Western U.S. RHP Status and Water for Foodbaskets GEWEX Grand Challenge

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GEWEX Hydroclimate Panel – RHPs
How are they developed?

Co-Chairs: Jason Evans

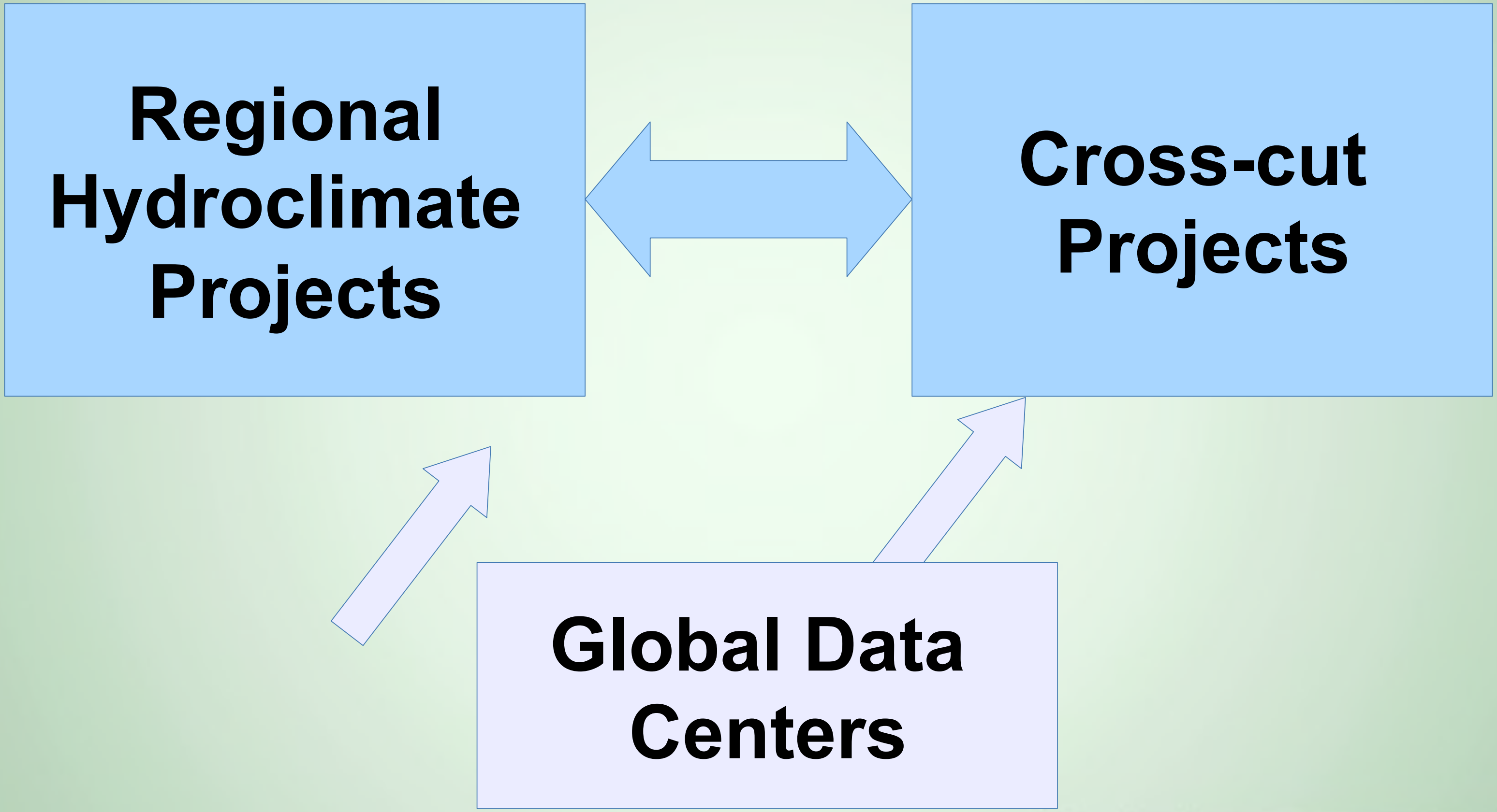
Joan Cuxart

The role of GHP within GEWEX

The GHP aims to address the GEWEX Science Questions from a regional and integrated perspective.

- Only at the regional scale can the water cycle be addressed from its physical to human and socioeconomic dimensions
- The Regional Hydroclimate Projects (RHPs) are an essential tool in this endeavour as they bring together various disciplines on water issues.
- The cross-cut projects allow GHP to propagate knowledge from one region to another and synthesize results at the global scale. They also allow development and testing of applications developed with the new knowledge. (actionable science)

GHP Structure



RHP Status

Active in 4 continents:

Europe: ***HyMEx*** (2010-2020) ======> High-impact weather events, societal response

Baltic Earth (2016-) ======> Sea and land changes, biogeochemical processes

PannEx (2018-) =====> Agronomy, air quality, sustainability & water mgnt

Australia: ***OzEWEX*** (2015-2020) =======> Water and energy cycle in Australia

Africa: ***HyVic*** (2015-2024) ========> Hydroclimatic variability over Lake Victoria basin

Recently finished:

Asia: ***MAHASRI*** (2007-2016) =====> Asian Monsoon

Eurasia: ***NEESPI*** (2004-2015) ====> Northern Eurasian climate-ecosystem-societal inte

North America: ***CCRN*** (2014-2018) => Cryospheric, ecological, hydrological interactions

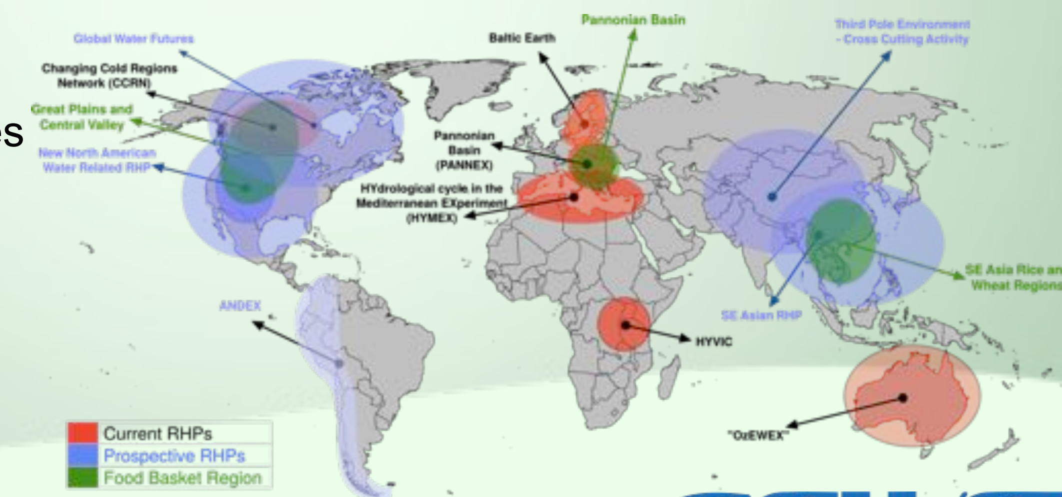
Prospective:

America: ***AndEx*** (2019?-) =====> Andes hydroclimate, high impact events, cryosphere…

North America: ***GWF*** (2018-2023) => Cryospheric, ecological, hydrological interactions

In discussion:

Exploring new possibilities in the Americas and Asia.



