

Climate modeling 101 and application to the Colorado River Basin

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Weather vs. Climate



*“Long term, I’m worried about global warming—
short term, about freezing my ass off.”*

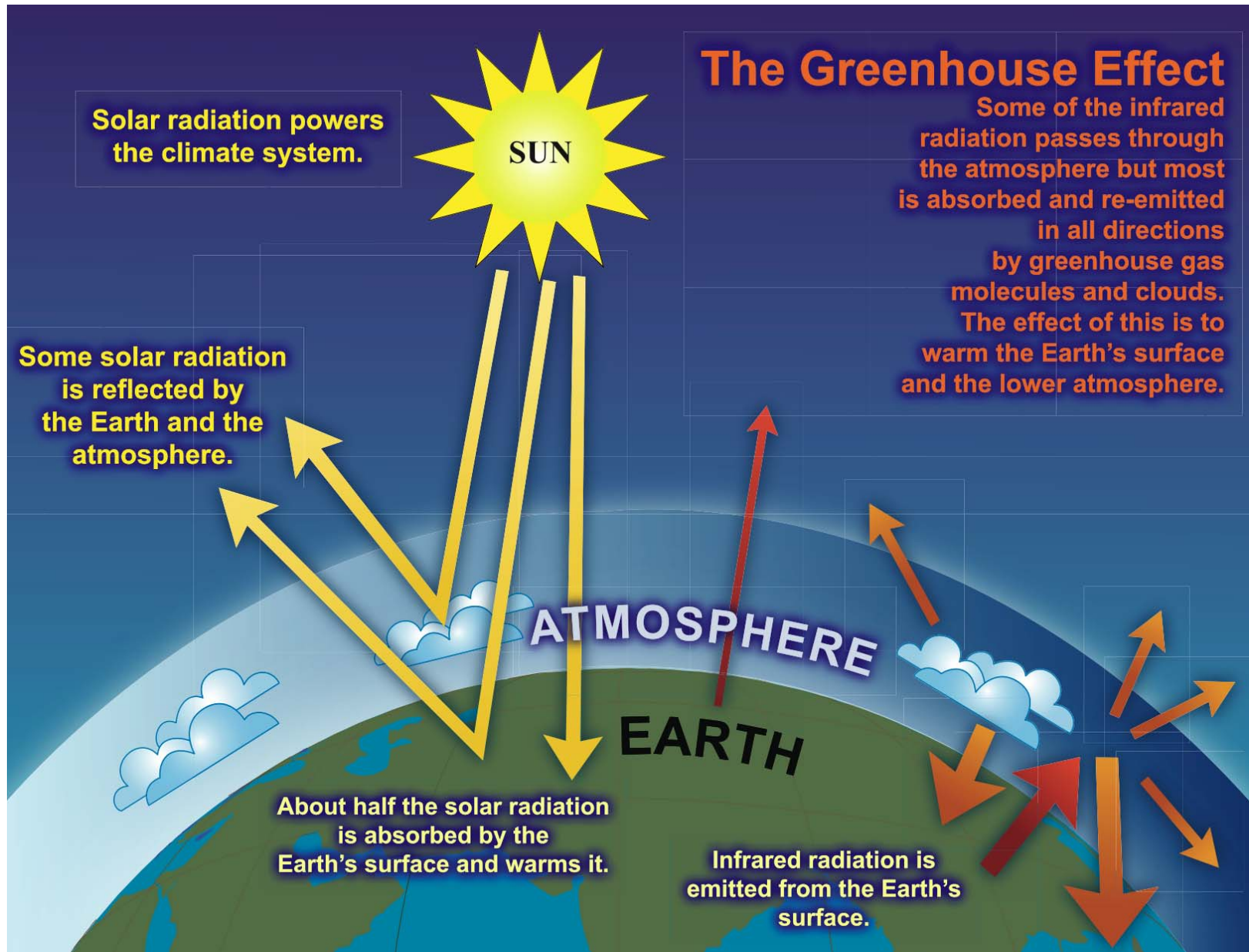
Weather vs. Climate

- Weather
 - Condition of the atmosphere at any particular time and place, day-to-day state of the atmosphere
- Climate
 - Accumulation of daily and seasonal weather events over weeks, months, years and longer
 - Long-term averages of weather variables departures of weather variables from normals

