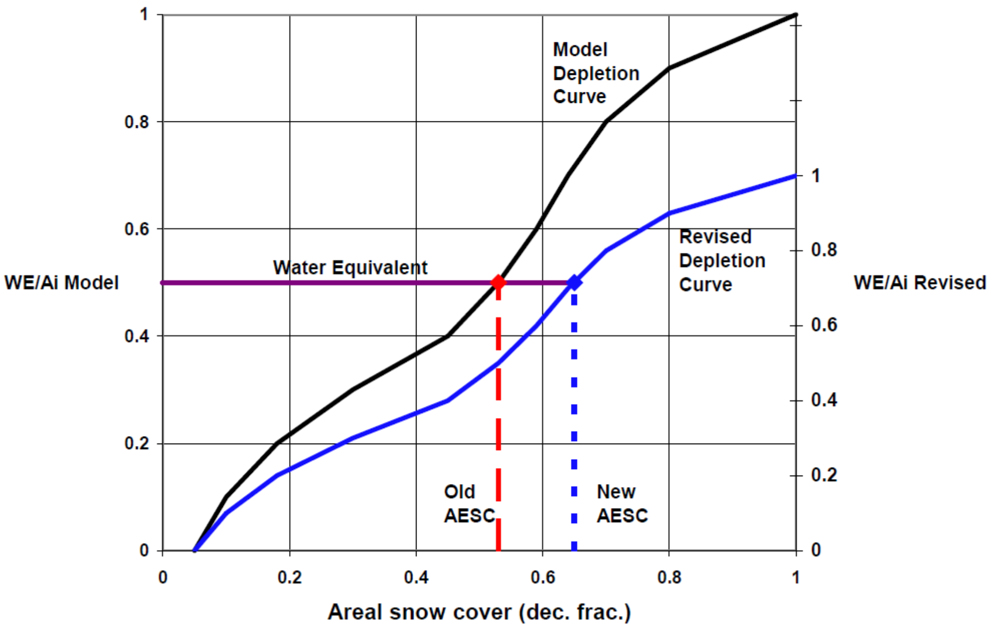


Figure 4.6.6: Effect of changing snow water equivalent on the areal extent of snow cover, during the data assimilation process, on the snow depletion curve (Anderson, 1976)

4.6.3. Activity 6.3. Implementation of the methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models

During this phase, was done the inventory and selection process for the software systems, modules and utilities that are needed for implementing the methodology of snowpack parameters assimilation in the operational hydrological forecasting models.

Using the selected software applications was started the implementation of scripts and programs for handling the export-import operations for the data flow, and for the specific processing steps for assimilating the snowpack parameters into the operational hidrological models NWSRFS and ROFFG.

As it was presented in the activity 6.2., the hydrological forecasting models NWSRFS and ROFFG are using the same snow model for simulation of the snow pack evolution, respectively the conceptual model SNOW-17.

Within the data assimilation process for these operational hydrological models the direct method approach will be used for assimilating the snow water equivalents values, and in a second step during the assimilation process, will be checked if there are significant differences between the percent of snow cover extent at the basin level simulated by the model using the depletion curve and the percent indicated by the data fusion procedure, also this parameter will be assimilated using the direct approach, for adjusting the SNOW-17 internal state.

4.7. WP7 Avalanche inventory, release and hazard mapping

4.7.1. Activity 7.1. Develop avalanche detection algorithms

4.7.1.1. Avalanche inventory based on GeoEye-1 satellite images

Mountains based on GeoEye-1 scene, April 2012, we used also information from terrain morphometry. The images were orthorectified using a digital surface model (DSM) at 0.5 m spatial resolution generated using an unmanned aerial vehicle (UAV). In several areas, beside spectral information, we used as additional information the terrain parameters derived from DSM. Spectral signature of avalanche deposits is similar with the deposits of undisturbed snow which makes it difficult to delineate. The avalanches were easily detected in panchromatic band, based mainly on texture, with the exception of shaded and overexposed areas (Figures 4.7.1 and 4.7.2). For a better visual detection and delineation of snow avalanche deposits, we used several bands combination, image differencing and PCA analysis (Figures. 4.7.3, 4.7.4, 4.7.5, and 4.7.6). The difference between NIR band and blue band outlined better the avalanche deposits (Figure 4.7.3). The best visualization was achieved using false-color images generated using panchromatic band, the difference between NIR and blue bands and PCA, which made possible the identification of two generation of avalanches produced on the same avalanche-path (Figure 4.7.6).

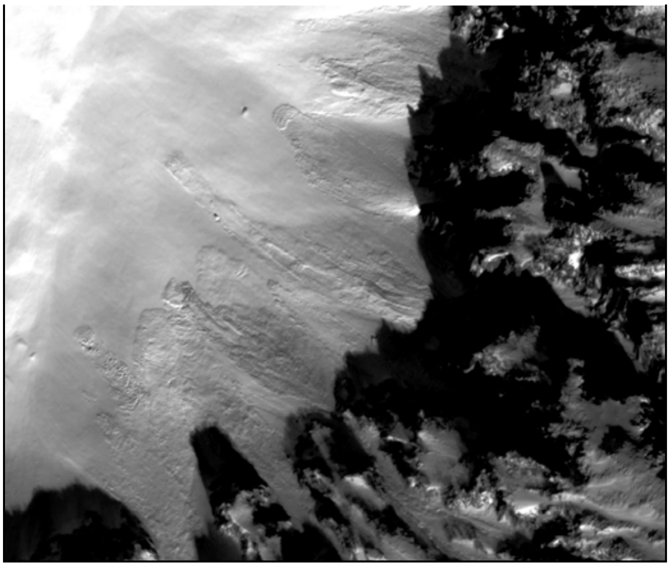


Figure 4.7.1: Avalanches in Arpașului valley (Făgăraș Mountains) visualized in panchromatic band of GeoEye-1 image (April 2012). Avalanches have a course texture as compared to the undisturbed layer of snow.

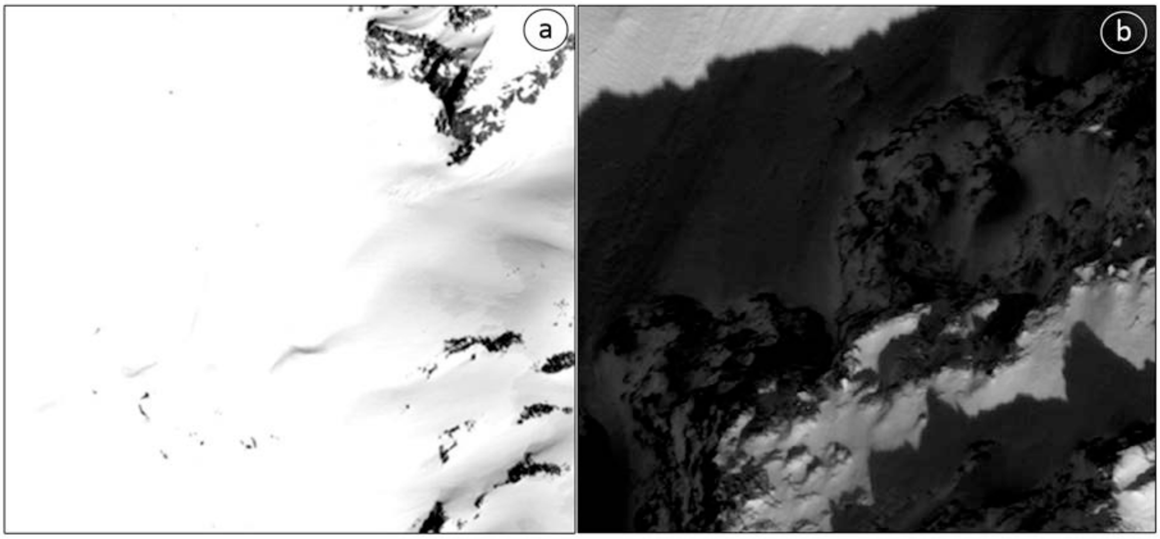


Figure 4.7.2: Overexposed areas (a) and areas in shadow (b) – panchromatic band (GeoEye-1).

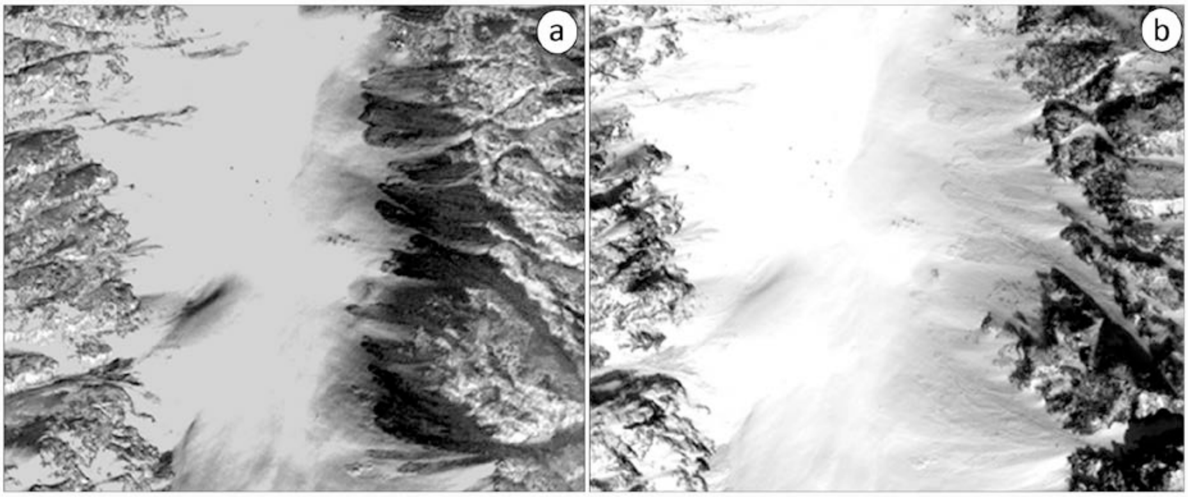


Figure 4.7.3: Image resulted from the difference NIR – Blue,
avalanches can be observed in dark tones (a); panchromatic band (b)

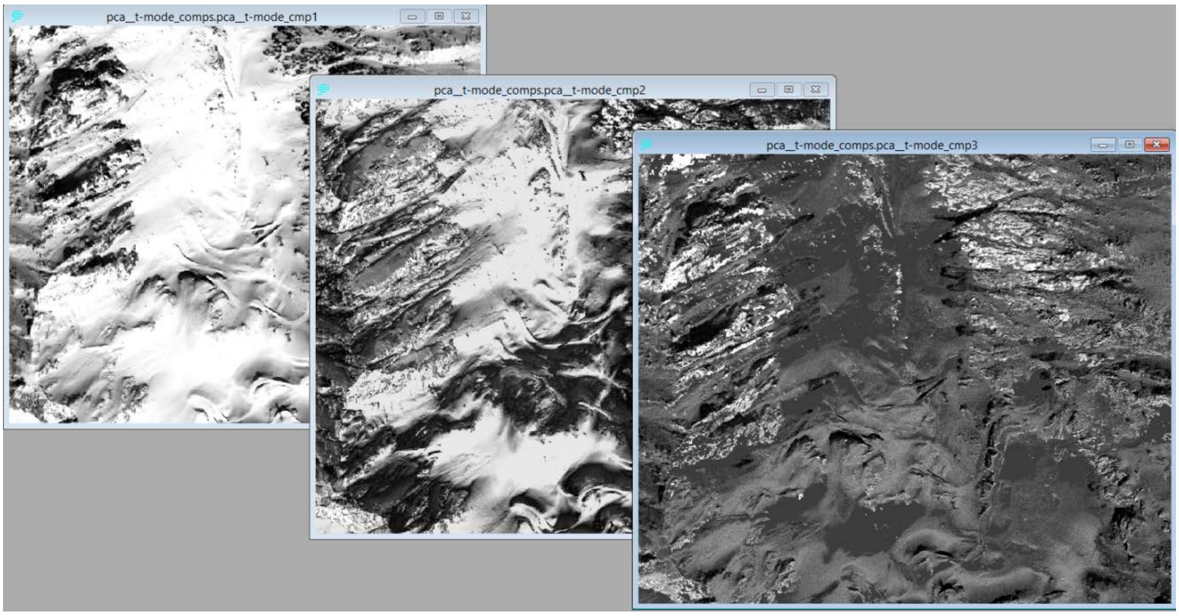


Figure 4.7.4: . First three principal component images derived from GeoEye-1 scene.

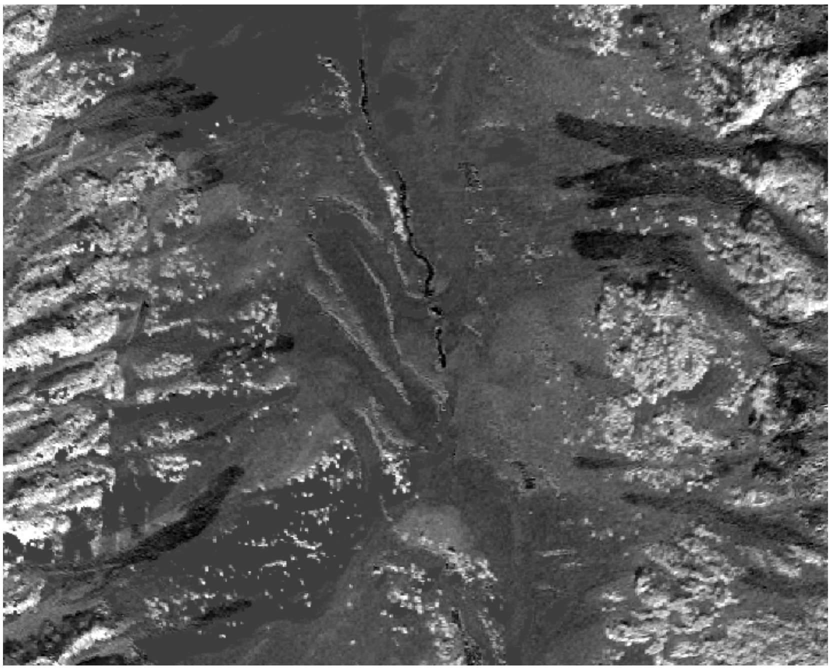


Figure 4.7.5: In component PCA - 3 the avalanche deposits can be observed in dark tones.

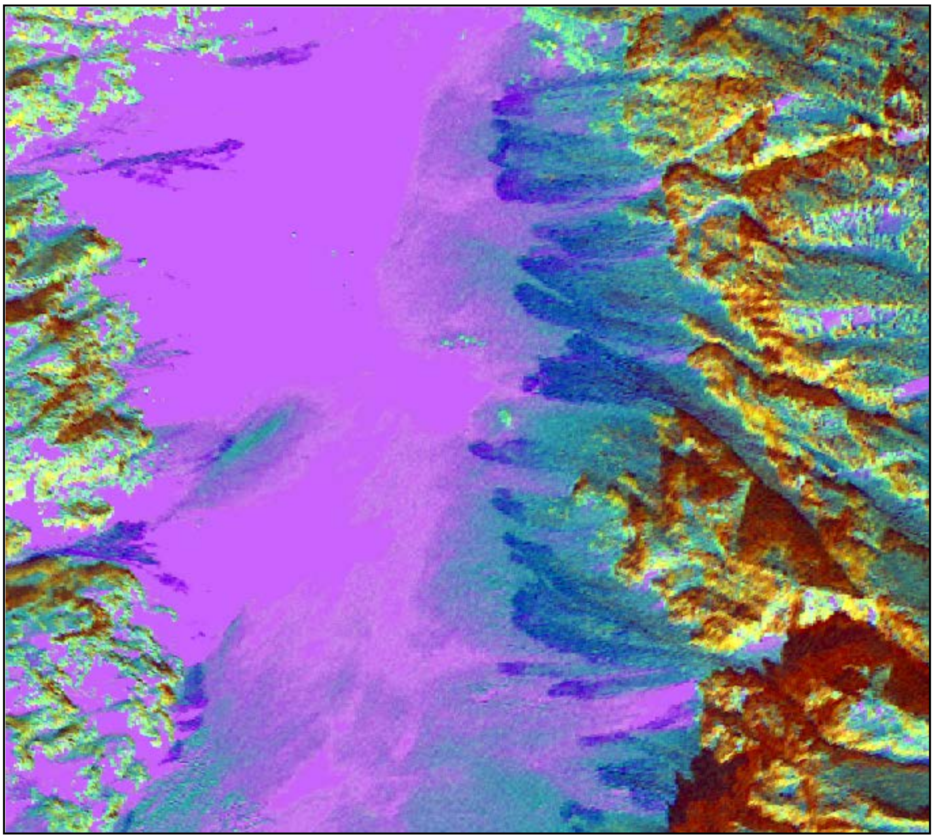


Figure 4.7.6: False-color image resulted by combining: panchromatic band, image difference (NIR-Blue) and PCA-3. Avalanches can be observed in dark blue.

Using the false color images mentioned above, we could identify and delineate two generations of avalanches on the same avalanche path. The avalanches that are more recent have more saturated and dark colors, as the snow characteristics are different as compared to those of the older snow deposits (Figure 4.7.7).

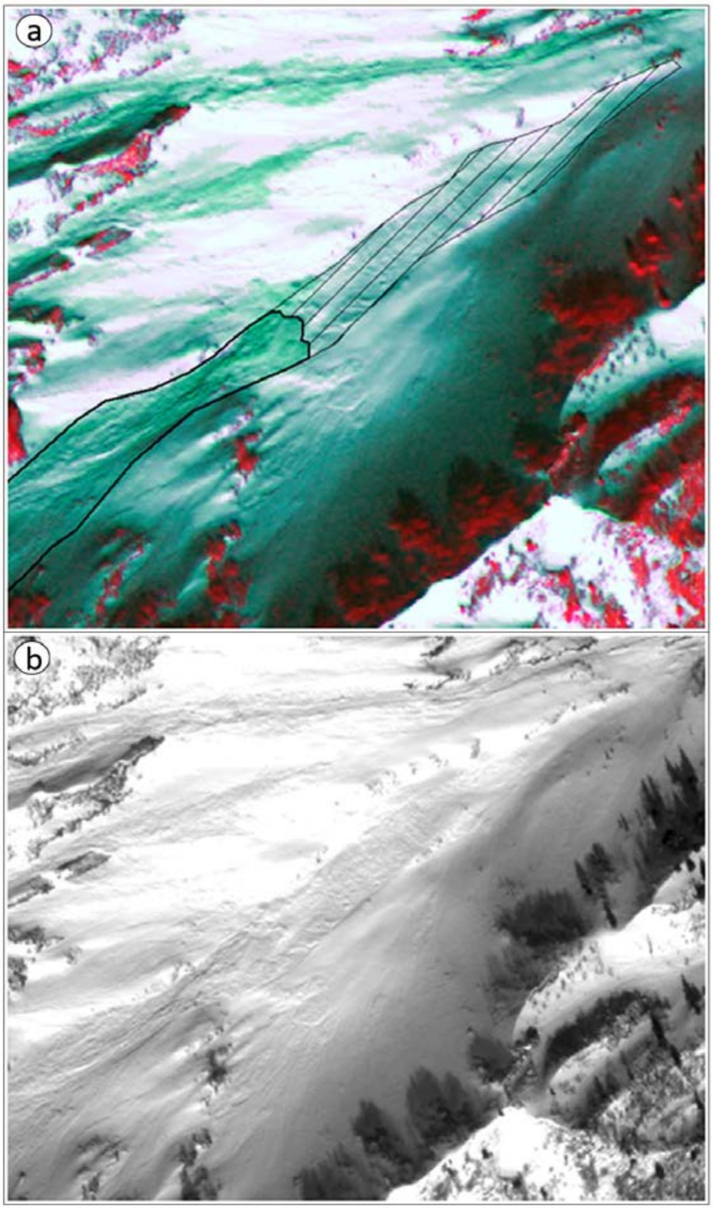
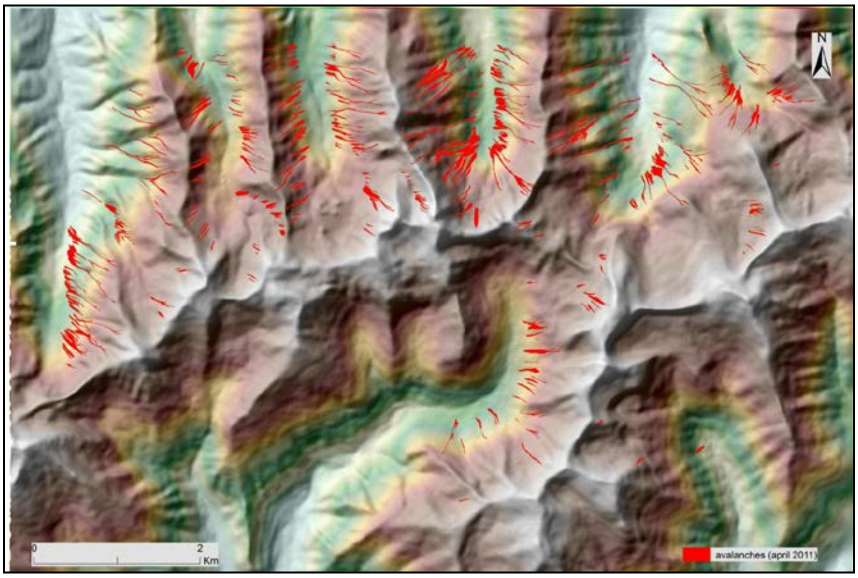


Figure 4.7.7: False color image with two generations of delineated avalanches, the one that is more recent is outlined in black, while the older deposits are marked with parallel lines texture (a); panchromatic band where avalanches are detected, but with no difference between older and fresh avalanches (b).

From the scene GeoEye-1 covering the central part of Făgăraș Mts., 542 avalanches were identified and delineated (Figure 4.7.8), with a total area of 55 sq. km and a density of 9.85 avalanches /sq.km. For each feature, spectral, dimensional (length and width, shape index) and morphometric characteristics (altitude, slope, aspect, curvature) have been extracted. The features length varied between 34 and 2644 m with a mean value of 445 m (Figure 4.7.9).

Avalanche inventory, as well as the parameters extracted for each feature, has been used to validate the automated avalanche detection algorithm based on snow texture, and also for the simulation of avalanche trajectories and snow thickness using mathematical models.



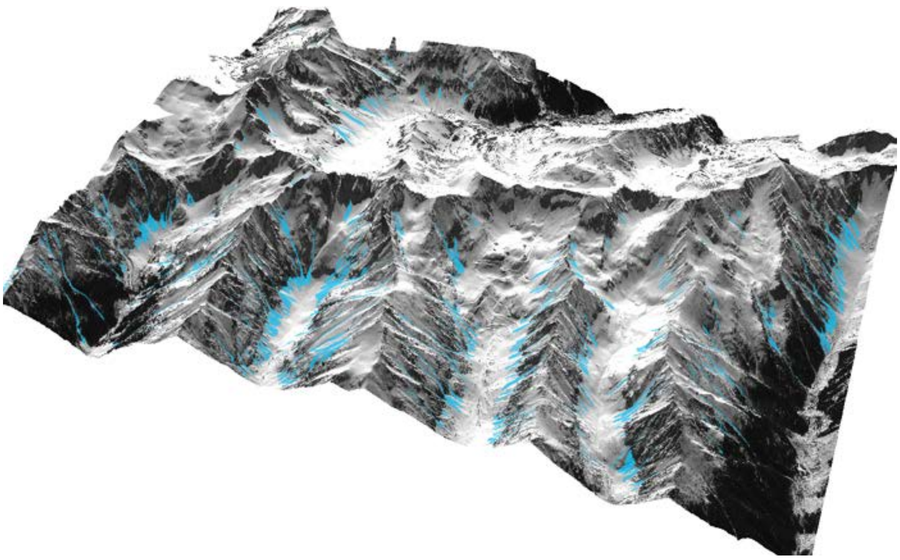


Figure 4.7.8: Spatial distribution of delineated avalanches based on GeoEye-1 satellite image (April 2012) in central part of Făgăraş Mts., draped on DEM (up); 3D visualization in panchromatic band (down).

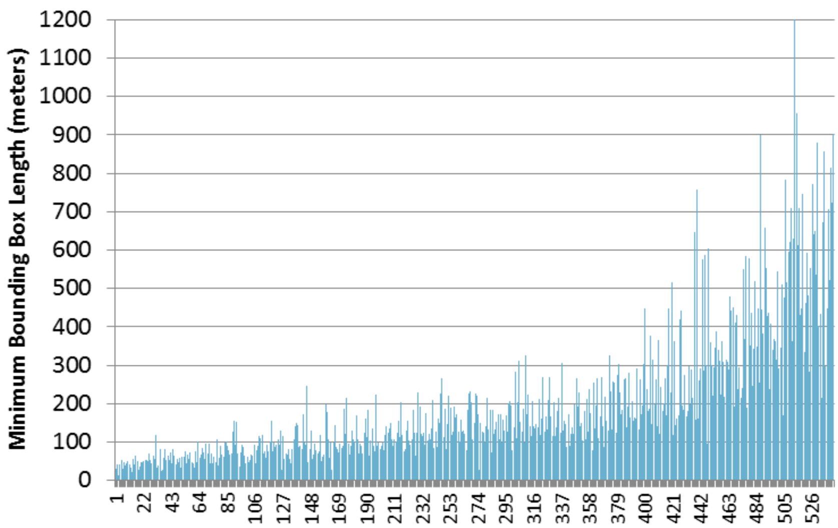


Figure 4.7.9: Distribution of avalanche lengths delineated from GeoEye-1 satellite images.

From the second GeoEye-1 image, that cover the central-eastern parts of Făgăraș Mts., 345 avalanches have been identified (Figures 4.7.10 and 4.7.11).

