

Relationship between surface temperature and extreme rainfalls: a multi-timescale and event-based analysis

Panthou G., Mailhot A., Laurence E., Talbot G.

GEWEX conference (Topic 4 : Observations and changes in climate extremes)

The Hague, The Netherlands, 15/07/2014

I. Introduction

Context

Global warming

- Temperature increase is observed in climate series
- Most of CMIP5 simulations predict an increase ranging from $1^{\circ}C$ to $4^{\circ}C$ until the end of the xxith century

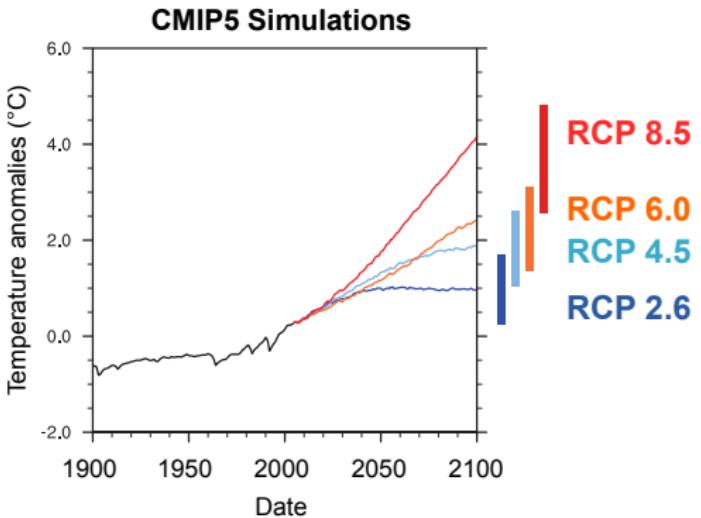


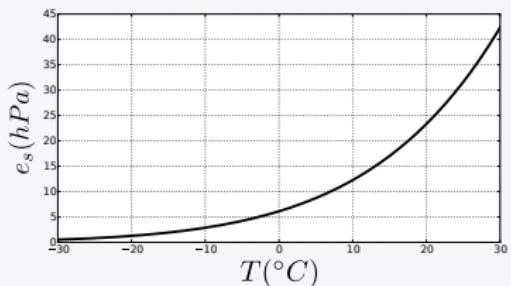
FIGURE : Source : IPCC [2013]
GEWEX conference, The Hague, 15/07/2014

Context

Impact on extreme rainfalls ?

Clausius–Clapeyron

$$\alpha_{C-C} \approx 7\% \cdot K^{-1}$$

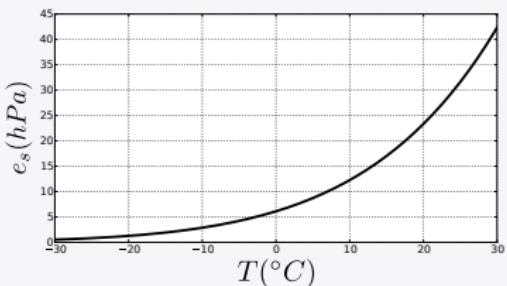


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Hypotheses C-C [*Trenberth et al., 2003*]

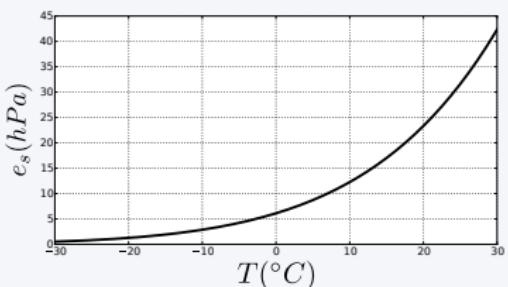
- HYP-1 : Constant relative humidity
- HYP-2 : Extreme rainfalls are driven by the actual atmospheric moisture
- HYP-3 : Atmospheric circulation does not impact extreme rainfalls

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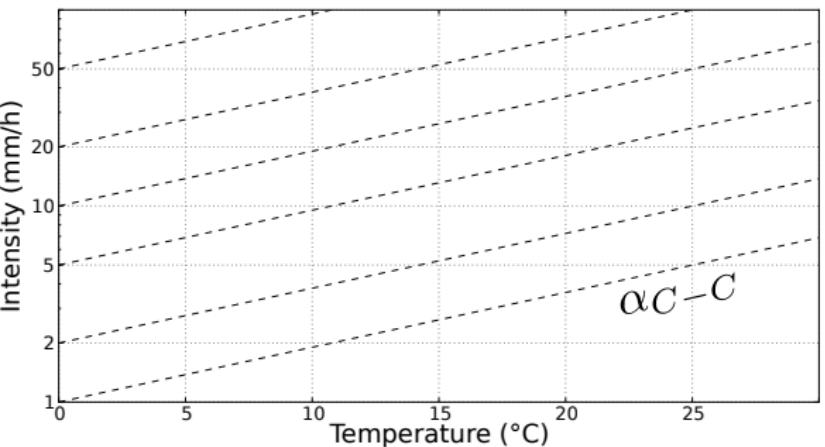
Increase of extreme rainfall would be equal to $\alpha_{C-C} \approx 7\%.K^{-1}$

Motivations

Relationship between P_{extr} and T_a

- Verify the C-C scaling hypotheses
- Better understand the processes involved in the increase of extreme rainfalls

High percentile (e.g. 95 th)

