LIFE+11 ENV/IT/000002

CLEAN-ROADS

Action A1
Experimental data collection campaign during a winter season

D.A1.3

Experimental data collection campaign

Project Coordinating Beneficiary	Provincia di Trento (PAT)
Project Associated Beneficiary n.1	Famas System (FAM)
Project Associated Beneficiary n.2	TIS innovation park (TIS)

PROVINCIA AUTONOMA DI TRENTO

innovation park

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[1] **PU** = Public.
CO = Confidential (accessible only by project partners and European Commission).
RE = Restricted Access, i.e. confidential but with a special access to a specific target of stakeholders defined by the project consortium and approved by the European Commission.

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1. Introduction

This report presents the results of the data analysis and correlation activities carried out in the scope of the preparatory action A1. In light of the recovery plan defined in the first stage of the project, and illustrated in detail in the deliverable D.A1.2 [1] and in the Inception Report [2] which were submitted to the European Commission in May 2013, this first version of the deliverable refers to the data collection campaign carried out during the winter season 2012-2013, which is only the first part of this initial empirical assessment of the targeted environmental problem. As stated in Table 1 (which is directly reported from D.A1.2), these preparatory activities are going to be completed during the winter season 2013-2014 based in particular on (i) the data of the first roadside road weather station and (ii) the first thermal mapping surveys performed by the initial mobile RWIS station prototype, which will be directly related to other data sets which are already available (i.e. winter road maintenance activities recording data, traffic levels, other meteorological data and weather bulletins). A second version of this deliverable will be thus produced based on this second data collection campaign and submitted to the EC in annex to the Mid-Term Report.

Winter season	Revised activity set	Original activity set

2012/2013	• the winter road maintenance procedures are empirically evaluated;
	• a comparison with a first reference dataset is performed, consisting of:
	  o traffic data measured in correspondence of the test site;
	  o meteorological data and forecasts;
		• a first complete data collection campaign is carried out, availing of:
		  o the full set of roadside road weather stations;

2013/2014	• a first complete data collection campaign is carried out, availing of:
	  o the first roadside road weather station;
	  o the mobile rwis station;
	• first test sessions of the clean-roads components are performed;
		• a first complete demo of the clean-roads is installed on site;
		• the road operators start to consider the data and the information provided by the system prototype, but in a unstandardized way;

2014/2015	• the whole clean-roads system is tested, calibrated and technically validated; • the road operators start to consider the data and the information provided by the advanced rwis system, but in a unstandardized way;	• the final version of the clean-roads system is tested, calibrated and technically validated; • the clean-roads system is finally evaluated and demonstrated through the introduction of optimized and standardized winter maintenance procedures.

2015	• the clean-roads system is finally evaluated and demonstrated through the introduction of optimized and standardized winter maintenance procedures.	• the clean-roads system starts to enter fully in operation in the test site area, eventually evolved by means of the experience gathered in the winter season 2014/2015.

Table 1: The re-allocation of empirical project activities during the different winter seasons of the project.

This first version of the deliverable is structured as follows. Chapter 2 gives an overview of the observed meteorological conditions in correspondence of the test area and a preliminary assessment of the potential risks of ice and snow. Chapter 3 illustrates the typical traffic patterns detected in this road stretch during this winter season, while Chapter 4 enters into the details of the recordings of winter maintenance activities (and in particular of salt usage) on the case study road. Chapter 5 is probably the most interesting section of this deliverable, since it describes the results of some preliminary correlation analysis performed by putting in direct relationship the different types of collected data. The deliverable is finally concluded with Chapter 6, which presents some additional data and outputs of additional, specific surveys organized in order to increase the comprehension of the physical phenomena characterizing the target case study road.

2. Meteorological analysis

It is difficult to associate the Trentino region to a well-defined climatology class. The region is in fact characterized by the presence of a plenty of very different geographical areas, with elevation ranging from the 70 [m] of the Garda's lake in the south part to the about 4000 [m] of the Ortles-Cevedale massif in the north-west (Figure 1). The orography of the valleys varies also significantly: some of them are characterized by an open shape in the direction of neighbouring Po valley, others have on the contrary a narrow shape and are located inside extended rock massifs.

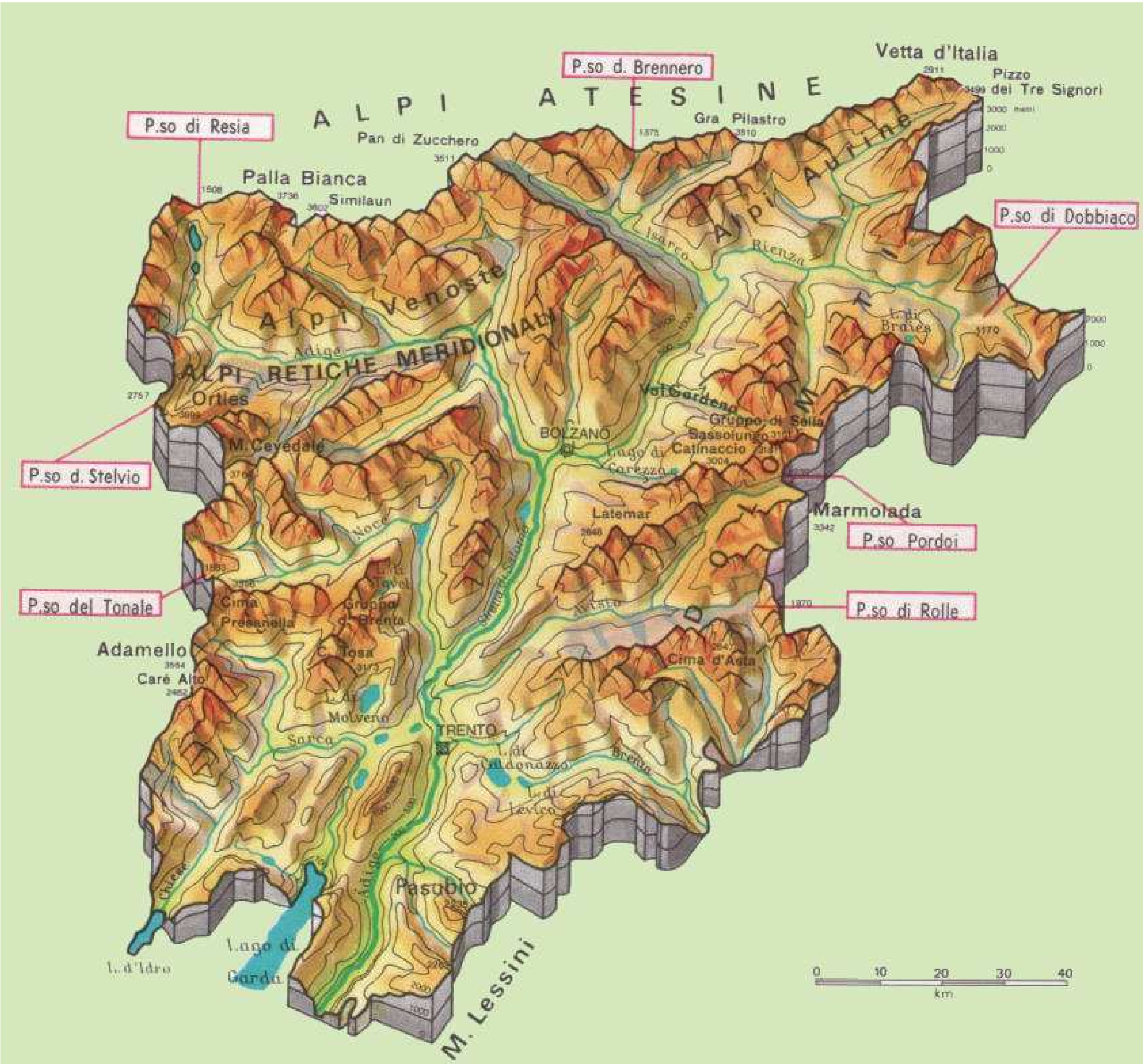

Figure 1: A comprehensive perspective of the orography of the Trentino Alto-Adige region (source: viaggidialex.altervista.org).

In general, the regional climate can be linked to the humid, temperate, oceanic climate which is typical of pre-alpine areas and in particular of those which are more open towards the Po valley and the Adriatic see; some areas (in particular the inner mountain valleys) show however clear features of transition to a more continental-alpine climate, which is cooler and often drier. Precipitations are normally distributed over two maxima, in autumn (main peak) and in spring (secondary peak), even if some mountain areas experience the rainfall peaks in summer; long dry periods usually don't characterize these areas.

Going more into the details of the meteorological peculiarities of the case study area, the climate in the Adige valley can be defined as temperate and of oceanic type, without any significant dry periods. The annual average air temperature ranges typically in the interval 10-13 [°C] with a cumulative annual precipitation of 900-1000 [mm] distributed mostly during autumn and spring [3]. The warmest month is generally July followed very near by August while the coldest ones are January and February. The average temperature is mainly influenced from altitude, but also the mountain side exposition and the wind circulation have demonstrated to play an important role on this. During the winter season, the minimum temperatures are often registered in correspondence of the bottom of the valley, as a demonstration of the local relevancy of thermal inversion phenomena which are typical of the alpine valley.

2.1. Climate overview during the winter season 2012-2013

The winter season 2012-2013 (considered in the time interval December 2012 - February 2013) was characterized by temperature and precipitation generally under the period average (i.e. if compared to the mean values calculated in the time horizon1978 - 2005). As far as the **air temperature** is concerned, in December and even more in February, more frigid temperatures than January where recorded. The maximum temperature was measured during the latter month by the Trento-Laste weather station, near the urban area of Trento, and was about 18° [C]. It was from 1921 that temperatures didn't reach similar high values in that month; on the other side the temperatures registered in February were extensively under the period average, as observed in all the alpine chain [4].

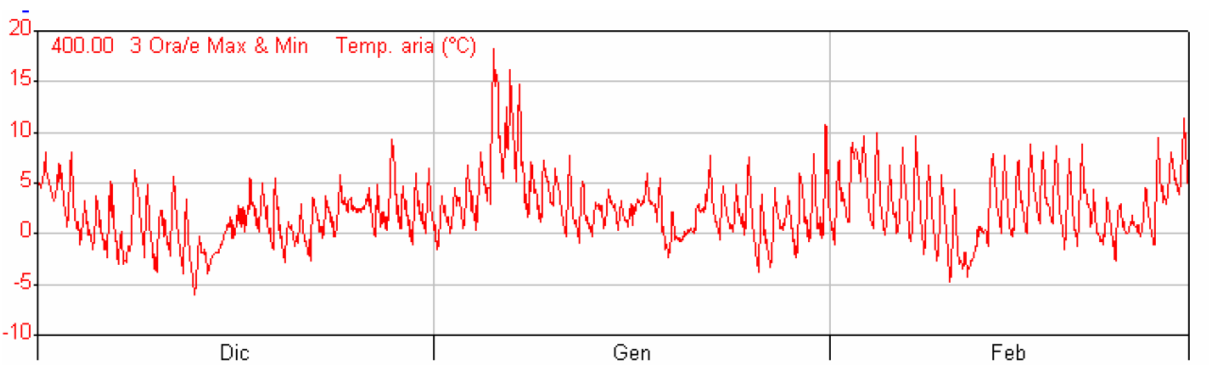

Figure 2: Air temperature measurements taken by Trento Laste station during the winter season 2012-2013.

As far as **precipitation levels** are concerned, the quantities recorded in December were significantly under the period average; on the contrary, in January and February the precipitation phenomena were quite comparable with the typical meteorological events of the period.

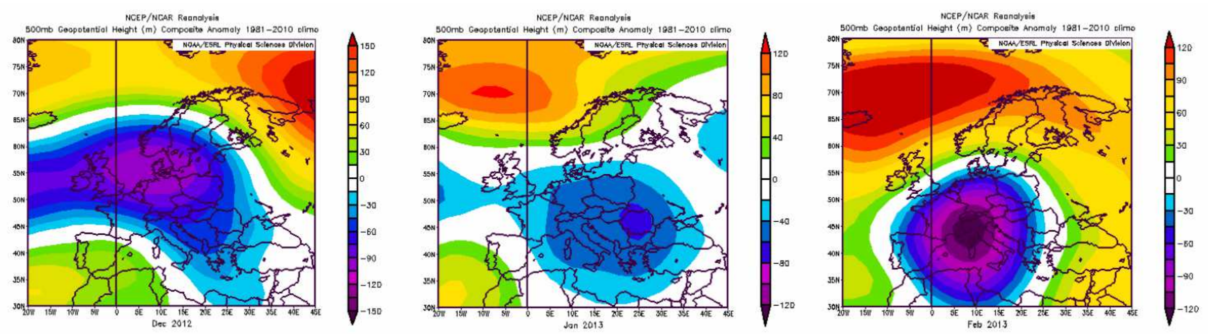

Figure 3: Geopotential height anomaly at 500 [hPa] (approximately 5500 m) registered in December 2012 (left picture), January 2013 (central picture) and February 2013 (right picture) [4].

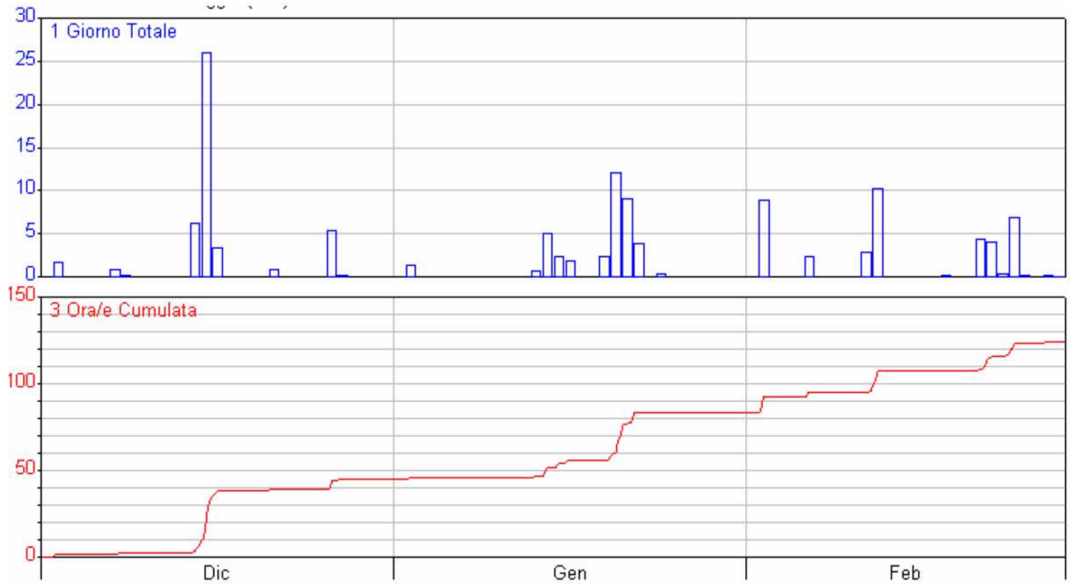

Figure 4: Daily precipitation (above picture) and accumulated rainfall (below picture) during the winter season 2012-2013 registered by the meteorological station of Trento Laste [4].

The first spring months of year 2013 in Trentino were characterized by temperatures a little under the period average, with frequent precipitations and perturbed weather situations. In particular, as observable from Figure 5 and Figure 6, March, but more specifically May, were unusually cold and exceptionally rainy months. During March, heavy snowfalls have occurred as well over 1500 [m] of altitude [5].

2.2. Meteorology of the case study road

2.2.1. Station choice

To perform a representative analysis about atmospheric conditions in which the portion of the SS12 road (i.e. the case study road of CLEAN-ROADS project) is included, the data gathered by the weather station installed in the small village of San Michele all'Adige, managed by the Edmund Mach Foundation, has been chosen [6]. Whilst awaiting the first roadside RWIS stations, this meteorological detection point has turned out to be the best choice for several reasons:

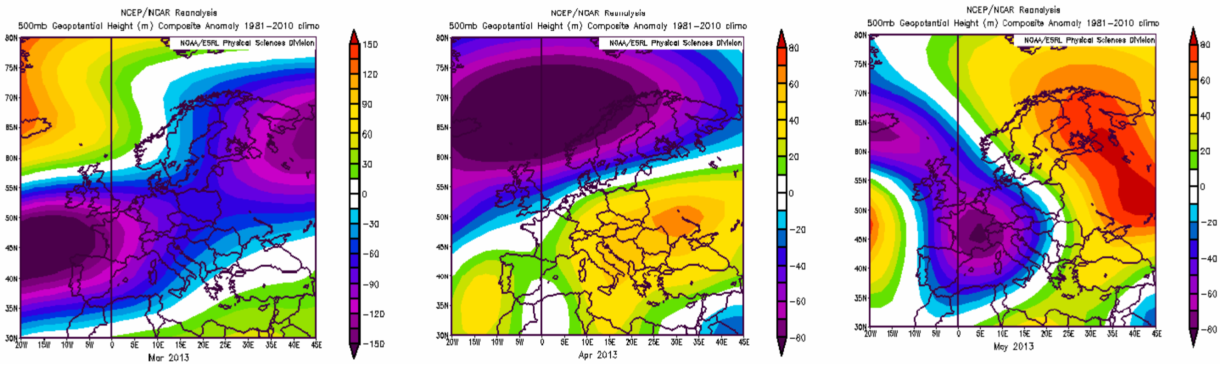

Figure 5: Geopotential height anomaly at 500 [hPa] (approximately 5500 m) registered in March 2013 (left picture), April 2013 (central picture) and May 2013 (right picture)[5].

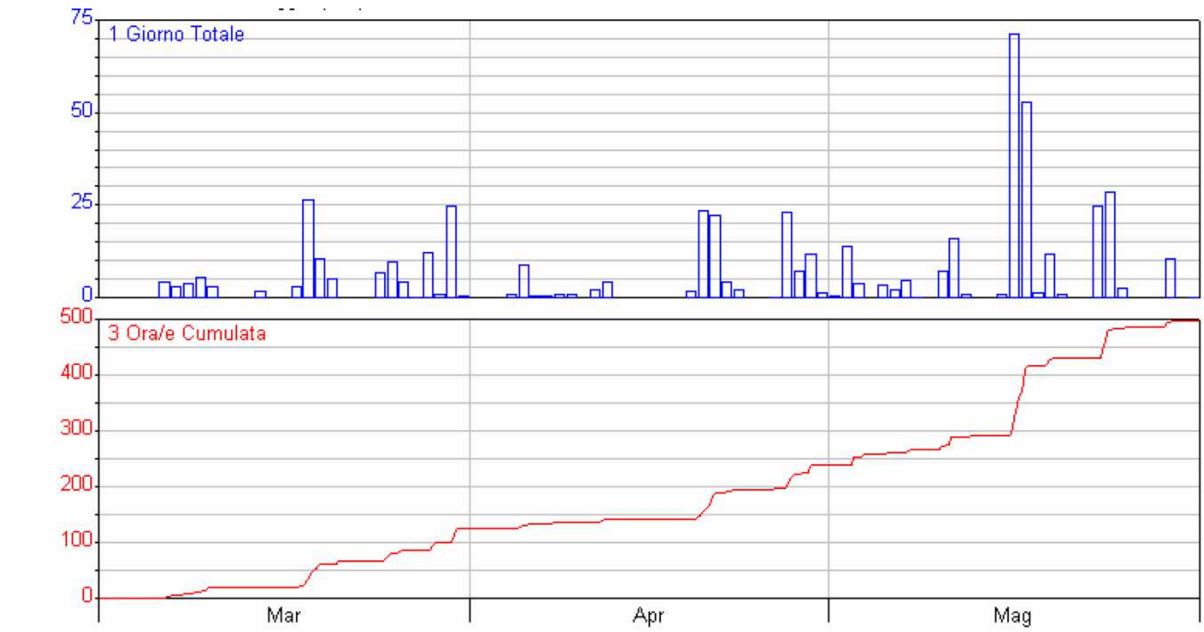

Figure 6: Daily precipitation (above picture) and accumulated rainfall (below picture) during the spring season 2013 registered by the meteorological station of Trento Laste [5].

- the availability of measurements for many weather variables;
- the presence of underground temperature gauges;
- *a central position with respect to the case study road;*
- a good representation of the Adige valley climate;
- the good quality of the collected data.

2.2.2. Historical data evaluation

A climate analysis of precipitation and temperature patterns in the period 1983 – 2013 has been performed with the intention to initially characterize the typical winter meteorology in correspondence of the case study road.

Precipitation

In Figure 7, Figure 8 and Figure 9 the number of days (in percentage) in which the registered daily precipitation levels have exceeded a reference threshold (i.e. 1, 10 and 30 [mm/day], respectively) is reported. This indicator is calculated over a time frame of 15 consecutive days for the whole period of interest; two values for each considered months have been therefore computed. It is worth noting that the months of October and April are represented by one value only, which refers to their last and first 15 days, respectively.