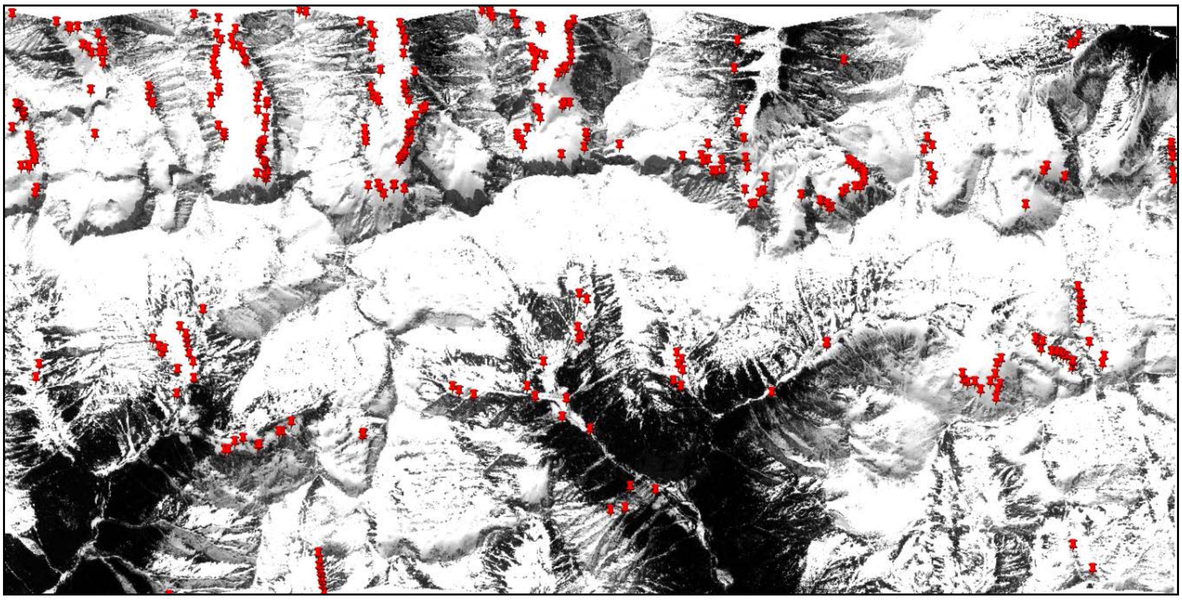


Figure 4.7.10: Spatial distribution of avalanches identified in GeoEye-1 scene (11.04.2012), from the central-eastern part of Făgăraș Mts. (panchromatic band).

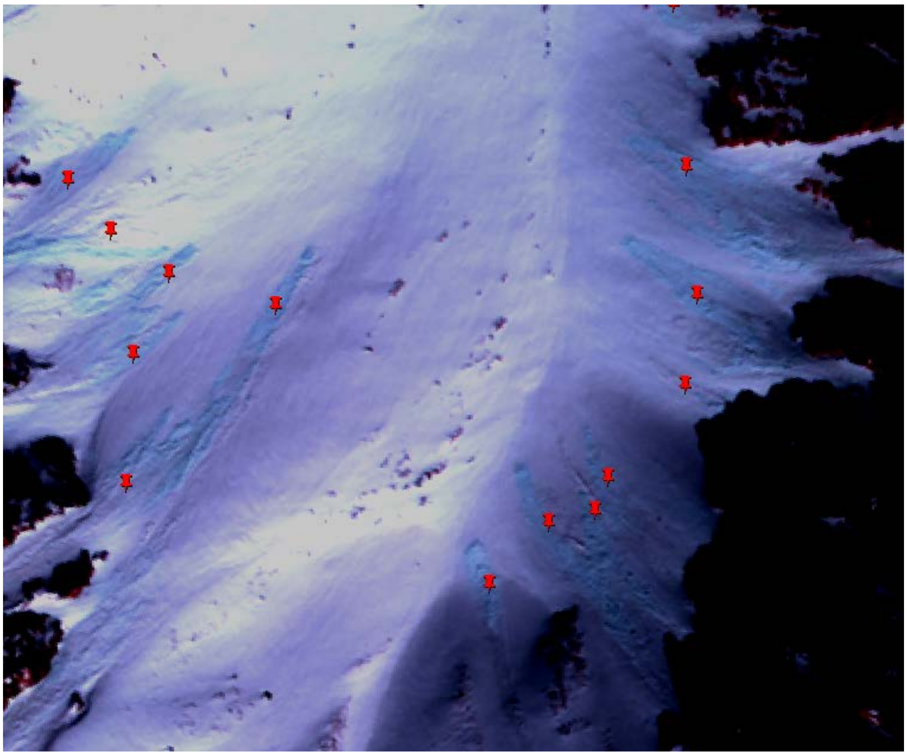


Figure 4.7.11: Avalanches identified in the upper Viștișoara valley using a false-color image based on Geo-Eye-1 bands.

4.7.1.2. Avalanche detection algorithm

In the SnowBall project, NR partner has further developed the textural filter based approach for automatic avalanche detection in very high resolution optical satellite imagery (Larsen et al., 2010). The key part of this detection algorithm involves texture analysis, seeking to distinguish avalanche snow from other relevant terrain cover types, such as smooth snow, rugged snow, trees and rock.

The texture characteristics of the avalanche-affected snow are extracted by convolving the image with a set of 12 multi-scale multi-directional filters. Six of the filters are oriented in the same direction as the terrain aspect, which is estimated from a digital elevation model, and six filters are oriented in the vertical direction. The reason for using vertical filters was that early experiments indicated that they provided useful features for distinguishing sparse forest from avalanches (fig. 4.7.12). A 4×4 max pooling is performed on the filtered response in order to reduce the dimension of the filtered image. The filtered responses for each pixel are also normalized according to Varma and Zisserman (2005), i.e.

$$F(\boldsymbol{x}) \leftarrow F(\boldsymbol{x}) \frac{\left[\log\left(1 + \frac{\|F(\boldsymbol{x})\|_2}{0.03}\right)\right]}{\|F(\boldsymbol{x})\|_2},$$

where *F(**x**)* denotes the filtered image at pixel location **x**.

Prior to the filtering illumination variations are reduced by subtracting a scaled shaded relief image from the panchromatic image, and normalizing the illumination compensated image to zero mean and unit variance.

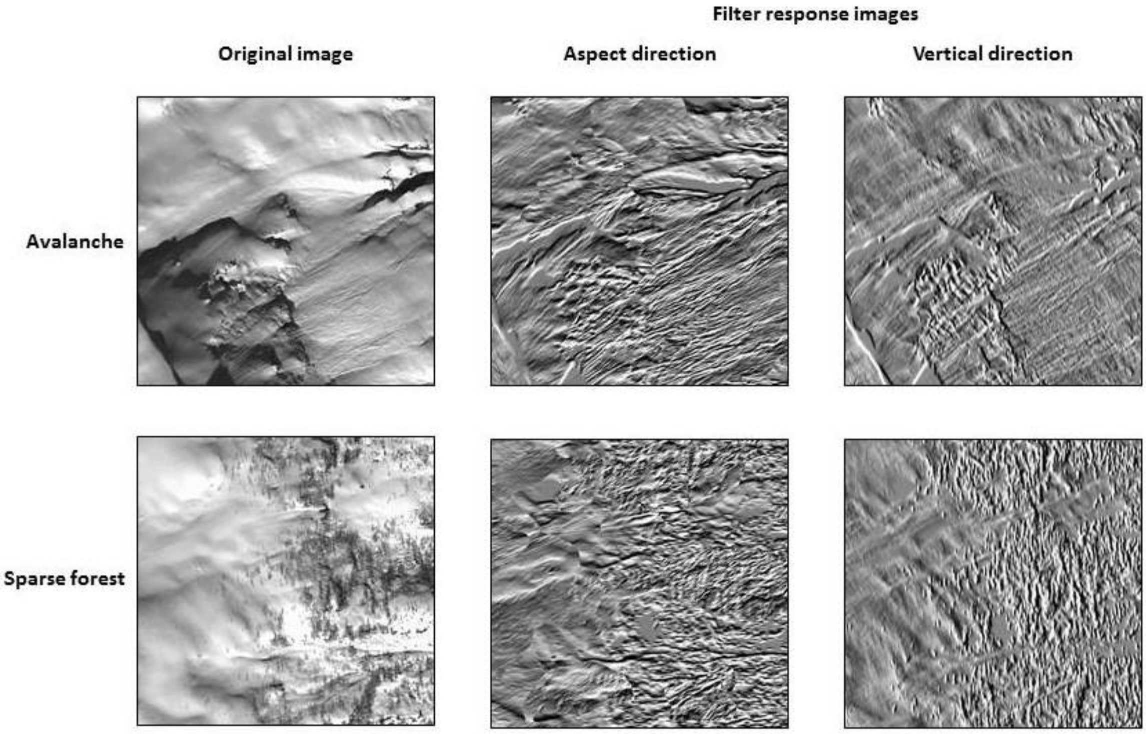


Figure 4.7.12: Comparison of filter responses from two texture classes (avalanche and sparse forest) at both aspect and vertical orientation. Avalanche snow is enhanced in the aspect direction, and not in the vertical direction, while sparse forest is more enhanced by filtering in the vertical direction.

4.7.1.3. Results

The algorithm has been applied on Worldview, Quick Bird and GeoEye-1 images at 0.4 – 0.6 m spatial resolution for the test areas and has been validated with digitized avalanches (Figures 4.7.13 and 4.7.14).

Often, the algorithm didn’t detect correctly avalanches or part of them in both shaded and over-illuminated areas. In many cases, the tightest and smoothest sections of avalanches are not detected as avalanches. For the Făgăraș Mountains, in the areas were the surface of snow was affected by wind pattern, detection errors can be observed (Figure 4.7.15).

To quantify the performance of the algorithm on the test image, we define the following metrics: Area error of commission: the fraction of area incorrectly classified as avalanche with respect to the total area classified as avalanche; Area error of omission: the fraction of area incorrectly classified as non-avalanche with respect to the total true avalanche area; object error of commission: the fraction of segments incorrectly classified as avalanche with respect to the total number of segments classified as avalanche; Object error of omission: the fraction of true avalanches incorrectly classified as non-avalanche with respect to the total number of true avalanches.

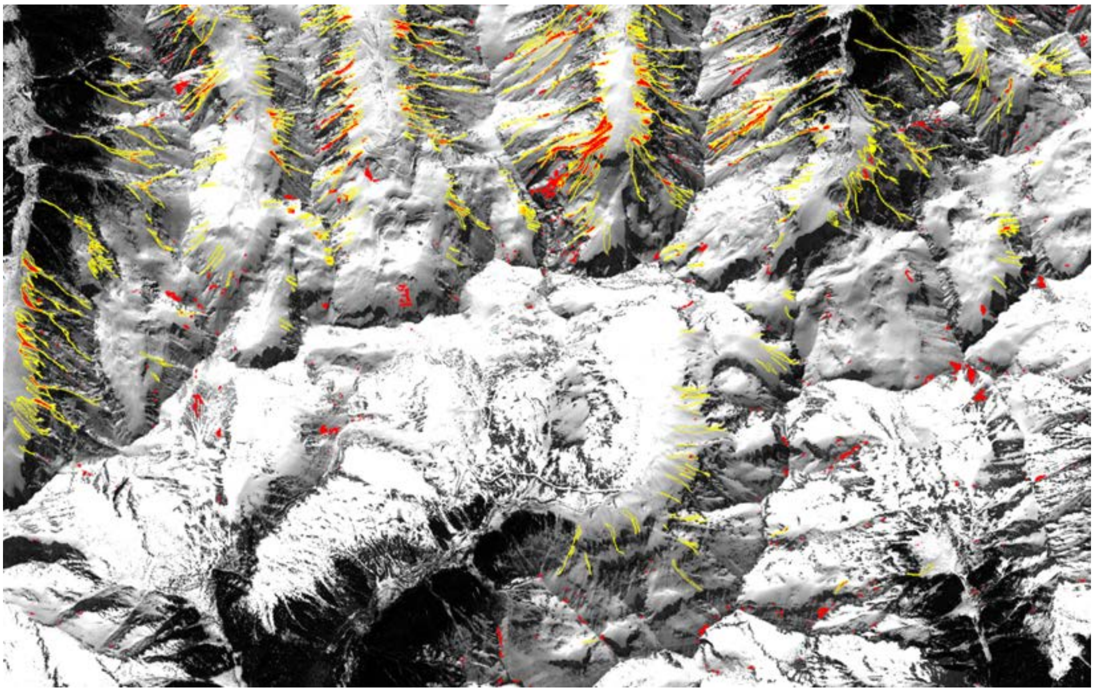


Figure 4.7.13: Detected avalanches (red areas) in the Făgăraș image. The yellow outlines represent avalanches manually identified in the image green lines identifies region of interests.

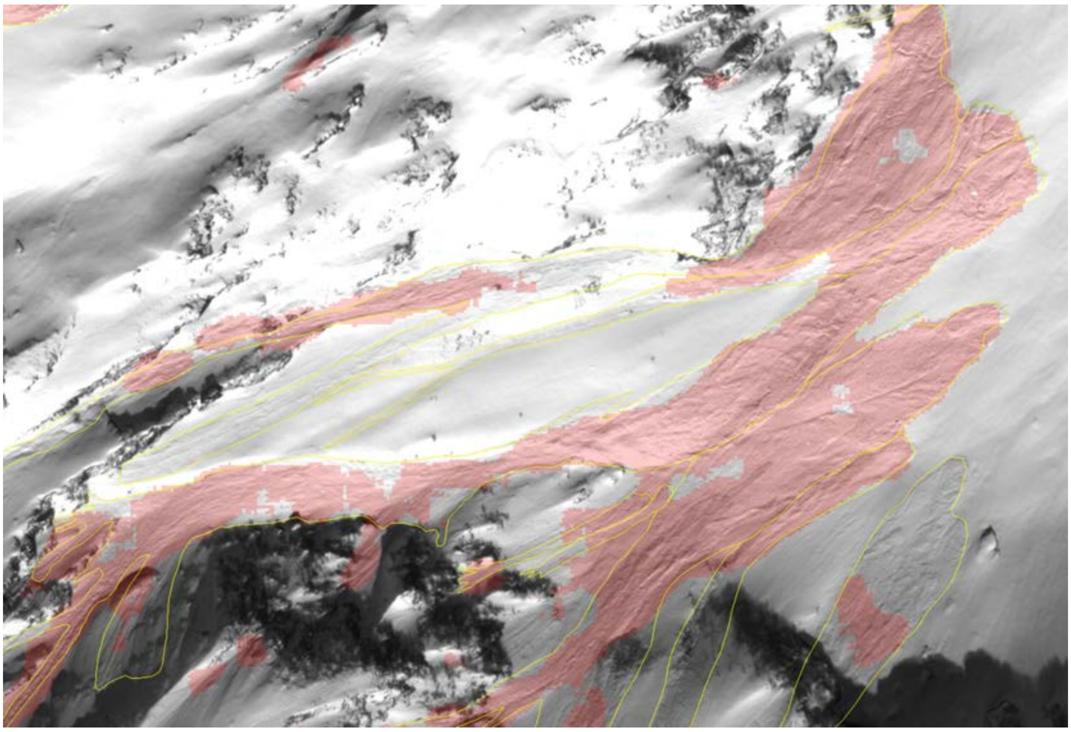


Figure 4.7.14: Close-up view of avalanches in the Făgăraș image.
Yellow lines indicate manually delineated avalanche borders.

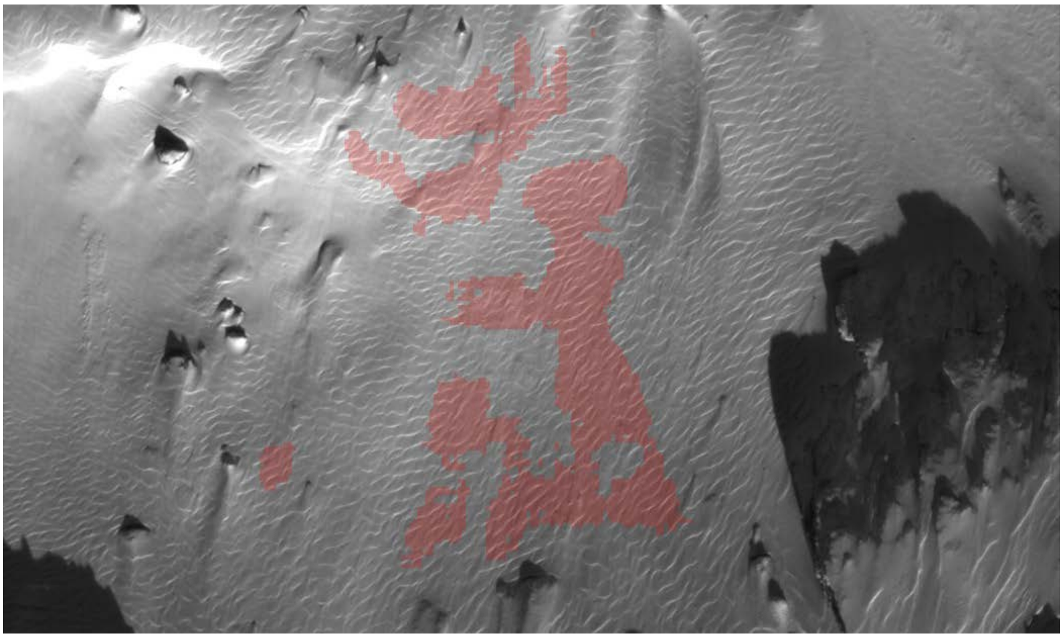


Figure 4.7.15: .: Close-up view of false detection of avalanches in the Făgăraș image, the areas being snow affected by a pattern created by wind.

For Făgăraș Mts., the performance metric indicate medium values (57-77%) as compared with other test areas, detection errors being generated by patterns created by wind at the surface of the snow layer or by very small avalanches. To compensate for that, one could extend the number of filters in the filter bank to a much large number, preferably with filters estimated from the data.

4.7.2. Activity 7.2. Change-detection algorithm for Sentinel-1 and Sentinel-2

The proposed method for detecting avalanches in Sentinel-1 images relies on the hypothesis that compacted rough snow of an avalanche has very high backscatter values (σ0) compared to homogeneous snow cover and bare ground, even if the snow is wet (Wiesmann et al., 2001). This principle was also utilized by Malnes et al. (2013). As suggested by Wiesmann et al. (2001), the proposed algorithm is also based on multi-date SAR images. The underlying principle is a pixel-wise comparison of the backscatter intensities of two SAR images, an event image (the one with avalanches) and a reference image. However, the algorithm applied in Malnes et al. (2013) and Wiesmann et al. (2001) assumes that both the event image and the reference image are acquired in the same beam mode, pass direction and be in the same repeat cycle. To avoid the need for reference images in the same imaging geometry, we have implemented an alternative method for detecting avalanches in SAR images. This is based on the flattening gamma radiometric terrain correction approach (Small, 2011). Without treatment, the hill-slope modulations of the radiometry threaten to overwhelm weaker thematic land cover induced backscatter differences, and comparison of backscatter from multiple satellites, modes, or tracks loses meaning. The flatting gamma SAR methodology suppresses a large part of the brightness variation in the SAR images caused by terrain variation, and may therefore provide a proper treatment to the hill-slope modulations (Small, 2011).

The steps in NR's avalanche detection algorithm may be summarized as follows (Figure 4.7.16):

- *Radiometric calibration*. Calibrate the SLC images to gamma-naught (γ0).
- *Multilooking*. Perform pixel averaging of the SAR images. For Sentinel-1 IW mode, we averaged over a 2×2 window, and for Radarsat-2 ultra-fine SAR images, we averaged over a 7×7 window.
- *Terrain-corrected gamma naught*. Convert the multi-looked image to a terrain-corrected gamma naught (flattening gamma) backscatter normalized image.

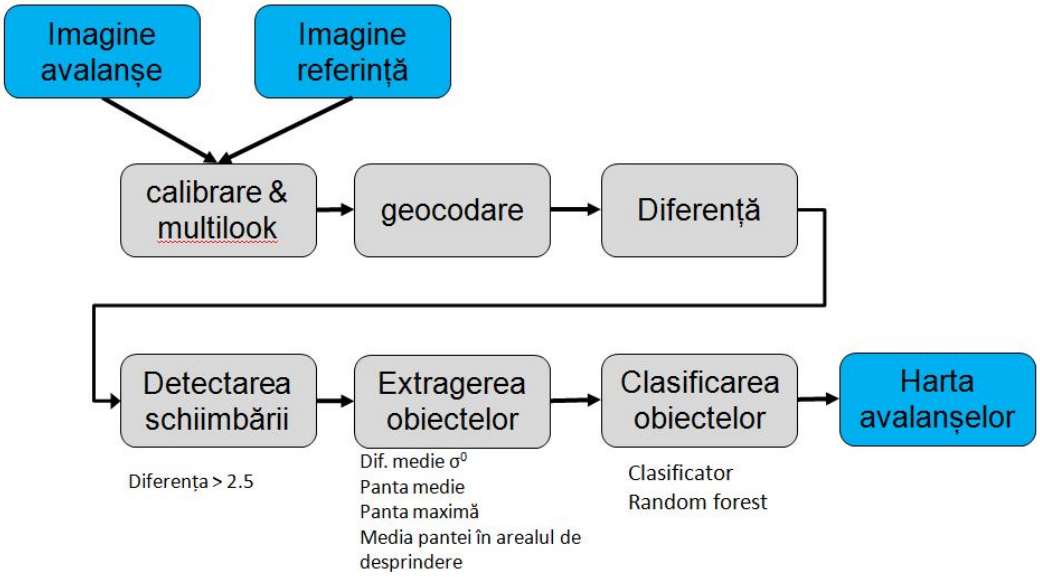


Figure 4.7.16 : Classification scheme of avalanche deposits in SAR images

- *Layover-shadow mask*. Compute the layover and shadow masks by tracing the DEM in the range direction.
- *Geocoding*. Geocode both event and reference image using the Range-Doppler geocoding algorithm. The geocoded SAR images are sampled to the same grid as the DEM. For the scenes evaluated here, the pixel spacing of the DEM is 20 m for Sentinel-1 and 10m for Radarsat-2 ultra-fine.
- *Daily mosaics* (optional). Construct a mosaic of all images covering the area of interest (AOI) at a given day.
- *Ratio/difference image calculation*. Calculation of the pixel-by-pixel ratio between the terrain-corrected gamma naught event image (daily mosaic) and terrain-corrected gamma naught reference image (mosaic of the AOI). If these images are reported in dB, the difference image is computed. Alternatively, the difference image may be computed in the slant-range domain, and then geocoded.
- *Change detection*. A pixel is marked as changed if the difference minus a local mean value, normalized with respect to the local standard deviation, is larger than a given threshold. The local mean and standard deviation are computed within a sliding window of 1×1 km2. The threshold value was determined from a set of avalanches manually delineated in the SAR images. In order to integrate spatial context (i.e. the avalanches are blob shaped), we apply a Markov random filed (MRF) in order to smooth the boundaries. First we construct two auxiliary Gaussian probability density distributions, one centered at threshold value plus 1 and the other centered at threshold value minus 1, both with standard deviation equal to two, and compute the log-probability values for each pixel. This is used as input to the iterative conditional mode algorithm in order to perform the MRF filtering.
- *Feature extraction*. Extract features from potential avalanche objects and include: average difference (in dB) between event and reference image, average slope, maximum slope, average upslope contributing area, object area, and average contrast between object and background in the reference image.
- *Object classification*. Classify the potential objects into 'avalanche'/'non-avalanche' using a random forest classifier (Breiman, 2001).

The benefit with this algorithm, compared to the one proposed by Malnes et al. (2013) and Wiesmann et al. (2001), is that we only need a single reference image for the area of interest.

In this stage, preliminary assessment of the mapping abilities of the algorithm on a set of Radarsat-2 (Figure 4.7.17) and Sentinel-1 (Figure 4.7.18) ultra-fine images of Norwegian mountain areas were performed. The automatically derived avalanche maps have then been compared to manually drawn avalanche outlines made by experts. The preliminary results show that we are able to locate most of the fresh avalanches in the image with some false detection, but that the outline of the avalanche is not always adequately determined.

