A Projection of the Impact of Climate Change on California's Major Watersheds during the mid-21st Century Period

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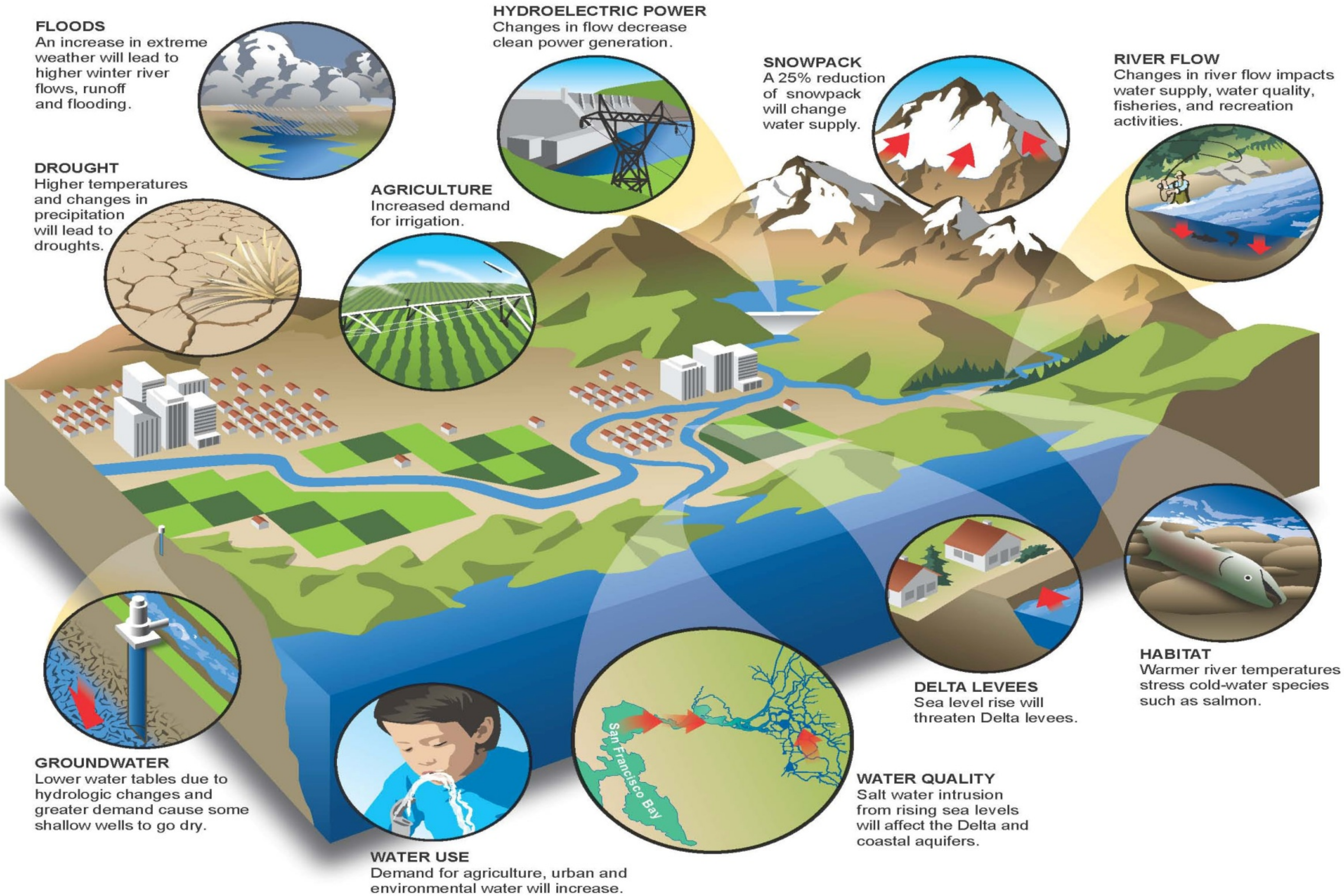
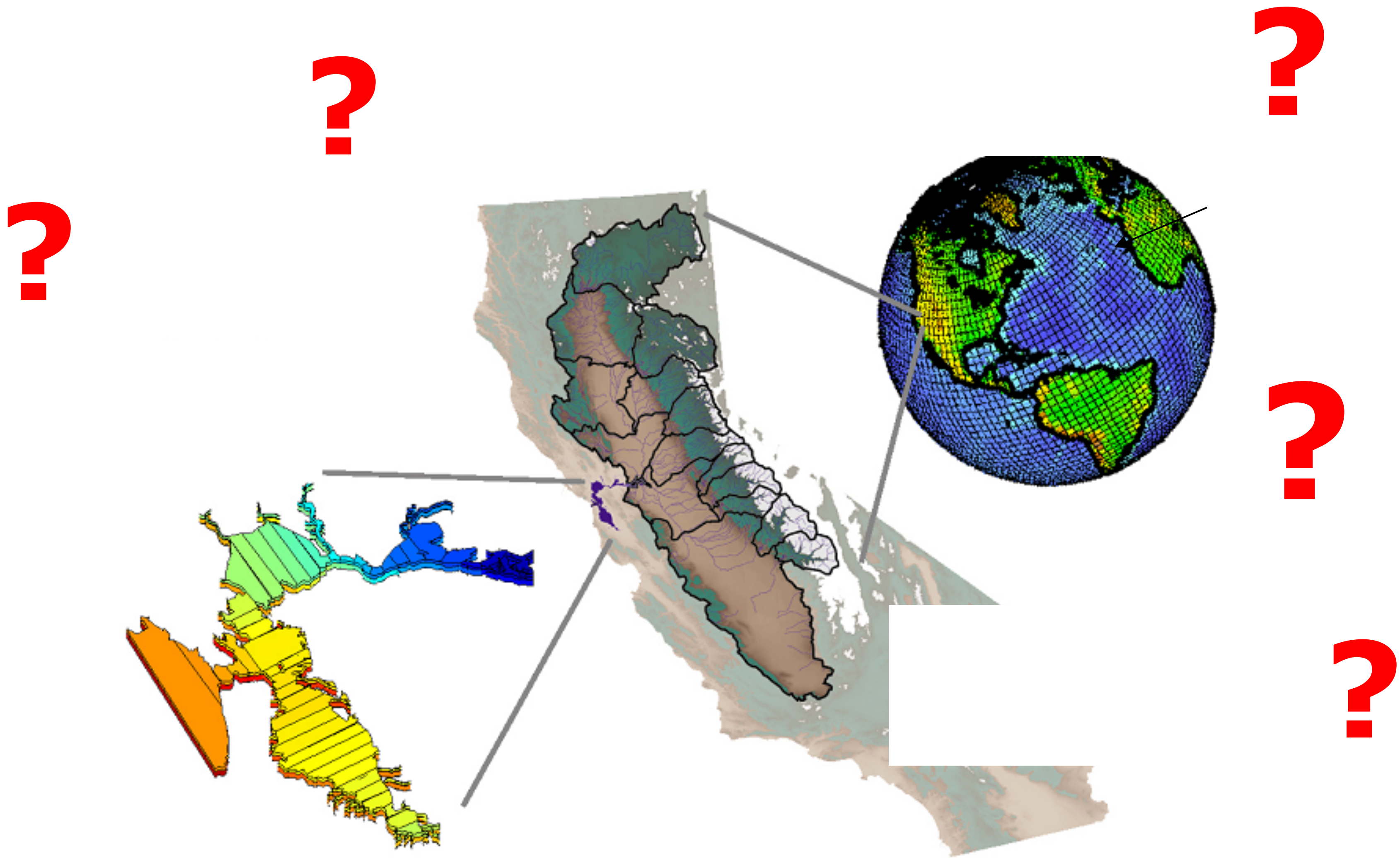
How climate change impacts a watershed



