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Improved Weather Information for the Road Sector (INCA-CE Project) INCA Surface Temperature Forecasting

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ABSTRACT

This paper presents the preliminary results of INCA weather forecast (nowcast) pilot implementation in winter road maintenance in Slovenia. The purpose of the study was to evaluate the INCA surface temperature forecasts and to provide possible stand-alone use of these forecasts for predicting road surface temperature. Another objective was to test a simple linear regression approach for 6-hour road surface temperature predictions, using the surface temperature and incoming solar flux forecasts and measurements from road weather stations as a learning data and only surface temperature forecasts for testing data.
Results showed that INCA forecasts could be used stand-alone for predicting road surface temperature at locations with simple topography. To increase the accuracy, simple linear regression equations can be used to achieve the average RMS error around or below 2°C.
However, the results are preliminary and could be speculative, so more road weather stations should be taken into account to confirm them and decide whether accurate weather forecasts with high spatial and time resolution are suitable for use as a stand-alone or in combinations with simple regression models for point-based/route-based road surface temperature predictions.

Keywords: INCA-CE project, Integrated Nowcasting through Comprehensive Analysis (INCA), Road Surface Temperature (RST), linear regression

1 INTRODUCTION

For the purpose to support the anti-icing operations, weather forecasts of high spatial and temporal resolution are essential. Precise forecasting of the time and duration of precipitation, precipitation type and amount, pavement surface condition as well as road surface temperature (RST) are critical. Cost benefit researches [5] show that the significance of weather forecasts decreases with the scale of time from nowcasts to short-term, medium-term, and long-term forecasts and that the improvement of weather information accuracy is critical to achieving more savings in winter maintenance.
Some preliminary results of the Slovenian partner within the road safety group in the INCA-CE project [2,4] are introduced in the paper. The project is scheduled for completion within 3.5 years, with an overall budget of 3.6 million Euros, which supports the research activities of 16 project partners from eight European countries.
INCA (Integrated Nowcasting through Comprehensive Analysis) short-term weather forecast system of good temporal (1 hour and less) and spatial resolution (1 km and less for diverse topography) [3] is under development in the project.
Pilot implementation of the INCA forecast within the Slovenian road weather information system (described in detail in [1]) started at the end of 2011. The INCA surface temperature forecasts were evaluated by the Slovenian partner to find out the possibility to use INCA forecasts stand-alone (without any additional model) for point-based and route-based RST predictions. Another aim was to test simple linear regression approach for 6-hour RST predictions, using surface temperature and incoming solar flux forecasts and RST measurements from road weather stations (RWSs) as a learning data and only INCA surface forecasts for testing data.

2 METHODS AND RESULTS

Two RWSs with quite different topography were selected in this study (Figure 1). The RWS *Jeprca* is situated between the central and north-western part of Slovenia, on a straight regional road. The terrain around the station is very flat and the nearest buildings and forest patches are 200 m away. The RWS *Mislinja* is situated in a small valley in northern Slovenia, on an ascending and winding regional road. The station is surrounded by trees and nearby objects.

RST measurements and INCA surface temperature forecasts were compared at the locations of both RWSs. Comparison for a few day periods in the middle of January 2011 is shown in Figure 2. The RMS error and bias (both calculated for each hour of the day) between INCA surface temperature analysis (0-hour 'forecasts'), 6-hour forecasts and RWSs RST measurements on the data from winter 2010/2011 are shown in Figures 3 and 4. For both RWSs, the RMS error for INCA surface temperature analysis is about 0.8°C below the RMS error for INCA surface temperature 6-hour forecasts. There is also a quite large negative bias for INCA surface temperature 6-hour forecasts. As expected, the RMS error on RWS *Mislinja* is higher due to its more complex topography.

