A cold-health watch and warning system, application to the province of Quebec

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Background & Objective

- Extreme cold weather has serious impacts on human life and health.
- Almost no studies focused on cold warning systems to prevent those health effects.
- In Nordic regions, winter mortality is generally higher than the rest of the year such as in the province of Quebec in Canada.
- **Objective**: establish a watch and warning system specifically for health impacts of cold, applied to different climatic regions of the province of Quebec.

Data

- **Location**: 16 heal regions (denoted RSS) of Québec.
- **Period:** December to March, 1994-2015
- **Weather variables:** daily temperatures (max, min, mean), wind speed (max, min, mean) and vapor pressure.
- **Health variables:** daily all-cause mortality and the daily all-cause hospitalization data for each RSSs.

Considered mthods

RSS clustering: use a hierarchical agglomerative clustering (HAC) on the daily climatic variables of the 16 RSSs of Quebec.

Cold warning system

The objective is to estimate temperature indicators and thresholds for each class of RSS. The considered method contains four main steps:

1. Choose appropriate lags for cold indicators, by a distributed lag non-linear model (DLNM). The cold indicators are define as $S_t = \sum_{l=0}^{L} \alpha_l X_{t-l}$, where X_t are the forecast temperatures of *Tmax* and *Tmin* at day t, and α_l are the weightings such that:

$$\begin{cases} \alpha_i \geq \alpha_j, for\ i < j < L \\ \sum_{l=0}^{L} \alpha_l = 1 \end{cases}$$

2. Compute the over-health (OH, includes over-mortality and over-hospitalization) series from the daily mortality and hospitalization: $OH_t = \frac{OD_t - ExpD_t}{ExpD_t} * 100 \ \ (\%)$. Determine the threshold of OH (OHT).

3. Determine the cold-related historical episodes of OH

4. Choose the appropriate indicators and corresponding thresholds, sensitivity and false alarms (FA) are used to evaluate the performance of results.

Results

RSS clustering :

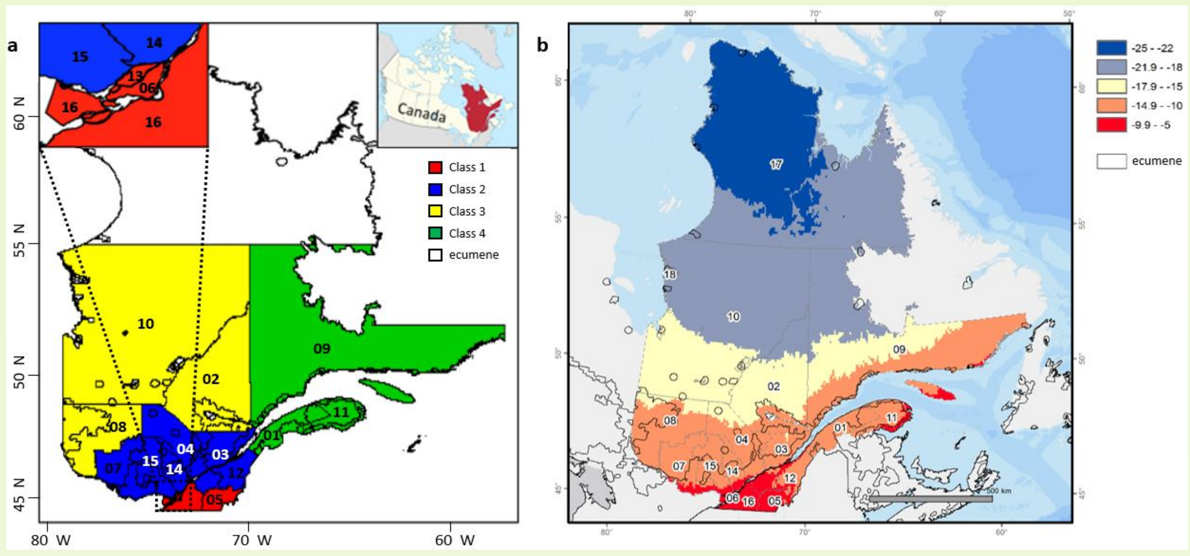

Fig. 1 a Grouping of the 16 RSSs of the province of Quebec for the winter period. **b** Quebec climatic map based on the average temperature of 1981-2010 (winter period only)

The final clustering (Fig. 1a) is geographically homogeneous and shows good agreement with the climatic map (Figure 1b)

