Evaluating Sustainability of Projected Water Demands under Future Climate Change Scenarios

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Overview

- Study focused on relating water use and availability at a national scale, using an index-based approach
- Developed business as usual estimates of water use 20-40 years into the future
- Consider climate change impacts to understand how risks to water sustainability might change with time

Report/data available electronically at:
http://rd.tetratech.com/climatechange/projects/nrdc_climate.asp
Freshwater Withdrawal in 2005

- Public supply + domestic: 40%
- Irrigation: 36%
- Livestock: 5%
- Aquaculture: 3%
- Industrial: 1%
- Mining: 1%
- Thermoelectric: 14%
US Population and Total Freshwater Withdrawal

![Graph showing US Population and Total Freshwater Withdrawal from 1950 to 2000. The graph includes bars for Groundwater, Surface Water, and Population.](chart.png)
2005 Freshwater Withdrawals
Approach to Perform a National Assessment of Water Availability and Demand

I) For current conditions, use available data on
   - Population (Census Bureau)
   - Temperature and precipitation (NOAA)
   - Water use (USGS)
   - Electricity generation (EIA)

II) Estimate future water use in 2050 (Business as usual scenario)
   - Extrapolating from current rates of change (population) or using published projections (electricity generation) extrapolated to 2050
   - Assuming no change in agricultural withdrawal

III) Climate projections based on median values of 16 models
### Climate Data from 16 GCMs

<table>
<thead>
<tr>
<th>Modeling Group, Country</th>
<th>IPCC Model I.D.</th>
<th>Primary Reference</th>
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<tbody>
<tr>
<td>1. Bjerknes Centre for Climate Research</td>
<td>BCCR-BCM2.0</td>
<td>[Furevik et al., 2003]</td>
</tr>
<tr>
<td>2. Canadian Centre for Climate Modeling &amp; Analysis</td>
<td>CGCM3.1 (T47)</td>
<td>[Flato and Boer, 2001]</td>
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<tr>
<td>3. Météo-France / Centre National de Recherches Météorologiques, France</td>
<td>CNRM-CM3</td>
<td>[Salas-Mélia et al., 2005]</td>
</tr>
<tr>
<td>4. CSIRO Atmospheric Research, Australia</td>
<td>CSIRO-Mk3.0</td>
<td>[Gordon et al., 2002]</td>
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<tr>
<td>5. U.S. Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA</td>
<td>GFDL-CM2.0</td>
<td>[Delworth et al., 2006]</td>
</tr>
<tr>
<td>6. U.S. Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA</td>
<td>GFDL-CM2.1</td>
<td>[Delworth et al., 2006]</td>
</tr>
<tr>
<td>7. NASA / Goddard Institute for Space Studies, USA</td>
<td>GISS-ER</td>
<td>[Russell et al., 2000]</td>
</tr>
<tr>
<td>8. Institute for Numerical Mathematics, Russia</td>
<td>INM-CM3.0</td>
<td>[Dianksy and Volodin, 2002]</td>
</tr>
<tr>
<td>9. Institut Pierre Simon Laplace, France</td>
<td>IPSL-CM4</td>
<td>[IPSL, 2005]</td>
</tr>
<tr>
<td>10. Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan</td>
<td>MIROC3.2 (mextres)</td>
<td>[K-1 model developers, 2004]</td>
</tr>
<tr>
<td>11. Meteorological Institute of the University of Born, Meteorological Research Institute of KMA</td>
<td>ECHO-G</td>
<td>[Legutke and Voss, 1999]</td>
</tr>
<tr>
<td>12. Max Planck Institute for Meteorology, Germany</td>
<td>ECHAM5/MPI-OEM</td>
<td>[Jungclaus et al., 2006]</td>
</tr>
<tr>
<td>13. Meteorological Research Institute, Japan</td>
<td>MRI-CGCM2.3.2</td>
<td>[Yukimoto et al., 2001]</td>
</tr>
<tr>
<td>15. National Center for Atmospheric Research, USA</td>
<td>CCSM3</td>
<td>[Collins et al., 2006]</td>
</tr>
<tr>
<td>16. Hadley Centre for Climate Prediction and Research / Met Office, UK</td>
<td>UKMO-HadCM3</td>
<td>[Gordon et al., 2000]</td>
</tr>
</tbody>
</table>
Energy demand for Different Energy Market Module Regions (EIA Projections)
Projected Change in Precipitation (inches)
Projected Change in Temperature (°C)
Evapotranspiration: Estimated Using Hamon (1961) Equation

\[
E = \frac{2.1H_t^2e_s}{(T_t+273.2)}
\]

- $E$ = evaporation, day $t$ (mm/day)
- $H_t$ = average number of daylight hours per day during the month in which day $t$ falls
- $e_s$ = saturated vapor pressure at temperature $T_t$ (kPa)
- $T_t$ = temperature, day $t$ (°C)

$H_t$ was calculated by using the maximum number of daylight hours on day $t$.

Saturated vapor pressure $e_s$ was estimated as:

\[
e_s = 0.6108\exp\left(\frac{17.27T_t}{237.3+T_t}\right)
\]
Available Precipitation:
Precipitation Minus PET for Summed for Nonzero Months
Change in PET from 2005 to 2050
Change in Available Precipitation (2005 to 2050)
Freshwater Withdrawal in 2050

Total Freshwater Withdrawal
2050 (inches/yr)

- 0.0 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 5.0
- 5.0 - 10.0
- >10.0

Kilometers
Ratio of Freshwater Withdrawal to Available Precipitation With and Without Consideration of Climate Change
A Proposed Index of Water Sustainability
Each of the Following is Scored 0 or 1
(4 or more = extreme risk; 3 = high risk; 2 = moderate risk; <2 = low risk)

1) Extent of development of available renewable water:
Greater than 25% of available precipitation currently used

2) Groundwater use:
Ratio of groundwater withdrawal to total withdrawal is greater than 25%

3) Susceptibility to drought:
Difference between water withdrawal during the three driest months of the year (June, July, and August) and available precipitation is greater than 10 inches

4) Growth of Water Withdrawal:
Business as usual requirements to 2050 increase current freshwater withdrawal by more than 20%

5) New requirements for storage or withdrawal from storage:
- Summer deficit (difference between withdrawal and available precipitation in an average year) increases more than 1 inch over 2005-2050
Water Sustainability Index With and Without Consideration of Climate Change
Findings/Next Steps

• Publicly available data provide a basis to evaluate sustainable water use and highlight regions that need more study and/or data; not all water supply/storage limitations are in the Western U.S.
• First step toward more local scale analysis
• Consider different assumptions for growth, including more sophisticated representations of future water use by different sectors of the economy (e.g., higher efficiency)
• Consider alternative climate scenarios besides the median
• Some larger-scale data needs:
  – A better representation of regulatory limits on water withdrawals, or an estimate of environmental flow requirements
  – Data on intra-annual use could be important in highlighting scarcity in the driest months of the year