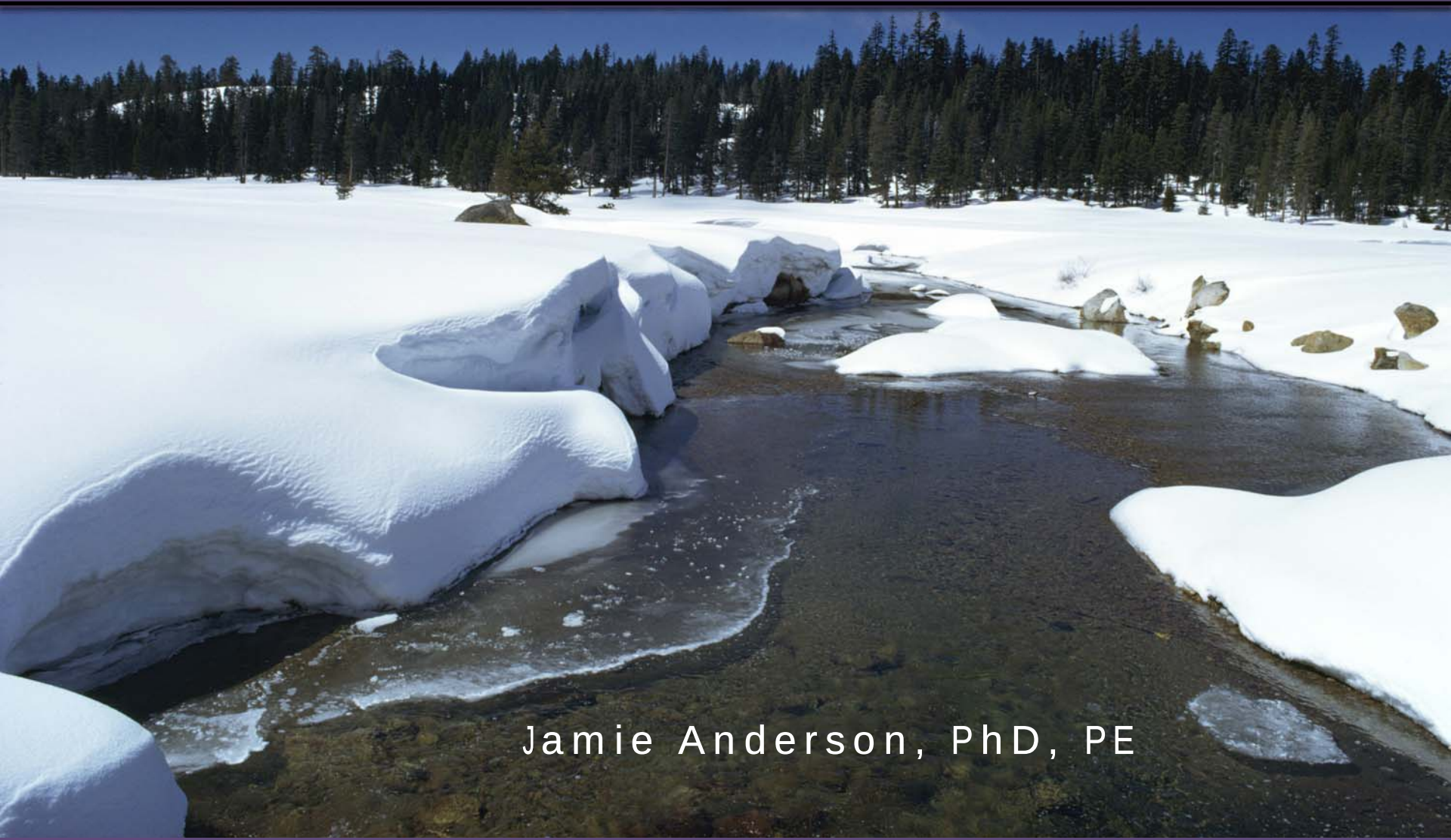
Climate Change Approaches



Jamie Anderson, PhD, PE

DWR Climate Change Approaches

Qualitative	Relative Change	Scenario Based	Ensemble Approach
Conceptual discussion	Based on general information apply a change factor to variables of concern	Use selected downscaled GCM simulations	Use multiple downscaled GCM simulations grouped into an ensemble(s)
Los Vaqueros EIR/S	Monterey Plus PEIR	CAT Report 2009 Water Plan 2009	Bay Delta Conservation Plan

CAT = Climate Action Team
GCM = Global Climate Model

Acknowledgements

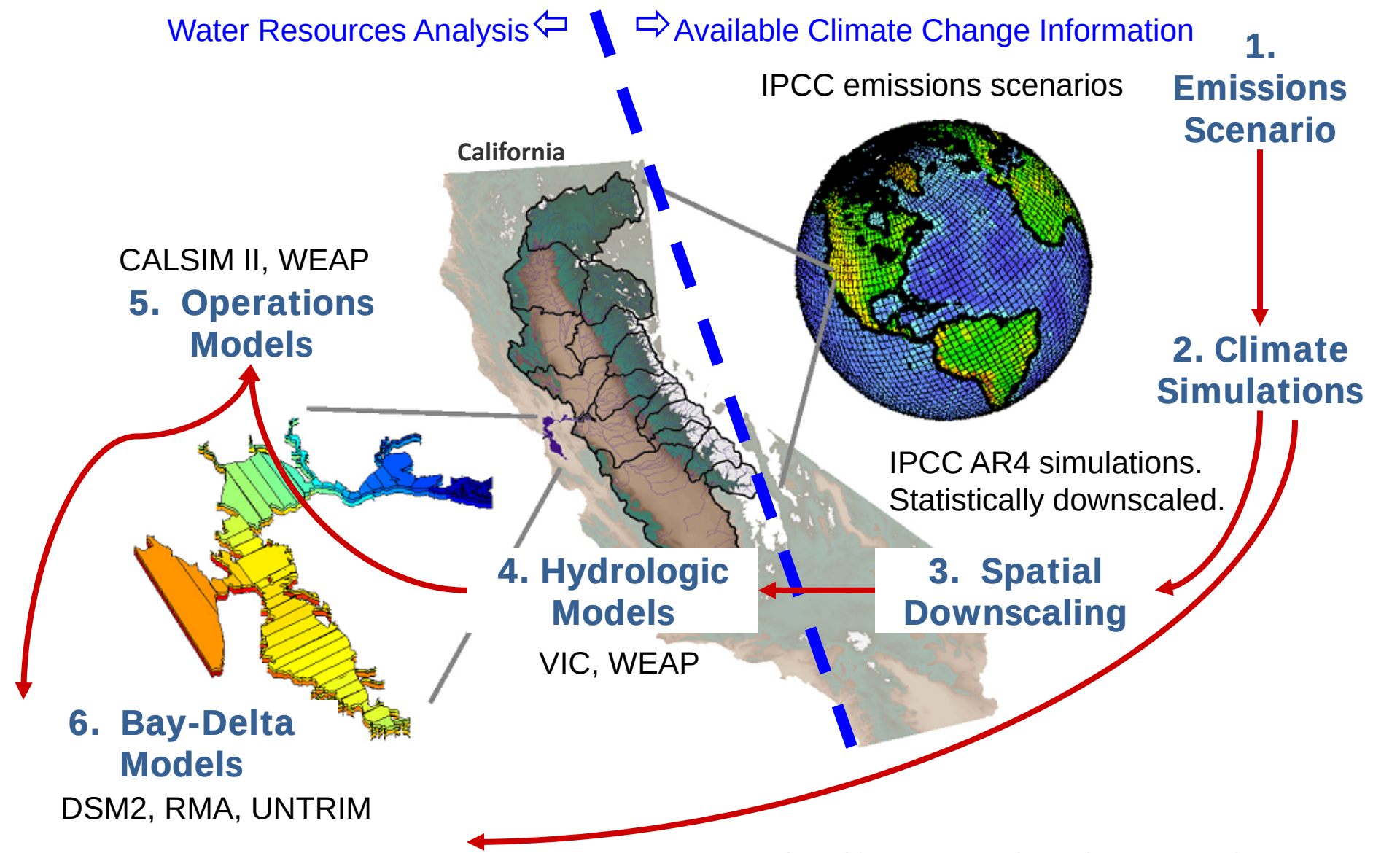
- U.S. Bureau of Reclamation
  - Levi Brekke
- CH2MHill
  - Armin Munevar
- NOAA Fisheries
  - Frank Schwing
- U.S. Fish and Wildlife Service
  - Derek Hilts, Dan Cox
- Scripps Institute of Oceanography
  - Dan Cayan, Mike Dettinger, Tapash Das

DWR Planning Studies

General Planning Studies
(high level, informational)

Project Level Studies
(detailed, decision documents)

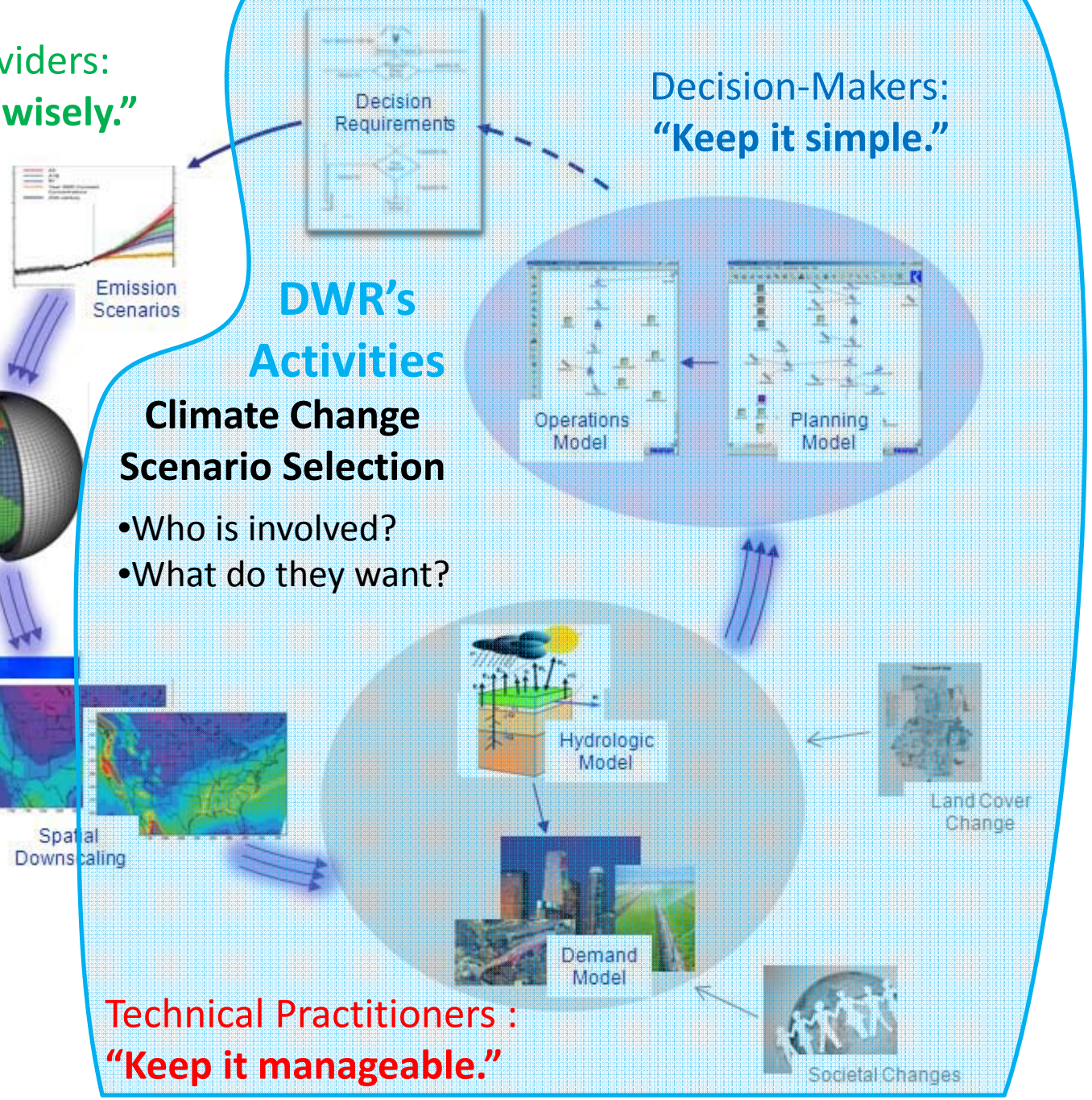
Characterizing Climate Change Impacts
Atmosphere to Ocean



Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

Climate Information Providers:
"Here's the info… use it wisely."

Decision-Makers:
"Keep it simple."



Technical Practitioners :
"Keep it manageable."

Adapted from Levi Brekke USBR

Goals for long term planning climate change scenarios

- Reflect range of available climate change projections
- Focus on information relevant to water resources
- Address uncertainty and changes in variability
- Provide a manageable number of scenarios

Example: BDCP EIR-EIS Alternatives Assessment

72 X 5 = 360 Alternatives

Full Alternative	X	Operations Options	X	Restoration Options	X	Analysis Period	X	**Climate Change Scenarios**
4	X	3	X	2	X	3	X	5

- Make it understandable for non-technical folks

Scenario Selection

How should I create my climate change scenarios?

1) Scenarios from individual GCM runs based on specified criteria
   - Climate Action Team (CAT)

2) Individual GCM runs selected from an ensemble of all runs
   - Operations Criteria & Plan (OCAP)

3) Ensemble-informed scenarios, information from several GCMs combined to create scenarios
   - Bay-Delta Conservation Plan (BDCP)

GCM=Global Climate Model

DWR Climate Change Scenario Methods

Project	Downscaled GCM	Rainfall-Runoff	Water Supply	Variability
2006 Climate Action Team (CAT) Report	4 CAT scenarios	VIC	CalSim	Change mapped to historical
2009 Climate Action Team (CAT) Report	12 CAT scenarios	VIC	CalSim	Change mapped to historical
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2013 Water Plan	TBD with CCTAG input	WEAP		Downscaled GCM timeseries

CCTAG=Climate Change Technical Advisory Group

How should I create my climate change scenarios?

1) Scenarios from individual GCM runs based on specified criteria
   - Climate Action Team (CAT)
     4 scenarios in 2006
     12 scenarios in 2009

Example: BDCP EIR-EIS Alternatives Assessment

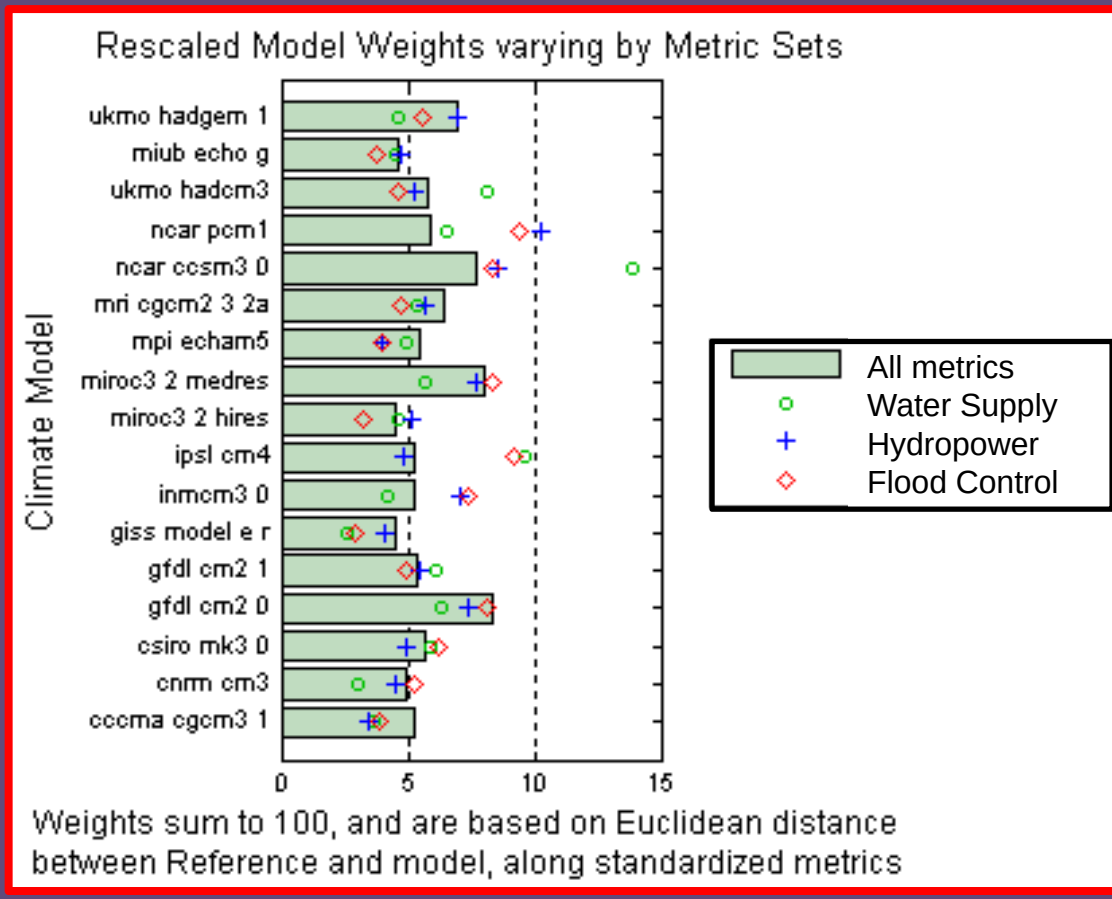
Full Alternative **X** Operations Options **X** Restoration Options **X** Analysis Period **X** **Climate Change Scenarios**

GCM=Global Climate Model

Can we reduce number of scenarios based on GCM performance for California?

Brekke et al. (2008)

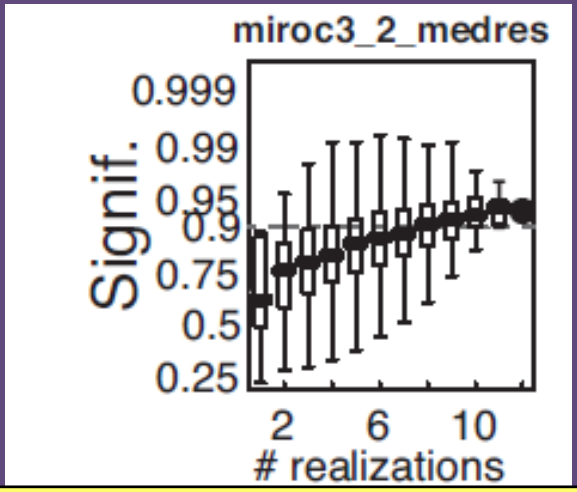
- Historical simulations from 17 GCMs
- Evaluated GCM performance for CA based on metrics for water supply, hydropower and flood control
- For a single metric, relative skill of individual GCMs can be evaluated
- Similar skill was found between GCMs when ***several*** metrics were considered
- Similar results for global studies
  Gleckler et al. 2008, Reichler et al. 2008



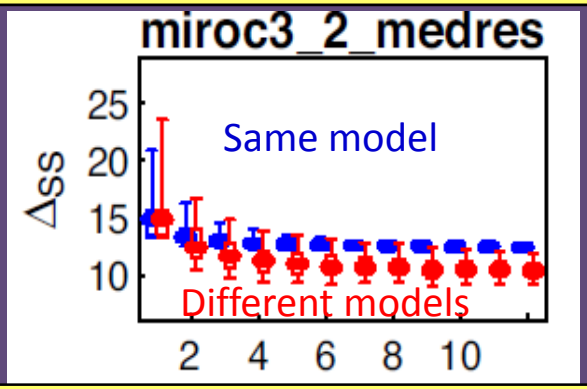
http://tenaya.ucsd.edu/~dettinge/brekke08_climchg.pdf

Adapted from Levi Brekke USBR

Multi-model **Ensemble** is Superior to Individual Model Projections for Historical Conditions

