

The SnowBall project will improve the monitoring and impact assessment of snow in Romania under present climate and future climate scenarios.

The project will implement innovative approaches based on satellite, in-situ and modelling data for snow monitoring and risk assessment of climate related changes in rapid snowmelt and avalanches hazards.

PROJECT OUTCOMES

- › A denser, operational, in-situ snow measurement network in the test zone. An usable ground truth dataset for the validation of satellite derived snow products, as a result of in situ data collection;
- › Development and implementation of a prototype for snow monitoring system, combining Sentinel-1/-3 satellite data, weather data and hydrological modelling for snowpack parameters estimation;
- › A data assimilation procedure for adjusting the snowpack related state parameters within the snow models module of the hydrological forecasting models;
- › Quantitative estimations (for the first time in Romania) of the snowmelt contribution to the aquifer replenishment;
- › Development of methods and models (e.g. satellite image texture segmentation approaches, numerical avalanche simulation tool, Snowpack and Rapid Mass Movement System models) for avalanche detection and related hazard assessment;
- › Output of climate model generation (CMIP5) runs will be downscaled and tuned on regional and local scales to assess climate change impact on snow water resources and hazards over the study area in Romania.

Project website: snowball.meteoromania.ro

www.norwaygrants.org



REMOTE SENSING, MODEL AND IN-SITU DATA FUSION
FOR SNOWPACK PARAMETERS AND RELATED
HAZARDS IN A CLIMATE CHANGE PERSPECTIVE-
SNOWBALL



The overall project goal is to develop methodology supporting the vision of a snow service providing national authorities and the general public with consistent information in cvasi-real time, of the snow cover spatio-temporal characteristics and of associated hazards (floods caused by sudden melting of snow and avalanches), in conditions of present and future climate, based on in situ measured data and satellite information.

RESULTS

› **Developing algorithms for avalanches detection.**

In order to detect avalanches, in a rapid and accurate way, and to evaluate the associated risk, GIS technics and very high spatial resolution satellite images have been used (GeoEye-1, QuickBird, Pleiades). Thus, digital maps have been produced and a statistical analysis of the climatic data and of the main factors involved in avalanches production was achieved. In the central glacial sector of the Fagaras mountain massif (Bălea-Valea Doamnei, Valea Capra), well known by its high incidence of avalanches, 34 avalanche corridors were mapped on the terrain and integrated in the GIS database. The affected areals due to over 540 avalanches events have been identified on very high

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.

The project supports the public priorities: emergency situations and water management, transport and tourism.

spatial resolution satellite images. This avalanches inventory represents a premiere for the Romanian Carpathian. For the avalanche hazard maps a semi-automated methods for the avalanche corridor detection has been developed, based on morphometrically characteristics integration,

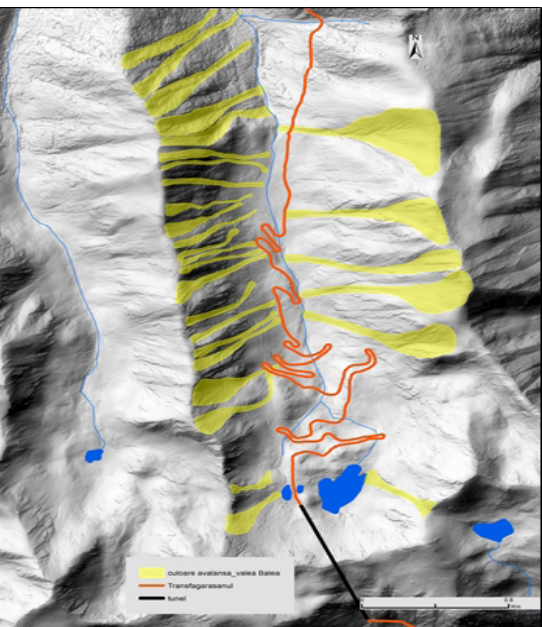
excerpts from topographic surface models, derived from the numerical terrain model. A preliminary analysis of the ability to identify avalanches by means of object-oriented algorithm was also achieved and succesfully tested on QuickBird satellite images, for some montains areas in Norway.

› **Developing algorithms for snow parameter estimation from satellite data.**

Methods and algoritms have been developed in order to achieve the snow parameters from satellite data for optical and radar spectral domain and for each specific parameter. The snow surface wetness estimation, based on satellite data in the optical domain (OWS), is achived by applying a temporal analysis of snow surface temperature, snow grain size and fractional of snow cover. For the wet snow assessment, from radar (SAR) satellite data, the developed algorithm is based on change detection using ratios of wet snow versus snow-free (or dry snow). The wet-snow and snow-free SAR images are acquired from the same satellite repeat pass. Radar images processing has been done with IDL code and Phthon scripting language that provides more flexibility in the processing chains. Currently, algorithms are used for MODIS and RADARSAT images, but they will be improved and implemented for Sentinel-1/-3 satellite images.

› **More accurate forecast of the snow melt water flow.**

For the improvement of the snow melt water flow warnings and forecasts the accurate estimation of the snow cover water equivalent is essential. A data fusion procedure was design based on simulations made with the hydrological model NOAH, that uses snow related parameters measured in the national meteorological and hydrometrical networks, as well as snow cover satellite-derived products. The forecasting hydrological model NOAH was reconfigured with a new simulation module dedicated for snow (represented in multi-layers).



The reconfiguration of the new snow module was accomplished at the national level, with a 1 km spatial resolution and the implementation was done with the open source hydrological model software WRF-HYDRO. The use of the new snow module in the multi-layers architecture will allow the elaboration of o more complex data fusion procedure and a better reliance of the snow related satellite products.

› **Climate variability and climate change impact on the snowcover and associated hazards.**

The anaysis of the results of six numerical experiments with regional climate models, in the framework of two climate scenarios (RCP 4.5 si RPC 8.5), regarding the snowcover thickness changes, in the period October – April, for Romania, for the timelines 2021-2050 and 2070-2099 with the refence period 1971-2000 has shown the following:

- decreasing the thickness of snow cover could accentuate to the end of XXI century, especially in the RCP 8.5 scenario where greenhouse gas concentrations are higher and the radiative override is more intense;
- spatial configurations of climate change indicate the orography impact, thus the location of the Carpathian arc toward large-scale circulations determine specific local effects;

- snow thickness decrease is stronger in the southern part of the Southern Carpathians, in the western part of the Apuseni Mountains and in the northwest part of the country, where it rise up to 90% in the worst conditions of the RCP 8.5 scenario;
- for the timeless 2021-2050, the northeast regions of Romania faced, in both scenarios, with significant reduction of snow cover up to 45%.

› **Evaluation of snowmelt water infiltration in unsaturated zone for aquifers refilling.**

Snowmelt water infiltration during the winter-spring period represents an important source for aquifer recharge. Evaluation of snowmelt water infiltration is based on the study of physical processes related to freezing-thawing processes, soil water migration, snowmelt water infiltration in frozen soil, interaction between the snow and frozen soil, soil heat and heat transfer between soil and snow and soil degradation through erosion processes. Modelling and prediction of the snowmelt water infiltration processes into the frozen soils can be used for risk and damage assessment related with climate change, especially for the mountain regions and regions with permafrost.