Joint occurrence of daily temperature and precipitation extreme events over Canada

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Introduction

The occurrence of individual extremes such as temperature and precipitation extremes can have a great impact on the environment. Agriculture, energy demands, and human health, among other activities, can be affected by extremely high or low temperatures and by extremely dry or wet conditions. However, the simultaneous or proximate occurrence of both types of extremes could lead to even more profound consequences. For example, a dry period can have more negative consequences on agriculture if it is concomitant with or followed by a period of extremely high temperatures. The relationship between temperature and precipitation has been studied mostly in terms of mean values. The main objective of this study is to answer the question: ***Is there a significant relation between the occurrence of heavy precipitation and extreme temperature events in Canada?***

Data

Daily precipitation, minimum and maximum temperature from the Adjusted and Homogenized Canadian Climate Data (AHCCD, Mekis and Vincent, 2011; Vincent et al, 2012) in the period 1980-2004 for 293 stations are used.

Simulated historical daily precipitation, minimum and maximum temperature from the NARCCAP project (Mearns et al, 2007, 2011) were also used to determine whether RCMs are able to simulate the joint distribution of extreme events.

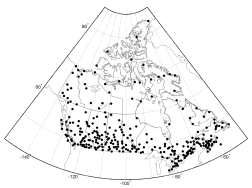

Figure 1. Stations used in this study (293 stations) in the period 1980-2004.

RCM \ GCM	CCSM	CGCM3	GFDL	HadCM3	NCEP
HRM3			X	X	X
RCM3		X	X		X
WRFG	X	X			X

Table 1. RCMs used in this study driven by NCEP in the period 1980-2004 and by two different GCMS each in the period 1971-2000.

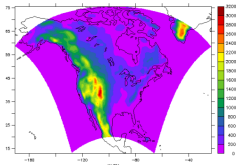

Figure 2. NARCCAP domain, with 50km resolution.

Definition of extremes

Name	Description
Heavy precipitation (Pr75)	daily precipitation above 75th percentile (computed over rainy days only)
Warm nights (Tn90)	daily minimum temperature above 90th percentile
Cold nights (Tn10)	daily minimum temperature below 10th percentile
Warm days (Tx90)	daily maximum temperature above 90th percentile
Cold days (Tx10)	daily maximum temperature above 90th percentile
Joint extreme	Pr75 and one of the temperature extremes occurring together

Table 2. Definition of the extreme events used in this study.

Methodology

The percentage of heavy precipitation events over all extreme temperature events was computed for each season and station in the period 1980-2004. This value is expressed as a ratio over the expected percentage of joint extreme events. Therefore, values greater than 1 show a ***positive*** relationship between the temperature and precipitation extremes, and values lower than 1 show a ***negative*** relationship. The significance of the relationship was defined based on a Chi-square test at the 5% significance level.

Observed joint extremes

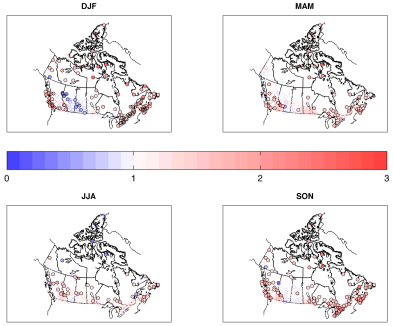

Figure 3. Percentage of warm nights occurring simultaneously with heavy precipitation events (Pr75 & Tn90) per season, expressed as a ratio over the expected value (see methodology for more detail). Filled symbols indicate a significant relationship at the 5% level.

Pr75 & Tn90	Positive		Negative	
	Mean (%)	Significant stations (%)	Mean (%)	Significant stations (%)
DJF	25.6	59.9	8.2	8.8
MAM	18.6	28.5	9.5	1.0
JJA	16.9	20.9	9.2	5.4
SON	22.6	49.5	9.1	1.9

Table 3. Global mean of the percentage of warm nights occurring simultaneously with heavy precipitation events (Pr75 & Tn90) per season and percentage of stations with a significant relationship at the 5% level, grouped by signed of relationship.

