Assessment of the Hydrologic Response to Climate Change in the Upper Deschutes River Basin, Central Oregon

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Citation Details
Work funder through BoR in collaboration with the USGS Oregon Water Science Center

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Purpose of Research

- There is broad interest on the part of resource managers and the general public regarding response of streams and groundwater to probable climate change.

- Most irrigation water in the upper Deschutes Basin comes from storage reservoirs that are supplied by streams flowing from the Cascade Range, many of which are groundwater fed.

- These interests are addressed here using coupled groundwater recharge and flow models driven by GCM output.

Concept of climate stationarity is breaking down.
Surface waters are fully appropriated.
Upper Deschutes Basin, Central Oregon

MODIS image, 25 November 2002, NASA Visible Earth archive
Inset from Gannot et al. 2001
Models and products used

- Global Climate Model (GCM) weather data downscaled to 1/16th degree using the Bias-Correction and Spatial Disaggregation method.


- A MODFLOW regional groundwater model calibrated to the upper Deschutes Basin by Gannett and Lite (2004).

...is a physically based mass and energy-balance model that operates on a daily time step to estimate groundwater recharge by partitioning precipitation through the major hydrologic fluxes.

The regional groundwater flow model--This 3D finite difference (numerical) model solves discretized equations for the movement of groundwater through porous media which is described by Darcy’s Law and the conservation of mass.
Methods

• 8 GCMs
  2 IPCC emission scenarios
  = 16 runs

• 2 ensembles: DPM hydrologic budget results from the eight runs are averaged for each emission scenario.
## Downscaled GCMs used as ensembles for both emission scenarios

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<thead>
<tr>
<th>Model Name</th>
<th>Institution</th>
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<tr>
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<td>National Center for Atmospheric Research</td>
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<td>HadCM3</td>
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</table>
Rows (primary output fields) such as SLP, temp, precip, and variables describing the circulation regime over a region.

Triangles by diagonal show relative errors with respect to different data sets (primary is upper left)

- adapted from Gleckler et al., (2007)
Methods (Continued)

• In-place recharge and runoff
  Examined using basin-wide averaged mean monthly hydrographs and seasonal spatial maps.

• DPM recharge and evapotranspiration output used for inputs to the regional groundwater flow model.
Methods (Continued)

- Changes in groundwater discharge to select stream reaches within the three main discharge areas of the basin were examined using mean monthly hydrographs.

- Statistical testing was employed to confirm changes between four climate periods in the 21st century for basin-wide mean monthly and mean seasonal results.

3 main discharge areas--These include the southern, uppermost portions of the basin within and near the Cascades; the Metolius sub-basin in the northwestern portion of the basin adjacent to the Cascades; and the area in and around the confluence of the Deschutes, Crooked, and Metolius rivers in the north-central portion of the basin.
For the distribution and partitioning of precipitation.

Important function of elevation: Lapse rate adjustments
Long term annual precip is used for interpolation of precip from weather stations. Ranges from 200 in along crest to about 10 in the high desert.
STATSGO (state soil geographic database), also US Forest Service soil coverage, soil types reduced by Boyd to 10 hydrologic soil types for the DPM using cluster analysis.
Say annual means
Basin-wide average response to climate change

2 emission scenario ensemble means

4 climate periods
Jan-march rate changing (changing sign) mar-may changing magnitude.
DPM basin-wide average changes

Recharge

Runoff
Spatial distribution of changes in recharge and runoff 2050s relative to 1980s

MODIS image, 25 November 2002, NASA Visible Earth archive
1980s simulated recharge
Six stream reaches were selected for analysis.
Shorter flow paths and lower storage coefficients. Integrate area under curve - volumetric increases

Large volumes of groundwater discharge to streams in three main areas of the upper Deschutes Basin. These include the southern, uppermost portions of the basin within and near the Cascades; the Metolius sub-basin in the northwestern portion of the basin adjacent to the Cascades; and the area in and around the confluence of the Deschutes, Crooked, and Metolius rivers in the north-central portion of the basin (Gannett et al., 2001).
Longer flow paths and Higher storage coefficients volumetric decreases
Summary

• The DPM predicts a shift in timing of runoff and recharge for both emission scenarios with a shift toward earlier runoff and recharge.

• Shifts in the timing of recharge are observed primarily in the baseflow hydrographs of high elevation streams.

• Volumetric changes in groundwater discharge to streams likely result from spatial changes in recharge.
References


Range of basin-wide average recharge and runoff anomalies

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<th>Winter 2020s</th>
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<th>Winter 2080s</th>
<th>Spring 2020s</th>
<th>Spring 2050s</th>
<th>Spring 2080s</th>
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<td>0.0</td>
<td>-0.5</td>
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<td>spring</td>
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<td>-1.7</td>
<td>-2.2</td>
<td>-0.6</td>
<td>-0.8</td>
<td>-1.0</td>
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</table>

Recharge (inches)
1) Inputted daily precipitation is converted into snow or rain, dependent upon whether the temperature for that day was above or below freezing.
2) Sublimation is subtracted from the snow pack storage and evaporation is subtracted from the intercepted precipitation storage.
3) Snowmelt and rainfall which were not intercepted are assigned as water on the ground surface.
4) A portion of the water on the ground surface is subtracted as surface runoff, the rest is allocated to soil moisture storage in the root zone.
5) Soil moisture in the root zone is then subjected to soil evapotranspiration and shallow subsurface runoff.
6) Deep percolation (groundwater recharge) is then determined to be the amount of water in excess of the water holding capacity of the root zone.
Acknowledgments

- Thesis Committee
  - Christina Hulbe, Department of Geology, PSU
  - Marshall Gannett, USGS Oregon Water Science Center
  - Heejun Chang, Department of Geography, PSU
  - Ken Cruikshank, Department of Geology, PSU

- Lenny Orzel, USGS Oregon Water Science Center

- Leslie Stillwater, Bureau of Reclamation

This work was funded through a Bureau of Reclamation Science and Technology Grant.