

Remote sensors tests on Lithuanian roads

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ABSTRACT

There is constant demand for high quality road surface state sensors to road maintenances works in winter. And new remote road surface state DSC111 and road surface temperature, air temperature and humidity DST111 sensors were tested on real conditions on motorway E77 in Northern part of Lithuania under the pilot project during 2006/2007 winter season to fill in the gaps. The data from the remote sensors were compared with Road Weather Station, Road Video Camera and the human visual observations. Also evaluation of operative potential of these sensors was performed for Lithuanian roads. The results showed that remote sensor's DSC111/DST111 complementing, installing, mounting, calibrating, software updating, maintaining tests ran mostly well for Lithuanian conditions. Road surface temperature values were very similar (diff. 0.05°C) if temperatures were below 5°C limit when comparing DST111 and Road Weather Station data. And remote sensor DSC111 data was mostly correct and representative for all road surface conditions types.

Keywords: remote sensing, winter maintenance, road surface temperature, winter driving conditions.

1. INTRODUCTION

Road surface temperature and state conditions are the most valuable information for winter maintenance specialists in our days. There are a lot of experience gained through last 40 years in concerning road surface state and conditions measurements and predictions in winter time [5],[17]. Different road weather conditions measuring equipment, models, systems and programs such as MDSS, SHRP etc. are formed in North America, Japan and the most parts of Europe. Now all Road Weather Information Systems (RWIS) etc. are closely involved into Intelligent Transport Systems (ITS) [8],[15].

RWIS in Lithuanian implementation started in 1998. During almost a decade system was developing with new measuring devices, winter maintenance courses, and technical issues [3],[10-11]. Also there scientific research some studies on local scale about road surface temperature provided by Vilnius University which includes road surface minimum temperature forecasting algorithms and its reliability on different parts of Lithuania [2],[9].

Lithuania has 21,320 km of National Significance road network. And RWIS includes 45 Road Weather Stations (RWS), 18 road video cameras (RVC) and 4 weather information signs. Information of RWS about current state of road temperature and driving conditions presented on the official internet site [12]. Also the main information about the road state of Baltic States and Finland are possible to find on internet site supported by National road Administrations [1].

There is still constant demand for high quality road surface state sensors to road maintenances works in winter. Road weather forecast systems are highly dependent on reliable meteorological data from RWS. Most of equipment is directly measuring parameters, but there are some efforts to introduce in our markets good quality remote sensors which have their own virtues [6-7],[13],[16]. Also surface state remote sensors development improved slipperiness and tyre friction studies [14],[18]. When Vaisala Oyj released new generation products – remote road surface state sensor DSC111 and road surface temperature, air temperature and humidity sensor DST111 it was suggested to test them on real conditions under the pilot project in Lithuania. For the first time in Lithuania high quality remote sensors are available to measure road surface temperature and state conditions comparing it with RWS data, RVC data and periodic field measurements.

The main objective of this study was to compare data from the remote sensors with RWS, RVC and the periodic field measurements and to evaluate operative potential of these sensors on Lithuanian roads.

To achieve this objective the following tasks had been defined:

- Verify applicability and creativity of RWS data.
- Analyse sensors and equipment specification.

- Form database and computing programs for further analysis.
- Perform data comparative study during different weather conditions.

2. REMOTE SENSORS TESTS ON LITHUANIAN ROADS

2.1 Equipment installation and primary data collecting

Vaisala Oyj's Remote Road Surface State Sensor DSC111 and Remote Road Surface Temperature Sensor DST111 were used in this study. DSC111 / DST111 sensors set was mounted on motorway E77 Riga – Siauliai – Taurage – Kaliningrad in Northern part of Lithuania (eastern part of Zemaiciu highlands) near the already operating RWS named “Bubiai” [fig. 1]. It is situated on the right side of the 4 lane road near the bridge across river Dubysa. Data was transmitted through GPRS modem every 10 minutes. Original software was created to data collecting, processing and storing.

