University of Victoria

PACIFIC CLIMATE IMPACTS CONSORTIUM

Extreme Value Analysis of Ground Snow Load in Canada

Yaqiong Wang, Charles Curry, Charlotte Ballantyne, Faron Anslow, Francis Zwiers

AGU Session: Extreme Precipitation in Past, Present, and Future Climates I

Dec 12, 2019

Why Study Extreme Snow Load?

- Provide basis for structural design and reliability

Source: Sooke News, Mar.7, 2018.

Previous Work

1. Blanchet, J. & Lehning, M. (2010)

- Compared different techniques to map extreme snow depth in Switzerland.
- Suggested a better performance of GEV fitting.

2. Hong, H. P. & Y, W. (2014)

- Described how the 2015 version of National Building Code of Canada (NBCC) snow load climate design value was developed.

Objectives

1. Which type of extreme value distribution best describes the snow data?
2. Do observations tell us the value of snow load have a finite upper bound?
3. To produce updated estimates of 50 year return value of snow load across Canada.

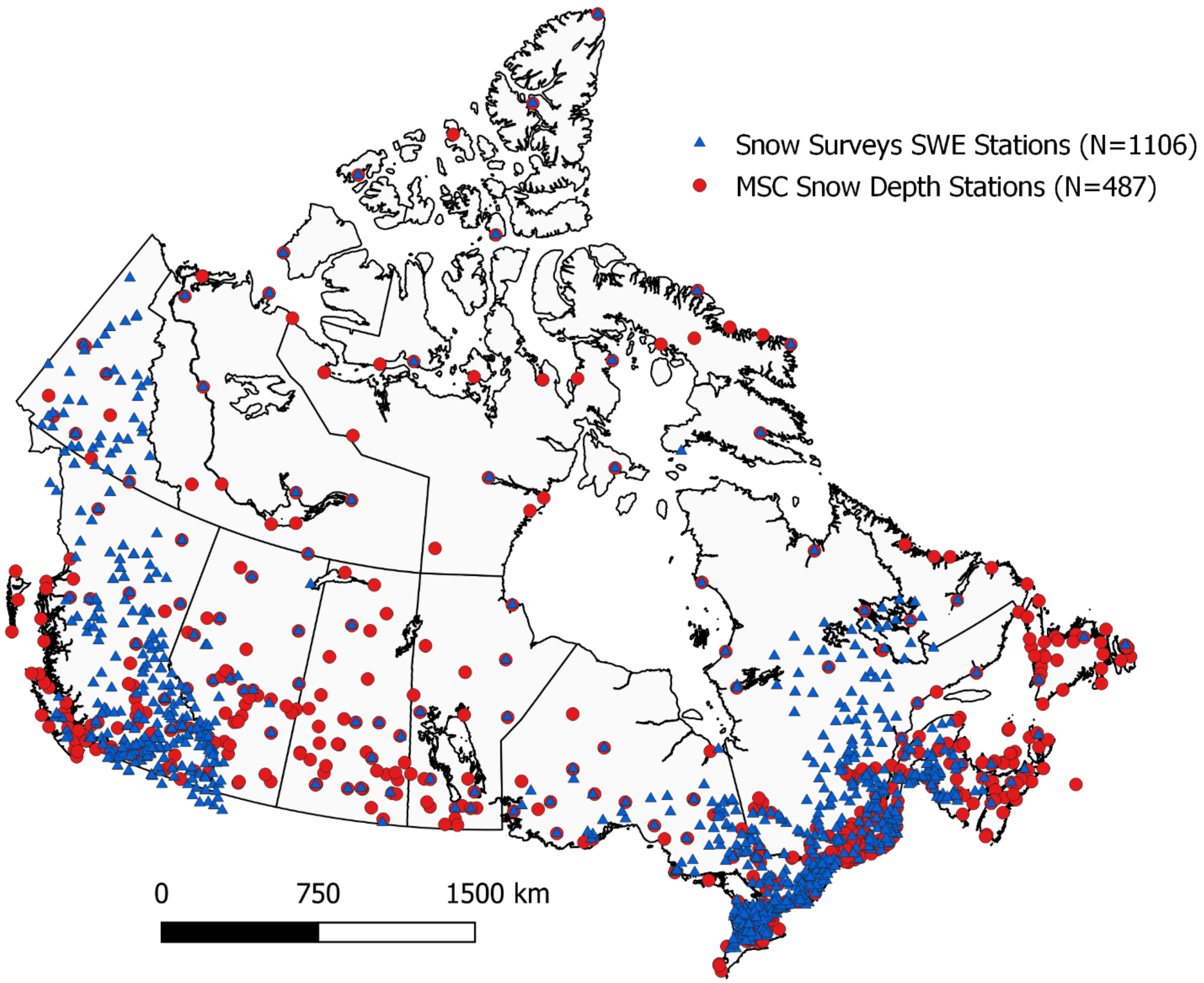
Data

Variables:
- Snow Depth: 1945 - 2017
- Snow Water Equivalent (SWE): 1939 - 2016

Data preparations:
- Quality assurance:
  errors & outliers check
- Screening for missing data

-> **Annual maximum SD and SWE time series**

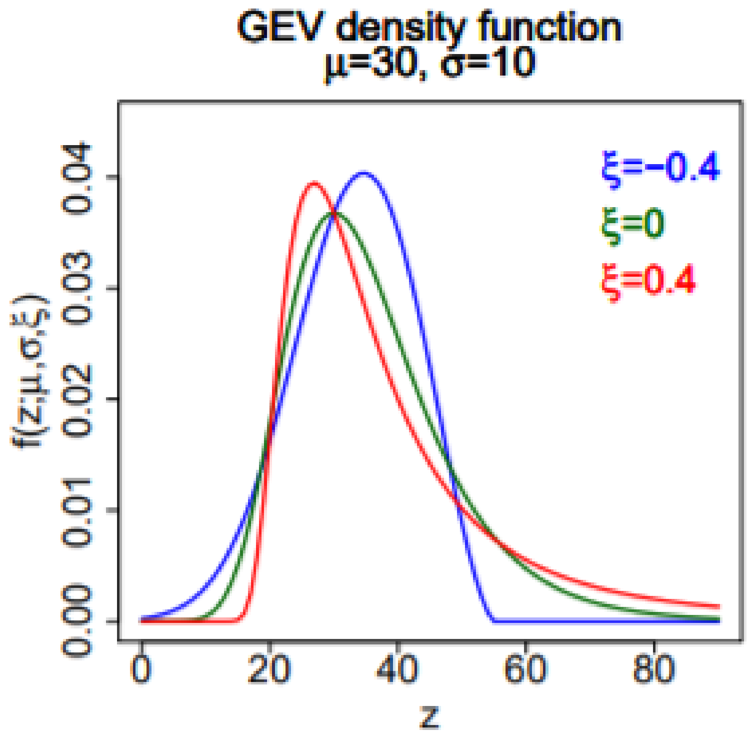
Stations with at least 20 years of useable data



The Generalized Extreme Value Distribution (GEV)

$$G(z) = \begin{cases} exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}, for\ \xi \neq 0 \\ \exp\left[-exp\left\{-\left(\frac{z-\mu}{\sigma}\right)\right\}\right], for\ \xi = 0 \end{cases}$$

μ: location, σ: scale, ξ: shape estimated by L-moments



Source: Blanchet, J. and Lehning, M. (2010)

Type I: light-tailed Gumbel Distribution ($\xi = 0$)

