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Customer oriented operations of the Finnish Meteorological Institute for road traffic sector

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ABSTRACT

Weather observations and forecasts are vital for many traffic related weather services and research. Related information is necessary indicator in weather sensitive decision-making, particularly enhancing safety of traffic. The paper focuses on the Finnish Meteorological Institute's (FMI) Customer Services' current topics relating to road traffic services by outlining some of studies and services aimed at particularly for traffic operations. The more closely discussed activities are open data and developments of the data-to-intelligence project with the emphasis in improving operational road weather services. FMI serves both public and contract clients as continuing processes, and the purposes of service demonstration and illustrating road model portability FMI has set up road weather model to Andorra during the SIRWEC 2014 conference.

Keywords: Weather services for road traffic operations, open data, data-to-intelligence, road weather.

1 INTRODUCTION

Weather observations and forecasts set grounds or support many functions of traffic related weather services and research. Weather related information is necessary indicator in weather sensitive decision-making, particularly enhancing safety of traffic. Demanding seasonal conditions cause notable challenges for traffic system in Finland. Disruptions are often explained by weather events. The paper discusses on the FMI Customer Services' current topics relating to road traffic services. Selected current activities focus on open data and developments of the Data-to-Intelligence project (D2I) with the emphasis in improving operational road weather services. In Finland, open data sources also include national road weather observations.

The FMI is a research and service agency under the Ministry of Transport and Communications of Finland. Its activities are based on scientific research as well as modern observation and ICT technologies. The principal objective of the Institute is to provide the best available information about the present and future state of the atmosphere, to guarantee public safety relating to potential atmospheric hazards, and to satisfy any user requirements for specialized meteorological services. Concerning road sector, a few examples of service products are illustrated here along with porting and running the FMI road weather model to Andorra for the duration of SIRWEC 2014.

2 OPEN DATA

2.1 Background

Historically the initial data produced by national weather services has not been free of charge for commercial value creators. European Union's directives on Infrastructure for Spatial Information (INSPIRE), Public Sector Information (PSI) and Intelligent Transport System (ITS) have steered publicly funded data producers towards opening of various information sources. At Finnish national level there have been also several rulings to the same direction, like the Council of State's decisions on opening publicly funded information sources and implementation of ITS directive, the Ministry of Finance's ICT strategy for 2012-2020 and KIDE-program (growth, innovations, digital services and evolution) of the Ministry of Transport and Communications. During the past few years the FMI and its steering ministry have conducted several studies on the effectiveness and effects on weather data opening. As an example of related studies, according to Hautala and Leviäkangas [1] money invested in weather services returns annually at least 5-fold benefits to the society, while 10-fold figures in potential benefits have been reported.

The term open data in this case refers to such information that can be used and distributed in machine-readable format, under open license conditions and free of charge. According to the open data licence anyone can freely copy, distribute and publish the information. It may be modified, combined with other products, utilized commercially or non-commercially, and used as a part of an application or a service. When using the information a user must acknowledge the original producer and the date of the data. Full licence conditions are available at http://en.ilmatieteenlaitos.fi/open-data-licence.

In order to promote usage of open data the FMI has organized helpdesk function for content-related and technical assistance. Helpdesk is available on web form and as phone service. While the data content is free of charge, if more extensive than minor service consultations or tailoring of data transactions are requested, related costs may be charged. Helpdesk also organizes paid consultation services for commercial users. The open data project has been described at length by Honkola et al. [2].

2.2 Information content

During 2013 the FMI has made significant portion of all national weather and oceanographic data freely available on the Internet. In defining the data content INSPIRE directive principles have been followed, but in practice the implementation exceeds aforementioned requirements. Opened data sets are produced operationally and continually and they consist of various observation and forecasting data sources. In Finland, these information also include national road weather observations. The latter data are administered by the Finnish Transport Agency and their production is organized by the Southeast Finland Centre for Economic Development, Transport and the Environment.

