Winter risk estimations through infrared cameras an principal component analysis

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Ressources, territoires et habitats
Énergie et climat
Développement durable
Prévention des risques
Infrastructures, transports et mer

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1- Objectives

Context:

- Instrument on a vehicle to establish road susceptibility to ice
- Measurements on one lane at a time ⇒ tests too long
- Measurements on a small spot *(radiometer FOV 20°)*
- No appreciation of road radiative environment
- No dynamic appreciation with season of ice occurrence susceptibility

Objectives:

-improve the winter risk determination of road network with an infrared camera

(several lanes, environment contribution evaluation, ...),

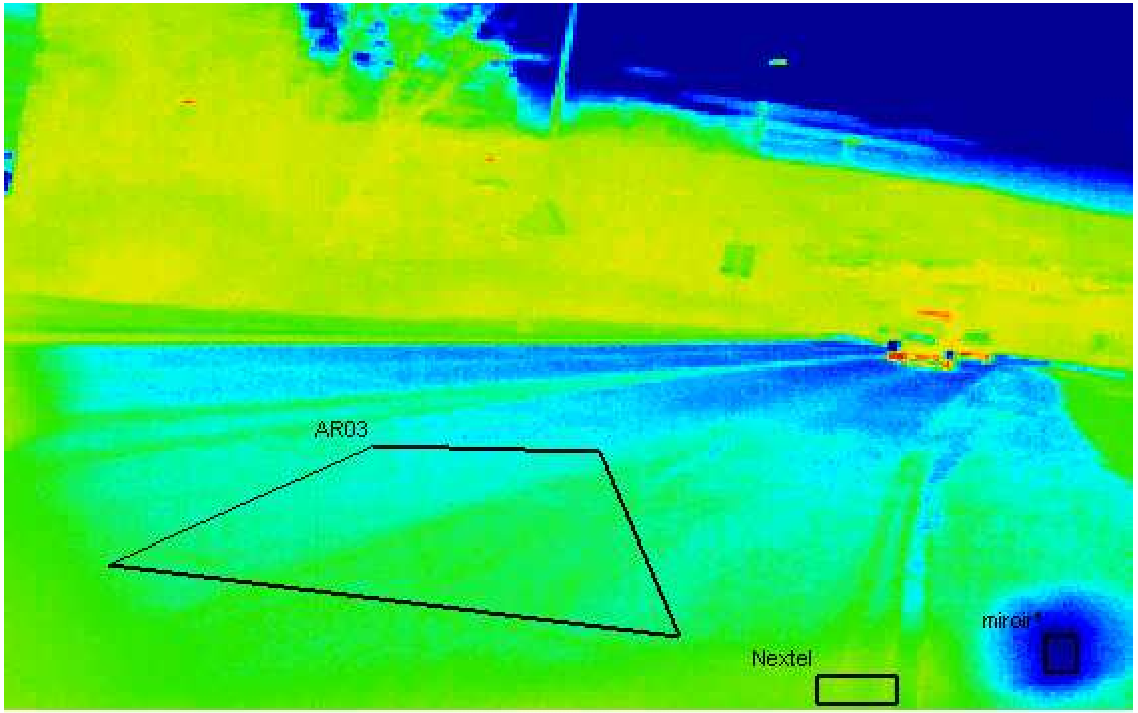
- extend measurements season

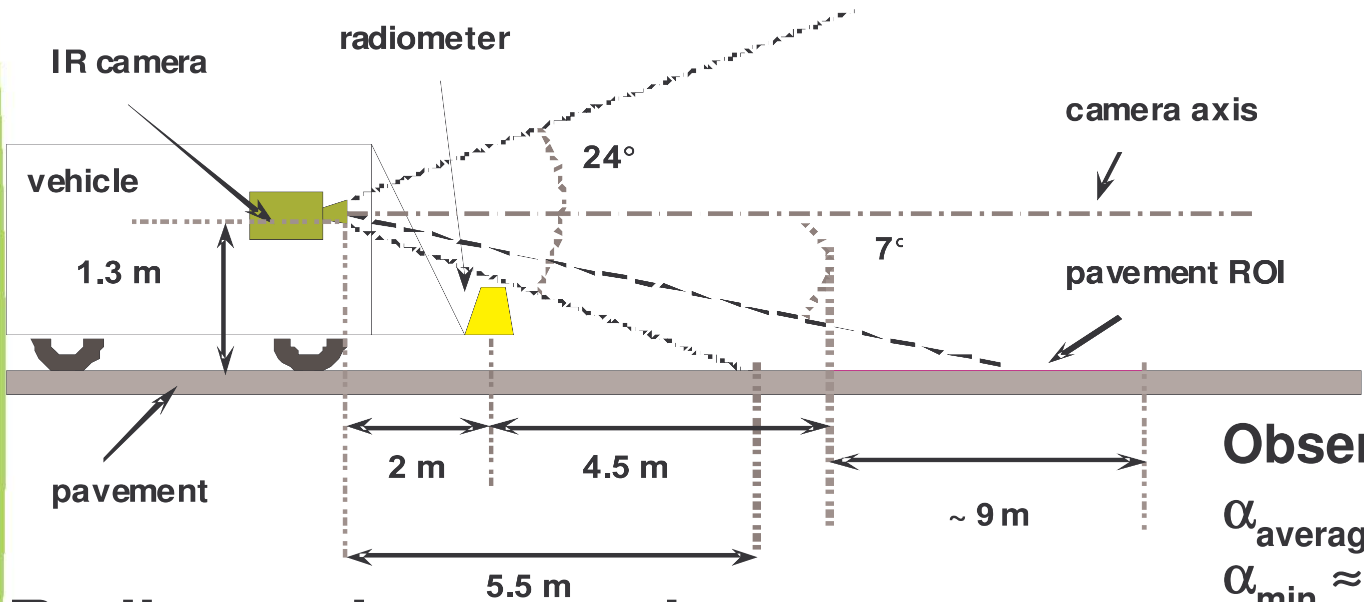
(spring and fall)

