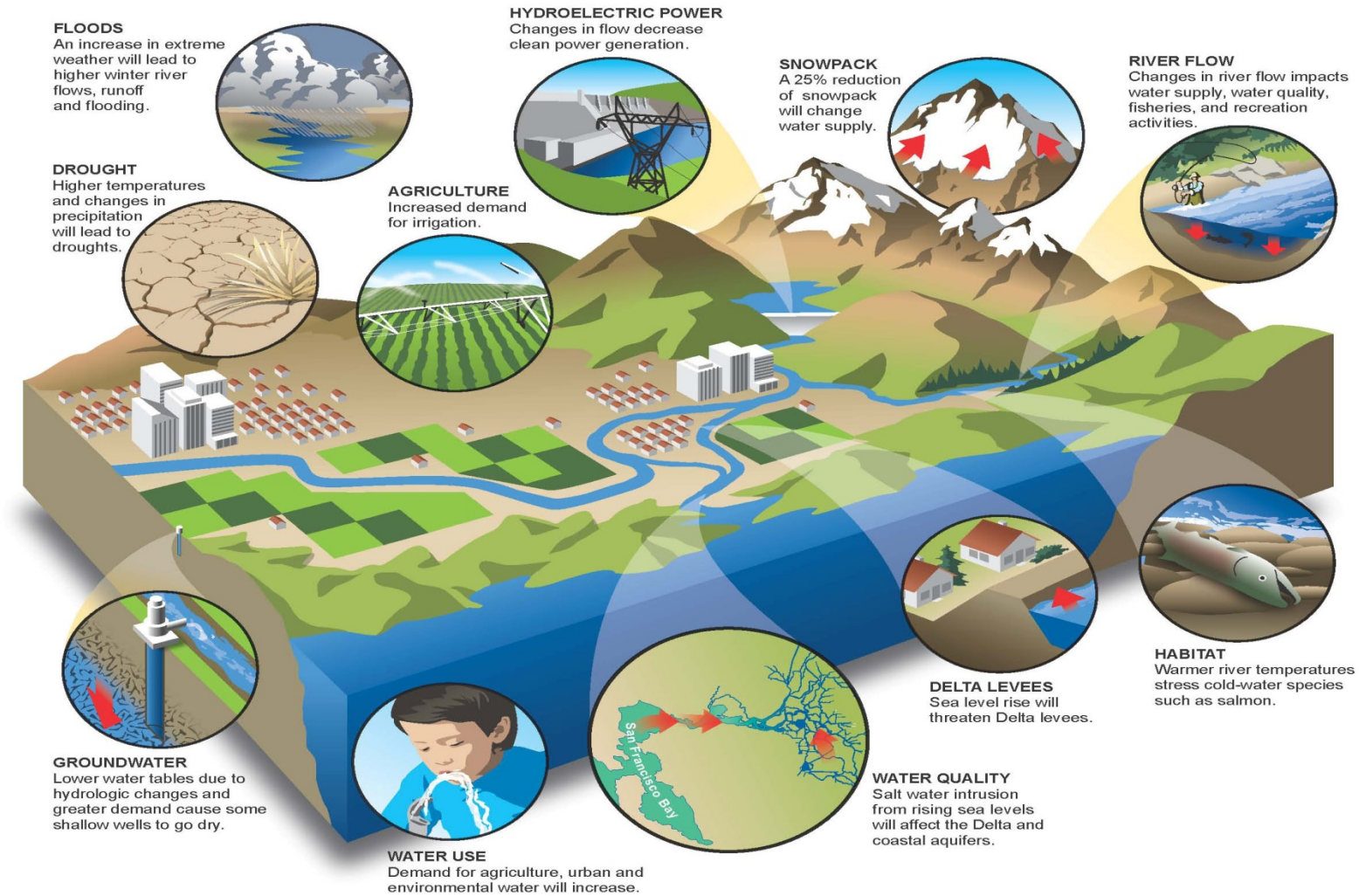
Experience with Downscaling Techniques at DWR

DFG USGS and USFWS Downscaling Workshop
November 3, 2010

Francis Chung, Ph.D., P.E.

How climate change impacts a watershed



Three Step Approach

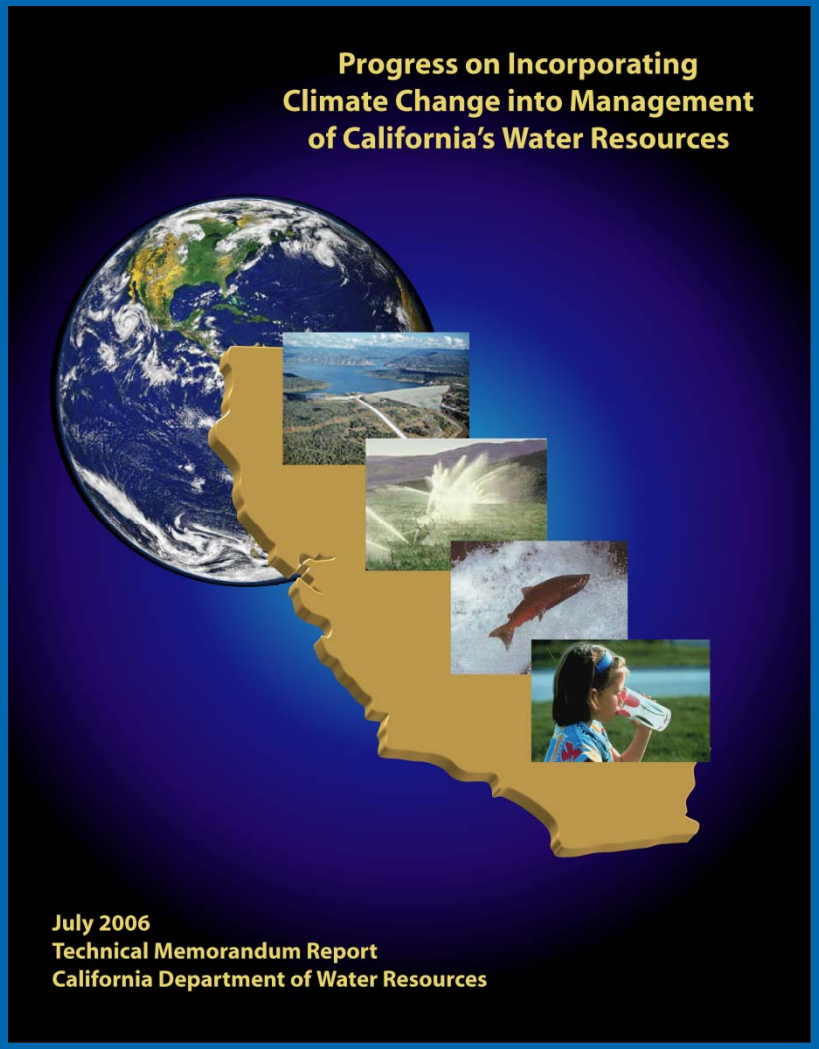
- Monitor: detect long-term trend
- Project Future: estimate system response under uncertainty
- Plan and Implement Response: Robust, Adaptive

