PACIFIC CLIMATE IMPACTS CONSORTIUM

University of Victoria

Scaling IDF curves to account for climate change in resource road stream crossings

An approach for estimating future extreme rainfall

Overview

- Climate and precipitation projections over BC
- IDF curves: characteristics & limitations
- Modelled precipitation: strengths & weaknesses
- Physically-based approach to scaling IDF curves using projections of local warming
- Example

Climate Projections in BC

Warmer winters
fewer days below freezing

High confidence

More hot summer days
longer dry spells in summer

High confidence

More precipitation in the fall,
winter and spring

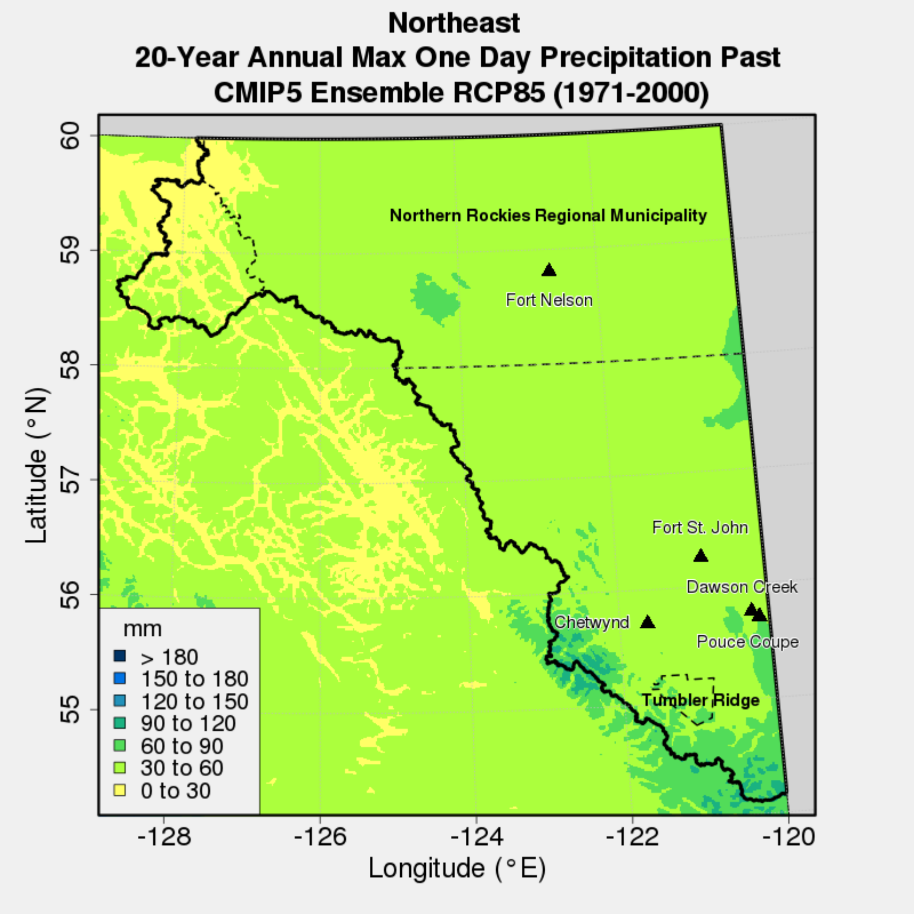
Medium confidence

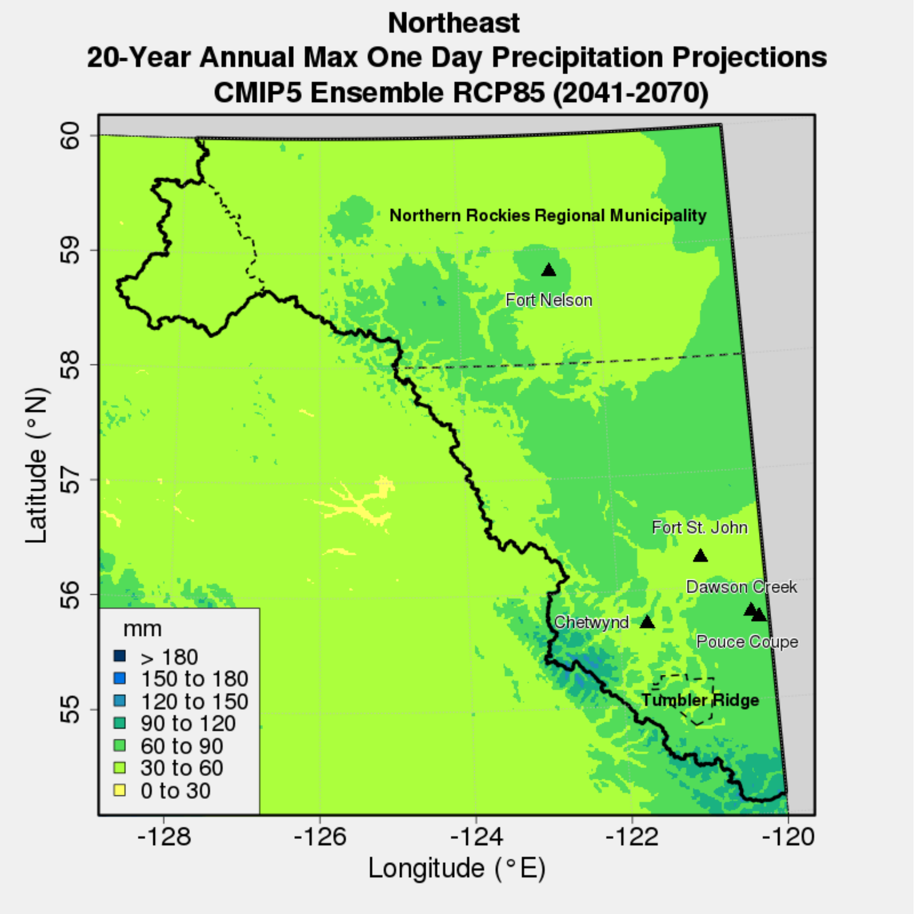
Increased frequency and intensity
of precipitation and storm events

