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

Patrick M. Miller, Jeffrey M. Freedman

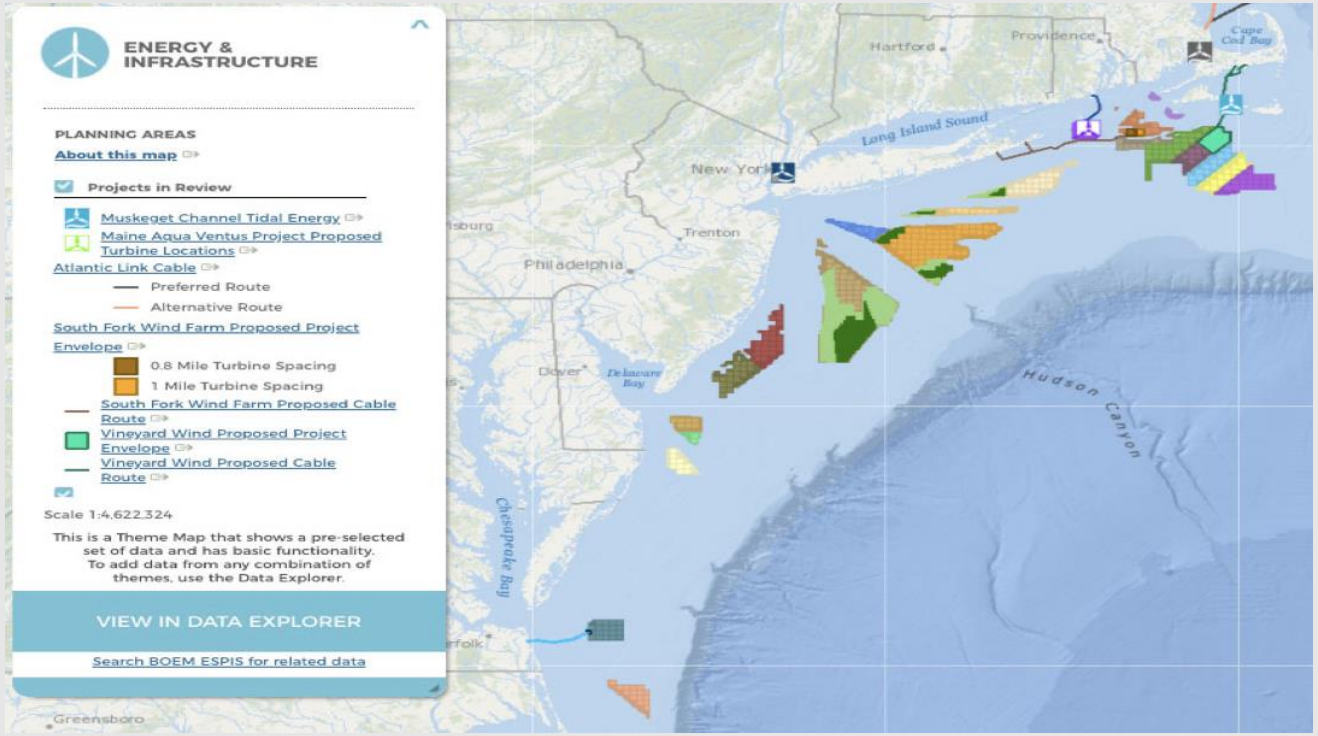
Atmospheric Sciences Research Center (ASRC), University at Albany (UAlbany),

State University of New York

105th Annual American Meteorological Society (AMS) Meeting
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OFFSHORE WIND IS BEING BUILT

- Cumulative nameplate capacity of wind farms planned for the New York Bight (NYB) may exceed 10,000 MW by 2035.
  - This does not include the farms planned south of MA, RI, and off the Mid-Atlantic coast.
  - Eventual development further down the East coast.
- It is essential to evaluate all weather risks to the region.



(BOEM, 2024)

WITH OFFSHORE WIND THERE ARE WEATHER/MARINE RISKS

- Wind ramps
- Wind droughts
- Tropical/extratropical storms
- Large waves
- **Lightning**
  - Known to be attracted towards tall metal structures, including turbines (McEachron, 1939) and (Wang et al. 2008)

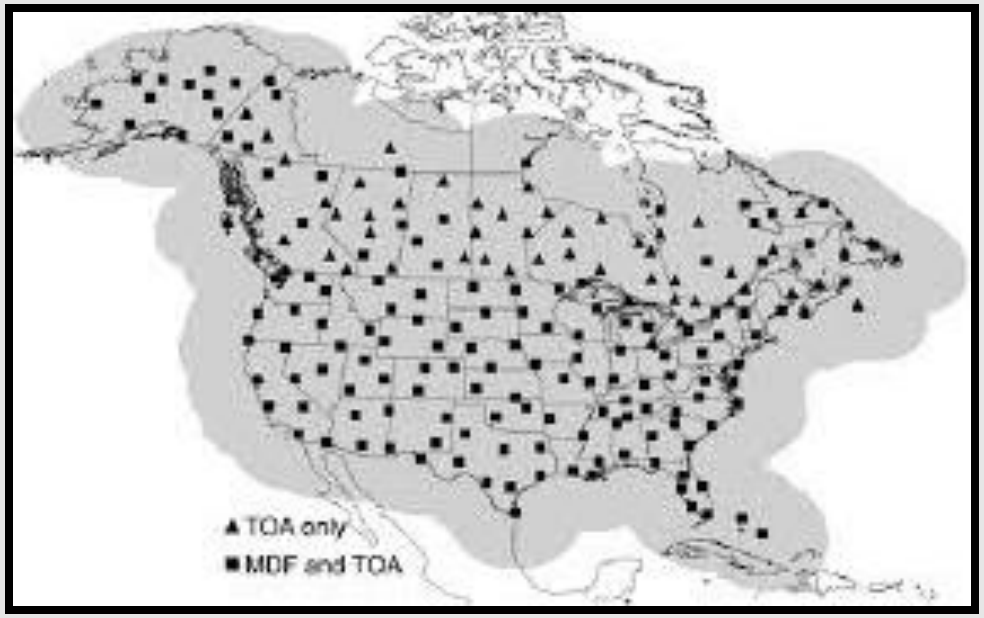


(NREL, 2017)