Sacramento-
San Joaquin
Delta

Temperature and Global Water

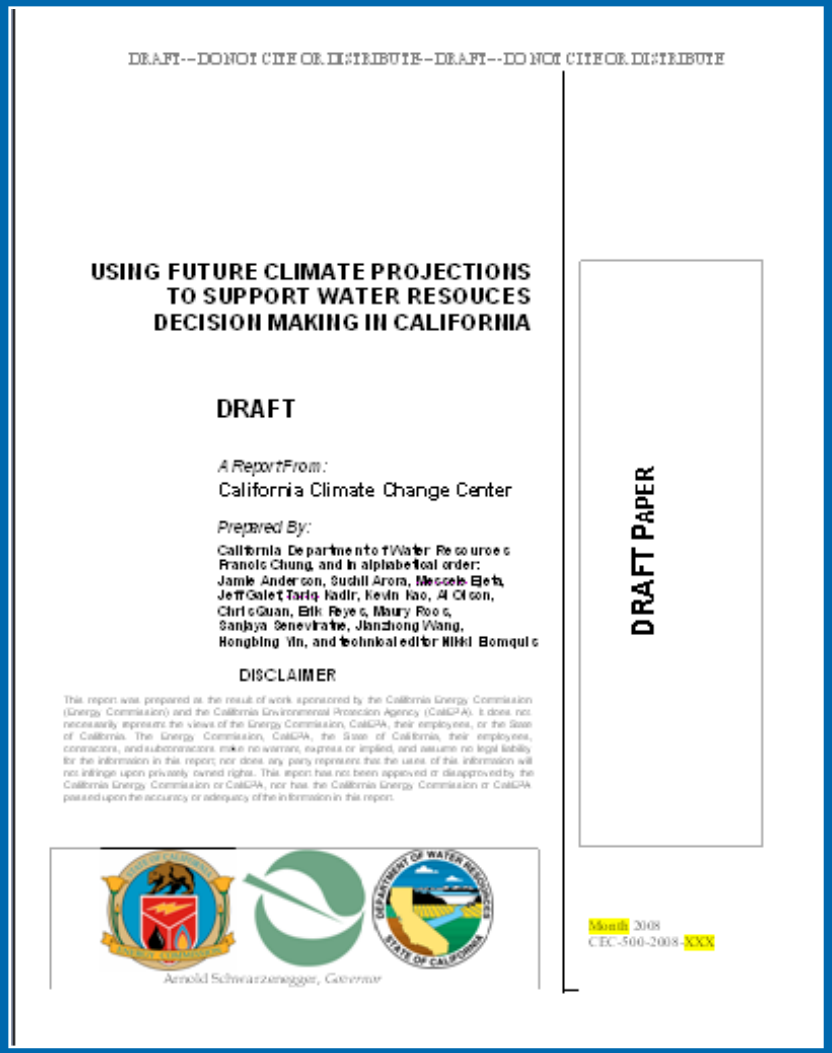
2006 Report

4 Scenarios (2 GCM x2 GHG)



2009 Report

12 Scenarios (6 GCM x2 GHG)



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USING FUTURE CLIMATE PROJECTIONS
TO SUPPORT WATER RESOUCES
DECISION MAKING IN CALIFORNIA

DRAFT

A Report From:
California Climate Change Center

Prepared By:
California Department of Water Resources
Francis Chung, and in alphabetical order:
Jamie Anderson, Sushil Arora, Messele Ejeta,
Jeff Galef, Tariq Kadir, Kevin Kao, Al Olson,
Chris Quan, Erik Reyes, Maury Roos,
Sanjaya Seneviratne, Jianzhong Wang,
Hongbing Yin, and technical editor Nikki Elomquis

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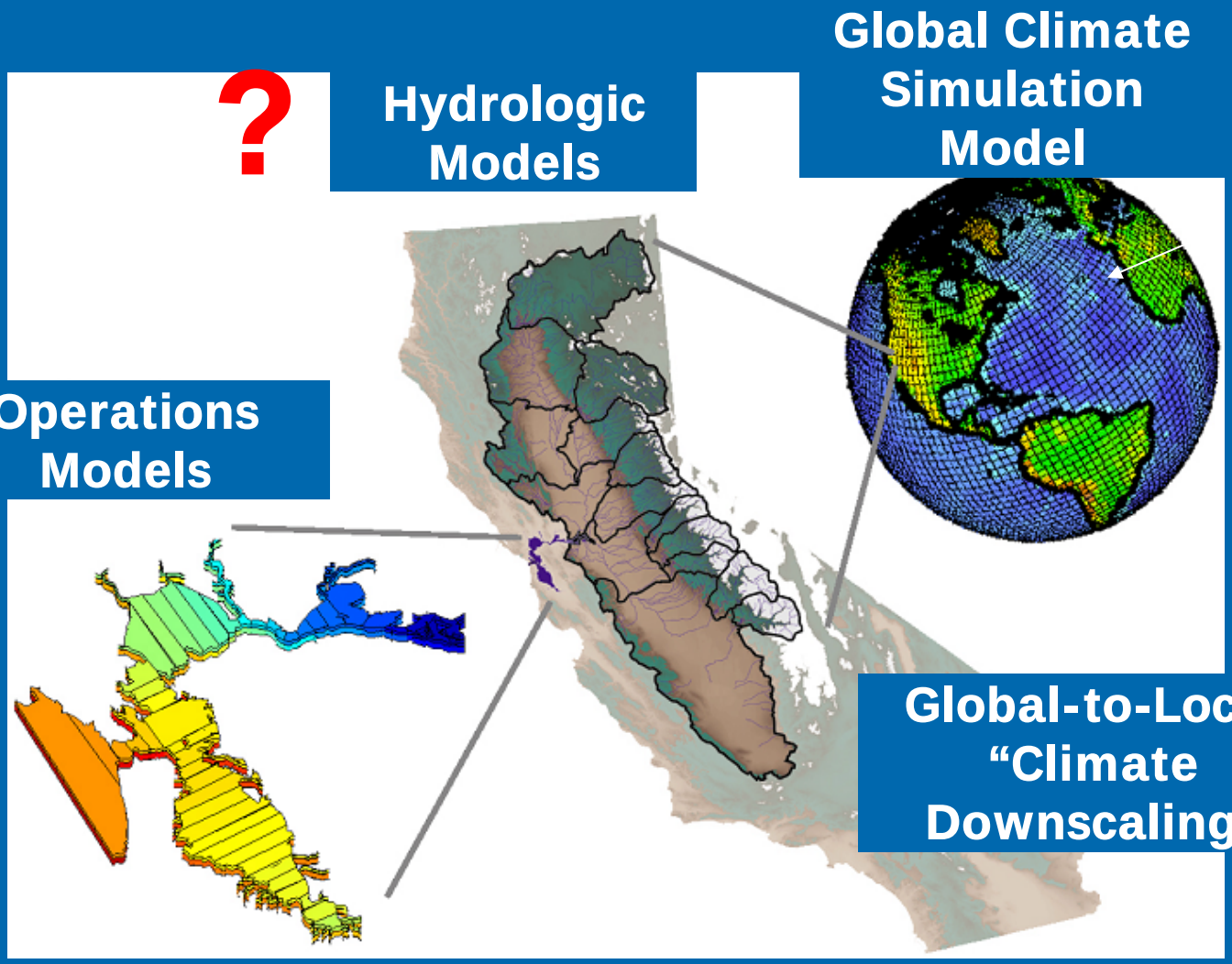
Arnold Schwarzenegger, Governor

