

# RECLAMATION

*Managing Water in the West*

## Introduction of West-Wide Climate Risk Assessment

February 2, 2012, Fountain Valley, CA

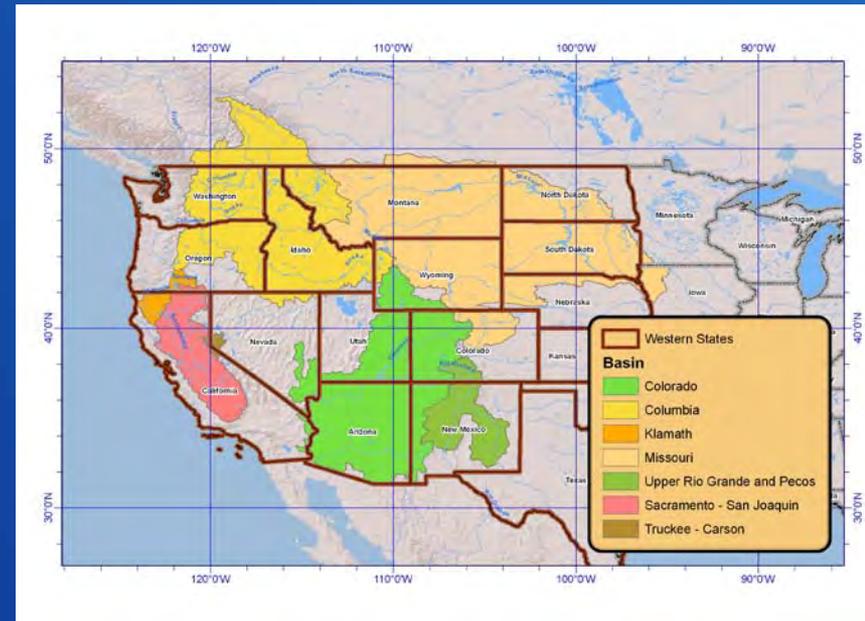
Water Resources Planning and Operations Support Group  
Technical Service Center, Denver, Colorado



U.S. Department of the Interior  
Bureau of Reclamation

# Background

- Public Law 111-11, Subtitle F (SECURE Water Act, **SWA, 2009**) § 9503.
- Climate change risks for water and environmental resources in “**major Reclamation river basins.**”
- Reclamation’s WaterSMART (**S**ustain and **M**anage **A**merica’s **R**esources for **T**omorrow) program
  1. Basin Studies
  2. West-Wide Climate Risk Assessments (**WWCRAs**)
  3. Landscape Conservation Cooperatives (**LCCs**)



8 major Reclamation River Basin

SECURE – Science and Engineering to Comprehensively Understand and Responsibly Enhance

RECLAMATION

# SECURE Water Act, 2009

Coordination

Risks

Impacts

Adaptation  
/ Mitigation

Feasibility

Monitoring

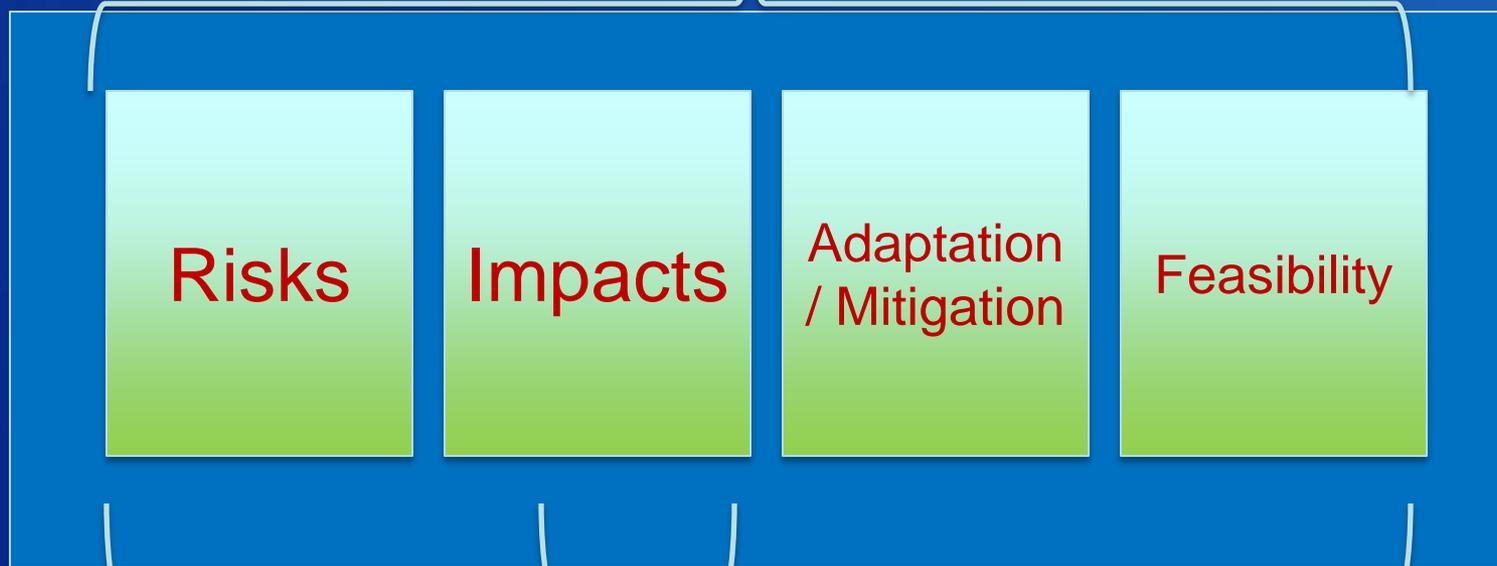
RECLAMATION

# Reclamation WaterSMART Program

*Comprehensive approach to incorporate the best available science into planning activities for climate change adaptation planning*

## LCCs

Science / Coordination / Communication



**WWCRA**

**Basin Studies**

**RECLAMATION**

# SECURE Water Act, 2009

- Risks
  - Change in snowpack
  - Groundwater recharge and discharge
  - Increases in water demand or reservoir evaporation as result of increasing temperature
- Impacts
  - Ability to deliver water
  - Hydroelectric power generation
  - Recreation at Reclamation facilities
  - Fish and wildlife habitat
  - Endangered, threatened, candidate species
  - Water quality issues
  - Flow dependent ecological resiliency
  - Flood control management



RECLAMATION

# West Wide Climate Risk Assessments

## *Baseline Assessments of Risks and Impacts*

- Transforming General Circulation Model information into a spatial and temporal scale relevant to a planning context
- Projections of Future Water Supply
- Projections of Future Water Demand
- Simulating future operations of Reclamation facilities
  - Hydropower, flood control, ... etc.
- Determining Ecosystem Responses and Resiliency

\* Consistent approach across 8 major Reclamation River Basins

RECLAMATION

# WWCRA Activities

CMIP3 & Updates

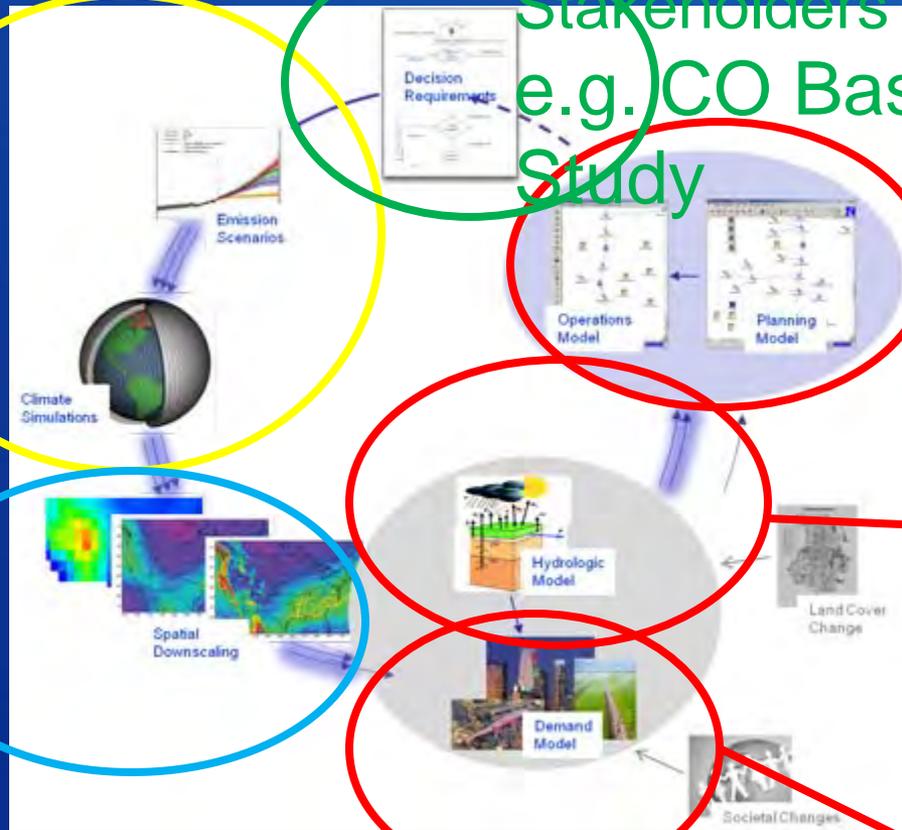
BCSD 2008 & Updates

With Stakeholders e.g. CO Basin Study

FY 2011 Rio Grande

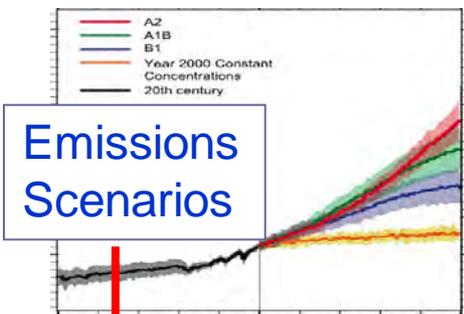
FY 2010 - 2011

FY 2011 - 2012

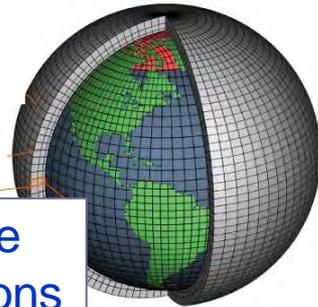


RECLAMATION

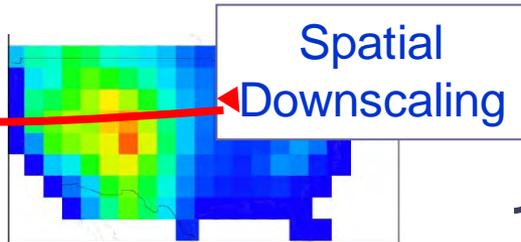
# Downscaled GCM Output



Emissions Scenarios



Climate Simulations



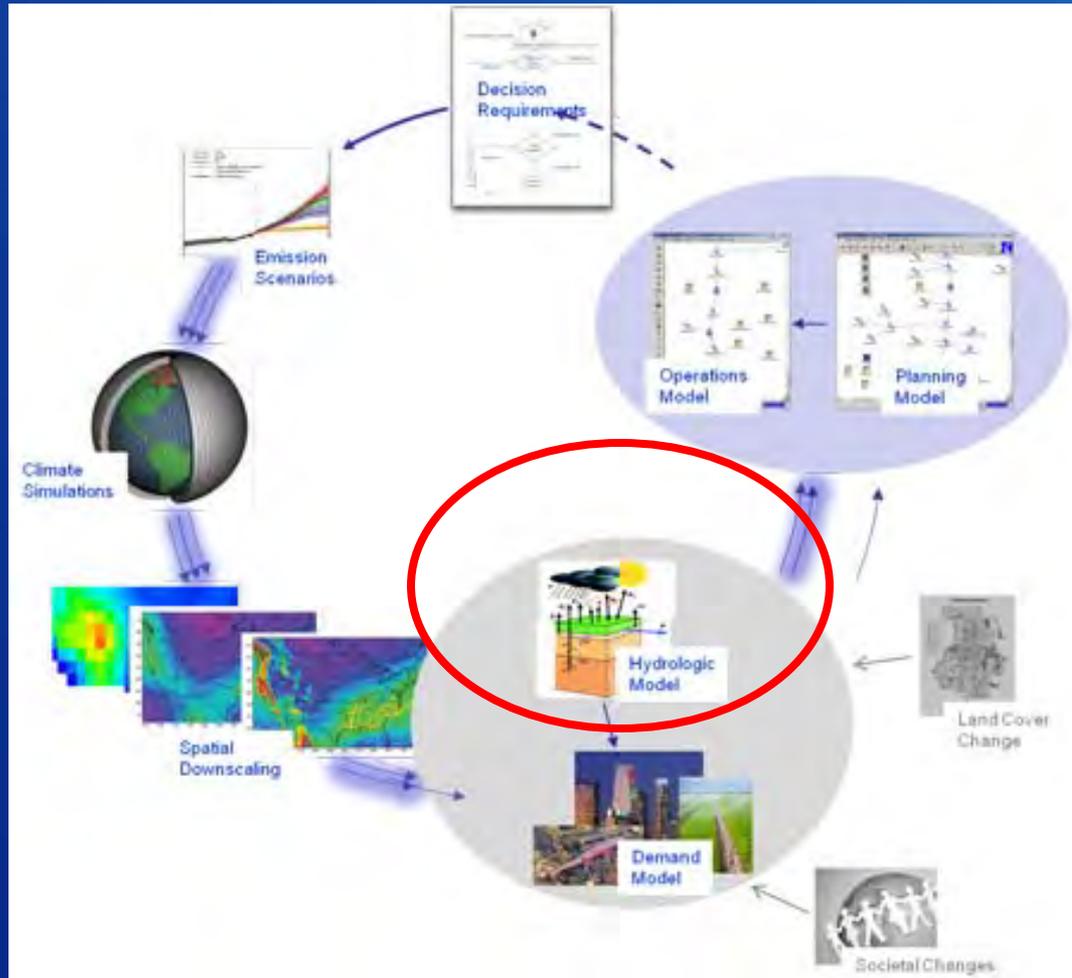
Spatial Downscaling

- 3 emissions scenarios
  - A1b, A2, B1
- Monthly P&T 1950-2099
- 1/8° (12 km) gridded data

