Central America Climate Change: Implications for the Rio Lempa

Ed Maurer
Civil Engineering Department
Santa Clara University
Santa Clara, CA, USA

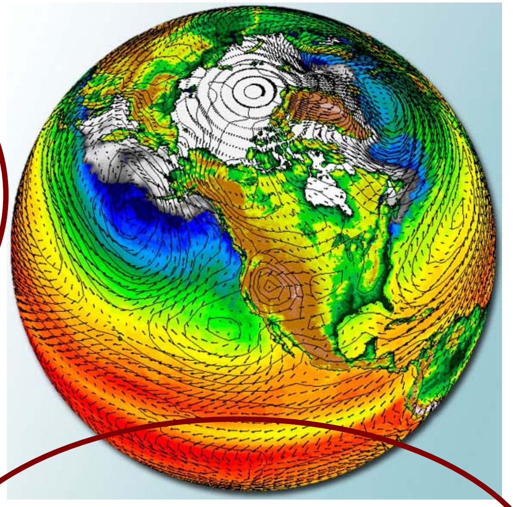
Andrew Wood
Civil and Environmental Engineering Dept.
University of Washington
Seattle, WA, USA

Santa Clara University

Tour of the Region

Cascading Uncertainties in Climate Change Impacts Studies

GHG Emissions Scenario



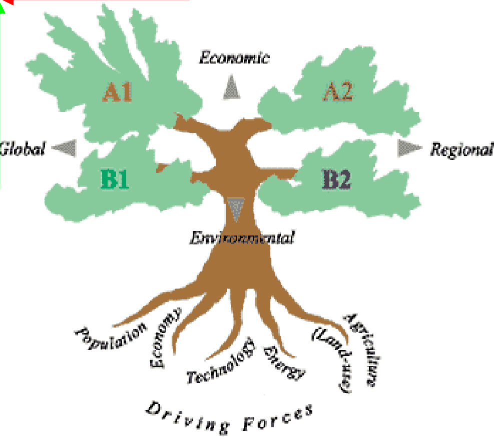
Global Climate Modeling

Spatial Downscaling

Hydrology Modeling

Etc.

This study includes first two levels of uncertainty



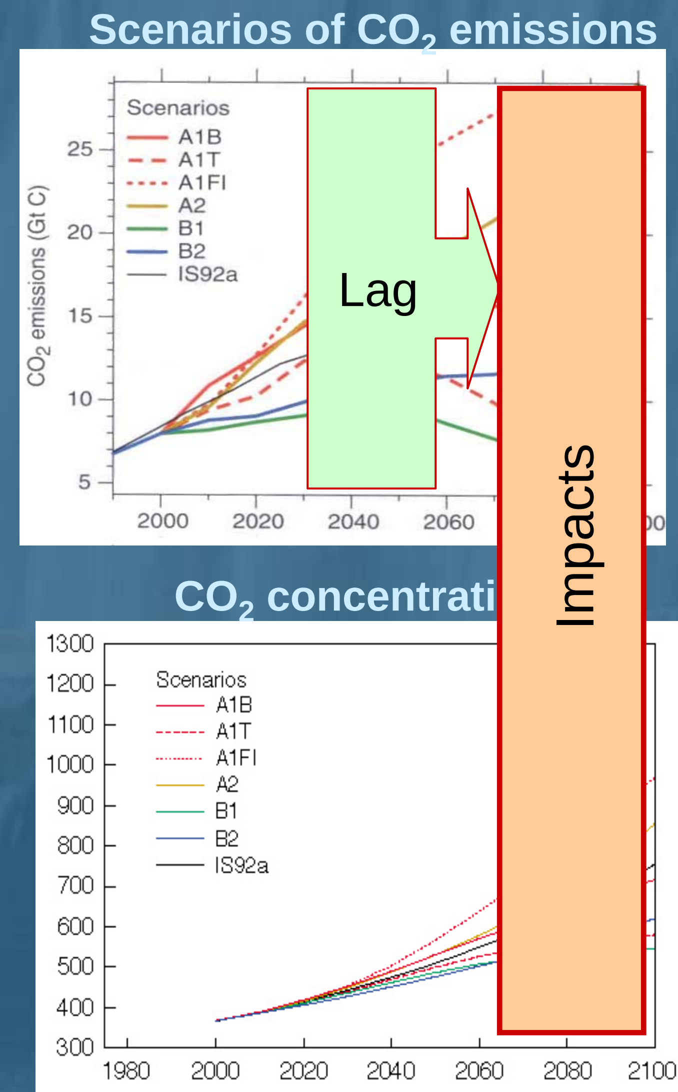
Future GHG Emissions

How society changes in the future:

"Scenarios" of greenhouse gas emissions:

