FINAL REPORT
of funded project under the Programme RO14 “Research within Priority Sectors”

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

Date of submission: 30.06.2017

Done by,
Project Promoter: National Meteorological Administration

Authorized Representative:	Position:	Director General
	Name:	Dr. Elena MATEESCU
	Signature: and stamp	....
Economic Director	Name:	Ec. Margareta MATEESCU
	Signature:	....
Principal Investigator :	Name:	Dr. Gheorghe STĂNCĂLIE
	Signature:	....

We declare, under our sole responsibility, that information and data provided through this Final Report of the project are authentic, accurate, compliant and complete for the Project Promoter as well as for the project partner(s) and that all expenditures were made from the resources provided by the Programme budget and, where appropriate, from the private cofinancing budget, exclusively for the project execution and in line with the provisions of the contract no. 19SEE/2014, funded by the Programme RO14 "Research within Priority Sectors".

Final Report shall be submitted as well in its editable version.

STRUCTURE OF FINAL REPORT

A. General Project Information

B. Final Summary Report

C. Report on scientific publications

D. Report (questionnaire) covering wider societal implications

E. Distribution of the financial contribution between the Project Promoter and project partners

A. General Project Information

GENERAL INFORMATION				
Number of project contract	19SEE/2014		**Acronym**	SnowBall
Duration of project	from	30.06.2014	to	30.04.2017
Project title	**Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective**			
Contract value	5.270.823,00 (lei)		1.199.000,00 (euro)	
Project Promoter	National Meteorological Administration			OTH[1]
Project Partner 1	Norwegian Computing Center			RES
Project Partner 2	Technical University of Civil Engineering, Groundwater Engineering Research Center			UNI
Project Partner 3	National Institute for Hydrology and Water Management			OTH
Project Partner 4	West University Timisoara, Department of Geography			UNI
Key words	Satellite images, snow wetness monitoring, climate change, avalanches, floods, hazards			
Type of R&D activities[2]	Basic research			(0-100%)
	Applied research			(0-100%)
	Experimental development		x	(0-100%)
Thematic area	Renewable energy to fight climate change			
	Health and food safety			
	Environmental protection and management			x
	Social sciences and humanities			

[1] Choose between research institute/center (RES), university (UNI), small and medium-sized enterprise (SME) and other (OTH).
[2] Choose the activity by ticking the corresponding box, as appropriate. In case of more than one type of activity, please also mention the percentage in the next box.

<table>
<tr><th colspan="8">PROJECT IMPLEMENTATION</th></tr>
<tr><td colspan="2">Work Package title and number[3]</td><td colspan="6">1. Management</td></tr>
<tr><td>Start date</td><td>planned</td><td colspan="2">30.06.2014</td><td>actual</td><td colspan="3">30.06.2014</td></tr>
<tr><td>End date</td><td>planned</td><td colspan="2">30.04.2017</td><td>actual</td><td colspan="3">30.04.2017</td></tr>
<tr><td>Cost of WP</td><td>planned</td><td>0,00 (lei)</td><td>0,00 (euro)</td><td>actual</td><td>0,00 (lei)</td><td colspan="2">0,00 (euro)</td></tr>
<tr><td>Implementing entities</td><td colspan="7">PP, P1, P2, P3, P4</td></tr>
</table>

An overview of the work towards the objectives of the project
No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 1.1. Project Management (Leader: PP; contributors: P1, P2, P3, P4)
The project management activity was developed by the Romanian National Meteorological Administration, as project promoter. The activity encompassed the research, administrative and financial activities, too, also the communication with the National Authority within the Ministry of Research and Innovation, as well as for the exploitation of the obtained results.
The Steering Committee of the Project (SCP) has been 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.
The Steering Committee and Project manager verified and analysed the documents requested by the program operator, 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".
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.
Four intermediate annual reports were made through the project partners' contribution to the planned activities for each year, plus the final report of the project.
Special attention was paid to the preparation of the annual and final reports, together with the deliverables, in Romanian and English; in accordance with the recommendations of the contracting authority, these documents included: general objectives, the objectives of the implementation phase, the summary of the stage, the scientific and technical description, the annexes and the conclusions.

Activity 1.2. Audit (Leader: PP; contributors: P1)
On November 2, 2015, the Snowballs project was monitored by the Contracting Authority. 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.
On November 26, 2015 representatives of the project promoter participated in the work meeting RO-14 "Research in Priority domains", organized by ANCSI at its headquarter in Bucharest. The agenda of the meeting included:

- Prepare the reporting set for 2015;
- Prepare the addendum of the contract;
- The outcomes of the 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.

From 16 March 2016 to 6 May 2016 the operational audit mission for SnowBall project took place, performed by the Central Harmonisation Unit for Internal Public Audit within the Ministry of Public Finance. The audit mission objectives targeted the following aspects:

[3] Add rows and provide information for all Work Packages of the project by following the table template.

– Project implementation stage and audited project budget execution stage; – Eligibility of declared expenses, disorder prevention, detection, recording and reporting, observance of regulations on acquisitions; – Justification and recording in accountancy of declared expenses; – Observance of project information and publicity demands. The final report of the audit team (no. 370638/02.06.2016) contained a series of findings and recommendations for each specific objective of the audit mission, detailed for each project partner. The final conclusion and opinion of the audit team mentioned that at the level of the Project Partners, NMA ensured the organizing framework necessary to SnowBall project implementation, i.e. to the fulfilment of attributions and responsibilities stipulated for PP in the applicable Set of Regulations but that certain improvements must be made in the following fields: correctness and completion of the Annual Financial Reports; completion of tasks and responsibilities of the persons appointed in the project implementation team; improving activities regarding the CFPP project; manner of dealing with disorders, Publicity and Dissemination; acquisitions and archiving. The audit team assessed that favourable premises exist for finalizing all the activities stipulated within the project. To elaborate a point of view regarding the findings and recommendations from the audit report, a series of meetings took place in the 6-27 May 2016 interval at the headquarters of PP - NMA with individuals responsible on behalf of the Romanian partner institutions. The point of view resulted following the discussions contained explanations and justifications on the grounds of administrative and financial documents and was supported on the occasion of the reconciliation meeting on 27 May 2016. In view to implement recommendations formulated in the audit Report, in the June – December 2016 interval, periodic meetings took place monthly along with discussions via Skype with an information and consultation purpose among the project partners, as well as with the contracting authority and the Ministry of European Funds. Following the discussions, reports were elaborated concerning the stage of implementing recommendations made at the operational audit performed by the Central Harmonisation Unit for Internal Public Audit on 5 July 2016 and 12 December 2016. Also, the additional Act no. 6 from 31 October 2016 to the financing contract no. 19 SEE/ 2014 was concluded, regulating a series of financial aspects noticed by the operational audit team.	
Milestones and deliverables[4]	***Faze 1: 30.11.2014*** D1.1. Project Management Plan (PMP) D1.2. Annual Project Report ***Faze 2: 31.12.2015*** D1.2. Annual Project Report ***Faze 3: 31.12.2016*** D1.2. Annual Project Report ***Faze 4: 30.04.2017*** D1.2. Annual Project Report D1.3. Final scientific and financial Report submitted to the PO, within 60 days after the project end
Description and justification of discrepancies and corrective actions *If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.*	

[4] Please provide basic information about all achieved milestones and deliverables described in the project proposal, including their numbers and names. Please give an explanation if the planned milestones and deliverables were not achieved.

Work Package title and number		2. In-situ snow parameters measurements				
Start date	planned	30.06.2014		actual	30.06.2014	
End date	planned	30.04.2017		actual	30.04.2017	
Cost of WP	planned	678,032.15 (lei)	154,235.00 (euro)	actual	687,351.60 (lei)	154,576.38 (euro)
Implementing entities	PP, P3, P4					

An overview of the work towards the objectives of the project
*No more than 2 A4 pages for each implemented WP: a description of the **results achieved** within the project, **activities carried out** and an **explanation of the use of resources.***

Activity 2.1. Design and implementation of new snow measuring devices and equipment (Leader: PP)

Professional grade weather stations are expensive and usually support sensors from the same manufacturer. The project requirements in terms of the type of snow parameters to be measured and the particular data collection setup have led to design and building of dedicated snow parameters measurements within the project Consortium.

Snow stations and calibration/validation stations capable to measure snow depth, snow temperature at 5 levels and snow dielectric permittivity at 2 levels respectively soil temperature at 6 levels, snow surface temperature, snow temperature at 5 levels, snow dielectric permittivity at 2 levels, snow depth and snow cover (using CCTV cameras) were designed, tested and deployed at 9 weather station locations. The stations are fully automated, configurable, run on solar power and transfer data using a cellular network. The core of each station is a data logger based on an open source microcontroller (Arduino compatible) where different modules can be added on a need be basis (e.g. GSM shield, RT clock, etc). Open source libraries have been used to interface the sensors to the data logger and C/C++ code has been written to control the operations of the snow station. The modular design of the data logger allows for an easy expansion of the snow stations with different/multiple sensors.

During the data collection period, the snow stations have been operating remarkably well, only with few interruptions caused in one case by a faulty contact and in another by snow infiltration in the battery compartment during a heavy snowstorm.

Activity 2.2. Snowpack parameters observation and measurements (Leader: PP; contributors: P4)

Using remote sensing to determine the snow parameters - such as the amount of snow 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. In 2016-2017, snow spectral data sets containing more than 300 measurements in the visible and infrared domain have been collected during the several field campaigns in Sinaia and Babele areas, using the DSR (StellarNet) portable spectroradiometer, that can measure both reflected radiation in the solar spectrum and the emission in the infrared spectrum (200-1700 nm). Snow transmittance and irradiance spectra covered a wide range of weather and snow conditions (sun angles, spectroradiometer viewing angles, air temperature, illumination, etc).

Snow depth, snow temperature at 5 levels and snow dielectric permittivity at 2 levels, during 2016-2017, were measured by the SnowBall automated stations at 7 sites of the study areas in Romania. The dielectric permittivity of snow has been successfully used to calculate the snow liquid water content using both Denoth and Topp equations. Other data collected includes air temperature, snow density, depth, temperature and moisture from the NMA weather network.

At the cal/val sites (Tg. Secuiesc, Joseni), soil temperature at 6 levels, snow surface temperature, snow temperature at 5 levels, snow dielectric permittivity at 2 levels, snow depth and snow cover (using CCTV cameras) were measured for the calibration of the satellite snow moisture algorithms and product validation.

Measurements were taken on an hourly basis and dispatched once a day to the project ftp server. The CCTV camera took daytime hourly snapshots of the surrounding snow cover.

Furthermore, air temperature data on a descending altitude gradient (every 100 m) from Sinaia 2000 to Sinaia 1500 and from Babele to Pestera has been collected using button size temperature sensors.

Activity 2.3. Create and set-up of a spatial database managed by GIS software (Leader: PP; contributors: P3, P4)

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;
- Compliance check with the INSPIRE directives;

The geospatial database includes classical data (maps, satellite images, in-situ data) or other data types (photos, graphs, statistical data, and descriptive documents). The geospatial database contains both historic and recent data. When not available in digital format, aerial photographs and maps have been digitised.

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, aerial imagery, satellite images or using GPS measurements.

The data have been obtained in ESRI Shapefile, 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.

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

Activity 2.4. Elaboration of spatial products using the spatial database (Leader: PP; contributors: P3)

Daily gridded data sets of air temperature (minimum, mean and maximum), precipitation, snow depth and snow water equivalent have been updated over the period 1 October 2005 – 30 April 2017 at 1000 × 1000 m spatial resolution.

The spatial interpolation procedure of the weather stations data was achieved through three steps, as follows:

(1) Spatial interpolation (at 1000 × 1000 m resolution) of the mean multiannual values corresponding to each month, computed from data extracted from the climatological database;

(2) The daily, 5-day and yearly deviations against the multiannual monthly mean were computed for each day, 5-day and 1-year periods, respectively, over 2005-2017, together with their spatial interpolation;

(3) The spatio-temporal datasets were obtained by merging the two surfaces obtained in the aforementioned stages.

For air temperature, the anomalies were considered to be the differences between the hourly values and the multiannual means, while for precipitation and snow depth, the ratio between hourly values and climatology was used. In order to build the maps with the climatological normals (multiannual means), the Regression-Kriging (RK) spatial interpolation method was used.

A number of interpolation methods were tested in order to choose – by a **cross validation** procedure – the optimum interpolation method of daily anomalies against the multiannual means: Inverse Distance Weighting (IDW), Multiquadratic (MQ) and Ordinary Kriging (OK). Comparing estimated and observed data was performed with the help of the following error measurement indicators: mean error (ME), mean absolute error (MAE), root mean square error (RMSE). Box-plot diagrams and Taylor-type diagram were also used.

For all analysed parameters, the cross validation procedure was applied to the anomalies computed over 2005-2017. Given that both validation methods of the interpolation procedures highlight the good results obtained by MQ, this method was selected for the spatial interpolation of anomalies. By summing the maps displaying the minimum temperature daily anomalies and the maps displaying the climatological normals, the daily minimum air temperature maps at 1000 × 1000 m spatial resolution were built.

The use of resources:

Total WP: 687,351.60 (lei), 154,576.38 euro

Activity 2.1: Total: 342,895.80 lei / 77,087.98 euro, distributed by partners: PP: 342,895.80 lei / 77,087.98 euro;

Activity 2.2: Total: 155,099.95 lei / 34,883.30 euro, distributed by partners: PP: 123,866.34 lei / 27,846.96 euro; P4: 31,233.61 lei / 7,036.34 euro;

Activity 2.3: Total: 105.180.19 lei / 23,673.13 euro, distributed by partners: PP: 65.941,50 lei / 14,824.61 euro; P3: 5.844,96 lei / 1,325.55 euro; P4: 33.393,73 lei / 7,522.97 euro;

Activity 2.4: Total: 84.175,66 lei / 18,931.96 euro, distributed by partners: PP: 76.931,75 lei / 17,295.38 euro; P3: 7.243,91 lei / 1,636.58 euro;

Milestones and deliverables	***Faze 1: 30.11.2014*** D2.1: Laboratory tested prototype for snow temperature profile – Version 1 D2.2: Laboratory tested prototype for snow temperature profile – Version 2 D2.11: Prototype of the spatial database for snow related parameters ***Faze 2: 31.12.2015*** D2.3: SD and SWE data sets (from AWS) – Version 1 D2.5: Reflectance spectral data sets of the snow – Version 1 D2.9: Snowpack parameters data sets – Version 1 D2.12: Spatial database over the test zone, in a GIS environment D2.13: Snow related in-situ data sets and historical meteorological and hydrological data – Version 1 D2:15: Mapping products derived from the spatial database (SD, SWE, precipitation, etc.) - Version 1 ***Faze 3: 31.12.2016*** D2.7: Measuring methodology of SWE dielectric constant sensor – Version 1 D2.8: Measuring methodology of SWE dielectric constant sensor – Version 2 ***Faze 4: 30.04.2017*** D2.4: SD and SWE data sets (from AWS) – Version 2 D2.6: Reflectance spectral data sets of the snow – Version 2 D2:10: Snowpack parameters data sets – Version 2 D2.14: Snow related in-situ data sets and historical meteorological and hydrological data – Version 2 D2.16: Mapping products derived from the spatial database (SD, SWE, precipitation, etc.) - Version 2
Description and justification of discrepancies and corrective actions *If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.*	

Work Package title and number	3. Satellite remote sensing, data fusion and modelling of snow parameters				
Start date	planned	30.06.2014		actual	30.06.2014
End date	planned	30.04.2017		actual	30.04.2017
Cost of WP	planned	1,335,288.74 (lei)	303,744.00 (euro)	actual	1,487,900.56 (lei)	334,988.73 (euro)
Implementing entities	PP, P1, P3				

An overview of the work towards the objectives of the project
No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 3.1. Single sensor algorithm porting to Sentinel 1/3 satellites (Leader: P1; contributors: PP)

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.

The algorithm validation results for the test sites in Norway and Romania for the three winter seasons have been presented (the winter seasons during the project life). The validation was limited to comparison with air temperature, snow cover and snow depth recorded at the weather stations.

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.

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.

Activity 3.2. MWS algorithm and product (Leader: P1; contributors: PP)

The snow wetness maps are in general quite consistent with the air temperatures. In most cases retrieval results of dry snow correspond with air temperatures below freezing point, and retrieval results of wet-snow with positive air temperatures. The highest air temperatures are usually associated with the wettest snow classes. When some inconsistencies were identified, most could be well explained with transitions from cold and dry conditions during the night, to short periods of positive air temperatures during daytime. If the air temperatures above 0°C have lasted for only a few hours, the snow surface may 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.

It was noted that the MWS maps are usually internally consistent in the way that the content follows the topography and the local climate. The temporal transitions are similar in the way that increasing air temperatures gives increasing snow wetness. Also, the snow wetness classes follow the topography logically (canonically) with wettest snow at lower altitudes and reduced wetness with increasing altitudes.

The inclusion of SAR data indeed improves the observational capacity when optical observations are obscured under clouds. But SAR gives less information than optical (it can only discriminate between dry and wet snow), and it is prone to noise showing false wet snow especially in agricultural areas. This is a well-known problem in the snow SAR community, but not fully understood. Ploughed fields give high backscatter when the ground is wet, and it might be that there are cases with wet soil under a layer of dry snow. However, fields might also give false snow in the summer. So, the problem is more complex and probably related to the use of reference data in the algorithms that might result from a mixture of soil tillage in the reference data giving significant variation in the backscatter properties of some fields.

The main added value of the MWS maps is that there is a new map every day, independent of meteorological conditions . The validation in the case of sharp weather shifts requires additional in situ observations, but otherwise the approach seems to produce useful estimates of the current conditions of the snow. However, it is important to stress that the Hidden Markov Model that is used in the retrieval algorithm is not a forecasting model – it is a data fusion model. Therefore, snow wetness maps from days with few or no observations have necessarily a higher uncertainty.

As an overall conclusion, the analysis of the novel multi-sensor/multi-temporal wet snow maps has confirmed that the approach of fusing temporal series of optical and SAR observations to make an estimate of the daily snow surface wetness state, seem to work well in general. The project reached the proposed goal of developing a fusion algorithm for optical and SAR data, and to tailor it to and validate and demonstrate it on Sentinel-1 SAR and Sentinel-3 optical data, utilising the operational capability in Earth Observation established by the Copernicus programme.

Activity 3.3. New multilayer snow model module in NOAH (Leader: P3; contributors: PP)

In order to reduce the errors associated with the estimation of the snow water equivalent, we designed and implemented within SNOWBALL Project a specific data fusion type approach.

The data fusion procedure, implemented for estimating the water equivalent in the snow layer, use the main following type of input data:

- snow water equivalent simulations performed with a distributed hydrological model;
- observations of the snow layer from the national monitoring networks;
- satellite products for the snow cover extent.

Given the limits of the initial NOAH model configuration, which use a simplified modelling with a single layer, it was done the reconfiguration of NOAH-R model with an improved module of snow simulation, with a multi-layer representation.

The configuration of the new snow module was done at a spatial resolution of 1km, the implementation being based on the open source software of hydrological modelling system WRF - HYDRO (http://www.ral.ucar.edu/projects/wrf_hydro/), which includes both the original version of NOAH-R model as well as an enhanced version with multiple configuration options of how to represent different hydrological processes.

Within the data fusion process, the different type of data and information are analysed 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 successive steps of interpolations and adjustments, depending on the degree of uncertainty associated with different type of data.

The software implementation was also done using a modular approach, flexible and easy adapted configuration, based on selected stable open source components.

This first version of the snow water equivalent estimates using the data fusion methodology was applied experimentally for estimating the gridded snow water equivalent at the end of month of December 2016, using the available data from the ground observation, distributed snow model simulations and snow cover extent satellite products.

The data fusion methodology for estimation of snow water equivalent, as a gridded product with 1 km spatial resolution, at national level, was applied experimentally during the period January – March 2017, in order to test, correct and improve the algorithms and data processing workflow.

The results were compared with a reference interpolation method, respectively with the IDW method, computed using the available snow water equivalent observations from the stations networks.

The use of resources:

Total WP: 1,487,900.56 lei / 334,988.73 euro

Activity 3.1: Total: 511,332.31 lei / 115,204.30 euro, distributed by partners: P1: 412,859.67 lei / 93,066.22 euro; PP: 98,472.64 lei / 22,138.09 euro;

Activity 3.2: Total: 802,324.66 lei / 180,747.44 euro, distributed by partners: P1: 617,864.30 lei / 139,278.06 euro; PP: 184,460.36 lei / 41,469.38 euro;

Activity 3.3: Total: 174,243.59 lei / 39,036.99 euro, distributed by partners: P3: 114,896.24 lei / 25,694.84

<table>
<tr><td colspan="2">euro; PP: 59,347.35 lei / 13,342.15 euro.</td></tr>
<tr><td>Milestones and deliverables</td><td>Faze 2: 31.12.2015
D3.1: Validated optical and SWS retrieval algorithms
D3.2: Validated MWS retrieval algorithm
D3.3: MWS prototype products for flood and avalanche warnings – Version 1
D3.5: Data fusion methodology for estimating the SWE, using distributed snow model simulations, ground observations and satellite products
Faze 3: 31.12.2016
D3.4: MWS prototype products for flood and avalanche warnings – Version 2
D3.6: Gridded SWE prototype products generated using data fusion methodology – Version 1
Faze 4: 30.04.2017
D3.4bis: MWS prototype products for flood and avalanche warnings – Version 2
D3.7: Gridded SWE prototype products generated using data fusion methodology – Version 2</td></tr>
<tr><td colspan="2">Description and justification of discrepancies and corrective actions
If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Work Package title and number		4. Climate change impact on snow-related hazards				
Start date	planned	30.06.2014		actual	30.06.2014	
End date	planned	30.04.2017		actual	30.04.2017	
Cost of WP	planned	641,405.82 (lei)	145,903.50 (euro)	actual	486,255.88 (lei)	109,040.22 (euro)
Implementing entities	PP, P2, P3, P4					

An overview of the work towards the objectives of the project

No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 4.1. Snow-related climate variability and change and associated impact (Leader: PP; contributors: P2)

The results from 5 regional climate models (RCMs) from the EURO-CORDEX program regarding the impact of variability and climate change on snow cover characteristics over Romania have been used.

The ensemble means of the results from the five RCMs under the moderate climate change scenario (RCP 4.5) and worst case one (RCP 8.5) reveal the decrease of snow depth and snow water equivalent in the cold season (October to April) throughout Romania, with regional and local differences. Under the scenario with the highest greenhouse gases (GHGs) concentration (RCP 8.5), the decrease in snow depth, snow amount and snow water equivalent is larger towards the end of 21^{st} century. The decrease in snow amount could be larger than 80% (compared with the reference period October-April 1972-2001) in areas from the Western, central and Southern Romania. In mountain areas, the reduction is slightly smaller ranging from 60% to 80% at the end of the 21^{st} century, in the worst case scenario. The analysis shows that the mean number of days in a season with good ski conditions also decreases under climate change scenarios at the locations in the Romanian Carpathians which were investigated. Also, the mean number of days with conditions for artificial snow making is decreasing, under climate change. On the other hand, the amount of melted snow is also changing, with a magnitude depending on the altitude. Due to the early and enhanced snow melting in low-altitude areas, the water contribution from the melting snow to the soil is reduced under the climate change. In contrast, at higher altitudes there is an increase in water contribution to the streamflow during the transition months when snow melting is taking place.

Activity 4.2. Variability and change in flash floods with snow melt contribution (Leader: PP; contributors: P3)

The results for Activity 4.2 are relevant for the variability and change in the statistics of maximum discharge which have an impact on flash floods with contribution from the melted snow. In this case, hydrological modelling was carried out in the sub-basins corresponding to the rivers Arges and Ialomita. The results of the hydrologic model (CONSUL) indicate that multiannual averages of maximum discharges during the interval from November to April show increases in the interval 2022-2050 compared with present climate (1981-2010) under best (RCP 2.6) and worst (RCP 8.5) climate change scenarios.

In the upper area of the Arges and Ialomita rivers, the average increases of maximum discharge are higher in the in the worst case scenario (RCP 8.5) in all months, except in November (Figure 1). For sub-basins covering larger area, the increases are systematically larger under the worst case scenario (RCP 8.5) compared with the best case scenario (RCP 2.6) showing how the climate change signal overcomes the noise beyond specific spatial scales of the river basins (Figure 1).

