Regional climate change and ecological impacts

Lara M. Kueppers, PhD
School of Natural Sciences
University of California, Merced
lkueppers@ucmerced.edu

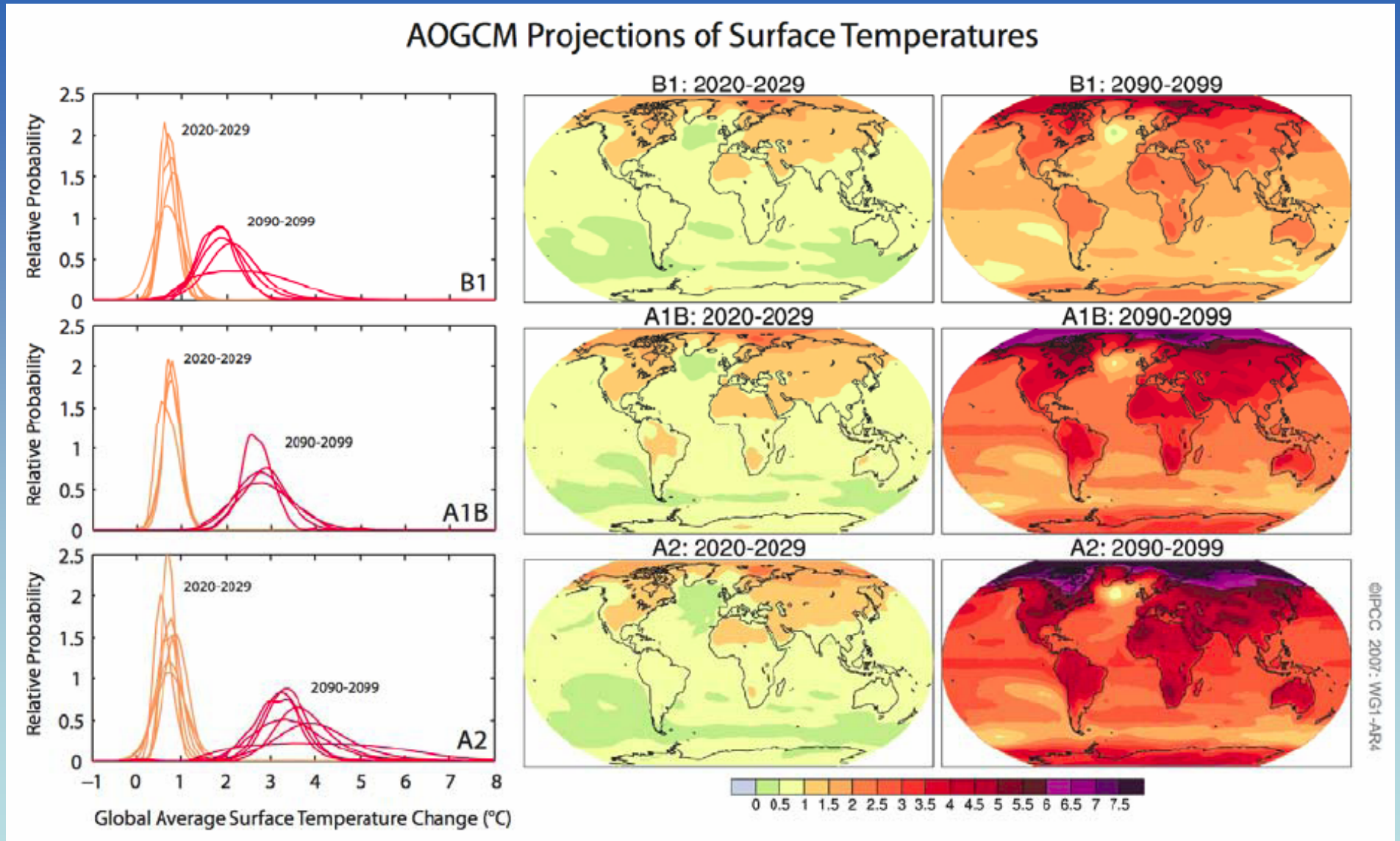
Lisa C. Sloan & Mark A. Snyder

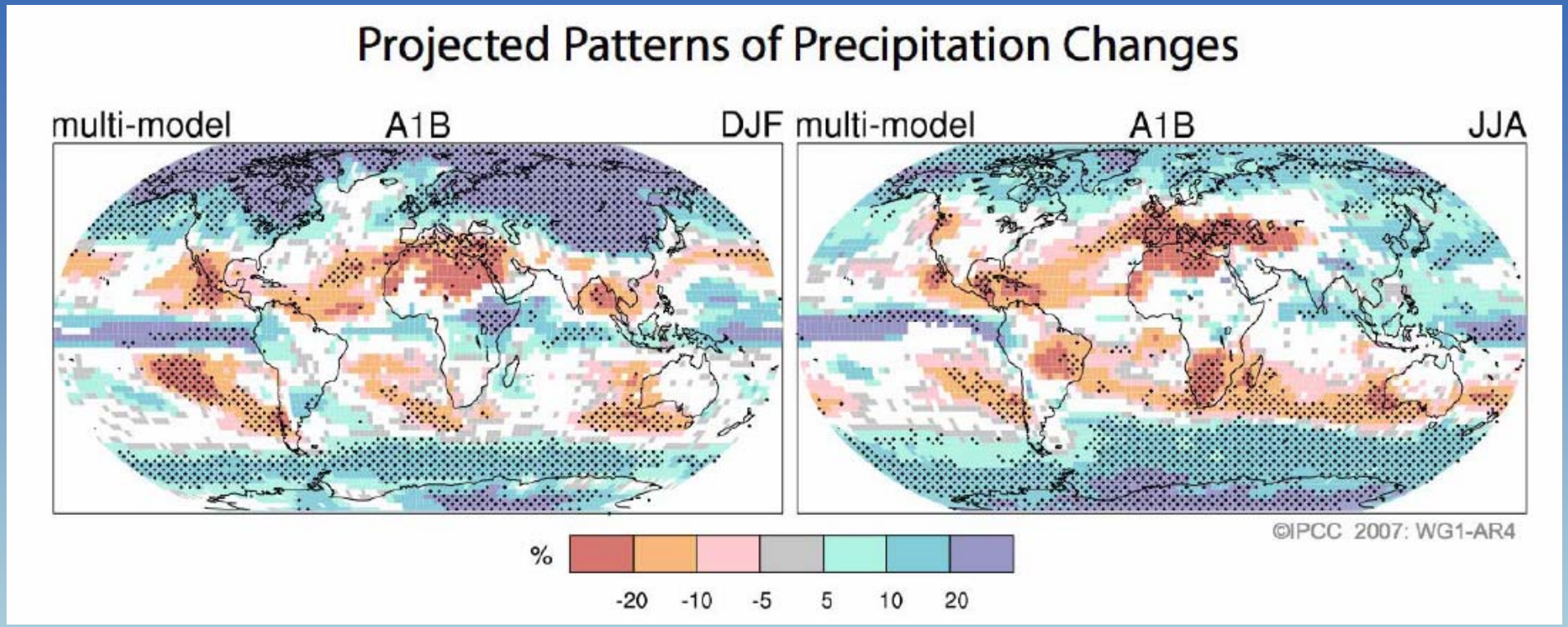
Global climate change has *regionally distinct* fingerprints

