SYNOPSIS, AN INNOVATIVE PLATFORM SUPPORTING AVALANCHE HAZARD FORECASTING IN FRANCE

C. Coléou[1]*, H. Merzisen[1], C. Gendre[1], Y. Danielou[1], J.-M. Willemet[1], F. Marty[2], A. Lasserre-Bigorry[2], S. Morin[1]

[1]Météo-France – CNRS, CNRM UMR 3589, CEN, Grenoble, France
[2]Météo-France, Toulouse, France

ABSTRACT: For more than 30 years, Météo-France has developed software which integrates a broad diversity of information for the daily operations of avalanche forecasters. Initially designed to renew the tools used for the meteorological forecasting activities of Météo-France, the Synopsis platform has also been developed to account for the specific needs and requirements of avalanche hazard forecasting. Synopsis can directly be used by local observers to register the observations, which are validated in real time by avalanche forecasters before entering the operational databases used by the operational chain of models. Beyond visualization of observed and simulated snow information (including snowpack profiles), Synopsis makes it possible to overlay snowpack model outputs directly onto complementary meteorological geospatial layers (e.g. radar observations, output of numerical weather prediction models). In addition, this allows extending the reach of tools initially devoted to snowpack monitoring and prediction to a wider audience of meteorological forecasters, making it possible to better address snow-related issues including hydrological hazards. Here we provide an overview of the principles and functioning of Synopsis with a focus on its snow and avalanches component, along with illustrations of the combined use of snow and meteorological information during the winter seasons 2014-2015 and 2015-2016 and its impact on the workflow of avalanche forecasters.

KEYWORDS: avalanche forecast, operational workstation.

1. INTRODUCTION

Avalanche hazard forecasting requires the simultaneous use of various data types and sources. This concerns primarily in-situ snow and meteorological observations carried out by observers in ski-resorts and the avalanche forecasters themselves, automated observations from snow and meteorological monitoring networks and remotely sensed information. Meteorological forecast, and the output of numerical simulations of current and future snow conditions, further inform the forecaster about the current avalanche hazard conditions and their likely unfolding for the forthcoming hours to days. In some cases, in particular under severe weather conditions, having all the necessary and regularly updated data at hand can make a significant difference for the efficiency of the forecaster workflow. For more than thirty years, Météo-France has developed software which integrates such a broad diversity of information for the daily operations of avalanche forecasters and the production of the bulletins. Since 2006, access to the results of the dedicated chain of models SAFRAN – Crocus – MEPRA (SCM) has been provided through the operational software “Poste Nivologie” (Dumas et al., 2006). More recently, and initially defined to meet the needs of the meteorological forecasting activities of Météo-France, the Synopsis platform has been from its early stages in 2011 developed to account for the specific needs and requirements of avalanche hazard forecasting. It is currently used by meteorological center forecasters everywhere in France, in particular in the 8 local forecasting centers in charge of the daily production of the avalanche bulletins. Furthermore, Synopsis is able to be directly used by in-situ observers to register the observations, which are validated in real time by avalanche forecasters before entering the operational databases used by the operational chain of models. The integration of tools dedicated to snow monitoring and avalanche hazard forecasting in Synopsis has allowed two main improvements. In particular it makes it possible to overlay S2M outputs directly onto complementary meteorological geospatial layers

* *Corresponding author address:*
C. Coléou, Météo-France Centre d’Etudes de la Neige, 1441 rue de la piscine, 38400 St Martin d’Hères, France ; email: cecile.coleou@meteo.fr

(radar observations, output of numerical weather prediction models). In addition, this allows extending the reach of tools initially devoted to snowpack monitoring and prediction to a wider audience of meteorological forecasters (at the national, regional and local scale). This ensures a stronger integration of issues related to snow in mountain areas (including hydrological hazards such as rain-on-snow or intense snow melt events) together with more general meteorological forecasting activities at Météo-France. Here we provide an overview of the functioning of Synopsis with a focus on its snow and avalanches component, along with illustrations of the combined use of snow and meteorological information during the winter seasons 2014-2015 and 2015-2016 in the French mountain regions and the impact of this new tool on the evolution of the workflow of avalanche forecasting activities.

