Consiglio Nazionale delle Ricerche

Project of Interest
“NextData”

Research project :

NextSnow

Coordination: Dr. Vincenzo LEVIZZANI

ISAC-CNR

Work Pachage :
WP2.1 e WP2.6

TITLE OF THE PROPOSED PROJECT:
NextSnow

Project duration: 2013-2015.
Start date: 1 June 2013.
End date: 30 September 2015.

Scientific coordinator of the proposed project:
Dr. LEVIZZANI Vincenzo

CNR Institute coordinating the proposed project:
Istituto di Scienze dell'Atmosfera e del Clima (CNR-ISAC)
Institute of Atmospheric Sciences and Climate (CNR-ISAC), via Gobetti 101, 40129, Bologna.

Participating units:

Unit 1 (CNR coordinating Institute):
CNR-ISAC. Scientific responsible: Dr. Sante Laviola.

Unit 2:
ARPA Valle d'Aosta. Scientific responsible: Dr. Umberto Morra Di Cella.

Unit 3:
CIMA Foundation. Scientific responsible: Dr. Roberto Rudari

Unit 4:
Politecnico di Torino, DIATI. Scientific responsible: Prof. Pierluigi Claps.

Unit 5:
Politecnico e Università di Torino, DIST. Scientific responsible: Prof. Stefano Ferraris.

Unit 6:
Università di Torino, Dip. di Fisica. Scientific responsible: Prof. Claudio Cassardo.

Unit 7:
Università di Torino, Dip. di Scienze della Terra. Scientific responsible: Dr. Simona Fratianni

Participating units

The consortium consists of 7 research units whose typology is as follows: 1 CNR, 1 Regional Agency, 1 Research Foundation, 4 Universities. The motivation for the consortium composition is to be found in the motivation of the project, i.e. its character of pilot project devoted to snow property investigation over Northwestern Italy. NextSnow aims at setting the scene for NextData as to snow properties on the ground and snowfall. For accomplishing this goal, the two northwestern Italian regions Valle d'Aosta and Piemonte were selected since the regional agencies and the local universities have a long standing experience in snow property measurements at the ground, use of satellite snow cover products and modeling. The measurement networks of these two regions are very advanced and represent a substantial asset for launching the NetSnow activities without having to implement brand new networks from scratch. Finally, CNR, CIMA, the Polytechnic and the University of Turin together with the Regional Environment Agencies of Valle d'Aosta and Piemonte form a research community that has along record of collaboration that is a guarantee of success for the project.
The above motivations also explain why the expertise of the various non-CNR units cannot be found within CNR. CNR can provide the additional expertise in measuring snow cover and snowfall from satellite passive microwave sensors. Note that the CNR-ISAC coordination is based on a substantial record of projects on measuring precipitation from the ground and from space at the national and international level.
The motivations for including the various units, apart from the general structural considerations listed above, can be summarized in some detail as follows.

Unit 1 (CNR coordinating Institute): CNR-ISAC

Scientific responsible: Dr. Sante Laviola

The Satellite Meteorology Group of CNR-ISAC is a leader research group in the field of clouds and precipitation studies. In particular, the group has extensive expertise in satellite precipitation retrieval algorithms, error characterization and validation. With the advent of high-frequency microwave radiometers on board of LEO satellites the interest of the group has concentrated also on snowfall and snow cover detection. Moreover, of specific interest are the quantification of the orographic effects on precipitation formation, the delineation of precipitating clouds from satellite, the climatology of precipitation in the Mediterranean basin, and the high altitude precipitation measurements.

Unit 2:ARPA Valle d'Aosta

Scientific responsible: Dr. Umberto Morra Di Cella

ARPA Valle d'Aosta has a consolidated experience on the monitoring and modeling of snow cover and its spatio-temporal evolution. It manages the regional monitoring network of snow water equivalent (SWE). It provides the periodic estimation of SWE at regional scale as input for regional hydrological models and at local scale for the optimization of hydropower production. ARPA Valle d'Aosta develops and applies both empirical and physically based models for the snow cover evolution modeling and related physical processes. It develops and tests innovative methods for the definition of the snow covered area and snow thickness (webcam, airborne, satellite).

Unit 3:CIMA Foundation

Scientific responsible: Dr. Roberto Rudari

CIMA Research Foundation is a non-for-profit organization under the Italian Legal Regulations. CIMA's main founding Institution is the Italian Civil Protection Department (DPC) of the Italian, along with the University of Genova, the Liguria Region, and the Province of Savona. The mission of the Foundation is to advance scientific knowledge and to provide technical solutions for disaster risk reduction and risk assessment. The Foundation supports and promotes research, technological development, high level training, seminars and professional courses, in areas related to weather forecasting and observations, hydrology, climate (including climate variability), natural, and man-made risk, ecosystem modeling (including social system dynamics), environmental chemical processes, and renewable energy sources.

Concerning snow hydrology, CIMA develops snowpack models used in operational hydrometeorological chains at regional and national scale, and tools for integrating satellite observations, models and ground measurements. Such tools are operational at the Valle d'Aosta Civil Protection Technical Support Centre and at the Hydro energy Services of the Compagnia Valdostana delle Acque (CVA). CIMA also supports DPC as regards the estimation of the snow mantle extension and evolution. CIMA is part of the validation team of EUMETSAT's H-SAF for rain and snow products. CIMA manages hydrometeorological observations at national level and also an experimental site at the boundary between Liguria and Piemonte.

