A *slippery* subject

Up to 2 billion people depend on water supplied by snow and glaciers – Project Coordinator **Dr Thomas Nagler** explains how CryoLand addresses the urgent need to unify services to monitor it

Could you explain CryoLand's main aims and objectives?

The primary objective of CryoLand is to develop, implement and validate a standardised and sustainable service on snow, glacier and lake/river ice monitoring. This will exploit the GMES Sentinels and other Earth Observation satellites to constitute a 'Downstream Service' within GMES in a value added chain. The project prepares the basis for a future cryospheric component of the GMES Land Monitoring Core Service.

What challenges is the project responding to?

Climate change has a strong impact on land ice and snow cover-based environments. Rising temperatures will lead to the retreat of seasonal snow extent and glaciers, jeopardising the supply of fresh water for human consumption, agriculture, and hydropower generation. In addition, changing snow and ice will affect ecosystems and biospheric diversity. Accurate and timely observations are necessary to prepare for these challenges: to support the management of snow and water resources, CryoLand is developing new services to monitor snow cover, glacier ice and lake/river ice.

Can you describe the approach CryoLand is taking to develop, implement and validate a standardised and sustainable service on snow and land ice monitoring?

The project builds upon, integrates and widens structural and technical capabilities of the project partners, who have long-term experience in running operational and pre-operational services on snow and ice. Users play a key role in the definition of service requirements and in the validation of the satellite-derived products and services. Based on the users' needs, the portfolio of snow and ice products is improved and augmented to better match user requirements and make full use of the advanced capabilities of the GMES Sentinel Satellite series. An important part of the project is the design, development and implementation of a network services system that will ensure interoperability of the infrastructure by compliance with INSPIRE and GEOSS, by integration with the Land Monitoring Core Service and GMES Space Component Data Access System, and the required in situ and reference data access.

How are you linked to GMES and what information will you be receiving from the GMES Space Component?

On one hand, CryoLand will make use of products from the GMES Land Core Service, which provides advanced and up-to-date land cover information, for providing improved snow and land ice products. CryoLand products are based on Synthetic Aperture Radar (eg. Sentinel1 SAR) and high- and medium-resolution optical satellite data, provided by the Sentinel 2 and Sentinel 3 satellites. The algorithms and processing lines will be developed to make use of the advanced capabilities of the Sentinel Satellite family. Data lines for near real-time access to the satellite scenes are important for providing actual information on snow and ice.

By what means will the project integrate and operationalise existing snow and land ice services?

The project developments build upon tools and processing lines that are available at the partner institutions, for generating snow and ice products as well as pre-operational snow services. The existing products serve as the prototype products which are improved and adapted according to user needs and to make use of the full observation capabilities of GMES Sentinel Satellite series.

What relevance could this project have for snow and ice services beyond Europe?

Snow and land ice are key elements of the water cycle in many parts of the world, especially mountain regions and mid- and high-latitude zones of Asia and America. Snow, lake ice and river ice are characterised by high temporal variability. Accurate observations of snow cover extent and physical properties are not only of interest for climate change research, but are of great socioeconomic importance. Snow and glacier melt are the dominant source of runoff in high-latitude regions as well as in many mountain regions in the world. Melt water from the mountains is also an important water resource downstream for lowland regions of Europe, Asia, South and North America. UNEP (2007) reports that 1.5 to 2 billion people are living in regions where reduced water flow, due to retreat of the seasonal snow cover and glaciers, could cause major water shortages.

The ice map cometh

Concerns for water security are increasing as the planet warms. The EU-funded **CryoLand** project kicks off this year, building a future of fully integrated and stakeholder-relevant snow, glacier and lake ice monitoring products

THERE ARE FEW more basic and pressing topics for study than the sustained supply of fresh water. As climate changes add yet more complexity to the distribution of fresh water, understanding the huge quantities which are contained within snow and glaciers are vital factors in planning for the future. The possible depletion of water from glaciers- and snow-covered environments has huge significance for human consumption, agriculture, hydropower generation and other uses, not to mention its impact on ecosystems and biospheric diversity.