The open data information content can be categorized as real-time observations, daily and monthly values of observations, and numerical model forecasts. The FMI's real-time weather observations are collected at 1-10 minute interval, oceanographic observations 30-60 minute interval, and road weather observations at 10-15 minute interval, respectively. All together about 100 000 observations per day are gathered for open data distribution. Weather and oceanographic model forecasts are updated four times a day.

Data categories are summarized in the tables (1), (2) and (3). For road weather observation data set a slightly more detailed list of possible reported parameters is given as follows: air temperature, road surface temperature, ground temperature -5cm below road surface, dew point temperature, frost point temperature, freezing point temperature (dependence on salting conditions) at road surface, road body temperature, mean wind speed, maximum wind speed, mean wind direction, barometric pressure, air relative humidity, precipitation amount (10 min, 1 hour, 24 hours) and type, road weather conditions, present weather, cloudiness, visibility, moisture amount on road surface, salt amount and concentration on road surface, snow depth, luminance, net radiation, solar position, friction factor, snow and ice amounts as liquid water equivalent, sensor faults and warnings, conductivity, ice frequency, and battery voltage.

Still more information will be added to open data interface as they become technically available and their publication are not restricted by any third party. For some information the FMI has right to use the data while it is not the owner of the data. Directions and examples to start using the described open data are presented on the FMI web-site (http://en.ilmatieteenlaitos.fi/open-data).

Topic	*Content description*	**Frequency**	**Since**
Waves	Significant wave height and direction, and sea surface temperature	0,5-1 h	2005
Solar radiation	Sunshine duration, UV-radiation, shortwave and longwave radiation	1 min	2012/2013
Sea level height	Sea level height	1 h	1971
Weather	Air temperature and humidity, wind, barometric pressure, visibility, precipitation intensity and amount etc.	10 min	2010
Road weather	See the text.	10-15 min	2010
Weather radars	Precipitation intensity, radar reflectivity factor, accumulated precipitation (1, 12, 24 h)	5 min	5 days
Lightnings	Lightning location coordinates, multiplication, current	5 min	1998

Table 1. Information content of the real-time observational open data.

Topic	*Content description*	**Frequency**	**Since**
Daily values of weather observations	Daily average temperature and accumulated precipitation, daily minimum and maximum temperatures, snow depth	day	1959
Monthly values of weather observations	Monthly average temperature, and accumulated precipitation	month	1959
Monthly values of gridded weather observations	Monthly average temperature and accumulated precipitation interpolated to grid	month	1961

Table 2. Information content of the daily and monthly values of observational open data.

Topic	*Content description*	**Forecast periods**
Wave forecast (WAM)	Significant wave height and direction	Latest 48h forecast, 4 times a day
Sea level height forecast	Sea level height	Latest 48h forecast, 4 times a day
Sea current forecast (HBM)	Sea surface temperature, surface current and saltiness	Latest 48h forecast, 4 times a day
Weather forecasts (RCR HIRLAM)	Air temperature and humidity, wind, cloudiness, barometric pressure, precipitation amount etc.	Latest 48h forecast, 4 times a day
Climate change scenarios	Monthly averages of temperature and precipitation for six greenhouse gas release scenarios, as average of 19 climate models	30-year periods for 2010-2039, 2040-2069 and 2070-2099

Table 3. Information content of the model forecasts as open data.

2.3 Technical implementation

In the implementation project new web service was built, which allows anyone with enough technical capabilities to access the data. The INSPIRE directive defines how spatial information infrastructure should be put into effect. For the FMI open data implementation the essential components are the information content as described in previous section, their metadata, and Internet services for using the information. The realized service architecture technically involves download service, view service, and discovery service (catalog), in accordance with INSPIRE terminology and they are based on Open Geospatial Consortium (OGC) standards (http://www.opengeospatial.org/standards).