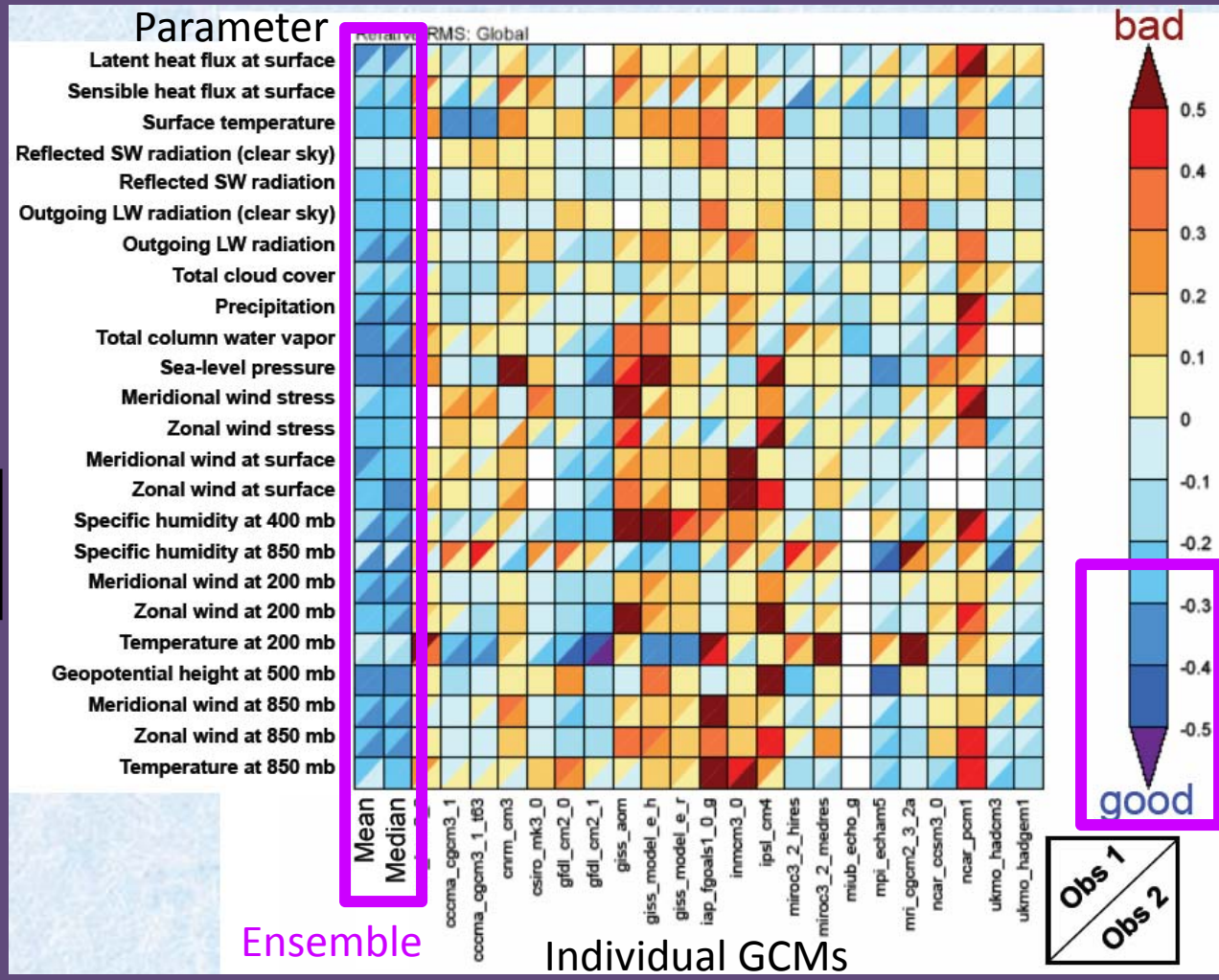


Statistical significance of model trend in JFM Tmin for western U.S. with increasing # of realizations



Change in model "skill score" with increasing # of realizations

Source: Pierce et al, 2009



Source: Gleckler et al, 2008

Adapted from Armin Munevar, CH2MHill

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GCM=Global Climate Model

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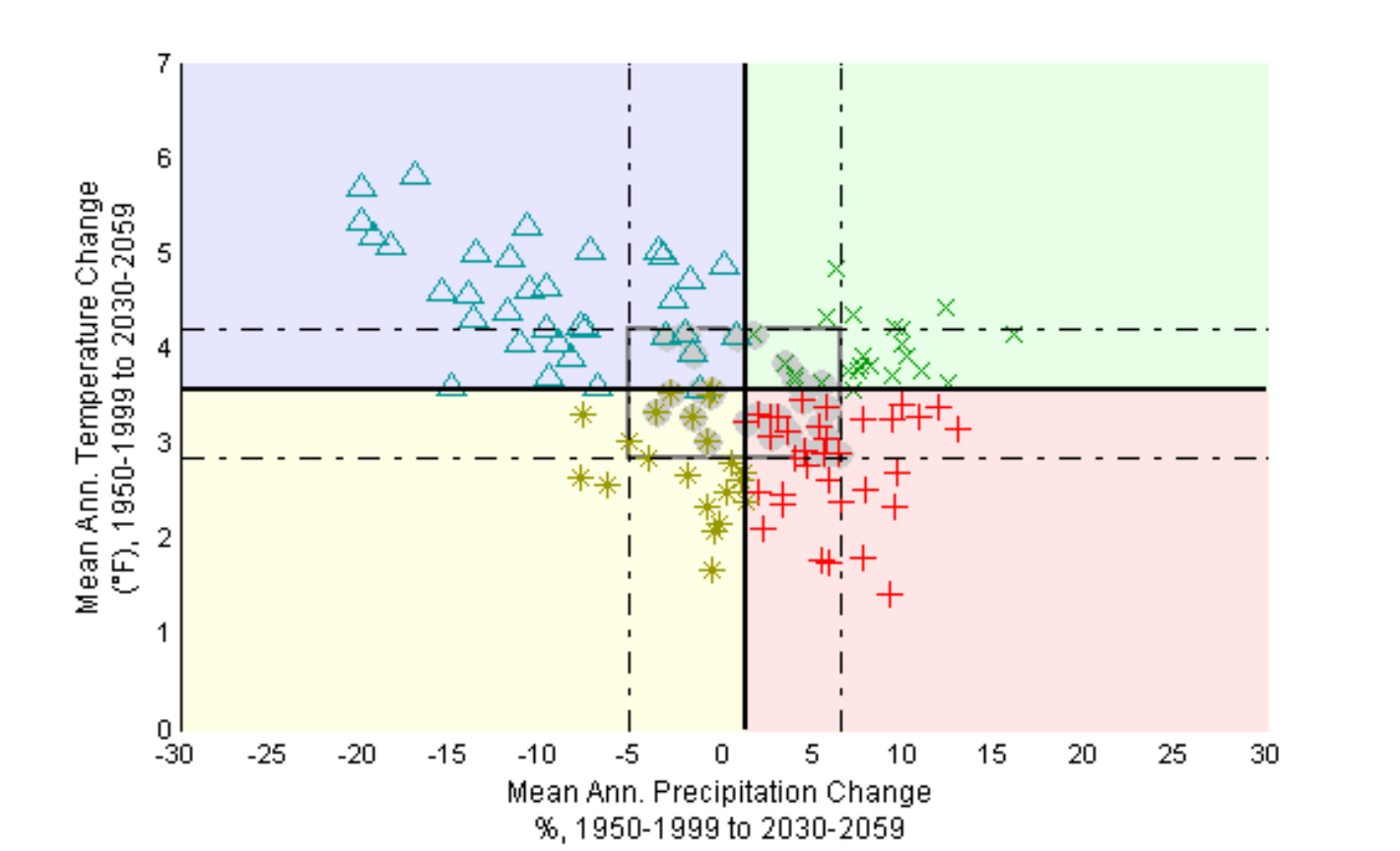
GCM=Global Climate Model

Ensemble-informed approach: projections are grouped and their pooled information defines scenarios



Reclamation 2010

Adapted from Levi Brekke USBR

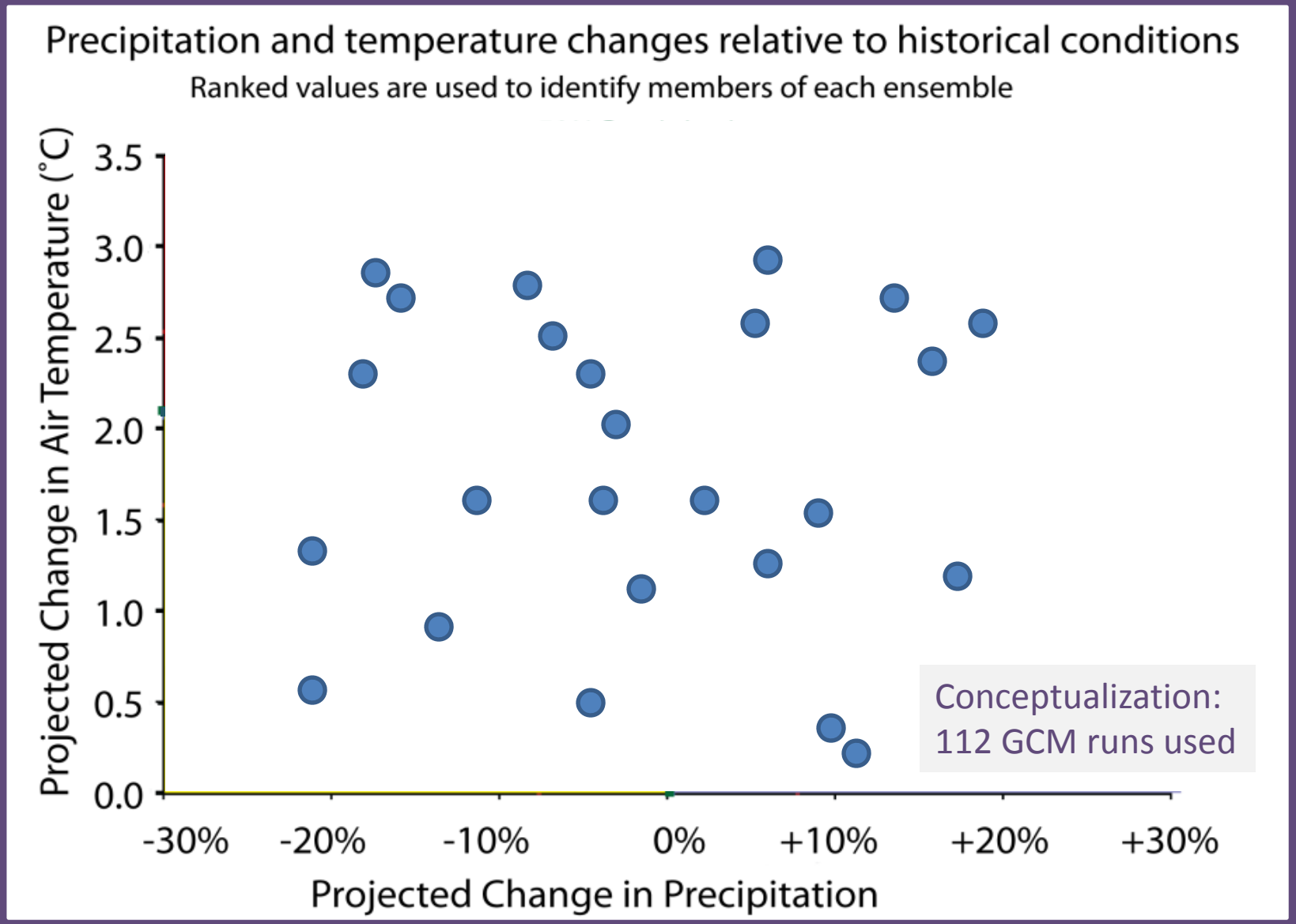
Ensemble-Informed Scenario Selection

For a given projection period an automated process

- Uses 112 GCM runs downscaled to every 12 km (1/8° lat/long) over California
- For each 12 km grid cell
  - Plots changes in temperature vs precipitation for each run

