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Managing Water in the West

Climate Change Overview

Levi Brekke (Reclamation, Technical Service Center)

Yakima River Basin Water Enhancement Program (YRBWEP) Workgroup Meeting,

7 Oct 2009, Yakima, WA

U.S. Department of the Interior
Bureau of Reclamation

Outline

- Historical Observations
- Future Climate Projections
- Studies on PNW Impacts
  - 2009 WA Climate Change Impacts Assessment
- Ongoing Studies
  - CIG Data Development (WA HB 2860)
  - RMJOC
  - Odessa Special Study

Global Climate Trends

Mean Air Temperature

Mean Sea Level

Northern Hemisphere snow cover

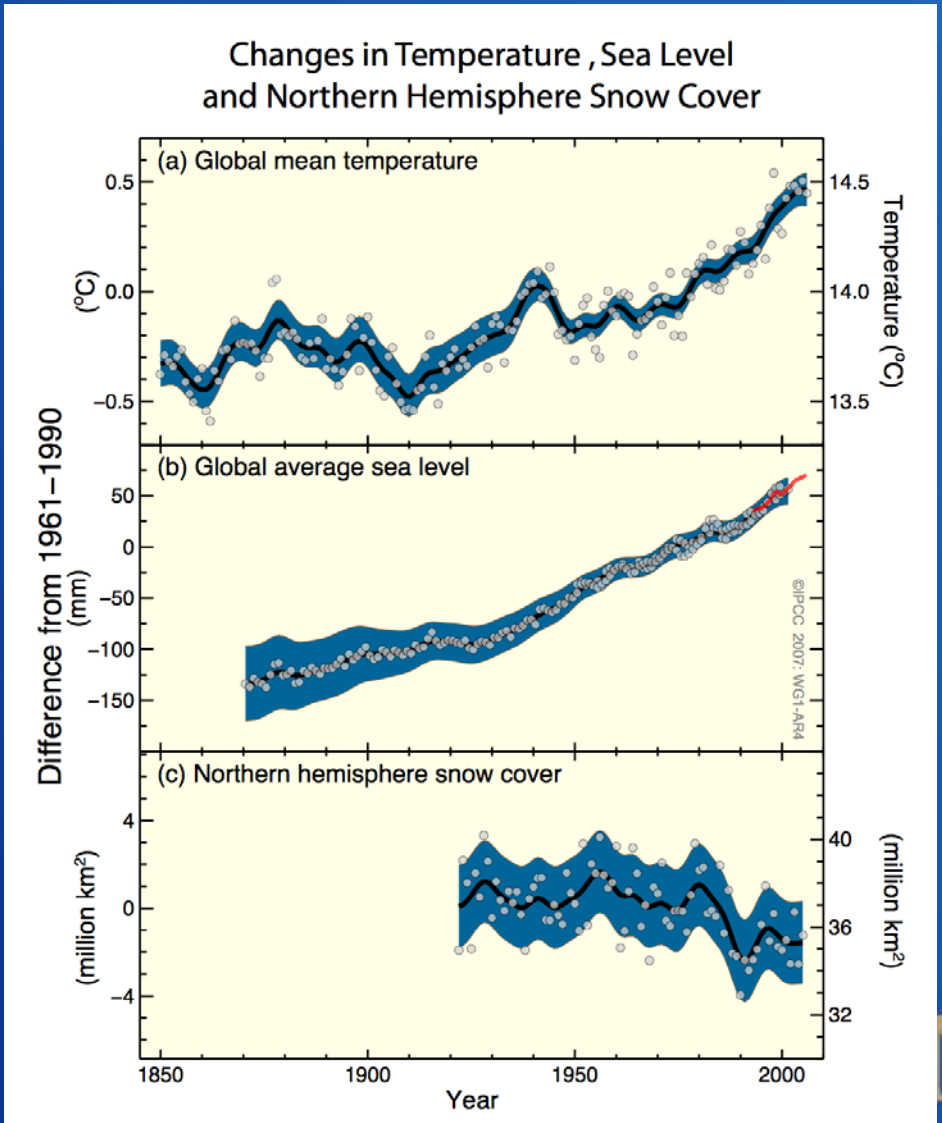
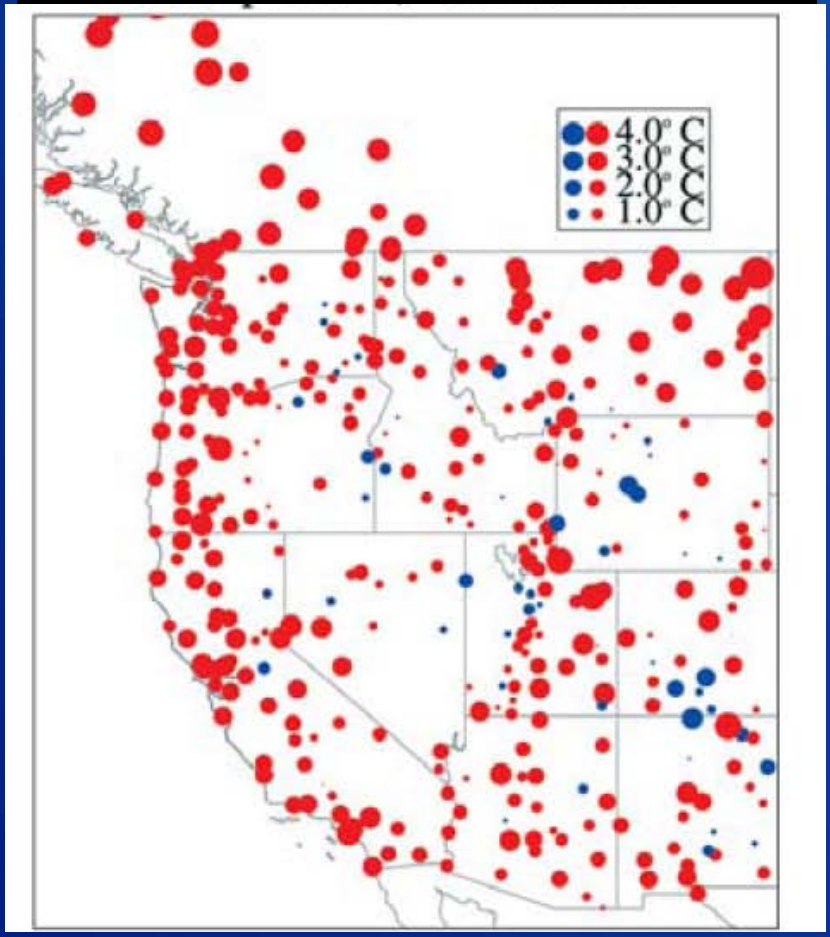


Fig. IPCC (2007)

Western U.S. Climate Trends

Temperature

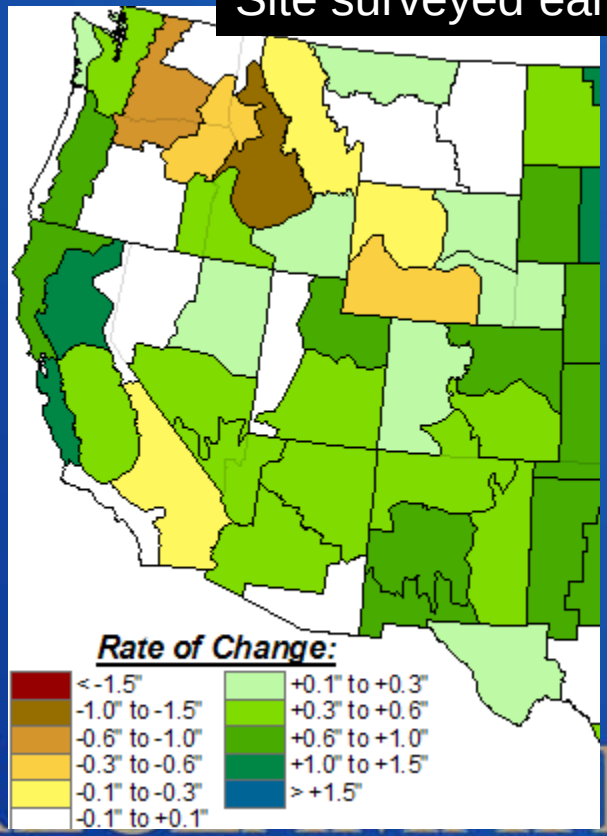
1950-1997 (Mote, et. al, 2005)



Precipitation

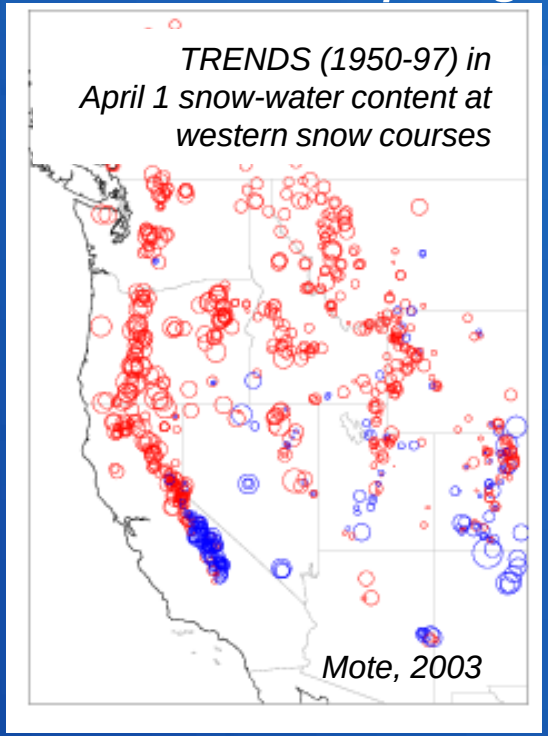
Post-1975 trend, “annual” inches/decade (www.cpc.noaa.gov/anltrend.gif)

Site surveyed early 2008

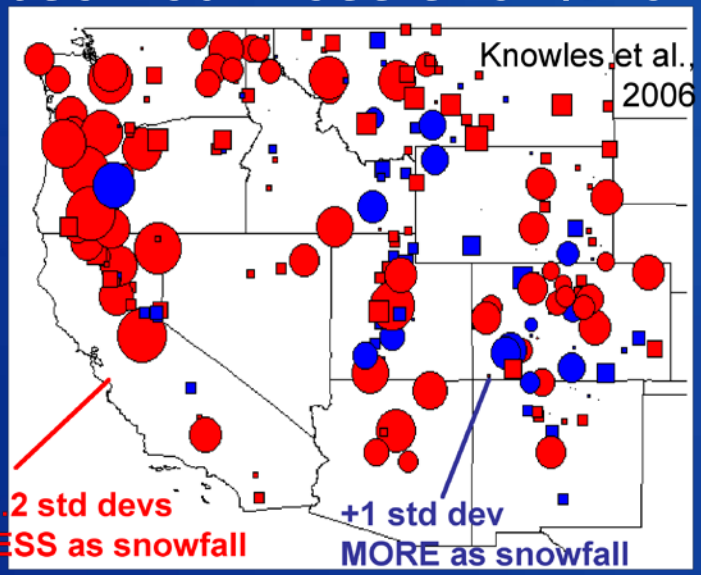


Hydrology & Vegetation

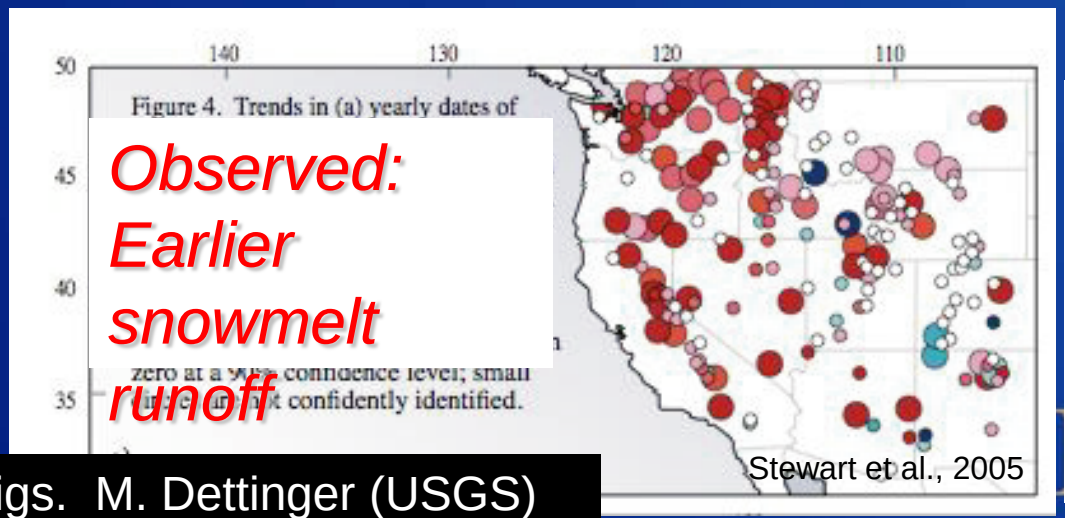
Observed: Less spring snowpa



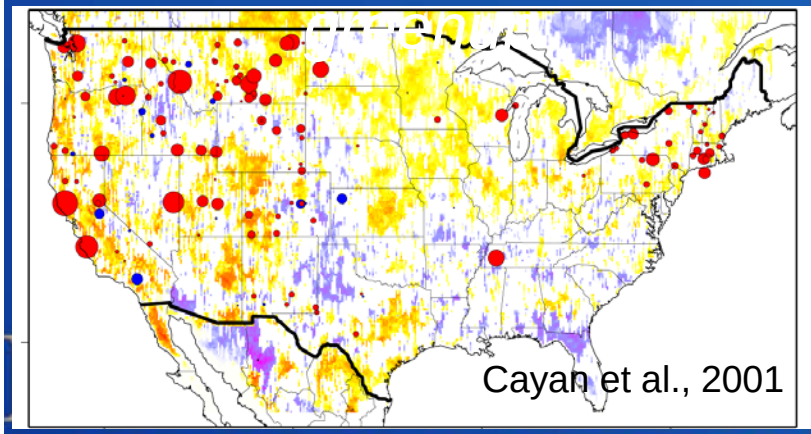
Observed: Less snow/more rain



Observed: Earlier



Observed: Earlier snowmelt runoff



Figs. M. Dettinger (USGS)

Western U.S. Trends: Natural or Human-Induced?

- Barnett et al. 2008
  - Asserts that up to 60% of the climate-related trends of Western U.S. river flow, winter air temperature, and snow pack from 1950 to 1999 are human-induced.
  - Similar findings for explaining trends in:
    - springtime snow-water equivalent (Pierce et al. 2008)
    - temperature in mountainous areas (Bonfils et al. 2008)
    - streamflow timing (Hidalgo et al. *in press*)
  - An additional key finding of these studies:
    - Evidence that human-induced effects is greatest at the scale of the entire Western United States and weak or absent at the scale of regional scale drainages *with the exception of the Columbia River Basin* (Hidalgo et al., *in press*).

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Climate System Narrative: Start with energy…

- Move heat from equator to poles through hydrologic cycle.

