GeoAvalanche - Spatial Data Infrastructure for avalanche awareness warning

Francesco BARTOLI and Carlo Maria MEDAGLIA, Italy

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SUMMARY

Avalanches are a serious problem across the Alps even more in the latest years, considering the number of people playing outdoor activities on snow areas. Dissemination of information across those stakeholders involved in all warning and rescue services is crucial at each stage. This paper figures out how people involved in risk mitigation might be allowed to fill this gap and exchange information in a common language both in term of contents and contexts without any kind of misleading. Furthermore, several user-oriented services might be acted on Web channels to reach mountaineers via mobile devices and make their experience safe-effective.
GeoAvalanche is an open-source project aimed at sharing information on snow avalanche (such as bulletins, incidents, snow-profile, weather observations…) with a common standard in order to build a Spatial Data Infrastructure for cross-border interoperability and early warning alert systems toward a mitigation risk of mountain activities across the Alps. The GeoAvalanche server has the OGC Web Feature Service capabilities to enable common warning services for snow avalanche information exchanges in compliance with CAAML (Canadian Avalanche Association Markup Language) specification data (adopted by the avalanche community as an international standard) and map visualization services for incident report and bulletin alert.

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1. STATE OF ART

Snow avalanches are the major natural hazard in Europe's mountain areas during the winter. Lately, climate changes influence even more snowfalls and snowpack by enhancing severe conditions in these areas where also the increase of tourism for winter sport activities generates more avalanches, which cause several deaths per year and significant damages to mountain villages, settlements, infrastructures and forests.
At the same time, the snow cover in the alpine space represents an invaluable resource (as a source of water for drinkable and irrigation use, hydropower generation, winter sport activities and tourism development on the Alps), which, in the near future, will need increased predictive performances intended to improve management policies.
Environmental risk management is also a major scope issued by INSPIRE directives; in fact the theme "Natural Risk Zones" is mentioned into the Annex III and is identified as all atmospheric, meteorological, hydrologic, geological and wildfire phenomena that, because of their location, severity, and frequency, have the potential to seriously affects population. Data specifications define punctual areas with significant snow cover combined with steep slopes, amplified by the creation of snowdrifts, as being prone to influence the occurrence of avalanches and snow slides.
In this context, the results mainly concern the provision of a compliant Spatial Data Infrastructure (SDI) that gives the opportunity to interoperate with systems for regulating land use and resource management in areas under certain restrictions that are linked to such risk as well as web mapping of areas susceptible to snow slides divided into zones with different susceptibility classes [Drafting Team "Data Specifications"].

Avalanche Warning Services (AWS) in Europe daily collect meteorological and snow data for their snowcasting and forecasting predictions. But as already stated in the recommendations of the NEDIES Project [Hervàs, 2003], it would be necessary to standardize the collection of these data and the subsequent sharing and exchange, in real-time, of information, data, knowledge and products in order to ensure that the most possible effort is made to handle the safety of the public and the resilient management of resources, thus maximizing the return on the investments of each nation.
Warning Services usually must inform the relevant authorities for letting them to take preventive actions immediately and leverage recreationists effectively about the possible danger of avalanches in those areas, where they are planning to venture (skitouring, mountaineering, snow shoeing, etc).
These two different targets have to be reached in the shortest time and in a manner that is more easily accessible and unambiguous for the largest audience possible. As a result, the underlying information system must be designed with geospatial standards in mind to affect

interoperability between applications and to ensure communication to all possible Web channels for delivering such geographical data as snow avalanches information to decision-makers and third-party weather systems as well as mobile devices (Smartphones, iOS, Androids). Furthermore, they should be able to connect snow avalanches observation centers since often a nationwide decentralisation takes place even more by the issue of regional forecasts and consequently a weak harmonisation of the final products is actually clear. This delay is still strengthened at cross-boarder level where a shared information system covering mountain areas across Alps misses and it is not allowed to access real-time collections of such data on contiguous land of neighboring member states.