Santa Clara Univ. (Maurer)  
Reclamation  
LLNL



# WWCRA Activities



RECLAMATION

# Objectives

- Develop future climate and hydrologic context common to all reporting basins → **west-wide hydrologic analysis**
- Use models to characterize **future natural hydrology**
- Serve the **hydrologic projections online**

# Outline – Developing WW CRA Hydrologic Projections

- Selecting a model network – hydrology model and routing model
- Applying the model network
- Example results – future hydrologic projections
- Products – reports, online data access ...

# Selecting a Model Network

RECLAMATION

# Objectives

- Work with available hydrologic model applications → no model building, no refinement, use what we have “as-is”
- WWCRA – University of Washington’s VIC (Variable Infiltration Capacity) applications

# Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model

[http://www.hydro.washington.edu/Lettenmaier/  
Models/VIC/VIChome.html](http://www.hydro.washington.edu/Lettenmaier/Models/VIC/VIChome.html)

RECLAMATION

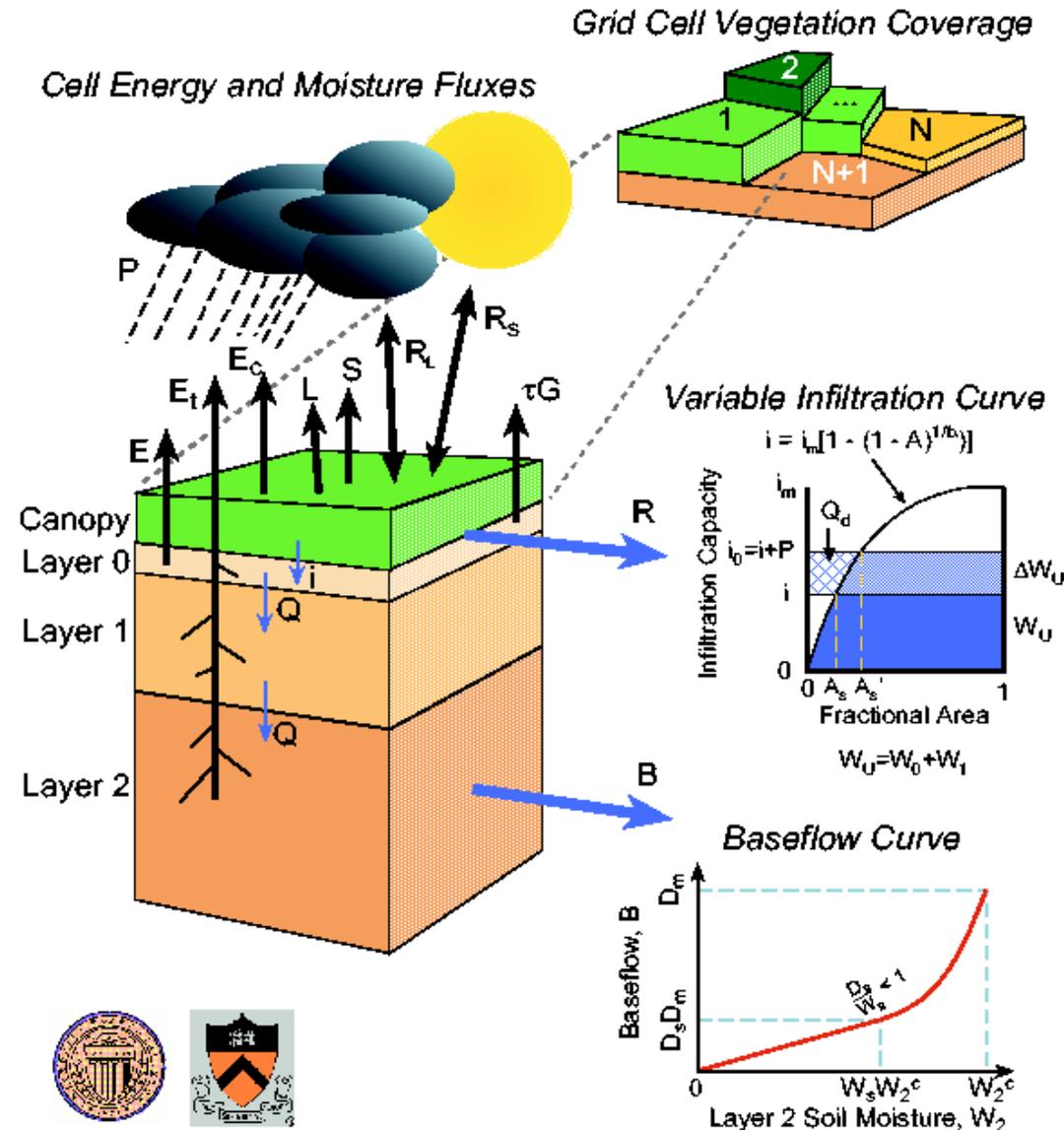
# Selection: VIC apps

- Selection Drivers
  - No geographic gaps for SWA reporting basins
  - Computed PET
- Quality of these models?
  - Calibrated to reproduce monthly to annual runoff in large sub-basins.
  - These models have *biases*
- Use of these models?
  - Relative changes

# VIC Model Details

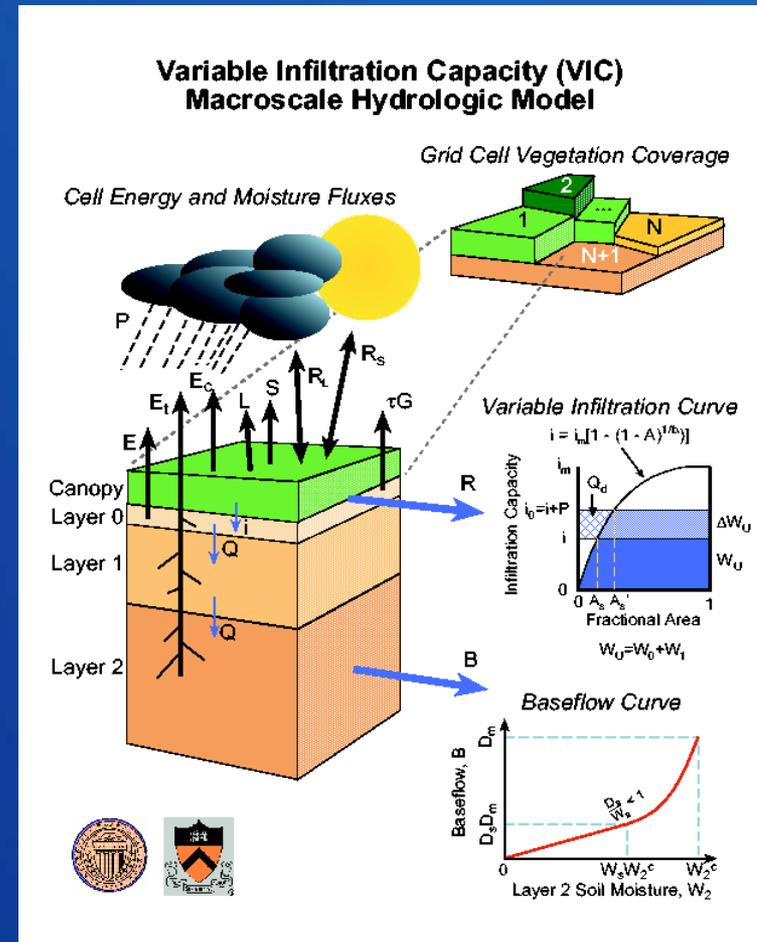
- Original Reference
  - Liang et al. 1994
- Motivated by desire to couple land surface hydrology over large areas with atmospheric models → **solve water and energy balance at each time step**
  - Computes PET rather than requiring input PET
  - Computes other surface energy terms (e.g., sensible heat, ground heat flux)
- Multiple vegetation classes in each cell
- Sub-grid elevation band definition (for snow)
- Sub-grid infiltration/runoff variability

## Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model

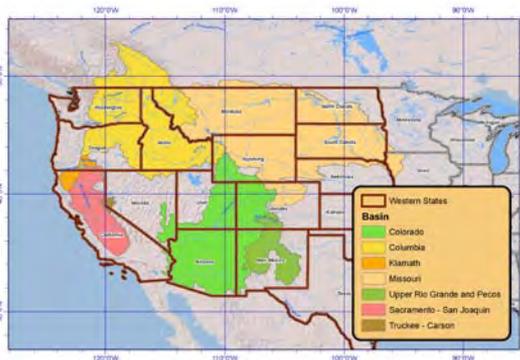
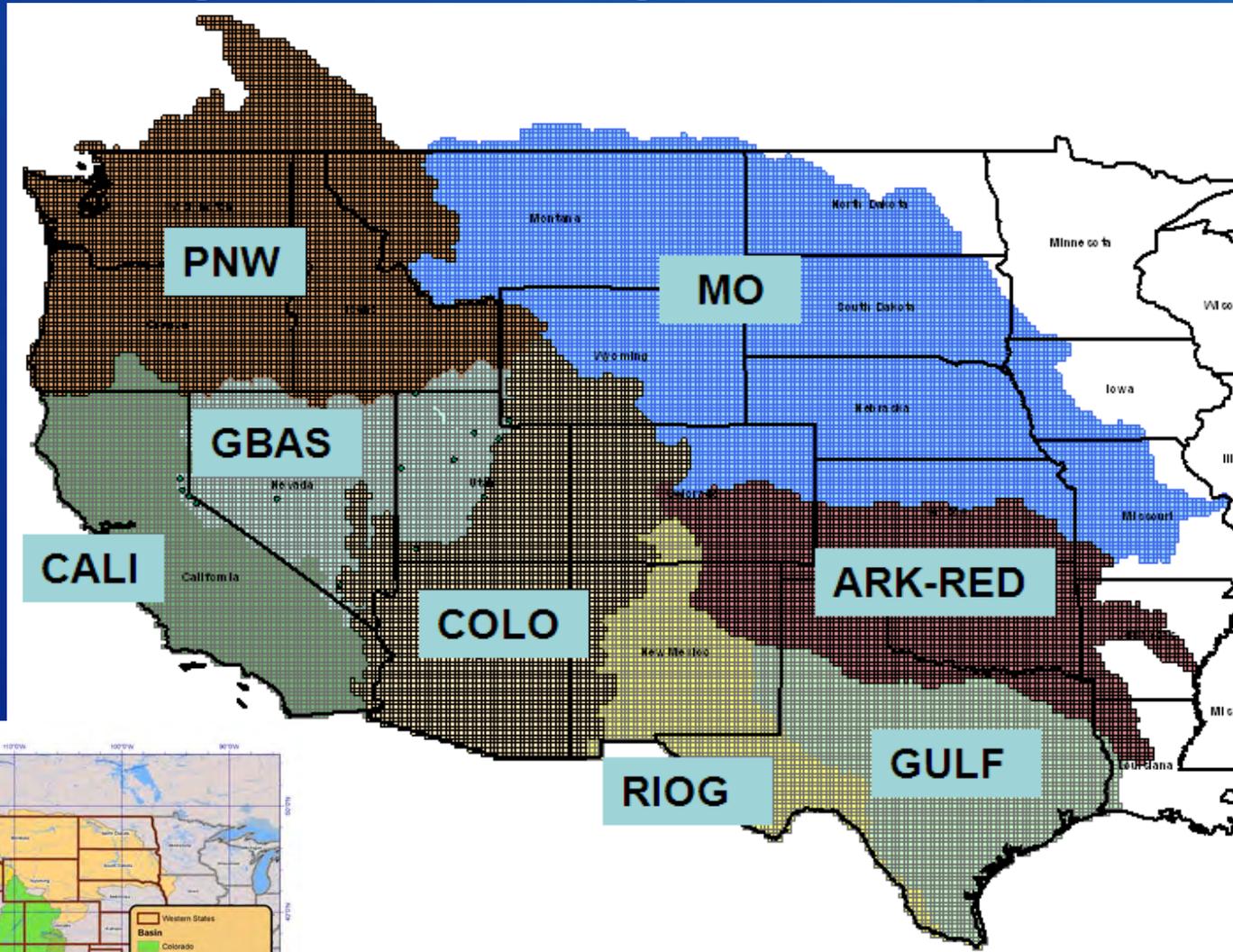