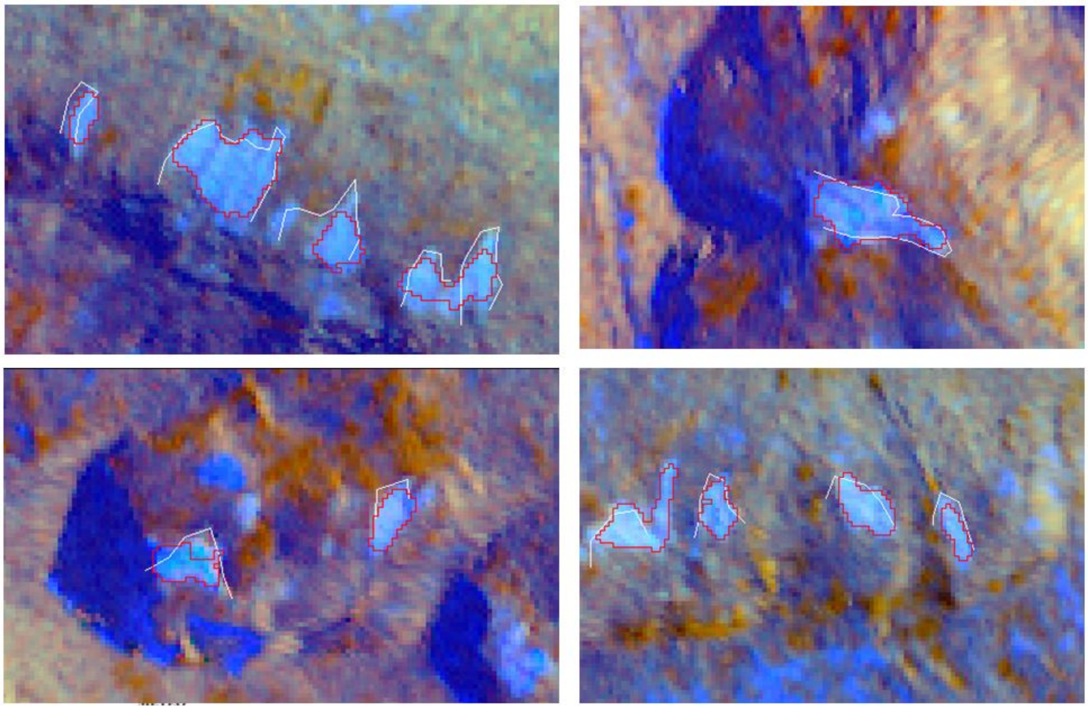
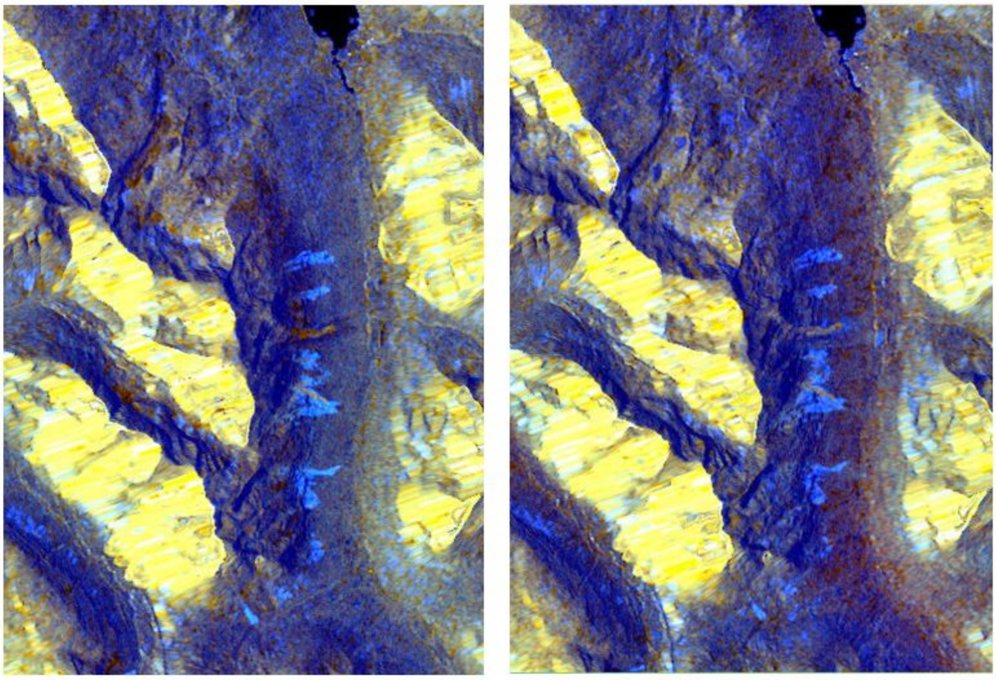


Figure 4.7.17: Avalanche detection on Radarsat image and the delineation made by experts (the algorithm identifies avalanches if they appear as bright «blobs» and favorable DEM)



8 ianuarie 2015 13 ianuarie 2015

Figure 4.7.18: Avalanche detection in Sentinel-1 images from January 2015 (avalanches appear as blue «blobs»; small differences have been identified between these two images)

The next steps would be to collect an extensive collection of training data, from images covering Romanian mountain areas, or similar conditions, and further modify the algorithm for best performance in those conditions.

4.7.3. Activity 7.3. *Avalanche simulation*

In this stage the calibration of the numerical model started for the simulation of past avalanche trajectories started. Several back calculation of avalanche trajectories have been generated for past avalanches in Făgăraș Mts. using different resolution elevation models. For the avalanche simulation we used the avalanche module from RAMMS (Rapid Mass Movement Simulation), which is a bi-dimensional numerical simulation model developed by the Institute for Snow an Avalanche Research in Davos, to calculate the motion of geophysical mass movements (snow avalanches, rockslides, etc.) from initiation to run-out in 3-D terrain. This model uses Voellmy-fluid friction model, which is based on the Voellmy-Salm approach (Salm 1993, Bartelt et al., 1999), which is a simplified model that considers the factors that influence the motion of the snow on the slopes (snow weight, pressure, friction with the topography).

This model divides the frictional resistance into two parts: a dry-Coulomb type friction (coefficient μ) that scales with the normal stress and a velocity-squared drag or viscous-turbulent friction (coefficient ξ). The frictional resistance S (Pa) can be calculated as:

$$S = \mu \rho H g cos(\phi) + \frac{\rho g U^2}{\xi}$$

where ρ is the density, g the gravitational acceleration, the slope angle, H the flow height and U the flow velocity (Bartelt et al., 2013).

The friction coefficients are responsible for the behavior of the flow: μ dominates when the flow is close to stopping, ξ dominates when the flow is running quickly, this model being currently used in Switzerland and a series of tested parameters are available for the alpine areas (Bartelt et al., 2013). The models implies the calibration of the two coefficients that express the internal friction, defined by μ (MU), and the roughness of the substrate defined by ξ (XI).

The calculation and classification of these friction parameters are based on data derived from DEM (altitude, slope, curvature), forested areas, and global parameters (return period and snow volume) (Figure 4.7.19). Also an important input parameter is the release information related to the snow release area and release height, which can influence the simulation results. These were delineated using information from avalanche statistics and descriptions from eyewitnesses. The global parameters are also important, being necessary to select a return period and an estimated volume of snow, as suggested in the classification of the MU-XI parameters offered by RAMMS module (Bartelt et al., 2013).

The simulation tests for past avalanches from Făgăraș Mts. have been applied in the surroundings of Transfăgărășan highway, that being an area with high frequency of avalanches that often resulted in victims and affected infrastructure and has been studied also in previous research (Voiculescu et al., 2011).

For Făgăraș Mts., several DEMs at different spatial resolutions (5, 10, 20 m) and several global parameters were tested. For the return period of avalanches in this area, data from dendrochronology reconstructions have been used (Voiculescu et al., 2016, Voiculescu and Onaca, 2014). Similar approaches using dendrochronology in avalanche simulations for events with high impact on population and infrastructure have been applied in Argentinian Andes by Casteller et al., 2008).

The avalanche module from RAMMS have been tested on several past avalanches that can be found in avalanche statistics and had been catalogued as high risk avalanche events in Făgăraș Mts. The simulation of avalanche trajectories for the events from Bâlea glacial valley resulted in map outputs for the spatial extent of the affected area, depth of the deposits, pressure and velocity of the snow. The resulted maps for the spatial extent were similar with the information found in the description of the events.

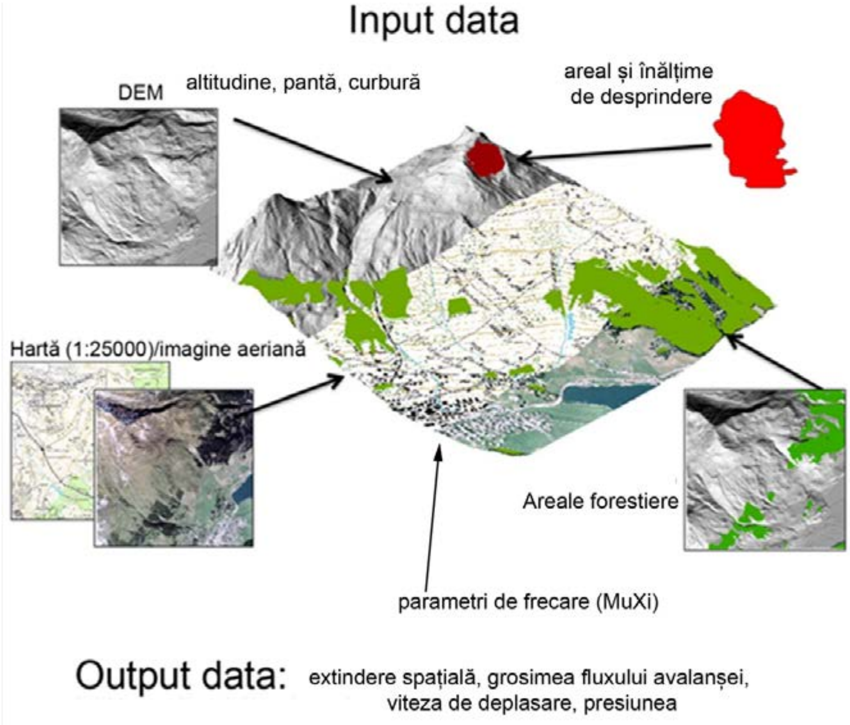


Figure 4.7.19: Structure of input and output data for simulation of avalanche trajectories
(after Christen et al., 2012)

For the simulation of the avalanche from Bâlea valley, June 1974, the best results were obtained when the release height was set to 1.5 m, the other characteristics being related to the constrained topography, return period up to 10 years and an estimated snow volume for medium avalanches (25-60000m^3).

This event resulted in victims in the area of Transfăgărășan highway, which was in construction at that time. From the spatial distribution of snow in the runout area, it can be seen that there are places where snow had 4 m depth and the victims were buried (Figure 4.7.20).

Another case of past avalanche simulation refers to the event from April 1977, when the avalanche caused 23 victims (with ages between 13 and 53). This event occurred in the glacial cirque of Bâlea valley in unconstrained topography conditions. The meteorological parameters at that time recorded at Bâlea meteorological station were min temperature=-11.2^{o}C; max temperature=-3.9^{o}C; precipitation =28.7 mm; snow layer depth =146 cm; wind speed=20 m/s.

For the release information we test several values of release height and for the global parameters we used 10 years return period and medium avalanche snow volume.

The spatial distribution of the simulated snow deposits showed an extension up to the Bâlea Lake (Figure 4.7.21), where the victims were found buried.

This activity will continue in the next period with the simulation of present avalanches identified on VHR satellite images and will be finalized with the generation of avalanche hazard maps for the test areas of Southern Carpathians.

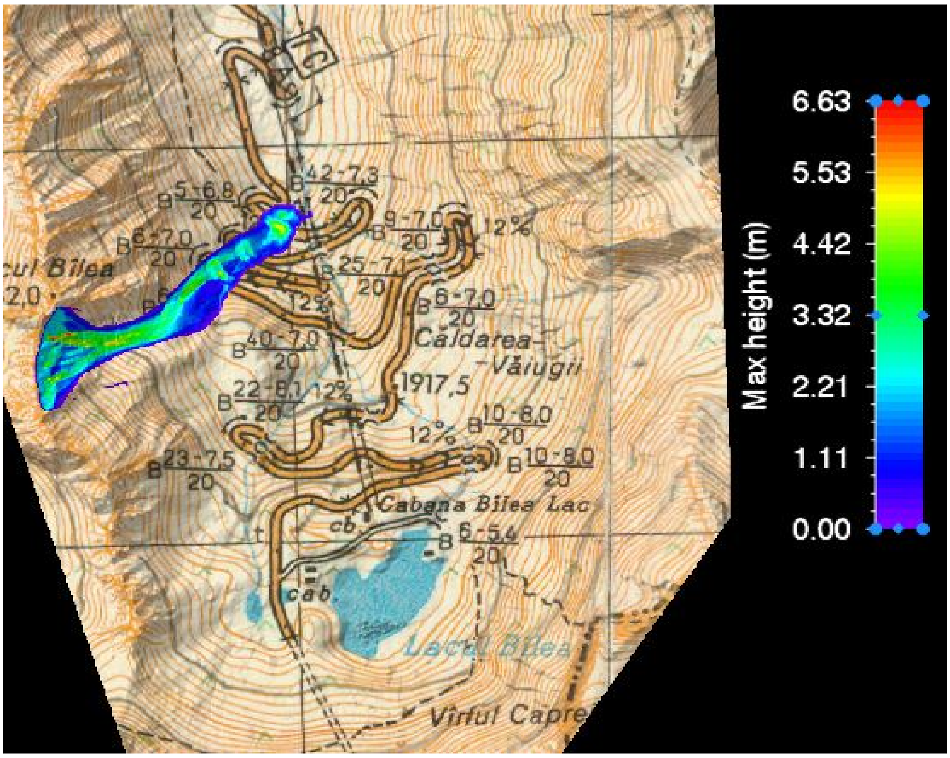


Figure 4.7.20 : Avalanche trajectory simulation in Bâlea glacial valley for the event in June 1974

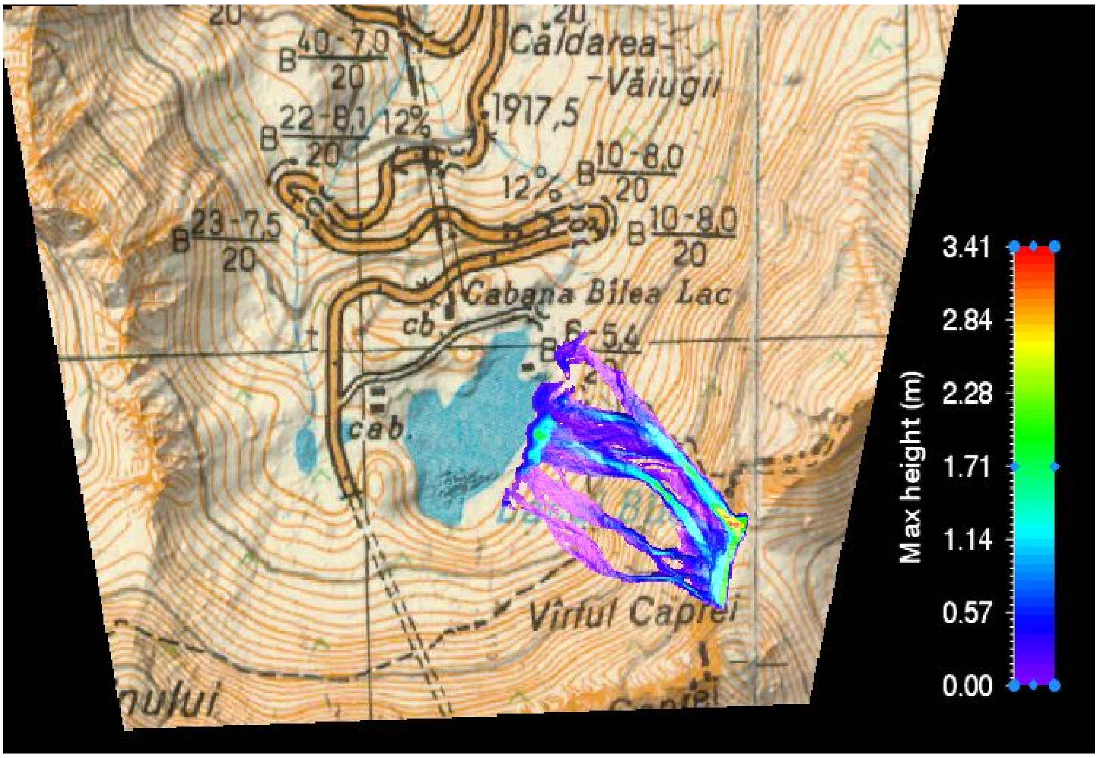


Figure 4.7.21: Trajectory simulation in Bâlea glacial valley for the event from April 1977

4.8. *WP8* Promotion and Dissemintion

4.8.1. Activity 8.1. Project website

There was updated the project website (http://snowball.meteoromania.ro), being included information about the Snowball consortium activity for the current stage of the project: obtained results, meetongs, disseminations, etc (figure 4.8.1). Also, have been realised the Romanian version of the website.

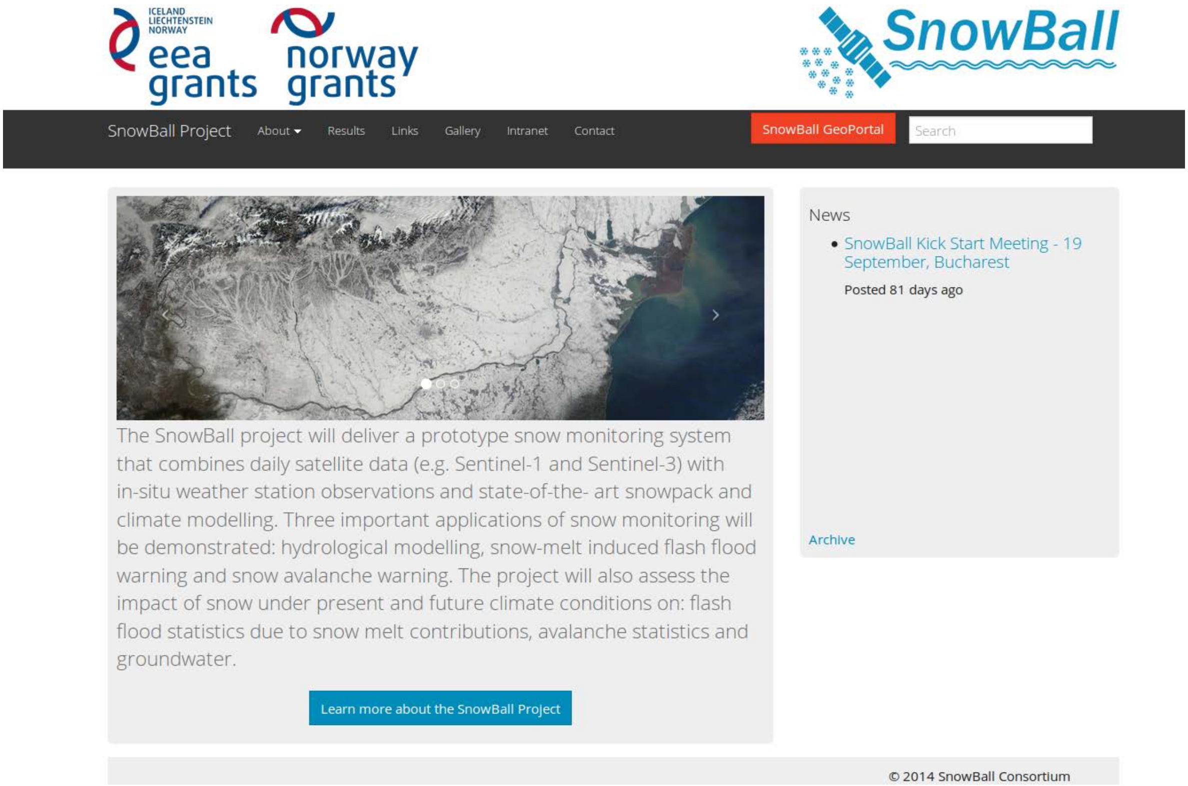


Figure 4.8.1: The web page of the project SnowBall

4.8.2. Activity 8.2. Dissemination strategy

The aim of the dissemination strategy is to define the suitable activities for an efficient promotion of the project Snowball results, both during the project and after its completion and to facilitate interaction with similar projects implemented at national or international level. It also aims to identify appropriate communication tools for creating links between the project consortium and the community of end users.

The main objectives of the dissemination strategy are :

- User community awareness about the opportunities offered by the Snowball project;
- Communicating the results achieved in the project;
- Facilitating collaboration and exchange of information within the consortium (internal dissemination);
- Creating the necessary framework for the efficient use of technologies, algorithms and methods developed in the project by end-users;
- Preparation of the support materials for products created within the project (eg. Documentations, flyers, posters, etc.);
- Creating a network of potential beneficiaries of technology and knowledge resulting from project implementation;
- Ensuring the project visibility at national and international level.

The following elements have been considered in creating the strategy of dissemination:

a) Identification of the target group of users;
b) Establishing appropriate messages drawing attention of target audience group;
c) Selecting channels of communication through which messages are sent to the target group.

4.8.2.1. Dissemination targe groups

The"target groups" term is used to describe different groups of users who can benefit from the project implementation. The main objective of dissemination activities of the Snowball project is to address these groups through appropriate communication methods.
There have identified two categories of beneficiaries that have to be targeted by dissemination campaigns:

- Non scientific communities at national and local level. These include institutions / companies involved in different fiels, such as environmental protection, water resource management, agriculture, energy, tourism and emergency management.
- National and international scientific community.

Depending on the roles and duties fulfilled, dissemination target groups can be classified into the following categories:

- **Government agencies.** They include representatives from various levels of government agencies (eg Ministry of Environment, Forestry and Water, National administration « Apele Romane », the General Inspectorate for Emergency Situations, National Environmental Protection Agency, etc.);
- **Research and education institutes.** They include organizations (eg universities, institutes for research & development, research networks, etc.) whose interest is related to the use of SnowBall products for scientific studies of different issues like estimating water resources, understanding climate change, weather avalanches, etc.;
- **The private sector.** It includes companies interested in providing value-added services using SnowBall products;
- **No-profit organizations ;**
- **Media ;**
- **Public**

4.8.2.2. Defining messages for promotion and dissemination Definirea mesajelor de promovare și diseminare

The key messages to be communicated to target groups must be closely related to the goal and objectives. Key messages can be expressed in one or more statements that include important information about monitoring parameters snow snowball project in general and in particular. Messages should emphasize:

- The importance of monitoing parameters associated to snow cover;
- Relevance of the results achieved in the SnowBall project to create an operational system for monitoring snow cover in Romania;
- The offered benefits and their importance.

It is important to realize that there is a limit to the number of messages that can be disseminated and, often, a compromise between the number and complexity of the message and the expected effect (Carada, 2006). Factors that determine a specific interest of a target group include:

- **Credibility.** The communication channel and source information must be convincing and credible;
- **Clarity.** Messages must communicate clear information. A clear message should be non-technical and only include key information without further explanation;
- **Consistency.** Messages must have a unitary message during the entire period of the project. There must be a consensus among partners;
- **The needs of the target group.** Messages must be based on what interest of the target group is perceived as important and interesting.

4.8.2.3. Selecting communication channels and tools.

Communication channels ensure the dissemination of project results to the target groups. There are several such channels, each with advantages and disadvantages.
The channels that can be used in the SnowBall project can be classified into two main categories:

- **Oral communication channels:** seminars, conferences, workshops, exhibitions, formal and informal meetings, etc.
- **Written communication channels:** websites, brochures, newsletters, articles in scientific journals, articles in generalist publications, press releases, postings on social networks, etc.

For the SnowBall project, the mechanism for selecting the most appropriate dissemination channels must answer the following questions:

- Which are credible sources of information for the target audience groups?
- In what context are more likely to pay attention to messages sent from the SnowBall consortium?
- How many people can be informed on a certain communication channel?
- What is the cost for a certain communication channel ?
- What is the time required for a communication channel to prepare a dissemination message?

4.8.3. Activity 8.3. Actions of dissemination and education.

The following outlines are followed for each dissemination activity:

- Consistent visual identity;
- The project logo has to be visible;
- Mention of partners and financiers;
- All documents have to include a standard paragraph that mention the name and the indicative of the project, the financier.

4.8.3.1. Attending national and international conferences

One of the best appropriate ways to disseminate the scientific results of the project SnowBall is the scientific conferences message. Snowball consortium has participated with oral presentations and posters at relevant events for the topics addressed in the the project. There have also been submitted some articles for publication in relevant journals for the project objectives. At the end of the project will be organized a conference dedicated to the presentation of the results.

4.8.3.2. The project brochure

The brochure contains information about the the project objectives and results structured in an attractive manner and in non-technical language, understandable by the general public. A first bilingual version was performed. The final version will be distributed before the official end of the project.

4.8.3.3. Newsletter

The first e-newsletter (electronic format) was elaborated and downloaded on the project website and distributed to the end-users of the project SnowBall.

