Progress on Incorporating Climate Change into Management of California's Water Resources

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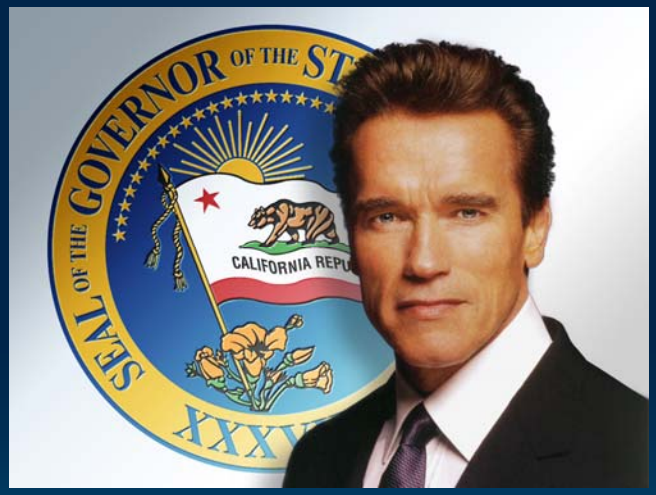
July 20, 2006

Modeling Support Branch
Bay Delta Office

Governor Arnold Schwarzenegger on Global Warming…….

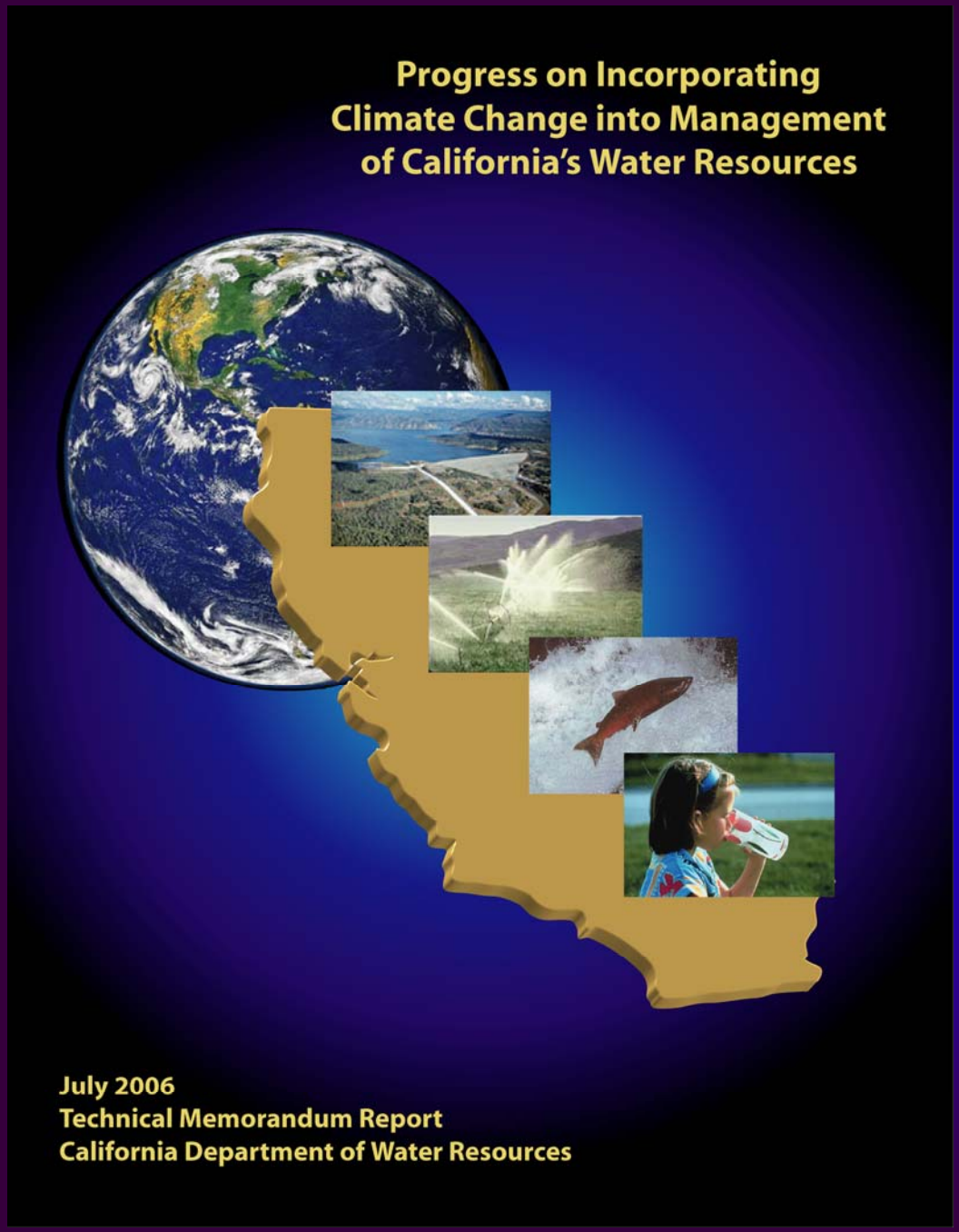


“ I say the debate is over. We know the science. We see the threat. And we know the time for action is now.”

United Nations World Environment Day Conference, June 1,2005, San Francisco

Governor's Executive Order

- EO S-3-05 June 1, 2005
- Targets to reduce emission levels of Green House Gases
- Biennial reports starting Jan06
  - Water supply
  - Public health
  - Agriculture
  - CA coastline
  - Forestry
- Formed Climate Action Team



CH1 Introduction

CH2 Background

CH3 DWR Studies

CH4 SWP-CVP Impacts

CH5 Delta Impacts

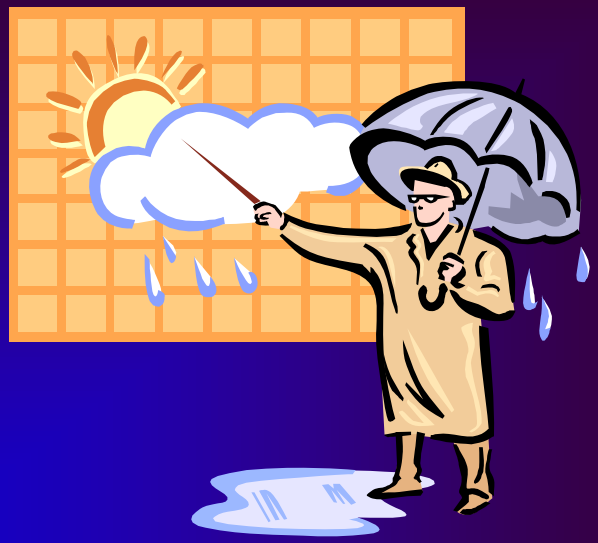
CH6 Flood Management

CH7 Evapotranspiration

CH8 Future Directions

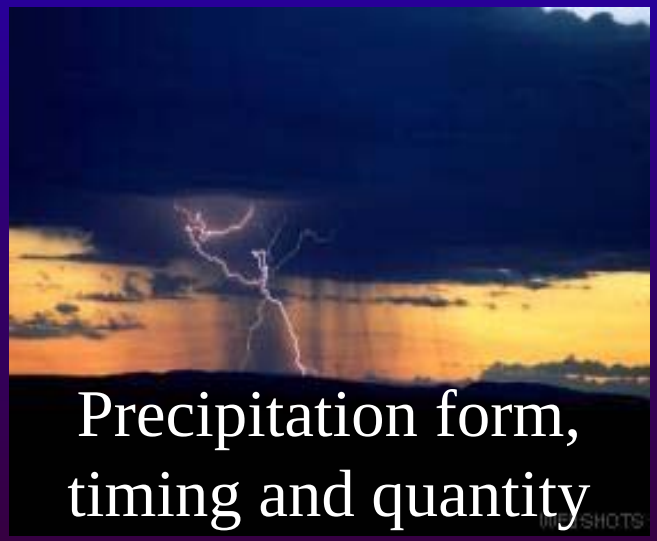
Peer reviewed chapters

Climate modelers forecast possible future climate conditions



Our climate change team assesses potential impacts and likelihoods of those climate change scenarios related to California's water resources

Potential Impacts of Climate Change



Potential Water Resources Impacts

- Water Supplies
- Water Demands
- Water Quality
- Ecosystems
- System Operations
- Flood Management

