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Enhanced Road Weather Warnings and Improved Communication Strategies within Central Europe as part of the INCA-CE project

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ABSTRACT

Among the main goals of the EU-funded INCA-CE project is to improve risk management standards and methodology in the field of road safety. In a transnational Central-European cooperation the INCA analysis and forecast system is advanced and refined scientifically and for applications in different sectors. Also, communication lines between developers, weather services, stakeholders and local authorities will be improved.
The INCA analyses and forecasts that are mostly widely used by Austrian road management authorities are 2m-temperature, ground temperature, precipitation and precipitation type. Moreover, criteria have been defined for automatically generated SMS warnings for snowfall and black ice. Also, INCA forecast fields have been compared to the Canadian METRo model, and it was found that INCA ground temperature fields generally meet the reality quite well. However, in case of rapidly changing road temperatures, METRo can refine the forecast quality in the first 1-12 hours.

Keywords: INCA, INCA-CE, Nowcasting, Road Weather Warning

1 INTRODUCTION

The INCA-CE project (http://www.inca-ce.eu) aims at reducing adverse effects of weather-related natural disasters by "establishing a state-of-the-art, high-resolution, real-time analysis and forecast system on atmospheric, hydrological, and surface conditions". Main goal is the improvement of risk management standards and methodology in order to enable management institutions and authorities to issue more detailed assessments and warnings. INCA-CE is also supposed to allow a more precise estimation of weather-related risks and potential hazards in the private sector. Within the project three trans-national working groups have been established, one of which is covering the application area 'Road Safety'.

The analysis and nowcasting system INCA (Integrated Nowcasting through Comprehensive Analysis, [2]) algorithmically combines station observations, NWP model output and remote sensing data (radar, satellite) in order to provide meteorological analysis and nowcasting fields at high temporal (5 min) and spatial (1 km) resolution. INCA is used to calculate analyses and forecasts of a huge variety of parameters. For applications at the Austrian road maintenance services, INCA fields of 2m-temperature, surface temperature, precipitation and precipitation type are automatically provided both on dedicated webportals at the operation centres and in a mobile version for field work and in situ verification. As the number of road temperature observations is too low for being used in a dedicated INCA road surface module, INCA is experimentally being coupled with the METRo model [1].

Project work on the INCA nowcasting tool includes algorithmic refinements, improvements in data flow, data quality control, and computational efficiency. Current work in the field of road weather forecasting is focusing on warnings for delayed ice formation due to falling temperatures after a precipitation event, and for slippery roads due to hoar frost formation. Also a test version of the INCA visibility module is implemented and assessed for practical use in road weather warnings.

User feedback is given much room within the INCA-CE project and there's frequent and gainful exchange with project partners and users.
This paper briefly summarizes the main characteristics of the INCA nowcasting system with a special emphasis on those parameters that are used by Austrian road maintenance services (section 2). In section 3, the criteria for automatic SMS warnings triggered by the INCA system are described, and in section 4 the potential benefits of a combination of INCA with the METRo model are summarized.

2 INCA

The INCA analysis and nowcasting system is being developed primarily as a means of providing improved numerical forecast products in the nowcasting range (up to +4 h) and very short range (up to about +12 h) even though it adds value to NWP forecasts up to +48 h through the effects of downscaling and bias correction. INCA algorithmically combines station observations and remote sensing data (radar, satellite) in order to provide meteorological analysis and nowcasting fields at high temporal (5min-1h, depending on parameter) and spatial (1 km) resolution [2].

2.1 Data

2.1.1 NWP background
For the three-dimensional INCA analyses of temperature, humidity, and wind, NWP forecast fields provide the first guess on which corrections based on observations are superimposed. Beginning with 1st of March 2011 a new operational ALADIN configuration named ALARO5-AUSTRIA was set to operations at ZAMG, replacing the old 9.6km version ALADIN-AUSTRIA. The new 4.8km version is coupled to the IFS model and uses the ALARO physics package. However, the INCA analysis and nowcasting methods do not depend critically on the horizontal resolution of the NWP fields and could as well be based on other NWP models.