Unit 4:Politecnico di Torino, DIATI

Scientific responsible: Prof. Pierluigi Claps

The hydrology group at DIATI, Politecnico di Torino, is formed by Pierluigi Claps (full professor), Francesco Laio (associate professor), Paola Allamano (post-doc researcher), graduate and undergraduate students. It is a leading group in alpine hydrology, with expertise ranging from the modeling of floods and water resources in mountainous areas, statistical analysis of climatic data retrieved in alpine regions, and field measurement of snow depth and density. This expertise will be exploited in the project through the collection and analysis of snow-water-equivalent data for freshly fallen snow in the Western Alps, in collaboration with ARPA-Piemonte (which is part of Unit 4) and Arpa VdA (Unit 2). The experience gathered in the measurement of snow-related variables will also be very useful in the field part of the project.

Unit 5: Politecnico e Università di Torino, DIST

Scientific responsible: Prof. Stefano Ferraris

The Agricultural and Forest Hydrology Group of DIST (Politecnico and Università di Torino) works since 1965 in the field of water in its different form (liquid, vapor, snow) in the rural environment. Although some numerical modeling is performed by the group, it works mainly on ground measurements. The objective of most research is the quantification of the terrestrial water balance from a dynamical point of view, therefore measuring fluxes and stocks. Most studies have been performed in the Piemonte and Valle d'Aosta area.

Unit 6: Università di Torino, Dip. di Fisica

Scientific responsible: Prof. Claudio Cassardo

The GEOFIT group of Università di Torino, Dip. di Fisica has a long standing experience on land surface processes and modeling, and has developed its own model, named UTOPIA, able to consider several interaction processes and phenomena, including those related to snow that represent a very relevant portion. The model has been used successfully in the past with data from Siberia, the Alps and Antarctica.

Unit 7:Università di Torino, Dip. di Scienze della Terra

Scientific responsible: Dr. Simona Fratianni

The research group of Earth Sciences Department has competences in physical Geography and Climatology, Geomorphology and terrain Cartography. In particular his activities is primarily focused on the rescue and analysis of the principal climatic variables (snow depth, precipitation, temperature) and metadata, measured daily in the meteorological stations of the Alps in the last century. The activity of the group has concentrated on the quality control and reconstruction of the long term daily time series in order to evaluate the trends over different time scales and to carry out the analysis of extreme events. Moreover, of specific interest is the interpretation of environmental phenomena using Geographic Information System (GIS) to perform a multi-scale (spatial and temporal) integrated analysis for monitoring strategies.

1. GENERAL INFORMATION

Abstract of the proposed project

Snow as part of the water cycle is the less quantified component, especially in mountain areas. The NextSnow pilot project aims at setting the ground for a snow cover and snowfall measurement and modeling strategy in Italian mountain regions using ground measurements, remote sensing observations and numerical models. Ground networks of snow cover and snowfall measurement sensors will be completed by advanced techniques for determining the characteristics of the snow mantle and of the fluxes at the air-snow interface. Satellite data will monitor wider areas for hydrologic and climate applications. The modeling of the snow cover and of the energy and water balance within the snow mantle are essential for meteorological, hydrological and climate modeling. In this sense the project adopts a novel snow characterization strategy in Italy, which is unprecedented. The rescue and the digitization of the climatic variables from meteorological stations in the NW Alps in the last 100 years will provide information climate change and extreme events.

Main goals of the project

NextSnow aims at 1) making available datasets and with error characterization, 2) monitoring both from satellite and at ground level, and 3) modeling the observed parameters and the snow mantle.

Extensive (spatially and temporally) snow datasets on the Alps for meteorological, hydrological and climate applications are necessary, only partially available and somehow scattered over the territory. An observation strategy needs to be setup and extended in the future from the N-W pilot region of the project to the rest of the Alpine chain. Long-term nivometric homogeneous data series are to be developed for the identification of trends and future scenarios and of extreme events.

The second overarching goal is to develop and test models of snow depth, snow water equivalent, air-snow exchanges, and energy and water balance within the snow mantle. These models and the resulting parameterizations are instrumental for meteorological, hydrological and climate modeling applications.

Expected results of the project

Ground measurements in the N-W Alps will be accompanied by field campaigns using sensors on the ground, on helicopter and on board GEO-LEO satellites. An extensive dataset will be made available over the Valle d'Aosta and Piemonte regions, including snow cover, snow depth and snow water equivalent.

Climatic variables and metadata from meteorological stations over the last 100 years will be collected, digitized and inserted into a GIS. Homogeneous time series will be delivered including the statistics of extreme events and their return period.
Datasets of meteorological parameters over snow-covered terrain will be instrumental for determining the snow conditions and the air-snow interactions.
The error structure will be characterized and uncertainty estimates provided.
The characteristics of snow cover and PBL at the snow/snow-free boundary will be investigated and measurements conducted to explore the behavior of the melting snow on slopes.
Imagery and products from passive satellite sensors will be delivered including EUMETSAT's H-SAF products, MODIS Maximum Snow Extent and novel snow cover and snowfall retrievals from AMSU-B/MHS microwave radiometers. A preliminary validation of satellite products will be conducted.
Model outputs will include snow cover, snow depth and snow water equivalent at the regional scale. Empirical and physically based models will be used and checked against ground measurements with an analysis of the input data degradation.
Quantitative model outputs of the energy and hydrologic budget within the snow mantle will be delivered with a quantification of the physical variables that characterize the terrain: radiation budget over a mountain slope, multilayer parameterization of the snow mantle, wind effects.
Apart from their scientific value, the NextSnow datasets also offer political, socio-economic outcomes and are required to:
1) Contribute to advanced identification and understanding of climate change.
2) Improve knowledge on the snow cover variability and the factors that influence it.
3) Contribute to the contextualization of the results.

