An Improved Climate Dynamical Downscaling at Regional Scales

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Introduction

Regional climate modeling is still a challenge due much to uncertainties in the model physics and forcing data (boundary conditions)

In this study, we attempt to improve precipitation simulations and forecasts for the western United States with an advanced regional climate model by calibrating its physics and correcting the biases in the forcing data.

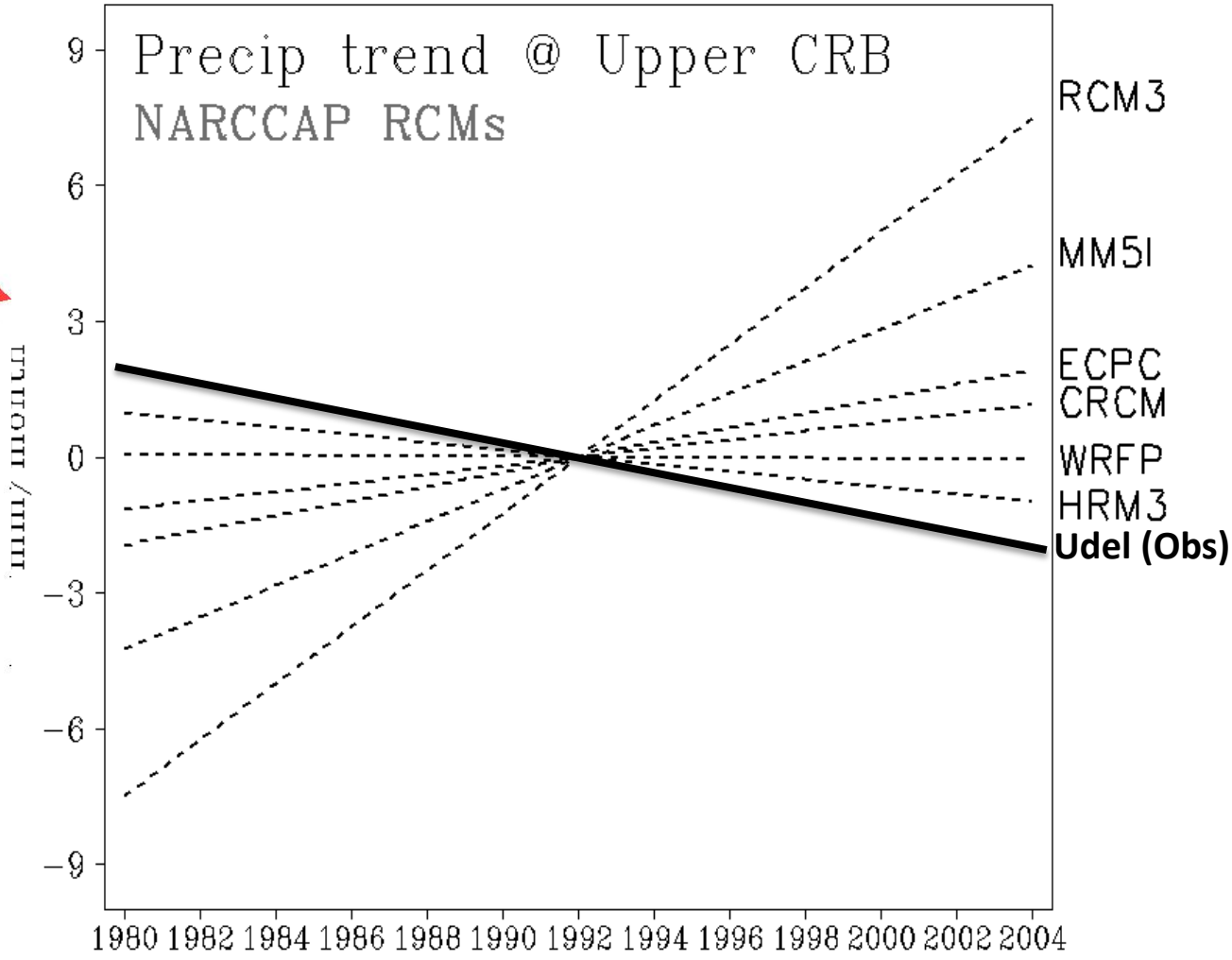
Introduction

The Regional Climate Model used in this study is the Weather Research and Forecasting model version 3.2 developed the National Center for Atmospheric Research.

Winter Precipitation Trends over the Upper Colorado River Basin

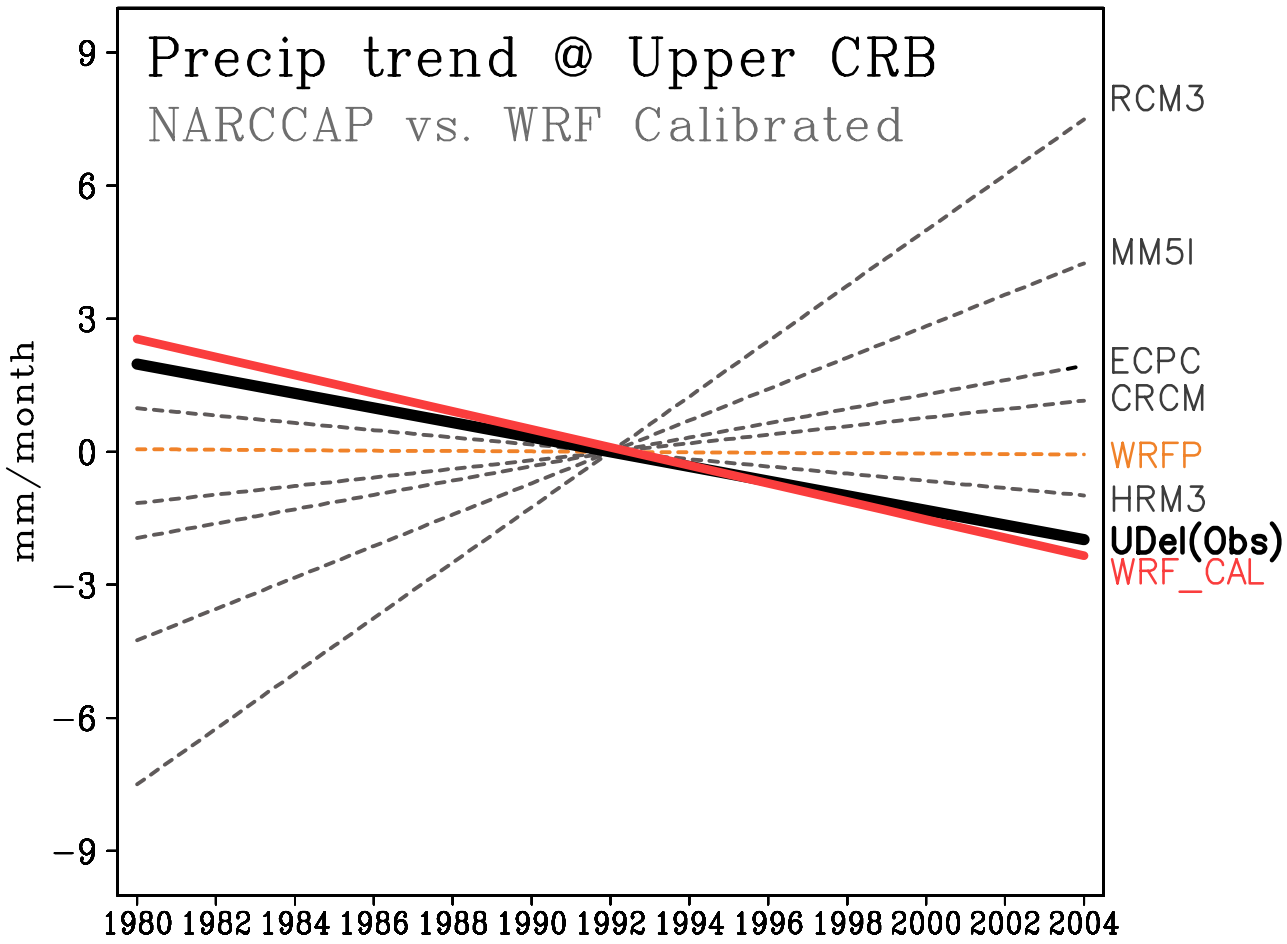
North American Regional Climate Change Assessment Program