5. ANNEXES

- **Annex A. Annual Progress Meeting (2015) – AGENDA;**
- **Annex B. Validation Plan for remote sensing of snow wetness .**

Annex A

SnowBall – Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective

Annual Progress Meeting (2015) - AGENDA
Date: 26-28 of October 2015
Venue: Timişoara, West University of Timişoara, Bd. Vasile Pârvan, 4, 300223-Timişoara, Room A01

26th of October 2015

16:30 – 17:30	Project management Technical / Financial Reporting, Deliverables, Templates	NMA / All
17:30 – 18:30	Steering committee meeting	NMA

27th of October 2015

9:00 – 9:10	Welcome NMA; Welcome WUT Round Table Introduction of Partners	
WPs Progress Reports		
9:10 – 9:55	**WP2 – In-situ snow parameters measurements** Activity 2.1 – Design and implementation of new snow measuring devices and equipment. Activity 2.2. – Snowpack parameters observation and measurements Activity 2.3. – Create and set-up of a spatial database managed by GIS software Activity 2.4. – Elaboration of spatial products using the spatial database	NMA, NR, NIHWM, WUT
9:55 – 10:40	**WP3 – Satellite remote sensing, data fusion and modelling of snow parameters (snow wetness products)** Activity 3.1. – Single sensor algorithm porting to Sentinel Activity 3.2. – MWS algorithm and product Activity 3.3. – New multilayer snow model module in NOAH	NR, NMA, NIHWM
10:40 – 11:25	**WP4 – Climate change impact on snow-related hazards** Activity 4.1. – Snow-related climate variability and change and associated impact Activity 4.2. – Variability and change in flash floods with snow melt contribution Activity 4.3. – Variability and change in avalanche statistics	NMA, UTCB, NIHWA, WUT
11:25 – 11:40	**Coffee break**	
11:40 – 12:25	**WP5 – Aquifer replenishment modelling from snow melt infiltration** Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone. Activity 5.2. – Aquifer modelling Activity 5.3. – Pattern matching and climate scenarios	UTCB, NIHWA

12:25 – 14:00	**Lunch**	
14:00 – 14:45	**WP6 – Assimilation of snowpack parameters in the National Flood Forecasting and Warning System** Activity 6.1. – Update the LC/LU map for the study area using high spatial resolution satellite images Activity 6.2. – Design of the algorithms and methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models	NIHWM, NMA, NR
14:45 – 15:30	**WP7 – Avalanche inventory, release and hazard mapping** Activity 7.1. – Develop avalanche detection algorithms Activity 7.2. – Change- detection algorithm for Sentinel-1 and Sentinel-2 Activity 7.3. – Avalanche simulation	WUT, NR, NMA
15:30 – 15:45	**Coffee Break**	
15:45 – 16:15	**WP 8 Promotion and Dissemination** Activity 8.1. – Project website Activity 8.2. – Dissemination strategy Activity 8.3 – Dissemination and training actions	NMA / All
16:15 -18:00	**Discussions**	All

28th of October 2015

9:00 – 11:00	Progress report in 30 November 2015 Next 2016 meeting Field campaigns	NMA / All
11:00 – 12:00	Final discussion / End of Meeting	All

Annex B

Validation plan for remote sensing of snow wetness

1 Introduction

The overall SnowBall project objective is to explore and develop methodology supporting the vision of developing a future service providing national authorities with hind-cast and real-time snow and avalanche information retrieved from earth observation data. SnowBall is aiming at providing and demonstrating the methods required for a snow service to deliver geospatial products on the seasonal snow cover (snow cover extent, melt state, snow water equivalent) derived from satellite data, to the scientific community in Romania, policy makers, users of snow information and the public. To meet its overall objective, SnowBall has identified six key project objectives. These key objectives and the related sub-objectives are directly mapped onto the tasks undertaken in each of the work packages:

- Improve the spatial and temporal resolution of in-situ snowpack parameters measurements (WP 2)
- Development of algorithms and implementation of a prototype snow monitoring system combining Sentinel-1/-3 satellite data, weather station data and hydrological modelling for snowpack parameters estimation (WP 3)
- Assess the impact of climate change on the snow-related resources and hazards (WP 4)
- Define and test a reliable methodology for the snowmelt infiltration component of the hydrogeological cycle (WP 5)
- Develop and implement a data assimilation procedure for adjusting the snowpack related state parameters within the snow models module of the hydrological forecasting models (WP 6)
- Develop methods for avalanche detection, modelling and hazard assessment (WP 7).

The remote sensing part of WP 3 will develop an algorithm and a product for retrieval of snow surface wetness. The sub-objectives of this work are:

- Adaptation of optical snow surface wetness algorithm to Sentinel-3 OLCI and SLSTR sensors
- Adaptation of SAR snow surface wetness algorithm to Sentinel-1 SAR
- Based on the single-sensor algorithms, develop a multi-sensor/multi-temporal algorithm for retrieval of snow surface wetness
- Validate the snow surface algorithms based on in-situ measurements
- Develop a processing chain for a pre-operational snow surface wetness product to be tested at large-scale in Romania

The algorithms will in a systematic and stepwise manner be implemented, validated and demonstrated. The work starts with the single-sensor optical and SAR algorithms. These will be individually validated before the next step, development of a multi-sensor/multi-temporal algorithm. A high-performance processing chain will be implemented for this algorithm in order to produce products with daily coverage of Romania. The products will be extensively validated, and then demonstrated within applications for flood warnings and snow avalanche hazard warnings.

The optical wet snow (OWS) product provides five wetness classes from dry snow to snow soaked with water, this according to the *International classification of seasonal snow on the ground* (Fierz, 2009) (Figure 1-1). The product is aiming for the use of Sentinel-3 OLCI and SLSTR as data source, and is also developed and validated for the use of Terra MODIS and Suomi NPP VIIRS data- The SAR wet snow (SWS) product provides two classes, one for wet snow and another which represents either bare ground or dry snow (Figure 1-2). A novel multi-sensor/multi-temporal product based on sensor fusion of Sentinel-3 and Sentinel-1 data provides the same five snow classes as the optical product.

Code	Class [vol. %]	Colour
220	Dry snow (0%)	
221	Moist snow (0-3%)	
222	Wet snow (3-8%)	
223	Very wet snow (8-15%)	
224	Soaked snow (>15%)	

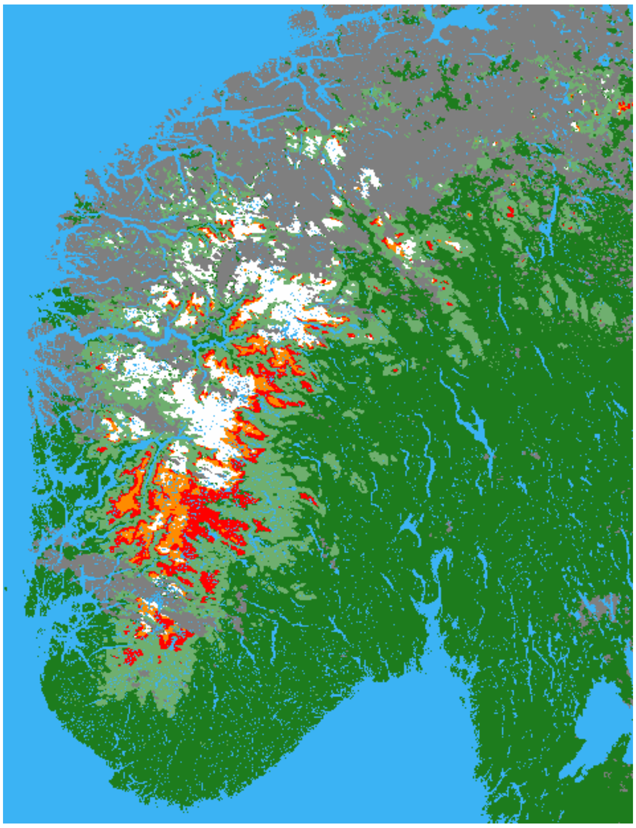


Figure 1-1. The OWS classes (left) and an example of an OWS product for southern Norway (right).

Code	Class	Colour
230	Wet snow	
231	Dry snow or bare ground	

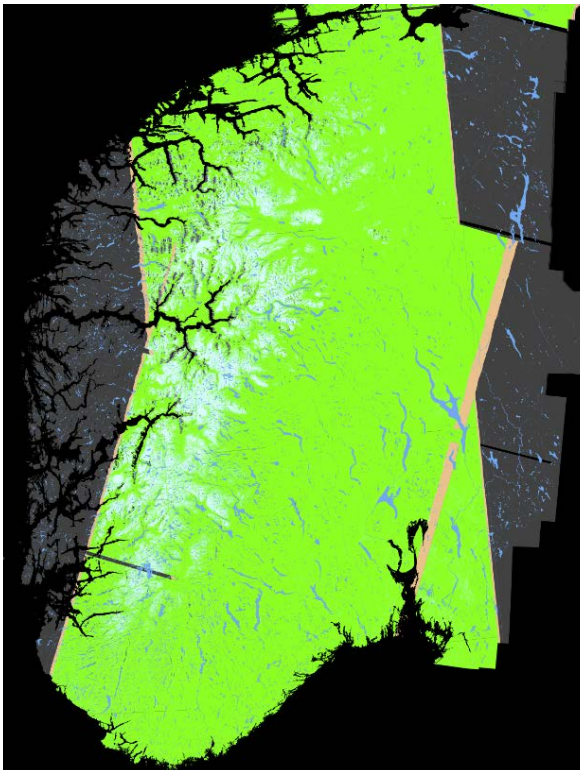


Figure 1-2. The SWS classes (left) and an example of an SWS product for southern Norway (right).

An important part of the product development is the calibration and validation. The work can be split into three main tasks:

- The algorithm calibration and validation (cal/val)
- The diagnostic data analysis
- The large-scale product validation.

The aim of this report is to document the plans for the validation work for the wet snow retrieval algorithms and products in the SnowBall project. Chapter 2 starts with an overall description of the validation approach. This is followed by a description of the product domains, test sites and data sources in Chapter 3. Thereafter follows in Chapter 4 a description of the planned diagnostic data analysis, and in Chapter 5 a description of the calibration and validation work based on the cal/val stations. Chapter 6 follows with a description of the large-scale product validation work. The report concludes with Chapter 7 providing a summary of the report and overall conclusions. The appendices include field measurement protocols and field report templates.

2 Validation approach

The development of a remote sensing product – in this case the snow wetness product – includes various stages and datasets for development and validation:

A. Diagnostic data and analysis
B. Algorithm calibration and validation
C. Product validation

Data will be collected in both countries.

The purpose of the diagnostic analysis is to obtain an understanding of the geophysical conditions behind the signal measured remotely for the determination of algorithm performance and limitations. The retrieval results of candidate algorithms are analysed under natural variability and the relationships to the diagnostic data are studied. The diagnostic data represent all relevant variables that can be measured (in practice), and they should be collected to include as much natural variability as possible, like seasonal variability and for different land cover and topography.

When a proper understanding is obtained on how the candidate algorithms work under different conditions, one algorithm may be chosen. The next step would typically be algorithm calibration and validation. Through the calibration a quantitative relationship, preferably of high quality, would be established between the satellite measurements and physical (or categorical) entities. This is done through a comparative analysis of satellite retrieval results and independent measurements of high quality, usually in situ measurements.

The final step would typically be product validation. The purpose of this is to study and quantify the product quality in general over the whole product domain. For the snow wetness product the general behaviour of the product can be reasonably validated against the temporal development of the air temperature. Supplementary snow depth measurements would be useful to control that the product only snows snow wetness values for snow-covered areas. Preferably a large number of in situ points (weather stations) should be used, covering the whole product domain (Romania and South Norway).

The three major steps described above do not necessarily follow each other in a strictly sequential way. For instance, calibration and validation might be followed by further diagnostic studies in order to determine limitations of the retrieval algorithm and to obtain a more comprehensive understanding of the physical processes affecting the performance of the algorithm.

3 Product domains, test sites and data sources

3.1 Product domains

Product domains for Romania and Norway have been fixed to comparable sizes. The whole Romania is covered, while the southern part of Norway is included, see Figure 3-1.

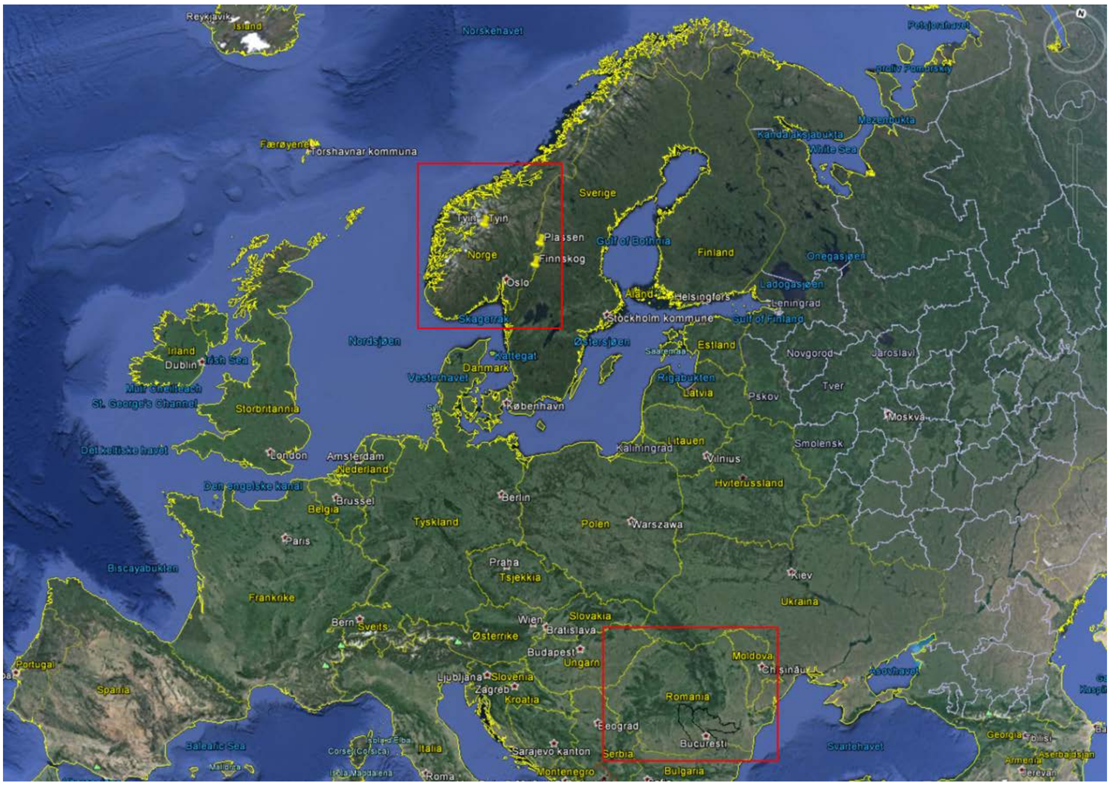


Figure 3-1: The product domains for Romania and Norway.

The products are of 1 km grid resolution in UTM projection of datum WGS 84. The corner coordinates are listed in Table 3.1.

Table 3.1: Corner coordinates of the product domains.

	Romania	Norway
UTM zone	35	33
North-west corner	426543, 5321643	-76000, 7060000 N
South-east corner	713487, 4830826	400000, 6440000 N

3.2 Sites and data sources in Romania

NMA has been using the upper part of the Arges river catchment for snow depth and snow density measurements for the last 35 years – in order to evaluate the snow water content used in hydrological evaluation (water resources). An extended area including the Arges site and the upper part of the Ialomita river catchment (Ialomita site) is used here for diagnostic data collection.

3.2.1 Sites for diagnostic data

The site for diagnostic data collection (Figure 3.2) has been selected as the upper sector of the Arges and Ialomita river catchments (the Arges and Ialomita sites), with altitudes of about 500 to 2500 m.

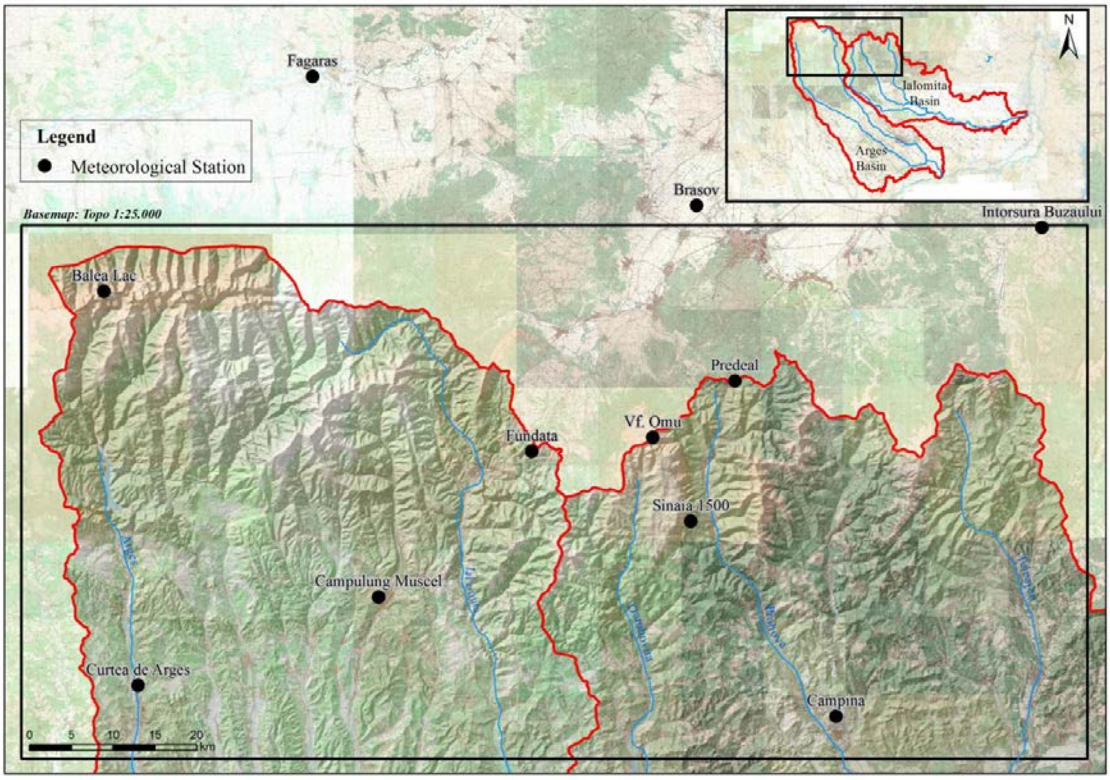


Figure 3-2. Romanian test area – the upper sector of the Arges and Ialomita river catchments

The Arges River Basin, located in southern of Romania, is a tributary of the Danube River, with a total area, 12,550 km^2, of which the upper sector is of 3,158 km^2. The upper sector of the Arges river is represented by mountains, including the highest altitudes in the country: Moldoveanu Peak (2544 m) and Negoiu peak (2535 m) are located on the southern slope of the Fagaras Mountain. The drainage density is between 1.1-1.4 km/km^2 and the river slopes about 80-150‰, while the mean altitude varies between 1000 to 1200 m. The main tributaries in the upper sector of the Arges River are Valsan, Doamnei and Tragului. 70% of the accumulated water volume is contained in the upper river sector. Here are natural lakes and reservoirs (storage lakes). The main classes of the land use/land cover are: forests (66%), agriculture (26%), artificial surfaces (7%) and hydrographical network – rivers and lakes (1%).

The Ialomita River Basin, located in southern of South Meridional Carpathians, is a tributary of the Danube River, with a total area of 10,350 km^2. The catchment area is composed of three main levels of relief: mountains, hills and plains, in which the upper basin occupies mostly, only the first two forms of relief. The Ialomita river basin limit, in the upper sector is the massive peaks of mountains Leota, Bucegi, Clăbucet and Ciucaș from Meridional Carpathians and Subcarpathians hills. Upper Ialomita runs from 2310 m to 600 m on about 28 km. The drainage density is about 0.6-0.8 km/km^2 and the river slope is about 71‰. Here are natural lakes and reservoirs (storage lakes). (http://www.limnology.ro/water2010/Proceedings/31.pdf)

The Arges site has been used since 1980 for snow measurement campaigns (total area of the two river catchments is about 5748 km^2) supporting applied research in remote sensing. The campaign measurements (Figure 3.3.), snow depth and snow density measurements, are used to evaluate the snow water content used in hydrological evaluation (water resources) within the storage reservoirs.

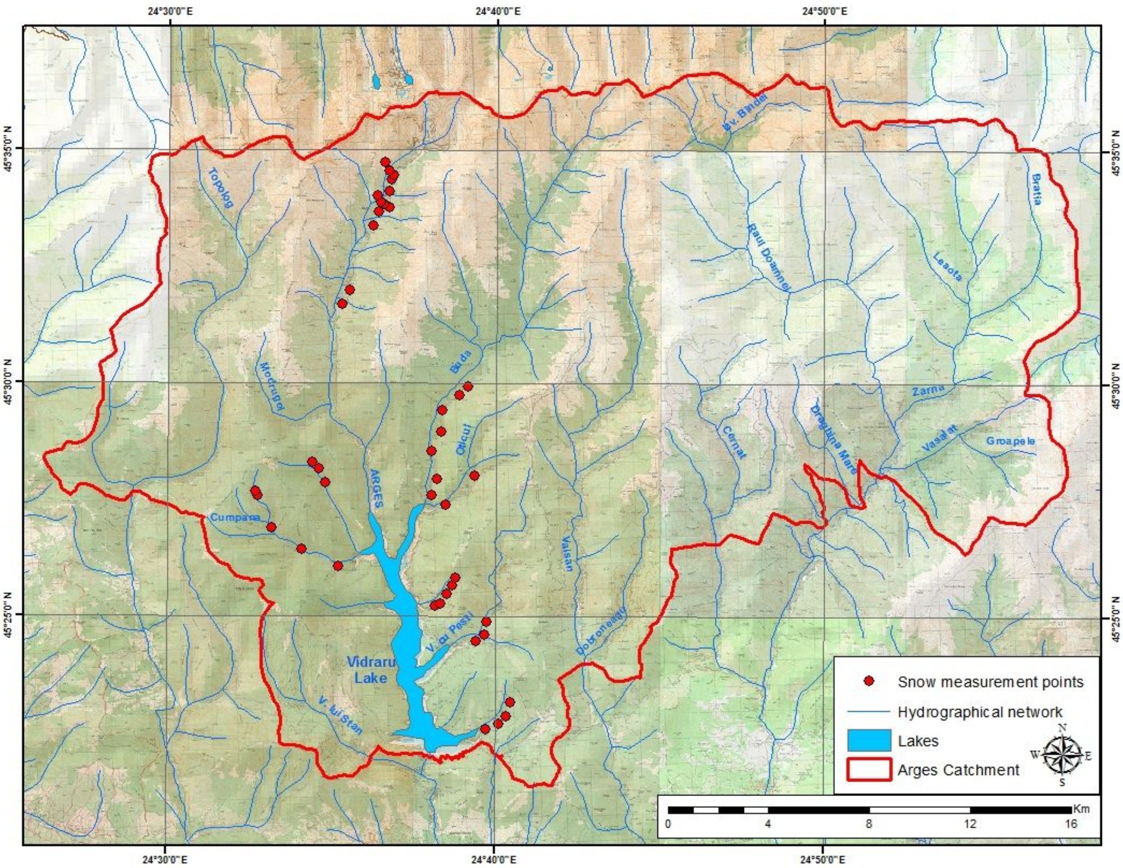


Figure 3-3. The snow measurements campaigns

There are eight meteorological stations in the diagnostic area, all operated by the National Meteorological Administration (NMA). They are located at Curtea de Arges (449 m.a.s.l.), Campina (461 m a.s.l.), Campulung Muscel (690 m a.s.l.), Fundata (1376 m.a.s.l), Sinaia (1500 m a.s.l.), Predeal (1096 m a.s.l.), Balea Lac (2037 m a.s.l.) and Varful Omu (2505 m a.s.l). Additional in-situ data will include measurements from field campaigns that will take place during the project lifetime, and meteorological data from mobile meteorological stations. About 20 air temperature sensors will be deployed for the winter 2015-2016 related to the field campaign site of Sinaia.

No. Crt.	Weather station	General information	Coordinates	Measured parameters used in the project	Other information
1	Bâlea Lac	01.11.1978; many 2500 m peaks around; glacial Balea Lake (100 m)	Latitude: 45° 36’ 14”; Longitude 24° 36’ 53"; Altitude: 2070 m a.s.l.; It is situated in the alpine.	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution, frozen deposits	Soil: metamorphic rocks, Spodisols. Hydrographical network : Glacial lake Balea is at 100 m distance from the station; Alpine vegetation; Anthropic activities: tourism and sheep grazing.
2	Vf. Omu	08.09.1927; first mountain peak weather station; the highest Romanian weather station.	Latitude: 45° 26’ 45”; Longitude 25° 27’ 24"; Altitude: 2504 m a.s.l.; It is situated in the	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution, frozen	Hydrographical network is at 2 km distance from the station; Alpine vegetation; Anthropic activities: tourism and sheep grazing.

			alpine.	deposits;	
3	Sinaia 1500	04.12.1960	Latitude: 45° 21’ 18”; Longitude 25° 30’ 51"; Altitude: 1510 m a.s.l.; Mountain weather station	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution, frozen deposits.	Hydrographical network: 2 tributaries of Prahova river; Forests and alpine vegetation; Anthropic activities: tourism and sheep grazing.
4	Predeal	1927 - first location; From 1985 - current location	Latitude: 45° 30’ 22”; Longitude 25° 35’; Altitude: 1090 m a.s.l.; Mountain weather station	From 14 January 1999 - automatic weather station (MAWS), with sensors for almost all meteorological parameters.	Hydrographical network: Prahova and Timis Rivers (+ tributaries); *Vegetation: Coniferous forests predominantly;* Anthropic activities: tourism (winter sports)
5	Fundata	01.12 1950 - first location; From 22.12.1954 - current location	Latitude: 45° 25’53"; Longitude 25° 16’18"; Altitude: 1384 m a.s.l.; Station placed on the top of a hill surrounded by mountains	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution, frozen deposits;	Vegetation: beech and fir forest mixed with alpine grass fields; cultures Anthropic activities: agro- tourism, forest activities, sheep grazing.
6	Câmpulung Muscel	1943	Latitude: 45° 16’29"; Longitude 25° 02’12"; Altitude: 681 m a.s.l.; Station placed on the top of a hill	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution	Hydrographical network: Dâmboviţa, Argesel, Râul Târgului, Bughea, Bratia Rivers Vegetation: deciduous, coniferous, mixed forests; Anthropic activities: economic activities, brick factory.
7	Curtea de Argeş	Sept. 1952 - first location; From May 1973 - current location	Latitude: 45° 10’44"; Longitude 24° 40’11"; Altitude: 448 m a.s.l.; Situated in Subcarpathians hills	Air temperature, snow depth, density and snow water equivalent; visual observation on: snow cover distribution	Hydrographical network: Arges River and tributaries; artificial lakes Vegetation: deciduous forests, orchards; Anthropic activities: agricultural and industrial activities, livestock.
8	Câmpina	January 1948	Latitude: 45° 08’37"; Longitude 25° 44’00"; Altitude: 462 m a.s.l.;	Air temperature, snow depth, density and snow water equivalent; actinometrical measurements	Hydrographical network: Prahova and Doftana rivers + tributaries Vegetation: deciduous forests, orchards; crops Anthropic activities: industry (oil processing)

3.2.2 Sites for algorithm cal/val

Two cal/val sites have been established in the intra-Carpathian depressions. The sites are situated in the region of Targu Secuiesc and Joseni, respectively, at no more than a few hundred meters away from NMA's Targu Secuiesc (566 m.a.s.l) and Joseni (747 m.a.s.l.) weather stations. The weather stations of Targu Secuiesc and Joseni have been established in 1954 and 1955, respectively.