Relation with GEWEX's Science questions and imperatives

i) understanding the precipitation variability,
ii) changing water availability,
iii) extreme events like drought and floods,
iv) processes in the water and energy cycles

Most of the RHP are in line with the questions and address most of the 7 imperatives:
i) Data sets; ii) analysis; iii) processes; iv) modelling; v) applications; vi) technology
Transfer & vii) capacity building.

Steps towards creating an RHP

1) Networking

Gather researchers who would like to participate in a large interdisciplinary project because: big science questions require expertise from many disciplines, they believe more can be achieved working together than alone.

1) Collaboration

Together identify: key science questions; ways these could be addressed; resources needed to do this; possible sources of funding. Also identify collaborative work that can be pursued immediately given existing resources and do this.

1) Write a white paper / science plan

Drafting a document allows you to refine your ideas, reach explicit agreement on science priorities, expand the collaborative network, get feedback from outside (GEWEX, existing RHPs, …) - ALSO agree a governance structure, data sharing arrangements,...

1) Apply for RHP status and funding

Finding funding is key for success of a RHP. The minimum is funding for a project office/ secretariat.

Western U.S. RHP

1) Networking

Workshop was held in May 2017 to gauge interest. Outcome of workshop indicated interest, but science needed to be more well defined and funding sources identified. There was a previous attempt to organize a North American RHP called TRACE that eventually faded out due to lack of a strong science focus for the community to rally around and lack of funding. However, a community of interested scientists formed. One of the previous leaders of TRACE was Dave Gochis of NCAR and he has volunteered to work on forming a new western U.S. RHP.

2) Collaboration

Science community is still interested, but need to identify a key science challenge. The recently completed U.S. CONUS convective permitting simulation for historical and future climate provides an excellent model dataset to explore key water cycle processes in the western U.S. The Water for Food Baskets Grand Challenge may also help to provide a science focus. Hope to connect to Global Water Futures RHP and INARCH activities in the Canadian Rockies.

3) Write a white paper/science plan

A draft white paper on Water for Foodbaskets has been written but not for the western U.S. RHP. Needs to be done.

4) Apply for RHP status and funding

Not there yet.

A Regional Hydroclimate Project for the western U.S.

integrate ongoing research activities in Canada and the USA

- Understanding the impacts of climate variability and change on water availability across the river basins of the Rocky Mountains and Central U.S.
- Key Questions:
  - *How do changes in seasonal cycles of snow affect the partitioning of precip. between ET and runoff?*
  - *How do results depend on limitations in water and energy as manifest in gradients across latitude and elevation?*
  - *How will expected changes in extreme events (floods and of drought) impact the timing and availability of seasonal water supplies?*
  - *To what degree do landscape disturbances alter the natural patterns land-atmosphere coupling and runoff partitioning?*

A Regional Hydroclimate Project for the western U.S.

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- Understanding the impacts of climate variability and change on water availability across the river basins of the Rocky Mountains and Central U.S.
- Research needs:
- ***Observational synthesis:***
  - *Coordinated multi-scale field and remote sensing campaigns to quantify cross-scale controls on regional hydroclimatic processes*
  - *Understanding of key processes and compilation of data to test model hypotheses*
- ***Modeling synthesis:***
  - *Controlled comparison of different modeling approaches*
  - *Improved model physics parameterization development for integrated water cycle projections*

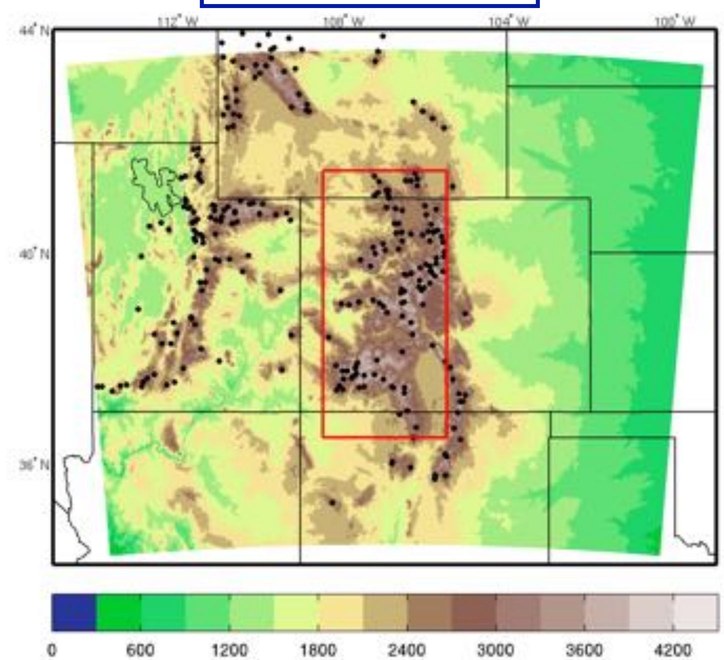
What is the CONUS Convective Permitting Modeling Effort?

Past work: High Resolution Simulations of the Colorado Headwaters snowfall, snowpack and runoff

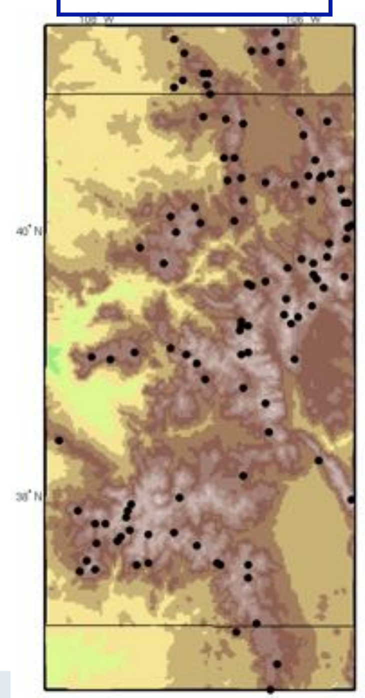
NCAR

1. Performed past climate simulations using high resolution WRF model
   - Grid spacing: 4 km.
   - Continuous eight years: 2000 – 2008
2. Verified results of WRF integrations using NRCS SNOTEL data and showed that grid spacing of at least 6 km needed to faithfully reproduce the spatial pattern and amount of precipitation (Rasmussen et al. 2011, J. Climate).
3. Investigate enhancement of water cycle by adding CCSM 10 year mean temperature and moisture perturbation from 50 year future A1B simulations from AR4 runs to NARR boundary conditions

