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Convection-permitting WRF regional climate simulations for Canada

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Global Institute for Water Security

University of Saskatchewan

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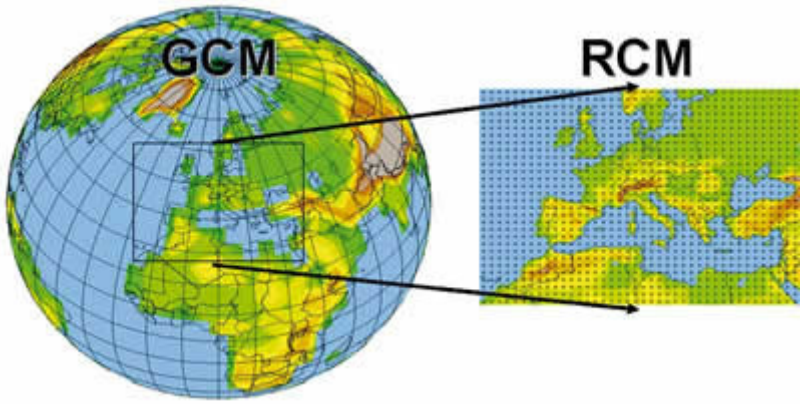
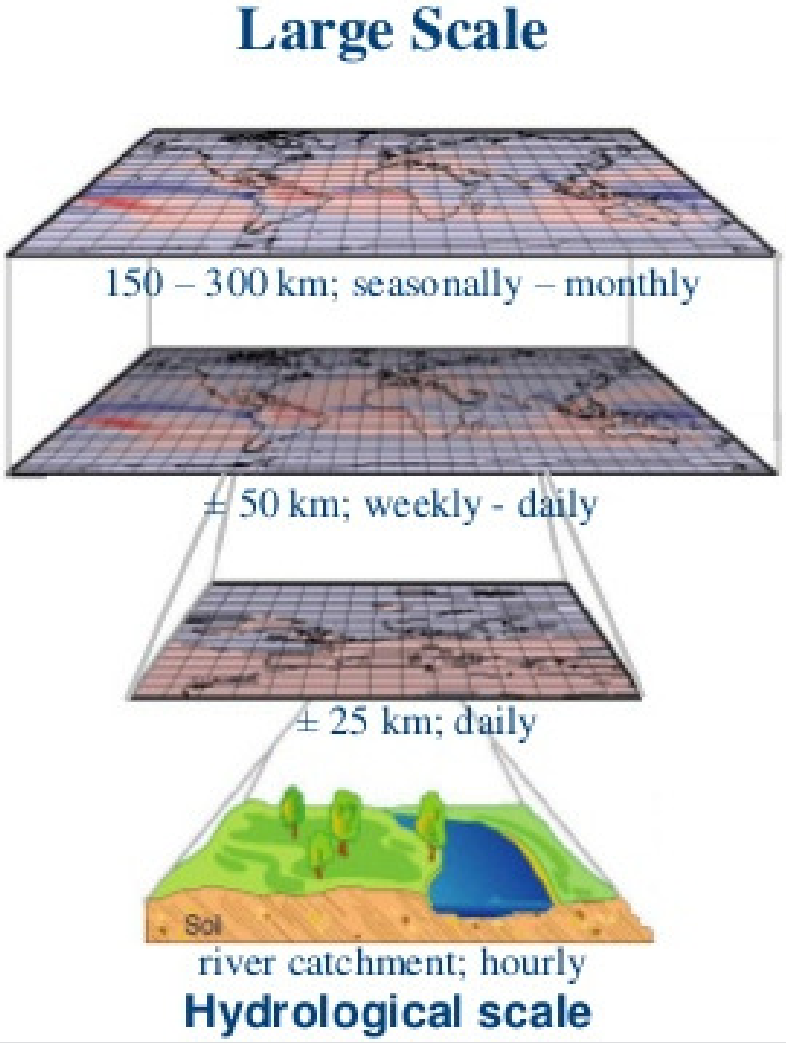
Downscaling of GCM output





General Circulation Models (GCMs)

Regional Climate Models (RCMs)

Advantage of Convection Permitting regional climate model

For mountainous regions: resolves mesoscale orography and the heterogeneous landscape;

For the prairies: more realistically simulation of summer convection

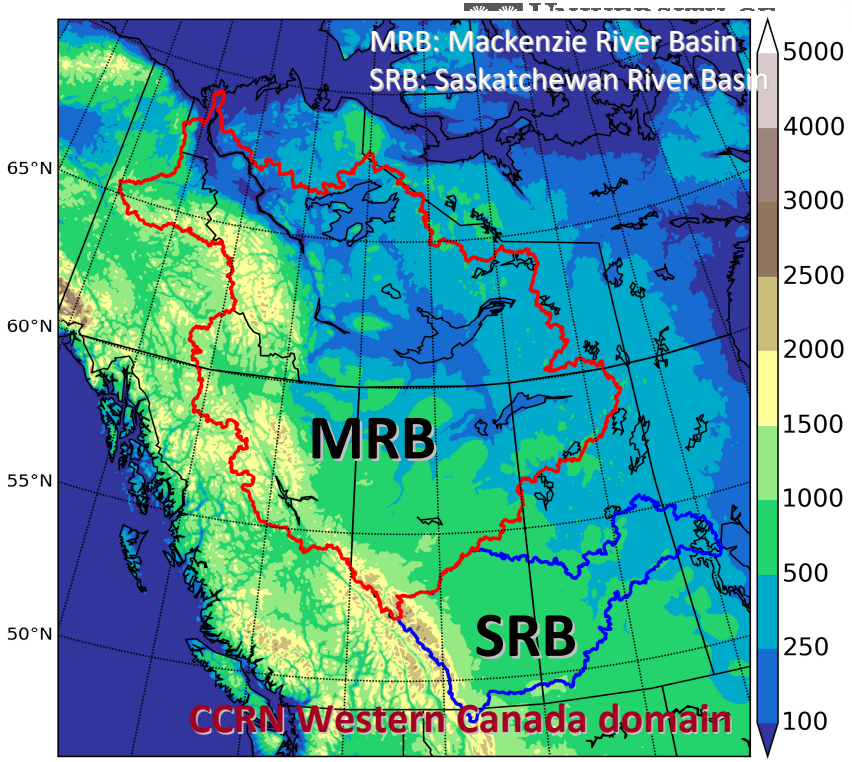
Continental Scale Regional Climate Simulation using 4-KM WRF

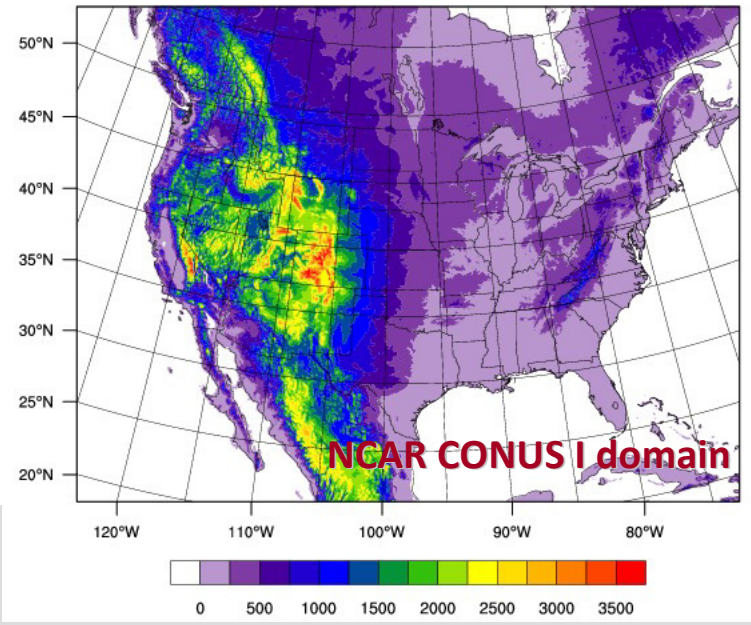
WRF Model Setup and Design

- WRF Model (Version 3.4.1)
- A single domain: 2560 x 2800 km^2;
  4 km grid spacing; 37 levels
- Microphysics Scheme: New Thompson et al.
- PBL scheme: YSU
- RRTMG Long-wave and Short-wave scheme
- No Cumulus parameterization used, assumed explicit

Forcing Data

- The 6-hourly, 0.703^0 x 0.703^0 resolution ERA-Interim reanalysis data provide the initial and lateral boundary condition