Medium confidence

Model-projected regional change

1-in-20 year maximum annual precipitation

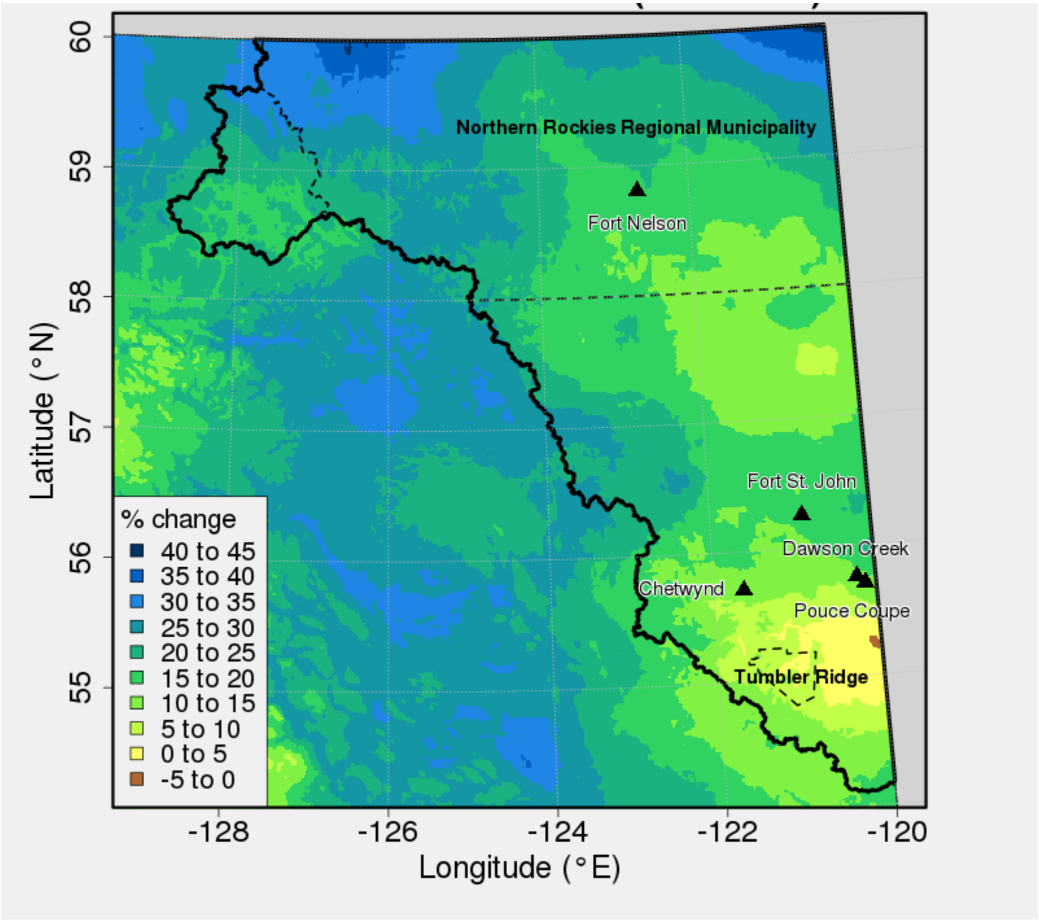




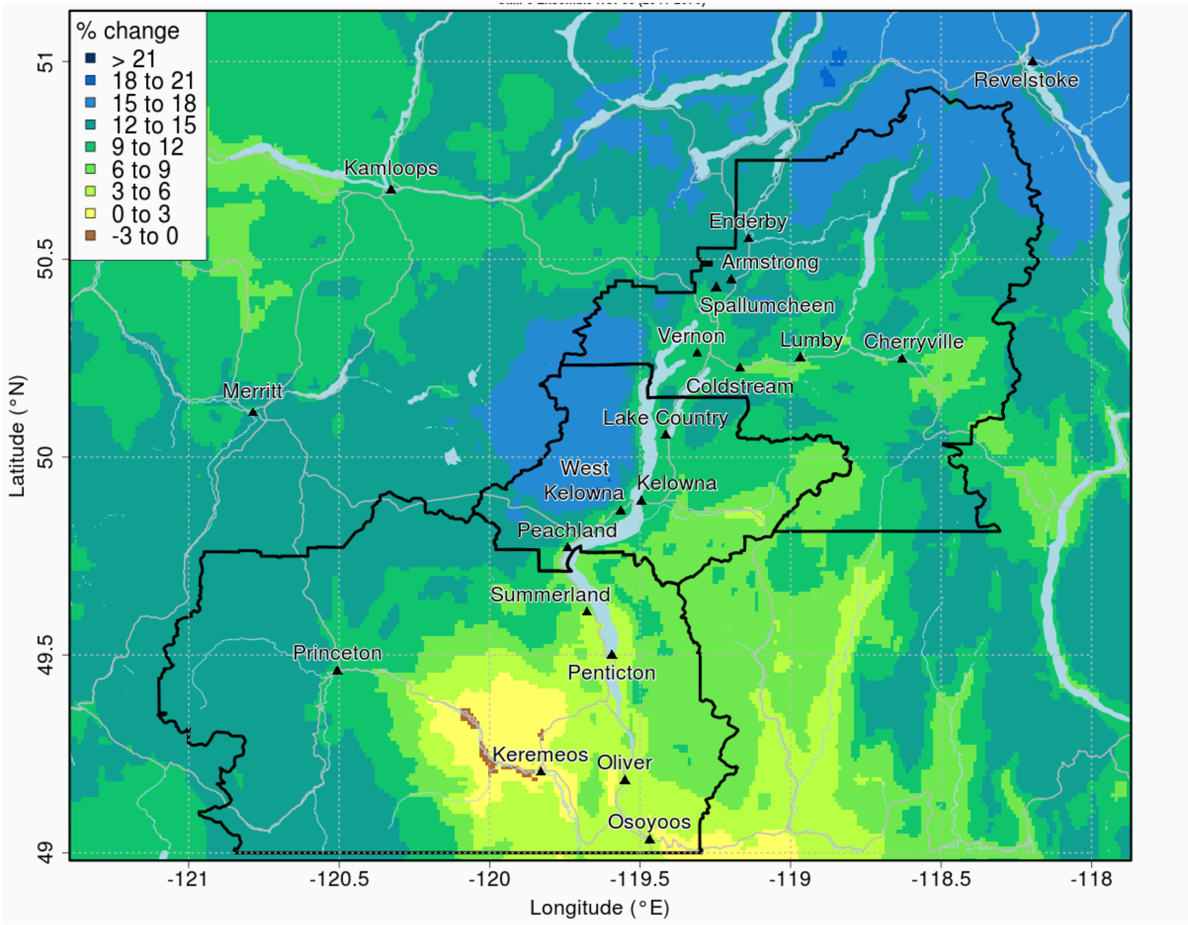
Source: PCIC Northeast BC Climate Assessment (2019)