Full Domain



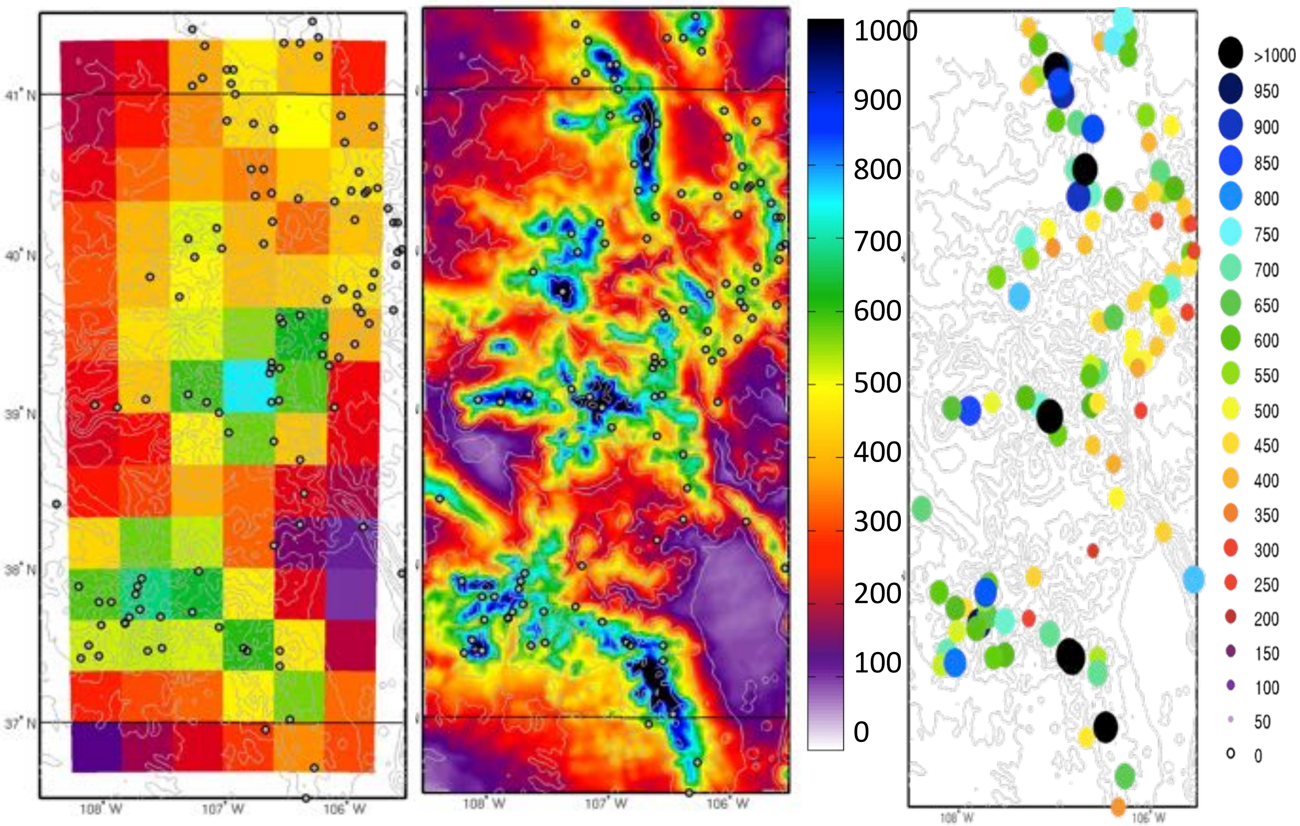
Headwaters domain



● SNOTEL sites

WRF model able to reproduce the amount and spatial distribution of snowfall and snowpack over a winter season over the Colorado Headwaters at spatial resolutions less than 6 km

36 km | 2 km | SNOTEL Obs.



6-mo. Total Precipitation (mm) Comparison
1 Nov. 2007-1 May 2008

SNOTEL Precip gauge

Ikeda et al, 2010, Rasmussen et al. 2011

Improvements to WRF model based on conducting high-resolution climate simulations

1. Computing requirements
   - Obtained 32M core hours on NCAR Yellowstone supercomputer
2. Significant model deficiencies found in test runs led to an intensive effort to improve the model over the CONUS domain.

	Improvements
Noah-MP LSM	1. Rain-snow partitioning using microphysics scheme 2. Vegetation-dependent snow fraction/melt curves 3. Allowing snow to be present at above 0^oC 4. Heat advection by precipitation 5. Bug fix for canopy snow unloading and snow density
Microphysics	Aerosol emission refinement, variable cloud droplet initiation though inclusion of cloud condensation nuclei prognostic equations (Thompson and Eidhammer 2014)
Re-analysis tests	NARR, CFSR, and ERA-Interim tested. ERA-Interim chosen.
Spectral nudging	Testing and parameter adjusting. Nudged above BL to small wave numbers (2 and 3).

CONUS Project Team

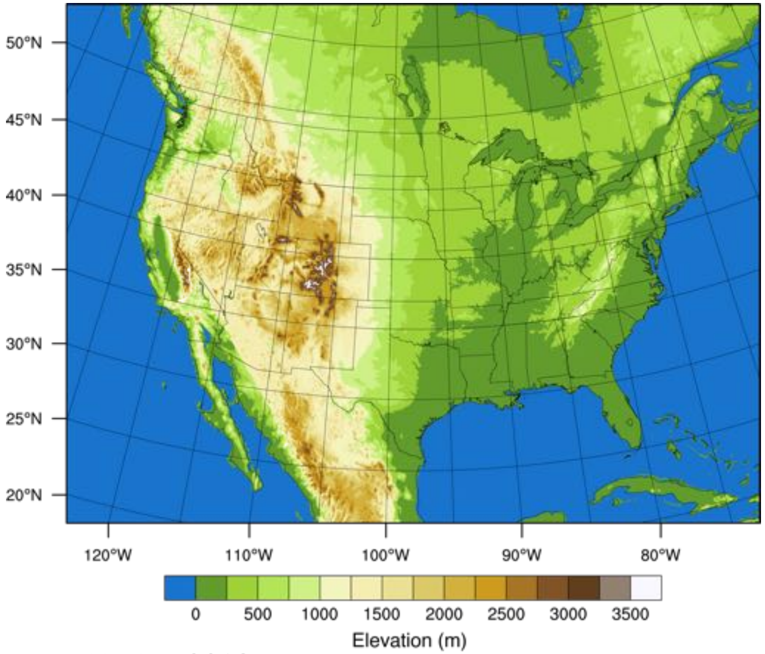
Project Lead	Roy Rasmussen	RAL/HAP
Experiment Designing and WRF Modeling	Changhai Liu	RAL/HAP
	Jimy Dudhia	MMM
	Liang Chen, Sopan Kurkute	University of Saskachewan
Data Analysis and Management	Kyoko Ikeda, Changhai Liu, Andreas Prein, Andrew Newman, Aiguo Dai	RAL/HAP MMM, U. of Albany
Microphysics	Greg Thompson	RAL/HAP
LSM modeling	Fei Chen, Mike Barlage	RAL/HAP
Hydrology modeling	David Gochis	RAL/HAP
Snow Physics	Martyn Clark	RAL/HAP
Dynamical Downscaling	Ethan Gutmann	RAL/HAP
Societal Impacts	Dave Yates	RAL/HAP

CONUS-I Project

CONUS-I Project

- 4-km WRF model simulation of historical and future climate over CONUS.
- Initial and boundary conditions taken from reanalysis and modified reanalysis data.
- Future climate simulation following a *Pseudo Global Warming* (PGW) approach.
- 13-year simulation from Oct. 2000 to Sept. 2013.