2. SYNOPSIS FUNDAMENTALS

Synopsis is a joint Météo-France / Météo-France International project aiming at producing a new workstation for meteorological forecasters, developed in the form of interoperable services (SOA). It builds on several functional and technical principles.

2.1 Functional principles

The main functional principles of Synopsis are provided below:

1) Interoperability

2) Zooming & panning free of geographic area (GIS functionalities)

3) Adaptive User Interface

4) Customizable GUI

5) Continuous link between past and future data (seamless approach)

Beyond, these principles, the Synopsis user experience heavily relies on the development and sharing of macros, which can be adjusted for specific uses or types of situations.

2.2 Technical principles

The main technical principles of Synopsis are provided below :

1) « OGC » Rules and SOA (Service-Oriented Architecture)

2) Multi-platform GUI and automatic deployment

3) Flexible architecture server

4) Horizontal Scalability and high performance

5) Dynamic adaptation to the data flow

Thanks to recent increase of internet speed, the Synopsis servers are centralized in Toulouse (Météo-France technical headquarters) and various technical options are available to access the data depending on the location of the client (inside or outside the Météo-France secured network). This differs markedly form the “Poste Nivologie” approach which relied on local implementation of some of the components.

2.3 Development strategy and training

Synopsis was developed based on users need, including snow avalanche forecasters. The group of users expresses requests for improvements or bug fixes, and pending approval by the project management the development teams implement the requested evolutions. This dynamic process ensures that development focuses on the most critical tasks that the software needs to achieve, and engages the users in the development process, thereby facilitating the transition to the new tool or during Synopsis upgrades. Furthermore, the training has partly been carried out by the group of forecasters responsible for functional specifications.

3. FEATURES FOR SNOWPACK MONITORING AND FORECASTING

Beyond the traditional data visualizations developed for meteorological applications (radar maps, in-situ observations, output of numerical weather prediction (NWP) models, satellite observations), specific visualization components and software features have been developed specifically for the use of the avalanche forecasters, and are briefly outlined below.

3.1 Registration of observation data

Snow and meteorological observations are carried out twice daily in the wintertime by trained ski patrollers, and approximately once weekly they also provide snow profile data. This data was hitherto mostly gathered by phone or fax by the avalanche forecasters and manually typed into operational databases. The possibility to directly register observations from observations sites was long awaited but challenging in many respects. Indeed, given that these observations are to be used by in the data assimilation step of snowpack modeling, they need to be checked

and validated by forecasters. Henceforth, Synopsis was designed to make it possible to register observations at the observation site (mostly ski resorts) and validated by the forecasters, which saves time both on the observer and forecaster sides although direct contact (mostly by phone) can still occur under critical information. In addition, through the Synopsis platform accessible to observers, it is possible for them to visualize observations performed by neighboring resorts, which increases the awareness level of the general snow conditions around each participating ski resort.

3.2 Snowpack numerical simulation

The Synopsis tool was designed to handle and plot information from the SAFRAN – SURFEX/ISBA-Crocus – MEPRA (S2M) model chain, providing past and forecast information about the mountain snowpack including lower-lying mountainous areas (Jura, Vosges and Massif Central) not accounted for in the previous version of the SAFRAN – Crocus – MEPRA (SCM) model chain (Lafaysse et al., 2013). S2M operates at the scale of "massifs", within which meteorological and snow properties vary depending on time (1h resolution for meteorological data, 3h resolution for snowpack data), altitude (by steps of 300m), orientation (flat, N, NW, W, SW, S, SE, E, NE) and slope (20 and 40°). In addition, a dedicated configuration is used to match the topographic configuration of observation sites (manual and automatic) making it easier to visualize the deviation between model estimates and in-situ observations. Four model runs are performed every day, in analysis (past day) and forecast (next two days) mode, which allows regularly updating observation and large scale meteorological forecast datasets used as input to S2M.

3.3 Data visualization

Similarly to the way Synopsis handles meteorological information (in particular from numerical weather prediction models, radar maps and in-situ observations), Synopsis makes it possible to scroll into the past and future in a seamless manner, using a set of predefined rules to visualize by default the "best dataset" within limits of all available data. It is however possible to force the visualization of a specific forecast time if need be. The data which can be displayed are accessible via a data-catalogue which intuitively guides the user towards the available data for each representation (map, time series, profile etc.). Regarding specific snow information, Synopsis makes it possible to visualize observed and simulated snow profiles, maps of massif-scale information (including aspect variations), pie-like plots representing scalar information for a given massif, and time series of snow and meteorological information at observation locations and for each massif/altitude/aspect/slope configuration. Examples of such data visualizations or provided throughout the examples given below.

