Quebec's health alert system for cold weather events

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Outline

I. Climate-Health context

Alert systems

Cold and health

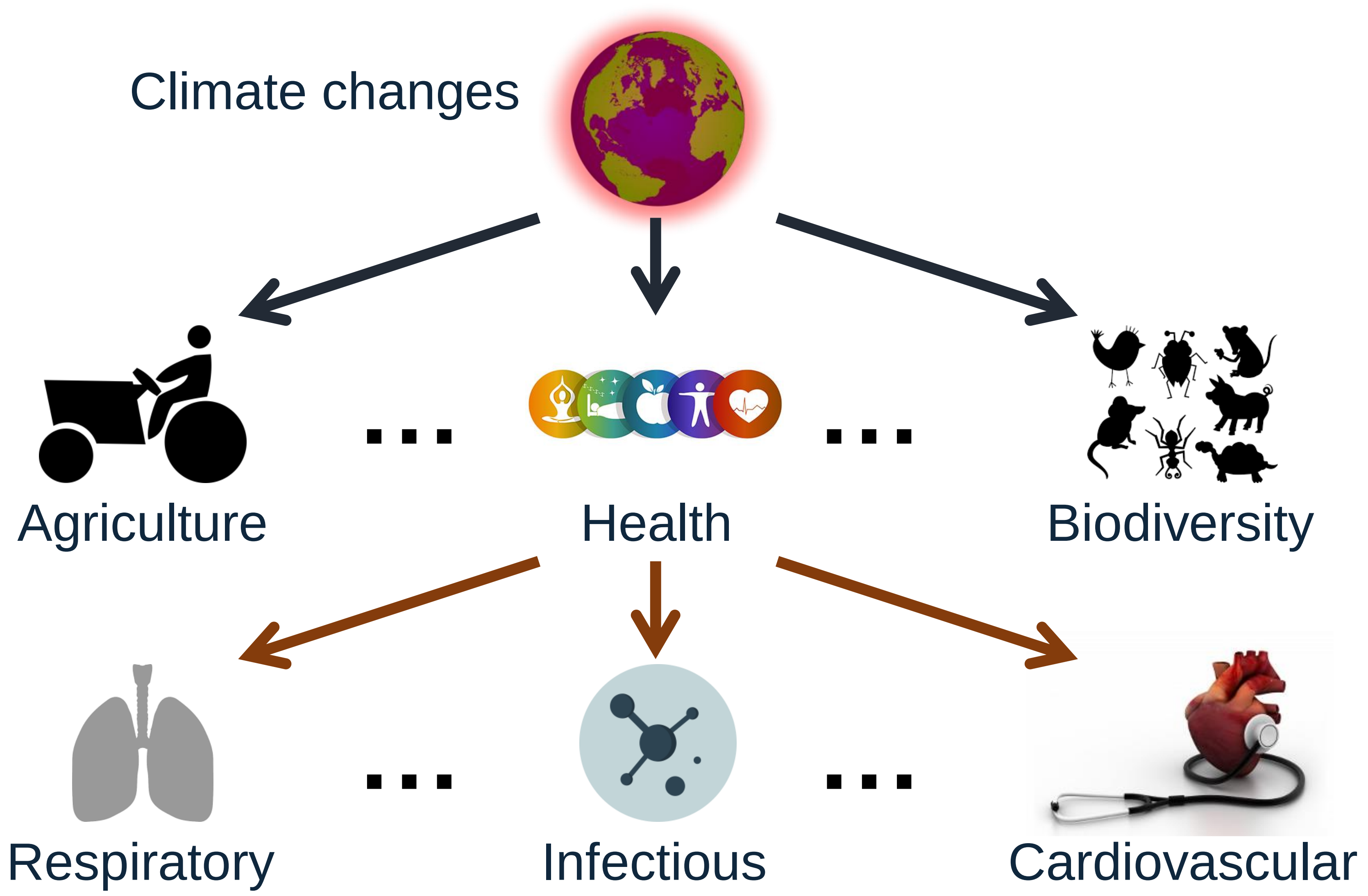
II. Proposed approach for Cold system

Application to the Québec context

III. Other systems (e.g. air pollution)

IV. Some conclusions

I. Climate-Health Context



I. Climate-Health Context

Extreme climate events have important effects on health population

Heat

- Western Europe (2003): 70 000 excess deaths
- Québec (2010): 300 deaths
- BC (2021): 500+ deaths (very interesting and detailed report by the Globe and Mail, 2021)
- Important stress on cardiovascular system

Extreme, deadly heat in Canada is going to come back, worse than ever. Will we be ready?

In 2021, Canadians sweated through oppressive temperatures that killed hundreds in the West. The heat also showed us where we must adapt to survive, from emergency responses to urban design and climate policy

KATHRYN BLAZE BAUM › ENVIRONMENT REPORTER
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TORONTO AND VANCOUVER
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THE GLOBE AND MAIL

I. Climate-Health Context

Extreme climate events have important effects on health population

Smog

- Usually in large cities
- Important air pollution
- Forest fire
- Respiratory diseases

Montreal

Coroner investigating after 2nd unhoused Montrealer dies in intense cold

CBC news

Woman in her 60s found in cardiac arrest near Berri-UQAM Metro station

CBC News · Posted: Jan 21, 2022 12:37 PM ET | Last Updated: January 22

Cold

- Recent extreme cold in Quebec (2022): 2 homeless died in Montreal
- Important stress on cardiovascular system

In Canada: Health Canada report (2022)

I. Climate-Health Context

Climate-Health studies: General objectives

- Investigate **relationships** between environmental/weather and health variables

  To understand these links in order to support public health authorities and researchers

- Issue **alerts** to the vulnerable population (target populations)

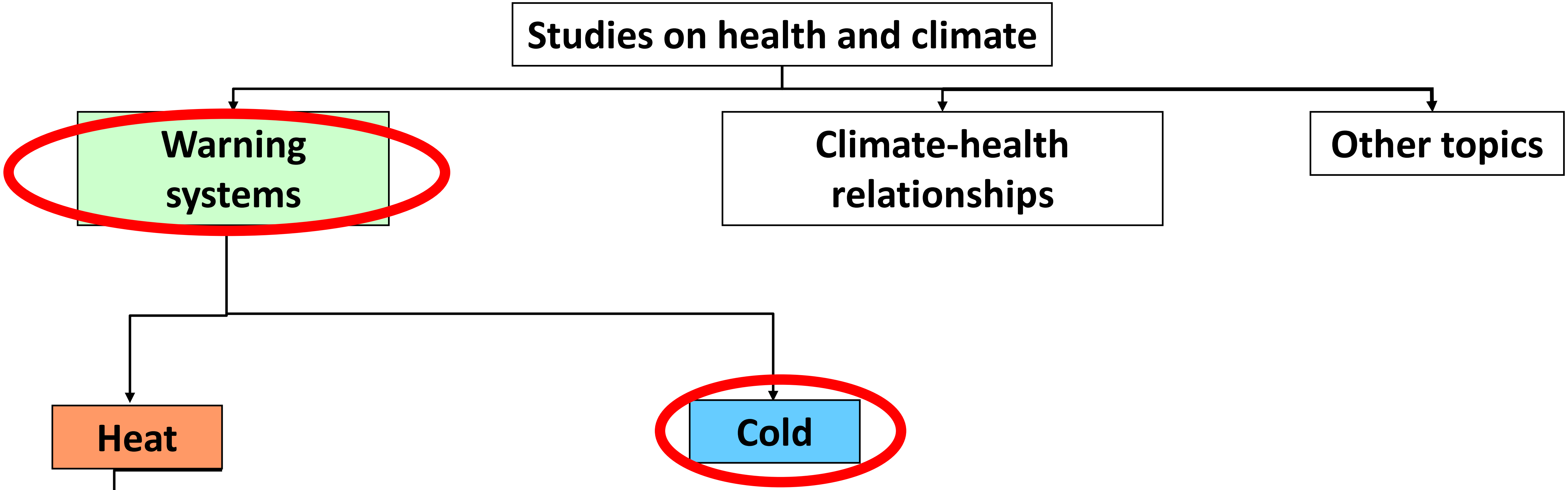
  To Make appropriate decisions for public health policy

- Management of neighborhood development (new or existing): green areas, public buildings with air conditioning, green roofs

- Many other subjects

We focus here on **Alert systems**

Environment watch and warning systems for health issues



Existing methods: e.g.
Laadi et al. 2005
Bernard and McGeehin 2004
Chebana et al. 2013

Health warning systems:

- Monitor environment wave events
- Launch alerts

In order to reduce heat waves health impact

Environment watch and warning systems for health issues

Several countries have already developed warning system to prevent the effects of heatwaves.

Heat

- Many regions have warning systems in place
- Europe and North America
- Local systems (Toronto, Rome), national (France, Quebec)

Smog

- Public Directives (WHO, Environment and Climate Change Canada)
- Warning systems in several Chinese provinces

Warning system is part of a large procedure including communications, post-event evaluation, actions!

Source: WHO 2019

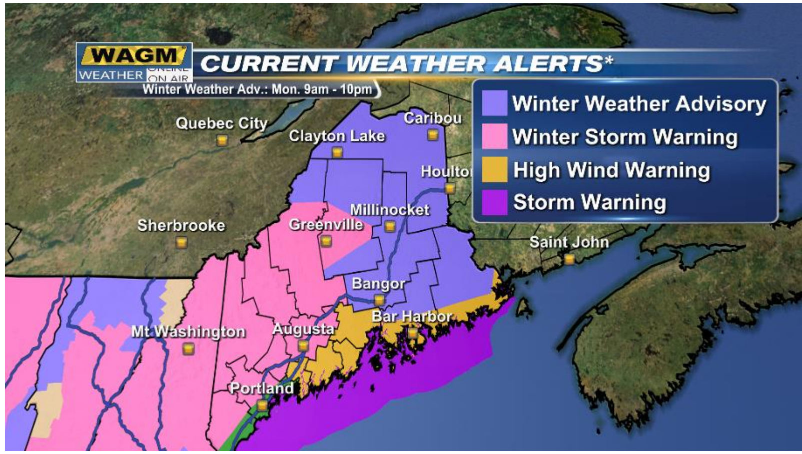
Environment watch and warning systems for health issues

Why developing and using those health-environment systems whereas there are already warning systems (as those shown in the media)?

- The **health**-environment systems
  - are health oriented
  - integrate health issues (data) in their design
  - are not issued directly to the media and not to general population
  - are designed for public health authorities to make decision for the health system (e.g. hospitals, personnel) and could be for specific targeted vulnerable sub-populations
  - respect administrative limitations of public health

Environment watch and warning systems for health issues

Why developing and using those health-environment systems whereas there are already warning systems (as those shown in the media)?



