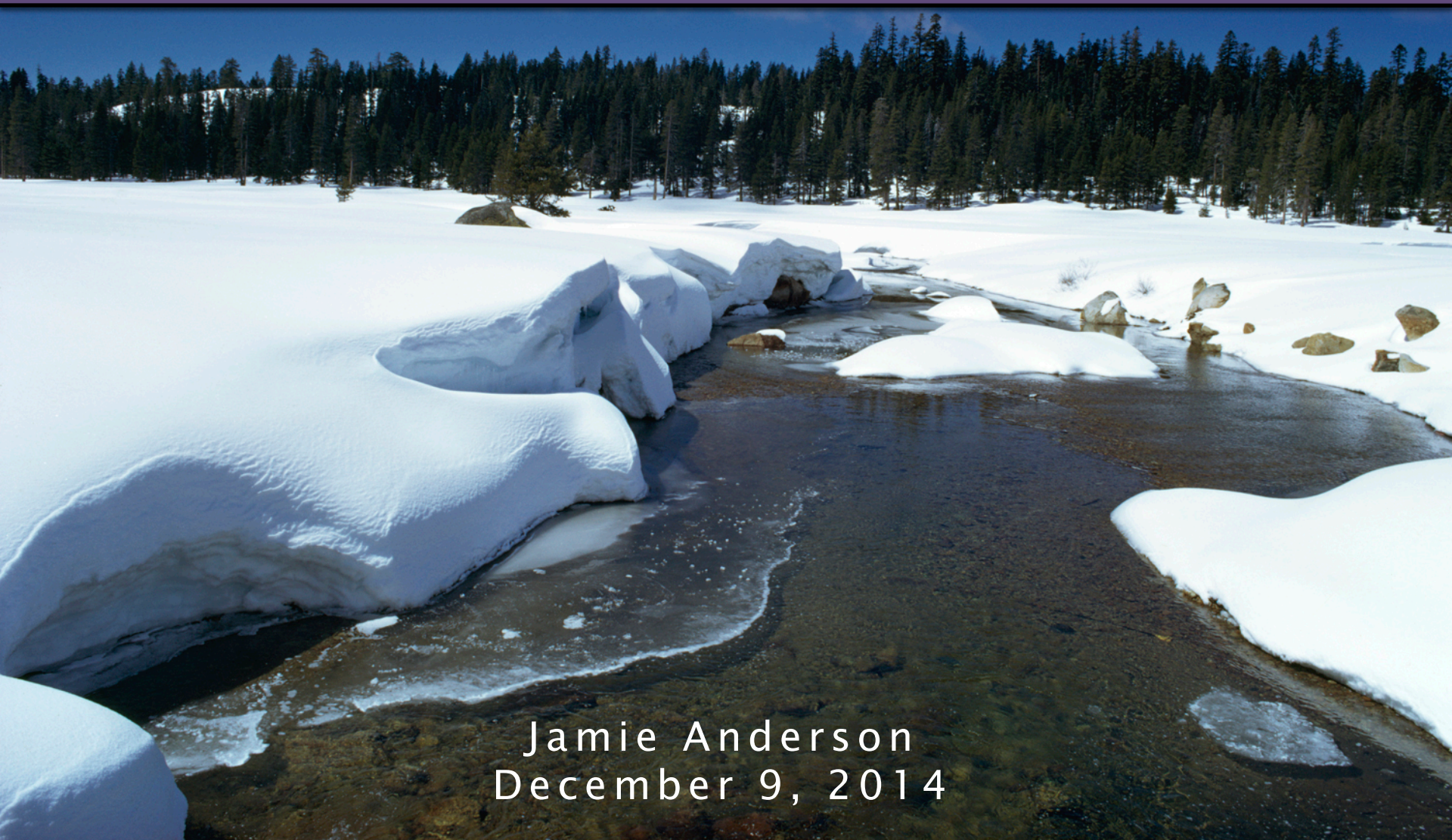
# Climate Modeling
## 101

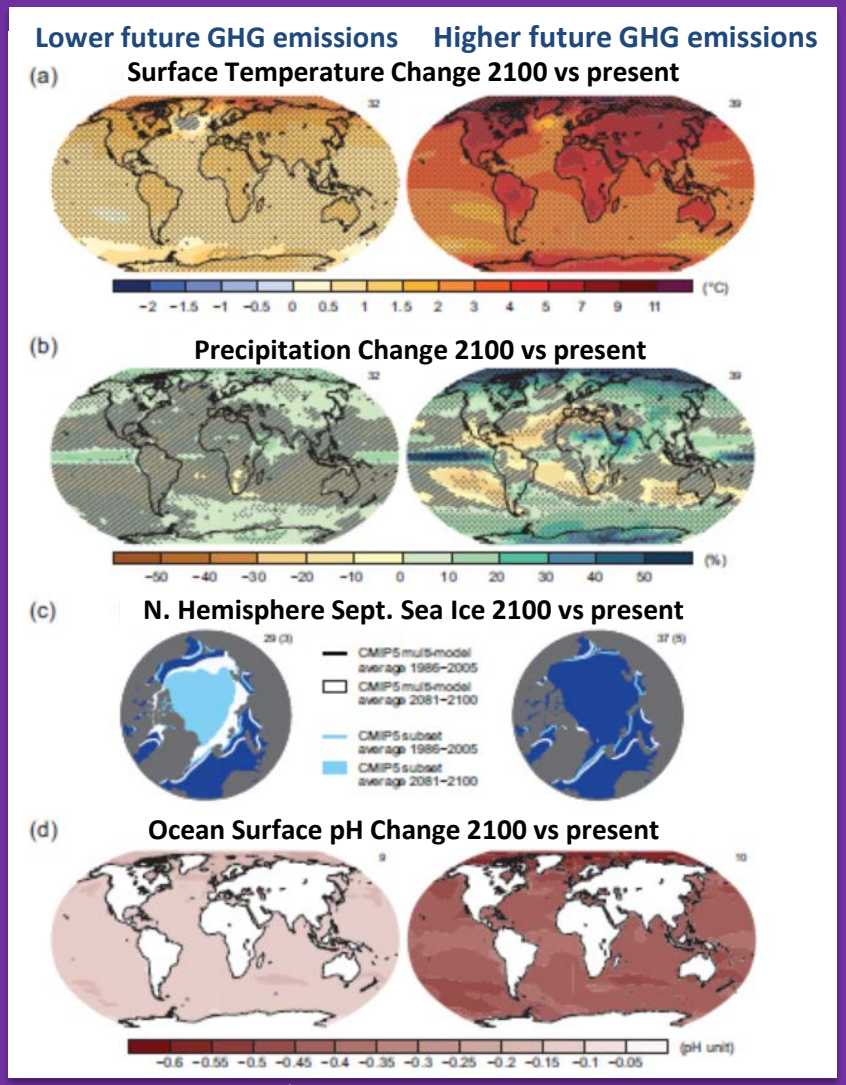


Jamie Anderson
December 9, 2014

# Climate Monitoring vs Climate Modeling

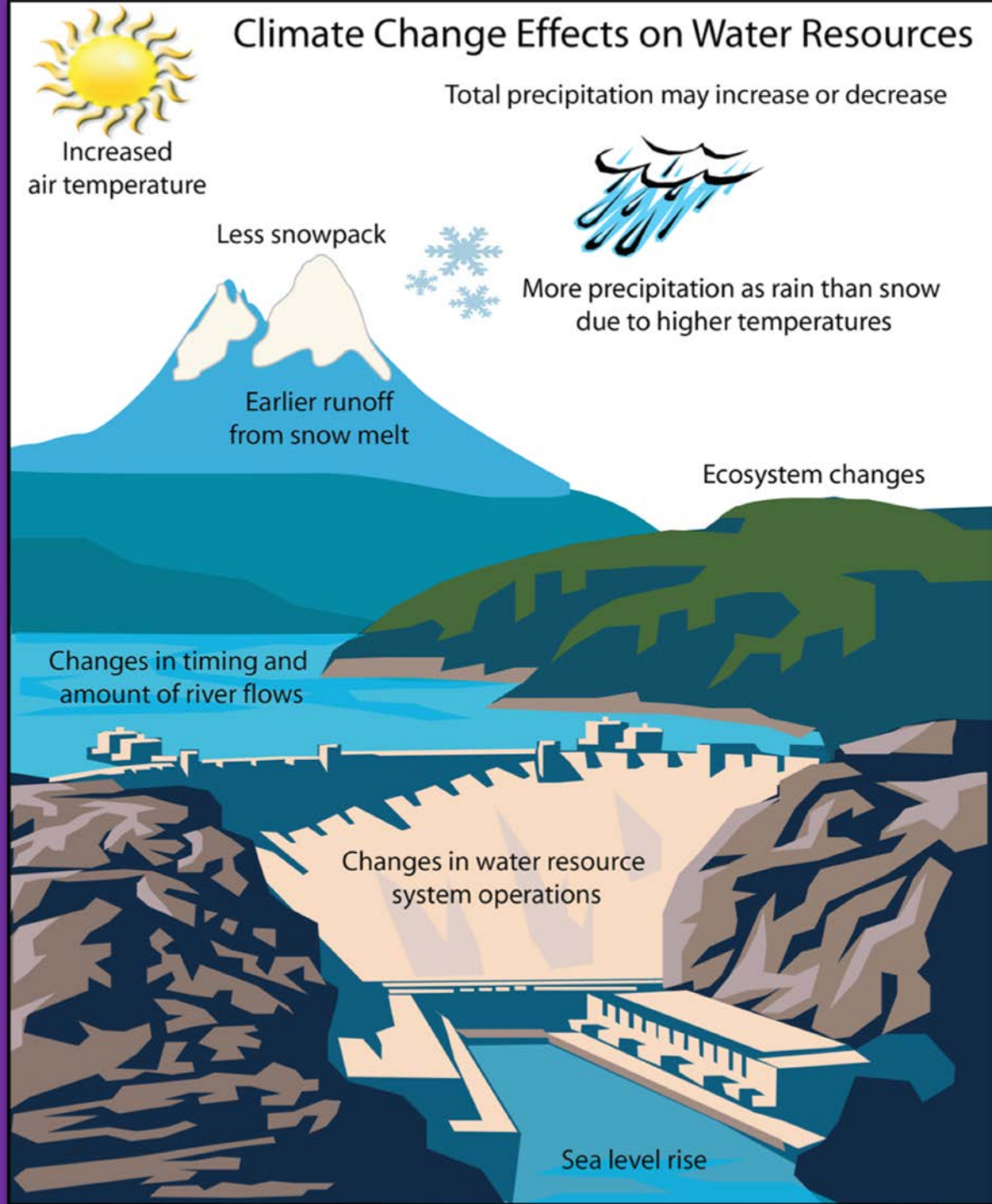
**Monitoring** tells us how the current climate has/is