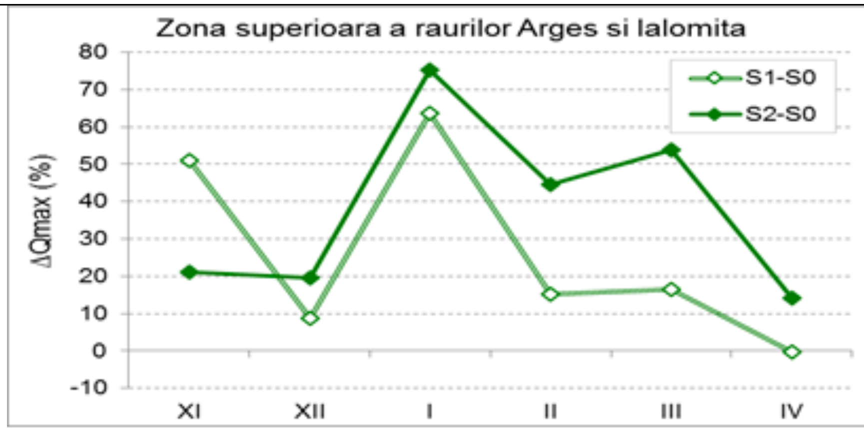

Figure 1: The monthly mean of the relative anomaly of maximum discharge (%) under the scenarios S1 (RCP 2.6) and S2 (RCP 8.5) for the time horizon 2022-2050 compared to the historical scenario S0 (1981-2010), for the upper part of the Arges and Ialomita rivers.

Activity 4.3. Variability and change in avalanche statistics (Leader: PP; contributors: P4)

The results of Activity 4.3 consist of the analysis of variability and change in observed avalanche statistics in order to identify the predictive potential for the climate conditions which lead to avalanches. In this context, we have firstly identified the climate conditions for avalanches in the Carpathians. Then we computed the composite maps for large scale variables for the days with episodes of avalanches using monthly stratified data. We used the NCEP/NCAR Reanalysis covering the time interval from January 1948 up to present. We selected as large scale variables daily geopotential heights at 500 hPa, daily sea level pressure, daily temperature at 850 hPa and daily zonal wind component at 300 hPa. The composite maps suggest we might use the approach of multifield analog prediction method. We selected the month of April, with a large number of avalanches, to build and test the predictive model. The components of the large scale climate vector are the standardized anomalies of geopotential heights at 500 hPa, temperature at 850 hPa, sea level pressure and zonal wind at 300 hPa for the Atlantic European sector. The components of the local scale vector are the daily snow depth and air temperature and 5-day snow water equivalent averaged over the Fagars Masiff for locations above 1800 m. Local data are derived from the high resolution data sets (1 km x 1 km) built in the project. Daily data available for the study are from year 2000 up to year 2016. In order to predict the events, we use the Euclidean distance between the past events and the actual conditions, in the hyperspace defined by the first 4 empirical orthogonal function (EOFs) modes. The states associated with avalanche events do not significantly cluster themselves in the state space defined by the first EOFs, so the skill of the model is not high. However, there is some sort of structure in the state space defined by, for instance, EOF1 and EOF 2 due to the smallest number of state points associated with avalanches for negative values of EOF 1 and positive values of EOF 2 (Figure 2). This fact suggests that the multifield analog approach could be improved by adding more local components.

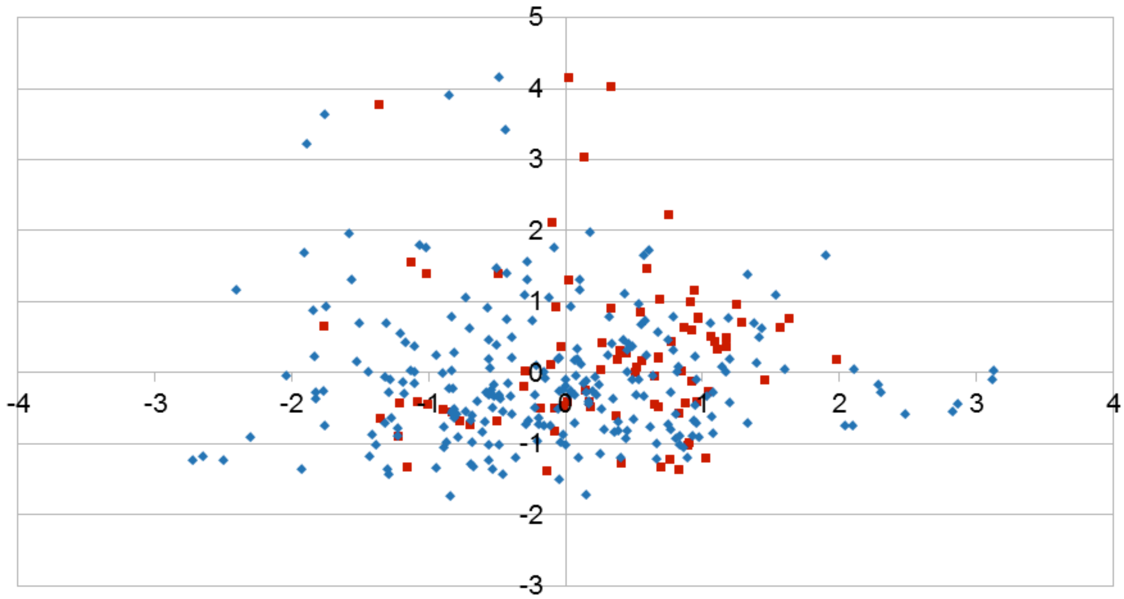

Figure 2: Projections in the space of states defined by the EOF 1 and EOF 2 modes of the correlation matrix associated with the climate state vector defining the avalanche conditions in April in the Fagaras Massiff. Red circles are appropriate for avalanche days, and blue for days without avalanche

The use of resources:
Total WP: 486,255.88 lei / 109,040.22 euro
Activity 4.1: Total: 117,381.35 lei / 26,230.05 euro, distributed by partners: PP: 84,141.35 lei / 18,916.20 euro; P2: 33,240.00 lei / 7,313.85 euro;
Activity 4.2: Total: 225,330.85 lei / 50,511.47 euro, distributed by partners: PP: 67,700.28 lei / 15,220.01 euro; P3: 157,630.57 lei / 35,291.46 euro;
Activity 4.3: Total: 143,543.68 lei / 32,298.69 euro, distributed by partners: PP: 83,525.90 lei / 18,777.84 euro; P4: 60,017.78 lei / 13,520.85 euro;

Milestones and deliverables	***Faze 2: 31.12.2015*** D4.1: Present (1981-2010) and future (2021-2050) assessment of snow-related parameters (e.g. monthly and daily SWE, 6-hour temperature and precipitation) from CMIP5 archive downscaled for selected hazard and resource analyses over the area of interest D4.2: Hydrological model with snow accumulation and snow melt capabilities calibrated in the upper part of Arges-Ialomita river basins ***Faze 3: 31.12.2016*** D4.3: Empirical model linking avalanche frequency and atmospheric conditions ***Faze 4: 30.04.2017*** D4.4: Assessment of climate change impact (2021-2050 vs. 1981-2010) on flash floods with snow melt contribution from winter to spring transition period in the upper part of Arges-Ialomita river basins D4.5: Public report on the impact of climate change for snow-related resources (snow contribution to aquifer) and hazards (flash floods with snow melt contribution, avalanche statistics) D4.6: GIS-enhanced maps of changes from present to future climate for snow water equivalent, statistics of flash floods with snow melt contribution, avalanche statistics, and snow contribution to aquifer over area of interests

Description and justification of discrepancies and corrective actions
If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.

Work Package title and number		**5. Aquifer replenishment modelling from snowmelt infiltration**				
Start date	planned	30.06.2014		actual	30.06.2014	
End date	planned	31.01.2017		actual	31.01.2017	
Cost of WP	planned	564,952.06 (lei)	128,512.00 (euro)	actual	586,249.28 (lei)	131,286.39(euro)
Implementing entities	P2, P3					

An overview of the work towards the objectives of the project
No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 5.1. Snowmelt infiltration assessment for the unsaturated zone (Leader: P2)
The assessment of the infiltration of snow melting in the unsaturated zone is based on the processes of aquifers recharge from snow melt. The assessment of snowmelt recharge was done for three study areas: **(1) Bolboci study area - Omu Peak (upper basin of Ialomita Valley):** From a geomorphologic point of view the study area belongs to Bucegi Mountains and to Leaota Mountains. The accumulation and flow of groundwater is also favoured by the existence of a well-developed fracture system. The area of Bucegi Mountains is characterized by a good regime of precipitation, both liquid and solid which favours the aquifers recharge. **(2) Prahovova-Teleajen alluvial cone study area.** We find developed a complex structure, consisting of two overlapping and independent aquifer complexes: (a) the confined complex (the lower one), included in Cândesti strata; (b) the unconfined complex (the upper one) included in the alluvial deposits. After analysing and interpreting the state network borehole data it resulted that the aquifer system that develops between the Prahova River and the Teleajen River presents a complex structure both from a lithological point of view and from a hydrodynamic point of view. **(3) Colentina area, Bucharest city.** This area was study because it has three essential characteristics: there is a sedimentary aquifer in this area, the area is an urban area and it is hydrogeological characterized. In Colentina area there is an experimental hydrogeological monitoring site consisting of five hydrogeological wells up to 25 m and a geophysical survey well up to a depth of 60 m. The studied formations from this area are Colentina and Mosiştea aquifer formations.

Activity 5.2. Aquifer modelling (Leader: P2; contributors: P3)
The Aquifer modelling activity together with the ***Assessment of the infiltration of snow melting in the unsaturated area*** was the basis for accomplishing the main delivery task of work package 5. Delivery task D5.2. Aquifers act as natural reservoirs which can be used as drinking or/and irrigation water supply. The estimation of snow melt is also extremely important for flood forecasting, for hydrological modelling of river basin processes (surface runoff, overexploitation, sediment transport, nutrient transport, depth of frozen soil), for general design projects (highways, footbridges, sewer systems, etc.) and for projects regarding safety and recreational activities (avalanche warnings, ski and road conditions). The modelling of surface leakage resulting from the melting of snow in a mountain watershed is perceived as difficult due to the complexity of the simulation, but also because of the difficulty in specifying the model parameters and the absence of a theory explaining the surface leakage mechanism resulting from the melting of the snow. It is still controversial how to incorporate temperature changes into the snow melting pattern, but also the leakage from a mountain basin.
In the A5.1 and A5.2 activities, a number of in-situ tests and measurements were carried out using the equipment purchased under the project (TDR Investigation System) as well as the equipment provided by the Groundwater Engineering Research Center.
The results of the two activities were described in Deliverables D5.1 and D5.2, and these can be synthesized:
(1) Flow modelling calibrated with the new methodology for determining the infiltrations from snow for the studied areas;
(2) Assessment Methodology for snow infiltration and aquifer recharge taking into account modeling energy and water flow.

Activity 5.3. Pattern matching and climate scenarios (Leader: P2; contributors: P3)
Pattern matching and climate scenarios were represented in climate projections in modelling water infiltration patterns in aquifers. Climate scenarios are alternative ways, where the future can take place. Climate scenarios have evolved from stylized representations of annual percentage increases in global GHG concentrations to advanced GHG representations that affect the climate based on detailed socio-economic and technological hypotheses. Climate scenarios based on emission estimates are used to explore the anthropogenic influences

that could contribute to future climate change, given the uncertainties of factors such as population growth, economic development and the development of new technologies. RCPs are the latest generation of scenarios that provide information on climate models. Scientific advances and increasing interest in exploring different approaches to achieving specific climate change objectives (such as limiting change to 2°C) and increasing interest in a "risk management" approach combining emission reductions and adaptation to reduce The damage caused by climate change also dictated the need for new scenarios. The result of this activity was to assess the future potential of infiltration and recharge of aquifers in from snow. Estimation has been made for the Padina area, the Bucegi Mountains. ***The use of resources:*** Total WP: 586,249.28 lei / 131,286.39 euro Activity 5.1: Total: 126,528.13 lei / 27,999.16 euro, distributed by partners: P2: 126,528.13 lei / 27,999.16 euro; Activity 5.2: Total: 232,655.26 lei / 52,919.24 euro, distributed by partners: P2: 172,970.31 lei / 39,460.01 euro; P3: 59,648.95 lei / 13,459.23 euro; Activity 5.3: Total: 227,065.89 lei / 50,367.99 euro, distributed by partners: P2: 190,228.65 lei / 42,168.98 euro; P3: 36,837.24 lei / 8,199.01 euro.	
Milestones and deliverables	***Faze 2: 31.12.2015*** D5.1: Sites description and conceptual models: The deliverable will describe in detail the geological, hydrogeological and climatic conditions of each of the targeted areas. Based on these studies, an integrated conceptual model will be developed ***Faze 3: 31.12.2016*** D5.2: Snowmelt infiltration methodology: The innovative aspect of the new methodology is the integration of measured data from the field test with remote sensing and meteorological data. The methodology will be tailored on the hydrogeological and climatological conditions ***Faze 4: 30.04.2017*** D5.3: Groundwater resources in the climate change framework: Based on the achievements of the WP4 (Climate Change) regarding the different climate change models and scenarios a holistic study for groundwater resources in correlation with snowmelt infiltration will be developed
Description and justification of discrepancies and corrective actions *If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.*	

<table>
<tr><td colspan="2">Work Package title and number</td><td colspan="5">6. Assimilation of snowpack parameters in the National Flood Forecasting and Warning System</td></tr>
<tr><td>Start date</td><td>planned</td><td colspan="2">30.06.2014</td><td>actual</td><td colspan="2">30.06.2014</td></tr>
<tr><td>End date</td><td>planned</td><td colspan="2">31.12.2016</td><td>actual</td><td colspan="2">31.12.2016</td></tr>
<tr><td>Cost of WP</td><td>planned</td><td>301,845.24 (lei)</td><td>68,662.00 (euro)</td><td>actual</td><td>246,458.79 (lei)</td><td>55,452.02 (euro)</td></tr>
<tr><td>Implementing entities</td><td colspan="6">PP, P1, P3</td></tr>
</table>

An overview of the work towards the objectives of the project

No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 6.1. Update the LC/LU map for the study area using high spatial resolution satellite images (Leader: PP)

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 aerial imagery 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) has been used for the implementation of the distributed hydrological model NOAH-R developed in the working 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 (Leader: P3; contributors: PP, P1)

In general the operational hydrological models include also a snow modelling component, but due to the cumulative effect of the errors in the estimation of the meteorological input parameters (especially precipitation and air temperature). There are frequently significant deviations between the real snow water equivalent of the snowpack and the simulated values.

The Romanian National Hydrological Forecasting and Modelling System are composed by specialized hydrological modelling modules, adequate for the real-time simulation and forecasting of hydrological processes at different spatial and temporal scales.

One of the main applications, of the improved detailed estimations of the snow water equivalent, is to update this important state parameter in the operational hydrological forecasting models, as the best possibility to reduce the errors of the simulated snow pack parameters within the hydrological models, and their potential negative impact on the hydrological forecasts and warnings accuracy.

Taking into account that the gridded SWE product generated using the data fusion approach represent the best estimate of this parameter, using detailed model simulation, satellite products and ground observation, the direct insertion method is used as data assimilation approach. This approach makes the explicit assumption that the models simulations have no supplemental useful information, other than the information used to derive the data fusion product.

The NOAH-R distributed hydrological model simulations is also one of the main input data in the data fusion methodology, so the state SWE parameters in the model are updated based on the adjusted gridded SWE output product, from the data fusion methodology have the same spatial resolution (1Km).

The other two important hydrological forecasting systems (NWSRFS and ROFFG) are using the same conceptual model SNOW-17, for simulating the snowpack evolution.

The adjusted gridded SWE product, output from the data fusion methodology, is used to compute the mean SWE for the sub-basins configured within the NWSRFS and respectively ROFFG operational models implementation. Taking into account the uncertainty related to the real time data, the mean sub-basin SWE from the model will be adjusted only if the difference is > 10 %. Using the same gridded SWE product for each basin it is computed also the basin areal snow cover extent (based on the distribution of cells with 0 SWE). Also, the areal snow cover extent will be adjusted only if the difference is > 10 %.

Activity 6.3. Implementation of the methodology for data assimilation of snow pack parameters in the main operational hydrological forecasting models (Leader: P3)

The data assimilation processing steps have been implemented independently for each of the main hydrological forecasting systems: NOAH-R, NWSRFS and ROFFG.

The processing chain was tested experimentally using the SWE 1 km gridded product generated using the new data fusion methodology based on the real time data and information at the end of December 2006.

In figure 3, is presented as example, the result of the mean sub-basins water equivalent values data assimilation, at the level of the river basins configured within NWSRFS system, computed based on the data fusion SWE gridded product output, for the Olt River Basin, on the date of 30.12.2016.

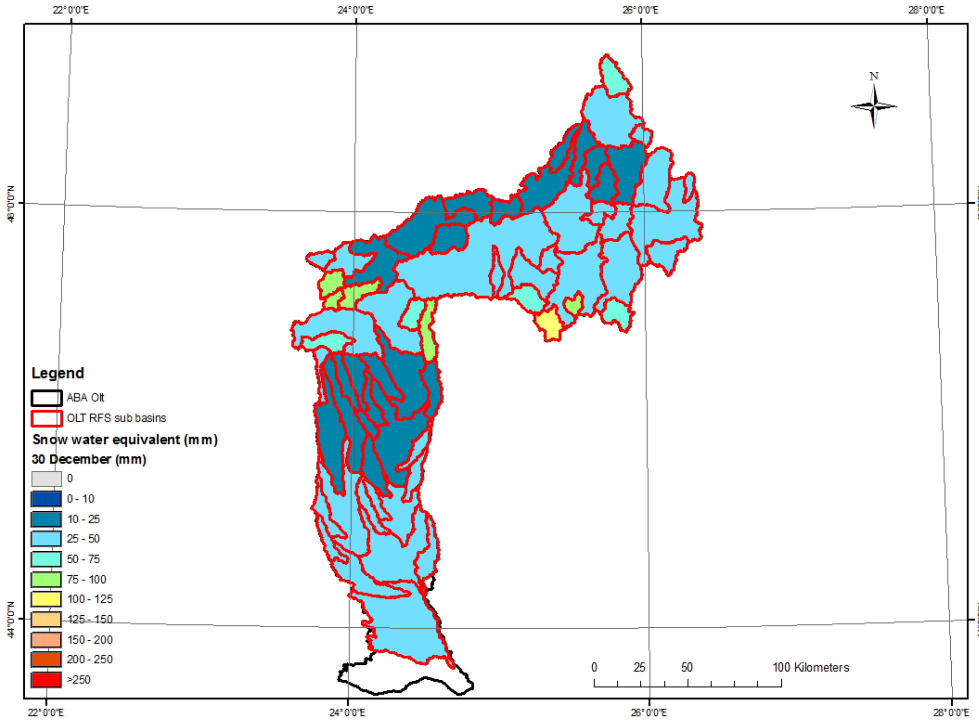

Figure 3: NWSRFS – mean subbasins SWE assimilated values, computed based on the product generated by the data fusion method, at level of Olt River Basin, for the date of 30.12.2016

For the NWSRFS System, taking into account that this forecasting system it is implemented and is running independently on each of the main 11 River Basins, the data assimilation process is done in parallel sequence for each of these basins, according to the NWSRFS sub-basins delineation.

The specific different data assimilation processing steps have been implemented using the same main open-source software components, as for the data fusion methodology, and the processing and data flow interfaces with the existing forecasting systems were implemented in R and Java languages.

The use of resources:

Total WP: 246.458,79 lei / 55,452.02 euro

Activity 6.1: Total: 37.366,85 lei / 8,400.61 euro, distributed by partners: PP: 37.366,85 lei / 8,400.61 euro;

Activity 6.2: Total: 137.793,69 lei / 31,050.71 euro, distributed by partners: P3: 17.472,44 lei / 3,945.33 euro; PP: 28.574,65 lei / 6,424.00 euro; P1:91.746,60 lei / 20,681.38 euro;

Activity 6.3: Total: 71.298,25 lei / 16,000.69 euro, distributed by partners: P3: 71.298,25 lei / 16,000.69 euro.

Milestones and deliverables	***Faze 2: 31.12.2015*** D6.1: Updated LC/LU map for the study area D6.2: Design of the methodology for snowpack parameter assimilation in the operational hydrological forecasting models ***Faze 3: 31.12.2016*** D6.3: Implementation of the snowpack parameter assimilation into the hydrological forecasting modelling system: NOAH-RNWSRFS (U.S. National Weather Service River Forecast System) and ROFFG

Description and justification of discrepancies and corrective actions

If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.

Work Package title and number		7. Avalanche inventory, release and hazard mapping				
Start date	planned	30.06.2014		actual	30.06.2014	
End date	planned	30.04.2017		actual	30.04.2017	
Cost of WP	planned	1,517,372.97 (lei)	345,163.50 (euro)	actual	1,469,719.10 (lei)	331,145.87 (euro)
Implementing entities	PP, P1, P4					

An overview of the work towards the objectives of the project

No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 7.1. Develop avalanche detection algorithms (Leader: P4; contributors: P1)

Snow avalanches represent one of the most important natural hazards during the winter in the Romanian Carpathians. Avalanche monitoring on large areas using field data and remotely sensed data is a difficult, time consuming task and satellite images have an important potential in mapping and monitoring of avalanche deposits. Based on multispectral HR (Sentinel-1 and 2) and VHR satellite images, as GeoEye-1 and DEM derived products acquired with an UAV (a drone), avalanches have been mapped for the central area of Făgăraș Massif in several years (with main focus on 2012 and 2016), when avalanches have been recorded in meteorological station reports.

A spatial database with polygon avalanches have been generated and for each record the information regarded the year, month, length, width of the avalanche, the morphometric parameters, as mean altitude, altitude range, slope, plan curvature, starting zone, runout zone, the existence of an avalanche track etc. In the frame of this activity, more than 1500 avalanches were mapped, most of these being medium and small size events, and only a few could be considered large as reported to the international classification.

However, generating digitized avalanche spatial databases is a time consuming approach and is highly dependent on the experience of the user. Thus, based on information extracted from the database mentioned above, semi-automated and automated algorithms have been developed to detect avalanche deposits based on VHR satellite images.

The approach was based on texture classification of the image, where avalanche texture has been enhanced using filters learned unsupervised from the image data. Filtered responses were aggregated using superpixels, and then classified using a two-stage classification approach. For the classification of avalanche deposits, a random forest classifier has been used and as a final step the multispectral bands were exploited to improve the classification using NDI (normalized difference index, based on Red and NIR bands). The results were exported in vector format and validated using the spatial database with manually digitized avalanches from central part of Făgăraș Mts. The results show that we were able to detect most of the fresh avalanches in the analysed images, while keeping the number of false detections low. With this approach, a map of avalanches can be delivered in short time after the events are triggered using automated algorithms and could be a useful tool for the management of emergency situations.

Activity 7.2. Change- detection algorithm for Sentinel-1 and Sentinel-2 (Leader: P1; contributors: P4, PP)

Monitoring of changes in the snow layer during a complete winter season using Sentinel time series imagery is important for the evaluation of avalanche dynamics and for identifying avalanche temporal and spatial patterns correlated with data delivered by weather stations. Thus automated algorithms might deliver rapid results for large mountains areas.

Unlike optical remote sensing imagery, the synthetic aperture radar (SAR) is able to acquire "cloud-free" images due to the cloud penetrating property of microwave in all weather conditions, and being an active remote sensing device, it is also capable of night-time operations. The methodology for detecting avalanches in Sentinel-1 images relied on the hypothesis that compacted rough snow of an avalanche has very high backscatter values (σ^0) compared to homogeneous snow cover and bare ground, even if the snow is wet.

Further an extensive collection of images used as training data, covering Norway and Romanian mountain areas, was created and the algorithm was modified for best performance in those conditions.