3.4 Registration of assessed data

The Synopsis tool was further designed to allow the forecaster to register two types of manually assessed data, i.e. on the one hand snow depth and thickness of freshly fallen snow at a given altitude, and on the other hand avalanche hazard level for each massif. The latter is performed using the Bavarian Matrix, i.e. for each massif the forecaster needs to estimates the avalanche hazard scenario relevant to accidental triggering and spontaneous release (Fig. 1). The information recorded through Synopsis can be visualized for all the massifs, which makes it possible for forecasters working on neighboring massifs to know what has been assessed. Sharing information could be sometimes helpful to homogenize the danger level assessment from neighboring massifs, originating from different danger assessments for different forecasters. The information recorded through Synopsis is directly used by the bulletin editor. Furthermore, the assessed data for snow depth, freshly fallen snow depth and danger level flows through the Météo-France information system and is used to feed various portal and outlets (web site, mobile apps etc.).

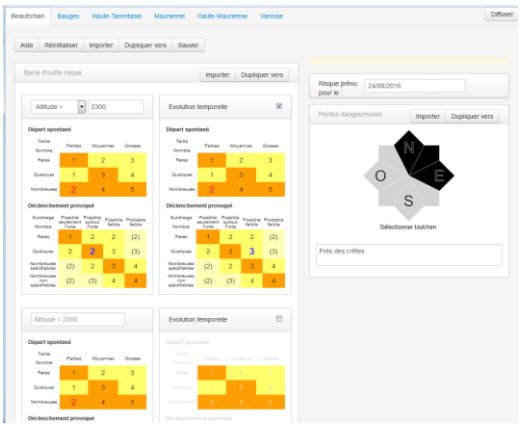

Fig. 1 : User input interface for entering avalanche danger level estimated by the forecaster.

4. EXAMPLES

Some examples below illustrate the interest to be able to cross information of different sources on the same working support however, these few printed illustrations are far from describing the numerous functionalities and the efficiency of the User Interface. An asset of Synopsis, essential for an operational use, is actually the speed of display. It usually takes a few seconds for a first requested visualization. The uses of cache memory speeds up the display time for images previously requested, so the temporal animations are most often fluid.