Model-projected regional change

Wettest day of the year (% change, historical to 2050s)



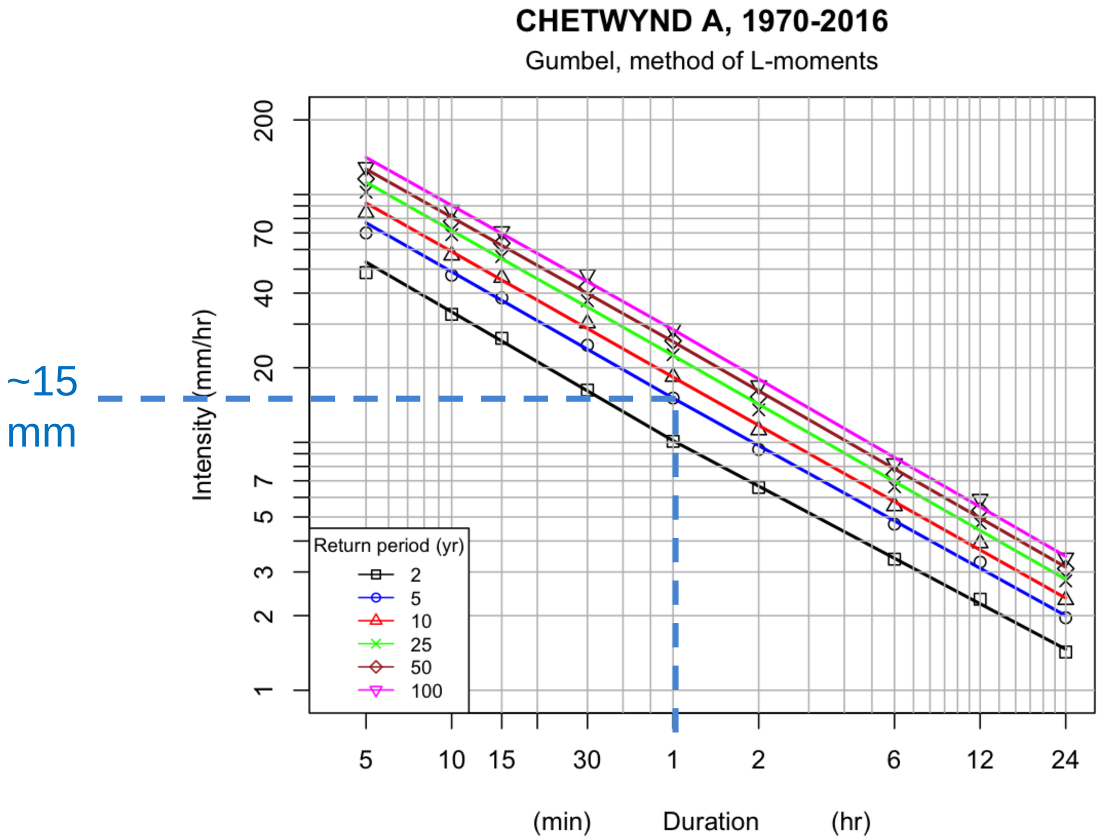
Source: PCIC Northeast BC Climate Assessment (2019)



