Use of Climate Information in Water Supply Planning

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CESM-SDWG
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Florida’s Largest Regional Public Water Supplier

Wholesale drinking water to six governments

2.4 Million Residents

220-250 mgd annual average

Seasonal to multi-year variable climate
Why Climate Variability is Important

Seasonal Rainfall Pattern

- 60% of the annual rainfall in 4 months

Monthly Rainfall, inches

- JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC

Monthly Mean Flow, cfs

- Hillsborough River
- Alafia River
ENSO Affects Local Rainfall Patterns

**Plant City rainfall probabilities (%) conditional of La Niña**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Below Normal</th>
<th>Normal</th>
<th>Above Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJF</td>
<td>65</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>JFM</td>
<td>65</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>FMA</td>
<td>71</td>
<td>21</td>
<td>8</td>
</tr>
</tbody>
</table>
Tampa Bay Water’s Seasonal Outlook

Climate Outlook & Real time observation

Contingency Table

<table>
<thead>
<tr>
<th></th>
<th>Below Normal</th>
<th>Normal</th>
<th>Above Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJF</td>
<td>65</td>
<td>35</td>
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</tr>
<tr>
<td>JFM</td>
<td>85</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

Conditional Markov Rainfall Model

Rainfall/Runoff Model
In this project we are using dynamically and statistically downscaled climate model output to drive hydrologic models and explore potential impacts of climate variability and climate change on water availability and water allocation decisions.
Integrated Hydrologic Model (IHM) Hydrologic Processes

IHM Sequential Integration

- **Start**
  - Read control file and data base, Launch processes

- **HSPF (Land Segments)**
  - Runoff, Surface/Vadose ET, Recharge, PET for Vadose/GW, Soil Moisture

- **HSPF (Reaches)**
  - Route land flows through reaches; Streamflow and Stage in reaches
  - Cell values: SY, recharge & GW PET
  - Update RIV stages; Write EVT, RCH, RIV packages, SY array

- **MODFLOW**
  - Groundwater head and ET, Baseflow
  - Land Segment values: LZS, LZSN, LZETP, INFILT (for saturation-excess)

- **M2H**
  - Reach values: Baseflow, PET Coeff
  - Cell values: Mass Balance Flux

- **Optional Second Reach Routing**

- **Time End**

- **End**
Integrated Northern Tampa Bay Model
Surface-Water Component (HSPF)

- Convective Rainfall (4 months)
  - 60% volume / 75% events
  - 1.25-mile event spatial scale
- 65% of basins with 2 mile radius
- Rain input: 300 gauges, 15-min.
- ET – 5x seasonal variation

### Average Annual Budget 1989-98

<table>
<thead>
<tr>
<th>Budget Term</th>
<th>Percent</th>
<th>Flux (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evap. &amp; Transp.</td>
<td>69</td>
<td>38.0</td>
</tr>
<tr>
<td>Stream &amp; Spring Q</td>
<td>21</td>
<td>11.0</td>
</tr>
<tr>
<td>Well Pumping</td>
<td>5</td>
<td>3.0</td>
</tr>
<tr>
<td>GW Flow to Gulf</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>SW Pumping</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Other GW Outflows</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>54.5</strong></td>
</tr>
</tbody>
</table>
1. Statistical downscaling
   - Comparative evaluation of 4 methods (BCSD_daily, BCCA, SDBC, BCSA)
     • Ready to submit Hydrology and Earth System Science
   - Hydrologic simulation
     • Submitting to ASABE transaction

2. Evaluation of downscaled reanalysis data
   • R1+MM5 (Hwang et al., 2011)
   • R2+RSM (Stefanova et al., 2011)
   • ERA40+RSM (Stefanova et al., 2011)
   • 20CR+RSM (DiNapoli and Misra, 2012)
   - Submitting to JAWRA

3. Uncertainty of Bias-correction in climate change impact assessment
Methodology

CMIP3 GCM predictions

Method 1 & 2. BCSD, BCCA
- Bias correction
  - CDF mapping

Spatial downscaling
- IDW interpolation

Spatial downscaling
- Constructed Analog

Gridded dataset: spatial resolution of 1/8° (~12 km)

Method 1 results
- SDBC GCMs

Method 2 results
- BCCA GCMs

Method 3 results
- BCSD GCMs

Evaluate against observation

Method 4. BCSA to generated spatially correlated precipitation field

172 sub-basin scale obs.

Normal score transformation
Estimate spatial correlation structure of obs.

