Road Weather Predictions Produced by MetGIS

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ABSTRACT

MetGIS is a new, Java-based, combined **Met**eorological and **G**eographic **I**nformation **S**ystem, with a specific emphasis on snow and mountain weather. This constantly upgraded prediction scheme has been developed within the framework of interdisciplinary international research projects. A principal focus of the system is the automated production of high-resolution, downscaled forecast maps of meteorological parameters like temperature, fresh snow amounts and the snow limit to support wintry road maintenance operations. Since the beginning of 2007, these maps are accessible to traffic operation centers via an easy-to-use, partly password-protected web interface (http://www.univie.ac.at/AMK/metgis), constructed in collaboration with Austrian highway authorities.
The geographic part of the system includes topographies relying on data bases such as SRTM (Shuttle Radar Topographic Mission) and representations of roads, rivers, railway lines, political borders and cities. On top of these, partly linked to terrain features, down-scaled meteorological information can be visualized in a variety of display styles. Meteorological forecast data of any numerical model can be used as a starting point for the downscaling procedures, provided the model output is present in form of NetCDF or GrADS-compatible formats. Currently the real-time output of the GFS (Global Forecast System of the US National Weather Service) is used as a base for MetGIS forecasts.
MetGIS is already in its current state a very helpful support tool for traffic operation managers. However, future upgrades may further improve the quality of the system. Possible ameliorations are the inclusion of road weather sensors and the output of point and line forecasts in addition to area forecasts.

Keywords: RWIS, GIS, downscaling, snow forecast, web-based GUI

1. INTRODUCTION

Many of the various currently used road weather forecast systems deliver quite reasonable support for highway maintenance engineers over flat of slightly hilly terrain, but are marked by severe quality problems over mountainous sections of highways. This is partly due to the fact that operational numerical weather forecast models still operate with grid point distances way too large to be able to cope with small scale variations of meteorological parameters as frequently observed over dissected terrain. In order to refine the forecast of these numerical models, a variety of statistical and dynamical downscaling methods have been developed [9]. However, many of these are still not suitable for operational application, and those who are normally do not take full advantage of the huge potential which the connection of the forecast model output with high-resolution terrain data bases may offer.
In an attempt to encounter the above depicted problem and to set the base for the successful development and application of meteorological downscaling algorithms based on high resolution topography, MetGIS ([13],[15-17]) has been created.

2. DEVELOPMENT OF METGIS

MetGIS was constructed having the latest techniques of software engineering ([3],[4]) and basics of geographic information systems ([2],[5]) in mind, using Java-based object-oriented approaches [8] and some graphics libraries employed in the construction of the successful snow cover visualization software SN_GUI [12]. Some basic ideas of MetGIS were inspired from the now outdated, but methodically interesting PC-based WeatherPro (formerly WELS) weather prediction scheme ([10],[11],[19],[22]).

The system is special in a way that meteorological mesoscale forecast data are downscaled to the points of high-resolution topographic databases, and subsequently stored in a format exactly the same as that of the terrain data. This allows performing complex transactions in which both meteorological and topographic data are involved.
From the start of the system development process, collaboration with international meteorological organizations and atmospheric research institutes has been established (for details, see [13]). This was to take advantage of the specific expertise of these institutions, to tune the emerging system with different sorts of geographic and meteorological data, and to facilitate a future international, wide-spread application of the system. Prototypes of MetGIS have successfully been operated with test data sets for specifically interesting meteorological situations over Japan and South America ([14],[18]).

3. COMPONENTS OF METGIS

3.1 Structure Review

The basic structure of MetGIS is depicted in Fig. 1. Part of MetGIS is an independent Geographic Information System (GIS) which essentially has two functions: to support the forecast visualization modules with geographic background information, and to deliver very detailled topographic input to the downscaling module. The latter is also fed by external mesoscale forecast models and produces high-resolution meteorological forecast fields. These refined predictions can be visualized by a stand-alone Java GUI (Graphical User Interface) or a MetGIS Web Interface.

