Climate Projections for Water Resources and Environmental Planning

Levi Brekke, Reclamation

Acknowledgments:
Presentation reflects thoughts and contributions from Martyn Clark (NCAR) and Jeffrey Arnold (U.S. Army Corps of Engineers)
The water management community has developed capabilities to use climate projections in long-term planning assessments.

Through CCAWWG, Reclamation is collaborating with Federal water science and management partners to understand limits of these capabilities, define community needs, and identify research opportunities.

CESM presents several unique research opportunities…
Early Activity: improve access to “many” downscaled climate (2007-present) and hydrology projections (2011-present)

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

- **CMIP3**
  - Climate, monthly (BCSD)
    - 16 GCMs
    - 3 emissions
    - 112 projections
    - 1950-2099, NLDAS, 1/8°
  - Climate, daily (BCCA)
    - 9 GCMs
    - 3 emissions
    - 57 projections
    - {1961-2000, 2046-2065, 2081-2100}, NLDAS, 1/8°
  - Hydrology (extend from BCSD)
    - same attributes
    - only western U.S. coverage
    - Serve (a) monthly water balance variables, and (b) daily forcings and gridded runoff
Early Applications
(leveraging the previous “archive” as well as other downscaled information sources)

- **Internal activity**
  - Reclamation 2008 (ESA Biological Assessment, CA Central Valley Project)
  - Reclamation 2009 (NEPA EIS, CA San Joaquin River Restoration Program)
  - RMJOC 2010 (Columbia Basin; BPA, USACE, and Reclamation development of future climate & hydrology change scenarios)
  - Others…

- **External Activity (tracked)**
  - CO Front Range Climate Change Vulnerability Study (2008-2012)
  - Colorado River Water Availability Study (same)
  - California Climate Action Team studies (2006, 2009)
  - NOAA RISA assessments (CIG, WWA)
  - Others…
Recent Application: West-Wide Hydrology Projection & SECURE 9503 report (2011)

112 BSCD CMIP3 Climate Projections…
http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html

...112 Hydrologic Projections covering western U.S.…. Analyses of Period-changes in climate and hydrology

SECURE Report to Congress, 2011 focus on median changes; future reports have broader scope

Data-service, Reclamation and broader public use


http://www.usbr.gov/climate
Downscaled CMIP5 Climate and Hydrology Projections (climate exp. ~Mar 2013)

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

- **CMIP5**
  - Climate, monthly (BCSD)
    - 37 GCMs
    - 4 emissions
    - 234 projections
    - 1950-2099, NLDAS, 1/8°
  - Climate, daily (BCCA)
    - 21 GCMs
    - 4 emissions
    - 134 projections
    - 1950-2099, NLDAS, 1/8°
  - Hydrology (extend from BCSD)
    - same attributes, although driven by projected changes in diurnal temperature range and average temperature, not just the latter (as in prior effort)
    - CONUS + Canadian portions of Columbia and Missouri River Basins
    - Serve (a) monthly water balance variables, and (b) daily forcings and gridded runoff
Defining User Needs...

C-CAWWG
February 2008
Workshop

USGS Circular
1331
January 2009

CCAWWG User
Needs Document
January 2011

http://www.ccawwg.us/
Role of Climate Information in Water Resource Management Studies

I. Climate Context Possibilities
- **Paleoclimate Data:** e.g., tree-ring based reconstructions of annual runoff
- **Instrumental Records:** observed weather (T and P) and runoff (Q)
- **Climate Projections:** modeled weather and runoff based on future scenarios of climate forcings

II. Relate to Planning Assumptions
- **Q**
- **T, P, and Q**
- **T, P, and/or Q**

III. Conduct Planning Evaluations
- **System Analysis, Evaluate Study Questions** (related to Resource Management Objectives)
Eight Technical Steps for incorporating climate change into Water Resource Management Studies