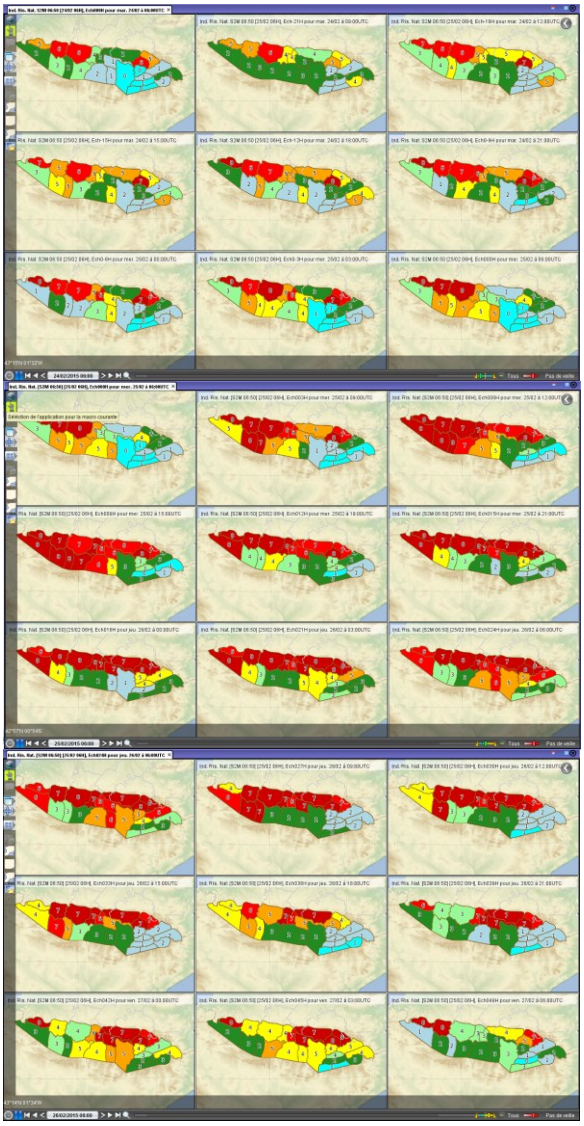

Fig 2 : S2M spontaneous release index assessment from 2015/02/24 6h to 2015/02/27 6h by steps of 3h.

4.1 Example 1 Pyrenees February 2015

From 21 to 27 February 2015, precipitation associated with a varying rain-snow limit occurred almost every day on the French Pyrenees. The total amount of precipitation reached in some places more than 200 mm. In such situation, the main challenge faced by the avalanche forecaster to address the expectations of the local risk managers and population is an accurate anticipation of the most critical period and a good estimation of the settlement and stabilisation of the recent snow is needed. The S2M index for spontaneous release assessment (Martin et al., 2001) provides synthetic information for each massif. Multi-map visualisation (Fig. 2) outlines the chronology of the situation and the rapid stabilisation after the end of the precipitation event.

The possibility of overlaying (Fig. 3) eases the comparison between the meteorological data use in the modelling chain S2M, adapted at the massif scale, and the more detailed information from the meteorological models.

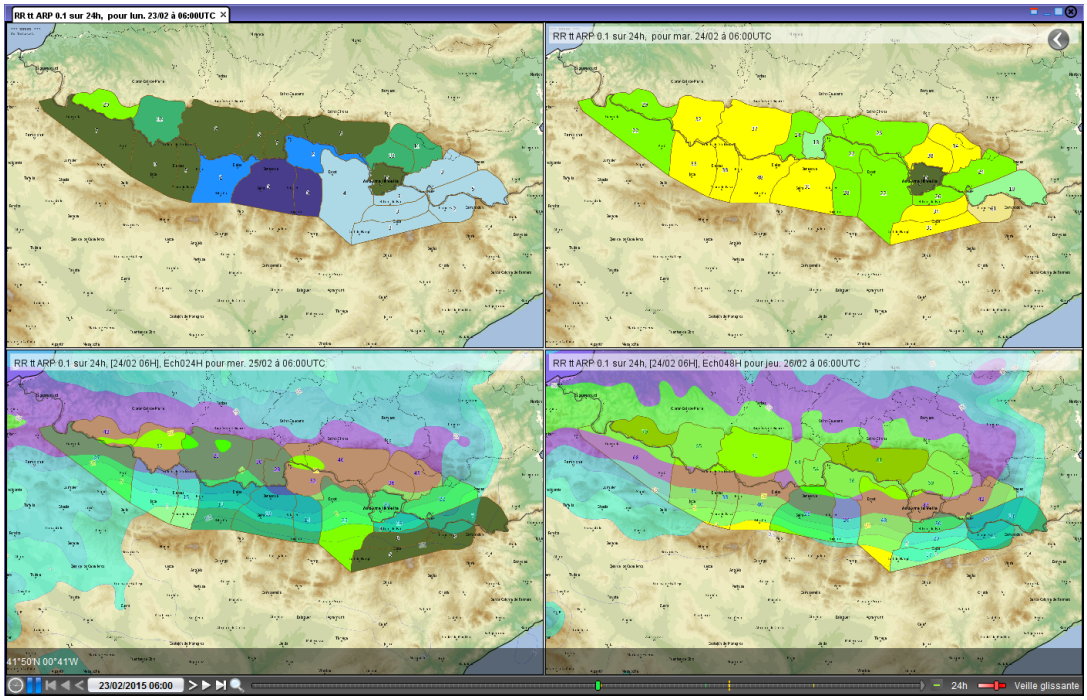

Fig. 3 (right) : Amount of precipitation in 24h on the Pyrenees massifs. Safran Analysis for the past 2 days (top) overlayed by Arpege NWP model forecast for the next 2 days (bottom).

