Research supported by NASA WR Applied Science (NNX15AC47G)

Future Snow Water Equivalent and Snowmelt Extremes from NA-CORDEX Ensembles

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Red River Flood in 1997 & 2009

2020 EGU
Sharing Geoscience Online
May 4th 2020

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Background – Snow-driven Extreme Events in U.S. and Canada

2006 Red River Basin, ND

- Snow and snowmelt driven extreme events can have large societal and economic consequences. Extreme snow can ***damage infrastructure and buildings***.
- Snow meltwater is a dominant driver of ***severe spring flooding*** in the north-central and -eastern U.S. and southern Canada.
- The current and future snowpack and snowmelt extreme design maps are very limited ***due to the lack of reliable long-term snow data***.

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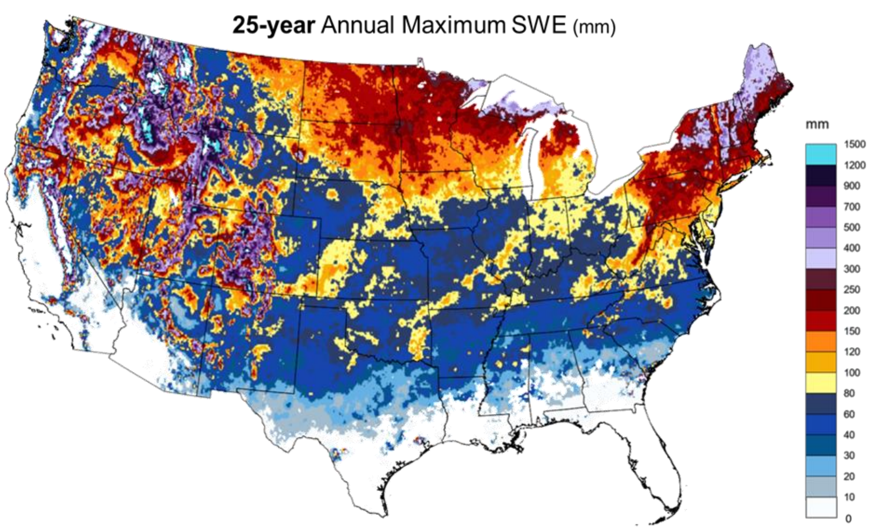
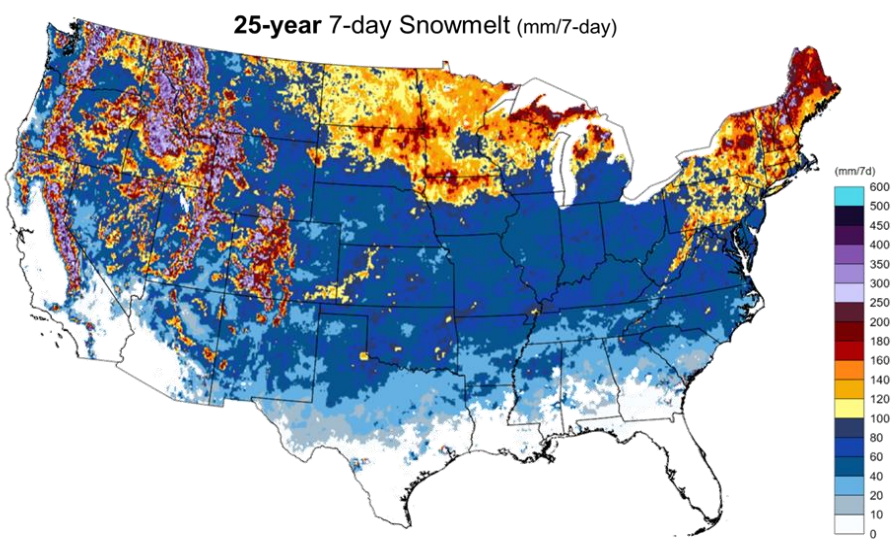
Motivation

The "current" U.S. government standard design precipitation maps (e.g. Atlas 14) are based on liquid precipitation data with **very limited guidance on snowmelt-driven floods**.

