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Exporting FMI Road Weather Expertise: Applications for Sochi 2014 Winter Olympics and for Spanish Highways

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ABSTRACT

Finnish Meteorological Institute's (FMI) road weather forecasting system is operationally implemented and piloted on four highway segments in Spain as part of the EU FP7 ITS (Intelligent Transport System) project FOTsis (Field Operational Test on safe, intelligent and sustainable road operation). Model results are post-processed to estimate expected road weather conditions and to issue warnings when adverse weather is anticipated along the highways. The first part of this paper presents the progress in this research. FMI road weather forecasting system will also be tested during the Sochi Winter Olympics and Paralympics as part of a pilot study within the ITS project CoMoSeF (Co-operative Mobility Services of the Future). FMI will test its road weather forecasting system to produce forecasts for the road stretches leading to the Mountain Cluster of the Sochi Games, the location of the outdoor sports activities. Some initial results are presented in the second part of this paper.

Keywords: Field Operational Tests (FOT), Road weather, Road weather modelling

1 INTRODUCTION

The FOTsis (Field Operational Test on safe, intelligent and sustainable road operation; www.fotsis.com) project was one of the two Integrated Projects approved in the European Commission Call ICT Mobility for the Future in 2009 (FP7-ICT-2009-6) and, consequently, the project was initiated in spring 2011. Some of the main objectives of FOTsis, being a large-scale ITS field test of infrastructure management systems, are to deliver services from the infrastructure to road end-users. The FOTsis weather applications are being developed and operated by the Finnish Meteorological Institute (FMI), the only project partner with meteorological and especially road weather expertise combined with know-how of integrating wireless networking systems for adopting weather information [4], [5].

The World Meteorological Organization (WMO) has carried out highly successful forecast demonstration projects during the past several Olympics Games under its World Weather Research Program (WWRP): Vancouver (winter 2010), Beijing (summer 2008) and Sydney (summer 2000). This legacy was to continue during the winter Olympics in Sochi, Russia. This lead to an idea to try out specialized forecast types that had not been tested before in an Olympics setting, when FMI as partner in the ITS project CoMoSeF (Co-operative Mobility Services of the Future) decided to make pilot studies with its road weather forecasting system in the Sochi Olympics environment. End-user focused products like road weather forecasts were seen very essential to depict the high impact weather phenomena in a complex terrain that might affect or even hinder the sports activities. Consequently, FMI's road weather forecasting system was to be adapted and fine-tuned to produce detailed forecasts for the road stretches leading to the Mountain Cluster of the Sochi Games, the location of the outdoor sports activities (alpine skiing, ski jumping, cross-country skiing, biathlon etc).

2 FMI ROAD WEATHER MODEL

FMI Road Weather Model (RWM) is a major ingredient in the projects introduced in the previous chapter. It is a one-dimensional energy balance model for calculating the vertical heat transfer in the ground and at the ground-atmosphere interface, and it takes also into account special conditions prevailing at and underneath the road surface [2]. The model is complemented with a so-called friction model, which is specifically developed to estimate (i.e. forecast) road surface friction or, in other words, slipperiness of the road surface [1]. The effects of the ambient atmosphere, turbulence as well as traffic volumes along the road are also considered. Hence, the model needs as its input information from the forcing adjacent atmosphere. FMI RWM is a stand-alone model that can exploit both computed and observed data. As input it requires initial values of simulated parameters and predicted values of atmospheric parameters at the top bound of the RWM domain encompassing near-surface air layer, road surface, and the soil layer adjacent to the road surface.

RWM simulations are done hourly in the present configuration. The accuracy of the local road weather forecast depends on the details of local meteorological information. The reference external data used as input to the RWM are the 3D fields simulated by FMI NWP (Numerical Weather Prediction) model HIRLAM (High Resolution Limited Area Model). The spatial computation and production domain of HIRLAM model covers explicitly the whole Europe and, hence, encompasses all of the individual FOTsis test sites and all the roads in the Sochi and Olympic Games areas as well. HIRLAM forecasts are produced 4 times a day at 00, 06, 12, 18 hours UTC with hourly interval between the forecast lead times, the maximum lead time being 54 hours. The computations start with the analysis of global synoptic observations. The resulted forecast data are presented on a 3D numerical grid, with horizontal grid spacing of c.a. 7.5 km and 65 vertical levels. Data computed on numerical grid are interpolated to the road points, specifically defined for the RWM simulations. Due to high computational demands NWP model simulations consume considerable amount of time (up to few hours). For the HIRLAM model installed on FMI’s mainframe, 24-hour long forecast takes 3-3.5 hours. Particularly, HIRLAM simulations, initiated at 00 h UTC, will produce meteorological fields valid for the lead time of 24 hour only at 3-3.5 h UTC. Therefore, the current weather estimations based only on the NWP model’s output will represent the 3 hour forecast at the shortest. Regarding 6 hours gap between NWP model simulations, the latest input data needed for the current time road weather estimations are 3 to 9 hours forecasts.