NARCCAP Models



Winter Precipitation Trends over the Upper Colorado River Basin

NARCCAP Models versus Calibrated WRF



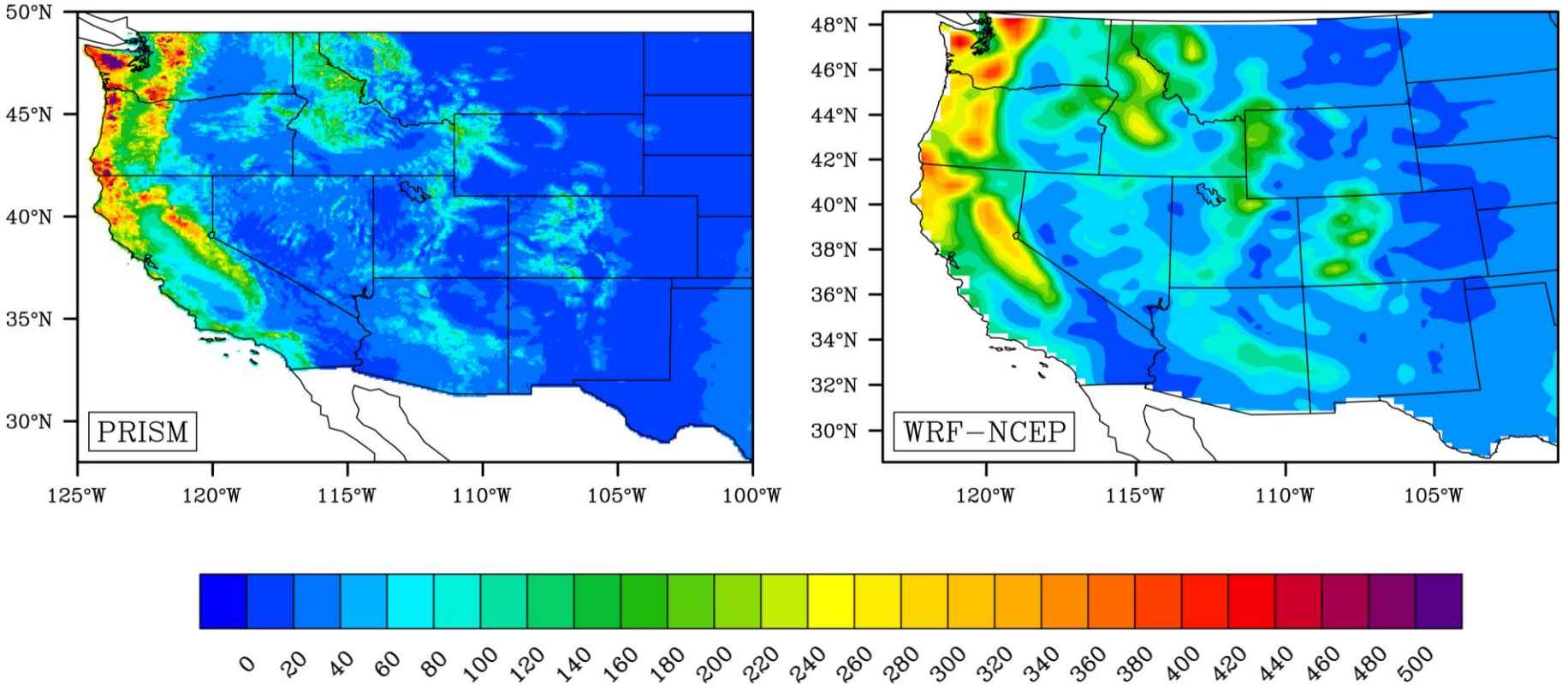
WRF Physics options

Physics Option	Scheme Used
Microphysics	Goddard
Cumulus	Grell-Devenyi
LW Radiation	CAM
SW Radiation	CAM
Planetary Boundary Layer	BouLac
Surface Physics	CLM V3.5

Precipitation (mm): DJFM 1989/90 – 1998/99

PRISM OBS (4 km)

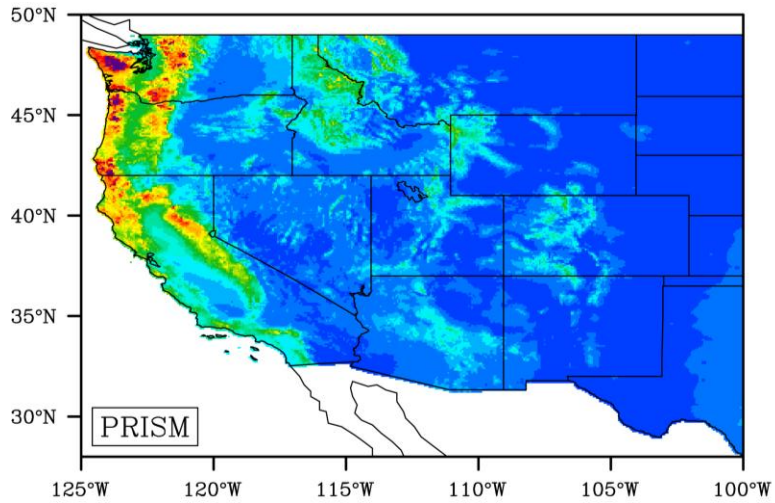
NCEP-WRF (32 km)



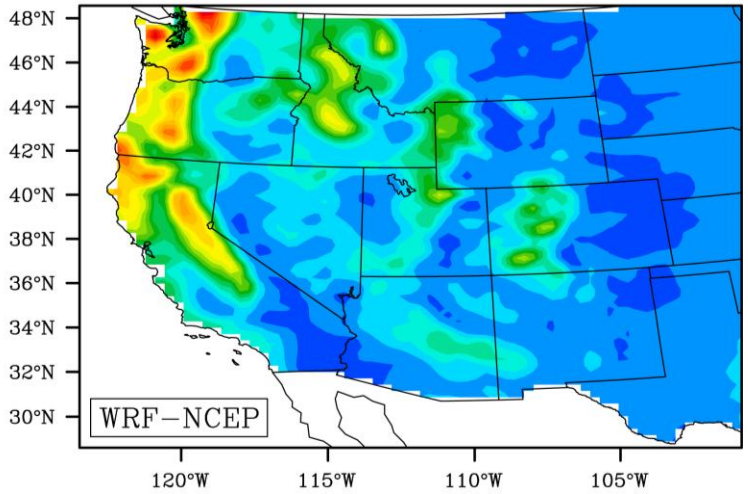
Parameter-elevation Regressions on Independent Slopes Model (PRISM)

