Learning from the Experts Webinar Series

Offshore Wind Resource Modeling

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Offshore Energy Assessment Lead
DNVGL

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October 20, 2021

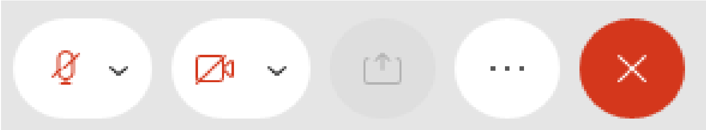
Meeting Procedures

Webinar recordings and presentations will be available at:

www.nyserda.ny.gov/osw-webinar-series

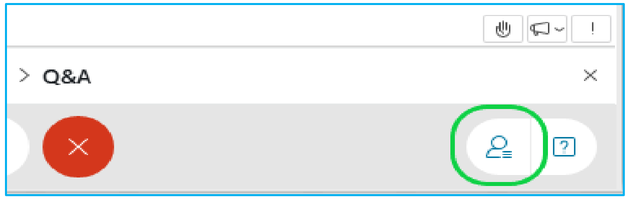
Participation for Members of the Public:

- Members of the public will be muted upon entry.



You'll see when your microphone is muted

- Questions and comments may be submitted in writing through the Q&A feature at any time during the event.



- If technical problems arise, please contact Sal.Graven@nyserda.ny.gov

Learning from the **Experts**

This webinar series is hosted by NYSERDA's offshore wind team and features experts in offshore wind technologies, development practices, and related research.

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

WHEN TRUST MATTERS

Wind Resource and Energy Characterization in NY Bight

NYSERDA Learning from the Experts, a webinar series

Josiah Mault, Offshore Energy Assessment Lead

20 October 2021

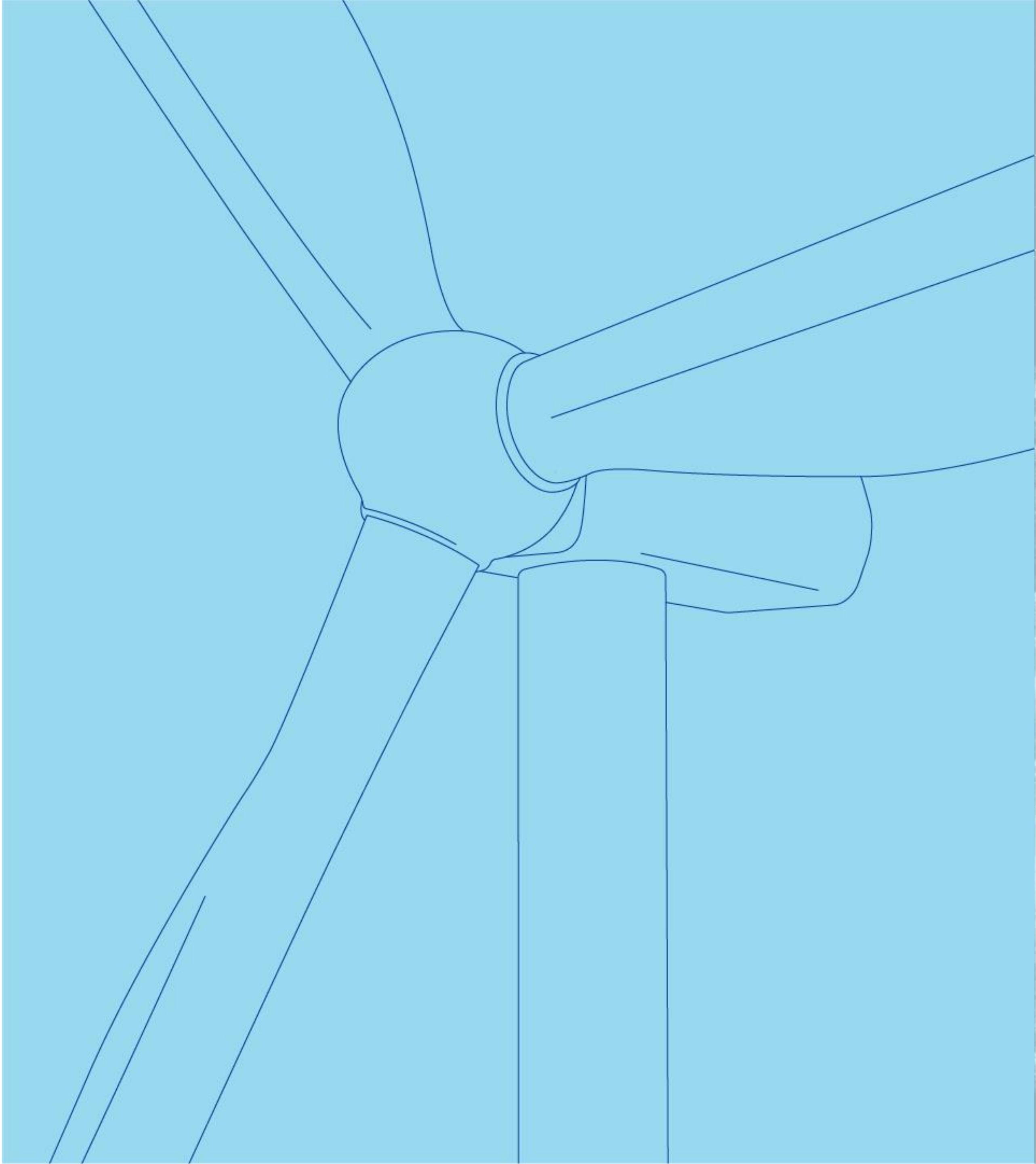
Overview

Who is DNV

DNV’s role

Measuring offshore wind resource

Wind resource and energy



Who is DNV

Why do we exist?

We love renewable energy

Contribute to the greenest energy mix in the grid

OUR PURPOSE

To safeguard life, property, and the environment

OUR VISION

A trusted voice to tackle global transformations

DNV’s data manager role for NYSERDA

DNV's data manager role for NYSERDA

- Prior to deployment
  - Assist NYSERDA in determining buoy deployment locations
  - LiDAR buoy type validation independent review
  - Onshore lidar verification (ZephIR lidar ZX300M)
  - Buoy pre-deployment verification in UK (NAREC Met Tower, Blythe)
  - Comparison of validation campaign to metocean conditions in NY Bight
  - 3rd Party Port Site Acceptance Testing in NJ
- During/after deployment
  - Manage and maintain public data website
  - Publish monthly reports on the data
  - Once-annual energy assessment reports (two total)
  - Provide general advice to NYSERDA over the course of the two year deployment

DNV

NYSERDA Floating LiDAR Buoy Data

Access data from both floating LiDAR buoys deployed in the New York Bight

Download   Select Category

All	Name	Category	Description	Modified Date	File size
	E06 Hudson South Hourly	Raw Buoy Data	E06 Hudson South Hourly	Oct 13, 2021	8 MB
	E06 Hudson South 10 Minute	Raw Buoy Data	E06 Hudson South 10 Minute	Oct 13, 2021	21.08 MB
	Monthly Report - September 2021	Monthly Data Reports	Monthly Report - September 2021	Oct 6, 2021	10 MB
	E05 Hudson North Hourly	Raw Buoy Data	E05 Hudson North Hourly	Sep 21, 2021	8.14 MB
	E05 Hudson North 10 Minute	Raw Buoy Data	E05 Hudson North 10 Minute	Sep 21, 2021	26.26 MB
	Monthly Report - August 2021	Monthly Data Reports	Monthly Report - August 2021	Sep 7, 2021	9.92 MB
	Monthly Report - July 2021	Monthly Data Reports	Monthly Report - July 2021	Aug 3, 2021	9.65 MB

https://oswbuoysny.resourcepanorama.dnvgl.com/

Measuring offshore wind resource

Wind measurement technologies

Conventional met masts

On-site or off-site

Fixed LiDAR devices

Typically off-site

Floating LiDAR Systems*

On-site or off-site

Other

Scanning LiDAR / Met buoys / Existing measurements etc

Fixed platform masts becoming less common.

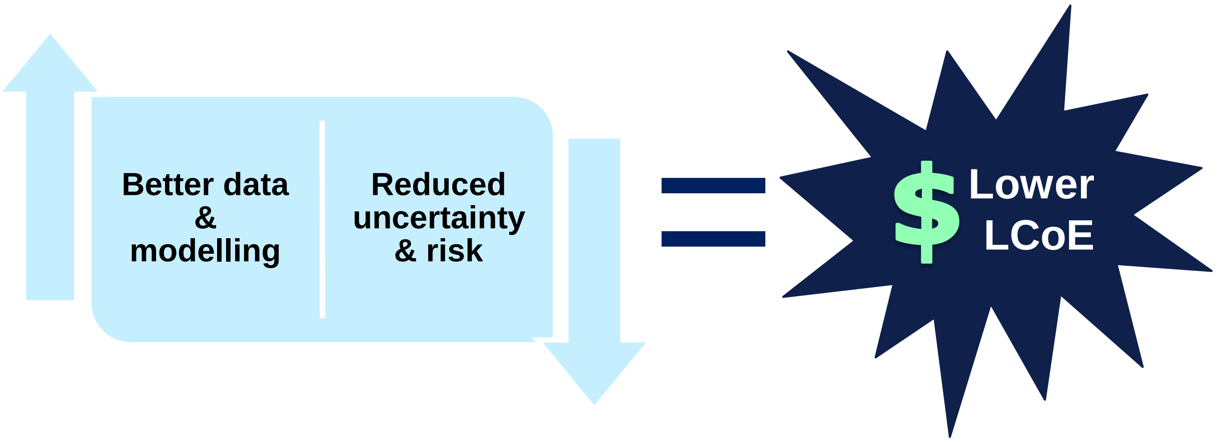
Floating LiDAR reaching higher level of industry acceptance – also significant cost savings.

** Not an exhaustive summary of currently available Floating LiDAR Systems!*

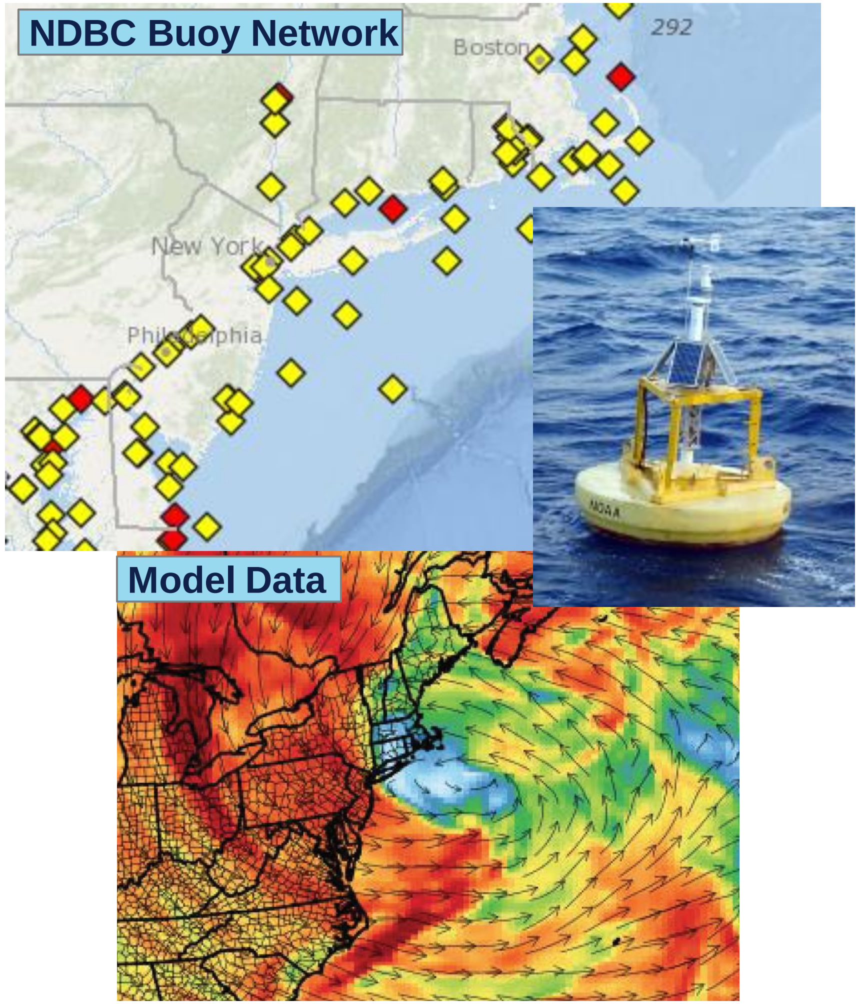
Importance of NYSERDA Floating LiDAR deployment

Existing in-situ metrological data sources by themselves are not sufficient

Wind farm energy analyses require a high-level of accuracy and precision

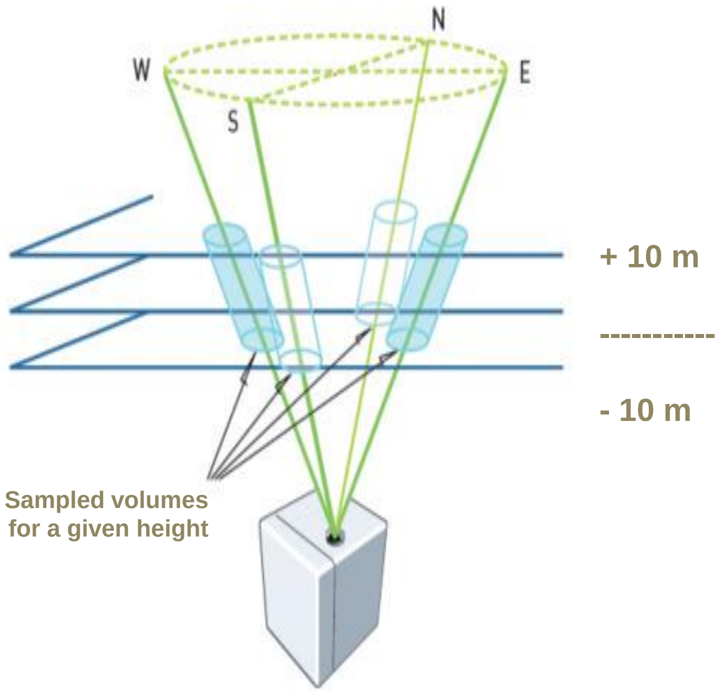


NYSERDA floating LiDAR deployment, first high-quality dataset available pre-lease sale



Remote sensing by LiDAR (Light Detection And Ranging)

- Laser pulse measures wind speed & direction
- Measurements up to 200 m height
- Deployed on fixed platform or buoy
- Becoming established standalone technology for wind resource analyses
- Additional metocean and environmental sensors attached for offshore



Floating LiDAR standards and best practices

The Carbon Trust Offshore Wind Accelerator Floating LiDAR Roadmap provides guidance for floating LiDAR users, OEMs and other stakeholders.

Baseline:

Lidar type considered as proven technology in onshore industry. Complementary use with offshore met mast.

Pre-Commercial:

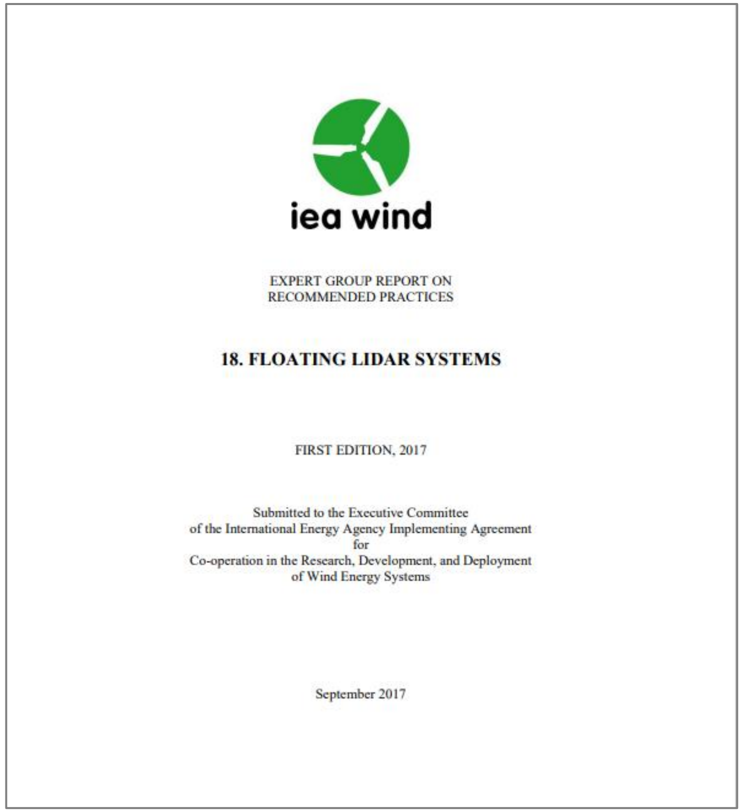
Pilot verification trial for FLS type completed successfully. Limited commercial use.

Commercial:

Commercial use in a range of conditions following further successful sea trial and pre-commercial deployments.

More info:
https://www.carbontrust.com/resources/roadmap-for-commercial-acceptance-of-floating-lidar

IEA Task 32 recommend practice 18: Floating LiDAR Systems "codifies existing industry and academic best practices to help ensure that the best quality FLS data are made available for use in the wind energy resource assessment process."



iea wind

EXPERT GROUP REPORT ON
RECOMMENDED PRACTICES

18. FLOATING LIDAR SYSTEMS

FIRST EDITION, 2017

Submitted to the Executive Committee
of the International Energy Agency Implementing Agreement
for
Co-operation in the Research, Development, and Deployment
of Wind Energy Systems

September 2017

More info:
https://iea-wind.org/task32/

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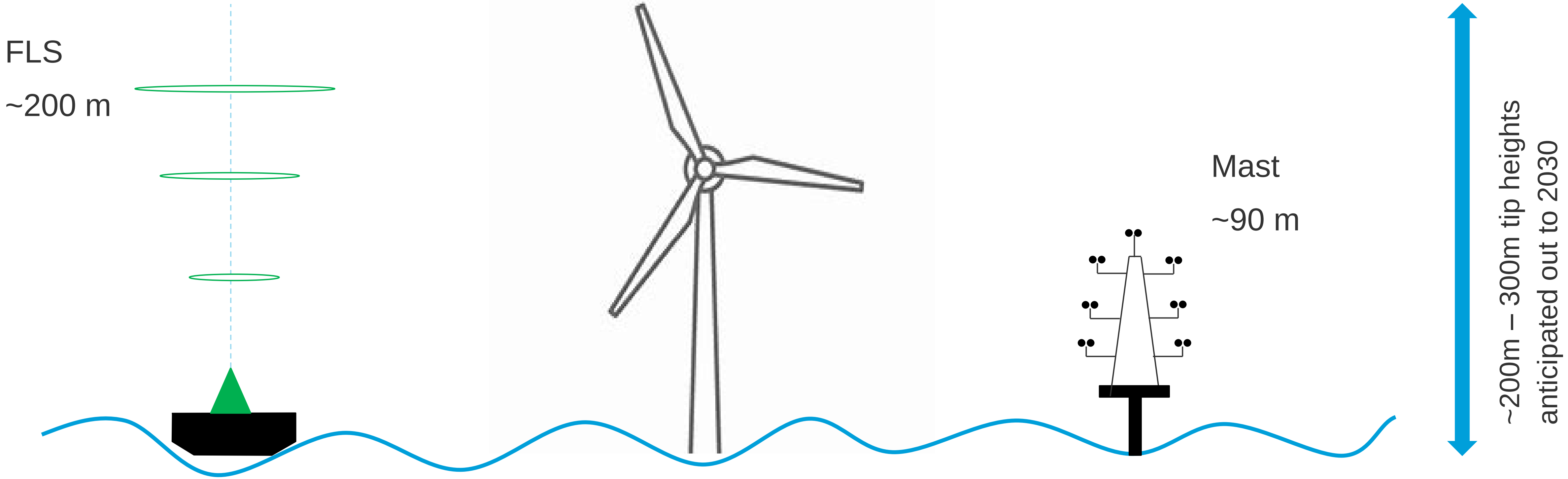
Mast vs Floating LiDAR: what are the key trade-offs?



