COMBINING METEOROLOGICAL AND GEOGRAPHIC INFORMATION SYSTEMS TO INCREASE THE CAPACITY OF ROAD WEATHER FORECASTS

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ABSTRACT

A new, Java-based downscaling approach related to road weather forecasting is presented. This technique is implemented through MetGIS, a combined Meteorological and Geographic Information System that puts a specific emphasis on snow and mountain weather. MetGIS has been developed within the framework of interdisciplinary international research projects with contributions from Austria, Switzerland, Japan, Peru, Chile, Argentina and the USA. A principal focus of the system is the automated production of high-resolution, down-scaled forecast maps of meteorological parameters to support wintry road maintenance operations. These maps are accessible to traffic operation centers via an easy-to-use web interface, constructed in collaboration with Austrian highway authorities. Meteorological information from any numerical mesoscale model can be down-scaled to horizontal resolutions of less than 100m. Currently the real-time output of the GFS-model of the US National Weather Service is used as a base for MetGIS forecasts. Displayed parameters include precipitation and fresh snow amounts, the snow limit, temperature, the mode of precipitation (snow, sleet, rain) and wind. The detailed terrain representation included in MetGIS allows for an easy detection of road sections above the snow line or the freezing level. Verification results are quite encouraging so far.

KEYWORDS

GIS / GUI / DOWNSCALING / SNOW FORECAST / MOUNTAIN WEATHER FORECAST

1. INTRODUCTION

High-resolution precise meteorological forecasts, in particular of snowfall, are of big importance for wintry road maintenance activities. Unfortunately, operational numerical mesoscale weather forecast models still operate with gridpoint 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 [8]. 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, a combined **Met**eorological and **G**eographic **I**nformation **S**ystem, has been created [11].

2. MILESTONES OF THE SYSTEM DEVELOPMENT

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 and some graphics libraries employed in the construction of the successful snow cover visualization software SN_GUI [10]. Some basic ideas of MetGIS were inspired from the now outdated, but methodically interesting PC-based WeatherPro (formerly WELS) weather prediction scheme ([9], [16]). 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 Table 1). 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 principals of the system. Prototypes of MetGIS have successfully been operated with test data sets for specifically interesting meteorological situations over Japan and South America ([12], [13]).

Table 1 - Contributions of international research institutions to the development of the system.

Research Institution	Country/City	Contribution/Achievement
Alden/WELS (Alden Electronics, Inc./WELS Research Corp.)	**USA** (Boulder, Colorado)	Some basic ideas about the combination between geographic information systems and meteorological forecasts
WSL/SLF (Swiss Federal Inst. for Forest, Snow and Landscape Res., Swiss Federal Inst. for Snow and Avalanche Research)	**Switzer-land** (Davos)	Java technology for GUI programming. Visualization of the output of snowpack models.
SENAMHI (Servicio Nacional de Meteorología e Hidrología)	**Peru** (Lima)	Start programming Java-based GIS. Tests of the prototype with a complete set of country-wide geographic vector data.
NIED/NISIS (National Research Institute for Earth Science and Disaster Prevention, Nagaoka Inst. for Snow and Ice Studies)	**Japan** (Nagaoka)	Continue GIS programming. Start programming interface for meteorological forecast models, using the NHM model.
CRICYT/IANIGLA (Centro Regional de Invest. Científicas y Tecnológicas, Inst. Argentino de Nivelogía y Glaciología)	**Argentinia** (Mendoza)	Inclusion of high resolution terrain data (SRTM, Shuttle Radar Topographic Mission).
DGF (Departamento de Geofísica, Universidad de Chile)	**Chile** (Santiago)	Integrate visualization of the output of the MM5 model for two domains covering the Andes range.
IMG (Institute of Meteorology and Geophysics, University of Vienna)	**Austria** (Vienna)	Construction of an operational forecast system. Inclusion of European forecast and terrain data.

3. STRUCTURE OF THE DOWNSCALING APPROACH

The basic structure of MetGIS is depicted in Fig. 1: The system is fed by the gridpoint output of meteorological mesoscale forecast models. Operating these models is not part of the MetGIS system proper. Currently the GFS (Global Forecast System) of the US National Weather Service is used, but any other numerical forecast model, delivering the output in common data formats like NetCDF and GRIB, might be utilized to drive MetGIS. In the past the NHM (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.

