CLEAN ROADS

FORECASTING ICE FORMATION ON ROADS

Application of a nocturnal cooling model to road surface temperatures for minima prediction in the Adige Valley (Trentino, Italy)

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INTRODUCTION

- We know from literature that ice forms on road pavements when road surface temperatures (RSTs) are below 0°C and are lower than dew point temperatures → Predicted temperatures below -1°C or -2°C might cause ice formation on roads, leading to potentially dangerous conditions for drivers

- Spreading de-icers such as sodium chloride to prevent icy roads is nowadays common practice but an excessive, uncontrolled use might be hazardous for the environment and cost-demanding for local road maintenance agencies

> Forecasting minimum temperatures for pavements is crucial in the management of salt as de-icing substance during winter road maintenance operations

FORECAST MODEL

We developed a system based on Reuter's nocturnal cooling model

Hypotheses ➤	Clear skies, Absence of wind, Low vapour pressure in the atmosphere, Low thermal conductivity / Low specific heat of the ground
Condition ➤	Radiative energy loss from the ground balanced with the energy flux from the air above the ground towards the ground.
Formula ➤	$RST(sunrise) = RST(sunset) - K\sqrt{\Delta t}$

with $RST(sunset)$ [resp. $RST(sunrise)$] being road temperatures at sunset [resp. sunrise], Δt the time interval in between and K the temperature decay coefficient

↪ $RST(sunrise)$ set to a dynamic $RST(t)$ with t equal to 2, 2.5, 3 … hours after sunset

Input data ➤ RSTs measured in winter 2014/2015 automatically by road weather information system (RWIS) stations installed on a test route along the Adige Valley

Cadino RWIS station
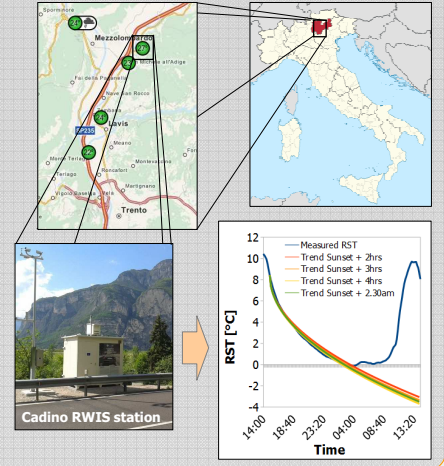
VERIFICATION METHODOLOGY

> In order to assess the goodness, quality and value of Reuter's model, the RST minimum value for each night is recorded at each RWIS station and compared with the RST value forecast at sunrise

- Occurrences of *observed* "Ice" events, i.e. events when measured RST minima are below 0°C, and occurrences of *forecast* "Ice" events are entered into a contingency table

Observation variable	➤ Threshold	Yes/No event	Meaningful to end-users
Forecast variable	➤ Probabilities	Model's initial hypotheses	Overnight changes

- By moving through different probability (or RST) thresholds and binning data correspondingly a probability 4x2 contingency table is transformed into yes/no 2x2 contingency tables.

Event forecast	Event observed	
	RST ≤ 0°C (Ice)	RST > 0°C (No Ice)
≥ 80%	339	60
20 – 80%	80	73
1 – 20%	27	466
< 1%	0	360

	RST ≤ 0°C	RST > 0°C
≥ 80%	339	60
< 80%		
≥ 20%	419	133
< 20%		
≥ 1%	443	599
< 1%	0	360

Hits [443] = Events forecast to occur, and did occur
False alarms, FA [599] = Events forecast to occur, but did not occur
Misses [0] = Events forecast not to occur, but did occur
Correct rejections [360] = Events forecast not to occur, and did occur

- For each 2x2 table the relationship between forecast and observation variable is evaluated through skill score and plots.