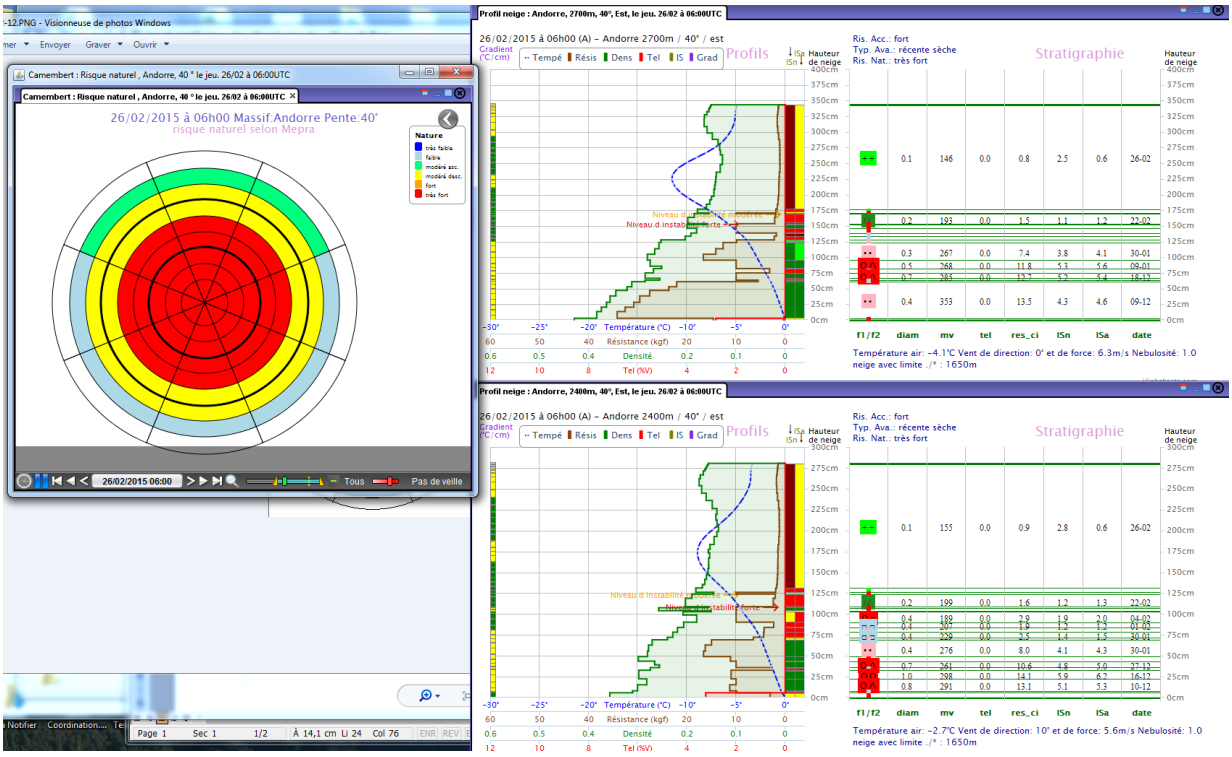

Fig. 4 : S2M natural risk assessment and two detailed snow profiles.

Figure 4 shows snow pies and vertical profiles. A snow pie is a virtual representation of the massif. At a requested time it provides information on the spatial repartition (altitude/aspect) within the massif and also provides access to the more detailed information of the simulated snow profiles or display the visualisations in an animated time sequence.