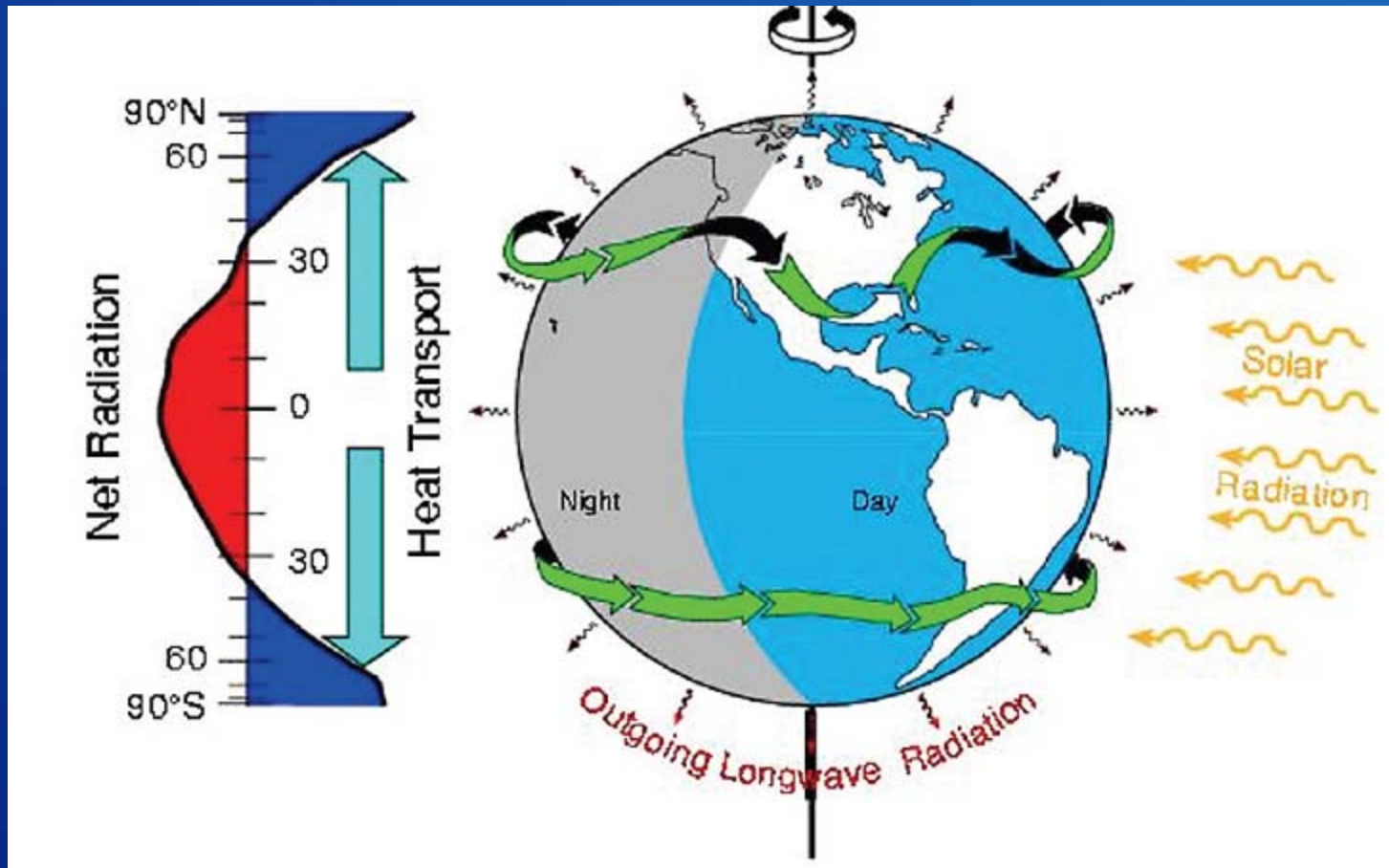
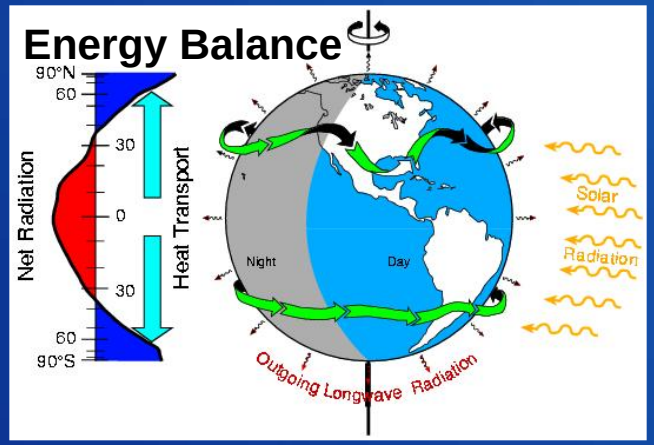


Figure 8. Heating dynamics of the Earth (courtesy of Kevin Trenberth).

Climate System Narrative:
…now add interactions



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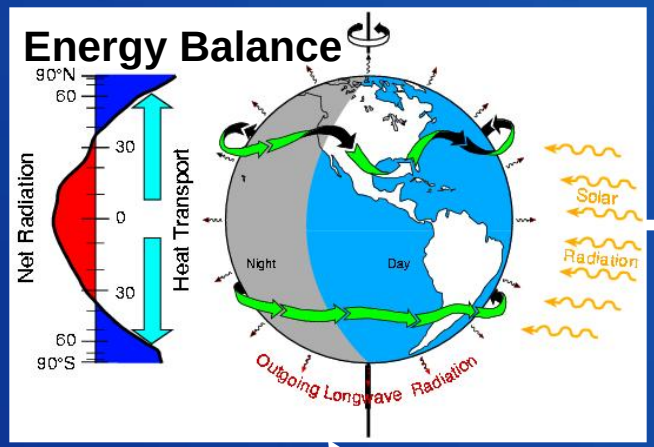
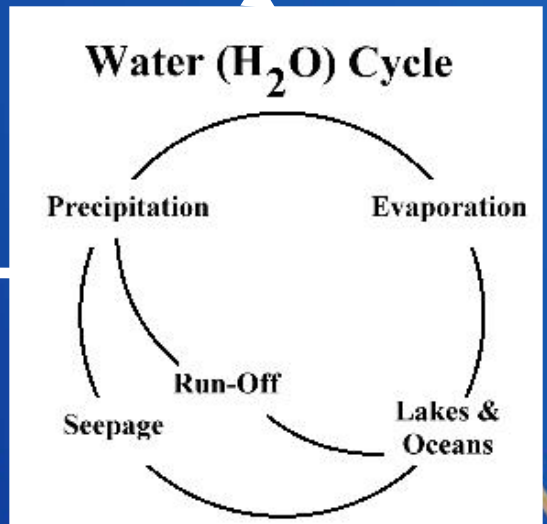
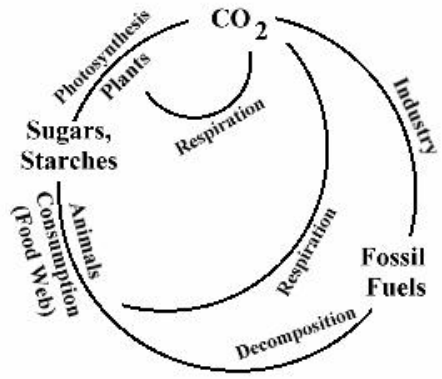
Climate System Narrative: …now add interactions

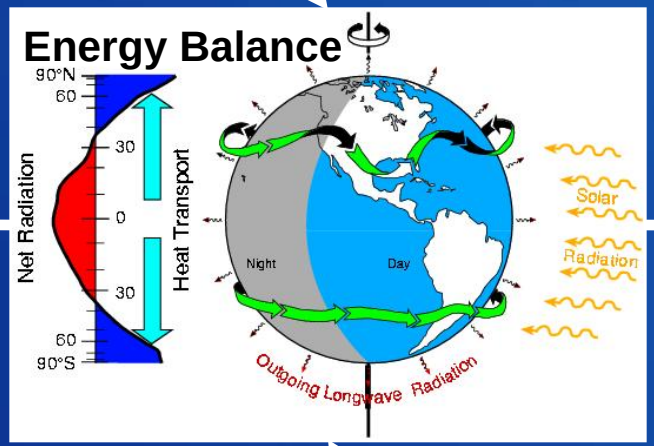


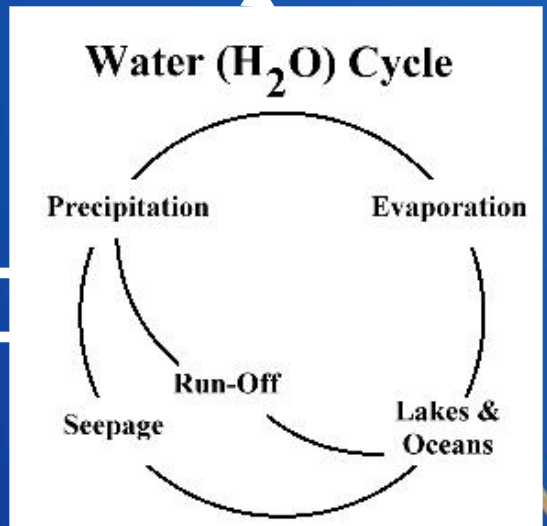


Climate System Narrative: …now add interactions

Biogeochemical Cycles (e.g., Carbon Cycle)







Global Climate Models: Time Steps and Grid Boxes

Schematic
"Coupled" models have grid continuing into the ocean

Time Step
~5 to 20 minutes

Grid Boxes
Horizontal: ~60-180 miles (or 100-300 km)
Vertical: ~30 layers of varying depth

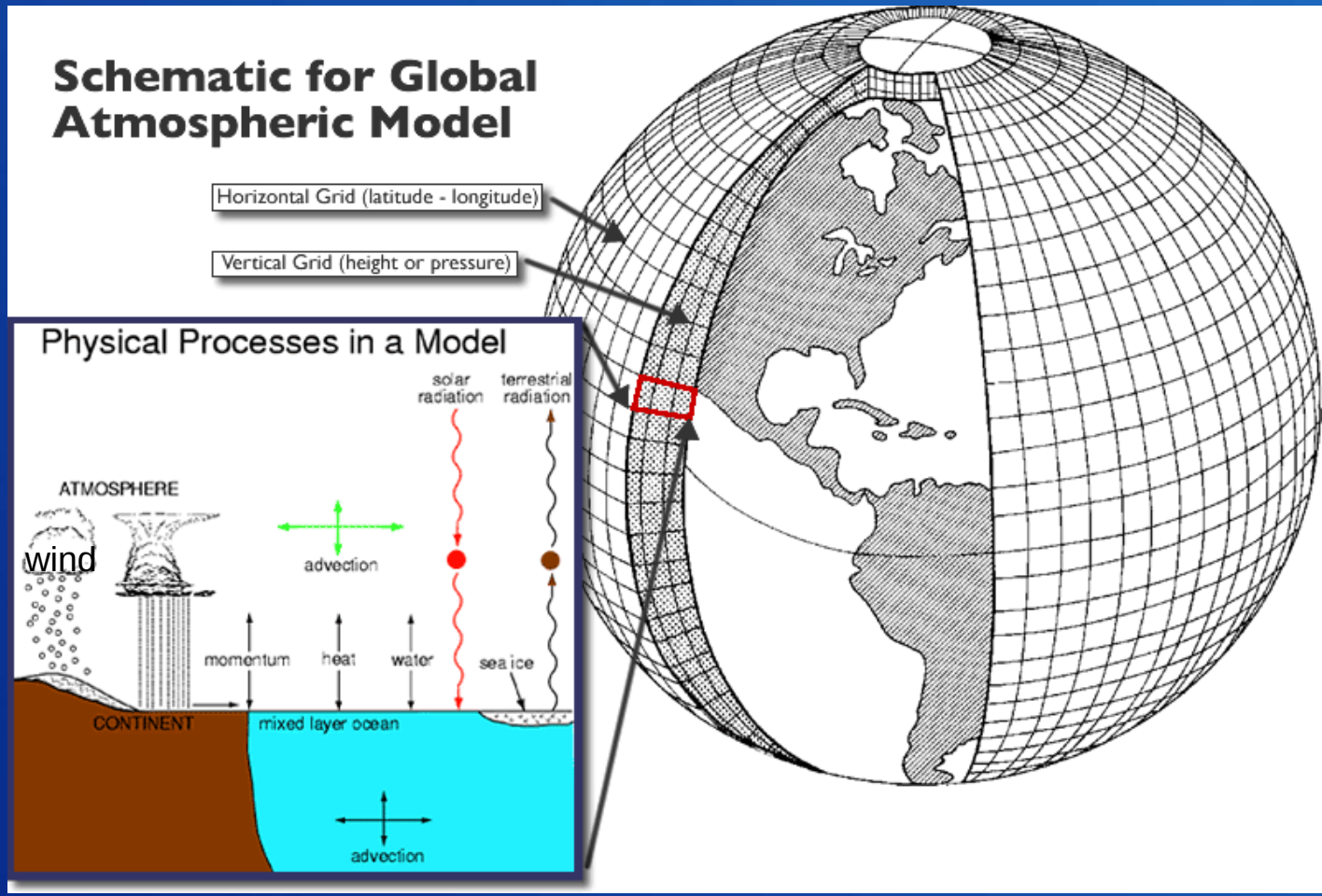


Fig. Barsugli

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Trends in Global Climate Modeling

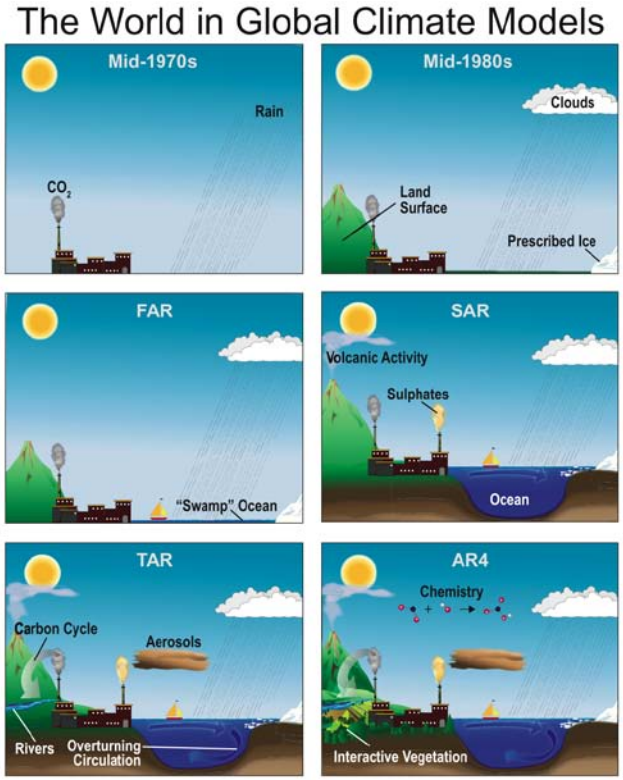
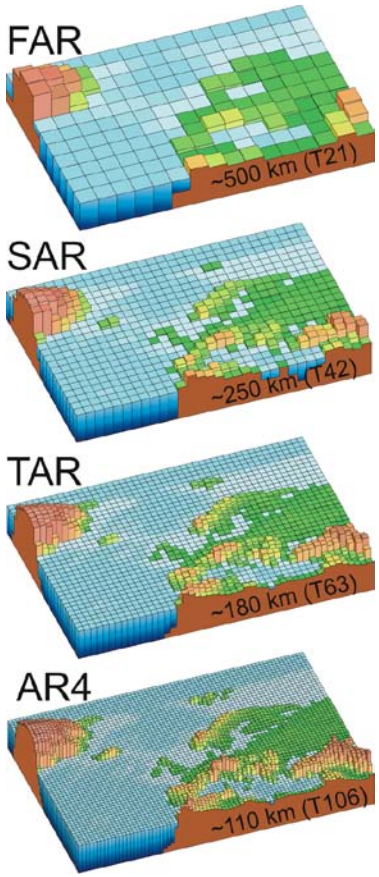


Figure 1.2

Increased Complexity -- more components of the Climate System (more sources of uncertainty!) Chemistry is expensive!