→ We recently developed 25- and 100-year return level snowpack (SWE; snow water equivalent) and snowmelt maps over the continental U.S. (*Cho & Jacobs, 2020*)





Cho & Jacobs (2020; in preparation)

Research Questions

However…
engineers are still challenged to plan and design infrastructure for ***the "future" SWE & snowmelt extremes in a changing climate****.*

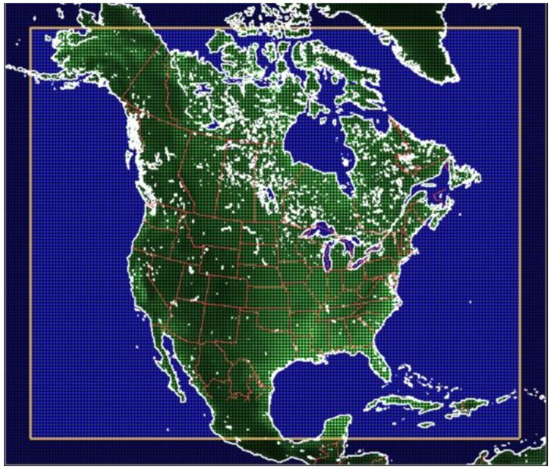
1. How much will snow-driven extreme events be changed in the mid-century and late-century from the current condition?

2. Which regions have the largest differences (uncertainty) among models in the future condition?

NA-CORDEX SWE data

- ***North America COordinated Regional Downscaling Experiment (NA-CORDEX)*** regional climate model (RCM) ensemble.
- Multiple RCMs are used to dynamically downscale multiple CMIP5 global climate models (GCMs).
- 25km resolution SWE simulations (3 RCMs, 7 GCMs, **9 Simulations**)

Full NA-CORDEX Domain



- **Study period**
  - **Historical (1976-2005)**
  - **Mid-century (2040 – 2069)***
  - **Late-century (2070 – 2099)***

*Future runs follows **RCP8.5** emissions scenario

GCMs ↓ / RCMs →	CRCM5 (UQAM)	RegCM4	WRF	CanRCM4
HadGEM2-ES		X	X	
CanESM2	X			X
MPI-ESM-LR	X	X	X	
MPI-ESM-MR	X			
GFDL-ESM2M		X	X	
GEMatm-Can	X			
GEMatm-MPI	X			

* RegCM4 models are excluded due to unrealistic wet estimates & numerical problems with snow.

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Method

Annual maximum 7-day snowmelt event ($Melt_{max,7d}$)

$$Melt_{max,7d} = \max(SWE_i - SWE_{i+7})$$

i is a date from 1 October to 31 May for each year

Generalized Extreme Value (GEV) Distribution

To estimate **25-yr** extreme values for the three periods, the GEV distribution was used. The standard cumulative distribution of the GEV can be expressed as

$$\Psi(x) = \exp\left\{ - \left(1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right)^{\frac{-1}{\xi}} \right\}$$

where the shape parameter (ξ), the location parameter (μ), the scale parameter (σ) and to specify the tail behavior, the center, and the deviation around μ of the GEV distribution, respectively.