The processing chain developed for the automated detection of changes in avalanche deposits consists of the following modules: module for downloading Sentinel-1 data- SAR images for a given region and dates are downloaded from the Copernicus Open Access Hub; module for calibration and geocoding of SAR images; module for mosaicking of SAR images corresponding to the region of interest, module for generation of

reference image and corresponding variance image; a reference image for ascending and one for descending orbit directions are constructed; module for change detection (this supports several techniques for change detection based on the difference between the event image and reference image, with and without correction for pixel-based variance); module for avalanche mapping. Based on output from the change detection, a water mask and slope mask, potential avalanches are identified and written to a shape file.
Avalanches were detected in each image in the time series, and for a given event image and also the avalanche age was estimated from the image where a given avalanche was first observed. When the avalanches look like bright “blobs”, the algorithm detects them in most cases. Large avalanches were reliably detected; however, the algorithm struggles to detect avalanches if the contrast is weak. The algorithm also detects some non-identified objects that appears as bright blobs and has favourable DEM conditions. Several methods and indices (i.e. PCA, NDI etc.) were tested also with Sentinel-2 images (as PCA, NDI). While the Sentinel-1 images were used successfully for detection of changes, the use of Sentinel-2 images has proved inefficient for the detection of small and medium size avalanches, specific for Southern Carpathians and due to the small number of images that were cloud free during a complete winter season.

Activity 7.3. Avalanche simulation (Leader: P4; contributors: PP)
For snow avalanche hazard in the potential affected mountain areas, the existence of snow avalanche databases with historical records of past avalanche events related to the triggering factors, extent and volume, regular observations are very important. The approaches for identification of hazard prone areas are divided into two types of models - topographic-statistical models and dynamic models.
For the simulation of avalanches, potential release areas are the starting points that drive the simulation of the extent, height and snow pressure in different snow conditions. For this activity we used slope, plan curvature (excluding the convex area such as peaks, ridges), terrain ruggedness (excluding area with high values that are not suitable to snow accumulation) and land cover data related to vegetation type were used to exclude classes that are not favourable for release areas.
Several release areas have been selected for further simulations in the central area of Făgăraș Mts., near Transfăgărășan highway. Simulation of avalanche trajectories is an important step in hazard analysis and has an important influence on the separation of hazard levels Snow avalanche simulation has been tested and calibrated using RAMMS. Calculation and classification of friction parameters was based on DEM derived data (altitude, slope, curvature), forest cover and global parameters (volume and return period). For the estimation of the return period of avalanches, also data from dendrochronologic reconstructions from other studies have been used. For the size of the avalanches, small and medium size events were used as resulted from the database calculations. Simulation of avalanche trajectories have been tested on several high impact past events identified in statistics. The avalanche trajectories, depth, velocity, pressure and spatial extent of the snow deposits were mapped for several magnitude scenarios in the test areas.
The hazard map integrated a combination of topographic-statistic and dynamic models and the processing steps for hazard evaluation and mapping included: avalanche inventory and analysis; statistical analysis of past documented events; morphometric and snow depth analysis; identification of potential release areas; simulation of avalanche trajectories and calculation of snow height and pressure for several magnitude scenarios; hazard level classification by integrating frequency and simulation results.
The map of hazard level for the test area exhibit the pattern of past and recent events for the central area of Făgăraș Mts. The simulation of potential level of hazard showed that for high magnitude events, the altitude road infrastructure and forested areas will be damaged, especially in the southern slopes of the mountains.

The use of resources:
Total WP: 1,469,719.10 lei / 331,145.87 euro
Activity 7.1: Total: 638,569.53 lei / 143,901.72 euro, distributed by partners: P4: 317,456.42 lei / 71,516.88 euro; P1:321,113.11 lei / 72,384.84 euro;
Activity 7.2: Total: 550,907.31 lei / 124,141.66 euro, distributed by partners: PP: 416,798.84 / 93,954.18 euro; P1: 52,753.20 lei / 11.859.69 euro; P4: 81,355.27 lei / 18,327.79 euro;
Activity 7.3: Total: 280,242.26 lei / 63,102.49 euro, distributed by partners: P4: 214,300.76 lei / 48,277.88 euro; PP: 65,941.50 lei / 14,824.61 euro.

Milestones and deliverables	***Faze 2: 31.12.2015*** D7.1: Validated algorithm for detection of avalanches in optical HR and VHR satellite images ***Faze 3: 31.12.2016***

	D7.2: Validated algorithms for detection of changes in land and snow cover caused by avalanches in HR SAR and optical satellite images ***Faze 4: 30.04.2017*** D7.3: Avalanche hazard maps
Description and justification of discrepancies and corrective actions *If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.*	

<table>
<tr><td>Work Package title and number</td><td colspan="6">8. Promotion and Dissemination</td></tr>
<tr><td>Start date</td><td>planned</td><td colspan="2">30.06.2014</td><td>actual</td><td colspan="2">30.06.2014</td></tr>
<tr><td>End date</td><td>planned</td><td colspan="2">30.04.2017</td><td>actual</td><td colspan="2">30.04.2017</td></tr>
<tr><td>Cost of WP</td><td>planned</td><td>232,026.02 (lei)</td><td>52,780.00 (euro)</td><td>actual</td><td>255,098.51 (lei)</td><td>57,934.34 (euro)</td></tr>
<tr><td>Implementing entities</td><td colspan="6">PP, P1, P2, P3, P4</td></tr>
</table>

An overview of the work towards the objectives of the project
No more than 2 A4 pages for each implemented WP: a description of the ***results achieved*** *within the project,* ***activities carried out*** *and an* ***explanation of the use of resources.***

Activity 8.1. Project website (Leader: PP; contributors: P1, P2, P3, P4)
The project web site: http://snowball.meteoromania.ro has been created and continuously updated. There is included information (in Romanian and English languages) concerning the Snowball consortium activity in the current stage: results, meetings, dissemination, etc. It has also been performed the Romanian version of the website.
The SnowBall portal provides communication and dissemination infrastructure.
The SnowBall Geoportal has been developed: snowball.meteoromania.ro/geoportal, where snowmobile products obtained from satellite imagery are stored for Norway and Romania.

Activity 8.2. Dissemination strategy (Leader: PP)
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 the Contracting Authority.

Activity 8.3. Dissemination and training actions (Leader: PP; contributors: P1, P2, P3, P4)
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 mentions the name and the indicative of the project, the financier.

One of the most appropriate way to disseminate the scientific results of the SnowBall project is the specialized conferences as well as the events organized by the Contracting Authority.
The SnowBall Consortium did 41 oral presentations and posters at the events relevant to the themes approached within the project. Also, 16 articles were published in journals relevant to the project's objectives. At the end of the project a conference was organized dedicated to the presentation of the results obtained.

The use of resources: Total WP: 255,098.51 lei / 57,934.34 euro Activity 8.1: Total: 39,564.90 lei / 8,894.77 euro, distributed by partners: PP: 39,564.90 lei / 8,894.77 euro; Activity 8.2: Total: 22,024.33 lei / 4,951.39 euro, distributed by partners: PP: 22,024.33 lei / 4,951.39 euro; Activity 8.3: Total: 193,509.28 lei / 44,088.18 euro, distributed by partners: PP: 58,028.52 lei / 13,045.66 euro; P1: 91,746.60 lei / 20,681.38 euro; P2: 19,555.61 lei / 4,914.17 euro; P4: 24,178.55 lei / 5,446.97 euro.	
Milestones and deliverables	***Faze 1: 30.11.2014*** D8.1: Project website D8.6: Visibility products (banners, posters etc.) D8.7: Conference project presentation package D8.8: Dissemination action report D8.9: Project newsletter (e-zine) - digital form ***Faze 2: 31.12.2015*** D8.2: Dissemination strategy D8.3: Project brochure - Version 1 D8.6: Visibility products (banners, posters etc.) D8.7: Conference project presentation package D8.8: Dissemination action report D8.9: Project newsletter (e-zine) - digital form ***Faze 3: 31.12.2016*** D8.4: Project brochure - Version 2 D8.6: Visibility products (banners, posters etc.) D8.7: Conference project presentation package D8.8: Dissemination action report D8.9: Project newsletter (e-zine) - digital form ***Faze 4: 30.04.2017*** D8.5: Project overall report D8.6: Visibility products (banners, posters etc.) D8.7: Conference project presentation package D8.8: Dissemination action report D8.9: Project newsletter (e-zine) - digital form
Description and justification of discrepancies and corrective actions *If there were discrepancies in project implementation, explanations should be given as regards reasons for the discrepancy, taken corrective actions, impact on the project and achievement of planned results of the project.*	

B. Final Summary Report

1) Publishable Summary Report[5]

This section allows for the description of the achievements of the completed project: it should assess whether the project's outcome and outputs have been achieved, indicate the main tools/methods applied to achieve the outputs, describe how the target group(s) has been involved in the project and how the group(s) has benefited from the project. The summary should cover the following compulsory points:

- **Why was the project needed? How will the results be sustained?**

SnowBall project approaches a challenge of national interest – thorough and timely knowledge of the seasonal distribution and characteristics of the snow layer. Snow monitoring is extremely important to the management of the water resources (surface and ground waters), to forecasting extreme events (floods caused by snowmelt, avalanches) and to assessing the impact, in present climate conditions and in the future climate scenarios.

The main result of the project is the prototype system for snow monitoring, based on fusing data supplied by Sentinel-1 and Sentinel-3 satellites with in-situ measurements of the snow layer.

Snow layer monitoring led to important applications in: meteorology, hydrological modelling, issuing warnings about the occurrence of fast floods and avalanches through snow melting. In the present and future climate conditions, the obtained results have significant applications in water management and hydro-energy, in agriculture, transport, tourism and emergency situations management.

Obtained results have already been integrated in the operational activity:

- Within the National Meteorological Administration, a prototype system has been implemented for snow monitoring based on Sentinel 1/3 satellite data and in-situ data;
- In the National Hydrological Forecasting and Warning System within the Romanian Waters National Administration a new module has been implemented for snow simulation (with a multi-layer representation), within the NOAH-R distributed model and in the system destined to the assessment of the fast floods occurrence hazard in Romania (ROFFG).

Results of the run numerical experiments in new generation climatic models (CMIP5), downscaled and adapted at regional and local level are used to evaluate the impact of climate change on the snow resources and the hazards in the interest areas.

Taking into account the necessity to correctly assess infiltration (from liquid precipitation and snow) in the urban areas for correct management of the water resources at the level of a town, results obtained within a the project will be used and will be expanded at the level of the whole Bucharest Municipium in the INXCES project together with the partners in Norway, Sweden and the Netherlands.

The algorithms for the detection of avalanches from high and very high resolution satellite images designed during project development will be further used to complete the spatial database with avalanches for the future winter seasons in the Southern Carpathians. Also, the algorithm for the detection of avalanche-induced changes (e.g. on the forest areas), developed on Sentinel-1 images will be applied in the following winter season to highlight the impact on the environment shortly after the occurrence of avalanches. At the same time, simulating the trajectories of avalanches by using data calibrated for the Southern Carpathians opens new possibilities to improve the hazard and risk maps for other mountain massifs in Romania.

- **What was the objective, and to what extent was it reached? What was the impact?**

The objective of the project was to improve snow monitoring with the help of satellite and in-situ data, for the assessment of water resources, of the water resulted from snowmelt and of the associated

[5] This information shall be uploaded in DoRIS, the web based system for the implementation of EEA and NO grants funded programs. This information might also be published on the Programme website and/or donor states website.

hazards, in the context of climate change. Through the obtained results, the project objective was achieved 100%.
The project impact is traceable in the developed/improved applications, in domains of great practical and scientific interest: hydrology and water management, meteorological and hydrological forecasts ad warnings, assessment and mitigation of natural risks (floods from snowmelt, avalanches). Information supplied by the project is a potential source of data useful in planning hydro-energy production and its commercialization.
The project brings an important contribution in rising awareness about the impact of climate change on the snow resources and on the associated hazards (fast floods, avalanches) at local or regional level, in an economic, social and/or ecological perspective.

- **What was the outcome, and to what extend was it reached?**

The main result has been the development of a new service capable to supply the national authorities but also the large public with significant information in quasi-real time, for the monitoring of the spatial and temporal evolution of the snow layer parameters and of the associated hazards (floods caused by sudden snowmelt and avalanches) in present and future climate conditions respectively, on the basis of data measured in-situ and supplied by satellites. This result was fully reached.

- **Which output were delivered?**

1. New instruments and equipment for measuring the snow layer

The mobile measurement systems are highly autonomous (with respect to power supply and communications), as regards modularity (all necessary transducers can be connected in various configurations) and scalability (8 or 32 bit-development platforms can be used), being made up of:
- 5 transducers for measuring the snow temperature profile;
- 1-2 ultrasonic transducers for measuring the snow layer height;
- 2 transducers for measuring the snow temperature and humidity at discrete levels;
- 6 transducers for measuring the ground temperature profile;
- one transducer for measuring the snow surface temperature in the infrared spectral domain.

The Decagon 5TM – type capacitive sensors measure the dielectric permittivity of the snow, wherefrom the snow liquid water content is computed (SLW).
The constructed systems are very reliable at both the hardware and software level.
Figure 1 renders the measuring system with two ultrasonic transducers for snow layer height, IRU 9429S (APG) – type model, two temperature-humidity transducers 5 TM model (Decagon Devices) and 5 snow layer temperature transducers, DS18B20 model (Dallas Semiconductors), installed at Vârful Omu (Omu Peak) weather station.

Figure 1: Measuring system with two snow height ultrasonic transducers, two temperature-humidity transducers and five snow layer temperature transducers. Location: Vârful Omu weather station.

2. <u>One set of highly performing algorithms and Sentinel-1, Sentinel-3 satellite data processing chains</u>

There were elaborated new methods and algorithms for obtaining the parameters characteristic to the snow layer from optical and radar (SAR) satellite data.
A multi-sensor/multi-temporal algorithm was developed for estimating the snow humidity (MWS), through a combined use of optical and radar satellite data. The concept is based on the combined use of multi-temporal observations from the optical and radar domain respectively of the snow layer characteristics in a fused model, so as to generate snow humidity maps with improved spatio-temporal resolution. The developed algorithm is based on an original and innovative approach that fuses the characteristics of the optical and radar satellite data using Hidden Markov Models (HMM).
MWS algorithm allows the estimation of the humidity degree of the snow layer. The map of the snow humidity is a novel product, at a 1-km spatial resolution, with a national coverage, which includes four thematic classes, based on the standard international classes (dry snow, humid snow, wet snow and very wet snow). The map yielded from satellite radar data - Sentinel-1 and Sentinel-3 (optical data). The obtained results in the studied areas from Norway and Romania were validated using data recorded by the sensors placed at meteorological and hydrometric stations or measurements collected during field campaigns. Validation results are very promising and the quality and temporal resolution of the products have increased starting 2015 once the European Sentinel-1B and Sentinel-3A were launched. The product can be applied in hydrological modelling, for the forecast of floods and in the monitoring and assessment of avalanche occurrence hazard.
Figure 2 renders an example of maps with the distribution of snow humidity obtained through the MWS algorithm, based on Terra MODIS satellite and Sentinel-3 SLSTR data for Romania, on 4 February 2017 and figure 3 – for southern Norway, on 30 April 2017.

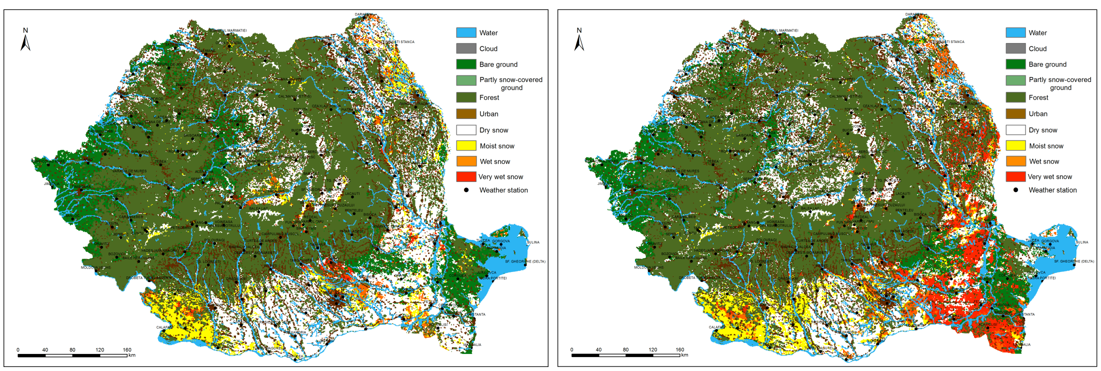

Figure 2: Maps for Romania based on Terra MODIS (left) and Sentinel-3 SLSTR (right) on 4 February 2017.

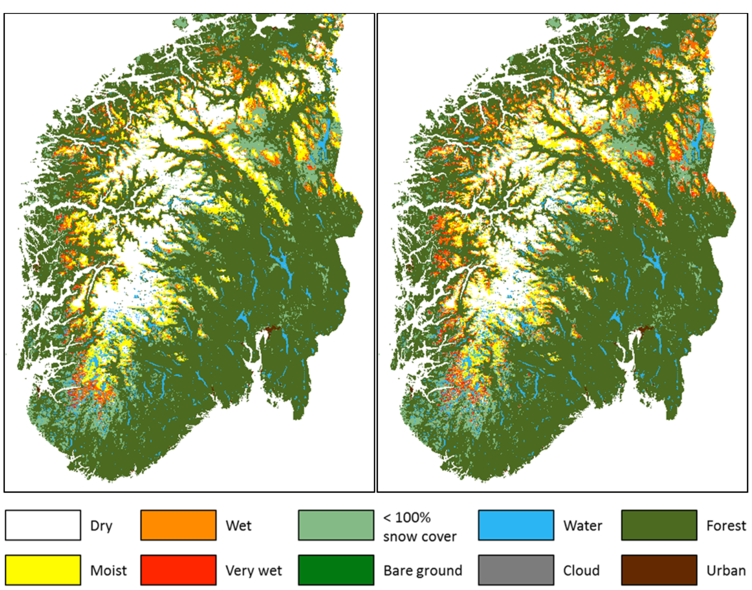

Figure 3: MWS maps for southern Norway based on Terra MODIS (left) and Sentinel-3 SLSTR (right) on 30 April 2017.

3. <u>Impact of climate variability and change on the snow layer and the associated hazards.</u>

From analysing the results of six numerical experiments with regional climatic models, under the conditions of two scenarios (RCP 4.5 and RCP 8.5) regarding the changes in the snow layer depth in October through April at the level of Romania, for the 2021-2050 and 2070-2099 time horizons, considering 1971-2000 the baseline, the following were noticed:

- thinning of the snow layer depth enhances with nearing the end of the 21st century, especially in the case of the RCP 8.5 scenario, where the greenhouse gas concentrations are stronger and the radiative forcing more intense;
- spatial configurations of the change points at the impact of orography, so that the disposition of the Carpathian arch against large scale circulations induces specific local effects;
- thinning of the snow layer is more significant south of the Southern Carpathians and west of the Western Carpathians but also in the north-west of the country, where it reaches 90% under the most unfavourable scenario – RCP 8.5.
- in the 2021-2050 interval, the north-eastern parts of Romania will be confronted in both scenarios with significant thinning of the snow layer, of up to 45%.

The reduction of the snow amount has an impact on many socio-economic activities:

The multiannual means of the maximum discharges in the November-April interval show increases in comparison with the present climate (1981-2010) in the case of the most optimistic scenario (RCP 4.5) as well as in the most pessimistic one (RCP 8.5) regarding the climate change. For the wider sub-basins, increases are systematically larger in the most pessimistic scenario compared to the most optimistic one, showing the manner in which the signal concerning climate change exceeds the "noise" beyond the spatial scales specific to hydrographic basins.

Figure 4 renders changes in the mean discharges (as %) in Argeş river sub-basins during the 2021-2050 interval vs. 1981-2010 under the pessimistic RCP 8.5 scenario. Areas coloured in blue and violet point at sub-basins with larger increases of maximum discharges.

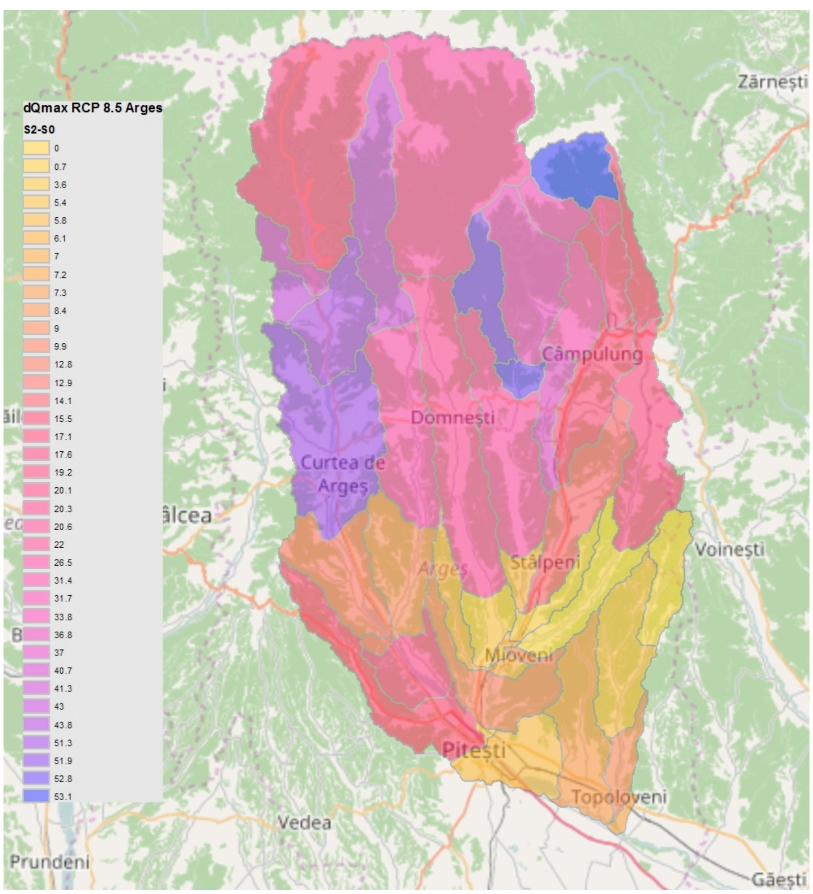

Figure 4: Changes in maximum discharges (as %) in Argeş river sub-basins in 2021-2050 vs. 2021-2050, under the pessimistic RCP 8.5 scenario. Areas coloured in blue and violet point at sub-basins with larger increases of maximum discharges.

On the basis of statistical analysis of the snow layer depth, daily precipitation and temperatures for Romania, the following significant trends were identified: an increase of the number of days with above zero temperatures along with a slight decrease of precipitation throughout the winter; a decrease of the number of days with precipitation falling as snow; a decreasing trend of the number of days with snow cover and of the mean snow depth.
The number of days with proper skiing conditions during a season is on the decrease in the Carpathians in climate change conditions. On the basis of data resulted from five numerical experiments with data measured at 32 weather stations (blue), the profitability of skiing conditions in the Carpathians was computed, based on the mean number of days with snow layer deeper than 30 cm, under the RCP 4.5 (upper) and 8.5 (lower) climate scenario respectively for the 2021-2050 (red) and 2071-2011 interval (green) respectively (figure 5).