The discovery service can be used for high-level searches of available data content. By using view service one can browse data values (e.g. temperature) or symbols (e.g. wind vectors) examples on map background via web map service (WMS). However, this method is not meant to be a user interface for the data. The main method in getting the data is the download service. The service allows a user to retrieve data in machine-readable format by using web feature service (WFS) 2.0. This way user may access point location data with geography markup language (GML) queries, and gridded data (e.g. weather radar observations and numerical forecasting model) in a suitable format for each data type. The information can be accessed on the following servers: http://catalog.fmi.fi (discovery service), http://wms.fmi.fi (view service), and http://data.fmi.fi (download service).

To get access to download service, a user has to register and accept license terms. In the process he gets a unique identification string (API-key) for data retrieval requests. Such procedure has been accomplished to prevent misuse of the services, the number of allowed user queries is managed by API-keys. The current limits for download service are 20 000 queries/day and 600 queries/5 min. Respective limits for view service are 10 000 queries/day and 600 queries/5 min. For discovery service there are no similar limitations. The beta version of the services was launched on FMI Facebook page (https://www.facebook.com/fmibeta) in February 2013, and was publicly announced for use in June 2013.

2.4 Expectations and first experiences

The opening of the data is expected to enable benefits wider than before for companies and industries and for the whole society. It is hoped that the use of the data also increases among citizens and researchers, and among and between authorities. New services and innovations are expected from anyone with skills and interest on the data. In particular it is desired that various information from any available data sources would be mixed (diverse data) to create new added value to users and stakeholders of weather and oceanographic data. The recent publication by the Committee for the Future of the Finnish Parliament [3] ranks open data and big data with the highest points among 100 radical technological solutions. All the listed expectations would increase the efficiency of the invested resources. Data opening also promotes transparency of operations.

During the first six months more than 3000 users have registered to the service. The helpdesk has received roughly 300 assistance requests via web form, and continues to receive varying number of phone calls each working day. Through the Apps4Finland 2013 open data innovation contest and the FMI's Facebook community new applications have been reported to use open weather data. Examples of such applications are given in the table (4). It is also known that several companies or authorities use data themselves or with the help of software consultants. For example, tens of companies, schools or authorities have participated to FMI organized introduction workshops for taking data into use. Some of the resources have been gathered to Github (https://github.com/fmidev/opendata-resources), which is a hosting service for software revision and source code management e.g. for open source projects.

Service type	***Web address***
Weather radar display	http://www.nordicweather.net/sadetutka.php?en
Veikkola lightning data	http://veikkola-weather.com/map-strikes.php?lang=en#
Veikkola forecast	http://veikkola-weather.com/wxFMIforecast.php?lang=en#
Thunderstorm application	http://www.geocache.fi/ukkostutka/
Wind for surfers	http://windz.apiruq.com
Tampere weather for one day	http://85.194.225.35/safetydev/opendata
Past weather visualization	http://www.cs.helsinki.fi/u/tituomin/apps4finland/
Weather radar animations	http://metanimi.com/radar-fin-south/

Table 4. Examples of services available on the internet that utilize open data.

3 DATA TO INTELLIGENCE

For longer term development of weather services the FMI conducts and participates various studies, such as Data-to-Intelligence project. In addition to following reported results it focuses on ICT-architecture and cloud services capable of handling increasing enormous data volumes, which are also utilized in the open data context. The interdisciplinary D2I aims overall to create service concepts, identify and tackle challenges for business, develop the data analysis methods, collect the required data, develop pre-processing methods for the data, and pilot the services. Next is described some of the research that has been done in the project concerning weather and traffic.

3.1 Spatial variation analyses between road traffic volumes and weather

The modelling of traffic flows and volumes has been an important topic of research in varied fields and has previously been studied with the use of a raft of methods and techniques. This research aims to explain the traffic volume with different weather variables. The goal is to find out how different weather conditions affect the amount of traffic. Previous studies that have examined the influence of weather variables upon traffic volumes have assumed that any relationships that are determined hold constant for the whole study area. In the study is explored whether this assumption is valid or whether there are intrinsic differences in the relationships affecting traffic volumes, which can be identified at disparate locations across the study area.