A2: Technological change and economic growth more fragmented, slower, higher population growth – **Mid-high for 21st century**

B1: Rapid change in economic structures toward service and information, with emphasis on clean, sustainable technology. Reduced material intensity and improved social equity - **Lowest estimate for 21st century**

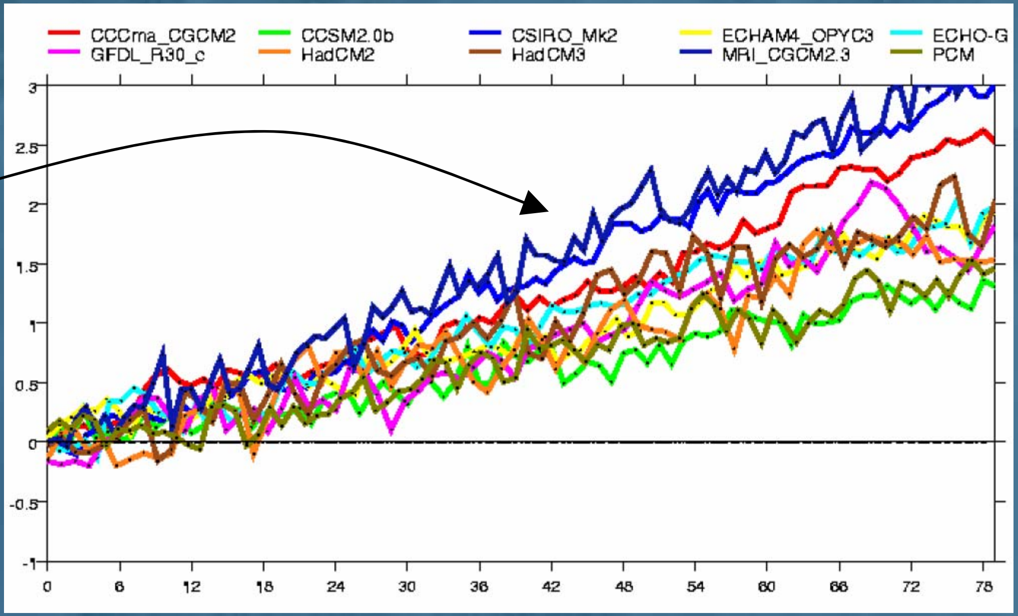


Global Climate Models - Uncertainty

The projected future climate depends on Global Climate Model (or General Circulation Models, GCM) used:

- Varying sensitivity to changes in atmospheric forcing (e.g. CO_2, aerosol concentrations)
- Different parameterization of physical processes (e.g., clouds, precipitation)

Global mean air temperature by 10 GCMs identically forced with CO_2 increasing at 1%/year for 80 years



Using GCMs for Regional Impact Studies

- The problems:
  - GCM spatial scale incompatible with hydrologic processes
    - roughly 2 – 5 degrees resolution
    - some important processes not captured
  - Though they accurately capture large-scale patterns, GCMs have biases
- Resolved by:
  - Bias Correction
  - Spatial Downscaling

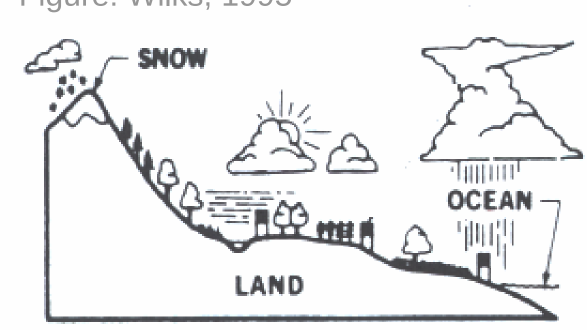
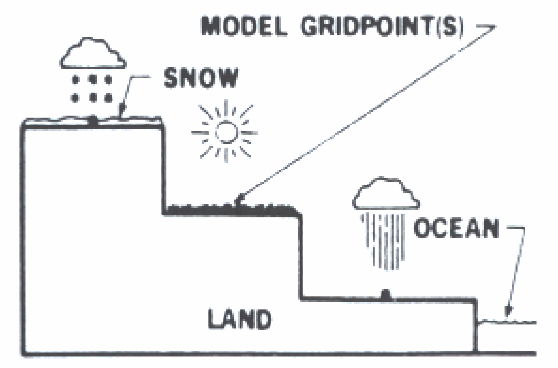


