

Connecting Fundamental Atmospheric Research and Technology at BNL to Urban and Coastal Applications

“Accelerating data-driven research to significantly improve the development of applied prediction systems in energy hot spots”

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Center for Multiscale Applied Sensing

www.bnl.gov/cmas



Fundamental Atmospheric Research and Technology at BNL

Atmospheric System Research at BNL:

Influences of Aerosols and Clouds on Climate and Climate Forcing

Process-level understanding of aerosol-cloud-precipitation interactions

Atmospheric Radiation Measurement Climate Research Facility at BNL:

Design and build mobile aerosol laboratories

Instrument development

Radar data analysis & retrievals

Support long-term measurements and field campaigns

Conduct Large Eddy Simulations



Urban and Coastal Areas

The urban and coastal environment is arguably the most critical interface between humans and the atmosphere

Urban and coastal areas are rarely built in flat, homogeneous terrain

Need to consider topographic effects and local circulations (e.g. see breeze)



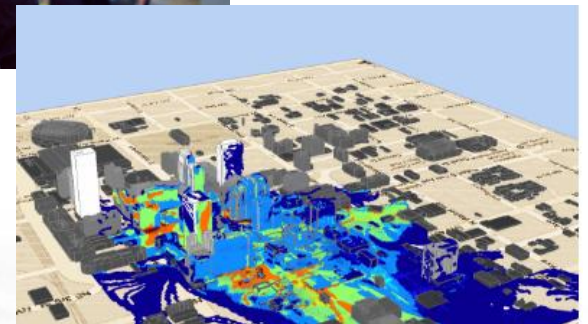
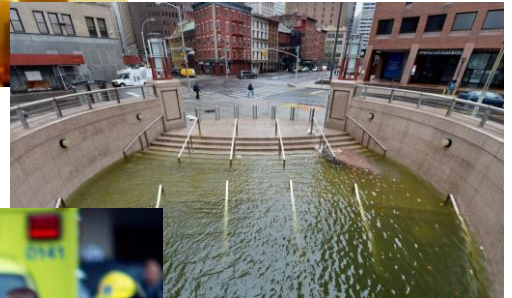
40% of global population live within 50 km of the coastline

Urban/Coastal Environment

Most of the world's population now lives in cities, which are already responsible for 70% of the world's carbon emissions

Extreme weather events are on the rise

Emergency services need urban dispersion model predictions



Cascading system failures

Disruptions of services in one infrastructure will almost always result in disruptions in one or more other infrastructures, especially in urban systems, triggering serious cross-sectoral cascading infrastructure system failures

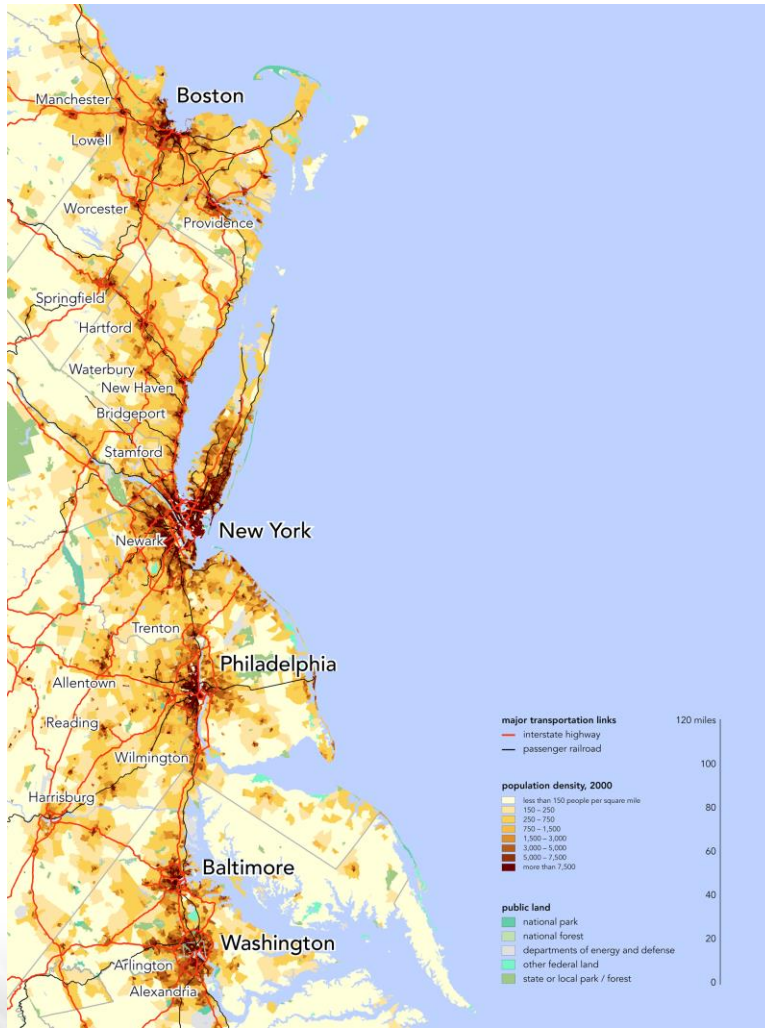


Northeast Megalopolis: Natural Laboratory?