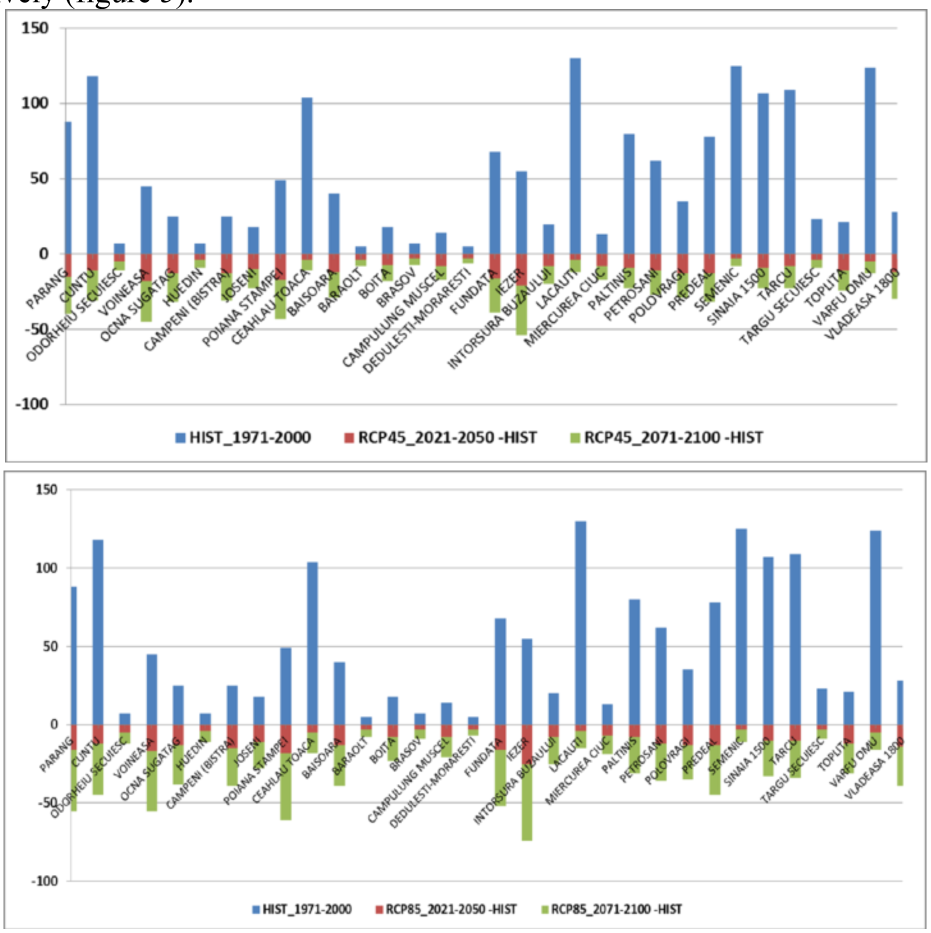

Figure 5: Profitability of skiing activities in the Carpathians on the basis of data from 32 weather stations (blue), based on the mean number of days with snow layer deeper than 30 cm, under RCP 4.5 (upper) and 8.8 (lower) climate scenarios for 2021-2050 (red) and 2071-2100 (green).

4. <u>Assessment of water volumes resulted from melting of snow infiltrated in the unsaturated area in view to replenish the aquifers.</u>

Snow melting is a major component of the hydrological cycle, tightly connected to replenishing aquifers and surface waters.
The methodology for the determination of infiltration from snow melting and the quantification of aquifer replenishing was performed for the first time in Romania. The methodology for the determination of infiltration from snow melting displays the analysis and interpretation mode for the information and data (in-situ, meteorological and satellite) that lead to assessing aquifer replenishing from snowmelt.

The original, innovative contribution consists in the process of adapting numerical models for the saturated and non-saturated area, so that information coming from in-situ and satellite measurements can be used.
Methodology was elaborated that allows to assess the contribution of water resulted from snow melting to aquifer replenishing in various climatic scenarios. This information is really valuable in present and future decisions concerning water resources management. The methodology was applied for the evaluation of the future potential of infiltration and replenishing of aquifer from snow in Padina area from Bucegi Mountains.

5. <u>Development of new algorithms for avalanche detection on the basis of satellite images, for the detection of changes induced in the environment and for the assessment of the associated hazard</u>

To detect the avalanche deposits and evaluate the risk of their occurrence GIS techniques and satellite images of very high spatial resolution were used (GeoEye-1, QuickBird, Pleiades). Thus, digital maps were elaborated and statistical analysis was performed for the climatic data and the main hazard factors involved in avalanche occurrence.
In the central glacier sector Făgăraş Massif (Bâlea-Valea Doamnei, Valea Capra), which is known for the high frequency of avalanches, 34 avalanche corridors were charted in the field. This information was further integrated in the GIS database. The areas affected by more than 540 avalanche events were delimitated on very high spatial resolution satellite images. The inventory of avalanches in the studied area has been performed for the first time ever in Romania.
In view to achieve the avalanche hazard maps, a semi-automatic method was developed for the detection of avalanche corridors on the basis of integrating the morphometric characteristics extracted from the numerical model of the terrain.
A preliminary evaluation was also performed of the capability to identify avalanches on the basis of the algorithm developed through object-oriented analysis, tested on QuickBird satellite images for certain mountain areas in Norway.
The impact from developing these algorithms is beneficial to determining the areas with a risk of avalanche occurrence through the use of statistics referring to the frequency of avalanches in the Carpathians and to completing the avalanche spatial database. The obtained results also contribute to the management of emergency situations through supplying data with precise charting shortly after avalanche occurrence.

Figure 6 presents the distribution of the avalanche hazard classes for the central area of Făgăraş Massif, close to the Transfăgărăşan highway.

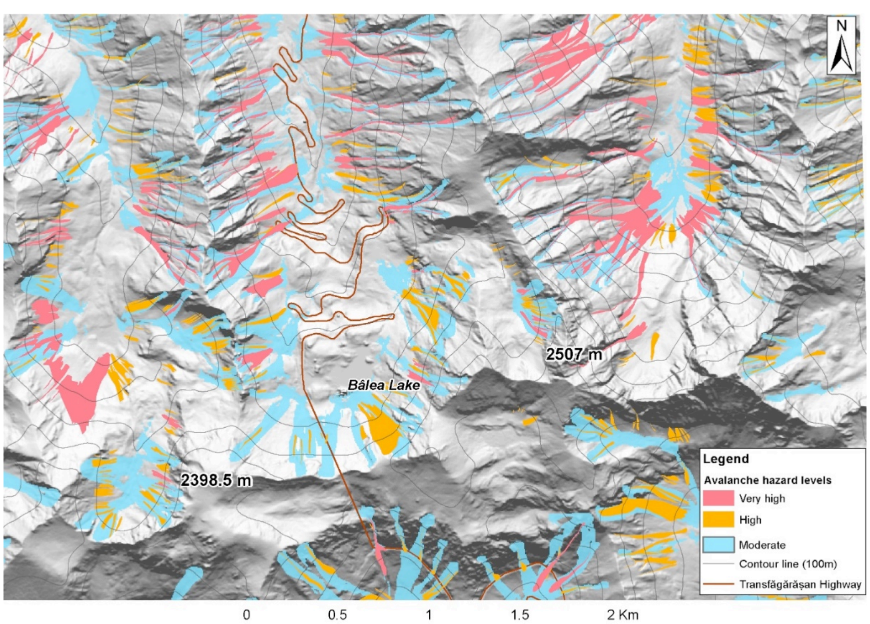

Figure 6: Map of avalanche hazard classes for the central area of Făgăraş Massif, close to Transfăgărăşan highway.

6. <u>More accurate forecast of water runoff as resulted from snowmelt</u>

In order to improve warnings and forecasts regarding the runoff of the water resulted from snowmelt, precise estimation of the water equivalent in the snow layer is essential. A data fusion procedure was elaborated on the basis of simulations performed with NOAH hydrological model that uses the parameters of the snow layer measured in the national network of weather and hydrometric stations, as well as the parameters derived from satellite data.
The product in grid format with the values of the water equivalent obtained through applying the data fusion methodology represents the best estimation of this parameter.
The data assimilation procedure was implemented by using “open-source” software components and it will be used operationally using the results from the data fusion methodology.
Reconfiguration was performed of NOAH hydrological forecasting model with a new snow simulation module, with muti-layer representation. Configuration of the new snow module was achieved at national level, with a 1-km spatial resolution, implementation being based on the open-source hydrological software system with the WRF-HYDRO distributed parameters.
The use of the new snow module in a multi-layer architecture will allow elaboration of a more complex data fusion procedure and most of all better use of the snow layer parameters derived from satellite data.
Figure 7 renders the mean values by sub-basins of the mean water equivalent from snow, assimilated in the ROFFG hydrological forecast, computed on the basis of the product generated through data fusion, for 30 December 2016.

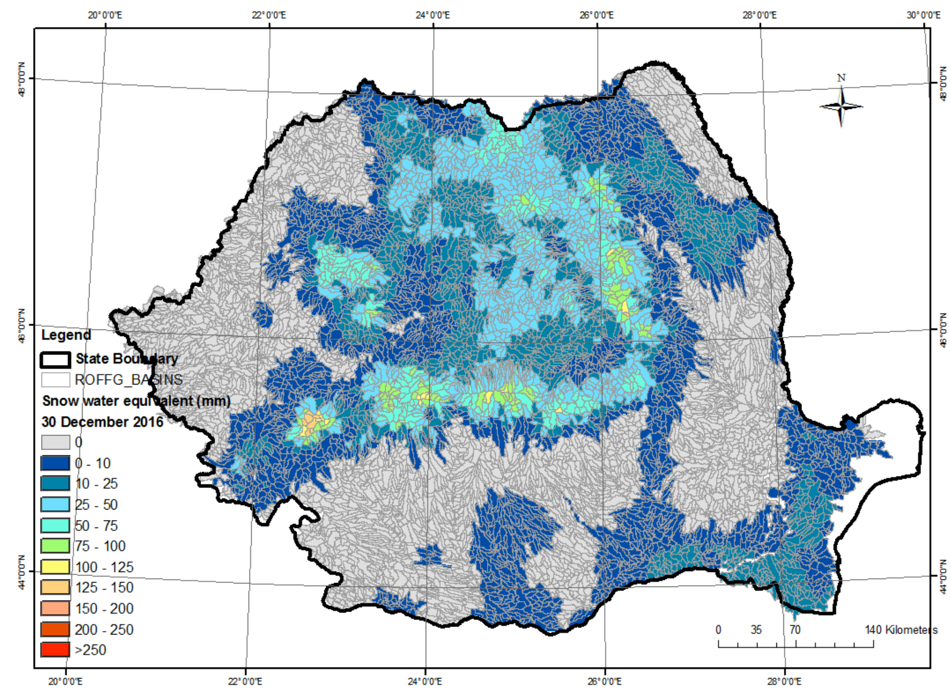

Figure 7: Mean values by sub-basins of the mean water equivalent from snow, assimilated in ROFFG hydrological forecasting system, computed n the basis of the product generated through data fusion, for 30 December 2016.

7. <u>Dissemination of obtained results through:</u>

- 13 scientific publications in international and national magazines with reviewers;
- 5 conferences/seminars organized through the common research program, 2 of which at international level;
- 41 dissertations in national and international conferences, workshops and seminars.

- **How were the beneficiaries involved? What was the main benefit?**

Beneficiaries of the results obtained in the project were involved through a variety of actions:

- promotion and use of obtained results addressed to target groups from meteorology, climatology, hydrology, water resources management, emergency situations, tourism, academic institutions and the research community;
- creation of communication channels with interested parties, academic and industrial communities for the dissemination of the project results and conclusions;
- dissemination and promotion actions as regards the project results, according to the dissemination strategy included in the project Publicity Plan.

- **What did the donor partnership achieve?**

  - Knowledge deepening in the issues of snow and remote sensing in nivology.
  - Significant improvement of the algorithms dedicated to the automatic snow avalanches detection using very high resolution satellite images and of the associated hazard in the Southern Carpathians.
  - Development of efficient cooperation among partners, within a new service capable of supplying the national authorities and the large public consistent information on the basis of data measured in-situ and supplied by satellites, for the monitoring of the spatio-temporal characteristics of the now layer and of the associated hazards (floods caused by the sudden snowmelt and avalanches), in climate change conditions.

<u>Project partnership achieved results</u>

- **What did the donor project partner(s) contribute to the project at a technical or professional level?**

The experience of the Norwegian partner (Norsk Regnesentral) in using satellite images for applications in nivology significantly contributed to the achievement of the project objectives referring to the assessment of the snow parameters from satellite data and to the development of algorithms for the detection of avalanches from high and very high spatial resolution images.

- **What did the partnership contribute towards the project outcome and outputs?**

Success of the partnership in reaching the expected results was based on the complementary expertise of the partners. Norsk Regnesentral and NMA developed and tested the MWS algorithms used to elaborate the snow humidity maps. Snow humidity data were used in hydrological models, to model aquifers and to estimate avalanche risk. In turn, in-situ data supplied by NHWMI, TUCE and WUT were used to check accuracy of the satellite products. Also, the expertise of NR in algorithm development and the advanced knowledge of WUT in nivology led to the elaboration of advanced methodology for the detection of avalanche deposits and for the assessment of their occurrence hazard.

Consortium contributed to technology transfer between Romania and Norway.

- **What has the partnership achieved towards strengthened bilateral relations?**

  - Better understanding of the expertise and knowledge existing in Norway and Romania in the field of determining the properties of snow from satellite images and from in-situ measurements, of applications in hydrology, water resources management and the management of hazardous phenomena.
  - Teamwork highlighted the complementary components and the wish to approach together other domains, too, where the experience accumulated within the project can be applied. In this sense, NR and NMA are already working on a new project proposal.

- Successful demonstration of the added value of the project final products has led to an increased interest in snow products derived from satellite data, flood and avalanche hazard maps and impact studies on the climate change.

- **Is any wider impact of the partnership expected? (e.g. wider international cooperation in the sector, dissemination of knowledge and experience etc.)**

Implementation of the project contributes to settling long-term cooperation among the partners, within a new service dedicated to the national authorities and the large public, supplying consistent information, in quasi-real time, for monitoring the spatio-temporal characteristics of the snow layer and of the associated hazards (floods cause by sudden snowmelt and avalanches) in the context of present and future climate.
The impact of the cooperation among the consortium partners will expand through dissemination of information in international conferences and workshops that will take place after the conclusion of the current project. Also, the cooperation initiated in this project will continue with the elaboration of scientific publications in the field of natural hazards, which require implementation at the level of programming in automation and simulations.

Socio-economic impact

Obtained result have a positive impact through the significant improvement of spatial information concerning the snow avalanches, that will further lead to better understanding the conditions and favourable areas for their occurrence. The mentioned information can be used in the institutions dealing with the management of emergency situations.
Ice and snow monitoring is extremely important in the management of natural resources, in forecasting extreme meteorological and hydrological events, like the floods caused by snowmelt, the avalanches and the impact of global warming.
The socio-economic impact of the project is important, taking into account the importance of the snow in the management of the water resources, in hydro-energy, agriculture, transport, tourism, urbanism and emergency situations management.

Conclusions

Project objectives were successfully accomplished through excellent cooperation between the Norwegian partner and the institutions in Romania and the obtained results fully correspond to the committed demands.

1. The prototype system for snow monitoring, based on Sentinel-1/-3 satellite data and in-situ measurements.
2. A set of highly performing algorithms for processing Sentinel–1/-3 data.
3. Improved performance of hydrological modelling based on updating the snow layer parameters.
4. Assessing the water volumes resulted from snow melting in replenishing the aquifer (for the first time ever in Romania).
5. Improved forecasts for the water runoff, as resulted from snow melting.
6. Assessing the hazard of snow avalanches occurrence, using in-situ measurements and satellite observations.
7. Modelling the avalanche corridors in the Southern Carpathians.
8. Improved knowledge of the impact of climate change on the water resources within the snow layer and of the associated hazards.
9. Articles published in magazines with reviewers and dissertations delivered in national and international scientific events.

2) Indicators

Indicators	Planned in total	Year	Planned by year	Achieved in total	Year	Achieved by year	Distribution (PP and pp)
1. Number of internationally referred joint scientific publications	7	2014	-	7	2014	-	-
		2015	1		2015	1	P4, P1: 1
		2016	3		2016	2	P1, PP: 1 P1, P4: 1
		2017	3		2017	4	P4, PP: 1 P1, PP: 3
2. Number of internationally referred scientific publications	6	2014	-	11	2014	-	-
		2015	1		2015	2	PP: 1 P1: 1
		2016	3		2016	2	PP: 2
		2017	2		2017	7	PP: 5 P2: 2
3. Number of patent / patent applications	-	2014	-	-	2014	-	-
		2015	-		2015	-	
		2016	-		2016	-	
		2017	-		2017	-	
4. Number of postdocs and / or PhD students involved in joint research project	1/8	2014	1 postoc 7 PhD students	1/8	2014	1 postoc 7 PhD students	PP: 3 PhD students P2: 4 PhD students P4: 1 postdoc
		2015	1 postoc 7 PhD students		2015	1 postoc 7 PhD students	PP: 3 PhD students P2: 4 PhD students P4: 1 postdoc
		2016	1 postoc 7 PhD students		2016	1 postoc 4 PhD students	PP: 2 PhD students P2: 2 PhD students P4: 1 postdoc
		2017	1 postoc 4 PhD students		2017	1 postoc 4 PhD students	PP: 2 PhD students P2: 2 PhD students P4: 1 postdoc
5. Number of researchers involved in joint research project	39	2014	23	39	2014	23	PP: 9 P1: 5 P2: 5 P3: 1 P4: 3
		2015	39		2015	39	PP: 16 P1: 5 P2: 5 P3: 10 P4: 3
		2016	37		2016	33	PP: 11 P1: 5 P2: 6 P3: 12 P4: 3
		2017	19		2017	38	PP: 12 P1: 5 P2: 3 P3: 8 P4: 3

6. New investments in R&D infrastructure (thousands of lei and euro)	-	2014	-	233,91 thousands lei 64,67 thousands euro	2014	145,14 thousands lei 23,86 thousands euro	**2014:** **- PP:** 67,75 thousands lei/ 15,34 thousands euro **- P2:** 40,10 thousands lei/ 9,08 thousands euro **- P3:** 21,20 thousands lei / 4,80 thousands euro **- P4:** 16,09 thousands lei/ 3,64 thousands euro
		2015	-		2015	88,76 thousands lei 22,09 thousands euro	**2015:** **- PP:** 84,17 thousands lei/ 21,05 thousands euro **- P4:** 4,59 thousands lei/ 1,04 thousands euro
		2016	-		2016	-	
		2017	-		2017	-	
7. Average level of use for purchased R&D equipments (%)	-	2014	-	71,45%	2014	4,24%	PP: 1,9% P2: 5,8% P3: 5%
		2015	-		2015	32,76%	PP: 33,4% P2: 26,6% P3: 50% P4: 21%
		2016	-		2016	43,51%	PP: 33,4% P2: 26,6% P3: 80% P4: 33%
		2017	-		2017	31,75%	PP: 14,1% P2: 8,9% P3: 80% P4: 24%
8. Number of conferences/seminars organized by joint research project, out of which held at international level	5/1	2014	-	5/2	2014	-	
		2015	3/1		2015	3/1	
		2016	1		2016	1	
		2017	1		2017	1	
9. Number of project proposals submitted to other calls under Horizon 2020 or European/international programs/initiatives	22	2014	2	24	2014	2	P2: 2
		2015	11		2015	11	PP: 6 P1: 2 P2: 3
		2016	6		2016	7	P2: 4 P3: 2 P4: 1
		2017	3		2017	4	P3: 2 P4: 2
10. Thesis (master, PhD, other)	-	2014	-	-	2014	-	-
		2015	-		2015	-	
		2016	-		2016	-	

		2017	-		2017	-	
11. Other (please specify)	29	2014	-	41	2014	3	P3: 1
		2015	14		2015	14	PP: 8 P1: 1 P3: 1 P4: 5
		2016	10		2016	18	PP: 9 P1: 5 P2: 1 P3: 1 P4: 5
		2017	2		2017	6	PP: 2 P1: 2 P2: 3 P4: 1

Details on internationally referred joint scientific publications and/or internationally referred scientific publications shall be provided separately in <u>section C "Report on scientific publications"</u>.

In case of patent or patent applications filled in, please provide detailed information in the table below.

Patent/Patent Applications						
No.	Title	Number	Status	Date	Patent Office (name, country)	Owner/Applicant(s)
1.	-	-	-	-	-	-

The situation on conferences or seminars organized during the lifetime of the joint research project.

Organization of Conferences/Workshops/Seminars[6]				
No.	Title	Venue	Date	Other information/webpage
1.	**International Conference:** *Methodological challenges in geography*	Timisoara	15-16 May 2015	Organised by West University of Timisoara http://geografie.uvt.ro/wp-content/uploads/2015/03/conference_program_Timisoara_may_2015.pdf
2.	**National Conference:** *Panta Rhei – Everything Flows*	Bucharest	2-3 November 2015	Organised by National Institute of Hydrology and Water Management http://www.inhga.ro/conferinta-stiintifica/arhiva
3.	**Annual Scientific Communications**	Bucharest	19-20 November 2015	Organised by National Meteorological Administration www.meteoromania.ro
4.	**Synasc:** *18th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing* **Workshop:** *Geoinformatics*	Timisoara	24-27 September 2016	Organised by West University of Timisoara together with the SnowBall Project Partners https://synasc.ro/2016/workshops/geoinformatics-2016/index.html
5.	**Final Workshop**	Bucharest	28 April 2017	Organised by National Meteorological Administration together with the SnowBall Project Partners http://snowball.meteoromania.ro.

[6] Events organized by the Project Promoter and/or by the project partners.

Project proposals submitted to calls open on Horizon 2020 or other European/international programs or initiatives shall be presented in detail in the next table.

Submitted Joint Project Proposals[7]					
No.	Title	Partners	Programme/Funding scheme/Call	Under preparation/ submitted/funded	Grant amount (EURO)[8]
1.	Current trends and approaches in urban hydrogeology	P2	EEA Financial Mechanism and Norwegian 2009-2014 (RO01)	Funded	15.780,00
2.	COST TU1206 Sub-Urban	P2, P3	COST Action	Funded	Funding mobilities, depending on the number of researchers
3.	SAtellite based Monitoring Initiative for Regional Air quality - SAMIRA	PP	ESA	Funded	200.000,00
4.	Improving Drought and Flood Early Warning, Forecasting and Mitigation using real-time hydroclimatic indicators - IMDROFLOOD	PP	H2020	Funded	331.229,00
5.	ERA for Climate Services (ERA4CS)	PP	H2020	Funded	180.125,00
6.	INnovations for eXtreme Climatic eventS – INXCES	P2	Water Works 2014 Cofounded Call - Research and Innovation for Developing Technological Solutions and Services for Water Systems	Funded	236.500,00
7.	BRIdges the GAp for Innovations in Disaster resilience – BRIGAID	P2	H2020	Funded	187.502,50
8.	Satellite DCP Technologies Applied to Early Warning Systems , SAT-DCP	PP	ECHO 2015	Submitted	38.627,00
9.	Polar Thematic Exploitation Platform (P-TEP)	P1	H2020-EO-2015	Submitted	50.000,00
10.	Engaging Citizens for Observations of Land Cover and Snow (ECOLES)	P1	H2020-SC5-2015	Submitted	350.500,00
11.	Alignment of Earth Observation Capacities in North African, Middle East and Balkan region with GEOSS regional Services – GEOregionS	PP	H2020	Submitted	200.000,00
12.	The impact information platform for flash flood emergencies – FLASHCASTNET	PP	H2020	Submitted	227.750,00
13.	Integrated Multiscale Modeling of the interActioN between surfacE water and	P2	Water Works 2014 Cofounded Call - Research and Innovation for	Submitted	245.000,00

[7] A full list of new projects submitted/funded as a continuation of the joint research project. At least one person from the Romanian research teams and one person from the Norwegian or Icelandic research teams should be involved.
[8] If the project will be implemented with partners from other countries than RO/NO/IS, please provide the information on the total amount granted only for the Romanian, Norwegian and Icelandic partners (jointly).

	grouNdwaTer – IMMANENT		Developing Technological Solutions and Services for Water Systems		
14.	Framework for urban groundwater and shallow geothermal energy e-learning platform	P2	EEA Financial Mechanism and Norwegian 2009-2014 (RO01)	Funded	10.007,00
15.	Nature Based Solution City Framework For Sustainable Development and The Enhancement of Climate and Water Resilience In Urban Areas	PP, P2	H2020	Submitted	1.371.250,00
16.	Aquifer intrinsic vulnerability mapping : experimentation and theoretical development in Romania	P2	Scientific Collaboration between Romanian Academy and Walon Region	Funded	Funding mobilities, depending on the number of researchers
17.	Danube Sediment Management – Restoration of the Sediment Balance in the Danube River, DanubeSediment	P3	Danube Transnational Programme	Funded	162.800,00
18.	Strengthening cooperation between river basin management planning and flood risk prevention to enhance the status of waters of the Tisza River Basin, JOINTISZA	P3	Danube Transnational Programme	Funded	193.200,00
19.	SAFE-NBS - Sound and sustAinable settlements without social FrontiErs	P2	H2020	Submitted	350.000,00
20.	Young people to remote sensing and geoinformation sciences and technologies for cultural and natural heritage conservation (GeoHeriToYoung)	P4	H2020-SwafS	Submitted	50.000,00
21.	Danube river basin enhanced flood forecasting cooperation, DAREFFORT	P3	Danube Transnational Programme	Submitted	93.050,00
22.	Development and Establishing of Contingency Plans for environmental risks in small river catchments with focus on flood events, COP4SRC	P3	Danube Transnational Programme	Submitted	249.970,00
23.	Tehnologii spațiale în managementul dezastrelor și crizelor majore, manifestate la nivel local, național și regional	PP, P4	Proiecte de cercetare tip Soluţii	Submitted	854.000,00
24.	Machine Learning Library based on Satellite Imagery for Accurate Solar Radiation and Cloud Coverage Predictions	P4	ESA	Submitted	168.402,00

If thesis were reported in the summary table (see point 2 Indicators), please provide details about them in the following table.