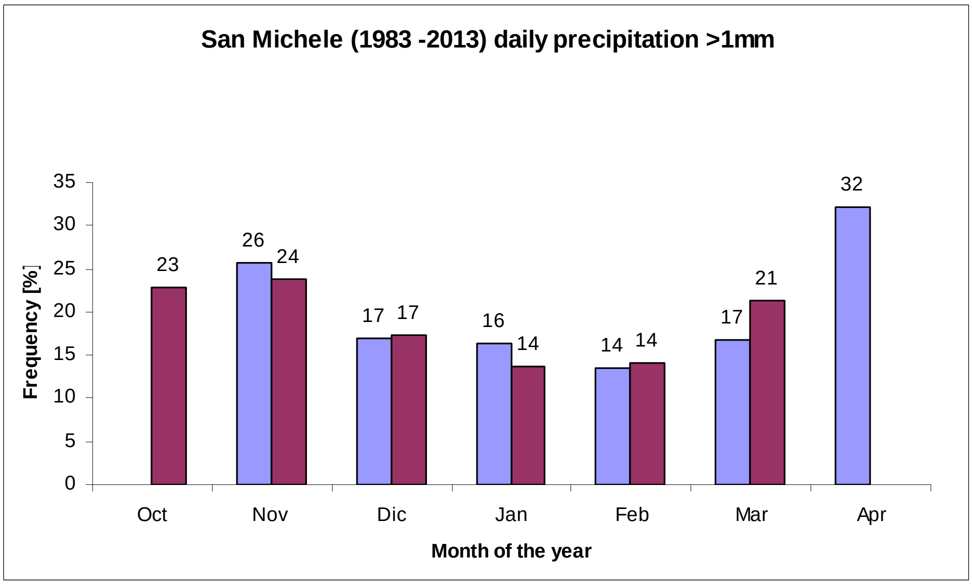

Figure 7: Percentage of days in which precipitation levels have exceeded the reference threshold of 1 [mm/day] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

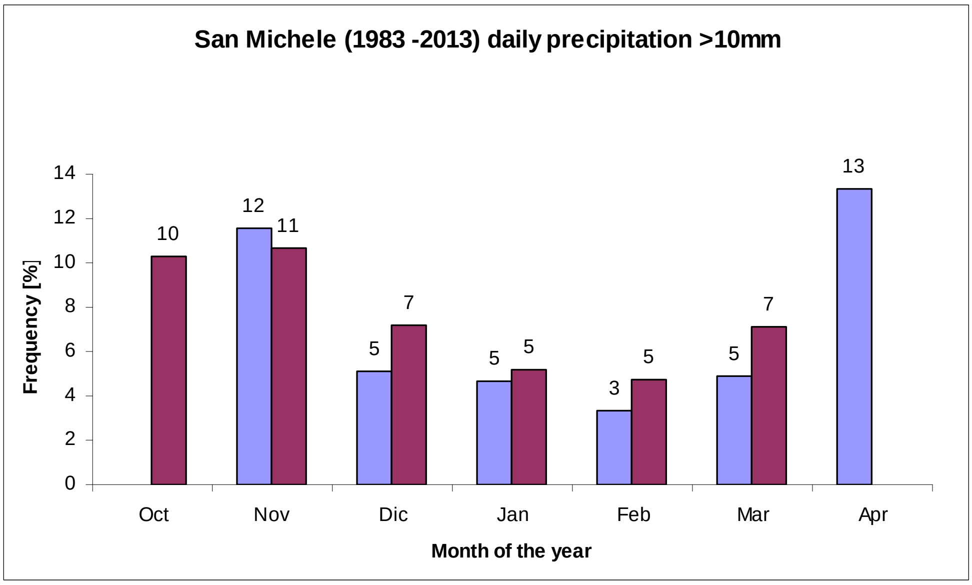

Figure 8: Percentage of days in which precipitation levels have exceeded the reference threshold of 10 [mm/day] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

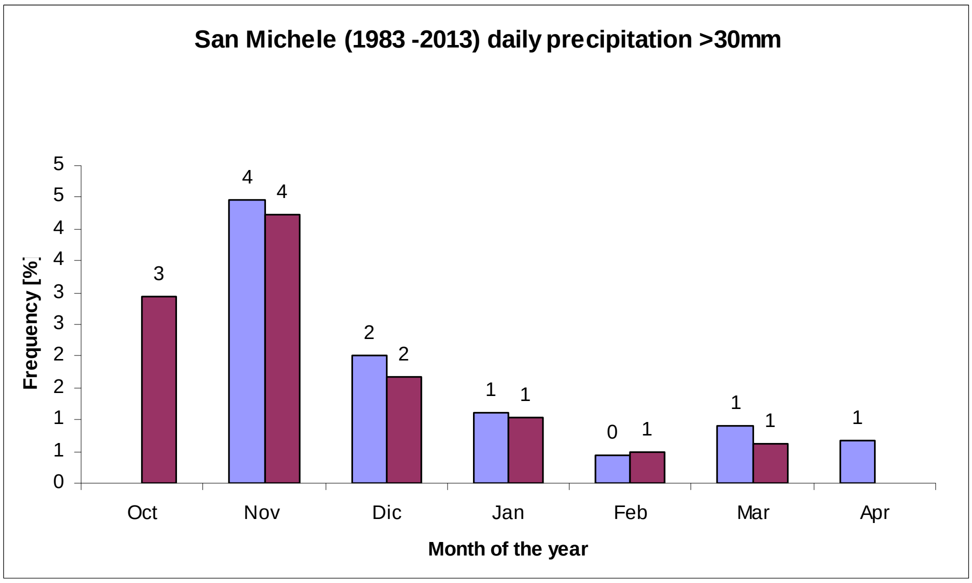

Figure 9: Percentage of days in which precipitation levels have exceeded the reference threshold of 30 [mm/day] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

The frequency of precipitations is stably limited during the most frigid months of the year and shows an increasing behavior starting from the second half of March and finishing in the months November. Heavy precipitation events are quite a few, especially during the winter season, and are typically more often during autumn months. To estimate the number of snowfalls in the period 1983-2013, a simple analysis combining both temperature and precipitation data has been made; the results are shown in Figure 10. Snowfalls are only a small fraction of total precipitations; the second part of January is the period of the year in which the probability of snow is higher (about 18%); relevant fractions have been registered in December as well.

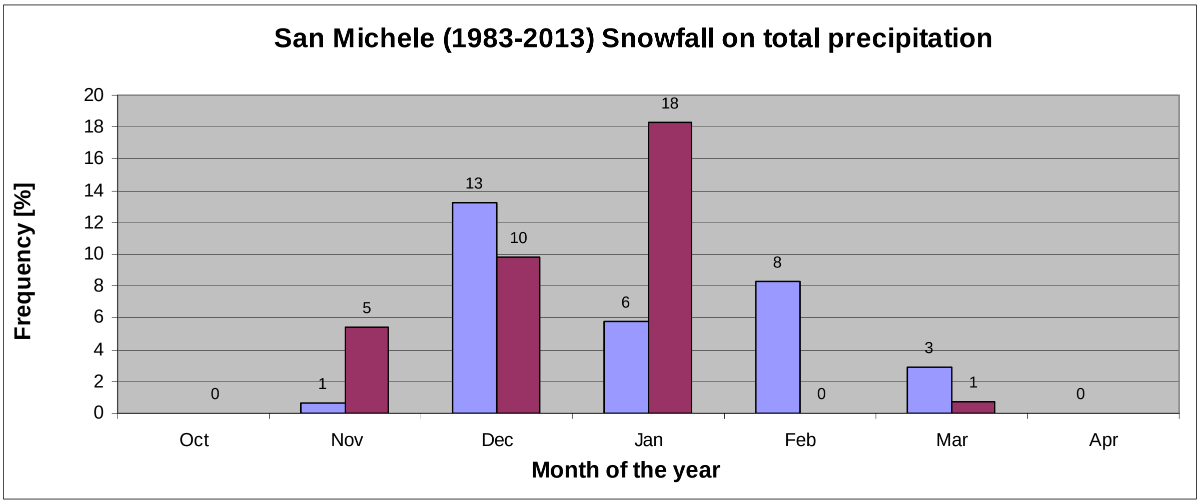

Figure 10: Percentage of snowfalls events compared to the whole precipitation phenomena in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

Minimum air temperature

A similar evaluation approach has been carried out in order to characterize historical air temperature patterns as well. In Figure 11, Figure 12 and Figure 13 the number of days (in percentage) in which the registered daily minimum air temperature has exceeded a reference threshold (i.e. 0, -4 and -6 [°C], respectively) is reported. This indicator is calculated even in this case over a time frame of 15 consecutive days for the whole period of interest. What is particularly relevant from the plots below is the non-negligible number of potentially critical situations (i.e. minimum air temperature below -6 [°C]) in which potential road treatments carried out with conventional sodium chloride could be inefficient in order to properly prevent the formation of ice and accumulation of snow on the road.

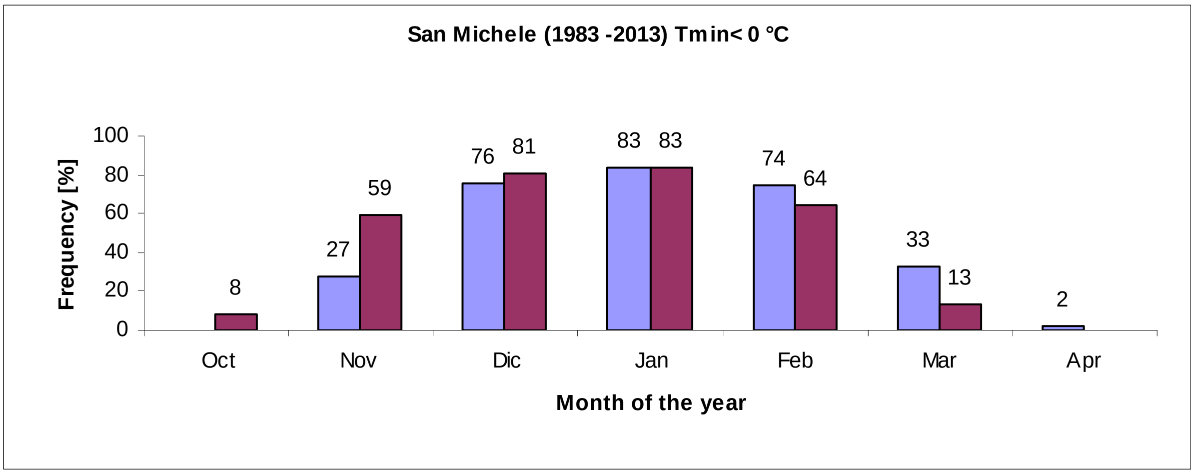

Figure 11: Percentage of days in which minimum air temperature was lower than 0 [°C] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

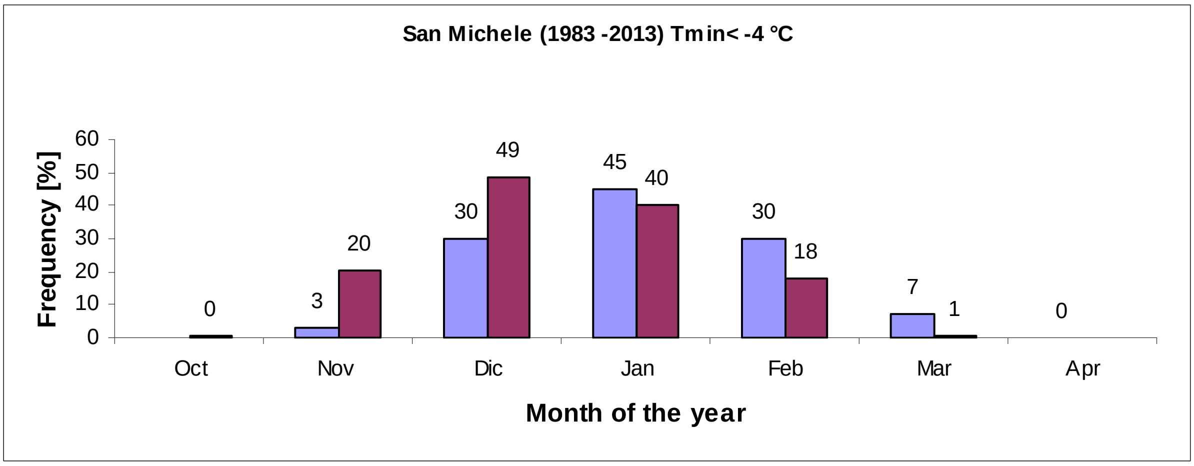

Figure 12: Percentage of days in which minimum air temperature was lower than -4 [°C] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

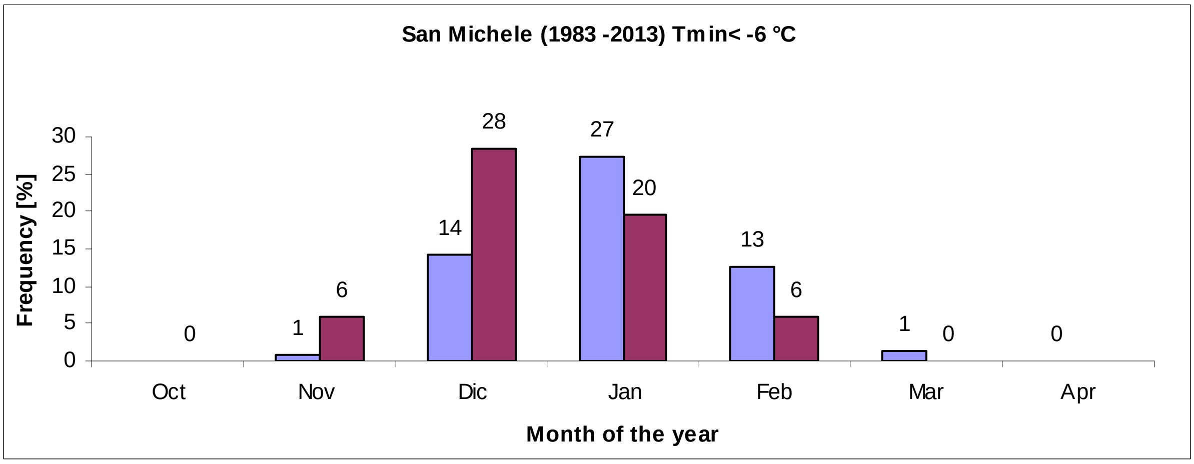

Figure 13: Percentage of days in which minimum air temperature was lower than -6 [°C] in correspondence of the village of S.Michele all'Adige (series of 15 days, 1983-2013).

Minimum soil temperature at a depth of 10 cm

The meteorological station of San Michele has been collecting measurements of soil temperature at a depth of 10 [cm] under the surface as well. For the purpose of this analysis, this data has been evaluated with the purpose to quantify the situations in which the soil is likely to start freezing and losing its capacity to transmit heat to surface. In Figure 14, a scatterplot putting in relationship the average daily soil temperatures and the number of times in which those were registered is illustrated. Most of negative soil temperatures have been recorded between the beginning of November and the end of March.

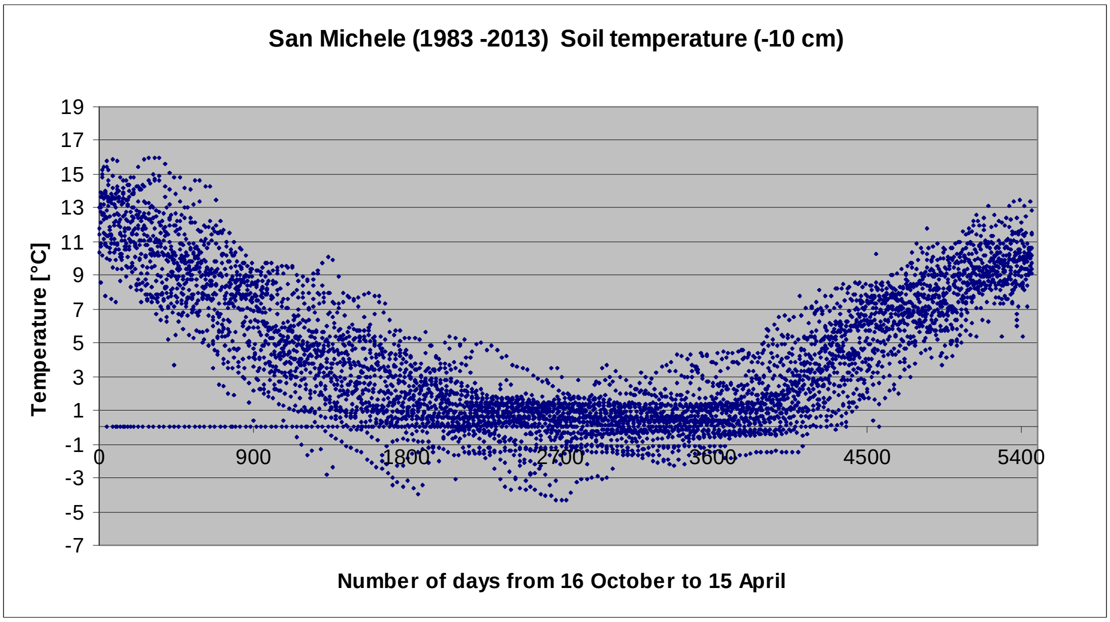

Figure 14: Historical soil temperatures patterns measured at a depth of 10 [cm] in correspondence of the village of S.Michele all'Adige (period 1983-2013).

2.2.3. Winter season 2012-2013 data evaluation

A specific analysis has been carried out during the winter season 2012-2013 in the period ranging from 01/11/2012 till 30/04/2013, based on the field measurements which are available with an hourly time step. The investigated parameters are those reputed more interesting from a road maintenance and meteorological point of view, namely:

- precipitation [mm/h];
- air temperature at 2 m. height [°C];
- total global radiation [W/m^2];
- relative humidity [%];
- surface pressure [hPa];
- air temperature at 5 cm. height [°C];
- wind speed at 10 m. height [m/s];
- wind direction at 10 m. height [°N].

Table 2 shows the main aggregate results from this data analysis process. The precipitation, as we can expect, has been poorer in the coldest months of December, January and February; the same has applied for the precipitation rate. The lower average temperatures have been registered in December that resulted to be the coldest winter month also for what the minimum temperature is concerned. It is worth putting in evidence the anomaly in terms of maximum temperature registered in January, that reached about 17 °C. The other thermal and rainfall data were in line with the normal climate trend.

PARAMETER	NOV 2012	DEC 2012	JAN 2013	FEB 2013	MAR 2013	APR 2013
Total Precipitation [mm]	300,2	59,4	33,0	22,0	143,0	128,2
Maximum precipitation rate [mm/h]	10,6	3,4	3,4	3,2	4,2	5,8
Average temperature [°C]	6,9	0,2	2,0	2,6	6,8	13,0
Minimum temperature [°C]	-2,7	-8,4	-6,2	-4,4	-1,7	1,5
Maximum temperature [°C]	16,5	9,4	16,9	12,3	16,2	26,6
Average pressure [hPa]	992	992,6	989	987,8	983,5	990,5
Average relative humidity [%]	88	78	78	69	73	75
Average global radiation [W/m^2]	56	48	58	96	124	167
Maximum global radiation [W/m^2]	483	356	450	639	831	892

Table 2: A comprehensive overview of the meteorological conditions registered by the station of S.Michele all'Adige during the winter season 2012/2013.

It's also interesting to underline the decrease in terms of incoming global radiation during the winter months; if the mutable cloud cover condition among months are neglected, this is mainly due to the different inclination of the solar rays. Less energy is therefore available to dry and warm up the roads and, in general, to promote their heat exchange. The precipitation data measured during the first winter season of the project are presented in Figure 15; the trend is in line with the typical values for this location; a decrease in the number and intensity of phenomena during the coldest months is clearly noticeable.

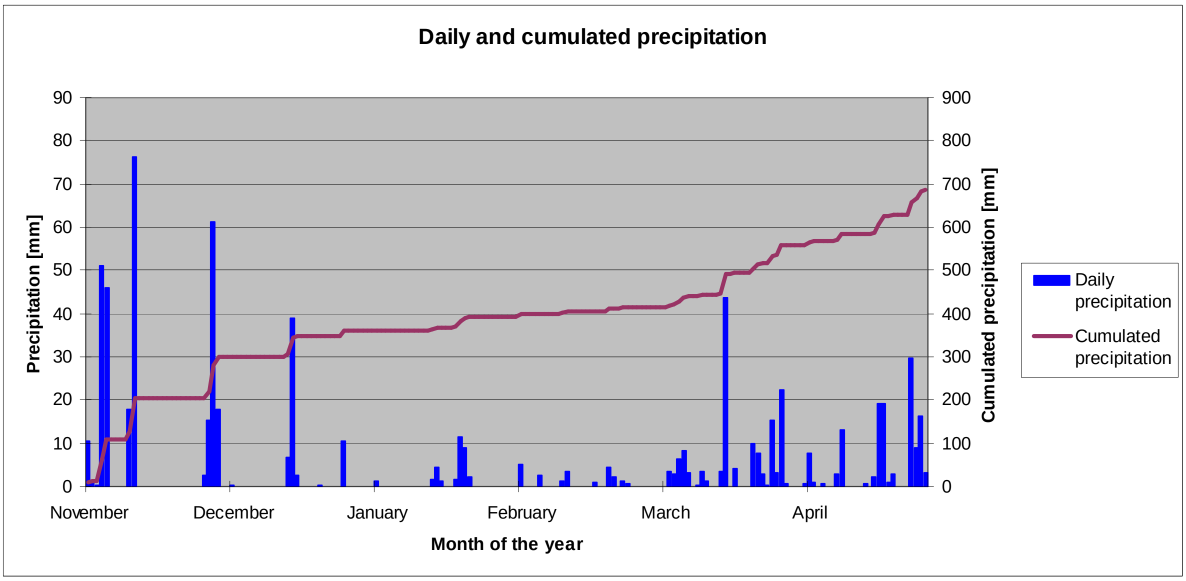

Figure 15: Daily and cumulated precipitation measured by the station of S.Michele all'Adige during the winter season 2012-2013.

The trend of the maximum and minimum air temperature measured at 2 [m] height is illustrated in Figure 16; the minimum temperatures are mostly under zero between December and March with a clear negative peak between December and January, when the solar radiation contribution is minimum.

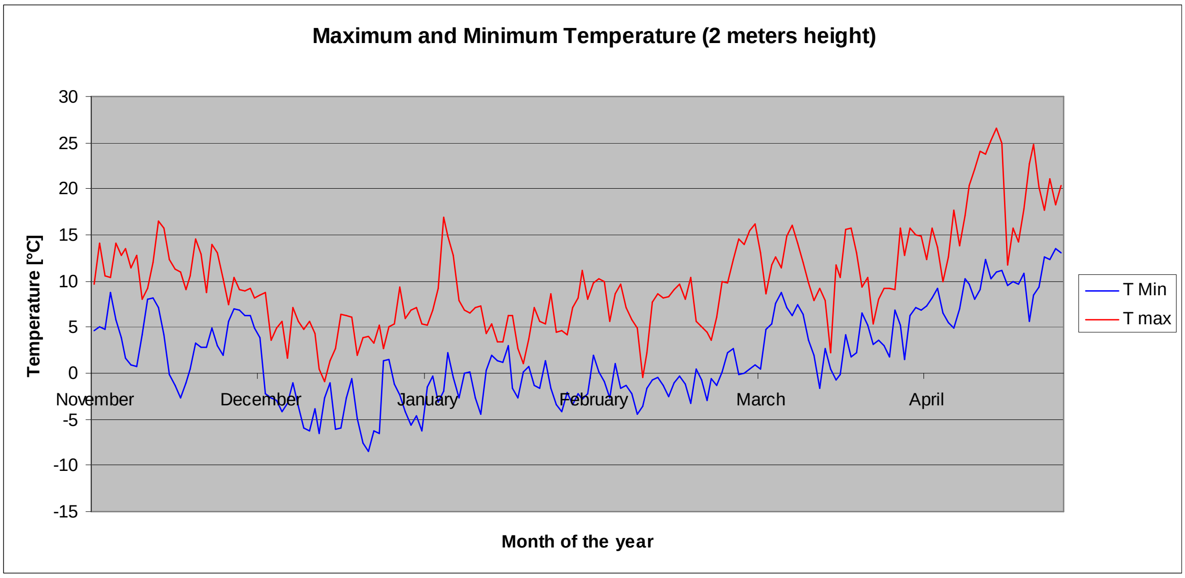

Figure 16: Maximum and minimum air temperature measured by the station of S.Michele all'Adige during the winter season 2012-2013 at a height of 2 [m].

Because of the specific purposes of the project, most of the collected parameters have been analysed by referring to the maximum time resolution available (i.e. with an hourly time step). Since the amount of data is considerable, only those elaborations that are considered most interesting are presented in the following pages. As indicated above, December has been the coldest month of the winter season under study, as far as both the minimum and the average temperatures are concerned. Figure 17 illustrates the hourly temperature distribution during this month; temperatures are divided into classes of amplitude equal to 2 [°C] starting from -8 [°C] to 12 [°C]. It's interesting to point out the Gaussian distribution with which this empirical data could be in first line approximated; the majority of data are in fact placed quite symmetrically between -2 [°C] and +2 [°C] with boundary values of -8.4 [°C] and 9.4 [°C], respectively.

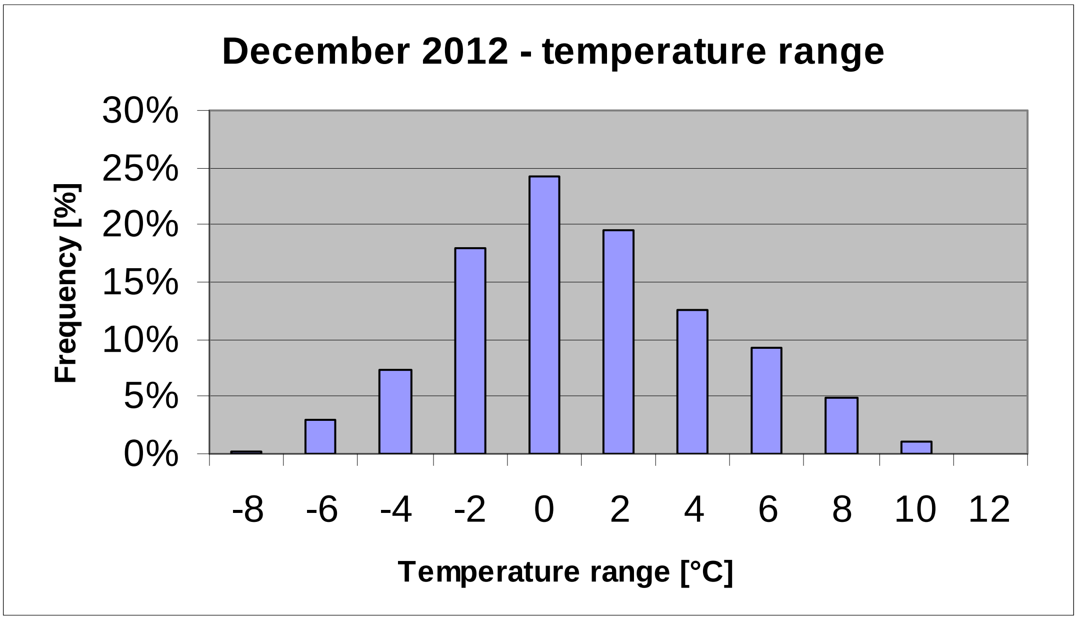

Figure 17: Distribution of hourly air temperature measurements collected by the station of S.Michele all'Adige during December 2012 at a height of 2 [m].

