Estimates of extreme precipitation to inform engineering design

Outline:

- Challenge
- Status
- Plans
- Examples of recent work and work in progress

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GWF Climate Extremes, Manitoba Hydro
29 November 2017

Challenge, Status, Plans

Challenge:

- Reliable estimation of idf curves for current and future climates despite
  - Short, sparse, precipitation records
  - The death of stationarity

Possibilities that have been / are being investigated, include:

- Temperature scaling based on ”binning scaling” derived from historical sub-daily records (Zhang, Zwiers, G. Li, Wan, Cannon; Nature Geo, 2017)
- Temperature scaling based on an RFA approach (C. Li, Zhang, Zwiers)
- Exploit dependence between two different attributes of precipitation (Ben Alaya, Zwiers, Zhang; JHM, submitted)
- Role of circulation change (Curry, Ul Islam, Déry, Zwiers, Tan)

Plans

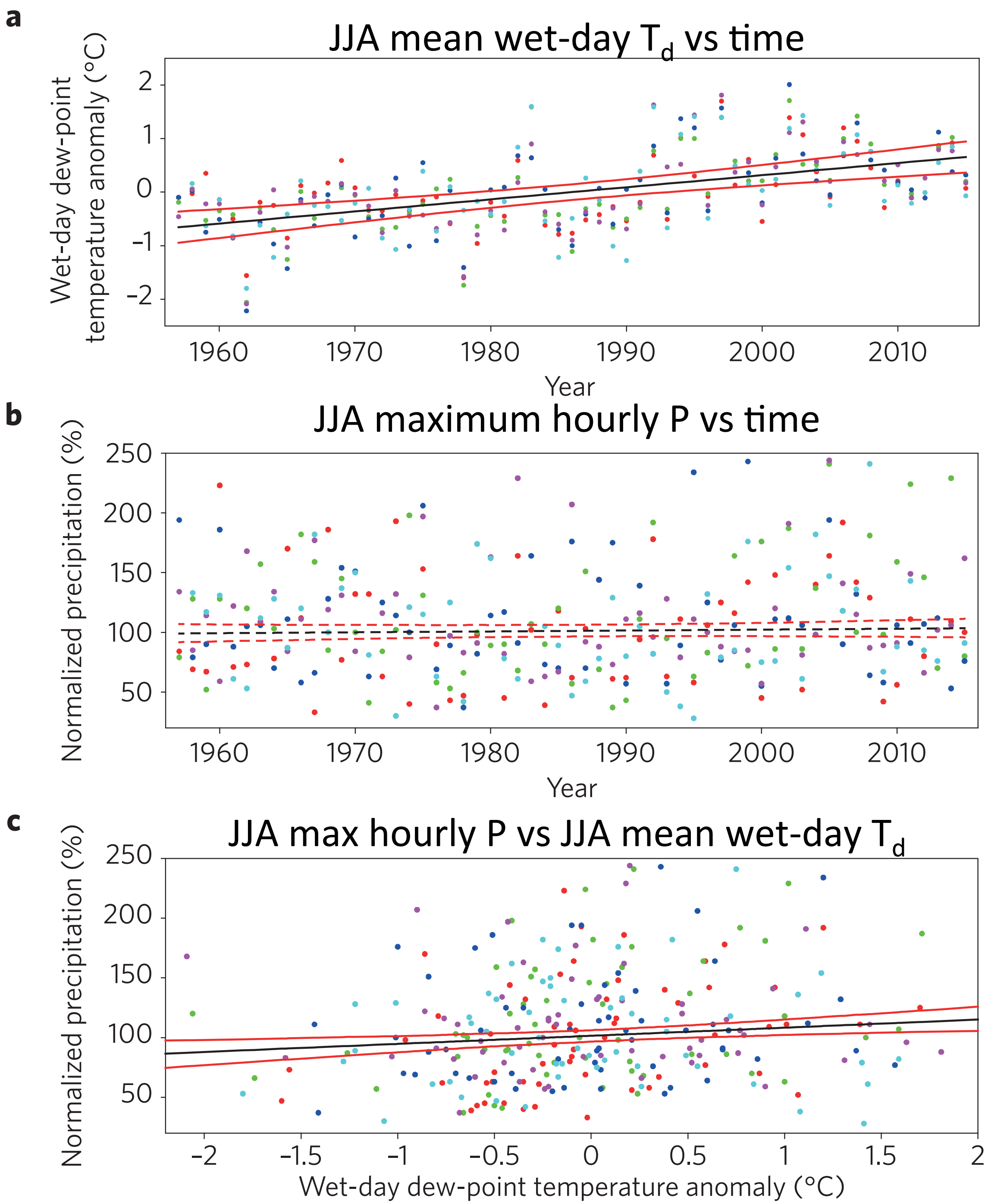
- Ben Alaya will come onto the project
- Student or other HQP remain to be identified
- Ben Alaya will continue investigation of temperature scaling and linking model simulate extremes to observations
- Pillar 1 project with Yanping will provide physical processes underpinning

