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Offshore Wind Energy at the Atmospheric Sciences Research Center

Renewable Energy Group
Jeff Freedman, Scott Miller, Elizabeth McCabe, Patrick Miller, and David Marcial

Research includes (but is not limited to):

1. Effects of climate change on offshore wind
2. Model development optimized to capture offshore wind mesoscale phenomena (e.g., sea breeze, cold water upwelling, wakes)
3. Analysis of extreme conditions (ramps, droughts, tropical and extra-tropical system) and lightning
4. Instrument development (buoy-based flux measurements—WFIP3)

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The Effects of Climate Change on the Renewable Energy Resource
(Focus here on offshore wind)

The Effects of Climate Change on the Renewable Energy Resource
(Focus here on offshore wind)

Sponsored by the New York State Energy Research and Development Authority (NYSERDA) Agreement #105161

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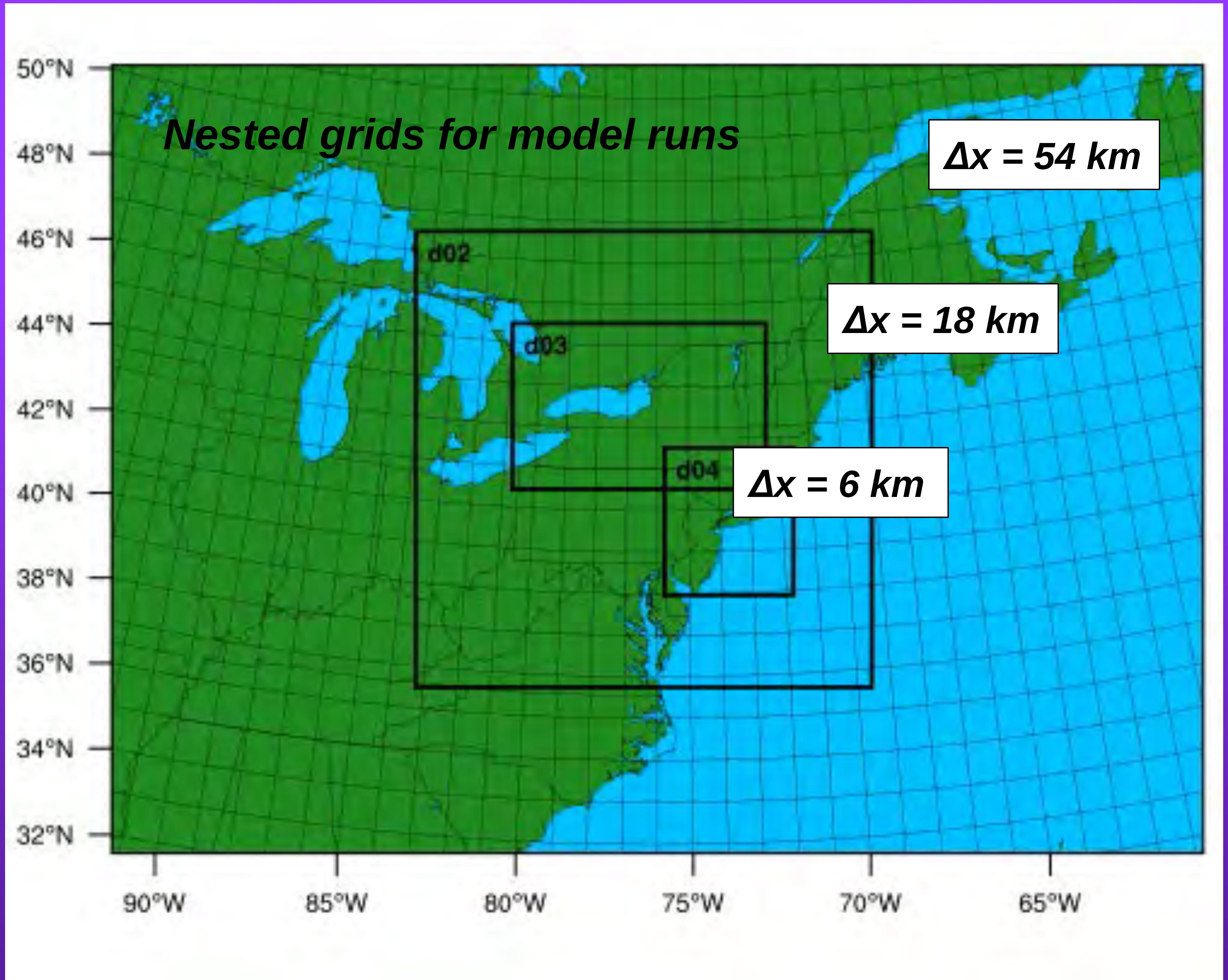
With
Richard Perez, and Geng Xi[1], UAlbany, Atmospheric Sciences Research Center
Aiguo Dai, UAlbany Department of Atmospheric and Environmental Sciences
Akila Gothandaraman, Philippe Beaucage and Dan Kirk-Davidoff[2], UL Renewables
John Manobianco[3], Mano NanoTechnologies, Inc.

1. *Now at the DOE NREL*
2. *Now at EPRI*
3. *Now at BASF, Inc.*

Climate change and the onshore and offshore wind resource in the Northeastern US



Climate change and the onshore and offshore wind resource in the Northeastern US

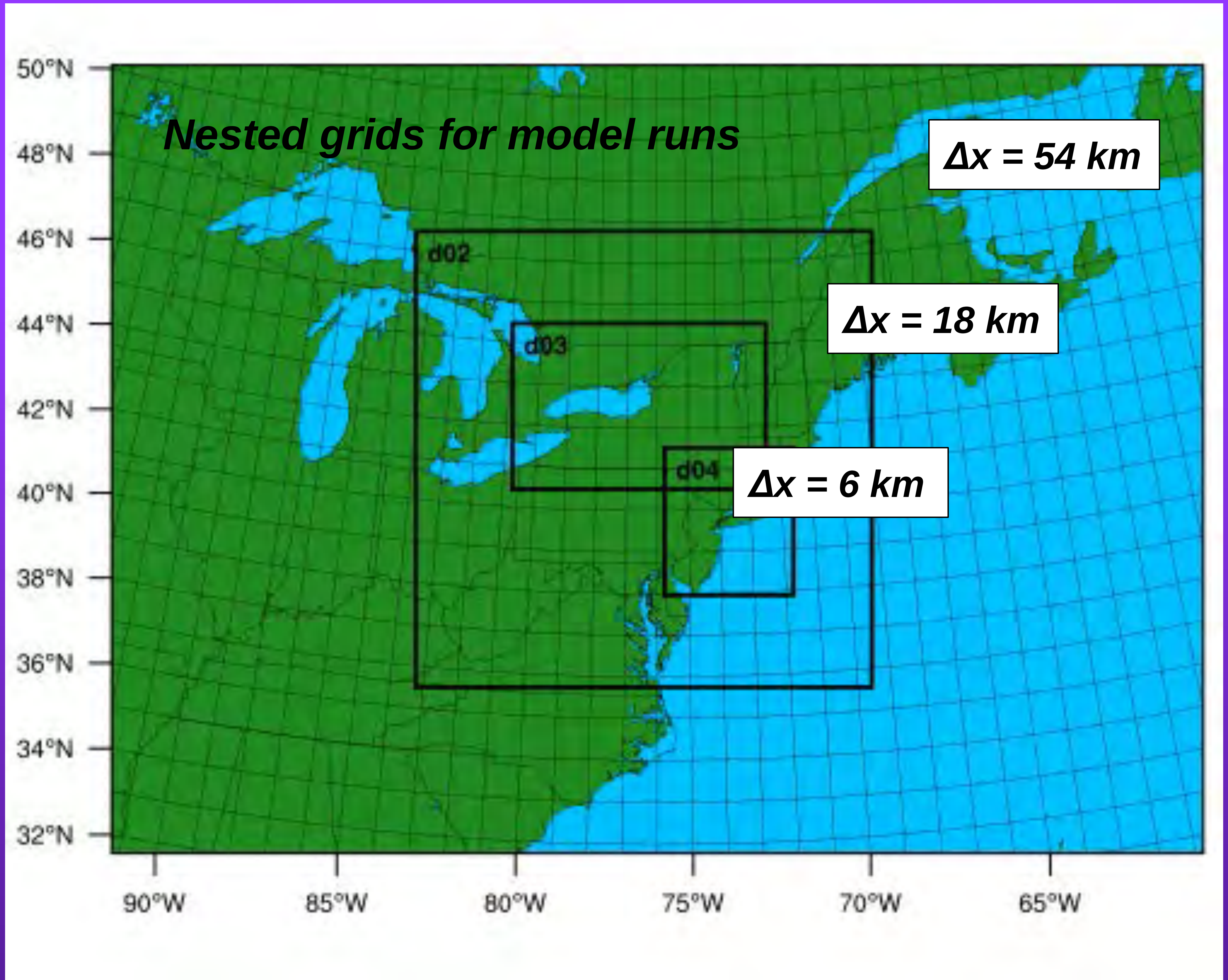
- Performed dynamic downscaling of selected (3 “representative”) CMIP5 models for 3 periods:

1. historical (1997 - 2017*)
2. near-future (2017 - 2037*)
3. mid-future (2037 - 2057*)

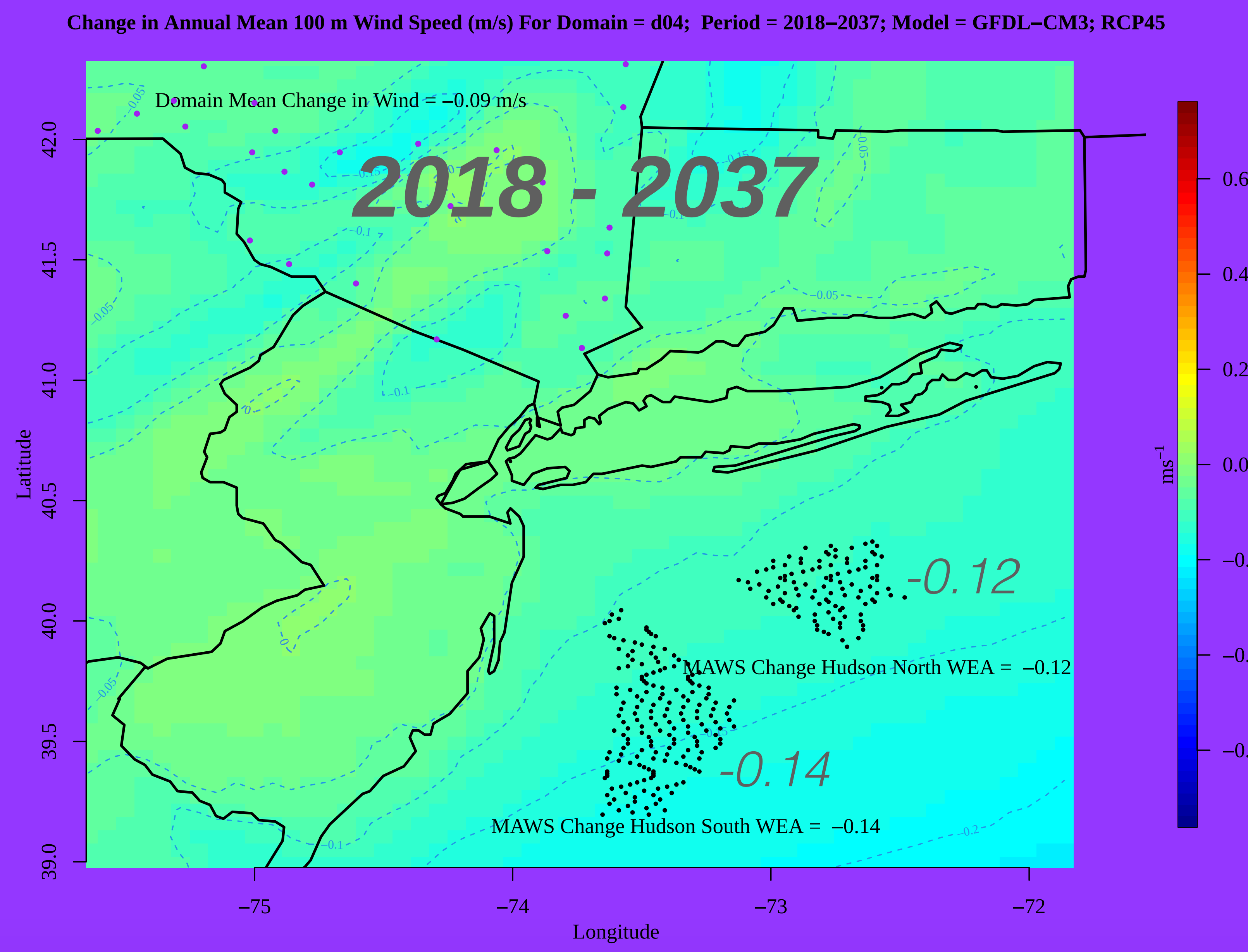
and two scenarios (RCP4.5 and RCP 8.5)

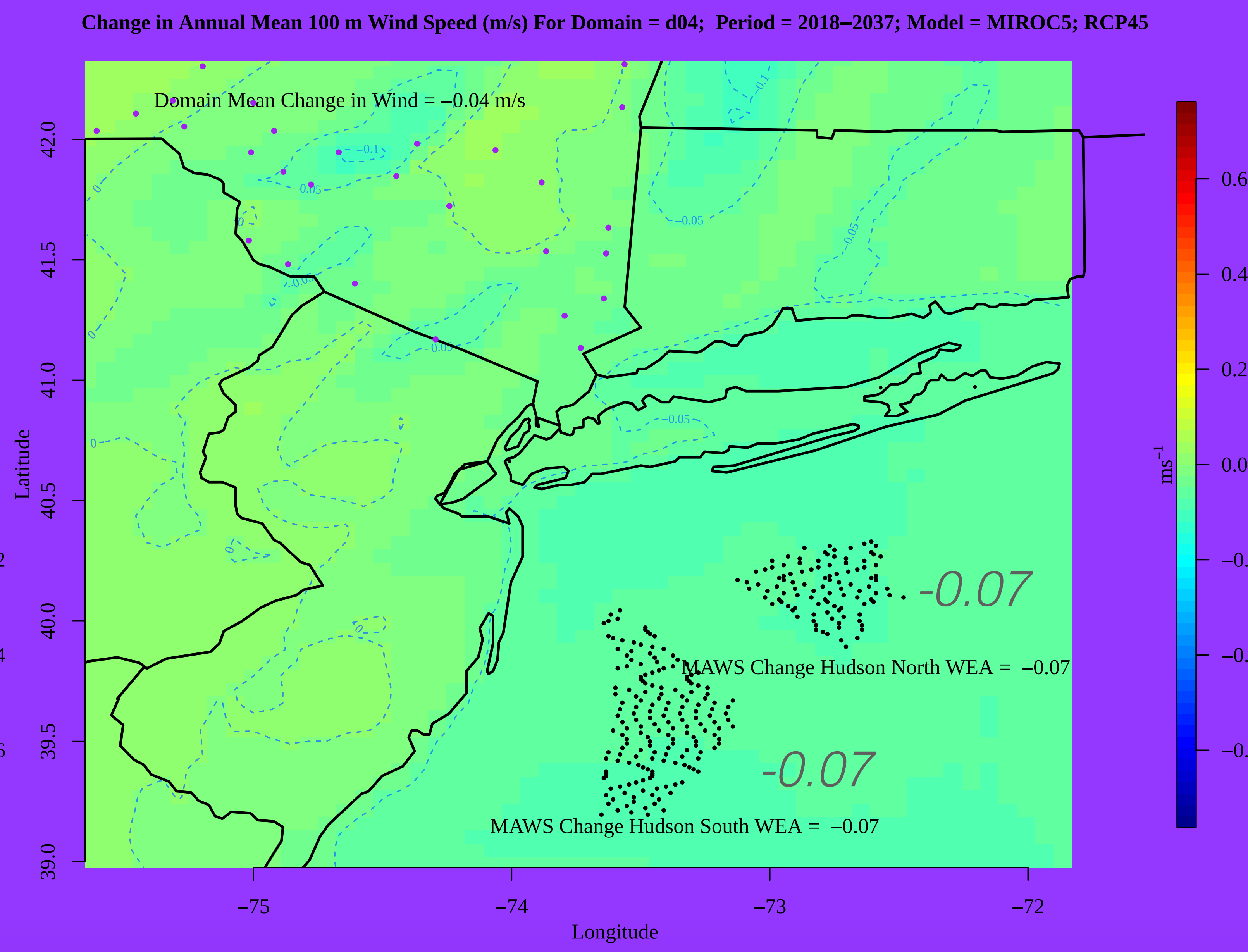
336 years of simulations—generating > 400 TB output!