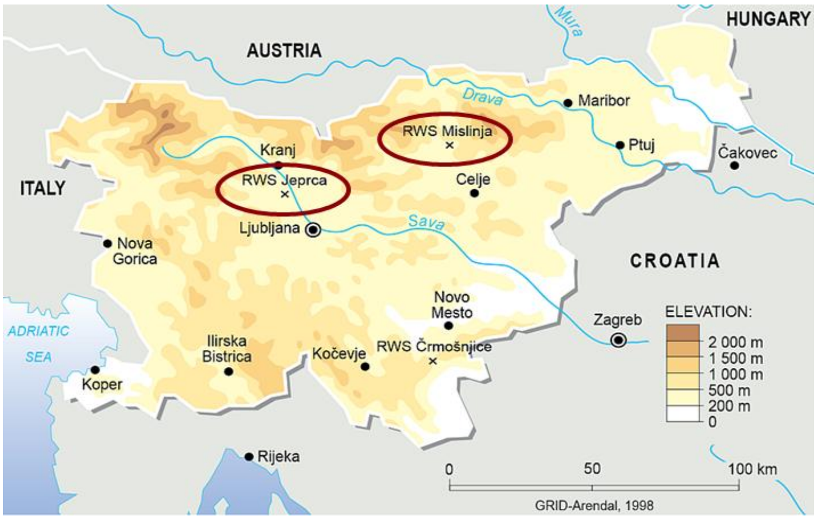

Figure 1. Map of Slovenia with the RWSs selected in this study.
[Source: Philippe Rekacewicz, Emmanuelle Bournay, UNEP/GRID-Arendal]

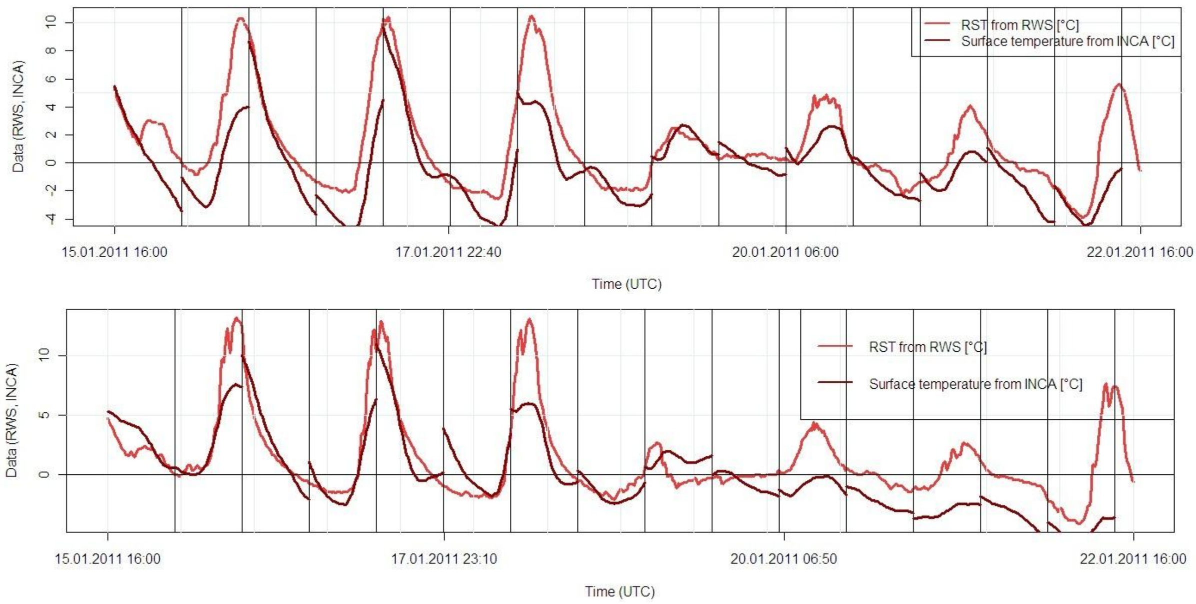

Figure 2. INCA surface temperature forecasts (from 0 to 11 hours ahead) compared by RST measurements from RWS *Jeprca* (top) and RWS *Mislinja* (bottom) for the selected time period. Dark vertical lines denote INCA forecast starting point (analysis).