$ **Wind speed uncertainties:**

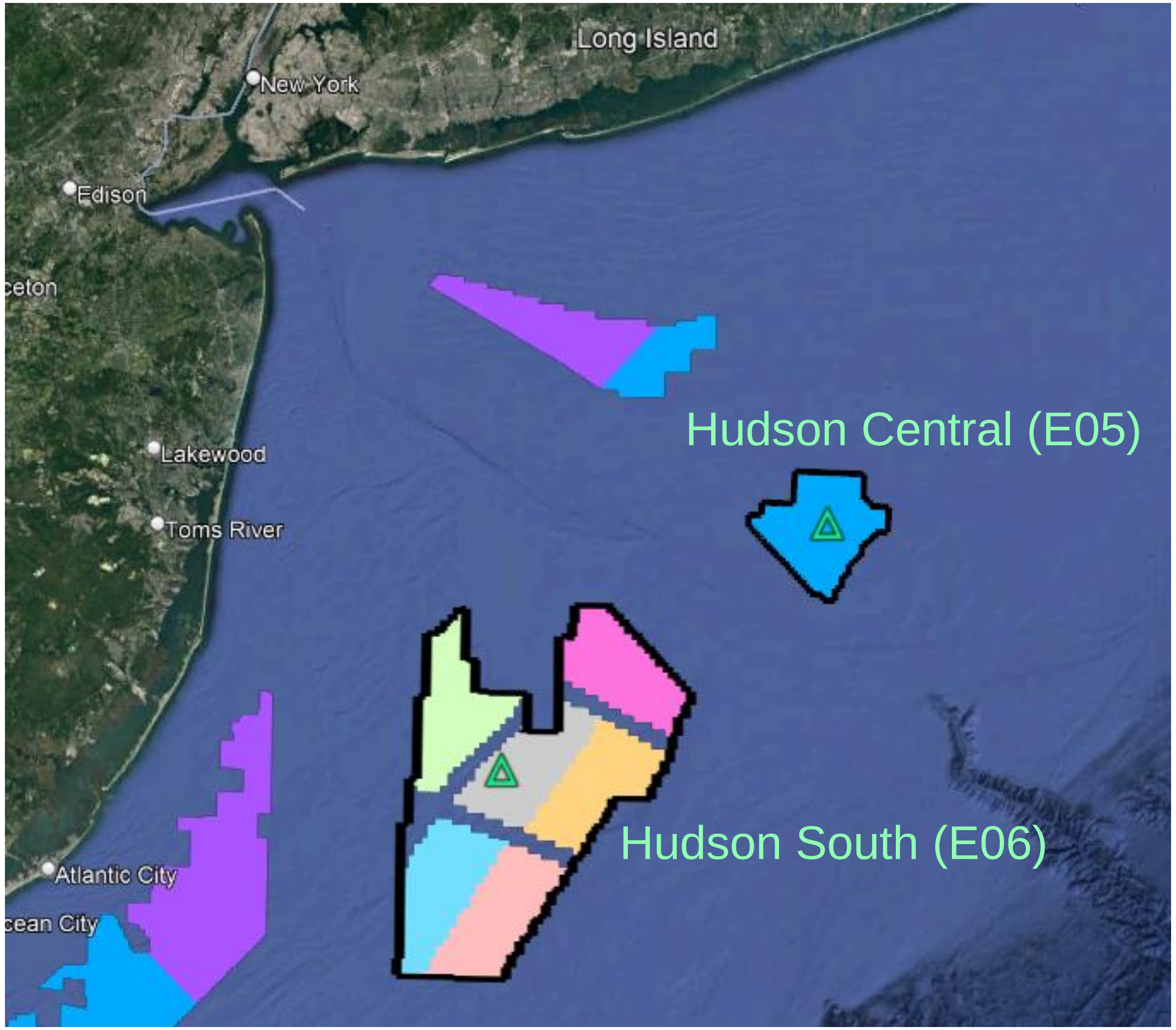
- Wind measurement accuracy
- Vertical extrapolation

$$ **Higher CAPEX Costs**

- Installation / fabrication / deployment
- Operation & maintenance
- Decommissioning

Wind resource and energy

Introduction to New York Bight



NYSERDA Deploys Floating LiDARs in New York Bight

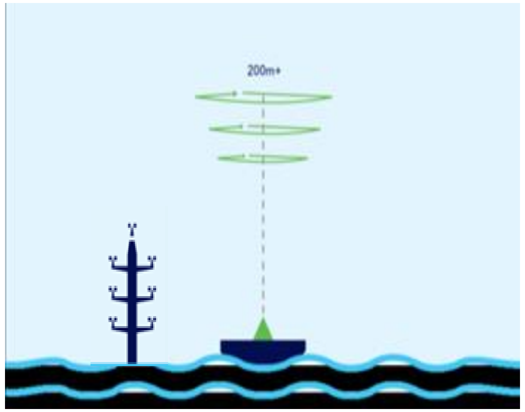
R&D

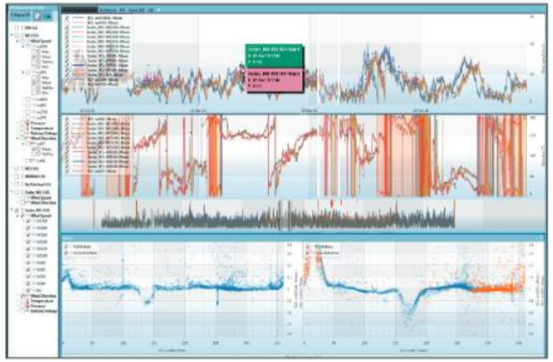
August 8, 2019, by Nadja Skopljak

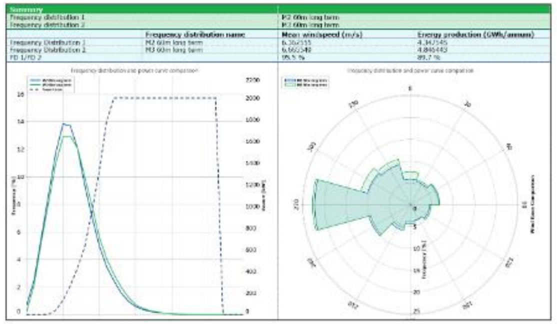
The New York State Energy and Research Development Authority (NYSERDA) has deployed two floating LiDARs in the New York Bight to study the metocean conditions.

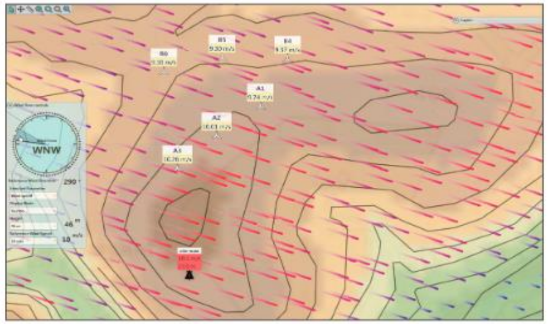
Wind resource assessment & energy prediction

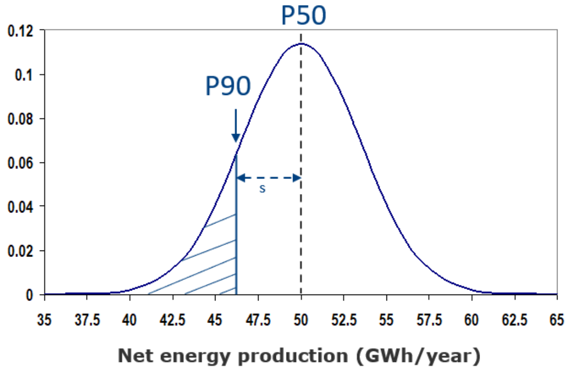
Data collection → Data Analysis → Wind Farm Modeling → Uncertainties







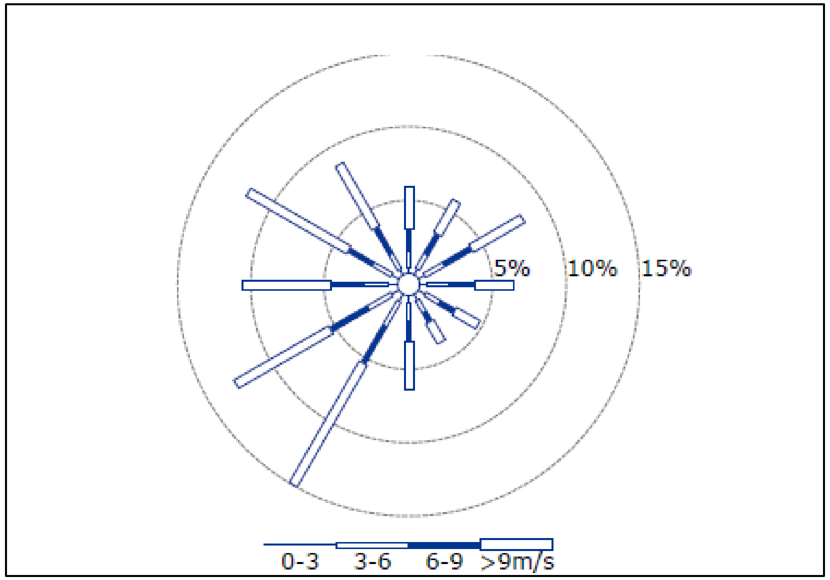




Long-term wind resource summary

Based on January 2021 wind resource and energy assessment, data measurement on going

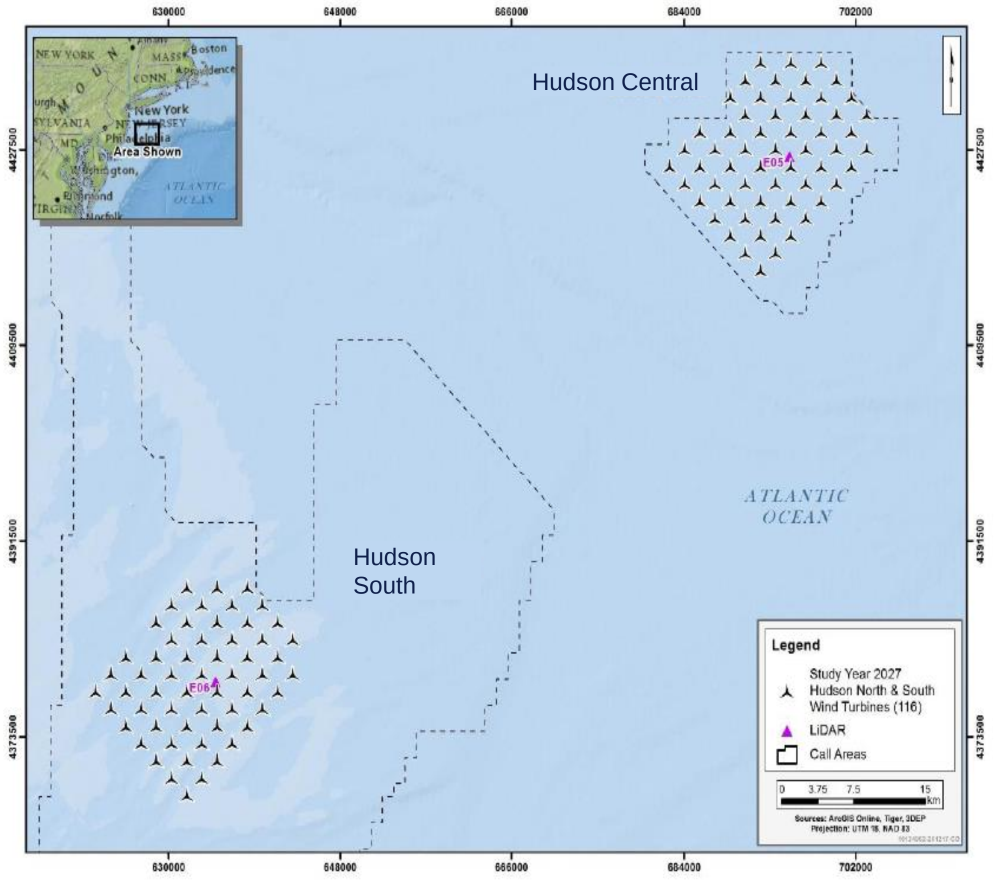
https://oswbuoysny.resourcepanorama.dnvgl.com/



Area	Hudson Central	Hudson South
Hub-height	140	
Avg. Wind Speed [m/s]	10.1	9.9
Wind Speed Range [m/s]	10.1 – 10.2	9.7 – 10.0
Shear	0.09	0.10
TI at 15 m/s [%]	4.5	4.5

Energy scenarios considered

Study Year	2027	2030	2033
Turbine Capacity [MW]	14	18	22
Rotor Size [m]	220	250	275
Hub-height [m]	140	155	165
Number of turbines	58	45	37
Project Capacity [MW]	812	810	814
Project Life [yrs]	30	30	30



- DNV derived hypothetical power curves
- Same fixed layout between Hudson Central & South
- Energy sensitivity to wind speed decreases as turbine size increases
- LCoE decreases over time with fewer turbines

Summary of Energy Results

Lease area	Hudson Central			Hudson South		
Study Year	2027	2030	2033	2027	2030	2033
Gross Energy [GWh/year]	4125.4	4143.5	4170.7	4010.7	4016.6	4043.6
Turbine interaction effects [%]	94.5	93.9	93.2	94.3	93.7	92.9
Availability [%]	94.3			94.3		
Electrical [%]	97.0			97.0		
Turbine performance [%]	96.7	96.6	96.5	96.6	96.5	96.5
Environmental [%]	100.0			100.0		
Curtailment [%]	Not considered			Not considered		
Total Losses [%]	83.5	82.8	82.1	83.2	82.5	81.8
P50 Net Capacity Factor [%]	48.4	48.3	48.0	46.9	46.7	46.4
P50 Net Energy [GWh/year]	3442.4	3431.3	3422.9	3337.3	3315.2	3309.5
P50 Net Energy Per Turbine [GWH/year]	59.4	76.3	92.5	57.5	73.7	89.4

DNV

Wind resource and energy comparison

Summary Hudson Central vs. Hudson South	
Metocean conditions	
- Shear	Slightly lower
- Wind speed at 140m	Slightly higher
- Wave height	Similar
- Bathymetry	Deeper
Energy	
- Energy losses (wakes, availability, etc.)	Similar
- Wind speed to energy sensitivity	Slightly lower
- Net Capacity Factor (NCF)	Higher

- Hudson Central better wind and energy resource, ~3%
- Net energy per turbine increases, LCoE decreases over time by study year
- Hudson South may have lower costs and more opportunity
  - closer to land
  - shallower water depths
  - Potentially larger project area (not modeled)
- Analysis to be updated following two years of data collection Q1 2022

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Thank you

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www.dnv.com

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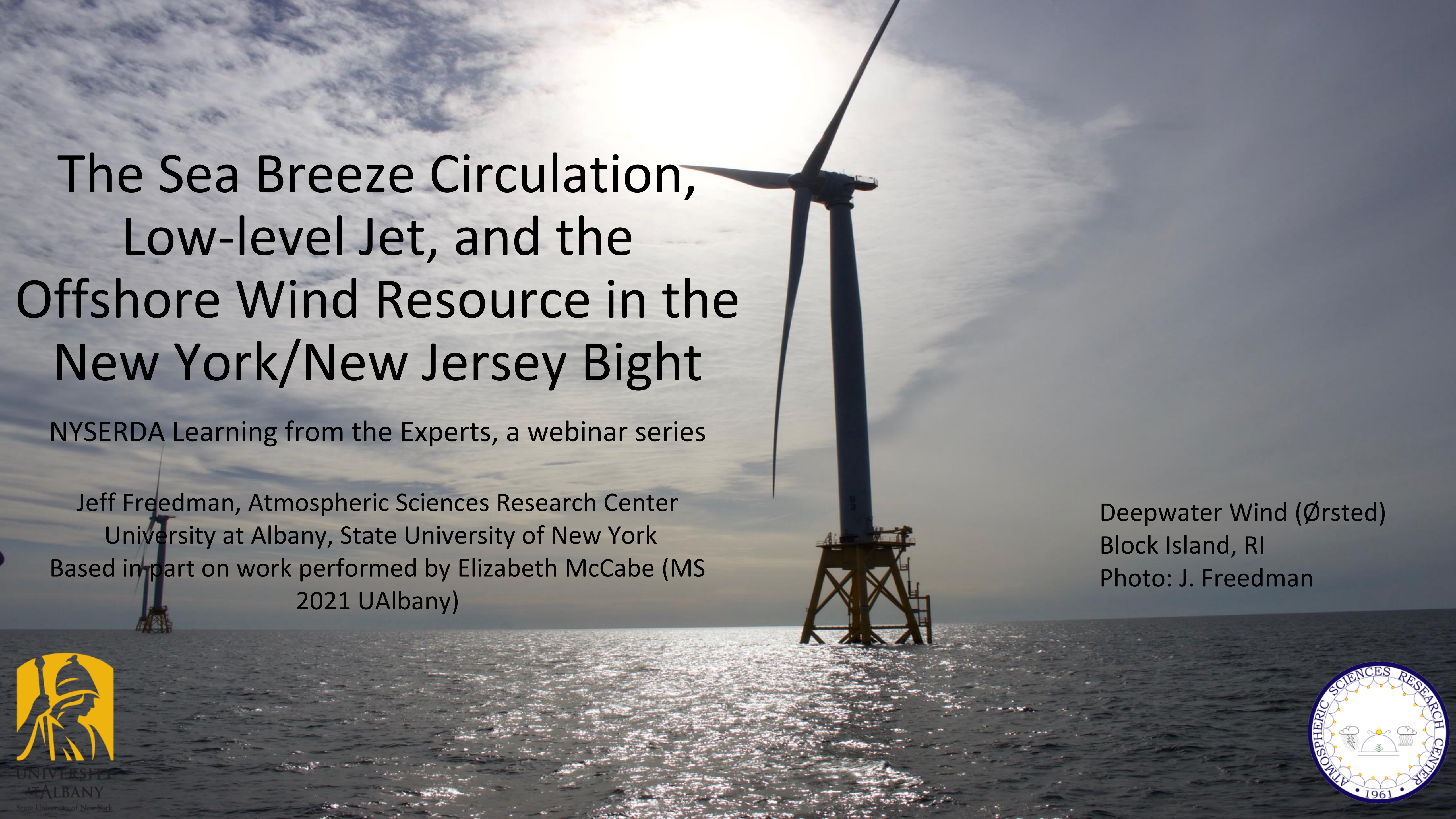