# VIC Model Details (cont'd)

- Gridded macro-scale hydrology model (grid size > 1 km )
- VIC model version 4.0.7 (32-bit)
- VIC model overview, <http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Overview/ModelOverview.shtml>



# Hydrologic Modeling - VIC Applications



RECLAMATION

# Hydrologic Modeling - VIC Applications

- **Eight “calibrated” VIC models covering the 17 state Reclamation region**
- **Grid resolution, 1/8<sup>th</sup> degree (~ 12 km)**
- **Total number of grid cells, ~36,000**

<i>Count</i>	<i>VIC Application Name</i>	<i>Number of Grid Cells</i>	<i>Secure Water Act (SWA) Major Reclamation River Basins</i>
1	PNW	6,392	Columbia River
2	CALI	2,906	Sacramento River San Joaquin River Klamath River
3	GBAS	2,710	Truckee River
4	COLO	4,518	Colorado River
5	RIOG	2,356	Rio Grande
6	MO	9,953	Missouri River
7	ARK-RED	3,999	x
8	GULF	2,989	x
<b>TOTAL</b>		<b>35,823</b>	

# Outline

- Selecting a model network – hydrology model and routing model
- **Applying the model network**
- Example results – future hydrologic projections
- Products

# Applying the Model Network

RECLAMATION

# Selected Climate Projections (Bias-corrected, Spatially Downscaled)

[http://gdo-dcp.ucllnl.org/downscaled\\_cmip3\\_projections/](http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/)

- 112 CMIP3 Projections
  - 16 models, 3 emission scenarios, and multiple initializations for model-emissions combination
- Variables:
  - Precipitation Rate (mm/day)
  - Mean Daily Temperature (°C)
- Temporal Coverage and Resolution
  - 1950-2099, monthly
- Spatial Coverage and Resolution
  - Contiguous U.S., 1/8° (~12km x 12 km)
- Developers
  - Reclamation, Santa Clara University (Ed Maurer), LLNL



## Bias Corrected and Downscaled WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer (IE) 6.\*, IE 7.\*, and Firefox 2.\*.  
*Requires JavaScript to be enabled.*

Welcome | About | Limitations | Tutorial | Data Source Request | Data Download Request | Feedback | Contact Us

### Announcements (updated January 25, 2010 - Now serving Gridded Observations and intermediate BCSD data products)

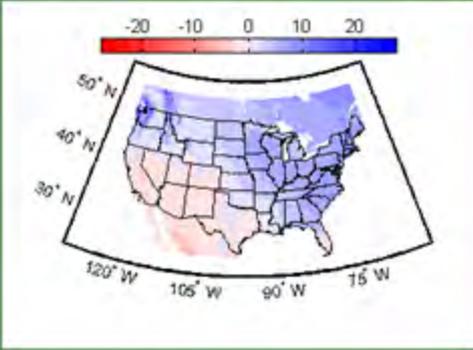
**Summary**

This archive contains fine spatial-resolution translations of 112 contemporary climate projections over the contiguous United States. The original projections are from the [World Climate Research Programme's \(WCRP's\) Coupled Model Intercomparison Project phase 3 \(CMIP3\)](#) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. Please see the "About" for information on data development, including the methodology to perform climate model bias-correction and spatial downscaling.

**Purpose**

The archive was developed to provide planning analysts access to climate projections spatially downscaled to a finer spatial resolution. Such access permits several types of analyses, including:

**Figure 1: Median projected change in average-annual precipitation (cm/year), 2041-70 versus 1971-2000**



**Figure 2: Geographic Distribution of Projection Requests through December 2009. Plot shows spatial histogram of projections, sum at each 1/8° downscaling location. Colorbar shows range of projection counts. Astenisks show locations of data requests.**



# Applying VIC

- **Generate weather inputs**
  - follow Wood et al. 2004
  - Spatial:
    - no reconciliation necessary, VIC grids coincide with BCSD grid (1/8deg)
  - Temporal:
    - translate “monthly BCSD T and P data” into “daily Tmin, Tmax, P and wind speed” necessary for VIC simulationn
    - ~historical resampling & scaling
    - Library of historical: daily Maurer et al (2002), 1950-1999
    - Sampling rules: similarity in like month, constraint P scaling (working with UW CIG (Salathe/Hamlet), Andy Wood, and Ed Maurer on this issue)
- **Simulate Runoff**

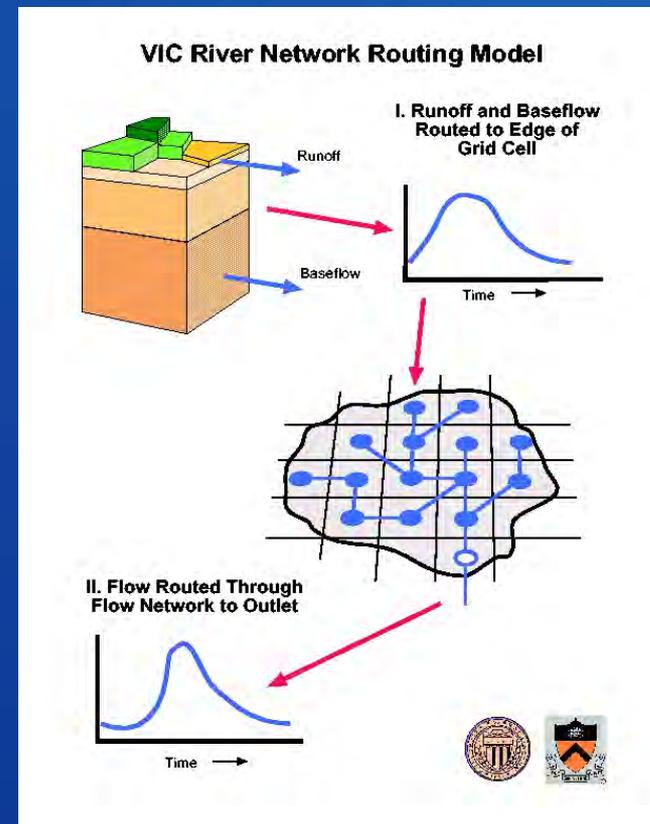
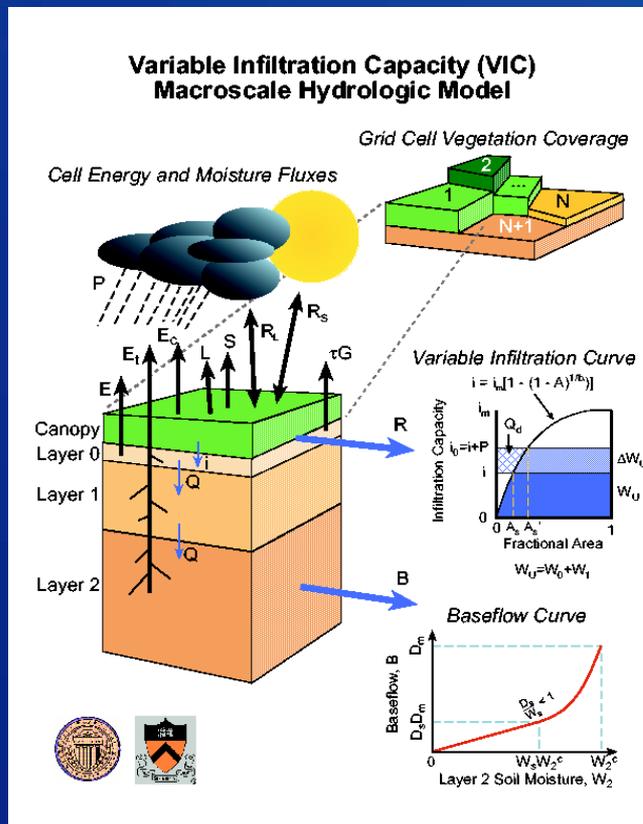
# Hydrologic Modeling – VIC Setup, 2 Steps

## 1. Land Surface Simulation

- simulate runoff (and other fluxes) at each grid cell

## 2. Streamflow Routing

- transport runoff from grid cell to outlet



# What's being simulated

- 112 gridded climate projections → 112 gridded hydrology projections (runoff, swe, et, pet)
- Time Period: daily 1950-2099
- ~36,000 grid cells at 1/8<sup>th</sup> degree (~12 km) spatial resolution

# Outline

- Selecting a model network – hydrology model and routing model
- Applying the model network
- **Example results – future hydrologic projections**
- Products

# Example Results – Future Hydrologic Projections

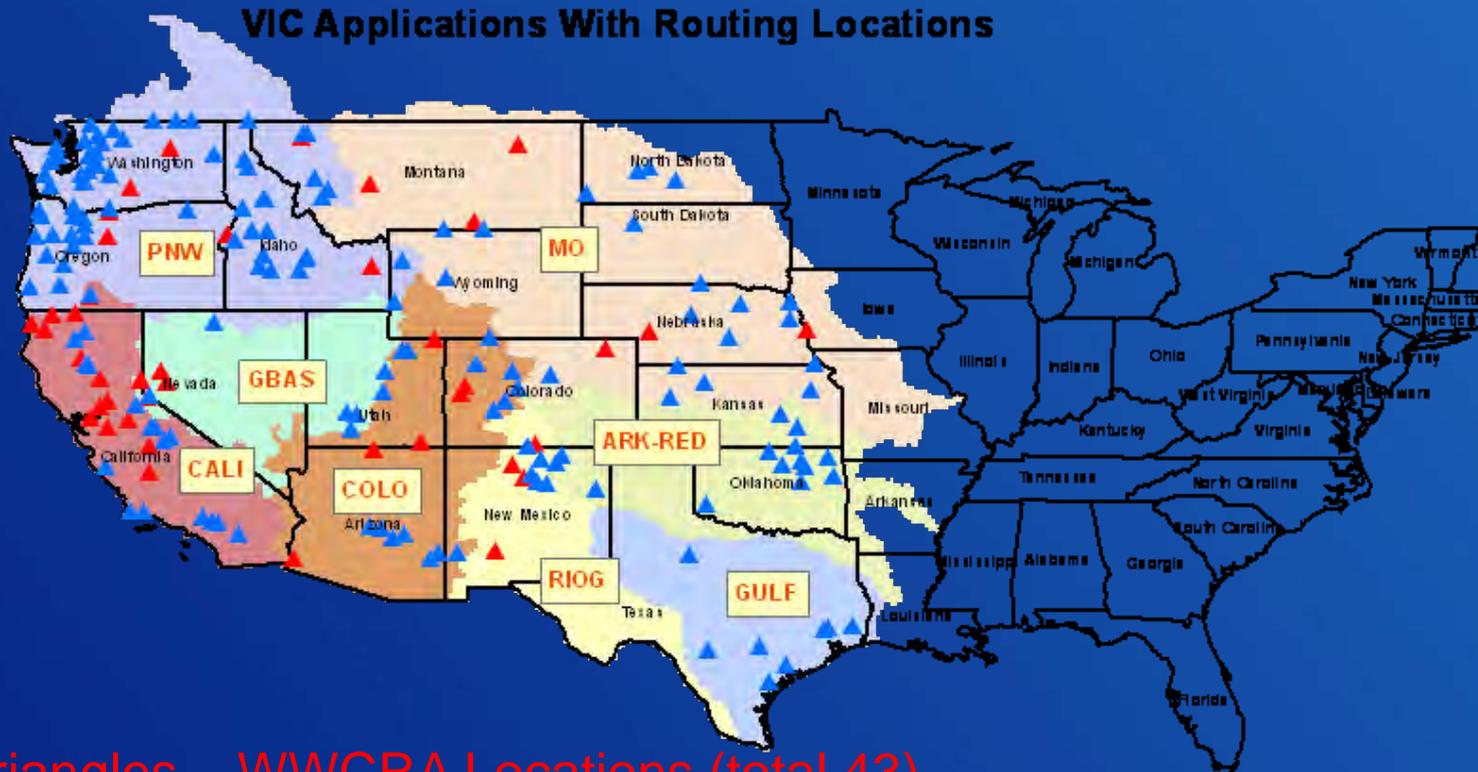
# Results - Background

- Continuous simulation – gridded (~12 km x 12 km)
  - 1950-2099 (daily)
  - Mostly variables aggregated to monthly for reporting
- Reference decade, 1990s - **water years, 1990-1999**
- Three future decades
  - 2020s - **water years, 2020-2029**
  - 2050s - **water years, 2050-2059**
  - 2070s - **water years, 2070-2079**
- Changes in future decades from the 1990s reference