Thesis (Master)					
No.	Title	Author	Entity	Year of completion	Link to the publication/reference
1.	Techniques for processing optical and radar satellite imagery for mapping flooded areas in Romania	Denis Mihailescu	National Meteorological Administration	2017	

Other type of indicator: **Communications at conferences/workshops/scientific sessions in Romania and abroad.**

Other indicator:	
1.	The paper "Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective" was presented to the annual scientific conference of the National Institute of Hydrology and Water Management, held in Bucharest, during 10 – 11 November 2014. The authors are: Mătreaţă, M., Corbuş, C., Mic, R., Mătreaţă, S., Pandele, A., Radu, E.
2.	The paper "Satellite snow cover products evaluation and validation platform for Romania" was presented to the 3rd International Conference on Remote Sensing and Geoinformation of Environment (RSCY 2015), held in Paphos, Cyprus, during 16-19.03.2015. The authors are: Crăciunescu, V., Irimescu, A., Stăncălie, G., Cătană, S., Ristea, A.
3.	At the International Conference Air and Water – Components of the environment, held in Cluj-Napoca, during 20-22.03.2015, was presented the paper "Synoptic Conditions for Avalanche Cases în Romania", author: Milian, N.
4.	On the 14th International Conference "Challenges in geography methodological" which was held on 15-16 May 2015, at the Department of Geography of the West University of Timisoara, was presented the paper: "An alternative solution for avalanche using semi-automated tracks mapping methods. A case study from Fagaras Mountains", authors: Ardelean, F., Török-Oance, M., Voiculescu, M.
5.	In the framework of the XI National Geomorphology Symposium, held from May 21 to 24, 2015 at Sf. Gheorghe Delta has been presented the paper: "Reconstruction and analys of exceptional snow avalanche events in Fagaras Mountains. Case Studies", authors: Voiculescu, M., Török-Oance, M., Ardelean, F.
6.	On the workshop "ESA Sentinel-3 for Science Workshop" held in Venice from 2 to 5 June 2015 was presented the paper: "Monitoring of snow properties with Sentinel-3", authors: Solberg, R., Due Trier, Ø., Rudjord, Ø.
7.	On the Conference of the European Avalanche Warning Services – EAWS, which took place in Rome, Italy between 4-6.06.2015 were presented the papers: - "Snow Avalanche risk estimation and measurements – the balance at the end of ten seasons", authors Milian, N., David, A. - „Remote sensing model and in-situ data fusion and related hazards for snowpack parameters in the climate change perspective (Snowball, 2014-2017) ", authors Stancalie, G., Solberg, R., Gogu, R., Matreata, M., Voiculescu, M.
8.	During the International Conference "Geobalcanica – Connects all geographers" that took place from 5 to 7 June 2015 in Skopje, in the Republic of Macedonia has been presented the paper: "Snow avalanche detection Using high resolution dem tracks and terrain analysis based object in Fagaras Mountains, Romania ", authors: Török-Oance, M., Ardelean, F., Voiculescu, M.
9.	At the 26th General Assembly of the International Union of Geodesy and Geophysics – IUGG 2015, held in Prague, Czech Republic from June 22 to July 2, 2015 was presented the paper: "Observed and modelled snow variability and change in Romania", authors: Bojariu, R., Dascălu, S., Gothard, M.
10.	At the 33rd International Conference on Alpine Meteorology – ICAM, held in Innsbruck, Austria, during the period 31 August to 4 September 2015 was presented the paper: "Study on snow, snow and Avalanches danger levels Bucegi and Fagaras Mountains in Southern Carpathians, (Romanian Carpathians). Preliminary results", authors: Voiculescu, M., Milian, N., Micu, D.
11.	At the fifth EUGEO international conference (Fifth EUGEO Congress on the Geography of Europe) held from August 30th to September 2nd 2015, in Budapest, Hungary, was presented the paper "Spatio-temporal

	reconstruction of snow-avalanche activity using dendrogeomorphologic approach in Capra glacial valley - Făgăraș Mountains (Southern Carpathians), Romanian Carpathians", authors Voiculescu, M., Ardelean, F., Chiroiu, P., Onaca, A.
12.	During the EUMETSAT Meteorological Satellite Conference 2015, held in Toulouse, France from 21 - 25.09.2015 was presented the paper:" Remote sensing model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective (Snowball)", authors: Nicola, O., Solberg, R., Stăncălie, G., Diamandi, A., Mihăilescu, D., Salberg, A.-B.
13.	At the annual scientific conference of the National Institute of Hydrology and Water Management, which took place in Bucharest from 2 to 3 November 2015, was presented the poster "Methodology for snow water equivalent estimation, using a fusion-type approach data (simulated data, observations from stations and satellite derived products) – SNOWBALL Project", authors: Mătreață, M., Mătreață, S.
14.	To the annual scientific conference of the National Meteorological Administration, held in Bucharest, between 19-20.11.2015, has been presented the paper: „The integration of remote sensing, in-situ and from modelling data to assess the snow cover parameters and associated hazards in the context of climate change – the project SNOWBALL", authors: Stăncălie, G., Diamandi, A., Dumitrache, C., Bojariu, R., Crăciunescu, V., Mihăilescu, D., Milian, M., Solberg, R., Salberg, A.-B., Voiculescu, M., Török-Oance, M.
15.	At the International Conference "Achievements and future steps" organized by ANCSI under the Program RO14 - "Research in Priority Sectors", the EEA Financial Mechanism 2009-2014, which took place in Bucharest on 10 December 2015 have been presented the results of the first half of the implementation period of the project.
16.	At the International Conference Air and Water – Components of the environment, held in Cluj-Napoca, during 25-27.03.2016, was presented the paper „Synoptic avalanche triggering conditions during 2014-2015 winter", authors: Milian, N., Paşol, A.
17.	On the „ESA Living Planet Symposium" which was held on 9-13 May 2016, in Prague, Czech Republic was presented the poster: „Single and multi-sensor snow wetness mapping by Sentinel-1 and Sentinel-3 data", authors: Solberg, R., Salberg, A.-B., Rudjord, Ø., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A.
18.	At the International Conference "Perspectives of geographical approach on territorial development: Theories, methods and practices", held on 13-14 May 2016 in Timisoara, Romania, was presented the paper: „Snow avalanche inventory based on remote sensing. A case study from Făgăraș Mountains", authors: Ardelean, F., Török-Oance, M., Voiculescu, M., Milian, N.
19.	In the framework of the 73rd Eastern Snow Conference, held from May 14 to 16, 2016 at Columbus, Ohio, USA has been presented the poster: „Single and multi-sensor snow wetness mapping by Sentinel-1 and MODIS data", authors: Solberg R., Salberg, A.-B., Rudjord, Ø., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A.
20.	During the "National Symposium on Geomorphology SNG, XXXII Edition", held from 19-22 of May 2016 at Piatra Neamt, Romania, the following paper was presented: „Morphometric, climatic and human influence as controlling factors in spatial distribution and frequency of avalanches in Balea glacial area - Fagaras Massif (Southern Carpathians)", authors: Voiculescu, M., Ardelean, F., Török-Oance, M.
21.	On the 36th EARSeL Symposium (Frontiers in Earth Observation) held in Bonn from 20 to 24 June 2016 was presented the paper: „First snow avalanche inventory in Romanian Carpathians based on very high-resolution satellite images", authors: Török-Oance, M., Ardelean, F., Voiculescu, M., Milian, N.
22.	On the Conference of GeoMLA 2016 - Geostatistics and Machine Learning, Applications in climate and environmental sciences, which took place in Belgrade, Serbia between 21-24.06.2016 was presented the paper: „Spatial interpolation of daily snow depth over Romania", authors: Dumitrescu, A., Bîrsan, M.-V.
23.	During the International Conference "Advancing the understanding of our living planet" that took place from 10 to 15 July 2016 in Beijing, in the Republic of China has been presented the poster: „Automated detection and mapping of avalanches in SAR images", authors: Hamar, J.B., Salberg, A.-B., Ardelean, F.
24.	The 18th International Symposium on Symbolic and Numerical Algorithms for Scientific Computing – SYNASC was held in Timisoara, between 24-27.09.2016, organised by the University of Timisoara. During the symposium a Workshop was dedicated to the SnowBall Project, where the following papers have been presented: - „Numerical simulation of documented snow avalanche events in Făgăraș Mountains", authors: Ardelean, F., Török-Oance, M., Salberg, A.B., Voiculescu, M., Milian, N., Irimescu, A. - „Snow avalanche hazard assessment in Făgăraș Mountains, Southern Carpathians", authors: Török-Oance, M., Irimescu, A., Milian, N., Diamandi, A., Ardelean, F., Voiculescu, M. - „Automatic detection and segmentation of avalanches in remote sensing images using deep convolutional neural networks", authors: Salberg, A.B., Hamar, J.B., Ardelean, F., Johansen, T., Kampffmeyer, M.; - „Single and multi-sensor snow wetness mapping by Sentinel-1 and MODIS data", authors: Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A. - „Some consideration on using Copernicus Sentinel satellite data for characterizing the snow cover in the Romanian Mountains", authors: Nedelcu, I., Irimescu, A., Mihăilescu, D., Diamandi, A., Crăciunescu, V., Stăncălie, G., Gogu, R. - „High Resolution temperature and precipitation under present and future climate scenarios", authors:

	Dumitrescu, A., Bojariu, R., Dascălu, I.S., Gothard, M., Bîrsan, M.V., Cica, R., Velea, L., Stăncălie, G., Irimescu, A. - „Snow water equivalent estimation using a data fusion approach”, authors: Mătreaţă, M., Mătreaţă, S.
25.	At the Future of the Carpathians: Smart, Sustainable, Inclusive, held in Bucharest, during the period 28-30 September 2016 was presented the paper: „Snow-related impact in the Carpathians under climate change conditions”, authors: Bojariu, R., Dascălu, I.S., Gothard, M., Velea, L., Cica, R., Dumitrescu, A., Bîrsan, M.V., Stăncălie, G.
26.	During International Conference “The future of Copernicus: extension and expansion”, held in Bucharest, 5-6 October 2016 was presented the paper: „Current achievements towards developing downstream services for snow monitoring in Romania", authors: Stăncălie, G., Crăciunescu, V., Diamandi, A., Irimescu, A., Dumitrache, C., Solberg, R., Rudjord, Ø., Due Trier, Ø.
27.	At the annual scientific conference of the National Institute of Hydrology and Water Management, which took place in Bucharest from 11 to 12 October 2016, was presented the poster: „Assimilation of snowpack parameters in the National Hydrological Forecasting System NWSRFS – SNOWBALL Project”, authors: Mătreaţă, M., Mătreaţă, S.
28.	To the annual scientific conference of the National Meteorological Administration, held in Bucharest, between 1-2.11.2016, has been presented the papers: - „Evaluation and mapping of snow wetness using optical and radar satellite data”, authors: Irimescu, A., Stăncălie, G., Diamandi, A., Crăciunescu, V., Solberg, R., Rudjord, Ø., Due Trier, Ø. - „Impacts of climate change on the snow cover in the Carpathian Mountains”, authors: Bojariu, R., Velea, L., Dascălu, I.S., Gothard, M., Bîrsan, M.V., Dumitrescu, A., Cica, R., Stăncălie, G.
29.	At the Workshop on Communication and Publicity, organised by Contracting Authority (ANCSI) under the Program RO14 - "Research in Priority Sectors", the EEA Financial Mechanism 2009-2014, which took place in Sibiu from 25 to 26 May 2016 have been presented the SnowBall Project Dissemination Strategy.
30.	At the 8th EARSeL Workshop on Land Ice and Snow, held in Bern, Switzerland, between 7-9 February 2017, has been presented the paper: “A multi-sensor multi-temporal approach to retrieving snow surface wetness from a combination of Sentinel-1 and Sentinel-3 data”, authors: Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A.
31.	During the International Conference Sub-urban 2017 Planning and management week, held in Bucharest, from 13 to 16 March 2017, has been presented the paper: „Snowmelt modeling in urban areas”, authors: Dobre, R.G., Gogu, R., Găitănaru, D.S.
32.	At the International Conference Air and Water – Components of the environment, held in Cluj-Napoca, during 17-19.03.2017, have been presented the papers: - „Synoptic conditions generating important snowfalls and their relation with avalanches in 2015-2016 winter”, authors: Grecu, C.L., Paşol, A., Milian, N. - „Winter extreme phenomena – Romanian Carpathians avalanches”, authors: Paşol, A., Grecu, Milian, N., C.L., Reckherth, U.
33.	During the “SnowBall User Workshop”, held in Bucharest, Romania on 27th of April 2017, the following papers were presented: - „Measuring snow from space starts at the ground: from new station designs to collecting snow truth data”, authors: Diamandi, A., Dumitrache, C., Rădulescu, C., Nicola, O., Luca, E., Chiriţescu, R., Milian, N., Paşol, A., Grecu, C., Irimescu, A., Mihăilescu, D.; - „Satellite remote sensing of snow wetness in Romania and Norway”, authors: Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Irimescu, A., Diamandi, A., Crăciunescu, V.; - „Climate change impact on snow-related processes”, authors: Bojariu, R., Corbuş, C., Mic, R., Mătreaţă, M., Crăciunescu, V., Milian, N., Dumitrescu, A., Bîrsan, M.-V., Dascălu, S.-I., Gothard, M., Velea, L., Cica, R., Grecu, C., Paşol, A.; - „Quantitative assessment of aquifer recharge from snowmelt”, authors: Găitănaru, D., Holban, R., Gogu, R.; - „Avalanche detection in very high resolution optical satellite images”, authors: Salberg, A.-B., Ardelean, F., Török-Oance, M.; - „Improved snow water equivalent estimation methodology, for better hydrological warnings and forecasting”, authors: Mătreaţă, M., Mătreaţă, S., Agiu, B.; - „Change-detection based mapping of avalanches in Sentinel-1 images”, authors: Salberg, A.-B., Reksten, J., Ardelean, F.; - „Snow avalanche inventory and hazard assessment in Fagaras Mountains”, authors: Török-Oance, M., Ardelean, F., Voiculescu, M., Milian, N., Salberg, A.-B.; - „River ice monitoring using remote sensing data. Case studies: Romania, winter season 2016-2017”, authors: Mihăilescu, D., Crăciunescu, V., Stăncălie, G., Constantinescu, Ş., Irimescu, A., Angearu, C.
34.	At the 20th Conference of the Probability and Statistics Society of Romania, held in Brasov, Romania during 28-29 April 2017, has been presented the paper: „Hydrogeological Parameters Estimation”, authors: Dobre, G.R.,

	Gogu, R., Găitănaru, D.S.
35.	The 33rd Edition of the Romanian Geomorphology Symposium, held in Iasi, from 11 to 14 May 2017, the paper was presented: „New findings related to snow avalanches and related hazard in Southern Carpathians. Case study: Făgăraș Mts”, authors: Voiculescu, M., Ardelean, F., Török-Oance, M.
36.	The 17th International Multidisciplinary Scientific GeoConference SGEM 2017, will take place in Albena, Bulgaria, between 27 July to 6 June 2017, the following paper has been accepted to be presented as oral presentation: „Snowmelt Infiltration Using Hydrus-1d Based On A Snow Surface Energy Balance Model For Bucegi Mountains, Romania”, authors: Dobre, R.G., Gogu, R., Găitănaru, D.S.
37.	The International Symposium „Polar Ice, Polar Climate, Polar Change" will take place in Boulder, Colorado, USA, between 14 to 19 August 2017, the following paper has been accepted to be presented as oral presentation: „Remote sensing of snow wetness using Sentinel – a multi-sensor approach", authors: Rudjord, Ø., Solberg, R., Due Trier, Ø., Salberg, A.-B., Stăncălie, G., Diamandi, A., Irimescu, A., Crăciunescu, V.

3) Equipment

List of the equipment(s) purchased and/or depreciated				
No.	Name of the equipment	Cost lei	Euro	How will the equipment be used after completion of the project?
Equipment purchased on project and depreciated during its lifetime				
1.	Spectroradiometer DSR-UVN-1024	79.432,42	19.981,31	The Spectroradiometer will be used to acquire and process the snow reflectance data in future field campaigns under different lighting, slope, orientation, snow types, snow melting conditions.
2.	Notebook	7.200,00	1.629,88	It will be used to collect data from field sensors and their primary processing during measurement campaigns.
3.	Notebook	13.839,52	3.132,89	It will be used to collect data from mobile stations and to ensure the maintenance of mobile stations (data-logger, microcontroller software loading etc.).
4.	Workstations (2 pieces)	41.400,00	9.371,82	The two workstations will be used for the daily storage and processing of the satellite data required for the quasi-real snow monitoring prototype system as well as the resulting snow wetness products (eg, snow wetness maps based on optical satellite data, snow wetness maps based on radar satellite data, snow wetness maps based on multi-temporal multi-sensor satellite data).
5.	Switch-catalyst	4.872,23	1.102,94	Interconnection of computers and users to the computer network of the National Meteorological Administration and transfer of data and satellite based products to users and beneficiaries.
6.	Soft VM ware fusion	442,87	100,25	It will be used to virtualize the computing systems, on which will be stored and processed the daily satellite data and satellite based products, and back-up data on the storage system of the National Meteorological Administration.
7.	Soft Microsoft office	891,75	198,66	The Microsoft Office will be used to develop the further project proposal documentation and reporting, ensuring full compatibility of the file format with project partners and contracting authority.
8.	Spectroradiometer command module	3.850,00	868,82	The Spectroradiometer command module will be used to control and download data measured by the DSR-UVN-1024 Spectroradiometer.
9.	Modelling Workstation	8.194,52	1.578,55	The modelling workstation will be used in the Groundwater Engineering Research Center to process and model

				data on groundwater flow and flow in the unsaturated zone. Specific modelling software was installed on this station
10.	TDR Investigation System	31,903.96	7,222.18	The TDR Investigation System is used to continue research on water infiltration in the vadose area. The equipment is used in the research project Waterworks 2014 - Innovation for Climate Events eXtreme - INXCES
11.	Processing server (composed by a main computing unit - Server TRUSTER RX2616/s and a management/archiving administration unit - PC Theon)	21,200.00	4,799.09	It will be used to run the data fusion and data assimilation methodologies implemented within the project, as support for the operational hydrological warnings and forecasts activities.
12.	RAMMS avalanche simulation software	16,086.91	3,641.63	Further use in research activities for simulation of avalanche trajectories in future projects in several test areas
13.	Laptop HP	4,594.20	1,038.87	Further use in data processing and data download and pre-processing in the field
	Total	**233,907.60**	**54,666.48**	
Equipment purchased on project and excepted from the general depreciation rule in line with art. 7.3.1 (c) of EEA Regulation				
1.	Spectroradiometru DSR-UVN-1024	83,282.42	20,850.13	The Spectroradiometer will be used to acquire and process the snow reflectance data in future field campaigns under different lighting, slope, orientation, snow types, snow melting conditions.
2.	TDR Investigation System	31,903.96	7,222.18	The TDR Investigation System is used to continue research on water infiltration in the vadose area. The equipment is used in the research project Waterworks 2014 - Innovation for Climate Events eXtreme - INXCES
	Total	**115,185.60**	**28,072.31**	
Equipment depreciated within the project lifetime				
1.	Notebook	7.200,00	1.629,88	It will be used to collect data from field sensors and their primary processing during measurement campaigns.
2.	Notebook	13.839,52	3.132,89	It will be used to collect data from mobile stations and to ensure the maintenance of mobile stations (data-logger, microcontroller software loading etc.).
3.	Workstations (2 pieces)	41.400,00	9.371,82	The two workstations will be used for the daily storage and processing of the satellite data required for the quasi-real snow monitoring prototype system as well as the resulting snow wetness products (eg, snow wetness maps based on optical satellite data, snow wetness maps based on radar satellite data, snow wetness maps based on multi-temporal multi-sensor satellite data).

4.	Switch-catalyst	4.872,23	1.102,94	Interconnection of computers and users to the computer network of the National Meteorological Administration and transfer of data and satellite based products to users and beneficiaries.
5.	Soft VM ware fusion	442,87	100,25	It will be used to virtualize the computing systems, on which will be stored and processed the daily satellite data and satellite based products, and back-up data on the storage system of the National Meteorological Administration.
6.	Soft Microsoft office	891,75	198,66	The Microsoft Office will be used to develop the further project proposal documentation and reporting, ensuring full compatibility of the file format with project partners and contracting authority.
7.	Modelling Workstation	8.194,52	1.578,55	The modelling workstation will be used in the Groundwater Engineering Research Center to process and model data on groundwater flow and flow in the unsaturated zone. Specific modelling software was installed on this station
8.	Processing server (composed by a main computing unit - Server TRUSTER RX2616/s and a management/archiving administration unit - PC Theon)	21,200.00	4,799.09	It will be used to run the data fusion and data assimilation methodologies implemented within the project, as support for the operational hydrological warnings and forecasts activities.
9.	RAMMS avalanche simulation software	16,086.91	3,641.63	Further use in research activities for simulation of avalanche trajectories in future projects in several test areas
10.	Laptop HP	4,594.20	1,038.87	Further use in data processing and data download and pre-processing in the field
	Total	**118.722,00**	**26.594,58**	

4) Improvement of the situation of the Roma population

- Did your project address the improvement of the situation of the Roma population?

Yes ☐ No ☐

If yes, please provide information on the following points:

- Areas of research and policy interventions focused on Roma issues (e.g. health and food safety, social sciences and humanities, education, etc.);
- Disciplinary vs. interdisciplinary approaches; research and/or policy oriented projects;
- Types of partnership agreements: the number and types of Roma organizations, including NGOs, which are involved in the projects and which have research and policy activities in their mission statement;
- Capacity and human resources development in and for the Roma communities;
- How the issues of sustainability of research and policy results are addressed;
- Research staff involved and trained in issues related to the Roma population;

Total number of researchers	**Total number of master students**	**Total number of PhD students**	**Total number of postdoctoral researchers**

- Roma people and communities included in the mappings and investigations;

	Number of Roma communities	**Number of Roma people**
Experimental and qualitative research techniques		
Quantitative research techniques		

- Research and policy-oriented reports and publications towards improvement of the situation of the Roma population.

	Number of research reports	**Number of policy reports**	**Number of workshops with Roma representatives**	**Number of workshops with academics and policy makers**	**Number of publications**
By Project Promoter and project partner					
…					
Total					

5) Audits

INFORMATION ON AUDITS/ON-THE-SPOT VISITS AND IMPLEMENTATION OF AUDIT RECOMMENDATIONS (date, type of audit, the entity carrying out the audit, recommendations, compliance with the audit recommendations, etc.)
On 2.11.2015 it took the site monitoring mission „On-the spot monitoring visit", carried out by the Contracting Authority: National Authority for Scientific Research and Innovation. In the following table are presented the objectives / audited fields, recommendations and the stage of their implementation.

Objectives / audited fields	Recommendations	Recommendations implementation stage
Verifying the Promoter's ability to implement the project.	No recommendations	
Checking the eligibility of expenditure (verification period: 01.07.2014-30.11.2014).	From the analysis of the personnel documents, the lack of the individual work contracts, the lack of the job description and the monthly activity report for the Project Promoter, respectively NMA, were found in the file of the Financial Report. Also for the travel supporting documents, the absence of the Travel Report was found. Please note that this has been communicated to the Project Promoter.	Until the end of the monitoring mission, the financial report was completed with missing documents.
Verification of the the financial and accounting activity of the project.	The amount of 103.09 RON is ineligible. This amount arises from CHF - Euro currency conversion and the conversion of Euro to Ron.	The amount declared ineligible (103.09 lei) was not requested by the payment request at the end of the 2014 financial year.
Checking public procurement. The Project Promoter's Public Procurement File was reviewed / verified. The conclusion was that it is complete and correctly drawn up.	No recommendations	
Checking the physical progress and the stage of the project.	No recommendations	
Verification of information, publicity, good governance, sustainable development and equal opportunities.	No recommendations	
Verification of the collection, storage and archiving of documents and maintaining the audit trail.	No recommendations	
Identification of issues that occurred / may occur during project implementation.	No recommendations	

During the period 14.03 - 16.05.2016 the Operational Audit of the project was carried out by the Ministry of Public Finance, the Central Amortization Unit for Public Internal Audit.
In the following table are presented the objectives / audited fields, recommendations and the stage of their implementation.