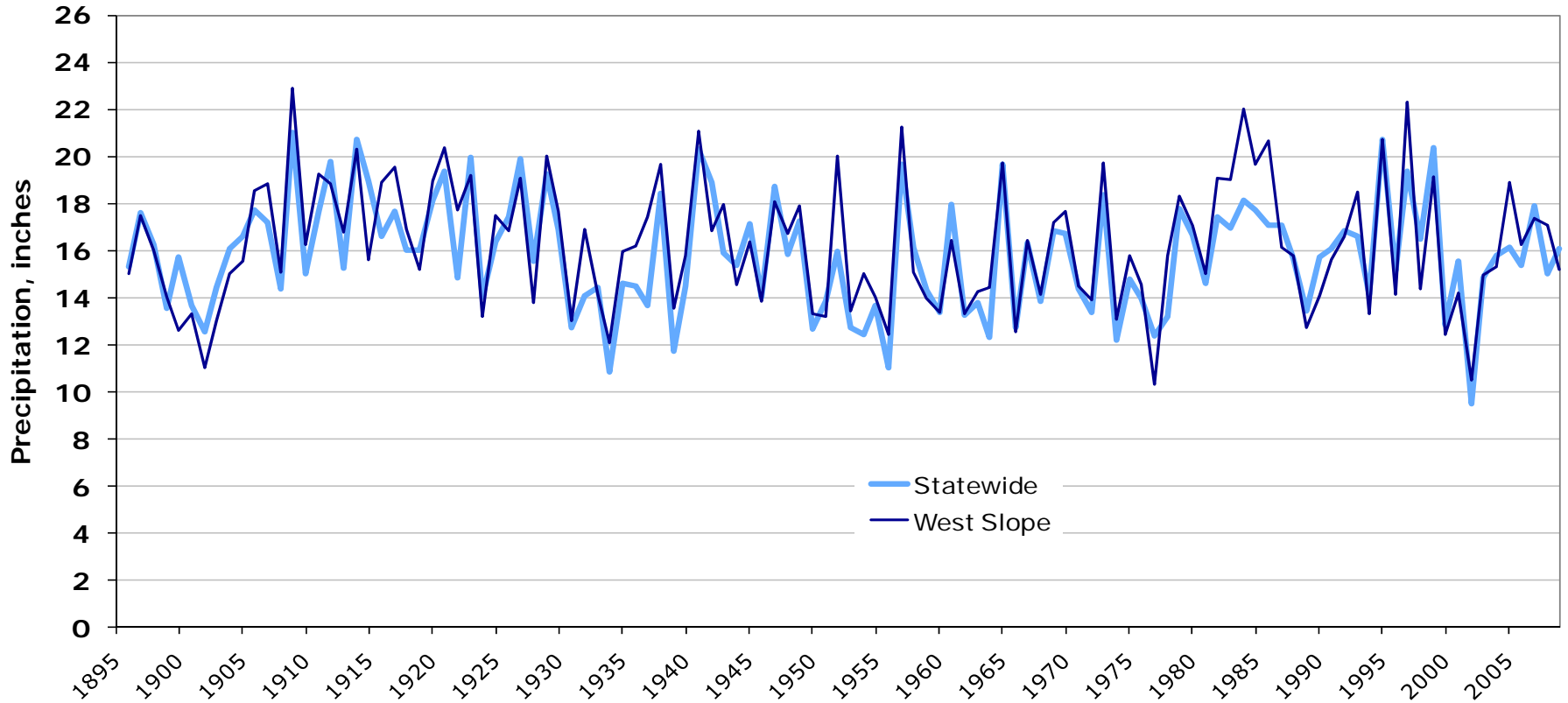
The Big Picture

- **The Sun**
 - Heats the earth unevenly
- **The atmosphere**
 - Redistributes sun's energy through its circulation, also prevents loss of re-emitted energy to space
- **The ocean**
 - Redistributes sun's energy through its circulation, stores more heat than atmosphere or land
- **The land**
 - Readily absorbs and re-emits heat
- *Weather and Climate are the result of these interactions*