Binning scaling

Zhang et al., Nature Geo, 2017

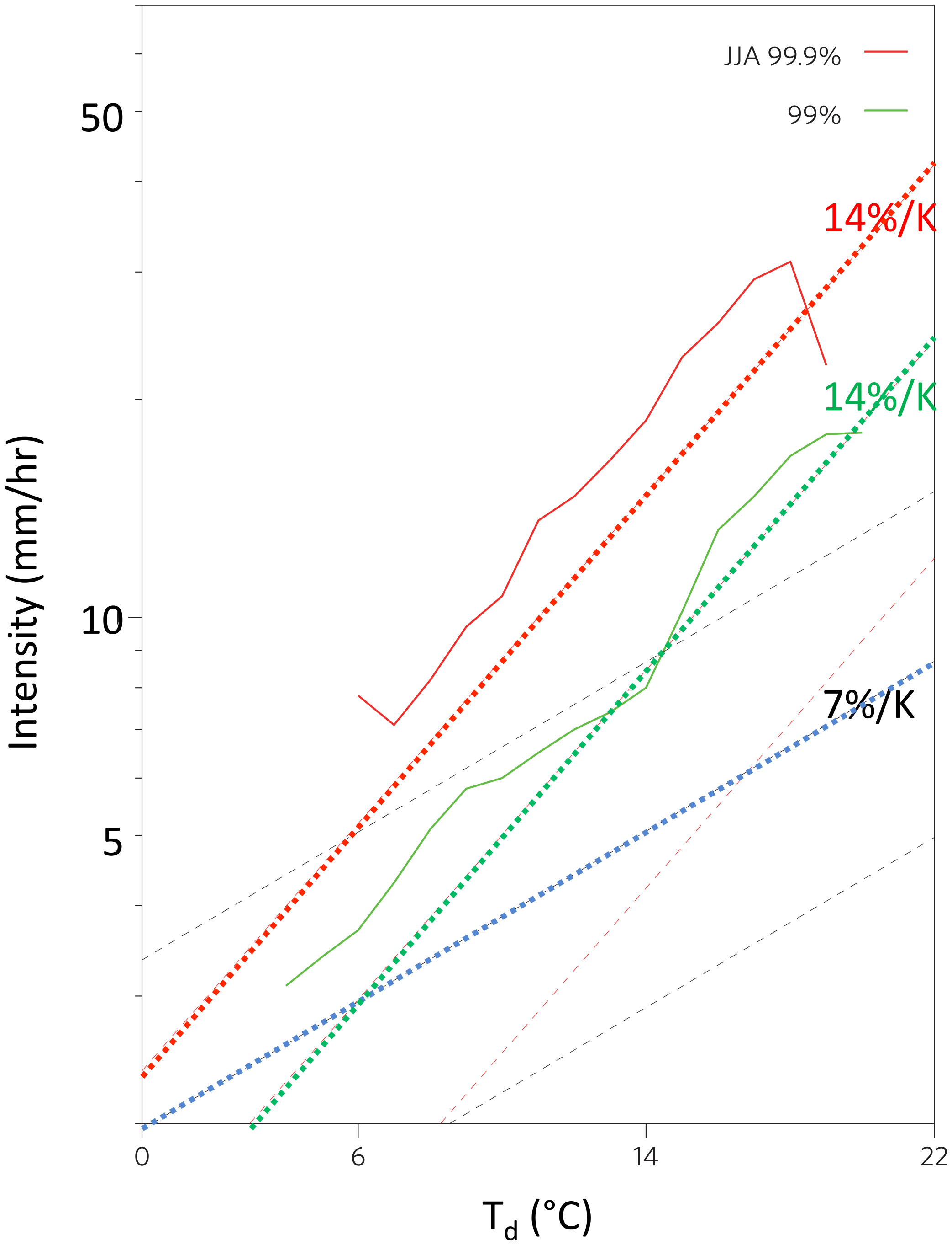
T_d and hourly precipitation at 5 NLD stations for 1957-2015 (colours indicate stations)

- Significant warming
- No discernable trend in extreme hourly P
- Significant (but noisy) relationship between T_d and summer max hourly P (we estimate ~6.8% intensity increase for a 1°C increase in T_d)



Conditional hourly precipitation percentiles (conditional on wet-day T_d) at 5 NLD stations for 1957-2015

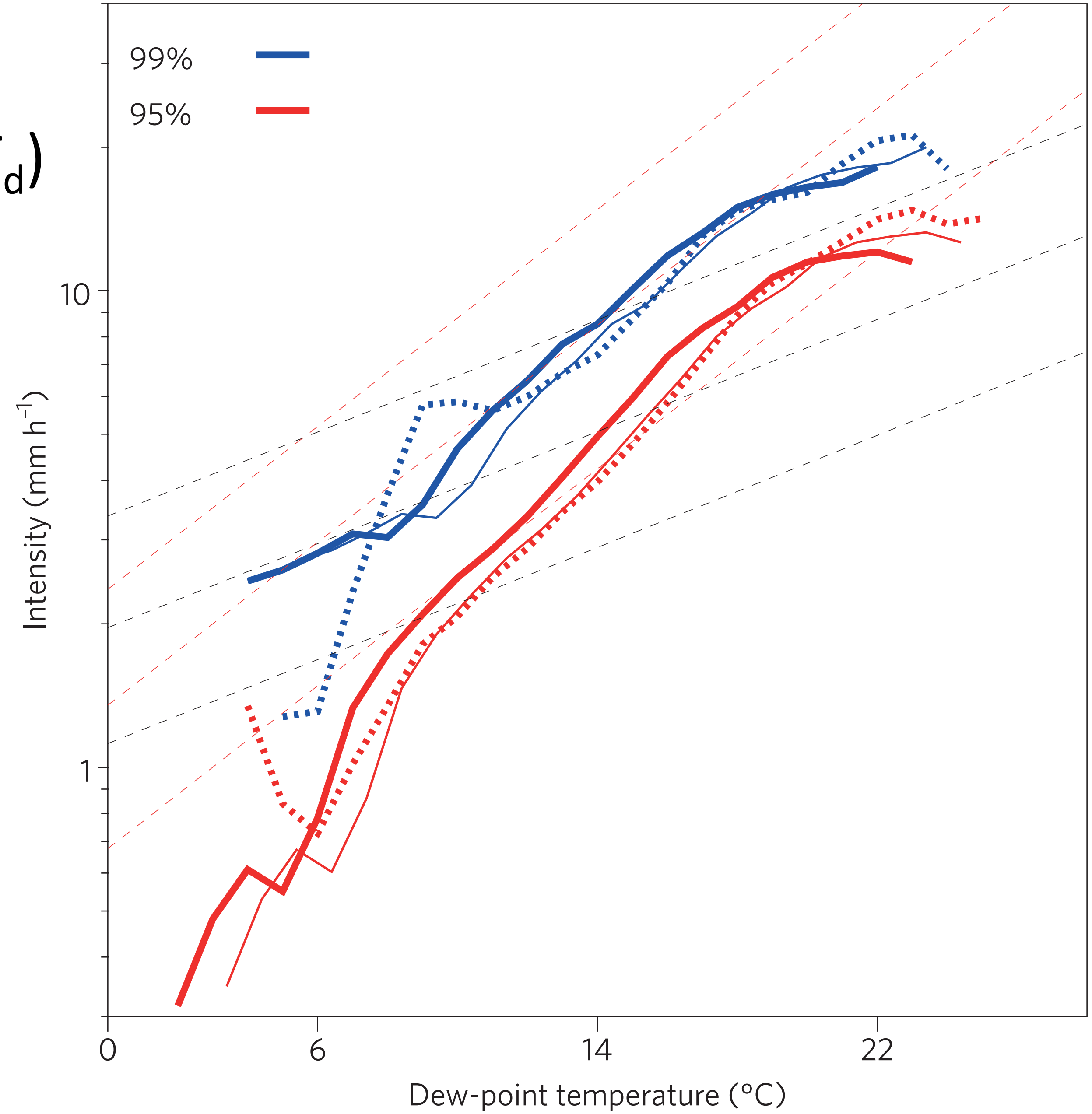
- Strong super-CC scaling is evident
- And warming is evident
- Why don’t we see significant long-term change in extreme hourly P?
- Can we use binning scaling to project future change in extreme hourly P?