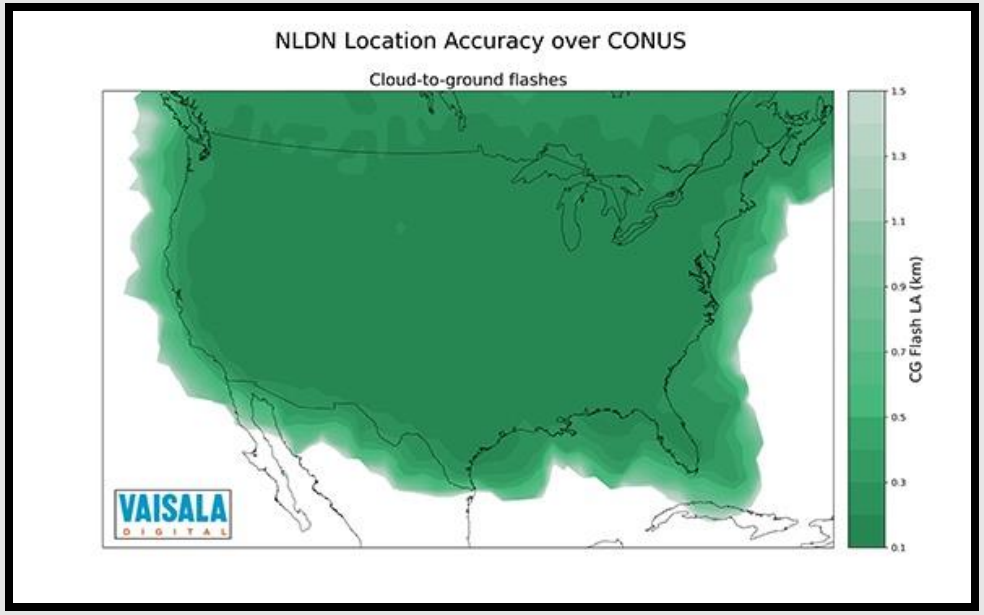
PREVIOUS TURBINE LIGHTNING WORK

- Field campaigns in Upstate NY near Maple Ridge Wind Farm on the Tug Hill Plateau have observed increased lightning, specifically in the winter season (Kristovich et al. 2017, Steiger et al. 2024).
  - **Will a climatology going back to 1990 support this?**
- Lightning climatology for onshore antenna structures has also shown higher cloud-to-ground (CG) lightning density (Kingsfield et al. 2017).
- Rotating and non-rotating turbines both can trigger upward lightning, that may not have occurred otherwise (Wang et al. 2008).

What about for offshore wind turbines?



(Orville et al. 2011)

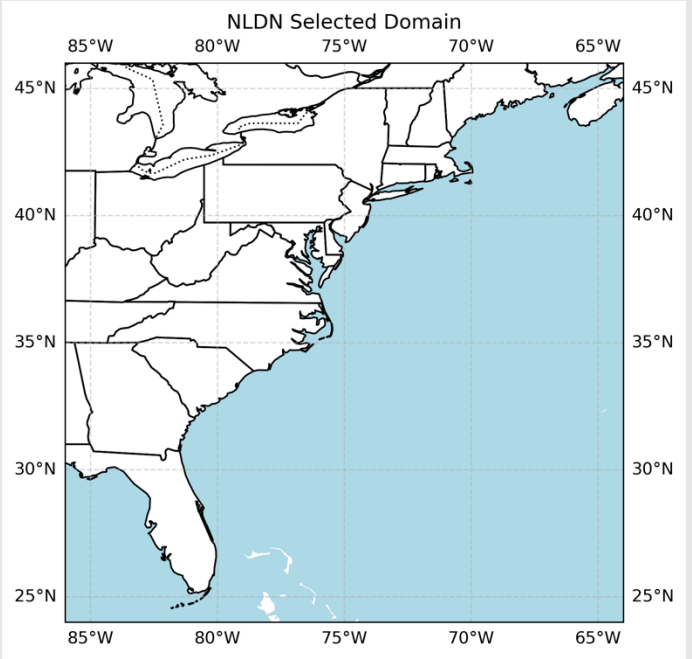


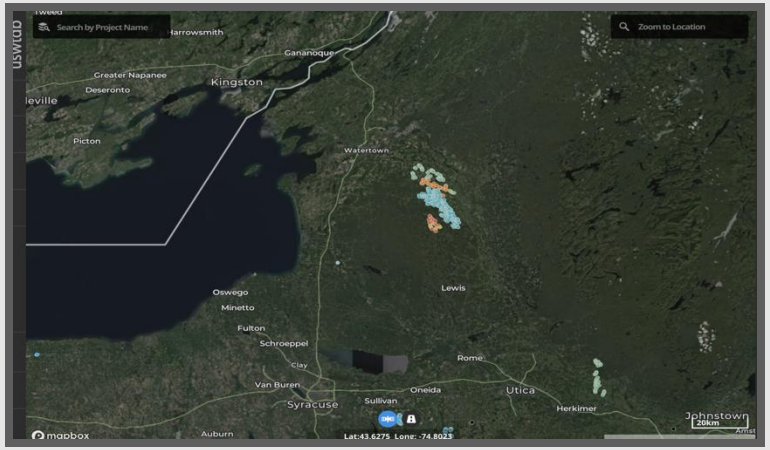
THE NATIONAL LIGHTNING DETECTION NETWORK (NLDN)

- NLDN was created by UAlbany (SUNY) in the 1980's (Orville et al. 1983).
  - UAlbany controls local data manager (LDM) access to the NLDN data, under an agreement with Vaisala.
- Network currently consists of approximately 105 sensors.
- Time-of-arrival (TOA) sensors uses the time difference of strikes reaching different sensors while magnetic direction finding (MDF) uses the magnetic field to improve the location detection.
  - Sensors were upgraded in 2013 to Vaisala's LS7002.
- Sensors went through several processor upgrades from 2013 through 2018.
- Canadian Lightning Detection Network (CLDN) shown here but not included in this work.
- Accuracy offshore varies from 0.2 to 0.5km.