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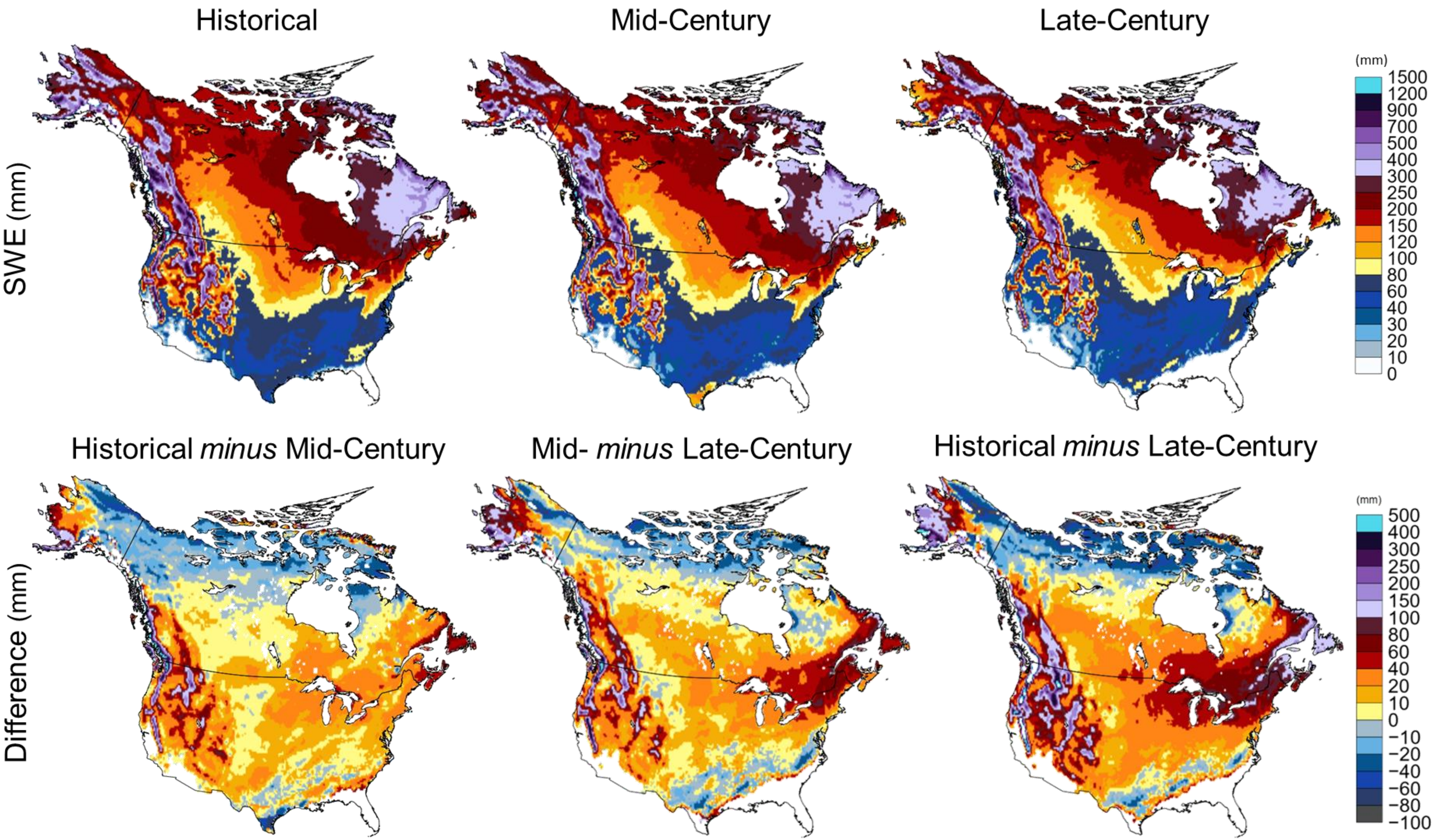
Result 1 – Future Changes in 25-yr Annual Max SWE ensemble



