Integration of roadside camera images and weather data for monitoring winter road surface conditions

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Source: thestar.com

Agenda

1. Introduction
2. Datasets and area of study
3. Methodology and experiments
4. Conclusions

Introduction

Winter road maintenance: Safety and resource optimization

tar Edition
E LOCATION

THE STAR

CANADA POLITICS WORLD OPINION LIFE SPORTS ENTERTAINMENT BUSINESS STAR INVE

Ontario British Columbia Alberta Quebec Nova Scotia

Ontario's winter roads 'less safe' since privatization: auditor

By **Rob Ferguson** Queen's Park Bureau
Wed., April 29, 2015

Ontario. 50% of the total highway maintenance budget is spent on winter maintenance operations. *MTO*

Toronto. Annual budget of $90 million to ensure that roads and sidewalks are clear and safe during the winter. *theweathernetwork.com*

Ottawa. The budget for winter operations in 2018 was $68.3 million, $2.3-million more than the previous year. *OttawaCitizen.com*

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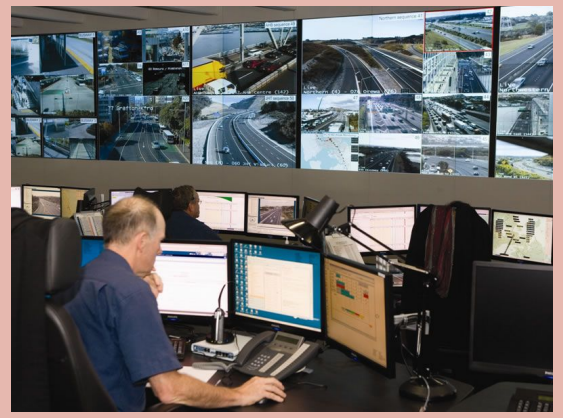
Winter road maintenance: Current approach

Road Weather Information Systems (RWIS)

Road patrolling visual inspection

Limited geographic coverage

Visual monitoring



Data-intensive process
Automation needed

Resource allocation

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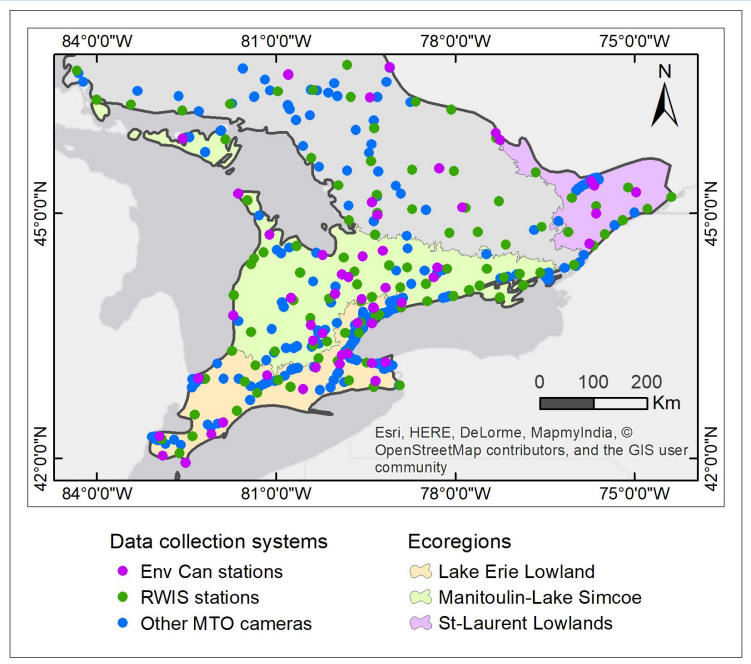
Winter road maintenance: Suggested approach