changing

**Modeling** tells us how the future climate might change




Adapted from IPCC 5th Assessment Summary for Policy Makers

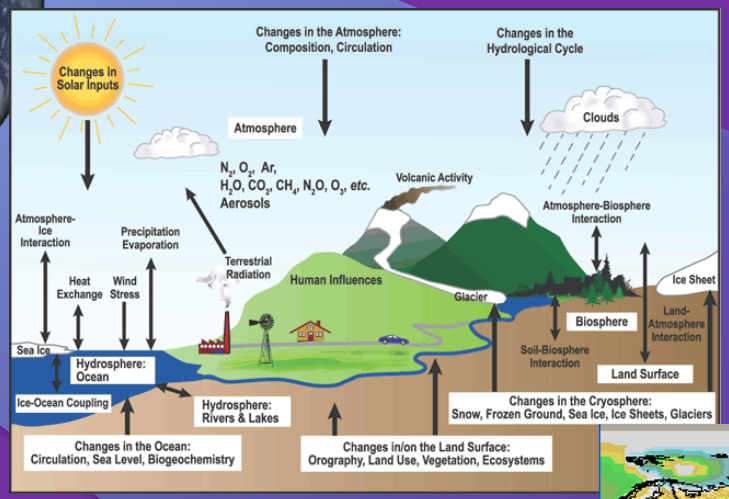
# Why are climate models important for DWR?



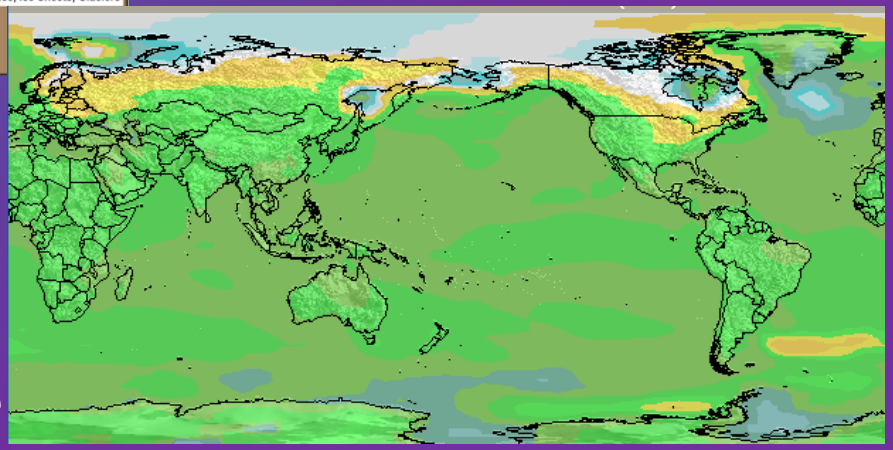
# What is a model?