DRAFT PAPER

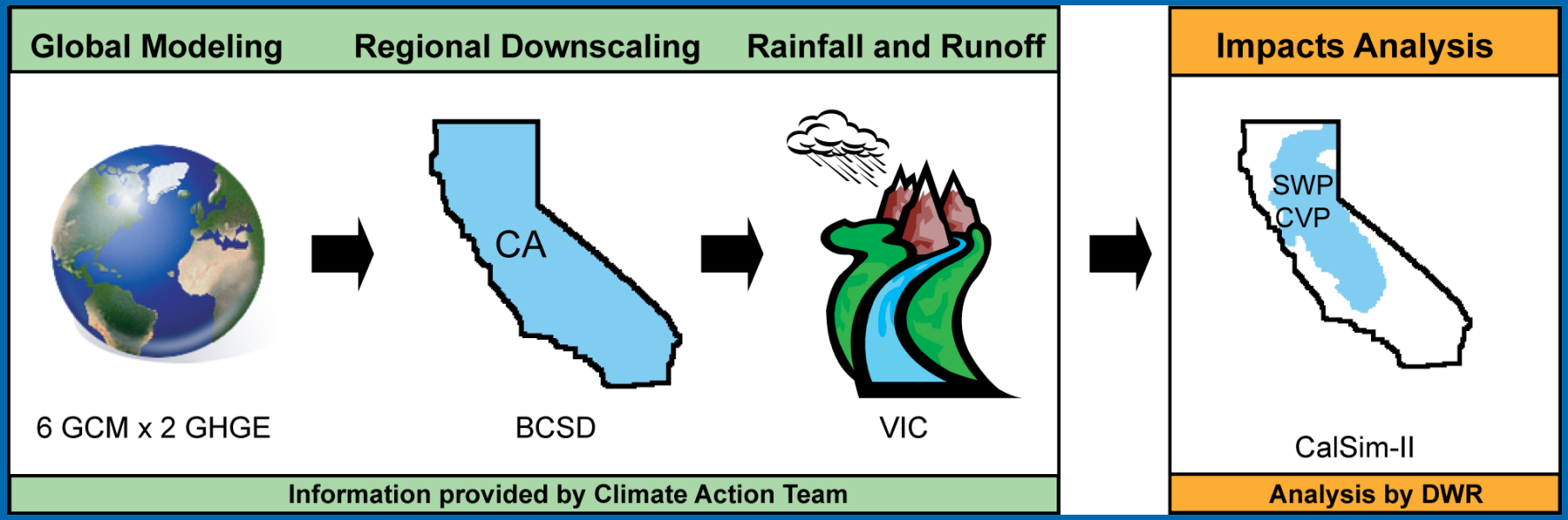
Month 2008
CEC-500-2008-XXX

We've got Issues!



Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

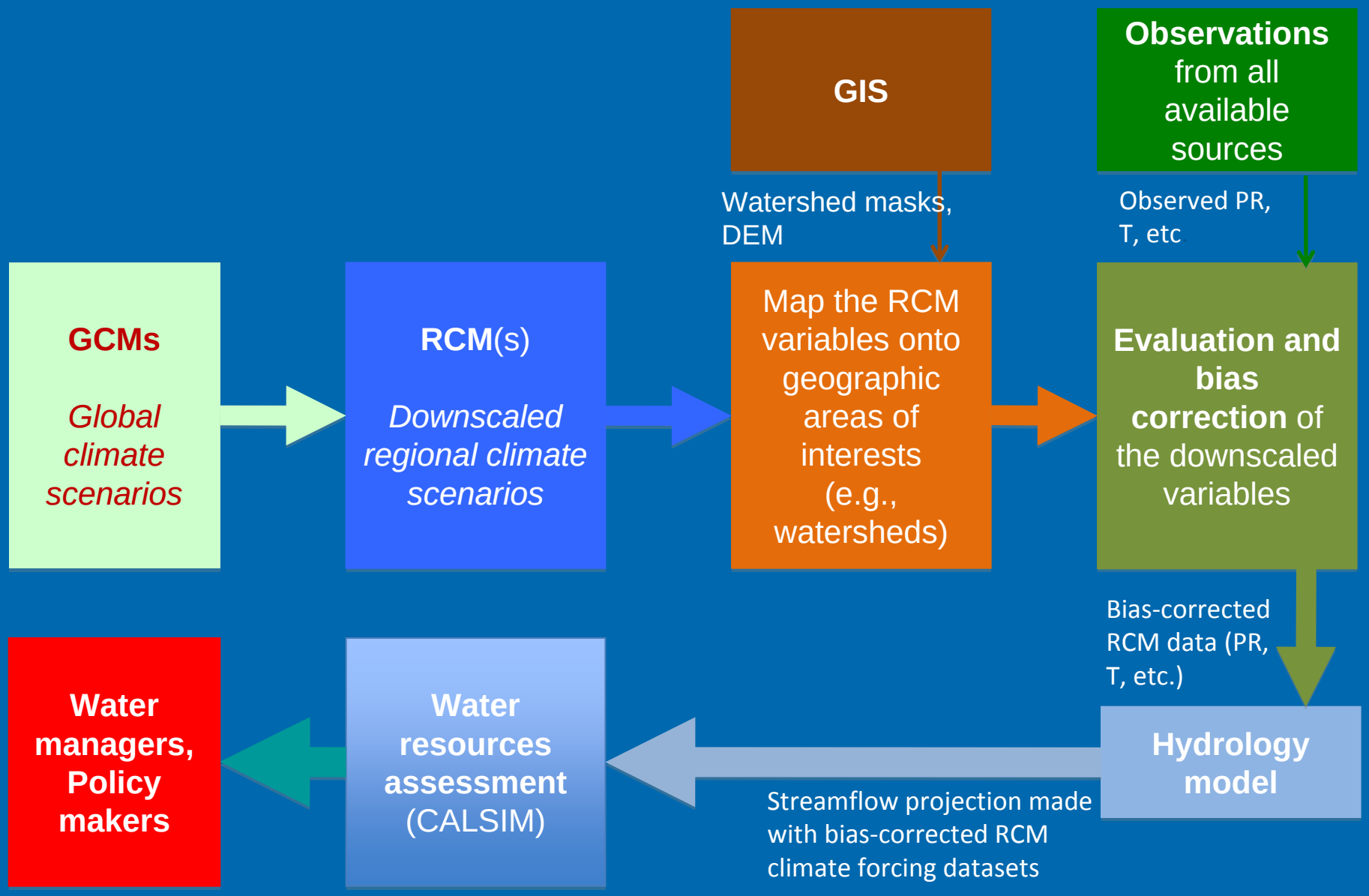
SWP-CVP Impact Assessment Methodology



- 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 Resources

A schematic illustration of regional climate projection and water resources assessment