The importance of data sharing among avalanche organizations is therefore emphasised by the geographical nature of the avalanche bulletins, which they publish on daily basis.
In order to make the most effective use of the data and since all of these have a spatial component it is crucial that they should be collected using modern geographic information systems (GIS) [Magnùsson, 2003].
The product most widely known to the public is the avalanche bulletin, which is issued accordingly to avalanche danger scale, the values of which are now commonly accepted and universally recognized by all agencies. This guarantees standardisation for what concerns the mapping of those areas at risk and allows to represent thematic maps with a unique legend understandable worldwide.

2. GEOAVALANCHE PROJECT

2.1 Scope of the initiative

GeoAvalanche is an open-source project carried out in experimental way with the aim to design, develop and test methods and architecture that establish a widen methodology to deal with snow avalanches datasets in a common way by assuring interoperability among cross-border European warning systems based on international geospatial standards in the realm of Open Geospatial Consortium (OGC).
The expected outcomes from this work reside on overcoming the current lack of data sharing and information dissemination by using GeoAvalanche as base tool for improving cooperation among regional/national risk management offices and serving as a reliable warning product to the public.
GeoAvalanche project aims at accessing datasets and making them available through the use of OGC Web Feature Service (WFS) for the share of snow avalanches information. It is also intended to provide maps of avalanche bulletins by using OGC Web Mapping Service (WMS) in order to provide them to third-party Internet sites and mobile devices enabled for geolocalisation services.
GeoAvalanche would form a core component for an upcoming snow avalanche SDI that benefits from all the major features of the geospatial Web.

2.2 Snow Avalanche standards

2.2.1 Avalanche Danger

Avalanche bulletins are basic tools which provide an overview on the snowcover, the state of the snowpack pointing to the avalanche danger issued in a given territory – on the basis of weather forecasts and the snowprofile's evolution – for nowcasting and expected forecasting, so as to contrast the triggers of avalanches and therefore incidents.
This assessment, whose semantic rules are standardised in Europe by the European Avalanche Warning Service organization (EAWS), is carried out for each given region by giving out a shortly text description on the basis of avalanche danger. Then it contains also the edge of the snow, dangerous places or elevations with critical rose of aspects, and finally a graphical representation in a map showing the color theme related to the danger level and the corresponding text portion [Chiambretti, Bartoli, 2011].

European Danger Scale with Recommendations

	Danger level	Snowpack stability	Avalanche triggering probability	Consequences for transportation routes and settlements / recommendations	Consequences for persons outside secured zones / recommendations
5	very high	The snowpack is poorly bonded and largely unstable in general.	Many large and multiple very large natural avalanches are expected, even in moderately steep terrain.	Acute danger. Comprehensive safety measures.	Highly unfavourable conditions. Avoid open terrain.
4	high	The snowpack is poorly bonded on most steep slopes*.	Triggering is likely even from low additional loads** on many steep slopes. In some cases, numerous medium-sized and often large-sized natural avalanches can be expected.	Many exposed sectors are endangered. Safety measures recommended in those places.	Unfavourable conditions. Extensive experience in the assessment of avalanche danger is required. Remain in moderately steep terrain / heed avalanche run out zones.
3	considerable	The snowpack is moderately to poorly bonded on many steep slopes*.	Triggering is possible, even from low additional loads** particularly on those steep slopes indicated in the bulletin. In some cases medium-sized, in isolated cases large-sized natural avalanches are possible.	Isolated exposed sectors are endangered. Some safety measures recommended in those places.	Partially unfavourable conditions. Experience in the assessment of avalanche danger is required. Steep slopes of indicated aspects and altitude zones should be avoided if possible.
2	moderate	The snowpack is only moderately well bonded on some steep slopes*, otherwise well bonded in general.	Triggering is possible primarily from high additional loads**, particularly on those steep slopes indicated in the bulletin. Large-sized natural avalanches are unlikely.	Low danger of natural avalanches.	Mostly favourable conditions. Careful route selection, especially on steep slopes of indicated aspects and altitude zones.
1	low	The snowpack is well bonded and stable in general.	Triggering is generally possible only from high additional loads** in isolated areas of very steep, extreme terrain. Only sluffs and small-sized natural avalanches are possible.	No danger	Generally safe conditions

Figure 1 European Danger Scale with Recommendations

Avalanche danger scale is encoded accordingly to an EAWS European-wide standard (now used internationally), divided into 5 classes (1-Low, 2-Moderate, 3-Considerable, 4-High, 5 -Very High), which are associated with the relevant safety information to the user.