Conditional hourly precipitation percentiles (conditional on wet-day T_d) in Rossby Centre RCM (ENSEMBLES)

- Thick curves – historical climate
- Dotted curves – future climate
- Thin curves – historical, scaled by CC rate

- Models shift the binning scaling curve upwards and to the right (at the CC rate)
- Annual or seasonal max precipitation increases at the CC rate where thermodynamics dominate
- Long return period extremes increase at the CC rate, not the super-CC rate



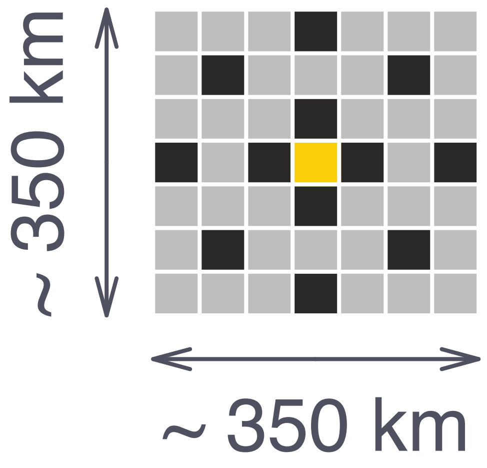
Temperature scaling using RFA

Chao Li, et al., in prep

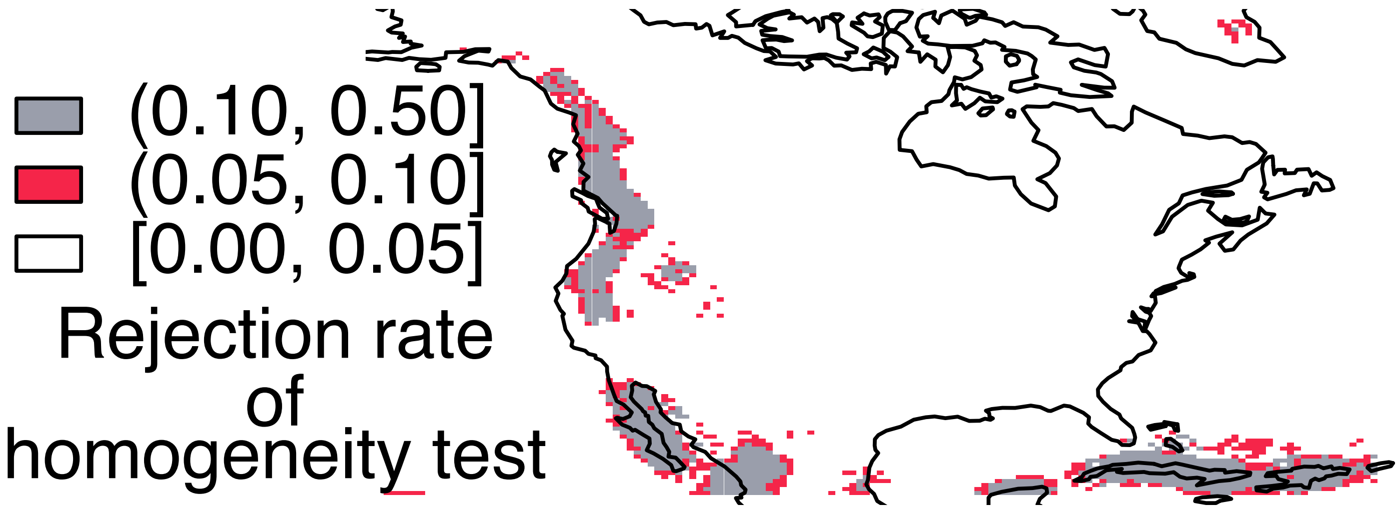
Evaluate the ”index flood” method (pools data from regions where extremes have the same distribution after scaling by the local ”index flood”)

- Fit non-stationary GEV at individual locations
- Use the estimated location parameter as the ”index flood”
- Scale annual extremes by the index flood, and pool regionally to estimate scale and shape parameters
- Test pairwise to see if scaled extremes are from the same population

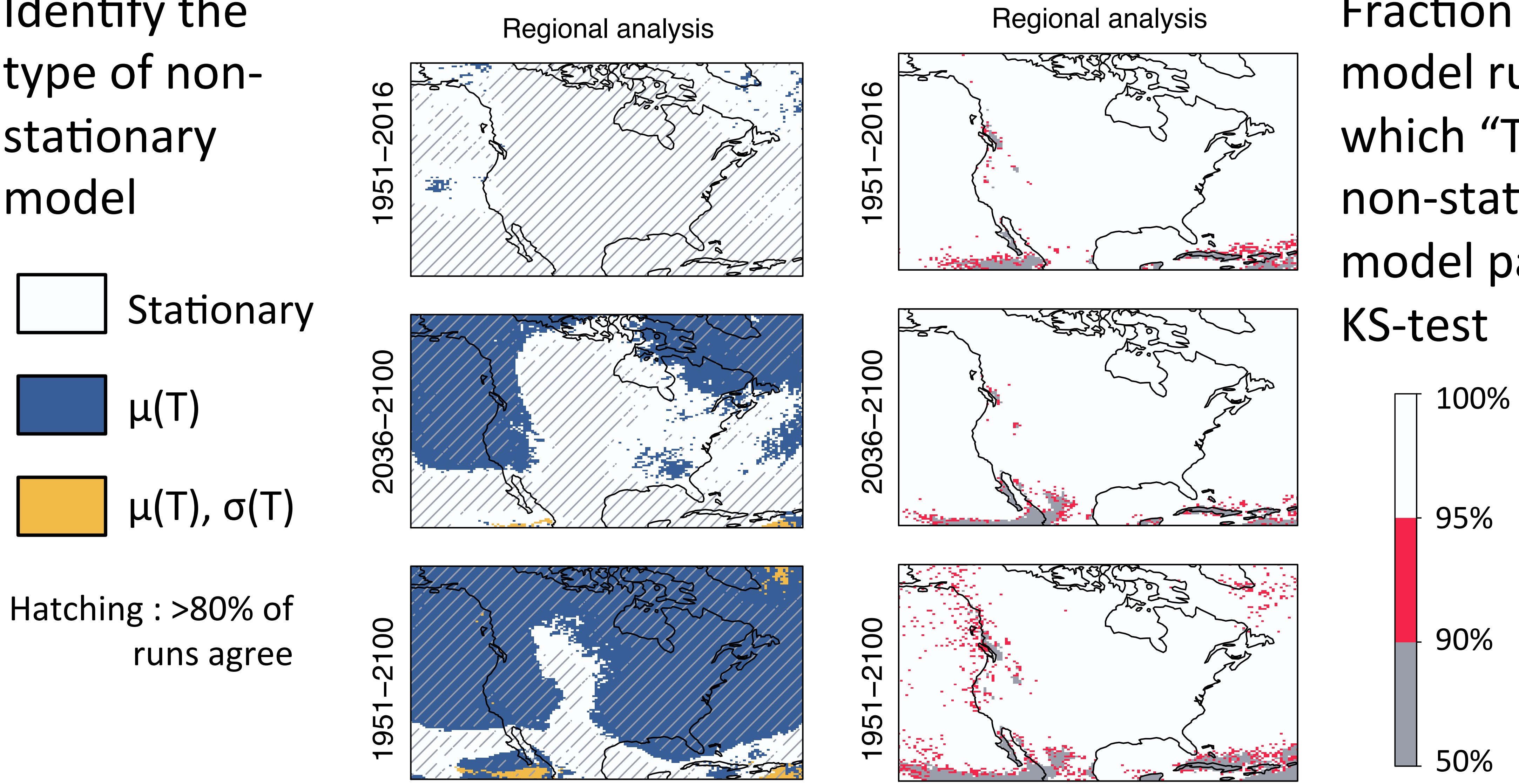
Applied to CanRCM4 large ensemble (35 runs, 1951-2100, hourly precipitation)