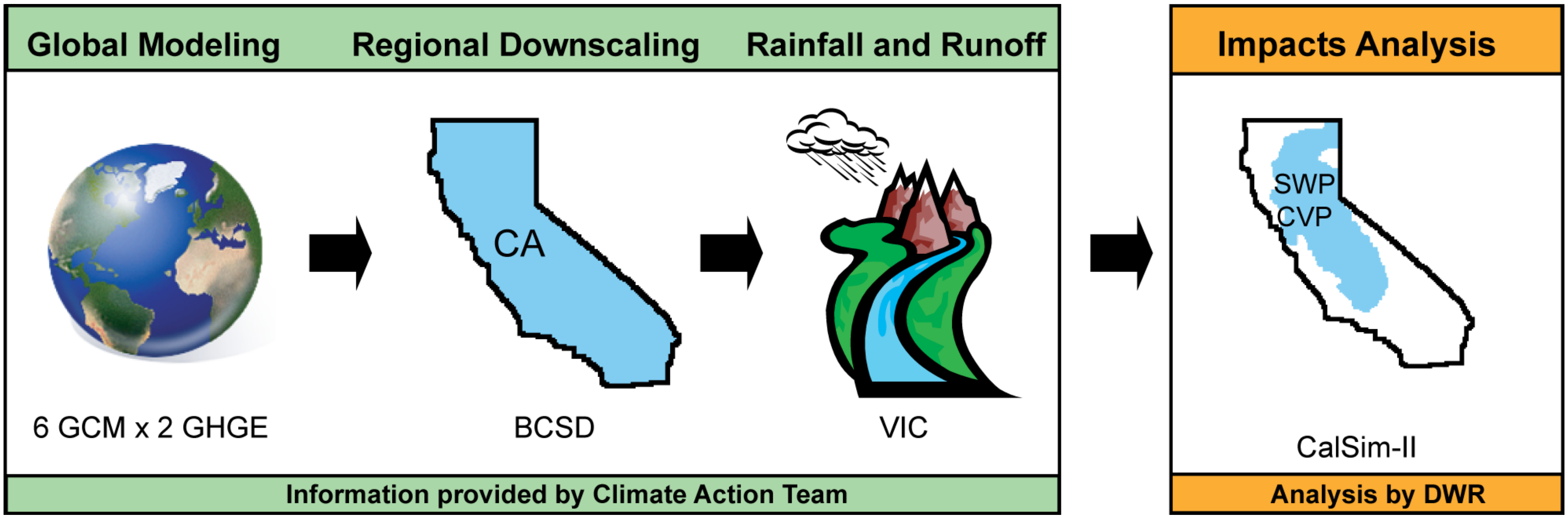

Sacramento-
San Joaquin
Delta
Redding
Sacramento
San
Francisco
Fresno
Los
Angeles
San
Diego
Major Rivers
State Projects
Federal Projects
Local Projects

We've got Issues!



Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

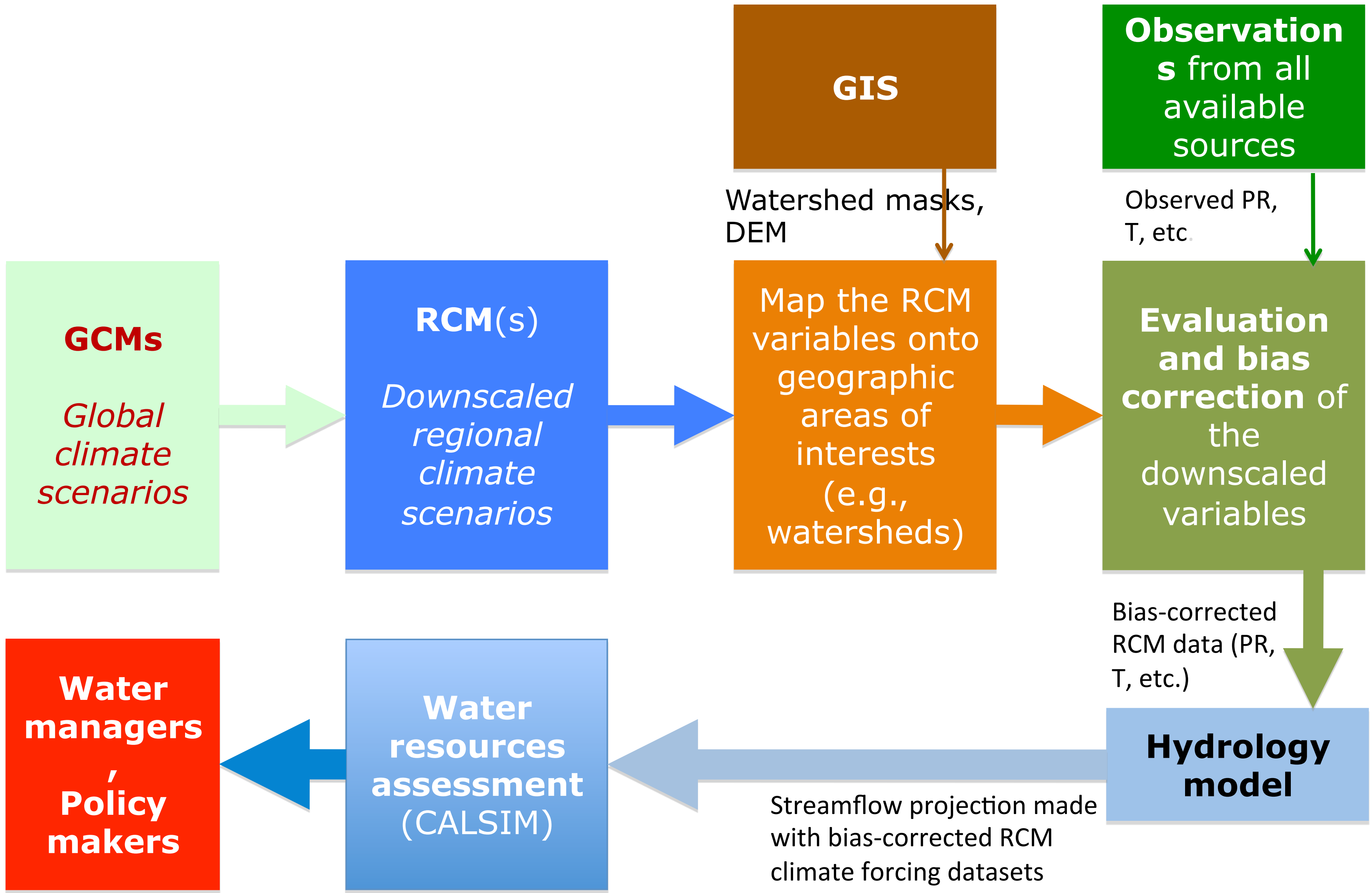
SWP-CVP Impact Assessment Methodology



- Delta exports
- Carryover storage
- Groundwater pumping
- Power Supply
- X2 location
- Vulnerability to System Interruption