1990

1995 CMIP

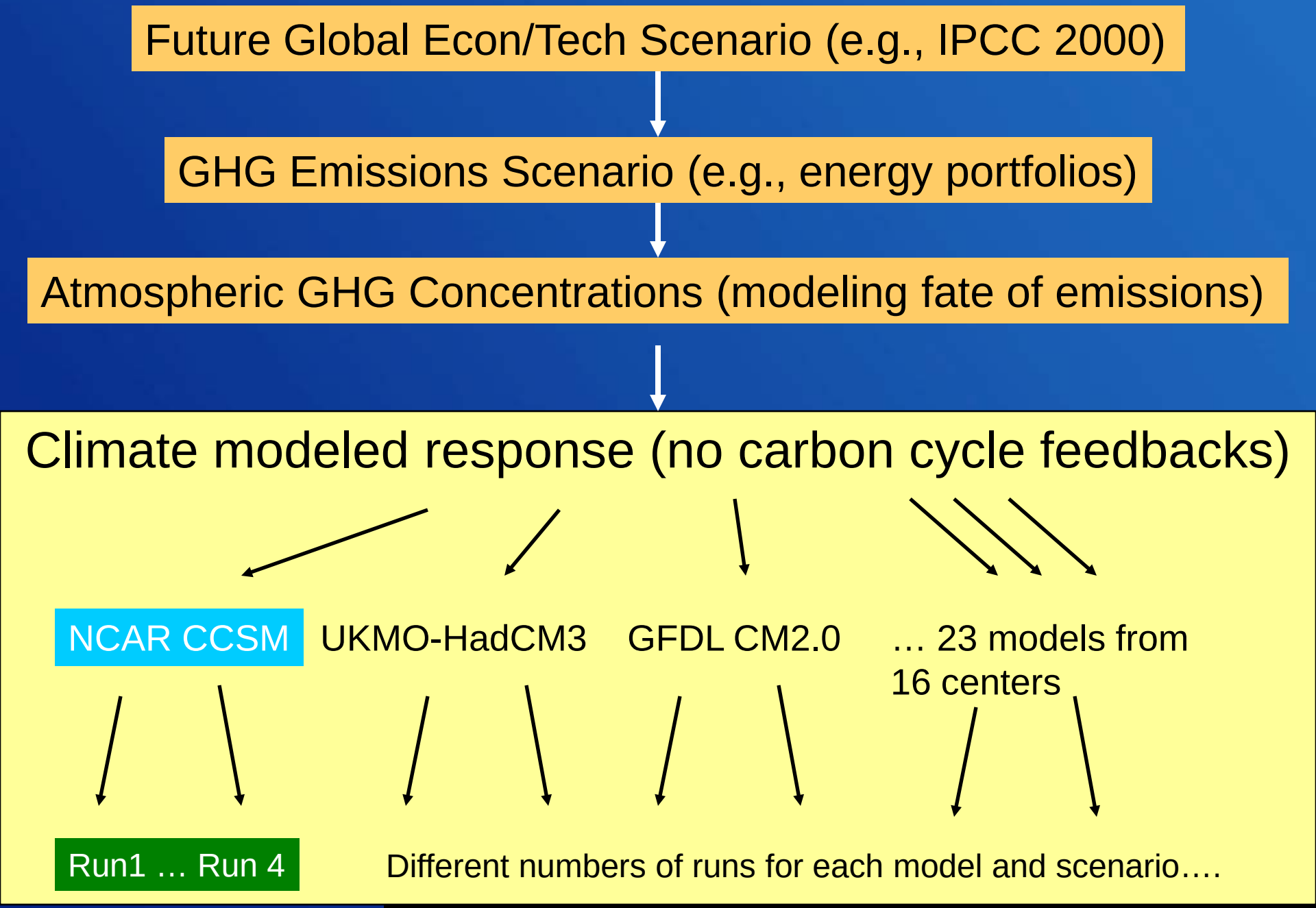
2001 CMIP2

2007 CMIP3

Figure 1.4

Increased Resolution; but computational cost increases rapidly! We won't be able to directly resolve cloud-scale processes (1km) on a global scale for long climate runs for quite a while.

Figs. IPCC 2007



Courtesy: Barsugli

Information at: http://www-pcmdi.llnl.gov/

More certain results: Temperature, global to large region

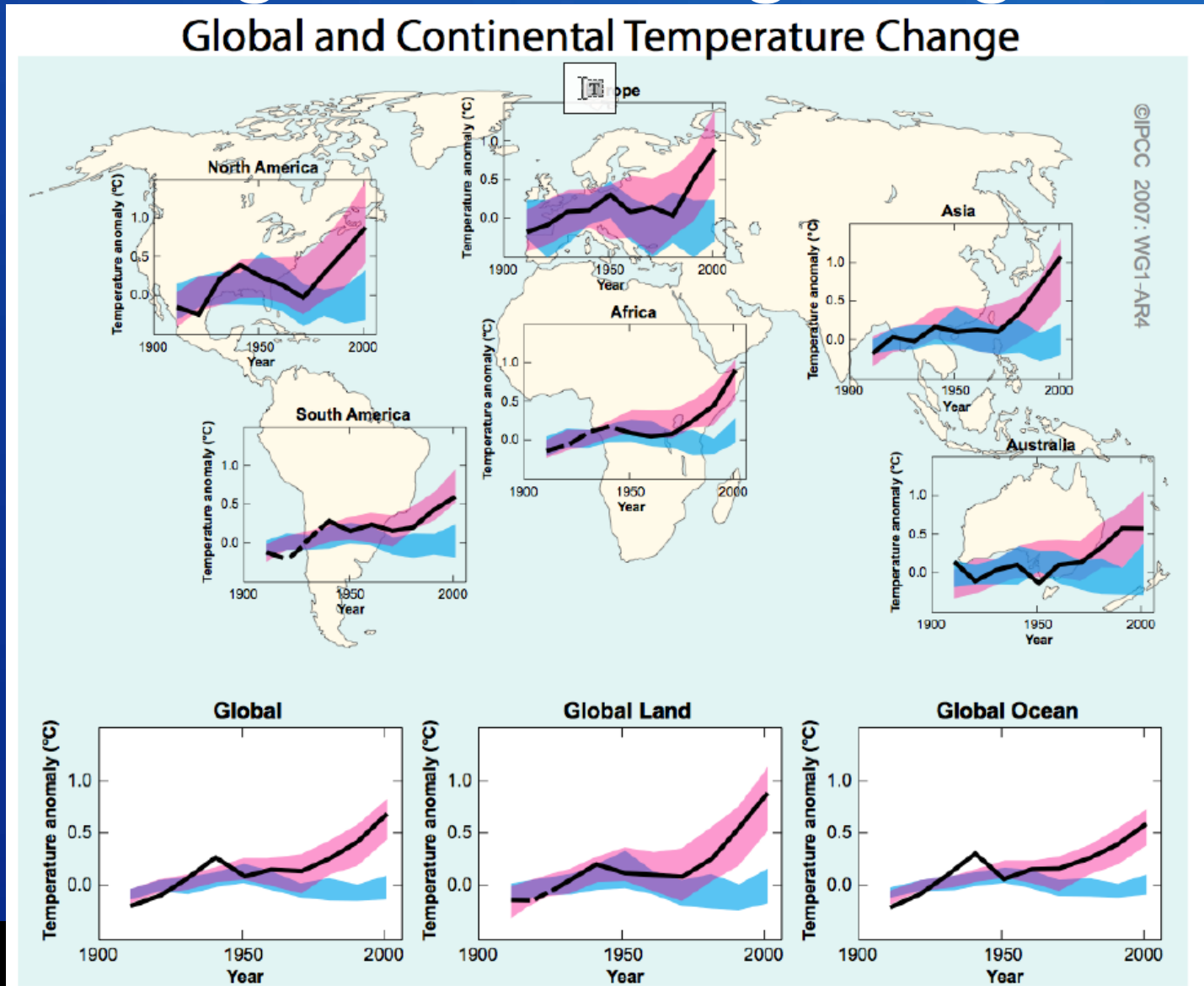


Fig. IPCC (2007)

Less certain results: Precipitation, local to small region

Figure U-8
Horizontal Spatial Resolution Depicted by Typical
Global Climate Models, and Where We Hope to Be in the Next 5 to 10 Years

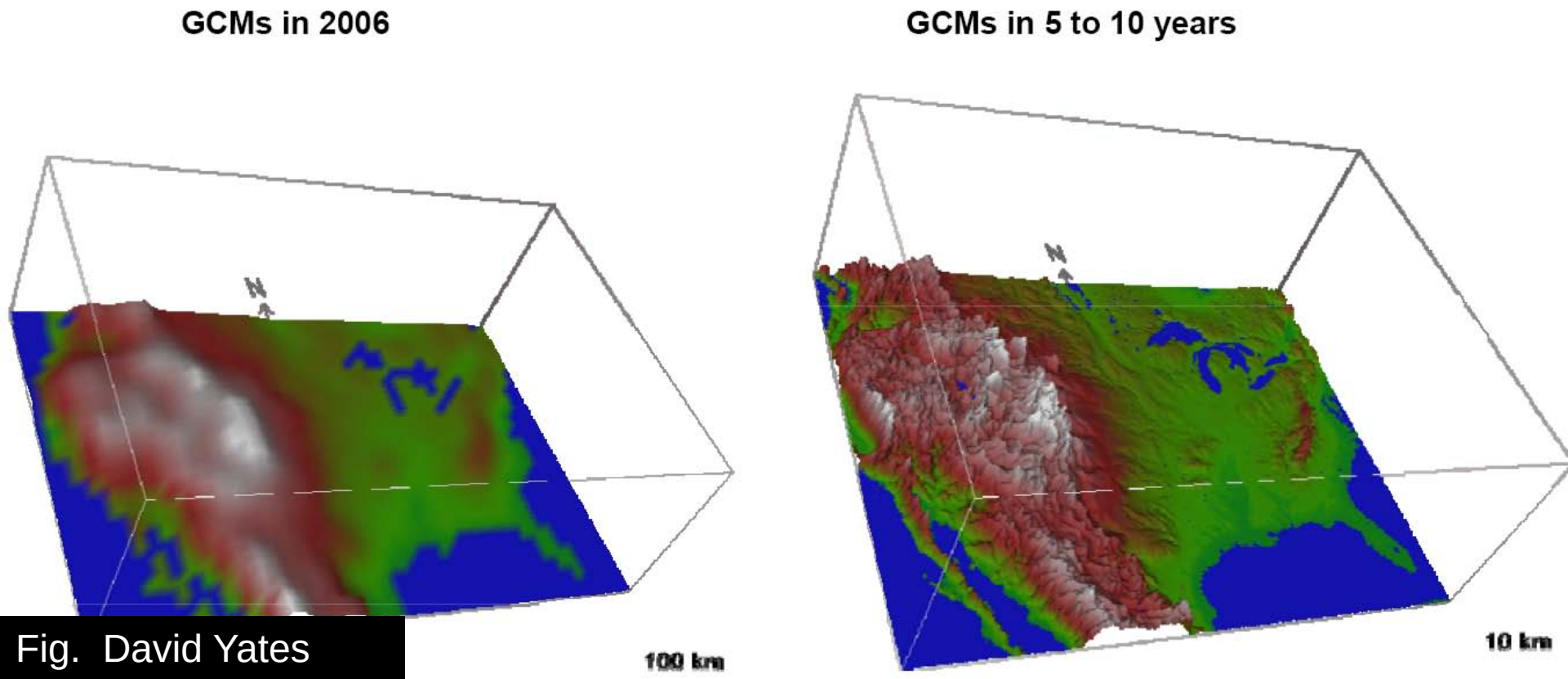
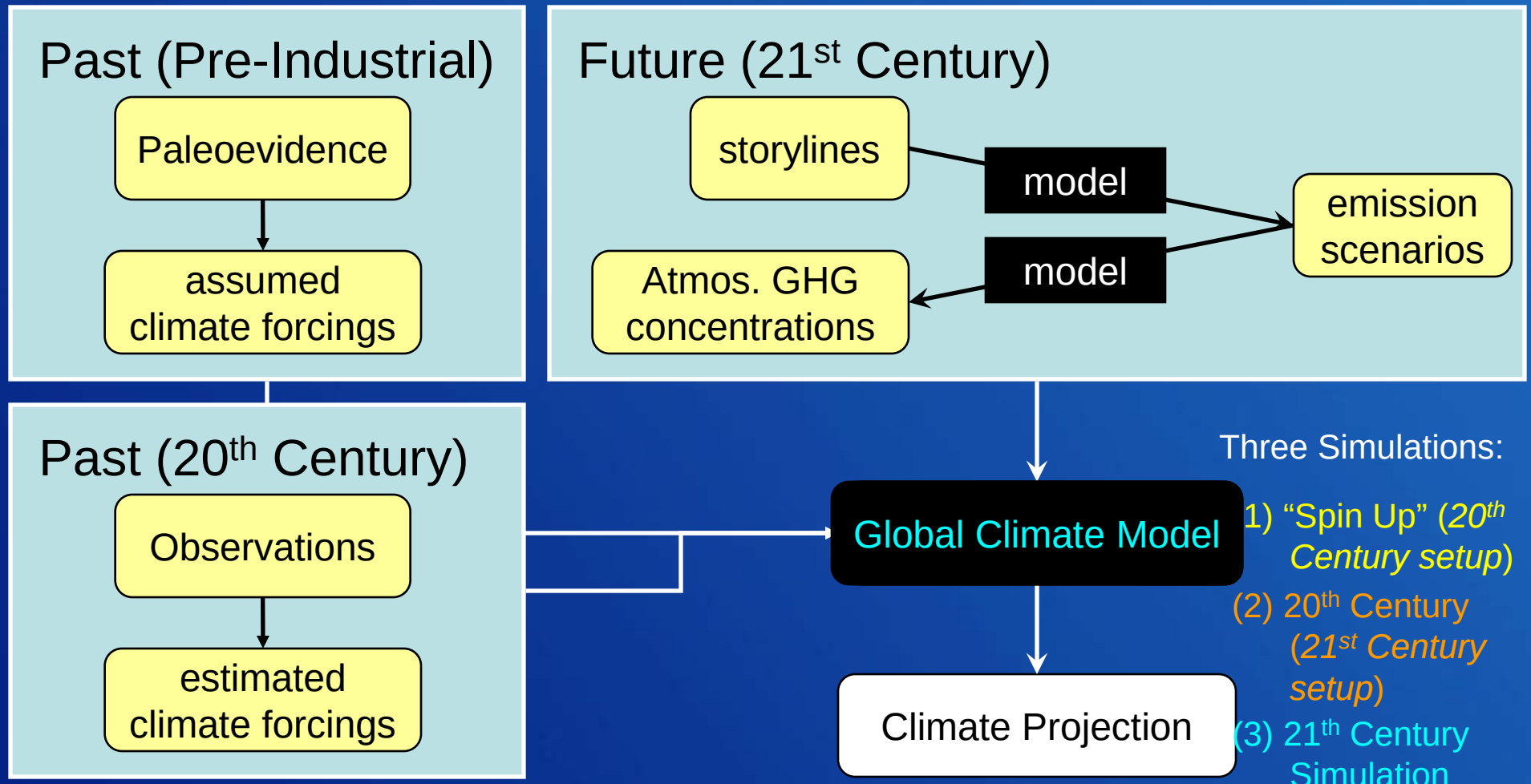


Fig. David Yates

Making a single CMIP3 projection: multiple simulations using a GCM…



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Bias-corrected and Spatially Downscaled versions of CMIP3 climate projections:

DCP Archive
(Maurer et al. 2007)

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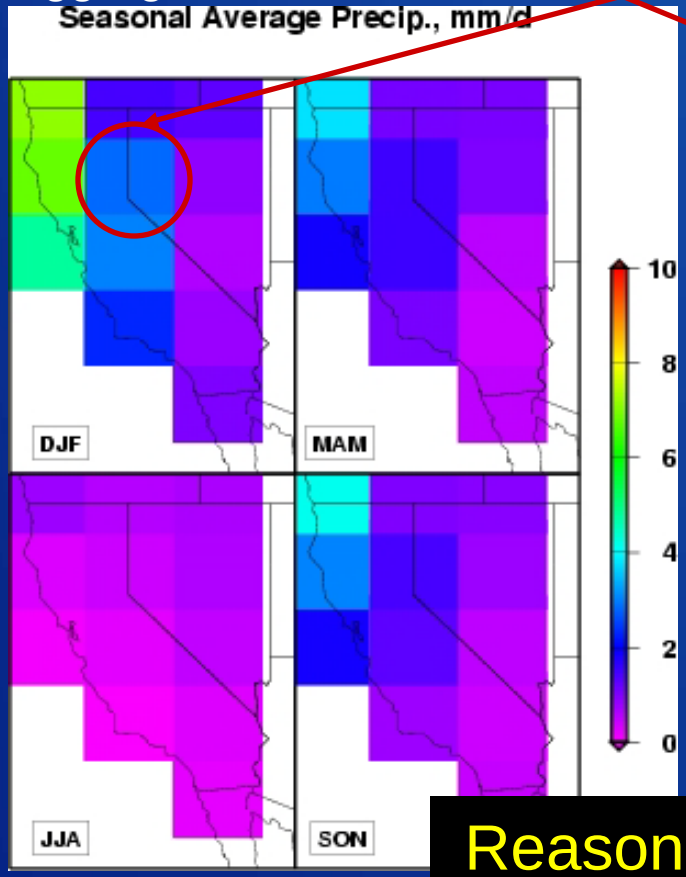
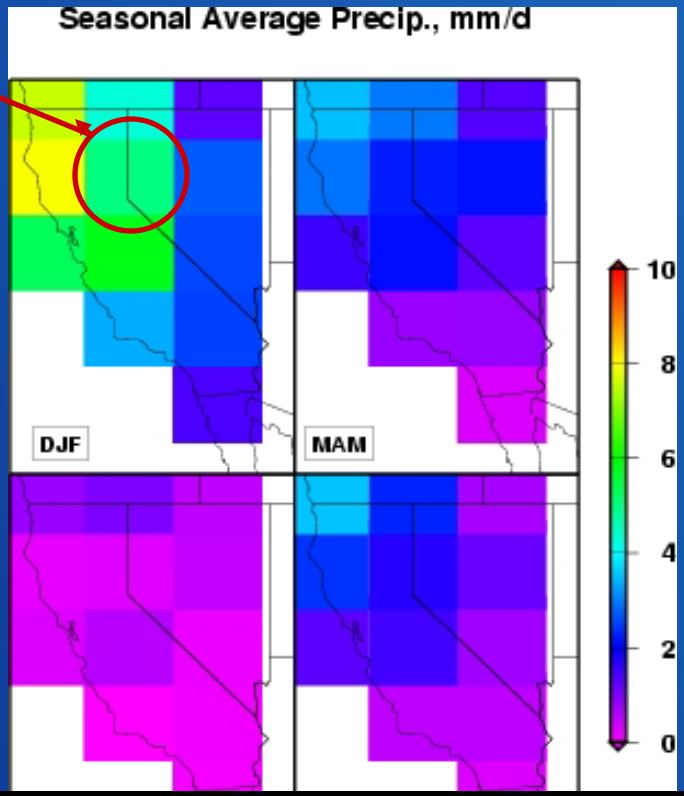
Motives for bias-correcting GCM data