METHODOLOGY

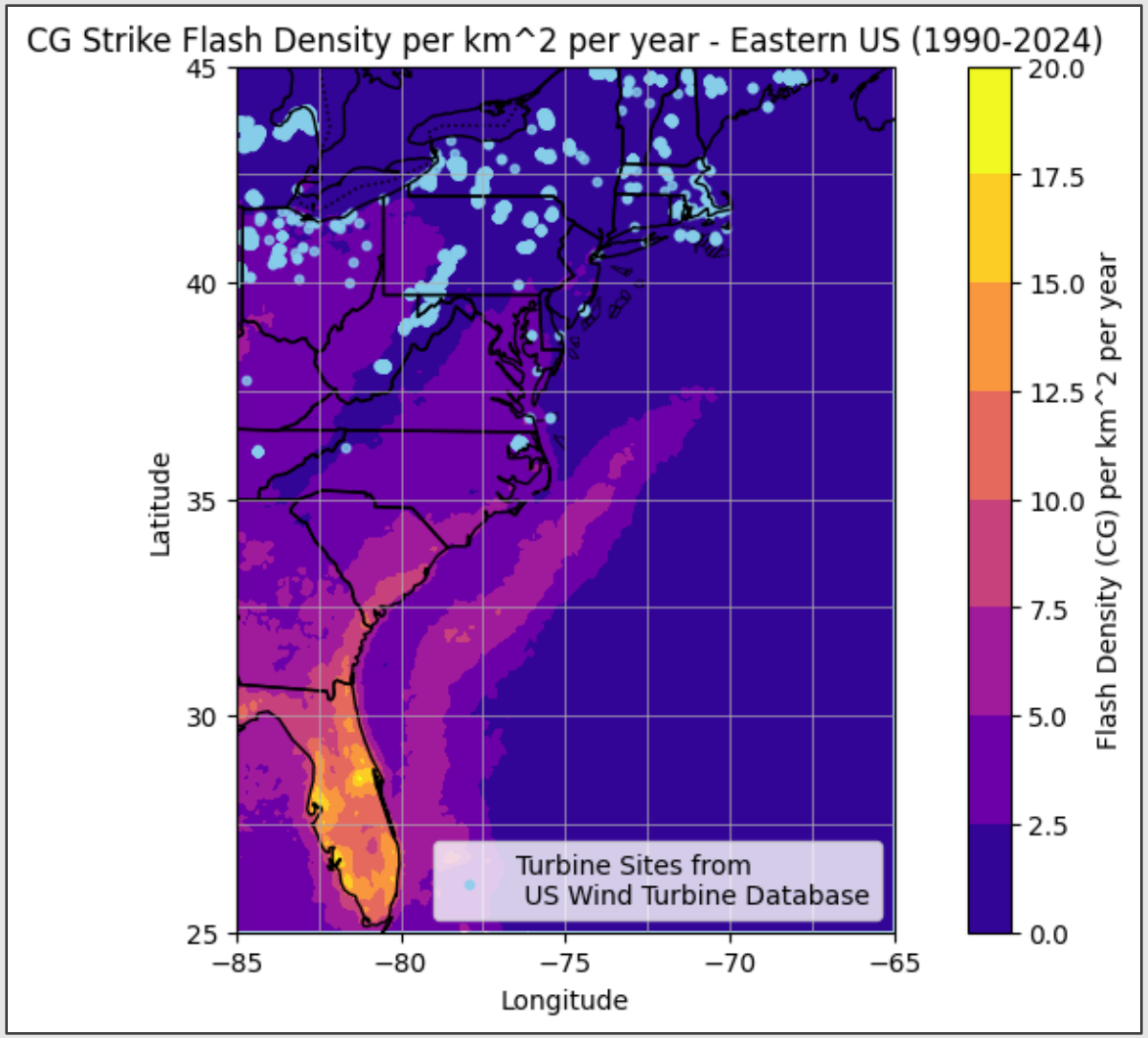
- NLDN data downloaded for 1990 through the end of October 2024.
  - Domain: -65° to -85° W and 25° to 45° N.
  - Areas of focus offshore include the Mid-Atlantic, up through the NYB, towards the planned wind farms south of RI and MA.
- Retrieved only cloud-to-ground (CG) lightning strikes for this period.
  - NLDN started recording intracloud (IC) flashes beginning 09/01/2013 but strikes impacting turbines would be CG, so IC are excluded during download.
- Filtered CG data to eliminate misrepresentation of low current (intensity) IC flashes.
  - Removed positive flashes (+CG) with a current of less than 15kA, and negative flashes (-CG) greater than -5kA. Similar filtering has been done in other work (Cummins et al. 2006).
- Examined impacts to CG flash density pre and post installation of the Maple Ridge Wind Farm on the Tug Hill Plateau in Upstate NY (installation occurred in 2005).