1. Summarize Literature on Climate Change and Water Resources
2. Obtain Climate Projections Data
3. Decide which Projections to use and how to use in Planning Scenarios
4. Assess Natural Systems Response
5. Assess Social Systems Response
6. Evaluate Study Questions (regarding Resource Management Objectives)
7. Assess and Characterize Uncertainties
8. Communicate Uncertainties and relate to Decision-Making
## Prioritization of Research relative to Technical Step (Gap Category)

<table>
<thead>
<tr>
<th>Technical Step</th>
<th>Technical Step (Gap Category)</th>
<th>Average Priority Rankings ¹</th>
<th>Reclamation/USACE</th>
<th>All Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summarize Relevant Literature</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Obtaining Climate Change Information</td>
<td>2.5</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Make Decisions About How To Use the Climate Change Information</td>
<td>3.0</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Assess Natural Systems Response</td>
<td>3.0</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Assess Socioeconomic and Institutional Response</td>
<td>2.5</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Assess System Risks and Evaluate Alternatives</td>
<td>1.5</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Assess and Characterize Uncertainties</td>
<td>2.0</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Communicating Results and Uncertainties to Decisionmakers</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

¹ Averaged across gaps in a given Step (1 = low, 2 = medium, and 3 = high)
### Technical Planning Steps and Associated Gaps in Tools and Information

<table>
<thead>
<tr>
<th>Step 2 – Obtaining Climate Change Information</th>
</tr>
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<tbody>
<tr>
<td><strong>2.01</strong> Improved skill in simulating long-term global to regional climate.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>2.02</strong> Downscaled data at finer space and time resolutions for different variables.</td>
</tr>
<tr>
<td><strong>2.03</strong> Information on the strengths and weaknesses of downscalned data and the down-scaling methodologies used to develop these data (including both statistical and dynamical methods and associated approaches for climate model bias-correction).</td>
</tr>
</tbody>
</table>

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1 Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Summary of Gaps and Priorities

(Steps 2 through 4 highlighted…)

- **2010 BCCA, 2011 WWCRA VIC-hydrology projections**
- **2011-2013 NCAR Project #1 (Sensitivity of Impacts to Downscaling/Hydrology Methods)**

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## Technical Planning Steps and Associated Gaps in Tools and Information

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<td>All Respondents</td>
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<td><strong>Step 2 – Obtaining Climate Change Information</strong></td>
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</table>

2.04 Indication of conditions of where and when the stationarity assumption of statistical downscaling may not hold should motivate use of dynamical downscaling techniques rather than statistical.

- Medium

2.05 Synthesis of sea level projection information and guidance on consistent use in planning for all Reclamation and USACE coastal areas.

- Low

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2011-2013 NCAR Project #1 (Sensitivity of Impacts to Downscaling/Hydrology Methods);

NOAA NCPP (Dixon/Hayhoe)
### Technical Planning Steps and Associated Gaps in Tools and Information

#### Priority Ranking 1

**Reclamation/USACE**

**All Respondents**

<table>
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<tr>
<th>Step 3 – Make Decisions About How To Use the Climate Change Information</th>
<th>Priority Ranking</th>
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<tr>
<td><strong>3.01 Understanding on observed climate variability from daily to multidecadal time scales, which underpins interpretation of future variability in climate projections and its relation to planning assumptions.</strong></td>
<td>High</td>
</tr>
<tr>
<td><strong>3.02 Understanding how to interpret future variability in climate projections and relevance to operating constraints on shorter- to longer-term time scales (from daily to multidecadal).</strong></td>
<td>High</td>
</tr>
<tr>
<td><strong>3.03 Basis for culling or weighting climate projections (if at all) when deciding which projections to use in planning.</strong></td>
<td>Medium</td>
</tr>
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### Technical Planning Steps and Associated Gaps in Tools and Information