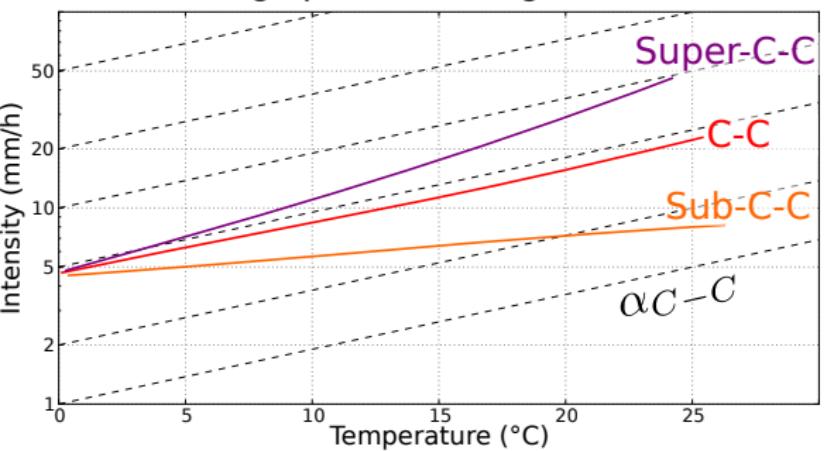


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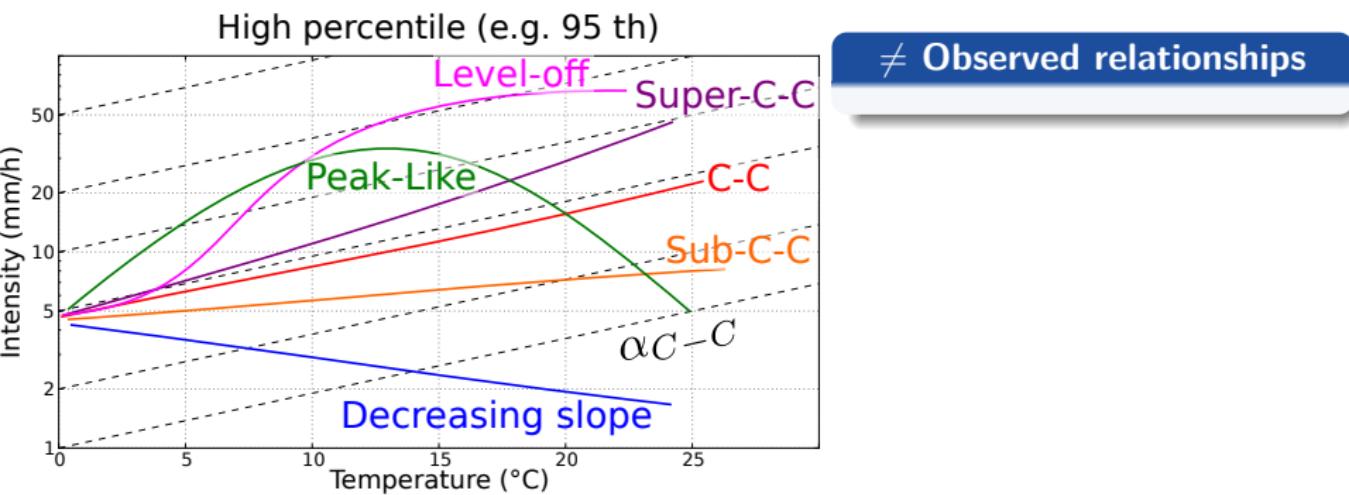


\neq Observed relationships

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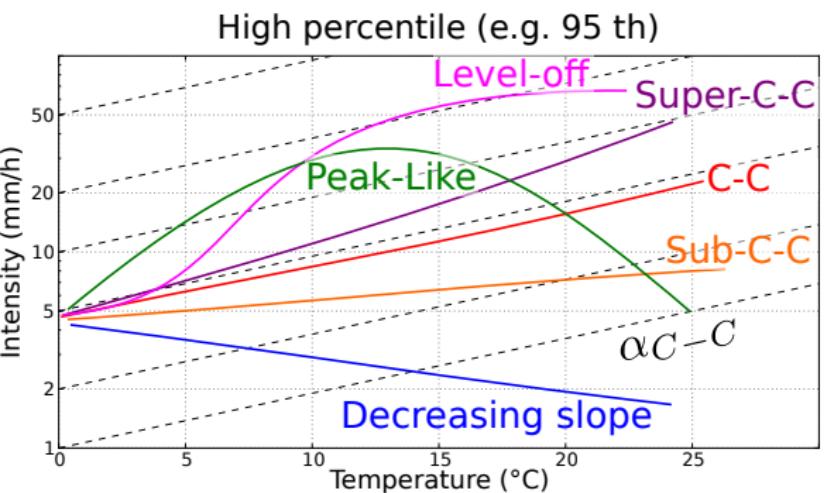
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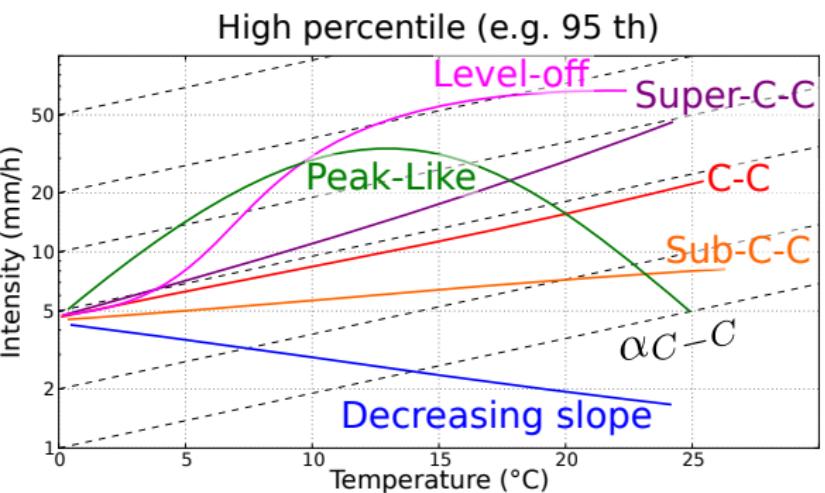
Factors affecting $P_{\text{extr}}(T_a)$

- Quantile [Hardwick Jones et al., 2010]
- Season [Berg et al., 2009]
- Duration [Haerter et al., 2010]
- Region [Utsumi et al., 2011]

Motivations

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Issues and lacks

- No study for the Canada
- Explanation of C-C scaling departures are under debate
- Published studies generally focus on one or two C-C hypotheses : none have analysed the three C-C hypotheses

Objective of the study

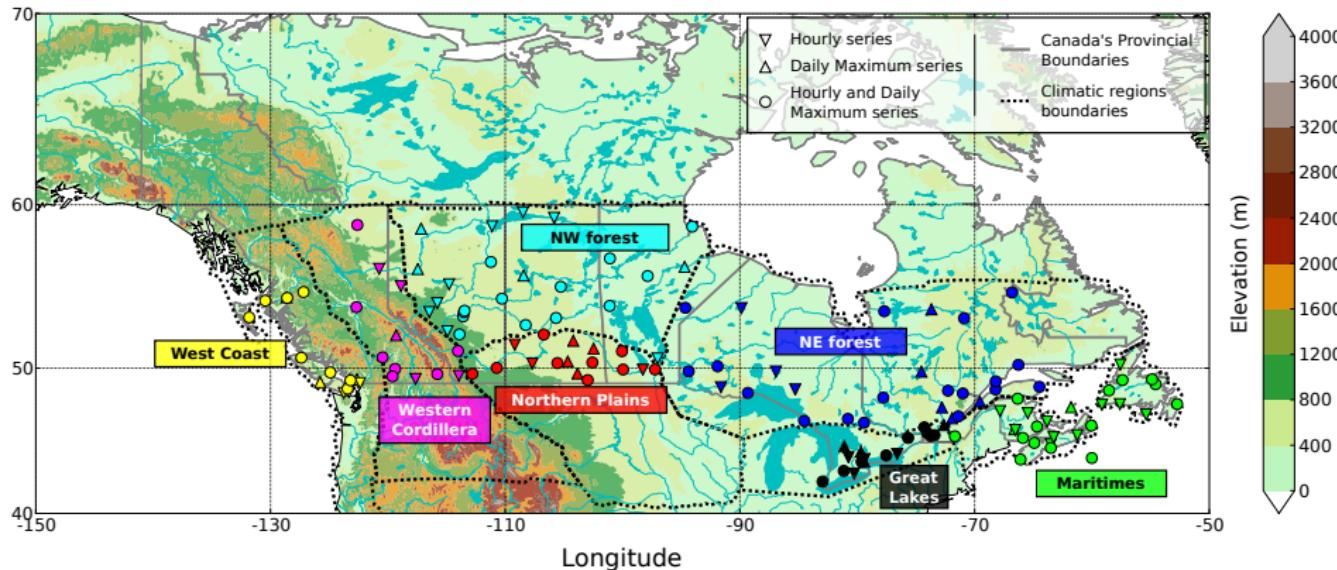
Analyse the three C-C scaling hypotheses over Canada