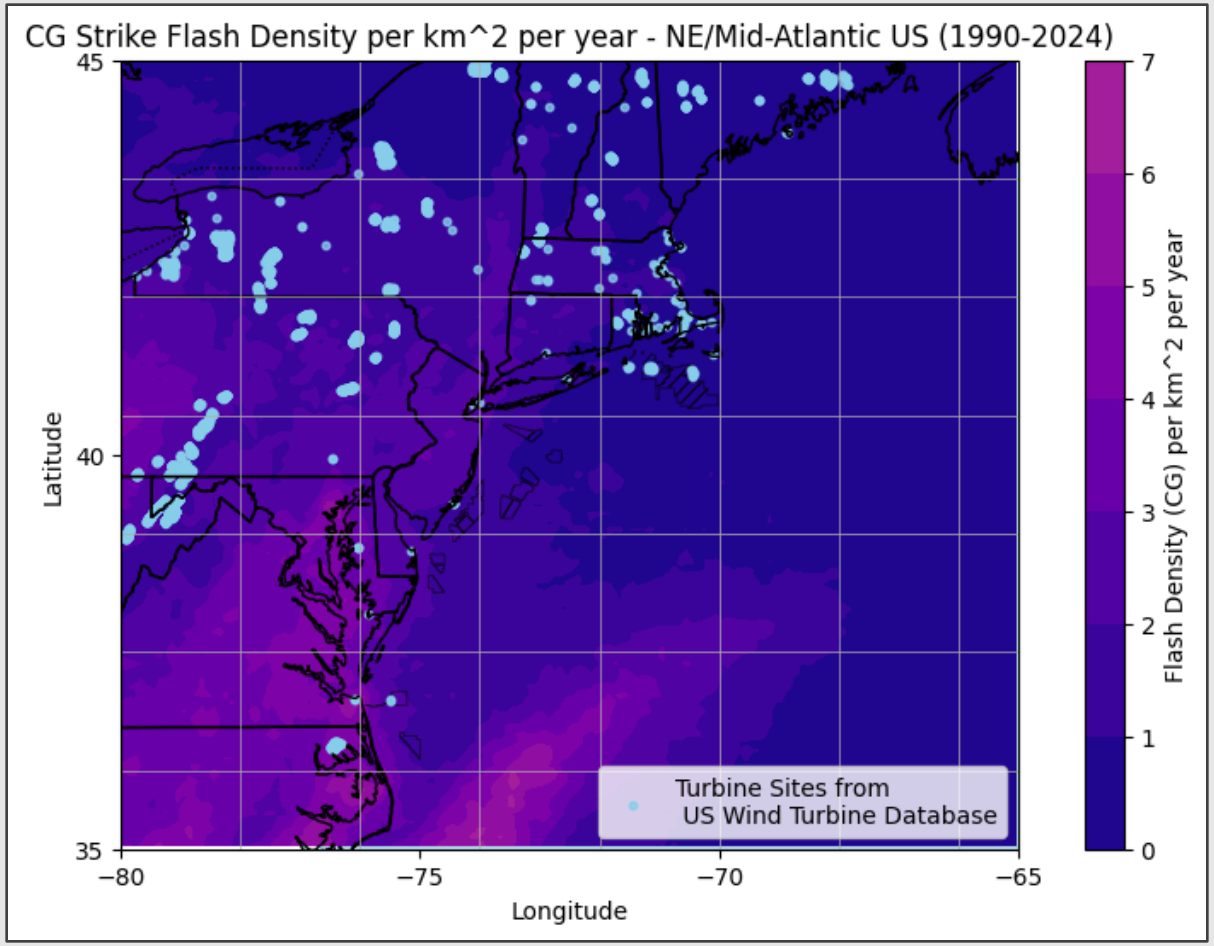




(USGS, 2024)