3 APPLICATION FOR SPANISH ROADS

FMI is a participant and the only provider of the road weather forecasts in the EU FP7 project FOTsis. FOTsis as a whole is aimed at large-scale testing of traffic management system, or intelligent transport systems (ITS), along eleven (11) highway segments located in Europe (four in Spain, three in Germany, three in Portugal, and one in Greece). All the roads located in each country represent a so-called test site. One of the main purposes in FOTsis is a construction of an automated traffic management system to be deployed in a test site’s control centre that would collect roadside information from various sensors and provide it using various communication technologies to drivers, road maintenance authorities, concessionaries or other services. The following seven services will be tested during the lifespan of FOTsis: (i) Emergency management, (ii) Safety incident management, (iii) Intelligent congestion control, (iv) Dynamic route planning, (v) Special vehicle tracking, (vi) Advanced enforcement, (vii) Infrastructure safety assessment. Figure 1 presents various components of the FOTsis ITS.

The FOTsis weather forecasting system is a stand-alone system that is linked to the ITS framework through the central FOTsis data base. Despite the test sites are mainly located in Southern Europe, the weather conditions can still be hazardous, especially during winter time, thus affecting traffic safety. All the raw data collected over a test site are stored in local test sites’ ITS data bases (DB). Central FOTsis data base will store the processed (time-averaged, controlled, and filtered) data for verifications and evaluations. Particularly, the predicted weather conditions and events are to be verified against road events, including observed weather, car accidents, and road congestions. Most of the seven FOTsis services will exploit weather information in one form or another, either as supporting background data or as one of the major driving factors behind the service conduction.

Since June 2013 FMI’s road weather model (RWM) has been implemented operationally for the four Spanish highways. These four highways are M12 passing the Madrid Barajas airport terminal 4, two pre-defined stretches along highway A2 connecting Madrid and Barcelona, and one stretch composed of parts of A2, N320, R2 and again A2 roads. Figure 1 shows schematically a FOTsis highway control configuration, and Figure 2 demonstrates a simplified example of one type of weather forecast output for the road stretch along the A2 highway in Spain.

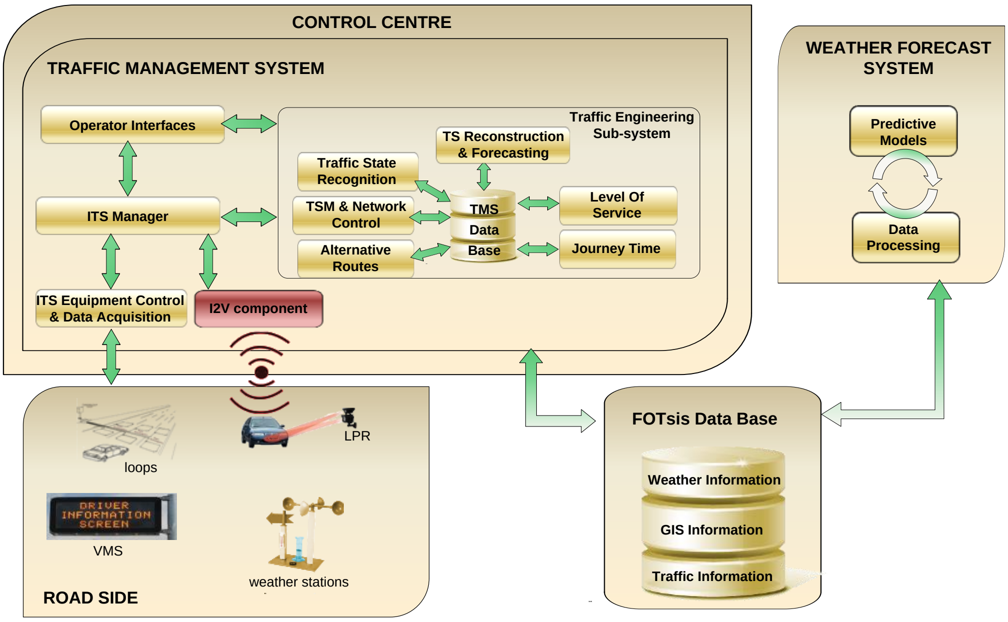

Figure 1. FOTsis highway control center structure.