Basic Energy Balance

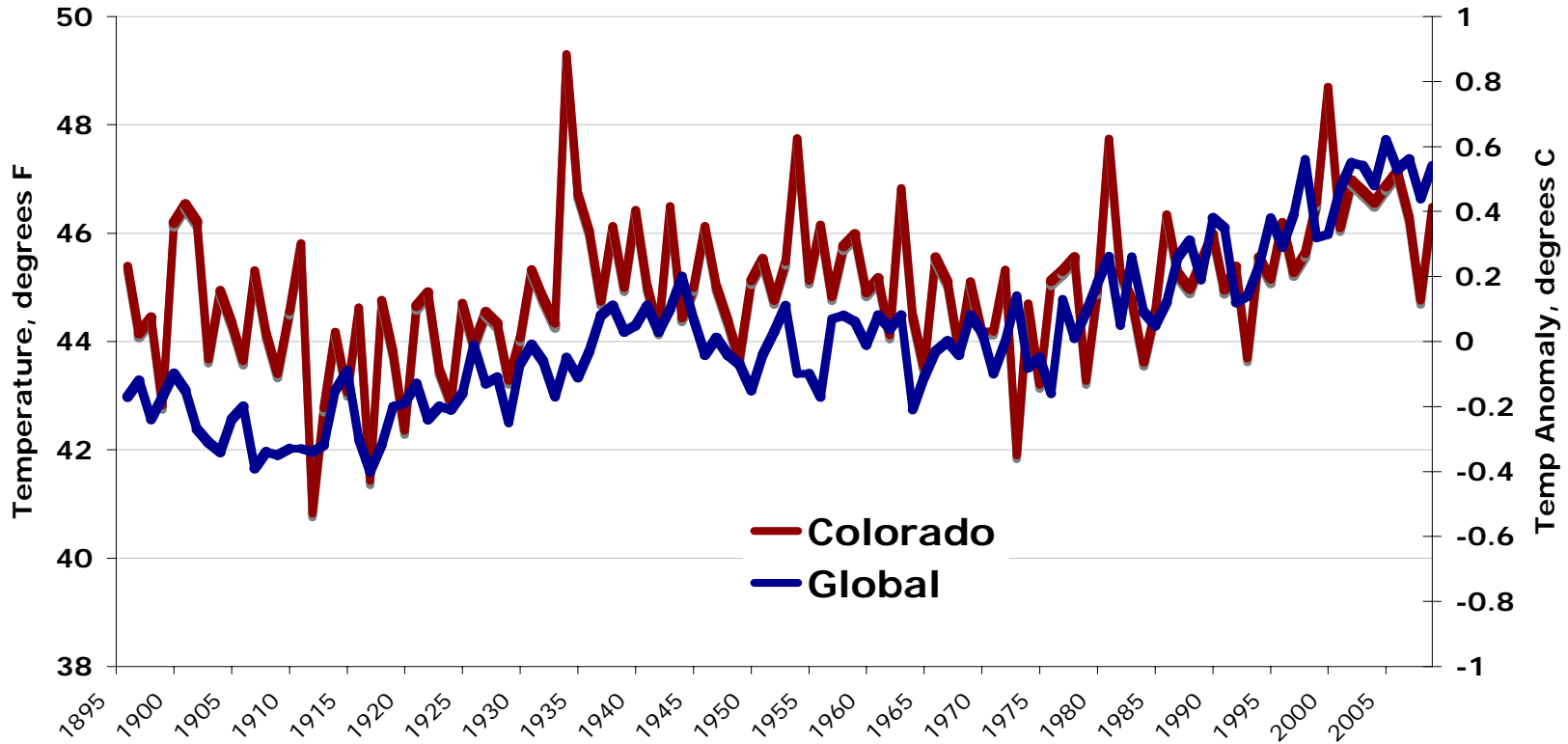


CO Statewide water year precipitation, 1896-2009



Large year-to-year variability - departures of +/- 30% of mean are common

CO vs. Global temperature variability, 1896-2008



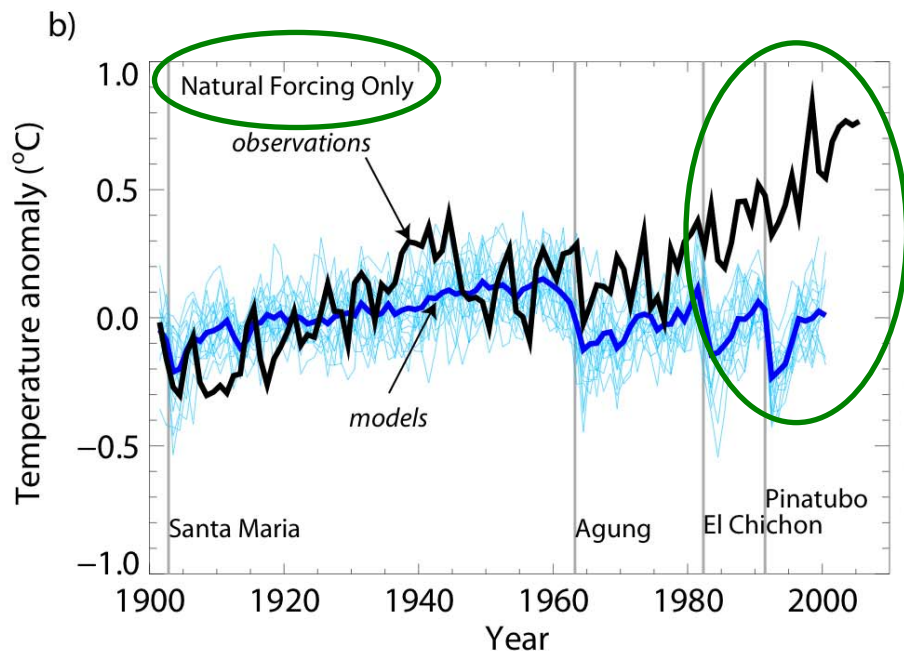
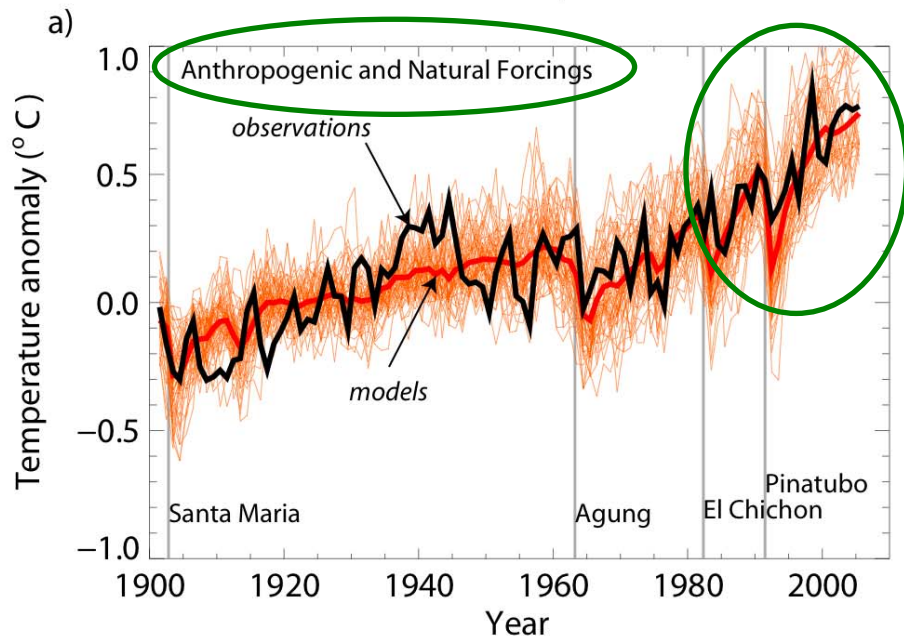
Decadal trends very are similar

NOTE: Colorado scale condensed 3x for comparison - so recent warming in CO is much greater than global

Global Climate Models (GCMs) reproduce the 20th century warming, if you add the gases

- GCM runs that **include manmade greenhouse gases** along with natural drivers of climate (red) **do** reproduce recent trends (black)
- GCM runs that **leave out** human-caused greenhouse gases (blue) **do not** reproduce recent trends