5 Ensembles ➔5 scenarios

Ensemble-Informed Scenario Selection



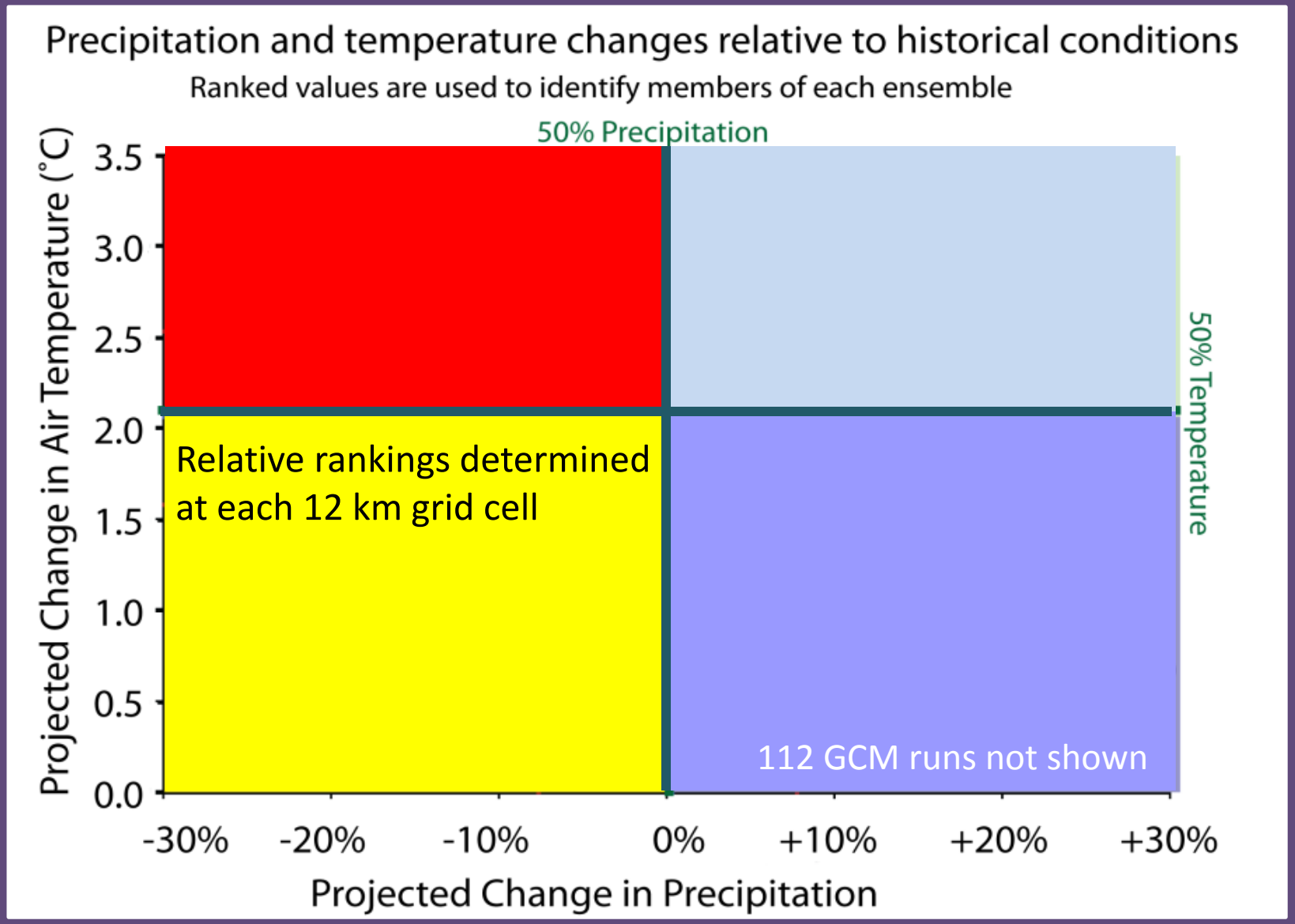
Ensemble-Informed Scenario Selection

For a given projection period an automated process

- Uses 112 GCM runs downscaled to every 12 km (1/8° lat/long) over California
- For each 12 km grid cell
  - Plots changes in temperature vs precipitation
  - Determines percentile ranks for each run

5 Ensembles ➔5 scenarios

Ensemble-Informed Scenario Selection



Ensemble-Informed Scenario Selection

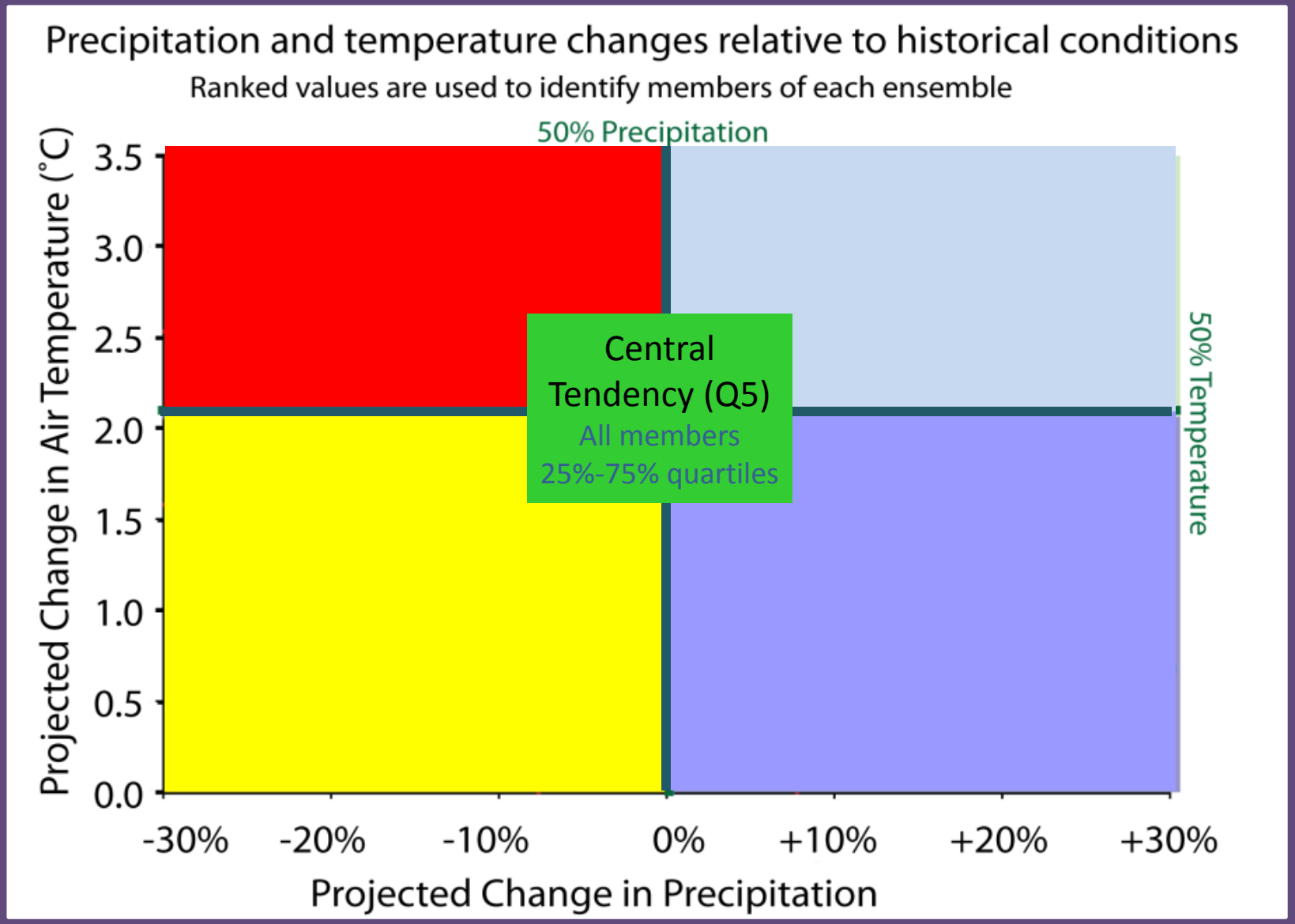
For a given projection period an automated process

- Uses 112 GCM runs downscaled to every 12 km (1/8° lat/long) over California
- For each 12 km grid cell

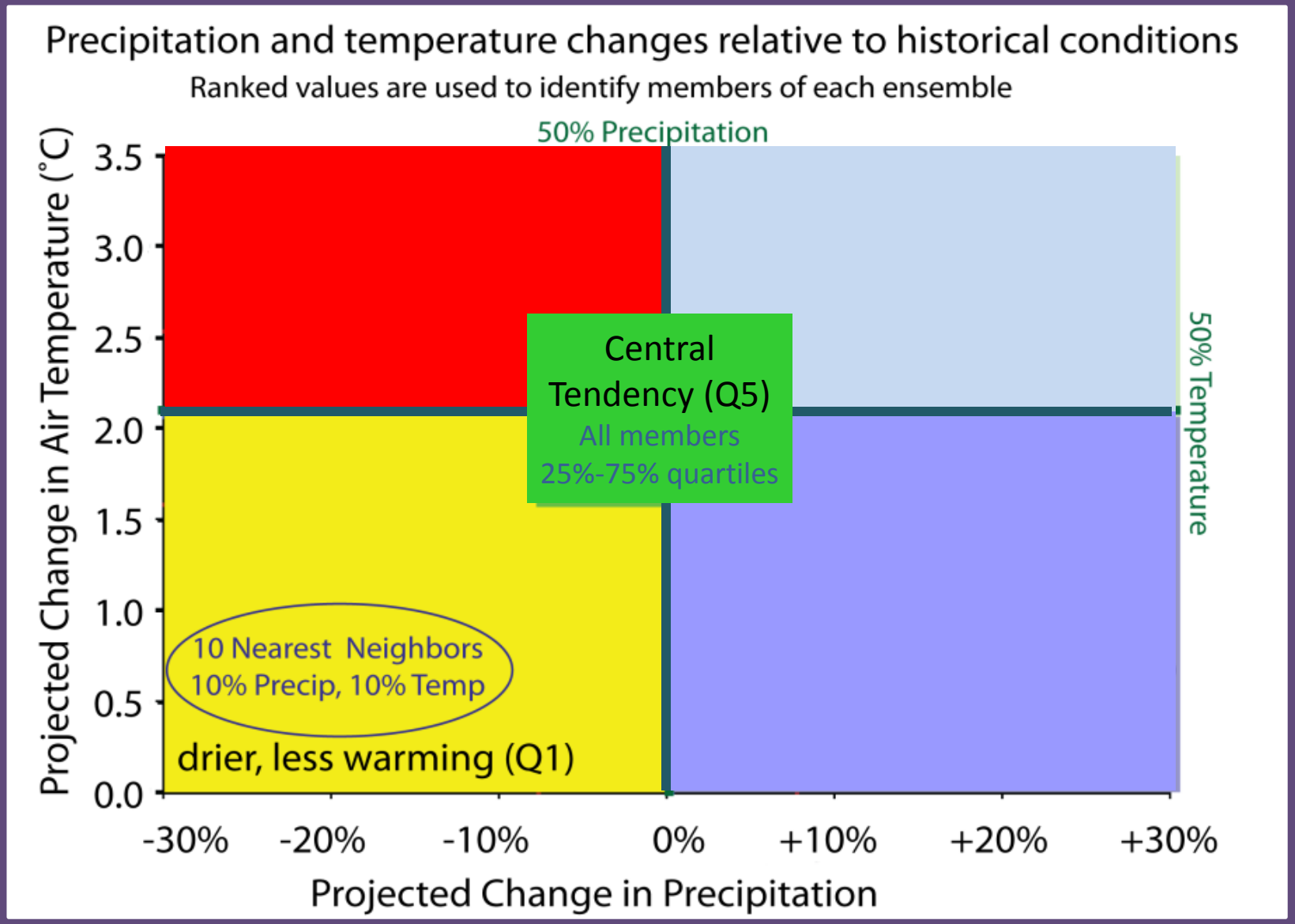
5 Ensembles ➔5 scenarios

  - Plots changes in temperature vs precipitation
  - Determines percentile ranks for each run
  - Selects five ensembles
    - Central tendency
    - Drier/wetter and less warming/more warming (4 combos)