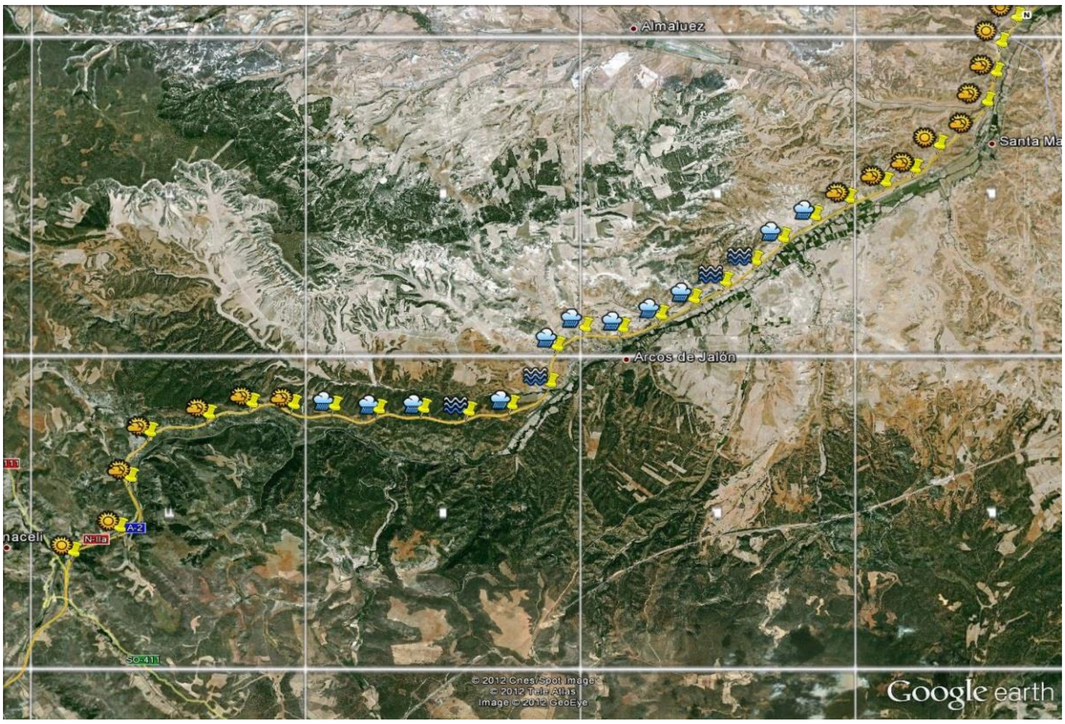

Figure 2. Graphical representation of a weather forecast along the Spanish A2 highway stretch.

Utilization of local data is essential in RWM simulations with the present time and spatial properties of the HIRLAM model. In this respect, collaboration with local weather services and data providers is of high importance. To increase the details of the RWM input information FMI has established fruitful collaboration with Spanish national weather service (AEMet) on local data acquisition and exploitation. The data provided by AEMet are the surface fields produced hourly by local weather observations analysis system and the forecast fields produced 6-hourly by the AEMet version of the HIRLAM model. At AEMet, HIRLAM simulations are initiated at 00, 06, 12, and 18 h UTC as at FMI, with the both models outputs available nearly at the same time, i.e. 3-3.5 hours past the simulation starting time. Though both AEMet and FMI HIRLAM models have similar properties regarding simulation and production times, the AEMet version is better adjusted to Spanish local conditions (specifically its analysis system) and has higher horizontal resolution than that of FMI. Both AEMet HIRLAM and the surface analysis system have c.a. 5 km grid spacing. Synoptic observations collected during a day within AEMet analysis domain are additionally provided once daily for verification of NWP and RWM results only.

FMI's public ftp server serves as data interface between FMI and AEMet. AEMet analysis provides initial weather state to the FMI RWM, whereas NWP model provides predicted weather state required by the RWM as input. Analysis of two-meter temperature and relative humidity, 10 meter wind speed, and surface pressure fields are provided with one hour delay and the analysis of precipitation with c. 1.5 hour delay. Presently, the simulation time for the RWM was chosen to be 2 hours prior to the current time to guarantee that all available initial data are available. Therefore, the current hour's road weather estimation represents essentially a 2-hour forecast.