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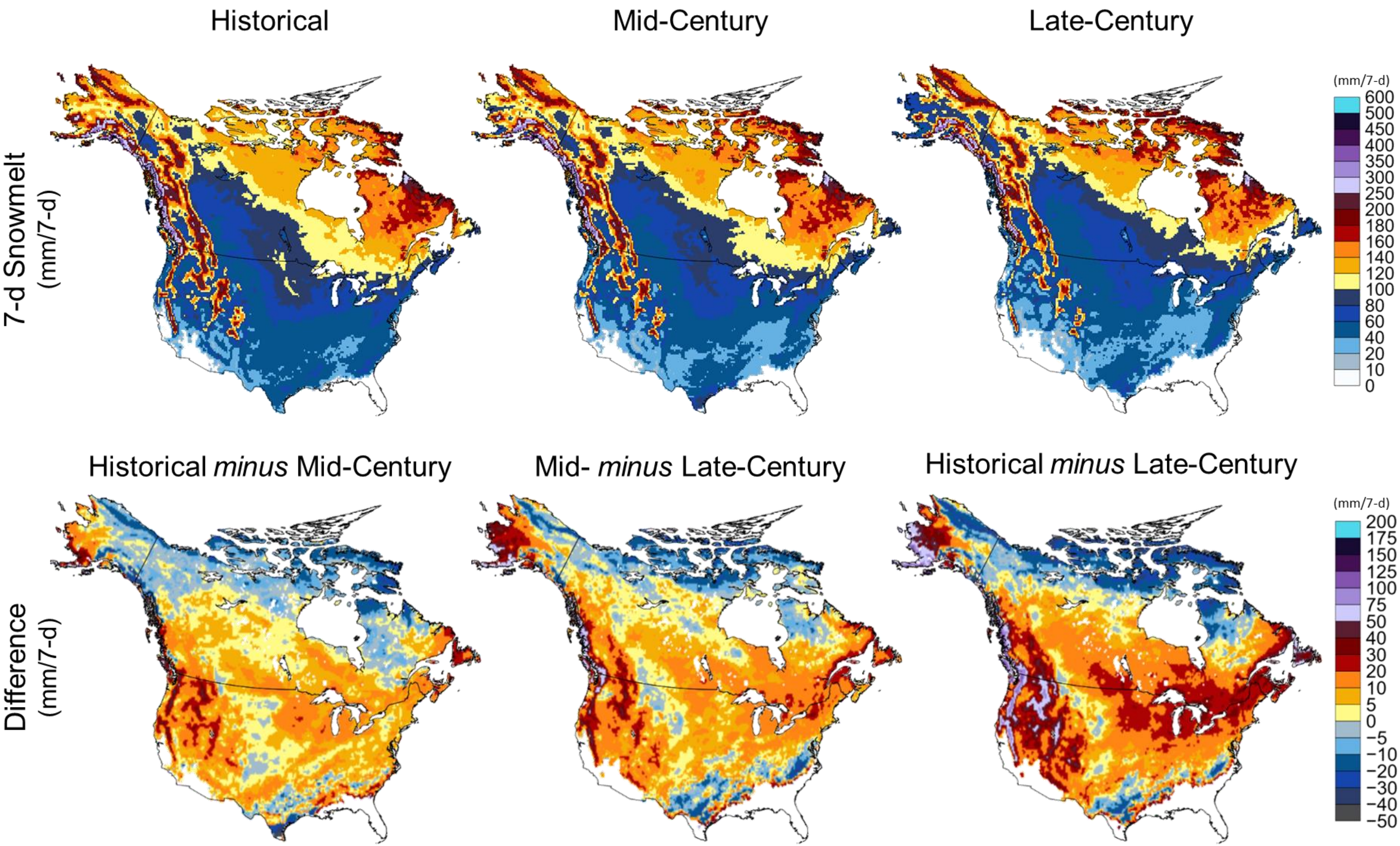
Result 1 – Future Changes in 25-yr Annual Max Snowmelt