- The weather alerts
  - are general
  - for all sectors (transportation, tourism, health, etc), general population
  - Health variables are not directly integrated in their design
  - Do not consider geographic limits of health regions

- The forecasting provided by the corresponding institutions are essential for health-environment systems use

Cold and health

A whole section was dedicated to cold in Health Canada (2022) report:

- Cold is known to increase the risk of cardiovascular, respiratory, and stroke-related illness and mortality:
  - E.g. people with pre-existing kidney or cardiac conditions had a higher probability of being admitted to the emergency department in extreme cold compared to those without this type of problem

- Intense cold periods can affect the volume of emergency department visits for at least one week

Cold and health

A whole section was dedicated to cold in Health Canada (2022) report:

- Schools can close in extreme cold as part of efforts to keep students safe
- People experiencing homelessness are also very exposed to cold
  - E.g. they accounted for 62% of those admitted to emergency departments for hypothermia or frostbite in winter from 2005 to 2009 (Paris, France)

- The duration of individual cold exposure that lead to these health effects is not well known (up to two weeks following extreme cold or longer)

Cold and health

- In Nordic regions, mortality is generally higher during winter than the rest of the year

- Unlike the summer (heat), very few health warning systems have been developed for **cold**, especially in the context of Canadian winters

- Few operational cold-health watch and warning systems (**C-**HWWS) documented (in England and Macedonia)

- Their methodologies present some limitations
  - Based only on mean temperature = not adapted for extremes
  - Not specific to cold but for the whole year
  - Established for a temperate climate

- It is of interest to establish a **C**-HWWS to mitigate the associate impacts

Warning Systems

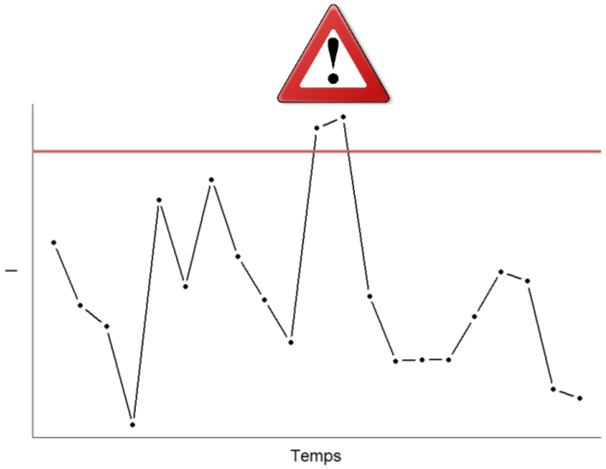
Heat-health warning systems

Two main components:

Climate Indicators $I(X)$

Thresholds s

$I(X) > s$



Alert:

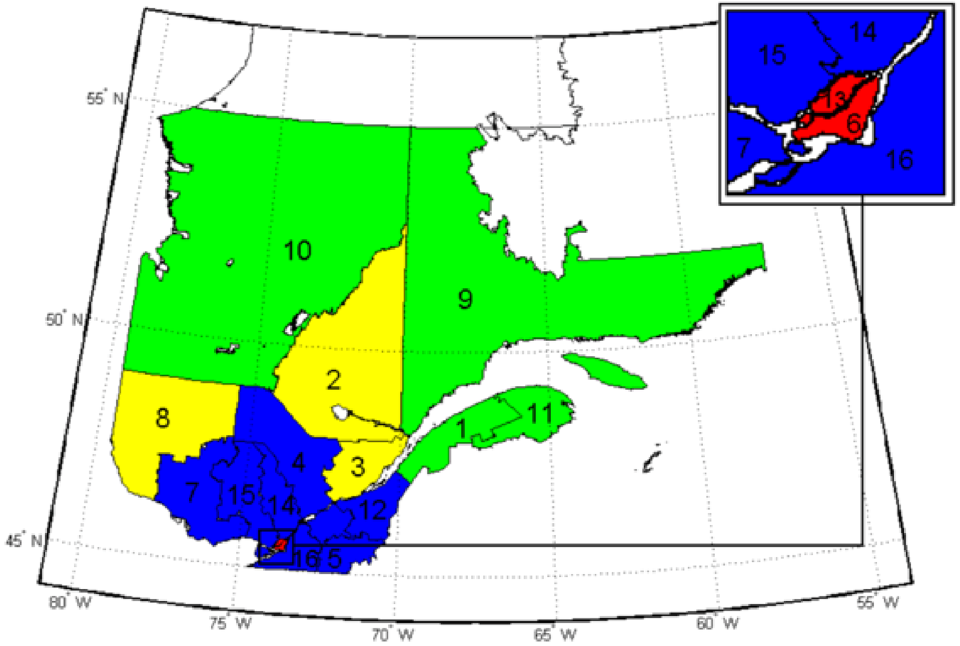
- Prepare hospitals
- Call vulnerable peasons
- Communicate to public

System used in Quebec since 2010 (**heat**-*mortality*)

They have already demonstrated their utility and effectiveness in reducing mortality from extreme heat events

	RSS	RSS name	Optimal weights a0	a1	a2	Threshold (°C)
classe 1	6	Montréal	0.4	0.4	0.2	(33;20)
	13	Laval				

- Indicator: weighted mean over three days: Tmax and Tmin



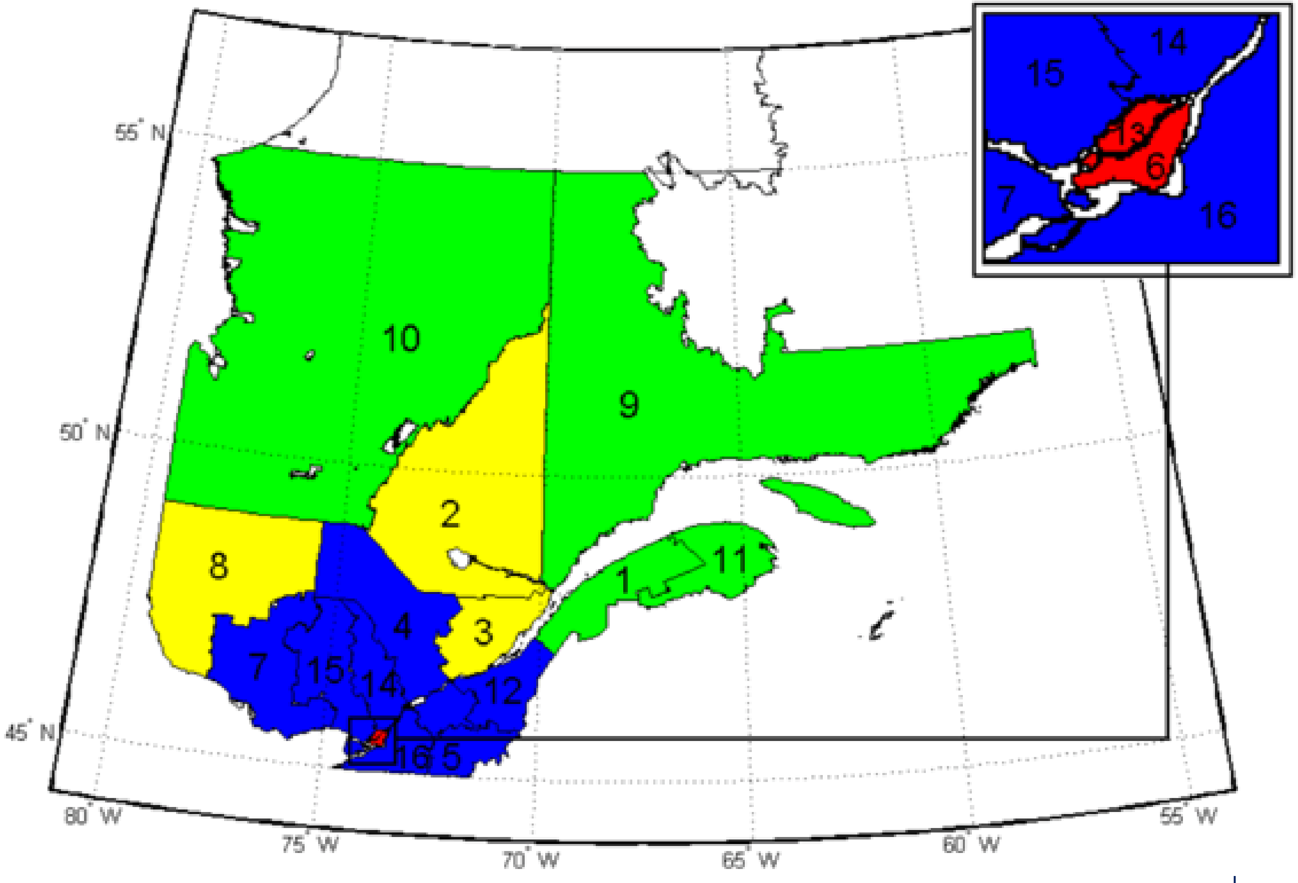
- It is implemented in the real-time Surveillance and Prevention of the impacts of Extreme Meteorological Events on public health (**SUPREME**) system in Quebec

- SUPREME is established by the *Institut national de santé publique de Quebec* (INSPQ) in 2010 for heat warning system

System used in Quebec since 2010 (**heat**-*mortality*)

They have already demonstrated their utility and effectiveness in reducing mortality from extreme heat events

	RSS	Nom RSS	Pondération			seuil (°C)
			a0	a1	a2	
classe 1	6	Montréal	0.4	0.4	0.2	(33;20)
	13	Laval				
classe 2	4	Mauricie	0.4	0.4	0.2	(31;19)
	5	Estrie				
	7	Outaouais				
	12	Chaudière-Appalaches				
	14	Lanaudière				
	15	Laurentides				
	16	Montérégie				
classe 3	2	Saguenay	0.4	0.4	0.2	(31;16)
	3	Capitale-Nationale				
	8	Abitibi				
classe 4	1	Bas-Saint-Laurent	0.4	0.4	0.2	(31;16)
	9	Côte-Nord				
	10	Nord-du-Québec				
	11	Gaspésie				



- Weighted mean over three days: Tmax and Tmin

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II. Proposed cold health warning system

- The proposed approach for **C**-HWWS is inspired by the one used for **H**-HWWS
- Some methodological improvements are introduced
- The main difference between heat and cold is in the magnitude and lags of the relationship with health: heat → relatively short (few days, well studied)

  cold → generally much longer (weeks, less studied)

- Two different systems (threshold/indicators) are proposed:
  - Mortality and Hospitalization
  - Not the case in other studies even for heat (only for mortality)