Integral part of MetGIS is an independent, purely Java-based Geographic Information System (GIS) which relies on data of the Shuttle Radar Topographic Mission (SRTM) with horizontal resolutions of up to 100m. The GIS essentially has two functions: to support the forecast visualization modules with geographic background information, and to deliver very detailed topographic input to the downscaling module. The latter, partly based on “VERA-style” techniques ([14], [15]), produces high-resolution meteorological forecast fields. These refined predictions can be visualized by two Graphical User Interfaces (GUIs). The complex, stand-alone MetGIS Java GUI (Fig. 2) can be operated in an automated mode to operationally produce forecast graphics that feed the MetGIS Web Interface (Fig. 3 and 4, see next section).

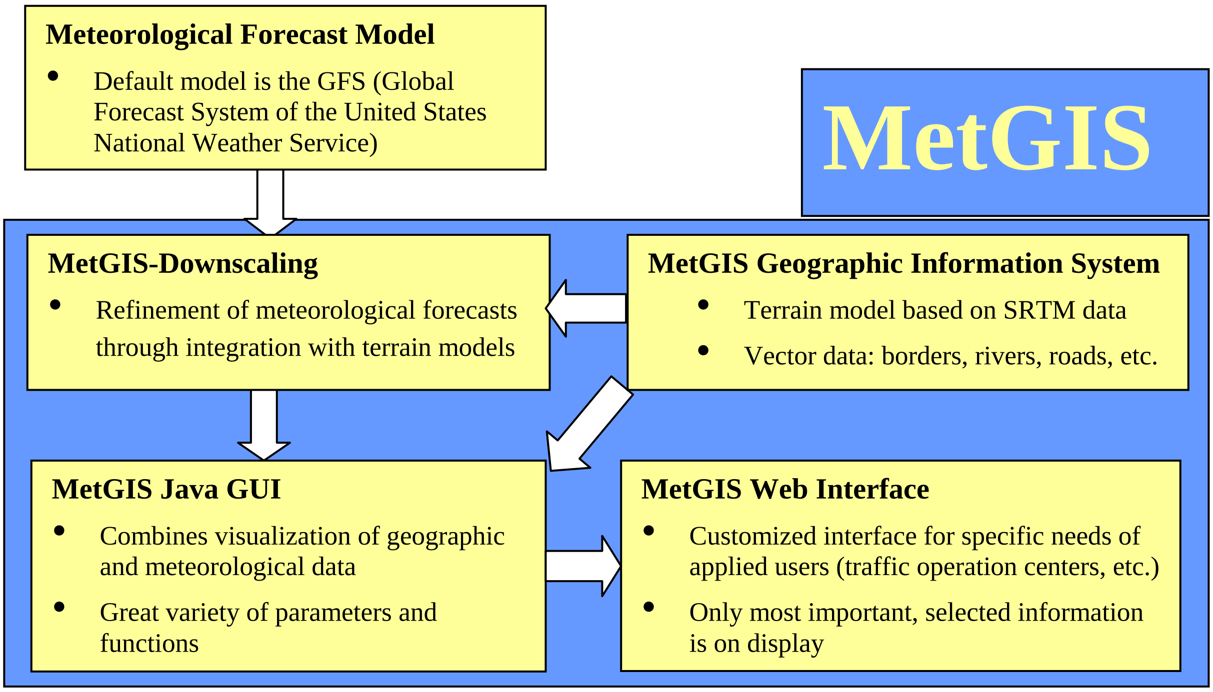

Figure 1 – Basic scheme of including geographic information in the generation of meteorological forecasts.