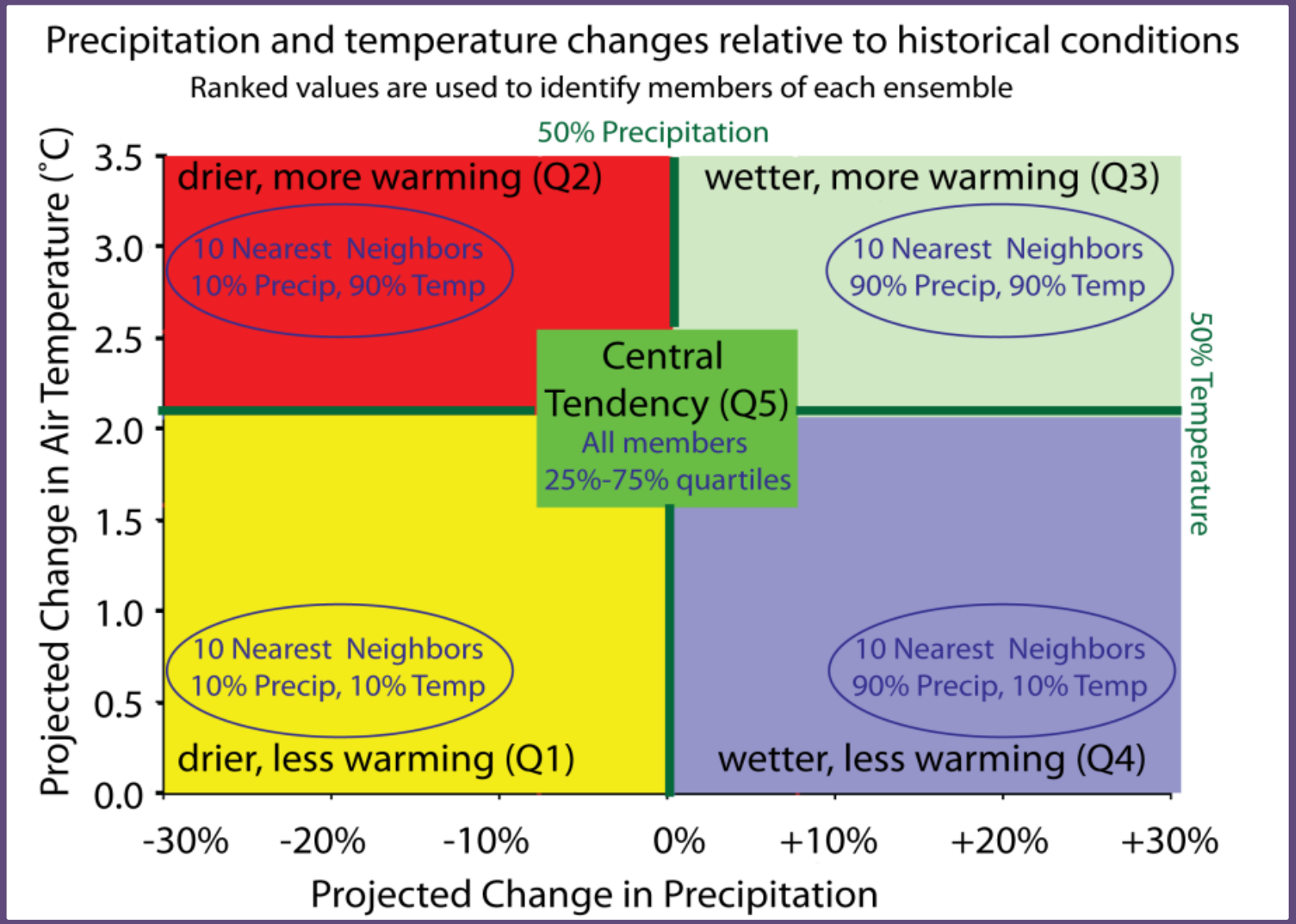
Ensemble-Informed Scenario Selection



Ensemble-Informed Scenario Selection



Ensemble-Informed Scenario Selection



Ensemble-Informed Scenario Selection

For a given projection period an automated process

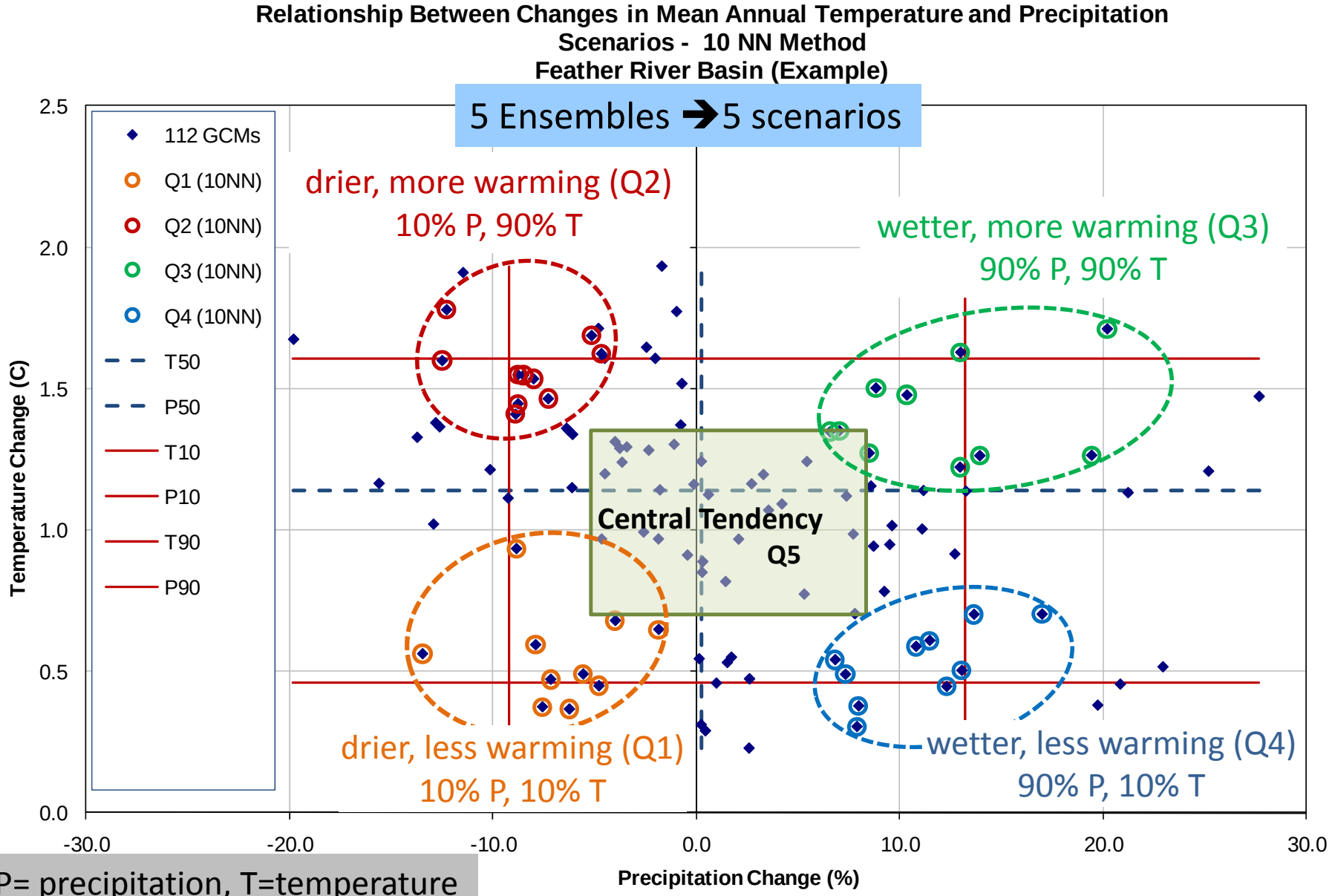
- Uses 112 GCM runs downscaled to every 12 km (1/8° lat/long) over California
- For each 12 km grid cell

5 Ensembles ➔5 scenarios

  - Plots changes in temperature vs precipitation
  - Determines percentile ranks for each run
  - Selects five ensembles
    - Central tendency
    - Drier/wetter and less warming/more warming (4 combos)
  - For each ensemble: Combines information from all members of the ensemble to determine a single scenario for change in air temperature and precipitation