Role of the different units

Unit 1–CNR-ISAC

Project coordination.

Snow cover determination and improvement of snowfall retrievals from space using passive microwave radiometers in the 183 GHz water vapor absorption band using AMSU-B/MHS sensors. Intercomparison of satellite data products with ground data and model outputs. Provision of a satellite database of meteorological parameters over snow-covered terrain for a more complete description of the Alpine environment when satellite retrievals will be combined with ground and model data.

UNIT 2–ARPA Valle d'Aosta

Implementation and sharing of datasets and time series for supporting the project activities (driving, validation, testing, etc). Response of selected empirical and physically-based models to the degradation of input data for estimating their applicability with driving data from climate scenarios. Validation of MODIS snow cover data at regional and local scale for supporting the SWE estimation and detection of snowfall events.

UNIT 3–CIMA Foundation

Coordination of the snow evolution model intercomparison. Provision of two internally developed models: 1) the Snow Multidata Mapping and Modeling (S3M) algorithm to integrate a dynamic snow model, satellite and ground data; 2) the physically based energy balance model Achab-SNOW. Validation of satellite snowfall products and preparation of satellite snow cover product for the alpine region. Contribution of experience in data sharing policies and geospatial data open standard.

UNIT 4–Politecnico di Torino-DIATI

Collection and validation of manual measurements of depth and density of freshly fallen snow in the Western Alps, in collaboration with ARPA Piemonte. Modeling of the relation between SWE and ancillary variables (temperature, snow depth, etc). A posteriori reconstruction of the SWE at automatic gauging stations equipped with a thermometer and a snow depth gauge. Building of the database of historical measures of SWE of fresh snow for the Western Alps.

UNIT 5–Politecnico e Università di Torino-DIST

Snow and water balance over areas where snow falls and melts several times during winter, and both snowfall and rainfall occur. At such sites, in fact, nonlinearities in the water and energy dynamics are more pronounced, making it crucial to know such dynamics in more detail in order to upscale fluxes and to provide inputs to climate models for the evaluation of land feedbacks. The investigated area will be a 30×30 km2 square in the middle of Valle d'Aosta, part of the area managed by Unit 2-3, with which strong interactions are deemed necessary. This area has strong altitudinal and precipitation gradients between Gran Paradiso and the town of Aosta, making it very useful for concept assessment for a subsequent research over the entire Alpine chain.

UNIT 6–Università di Torino–Dipartimento di Fisica
The model UTOPIA will be used for running simulations driven by existing databases taken from observational datasets. UTOPIA is capable of computing the energy and hydrological balance in the snowpack, considering snow as a single layer. The performance of UTOPIA in Alpine stations will be tested, selecting a few places where all required input data are available, with special emphasis on parameterizations related to snow processes (multilayer snow, slope, wind effects).

UNIT 7–Università di Torino–Dipartimento di Scienze della Terra
Rescue of long-term (50-100 years) homogeneous climatic series. Gathering of metadata on the quality of the time series to obtain homogeneous records for evaluating the occurrence of extreme events and the climate changes in the Alps. Cooperation for the interpretation and dissemination of results, focusing on climate change impact on alpine ecosystems. Multiscalar and integrated analyses using satellite data (MODIS) and geomatic tools (GIS).

2. DETAILED PROJECT DESCRIPTION

State of the art and motivations

Snow is part of the cryosphere together with ice and permafrost. How are snow cover and properties changing in a changing climate context? Snow provides first hand evidence of temperature changes in terms of varying snow cover and frequency and duration of snowfalls. However, the pressing questions are as follows. What are the magnitudes, patterns and rates of change in snow properties on seasonal-to-century time scales? What are the associated changes in the water cycle, especially in a mountain environment where it tightly depends on snowfall?

In order to characterize the cycle of water, energy and matter between the terrestrial cryosphere and the atmosphere several disciplines have been involved in time including, among others, meteorology, climatology and hydrology. Specific international efforts are in place to better understand the changing character of the cryosphere and its climate connections, such as the Climate and Cryosphere (CliC[1]) project of the World Climate Research Project (WCRP). Very large efforts have also been devoted to creating large data repositories such as the US National Snow & Ice Data Center (NSIDC[2]), the GlobSnow project[3], and EUMETSAT's H-SAF project[4]. However, while each discipline is relatively well developed in itself, multi-disciplinary research remains a challenge and a necessity. Moreover, many of the processes involving the terrestrial cryosphere are poorly represented in the majority of climate models and of numerical weather prediction models. Land surface models play a crucial role in this respect and snow is a fundamental component of such models[5][6], also in view of the impact of snow schemes on surface energy and hydrology[7].