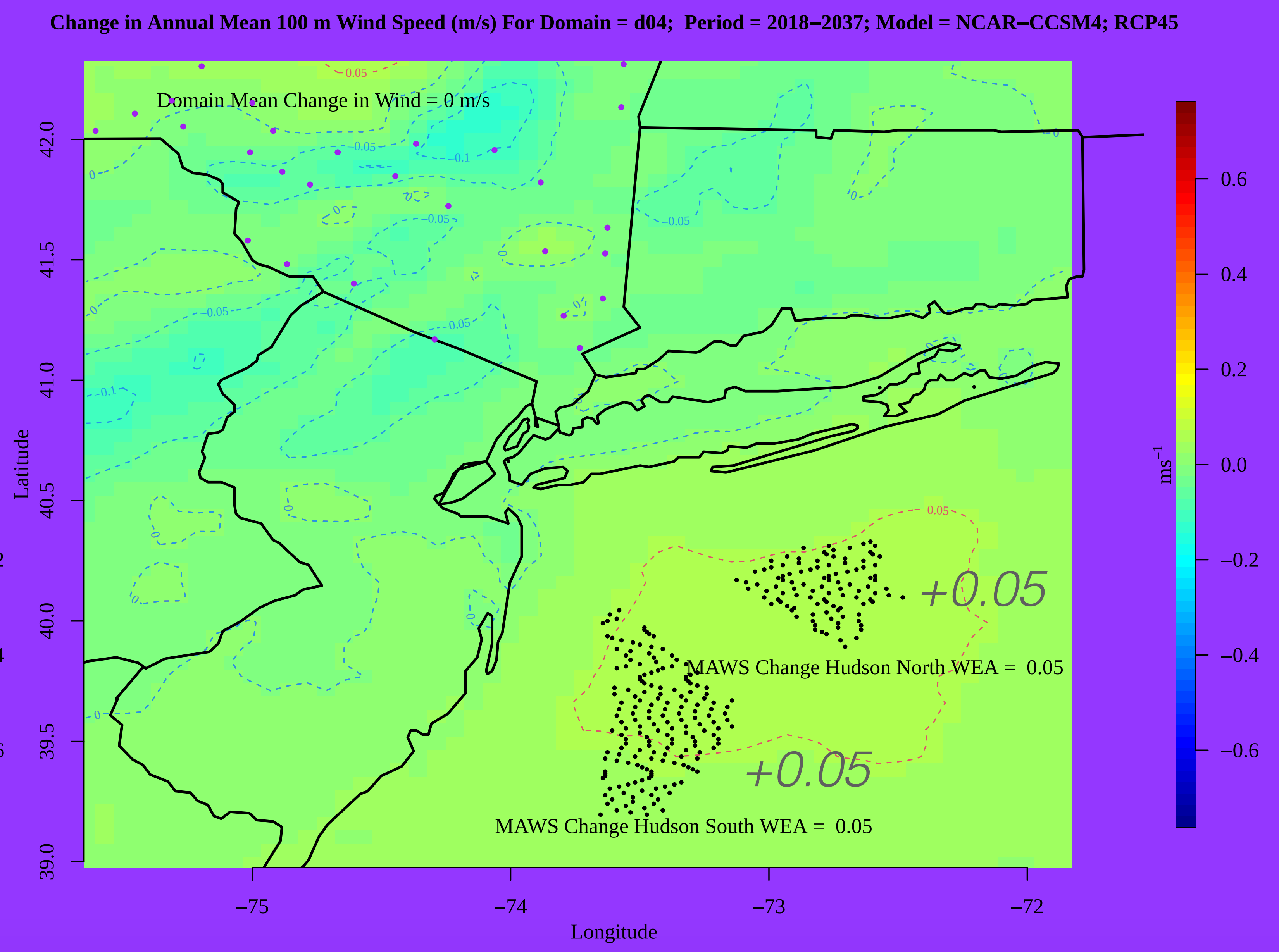
* (21-yr periods include 1-yr spin up)



100 m wind speed change (ms^{-1})



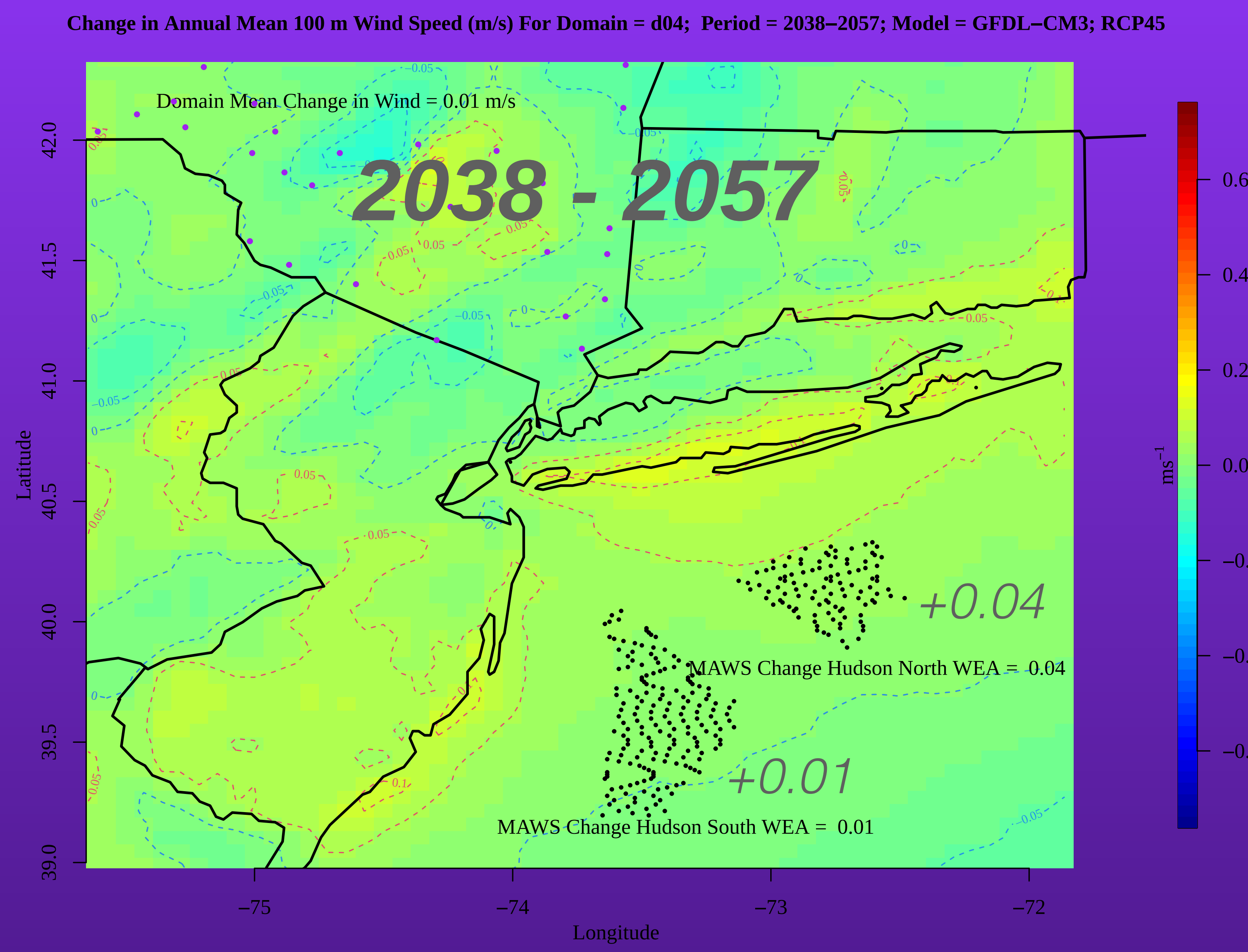


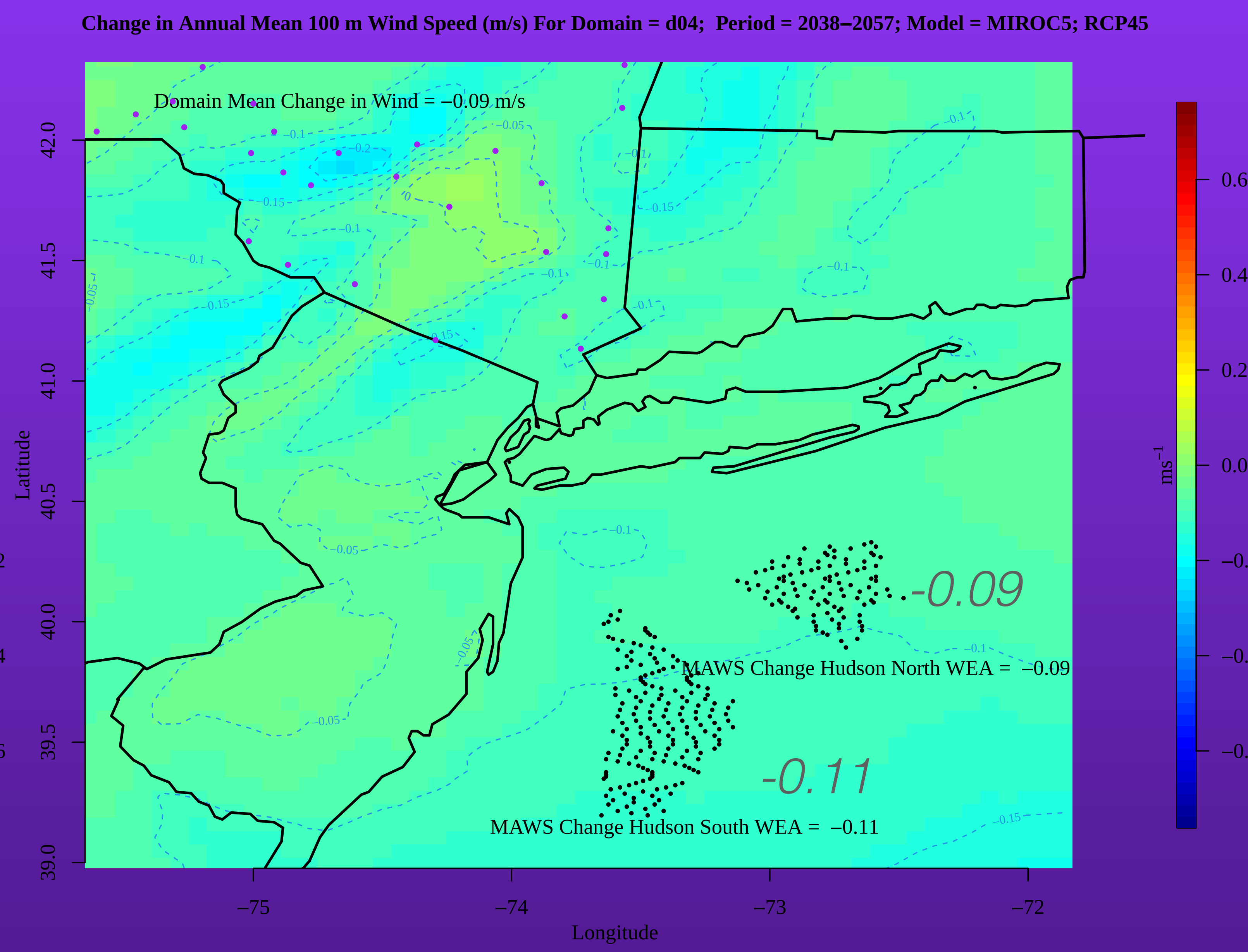


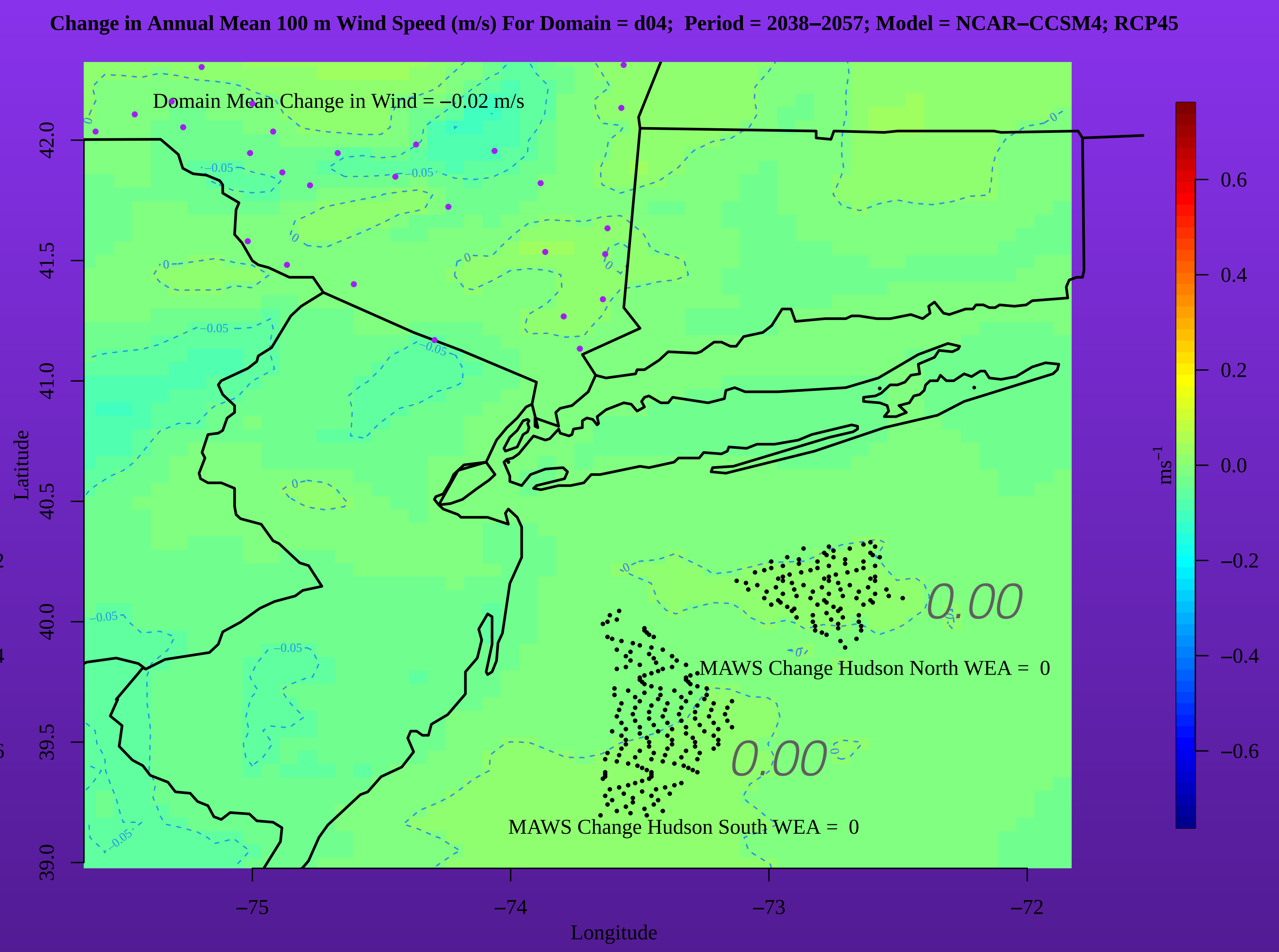
GFDL-CM3 RCP4.5

MIROC5 RCP4.5

NCAR-CCSM4 RCP4.5







100 m wind speed change (ms^{-1})