Global climate models agree that...

- Continents to warm more than oceans
- High latitudes to warm more than low latitudes
- Precipitation to *increase* at high-latitudes and *decrease* over subtropical land masses
- How much depends on timeframe, scenario

DRAFT Climate 2007: The Physical Science Basis, Summary for Policymakers

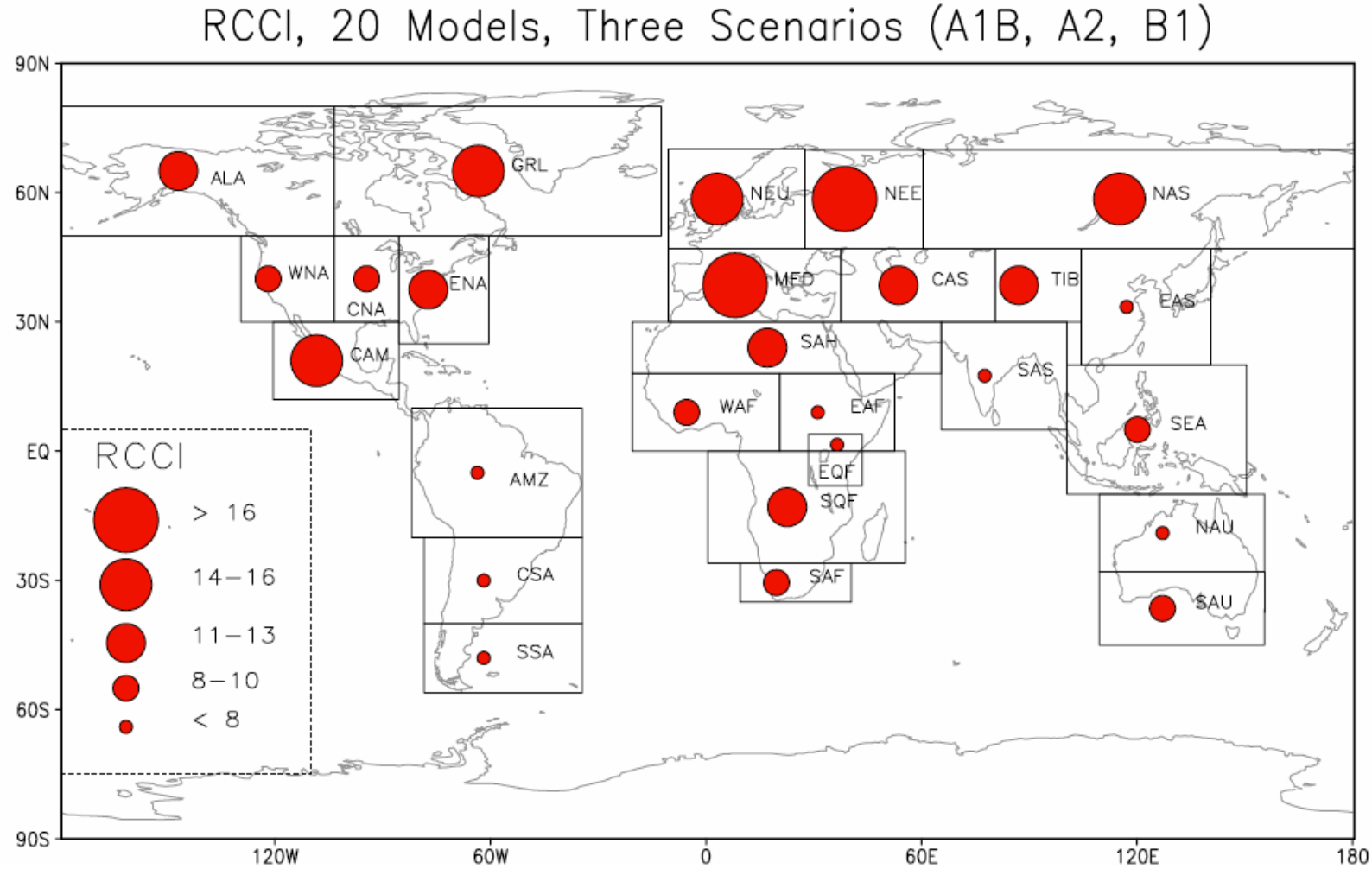

AOGCM Projections of Surface Temperatures
B1: 2020-2029
B1: 2090-2099
A1B: 2020-2029
A1B: 2090-2099
A2: 2020-2029
A2: 2090-2099
Relative Probability
2020-2029
2090-2099
B1
A1B
A2
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
Global Average Surface Temperature Change (°C)
©IPCC 2007: WG1-AR4



Winter

Summer

Climate change “hotspots”



Giorgi (2006) Climate change hotspots, *Geophysical Research Letters*

Global-scale analysis not well suited to single region or watershed

- GCM grid is coarse
  - Problem for topographically complex regions
    - Elevation affects temperature
    - Topography affects precipitation
    - Snow-albedo feedbacks important to snowmelt timing
- Modeling precipitation is difficult
  - High seasonal, diurnal and spatial variability
    - Convection (i.e., thunderstorm formation) not modeled explicitly --> too much “drizzle”
  - Interactions between large-scale weather systems and local influences (topography, soil moisture)