Objectives / audited fields	Recommendations	Recommendations implementation stage
Project Budget Execution	Establishment of additional and adequate control devices at the PP NMA and Romanian Partners level, recording and accurate reporting of the costs declared in the SnowBall Project. Deadline: 31.08.2016	The procedure for additional and appropriate control devices on how to report and correctly record of the Snowball project costs are underway.
The eligibility of expenditure declared in the Financial Statements included in the audit	OP ANCSI will notify PP NMA and the latter in turn will notify P2-UTCB, P3-INHGA and P4-UVT partners to make the corrections and adjustments required for the July-November 2014 and December 2014-December 2015 Reports. Deadline: 31.08.2016	It was concluded the Additional Act no. 6/2016 to the Financing Agreement no. 19SEE / 2014.
	In the cases of ineligibility of the mentioned costs, the NMA will take action to highlight the irregularities and will notify the ANCSI OP to proceed to the application of art. 20 of GEO no. 66/2011 regarding the prevention, detection and sanctioning of irregularities in the obtaining and use of corresponding European funds and / or national public funds, with subsequent amendments.. Deadline 31.07.2016	The communication on the notification of ineligibility of expenses as well as the recording of the irregularities to the OP ANCSI was made by e-mail (message dated 02.06.2016 sent to the Director Mrs. Anca Ghinescu and to the Project Officer Mrs. Ruxandra Popescu), followed by discussions with representatives of OP ANCSI and the Ministry of European Funds. On this occasion were analysed the situations related to GEO no. 66/2011, art. 20. Under Additional Act no. 6/2016 to the Financing Agreement no. 19SEE / 2014, in art. 4 and 5, were established the criteria for the personnel designated to be remunerated under the Snowball project, the reallocation of funds and personnel expenses from indirect costs into direct expenditure, as well as the change in the percentage of the fixed rate of indirect costs.
	PP ANM together with the OP ANCSI will request to the partner P1 NR to submit the Independent Auditor's Report and the Certified Auditor's Report that should accompany the project Report in which the expenditures were declared in the amount of 391,339.27 lei for the period July-November 2014. Deadline: 31.07.2016	The partner P1 NR was required to draw up the audit report for July 2014 - December 2016 (Address 2435/30 June 2016). Until the receipt of the audit certificate from the partner P1 NR, ANCSI took the decision to rectify the 2014 and 2015 Authorization Note, which would reduce the total amount by the amount of expenditure declared by the Norwegian partner. When submitting the audit certificate, these costs will be re-authorized by the OP (Address 1073/9 December 2016).

		The Norwegian partner confirmed by e-mail of 6 December 2016 the preparation of the procedure for obtaining the audit certificate.
	Designation at PP NMA level of a substitute holder of CFPP for the SnowBall Project. Deadline: 30.06.2016	Mrs. Marina Stoian - Chief Accountant was appointed to replace the holder of CFPP for the SnowBall Project (Decision No. 9/30 June 2016). Associated attributions were included in the job description.
Procurement of products, services and works performed within the Project during the audited period	Updating the existing Operational Procedure and for public procurement by direct purchase. Deadline: 31.07.2016	The direct purchase procedure for the SnowBall project was carried out.
	PP ANM and the 3 Romanian Partners will prepare the Annual Procurement Program to meet the standard format, to contain the correct CPV codes and to be based on the need for products and services to be purchased for the project. Deadline: At the time of the 2017 Annual Procurement Program Preparation.	The recommendation was taken into account.
	Purchasing justifications reports shall state the CPV for the procurement and the applied procurement procedure. Deadline: At the time of the procurement.	The recommendation was fulfilled. In Procurement Reports the CPV codes and the applied procurement procedure were mentioned.
	The P2 and P4 partners will designate those who are responsible for project procurement. Deadline: 30.06.2016	Mr. Dragoş Găitanaru was appointed responsible for public procurement for the SnowBall project from P2 - UTCB (Address 6135 of 30.06.2016). Mr. Debretin-Frasie Virgiliu has been appointed responsible for public procurement for the SnowBall project from P4 - UVT (Address 15242 of 30.06.2016).
The treatment of irregularities and applied financial corrections	The designation of a person responsible for recording and reporting irregularities. Deadline: 30.06.2016	According to the project proposal, there was established the Project Steering Committee (PSC), composed by the project leaders of the consortium partners and led by the project manager. The PSC is responsible for organizing, coordinating and supervising the implementation of the necessary activities, including highlighting and reporting irregularities, so that the project tasks to be completed in time.
Justification of the expenses incurred in the project and their recording in the accounting	Designate a person responsible for archiving and retaining the project documentation whose tasks are to be provided in the record of duties and responsibilities. Deadline: 30.06.2016	Mrs. Anişoara Irimescu CS III was appointed responsible for archiving and keeping the SnowBall project documentation (Decision No. 9/30 June 2016). Associated duties were included in the job description.

	Making regularly accounting reconciliations between OPs and PPs to identify possible errors. Deadline: starting from 01.06.2016.	Discussions were held between the OP-ANCSI and PP-NMA financial officers in order to identify and correct the errors. In this context, OP ANCSI sent the address no. 920 / 04.07.2016 on reconciliation. PP ANM responded to this request by address no. 4735 of 08.12.2016 and notification no. 4718 of 8.12.2016.
Actions developed and delivered to meet the Information and Publishing Requirements	Preparation of the Advertising Plan as required by Annex 4 of the applicable regulation Deadline: 31.07.2016	The Advertising Plan (in Romanian and English) was prepared, as required by Annex 4 of the applicable regulation.
	Placement of Advertising posters on the NAM's site with information regarding the name and objectives of the SnowBall Project run by the NMA Deadline: 31.07.2016	The advertising roll-up with information on the name and objectives of the SnowBall Project was made (in May 2016) and placed within PP ANM.
	Updating the website containing all project information in Romanian. Deadline: 30.06.2016	There was updated the two versions (in Romanian and English) of the project website (http://snowball.meteoromania.ro)
	Designate, at the NMA level, a person responsible for SnowBall Advertising and Dissemination. Deadline: 30.06.2016	Mr. Vasile Craciunescu – senior researcher (CS III) was appointed responsible for the Advertising and Dissemination of the SnowBall Project (Decision No. 9/30 June 2016). Associated attributions were included in the job description.

C. Report on scientific publications

1) Joint scientific publications

The full list of internationally referred joint scientific publications with references is presented below. The abstracts for all joint scientific publications resulted from this joint research project are presented in Annex1.

No	Title of scientific publication	Authors	Institutional affiliation and country	Name of journal	Number, year, pages	Citation index	Submitted/ Accepted/ Published and date	Link to publication (if relevant)
1.	Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective	Coordinator: Stancalie G.	PP Romania P1 Norway P2 Romania P3 Romania P4 Romania	Book	163		Published Printech Publishing	100 copies distributed within the SnowBall Final Workshop
2.	Topographical factors, meteorological variables and human factors in the control of main snow avalanche events in the Făgăraș massif-Southern Carpathians (Romanian Carpathians: case studies	Voiculescu, M.[1], Ardelean, F.[1], Török-Oance, M.[1], Milian, N.[2]	[1] P4 Romania [2] PP Romania	Geographia Polonica	89 (1), 2016, 47-64		Submitted: October 2015; Accepted: January 2016;	https://www.geographiapolonica.pl/article/item/10463.html
3.	Automated detection and mapping of avalanches in SAR images	Hamar, J.B.[1], Salberg, A.-B.[1], Ardelean, F.[2]	[1] P1 Norway [2] P4 Romania	IGARSS	2016		Published	http://ieeexplore.ieee.org/document/7729173/
4.	Single and multi-sensor snow wetness mapping by Sentinel-1 and MODIS data	Solberg, R.[1], Salberg, A.-B.[1], Rudjord, Ø.[1], Due Trier, Ø.[1], Stancalie, G.[2], Diamandi, A.[2], Irimescu, A.[2],	[1] P1 Norway [2] PP Romania	73 rd Eastern Snow Conference	2016		Accepted	https://u.osu.edu/durand.8/files/2016/06/Final-Program-1ecm6dd.pdf
5.	Snow avalanche activity in the Romanian Carpathians: new findings from VHR satellite and drone based image analysis	Török-Oance, M.[1], Ardelean, F.[1], Voiculescu, M.[1], Milian, N.[2]	[1] P4 Romania [2] PP Romania	Cold Regions Science and Technology	2017		Submitted	
6.	Remote Sensing of Snow Wetness in Romania by Sentinel-1 and Terra Modis Data	Solberg, R.[1], Salberg, A.-B.[1], Due Trier, Ø.[1], Rudjord, Ø.[1],	[1] P1 Norway [2] PP Romania	Romanian Journal of Physiscs	2017		Accepted	http://www.nipne.ro/rjp/accpaps/028-Solber_FE3524.pdf

		Stancalie, G.[2], Diamandi, A.[2], Irimescu, A.[2], Craciunescu, V.[2]						
7.	A multi-sensor multi-temporal approach to retrieving snow surface wetness from a combination of Sentinel-1 and Sentinel-3 data	Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A,	[1] P1 Norway [2] PP Romania	EARSeL	2017		Accepted	http://www.earsel.org/SIG/Snow-Ice/files/abstracts_ws2017/EARSeL_LISSIG_2017_Solberg_et_al.pdf
8.	Remote sensing of snow wetness using Sentinel – a multisenzor approach	Rudjord, Ø.[1], Solberg, R.[1], Due Trier, Ø.[1], Salberg, A.-B.[1], Stăncălie, G.[2], Diamandi, A.[2], Irimescu, A.[2], Crăciunescu, V.[2],	[1] P1 Norway [2] PP Romania		2017		Accepted	https://www.igsoc.org/symposia/2017/boulder/proceedings/procsfiles/acceptedabstracts.html

2) Scientific publications

The full list of internationally referred scientific publications with references is presented below. The abstracts for all scientific publications resulted from this joint research project are presented in Annex 2.

No	Title of scientific publication	Authors	Institutional affiliation and country	Name of journal	Number, year, pages	Citation index	Submitted/ Accepted/ Published and date	Link to publication (if relevant)
1.	Monitoring of snow properties with Sentinel-3	Solberg, R., Due Trier, Ø., Rudjord, Ø.	P1 Norway	Proceedings of ESA Sentinel-3 for Science Workshop	2015		Published	http://seom.esa.int/S3forScience2015
2.	Synoptic conditions for avalanche cases in Romania	Milian, N.	PP Romania	Air and Water – Components of the environment	2015, 299-306		Published	http://aerapa.conference.ubbcluj.ro/2015/40_MILIAN.htm
3.	Synoptic avalanche triggering conditions during 2014-2015 winter	Milian, N., Pasol, A.	PP Romania	Air and Water – Components of the environment	2016, 306-313		Published	http://aerapa.conference.ubbcluj.ro/2016/39_Milan.htm
4.	Spatial interpolation of daily snow depth over Romania	Dumitrescu, A., Bîrsan, M.-V.	PP Romania	Proceedings of GeoMla 2016 Conference	2016, 67 - 72		Published	http://geomla.grf.bg.ac.rs/site_media/static/Proceedings%20of%20GeoMla%202016%20Conference.pdf
5.	Synoptic conditions generating important snowfalls and their relation with avalanches in 2015-2016 winter	Grecu, C.L., Paşol, A., Milian, N.	PP Romania	Air and Water – Components of the environment	2017, 379-386		Published	Not yet available online
6.	Winter extreme phenomena – Romanian Carpathians avalanches	Paşol, A., Grecu, C.L., Milian, N., Reckherth, U.	PP Romania	Air and Water – Components of the environment	2017, 101-107		Published	Not yet available online
7.	Snow-related impact in the Carpathians under climate change conditions	Bojariu, R., Dascălu, I.S., Gothard, M., Velea, L., Cica, R., Dumitrescu, A., Bîrsan, M.V., Stăncălie, G.	PP Romania	Future of the Carpathians: Smart, Sustainable, Inclusive	2017			http://geo.unibuc.ro/fc/Abstract_Conference_Book_FC2016_C%20%281%29.pdf
8.	Snowmelt Infiltration Using Hydrus-1d Based On A Snow Surface Energy Balance	Dobre, R.G., Gogu, R.,	P2 Romania	International Multidisciplinary	2017		Accepted	https://www.sgem.org/

	Model For Bucegi Mountains, Romania	Găitănaru, D.S.		Scientific GeoConference SGEM 2017				
9.	Snowmelt modeling in urban areas	Dobre, R.G., Gogu, R., Găitănaru, D.S.	P2 Romania	Proceedia Enginnering, Elsevier	2017		Submitted (in review)	
10.	A Romanian daily high-resolution gridded dataset of snow depth (2005-2015)	Dumitrescu, A., Birsan, M.V.,	PP Romania	Geofizika, Spatial Statistics in Environmental Modelling	2017		Submitted (in review)	
11.	Geostatistical downscaling of temperature and precipitation under present and future climate scenarios	Dumitrescu, A., Bojariu, R., Dascalu, S.I., Gothard M., Birsan, M.V., Cica, R., Velea, L., Stancalie, G., Irimescu, A.	PP Romania	Acta Geophysica	2017		Submitted (in review)	

D. Report (questionnaire) covering wider societal implications

1) Gender equality actions

- 16 female (researchers) and 26 men (researchers) in total were involved in the project. Out of these values:
  - 6 female researchers and 5 men researchers at the management level (coordinator for Project Promoter and team leader for project partners) and respectively 10 female researchers and 21 men researchers at the level of execution (for Project Promoter and project partners);
  - 4 female researchers and 4 men researchers for PhDs and postdocs.
- Do the funded research activities address women in particular?

  Yes ☐ No ☐

If yes, briefly specify (max. 1.000 characters no spaces - in the form of a running text) the situation and the actions pursued.

- Will your research results have an impact on gender dimension in future research activities of the Project Promoter and project partner(s)?

  Yes ☐ No ☐

If yes, explain on what extent (max 1.000 characters no spaces - in the form of a running text).

2) Ethical issues

- Did the funded research activities have components that are ethically sensitive?

  Yes ☐ No ☐

Please base your reply on ethical issues table filled in at the project proposal stage.

If yes,

- Did the local Research Ethics Committee monitor your project?

If yes, please attach the conclusions of the local Research Ethics Committee.

If no, please contact your local Research Ethics Committee for getting the ethics assessment document.

- Did you appoint an Ethics Advisory Board for your project?

If yes, please briefly describe your experience.

3) Efforts to involve other actors and to spread awareness, as well as the plan for the use and dissemination of foreground

During the SnowBall project implementation period, more actions were organized for dissemination and training, according with project publicity plan, which was aimed at user's community awareness regarding the opportunities offered by project results, by organizing conferences/seminaries, publishing articles with impact factor, by dissemination of results achieved at scientific prestige events and by disseminating support materials. The successful demonstration of added value of project products, has led to an increased interest from some institutions and organizations from Romania (IGSU, Romanian Waters, Hidroelectrica, Technical Cluj University) and Norway (two institutions similar with Hidroelectrica), who appreciated the immediate applicability in operational and research activities of project results in: snow monitoring using satellite data, in-situ measurements, risk assessment of flash flood caused by snow melting and avalanches, water resources management, climate change impact studies, estimating the water volumes from snow melting in aquifer recharging.

<table>
<tr><th colspan="4">Dissemination activities of research results</th></tr>
<tr><td>Number</td><td>1.</td><td>Activity</td><td>National Institute of Hydrology and Water Management Annual Scientific Conference</td></tr>
<tr><td>Description (topic, aim, communication tools)</td><td colspan="3">• It was presented the work communication: "Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective". Authors: Mătreaţă, M., Corbuş, C., Mic, R., Mătreaţă, S., Pandele, A., Radu, E. It has been noted the contribution of NIHWM and project partners to improving snow melt runnoff warnings and forecasts, by developing a new data fusion procedure based on simulations performed with the NOAH hydrology model.</td></tr>
<tr><td>Target groups</td><td colspan="3">- Representatives from different governmental institutions: Ministry of Environment, Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations, Water Management Service etc.;
- Education and research institutions: Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Şişeşti", Institute of Geography of the Romanian Academy, Research Institute for Pedology and Agrochemistry, Technical University of Civil Engineering Bucharest, National Meteorological Administration;
- Commercial companies: Hidroelectrica;
- Mass-media.</td></tr>
<tr><td>Date and venue</td><td colspan="3">10-11 November 2014, Bucharest</td></tr>
<tr><td>Organizer</td><td colspan="3">P3 - NIHWM</td></tr>
<tr><td>Partners involved</td><td colspan="3">P2 – UTCB, PP - NMA</td></tr>
<tr><td>Assessment of activities</td><td colspan="3">The use of the new snow module has led to the development of a more complex data fusion procedure, and in particular, a better use of snow layer parameters, derived from satellite data, in the operational models of hydrological forecasting.</td></tr>
<tr><td>Number</td><td>2.</td><td>Activity</td><td>International Conference "Methodological challenges in geography"</td></tr>
<tr><td>Description (topic, aim, communication tools)</td><td colspan="3">• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.);
• A paper was presented: "An alternative solution for avalanche tracks mapping using semi-automated methods. A case study from Făgăraş Mountains", authors: Ardelean, F., Török-Oance, M., Voiculescu, M.</td></tr>
<tr><td>Target groups</td><td colspan="3">- Representatives from different governmental institutions: Ministry of Environment, Waters and Forests, Ministry of Education and Scientific Research, National Administration "Romanian Waters" etc.;
- Education and research institutions: University of Bucharest, Faculty of Geography,</td></tr>
</table>

	National Meteorological Administration, Technical University of Civil Engineering Bucharest;		
Date and venue	15-16 May 2015, Timisoara		
Organizer	P4 - WUT		
Partners involved	PP - NMA		
Assessment of activities	The results obtained contribute to the management of emergency situations by providing accurate map data, shortly after avalanches occurred.		
Number	3.	**Activity**	National Institute of Hydrology and Water Management Annual Scientific Conference
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • A paper was presented: „Estimation methodology of snow water equivalent, using data fusion approach (simulated data, in-situ observations and satellite products – SnowBall Project", authors: Mătreață, M., Mătreață, S.		
Target groups	- Representatives from different governmental institutions (Ministry of Environment, Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations, Water Management Service etc.) - Education and research institutions: Academy of Agricultural and Forestry Sciences, Research Institute for Pedology and Agrochemistry, Technical University of Civil Engineering Bucharest, National Meteorological Administration; - Commercial companies: Hidroelectrica; - Mass-media.		
Date and venue	2-3 November 2015, Bucharest		
Organizer	P3 - NIHWM		
Partners involved	PP – NMA, P2 - UTCB		
Assessment of activities	The grid product with the snow water equivalent, obtained using the data fusion methodology, is an optimal estimate of this parameter, based on real-time data available and is used to update this important status parameter in the hydrological forecasting operational models, through a data assimilation procedure.		
Number	4.	**Activity**	National Meteorological Administration Annual Scientific Conference
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • A paper was presented: "Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective – SnowBall Project", authors: Stăncălie, G., Diamandi, A., Dumitrache, C., Bojariu, R., Crăciunescu, V., Mihăilescu, D., Milian, M., Solberg, R., Salberg, A.-B., Voiculescu, M., Török-Oance, M.		
Target groups	- Representatives from different governmental institutions: Ministry of Environment, Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations etc.; - Education and research institutions: Academy of Agricultural and Forestry Sciences, University of Bucharest, Faculty of Physics, Faculty of Geography, Institute of Geography of the Romanian Academy, Research Institute for Pedology and Agrochemistry; - Mass-media.		
Date and venue	19-20 November 2015, Bucharest		
Organizer	PP - MeteoRomania		

Partners involved	P3 - NIHWM		
Assessment of activities	The new snow wetness maps, developed by multi-sensor / multi-temporal algorithms based on new optical satellite data (Terra MODIS) and SAR (Sentinel-1), have been validated and represent very useful snow monitoring information, especially during the melting periods.		
Number	5.	**Activity**	International Conference "Achievements and future steps"
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • The results obtained during the first half of SnowBall project implementation period were presented.		
Target groups	- Contracting Authorities representatives from Romania, Norway and Island ; - Other running project representatives from "Research in Priority Sectors" Program.		
Date and venue	10 December 2015, Bucharest		
Organizer	Contracting Authority		
Partners involved	PP – NMA, P1 – NR, P2 – UTCB, P3 – NIHWM, P4 - WUT		
Assessment of activities	The importance of developing a new service to provide national authorities and the general public with consistent, real-time information to monitor the spatio-temporal evolution of snow cover parameters and related hazards (floods caused by sudden snow meltdown and Avalanches) in the current and future climate, based on in-situ measured data and those provided by satellites.		
Number	6.	**Activity**	The 18th International Symposium "Symbolic and Numerical Algorithms for Scientific Computing – SYNASC"
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • The following paper were presented: - „Numerical simulation of documented snow avalanche events in Făgăraș Mountains", authors: Ardelean, F., Török-Oance, M., Salberg, A.B., Voiculescu, M., Milian, N., Irimescu, A. - „Snow avalanche hazard assessment in Făgăraș Mountains, Southern Carpathians", authors: Török-Oance, M., Irimescu, A., Milian, N., Diamandi, A., Ardelean, F., Voiculescu, M.; - „Automatic detection and segmentation of avalanches in remote sensing images using deep convolutional neural networks", authors: Salberg, A.B., Hamar, J.B., Ardelean, F., Johansen, T., Kampffmeyer, M. - „Single and multi-sensor snow wetness mapping by Sentinel-1 and MODIS data", authors: Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Diamandi, A., Irimescu, A. - „Some consideration on using Copernicus Sentinel satellite data for characterizing the snow cover in the Romanian Mountains", authors: Nedelcu, I., Irimescu, A., Mihăilescu, D., Diamandi, A., Crăciunescu, V., Stăncălie, G., Gogu, R. - „High Resolution temperature and precipitation under present and future climate scenarios", authors: Dumitrescu, A., Bojariu, R., Dascălu, I.S., Gothard, M., Bîrsan, M.V., Cica, R., Velea, L., Stăncălie, G., Irimescu, A. - „Snow water equivalent estimation using a data fusion approach", authors: Mătreaţă, M., Mătreaţă, S.		
Target groups	- Representatives from different governmental institutions: Ministry of Environment, Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations, National Meteorological Administration, Water Management Service etc.; - Education and research institutions: West University of Timisoara, University of		

	Bucharest, Faculty of Geography; - Commercial companies: Hidroelectrica; - Mass-media.		
Date and venue	24-27 September 2016, Timişoara		
Organizer	P4 – WUT, PP		
Partners involved	P1 – NR, P2 – UTCB, P3 – NIHWM		
Assessment of activities	The contribution of the project to the deeper understanding of snow domain and of remote sensing technics for snow monitoring, was emphasized.		
Number	7.	**Activity**	International Conference „The future of Copernicus: extension and expansion”
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • A paper was presented: „Current achievements towards developing downstream services for snow monitoring in Romania”, authors: Stăncălie, G., Crăciunescu, V., Diamandi, A., Irimescu, A., Dumitrache, C., Solberg, R., Rudjord, Ø., Due Trier, Ø.		
Target groups	- Representatives from: European Commission, European Space Agency (ESA), European Environmental Agency (EEA), Romanian Parliament, Ministry of Education and Scientific Research, Romanian National Environmental protection Agency, National Meteorological Administration, Romanian Agency for Cadastre, the Agency for Sustainable Development, European GNSS Agency etc.; - Education and research institutions: Technical University of Civil Engineering in Bucharest, Technical University of Republic of Moldavia; - Commercial companies: Hidroelectrica, Eurisy, Commnunication & Systemes, Sintef Norvegia; - Mass-media.		
Date and venue	5-6 October 2016, Bucharest		
Organizer	Romanian Space Agency		
Partners involved	PP		
Assessment of activities	The snow monitoring prototype system, based on the combination of data from new Sentinel satellites, with snow-in-field measurements, allows snow monitoring to be applied in: meteorology, hydrological modelling, warnings of snow melting flash flood and snow avalanches. Under current and future climatic conditions, the obtained results have also significant applications in water management and hydropower and emergency management.		
Number	8.	**Activity**	National Institute of Hydrology and Water Management Annual Scientific Conference
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • A paper was presented: „ Assimilation of snowpack parameters in the National Hydrological Forecasting System NWSRFS – SNOWBALL Project”, authors: Mătreaţă, M., Mătreaţă, S.		
Target groups	- Representatives from: Ministry of Environment, Waters and Forests, Academy of Agricultural and Forestry Sciences, National Administration “Romanian Waters”, General Inspectorate for Emergency Situations, National Meteorological Administration, Water Management Service etc.; - Education and research institutions: Institute of Geography of the Romanian Academy, Research Institute for Pedology and Agrochemistry, University of Agronomic Sciences and Veterinary Medicine of Bucharest;		

