Assessing impacts of climate change in a semi-arid watershed using downscaled IPCC climate output

Seshadri Rajagopal, Francina Dominguez\textsuperscript{2}, Hoshin V Gupta, Peter A Troch, Christopher L Castro\textsuperscript{2}

Department of Hydrology and Water Resources, University of Arizona, Tucson

\textsuperscript{2}Department of Atmospheric Science, University of Arizona, Tucson
What we know – Tree Rings

Discharge – Salt River near Roosevelt

Figure 2. Reconstructed and Actual Discharge of the Salt River near Roosevelt (calibration period is from 1914-1979).

Smith and Stockton, 1981
What we know – Tree Rings

Discharge – Verde River near Tangle Creek

Figure 5. Actual and Reconstructed Stream Flow of the Verde River Below Tangle Creek (calibration period is from 1895-1979).

Smith and Stockton, 1981
Focus - Regional

Conceptual model of the system

Winter Flow Pattern

Evaporation

Mogollon Rim

Streamflow

Phoenix

Tucson

Summer Flow Pattern
Hydro-Climatology of the Salt River

[Graph showing Obs Precipitation and Obs Streamflow, with Obs Temperature and Obs Streamflow for comparison]
Hydro-Climatology of the Verde River

[Graphs showing precipitation, streamflow, and temperature over the year.]
Methodology

Atmospheric models

Ocean models

Coupled AOGCM

Spatial Scales don’t match!

Land Surface model

Impacts?

http://www.iac.ethz.ch/

http://hydro.washington.edu/
Methodology - AOGCM Selection

Domain of Interest

Precipitation

Temperature

Source: Dominguez F., Cañon J., Valdes J., IPCC - AR4

Methodology – Bias Correction and Downscaling

GCM

Observed

Monthly Mean Values

Ranked probability curve

Corrected GCM Probability Curve
Pros and Cons

PRO

There are many downscaled scenarios/models available
This helps account for uncertainty
Computationally less expensive

CON

Assume historical relationships to be true in the future (non-stationarity!)
Does not account for feedbacks
Results – Hydrologic Model Calibration

VIC Streamflow Calibration
Salt R above Roosevelt Reservoir, AZ

Verde R below Tangle Creek, AZ
Results – Hydrologic Model Validation

VIC Streamflow Validation
Salt R above Roosevelt Reservoir, AZ

Verde R below Tangle Creek, AZ
Results – Basin Averaged Downscaled Temperature

~ 2.5 deg C increase from historical mean
Results – Basin Averaged Downscaled Precipitation
Results – Meteorological Variables

**Precipitation**

- **Observed**
- **2009-2038**
- **2039-2068**
- **2069-2098**

**Air Temperature**

- **MPI-ECHAM5**
- **UK-HADCM3**
- **IPSL-CM5A-MR**
- **SM3**

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### Observed Precipitation

- **2009-2038**: Observed values for the years 2009 to 2038.
- **2039-2068**: Observed values for the years 2039 to 2068.
- **2069-2098**: Observed values for the years 2069 to 2098.

### Modelled Precipitation

- **MPI-ECHAM5**
- **UK-HADCM3**
- **IPSL-CM5A-MR**
- **SM3**

### Air Temperature

- **MPI-ECHAM5**
- **UK-HADCM3**
- **IPSL-CM5A-MR**
- **SM3**
Salt and Verde Future Streamflow

8% moderate
15-20% extreme
Results – Hydrologic Fluxes

Baseflow

Evapotranspiration

 MPI-ECHAM5
Results – Hydrologic States

Soil Moisture

Snow Water Eq

MPI-ECHAM5
Summary

• Presented a framework to assess impacts on Watershed

• Meteorological Variables
  – Precipitation
  – Temperature

• Hydrologic Fluxes
  – Streamflow
  – ET

• Hydrologic States
  – Soil moisture
  – SWE
Thank you

Questions?
• Maurer E.P., Wood A.W., Adam J.C., Lettenmaier D.P., Nijssen B., A Long-Term Hydrologically Based Dataset of LandSurface Fluxes and States for the Conterminous United States, American Meterological Society, 2002, 3237-3251
Results – Hydrologic Fluxes

- **Baseflow**
  - MPI-ECHAM5

- **Evapotranspiration**
  - IPCC-CCSM3
  - SM3
Results – Hydrologic States

**Soil Moisture**

- MPI-ECHAM5

**Snow Water Eq**

- Observed
- 2009-2038
- 2039-2068
- 2069-2098
Objectives

Assess future climate impacts to

- Meteorological variables
  - Temperature
  - Precipitation
- Hydrologic fluxes
  - Streamflow
  - Evapo-transpiration
- Hydrologic States
  - Soil moisture
  - Snow Water Equivalent
Important to compare data of equal length!
Future Work

Climate Elasticity of Streamflow

\[
\frac{\delta Q}{Q} = \phi \left( \frac{\delta P}{P}, \delta T \right)
\]
What we know – Climate

Winter Flow Pattern

Summer Flow Pattern

Sheppard et al. 2002