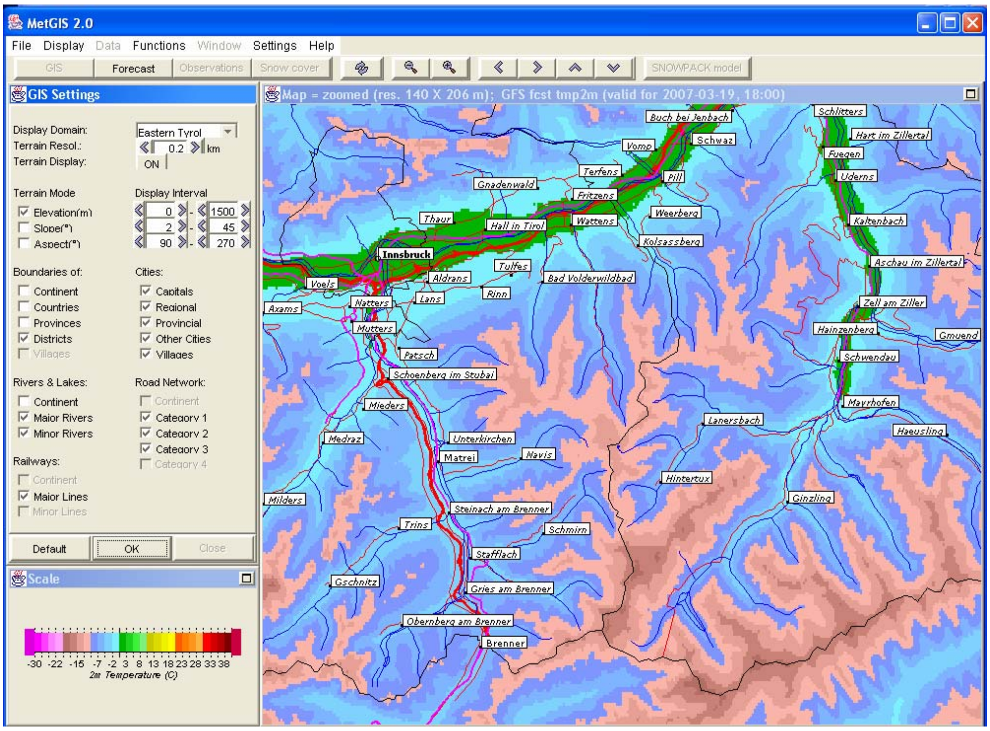

Figure 2 - Example of the MetGIS Java GUI, displaying an area forecast of the temperature 2 m above the ground for some mountain ranges and valleys southeast of Innsbruck, Austria. The horizontal resolution of the depicted prediction is 200 m. Green colors stand for temperatures above zero; check the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

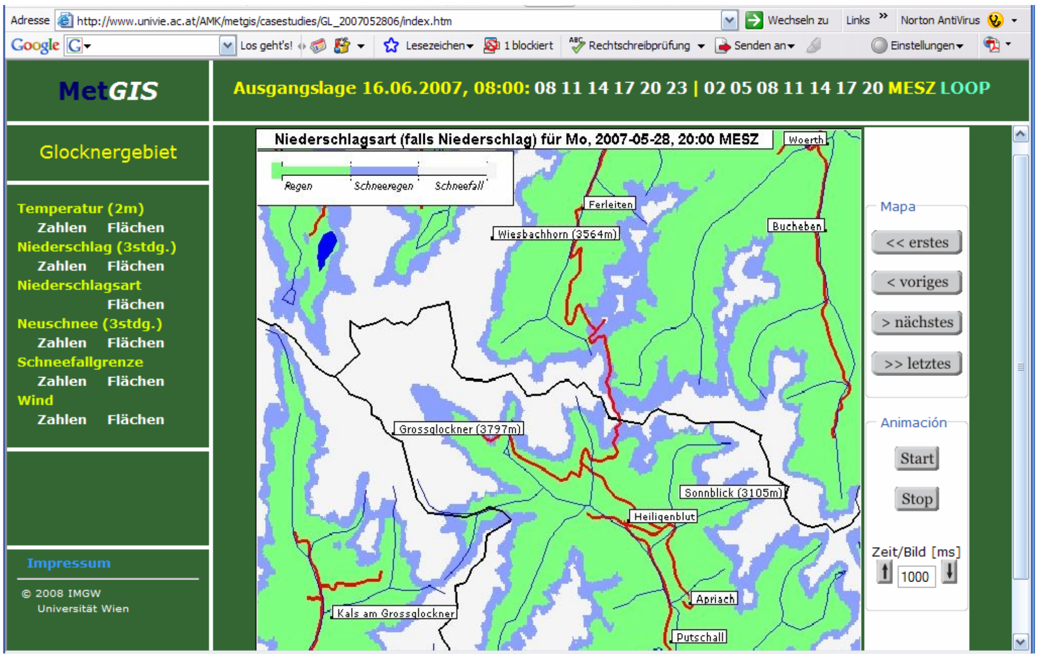

Figure 3 - Example of a MetGIS forecast of the mode of precipitation for a pass road near Grossglockner, the highest mountain of Austria, visualized by the MetGIS Web Interface. For whitely-colored areas snow is expected, blue areas can expect sleet and in green areas precipitation is supposed to fall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