Ensemble members can change by location and for each projection period

Climate Scenarios – 10 Nearest-Neighbor Method

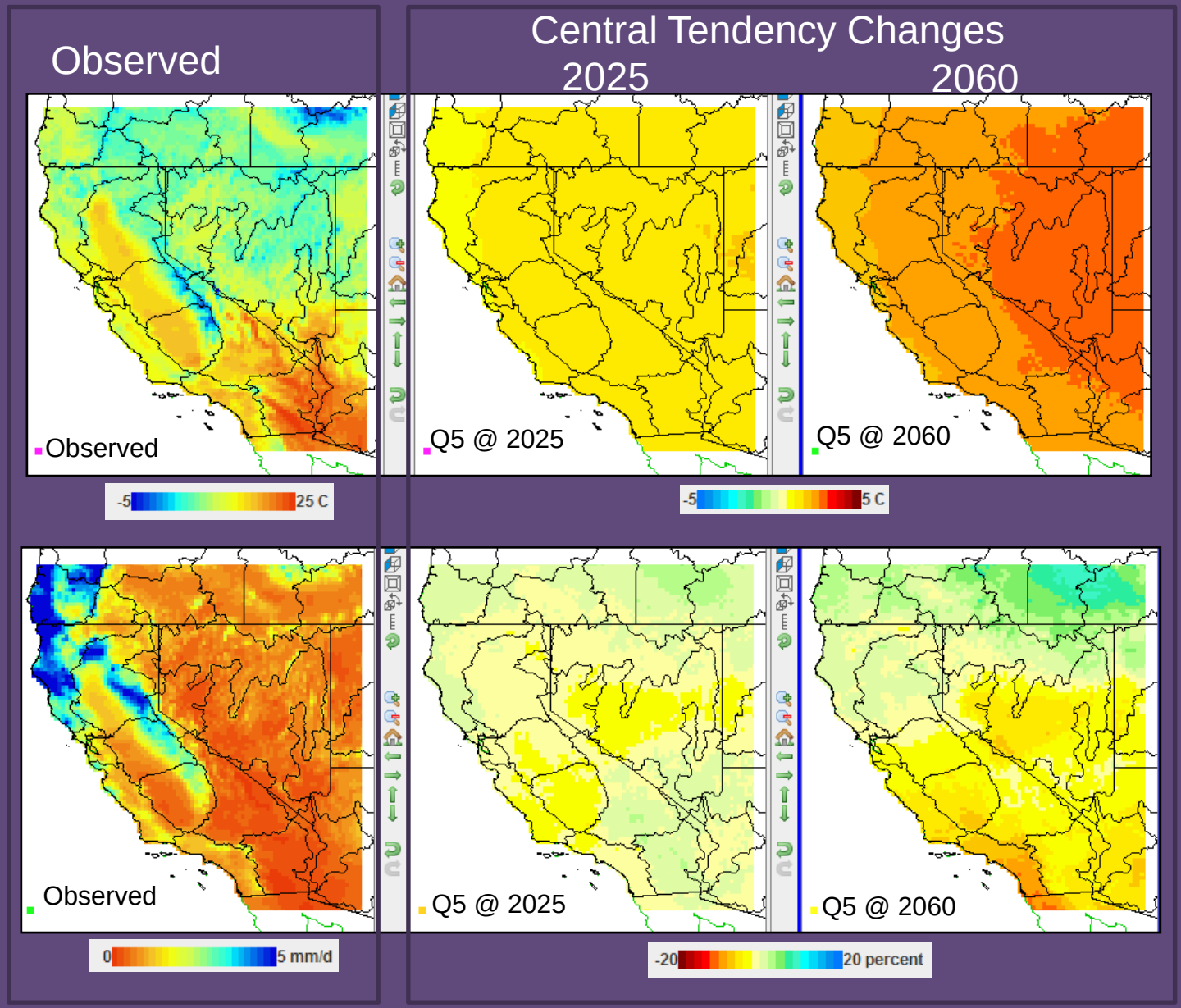


P= precipitation, T=temperature

Annual Spatial Change Patterns

Annual Mean Temperature

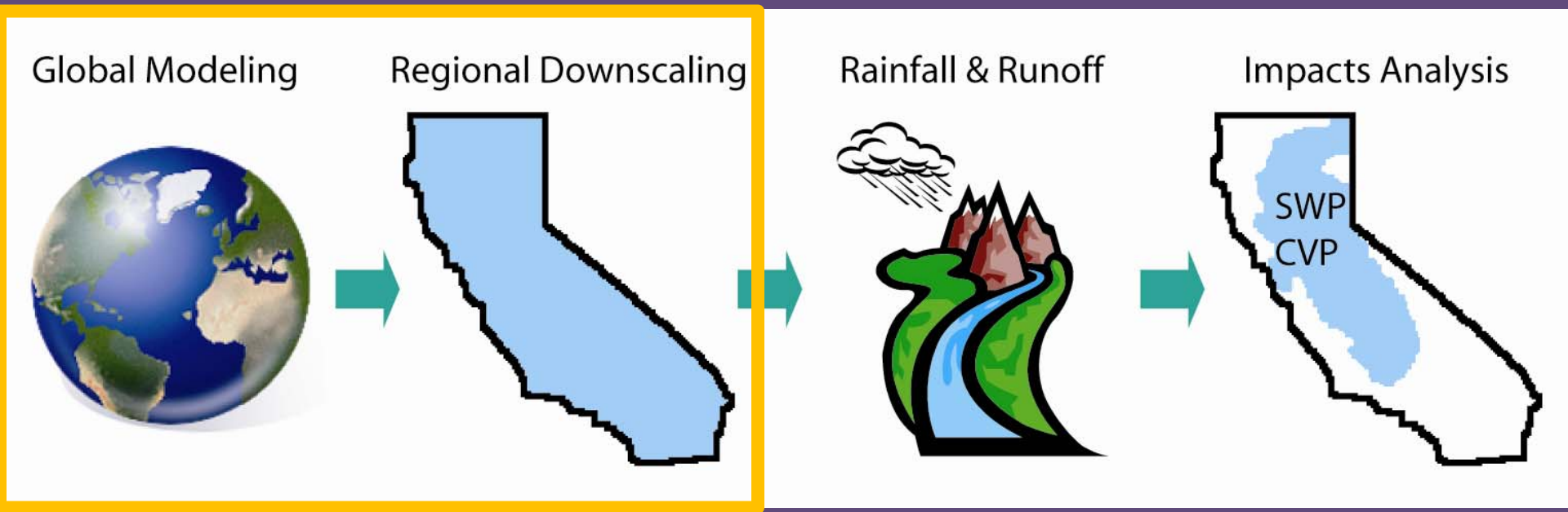
Annual Mean Precipitation



Next Step for Water Resources Streamflows

GCMs provide changes in temperature and precipitation

Also need changes in stream flows



VIC

WEAP

CalSimII

WEAP

CVP=Central Valley Project
SWP= State Water Project
VIC=Variable Infiltration Capacity Model
WEAP=Water Evaluation and Planning system

Sequencing and Variability

for planning studies

How do we deal with sequencing climate change information to reflect variability and possible changes in variability?

Observed historical variability

GCM data, projected changes in variability (?)

Map projected changes to historical time series

- Reflects magnitude of projected changes
- Uses historical variability and sequencing

Use GCM output directly

- Reflects magnitude of projected changes
- Uses sequencing from GCM

GCM=Global Climate Model

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2013 Water Plan	TBD with CCTAG input	WEAP		Downscaled GCM timeseries

CCTAG=Climate Change Technical Advisory Group

How to represent changes from climate scenarios in planning studies?

- Map change to historical patterns (Perturbation method)

$$\text{Change Ratio} = \frac{\text{Monthly Avg. Climate Change Value (30 year period)}}{\text{Monthly Avg. Historical Value (30 year period)}}$$

Multiply historical time series by change ratio
  - Maintains historical sequencing, changes magnitudes
  - Used for temperature, precipitation and streamflow

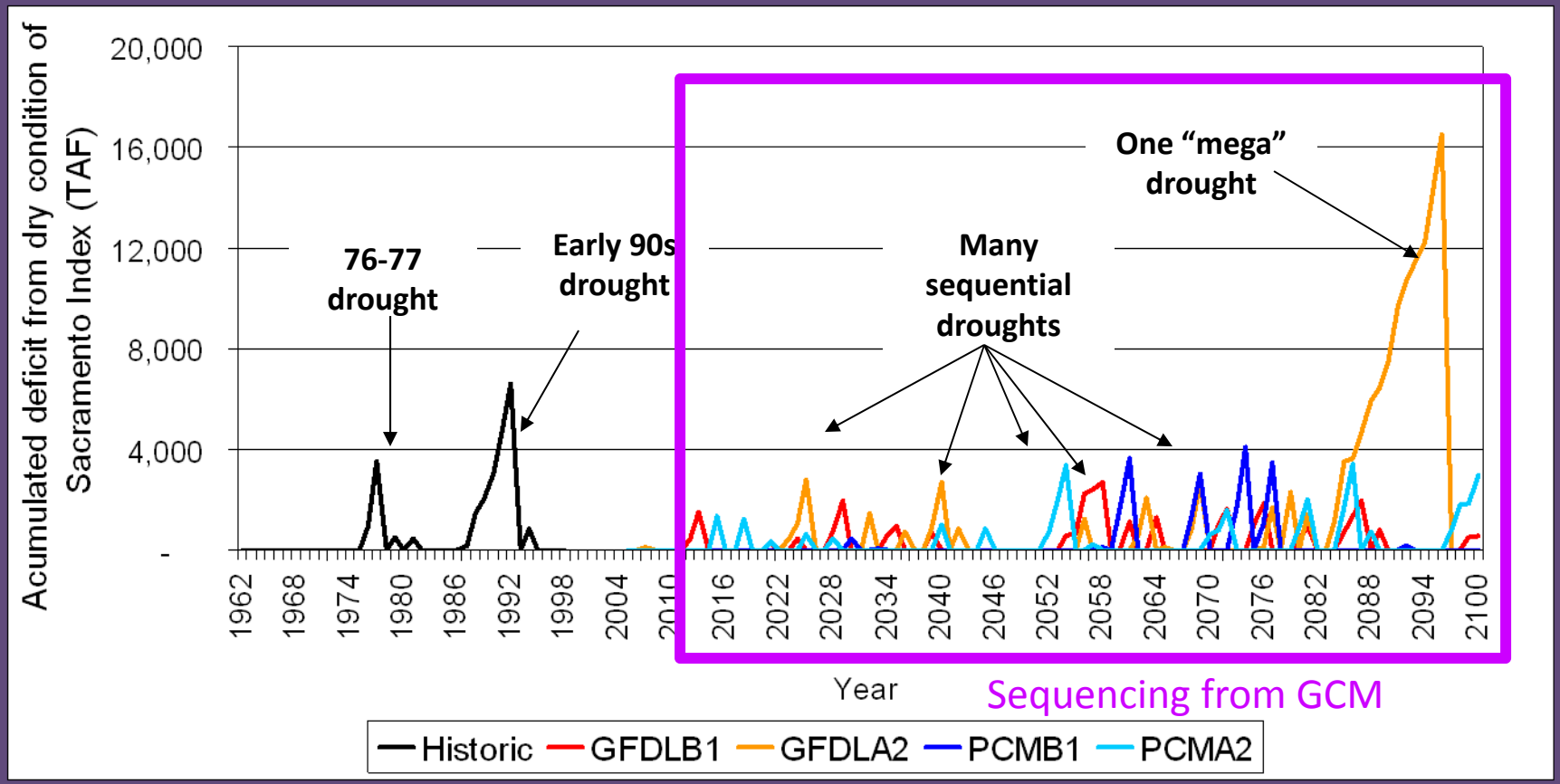
- Time series from GCM downscaled data
  - Reflects sequencing from GCM runs
  - Used for temperature and precipitation; streamflow from WEAP maintains the GCM sequencing

Use downscaled GCM time series directly

- Used with WEAP model (integrated rainfall/runoff and operations)
- Reflects changes in event sequences in GCM output

Example: Drought frequency analysis using WEAP

Accumulated deficit from a dry condition based on Sacramento 40-30-30 index



Adapted from Sebastian Vicuña, UCB

Where do we go from here?

UNCERTAINTY

Climate Projections

Population

Sea level rise

Converting global data to local/regional scales

Water cycle changes

$$$$

Ecosystem response

Future water demands

Land use changes

Adaptation Strategies

Changes in societal values

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   - Bay-Delta Conservation Plan (BDCP)

GCM=Global Climate Model

Questions to Ponder

- Is there a preferred method for scenario selection?
- Is the same method preferred for all types of studies?
- Can the preferred method adapt to changing science?
- Are there other methods that we should consider?
- How should we deal with sequencing and variability for planning studies?