II. Data and methodology

Recorded series

≈ 100 meteorological stations

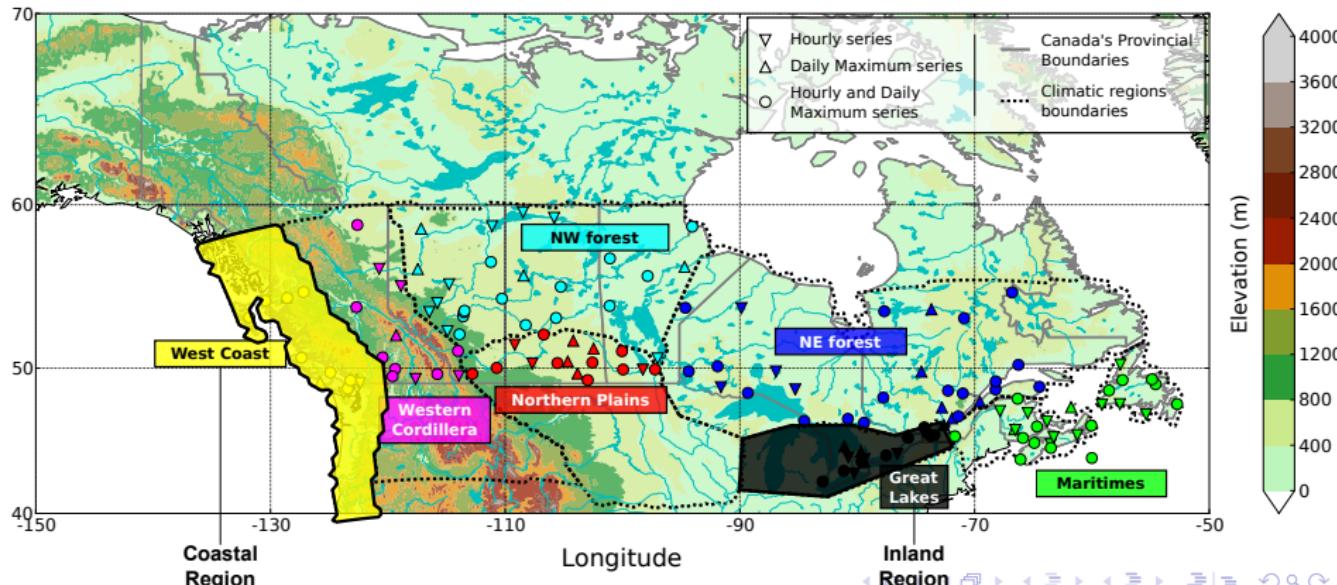
- Rainfall series (various durations)
- Mean daily temperature : T_{air} and T_d (Dew point temperature)



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Canadian Regional Climate Model simulations

Experiment

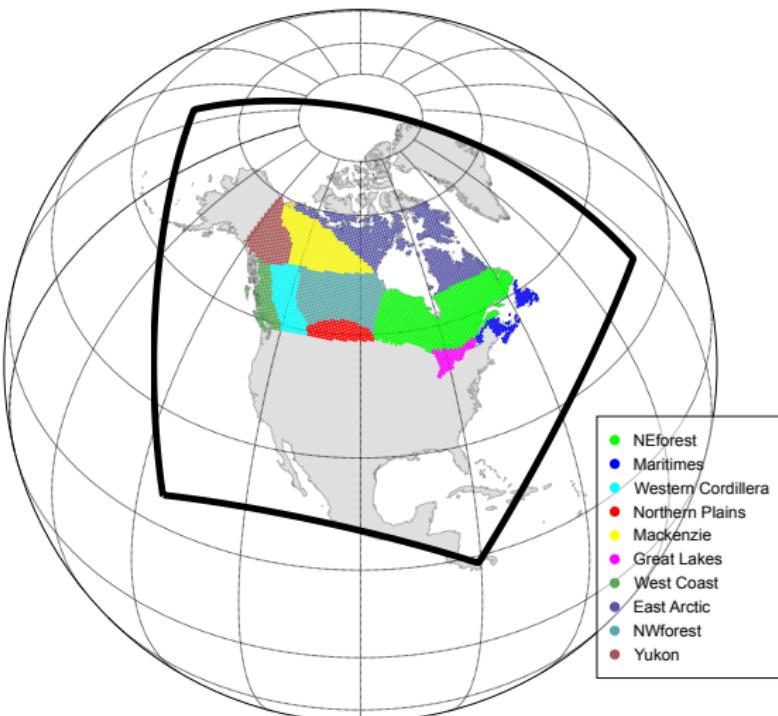
- Pilot : CGCM3.1v2
- GES scenario : SRES A2
- Domain : North America
- Spatial resolution : 45×45 km

Variables

- Precipitations
- T_a , specific humidity (T_d)
- Air instability (CAPE),
moisture divergence flux

Periods

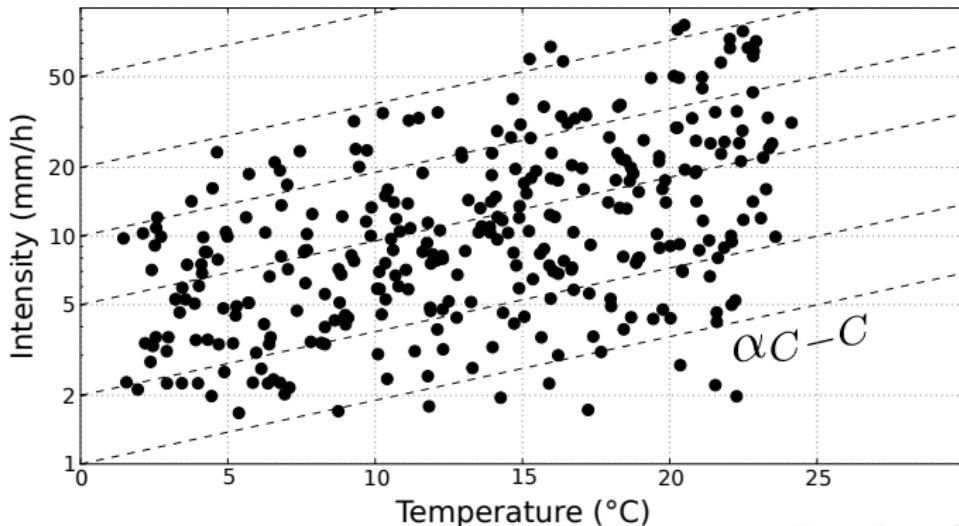
1961-1990 and 2071-2100



$P_{extr}(T_a)$ relationship

Approach firstly proposed by *Lenderink and van Meijgaard [2008]*

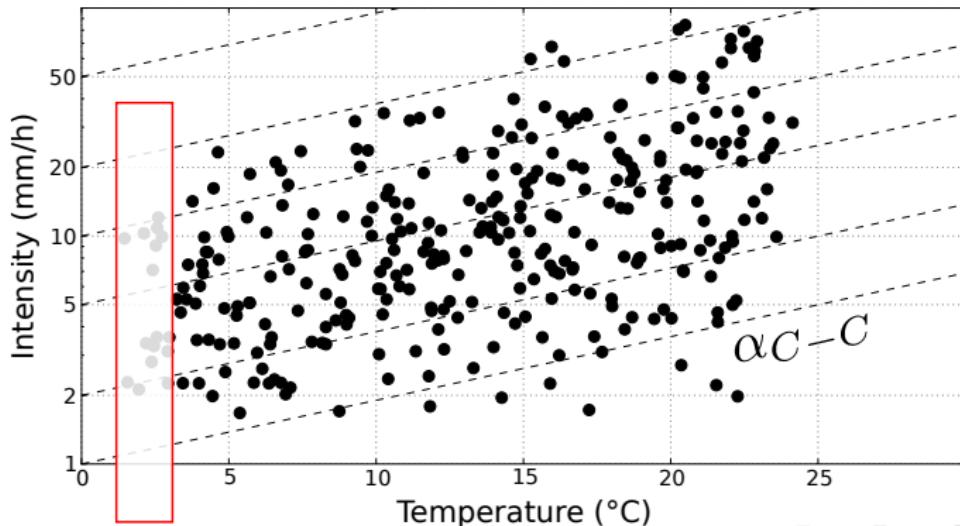
- Temperature bins : 2°C
- Percentile computation : e.g. 95th
- Moving window : 1°C