100 m Annual Wind Speed Change (ms^{-1} [%]) at Hudson North and Hudson South Offshore WEAs (Mean Hist. = 9.2 ms^{-1})

		Hudson North		Hudson South	
Model	Scenario	2018-2037	2038-2057	2018-2037	2038-2057
GFDL-CM3	RCP45	-0.12 (-1.3)	0.04 (0.4)	-0.14 (-1.5)	0.01 (0.1)
	RCP85	-0.19 (-2.1)	-0.27 (-2.9)	-0.2 (-2.2)	-0.31 (-3.4)
NCAR-CCSM4	RCP45	0.05 (0.8)	0.00	0.05 (0.8)	0.00 (0.0)
	RCP85	0.22 (2.4)	0.22 (2.4)	0.18 (2.0)	0.19 (2.1)
MIROC5	RCP45	-0.07 (-0.8)	-0.09 (-1)	-0.07 (-0.8)	-0.11 (-1.2)
	RCP85	0.00 (0.0)	-0.14 (-1.5)	0.00 (0.0)	-0.18 (-2.0)
Mean		**-0.11 (-1.4)**	**-0.04 (-0.5)**	**-0.03 (-0.4)**	**0.045 (0.5)**

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Reducing Errors in Offshore Wind Forecasting during Peak Demand

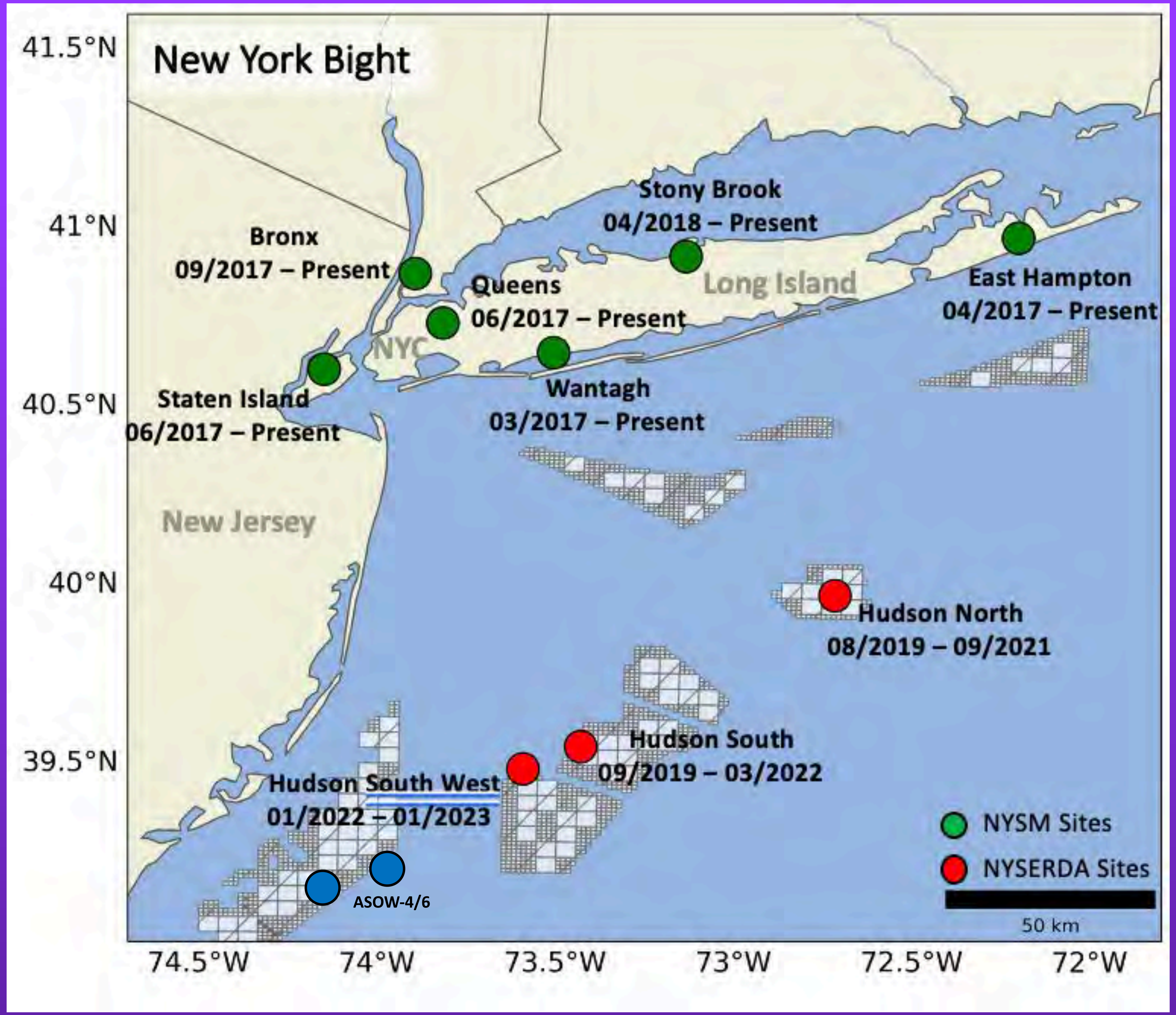
Elizabeth McCabe—presented at NAWEA (2024)

PROBLEM:
Warm season **SEA BREEZE** and **Low-Level Jet** (LLJ) is important for offshore wind energy development –

Circulation increases afternoon wind speeds and cools air temperatures when energy demand is high

OBJECTIVE: **REDUCE RISK** in power production forecasts by determining the best model setup for the sea breeze and LLJ in the New York Bight

→ *Test 18 different model combinations*



Limited measurements in offshore and coastal regions means that we must rely on models

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HUDSON SOUTH

HUDSON NORTH

Largest model errors in the hours prior to and during sea breeze onset (~ 10 AM to 2 PM LT)
Models underestimate wind speed = good error for utilities!

Models and observations at 100% capacity during sea breeze

The Winner: The Mellor-Yamada-Janjic (MYJ) planetary boundary layer scheme is best suited for the NYB under sea breeze and LLJ conditions.

Understanding model limitations and improving model forecast error can help to REDUCE ERRORS in power production (capacity factor) forecasts under sea breeze and LLJ conditions. Models need to be "fine tuned" to the specific region and meteorological conditions for which we are using them to predict.

See McCabe, E., and J. M. Freedman, 2024: *Quantifying the uncertainty in the Weather Research and Forecasting Model under sea breeze and low-level jet conditions: Importance to offshore wind energy. Accepted Weather and Forecasting.*
McCabe, E., and J. M. Freedman, 2023: *Development of an Objective Methodology for Identifying the Sea Breeze Circulation and Associated Low-Level Jet in the New York Bight. Wea. Forecasting, 38, 571–589, https://doi.org/10.1175/WAF-D-22-0119.1.*

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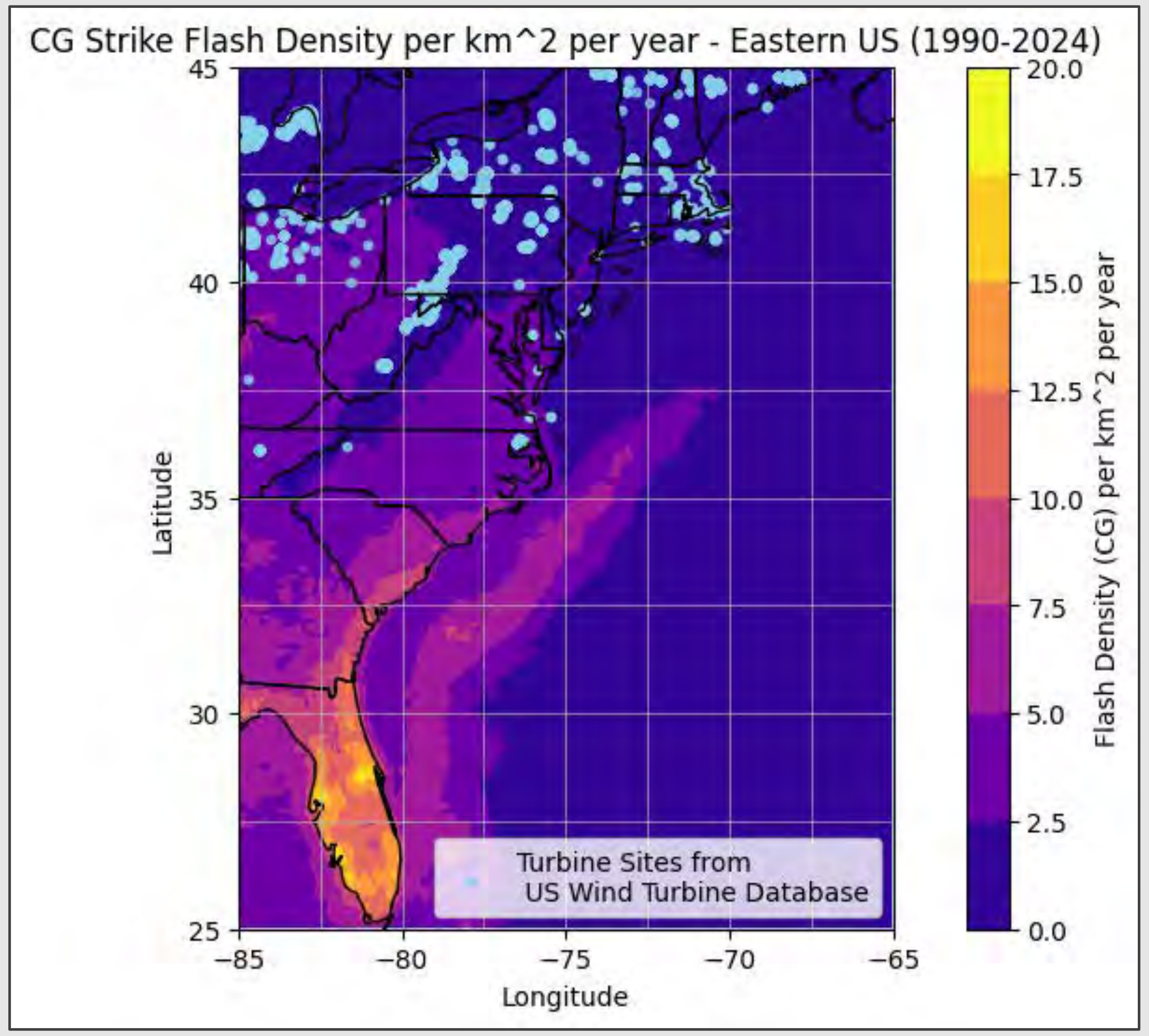
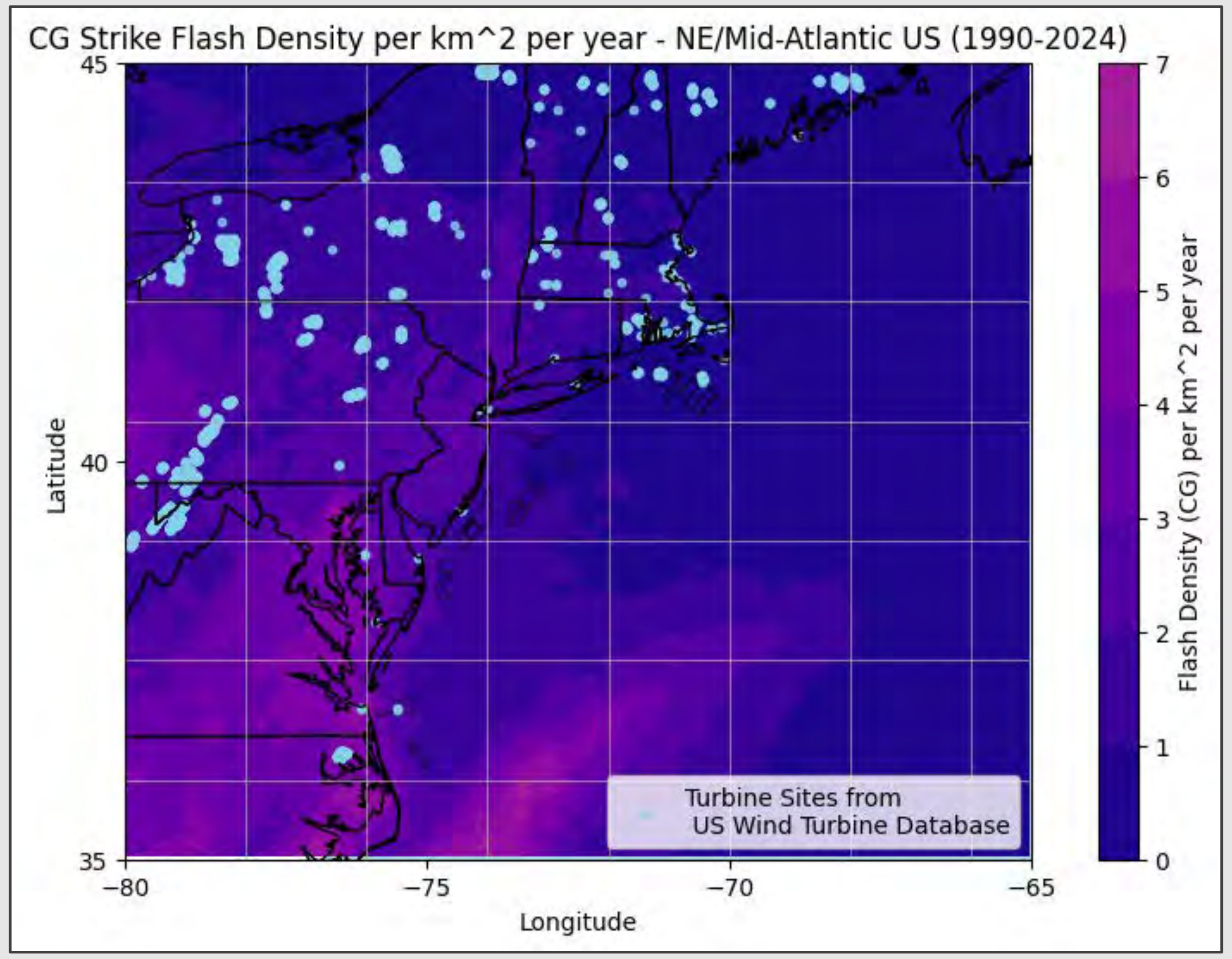
Development of a Lightning Climatology for Wind Farms in the Eastern United States: Focus on the New York Bight and Upstate NY