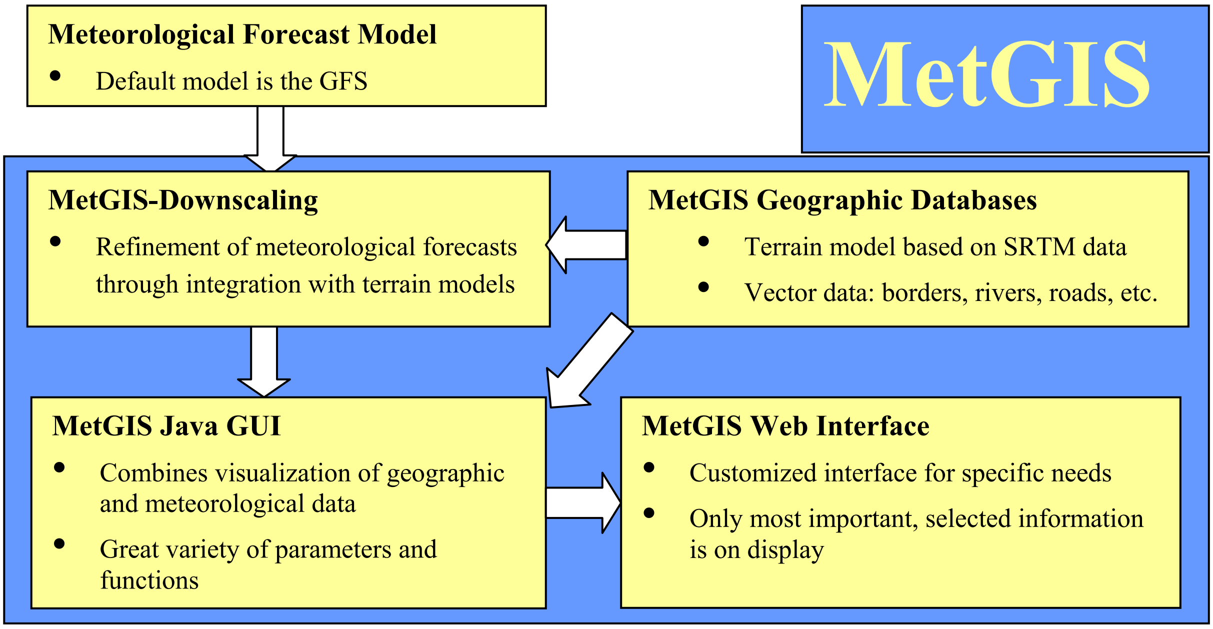

Fig. 1. Components of MetGIS.

3.2 The Meteorological Input Forecast Model

As depicted above, MetGIS is driven by the gridpoint output of atmospheric mesoscale forecast models, but operating these is not part of MetGIS proper. In the past the NMH (Non-Hydrostatic Model) of the Japan Meteorological Agency and a version of the MM5 model, operated by the University of Chile, have been used to launch MetGIS forecasts. However, operational MetGIS forecasts are currently calculated based on the output of the GFS (Global Forecast System) of the United States National Weather Service. Principally all numerical model output which is based on NetCDF and simple GrADS-compatible binary formats can be processed and refined by MetGIS; GRIB/GRIB2 formats are planned to follow in the near future.

3.3 Geographic Data Bases

This module is independent of commercial software such as ArcGIS and structured in the form of layers that can be selected for display independently of each other. This permits the individual or combined visualization of city positions, vector data information (the road system, rivers, railways and boundaries) and of various terrain characteristics (elevation, slope and azimuth) in different resolutions and color scales. Using map generalization

techniques, the detail of geographic information displayed is automatically adjusted when zooming or switching between differently sized domains. These can cover everything between entire mountain ranges and small areas of a few square kilometres.
Data coverage is currently fragmentary and restricted to Japan, Europe and parts of South America. However, the geographic databases are constantly upgraded in agreement with external demand.
Geographic data used by MetGIS stem from a variety of sources. Concerning topographic properties, the system relies on data of the Japanese Geographic Survey Institute (GSI) and the US Geological Survey. Data bases used from the latter include GTOPO30 (Global Topographic Data) and SRTM (Shuttle Radar Topographic Mission). The best horizontal terrain resolutions used are around 100m.

3.4 Downscaling

The downscaling module uses the high-resolution geographic information included in MetGIS to assess meteorological information for scales much smaller than those resolved by operational mesoscale models. For this, it relies on "VERA-style" techniques. VERA (Vienna Enhanced Resolution Analysis, [20-21]) incorporates an objective, automated downscaling and analysis approach for meteorological data over complex topography. The method includes the influence of the high-resolution topography on specific meteorological parameters in the form of so-called "fingerprints".