Source: PCIC Climate Projections for the Okanagan Region (2020)

Rainfall Intensity-Duration-Frequency (IDF) curves

Local IDF curves are an important tool for civil infrastructure design & starting point for flood protection



Observations of accumulated rainfall at various durations from 5 min to 24h

Construct time series of observed annual maximum rainfall

Conduct EVA to estimate return levels of rainfall intensity at each duration

Data source: Environment & Climate Change Canada (2020)

Limitations of IDF curves

- Only available at selected locations (~650) across Canada

Solution? Spatial interpolation, possibly aided by digital elevation models and/or regional climate models

- While minimum record length for inclusion is 10 years, very few stations have data spanning 50 years or more, normally considered minimum required for estimating 100-year return levels

Solution? Combining nearby stations with homogeneous rainfall behaviour increases record length and may lower uncertainty in return level estimation

- Until recently, not easily constructed from future climate projections

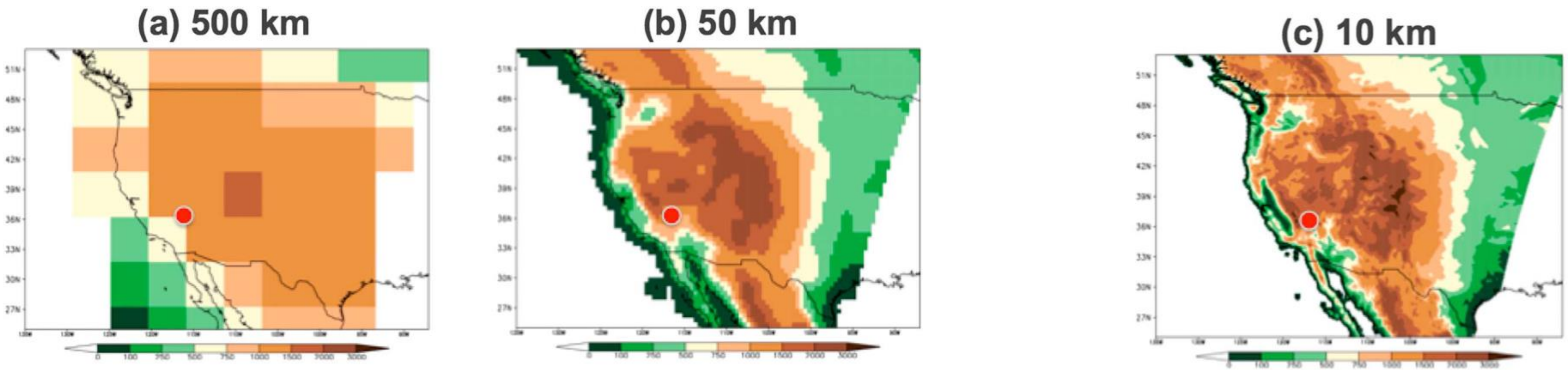
Solution? IDF curves can be constructed from climate models in several ways, both direct and indirect

Direct use of climate model precipitation

Why not use rainfall estimates directly from global and regional climate models?

- Modelled rainfall is an area average, distributed over a cell of size $\gtrsim$ 100 km^2, and not comparable to point measurements. Modelled rain also subject to bias in other variables, e.g. temperature.
- Most models don't spatially resolve convective storms (~10 km) → heaviest, short-duration rain events reflected in IDF curves in continental climates

Typical GCM | Typical RCM | RCM (development/research)



Source: Giorgi (2019)