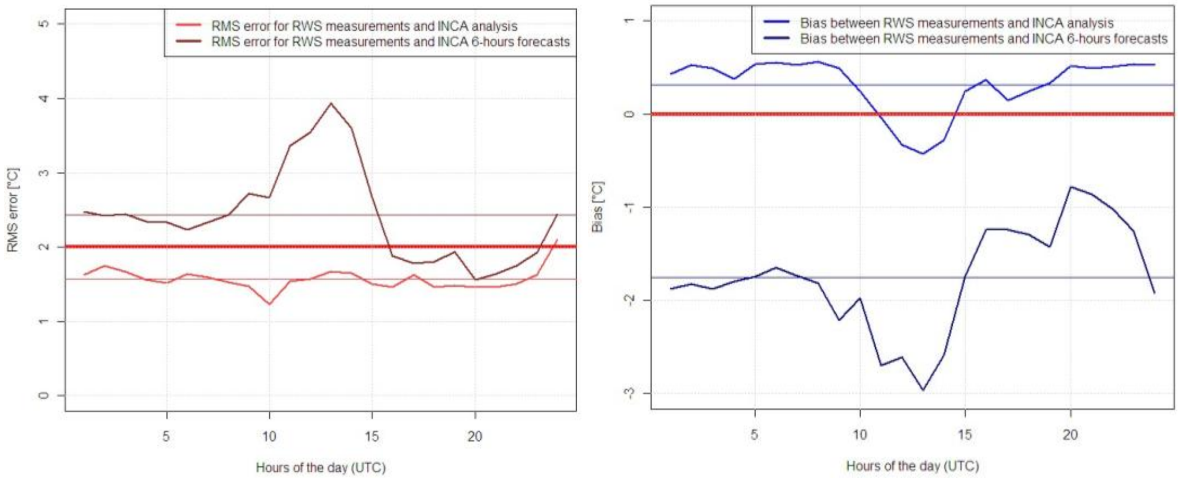

Figure 3. RMS error (left) and bias (right) for RWS *Jeprca*, calculated for each hour of the day between INCA surface temperature analysis and 6-hour forecasts, and RWS RST measurements. Average RMS error and bias are denoted with thin horizontal line and 2°C / 0°C line is denoted with heavy horizontal line.

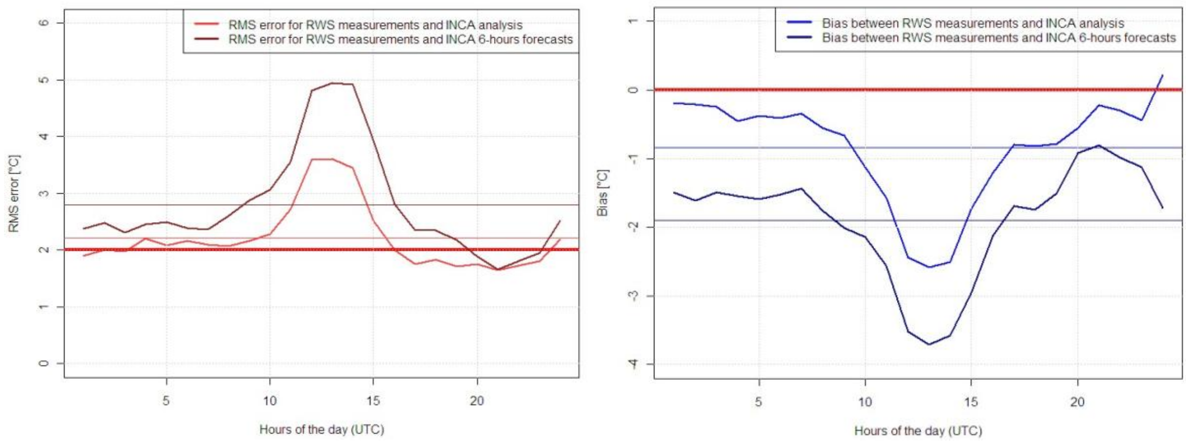

Figure 4. RMS error (left) and bias (right) for RWS *Mislinja*, calculated for each hour of the day between INCA surface temperature analysis and 6-hour forecasts, and RWS RST measurements. Average RMS error and bias are denoted with thin horizontal line and 2°C / 0°C line is denoted with heavy horizontal line.

Another purpose of this study was to test a simple linear regression approach for 6-hour RST predictions, using INCA surface temperature forecasts, incoming solar flux forecasts (from ALADIN numerical weather prediction model with a coarser spatial and time resolution as compared to INCA), and RWS RST measurements as a learning data from winter 2009/2010. For testing purposes, only the data of INCA surface temperature 6-hour forecasts (and ALADIN incoming solar flux 6-hour forecasts) from winter 2010/2011 were used.
The regression equations are:

$$RST = ST_{INCA\ 6h} \cdot \alpha + \beta \text{ and} \qquad (1)$$
$$RST = ST_{INCA\ 6h} \cdot \alpha_1 + SF_{ALADIN\ 6h} \cdot \alpha_2 + \beta\,, \qquad (2)$$

where RST means road surface temperature, $ST_{INCA\ 6h}$ the INCA surface temperature 6-hour forecasts and $ST_{ALADIN\ 6h}$ the ALADIN incoming solar flux 6-hour forecasts. α, $\alpha_{1,}$ α_2 are regression coefficients and β the intercept.
Linear regression models were constructed for each hour of the day on the described data from winter 2009/2010. The coefficient importance for regression equations (1) and (2) is shown in Figure 5 and Figures 6-7, respectively.
The RMS errors for regression equation (1) and (2) were calculated on the data from winter 2009/2010 (Figure 8). Only INCA/ALADIN forecasts were necessary for calculations, RWS RST measurements were used solely for evaluation purposes.