EASTERN US CG STRIKE FLASH DENSITY

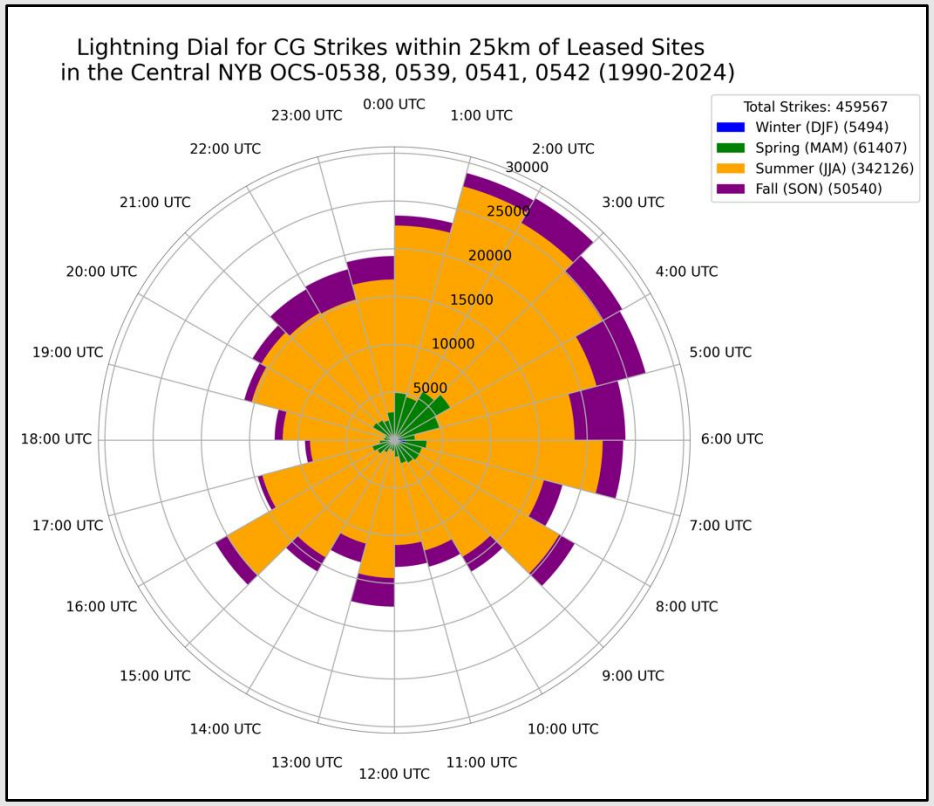


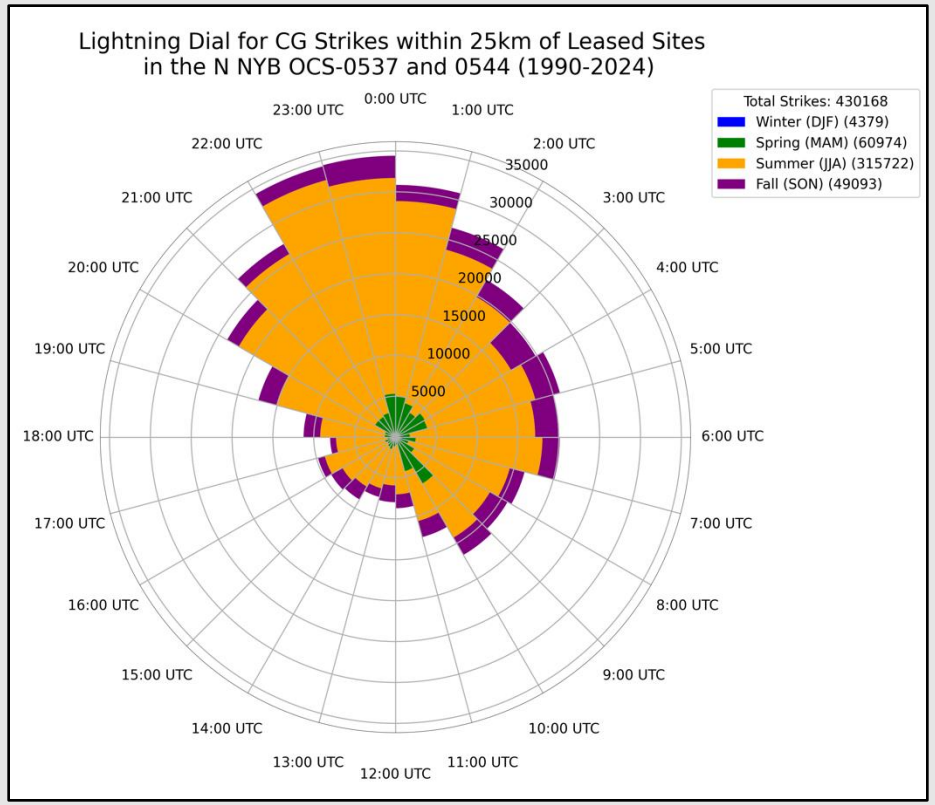


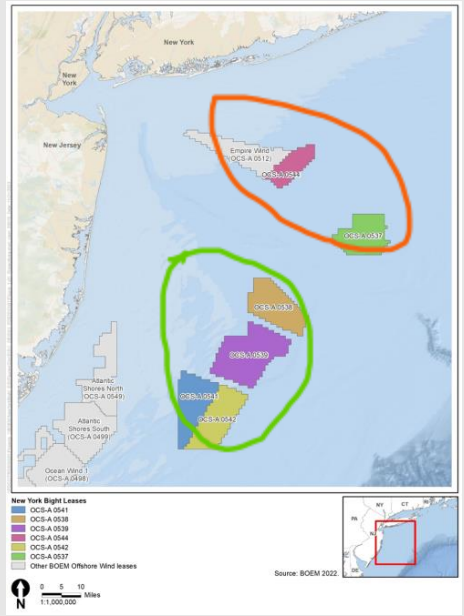
Slight variability from SW to NE across Mid-Atlantic and NYB

SEASONAL AND DIURNAL LIGHTING PATTERNS

- Lightning dials, highlight seasonal and diurnal variability across wind lease sites offshore the Eastern US.
  - Variability is evident across the NYB.
- Smaller, secondary maxima overnight in the late winter/early spring for all lease sites in the NYB.