# Mathematical representation of the climate system

GCM-
Global Climate Model
or
General Circulation Model




**Complex ocean and atmospheric interactions represented by equations**



**Solves equations to show how climate may evolve in the future**

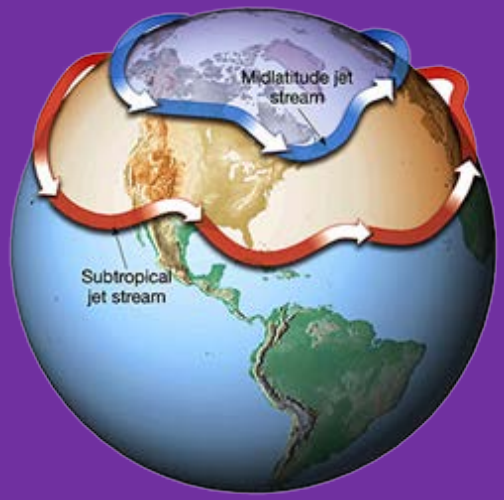
# Building a Global Climate Model

National Earth Science Teachers Association

http://www.windows2universe.org/earth/climate/climate_modeling.html

# Why so hard to do?

- *Natural climate variability*
- *Future Uncertainty*
- *Data collection*
- *Physical processes and Feedback mechanisms*
- *Spatial Resolution*




**Trivia Time: How long does it take a modern global climate model to simulate 150 years?**

Climate models are used to explore possible future changes in climate

Climate models don't predict future changes in climate

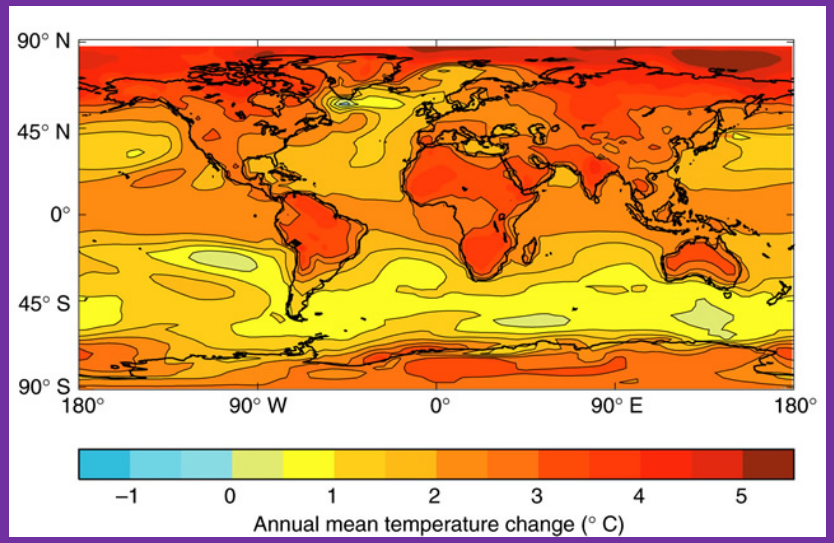
# Weather vs Climate Modeling

## Weather Forecasting

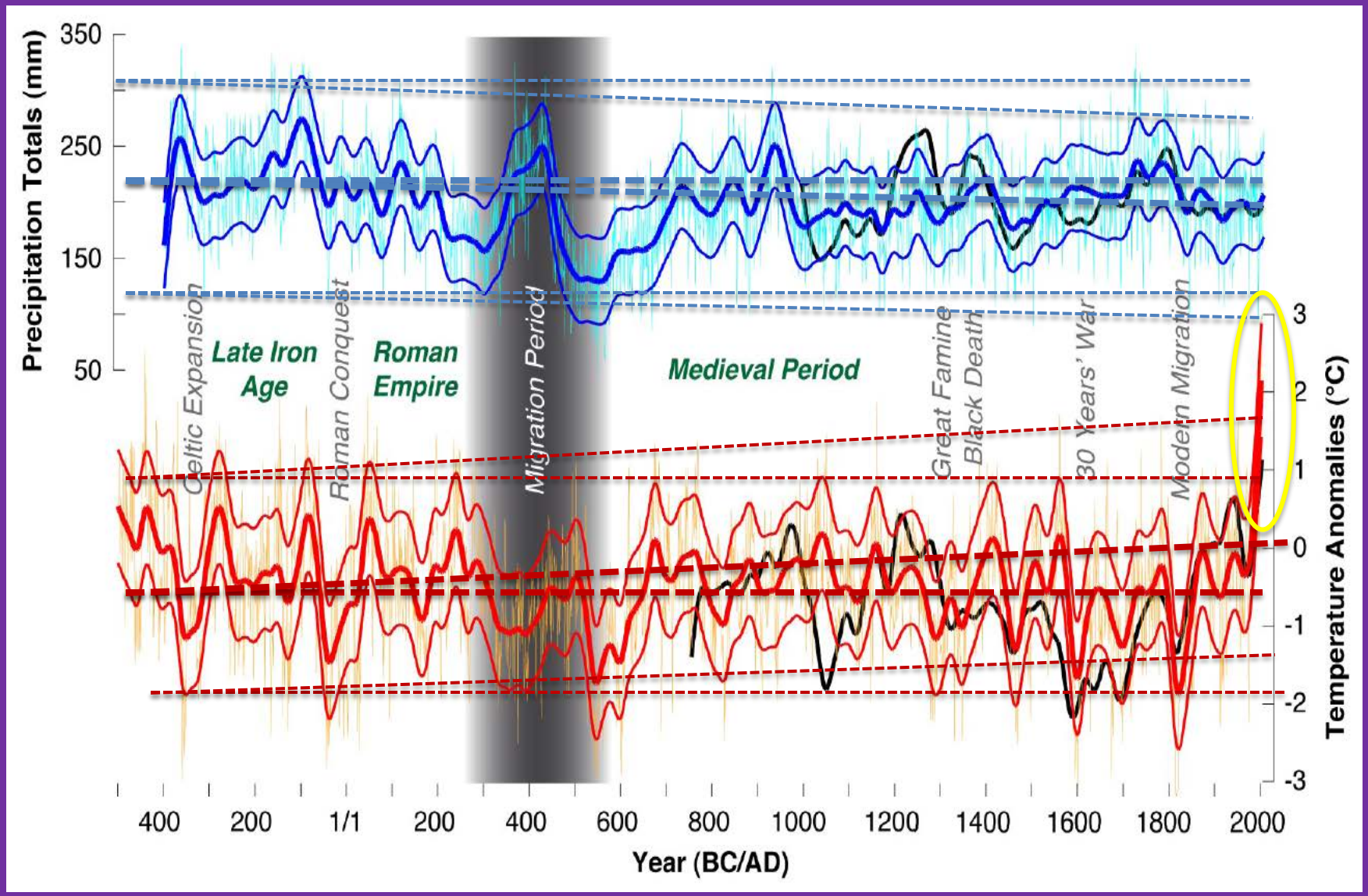
- What will the weather be on a specific day in a specific place
- Short term (7-10 days)

## Future Climate Simulations

- What will the climate trends be in a region in the future
- Long term (100 years)