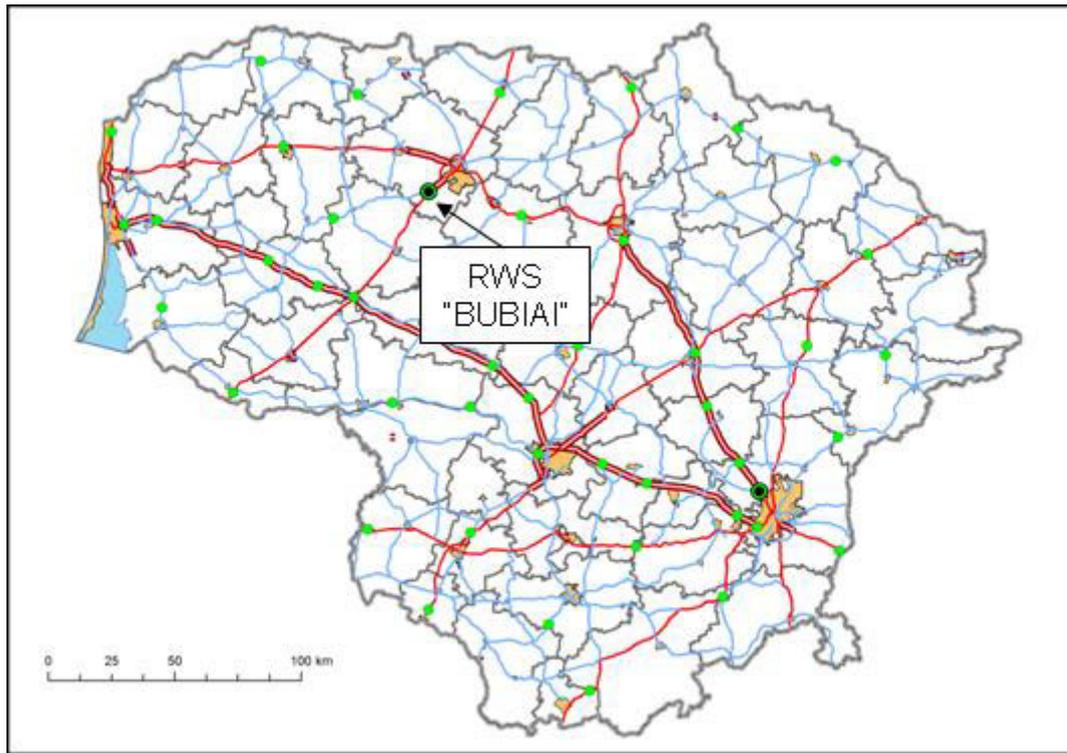


Fig. 1. RWS network (green spots) and RWS “Bubiai” location in Lithuania.

Road Weather Station was equipped with the following sensors:

- Pentronic AB road surface temperature PT100,
- Lambrecht air temperature/relative air humidity 3110,
- Combitech AB precipitation type and amount OpticEye,
- Vaisala Oyj wind speed and direction WA15,
- JAYCOR visibility,
- Pentronic AB/Combitech AB ground frost 6xPT100.

Data from these sensors are collected every 30 minutes in winter time. RVC with IR lamp was also included in this set. Moreover periodic field measurements of road surface conditions were possible.

Test was run from the 6th of December, 2006 to the 17th of April, 2007 (till the end of the cold season). Along with the automatic measurements, periodic field studies (from December 29th) of road surface's state during non standard weather conditions were pursued.

All stationary and new remote sensors of RWS “Bubiai” are mounted on the same roadside pole. The spot of remote sensor are close to road surface sensor on the first lane between the ruts close to right side. Meanwhile visual range of RVC is oriented towards bridge side which could change properties of road surface thermal conditions [fig. 2].



Fig. 2. The spot of remote sensor (white square) on the left and visual range of RVC on the right.

Original data base was created including remote sensors DSC111 & DST111 (measuring period 6th of December 2006 – 17th of April 2007), RWS “Bubiai” air and road surface temperature and humidity sensors (6th of December 2006 – 17th of April 2007), direct field (6th of December 2006 – 17th of April 2007) measurements and pictures of RVC (6th of December 2006 – 31st of March 2007). All datasets were possible to be compared in between.

2.2 Vaisala Remote Road Surface State Sensor DSC111

2.2.1 Sensor characteristics

Vaisala DSC111 provides an accurate reading of surface conditions, including water, ice and snow amounts and a high resolution value for grip level [fig. 3]. Features and benefits of the sensor given by Vaisala Oyj [19]:

- Remote surface state sensing (measuring distance 2 ... 15 m, operating temperature -40 ... +60°C, operating humidity 0 ... 100% RH);
- Spectroscopic measuring principle (surface states: dry, moist, wet, snow/frost, ice, slush);
- Unique measurement of grip (level of grip 0.01 ... 1.00);
- Accurate and stable measurement results even with intense traffic (layer thickness: water 0.00 ... 2 mm, ice 0.00 ... 2 mm, snow 0.00 .. 10 mm);
- Eye-safe laser technology (eye-safe, laser class 1);
- Easy installation and service;
- Low maintenance costs;
- Weather-proof, durable design;
- Easy integration with Vaisala ROSA Road Weather Station, or can operate as a standalone solution with solar/GSM options.