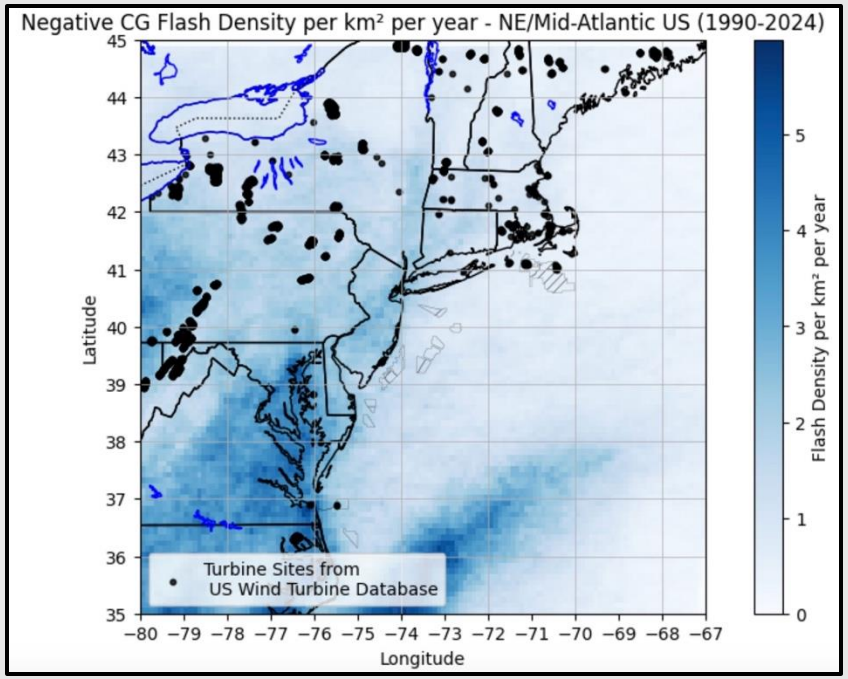


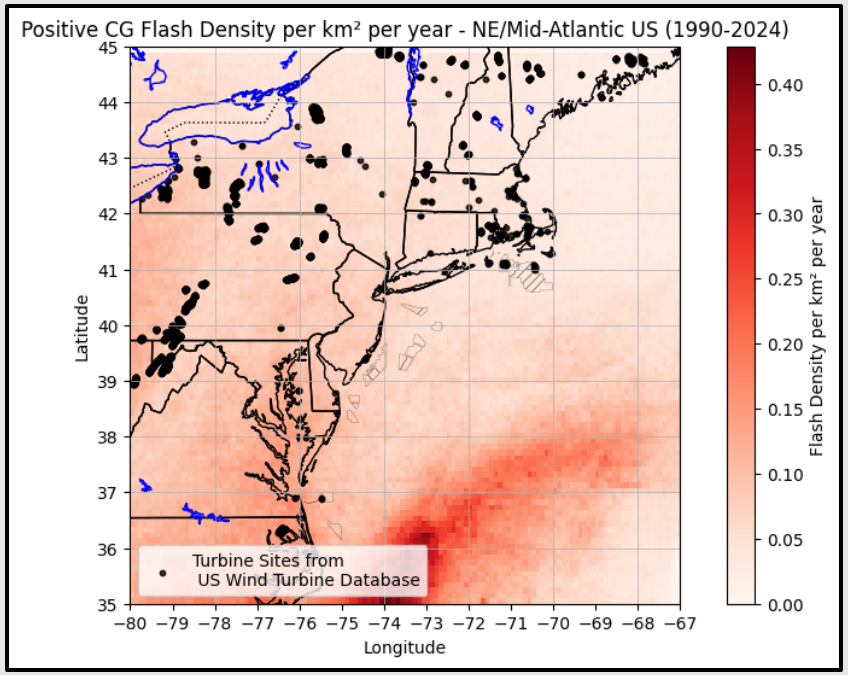


(BOEM, 2024)

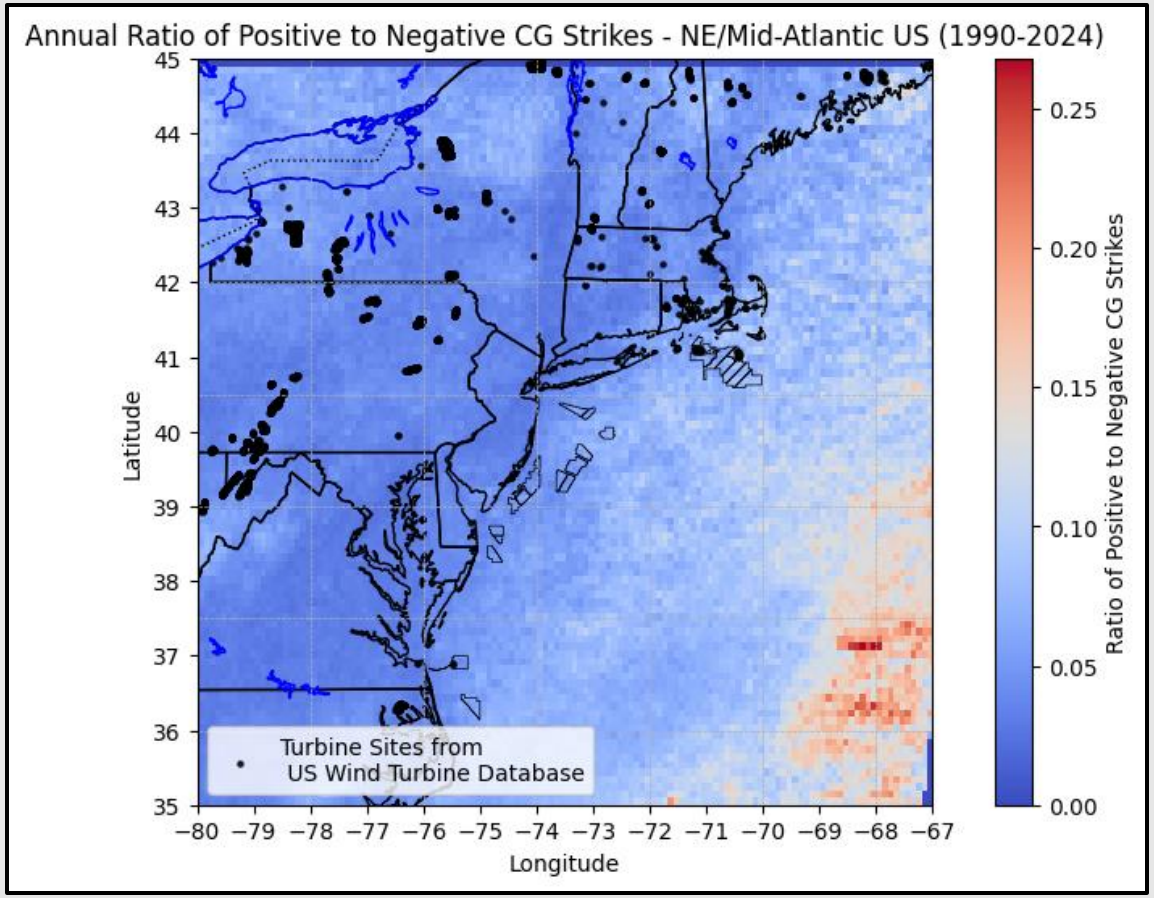
NEGATIVE VERSUS POSITIVE CG FLASH DENSITY

1. -CG flashes are more common across the domain.
   - ❖ Negative charges reside lower in the cloud.
2. Clear maximum over the Gulf Stream current.
3. While less common, +CG strikes are more intense as they generally require more energy to reach the ground.
   - ❖ Wind lease sites closer to the Gulf Stream offshore VA and NC are at increased risk of +/-CG strikes.