The Sea Breeze Circulation, Low-level Jet, and the Offshore Wind Resource in the New York/New Jersey Bight

NYSERDA Learning from the Experts, a webinar series

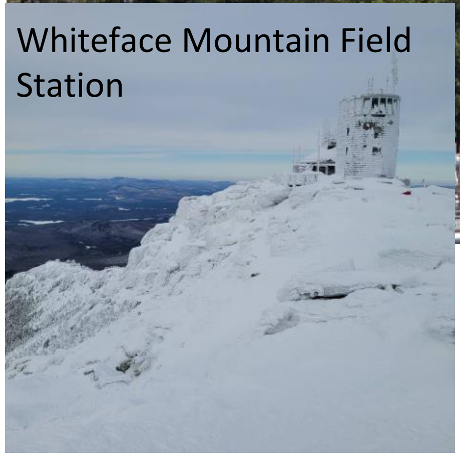
Jeff Freedman, Atmospheric Sciences Research Center
University at Albany, State University of New York
Based in part on work performed by Elizabeth McCabe (MS 2021 UAlbany)

Deepwater Wind (Ørsted)
Block Island, RI
Photo: J. Freedman

Atmospheric Sciences Research Center

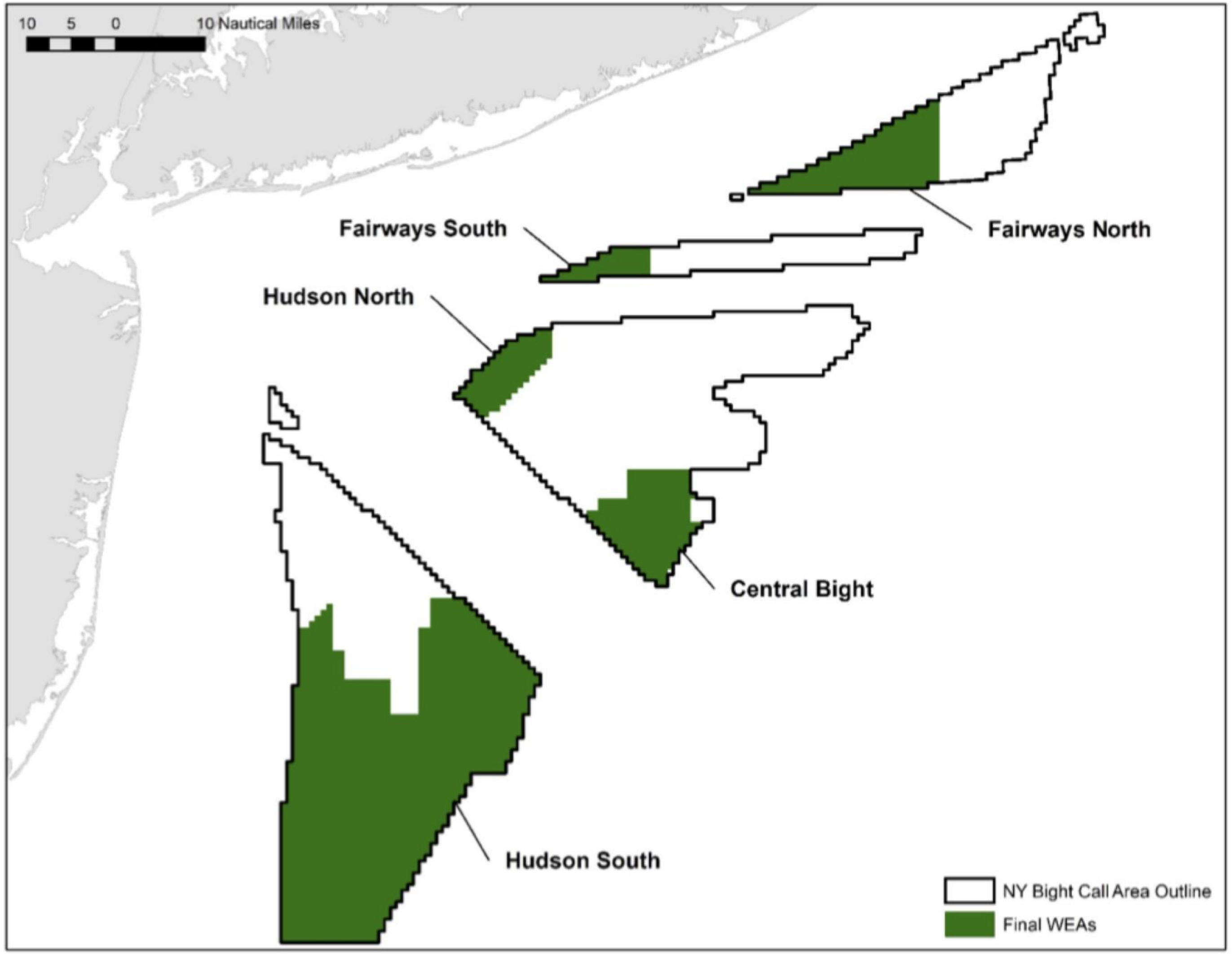
Established by the State University of New York in 1961, the mission of the Atmospheric Sciences Research Center is to expand our knowledge and understanding of the physical and chemical processes of the atmosphere and its interaction with land and water systems. ASRC engages in interdisciplinary research to improve the quality of life and economic well-being of New York State, the nation, and the globe.

ASRC’s new home at UAlbany’s ETEC



Whiteface Mountain Field Station

Significance of the New York Bight



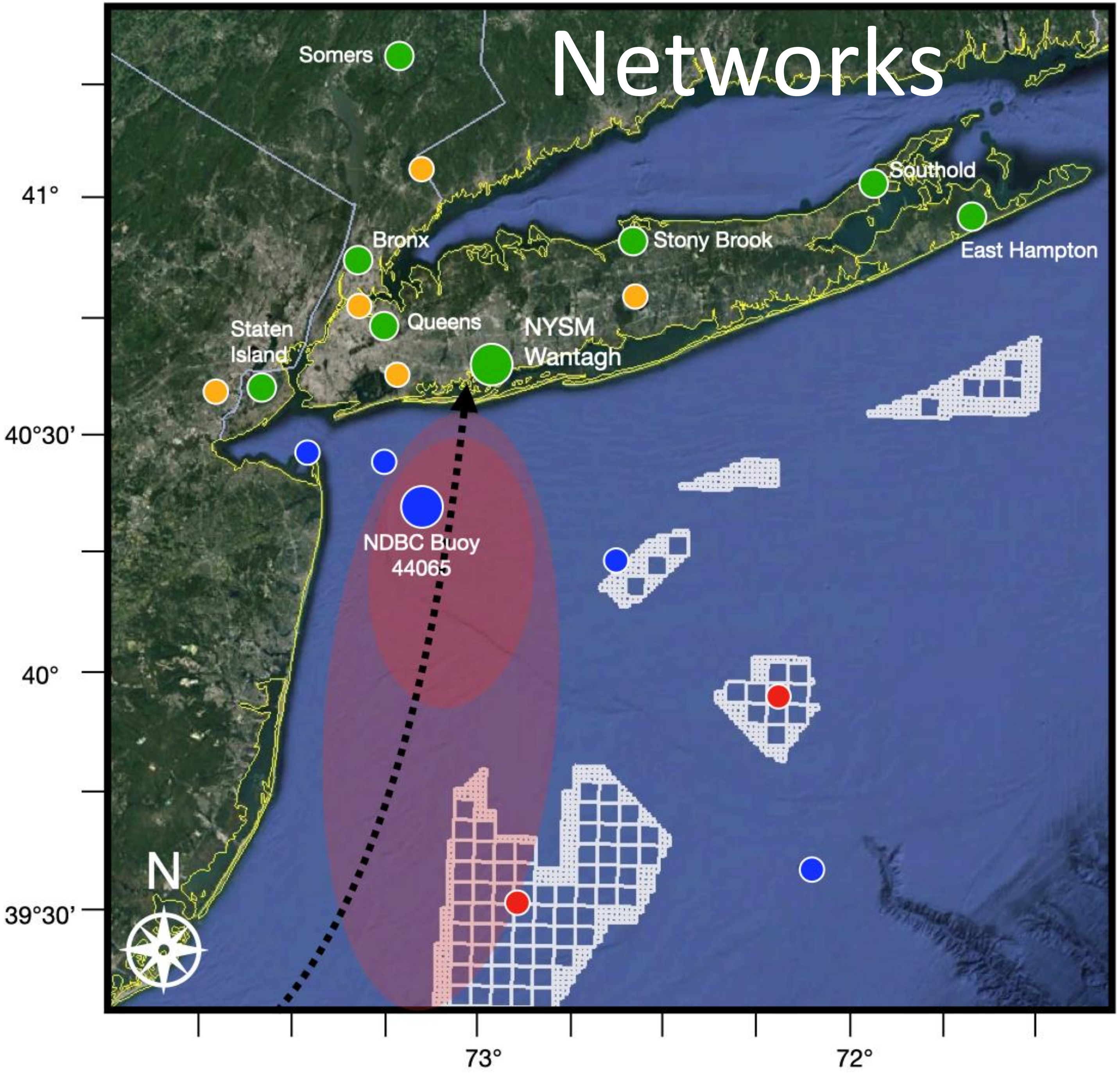
- Area of Shallow water south of Long Island and east of the New Jersey Coast
- Limits extend south to Cape May, NJ and east to Montauk, NY (Geyer 1981)
- 5 Lease Areas for Wind Energy Development **807,383 Acres/ 3,267 km2 total (shaded in green)**

Multiple phenomena affecting the region—need for more sophisticated long-term observations to inform modeling improvements

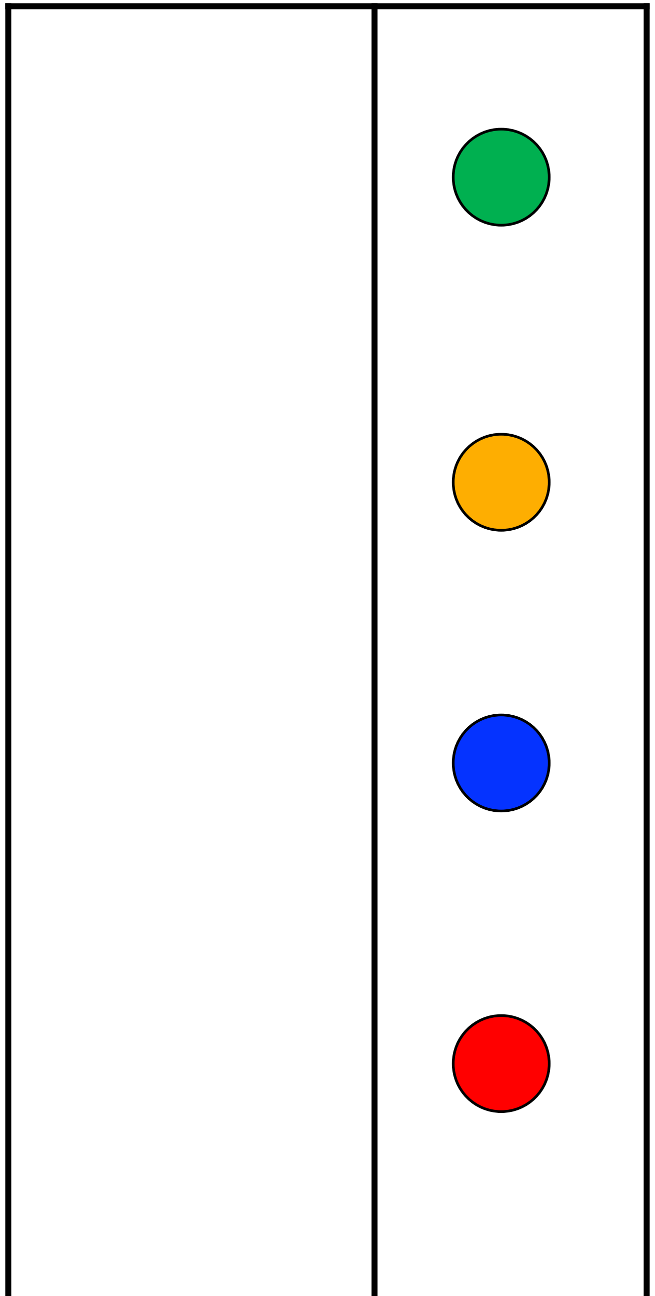
Phenomena affecting the offshore wind met-ocean environment. Abbreviations are: AP (atmospheric profiles), OP (oceanic profiles), ODA (ocean data assimilation), Fluxes (include exchanges of momentum, heat, and moisture), Z_0 (surface roughness), ScanLiD (Scanning LiDAR), Sat SST (derived--satellite sea surface temperature). ∇p and ∇T refer to gradients of pressure and temperature; GS = Gulf Stream.

Phenomena	Spatial	Temporal	Season	Forecast uncertainty	Proposed modeling improvements	Proposed observations
Sea breeze & NY Bight LLJ	Mesoscale	Hours | daily sequences	Warm	High	PBL, Ocean initializationDA	AP, OP, ∇p, ∇T, ScanLiD, Fluxes
pre-frontal LLJs	Mesoscale	Hours | daily sequences	All	High	PBL, Zo, wave state, DA	AP,∇p, ∇T,SST, ScanLiD, Fluxes
Convection	Mesoscale	Hours	All	High	μ-physics,gust,lightning	Radar, AP
Waking	Mesoscale	Hours to days	All	Medium	Wind farm parameterization	AP, ScanLiD
Offshore flow	Synoptic	Hours to days	Cold	Medium	DA	AP, OP, SST
Easterly flow	Synoptic	Hours to days	All	Low/medium stability issues	PBL, DA, ODA,	AP, OP, Fluxes,∇p,∇T
Extra-tropical Tropical Systems	Synoptic	Hours to days	All Warm	Low	PBL; Z_0, waves, DA	AP, Fluxes,OP,∇p,∇T
Sea state	Cross-scale	Hours to week+	All	Medium	A-S interaction, waves, Z_0	Wave obs, HF surface obs, Fluxes
Coastal upwelling	Cross-scale	Hours to days	Warm	High	A-S interaction	OP, AP
GS meanders	Cross-scale	Days	All	Low	A-S coupling	Sat SST
Ramp events			Ramps can occur with many mesoscale/synoptic phenomena and at defined timescales (e.g. Akish et al. 2019)			

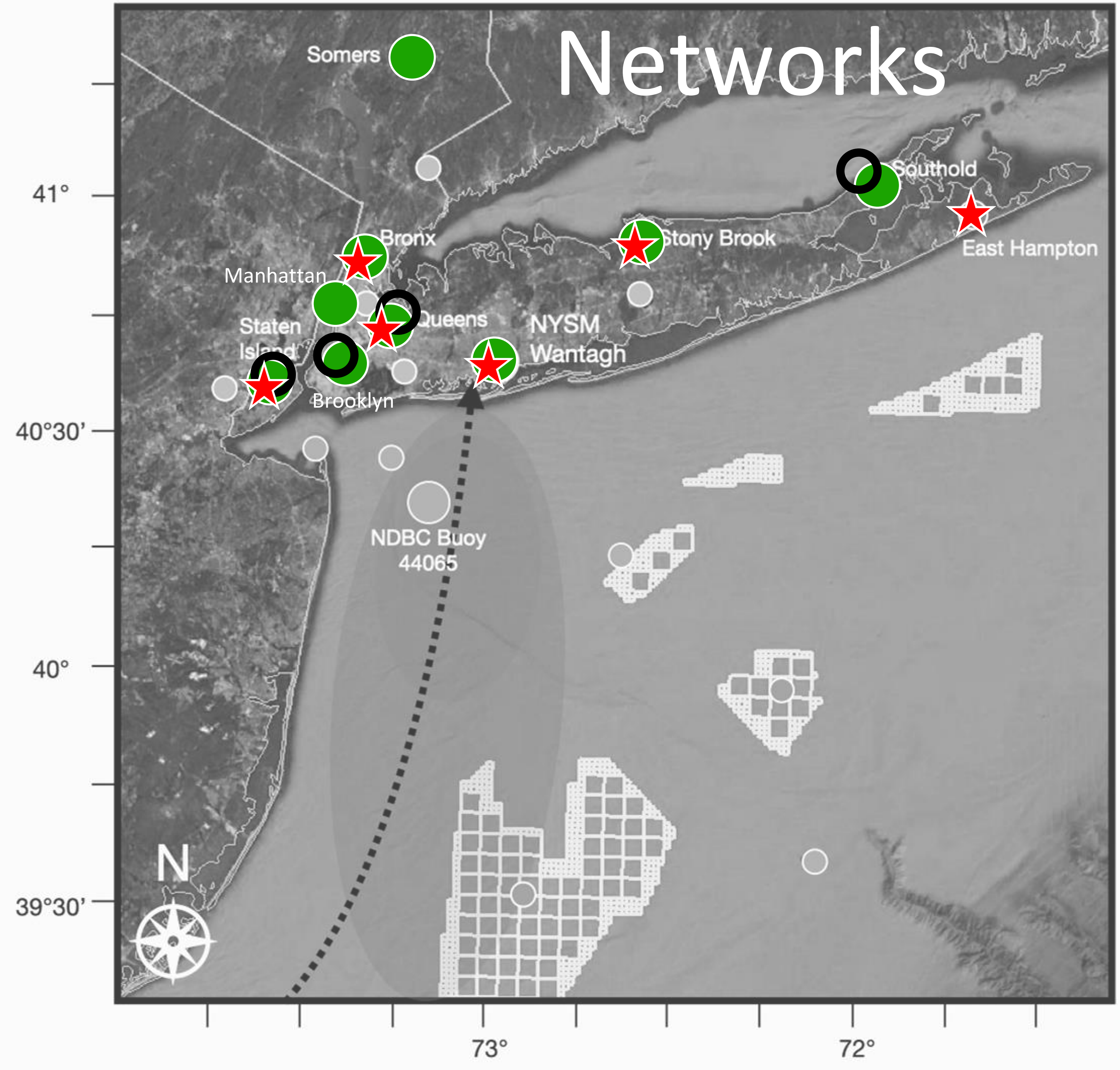
Networks

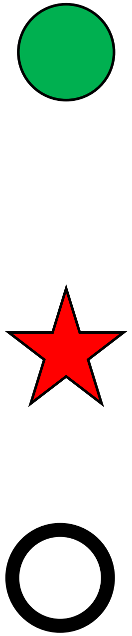


Somers
Southold
41°
Bronx
Stony Brook
East Hampton
Queens
NYSM
Wantagh
Staten
Island
40°30'
NDBC Buoy
44065
40°
N
39°30'
73°
72°