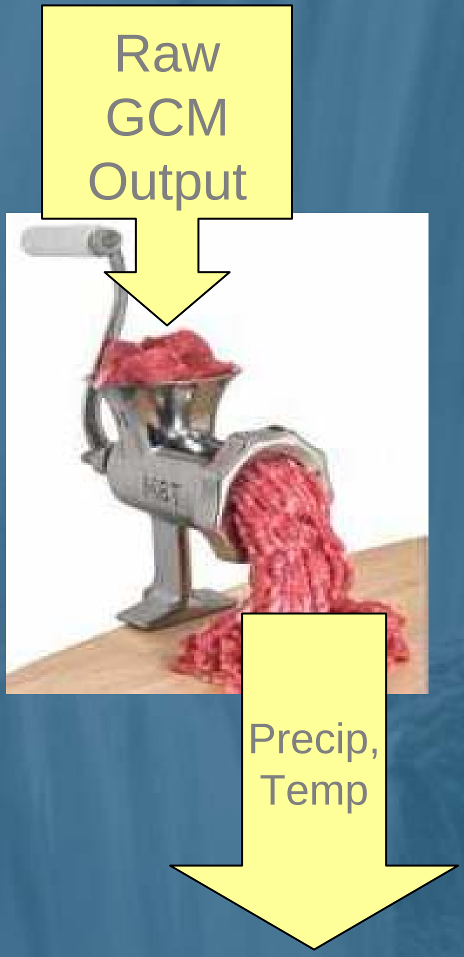
Figure: Wilks, 1995



Bias Correction and Downscaling

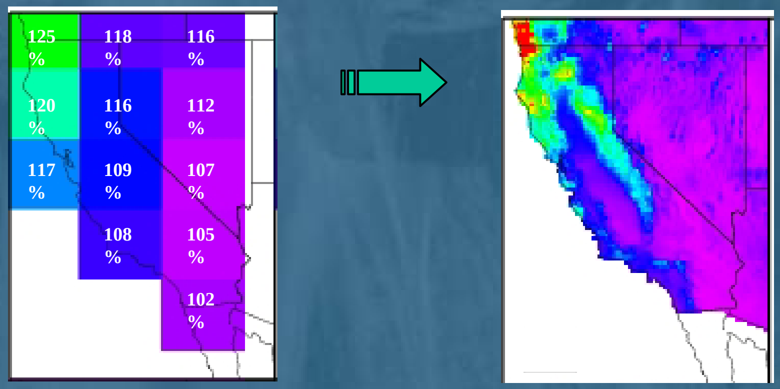
Bias Correction (at GCM scale):

a. preserves GCM-simulated trends
b. changes in mean variance per GCM
c. corrected GCM matches historical period (statistically)



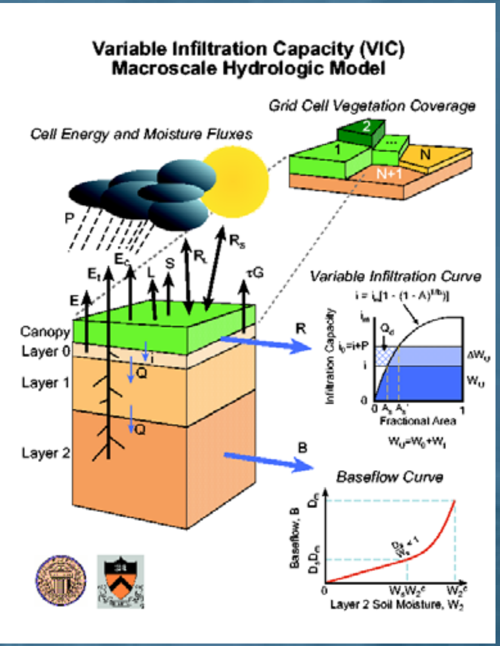
Spatial downscaling (to ½ degree)

a. Monthly time series at each GCM cell
b. P (scale) and T (shift) factors
c. Factors interpolated to ½° grid cells
d. Factors applied to historical monthly data
e. Daily data derived with random resampling



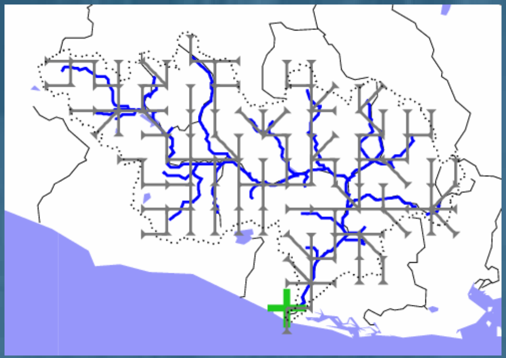
Hydrologic Model

- **Drive a Hydrologic Model with GCM-simulated (bias-corrected, downscaled) P, T**
- **Reproduce Q for historic period**
- **Derive runoff, streamflow, snow, soil moisture**