A “natural” laboratory for the study of the urban environment which is arguably the most critical interface between humans and the atmosphere

... most complex
... least understood

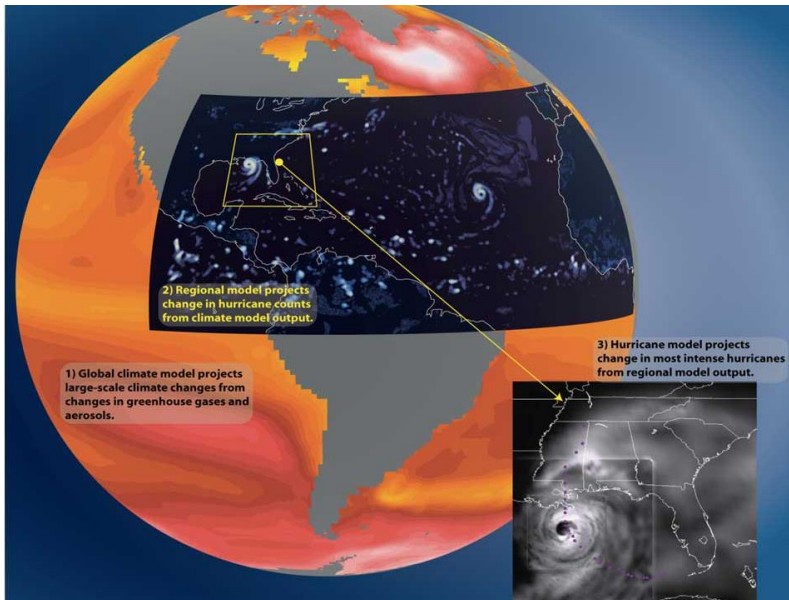
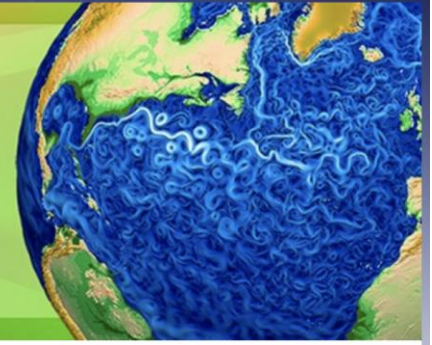
- Security
- Transportation
- Energy
- Air quality
- Weather
- Climate



60-80 million population
25% of the GDP

E³SM

Energy Exascale
Earth System Model



The Energy Exascale Earth System Model (E3SM) project, it is developing a computationally advanced coupled climate-energy model to investigate the challenges posed by the interactions of weather-climate scale variability with energy and related sectors.