# Natural Climate Variability

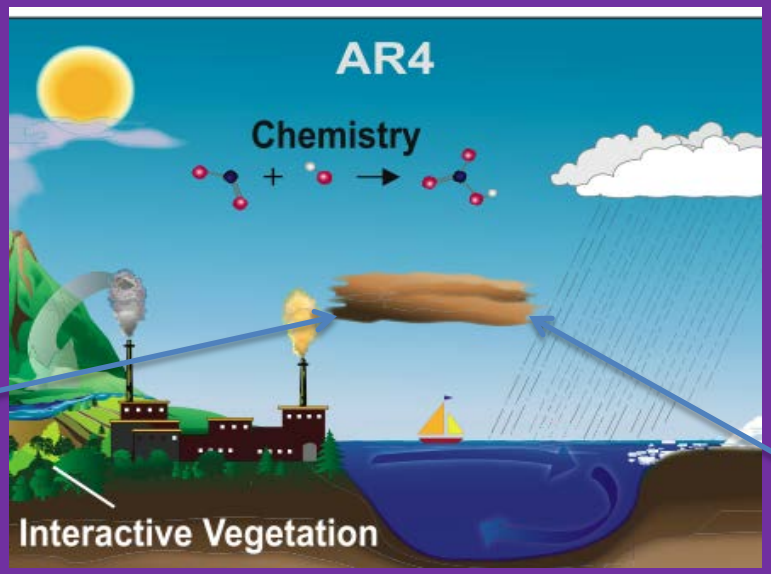


Climate models are useful for exploring possible future changes in climate

Climate models don't predict future weather or when extreme events will occur

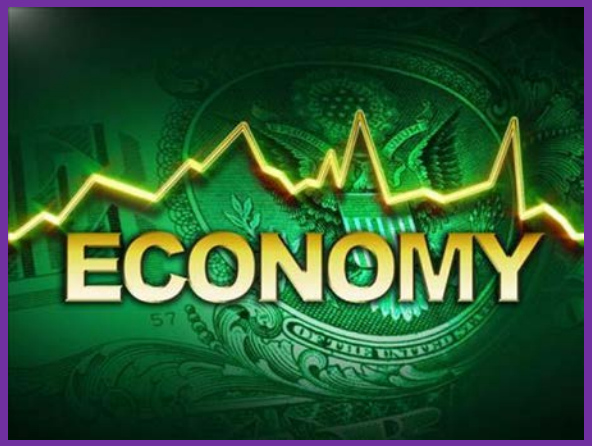
Scientists & planners use information from many models to make decisions

# Future Uncertainty-
## Atmospheric Composition



# Other Future Uncertainties

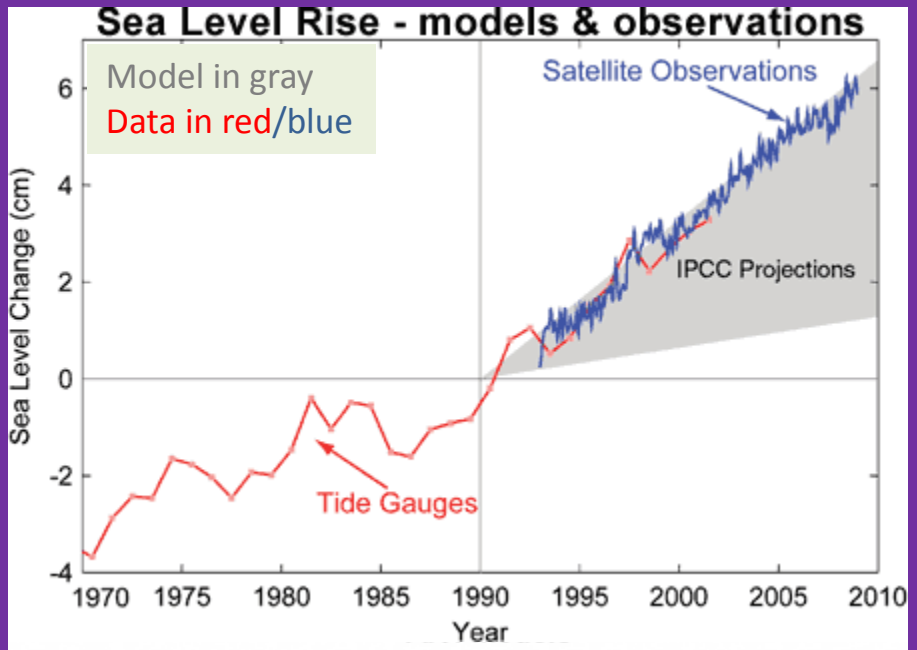
Population

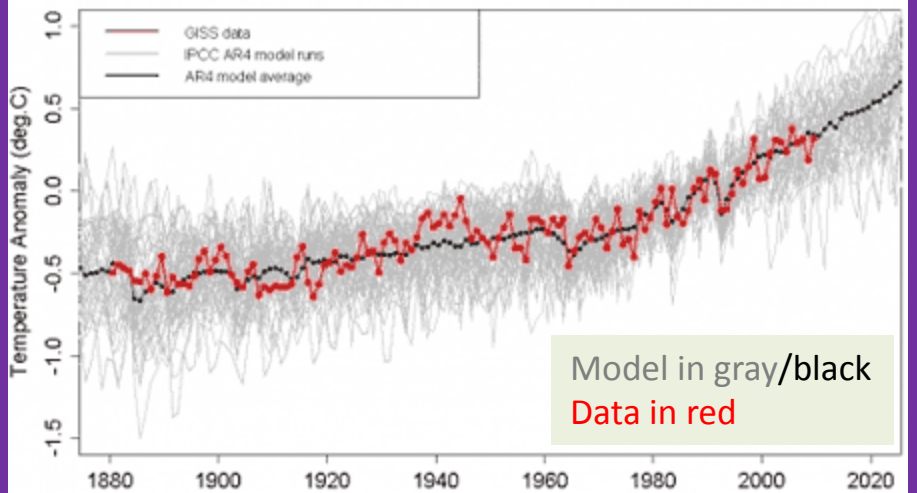


Technological Development

# That's a lot of Uncertainty… What do we really know?

- Global Climate Models (GCMs) from the 90's did a reasonable job predicting warming for the last 20 yrs.
- GCMs also predicated the increase in extreme events for last decade.
- At the global and super-regional scale, these models do a good job
- GCM's aren't designed to provide more local information, so an additional step called downscaling is needed
- GCMs give us information that improves our future decision making capabilities