Presented by Patrick Miller at the 105th Annual American Meteorological Society (AMS) Meeting New Orleans, LA | 13 January 2025

EASTERN US CG STRIKE FLASH DENSITY





Slight variability from SW to NE across Mid-Atlantic and NYB

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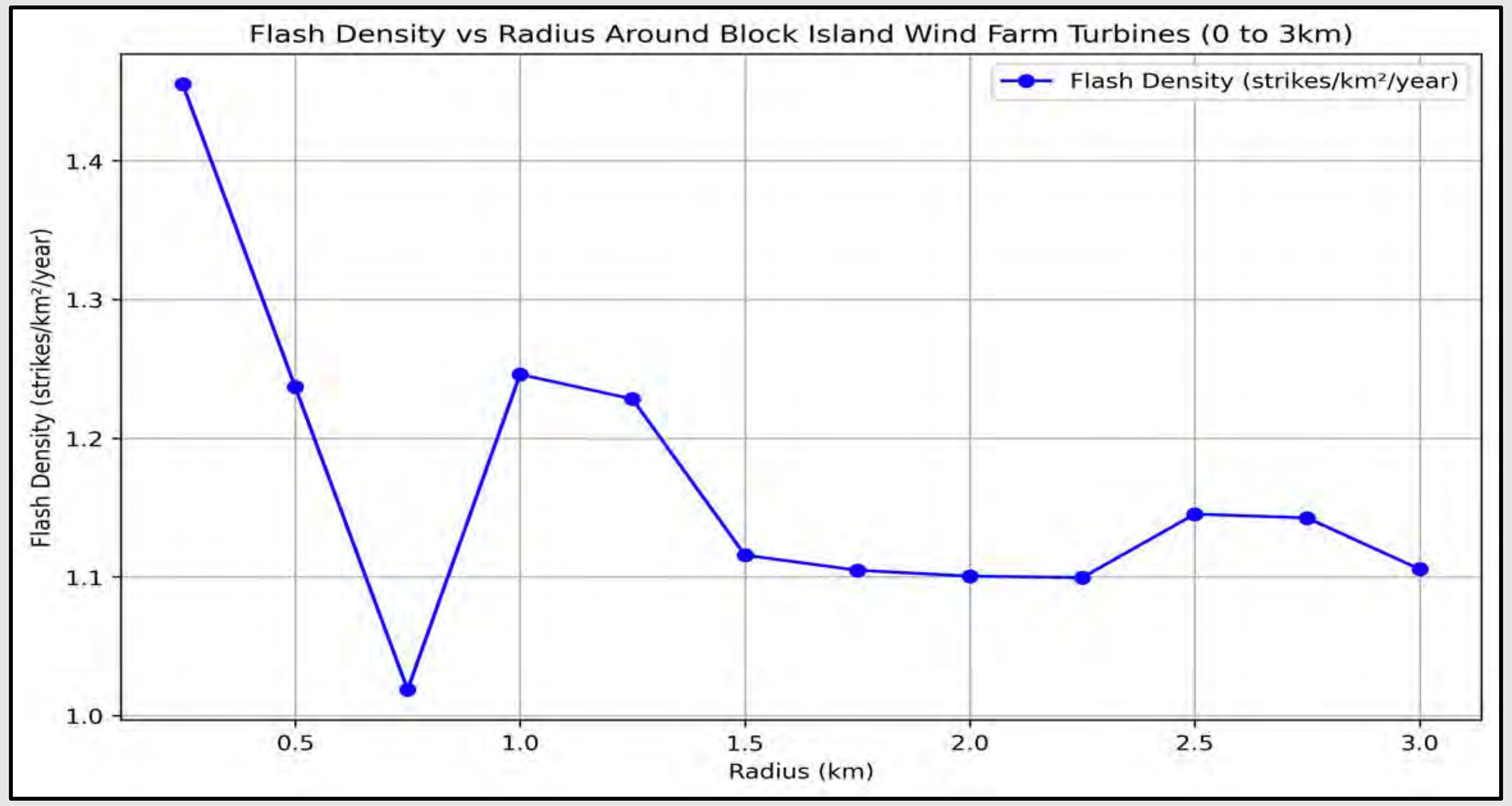
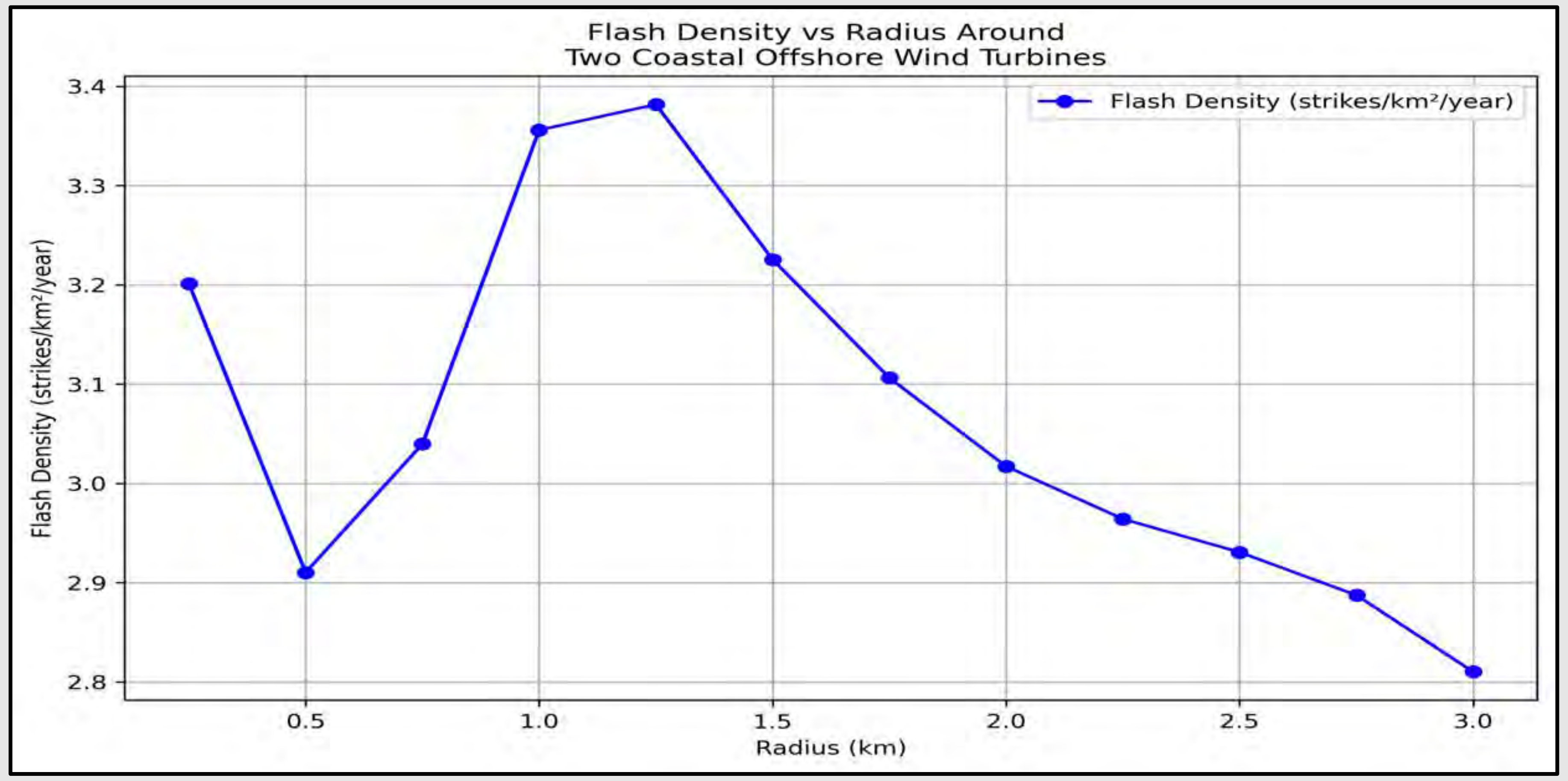
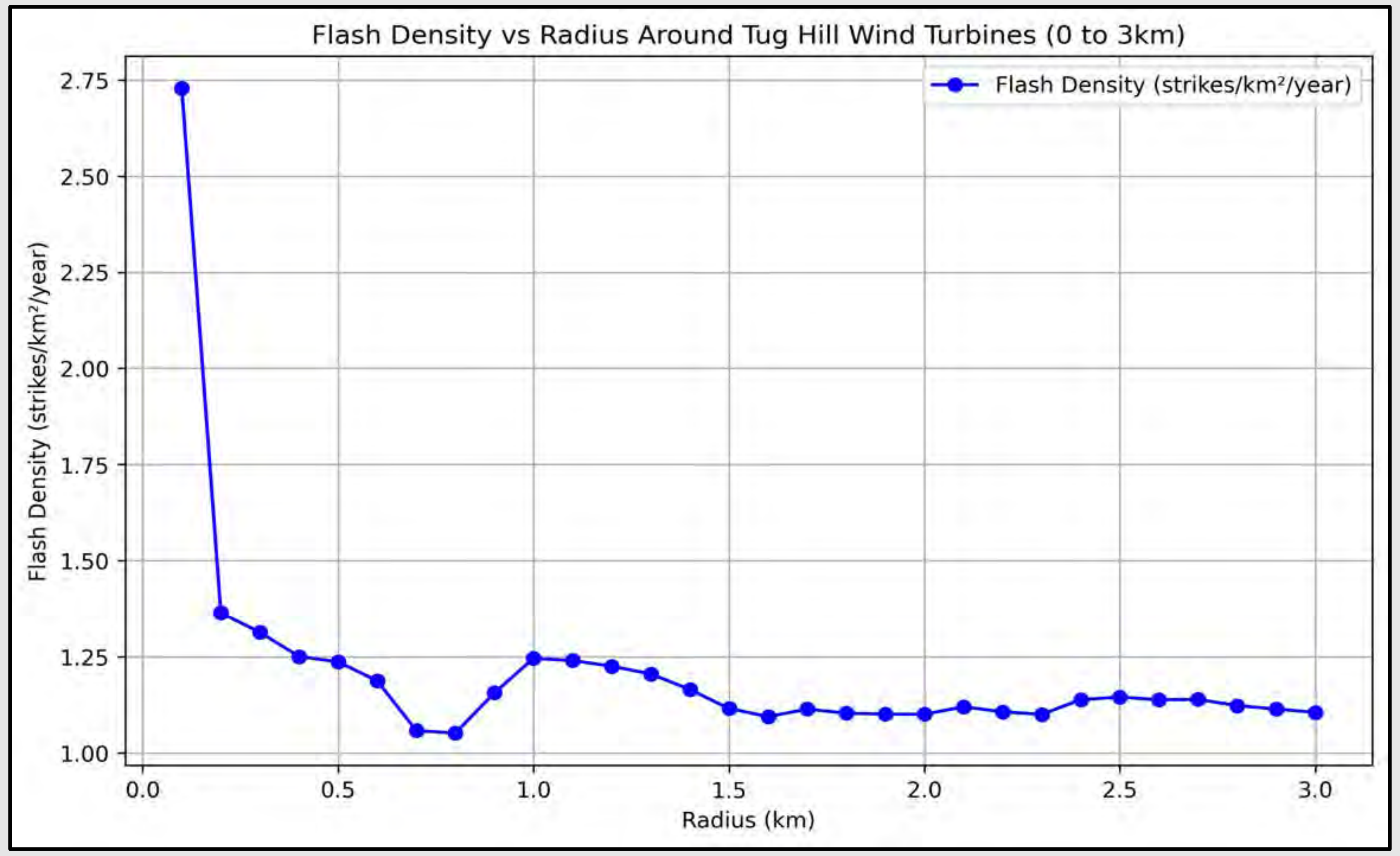
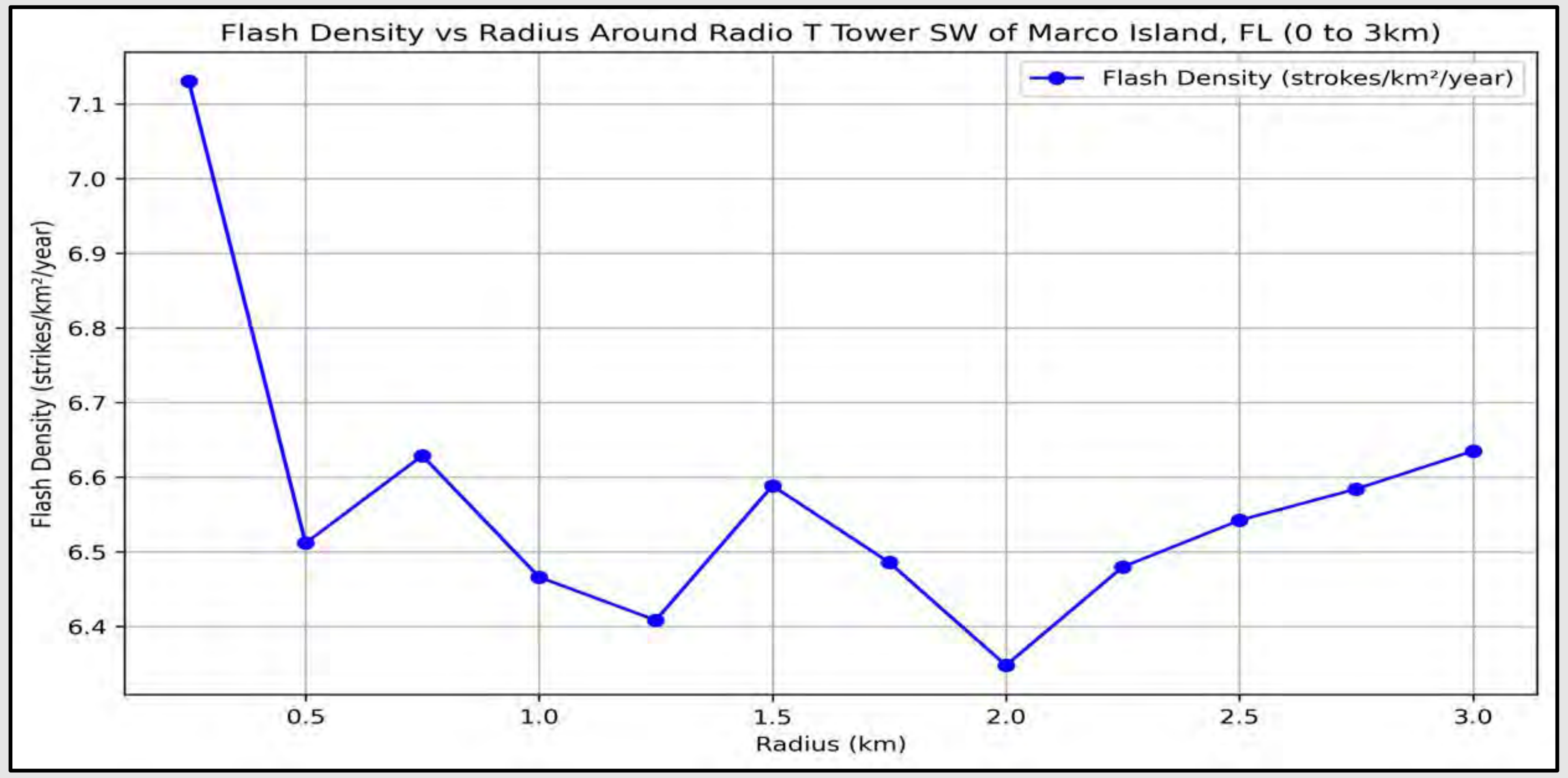
TURBINES AND TALL METAL TOWERS ATTRACTING LIGHTNING





Onshore locations have radii every 0.1km, versus 0.25km for offshore.





