Presentation Outline

- **Climate Variability – Seasonal to Interannual**
  - Climate Forecasts and Model Uncertainty
  - Water Allocation and Water Supply (Falls Lake)
  - Water and Energy Management

- **Climate Change – Long-term Planning**
  - Near-term Climate Change
  - System Design, Capacity Expansion
  - Water Sustainability and Climate (Cat 3) Project

- **Opportunities and Challenges**
Climate Variability and Change

- **Climate Variability**
  - Structured Interannual and Longer Variations
  - Due to internal feedback processes
  - Adaptive seasonal/interannual water management

- **Climate Change and Land Use**
  - Increased CO$_2$ concentration and population growth
  - Non-stationary hydroclimatology
  - Relevant to System Design, Planning and Capacity Expansion Projects, Instream Ecology

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**Downscaling Climate Information – Two Approaches**

- General Circulation Model
  - "Downscaling" Regional Climate Model
  - Dynamical Downscaling
  - Precipitation & Temperature

- Climatic Predictors/Projections Land-Surface Conditions
  - Statistical Model
  - Statistical Downscaling
  - Streamflow Projections/Forecasts
Hydroclimatic Risk on Water Management

- **Forecast Producers**
  - Climate Scientists and Hydrologists
  - Express seasonal streamflow uncertainty as terciles/ensembles

- **Forecast Consumers**
  - Water Managers and Reservoir Operators
  - Often risk averse; No reward for using forecasts
  - Difficulty interpreting/relating forecasts to releases
  - Often manages the system based on rule curves
  - Need not quantify conditional risk

Forecasting Summer Flows into Falls Lake

![Graph showing streamflow with correlation = 0.52](image)

**Correlation = 0.52**

Golembesky and Sankar, JWRM, 2009
Probability of Meeting the Target Storage

Golembesky and Sankarasubramanian, JWRM, 2009

Increased Hydropower – Angat Reservoir, Manila
How Climate Forecasts can improve long-term operation?

Sankarasubramanian et al., 2009, WRR

State Climate Office of North Carolina

Experimental Reservoir Inflow Forecast

Individual Year Forecasts

Model Description

Individual Year Forecasts

Retrospective Forecasts and Unit Summary

Site: Scott Lake Project
Forecast timestep: Seasonal
Candidate model(s): PCR Retrospective
Select the subtype: Inflow
Forecast date: January 2011
Select climatological percentiles: 10, 33, 50, 67, 90
Select model percentiles: 10, 33, 50, 67, 90
Number of seasons of climatological percentiles before forecast: 1
Number of seasons of climatological percentiles after forecast: 2
Forecast Portal - Automation

IRI Data Library
Precipitation Forecasts ($P_t$) from GCMs

Predictors
Observed Streamflow ($Q_{t-1}$)
State Climate Office of NC

Predictand
Forecasted Streamflow ($Q_t$)

Skill Measures:
Correlation, Mean Square Skill Score, Rank Probability Skill Score

1957-1989
1990-till date

Inflow Forecast Portal –
http://www.nc-climate.ncsu.edu/inflowforecast

Skill - Correlation – Seasonal and Monthly

<table>
<thead>
<tr>
<th>Site</th>
<th>Winter</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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<tbody>
<tr>
<td>Falls Lake</td>
<td>0.50</td>
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<tr>
<td>Jordan Lake</td>
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<td>0.59</td>
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<td>Rocky Creek</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.49</td>
</tr>
</tbody>
</table>
Integrated Drought Management Portal

Under Monthly Updated Streamflow Forecasting Scheme:

- Precipitation Forecasts (GCM)
  - 2.8° Spatial Scale
  - Monthly Temporal Scale
- Spatial Downscaling
- Temporal Disaggregation
- Climatological Forcings (excluding Precipitation)
  (e.g., Wind, Solar Radiation, Pressure, etc.)

Soil Moisture Forecasts (2002 Drought) – NASA LIS (Noah LSM)
Climate-Water-Energy: Opportunities and Challenges

• For seasonal forecasts to be useful
  – Initial storage should constrain the allocation; If not, 100% reliability;
• Use end of season target storage constraint
  – If initial storage does not constrain allocation
  – If skill is good only during a particular season
  – To enforce restrictions for below normal conditions
  – To reduce spillage and increase allocation (primarily hydropower) for above normal conditions
• Perspectives from Forecasting
  – Update the forecasts within the season (very beneficial for hydropower systems)
  – Multimodel climate forecasts are better, since it reduces overconfidence of individual models
  – Provides better correspondence between forecast probability and its observed frequency

Water Sustainability under Near-term Climate Change: A Cross-Regional Analysis Incorporating Socio-Ecological Feedbacks and Adaptations

http://www.waterforthesunbelt.org/

NCSU: Sankar Arumugam, Emily Zechman, Kumar Mahinthakumar, Tushar Sinha, Seung Seo, Raj Bhowmik, Shams Al-Amin; NOAA: Ken Kunkel and Wei Liu
ASU: John Sabo, Albert Ruthi, Kelli Larson, Deborah Ayodale
FIU: John Kominoski, Megan Hagler
Reliability-Resiliency Impacts – CMIP3

Resiliency = \( \frac{1 - \text{mean annual Release}}{\text{mean annual inflow}} \div CV \)

Singh et al., 2014, JWRPM

Climate-Water-Energy : Opportunities and Challenges

- **Forecasts are more useful than climatology**
  - Within year storage systems (typically humid basins) than over year (arid basins) systems
  - Reducing system losses (spill and evaporation)
  - Systems with low storage/annual demand ratio
  - Multiple uses constraining the allocation process

- **Near-term Climate Change Projections**
  - 10-year updated and 30-year updated hindcasts
  - Adaptive Management and feedback representation
  - Climate variability vs Climate Change
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