Thank You!

jamiea@water.ca.gov

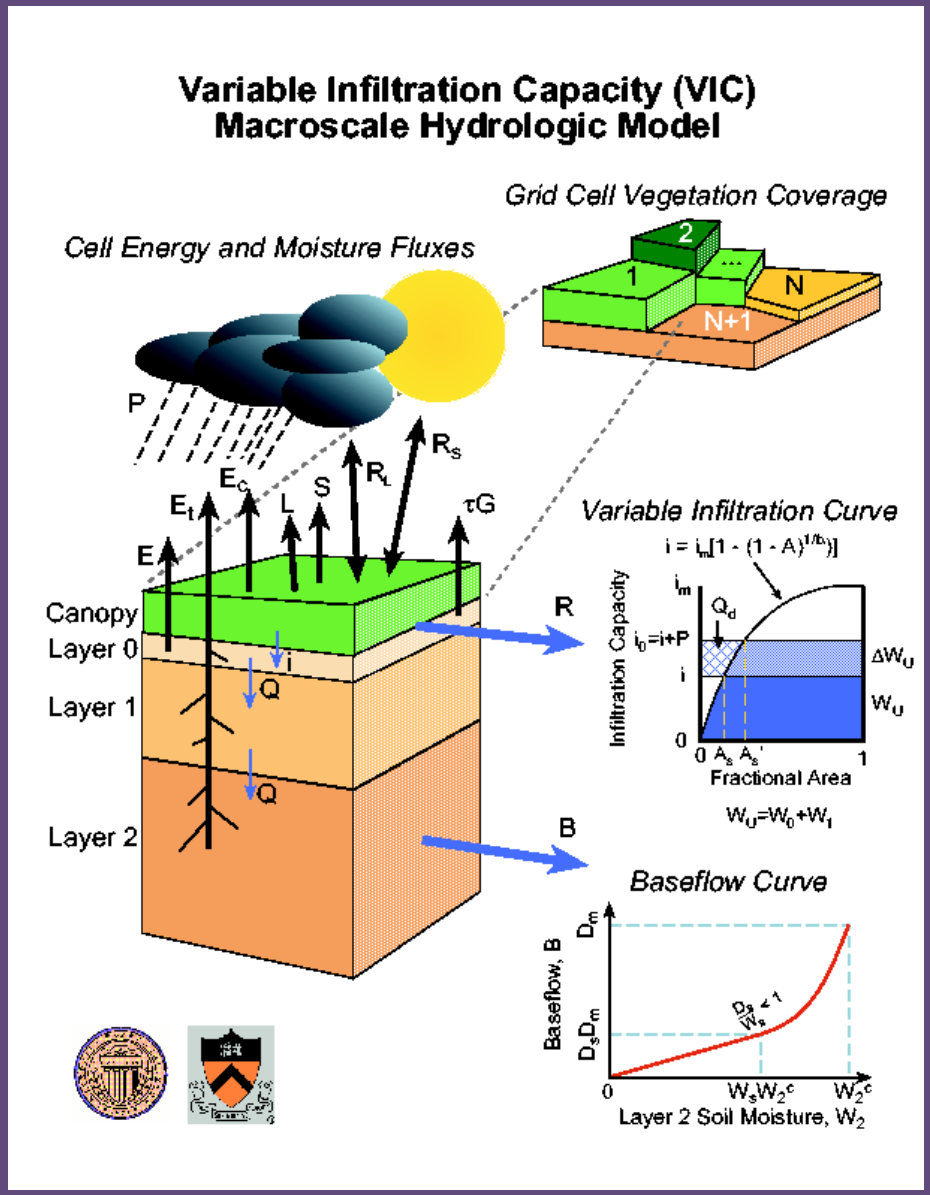
Extra Slides

Variable Infiltration Capacity Model (VIC)

Hydrologic Model

VIC Model Features:

- Developed over 10 years
- Energy and water budget closure at each time step
- Multiple vegetation classes in each cell
- Sub-grid elevation band definition (for snow)
- Subgrid infiltration/runoff variability
- 3 soil layers used
- Non-linear baseflow generation



Side from Ed Maurer, Santa Clara University

VIC Processes Summary

- Flux and storage of water and heat in each cell-sized system of vegetation and soil structure include:
  - Evaporation from the soil layers (E)
  - Evapotranspiration (Et)
  - Canopy interception evaporation (Ec)
  - Latent heat flux (L)
  - Sensible heat flux (S)
  - Longwave radiation (RL)
  - Shortwave radiation (RS)
  - Ground heat flux (t G),
  - Infiltration (i)
  - Percolation (Q)
  - Runoff (R)
  - Baseflow (B)

Side from Ed Maurer, Santa Clara University

BDCP

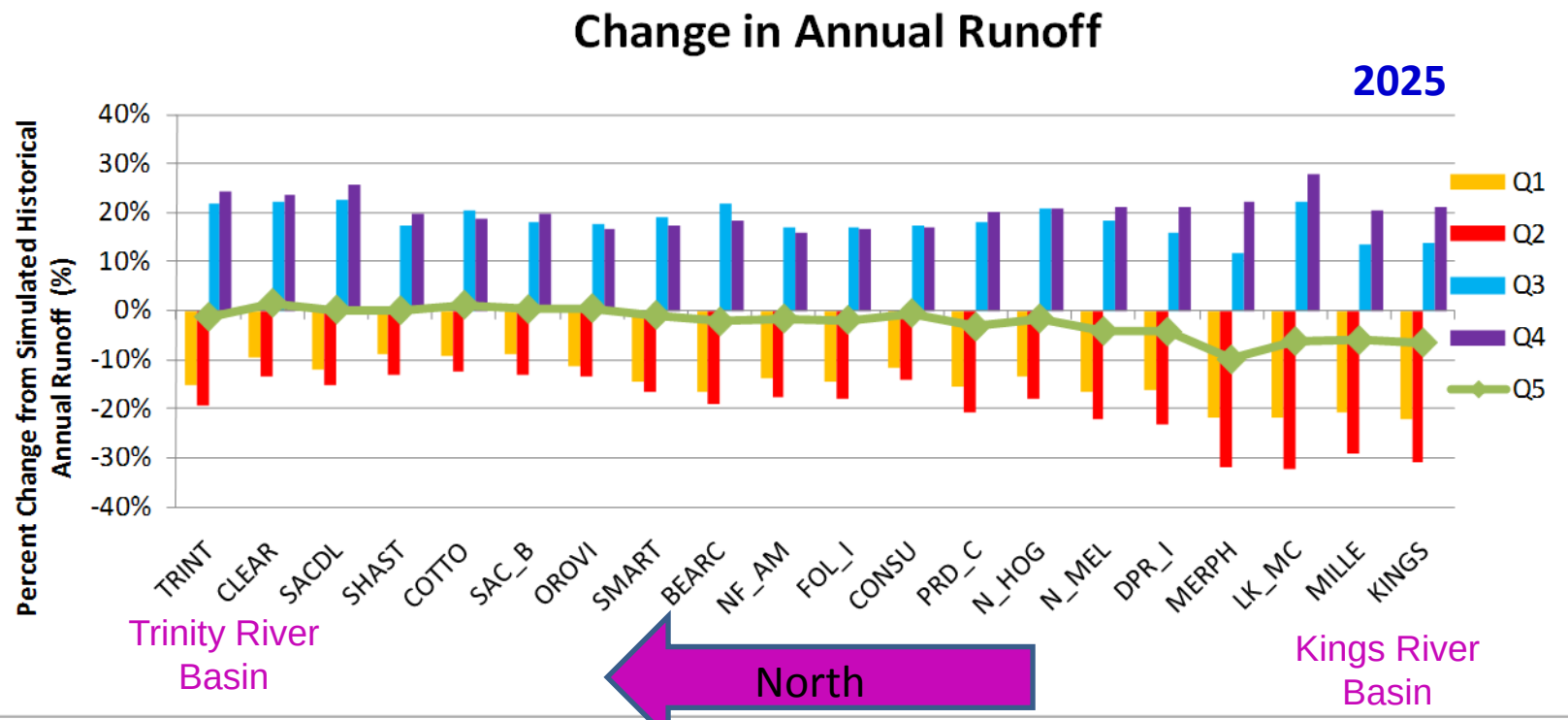
Bay Delta Conservation Plan (BDCP)

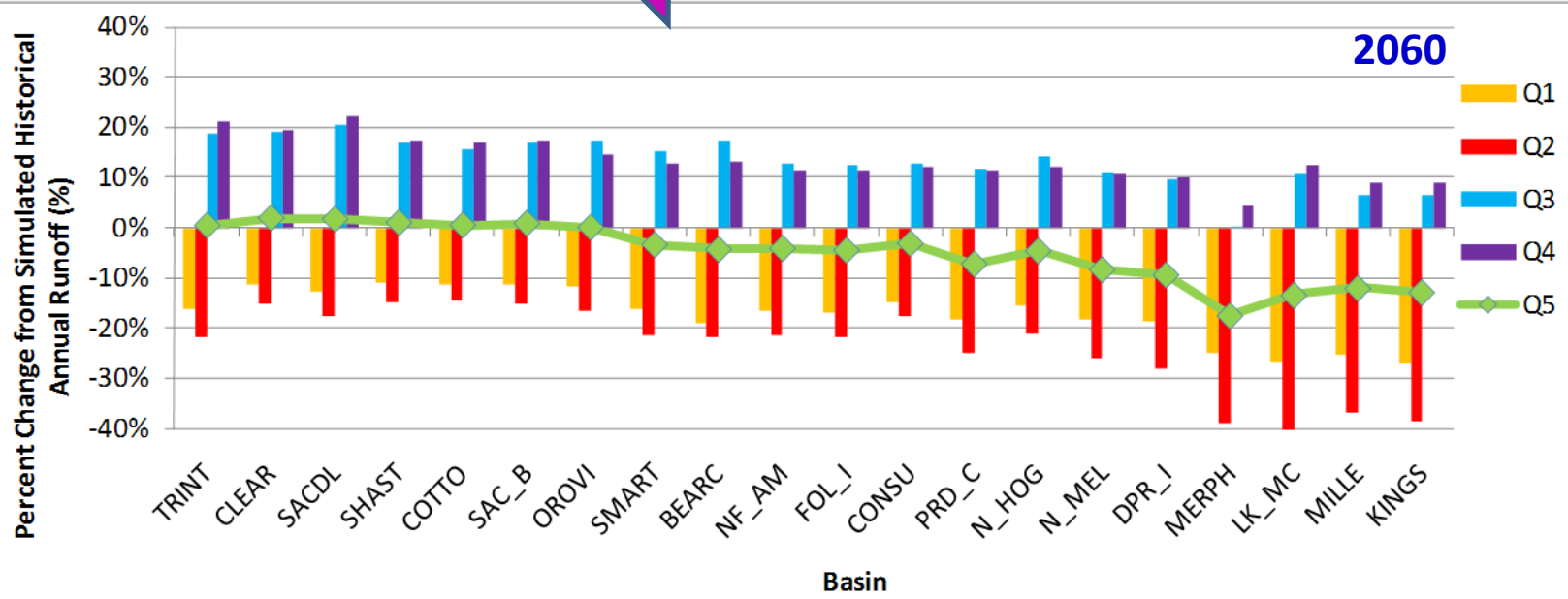
- Collaborative approach to restore the Sacramento-San Joaquin Delta's ecosystem and protect water supplies
- Conservation measures being considered by the BDCP
  - tidal marsh restoration,
  - floodplain restoration,
  - alternative ways for conveying water for exports,
  - changes to operations of current facilities, and
  - control of toxic pollutants, invasive species, and other impairments to water quality