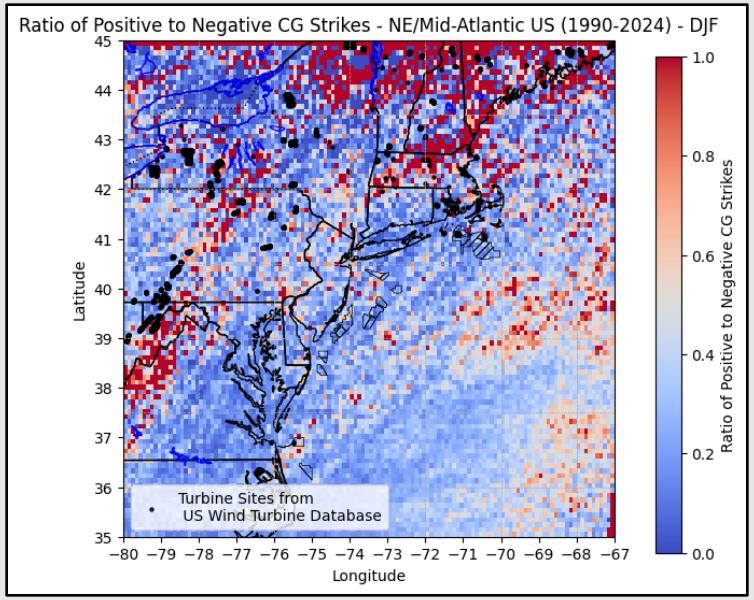


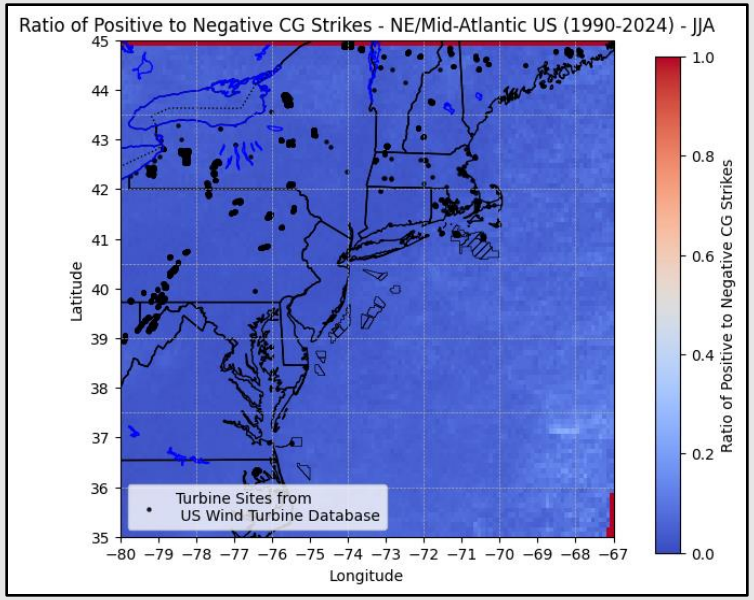
RATIO OF POSITIVE TO NEGATIVE CG STRIKES



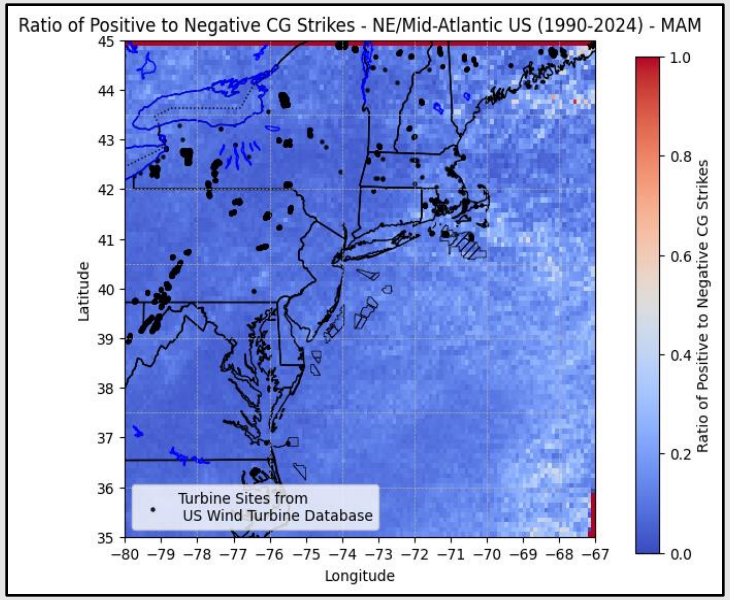
- Total positive CG strikes / total negative CG strikes.
- Limited spatial variability for the 34-year annual average.
- Higher ratio NE of the Gulf Stream.