Another example…

Observed Data
aggregated to GCM resolution



Raw **GCM output**
for same period as observations

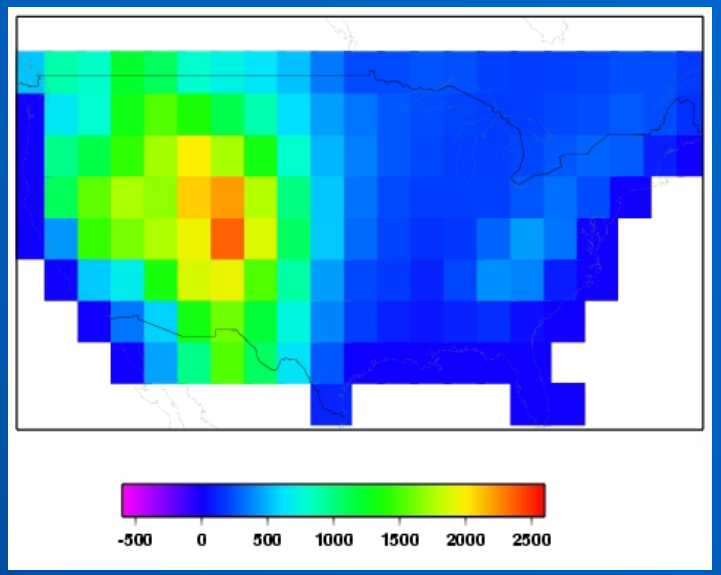


Reasonable seasonal and spatial patterns;
locally there can be large differences

Figs: E. Maurer

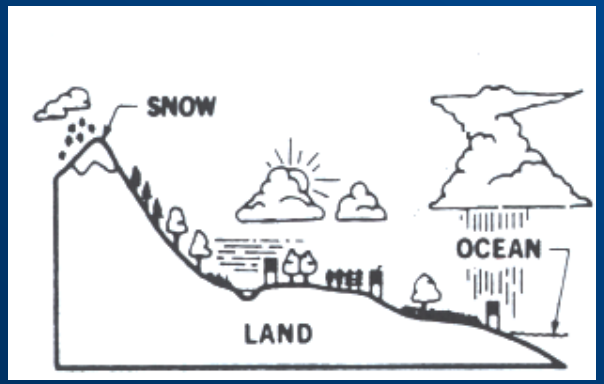
Motives for spatially downscaling GCM data

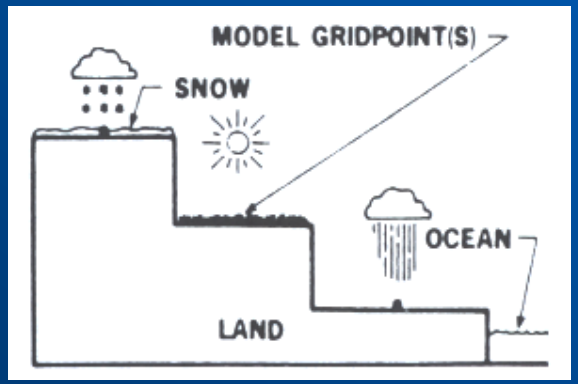
- GCM spatial scales are incompatible with smaller-scale hydrologic processes
  - roughly 2 – 5 degrees resolution
  - some important hydrologic processes not captured



Elevation at 2.5° resolution

Figs: E. Maurer

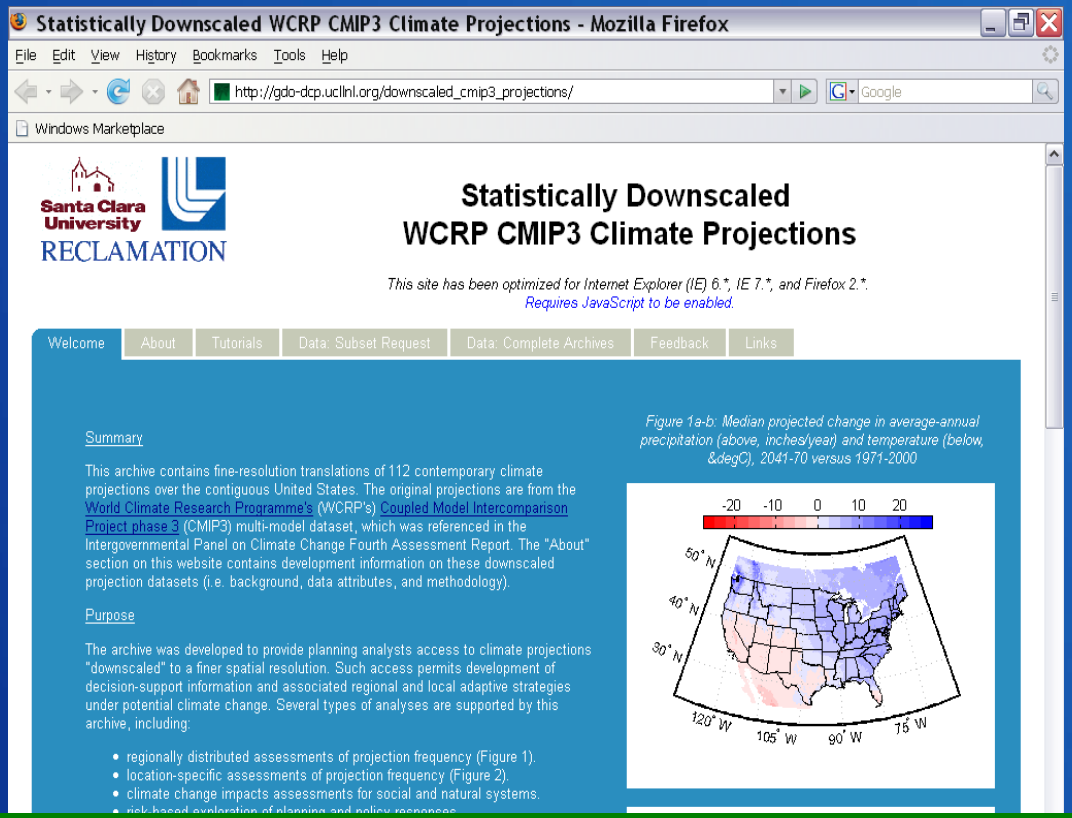




DCP Archive and Website

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

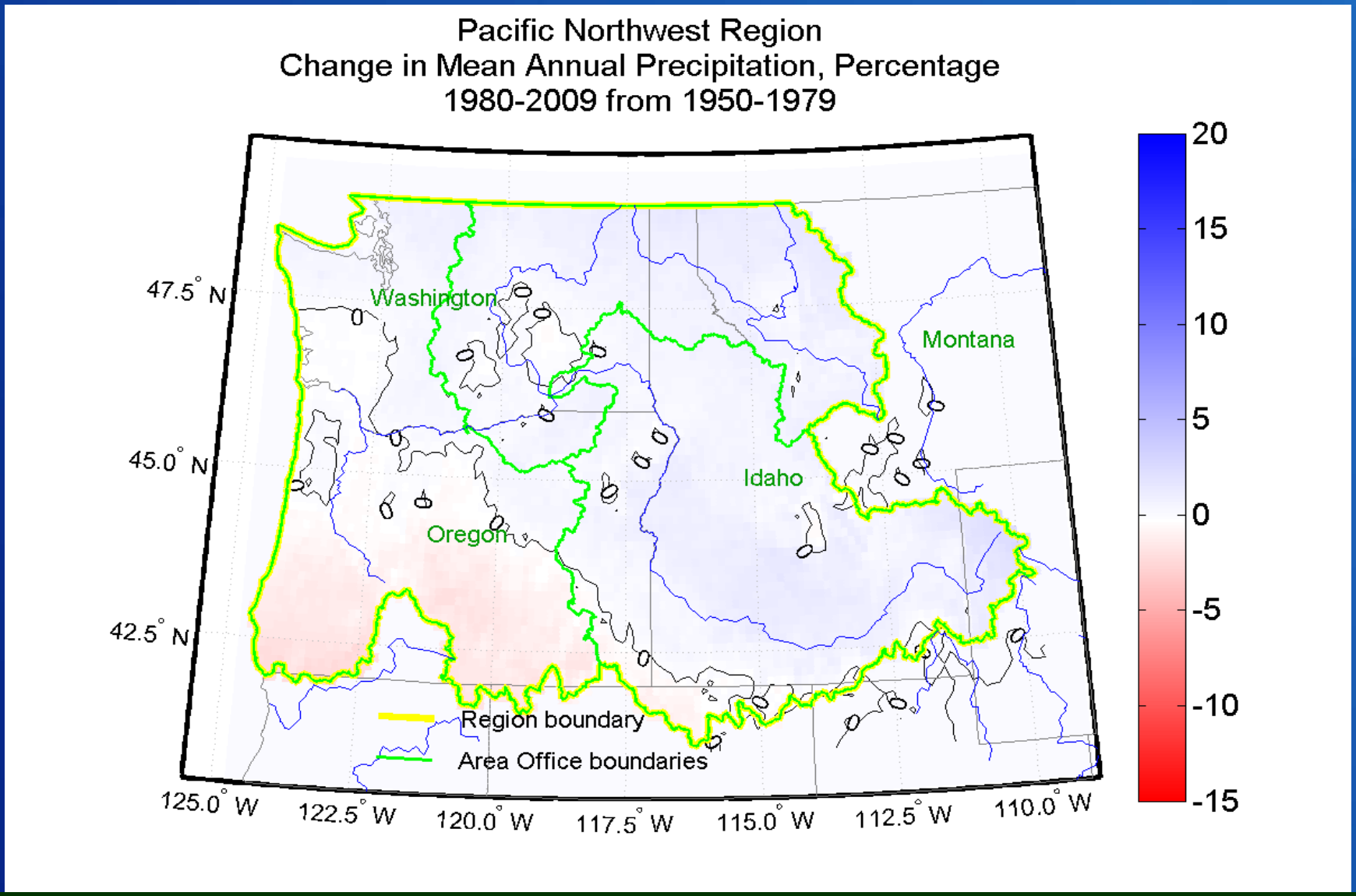
- Many Projections
  - 112 total projections
    - 3 Emissions (B1, A1b, A2)
    - 16 GCMs
    - Multiple “runs” per Emission-GCM combo
- Two Variables…
  - surface T and P
- Method
  - BCSD
- Coverage
  - 1950-2099
  - lower 48 states
- Resolution
  - monthly, ~12km



BCSD technique developed at Univ WA (Wood et al. 2002); still one of the downscaling methods used by CIG

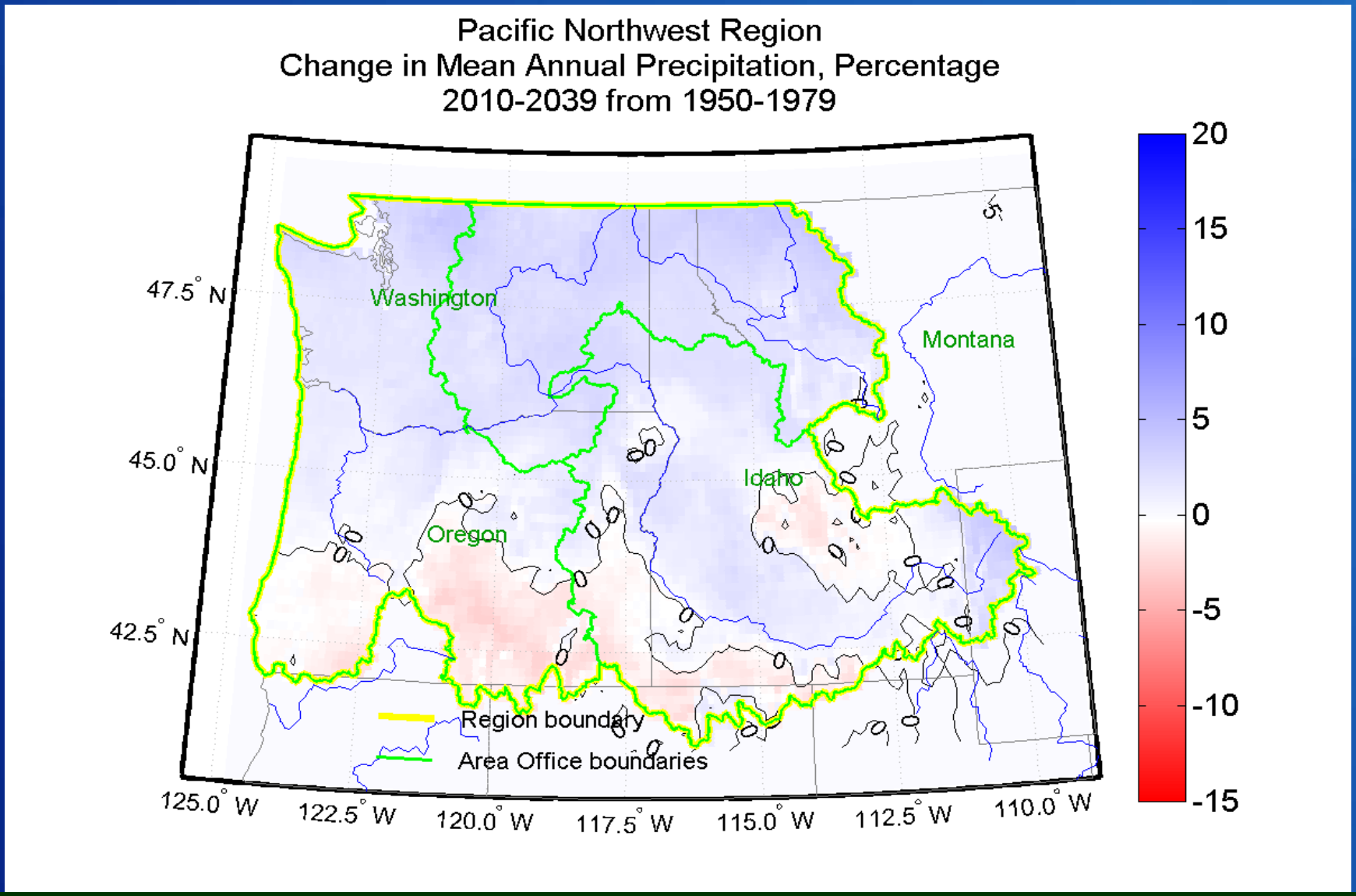
DCP Archive – PNW messages

- Temperature
  - Projections consensus, warmer future
- Precipitation
  - Projections majority, slightly wetter future over much of the Columbia-Snake basin
- Yakima-specific changes
  - Changes follow “big basin” trends;
  - Interpreting projections’ uncertainty depends on how you look at the projections…



Source: DCP Archive.

Map shows middle change (from 112 projections) across periods shown, computed for each 12km grid cell in the DCP Archive.