CONUS Model Domain
4 km horizontal grid spacing
1360 x 1016 x 51 grid points



CONUS-I Project : Science Objectives

CONUS-I Project

- 4-km WRF model simulation of historical and future climate over CONUS.
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Science Objectives

- Evaluate WRF's ability to capture orographic precipitation/ snowpack in western US and convective precipitation in eastern US
- Assess future changes of snowfall/snowpack and associated hydrological cycles
- Examine precipitation changes under the CMIP5 projected global warming, including extremes and warm-season precipitation in central US
- Provide a valuable community resource for regional climate changes and impact studies by university groups

Historical and Pseudo Global Warming (PGW) Climate Simulation Forcing Data

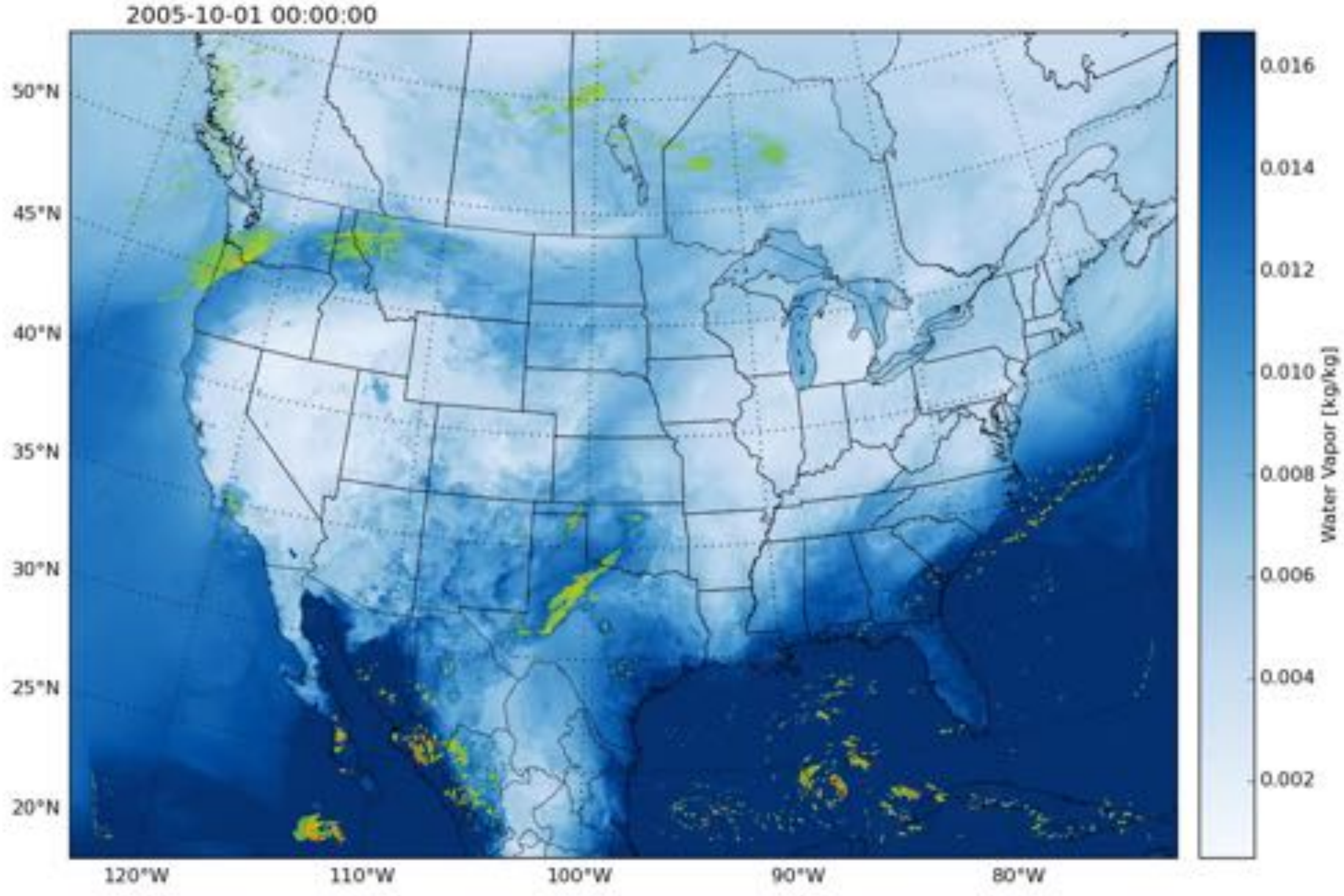
CONUS-I Historical Climate Simulation

$$WRF_{input} = ERA-I$$

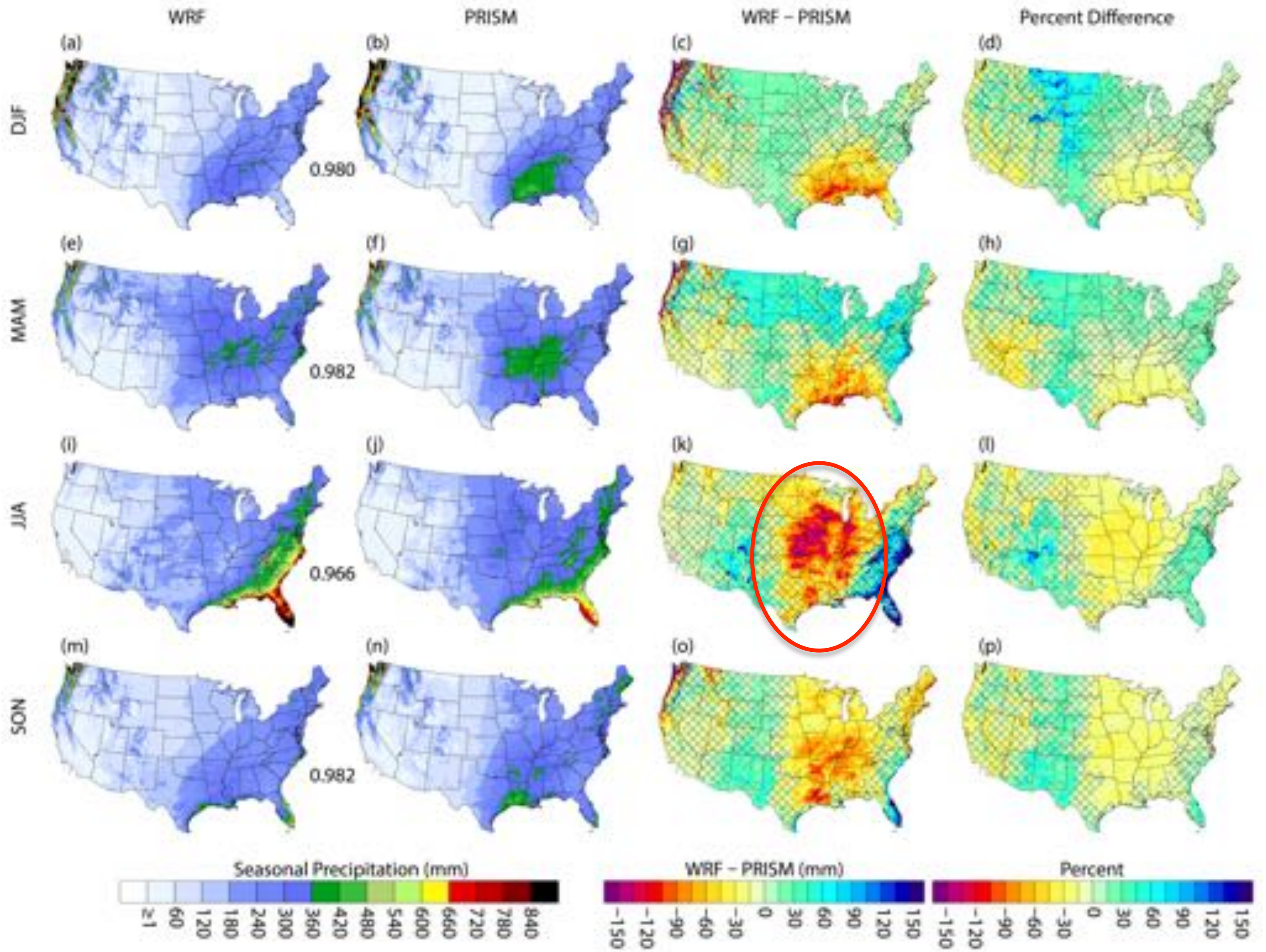
CONUS-I Future Climate Simulation (PGW)