In Figure 18 the hourly measurements of three different parameters collected in the month of January are compared:

- maximum and minimum temperature at 2 [m] height;
- maximum and minimum temperature at 5 [cm] height;
- precipitation.

What's important to observe in the graph is the trend of temperature during rainy days or days with snowfall. In these conditions, and in particular during snowfall events, precipitations tend to mix the air of different heights locally reducing the vertical gradient of the temperature. This is particularly noticeable during the two main precipitation events of January and also in Figure 19, where a detail of an exception snowfall event registered in the beginning of March is given. In this plot, it's also worth noting to underline the different temperature patterns during dry and wet conditions.

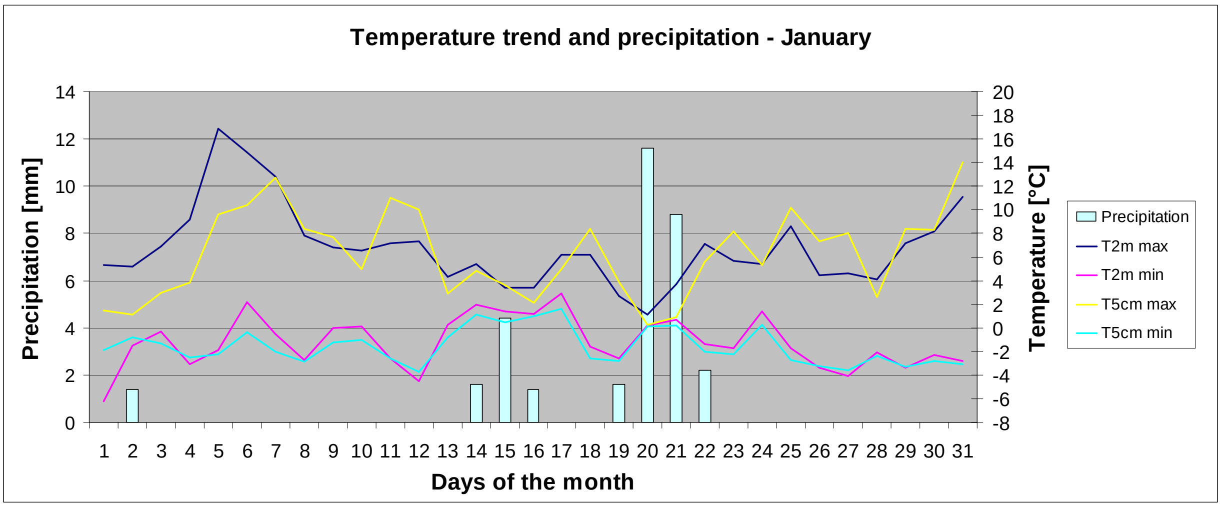

Figure 18: Comparison between hourly precipitation levels, air temperatures at 2 [m] and 5 [cm] measured by the station of S.Michele all'Adige during January 2013.

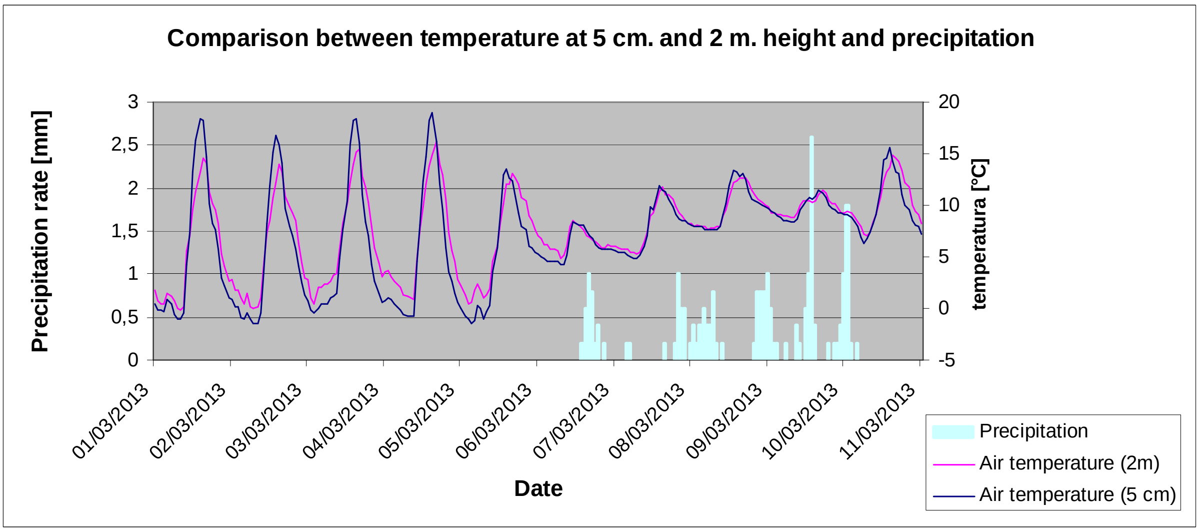

Figure 19: Comparison between hourly precipitation levels, air temperatures at 2 [m] and 5 [cm] measured by the station of S.Michele all'Adige during March 2013.

In the following plots four different weather parameters are jointly compared:

- temperature at 2 [m] and 5 [cm] height;
- global radiation;
- wind speed;
- relative humidity.

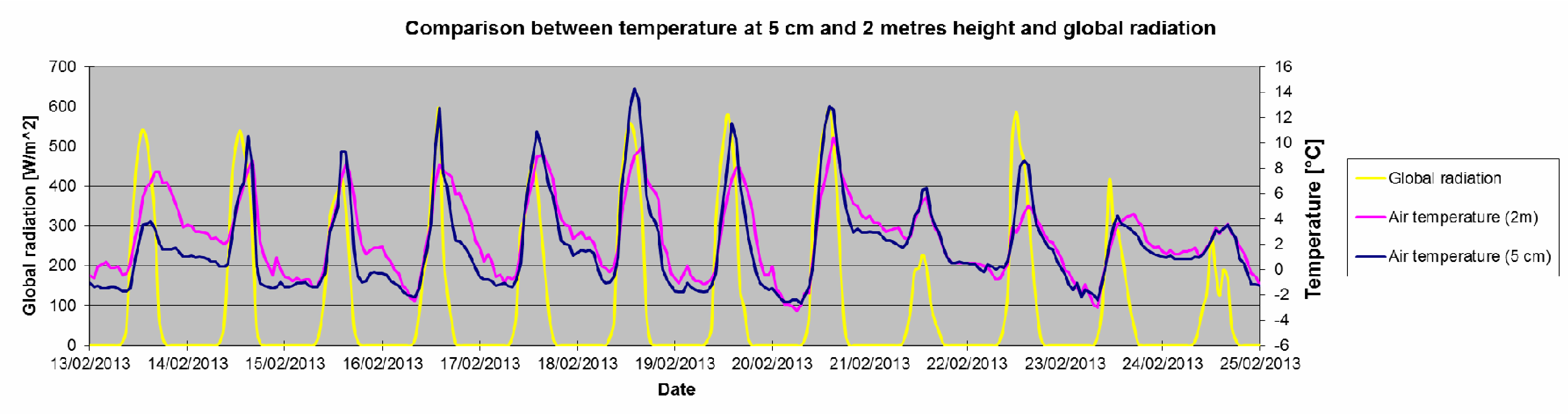

Figure 20: Comparison between global radiation and air temperatures at 2 [m] and 5 [cm] measured by the station of S.Michele all'Adige – detail on February 2013 patterns.

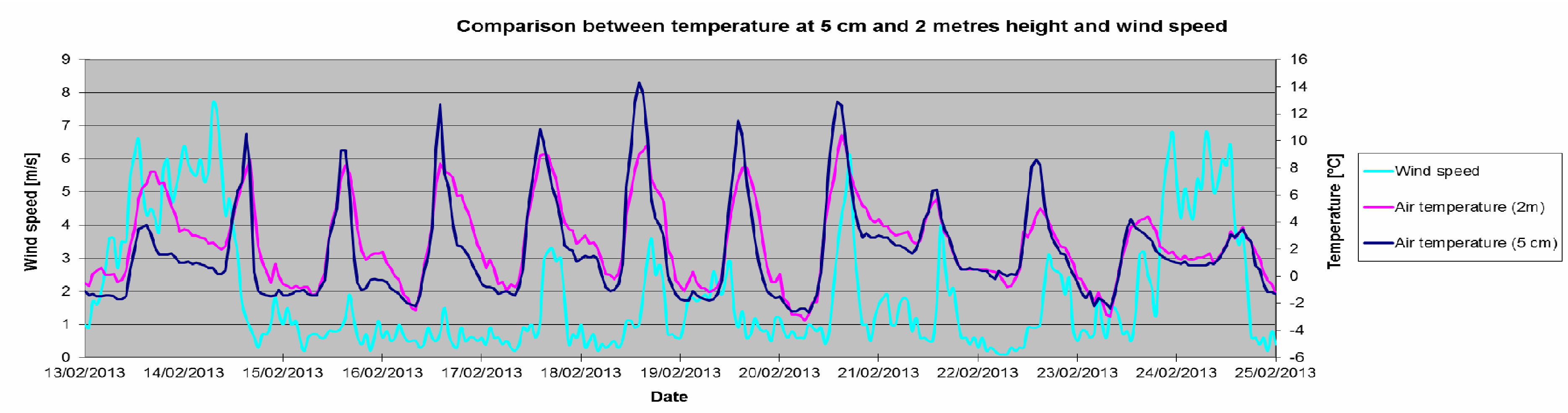

Figure 21: Comparison between wind speed and air temperatures at 2 [m] and 5 [cm] measured by the station of S.Michele all'Adige – detail on February 2013 patterns.

Global radiation, carrying energy from the sun, is the primary factor influencing temperature; its raising and decreasing pattern anticipates the ones associated to temperature's measurements and directly influences their shape. Air temperature at 5 [cm] height is influenced at first by global radiation variations; the incoming energy from the sun is absorbed from the soil and partly made available to increase the levels of air temperature at this height. This energy, in the form of heat, is then transported and transmitted at the higher layers, as observable from the measurements taken at 2 [m]. The same applies during night times, when the soil is not in the condition to provide heat anymore and the air is cooling down starting from the bottom layers. This phenomenon is particularly relevant (and quick) on calm days with poor or no wind; in case of significant windy days, this variable has showed to have more influence on the temperature than the global radiation, and the temperature patterns don't follow the behaviour described just before. This is quite evident from the plot of Figure 22, in which data related to some particular windy days registered in February 2013 is reported.

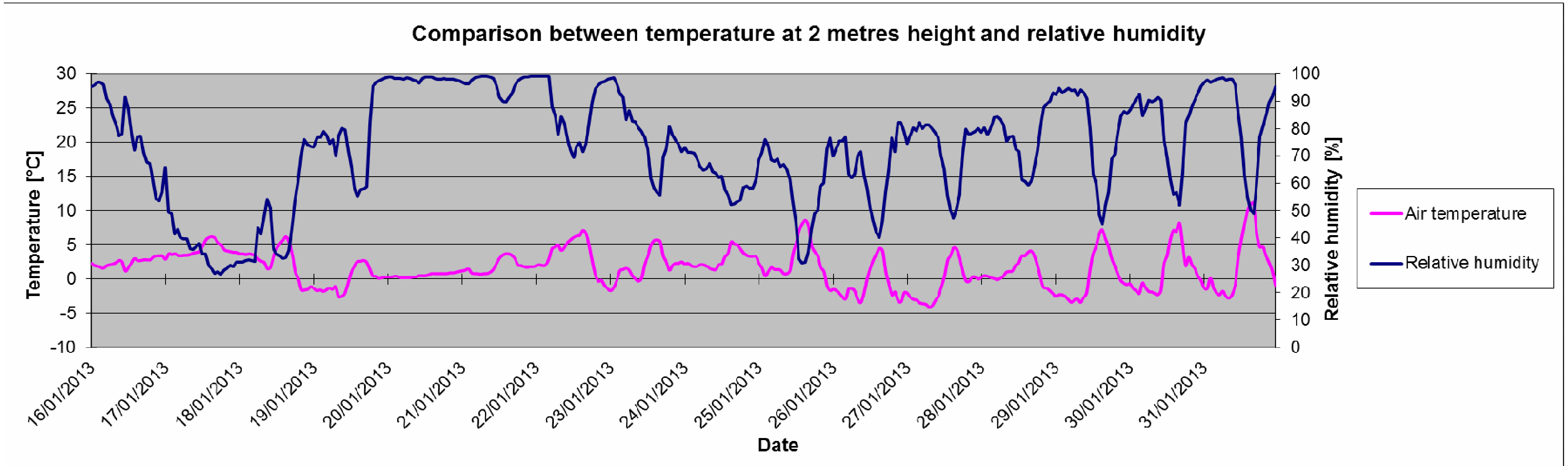

Figure 22:Comparison between relative humidity and air temperatures at 2 [m] measured by the station of S.Michele all'Adige – detail on January 2013 patterns.

As far as the correlation between air temperature (measured at 2 [m]) and relative humidity three different relevant use cases have been identified:

- situations in which the climate is dominated by **Föhn winds** (e.g. January 17th – 18th 2013): the relative humidity dropped down to values of 28% and the temperatures remained over the zero;
- a period with **precipitations** (e.g. January 20th – 22nd 2013) in which relative humidity is continuously nearly 100%;
- **stable conditions with high pressure values** (e.g. last period of the month): in this case, the relative humidity presents an opposite relationship with respect to temperature (i.e. an increasing of this last parameter is associated to a decrease in the relative humidity, and vice versa).

2.3. Parametric data analysis

To better understand and predict the behaviour of the roads during winter months, and whilst awaiting for the first RWIS stations of the project, which will be able to collect road conditions data as well, an initial parametric analysis has been performed in order to estimate icy or snow accumulation conditions on the ground and as a consequence potential dangerous conditions for the traffic circulation which may be needed to addressed through proper salting treatment. The objective of this analysis is to give evidence and weight to the most relevant road weather issues, and to initially quantify how those are today targeted by the local winter road maintenance service. The results of this comparison analysis will be more specifically presented in Chapter 4.

The analysis is based on the evaluation model presented in Figure 23. Different detection controls are matched together in order to automatically classify the road conditions, identify the presence of a possible situation of danger, and furthermore estimate the amount of salting resources which would be needed in order to address it. The different detections controls are more specifically presented in the next paragraphs.

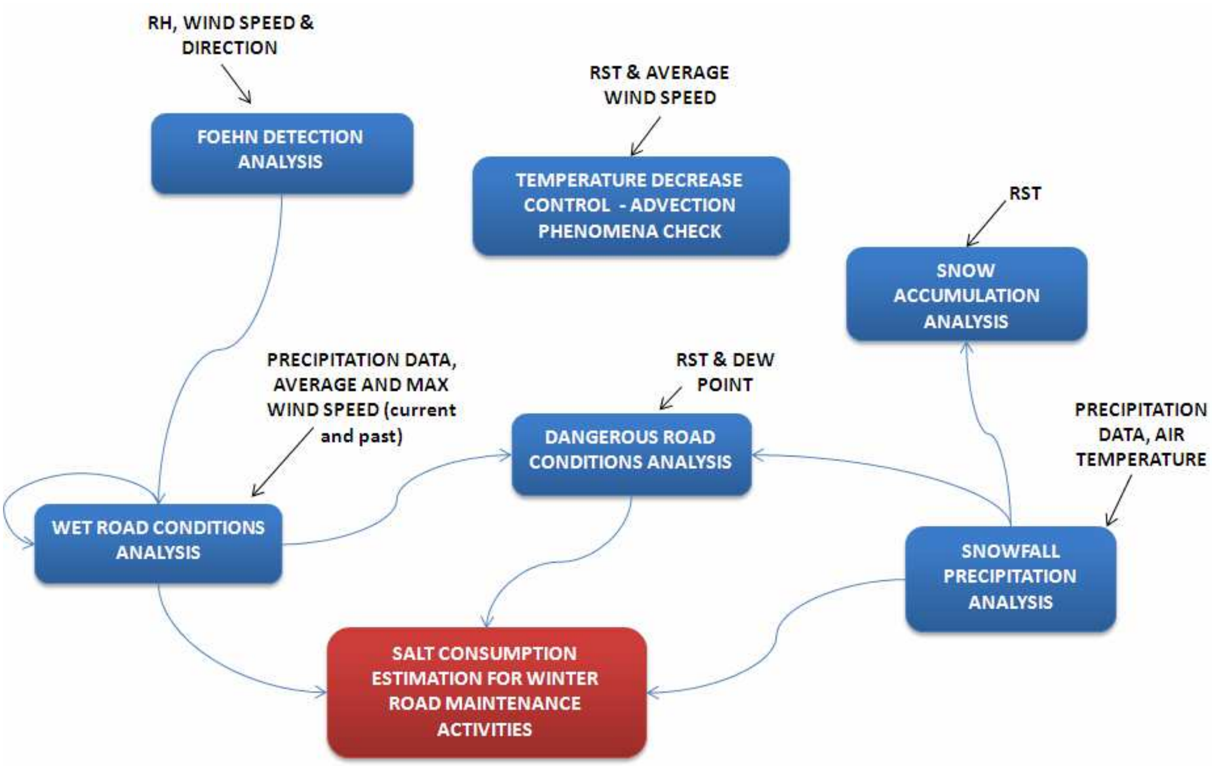

Figure 23: The evaluation model at the basis of the parametric analysis carried out on top of the meteorological data set.

2.3.1. Dew point / frost point

Dew point is the temperature in correspondence of which a given air parcel must be cooled at constant pressure and constant water vapour content in order to saturate. If this temperature is below 0 [°C] the dew point is labelled as "*frost point*" and if the air temperature falls below freezing after dew has formed, the frozen dew is known as "*white dew*". This situation can be dangerous from a winter road maintenance point of view, because these saturation phenomena can be the reason of ice formation events on the roads and more generally responsible of a reduction of the friction conditions. In order to estimate the dew point T_d based on available data (i.e. relative humidity RH and air temperature T at a height of 2 [m]), the **Magnus - Tetens formula** has been considered in the model [7]:

$$T_d = \frac{b \cdot (\frac{aT}{b+T} + lnRH)}{a - \frac{aT}{b+T} - lnRH} \qquad [1]$$

where a and b are two fixed constants (i.e. $a = 17{,}27$ and $b = 237{,}7\ [^{\circ}\ C]$). It is worth noting that one of the most relevant approximations introduced is related to the hypothesis to estimate the road surface temperature (RST) with the air temperature measured at a height of 5 [cm].

2.3.2. Snowfall precipitation and snow accumulation detection

The estimation of snowfall precipitation and snow accumulation based on the limited available data set has been quite difficult, since a series of additional physical parameters that should be included in this detection analysis has not been available. These controls have been extremely simplified and rely on the measurements of air temperature and precipitation rate only. It's known that generally, in the presence of a heavy precipitation, the snow can fall even 600-800 [m] under the freezing level while during light ones this threshold layer is reduced to 100-300 [m] only.

A precipitation phenomenon is thus classified as "**snowfall event**" if *(i) the precipitation rate is sufficiently strong (i.e. 4 [mm/h]) and the air temperature is below a first threshold temperature (i.e. 2 [°C]) or (ii) the precipitation rate is of minor intensity (i.e. between 0 - 4 [mm/h]) and the air temperature is below a second threshold temperature (i.e. 1,2 [°C]).* **Snow accumulation** is moreover determined by additionally checking the estimated conditions of the road; more in particular, this is considered to take place *if RST is below a certain road temperature threshold value (equal to 1 [°C]).*

2.3.3. Advection phenomena detection

Air temperature is considered to fall down because of advection phenomena *if RST is higher than air temperature and the wind speed is higher than a threshold value (i.e. 2 [m/s]).*

2.3.4. Föhn presence identification

The case study road is often characterized by strong and gusty down-sloping winds known as Föhn which are typical for the lee sides of Alps; more specifically, we are speaking of a rain shadow wind that results from the subsequent adiabatic warming of air that has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes. This relatively warm and dried air can have a great influence on road winter management activities, since in few hours they are in the condition to completely dry the road surface.

In the model, the **presence of Föhn** is signalled if *(i) relative humidity is sufficiently low (i.e. under a reference threshold value of 50%), (ii) the wind speed is sufficiently high (i.e. higher than 4 [m/s]) and (iii) the wind is coming from the north (between -20 and +50 [°]).*

2.3.5. Road dangerous conditions estimation

Combining all different parameters directly available from the measurements of the weather station and indirectly assessed from the aforementioned detection controls, the possible danger states of the road have been estimated. It is obviously worth underlining again the scope of this initial assessment, which is to initially give evidence and weight to some reference road conditions which will then need to be more specifically assessed through a direct evaluation of the data collected by the RWIS stations.

Different states describing the slippery of the road, have been considered, namely:

- **wet road**: this condition is evaluated from actual and past values of precipitation rates and wind speed intensity. More specifically, road is said to be "wet" *if (i) the sum of the precipitation levels registered in the previous three hours is higher than zero or (ii) at the previous time step the road was already classified as "wet", the previous precipitation levels summation is higher than a reference threshold (i.e. 0,2 [mm]) (or in alternative this summation extended to the previous 24 or 48 hours is higher a second and third reference threshold (i.e. 2 [mm] and 6 [mm]), respectively), and the sum of the average wind speeds in the previous three hours is higher than a reference threshold (i.e. 10 [m/s]) (or in alternative the maximum of these three values is higher than a second reference threshold, i.e. 5 [m/s]).*

- **snow on the road**: this condition is simply associated *in case the precipitation phenomenon is classified as "snowfall event";*

- **ice on the road**: the road is classified to this state *if the road is considered to be "wet" and RST is below a certain threshold temperature (i.e. 2 [°C]);*

- **frost on the road**: the road is classified to this state *if the road is considered not to be "wet" and either RST is below the dew point or the reference threshold considered for the ice detection analysis (i.e. 2 [°C]);*

2.3.6. Results and comments

In this paragraph the results obtained from the above parametric analysis applied to the data collected during the winter season 2012/2013 are presented. In particular, the hourly measurements collected by the weather station of San Michele all'Adige from November 1st 2012 to April 30th 2013 have been considered; the total number of hours in which the specific road weather conditions are detected are reported synthetically in Table 3.

Road weather conditions	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013
Probable snowfall event	0	43	25	21	18	0
Snow accumulation danger	0	43	25	21	5	0
Föhn wind presence	4	28	51	73	53	1
Wet road condition	207	104	93	117	303	245
Possible frost hazard	24	71	120	27	22	0
Possible ice formation	0	58	59	72	35	0

Table 3: Road weather conditions expressed in number of hours detected on top of the measurements gathered by the station of S.Michele all'Adige during the winter season 2012/2013.