4. REALTIME APPLICATION OF METGIS

The partly password-protected MetGIS Web Interface (http://univie.ac.at/amk/metgis/) is the main point of access to the system for applied users such as traffic operation centers. Beside MetGIS sample forecasts for mountain regions around the world, this user-friendly web site offers real-time downscaled short-range forecasts for a number of predefined geographic areas, parameters and display styles in 4 languages (English, German, Spanish and Russian). At present, graphical forecasts for a number of defined regions over the Alps, Pyrenees and Andes, all with a forecast range of 36 or 48 hours and a forecast interval of 3 hours, are computed 4 times a day. Furthermore, point forecasts for predefined locations are generated. User response has been quite encouraging so far.

Currently delivered forecast parameters are air temperature (Fig. 2), mode of precipitation (snow, sleet or rain, Fig. 3), fresh snow amount (Fig. 4), precipitation amount, snow limit, and wind. Display styles available are "Color Areas" (used in Fig. 2 – Fig. 4) or "Numbers" (numerical values on a regular grid). The detailed terrain representation included in MetGIS allows for an easy detection of areas above the snow line or the freezing level. Forecast fields can be displayed for specific times or in a time-lapse mode. The MetGIS Web Interface also offers the possibility to display forecast histograms (time evolution of selected parameters), valid for specific locations that are clicked in the forecast maps.

Applied users may access MetGIS predictions not only via the MetGIS Web Interface, but since recently they can also receive downscaled forecasts in form of JPG files (which can be included in their own web pages) or ASCII files of the gridpoint forecast values. The latter provides the opportunity to include MetGIS forecasts as layers in external Geographic Information Systems (see Fig. 5).

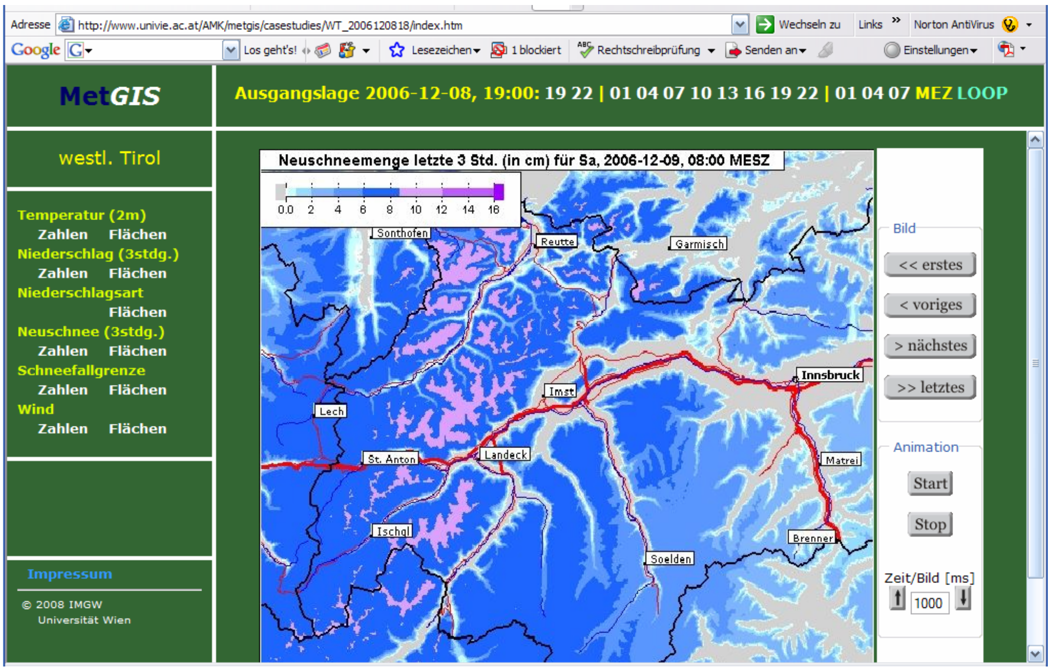

Figure 4 - MetGIS Web Interface, holding a sample forecast of 3-hourly amounts of fresh snow (in cm) for the western part of Tyrol. Check the color scale in the upper left of the forecast map.