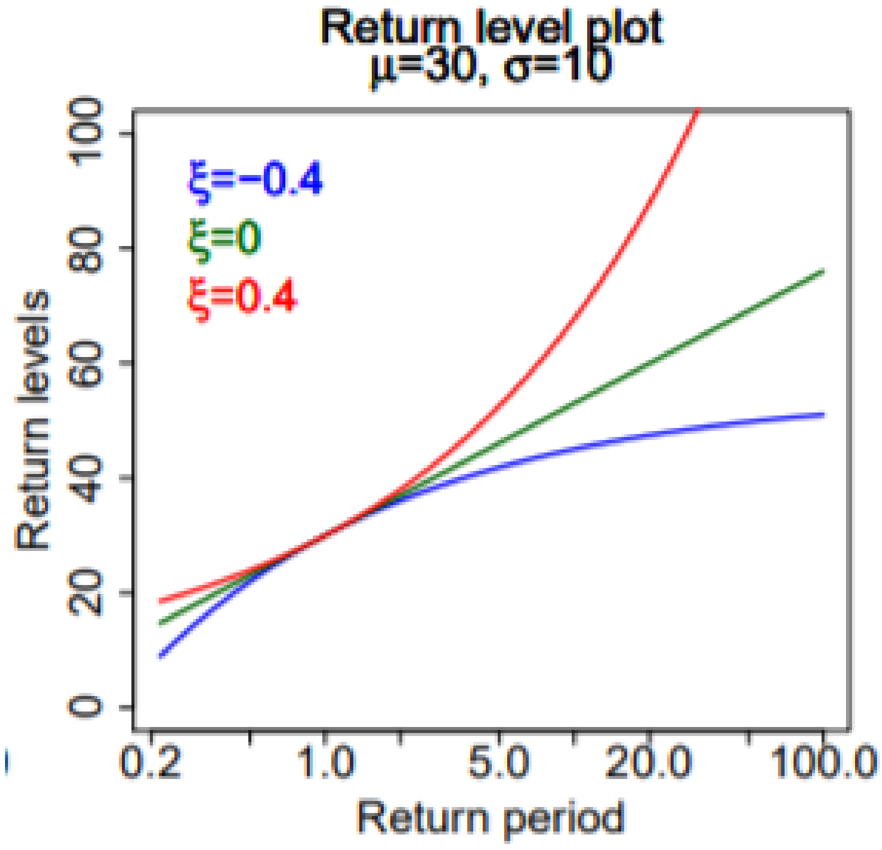
Type II: heavy-tailed Fréchet Distribution ($\xi > 0$)

Type III: finite tail Weibull Distribution ($\xi < 0$)

Return level estimation

$$Z_p = \begin{cases} \mu - \frac{\sigma}{\xi}\left[1 - \{-\log(1-1/p)\}^{-\xi}\right], for\ \xi \neq 0 \\ \mu - \ \sigma \log\{-\log(1-1/p)\}, for\ \xi = 0 \end{cases}$$

(p: return period)



Source: Blanchet, J. and Lehning, M. (2010)

Significance Testing for the Shape Parameter
(Hosking et al. 1985)

- H_0: $\xi = 0$
- L-moment estimator $\hat{\xi}$ is asymptotically distributed as *N(0, 0.5633/n)*
- Test statistics: $Z = \hat{\xi}(n/0.5633)^{1/2}$

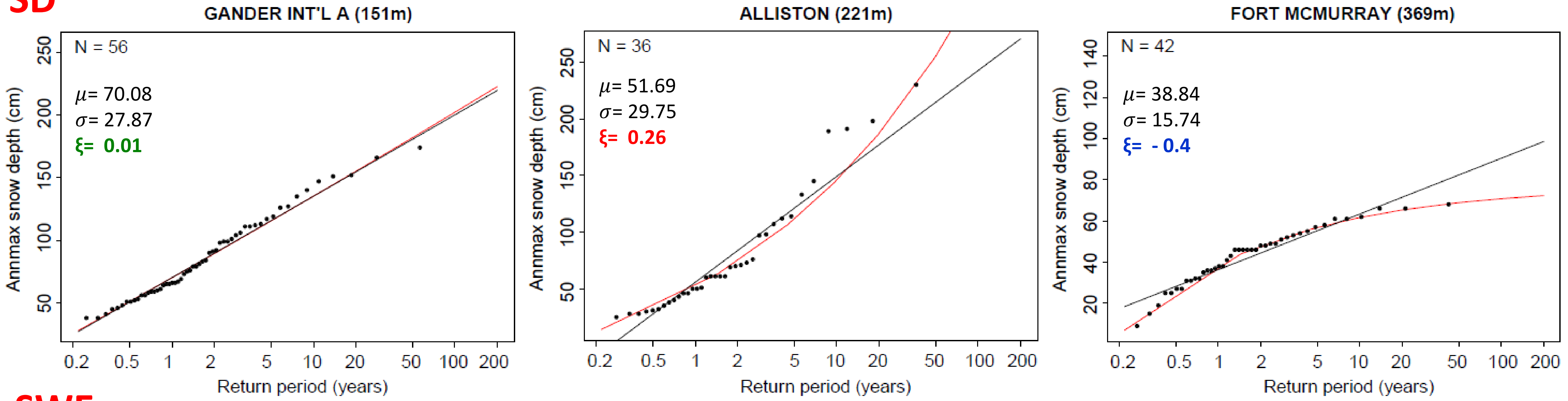
Significant Z > +2 -> rejection of H_0 in favor of **$\xi > 0$ Fréchet**