Simulated Changes in Annual Runoff

2025

2060





OCAP Methodology

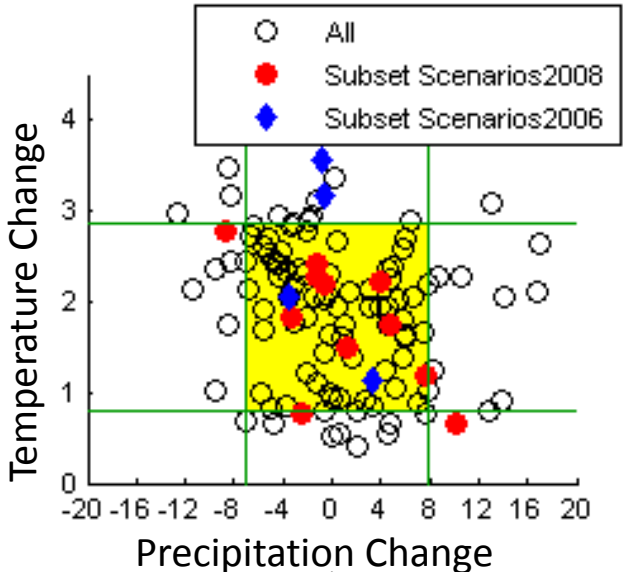
Scenario selection from an ensemble

For a given projection period an automated process

- Uses 112 GCM runs downscaled to every 12 km (1/8° lat/long) over California
- For each 12 km grid cell
  - Plots changes in temperature vs precipitation

Ensemble all runs ➔selecting 4 runs

Select 4 scenarios from ensemble of all runs



Scenario selection from an ensemble

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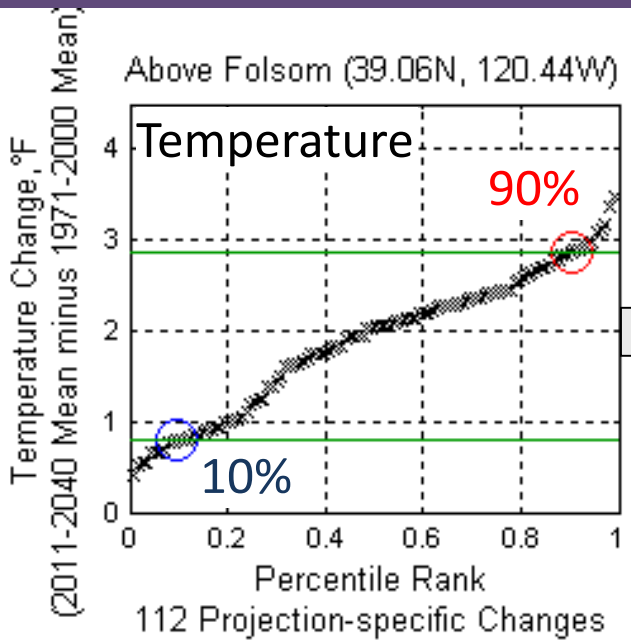
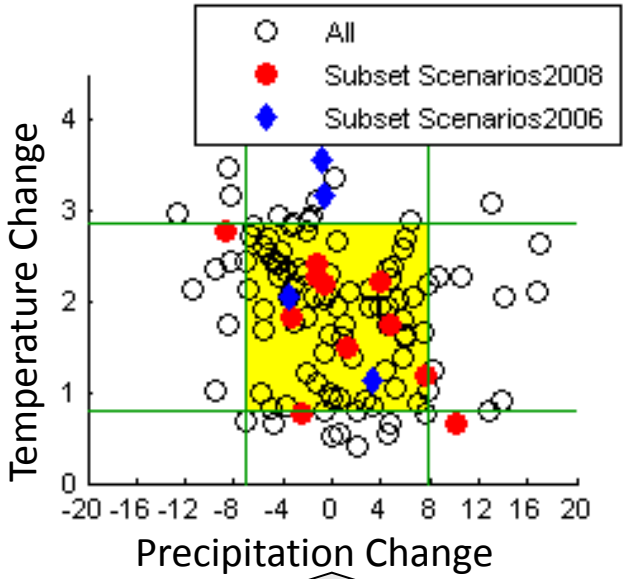
- For each 12 km grid cell

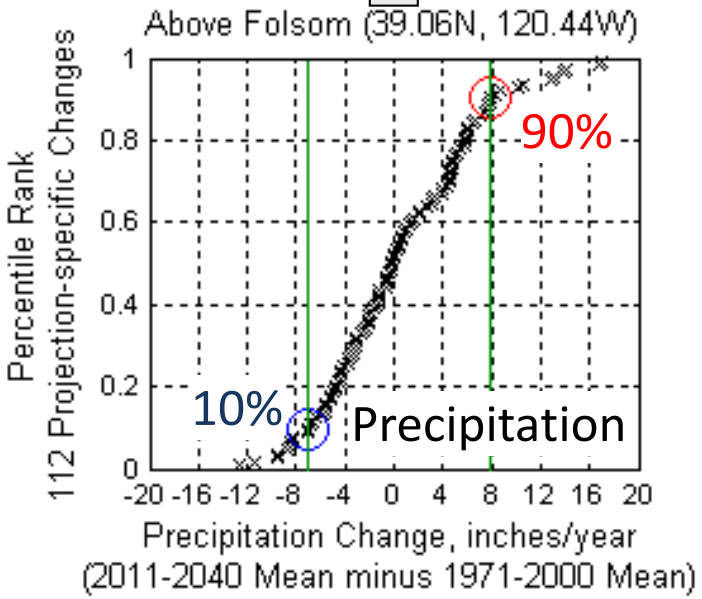
Ensemble all runs ➔selecting 4 runs

  - Plots changes in temperature (T) vs precipitation (P)
  - Determines percentile ranks for each run for T & P
  - Selects 4 points in the ensemble of all runs
    - 10%/90% temperature, 10%/90% precipitation (4 combos)

Select 4 scenarios from ensemble of all runs







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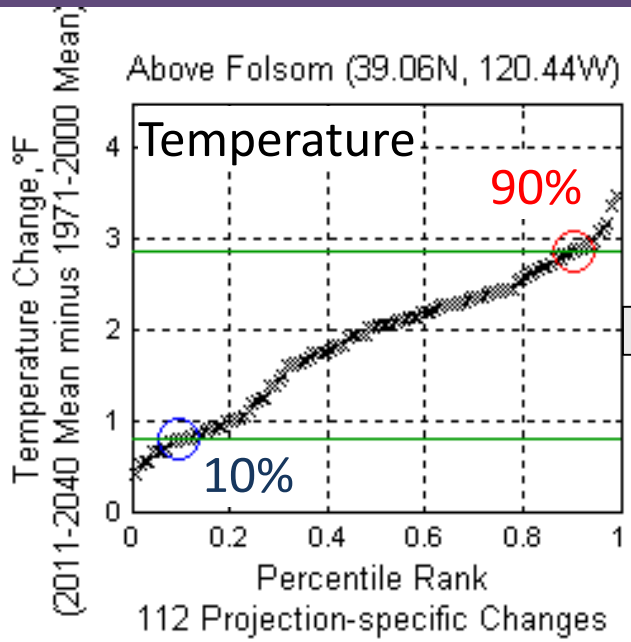
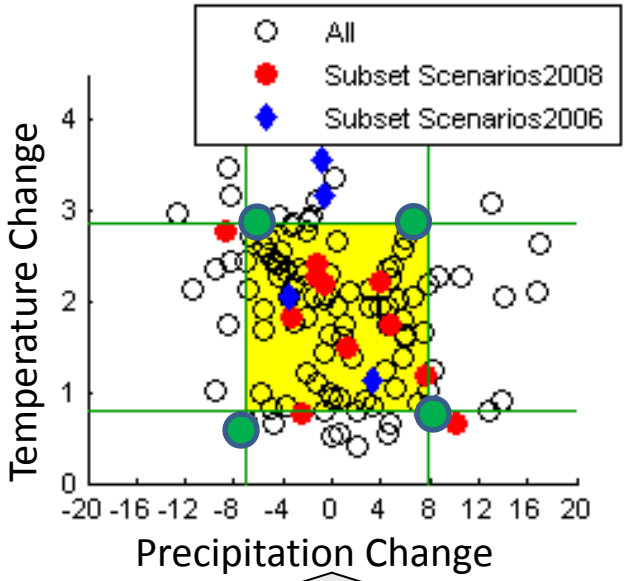
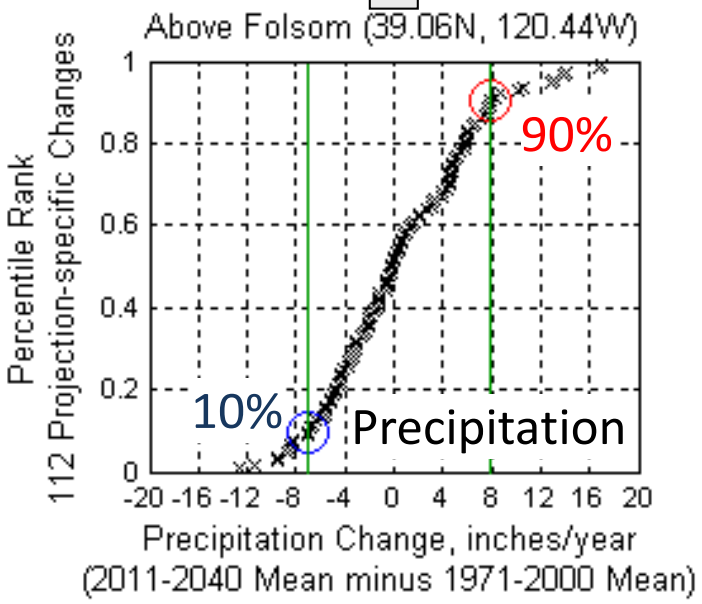
  - Determines percentile ranks for each run for T & P
  - Selects 4 points in the ensemble of all runs
    - 10%/90% temperature, 10%/90% precipitation (4 combos)
  - Select individual GCM run that is closest to each point

GCM runs selected can change by location and for each projection period

Select 4 scenarios from ensemble of all runs







Ensemble all runs ➔selecting 4 runs

- Each scenario selected is a single downscaled GCM run

GCM runs selected can change by location and for each projection period