	- Mass-media.		
Date and venue	11 - 12 October 2016, Bucharest		
Organizer	P3 – NIHWM		
Partners involved	PP – NMA, P2 - UTCB		
Assessment of activities	It has been pointed out within the hydrological forecasting system NWSRFS, the assimilation of average snow water equivalents at the level of sub-basins, (computed on the basis of the grid product resulting from the data fusion method), will lead to an improvement in the water flow forecast from snow melting.		
Number	9.	**Activity**	National Meteorological Administration Annual Scientific Conference
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • The following paper were presented: - „Evaluation and mapping of snow wetness using optical and radar satellite data”, authors: Irimescu, A., Stăncălie, G., Diamandi, A., Crăciunescu, V., Solberg, R., Rudjord, Ø., Due Trier, Ø. - „Impacts of climate change on the snow cover in the Carpathian Mountains”, authors: Bojariu, R., Velea, L., Dascălu, I.S., Gothard, M., Bîrsan, M.V., Dumitrescu, A., Cica, R., Stăncălie, G.		
Target groups	- Representatives from: Ministry of Environment, Waters and Forests, National Administration “Romanian Waters”, General Inspectorate for Emergency Situations, National Institute of Hydrology and Water Management, Romanian Space Agency etc.; - Education and research institutions: Academy of Agricultural and Forestry Sciences, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Research Institute for Pedology and Agrochemistry, University of Bucharest- Faculty of Physics, Institute of Geography of the Romanian Academy; - Commercial company: Terrasigna; - Mass-media.		
Date and venue	1-2 November 2016, Bucharest		
Organizer	PP		
Partners involved	P3 - NIHWM		
Assessment of activities	The impact of climate change on the snow cover in the Carpathian Mountains has been noted, which refers to: increasing the number of days with positive air temperatures together with a slight decrease in rainfall during the winter, diminishing days with snow precipitation, a trend decreasing the number of days with snow cover and the average snow thickness.		
Number	10.	**Activity**	Workshop on Communication and Publicity
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • Project roll-up was presented; • A paper was presented: SnowBall Dissemination Strategy (considered to be one of the best strategy from RO14 Program framework).		
Target groups	- Contracting Authorities representatives from Romania, Norway and Island ; - Other running project representatives from SEE “Research in Priority Sectors” Program.		
Date and venue	25-26 May 2016, Sibiu		

Organizer	Contracting Authority		
Partners involved	PP – NMA, P1 – NR, P2 – UTCB, P3 – NIHWM, P4 - WUT		
Assessment of activities	The dissemination strategy of the project, which includes a series of activities suitable for effective promotion of the results of the SnowBall project, both during the project and its completion, as well as for facilitating the interaction with similar projects, implemented at national or international level, has been highly appreciated . Also, appropriate communication tools have been noted to link the project consortium to the end user community.		
Number	11.	**Activity**	International Conference Sub-urban 2017 Planning and management week
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter etc.); • Project roll-up was presented; • A paper was presented: „Snowmelt modelling in urban areas", authors: Dobre, R.G., Gogu, R., Găitănaru, D.S.		
Target groups	- Education and research institutions**:** o International: Delft University of Technology, Ostrava University, EAWG Zurich, Polytechnic University of Catalonia, Basel University, Skopje University, Kocaeli University, University College London; o National: Bucharest University, Faculty of Geology, University of Architecture and Urbanism "Ion Mincu", Ecological University, Polytechnic University of Bucharest; - 27 geological institutes from Europe: Norway, Denmark , Great Britain, Finland, Sweden, Slovenia, France, Ireland, Spain, Austria etc.; - Professional associations: International Association of Hydrogeologists, Professional Association of Urbanists from Romania, State Inspectorate of Construction, Romanian Water Association, Associated Research Centres for the Urban Underground Space, International Tunnelling and Underground Space Association; - Commercial companies and water operators: Apa Nova Bucharest, Asset Portfolio Servicing Romania, Aquaproiect, Someş Water Company, Cefain Construct, Connecta Eco Prest, Deltares Netherlands, Infrawater S.R.L. Keller Geotehnica, I GIS Denmark, Apa Prod S.A. Deva, Apavital SA, Steinzeug-Keramo NV Belgium, TNO Netherlands, Terratest Geotehnic SA, Tauw Group Netherlands, TehnoWorld; - Authorities and public institutions: National Administration "Romanian Waters", Ministry of Environment, Municipality of Rotterdam, Municipality of Oslo, Municipality of Odense, Municipality of Tampere.		
Date and venue	13-16 March 2017, Bucharest		
Organizer	P2 - UTCB		
Partners involved	P3 - NIHWM		
Assessment of activities	It was highlighted the first development in Romania of the methodology for determining the infiltration of snow melting and the quantification of aquifers replenishment. The significant original contribution lies in the process of adapting numerical models for the saturated and unsaturated areas so that in-situ and satellite information can be used.		
Number	12.	**Activity**	2016 SnowBall Project Annual Meeting
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter, book etc.); • Meeting and discussions with end-users from hydro-energy domain.		
Target groups	- Representatives from governmental organization from Norway;		

	- Commercial companies: Statkraft Company and Glomma and Laagen Water Management Association (GLB);		
Date and venue	7-10 November, Beitostølen, Oslo		
Organizer	P1 - NR		
Partners involved	PP- NMA		
Assessment of activities	New opportunities for cooperation within the EEA Program to be launched in 2017 with representatives of some Norwegian institutions (Statkraft and Glomma and Laagen Water Management Association) interested in developing applications for the use of information on characteristics Snow cover for managing the water volumes in storage lakes.		
Number	13.	**Activity**	SnowBall Project Final Workshop
Description (topic, aim, communication tools)	• Material has been disseminated for project visibility (brochure, leaflet, newsletter, project book etc.); • Project roll-up was presented; • The following paper were presented: - „Measuring snow from space starts at the ground: from new station designs to collecting snow truth data", authors: Diamandi, A., Dumitrache, C., Rădulescu, C., Nicola, O., Luca, E., Chiriţescu, R., Milian, N., Paşol, A., Grecu, C., Irimescu, A., Mihăilescu, D.; - „Satellite remote sensing of snow wetness in Romania and Norway", authors: Solberg, R., Rudjord, Ø., Salberg, A.-B., Due Trier, Ø., Stăncălie, G., Irimescu, A., Diamandi, A., Crăciunescu, V.; - „Climate change impact on snow-related processes", authors: Bojariu, R., Corbuş, C., Mic, R., Mătreaţă, M., Crăciunescu, V., Milian, N., Dumitrescu, A., Bîrsan, M.-V., Dascălu, S.-I., Gothard, M., Velea, L., Cica, R., Grecu, C., Paşol, A.; - „Quantitative assessment of aquifer recharge from snowmelt", authors: Găitănaru, D., Holban, R., Gogu, R.; - „Avalanche detection in very high resolution optical satellite images", authors: Salberg, A.-B., Ardelean, F., Török-Oance, M.; - „Improved snow water equivalent estimation methodology, for better hydrological warnings and forecasting", authors: Mătreaţă, M., Mătreaţă, S., Agiu, B.; - „Change-detection based mapping of avalanches in Sentinel-1 images", authors: Salberg, A.-B., Reksten, J., Ardelean, F.; - „Snow avalanche inventory and hazard assessment in Fagaras Mountains", authors: Török-Oance, M., Ardelean, F., Voiculescu, M., Milian, N., Salberg, A.-B.; - „River ice monitoring using remote sensing data. Case studies: Romania, winter season 2016-2017", authors: Mihăilescu, D., Crăciunescu, V., Stăncălie, G., Constantinescu, Ş., Irimescu, A., Angearu, C.		
Target groups	- Representatives from: Ministry of Research, Ministry of Environment, Ministry of Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations, Romanian Space Agency, Water Management Service etc.; - Education and research institutions: University of Bucharest - Faculty of Geography, Technical University Cluj Napoca, University of Agronomic Sciences and Veterinary Medicine in Bucharest, Institute of Geography of the Romanian Academy; - Commercial companies: Terrasigna; - Non-profit organizations; - Mass-media.		
Date and venue	27 April 2017, Bucharest		
Organizer	PP - NMA		
Partners	P1 - NR, P2 - UTCB, P3 - NIHWM, P4 - WUT		

involved	
Assessment of activities	The end-users representatives highly appreciated the development of a new service capable to supply the national authorities but also the large public with significant information in quasi-real time, for the monitoring of the spatial and temporal evolution of the snow layer parameters and of the associated hazards (floods caused by sudden snowmelt and avalanches). It was highlighted the project applications developed/improved applications, in domains of great practical and scientific interest: hydrology and water management, meteorological and hydrological forecasts ad warnings, assessment and mitigation of natural risks (floods from snowmelt, avalanches). Information supplied by the project is a potential source of data useful in planning hydro-energy production and its commercialization. It was mentioned that the project brings an important contribution in rising awareness about the impact of climate change on the snow resources and on the associated hazards (fast floods, avalanches) at local or regional level, in an economic, social and/or ecological perspective. Implementation of the project results contributes to settling long-term cooperation among the Norwegian and Romania partners, within a new service dedicated to the national authorities and the large public, supplying consistent information, in quasi-real time, for monitoring the spatio-temporal characteristics of the snow layer and of the associated hazards.

Publicity measures			
Number	1	**Measure**	Project web page: http://snowball.meteoromania.ro
Description (topic, aim, communication tools)	The project web page has a permanent URL, the content being permanently filled as the results are obtained. The portal offers communication and dissemination within the consortium and contains information on both project activities (details of partners, objectives, study areas, results, scientific papers), as well as links to relevant elements relevant to the project (links to other projects, services, collaborations, etc.). The site allows the downloading of the materials (articles, brochures, etc.), as well as an annual periodical publication, including the latest news and achievements.		
Target groups	- Representatives from different organizations - Education and research institutions; - Commercial Companies - Non-profit organizations; - Media.		
Date and venue	The site is hosted by the National Meteorological Administration since November 2014		
Organizer	National Meteorological Administration		
Partners involved	All project partners		
Assessment of activities	The website has contributed to increase visibility of the project and information in Romania and European Union, as well as to promote the use of technologies and the results obtained within the target groups.		
Number	2	**Measure**	Making advertising materials: roll-up, brochures, flyers, newsletter, blog article
Description (topic, aim, communication tools)	Promotional products for the visibility of the project were produced according to the communication manual provided by the Contracting Authority: project banner, leaflets in Romanian and English, brochure of the project in Romanian and English, the newsletter of the project in Romanian and English, blog post, posters, etc.		
Target groups	- Representatives from different governmental organizations - Education and research institutions; - Commercial Companies		

	- Non-profit organizations; - Media.		
Date and venue	The materials were disseminated during the various national scientific events, the annual meetings, organized through the joint research project, throughout the project implementation period.		
Organizer	PP - National Meteorological Administration		
Partners involved	All project partners		
Assessment of activities	Advertising materials have contributed to the dissemination of scientific and technical results within the scientific community interested in the topic of the project, ensuring the visibility of the project and the information in Romania and in the countries of the European Union.		
Number	3	**Measure**	Publishing the book "Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective", coordinator Gheorghe Stancalie, editor Anisoara Irimescu, ISBN 978-606-23-0733-2, PRINTECH, 163 pages.
Description (topic, aim, communication tools)	The book presents the main results achieved during the SnowBall project. The paper highlights the innovative approaches developed within the SnowBall project: data fusion of satellite products, in-situ observations and modelling outputs, snow contribution to aquifers replenishment, risk assessment snow avalanches, of rapid snowmelt floods in a climate change perspective.		
Target groups	- Governmental organizations: Ministry of Environment, Ministry of Waters and Forests, National Administration "Romanian Waters", General Inspectorate for Emergency Situations, Romanian Space Agency; - Education and research institutions: Academy of Agricultural and Forestry Sciences, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Research Institute for Pedology and Agrochemistry, University of Bucharest- Faculty of Physics, Institute of Geography of the Romanian Academy,. - Commercial Companies: Hidroelectrica, Terrasigna.		
Date and venue	Bucharest, aprilie 2017		
Organizer	PP - National Meteorological Administration		
Partners involved	All project partners		
Assessment of activities	The book highlihts the socio-economic impact of snow is significant, ranging from water management and hydropower, to agriculture, transport, tourism, urbanism and emergency situations management. The monitoring of ice and snow is vital for the management of natural resources, extreme events prediction such as snowmelt induced floods, snow avalanches and for analysing the impact of global warming.		
Number	4	**Measure**	Presentation of 41 communications at conferences, workshops, national and international seminars.
Description (topic, aim, communication tools)	There were presented 41 scientific papers at conferences, workshops, national and international seminars.		
Target groups	- Representatives from different governmental organizations - Education and research institutions; - Commercial Companies - Non-profit organizations; - Media.		
Date and venue	During the implementation of the project (2014-2017)		
Organizer	All project partners		

Partners involved	All project partners
Assessment of activities	The presented communications have contributed to raising the visibility of project results, as well as promoting the results obtained for different target groups in the fields of meteorology, climate, hydrology, water resources management, emergency situations and tourism.

E. Distribution of the financial contribution between the Project Promoter and project partners

Financial information at project completion

Project grant[9]	5.270.923 (lei)	1.199.000(Euro)
Project level co-financing[10]	0,00 (lei)	0,00 (Euro)
Final project cost[11]	5,219,033.72 (lei)	1,174,423.95(Euro)
Project grant rate[12]	(100,99) %	

No.	Amount in lei of project grant	Amount in Euro of project grant	Project Promoter/partner name	Partnership agreement duration (no. of months)
1	1,491,537.22	335,319.35	National Meteorological Administration	34 months
2	1,952,129.12	440,046.06	Norwegian Computing Center	34 months
3	542,522.70	121,856.17	Technical University of Civil Engineering, Groundwater Engineering Research Center	34 months
4	470,908.56	105,552.69	National Institute for Hydrology and Water Management	34 months
5	761,936.12	171,649.68	West University Timisoara, Department of Geography	34 months

This section shows the actual disbursements (including co-financing) to the project at project completion. As regards the financial information concerning the project partner(s), show the amount allocated to each partner, starting with the largest amount and identifying the partner against whom the amount has been allocated.
In case there are more partners than fields for this information,

i) ensure this information is available for each project partner from a donor state, and

[9] It includes the EEA grant (85%) and public co-financing at Programme level (15%).
[10] Amount provided by beneficiaries of funds from their own resources and used for project implementation.
[11] Total amount includes project grant and project level co-financing.
[12] To be calculated by dividing project grant to final project cost.

ii) aggregate the financial amount for any additional partners that cannot be identified separately, indicating the number of partners concerned in the field “Project Promoter/partner name”.

Please remember that financial information on the project partner does not concern contractors.

In case the project has benefited from support through the fund for bilateral relations at Programme level, please show the amounts actually disbursed under these funds and describe what activities took place under each measure as seen below.

- Did you receive funds from the bilateral fund at Programme level Measure A[13]?

NO

- How much?

- What activity took place?

- Did it result in a partnership project?

- Did you receive funds from the bilateral fund at Programme level Measure B[14]?

NO

- How much?

- What activity took place?

Detailed information on incurred expenditure during the whole period of joint research project implementation by partners, type of costs and reporting periods shall be presented separately, by filling in the financial template attached (see the **Annex**).

[13] If you have been reimbursed for the preparatory costs of the joint research project further to a separate application request submitted to the Programme Operator. Measure A provided funding for seeking of partners for joint research projects prior to or during the preparation of a project application, development of such partnerships and preparation of an application for projects.

[14] If you have been granted support for a project funded under the bilateral relations call. Measure B provided funding for networking, exchange, sharing and transfer of knowledge, technology, experience and best practice between entities from Romania and Donor States.

Annex 1. The abstracts of scientific publications resulted from this joint research project.

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

Coorinator: Stăncălie G.
Authors (per partner): Stăncălie, G.[1], Diamandi, A.[1], Bojariu, R.[1], Irimescu, A.[1], Dumitrescu, A.[1], Bîrsan, M.V.[1], Crăciunescu, V.[1], Nerţan, A.[1], Mihăilescu, D.[1], Catană, S.[1], Nicola, O.[1], Dumitrache, C.[1], Luca, E.[1], Dascălu, S.I.[1], Gothard, M.[1], Cica, R.[1], Milian, N.[2], Grecu, C.[2], Paşol, A.[2], Velea, L.[3], Solberg, R.[4], Salberg, A.B.[4], Due Trier, Ø.[4], Rudjord, Ø.[4], Găitănaru, D.S.[5], Dobre, R.G.[5], Gogu, R.[5], Mătreaţă, M.[6], Corbuş, C.[6], Mic, R.[6], Mătreaţă, S.[6], Agiu, B.[6], Voiculescu, M.[7], Török-Oance, M.[7], Ardelean, F.[7]
[1] National Meteorological Administration, Bucharest, Romania
[2] National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania
[3] National Meteorological Administration/Oltenia Regional Meteorological Center, Craiova, Romania
[4] Norwegian Computing Center, Oslo, Norway
[5] Technical University of Civil Engineering of Bucharest, Romania
[6] National Institute of Hydrology and Water Management, Bucharest, Romania
[7] West University of Timisoara, Timisoara, Romania

CONCLUSIONS: The topic of the book is related to a problem of national interest: accurate and timely knowledge of the seasonal snow distribution and characteristics. The socio-economic impact of snow is significant, ranging from water management and hydropower, to agriculture, transport, tourism, urbanism and emergency situations management. The monitoring of the snow is extremely important for the management of natural resource, extreme event prediction such as snowmelt floods, avalanches and the impact of global warming.
The presented results have been achieved during the implementation of the SnowBall project, in the framework of the "Research within Priority Sectors" Program funded by the Financial Mechanism of the European Economic Area (SEE) 2009-2014.
The project aims to improve the monitoring and impact assessment of snow in Romania under present climate and future scenarios.
The papers successfull highlight the main outcomes of the project namely: a reliable ground truth data to improve the snow parameters assessment and monitoring as well as for the validation of EO derived snow products using low-cost modular automated stations; a novel model based on multi-sensor/multi-temporal wet snow (MWS) algorithm fusing optical and SAR data (Sentinel 1-3); new methodology to estimate the aquifer recharge from snowmelt, based on the numerical flow model for the unsaturated zone; data fusion methodology for estimating the SWE, as a gridded product of 1 km spatial resolution, using distributed snow model simulations, ground observations and satellite products; pattern recognition techniques to detect and map the outline of avalanches in very high resolution optical satellite data; detailed assessment of snow and other related atmospheric and hydrologic variable over the regions of interest, under present (1981-2010) and future climate scenarios (2022-2050 and 2070-2099) and the associated impact, based on regional climatic EURO-CORDEX models using representative Concentration Pathways Scenarios (RCP 2.6 and RCP-8.5).

2. Topographical factors, meteorological variables and human factors in the control of main snow avalanche events in the Făgăraș massif-Southern Carpathians (Romanian Carpathians): case studies

Voiculescu, M.[1], Ardelean, F.[1], Török-Oance, M.[1], Milian. N.[2]

[1] West University of Timisoara, Timisoara, Romania
[2] National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: Snow avalanches are common geomorphic processes and natural hazard in Southern Carpathians (Romanian Carpathians). Spatial distribution of snow avalanches is controlled by topographical factors, meteorological variables and human factors.
This study examines the occurrence of snow avalanches in the Făgăraș Massif in two glacial areas, Bâlea (on the northern slope) and Capra (on the southern slope). In the Făgăraș Massif 27 serious snow avalanche accidents with 76 fatalities and 50 burials/injuries were recorded, during the period from 1963 to 2015 for the months

November through to June. Among these snow avalanche, we used five major avalanche accidents: the snow avalanche of June, 1974 which caused 6 fatalities and 8 burials/injuries; the snow avalanche of April 17, 1977 which caused 23 fatalities; the snow avalanche of December 23, 1988 which caused 3 fatalities; the snow avalanche of December 28, 2002 which caused 4 fatalities and the snow avalanche of February 20, 2010 which caused one fatality and 2 burials/injuries.
Our results indicate a good correlation between some topographical factors. On the other hand, the increase of snowfalls and of snowstorm especially are responsible factors for one avalanche event; the early snowfalls and sudden increase of temperature are responsible factors for two avalanche events and snowfalls and sudden increase of temperature are responsible factors for one avalanche event. Using the weather scenarios we found high snowstorm frequency for one case, early-season weak layers of faceted crystals and depth hoar for two cases and well above-average total snowfall for one case.
Keywords: Topographical parameters, climate variables, human factors, snow avalanche accidents, Făgăraș massif, Romanian Carpathians

3. Automated detection and mapping of avalanches in SAR images

Hamar, J.B. [1], Salberg, A.-B. [1], Ardelean, F.[2]

[1] Norwegian Computing Center, Oslo, Norway
[2] West University of Timisoara, Timisoara, Romania

ABSTRACT: Detection and characterization of avalanches are important for making avalanche inventories as well as for the management of emergency situations. In this paper we propose a scheme for automatic detection and mapping of avalanches in SAR images. The approach builds upon the hypothesis that compacted rough snow of an avalanche has very high backscatter intensity values compared to homogeneous snow cover and bare ground, and hence, by comparing the event image with a reference image we may detect and map avalanches in the scene. The proposed approach consists of two steps: (i) an initial detection of potential avalanche objects and, (ii) supervised classification of avalanche candidates using a random forest classifier. The approach is evaluated on a set of Radarsat-2 ultra-fine images, and the out-of-bag error rate is 6.4%. We conclude that an operational automatic algorithm may be feasible provided enough training data is available.

4. Single and multi-sensor snow wetness mapping by Sentinel-1 and MODIS data

Solberg, R.[1], Salberg, A.-B.[1], Rudjord, Ø.[1], Due Trier, Ø.[1], Stăncălie, G.[2], Diamandi, A.[2], Irimescu, A.[2]
[1]Norwegian Computing Center, Oslo, Norway
[2]National Meteorological Administration, Bucharest, Romania

ABSTRACT: Snow monitoring is essential for prediction of flooding due to rapid snowmelt, to provide snow avalanche risk forecasts and for water resource management – including hydropower production, agriculture, groundwater and drinking water. Sentinel-1 C-band SAR is sensitive to presence of wet snow and can be used to binary snow wetness classification. Wet snow mapping into more categories has been demonstrated in the past by using MODIS data. The combination of surface temperature and the temporal development of the effective snow grain size are used to infer approximately how wet the snow is. Here we developed a sensor-fusion approach combining SAR and optical observations. The algorithm applies a Hidden Markov Model (HMM) to simulate the snow wetness states the snow surface goes through, given the temporal observations of the surface conditions. The most likely current snow state is estimated, giving the current snow liquid water category.

