UNIVERSITY OF SASKATCHEWAN

Global Institute for Water Security

www.usask.ca/water

Convection-permitting WRF regional climate simulations over Canada

GWF Pillar 3 Climate-Related Precipitation Extremes

Yanping Li

Continental Scale Regional Climate Simulation using 4-KM WRF

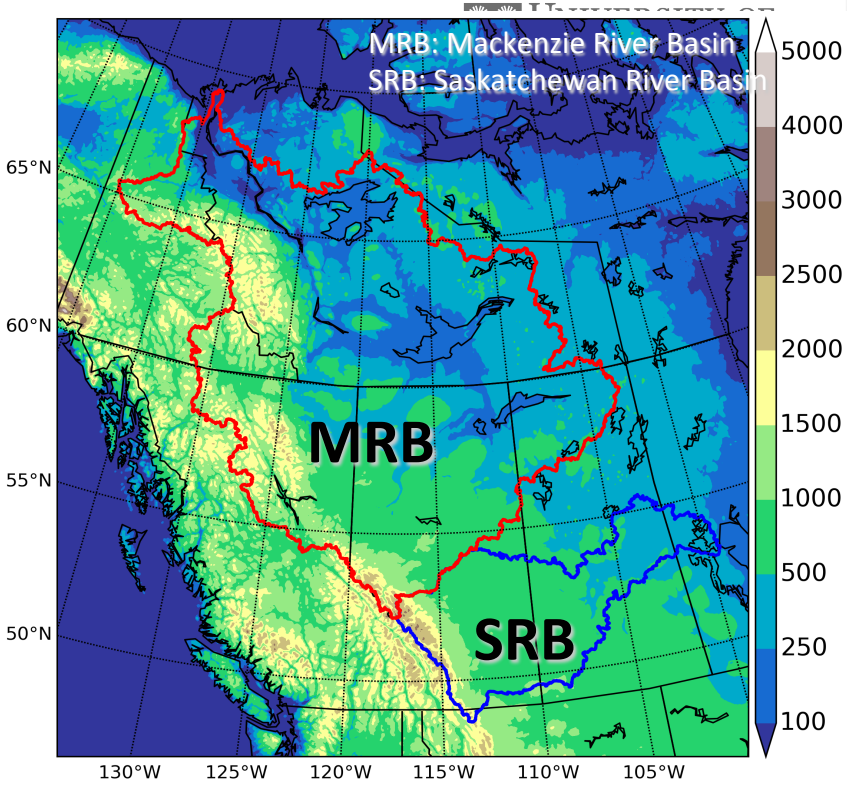
WRF Model Setup and Design

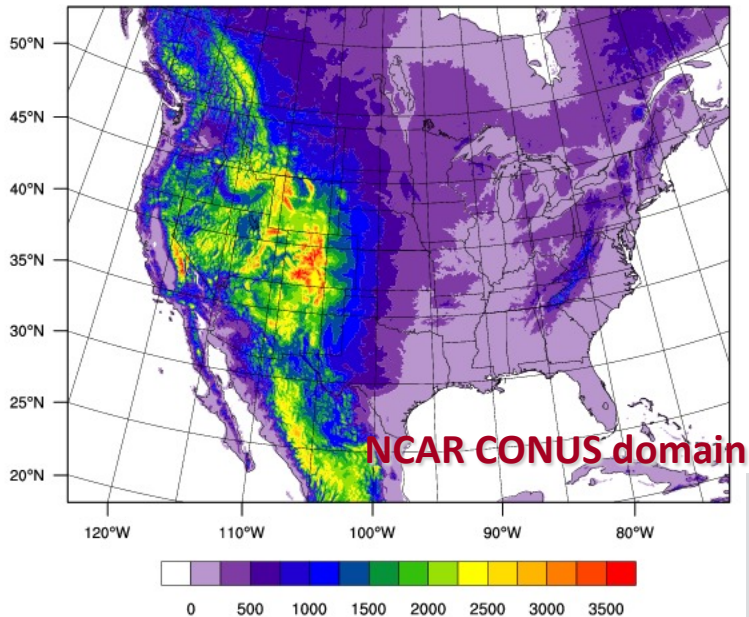
- WRF Model (Version 3.4.1)
- A single domain: 2560 x 2800 km^2;

  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





WRF Dynamical downscaling and PGW method

Historical simulation (CTRL)

OBSERVATION PERIOD 2001-2015

6-hours historical boundary conditions from: ERA-Interim reanalysis (ERA-I)

- Sea surface temperature and ice
- Air temperature
- Horizontal wind
- Specific humidity
- Air pressure
- Geopotential height

Future simulation (PGW)

GLOBAL FUTURE SCENARIOS

RCP8.5 *"the business as usual"* scenario projects a 3.7°C warming by the end of the 21 century.

CMIP5 models under RCP8.5

ACCESS1-3	GFDL-CM3	IPSL-CM5A-MR
CanESM2	GFDL-ESM2M	MIROC5
CCSM4	GISS-E2-H	MIROC-ESM
CESM1-CAM5	HadGEM2-CC	MPI-ESM-LR
CMCC-CM	HadGEM2-ES	MPI-ESM-MR
CNRM-CM5	Inmcm4	MRI-CGCM3
CSIRO-Mk3-6-0		

Global monthly multi-model average increments:
ΔCIMP5 = projection ensemble − historical ensemble
(2070 to 2099) (1976 to 2005)

PSEUDO GLOBAL WARMING
ERA-I + ΔCIMP5

HIGH-RESOLUTION (4-km) REGIONAL CLIMATE MODEL
Weather Research Forecast V3.6

DYNAMICAL DOWNSCALING HINDCAST

DYNAMICAL DOWNSCALING FUTURE PGW

WRF dynamical downscaling for 2000-2013

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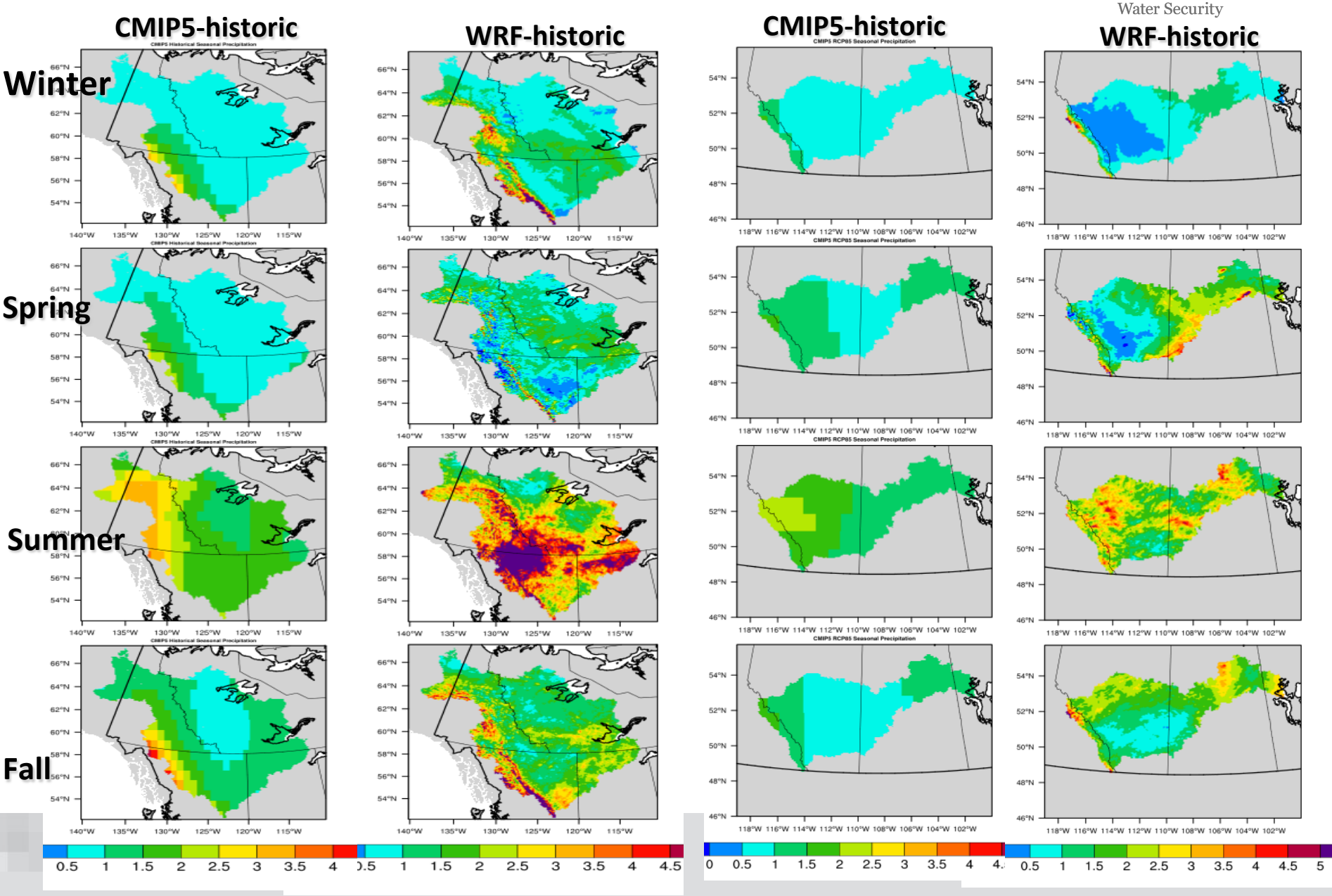
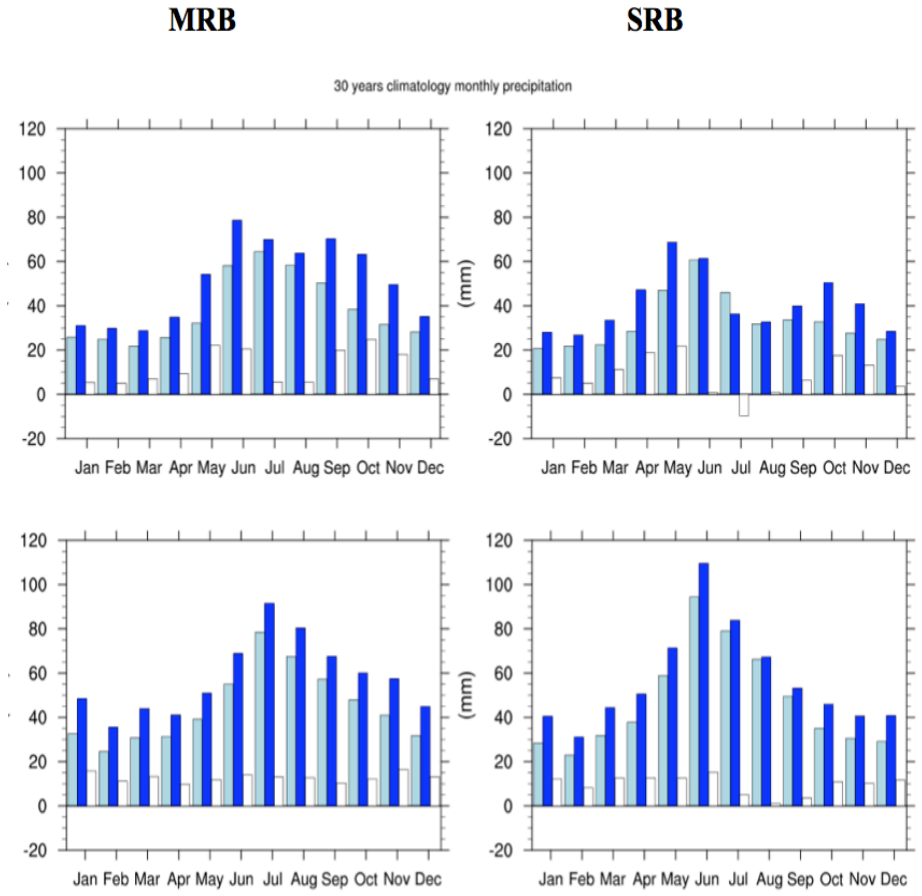
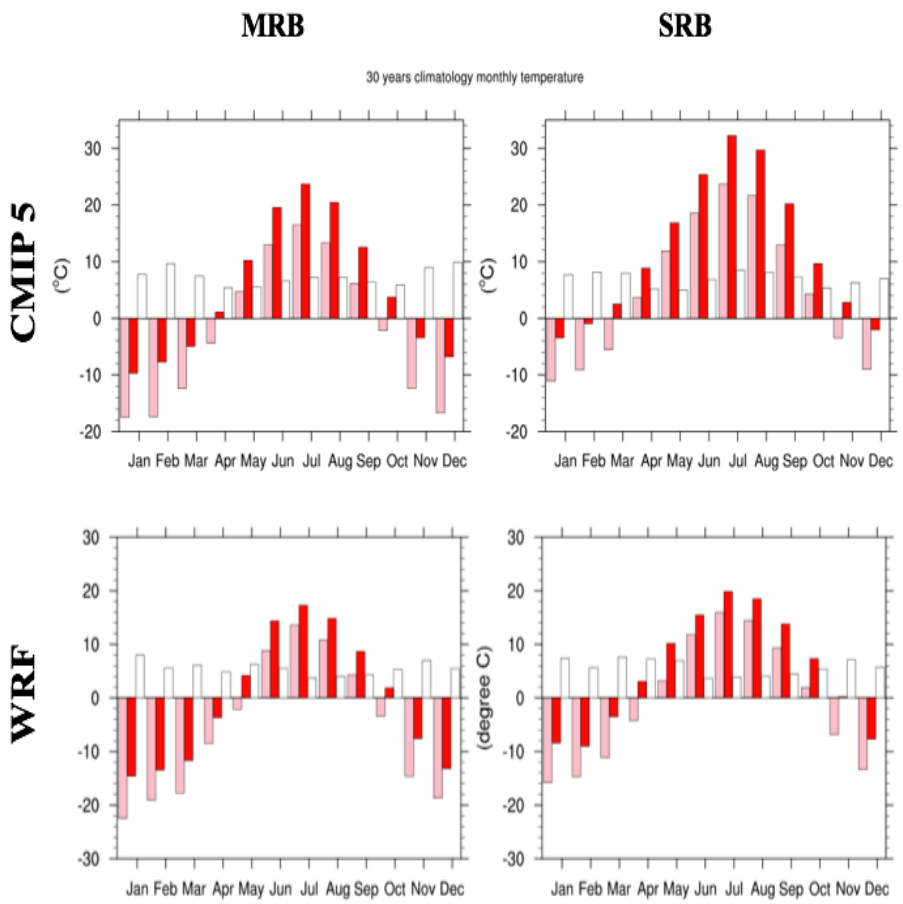
Global Institute for Water Security