Networks



NYSM Sites	
	

New York State Mesonet Enhanced Site at Wantagh

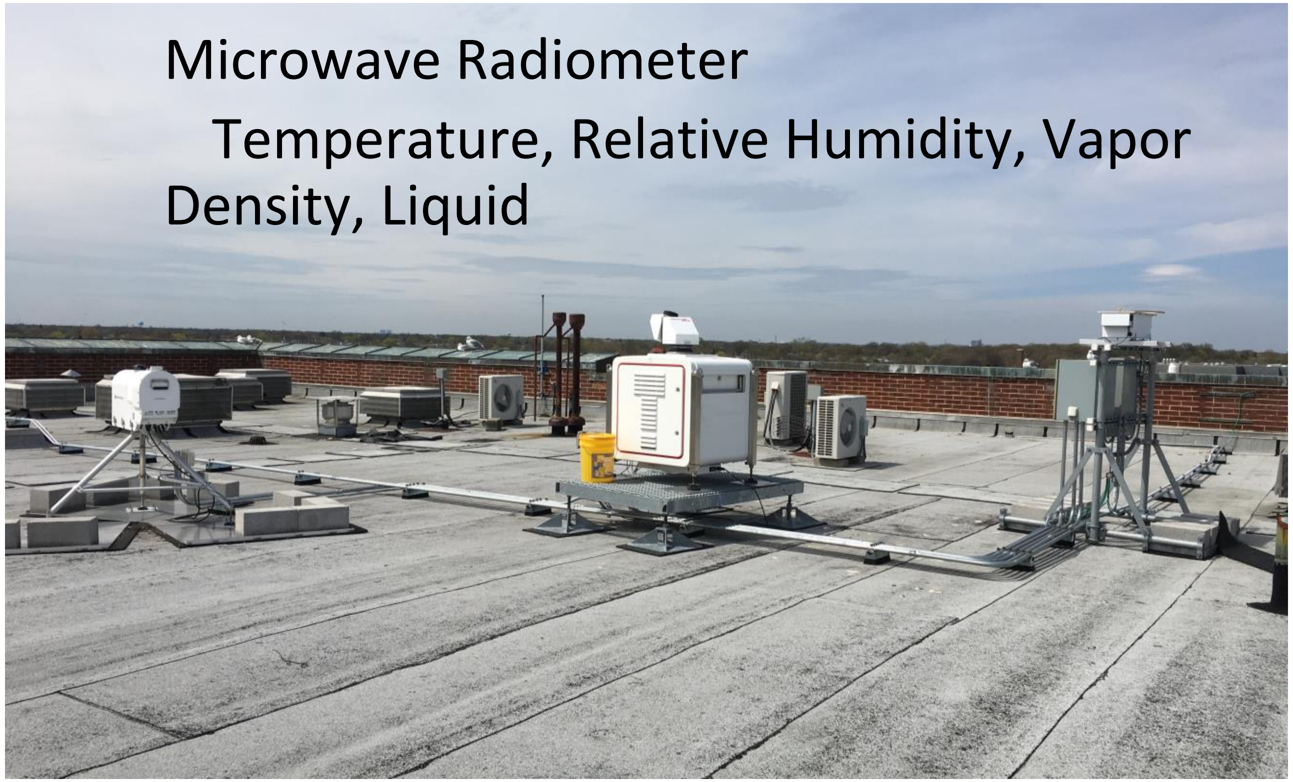
Profilers

WindCube Doppler LiDAR (~10m above surface)

Scans every 25m from 100-1,000m, then every 50m from 1000-7000m

Microwave Radiometer

Temperature, Relative Humidity, Vapor Density, Liquid



Surface Station

Air Temperature, Relative Humidity, Solar Rad., Pressure, Windspeed, Wind Direction, Soil moisture and temperature

NYSERDA-deployed Buoys—data available from https://oswbuoysny.resourcepanorama.dnvgl.com

Hudson North: 08/12/19 – Current
Hudson South: 09/04/19 – Current

- Current Velocity and Direction
  - *Depths 4.3m - 61m (Hudson North)*
  - *Depths 3.5m - 35m (Hudson South)*
- Wave Height, Period, and Direction (0.8m BSL)
- Water Temperature (0.8m BSL)
- Air Temperature and Pressure (2m ASL)
- Incoming Solar Radiation (2m ASL)
- LiDAR System (2m ASL)

  Measures 20m - 200m, at 20m intervals
  - *Windspeed and Wind Direction*
  - *Windspeed minimum and maximum*
  - *Turbulence Intensity*
  - *Vertical Windspeed (w)*

Two 2 EOLOS FLS200 units

Standard Met Data

ASOS (Automated Surface Observation System)

- 1-minute temporal resolution, measures wind speed/wind gusts, wind direction, temperature, dew point, sea level pressure (SLP), cloud cover, visibility, and precipitation

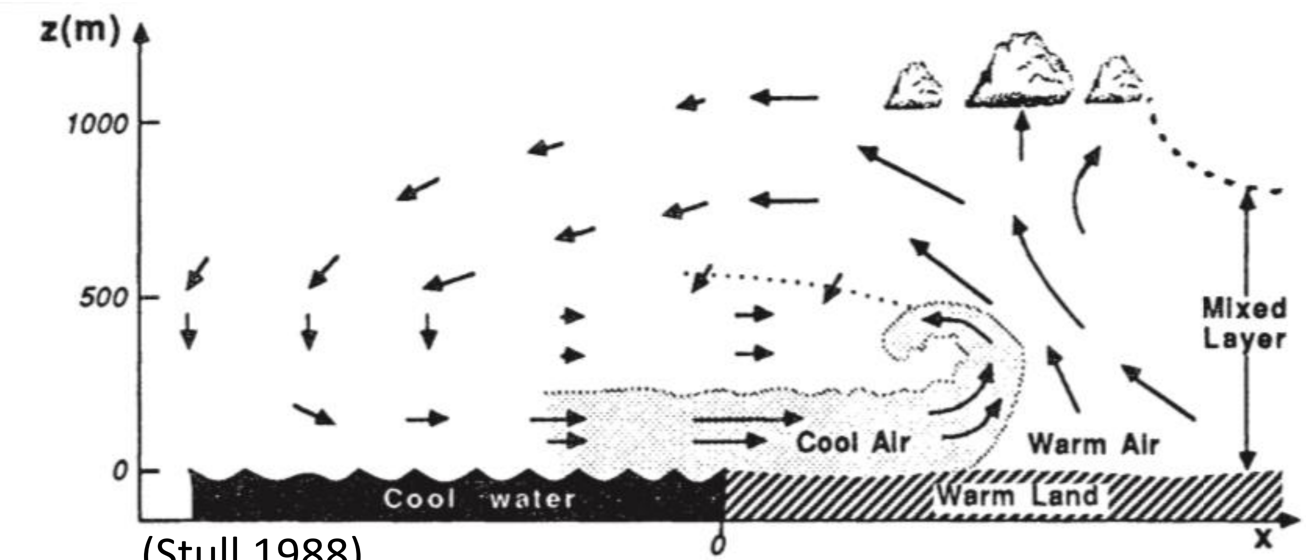
ISD Lite (Integrated Surface Station Data)—ASOS data archived at National Centers for Environmental Information

- 1-hour temporal resolution
- Measures wind speed and direction, temperature, dew point, SLP, sky condition, and precipitation

JFK (North)

JFK (South)

Sea Breeze Circulation



(Stull 1988)

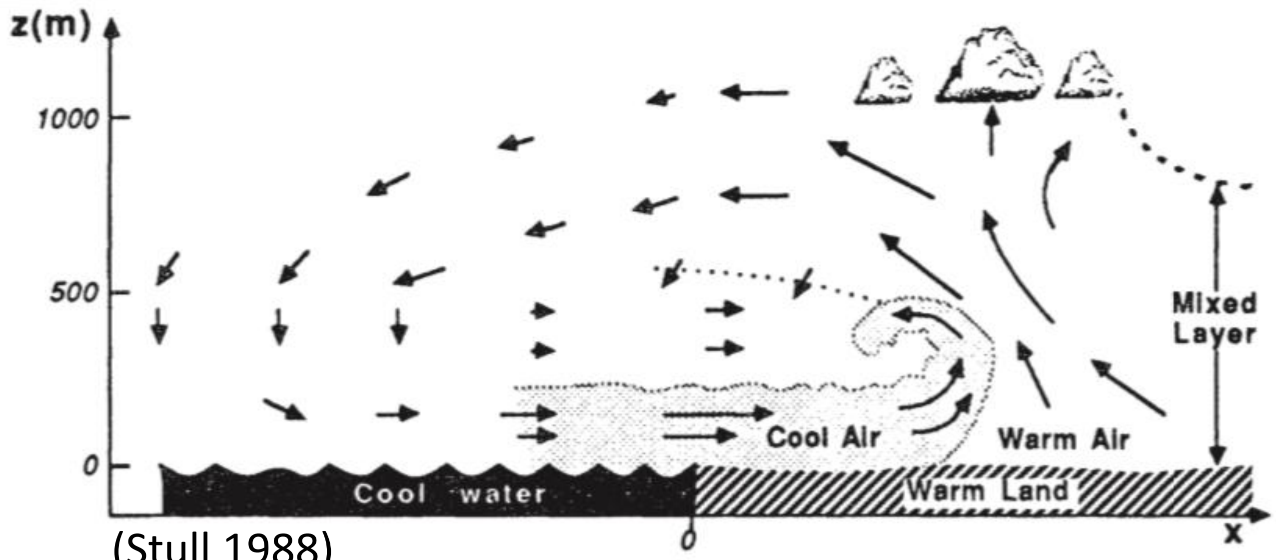
Offshore

- Colder SST
- Higher Pressure

Onshore

- Higher surface temperature
- Lower Pressure

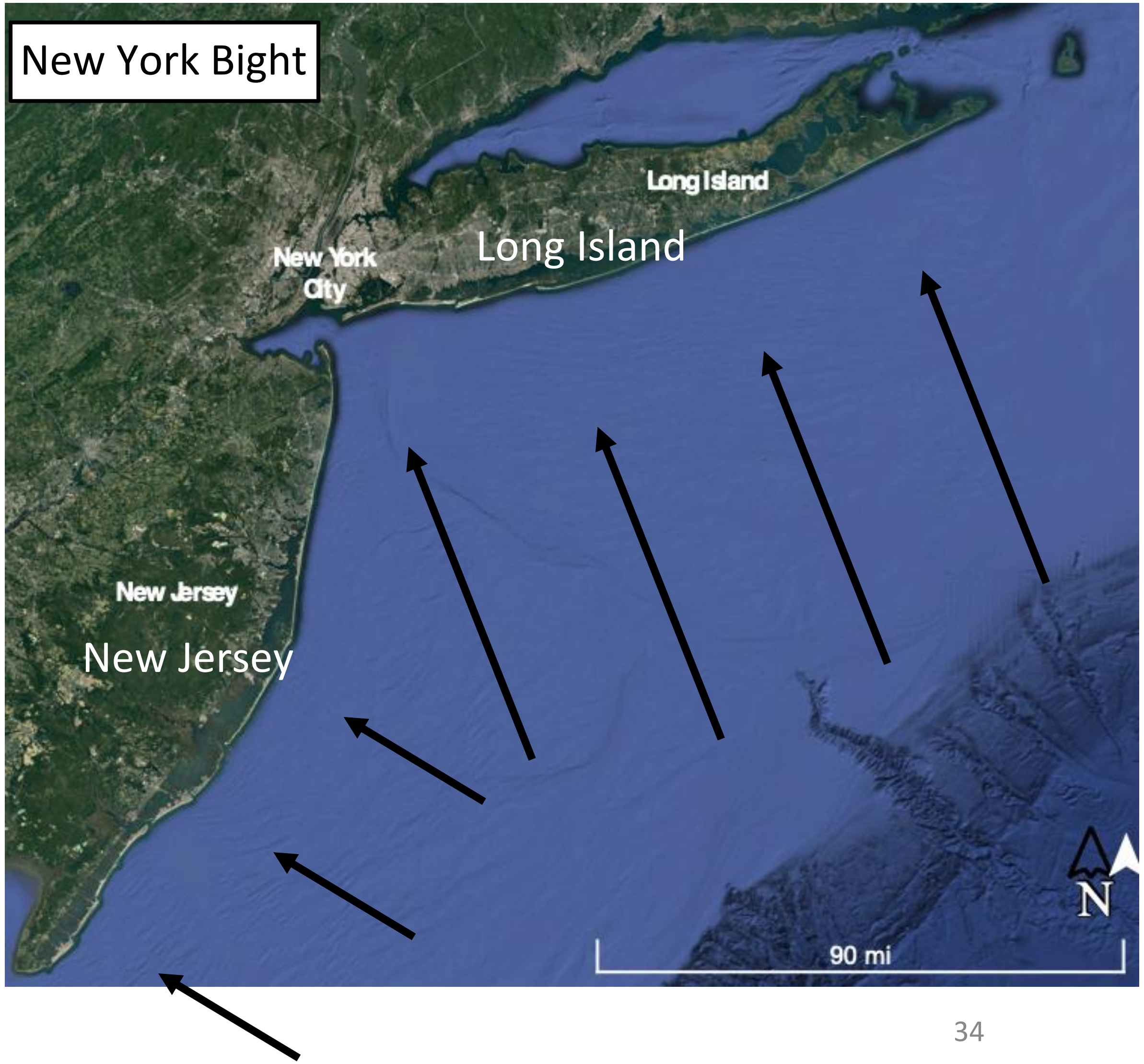
Sea Breeze Circulation



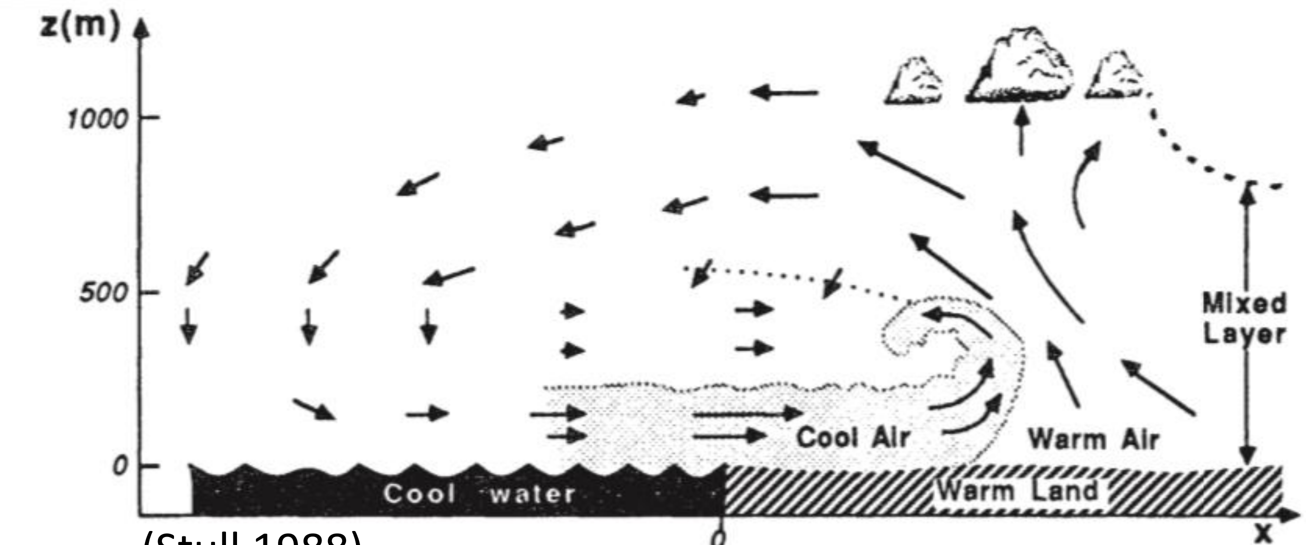
(Stull 1988)

Offshore
- Colder SST
- Higher Pressure

Onshore
- Higher surface temperature
- Lower Pressure



Sea Breeze Circulation



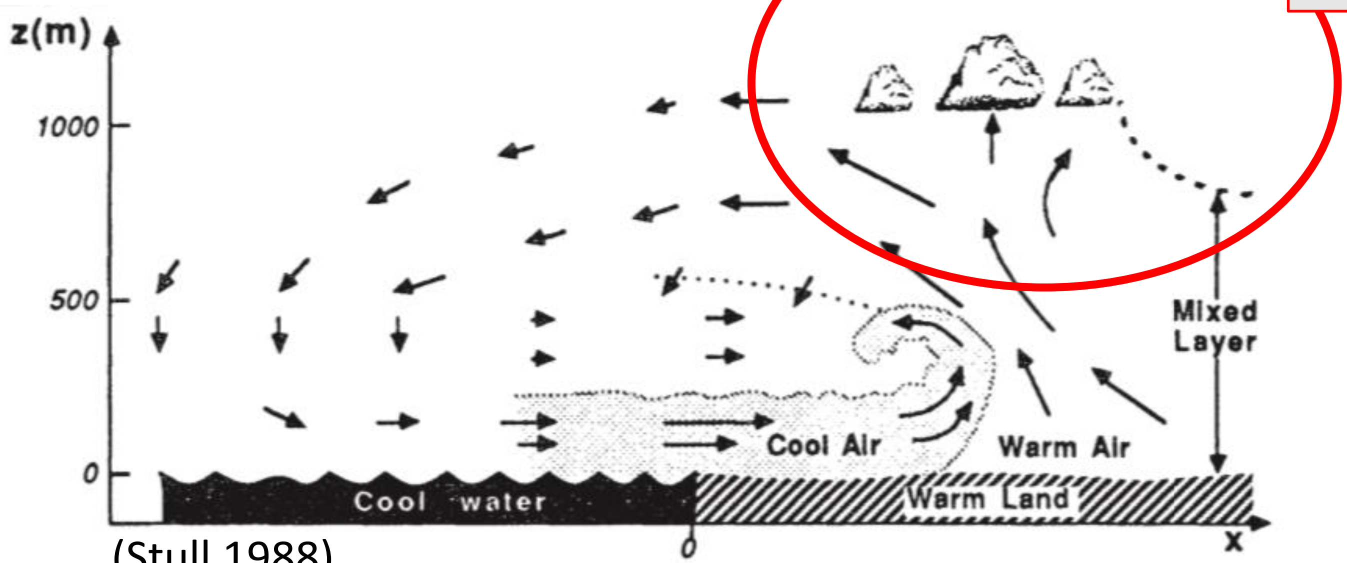
(Stull 1988)

- **Sea Breeze Circulation generally comes onshore at approximately 1800 UTC**

- **Can continue to persist until sunset (when the temperature gradient reaches zero)**

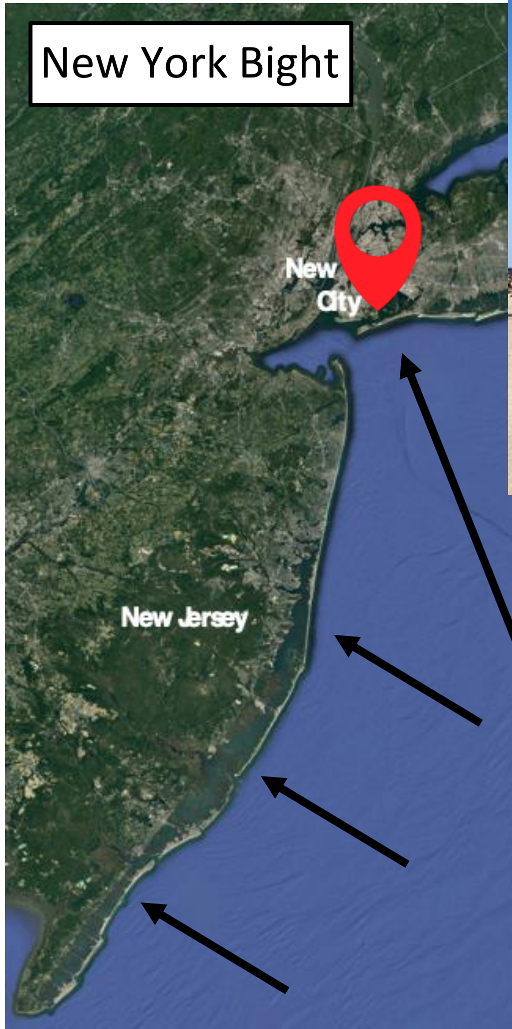
July 21, 2020
Riis Park in Rockaway, Queens
(photo by J. Freedman)