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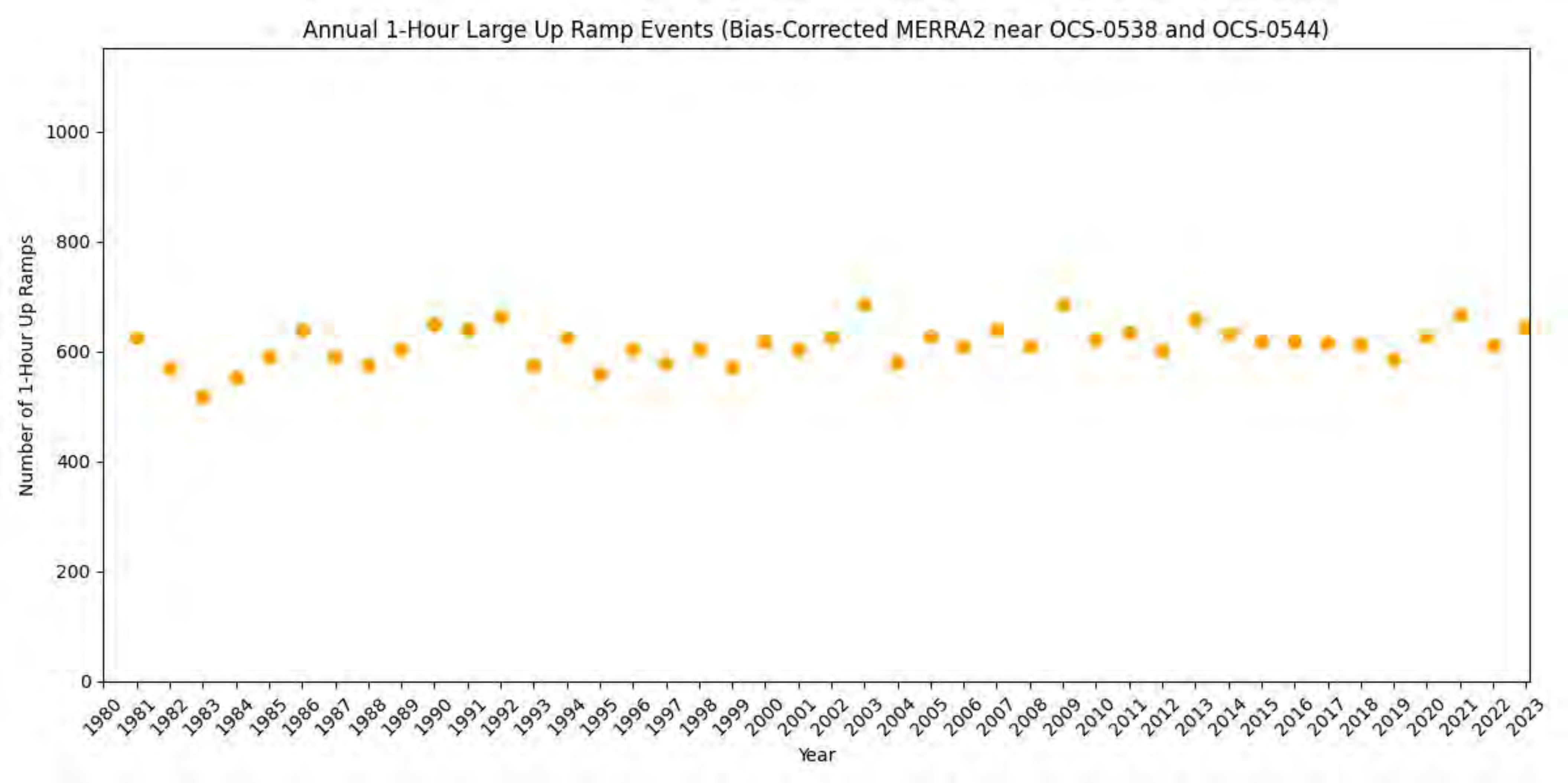
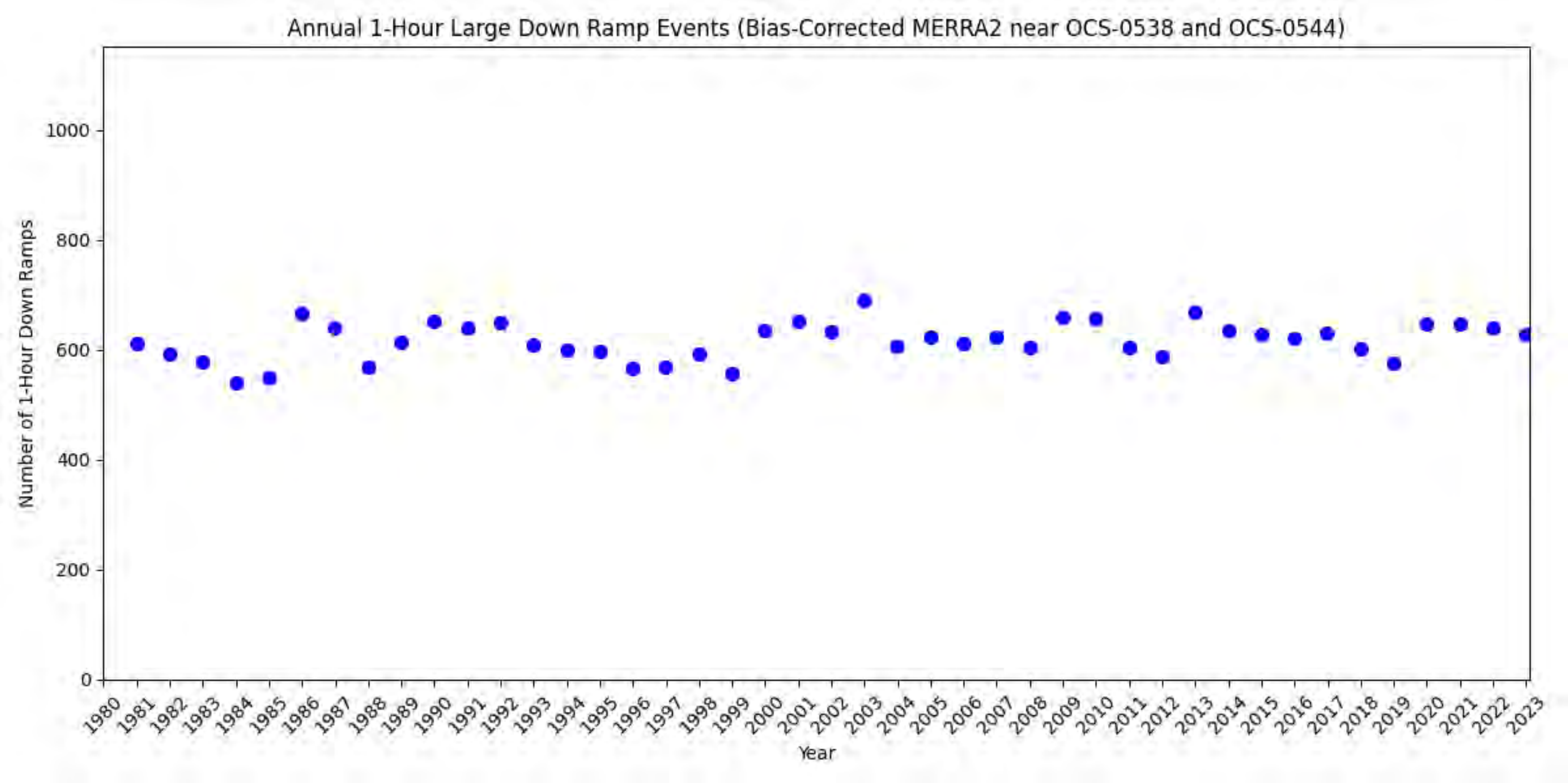
44-yr analysis of wind ramp events in the New York Bight

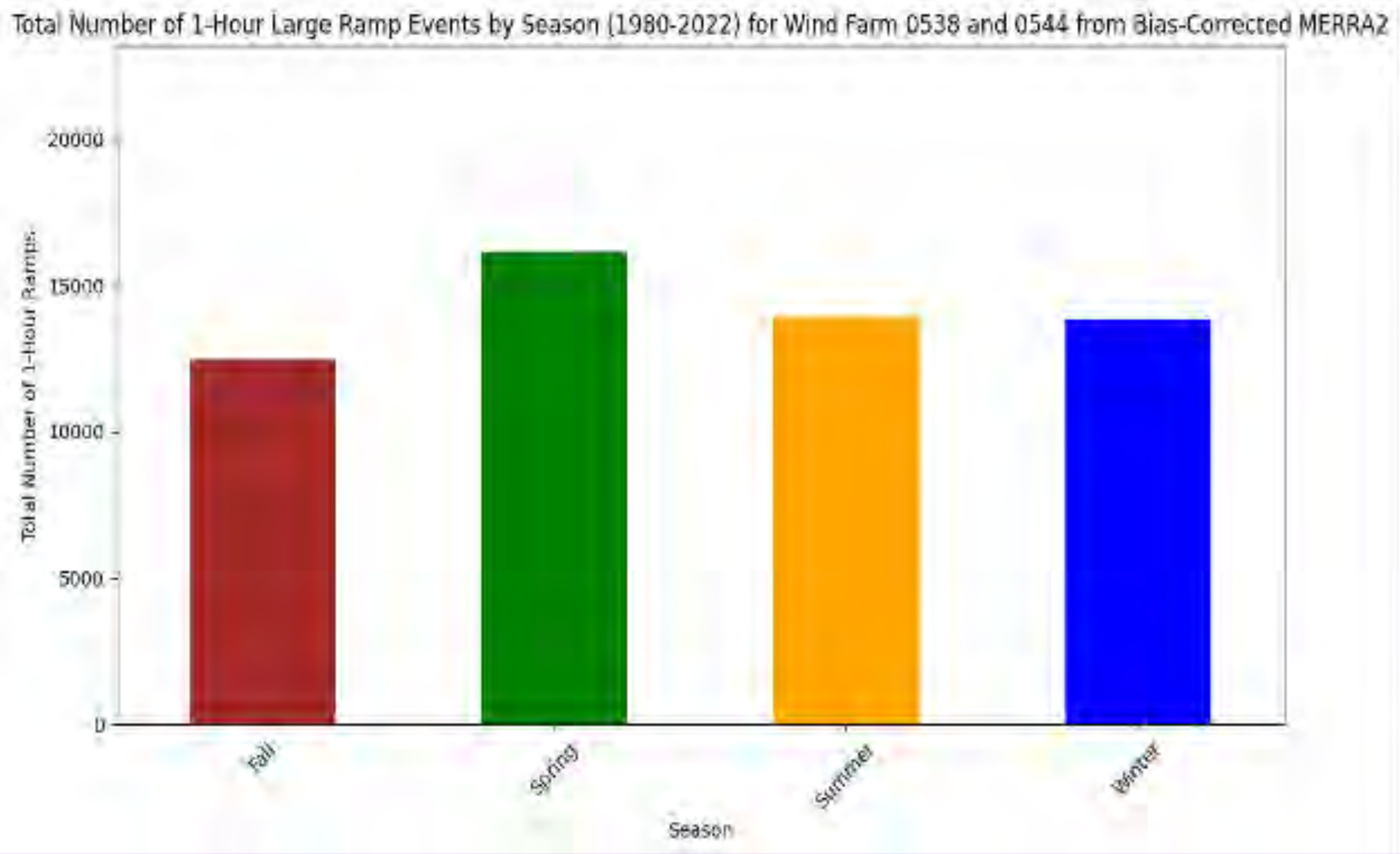
Patrick Miller

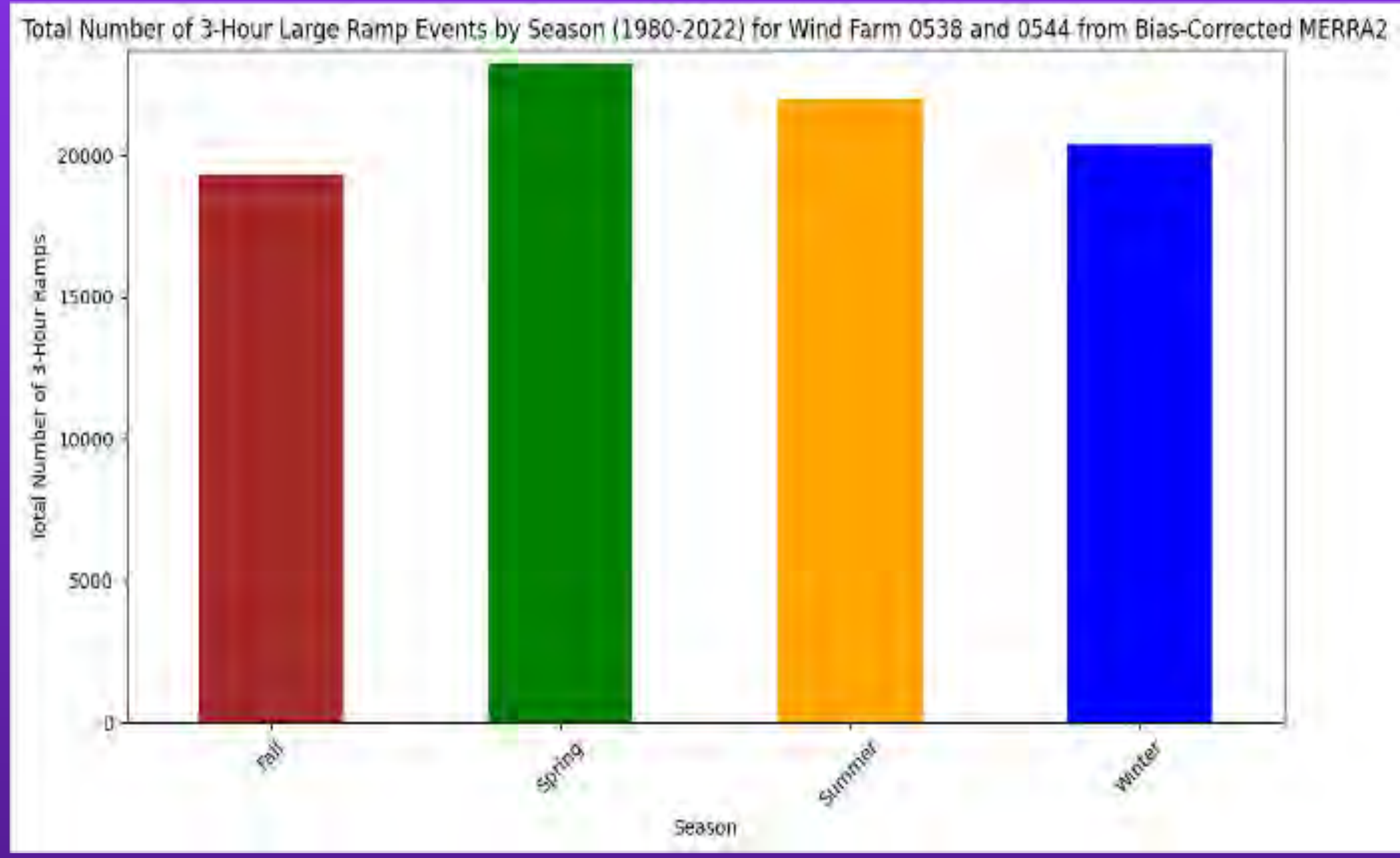




A 1-hour large ramp is defined as a 10% change in relation to the 15MW rated capacity
A 3-hour large ramp is defined as 20% change.