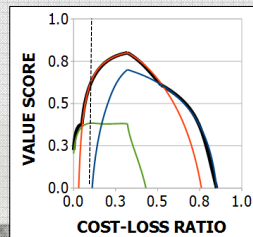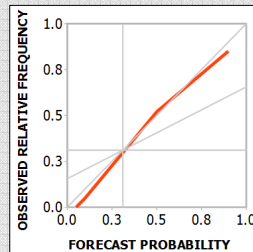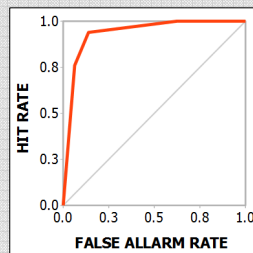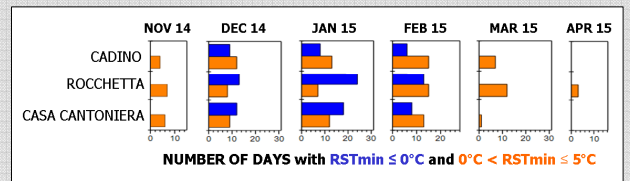|		
Hit Rate	=	Fraction of observed "Ice" events that were correctly forecast
False Alarms Ratio	=	Fraction of predicted "Ice" events that actually did not occur
Brier Score	=	Magnitude of probability forecast errors
Brier Skill Score	=	Relative skill of probabilistic forecast over that of climatology in predicting whether or not the event occurred
ROC Skill Score	=	Relative skill of probabilistic forecast over that of climatology in discriminating between events and non-events
Value Score	=	Score of expected expenses with climatology as reference forecast

References
- Pretto I. *et al.*, SIRWEC 2014 conference proceedings, ID:0019 (2014)
- Reuter H., Tellus, 3:141, 147 (1951)
- WWRP/WGNE Joint Working Group on Verification, "Forecast Verification: Issues, Methods and FAQ", The Centre for Australian Weather and Climate Research
- Thornes J.E. and Stephenson D.B., Meteorological Applications 8, 307 (2001)

RESULTS

> For each RWIS station Reuter's forecast of "Ice" events is verified on nights when measured RST minimum values are equal to or below 5°C

- January 2015 coldest month
- Rocchetta and Casa Cantoniera coldest stations
- Cadino warmest station

NUMBER OF DAYS with RSTmin ≤ 0°C and 0°C < RSTmin ≤ 5°C

HIT RATE / **FALSE ALARM RATE**

		CADINO	CASA CANTONIERA	ROCCHETTA
RSTs for probability ranges	≥ 80%	≤ -1°C	≤ -1°C	≤ -1°C
	20-80%	-1 – 0°C	-1 – 0°C	-1 – 2°C
	1-20%	0 – 3°C	0 – 3.1°C	2 – 5.1°C
	< 1%	> 3°C	> 3.1°C	> 5.1°C
Brier Score		0.08	0.11	0.11
Brier Skill Score		0.74	0.77	0.78
ROC Skill Score		0.87	0.82	0.84
Forecast value	Benefit	66%	29%	43%
	Threshold	20%	1%	20%

- It *likely* (20-to-80% probability to occur) that RSTs will *actually* go below 0°C overnight when the forecast RST at sunrise is between:
  → -1°C and 0°C at Cadino, Casa Cantoniera RWIS stations
  → -1°C and 2°C at Rocchetta RWIS station (föhn winds)

- Skill scores and plots indicate that Reuter's forecast:
  → distinguishes well "Ice" events from "No ice" events
  → has a good reliability (slight under/overforecasting)
  → has small probability-associated errors
  → has a good predictability skill with respect to climatology

OBSERVED RELATIVE FREQUENCY / **FORECAST PROBABILITY**

VALUE SCORE / **COST-LOSS RATIO**

Verification of RSTs forecast by Reuter's model at Cadino RWIS station

CONCLUSIONS

> In a *cost/loss* model where the ratio between the cost of salting roads and the potential loss (i.e. accidents and delays) incurred when not salting roads is 1:8, the road maintenance team has an **economic benefit** if they salt roads when the forecast RST at sunrise is below:
> → **0°C** in Cadino RWIS station
> → **2°C** in Rocchetta RWIS station
> → **3.1°C** in Casa Cantoniera RWIS station

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