The first two rows of the table focus on the **impact of snow events on the road infrastructure**, in particular the occurrence of snowfall events and the potential accumulation of snow on the roads. From the correlation of these two parameters it is possible to note that in the winter 2012-2013, based on the assumption made in the evaluation model, the road temperature was sufficiently cold to permit the creation of a rapid bond between snow and road surface, if not properly treated with anti-icing chemicals. Only in March, most of the snowfalls enter in contact with a warmer road surface, thus avoiding such bonding effects. It is moreover worth noting that snowy events are on average not more than one day per month, with a peak in the month of December (about 2 days).

As far as the presence of **Föhn winds** is concerned, data have revealed that this phenomenon is likely to occur more frequently in the late winter, in particular in February, in which four significant windy events were recorded for a total of about three equivalent days.

The evaluation of other possible danger situation on the roads has been carried out by considering the hazards on a hierarchical scale and in a solely way, in order to account for only one critical condition at a time. In the considered hierarchy, the presence of snow is the highest risk, followed by the formation of ice and frost; wet conditions are the less critical ones and take into account all hours in which the road is covered by water, snow or ice (but not frost). As far as **ice formation** issues are concerned, the model indicates again February as the month in which these events are more probable, immediately followed by January and February; even in this case, this issue affects the road on average not more than 3 days a month. It is interesting to observe that November, March and April are characterized by much more evident cases of **wet roads** than during the central months of the winter and on the contrary by very limited ice formation situations. Finally, **frost roads** are more likely to be observed during the coldest period of the year (December and January), and typically for a more extended duration (on average, up to 5 days a month).

In the next pages the results of this parametric analysis are presented visually through a set of different plots, in which the light blue blocks refer to the hourly amount of precipitation, the blue and violet lines are the trend of the air temperature measured at 2 [m] and 5 [cm] height, respectively (with the second one associated to RST); and the red dashes identifying the estimated road conditions' state. Regarding this latter classification, the following convention has been considered:

- 0 = dry road;
- 1 = wet road;
- 2 = frost on the road;
- 3 = ice on the road;
- 4 = snow on the road.

From a road maintenance point of view, the month of November, the last days of March and April didn't request particular treatments' activities by road operators, since the risk was at maximum associated to wet conditions. The situation is clearly different in the other considered months (e.g. December, January, February and the first half of March), in which stable conditions quickly alternate to dangerous conditions, including snowy precipitations. This consideration is a first strong indicator of the need of efficiently use the available resources in order to properly manage those critical situations and avoid wasting them when it's not necessary.

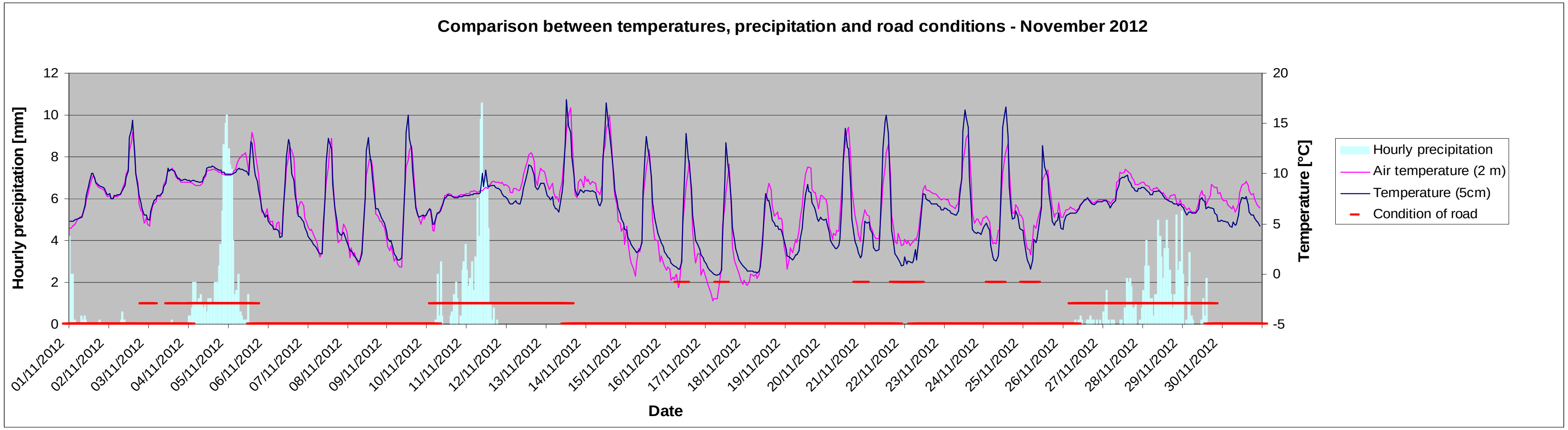

Figure 24: Comparison between air temperatures, precipitation levels and estimated road conditions in November 2012.

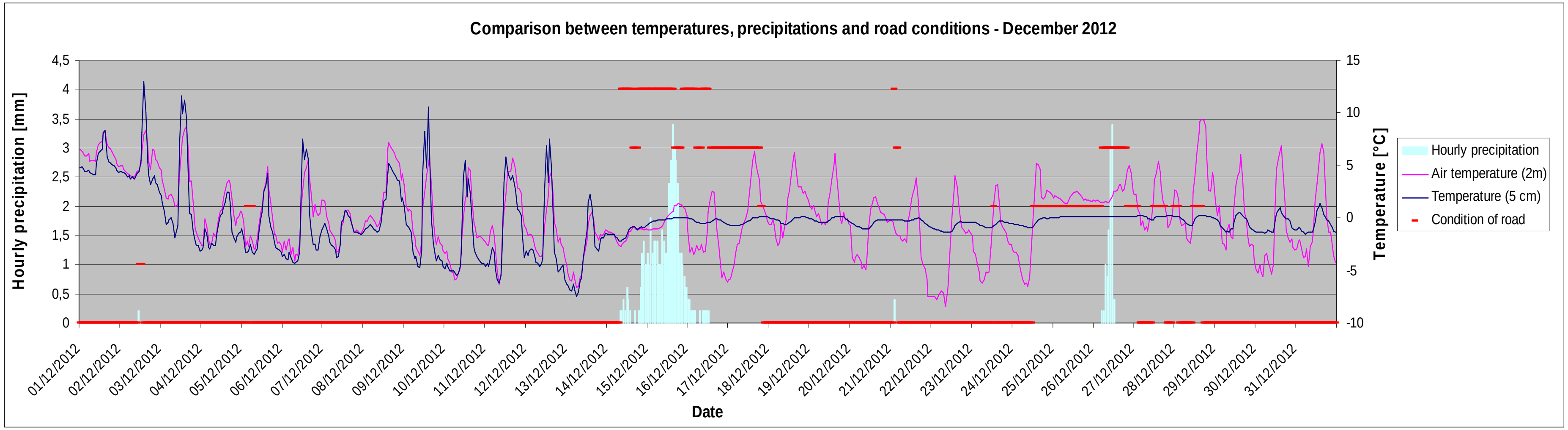

Figure 25: Comparison between air temperatures, precipitation levels and estimated road conditions in December 2012.

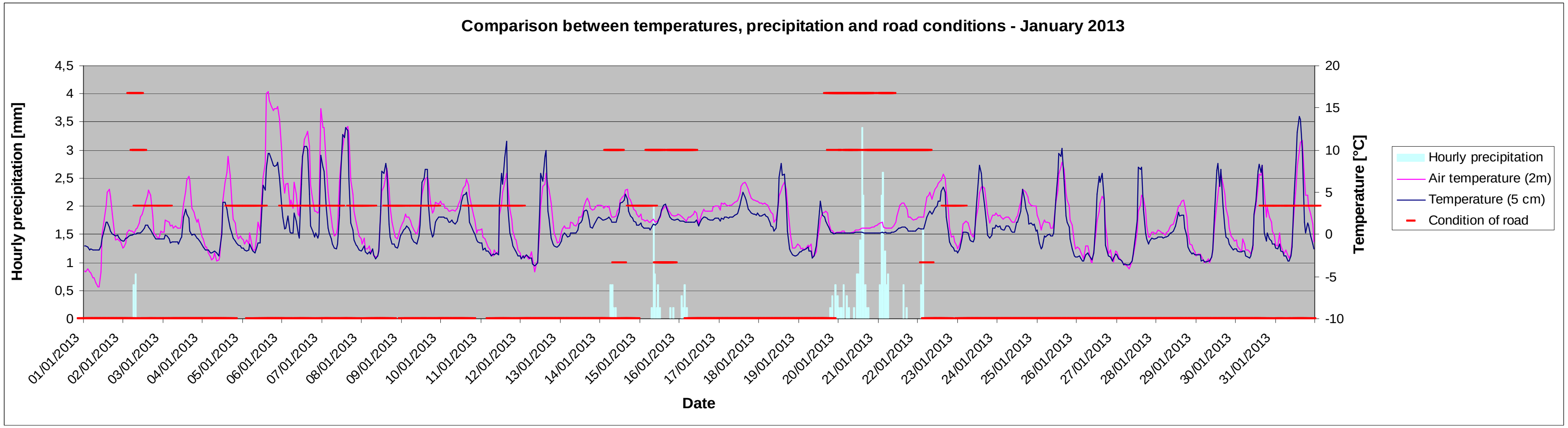

Figure 26: Comparison between air temperatures, precipitation levels and estimated road conditions in January 2013.

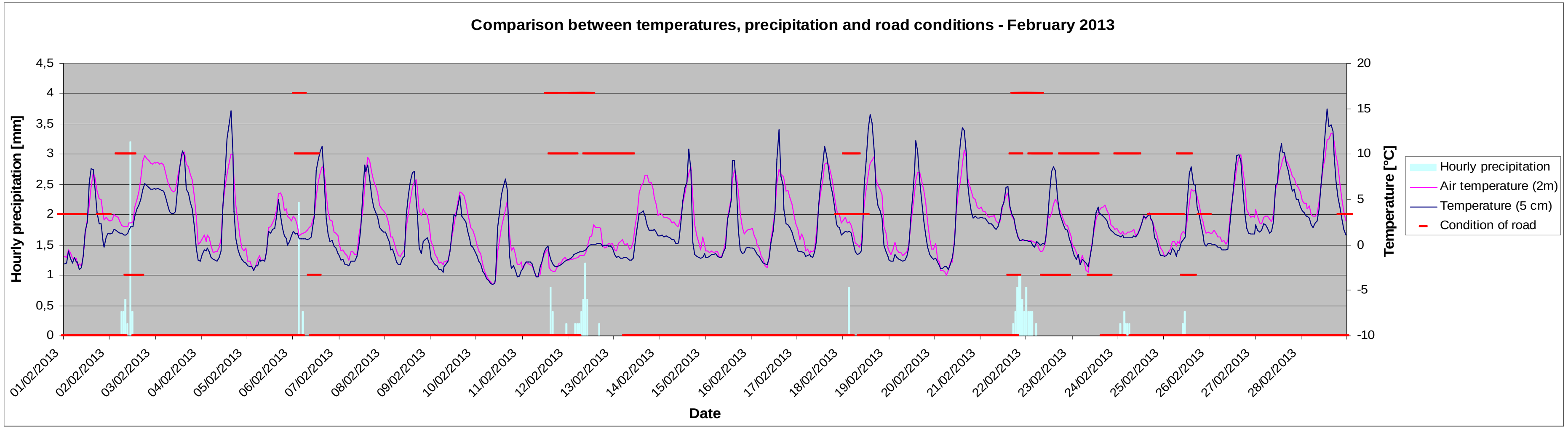

Figure 27: Comparison between air temperatures, precipitation levels and estimated road conditions in February 2013.

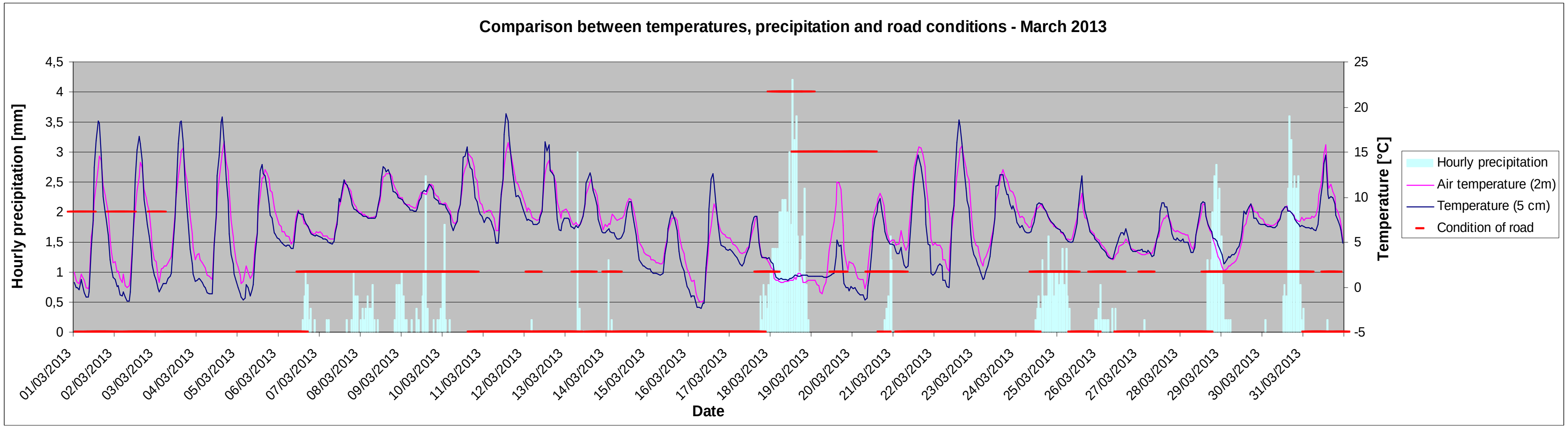

Figure 28: Comparison between air temperatures, precipitation levels and estimated road conditions in March 2013.

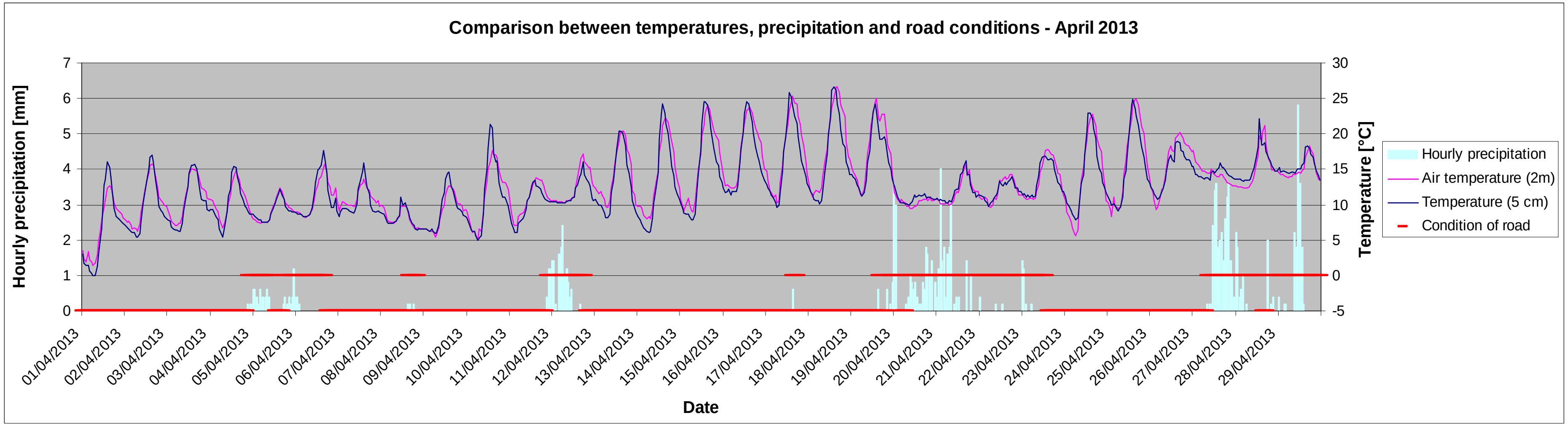

Figure 29: Comparison between air temperatures, precipitation levels and estimated road conditions in April 2013.

3. Traffic analysis

3.1. Station choice

Traffic data come from automatic detection units positioned in strategic places of the road network. Whilst waiting for the traffic detection sensors integrated in the static RWIS stations, the data collected by an existing traffic monitoring station installed within the case study road has been considered. More specifically, the traffic detection station is located within the SS12 road in correspondence of the small village of **San Michele all'Adige** (km 395.0), in a point of the road network where, despite actual legal urban limits of 50 [km/h], vehicles' speed is typically above 60-70 [km/h] because of the high capability of the roadway. The decision to consider this point for these analyses is also referred to the fact that it is quite near (i.e. a couple of hundred of meters) one of the main local traffic bottlenecks, i.e. a very narrow bridge connecting to the west side of the town where the access to the A22 highway as well to other arterial roads in direction to several local valleys is located (Figure 30). This point is inevitably the reason for several traffic jams in the area, which should be in some extensions be detectable also by the traffic detection station. This point thus offered all the potential for jointly assessing, directly in the case study road, all the different inefficiency aspects that have been evaluated in the requirements analysis action A2 [1].

Figure 30: The location of the traffic detection point considered for the traffic analysis.

3.2. Data analysis approach

Traffic data are available with a resolution of one hour, but are considered in this data analysis work in daily aggregated forms only. More detailed assessment at a higher temporal resolution are available in [1]. The data are classified on the base of the Italian “9+1” standard, which associates each vehicle to one of the following nine categories:

- motorcycles;
- cars;
- cars with trailer;
- vans;
- trucks shorter than 8,7 [m];
- trucks longer than 8,7 [m];
- trucks with trailer;
- tractors with trailer;
- busses.

These categories are then clustered in two main classes for more simplicity sake:

- **light vehicles** (i.e. motorcycles, cars and cars with trailer);
- **heavy vehicles** (i.e. vans, trucks, tractors and busses).

The purpose of this specific analysis was twofold, and more specifically to (i) characterize the typical traffic patterns that characterize this study road and (ii) to understand how they are altered by weather related factors, including not any current meteorological conditions but also weather forecast, which may locally alter the mobility choices of travellers. This second aspect is evaluated more specifically in the requirements analysis work; in this report only daily-resolution results are highlighted. Traffic data have been in particular matched with the following indicators:

- **snow precipitation data obtained from road maintenance staff’ observations**, which is reported directly on a daily basis from the road operators in charge to spread the salt and shovel the snow with the blades;
- **snow precipitation data obtained from the aforementioned parametric analysis** on meteorological data;

- **snow forecasts under 600 [m] of altitude** (with associated probability class of such event) generated by the Weather Service of the Autonomous Province of Trento to the Civil Protection;

- **snow icons used into the weather bulletins**.

The range of probability considered in the weather probabilistic bulletin is defined as follows:

- *very low probability* (<1%): probability class "0";
- *low probability* (1% - 30%): probability class "1";
- *medium probability* (30% - 70%): probability class "2";
- *high probability* (>70%): probability class "3".

In the analyses, traffic data referring to the period November 1st 2012 - April 30th 2013 has been specifically correlated with a reference situation of 10 [cm] precipitation probability above 600 [m] of altitude for the current day, and with both weather bulletins and reference website indicating at least a snowflake.

3.3. Monthly analysis results

The monthly traffic patterns registered during the winter season 2012-2013 are briefly presented in Table 4 and Figure 31, and are expressed in terms of *average daily traffic* (ADT); no distinctions between working and non-working days has been made. The month with the lowest traffic levels, both for light and heavy vehicles, was January; this is probably a direct consequence of a **decrease in the mobility demand**, in part motivated by the first nonworking days of the month when many companies and schools are closed but also by the meteorological conditions, which have demonstrated to be particularly harsh during these weeks. The months of November and April, the marginal months of the considered period, present indeed an average number of circulating vehicles which is slightly higher than winter months (in the order of 1.000 ADT, more or less the 15% of traffic flows), as a further evidence to this consideration. The minimum value of ADT was registered on Sunday, January 20th 2013, with only 2.455 of circulating vehicles, in correspondence of a significant snowfall event between 10 and 20 [cm]. The maximum value of light vehicles was registered on Sunday, April 14th 2013 and was essentially due to the increase of motorcycles.

MONTHLY ANALYSIS	NOV. 2012	DEC. 2012	JAN. 2013	FEB. 2013	MAR. 2013	APR. 2013
Average of light vehicles	6.615	6.366	5.780	6.068	6.358	7.063
Min of light vehicles	4.983	4.146	2.455	4.290	4.382	6.036
Max of light vehicles	7.677	8.371	7.696	6.772	7.479	9.758
Average of heavy vehicles	1.829	1.235	1.155	1.360	1.416	1.610
Min of heavy vehicles	265	93	166	213	227	333

Max of heavy vehicles	3.339	2.233	1.762	1.892	2.093	2.345
Vehicles to Bolzano	48,5%	47,8%	46,8%	48,1%	48,0%	48,0%
Vehicles to Trento	51,5%	52,2%	53,2%	51,9%	52,0%	52,0%
Probability 1 of snow under 600m	0	3	6	9	2	0
Probability 2 of snow under 600m	0	1	2	1	1	0
Probability 3 of snow under 600m	0	0	0	2	0	0
Homepage with snow icon	0	3	8	9	4	0
Bulletin with snow icon	9	7	9	9	15	7

Table 4: Traffic data evaluation – monthly analysis overview .

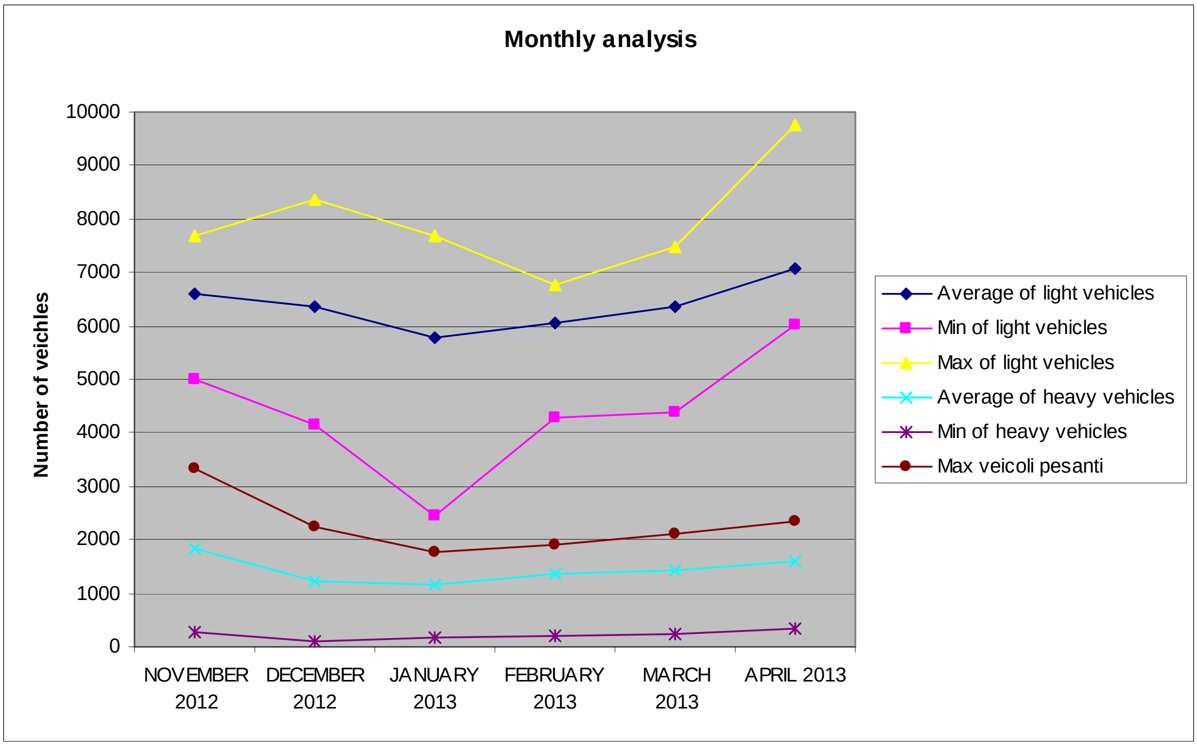

Figure 31: Traffic data evaluation – heavy and light vehicles monthly patterns plots.