The assessment of the role of the cryosphere, snow in particular, in climate variability and change of mountainous regions is a hot research topic in this context. This is particularly true since the characteristics of the snow cover vary very much from

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[1] http://www.climate-cryosphere.org/

[2] http://nsidc.org/

[3] http://www.globsnow.info/

[4] http://hsaf.meteoam.it/

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[7] Dutra, E., P. Viterbo, P. M. A. Miranda, and G. Balsamo, 2012: Complexity of snow schemes in a climate model and its impact on surface energy and hydrology. *J. Hydrometeor.*, 13, 521-38.

place to place[8] and are often a peculiarity of the site, while at the same time varying with season and over the long term[9].
In order to analyze the variability of snow cover on different spatial and temporal scales several studies have used satellite images[10][11] processed through algorithms based on spectral tests, with the aim of estimating the surface snow cover[12]. The most recent uses of such images aimed at improving the quality of the images trough different approaches, including image preprocessing for reducing cloud effect[13] and combination of multiple images from different satellites, e.g. Aqua and Terra. With respect to image analysis, a number of integrated approaches have been proposed that enable to extract information for prediction and modeling[14], or to extract new data[15], also in a climate research perspective[16].
Substantial efforts are being devoted to snowfall detection from the ground and from space. Well-defined pros and cons due to the sensors and measuring strategies are associated with both approaches. At the ground the measurement errors, often ignored for automated systems, range from 20 to 50% due to the undercatch in windy conditions[17]. Obtain such measurement accuracy is crucial for monitoring and assessing climate variability and change, and reducing the uncertainties is essential given the projected increase in precipitation over land over the next 100 years[18]. Measurements of snowfall from space have an extensive areal coverage and are free from local undercatch problems. However, the remote sensing perspective suffers from a basic snowfall detection limit over frozen ground and the physical characteristics of the snow-bearing clouds are mostly unknown and this prevents unambiguous snowfall detection[19].

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[8] Sturm, M., J. Holmgren, and G. E. Liston, 1995: A seasonal snow cover classification system for local to global applications. *J. Climate*, 8, 1261-1283.
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[12] De Ruyter de Wildt, M., G. Seiz, and A. Gruen, 2007: Operational snow mapping using multitemporal Meteosat SEVIRI imagery. *Remote Sens. Environ*., 109, 29-41.
[13] Paudel, K. P., and P. Andersen, 2011: Monitoring snow cover variability in an agropastoral area in the Trans Himalayan region of Nepal using MODIS data with improved cloud removal methodology. *Remote Sens. Environ*., 115, 1234-1246.
[14] Sauter, T., B. Weitzenkamp, and C. Schneider, 2010: Spatio-temporal prediction of snow cover in the Black Forest mountain range using remote sensing and a recurrent neural network. *Int. J. Climatol*., 30, 2330-2341.
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[18] IPCC, 2007: Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmenatal Panel on Climate Change. Cambridge Univ. Press, 996 pp.
[19] Levizzani, V., S. Laviola, and E. Cattani, 2011: Detection and measurement of snowfall from space. *Remote Sens*., 3, 145-166.

To date, scarce information on the spatial and temporal variability of snow cover in the Alps are available, as no systematic study has been made yet. Climate models often show quite significant errors with respect to observation in the control period, particularly in areas of complex orography like the Alps. To reduce these errors, validation of the yearly snow cover duration maps by means of additional independent snow depth data measured by snow sensors, installed on automated nivo-meteorological stations, is very important. Moreover, eddy covariance technique is best suited for water and energy fluxes determination over land. Measurements within the snow layer are complex because they are heavily intrusive. In this respect, time domain reflectometry (TDR) shows good results in measuring SWE in several sites in a day.
Several models of different structure and complexity are actually available for simulating the processes of snowpack formation or ablation. Most of them have been tested on particular locations. What is lacking is a thorough intercomparison on an alpine site to show performances and guide the decision on the best-suited model to be coupled with global climatological and regional models to produce snow related scenarios.
Models mimicking snow evolution can be developed for several purposes: water management, avalanches forecasting, and energy flux estimation in meteorological and climatological models. The degree of complexity of these models ranges from simple index methods to physical multilayer models. Each of them can be a good choice for a specific task. The thorough understanding of the behavior of different models during both the melting and the accumulation periods with the final aim of identifying advantages and weaknesses for their estimation is a fundamental open science and operational issue.

Detailed description of the project, including the work plan, deliverables and milestones (explicitly indicating the activities of the different years)

All datasets and model outputs will be provided in a standard format so as to facilitate the uptake into the General Portal of the NextData Project.

UNIT 1– CNR-ISAC

1) Snow cover maps. Snow cover determination based on window and high-frequency channels (90, 150 and 190 GHz) of AMSU-B/MHS microwave radiometers on board NOAA and EPS satellites using the CNR-ISAC 183-WSL algorithm. The scattering of ice crystals over frozen soils is exploited. The signal attenuation of the threshold Δ=(90–150) over snow-covered or frozen terrain is radiometrically similar to that of rain clouds. To mitigate this effect the 190 GHz channel is used. This activity will be supported by the validation using the snow products made available by Unit 3 and Unit 4. The comparison is deemed very useful to improve both the 183-WSL snow cover detection mask and the classification type of the snow mantle in dry and wet snow conditions.