<https://www.gfdl.noaa.gov/climate-model-downscaling/>

Dynamical and statistical downscaling

Urban/Coastal system: Multi-scale Grand Challenge



Global – Regional Scale
~ 20 km resolution



Mesoscale
~ 1 km resolution

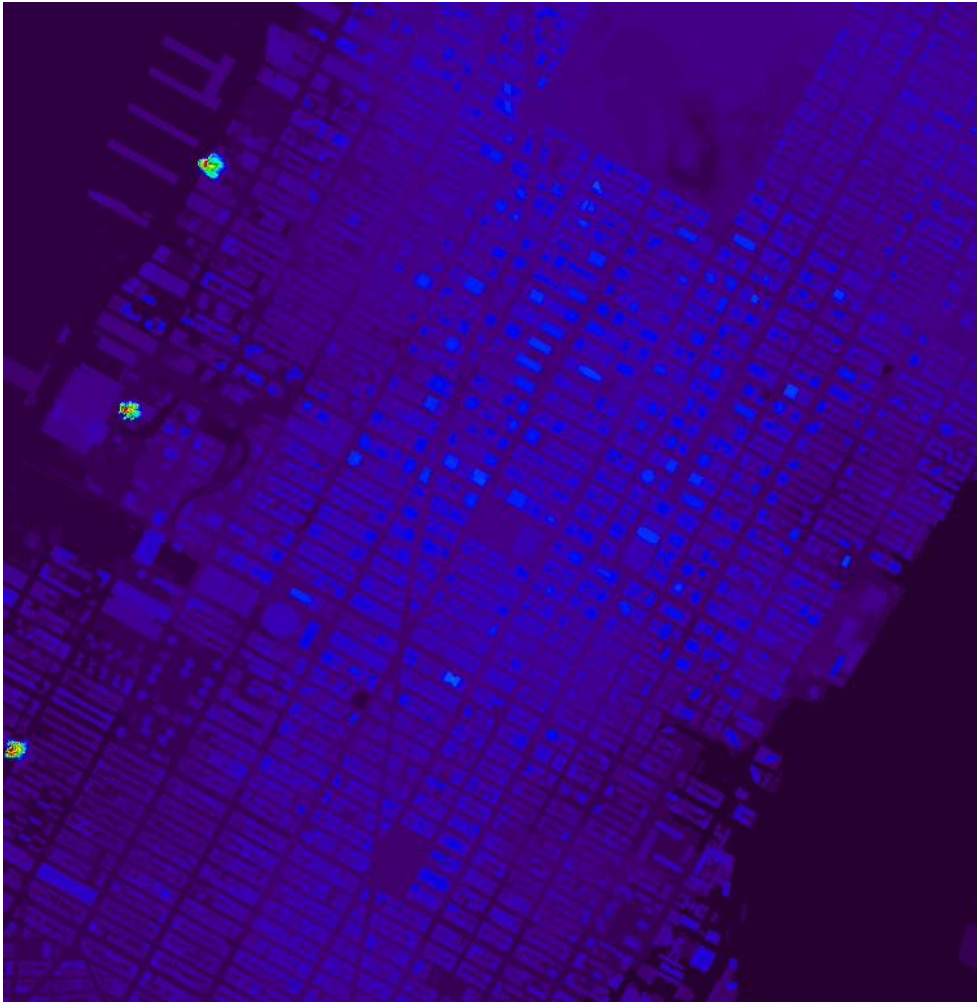


City – Street Scale
~ 5 m resolution



Downscaling

Transport of tracers over Manhattan



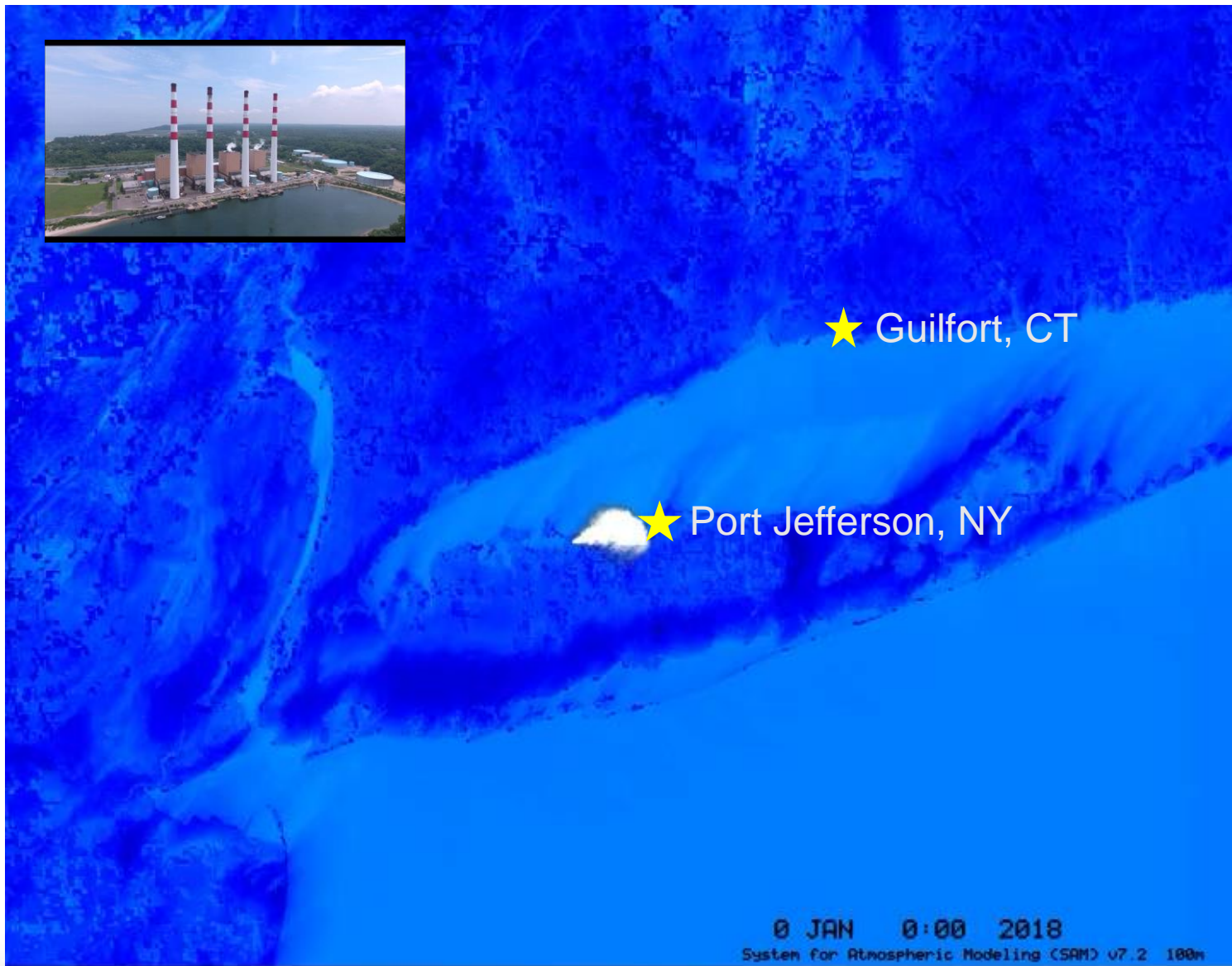
Are models able to reliably simulate the environment around buildings?

What disruptive technologies are available to provide these multiscale observations?

At what levels and how many urban measurements are needed?

The BNL truck-mounted sensors will allow to fingerprint the urban area, identify critical sites and to provide data validation of permanent met sensors in the urban environment