Step 1: lag for cold indicators

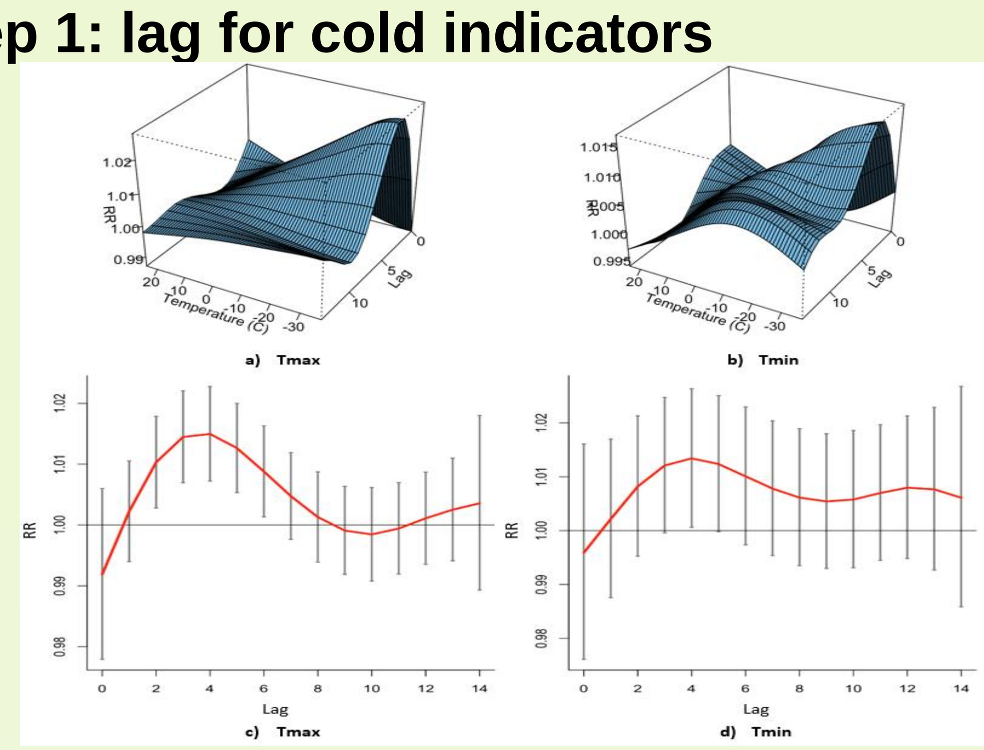

Fig. 2 **a)** DLNM surfaces between Tmax and mortality. **b)** DLNM surfaces between Tmin and mortality. Lag-response relationships between daily mortality and *Tmax* **(c)** and *Tmin* **(d)** for winter period of class 1, at *Tmax=-12 °C / Tmin=-23 °C*, grey bars show 95% CI.