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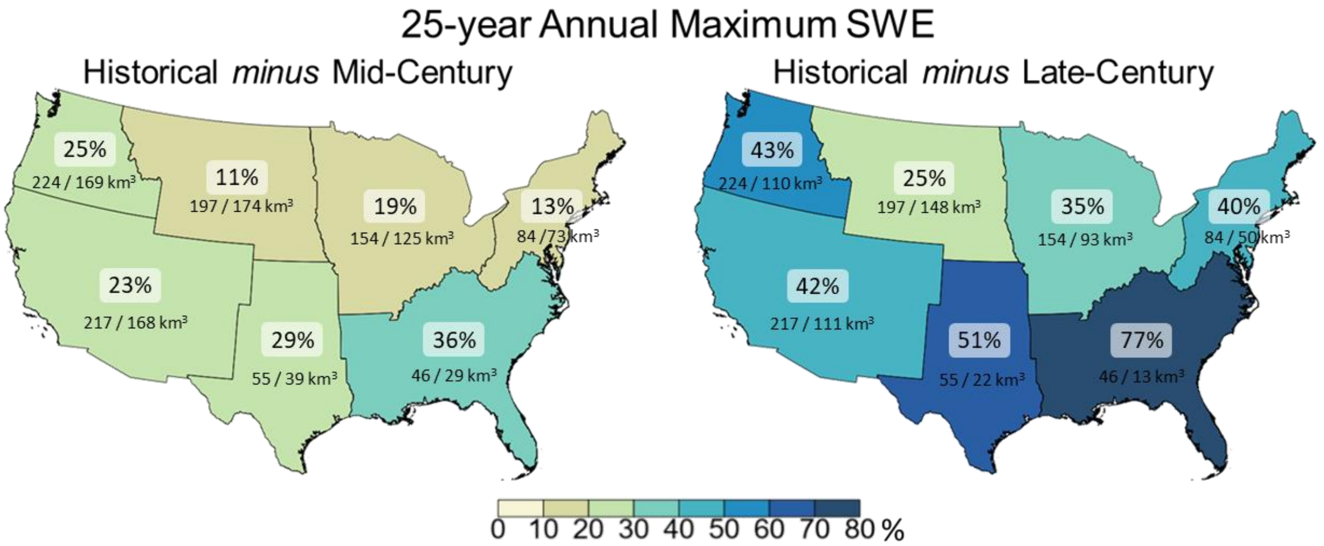
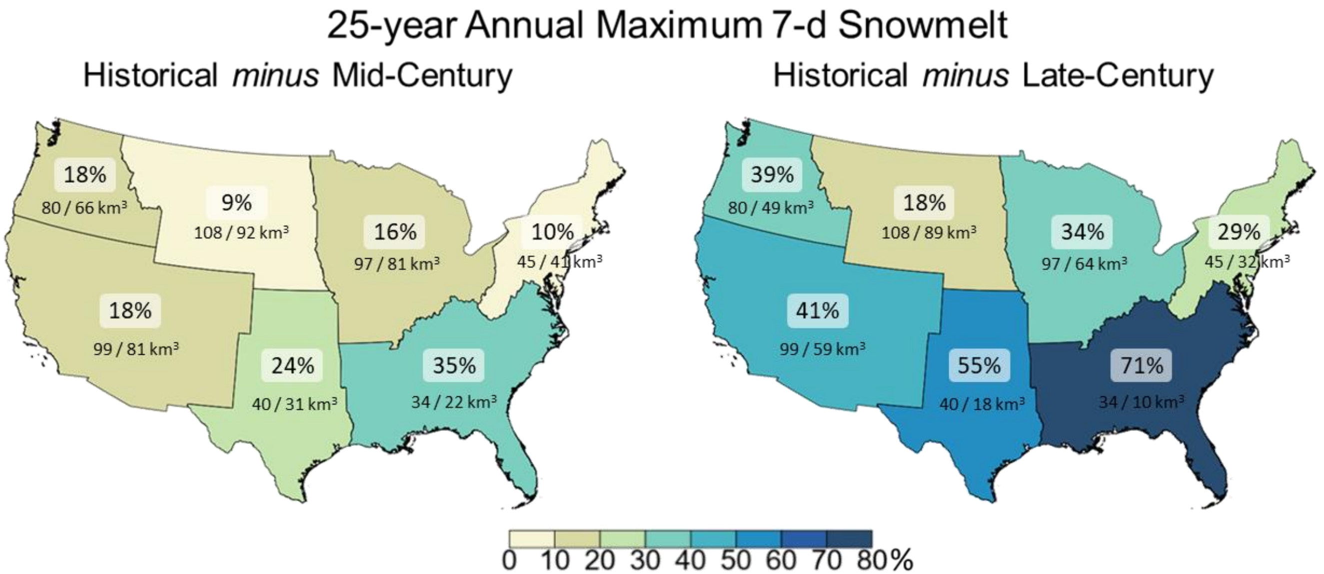
Result 2 – How much change by U.S. regions?