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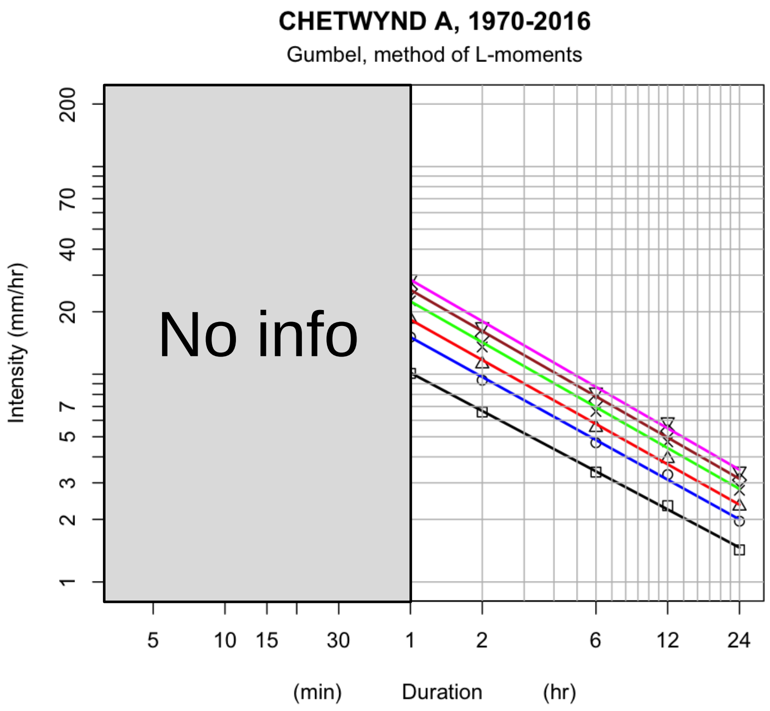
Direct use of climate model precipitation

Why not use rainfall estimates directly from global and regional climate models?

- Temporal resolution of climate model output is usually not less ~ 1 hour



Consequently, *typical climate model skill for simulation of rainfall intensity at local scale is generally low. Can we find another way?*

Temperature dependence of humidity & rainfall