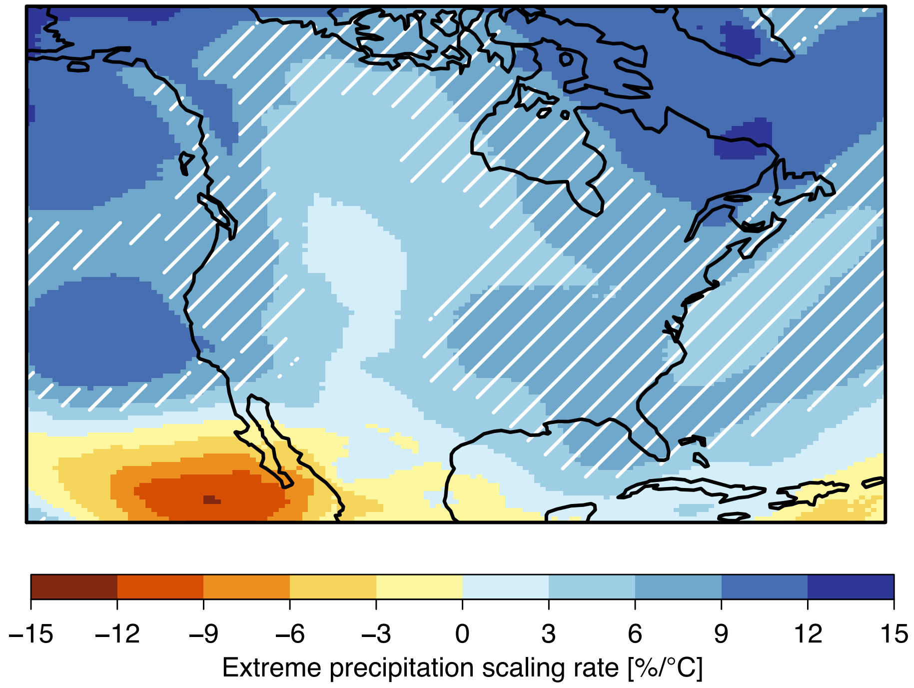
Homogeneity of scaled extreme precip in 7x7 regions



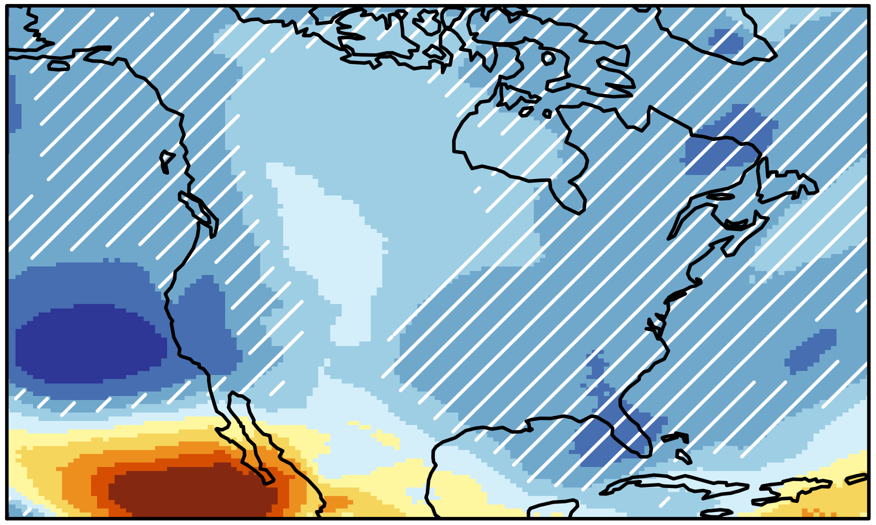
Identify the type of non-stationary model



Fraction of model runs for which “Type-I“ non-stationary model passes KS-test



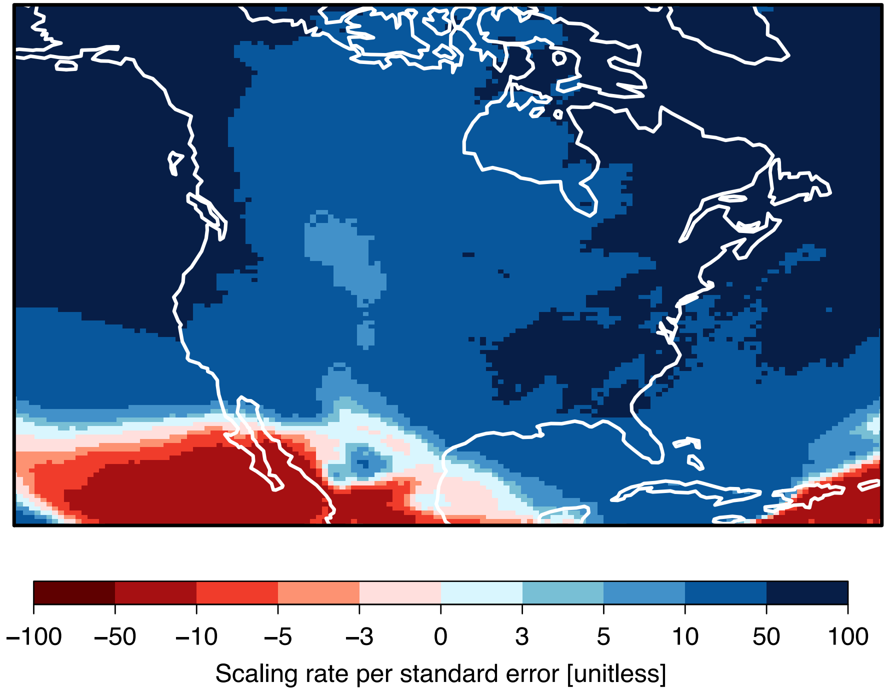
Estimated scaling rate for annual max hourly precipitation