2.2.2 CAAML

Canadian Avalanche Association Markup Language (CAAML) is an XML grammar language initially developed since 2003 and still maintained by the Canadian Avalanche Association to provide a common encoding structure and exchange snow avalanches related information over the Internet.

Types of information currently supported by CAAML include:

- Avalanche incident information
- Avalanche activity comments
- Avalanche observations
- Avalanche bulletins
- Avalanche closures
- Observations on the field
- Snowpack structure comments
- Snow profile observations
- Weather observations

Following the development of GML [Geography Markup Language], the organization of elements in CAAML reflects the object-property-value model pattern, which encodes types in CAAML and then assigns properties to each of them.
The latest version 5.0 consists of 9 schema files structurally organized as follows:

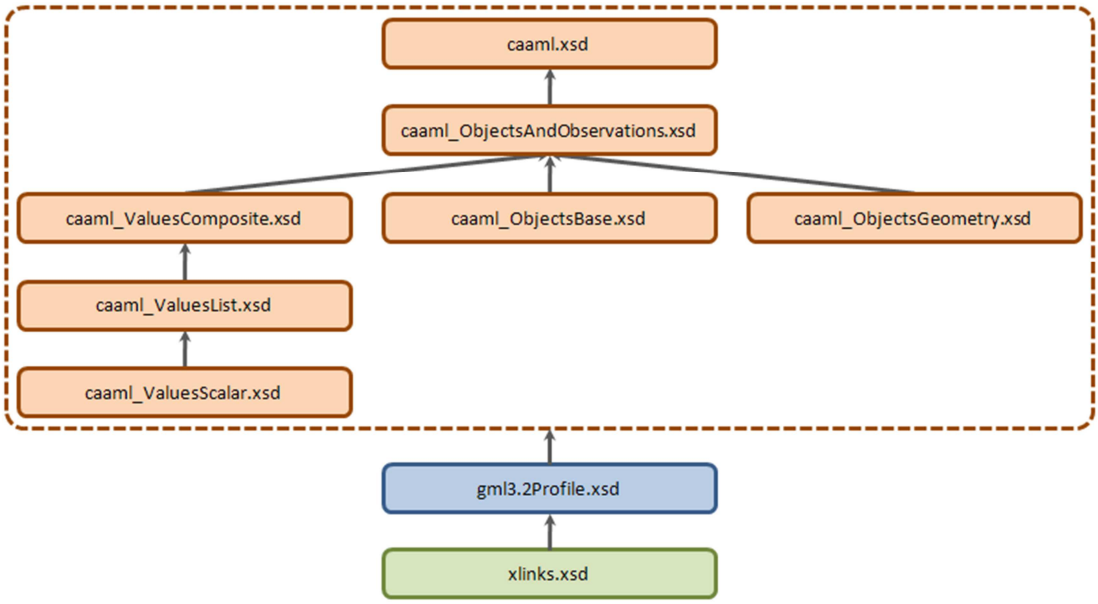


Figure 2 Schema file structure of CAAML version 5.0

Since the nature of CAAML is strictly derived from GML itself then it has been design with the same flexibility in mind. In fact this recent version borrows the concept of profile from GML, which permits to deal with a logical limitation of elements relevant for a specific application while maintaining the ability to be validated against the overall CAAML standard.
The current experiments have investigated a profile just suitable in the realm of EAWS avalanche agencies for their CAAML-scoped avalanche bulletins.
This specific schema file is currently maintained at this location http://caaml.org/Schemas/V5.0/Profiles/BulletinEAWS/CAAMLv5_BulletinEAWS.xsd