IPCC AR5 future scenarios

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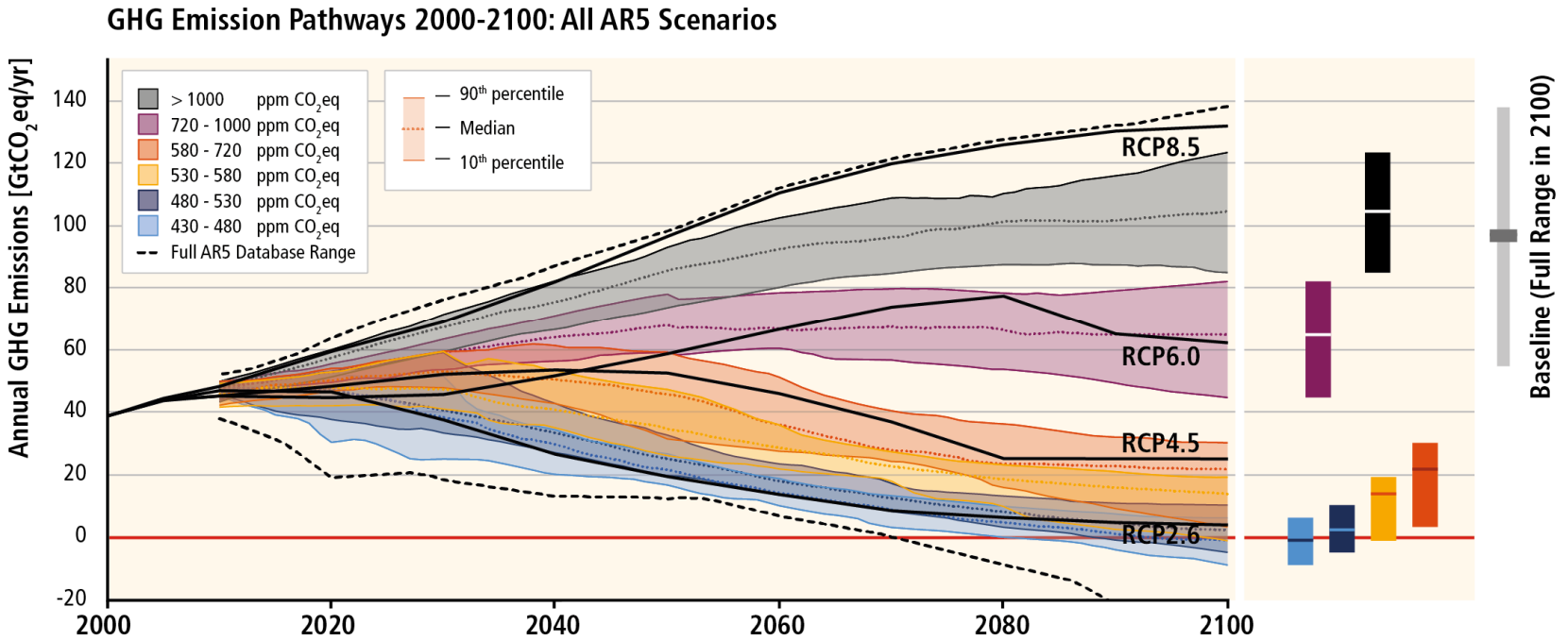

Simulation period

WRF-CCRN simulation: Covers western Canada from British Columbia to Manitoba (135-96W) in the west-east direction and from northern US to Arctic Ocean in the south-north direction (47-69N).
The current climate (CTL) from 2000-10 to 2015-09 and a pseudo-global warming (PGW) scenario representing the condition of 2085-2100 under RCP8.5.

WRF-CONUS I simulation: goes to 56N.
Two 13 years simulations consisting of a retrospective simulation and a future climate sensitivity simulation with initial and boundary conditions derived from reanalysis and modified by adding the CMIP5 ensemble mean of the high emission scenario climate change. Simulation period: 2000-10-01 to 2013-09-30, PGW representing the condition of 2086-2099 under RCP8.5.

GWF WRF 4-KM CONUS II simulation

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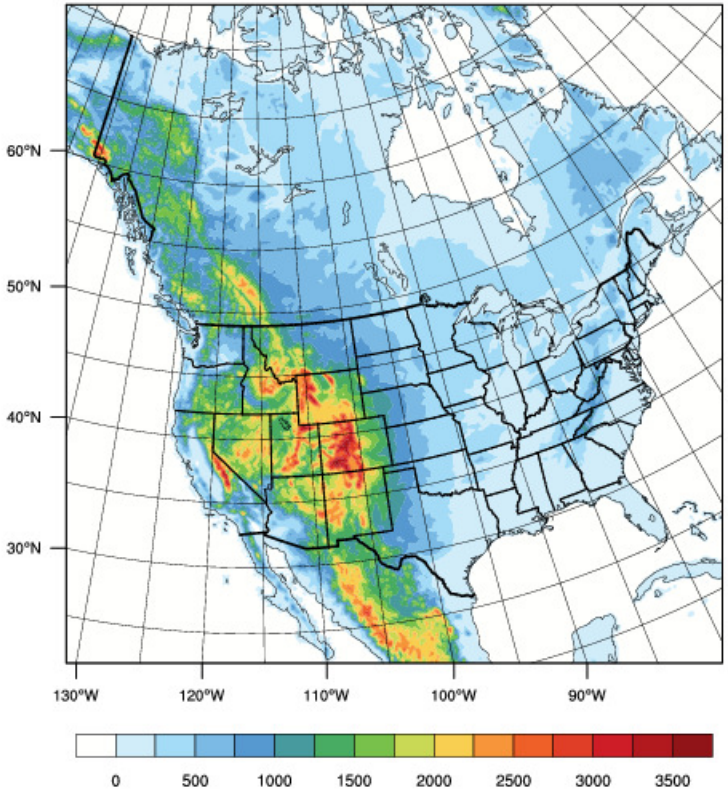

WRF Model Setup and Design

- WRF Model (Version 3.9.1)
- A single domain: 5640 x 5640 km^2; 4-km grid spacing; 51 levels
- Microphysics Scheme: New Thompson et al.
- PBL scheme: YSU
- RRTMG Long-wave and Short-wave scheme
- No Cumulus parameterization used, assumed explicit
- Land surface model: Noah-MP with ground water impact
- Cloud fraction: Xu-Randall; Thompson
- Model input: bias-corrected to CCSM data

Simulation time periods:

1) Historical period simulation: 20-year integration plus 1-year spinup: 1995-2015
2) Future period simulation: 20-year integration plus 1-year spinup: 2080-2100

Forcing information:

1) Historical period simulation: forced with 6-hr CCSM4 data, ERA-Interim reanalysis will be used for bias correction;
2) Future period simulation: forced with 6-hr CCSM4 data, 19 CMIP5 model ensemble mean will be used for bias correction.

GWF WRF 4-KM CONUS II simulation

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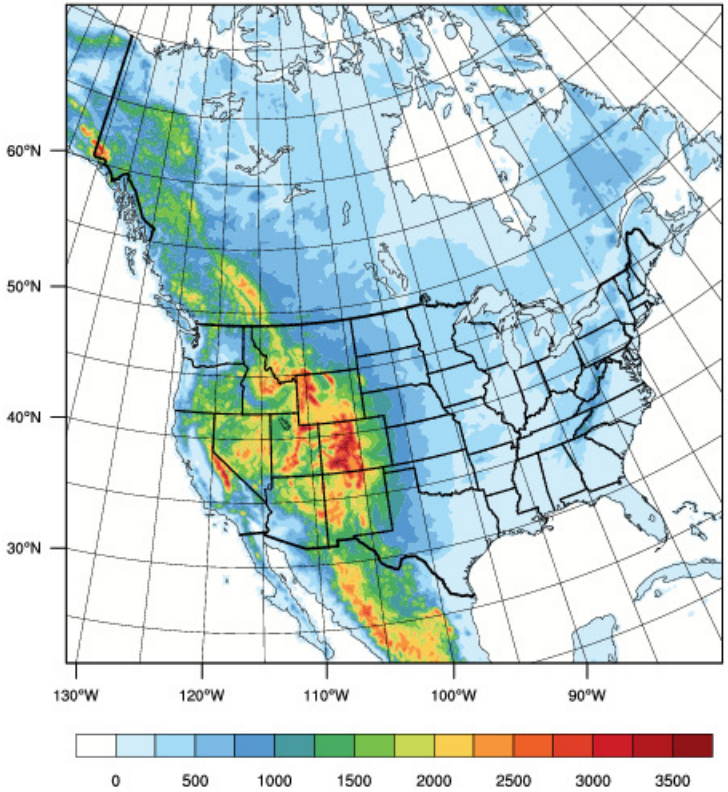