3.5 MetGIS Java GUI

The MetGIS Java GUI (see Fig. 2) is used to visualize and further manipulate the data delivered by the downscaling module. The Java GUI is the proper heart of MetGIS and a quite complex software package, composed of numerous individual Java classes and linked to a number of external software libraries. It may be used to deliver forecast maps for external web pages, but its current main task is to automatically feed the MetGIS Web Interface.

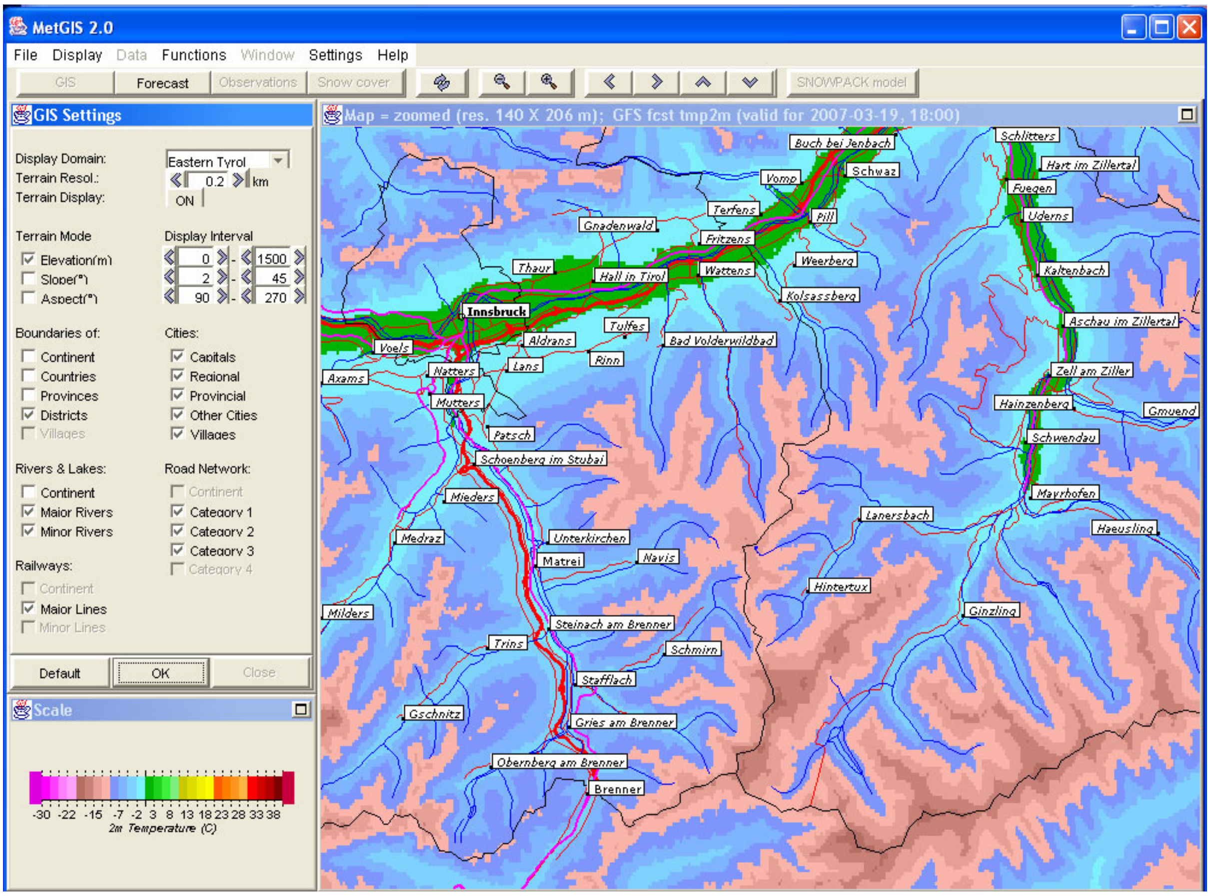

Fig. 2. Example of the MetGIS Java GUI, displaying an area forecast of the temperature 2 m above the ground for some mountain ranges and valleys southeast of Innsbruck, Austria. The horizontal resolution of the depicted prediction is 200 m. Green colors stand for temperatures above zero; check the color scale to the lower left. The upper left displays a steering window of the geographic information subsystem.

