Border Region
Climate Change Summary

Water and Energy Sustainability
with Rapid Growth in the
Arizona-Sonora Border Region

June 1, 2009 – Arizona Water Institute

Gregg Garfin
Deputy Director for Science Translation and Outreach
Basic message: HOT (confident), DRY (less confident; no confidence in summer)

Annual Temperature and Precipitation Change
End of 21st Century — Scenario: A1b

IPCC 4th Assessment: Working Group I, Chapter 11, Regional Projections
These graphs express the confidence statement mentioned in the previous slide. (example for Northern California)

Basic message: by mid-century, water balance gets drier, due to increased ET, and decreased precipitation.
Northern Annular Mode Impact on Spring Climate in the Western United States
McAfee and Russell, 2008 Geophysical Research Letters

Higher TEM in the Southwest
Lower PRECIP in the Southwest

Basic message: Storm track is migrating northward; effects greatest in spring time, which contributes to early snow melt.
Projected Change in North American Precipitation by 2080-2099

Hatching Indicates Areas of Strong Model Agreement

Brad Udall
Presented at 2009 Border Gov. Drought Workshop
Basic message: well selected models over-predict summer precip, but IPCC average is not realistic for summer.
Basic message: 6 models selected for monsoon get basic spatial features right

Annual Precipitation (mm): 1961-1990

CRU-OBS (50km)

IPCC-6 (Downsc 12 km)

T. Cavazos, CICESE
Presented at 2009 Border Gov. Drought Workshop

Statistically downscaled model data from (Ed Maurer):
http://gdo-dcp.ucar.edu/downscaled_cmip3_projections/
Decadal change of precipitation (%) under B1 and A2 scenarios
Plotted when 2/3 of the models agree on the sign of change, relative to 1961-1990

Basic message: using the 6 good monsoon models, the region still dries out

B1: Low emissions
A2: High emissions

2010-2029
Cavazos and Arriaga, 2009 (in prep.)
CICESE

2030-2049
Surface air temperature trends

Basic message: Regardless of precip, temperatures are increasing

(Fig. 2c from Karoly and Wu, 2005, J. Climate)

Changes in median temperature ± 1 std in the NAM region for A2 and B1 climate change scenarios from 6 downscaled IPCC models (12 realizations) at 12 km resolution. Based period 1961-1990.

(Cavazos and Arriaga, 2009, in preparation)
Longer Heat Waves
Basic message: enhanced snow melt in Upper Basin; enhanced demand in lower basin

Diffenbaugh et al., 2005; Proceedings of the National Academy of Science
Colorado Water System Demand – Supply
*(stressed in recent decades)*

NOTES: Does not include evaporative losses from Flaning Gorge, Blue Mesa, Morrow Point, Lake Powell, Lake Mead, Lake Mohave, and Lake Havasu

Basic message: not rocket science: Colorado River is stressed

Balaji Rajagopalan et al. (CU, Reclamation, NOAA)
Recent Colorado River Studies Table

Source: Climate Change in Colorado, 2008

Basic message: hydrologic projections say Colorado River flow will decrease

<table>
<thead>
<tr>
<th>Study</th>
<th>GCMs (runs)</th>
<th>Spatial Scale</th>
<th>Temperature</th>
<th>Precipitation</th>
<th>Year</th>
<th>Runoff (Flow)</th>
<th>Risk Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christensen et al. 2004</td>
<td>1 (3)</td>
<td>VIC model grid (~8 mi)</td>
<td>+3.1°F</td>
<td>-6%</td>
<td>2040–69</td>
<td>-18%</td>
<td>Yes</td>
</tr>
<tr>
<td>Milly 2005, replotted by P.C.D. Milly</td>
<td>12 (24) (~100–300 mi)</td>
<td>GCM grids</td>
<td>—</td>
<td>—</td>
<td>2041–60</td>
<td>-10 to -20%</td>
<td>96% model agreement</td>
</tr>
<tr>
<td>Hoeting and Eiseheid 2006</td>
<td>18 (42)</td>
<td>NCDC Climate Division</td>
<td>+5.0°F</td>
<td>~0%</td>
<td>2035–60</td>
<td>-45%</td>
<td>No</td>
</tr>
<tr>
<td>Christensen and Lettenmaier 2007</td>
<td>11 (22) (~8 mi)</td>
<td>VIC model grid</td>
<td>+4.5°F</td>
<td>-1%</td>
<td>2040–65</td>
<td>-6%</td>
<td>Yes</td>
</tr>
<tr>
<td>Seager et al. 2007*</td>
<td>19 (49)</td>
<td>GCM grids (~100–300 mi)</td>
<td>—</td>
<td>—</td>
<td>2050</td>
<td>-16% (-8% to -25%)</td>
<td>No</td>
</tr>
<tr>
<td>McCabe and Wolock 2008</td>
<td>—</td>
<td>USGS HUC8 units (~25–65 mi)</td>
<td>Assumed</td>
<td>3.6°F</td>
<td>—</td>
<td>-17%</td>
<td>Yes</td>
</tr>
<tr>
<td>Barnett and Pierce 2008*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2057</td>
<td>Assumed -10% to -30%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Values and ranges (where available) were extracted from the text and figures of the references shown. Columns provide the number of climate models and individual model runs used to drive the hydrology models, the spatial scale of the hydrology, the temperature and precipitation changes that drive the runoff projections, and whether or not the study quantified the risk these changes pose to water supply (e.g., the risk of a compact call or of significantly depleting reservoir storage).
Reconciling Year 1 - Runoff “Elasticity”

- How Do Hydrology Models Perform During Historical Period?
  - If you only modify Temperature by 1°C?
    - +1°C = -2% to -9% runoff
    - Results very model dependent
  - If you only modify Precipitation by -10% / + 10%
    - -10% precipitation = -20% runoff
    - +10% precipitation = +20% runoff
    - Results independent of the hydrology model

- +1°C Warming Equivalent to -1% to -5% Precipitation
- At 2050 with 2°C Warming, -4% to -18% Runoff w/ No Changes in Precipitation
Risk of Reservoir Drying at 2026 and 2050
Rajagopalan, et al., 2009 Water Resources Research

Risk of Empty Reservoirs in
at 2026…
Low = 5-10% For All Flows

at 2058….
No Flow Change = 3%
-10% Flows = 10%
-20% Flows = 40%

Key Lesson: Large Non-linear increase in risk with
20% CC – Understanding -10% vs -20% is Important!
Aquifer storage/baseflow change ratios

Republican River Basin:

3% depletion of groundwater storage led to 50% decline in baseflow

Basic message: projected decreases in snowpack and effective recharge can result in declining groundwater recharge rates

S. Earman, Scripps

(Data from Alley, 2005)
consumptive use
total availability

Basic message: currently Mexican aquifers are stressed
PROYECCIÓN AL 2030 SI SE CONSIDERA TAMBIÉN CAMBIO CLIMÁTICO

Basic message: with climate change and no changes to demands or practices, aquifers will be even more stressed.
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