- build itinérary thermal fingerprints forecasts *(Principal Component Analysis)*.

2- Winter risk index and thermography

Thermal images sequence of the Itinerary



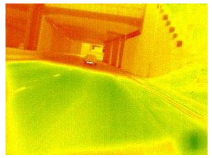


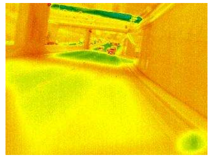
Observation angle:

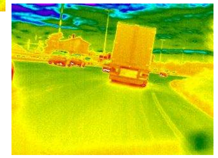
$\alpha_{average} \approx 7°$

$\alpha_{min} \approx 4°$

$\alpha_{max} \approx 11°$





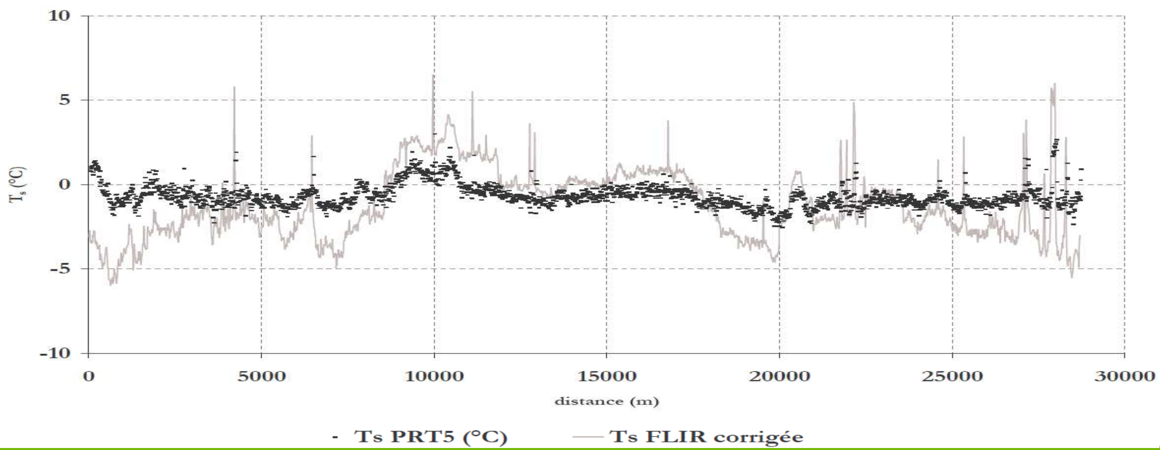


Radiometric corrections

- low distance and clear atmosphere: $\tau_{atmosphere}$ ~1
- no specularity: Stefan law $L=\sigma T^4$
- emissivity correction over the pavement ROIs

⇒ emissivity distribution over pavement ROI

$$T^4_{measured} = \varepsilon_{pavement}.T^4_{pavement} + (1-\varepsilon_{pavement}).T^4_{environment}$$