The month with the most frequent probability of snow under 600 [m] of altitude was February followed from January; this month has also been the only one in which a high probability of snowfall has been communicated. The days with icons representing at least a snowflake are more or less the same (9) for the month of January and February, but with a surprising peak in March (15). The following plots show the recorded ADT pattern, both light and heavy vehicles, over the single months, in direct comparison with the snowfall precipitations. It is worth noting the typical weekly traffic trend, with a decrease of vehicular transits during the week-ends. This is especially marked for heavy vehicles, and is less stressed for light vehicles, since free time demand can occasionally increase in correspondence of certain periods (e.g. in particular during the Christmas Advent); this is particularly evident in the data measured in **December** (Figure 33). During that months, it is particularly interesting to observe <u>two opposite traffic situations related to the consecutive weekends</u> (i.e. 08-09/12 and 15/16): <u>the first week-end, characterized by dry road and sunny conditions, registered the monthly peak of traffic</u> (probably due to tourist phenomena moving during the Immaculate

Conception festivity), while the following one, in which similar flows were expected, registered a local minimum probably caused by the intense snowfalls. If compared to the average monthly ADT, **this reduction is in the order of 40%**.

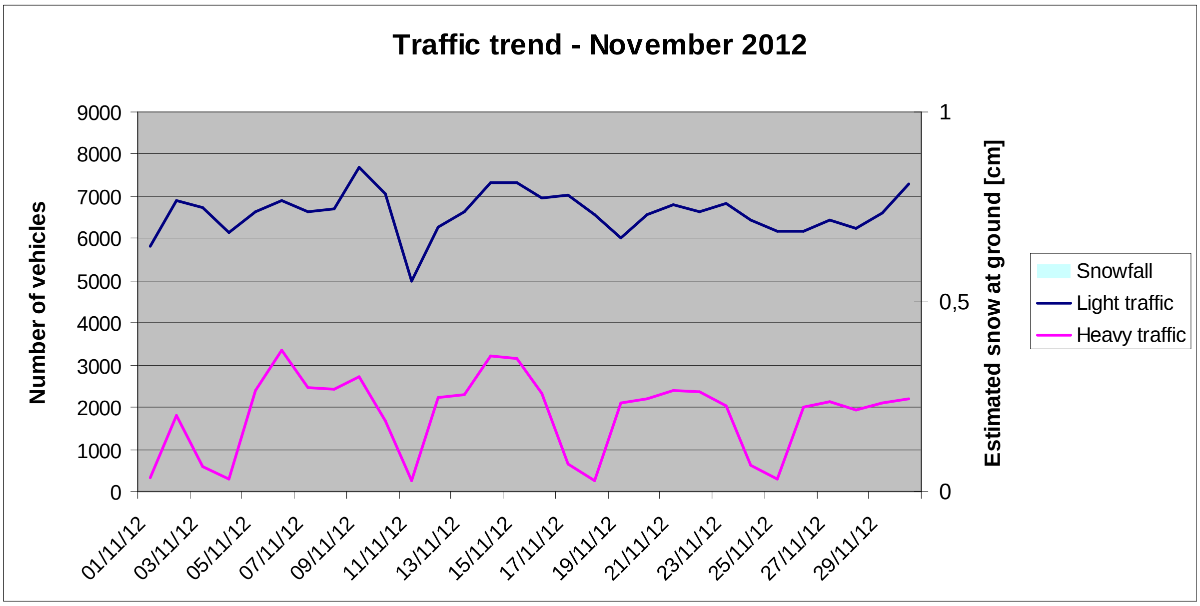

Figure 32: November 2012 traffic trend detail – light and heavy traffic flows compared to snowfall precipitations.

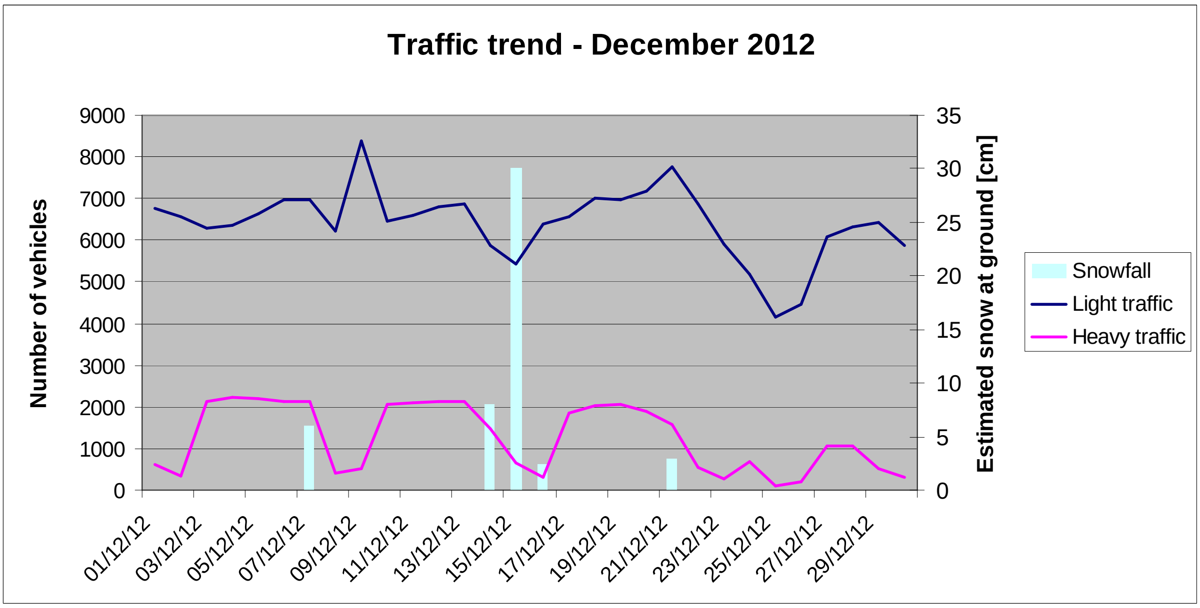

Figure 33: December 2012 traffic trend detail – light and heavy traffic flows compared to snowfall precipitations.

Similar patterns are also easily observable in the plots referred to **January** 2013 (Figure 34). In this case the reduction caused by a snowfall event is even higher (**up to 50% if compared to the previous week-end**), probably because this period is in general characterized by a lower mobility demand. It is however important to point out that the **such traffic "depressions" are directly proportional to the intensity of the meteorological event**: in fact, light and quick snowfalls do not significantly alter average traffic flows. This is confirmed by the trends recorded in **February** (Figure 35), in which it's quite evident the different impact on traffic (in particular lighter one) of snowfall events of different entities; **the effects on heavy traffic is less stressed because of the commercial purpose of most of these trips** – and observable effects are much more emphasized in case the road maintenance service decides to limit the traffic circulation because of exceptional weather events like that of February 10th and 11th.

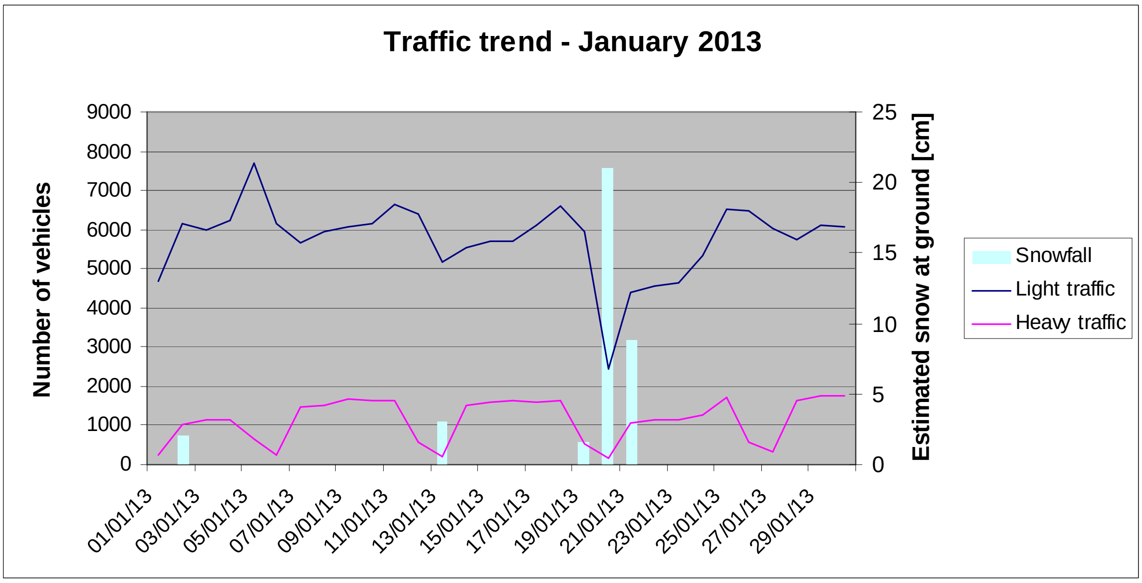

Figure 34: January 2013 traffic trend detail – light and heavy traffic flows compared to snowfall precipitations.

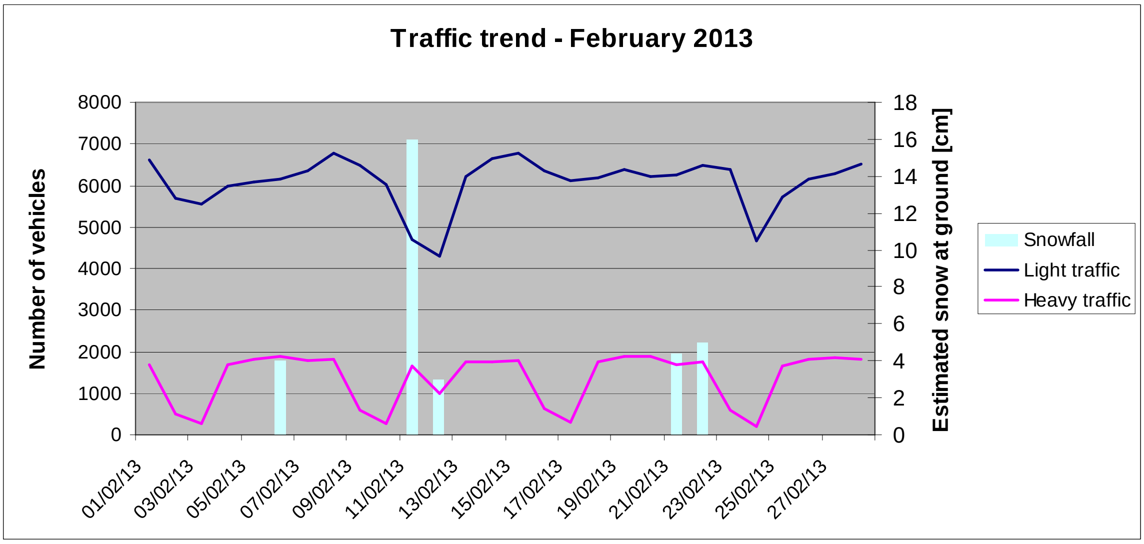

Figure 35: February 2013 traffic trend detail – light and heavy traffic flows compared to snowfall precipitations.

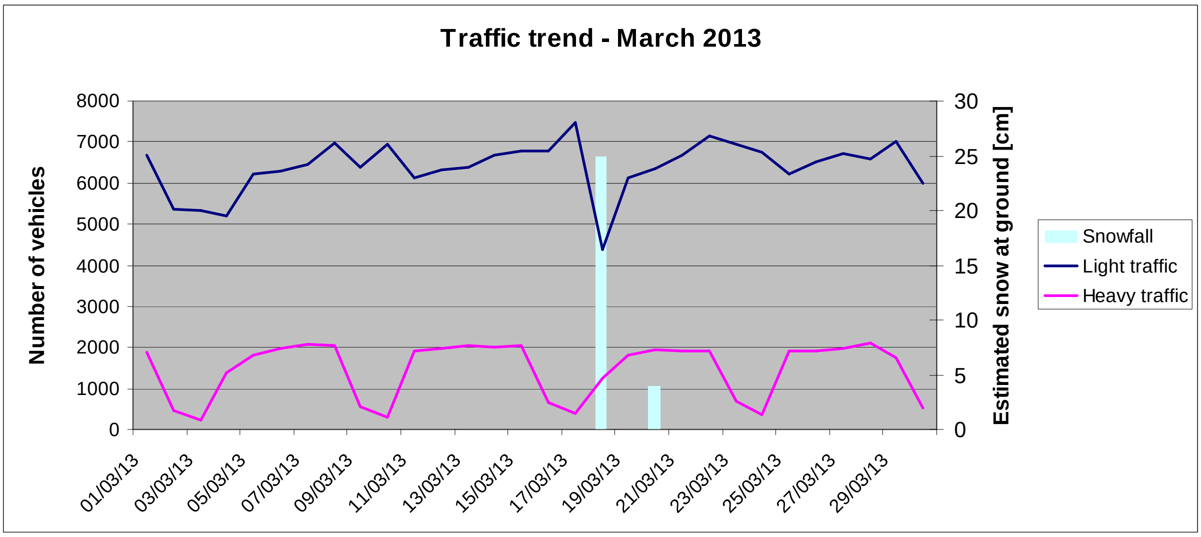

Figure 36: March 2013 traffic trend detail – light and heavy traffic flows compared to snowfall precipitations.

In order to further investigate the existing dependency between snowfall events and traffic flows, and in particular to have other assessment of the typical travellers' behaviour in such conditions, ADT was calculated by distinguishing days characterized or not by such meteorological phenomena; days with snowfall were further subdivided into classes of different probability of snow intensity. It is worth noting how such phenomena are much fewer than those registered on normal dry conditions, so these are statistically weaker; moreover, in some months there are no records for some particular snowfall conditions.

From Figure 37, it is possible to notice how the **number of the circulating light-vehicles during days with precipitations** is significantly lower than those registered during normal conditions. The decrease is on average about 19%, 10% and 16% for January, February and March, respectively. December, on the contrary, showed an opposite trend with a limited increase of about 2%, as a demonstration of the relevant role played by the "seasonal" mobility demand in this patterns (i.e. before Christmas, travellers tend to move much more for commercial or occasional purposes than the following months). Please note finally the absence of snowfall events under 600 [m], as already stated.

Figure 38 shows on the other side the **less relevant impact that snowfalls have on heavy vehicles trips**. On the contrary, February and March show a non-negligible increase in the number of circulating heavy vehicles.

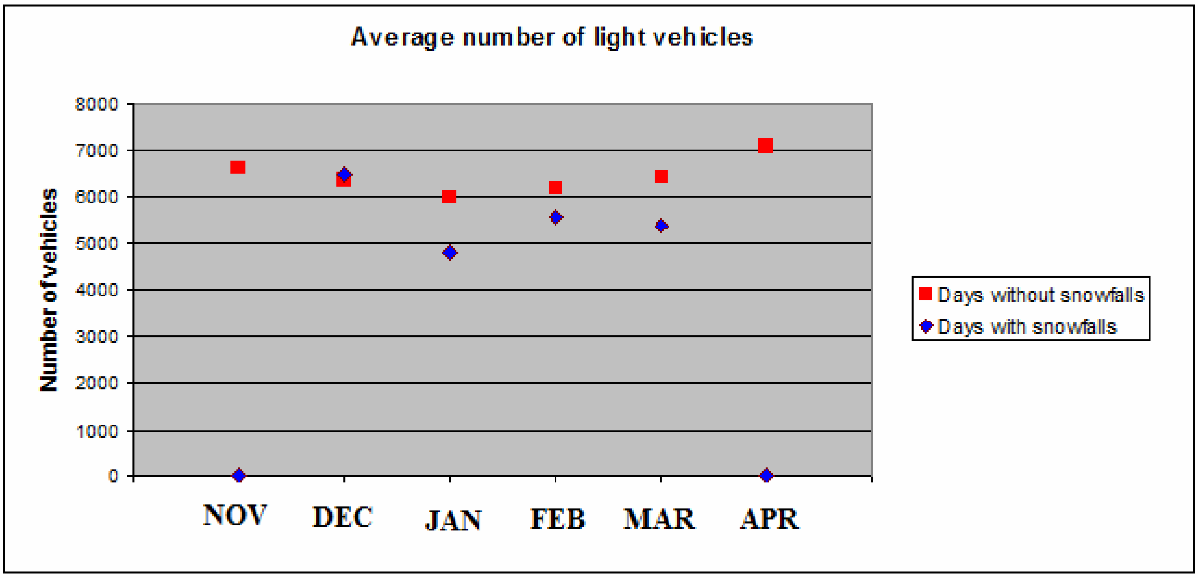

Figure 37: Monthly light vehicles ADT calculated in case of days with and without snowfalls.

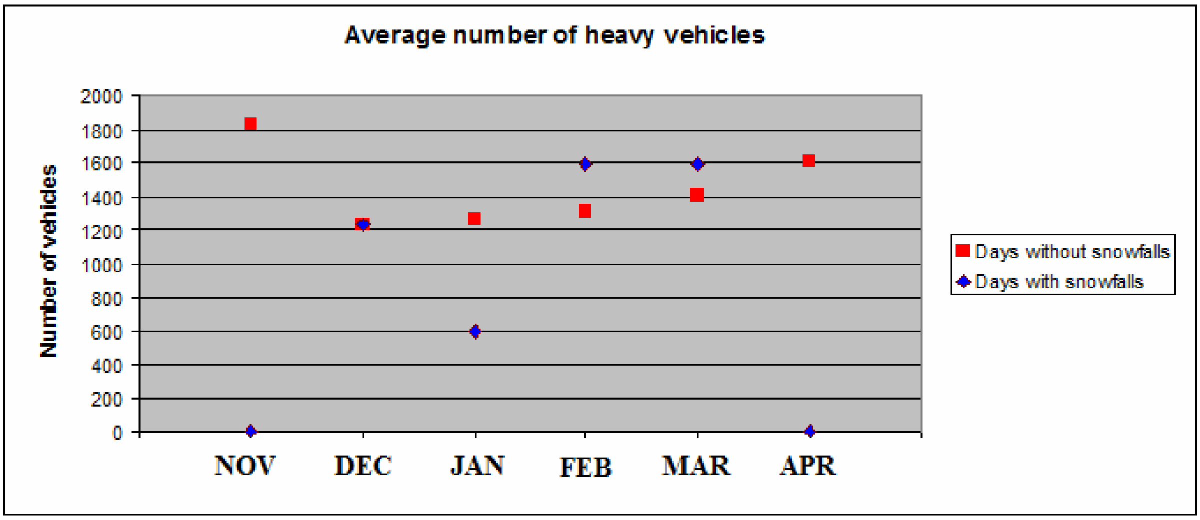

Figure 38: Monthly heavy vehicles ADT calculated in case of days with and without snowfalls.

Figure 39 and Figure 40 show finally the **number of light and heavy circulating vehicles compared to the probability of snow for the day**. Several markers report no data (i.e. on the horizontal axis) for the lack of data for that specific event. <u>The results do not offer a clear picture of how travellers are influenced by the probability of the intensity of the snowfall event</u>, and this is probably related on one side on the scarcity of reference data for the different reference situations, and on the other side on the complex and various way with which a single traveller may perceive a certain meteorological event, which could be more or less emphasized by different weather forecasts services or by their personal experience.

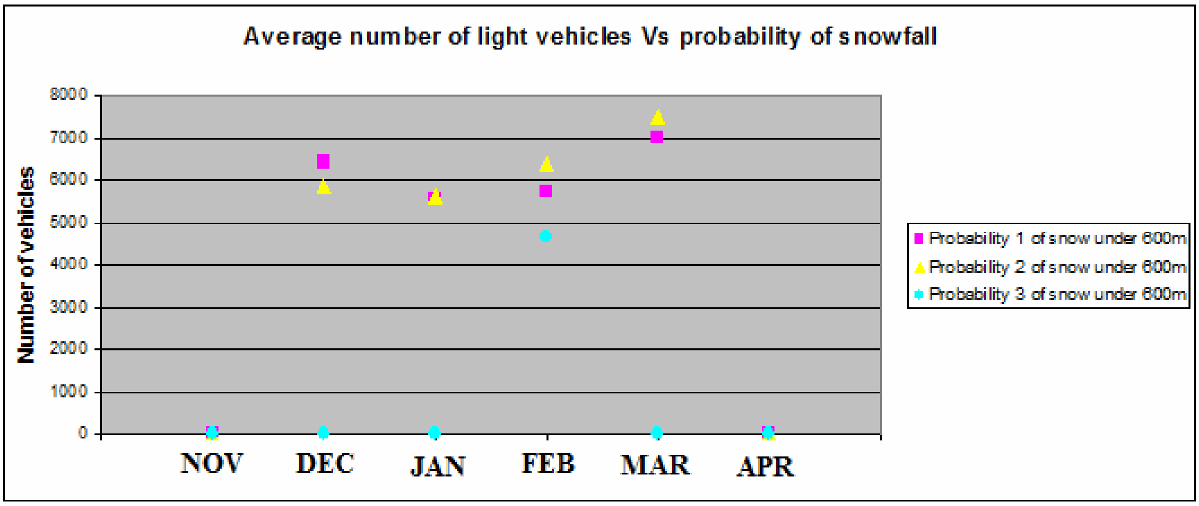

Figure 39: Monthly light vehicles ADT calculated in case of days with different probability of snowfall intensity.

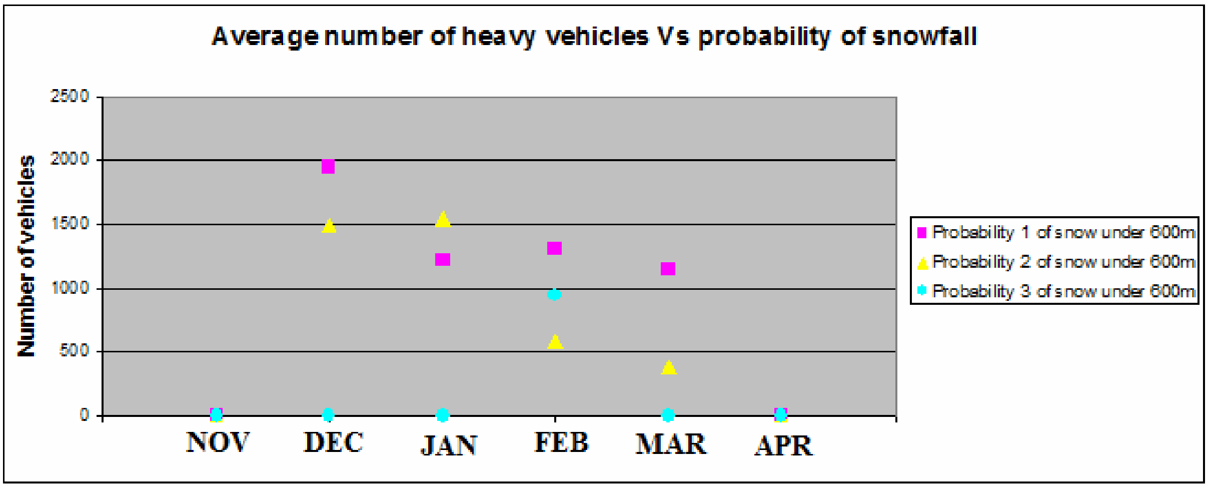

Figure 40: Monthly heavy vehicles ADT calculated in case of days with different probability of snowfall intensity.