As above, adjusted for poleward amplification of warming

✻ Hatching indicates rates consistent with CC

Scaling rate per standard error



Scaling rates are slightly lower for longer accumulations

Probable Maximum Precipitation

M.A. Ben Alaya, et al., JHM, submitted

Moisture maximization

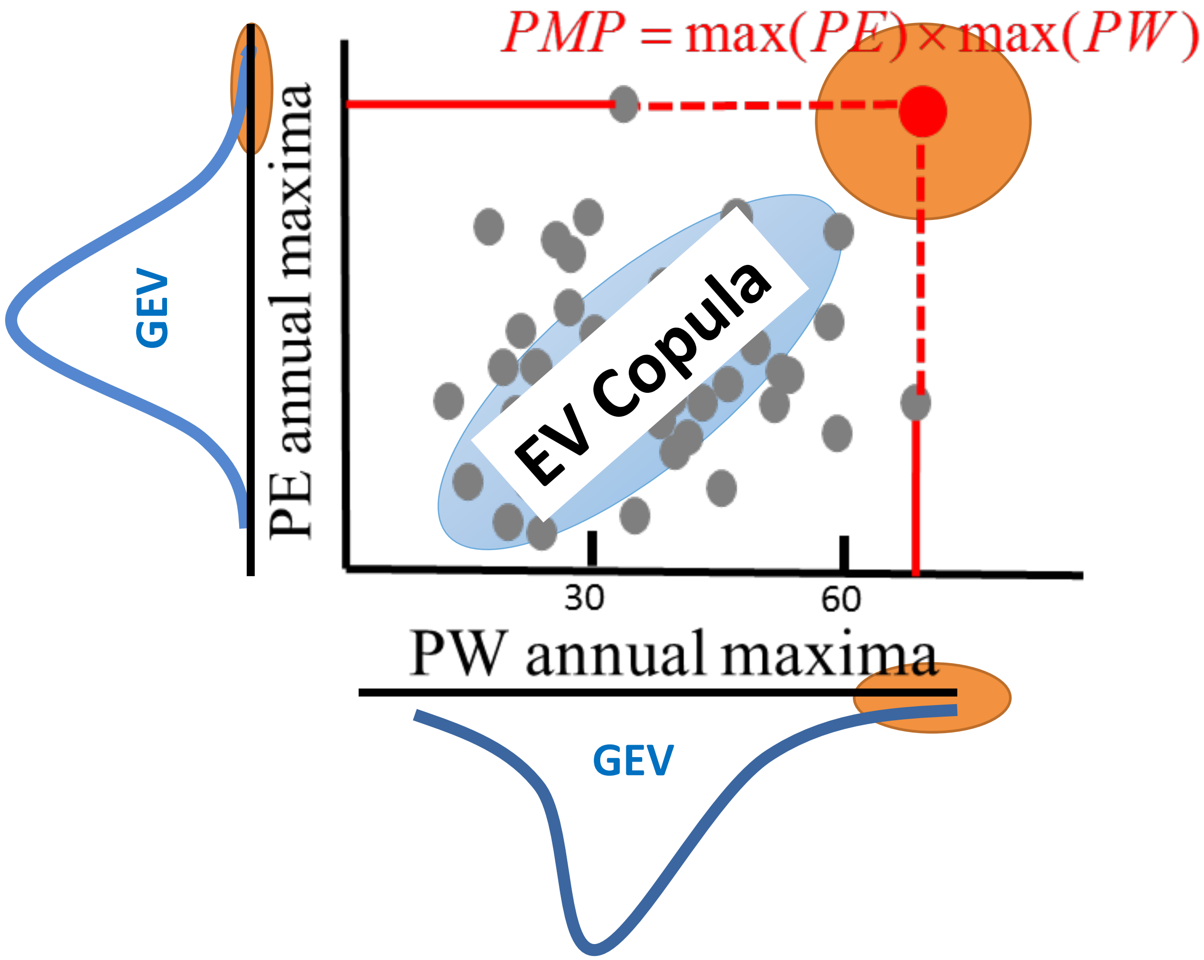
- The idea is to inflate individual observed precipitation events to their plausible upper bounds
  - the event that might have been, given suitable atmospheric conditions
- Let
  - $p(t)$ be an observed precipitation amount at time t
  - $PW(t)$ be the amount of precipitable water in the atmospheric column
  - PW_{max} be a maximum value for $PW(t)$
  - $PE(t)=p(t)/PW(t)$ be precipitation efficiency, and
  - $q(t)=PE(t)PW_{max}$ be the maximized value of $p(t)$
- Then PMP = $max\{q(t), t=t_1, \ldots, t_n\}=PE_{max} PW_{max}$

A probabilistic framework

Use a bivariate extreme value model for annual (PW, PE) pairs to infer the distribution of