# Results - WWCRA

- **Precipitation and temperature trends**
- **Change in snowpack – SWE**
- **Timing of runoff**
- **For reporting**
  - 43 WWCRA locations spanning the major Reclamation basins
  - 152 HCDN (Hydroclimate Data Network) sites spanning the western US

# VIC Applications With Routing Locations

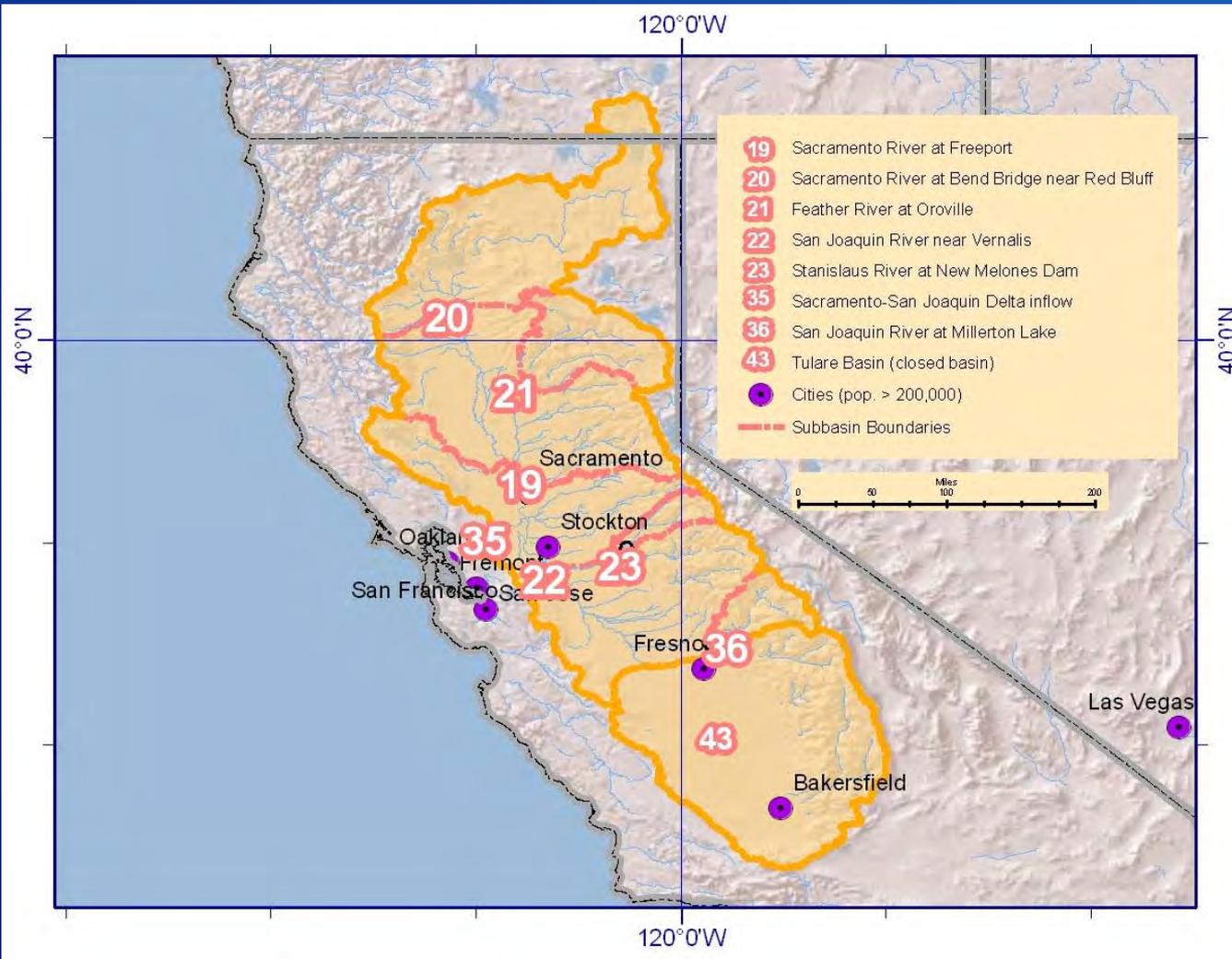


Red triangles – WWCRA Locations (total 43)

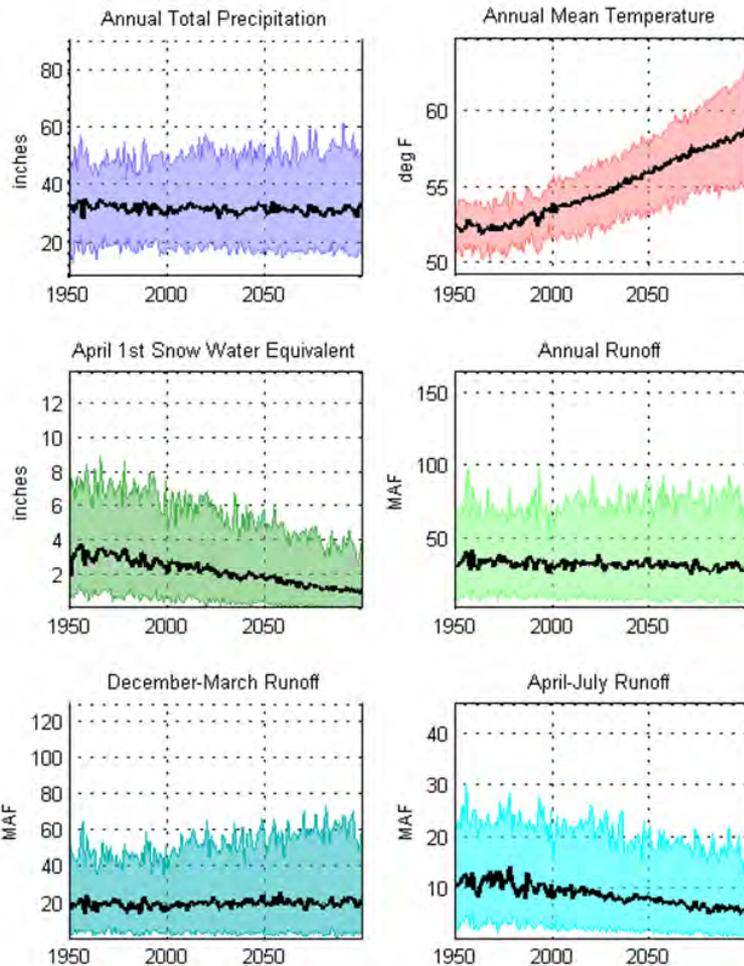
Blue triangles – HCDN locations (total 152)

RECLAMATION

# Sacramento R., San Joaquin R. and Tulare Basins



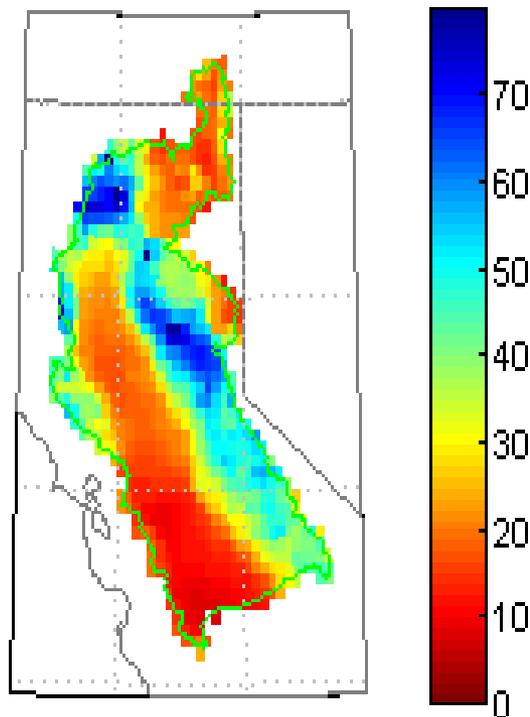
# Sacramento and San Joaquin Rivers at the Delta – Location 35



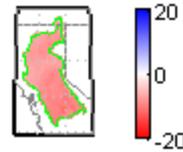
RECLAMATION

# Sacramento and San Joaquin Rivers at the Delta – Precipitation

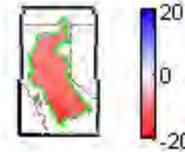
Decade-Mean Precipitation, inches  
1990s, Ensemble-Median



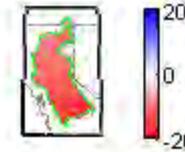
Change Decade-Mean Prop. %  
2020s-1990s, 25th



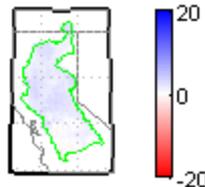
Change Decade-Mean Prop. %  
2050s-1990s, 25th



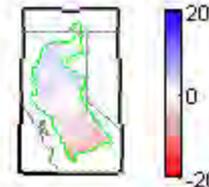
Change Decade-Mean Prop. %  
2070s-1990s, 25th



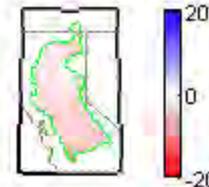
Change Decade-Mean Prop. %  
2020s-1990s, 50th



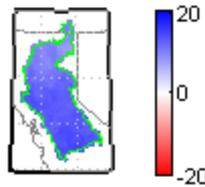
Change Decade-Mean Prop. %  
2050s-1990s, 50th



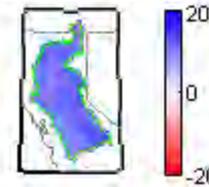
Change Decade-Mean Prop. %  
2070s-1990s, 50th



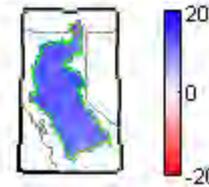
Change Decade-Mean Prop. %  
2020s-1990s, 75th



Change Decade-Mean Prop. %  
2050s-1990s, 75th

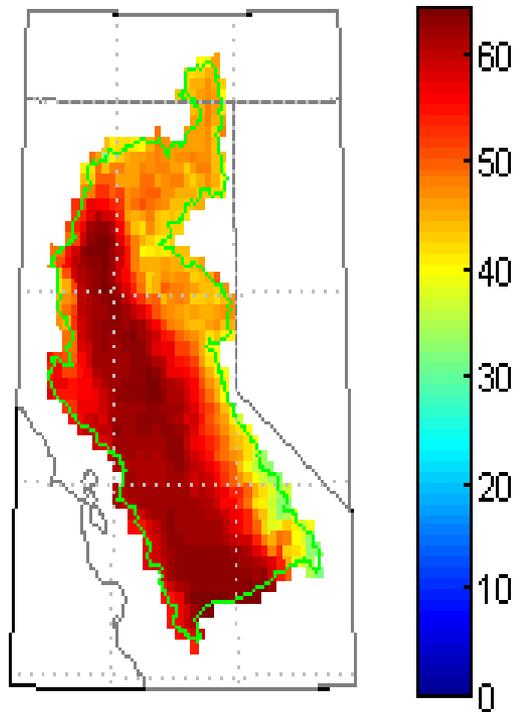


Change Decade-Mean Prop. %  
2070s-1990s, 75th

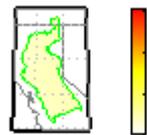


# Sacramento and San Joaquin Rivers at the Delta – Temperature

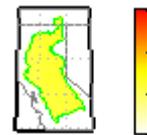
Decade-Mean Temperature, deg F  
1990s, Ensemble-Median



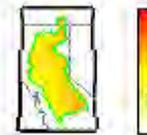
Change Decade-Mean Tmp, °F  
2020s-1990s, 25th



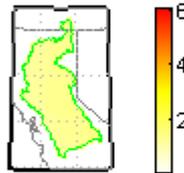
Change Decade-Mean Tmp, °F  
2050s-1990s, 25th