Evidence of Climate Change

Changes in Air Temperature

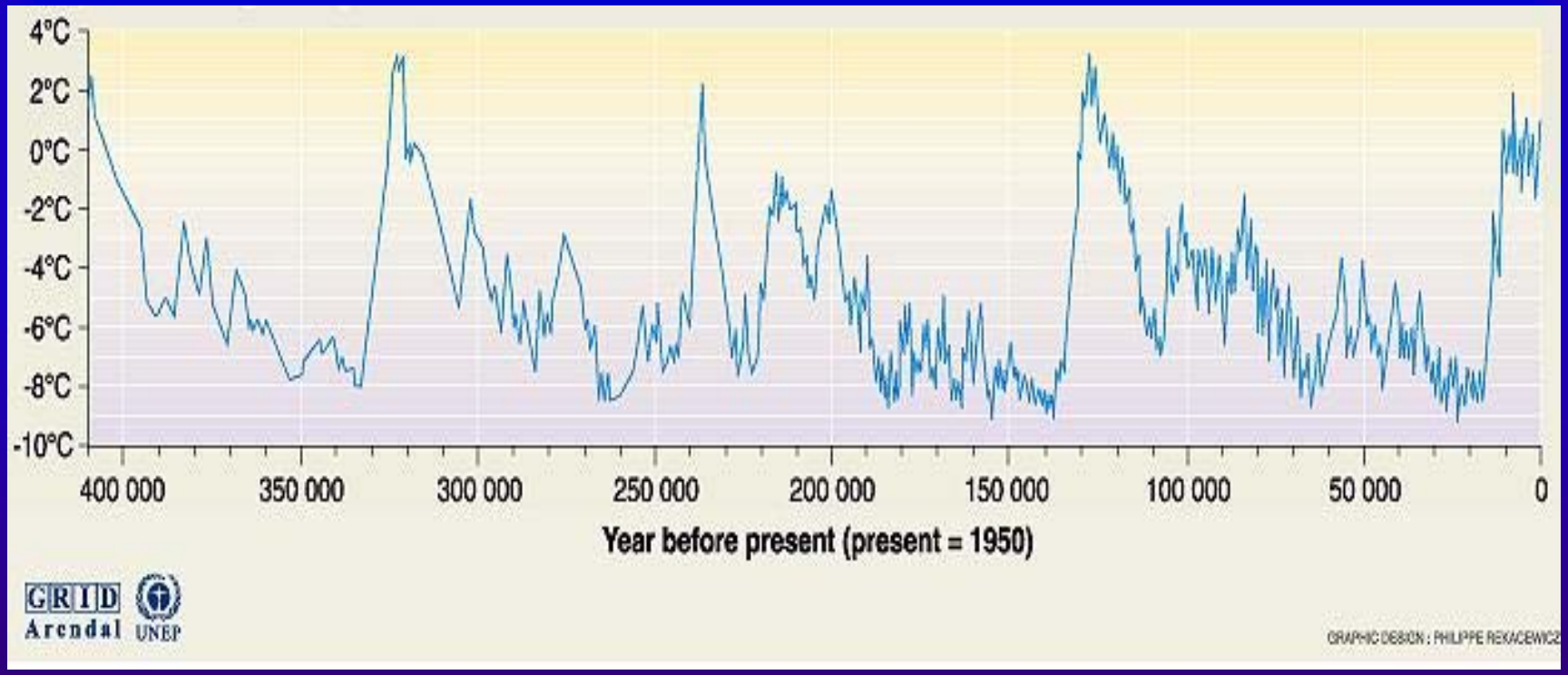


Figure 2-3 Changes in Air Temperature Over About the Past 400,000 Years
Explanation: Graph depicts changes in air temperature as evidenced by isotopic analysis of ice cores obtained at the Russian Vostok station in central east Antarctica. For additional explanation visit: http://cdiac.esd.ornl.gov/trends/temp/vostok/jouz_tem.htm.
Source: United Nation's Environment Programme Global Resource Information Database - Arendal website at http://www.grida.no/climate/vital/02.htm.

Surface Temperature Trends

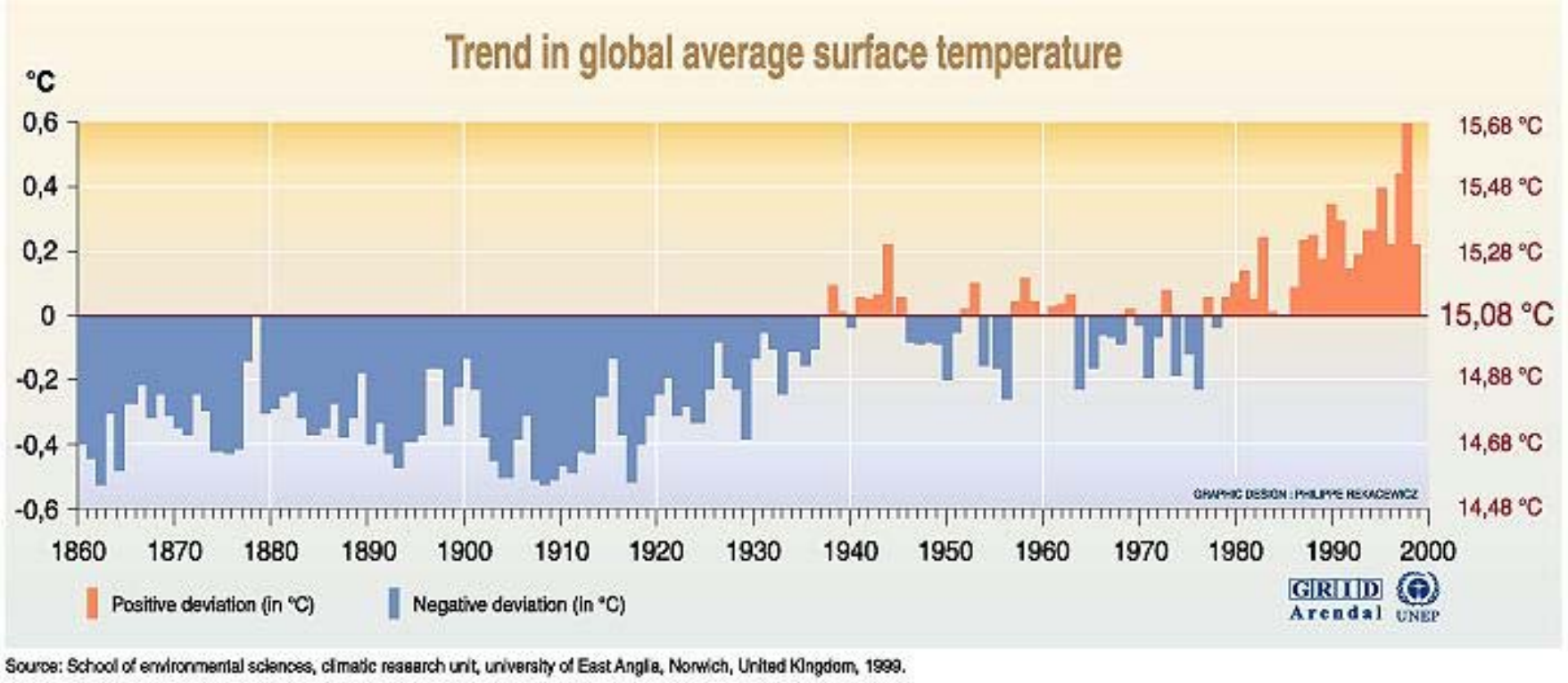


Figure 2-4 Trend in Global Average Temperature from 1860 to 2000

Explanation: The figure depicts global average combined land-surface air and sea surface temperatures from 1861 to 1998 relative to the average temperature between 1961 and 1990. The left vertical scale is in degrees Celsius.

Source: United Nation's Environment Programme Global Resource Information Database - Arendal website at: http://www.grida.no/climate/vital/17.htm.

Atmospheric Carbon Dioxide

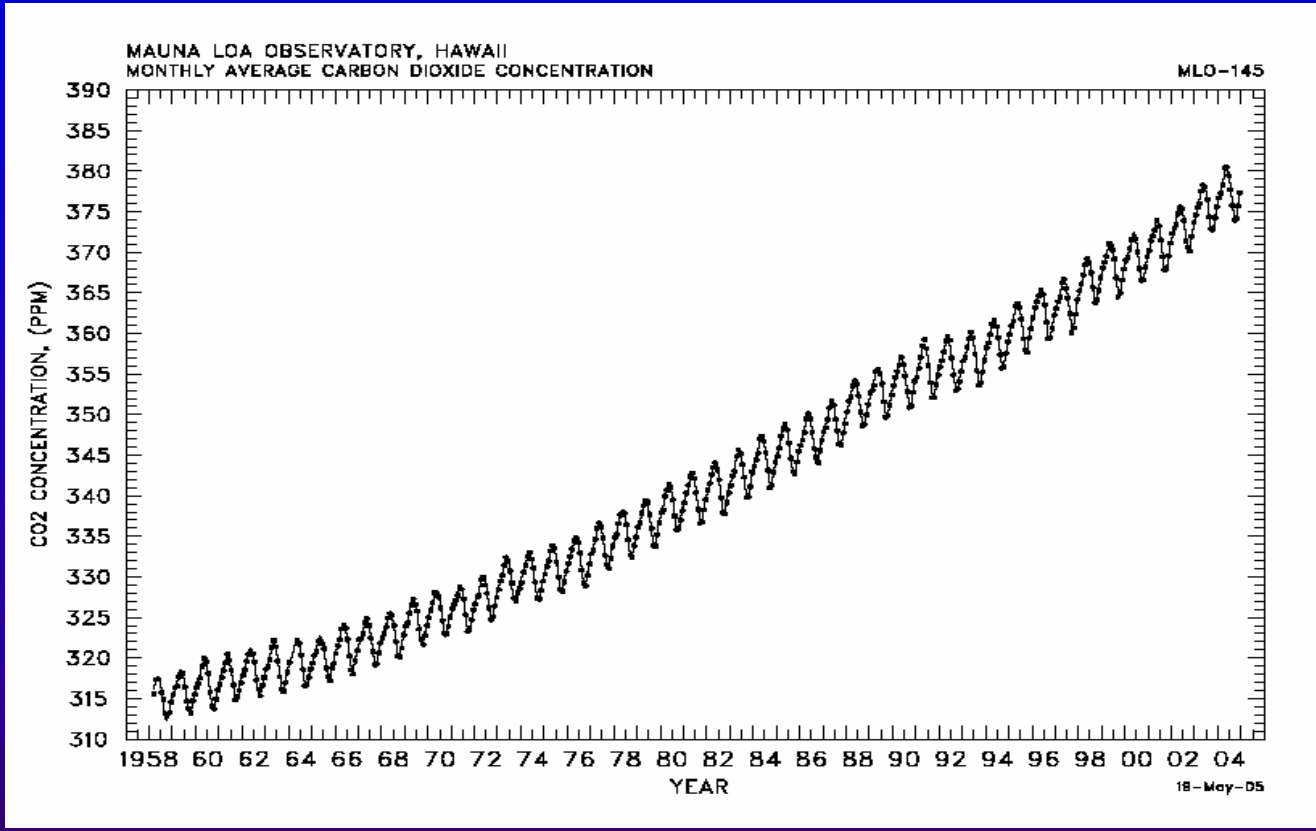


Figure 2-5 Changes in Atmospheric Carbon Dioxide Concentration Measured at Mauna Loa, Hawaii from 1958 to 2005.

Source: United States Department of Energy, Carbon Dioxide Information Analysis Center website at: http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm **.**

Explanation: PPM = parts per million. Annual decreases in atmospheric carbon dioxide concentration at Mauna Loa, Hawaii occur each summer and are due to seasonal increases in plant respiration in the Northern Hemisphere.