$$WRF_{input} = ERA-I + (CMIP5_{2071-2100} - CMIP5_{1976-2005})$$

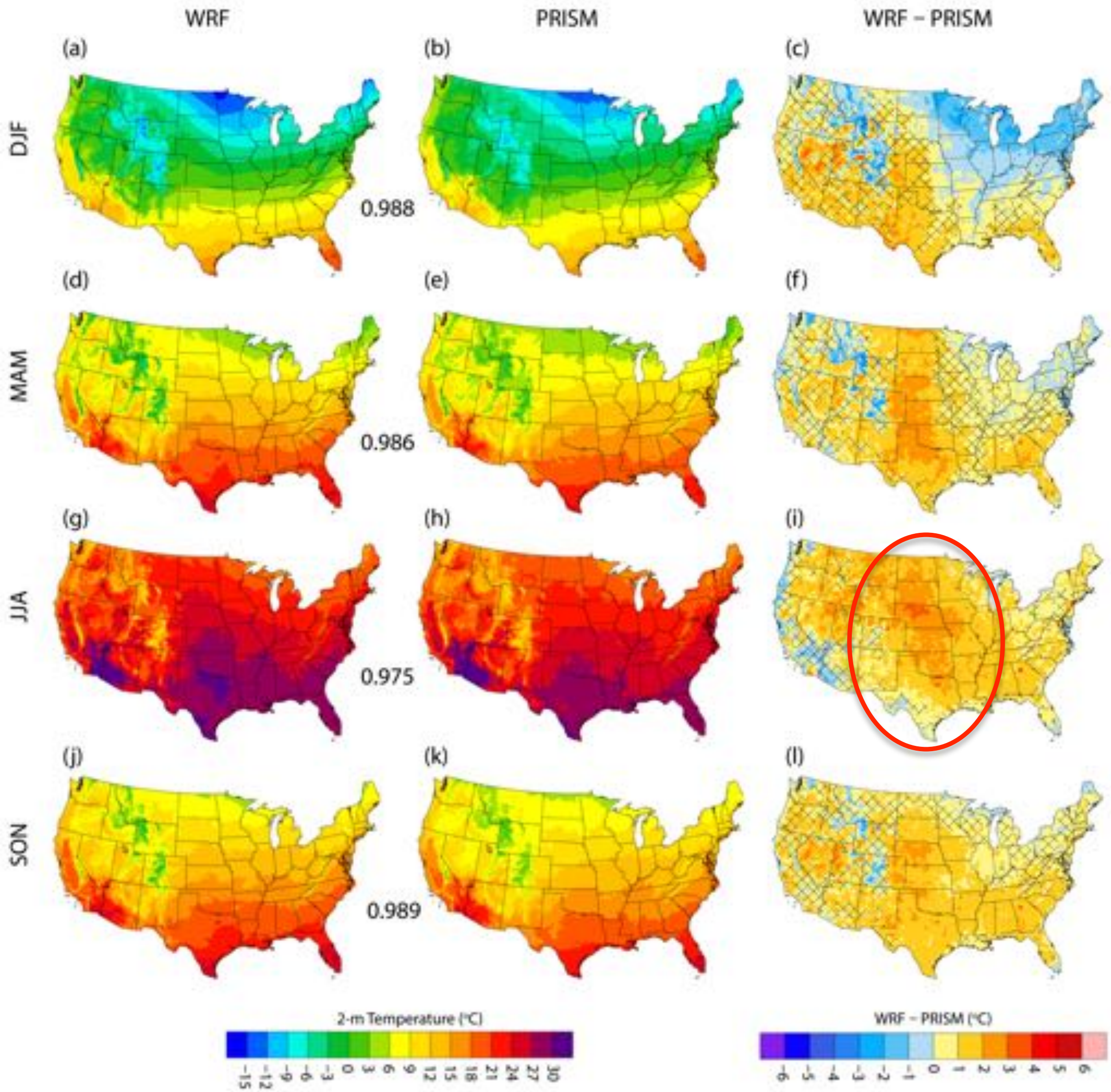
- 30-year monthly mean climate change signals from 19 ensembles from CMIP5 GCMs were added to 6-hrly ERA-interim data .
- Minimal storm track change
- Spectral nudging is applied above boundary layer for both simulations.


2005-10-01 00:00:00
50°N
45°N
40°N
35°N
30°N
25°N
20°N
120°W
110°W
100°W
90°W
80°W
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
Water Vapor [kg/kg]

13-yr Average Seasonal Precipitation from Historical Simulation and PRISM Observation



13-yr Average Seasonal 2-m Temperature from Historical Simulation and PRISM Observation