2.1.2 Surface observations
The single most important data source for the INCA system are surface stations. ZAMG operates a network of ~260 automated (TAWES) across the country which provide data in high temporal resolution. In addition, a high number of data from other providers such as hydrological services, avalanche warning services etc. are used.

2.1.3 Radar data
The Austrian radar network is operated by the civil aviation administration (Austrocontrol). It consists of five radar stations and ZAMG operationally obtains 2-d radar data synthesized from these five locations, containing column maximum values in 14 intensity categories, at a time resolution of 5 minutes. Ground clutter has already been removed from the data.

2.1.4 Satellite data
The Meteosat 2nd Generation (MSG) satellite products used in INCA are 'Cloud Type' which consists of 17 categories, and the VIS image. Cloud type differentiates between three cloud levels (low, medium, high) as well as different degrees of opaqueness. It also diagnoses whether clouds are more likely convective or stratiform in character. The VIS image is used to downscale the infrared-based (and thus coarser resolution) cloud types during the day.

2.1.5 Elevation data
The 1-km topography used in INCA was obtained through bilinear interpolation from the global 30'' elevation dataset provided by the US Geological Survey. The resolution of 30'' of the original dataset corresponds to ~930 m in latitudinal, and ~630 m (at 48°N) in longitudinal direction.

2.2 INCA output fields used for road maintenance services

Road maintenance services have access to INCA analyses and forecasts through customized webportals. The features of the three most important fields are described in the following.

2.2.1 Temperature
The three-dimensional analysis of temperature in the INCA system starts with the ALADIN/ALARO5 forecast as a first guess. This first guess is corrected based on differences between observation and forecast at surface station locations. Since the station observations are all made in the atmospheric surface layer it is important to take the daytime temperature surplus and the nighttime temperature deficit near the surface into account in the interpretation of these differences. Thus the model 2m-temperature forecast is conceptually and computationally separated into a '3-d' or model-level part, and a 2-d surface-layer contribution.

$$T_{ALA} = TL_{ALA} + DT_{ALA} \quad (1)$$

Here, T_{ALA} is the standard model 2m-temperature output, and TL_{ALA} is the temperature at the lowest model level. The difference DT_{ALA} between the two temperatures is the temperature surplus (or deficit) in the surface layer. To construct the first guess, model forecasts of temperature on pressure levels are interpolated trilinearly onto the 3-d INCA grid.

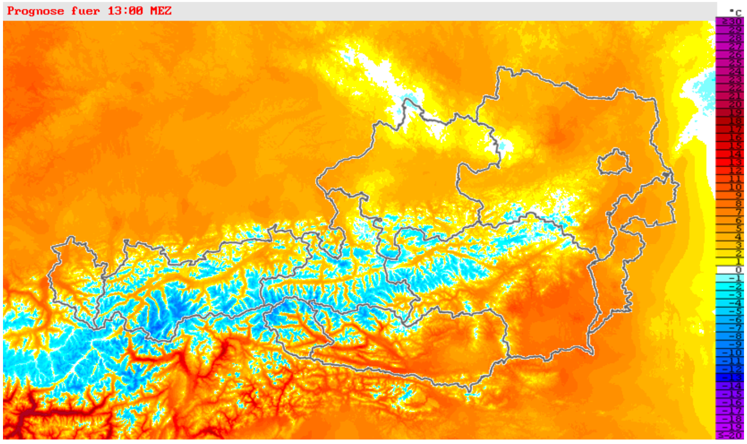

Figure 1. INCA temperature nowcast for 2012022812 UTC +001h for the Austrian domain.

3.1.2 Surface temperature

The analysis of ground surface temperature in INCA is a derived parameter and is based on observations of the +5 cm air temperature, -10 cm soil temperature, and 2 m air temperature. Outside the nowcasting range, the NWP forecast of ground surface temperature is used (corrected for the actual terrain height based on 2-m temperature). INCA surface temperature serves as a main input for INCA precipitation types.