2) Snowfall detection. Snowfall detection based on combinations of the AMSU-B/MHS 90 and 190 GHz channels to identify snowy areas in the precipitating cores. Precipitating clouds from a few hundred meters to 5-6 km are considered as snow bearing. The snowfall detection and the quantification of falling snow will be supported by the activities of Unit 3 and 4.

3) Meteorological parameters. Production of a database of meteorological parameters over snow-covered terrain for combining satellite retrievals with ground and model data.

Milestones: Continuous provision of snow cover and snowfall maps over the project duration.

Deliverables: 1), 2) and 3) Datasets in quasi-real-time to be used by the other Units; 1) and 2) Reports on snow cover (31st December 2013) and snowfall detection (31st December 2014).

UNIT 2–ARPA-Valle d'Aosta

1 – Datasets. The following datasets from the Valle d'Aosta region will be assembled or implemented during the project and shared with other Units:

a) High-quality meteorological datasets from two high-elevation eddy-covariance monitoring sites (Torgnon, Valle d'Aosta, 2100 m a.s.l.);

b) Regional database of point SWE measures (since 2005);

c) Regional database of point HS measures (since 2004);

d) Monthly maps of regional SWE estimation over the period November-May (since 2007);

e) Daily cropped and reprojected MODIS-derived (MOD10A2) SCA maps (since 2000);

f) Manual and GPR intensive SWE measures for the estimation of maximum snow accumulation in specific mountain basins (since 2009);
g) Space-time variability analysis of snow density at regional scale and test of predictive models.
Milestones: 1) a, b July 1st, 2013; 2) c, d, e, f January 1st, 2014; 3) g September 1st, 2014.
Deliverables: a, b, c, f datasets and metadata; d, e maps; g report.

2 – Satellite data. Validation of MODIS Maximum Snow Extent data (MOD10A2) at regional scale using selected nivometer data from Valle d'Aosta, Piemonte and Valais (CH).
Milestones: March 1st, 2015.
Deliverable: report.

3 – Snow cover modeling.
a) Implementation and sharing of methodologies for regional and local estimation of HS and SWE.
b) Analysis of the effect of progressive degradation of input data on the performances of empirical and physically based models (Amundsen and GEOtop).
Milestones: a January 1st, 2015, b look unit 3 for details.
Deliverables: a, b: reports.

<u>UNIT 3–CIMA Foundation</u>

1. Intercomparison of different empirical and physically based snow models for 1) determination of the parameter settings that are more sensitive to the lack of reliable data and the effects of interpolated meteorological data from observations or model analysis; 2) selection of models to be coupled with global climatological and regional models to produce snow related scenarios.

The models used in the comparison are:

- Amundsen (empirical) and Geotop (physically based) provided and managed by Unit 2;
- S3M and (empirical) and Achab-SNOW (physically based) by Unit 3;
- UTOPIA (physically based) by Unit 6.

The models will be evaluated at a point scale on the Torgnon site gradually degrading the input from all the observed variables down to interpolated fields or climate model analyses. The performances of the models will be evaluated in terms of their ability to reproduce observed SWE, energy fluxes and soil temperatures by using classical statistical scores (Absolute Error, RMSE, correlation coefficient). CIMA Foundation will realize the interpolated fields and the statistical analysis. Three experiments are planned: 1) Compare the model results at point scale feeding the models with all the input data from the Torgnon site to exclude the model parameterizations; 2) Feed the models with the standard configuration input (operational configuration); 3) Use the

inputs from the interpolation of a dense meteorological network using state-of-the-art interpolation techniques benefitting from the bias correction algorithm from Unit 4. In a second phase of the experiment the performances will be tested at regional scale against field campaign measurements (ground and air dispatch sensors) and satellite products (considering the models that are already suited for distributed running).
Milestones: Month 8 for the first experiments, month 12 for the second experiment, and month 24 for the third experiment.
Deliverables: Reports of the activities and model-derived variables.

2. Satellites provide data to estimate snow extension and to model SWE. Snow Cover Area (SCA) MODIS products will be delivered as mosaicked and georeferenced maps for the entire alpine region from 2009 and from 2000 for the Valle d'Aosta area.
The MODIS products are:

- MOD10A2 product elaborated and provided by Unit 2;
- MODIS SCA product over Italy (2009-present) realized with the Decision Tree Classifier–Optimum Threshold (DTC-OT) algorithm[20].

HSAF snow product SN-OBS1 will be provided cropped on the region of interest since 2009.
Deliverables: data sets.
Milestones: January 1st, 2014.

Unit 2 and 3 will support the validation activities of low-resolution satellite products (e.g., low resolution radar SCA 16×16 km2 and snowfall maps).

3. - Meteorological and snow data collected by a low cost experimental station at Pian dei Corsi, Col Melogno (900 m asl) at the boundary between Liguria and Piemonte.
Deliverables: data sets.
Milestones: January 1st, 2015.

4. – Outputs of the S3M algorithm in operational configuration on the study region. The SCA in this configuration are assimilated with a nudging scheme to correct the model state variables.
Deliverables: assimilated fields.
Milestones: April 1st, 2015.