Joseni is located in the Giurgeu depression with altitude about 640-850 m.a.s.l., along the Mures River. The surrounding region of Joseni station has altitude about 730-850 m.a.s.l. and has an area about 1621 km^2. The slopes around the depression have altitudes from 800 to 1200 m.a.s.l. The surrounding mountains go up to 1800 m.a.s.l. The relief is formed by the foothills, terraces and residual relief.

Targu Secuiesc is located in the Targu Secuiesc Depression at about 560 m.a.s.l. The relief of the Targu Secuiesc depression is descends from the north (600 m a.s.l.) to south (530-550 m.a.s.l.) on about 35 km from north to south and 15-20 km from east to west, with 600 km^2. It is surrounded by mountains with altitudes varying from 600 to 1640 m.a.s.l.

Both sites will be used to study the performance of the retrieval algorithms under 'controlled' conditions without topographic influence, bridging in situ point measurements and satellite data scales. The weather stations are useful as accurate in situ references for three study locations, and elsewhere for setting boundary conditions of air temperatures at the time of satellite acquisitions. In addition to the daily snow depth and snow cover measurements and 5-days snow density, a mobile station will sample the profile ground temperature, snow wetness, temperature, and depth with a higher temporal frequency. A video camera will take hourly snapshots to help evaluate the snow cover at the cal/val site.

3.2.3 Meteorological stations for product validation

Snow depth, snow density and snow cover is reported by all the 158 weather stations of the NMA network. The measured snow parameters together with the air temperature will be used for additional quality-checking of the snow products. The map of the weather station network is shown in Figure 3-6. There are no dedicated snow stations operated by NMA. However, for the needs of the SnowBall project, snow stations will be deployed, at the same location of eight weather stations – and possibly at a few other locations in the diagnostic site area. They will be equipped with ultrasonic snow depth, snow temperature and snow wetness sensors. Measurements will usually be taken on an hourly basis. Data will be transferred by cellular networks, and the stations will run on solar power.

Measurements go as far back as 1927, but the quality is variable and data may be missing in periods. The longest running time series is from 1960. Measurement quality has typically increased with time, and the highest quality data are from the last 30-40 years.

The instrumentation of the stations is identical. Measurements are usually taken on a daily basis for snow depth and snow cover and on a 5-days basis for snow density. Data is transferred through the NMA communication network to the main meteorological database (Oracle).

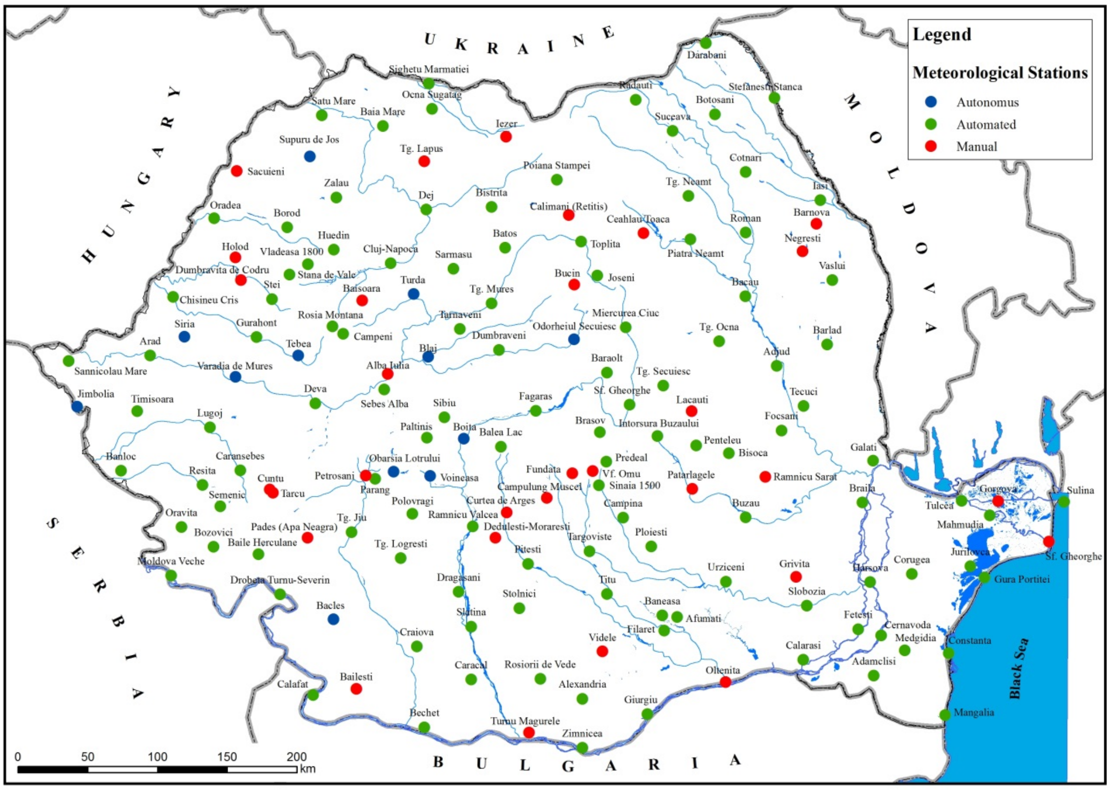


Figure 3-4. Romanian weather stations network (including snowpack measurements)

3.3 Sites and data sources in Norway

NR's well-established sites for snow studies in Jotunheimen are here used for both collection of diagnostic data and for algorithm calibration/validation.

3.3.1 Sites for diagnostic data and cal/val

Valdresflya and the western part of the Jotunheimen mountain region (Figure 5-4) were established as sites for snow remote sensing algorithm development, calibration and validation in 1997 (total area ~265 km^2). NR has since then carried out numerous field campaigns combined with data acquisition from airborne sensors and spaceborne high-resolution sensors as reference data for parallel satellite acquisitions (Solberg et al., 2010). Valdresflya is a rather flat mountain plateau at altitudes of about 1200-1400 m a.s.l. The surrounding region in Jotunheimen is composed of both steep and more eroded peaks with U-shaped valleys in between. The mountains are typically steeper in the west than in the east. Most of the region is above the tree line. Valdresflya was chosen as a main site for diagnostic data and calibration/validation as topographic effects could be discarded. It is then possible to bridge the scale gap between in situ measurements (points) and satellite data pixels (IFOVs of typically 0.01-1.0 km^2) as the site is very homogeneous, not only with respect to topography, but also land cover, snow accumulation and snow ablation.

3.3.2 Snow stations and meteorological stations for product validation

Snow depth is reported by many stations operated by the Norwegian Meteorological Institute (MET Norway), Norwegian Water Resources and Energy Directorate (NVE), Norwegian Public Roads Administration (SVV) and Norwegian National Rail Administration (JBV). Those located in southern Norway are shown in Figure 3-5.

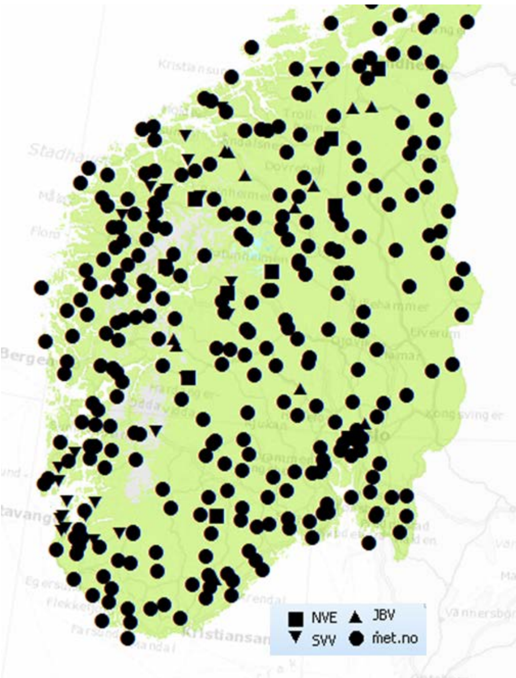


Figure 3-5: Operational snow stations in southern Norway.

Those operated by the Norwegian Water Resources and Energy Directorate are dedicated for snow and might be regarded as the most accurate and reliable stations. Currently NVE operates 26 automated snow stations for hydrological purposes distributed all over Norway. 18 stations are located in southern Norway (Figure 3-6). The majority of stations are situated in the mountains, but there are also costal and other low-land locations included. Stations measure SWE or SD, or both. Measurements go as far back as 1957, but the quality is variable and data may be missing in periods. The longest running snow pillow time series is from 1967. Measurement quality has typically increased with time, and the highest quality data are from the last 15-25 years.

The instrumentation of the stations varies. Most stations include instruments for measuring SWE, usually at least one 2-m diameter white PVC pillow filled with ethanol or glycol, with pressure sensors measuring the hydrostatic pressure. Some stations also include snow weights and gamma sensors. Ultrasonic sensors are used for snow depth. Measurements are usually taken on an hourly basis. Daily data might be derived from those. Data is transferred by cellular networks, and the stations run on solar power.

Some of the stations are used as research stations. The most comprehensive is Filefjell Research Station, which includes instruments of all abovementioned types, also multiple instruments but of different manufacturers.

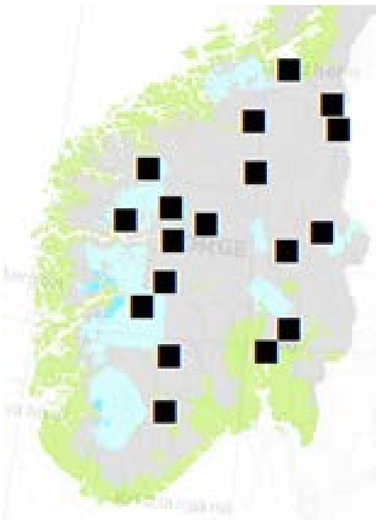


Figure 3-6: Network of NVE snow stations in Norway.

3.4 Satellite data

Optical data from Terra MODIS (NASA) and Suomi NPP VIIRS (NASA/NOAA) have been used in the initial work, and is planned to be substituted with Sentinel-3 (ESA) when it starts to deliver data operationally in 2016. Sentinel-1 SAR data (ESA) become available already in the first project year and is therefore applied throughout the project. The sensors and the data they provide are briefly described in the following.

3.4.1 Terra and Aqua MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south (descending orbit) across the equator in the morning (10:30 UTC), while Aqua passes south to north (ascending orbit) over the equator in the afternoon (13:30 UTC). The corresponding night passes are 22:30 and 01:30 (relevant for temperature measurements). Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days. The Terra satellite was launched 18 December 1999, and the Aqua satellite was launched 4 May 2002.

The MODIS instrument is acquiring data in 36 spectral bands covering the spectral range 405-14,385 nm. The spatial resolutions are 250 m for bands 1-2, 500 m for bands 3-7 and 1000 m for bands 8-36. The quantization is 12 bits, and the swath width is 2330 km.

3.4.2 Suomi NPP VIIRS

The Suomi NPP satellite was launched in October 2011. The VIIRS sensor might be regarded as an upgraded AVHRR sensor taking into account the experiences with MODIS. VIIRS operates in 22 wavelength bands from visual to thermal. VIIRS includes the AVHRR channels. Five channels from visible to thermal are of 375 m spatial resolution, while there are 16 channels of 750 m spanning approximately the same wavelength range. In addition there is a very light-sensitive band spanning the visual and near-infrared part of the spectrum for night observations (when there is moonlight). The swath width is 3040 km, and the nominal descending orbit passage time over the equator is 13:30.

3.4.3 Sentinel-1

Sentinel-1 carries an advanced radar instrument to provide an all-weather, day-and-night supply of imagery of Earth’s surface. The C-band Synthetic Aperture Radar (SAR) builds on ESA’s and Canada’s heritage SAR systems on ERS-1, ERS-2, Envisat and Radarsat. Sentinel-1A was launched 3 April 2014, and Sentinel-1B is scheduled for launch in 2016. The nominal operational lifespan is 7 years (with consumables for 12). The satellite has a repeat cycle of 12 days. The C-band SAR operates in four modes: 1) Strip Map Mode (SMM), 80 km swath, 5 x 5 m spatial resolution; 2) Interferometric Wide Swath (IWS), 250 km swath, 5 x 20 m spatial resolution; 3) Extra-Wide Swath Mode (EWSM), 400 km swath, 25 x 100 m spatial resolution; and 4) Wave-Mode (WM), 20 km x 20 km, 5 x 20 m spatial resolution.

3.4.4 Sentinel-3 OLCI and SLSTR

Sentinel-3A, planned to be launched in December 2015, is primarily a mission to support services related to the marine environment, with capability to serve numerous land-, atmospheric- and cryospheric-based application areas. The Ocean Land Colour Instrument (OLCI) is based on the heritage from Envisat's Medium Resolution Imaging Spectrometer (MERIS) instrument. The OLCI operates across 21 wavelength bands from ultraviolet to near-infrared and uses optimised pointing to reduce the effects of sun glint. The swath width is 1270 km, and the spatial resolution is 300 m. The Sea Land Surface Temperature Radiometer (SLSTR) is based on the heritage from Envisat's Advanced Along-Track Scanning Radiometer (AATSR). The SLSTR uses a dual-viewing technique and operates across eight wavelength bands providing better coverage than AATSR because of a wider swath width (1675 km for the nadir view angle). The spatial resolution is 500 m at visible and near-infrared wavelengths and 1 km at mid-infrared and thermal wavelengths.

4 Diagnostic data and analysis

This chapter describes the diagnostic data and the analysis of these for Romania and Norway. For the most important measurements a more detailed description is provided of the measurement principles and instrumentation.

Ideally, the same set of instrument and measurement protocols should be used in the two countries. However, due to some differences in the instrumentation in the countries and the heritage of protocols etc., there are some deviations. These deviations have been taken into account for making comparable measurements, i.e. by carrying out common field campaigns.

4.1 Romania

The diagnostic data collected by NMA in a SnowBall snow field campaign include those shown in **Error! Reference source not found.**.

Table 4.1: Diagnostic data typically collected during a snow field campaign by NMA.

Variable	Measurements principle	Instrument type
Snow spectrum	Field spectrometer	StellarNet using bare optical fibre
Snow liquid water	Time domain reflectometry	Dielectric probe
Snow density	Weight of 0.5 dm^3	Snow sampler of steel of 0.5 dm^3. Snow content is weighted with a spring type tubular scale
Snow depth	Snow stick	Carbon epoxy stick used by avalanche personnel. Scale of cm resolution
Snow cover	Aerial or VHR imagery	Third party service for aerial photo or satellite imagery ordered and purchased for a given date or period

The DSR measures the spectral range 200-1700 nm. The sensors are one 2048 element photo diode array (200-1150nm) and one thermoelectrically cooled, "graded index", InGaAs photodiode (900-1700 nm). The sampling intervals are 1.6 nm for 200-1150 nm and 2.5 nm for 900-1700 nm giving spectral resolutions of 3 nm at 700 nm, 10 nm at 1500 nm and 10 nm at 2100 nm.

Besides snow field measurements campaigns, air temperature sensors will be deployed every 100 m on the slope gradient from pic of Varful cu Dor down to the town of Sinaia. The sensors will record and store the temperature measurements every hour, with an accuracy of 0.5 °C and the data will be collected every 30 days.

4.2 Norway

The diagnostic data collected by NR in a snow field campaign will vary with the purpose of the campaign, but typically include those shown in **Error! Reference source not found.**. At least the five first are collected during the SnowBall campaigns.

The ASD Fieldspec Pro FR measures the spectral range 350-2500 nm. The sensors are one 512 element photo diode array (350-1000 nm) and two thermoelectrically cooled, "graded index", extended range InGaAs photodiode (1001-2500 nm). The sampling intervals are 1.4 nm for 350-1000 nm and 2 nm for 1000-2500 nm giving spectral resolutions of 3 nm at 700 nm, 10 nm at 1500 nm and 10 nm at 2100 nm. For the entire region 350-2500 nm there are 1512 channels.

The ASD Contact Probe is designed for spectroscopic contact measurements of solid raw materials. It includes internal light from a halogen bulb of colour temperature 2901K. It measures a spot of 10 mm diameter. We have custom made light shields to avoid stray light from the sun. Software has been obtained from the University of California, Los Angeles, including calibration constants, for transformation of radiance measurements into effective, optical snow grain size.

Table 4.2: Diagnostic data typically collected during a snow field campaign by NR.

Variable	Measurements principle	Instrument type
Snow spectrum	Field spectrometer	ASD Fieldspec Pro FR using bare optical fibre
Snow grain size	Contact spectroscopy	ASD Fieldspec Pro FR with ASD contact probe
Snow liquid water	Dielectric probe	The Denoth capacitance probe measuring permittivity of snow of area 13 × 13.5 cm^2
Snow density	Weight of 1 dm^3	Snow sampler of steel of 1 dm^3. Snow content is weighted with a spring type tubular scale
Snow depth	Snow stick	Carbon epoxy stick used by avalanche personnel. Scale of cm resolution
Snow cover	Aerial or VHR imagery	Third party service for aerial photo or satellite imagery ordered and purchased for a given date or period
Snow sample	Chemical analysis or particle study	Third party service for chemical analysis of ions and/or minerals and/or filtrates of larger particles (like soil and vegetation litter)

The Denoth meter is a capacitance probe measuring permittivity of snow of area 13 × 13.5 cm^2 (Techel and C. Pielmeier , 2011). A separate measurement of density is required to solve for the imaginary part of the permittivity, which is necessary to estimate liquid water content. The accuracy of measurements made by dielectric methods is ±0.5 vol. %. Additional uncertainty can arise if sensors near the surface are affected by solar radiation.

5 Algorithm calibration and validation

This chapter describes the calibration/validation (cal/val) data and procedures for the algorithm. The objectives are to calibrate the algorithm to give as accurate as possible quantitative results and validate the algorithm’s performance through the snow season. The sites for cal/val are described in the following, as well as the relevant variables to be measured, the measurement principles and the instrumentation.

The ideal cal/val site hase the following main characteristics:

- Open plain, at least 5 × 5 km (flat area with no tall vegetation; agricultural, pasture or mountain plateau);
- Includes a weather station;
- Area with substantial snow accumulation and snow cover for a longer period;
- Regular (daily) field measurements of snow wetness at satellite acquisition time.

Two such sites were identified and established in Romania in 2015. In Norway the cal/val site in Jotunheimen (Valdresflya), which was established in the 1990s, is used.

5.1 Cal/val stations in Romania

The locations of the two sites established are shown in Figure 5-1. Each site is located close to a meteorological station.

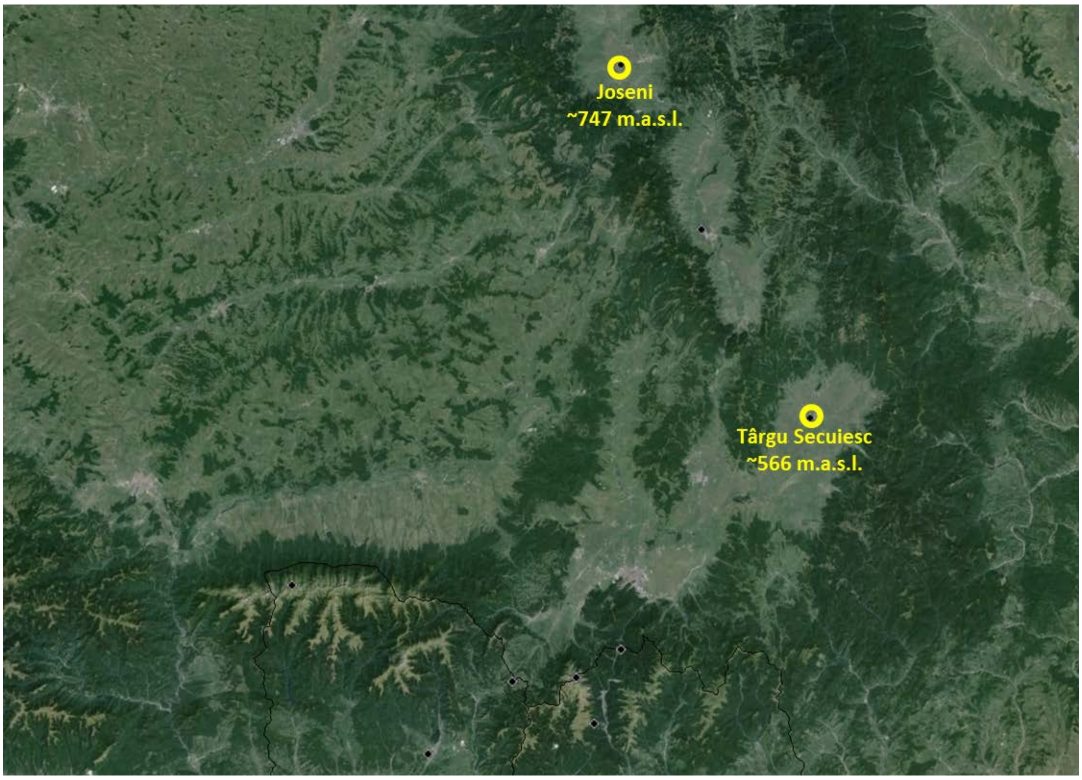


Figure 5-1: Cal/val stations chosen for Romania. These are operational meteorological stations that have been specially equipped for additional snow measurements to be used in the project.

The main agricultural crops in both Targu Secuiesc and Joseni areas are potato followed by wheat, barley, maize, sugar beet and vegetables. The layout of cal/val areas, which correspond to a subset of Sentinel-3 SLSTR 1 × 1 km IFOVs ("pixels"), are shown for the two sites in Figure 5-2 and Figure 5-3. The inner 3 × 3 pixels (in green) will be used for the analysis, while the outer border of 5 × 5 pixels (in blue) represents a positional uncertainty zone that should have similar quality as the inner part.

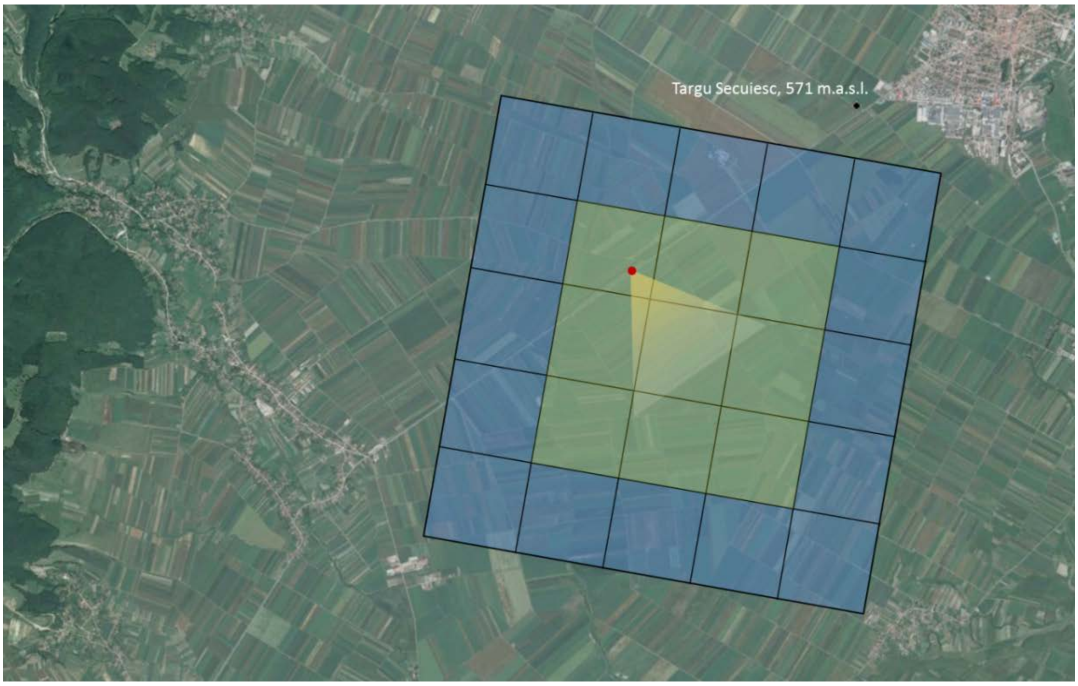


Figure 5-2: Targu Secuiesc meteorological station (black dot) and the satellite data site nearby. Squares are 1 × 1 km corresponding to SLSTR pixels. The red dot and the "illuminated sector" indicate the ideal position and direction for in situ photos of snow coverage.

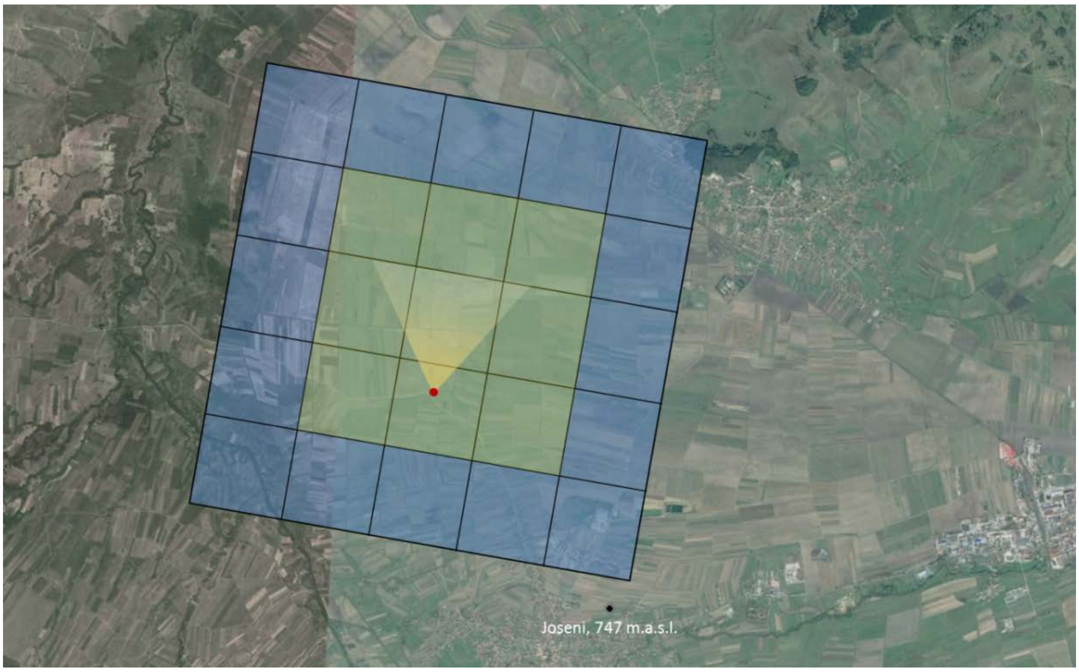


Figure 5-3: Joseni meteorological station (black dot) and the satellite data site nearby. Squares are 1 × 1 km corresponding to SLSTR pixels. The red dot and the "illuminated sector" indicate the ideal position and direction for in situ photos of snow coverage.