Wind speeds interpolated to 100 m and based upon to NREL's 15 MW wind power curve to estimate production.





Surface fluxes => atmospheric stability => shape of ABL wind profile

Evaluation of an Automated Eddy Covariance Air-Sea Flux Package on a Lidar Buoy

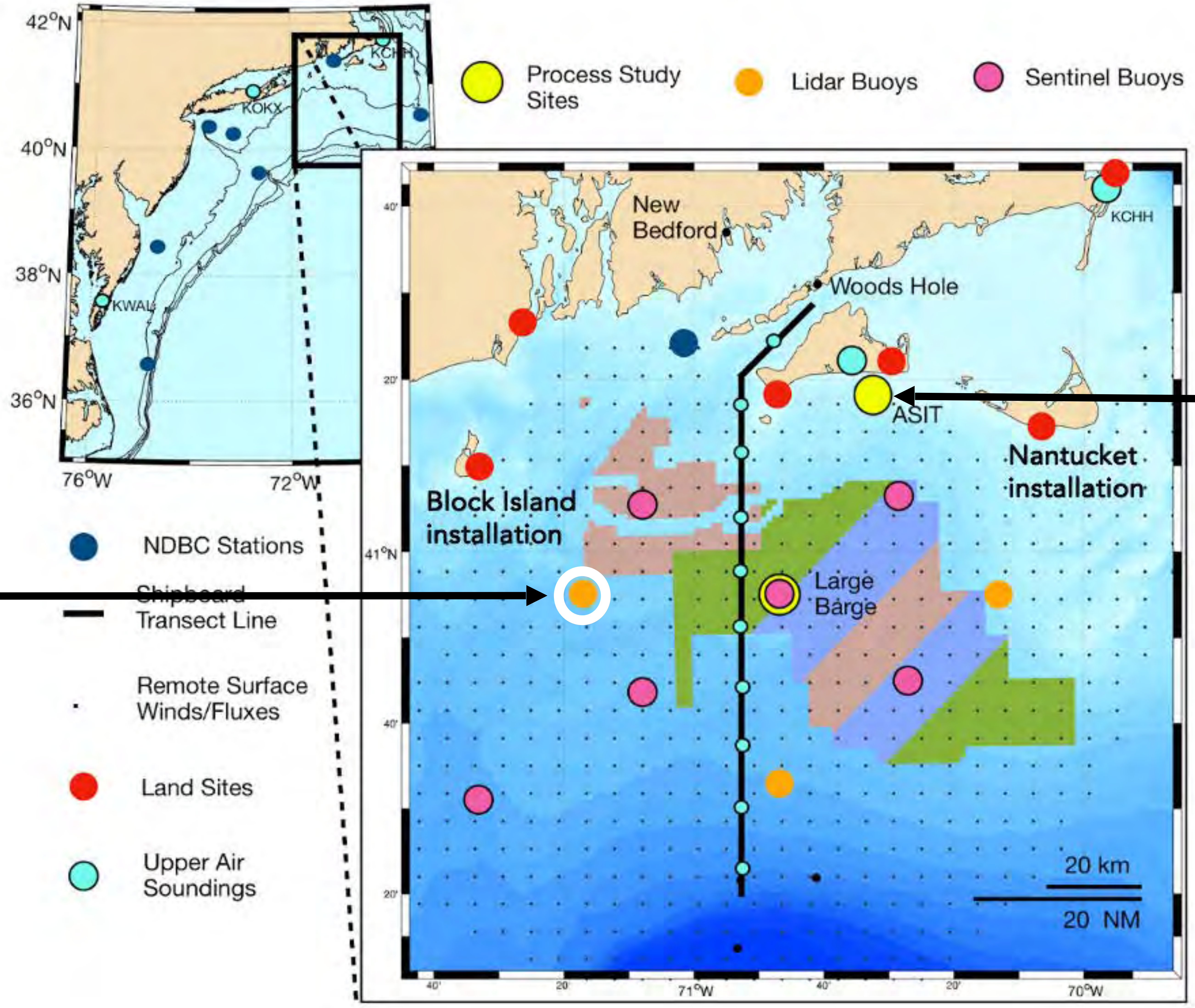
- *“Flux-profile” relationships (e.g., Businger et al., 1971; Dyer, 1974) form backbone of surface, boundary layer parameterization schemes in weather models*
- *Do these relationships hold in coastal environments where offshore turbines are being sited?*
- *In situ* fluxes and profiles are useful evaluation tools

Surface fluxes => atmospheric stability => shape of ABL wind profile

David Marcial, Michael Jacques, Jason Covert, Matt Brooking, Janie Schwab,
Kit Moore, Jeff Freedman, Scott Miller, Raghavendra Krishnamurthy*
Atmospheric Sciences Research Center, University at Albany, *Pacific Northwest National Laboratory

Surface fluxes => atmospheric stability => shape of ABL wind profile

Wind Forecast Improvement Project-3 (WFIP3)
***
May 2024 - present;
18 month deployment



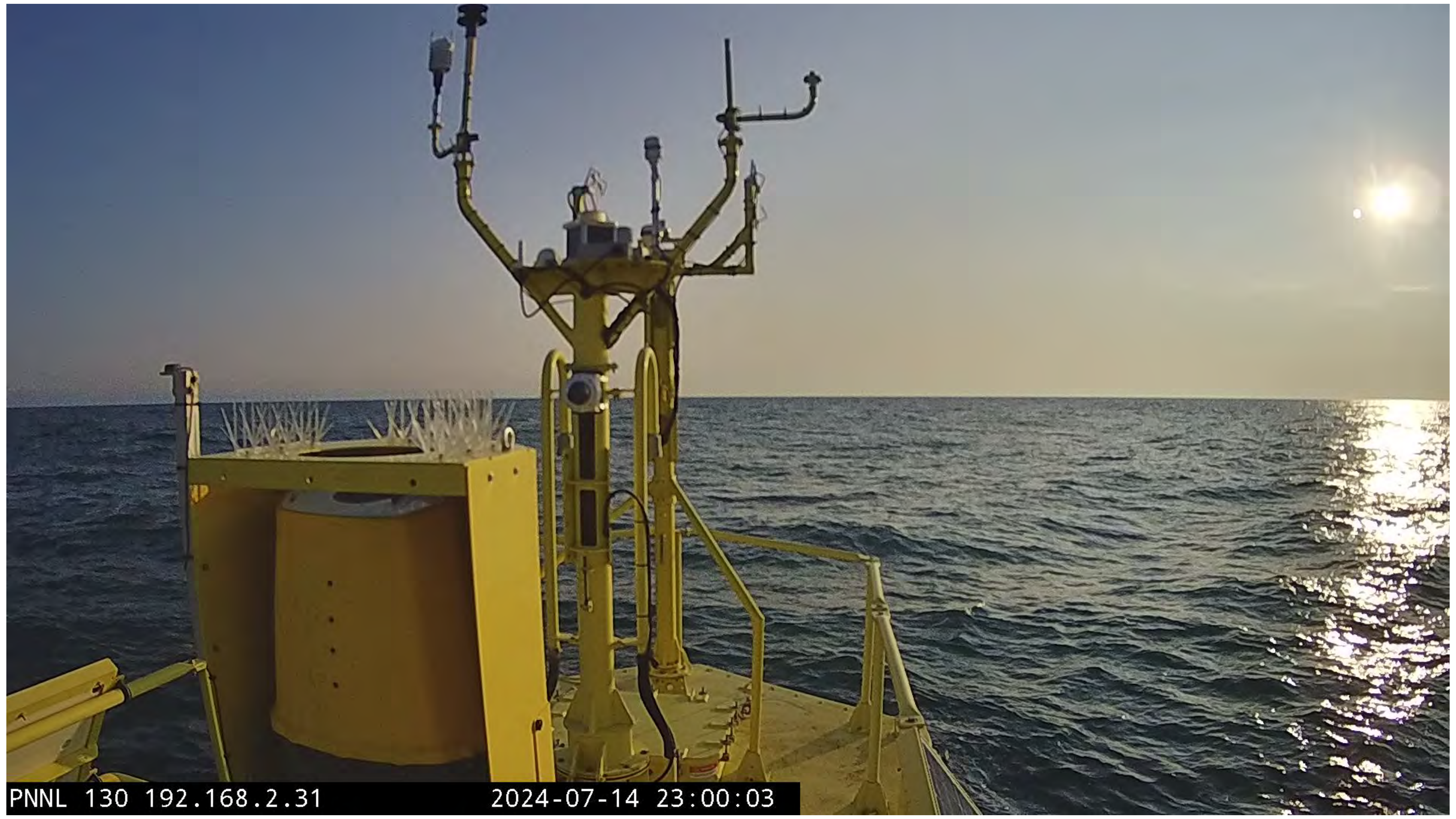
Woods Hole Oceanographic Institution (WHOI) Air-Sea Interaction Tower (ASIT)
***
Test site
Jan - May 2024

Summary

- ~ 40,000 (and counting) 10-min fluxes that are *QC'd, motion-corrected, calculated onboard* and sent via satellite in *near real-time* from an *unattended* EC flux system

Future work

- Continue evaluating heat and vapor fluxes
- Compare buoy fluxes to fixed ASIT tower
- Evaluate NOAA COARE bulk algorithm with EC fluxes
- Integrate fluxes with collocated lidar data to assess / refine / improve flux-profile relationships



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Effect of Cold-Water Coastal Upwelling on Sea Breeze and Low-Level Jet Enhancement, and its Relationship to Easing Loads in Urban Areas

ELIZABETH MCCABE AND JEFF FREEDMAN

ATMOSPHERIC SCIENCES RESEARCH CENTER,

UNIVERSITY OF ALBANY, STATE UNIVERSITY OF NEW YORK, ALBANY, NY, USA

AMS 105th Annual Meeting, New Orleans, LA
16th Conference on Weather, Climate, and the New Energy Economy
Load Forecasting in a Transitioning Energy Economy
Joint Paper 3.3

Contact: emccabe@albany.edu

Objective and Motivation

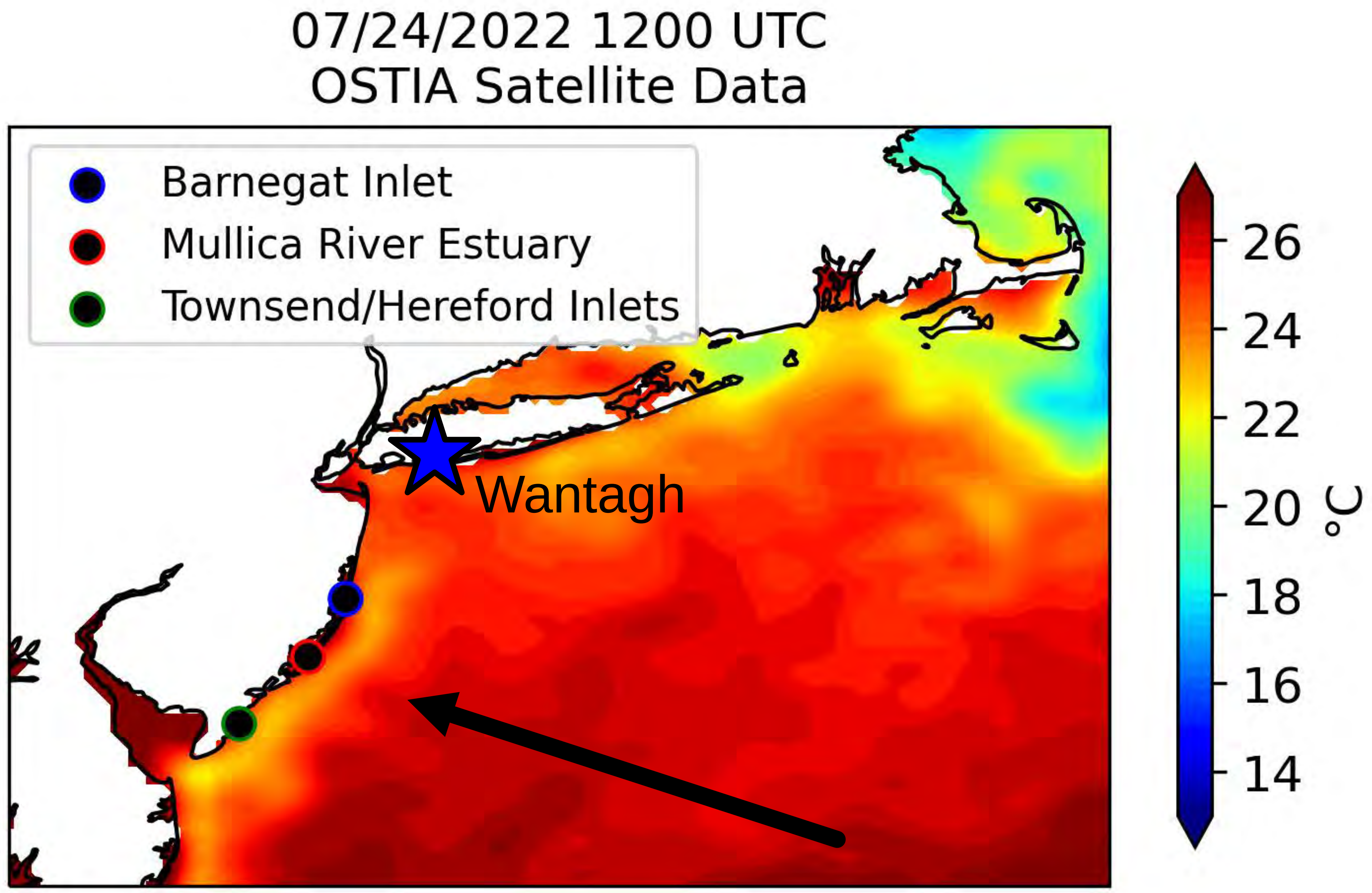
New York Bight is important region for offshore wind development!