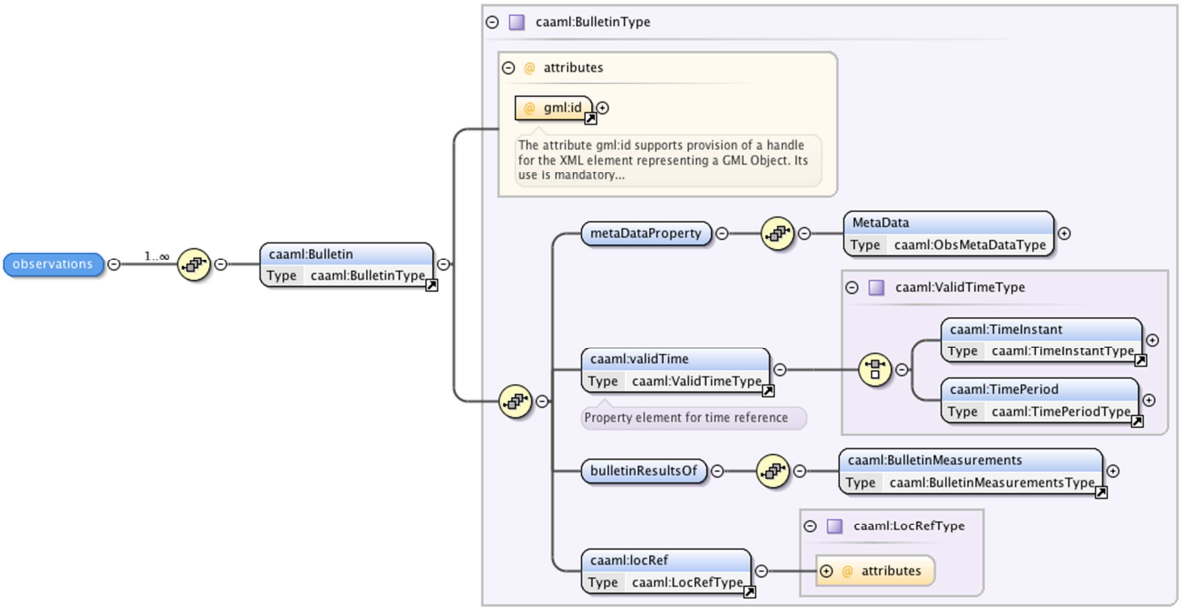


Figure 3 XML schema definition for CAAML bulletin type asserted in the EAWS profile

Figure 3 shows an example of the data types listed above and specifically how a bulletin element has to be semantically expressed in the European profile. This data type is a kind of complex feature, which needs to be discussed further in order to explained how it can be publish through an endpoint service.
This approach doesn't mean that GeoAvalanche architecture has been designed for a limited set of CAAML profiles but further with the principle to handle whatever kind of them. As result the GeoAvalanche server would be able to manage with the exchange of any snow avalanches profiled elements and hence to achieve interoperability at different levels (regional/national/European).