Alternate or enhanced approaches

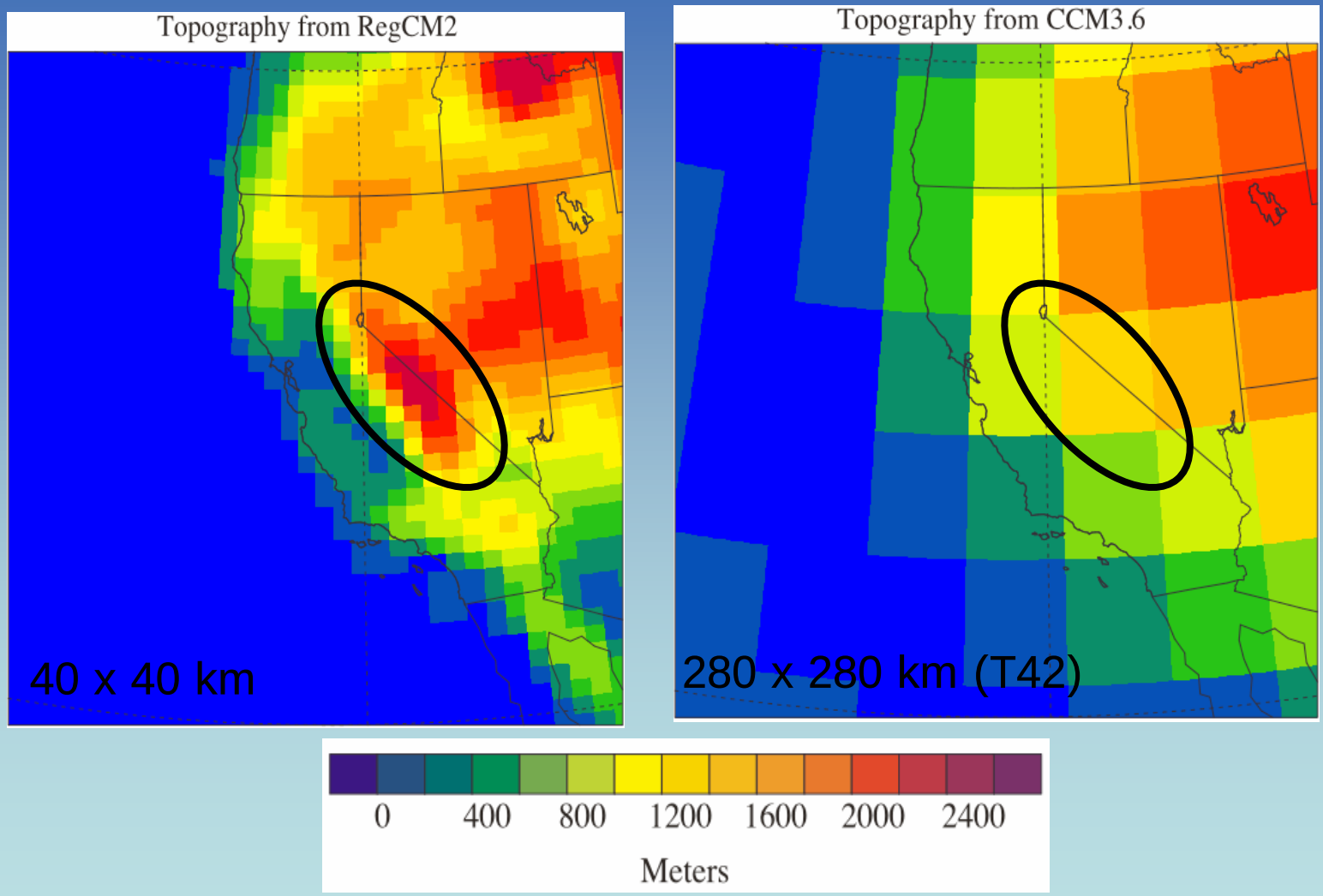
- High-resolution GCM experiments
  - 55km vs. 300km grid cell size
- “Stretched-grid” GCMs
  - High resolution in single region, coarse elsewhere
- Statistical downscaling
  - Quantitative relationship between large-scale atmosphere and local surface
- Regional climate models (RCMs)
  - Limited area climate models run at high resolution

Statistical downscaling vs RCMs

- Fast - can cover broad selection of GCMs and scenarios
- Not physically based, therefore no internal dynamics/feedbacks
- No guarantee that past relationships will hold in future

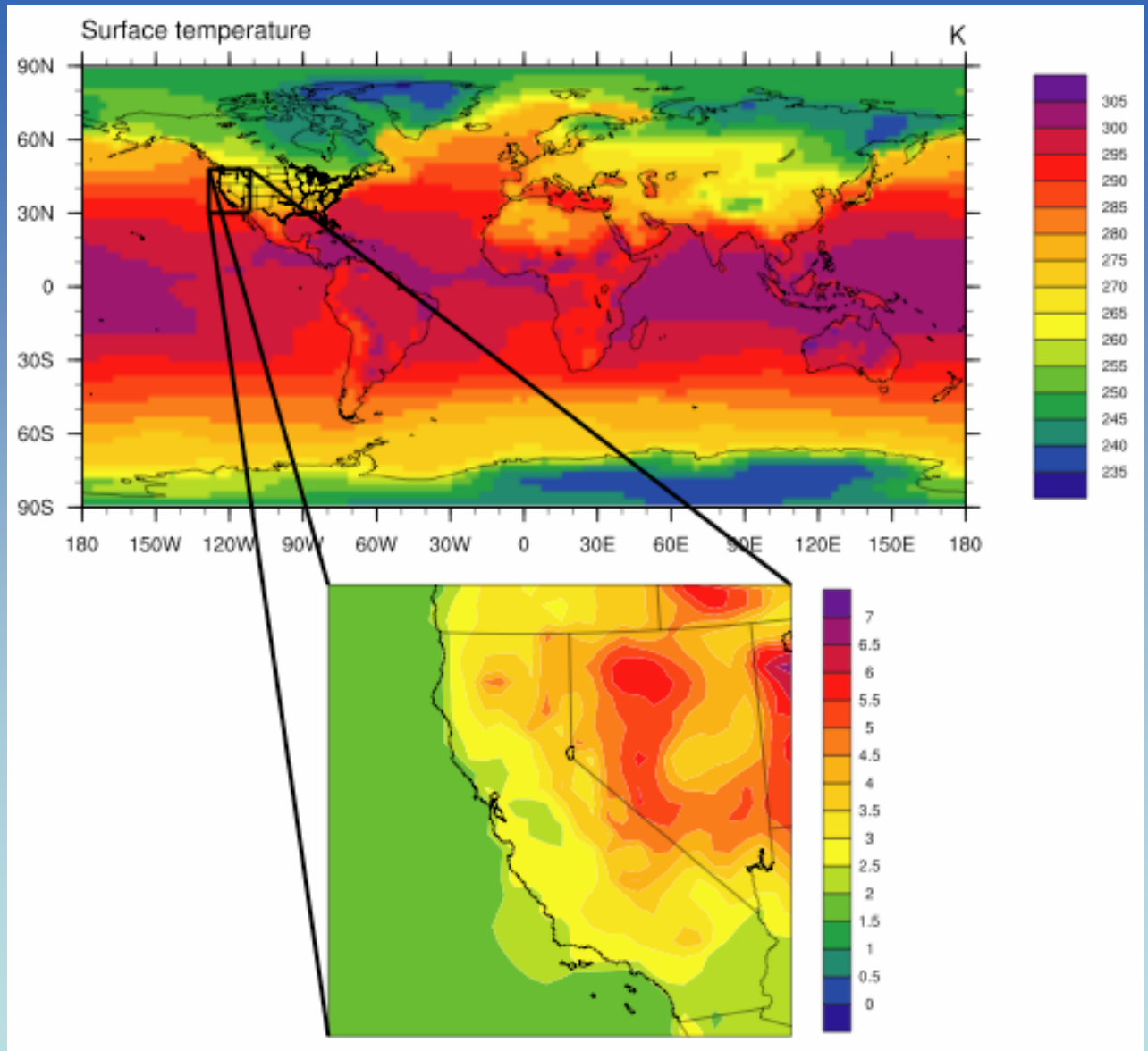
- Slow - requires significant computing capacity, therefore fewer GCMs/scenarios
- Physically based, includes local feedbacks, but diverse like GCMs
- Has biases, and still not fine scale enough for some impacts studies