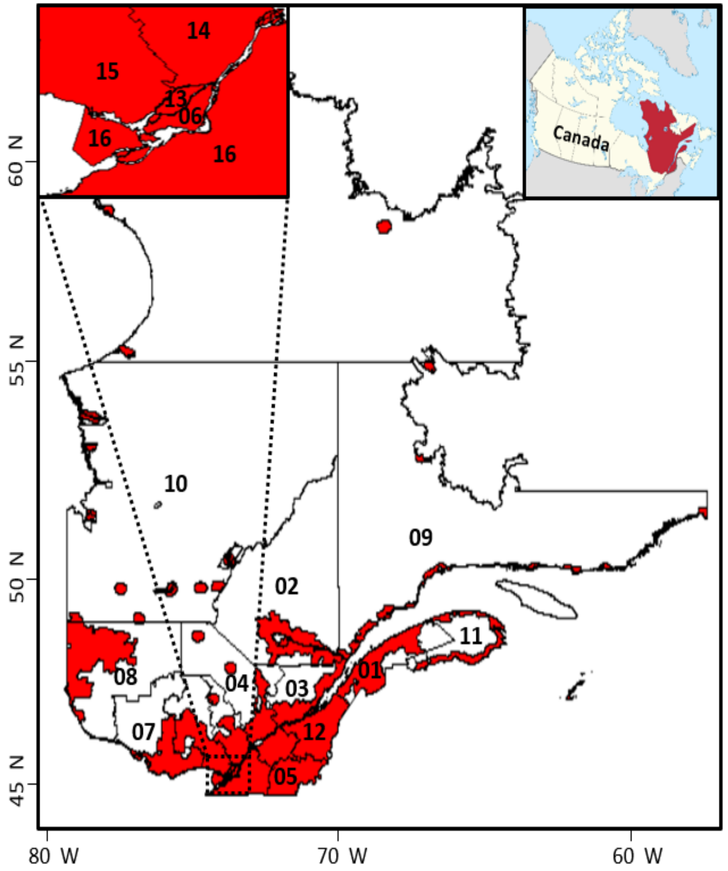
- Cold effects on *Mortality* and *Hospitalization* are different, in particular:
  - over-mortality and over-hospitalization events do not always occur simultaneously
  - and without the same amplitude

Considered Data

Regions and periods :

Province of Québec : 16 RSS of Québec (*RSS : Régions Socio-Sanitaires*)

Winter period : December 1st to March 31st for years 1994 to 2015



Health (daily) :

Deaths : all-cause mortality

Hospitalizations : all-cause hospitalization, influenza (Confounding effect)

Meteorological (daily) :

Temperatures (max, min, mean),

Wind speed (max, min, mean) and vapor pressure

Except wind speed, all var. extracted from the *DayMet* database

DayMet database:

An interpolated/extrapolated data on a spatial 1 km^2 grid (most of North-America)

Proposed Cold warning system: approach

For each region

Step 0 :
- Grouping of RSSs regions

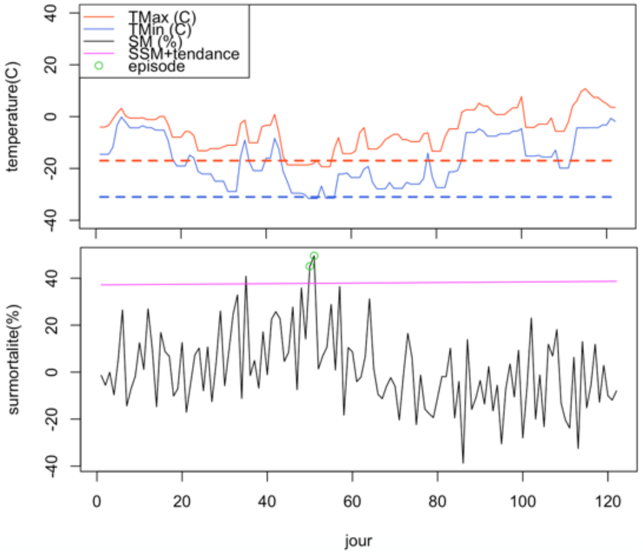
Step 1 :
- Lag selection

Lag selection

Step 2 :
- Over-mortality (OM)
- OM threshold (OMT)

Splines

Step 3: historical episodes
Preliminary temperature thresholds

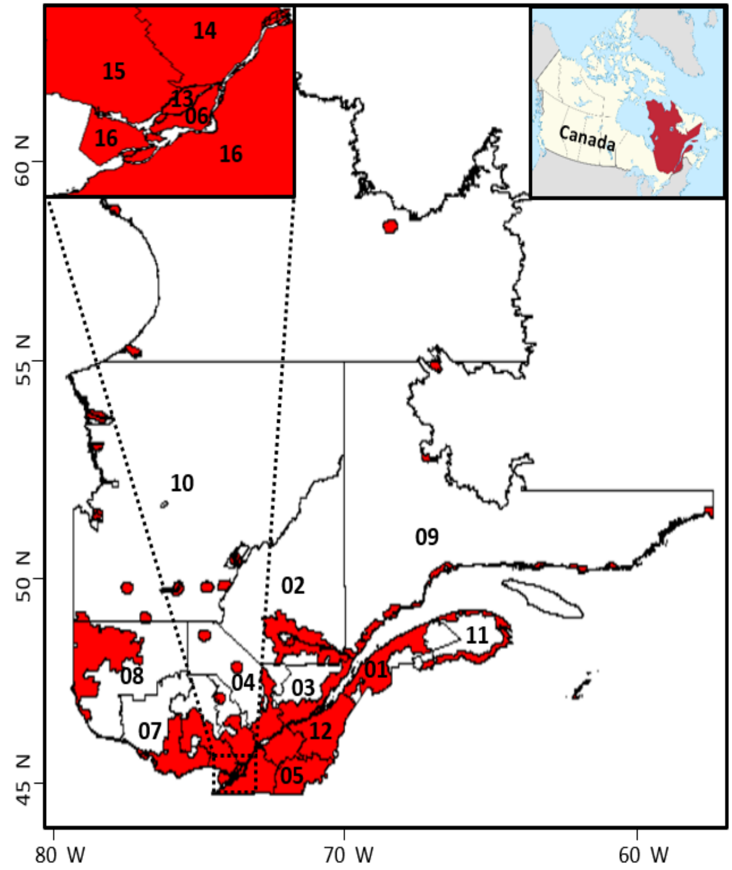


- Based on the heat system approach (Chebana et al. 2013)
- **But adapted and improved**

Step 4: final system (optimisation)
- Appropriate Indicators
- Meteo thresholds

II. Proposed cold health-system – clustering of RSS

- The province of Quebec :
  - large area but has a small population (8.3 M inhabitants in 2018, density 5.5/km^2),
  - non-uniform spatial distribution
  - 16 administrative health regions (*Région Socio-Sanitaires*, RSS)

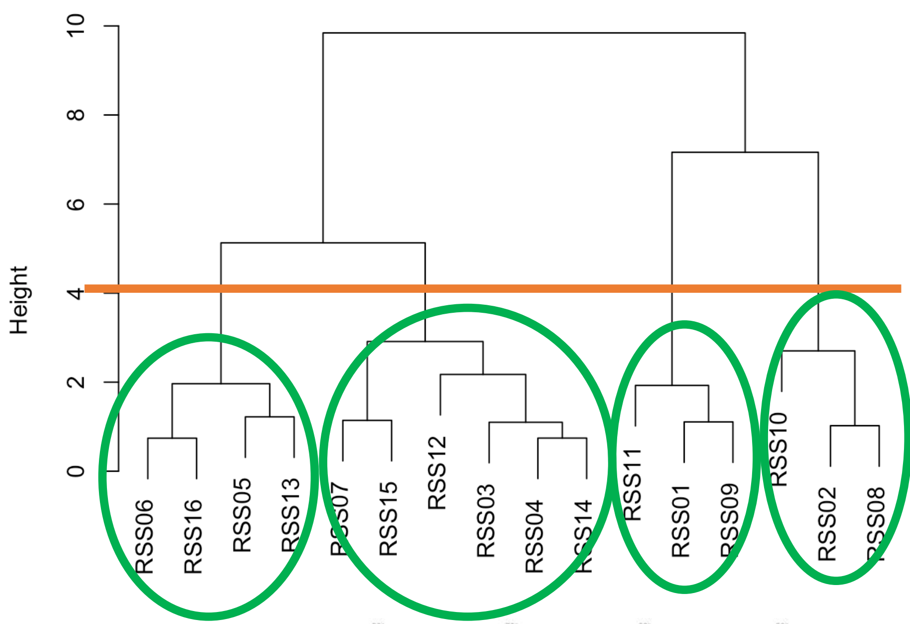


- The weather conditions of each region are very different and the very sparse population in some of them (less satisfactory statistical analyses)

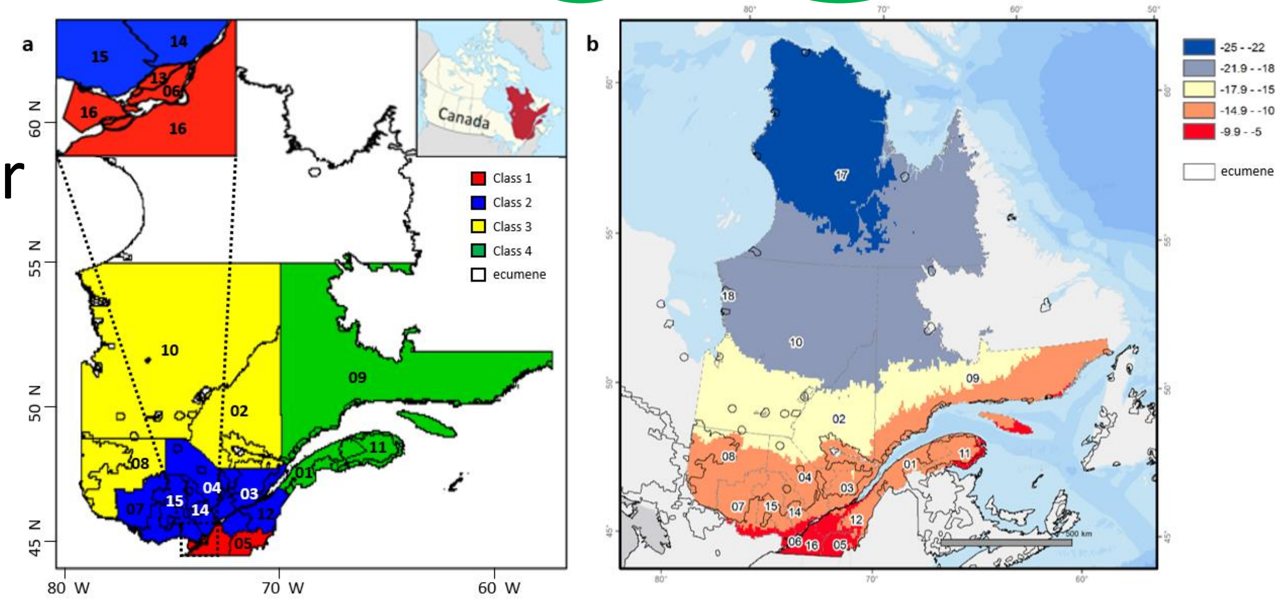
- Hence, it is necessary to <u>cluster</u> RSS into climatically homogeneous classes with enough number of data

