Hydrologic Cycle – will it remain stationary?

Primary Variables of interest:
- Temperature
- Precipitation
- Evapotranspiration
- Groundwater/Surface Water
- Saltwater Intrusion

Implications for:
- Water Management, Natural Systems
- Energy
- Agriculture
- Tourism, Transportation
- Health
Evaluation of Downscaled Climate Model Information for Florida

Jayantha Obeysekera (‘Obey’)
Chief Modeler, SFWMD
Affiliate Research Professor, CES, FAU

Hydrology of the Everglades in the Context of Climate Change Workshop
March 29-30, 2012, FAU Davie Campus
Research publications

Climate change and its implications for water resources management in south Florida
Jayantha Obeysekera · Michelle Irizarry · Joseph Park · Jenifer Barnes · Tibebe Dessalegne

Past and Projected Trends in Climate and Sea Level for South Florida

Historical Trends in Florida Temperature and Precipitation
Michelle M. Irizarry-Ortiz1,*, Jayantha Obeysekera1, Joseph Park1, Paul Trimble1, Jenifer Barnes1, Wunifred Park-Saíd1, Erik Gadzinski2

The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S.
David B. Enfield, Alberto M. Mestas-Nuez and Paul J. Trimble
Everglades Restoration – Will traditional planning approach work?

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly, Julio Betancourt, Malin Falkenmark, Robert M. Hirsch, Zhigui W. Kundzewicz, Dennis P. Lettenmaier, Ronald J. Stouffer
Is there evidence that climate is changing in Florida?

- General Circulation Models (GCMs)
- Simulation of Late 20th Century
- 21st Century Climate Projections
  - Downscale (Statistical & Dynamical) global information to regional information
    - How well are south Florida’s climate and teleconnections represented by climate models?
    - How do climate projections affect water resources management?
Climate Projection Uncertainties

### General Circulation Models (GCMs)

- BCM2
- CGHR
- CGMR
- CNCM3
- CSMK3
- ECHAM
- ECSC
- GCM21
- GLOM
- INC3
- IPCM4
- MIHR
- MIMR
- MIPH5
- NCCSM
- NIPCM

### Downscaling Methods

- Statistical
- Dynamical
- Constructed Analogues (CA)
- Bias Correction and Spatial Downscaling (BCSD)
- Weather Generators
- Regional Climate Models (RCMs)

### Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Temperature (°C)</th>
<th>Sea Level Rise (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1.1-2.9</td>
<td>0.18-0.38</td>
</tr>
<tr>
<td>A1T</td>
<td>1.4-3.8</td>
<td>0.20-0.45</td>
</tr>
<tr>
<td>B2</td>
<td>1.4-3.8</td>
<td>0.20-0.45</td>
</tr>
<tr>
<td>A1B</td>
<td>1.4-3.8</td>
<td>0.20-0.45</td>
</tr>
<tr>
<td>A2</td>
<td>2.0-5.4</td>
<td>0.23-0.51</td>
</tr>
<tr>
<td>A1FI</td>
<td>2.4-6.4</td>
<td>0.26-0.59</td>
</tr>
</tbody>
</table>

### Climate Change Implications in Water Resources Planning:

- **Scenario based approaches**
- **Use all models**
- **Model Culling?**
Uncertainties in GCM predictions due to:

- **Poor resolution** – South Florida not even modeled in some GCMs; greater errors at smaller scales

- From IPCC AR4-WG1, Ch. 8 - Simulation of tropical precipitation, ENSO, clouds and their response to climate change, etc.
Statistically Downscaled Data for US (1/8 degree) – BCSD/BCCA methods
A2 Emissions Scenario

GFDL
- Time slice 50 km

CGCM3

HADCM3
- Link to European Prudence

CCSM

RegCM3
- UC Santa Cruz
- ICTP

CRCM
- Quebec, Ouranos

HADRM3
- Hadley Centre

RSM
- Scripps

WRF
- NCAR/PNNL

Provide boundary conditions

1971-2000 current

2040-2070 future

GFDL

NARCCAP Scenario & Model Suite
What exactly we find for Florida?
1. GCMs
2. Statistically downscaled
3. Dynamically downscaled
GCM Skill for Florida
Projected Temperature Change from AOGCMs (for 2050) – Posterior Distribution

- The vertical bars correspond to the percentiles, 5% and 95% of the posterior distributions of temperature change for b1, a1b, and a2 scenarios (red, black and blue)
Future Projections – Temperature & Precipitation

**Climate Division 5**

- **Temperature (°C)**
  - Ensemble mean
  - Models b1, a2
  - Years: 2000 to 2100

- **Precipitation (mm)**
  - Models b1, a1b, a2
  - Years: 2000 to 2100
Change: Magnitude & Seasonality

- **Everglades**
  - %Change in Mean Annual Precip.
  - Change in Mean Annual Temp.
  - 2041:2070 versus 1971:2000
  - b1, A1b, A2

- **Average Temperature**
  - 2050-2090
  - a2 scenario
  - Color scale: 15 to 30

**HYDROLOGIC & ENVIRONMENTAL SYSTEMS MODELING**

**SOUTH FLORIDA WATER MANAGEMENT DISTRICT**
Spatial Trends

 Latitude increasing →

 Temperature

 Latitude increasing →

 Precipitation
Changes in duration of “dog days” & “freezing temperatures”