Add **6x** more input data

Automated monitoring

Evaluate & improve

(RWIS) + other MTO Cams + Env. Can Weather



Efficient decision making

Deep Learning for detecting road surface condition

Better resource allocation, improved operations

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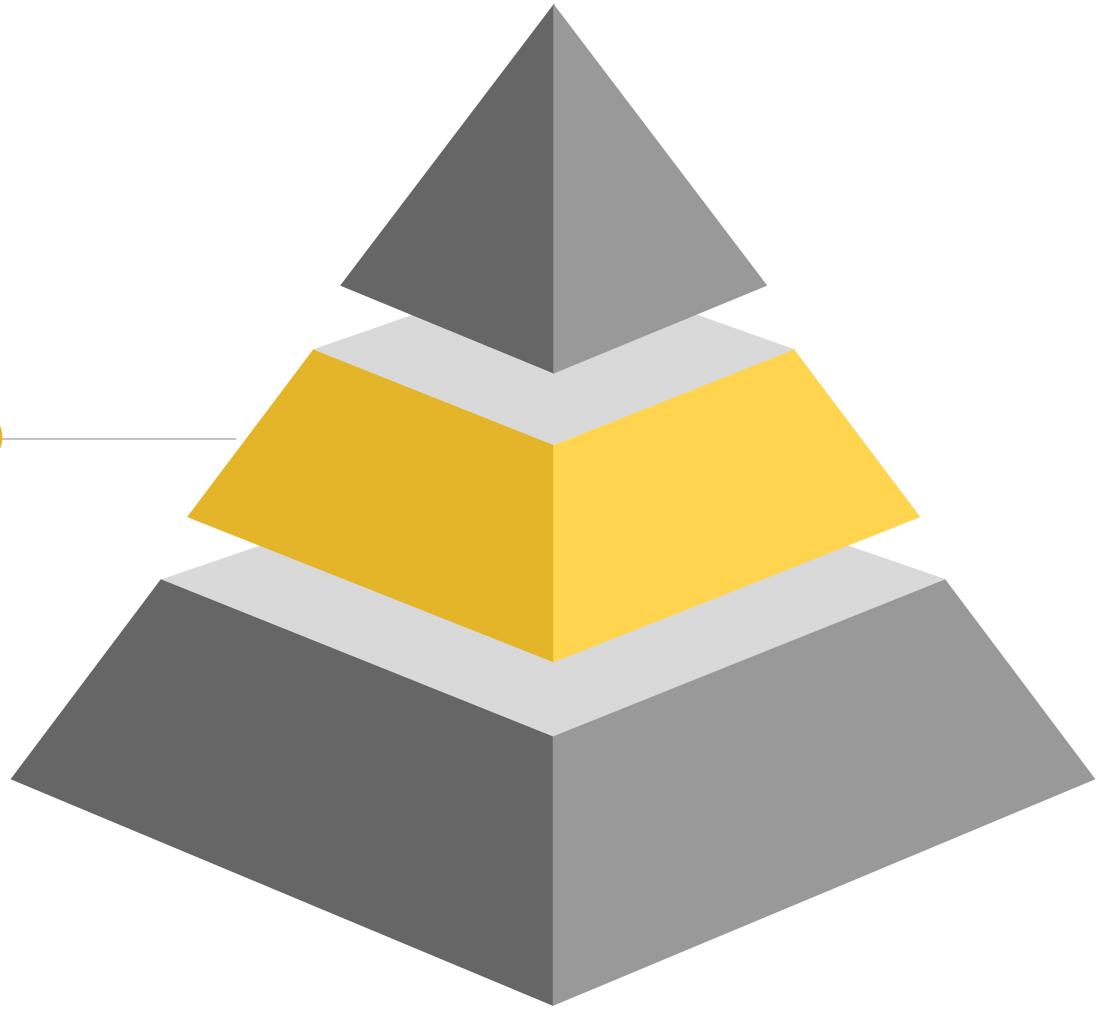
Datasets and area of study



Road Weather Information System (RWIS)

Image source

139 stations
in Ontario

Image source

- Roadside camera
- Weather sensors
- Embedded pavement sensors

Station NWR-06

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Other MTO camera stations

Image source

439 cameras in Ontario

- ✅ Roadside camera
- ❌ Weather sensors
- ❌ Embedded pavement sensors

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Environment Canada weather stations