Step 0 : clustering of RSSs

- A hierarchical agglomerative clustering (HAC) is performed on the daily meteo variables
  - temperatures, wind speed and vapor pressure
- Resulting in 4 classes
- Overall agreement with the Quebec climate map
  - based on the winter average temperature 1981-2010



A cold system C-HWWS is established for each of these 4 classes

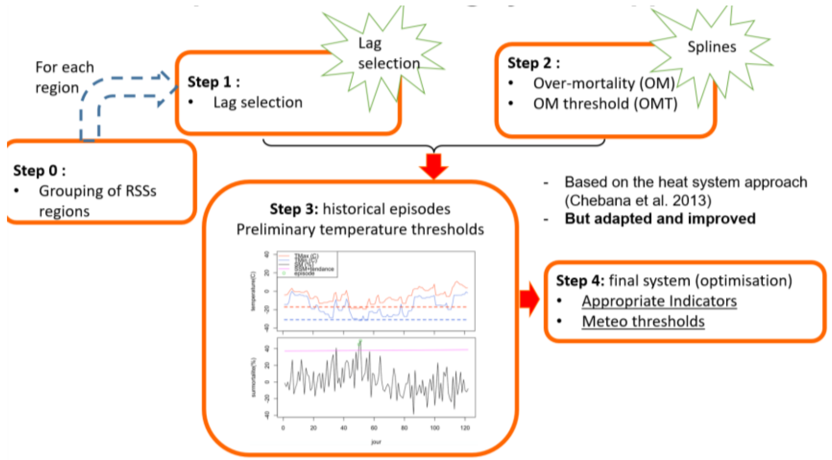


Step 1 : Select appropriate lags value for cold indicators

Cold indicators: Cold indicators are defined as a linear combination of *Tmax* and *Tmin* on some consecutive days.

For a maximum lag value =*L*, the indicators S_t are expressed as:

$$S_t = \sum_{l=0}^{L} \alpha_l X_{t-l}$$



X_t = forecast temp. of *Tmax* or *Tmin* at day t

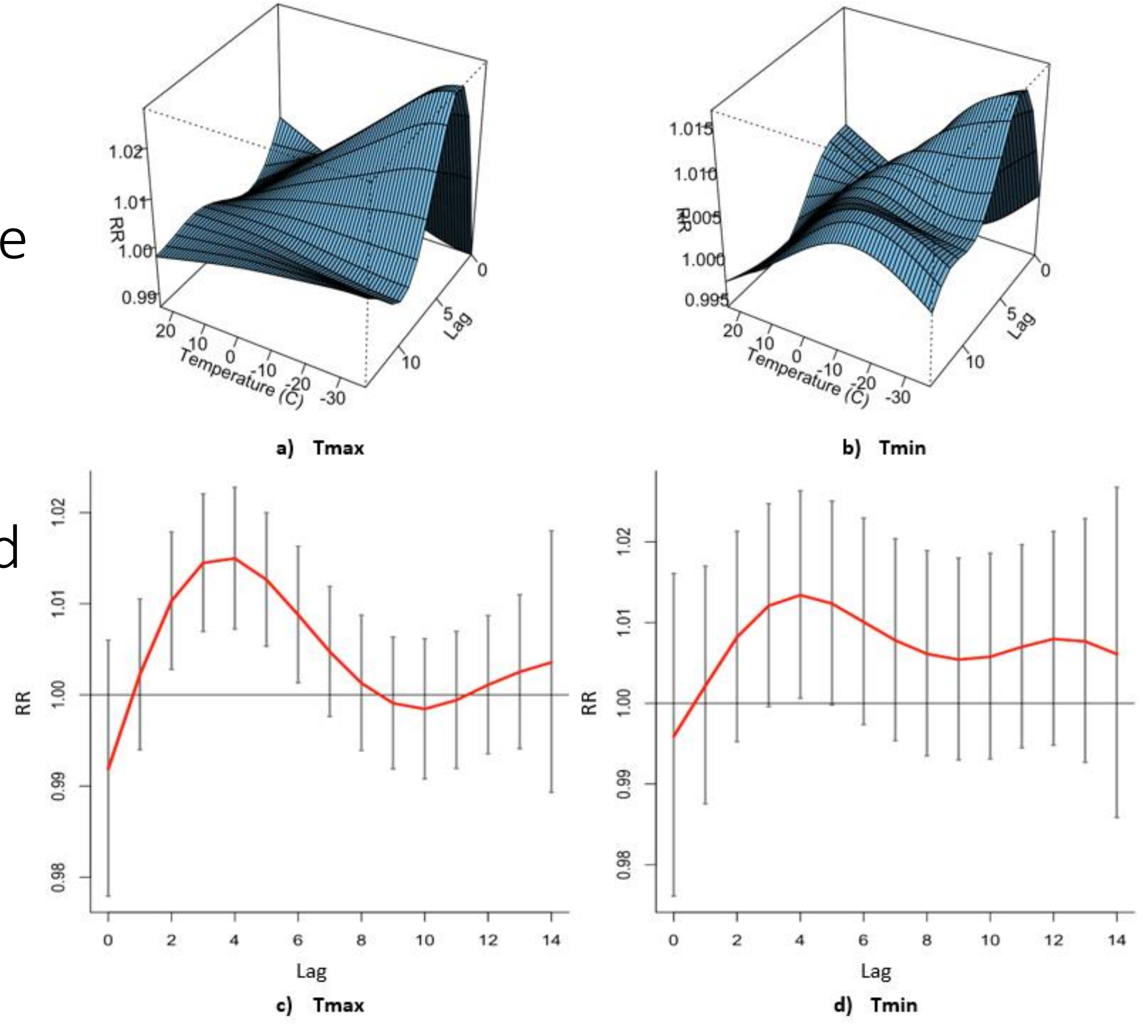
α_l = weightings such that $\alpha_i \geq \alpha_j, for\ i < j < L$ and $\sum_{l=0}^{L} \alpha_l = 1$

Goal : select objectively the maximum lag value for cold indicators

Method : by distributed lag non-linear model (DLNM)

Step1 : Lag selection

- Heat: it is generally chosen ***a priori*** as $L = 2\ days$
- Cold: L can be chosen by examining the lag-response relationship between temp. and the health issue
- In this study, a quasi-Poisson DLNM is used, with penalized splines on both temperature variables and lags from 0 to 14 days
- A lag of *L*=4 days is selected for hospitalization and mortality for both Tmax and Tmin indicators.

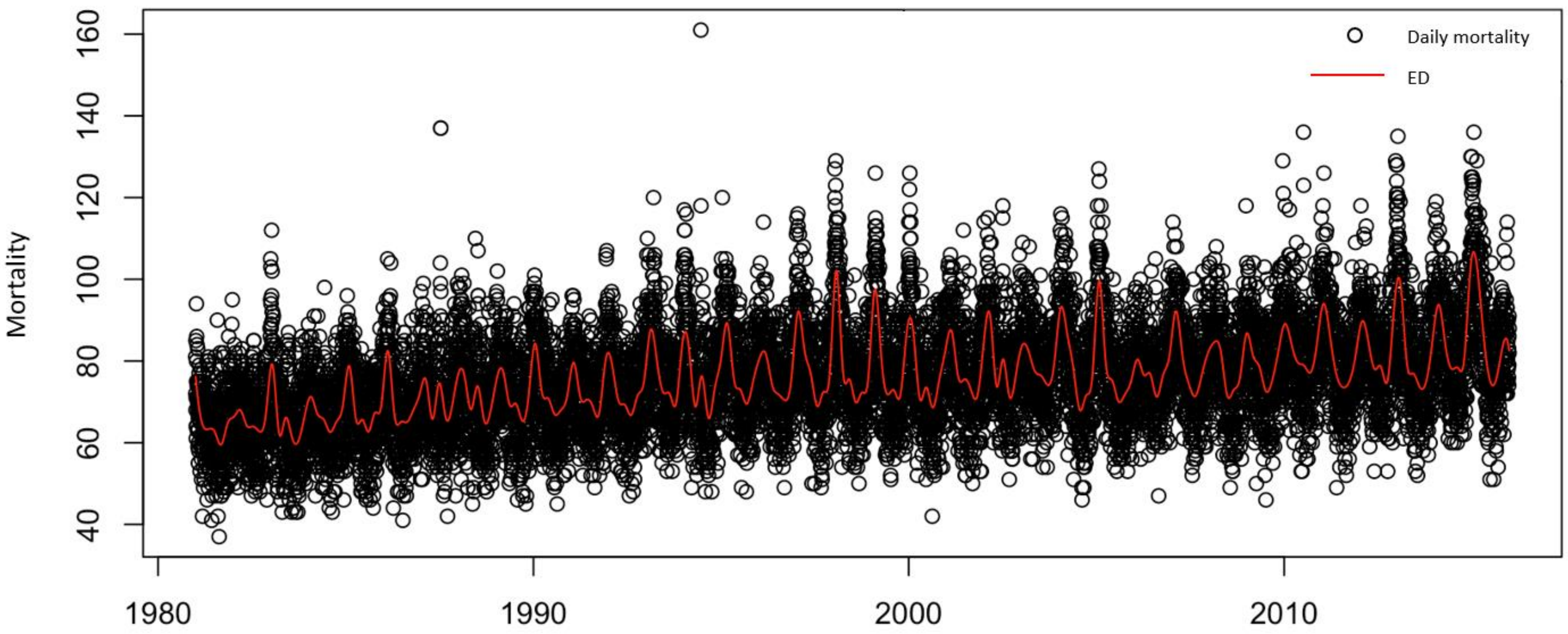


Slices of the DLNM surface at the 5th percentile of the temperature, i.e. corresponding to Tmax=-12 °C, Tmin=- 23 °C

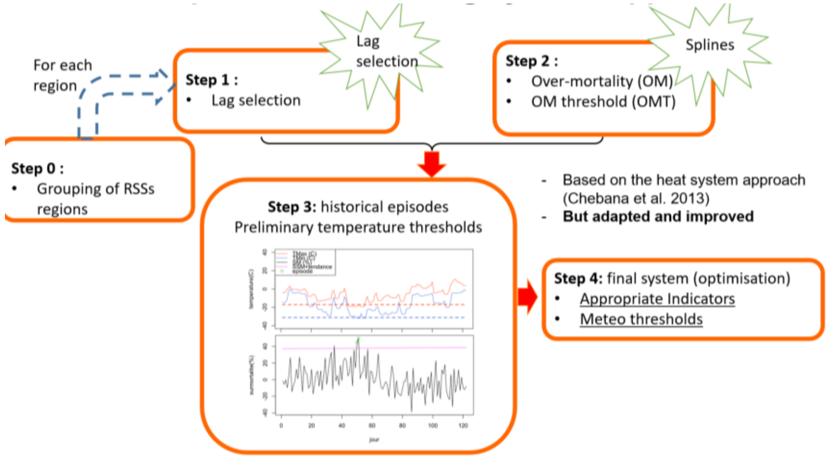
Step 2 : estimate *Over-health (OH) series*