BCSD= Bias Corrected Spatial Downscaling VIC= Variable Infiltration Capacity Model
SWP= State Water Project CVP=Central Valley Project DWR= Dept. of Water Resou

A schematic illustration of regional climate projection and water resources assessment



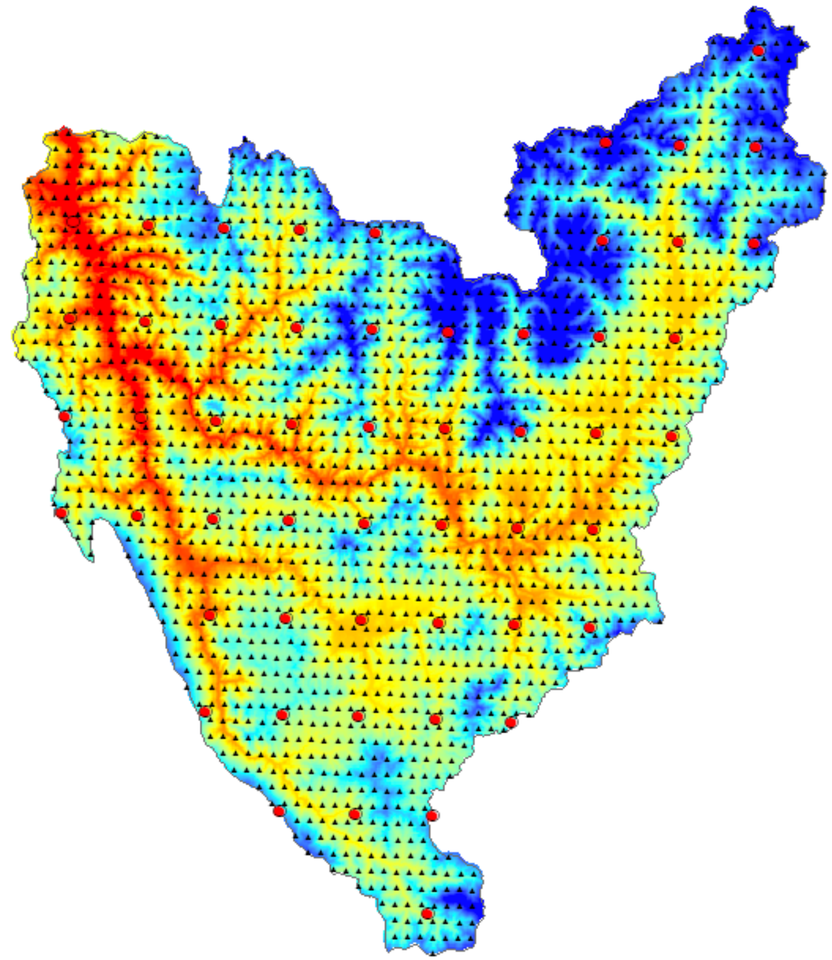
Slide from Jinwon Kim, UCL

Downscaling: *Dynamical vs. Statistical method*

1. Background
    - regional orography is important in California
    - *O*[10km] resolutions are typically needed to properly resolve the terrain effects
2. Statistical methods
    - Economical in terms of computational resources
    - *Validity of the statistical relationships derived from the past climate data in future climate is not established*
    - No mechanisms exist to preserve dynamical/physical consistency among downscaled variables *– Can be a problem in using assessment models that require multiple variables and the consistency among the downscaled variables*
3. Dynamical downscaling
    - Dynamical/physical consistency among downscaled variables are generally maintained – *Can be used to drive assessment models that involves multiple variables and consistency between the downscaled variables*
    - RCMs are largely *invariant to a wide range of climate regimes*
    - *Computationally demanding* in CPU cycles, storages, and data traffic
    - The method is *susceptible to errors in model formulation*
    - Thorough evaluation of climate models (and their results) is necessary

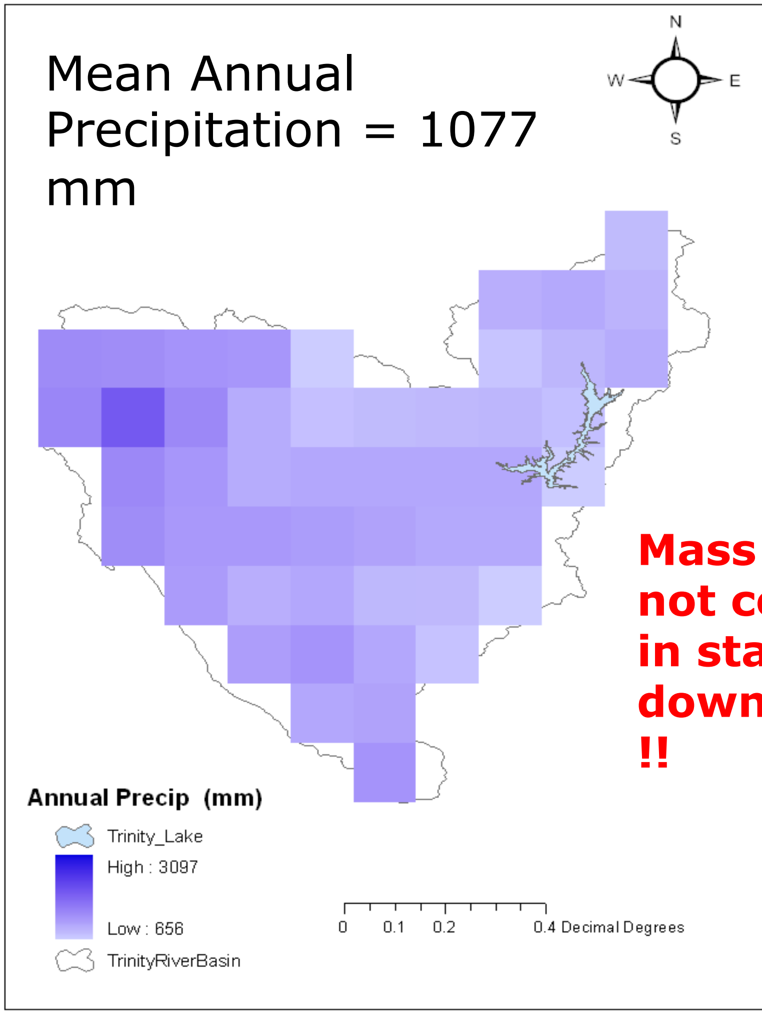
Experiments on Trinity Basin

- Currently available downscaled climate model products are too coarse for California: 1/8°
  - Develop higher resolution of downscaled product: 2km, based on PRISM data