Slide from Jinwon Kim, UCLA

Schematic of Procedures

DWR Climate Change Studies

	CAT Assessments		BDCP
	2006	2009	Ongoing
Downscaling	BCSD	BCSD, CA	BDCP
# Scenarios	4	12	5
Type of scenarios	Individual GCM model for a specific GHGE scenario		Info. from 116 GCM runs

BDCP = Bay Delta Conservation Plan
CA = Constructed Analog Downscaling
GHGE = Greenhouse Gas Emissions
BCSD = Bias Corrected Spatial Downscaling
GCM = Global Climate Model

2009 CAT Future Climate Scenarios

6 Global Climate Models

- GFDL-CM2.1 (USA)
- NCAR-PCM1 (USA)
- CNRM-CM3 (France)
- MPI-ECHAM5 (Germany)
- MIROC3.2med (Japan)
- NCAR-CCSM3 (USA)

2 GHG Emissions Scenarios

- A2 (higher GHG emissions)
  - high population growth
  - regional economic growth
  - fragmented technological changes
- B1 (lower GHG emissions)
  - low population growth
  - rapid economic growth
  - sustainable technology

12 Total Scenarios = 6 GCM x 2 GHG Emissions Scenarios

How to Make Use of Downscaled Precipitation and Temperature ?

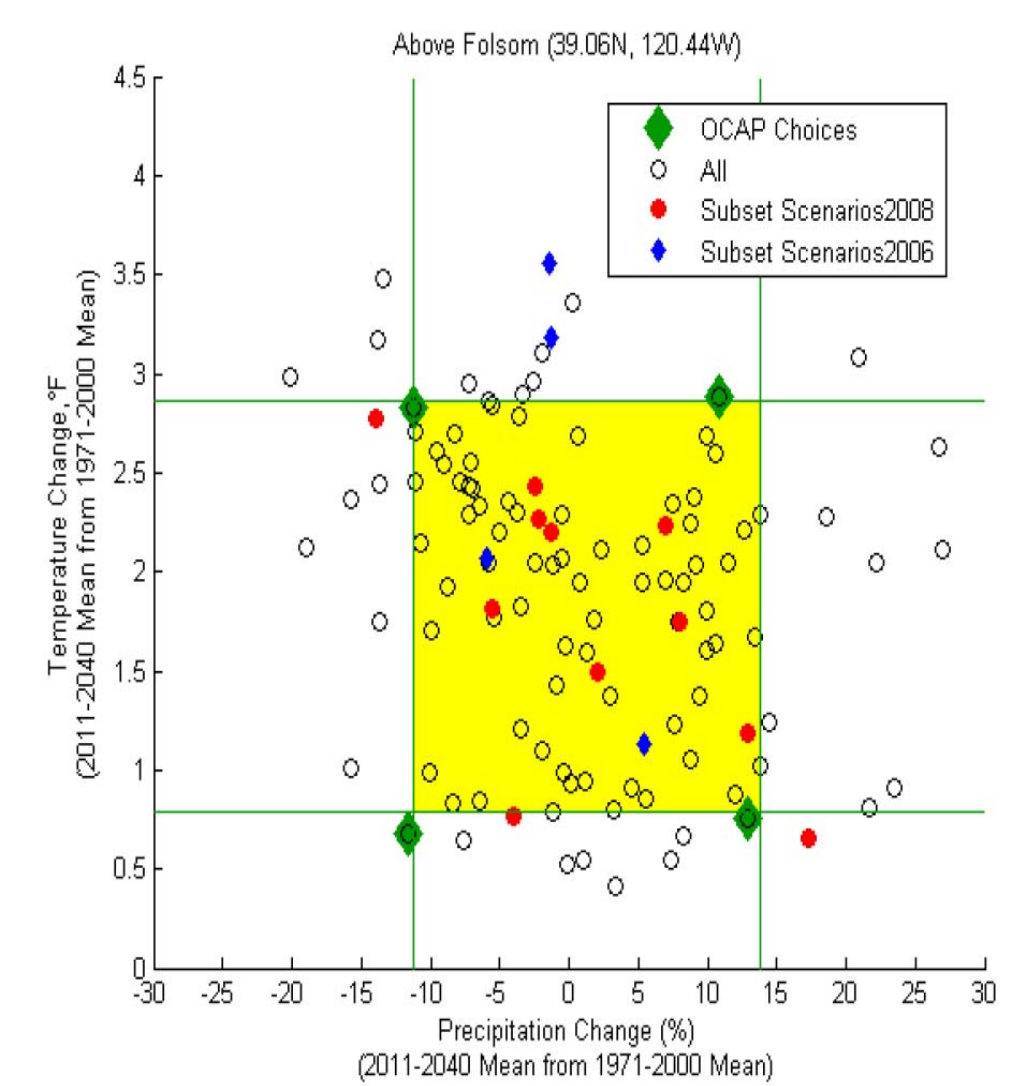
- 112 downscaled climate model projections by BCSD (Bias Correction Statistical Disaggregation), Including:

  16 GCMs, 3 emission Scenarios (A2, B1, A1B), and ensemble runs (1 to 7)

#	WCRP CMIP3 Model I.D.	# A1b	# A2	# B1
1	BCCR-BCM2.0	1	1	1
2	CGCM3.1 (T47)	1…5	1…5	1…5
3	CNRM-CM3	1	1	1
4	CSIRO-MK3.0	1	1	1
5	GFDL-CM2.0	1	1	1
6	GFDL-CM2.1	1	1	1
7	GISS-ER	1	2, 4	1
8	INM-CM3.0	1	1	1
9	IPSL-CM4	1	1	1
10	MIROC3.2(medres)	1…3	1…3	1…3
11	ECHO-G	1…3	1…3	1…3
12	ECHAM5/MPI-OM	1…3	1…3	1…3
13	MRI-CGCM2.3.2	1…5	1…5	1…5
14	CCSM3	1…4	1…3, 5…7	1…7
15	PCM	1…4	1…4	2…3
16	UKMO-HadCM3	1	1	1