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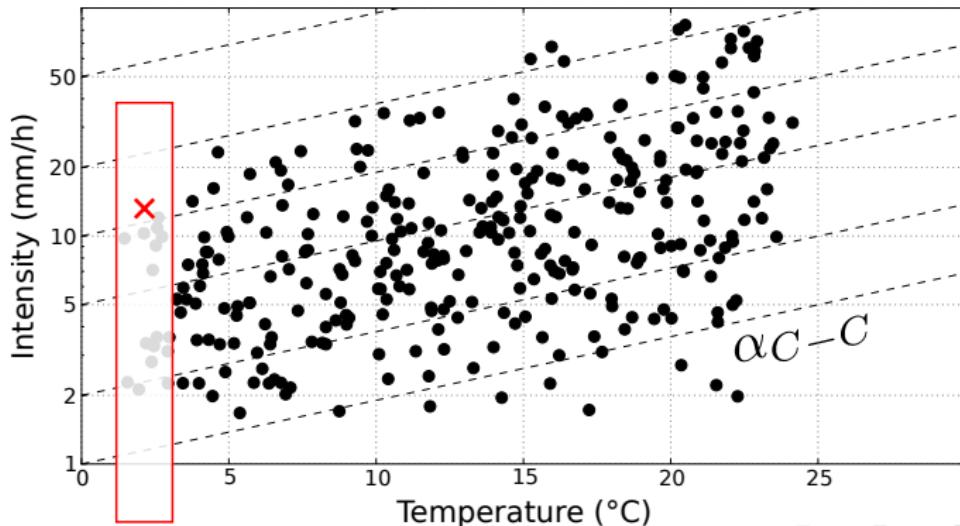
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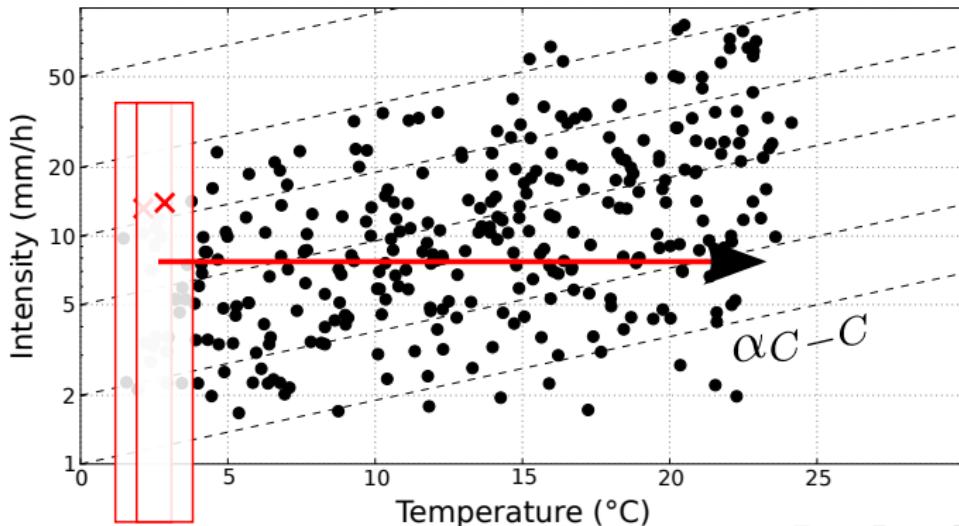
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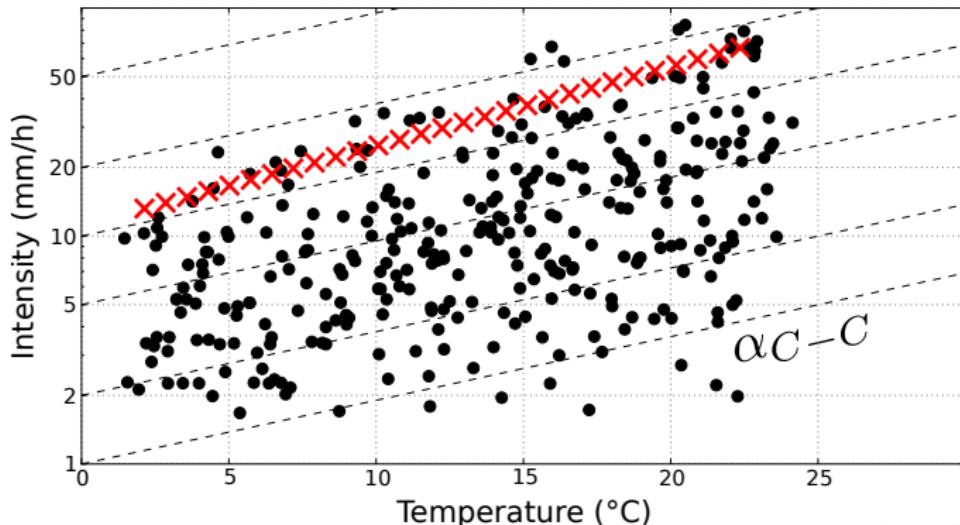
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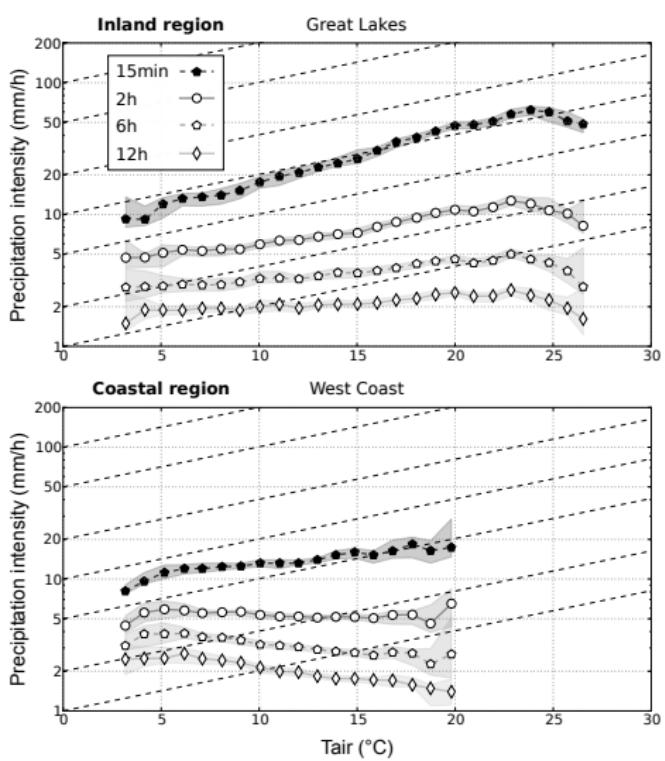
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III. Results $P_{extr}(T_a)$ from recorded series