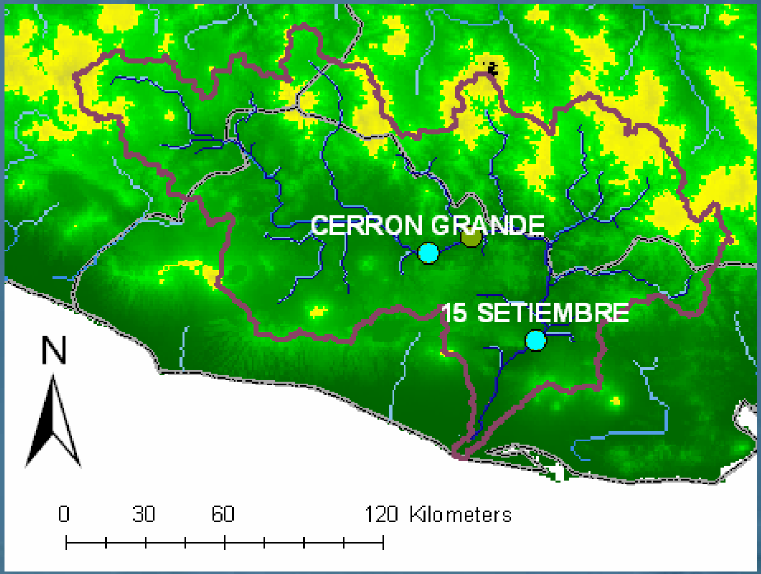
VIC Model Features:

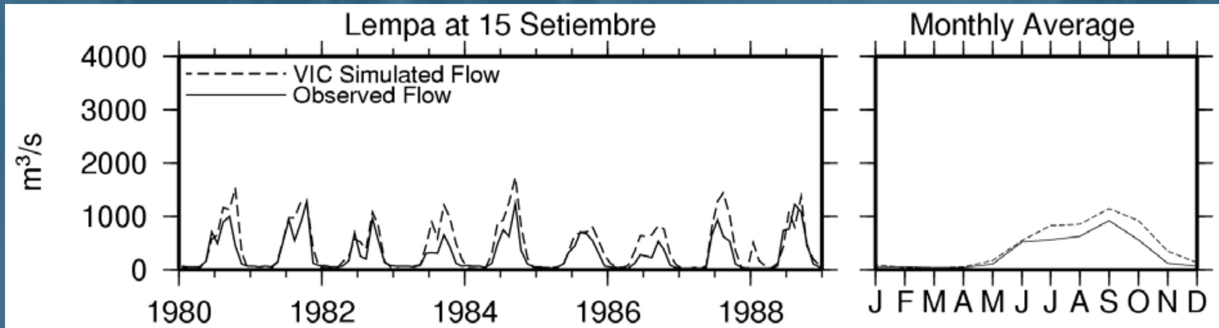
- Developed over 10 years
- Energy and water budget closure at each time step
- Multiple vegetation classes in each cell
- Sub-grid elevation band definition (for snow)
- Subgrid infiltration/runoff variability



VIC streamflow calibration

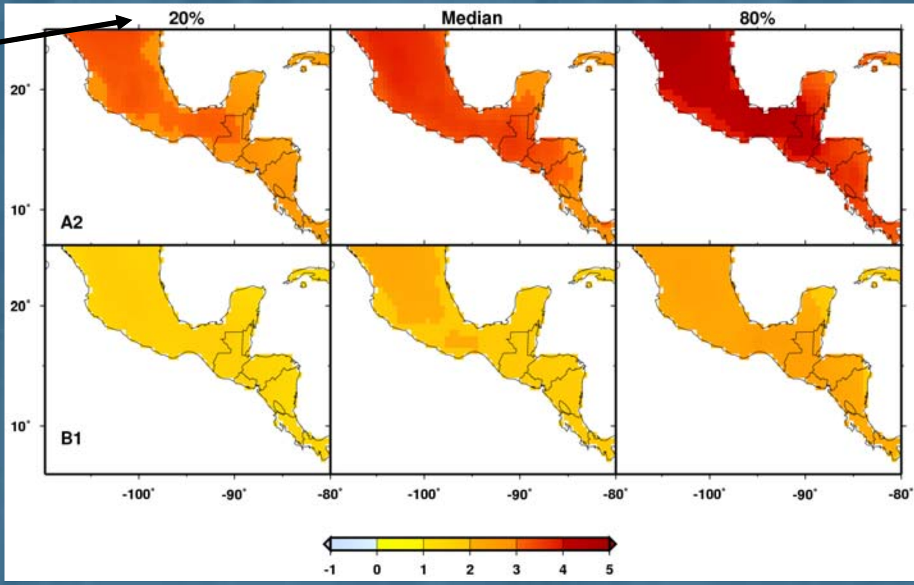
- Automated calibration for 1970-1979
- Validation for 1980-1989
- 123 m^3/s (or about 28.8% of mean flow)
- Correlation to Observations = 0.85
- Simulations do not account for diversions, losses, or management