Summary of CONUS-II Test Runs

1. Bias correction
2. Monthly sea ice vs. daily sea ice
3. Lake ice treatment
4. Snow cover fraction models:

(a) melting parameter; (b) Z0

5. Cloud fraction: Xu-Randall vs. Thompson
6. New version of Thompson MP
7. Domain configuration
8. Convection scheme: Tiedtke vs. MKF
9. Lake model
10. Surface layer scheme - convective eddy

Simulation time periods:

1) Historical period simulation: 20-year integration plus 1-year spinup: 1995-2015
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Currently available Continental Scale Regional Climate 4-KM WRF Simulation

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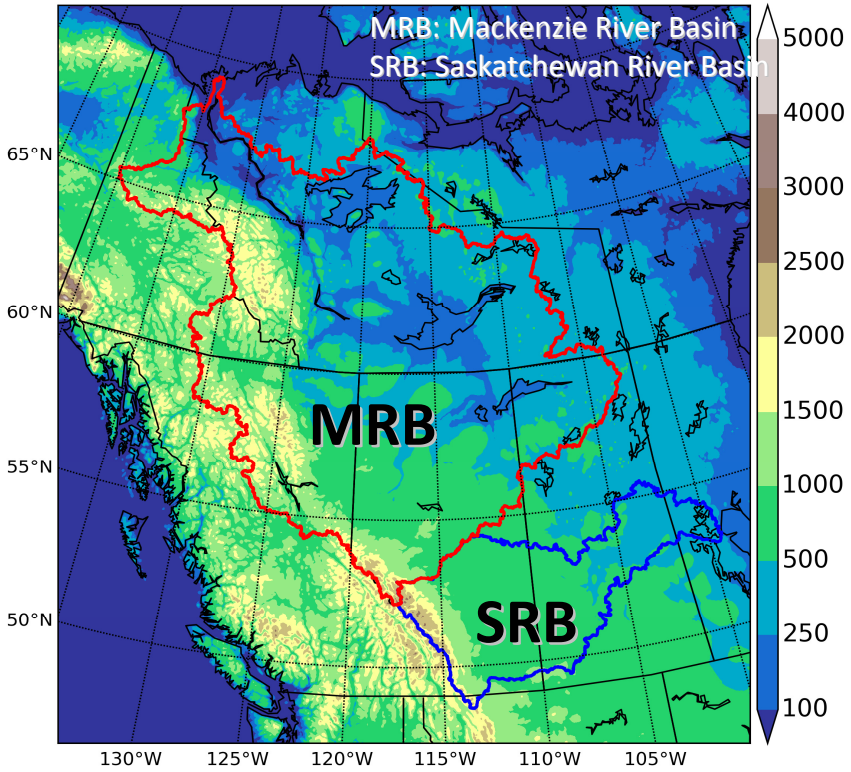
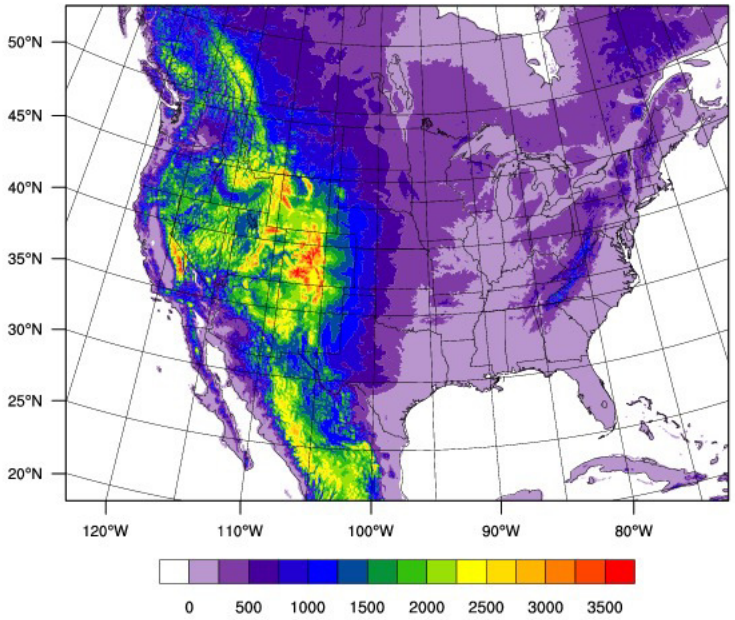
WRF-CCRN



WRF-CONUS I



WRF-CCRN: **Yanping Li**, Z. Li, Z. Zhang, L. Chen, S. Kurkute, L. Scaff, X. Pan, 2019: High-Resolution Regional Climate Modeling and Projection over Western Canada using a Weather Research Forecasting Model with a Pseudo-Global Warming Approach, Hydrol. *Earth Syst. Sci. Discuss*. DOI: https://doi.org/10.5194/hess-2019-201

WRF-CONUS I: Liu C., K. Ikeda, R. Rasmussen, M. Barlage, A. J. Newman, A. F. Prein, F. Chen, **L. Chen**, M. Clark, A. Dai, J. Dudhia, T. Eidhammer, D. Gochis, E. Gutmann, **S. Kurkute**, **Y. Li**, G. Thompson, D. Yates, 2017: Continental-Scale Convection-Permitting Modeling of the Current and Future Climate of North America, *Climate Dynamics,* Vol. 49, 71-95.

The performance of WRF-CCRN: Temperature vs ANUSPLIN

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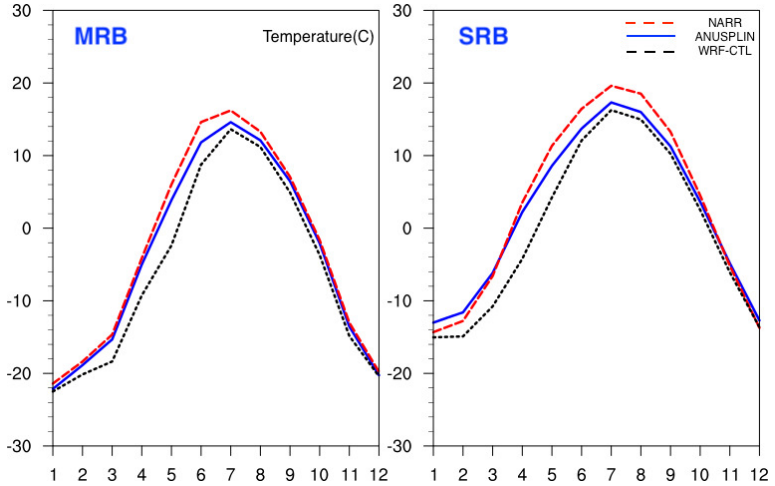