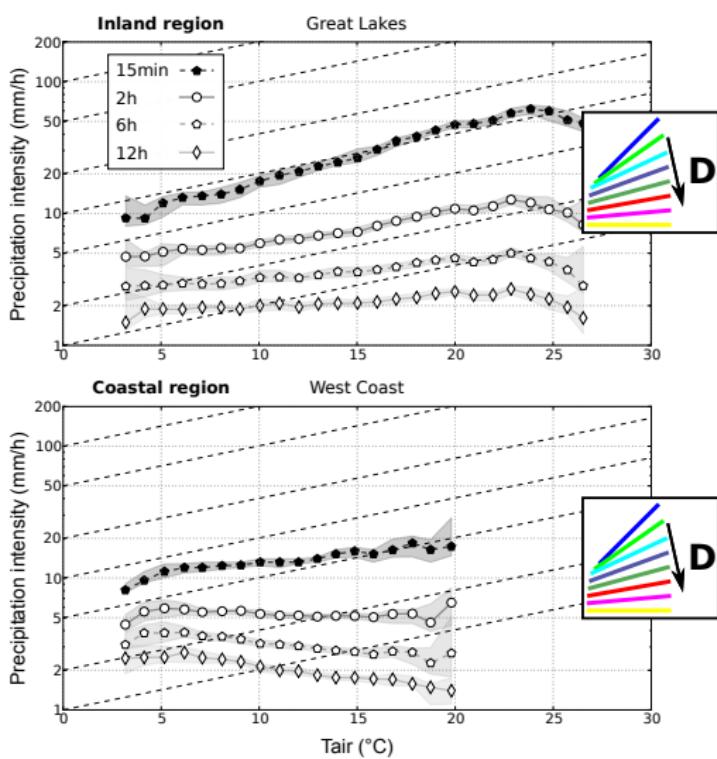
Results : 95th percentile



Factors having a minor impact

- Season
- Percentile (80th, 90th, 95th, 99th have been tested)

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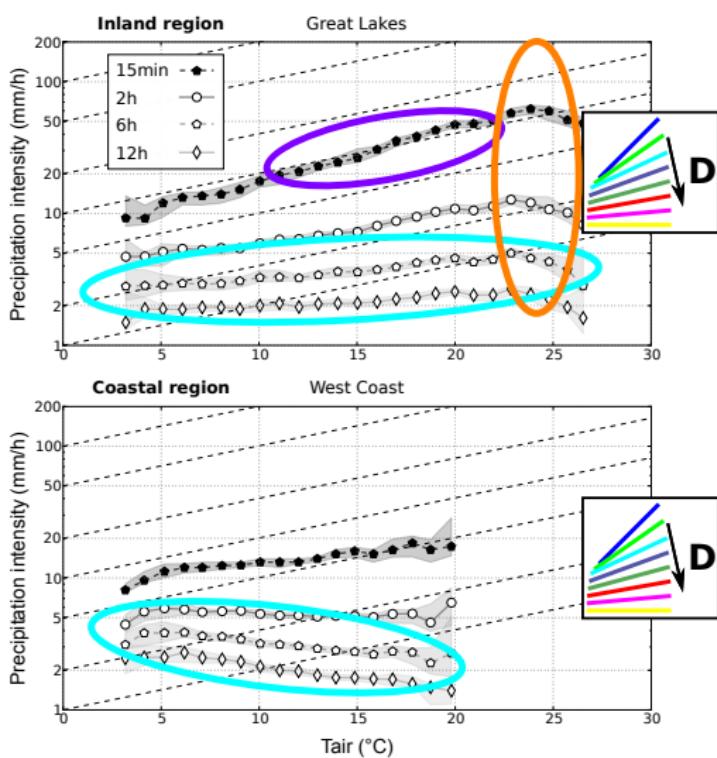
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Factors having a strong impact

- Duration
- Region

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Factors having a strong impact

- Duration
- Region

IV. Testing the three C-C scaling hypotheses

HYP-1 : Constant relative humidity

Dew point temperature

- *Lenderink and van Meijgaard [2010]*
- Measure of atmospheric moisture
- Dew point depression
 - $= T_{air} - T_{dew}$
 - cst if relative humidity = cst



If relative humidity = cst

⇒ The $P_{extr}(T_a)$ shape is **similar** to the $P_{extr}(T_d)$ shape

If relative humidity \neq cst

⇒ The $P_{extr}(T_a)$ shape is **different** to the $P_{extr}(T_d)$ shape

HYP-1 : Constant relative humidity

 $P_{extr}(T_a)$

V.S.

 $P_{extr}(T_d)$

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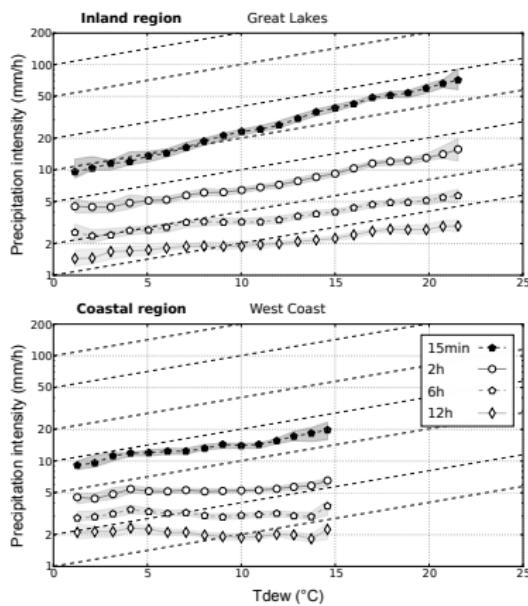
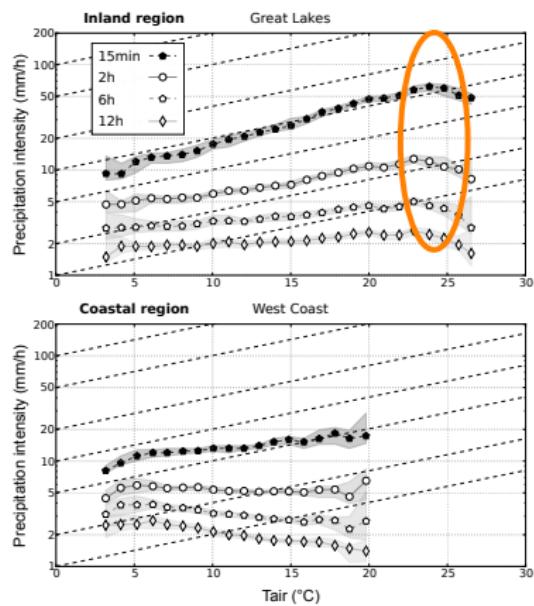
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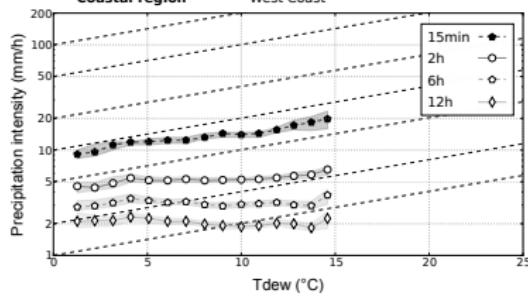
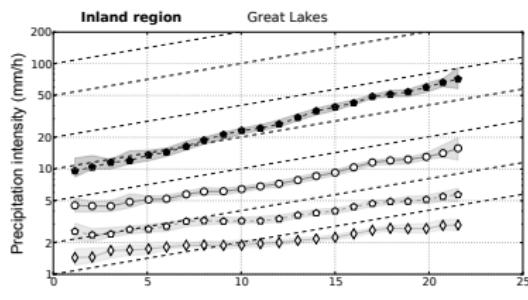
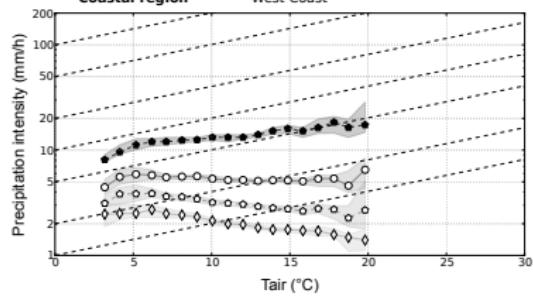
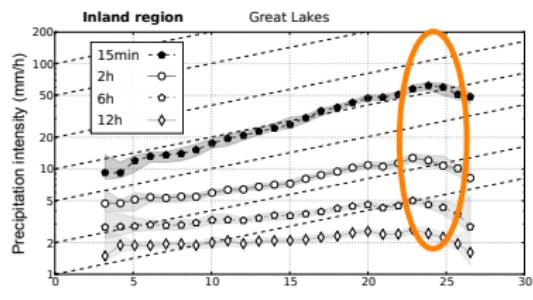
Relative humidity : limiting for inland regions, not for coastal regions