Generate random field sequences for 172 stations

Using correlation matrix of normal score

Spatially correlated field

Library of spatially distributed precipitation fields

Back transformation

Method 4 results
- BCSA GCMs

Select field from library
Spatial distribution of the temporal standard deviation for wet season (June through September), units in mm
The same but for dry season (October through May)
Spatial variability (Variograms)
Dynamical Downscaling

• Assessment of the utility of dynamically-downscaled regional reanalysis data to predict streamflow in west central Florida
  – Reanalysis data – robust proxy of historic atmospheric observations
  – Verifying accurate prediction of historic climatic and hydrologic behavior using reanalysis data is an essential first step before using retrospective and future GCM projections to predict potential hydrologic impacts of future climate change
Study period from 1989 to 2001

1. R1+MM5 (Hwang et al., 2011)  
   1986-2008
2. R2+RSM (Stefanova et al., 2011)  
   1979-2001
3. ERA40+RSM (Stefanova et al., 2011)  
   1979-2001
4. 20CR+RSM (DiNapoli and Misra, 2012)  
   1903-2008

IHM calibration/verification period  
1989-2006
Comparison of the mean annual cycles of (a) monthly mean and (b) standard deviation of daily precipitation.

**Raw results**

**monthly mean precipitation**

- **Basin_obs**
- **DR_ERA4**
- **DR_R1**
- **DR_R2**

**standard deviation of daily precipitation**

- **Basin_obs**
- **DR_ERA4**
- **DR_R1**
- **DR_R2**
Comparison of time series of (a) annual total precipitation and (b) standard deviation of daily precipitation over the year

**Raw results**

![Graph showing raw results for annual total precipitation](a1)

![Graph showing raw results for standard deviation of daily precipitation](b1)

**Bias-corrected results**

![Graph showing bias-corrected results for annual total precipitation](a2)

![Graph showing bias-corrected results for standard deviation of daily precipitation](b2)
Comparison of error statistics of monthly areal precipitation predictions

(a) PBIAS (%)

(b) RSR

(c) R²

(d) NSE

Key:
- △ Alafia R at Lithia
- ◦ Hillsborough R at Morris Bridge
- □ Hillsborough R near Tampa
- ○ Cypress Creek at Worthington
- + Cypress Creek near Sulfur spring
- × Anclote R near Elfers
Hydrologic implication
Comparison of observed vs. simulated mean monthly streamflow

Raw results

Bias-corrected results
Comparison of observed vs. simulated annual time series

**Raw results**

- **Alafia at Lithia**
  - Observed data
  - Calibration data (-0.67)
  - Different simulated series with coefficients

- **Hillsborough R at Morris Bridge**
  - Observed data
  - Calibration data (1.24)
  - Different simulated series with coefficients

**Bias-corrected results**

- **Alafia at Lithia**
  - Observed data
  - Calibration data (-0.67)
  - Bias-corrected simulated series with coefficients

- **Hillsborough R at Morris Bridge**
  - Observed data
  - Calibration data (1.24)
  - Bias-corrected simulated series with coefficients
Comparison of error statistics of monthly streamflow simulations for each target station; (a) PBIAS, (b) RSR, (c) $R^2$, and (d) NSE

- **Alafia R at Lithia**
- **Hillsborough R at Morris Bridge**
- **Anclote R near Elfers**
- **Cypress Creek at Worthington**

### (a) PBIAS

<table>
<thead>
<tr>
<th>Obs</th>
<th>CLARRReS10 (Reanalysis+RSM)</th>
<th>MM5</th>
<th>FLARRReS10</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>DR_ERA40</td>
<td>DR_R2</td>
<td>BCDR_ERA40</td>
</tr>
<tr>
<td></td>
<td>BCDR_R2</td>
<td>BCDR_R1</td>
<td>DR_20CR</td>
</tr>
<tr>
<td></td>
<td>BCDR_20CR</td>
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### (b) RSR

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### (c) $R^2$

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### (d) NSE

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<tr>
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• Uncertainty of Bias-correction in climate change impact assessment
• 3 GCMs + Regional Spectral Model (RSM)
  – CCSM, HadCM3, and GFDL (not available yet)
• Spatial resolution (10kmx10km)
  over southeastern US
• Variables
  – hourly Prec., humidity, wind speed, roughness, etc.
  – daily Tmax/min data
  – Daily bias-corrected Prec. data are available
• Retrospective simulation period
  – 1968-2000
• Future simulation (AR4 A2 scenario)
  – 2038-2070
Bias-correction (BC) Methodology

4 Future Bias Correction methods

1. Correct using historic bias *amount* corresponding the ‘magnitude’ of future prediction (CDFm, Wood et al)
2. Correct using historic bias *amount* corresponding the ‘Percentile’ of future prediction (EDCDFm, Li et al., 2010)
3. Correct using historic bias *percentage* corresponding the ‘magnitude’ of future prediction (CDFm_%bias)
4. Correct using historic bias *percentage* corresponding the ‘Percentile’ of future prediction (EDCDFm_%bias)

3 methods for CDF development

1. Monthly CDF (≈30 data)
2. CDF for moving window (± 30 days, 61 data)
3. CDF for moving window (± 15 days, 31 data)

*Total 12 combination of methodologies!*
1. Mean daily precipitation

HadCM3+RSM

Bias-corrected results
1. Mean daily precipitation

**CCSM+RSM**

**Bias-corrected results**
2. Std. of daily precipitation

HadCM3+RSM

Bias-corrected results
2. Std. of daily precipitation

**Raw results**

**CCSM+RSM**

**Bias-corrected results**
• QUESTIONS??