3.4. Weekly analysis results

The monthly analysis is useful to get an idea of what can be the existing relationships between traffic and snowfalls from a high-level perspective. A more detailed analysis is however necessary in order to distinguish daily patterns that are clearly associated to different mobility demand conditions (i.e. working and non-working days). Using the approach considered for the monthly evaluation (i.e. calculating plots that merge at different layers heavy and light vehicles traffic flows with snowfall precipitations), the daily ADT calculated for all specific week days (i.e. Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday) falling in the time interval of interest has been considered. The following plots present the most interesting results obtained for typical working week days (Monday, Figure 41 and Wednesday, Figure 42) and non-working days (Saturday, and Sunday). It is worth noting that also special feast days are considered, so it is recommended to properly consider this while evaluating possible outlayers in the time series.

Mondays with snow precipitations confirm the evident decreases in the light traffic flow, quantifiable in the order of 1.000 vehicles (about 20% if compared to the average ADT value) **and the reduced impact on heavy traffic**, as detected in particular on February 11th 2013. This is however not always true, for example during snowfalls of January 21st and March 18th local minima can be observed, with a heavy traffic depression of some hundreds of trucks, which is somehow comparable with the above percentages. Results considering ADT values for **Wednesdays** confirm these considerations, and put in evidence how traffic flows reductions are directly proportional to the effective intensity of the snowfall event – in case of "light" conditions even light traffic is much less (or even no) affected by these meteorological issues.

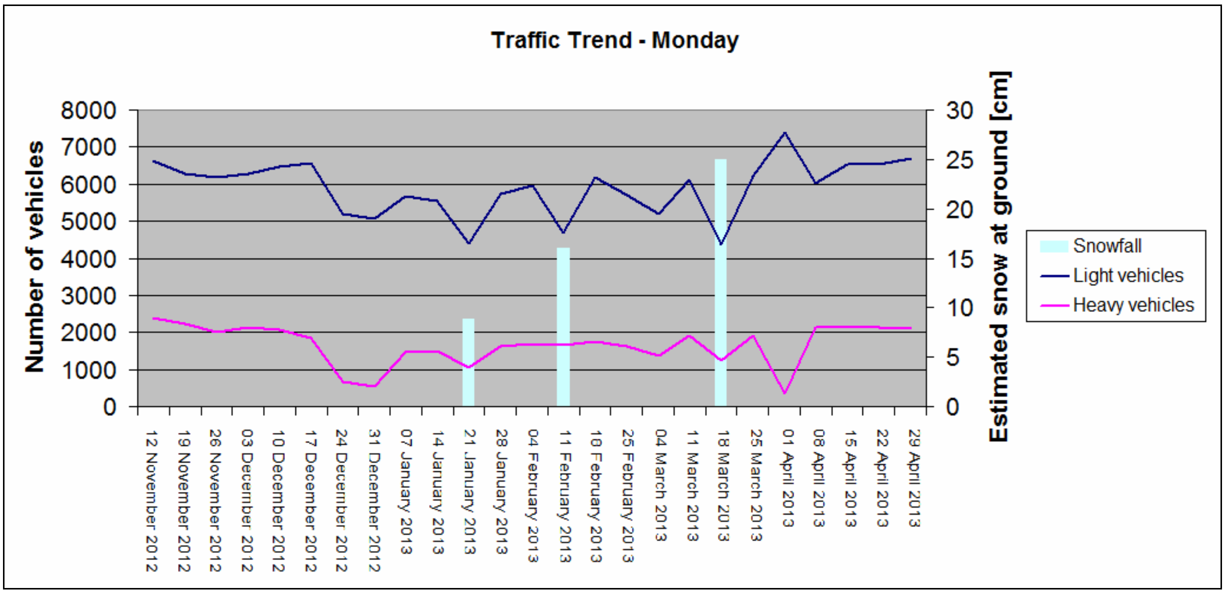

Figure 41: Weekly ADT of specific week day (Monday) compared with snowfall precipitation.

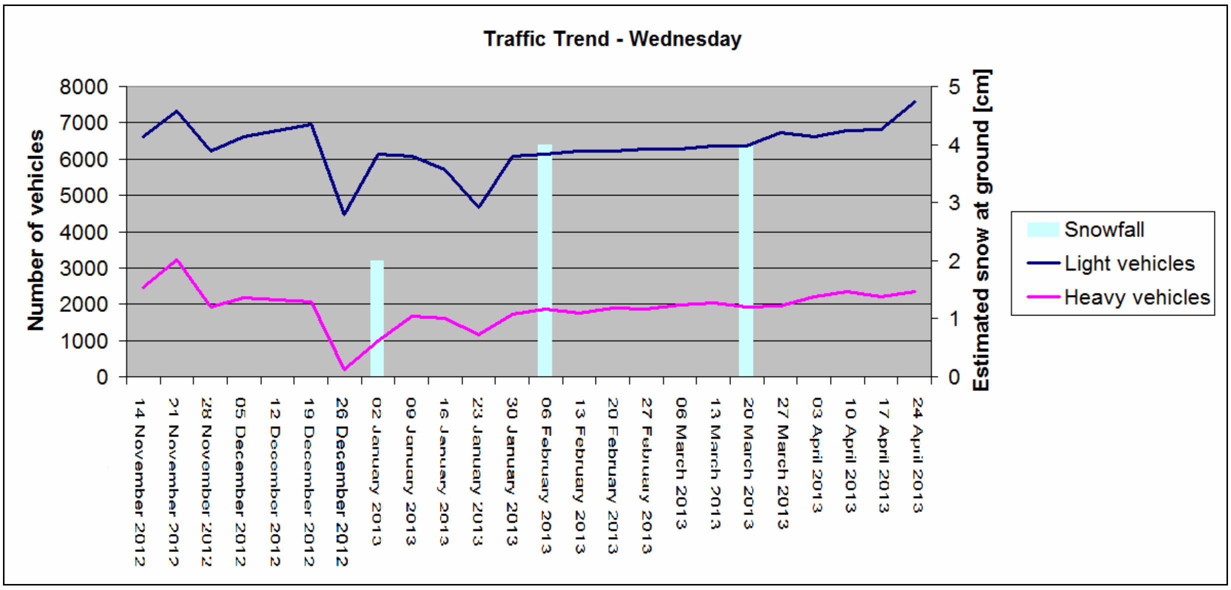

Figure 42: Weekly ADT of specific week day (Wednesday) compared with snowfall precipitation.

Figure 43 reports the traffic flow for a nonworking day, Sunday. This plot puts in evidence **the most likely situation that can get down traffic flows because of meteorological phenomena**: <u>heavy snowfall during a non-working day, and period with general low mobility demand</u>. The reduction registered during the snowfall occurred on January 20th is quantifiable in the order of 60% if compared to adjacent values. This consideration is in part confirmed by the trends observed in Figure 44 during Saturdays, even if typical traffic patterns are on average different from Sundays, it is clearly recognizable how the reduction caused by the snowfall occurred on December 15th is less evident because of the high mobility demand which is typical for the days before Christmas.

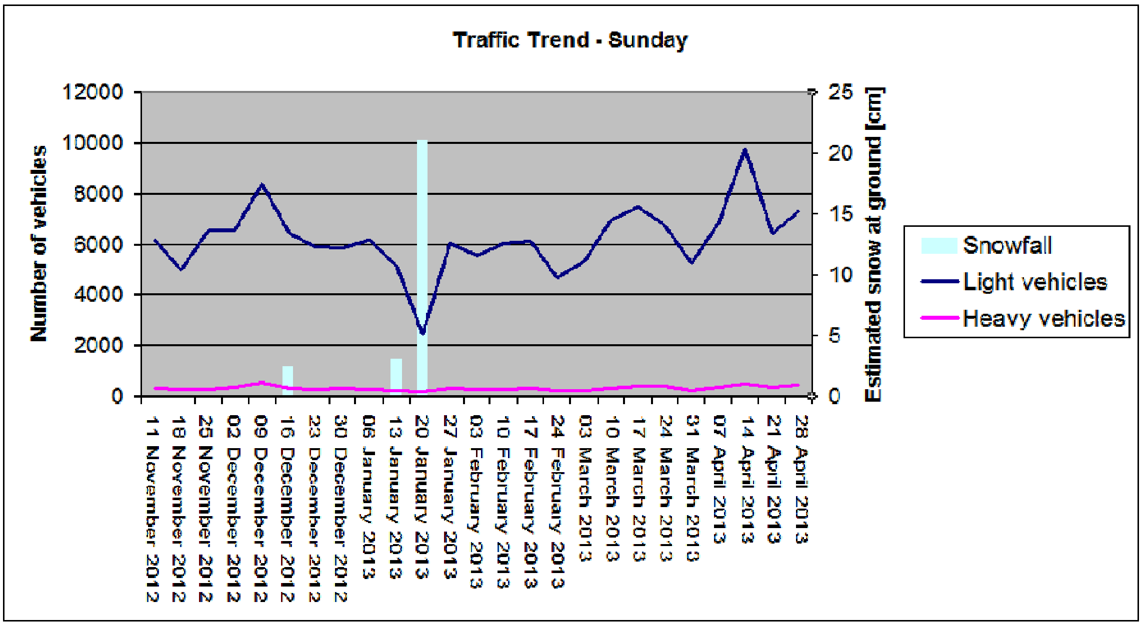

Figure 43: Weekly ADT of specific week day (Sunday) compared with snowfall precipitation.

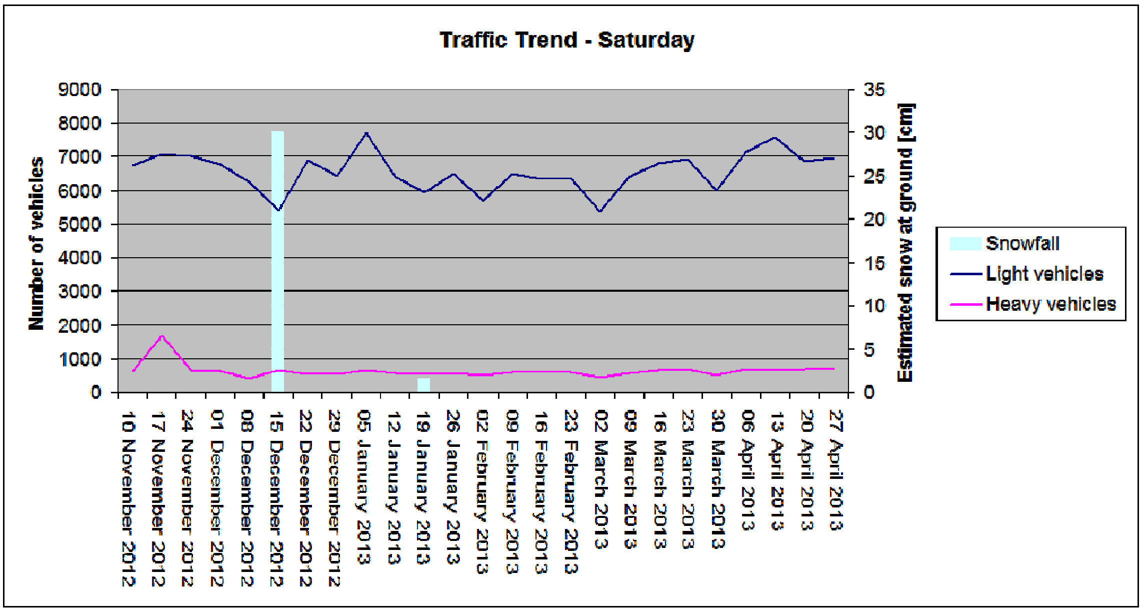

Figure 44: Weekly ADT of specific week day (Saturday) compared with snowfall precipitation.

3.5. Final correlation assessment

The previous results have put in evidence several interesting insights about the relationship between traffic and snowfall events, which can be generally indicated through this mathematical expression:

$$ADT = f(d, MIB) \quad [2]$$

where d is the mobility demand, and MIB is an indicator associated to meteorological information and bulletins, which is not exactly the published one, but more precisely the perceived one (and thus more difficult to estimate). Further research studies could try, based on these analysis, to suggest a possible discrete choice model in order to take into account this relationship in the engineering of a complete transportation systems.

In percentage, data show **on average** (by considering all different daily patterns) a quite **comparable traffic reduction for heavy and light vehicles** (32,18% and 33,23%, respectively), but previous analysis have shown that **this percentage can be much higher for light vehicles, in particular during non-working days**. Moreover, being light traffic much more higher than heavier one, this effect is (obviously) quantitatively much more evident. The hourly ADT is estimated to be 282 vehicles during normal dry conditions, 240 during rainy conditions and 186 during snowfall events; as evidenced in the analysis illustrated in [1], however light rain can have an opposite effect and increase average ADT because of the localized shifts to private cars mode.

An additional analysis has been carried out in order to identify the **potential impact that snowfall events can have on the appearance of traffic congestions,** presents the results of this analysis; congestion situations are detected based on the speed profile data and using a reference congestion index [1]. Most of the congestion situations occurred during the harsher winter months are likely to be associated to snowfall events; on average, during 40% of snowfall events a traffic jam can be detected in correspondence of the traffic detection point.

	Non-congestions [nr. of hours]	Congestions [nr. of hours]	Congestion rate [%]
Absence of precipitation	2612	226	8,65
Rainfall	184	23	12,50
Snowfall	108	44	40,74

Table 5: Traffic congestion events compared to meteorological events.

Finally, a **direct correlation between vehicular speeds and meteorological conditions** has been carried out in order to check possible suboptimal use of the road infrastructure and/or typical driver behaviours in these cases.

The mean variation in speed recorded during a snowfall is approximately equal to half of a “speed interval”, which is equal to [10 km/h]; this means that the average speed reduction can be quantified on average between 5 and 10 [km/h]. If congestion phenomena are not taken into account into the calculation (since they have demonstrated to influence more snowy events), this reduction reveals to be even slower, as a demonstration that (i) road maintenance service is able to guarantee almost the same levels of service during all meteorological conditions, and (ii) drivers do not seem to take a more conservative driving approach when such conditions are in place. This assessment is in line with the results directly obtained by local travelers through the public survey, which are presented more deeply presented in [1] - [8].

4. SALT USAGE

4.1. Generalities

Every year, considerable quantities of snow and ice control products are spread on the roads of the Autonomous Province of Trento; the most common chemical alternatives are: sodium chloride (NaCl), magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), calcium magnesium acetate (CMA), and potassium acetate (KA). The de-icing salt which is mostly used locally for road winter management is the sodium chloride. This chemical reduces the freezing point of the water, and, if present on the road surface before or after a precipitation, avoids critical situations for the vehicular circulation. The reduction capacity of the freezing point of the water depends on its concentration in the "solution" and partially to its solubility. Figure 45 presents one of the reference solubility – temperature diagram available in the literature [9] .

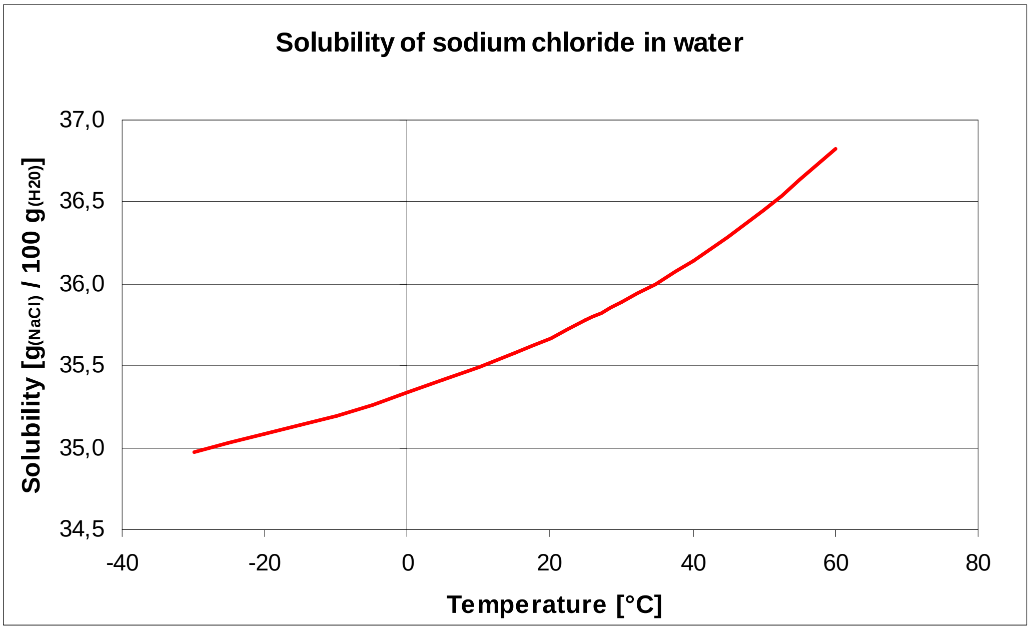

Figure 45: Solubility of sodium chloride in water.

In saturated solution, the lowest temperature reachable is approximately -21 [°C] (or -23 [°C] with other formulas), as illustrated in Figure 46. For the considered application domain, the solubility of salt into water and the minimum freezing temperature reachable doesn't influence the operational condition of its use. The long empirical experiences of road operators demonstrate however that with the solution concentrations, sodium chloride becomes ineffective in conditions of air temperature lower than -5/-6 [°C].

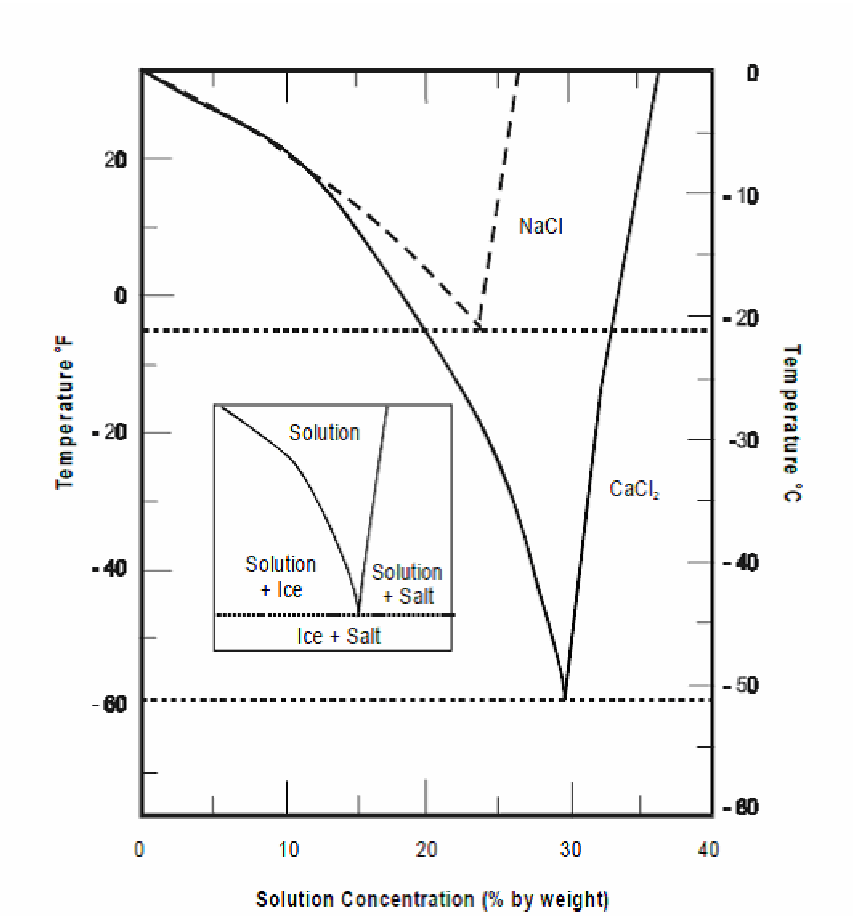

Figure 46: Phase diagrams for sodium and calcium chlorides [11].

How much salt (and in particular sodium chloride) must be used in order to decrease the freezing point of a solution characterized by a certain capacity? The answer to this question is given in Figure 47, based on the consideration that one litre of solution corresponds to one millimetre of water on a surface of one square metre, and assuming the presence of a water film of 0.5, 1 and 2 [mm] thickness (i.e. the three different curves). If the target is to reduce the freezing point up to temperature of -5 [°C], 40, 80, 160 [g/m^2] of salt (with a purity of 98%) are required, respectively. It is worth remember here that the maximum salt flux manageable by salting trucks is 40 [g/m^2], and typically most of the treatments are carried out at a rate of 5-10 [g/m^2]. This information puts in particular evidence the effort which is needed during **de-icing** actions, which aim to melt existing ice and snow on the road, and which is significantly higher than those which is typically required in order to achieve similar road conditions during **anti-icing** activities, that aim to prevent the formation of such bonds.

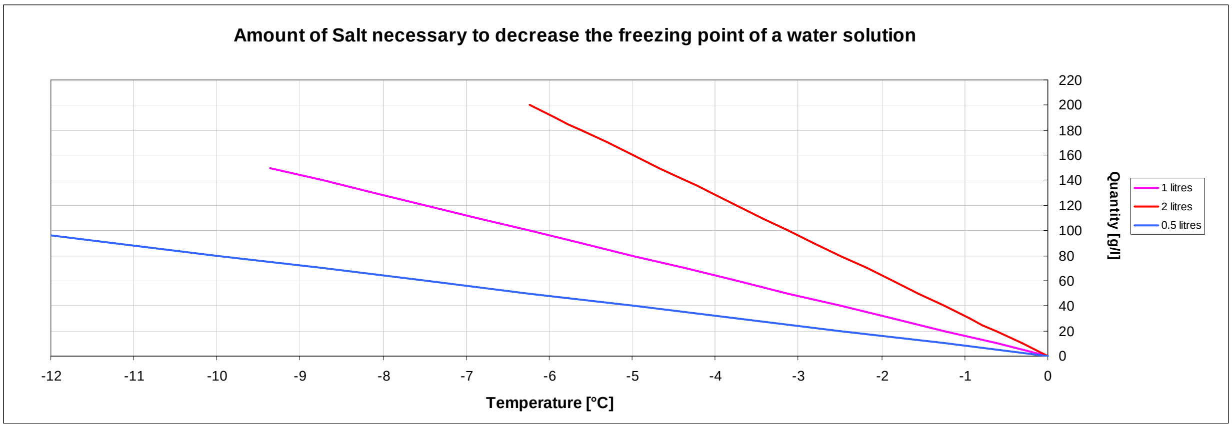

Figure 47: Amount of sodium chloride needed to decrease the freezing point of a water solution.

4.2. Salt type utilized in the Province of Trento

Different types of sodium chloride can be usable as de- or anti-icing product and can be purchased on the market. The most commonly used are **sea salt**, **mineral salt** and **re-crystallized mineral salt**. Each of them present different chemical properties, as summarized in Table 6 [10]:

CHEMICAL PROPERTIES			
	Sea salt	Mineral salt	Re-crystallized mineral salt
NaCl concentration [%]	96,62	97,68	99,75
Insoluble residue [%]	0,29	1,2	0,02
Ca^{2+} [mg/kg]	1695,4	678,05	44,38
SO_4^{2-} [mg/kg]	5943,25	3523,3	289,68

Table 6: Chemical properties of different sodium chlorides.