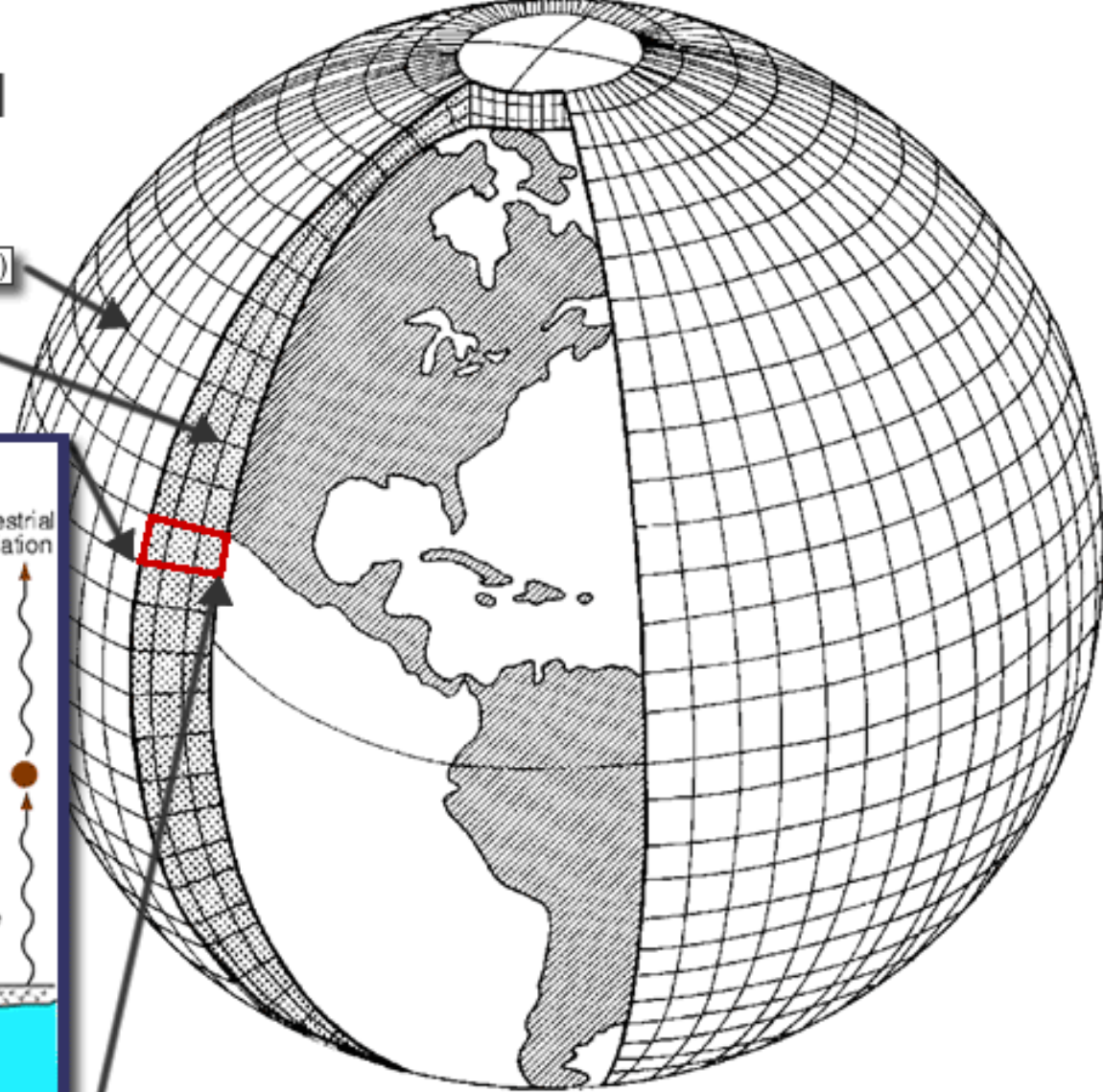
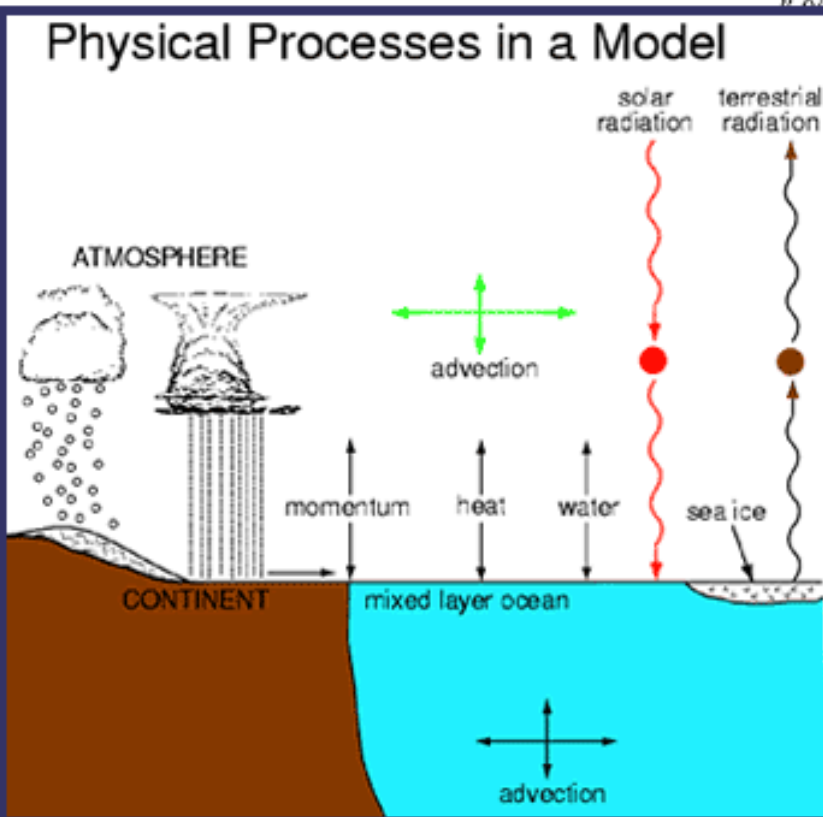
Global Mean Surface Temperature Anomalies



Schematic for Global Atmospheric Model

Horizontal Grid (latitude - longitude)