Significant Z < -2 -> rejection of H_0 in favor of **$\xi < 0$ Weibull**

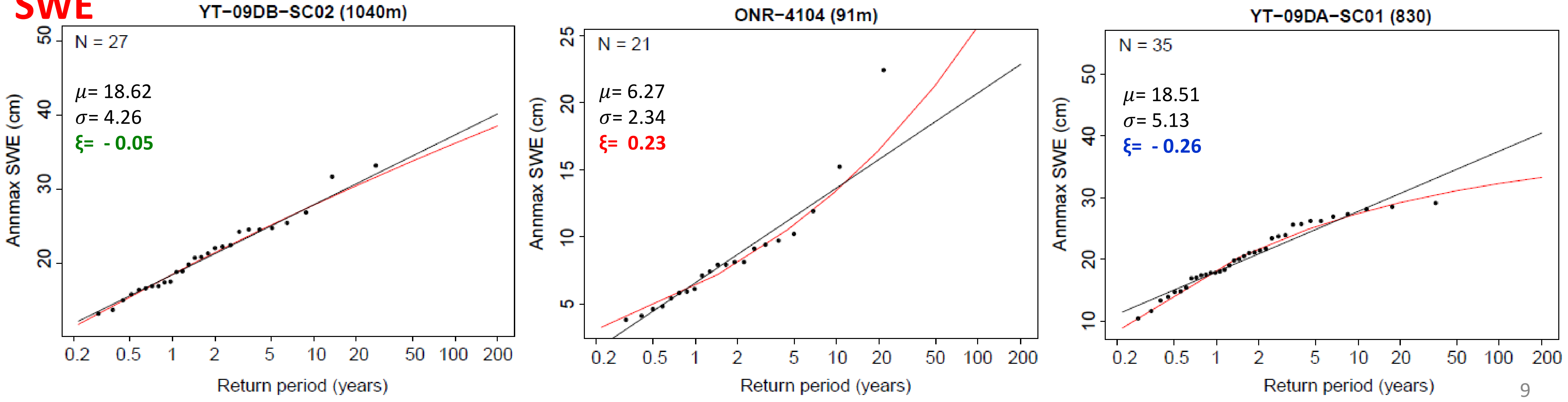
Otherwise, accept H_0 **Gumbel**

Return Level Comparison

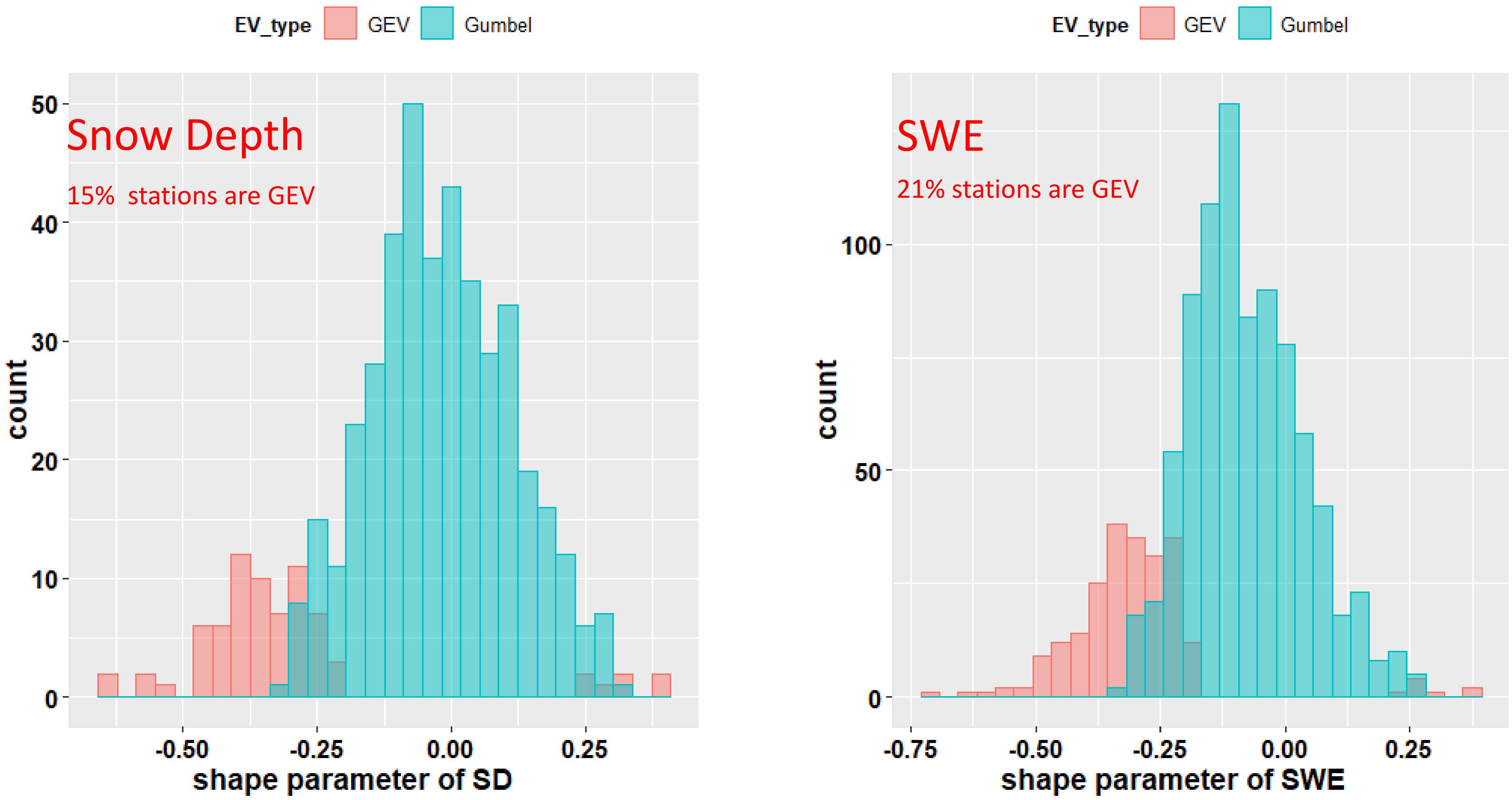
SD



SWE