Image source

99 stations in Ontario

- ✗ Roadside camera
- ✓ Weather sensors
- ✗ Embedded pavement sensors

Image source

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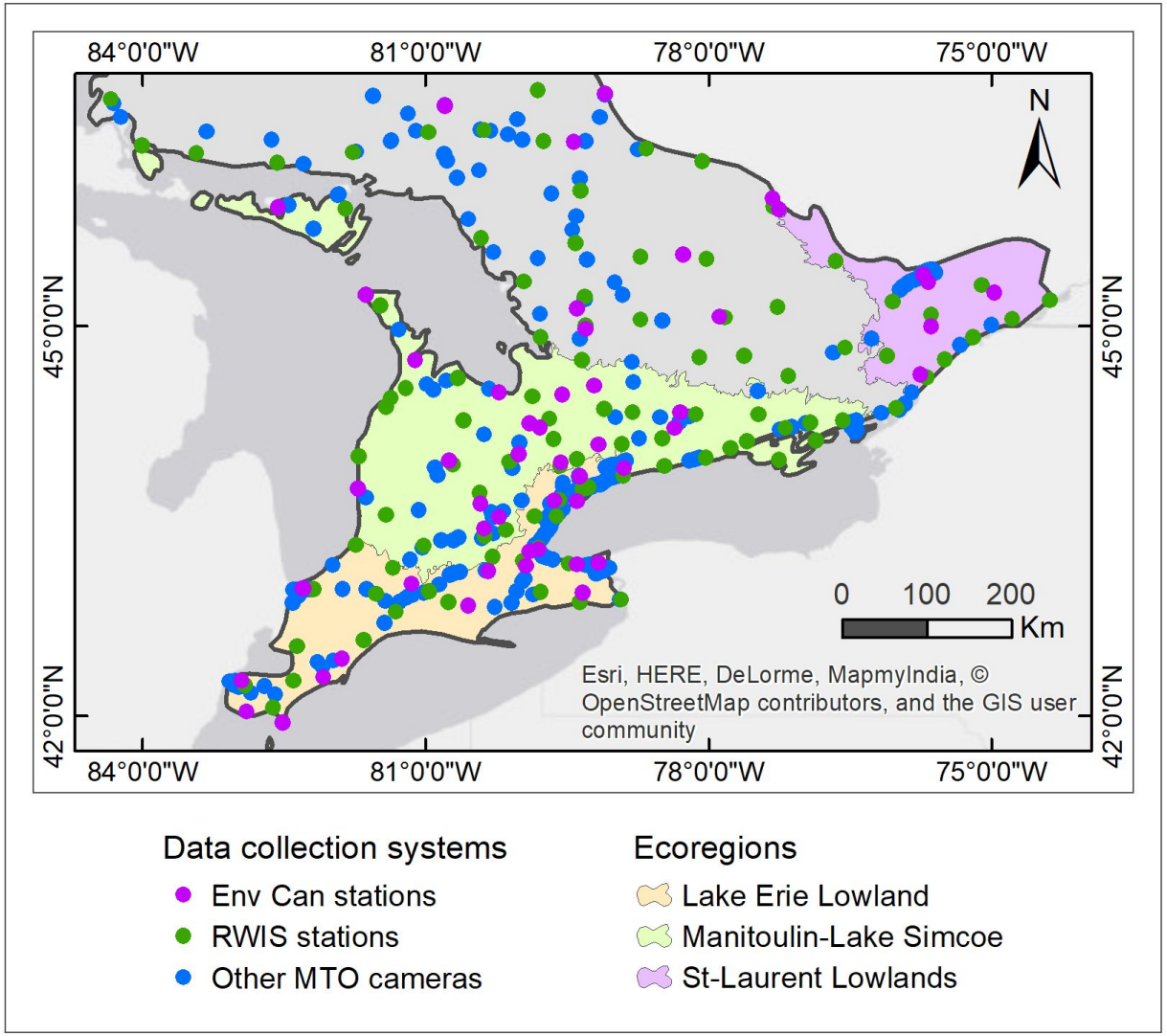
Area of study

Ecoregion	Population density inhabitants/km²	Rank across Canada
Lake Erie Lowland	344	2nd
St. Lawrence Lowlands	179	3rd
Manitoulin-Lake Simcoe	66	6th

Table 1. The three most densely inhabited ecoregions in Southern Ontario, StatCan 2016.