- Atmospheric (specific) humidity increases with T; specifically, its saturation value e_S increases ~exponentially with T, at ~7% per °C → "Clausius-Clapeyron T scaling"

- Mathematically, C-C scaling of rain intensity is

$$P/P_0 = (1 + \alpha)^{\Delta T}$$

where P_0 and P are historical & future rainfall, $\alpha \approx 0.07$, and ΔT is air temperature change (future – historical)

- *Note*: Climate model-projected temperature change, ΔT, more secure than projected precipitation, ΔP, at all spatial scales

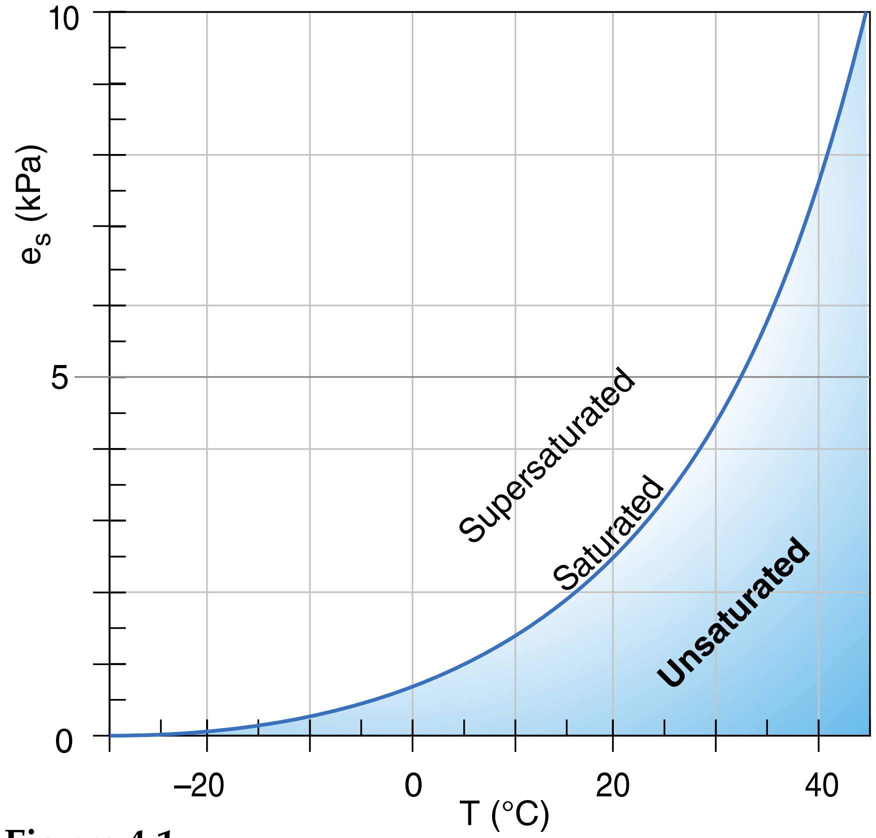
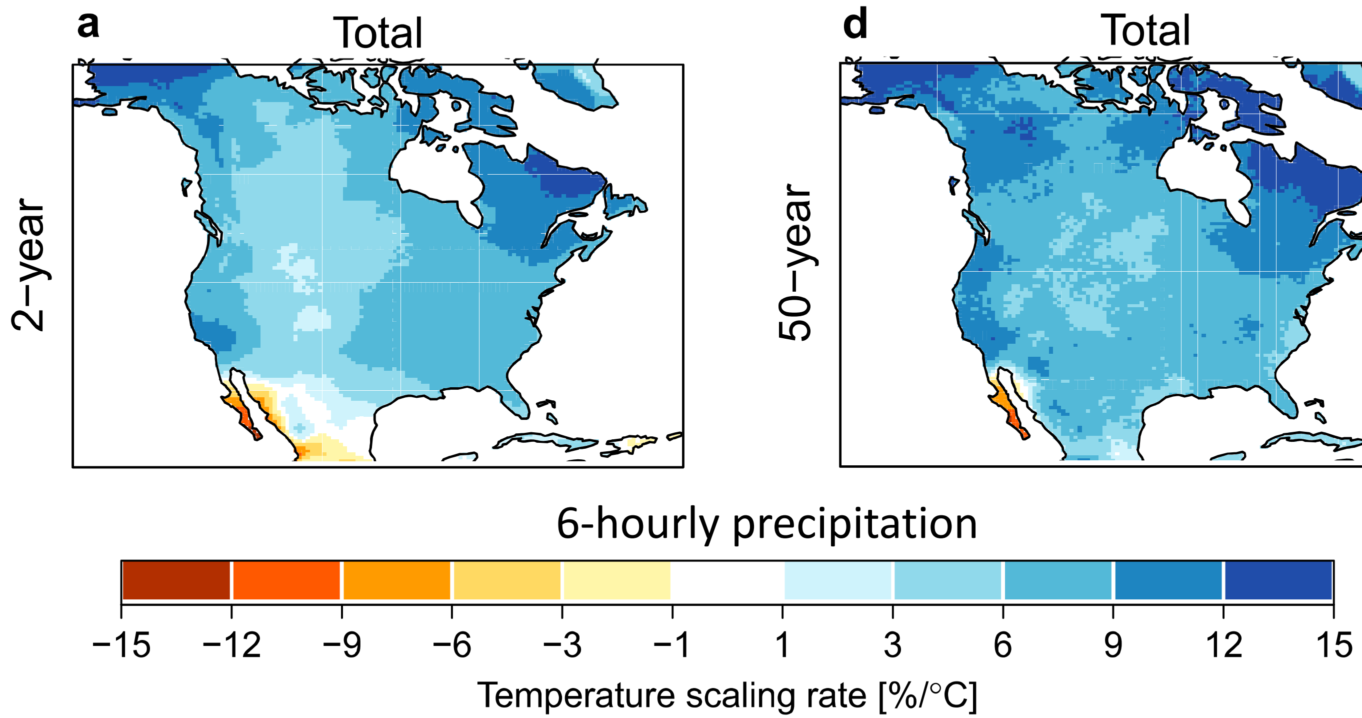