RCM vs GCM Topography



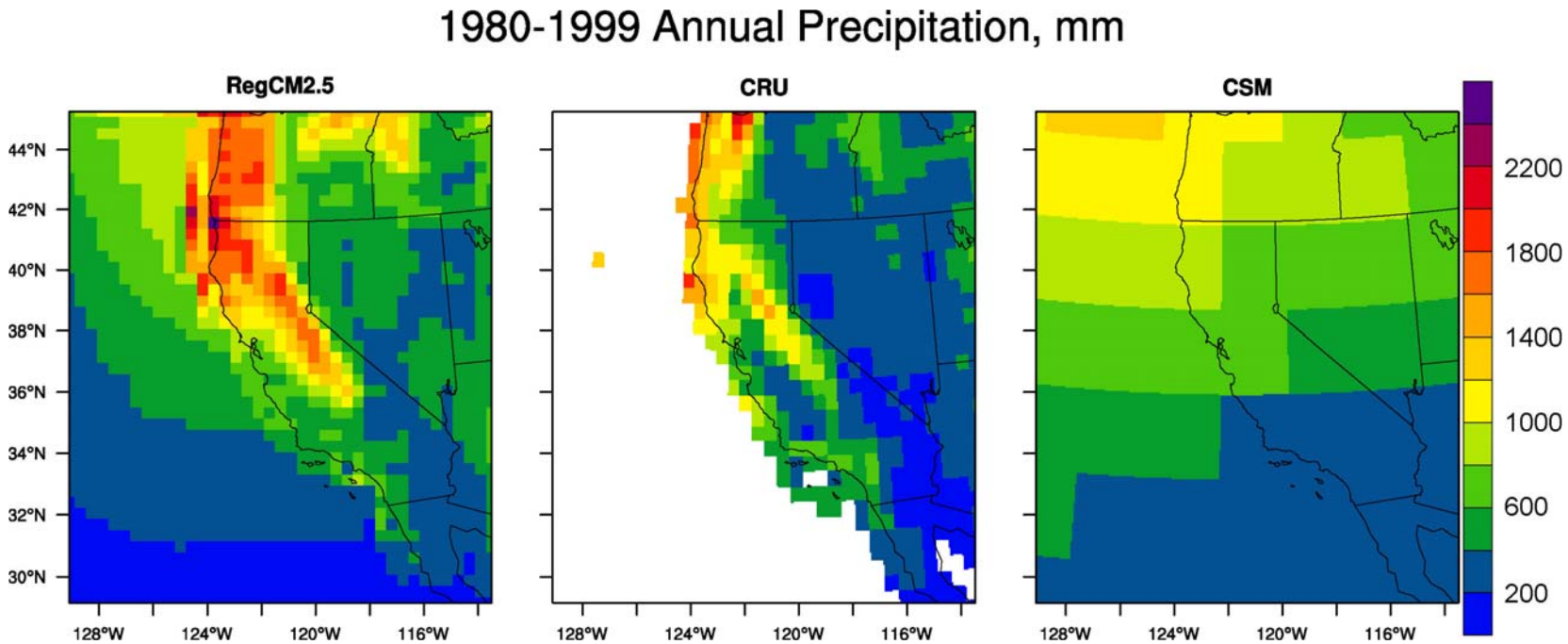
RCM “Nested” within GCM

- 3-D physical model of atmosphere and land
- Driven by global climate model (GCM) output or by observations
- One way nesting- no feedback to GCM



(M. Snyder, 2004)