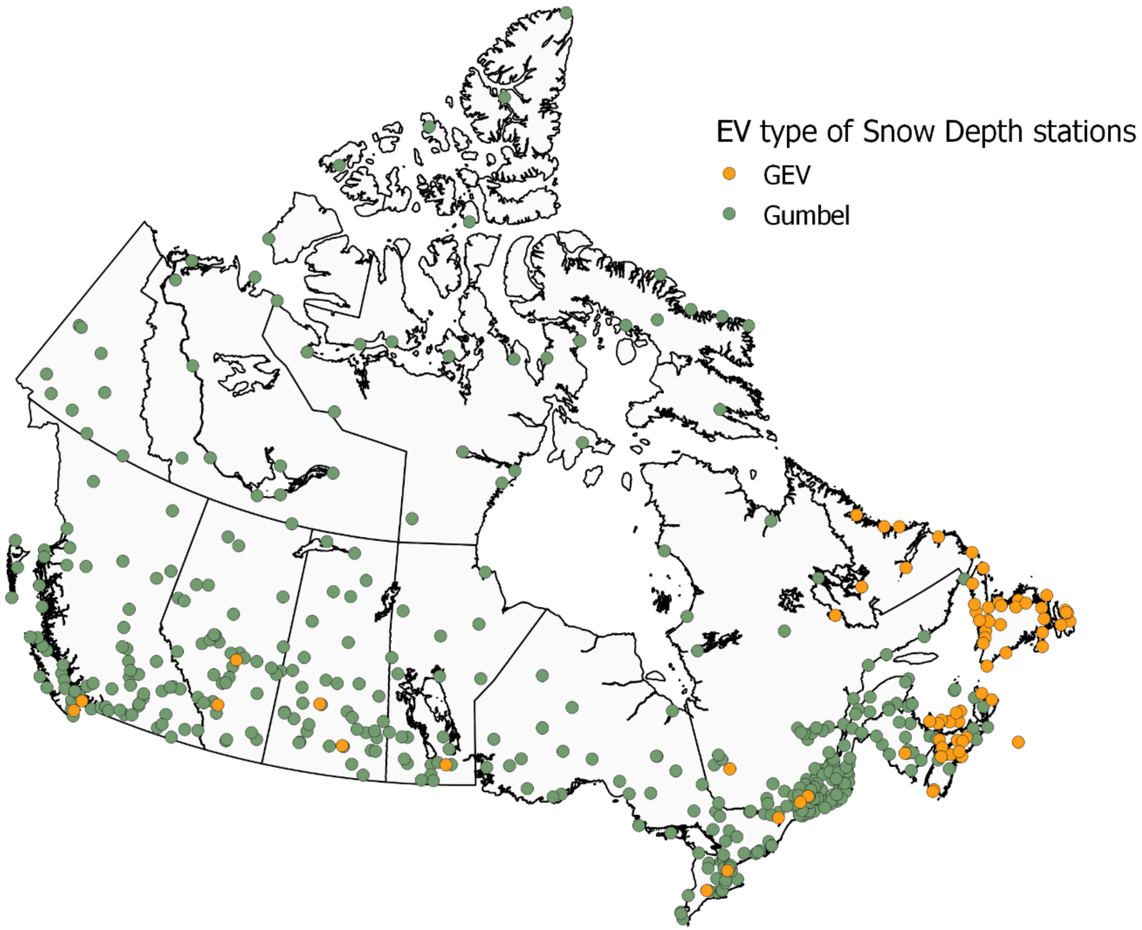


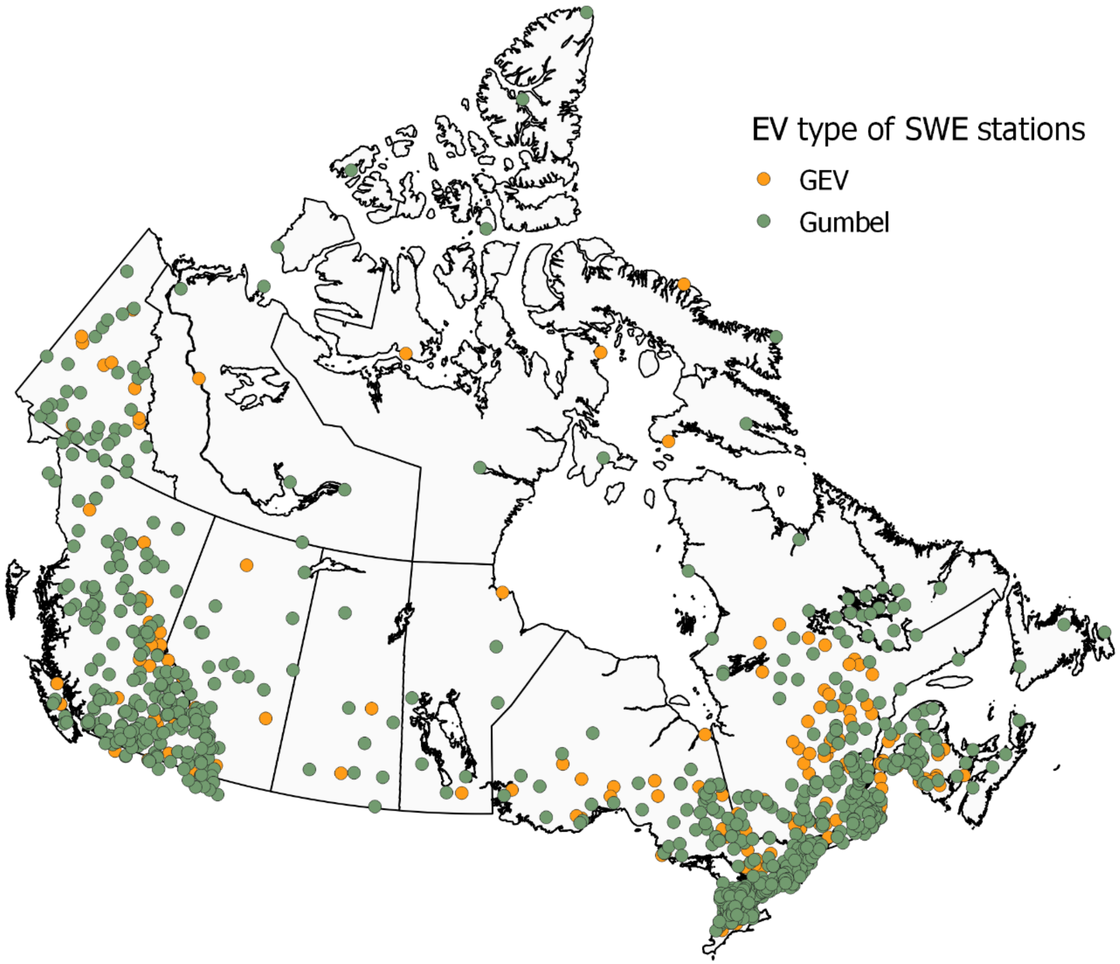
How many stations are well fitted as GEV?



Histogram of Shape Parameter (ξ)

Geographical Pattern of EV Distribution





Implications of the upper tail of snow data fitted by GEV

1. For those stations that are suitable for GEV, most of them have finite right tail with $\xi < 0$ (**Weibull distribution**), which explains snow behaviours. For SD, because of snow compaction, SD decreases after the peak SD. For SWE, snow melt could lead to a decrease of water content in the snow. Wind also lessens both SD and SWE.

2. For the risk management, cases when $\xi > 0$ (**Fréchet**) are of particular concern because very large snow load may occur.