Vertical Grid (height or pressure)



- Parameterization
- Scale

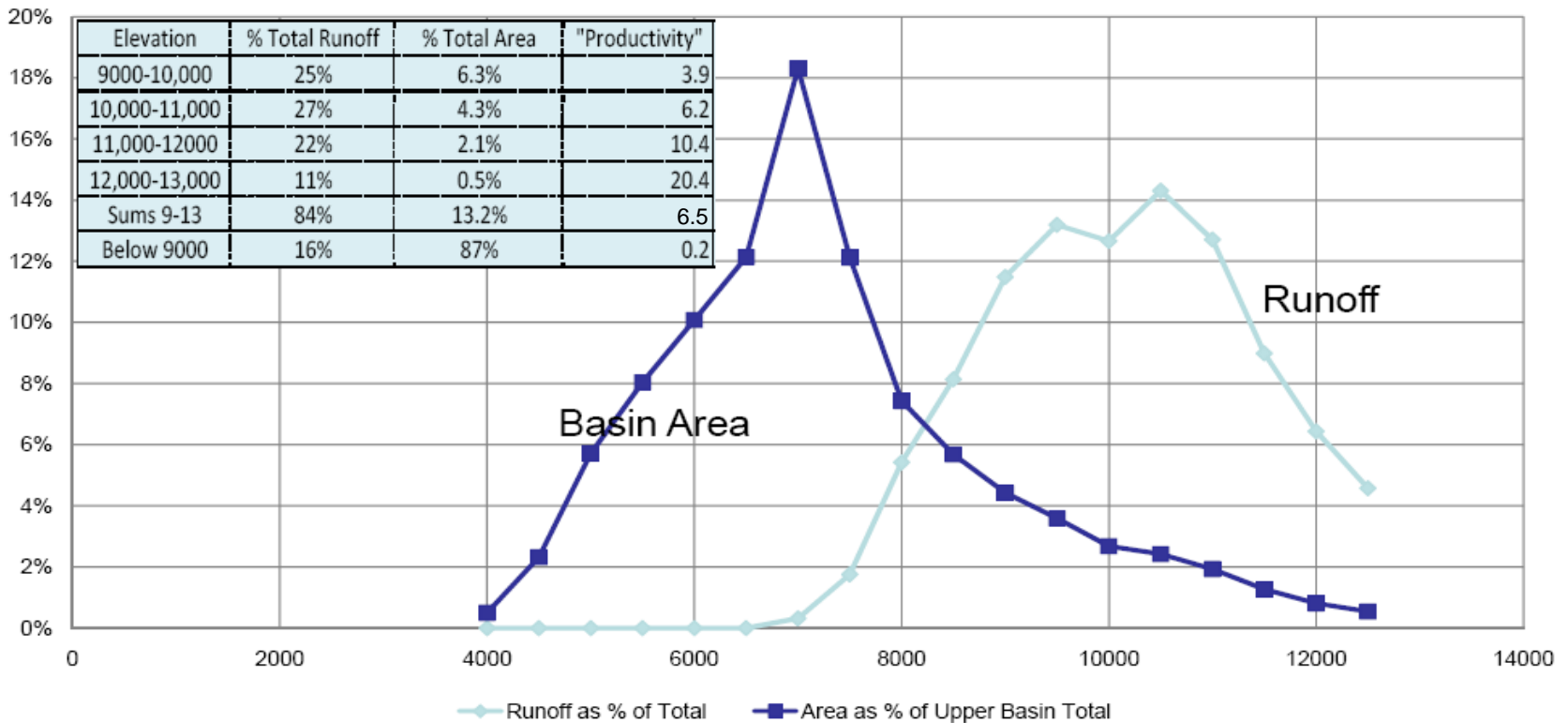
“All models are wrong; some are useful.” – George Box

Downscaling and Bias Correction

- Bias Correction
 - Models aren't perfect (duh!)
 - Results for the historic period may not match observations
 - So model is said to have a “bias” when results are consistently skewed
 - Too wet or dry, etc.
 - Based on these identified biases, results are adjusted appropriately
- Downscaling
 - Statistical downscaling establishes relationships between the grid cell average and finer spatial distribution based on history
 - Dynamical downscaling develops a “mini model” for a grid cell and is forced by results for that cell and boundary conditions from neighboring cells