The concentration of NaCl indicates the amount of the active principle in the salt; given the same spreading quantity, the higher is this parameter, the better works the salt. The remaining solid part, after the melting of the salt, is called "*insoluble residue*". These particles are likely to increase dusts raised by traffic flows. The anion SO_4^{2}- dissolved in water can chemically attack the concrete structure if it's not adequately protected. Other important parameters to take into account for the choice in the purchase of the suitable product are the melting action speed, the presence of additives, the pH, the particle size distribution, humidity and others.

The minimum specification on road salt considered in the Autonomous Province of Trento are presented in Table 7, and are based on the last purchasing activities carried out during the past winter seasons. In addition to this, salt suppliers have to guarantee that the packaged and unpackaged material is in the condition to avoid possible agglomeration processes for a period of two years.

PARTICLE SIZE DISTRIBUTION		
Size range	Min	Max
sieve	Through the sieve	
5,00	99,0%	100,0%
4,00	95,0%	100,0%
3,15	75,0%	95,0%
2,00	40,0%	65,0%
0,80	5,0%	30,0%
0,16	0,0%	5,0%
PHYSICAL CHARACTERISTICS		
Feature	Reference value	Tolerance (by convention)
pH	Between 5 and 10	none
Specific weight	Between 1,00 and 1,30 [g/cm^3]	Between 0,9 and 1,40 [g/cm^3]
CHEMICAL CHARACTERISTICS		
Feature	Reference value	Tolerance (by convention)
Active principle	Not less 98%	Not less 96%
Insoluble residue	< 2%	< 4%
Anti packaging	< 200 [p.p.m.]	none

Table 7: Road salt specifications considered in the Autonomous Province of Trento.

4.3. Salt consumption analysis in Province of Trento

The overall quantities of salt used in the Autonomous Province of Trento during years 2010, 2011, 2012 are presented in Figure 48. It is worth noting that the results reported below are referred to the quantities used during the solar years, and are therefore not directly linked with the different winter seasons.

The details of salt consumption in the reference sector of the project (sector nr. 4) is given in Figure 48. The patterns are similar to the total ones, apart for the usages in 2011 and 2012 (in this sector there has been a lower consumption in 2012 and not in 2011).

4.1. Salt usage data for the SS12 during winter season 2012/2013

Thanks to the active recording work of the road operators done during the first winter season of the project it has been possible to keep specific trace of the winter road treatments carried out on the case study route. Road operators have manually recorded in particular the following information [1]:

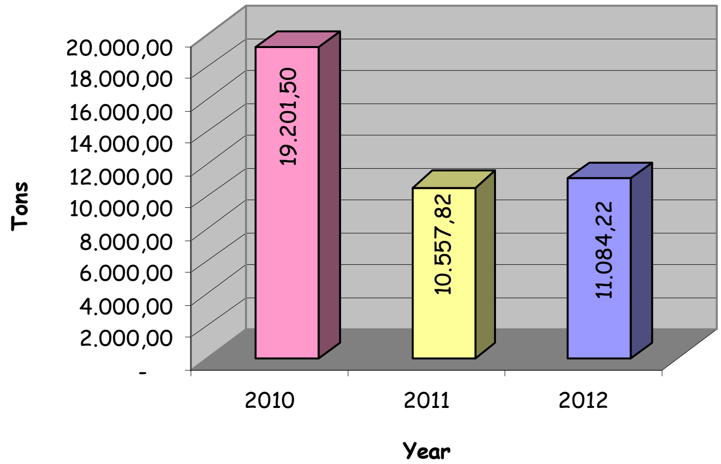

Figure 48: Overall road salt consumption in the Autonomous Province of Trento during years 2010, 2011 and 2012.

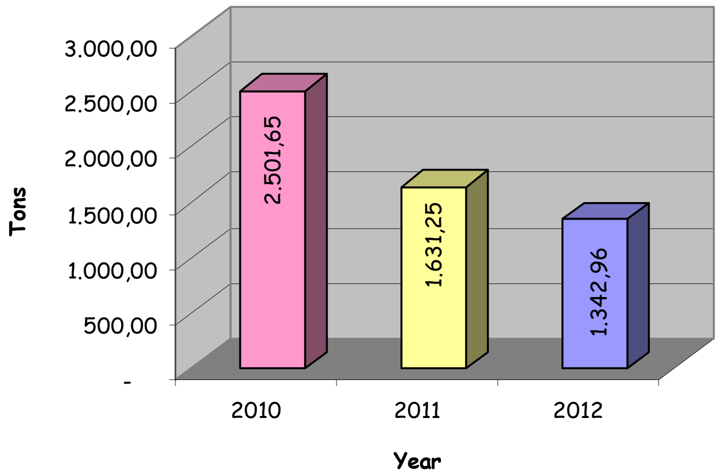

Figure 49: Road salt consumption in the Autonomous Province of Trento during years 2010, 2011 and 2012 in the sector nr.4.

- **date and time of the treatments**;
- **type of the treatments** (*preventive anti-icing, preventive before a snowfall, during a snowfall, after a snowfall*);
- **quantity of salt spread** (expressed in [g/m^2]).

Figure 50 presents the quantity of salt used at the road inspector's house in which study road stretch of the CLEAN-ROADS project is collocated. The trend is clearly different from the total one; being located at the valley bottom, in year 2010 snowfall events have been fewer and less intense if compared to areas located at higher altitude.

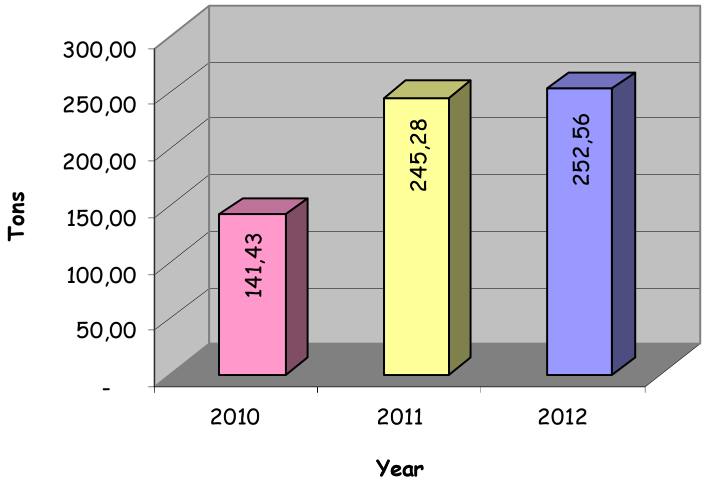

Figure 50: Road salt consumption during years 2010, 2011 and 2012 in the case study road.

The details of the winter road treatments carried out during the winter season 2012-2013 on the case study road are illustrated in Table 8.

SALT USAGE MODALITIES – WINTER SEASON 2012/2013								
	Wet deicing	Preventive snow	Snowfall	Post snowfall	Wet deicing	Preventive snow	Snowfall	Post snowfall
	[q.li]	[q.li]	[q.li]	[q.li]	[g/m^2]	[g/m^2]	[g/m^2]	[g/m^2]
December	236,30	118,00	-	79,40	6,16	8,73	-	8,25
January	73,00	29,70	12,00	7,00	5,73	8,33	10,00	10,00
February	45,00	26,00	-	7,00	7,50	8,33	-	5,00
March	7,00	12,00	-	-	5,00	10,00	-	-
TOT. (AV.)	361,30	185,70	12,00	93,40	6,10	8,85	10,00	7,75
TOT. [%]	55%	28%	2%	14%				

Table 8: Details of winter road treatments in the case study road during the winter season 2012-2013.

The type of treatments are internally defined as follows:

- **wet de-icing**: typically carried out after a rainy event followed by clear skies (high risk of wet road or standing water that can freeze) or in conditions of wet asphalt after morning dew;
- **preventive snow**: applied in order to anticipate an incoming snowfall forecasted by the weather service;
- **snowfall**: performed during the snowfalls, in combination with snow removal operations;
- **post snowfall**: activated immediately after a snowfall (typically during the evenings), in particular if followed by clear sky (snow residuals on the roads can freeze).

Data reveal that most of the treatments (about 55%) are “wet de-icing”; particular attention is given to “preventive snow” activities (28%), while “post snowfall” and “snowfall” activities are only a limited part of the work, which can however increase in case of particular snowy winter seasons.

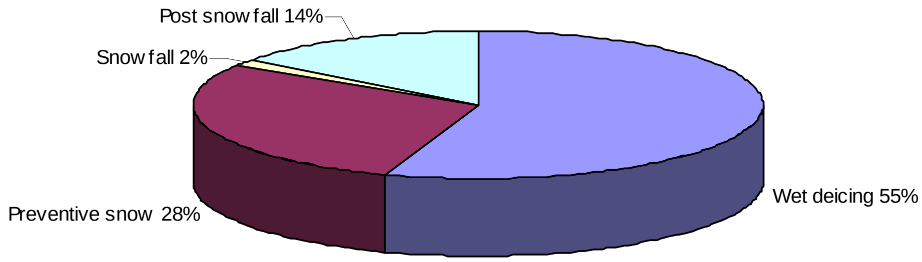

Figure 51: Percentage of winter road treatments in the case study road during the winter season 2012-2013.

In total, there have been 75 road treatments during the entire winter season, distributed as indicated in Table 9. More than half of the activities were carried out during December, as a consequence of the worst meteorological conditions already illustrated in Chapter 2.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
Preventive anti-icing	1	30	10	4	2	0	46
Preventive before snowfall	0	11	3	3	1	0	18
During a snowfall	0	0	1	0	0	0	1
After a snowfall	0	8	1	1	0	0	10
Total number of treatments	1	41	14	7	2	0	75

Table 9: Winter road treatment details per type and month in the case study road during the winter season 2012-2013.

Treatments are also aggregated in terms of average salt flux used (Table 10). This analysis however lacks of some missing record, and is unfortunately not fully representative of the work done; two trends are noticeable, i.e. (i) a majority of low fluxes treatments, probably associated to preventive anti-icing actions, and (ii) a non-negligble number of high fluxes treatments, probably associated to the snowfalls.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
10 [g/m²]	0	12	3	4	1	0	20
8 [g/m²]	0	9	1	0	0	0	10
5 [g/m²]	1	19	10	3	1	0	33

Table 10: Winter road treatment details per salt flux in the case study road during the winter season 2012-2013.

Thanks to internal data recorded by road operators during the previous winter seasons it is exceptionally possible to have a direct comparison of the total amount of salt consumed during the last years (Table 11 and Figure 52).

	Salt used [quintals]					
	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
November	0	213	0	162	41	9
December	15	289	322	462	150	360
January	178	380	198	98	218	103
February	58	208	158	0	95	71
March	0	8	0	13	0	19
April	0	0	0	0	0	0
Total	251	1098	678	735	504	562

Table 11: Winter road treatment details in the case study road: comparison with past years.

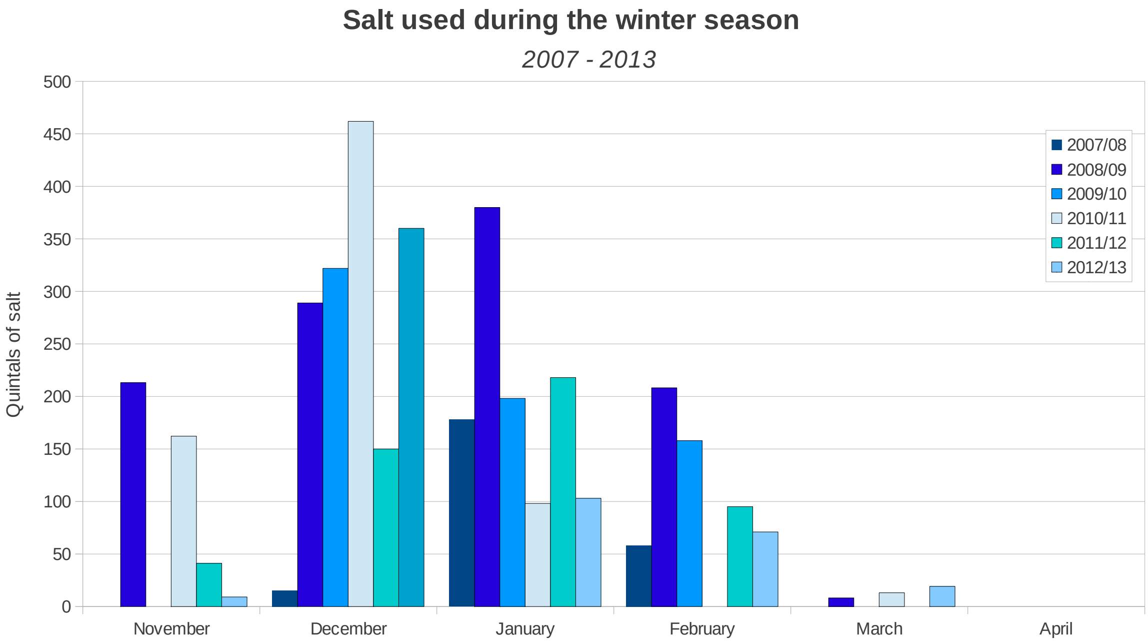

Figure 52: Winter road treatment details in the case study road: comparison with past years comparison of quantity of salt used during the winter seasons from 2007 till 2013.

The data are of complex interpretations, because they show a significant dependency with respect to the variability of climate conditions during the winter seasons. On average, 500 – 700 [q] of salt are used every season for treating the case study road. Positive and negative peaks have been recorded during the winter season 2008-2009 (1098 [q], exceptional snowy months) and 2007 – 2008 (251 [q], exceptional mild winter). In order to compare the different winter seasons and in particular the efficiency of road maintenance operations, there will be the need to define one or more proper indicators which are able to eliminate this major bias.

4.2. Preliminary assessment of road operations' optimization margins

As a final preliminary data analysis activity on salt consumption in the case study road, road treatments details have been directly put in relationship with the reference meteorological data considered in Chapter 2, gathered by a weather station located in the area not far from the road infrastructure. The purpose of this analysis, which will inevitably need to be further improved during the second project winter season because of the weakness of the underlying hypothesis, is to initially detect and quantify the existing spaces of improvements of the winter road maintenance activities.

4.2.1. Salt need estimation model

Considering that during the winter season, in days with ordinary weather conditions, the road operators go on patrol at 5 AM and that if in case of critical conditions expected at night an evening preventive treatment is typically carried out at 5 PM, available meteorological data has been aggregated in 12 hours periods, exactly from 5 AM to 5 PM and vice versa. On top of this aggregation, data have been analyzed based on the parametric model already described in paragraph 2.3 in order to identify the presence of the following conditions:

- snowfall events;
- snow accumulation on the ground;
- wet conditions;
- Föhn presence;
- slippery road conditions (ice or frost formation);
- road conditions level;

Additionally, based on this detection controls, the **need for road treatments** has been estimated, as well as an indication of the **reference amount of salt** to be used (expressed in [g/m^2] and its **translation to practical operations** (i.e. based on available salt flux rate options).

The need for road treatments is estimated based on the following reasoning:

- *a treatment is considered necessary if (i) road conditions are classified as "wet" and a danger of snow, ice or frost is detected and (ii) the RST, unless a parametric temperature bias to be properly set, is beyond a certain threshold, which is different in case of snowfall precipitations or ice / frost formation conditions.*

The second control is also used to estimate the reference amount of salt s, which is based on the following linear relationship:

$$s = a(RST - \Delta T) + b \qquad [3]$$

where a and b are two parameters influencing the entity of the treatment, to be directly related to the type of precipitation, and ΔT is an arbitrary quantity which has been introduced in order to take care of the fact that the estimation of RST is based on the air temperature measurement gathered at a height of 5 [cm]. This is exactly the application of the theory already presented in the first paragraph of this chapter; the reference freezing point reduction values obtained through certain quantities of sodium chloride in the solution (with purity of 98%) obtained in correspondence of water film layers of specific height are reported for completeness sake in Table 12.

In the model, it has been assumed to be in the condition of a water film layer of 1 [mm] in case of snowfall event, and of 0.5 [mm] in case of ice / frost formation conditions. Under these hypothesis, we have for a the approximated values -16.03 and -8.02, and for b +0.024 and -0.0121, respectively. The treatment is considered not necessary if $s < 0$; otherwise the treatment recommendation s, properly approximated by the practical spreading options of maintenance vehicles, is suggested.

Sodium chloride quantity [g/m²]	**Freezing point reduction [°C]**			
	Film of 0.5 mm	**Film of 1 mm**	**Film of 2 mm**	**Film of 3 mm**
0	0,0	0,0	0,0	0,0
10	-1,3	-0,62	-0,3	-0,2
20	-2,5	-1,25	-0,6	-0,4
30	-3,7	-1,87	-0,9	-0,6
40	-5,0	-2,50	-1,3	-0,8
50	-6,2	-3,12	-1,6	-1,0
60	-7,5	-3,74	-1,9	-1,3
70	-8,7	-4,37	-2,2	-1,5
80	-10,0	-4,99	-2,5	-1,7
90	-11,2	-5,61	-2,8	-1,9
100	-12,5	-6,24	-3,1	2,1
110	-13,7	-6,86	-3,4	-2,3
120	-15,0	-7,49	-3,7	-2,5
130	-16,2	-8,11	-4,1	-2,7
140	-17,5	-8,73	-4,4	-2,9
150	-18,7	-9,36	-4,7	-3,1
160	-20,0	-9,98	-5,0	-3,3
170	-21,2	-10,60	-5,3	-3,5
180	-22,5	-11,23	-5,6	-3,7
190	-23,7	-11,85	-5,9	-4,0
200	-25,0	-12,48	-6,2	-4,2

Table 12: Reference freezing point reductions – sodium chloride quantities for different water film thicknesses.

4.2.2. Results and comments

The results of the aforementioned evaluations are reported in Table 13. It is worth noting that each single event is detected if at least one of the controls on the road weather conditions within the considered 12 [h] time frame has given a positive hit. This assumption has the consequence that the detected events may have different levels of danger, which is an aspect that is analysed more specifically through the evaluation of the road treatments necessity. It is also important to notice that the model has not taken in consideration the presence of residual salt of the road because of the unavailability of this information, so some of the indicated treatments could be effectively not be necessary.

Despite the numerous lacking and limitations of the proposed evaluation model, the calculation has given a result which is somehow comparable with the effective treatments carried out by road operators. At a first glance, two main aspects can be underlined: (i) the excessive number of treatments carried out in December (***false alarms***), and (ii) the reduced number of treatments carried out in the other winter months (***missed alarms***), which is particularly emphasized during the warmest months (e.g. February and March). This second issue is particularly interesting and in some way surprising, since it was expected that the actual winter road maintenance activities were calibrated in order to minimize the probability of missed alarms. This patterns could be related to the significant limitations considered by the model, but further assessment analysis are surely needed here.

Road weather conditions	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	TOTAL
Probable snowfall event	0	6	5	6	3	0	20
Snow accumulation danger	0	6	5	6	1	0	18
FÖhn wind presence	0	5	3	8	3	0	19
Wet road condition	24	12	11	17	35	28	127
Possible ice / frost hazard	24	19	26	21	39	28	157
Road treatment necessity	0	15	20	16	9	0	60
Effective treatments	1	41	14	7	2	0	65

Table 13: Road conditions hazard and treatments 'necessity estimation for winter season 2012/2013 in the case study road.

Avoidable patrol trips

The first indicator which has been assessed is the one related to the number of patrol trips which could be avoided through a proper knowledge of current road conditions. A patrol trip is considered avoidable if (i) *the time interval is related to the period 5:00 PM – 5:00 AM (night time), (ii) it has been estimated that there is no necessity for road treatment and (iii) in case there has not been a danger of wet conditions, the registered minimum air temperature has been above of the threshold 0 [°C], and in the case wet conditions are detected, this temperature has been above a safety threshold fixed at 10 [°C]*. The third condition has been added in order to have an additional constraint check that can really put road operators in the condition to say that there is no need for human control of the road infrastructure.

The results obtained from these assumptions are presented in Table 14. The indicated percentage refers to the fact that a patrol trip is carried out once a day for all the considered time period. In total, 73 avoidable trips have been detected, which is about the 40% of the overall trips. Most of the potential is located in the warmest months of the period, April and November above all. The central winter months have shown an optimization margin which is in the order of 15-30%, and is directly related to the specific meteorological conditions which have been registered.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
Avoidable patrol trips	16	5	7	8	10	27	73
	53,3%	16,1%	22,6%	28,6%	32,3%	90,0%	40,3%

Table 14: Avoidable patrol trips calculation's results.

Avoidable treatments

Avoidable treatments have been simply considered by comparing the estimated necessity of salting activities with the effective operations carried out the road maintenance staff. The results are reported in Table 15, and show that there is a significant potential of avoiding treatments during central winter months, in which most of the road maintenance activities are concentrated. This margin is estimated to be in the order of 50%, and becomes much less relevant during the marginal periods of the winter season.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
Avoidable treatments	0	23	9	1	1	0	34
	0,0%	56,1%	64,3%	14,3%	50,0%	0,0%	52,3%

Table 15: Avoidable treatments calculation's results.

Missed treatments

Missed treatments have been estimated by considering the opposite control with respect to false alarms (avoidable treatments), i.e. by counting estimated salting activities that do not match with effective treatments. Since residual salt is not taken in consideration in the model, the missed treatments have been moreover counted by considering the presence (or not) of a previous treatment in the previous 24 [h]; the indicated percentages refer to those calculated missed treatments compared to effective salting operations. The results are reported in Table 16, and show that particularly in January, February and March there a certain number of situations that are at risk for a treatment. The high number of patterns identified are probably related to the conservative assumptions made by the model (empirical patrol trips done by operators would have realized the presence of some localized danger), but are an interesting indicator of the relevant number of "boundary conditions" that are perfectly at the limit of a treatment action. This is an additional indication which is provided to the requirements of the demonstrative RWIS, that will need to properly support the experience of the staff with objective decision-support instruments in order to allocate salting resources in a more optimized way for the joint reduction of false and missed alarms.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
Missed treatments	0	4	16	10	7	0	37
Missed treatments (24h)	0	2	15	8	5	0	30
	0,0%	4,9%	107,1%	114,3%	250,0%	0,0%	46,1%

Table 16: Missed treatments calculation's results.

Detection probability and correct scaling of salting operations

Finally, a quantitative assessment of the detection probability, defined here empirically as the ratio between estimated and effective road treatments, and a comparison with the salting operation details has been carried out. Regarding this last point, salting activities have been classified as oversized, correct or undersized depending on the difference between estimated and effective salt flux; more specifically, correct salting activities are determined if this difference is in absolute terms under 5 [g/m2], and oversized and undersized in the opposite case, depending on the sign of this value. The results are presented in Table 17.

	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	Total
Undersized treatments	0	14	2	5	0	0	21
Correct treatments	1	4	2	1	1	0	9
Oversized treatments	0	0	1	0	0	0	1
TOTAL	1	18	5	6	1	0	31
	100%	43,9%	35,7%	85,7%	50%	-	47,7%

Table 17: Detection probability and correct scaling of salting operations calculation's results.

Different considerations can be carried out based on these values. In particular, based on the model assumptions, there is a strong majority of undersized treatments – but this can be related to the fact that residual salt is not taken in consideration; therefore it is reasonable to expect that the quantities of salt that are actually applied are more or less in line with the theoretical maintenance needs of the roads. Salting route optimization approaches are therefore expected to produce minor gains, but this needs to be further investigated in spatial terms through thermal mapping surveys. The significant number of matches (about 50%) indicates that the proposed model is somehow reliable for the purposes of this initial assessment, and reveals how half of the effective treatments are related to false alarms, which are in the same order of magnitude of the estimated missed alarms. The initial indication which in summary comes out from this initial assessment analysis is that the number of treatments in total will probably not dramatically change through a RWIS, but for sure they will organized in order to jointly minimize false and missed alarms; the most relevant optimization margin is likely to be the one associated to the avoidance of patrol trips.