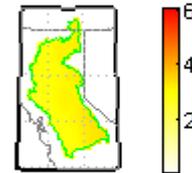
Change Decade-Mean Tmp, °F  
2070s-1990s, 25th



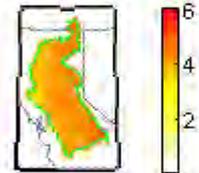
Change Decade-Mean Tmp, °F  
2020s-1990s, 50th



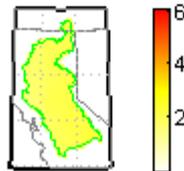
Change Decade-Mean Tmp, °F  
2050s-1990s, 50th



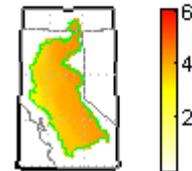
Change Decade-Mean Tmp, °F  
2070s-1990s, 50th



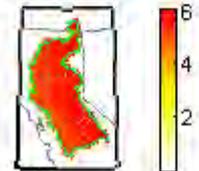
Change Decade-Mean Tmp, °F  
2020s-1990s, 75th



Change Decade-Mean Tmp, °F  
2050s-1990s, 75th

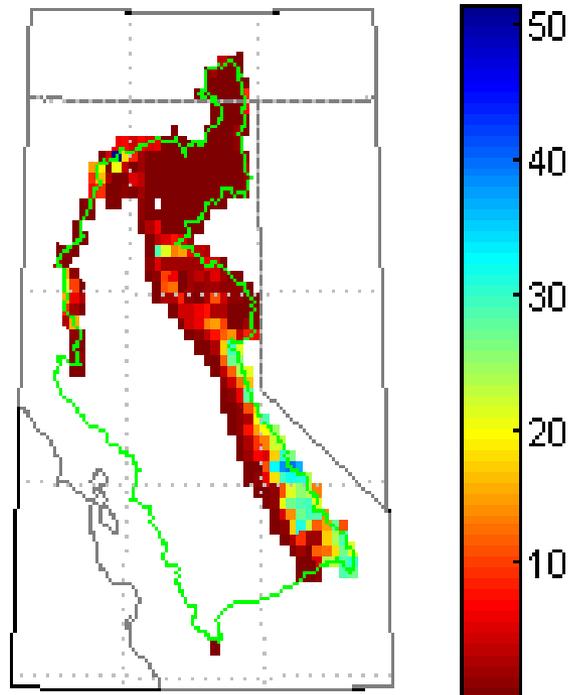


Change Decade-Mean Tmp, °F  
2070s-1990s, 75th

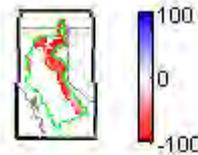


# Sacramento and San Joaquin Rivers at the Delta – SWE

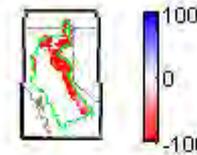
Decade-Mean April 1st SWE, inches  
1990s, Ensemble-Median



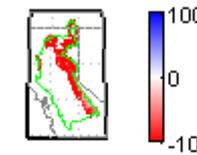
Change Decade-Mean SWE, %  
2020s-1990s, 25th



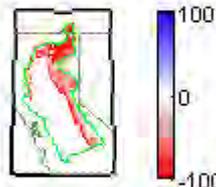
Change Decade-Mean SWE, %  
2050s-1990s, 25th



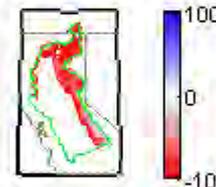
Change Decade-Mean SWE, %  
2070s-1990s, 25th



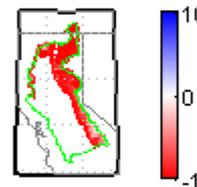
Change Decade-Mean SWE, %  
2020s-1990s, 50th



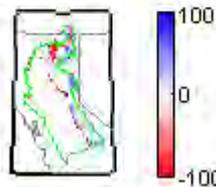
Change Decade-Mean SWE, %  
2050s-1990s, 50th



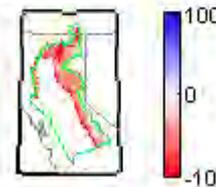
Change Decade-Mean SWE, %  
2070s-1990s, 50th



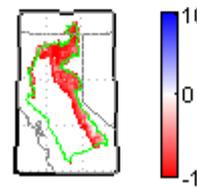
Change Decade-Mean SWE, %  
2020s-1990s, 75th



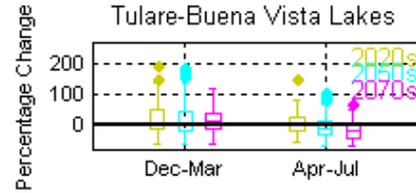
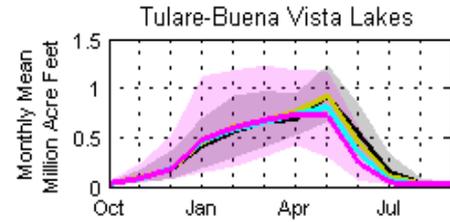
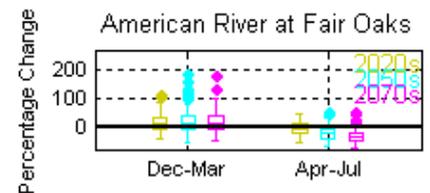
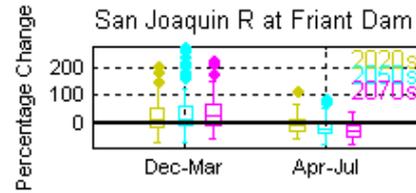
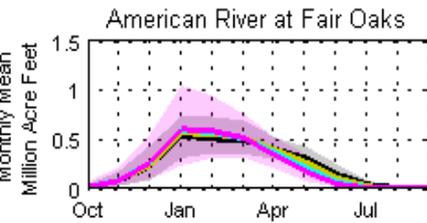
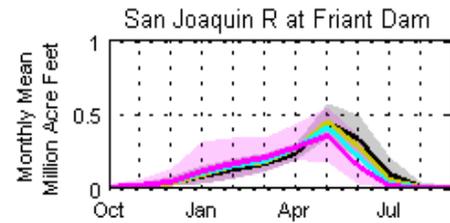
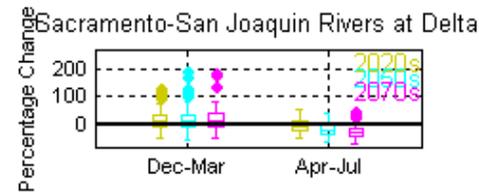
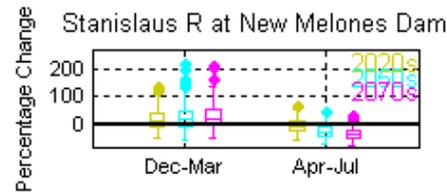
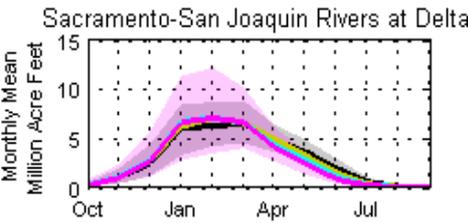
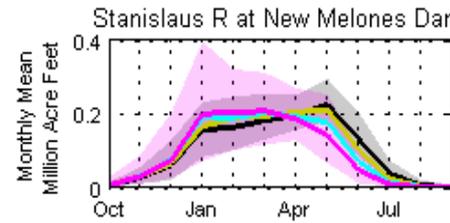
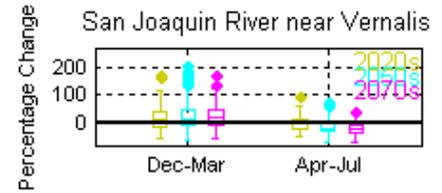
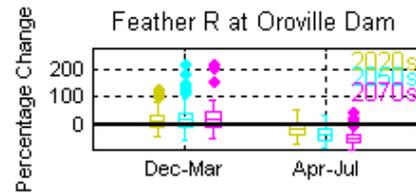
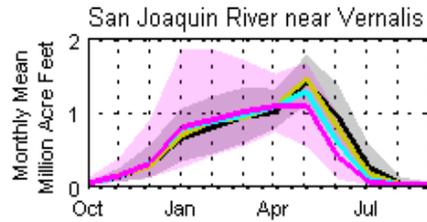
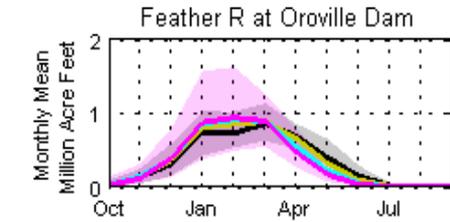
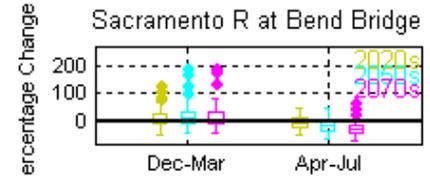
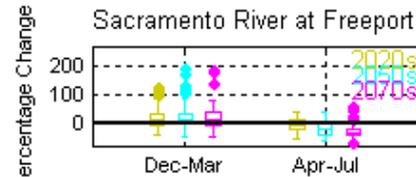
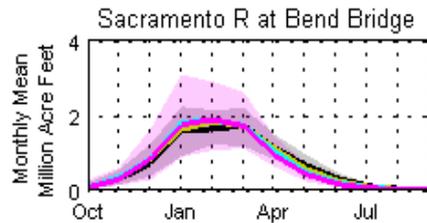
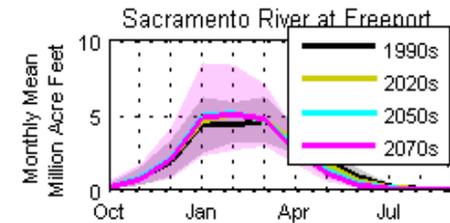
Change Decade-Mean SWE, %  
2050s-1990s, 75th



Change Decade-Mean SWE, %  
2070s-1990s, 75th

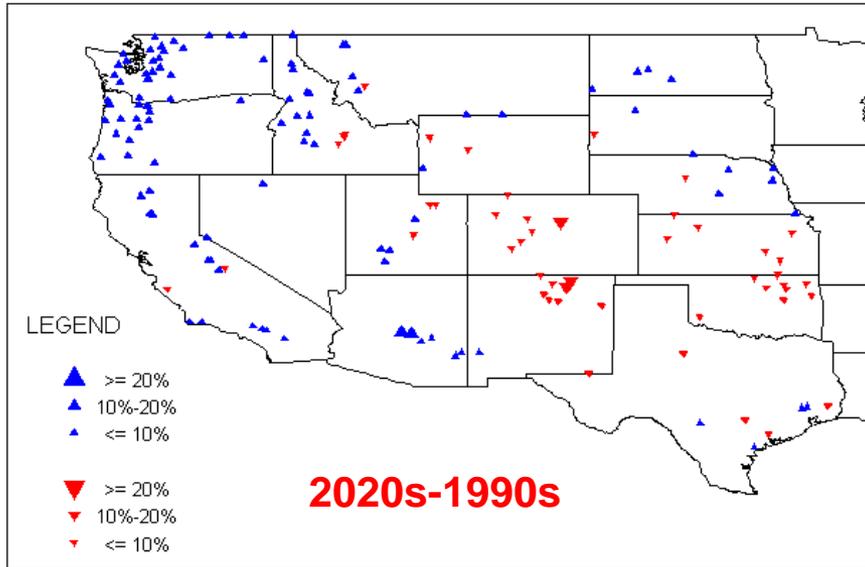


# Streamflow Impacts

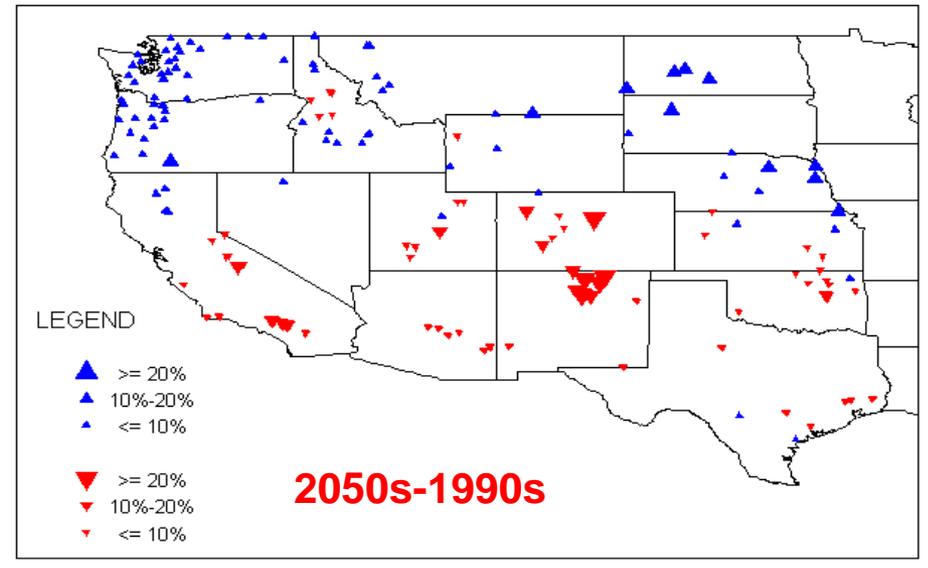


# West-Wide Streamflow Impacts - HCDN

2020s-1990s  
Ensemble Median Change [%]