Simulations: Prof. Marat Khairoutdinov, Stony Brook University



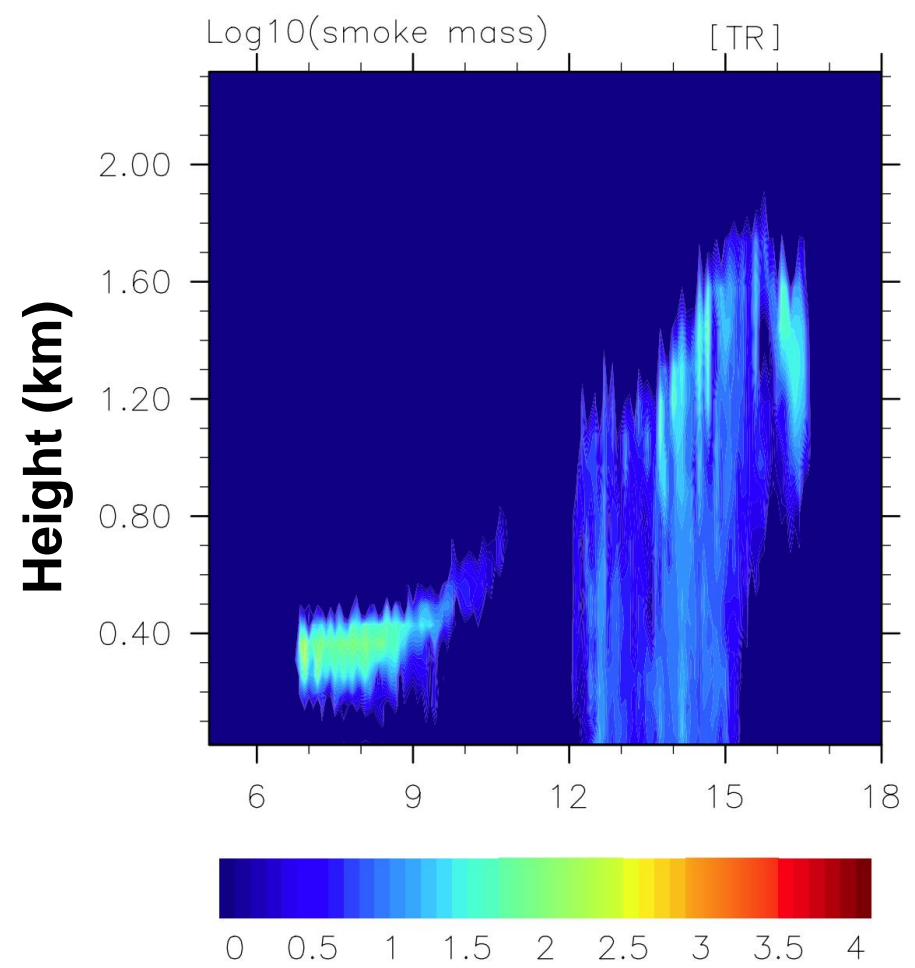
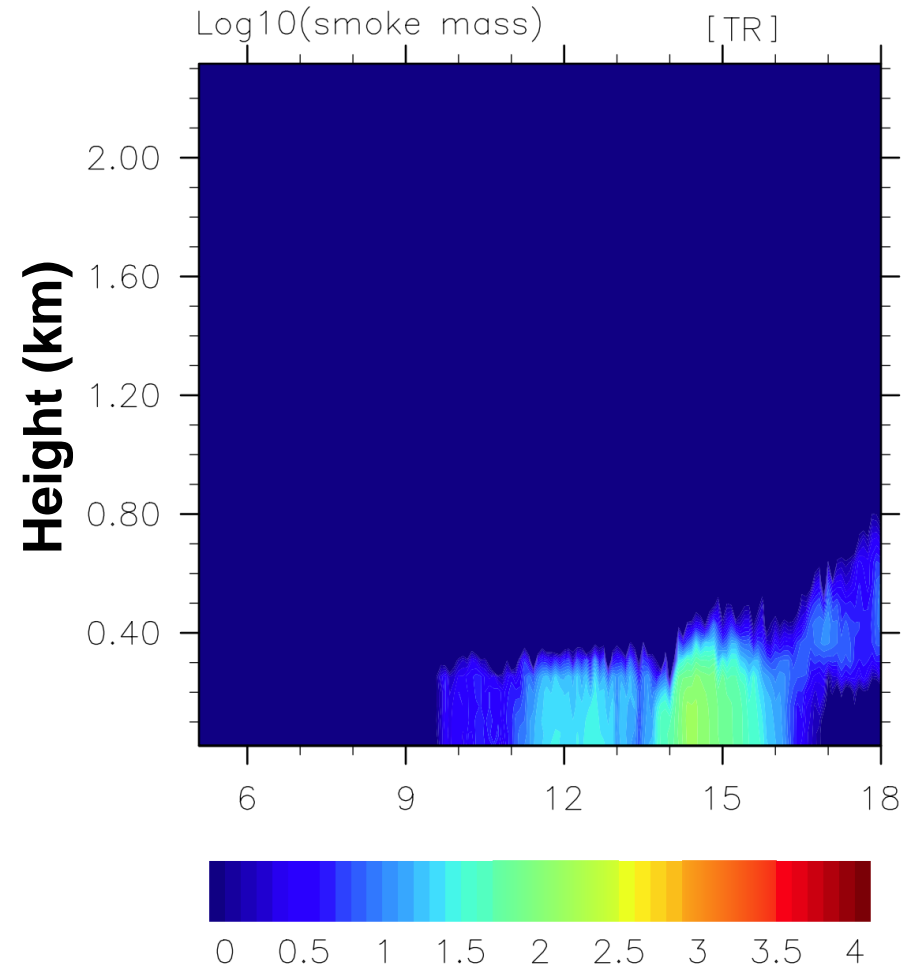
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System for Atmospheric Modeling (SAM) v7.2 100m



Simulations: Prof. Marat Khairoutdinov, Stony Brook University

Guilfort, CT

Port Jefferson, NY



Local time (hour)

Local time (hour)

Research and Development on Predicting the Solar and Wind Resource

CMAS Research Components



Multi-scale

Heterogeneous energy sources, landscapes, and amplified micro-climates



Applied

Using observational data to improve high-resolution modeling capabilities



Sensing

Providing expertise in measurement theory, instrument development, and advanced geophysical data analysis



3D Cloud Detection and Tracking System for Solar Forecast Using Multiple Sky Imagers



(a) TSI_1



(b) TSI_2



(c) TSI_3

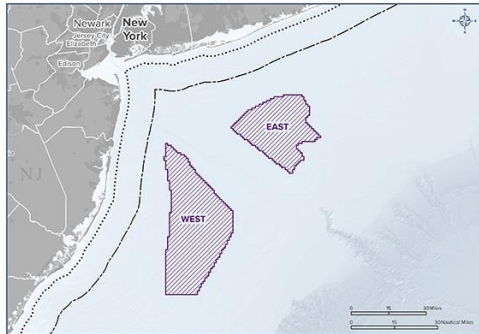
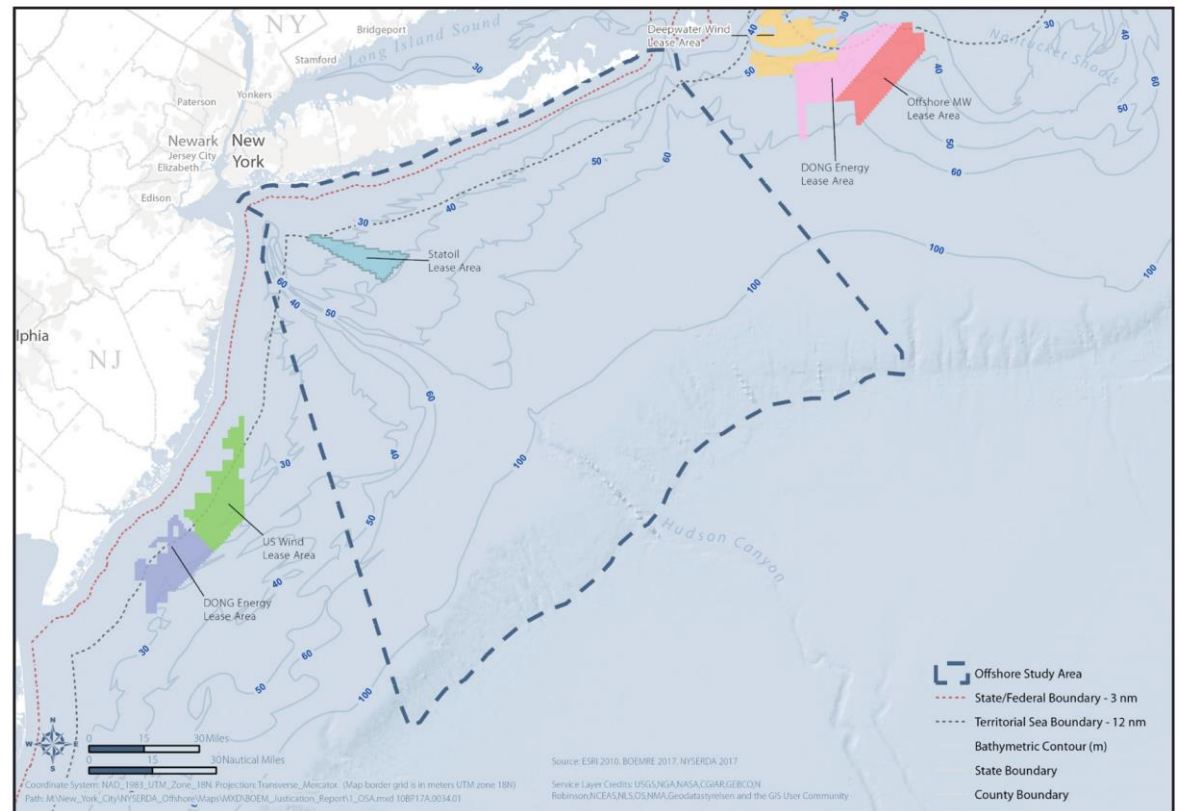