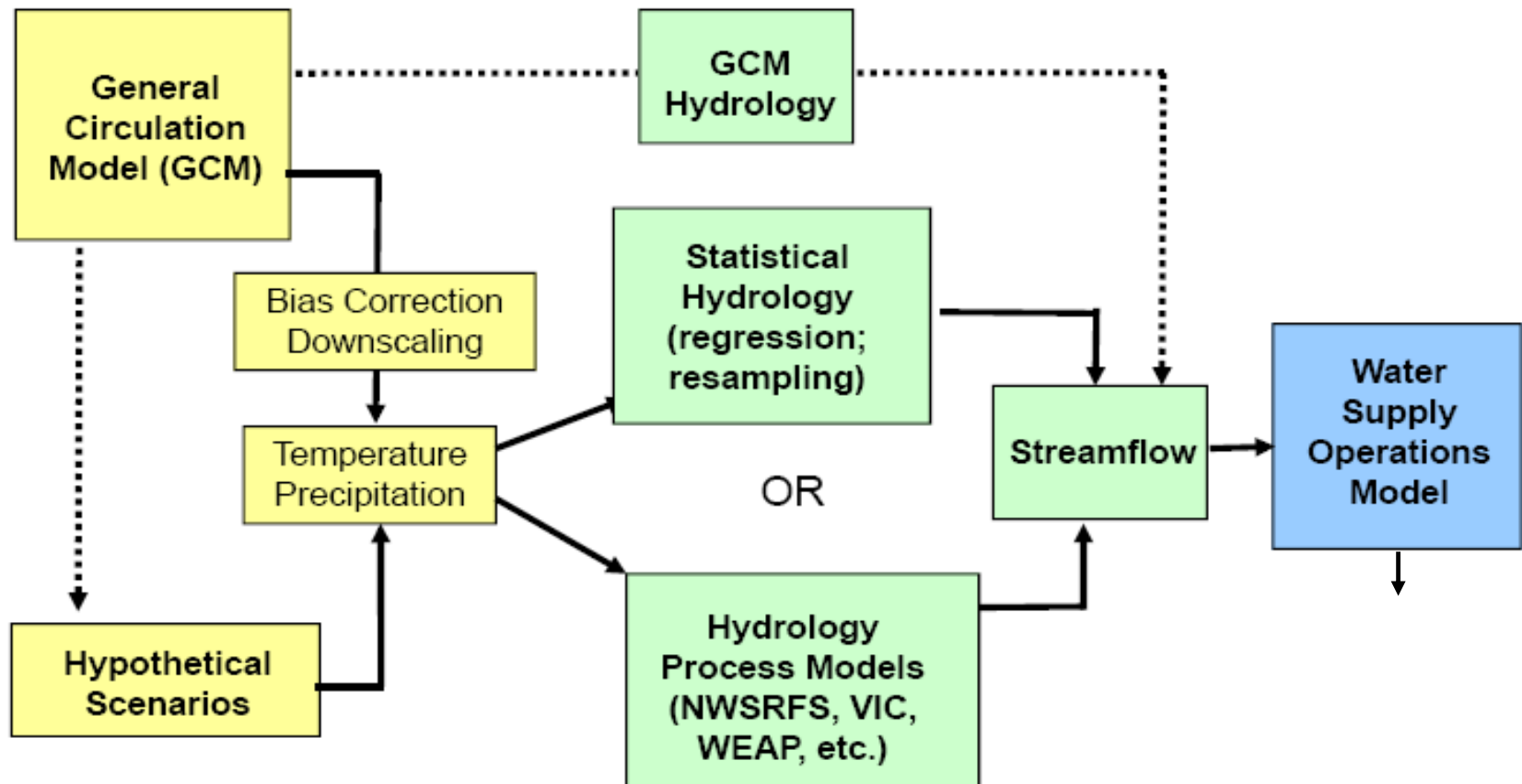
Runoff and Elevation

Basin Area and Runoff By Elevation



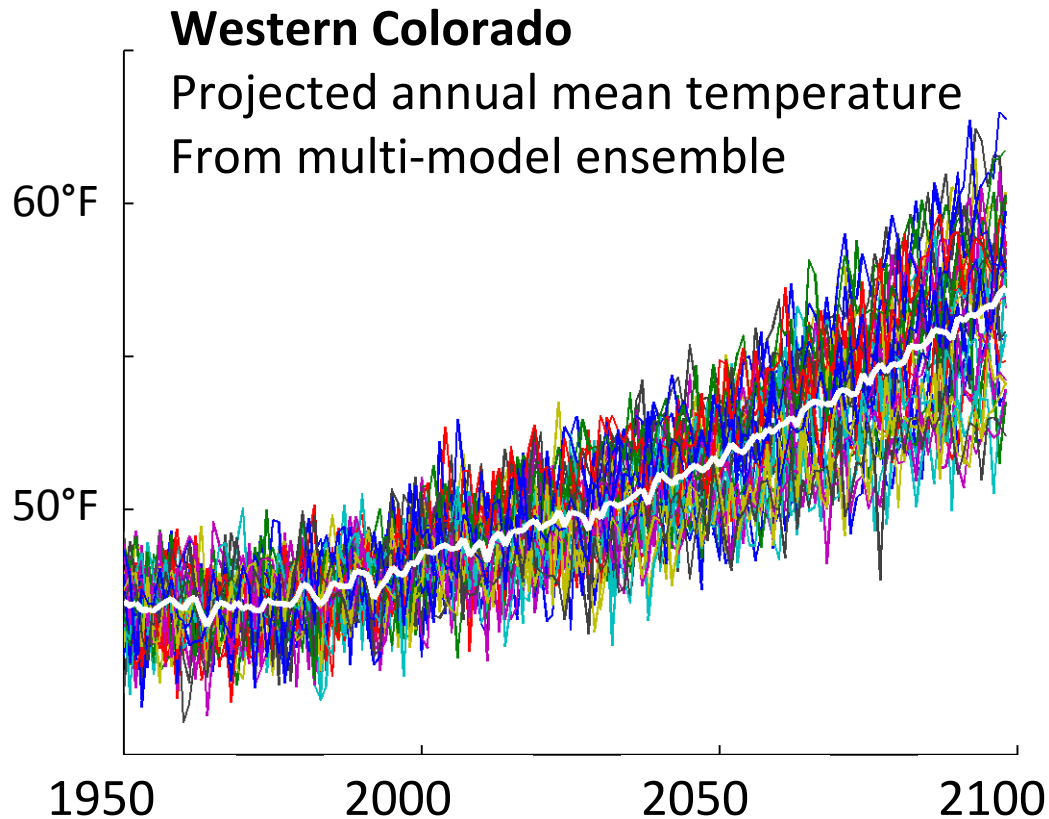
Source: Udall 2009

Transforming GCM climate projections into streamflow projections



- Uncertainties are propagated at every step...