Fig. 3. View of Vaisala Remote Road Surface State Sensor DSC111 [19].

The Winter Service engineer is therefore able to carefully monitor all of the weather elements which create a hazardous driving surface in order to take the appropriate remedial action. Together with DST111, which remotely measures surface temperature, DSC111 forms a versatile standalone weather station [19].

Beside the official Vaisala Oyj authorities information some weaknesses found in DSC111 complementing, installing, mounting, calibrating, software updating, maintaining during our pilot study. Complementation kit lacks power supply for the device. Also there is constant need of cable for calibrating procedure and knitting

elements to mount DSC111 onto the pole. It is not very clear how to spot the devices into their measuring area (poor instructions) especially in period of heavy traffic. Also the software updating instructions is not obvious enough.

2.2.2 Road surface conditions data comparison

There are some examples of remote sensors and grip measurements available using Vaisala's remote sensors [4],[14],[16]. The results are quite controversial: Vaisala's research showed good correlation between grip levels and tyre friction [7],[16]. In contrary experiments in Canada and USA founded the correlation between grip levels and frictions were very weak, especially under conditions of low friction [4],[13].

In our case DSC111 data was compared with RVC data. Three main road surface condition categories were postulated: dry, damp/wet and slush/snow/ice [table 1]. Analysis was made in two ways. First of all RVC data were compared with DST11 under the postulated conditions. After that reverse procedure was done – DSC111 data was compared with RVC data under the same conditions.

Road surface conditions	RVC		DSC111	
	Mismatch / Overall		Mismatch / Overall	
Dry	4 / 245	2%	34 / 275	12%
Damp / Wet	13 / 183	7%	144 / 314	46%
Slush / Snow / Ice	138 / 474	29%	7 / 343	2%

Table. 1. Mismatch cases for RVC and DSC111 data under different road surface conditions.

Best reliability was found in cases when road surface was dry. It seemed that it is very hard to identify wet, slushy and icy conditions in between. There are some reasonable explanations for this situation. First, different road surface thermal conditions on the DSC111 spot and RVC witch was directed to bridge side. It was very obvious under dump weather conditions when air temperature stays around 0°C and field measurements proved it.

Second, there was no information about road salting procedures. It is possible to detect that salt was spread because of quick road surface state change. Especially it occurred during slash and wet conditions. Also the salt reacts differently on the road and bridge side (more salt on bridge?).

Third, it is very hard to detect mismatches during several hours. Mismatch could occur accidentally. It will be better to compare all data from all possible sensors and analyse situation in general for winter maintenance specialists. And only then make some action.

And the last, unfortunately 2006-2007 winter season was very short and only few cases of danger driving conditions and ice formation on road surface were present. More data is needed for further research.

2.2.3 Case studies

Before the analysis of the case studies some methodological modifications on data were done. Remote sensor DSC111 had these variables of road surface conditions: 1- dry, 2 – damp, 3 - wet, 6 – snow, 7 –ice, 9 – slush. Precipitation type was extracted from RWS “Bubiai” data: 1 - no precipitation, 2 – rain, 3 – freezing rain, 4 - snow, 6 – sleet, 7 – snowstorm. Also some criteria for road surface conditions were selected for RVC: 1 - dry, 2 – damp, 3 – wet, 4 – snow, 5 – slush.

All the information was put together and 6 variables were derived:

- *Water* - water film thickness, mm;
- *Ice* - ice thickness, mm;
- *Snow* - snow thickness, mm;
- *PrecType* – precipitation type from RWS “Bubiai” varying from 1 to 7;
- *SurfState* – road surface state from DSC111 varying from 1 to 9;
- *CCTV* – RVC data varying from 1 to 5.