Air Temperature Projections

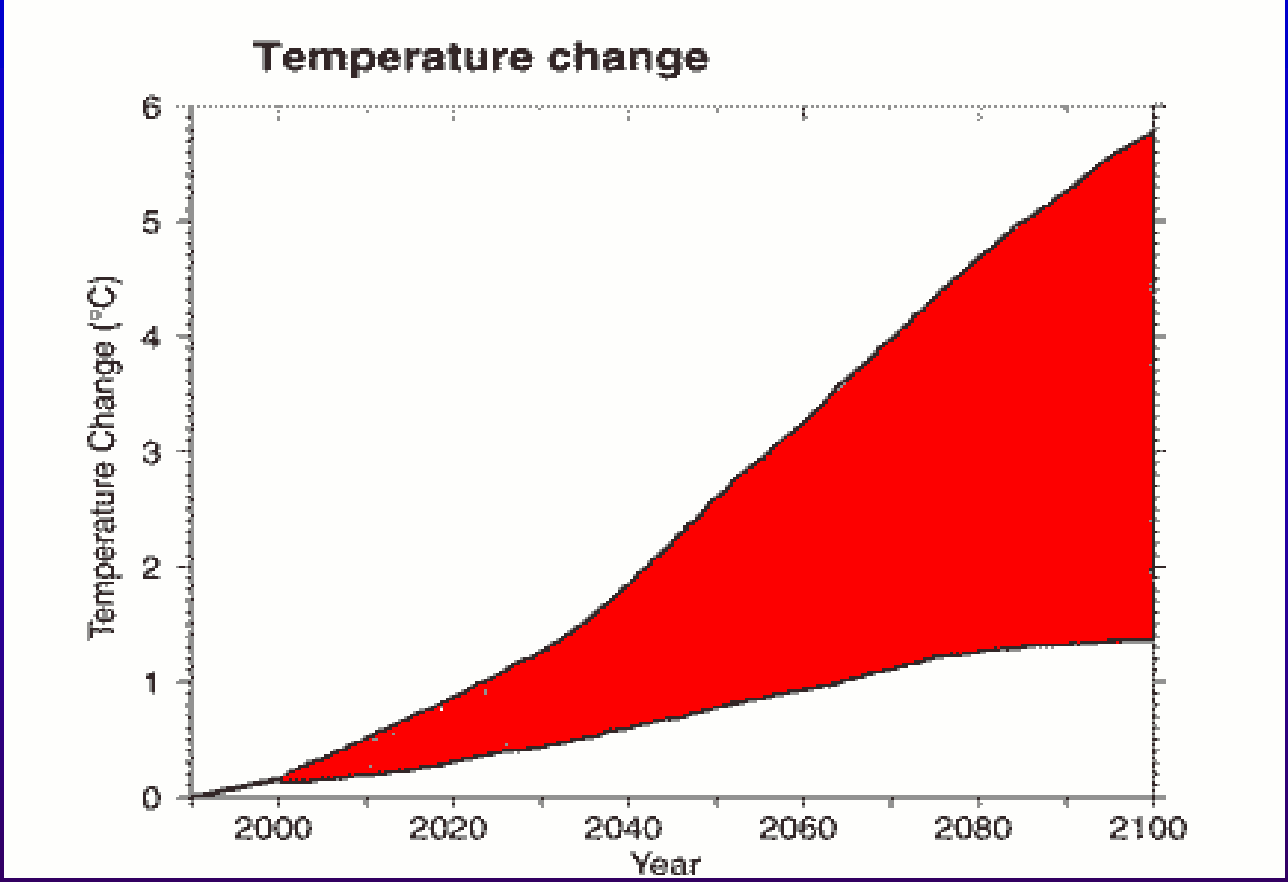
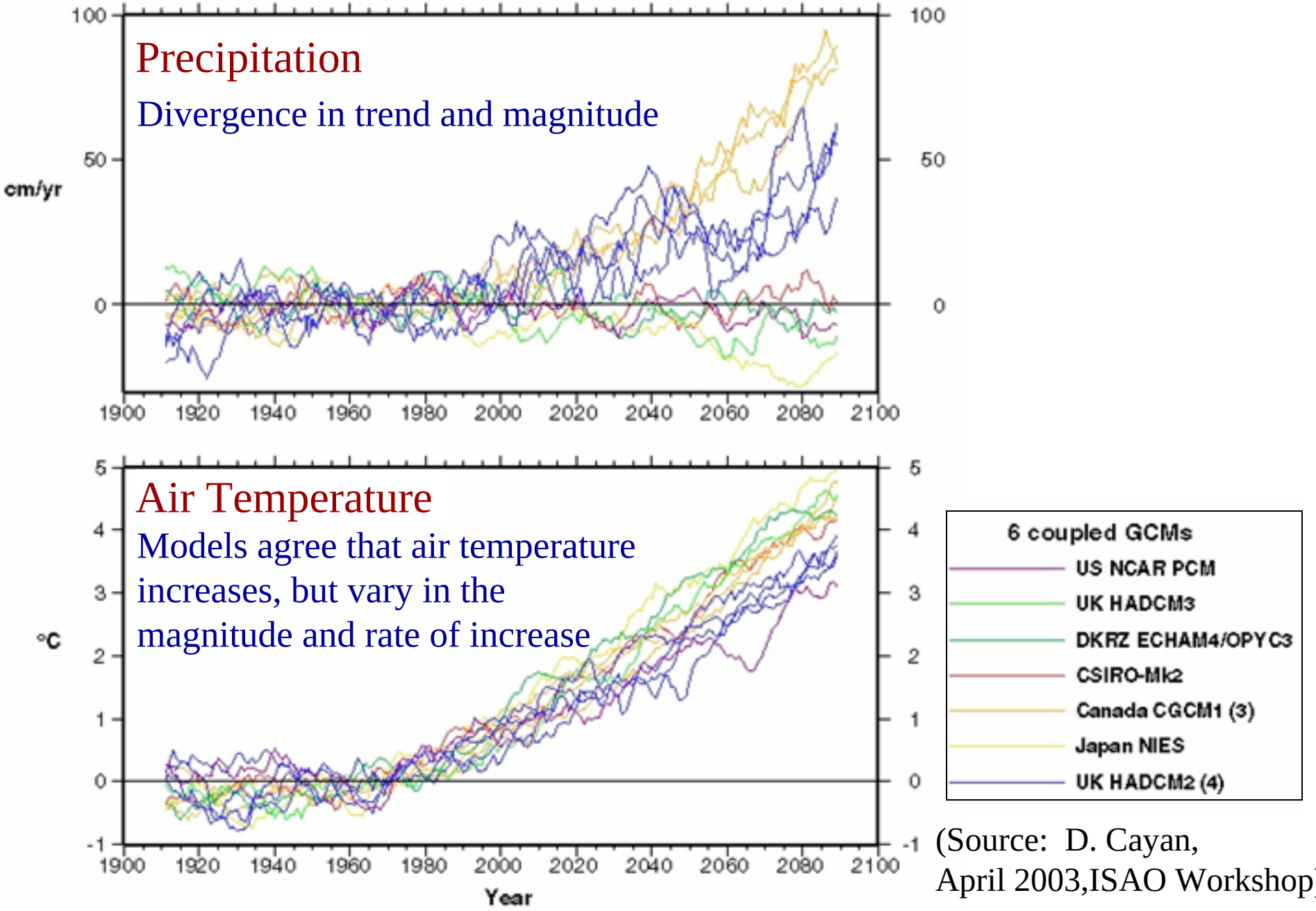


Figure 2-6 Range of Projections Reported by the Intergovernmental Panel on Climate Change for Increasing Global Average Surface Temperature Through 2100.

•Source: United States Environmental Protection Agency website at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ClimateFutureClimateGlobalTemperature.html

Climate Change Predictions for Northern California Differ



(Source: D. Cayan, April 2003,ISAO Workshop)