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UNIT 4–Politecnico di Torino-DIATI

Historical information related to freshly fallen snow, gathered by ARPA-Piemonte and ARPA-VdA, 1985-2010, will be exploited from 65 snowfields located in the mountain areas of the region between 700 and 2700 m a.s.l. Each measurement typically includes information on date of occurrence, manually measured snow depth and snow density. Ancillary variables include the value of minimum, maximum and average temperature in the 24 hours preceding the snowfall. The aim of the analysis is the assessment of a relationship to estimate the Snow Water Equivalent (SWE) of fresh snow from indirect measures, such as air temperature, and snow depth will also be quantified, paying attention to the uncertainties. More in detail, information about the difference between predicted and observed SWE values will be collected and organized; the probability distribution of the prediction error will be characterized in terms of its moments of order 2 and 3, and the possible dependence of these moments on the ancillary variables mentioned above will be suitably accounted for in the uncertainty representation. Fully probabilistic predictions of the SWE will thus be obtained. Once the relation among ancillary variables and SWE will be established, the SWE of fresh snow in any automatic gauging station will be determined where data from a thermometer and a snow depth-meter are jointly available. A database of historical measures of SWE of fresh snow will thus be prepared for the Western Alps, combining manual and automatic measurement networks.

Deliverables and milestones:

2013: Organization and validation of the manual measurements of depth and density of fresh snow. Mathematical modeling of the relation between the SWE of fresh snow and ancillary variables (with uncertainty).

2014: Reconstruction of the SWE in automatic gauging stations. Buildup of the database of historical measures of SWE of fresh snow for the Western Alps.

2015: Cooperation with other research units to the achievement of the project goals.

UNIT 5–Politecnico e Università di Torino-DIST

Water and energy fluxes analysis on alpine slopes during rapid changes of snow covered area, density and thickness, measure of stocks, namely through the soil temperature and moisture consequent variations.

Such variables vary in time and space in south faced slopes, where global radiation is particularly high also in winter. Eddy covariance will be used for vapor fluxes, and time domain reflectometry (TDR) for soil moisture and snow density. The uncertainty in vapor fluxes will be assessed through energy closure evaluation, and in stocks through calibration with gravimetric measurements. These variables are important in relation to the dynamics of the atmospheric surface layer. The snowfall line knowledge will be useful for the validation of radar and satellite snowfall estimation.

Data on a slope at 1800 m altitude are collected and additional instruments will be installed.

In detail, the tasks will be:
Measuring campaigns by using TDR to estimate SWE and soil moisture, along a 12 km transect, with 47 points of measurement centered in Aosta and spread over both north and south faced slopes. Analysis of variance will be done on the data.
Fluxes and stock monitoring at the eddy covariance site of Cogne Gimillan, 1800 m. a.s.l.
Snow covered area assessment at watershed scale from TIR, NIR, and visible images (also webcams) from 2007 to the end of the research. All fluxes and stock data will be available on the website.
Collaboration with Centro Funzionale of Regione Valle d'Aosta and Corpo Forestale Valdostano will be very useful for precipitation and height of snowpack.
Milestones: Continuous provision of ground data in the test area over the project duration.
Deliverables: 1)30th June 2014. 2)30th June 2014, regarding the datasets of 2011 and 2012 and 30th June 2015, for the datasets taken during the project. 3) 30th June 2014, datasets taken before the starting of the project, 30th June 2015, datasets collected during the project.

UNIT 6–Università di Torino–Dipartimento di Fisica

The University of Torino model of land Process Interaction with Atmosphere (UTOPIA) will be calibrated using all available data retrieved from the existing databases in the Northwestern Alps. More specifically, ARPA Piemonte, ARPA Valle d'Aosta and ARPA Liguria databases include more than 500 stations, some of which equipped with snow meters and specific instrumentation for snow measurements. To run the model, it is required that the station collects also other relevant data, such as air temperature and humidity, pressure, precipitation, wind speed and direction, and radiation or cloudiness (the latter could be also derived by other sources). Once the model has been calibrated, some sensitivity experiments will be performed by perturbing initial data in order to assess the expected error of the model in function of the error in the data. When the model will be considered suitable for carrying out simulation in the Western Alps, it can be used also in other locations in which snow data are not available, in order to assess some information on the snowpack.
Further tests will be performed using databases relative to other snow-covered locations in the world, such as Siberia, northern Canada or Tibet, using the existing databases (Ruswet, Boreas, Game,...). The utility of these simulations will be twofold: a) testing the model performance and the specific validity of the parameterizations; b) assessing the model capability of reproducing the physical processes also in conditions different from those of the western Alps.

1 - Input data preparation.
Collection of data required for the simulations, also benefiting from the work of other units.
Period: first six months.
Milestone & deliverable: input database for physically based snow model simulation, month 6.

2 - Model optimization.
Parameterizations related to snow processes (multilayer snow, soil slope, wind effect), verified and eventually updated or reformulated, based on model results and the literature.
Period: from month 7 to month 28
Milestone & deliverable: updated model UTOPIA updated for parameterization processes affecting the snow, month 28.