# UNCERTAINTY

Climate Projections

Population

Converting global data
to local/regional scales

Water cycle changes
Future water demands

$$$$

Sea level rise

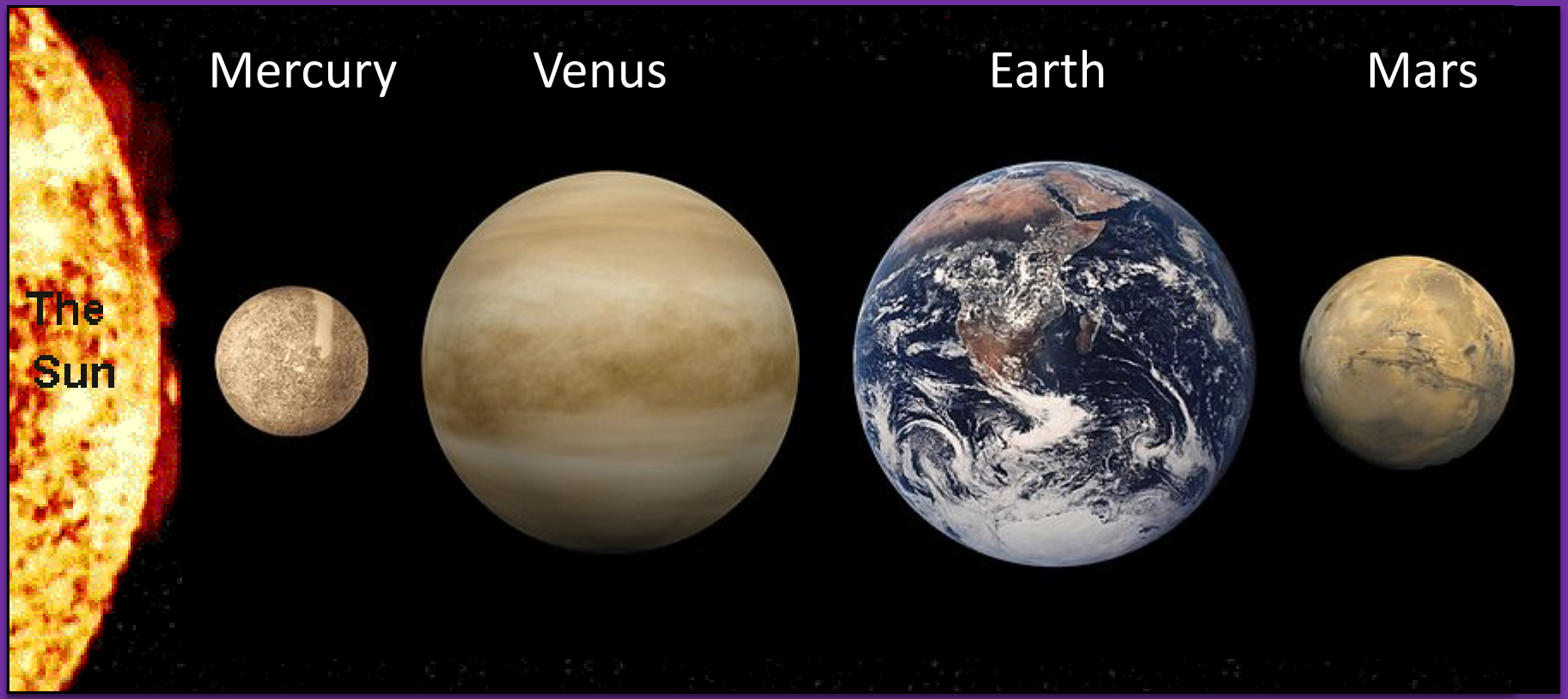
Ecosystem response

Adaptation Strategies

Land use changes

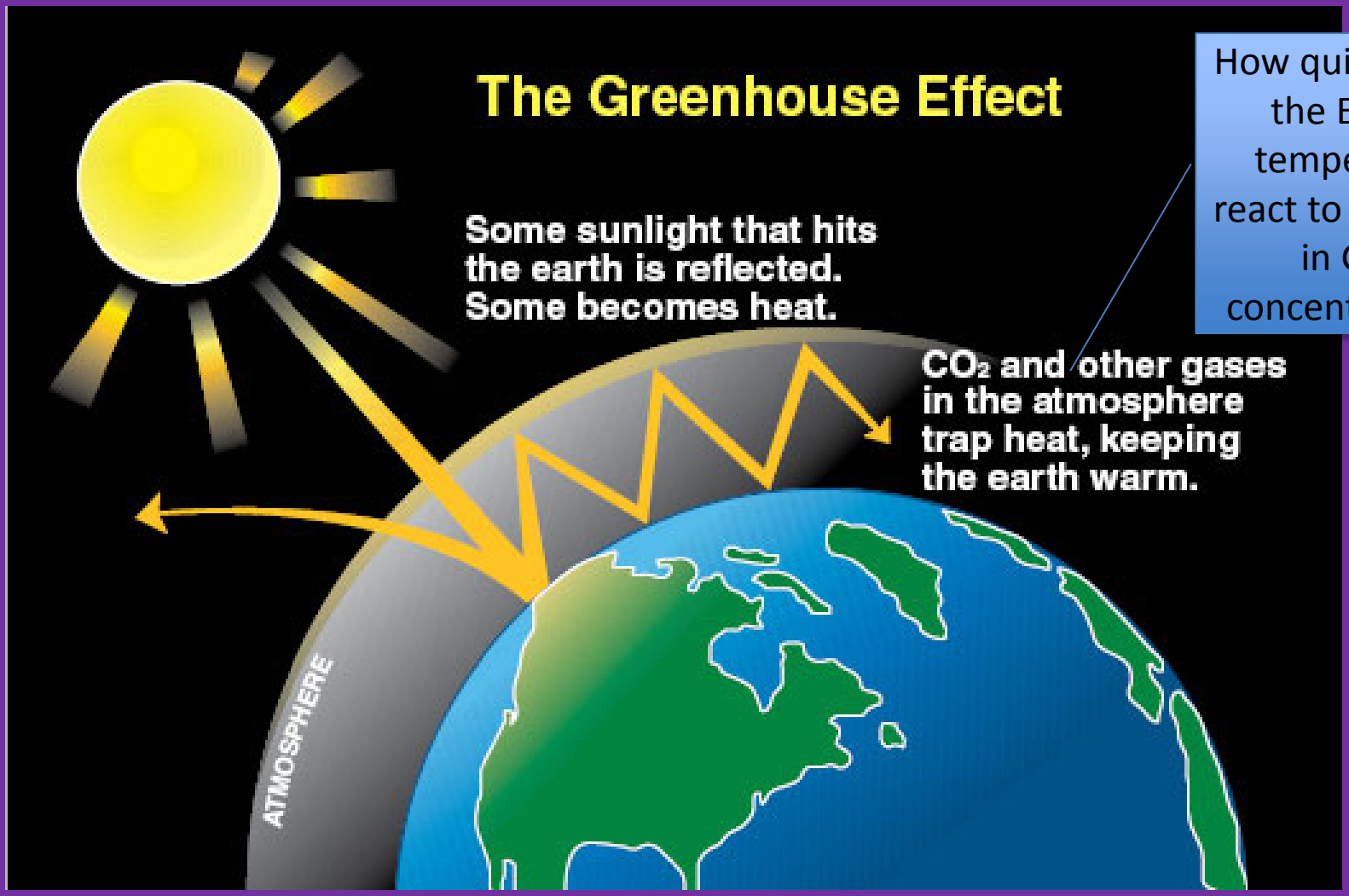
Changes in societal values

# Physical Processes and Feedback Mechanisms




Which planet is the warmest?

# Physical Processes and Feedback Mechanisms

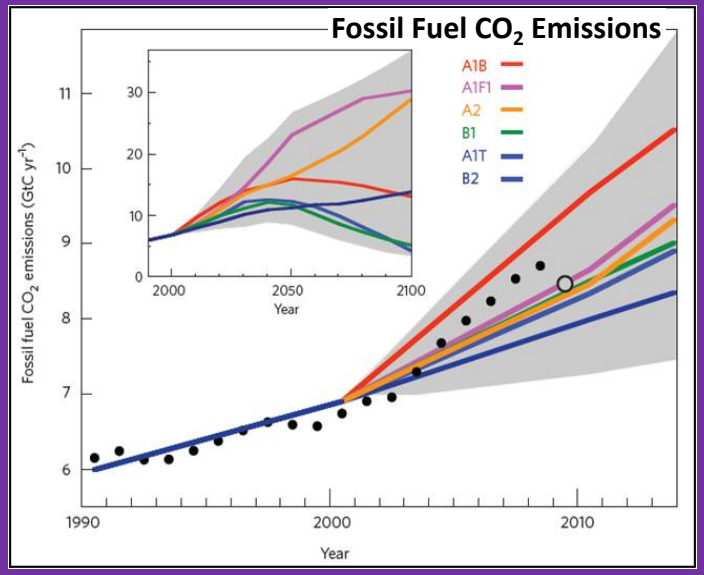



How quickly does the Earth's temperature react to increases in GHG concentrations?