3.6 MetGIS Web Interface

The MetGIS web interface (http://univie.ac.at/amk/metgis/) is a highly simplified version of the MetGIS Java GUI. It has been designed as an easy-to-use tool for traffic operation managers who have only very limited knowledge of meteorological processes. It offers partly password-protected real-time access to MetGIS downscaled short-range forecasts in currently three languages (English, German and Spanish). A number of predefined forecast domains for various countries are available. Very detailed forecast information about some of the meteorological parameters most relevant for the work of traffic operation centers is offered, e.g. the spatial distribution of temperature, the form of precipitation (snow, sleet, rain; Fig. 3) and the depth of fresh snow (Fig. 4). The detailed terrain representation included in MetGIS allows for an easy detection of road sections above the snow line or the freezing level. Forecast fields can be displayed for specific times or in a time-lapse mode, and links to MetGIS sample forecasts for mountain regions around the world (Alps, Caucasus, Japanese Alps, Andes) can be clicked (see Fig. 5).

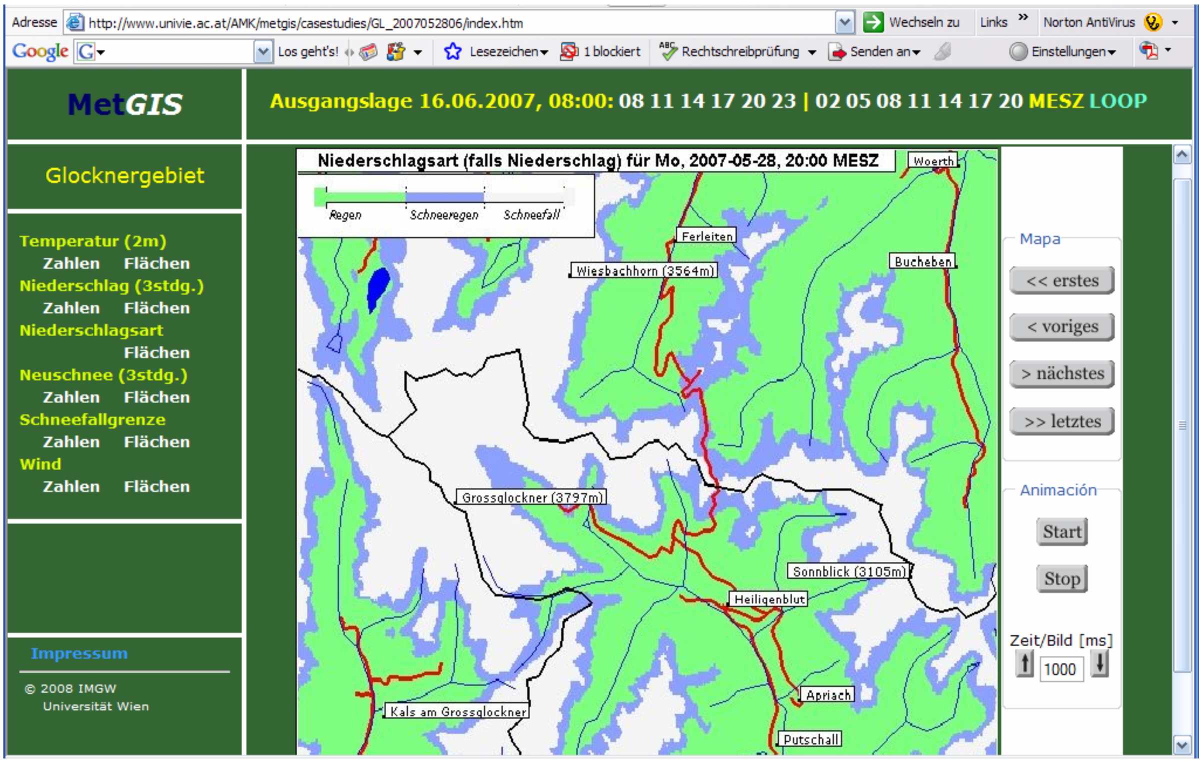

Fig. 3. Example of a MetGIS forecast of the mode of precipitation for a pass road near the highest mountain of Austria, visualized by the MetGIS Web Interface. For whitely-colored areas snow is expected, blue areas can expect sleet and in green areas precipitation is supposed to fall as rain.