Traffic volume data was received from the city of Oulu. It consists of the daily totals of traffic volumes from 92 crossroads as measured by sensors located at each of them. Weather data was received from the FMI. From the data measured every ten minutes was obtained variables relating to the daily average temperature, amount of precipitation, and average road friction. Within the data supplied, the effect of snowfall is not considered separately from that of rain. Although the friction coefficient correlates closely with the times of snow or rain it does lack the ability to relate to the loss of visibility that heavy snowfall causes, which has been shown to reduce traffic volumes [4]. Ordinary least squares (OLS) regression is applied to the data first with normalised traffic volume as dependent variable and weather variables as well as dummy variables for different days of the week and holidays as explanatory variables. Moran's I values [5, 6] are then calculated for the coefficients to study the spatial autocorrelation. For the local model, a regression model is calibrated on all data that lies within the distance of 1500 metres of the regression point, a crossroads, and the process is repeated at all the regression points.

For the global regression model, all the coefficients for the weather variables are statistically significantly different from zero. All the Moran's I values for the coefficients show a positive spatial autocorrelation. Thus the relationship between the weather variables and the amount of traffic varies spatially. This indicates that when studying the effect of these variables upon traffic volumes we need to take the location into account. This study strongly indicates that modelling the correlation between traffic volumes and weather variables needs a spatial approach. This is because the relationship between the variables depends on location. It can easily be seen from our results that the centre of Oulu differs from other areas. For example, figure (1) shows that in the central area and northern part of Oulu the coefficients are bigger than in the other areas on the outskirts, which means that in those areas the traffic increase on days when there is precipitation is bigger, up to almost 4% compared to the median.

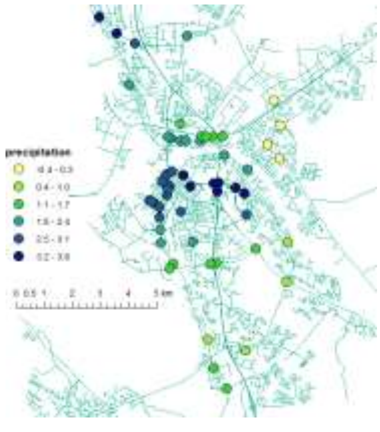

Figure 1. Local coefficients for the precipitation variable.

In the study area slippery weather reduces the amount of traffic. However, this research also shows that in the Oulu area precipitation seems to increase traffic volumes, whereas other research studies on the subject seem to show the opposite [7]. The results can help when predicting traffic volumes in Oulu. As the amount of traffic affects travelling time, this can be used for navigational purposes. In order to create a better spatial model, more sensors are needed outside the city centre of Oulu.

3.2 Different factors affecting to driving behaviour

For the purpose of evaluating factors affecting to driving behavior, driving data has been collected and fused with weather and map related data. Driving data are collected from 8 taxis in Oulu. These cars are equipped with the Driveco devices (http://eco.driveco.fi/www/), which measure driving properties of the trip, like fuel spent, speed, etc. These data are preprocessed (cleaned, filtered and segmented) and saved for further analyses. Weather data are supplied by the FMI. Currently road weather data is utilized, which is calculated from the model for the point closest to the center of Oulu. Map data are retrieved from Digiroad database (http://www.digiroad.fi), which is a national road and street database of Finland. Digiroad contains very detailed attributes and properties of street and road network.

First, we apply general statistical analysis to both driving and weather data. As idling seems to be one of the factors strongly affecting fuel consumption, we addressed how this factor and fuel consumption are affected by weather. This analysis was carried for all the 8 cars, for time period from October 2012 till July 2013.