First case of 18-19th of January 2007 when DSC11 sensor showed road surface conditions changing from wet to snow/wet snow [fig. 4]. Also there is significant decrease in water film thickness (mm) and increase of ice and snow thicknesses (mm) in this case. RWS “Bubiai” sensor showed changing in precipitation type from rain to snow and RVC showed changes conditions with some time lag. Then it stopped snowing all devices are showing the same situation almost synchronal.

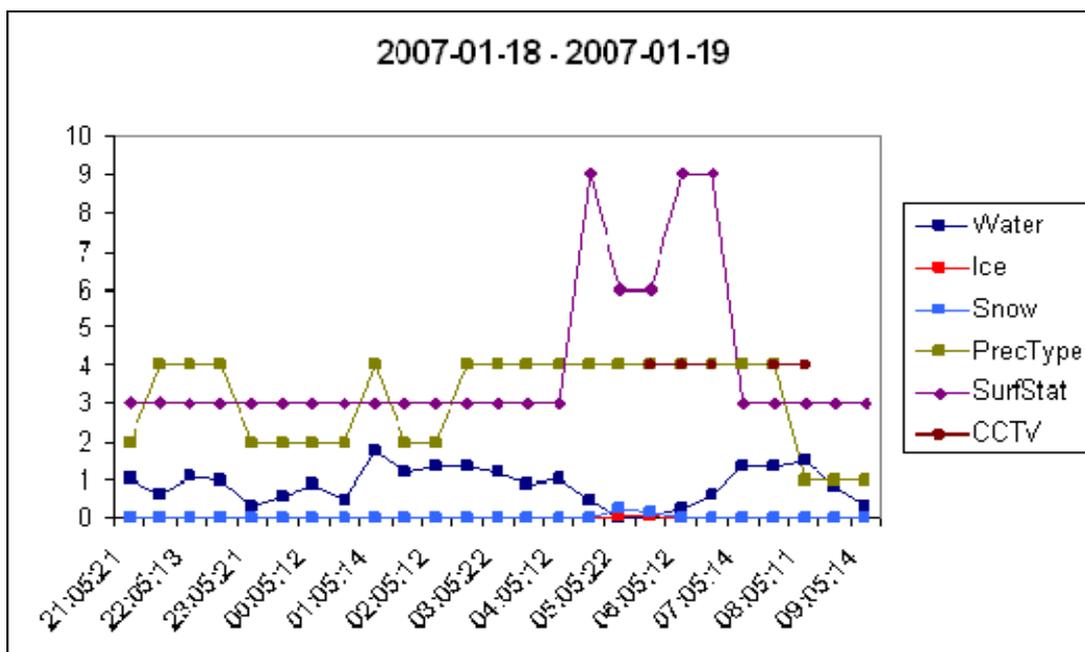


Fig. 4. Road weather conditions change measured by different devices on 18-19th of January, 2007.

Visual information of RVC time lag could be explained by limited visibility or nighttimes. Another possible explanation is higher salt concentration and no ice formation on the bridge side. Only Vaisala's sensor could spot this thin (about 0.2mm), but real dangerous icing on the road surface.

Another road icing case occurred on 21-22nd of January on the same year and could be divided into two parts [fig. 5]. At first RVC showed snow on the road surface and other devices did not. It was possible to explain that after the snowstorm (that was present before this case) snow is drifting and could form snowdrifts on road. Especially at bridge there road surface temperature is relatively lower than on another road sections.

After that in early morning another portion of the snow fall and was detected by RWS/RVC. DSC11 did not showed accumulation of snow. Only wet road surface cooling process formed the ice.