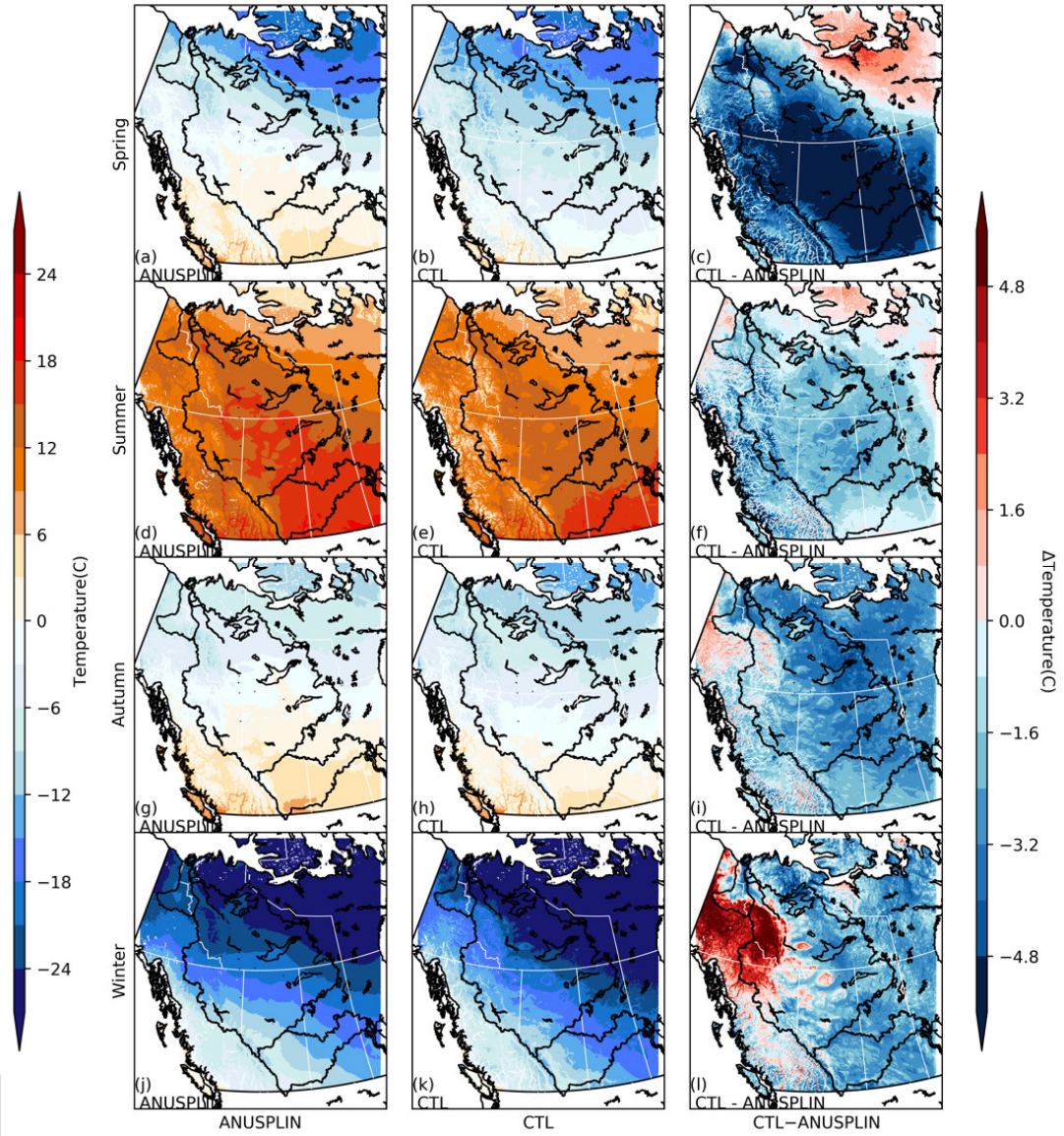

Precipitation vs CaPA

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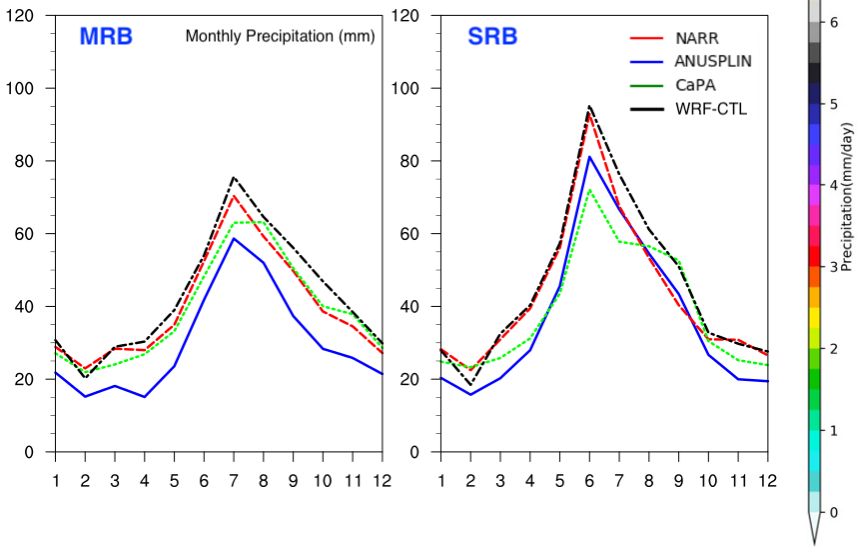