The analysis reveals that wind speed does not show any noticeable effect on relative fuel consumption and idle proportion. Surface condition plots demonstrate that water on the road may affect relative fuel consumption more than other surface condition values. However, snow amount demonstrates decrease in idling proportion. Interesting that friction coefficient did not demonstrate significant difference for some cars, like cars 5, 7, and 8. Two cars (2, 4) demonstrated increase in fuel and idling when slipperiness increases. Very bad traffic index demonstrated increase in relative fuel in idling for all cars except cars 1 and 6. Probably, precipitation intensity alone cannot tell about the effect on fuel consumption and idling, as plots for cars differ. Some cars demonstrate rise in fuel and idling for high precipitation intensity values (like cars 5 and 8), others demonstrate the opposite effects (cars 6, 7). Difference between surface temperature and dew point temperature also does not provide clear effect on relative fuel consumption and idling proportion. As well as temperature factor demonstrates different effect on different cars.

The first statistical analysis reveals two main issues to proceed further. First, we should identify other response variables than fuel consumption and idling proportion. Even though, these factors are affected a lot by driving behavior and other parameters (like weather and map related features), the car model has significant impact on these. Some cars were replaced by others, and unfortunately we don’t have any information on these changes and dates. Second, we should explore factors in connection to each other, this may bring more meaningful and reliable observations. To proceed further with analysis we’re now processing the data with respect to Origin and Destination pairs. We have selected 6 roads in the center of Oulu and analyze different alternatives for cars to cross the city center between these selected roads. We utilize map related features, like amount of traffic lights, crossings, pedestrian crossing, etc. together with weather information. This would allow us to discover whether certain weather conditions affect the driving differently at different roads. To overcome mentioned difficulties, we select the proportion of slow speed and the proportion of the speed at a given speed limit as the response variables. These factors affect overall fuel consumption and depend more on driving behavior and route selected than on the specific car model type.

4 OTHER FMI SERVICE OFFERINGS

As ongoing processes, the FMI serves both the public and contract clients. It automatically produces more than million information products each day. It offers 24/7 based weather services for transport sector including e.g. road traffic and maintenance, public transportation, commercial shipping and recreational boating, air traffic and pedestrians. Other service areas include media’s weather services, agriculture, retail, and energy industry. The institute generates warnings for authorities and public against wind storms at sea and over land, waves, thunderstorms, heavy precipitation causing warm season floods or wintertime snow accumulation, ice formation on structures, forest and grass fires, hazardous UV radiation, warnings against high-impact road weather, and pedestrian slipperiness conditions.

One core activity is to actively develop and deliver multifaceted services and products through automatic systems for various safety purposes. Producing new weather services can be seen as providing new, richer and more-targeted content of the data, combining and reformatting the data sources, unbundling data by extracting data from existing products, exploiting understanding in providing data to less-informed party, and making it easy for consumers to find and use the data they need. Among applied technologies are internet, mobile phone, direct data transfer and personal navigation based products. The FMI also provides expert services in international R&D cooperation projects. It facilitates connecting end-users and their needs of weather services, other service providers, related research and government strategies.

An important tool in producing road weather forecasts is the FMI's own road weather model, which is run on top of a numerical weather prediction model (NWP). It is possible to use road weather model anywhere where NWP model is available. Few examples of the road sector relevant services are described in the following and in the figure (2). For the purposes of service demonstration and illustrating the road model portability the FMI has set up road weather model to Andorra area during the SIRWEC 2014 conference, where some of the road weather forecast products are presented. Test run outputs are shown in the figure (3).

4.1 Driving condition forecast

Road customers that the FMI serves include authorities and on commercial side cities and road maintenance companies. Road weather forecasts are also delivered through some navigation systems, where the driving conditions are transmitted to users. The forecasted driving conditions are categorized by using 11 different classes: supercooled rain, rain on icy road, sleet on icy road, quick change on conditions, heavy snow, blowing snow, warning for wind, slipperiness due to very low temperatures, snowy road, freezing of wet roads and frost. An example on driving condition forecast on a map is shown on left in the figure (2). Road conditions are divided into five different classes: dry, wet, snowy, frosty and icy. Using numerical weather prediction model and then running road weather model on the top of that do the classifications.