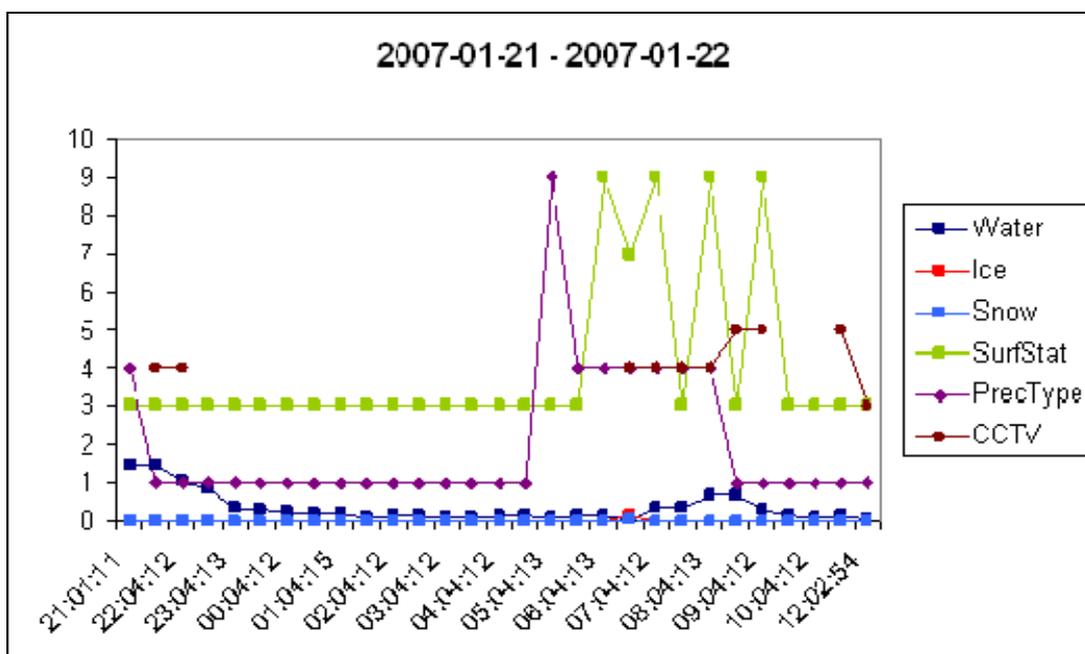


Fig. 5. Road weather conditions change measured by different devices on 21-22nd of January, 2007.

This complicated case showed that ice formatting could occur during road cooling that is detected by remote sensor and also is possible to have icy road because of snow that is not present on remote measuring spot due to snow drifting process.

2.3 Vaisala Remote Road Surface Temperature Sensor DST111

2.3.1 Sensor characteristics

The unique DST111 sensor provides a remote alternative to measuring road surface temperature [fig. 6]. Features and benefits of the sensor given by Vaisala Oyj [20]:

- Remote temperature measurement (measuring distance 2 ... 15 m, operating temperature -40 ... +60°C, operating humidity 0 ... 100% RH);
- Unique correction of the error caused by the emission of the road surface, negating the need for emission adjustment;
- Easy installation and service;
- Low maintenance costs;
- No internal moving parts;
- Stable measurement results even with intense traffic (resolution 0.1 °C, surface temperature -40 ... +60 °C, time constant 1 min, data refresh time 30 s);
- Weather-proof, durable design;
- Reports air temperature and humidity;
- Easy integration with Vaisala ROSA Road Weather Station;
- Capability to act as stand-alone device in remote locations with solar/gsm option.



Fig. 6. View of Vaisala Remote Road Surface Temperature Sensor DST111 [20].

Together with DSC111, which measures surface state, DST111 forms a versatile stand-alone weather station. DST111 device complementing, installing, mounting, calibrating, software updating, maintaining problems are very similar to DSC111. Only one thing is special for DST111. It is impossible to change temperature measuring device at working place (you must send it to the company). And we found it very unpractical.

2.3.2 Road surface temperature data comparison

Vaisala’s remote sensor DST111 studies in Canada showed large overestimation when temperature was well below and large underestimation when road surface temperature was above zero compared to road temperature sensor PT100. Otherwise when road surface temperature was around 0°C both sensors showed almost equal results [4]. Difference between RWS “Bubiai” sensor and Vaisala’s remote sensor DST111 was calculated in our study. Test was run with air, road surface and dew point temperatures datasets for 5248 times. Air, dew point and road surface temperatures averages and standard deviation presented in table 2. Also the same procedures made for danger road surface condition (rain, snow, slush, ice) were present.

	Air, °C	Dew point, °C	Road surface, °C
Mean difference	-0,14	-0,86	0,05
Standard deviation	0,32	0,98	0,60
Mean difference (dangerous conditions)	-0,05	-1,25	0,17
Standard deviation (dangerous conditions)	0,32	0,61	0,54

Table. 2. Air, dew point, road surface temperature differences between RWS “Bubiai” and DST111.

Remote sensor DST111 mean temperature was a little bit higher than RWS sensor's. Also dew point temperature showed higher values because it is a function of air temperature and humidity. Meanwhile road surface temperature was lower. But difference in 0.05°C was almost unimportant one. Mean difference could hide some information. Standard deviation showed that dew point temperature varying mostly. Possible reason was different air humidity values which may occur because of micro processes. Sensors were spotted not in the same place and micro variations of air temperature and humidity, wind velocity, solar radiation, road conductivity and capacity features were possible.