Precipitation (mm): DJFM 1989/90 – 1998/99

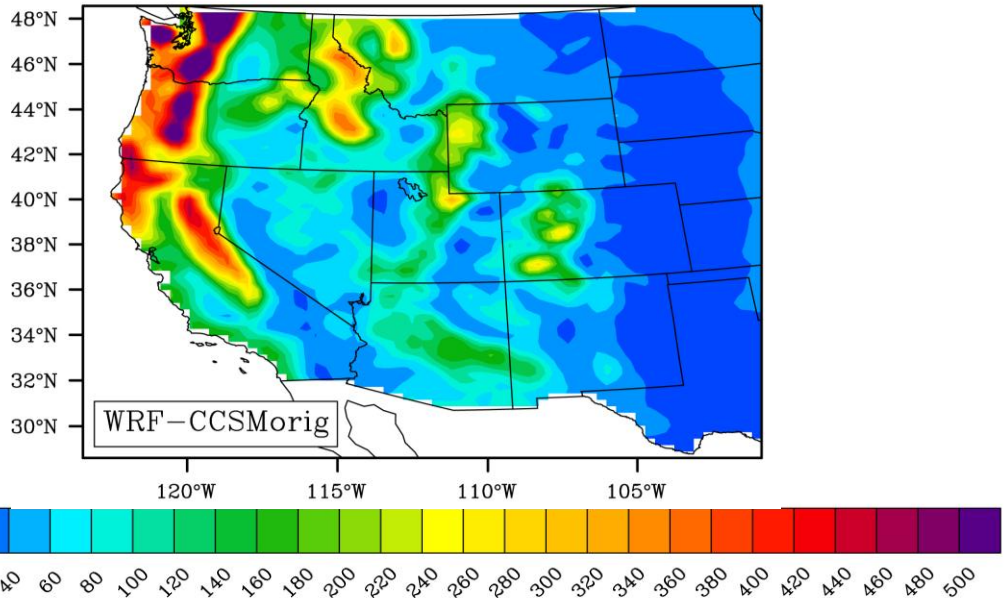
PRISM OBS (4 km)



NCEP-WRF (32 km)

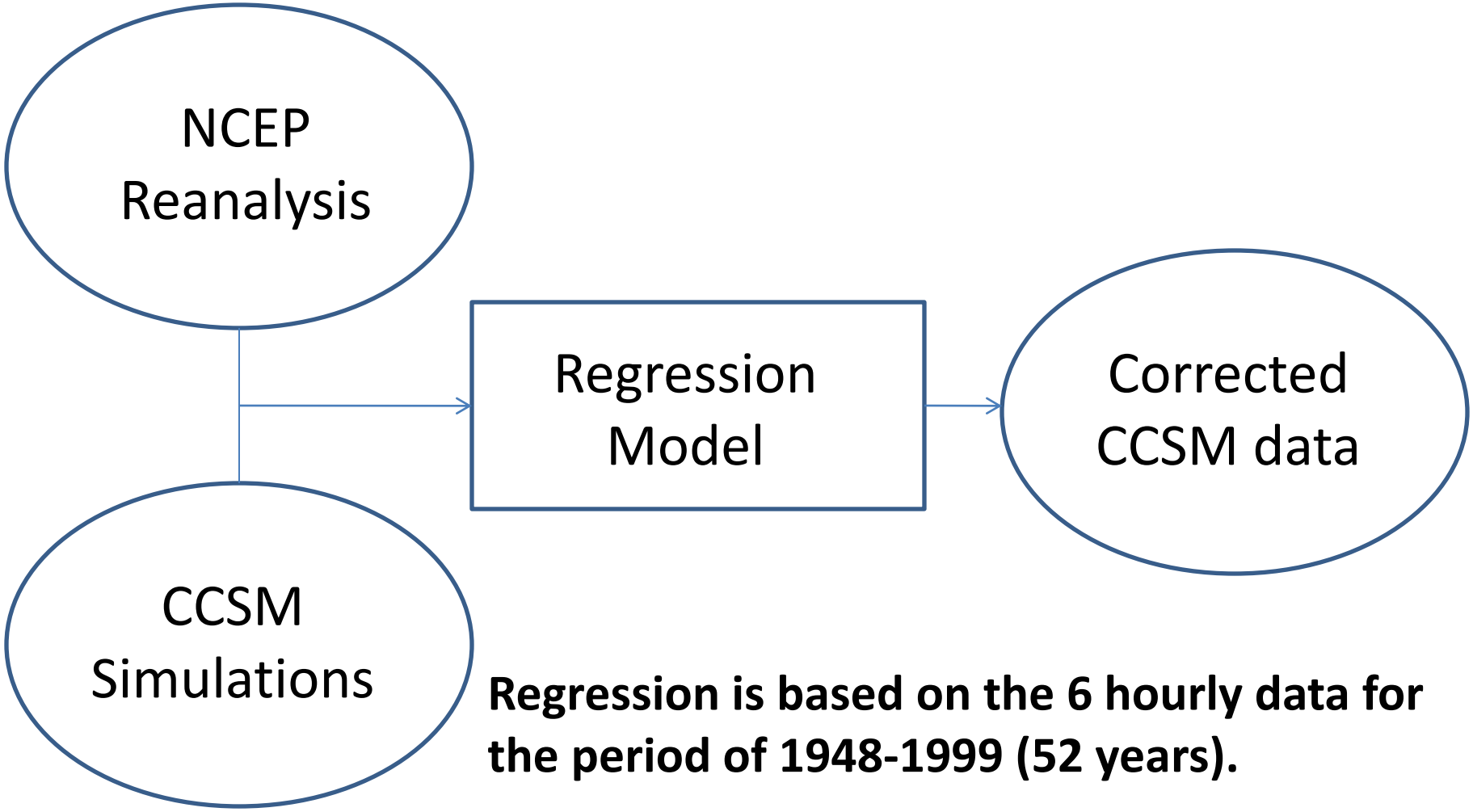


Original CCSM -WRF (32 km)



Community Climate System Model (CCSM)

CCSM Data Correction



Regression is based on the 6 hourly data for the period of 1948-1999 (52 years).

Variables Required for Running WRF

Temperature (including sea surface temperature)

Specific humidity

Geopotential height

Wind

CCSM Wind Field Correction

$$\vec{V} = \vec{V}_g + \vec{V}_a$$

$\vec{V}_g$: **Geostrophic Wind**

$\vec{V}_a$: **Ageostrophic Wind**

CCSM Wind Field Correction

$$U_g = -\frac{g}{f}\frac{\partial Z}{\partial y} \qquad V_g = \frac{g}{f}\frac{\partial Z}{\partial x}$$