Figure 4.1
Pure-water saturation vapor pressure over a flat water surface.

Source: Stull (2017), *Practical Meteorology*

Model studies of future T scaling

- Medium and high-resolution RCMs indicate that C-C relation bears out, but with α ranging from ~5-10% depending on location and return period (Li et al., 2019)
- Suggests estimation of *local change factor* in precipitation, $(1 + \alpha)^{\Delta T}$, using *local ΔT* from climate model projections



Source: Li et al. (2019)

Future-shifted IDF curves: An example

Coloured bands: 5th-95th percentile range for 24 CMIP5 GCMs under RCP8.5, circa 2071-2100

Computed from:

$P = P_0\,(1 + \alpha)^{\Delta T}$, with $\alpha = 0.07$

and

$\Delta T = 6.4\ (3.5 \text{ to } 7.8)\ ^{o}\text{C}$ at this location.

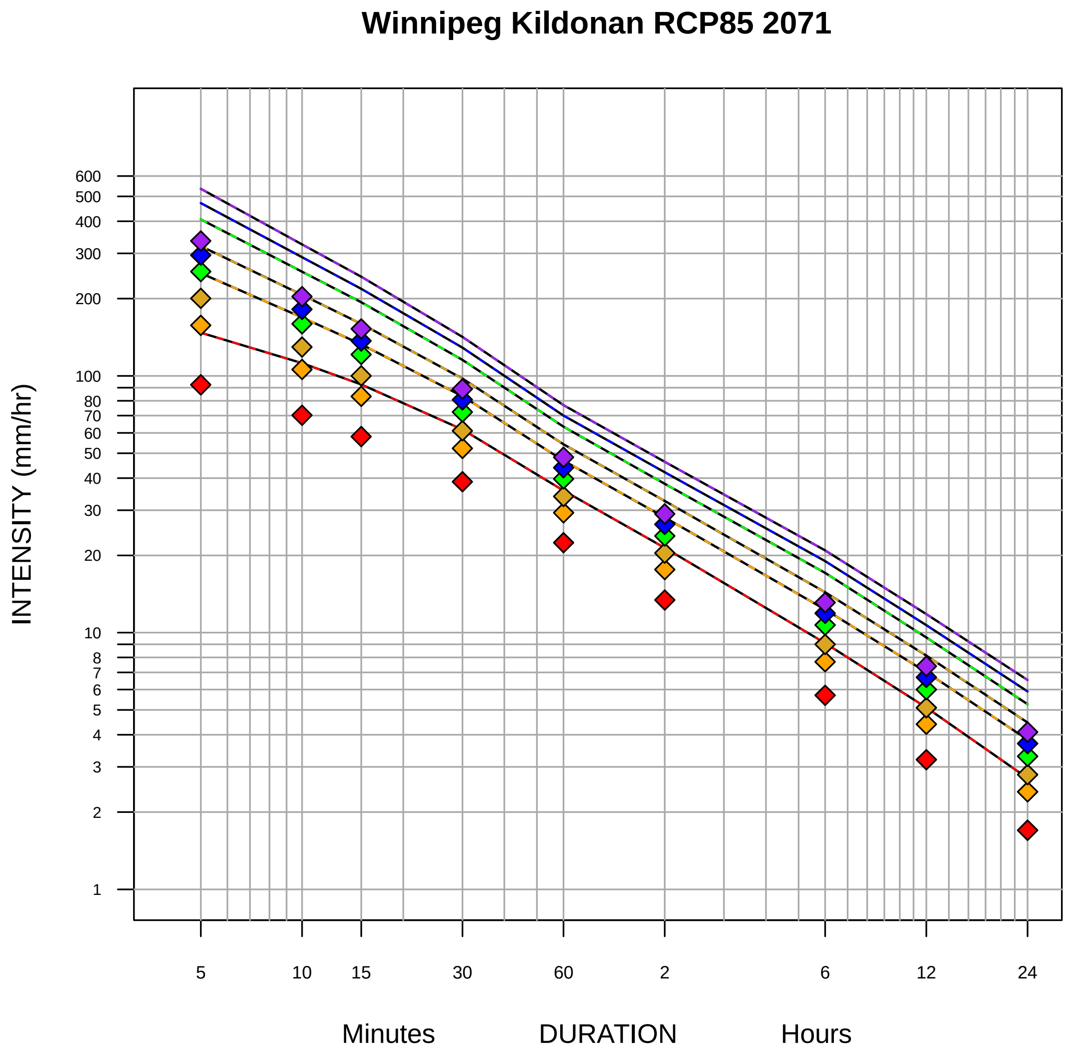
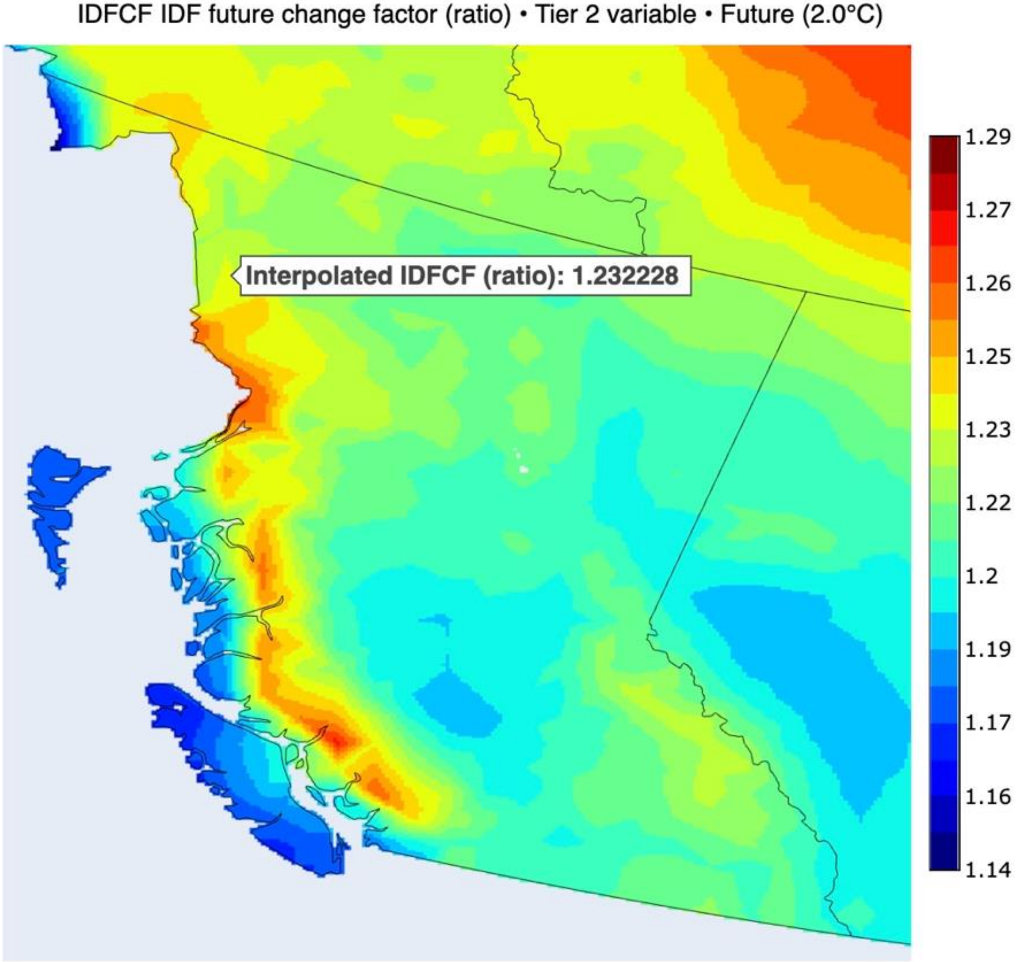


Fig. courtesy of S. Sobie (PCIC), with data provided by J. Fyke (ECCC)