The most important thing that mean value range of air, dew point and road surface temperatures did not change under dangerous traffic conditions. Especially it was important during elevated humidity situation. Mean dew point temperature values increase though standard deviation decreased in range. It means that during dangerous conditions (rain, snow etc.) both sensors showing comparable results.

Mean road surface temperature for every 30 minutes (measuring period 6th of December 2006 – 17th of April 2007) chart showed that temperatures measured by both sensors are very similar [fig. 7]. Only at afternoon hours DST111 overestimated RWS sensor by more than 0.2°C .

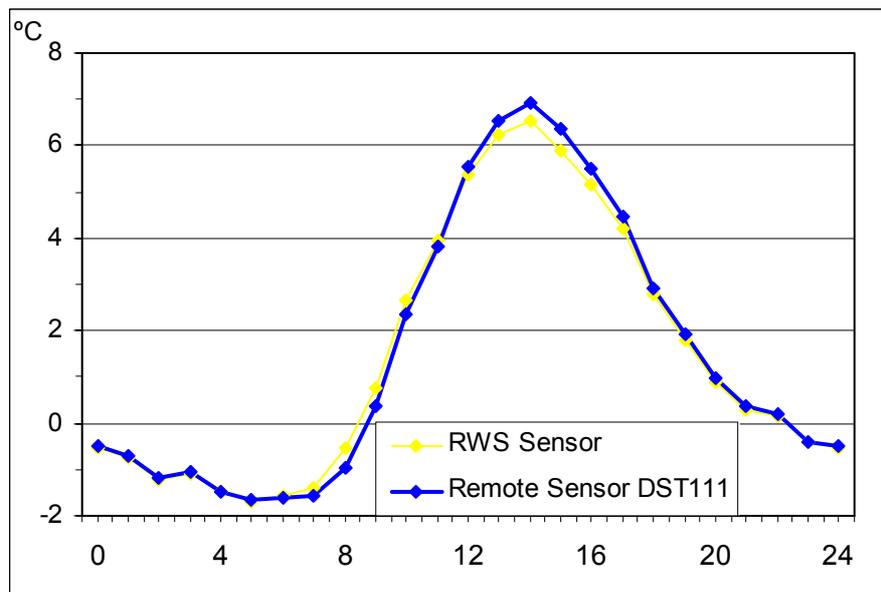


Fig. 7. Averaged daily road surface temperature fluctuation.

2.3.3 Case studies

The same two examples were selected for road surface temperature comparison between RWS “Bubiai” sensor and remote sensor DST111.

First case of 18-19th of January 2007 showed very small differences in temperature range between two sensors [fig. 8]. At 22:00 and 3:30 DST111 had some intense change in road surface temperature compared to RWS sensor. Meanwhile temperature returned to normal range by next half an hour. It could occur because of vehicles and road surface conditions change (water, snow etc.). Meanwhile DST111 was measuring road surface temperature every 10 minutes. It gives possibility to view next measurement and correct temperatures.

Another example on 21-22nd of January, 2007 showed that road surface temperature measured by DST111 had rapid fluctuations [fig. 9]. It was possible to explain by sensitivity of remote sensor. RWS drew approximated line meanwhile temperature measured by DST111 was changing due to road surface conditions change. Otherwise difference between two temperatures never exceeded more than 0.4°C .