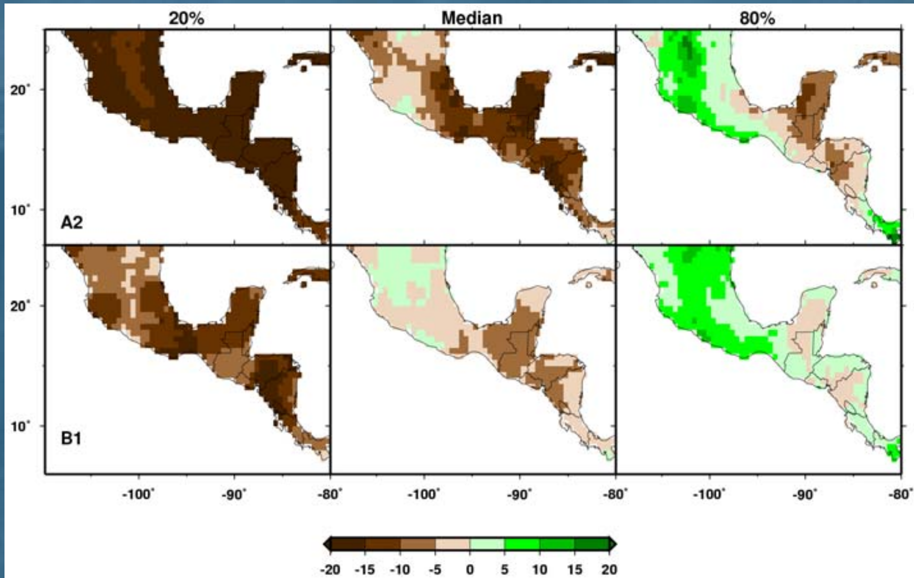


Regional Climate Projections for 2070-2099 using 16 GCMs

Non-exceedence probabilities for 16 GCMs

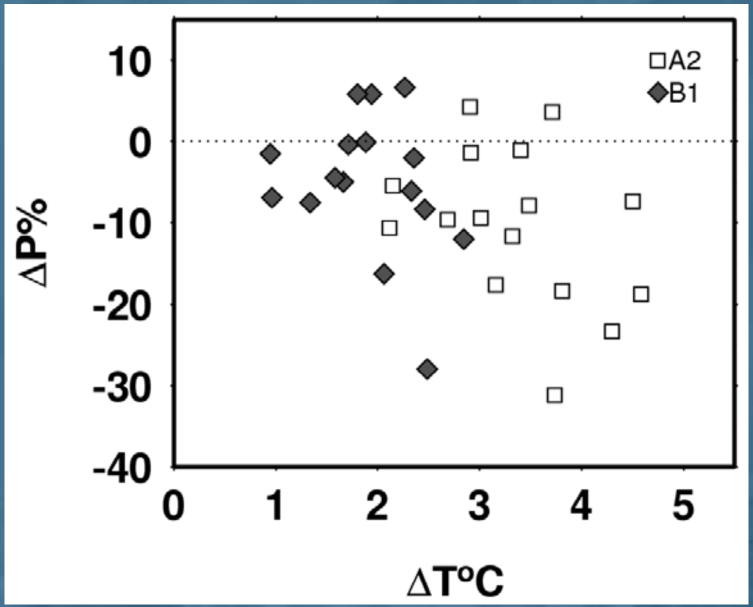


- Median warming:
  - 1-3°C (B1)
  - 2-4°C (A2)
- Drying trends up to 20%
- More severe drying under A2
- Even with less dry GCMs (80%) El Salvador is projected generally to experience drying



