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Future hydrological changes in United States: Methods and projections

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Near term
Future hydrological changes in United States: Methods and projections

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Science Questions

How do

1) “Biases” in climate model data
2) Changes in the “occurrence and intensity” of daily extremes
3) Changes in the “daily distributions”

affect process-based hydrological assessments
## Experimental Details

<table>
<thead>
<tr>
<th>Driving Data</th>
<th>Historic Period (1961-1990)</th>
<th>Future Period (2071-2100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RegCM3-<strong>ORG</strong></td>
<td><strong>Original</strong> daily precipitation, minimum temperature, maximum temperature, surface winds</td>
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<td><strong>Bias-corrected</strong> daily precipitation, minimum temperature, maximum temperature, original surface winds</td>
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</tr>
<tr>
<td>RegCM3-<strong>BCD</strong></td>
<td>Same as RegCM3-<strong>BC</strong></td>
<td>Bias-corrected daily precipitation, minimum temperature, maximum temperature, original surface winds (<em>Bias correction applied to the historic period daily values</em>)</td>
</tr>
<tr>
<td><strong>OBS</strong></td>
<td>Maurer et al, 2002</td>
<td></td>
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### Experiments

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Bias Correction Methodology

Monthly data (RegCM3) → Bias Correction / Spatial Disaggregation → Adjusted RegCM3 daily data based on monthly corrected fields

Hydrological Model (VIC)
Bias Correction Methodology

Graph 1: Non-exceedance probability vs. Obs vs. Model.

Comparison of daily extremes in RegCM-BC and RegCM-ORG with daily extremes in NARR
Role of climate model biases
Statistical comparison of **VIC-OBS** with **VIC-ORG** and **VIC-BC** – Taylor diagram
Statistical comparison of **VIC-OBS** with **VIC-ORG** and **VIC-BC** – Taylor diagram

**VIC-OBS** vs **VIC-ORG**  
**VIC-OBS** vs **VIC-BC**
Statistical comparison of **VIC-BC** simulated changes with **VIC-ORG** simulated changes – Taylor diagram

![Taylor diagram with VIC-BC vs VIC-ORG comparison](image)
Role of daily extremes
“Runoff” versus “Intensity of heavy precipitation events”
“Changes in the Soil Moisture” versus “changes in the intensity of heavy precipitation events”

“Changes in the Soil Moisture” versus “changes in the occurrences of extreme hot days”

Change in soil moisture (mm)

Change in intensity of events above P75

Change in number of days above T95

DJF  MAM  JJA  SON
Role of changes in daily distributions
Statistical comparison of **VIC-BC** simulated changes with **VIC-BCD** simulated changes – Taylor diagram

**VIC-BC** vs **VIC-BCD**
Why are the “simulated hydrologic changes” NOT sensitive to the “changes in daily distribution”? 

Blue = RegCM-BC “future period”

Red = RegCM-BC “historic period”

Green = RegCM-BCD “future period”
However, ...

Evapotranspiration

Runoff

Difference in P75 days
RegCM-BC minus RegCM-BCD

VIC-BC

VIC-BCD

mm/day

mm/day

days/season
PART II – Projections
Experimental Details

- Five member ensemble VIC simulations at 1/8 degree grid spacing
- Simulation periods
  - Historic 1960-1999
  - Future 2000-2040
- Driving Fields :: Bias corrected P, TMIN, TMAX and original RegCM3 winds
- RegCM3 was driven with five CCSM ensemble members. Each simulation was driven at 25km horizontal grid spacing
What is so special about Western US Snow cover?

Observed April 1 SWE trend

1950-1997

Mote et al, 2004

Observed S/P ratio trend

1949-2001

Knowles et al, 2005

Observed CT Trends (1948-2000)

Stewart et al, 2003
Historic trends in April 1 SWE


Trend is shown as % change relative to the 1960 value on the linear fit line
April 1 SWE Trend versus Elevation


Trend is shown as % change relative to the 1960 value on the linear fit line
Historical trends in the timing of center of mass flow

**RED** represents trend towards earlier melt

**BLUE** represents trend towards earlier melt
Historic trends in snow to precipitation ratio


RED represents **less** snowfall and **more** liquid precipitation.

BLUE represents **more** snowfall and **less** liquid precipitation.

Trend is shown in terms of Standard Deviation relative to the base value on the linear fit line.
Driving forces....

Precipitation Trends NDJFM

TMIN>0 Trends NDJFM
Future Trends in April 1
SWE (2000-2039)

Trend is shown in terms of Standard Deviation relative to the base value (average of 1960-1999) on the linear fit line.

Trend is shown in terms of percent change relative to the base value (average of 1960-1999) on the linear fit line.
Future Trends in April 1 SWE versus Elevation
Future Changes (days) in the timing of snow melt (2000-2039)

Changes are shown relative to the baseline (1960-1999)
Days with TMIN > 0 NDJFM (2000-2039)

Snow melt Trend Water Year (2000-2039)

Snow to precipitation ratio NDJFM (2000-2039)
S/P ratio versus Days with TMIN > 0
Summary

- Multi-ensemble high-resolution hydrological modeling system is able to simulate historic western US hydrological trends.

- Simulated changes show further strengthening of historic trends over the next few decades, which may lead to substantial decrease in the late season snow-melt driven runoff.
Role of fine spatial scales