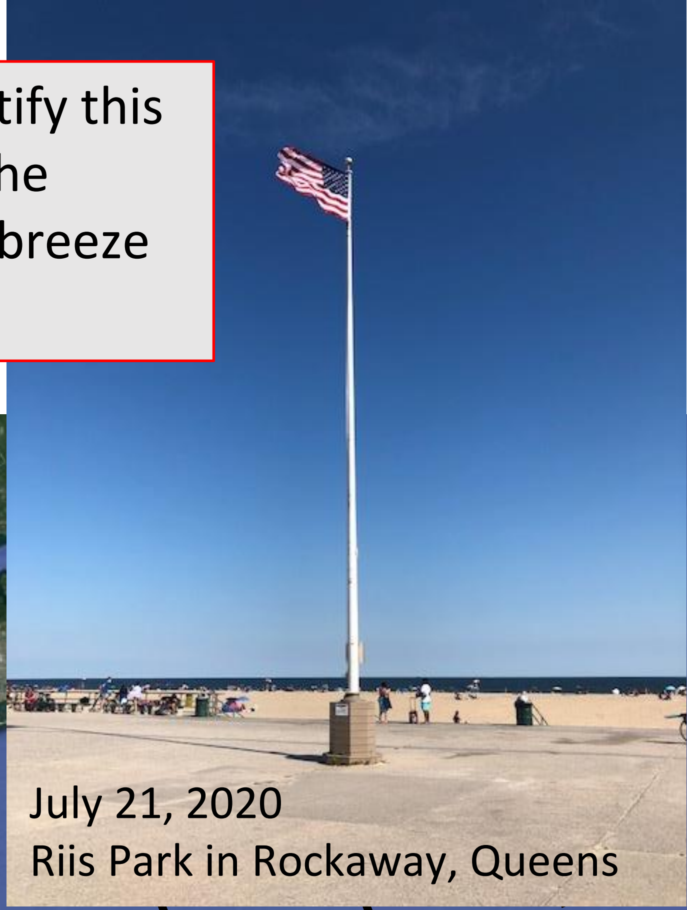
Sea Breeze Circulation



(Stull 1988)

Sometimes we can identify this cloud front created by the convergence of the sea breeze circulation





July 21, 2020
Riis Park in Rockaway, Queens

- **Sea Breeze Circulation generally comes onshore at approximately 1800 UTC**
- **Can continue to persist until sunset (when the temperature gradient reaches zero)**

Sea Breeze Days — Classic & Hybrid

Classic

Sea Breeze Days that exhibit:

- High pressure and a minimal pressure gradient
- Typically hot (strong delta(T)), sunny days
- Light prevailing winds in the morning, and a sea breeze circulation dominating in the afternoon.

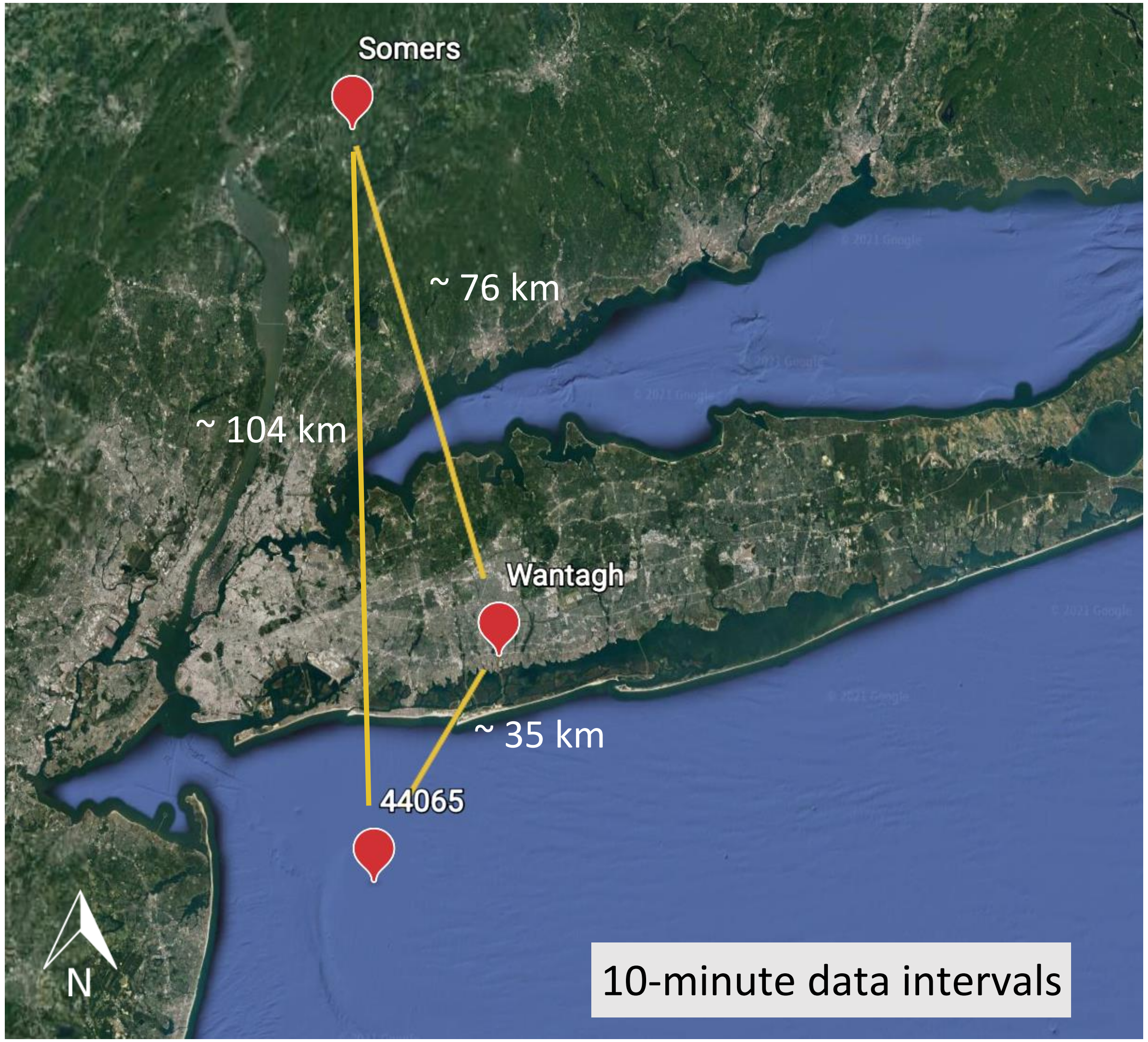
Hybrid

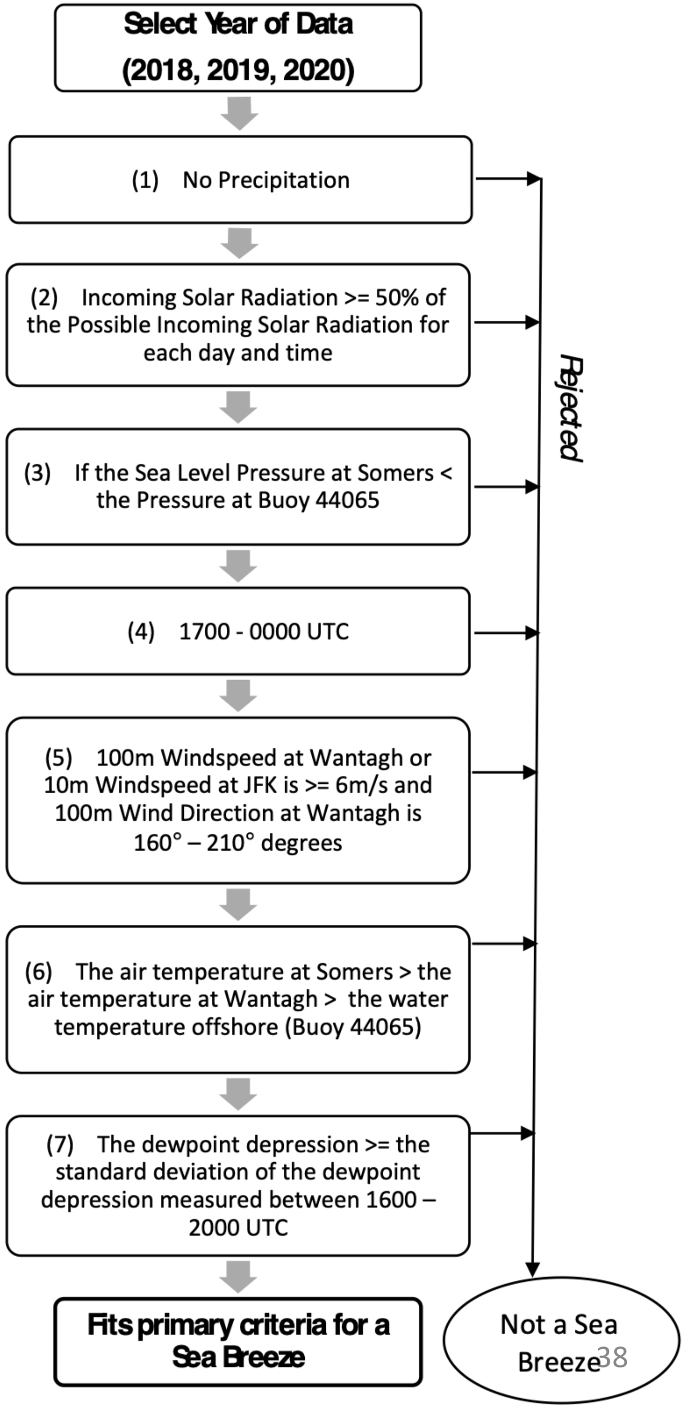
Sea Breeze Days that exhibit:

- Evidence of a sea breeze circulation, but in combination with other background synoptic activity.
  - *Stronger background winds*
  - *Pre-Frontal/ Pre-Trough, Thunderstorms, etc.*

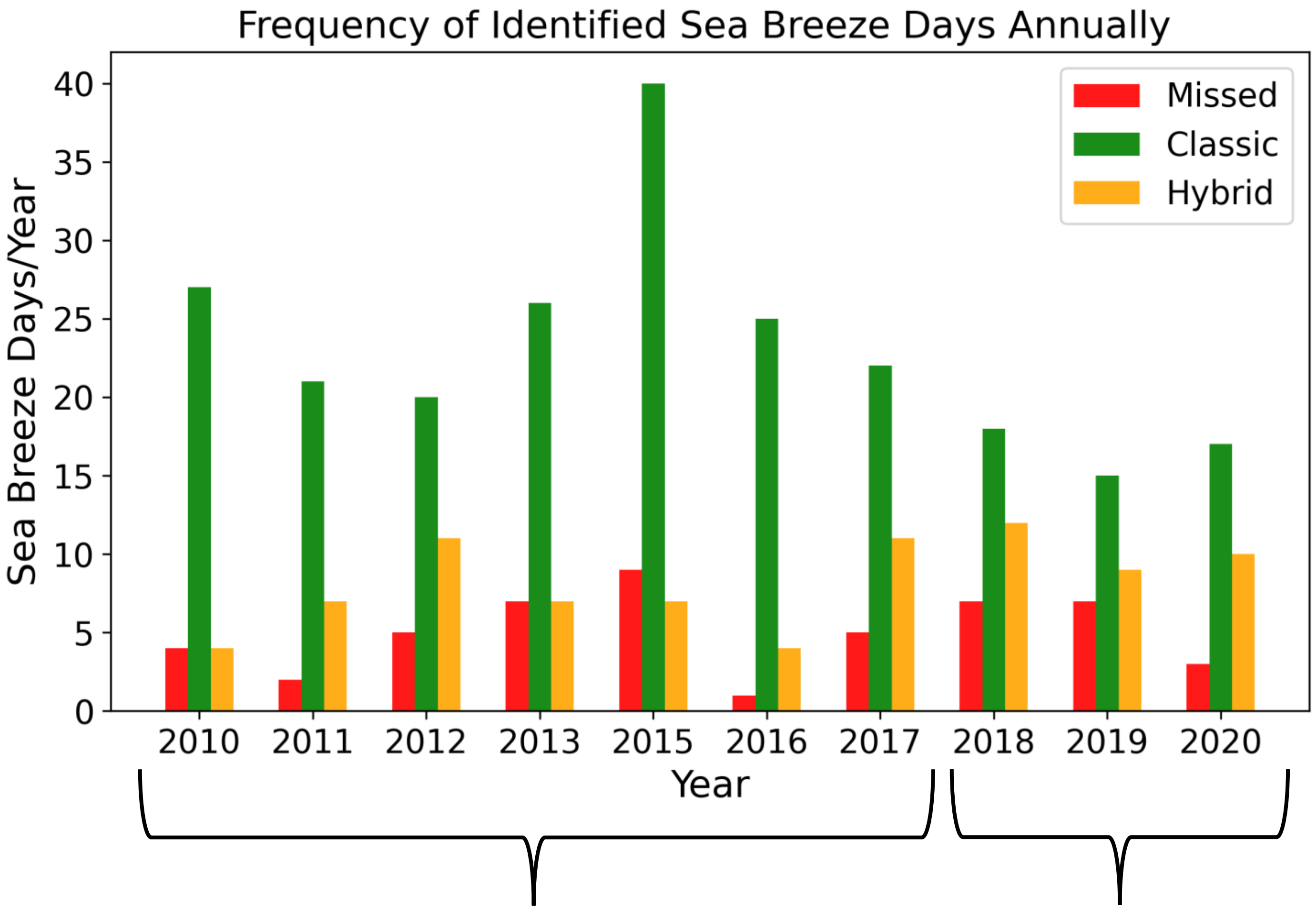
Sea Breeze Classification 2018, 2019, 2020

E. McCabe 2021





Sea Breeze Climatology



Using ***JFK*** as the
Land Based Station

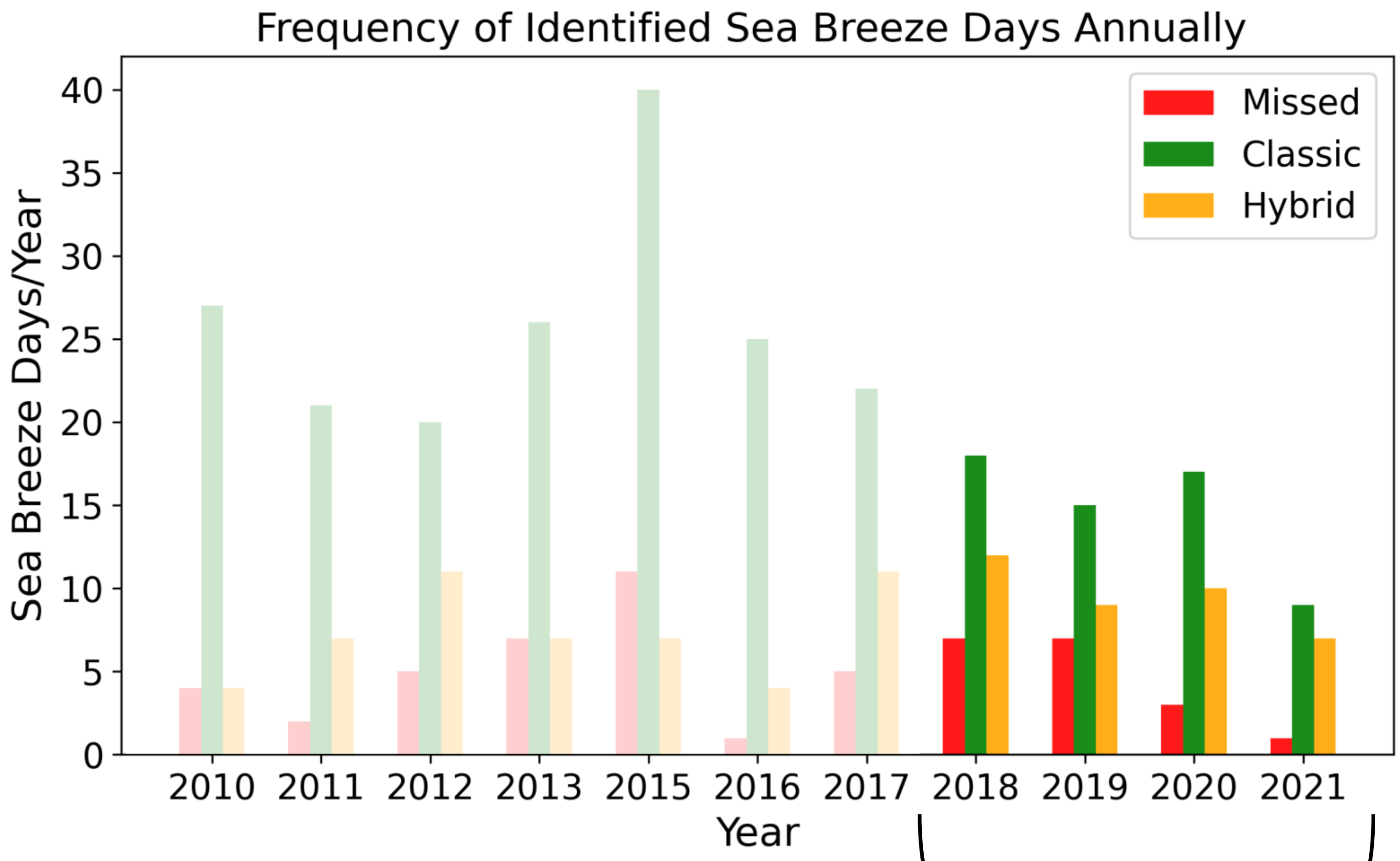
Using ***Wantagh*** as the
Land Based Station

Average of **31.3** Sea Breeze Days Annually

Total Sea Breeze Days Identified: 365 Days

- Classic = 63.3 %
- Hybrid = 22.5 %
- Missed = 14.2 %

Sea Breeze Climatology



Using ***Wantagh*** as the Land Based Station

Classification expanded to include 2021:

* But no data available at Wantagh until June 19, 2021

New York Bight Low-Level Jet

Associated with the sea breeze circulation

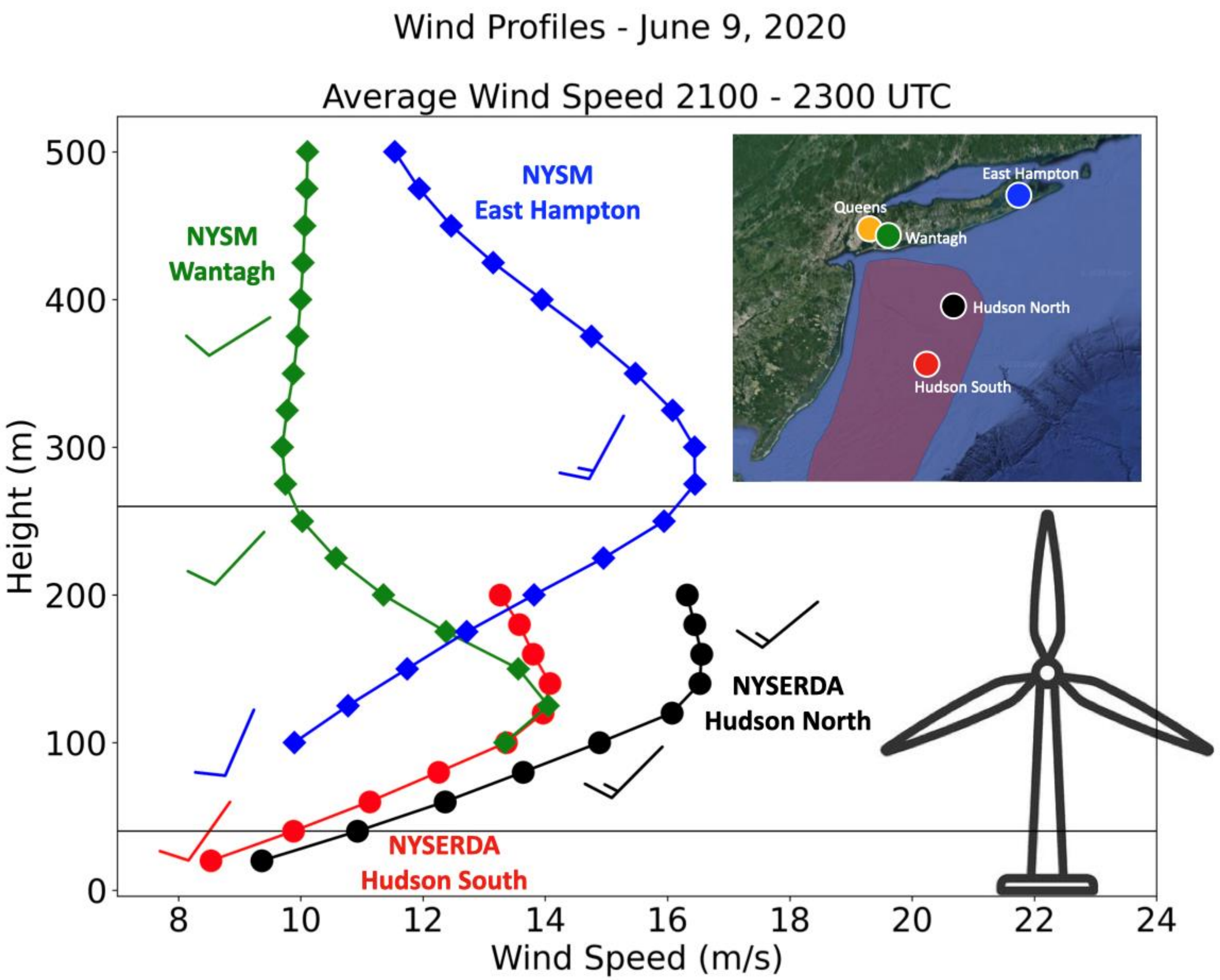
Wind speed maximum between 150 m and 300 m ASL, with max speed between 2100 and 2300 UTC

(Colle and Novak 2010)

LLJs are well documented along West Coast

- 300 m – 700 m ASL
- ~ 15 to 30 m s^{-1}

(Beardsley et al. 1987; Burk and Thompson 1996; Parish 2020)



Low Level Jet Classification – Wantagh

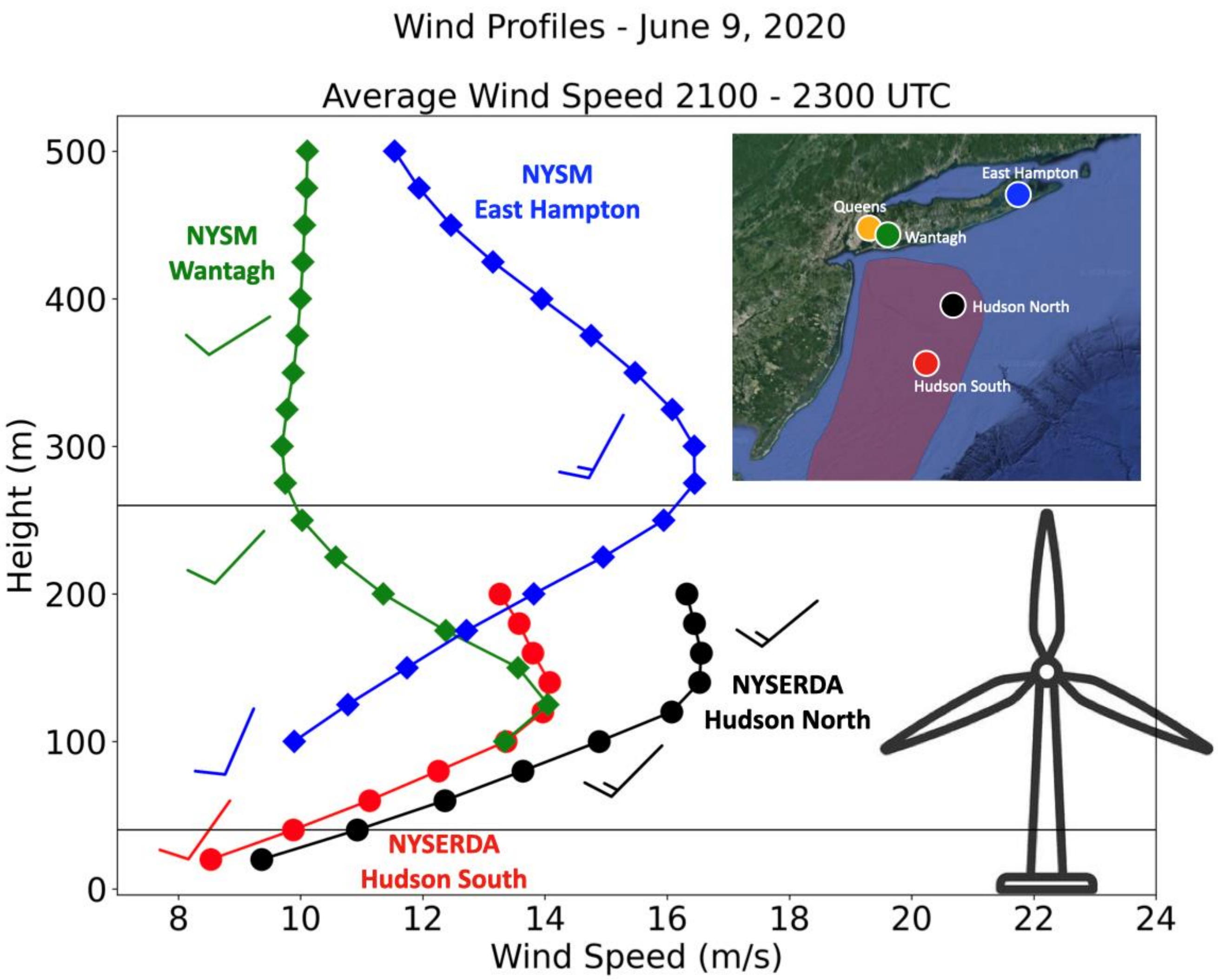
The wind shear using **Wind Profile Power Law Relationship**

$$\propto = \frac{\ln(U/U_r)}{\ln(z/z_r)}$$

Where ∝ is the wind shear, Ū is the windspeed and z is the height; with $\bar{U}_r$ as windspeed at reference height z_r (St. Pé et al. 2017)

Between 2100 and 2300 UTC:

- Wind shear Exponent (∝):
  - *100m to 150m is >= 0.2 (windspeed is increasing)*
  - *250m to 500m is <= -0.2 (windspeed is decreasing)*
- Jet windspeed maximum must be at least >= 7 ms^{-1}
- Windspeed at 200m is > Windspeed at 400m
- Windspeed at 150m is > Windspeed at 100m

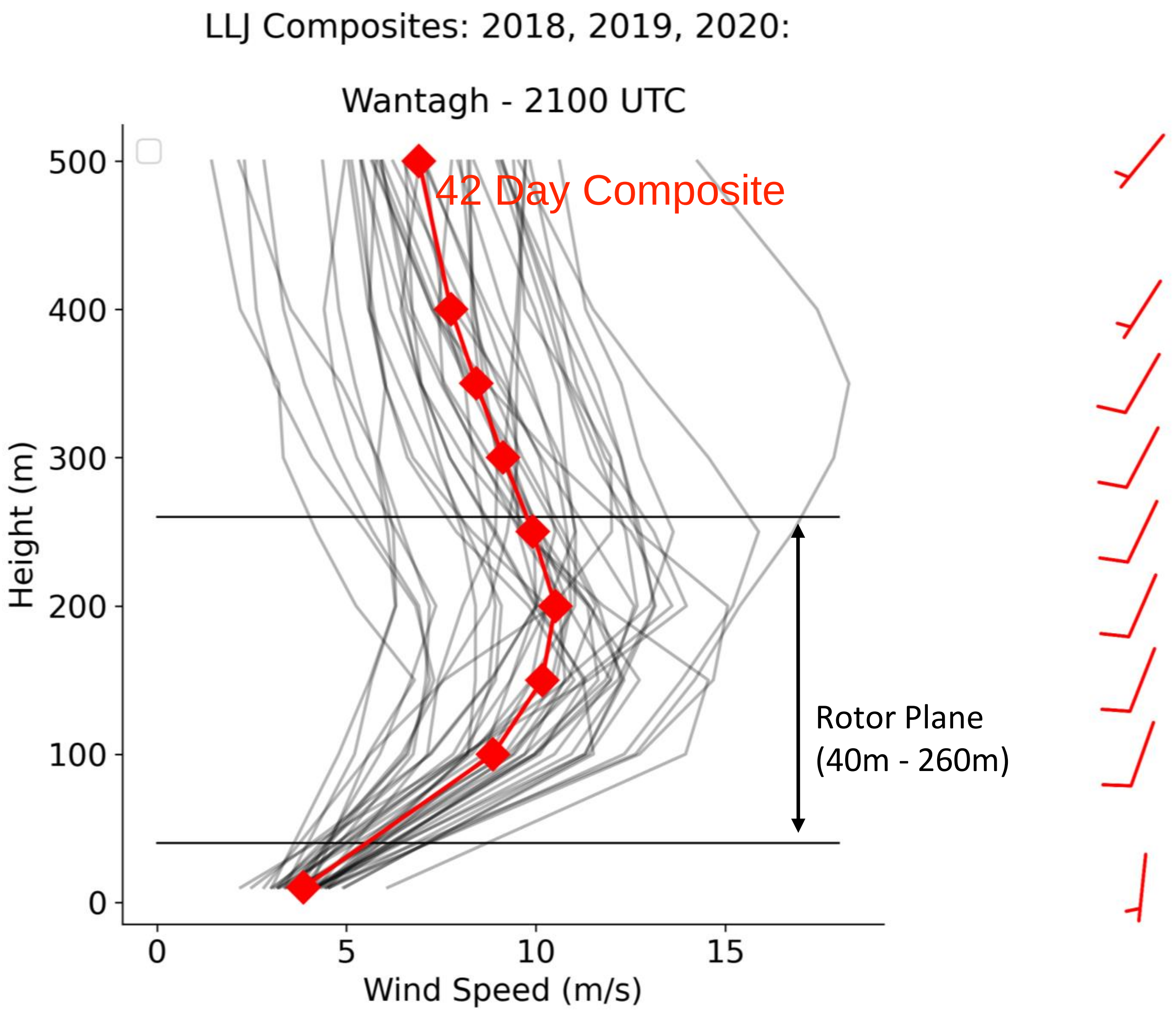


Low Level Jet Classification – Wantagh (2018, 2019, & 2020)

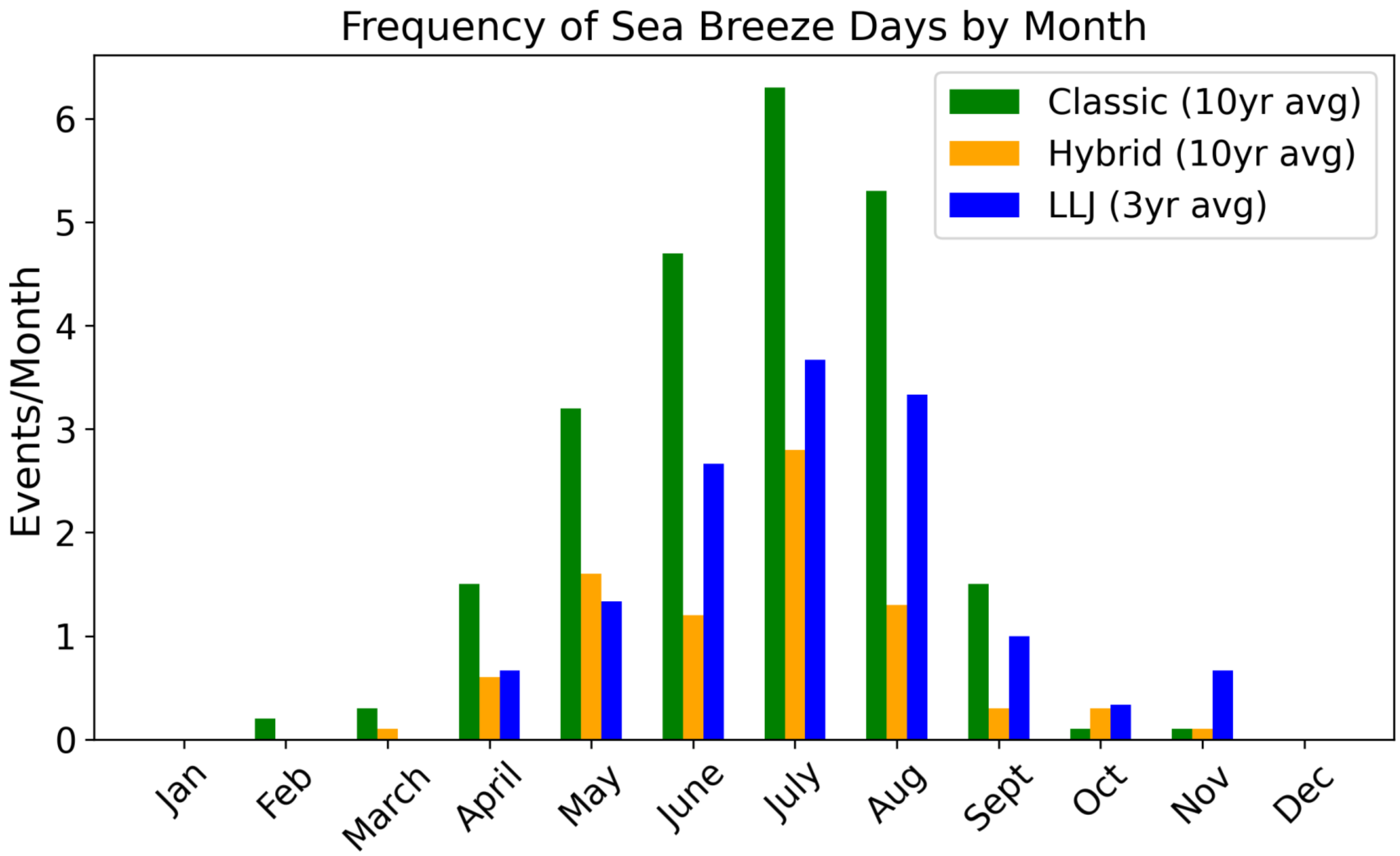
Total Low Level Jets Identified: 54 Events

42 Correctly Identified
3 Missed
9 LLJs occurring on non/missed sea breeze d

Mean jet maximum of 10.5 m s^{-1} ranging from 7 – 15 m s^{-1}



Sea Breeze and LLJ Climatology



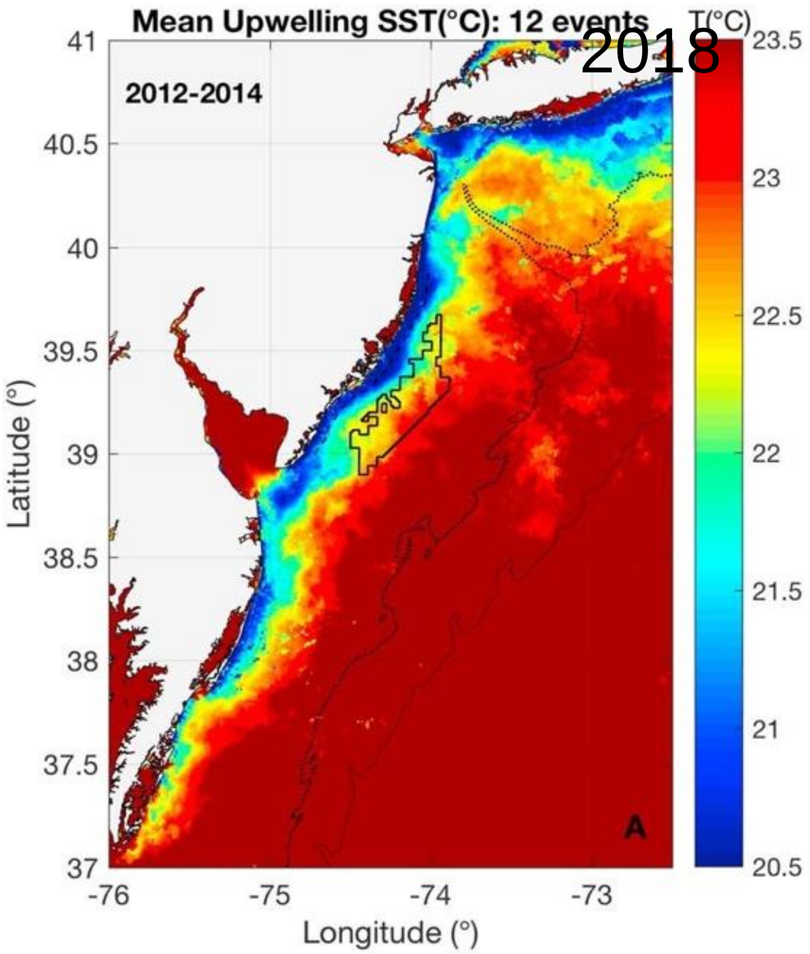
Classic Sea Breezes, Hybrid Sea Breezes, and LLJs maximize in **May, June, July, and August**

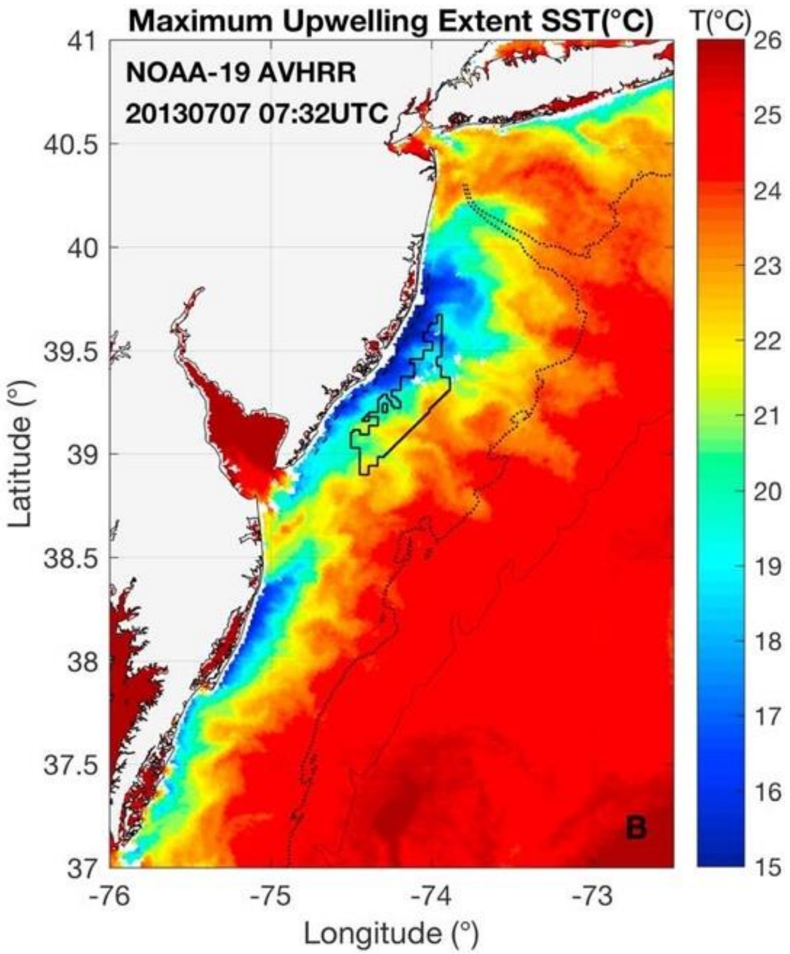
Sea breeze and LLJ peak frequency peaks in July

A Warm Season Phenomena!