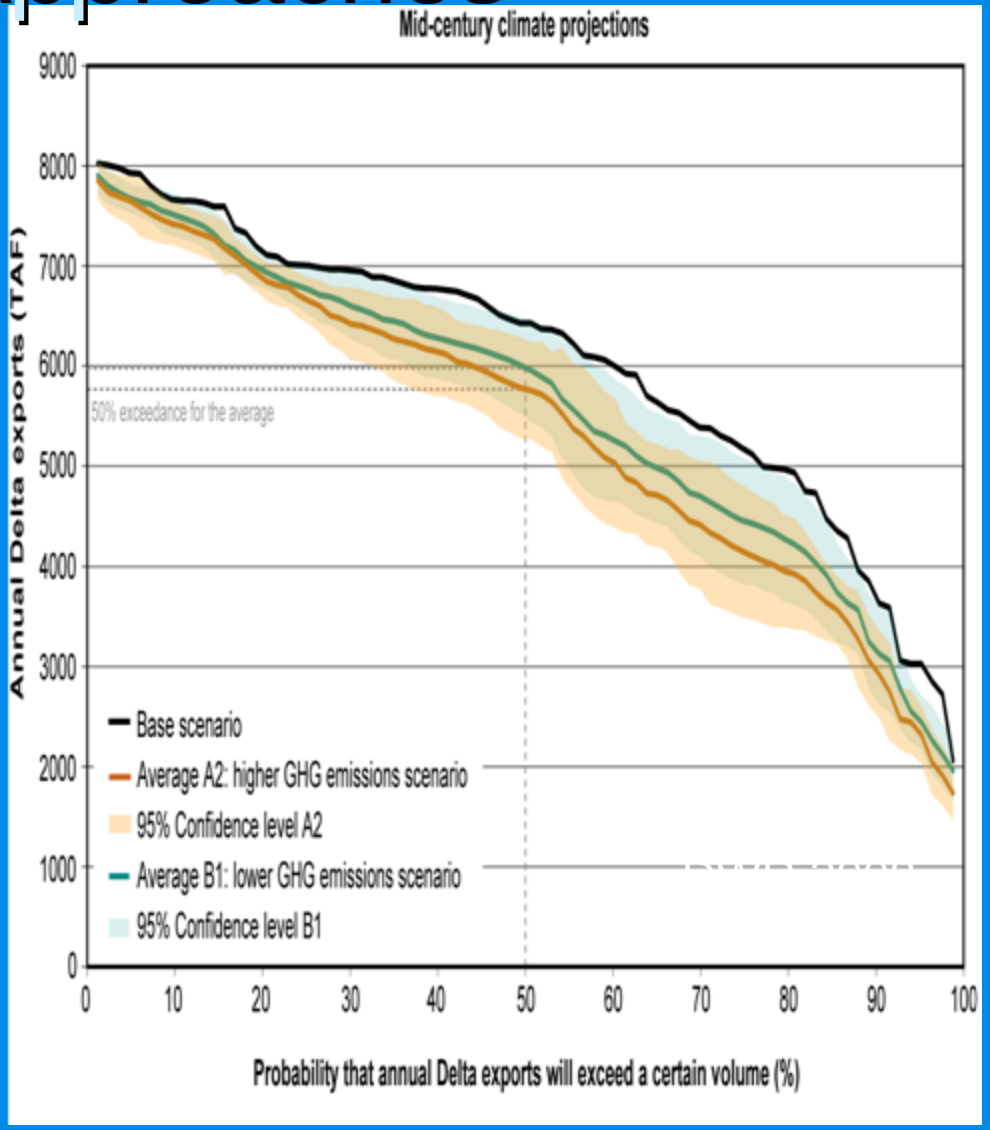
Current Climate Change Impact study approaches

- (1) Scenario Based
  - DWR 2006:
    NCAR PCM1 A2
    NCAR PCM1 B1
    GFDL CM2.0 A2
    GFDL CM2.0 B1
  - OCAP 2008 (nicknamed Bracket_Approach):
    MRI CGCM2.3.2a A2 (run 5)
    MRI CGCM2.3.2a A2 (run 2)
    NCAR CCSM3 A1B (run 3)
    UKMO HADCM3 A2 (run 1)



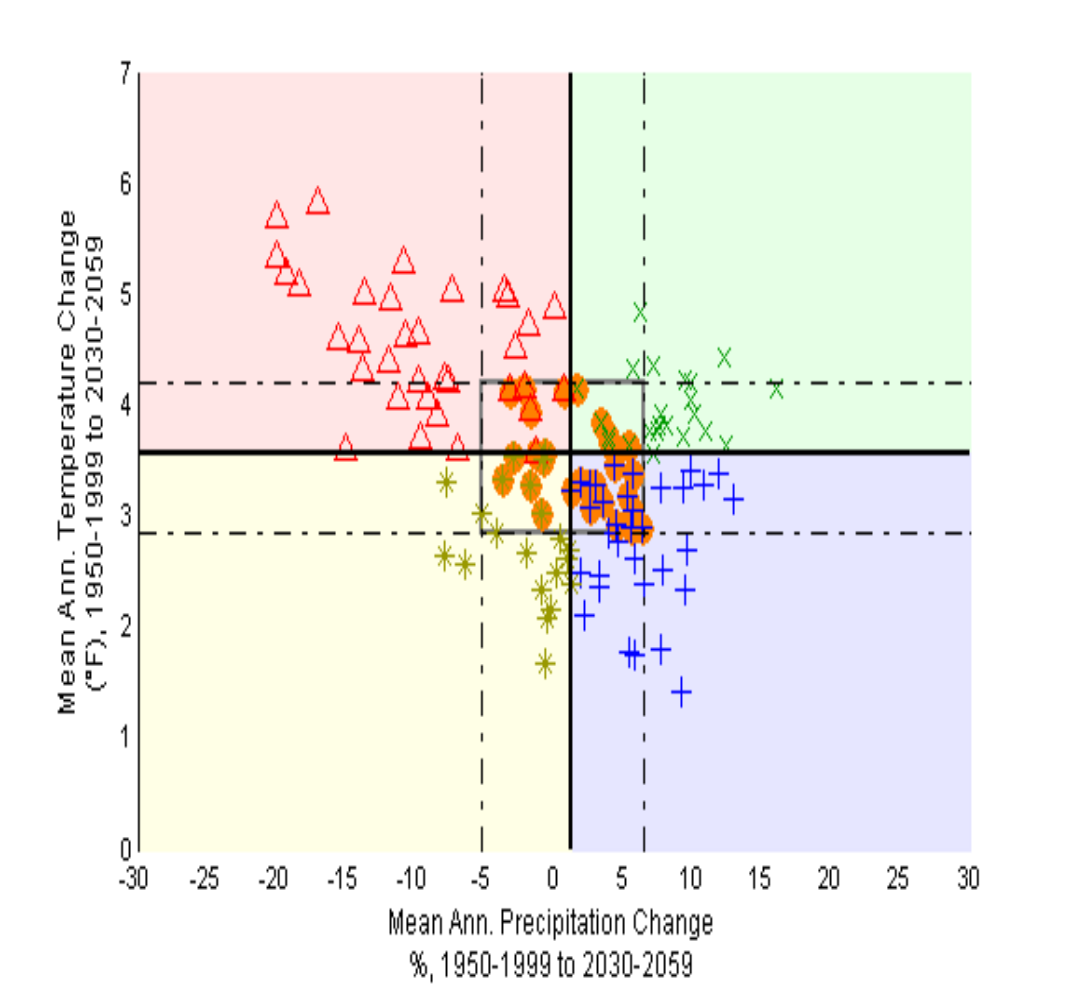
Current Climate Change Impact Study Approaches