HYP-1 : Constant relative humidity

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Same conclusion in a future climate (CRCM simulations)

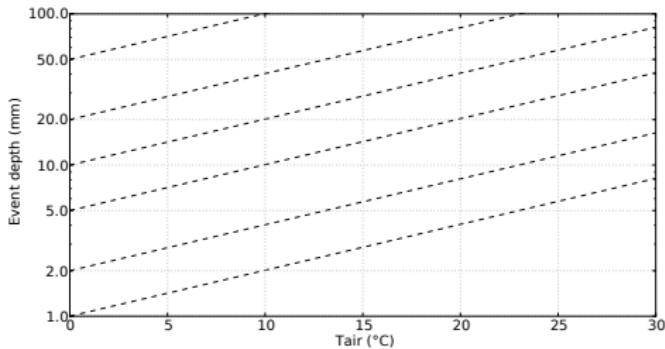
HYP-2 : Extreme rainfalls are driven by atm. moisture

Event-based analysis

If $P_{extr}(T) \neq 7\%.K^{-1}$

- Which other factors are involved ?
- Synoptic vs convective events

Inland region : Great Lakes



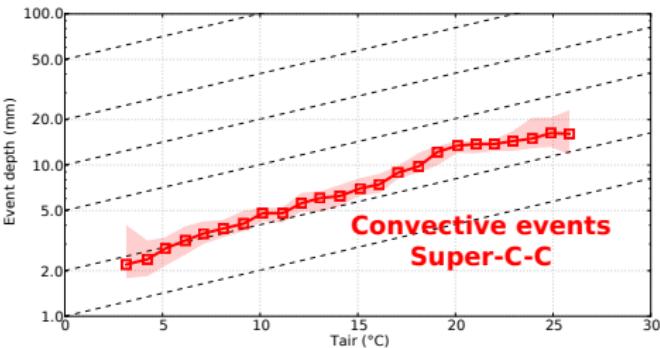
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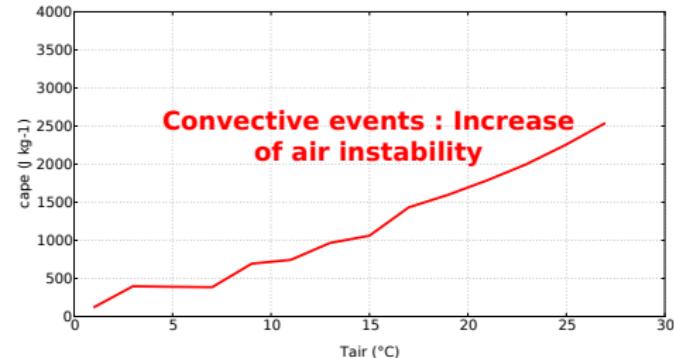
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CAPE



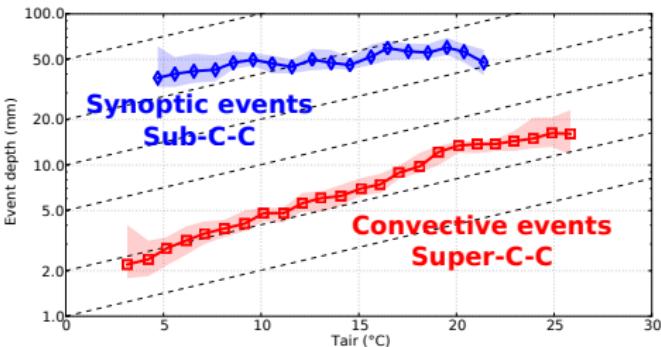
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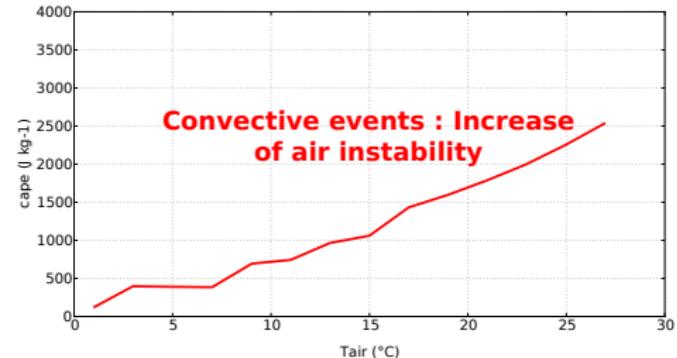
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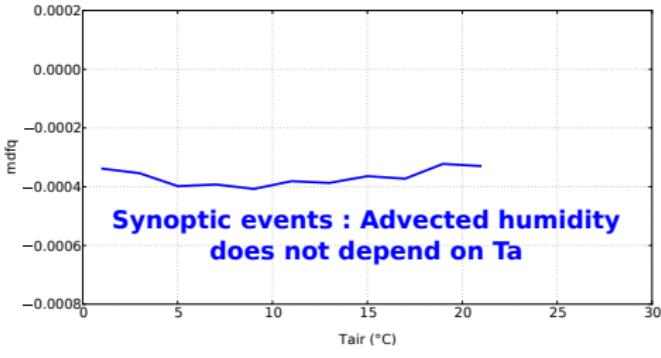


