Science Theme #1
Climate assessments and projections
Radley Horton, Ph. D., Columbia
Lorraine L. Janus, Ph. D., NYCDEP
Talk Outline

Theme # 1: Climate assessments and projections

• Radley Horton, Columbia
  – Background: Climate scientist, impact and adaptation researcher
  – Consortium Expertise: Regional Climate Projections for Decision Making, Sea level Rise, Preparing for Potential Surprises

• Lorraine L. Janus, NYCDEP
  – NYCDEP Mission = clean water for 9 million
  – Case study – CCTF and CLIME
Theme # 1: Climate assessments and projections

• Intro Consortium speaker
  – Columbia University / NASA Goddard Institute for Space Studies; research interests include Extreme climate events, Sea level rise, and Arctic sea ice and its teleconnections to mid-latitudes

• Broad science background of theme
  – Global climate models and their evaluation; uncertainties associated with regional/local climate projections and downscaling; approaches to impact and adaptation assessment

• Consortium expertise/Ongoing Projects
  – Extreme event projections based on (downscaled) global climate models; urban impacts and adaptation strategies being assessed through the
Global Climate Models and Projections

- Global climate models:
  - Are physics-based, and solve equations for mass, momentum, and energy within ‘gridboxes’
  - Include parameterizations of hydrology, clouds, vegetation, and ocean
  - Couple fluxes between the atmosphere, ocean, land, and cryosphere
  - Contain hundreds to thousands of pages of computer code, divided into interacting components (e.g., dynamics, radiation, and clouds)
  - Require the use of supercomputers and or parallel computing
  - As computing power increases, model resolution (in time and space), complexity, and interactivity are all being improved

Global climate models are our most powerful tool for making climate predictions
CMIP 3 and CMIP 5

Sea Level Rise Methods and Projections

- IPCC-based approach
  - Global thermal expansion
  - Local land subsidence (GIA)
  - Meltwater from glaciers, ice caps, and ice sheets
  - Local water surface elevation

- Rapid ice-melt approach
  - Based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets and paleoclimate studies

- Rationale:
  - Observed sea level slightly above high end IPCC projections
  - Climate models cannot yet fully capture processes such as:
    - Surface ponding and basal lubrication of glaciers
    - Thinning of ice shelves that buttress land ice
    - Thinning of ice at grounding lines

Horton and Rosenzweig, NYAS, 2010
Extreme Events: Heat Events as Simulated by Regional Climate Models, 2050s vs. 1980s baseline

Change in hottest JJA Tmax per year minus change in mean JJA Tmax

Horton, et al., in preparation

Tmax - % of Gridboxes in the Northeast
Extreme - Mean > 1.5 C = 8.3%
Extreme - Mean > 1 C =
Possible Climate Surprises

Are all key sources of climate, and other, uncertainty being considered?

- For example, there are things GCMs do not do well that could be associated with tipping points (e.g., sea ice anomalies)

Stroeve et al. GRL, 2007, observed line updated/adapted at climatecrocks.com

Liu et al. PNAS, 2012

Change in winter snow cover (%) corresponding to a 1 million square km decrease in autumn arctic sea ice area
National Climate Assessment

• Will include short regional and sector chapters
• Supported by technical input reports; Northeast Sourcebook, based on contributions from approximately 60 authors contains:
  – I. Introduction
  – II. Climate Change Problem-Solving in the NE – A Legacy of Action
  – III. Need-to-Know Information for Systems and Sectors
  – IV. Climate Change Impacts and Solutions by Sectors and Systems
  – V. Climate Change and Regional and Local Identities Within the Northeast: New England, Mid-Atlantic, Appalachia and Western Interior, and the Urban Northeast Corridor
  – VI. Climate Change Decision Support Tools and Resources
  – VII. Conclusions and Recommendations
Theme # 1: Climate assessments and projections

• Stakeholder (introduction):
  – NYCDEP operates the NYC water supply for 9 million consumers
  – limnologist; WQ manager in FL and NY >20 years; active in CC projects for > 13 years
  – watershed and reservoir WQ perspective

• Broad explanation of science needs; (set by “mission statement”):
  – **Long-term monitoring records** for status, trends, and model development
  – **Models** used to guide operations and project future water quality
  – **GCM Downscaling methods**; develop reasonable future scenarios of changes in forcing factors for WQ models (precipitation, temperature, flow)
  – Need to **understand ecology** and trigger points for major ecological or biogeochemical changes

• Some of climate-related research activities:
  – Monitoring: long-term and continuous monitoring – trends observed
  – Statistical evaluation of extreme event frequency
  – Model input with “change factors” derived from emission scenarios
  – Qualitative observations of ecological relationships
What is at stake? The NYC Water Supply Watershed

Climate Change will affect the vast resource of the water supply and its ecology in many ways.

- Primarily a surface water supply
- 19 reservoirs & 3 controlled lakes
- Serves **9 million people** (1/2 of population of New York State)
- Delivers approx. **1.2 billion gallons** (**4.5 million kiloliters**) per day to the City
- Source of water is a 2,000 square mile (**5,180 square kilometer**) watershed in parts of 8 upstate counties
- Operated and maintained by NYCDEP

![Map of New York City's Water Supply System](image)
Data Needs - largely set by a mission statement.