Snow stations will be deployed at the location of the existing weather stations. The stations are developed by a team of engineers and technicians at NMA and will be equipped with ultrasonic snow depth sensors, snow temperature, soil temperature and snow wetness sensors (Table 5.1). Measurements will be taken on an hourly basis. A CCTV camera will take hourly snapshots (during the day) of the cal/val area for assessment of the snow cover. Data will be transferred by cellular networks and the stations run on solar power.

Table 5.1: Cal/val snow station – sensor types and data acquisition.

No.	Parameter	Sensor/ instrument	Setup	Unit
1	Snow depth	2 x ultrasonic	At 2m above ground	cm
2	Snow profile temperature	5 x digital thermometer	At +10,+20,+30,+40,+50 cm (Tg. Secuiesc) At +8, +18, +28, +38, + 48 cm (Joseni)	°C
3	Snow surface temperature	1 x infra red thermometer	90^o FOV, 2 m height 30^o FOV, 2 m height	°C
4	Snow wetness	2 x moisture probe	At +15 and +25 cm (Tg.Secuiesc) At +15 and +24 cm (Joseni)	mc/mc (1)
5	Soil profile temperature	6 x digital thermometer	At -5, -10, -15, -20, -25 cm	°C
6	Snow cover	1 x CCTV camera 1 x still Camera	Mast, at 8m (Tg. Secuiesc) Mast, at 10m (Joseni) Hand held	N/A

(1) - should be converted to vol %.

Data acquisition frequency: Hourly for all instruments/sensors except the still camera (once a day around satellite overpass).

Transmission to the SnowBall database server: Daily, at 00:00 for the previous day for 1-5 and 6 (still camera), hourly for 6 (CCTV camera).

5.2 Cal/val station in Norway

The cal/val station to be used in Norway is Valdresflya in Jotunheimen. The site is situated within the test area used for diagnostic data collection in Jotunheimen. The general description of the site is in Section 3.3.1, while a more detailed description of Valdresflya cal/val site and instrumentation follows here.

The main aim here is to use the Valdresflya site (Figure 5-4) to study the performance of the retrieval algorithms under 'controlled' conditions without topographic influence and bridging in situ point measurement and satellite data scales. Additionally, the region west of Valdresflya is used to study topographic effects, including the influence of altitude, slope and aspect. The permanent weather stations are useful as accurate in situ references for three study locations, and elsewhere for setting boundary conditions of air temperatures at the time of satellite acquisitions.

The layout of cal/val area, which correspond to a subset of Sentinel-3 SLSTR 1 × 1 km IFOVs ("pixels"), are shown for the site in Figure 5-5. The inner 3 × 3 pixels (in green) will be used for the analysis, while the outer border of 5 × 5 pixels (in blue) represents a positional uncertainty zone that should have similar quality as the inner part.

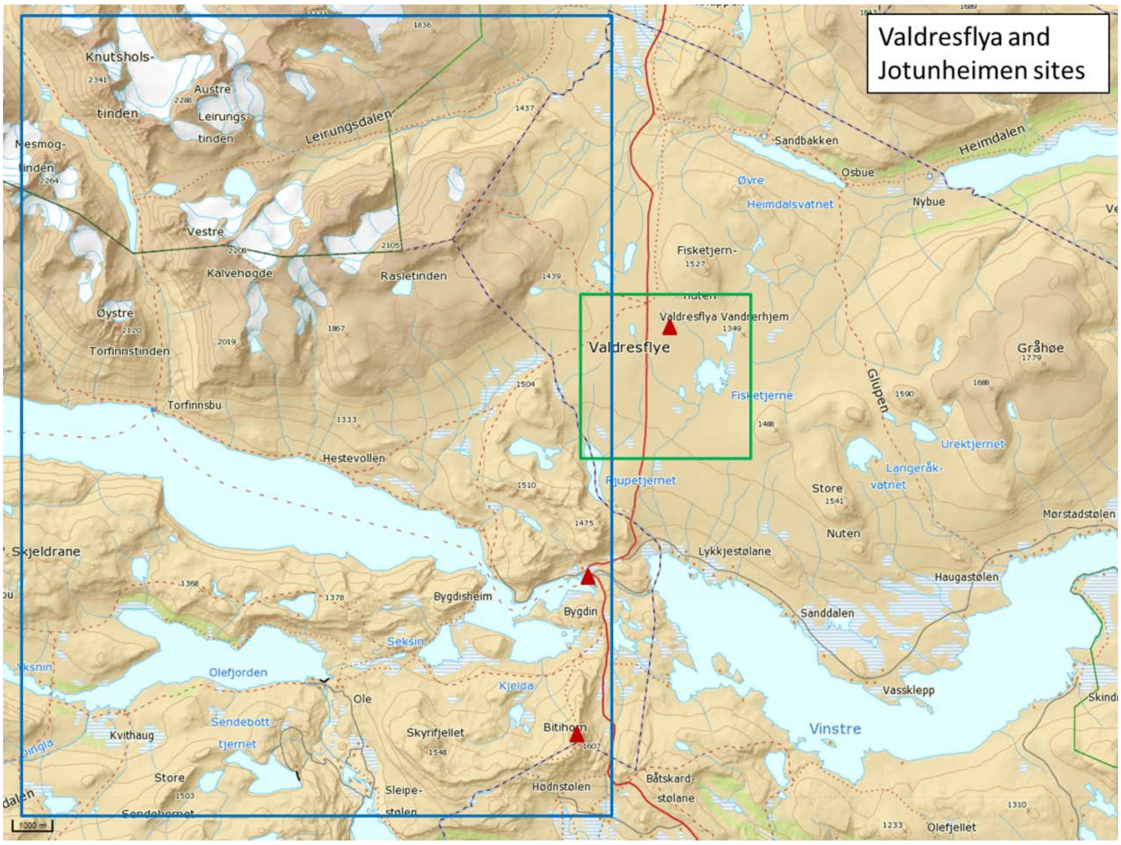


Figure 5-4: Valdresflya and Jotunheimen sites for diagnostic data and cal/val for a thorough study of the algorithm performance. The locations of the weather stations are shown as red triangles. The green rectangle represents the approximate extent of Valdresflya, while the blue rectangle shows the Jotunheimen site for topographic studies.

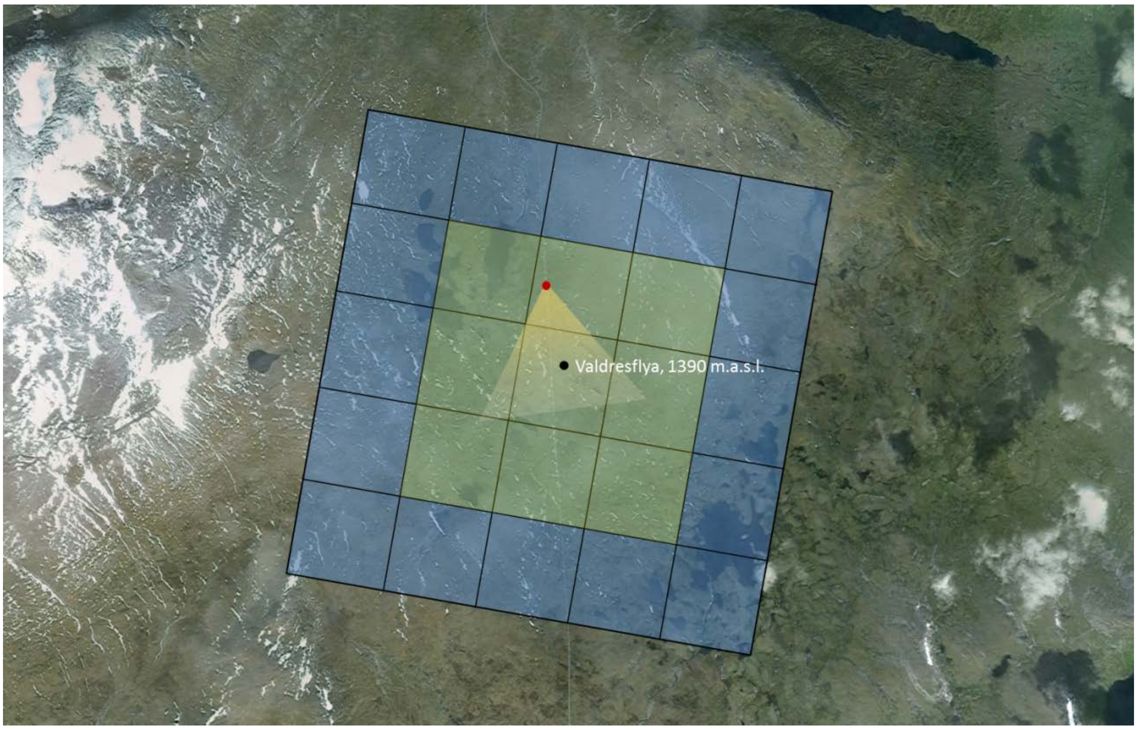


Figure 5-5: Valdresflya meteorological station (black dot) and the satellite data site nearby. Squares are 1 × 1 km corresponding to SLSTR pixels. The red dot and the "illuminated sector" indicate the ideal position and direction for in-situ photos of snow coverage.

There are three permanent meteorological stations in the region; all operated by the hydropower company Glommens og Laagens Brukseierforening (GLB). They are located at Vandrerhjemmet (in the middle of Valdresflya at 1389 m a.s.l.), just outside the mountain plateau at Bitihorn (1607 m a.s.l.) and at Bygdin (1060 m a.s.l.) The stations only measure air temperature and wind. GLB kindly make the data from these stations available to NR.

NR operates a mobile weather station to supplement the fixed stations. The station is used in the melting season to supplement the permanent stations with meteorological variables. The station builds on the HOBO Master Kit (M-TPA-KIT) and is supplemented with a 6 W solar panel (SOLAR-6W). It is instrumented for measurements of air temperature, humidity and radiation, see Table 5.2. The master kit includes a data logger. Data are dumped to a laptop when the station is visited.

Table 5.2: Mobile weather station used at Valdresflya in the melting season.

Parameter	**Sensor/ instrument**	**Unit**
Air temperature, top	1200093 HOBO S-THB-M002 Temperature/RH Smart Sensor	°C
Relative humidity, top	1200093 HOBO S-THB-M002 Temperature/RH Smart Sensor	%
Air temperature, bottom	1200093 HOBO S-THB-M002 Temperature/RH Smart Sensor	°C
Relative humidity, bottom	1200093 HOBO S-THB-M002 Temperature/RH Smart Sensor	%
Wind	1200191 HOBO Wind Direction and Speed	°, m/s
Wind gust	1200055 HOBO Wind	m/s
Solar radiation, upward	1200058 HOBO Silicon Pyranometer 300 to 1100 nm	W/m^2
Solar radiation, downward	1200058 HOBO Silicon Pyranometer 300 to 1100 nm	W/m^2

NR also operates a mobile spectral radiance station instrumented with a Spectral Evolution UDS-1100SA spectroradiometer measuring simultaneous upwelling and downwelling radiation (Figure 5-6). The UDS-1100SA is configured for standalone automatic and unattended collection of scans. The instrument uses a single, 512-element photodiode array with a spectral range of 320-1100 nm.

The system is configured with a 25° optic window for the bottom optics. The UDS-1100SA receives electricity from a 12 V solar powered battery. The instrument includes a data logger. Data are dumped to a laptop when the station is visited.

Figure 5-6: The mobile weather station (left) and the spectral radiance station (right) with the solar panel (middle) in Valdresflya spring 2015.

6 Product validation

This chapter describes the product validation, which is the validation of the products quality in general for the whole product domain throughout the year. As snow wetness cannot be measured in situ over the whole product domain (for a whole country in the case of Romania), we need to use proxy data to obtain a reasonable understanding of the product's performance in general. The very accurate understanding of the products performance is relying on the algorithm validation work. Additional measurements of snow wetness from "independent" sites are certainly welcome and will be collected – in particular from the test area in Romania, but such data will in any case be limited compared to the national network of meteorological stations.

6.1 Approach

6.1.1 Validation from meteorological station data

The national networks of meteorological stations are expected to be able to assist a reasonable good assessment of the overall product quality in the plains and elsewhere where the topography is not steep. In mountain areas the stations' representativeness on a kilometre scale needs to be assessed in each case.

Air temperature gives a reasonable indication whether the snow can be expected to be dry or wet. If the air temperature is well above 0°C, a higher level of liquid water content should be expected.

Wind speed is also a valuable additional parameter as wind drives the snowmelt speed for air temperatures above 0°C, and the snowmelt intensity strongly depends on the wind speed.

The snow wetness products should only provide wetness values when the snow cover is close to 100% FSC. The snow parameters measured at manual or automatic stations are therefore useful to assess whether the product also has caught the snow cover accurately.

6.1.2 Validation from test site data

The test sites will be equipped with automated measurement stations of various types (see Chapter 3). As the measurements take place several times a day, the temporal resolution makes direct comparison of accurate data with the product possible. This is however only possible for a very limited area where the station is representative, often for one product grid cell only (1 km^2).

Field campaigns in the test sites are also valuable for product validation. While the campaigns are limited compared to the number of products, and the spatial distribution of measurements is also very limited, the accuracy of each measurement is high.

6.2 Romania

6.2.1 Validation from meteorological station data

The network of meteorological stations in Romania is shown in Figure 6-1. The network includes 158 stations. Air temperature and wind are measured automatically on an hourly basis at all stations. The snow depth measurements (in cm) at the manned stations are taken daily at 06 UTC hour with a fixed ruler installed in the corners of an equilateral triangle with sides of 10 m (Romania Climate, 2008). At the same time the snow cover distribution is visually assessed. The snow density is measured every 5^{th} day using a dedicated device at 06 UTC (if there is a snow depth of at least 5 cm).

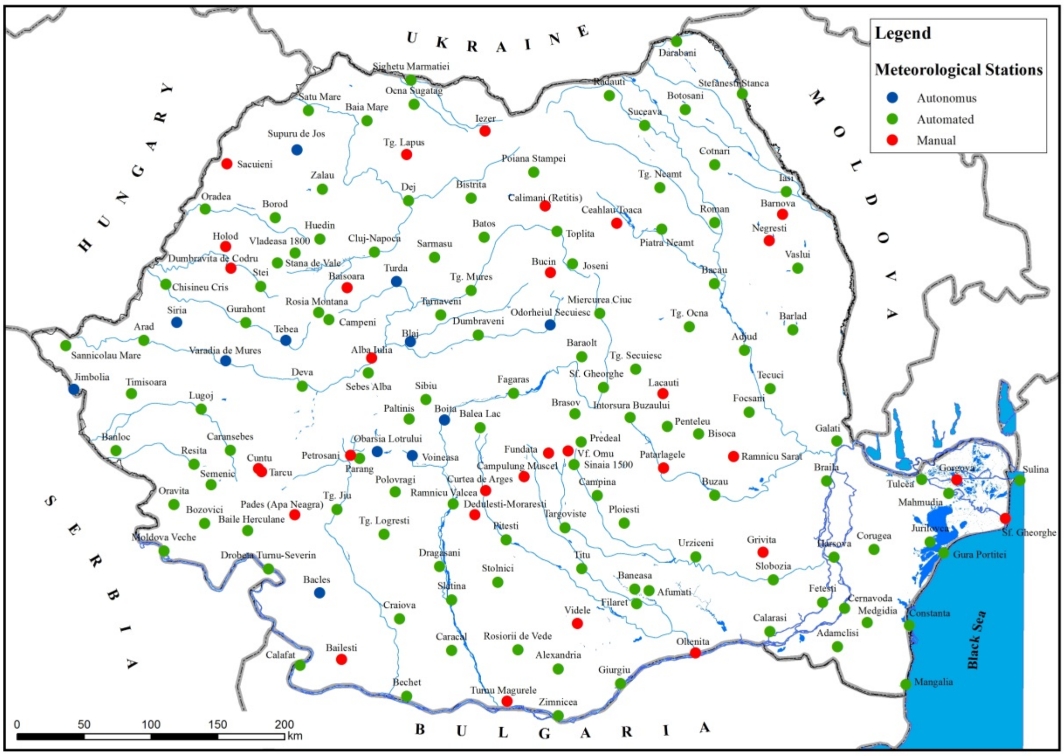


Figure 6-1. Romanian weather stations network (including snowpack measurements).

The weather stations have a good spatial coverage across the country, ranging from 1 to 2505 m.a.s.l. (Birsan, 2014). At the mountain level (including the inner depressions), there are about 40 weather stations from which 24 above the 800 m.a.s.l. The network is assumed to be able to assist a reasonable good assessment of the overall product quality in the plains.

6.2.2 Snow climatology

Romanian terrain is fairly equally distributed between mountainous, hilly and plains. The climate is transitional from temperate to continental with four seasons. Snow seasonality is shown in the maps below. The calculations are based on the period 1981-2010.

The first snow (Figure 6-2) is linked to the emergence of low temperatures (below 4°C) in late autumn and early winter and depends on latitude, closeness to the Black Sea, but especially on the altitude (Climate Romania, 2008). In general, in the mountains area, the date of the first snowfall occurs from the last day of October. On the peaks exceeding 2000 m, the average date of the first snowfall is recorded at the end of August.

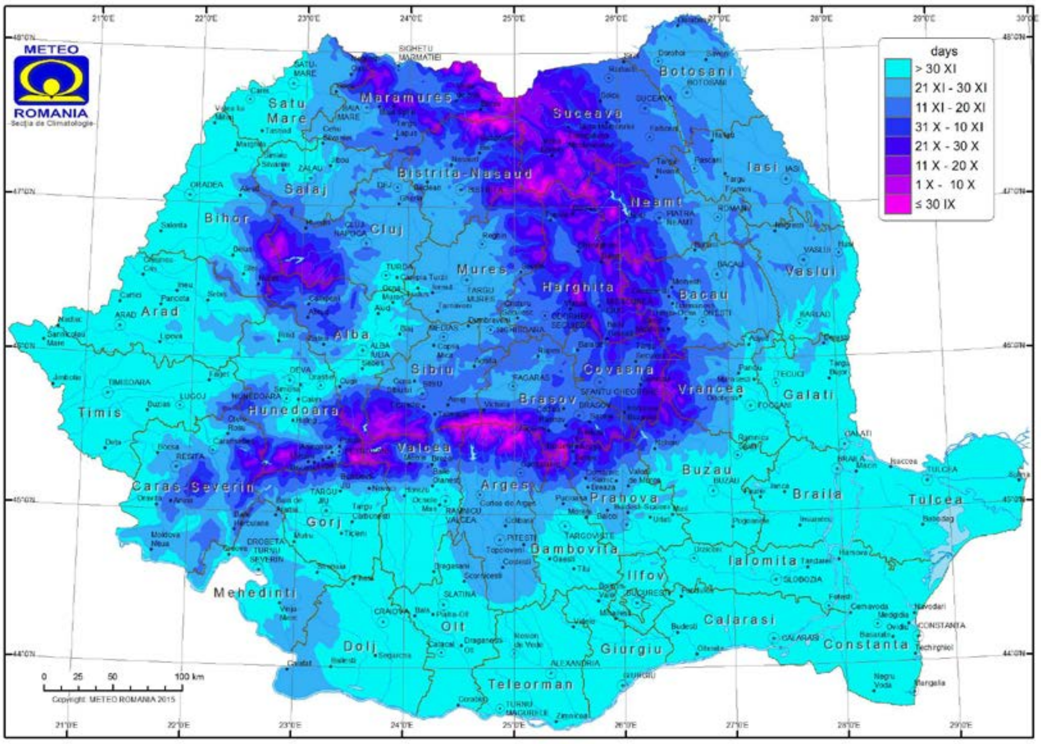


Figure 6-2: Annual average date of the first day with snow (1981-2010).

The last snow is linked to the process of air temperature rising, once the spring comes. The spatial distribution of the last day with snow (Figure 6-3) is relatively symmetrical with the one of the first snow. The mountainous area is limited by the 11.IV isochronous.

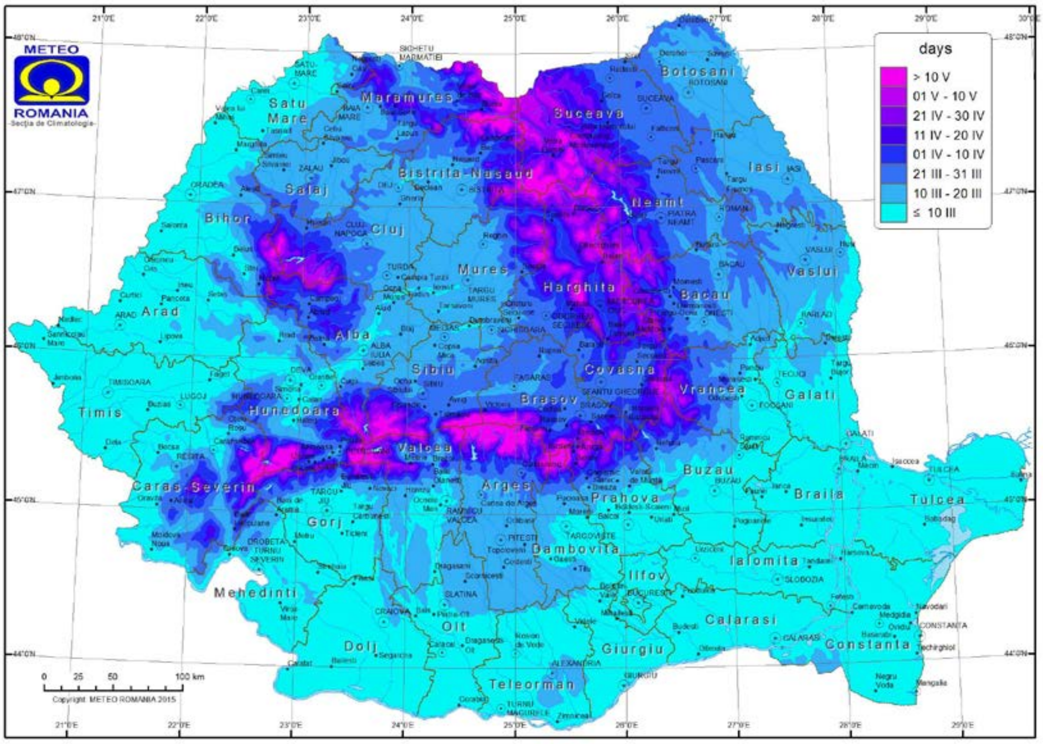


Figure 6-3: The average annual date of the last day with snow (1981-2010).

The spatial distribution of the annual number of days with snowfall (Figure 6-4) is mainly determined by the altitude and slope orientation, by the local temperature, but also by large-scale atmospheric circulation (Romania Climate, 2008).

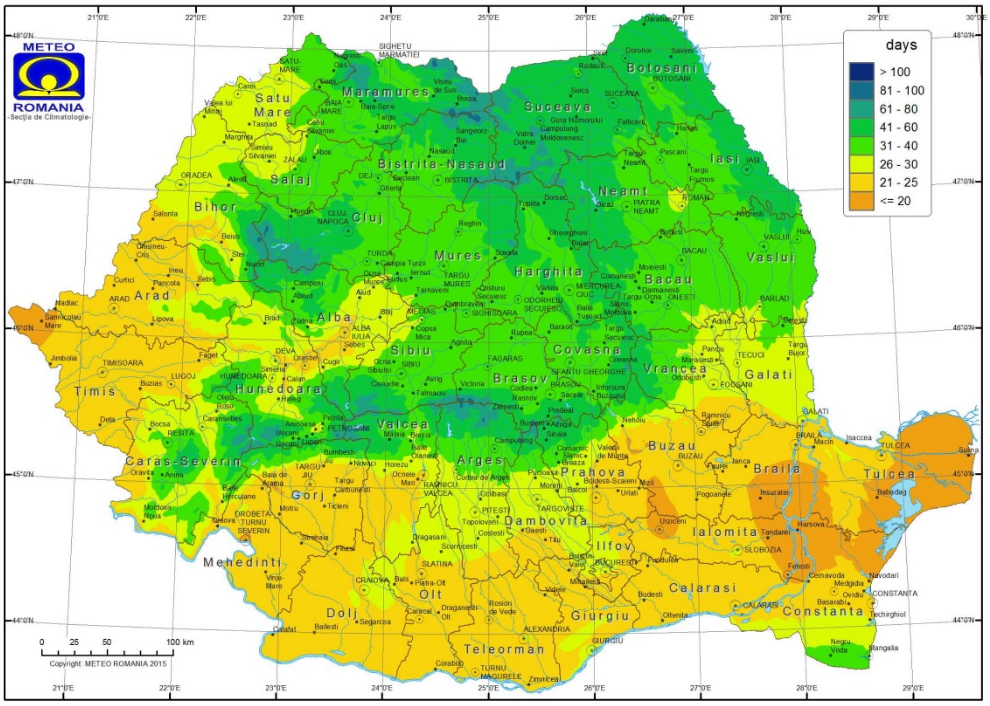


Figure 6-4: Average annual number of days with snowfall (1981-2010).