4.2 Road warnings based on friction

Friction is one of the main variables when we try to determine vehicle's ability to stop from movement. Therefore, one of the road model output parameters is friction on road. Based on friction values (varying from 0 to 1) conditions are categorized into three classes: very poor (less than 0,15), poor (between 0,15-0,30) and normal (bigger than 0,30) winter road condition. These warnings can be delivered out to different users' mobile or other terminals. One of the applications that is using the FMI's forecasted friction value is D2I project's braking distance application. The information of the distance for the vehicle to come to stop is brought to the driver for example through a smart phone.

4.3 Time for the next snowplough

For road maintenance it is important to know when it is time for the operations. With the road model we help the operators of road maintenance with their decision making in optimising the maintenance work. One of our applications gives the user the time when and where the next snowplough should take place (figure 2, on right). It gives the operator estimated time when the next snowplough should be started with a half an hour steps for the first six hours and then with one hour steps up to six hours. Calculation is based on precipitation forecast with certain limit values for the predicted snow amount.

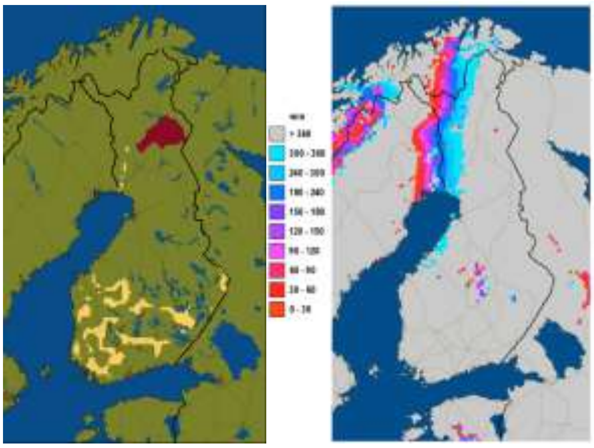

Figure 2. Examples of the FMI road weather service products. On left: Driving condition forecast indicating road slipperiness due to very low temperatures in the northern Finland and frost more spatially scattered in the southern Finland. On right: forecasted timing before the next snowplough fleet activation.

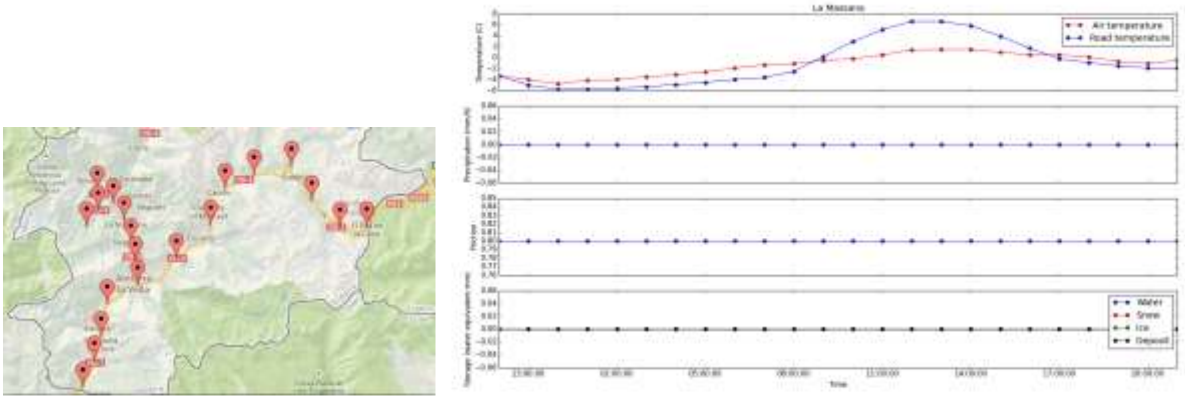

Figure 3. Locations for road model point forecasts (left), and road model forecast for La Massana (right).

5 SUMMARY

In this paper we have given an overview of timely road weather related activities of the Finnish Meteorological Institute's Customer Services unit. The topics involve statuses of the open data distribution, selected FMI service offering examples, and achievements in the D2I project. Presented studies particularly indicate that when studying the effect of weather variables upon traffic volumes the location needs to be taken into account with spatial approach.

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