Climate, Weather, and Water Science

Kristen Averyt
Brad Udall

Western Water Assessment
Western Water Assessment

• NOAA Regional Integrated Sciences & Assessments (RISA) Program
• Connect climate research with decision making
• Established 1998, Recompeted 2009

WWA MISSION

“To identify and characterize regional vulnerabilities to, and impacts of, climate variability and change, and to develop information, products, and processes that assist decision-makers throughout Colorado, Utah, and Wyoming.”
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“To identify and characterize regional vulnerabilities to, and impacts of, climate variability and change, and to develop information, products, and processes that assist decision-makers throughout Colorado, Utah, and Wyoming.”

Source: Reclamation
Climate Change in the West

In the Intermountain West, many impacts of climate change will be delivered through changes in the nature of water resources.

Projected declines in snowpack

Projected earlier peak streamflow timing

CO Climate Report 2008;
Redrawn from Christensen & Lettenmeier 2007

Stewart et al. 2004
Regional Challenges

- Rapidly growing population
- Social & environmental stresses
- Highly variable and complex climate

Population of Colorado River Basin States 1900-2010 (2008-2010 estimated)

Population Data Source: www.census.gov
Actual data to July 2007, Estimates thereafter.

AZ, CO, NM, NV, UT, WY

California
Regional Challenges

- Rapidly growing population
- Social & environmental stresses
- Highly variable and complex climate

Water 2025, 2003
Regional Challenges

- Rapidly growing population
- Social & environmental stresses
- Highly variable and complex climate
Cognitive Challenges

Within the water resources engineering community, the **stationarity assumption** is a fundamental element of professional training.

Confusion in conceptually melding the **burgeoning climate change impacts** literature.

**Time scales of climate change** exceed typical planning and infrastructure design horizons and are remote from human experience.

Source: CCSP SAP 5.1 2009

Milly et al. 2007

Meko et al. 2007
## WWA Team

- **Core Office**
- **Research Team**
- **Advisory Board**

### Core Office
- Alexander, Michael
  - Scientist, NOAA ESRL Physical Sciences Division
  - Climate Extremes
- Bates, Gary
  - Research Associate, CIRES, Univ. of Colorado
  - Climate Modeling

### Research Team
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  - Hydrology

### Advisory Board
- Avery, Kristen
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  - Assistant Professor, Environmental Studies, Univ. of Colorado
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  - Director, Western Water Policy Program, NRLF, Univ. of Colorado
  - Western Water Policy and Law
- McCutchan, James
  - Deputy Director, Center for Limnology, CIRES, Univ. of Colorado
  - Limnology
- Nowak, Kennith
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- Prasopiman, Balaji
  - Associate Professor, Civil Engineering, Univ. of Colorado
  - Hydrology
- Steffen, Konrad
  - Director, CIRES, Univ. of Colorado
  - Climatology
- van Drunick, Suzanne
  - Assistant Director for Science, CIRES, Univ. of Colorado
  - Hydrology and Ecology
WWA Team

- Core Office
- Research Team
- Advisory Board

<table>
<thead>
<tr>
<th>Core Office</th>
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<th>Advisory Board</th>
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<tbody>
<tr>
<td>Patricia Mauzy</td>
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<td>Michelle Schmidt</td>
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<td>James Verdin</td>
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<table>
<thead>
<tr>
<th>Curtis Brown</th>
<th>Director Research and Development, Reclamation Science and Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrance Fulp</td>
<td>Deputy Regional Director of the Bureau of Reclamation’s Lower Colorado Region</td>
</tr>
<tr>
<td>Jennifer Gimbel</td>
<td>Director, Colorado Water Conservation Board</td>
</tr>
<tr>
<td>Melinda Kassen</td>
<td>Director, Western Water Project, Trout Unlimited</td>
</tr>
<tr>
<td>Eric Kuhn</td>
<td>General Manager, Colorado River Water Conservation District</td>
</tr>
<tr>
<td>Chuck Kutscher</td>
<td>Principal Engineer, National Renewable Energy Laboratory, Department of Energy</td>
</tr>
<tr>
<td>Patricia Mulro</td>
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<td>Robert Wigington</td>
<td>Western Water Policy Counsel, The Nature Conservancy</td>
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<td>James Verdin</td>
<td>Deputy Director, National Integrated Drought Information System (NIDIS), USGS</td>
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Past Successes

- **Intermountain West Climate Summary**  
  (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)

- **Experimental SW Forecasts** (PSD: Wolter)

- **Appendix U** (PSD: Udall)