Annual precipitation – CMIP5 vs WRF

University of Saskatchewan
Global Institute for Water Security





WRF dynamical downscaling of CMIP5

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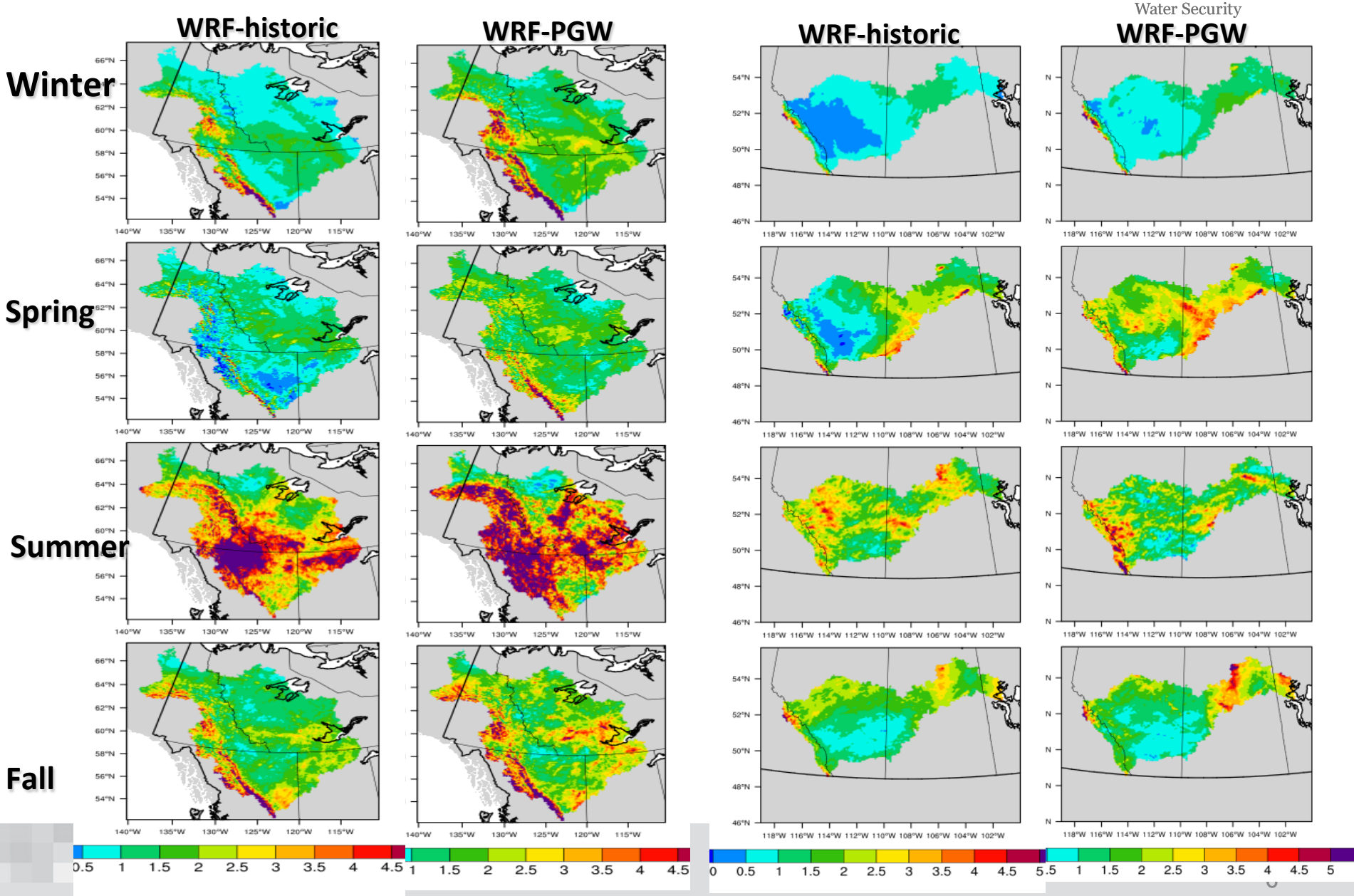
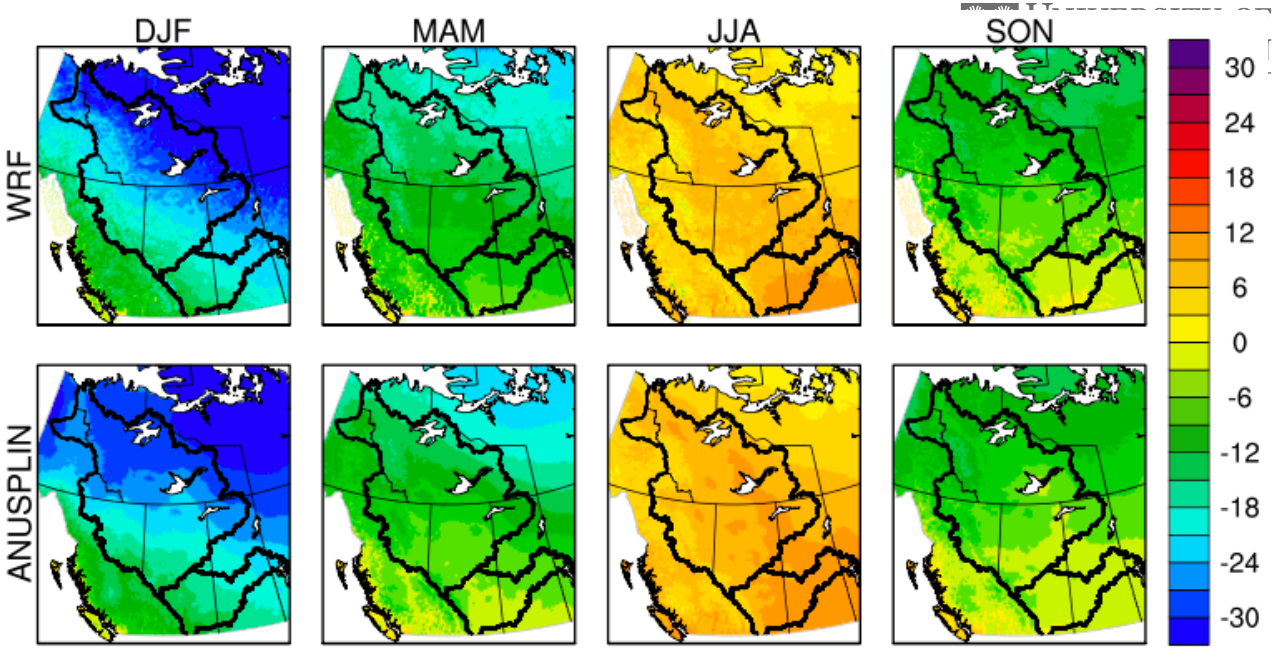
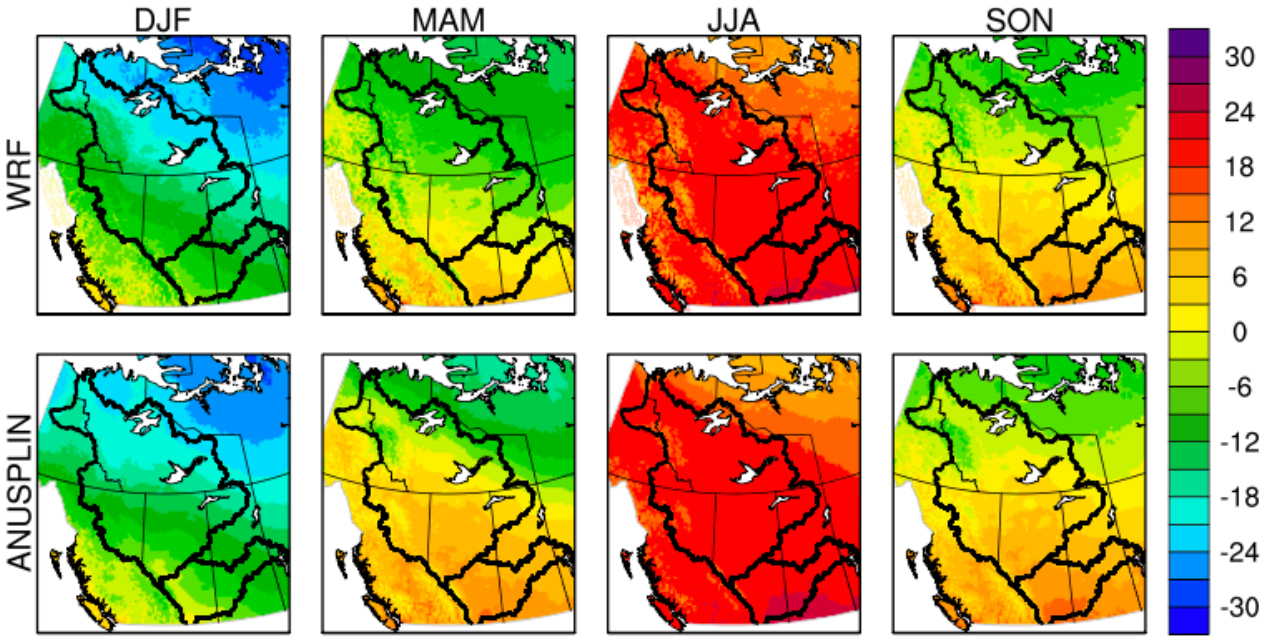


Geographic distribution of seasonal mean precipitation (a), *T*min (b) and *T*max (c), over the period from Oct 2000 – Sept 2013 for WRF and ANUSPLIN.

Daily Tmin



Daily Tmax



Monthly T2: CONUS-WRF

CCRN-WRF

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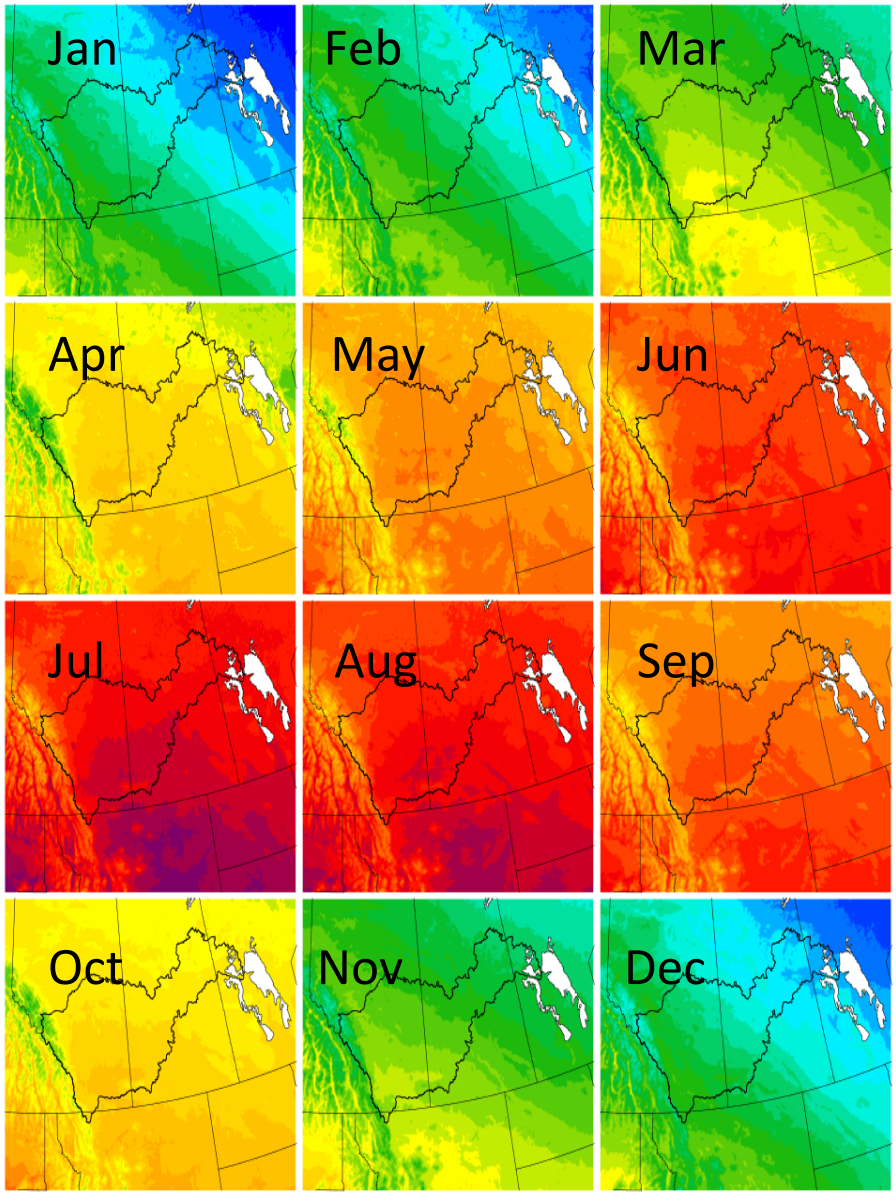
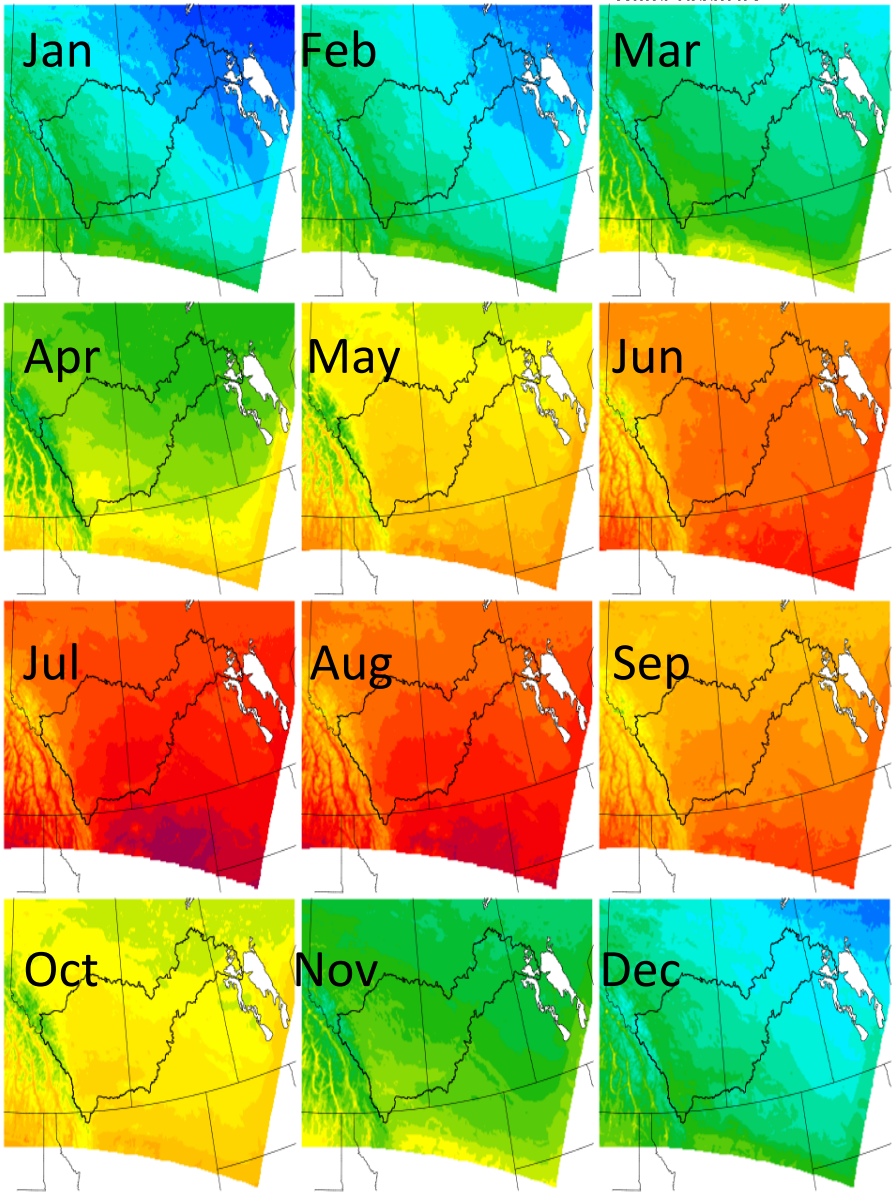
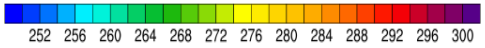
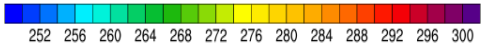
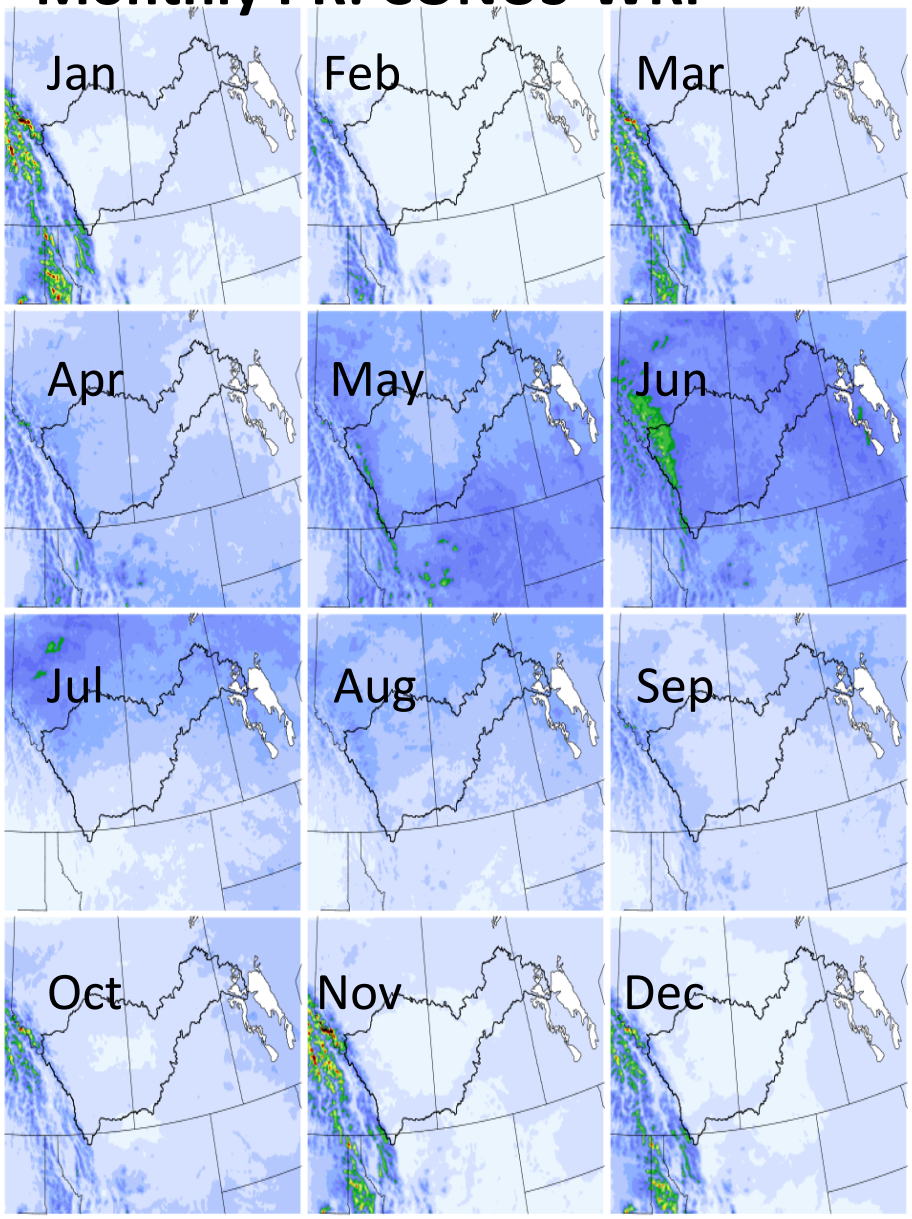