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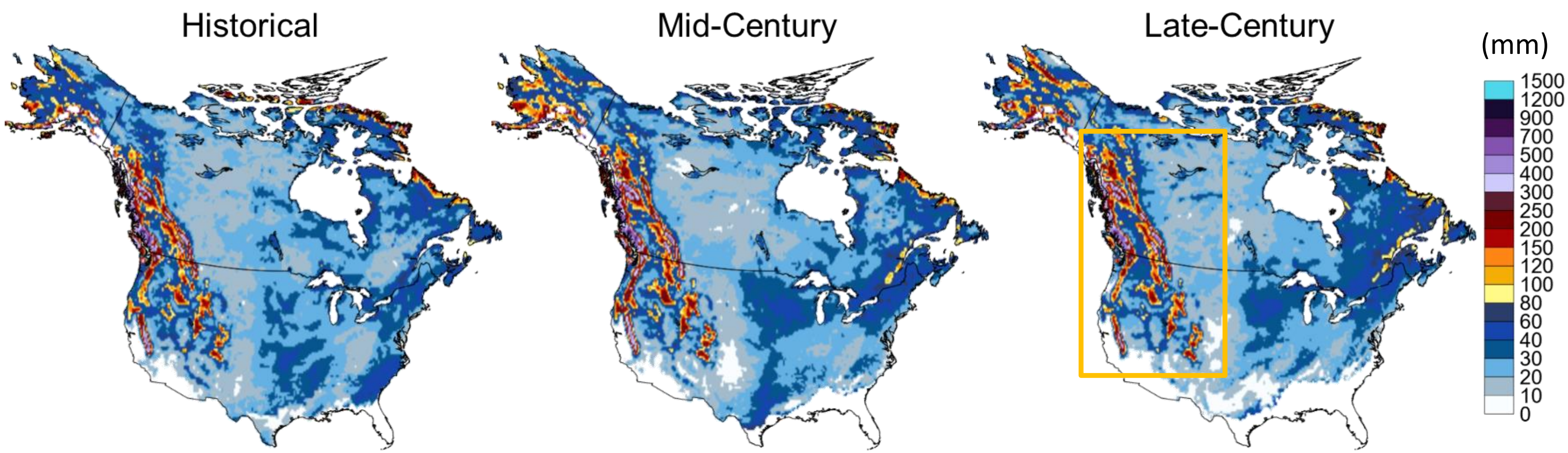
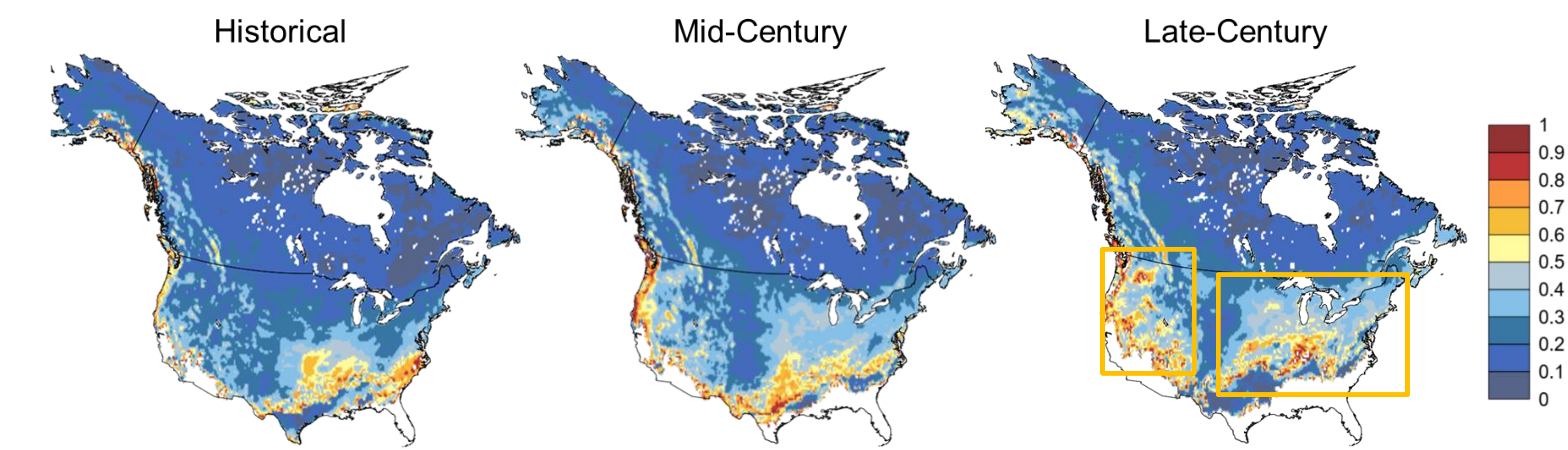
Result 3 – Which regions have the largest differences among models