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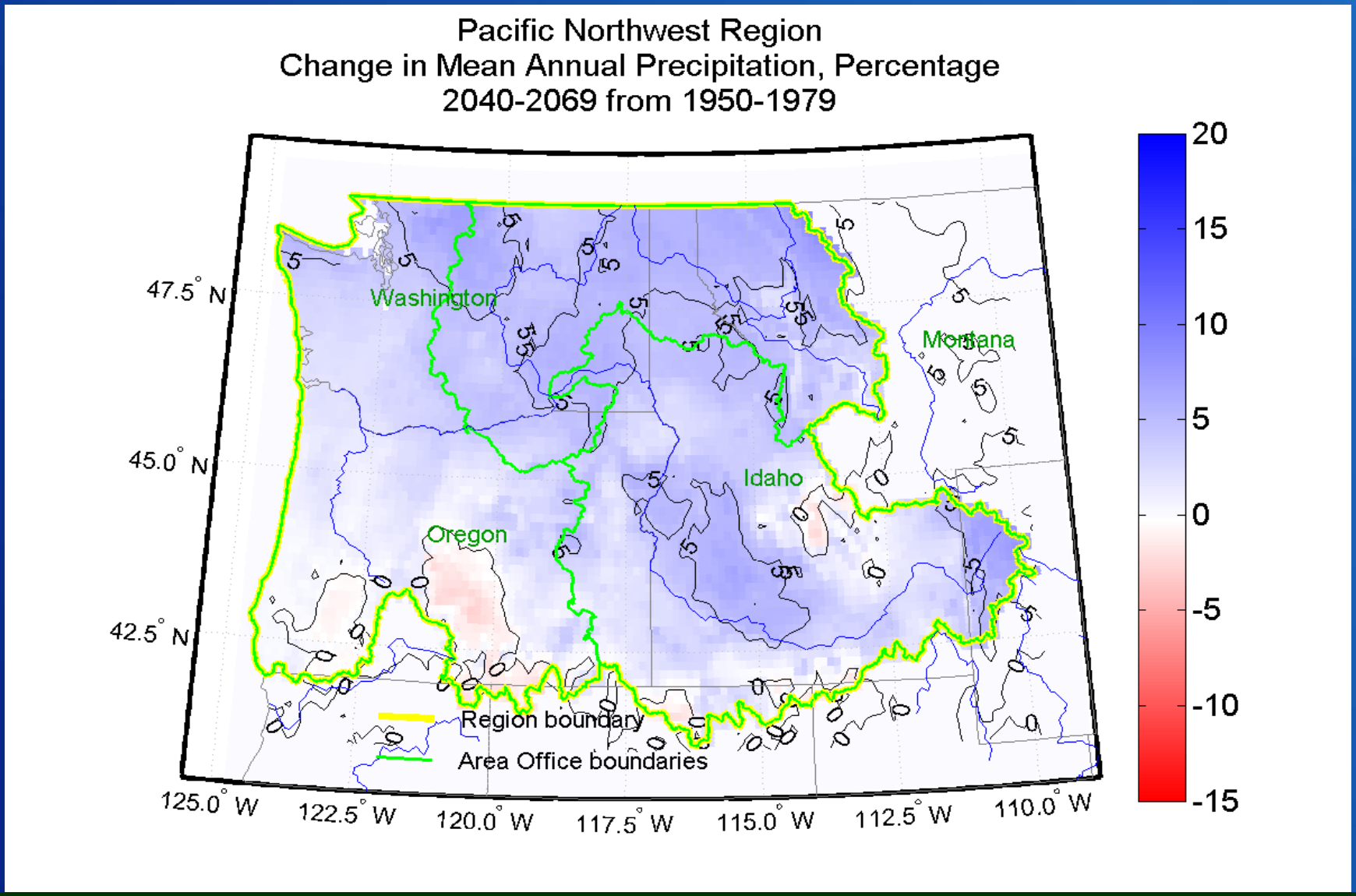

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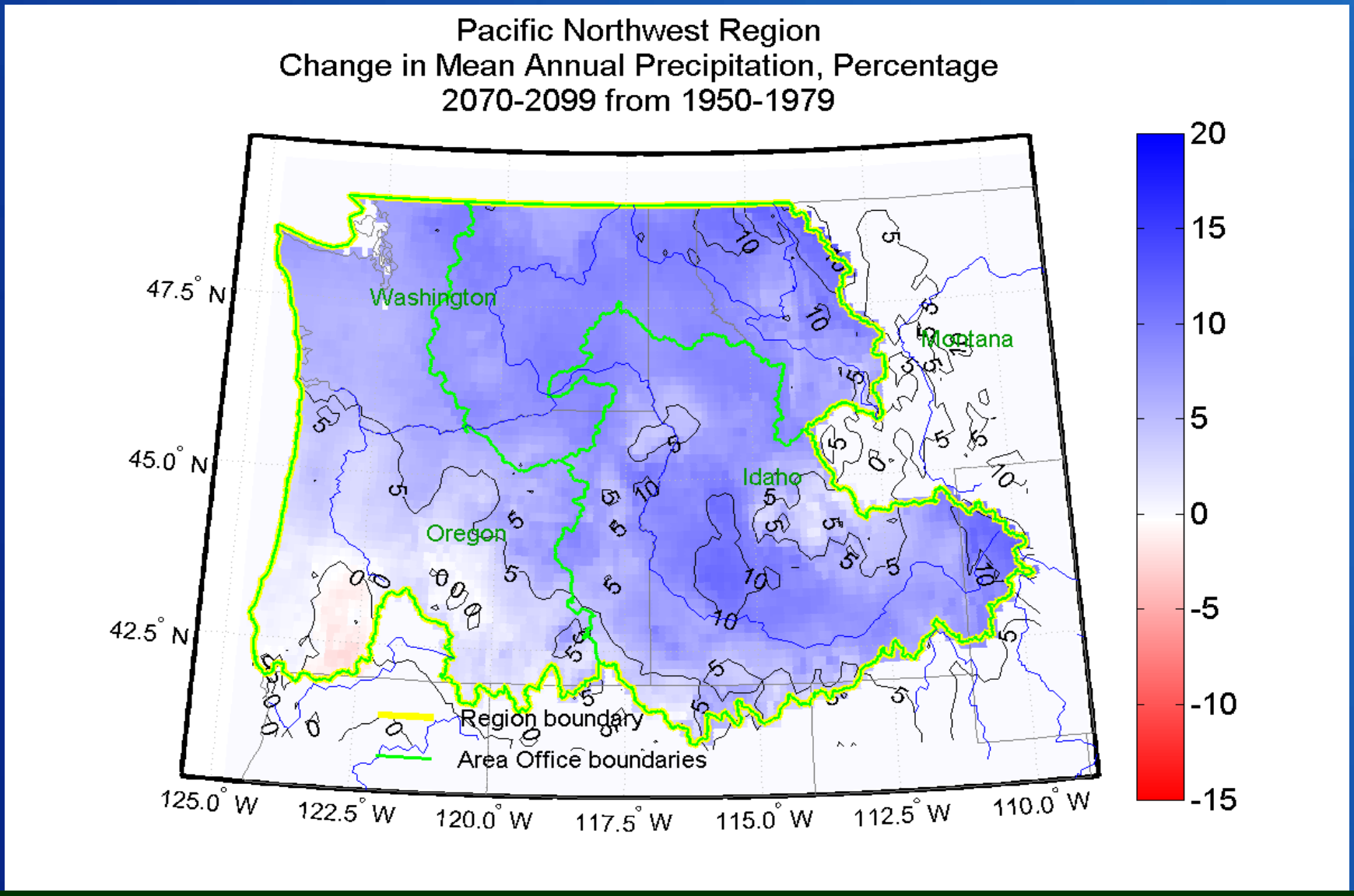

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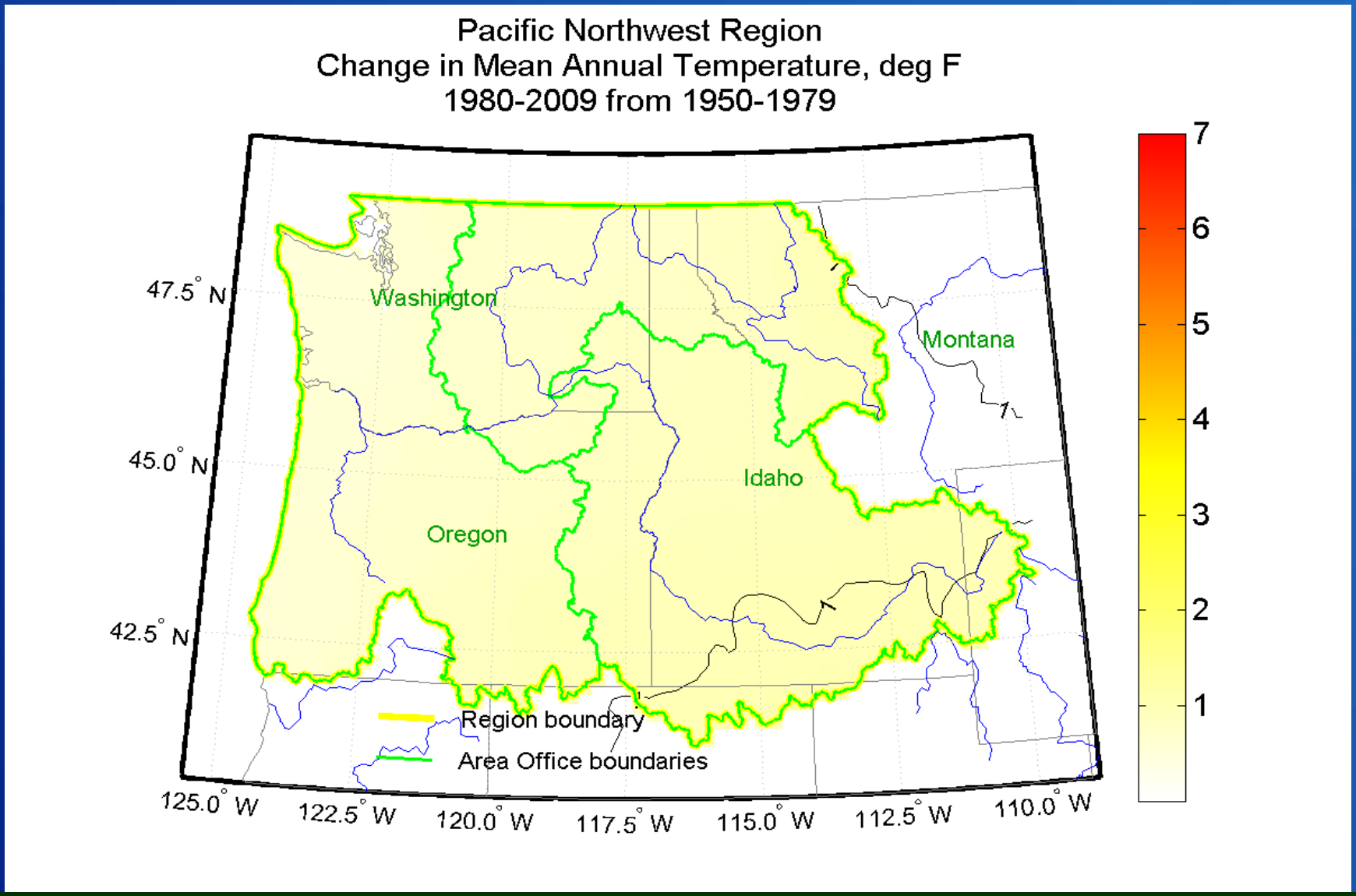

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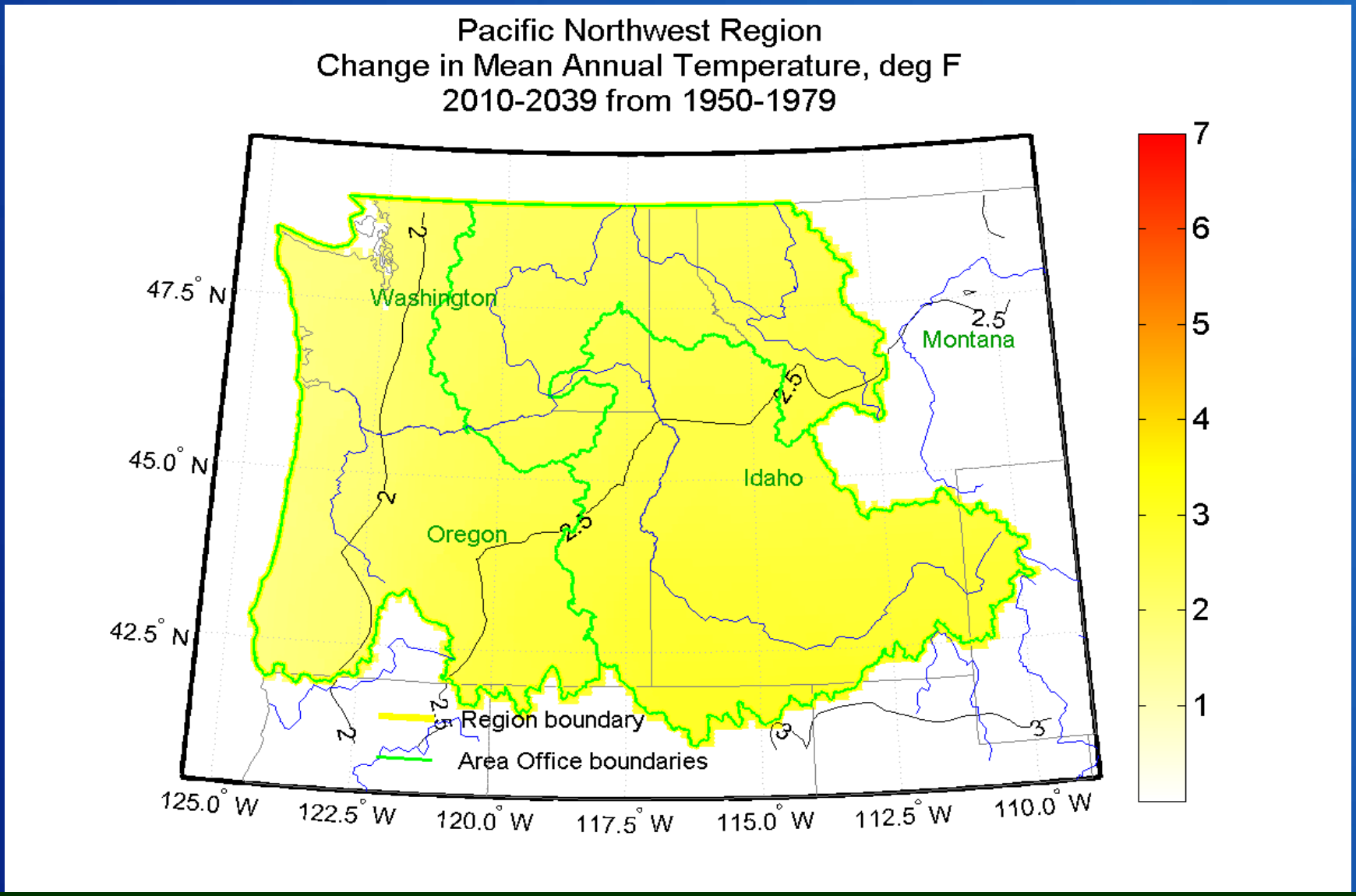

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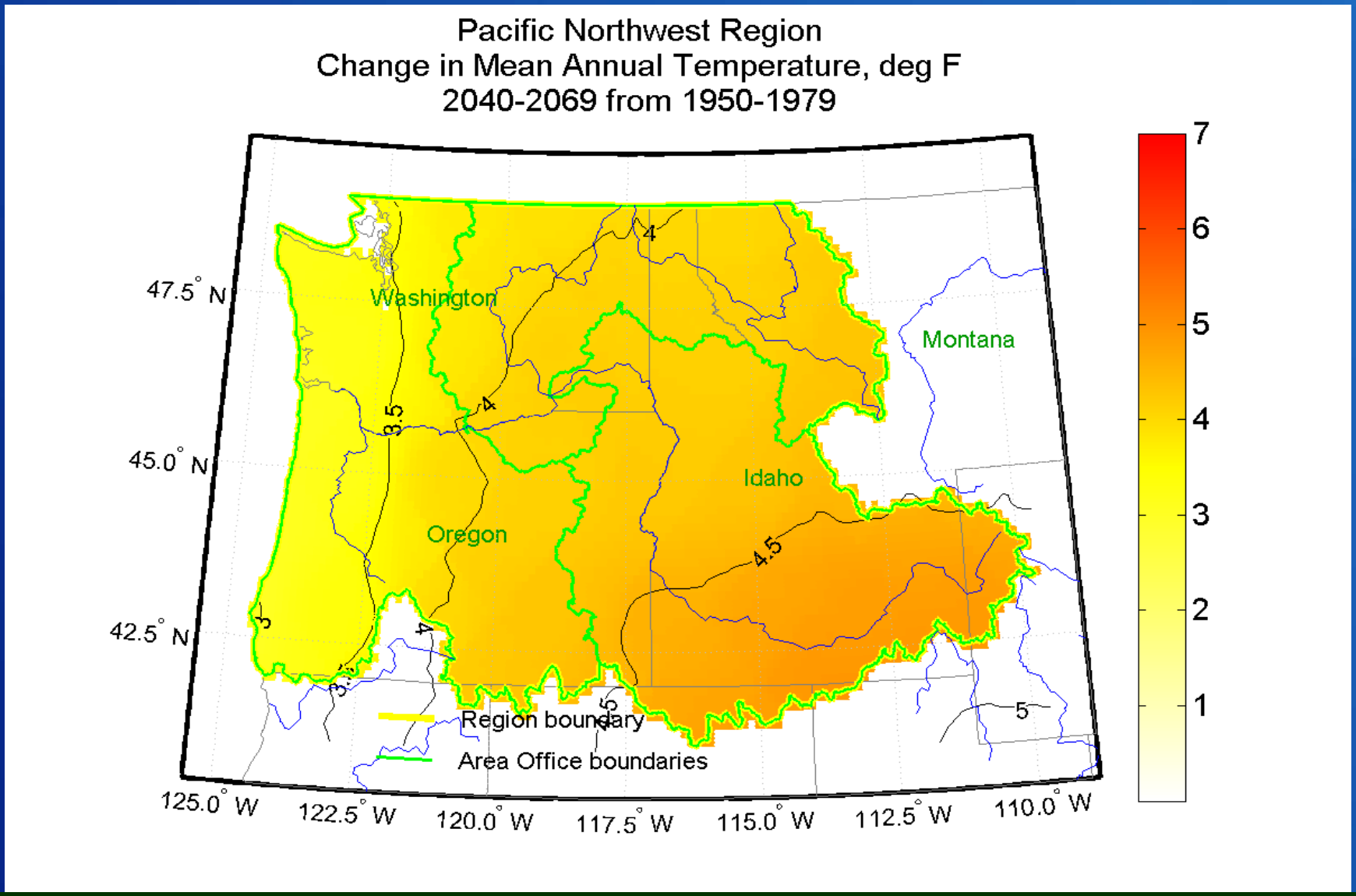