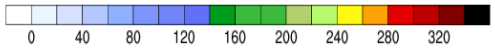




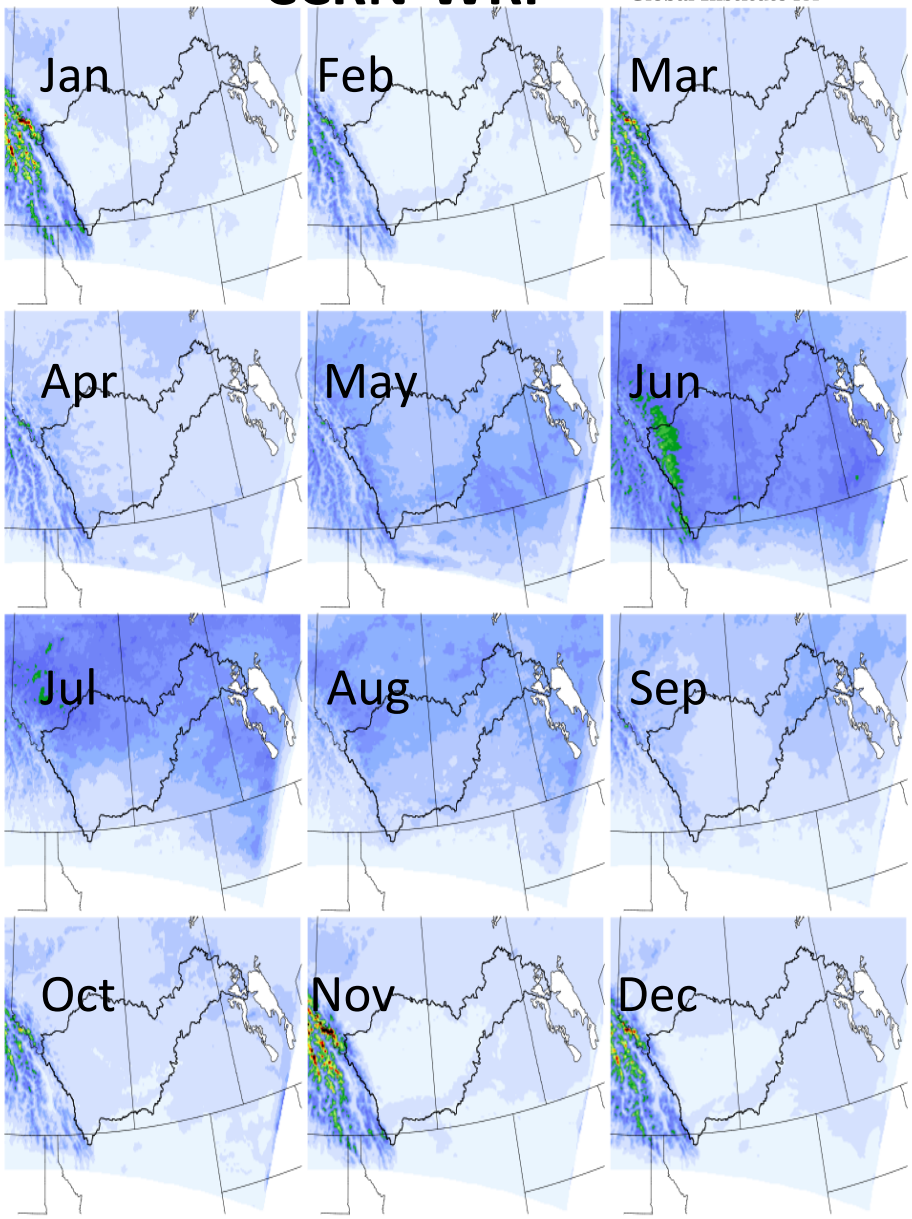


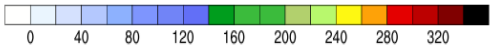
Monthly PR: CONUS-WRF



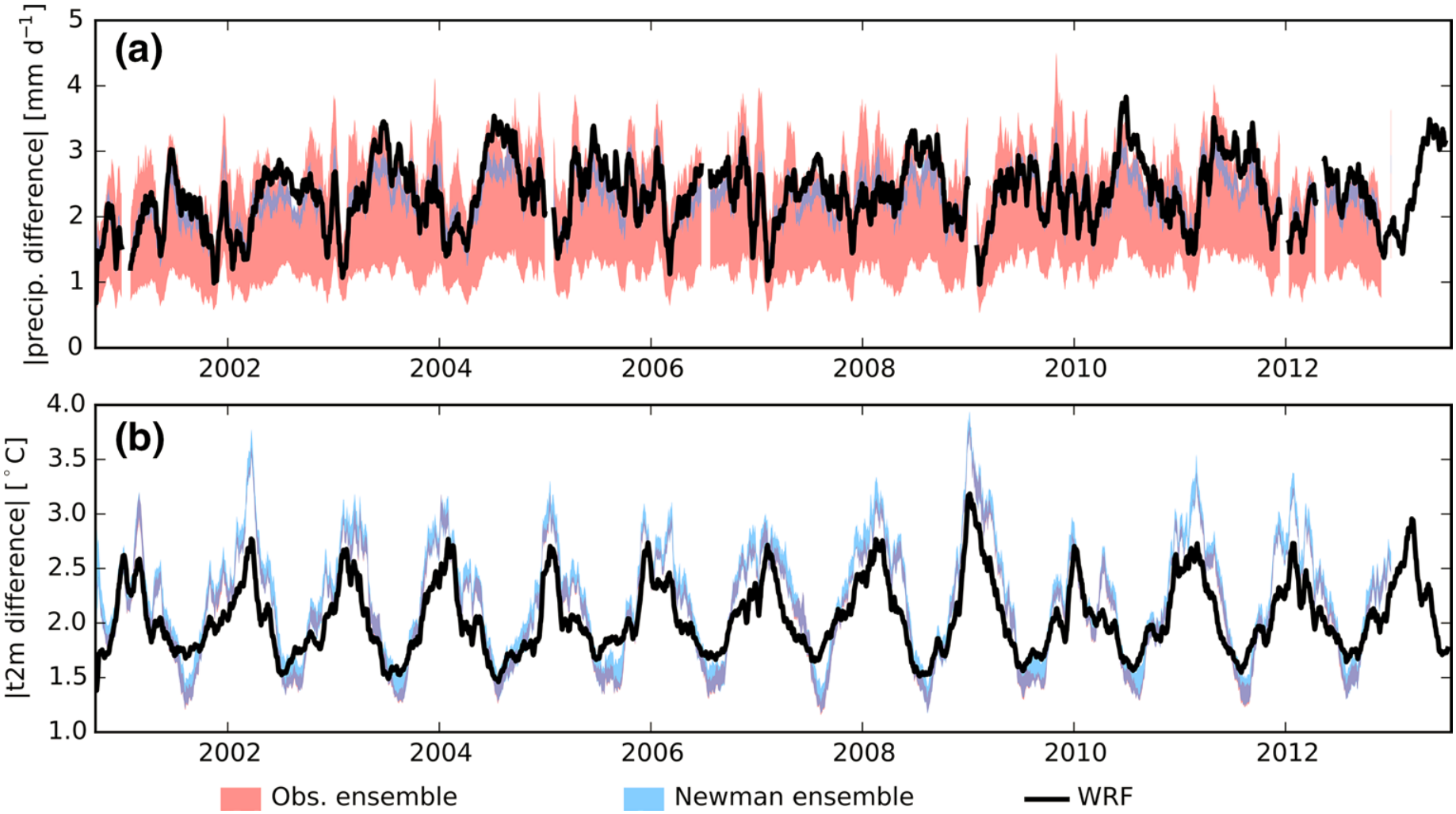


CCRN-WRF



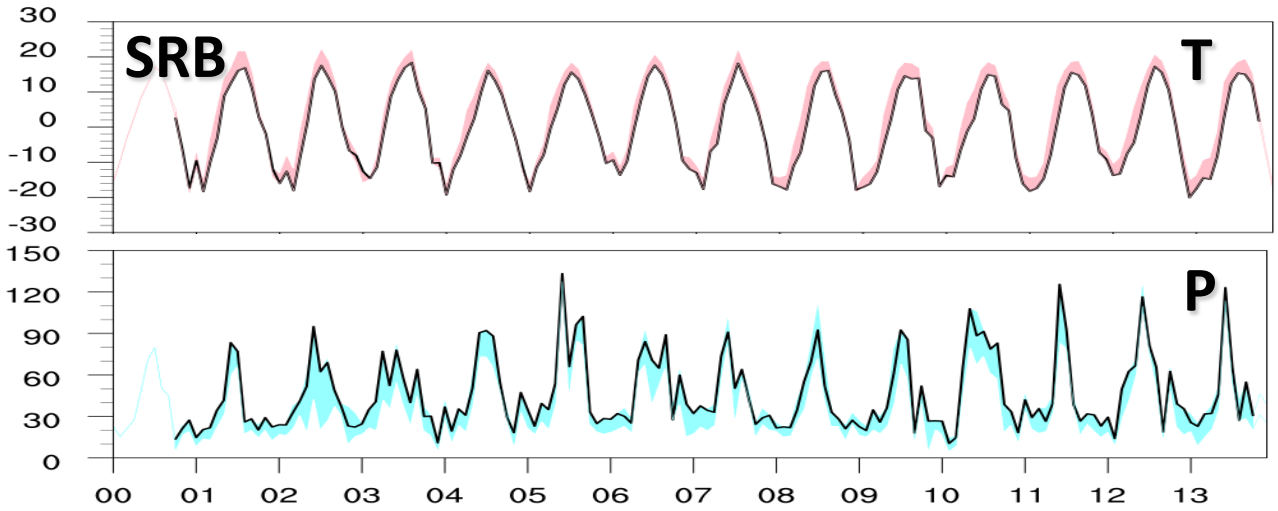


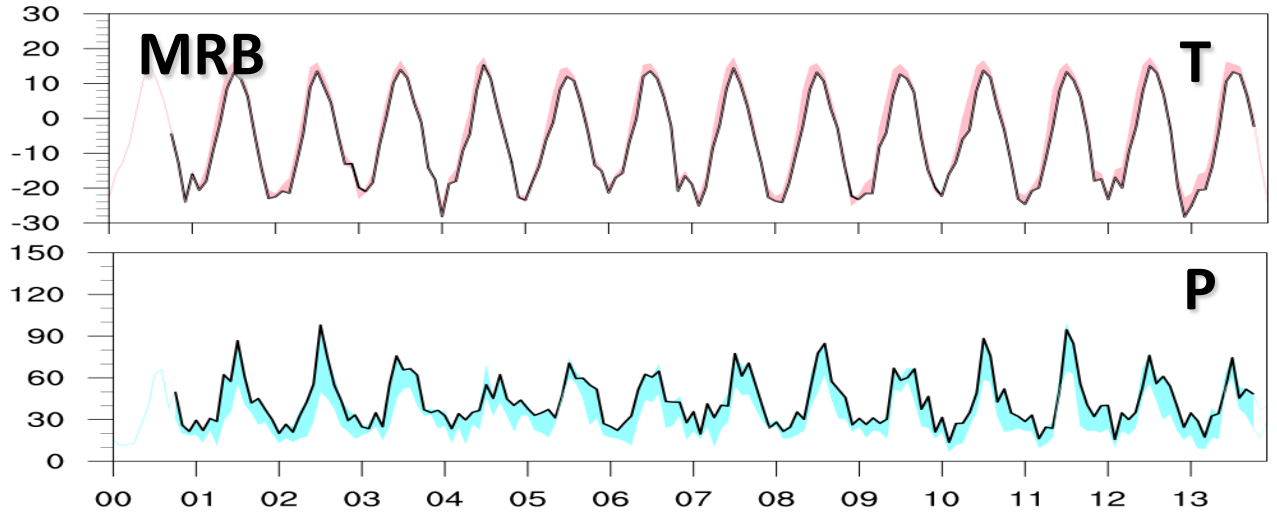
CONUS-WRF precipitation validation

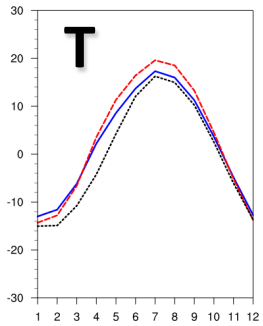


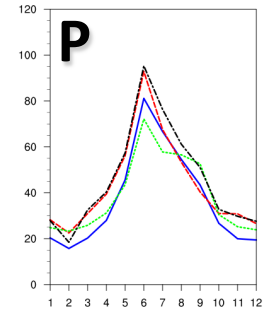
Liu C., K. Ikeda, R. Rasmussen, M. Barlage, A. J. Newman, A. F. Prein, F. Chen, L. Chen, M. Clark, A. Dai, J. Dudhia, T. Eidhammer, D. Gochis, E. Gutmann, S. Kurkute, **Y. Li**, G. Thompson, D. Yates, 2017: Continental-Scale Convection-Permitting Modeling of the Current and Future Climate of North America,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