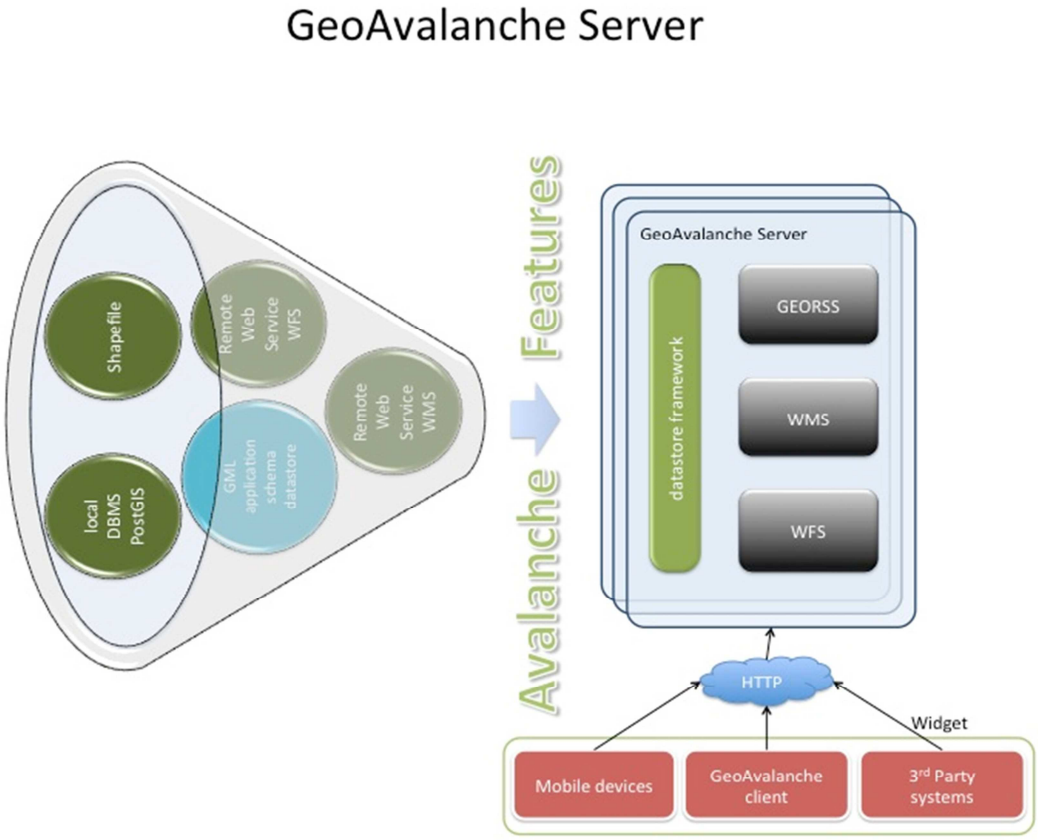
2.3 GeoAvalanche Server

GeoAvalanche server is built upon a core GeoServer module equipped with its plugin for supporting third-party GML application schemas. This latter capability allows to serving complex snow avalanche features encoded by CAAML. The project is developed under GNU General Public License as published by the Free Software Foundation, the same of the core module.

2.3.1 GeoServer

GeoServer [GeoServer] is an open source geospatial web service implementation with an established user base and an international developer community. GeoServer is written in Java and is built on the GeoTools library [GeoTools]. GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) standard and also supports OGC Web Map Service (WMS) as well. WFS is of particular interest for data interoperability because, unlike a portrayal service such as WMS, it allows direct querying of

the underlying data.
GeoServer is a powerful geospatial engine, which is capable to aggregating different datastores in one single point and letting them republished as cascaded Web Services from distributed sources, which includes also remote WFS as depicted in the figure below.



Since the support for GML 3.2.1 is ready yet then subsequently GeoAvalanche can be potentially complaint with the INSPIRE Directive, which requires to issue WFS service conforming to the GML version above.

2.3.2 Snow avalanches application schema support

GML application schemas can represent indiscriminately complex information models such as CAAML for snow avalanches. GeoServer application schema support is applicable to the snow avalanches model because of being a spatially described information that is represented in complex features expressed as GML 3.2.1 application schema profile.
It is currently maintained as standard GeoServer plugin, which makes use of the simple feature access provided by GeoTools and converts each of them, retrieved as database tables, into complex features by using mapping rules.
Because a single `caaml:Bulletin` can be observed at several distinct locations on the Earth's surface, it can have a multivalued `caaml:bulletinResultsOf` property, each being

a *caaml:BulletinMeasurements*. The resulting mapping would be as follows:

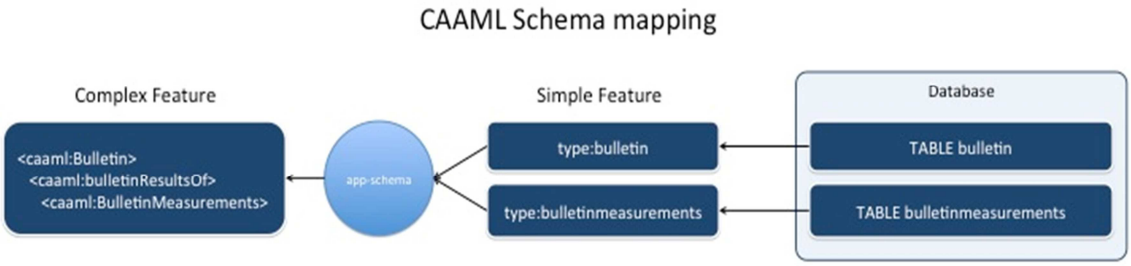


Figure 4 Simple feature mapping of the CAAML complex feature

GeoAvalanche deployments include also a spatial DBMS such as PostGIS to supplement GIS functionalities for CAAML complex features and hence they become together a good fit for all those features that you might expect from an SDI.
The GeoAvalanche component within a CAAML data infrastructure becomes a key role because it manages both of reading and writing operations regardless of the database schema used to store the data. It can perform WFS filter queries and acts also accordingly to OGC WFS-T transactional specification because each single service has been conformed to the same CAAML application schema.