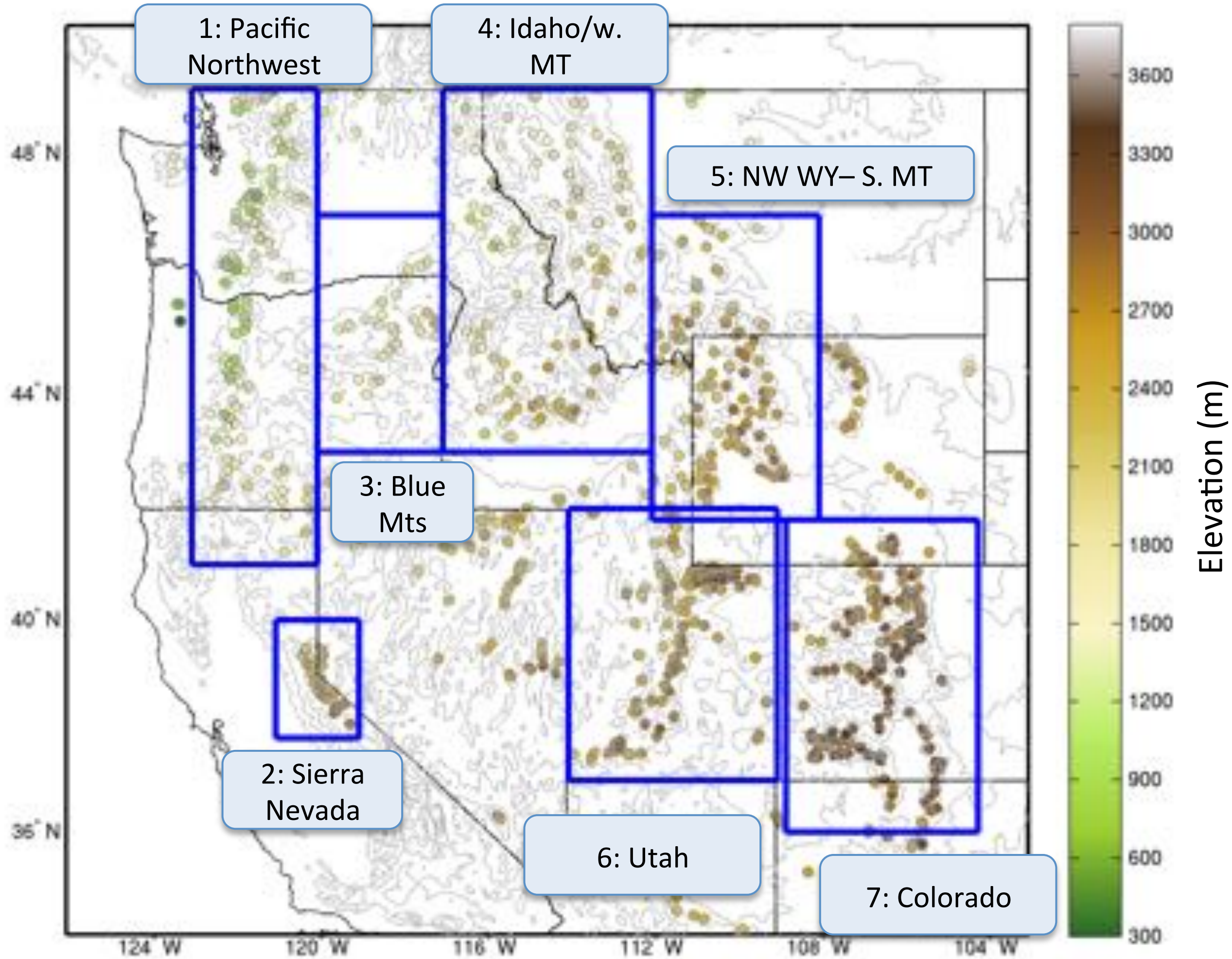


PGW Results at Western SNOTEL Sites

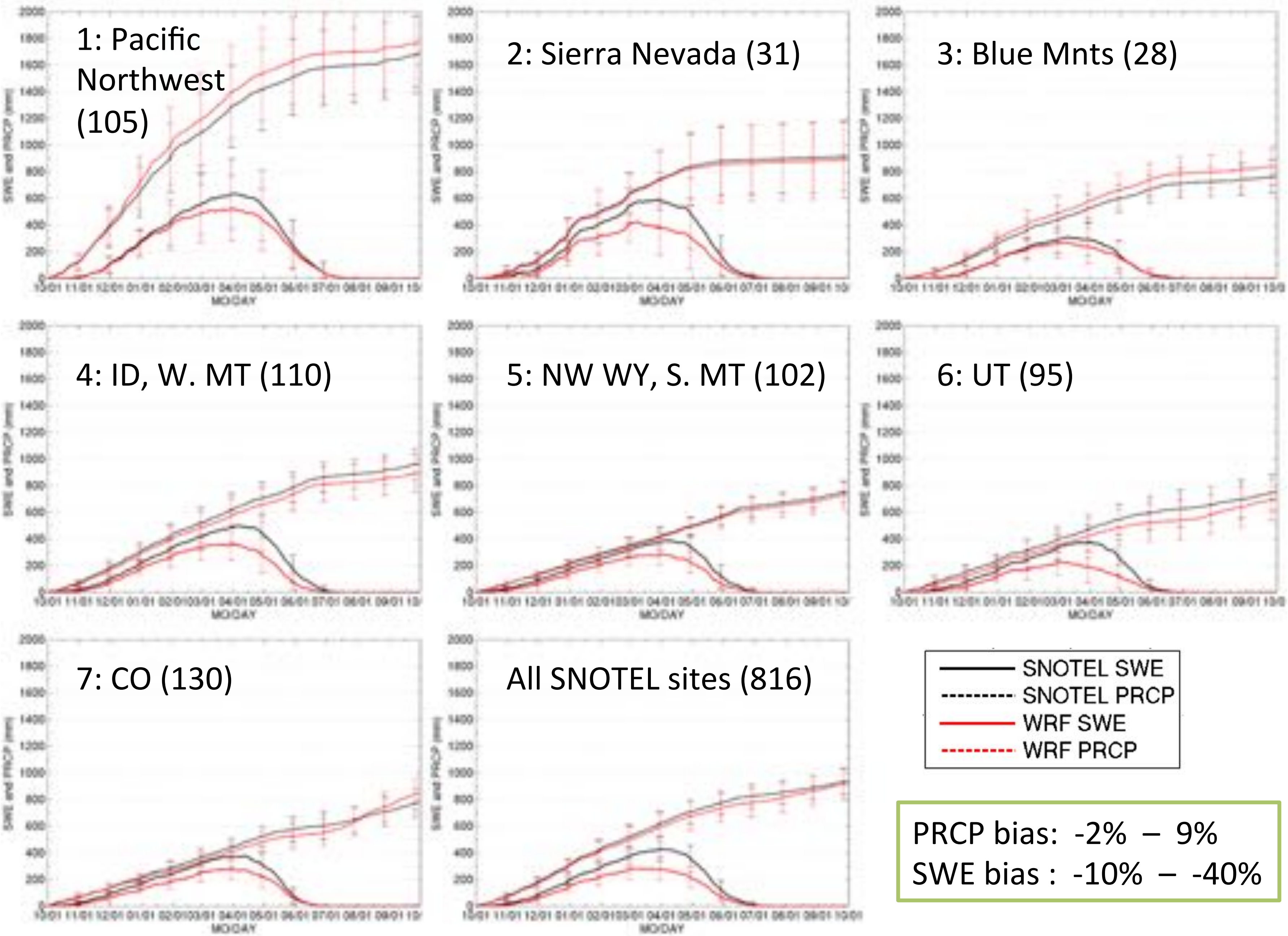
SNOTEL site at Brooklyn Lake, WY

Snow gauge

Snow pillow



SNOTEL vs WRF at Western SNOTEL sites: 13-year climatology



PRCP bias: -2% – 9%
SWE bias : -10% – -40%

Mean difference in monthly precipitation between WRF and SNOTEL from 8-year climatology data