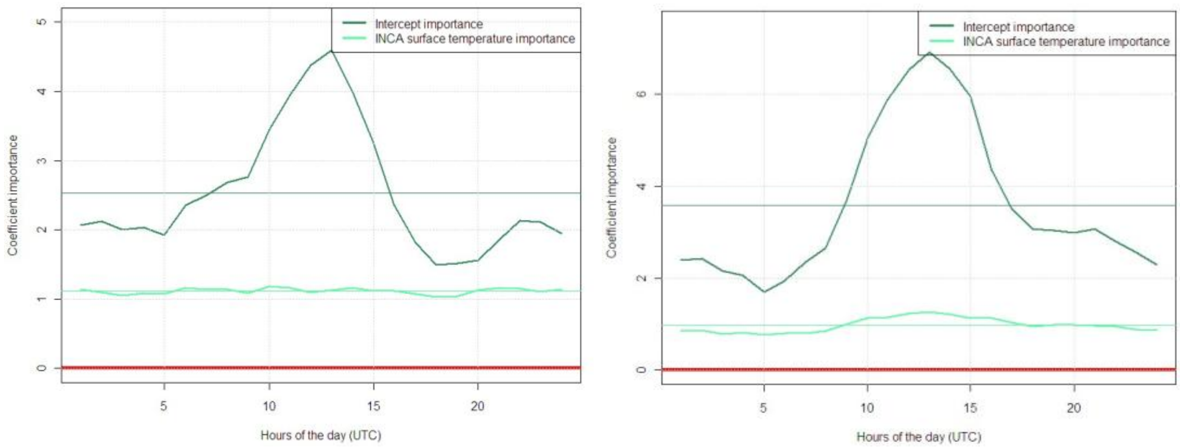

Figure 5. Coefficient importance for regression equations (1) for each hour of the day for RWS *Jeprca* (left) and RWS *Mislinja* (right). Average coefficient importance is denoted with thin horizontal line.

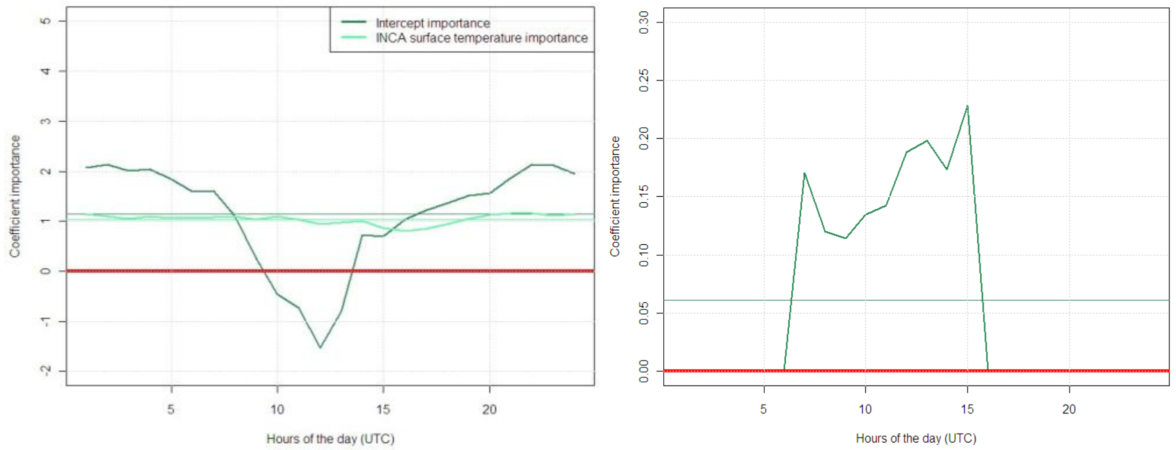

Figure 6. Coefficient importance for INCA surface temperature 6-hour forecasts and intercept (left) and for ALADIN incoming solar flux 6-hour forecasts (right) for regression equations (2) for each hour of the day for RWS *Jeprca*. Average coefficient importance is denoted with thin horizontal line.