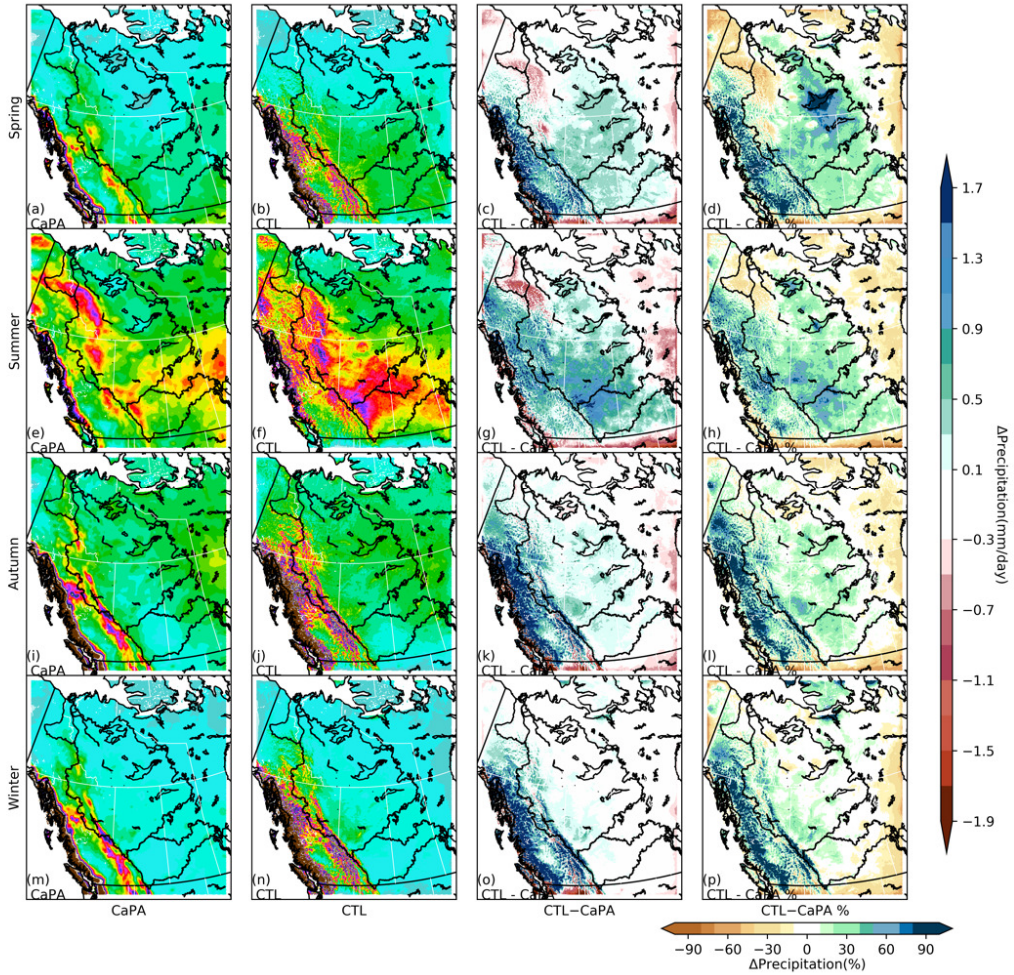

Temperature Change under RCP8.5 till the end of the century

PGW - CTL

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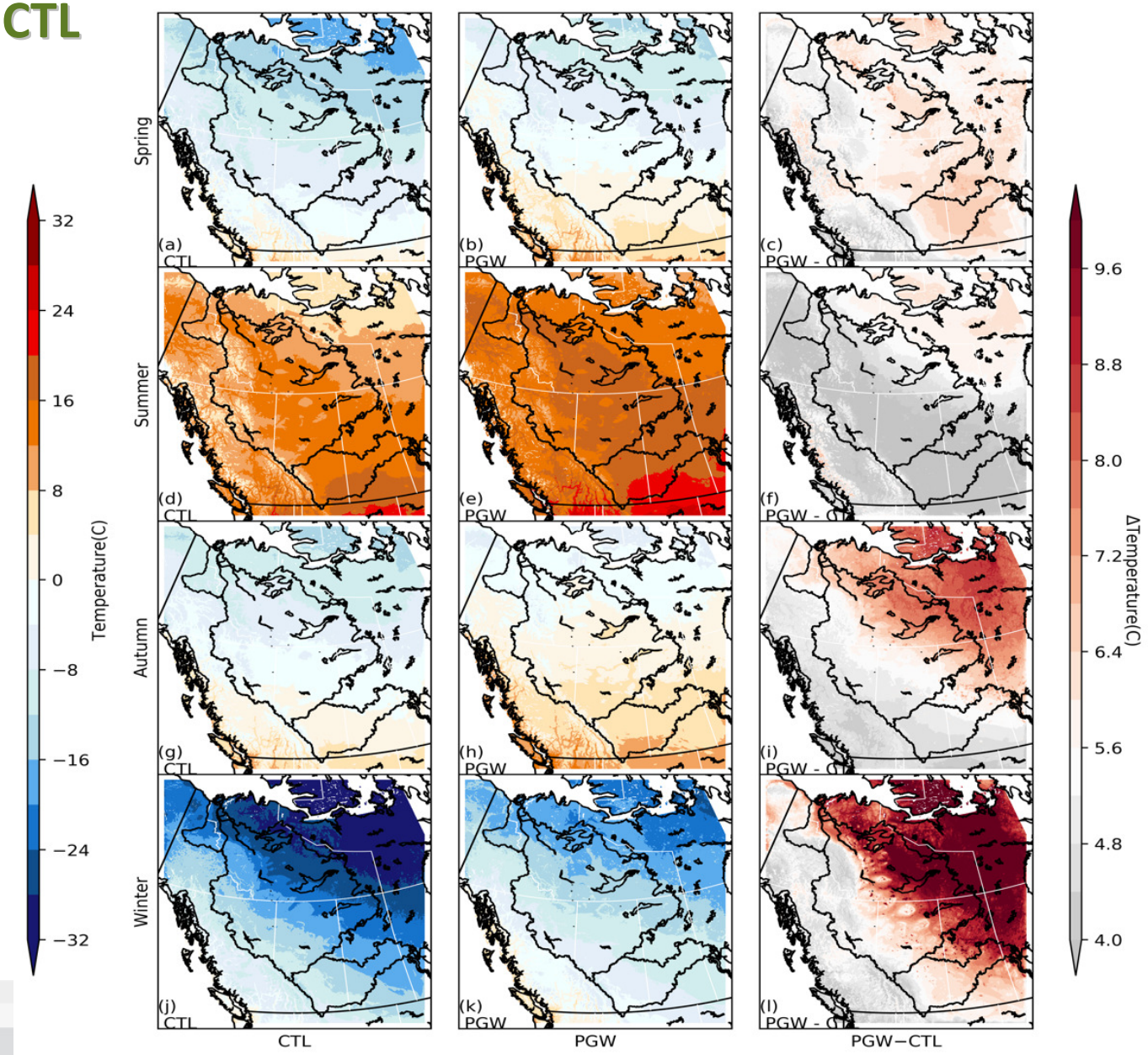
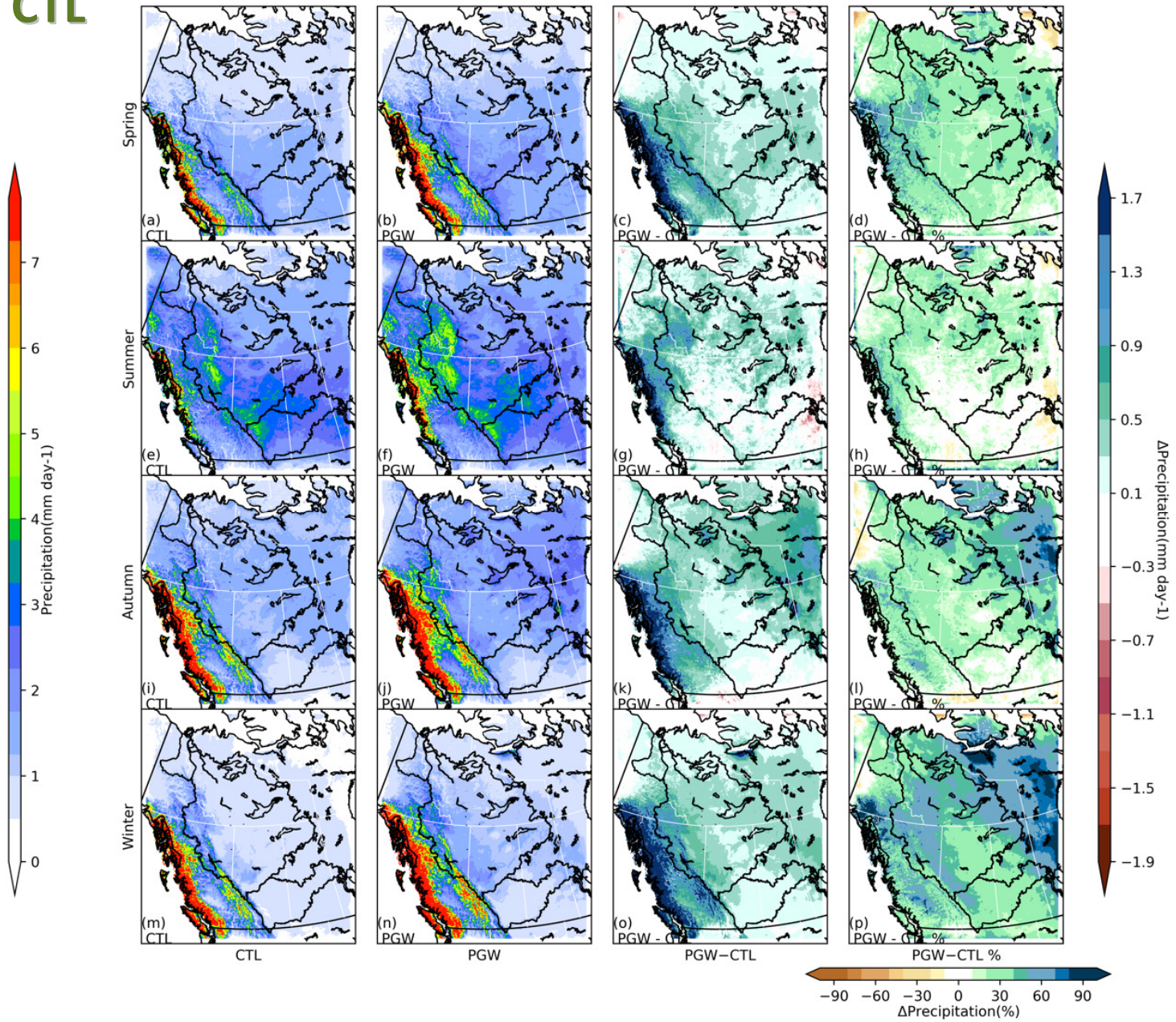


