Extreme Value Theory to analyse, validate and improve extreme climate projections

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**Extremes**: events in the tail of the distribution

**Extreme Value Theory (EVT)**: branch of statistics which studies the properties of extreme values and enable to fit them with theoretical distributions

**Why EVT?** robustness (large values); inference (rare events); modelling (evolution of extremes with CC)
**Objective:** quantify future extremes in OBS space

1. bias + representativeness: diagnose relation between CRCM and OBS extreme distributions in the present (stationary GEV distributions)

2. evolution: detect trends of the CRCM extreme distributions with climate change (non-stationary GEV distributions)

3. use these relations to estimate future (OBS) extremes
• 12 climatological regions over the AMNO domain, from Plummer et al (2006)

• Daily Tmax and Tmin, 24 hour precipitation accumulations

• GEV distributions of annual extremes

• Ensemble of Canadian Regional Climate Model (CRCM) simulations: 1961-2000 = present 1961-2100 = future

• Observations from Canadian (DAI), US (NCDC) and WMO (Res40) station networks
Block maxima (e.g., max annual temperature) are distributed as a Generalised Extreme Value (GEV) distribution (Coles 2001).

GEV distributions are characterised by location (typical value), scale (spread/variability), and shape (tail values) parameter.

A return value with a return period of T years is the extreme event exceeded once every T years (its probability of exceedance is 1/T).
1. CRCM vs OBS - present climate (1961-2000)

PCPN extremes are systematically underestimated (location, variability and tails)

Note: expected result, representativeness
CRCM~45km resolution vs precipitation extremes = small-scale convection.
Systematic behaviour ⇒ downscaling relation
1. CRCM vs OBS - present climate (1961-2000)

**Tmin** extremes are un-physically cold in the Arctic (CRCM glacier parametrization)

**Tmin** extremes exhibit a cold bias in the west

**Tmin** extremes are well simulated in the centre and east
1. CRCM vs OBS - present climate (1961-2000)

Tmax extremes are cold in the north-west, warm in the south-east
2. CRCM projections of annual extremes (1961-2100)

extreme values and their variability increases
parabolic? linear? logistic?
2. CRCM projections of the GEV distributions (1961-2100)

Fit annual xtr with a non-stationary GEV distribution: GEV parameters (loc, scl, shp) are allowed to have linear, parabolic or logistic trend

Technical Details:
Maximum Likelihood Estimation; Swartz Bayesian Criterion
3. Δ method: apply the CRCM trends to the OBS GEV distribution parameters
3. Future extreme projections in OBS space

representativeness
Tmin CRCM projections for the Great-Lakes

Logistic behaviour: equilibrium-change-equilibrium?
Temperature increases, variability in Tmin increases (more ice-free lakes?)
Tmin OBS projections for California

Temperature increases, variability in Tmin diminishes (mountain glaciers disappear?)
Tmax OBS projections for the Pacific Coast

CRCM cold bias in the north-west
Tmax OBS projections for the Plains

CRCM warm bias in the south-east
Tmax OBS projections for the Gulf

amnogulf annual xtr
GEV distribution qq-plot

CRCM warm bias in the south-east
Preliminary Results

**PCPC:** Precipitation extremes increases either linearly or parabolically ~ 10 to 20 mm/century (in most regions). Representativeness issue: CRCM underestimate precipitation extremes, their variability and tail values (in all regions).

**Tmin:** minimum temperatures increase linearly ~ 7°C/century. Logistic behaviour in Tmin variability and tails: equilibrium-change-equilibrium? CRCM exhibit a cold bias in the west, well represent Tmin extremes in the centre and east. Tmin extremes in the Arctic are un-physically cold (glacier parametrization).

**Tmax:** maximum temperatures increases either linearly or parabolically ~ 5°C/century. CRCM exhibits a cold bias in the north-west and a warm bias in the south-east
Conclusions & Future Work

**Conclusions**

1. EVT: powerful tool to investigate extremes future projections
2. Estimates of future precipitation and temperature extremes in OBS space are obtained by applying the $\Delta$ method to the GEV distribution parameters
3. Model biases and representativeness errors are “corrected” by the $\Delta$ method

**Future Work:**

- Include other CRCM simulations
- Apply the extreme analysis grid-point by grid-point
- Define downscaling relation
- Separate bias and representativeness

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THANK YOU!
PCPN extremes are systematically underestimated (location, variability and tail values) in all regions.

Note: expected result, representativeness
CRCM ~45km resolution; extreme precipitation = small-scale convection
Systematic behaviour = downscaling relation
1. CRCM vs OBS present climate (1961-2000)

Tmin extremes are

- un-physically cold in the Arctic (CRCM glacier parametrization)
- cold in the west
- well simulated in the centre and east
1. CRCM vs OBS present climate (1961-2000)

$T_{\text{max}}$ extremes are cold in the north-west, warm in the south-east