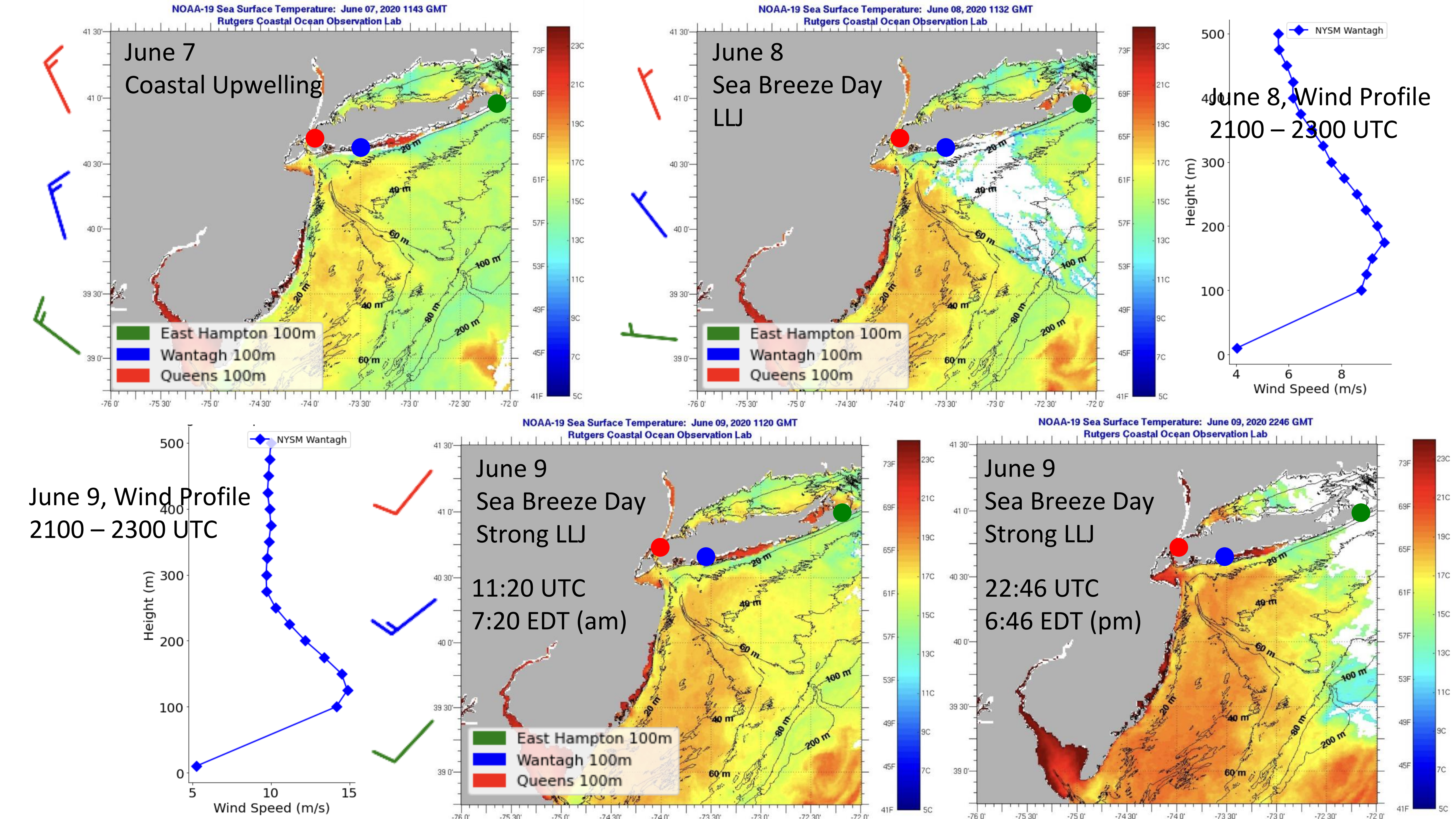
Cold Water Coastal Upwelling Sea Breeze Sensitivity to Land-SST Difference

Seroka et al. 2018

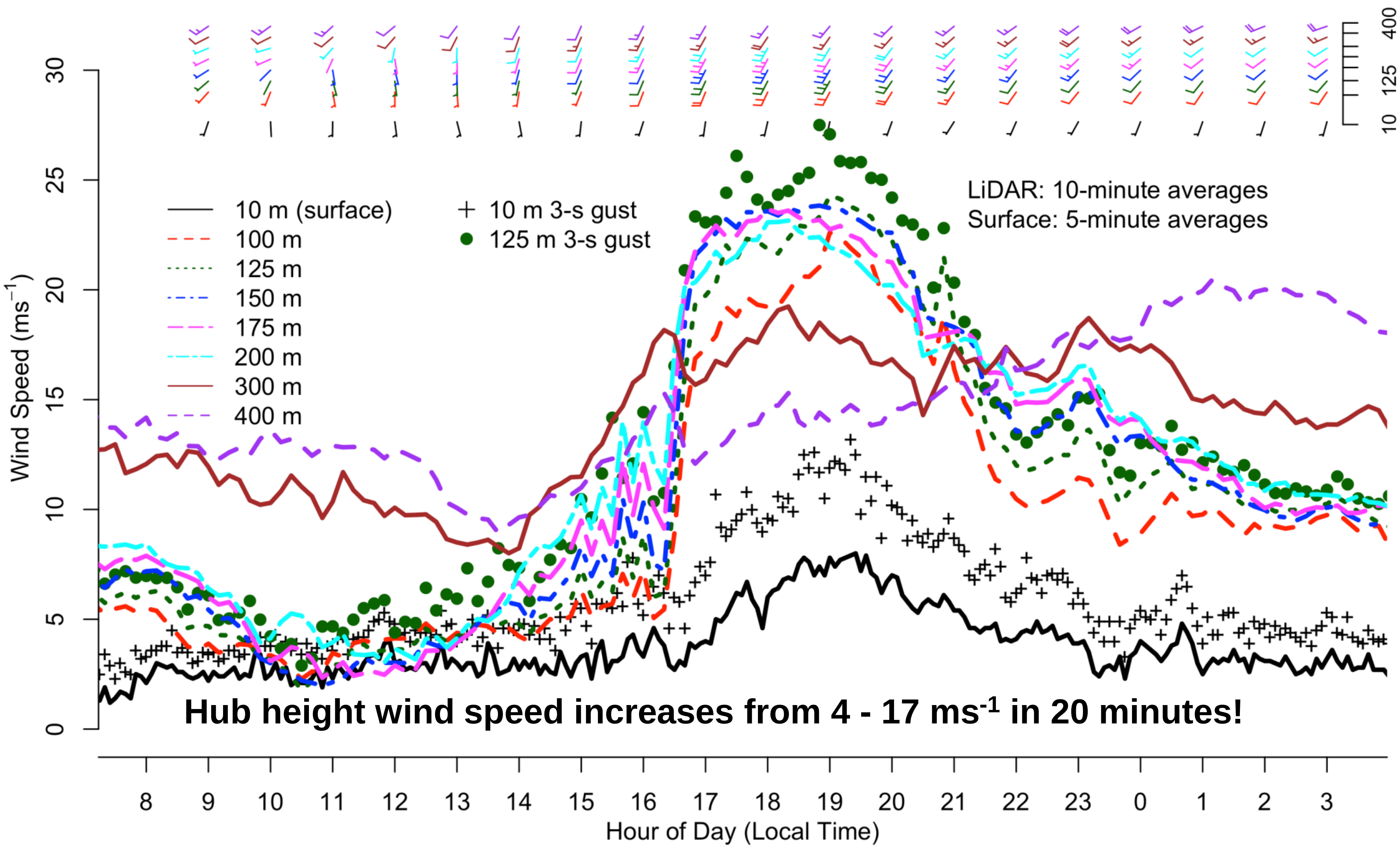




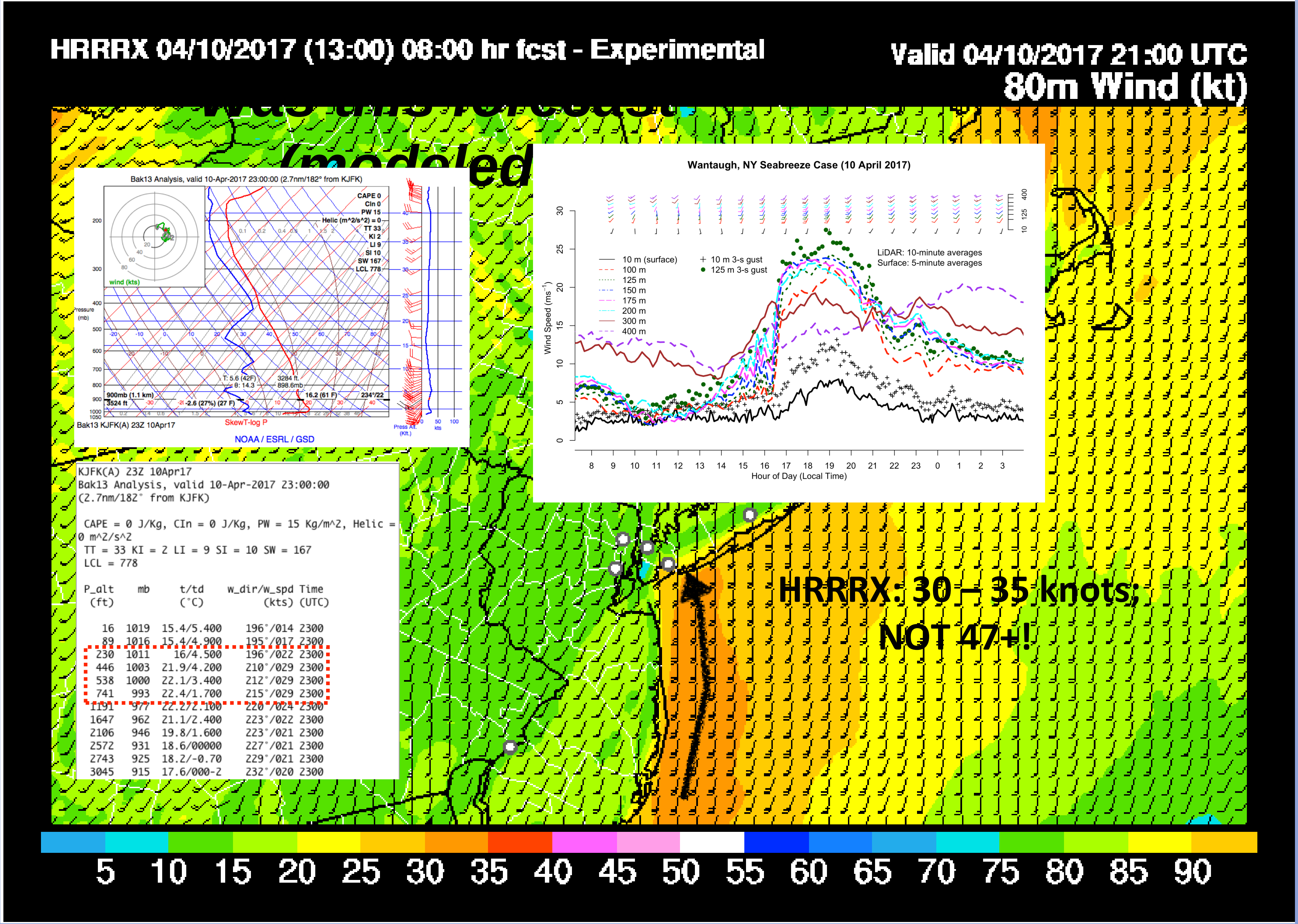
- Warm season waters in NYB are 2-layer stratified
- Cold water upwelling occurs along the coastlines of New Jersey and Long Island
- Results in a sharper & shallower sea breeze circulation


NOAA-19 Sea Surface Temperature: June 07, 2020 1143 GMT
Rutgers Coastal Ocean Observation Lab
June 7
Coastal Upwelling
East Hampton 100m
Wantagh 100m
Queens 100m
NOAA-19 Sea Surface Temperature: June 08, 2020 1132 GMT
Rutgers Coastal Ocean Observation Lab
June 8
Sea Breeze Day
LLJ
East Hampton 100m
Wantagh 100m
Queens 100m
June 8, Wind Profile
2100 – 2300 UTC
NYSM Wantagh
Height (m)
Wind Speed (m/s)
June 9, Wind Profile
2100 – 2300 UTC
NYSM Wantagh
Height (m)
Wind Speed (m/s)
NOAA-19 Sea Surface Temperature: June 09, 2020 1120 GMT
Rutgers Coastal Ocean Observation Lab
June 9
Sea Breeze Day
Strong LLJ
11:20 UTC
7:20 EDT (am)
East Hampton 100m
Wantagh 100m
Queens 100m
NOAA-19 Sea Surface Temperature: June 09, 2020 2246 GMT
Rutgers Coastal Ocean Observation Lab
June 9
Sea Breeze Day
Strong LLJ
22:46 UTC
6:46 EDT (pm)

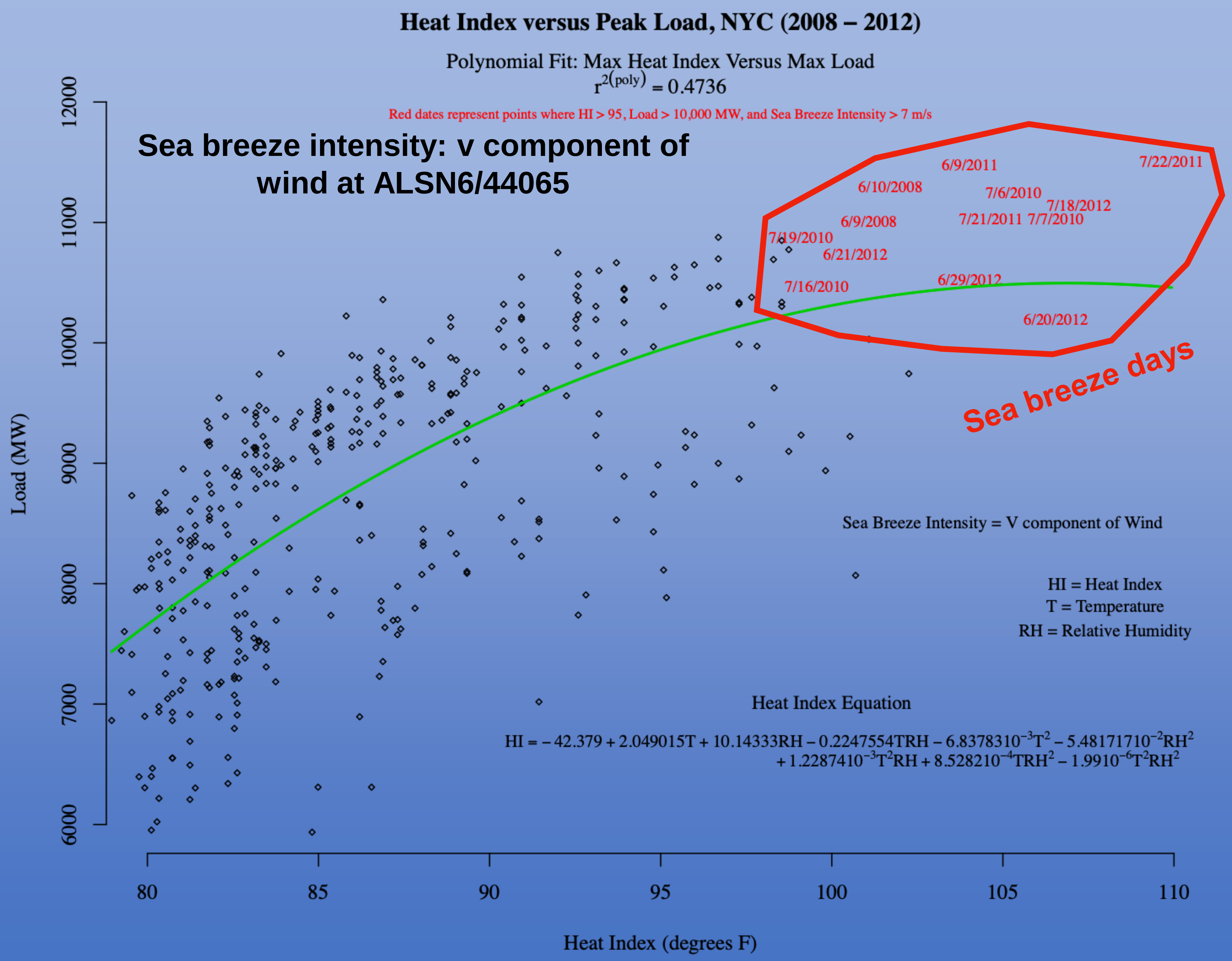
Wantagh, NY Seabreeze (10 April 2017)