Precipitation Change under RCP8.5 till the end of the century

PGW - CTL



T, Precip Annual cycle – Historical vs Future

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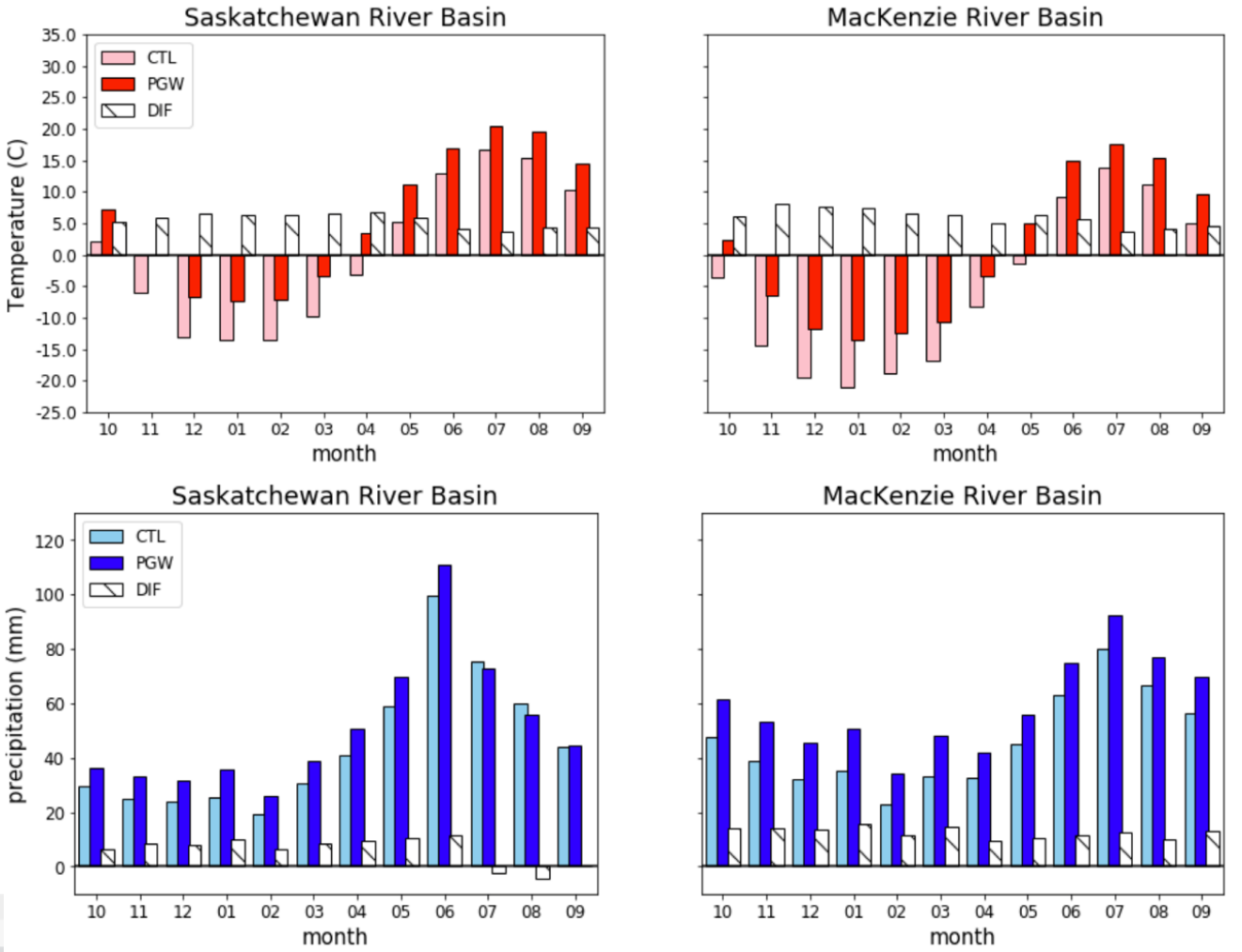
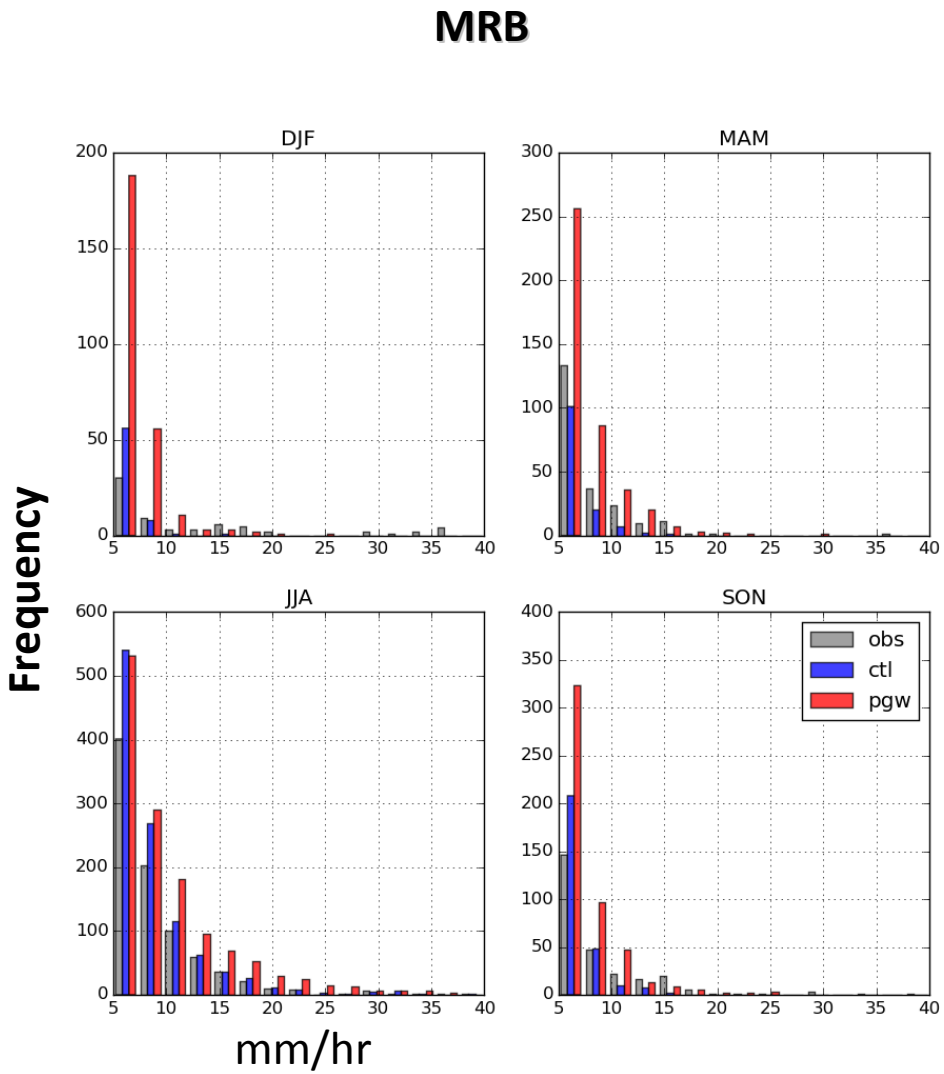
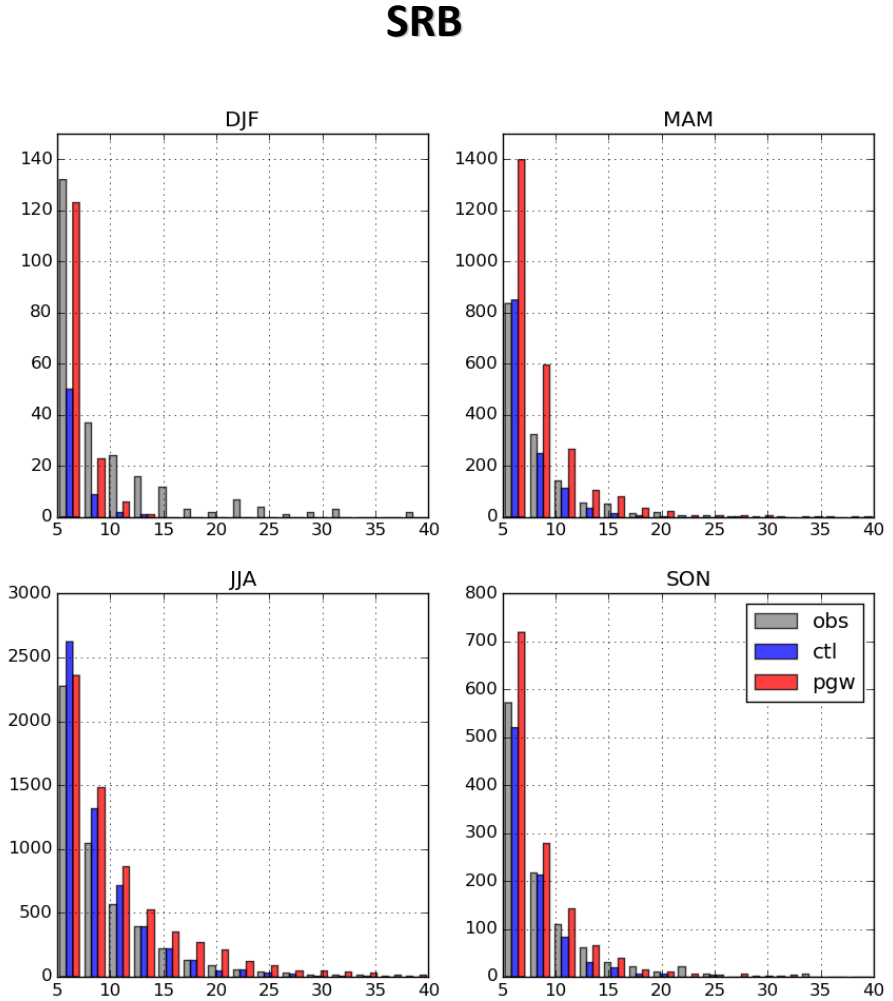
WRF west Canada 4-km downscaling