- Evaluate Over-health (OH, including over-mortality and over-hospitalization) series.
  - 'Spline' function and generalized linear model (GLM): $OH_t = \frac{OD_t - ExpD_t}{ExpD_t} * 100 \quad (\%)$

- Choose the threshold of OH (noted OHT) : by exceedance function (total and cold-related)



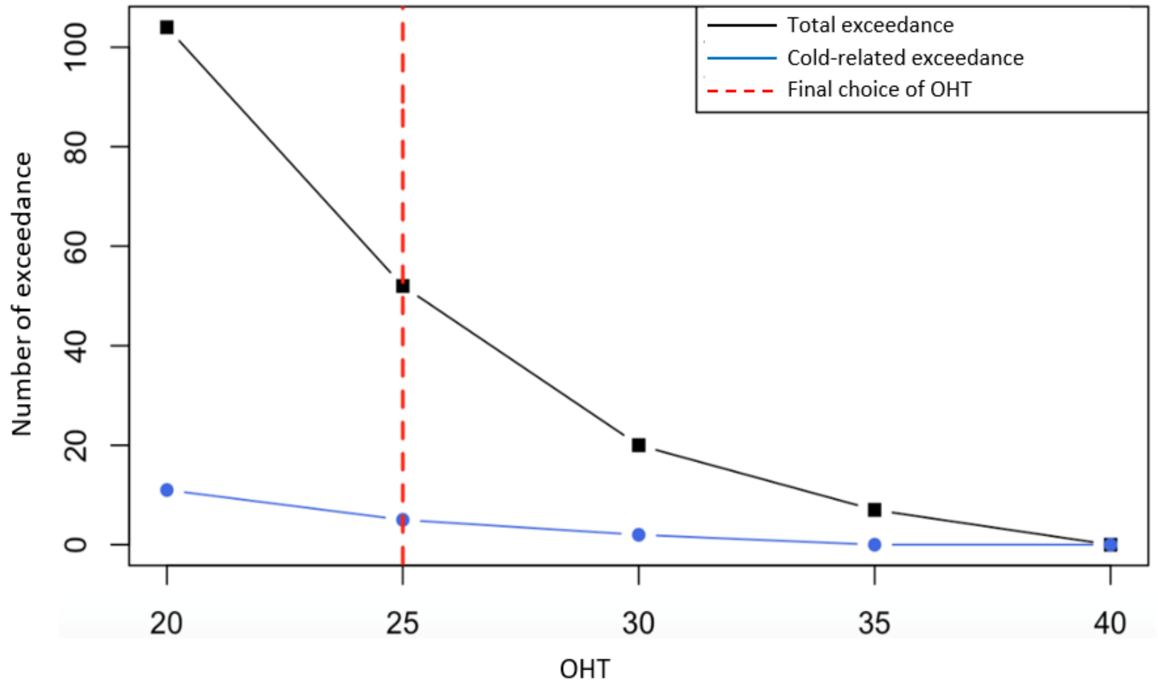
Example of expected number of daily deaths (ED) for class 1 (Montreal area)

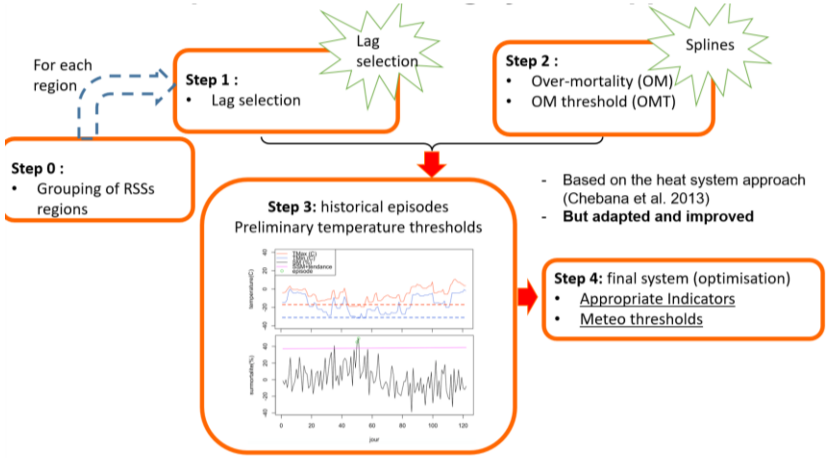


Step 2 : determine the threshold of OH (OHT)

The choice of OHT is based on the total exceedance function and the cold-related exceedance function

EX: for mortality data and class 1 (**Montreal**)





- OHT must reach a trade-off between enough OH extremes and high enough values of OH.

- Only 2 episodes are detected with OHT = 30% which means that some important episodes may be missed.

→ OHT=25% is chosen for class 1

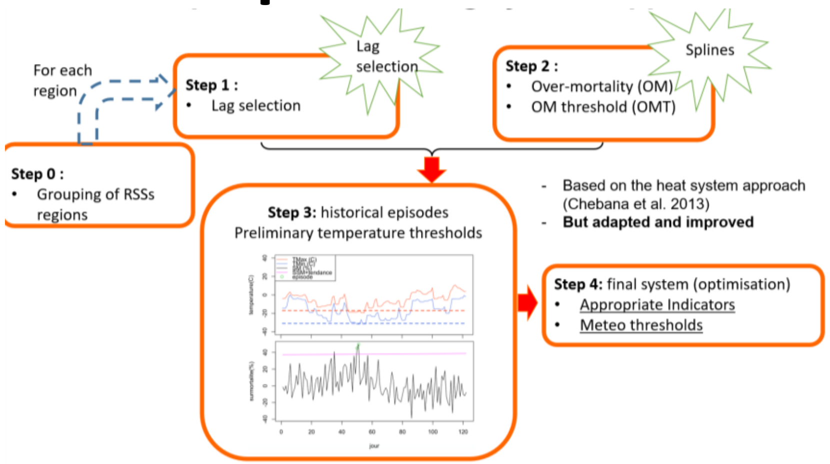
Leading to 4 OH episodes detected.

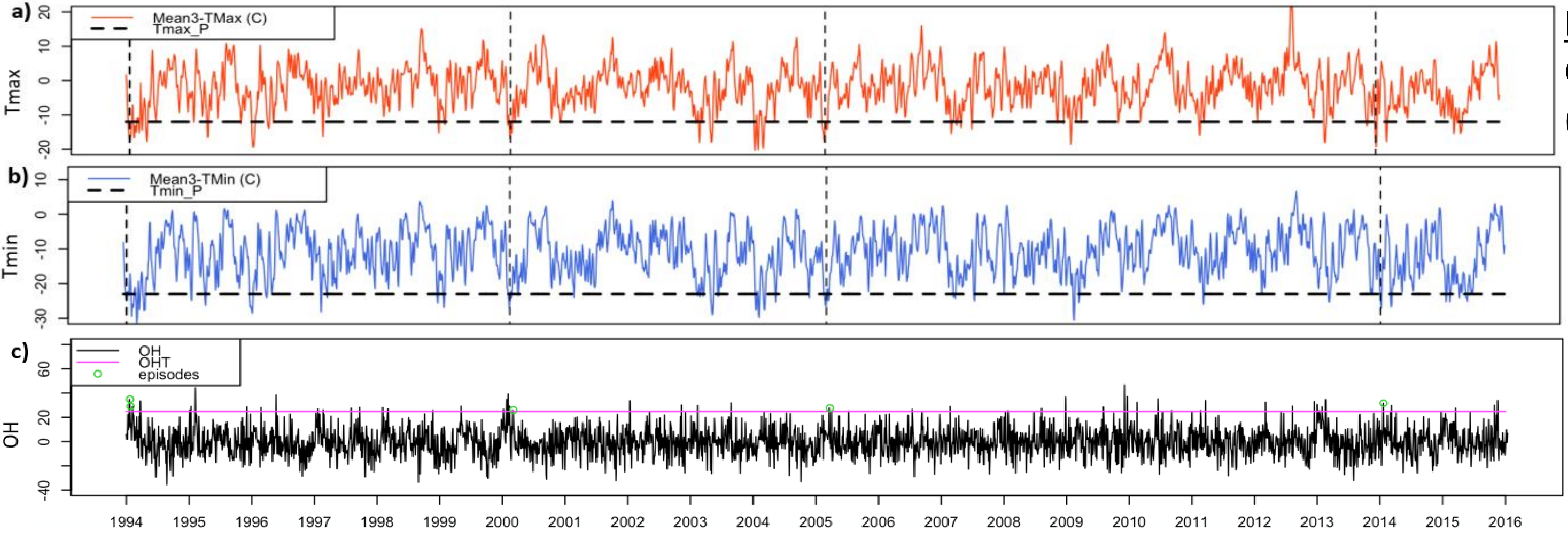
Step 3 : determine preliminary thresholds and historical episodes of OH

All episodes detected should meet the following three conditions:

OH > OHT & Tmax < Tmax prelim & Tmin < Tmin prelim

T prelim : 5th percentile of 3-day means of Tmin and Tmax series over the whole winter periods