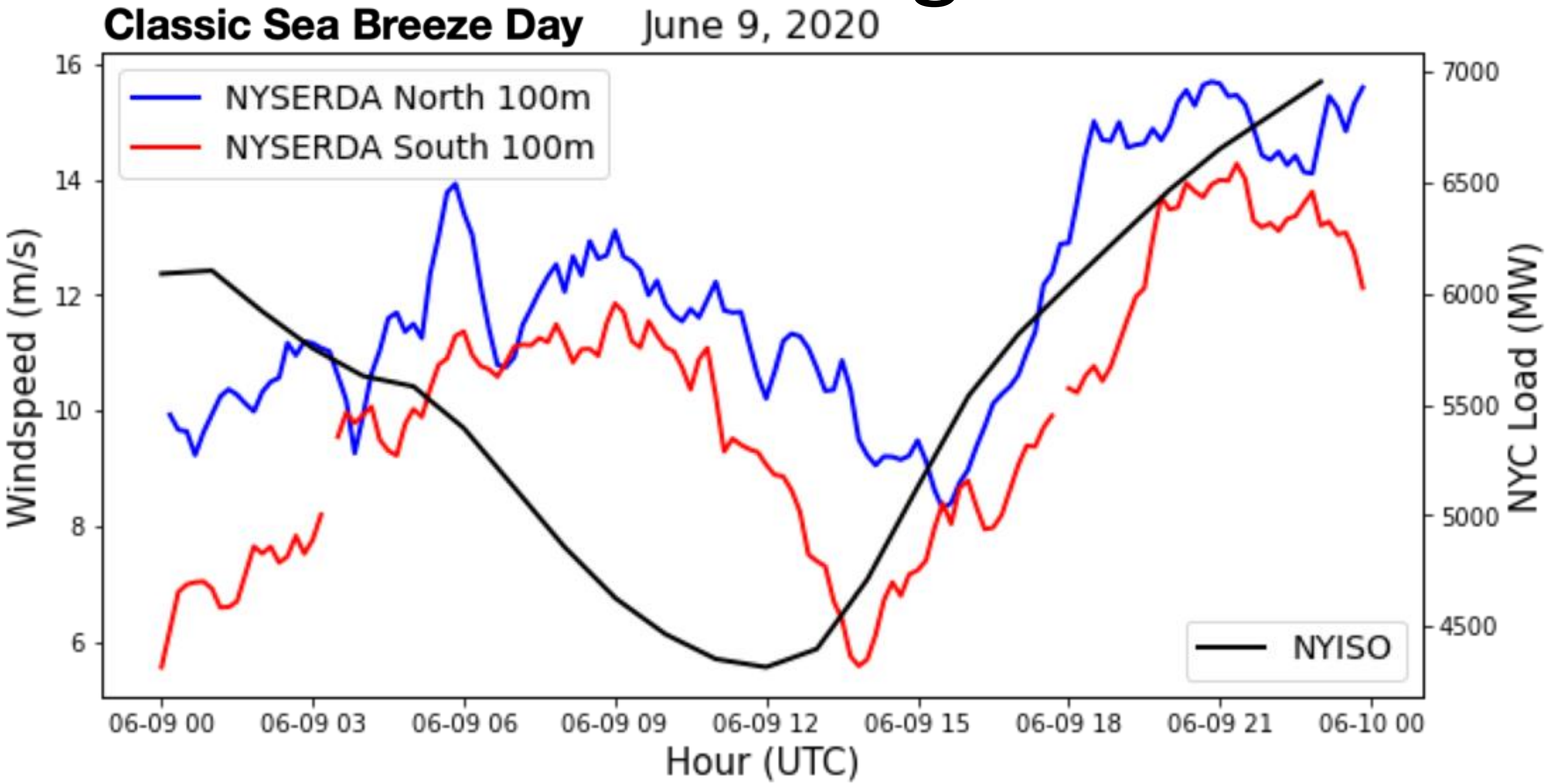
Hub height wind speed increases from 4 - 17 ms^{-1} in 20 minutes!


HRRRX 04/10/2017 (13:00) 08:00 hr fcst - Experimental
Valid 04/10/2017 21:00 UTC
80m Wind (kt)
Bak13 Analysis, valid 10-Apr-2017 23:00:00 (2.7nm/182° from KJFK)
Bak13 KJFK(A) 23Z 10Apr17
SkewT-log P
NOAA / ESRL / GSD
Wantaugh, NY Seabreeze Case (10 April 2017)
10 m (surface)
100 m
125 m
150 m
175 m
200 m
300 m
400 m
10 m 3-s gust
125 m 3-s gust
LiDAR: 10-minute averages
Surface: 5-minute averages
Wind Speed (ms⁻¹)
Hour of Day (Local Time)
KJFK(A) 23Z 10Apr17
Bak13 Analysis, valid 10-Apr-2017 23:00:00
(2.7nm/182° from KJFK)
CAPE = 0 J/Kg, CIn = 0 J/Kg, PW = 15 Kg/m^2, Helic = 0 m^2/s^2
TT = 33 KI = 2 LI = 9 SI = 10 SW = 167
LCL = 778
P_alt (ft) | mb | t/td (°C) | w_dir/w_spd (kts) | Time (UTC)
16 1019 15.4/5.400 196°/014 2300
89 1016 15.4/4.900 195°/017 2300
230 1011 16/4.500 196°/022 2300
446 1003 21.9/4.200 210°/029 2300
538 1000 22.1/3.400 212°/029 2300
741 993 22.4/1.700 215°/029 2300
1191 977 22.2/2.100 220°/024 2300
1647 962 21.1/2.400 223°/022 2300
2106 946 19.8/1.600 223°/021 2300
2572 931 18.6/00000 227°/021 2300
2743 925 18.2/-0.70 229°/021 2300
3045 915 17.6/000-2 232°/020 2300
HRRRX: 30 – 35 knots;
NOT 47+!
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

Putting it all together….


Heat Index versus Peak Load, NYC (2008 – 2012)
Polynomial Fit: Max Heat Index Versus Max Load
$r^{2(poly)} = 0.4736$
Red dates represent points where HI > 95, Load > 10,000 MW, and Sea Breeze Intensity > 7 m/s
Sea breeze intensity: v component of wind at ALSN6/44065
6/9/2011
7/22/2011
6/10/2008
7/6/2010
7/18/2012
6/9/2008
7/21/2011
7/7/2010
7/19/2010
6/21/2012
7/16/2010
6/29/2012
6/20/2012
Sea breeze days
Sea Breeze Intensity = V component of Wind
HI = Heat Index
T = Temperature
RH = Relative Humidity
Heat Index Equation
$HI = -42.379 + 2.049015T + 10.14333RH - 0.2247554TRH - 6.83783 10^{-3}T^2 - 5.481717 10^{-2}RH^2 + 1.22874 10^{-3}T^2RH + 8.5282 10^{-4}TRH^2 - 1.99 10^{-6}T^2RH^2$
Load (MW)
12000
11000
10000
9000
8000
7000
6000
80
85
90
95
100
105
110
Heat Index (degrees F)

The Sea Breeze Circulation and Load Matching



Mean Load:
6,021.50 MW

Load (MW)
< 4000
4000 - 5000
5000 - 6000
6000 - 7000
7000 - 8000
8000 - 9000
> 9000

NYISO Actual Load - NEW YORK CITY (NYC) 2016 - 2019 (MW)												
Hour (UTC)	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	6489.43	6317.28	6059.84	5686.83	5876.18	6808.55	8035.24	7932.01	6961.46	5925.77	5928.69	6277.19
2	6316.45	6147.15	5880.60	5507.29	5720.65	6699.90	7941.98	7769.76	6737.36	5704.72	5752.99	6117.37
3	6101.54	5936.54	5616.05	5218.06	5422.71	6411.06	7661.95	7459.79	6410.83	5397.88	5532.89	5924.24
4	5795.37	5634.15	5272.24	4857.69	5047.37	6013.08	7261.75	7051.97	6012.06	5030.23	5228.49	5634.41
5	5432.68	5276.76	4932.57	4532.37	4696.45	5617.22	6849.01	6648.00	5634.62	4692.58	4886.46	5281.81
6	5111.93	4957.96	4674.76	4312.07	4453.96	5321.27	6529.30	6341.20	5357.81	4458.50	4591.21	4958.72
7	4899.43	4746.21	4511.13	4175.68	4297.44	5118.67	6299.19	6121.24	5167.62	4308.23	4395.81	4739.37
8	4762.39	4614.04	4426.01	4110.22	4218.45	5002.45	6155.30	5990.17	5059.48	4229.48	4276.80	4601.01
9	4701.61	4554.02	4420.40	4121.99	4213.96	4975.43	6107.03	5958.75	5043.05	4232.50	4228.71	4534.72
10	4724.17	4578.50	4558.88	4303.08	4362.75	5100.56	6212.45	6114.76	5209.31	4414.55	4272.97	4553.39
11	4918.58	4778.17	4906.62	4683.64	4753.16	5506.29	6559.94	6464.55	5606.11	4853.79	4503.33	4738.59
12	5325.32	5180.85	5325.08	5111.35	5230.28	6021.87	7060.35	6929.78	6022.50	5286.89	4914.48	5124.47
13	5741.18	5591.15	5667.44	5441.05	5599.43	6458.81	7510.66	7360.44	6401.40	5613.22	5305.80	5517.40
14	6030.54	5896.01	5904.54	5654.93	5856.04	6788.20	7874.25	7707.88	6699.79	5843.80	5592.81	5809.56
15	6237.60	6102.58	6036.30	5762.97	6010.58	7007.56	8148.85	7968.73	6904.65	5974.30	5776.97	6014.91
16	6346.88	6205.94	6092.19	5815.38	6113.31	7159.46	8348.59	8162.95	7061.36	6058.46	5869.01	6122.88
17	6398.98	6249.98	6104.03	5830.38	6170.96	7254.39	8478.54	8295.30	7173.12	6107.47	5915.11	6174.01
18	6407.33	6255.30	6090.87	5825.10	6204.93	7318.77	8576.45	8389.42	7253.73	6137.30	5925.70	6185.02
19	6395.50	6239.21	6059.14	5802.06	6217.02	7362.71	8644.52	8454.58	7298.96	6143.72	5920.87	6179.63
20	6376.73	6213.92	6041.40	5804.17	6250.28	7420.28	8683.52	8509.68	7351.92	6168.45	5916.20	6169.72
21	6408.39	6223.52	6051.34	5821.28	6281.50	7458.57	8705.69	8542.49	7385.01	6196.05	5952.13	6212.28
22	6521.95	6282.65	6071.14	5813.40	6252.29	7410.53	8643.65	8473.24	7331.20	6201.90	6070.17	6366.00
23	6697.84	6405.21	6059.39	5707.66	6083.25	7185.07	8405.18	8209.15	7122.18	6165.15	6192.83	6512.69
24	6632.90	6413.22	6117.77	5697.62	5966.45	6985.38	8186.83	8008.37	7047.78	6102.55	6080.09	6410.92

Capacity Factor (%)
0% - 29%
30% - 49%
50% - 74%
75% - 90%
91% - 100%

NYSERDA Hudson North
Predicted 100m Capacity Factors (%)

Hour (UTC)	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	79.63	74.86	65.34	53.18	46.45	37.22	39.65	41.05	46.14	67.67	75.67	90.23
2	83.64	77.37	66.41	52.34	45.83	35.39	38.67	40.32	47.46	68.53	76.96	89.86
3	82.41	77.39	67.77	52.37	44.51	37.11	37.65	39.03	47.81	68.55	76.80	87.38
4	85.00	81.20	69.68	51.13	44.15	37.22	36.18	37.64	48.33	67.56	75.00	88.25
5	85.58	81.93	71.01	50.71	43.83	37.00	34.92	35.60	48.33	66.88	76.53	89.48
6	85.84	80.47	71.25	50.84	43.33	35.97	34.27	36.10	47.89	67.31	74.06	90.10
7	85.73	79.21	71.06	49.59	41.00	34.71	31.28	35.11	47.20	66.62	74.18	89.00
8	86.21	79.19	69.55	50.28	41.33	34.06	29.47	34.65	48.15	66.90	73.79	86.15
9	85.96	76.42	68.47	51.77	40.68	33.46	28.10	33.67	49.58	66.86	73.07	85.61
10	87.17	76.85	69.86	51.17	40.83	33.00	27.41	33.81	48.44	67.94	70.63	85.68
11	85.00	78.28	71.18	52.40	40.86	32.66	27.26	32.78	48.09	67.56	70.68	81.20
12	86.22	78.78	70.46	52.13	41.76	33.47	27.01	33.28	47.57	66.30	70.20	82.38
13	85.84	78.69	69.40	51.84	41.80	32.50	26.58	33.18	49.09	67.67	69.83	82.86
14	83.42	76.85	67.63	51.07	40.11	29.90	26.19	33.59	47.25	67.09	70.86	82.82
15	81.60	74.05	65.35	49.00	37.93	28.02	24.99	30.63	44.82	65.97	70.36	80.80
16	79.32	71.88	62.44	46.16	36.18	28.16	25.05	30.99	43.71	65.11	70.13	77.28
17	75.12	70.38	59.81	45.76	35.39	28.23	25.48	30.99	42.62	62.21	70.56	78.51
18	75.01	69.20	58.05	43.44	36.21	29.64	25.28	31.32	41.94	61.41	70.11	77.53
19	73.48	68.24	56.59	44.02	38.21	30.15	27.89	33.08	40.11	61.81	69.83	79.70
20	72.13	67.79	57.42	46.29	40.51	33.08	33.00	34.28	40.89	62.50	69.97	80.07
21	72.44	67.05	58.89	46.70	43.13	35.93	36.77	35.78	42.18	62.89	71.52	79.13
22	73.31	70.14	59.71	48.50	44.61	38.11	38.92	37.35	42.87	63.18	72.58	81.55
23	74.88	72.31	62.12	50.58	46.93	38.40	38.82	39.94	43.99	64.37	73.21	83.71
24	77.60	74.91	63.99	51.54	46.44	37.12	39.47	42.12	45.72	65.23	74.12	85.49

Using capacity factors calculated for NYSERDA Hudson North

Number of 8MW Turbines
< 1000
1000 - 1500
1500 - 2000
2000 - 3000
3000 - 4000
> 4000

Number of 8 MW Wind Turbines Needed to Match Load
NYC (2016 - 2019)

Hour (UTC)	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	1019	1055	1159	1337	1581	2287	2533	2415	1886	1095	979	870
2	944	993	1107	1315	1560	2366	2567	2409	1774	1041	934	851
3	925	959	1036	1245	1523	2159	2544	2389	1676	984	901	847
4	852	867	946	1188	1429	2019	2509	2342	1555	931	871	798
5	794	805	868	1117	1339	1898	2452	2334	1457	877	798	738
6	744	770	820	1060	1285	1849	2382	2196	1398	828	775	688
7	714	749	794	1053	1310	1843	2517	2179	1369	808	741	666
8	691	728	795	1022	1276	1836	2611	2161	1313	790	724	668
9	684	745	807	995	1295	1859	2717	2212	1271	791	723	662
10	677	745	816	1051	1336	1932	2833	2261	1344	812	756	664
11	723	763	862	1117	1454	2107	3008	2465	1457	898	796	729
12	772	822	945	1226	1566	2249	3267	2603	1583	997	875	778
13	836	888	1021	1312	1674	2484	3532	2773	1630	1037	950	832
14	904	959	1091	1384	1825	2838	3758	2868	1772	1089	987	877
15	956	1030	1155	1470	1981	3126	4076	3252	1926	1132	1026	931
16	1000	1079	1220	1575	2112	3178	4166	3293	2019	1163	1046	990
17	1065	1110	1276	1593	2180	3212	4159	3346	2104	1227	1048	983
18	1068	1130	1312	1676	2142	3087	4241	3348	2162	1249	1057	997
19	1088	1143	1338	1648	2034	3053	3874	3195	2275	1242	1060	969
20	1105	1146	1315	1567	1929	2804	3289	3103	2247	1234	1057	963
21	1106	1160	1284	1558	1821	2595	2960	2984	2189	1232	1040	981
22	1112	1120	1271	1498	1752	2431	2776	2836	2138	1227	1045	976
23	1118	1107	1219	1411	1620	2339	2706	2569	2024	1197	1057	973
24	1068	1070	1195	1382	1606	2352	2593	2377	1927	1169	1025	937

3,267 Turbines Available -

Number of 8MW Turbines
< 1000
1000 - 1500
1500 - 2000
2000 - 3000
3000 - 4000
> 4000

Number of 8 MW Wind Turbines Needed to Match Load
NYC (2016 - 2019)

Hour (UTC)	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	1019	1055	1159	1337	1581	2287	2533	2415	1886	1095	979	870
2	944	993	1107	1315	1560	2366	2567	2409	1774	1041	934	851
3	925	959	1036	1245	1523	2159	2544	2389	1676	984	901	847
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5	794	805	868	1117	1339	1898	2452	2334	1457	877	798	738
6	744	770	820	1060	1285	1849	2382	2196	1398	828	775	688
7	714	749	794	1053	1310	1843	2517	2179	1369	808	741	666
8	691	728	795	1022	1276	1836	2611	2161	1313	790	724	668
9	684	745	807	995	1295	1859	2717	2212	1271	791	723	662
10	677	745	816	1051	1336	1932	2833	2261	1344	812	756	664
11	723	763	862	1117	1454	2107	3008	2465	1457	898	796	729
12	772	822	945	1226	1566	2249	3267	2603	1583	997	875	778
13	836	888	1021	1312	1674	2484	3532	2773	1630	1037	950	832
14	904	959	1091	1384	1825	2838	3758	2868	1772	1089	987	877
15	956	1030	1155	1470	1981	3126	4076	3252	1926	1132	1026	931
16	1000	1079	1220	1575	2112	3178	4166	3293	2019	1163	1046	990
17	1065	1110	1276	1593	2180	3212	4159	3346	2104	1227	1048	983
18	1068	1130	1312	1676	2142	3087	4241	3348	2162	1249	1057	997
19	1088	1143	1338	1648	2034	3053	3874	3195	2275	1242	1060	969
20	1105	1146	1315	1567	1929	2804	3289	3103	2247	1234	1057	963
21	1106	1160	1284	1558	1821	2595	2960	2984	2189	1232	1040	981
22	1112	1120	1271	1498	1752	2431	2776	2836	2138	1227	1045	976
23	1118	1107	1219	1411	1620	2339	2706	2569	2024	1197	1057	973
24	1068	1070	1195	1382	1606	2352	2593	2377	1927	1169	1025	937

Conclusions

1. The sea breeze and associated low-level jet play an important role in the offshore wind resource (enhanced capacity factors and load matching)—but questions remain regarding extent of circulation (e.g., where the WEAs are!)
2. We have created a new methodology (McCabe 2021; McCabe and Freedman 2021) to identify sea breeze days and an associated LLJ in the New York Bight
    1. Distinguishing between ***Classic*** and ***Hybrid*** Sea Breeze events
    2. Cold water upwelling can enhance land-sea temperature gradient –strengthening the sea breeze circulation and potentially precipitating the development of a LLJ
    3. **New York State Mesonet will be (very soon!) producing sea breeze/LLJ forecasts using this method**
3. The methodology and better understanding of the sea breeze and LLJ will have positive benefits for:
    1. **The development and siting of offshore wind energy facilities**
    2. Aviation, marine, and **power demand forecasts**
4. **We need more offshore measurements (long-term), (to facilitate) better modeling, understanding of air-sea interaction with the marine atmospheric boundary layer!**

Thank You!
Questions and Discussion

Coming Next:

October 27, 1:00 p.m. ET

How Does an Offshore Wind Supply Chain Work?

Jeffrey Tingley and Jamie MacDonald, Xodus

Visit wind.ny.gov to register

We want your feedback! Send suggestions for future webinar topics to offshorewind@nyserda.ny.gov.

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