EMPLOYING THE METGIS-SYSTEM FOR THE PRODUCTION OF HIGH-RESOLUTION METEOROLOGICAL AND SNOW-RELATED FORECASTS OVER ALPINE TERRAIN

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Abstract: MetGIS is a new, international, Java-based, combined **Met**eorological and **G**eographic **I**nformation **S**ystem, with a specific emphasis on snow and mountain weather. A principal focus of the system is the automated production of down-scaled forecasts of meteorological parameters for horizontal resolutions as low as 100m, partly in an operational mode. The predictions can be viewed via a sophisticated Graphical User Interface or via the Internet. Any numerical forecast models can be used as a base for the downscaling procedures, provided the model output is compatible with NetCDF or GrADS-compatible formats, and the application of MetGIS is not restricted to certain geographic regions.

1. INTRODUCTION

Most of the currently employed meteorological information systems include geographic information just in the form of "dead", unchangable background maps. These frequently include only the positions of cities or meteorological stations and some coarse resolution state boundaries and coastlines. This is a real deficiency, since coupling meteorological information with detailled geographic data bases could not only provide "esthetically" more decent, eye-catching weather maps, but also – more interestingly – offer the possiblity to introduce real interactivity between the geographic and meteorological information modules. That may include the introduction of effective downscaling procedures applied to model forecast data, depending on the current settings of the geographic properties. Concerning the employment over alpine terrain, another drawback of many standard meteorological information systems is the neglecting treatment of snow and related parameters.

In an attempt to cope with the above indicated problems, MetGIS, a combined **Met**eorological and **G**eographic **I**nformation **S**ystem was created. From the start of the system development process, collaboration with international meteorological organizations and snow research institutes has been established (see Tab. 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 system.

Some basic ideas of MetGIS were inspired from the now outdated, but methodically interesting WeatherPro weather prediction scheme (Teixeira and Reiter, 1995; Spreitzhofer, 2000).

2. SYSTEM DESIGN

2.1 General structure

The principal component of MetGIS is a Graphical User Interface (GUI), comprising subsystems related to meteorological and geographic information (see below). As a programming language, the object-oriented and platform-independent Java is used, which includes some specific tools and procedures related to the "internationalization" of programs. Using these techniques, a language switch was implemented, allowing the operation of the GUI alternatively in English, German or Spanish.

Since the start of 2007, the GUI can also be run in an automated mode, operationally producing a set of high-resolution, GIS-based weather forecasts, derived from the output of the American GFS model. Case studies and real-time forecasts for a number of geographic sections, parameters and display styles can be accessed via the partly password-protected website http://univie.ac.at/amk/metgis/ (compare Fig. 1).

Table 1: Contributions of international research institutions for the development of the MetGIS 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.

2.2 The geographic information subsystem

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 big parts of South America. However, the geographic database is 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 resolutions used are around 45m.

2.3 The meteorological information subsystem

MetGIS uses the output of external meteorological mesoscale forecast models as the base for its own, refined meteorological predictions. Model output formats currently readable by MetGIS are NetCDF and simple GrADS-compatible binary formats.

MetGIS has already been successfully operated with a number of models, such as:

1. A research version of NHM (Non-Hydrostatic Model), run by the Nagaoka Institute of Snow and Ice Studies (Japan) with horizontal resolutions of 1-2 km over the heavy-snowfall areas of the island of Honshu.
2. A version of the MM5 model (NCAR/Penn State University), operated by the Universidad de Chile in Santiago for some sections of the Central Andes.
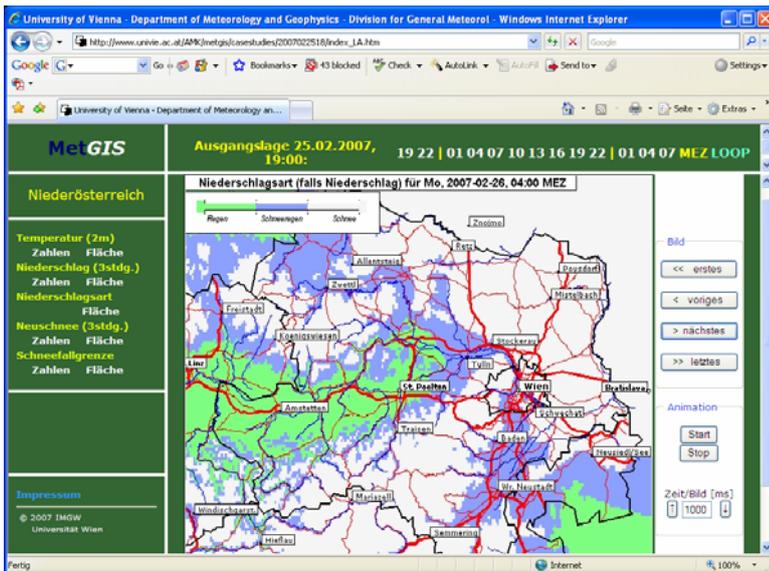3. The GFS (General Forecast System) of the US National Weather Service.