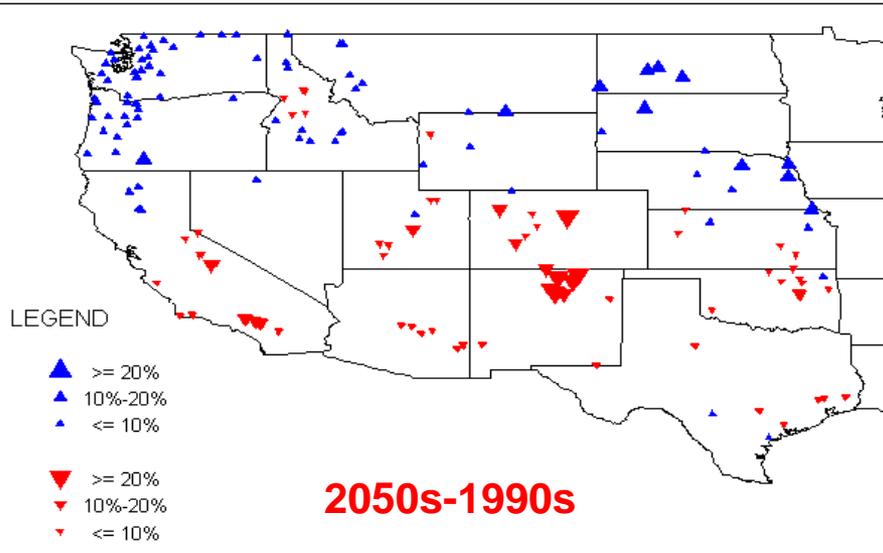


2050s-1990s  
Ensemble Median Change [%]

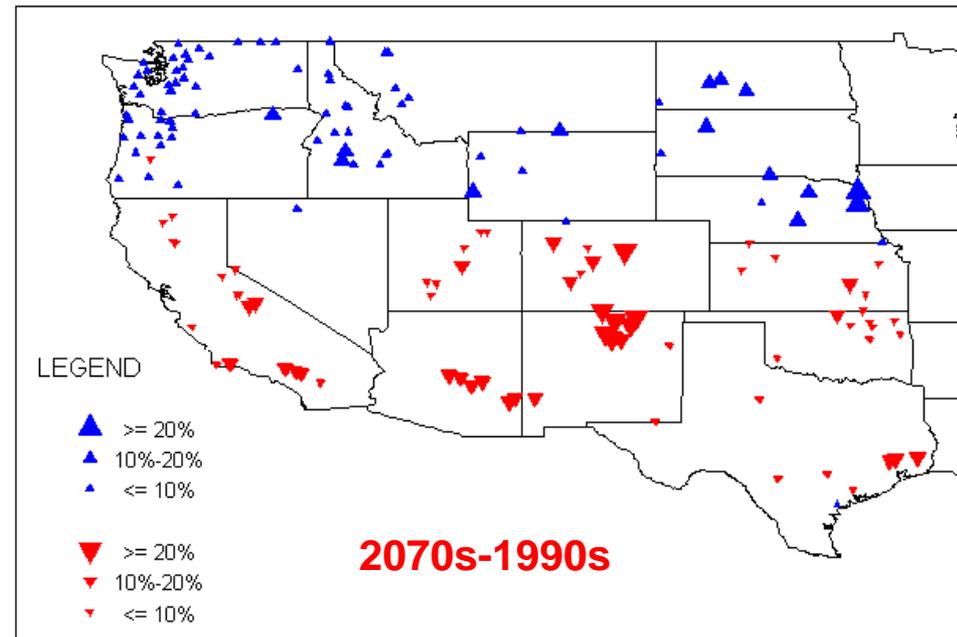


# West-Wide Streamflow Impacts - HCDN

2050s-1990s  
Ensemble Median Change [%]



2070s-1990s  
Ensemble Median Change [%]



# Results – West-Wide Summary

- Precipitation is expected to increase from the 1990s level during the 2020s and 2050s, but declines nominally during the 2070s.(though the early to middle 21<sup>st</sup> century increases could be artifacts of the BCSD climate projections development leading to slightly wetter projections).
- Temperature shows a persistent increasing trend from the 1990s level.
- April 1<sup>st</sup> SWE shows a persistent decreasing trend from the 1990s level.
- Annual runoff shows some increase for the 2020s decade from the 1990s level, but shows decline moving forward to the 2050s and 2070s decade from the 1990s reference, suggesting that although precipitation changes are projected to remain positive through the 2050s, temperature changes begin to offset these precipitation increases leading to net loss in the water balance through increased evapotranspiration losses.
- Winter season (December-March) runoff shows an increasing trend.
- Spring-summer season (April-July) runoff shows a decreasing trend.

# Outline

- Selecting a model network – hydrology model and routing model
- Applying the model network
- Example results – future hydrologic projections
- **Products – reporting, online data access**

# Reporting

<http://www.usbr.gov/climate>

## RECLAMATION *Managing Water in the West*

Technical Memorandum No. 86-68210-2011-01

### West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections



  
U.S. Department of the Interior  
Bureau of Reclamation

Technical Report

March 2011

## RECLAMATION *Managing Water in the West*

### SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2011



U.S. Department of the Interior  
Policy and Administration  
Bureau of Reclamation  
Denver, Colorado

Report to Congress

April 2011

# RECLAMATION

# Online Data Access Gridded Hydroclimate

- **Co-hosted with the current CMIP-3 archive at LLNL**

[http://gdo-dcp.ucllnl.org/downscaled\\_cmip3\\_projections](http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections)

- **American Geophysical Union (AGU) Eos Article describing the online gridded hydroclimate archive**

**Gangopadhyay, S., T. Pruitt, L. Brekke, and D. Raff (2011), Hydrologic projections for the western United States, Eos Trans. AGU, 92(48), 441, doi:10.1029/2011EO480001.**

# Online Data Access

Bias Corrected and Downscale x +

gdo-dcp.ucllnl.org/downscaled\_cmip3\_projections/dcpInterface.html

RECLAMATION USGS  
Santa Clara University CLIMATE CENTRAL SCRIPPS INSTITUTION OF OCEANOGRAPHY

## Bias Corrected and Downscaled WCRP CMIP3 Climate and Hydrology Projections

*This site is best viewed with [Chrome](#) (recommended) or [Firefox](#). Some features are unavailable when using Internet Explorer. [Requires JavaScript to be enabled.](#)*

Welcome About Tutorials Projections: Subset Request Projections: Complete Archives Feedback Links

### Summary

This archive contains fine spatial-resolution translations of:

- climate projections over the contiguous United States (U.S.) developed using two downscaling techniques (monthly BCSD Figure 1, and daily BCCA Figure 2), and
- hydrologic projections over the western U.S. (roughly the western U.S. Figure 3) corresponding to the monthly BCSD climate projections.

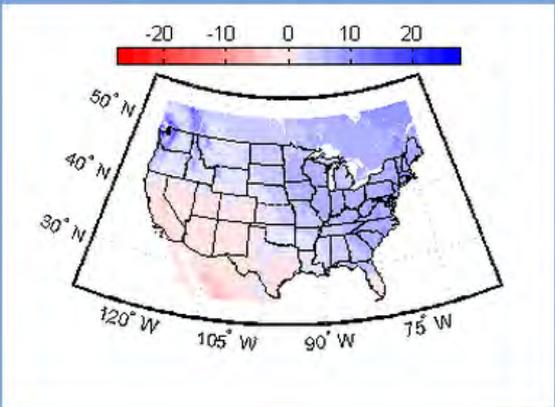
Archive content is based on global climate projections from the [World Climate Research Programme's \(WCRP's\) Coupled Model Intercomparison Project phase 3 \(CMIP3\)](#) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. Please see the "About" page for information on projection development, including the methodology to perform climate model bias-correction and spatial downscaling.

### Purpose

The archive is meant to provide access to climate and hydrologic projections at spatial and temporal scales more relevant to some of the watershed and basin-scale decisions facing water managers and planners dealing with climate change. Such access permits several types of analyses, including:

- assessment of local to regional climate projection uncertainty;
- assessment of potential climate change impacts on natural and social systems (e.g., watershed hydrology, ecosystems, water and energy demands);
- risk-based exploration of planning and policy responses framed by potential climate changes exemplified by these

*Figure 1: BCSD CMIP3 Monthly Climate Analysis example - Median projected change in average-annual precipitation (cm/year), 2041-70 versus 1971-2000.*



*Figure 2: BCCA CMIP3 Daily Climate Analysis example -*

# Online Data Access

The screenshot shows a web browser window with the URL `gdo-dcp.uclnl.org/downscaled_cmip3_projections/dcpInterface.html#Projections:%20Subset%20Request`. The page header includes logos for Reclamation, Santa Clara University, USGS, and the Scripps Institution of Oceanography. The main title is "Bias Corrected and Downscaled WCRP CMIP3 Climate and Hydrology Projections". A navigation bar contains tabs for "Welcome", "About", "Tutorials", "Projections: Subset Request" (selected), "Projections: Complete Archive", "Feedback", and "Links".

A blue instruction box states: "Click on the sub-tabs below to select the projection archive for a custom request. Then customized retrieval is specified using the forms specific to each projection archive, spread among three sub-tabs ('Page 1: Products, Variables & Projections', 'Page 2: Temporal & Spatial Extent', 'Page 3: Analysis, Format, & Notification'). The form permits specification of projection subsets according to user selections for products, variables, models, emissions scenarios, time periods, geographical areas, series versus statistical output, and output format. Submissions are constrained so that the resulting file download size does not exceed approximately 1 gigabytes. The form tracks user selections and indicates whether the specified request is within this size constraint. Requests are queued at LLNL Green Data Oasis for processing. When the request has been processed and made ready for download, the user is notified via the email submitted in the form below (sub-tab 'Page 3: Analysis, Format, & Notification')."

Below the instruction box are three sub-tab buttons: "BCSD-CMIP3-Climate-monthly", "BCCA-CMIP3-Climate-daily", and "BCSD-CMIP3-Hydrology-monthly". The "BCSD-CMIP3-Hydrology-monthly" button is highlighted with a red rectangle.

A blue bar below the sub-tabs reads: "Enter specifications on three page form below. Then press 'Submit Request'." followed by a help icon. Below this is a "Submit Request" button, a "Form Status (completed == green)" indicator, and a "Size (% , 100 max): 1" label. A row of nine small buttons labeled 1.1 through 3.8 is visible.

Three page navigation tabs are shown: "Page 1: Products, Variables, Projections" (selected), "Page 2: Temporal & Spatial Extent", and "Page 3: Analysis, Format, & Notification".

The selected page shows "Step 1.1: Products & Variables – monthly projections" with a help icon. It contains two columns of options:

- Products**
  - 1/8 degree BCSD projections
  - 1/8 degree Observed data (1950-1999)
  - 2 degree Raw GCM projections
- Variables**
  - Precipitation Rate (mm/day)
  - Ave Surface Air Temperature (deg C)

# Online Data Access

Bias Corrected and Downscale x

gdo-dcp.ucllnl.org/downscaled\_cmip3\_projections/dcpInterface.html#Projections:%20Subset%20Request

This site is best viewed with [Chrome](#) (recommended) or [Firefox](#). Some features are unavailable when using Internet Explorer. Requires JavaScript to be enabled.

Welcome About Tutorials Projections: Subset Request Projections: Complete Archives Feedback Links

Click on the sub-tabs below to select the projection archive for a custom request. Then customized retrieval is specified using the forms specific to each projection archive, spread among three sub-tabs ("Page 1: Products, Variables & Projections", "Page 2: Temporal & Spatial Extent", "Page 3: Analysis, Format, & Notification"). The form permits specification of projection subsets according to user selections for products, variables, models, emissions scenarios, time periods, geographical areas, series versus statistical output, and output format. Submissions are constrained so that the resulting file download size does not exceed approximately 1 gigabytes. The form tracks user selections and indicates whether the specified request is within this size constraint. Requests are queued at LLNL Green Data Oasis for processing. When the request has been processed and made ready for download, the user is notified via the email submitted in the form below (sub-tab "Page 3: Analysis, Format, & Notification").