Changes for the Rio Lempa basin between 1961-1990 and 2070-2099

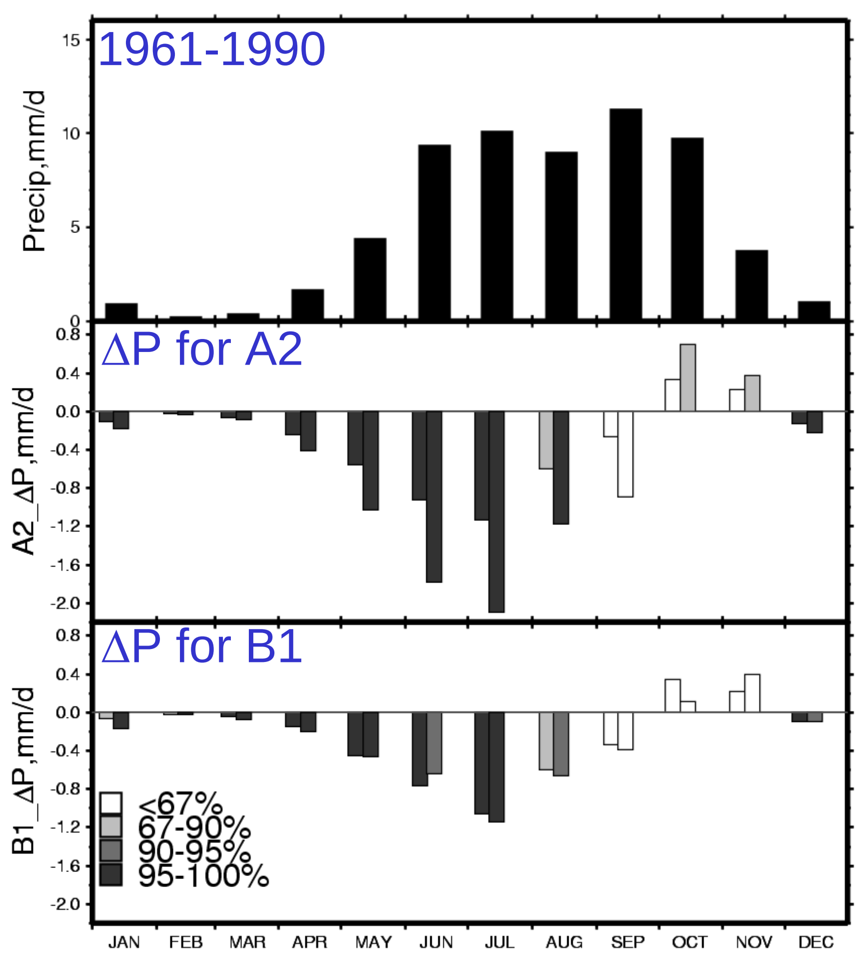
- Temperature increases under A2 (3.4°C) and B1 (1.9°C)
- Difference between A2 and B1 highly significant ($p<0.01$)



- Only 5 of the 32 GCMs show wetter futures
- Precipitation drops 10.4% (A2) to 5.0% (B1)
- Relationship between warmer and drier weak within A2 or B1
- GCMs under warmer A2 are drier than B1.

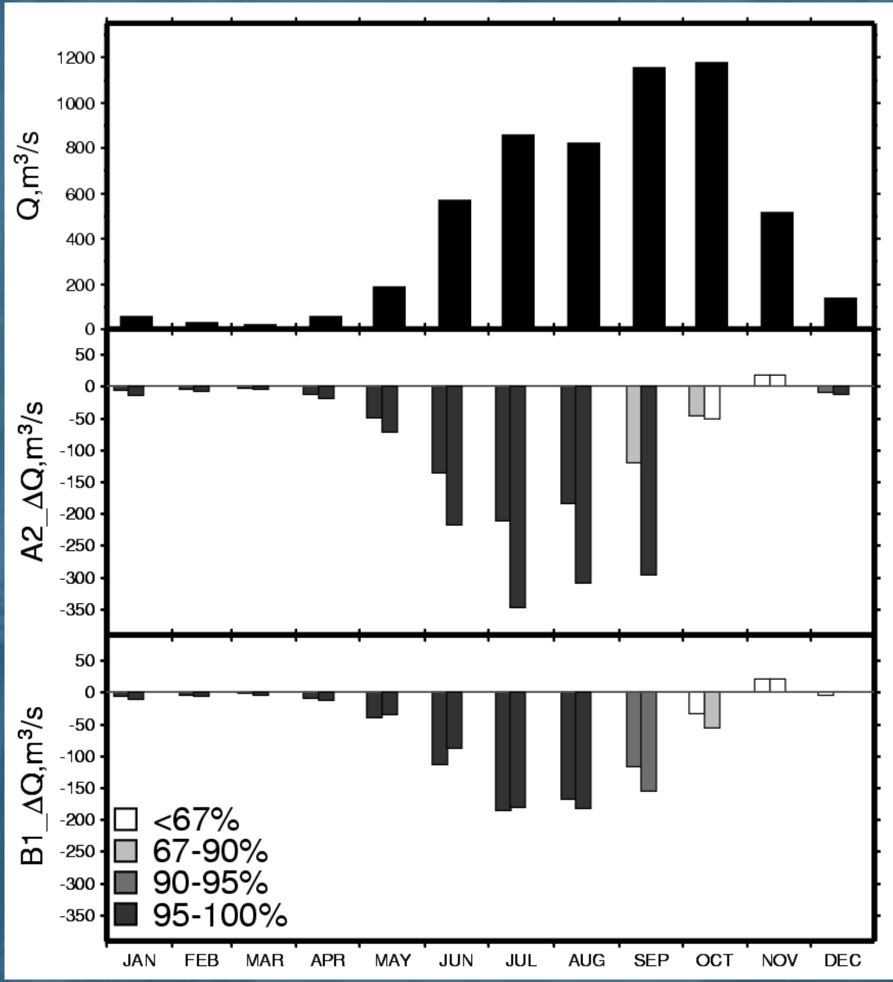
Monthly Precipitation Changes Rio Lempa Basin