Figure 1: Example of an operational, web-based forecast of a snowstorm hitting Vienna in the morning hours of 28 February 2007, using MetGIS. The downscaled parameter on display is the mode of precipitation (if precipitation occurs): Green areas can expect rain, purple areas are forecast to experience sleet and white areas are above the predicted snow line.
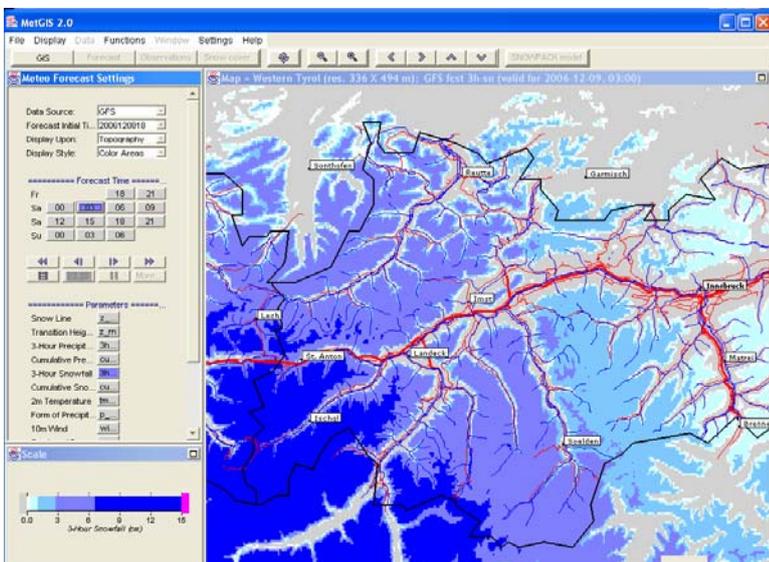

Figure 2: MetGIS GUI, visualizing a forecast of the three-hour accumulation of fresh snow for a snowfall episode over western Tyrol in December 2006. Check the color scale in the lower left of the image. The upper left reveals some settings of the meteorological information subsystem to produce this graph..
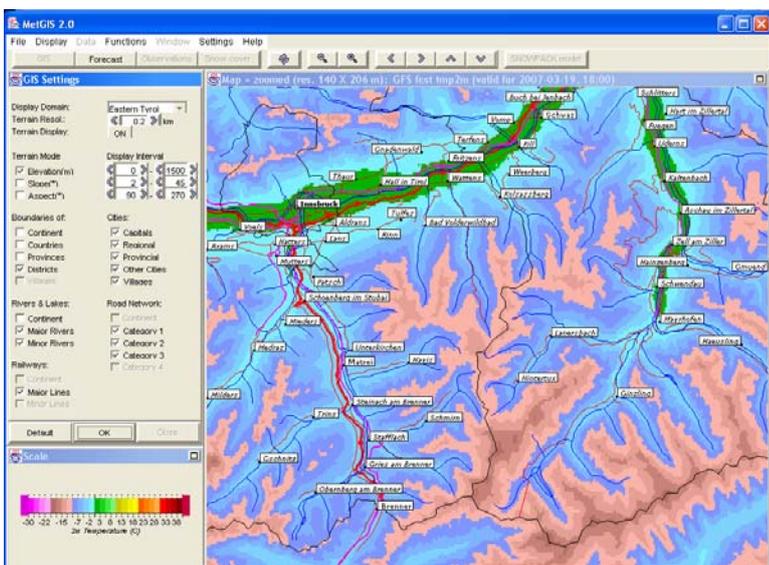

Figure 3: MetGIS GUI, displaying a forecast of the temperature 2 m above the ground for some mountain ranges southeast of Innsbruck, Tyrol. The horizontal resolution of the depicted prediction is 200 m. Temperatures above zero centigrade are printed in green colors, between -10 and 0 in blue colors and below -10 in brownish color tones; check the color scale to the lower left. The upper left displays a steering window of the geographic information subsystem.