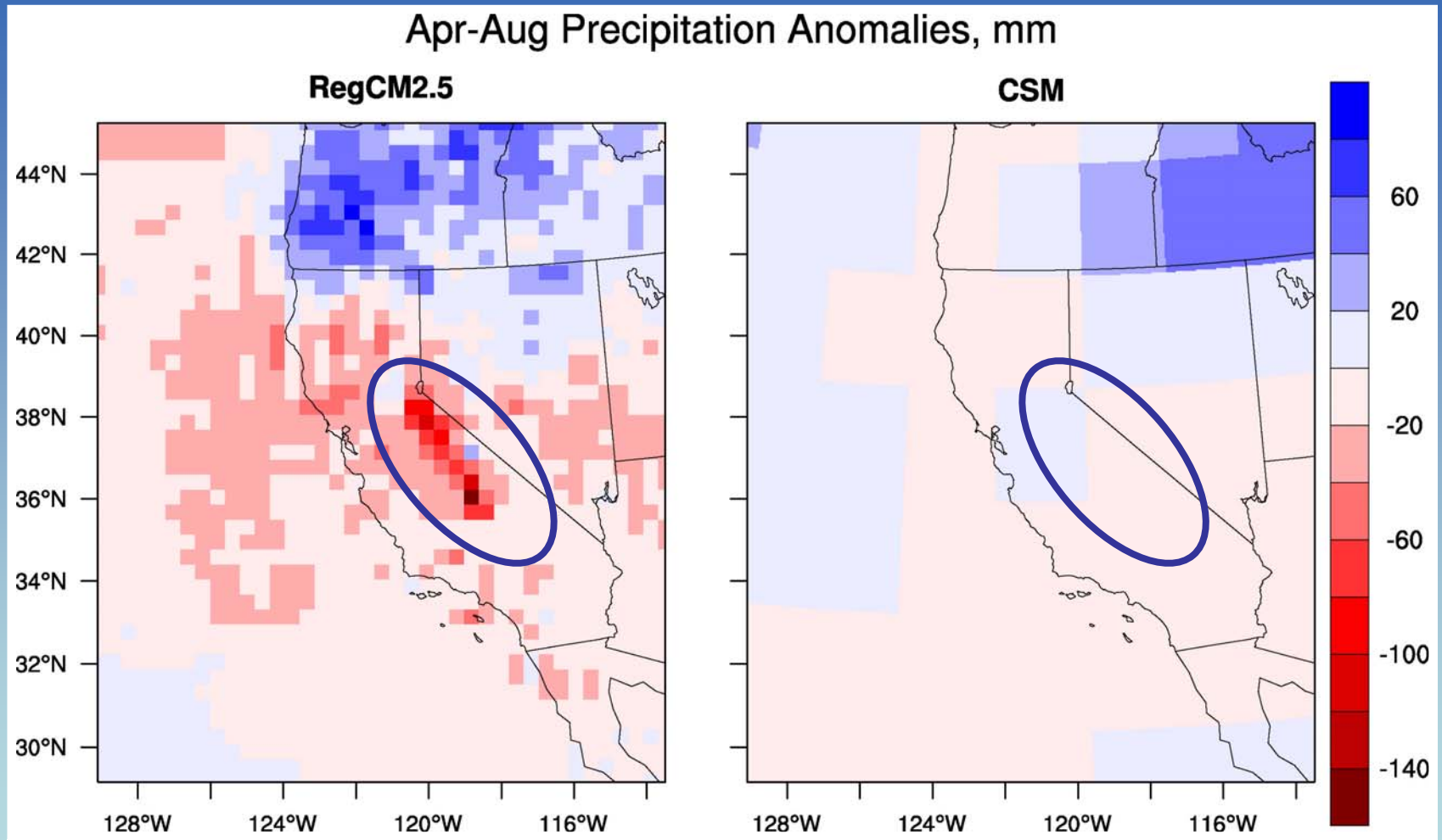
RCM vs. Observations vs. GCM



Kueppers et al. (2005) *Proceedings of the National Academy of Science*

- RCM improves precipitation patterns
- RCM inherits large-scale GCM influences/biases