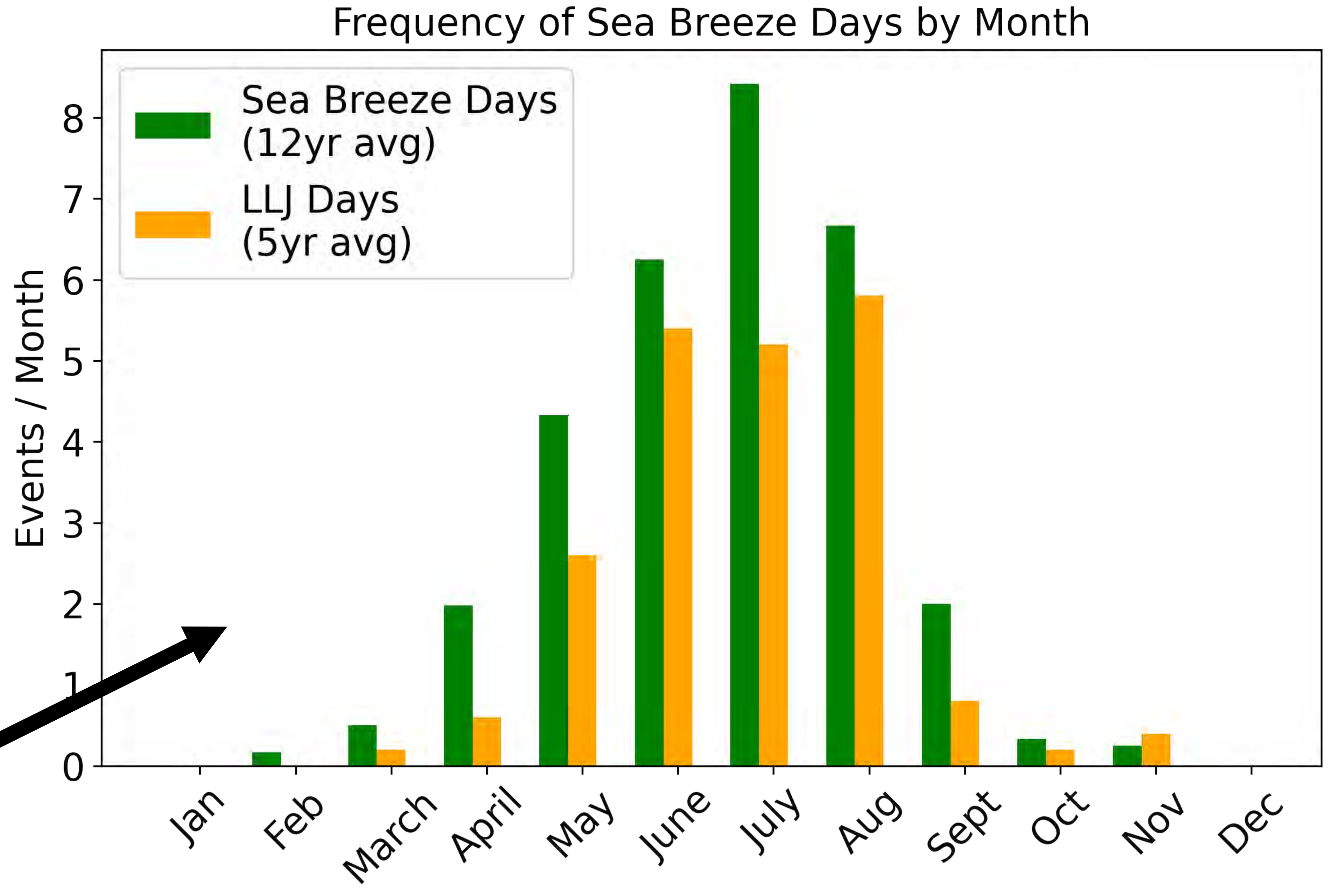
Frequently experiences:

- Warm season **Sea Breeze** and **Low-Level Jet (LLJ)**
  increasing windspeeds during times of peak load

- Episodes of **Cold-Water Coastal Upwelling** especially along New Jersey coastline

Average of **31 Sea Breeze Days Annually** are identified at the **NYSM Wantagh** site, with more than **2/3 featuring an associated LLJ**
(LLJ = wind speed maximum between 150–300 m)





(McCabe and Freedman 2023)

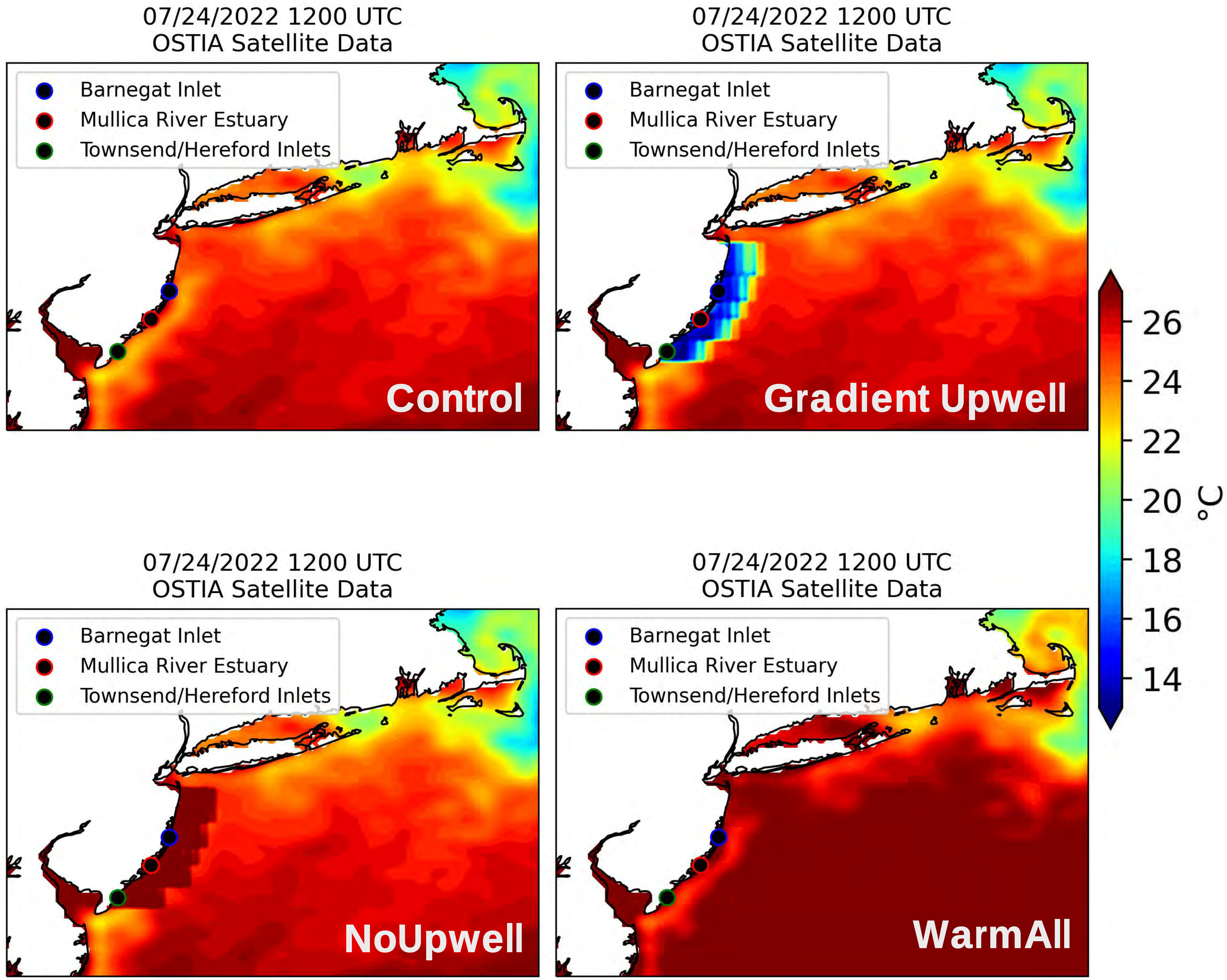
Coastal Upwelling Experiments: SST Sensitivity

Control

GradientUpwell:
From closet to furthest from NJ coast: SSTs reduced by
-10°C, -8°C, -5°C, -2°C

NoUpwell:
From closet to furthest from NJ coast: SSTs increased by
+5°C, +4°C, +3°C, +2°C

WarmAll:
All SSTs are increased by
+2°C



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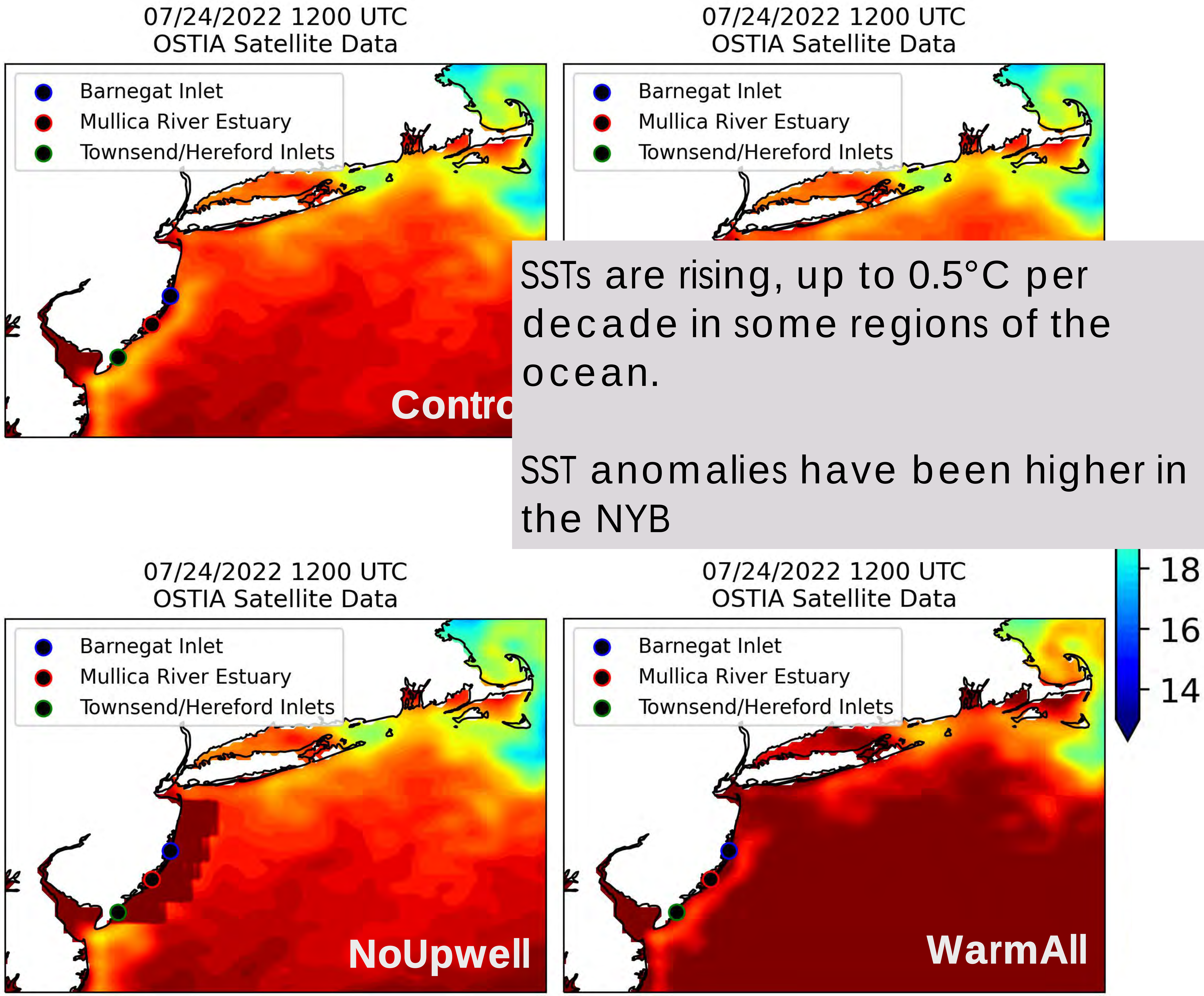
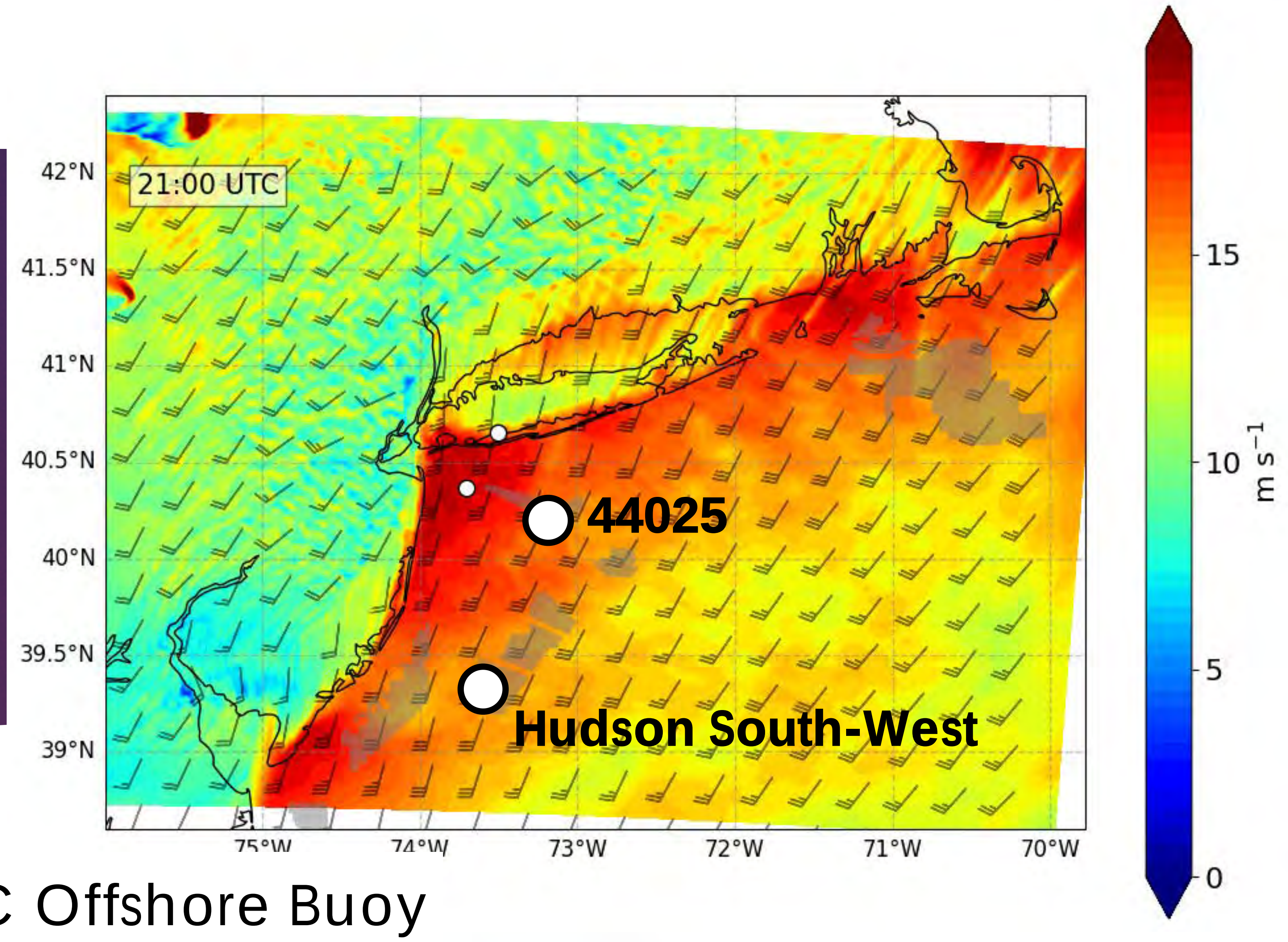


SSTs are rising, up to 0.5°C per decade in some regions of the ocean.