CA Precipitation Changes

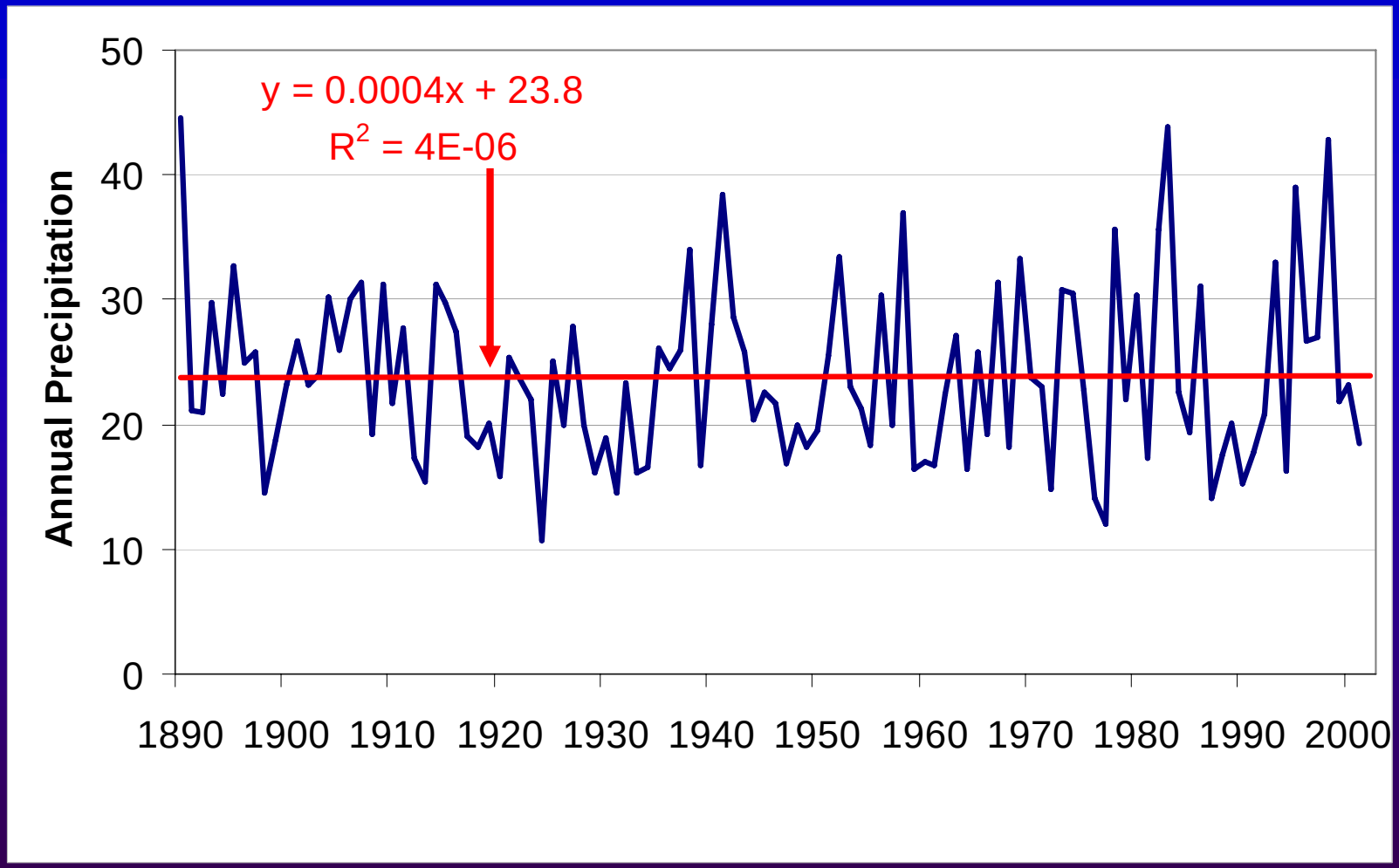
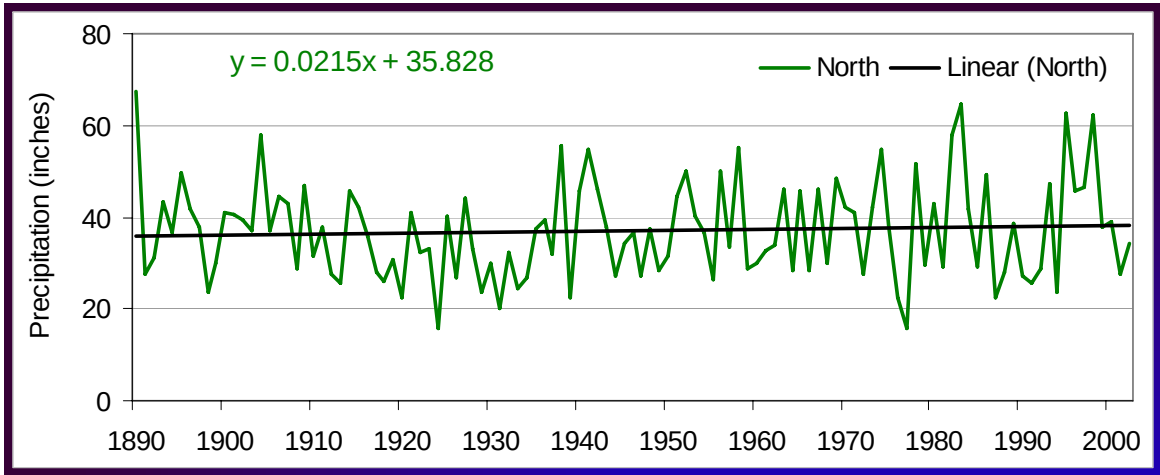
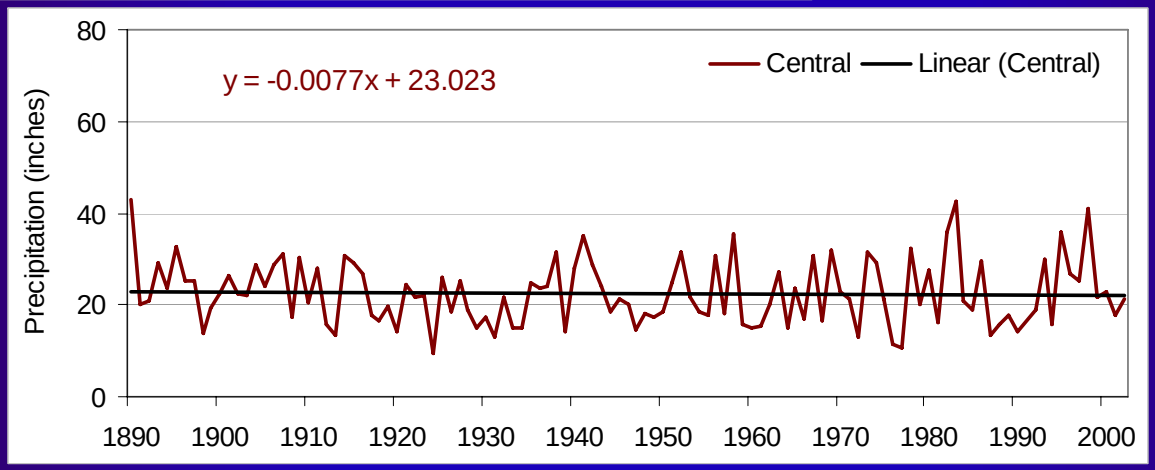


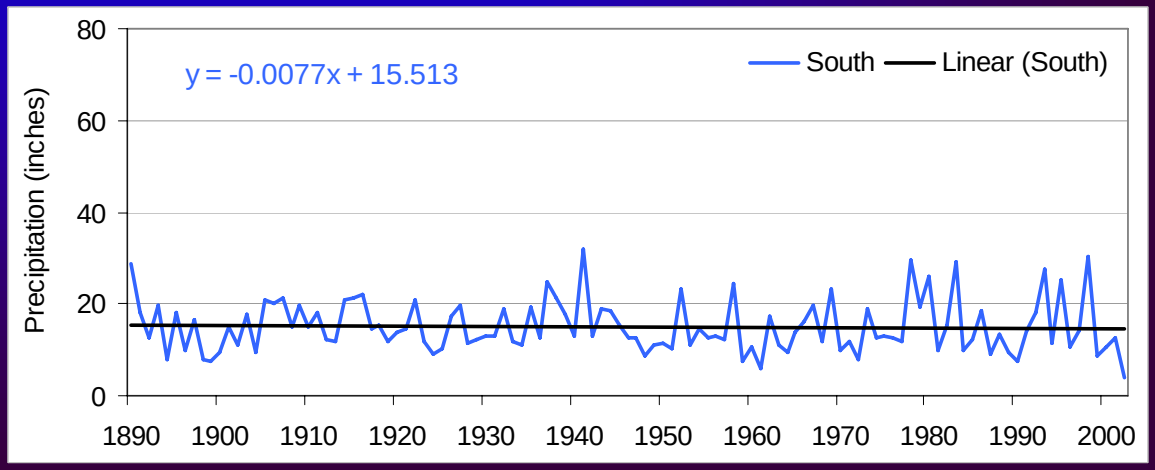
Figure 6-2 Average annual precipitation for California 1890-2002 with trend line.



a) Northern Region: California-Oregon border to 39º latitude



b) Central Region: 35 º - 39º latitude



c) Southern Region: 35 º latitude to California-Mexico border

Figure 6-3
Annual average precipitation with trends by region

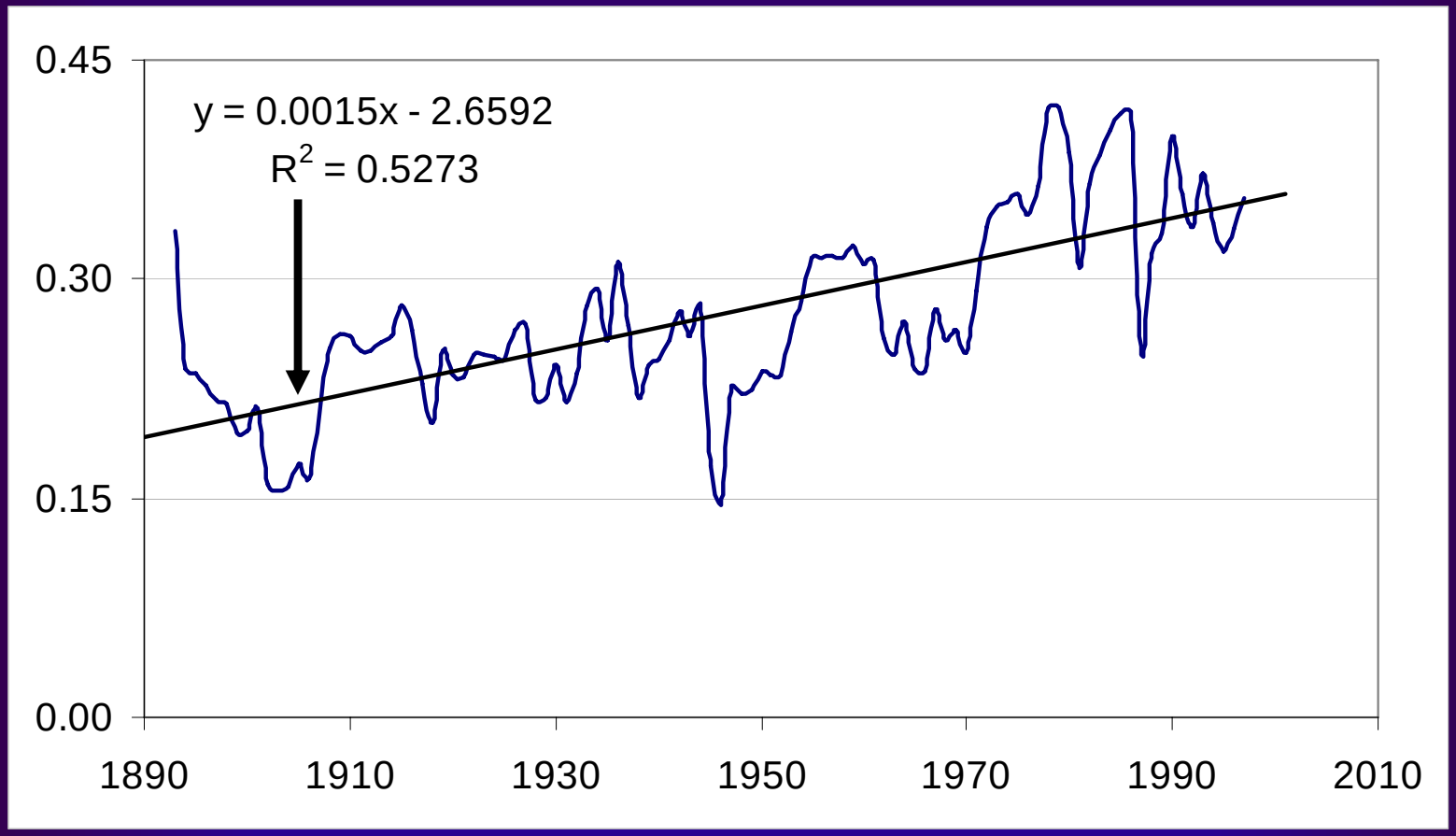


Figure 6-5 Coefficient of variation for statewide average precipitation with trend line