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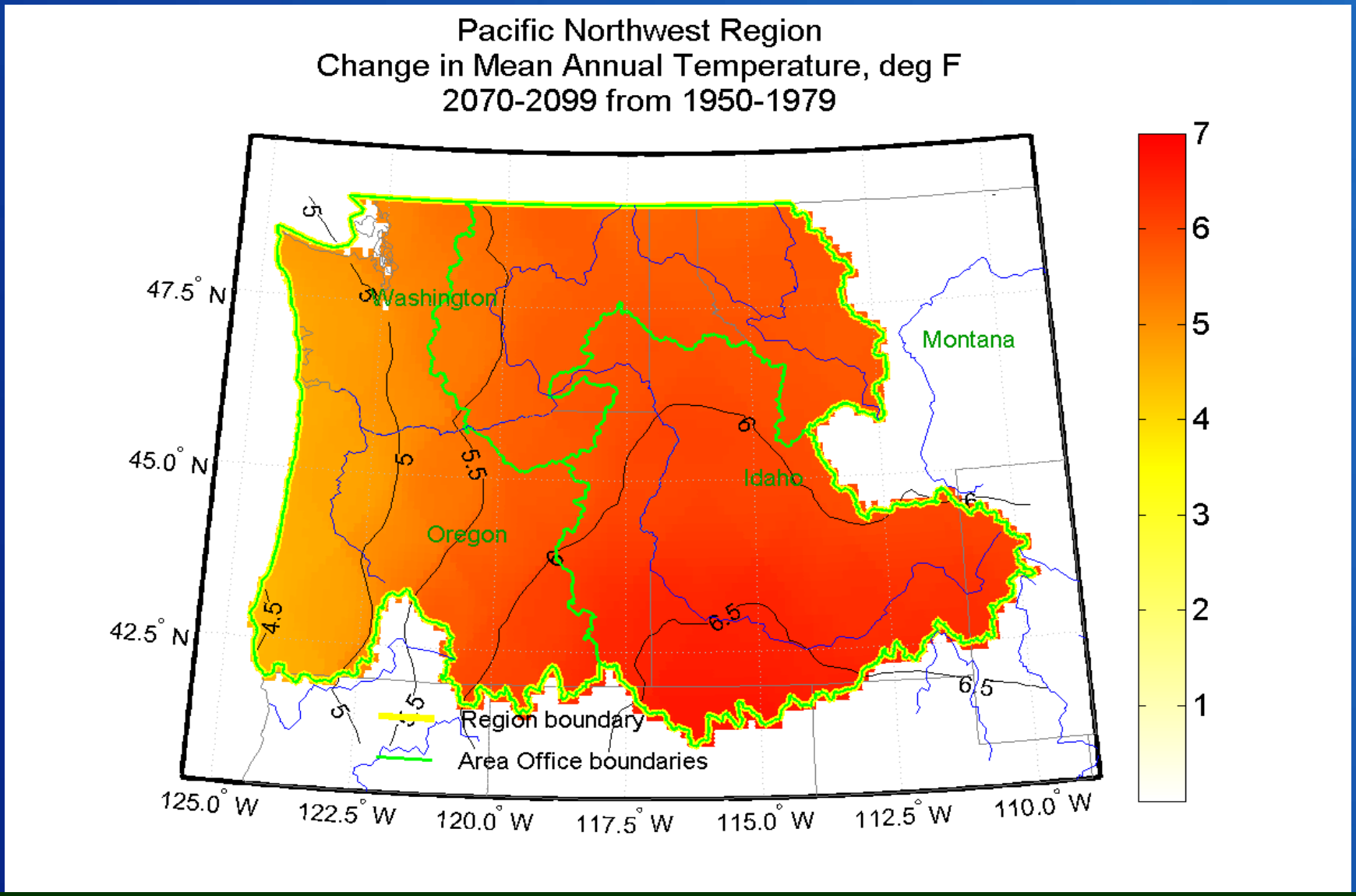

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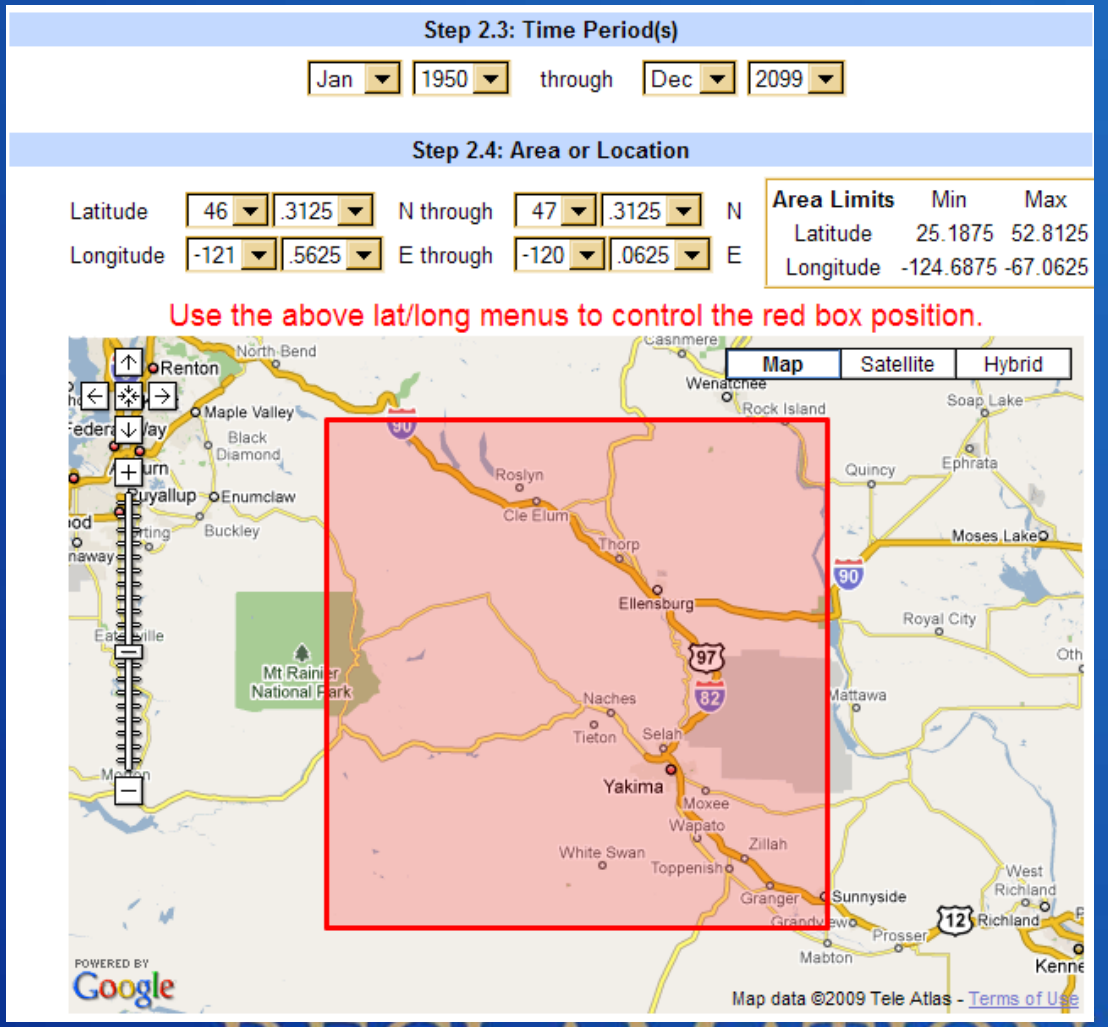
DCP Archive – PNW messages

- Temperature
  - Projections consensus, warmer future
- Precipitation
  - Projections majority, slightly wetter future over much of the Columbia-Snake basin
- Yakima-specific changes
  - Changes follow “big basin” trends;
  - Interpreting projections’ uncertainty depends on how you look at the projections…

Projections Spread Assessment over the Yakima Region

- Subjectively choose area over the Yakima River Basin
- Get data from DCP archive
  - All 112 projections
  - Mean-area time series
    - monthly, 1950-2099
    - area shown
    - Both variables (T, P)
- View #1
  - time-evolving quality
- View #2
  - Assess period-changes, interpret as “climate change” possibilities (questionable! Ignores multi-decadal variability)



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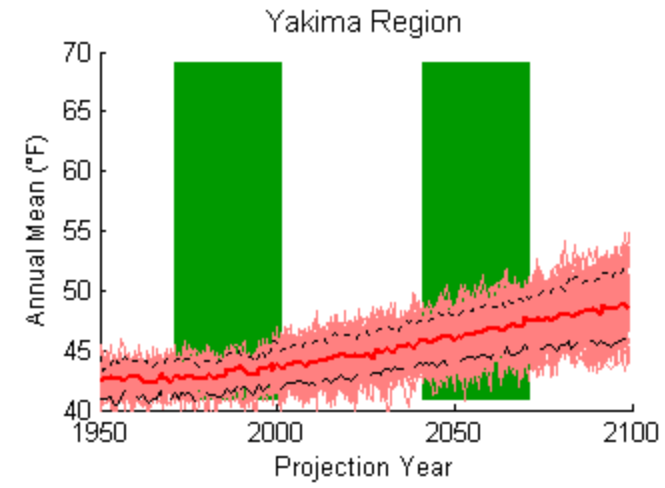
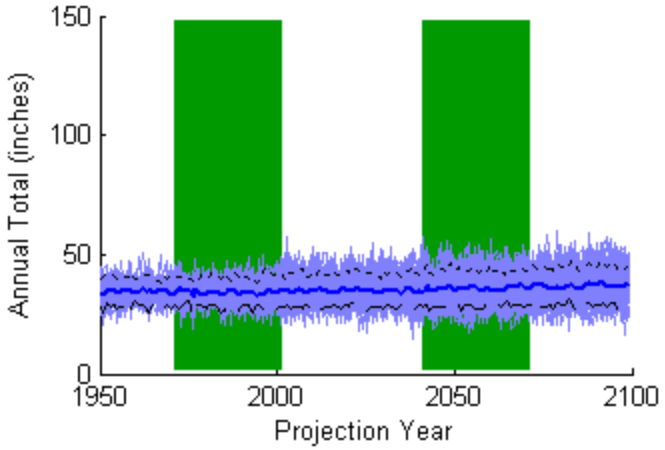
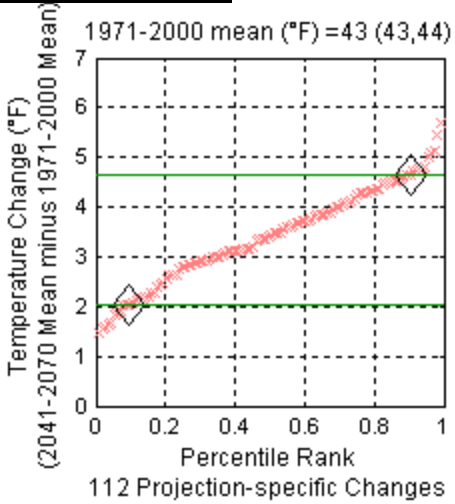
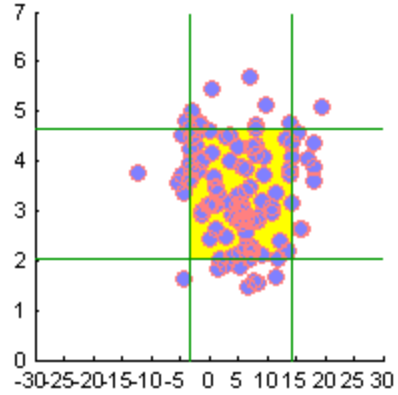
View #1

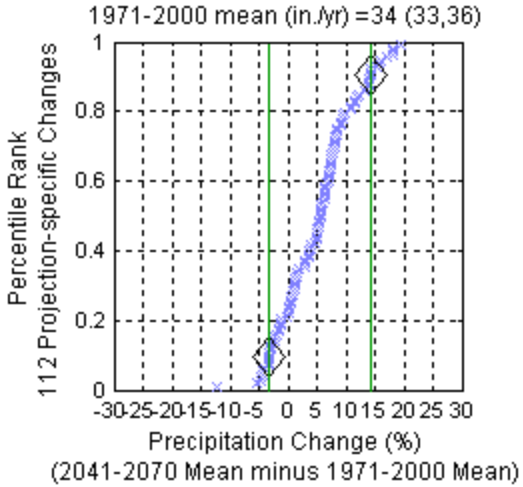




View #2







Source: DCP Archive. Left shows annual time series, Tavg and Prcp. Right shows sampled changes in 30yr means (1971-2000 to 2041-2070). *Historical data are simulated, not observed.*