***g*: the gravitational constant**

***f*: the Coriolis parameter**

Z: the geopotential height

NCEP Reanalysis Wind Field

$$\vec{V}^R = \vec{V}_g^R + \vec{V}_a^R$$

$\vec{V}^R$: the NCEP Reanalysis wind

$\vec{V}_g^R$: the NCEP Reanalysis geostrophic wind

$\vec{V}_a^R$: the NCEP Reanalysis ageostrophic wind

CCSM Wind Field Correction

$$\vec{V}_a^R = f(T^C, Q^C)$$

$\vec{V}_a^R$: the NCEP Reanalysis ageostrophic wind

T^C : the corrected CCSM temperature

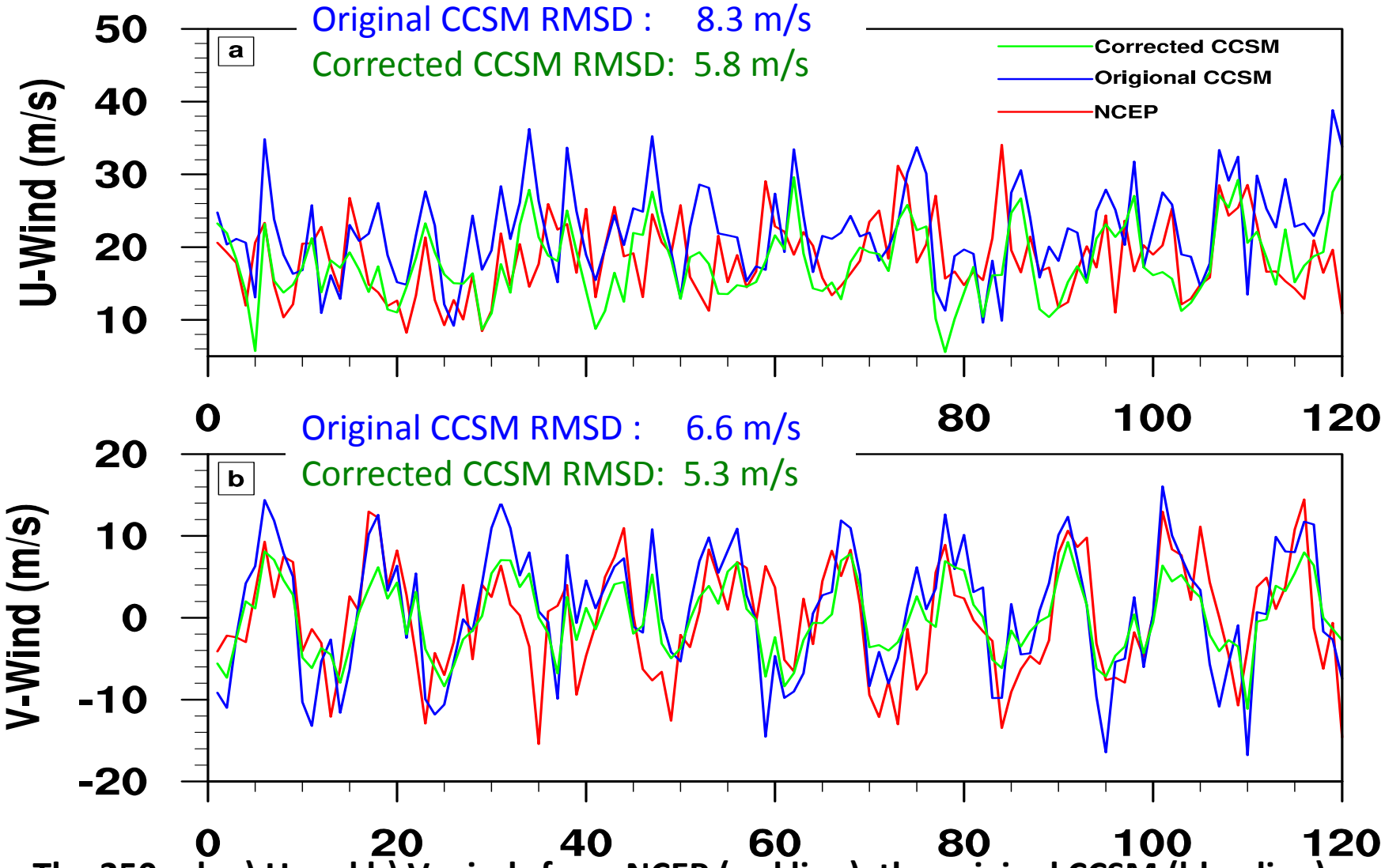
Q^C : the corrected CCSM specific humidity

CCSM Wind Field Correction

$$\vec{V}_a^C = \hat{f}(T^C, Q^C)$$

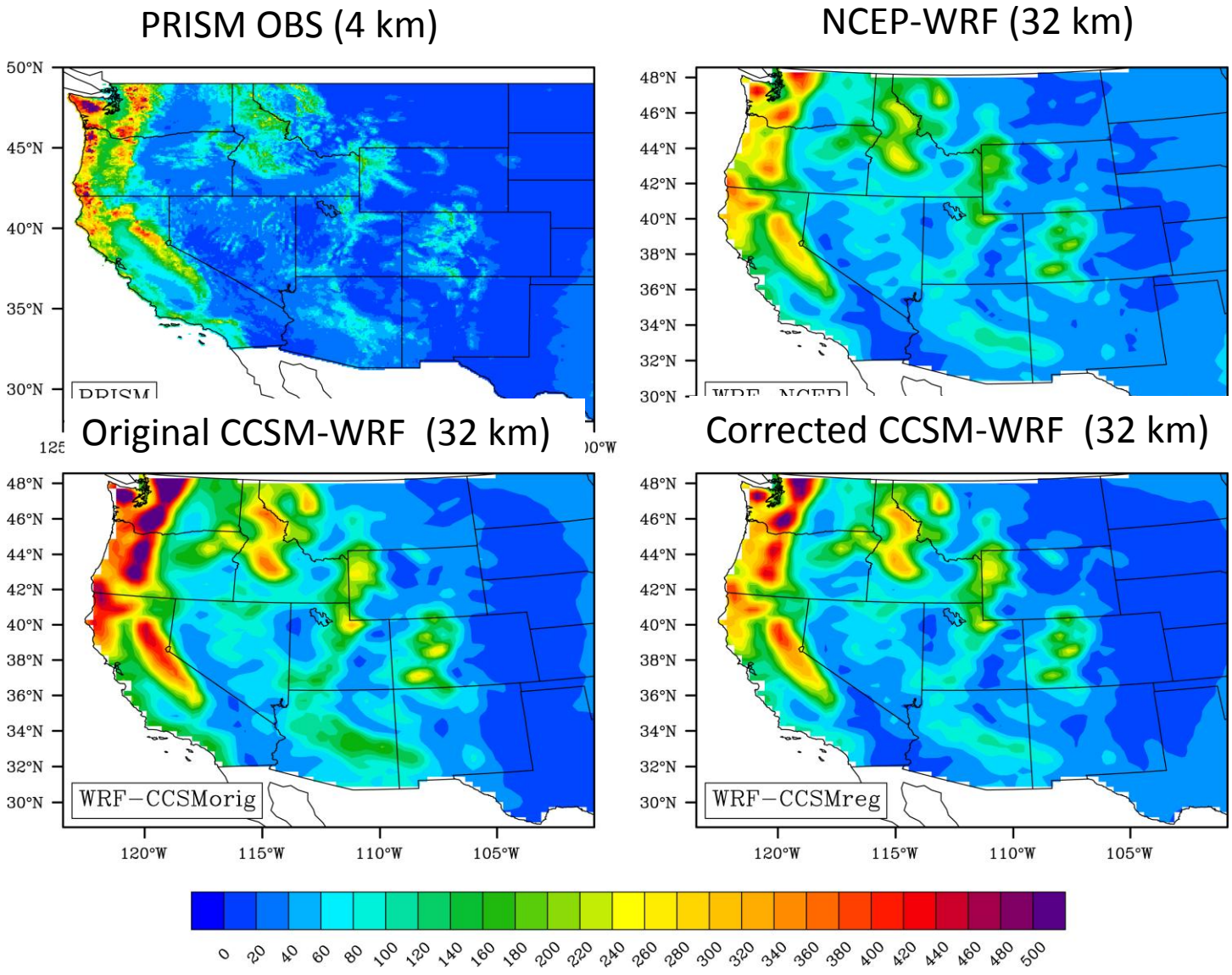
$$\vec{V}^C = \vec{V}_g^C\left(Z^C\right) + \vec{V}_a^C(T^C, Q^C)$$

CCSM Wind Correction – Root-Mean-Square Difference (RMSD)



The 250 mb a) U and b) V winds from NCEP (red line), the original CCSM (blue line), and the corrected CCSM (green line) for 1990-1999 averaged over the Utah area.