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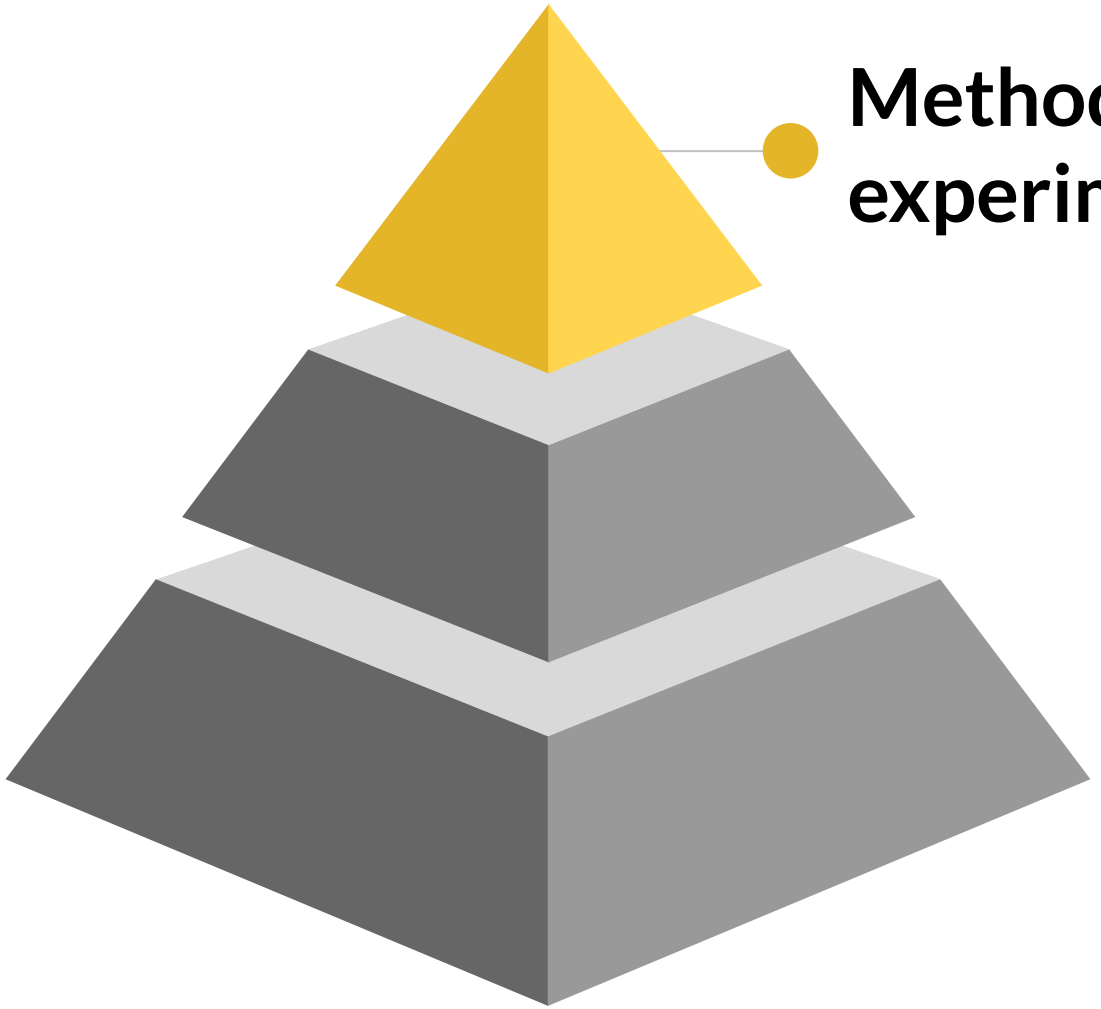