(d) Google Maps View

New York State to pursue the development of 2,400 megawatts (MW) of offshore wind energy by 2030— enough to power up to 1.2 million homes

Source: New York State Energy Research and Development Authority (NYSERDA)

Figure 1. Offshore Study Area.



Home

Multi-scale

Applied

Sensing

CR-SIM

People



Cities are subject to topographic effects and local circulations

Accelerating data-driven research to significantly improve the development of applied prediction systems in energy hot spots.

BNL Research Truck

A mobile laboratory containing sensors that measure winds, air quality, precipitation, and other variables is being deployed in urban and coastal areas as part of a larger effort to improve local forecasting capabilities in complex environments.

A portable scanning Doppler lidar for detecting wind speed and direction in the atmospheric boundary layer

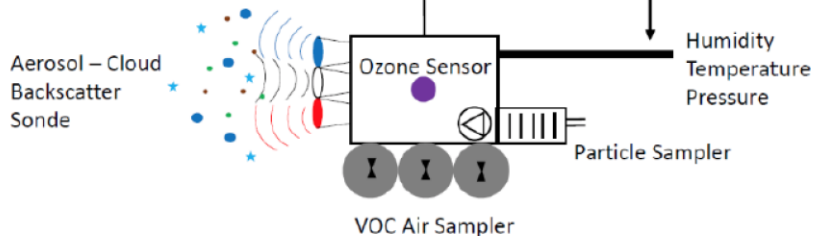


Air Quality and Meteorology Research Using Drones

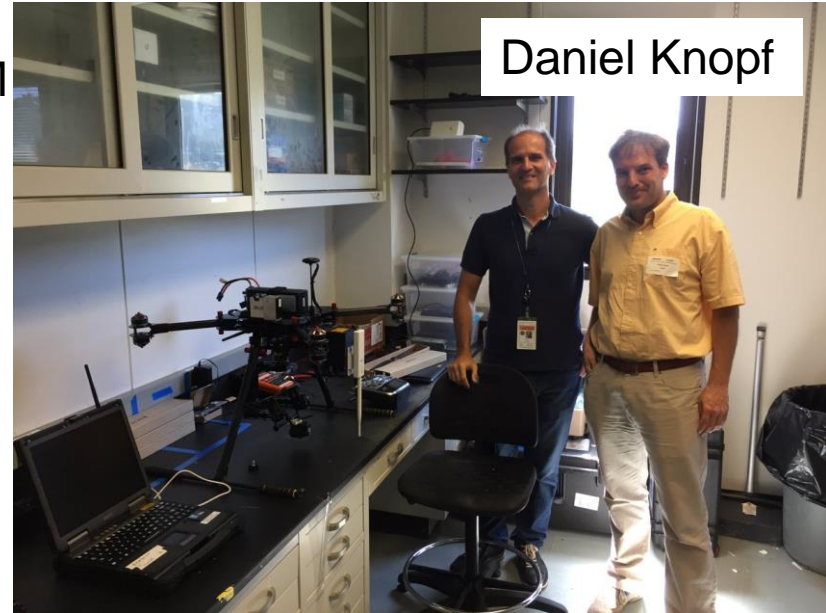
2018 SBU/BNL SEED GRANT PROGRAM



Distance to avoid rotor wash



Atmospheric chemistry parameters to be measured will include ozone, aerosol size distribution via backscatter, particle composition by collection on substrates, and air sampling for VOC characterization



Daniel Knopf



Andrew McMahon
Brookhaven National
Laboratory
Environmental & Climate
Sciences Department