In real-time operations, the key information to be delivered to the end users are the warnings of weather events, affecting traffic safety. Thus, FMI RWM simulation results were post-processed for the issues of distinct warnings against potentially adverse weather events. To deliver these kinds of weather alerts, FMI together with AEMet and the local Spanish FOTsis partners specified jointly critical threshold values for selected meteorological variables classifying weather events into different levels of severity per variable. The classification thresholds are shown in Table 1, where the respective alert thresholds are complemented with corresponding textual recommendations (right-hand-side column), which are delivered to the road users as text messages via the FOTsis network. These thresholds were assigned considering carefully the specific local weather conditions in Spain. Verification of the effectiveness of the weather warnings will be performed after the information on weather-related traffic incidents become available in the FOTsis database. These events are divided into the three levels of road weather adversity (Table 1)

The weather warnings are provided for FOTsis services by two means: 1) by uploading xml-formatted messages on the FMI public ftp server and 2) by storing the data in the FOTsis test data base which is a prototype of the final central FOTsis data base. Upon accomplishment of the FOTsis data base design and tests, the weather forecasting system applied for Spanish highways is planned to be extended to other FOTsis test sites in Portugal, Greece and Germany.

4 APPLICATION IN SOCHI

The Sochi Olympics area is located on the eastern coast of the Black Sea (c. 43.4º N, 40.0º E). Indoor sports are held in the city of Adler right on the coastline and outdoor sports events in the so-called Mountain Cluster, which is located some 40 km inland from the coast. There is the road A148 up to the mountains following an approximately 3-6 km wide valley surrounded by mountains with heights between 2000-2500 m. The Mountain Cluster is centered around the village Krasnaya Polyana at about 550 m above the sea surface. Such an environment provides a very interesting and challenging setting to adapt and test a road weather model. Our model was run for 26 selected points along the A148 road (Figure 3). First nine points are distributed at 2.5 km from each, and after a long tunnel about midway to Krasnaya Polyana the forecast point distance is 1.5 km. Before the tunnel there are typically no icy conditions and hence the bigger distance between points. The altitude of points is shown in Figure 4.

The road weather model runs for the Sochi region were started on 24 August 2013. The project is still in an experimental phase and no comprehensive verifications have been made thus far. However, the results look promising by visual investigations ("eyeball" verification). As an example, we present in Figures 5 and 6 a road weather model forecast run on 7 January 2014 basing on the 00 UTC HIRLAM run and verifying at 18 UTC the same day. Figure 5 shows the distribution of road surface and air temperatures along the road. Figure 6, on the other hand, represents the 24-hour forecast at the uppermost forecast point for this date. The forecast covers road and air temperatures, precipitation, friction and the so-called storage terms. The storage terms depicts the amount of ice, snow, water and deposit on the road transferred to water equivalent in mm. One can see in the figure a notable decrease in friction as soon as the precipitation has started. When temperature falls below freezing the rain is transformed into snow. Most of the precipitation remains on the surface as ice until the end of the forecast. The surface temperature is quite much higher than air temperature during midday. This means that there was not much cloudiness in the HIRLAM forecast. The surface temperature is typically much closer to air temperature in cloudy situations.

event_name	threshold	action message
Snow/Sleet	" Any snowfall, incl. hail "	"Minimize your speed"
Heavy snowfall/sleet	≥ 2 cm/h or 10 cm/6h	"Stop driving"
Cold snowfall/sleet	or 1 cm/h + T ≤ -10C	"Stop driving"
Rain	1 - 5 mm/h	"Control your speed"
Heavy Rain level 1	5 - 10 mm/h	"Minimize your speed"
Heavy Rain level 2	≥ 10 mm/h	"Stop driving"
Freezing Rain	Rain 1 mm/h + Tair < 0C or rain + Tsurface < 0C	"Stop driving"
Damp surface		"Control your speed"
Wet surface		"Minimize your speed"
Snow on the road		"Stop driving"
Icy road		"Stop driving"
Low Visibility Level 1	Visibility ≤ 400 m	"Control your speed"
Low Visibility Level 2	Visibility ≤ 250 m	"Minimize your speed"
Low Visibility Level 3	Visibility ≤ 80 m	"Stop driving"
Blizard	Max wind gust ≥ 17 m/s & Tmean ≤ 0C (24 hrs) & Precip ≥ 10 mm (24 hrs)	"Stop driving"
Strong Wind Level 1	≥ 12 m/s	"Control your speed"
Strong Wind Level 2	≥ 17 m/s	"Minimize your speed"
Strong Wind Level 3	≥ 21 m/s	"Stop driving"
Wind Gust Level 1	≥ 17 m/s	"Control your speed"
Wind Gust Level 2	≥ 25 m/s	"Minimize your speed"
Wind Gust Level 3	≥ 32 m/s	"Stop driving"
Low Firiction level 1	≤ 0.4	"Control your speed"
Low Firiction level 2	≤ 0.3	"Minimize your speed"
Low Firiction level 3	≤ 0.2	"Stop driving"