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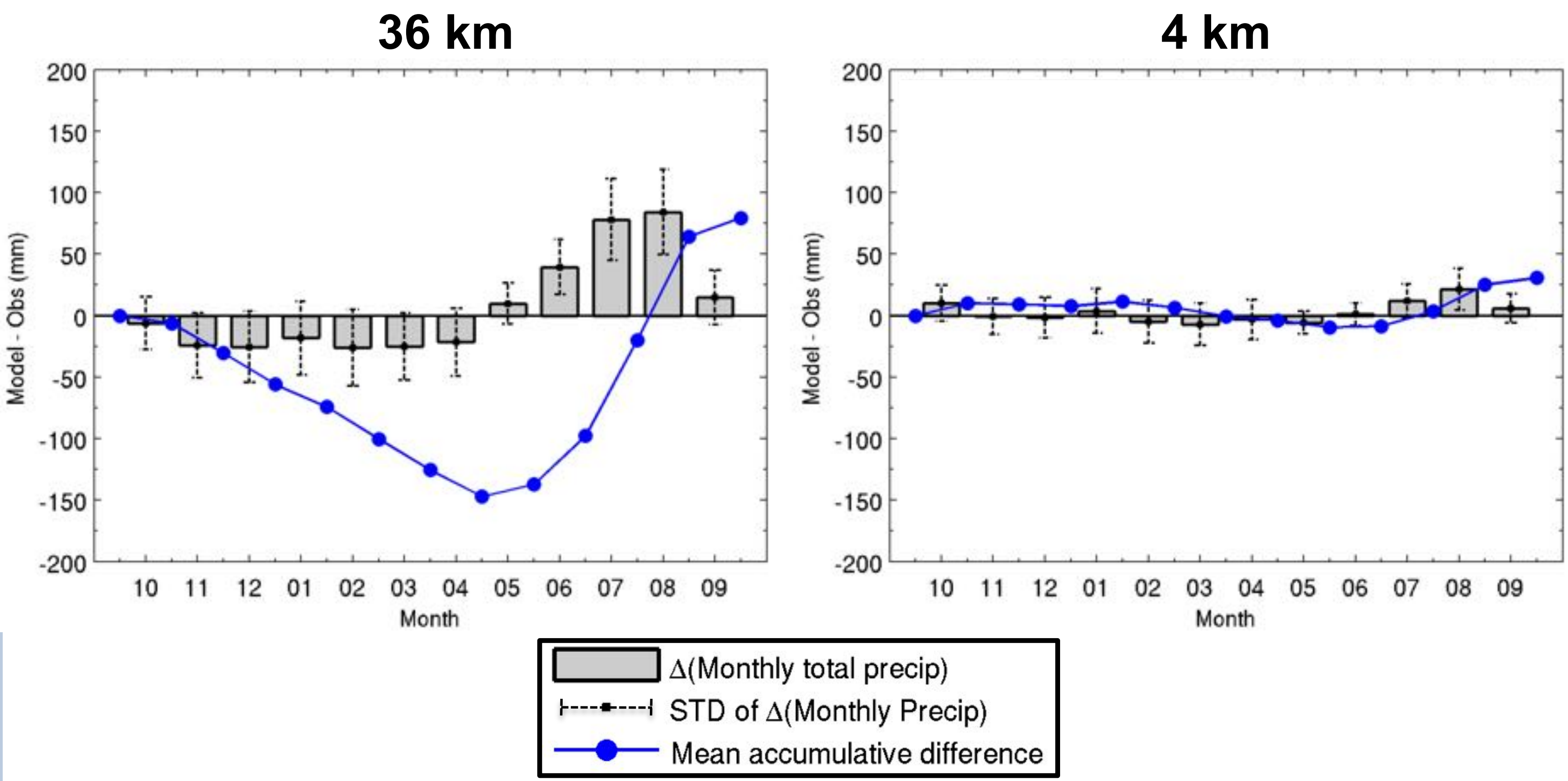
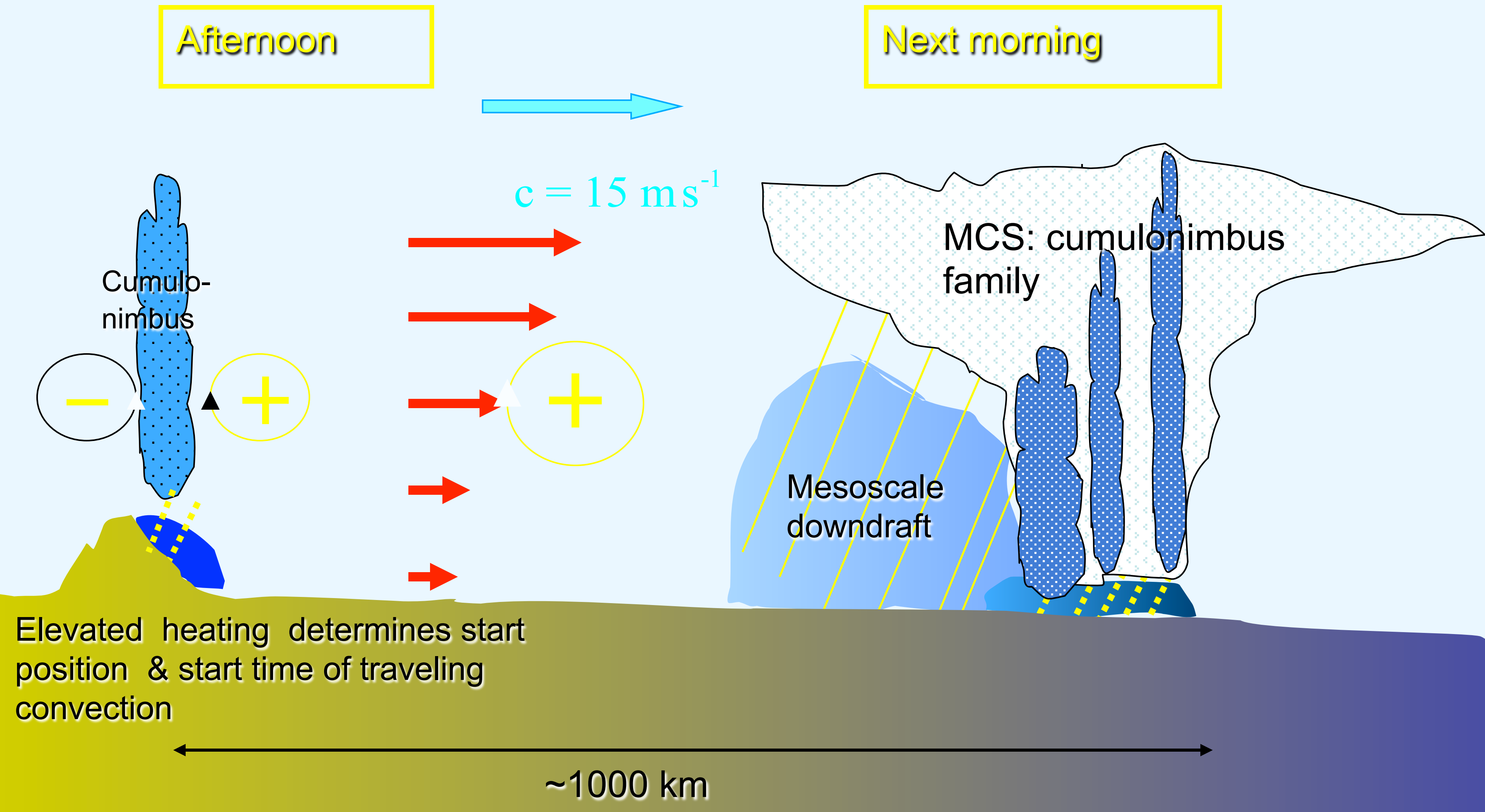