Air Quality and Meteorology Research Using Drones



04/10/2019

First flight testing

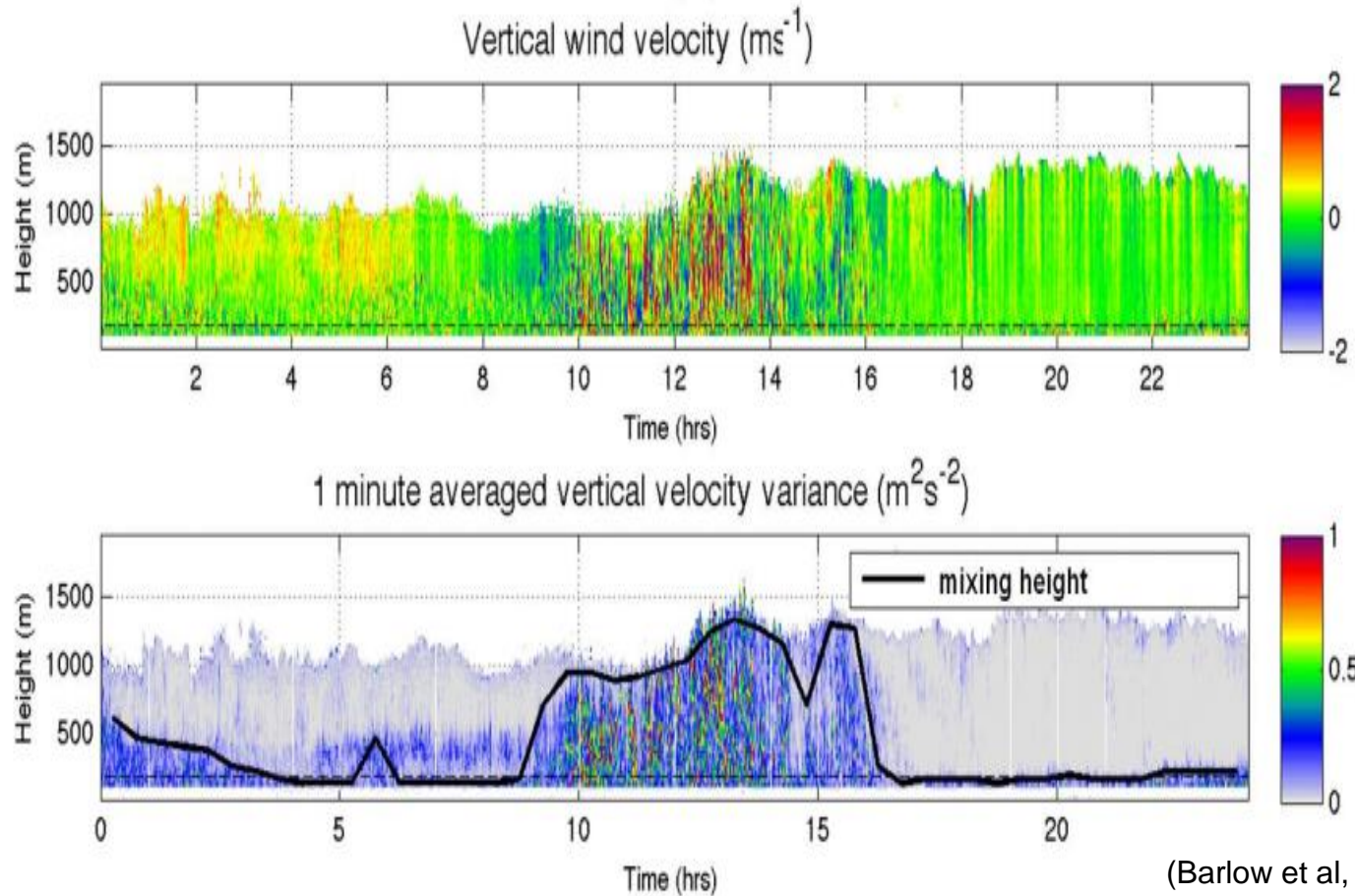


Urban Footprint

- Permanent observations station in Manhattan
- Doppler lidar
- Doppler radar
- Complete surface flux system



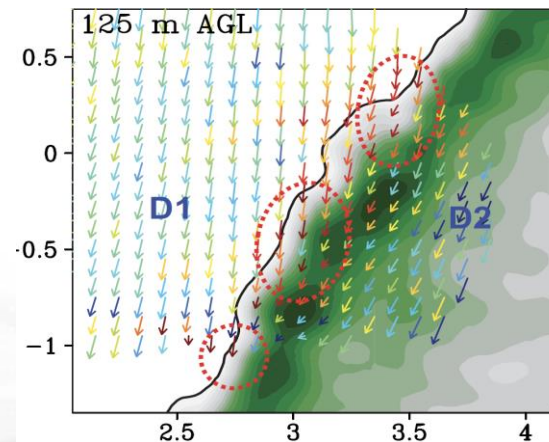
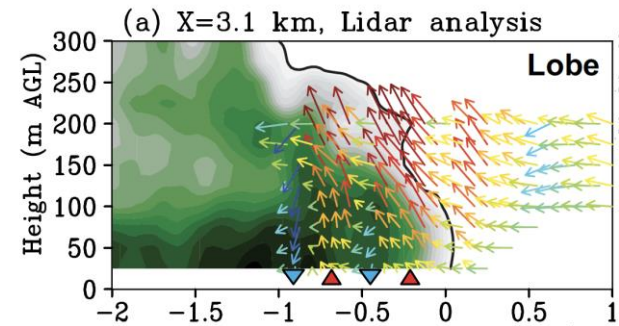
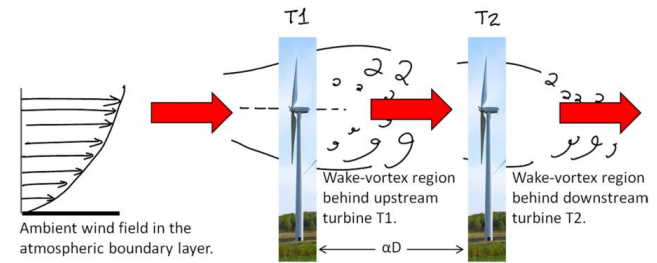
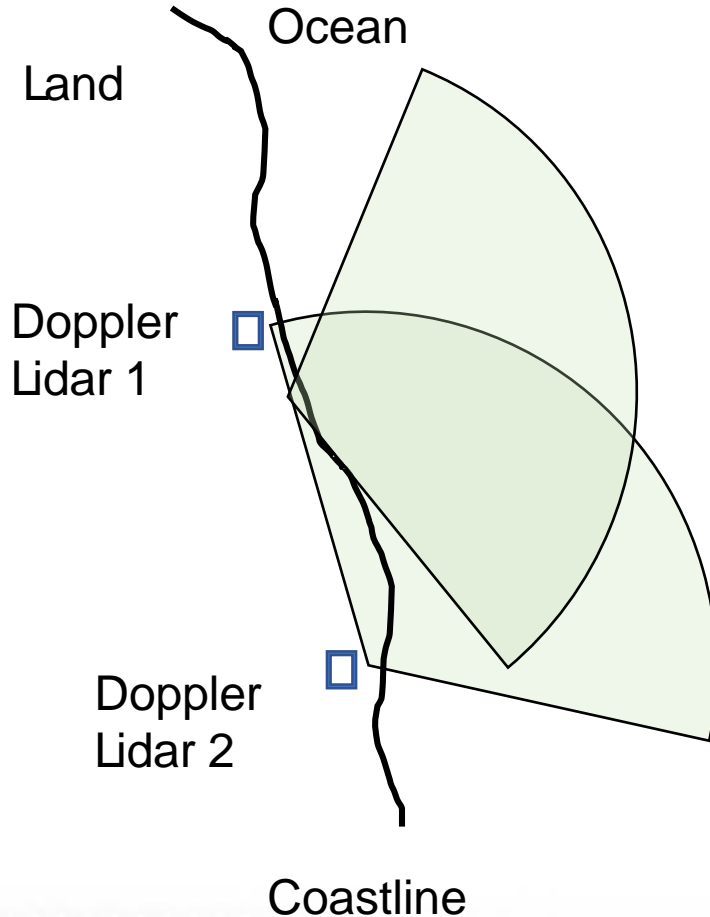
Vertical Structure of the Urban/Coastal Boundary Layer using Profiling Doppler Lidar