CCRN-WRF Performance Evaluation (Annual cycle)

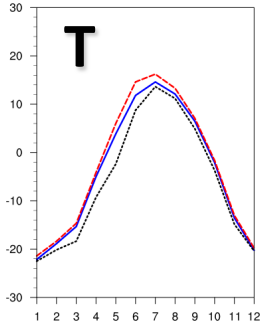


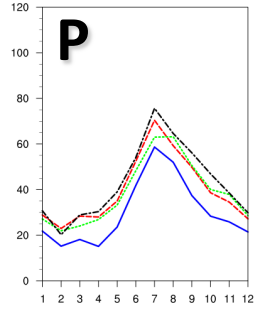




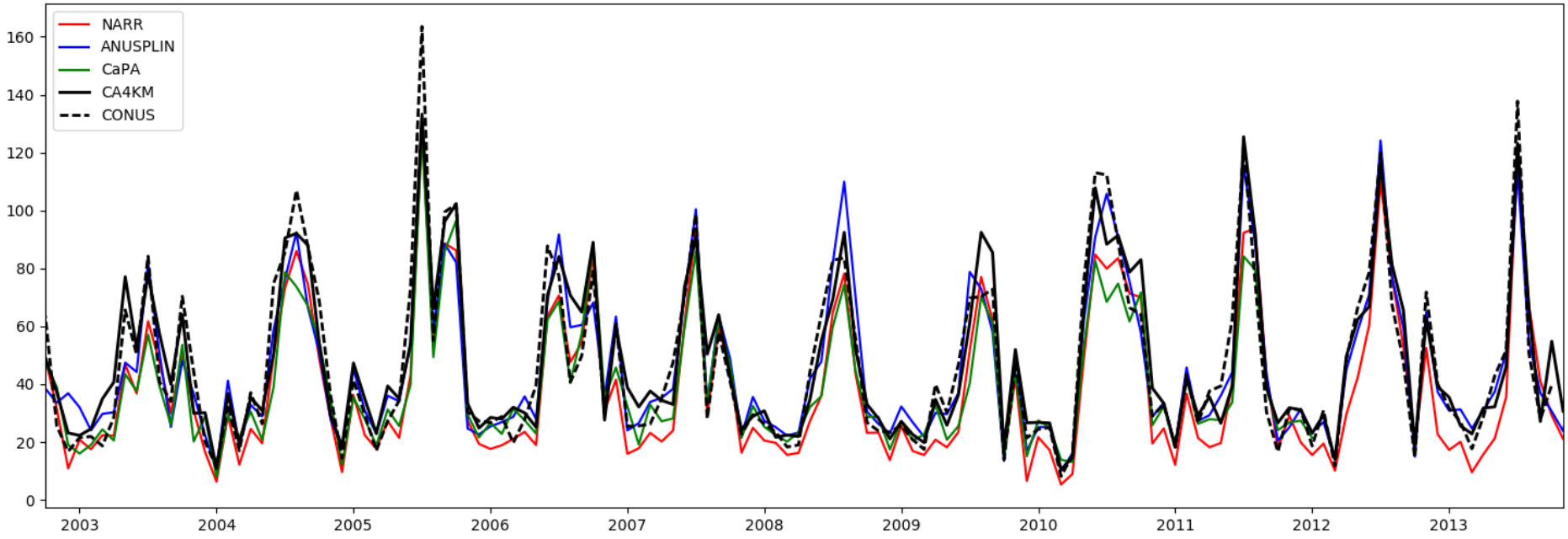


ANUSPLIN
NARR
WRF
CaPA





WRF Precipitation Annual cycle for SRB



WRF Temperature Annual cycle for SRB

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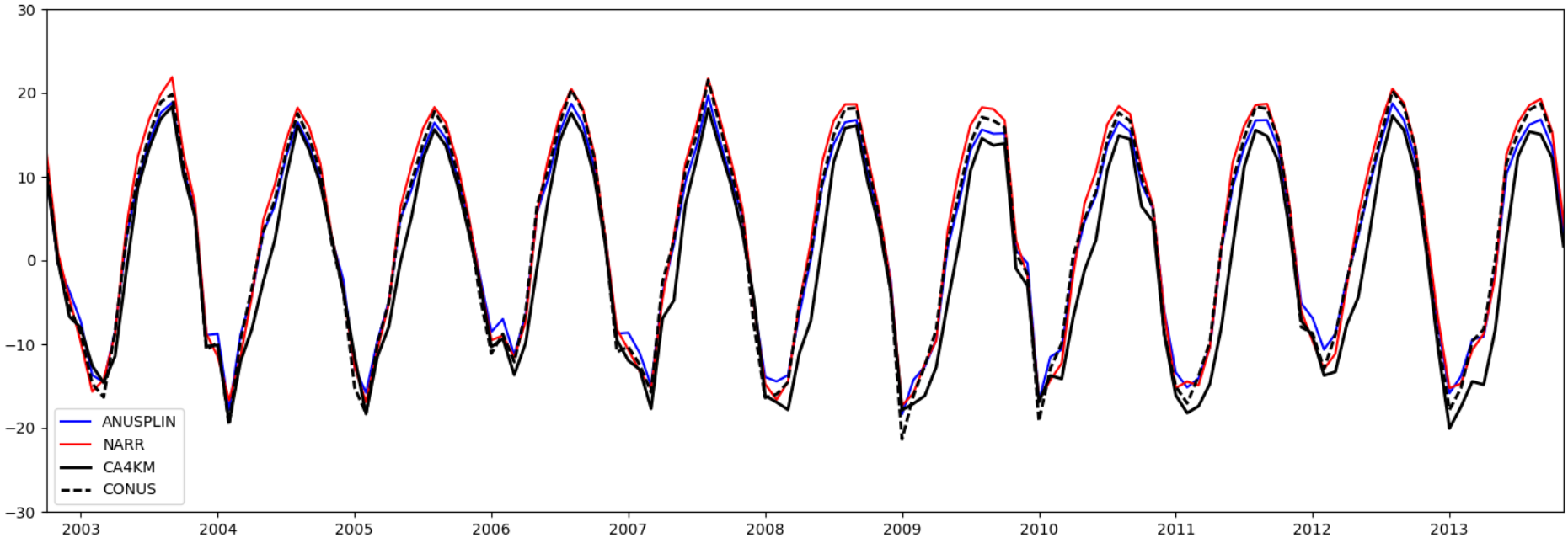
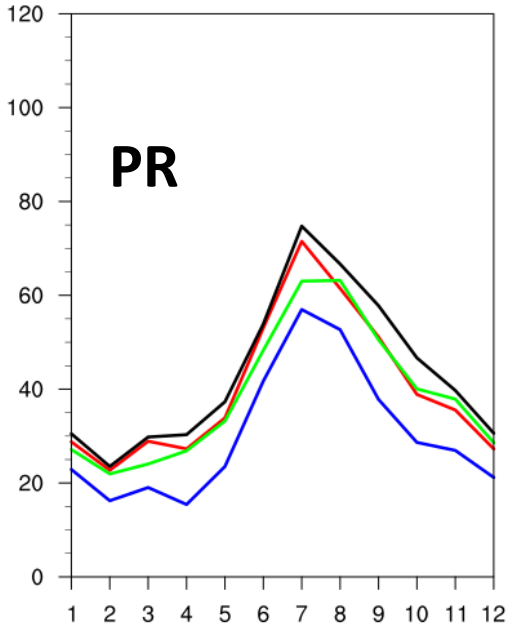
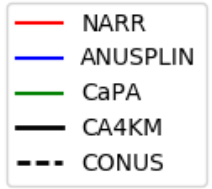
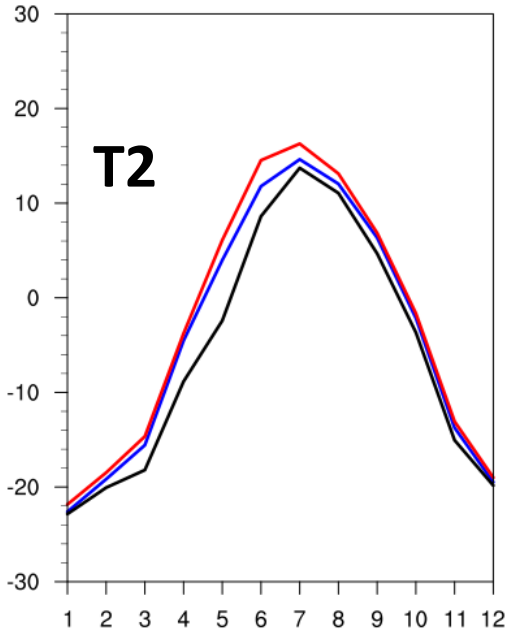


Precipitation, Temperature Annual cycle for MRB, SRB

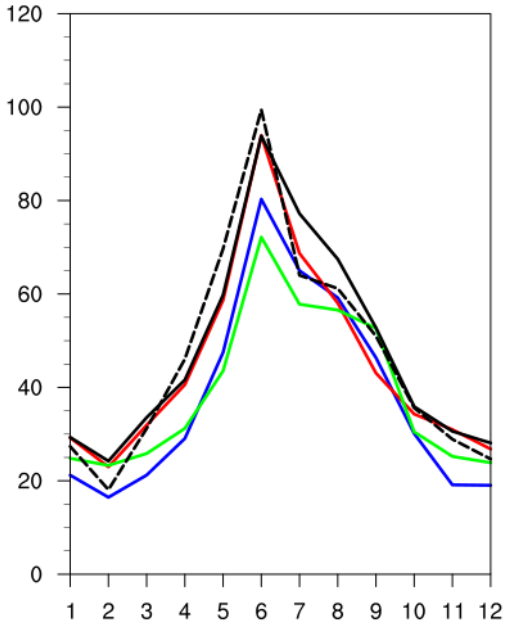
MRB

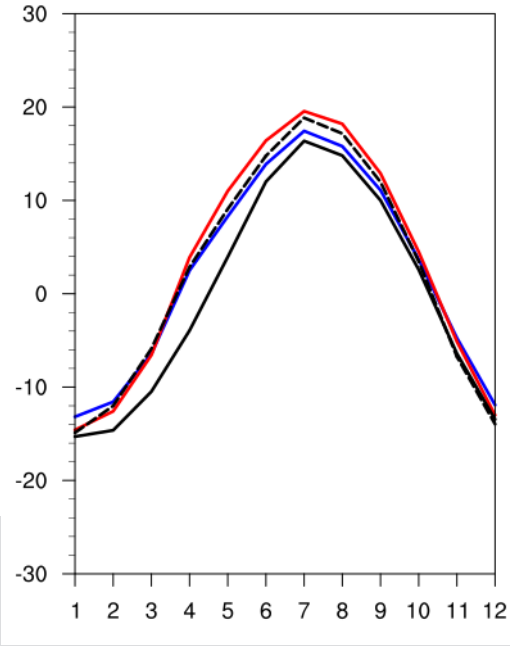






SRB





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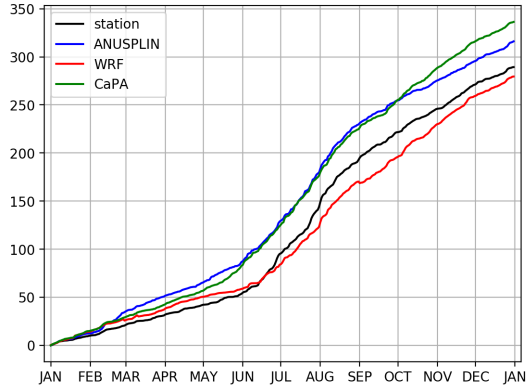
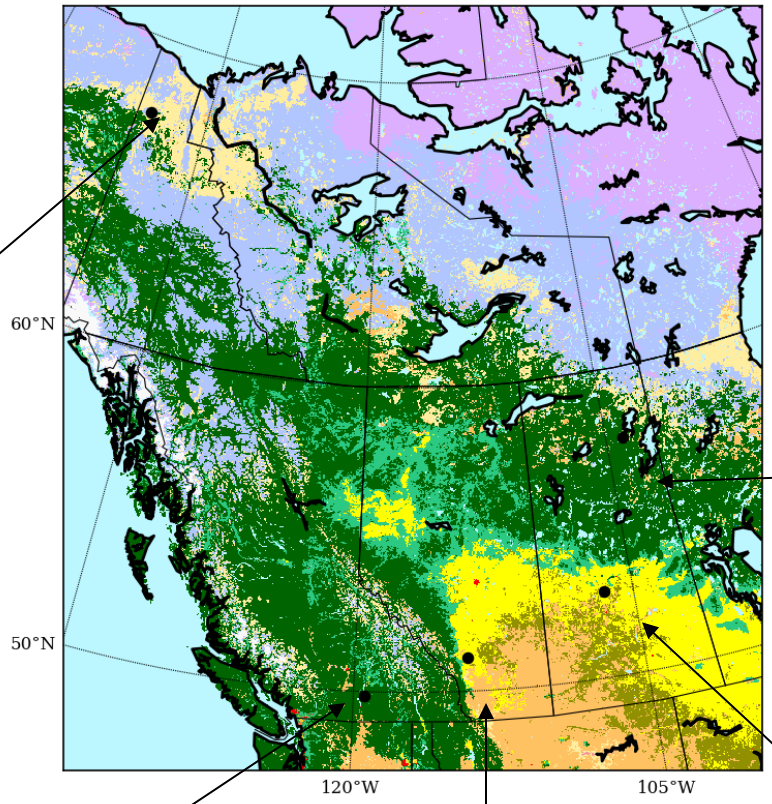
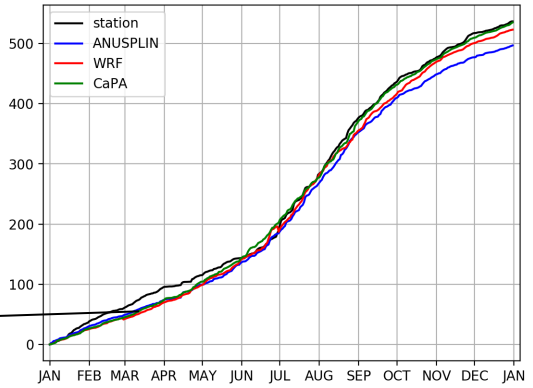


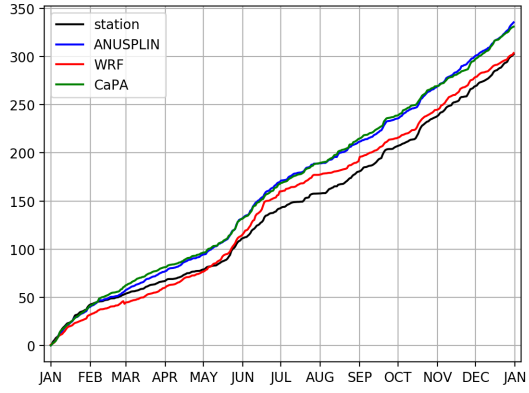
Old Crow, YK, (67.56, -139.83)