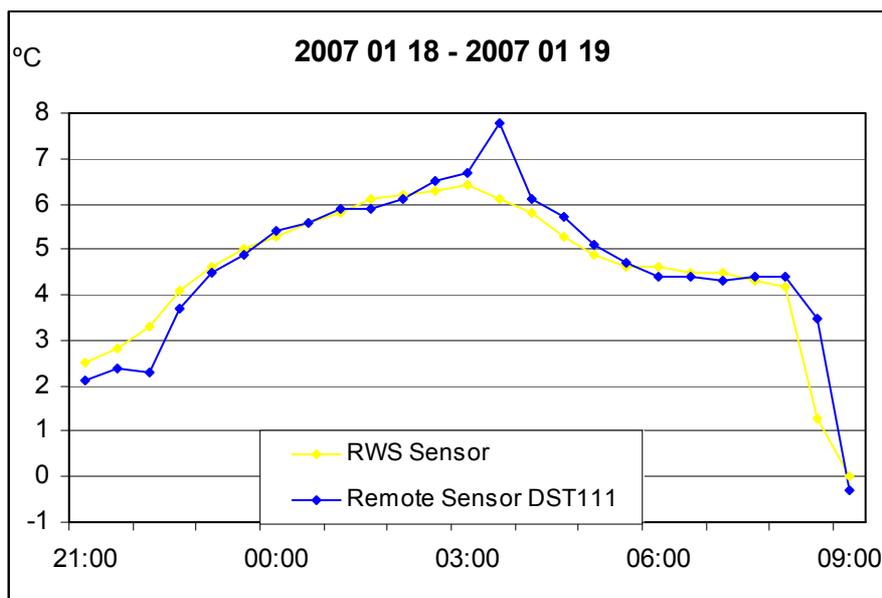


Fig. 8. Road weather temperature change measured by two sensors on 18-19th of January, 2007.

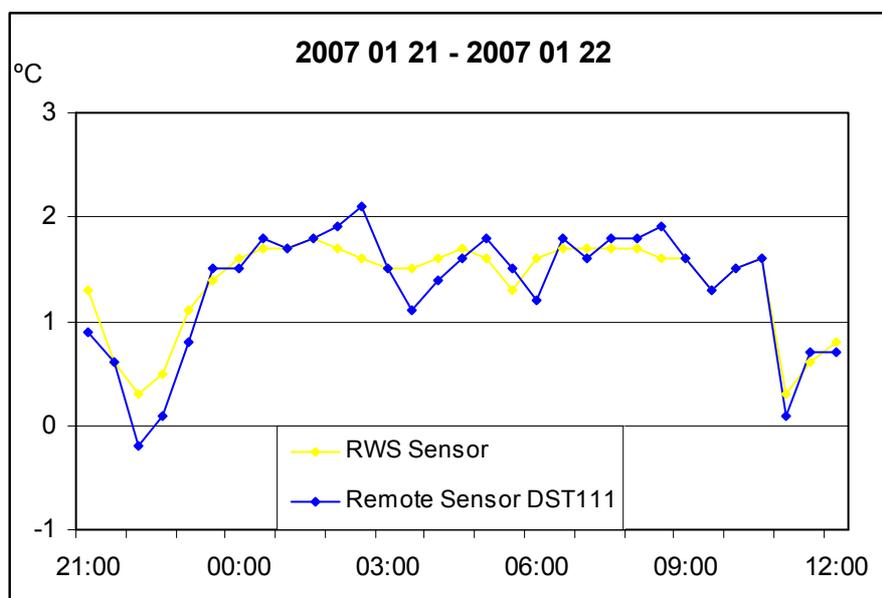


Fig. 9. Road weather temperature change measured by two sensors on 21-22nd of January, 2007.

3. CONCLUSIONS

Road surface temperature values were very similar (diff. 0.05°C) if temperatures were below 5°C limit when comparing DST111 and RWS sensor's data. Temperature range level was permissible (standard dev. 0.6°C) and the data were possible to be use for the road condition forecast. However, when the road surface temperature exceeded 10°C the difference between the two sensors increased (even to 4-7°C). Remote sensor is not recommended to be used during the warm season.

Remote sensor DSC111 data were mostly correct and representative when compared with RVC measurements. The most inadequate results were under heavy driving conditions (ice / rammed snow on road surface). First reason was that the remote sensor was able to recognize 0.01 mm thick water film on the road's surface which human observation and other devices could not recognise. And the other reason was that the remote sensor has a narrow-gauge field of view which was decreasing under snow conditions compared to the road surface size. Also it is considered that RVC is very useful as an extra device especially for particular road segments (bridge, hill foots ant tops etc.). The measurement results were the most different under heavy driving conditions (wet/damp road surface conditions). The primary reasons for inadequacy were different thermal road conditions (RVC was turned more to the bridge-side while DSC111 was turned more to the regular road section) and the diverse spread of salt on the road surface.

Remote sensor's DSC111/DST111 complementing, installing, mounting, calibrating, software updating, maintaining tests ran mostly well for Lithuanian conditions. Since winter season of 2006-2007 was very short and atypically warm, there is a need for further testing. We need to evaluate all pros and cons; data mismatch cases are to be considered and after extra testing decide whether the extensive usage of these sensors in Lithuania is necessary.

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