5. Results from other supplementary analysis

5.1. Asphalt characterization

In this paragraph will illustrates the results of the skid test conducted on the “study road stretch” of the S.S.12 (Figure 53). Pavement skid resistance or friction is one of the most important properties of the road surface for road users and one of the main safety considerations in pavement design and construction. Lower pavement friction increases the stopping distances and is a cause of accidents.

The test simulates the slipping of a locked wheel of a vehicle, travelling at a speed of 50 km per hour on the asphalt surface course in wet conditions. The test is normally carried out on site and the instrument is used to measure friction sliding the horizontal signal. The degree of slip resistance is expressed in units SRT, which stands for Skid Resistance Test.

Figure 53: Skid test on a site location of the study road S.S.12

In other words skid resistance designates the impact of roughness on the frictional resistance (grip) between the vehicle tyres and the roadway. The surface texture and the surface course properties affect the roughness (microtexture, macrotexture and megatexture) which is influenced by traffic, weather and the environment.

The requirement that surface courses have sufficient roughness has always been part of the Italian law, which refer to the UNI EN 13036/04 Law.

In Table 18 are listed the limit of acceptance for the different type of asphalt recorded on the road S.S.12. To be noted that the minimum value required by standard, for wet road markings is 45.

Type of asphalt	BPN Limit	Acceptance Value
ASD	60	50
SMA	60	50
D mod	55	45

D	50	40
markings		45

Table 18: Pavement skid resistance limit by the UNI EN 13036/04 Law

For the study road stretch it were chosen 5 different significative locations where to conduct the test (see Figure 54). On the 16 October 2013 was conducted a road survey. The relative results are reported in Figure 47.

Progressive km	side	Location	Type of asphalt	State of asphalt	Value SRT	BPN Limit	Acceptance Value	note	
389,6	DX	Margin	ASD	Good	48		45	markings	**OK**
389,6	DX	Margin	ASD	Good	76	60	50	asphalt	
392	DX	Margin	ASD	Good	47		45	markings	**OK**
392	DX	Margin	ASD	Good	69	60	50	asphalt	
396,55	SX	Margin	ASD	Good	49		45	markings	**OK**
396,55		Margin	ASD	Good	73	60	50	asphalt	
396,55	DX	Margin	D	Good	45		45	STOP	**OK**
396,55	SX	Margin	D	Good	67	50	40	asphalt	
398,2	SX	Margin	SMA	New	54		45	markings	**OK**
398,2	SX	Margin	SMA	New	79	60	50	asphalt	
400,35	SX	Margin	D mod	Good	48		45	markings	**OK**
400,35	SX	Margin	D mod	Good	66	55	45	asphalt	

Table 19: Results of the skid test on S.S.12

It is shown that all the 5 locations has acceptable values of skid resistance, that means that in all the chosen locations the road is safe and well kept, and even for different kind of asphalt no critical zones are detected.

Km 389,600

Km 392,000

Km 396,550

Km 389,200

Km 400,350

Figure 54: Road site where the skid test was conducted

5.2. Accident occurrence

This chapter will illustrate the results of the analysis conducted on the accident occurrence for the Trentino's Region.

Data were acquired in an internal database, where are reported only the accident which caused injured or deaths.

In Figure 55 are reported all accident recorded form 2002 to 2012, divided by season.

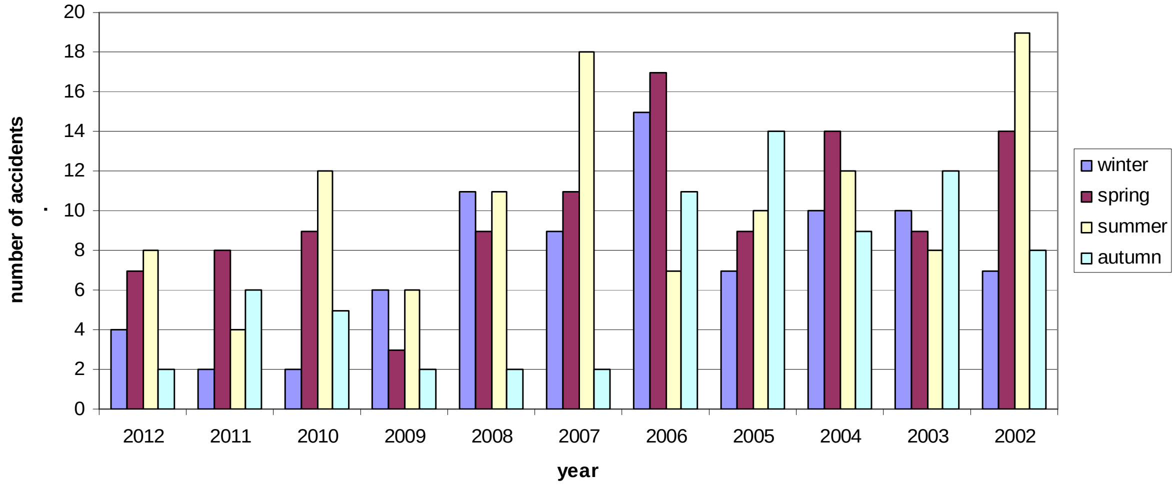

Figure 55: Seasonal accident frequency

Figure 56 shows the numerosity (in percentage) of the accident recorded in the last 10 years, in winter season, spread only on the stretch of the study road S.S.12.

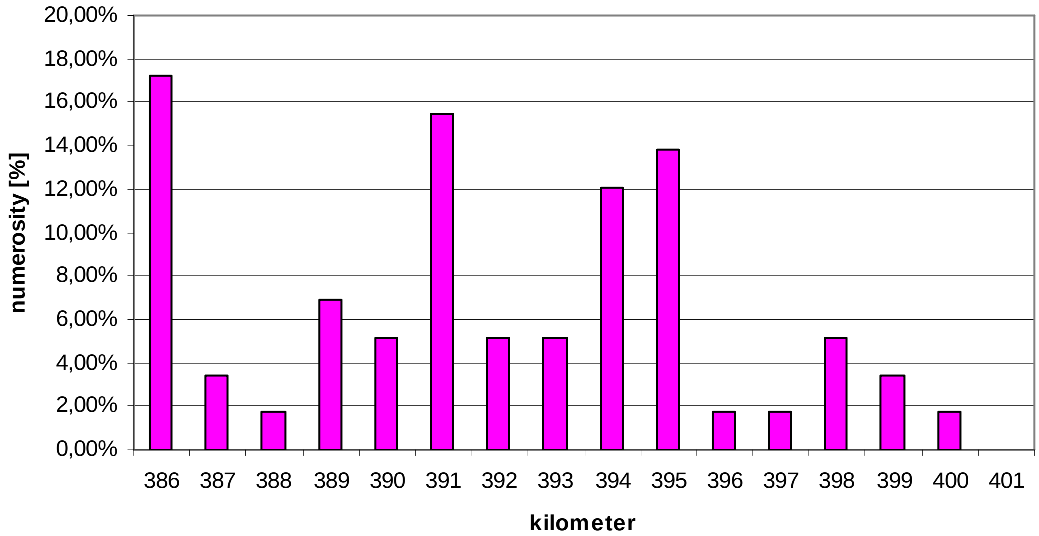

Figure 56: Numerosity of road accidents by kilometre in winter season

It can be seen that the most dangerous kilometres are the 386, 391, 394, 395. Below (Figure 57) is reported a map with the indication of the most dangerous location. They are all in a correspondence of junctions or bridges.

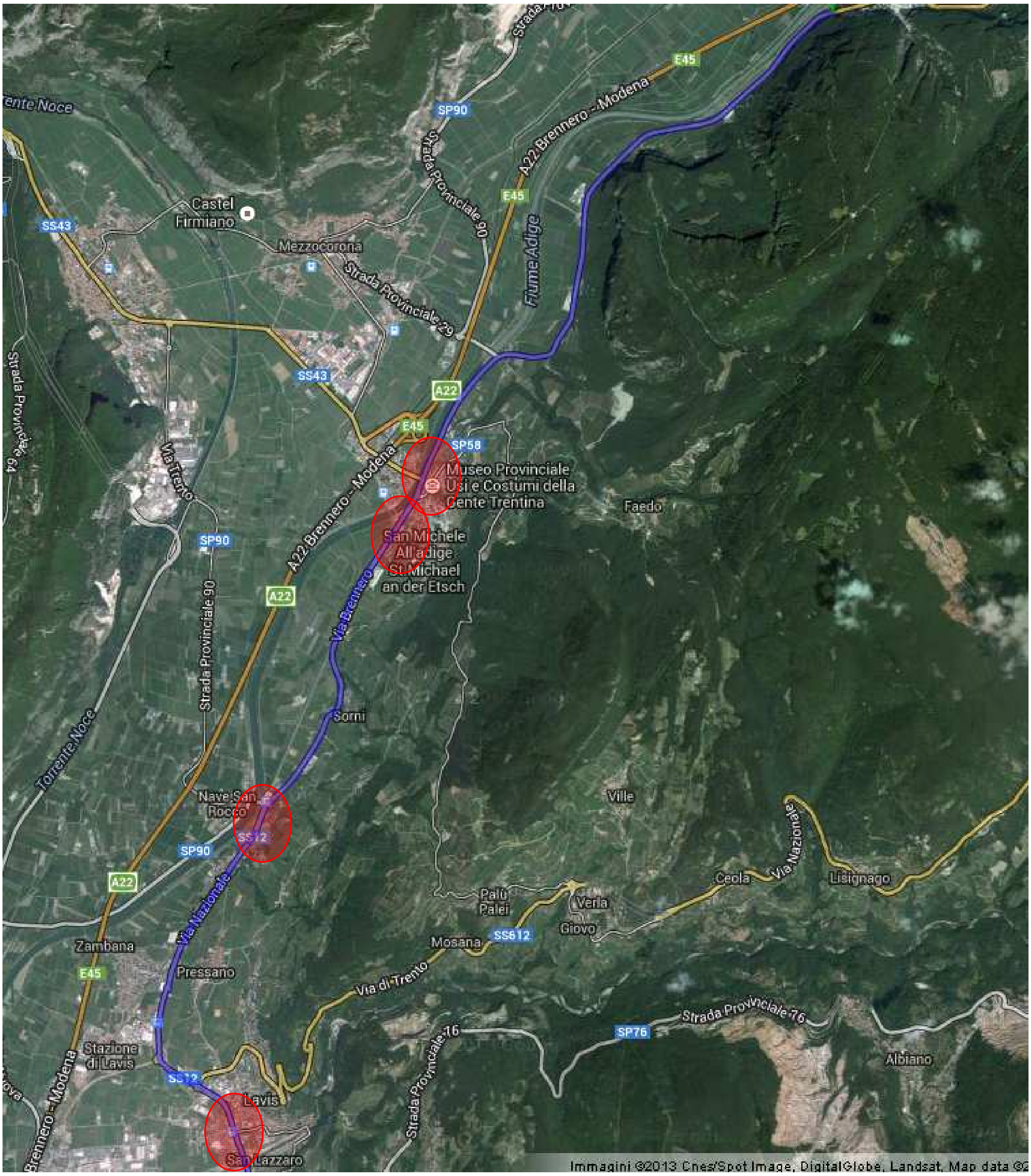

Figure 57: Study road stretch – in evidence the most dangerous areas

Below (Figure 58) is represented the numerosity (in percentage) of the accident recorded in the last 10 years, in winter season, on the stretch of the study road S.S.12, divided by road conditions which caused it. It can be seen that the majority of accident occurred in dry conditions. Only a small percentage occurred in slippery or snowing conditions.

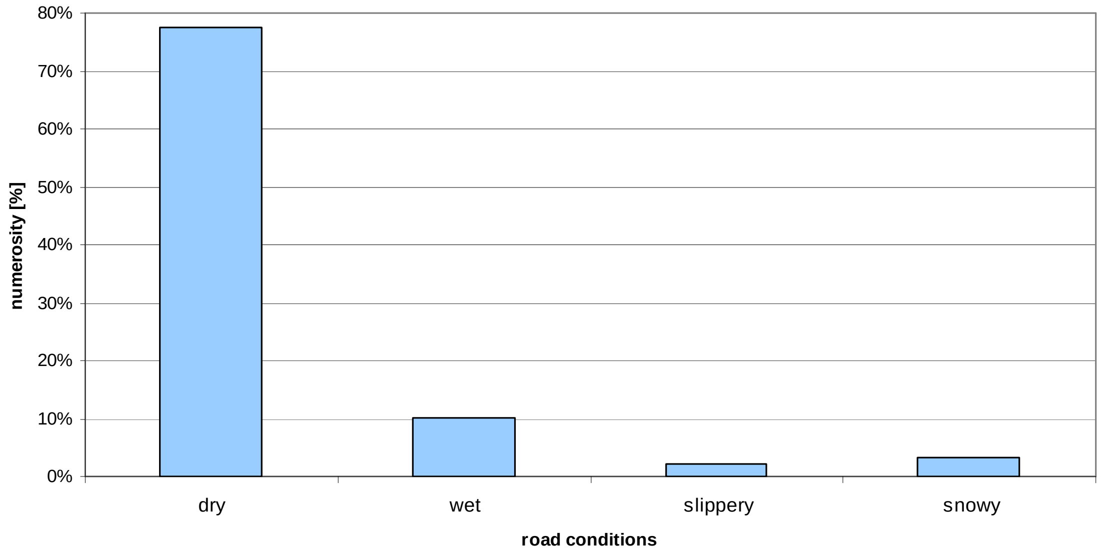

Figure 58: Numerosity of road accidents by road conditions

Below (Figure 59) is represented the numerosity (in percentage) of the accident recorded in the last 10 years, in winter season, on the stretch of the study road S.S.12, listed by the type of accident.

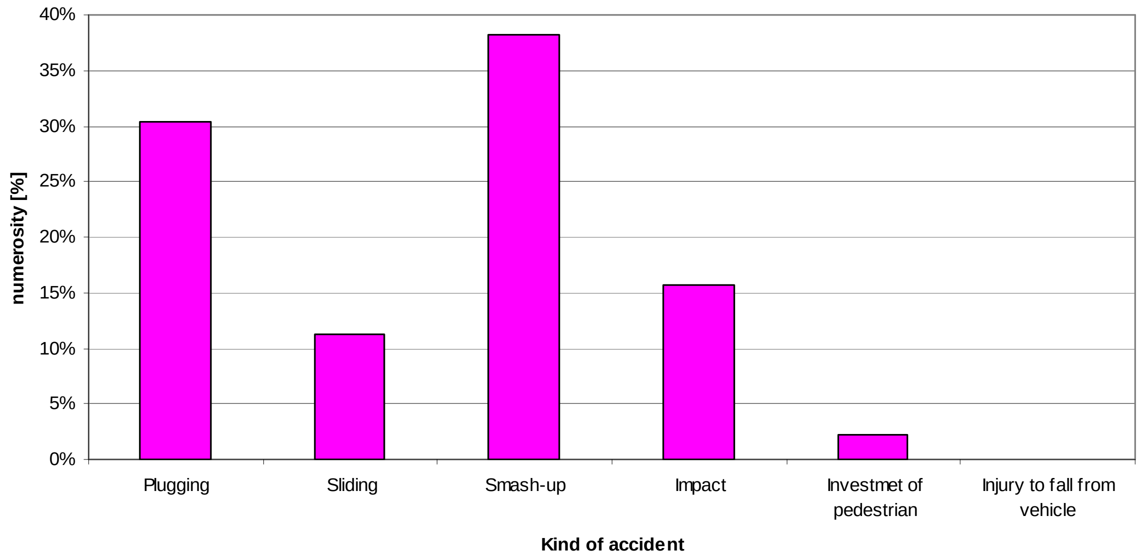

Figure 59: Numerosity of road accidents by kind of accident

It can be seen that 37% of accidents type is smash-up, 30% is plugging, 15% is impact and 11% is sliding.

5.3. Site usage statistics of the Weather Service

5.3.1. Generalities

The main purpose of this analysis is to investigate the user's behaviour regarding the collection of weather information during winter season. These information can be collected from many sources and with different modalities; an appreciated service of local forecast is provided by Meteotrentino. This public Service, in addition to the weather forecast, offers many other information such as real time data from more than a hundred automatic weather stations, images from satellites and a meteorological Radar, webcams, thematic maps about the distribution of temperature, precipitation, wind, snow and so on. The weather Service is also in charge to the severe weather alert emission and targeted messages for the local Civil Protection.

Users can obtain information from several different services offered from Meteotrentino:

- Detailed weather forecast (six days);
- Semi automatic forecast for 17 areas of the Province;
- Snow report with avalanche hazard forecast (available during winter time);
- Synthetic forecast (twice a day);
- Probabilistic forecast for the next five days (for the Civil protection);
- Mountain weather forecast (available during summer time).

The principal ways to obtain information from Meteotrentino are:

- Mailing list;
- Website;
- Mobile site;
- Daily video interview with the meteorologist (published on the site);
- Automatic answering service.

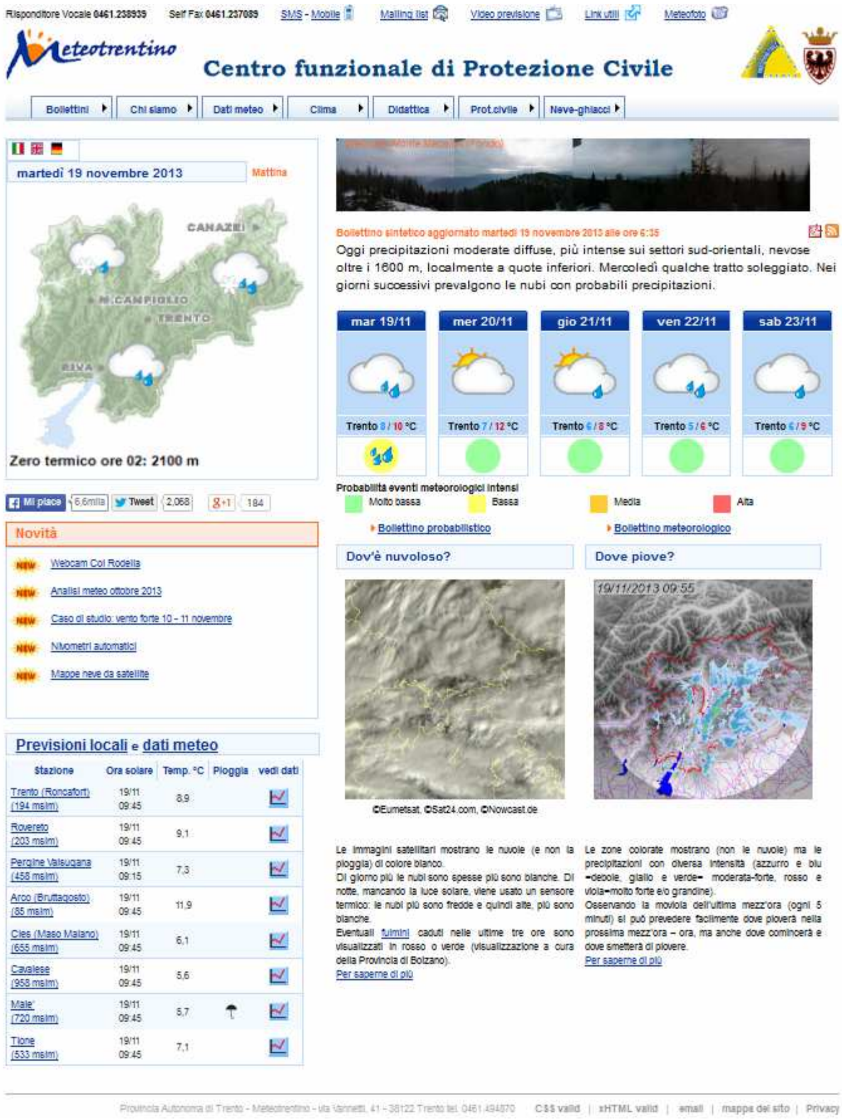

Figure 60: main page of Meteotrentino site.

5.3.2. Analysis

To investigate users' behaviour during winter season and the influence of weather information on them, it was analyzed their access and visualized pages in two different situations:

- days with a probability of at least 10 cm of snowfall under 600m of height (throughout the 24 hours) for the current and following day;
- days in which the snowfall probability at less than 600m of altitude is very low (< 1 %).

The value of altitude chosen, 600 metres, is a prudential threshold whereby the snow could starts to concern the bottom of the main valleys of the Province where is located the majority of people living in Trentino. Often, the arrival of precipitations at low altitudes is also reported from local newspapers.

The time range used for this analysis begin on the 1/11/2012 and ends on the 30/04/2013 and the analyzed variables; this range, longer of the longer of the usually considered winter time, permits to investigate also early and late events. The variables take into account in the web site analysis is:

- Number of visitors;
- Week day of the visit;
- Flow of visualization;
- Audience data & reporting.

SITE ACCESSES		
Counters	**Value**	**Increase during the forecasted snowfall days**
N. of access without snow forecast	37.443	
N. of access with snow forecast	46.772	11%
N. accesses during weekend days	32.069	
N. accesses during weekdays	42.919	
Monday accesses	46.021	
Tuesday accesses	43.239	
Wednesday access	42.012	
Thursday accesses	42.689	
Friday accesses	40.633	
Saturday accesses	30.128	
Sunday accesses	34.010	
Average duration accesses without snow forecast	00:01:46	
Average duration accesses with snow forecast	00:02:01	6%
N. of visualized pages without snow forecast	74.485	
N. of visualized pages with snow forecast	100.375	15%

Table 20: analysis of users' behaviour in two different forecast situation type during 2012-2013 winter.

As you can see in Table 20, during those days with a probability of at least 10 cm of snowfall under 600m of altitude for the current and following day, more users spent more time on the website visualizing more pages to find the information they need. The increase of website accesses is nearly of 11%, the increase of the time spent to surf into the pages is nearly of 5% while the greater increase regards the number of visualized pages reaching the value of 100.000. The day with the major users flow is Monday.

SITE ACCESSES		
Counters	**Value**	**Increase during the forecasted snowfall days**
Homepage accesses	41450	
Homepage accesses with snow forecast	54138	13%
Probabilistic report accesses	3150	
Probabilistic report accesses with snow forecast	4723	20%
Radar animation accesses	1267	
Radar animation accesses with snow forecast	3119	42%
Satellite animation accesses	1038	
Satellite animation accesses with snow forecast	1789	27%
Snow report accesses	1195	
Snow report accesses with snow forecast	1249	2%
Local report accesses	2695	
Local report accesses with snow forecast	3475	13%
N. of accesses for the Trento weather station	269	
N. of accesses for the Trento weather station with snow forecast	340	12%
N.of accesses for the Macaion webcam	278	
N.of accesses for the Macaion webcam with snow forecast	449	24%

Table 21: visualized pages in two different forecast situations type during the winter 2012-2013.

Table 21 reports the observed increase of some internet pages due to the approaching of snowfall; the greater increase have been reported for those pages that allow to look into real time data as for instance the webcams, Radar and Satellite data. After that, we can notice the increase of the weather forecast (home page and probabilistic report).

The same discussion may be done for the mobile site; during those days in which there is a probability of at least 10 cm of snowfall fewer than 600m of altitude, we can observe an increase of accesses, visited pages, time spent on the site. The number of users taking advantage of this kind of access is still limited, reaching only a few hundreds.

After presenting all these data related to the use of the Meteotrentino site, it's important to point out some considerations about the users' habits. A good number of people are interested in weather forecast to organize theirs activities, both during weekend both at the start of the week. They utilize the website to get information and many of them, when climate adversities are approaching, utilize a series of real time instruments to monitor the situation. Very important appears to be the organization of the site and where the users can find what they are searching for; the average time spent to searching it is very limited: only 2 minutes.

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