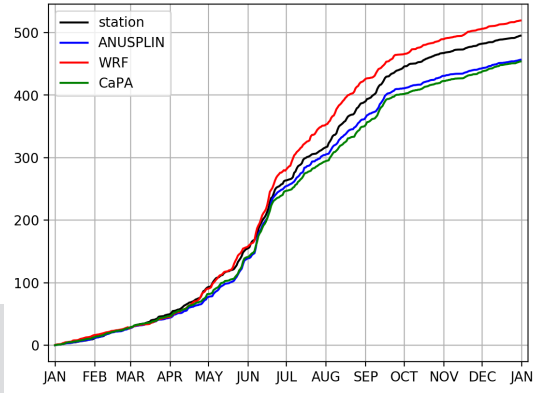


Wollaston Lake, SK, (57.7,-103.95)

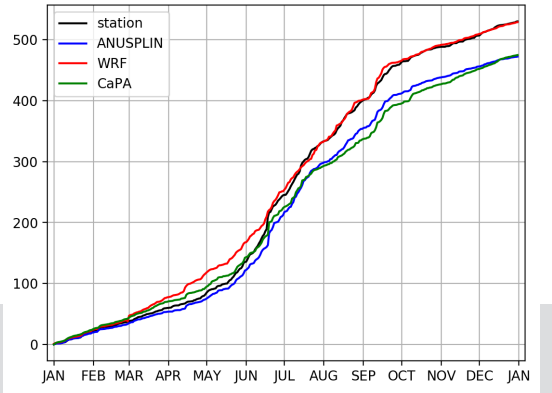
Kelowna, BC, (49.85, -119.45)



Calgary, AB, (51.08, -114.13)



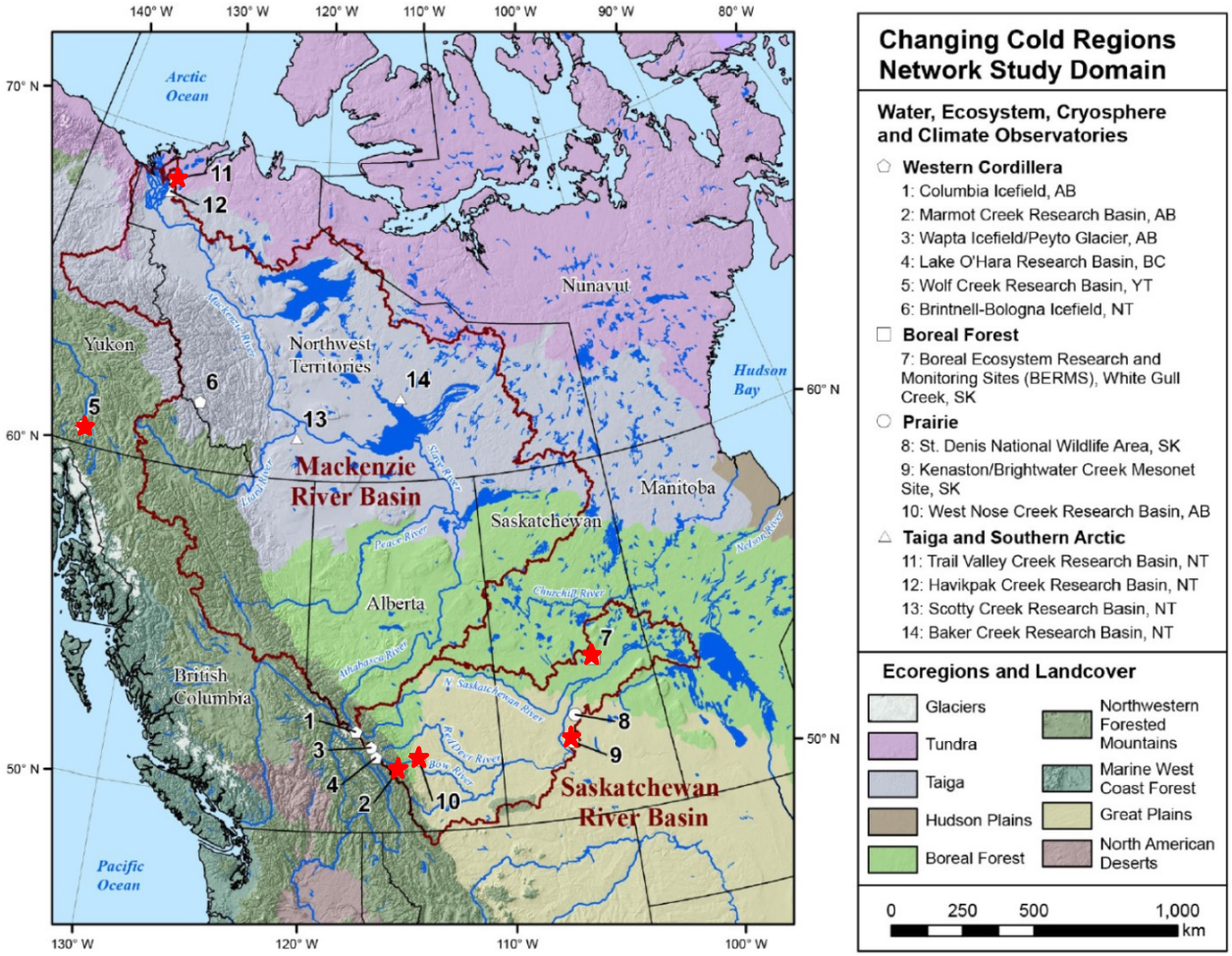
North Saskatoon, SK, (52.80, -106.57)



Bias Corrections of Precipitation measurements across different ecoclimate regions

University of Saskatchewan
Global Institute for Water Security

Xicai Pan
PDF



Changing Cold Regions Network Study Domain

Water, Ecosystem, Cryosphere and Climate Observatories

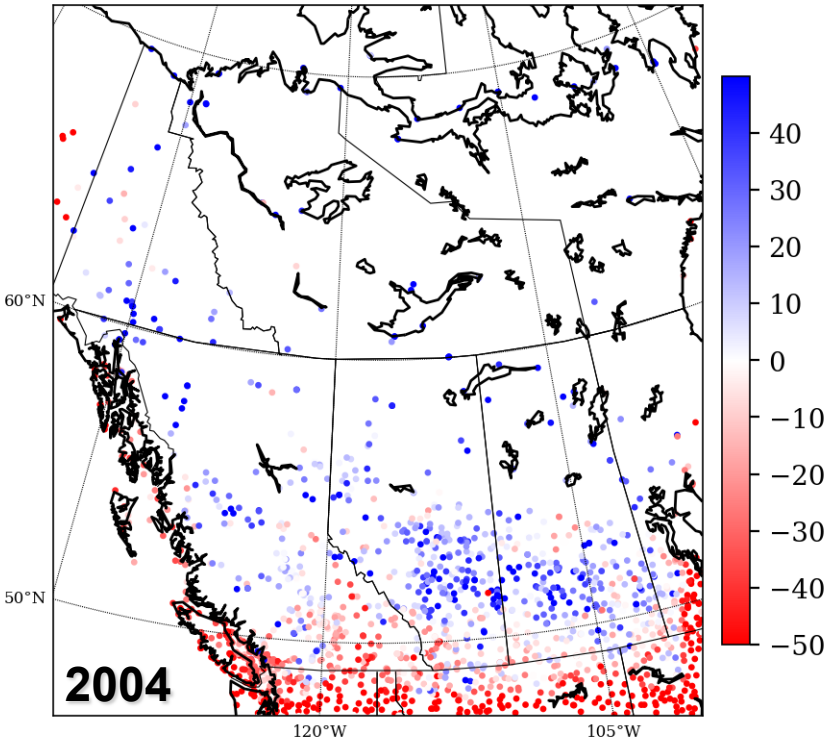
- **Western Cordillera**
  - 1: Columbia Icefield, AB
  - 2: Marmot Creek Research Basin, AB
  - 3: Wapta Icefield/Peyto Glacier, AB
  - 4: Lake O'Hara Research Basin, BC
  - 5: Wolf Creek Research Basin, YT
  - 6: Brintnell-Bologna Icefield, NT
- **Boreal Forest**
  - 7: Boreal Ecosystem Research and Monitoring Sites (BERMS), White Gull Creek, SK
- **Prairie**
  - 8: St. Denis National Wildlife Area, SK
  - 9: Kenaston/Brightwater Creek Mesonet Site, SK
  - 10: West Nose Creek Research Basin, AB
- **Taiga and Southern Arctic**
  - 11: Trail Valley Creek Research Basin, NT
  - 12: Havikpak Creek Research Basin, NT
  - 13: Scotty Creek Research Basin, NT
  - 14: Baker Creek Research Basin, NT

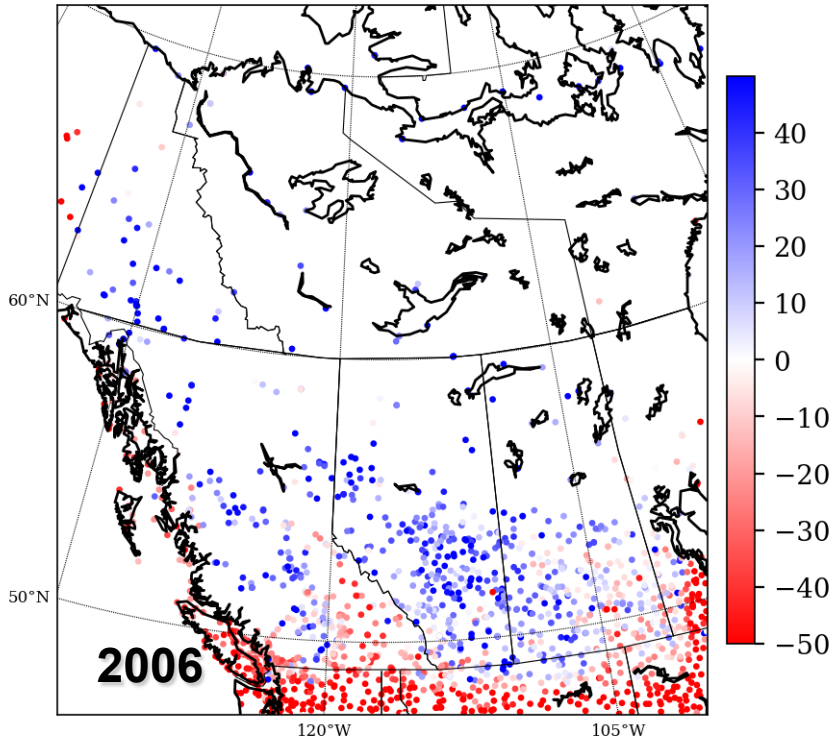
Ecoregions and Landcover

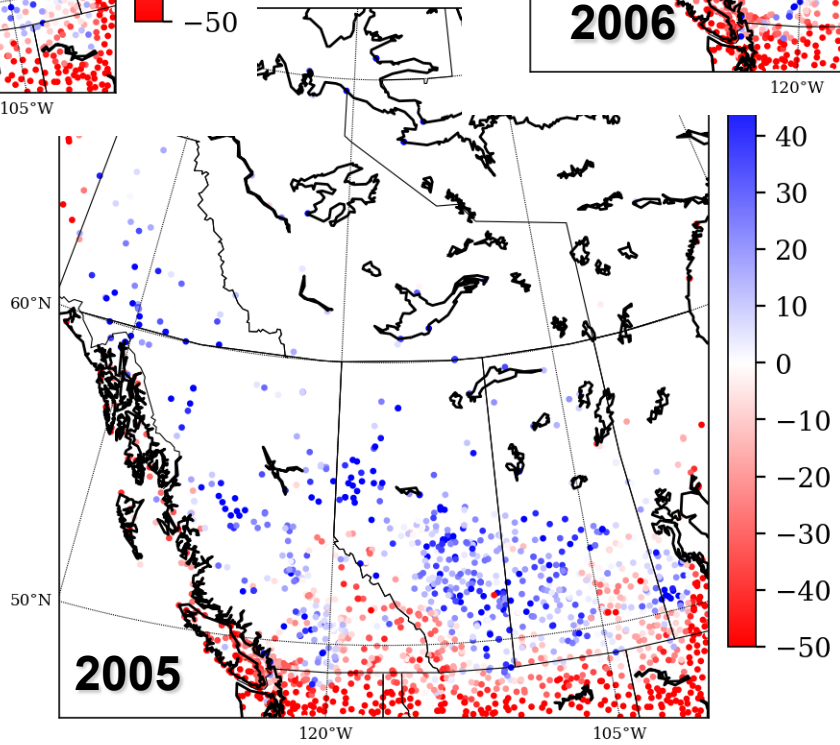
- Glaciers
- Tundra
- Taiga
- Hudson Plains
- Boreal Forest
- Northwestern Forested Mountains
- Marine West Coast Forest
- Great Plains
- North American Deserts

0 250 500 1,000 km

Xicai Pan, Daqing Yang, **Yanping Li***, Alan Barr, Warren Helgason, Masaki Hayashi, Philip Marsh, John Pomeroy, Richard Janowicz, 2016:Bias Corrections of Precipitation Measurements across Experimental Sites in Different Ecoclimatic Regions of Western Canada, *The Cryosphere,* 10, 2347-2360