2.3.3 Spatial Data Infrastructure

Interoperability is the first stage to a Spatial Data Infrastructure where distributed observation centers and central avalanche services can mutually exchange these data with a common semantic structure.
GeoAvalanche server leaves a large flexibility to building a nationwide network of regional AWS departments, which are endorsed centrally by the relevant authority because of their interoperable standardization and hence can contribute to share their locally nowcasting and forecasting products.
The relevance of this methodology resides above all on its deep nature of openness by taking on the most important geospatial standards.
As a result a proposal for a preliminary European CAAML Spatial Data Infrastructure has been issued as shown in the figure below.

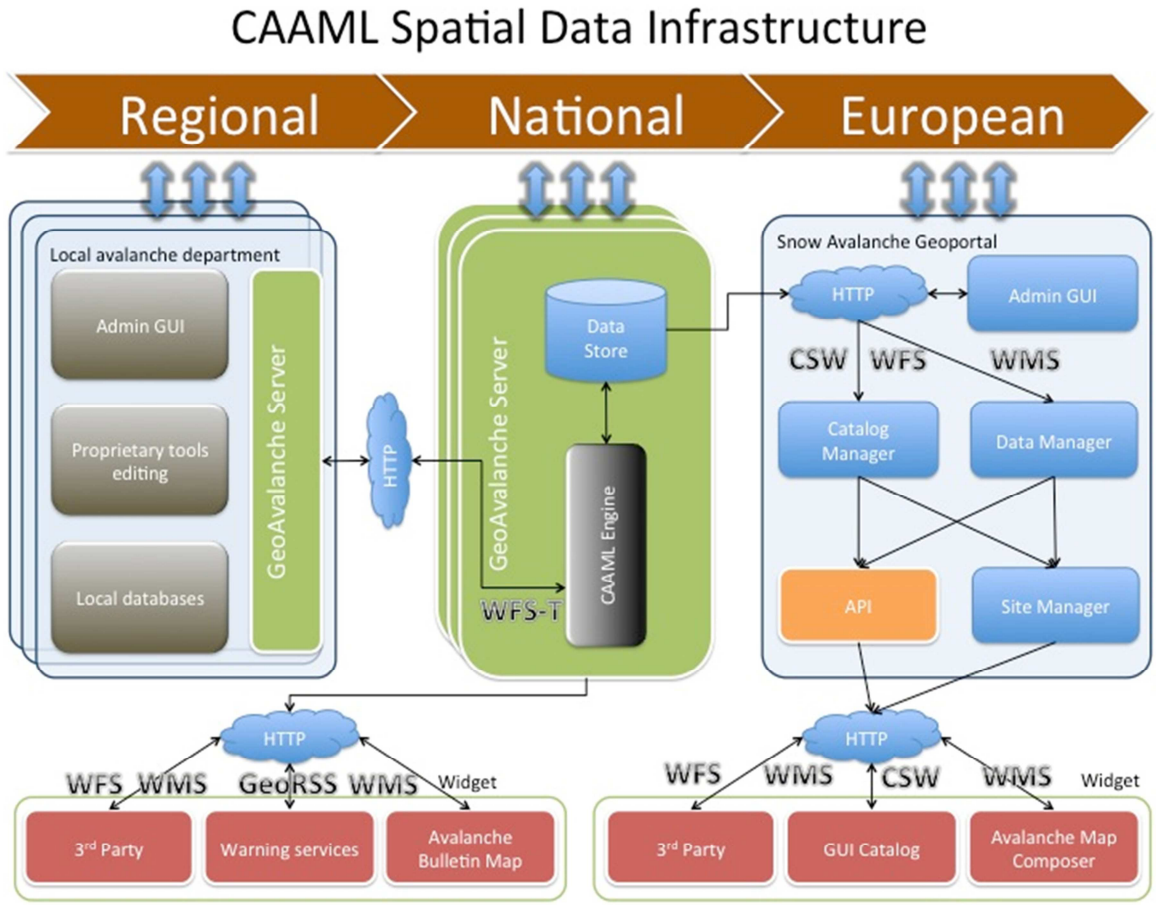


Figure 5 Proposal for an European snow avalanches Spatial Data Infrastructure

3. RESULTS AND CONCLUSIONS

The development of a Spatial Data Infrastucture shared among European Avalanche Warning Services (and other possible stakeholders), based on Geoavalanche, will assure data sharing, interoperability, and better information of nowcasting and forecasting.
From an application point of view the use of GeoAvalanche WFS services would achieve an interoperable network, either among European AWS or making regional observation offices linked to a central repository, and further leverage new improvements to develop innovative services of early warning systems, which take into account the safety of backcountry tourists.
The system has been easily prototyped and tested to focusing on a simply CAAML datastore to effectively demonstrate the feasibility of such an experimental SDI even if the overall results have to be validated locally against a real environment so as to collect centrally, at a national avalanche agency, data from distributed sources and then publish avalanche bulletin maps of selected regions.
The proposed solution would be capable to achieve:

- At European level, a snow avalanches geoportal, which collects data, from each member states and represents the contribution to define natural risk zone in INSPIRE;
- At National level, a geospatial tool to provide avalanche bulletin maps, value added location-based services to mobile users such as alerts and finally a complement for resource management by taking into account the snow water equivalent;
- At Regional level, a measure to supplement the observations collected from the ground in a format easily shared and commonly agreed that it is useful to a single national container for such information.

4. FUTURE WORKS

Despite the outcomes have confirmed the ability to exchange snow avalanche datasets with a standard common language, more challenges can be raised. The upcoming implementation of services, which requires compliance with the INSPIRE data themes, actually needs to be investigated further and a schema transformation for CAAML datasets defined.