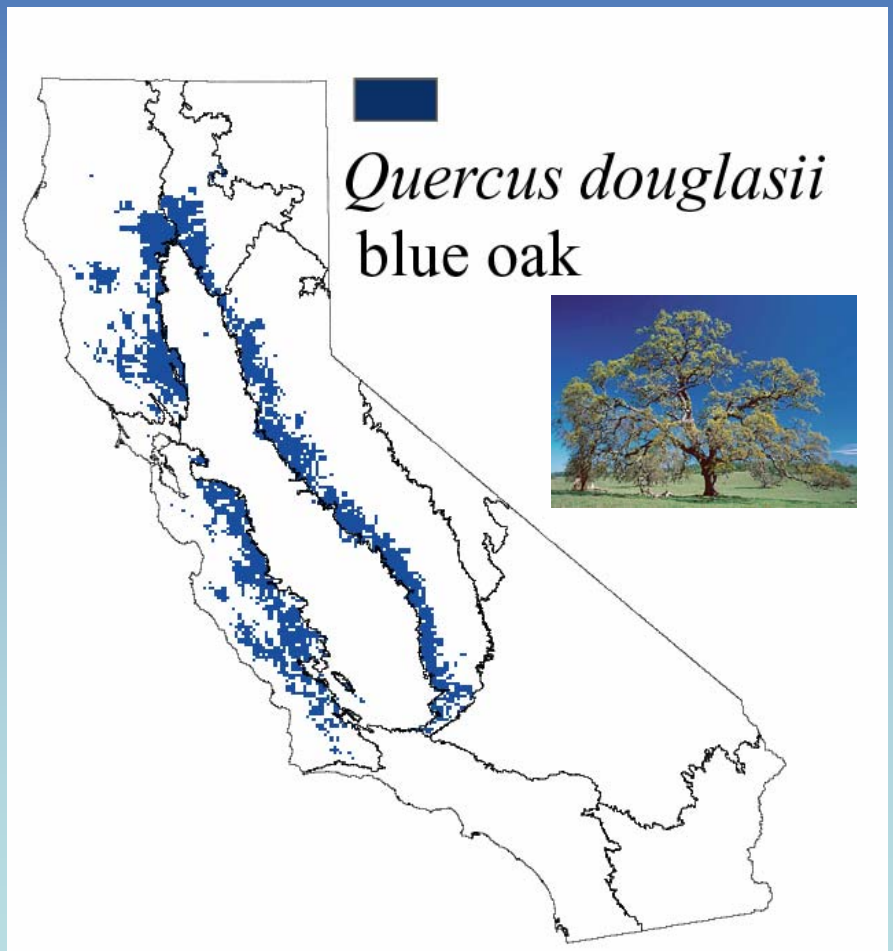
RCM vs. GCM Rainfall Change



Kueppers et al. (2005) *Proceedings of the National Academy of Science*

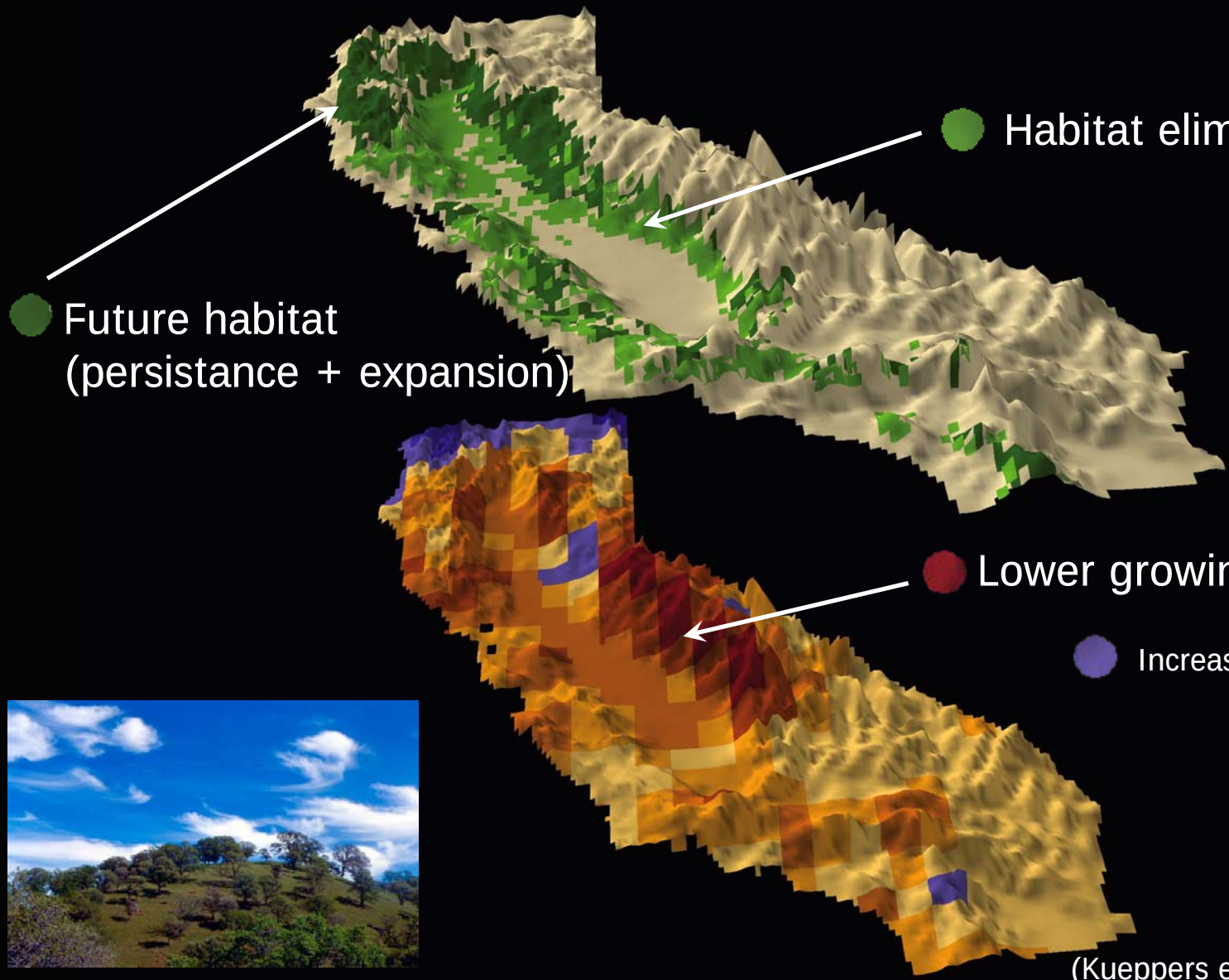
'Business-as-usual' greenhouse gas scenario to 2099

Ecological Impacts Example: Species Range Shifts with Climate Change



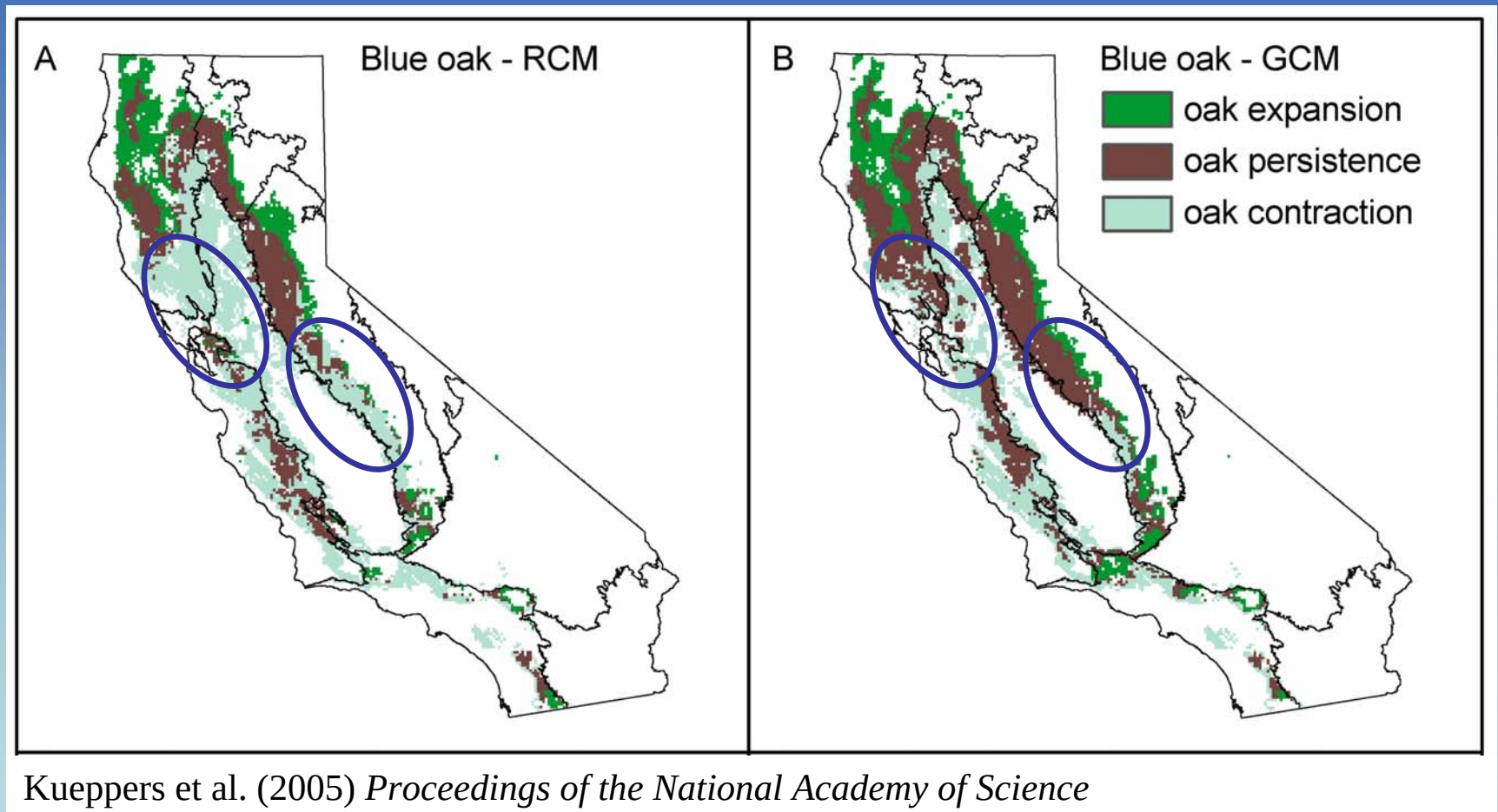
- Plant species' ranges determine habitat for animals, biogeochemical cycling, climate interactions
- Statistical model relating modern blue oak range to 4 climate and 3 soil variables
- Future *potential* range predicted after 'business-as-usual' climate change at end of 21st century

