Climate Hazard Assessment and Risk Management in the Southeastern United States

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• Climate Science--Forecasts and Projections
• Impacts and Vulnerabilities
• Solutions
Climate Science
Water resources are increasingly stressed in the Southeast
Monthly/Seasonal Projections

- Mean temperature and precipitation anomalies are forecast up to ~ 1 year in advance, based on:
  - Observed and Projected Remote Sea Surface Temperatures (e.g. ENSO)
  - Land surface conditions (e.g. soil moisture, snow cover)
  - Historical trends

- Skill is limited, especially for precipitation
Modes of Climate Variability: El Nino Southern Oscillation

The majority of GCMs indicate a more El Nino-like mean state in the future. However, most GCMs are not able to reproduce the observed magnitude or frequency of ENSO.
Climate Change – Models

• Need both natural and man-made influences (as well as feedbacks) to accurately represent historical climate

  – Natural:
    • Volcanoes
    • Natural gas transfers
    • Solar cycles
      – Sun spots,
      – Changes in axis and orbits

  – Man-made:
    • Greenhouse gas emissions
    • Aerosol emissions
    • Land-use changes

IPCC, 2007
Climate Change – Model Validation

Global and Continental Temperature Change

IPCC, 2007
Sources of Uncertainty in Climate Change Projections

- Role of climate variability, much of which is unpredictable, relative to climate change
- Future concentrations of greenhouse gases, aerosols, and other climate drivers
- Climate system response/sensitivity to greenhouse gases and other climate drivers
- Role of local phenomena not captured by global climate models
Climate Change – Models

• Use calibrated models to make “projections” of the future
  – The course of the future depends on the steps we take

• Scenarios of the future depend upon:
  – new technologies
  – technology sharing
  – population
  – volcanoes
  – emissions controls

If we stop all emissions now, we still get warming

IPCC, 2007
- Enhanced water cycle with warmer temperatures
  - More evaporation and rainfall
  - Dry areas get drier
  - Storms release more water at a time
  - Wet areas get wetter
### GCM-based Regional Projections for Titusville, FL--Mean Changes

#### Air temperature
- **Baseline (1971–2000):** 71 °F
- **2020s:** +1 to 2 °F
- **2050s:** +2 to 3.5 °F
- **2080s:** +3 to 6 °F

#### Precipitation
- **Baseline (1971–2000):** 52.0 in
- **2020s:** -5 to +5 %
- **2050s:** -5 to +5 %
- **2080s:** -10 to +5 %

#### Sea level rise
- **Baseline:** NA
- **2020s:** +2 to 3 in
- **2050s:** +5 to 8 in
- **2080s:** +9 to 15 in

#### Rapid ice-melt
- **Sea level rise:** NA
- **2020s:** ~6 to 8 in
- **2050s:** ~21 to 24 in
- **2080s:** ~43 to 49 in

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1 Based on 16 GCMs (7 GCMs for sea level rise) and 3 emissions scenarios. Baseline is 1971-2000 for temperatures and precipitation and 2000-2004 for sea level rise. Data from National Weather Service (NWS) and National Oceanic and Atmospheric Administration (NOAA). Temperature data and precipitation data are from Titusville, Florida.

2 Central range = middle 67% of values from model-based probabilities; temperature ranges are rounded to the nearest half-degree, precipitation to the nearest 5%, and sea level rise to the nearest inch.

3 The model-based sea level rise projections may represent the range of possible outcomes less completely than the temperature and precipitation projections.

4 "Rapid ice-melt scenario" is based on acceleration of recent rates of ice melt in the Greenland and West Antarctic Ice sheets and paleoclimate studies.

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**Combined observed and projected temperature and precipitation. The three thick lines (green, red, and blue) show the average for each emissions scenario across the 16 GCMs. Shading shows the central range. The bottom and top lines, respectively, show each year’s minimum and maximum projections across the suite of simulations. A ten-year filter has been applied to the observed data and model output. The dotted area between 2002 and 2015 represents the period that is not covered due to the smoothing procedure.**

Source: Columbia Center for Climate Systems Research
Comparison of Long Term Greenhouse Gas Signal to Interannual Variability
GCM-based Regional Projections—Extreme Events

1) Natural variability will continue
2) Large impacts when natural variability combines with gradual mean changes
3) Subtle shifts in mean values can lead to large changes in the frequency of extremes
4) This suggests policy relevance, although uncertainties associated with extreme event projections are large

### Extreme Event

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Baseline (1971-2000)</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td># of days/year with maximum temperature exceeding: 90°F</td>
<td>14</td>
<td>23 to 29</td>
<td>29 to 45</td>
<td>37 to 64</td>
</tr>
<tr>
<td>100°F</td>
<td>0.4</td>
<td>0.6 to 1</td>
<td>1 to 4</td>
<td>2 to 9</td>
</tr>
<tr>
<td># of heat waves/year</td>
<td>2</td>
<td>3 to 4</td>
<td>4 to 6</td>
<td>5 to 8</td>
</tr>
<tr>
<td>Average duration (in days)</td>
<td>4</td>
<td>4 to 5</td>
<td>5 to 5</td>
<td>5 to 7</td>
</tr>
<tr>
<td># of days/year with minimum temperature below 32°F</td>
<td>72</td>
<td>53 to 61</td>
<td>45 to 54</td>
<td>36 to 49</td>
</tr>
<tr>
<td>1-in-10 yr flood to reoccur, on average</td>
<td>~once every 10 yrs</td>
<td>~once every 8 to 10 yrs</td>
<td>~once every 3 to 6 yrs</td>
<td>~once every 1 to 3 yrs</td>
</tr>
<tr>
<td>Flood heights associated with 1-in-10 yr flood (in feet)</td>
<td>6.3</td>
<td>6.5 to 6.8</td>
<td>7.0 to 7.3</td>
<td>7.4 to 8.2</td>
</tr>
</tbody>
</table>
Increases in Amounts of Very Heavy Precipitation (1958 to 2007)