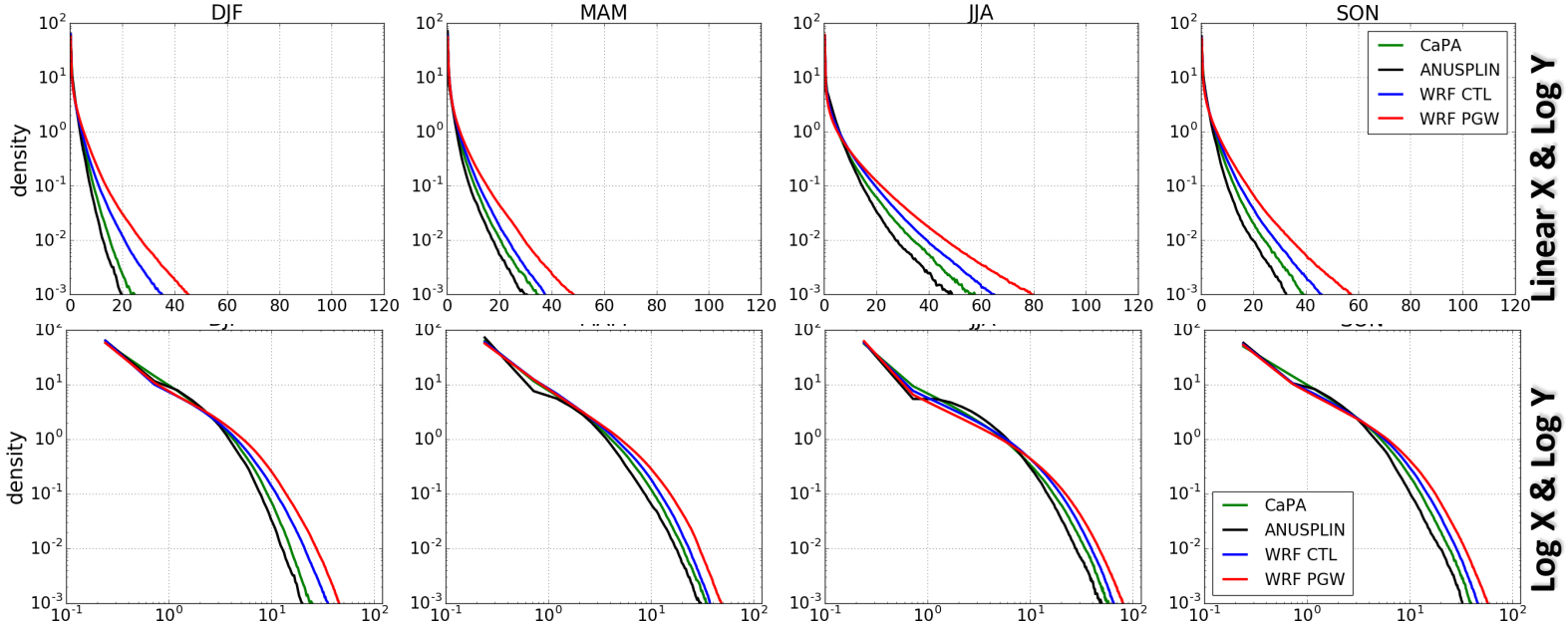




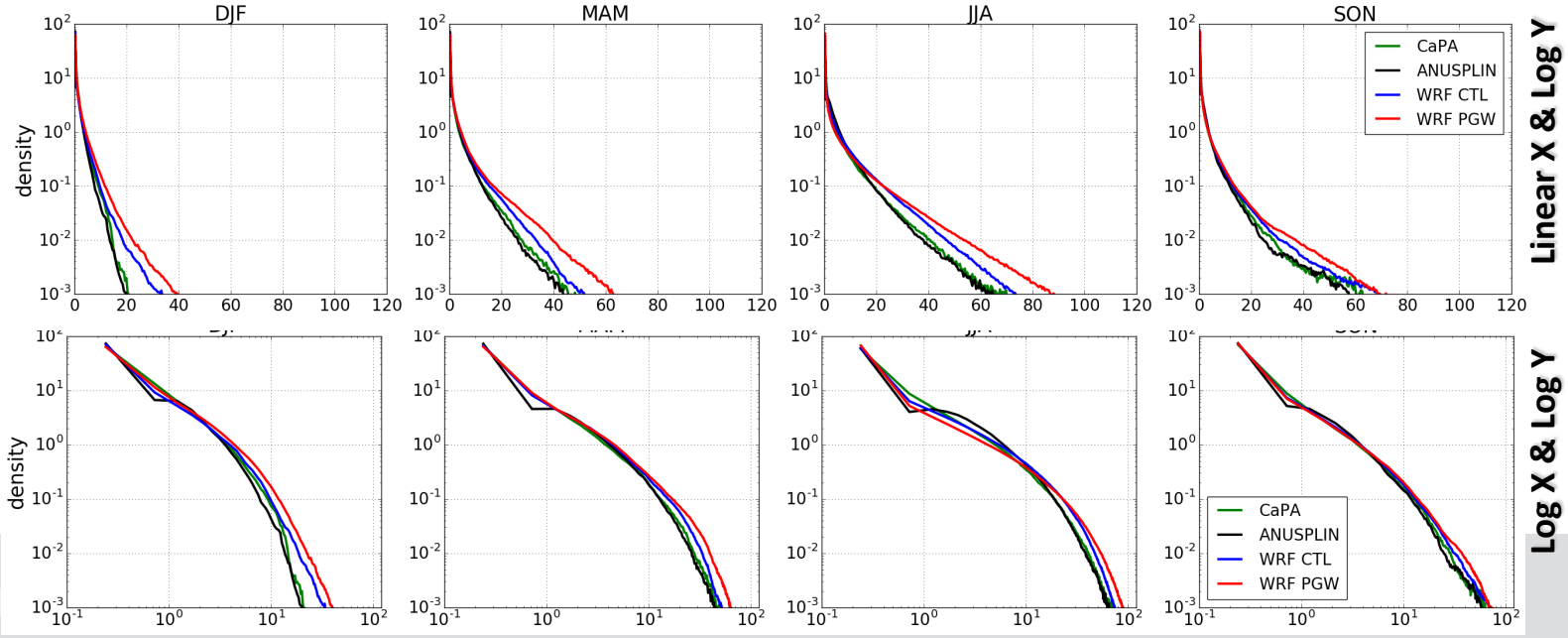
(WRF-OBS)/OBS in %

CCRN-WRF Performance Evaluation -PDF for daily precipitation intensity

MRB

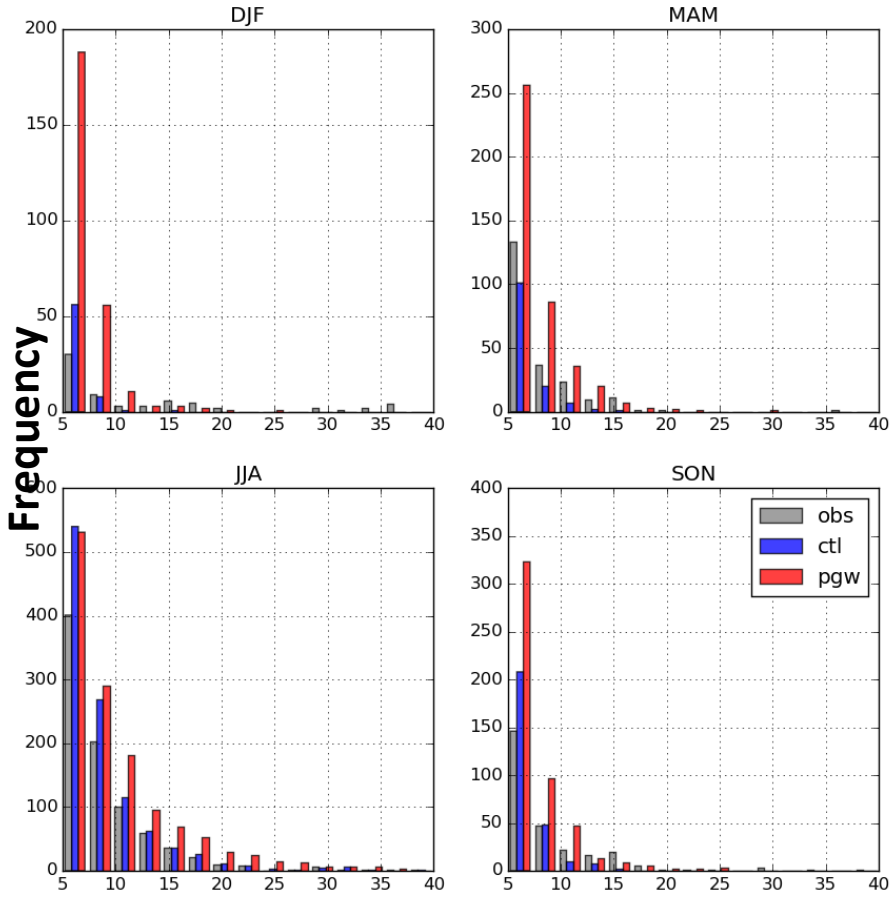


SRB



CCRN-WRF Performance Evaluation -PDF for hourly precipitation intensity

MRB



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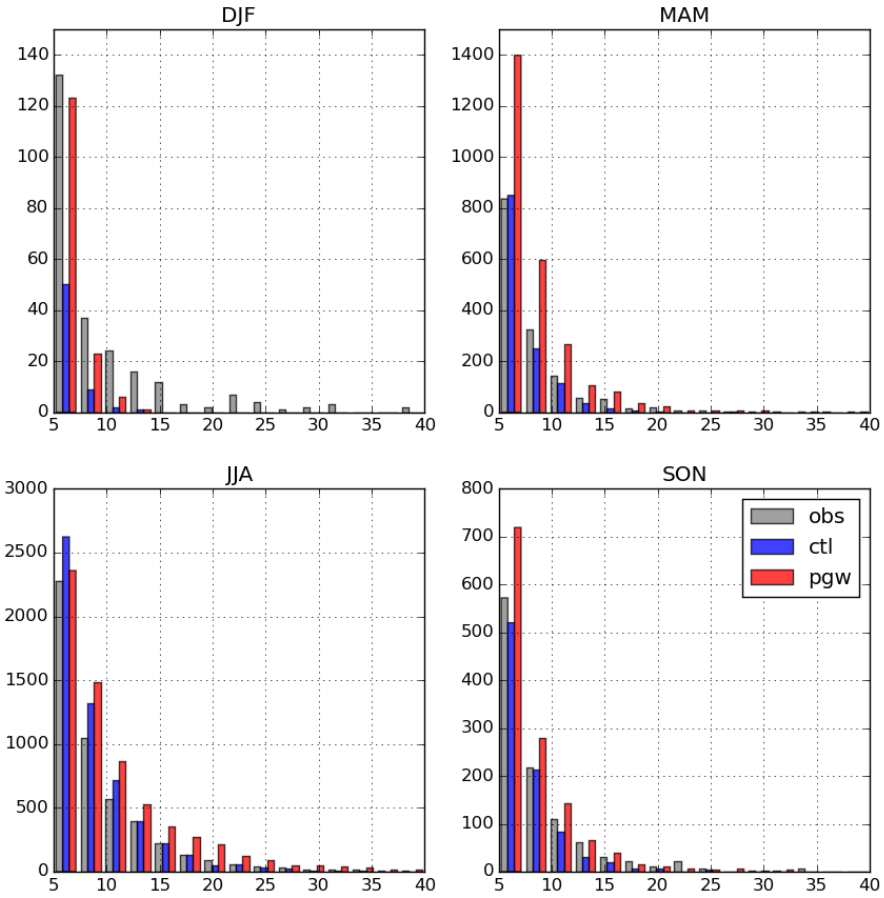
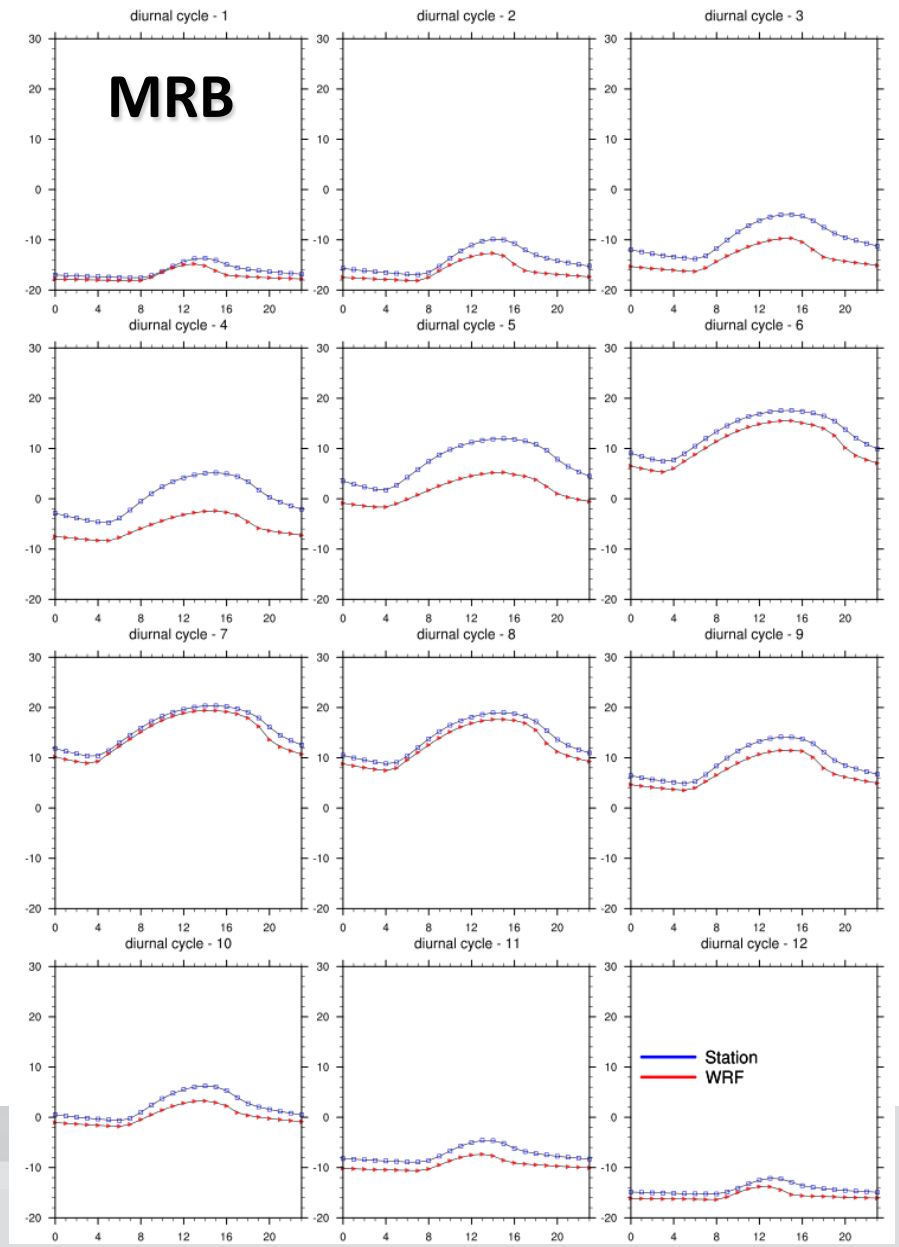
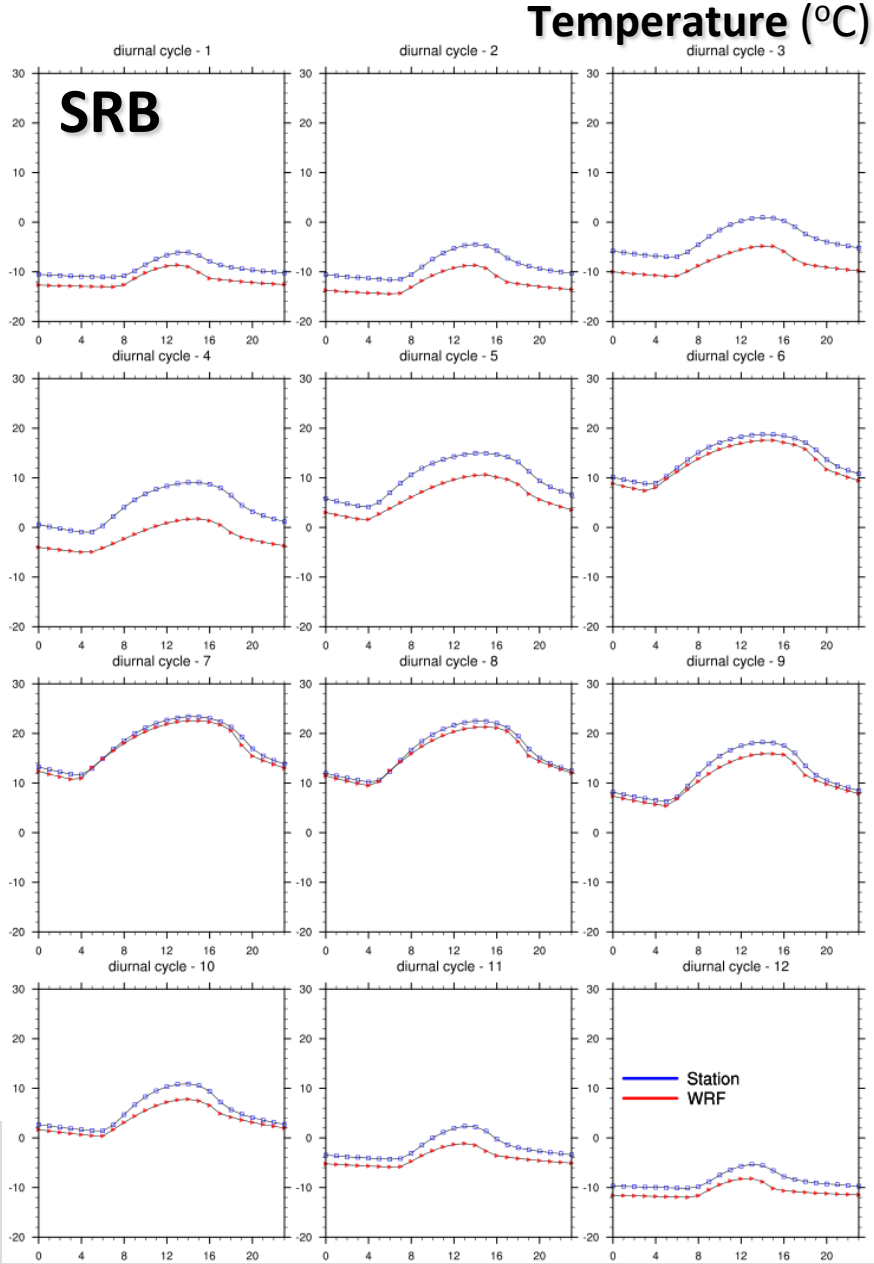
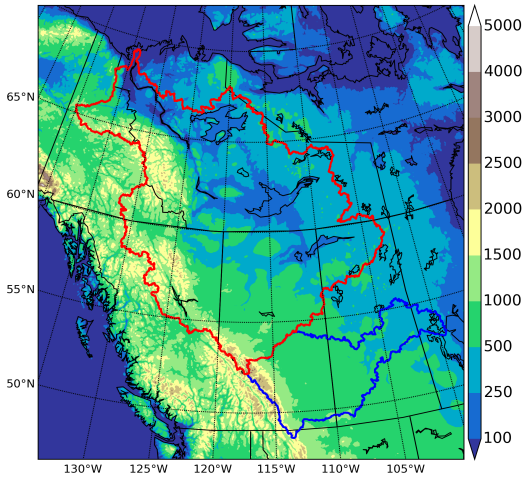