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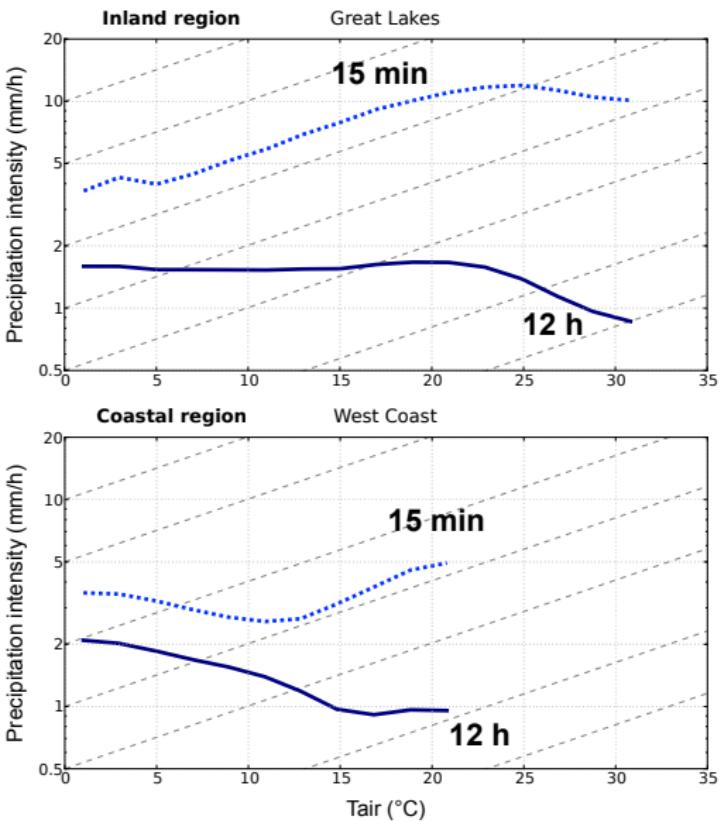
Convective events : Increase of air instability

Divergence Flux



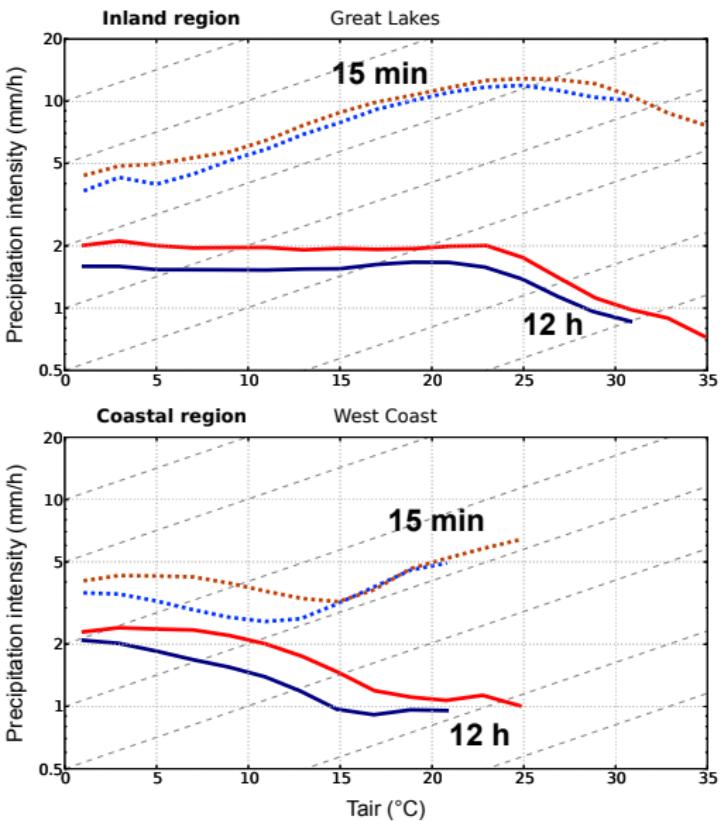
Synoptic events : Advectioned humidity does not depend on Ta

HYP-3 : Atm. circulation does not impact P_{extr}



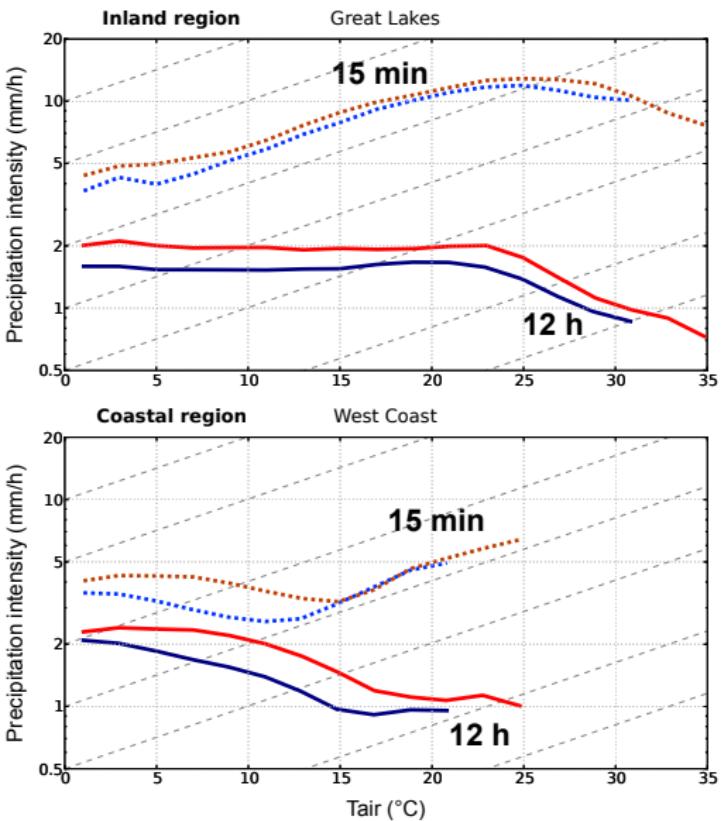
$P_{extr}(T)$ relationships comparison
Historical

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 Historical V.S. Future

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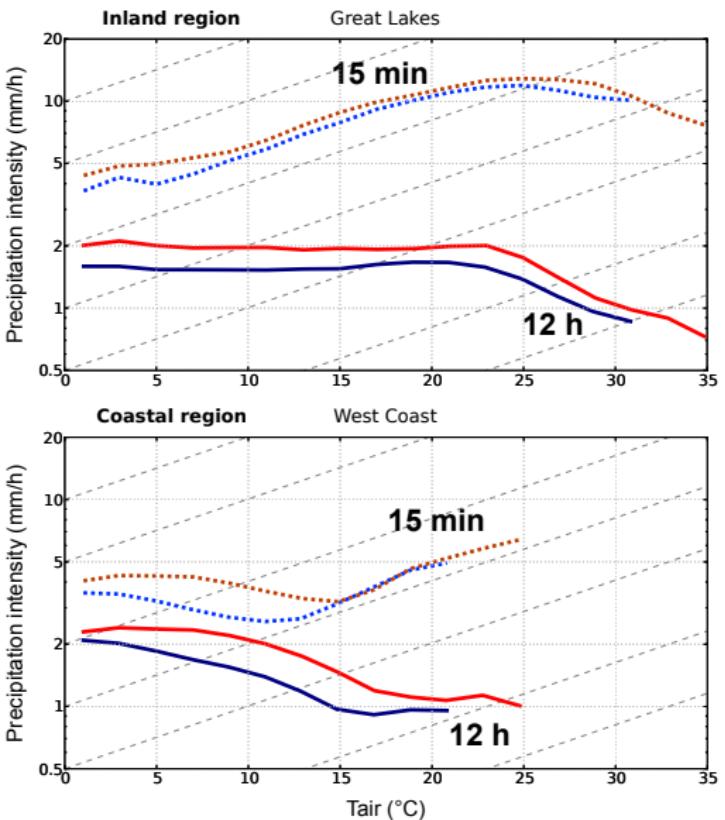


$P_{extr}(T)$ relationships comparison
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Short durations

- Small changes in the $P_{extr}(T)$
- For given $\{Ta; Td\}$: Small changes in the air instability (CAPE)