- Precipitation decreases in the early rainy season
- Most precipitation changes are highly significant
- For A2 changes grow through the 21st century
- For B1 most 21st century changes occur by 2040-2069



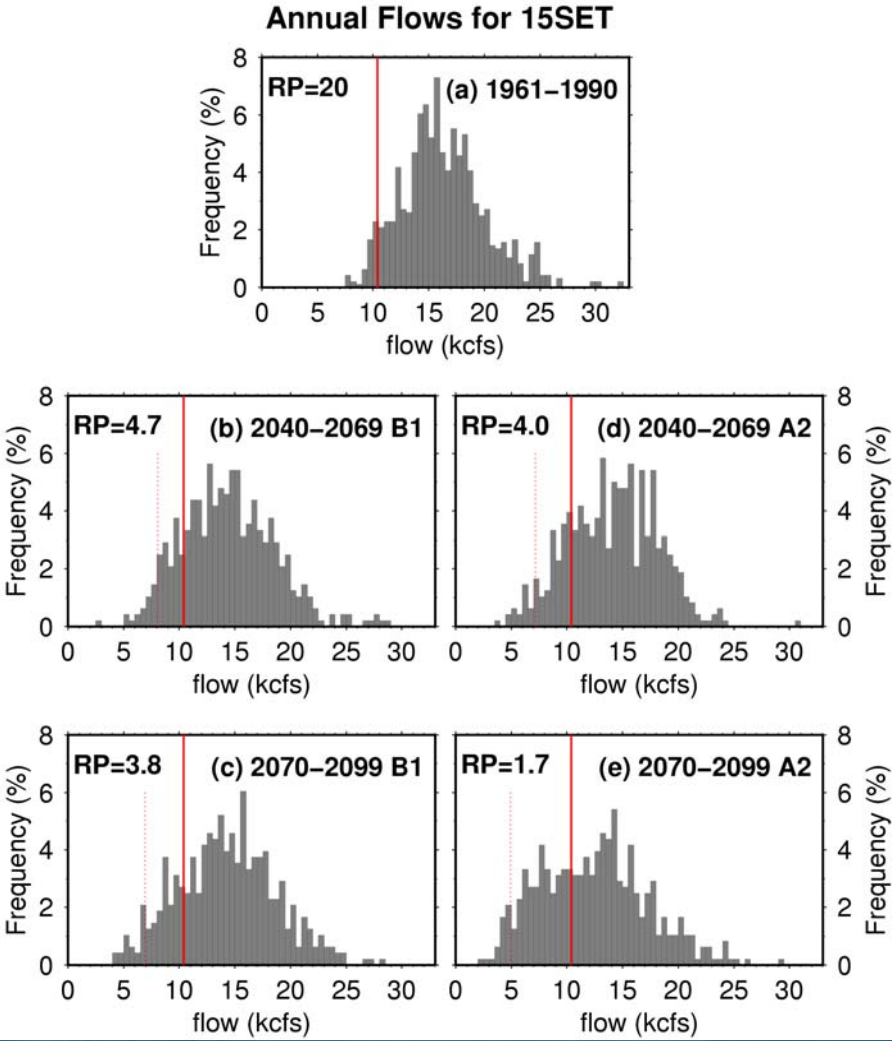
Inflow Changes to 15 Setiembre

- By 2070-2099 annual avg. inflow drops:
  - 13% (B1)
  - 24% (A2)
- Max drop for A2:
  - July (39% at Cerron Grande and 41% at 15 Setiembre)
- Max drop for B1:
  - August (21% at Cerron Grande and 22% at 15 Setiembre)
- Differences between A2 and B1 (by 2070-2099) for Jan-Sep are statistically different (at high confidence levels)



Changes to Low Flow Frequency at 15 Setiembre

- RP=20: lower annual flows will only occur 5% of the time
- As flows drop more years have average flow below that of the historic 20-year return period.
- 20-year return flow drops
  - 22% (B1) to 31% (A2) by 2040-2069
  - 33% (B1) to 53% (A2) by 2070-2099
- Streamflow impacts amplified when translated to hydropower.
- If reservoirs at historic levels, decline translates to drop in firm power production