Supported by the EU Seventh Framework Programme (FP7), CryoLand aims to generate integrated and comprehensive products for the imaging – and subsequent management – of snow and ice resources. Over a four-year period, CryoLand (GMES Service Snow and Land Ice) will deliver broad-ranging products to that end, as Project Coordinator, Dr Thomas Nagler, outlines: "The baseline products of CryoLand include the extent of seasonal snow cover, extent of melting snow, statistical snow information for basins and sub-basins, glacier outlines and time series of snow/ice maps on glaciers, and lake/river ice extent".

VITAL OBSERVATIONS

While significant steps have been made with the GMES (Global Monitoring for Environment and Security) utilising Europe's investment in the space sector, at present, there is insufficient integration of the system where ice and snow is concerned. Given that snow and ice are key elements of the water cycle in many parts or Europe, this integration must be enhanced. Snow and ice cover are characterised by a high level of temporal variability: snow is, of course, altered by meteorological events in the short term, as well as having year to year and seasonal variability. Given this variability, the facility to cross-reference and superimpose broad-ranging temporal and spatial data could be vital in assessing and planning for the impact of climate change.

FIGURE 1. Map of snow extent (red – snow covered) from optical satellite data of the Tyrolean Alps, Austria. (View direction: towards North).

Satellites are therefore a crucial tool in monitoring glaciers and seasonal snow cover and their physical properties, giving accurate observations which are not only relevant for climate change research – but also for the socioeconomic wellbeing of entire nations. As a Downstream Service, CryoLand will receive Earth Observation satellite data input directly from the GMES Space Component. From this data, it will develop, implement and validate a standardised and sustainable service on snow and ice monitoring, which could have implications and uses for such diverse stakeholders from traffic security and guidance (roads, railways, and rivers), to supporting geotechnical and construction activities, the tourism industry and agricultural management.

GEOSPATIAL PRODUCTS

CryoLand's intention is to create a self-sustainable service to support the better management and realisation of a wide range of economic and ecologic activities relating to snow and ice. Capitalising on the high investments Europe has made in the space sector, the project will build upon the methods and processing algorithms developed by scientists and technicians to generate satellite-based snow and ice products for the diverse stakeholders mentioned. As Nagler elaborates, the full range of available data will be exploited: "Geospatial products on seasonal snow, glaciers, and lake/river ice are derived from Earth Observation satellite data, optionally including information from field stations," he points out.

Products in and of themselves are one thing: ensuring their timely and efficient delivery is another. The project's architecture thus ensures its products are made available to users through modern and efficient mechanisms for information distribution and data access with well-defined interfaces. Through FTP, web pages and up-to-date OGC Web services, Nagler believes they are doing all they can to widen access: "Advanced information technology will be applied to process and distribute snow and land ice products tailored to customer needs in near real-time," he enthuses. The group hopes that this will allow direct integration of CryoLand results into GIS, modelling tools and decision-support environments. Information should be available for targeted areas and times, without the download of extraneous large files containing only small amounts of relevant information.

Advanced information technology will process and distribute tailored snow and land ice products in near real-time

WELL-DEVELOPED DATA FLOW

Crucially, the design, development and implementation of this network of services has been conceived with a high level of interoperability and compliance with INSPIRE and GEOSS, as well as with the Land Monitoring Core Service, the GMES Space Component Data Access System, and the required in situ and reference data access. With this type of monitoring, achieving smooth movement of information between different systems has been vital, in Nagler's opinion: "Due to the high temporal changes of the snow extent, fully automatic processing lines and well developed data flow lines are needed in order to provide the products in near real-time".

Through full end-to-end tests and verification of products and services in pre-operational environments, Nagler's team will ensure rigorous procedures and protocols for validation and qualification. The second phase of the project will provide a full performance demonstration of the system, which includes products at regional to continental scale, utilising high and medium resolution optical sensors relying on single, as well as dual or multi-sensor, algorithms. Nagler believes they will make progress in this area: "CryoLand will work to improve the snow algorithms, integrating accurate land cover data of the GMES Land Monitoring Core Service and taking digital elevation models into account," he explains.