Methodology and experiments

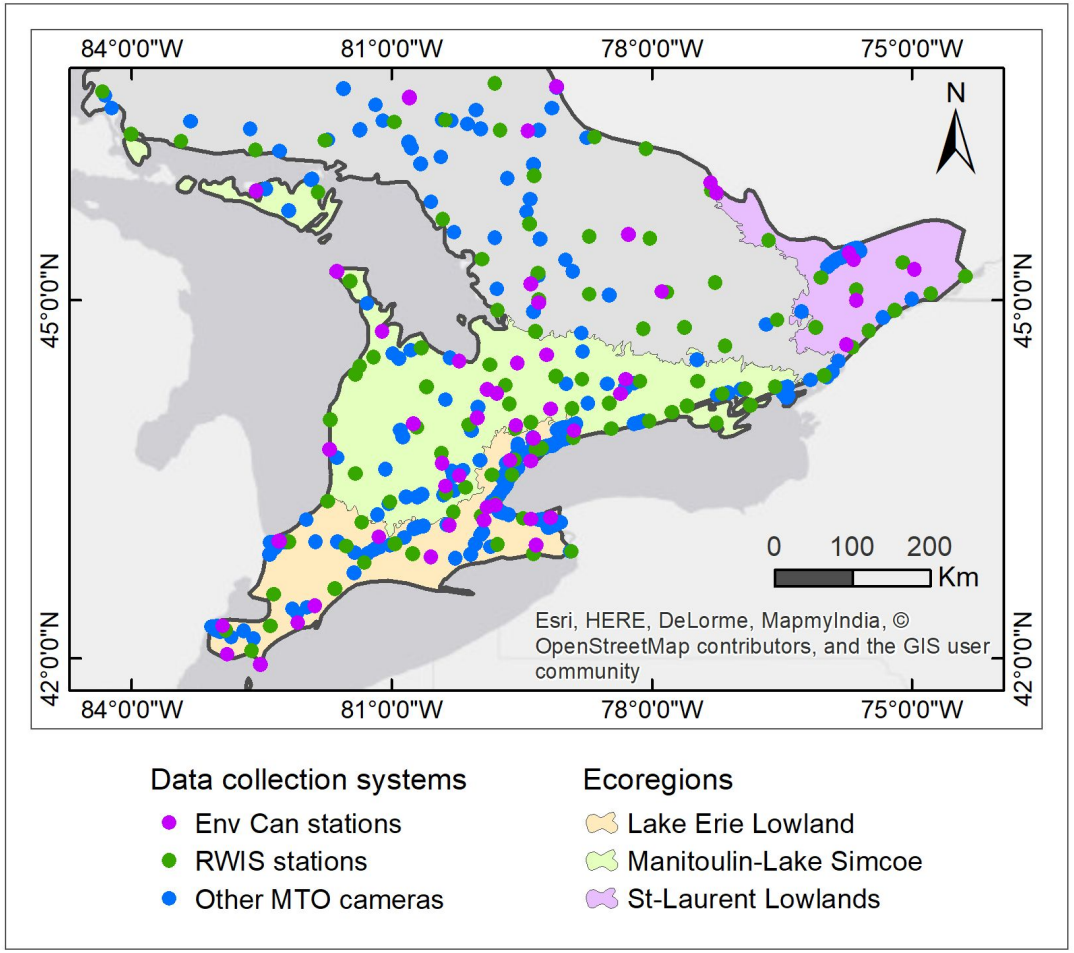
Nearest neighbor NN analysis

Type	# of locations in Ontario	Avg. distance to NN (km)	# of locations in three populous ecoregions
RWIS	139	38.4	68
Other MTO	439	7.2	364
RWIS + MTO	578	9.4	432

Table 2. Adding other MTO roadside cameras to increase the number of images.

Type	# of locations in Ontario	Avg. distance to NN (km)	# of locations in three populous ecoregions
RWIS	139	38.4	68
Env. Canada	99	35.8	45
RWIS + Env. Can	238	25.7	113

Table 3. Adding Environment Canada stations to interpolate weather data.