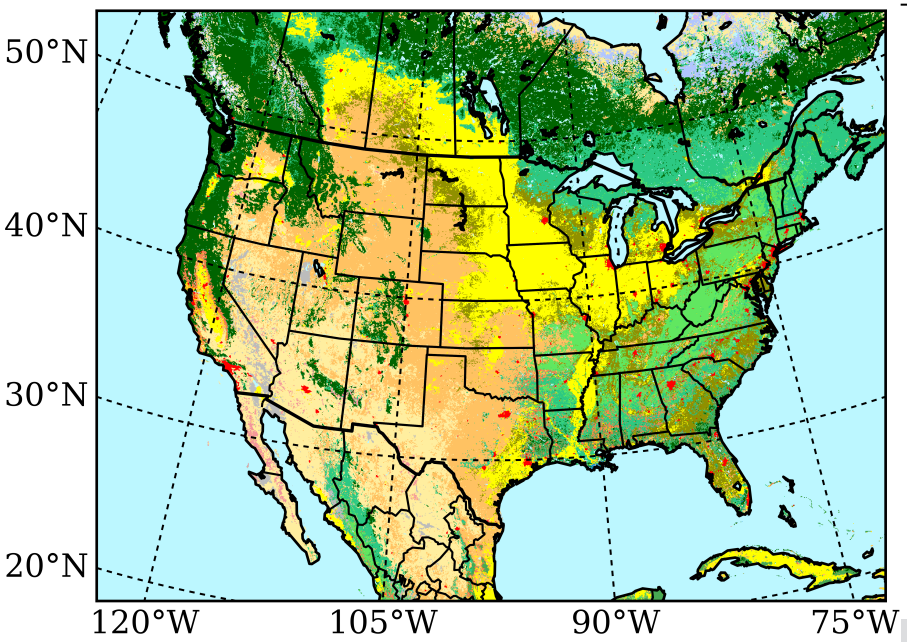
CCRN-WRF Performance Evaluation (Diurnal cycle)

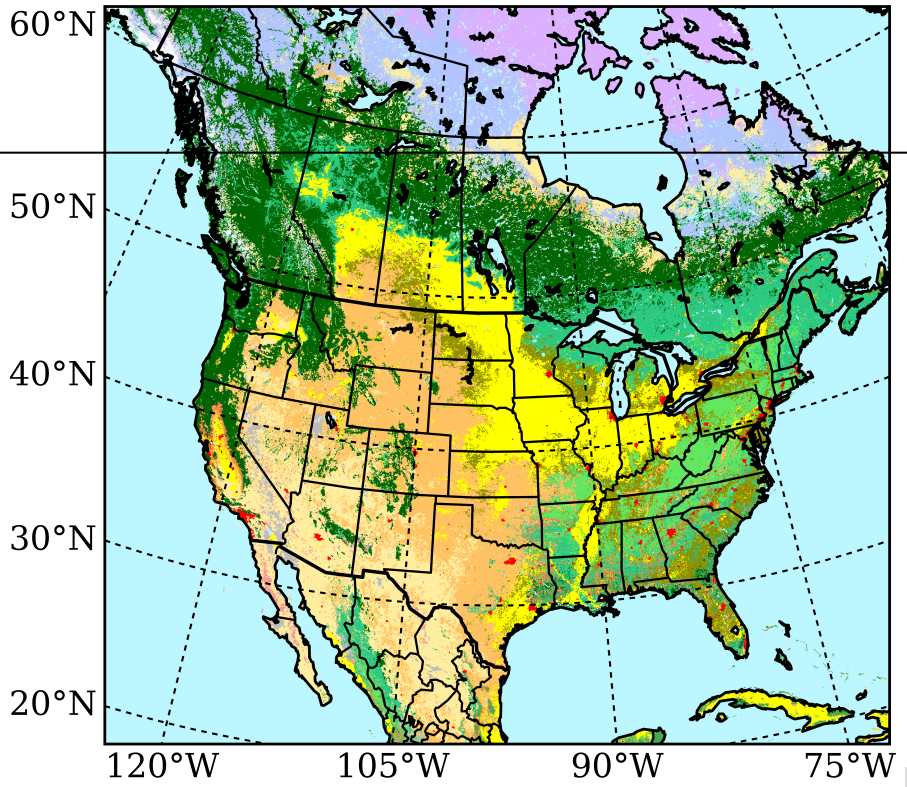




WRF Domain – CCRN + CONUS & Extended GWF

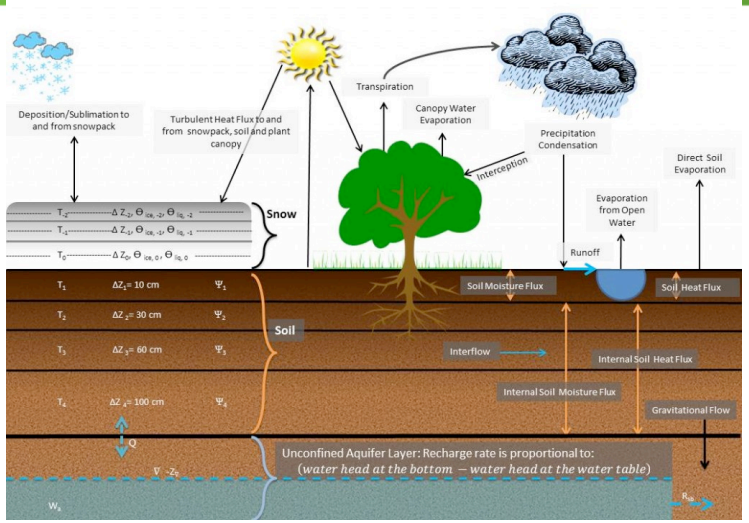


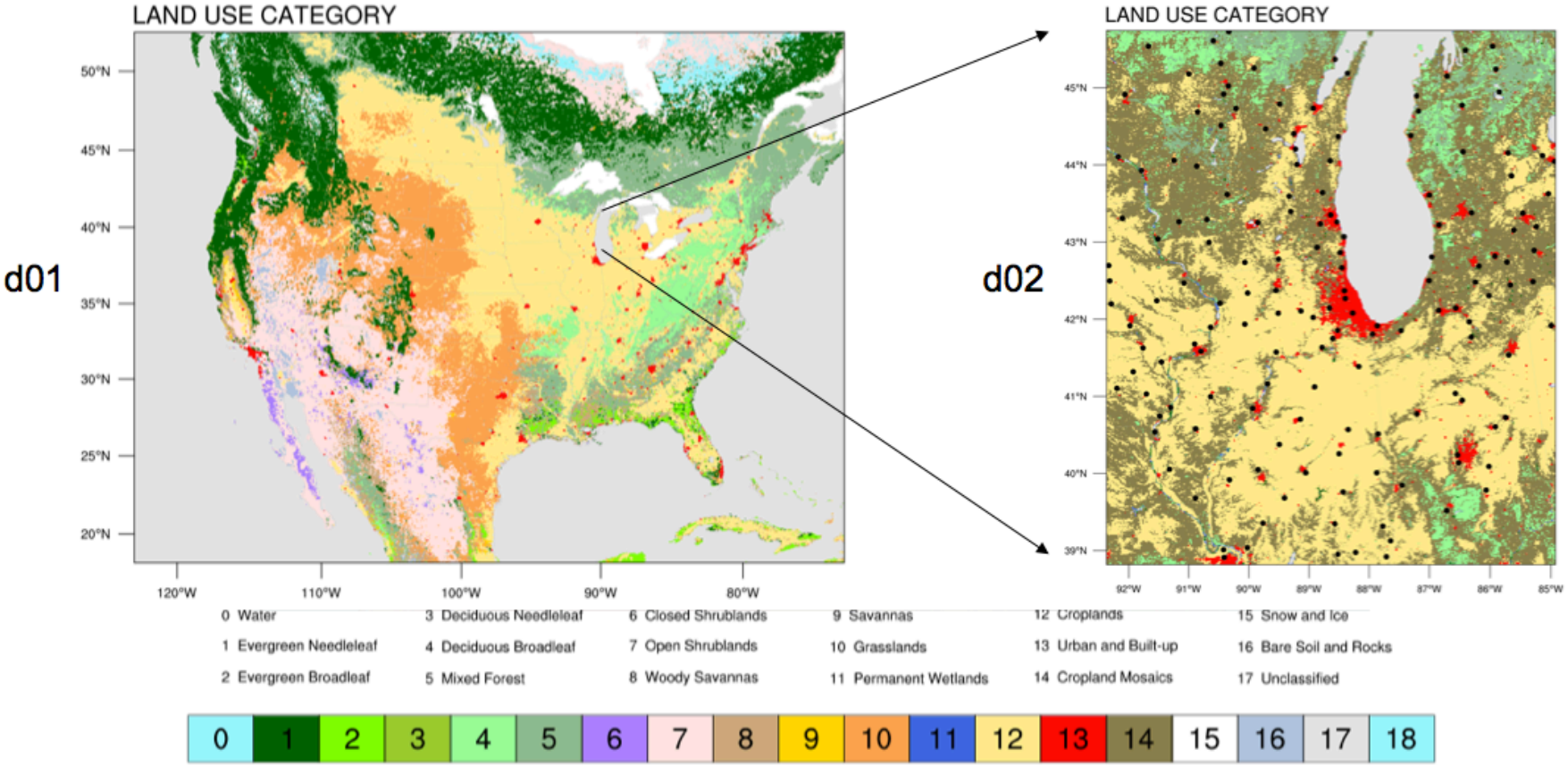




WRF NDOWN

- Sensitivity test for land-atmosphere interaction





Using 4-km WRF CONUS simulations to diagnose surface coupling strength

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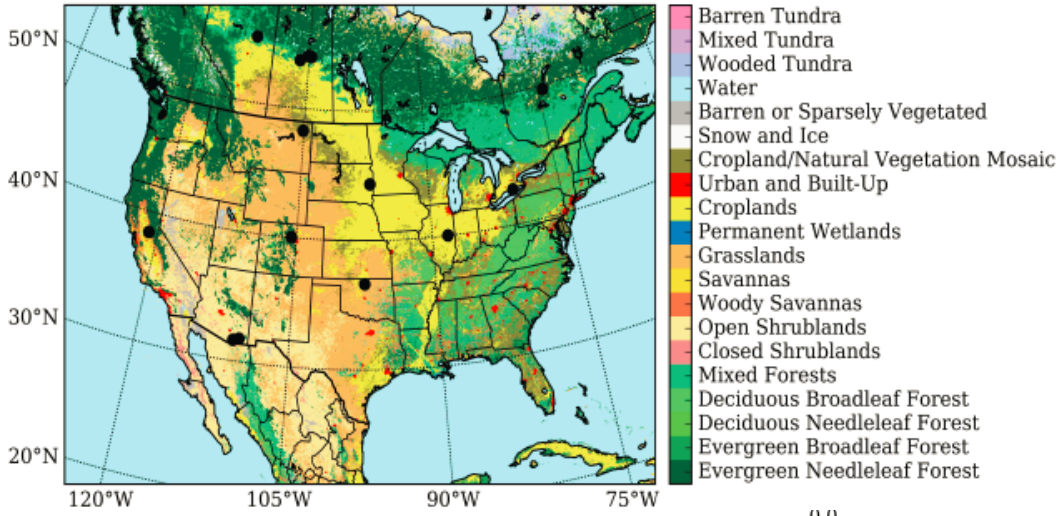
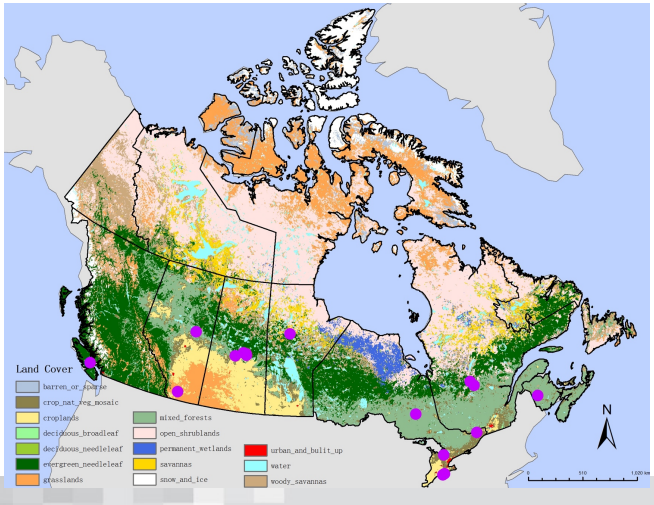
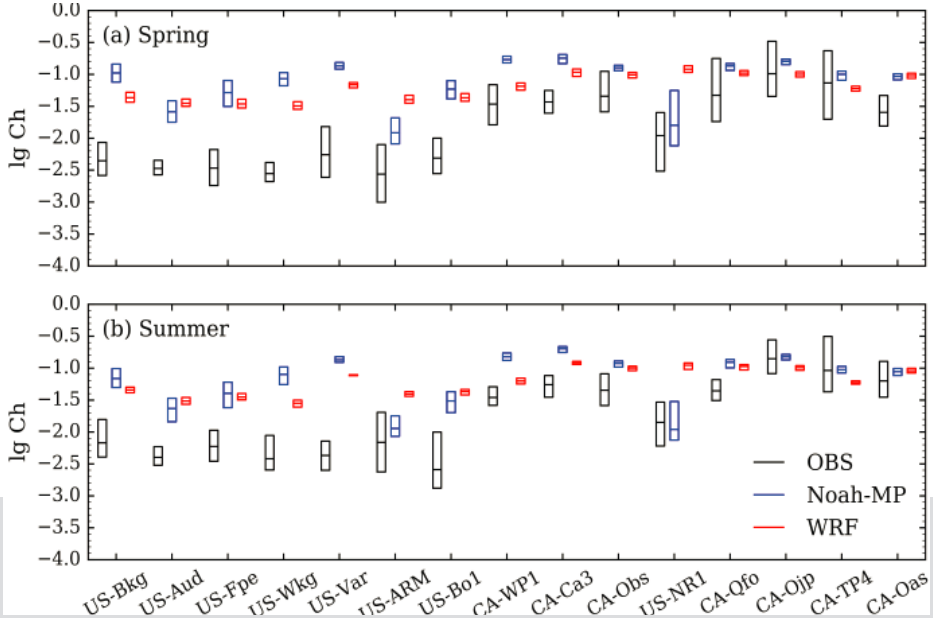