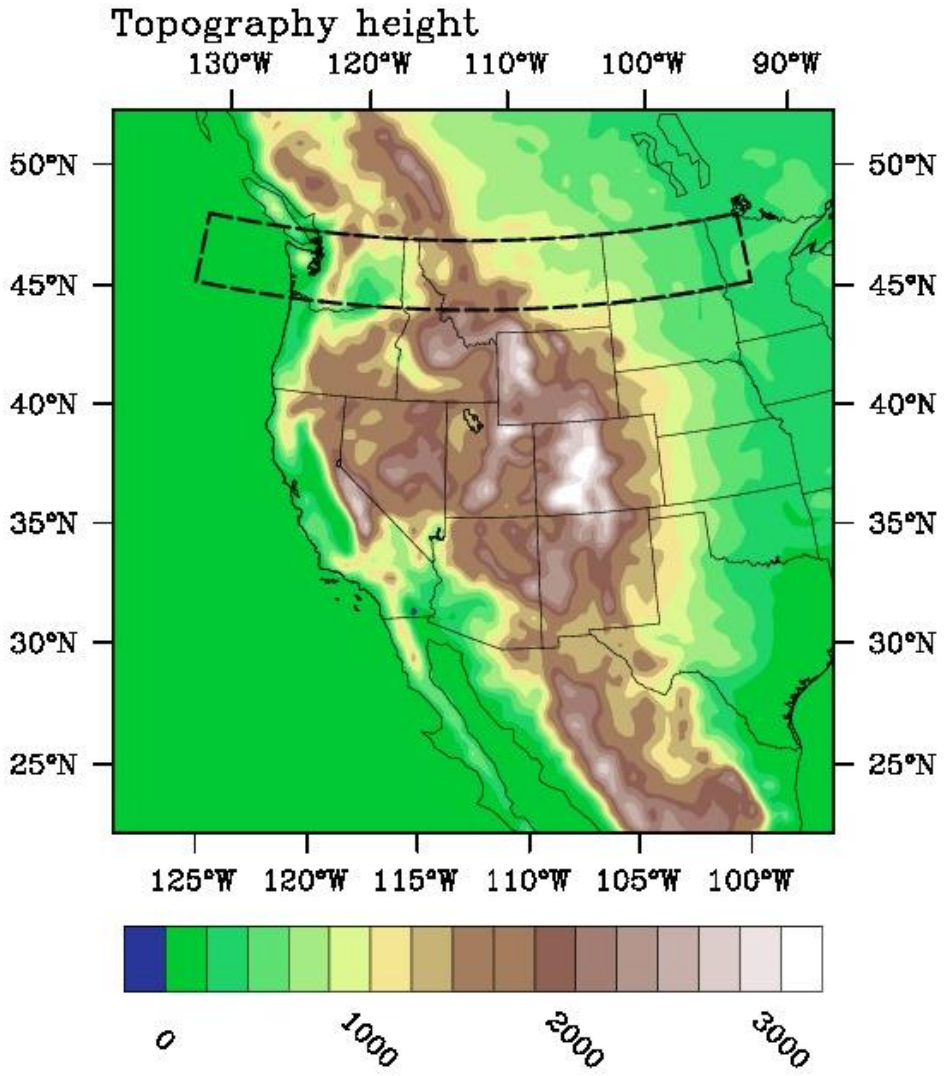
Precipitation (mm): DJFM 1989/90 – 1998/99



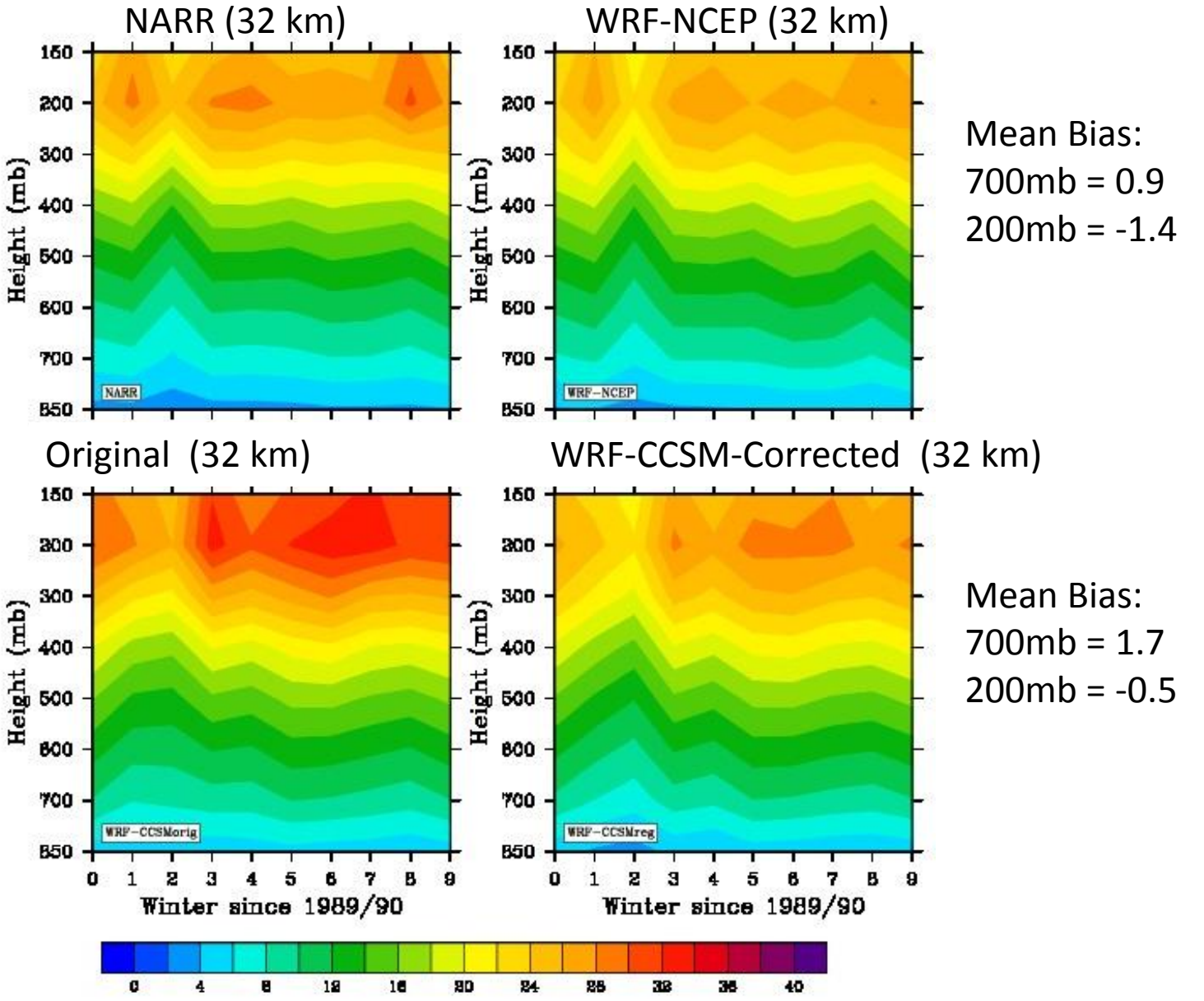
Precipitation (mm): DJFM 1989/90 – 1998/99