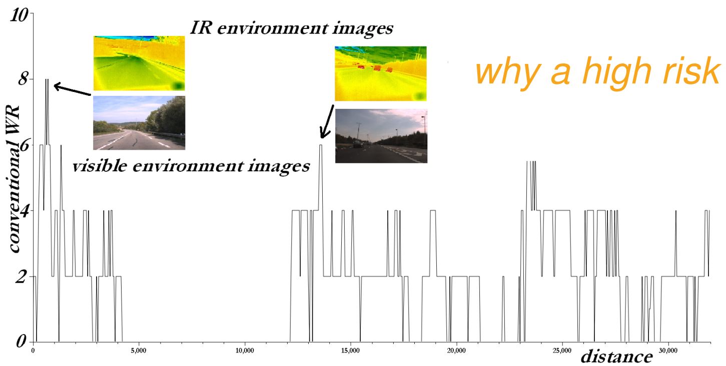
Consistency with seasons and infrastructure

Approach based on a moving average

$$WR = 2.WR(T_s) + WR(T_d),$$

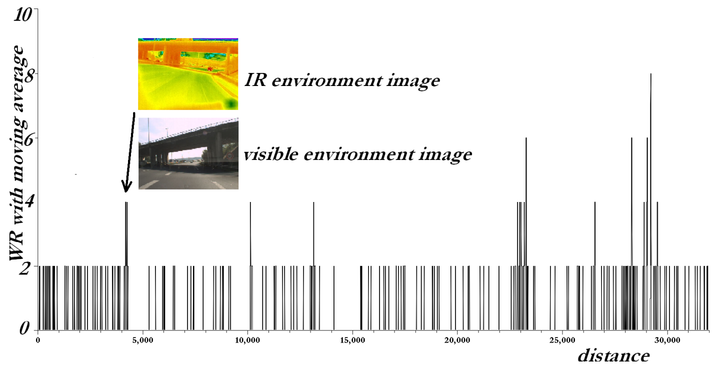
$$\text{with } WR(T_s) = 0 \text{ if } 0°C \le T_{s,\text{moving average}} - T_s < 0.5°C; 1 \text{ if } 0.5°C \le T_{s,\text{moving average}} - T_s < 1°C; \ldots$$

$$\text{and } WR(T_d) = 0 \text{ if } 0°C \le T_{d,\text{moving average}} - T_d < 0.5°C; 1 \text{ if } 0.5°C \le T - T_{d,\text{moving average}} < 1°C; \ldots$$



why a high risk here ???

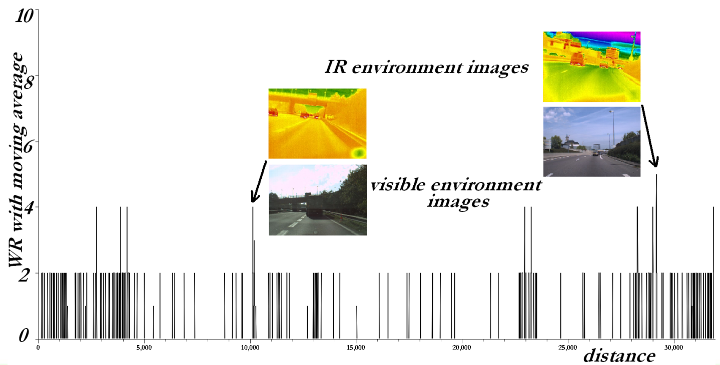
2009-01-31
former conventional WR as a function of distance (in m)



2009-01-31
moving average WR as a function of distance (in m)

greater consistency with the infrastructure ...

... and with seasons



2009-08-19
moving average WR as a function of distance (in m)

3- Winter risk index and PCA

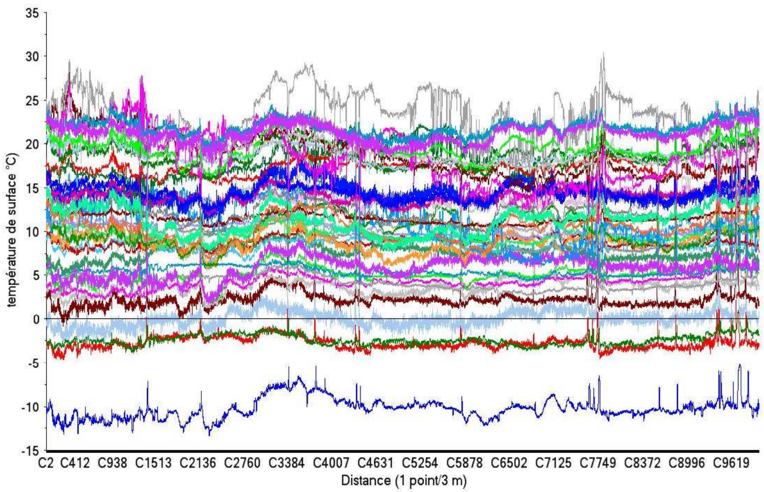
Principal Component Analysis (PCA) =statistical sensitivity analysis method to deal with a large set of data.