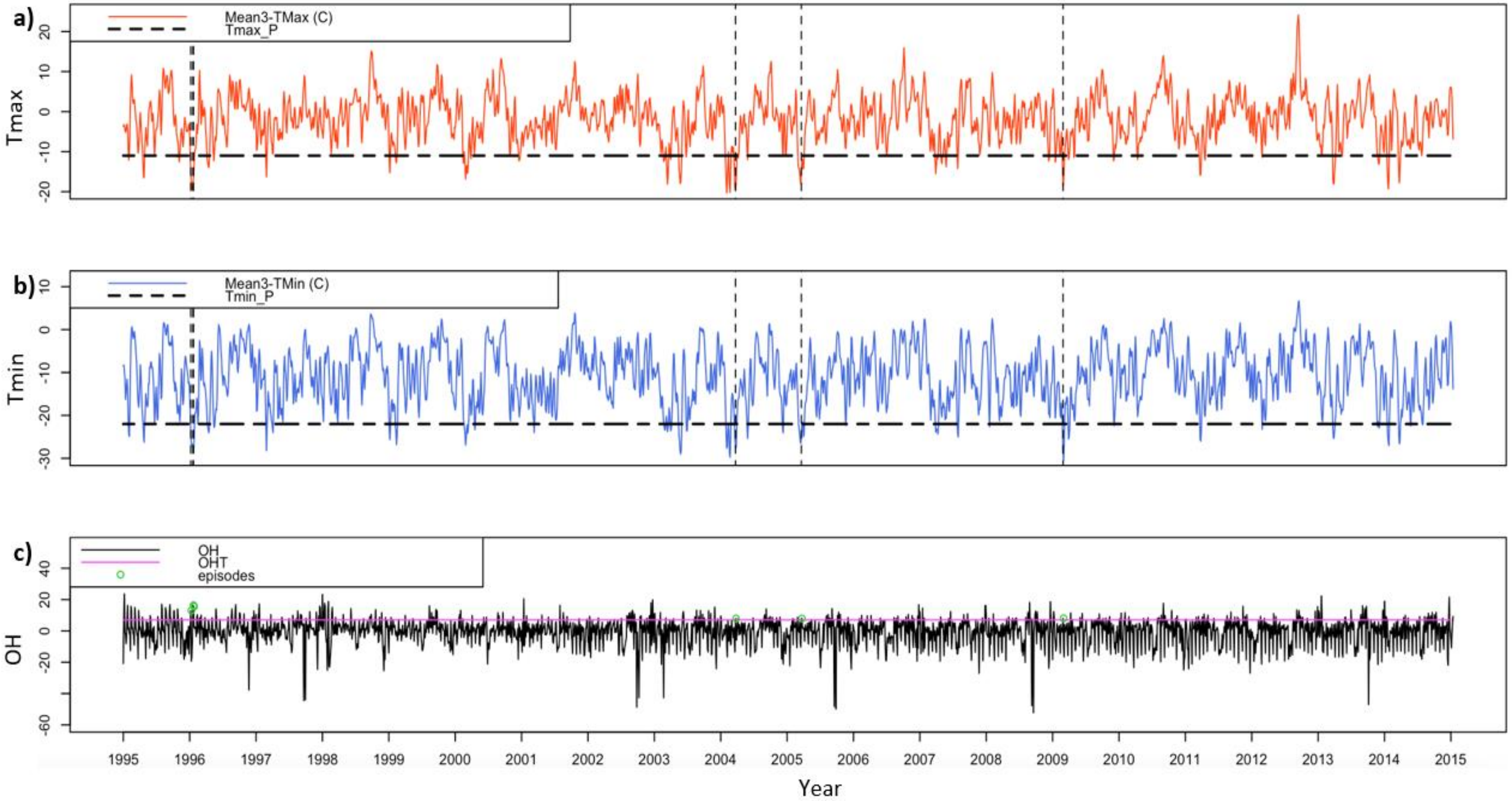
Mortality

Class 1

(Montreal)

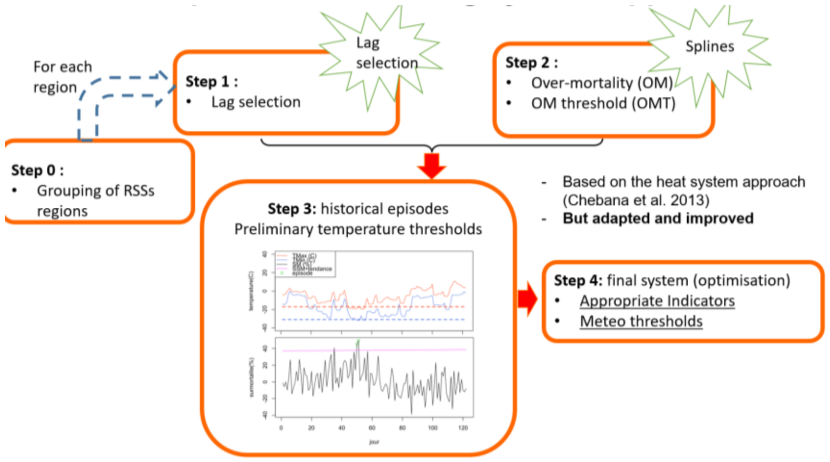
Step 3 : preliminary thresholds and historical episodes of OH - Hospitalization

- The level of OH is much lower than that of mortality data : OHT=7% is chosen in the case of hospitalization (was 25% for mortality)
- This low value is quite significant for over-hosp. (the average number of daily hospitalization is almost 20 times the daily mortality)



Step 4 : choose the appropriate indicators/thresholds

Find the **optimal** indicator weights and the corresponding final cold thresholds



Evaluation criteria

- Sensitivity
- Number of false alarms (FA)

A threshold/indicator corresponding to high sensitivity and fewer FAs is preferred

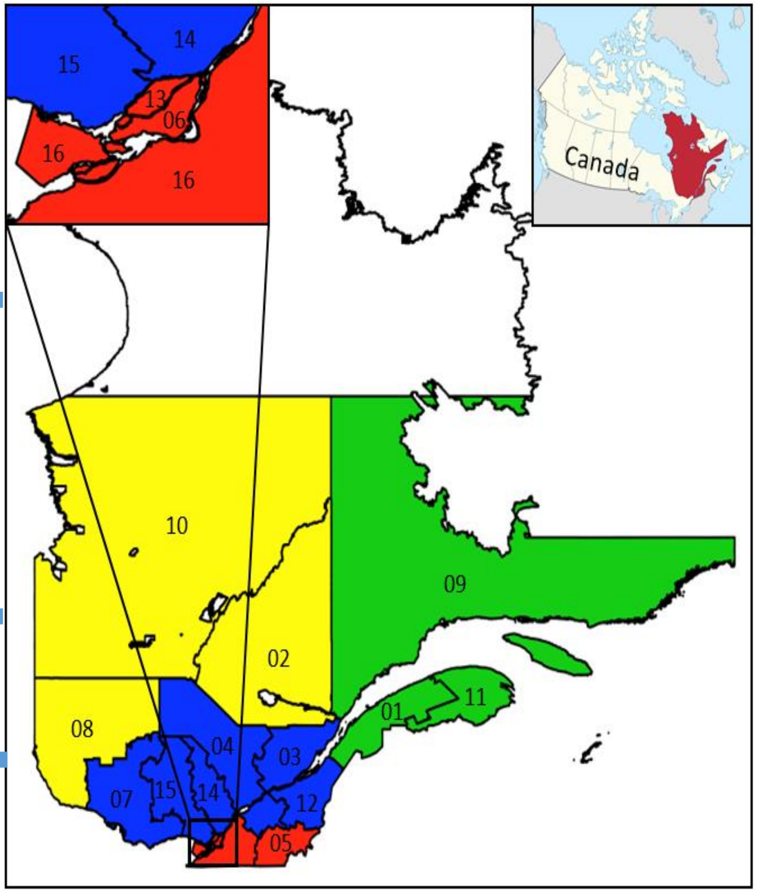
Mortality:

	RSS	RSS name	Episodes #	Optimal weights a1	Optimal weights a2	Threshold (°C)	Sensitivity (%)	FA (per year)
class 1	5	Estrie	4	0.5	0.5	(-15,-23)	100	0.68
	6	Montréal						
	13	Laval						
	16	Montérégie						

Final thresholds/indicators proposed for each class

For all-cause mortality :

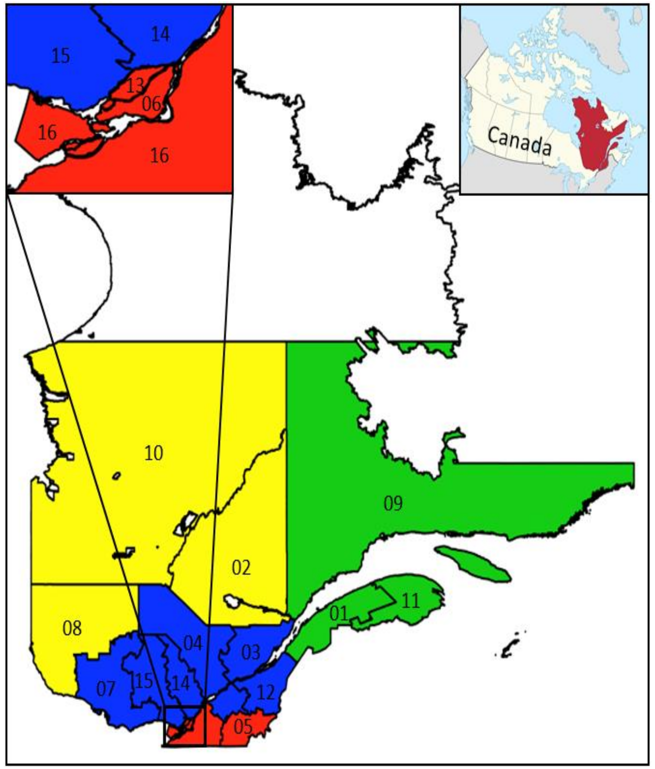
	RSS	Nom RSS	Episodes/jours	Pondération a0	Pondération a1	seuil (°C)	Sensibilité (%)	FA (par an)
classe 1	5	Estrie	4/5	0.5	0.5	(-15,-23)	100	0.68
	6	Montréal						
	13	Laval						
	16	Montérégie						
classe 2	3	Capitale-Nationale	4/5	0.5	0.5	(-16,-28)	100	0.68
	4	Mauricie						
	7	Outaouais						
	12	Chaudière-Appalaches						
	14	Lanaudière						
	15	Laurentides						
classe 3	2	Saguenay	5/6	0.7	0.3	(-20,-29)	67	1.05
	8	Abitibi						
	10	Nord-du-Québec						
classe 4	1	Bas-Saint-Laurent	4/5	0.5	0.5	(-15,-23)	100	1.27
	9	Côte-Nord						
	11	Gaspésie						



Final thresholds/indicators proposed for each class

For all-cause hospitalization :

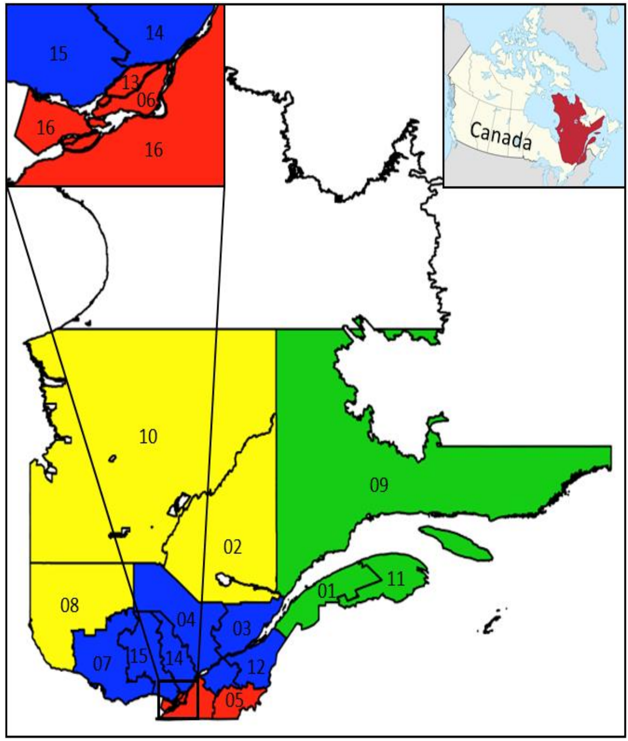
Class	RSS	RSS name	Episodes #	Optimal weights		Threshold (°C)	Sensitivity (%)	FA (per year)
				a1	a2			
class 1	5	Estrie	5	1	0	(-14,-24)	100	0.75
	6	Montréal						
	13	Laval						
	16	Montérégie						
class 2	3	Capitale-Nationale	7	0.7	0.3	(-13,-26)	100	1.10
	4	Mauricie						
	7	Outaouais						
	12	Chaudière-Appalaches						
	14	Lanaudière						
	15	Laurentides						
class 3	2	Saguenay	6	0.7	0.3	(-17,-30)	100	1.30
	8	Abitibi						
	10	Nord-du-Québec						
class 4	1	Bas-Saint-Laurent	5	1	0	(-13,-23)	100	1.95
	9	Côte-Nord						
	11	Gaspésie						