Std. of the 25-year Annual Maximum SWE Ensemble



CV (coefficient of variation) of the 25-year Annual Maximum SWE Ensemble



*CV (= std/mean; coefficient of variation)

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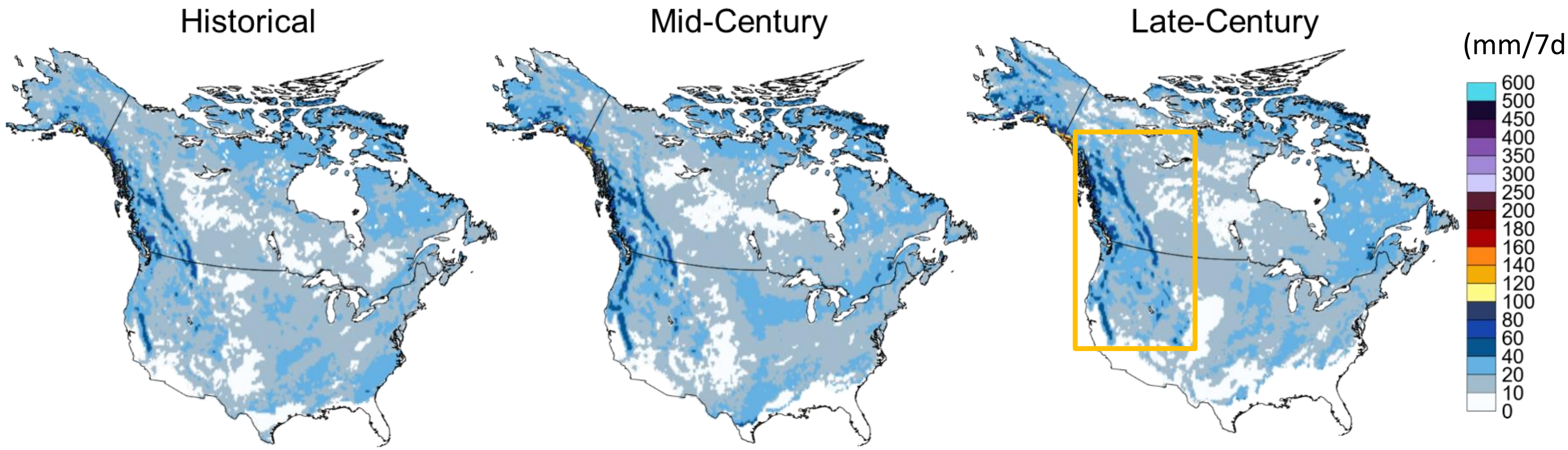
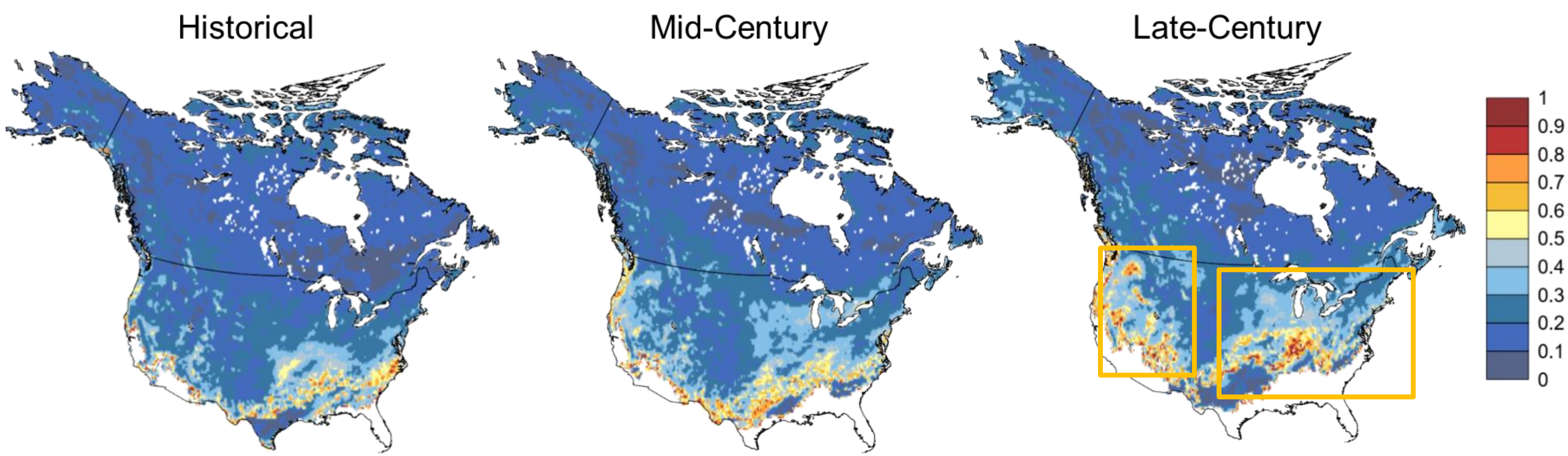
Result 3 – Which regions have the largest differences among models

Std. of the 25-year Return Maximum 7-d Snowmelt Ensemble



CV. of the 25-year Annual Maximum 7-d Snowmelt Ensemble



*CV (= std/mean; coefficient of variation)

Conclusion

Q1. **How much** will **snow-driven extreme events change** in the mid-century and late-century across the north America?

1. Extreme SWE events will decrease by up to 150 mm (mid-century) and 500 mm (late-century) and, for snowmelt, 50 and 100 mm over the western mountain ranges.
2. Also, there are considerable decreases in northeastern U.S. and southern Ontario and Quebec, Canada.

Q2. **Which regions** have the **largest differences** (uncertainty) among models in the future condition?

1. For absolute variations (Std), there are the largest differences in the western mountain regions.
2. For relative values (CV), the mountains have relatively low variability, the central and southern parts of the U.S. have large differences among models.

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Acknowledgement

We gratefully acknowledge the support from ***NASA Water Resource Applied Science Program*** (NNX15AC47G). The authors are grateful to all colleagues who contributed to the NA-CORDEX datasets.

Reference

Cho, E. & Jacob, J. M. (2020) Extreme Value Snow Water Equivalent and Snowmelt for Infrastructure Design over the Contiguous United States, preprinted at ESSOAr *https://doi.org/10.1002/essoar.10501588.1*

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Thank you!

Question?

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