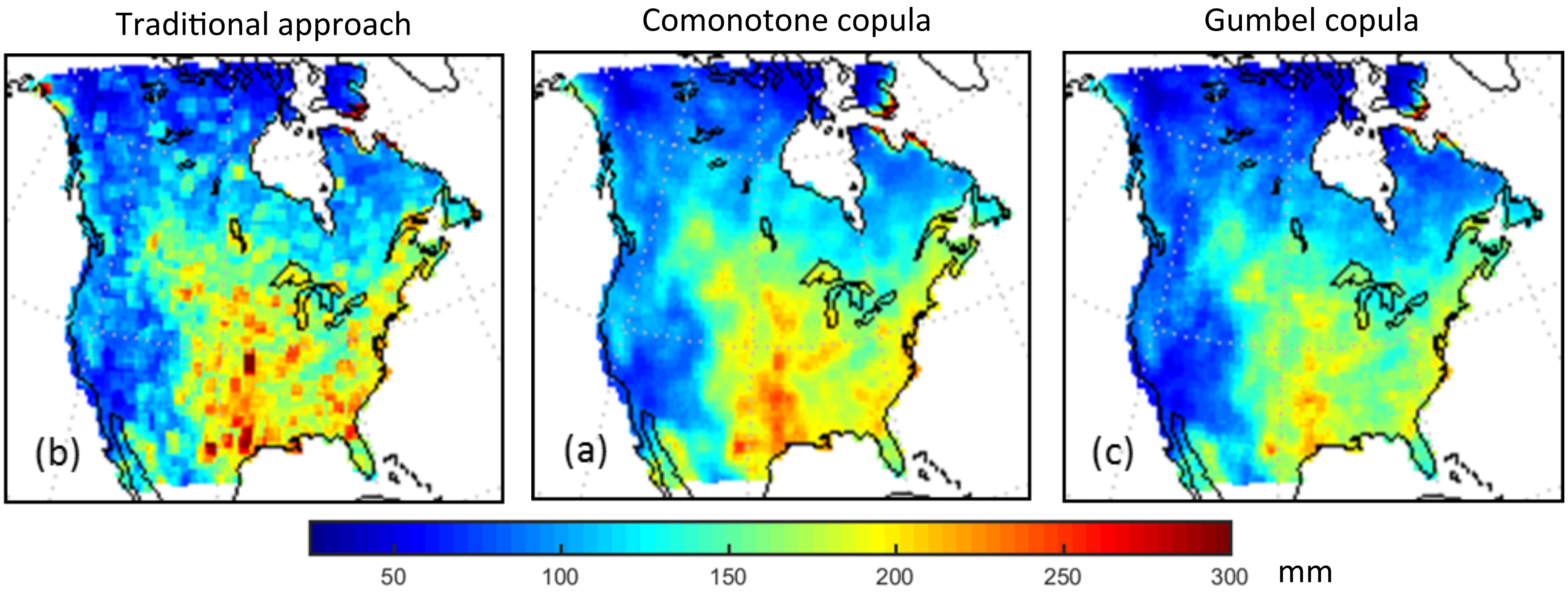
$$PMP_{BV} = \max_{t}\{PW(t)PE(t)\}$$

Tested by applying the method to a single 50-year CanRCM4 simulation covering 1951-2000



PMP estimates for 6-hour accumulations

based on a seasonally restricted model with storm transposition



- Panels display mean values based on 50-yr *(PW,PE)* time series resampled from the corresponding fitted bivariate EV distributions
- Compared to the Gumbel copula, the comonotone copula overestimates PMP by ~15%

PMP estimates for 6-hour accumulations

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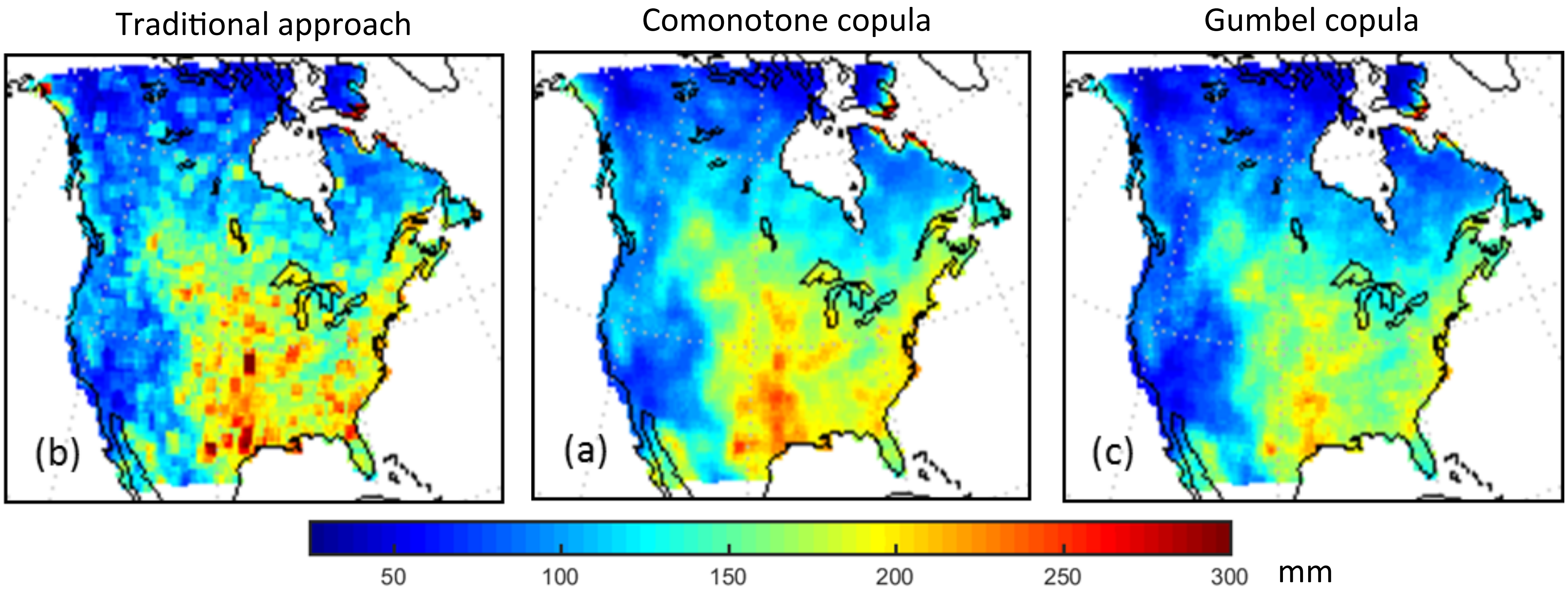


- Port Arthur, TX, received 661 mm in 24 hours on 29 Aug 2017 during Hurricane Harvey (~24-31 Aug 2017)
- The NOAA/NWS analyzed product (station and radar blend) indicates a few hourly accumulations in the area on 27 Aug 2017 of more than 500 mm

Fraser River Flooding

Siraj Ul Islam (UNBC), Charles Curry (PCIC), Dery, Zwiers (papers in prep)