Projected Changes in Light, Moderate, and Heavy Precipitation (by 2090s)

Updated from Groisman et al.\textsuperscript{113}
The IPCC 2007 approach to sea level rise may be too conservative

Observed sea level has been tracking slightly above the high end IPCC projections.

Climate models, due to low spatial resolution and incomplete physics, cannot capture important dynamical ice melt processes that are being observed, especially:

1) meltwater ponds and basal lubrication of glaciers
2) thinning of buttressing ice shelves that hold back land-based ice
3) thinning of ice at grounding lines

The IPCC 2007 approach to sea level rise may be too conservative.
Feedbacks and Possible Surprises

**Negative feedbacks that might minimize warming:**

An increase in thick, low clouds
More sun-blocking airborne dust due to disturbed conditions

**Positive feedbacks that might increase warming:**

Greater surface absorption of sunlight as snow and ice melt
Release of greenhouse gases from “permafrost” as it melts
Decreased CO2 uptake by the ocean as it warms
An increase in high, thin clouds
More forest fires with heating release more CO2
Poleward forest expansion may cause more sunlight absorption
Deep ocean warming might release greenhouse gases
Arctic Sea Ice Loss--Underestimated by GCMs

September 2007

September 2007 sea ice extent was 36% below the 27-year average, 23% below the prior minimum, and approximately 50% below the average values of the 1950s.

Implications for the Southeast?
- Cold air outbreaks?
- Storm tracks?
- Indirect sea level rise effects?

Source: National Snow and Ice Data Center
Impacts and Vulnerability
Potential Impacts – Ocean Ecosystems

• Ocean acidification
  – lowered pH will dissolve calcium-based shells and skeletons

<table>
<thead>
<tr>
<th>Current Levels of CO2</th>
<th>Scanning electron microscopy of calcifying phytoplankton for:</th>
<th>Projected Levels of CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Calcisclus Leptoporus</strong></td>
<td></td>
</tr>
<tr>
<td>Current CO2 of 280 to 380 ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projections of CO2 of 580 to 720 ppm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Coral Reefs
  – Require a narrow range of ocean temperatures
  – Require sea level to be at a certain level
  – Cannot migrate and grow as fast as temperatures and depths will change

From Robert Corell
Potential Impacts: Energy Sector

During heat waves, even a small increase in temperature can mean a large increase in energy load....

...Leading to an increased risk of power outages and deteriorating air quality

Indirect effects

= More stress on systems
**Impacts: Heat Waves and the Energy and Health Sectors (2)**

**Asthma Hospitalizations, 1997 – All Ages**

**Vulnerability**

Non-linearity

Remote climate hazards

Combined effects of multiple climate hazards

=Cascading uncertainty
Adaptation
1. Identify current and future climate hazards
2. Conduct risk assessment inventory of infrastructure and assets
3. Characterize risk of climate change on infrastructure
4. Develop initial adaptation strategies
5. Link strategies to capital and rehabilitation cycles
6. Identify opportunities for coordination
7. Prepare and implement Adaptation Plans
8. Monitor and Reassess

The 8 Steps of Adaptation Assessment

New York City Panel on Climate Change, 2009
Water Availability and Quality--Adaptation

**Water Availability**
- Diversify water sources (desalinization, expand groundwater system)
- Expand water conservation and usage restrictions
- Expand water transfer capabilities

**Water Quality**
- Acquire additional land and expand conservation programs
- Increase operational flexibility
- Treat with chemicals as necessary
Drainage and Wastewater Management Adaptations

Rainwater Drainage

• Improve collection (expand sewers and pumps, and retain stormwater above ground)
• Enhance natural landscape and drainage
• Plan for controlled flooding

Storm Surge & Water Treatment

• Raise elevation of key infrastructure
• Use watertight containment of key equipment
• Have reserves of key equipment
• Install local protective barriers
• Allow some inundation in defined areas

August 8, 2007

NYC Department of Environmental Protection, 2008
Risk Management Approach

Flexible Adaptation Pathways to managing flood

Risk = Probability x Outcome

Based on London’s model
Conclusions

- The Southeast faces a range of current and future climate hazards

- In the coming decades, the climate change signal associated with mean temperatures and mean sea level is expected to dominate the climate variability term, leading to dramatic and policy-relevant shifts in the probability of extreme events

- The most cost-effective and efficient adaptation strategies are often relatively low-tech; these strategies are often focused on the most vulnerable populations and climate & climate change concerns may be secondary

- Our understanding of climate, climate impacts, and climate change solutions remains limited

- Uncertainty is widespread in all systems, and does not argue for inaction (although it does present a host of challenges)

- Long-term planning can lessen negative outcomes of climate change, and increase positive outcomes

- Responding to today’s weather risks helps to prepare for climate change risk in the future, and increases resiliency generally