Reduction in Spring Runoff

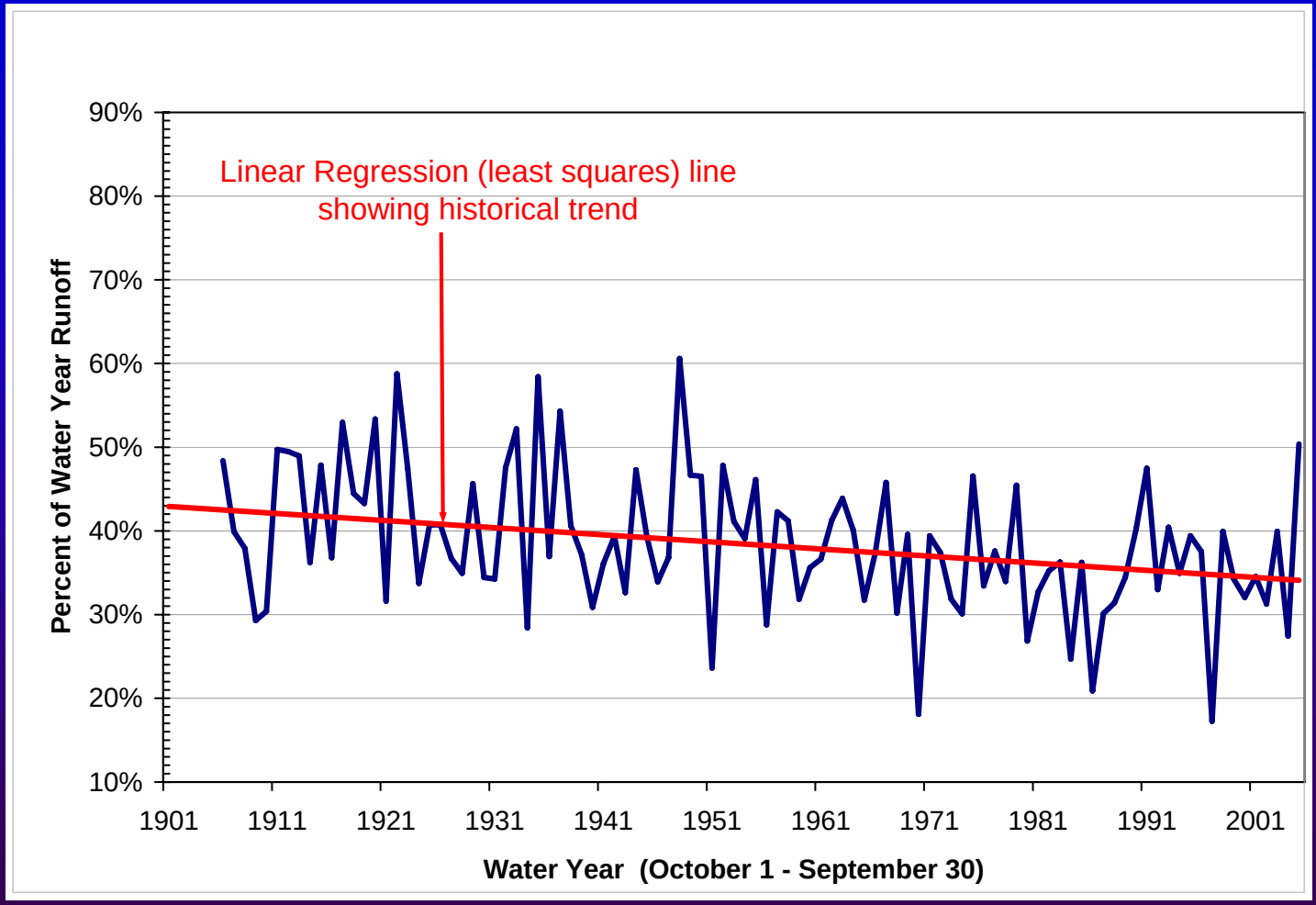
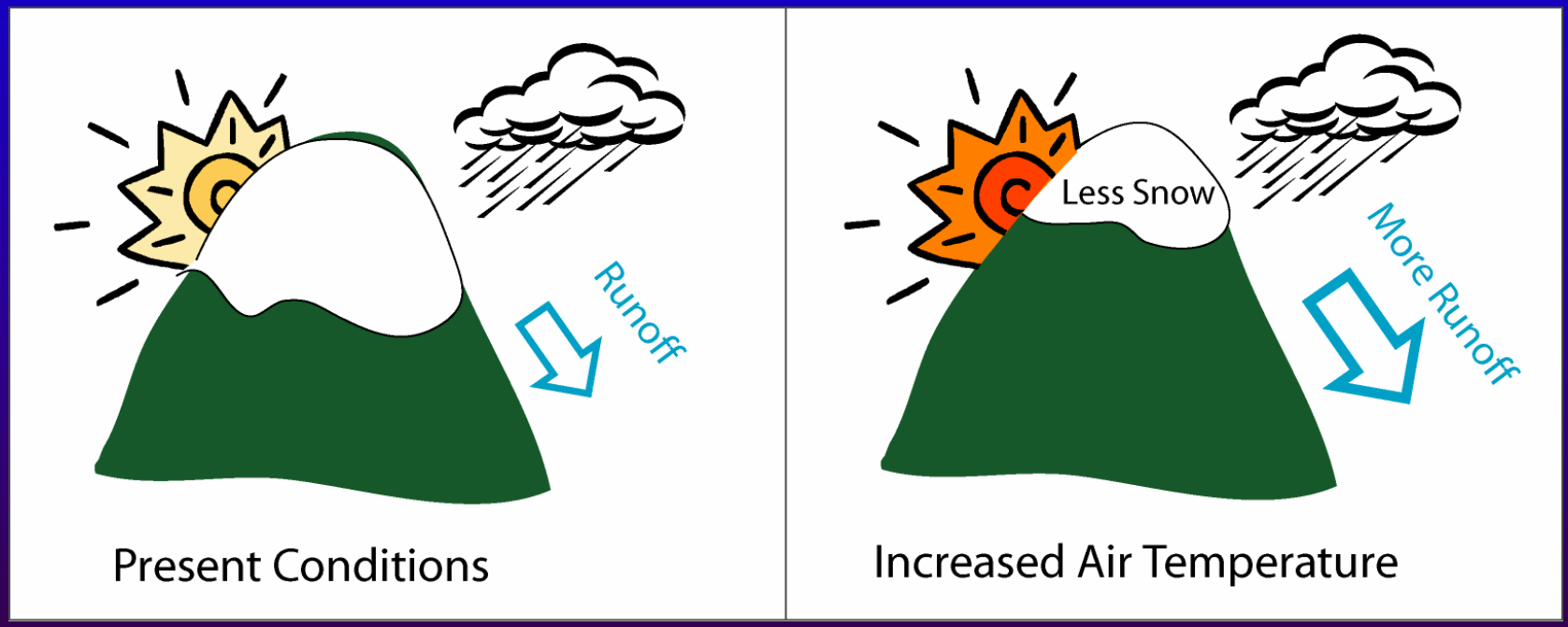


Figure 6-14 April-July Runoff as a percent of water year runoff for the Sacramento River

Storm Runoff Impacts



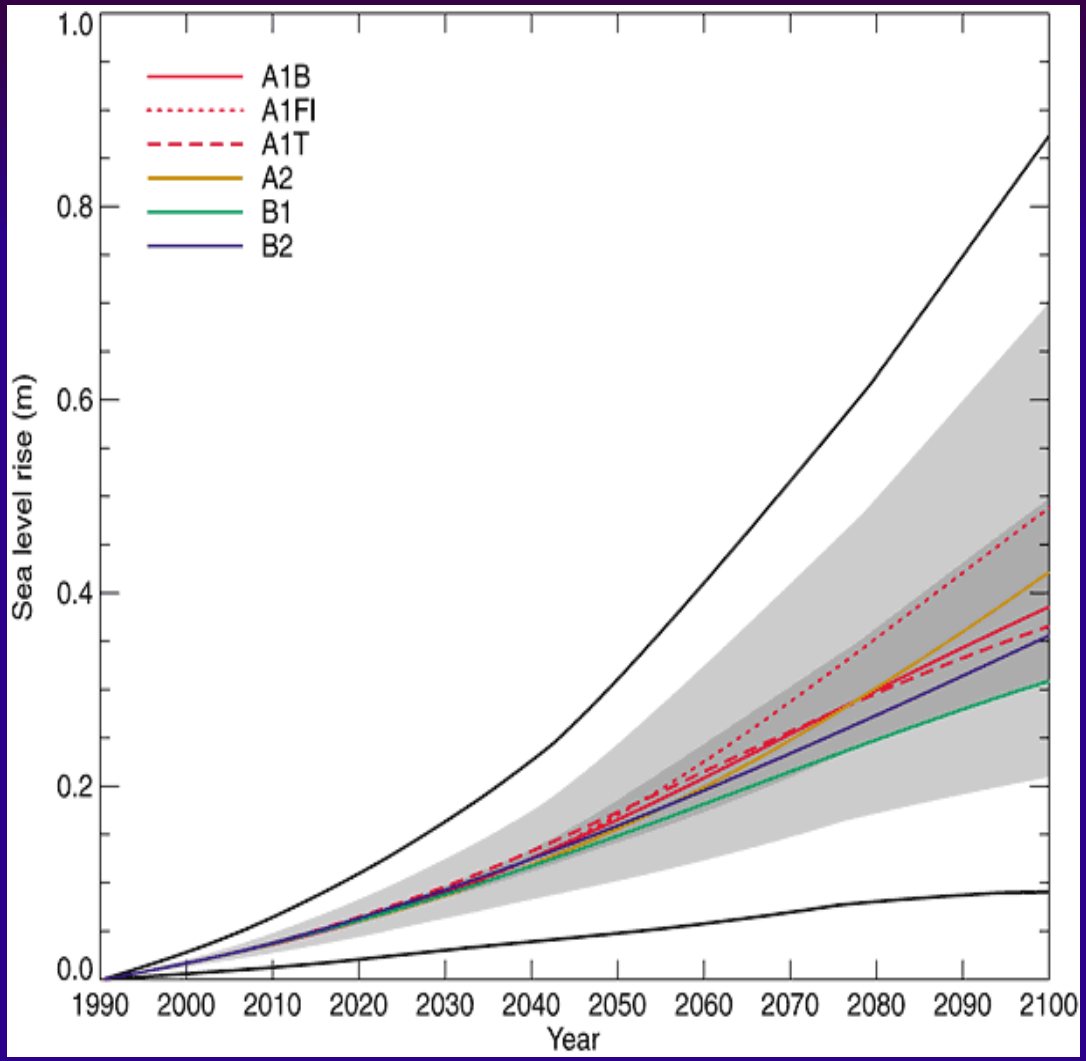


Figure 2-26 Projected Rise in Global Average Sea Level from 1900 to 2100

Source: Adapted from IPCC, 2001a (http://www.grida.no/climate/ipcc_tar/wg1/fig11-12.htm)

Explanation: Global average sea level rise from 1990 to 2100 for the SRES (Special Report on Emission Scenarios; IPCC 2000) scenarios and seven climate models.