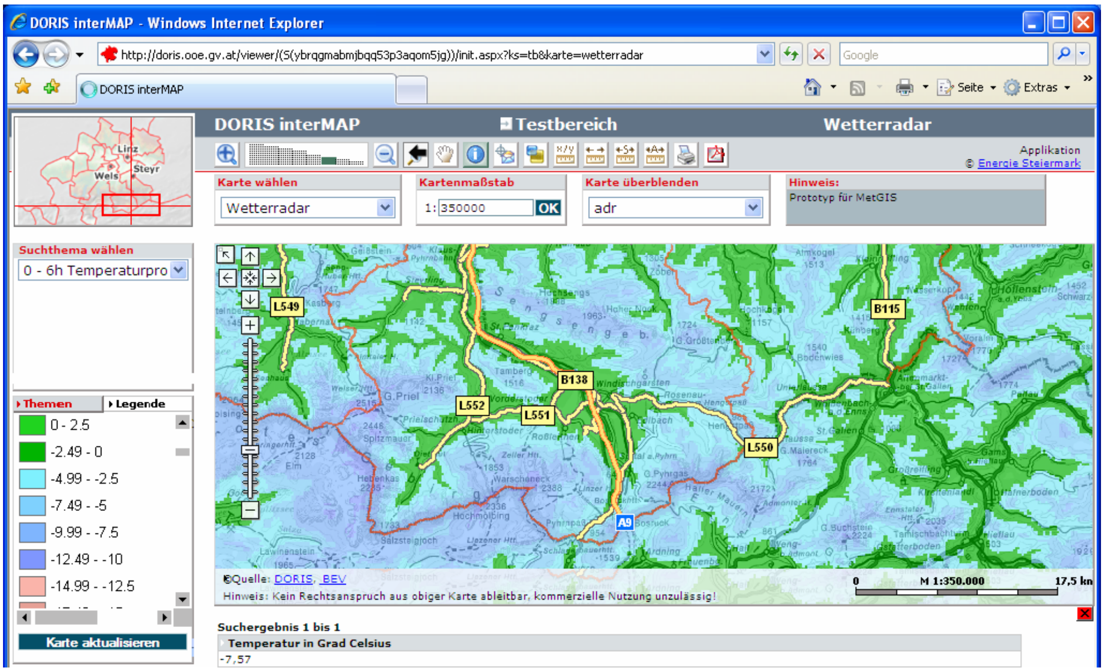

Figure 5 - Example of a MetGIS temperature forecast included as layer in the geographic information system DORIS of the state of Upper Austria.

5. FORECAST VERIFICATION

The forecast quality of MetGIS is constantly monitored. A recent verification study, covering most of the year of 2008 and comparing MetGIS point forecasts with the measurements at a number of SYNOP stations around Austria yielded quite reasonable scores. Concerning temperature, high-altitude stations delivered in the case of 36-hour forecasts a mean absolute error of around 1.5 degrees centigrade. The error was slightly higher at lowland locations where temperature inversions are not uncommon in winter. Precipitation scores were screened mainly for 24-hour periods, with four different classes included (< 0.1mm, 0.1-1mm, 1-10mm, >10mm). In around 90 % of the predictions the observed and forecast precipitation amounts were in the same class or in adjacent classes. Snowfall verification is planned for the near future, but the main problem in this task will be the detection of reliable observation data.

6. CONCLUSIONS AND OUTLOOK

MetGIS is a promising interface between geographic and meteorological information systems which produces terrain-adjusted meteorological forecasts with a specific focus on snow in resolutions till now unknown in operational weather prediction systems. The forecast quality of MetGIS will permanently increase, since gradually more VERA-style downscaling techniques will be implemented. Due to the global coverage of GFS forecasts and the sort of geographic data used, operational MetGIS predictions can be produced for any region of the world. If for specific regions higher-resolution limited area models are available, these can easily be integrated with MetGIS, since the meteorological input 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 calculation of “line forecasts” along the extension of highways. Specific parameters of the valley geometry, easily computed from the high-resolution terrain, can be used to meliorate the prediction of the height of the snow line. Also, the employment of energy balance models, assessing the system inherent terrain slope and orientation, may improve the temperature forecast. Another option that could increase the power of MetGIS over alpine terrain is to implement coupling mechanisms with snow cover models such as SNOWPACK ([1], [6], [7]).

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