- **Climate Change in Colorado Report**  

[Link to IWCS report](wwa.colorado.edu/IWCS/index.html)
Past Successes

- Intermountain West Climate Summary (PSD: Lukas, Alvord, Averyt, Wolter, Ray, Bates)
- Experimental SW Forecasts (PSD: Wolter)
- Appendix U (PSD: Udall)
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## Current Projects

**Decision Support for the Colorado River Basin & Headwaters**
- Dust on Snow
- Reconciling CO River Flows
- Utah Paleohydrology
- CO River “24-month study”
- CO River Governance Initiative
- Comparison of CO River and Australian drought management practices

**Ecosystem Services: Vulnerabilities, Impacts, & Adaptation**
- Pine Beetle Survey
  - Community Adaptations to Pine Beetles
  - Pesticides, Beetles, Water Quality and Fish
  - San Juan High Desert ecosystem climate vulnerability

**Emerging Initiatives & Adaptation Strategies to Inform Climate Services**
- Energy-Water-Climate-Security Nexus
- Toolkit for Engaging Users in Climate Services
- CO Climate Workshops

*Bold* indicates PSD-collaborative efforts
Reconciling Projections of CO River Flows

- Wide range of 2050 projections
- NOAA PSD, WWA, Scripps, U. Arizona, U. Washington, Reclamation

### TABLE 5-1. Projected Changes in Colorado River Basin Runoff or Streamflow in the Mid-21st Century

<table>
<thead>
<tr>
<th>Study</th>
<th>GCMs (runs)</th>
<th>Spatial Scale</th>
<th>Temperature</th>
<th>Precipitation</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>Yes</td>
</tr>
<tr>
<td>Milly 2005, replotted by P.C.D. Milly</td>
<td>12 (24)</td>
<td>GCM grids (~100-300 mi)</td>
<td>—</td>
<td>—</td>
<td>No</td>
</tr>
<tr>
<td>Hoerling and Eischeid 2006</td>
<td>18 (42)</td>
<td>NCDC Climate Division</td>
<td>+5.0°F</td>
<td>-0%</td>
<td>No</td>
</tr>
<tr>
<td>Christensen and Lettenmaier 2007</td>
<td>11 (22)</td>
<td>VIC model grid (~8 mi)</td>
<td>+4.5°F</td>
<td>-1%</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>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>Yes</td>
</tr>
<tr>
<td>Barnett and Pierce 2008*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Yes</td>
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</tbody>
</table>

(PSD: Webb, Udall, Hoerling, Eischeid, Barsugli)
Reconciling Projections of CO River Flows

- Wide range of 2050 projections
- NOAA PSD, WWA, Scripps, U. Arizona, U. Washington, Reclamation

ISSUES
- Topography & resolution matter
- Physical processes are not well observed or represented in models
- Communication matters

Source: CO Climate Report 2008

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**TABLE 5-1. Projected Changes in Colorado River Basin Runoff or Streamflow in the Mid-21st Century from Recent Studies**

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<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>
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<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>Hoerling and Eischeid 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)</td>
<td>VIC model grid (~8 mi)</td>
<td>+4.5°F (+1.8 to +5.0) (-21% to +13%)</td>
<td>-1%</td>
<td>2040–69</td>
<td>-6% (-40% to +18%)</td>
<td>Yes</td>
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<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>
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<tr>
<td>McCabe and Wolock 2008</td>
<td>—</td>
<td>USGS HUC8 units (~25–65 mi)</td>
<td>Assumed</td>
<td>—</td>
<td>—</td>
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<td>Yes</td>
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<td>—</td>
<td>—</td>
<td>+3.6°F</td>
<td>0%</td>
<td>2057</td>
<td>Assumed -10% to -30%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*(PSD: Webb, Udall, Hoerling, Eischeid, Barsugli)*

Source: CO Climate Report 2008
Bark Beetles: Adding the Ecosystem Dimension

CHALLENGES
Multi-stressors
- Temperature
- Moisture
- Hydrologic Cycle
- Wildfire
- Forest Management
- Water Quality

(PSD: Lukas, Gordon)

Raffa et al. 2008
Engaging Users in Climate Services

**INFORMATION PROVIDERS**

**PRODUCTS**

**RESEARCH**

**OUTREACH**

**TOOL & PRODUCT DEVELOPERS**

**ENGAGING USERS IN CLIMATE SERVICES**

Users & Existing Climate Information

Better Climate Information & Informed Users

Informed Users & Better Climate Information

PROTOTYPEING EFFORTS:

- Colorado Water Conservation Board
- USFS
- NOAA NWS RFC

(PSD: Averyt, Lukas, Alvord)
Questions?