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L-Function analysis

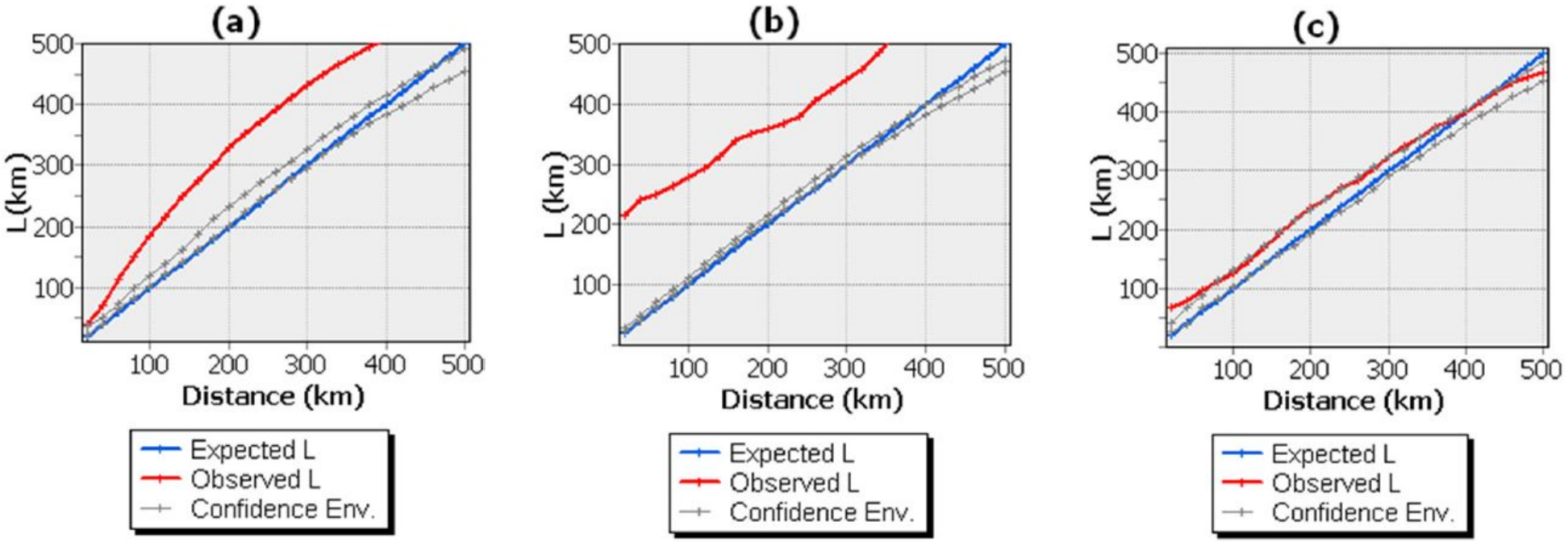

Figure 3. Multi-distance spatial cluster (L-Function) plots for: (a) RWIS stations, (b) other MTO cameras, and (c) Environment Canada stations.

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Weather interpolation for MTO locations

Sample of weather data

- 40 RWIS + 40 Env. Canada = 80 stations
- Three weather variables
- No-snow and snowy days
- 480 observations in total

Summary statistics	T1 - No snow - 2017/11/07 08:00			T2 - Snow - 2017/12/25 08:00		
	air temp. (°C)	wind speed (km/h)	pressure (kPa)	air temp. (°C)	wind speed (km/h)	pressure (kPa)
Mean	-1.921	4.912	99.950	-12.186	13.587	98.518
Std. dev.	5.195	6.419	2.809	9.509	11.128	2.782
CV%	----------	131%	3%	----------	82%	3%

Table 4. Summary statistics of three weather variables for a no-snow day and a snowy day.