3.1.3 Precipitation

The precipitation analysis is a combination of station data interpolation including elevation effects, and radar data. It is designed to combine the strengths of both observation types, the accuracy of the point measurements and the spatial structure of the radar field. The radar can detect precipitating cells that do not hit a station. Station interpolation can provide a precipitation analysis in areas not accessible to the radar beam. Naturally, the combination method has to deal with the weaknesses of both types of observation as well, namely the potentially unrepresentative locations, and low density, of stations, and the fundamental quantitative uncertainty of precipitation estimated by radar. The precipitation analysis and forecasts are computed in 7 steps

- Interpolation of station data: The irregular point values are interpolated onto the regular 1 km INCA grid using distance weighting.
- Climatological scaling of radar data: The radar data is bilinearly interpolated onto the INCA grid. Since the radar field is strongly range-dependent and contains biases due to topographic shielding it must be scaled before use in the precipitation analysis.
- Re-scaling of radar data using the latest observations: The climatologically scaled radar field is re-scaled on the basis of a comparison at analysis time of station observations and radar values at the stations.
- The interpolated station and radar data are finally combined to one field that gives a better estimate of the precipitation distribution than each individual field.
- Parameterization of elevation effects.
- Computation of motion vectors from previous analyses and INCA nowcast.
- Merging of nowcasting fields into NWP after 2-6h

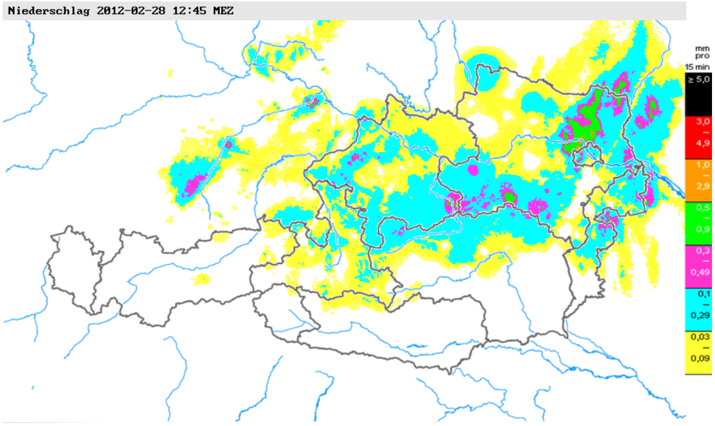

Figure 2. INCA precipitation analysis for 20120228 1245 UTC for the Austrian domain.

3.1.4 Precipitation types

For many applications, the distinction between rain and snow may not be sufficient. In cases where the atmosphere is well-mixed, and the temperature continuously decreases with height, the boundary between snowfall and rainfall will be relatively narrow. However, in more stable cases, or when the snowfall line works its way downwards due to latent heat effects, there may be a broader height range with temperatures close to 0°C and associated snow/rain mix. According to the observational study of Steinacker [4] a snow/rain mix is most likely to occur in the range 0°C ≤ T_W ≤ +2°C where T_W is the wet bulb temperature. Below 0°C precipitation predominantly falls as pure snow, and above +2°C it is most likely pure rain.

If rain falls into a near-surface layer of cold air, or on a surface with sub-freezing temperature, freezing rain will occur. This precipitation type is the most critical of all since it has enormous effects on transportation and may cause widespread structural damage in severe cases [3]. In INCA the distinction between rain and snow is based on the vertical profile of the wet-bulb temperature at each grid point, derived from the 3D temperature and humidity fields.