BCSD-CMIP3-Climate-monthly BCCA-CMIP3-Climate-daily **BCSD-CMIP3-Hydrology-monthly**

Enter specifications on three page form below. Then press 'Submit Request'.

Submit Request Form Status (completed == green) Size (% , 100 max): 1

1.1 1.2 2.3 2.4 3.5 3.6 3.7 3.8

Page 1: Products, Variables, Projections Page 2: Temporal & Spatial Extent Page 3: Analysis, Format, & Notification

**Step 1.1: Variables – monthly projections**

Precipitation (mm/m)  Total runoff (mm/m)

Maximum Air Temperature (deg C)  Evapotranspiration - Actual (mm/m)

Minimum Air Temperature (deg C)  Evapotranspiration - Potential, natural veg (mm/m)

Wind Speed (m/s)  Evapotranspiration - Potential, open water (mm/m)

Soil Moisture Content (mm – 1st day of month)  Evapotranspiration - Potential, tall reference (mm/m)

Snow Water Equivalent (mm – 1st day of month)  Evapotranspiration - Potential, short referenece (mm/m)

Step 1.2: Emissions Scenarios, Climate Models and Runs

De-select all runs None None None



# Online Data Access

## Daily and Monthly Streamflow Projections

Jan 1, 1950 – Dec 31, 2099

195 locations West-Wide

[http://gis.usbr.gov/streamflow\\_projections/](http://gis.usbr.gov/streamflow_projections/)



# RECLAMATION

# Ongoing Activities

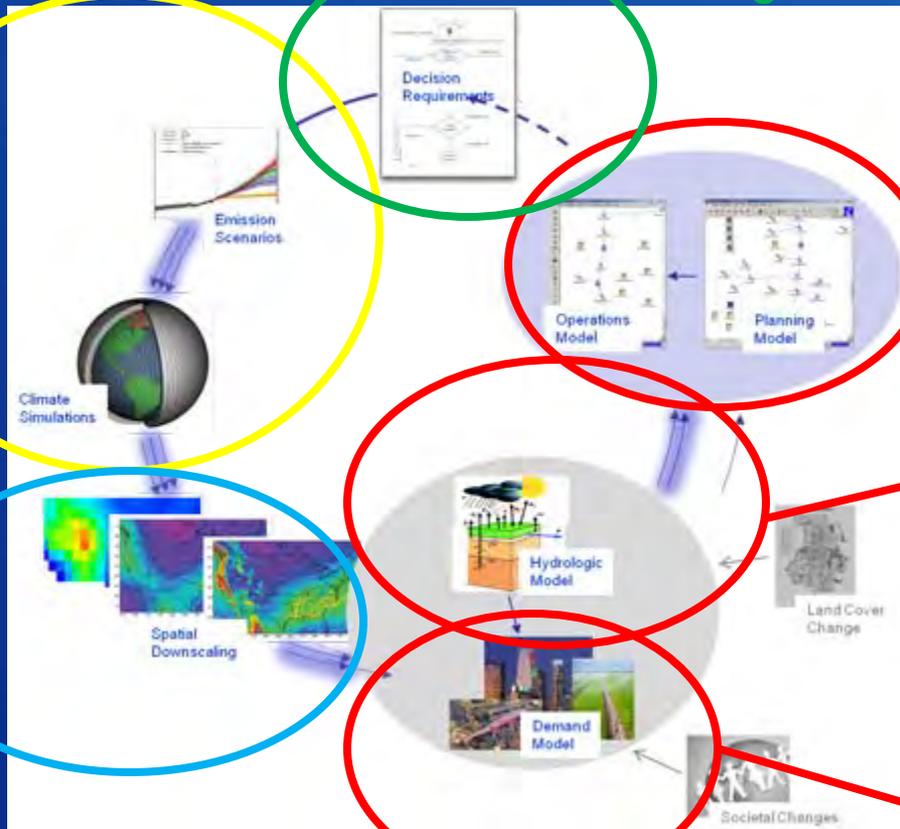
- Runoff Projections to Operations Model Hydrology
- Maintaining the online projections archive
  - updated hydrology models
  - new projections (e.g. CMIP-5)
- Demands
  - agricultural demands
  - open water (reservoir) evaporation
- Ecosystem Response
- Ongoing SWA Reporting Requirements (next report 2016)

# WWCRA Activities

<http://www.usbr.gov/WaterSMART/wcra/index.html>

With Stakeholders  
e.g. CO Basin Study

CMIP3 &  
Updates



FY 2011 Rio Grande

FY 2010 - 2011

FY 2011 - 2012

BCSD 2008 &  
Updates

Next Report in 2016

RECLAMATION

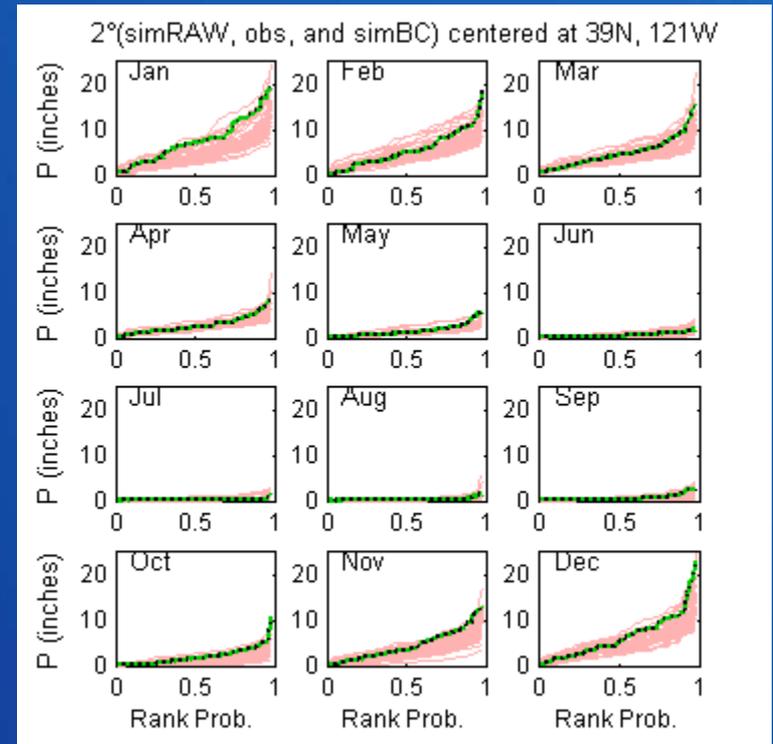
Bias Correction and Spatial Downscaling

**EXTRAS**

RECLAMATION

# BCSD: Bias Correction part 1

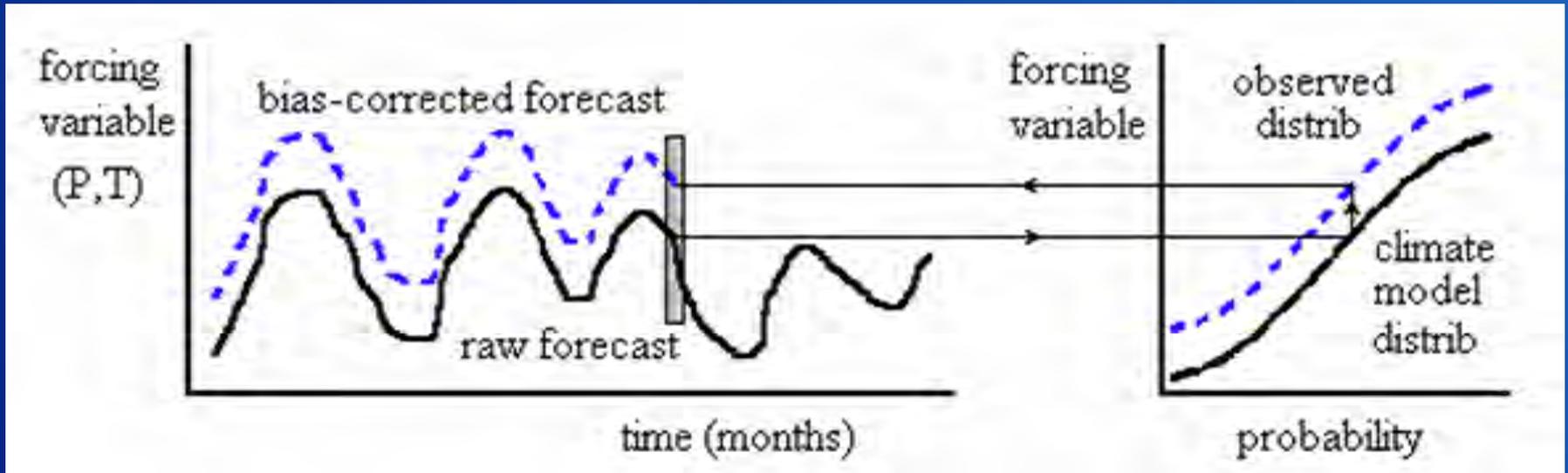
- Historical Evaluation Period
  - 1950-99 (longer period provides better assessment of bias)
- Adopt common grid
  - Interpolate GCM output
  - aggregate station observations
- Assess bias at each grid cell for each month
  - 50 modeled vs observed values
  - Two CDFs, GCM and OBS
  - → **Quantile Map**



**Example: location NE of Folsom Lake, CA (black = obs, red = GCMs' raw data, green = GCMs' bias-corrected data)**

# BCSD: Bias Correction part 2

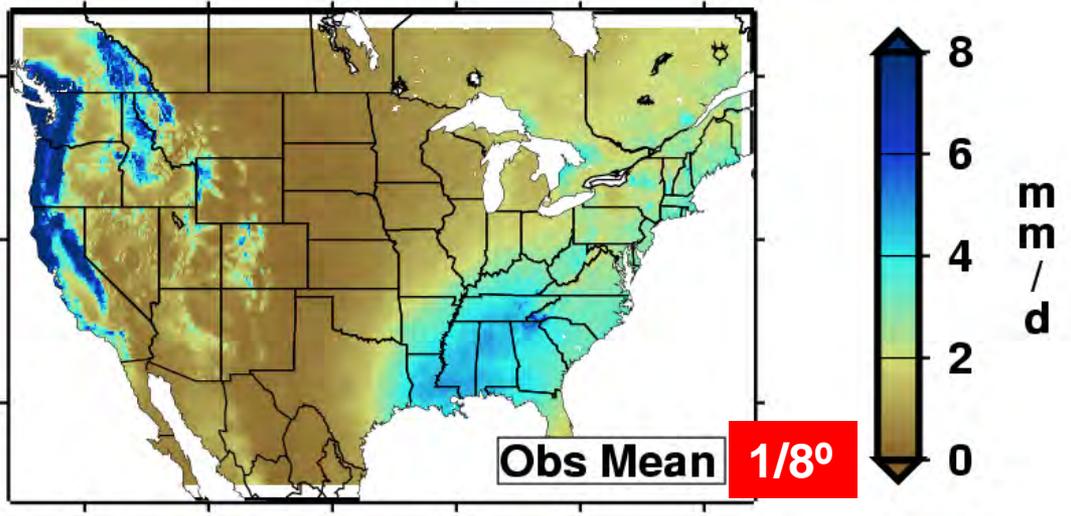
- Progress through GCM projection time-series, by time step and grid point...