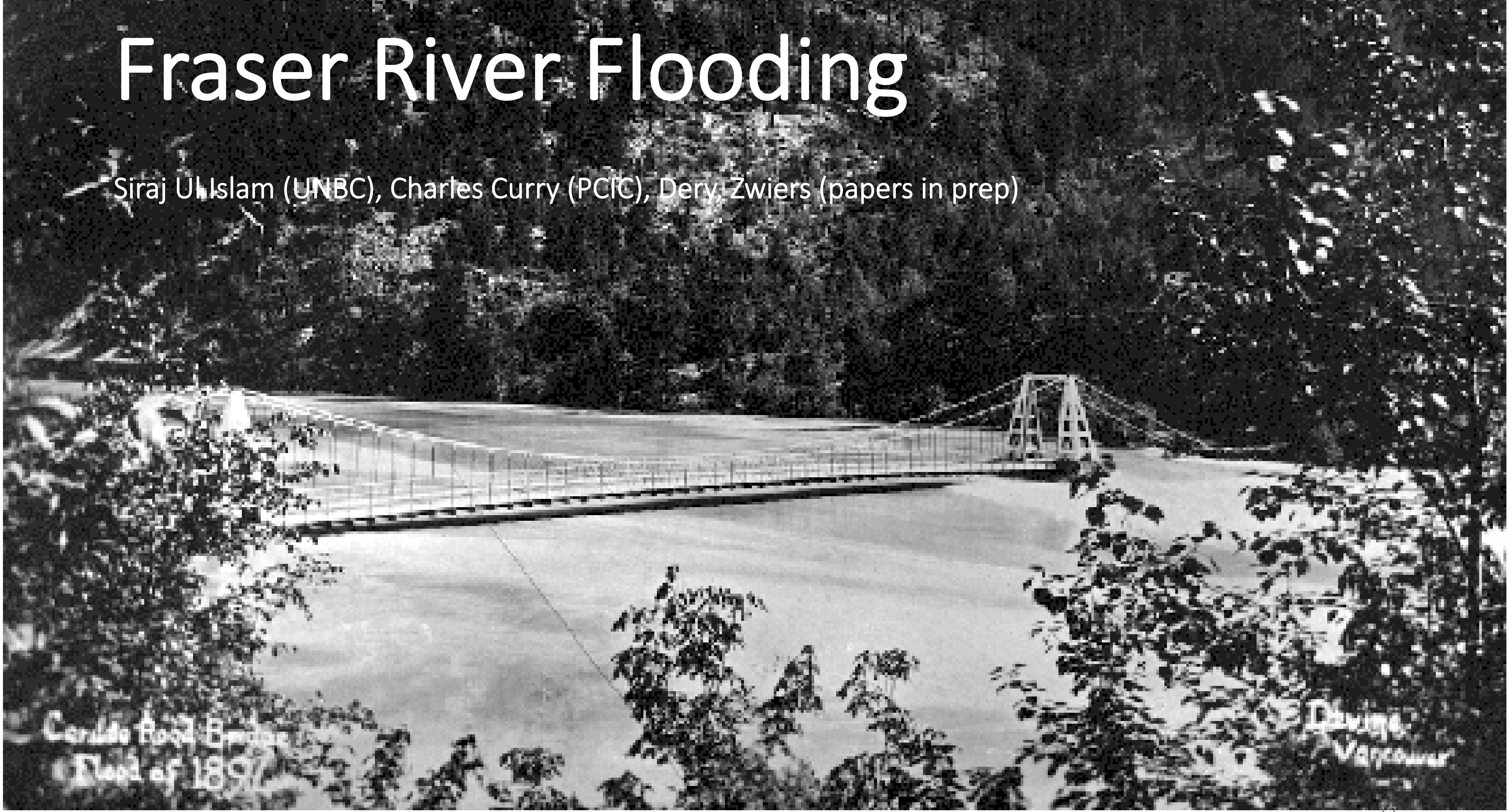
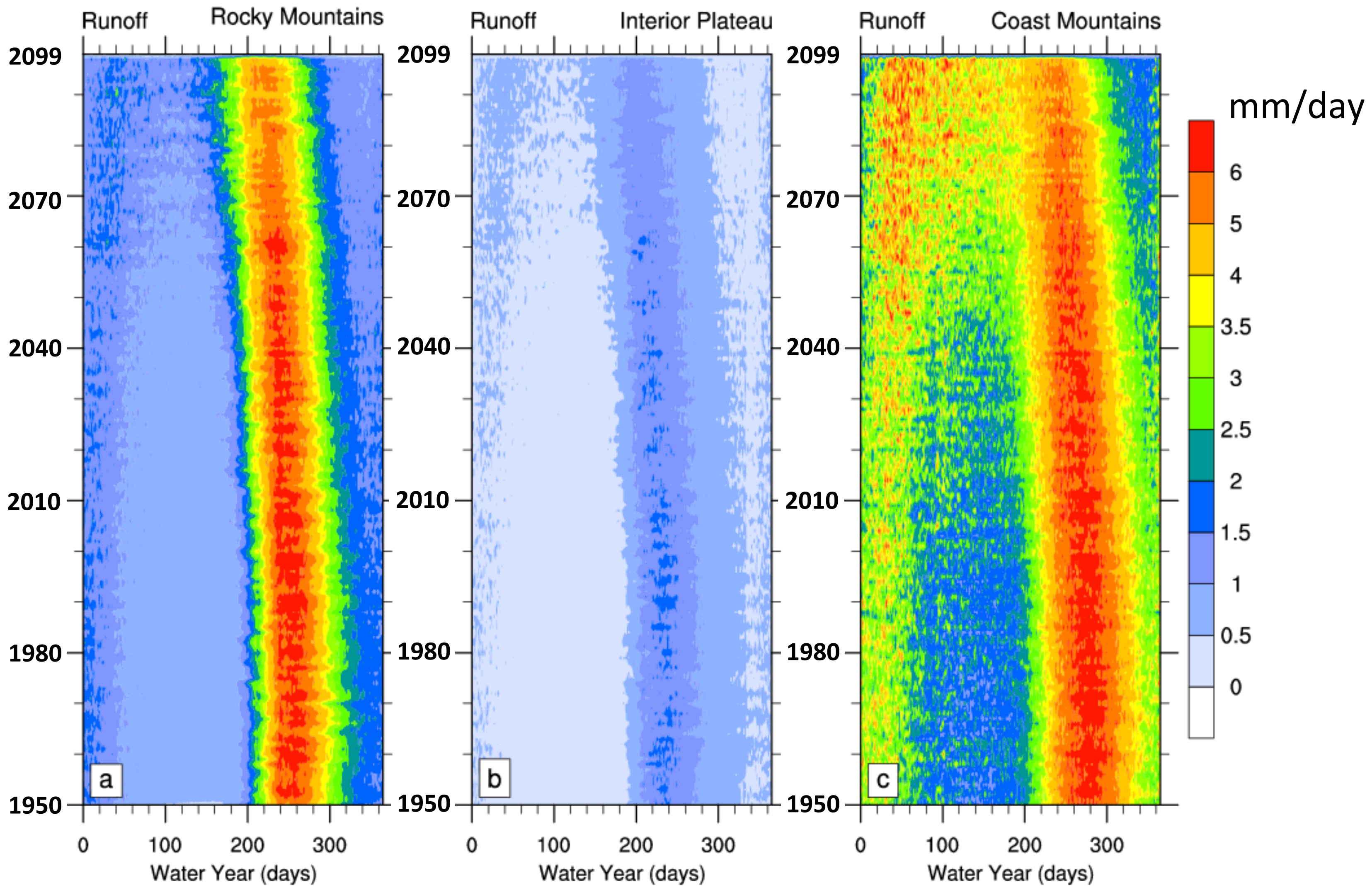