Figure 6-5 illustrates the average annual number of days with snow cover for the period 1981-2010. The altitude, the sea, but also the presence of föhn wind events configures the spatial distribution of this parameter. The highest values are in the high mountain areas, while the lowest are close to the sea. There are relatively small values in regions like those near the Curvature Carpathians where the föhn wind is present.

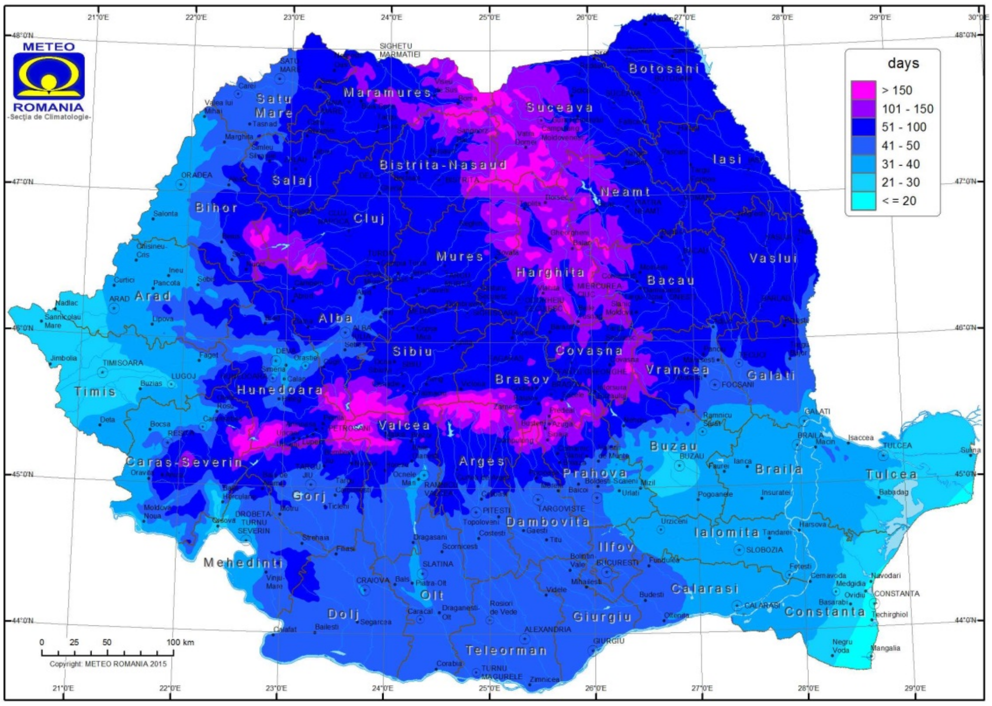


Figure 6-5: Average annual number of days with snow cover (1981-2010).

Figure 6-6 illustrates the average thickness of snow for the period 1981-2010. Spatial and temporal variation of this parameter depends on the values of solar radiation, the geographical position in relation to the Carpathian arc, to the Black Sea and factors involved in the atmospheric circulation on the European scale (Romania Climate, 2008).

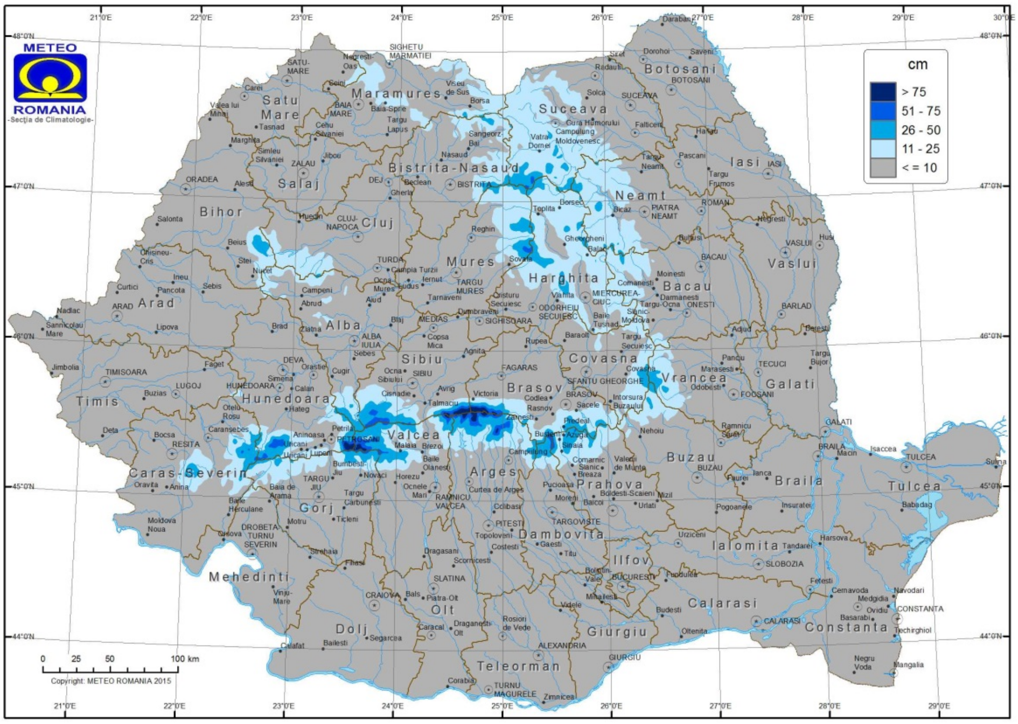


Figure 6-6: The average thickness of snow (1981 to 2010).

6.3 Norway

6.3.1 Validation from meteorological station data

The network of meteorological stations in Norway is shown in Figure 6-7. The network includes 750 stations. About 200 of these are fully owned and operated by the Norwegian Meteorological Institute (MET Norway). About half of those are fully automated, a quarter is manual and the rest are automated with a dedicated observer operating the station. Air temperature is measured at least on an hourly basis, while snow depth is measured daily at the manual stations.

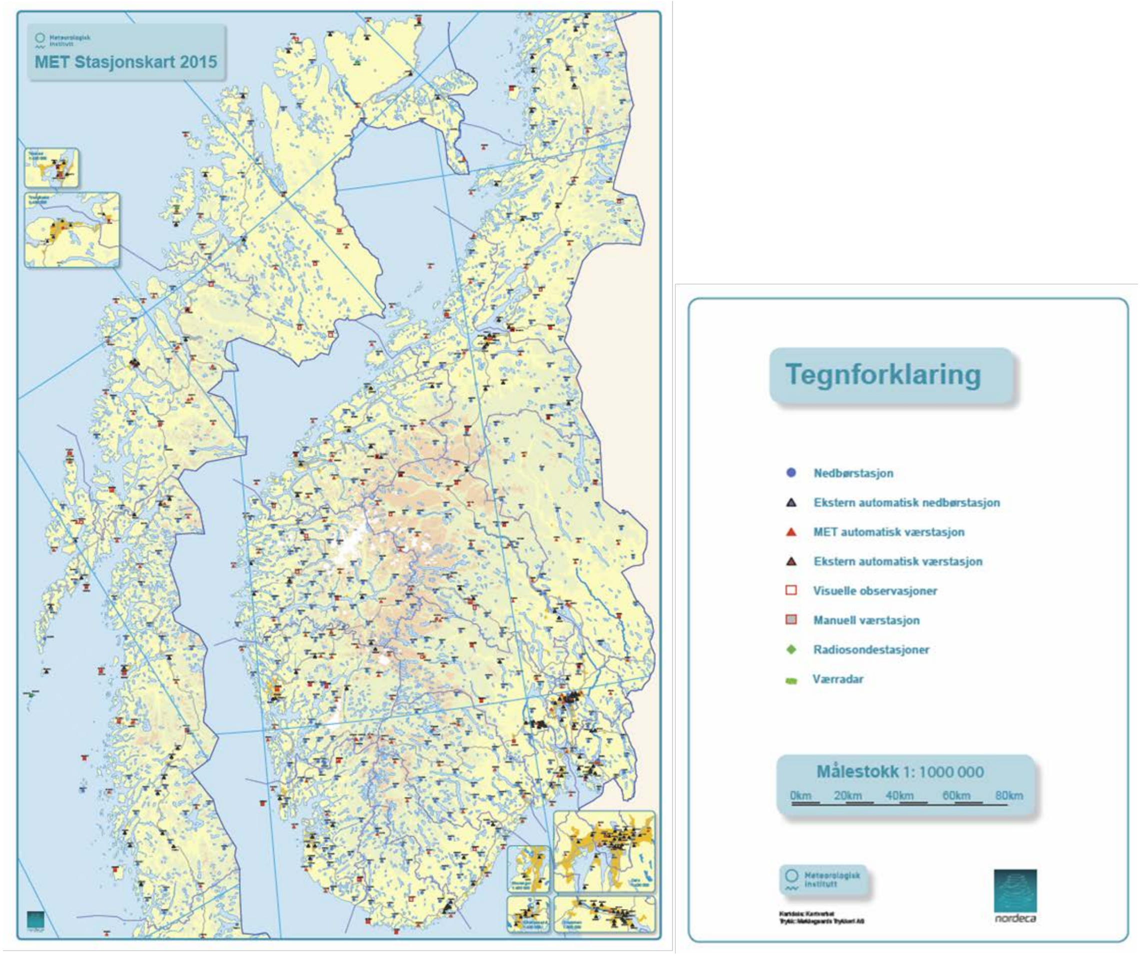


Figure 6-7: Weather stations in Norway operated by MET Norway and other organisations (black triangles). (MET Norway, 2015)

6.3.2 Snow climatology

Norway's climate shows great variations. From its southernmost point, Lindesnes, to its northernmost, North Cape, there is a span of 13 degrees of latitude, or the same as from Lindesnes to the Mediterranean Sea. Furthermore Norway has great variations in received solar energy during the year. The largest differences we find in Northern Norway, having midnight sun in the summer months and no sunshine at all during winter. The rugged topography of Norway is one of the main reasons for large local differences over short distances.

When it comes to the normal temperature distribution in winter, two main features are evident: firstly, the mean temperature in the winter months is above freezing all along the Atlantic coast. Secondly, the lower inland areas, both in the southern and northern part of Norway, have very low mean temperatures in winter. The Finnmark Plateau is the coldest area with mean monthly temperatures around in the winter -15°C. The increasing solar energy during springtime eventually melts the snow cover, and the land areas are being warmed up faster than the sea. In early spring, a zone near the coast of western Norway has the highest mean temperatures, but in May the highest temperatures are found in the south-eastern part. In summer the warmest areas are the south-eastern part and the coastal areas in the south. During autumn the land areas loose more heat than the sea, and eventually the coastal areas have the highest temperatures.

The figures below show snow climatology based on the period 1971-2000. Figure 6-8 a) shows mean annual maximum SWE. The snow volume typically is largest at the highest elevations, in particular for the glaciated areas. The coastal regions show rather low amounts. The same pattern can be seen in

Figure 6-8 b), while this figure also shows a latitude gradient and that the outer coastal regions in the south-west are almost snow-free.

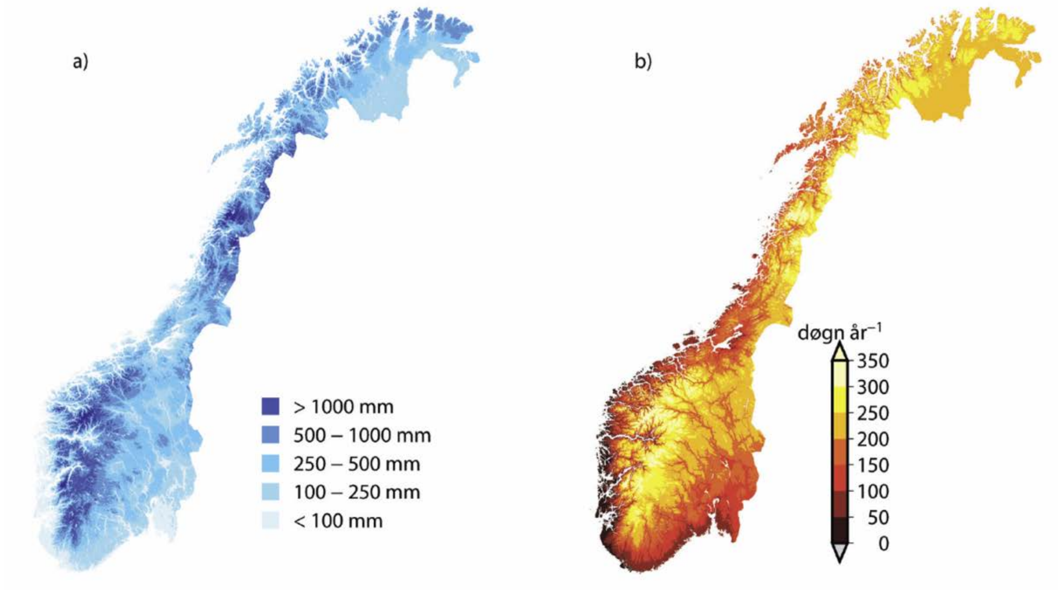


Figure 6-8: Mean annual maximum SWE and number of days with snow cover (1971-2000). (I. Hanssen-Bauer, 2015)

Figure 6-9 shows mean annual number of days with dry snow. The figure clearly shows that the inner pars of the country, those least affected by the coastal climate, are driest. The glaciated areas are not among those. The largest dry regions with long snow periods are in the inner part of the south-east (Østlandet) and in the far north (Finnmark).

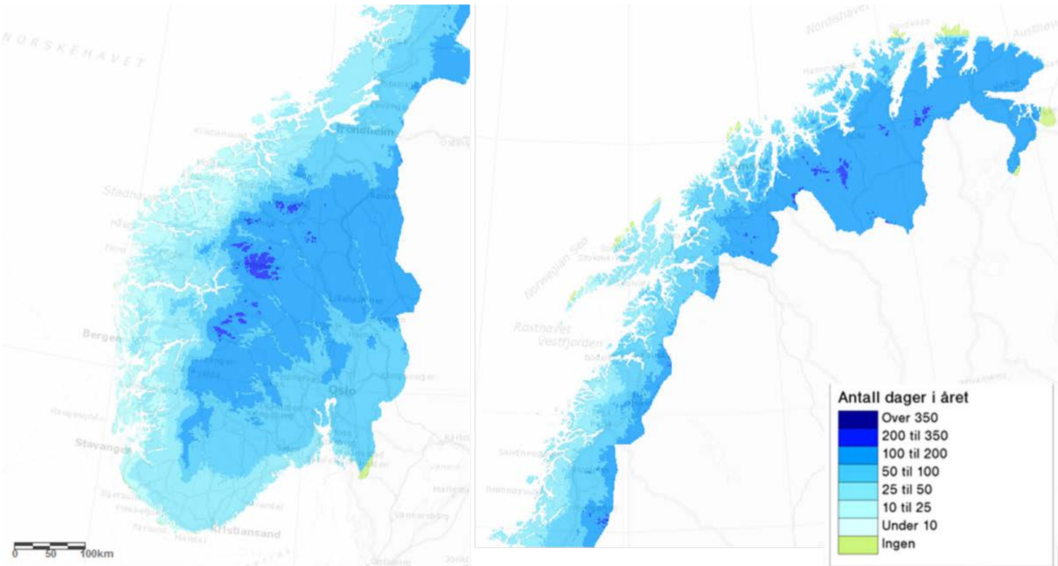


Figure 6-9: Mean annual number of days with dry snow (1971-2000). (NVE)

7 Summary and conclusions

The overall SnowBall project objective is to explore and develop methodology supporting the vision of developing a future service providing national authorities with hind-cast and real-time snow and avalanche information retrieved from earth observation data. SnowBall is aiming at providing and demonstrating the methods required for a snow service to deliver geospatial products on the seasonal snow cover (snow cover extent, melt state, snow water equivalent) derived from satellite data, to the scientific community in Romania, policy makers, users of snow information and the public.

To meet its overall objective, SnowBall work includes development of algorithms and implementation of a prototype snow monitoring system combining Sentinel-1/-3 satellite data, weather station data and hydrological modelling for snowpack parameters estimation. This includes development of an algorithm and a product for retrieval of snow surface wetness, mainly utilising data from the Sentinel-3 OLCI and SLSTR sensors.

An important part of the wet snow product development is the calibration and validation, and this report documents the plans for these tasks. The work can be split into three main tasks: 1) Algorithm calibration and validation (cal/val); 2) Diagnostic data analysis; and 3) Large-scale product validation.

The purpose of the diagnostic analysis is to obtain an understanding of the geophysical conditions behind the signal measured remotely for the determination of algorithm performance and limitations. When a proper understanding is obtained on how the candidate algorithms work under different conditions, one algorithm may be chosen. The next step would typically be algorithm calibration and validation. The final step would typically be product validation. The purpose of this is to study and quantify the product quality in general over the whole product domain.

The three major steps described above do not necessarily follow each other in a strictly sequential way. For instance, calibration and validation might be followed by further diagnostic studies in order to determine limitations of the retrieval algorithm and to obtain a more comprehensive understanding of the physical processes affecting the performance of the algorithm.

This report is intended to provide an overview of the complete validation work in the project, including data sets and approaches. However, it does not specify in detail how each validation step will be performed. Validation is no exact science, and “the road must to some degree be built while we drive”. Therefore, the report is also intended to be a “living document” updated during the course of the project when approaches are refined and final methodology chosen.

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9 Appendix 1: Templates for fieldwork reporting

9.1 NR's template for satellite-related in-situ surface measurements

Field report

General information			
Report type:			
Campaign name:			
Campaign site:			
Campaign part:		Field area name:	
Project name:		Field location ID:	
Project no:		Document name:	
Written by:		Participants:	
Start time:		Start time UTC:	
End time:		End time UTC:	
Position system:		Elevation:	
East/west:		North/south:	

Weather information	
Air temp. at 0,1 m:	
Cloudiness:	
Air transparency:	
Photo ref:	

Spectral measurements			
Instrument ID:			
Base filename:		Sub-directory:	
Series 1 start time:			
Series 1 first ext.:		Series 1 last ext.:	
Series 1 comments:			
Series 2 start time:			
Series 2 first ext.:		Series 2 last ext.:	
Series 2 comments:			
Series 3 start time:			
Series 3 first ext.:		Series 3 last ext.:	
Series 3 comments:			
Series 4 start time:			
Series 4 first ext.:		Series 4 last ext.:	
Series 4 comments:			
Series 5 start time:			
Series 5 first ext.:		Series 5 last ext.:	
Series 5 comments:			
Series 6 start time:			
Series 6 first ext.:		Series 6 last ext.:	
Series 6 comments:			
Series 7 start time:			
Series 7 first ext.:		Series 7 last ext.:	
Series 7 comments:			

Snow surface characteristics	
Even or uneven distribution of snow types?	
Crust present, everywhere or scattered?	
Crust in the upper 10 cm of snow pack?	
Additional description:	
Photo ref:	

Snow grain shape, visual					mm
Instrument ID:		Shape types:			
Mean width:		Min width:		Max width:	
Mean length:		Min length:		Max length:	

Snow grain shape, photographic					mm
Instrument ID:		Shape types:			
Photo ref:					
Mean width:		Min width:		Max width:	
Mean length:		Min length:		Max length:	

Snow depth									cm
Instrument ID:									
H1:		H2:		H3:		H4:		H5:	
H mean:	#DIV/0!			H stdv.	#DIV/0!				

Snow temperature									° C
Instrument ID:				Snow depth:					
T1:		T2:		T3:		T4:		T5:	
Korr T	NO DATA		NO DATA		NO DATA		NO DATA		NO DATA
T mean:	#DIV/0!			T stdv.	#DIV/0!				

Snow density									g/cm^3
Instrument ID:				Snow depth:		cm	Tara:		g
Instrument volume:			ml (cm^3)						
V1:		V2:		V3:		V4:		V5:	
D1:	NO DATA	D2:	NO DATA	D3:	NO DATA	D4:	NO DATA	D5:	NO DATA
D mean:	#DIV/0!			D stdv.	#DIV/0!				

Snow wetness									vol %
Instrument ID:				Volume (Yes=1):		Snow depth:			
Air wetness number (WN):				Surface (Yes=1):					
WN1:		WN2:		WN3:		WN4:		WN5:	
eps	MISSING ID		MISSING ID		MISSING ID		MISSING ID		MISSING ID
W%1:	NO DATA	W%2:	NO DATA	W%3:	NO DATA	W%4:	NO DATA	W%5:	NO DATA
W% mean:	#DIV/0!			W% stdv.	#DIV/0!				

9.2 NMA's template for in-situ snow surface measurements

Observer: ……………………………… **Data:**………………….. **Hour: 06.00 UTC**		
Group	**Observation**	**Value**
iii	Station (site) indicative	….
H VV	Low cloud base height above station (h) Visibility (VV)	…. ….
N Dd ff	total cloudiness wind - direction (dd) - speed (ff) (m/s)	…. …. ….
$\pm$ TTT	Air temperature ($0\,^0$C)	….
ww W_1 W_2	present weather (ww) past weather (W_1) past weather (W_2)	…. …. ….
N_h C_L C_M C_H	Low cloudiness low clouds type medium clouds type high clouds type	…. …. …. ….
$\pm T_xT_xT_x$	Maximum air temperature during last 24 hours (^{0}C)	….
$\pm T_nT_nT_n$	Minimum air temperature during last 24 hours (^{0}C)	….
sss	Snow depth (cm)	….
RRRR	Precipitations during last 24 hours (mm)	….
s's'	Fresh snow height during last 24 hours (cm)	….
$-T_sT_sT_s$	Snow temperature below snow surface (^{0}C)	….
E_n P_sP_s N_V C_n	Snow type at surface (E_n) Sonde penetration (P_s) (cm) Valley clouds (N_V) Drifted snow (C_n)	…. …. …. ….
L_1 L_2 L_3 L_4 L_5	Observed avalanches: - number of observed avalanches (L_1) - avalanche type (L_2) - triggering altitude (L_3) - avalanche slope exposure (L_4) - local avalanche risk estimation (L_5)	…. …. …. …. ….
2 dd ff	Wind on altitudine - Direction (dd) - speed (ff) (m/s)	…. ….
sss s's'	Snow on altitudine: - snow depth (sss) - fresh snow depth (s's')	…. ….
3 UU T_LT_L	Relative air humidity (UU) - în % snow water content (T_LT_L – în %) (if $T_sT_sT_s \approx 0\,^0$C)	…. ….
4 F_1 (dominant crystal type) F_2 (second crystal type) D_m D_m	Snow crystal type on surface (F_1; F_2) 1: **+** fresh snow | 6: ○ snowmelt 2: **λ** decomposed snow | 7: ▬ ice crust 3: ● round snow | 8: V surface hoar 4: □ faceted snow | 9: * graupel 5: ^ depth hoar Medium diameter of dominant snow crystals on surface (mm)	…. …. ….
5 i $M_vM_vM_v$	Snow surface homogenity indicator **i = (0-1-2)** Volumique mass $M_vM_vM_v$ (kg/m^3)	…. ….

9.3 NMA's template for in-situ snow depth measurements

Station (or site): ……………… **Data**: ……………………………………. **Hour (local)**: ………………………. **Observer**: ……………………….. **Location**: ………………. ……….. **Altitude**: ……………………..	**PROFIL STRATIGRAFIC No:** **Exposure**: …………………… **Slope inclination (grades)**: ………………… **Weather**: …………………………………. **Air temperature (at 2 m)**: ……………………….

Snow temperature		**H**	**F1 F2**	**Dm**	**d**	**U**	**MV**	**TEL**	**CISA**		**(h)**
H (cm)	°C	cm	symbol	mm			kg/m^3	%	ø	C	cm

H – snow height (cm)

For the temperature: H indicates the level where the measurement is made. For stratigraphy: H indicates the levels between snow crystals are examined.

F1 F2 - crystal shape

1. + fresh snow
2. λ decomposed snow
3. ● round snow
4. □ faceted snow
5. ∧ depth hoar
6. o snowmelt
7. **–** ice crust
8. ∨ surface hoar
9. * graupel

Dm - dominant snow crystals medium diameter (tenth of mm. ex.: 0.5/1.0)

d – snow hardness

1. fist: very soft
2. 4 fingers : soft
3. 1 finger : hard
4. pen : very hard
5. knife blade: compact

U – snow wetness

1. dry (T≤ -1°C, or cannot make snowballs)

T≥ -1°C ; can easily make snowballs:

2. slightly wet (glove stays dry)

3. wet (glove is wet)

4. soaked (water flows when clenching the fist)

5. very soaked (water and snow mixture)

MV - volumique mass (kg/m3)

MV = net weight x 2 (weight in grams) (measured with a 500 cm^3 cylinder)

10 Appendix 2: 5TM sensor

Accuracy	Apparent Dielectric Permittivity (ε_a): ± 1 ε_a from 1 - 40 (soil range); ± 15% from 40 - 80 Soil Volumetric Water Content (VWC): Using Topp equation: ± 0.03 m^3/m^3 (± 3% VWC) typical in mineral soils that have solution electircal conductivity < 10 dS/m; using medium specific calibration, ± 0.02 m^3/m^3 (± 2% VWC) in any porous medium Temperature: ± 1°C
Resolution	ε_a: 0.1 ε_a from 1-20, < 0.75 ε_a from 20-80 VWC: 0.0008 m^3/m^3 (0.08% VWC) from 0 to 50% VWC Temperature: 0.1°C
Range	ε_a: 1 (air) to 80 (water) Temperature: -40 - 60°C* *Sensors can be used at higher temperatures under some conditions.
Dimensions	10 cm x 3.2 cm x 0.7cm
Cable Length	Sensors come standard with 5 m cable. Custom cable lengths available. Maximum cable length of 75 m. Please contact Decagon if you need longer cable lengths.
Measurements Time	150 ms (milliseconds)
Power	3.6 - 15 VDC, 0.3 mA quiescent, 10 mA during 150 ms measurement
Output	RS232 or SDI-12
Connector Types	3.5mm "stereo" plug, or stripped and tinned lead wires (3)

6. CONCLUSIONS

This report presents the results obtained during 2015 in implementing the objectives of the Snowball project, according to the work plan, broken down by work packages, activities and related deliverables.