Mesoscale Convective Systems (MCS) downstream of mountains



MCS tracks: observed vs. modeled

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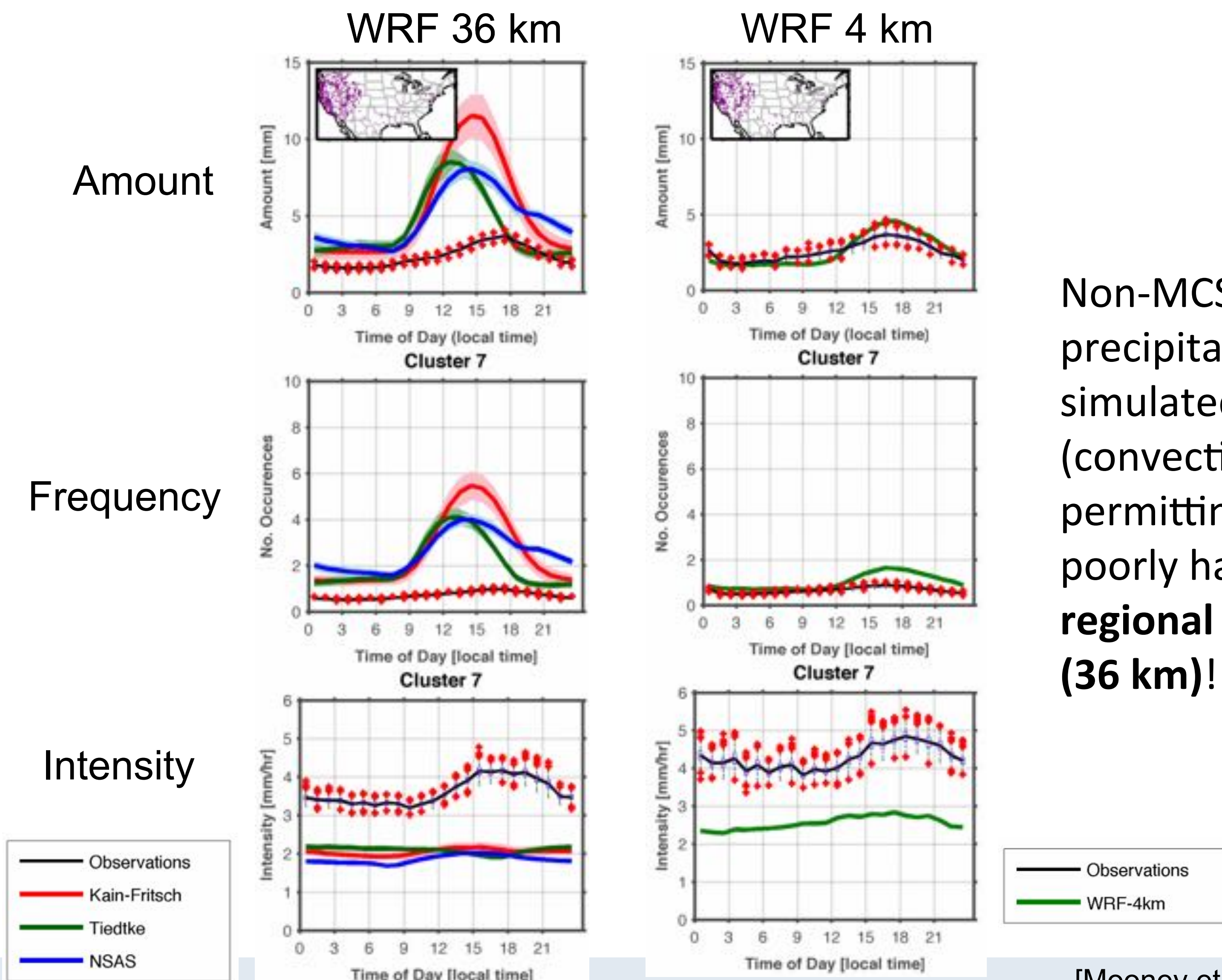
WRF - current climate

STAGE4 - observations

- All MCS tracks from 13-years (2001-2013)
- Tracks fade out after 7-days

Summertime rainfall diurnal cycle in Western U.S.

NCAR



Non-MCS precipitation well simulated at 4 km (convective permitting) but poorly handled in **regional models (36 km)**!

[Mooney et al. 2016]

CONUS-I Accomplishments

- Data have been published with DOI
  - Available via the Research Data Archive Portal (CISL)
  - 72 external researchers plus NCAR users have accessed the data since Dec. 2017.
- Publications
  - Extreme precipitation
  - Summertime Convection
  - Rain-on-snow events in Western U.S.
  - U.S. and Canadian flood events
- Expanded collaborations with international institutions and university collaborators
- Multiple sessions at Fall AGU Meetings
- Convective-Permitting Climate Modeling Workshop II in Sept. 2018 hosted by GEWEX and NCAR Water System Program.

GEWEX
Convection-Permitting Climate Modeling Workshop

Workshop Program

September 6th - 8th 2016
NCAR Foothills Lab 2
3450 Mitchell Ln, Boulder, CO 80301, USA

The **GEWEX Convection-Permitting Climate Modeling Workshop** brings together the international research community that works in the field of high-resolution climate data. The aim is to address scientific and technical challenges related to convection-permitting climate modeling (horizontal grid spacing ≤4 km). These challenges include the model setup, observational datasets, evaluation techniques, computational resources, model intercomparisons, and the use of convection-permitting simulations in impact research. The 3-day meeting's aim is to foster collaborations and synergies to work on this challenging topic as a community.

Proposed setup of WRF for western U.S. Water for Foodbaskets 50 year simulations: With and without agriculture

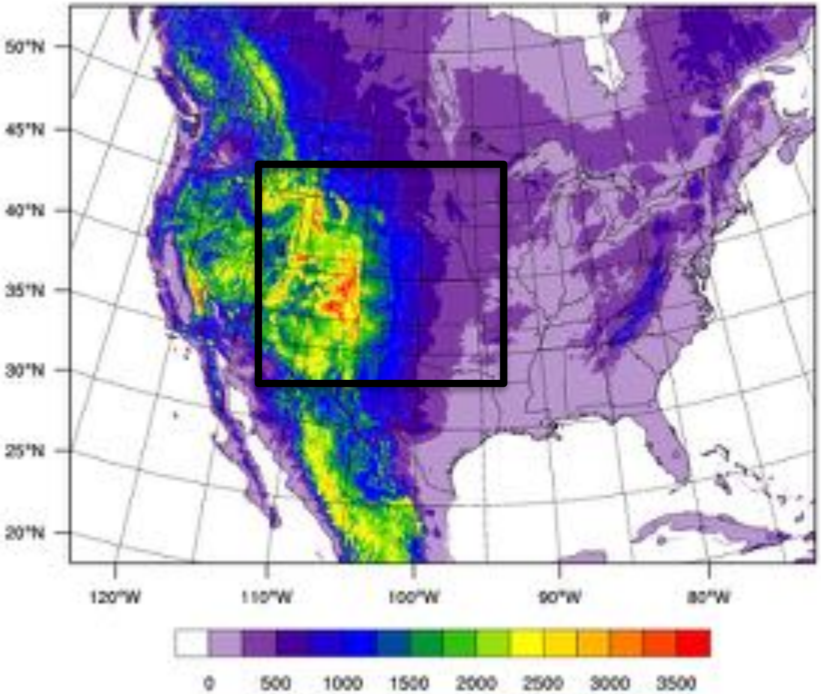
- V3.4.1 WRF model with a 4-km-spacing over domain in black outline

- Physics parameterizations:

  1. Thompson aerosol-aware microphysics
  2. Noah-MP LSM
  3. YSU PBL
  4. RRTMG radiation

- Simulation: 50 years current climate with and without agriculture (natural versus managed water cycle).

WRF Model Domain



Liu, Changhai, Kyoko Ikeda, Roy Rasmussen, Michael Barlage, A. J. Newman, A. F. Prein, F. Chen, L. Chen, Martyn Clark, Aiguo Dai, Jimy Dudhia, Trude Eidhammer, David Gochis, Ethan Gutmann, Sopan Kurkute, Yanping Li, Gregory Thompson, David Yates, 2016: Continental−scale convection−permitting modeling of the current and future climate of North America, *Climate Dynamics*, DOI 10.1007/s00382-016-3327-9.

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Thank You!

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