Final thresholds/indicators proposed for each class

Summary : mortality and hospitalization

	RSS	Nom RSS	Episodes #	Optimal weight a0	Optimal weight a1	Thresholds (°C)	Sensitivity (%)	FA (par year)
class 1	5 6 13 16	Estrie Montréal Laval Montérégie	4	0.5	0.5	(-15,-23)	100	0.68
			5	1	0	(-14,-24)	100	0.75
class 2	3 4 7 12 14 15	Capitale-Nationale Mauricie Outaouais Chaudière-Appalaches Lanaudière Laurentides	4	0.5	0.5	(-16,-28)	100	0.68
			7	0.7	0.3	(-13,-26)	100	1.10
class 3	2 8 10	Saguenay Abitibi Nord-du-Québec	5	0.7	0.3	(-20,-29)	67	1.05
			6	0.7	0.3	(-17,-30)	100	1.30
class 4	1 9 11	Bas-Saint-Laurent Côte-Nord Gaspésie	4	0.5	0.5	(-15,-23)	100	1.27
			5	1	0	(-13,-23)	100	1.95



Confounders control

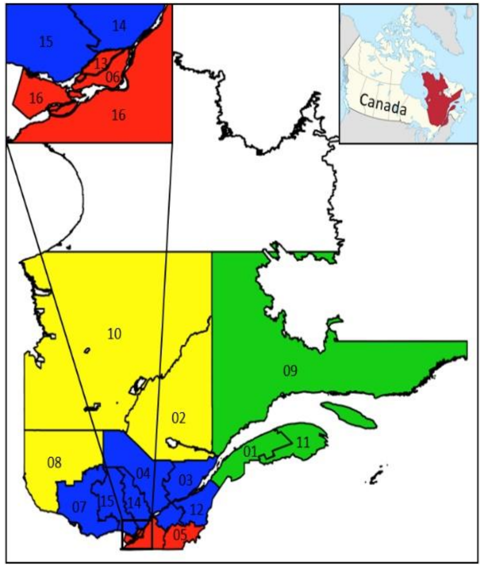
- To evaluate the potential confounding of **influenza** and viral **pneumonia (IVP)**, a sensitivity analysis is performed to isolate the direct effect of cold

- This analysis is applied only on hospit.
  - IVP usually bring more changes on the daily numbers

- Detected episodes: : exactly the same for class 1, 2, 4

  For class 3 (yellow), two more episodes are found,

  but not related to influenza or viral pneumonia



- IVP do not affect the obtained results with the all-cause data (the final cold indicators and thresholds are exactly the same)

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Cold and health

II. Proposed approach for Cold system

Application to the Québec context

III. Other systems (e.g. air pollution)

IV. Some conclusions

III. Other systems and approaches: Warning system for air pollution

The available thresholds do not necessarily reflect pollutants on public health

- Thresholds are similar for all countries, poorly reflect the characteristics of the local population

Proposed system

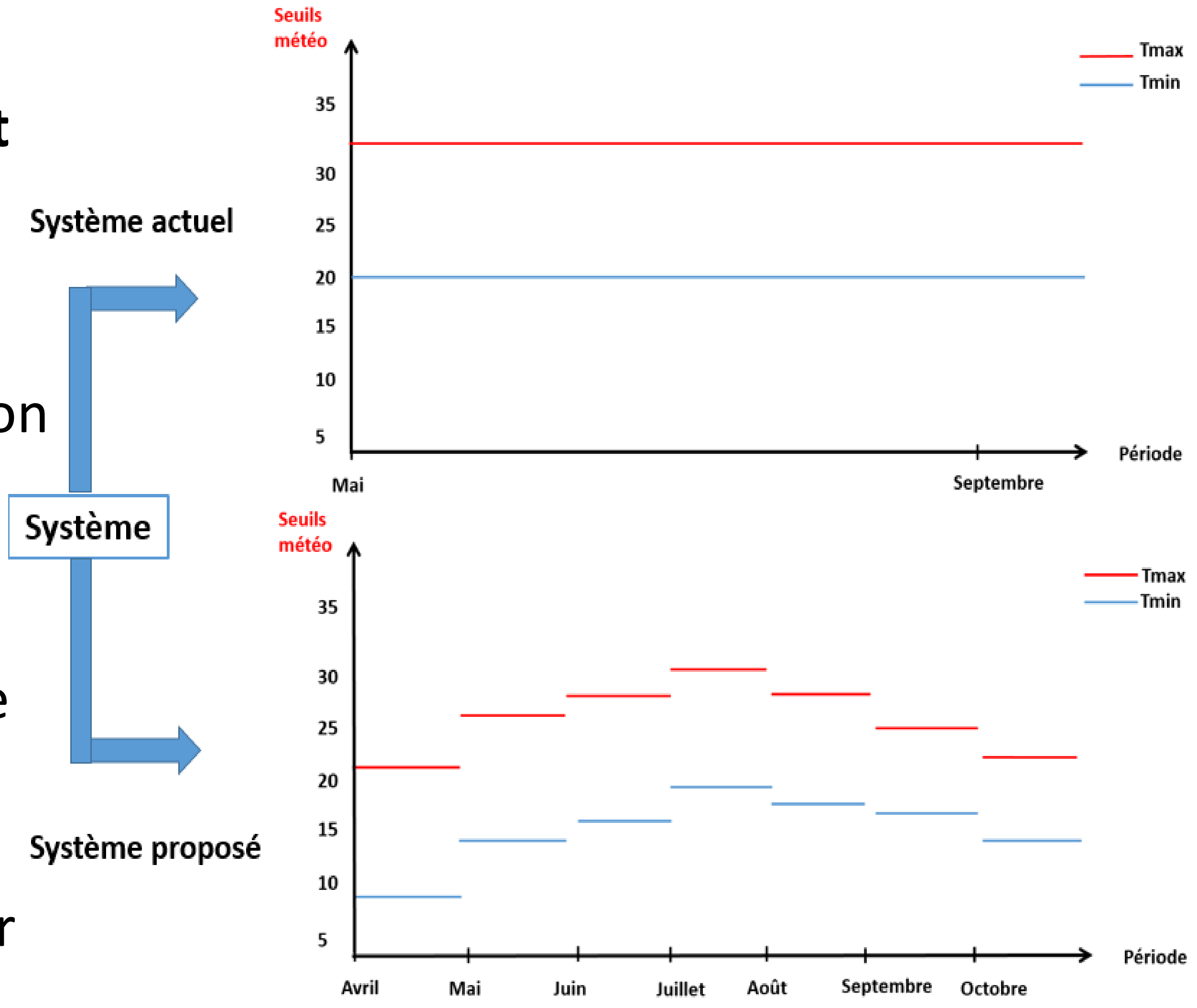
City	Season	$PM_{2.5}$ (µg/m³)			O_x (ppb) O3 and NO2			Sensitivity (%)	FA per Year
		α_0	α_1	*threshold*	α_0	α_1	*threshold*		
Montreal	Summer	0.9	0.1	**31**	0.5	0.5	**43**	87.5	1.5
	Winter	0.5	0.5	**25**	0.8	0.2	**26**	71.4	3.7
Quebec City	Summer	0.5	0.5	**32**	0.8	0.2	**23**	85.7	2.6
	Winter	0.5	0.5	**33**	0.7	0.3	**21**	50.0	7.4

Main difference: performance, much lower in Quebec City than in Montreal

III. Other systems and approaches:

Evolving threshold over extended season

- Current systems generally focus on the **hottest months** of the year and impose the **same threshold** on all these months
- According to climate projections, the hot season is expected to expand and/or shift
- The impacts of heat waves are more serious when the human body is not acclimated to the heat (during **intermediate** seasons)
- Monthly heat thresholds are thus proposed for an extended season (April to October)



IV. Other systems and approaches:
2. Evolving threshold over extended season

Optimum warning threshold for the system (Heat, Mortality, Greater Montréal)

Season	α_0 *Tmax*	α_1 *Tmax*	α_0 *Tmin*	α_1 *Tmin*	Tmax (°C)	Tmin (°C)
Spring	1.0	0.0	0.8	0.2	23	12
	0.5	0.5	1.0	0.0	27	13
Summer	0.8	0.2	0.6	0.4	32	20
	1.0	0.0	0.7	0.3	32	21
	0.6	0.4	0.5	0.5	31	19
Autumn	1.0	0.0	0.6	0.4	28	19
	1.0	0.0	1.0	0.0	25	13