Sea Level Trends in California

Table 2-6 Relative Sea Level Trends for Eight Tide Gauges Along the Coast of California with 50 Years or More of Record

CO-OPS Gauge Number--Name	**Sea Level Trend** (feet/century)
9419750--Crescent City	-0.16
9414750—Alameda	0.29
9414290--San Francisco	0.70
9412110--Port San Luis	0.30
9410840--Santa Monica	0.52
9410660--Los Angeles	0.28
9410230--La Jolla	0.73
9410170--San Diego	0.71

Incorporating Climate Change into Water Resources Management Tools

Analysis Approach

Global Modeling

Models used:
GFDL or PCM

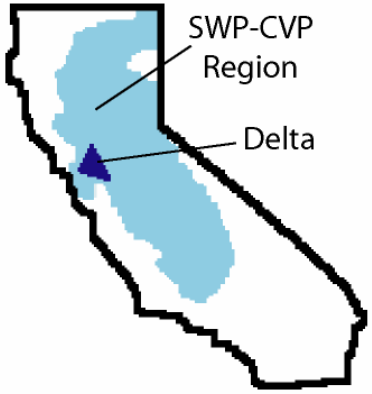
Analysis includes:
Air Temperature
Precipitation
Specific Humidity
Latent Heat Flux
Radiation Fluxes
Wind Speeds

Regional Downscaling

Model used:
VIC

Analysis includes:
Air Temperature
Precipitation
Wind Speed
Surface Humidity
Soil Moisture
Streamflows

Water Resources Impact and Risk Analysis

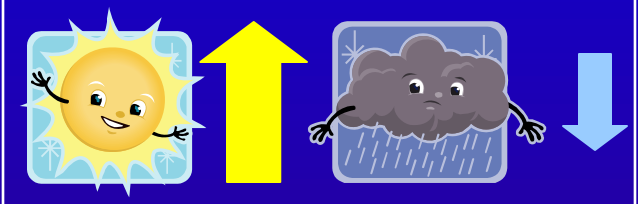
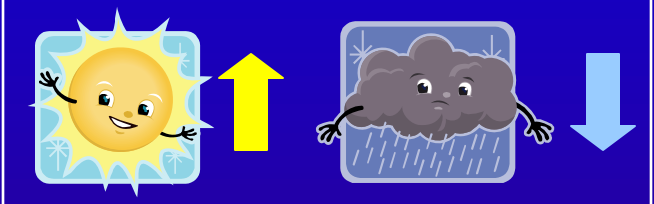
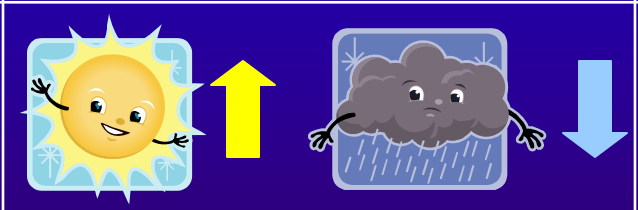
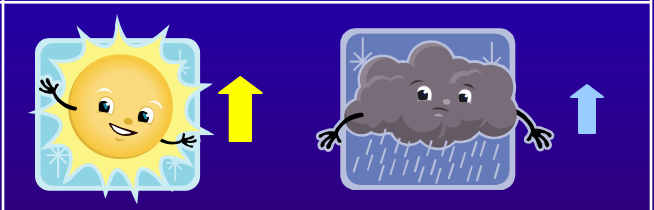


Models used:
CALSIM, DSM2, SIMETAW

Analysis includes:
SWP/CVP Operations
Delta Water Quality
Sea Level Rise
Flood Management
Water Supply Forecasting
Evapotranspiration

Analysis by DWR-Reclamation
Climate Change Work Team

Precipitation and Air Temperature Projections

Scenario/ Model	A2	B1
GFDL		
PCM		

Climate Action Team selected four scenarios

2 models x 2 emissions scenarios

GCMs all show increasing air temperatures for the next century

There is no consistent trend in precipitation projections.

Operations Modeling

Global Modeling	Regional Downscaling	SWP & CVP Operations	Delta Flow & Water Quality
			
GFDL or PCM	VIC	CALSIM	DSM2
Air Temperature Precipitation Humidity Radiation	Streamflow Snowpack Snow melt Soil Moisture	Reservoir Ops Deliveries Storage Delta Outflow	Flow Salinity

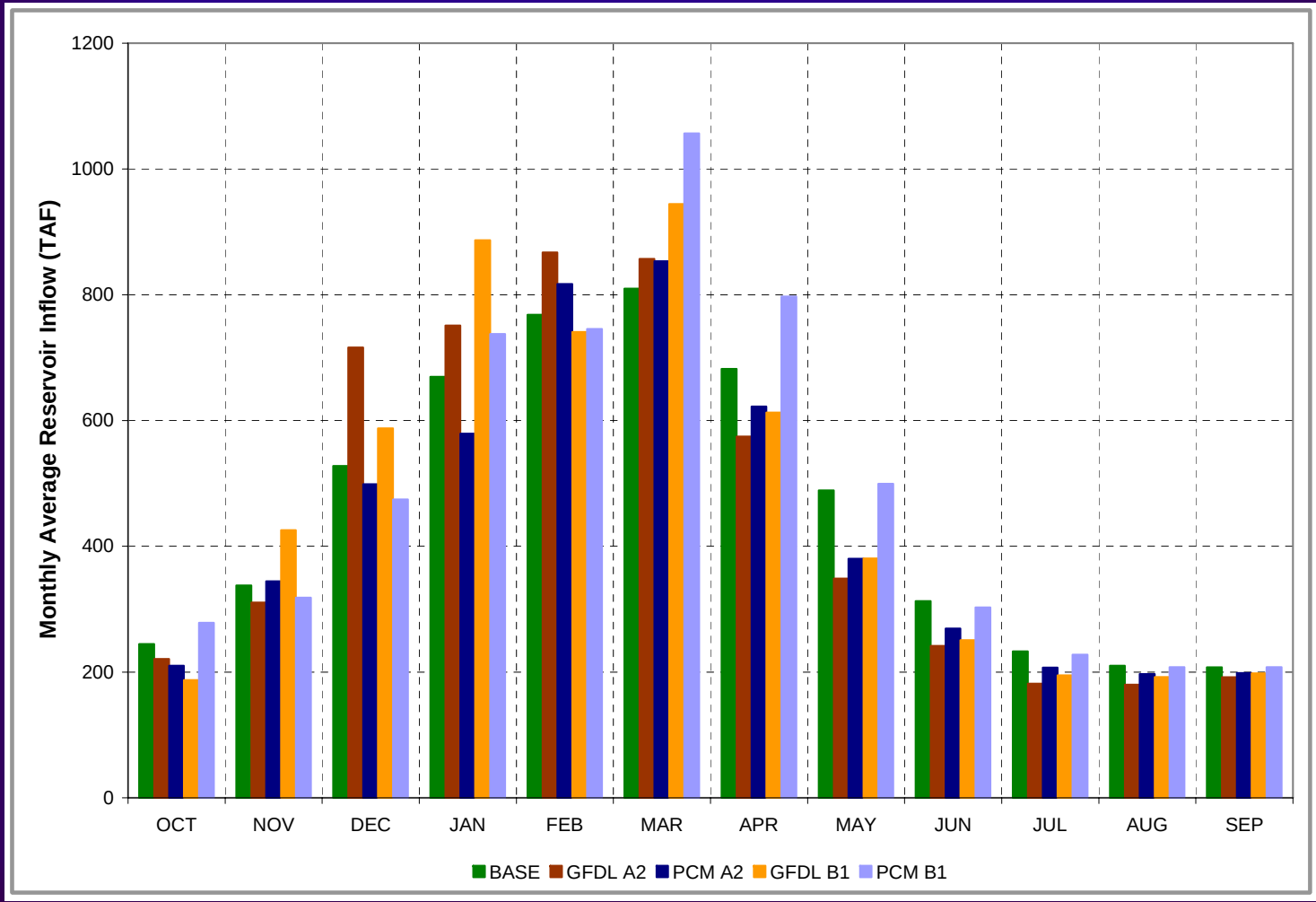
Preliminary Operations Impacts
2050 Runoff Projections, No Sea Level Rise

- Upstream reservoir shortages during droughts
- Deliveries
  - Decreased for the dry scenarios
  - Increased slightly for wet scenario
- Carryover storage
  - Reduced for drier scenarios
  - Increased in dry years for wet scenario
- Power generation was negatively impacted for drier scenarios
- Stream temperature changes were examined