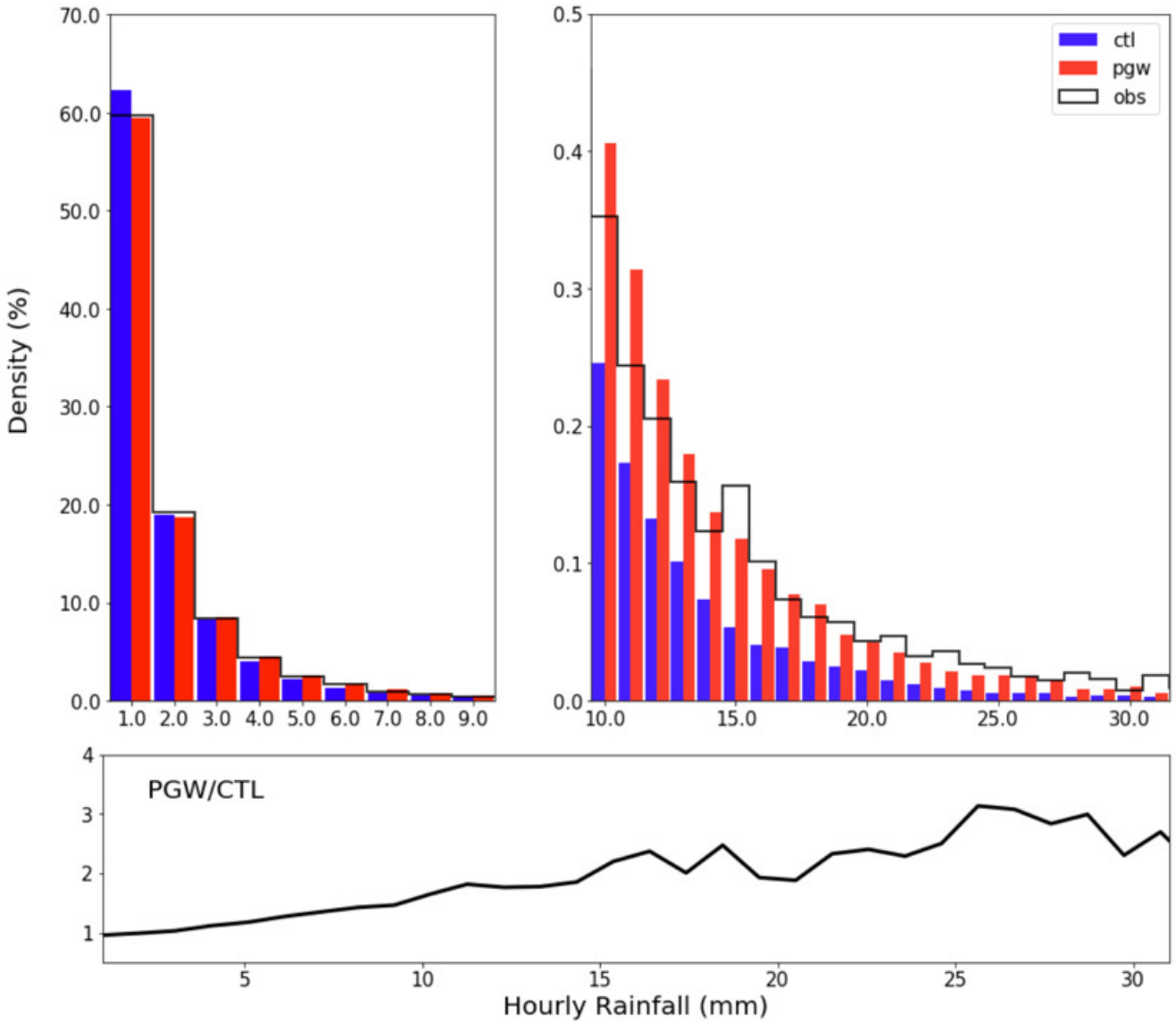


PDF for hourly precipitation intensity, WRF vs Station Obs





Hourly precipitation distribution change



- No much change in light-to-moderate rain (1~9mm/hr)
- Extreme precipitation (> 10 mm/hr) will increase significantly
- The occurrence will increase with the intensity of the precipitation

Yanping Li, Li Z., Zhang Z., Chen L., Kurkute S., Scaff L., Pan X., 2019: High-Resolution Regional Climate Modeling and Projection over Western Canada using a Weather Research Forecasting Model with a Pseudo-Global Warming Approach, Hydrol. *Earth Syst. Sci. Discuss*. DOI: https://doi.org/10.5194/hess-2019-201

WRF-CCRN simulation: PGW vs CTL

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- Pseudo-Global Warming approach, RCP8.5.
- Temperature increase is higher in the north and northeast, especially in winter and spring.
- Temperature increase in spring is high due to the snow albedo feedback.
- Precipitation increase is consistent over the domain except in summer.
- Over the Canadian Prairies, the PGW precipitation keeps the same level or decrease in summer.
- Extreme precipitation shows mid-high daily precipitation decrease over the Prairies whereas both the lower and higher percentile precipitation increases during summer, which poses a problem for bias correction based on quantile mapping.

Yanping Li, Li Z., Zhang Z., Chen L., Kurkute S., Scaff L., Pan X., 2019: High-Resolution Regional Climate Modeling and Projection over Western Canada using a Weather Research Forecasting Model with a Pseudo-Global Warming Approach, Hydrol. *Earth Syst. Sci. Discuss*. DOI: https://doi.org/10.5194/hess-2019-201

Surface water budget

$$\frac{\mathrm{dS}}{\mathrm{dt}} = P - ET - Q + RESW$$

Snow + Soil M + Canopy water

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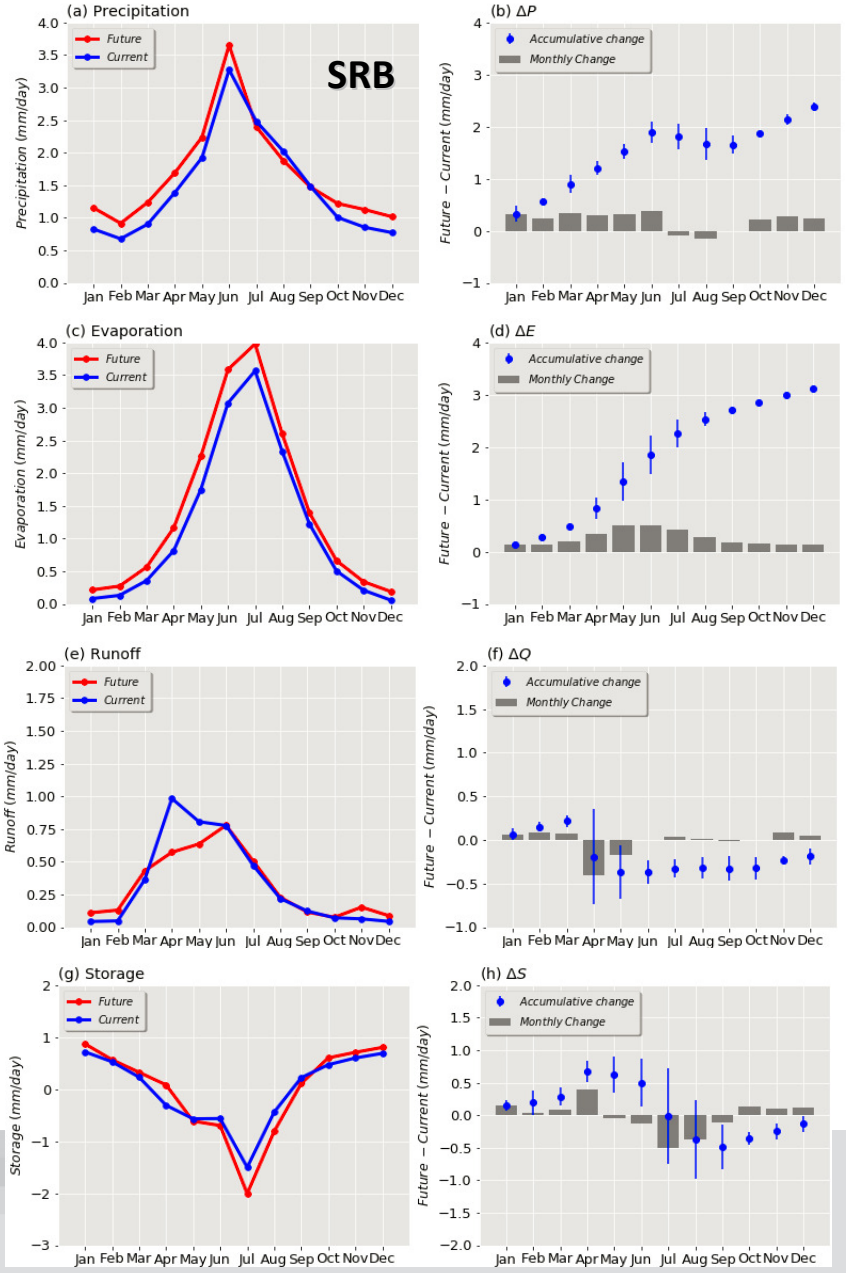