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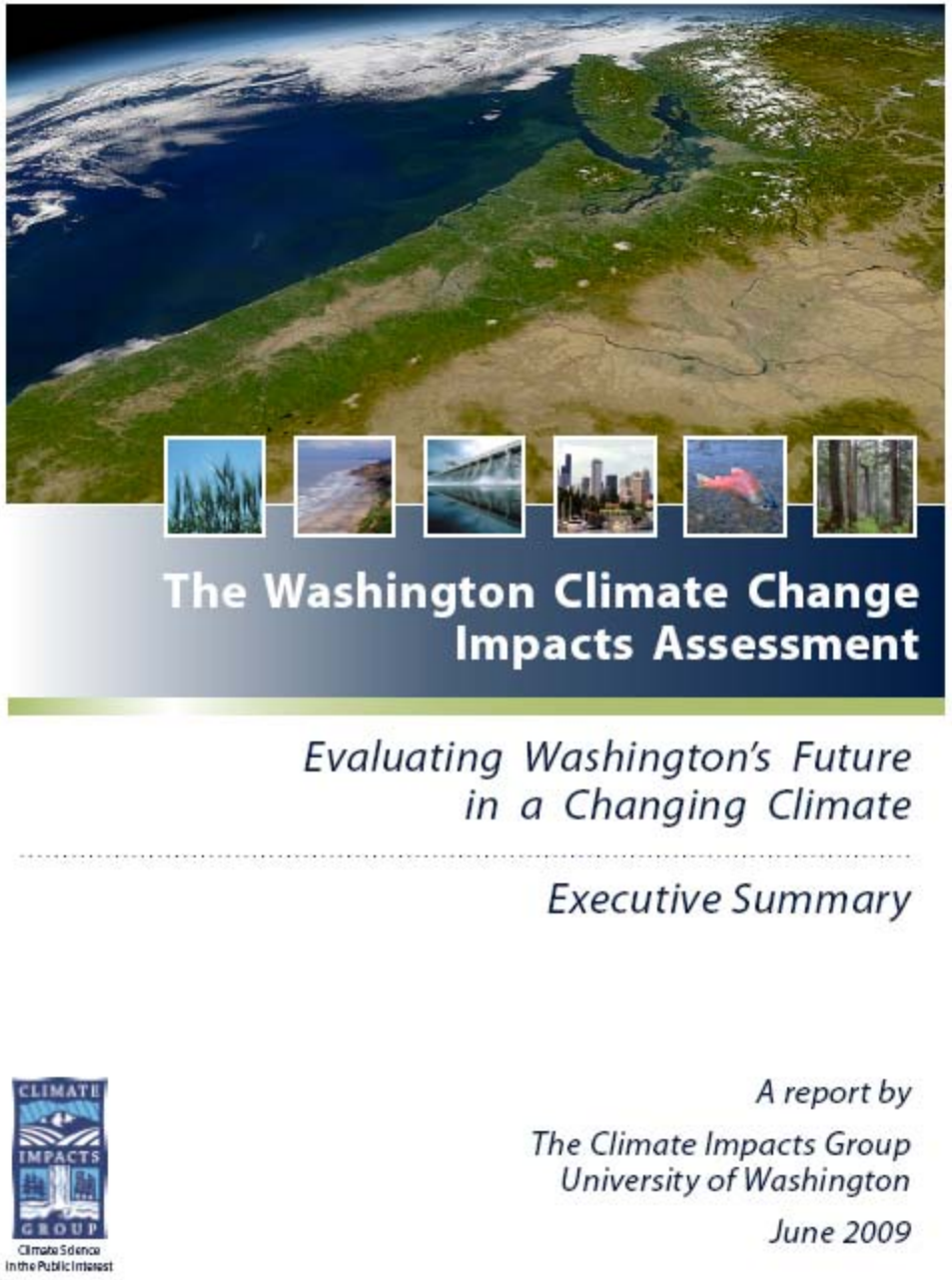
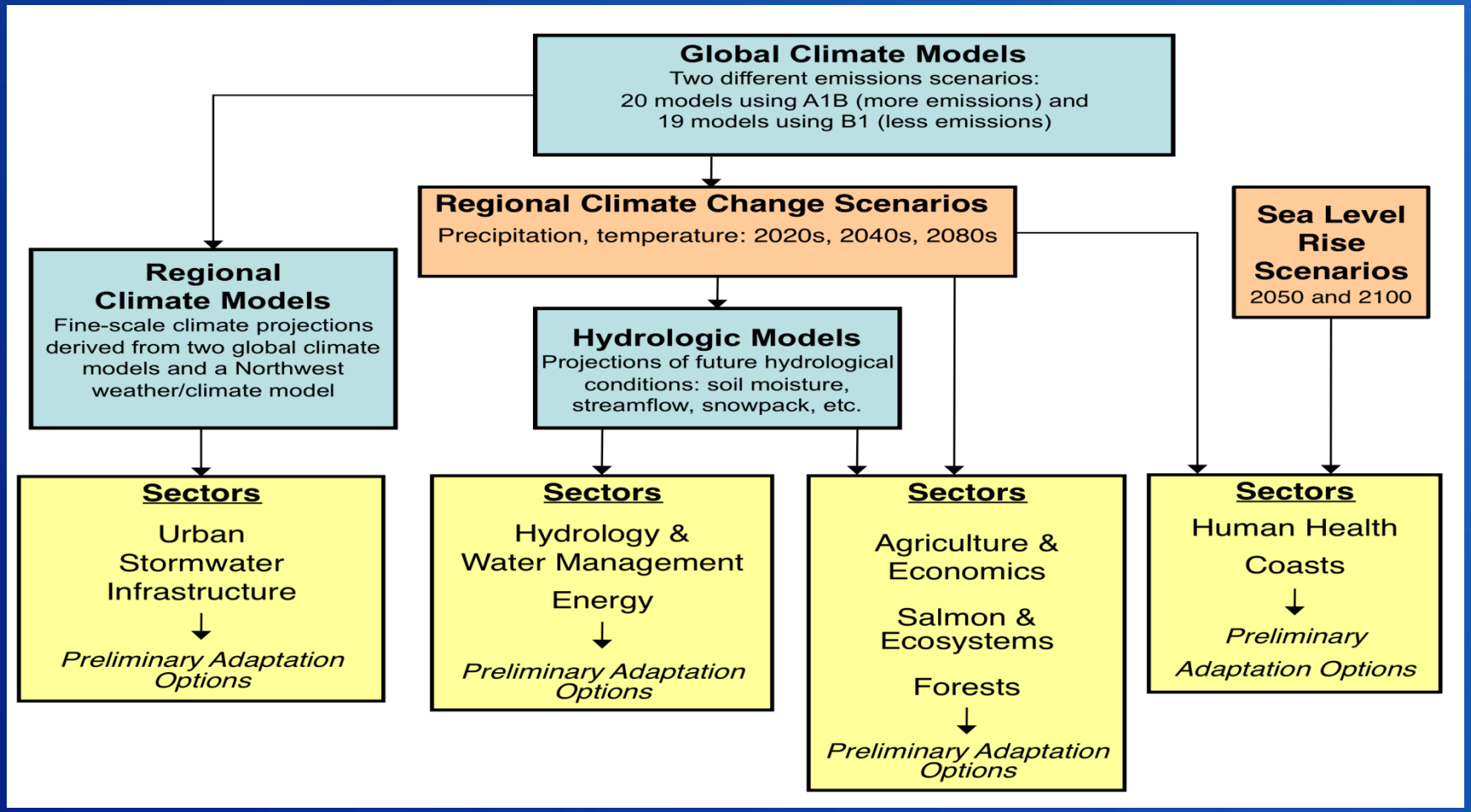
- Littell et al. 2009 (Executive Summary)
  - www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf



WACCIA (2009)



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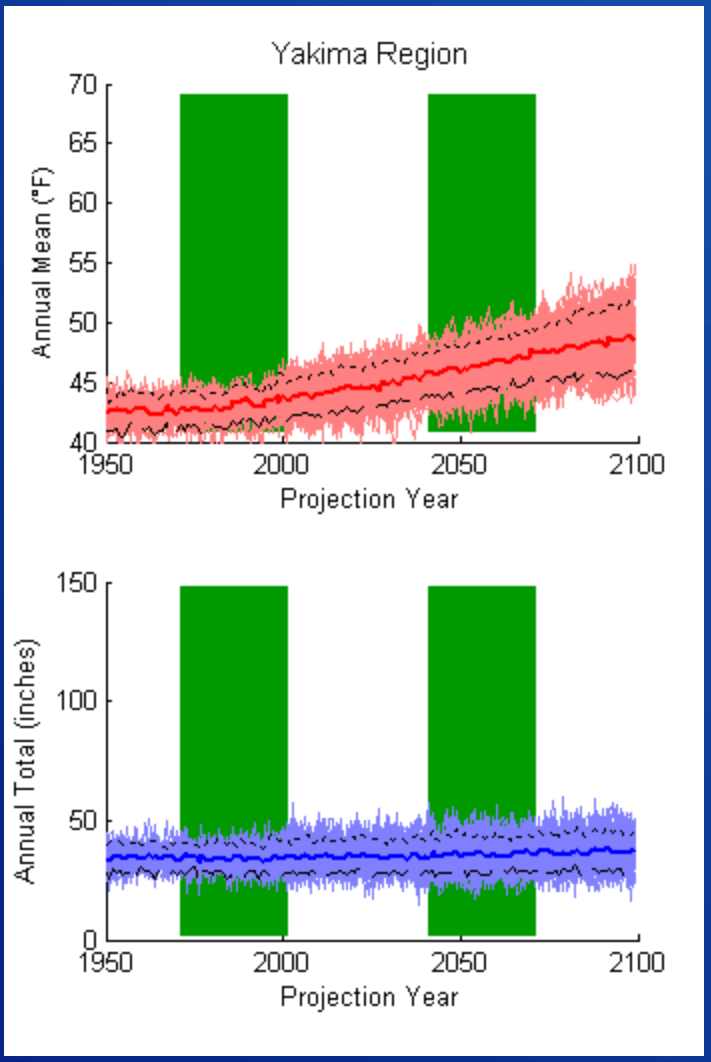
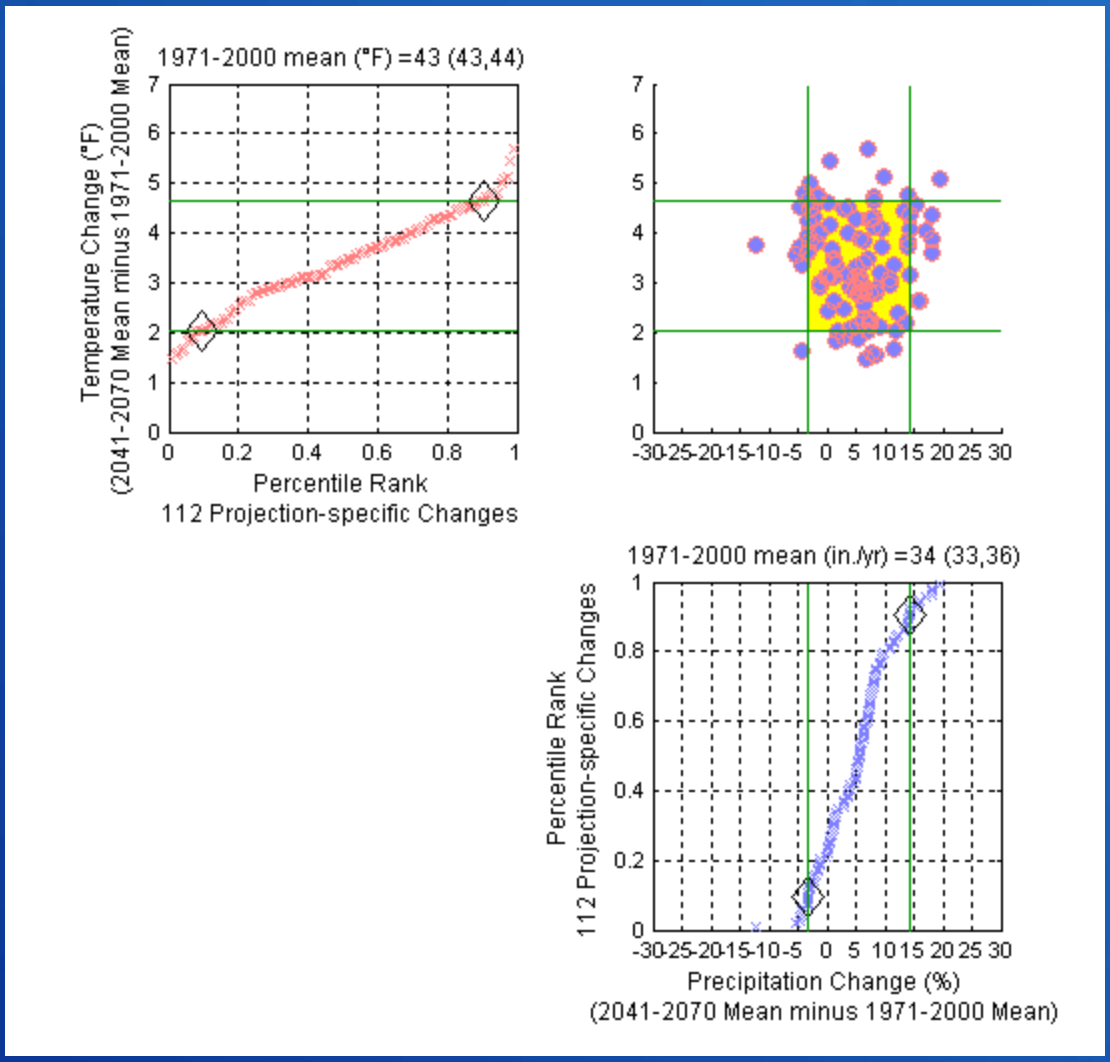
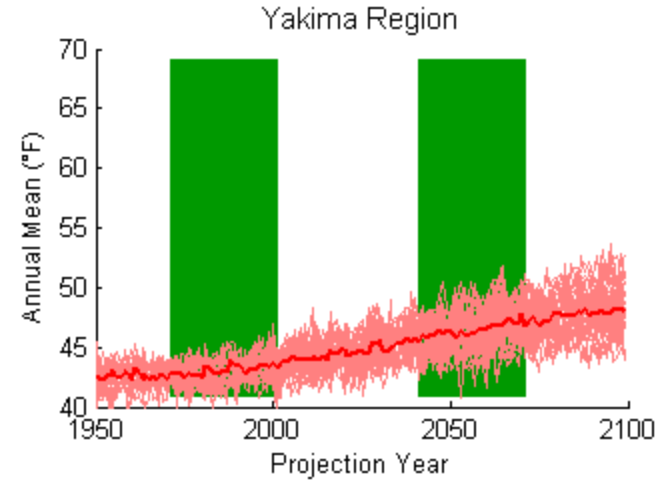
Future Climate Story: DCP Archive vs. WACCIA 2009

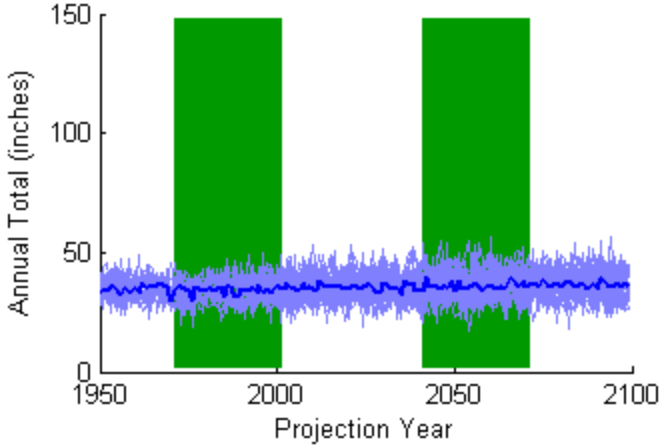
- WACCIA 2009
  - 20 CMIP3 models, primary focus on 2 emissions scenarios (A1b, B1), 1 run each model-emissions combo = 40 projections
- DCP Archive (2007)
  - 16 CMIP3 models, 3 emissions scenarios, multiple runs per … combo = 112 projections
- Overlap
  - 15 common CMIP3 models
  - *30 common projections*