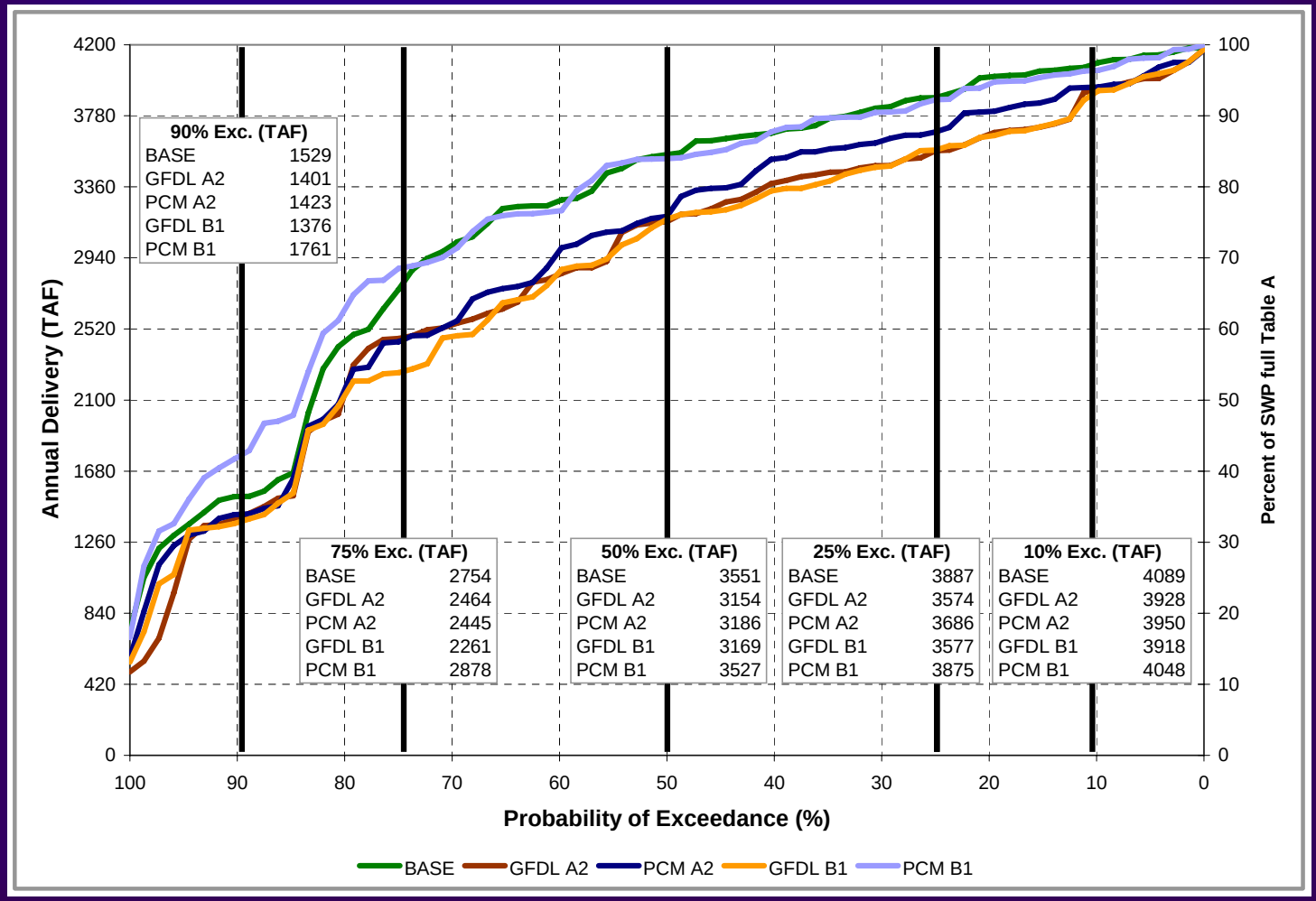
Qualification of Results

- Four climate scenarios with no probability of occurrence.
- Perturbation method accounts for seasonal shift in runoff, not potential changes in weather variability.
- Not accounting for sea level rise or changes in demand.

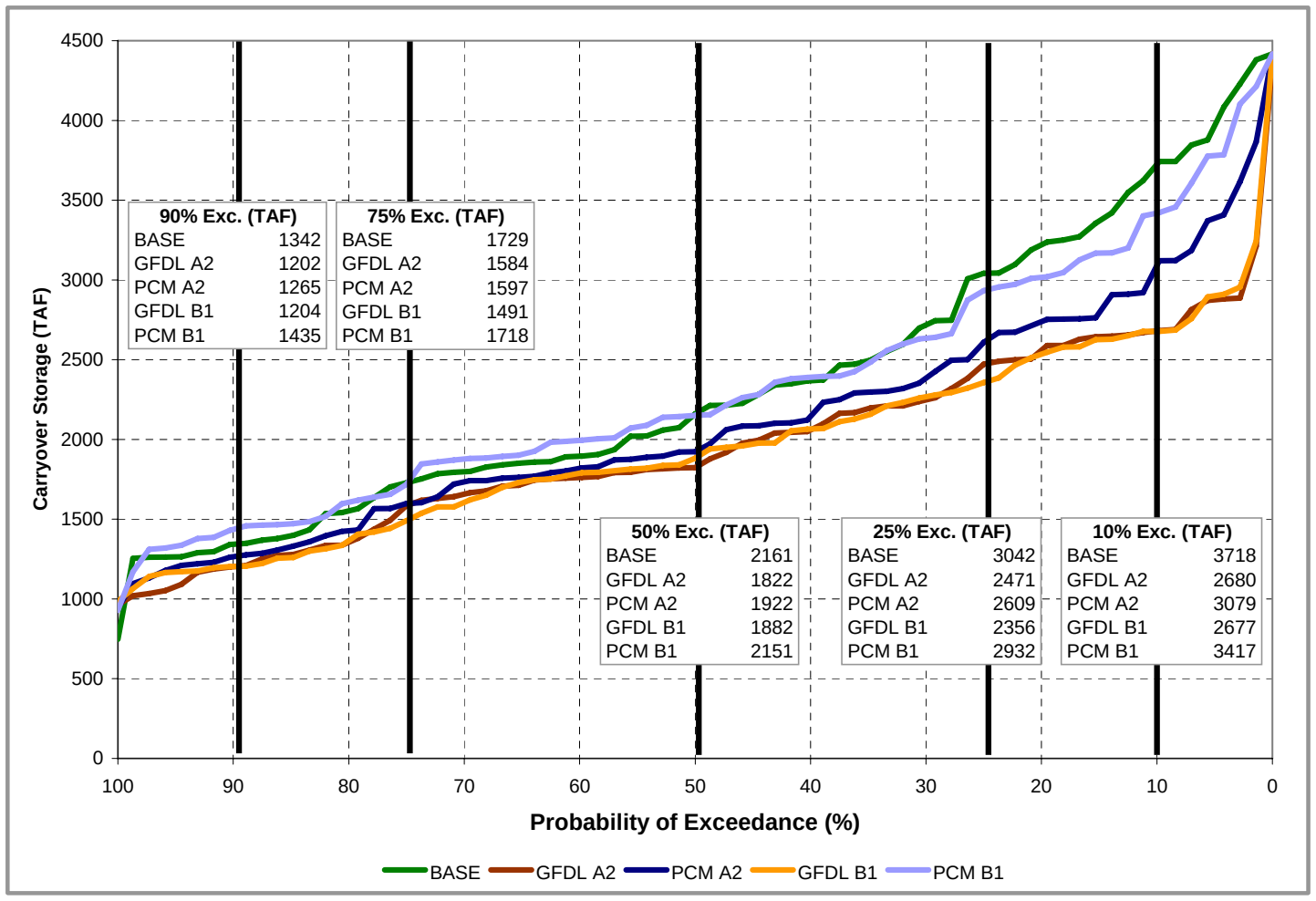
Lake Shasta Average Monthly Inflow (1922-1994)



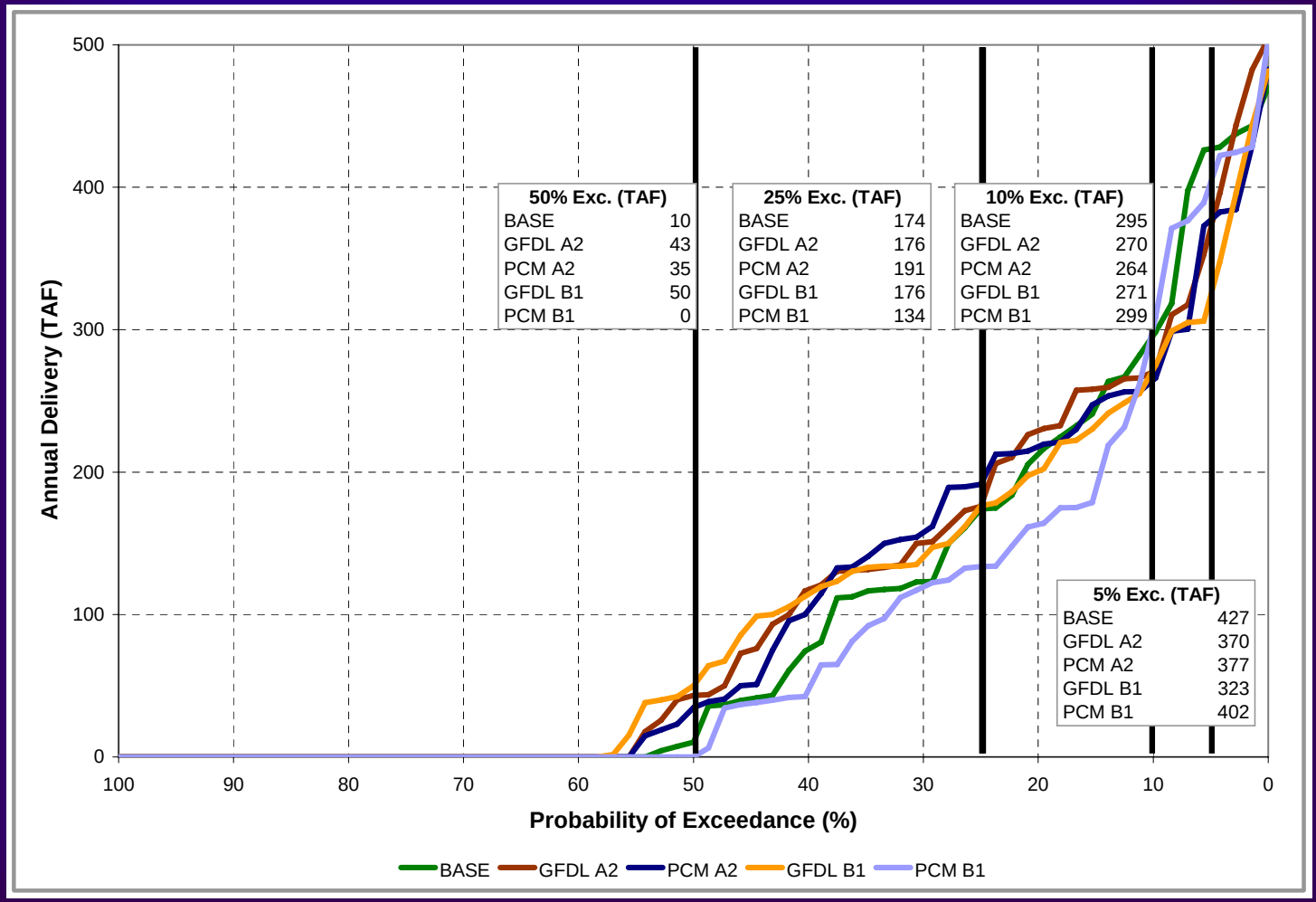
Exceedance Probability Plot of SWP Table A Deliveries