Extreme rainfall change factors over BC

- Change factor: $[1 + (\alpha/100)]^{\Delta T}$ with α = 7%.
- By late 2050s (ΔT_{global} = +2°C), change factor ranges from ~1.15 to 1.30 over BC
- Available at all locations on the climate model grid



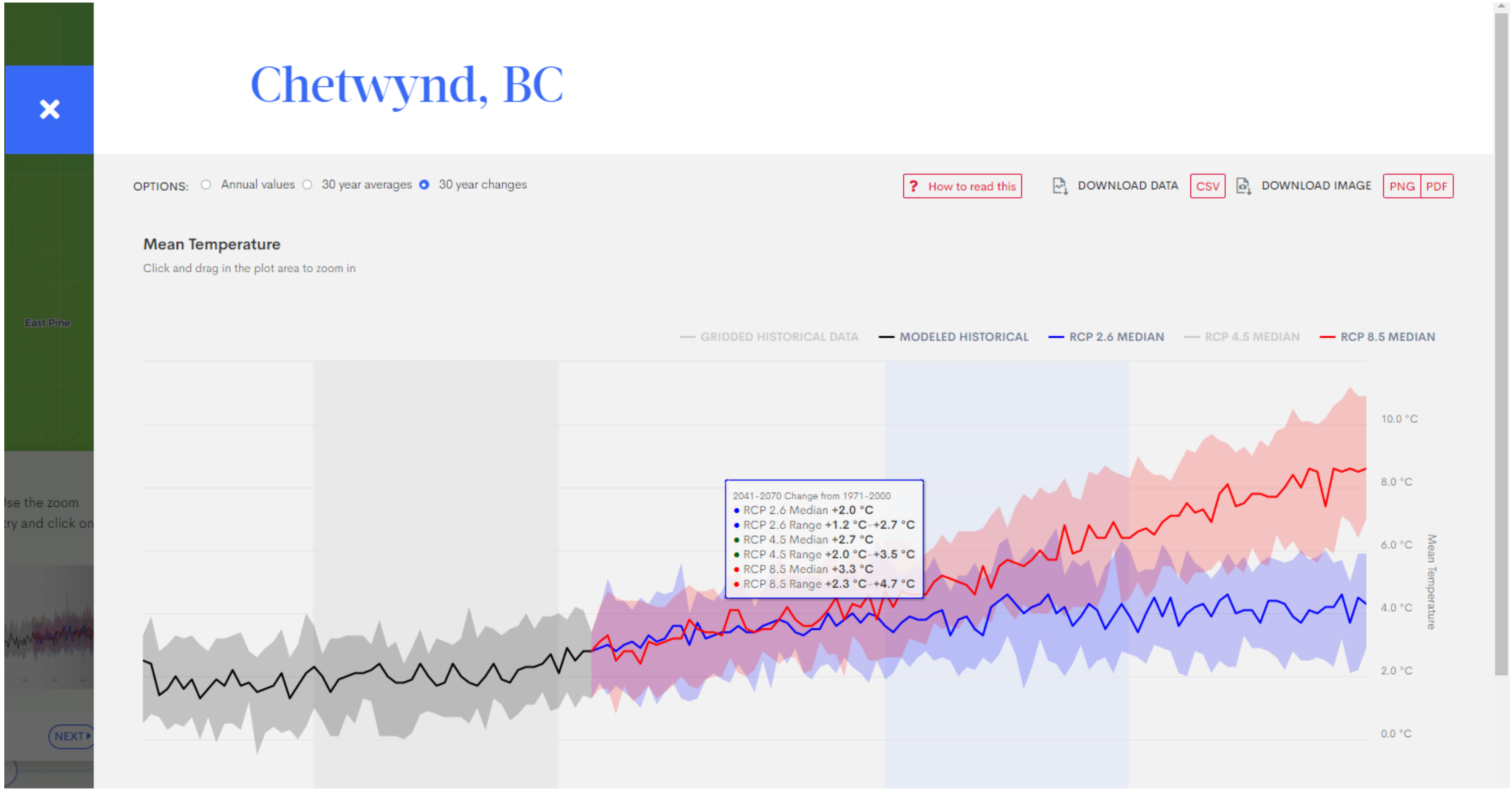
Source: PCIC's Design Value Explorer (under development)

Annual mean temperature change projections

E.g., ClimateData.ca

Provides 30-yr average ΔT for several time periods and RCP scenarios.

ΔT = 3.3 (2.3-4.7) ºC for RCP8.5 at this location



Source: ClimateData.ca

Takeaways

- Use of direct output from global & regional climate models for precipitation analysis is not advisable unless region of interest is much larger than model grid scale, and durations of interest are > 1 hour
- Temperature projections from such models are more secure, and not as sensitive to limiting spatial and temporal scales (but these should still be respected)
- Where IDF curves are available and their use is appropriate—e.g. in small, rainfall-dominated watersheds—*T*-scaling of historical IDF curves is a physically-based, simple way of estimating future *P* at a given probability (return period)
- Given that results from hydrologic models are available for larger watersheds, ad hoc methods of future rainfall estimation should be avoided