Weather interpolation for MTO locations

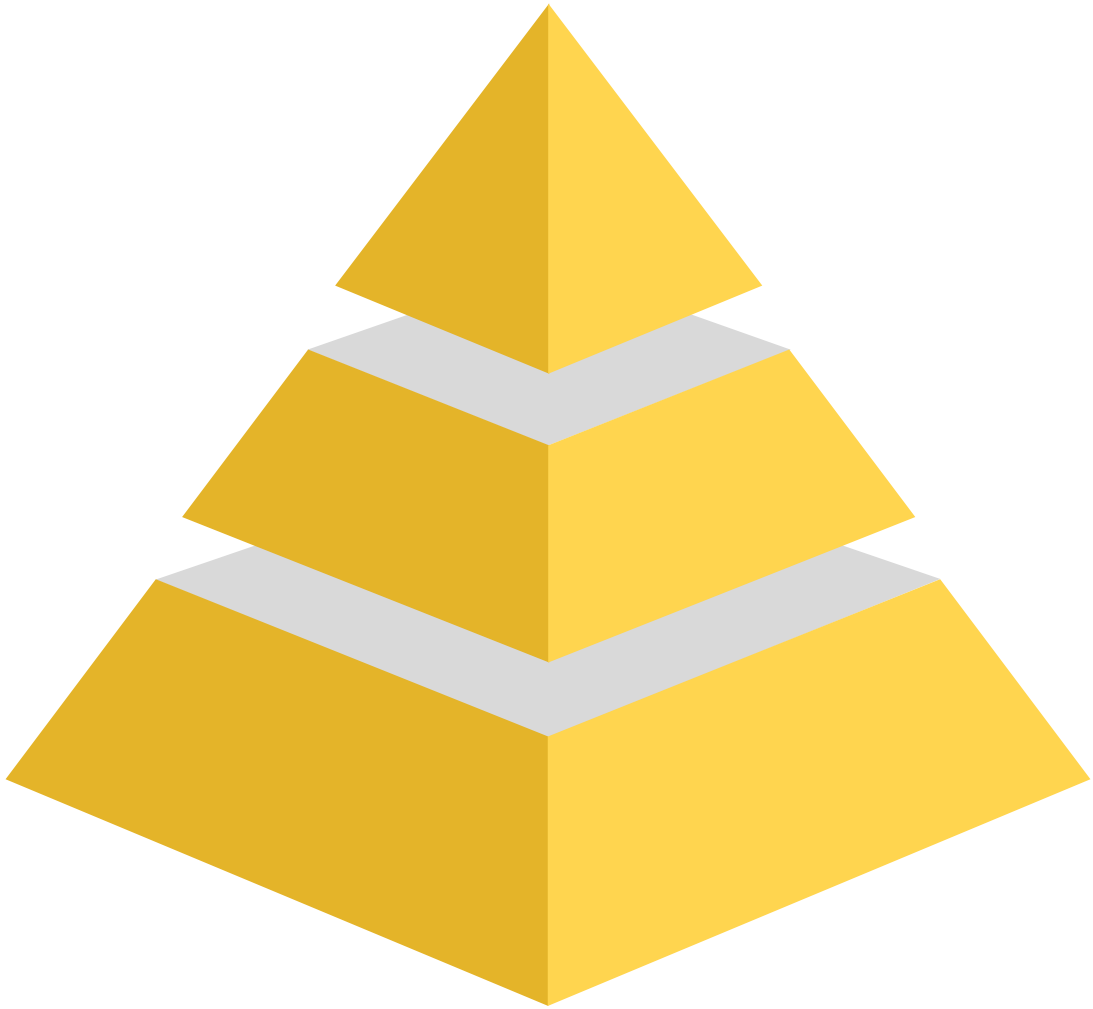
Interpolation methods

- Inverse distance weighted (IDW)
- Radial Basis Function (RBF)
- Ordinary Kriging (OK)

Interpolation Method	T1 - No snow - 2017/11/07 08:00			T2 - Snow - 2017/12/25 08:00		
	Air temp. (°C)	Wind speed (km/h)	Pressure (kPa)	Air temp. (°C)	Wind speed (km/h)	Pressure (kPa)
IDW	2.054	6.073	3.094	4.139	8.761	3.053
RBF	1.971	6.156	3.001	**3.898**	8.718	**2.963**
Ord. Kriging	**1.868**	**5.660**	**2.992**	3.921	**8.654**	2.999

Table 5. Root Mean Square of three interpolation methods applied on a no-snow and snowy day.

Conclusions



Conclusions

For the three most populated ecoregions in Ontario

- By adding all other MTO cameras as image data sources to the RWIS system, **six times** more cameras are available.

- Adding weather stations from Environment Canada to the RWIS system increases the number of weather stations by **1.7x**.

For weather interpolation in Ontario

- The best tradeoff between complexity and accuracy is offered by Radial Basis Functions (RBF).

Future work

Technical perspective

- Evaluate interoperability between different systems
- Include data from embedded pavement sensors

Policy and implementation perspective

- Design cooperation agreements
- Improve interaction with subcontractors

Questions