Table 1. General Information About 15 FLUXNET Sites Used in This Study

Site Location	Latitude, Longitude	Elevation(m)	Land-Cover Type	Canopy Height(m)	Years of Data Used
US-Bkg	44.35, -96.83	510	Croplands	0.2-0.4	2005-2007
US-Aud	31.59, -110.51	1469	Open Shurblands	0.1-0.2	2003-2007
US-Fpe	48.31, -105.10	634	Grasslands	0.2-0.4	2001-2007
US-Wkg	31.74, -109.94	1531	Grasslands	0.5	2005-2007
US-Var	38.41, -120.95	129	Woody Savannas	0.55+/-0.12	2001-2007
US-ARM	36.61, -97.49	311	Croplands	0-0.5	2003-2007
US-Bo1	40.01, -88.29	219	Croplands	3.0(mz)0.9(sb)	2001-2007
CA-WP1	54.95, -112.47	549	Permanant Wetlands	3.4	2004-2007
CA-Ca3	49.53, -124.90	153	Evergreen Needleleaf	7.6	2001-2007
CA-Obs	53.99, -105.12	598	Evergreen Needleleaf	9.4	2001-2007
US-NR1	40.03, -105.55	3050	Evergreen Needleleaf	11.5	2001-2007
CA-Qfo	49.69, -74.34	390	Evergreen Needleleaf	13.8	2004-2007
CA-Ojp	53.92, -104.69	518	Evergreen Needleleaf	16.7	2001-2007
CA-TP4	42.71, -80.36	219	Mixed Forest	20.3	2002-2007
CA-Oas	53.63, -106.20	580	Deciduous Broadleaf	21.5	2001-2007



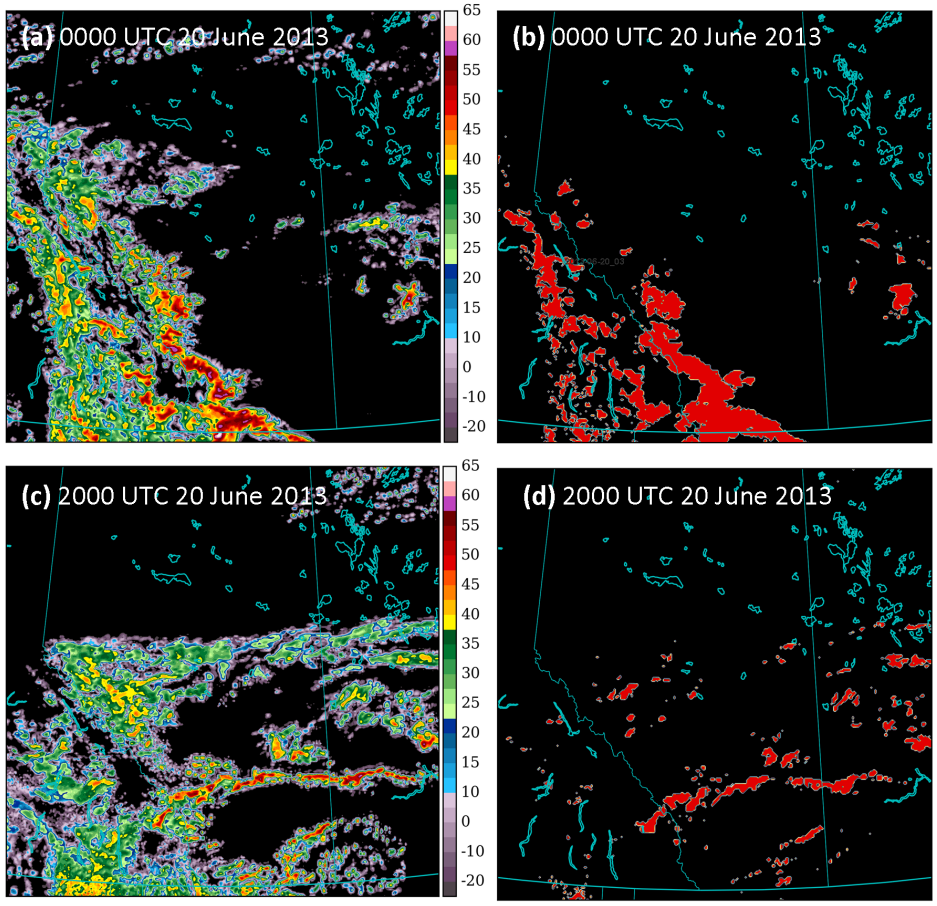


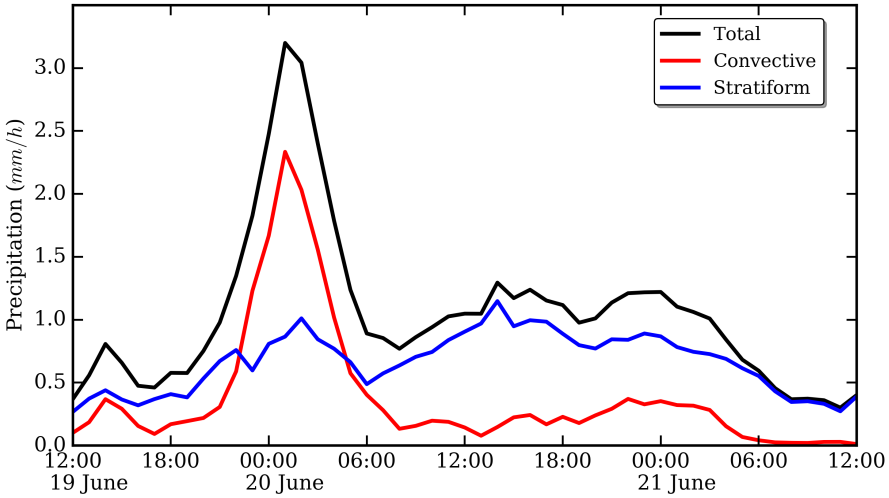
Storm characteristics during the lifecycle of the June 2013 Albert flood

Convective/Stratiform separation

WRF derived radar reflectivity

Convective component





Li Yanping, K. Szeto, R. Stewart, J. Theriault, L. Chen, B. Kochtubajda, A. Liu, S. Boodoo, R. Goodson, C. Mooney, S. Kurkute, 2017: **A numerical study of the June 2013 flood-producing extreme rainstorm over southern Alberta.** *Journal of Hydrometeorology*, http://dx.doi.org/10.1175/JHM-D-15-0176.1

The relationships between precipitation scaling defined intra-annually (binning scaling) and defined inter-annually (trend scaling)?

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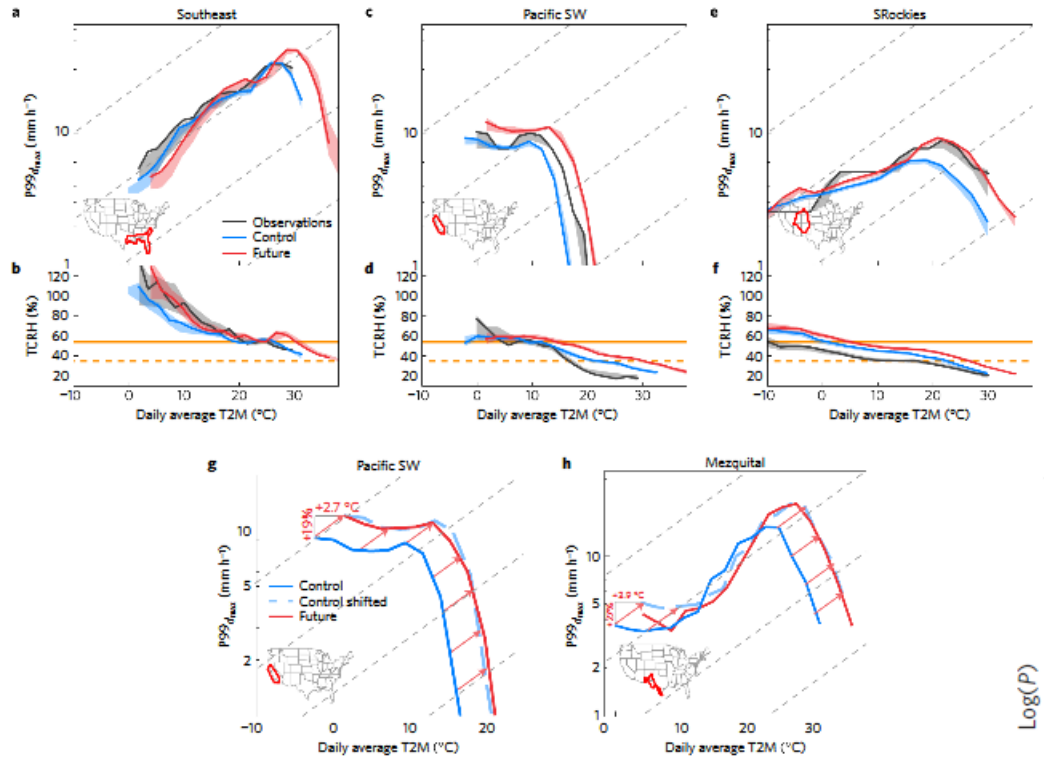
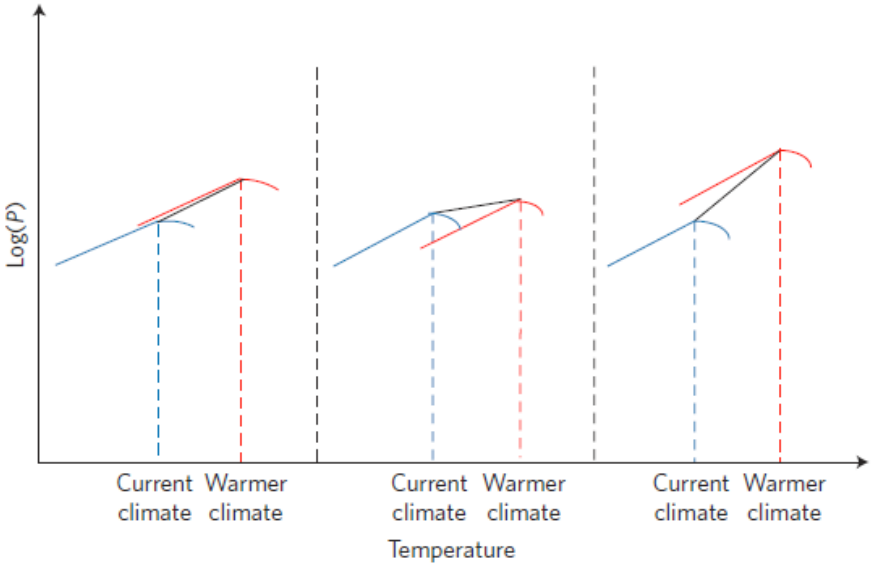


Prein et al. (2017)



Zhang et al. (2017)

How will mesoscale convective systems (MCSs) change in the future?

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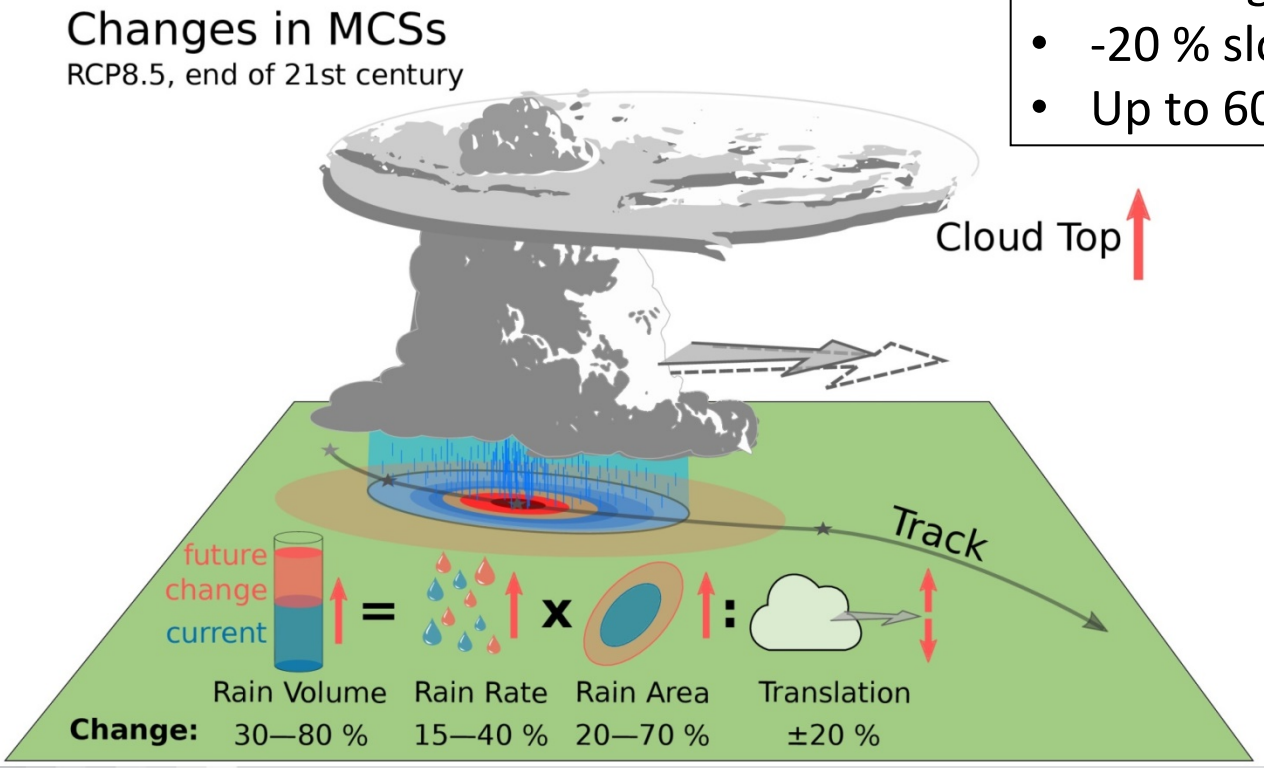
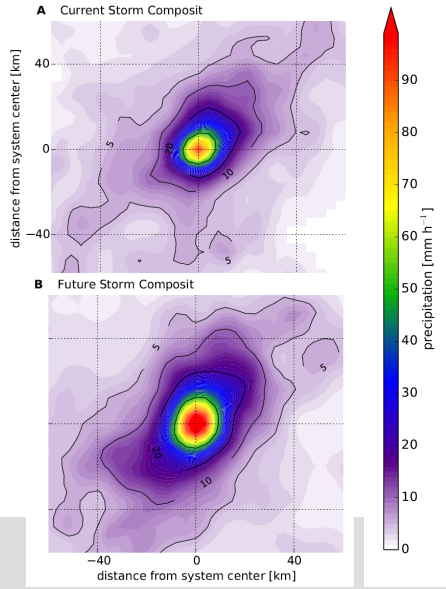
MODE-TD analysis for Storm Characteristics:
Speed, Lifetime, Size, maximum intensity, total P

For U.S. in a warmed climate:

- 250 % more MCSs in JJA
- 40 % higher hourly max rain rates
- -20 % slower moving storms
- Up to 60 % higher rainfall volumes





from Andreas Prein, NCAR

Pillar 1: Short-duration extreme precipitation in future climate

University of Saskatchewan
Global Institute for Water Security

Continental Scale Regional Climate Simulation using 4-KM WRF

1. Binning scaling (T-P relation)
2. Convective vs non-Convective precipitation
3. Physical mechanisms for Convection

   US Great Plains vs Canadian Prairies
4. Characteristics of MCSs (MODE-TD)

   speed, duration, Size, max intensity, total P

Land-atmosphere coupling

1. Surface water budget, precipitation partitioning, remote moisture source
2. 2nd dynamical downscaling (NDOWN)

   Small region & Very high-resolution