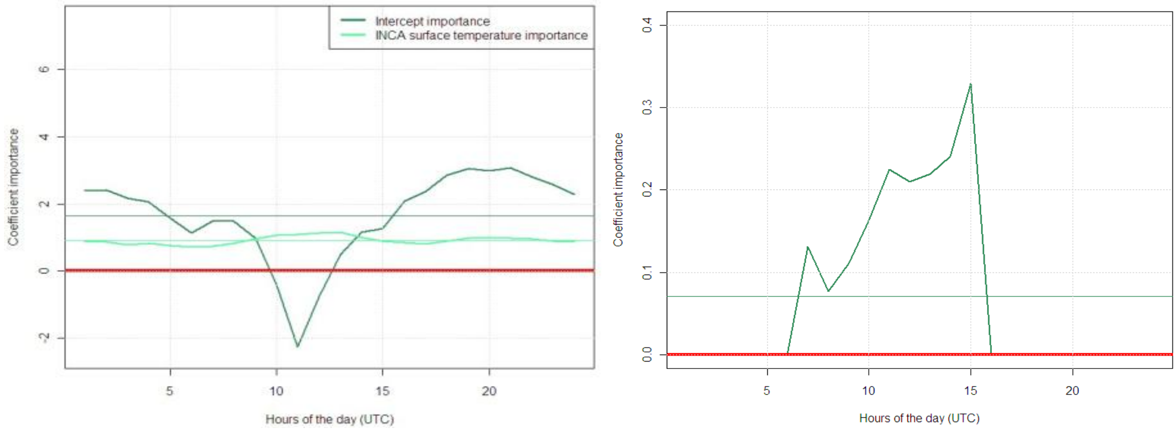

Figure 7. Coefficient importance for INCA surface temperature 6-hour forecasts and intercept (left) and for ALADIN incoming solar flux 6-hour forecasts (right) for regression equations (2) for each hour of the day for RWS *Mislinja*. Average coefficient importance is denoted with thin horizontal line.

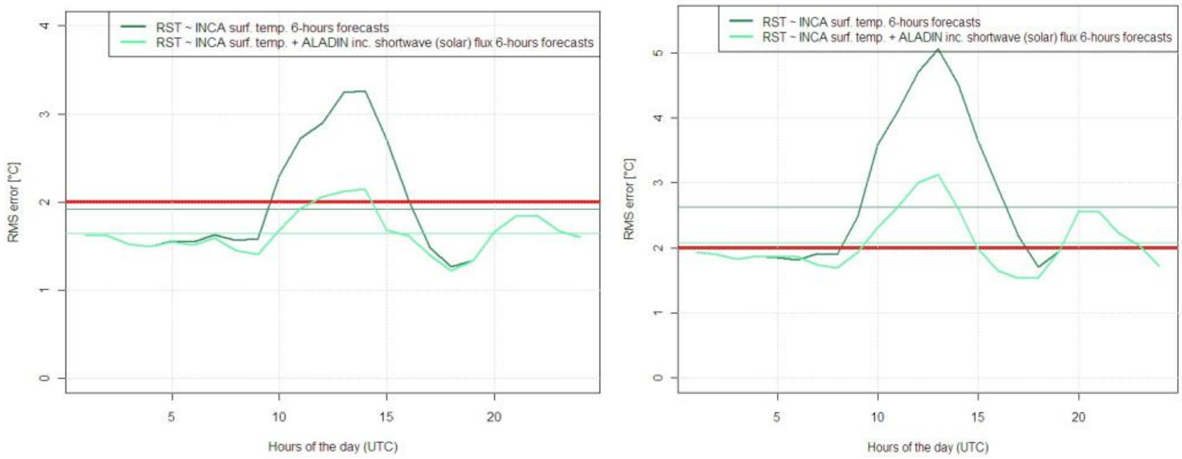

Figure 8. RMS error for regression equations (1) and (2) at RWS *Jeprca* (left) and RWS *Mislinja* (right). Average RMS error is denoted with thin horizontal line and 2°C line is denoted with heavy horizontal line.

3 DISCUSSION AND CONCLUSIONS

The results show that INCA forecasts can be used stand-alone for predicting the RST at locations with simple topography where the average RMS error is around 2.5°C for 6-hour RST forecasts, especially for night predictions when the RMS error is around or below 2°C. To increase the accuracy, simple linear regression equations can be used where INCA surface temperature and ALADIN incoming solar flux forecasts are taken into account. The learning data obtained over few months of harsh winter are sufficient to establish the regression coefficients. With such approach, the average RMS error can be around or below 2°C at locations with simple topography.

However, the results are preliminary and could be speculative, so more RWSs should be taken into account to confirm them and decide whether accurate weather forecasts with high spatial and time resolution are suitable to use them as a stand-alone or in combinations with simple regression models for point-based/route-based RST predictions.

INCA surface temperature forecasts and other parameters are still under development: therefore, better results are expected at the end of the project.

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ACKNOWLEGEMENTS

The INCA and ALADIN data were obtained from the Slovenian Environment Agency (ARSO). The RWSs data were obtained from the Slovenian Roads Agency (DRSC). INCA-CE project is implemented through the CENTRAL EUROPE Programme, co-financed by the ERDF.