Blue Oak Habitat Shift - RCM Case



(Kueppers et al., 2005 *PNAS*)

RCM vs. GCM Oak Habitat Shift



Kueppers et al. (2005) *Proceedings of the National Academy of Science*

Total contraction: 41% 19%

Summary: Oak Range Shifts

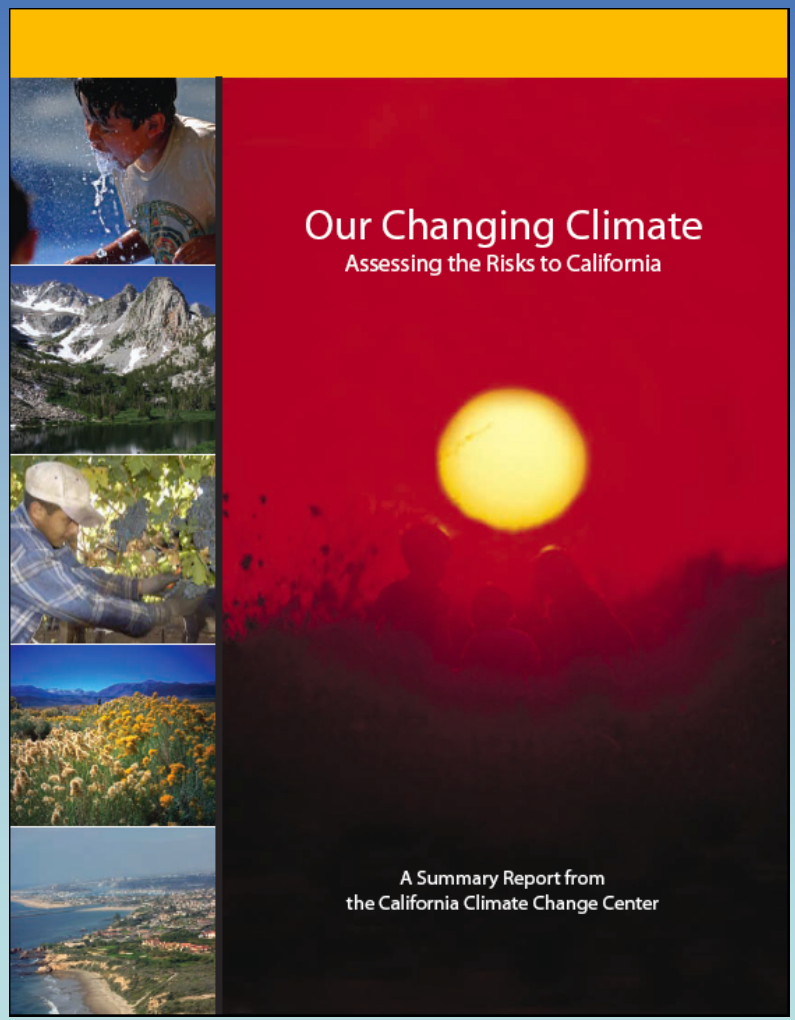
- Warming + less annual and growing-season rainfall led to northward shifts and contraction in blue oak habitat
- Greater effects using RCM output (-41 % of range size) than using GCM output (-19 % of range size)
- When predicting potential ecological impacts, regional & seasonal details of climate change matter!
- Implications for management, “restoration,” and adaptation (e.g., conservation planning, water resource allocation)

Present Range of Coho Salmon

Anticipating Ecological Impacts

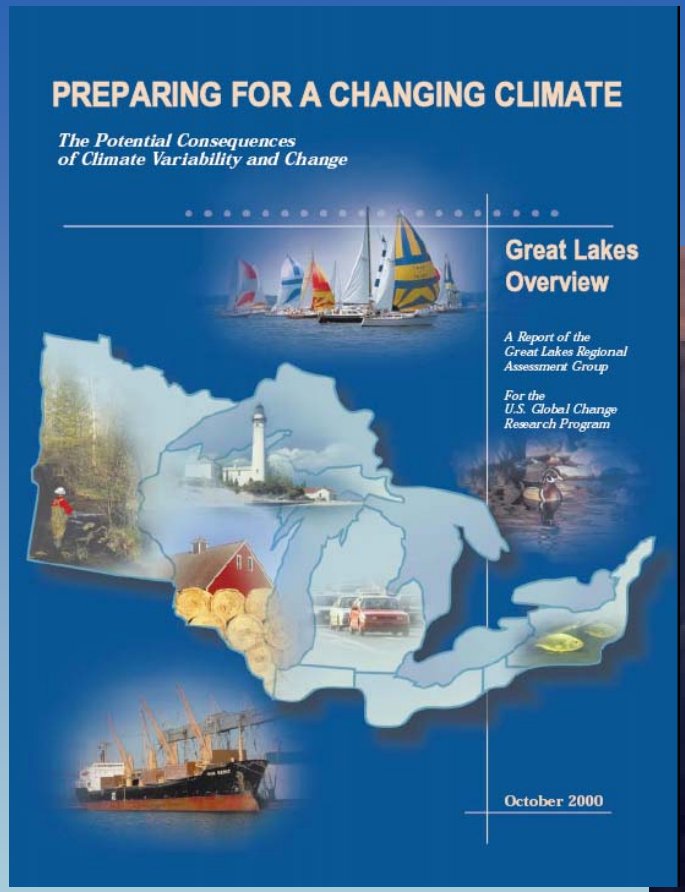
- Source of future climate information may affect predictions (GCM vs RCM vs other method)
- Some variables improved by RCM more than others
  - Extreme precipitation and strong wind
  - Surface temperature, precipitation and winds affected by topography and land use
- Models and model configurations vary widely - some better matched to your region of interest