A lag of *L*=4 is chosen for Tmax and Tmin

Step 2-3: calculate OH series and determine cold related historical episodes

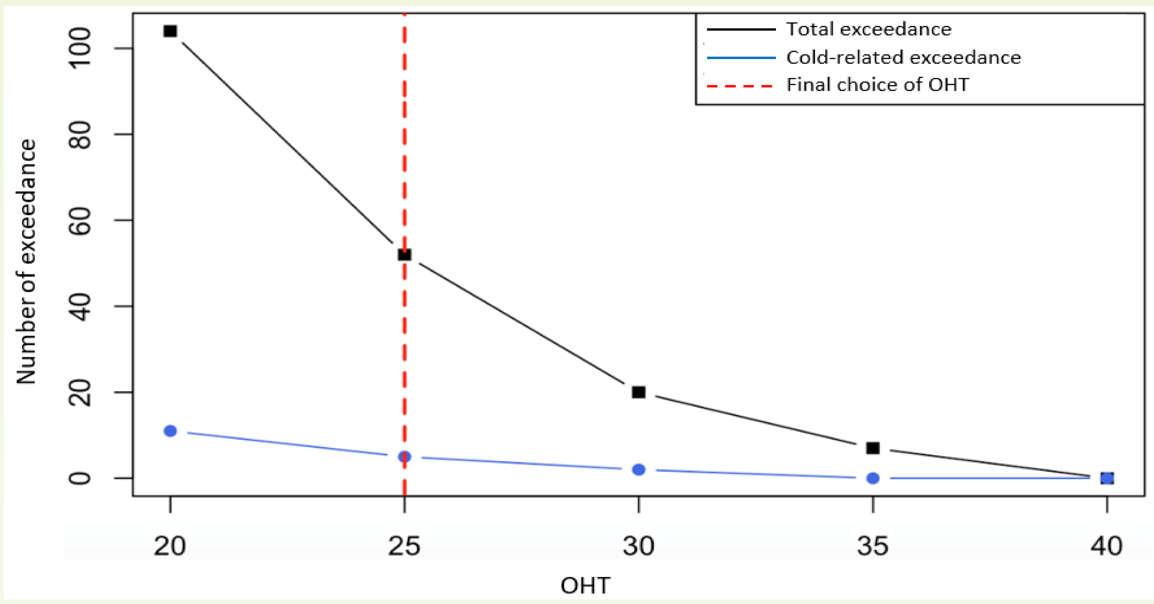

Fig. 3 Total exceedance function and the cold-related exceedance function. For mortality data and for class 1.

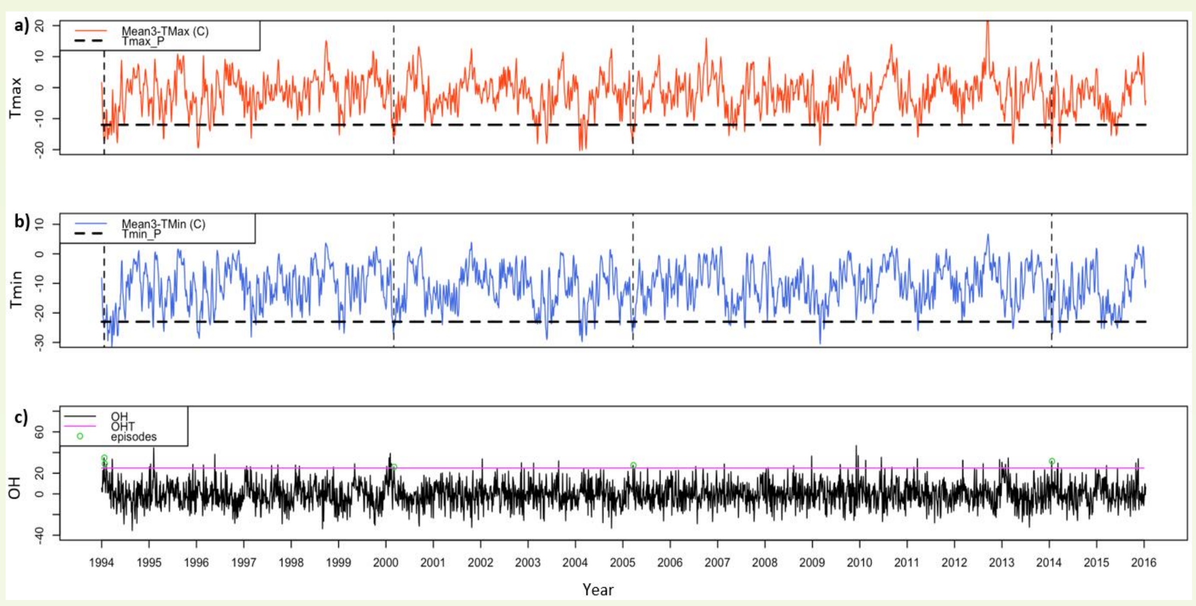

Fig. 4 **:** Temperature series and OH (mortality) series for class 1. **a)** *Tmax* series and preliminary threshold. **b)** *Tmin* series and preliminary threshold. **c)** OH series and the detected episodes with OHT=25%.

Step 4: final indicators and corresponding thresholds

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

Tab. 1 Results of optimal indicator weightings and thresholds for classes 2-4. Results of mortality data showed in orange color.

Conclusion

- For over-mortality, the final health-related thresholds proposed are between (-15 °C, -23 °C) and (-20 °C, -29 °C) according to the climatic region
- For over-hospitalisation, the fina thresholds proposed are between (-13 °C, -23 °C) and (-17 °C, -30 °C).
- The results suggest that the current system model has a high sensitivity and an acceptable number of false alarms.
- This could also help the public health authority to establish the cold-health watch and warning system with valid indicators and thresholds for each climatic region of Quebec.
- It can be seen as a complementary system to the existing one for heat warnings, in order to help the public health authorities to be well prepared during an extreme cold event.

Further informations : Yan et al. 2020, A cold-health watch and warning system, applied to the province of Quebec (Canada)