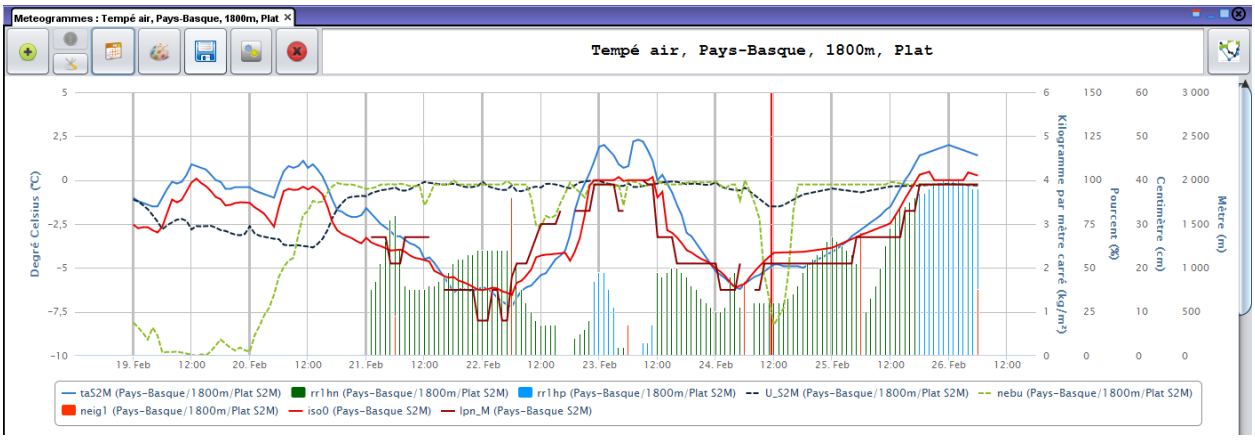

Fig. 5 : Time serie of S2M output for a massif/altitude from 2015/02/19 6h to 2015/02/26 6h. Temperature, precipitation (intensity and phase), amount of snow in 24h, altitude of the rain-snow limit and altitude of the 0°C isotherm. The red vertical line represents the limit between past and future.

Time-series of the analysed and forecasted parameters from S2M simulations (Fig. 5) at a given altitude are suited to report the succession of snow and rain periods.

4.2 Example 2 Southern Alps March 2016

Early in March 2016, an intense one but a brief snowy episode crossed the Southern Alps. The amount of precipitation reached around 100 mm in less than 12 hours with a rain-snow limit that maintained at altitude below 900 meters as shown on the temperature and precipitation time series of the automatic weather station of Tende (Fig. 6).

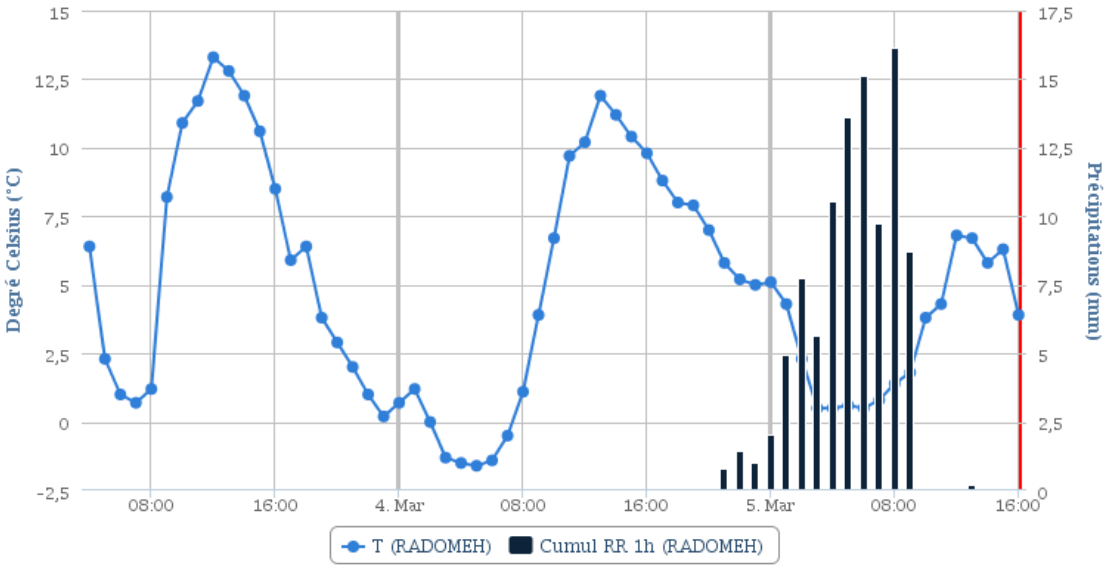

Fig. 6 : Temperature and rainfall records at Tende (645 m.).