	NCEP-WRF	Original CCSM-WRF	Corrected CCSM -WRF
Mean bias (mm/mon) (vs. PRISM)	23	40	23
RMSE (mm/mon) (vs. PRISM)	43	71	52

Cross Section



Mean U-Component Wind (m/s) (1989-1999)

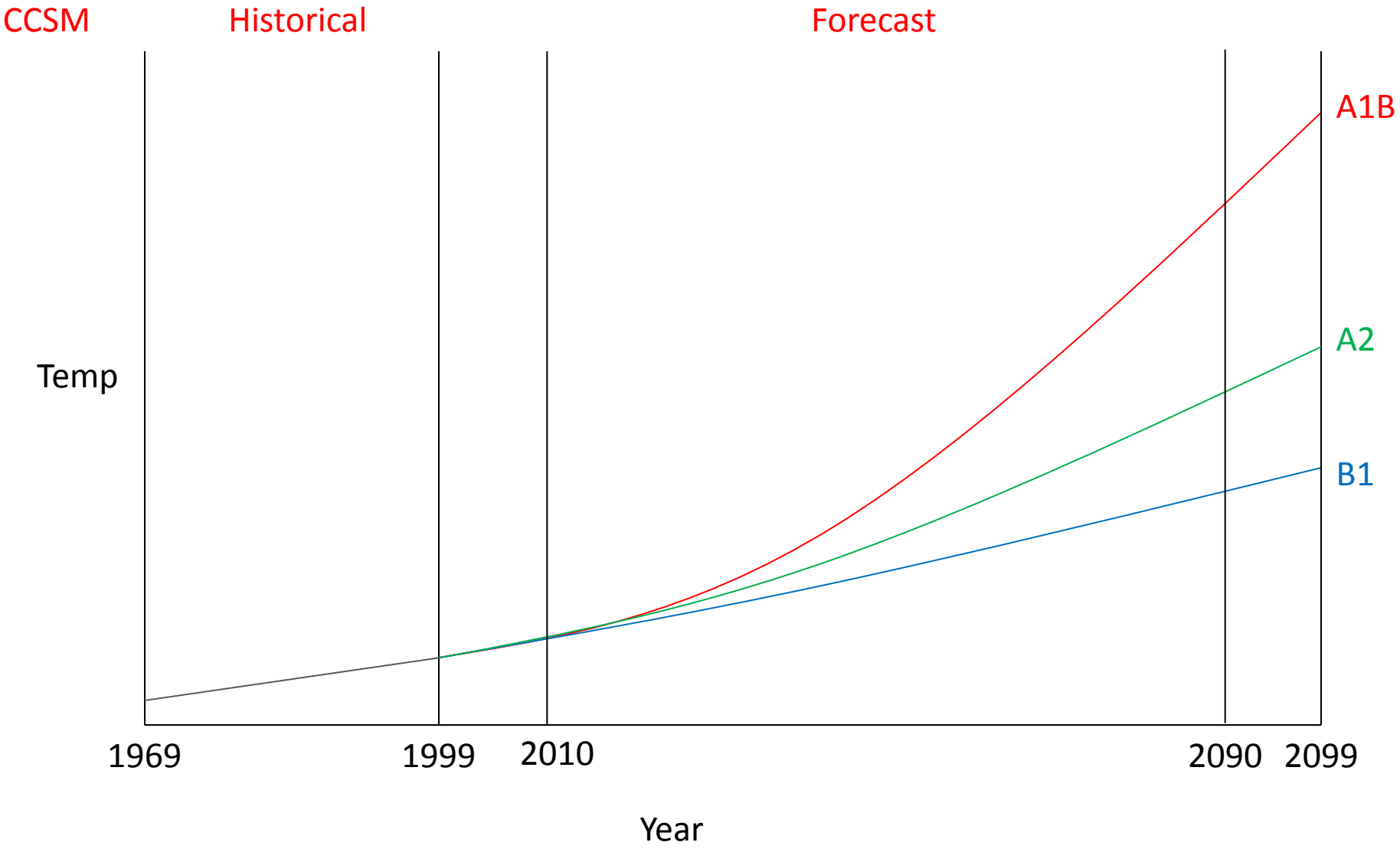


Mean Bias:
700mb = 0.9
200mb = -1.4

Mean Bias:
700mb = 1.9
200mb = 3.4

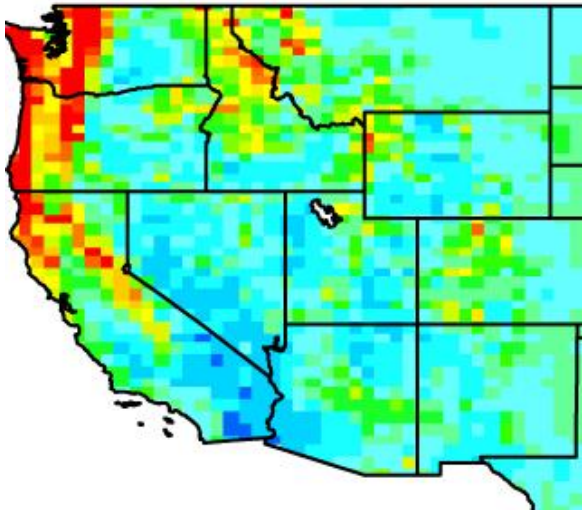
Mean Bias:
700mb = 1.7
200mb = -0.5

Carbon Emission Scenarios

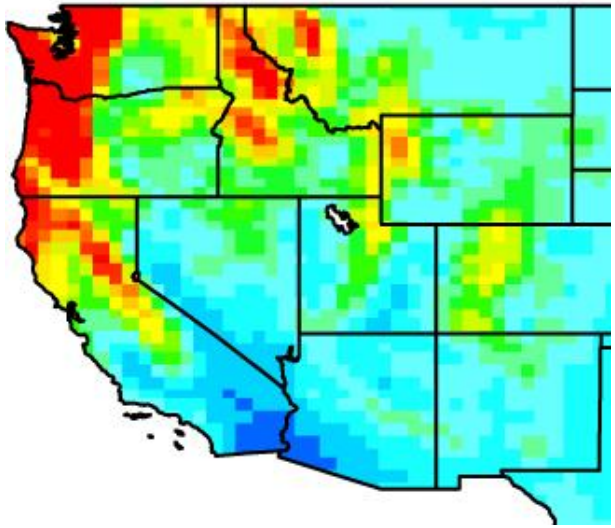


Annual Precipitation Simulations with WRF for the period of 1969-1999

PRISM (4 km)