Figure 2.8: Alexandra Bridge during Flood of 1894

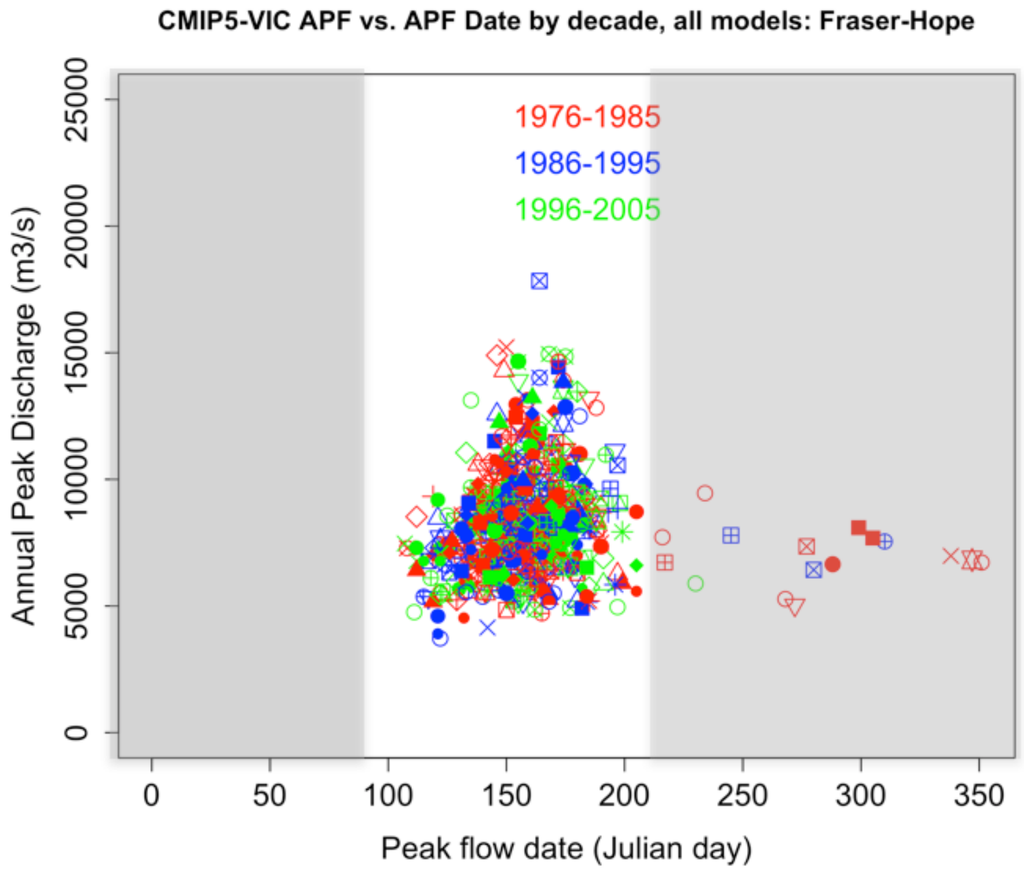
CMIP5 ensemble mean area-averaged runoff for Rocky Mountains, Interior Plateau and Coast Mountains.



Courtesy Siraj Ul Islam

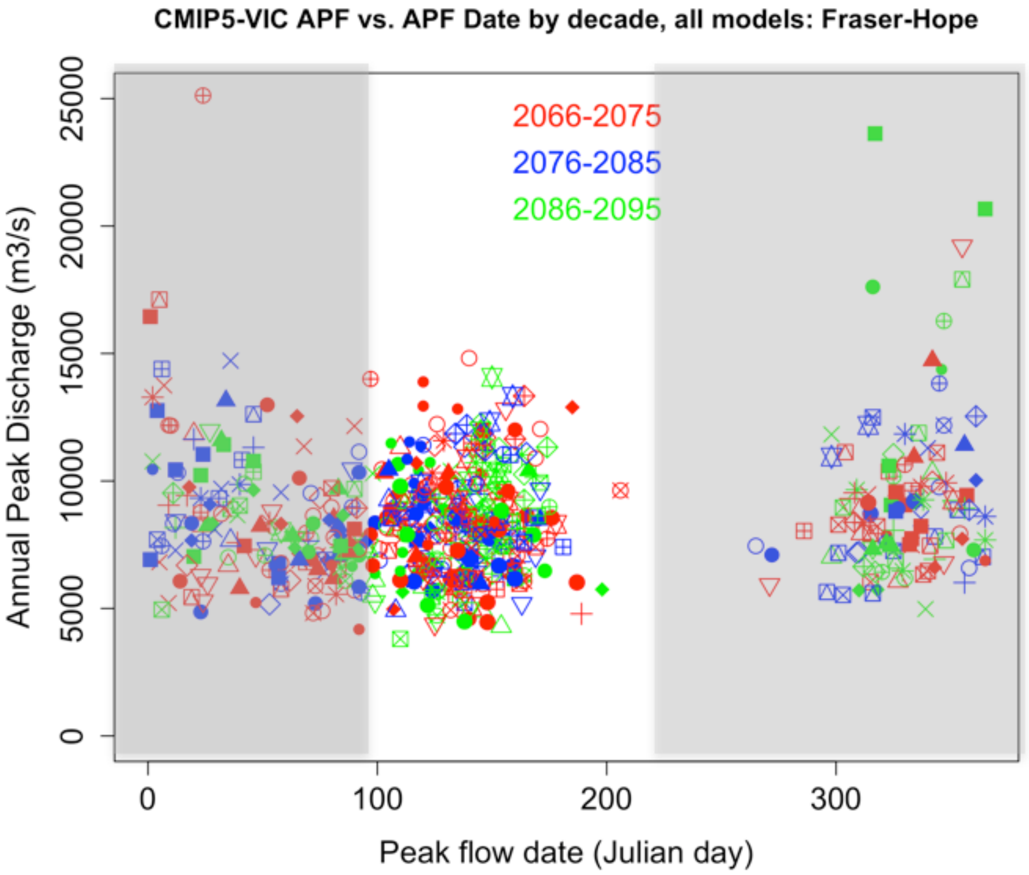
Annual peak flow timing and magnitude

Late 20th century



Days 1-90 & 215-365: 16 occurrences over 10 different runs (2.5% of total = 630)

Late 21st century



Days 1-90 & 215-365: 167 occurrences over all 21 runs (27% of total = 630)

Courtesy Charles Curry


Discussion