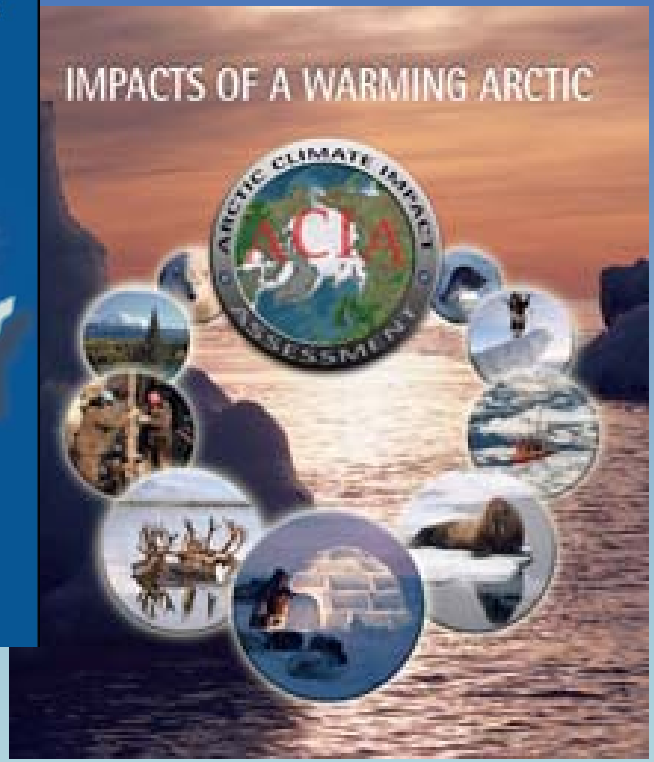
Regional Climate Impacts Assessments: California



Water resources risks:

- Progressive decrease in snow accumulation over 21st c.
- Earlier snowmelt
- More rain than snow
- Decreases in stream flow
- Change in timing of stream flow

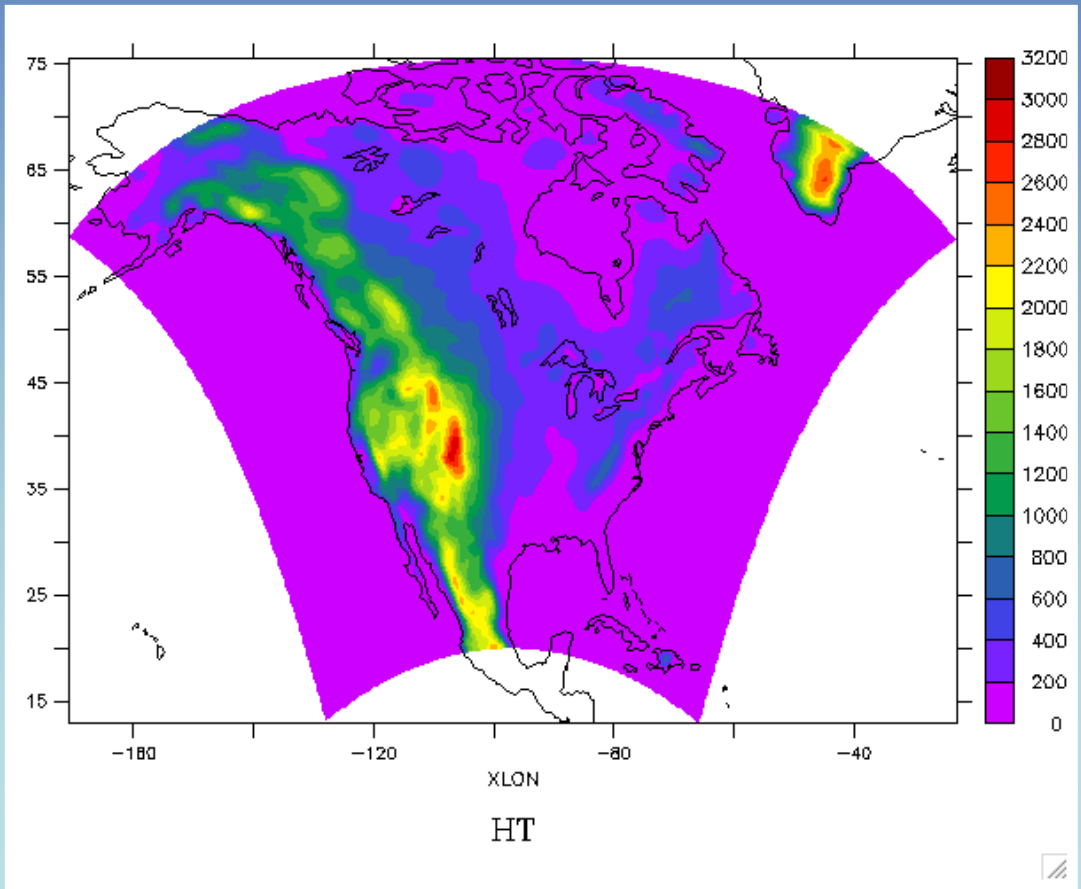

PREPARING FOR A CHANGING CLIMATE
The Potential Consequences of Climate Variability and Change
Great Lakes Overview
A Report of the Great Lakes Regional Assessment Group
For the U.S. Global Change Research Program
October 2000


IMPACTS OF A WARMING ARCTIC
ARCTIC CLIMATE IMPACT ASSESSMENT
ACIA

Relevant climate variables & ecological processes?

- Climate model output copious - readily available variables scratch surface of what can be extracted
  - E.g. Increasing emphasis on “extremes”
- RCM output not readily accessible - how can RCModelers do better?
- Do biogeographic shifts matter? Physical processes? Riparian vegetation properties? Which climate variables critical?

NARCCAP RCM output coming soon... What can we do with it?



NARCCAP Goals

- Exploration of multiple uncertainties in regional model and global climate model regional projections.
- Development of multiple high resolution regional climate scenarios *for use in impacts assessments.*
- ...