Table 1. Meteorological parameters, thresholds, and messages of the actions used as weather alerts for the Spanish test highways.

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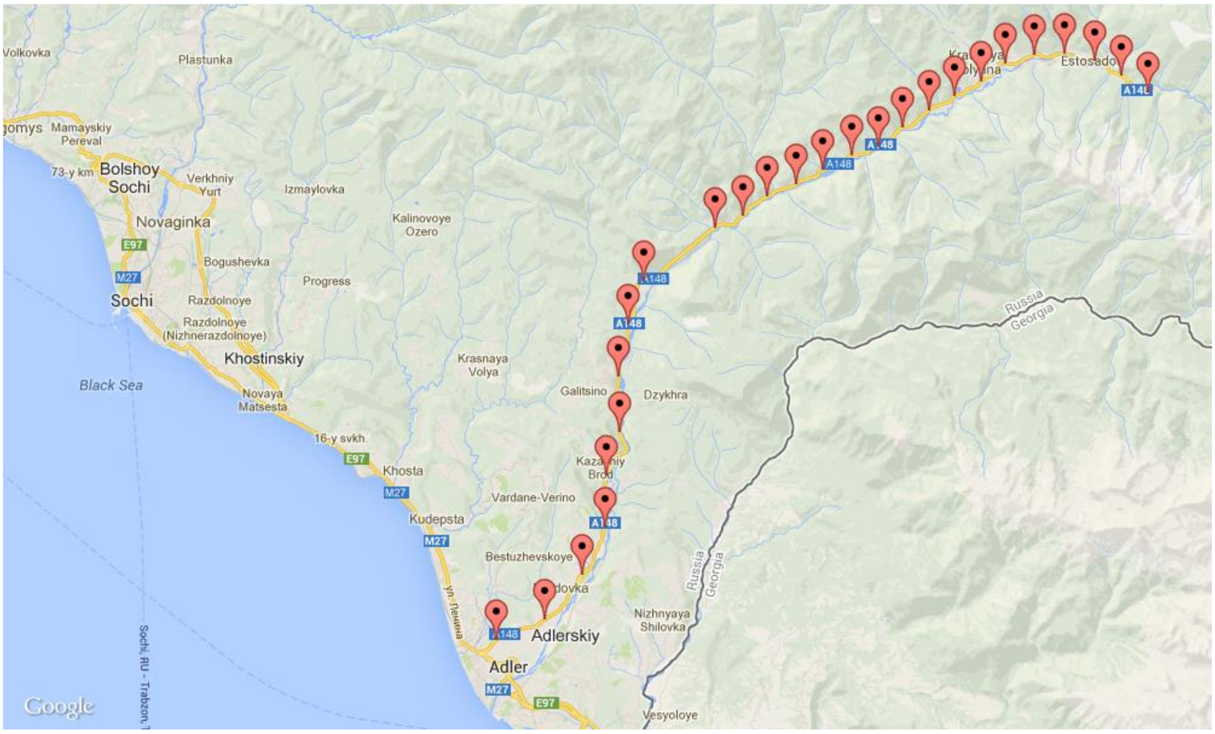

Figure 3. The locations of road weather model forecast points.