Temperature projections: clear warming signal globally and for UCRB

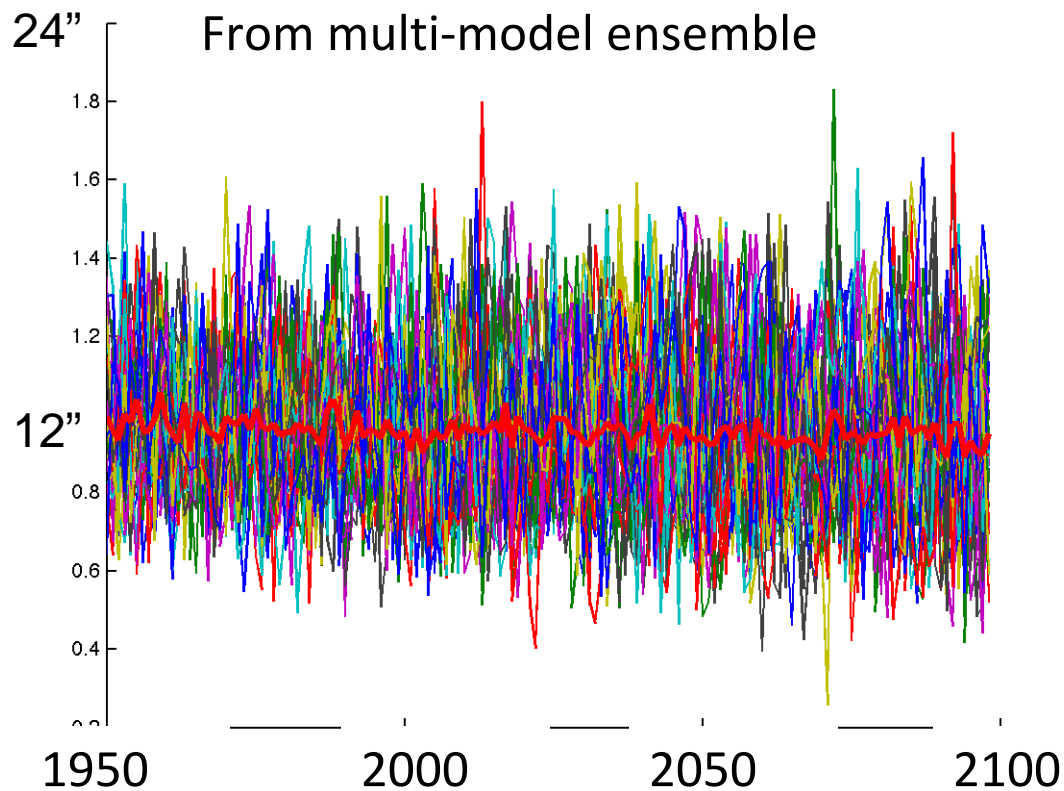


- GCM projections for the western US consistently show warming of 3-5°F by 2050 with continued GHG emissions
- Higher temps = more evapotranspiration
- *Also, warmer stream temps*

Precipitation projections: no clear signal for Upper Colorado Basin

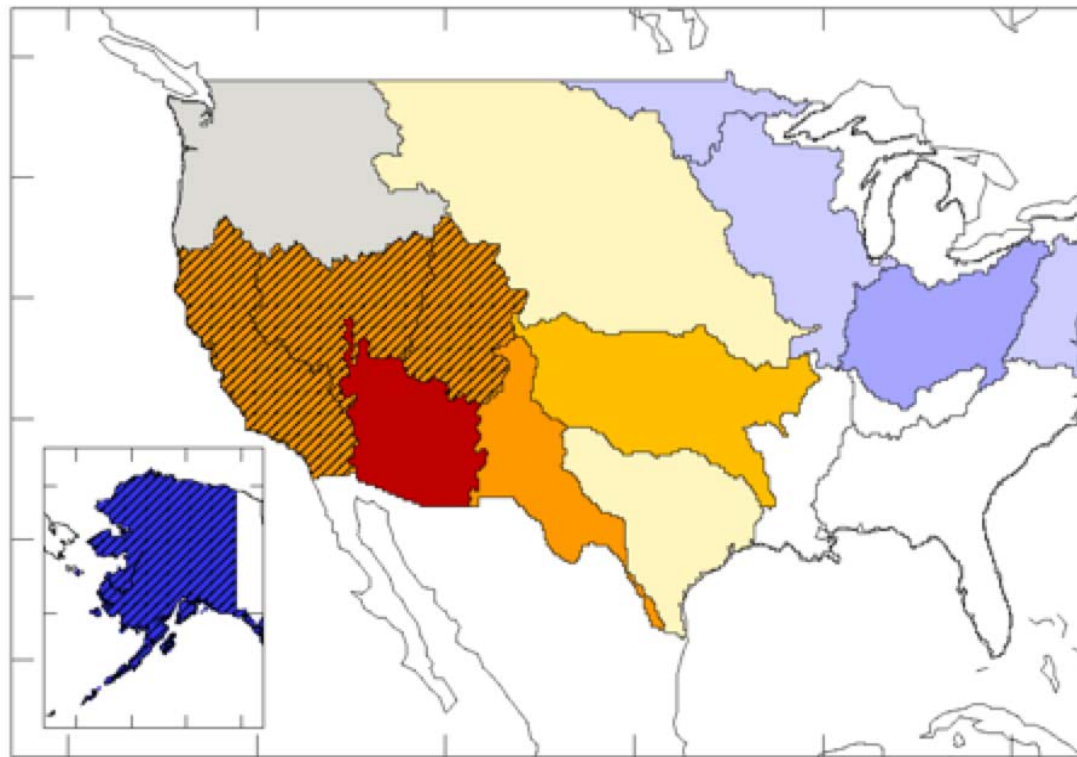
Western Colorado

Projected annual precipitation
From multi-model ensemble

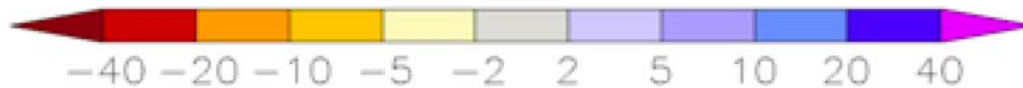


- No consensus among GCMs on precip trends for UCRB—some tendency towards drying to the south
- Projected interannual variability is consistent with historic variability