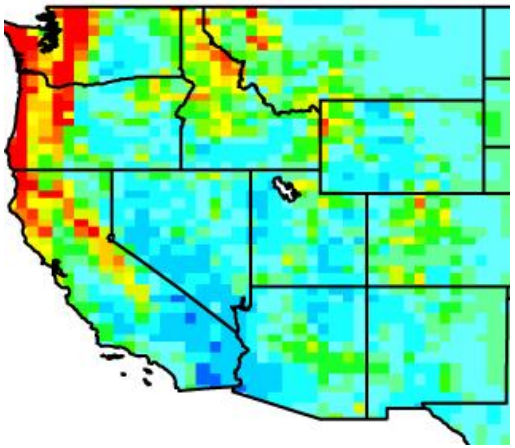
NCEP-WRF (50 km)



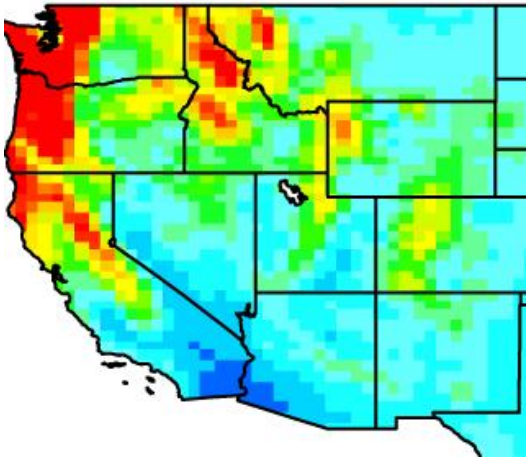
unit: mm/year

WRF Precipitation Simulations for the period of 1969-1999

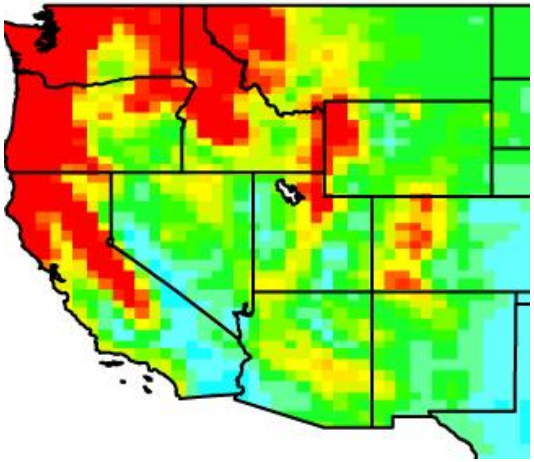
PRISM (4 km)



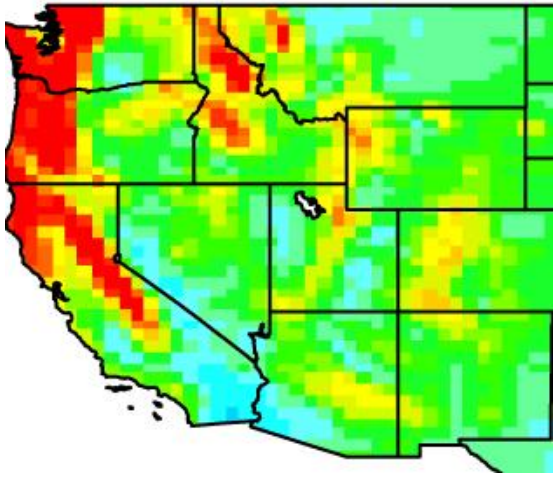
NCEP-WRF (50 km)



Original CCSM -WRF (50 km)



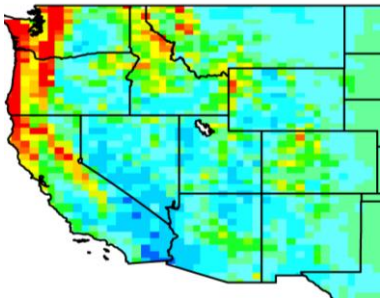
Corrected CCSM -WRF (50 km)



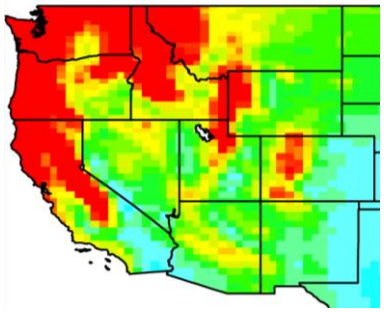
unit: mm/year

WRF Precipitation Forecasts – A2 Carbon Emission Scenario

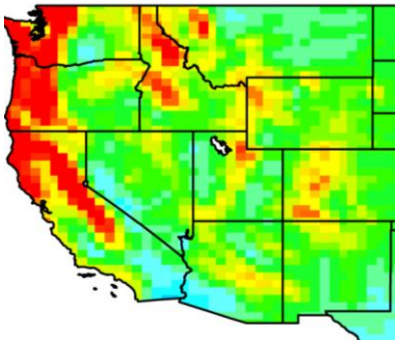
PRISM (4 km)



Original CCSM -WRF (50 km)

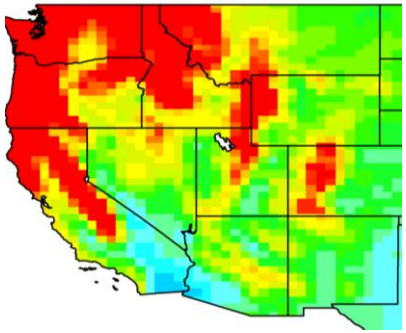


Corrected CCSM -WRF (50 km)

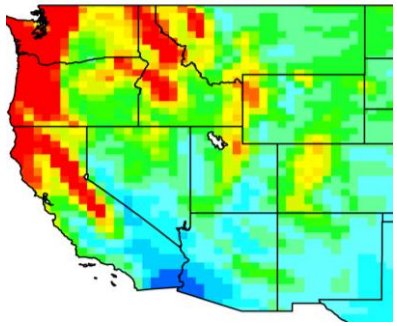


2001-2010

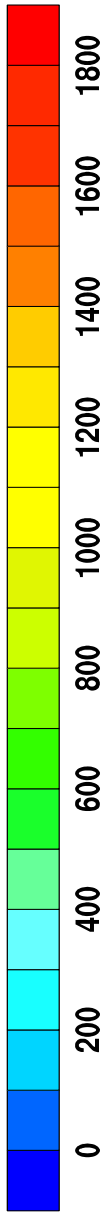
Original CCSM -WRF (50 km)



Corrected CCSM -WRF (50 km)



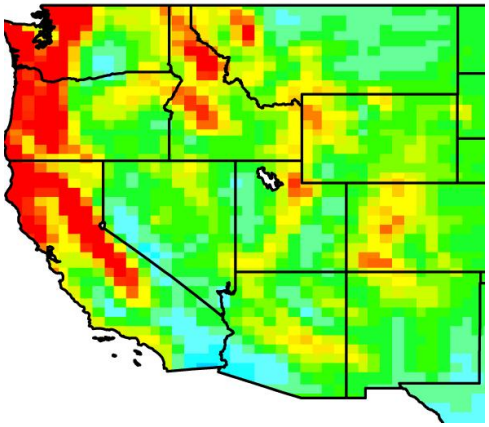
2090-2099



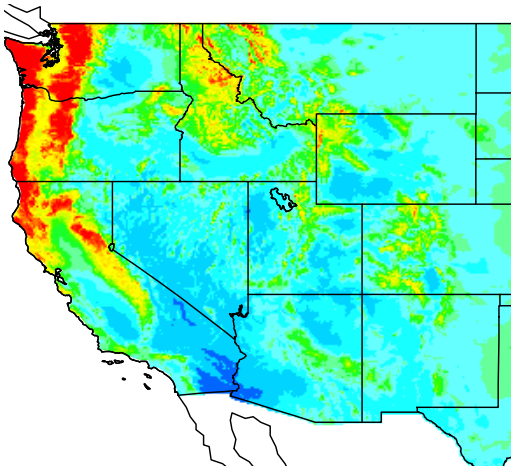
unit: mm/year

Statistical Precipitation Downscaling – 2001-2010 (A2 Emission)