Furthermore interoperability has to be complemented by catalogue functionalities in such a way as to offer search capabilities on avalanche metadata and thus improve the impact on the user experience.
Therefore future works will be focused on achieving Catalogue Service for the Web (CSW), which will enable extended WMS configuration for serving relevant WMS 1.3 bulletin alerts to map visualization services INSPIRE conformed.

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BIOGRAPHICAL NOTES

Francesco Bartoli is Chief Technical Officer and Founder at GeoBeyond Srl, a firm that aims at achieving innovation technology and strategic consultancy into geographic information system (GIS) and spatial data infrastructure (SDI).
He was graduated from "Tor Vergata" University of Rome in 2003 with Electronics Engineering M.Sc. degree and has extensively experienced design and implementation of Web architecture on managing with geospatial solutions in the telco, infomobility, space and defense industries.
He acts as OGC Standards and EU Inspire Directive Advisor to assisting business programs at largest extent of interoperability and common EU regulations compliance.
He has also acquired proficiency and expertise as security consultant with Identity and Access management solutions for large organizations and governments to endorse Web Single Sign-On best practice and secure information.
He is currently deputed as GIS expert to handle national and european research projects at CATTID "La Sapienza" University of Rome.
He is also columnist at geomatic magazine "Rivista Geomedia" leading to his mastery of Open Source, Open Government and Open Data topics.

Carlo Maria Medaglia was born in Rome, Italy, in 1974, he had his degree in physics at University of Rome "La Sapienza", Rome in 1999. He got his PhD in Remote Sensing at the Engineering faculty of University of Rome "La Sapienza", Rome, Italy in 2004. He is professor of Human Computer Interaction at Mass Communication Department of University of Rome "La Sapienza" and Scientific Coordinator of CATTID (Centre for Television Applications and Distance Learning Techniques) of University of Rome "La Sapienza". His main academic research activities regard RFID, Geolocalization, satellite remote sensing and mobile/wireless communication. He has more than 80 contributions in peer-reviewed journal and conference proceedings.

CONTACTS

Ing. Francesco Bartoli
Geobeyond Srl
Via M.Augusta, 68
Vacone (RI)
ITALY
Tel. + 39 0746 676843

Fax + 39 0746 676843
Email: mailto:francesco.bartoli@geobeyond.it
Web site: http://www.geobeyond.it

Prof. Carlo Maria Medaglia
University La Sapienza of Rome – CATTID
Piazzale Aldo Moro, 5
Roma
ITALY
Tel. + 39 06 49910842
Fax + 39 06 4456696
Email: mailto:carlomaria.medaglia@uniroma1.it
Web site: http://www.cattid.uniroma1.it