- (2) Multiple Model Ensemble (or Probability) Based
  - DWR/CAT 2008: 6 GCMs and 2 emission scenarios (A2 and B1)
  - N. S. Christensen and D. P. Lettenmaier (2007): 11 GCMs and 2 emission scenarios (A2and B1)
  - California Vulnerability and Adaptation (V&A) project (2011): 16 GCMs, 2 emission scenarios (A2 and B1), and 2 downscaling methods (BCSD and BCCA)



Current Climate Change Impact study approaches

- (3). Ensemble Informed Approach
  - Climate and Hydrology Scenarios for Oklahoma Yield Studies (*Levi et al, 2010*)
  - BDCP (2010) (Armin et al)



Levi et al., 2010

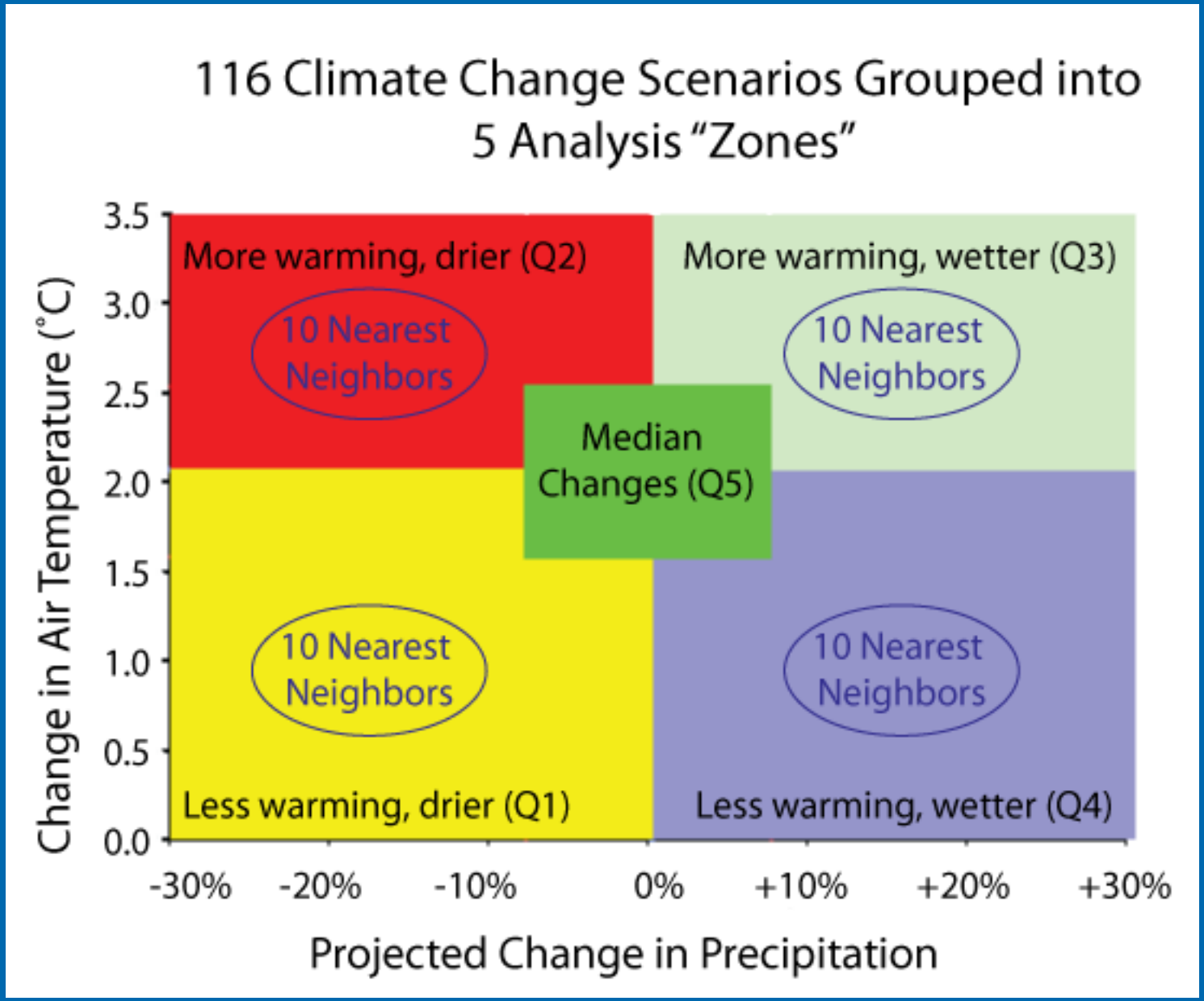
Why BDCP adopts Ensemble-Informed Approach (EIA)?

BDCP is evaluating

- *at least 4 full alternatives*
- *each alternative with differing restoration*
- *each alternative with operational ranges*
- *each alternative at various points in time*
- *roughly: 4 x 2 x 3 x 3 = 72 scenarios*

Incorporating climate and sea level uncertainty is a multiplier to the analytical effort.

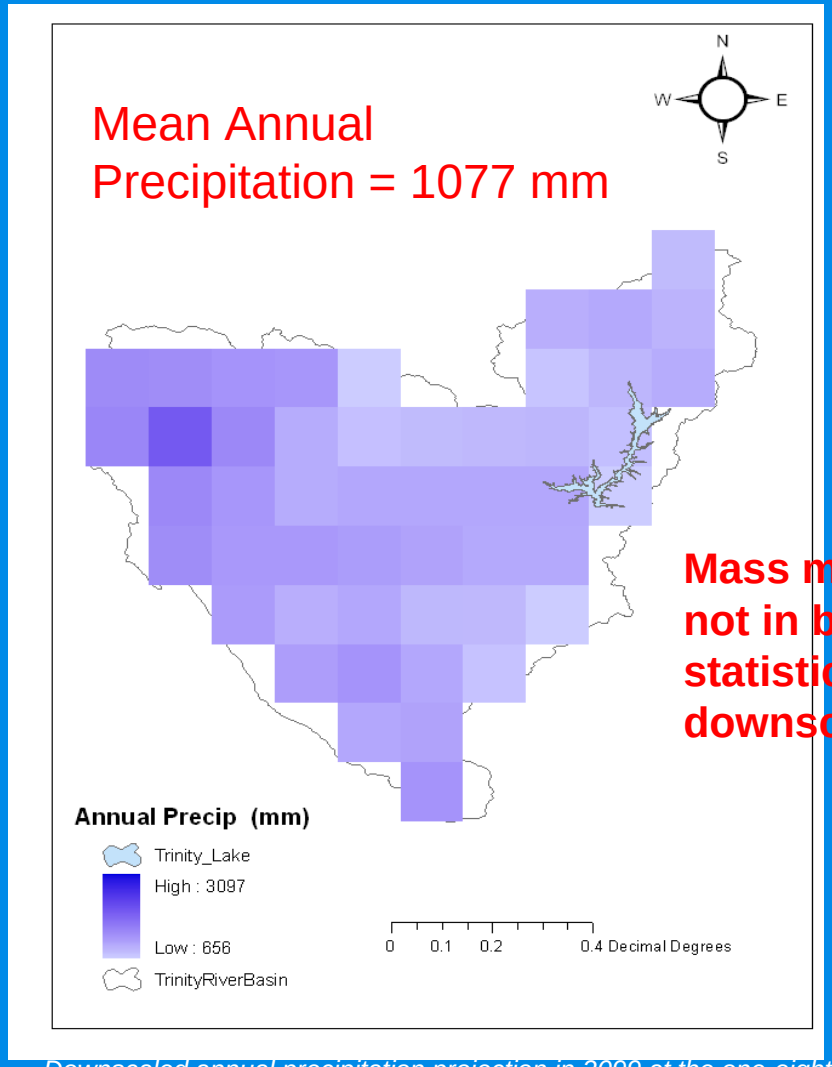
Basically, EIA reduces 112 downscaled climate model projections to 5 composite projections (Q1-Q5) to find median and ranges of climate change impact