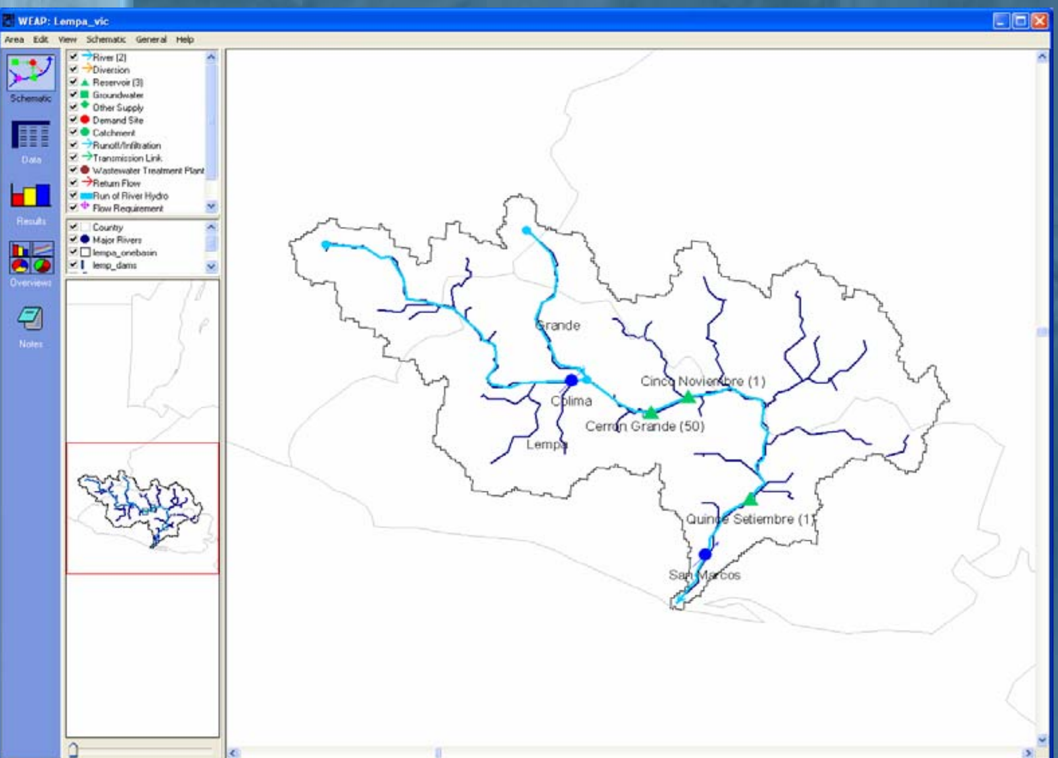


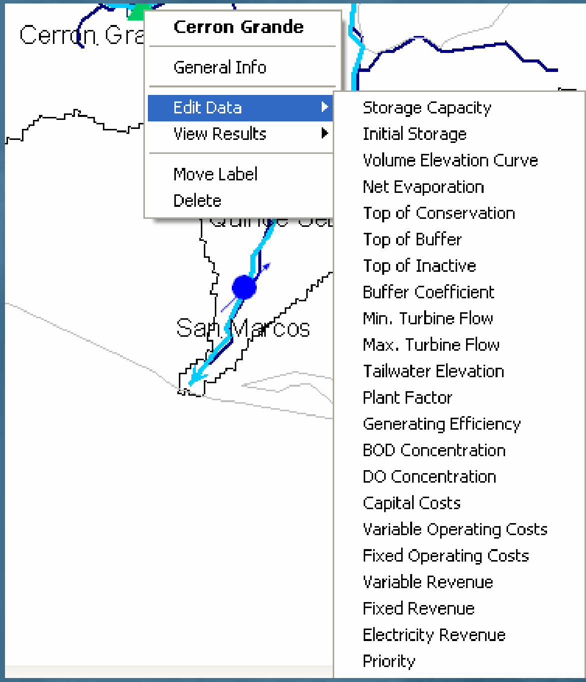
Summary

- IPCC: Effectiveness of adaptation efforts depends on the availability of general information on vulnerable areas and projected impacts.
- For Rio Lempa Basin, by 2070-2099:
  - Average temperatures will rise from 1.9-3.4°C
  - greatest temperature increase in June-July.
  - The consensus of GCMs indicates a 5-10% drier future
  - Greatest drop in precipitation in May-July
  - Inflows to the major reservoirs will decline by 13-24%
  - Greatest drops in reservoir inflow July-August, 21 to 41%.
  - Drop in firm hydropower generation capability may range from 33% to 53% near the end of the 21st century.

What's Next?
System Simulation: Adaptation Options

- Water analysis tool for analyzing system response
- Allows system definition
- Future scenario analysis for adaptation studies





Thank You!

SNET
Servicio Nacional de Estudios Territoriales

CEL

UNIVERSIDAD CENTROAMERICANA
"JOSÉ SIMEÓN CAÑAS"