www.ecy.wa.gov/climatechange/whatis.htm

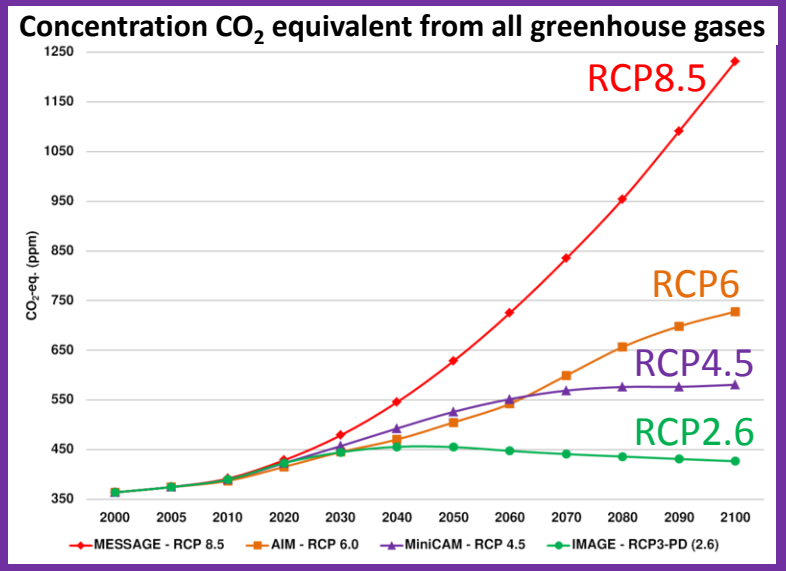
# Greenhouse Gases in Climate Models

- Actual greenhouse gas emissions were higher than future scenarios used in 2007 IPCC studies



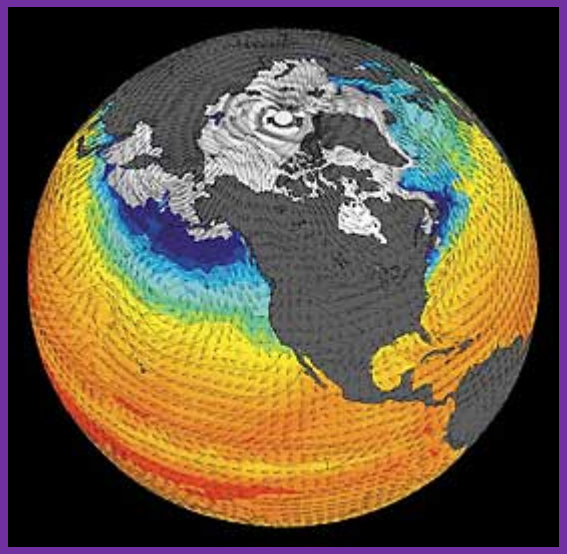

Colored lines – greenhouse gas emissions scenarios
Black dots – actual greenhouse gas emissions

- Future greenhouse gas concentrations cover a higher range in 2013 IPCC studies
  - -Called RCP or Representative Concentration Pathway
  - -Number at end indicates radiative forcing value at the end of the century 2.6, 4.5, 6.0, and 8.5 $W/m^2$ in 2100

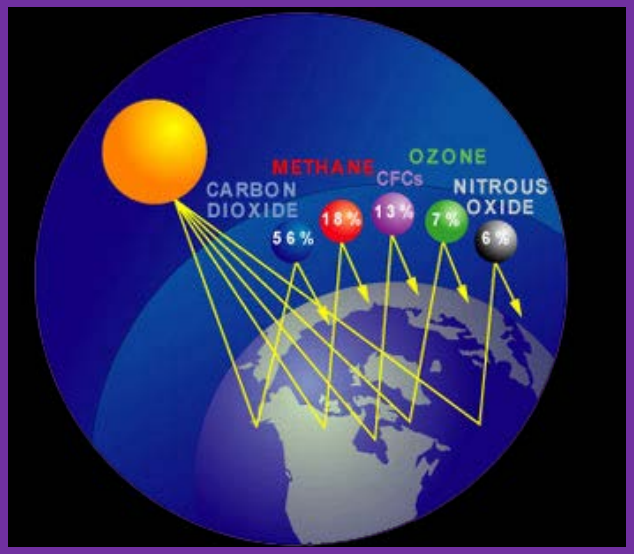



IPCC = Intergovernmental Panel on Climate Change, RCP = Representative Concentration Pathway

# Climate models are used to explore possible future changes in climate.



Global Climate Model




Estimate of Future Greenhouse Gases

# Future Climate Projections

National Center for Atmospheric Research

http://www.youtube.com/watch?v=U9YAzrmeOGI

# Projected Climate Changes

*Temperatures*

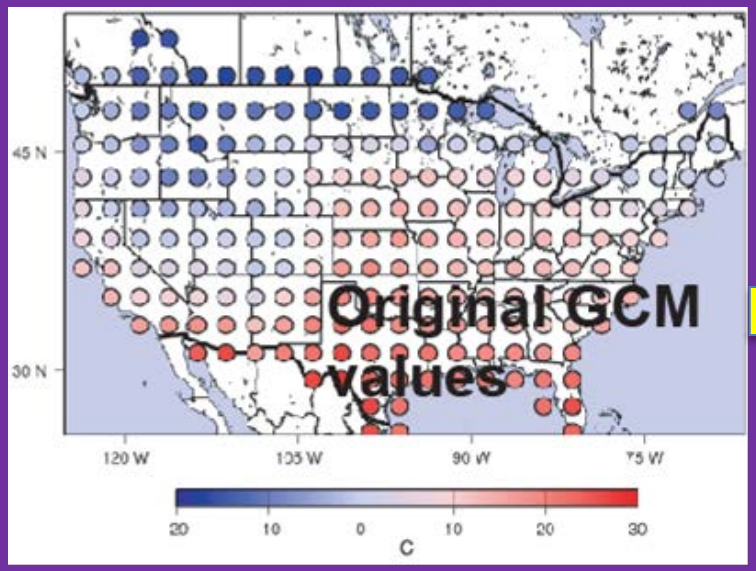
- *OBSERVED*
  - *Summer warming higher than winter*
  - *Interior warming greater than coastal/marine*
  - *Nighttime warming has exceeded daytime in last few decades*
- *PROJECTED*
  - *Heat wave incidence: more frequent, intense, durable*

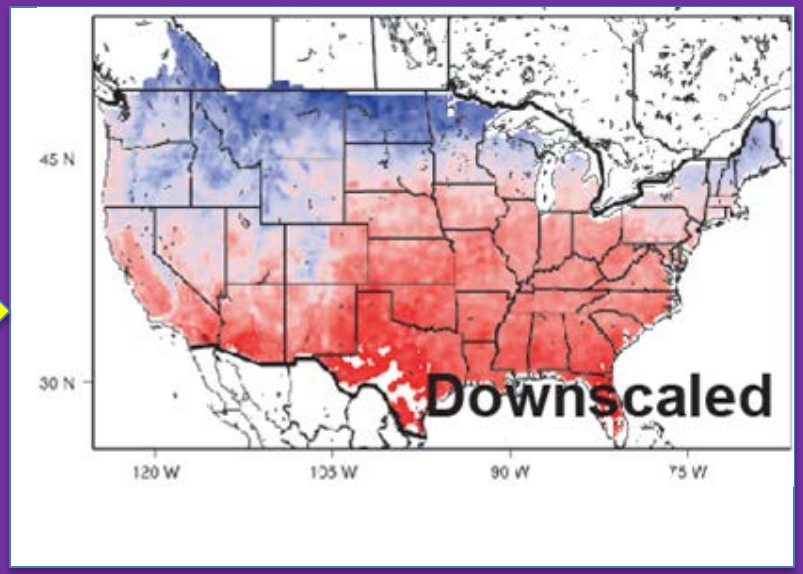
*Precipitation change uncertain*

- Probably will remain extremely variable
- Consensus of newest models shows little change in Northern Cal
- Continued potential for extremely heavy events