116 Climate Change Scenarios Grouped into 5 Analysis "Zones"
More warming, drier (Q2)
More warming, wetter (Q3)
10 Nearest Neighbors
10 Nearest Neighbors
Median Changes (Q5)
10 Nearest Neighbors
10 Nearest Neighbors
Less warming, drier (Q1)
Less warming, wetter (Q4)
Change in Air Temperature (°C)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-30%
-20%
-10%
0%
+10%
+20%
+30%
Projected Change in Precipitation

Higher Resolution Downscaling at DWR (Jay Wang)

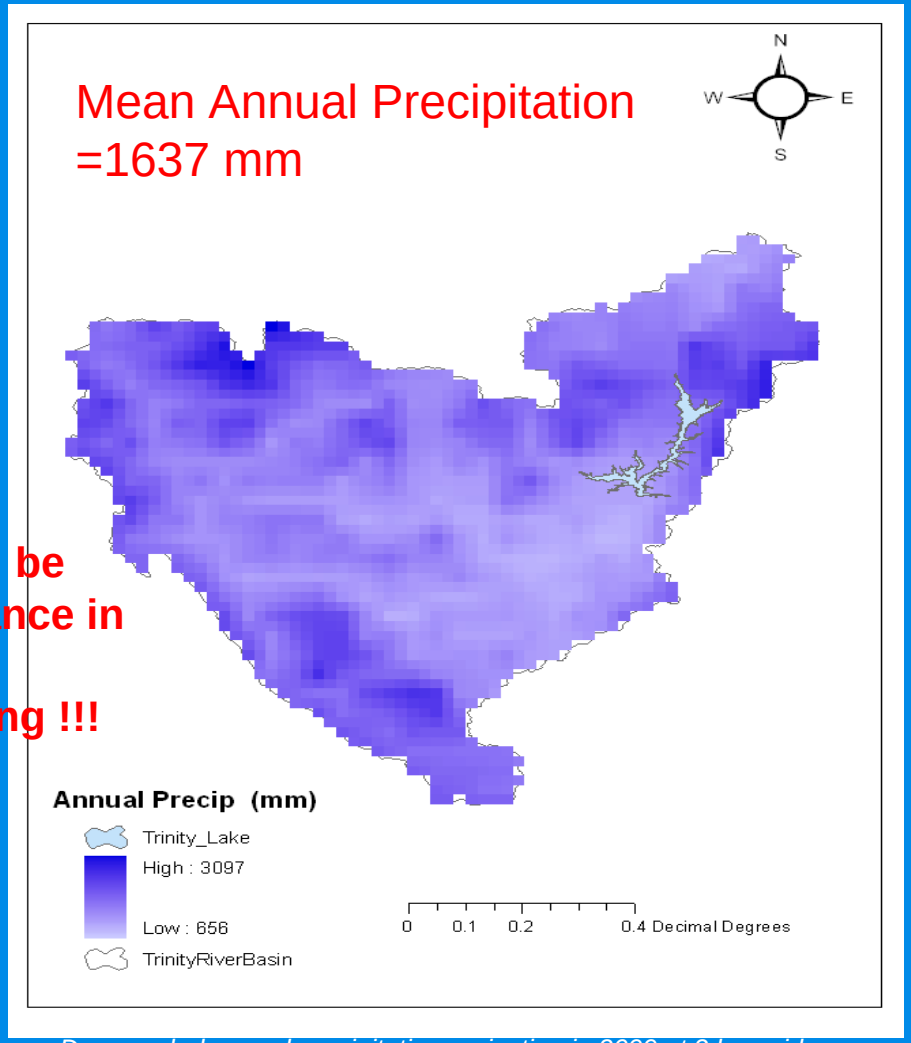
- Bias Corrected Spatial Downscaling
  - From 2km
  - Validated for precipitation and surface temperature
    - spatial distribution,
    - monthly variations
    - long term trends
    - compared with the existing 1/8° (~12km) downscaled data

Comparison Between 1/8° and 2km PRISM-based Downscaled Product



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

Mass may be not in balance in statistical downscaling !!!



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

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

GC21, AGU Fall Meeting, 13-17 December 2010
San Francisco, California

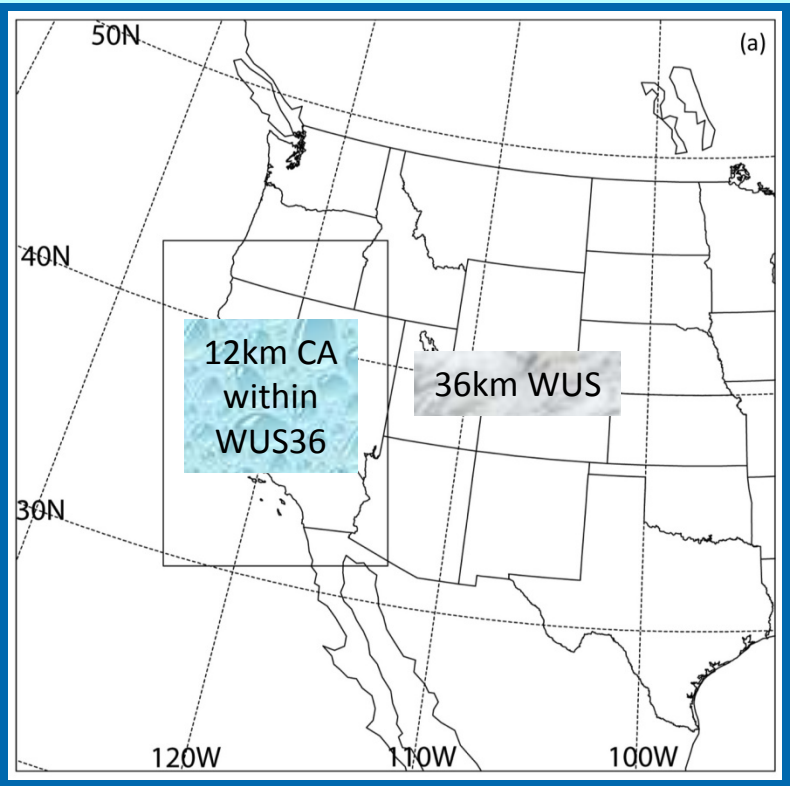
Francis Chung1, Jinwon Kim2, Xiaogang Gao3, Soroosh Sorooshian3, Duane E. Waliser2,4, Messele Z. Ejeta1, and Jay Wang1