Climate Change Task Force
Mission Statement:

Ensure that DEP’s strategic and capital planning take into account the potential risks posed by climate change — sea level rise, higher temperature, increase in extreme events, and changing precipitation patterns — on the City’s water supply, sewer and wastewater treatment systems.
Theme # 1: Climate assessments and projections

Data Needs: Importance of long-term monitoring

• Example: USGS study in Catskills (D. Burns, et. al., 2007)
  – Temperature trends increase 0.5 - 2.0 C in 50 years (1952 – 2008).
    Trend was significant for 5 of 9 sites throughout Catskill Mountains
  – Precipitation trends increase about 7.9 - 26.3 cm in 50 years. Trend
    significant for 6 of 12 precipitation sites throughout Catskills
  – Shifts in the winter streamflow patterns have been detected, with a
    movement of the traditional high spring runoff period from early April to
    late March. Trend significant for 2 of 8 stream gauges in Catskills

• Long-term data records are needed to define status, range of
  variation, and trends in “baseline”

• Continuous monitoring is valuable for capture of short-term
  events (e.g., storm flow peaks or stratification changes due to
  extreme events) that are usually missed by fixed-frequency
  monitoring
Statistical analysis to show trends in frequency of extreme events (A. Matonse et al., 2012)

Changes in frequency of extreme events:
Number of daily streamflow events exceeding long term 95th %tile

**Annual**

**Cold Season**

**Warm Season**
Projections of critical forcing factors (D. Pierson, et. al., 2010)

Modeling results of seasonal changes in air temperature, precipitation, snowpack and streamflow

Air Temperature (°C)

Total Precipitation (cm)

Snowpack Water Equivalent (cm)

Stream Discharge (cm)

Line shows current climate results

max
87.5 %tile
median
12.5 %tile
min
Models used to evaluate effects of climate change

**Changes**
- Watershed Management
- Land Use Changes
- Climate Change (*Delta Change, SDM, RCM*)

**Data**
- Watershed
  - Land Use
  - Soils
  - Topography
  - Hydrography
  - GIS Based
  - Management
- Time Series
  - Meteorology
  - Flows
  - WQ
- Reservoir
  - Bathymetry
  - Infrastructure
- System
  - Operating Rules
  - Demand

**Models**
- Watershed Models (*GWLF-VSA, SWAT*)
- Reservoir Models (*1D Hydrothermal Eutrophication, CEQUAL-W2*)
- System Model (*OASIS*)

**Results**
- Trophic State
- Turbidity
  - Freq / Magnitude
  - Alum Decisions
- System Performance
  - Storage
  - Demand
  - Spills
Reservoir thermal structure under different climate scenarios

Surface Water Temperature

Onset of Stratification

Loss of Stratification

Duration of Stratification

Schmidt Stability

Reservoir + thermal structure under different climate scenarios
Modeling used to guide flow operations and control turbidity

Delaware Effluent Median Trace Turbidity

Catskill Influent Turbidity = 15 NTU

Catskill Influent Turbidity = 20 NTU

Catskill Influent Turbidity = 25 NTU

Catskill Inflow

- Blue: 50 mgd
- Yellow: 150 mgd
- Red: 250 mgd
Ecological consideration: climate will affect waterfowl migrations - a significant source of coliform bacteria

BIRDS:

COLIFORMS:
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Methods of engagement in regional climate change issues:

• University collaborations – CUNY contracts for post docs that provide on-site interaction of researchers
  – Support permanent staff

• WaterRF projects and Tailored Collaborations

• Participation as co-researchers in university projects supported by grants
The DEP Modeling Group

- Don Pierson – NYCDEP – Section Chief; senior modeler
- Don Kent – NYCDEP – data specialist contract manager
- David Lounsbury – NYCDEP GIS specialist
- Elliot Schneiderman – NYCDEP senior modeler
- Mark Zion – NYCDEP senior modeler
- Adao Matonse – CUNY reservoir system modeling
- Soni Pradhanang – CUNY watershed nutrient modeling
- Rajith Mukundan – CUNY watershed sediment modeling
- Yongtai Huang – CUNY reservoir modeler
- Nihar Samal – CUNY reservoir modeler
- Guoping Tang – CUNY forest modeler
- Aavudai Anandhi – CUNY climate data analysis
Key Climate Scenario Questions

• Variables?
  – Temperature, precipitation, radiation?

• Spatial?
  – What are the spatial scales of interest (1 km, 15 km, 275 km)?
  – What is the spatial extent of interest (local, regional, global)?

• Temporal?
  – What are the temporal scales of interest (daily, monthly, climate)?
  – What is the temporal extent of interest (historical, near-term, end-of-century)?

• Sensitivity of impacts models to climate?
Theme # 1: Climate assessments and projections

Thank you!

Please join our discussion:
[room #]
Models used to evaluate turbidity at different flow rates to avoid alum use

- Modeling to support operations is based on “forecast” flows.
- Long term forecasts are based on statistics of historical streamflow records.
- This assumes stationarity of long term statistics – is this still appropriate under changing climate?
- How should these long-term forecasts be adjusted to account for climate change?

Forecast Turbidity Input (based on flow)  
Predicted Aqueduct Turbidity