SST anomalies have been higher in the NYB

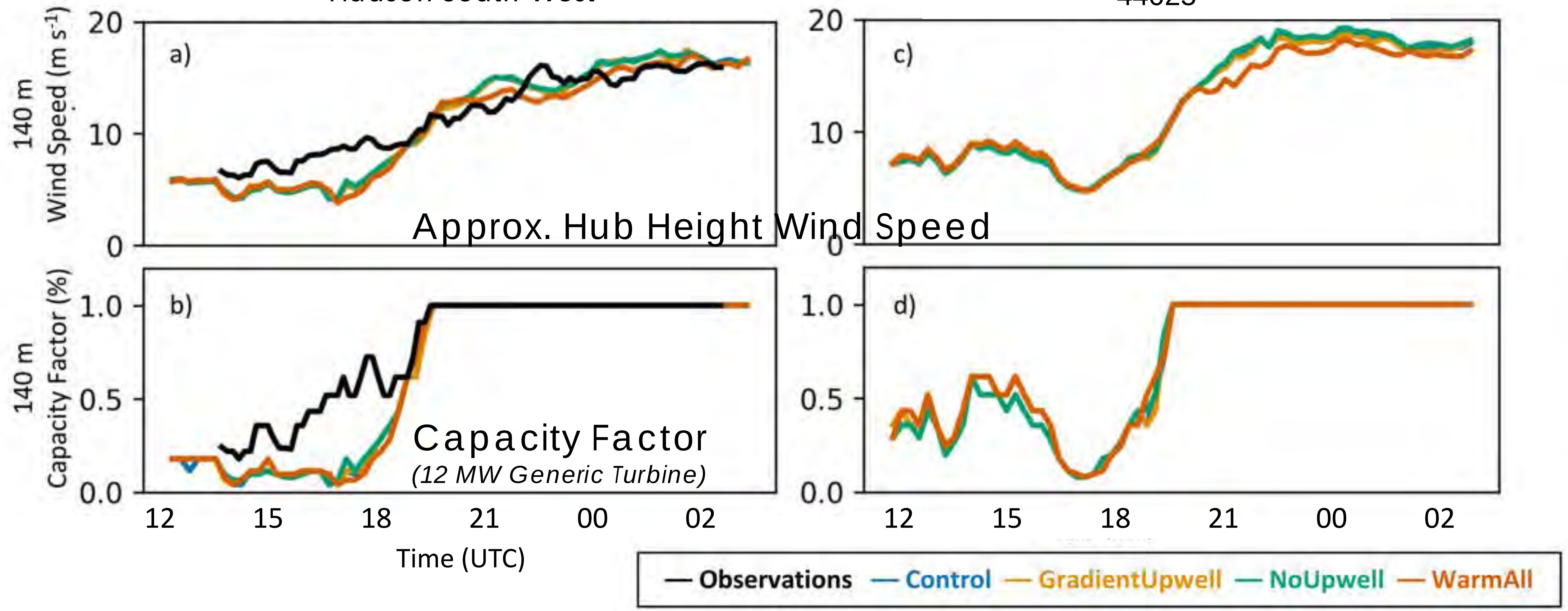
Little Impact on Offshore Gross Capacity Factors



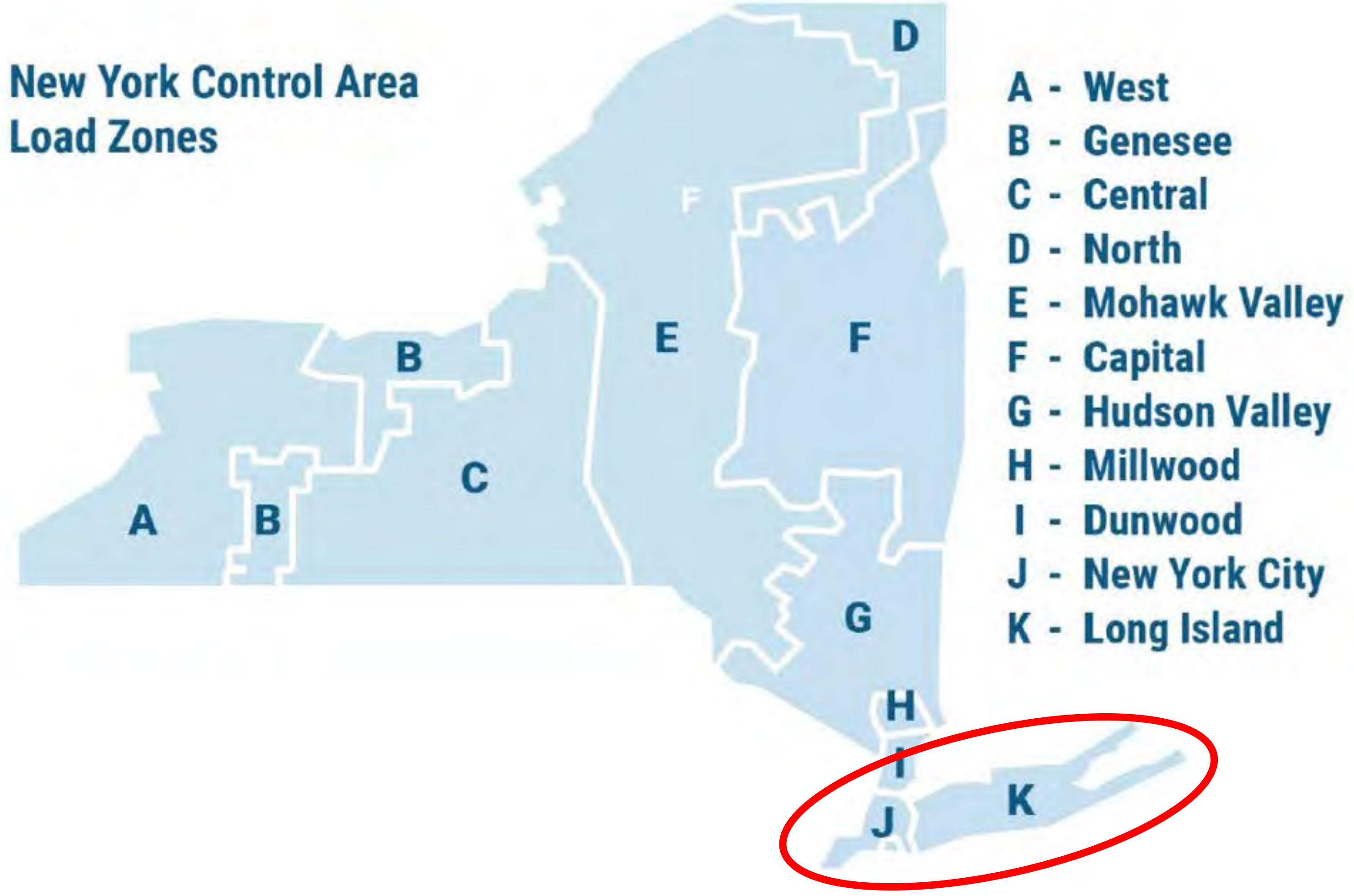
24 July 2022

Location of NYSERDA Offshore LiDAR Buoy Hudson South-West

Location of NDBC Offshore Buoy 44025



Summertime Energy Load vs. Heat Index
June, July, August



Across 4 Upwelling/Sea Breeze Case Studies
06/09/20, 06/28/21, 07/24/22, & 08/04/22

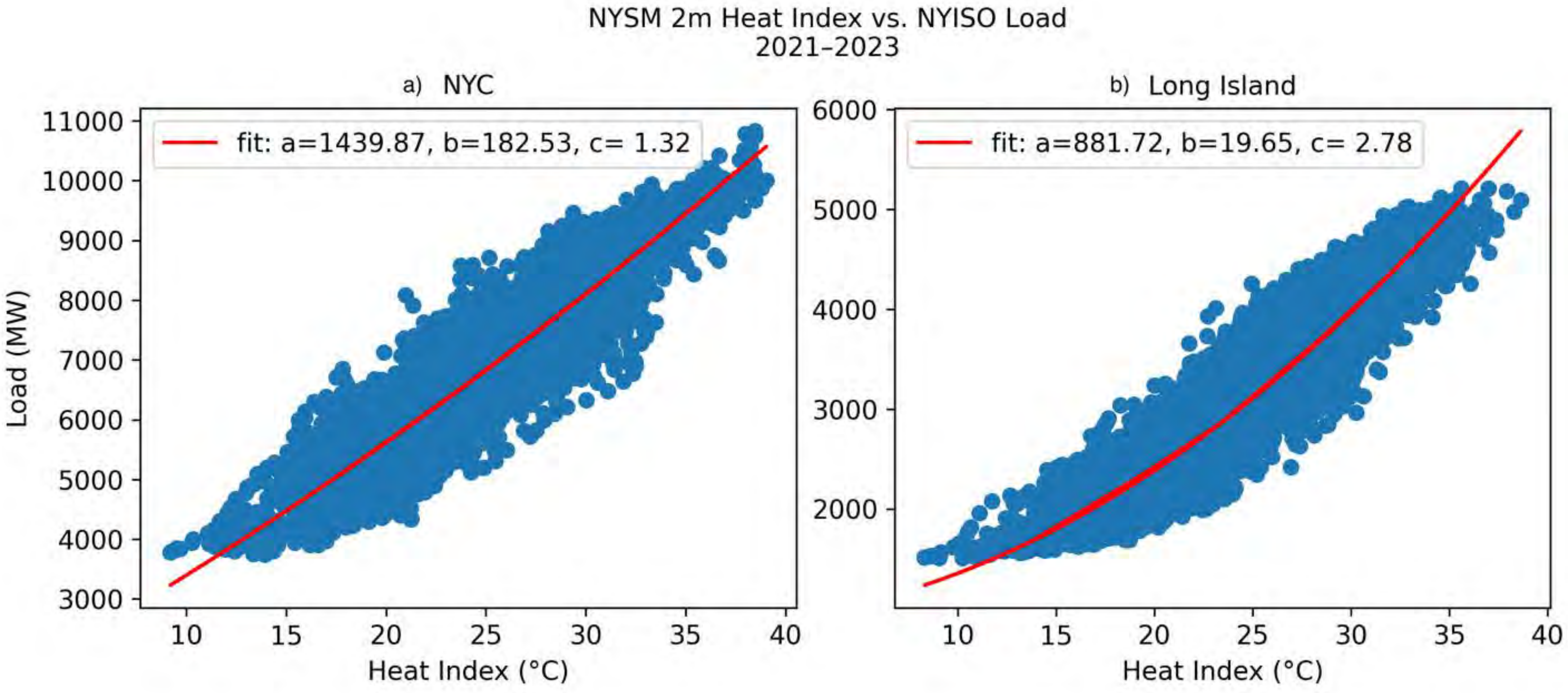
Average reduction in Heat Index at:

NYSM Queens site = 1.8 °C

16 km north of coastline

John F. Kennedy International Airport = 3.8 °C

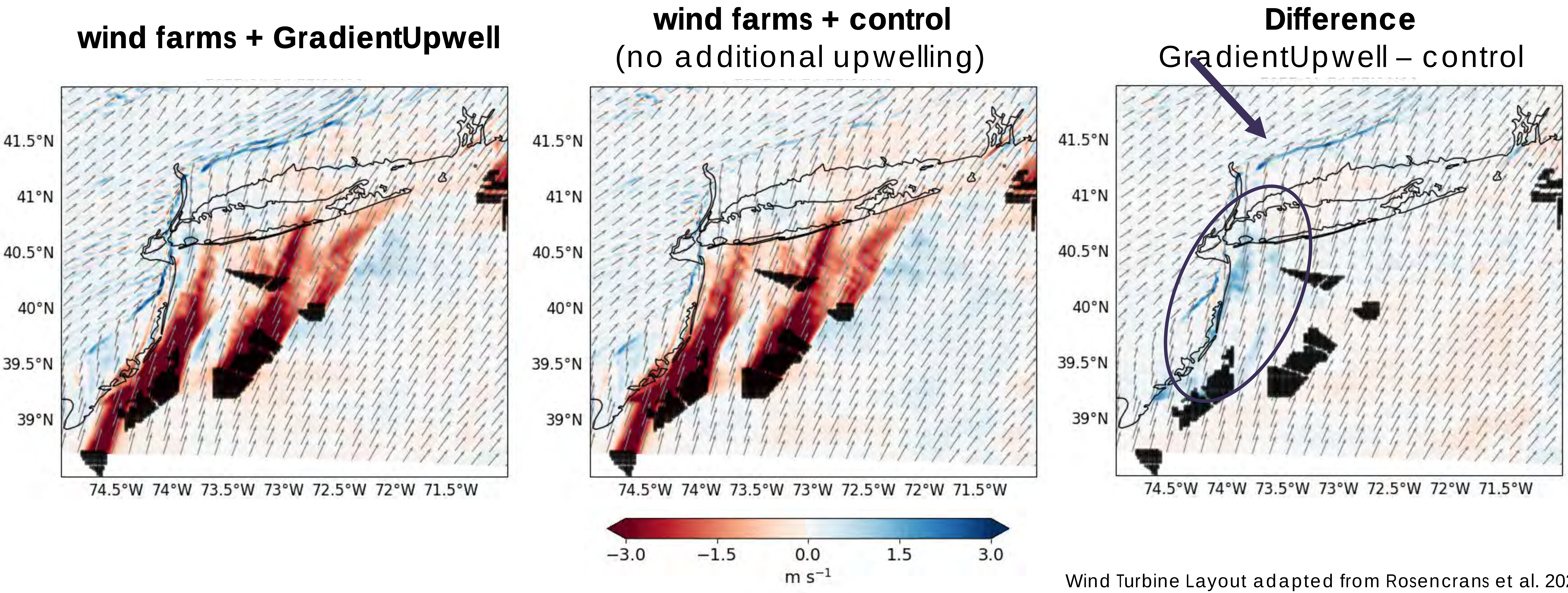
6 km north of coastline



Based on the relationship between load and heat index, temperature reductions can ease energy demand by close to **1000 MW**

Wind Farm Wake Deficits
24 July 2022
150 m Wind Speed

Blue colors indicate wind speed *increase*
Red colors indicate a wind speed *reduction*



Wind Turbine Layout adapted from Rosencrans et al. 2023

Thank You!

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