# Downscaling

## Converting Global model output into Regional or Local information



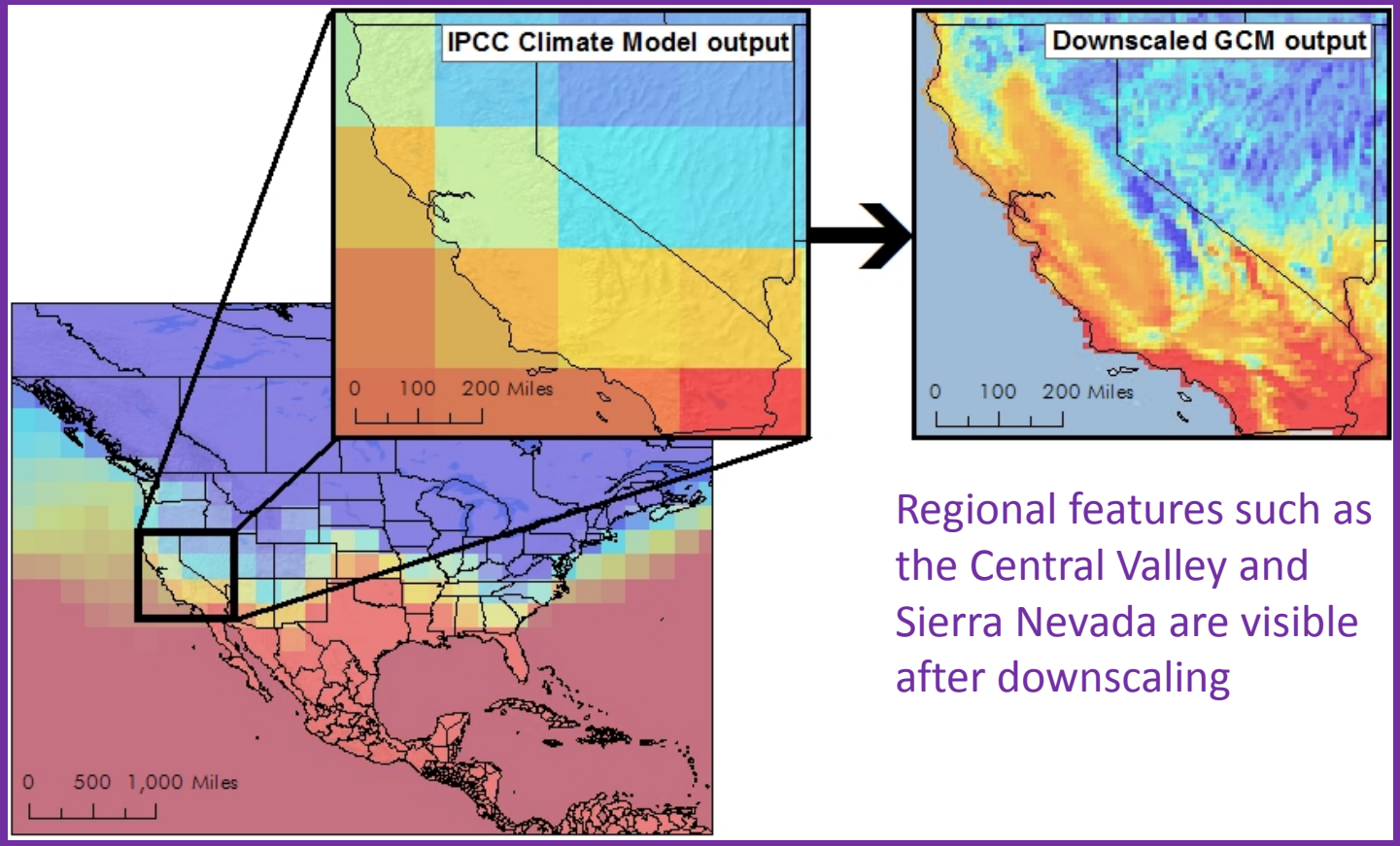




**More specific, Higher resolution, More useful**

Demonstration: Climate Modeling and Legos

Images from Mike Dettinger, Scripps/USGS

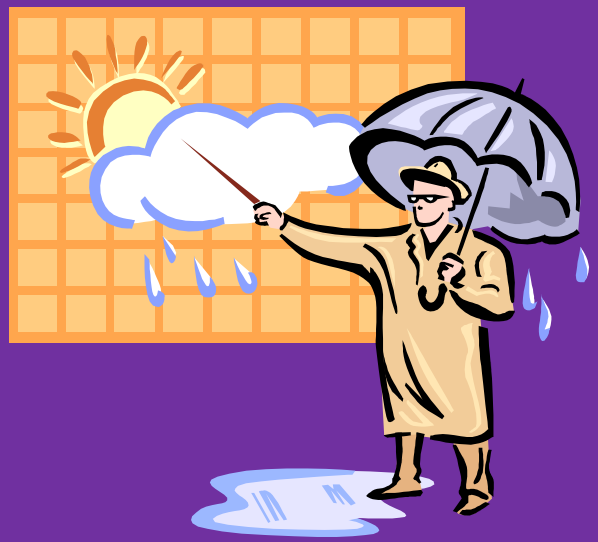
# Spatial Scale and "downscaling"




Regional features such as the Central Valley and Sierra Nevada are visible after downscaling

IPCC = Intergovernmental Panel on Climate Change

Climate scientists and modelers explore possible future climate conditions



DWR staff assess potential impacts and risks that those climate change conditions could have on California's water resources

http://www.water.ca.gov/climatechange/articles.cfm

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

Decision Requirements

Decision-Makers:
**"Keep it simple."**

Emission Scenarios

**Climate Change Information**

- Who is involved?
- What do they want?

Operations Model

Planning Model

Climate Simulations

Modeling to support Decision Making

Hydrologic Model

Land Cover Changes

Spatial Downscaling

Demand Model

Societal Changes

Modelers and Data Analyzers:
**"Keep it manageable."**

Adapted from Levi Brekke USBR

# Climate Change Technical Advisory Group

http://www.water.ca.gov/climatechange/cctag.cfm

# Take Home Message

Global climate models explore possible future climate conditions, they don’t predict specific future conditions or events

DWR uses results from global climate models to evaluate possible impacts of climate change on California’s water resources

Current modeling indicates that climate change with increase stress on water resources systems