Gumbel distribution is preferred for 80%- 85% of stations

Calculation of Ground Snow Load

- Snow component

$$\boldsymbol{S_S = 10^{-3}\,\rho_w g\, SWE_{50}}$$

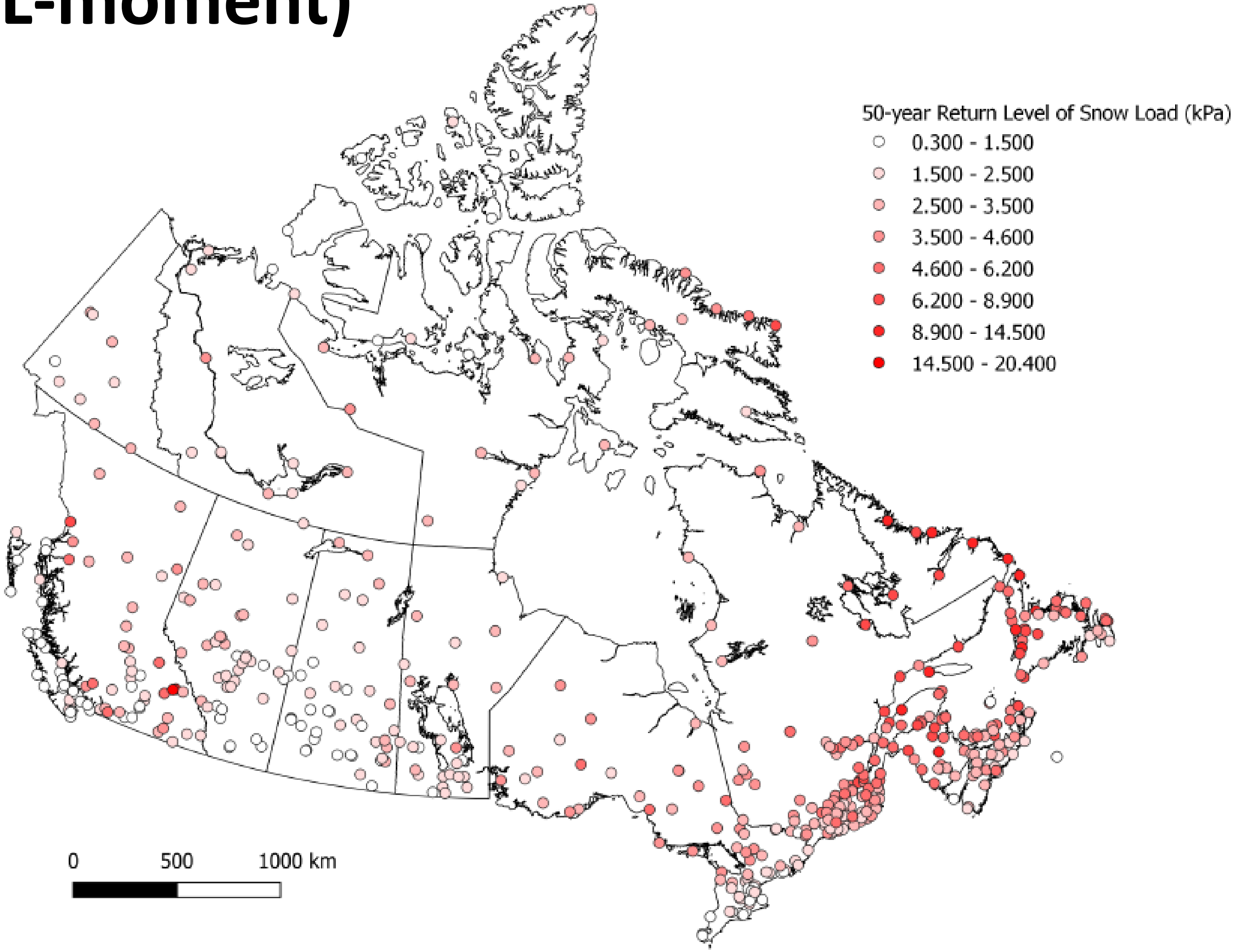
$\boldsymbol{S_S}$: snow load (kPa)

$\boldsymbol{\rho_w}$: density of liquid water (kgm^{-3})

$\boldsymbol{g}$: 9.8 ms^{-2}

$\boldsymbol{SWE_{50}}$: 50 year return value of SWE (m), determined from Gumbel fit

50 year return level of Snow Load – Gumbel (L-moment)



Summary

1. Gumbel distribution is the best fit for most of the snow stations;
2. When $\xi \neq 0$, most stations have finite upper bound, which means snow value peaks at a finite number.
3. In Canada, the updated estimation of 50-year snow load range from 0.38 kPa to 20.4 kPa.

Thank you!

yaqiongw@uvic.ca

References

- Blanchet, J., & Lehning, M. (2010). Mapping snow depth return levels: smooth spatial modeling versus station interpolation.
- Newark, M.J., Morris, J.R. & Dnes, W.V. (1988) Revised ground snow loads for the 1990 National Building Code of Canada.
- Hong, H. P. & Y, W. (2014). Analysis of extreme ground snow loads for Canada using snow depth records.
- Hosking, J.R., Wallis, J.R. & Wood, E.F. (1985). Estimation of the Generalized Extreme Value Distribution by the Method of Probability-Weighted Moments.
- Wilks, D. S., and McKay, M., 1996. Extreme-value statistics for snowpack water equivalent in the northeastern United States using the cooperative observer network.

Comparison between NBCC 2015 and ours