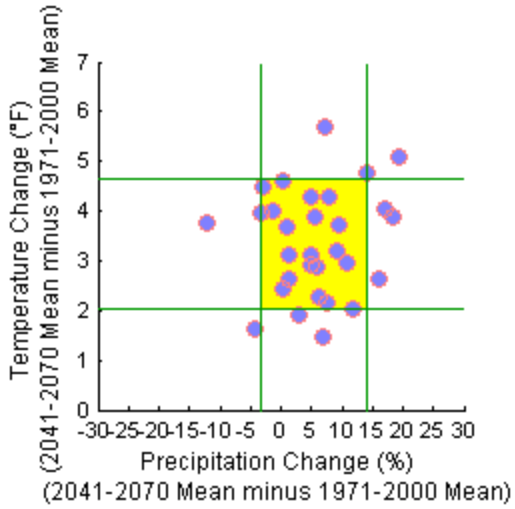




DCP Archive: all 112 projections



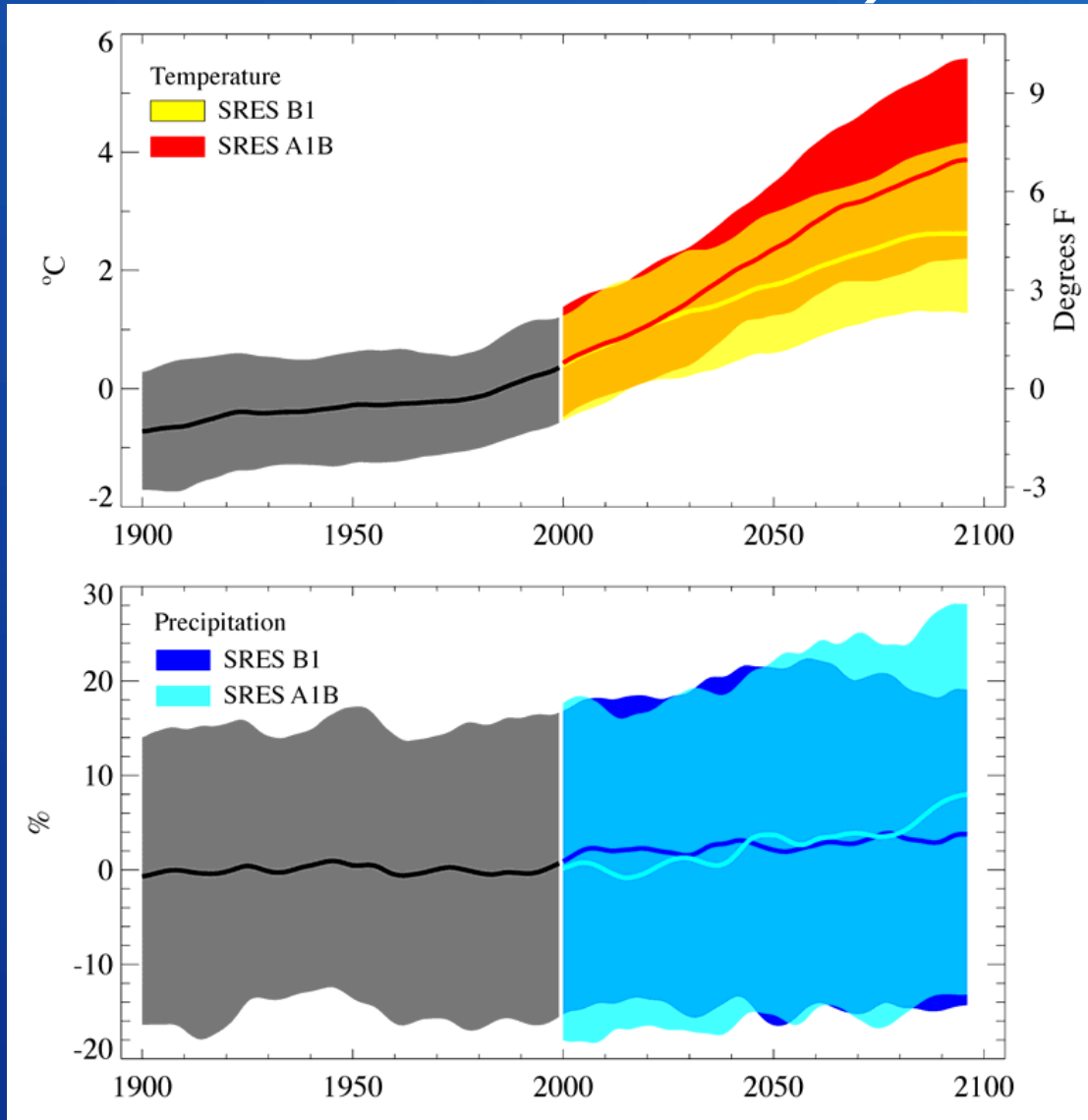




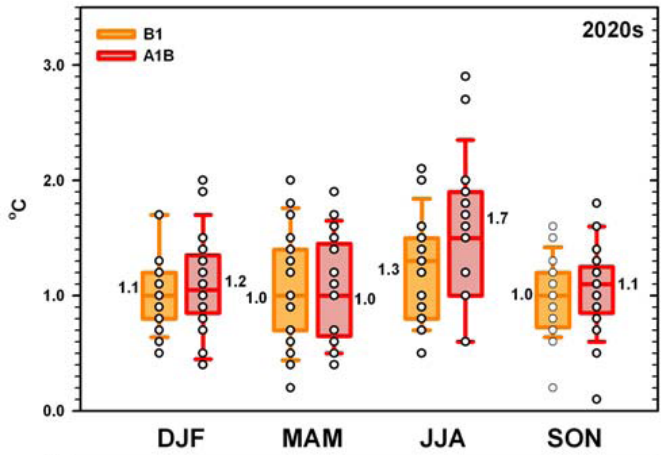
DCP Archive: only the 30 common projections…
Main point = WACCIA 2009 and DCP Archive have ~consistent subsets of CMIP3 information.

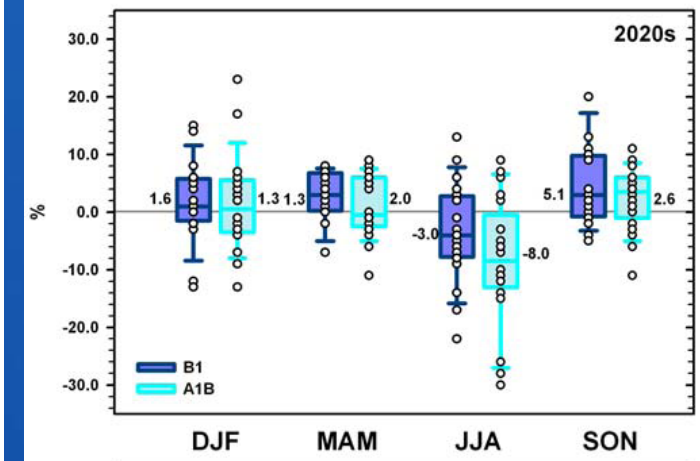
Mote and Salathe 2009 (State of WA Assessment, Ch 2)

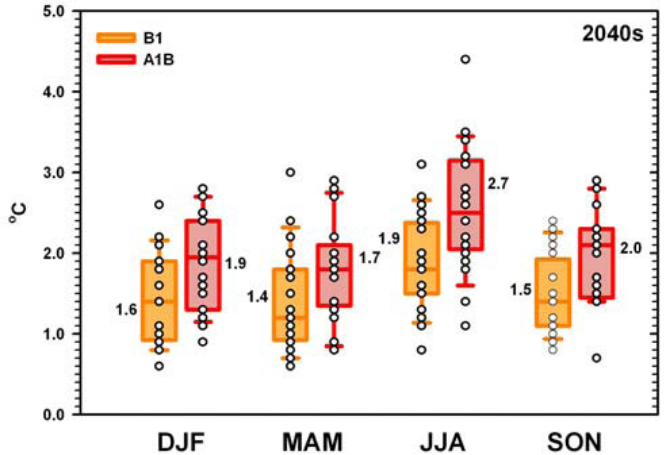
- Plots from source above
  - Fig 7
  - regional averages
- Emissions scenario influence:
  - T change by mid-21st century
  - P change by late-21st century?

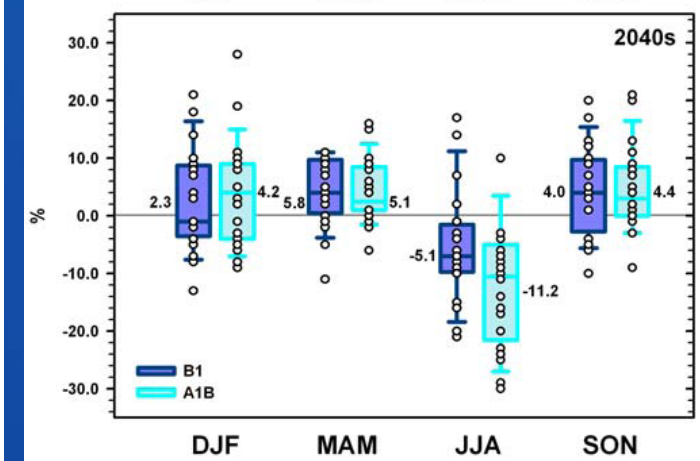


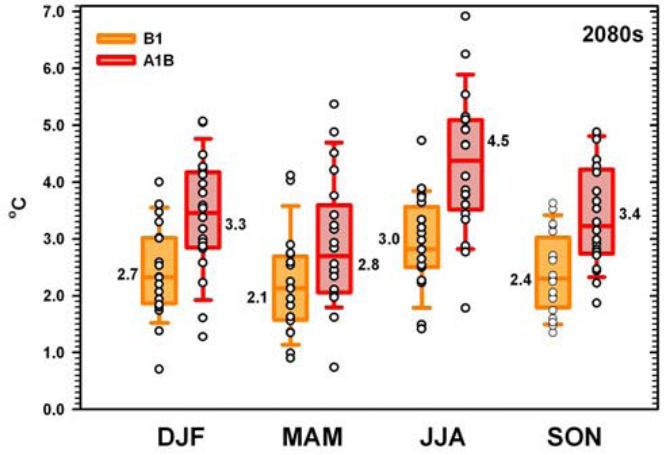
- Plots from same source
  - (Figs 9 and 10
  - mean-seasonal changes, computed for each projection
  - Boxplots show projection-distributions by emissions scenario and season

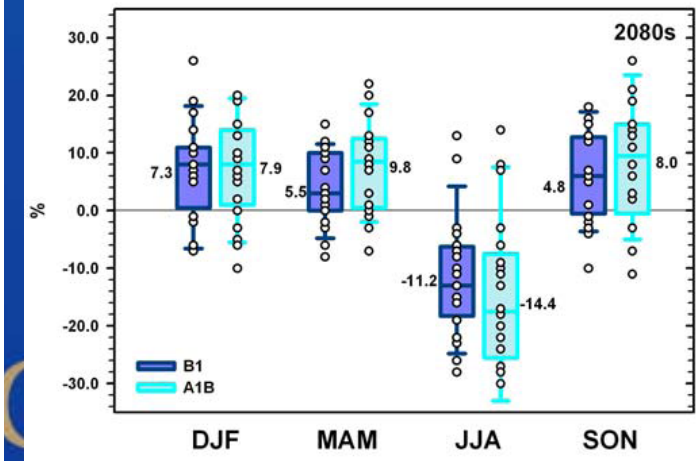












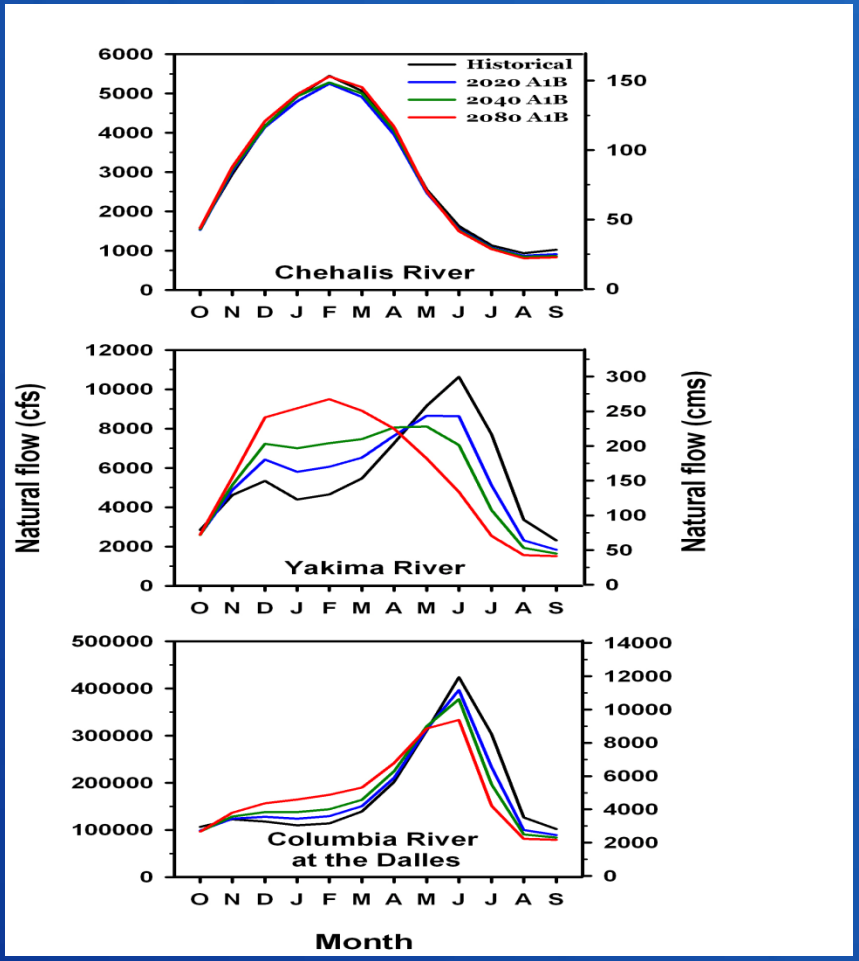
WACCIA 2009, Ch. 3: Hydrology and Water Resources

- April 1st snow water equivalent is projected to decrease
  - Projections' mean "state-wide average" change of
    - 28% to 29% by the 2020s
    - 37% to 44% by the 2040s
    - 53% to 65% by the 2080s

WACCIA 2009, Ch. 3.1 (Elsner et al) Hydrology and Water Resources

- By the 2080s, seasonal streamflow timing in snowmelt-dominated and transient rain-snow watersheds would shift significantly due to the decrease in snowpack and earlier melt.
  - Fig 6 from Exec Summary (Littell et al. 2009)
  - Projections' mean hydrograph, A1b, three future periods

- For Washington State as a whole, projected changes in runoff depend strongly on season.



RECLAMATION

WACCIA 2009, Ch. 3.3 (Vano et al) Water Management and Irrigated Agriculture, Yakima Basin

- *Supply Side impact:* The Yakima basin reservoir system will gradually become less able to supply water to all users, especially those with junior water rights.
  - Base simulation: "water short" 14% of yrs
  - Mean 2020s: … 32% of yrs (no adaptation)
  - Mean 2040s: … 36% …
  - Mean 2080s: … 77% …

Simulation period contains 1916-2006 variability, adjusted to reflect given period-climate condition. Models described in 3.1 & 3.3.

"Water short" defined as 75% prorating (effectively, a legal loss of 25% of water rights during drought) for junior water rights holders.

RECLAMATION

WACCIA 2009, Ch. 3.3 (Vano et al) Water Management and Irrigated Agriculture, Yakima Basin

- *Demand-Side Impact:* Due to increases in temperature … the growing season will likely be earlier by about two weeks, and crop maturity will likely be earlier by two to four weeks by the 2080s

WACCIA 2009 compared to Earlier Efforts

- There have been numerous efforts based on earlier climate projections information.
- Qualitatively
  - WACCIA 2009 impacts results are consistent.
- Quantitatively
  - earlier results and WACCIA 2009 differ in some ways
  - largely due to selection of input global climate projections.
- *Main point: impacts themes have been consistent through multiple PNW study efforts.*

Outline

- Historical Observations
- Future Climate Projections
- Studies on PNW Impacts
  - 2009 WA Climate Change Impacts Assessment
- Ongoing Studies
  - CIG Data Development (WA HB 2860)
  - RMJOC
  - Odessa Special Study

HB 2860 Data Development

- "Comprehensive Hydrologic Data Base Incorporating IPCC Climate Change Scenarios to Support Long-Range Water Planning in the Columbia River Basin"

- Objectives
  - support water planning at a range of spatial and temporal scales in the Columbia River basin & PNW
  - Increase spatial resolution of hydrologic models to capture smaller basins relevant to planning
    - i.e. daily time-step VIC hydrologic model of CSRB at ~6km spatial resolution… same as WACCIA 2009, but with refined calibration (summer 2009)

RECLAMATION

HB 2860 Information vs. WACCIA 2009 Information

	WACCIA 2009: "**Delta**" scenarios	HB2860: **Transient**	HB 2860: **Hybrid**
Source	40 global climate projections	(?) subset of 20 projections from "better GCMs"	(?) subset of 20 projections from "better GCMs"
Processing	Raw GCM output	Bias-corrected GCM, spatially downscaled	Bias-corrected GCM, spatially downscaled
What's sampled from these source data?	Change in 30-year monthly mean	Monthly time series conditions*	Change in 30-year monthly distribution

Same as DCP Archive, but at 1/16deg rather than 1/8deg

* - This technique can be implemented to do time-disaggregation to sub-monthly time steps (Wood et al. 2004, Maurer 2007).

RECLAMATION

Odessa effort is using consolidated WACCIA 2009 information

- From WACCIA 2009, CIG provided assistance to Reclamation, producing “composite Delta” scenarios.
  - Compute “Deltas” for each projection and period.
  - Group “Deltas” by emissions scenario (A1b or B1) and period = 20 Deltas per group.
  - For each group, compute average of the Deltas
    - i.e. 20 projections, each having a Delta (i.e. change in mean-monthly climate); “composite Delta” = average, by month
  - Available “composite Delta” scenarios: 2020s, 2040s, and 2080s, each for A1b and B1…
  - Those used in Odessa effort: 2040s A1b and B1

RMJOC effort will be using HB2860 information

- Federal leads
  - BPA, USACE NWD, Reclamation PN/TSC
- Goals
  - adopt common dataset (climate and hydrology)
  - establish consensus methods for data use
  - efficiently use limited resources through coordinated development of data and methods
- Motive
  - consistent incorporation of climate projection information into Agencies' longer-term planning studies
- Schedule
  - Oct 2009 – July 2010

SLIDES

RECLAMATION

RMJOC effort's relevance to YRBWEP activities?

- RMJOC effort will:
  - produce supply-side data for Yakima Basin efforts
  - demonstrate how to use of these data
    - i.e. Yakima Basin water management modeling, using both Hybrid and Transient information types

- Potential influence on YRBWEP technical activities
  - Maybe motivates focus on areas not well-covered by the RMJOC effort
    - e.g., climate change impacts on crop-specific water demands
    - e.g., climate change impacts on environmental water demands
    - planning assumptions other than surface water supplies

Questions?

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RECLAMATION