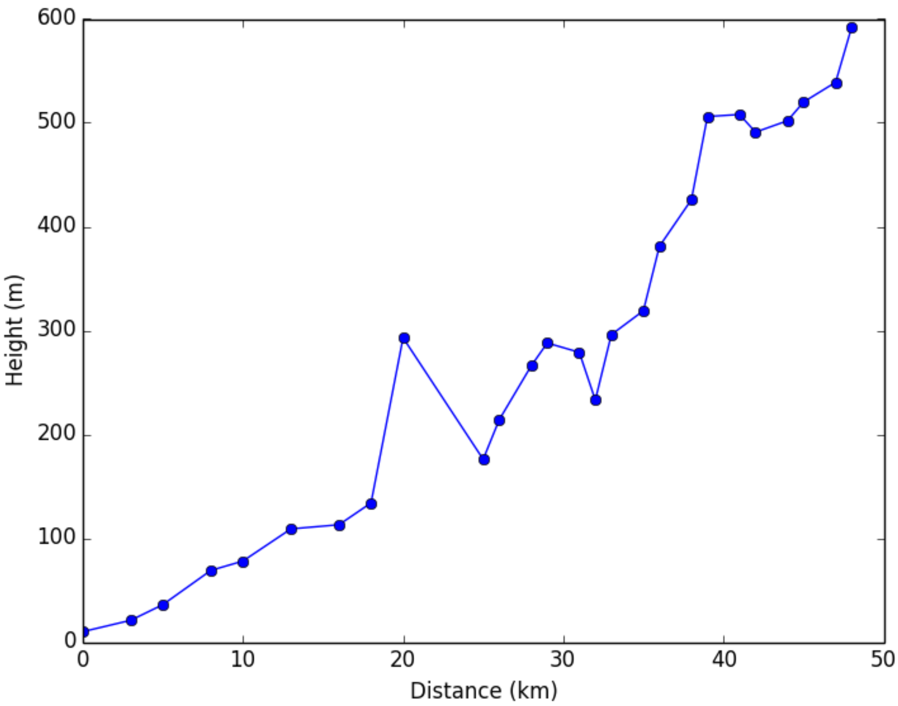

Figure 4. The height distribution of the 26 forecast points along the road stretch from the coast to the Mountain Cluster (cf. Fig. 3).

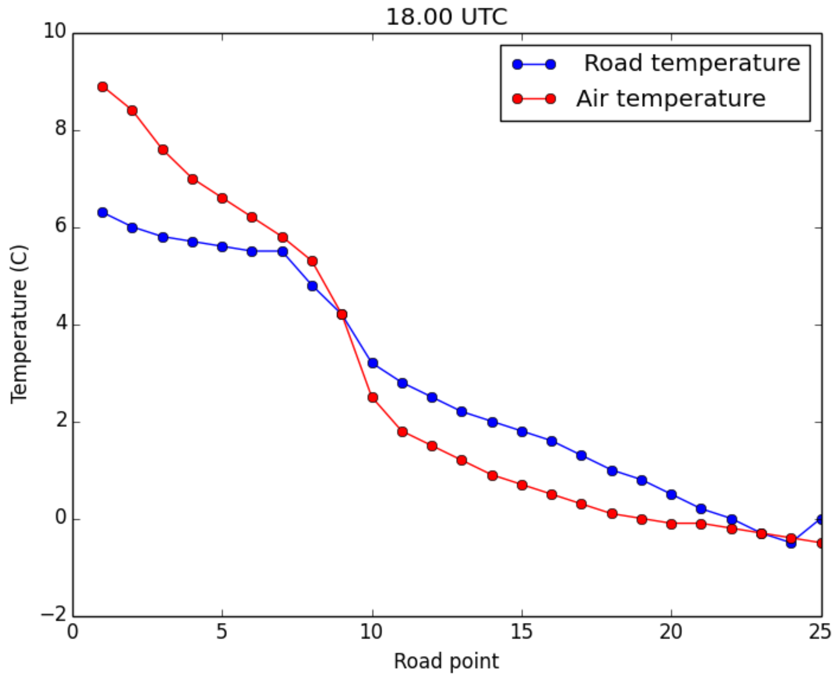

Figure 5. Forecasted road surface (blue) and air temperature (red) along the road, 7.1.2014, 18 UTC. Forecast point numbering is on the x-axis starting from the coast.