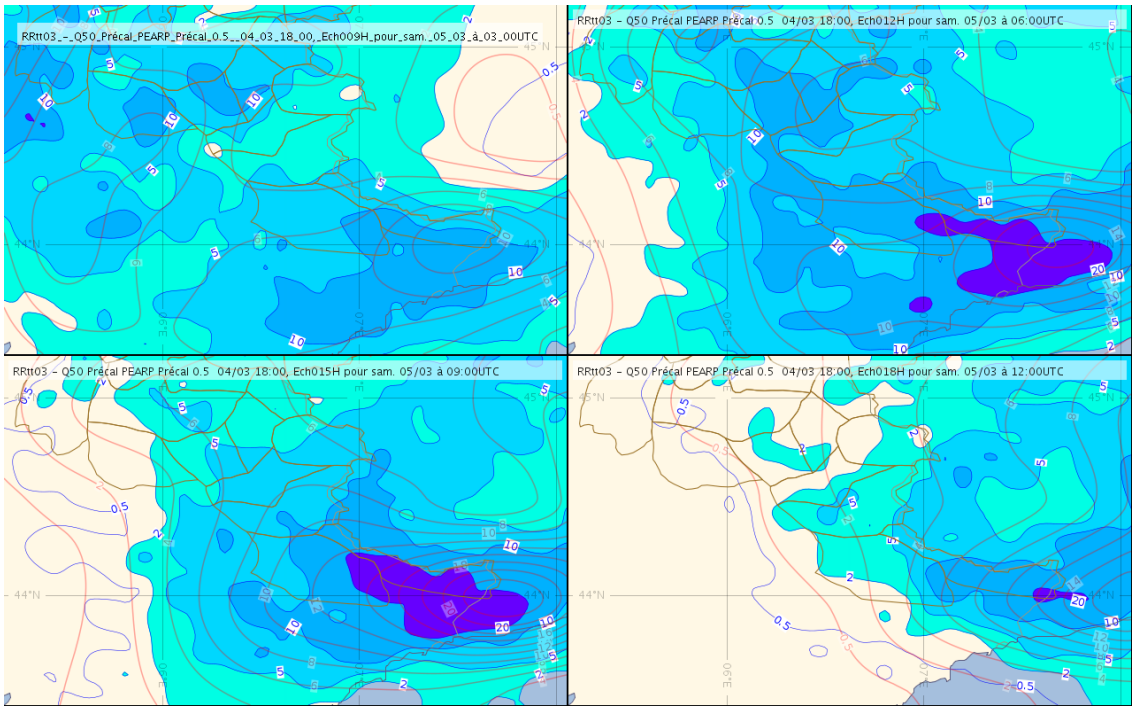

Fig 7 : Results from ensemble prediction of Arpege NWP model. Precipitation in 3 hours, 50% and 80% quantiles.

The access through Synopsis of results from ensemble NWP outputs provides information on the uncertainties of the forecasts (Figure 7).

Overlaying of the various sources of simulated and observed precipitation (Fig. 8), e.g. spot measurements from surface weather stations, estimation from radar returns, results from S2M or numerical weather forecast models, offers the possibility to a better real-time follow up of the situation. A layer pane allows easy changes of the look of the display such as layer order (Fig. 8), transparency, adding a new layer …