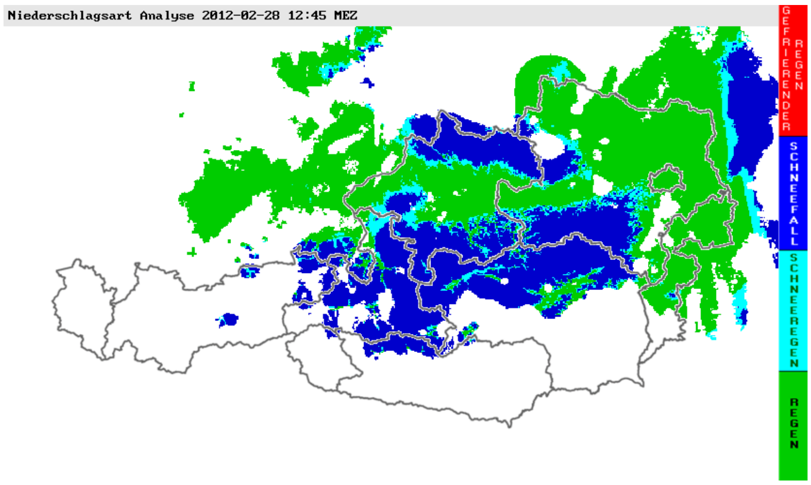

Figure 3. INCA precipitation type analysis for 20120228 1245 UTC for the Austrian domain.

3 SMS warnings derived from INCA fields

Starting in November 2011, warning SMS derived from INCA grid point information are tentatively sent to responsible persons of road maintenance services and to local authorities. The warning criteria were defined in accordance with the requirements of the recipients. The following subsections show some examples.

3.1 Warning criteria

3.1.1 Snow

For INCA precipitation type "snow", a threshold of 0.1 mm/15min is defined. A warning is sent out, if there was no significant precipitation within the last 5 hours, and if two consecutive forecast steps within the next two hours exceed this threshold in a predefined region.

3.1.2 Freezing rain

Same criteria as above, but for INCA precipitation type "freezing rain".

3.1.3 Delayed ice formation due to falling temperatures after a precipitation event

A warning is created if precipitation of at least 0.01 mm/15 min has been observed anytime within the last 4 hours, and if the forecast shows a drop of temperature below 0°C within the next two hours. In addition, the mean value of temperature and dewpoint must exceed 1°C.

4 Road temperature modeling with INCA and METRo

METRo (Model of the Environment and Temperature of Roads, [3]) is a road weather forecast model developed by Environment Canada. Given surface observations and NWP data, METRo provides information on road surface temperature and road conditions. Previous tentative investigations have shown that due to the lack of information on the road composition and the lack of road temperature observations, INCA outperforms the METRo ground temperature forecasts in many cases.

However there are situations where INCA ground temperature does not adequately reflect the road surface observations. Efforts were made to find out from which absolute difference between INCA ground temperature and road observations, METRo forecasts add value. For this study data from a road section north of Vienna have been evaluated for the period 27 Nov 2009 to 7 Feb 2012, and those dates were selected where the INCA forecast errors with respect to five observation stations were largest. The dates had in common that the weather situation was changing very rapidly. Fig. 4 shows the RMSE difference between INCA and METRo for different forecast lead times with respect to INCA analysis errors of 1, 1.5, 2, 2.5, 3, 3.5 and 4 °C.

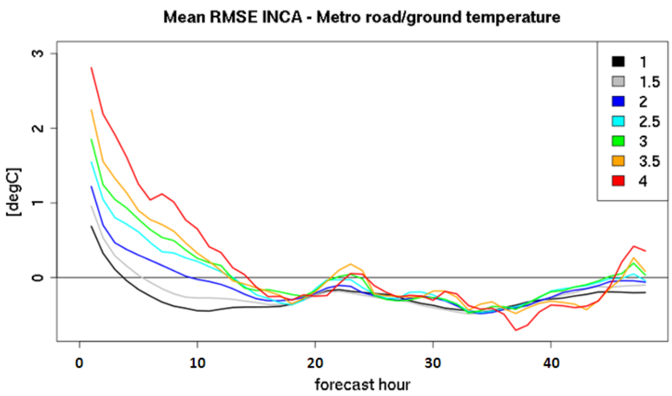

Figure 4. Mean RMSE INCA-METRo road/ground temperature error for different thresholds and lead times.

It can be seen that for small INCA analysis errors of 1-1.5°C, METRo provides better results in terms of RMSE for the first 4-5 hours of the forecast period. For an analysis error of 2°C, METRo performs better for the first 10 hours, and for larger analysis errors, METRo forecasts should be favored for the first 12 hours.

4 REFERENCES

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