#### Step 4 – Assess Natural Systems Response

| Watershed Hydrology (WH), Ecosystems (E), Land Cover (LC), Water Quality (WQ), Consumptive Use on Irrigated Lands (CU), and Sedimentation and River Hydraulics (SRH) |
|---|---|---|---|
| **4.01 (WH)** Guidance on strengths and weaknesses of watershed hydrologic models/methods to support scoping decisions in planning. |
| **4.02 (WH)** Understanding how climate change should impact potential evapotranspiration and how it is represented in watershed hydrologic models. |
| **4.03 (WH)** Method and basis for estimating extreme hydrologic event possibilities, deterministically or probabilistically. |

#### Priority Ranking

<table>
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Summary of Gaps and Priorities *(Steps 2 through 4 highlighted…)*

- 2009-2011 Reclamation/USGS/NWS project on models’ preferences; 2011-2013 NCAR Project #1; tracking literature
- 2011-2013 NCAR Project #1; tracking literature
- PACE Mahoney; 2012-2013 NOAA/CIRES project #1
### Technical Planning Steps and Associated Gaps in Tools and Information

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<td>Watershed Hydrology (WH), Ecosystems (E), Land Cover (LC), Water Quality (WQ), Consumptive Use on Irrigated Lands (CU), and Sedimentation and River Hydraulics (SRH)</td>
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<tr>
<td>4.04 (WH) Guidance on strengths and weaknesses of available versions of spatially distributed hydrologic weather data that may be used for both watershed hydrologic model development (Step 4) and in climate model bias-correction (Step 2).</td>
<td>Medium</td>
</tr>
<tr>
<td>4.05 (WH) Understanding how climate change should impact groundwater recharge and groundwater interaction with surface water supplies.</td>
<td>Medium</td>
</tr>
<tr>
<td>4.06 (E) Understanding how climate change should impact inland and coastal anadromous fisheries.</td>
<td>Medium</td>
</tr>
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**Summary of Gaps and Priorities** *(Steps 2 through 4 highlighted…)*

- **2011-2012 Reclamation/NWS (Elsner); 2011-2013 NCAR Project #1**
CESM Opportunities

- **Overarching question:** How can SDWG scope CESM research to inform use of climate projections in long-term planning?

- **Opportunities:**
  1. Provide finer-resolution sneak preview
  2. Prep users for “hydroclimate” projections
  3. Foster offline use of CESM hydrology model
1) Finer-Res. Sneak Preview

- **Goal:** provide sneak preview on what GCMs may be able to produce in the coming years

- **Approach:**
  - conduct CESM experiments across multiple resolutions (“current” to “future” higher resolution); leverage MPAS initiative
  - complement with nested RCM simulations

- **Questions:**
  - How does finer resolution CESM simulation affect the regional to local climate change “story”?
  - How are simulated regional/local climate changes different when using hi-res CESM vs. coarser-res CESM w/ nested RCM? … and with different RCMs?
  - How does CESM representations of hydrology differ from other land models?
2) “Hydroclimate” Projections

- **Goal:** prepare user community for future where GCMs produce meaningful local hydroclimate projections (*eliminating need for downscaling*)

- **Approach:**
  - educate users on hydrology schemes in GCMs
  - conduct experiments to understand GCM structure and resolution controls on simulated local hydroclimate

- **Questions:**
  - At what resolutions are GCMs’ projections of “local” hydroclimate meaningful? For which hydroclimate variables & statistics?
  - How are these findings sensitive to chosen land-surface hydrology scheme?
3) Offline Use of CESM LSM

• **Goals:** enhance user feedback to the broader CESM land-surface modeling efforts; facilitate users’ migration to applying more process-based hydrology models

• **Approach:**
  – educate users on CESM’s land-surface hydrology scheme (LSM)
  – scope research explore how to maximize utility of CESM LSM for water management applications:
    1. improve input datasets and associated estimates of uncertainty
    2. meld model application approaches found in “engineering hydrology” with those featured in the “land surface” modeling community
    3. include CESM LSM in multi-physics and process-diagnostic experiments designed to increase understanding on model application preferences

• **Questions:**
  – Ask Martyn 😊
Questions?