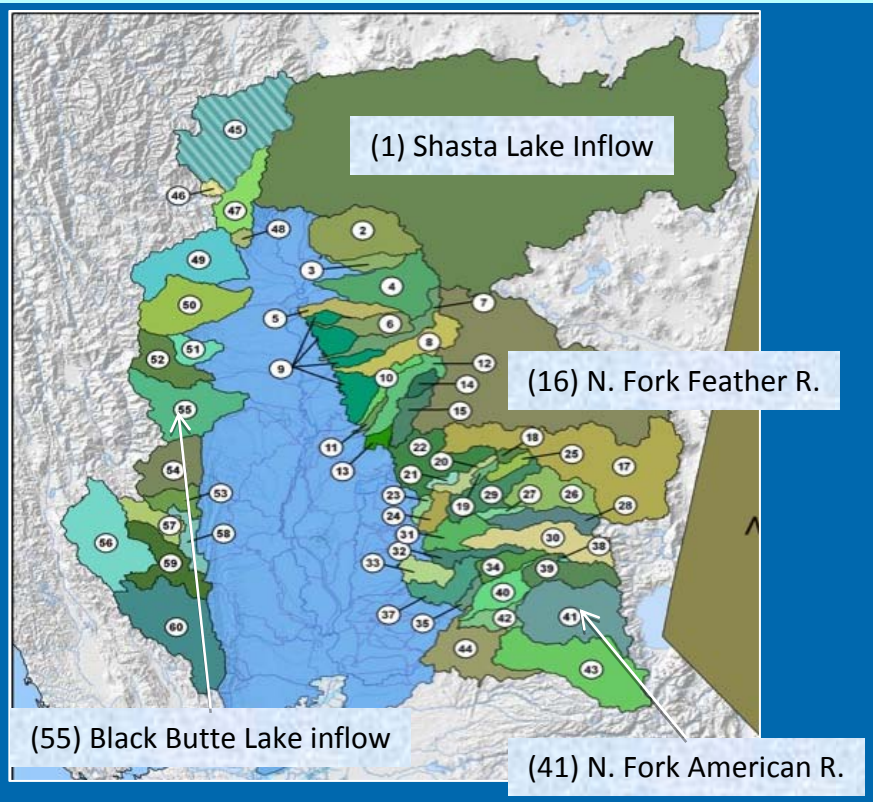
1California Department of Water Resources
2Joint Institute for Regional Earth System Science and Engineering
3University of California, Irvine
4Jet Propulsion Laboratory/California Institute of Technology

Downscaling: *Dynamical vs. Statistical method*

- Statistical methods are based on *statistical relationships between predictors and predictands established in the past climate records*
  - 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*
- Dynamical downscaling utilizes regional climate models
- Dynamical/physical consistency among downscaled variables are generally maintained – *Can be a 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 formulations*
- Thorough evaluation of climate models (and their results) is necessary

Regional Modeling and the CA Watersheds



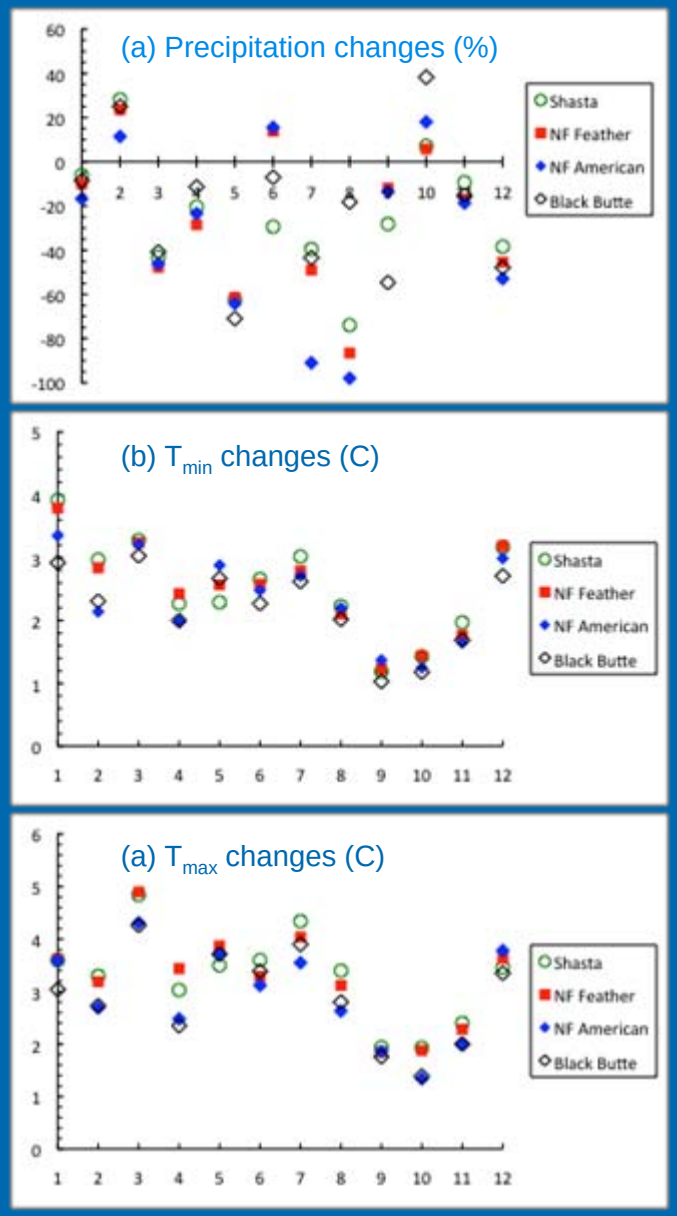


- The WRF version 3.0.1 has been used for a one-way nested WUS-CA domain
- The global climate scenario from *NCAR CCSM3* based on the *SRES-A1B emissions* is used to drive the RCM
- The mid-21st century climate change signals are calculated as the differences between the means over the two 10-year periods,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

Climate Change Signals



- The climate change signals are calculated from the control and the mid-21st century runs as:
- **PRECIP**: *Percentage of the control*: [$\text{Signal}_P=(P_{\text{mid-21}}-P_{\text{CNTL}})/P_{\text{CNTL}}$]
- **TEMPERATURE**: *Differences*: [$\text{Signal}_T = T_{\text{mid-21}} - T_{\text{CNTL}}$]
- 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.

Concluding Thoughts …

- Planning under uncertainty
  - Noise vs. Signal
- Define the study purpose and scope and determine the need on climate information
  - Sensitivity study
  - Book End study
  - Compatibility with other scientific information
- Experiment on the level of spatial and temporal detail
  - Select the downscaling scheme
  - Decide on an approach: Average, Range, Scenario or Ensemble
- Be aware on the variations on projections and interpret the results accordingly

Thank you!

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