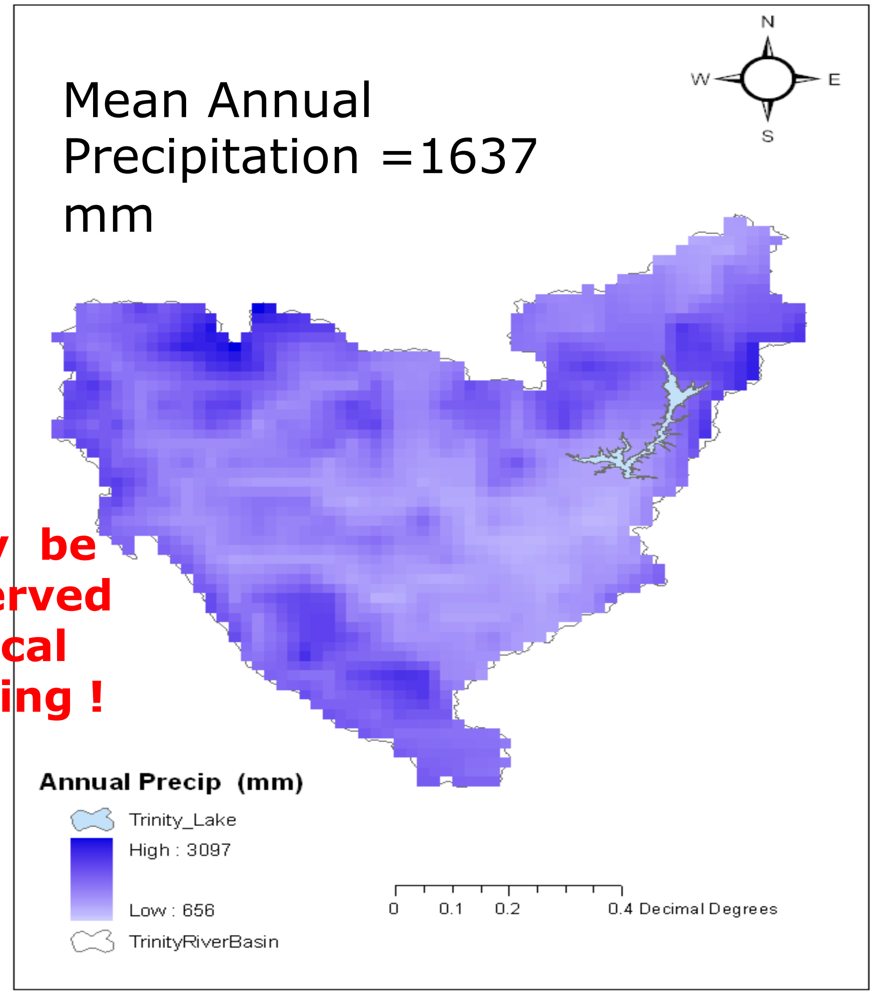
Topography map (shaded) and one-eighth degree grid points used in the Maurer's 1/8° BCSD downscaling scheme (large red points) and PRISM 2km grid points used in the DWR's BCSD scheme (smaller black points) in the Trinity River basin.

Comparison Between 1/8° and 2km Downscaled (BCSD) Product



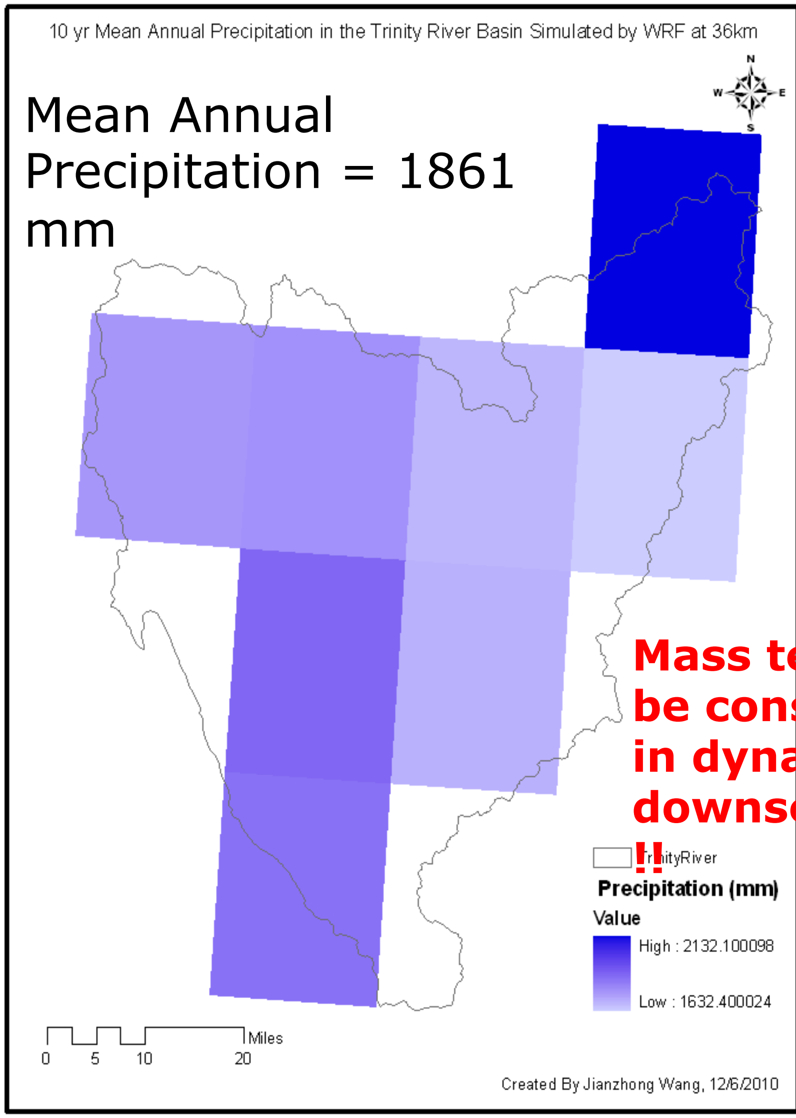
Downscaled annual precipitation projection in 2099 at the one-eighth degree grid resolution by Maurer (2009)

Mass may be not conserved in statistical downscaling ! !!