5. Snow avalanche activity in the Romanian Carpathians: first findings from Very High-Resolution Satellite and drone based Images analysis

Török-Oance, M.[1], Ardelean F.[1], Voiculescu, M.[1], Milian, N.[2]

[1] West University of Timisoara, Timisoara, Romania
[2] National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: Snow avalanches represent one of the most important natural hazards and cause loss of life and important infrastructure damages in snow - mountain areas worldwide. Although a total of 845 past snow avalanches have been recorded in different documents since 18th century till nowadays for the Romanian Carpathians, the information is sparse, derived from point-scale field observations and no consistent database

exists for the entire mountain area. Even the alpine belt of the Carpathians is not permanently inhabited, the increasing development of winter tourism and ski domains require the need for an avalanche inventory and reliable data on avalanche activity. The current study presents the first avalanche inventory based on very high resolution (VHR) satellite and drone images in the Făgăraș Mountains, Southern Carpathians. We used a GeoEye-1 scene from late winter season of 2012 (April 11th) which covers 157 km^2 from the main ridge of the Făgăraș Mountains and a drone based image from 12 April 2016 which covers 40.8 km^2 and overlaps the GeoEye-1 scene in the Transfăgărășan highway sector. The meteorological data were used to quantify the time lag between avalanches triggering and acquisition of the satellite data, because both spectral signature and texture of the avalanche debris are related with this factor. The mapping of snow avalanches was made by manual detection and we used image enhancing and transformation for a better avalanches visualisation, mainly in the shaded and over-exposed areas. We used for the first time the grain size, expressed by a normalized differentiating index (NDI) derived from red and NIR bands for the snow avalanches detection. The best avalanche visualizing was obtained by using RGB false-colour composite with panchromatic shown in red, NDI in green and principal component 3 in blue. A total of 1069 avalanches were identified and delineated from the GeoEye-1 image and 429 avalanches were mapped from drone image. 37% of the avalanches identified on UAV image were identified also on GeoEye-1 image, which suggest a much higher avalanche activity than in previous statistics. For each feature, dimensional (length and width, shape index) and geomorphometric characteristics (altitude, slope, aspect, curvature) have been extracted. The analysis of the inventoried events showed that in the Carpathians snow avalanches occur mainly in alpine and subalpine belts, avalanche starting zones are found at altitudes of 1543 – 2511 m a.s.l. The avalanches and are almost in totally small and middle size events, with lengths under 1000 m, with some few exceptions. Thus, the detection of the avalanches in Carpathians is possible only on VHR images. The number and density of mapped avalanches is much higher than mentioned in previous studies and can be considered the most important winter hazards in the Romanian Carpathians.

6. Remote Sensing of snow wetness in Romania by Sentinel-1 and Terra Modis data

Solberg, R.[1], Salberg, A.B.[1], Due Trier, Ø.[1], Rudjord, Ø.[1], Stăncălie, G.[2], Diamandi, A.[2], Irimescu, A.[2], Crăciunescu, V.[2]

[1] Norwegian Computing Center, Oslo, Norway
[2] National Meteorological Administration, Bucharest, Romania

ABSTRACT: Snow monitoring is essential for prediction of flooding due to rapid snowmelt, to provide snow avalanche risk forecasts and for water resource management – including hydropower production, agriculture, groundwater and drinking water. Sentinel-1 C-band SAR is sensitive to presence of wet snow and can be used to binary snow-wetness classification. Wet-snow mapping into more categories has been demonstrated in the past by using MODIS data. The combination of surface temperature and the temporal development of the effective snow grain size are used to infer approximately how wet the snow is.

7. A multi-sensor multi-temporal approach to retrieving snow surface wetness from a combination of Sentinel-1 and Sentinel-3 data

Solberg, R.[1], Rudjord, Ø.[1], Salberg, A.-B.[1], Due Trier, Ø.[1], Stăncălie, G.[2], Diamandi, A.[2], Irimescu, A.[2];

[1] Norwegian Computing Center, Oslo, Norway
[2] National Meteorological Administration, Bucharest, Romania

ABSTRACT: Snow surface wetness is an essential variable for monitoring the snow state and providing early warning of flood risk and snow avalanches. This presentation shows results from the EEA Grants SnowBall project on a sensor fusion algorithm combining Sentinel-1 SAR and Sentinel-3 optical data.
The basis of the work has been the existing and improved algorithms for single sensor retrieval of wet snow from SAR and optical data. Since optical sensors are limited by cloud cover and the application of C-band SAR sensors is limited to the detection of wet snow, a combination of these sensors should give synergy. In our multi-sensor/multi-temporal retrieval approach we simulate a set of snow wetness states each 'pixel' (IFOV) might go through during the winter and melting season. The model includes five wetness classes. We have chosen to use a hidden Markov model (HMM) for modelling the states and state transitions. The model is described by the probabilities of the initial states, the probabilities of the observable signals of each state and the transition probabilities between each pair of states. The states are not directly observable, but the remote sensing

observations describe the snow conditions, which are related to the snow states. As the initial probabilities for each state and the transition probabilities clearly are dependent on the season, we have defined time-dependent probabilities. We use the Viterbi algorithm to find the most likely sequence of snow states, given a time series of snow products.

As Sentinel-3 data have only now become available, we have so far developed and tested our algorithm with Terra MODIS data combined with Sentinel-1 data. Sentinel-3 SLSTR will be studied in the winter and melting season 2017. The algorithm was tested in 2015 and 2016 for the Scandinavian Mountains (Norway) and the southern Carpathian Mountains (Romania). The retrieved snow wetness classes have been compared with the diurnal development of air temperature for a selection of meteorological stations and with in situ measurements of liquid water in the snow surface. The overall structure of the maps is similar to the optical maps with the degree of wetness following the topography quite much. The classes follow the topography logically (canonically) with wetter snow at lower altitudes and reduced wetness with increasing altitude. The temporal transitions are similar in the way that increasing temperatures give increasing wetness. Ongoing work includes calibration to international standards and training of the HMM.

8. Remote sensing of snow wetness using Sentinel – a multi-sensor approach

Rudjord, Ø.[1], Solberg, R.[1], Due Trier, Ø.[1], Salberg, A.-B.[1], Stăncălie, G.[2], Diamandi, A.[2], Irimescu, A. [2], Crăciunescu, V.[2]

[1] Norwegian Computing Center, Oslo, Norway
[2] National Meteorological Administration, Bucharest, Romania

ABSTRACT: Snow monitoring is crucial for predicting floods caused by rapid snowmelt. It is also important to predict risks for snow avalanches, and it is important for water resource management, including hydropower, drinking water and agriculture. While monitoring the snow cover is important, measuring other aspects of the state of the snow provides more information. The liquid water content of the snow, here referred to as snow wetness, is such a variable. Monitoring the snow wetness through the melting season may give early indications of snowmelt or increased avalanche risk.

Satellite sensors provide the optimal way to monitor the snow condition. The Sentinel-1 and Sentinel-3 satellites provide frequent coverage in the northern regions. The Sentinel-1 C-band SAR can be used to detect wet snow, as the backscatter drops significantly. With C-band SAR however, it is difficult to determine how wet the snow is. It can also be difficult to distinguish bare ground from dry snow cover. Optical sensors such as Sentinel-3 SLSTR on the other hand, through monitoring of the temperature and snow grain size, can be used to estimate the degree of wetness. However, optical data are limited by cloud cover. Within the SnowBall project we have developed an approach for merging these two products in a multi-temporal multi-sensor snow wetness product.

The method makes use of a hidden Markov model (HMM) to describe the different states the snow goes through during the melting season, and the possible transitions between these states. The states include dry snow, “moist snow”, “wet snow”, “very wet snow”, “no snow or partial snow cover” and “temporary snow cover”. The transition probabilities of the HMM vary throughout the season, and are trained using 16 years of modelled snow wetness data from Norway. This model is combined with the available optical and SAR snow wetness products and used to estimate the state of the snow for every 1 km grid cell. The Viterbi algorithm is used to produce the most likely sequence of snow states, given the observations.

The result of the method is daily multi-sensor snow wetness products, providing the best estimate for each grid cell for every day. The algorithm will be presented along with test products from southern Norway and Romania.

Annex 2. The abstracts for all scientific publications resulted from this joint research project.

1. Monitoring of snow properties with Sentinel-3

Rune Solberg, Øivind Due Trier and Øystein Rudjord.

Norwegian Computing Center, Oslo, Norway

ABSTRACT: Seasonal snow is an important component of the Earth system heavily affecting the energy balance and the water cycle at high latitudes and elevations. Vast land areas in the north and in mountainous regions are weakly monitored by in situ sensors due to the fact that most of these regions are sparsely populated. Earth observation is the only practical means of frequent and accurate monitoring of snow properties in these regions.

This presentation gives an overview of Sentinel-3's potential for retrieval of snow properties together with examples of retrieval methods and results where we successfully demonstrate the capability of Envisat MERIS and AATSR plus other optical sensors of moderate spatial resolution.

The Sentinel-3 sensors Ocean and Land Colour Instrument (OLCI) and Sea and Land Surface Temperature Radiometer (SLSTR) together represent a powerful set of instruments for monitoring of properties of the seasonal snow cover. The revisit time is 0.5-1.0 day over most regions with seasonal snow cover (with two satellites). The excellent improvement compared to Envisat with almost full spatial overlap between OLCI and SLSTR allows for the use of both sensors for snow mapping, relying on cloud screening with SLSTR.

The thermal bands of SLSTR are very suitable for snow surface temperature monitoring. As weather stations are typically sparse in the relevant regions, snow surface skin temperature monitoring is a valuable supplement to meteorological measurements of the 2 m air temperature.

For full snow cover, which should be possible to screen with high precision using OLCI, the exact emissivity is known for the ground surface and accuracy temperature surface temperature measurements should be possible (< 0.5 K).

The snow reflectance spectrum at visible and near-infrared wavelengths is dominated by the optical effects of snow grain size and impurities. The bands O20, O21 and S4 are suitable to quantify the effects of the grain size, while most visual bands of both sensors are suitable for impurity quantification. Additionally, OLCI is suitable for impurity characterisation. This enables accurate estimation of the snow spectrum, which again is important for deriving the spectral albedo, an important quantity in, e.g., energy balance modelling.

The fractional snow cover is another and fundamental variable in snow hydrology that will benefit from accurate estimation of the snow spectrum and OLCI's dense coverage of visual and near-infrared wavelengths with 21 bands. With the ability to do snow retrieval with OLCI and cloud screening with SLSTR, 300 m spatial resolution will be obtained compared to 1 km from AATSR (as MERIS could in practice not be used together with AATSR due to the small overlap). This is a significant achievement as the increased resolution would enable far more accurate snow mapping in complex terrain.

Retrieval of the snow spectrum and the temporal development of the snow grain size, together with thermal measurements, are important for estimation of the snow wetness and surface hoar formation. Wet snow and the degree of wetness are together with meteorological measurements and hydrological modelling suitable for snow runoff prediction, and in particular flood warning. Surface hoar may lead to formation of a weak layer in the snowpack, which in steep mountain areas may result in avalanche risk. Detection of surface hoar as well as formation of snow crust due to events of warm and wet weather, is information likely suitable as input to avalanche risk models in the future.

2. Synoptic Conditions for Avalanche Cases in Romania

Milian, N.

National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: The paper presents the avalanche triggering synoptic conditions in our country that caused victims or extensive damage to the forest. One of the first mentions about avalanches in the Romanian Carpathians is from April 1702 (or 1704), in the Ceahlău Massif, that destroyed the Hermit's Monastery, killing all the monks which were in the monastery on Resurrection Night, except one. Other avalanche mentions are from the interwar period, in mountain clubs publications (Romanian Alpine Club, Touring Club, SKV). With the

development of mountain tourism in Romania and construction of the first shelters and chalets, more avalanche accidents happened, in wich tourists and climbers from all mountain ranges were involved; the most common happened in the alpine area of Făgăraş and Bucegi Mountains.
First studies on avalanches have been made during 1963-1964, when a large number of avalanches happend in all our mountains, blocking roads and railways: 150 in Maramureş Mountains, about 30 in Rodnei Mountains and 20 in Bihor Mountains. The avalanche with the highest number of casualties was on 17 April 1977 at Bâlea-Lac, when 23 people from Bruckental German High School in Sibiu died, from wich 7 adults and 16 children. After this tragic event, the meteorological station at Bâlea-Lac was established, with complete measurements from 01.01.1979, but no snow and avalanche studies were made.
Although concerns about snow and avalanche studies and prevention began with the establishment of the first Carpathian mountain rescue units, the National Meteorological Administration program called "Nivologie" (the study of snow and providing risk of avalanches) started only in February 2004.

3. Synoptic avalanche triggering conditions during 2014-2015 winter

Milian, N., Paşol, A.

National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: The paper presents and analyses the synoptic and nivo-meteorological conditions that led to avalanche triggering during 2014-2015 winter, especially for the monitored area of Bucegi and Făgăraş Mountains. The study is part of a Snowball project, which aims to inventory the cases of avalanches previously known in our country and favourable triggering conditions, for better estimate the risk of avalanche and lower what effects they might have on the environment and people.
At Bâlea-Lac, Sinaia and Vârful Omu, the first snow layer was reported since November 17, 2014, and in Predeal on November 20, 2014. The snow layer lasted until the beginning of June 2015 in the high areas and was continuously at all meteorological stations between 21 November 2014 and 27 March 2015.
Avalanche triggering conditions were due both to significant snowfall, high thermal values or the sudden temperatures increase, as well as to the transformations that take place inside the snow layer, resulting in unstable structures.
During this winter, there were 60 records of avalanches and snow flows observed in the field over 43 days, in both monitored area and other mountain massifs in the country.
Most avalanches occurred in March (36), February (35), April (16), December (15), January (11) and May (7), both spontaneously and accidentally, triggered by tourists or skiers. There was no deceased victim.

4. Spatial interpolation of daily snow depth over Romania

Dumitrescu, A., Bîrsan, M.-V.

National Meteorological Administration, Bucharest, Romania

ABSTRACT: Snow cover has major effects on surface albedo and energy balance, and represents a major storage of water. The snowpack strongly influences the overlying air, the underlying ground and the atmosphere downstream. Snow cover duration influences the growing season of the vegetation at high altitudes. This study presents the spatial interpolation procedure from snow depth measurements at weather stations implying the following stages: (1) Spatial interpolation at 1 km by 1 km resolution of the mean multiannual values (2005-2015) corresponding to each month, computed from the data extracted from the climatological database; (2) Computation of the daily deviations against the multiannual monthly mean for every day and year over 2005-2015 and their spatial interpolation; (3) Spatio-temporal datasets were obtained through merging the two surfaces obtained in stages 1 and 2. The anomalies were considered to be the ratio between the daily snow depth values and the climatology. The spatial variability of the data used in the first stage was accounted for through the use of a series of predictors derived from the digital elevation model DEM and CORINE Land Cover product. To plot the maps with the climatological normals (multiannual means), the Regression-Kriging (RK) spatial interpolation method was used. In order to choose the optimum method applied in spatializing deviations, four interpolation methods were tested using a cross validation procedure: Multiquadratic, Ordinary Kriging (separated and pooled variograms) and 3d Kriging.

5. Snow-related impact in the Carpathians under climate change conditions

Bojariu, R.[1], Dascălu, I.S.[1], Gothard, M.[1], Velea, L.[2], Cica, R.[1], Dumitrescu, A. [1], Bîrsan, M.V.[1], Stăncălie, G.[1];

[1] National Meteorological Administration, Bucharest, Romania
[2] National Meteorological Administration/Oltenia Regional Meteorological Center, Craiova, Romania

ABSTRACT: Winter sports are an important source of income in many mountain regions. Reduced snow cover affects winter tourism which leads to local socio-economic problems. On the other hand, the ski industry tends to adapt to reduced snow cover either by snowmaking facilities or by shifting to higher altitudes in mountains so as to reach snow-reliable areas, which creates further pressure on the alpine environment and water resources. Our study aims at assessing snow-related impact of climate change in the Carpathians. In this context, we started from the results of five regional climate models which are available thanks to the EURO-CORDEX initiative (Jacob et al., 2014). We have used the 1972-2001 period as the reference interval for the present climate and analysed projections for the 2021-2050 and 2071-2100 intervals. The analysis has been performed under the greenhouse gases (GHG) concentrations scenarios RCP 4.5 and RCP 8.5. Both scenarios indicate a decrease of the average snow depth over October to April season, the largest reduction taking place towards the end of the 21st century, under the highest concentrations scenario. Topography influences as well the local response to climate change signal. Under the RCP 8.5 scenario, considering high global GHG concentrations, regional model results suggest reductions in the snow depth up to 90% for certain regions (e.g. areas from the Western Carpathians in Slovakia and the Eastern Carpathians in Ukraine and Romania) towards the end of this century. Furthermore, strong increases in minimum temperatures will limit the effectiveness of snowmaking as an adaptation strategy for ski resorts, contributing also to water resources reduction. A ski resort is snow-reliable and profitable for winter tourism if in 7 out of 10 winters snow depths reach at least 30 to 50 cm, for a minimum of 100 days, from 1st of December to 15th of April (Abegg, 2007). Based on this estimation we have further assessed the impact of climate change on the potential snow reliability for ski resorts in the Carpathians, under moderate and high concentrations scenarios. In general, one has to take into account the assessment based on climate projections and the intrinsic level of uncertainty which remains in quantifying both future climate change and associated economic impact when making decisions for sustainable adaptation to climate change (Bojariu et al., 2015). This approach also applies when selecting adaptation measures to cope with snow reduction. The research leading to these results has received funding from EEA Financial Mechanism 2009 - 2014 under the project contract no 19SEE/2014.

6. Synoptic conditions generating important snowfalls and their relation with avalanches in 2015-2016 winter

Grecu, C.L., Paşol, A., Milian, N.

National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: The paper presents and analyses the variations of the meteorological and nivological (snow specifics) parameters that influenced avalanche triggering of the 2015-2016 winter season in the Bucegi and Făgăraş Mountains, the area monitored by the National Meteorological Administration.
The analyzed parameters are measured in the daily and weekly measurements at Bâlea-Lac, Vârful Omu, Sinaia and Predeal, as well as during the Snowball Project measurement campaigns, where the avalanche cases known by now in our country and the favourable avalanche triggering conditions, in order to use them to better estimate avalanche risk and to reduce their environmental and human impacts.
Although the first snowfall was on October 13, 2015, a continuous snow layer was formed only after November 24 and lasted until June, 04 and 20, 2016, respectively, in the high areas of Bucegi and Făgăraş (at Bâlea-Lac and Vârful Omu).
Avalanche triggering conditions are determined by important snowfall, high temperatures and rapid temperature increase, but also by transformations inside the snow layer and internal instability.
During 2015-2016 winter, there were 41 avalanche reports, during 39 days, in both monitored area and also in other mountain massifs of Romania.

7. Winter extreme phenomena – Romanian Carpathians avalanches

Paşol, A., Grecu, C.L., Milian, N., Reckherth, U.

National Meteorological Administration/Transilvania-South Regional Meteorological Center, Sibiu, Romania

ABSTRACT: Avalanches are complex risk phenomena, resulting in loss of human lives and material damages. They are included in the category of geomorphological hazards (because they are determined by sliding or collapsing of the masses of non-cohesive along the slope: snow, ice, sometimes soil, vegetation, etc.), climatic hazards (due to the fact that one of the determining factors is the existence of a sufficiently thick snow layer, which can only exist in certain climatic conditions), or hydrological risk phenomena (because the moving factor consists of water, but in a predominant solid form: snow, ice).
The paper presents a statistic of avalanche cases in the Romanian Carpathians, recorded with the beginning of the National Meteorological Administration nivological program
in February 2004, as well as those recorded over time by the Mountain Rescue Teams, in various articles or paper works, as well as similar conditions that have favoured the increase of avalanche risk and their triggering. The study is part of the Snowball Project.

8. Snowmelt Infiltration Using Hydrus-1d Based On A Snow Surface Energy Balance Model For Bucegi Mountains, Romania

Dobre, R.G., Gogu, R., Găitănaru, D.S.

Technical University of Civil Engineering of Bucharest, Romania

ABSTRACT: An accurate simulation of snowmelt infiltration rates for an area of Bucegi Mountains, during spring thaw, has been made using the snow routine of HYDRUS- 1D. The model is based on coupled flow and heat transport in the vadose zone. The snowmelt routine is based on degree day concept. As boundary conditions are used, surface water and heat fluxes can be calculated from the energy balance equation. The variables of the surface energy balance equation and melt rates can be calculated using meteorological data: air temperature, precipitation, relative humidity, wind speed and cloud cover. For the inverse estimation of soil hydraulic properties given by van Genuchten-Mualem (vG-M) model, we used direct measurements of the soil water content. HYDRUS-1D code is based on the Levenberg-Marquardt (LM), a nonlinear minimization local algorithm with good results for homogenous soil. Multiple soil layers usually require the use of global optimization methods. We compare parameter estimation using LM local minimization algorithm and another promising method: ant colony optimization (ACO). ACO is based on the behavior of a colony of ants in order to find the shortest route between their nest and a food source. The climate change that impacts snowmelt infiltration rates in Bucegi Mountains were evaluated for Representative Concentration Pathway (RCP) 2.6 and 8.5 scenarios. The climate change scenario is considering that temperatures are rising, so the amount of snow and ice has diminished. This allows a deeper seepage of the water into the ground as well as the ground temperature increase.
Keywords: snowmelt; HYDRUS-1D, energy balance, soil parameter estimation, climate change

9. Snowmelt modeling in urban areas

Dobre, R.G, Gogu, R., Găitănaru, D.S.

Technical University of Civil Engineering of Bucharest, Romania

ABSTRACT: As there are only few studies about the characteristics of urban snow and melt rates in cities, urban winter hydrology is generally poorly understood, despite the large number of cities which have annual seasonal snow cover. In urban areas the snow has a heterogeneous distribution and the melting rate depends also on the degree of urbanization. Flood forecasting for urban catchments can be performed only by accurate modelling of urban winter runoff.
Urban snow characteristics are different from those in rural area. Urban snow cover was classified into several types: snow piles, snow on road shoulders, snow on sidewalk edges, and snow in open areas. In the northern hemisphere severe urban flooding during spring melt are observed, although the major flood-generating events in urban areas are intensity rainfalls. A frozen soil layer generally increases the amount of snowmelt runoff by decreasing soil permeability and thereby impeding infiltration, reduced soil moisture recharge and deep percolation. Infiltration rate can be affected by: rates of snowmelt, soil thaw, ice content, soil structure. Floods

can result from adverse combinations of precipitation and basin conditions such as antecedent wetness, water stored in the snow cover, and frozen ground during the winter. The objective of the present study is to compare and assess the suitability of widely-used snowmelt models for urban areas. Basic approaches used to model snowmelt are physically based methods (Energy balance models-EBM) requiring detailed description of the mass or energy balance and empirical (Temperature index models- TIM) approaches in which air temperature is used to index all of the energy fluxes. The advantage of EBM is that accuracy is well-established; however the method is more complex to be implemented and usually needs more input data sets than TIM.

10. A Romanian daily high-resolution gridded dataset of snow depth (2005-2015)

Dumitrescu, A., Birsan, M.V.

National Meteorological Administration, Bucharest, Romania

ABSTRACT: This study presents the spatial interpolation procedure from snow depth measurements at weather stations implying the following stages: (1) Spatial interpolation at 1 km by 1 km resolution of the mean multiannual values (2005–2015) corresponding to each month, computed from the data extracted from the climatological database; (2) Computation of the daily deviations against the multiannual monthly mean for every day and year over 2005–2015 and their spatial interpolation; (3) Spatio-temporal datasets were obtained through merging the two surfaces obtained in stages 1 and 2. The anomalies were considered to be the ratio between the daily snow depth values and the climatology. The spatial variability of the data used in the first stage was accounted for through the use of a series of predictors derived from the digital elevation model DEM and CORINE Land Cover product. To plot the maps with the climatological normals (multiannual means), the Regression-Kriging (RK) spatial interpolation method was used. In order to choose the optimum method applied in spatializing deviations, four interpolation methods were tested using a cross-validation procedure: Multiquadratic, Ordinary Kriging (separated and pooled variograms) and 3d Kriging.

11. Geostatistical downscaling of temperature and precipitation under present and future climate scenarios

Dumitrescu, A.[1], Bojariu, R.[1], Dascălu, S.I.[1], Gothard M.[1], Bîrsan, M.V.[1], Cica, R.[1], Velea, L.[2], Stăncălie, G.[1], Irimescu, A.[1]

[1] National Meteorological Administration, Bucharest, Romania
[2] National Meteorological Administration/Oltenia Regional Meteorological Center, Craiova, Romania

ABSTRACT: Impact studies such as hydrological and crop modelling need data at very high spatial and temporal resolutions in order to describe the specific processes taken place on local scales. Numerical experiments with global and regional climate models usually provide data at lower resolutions one would need for impact assessments of climate variability and change. Our aim here is to test a geostatistical technique to disaggregate climate model data at sub-daily time scales from the spatial resolution of 0.125° to the resolution of 0.01° (approx. 1000x1000m) applied to the area of interest from 24.3125° E to 27.1875° E and from 44.5625° N to 45.8125° N.