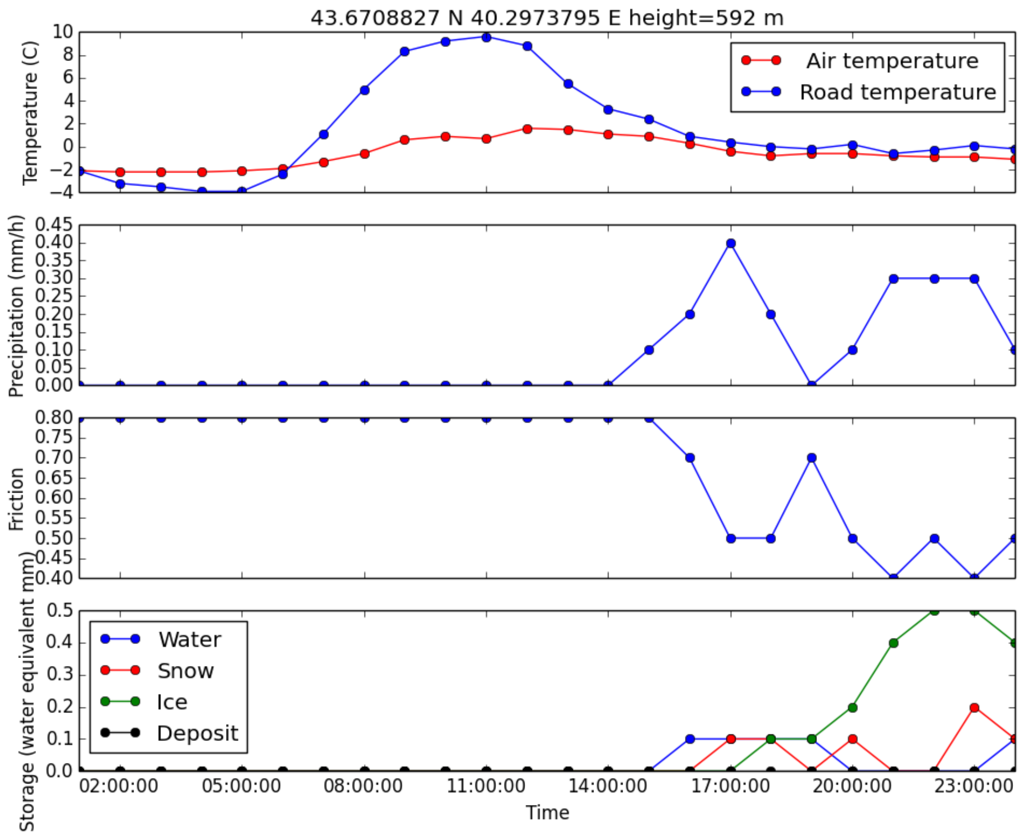

Figure 6. Road weather forecast, 7.1.2014, at the uppermost forecast point. Time is on the x-axis in UTC. Air temperature and road surface temperature are in the top panel, precipitation in the second panel, friction in the next, and storage terms in the bottom panel.

5 CONCLUSIONS

The pre-operational road weather service and the resulting alerts against adverse weather as the fundamental service output were implemented for the Spanish test highways in summer 2013. Development work to improve these services will continue in close collaboration with local actors and other FOTsis partners, because such cooperation is a necessity to fulfil the project goals. A similar road weather forecasting framework will eventually be implemented for the remaining test sites and the corresponding services in Germany, Portugal and Greece, provided that there is a consensus with the local actors to install such a system. FMI will carry out an extensive verification study at later stages of the project to explore the quality of its road weather products delivered to the FOTsis framework. The potential correspondence between road accidents, traffic congestions and observed as well as predicted road weather conditions will be analysed in this evaluation process.

In Sochi the mountainous environment can affect greatly the accuracy of road weather forecasts. Although the HIRLAM model can take mountains into account, its grid is so coarse that it may not simulate the valley realistically. The grid size of the present HIRLAM version is 7.5 km and the valley's width is about half of it. Mountains can cause great screening effects on the road decreasing surface temperature significantly. To obtain more precise forecasts with the road weather model we will eventually use a model version with a smaller grid size. The HARMONIE model having a grid size of 2.5 km will be run for the Sochi region during the winter Olympics 2014. First tests with this fine-scale model were reported in [3]. The smaller grid size will simulate mountains and valleys better, so there are good chances for higher quality road weather forecasts with HARMONIE data.

FMI road weather model can be relatively easily adjusted and applied in whatever other regions that are covered by the HIRLAM model domain, which is the whole Europe and surroundings. The model configuration has already been tested in Russia and in Andorra. HARMONIE will soon be expanded from covering Finland to extend over the whole of Scandinavia region, which will enable producing also more precise road weather forecasts for larger regions than before.

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