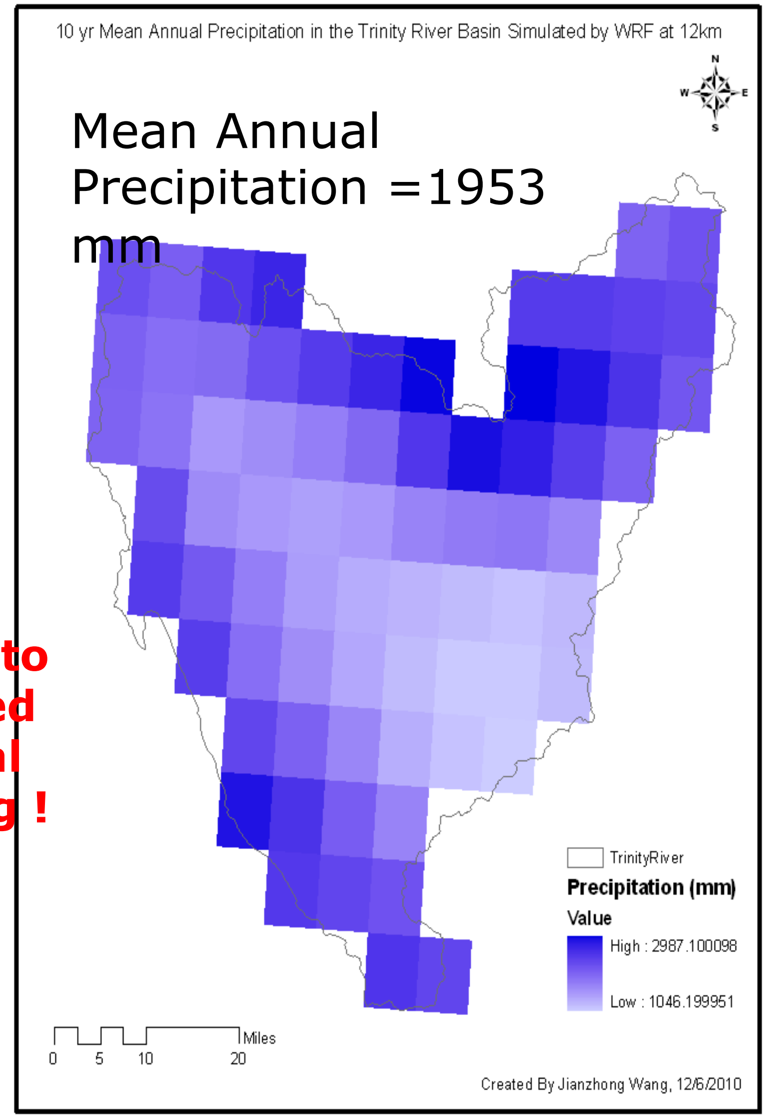
Downscaled annual precipitation projection in 2099 at 2 km grid resolution.

Comparison Between 36km and 12km Dynamically Downscaled Product



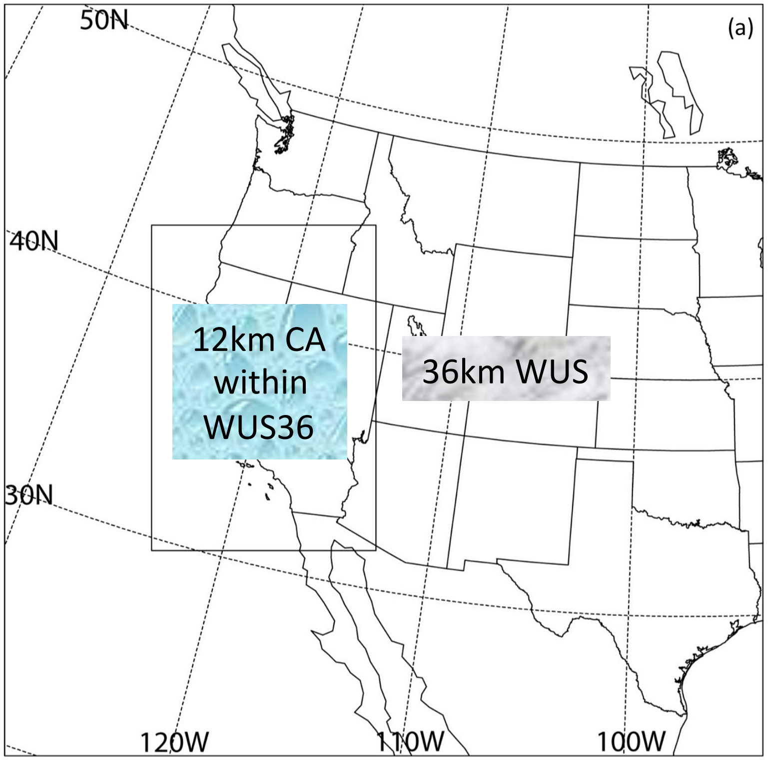
10 yr Mean Annual Precipitation Simulated By WRF at 36km

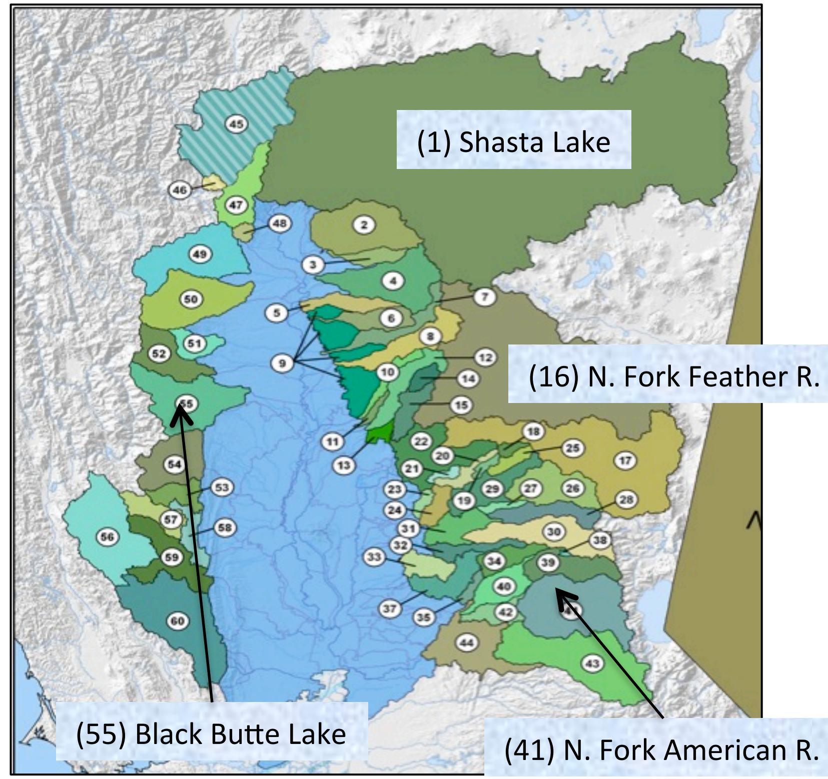
Mass tends to be conserved in dynamical downscaling !!!



10 yr Mean Annual Precipitation Simulated By WRF at 12km

Regional Modeling and the CA Watersheds





- The WRF version 3.0.1 has been used for a one-way nested WUS-CA domain
- The global climate scenario from *NCAR CCSM3* based on the *SRES-A1B emissions* is used to drive the RCM
- The mid-21st century climate change signals are calculated as the differences between the means over the two 10-year periods, 1990-1999 & 2040-2049.