Pr75 & Tx10	Positive		Negative	
	Mean (%)	Significant stations (%)	Mean (%)	Significant stations (%)
DJF	13.6	3.2	5.1	45.4
MAM	22.2	36.6	7.2	12.1
JJA	30.6	45.8	12.1	0.0
SON	19.8	25.8	10.9	12.7

Table 4. Global mean of the percentage of cold days occurring simultaneously with heavy precipitation events (Pr75 & Tx10) per season and percentage of stations with a significant relationship at the 5% level, grouped by signed of relationship.

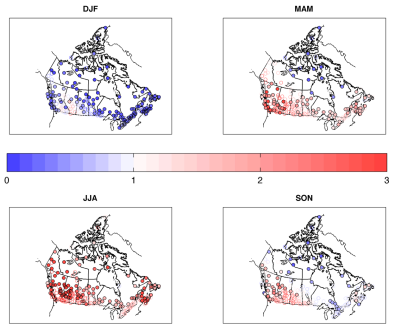

Figure 4. Percentage of cold days occurring simultaneously with heavy precipitation events (Pr75 & Tx10) per season, expressed as a ratio over the expected value (see methodology for more detail). Filled symbols indicate a significant relationship at the 5% level.

Simulated joint extremes

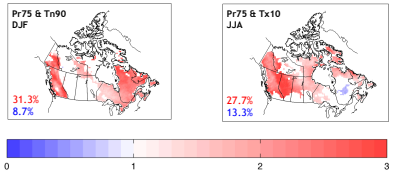

Figure 5. Percentage of (left) warm nights (Tn90) in winter and (right) cold days (Tn10) in summer occurring simultaneously with heavy precipitation events (Pr75), expressed as a ratio over the expected value, as simulated by the ensemble of the RCMs driven by NCEP reanalysis. Only grid points with a significant relationship at the 5% level are shown. Numbers in the bottom left corner show global means of the actual joint extreme occurrence (percentage of Pr75 over temperature extreme days) for all grid points with a positive (red) and negative (blue) relationship.

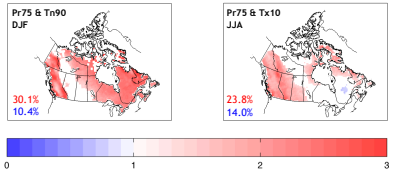

Figure 6. Percentage of (left) warm nights (Tn90) in winter and (right) cold days (Tn10) in summer occurring simultaneously with heavy precipitation events (Pr75), expressed as a ratio over the expected value, as simulated by the ensemble of the RCMs driven by GCMs. Only grid points with a significant relationship at the 5% level are shown. Numbers in the bottom left corner show global means of the actual joint extreme occurrence (percentage of Pr75 over temperature extreme days) for all grid points with a positive (red) and negative (blue) relationship.

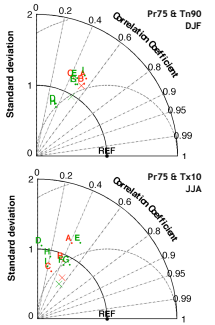

Figure 7. Spatial Taylor diagrams of the combined extreme events of heavy precipitation events (Pr75) and (upper panel) warm nights (Tn90) in winter and (lower panel) cold days (Tx10) in summer, comparing model simulations with observations. Standard deviations and root mean square differences are normalized by the reference standard deviation. Red letters indicate RCMs driven by NCEP, green letters indicate RCMs driven by GCMs. Crosses show the ensemble of all the RCM.

Conclusions

- ✓ There is a significant relation between the simultaneous occurrence of heavy precipitation events and warm nights in Canada, strongest and positive in the western and southeastern coasts, during fall and winter, and negative on the west side of the Rocky Mountains.
- ✓ Similar results are found for heavy precipitation events and warm days (not shown).
- ✓ There is a significant relation between the simultaneous occurrence of heavy precipitation events and cold days in Canada, strongest and positive during spring and summer, while the relationship is negative during winter.
- ✓ Cold nights and heavy precipitation events have a negative relationship throughout the year (not shown).
- ✓ Overall, RCMs succeed in reproducing the seasonality of the joint extremes, as well as the spatial distribution, although some models present large biases.
- ✓ The negative relationship between warm extremes and heavy precipitation events in winter on the west side of the Rocky Mountains was not captured by the models.

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