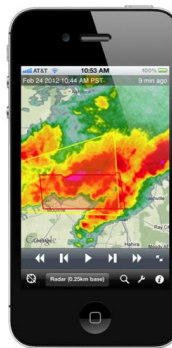
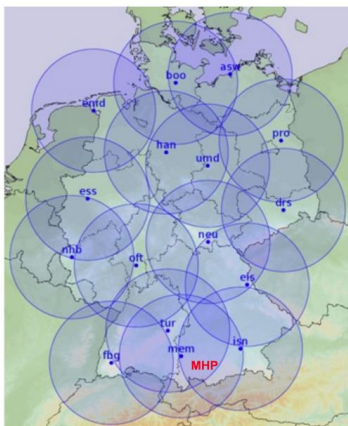
Amongst the meteorological characteristics that describe the status of the lower atmosphere where humans live, Mixing Height (MH) and wind turbulence are of importance.

MH represents the height reached by pollutants after release from sources at ground-level.

3D wind field from 30 m to 10 km



Radar Applications



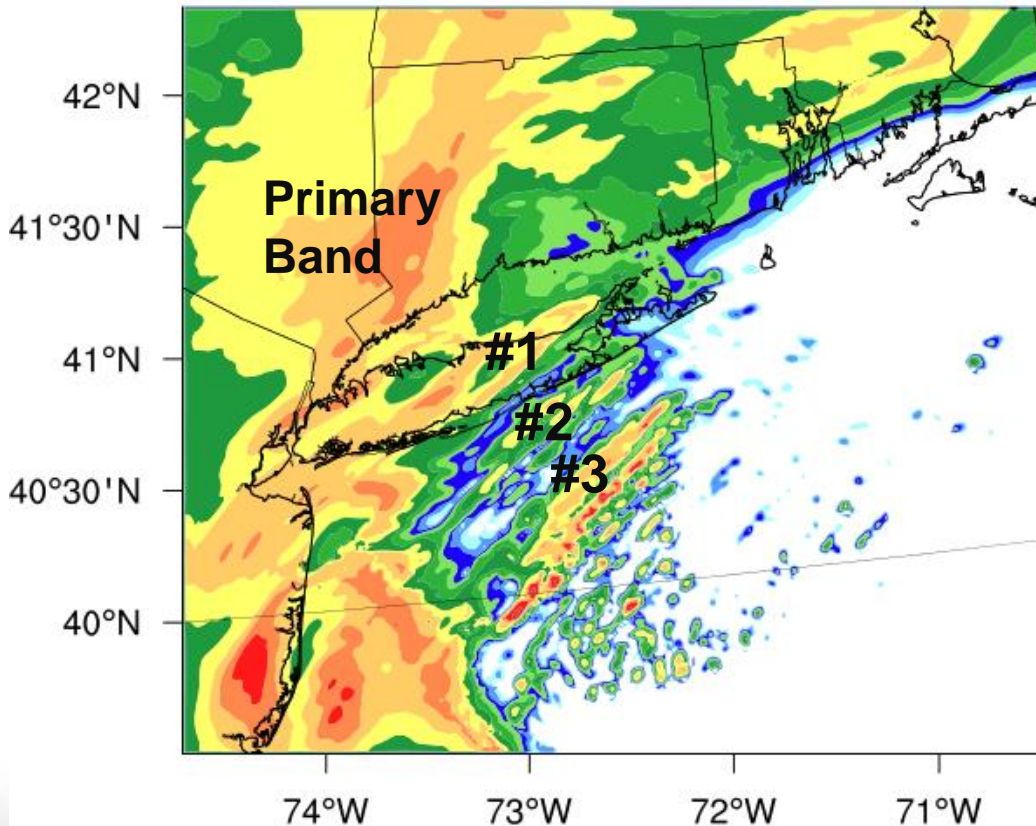
Agriculture
Aviation
Energy & Utilities
Ground Transportation
Insurance
Hydrology
Flash Flooding

New technology weather radars



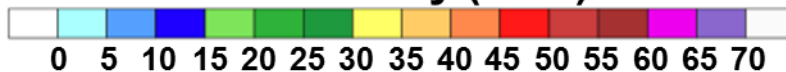
Radar Data Assimilation Needed to Study Physical Mechanisms of High-Impact Weather

WRF 1 km AGL Reflectivity (dBZ)