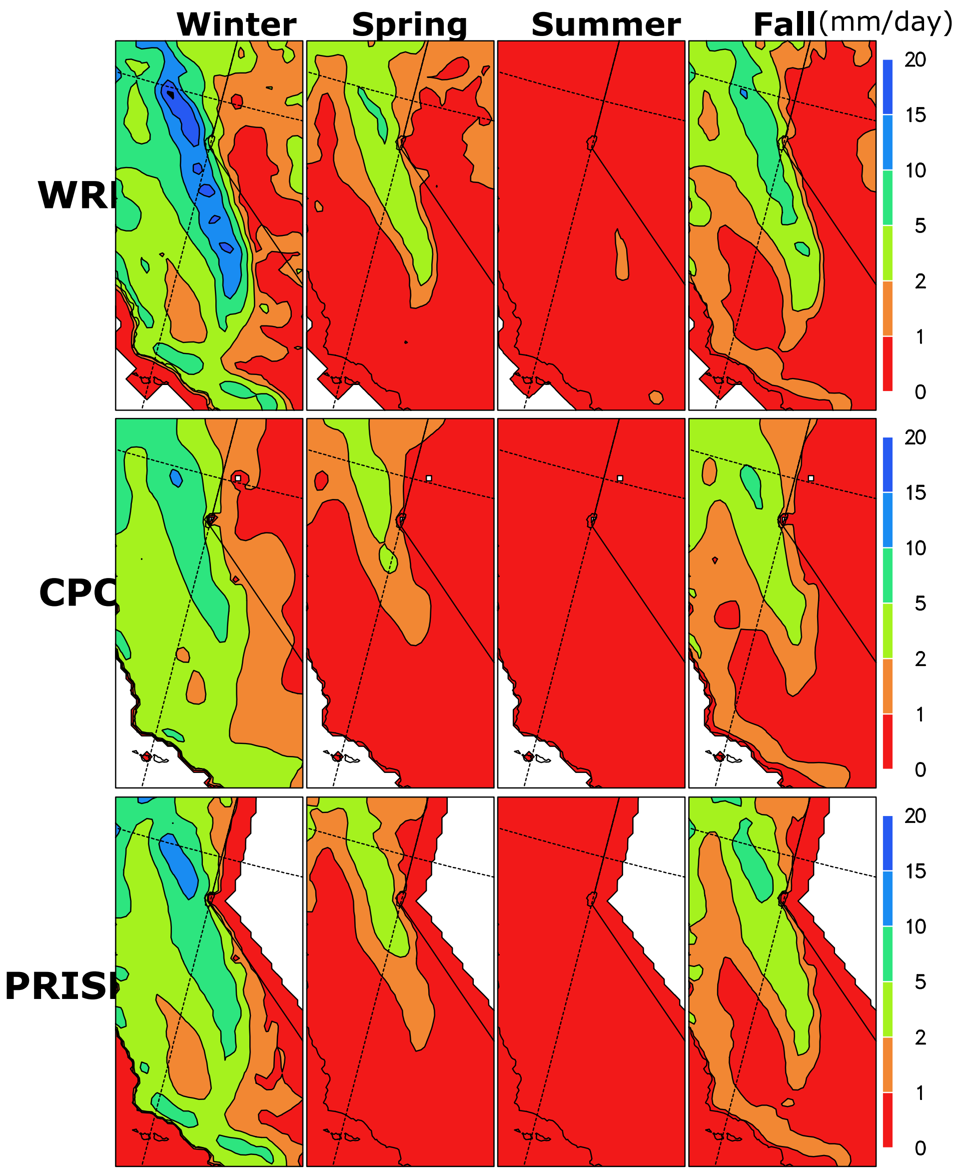
Four watersheds of varying hydroclimate features are selected for presentation

- *Shasta Lake inflow*: A northern watershed fed by westerly as well as southerly inflows
- *N. Fork Feather R*: A low-elevation northern Sierra Nevada watershed
- *N. Fork American R*: A high elevation Sierra Nevada watershed
- *Black Butte Lake inflow*: A low-elevation watersheds in the downwind side of the northern Coastal Range

Evaluation of the Precipitation Climatology in the Hindcast

•The *NCEP-CPC* and *PRISM* analysis are used to evaluate the hindcast precipitation

•The evaluation is performed over the area covered by the PRISM analysis



- Orographic effects on the general geographical variations in precipitation, *largest in the high elevation Sierra Nevada watersheds* (*NF American*) and smallest in the *eastern Coast Range* (*Black Butte*)/ *northern central valley* (*Shasta*), are well represented in the hindcast.
- The hindcast noticeably overestimated precipitation in the winter season.
- The precipitation bias in winter may result from model errors and uncertainties in the gauge data due to undercatch problem (Yang et al. 1999)

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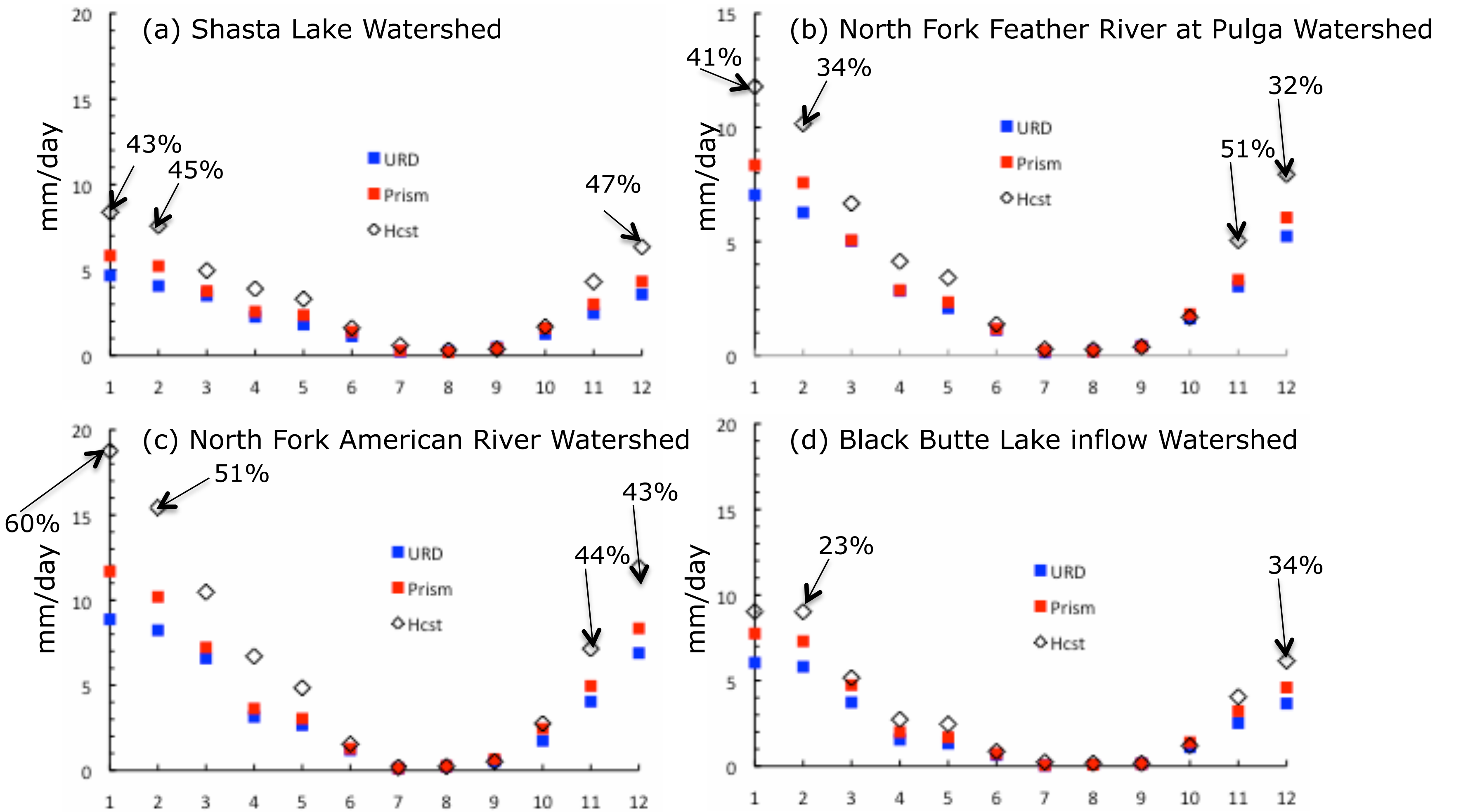
Evaluation of the Hindcast: Watershed-mean precipitation climatology