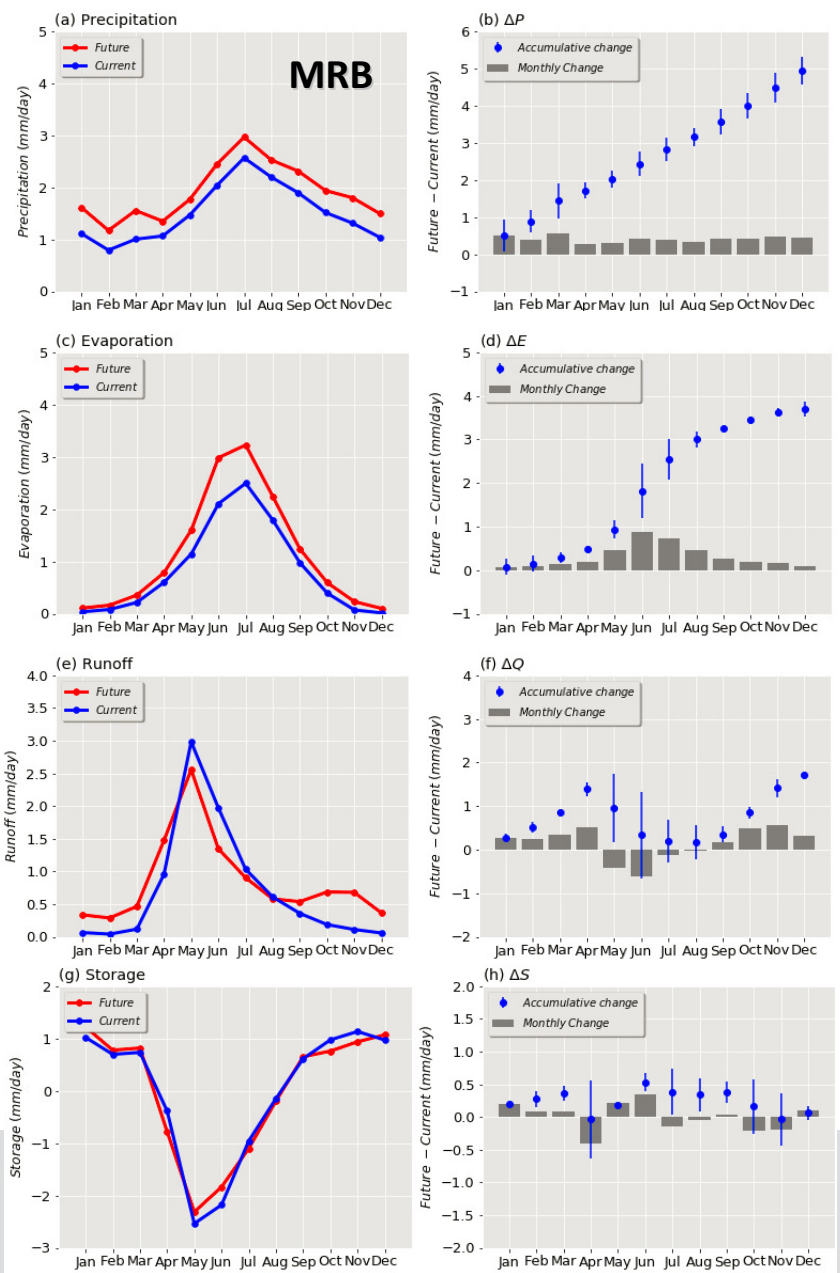

Atmospheric water balance

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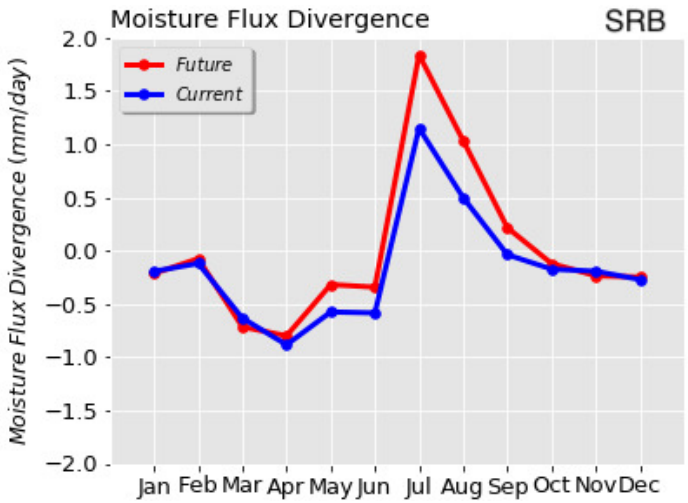
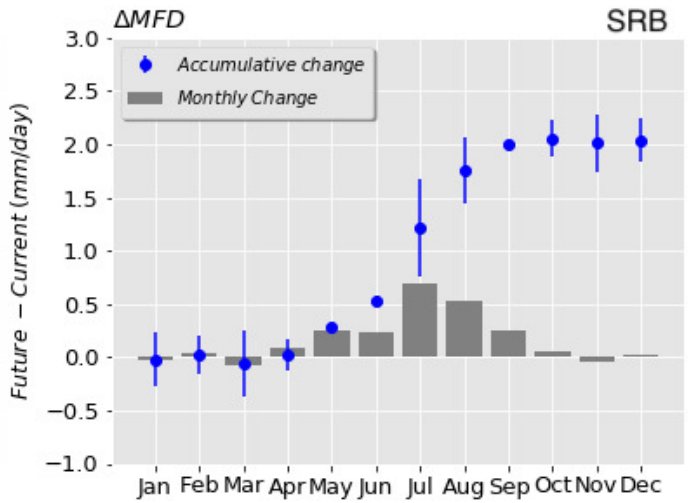
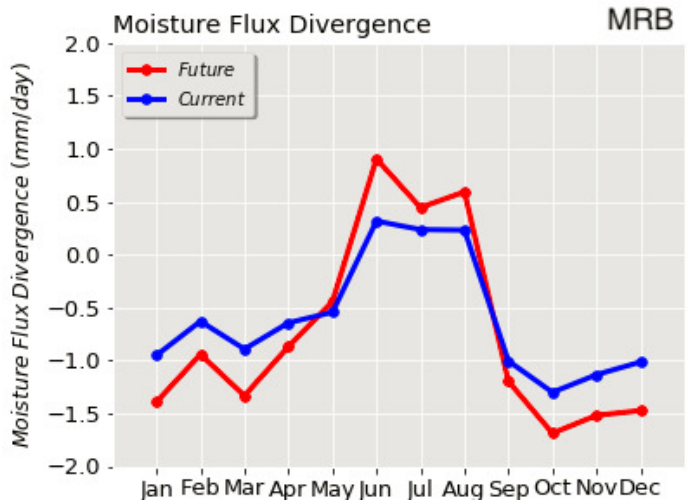
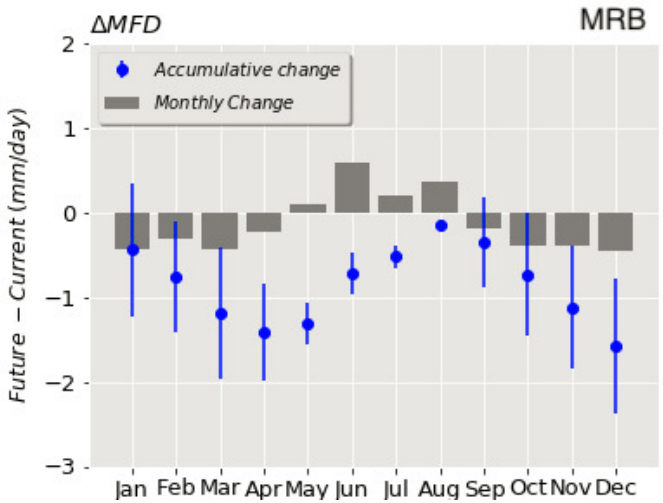
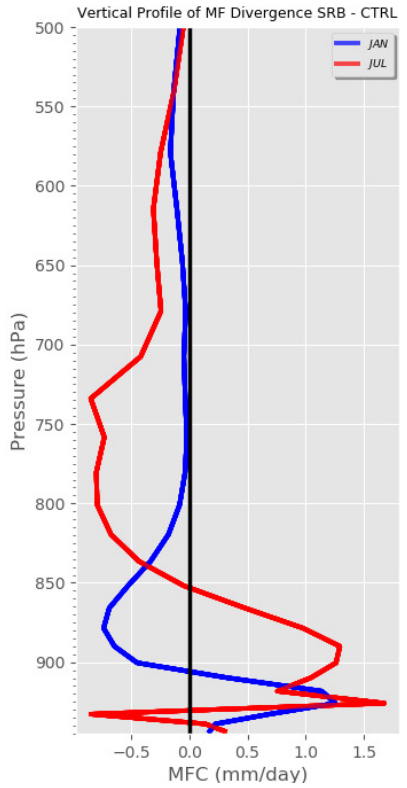
$$\frac{\mathrm{dW}}{\mathrm{dt}} = E - P + \nabla.Q$$











Sopan Kurkute, Zhenhua Li, and Yanping Li, 2019: Assessing Water Balance and Moisture Flux Convergence over Western Canada using Convection Permitting WRF Simulations, *to be submitted*