- Weather systems that affect the energy grid and water resources of dense population centers in the Northeast and along the Eastern Seaboard are influenced by large topography and land-ocean boundaries
- A mechanistic understanding requires mobile, localized observations of pre-storm conditions, storm dynamics and microphysics
- The mobile facility can be used to intercept and contribute high-value measurements for understanding the mesoscale organization of these events

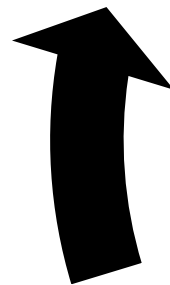
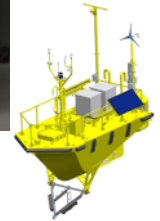
Reflectivity (dBZ)



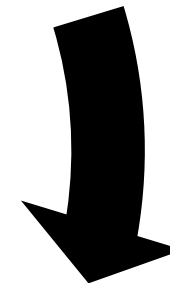
Cyber Infrastructure Computer Science Initiative



Mobile Observations

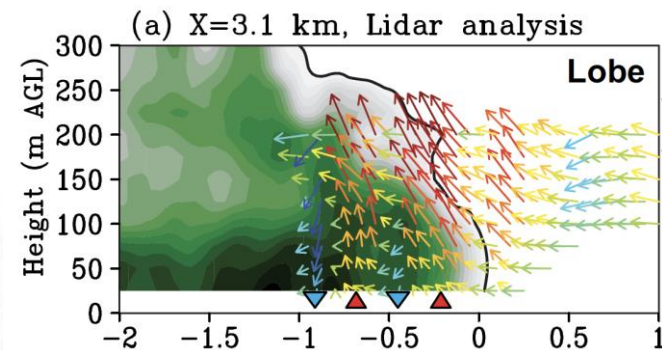


Center for Multiscale Applied Sensing

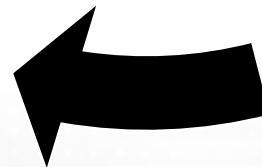
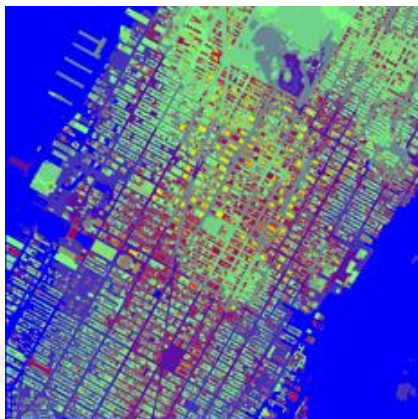


+ crowdsourcing

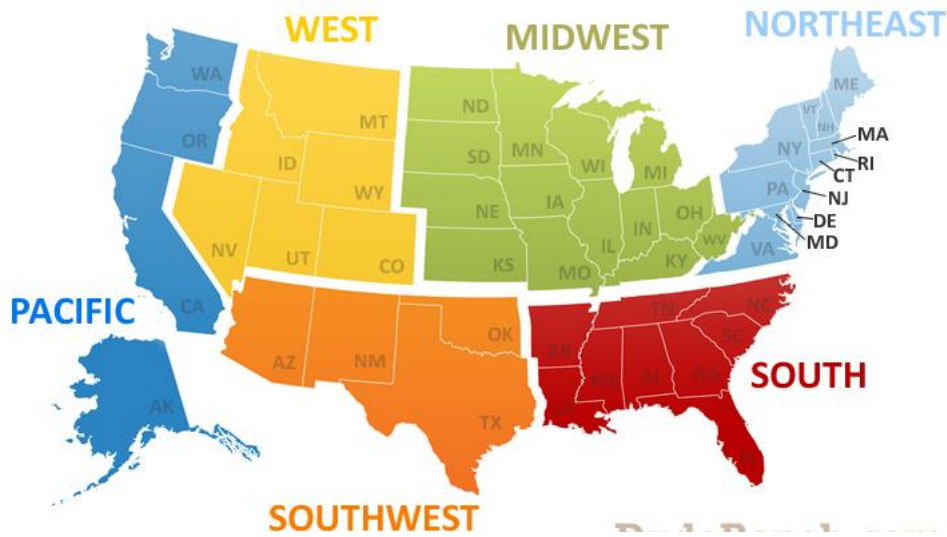
Data Analysis



Numerical Modeling



Regional and National Leadership in Sensing and Predicting Weather and Climate in Energy Hotspots



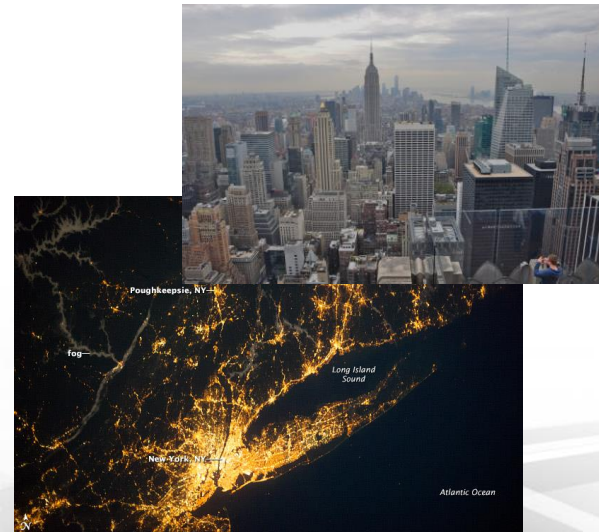
Extreme Weather



Renewable Energy



Urban/Coastal Environment



Summary

BNL has considerable experience in multiscale, atmospheric measurements with state-of-the-art, transportable instrumentation

BNL has unique expertise in mobile observing systems, data processing/analysis, high resolution modeling and field deployments

CMAS: Connect Fundamental Atmospheric Research and Technology to Urban and Coastal Systems to Address Security, Transportation, Energy, Air Quality, Weather and Climate

Develop a high-resolution observations/modeling testbed in the “natural” laboratory of the NYC and LI area.

Questions?