# Thank You!

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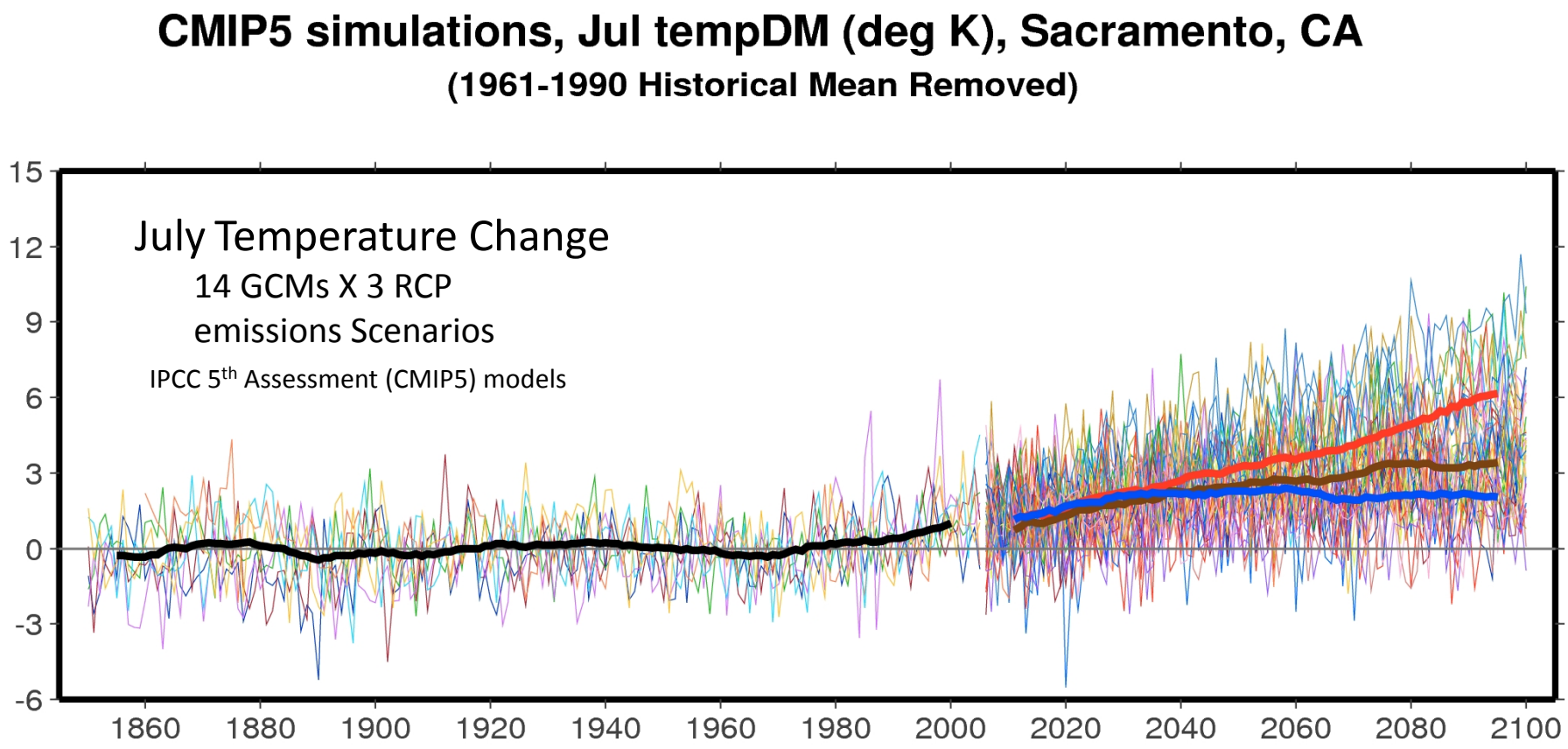
# Extra Slides

# Warming is substantial in climate projections



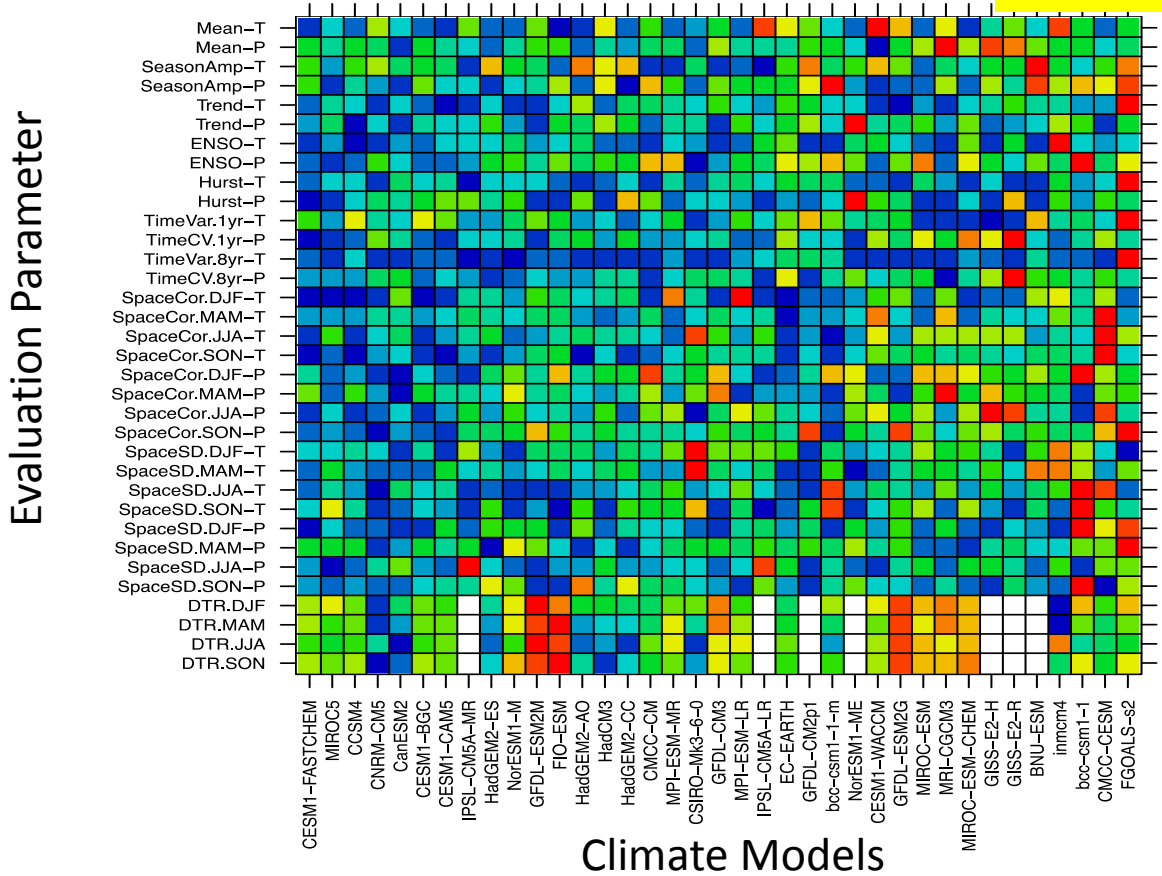

Cayan et al. Scripps/USGS 2013

What model best represents California's historical climate?
No clear best model, depends on criteria
Models that didn't perform well in SW US may be excluded in future analysis

Adapted from Cayan 2013

# Ranking Global Climate Models by Rupp and Mote

using a multi-factor historical climate evaluation scheme for the Southwestern United States




High relative error in SW United States

Relative Error

Low relative error in SW United States

Least total relative error ⇨ Most total relative error

**Figure 19.** Relative error of the ensemble mean of each metric for each CMIP5 GCM. Models are ordered from least (left) to most (right) total relative error, where total relative error is the sum of relative errors from all metrics, excluding the diurnal temperature range (DTR) metrics. For 7 GCMs, the diurnal temperature range (DTR) metrics were not calculated (white squares).

# Building Coalitions

SCRIPPS Institute of Oceanography

U.S. Geological Survey

Lawrence Livermore Lab

Santa Clara University

Lawrence Berkeley Lab

UC Davis

California Energy Commission

UC Berkeley