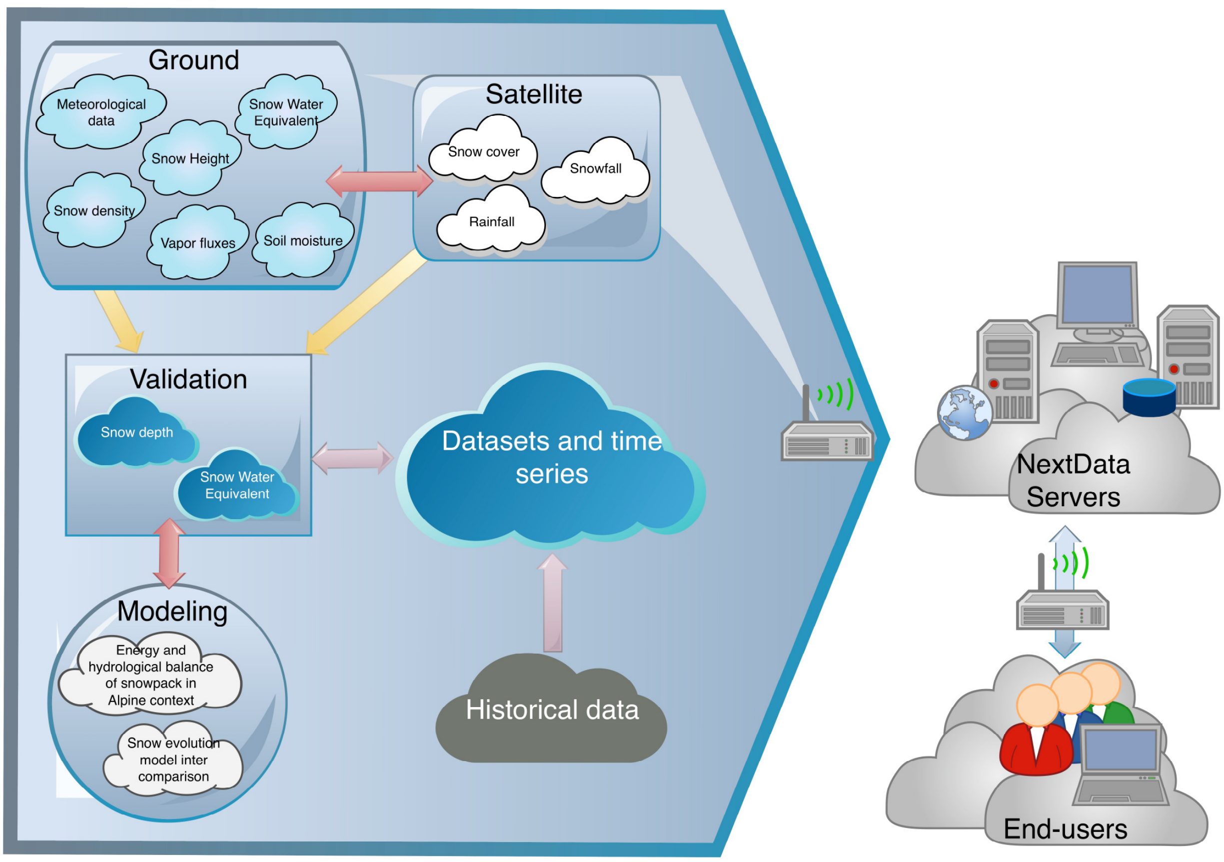
3 - Simulation output database.
Simulations with the UTOPIA model on the station coming from the database created in phase 1.
Period: month 18 to month 30.
Milestone & deliverable: output database from UTOPIA, month 30.

UNIT 7-Università di Torino-Dipartimento di Scienze della Terra
Large amounts of historical daily meteorological data belonging to several Institutions (Regions, Arpa, Servizio Meteomont, Corpo Forestale dello Stato) are collected. At the same time, data from the SEVIRI radiometer in orbit aboard Meteosat and the snow cover products generated from measurements of the radiometer MODIS are made available.
Objective difficulties in homogenizing liquid and solid precipitation measurements in time series are found to date. Already developed algorithms will be implemented to quality control rain and snow precipitation time series on seasonal and monthly scale in order to extend their use on a daily scale. Thanks to the participation the COST ACTION ES0601, a homogenization test will be developed to detect the discontinuities and their correction factor, even for liquid and solid precipitation. Advanced statistical techniques based on the distribution of the Generalized Extreme Events will be applied to the trends in frequency and intensity of extreme events and to determine the return periods.
The satellite snow cover will be used together with surface nivo-meteorological stations data to estimate the spatial distribution of snow depth and new snowfall by the Kriging interpolation technique.
The processing of MODIS images will be performed in an open source environment, in order to provide a fully distributable final application and a widespread usage.

Deliverables: Homogeneous time series of snow properties
Milestones: End of the project.
Surface snow measurements are very limited and distributed non-uniformly on the territory, so that the assessment of snow cover over large scale with high spatial resolution is only possible through the use of remote sensing. In order to improve the quality of the snow cover estimate over the Alpine complex terrain, the existing algorithms will be optimized using Meteosat SEVIRI data and MODIS snow cover products.
Deliverables: Satellite product datasets.
Milestones: At various stages throughout the project.

Coordination plan

The overall NextSnow activity can be grouped into four major tasks: ground measurements, satellite observations, validation, modeling and dataset/time series production. Ground and satellite measurements and retrievals are subject to validation using "ground truth" data and represent a fundamental input for the models. The validated datasets, including their error structure, will be available for inclusion into the NextData servers for their dissemination to end-users.