Milly et al. 2005: Runoff projections for mid-century directly from GCMs



- 10-20% decline in runoff projected for Upper Basin by 2041-2060, relative to 1900-1970 baseline
- 23 of 24 models (96%) agree on decline
- 20-40% decline projected for Lower Basin, with less model agreement (86%)



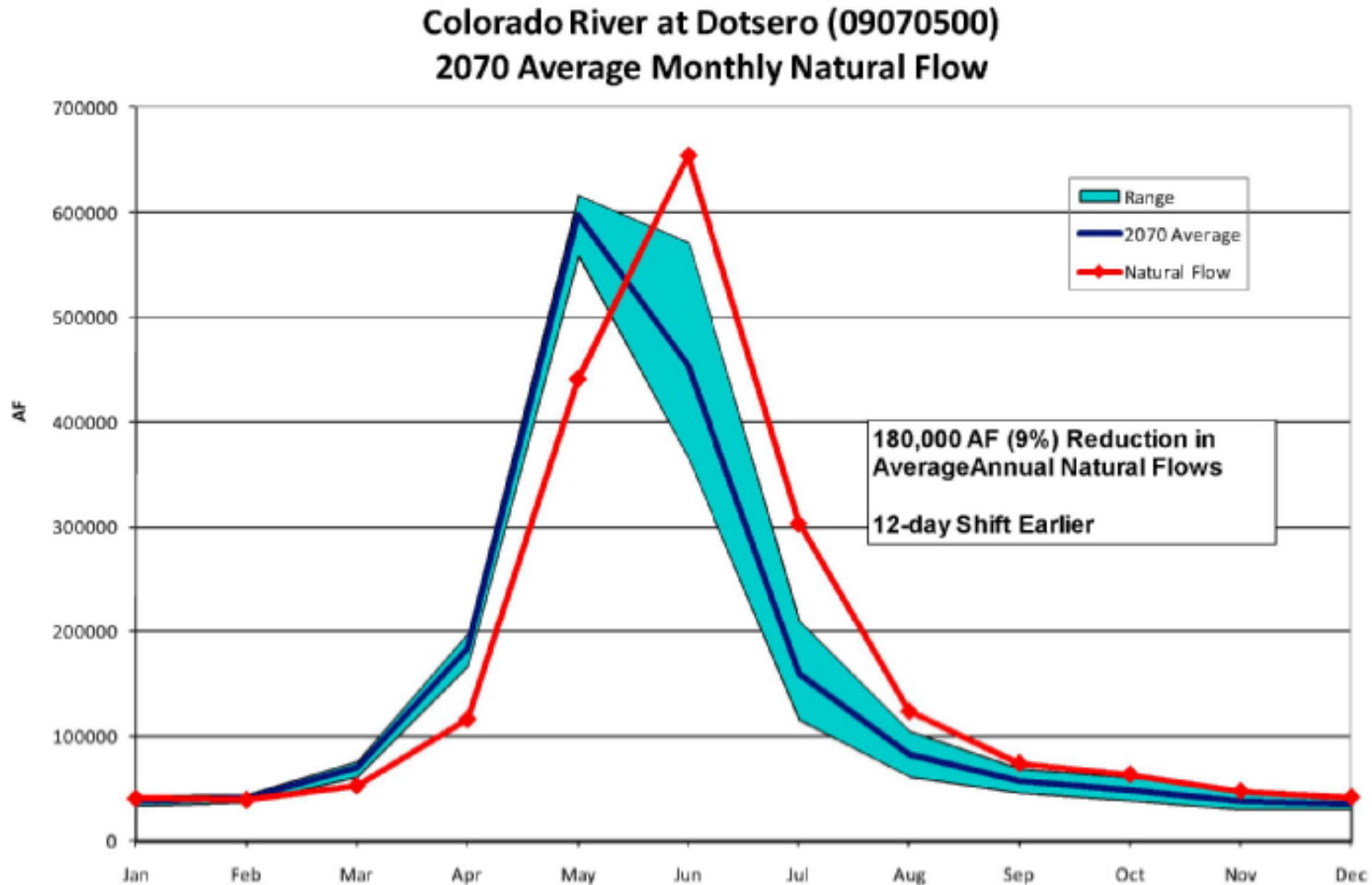
% change in runoff by 2041-2060

Other modeling studies for the UCRB are consistent with Milly et al.: 6-20% decline in flow by ~2050

Study	Temp	Runoff (Avg.)
Christensen et al. (2004)	+3.1F	-18%
Christensen and Lettenmaier (2006)	+4.5F	-6%
McCabe and Wolock (2007)	+3.6F	-17%
Colorado River Water Availability Study Phase 1 (2009)	+5.8F	-9% (Colorado at Dotsero, by 2070)

- Even without a decline in precipitation, warming alone is expected to drive a substantial decline in UCRB runoff
- WWA Project: *Reconciling Projections of Colorado River Flows*

All studies for UCRB show shift in hydrograph to earlier peak, large decline in summer flows



- Preliminary results from CRWAS Phase 1 – Natural Flow

Summary

- Climate vs. Weather
- Temperature changes seem linked to GH gasses
- No real change in precipitation seen
- Models are helpful and improving but are not perfect
- Studies project warming and reduced flow
- Precipitation projections are inconclusive
- Earlier run-off is also expected

Questions?