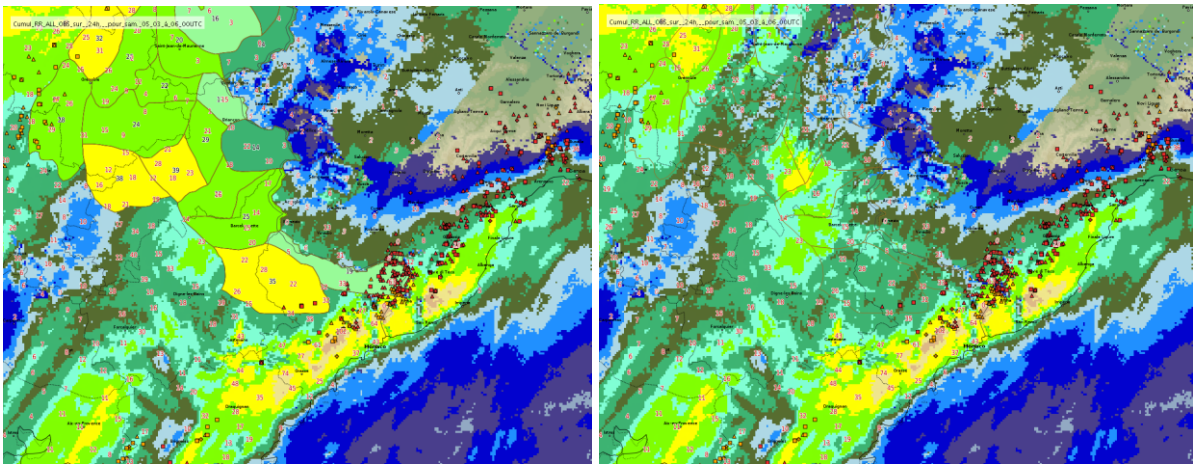

Fig 8 : Amount of precipitation in 24h. Overlaying of measurements, radar, S2M estimation and location of lightning stroke.

Customizable additional features facilitate the work of the forecaster. The possibility of prerecording visualisations in the form of macro allows for example during the taking of service every user to display ones favourite environment with the last data available on the opening of its session. An alarm system is also available to be informed about new events such as the overtaking of thresholds on selected parameters. Furthermore, Synopsis allows every user to personalize its interface and to keep its preferences.

CONCLUSIONS AND OUTLOOK

The Synopsis software was recently developed as the main workstation for Météo-France weather and avalanche forecasters. It thus includes all the requirements needed to visualize and use state-of-the-art snow and meteorological observations, numerical model analyses and forecasts, and register the corresponding assessments (e.g. avalanche danger level). Several improvements are planned for the next winter seasons, including additional model output visualizations and extension to access information from past winter seasons. The modular structure of Synopsis makes it possible to add more real-time data to the system, including for example the output of the ensemble prediction version of S2M (Vernay et al., 2015) or currently developed high resolution model configurations (e.g. Queno et al., 2016, Vionnet et al., in press). The main challenge will then most probably concern the ability to provide to the forecasters the “right” amount of information, which can be readily used without overflowing them with scientifically accurate yet impractical data.

ACKNOWLEDGEMENTS

We would like to acknowledge the broader Synopsis development team, the group of users who has provided specifications and contributed to the testing of the software, and people involved in running the software operationally and providing data visualized by the software (in particular the S2M model chain which has been deployed simultaneously to Synopsis).

REFERENCES

Dumas, J.-L., Y. Danielou, C. Gendre, G. Giraud and E. Pougatch 2006: the French nivological workstation - an integrated software for regional snow data analysis, Proceedings of the *2006 International Snow Science Workshop*, Telluride, Colorado.

Quéno, L., Vionnet, V., Dombrowski-Etchevers, I., Lafaysse, M., Dumont, M., and Karbou, F., 2016: Snowpack modelling in the Pyrenees driven by kilometric-resolution meteorological forecasts, *The Cryosphere*, 10, 1571-1589, doi:10.5194/tc-10-1571-2016.

Lafaysse, M., S. Morin, C. Coléou, M. Vernay, D. Serça, F. Besson, J.-M. Willemet, G. Giraud and Y. Durand, 2013: Towards a new chain of models for avalanche hazard forecasting in French mountain ranges, including low altitude mountains, Proceedings of the *2013 International Snow Science Workshop*, Grenoble - Chamonix Mont-Blanc, France.

Lasserre-Bigorry, A., Marty F. and Nicolau J., 2011. French forecasters workstation. Synergie-next: Synopsis project 27th Conference on Interactive Information Processing Systems (IIPS)

Martin, E., Giraud, G., Lejeune, Y., Boudart, G., 2001. Impact of climate change on avalanche hazard. *Annals of Glaciology* 32, 163–167.

Vandeputte H. and Marchand L. Synergie-Web: Synopsis Project. 26th EGOWS 2015, Reading.

Vernay, M., M. Lafaysse, L. Mérindol, G. Giraud and S. Morin, 2015: Ensemble forecasting of snowpack conditions and avalanche hazard, *Cold Reg. Sci. Technol.*, 120, 251-262, doi:10.1016/j.coldregions.2015.04.010.

Vionnet V., Dombrowski-Etchevers I., Lafaysse M., Quéno L., Seity Y., and Bazile, E., in press : Numerical weather forecasts at kilometer scale in the French Alps : evaluation and applications for snowpack modelling, *J. Hydrometeor*.