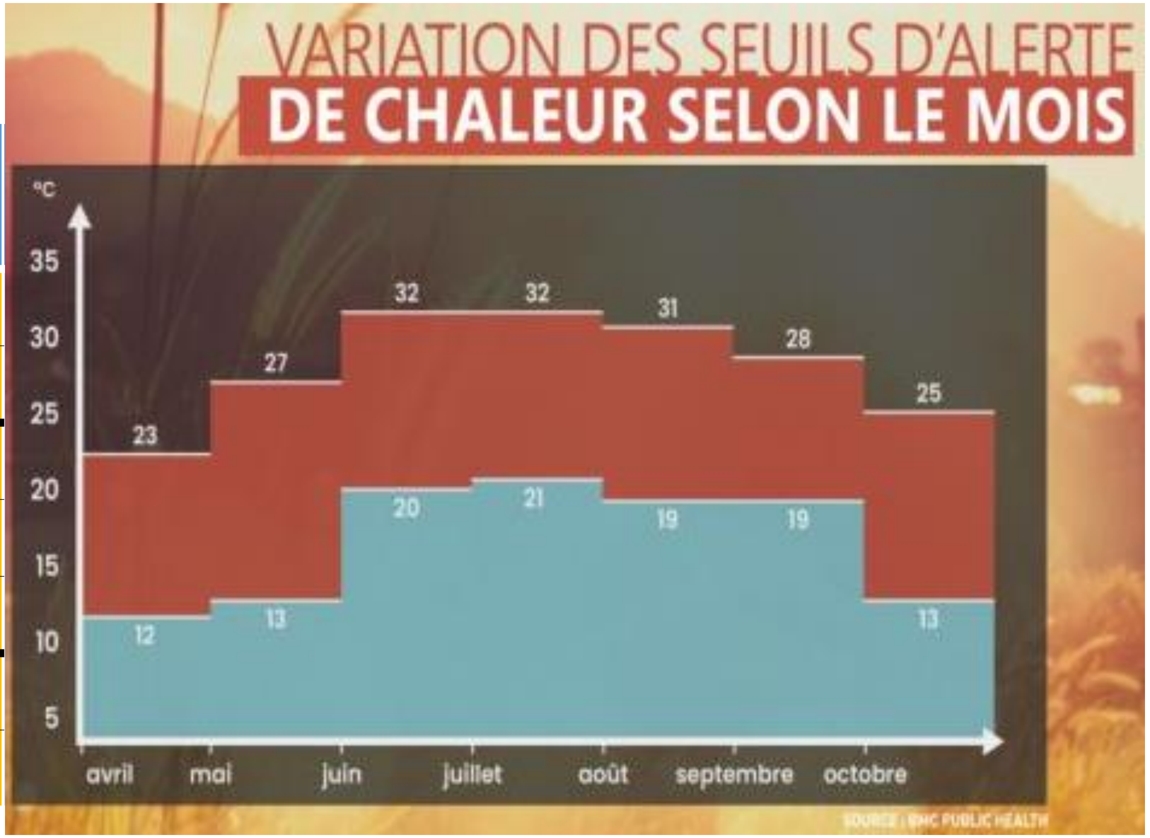


Illustration source: meteo media

Outline

I. Climate-Health context

Alert systems

Cold and health

II. Proposed approach for Cold system

Application to the Québec context

III. Other systems (e.g. air pollution)

IV. Some conclusions

IV. Some concluding remarks

- The present study proposes a starting point to establish a C-HWWS based on H-HWWS in the province of Quebec

- Some methodological improvements are introduced to reduce subjectivity and to adapt to cold

- To cover not only large cities but all regions of the province, a clustering of regions was performed for winter

- For a given class, the thresholds of hospitalization are usually higher than those of mortality

- Confounding variables seem not to affect the obtained results

- **General and flexible methodology: can be applied to other provinces or cities over Canada**

IV. Some thoughts

- Local and on the ground testing of the proposed system is a natural next step to allow better practical adjustments prior official implementations

- The obtained thresholds can be used as preliminary guidelines (to have an idea) in situations where no enough data is evaluable (e.g. establishing cold thresholds for homelessness, school closures)

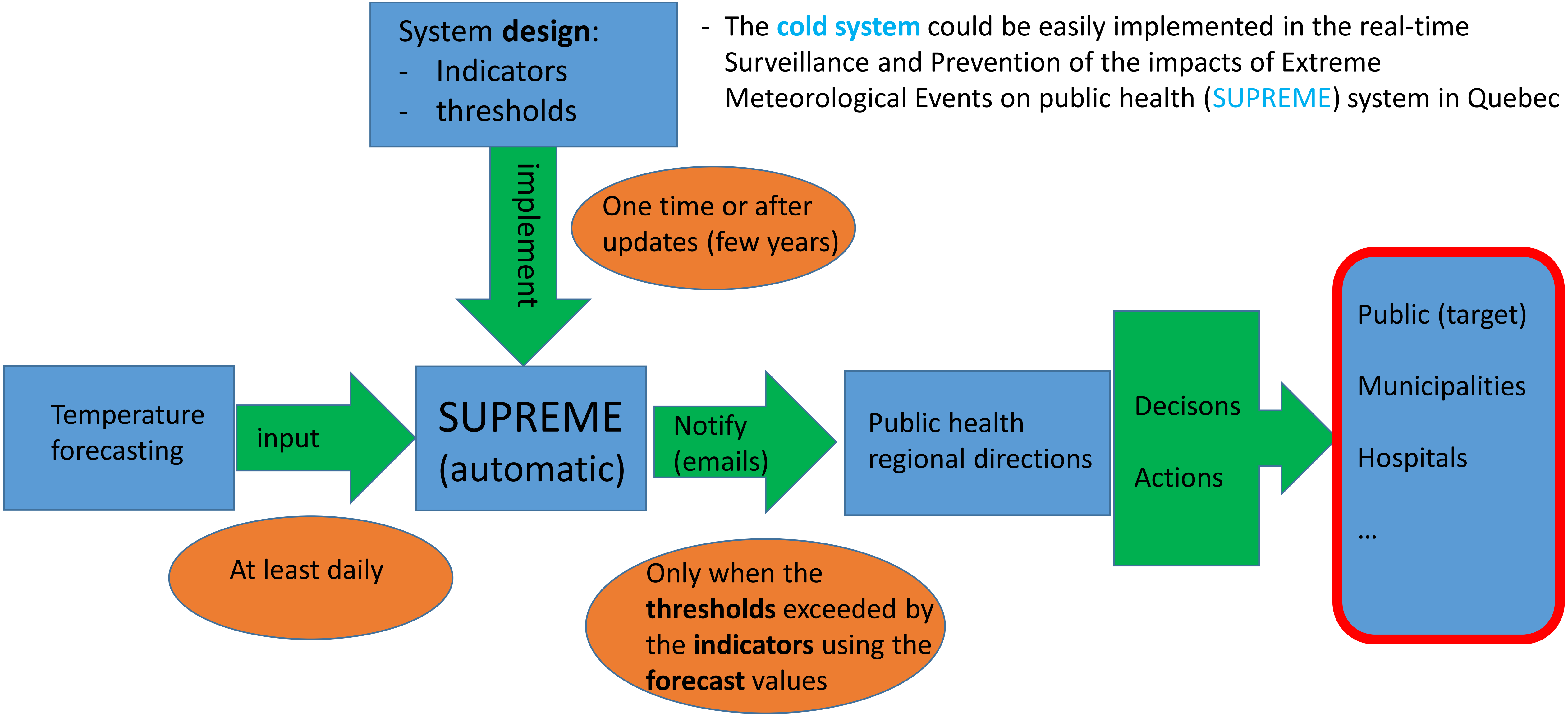
- The obtained thresholds apply to mortalities and hospitalizations, but not for acute cold risks, such as frostbite

- Even if the temperatures will warm up (depending on climate scenarios), and there will be fewer cold snaps, there will still be cold snaps, and we will probably be less adapted

- Cold mortalities will remain in higher compared to heat mortalities, although they will be less in the future

Implementation and operation:

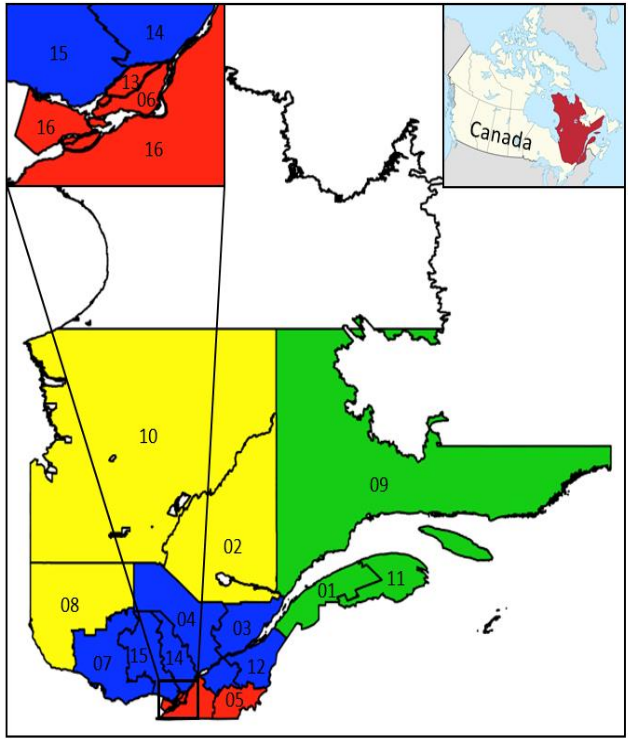
- The **cold system** could be easily implemented in the real-time Surveillance and Prevention of the impacts of Extreme Meteorological Events on public health (SUPREME) system in Quebec



Final thresholds/indicators proposed for each class

Summary : mortality and hospitalization

	RSS	Nom RSS	Episodes #	Optimal weight a0	Optimal weight a1	Thresholds (°C)	Sensitivity (%)	FA (par year)
class 1	5 6 13 16	Estrie Montréal Laval Montérégie	4	0.5	0.5	(-15,-23)	100	0.68
			5	1	0	(-14,-24)	100	0.75
class 2	3 4 7 12 14 15	Capitale-Nationale Mauricie Outaouais Chaudière-Appalaches Lanaudière Laurentides	4	0.5	0.5	(-16,-28)	100	0.68
			7	0.7	0.3	(-13,-26)	100	1.10
class 3	2 8 10	Saguenay Abitibi Nord-du-Québec	5	0.7	0.3	(-20,-29)	67	1.05
			6	0.7	0.3	(-17,-30)	100	1.30
class 4	1 9 11	Bas-Saint-Laurent Côte-Nord Gaspésie	4	0.5	0.5	(-15,-23)	100	1.27
			5	1	0	(-13,-23)	100	1.95



Some selected resources

hhws Public
Functions for heat-health warning systems
R

Paper--2019--Air-pollution-warning-system Public
R code for the air pollution-health warning system in the province of Quebec
R

https://github.com/PierreMasselot

- Yan, B., Chebana, F., Masselot, P., Campagna, C., Gosselin, P., Ouarda, T. B., & Lavigne, É. (2020). A **cold-health** watch and warning system, applied to the province of Quebec (Canada). *Science of The Total Environment*
- Health Canada (2022) Health of Canadians in a Changing Climate.
- Issa, Chebana, Masselot, Campagna, Lavigne, Gosselin, Ouarda (2020). A Heat-Health Watch and Warning System with Extended Season and Evolving Thresholds. *BMC Public Health*
- Masselot, Chebana, Lavigne, Campagna, Gosselin, Ouarda (2019) Toward an Improved Air Pollution Warning System in Quebec. *Int. J. Env. Res. Public health*
- Gasparini et al. (2017) Projections of temperature-related excess mortality under climate change scenarios. The Lancet Planetary Health
- Chebana, F., Martel, B., Gosselin, P., Giroux, J. X., & Ouarda, T. B. (2013). A general and flexible methodology to define thresholds for heat health watch and warning systems, applied to the province of Québec (Canada). *Inter. J. biometeorology*

MERCI, THANK YOU

"…*warning systems* ~~models~~ are like maps: never final, never complete until they grow as large and complex as the reality they represent" James Gleick

Québec

- Institut national de santé publique
- Ministère de la Santé et des Services sociaux