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$P_{extr}(T)$ relationships comparison
 Historical V.S. Future

Short durations

- Small changes in the $P_{extr}(T)$
- For given { T_a ; T_d } : Small changes in the air instability (CAPE)

Long durations

- Increase of intensities
- For given { T_a ; T_d } : increase of the advected moisture

V. Conclusion

Summary

1. Study $P_{extr}(T)$ from recorded series

- Factors affecting $P_{extr}(T)$:
 - Quantile : Minor impact
 - Season : Minor impact
 - Duration : The longer the duration, the lower the slope of the $P_{extr}(T)$
 - Region : Inland vs Coastal
- More infos : *Panthou et al. [2014], J. Of Hydrometeorology*

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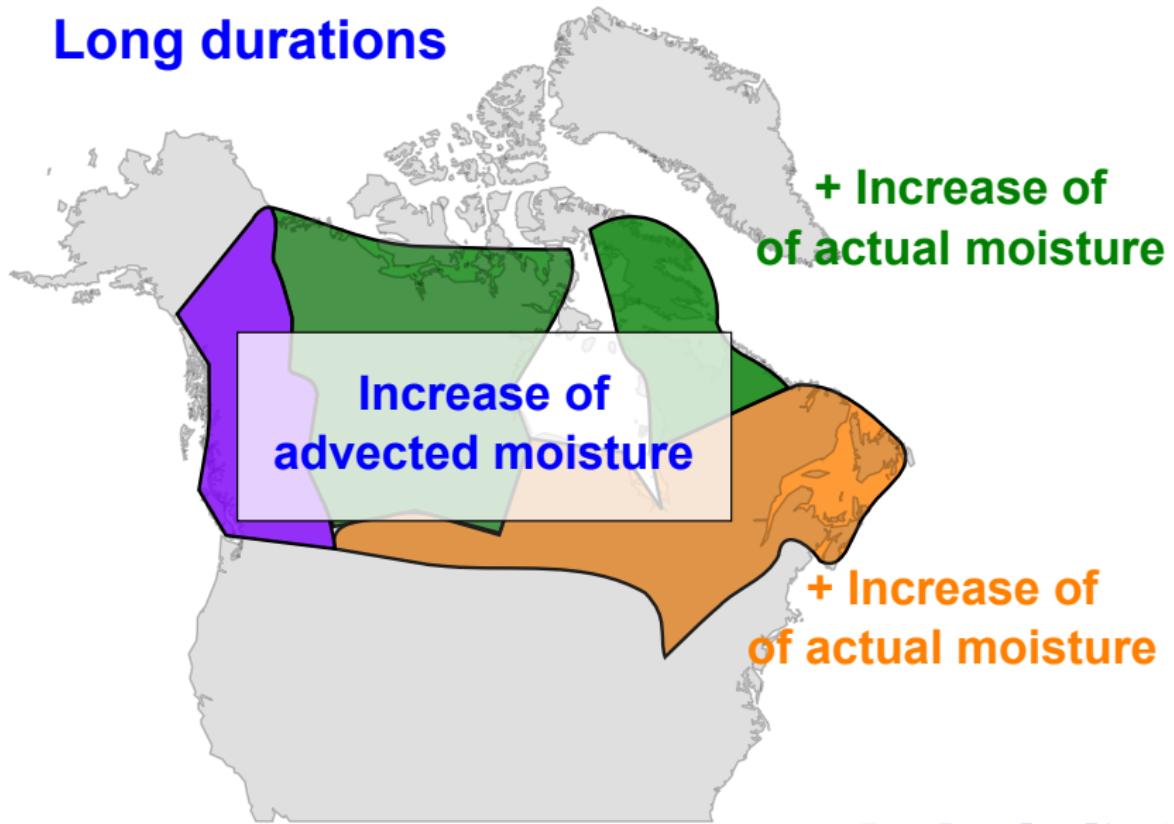
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3. Testing the C-C scaling hypotheses by using recorded series and CRCM

- Better understanding of the processes involved in the increase of extreme rainfalls
- *Panthou et al. [In prep]*, to be submitted to *JGR-Atmospheres*

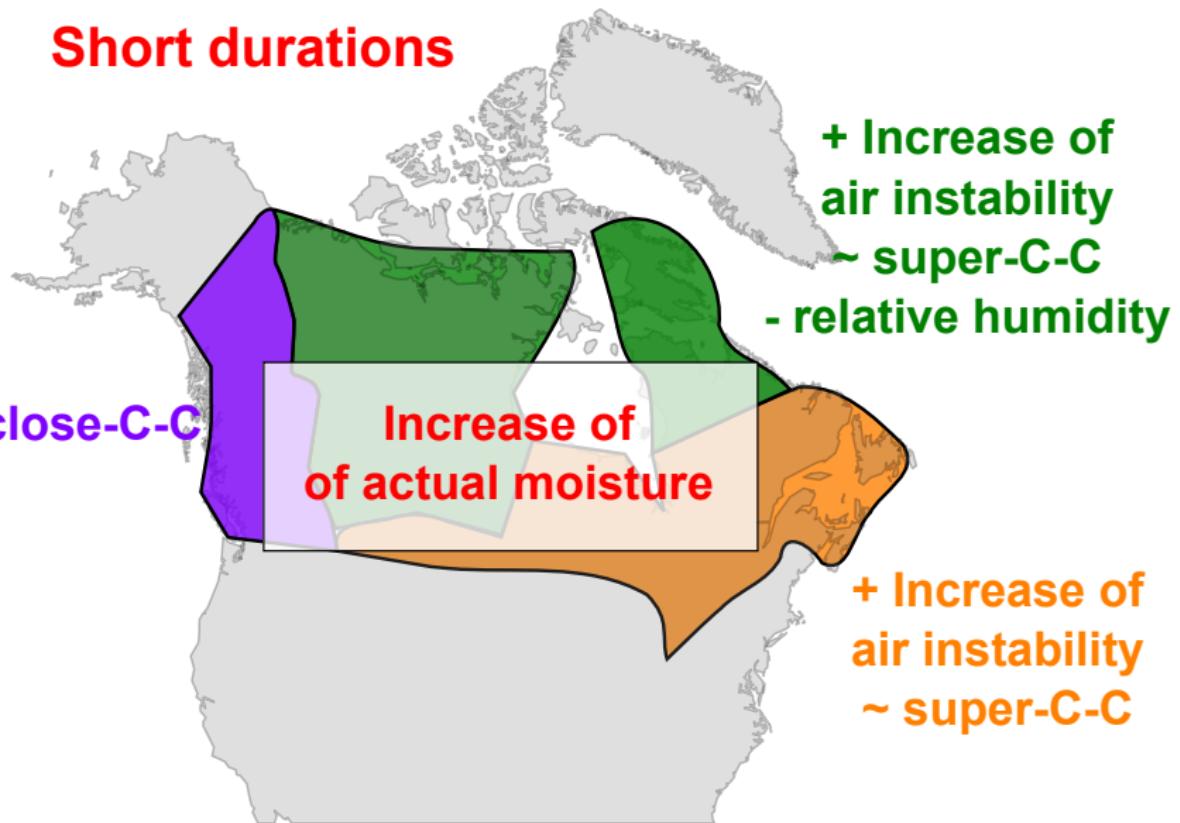
Main findings processes involved in increase of P_{extr}

Long durations



Main findings processes involved in increase of P_{extr}

Short durations



Thanks for your attention

VI. Biblio

References |

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