WP1 Management
Activity 1.1. Project Management

The Project Steering Committee (PSC), composed by officials from partner institutions and led by the project manager continued to provide during 2015 a concrete and efficient project management that covered scientific, administrative, financial and communication with the contracting authority problems.

The annual conference of the SnowBall project (19 SEE / 30.06.2014) held at the West University of Timisoara, during 26 - 28 October 2015. During the conference took place the meeting of the Steering Committee that analyzed the implementation stage of the project according to plan of activities and discussed issues that may affect the achievement of the project objectives. It was verified and updated the Management Plan of the project and discussed the latest instructions received from the contracting authority regarding the verification of expenditure incurred at the project level and the achievement of the indicators from the 2015 annual Scientific and Technical Report.

WP2 In-situ snow parameters measurements
Activity 2.1. Design and implementation of new snow measuring devices and equipment

For the measurement of the snow parameters was continued the design, development, testing and installation of automatic devices and equipment which continuously measure in the perimeter of the existing meteorological stations, continuously measure during the winter season in various areas of interest respectively.

Thus were designed and implemented new tools and modern equipment for measuring deptht and snow surface temperature, soil temperature profile and volumetric snow moisture (snow liquid water content).

In order to achieve the portable systems was decided the use of "open source" development platforms based on 8 or 32 bits microcontrollers.

The deliverable D2.2. "The prototype tested in the laboratory for the snow temperature profile measurements - version 2" was completed.

Activity 2.2. Snowpack parameters observation and measurements

Monitoring and assessment of the snow cover parameters using satellite data requires calibration / validation with in-situ measurements of snow cover spectral properties from visible and infrared. For this purpose, measurements were performed by both the NMA and by NR with portable spectrometers DSR (StellarNet) and with FieldSpec Pro FR (ASD Inc.).

There were completed the following deliverables: "Snow thickness data sets (SD), snow water equivalent (SWE) (provided by automatic stations)" and D2.5 "Snow spectral reflectance data sets - version 1".

Activity 2.3. Create and set-up of a spatial database managed by GIS software

There have been inventoried required, have been designed adequate models of data and set clear procedures for integrating them into the GIS database. The geospatial database includes classical data (maps, satellite images, in-situ data) or other data types (photos, graphs, statistical data, and descriptive documents).

The following sources of data was used to create the database: database created by national institutions; free available database from Internet; free available database created within national projects and data produced by the SnowBall consortium by vectorization the topographic maps, orthophotomaps, satellite images or using GPS measurements.

Existing vector data have been obtained in different file formats (ESRI Shapefile, ESRI Geodatabase, CAD) with variable spatial domains. Were performed a series of operations for the homogenization of attributes, geometrical and topological correction, derivation of new layers or combination of certain information in the same layer, defining relationships between layers and tables, centralizing data in a database. The information about each layer stored and managed by the system Snowball include: name, title, abstract, keywords, addresses, metadata, reference coordinate system, layer limits, publishing options (interpolation method, ensemble style applied default identifiers layer).

They were implemented the network services according the INSPIRE directive: viewing, downloading and data processing services.

There were completed the deliverables D2.9 "Snowpack parameters data sets – Version 1", D2.11 "Prototype of the spatial database for snow related parameters", D2.12 "Spatial database over the test zone, in a GIS environment" and D2.13 "Snow related in situ data sets and historical meteorological and hydrological data – Version 1".

Activity 2.4. Elaboration of spatial products using the spatial database

Under this activity were performed daily gridded data sets at a 1000 m x 1000 m spatial resolution for the period October 1 2005 - April 30 2015, for the following parameters: air temperature (minimum, average and maximum); rainfall; snow depth (SD) and snow water equivalent (SWE). Maps obtained during this stage gives an overview of the analyzed variables, but whose accuracy is directly influenced by the scale on which they were made, by the errors of estimation and by specific geostatistical methods spatial and density measurements points. For some areas, with special climatic conditions and no meteorological measurements, there are recommended detailed studies on the spatio-temporal variability of parameters of interest, to emphasize the local nature of weather events in time and space.

There was finalized the deliverable D2.15 "Mapping products derived from the spatial database – Version 1".

WP3 Satellite remote sensing, data fusion and modelling of snow parameters
Activity 3.1. Single sensor algorithm porting to Sentinel

In the work reported here we have adapted and validated algorithms for wet snow mapping. The optical algorithm is based on monitoring of the snow properties fractional snow cover (FSC), surface temperature of snow (STS) and snow grain size (SGS) in addition to cloud masking from the Sentinel-3 optical sensors Ocean Land Colour Instrument (OLCI) and the Sea Land Surface Temperature Radiometer (SLSTR), in combination, leading to the optical snow wetness (OWS) product. The SAR wet snow (SWS) product is based on data from the synthetic aperture radar (SAR) aboard Sentinel-1.

The algorithm validation results for the test sites in Norway and Romania for the 2015 season have been presented. The validation was limited to comparison with air temperature as this was what was available for the 2015 season, but will be extended with comparison with in situ snow liquid water measurements when these become available for the 2016 season.

The optical-based (OWS) maps were in general quite consistent with the air temperatures. In most cases retrieval results of dry snow corresponded with air temperatures below freezing point, and retrieval results of one of the wet-snow classes with air temperatures above freezing point. The OWS maps are also internally consistent in the way that the content usually follows the topography and local climate very well and without being noisy.

By comparing SAR wet snow (SWS) maps with the temperature profiles at the five weather stations, we conclude that Sentinel-1 is suitable for mapping wet snow in mountain regions. The use of flattening gamma terrain correction reduces the terrain effects substantially, and we may therefore create daily mosaics by combing ascending and descending satellite passes. However, for mapping of wet snow, this may not be desirable since the snow wetness varies between night and day due to varying temperatures. We have therefore chosen only to consider the afternoon (ascending) passes.

Some of the wet snow maps for Romania seem to underestimate the snow-covered area, in some cases seriously. As the OWS and MWS algorithms require and area to have almost 100% snow cover fraction to be able to retrieve the snow wetness, also the area of wet snow gets underestimated in these cases. The problem is probably related to the lack of specific calibration and adaptation of the Norwegian algorithms to Romania. It might be related to differences in the solar zenith angle between Norway and Romania. Other causes that might be involved include the topography (steep relief) and the uncertainties in the Corine Land Cover data set (used for the land-cover masking). These do not allow mapping the whole dry snow extent, which is shown on the map as partly snow-covered ground (mostly due to trees partly hiding the snow on the ground in forests). The problems will be mitigated as far as possible when we obtain data from the new cal/val sites in Romania in the 2016 winter and spring season.

As an overall conclusion, the validation analysis of the retrieval results for snow wetness from optical data has confirmed that the approach of combining snow surface temperature and snow grain size, analysed in a time series of observations, can be used to infer wet snow. Air temperature measurements from meteorological stations confirm in general the maps produced. Furthermore, C-band SAR data is very sensitive to whether the snow is wet or dry, which was confirmed in our work. However, C-band alone cannot be used to determine the degree of wetness.

The deliverable D3.1 „Validated optical and SAR snow wetness retrieval algorithms" has been finalised.

Activity 3.2. MWS algorithm and product

The multi-sensor/multi-temporal wet snow (MWS) algorithm fuses optical and SAR data to map the wet snow area. Multi-temporal observations of wet snow with optical and SAR are fused in a novel model simulating states of surface properties to generate reliable wet snow maps. The algorithm is based on NR's experience of combining data from multiple sensors using Hidden Markov Model (HMM) approaches. The basic idea of the approach is to simulate the states the snow surface goes through during the snow season with a state model. The HMM model is applied per pixel, so each pixel's history through the snow season is modelled. The snow maps include the thematic classes *dry snow*, *moist snow*, *wet snow*, *very wet snow* and *soaked snow*, in addition to *partial snow cover*, *temporary snow* and *bare ground*.

The first prototype version of the multi-sensor/multi-temporal product for wet snow mapping has been demonstrate and validate. The optical component of the algorithm is based on monitoring of the snow properties fractional snow cover (FSC), surface temperature of snow (STS) and snow grain size (SGS) in addition to cloud masking from the Sentinel-3 optical sensors Ocean Land Colour Instrument (OLCI) and the Sea Land Surface Temperature Radiometer (SLSTR), in combination, leading to the optical snow wetness (OWS) product. The SAR wet snow (SWS) component algorithm is based on data from the synthetic aperture radar (SAR) aboard Sentinel-1.

The validation analysis of the retrieval results for snow wetness from the novel multi-sensor/multi-temporal approached seems very promising, delivering retrieval results on a daily basis as categorical degrees of snow wetness independent of cloud cover. The main added value with the MWS maps is certainly that there is a new map every day. The products are foreseen to be applied with hydrological modelling for flood prediction and for snow avalanche applications.

The “Validation plan for remote sensing of snow wetness” has been elaborated in order to validate the MWS products.

The deliverables D3.2 „Validated MWS snow wetness retrieval algorithm” and D3.3 „Multi-sensor/multi-temporal prototype wet snow product – Version 1” have been finalised.

Activity 3.3. The new module of the multilayer model for snow in NOAH

The methodology for estimating the snow water equivalent, by data fusion approach, using the distributed model NOAH simulations, ground observations and satellite products was elaborated. Within the methodology, the diferrent type of data and information are analyzed and compared, using a series of automatic cross-validation algorithms, and then the snow water equivalent is estimated in grid format, at spatial resolution of 1 km, by multiple succesive steps of interpolations and adjustments, depending on the degree of uncertainty associated with different type of data.

Was finalized the deliverable D3.5. „Design the data fusion methodology for estimating the snow water equivalent, using simulations from the distributed parameters hydrological model NOAH, ground observations and satellite products”.

WP4 Climate change impact on snow-related hazards
Activity 4.1. Snow-related climate variability and change and associated impact

The analysis of snow-related climate variability and change and associated impact have continued. For the analysis were used the results of the 5 regional climate models with 12.5 km resolution, from the EURO-CORDEX 2014 archive, used also in the previous stage. It can be observed that for a radiative forcing more intense (RCP 8.5 scenario), the decreasing of the snow thickness, the amount of snow and snow melted during the considered time intervals are higher. . This increase gets stronger towards the end of the 21st century, especially under the RCP 8.5 scenario.

The input data for the hydrological model was developed by National Meteorological Administration based on numerical experiments under climate change (RCP 2.6 and RCP 8.5) with regional climate model RCA4 (EURO-CORDEX) driven by the global climate model ICHEC-EC-EARTH (CMIP 5). Simulated data using RCM have a spatial resolution about 12.5 km; the data were disaggregated at a spatial resolution of 1 km, using geostatistical methods, in order to be used at the scale studied basins and to correct the differences between the model orography and the real orography. These data were analyzed from the perspective of climate change in the region of interest of the studied sub-basins.

Using the disaggregated data at 1 km spatial resolution obtained by National Meteorological Administration team, was calibrated the hydrologic model by the INHGA team. In this context had begun preparations for its use in the Activity 4.2 related to the variability and climate change from flash floods associated to snow melt.

It was completed the deliverable D4.1 "Present (1981-2010) and future (2021-2050) assessment of snow-related parameters from CMIP5 archive downscaled for selected hazard and resource analysis over the area of interest".

Activity 4.2. Variability and change in flash floods with snow melt contribution

Within this activity was done the calibration of the hydrological model with simulation of the snowpack accumulation and melting for the upper part of the Arges and Ialomita River.

The conceptual hydrological model Consul was used for simulating the runoff and flow formation in the upper part of the Argeş and Ialomiţa River Basins, model developed within the N.I.H.W.M..

Calibration of Consul hydrological model parameters was performed by simulating the most important events rainfall-runoff selected particularly during the transition from winter to spring, from the calibration period considered, 2001 to 2005.

The results of flow simulation with the Consul model in the analysed river basins showed that the model gives the best results, in particular in the case of floods generated by precipitation evenly distributed in space. Deviations between discharge hydrographs simulated by Consul and observed are due to both model errors and insufficient meteorological and hydrological data. The main error is caused by the uncertainty related to the determination of average precipitation on the river basin and its variable spatial and temporal distribution.

Was finalized the deliverable D4.2. „Hydrological model with snow accumulation and snow melt capabilities calibrated in the upper part of Argeş-Ialomiţa river basins".

WP5 Aquifer replenishment modelling from snowmelt infiltration

This report presents the results obtained during 2015 in implementing the Snowball project,according to the work plan, split into work packages, activities and deliverables related.

Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone

It highlighted the advantages or disadvantages of using models based on energy balance equation or the method based on temperature index. The temperature index method is easy to apply and provides reasonable results, but is sensitive to weather, especially to wind and solar radiation. To improve these models and increase the accuracy of the results it is recommended to add wind and moisture data. Models based on the equation of energy balance are susceptible to estimation errors of data such as wind, solar radiation, albedo factor. Better parameterization of the albedo factor, the wind function and an improvement of weather conditions estimation may increase the result accuracy.

Measurements that were done to determine snowmelt infiltration and the mathematical model for flow simulation in the unsaturated area were also presented.

Activity 5.2. Aquifer modelling

Three representative study areas were chosen and described in detail with respect to geological, hydrogeological and climate conditions: 1. Bolboci – Omu Peak area (superior basin of Ialomita valley); 2. Study area – Prahova – Teleajen alluvial cone; 3. Colentina area, Bucharest. The recharge process of three major hydrostructures was taken into account when selecting the sites: for fissurated mountain aquifers the north eastern part of Bucegi Mts was chosen, for regional aquifers in alluvial area, the alluvial cone Prahova – Teleajen and for small aquifers, Colentina area (Laboratory Complex Colentina, Bucharest) located in the Romanian Plain.

The structure of a conceptual model for the aquifer recharge from snowmelt was developed. In this respect, a diagram of processes and factors involved in determining infiltrations from the soil layer was created, including: weather conditions, global solar radiation, interception of fallen snow and rain within forest areas and rain and sublimation and evaporation losses at the interface with the forest, redistribution of wind on snow, the snow melting phenomenon is influence by the weather conditions as well as by soil heat and sublimation process.

Modelling and predicting water infiltration in frozen soil can be used in evaluating risks and damage related to climate change, especially for mountainous and permafrost areas.

The deliverable D5.1 "Sites description and conceptual models" was completed.

WP6 Assimilation of snowpack parameters in the National Flood Forecasting and Warning System

Activity 6.1. Update the LC/LU map for the study area using high spatial resolution satellite images

The methodology to obtain the updated land cover / land use map for the Romanian study area was elaborated. The methodology assumes the satellite data fusion for a first classification followed by classification based on three sources of thematic information: CLC 2012 version, Land Parcel Identification System (LPIS) and the supervised and unsupervised classification of the acquired satellite images. Accessing and comparing recent information regarding land cover / land use produce an updating and improving existing database quality. In a GIS system, by integrating with Orto photos and / or satellite images can have a good management and a good monitoring of agricultural and non-agricultural land from the study area.

The updated land cover / land use map for the study area (Arges-Ialomita river basins) is necesary for the implemantation of the distributed hydrological model NOAH-R developed in the working package WP3.

It was completed the deliverable D6.1 "Update the LC/LU map for the study area using high spatial resolution satellite images"

Activity 6.2. Design of algorithms and methodology for snowpack parameter assimilation in the operational hydrological forecasting models

The methodology for data assimilation of snowpack parameters in the hydrologic model NWSRFS and in the system for estimation of flash floods occurence risk in Romania – ROFFG was done. The hydrological forecasting systems NWSRFS and ROFFG, are using the same conceptual model SNOW-17 for simulating the snowpack evolution, and the optimal values of snow water equivalent resulted as output from the data fusion procedure will be used for data assimilation, specific to each system, for adjusting the snow model state parameters. SNOW-17 model is part of the index-type snow models, using air temperature as sole index to determine and characterize the energy exchange processes that occur at the snow-air interface. In addition to data on air temperature, the only supplementary input data necessary for running the model is the precipitation quantities.

The simulations from the distributed hydrological model NOAH-R will be used as input in the data fusion procedure for estimating the snow water equivalent, and the final adjusted values resulted from the procedure will be assimilated in the operational model, in order to adjust the state parameters related to snowpack.

Deliverable D6.2. was finalized ”Designing the methodology for the assimilation of snowpack parameters in hydrological forecast operative models”.

Activity 6.3. Implementation of algorithms and methodology for snowpack parameter assimilation in the operational hydrological forecasting

During this phase, was done the inventory and selection process for the software systems, modules and utilities that are needed for implementing the methodology of snowpack parameters assimilation in the operational hydrological forecasting models.

Using the selected software applications was started the implementation of scripts and programs for handling the export-import operations for the data flow, and for the specific processing steps for assimilating the snowpack parameters into the operational hidrological models NWSRFS and ROFFG.

Within the data assimilation process for these operational hydrological models the direct method approach will be used for assimilating the snow water equivalents values, and in a second step during the assimilation process, will be checked if there are significant differences between the percent of snow cover extent at the basin level simulated by the model using the depletion curve and the percent indicated by the data fusion procedure, also this parameter will be assimilated using the direct approach, for adjusting the SNOW-17 internal state.

WP7 Avalanche inventory, release and hazard mapping
Activity 7.1. Develop avalanche detection algorithms

During this activity was completed the spatial validation database corresponding to the Fagaras Mountains region, being obtained the first avalanches inventory based on satellite images GeoEye-1.

This set of spatial data allows a more objective estimation of the avalanches magnitude and an accurate location, comparing with information obtained from people who caught avalanches. It also offers information over larger area than those provided by meteorological stations. The inventory of the avalanches formed in this project is a novelty for Romanian part of Carpathian Mountains and also an example of using GeoEye images in avalanches analysis. It demonstrates that avalanches in the Carpathians are far greater than previously known, and remote sensing data plays an important role in the development of a complete spatial database covering the whole area of mountainous areas in Romania.

The algorithm for detection avalanches using high (HR) and very high resolution data (VHR) was completed and validated. The Norwegian partner has further developed the textural filter based approach for automatic avalanche detection in very high resolution optical satellite imagery. The key part of this detection algorithm involves texture analysis, seeking to distinguish avalanche snow from other relevant terrain cover types, such as smooth snow, rugged snow, trees and rock. The texture characteristics of the avalanche-affected snow are extracted by convolving the image with a set of 12 multi-scale multi-directional filters.

The proposed algorithm has been detected 87% of the avalanches on the test images. The detection errors of avalanches are due to the physical and geographical conditions that differ from one area to another as well as from the time acquisition of the satellite image. To compensate for that, one could extend the number of filters in the filter bank to a much large number, preferably with filters estimated from the data. Also, delineation of areas with high probability in avalanche occurrence in GIS environment with multicriteria analysis of standardized factors using fuzzy functions may provide a thematic layer that can be integrated in the detection algorithm in order to reduce the overestimation errors.

It was completed the deliverable D7.1 "Validated algorithm for avalanche detection in HR and VHR satellite images".

Activity 7.2. Change-detection algorithm for Sentinel-1 and Sentinel-2

There were settled the methodology and the stages for algorithm development in order to detect the changes in satellite images by selecting images from archives and making corrections on test images. It was tested the ability to map the algorithm on a set of images Sentinel-1 and RADARSAT-2 in mountain areas in Norway. Preliminary results have shown that by using this algorithm were detected most of the avalanches from images, with some false detections, but their limit is not always appropriate to that undertaken by experts.

Activity 7.3. Avalanche simulation

During the activity of simulation the avalanches trajectories were selected a number of altitude terrain models and were tested global and friction parameters of snow. The RAMMS model was applied for a range of avalanches recorded in the statistics for Fagaras Mountains with high risk that had recorded casualties and information about the area affected by avalanche deposits. Thereby, the simulation of the trajectories of the avalnches in Balea Valley have allowed reconstructing the spatial extent and thickness of snow disloxated deposits, which were similar to statistical data. This activity will continue in the next stage of the project in which iwill be generated the avalanche hazard maps for the test areas.

WP8 Promotion and Dissemination
Activity 8.1. Project website

The project web site (http://snowball.meteoromania.ro) has been updated. There were included information concerning the Snowball consortium activity in the current stage: results, meetings, dissemination, etc. It has also been performed the Romanian version of the website.

Activity 8.2. Dissemination strategy

The dissemination strategy aims to define a number of activities suitable for an efficient promotion of the Snowball project results, both during and after the project and to facilitate the interaction with similar projects implemented at national or international level. It also aims to identify appropriate communication tools for creating links between the consortium and the community of users. To create the dissemination strategy were taken into consideration the following: identification of the target group of users; creation of appropriate messages to attract attention of target audience group; selecting the communication channels through which messages are sent towards the target group.

There were achieved a number of products for the promotion and visibility of the project: leaflets in Romanian and English, the project brochure in Romanian and English, posters, banners, according to the recommendations from communication and design guide of the project, provided by ANCSI.

There were completed the deliverables D8.2 "Dissemination strategy" and D8.3 "Project brochure – version 1".

Activity 8.3. Dissemination and training actions

Results obtained within the project were presented in national and international conferences and symposia like: 3-rd International Conference on Remote Sensing and Geoinformation of Environment – RSCY2015, Cyprus, 16-19 March 2015; International Conference Water and Air – Environmental Components, Cluj-Napoca, 20-22 March 2015; International Conference "Methodological challenges în geography", 15-16 May 2015, Timișoara; 31st National Symposium on Geomorphology, 21-24 May 2015, Sf. Gheorghe Deltă; ESA Sentinel-3 for Science Workshop, Venice, 2-5 June 2015; EAWS Conference – European Avalanche Warning Services, Rome, 4-6 June 2015; "Geobalcanica-Connects all geographers" Conference, Skopje, 5-7 June 2015; 26-th General Assembly of the International Union of Geodesy and Geophysics-IUGG 2015, Prague, 22 June - 2 July 2015; 33-rd International Conference on Alpine Meteorology – ICAM, Innsbruck, 31 August - 4 September 2015; EUMETSAT Meteorological Satellite Conference 2015, Toulouse, 21-25 September 2015; Annual; Scientific Conference of the National Institute of Hydrology and Water Management, Bucharest, 2-3 November 2015; Annual session of scientific papers of the National Meteorological Administration, Bucharest, 19-20 November 2015.

During the "Achievements and future steps" International Conference organized by ANCSI in the frame of RO-14 Program – "Research Within Priority Sectors", EEA 2009-2014 Financial Mechanism which took place in Bucharest on 10 December 2015 there were presented results obtained during the first half of the project implementation period.

There were completed the following deliverables : D 8.6 "Visibility products (banners, posters etc.)", D8.7 "Conference project presentation package", D8.8 "Dissemination action report" and D8.9 ". Project newsletter (e-zine) - digital form".

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*** Site Administrația Naţională de Meteorologie (ANM)

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*** Site Administrația Națională Apele Române (ANAR)

Sursă link: (http://www.rowater.ro/daarges/sgailfov/default.aspx)

*** Administrația Lacuri, Parcuri și Agrement Bucureşti (ALPAB)

Sursă link: http://www.alpa.ro/

Sursa link: http://hydrology.usu.edu/taudem/taudem5/downloads5.0.html

LIST of ACRONIMS

ANCSI	National Authority of Scietific and Inovation Research
ASAR	Advanced Synthetic Aperture Radar
CMIP5	Coupled Model Intercomparison Project Phase 5
DEM	Digital Elevation Model
EEA	European Economic Area
EO	Earth Observation
ESA	European Space Agency
FSC	Fractional Snow Cover
GIS	Geographic Information Systems
GPS	Global Positioning System
HR	High Resolution
HRLDAS	Data Assimilation System for High Resolution
IR	Infrared
LC/LU	Land Cover / Land Use
LSM	Land Surface Model
MODIS	Moderate Resolution Imaging Spectroradiometer
MWS	Multi-Sensor/Multi-Temporal Wet Snow
NASA	National Aeronautics and Space Administration
NIHWM	National Institute of Hydrology and Water Management
NIR	Near-infrared
NMA	National Meteorological Administration
NR	Norsk Regnesentral
NWSRFS	National Weather Service River Forecast System
OLCI	The Ocean Land Colour Instrument
OWS	Optical Wet Snow
PSC	Project Steering Committee
RCPs	Representative Concentration Pathways
ROFFG	Romanian Flash Flood Guidance System
RS	Remote Sensing
SAR	Synthetic-Aperture Radar
SCE	Snow Cover Extent Area
SGEM	International Multidisciplinary Scientific GeoConferences
SGS	Snow Grain Size
SLSTR	Sea Land Surface Temperature Radiometer
SPOT	Satellite for observation of Earth
SSW	Snow Surface Wetness
STG	Scientific and Technical Group
STS	Snow Surface Temperature
SW	Snow Wetness
SWCC	Soil Water Characteristic Curve
SWE	Snow Water Equivalent
SWS	SAR Wet Snow
TDR	Time-Domain Reflectometer
USGS	U.S. Geological Survey
UTCB	Technical University of Civil Engineering
UTM	Universal Transverse Mercator
VHR	Very-High Resolution
WUT	West University of Timisoara