To measure *the absolute RCM skill*, a 10-year (1991-2000) hindcast is performed using the NCEP REAN 1

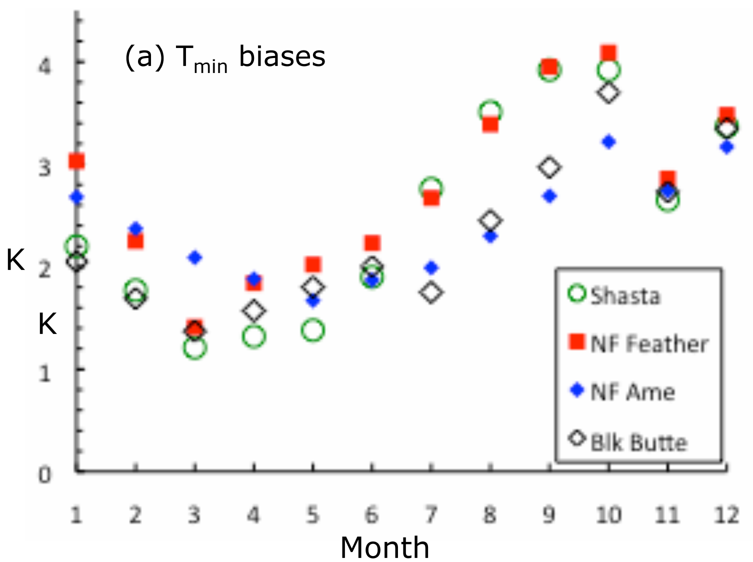


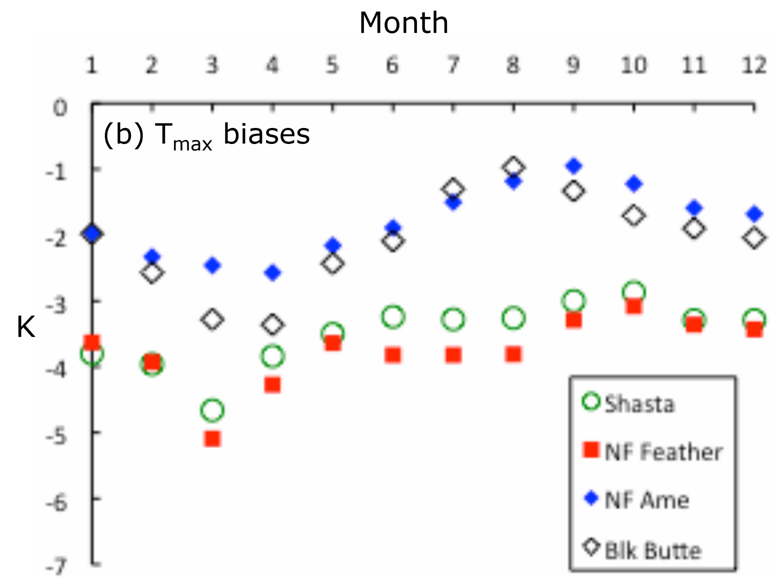
The model has generally overestimated precipitation represented in the PRISM analysis

Precipitation error is largest in high elevation watersheds during the wettest season (DJF).

The general geographical variations in precipitation, *largest in the high elevation Sierra Nevada watersheds* (*NF American*) and smallest in the *eastern Coast Range* (*Black Butte*)/*northern central valley* (*Shasta*), are well represented in the hindcast.

Hindcast Evaluation: Biases in watershed-mean T_{min} and T_{max} climatology





The hindcast has generally *overestimated the daily minimum temperatures* and *underestimated the daily maximum temperatures* in all watersheds.

The overestimation of the daily minimum temperatures are smallest in spring (Mar-Apr-May) and largest in fall (Sep-Oct-Nov).

The underestimation of daily maximum temperatures are smallest in late summer and fall (Aug-Sep-Oct) and largest in spring (Mar-Apr).

The timing of the minimum and maximum errors in the daily maximum and minimum temperatures are largely consistent in all four watersheds.

Unlike the precipitation errors, the dependence of the temperature errors on elevation is not clear.

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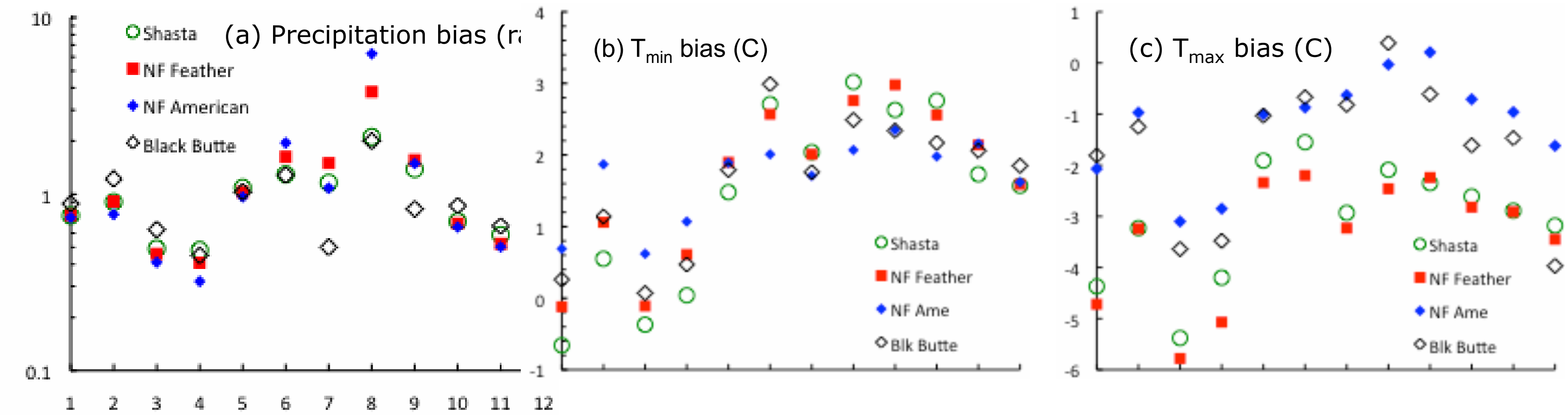
The Biases in the Control Climate