The coordination and project management need necessarily to make sure that the critical links between the various activities are constantly working throughout the project duration so as to produce final datasets that are the results of a coordinated effort and not the mere collection of uncorrelated data gathering. In order to do that the coordinator will avail himself of the collaboration of the Responsibles of the Research Units who will be part of the Project Management Group. The group will work via e-mail and/or web conference to take the necessary decisions in near real time.

The following meetings are foreseen (months):

Kick-off meeting T0
Spring meeting 2014 T0+10 (spring 2014)
Spring meeting 2015 T0+22 (spring 2015)
Final meeting End of the project (September 2015).

Note that the project is rather small and thus a more complex management structure and more meetings would overly complicate the activities. If necessary, bilateral meetings or visits to the measurement sites can and will be organized from time to time by the Coordinator in agreement with the Management Group.

A mid-term internal review monitor is also foreseen to check the project progress and take adequate measures in case of critical aspects that will have eventually emerged during the first half of the project duration.

A simple project schematic is provided in the following flux diagram.

Links with the other NextData research projects

NextSnow's main goal is to produce a first complex dataset on snow cover, snow state and snowfall in the Western Italian Alps. It is thus natural for the project to actively collaborate with the following NextData projects of interest:

- Line 1 – Development of the NextData web portal. The snow products will be made readily available for the dissemination using standard formats (e.g., HDF, NetCDF,…).
- Line 3 – Estimation of the status and evolution of the cryosphere in the Italian Alps. NextSnow data are considered very important as an input for the evaluation of the status of the glaciers in a changing climate.
- Line 4 – Global and regional hydrostatic and nonhydrostatic high-resolution simulations. The snow-covered ground still represents an unsolved problem for regional and global models and the NextSnow data will contribute unprecedented data in a complex orography region.
- Line 7 – Estimate of spatial high-resolution distribution of temperature and precipitation at monthly scale. Precipitation measurements from NextSnow

will be a precious input in the area thus enriching the time series and providing error estimates.

NextSnow as a pilot project and "proof-of-concept"

NextSnow represents a "proof of concept" by implementing a working demonstrator as allowed by the limited available funding. The idea is to carry on a research activity, which will demonstrate the feasibility of the measurements, the modeling and the data delivery in view of their value for climate modeling. This needs to be proved initially on an area where there is a previous experience in the field so as to ensure the best possible outcome. The participating research groups ensure exactly this important starting point. Follow-on projects will surely have to extend the activities to the rest of the Italian Alps and possibly involve the neighboring countries, which are already involved in NextSnow to a certain extent.

Apart from the previous experience by the participating groups in conducting measurements in the area, it must also be noted that the Val d'Aosta and Piemonte Alpine region is particularly suited to conduct such a pilot project given the altitude gradient (from 500 m.a.s.l. of Aosta to 4061 m.a.s.l. of the Gran Paradiso and 4314 m.a.s.l. of the Grand Combin), the highest in the Alpine chain. Moreover, the precipitation gradient in only about 20 km distance is from 500 mm/year of Aosta to 2200 of St. Rhemy at 2472 m.a.s.l. it is thus very challenging to measure the precipitation at such very high spots and compare with other places, such as Val Venosta in Süd Tyrol, where the precipitation is not too high as in Aosta, but where the surrounding mountains are not as high as in Val d'Aosta.

Finally, the use of satellite data allows for broadening the area of interest thus partially correcting the relatively "local" character of the project. Moreover, the use of satellite data in the VIS/IR and MW spectral range will be very interesting over such an orographically complex area. Future extensions to the rest of the Alpine region will clearly benefit from these tests.

Glossary

AGU	American Geophysical Union
AMS	American Meteorological Society
AMSU	Advanced Microwave Sounding Unit
ARPA	Agenzia Regionale Prevenzione e Ambiente
CGMS	Coordination Group for Meteorological Satellites
CIMA	International Centre on Environmental Monitoring
CliC	Climate and the Cryosphere
CNR	Consiglio Nazionale delle Ricerche
CVA	Compagnia Valdostana delle Acque
DIATI	Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
DIST	Dipartimento Interateneo di Scienze, progetto e politiche del Territorio
DPC	Dipartimento della Protezione Civile
DTC-OT	Decision Tree Classifier–Optimum Threshold
EGU	European Geosciences Union
EPS	EUMETSAT Polar Satellite
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
GEO	Geostationary Earth Observation satellite
GIS	Geographic Information System
GPR	Ground Penetrating Radar
HS	Height of Snow
H-SAF	Satellite Application facility on Support to Operational Hydrology and Water Management
IPWG	International Precipitation Working Group
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (CNR)
LEO	Low Earth Orbit satellite
MAP	Mesoscale Alpine Project
MHS	Microwave Humidity Sounder
MODIS	MODerate resolution Imaging Spectroradiometer
NIR	Near InfraRed
NOAA	National Oceanic and Atmospheric Administration
NSDIC	National Snow & Ice Data Center
RMS	Royal Meteorological Society
SCA	Snow Covered Area
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SMHI	Swedish Meteorological and Hydrological Institute
SWE	Snow Water Equivalent
S3M	Snow Multidata Mapping and Modeling algorithm
TDR	Time Domain Reflectometry
TIR	Thermal InfraRed
UNEP	United Nations Environment Programme
VdA	Valle d'Aosta
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
183-WSL	Water vapour Strong Lines at 183 GHz