Among a set of descriptive techniques (mainly mathematical matrix algebra) without guessing any probabilistic model.
Statistical tool = correlations matrix, or the variance-covariance matrix

Research of the correlations within the dataset.

Related variables considered as a single entity, to produce an overall result taking the relationship among the variable into account.
Linear transformations of a group of correlated variables obtained in such a way that certain optimal conditions are reached.

Most important conditions: transformed variables are uncorrelated.



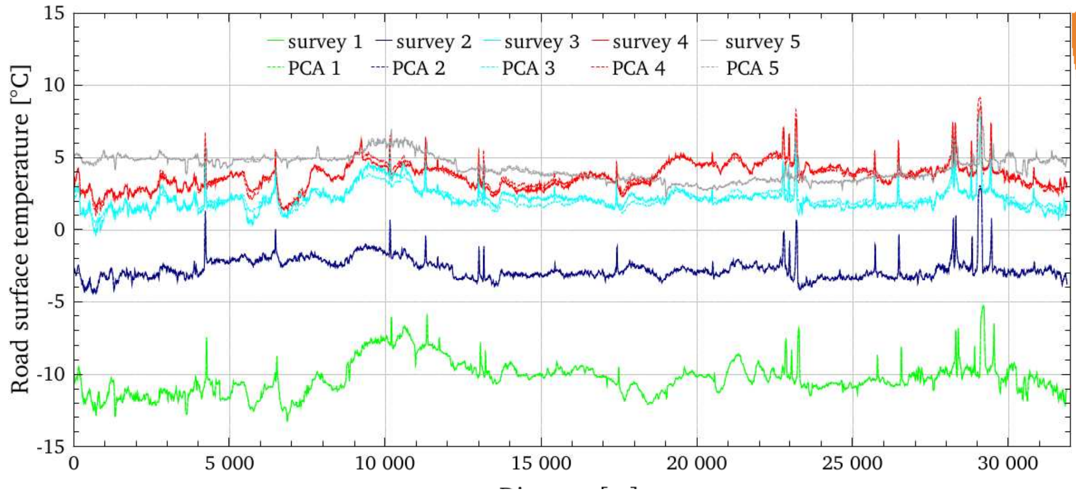
Existence of a generic profile to be adapted
- with seasons,
- with weather conditions

Case study	Case 1 All measurements (53)	Case 2 All measurements under 5°C (8)	Case 3 5 selected measurements under 5°C
Number of principal components (PC) used	10	6	3
Percentage of explained variance (with 1st PC)	98%	99%	99%
Outliers detected (number of data points)	1000	91	94

calculations on the whole itinerary

excellent match between field measurements and thermal fingerprints re-calulated with PCA data

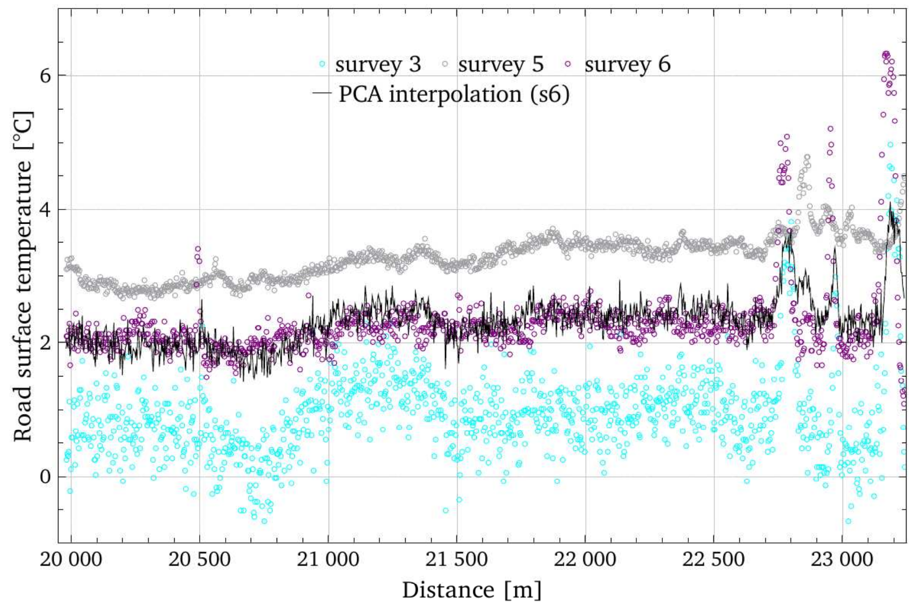
(mean matrix + (scores matrix)x(loading matrix)



calculations on specific itinerary section

+

interpolations between PCA results



Excellent match with field measurements

Possibility to generate winter risk index based on measurements/forecast of atmospheric parameters

Thanks for your attention

additional contacts:

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