Other snow products will include melting snow areas being mapped using Synthetic Aperture Radar data – sensitive only to wet snow – which provide complementary information to snow maps from optical satellite data, which monitor the total (wet and dry) snow cover. Additionally, dataflows and algorithms for glacier parameters and lake/river ice products will be improved and automated. An important issue of CryoLand is to provide also detailed information on the accuracy and performance of generated products, an information which is highly needed by organisations making use of CryoLand products for their activities.

SUPPORTING RESOURCE MANAGERS

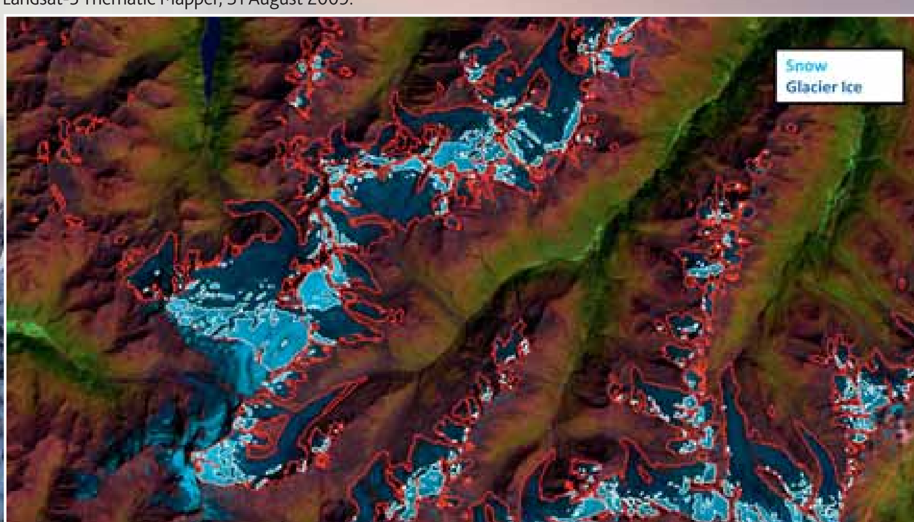
The project partners involved in Cryoland have carried out various national and international projects over the last several years, to develop and test product lines and services such as those outlined. Nagler hopes that, through their strong teamwork, CryoLand could really represent the coordination of individual approaches into an operational service framework – something which has been lacking at a European level up to this point. During the second phase of the project, they intend to carry out comprehensive promotion and dissemination work, in order to prepare for the transition to a self-sustained operational snow and land ice monitoring service.

Users have and will continue to play a key role in what these services look like and provide, reaching a pan-European community. Nagler states clearly how much this community of stakeholders is at the core of their work: "The CryoLand service is very relevant to supporting a huge range of environmental and resource management activities in Europe". Far from being a fixed service, CryoLand will be improved and augmented as time goes on, to better match the user requirements at the partner institutions.

A SELF-STANDING SERVICE

The SMEs and publicly mandated institutions which comprise the project consortium stand to benefit hugely as the project evolves. Moreover, as information on climate change and water availability is important in many regions in the world, the project will provide improved and easy accessible information on snow and ice to the public. As Nagler explains, he is excited about the coming challenges and rewards: "Within the timeframe of the project, we are working towards a self-standing service. We will modify the products, enabling open standards for accessing data via the Internet and allowing users simple and automatic access to snow and ice information," he concludes.

FIGURE 2. Glacier outlines (red line) and map of snow/ice extent of glaciers. Ötztal Alps, Austria, derived from Landsat-5 Thematic Mapper, 31 August 2009.



INTELLIGENCE

CryoLand

GMES SERVICE SNOW AND LAND ICE

OBJECTIVES

To develop, implement and validate a standardised and sustainable service on snow and land ice monitoring as a Downstream Service within GMES in a value added chain with the Land Monitoring Core Services.

PARTNERS

ENVEO IT GmbH (coordinator), Austria • **EOX IT Services**, Austria • **Finnish Environment Institute**, Finland • **Finnish Meteorological Institute**, Finland • **Kongsberg Satellite Services**, Norway • **Northern Research Institute**, Norway • **Norwegian Computing Center**, Norway • **National Meteorological Administration**, Romania • **GAMMA Remote Sensing**, Switzerland • **Swedish Meteorological & Hydrological Institute**, Sweden

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