Exceedance Probability Plot of SWP Carryover Storage



Exceedance Probability Plot of SWP Article 21 Deliveries



Delta Modeling

Global Modeling	Regional Downscaling	SWP & CVP Operations	Delta Flow & Water Quality
			
GFDL or PCM	VIC	CALSIM	DSM2
Air Temperature Precipitation Humidity Radiation	Streamflow Snowpack Snow melt Soil Moisture	Reservoir Ops Deliveries Storage Delta Outflow	Flow Salinity

Preliminary Delta Impacts

- **2050 runoff projections, no sea level rise**
  - **System flexibility maintained compliance levels with Delta water quality standards**
- **2050 runoff projections with 1ft sea level rise with no changes in system operations**
  - **Changes to operations would be required to maintain standard compliance**
  - **Increased potential to overtop Delta levees**

250 mg/l Chloride Standard Compliance

Scenario/ Location	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Contra Costa-Old R at Rock Sl.	97.2%	98.0%	98.0%	98.2%	97.4%
Contra Costa-Los Vaqueros	99.9%	100%	100%	100%	100%
SWP-Clifton Court	100%	100%	100%	100%	100%
CVP-Tracy	100%	100%	100%	100%	100%

Operational flexibility is able to mitigate for changes in runoff and still meet Delta water quality standards most of the time

Preliminary Results
1ft Sea Level Rise Only
with no changes in operations

% time below 250 mg/l Chloride Threshold

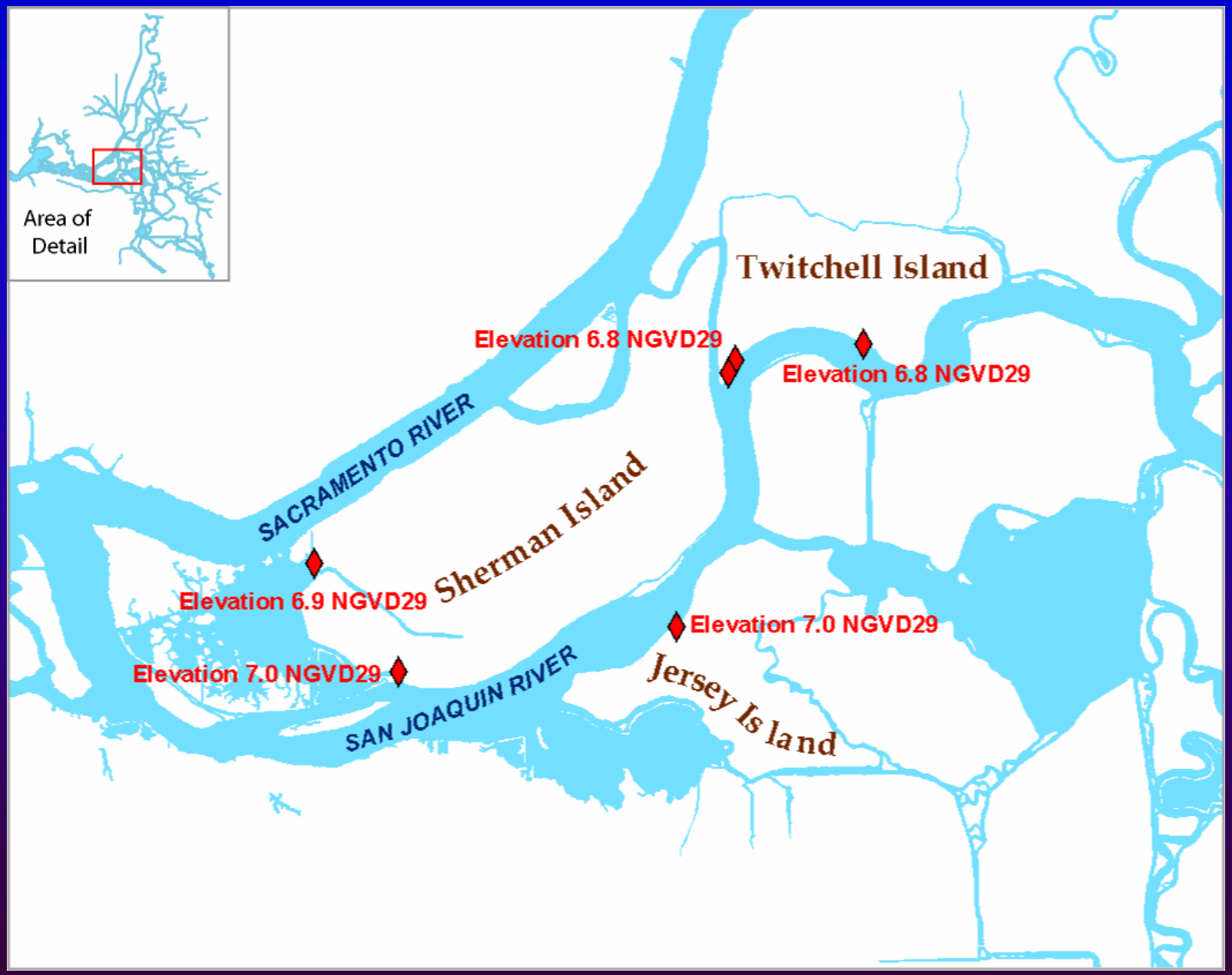
Scenario/ Location	BASE	1ft Sea Level Rise same Martinez EC	1ft Sea Level Rise increase Martinez EC
CCWD-Old River at Rock Sl.	97.2%	89.9%	87.5%
CCWD-Old River at Hwy 4*	99.9%	99.7%	99.4%
SWP-Clifton Court	100%	100%	100%
CVP-Tracy	100%	100%	100%

Salt intrusion from a 1ft sea level rise and no changes in operations exceeds threshold at Old R at Rock Sl ~10% of the time

Sea Level Rise Impacts on Levee Overtopping Potential

Photo by Rob Duvall Jan 1, 2006

Minimum Levee Crest Elevations

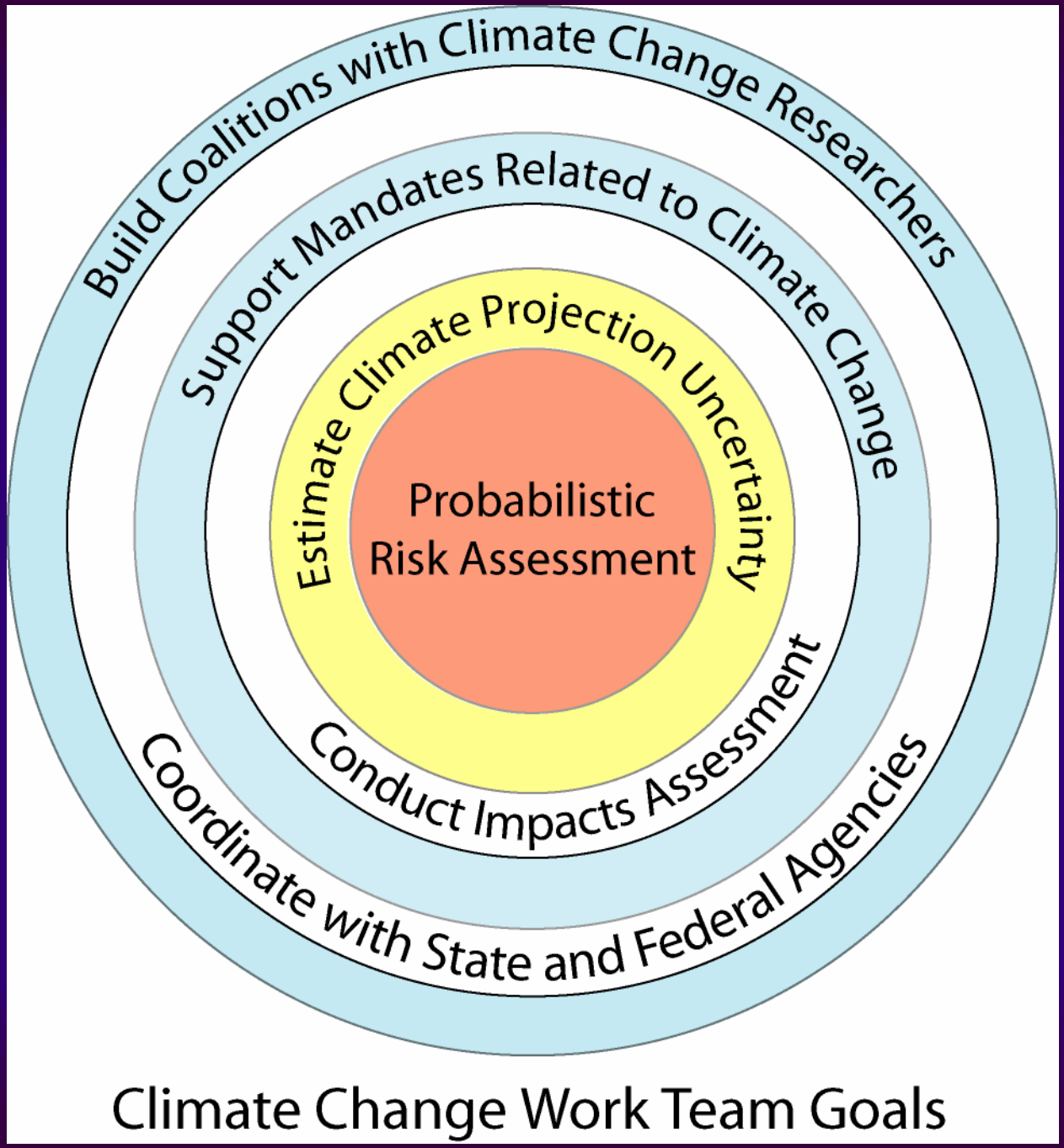


Levee Overtopping Potential

Location	Min Crest Elev., ft	# of Potential Overtopping Events in 16 yrs			
		Base	4 Climate Change Scenarios	1 ft SLR	4 Climate Change Scenarios 1ft SLR
NW Sherman Is	6.9	0	0	2	2
SW Sherman Is	7.0	0	0	2	2
SW Twitchell Is	6.8	0	0	2	2
SE Twitchell Is	6.8	0	0	2	2
W Jersey Is	7.0	0	0	2	2

Climate change scenarios reflect historical variability

Future Directions



Climate Change Work Team Goals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http://baydeltaoffice.water.ca.gov/climatechange.cfm
www.climatechange.ca.gov
Photo by Ralph Finch Jan 4, 2006