4. REALTIME APPLICATION AND PRELIMINARY EXPERIENCES

Since the start of 2007 MetGIS forecasts are being calculated in realtime at the University of Vienna for various geographic regions, using four daily runs of the GFS model with a forecast range of 36 hours as the meteorological input. At first the system was operated in a test mode in close collaboration with Austrian highway authorities who were carefully checking the MetGIS predictions and judging their usefulness for their daily work. Their valuable comments lead to repeated improvements of various modules of MetGIS, modifying the system in a way that applied users from traffic operation centers can get an optimal benefit out of it.

Meanwhile MetGIS forecasts are used at a steadily increasing number of locations by traffic operation and avalanche control centers, also outside the Alpine region. Preliminary user feedback indicates that the quality of MetGIS forecasts is quite reasonable, although this has still to be quantified by means of a thorough verification study. Such a study is in a preparatory stage; it is planned to involve the observation and forecast data gathered during the 2007/08 winter season at a variety of locations.

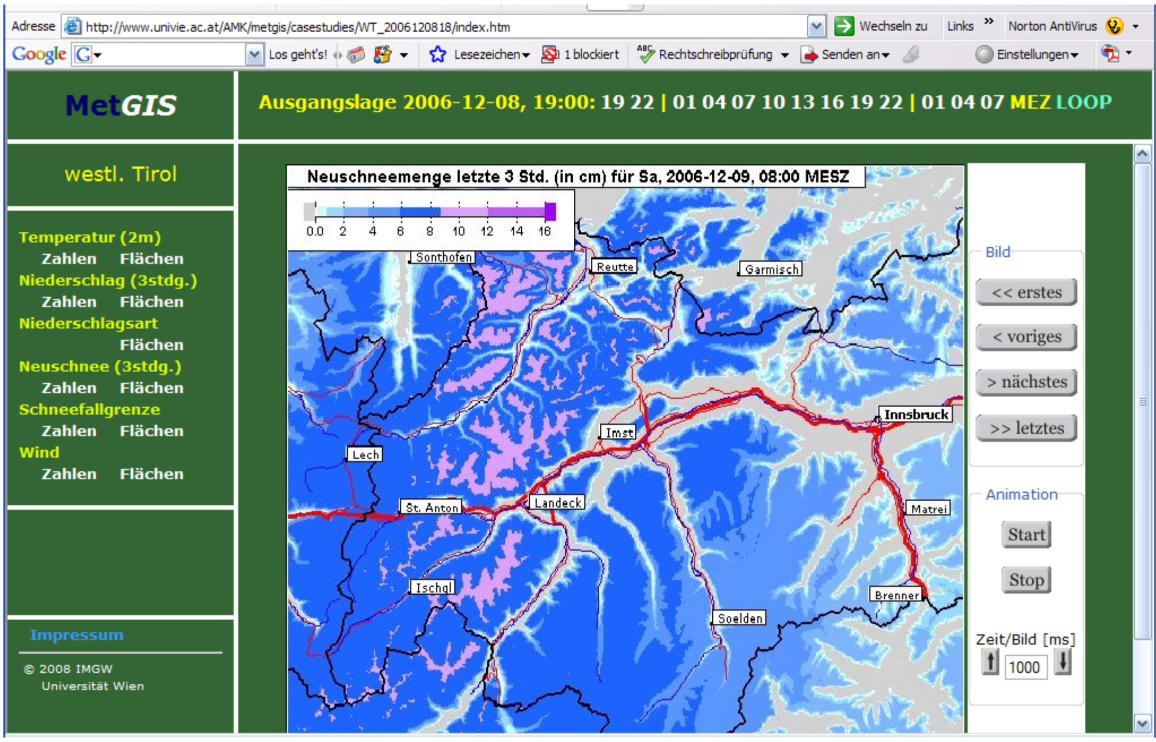

Fig. 4. MetGIS Web Interface, holding a sample forecast of 3-hourly amounts of fresh snow (in cm) for the western part of Tyrol. Check the color scale in the upper left of the forecast map.