MetGIS allows the display of a wide choice of direct model output and derived parameters, related to the surface or to higher model levels. It can be chosen among a number of distinct display styles like numbers, colored boxes and color areas (isoline style).

The high-resolution geographic information subsystem helps to assess meteorological information for scales much smaller than those resolved by mesoscale models. The derivation of adequate "VERA-style" techniques to process this "downscaling" is part of ongoing research activities. VERA (Vienna Enhanced Resolution Analysis, Steinacker et al., 2000; Steinacker et al., 2006) incorporates an objective, automated downscaling and analysis approach for meteorological data over complex topography. The method, working without first guess or prognostic model fields for initialization, is formulated for and applied to scalar and vector quantities on one- and two-dimensional domains. VERA includes the influence of the high-resolution topography on specific meteorological parameters in the form of so-called "fingerprints". Examples of some downscaled forecast fields based on GFS predictions can be found in Fig. 1 (mode of precipitation), Fig. 2 (fresh snow depth) and Fig. 3 (temperature).

4. CONCLUSIONS AND FINAL REMARKS

MetGIS is a promising interface between geographic and meteorological information systems which produces terrain-adjusted meteorological forecasts 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 could be produced for any mountain region of the world. If for specific regions higher-resolution models are available, these can easily be integrated with MetGIS, since the meteorological model interface of MetGIS is quite flexible.

A future option that can increase the power of MetGIS over Alpine terrain is the inclusion of snow cover characteristics via the application of snow cover models such as SNOWPACK (Bartelt and Lehning, 2002; Lehning at al., 2002a,b). Even without this, conditional display modes of the type "Show all gridpoints above 2000 m, with a slope exceeding 30 degrees, predicted fresh snow accumulation of more than 30 cm and a wind speed exceeding 20 m/s" will soon be possible, aiming at specific applications such as the estimation of the avalanche danger.

REFERENCES

Bartelt, P.B., M. Lehning, 2002: A physical SNOWPACK model for avalanche warning services. Part I: Numerical Model. Cold *Regions Science & Technology* **35** (3), 123-145.

Lehning, M., P. B. Bartelt, R. L.Brown, C. Fierz, P. Satyawali, 2002: A physical SNOWPACK model for the Swiss Avalanche Warning Services. Part II: Snow Microstructure. *Cold Regions Science & Technology* **35** (3), 147-167.

Lehning, M., P. B. Bartelt, R. L. Brown, C. Fierz, P. Satyawali, 2002: A physical SNOWPACK model for the Swiss Avalanche Warning Services. Part III: Meteorological Boundary Conditions, Thin Layer Formulation and Evaluation. *Cold Regions Science & Technology* **35** (3), 169-184.

Spreitzhofer, G., 2000: The WeatherPro system: recent developments. Proceedings *of the 10th International Road Weather Conference in Davos, Switzerland, March 2000,* 128-135.

Steinacker, R., C. Häberli, W. Pöttschacher, 2000: A transparent method for the analysis and quality evaluation of irregularly distributed and noisy observational data. *Monthly Weather Review* **128**, 2303-2316.

Steinacker, R., M. Ratheiser, B. Bica, B. Chimani, M. Dorninger, W. Gepp, C. Lotteraner, S. Schneider, S. Tschannett, 2006: A mesoscale data analysis and downscaling method over complex terrain. *Monthly Weather Review* **134**, 2758 - 2771.

Teixeira, L., E. R. Reiter, 1995: Hybrid modeling in meteorological applications; Part II: An operational system. *Meteorol. Atmos. Phys.* **55**, 135-149.