Dog days – Mean Number of days average above 80º F

- Historical
- CGCM3-CRCM
- HADCM3-HRM3

Freezing – Mean Number of days minimum below 32º F

- Historical
- Change from 1970-1999 to 2040-2069
- Change from 1970-1999 to 2040-2069

BCCA
Bias Temperature

Comparison of CGCM3_CRCM and Historical Data

Comparison of CGCM3_RCM3 and Historical Data

Comparison of GFDL_RCM3 and Historical Data

Comparison of HADCM3_HRM3 and Historical Data
Change Temperature

NARCCAP
Change in Precipitation

Comparison of CGCM3_CRCM current vs. future

Comparison of CGCM3_RCM3 current vs. future

Comparison of GFDL_RCM3 current vs. future

Comparison of HADCM3_HRM3 current vs. future

NARCCAP
Model skill: Precipitation Extremes (Rainfall Depth – Duration)

50-Year, Location: WEST PALM BEACH INTERNA

50-Year, Location: PENSACOLA REGIONAL AP

Return Level (inches)

Duration (hrs)
By 2050 (findings to date - may change as science evolves)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Global Models</th>
<th>Statistically Downscaled Data</th>
<th>Dynamically Downscaled Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Temperature</td>
<td>1 to 1.5°C</td>
<td>1 to 2°C</td>
<td>1.6 to 2.4°C</td>
</tr>
<tr>
<td>Precipitation</td>
<td>-10% to +10%</td>
<td>-5% to +5%</td>
<td>-3 to 6 inches</td>
</tr>
<tr>
<td>Reference Crop Evapotranspiration</td>
<td></td>
<td></td>
<td>3 to 6 inches*</td>
</tr>
</tbody>
</table>
Water Supply Threats
Precipitation & Temperature Change Sensitivity

(2050 with Climate Change) minus 2050
(CERP with CC) minus CERP0

*Surface Ponding decrease > 0.3 feet

CC change: Precipitation decrease of 10% while potential evapotranspiration (PET) was estimated using an increase the daily temperature by 1.5°Celsius. The exact impact of global climate change on evapotranspiration is not known and therefore a simple temperature based method was used to estimate the change in solar radiation for computing PET.
Hydrologic & Environmental Systems Modeling

Ocean Land Atmosphere Model (RAMAS)

- Team at RSMAS:
  - Dr. Brian Soden
  - Dr. Amy Clement
  - Dr. Robert Walko
  - Dr. Craig Mattocks
  - Roque Vinicio Cespedes (MS student)

- How will landuse changes affect micro-climate?
Summary

- Resolutions of GCMs inadequate to capture hydro-meteorology of Florida peninsula
- Skills of models for regional climate information may not be adequate, yet. More work is need to verify and improve the methods/models.
- Need to work together on a “unified set of climate scenarios” for Florida.
Questions?
Extra slides
Tropical Storms & Climate Change

- Premature to conclude that human activities have had detectable impact on hurricane activity
- Tropical cyclones to shift towards strong storms (2-11% intensity increase by 2100)
- Decrease in global frequency of tropical cyclones (6-34%)
- Increase in the frequency of the most intense cyclones
- Increase in rainfall rate, 20% within 100 km of storm center

Knutson et al., Nature Geoscience, 2010
Natural Variability (Teleconnections)

Rainfall patterns:
- Drier
- Wetter
- More Variable

Tropical storm patterns:
- 'Warm' 2000

Lake Okeechobee Inflow
What is OLAM?

- Ocean Land Atmosphere Model
- New, full-physics non-hydrostatic Earth System Model based on Regional Atmospheric Modeling System (RAMS)
- Unstructured grid (triangular or hexagonal mesh)
- Local mesh refinement instead of nesting: two-way seamless communication between regional/mesoscale and global portions of grid domain through conservative advection and turbulent transport

Fig. 2. Example of local mesh refinement applied to left portion of figure, and projection of a surface triangle cell to larger concentric spheres to generate multiple vertical model levels. In this example, $N = 5$. 
Florida - Main Observations

- **↑** number of wet days during the dry season – POR
- **↓** May precipitation throughout the state – POR and especially post-1950. *May* be linked to changes in start of the wet season.
- Urban heat island effect – urban (and drained) areas
  - **↑** Tave and **↑** number of dog days for wet (warm) season especially post-1950
  - Decrease in DTR (**↑** Tmin > **↑** Tmax)
  - **↑** Annual maximum of Tave and Tmin for all seasons in POR and especially post-1950
GEV parameters of annual maxima

Duration = 6-hours

Duration = 24 hours
Comparison of CGCM3_CRCM and Historical Data

Comparison of CGCM3_RCM3 and Historical Data

Bias Temperature

Comparison of GFDL_RCM3 and Historical Data

Comparison of HADCM3_HRM3 and Historical Data
Change Temperature
Bias in Precipitation
Change Precipitation
Bias

Temperature
Bias

Precipitation

NARCCAP
Regional Climate Change Projections from Multi-Model Ensembles (Tebaldi et al., 2008)

- A Bayesian approach
- Reward models with respect to BIAS (w.r.t. current climate) and CONVERGENCE (consensus on future projections)
- 23 Models, SRES scenarios A2(high), A1B (midrange), B1(low)
- Posterior distribution of precipitation & temperature for each season & future decades