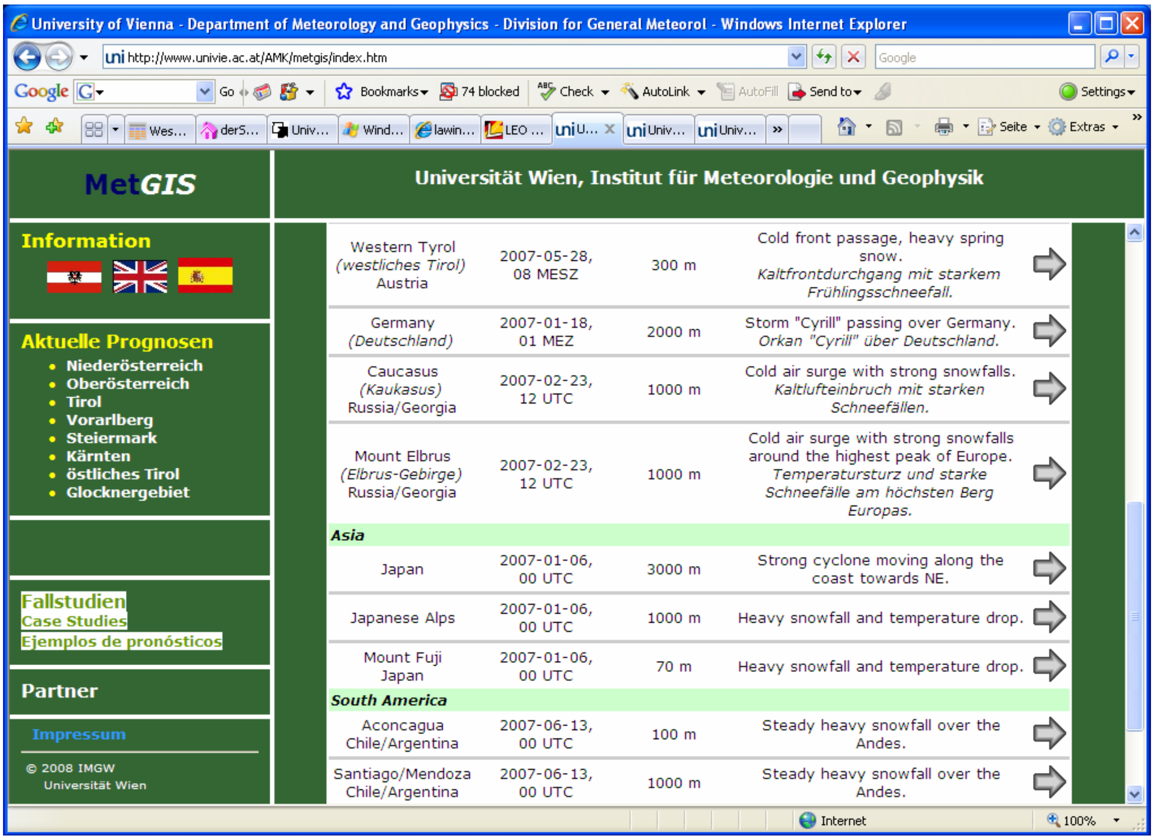

Fig. 5. Start page of the MetGIS Web Interface. MetGIS sample forecasts for a variety of regions can be screened.

5. CONCLUSIONS AND OUTLOOK

MetGIS has all the potential to be a valuable tool for traffic operation managers who want to organize the wintry road maintenance process as efficient as possible. It is a promising combination between geographic and meteorological information systems which produces terrain-adjusted meteorological forecasts in resolutions till now unknown in operational numerical prediction.

Due to the global coverage of GFS forecasts and the type of geographic data used, operational MetGIS predictions could be produced with relatively low effort for any mountain region of the world. If for specific regions higher-resolution atmospheric models are available, these can easily be integrated with MetGIS, since the meteorological model interface of MetGIS is quite flexible.

Further upgrades of MetGIS may include the usage of meteorological observation data (e.g. road weather sensors) for the purpose of forecast adjustment and fine-tuning, and the visualization of forecasts not only for areas, but also for individual points and along the extension of highways. Moreover, in the future specific parameters of the valley geometry, easily computed from the high-resolution terrain, might be used to meliorate the prediction of the height of the snow line. Energy balance models, assessing the system inherent terrain slope and orientation, may be used to meliorate the temperature forecast. A further option that can increase the power of MetGIS over Alpine terrain is the inclusion of snow cover characteristics via the inclusion of snow cover models such as SNOWPACK ([1],[6],[7]).

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