**Figs: A. Wood, CBRFC**

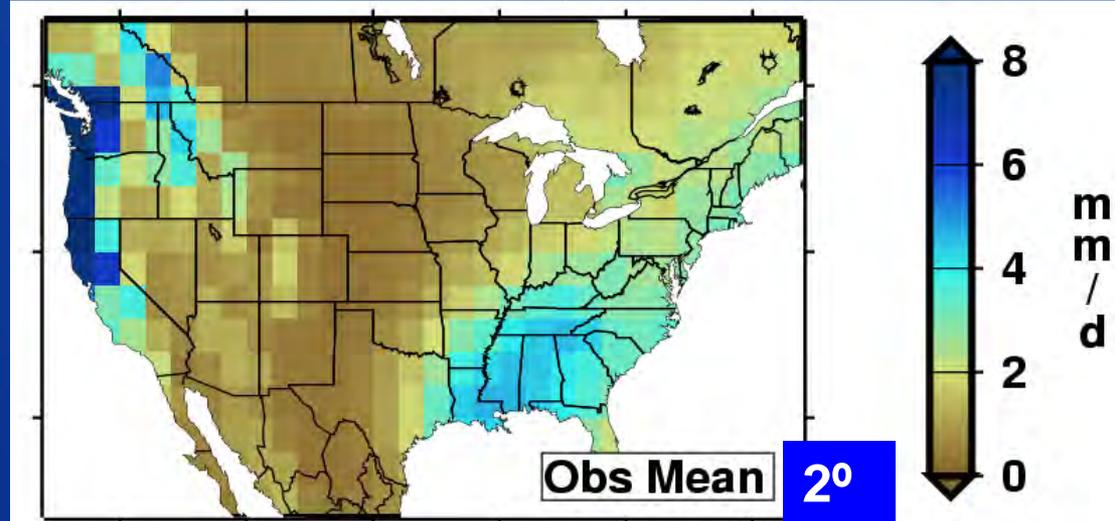
# BCSD: Spatial Downscaling

## 1. Get reference historical pattern



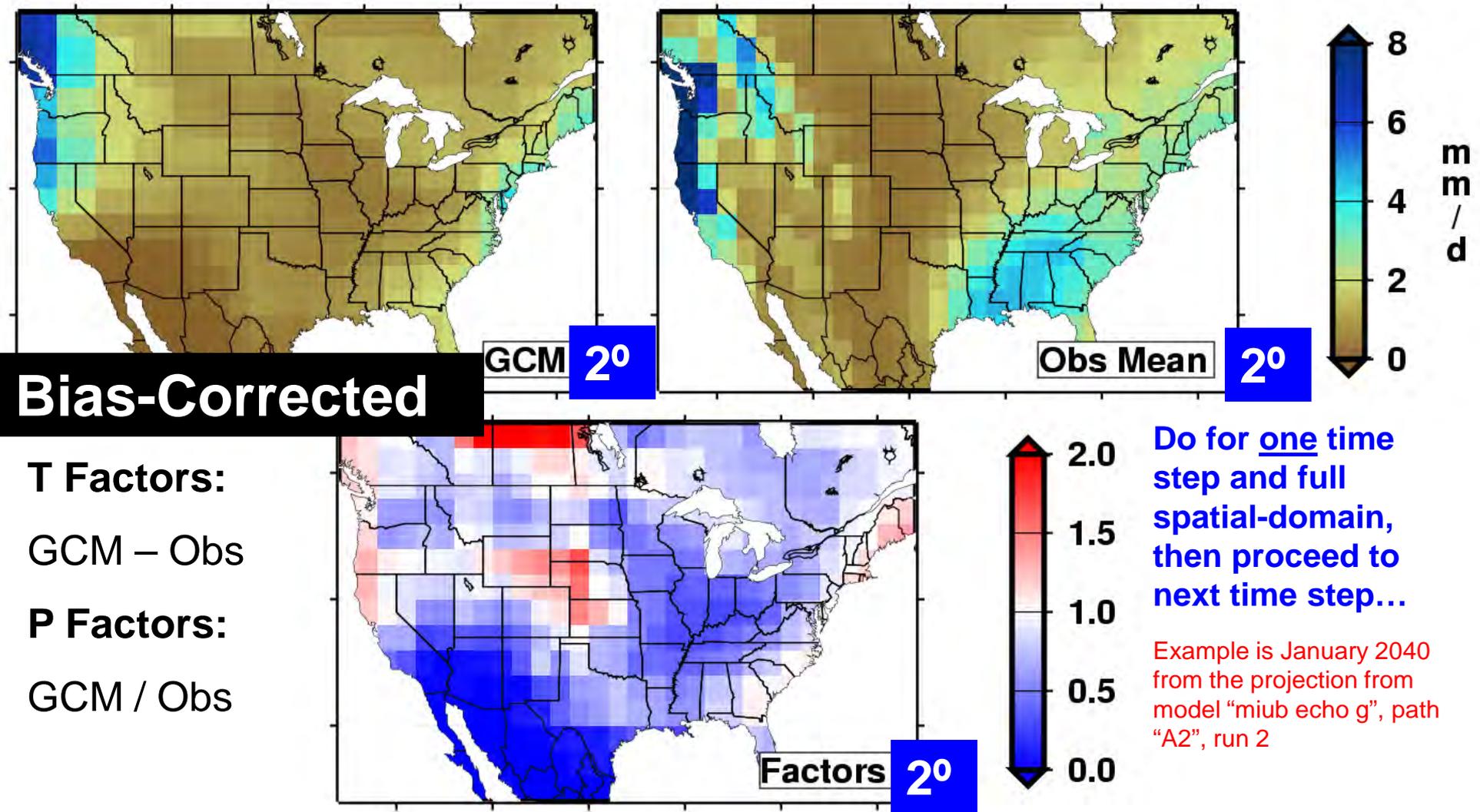
Subjective, e.g., 1950-1999 month mean conditions (OBS, from Maurer et al. 2002)

Aggregate pattern to  $2^\circ$  grid, same resolution used in bias-correction



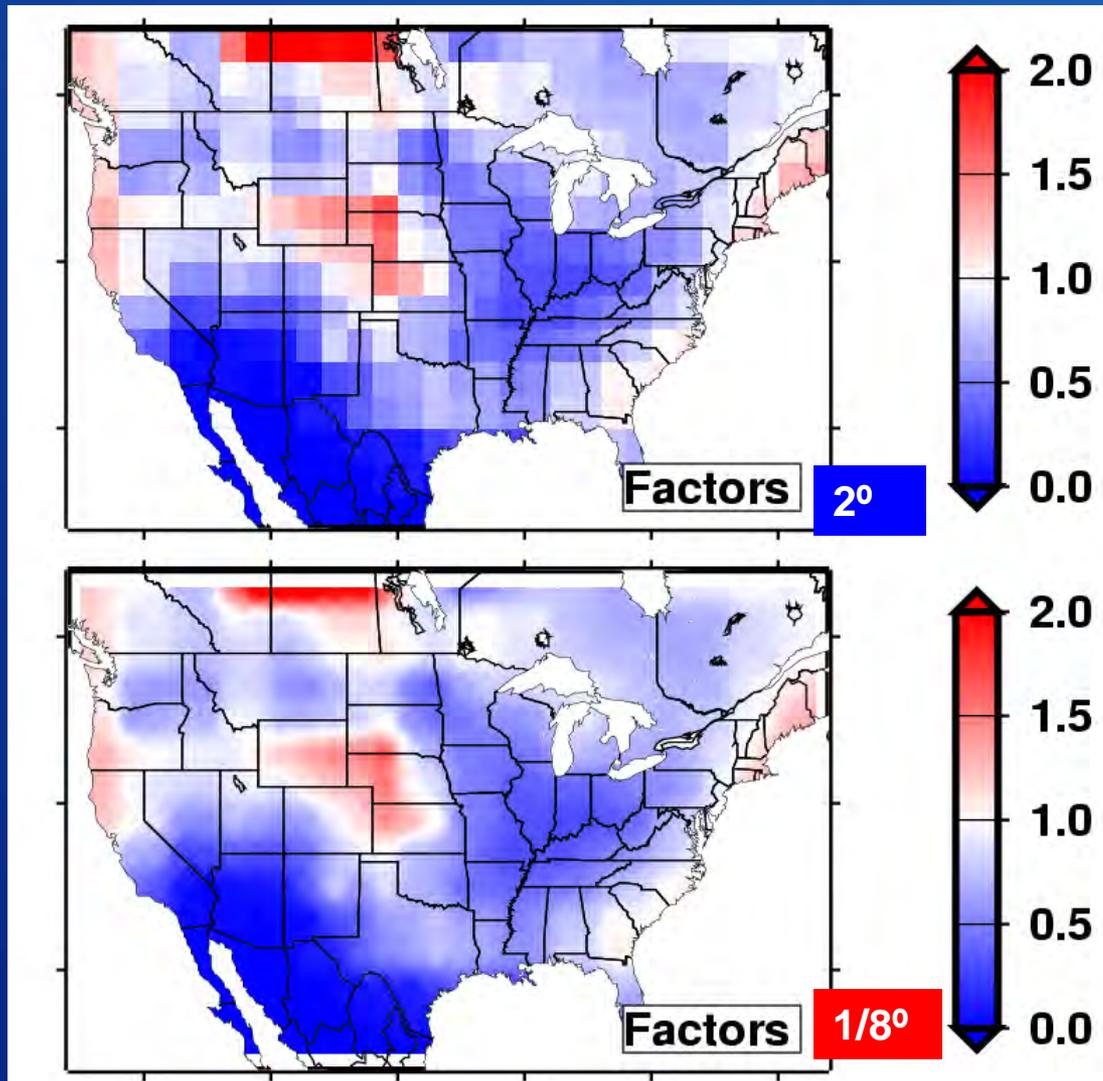
# BCSD: Spatial Downscaling

## 2. Compute Factors



# BCSD: Spatial Downscaling

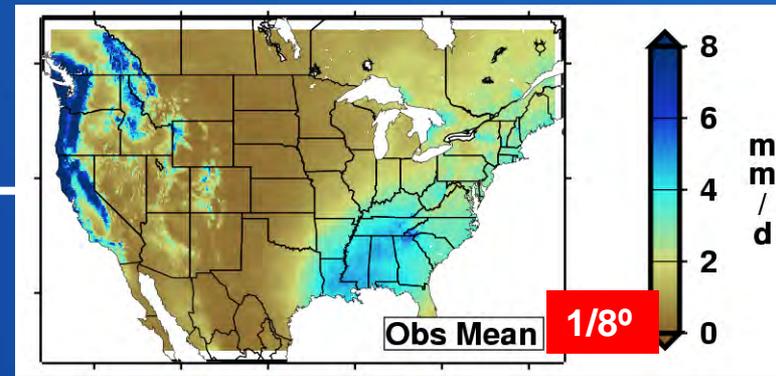
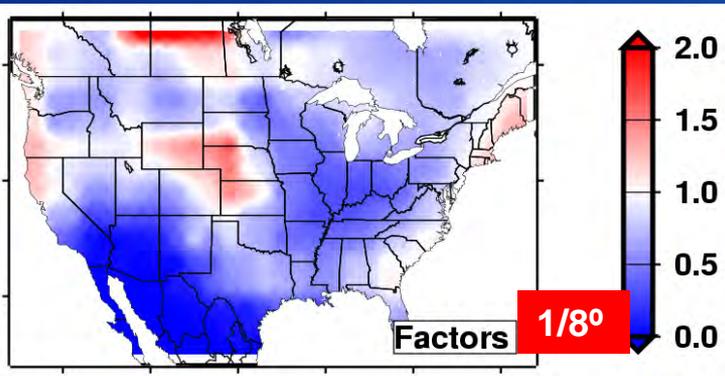
## 3. Disaggregate Factors



Two-way  
interpolation  
scheme, using  
SYMAP  
algorithm  
(Shepard,  
1984)

# BCSD: Spatial Downscaling

## 4. Merge Factors and Historical Pattern

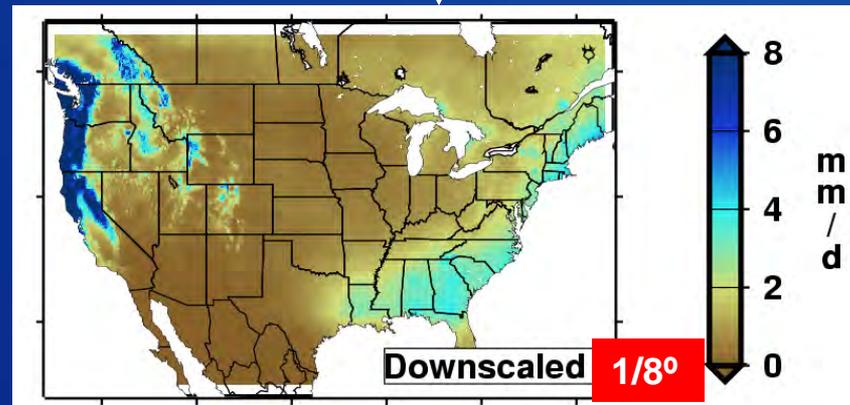


**T Merge:**

Obs Mean +  
Factors

**P Merge:**

Obs Mean x  
Factors



This time step  
has been  
downscaled...  
move on to  
next time step.

# BCSD Uncertainties

- Bias-Correction:
  - Reasonable to regrid GCM output from native to  $2^\circ$ ?
  - Reasonable to assume constant bias into the future?
  - Reasonable to independently bias-correct T and P?
- Spatial Downscaling
  - Significance of assuming “stationarity” in relation between large-scale circulation and local surface climate?
    - Will spatial datum pattern be relevant in the future?
    - Recent findings... (Wood et al. 2004, Salathe et al. 2007)
  - Reasonable to interpolate “Factors”? ( $2^\circ$  to  $1/8^\circ$ )