- The climate change signals are calculated as the difference between the 10-year means for the control (1990-1999) and mid-21st century (2040-2049) runs.
- The biases in downscaled climate change signals result from the combined effects of the errors in GCM and RCM.
- Exact attribution of the biases to the GCM and RCM errors are generally un-achievable.
- The combined GCM-RCM biases are examined by comparing the present-day climate against corresponding PRISM data

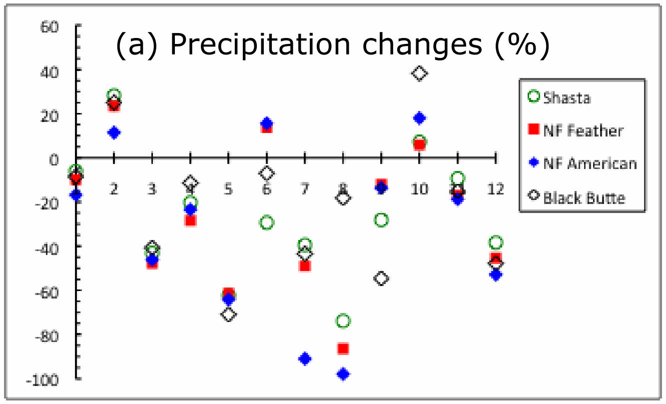
Biases in Precipitation and Temperature in the Control Run

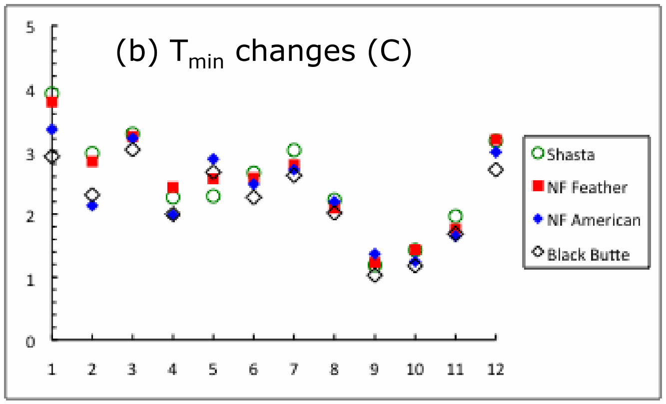
- The bias correction factors are calculated from the control run and PRISM
  - **PRECIP**: *The ratio* between the control run and the PRISM data (PR_{PRISM}/PR_{CNTL}).
  - **TEMP**: *The differences* between the control run and the PRISM data ($T_{CNTL}-T_{PRISM}$).

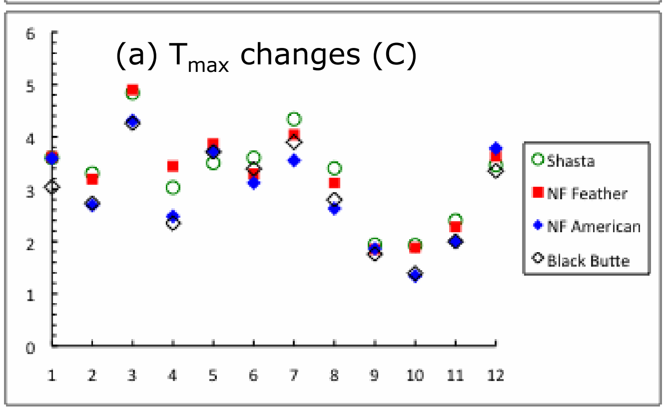


- The control run generally overestimates the cold season precipitation
  - The notable overestimations in all watersheds for March and April suggests that these biases are mainly driven by the errors in the GCM field
  - The underestimation of summer precipitation is practically insignificant
- The daily min/max temperatures are over-/underestimated
  - Overestimation of T_{min} is most serious during the warm/dry season
  - Underestimation of T_{max} is most serious during the cold/wet season
  - The daily mean temperatures agree well with the PRISM data

Climate Change Signals







- The climate change signals are calculated from the control and the mid-21st century runs as:
- **PRECIP**: *Percentage of the control*: [Signal$_P$=(P_{mid-21}-P_{CNTL})/P_{CNTL}]
- **TEMPERATURE**: *Differences*: [Signal$_T$ = T_{mid-21} – T_{CNTL}]
- Additional bias correction is not necessary for the climate change signals defined in this way if we assume:
  - *Precipitation errors behave as percentages of the control climate*
  - *Temperature errors are additive*

- The projected climate change signals imply:
  - Wet-season (Oct-Mar) precipitation to *decrease by 10-50%* except for Feb (increase by 10-30%).
  - The large decrease in summer precipitation is not likely to affect water resources in California.
  - The daily minimum and maximum temperatures will increase by 1-4C, with larger increases in T_{max}.
  - Smallest increases in both T_{min} and T_{max} in late summer-early fall (Sept-Nov) are projected.
  - Larger temperature increases during the cold season, especially in spring, suggests that snow-albedo feedback plays an important role in determining the temperature change signals.

Conclusion

- The impact of anthropogenic climate change on the hydroclimate in California's major watersheds has been projected using a nested modeling using the global climate scenario from NCAR-CCSM3 on the basis of the SRES-A1B emissions
- RCM biases have been examined in a 10-year hindcast
  - Precipitation is overestimated in major northern California watersheds
  - Daily maximum/minimum temperatures are over-/underestimated.
  - The bias in the daily mean temperature is small.
- Biases in the today's climate scenario are examined using the URD and PRISM
  - The present-day climate run overestimates cold season precipitation
  - The daily minimum and maximum temperatures are over- and underestimated in all four watersheds similarly as in the hindcast.
- The regional climate change signals projected in this study:
  - 10-50% decrease in the cold season monthly precipitation except in February
  - Increases of 1-4C in the daily minimum and maximum temperatures, with larger increases in the daily maximum temperatures
  - Largest and smallest warming in spring and fall, respectively.
- Next step
  - Sensitivity of streamflow calculations to the bias corrections in precipitation and temperatures
  - Utilize the climate data for streamflow and water resources assessments.