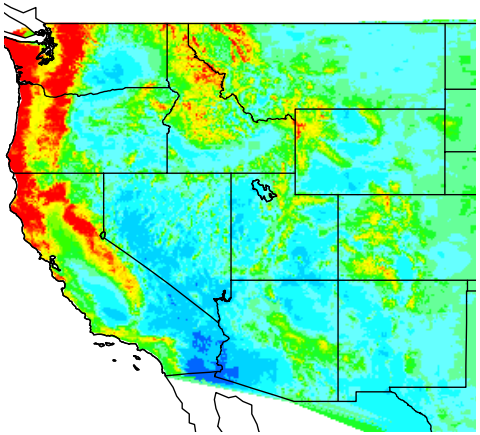
Corrected CCSM -WRF (50 km)



PRISM (4 km)



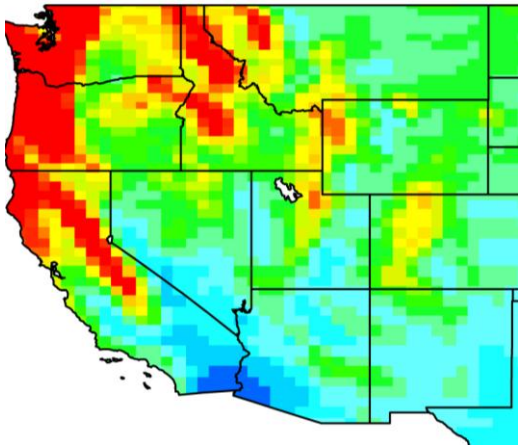
Corrected CCSM –WRF- Downscaling (4 km)



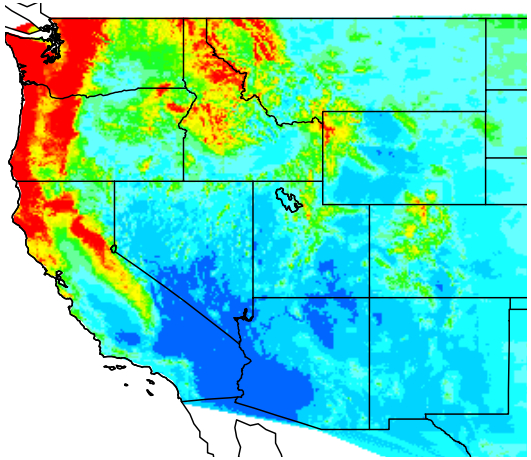
Regression was performed based on the data for the period of 1969-1999

Statistical Precipitation Downscaling – 2090-2099 (A2 emission)

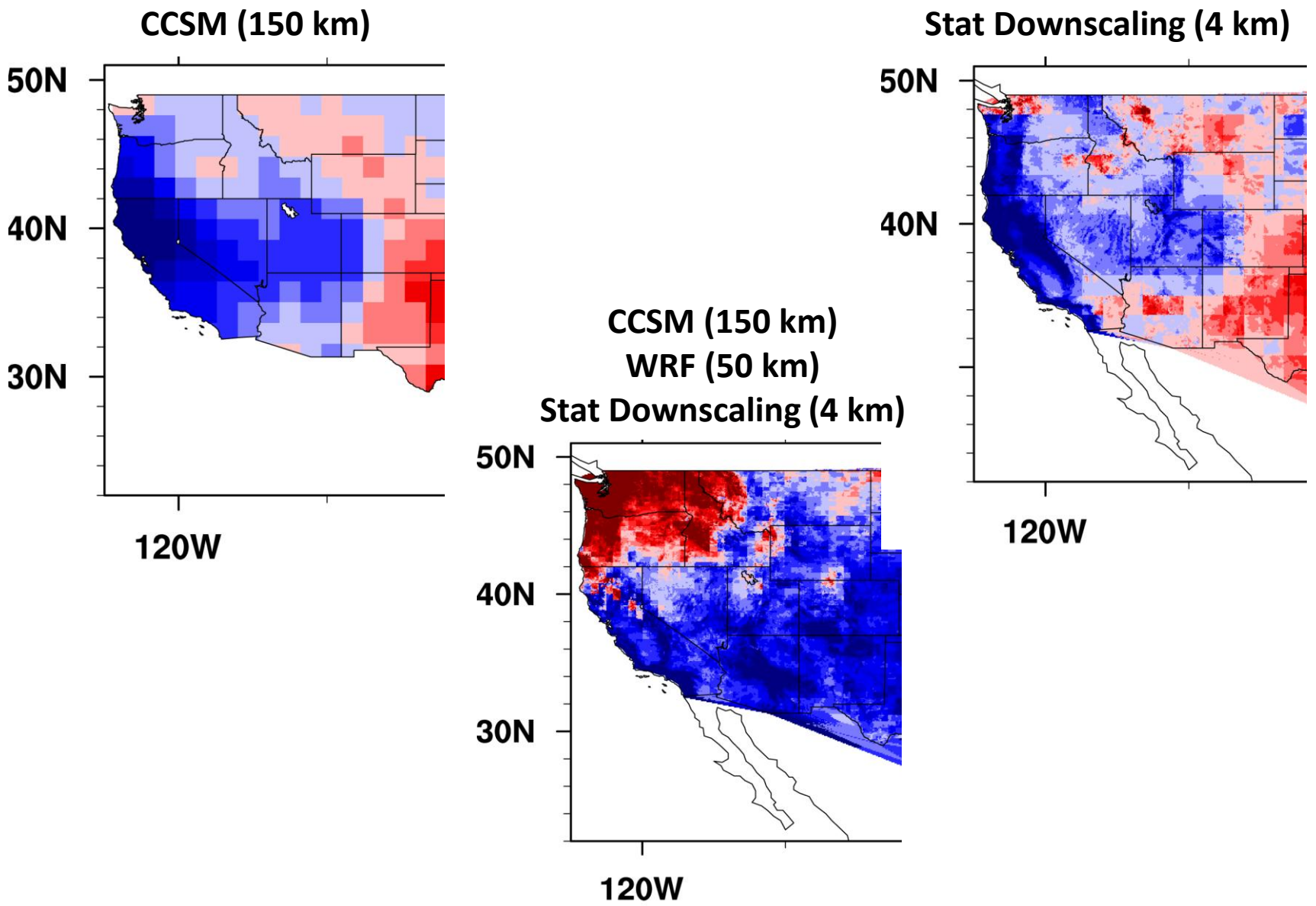
Corrected CCSM -WRF (50 km)



Corrected CCSM –WRF- Downscaling (4 km)



Precipitation Downscaling – 2090-2099 – 2001-2010 (A2 emission)



Conclusions

Through the physics calibration and forcing data bias correction for WRF, we significantly improve the precipitation simulations and forecasts for the western United States.

However, biases still exist in the WRF precipitation simulations.

These biases are further reduced through statistical downscaling with the PRISM data.