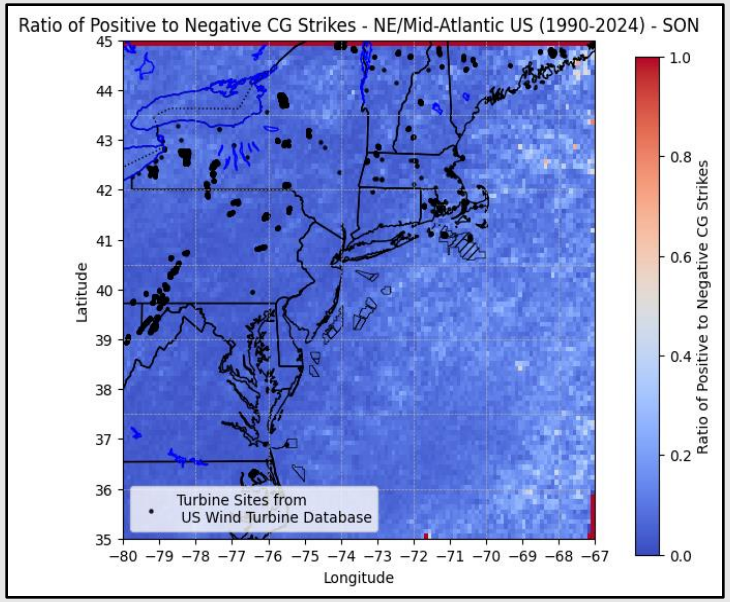
SEASONALITY OF POSITIVE TO NEGATIVE CG STRIKES RATIO





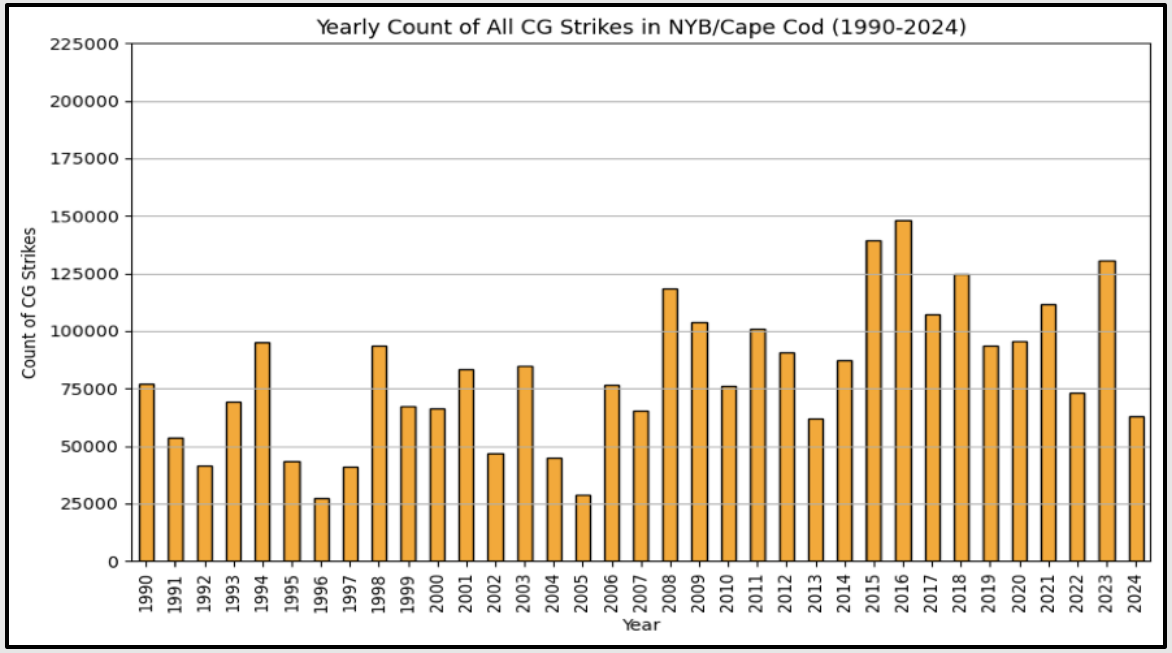
- More balanced ratio in the winter, particularly at higher elevations.
- Pockets of higher ratios offshore in spring and fall.
  - Lowest ratios occurs region-wide in the summer.

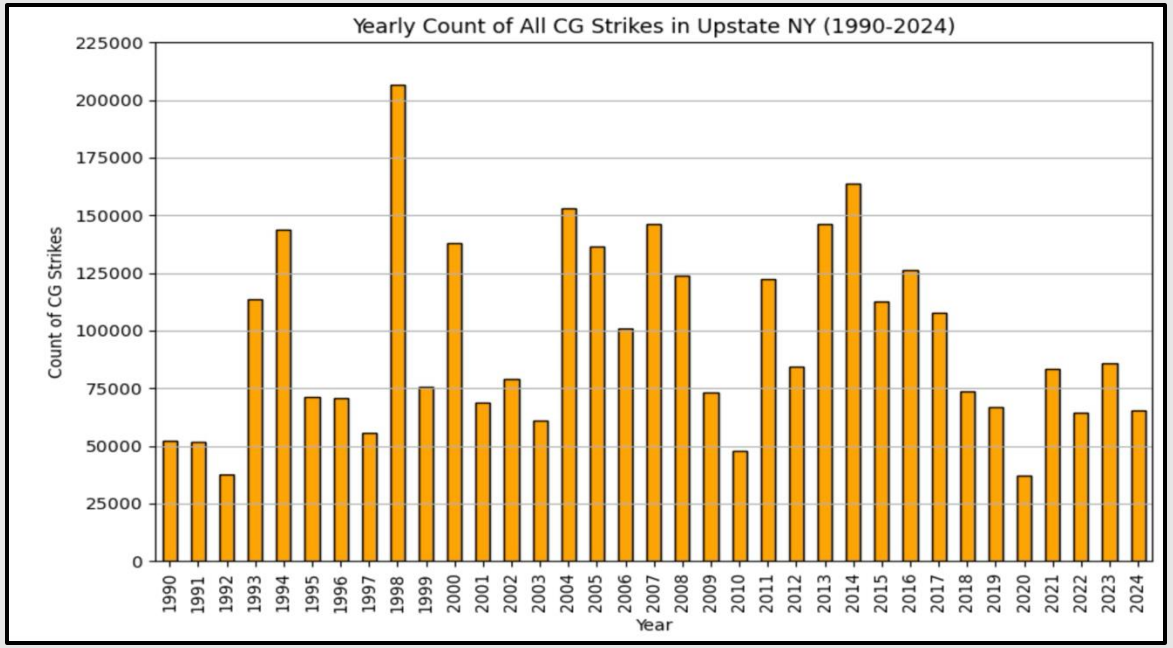




IS THERE A TREND IN TOTAL LIGHTNING STRIKES REGION-WIDE?

No statistically significant trends evident

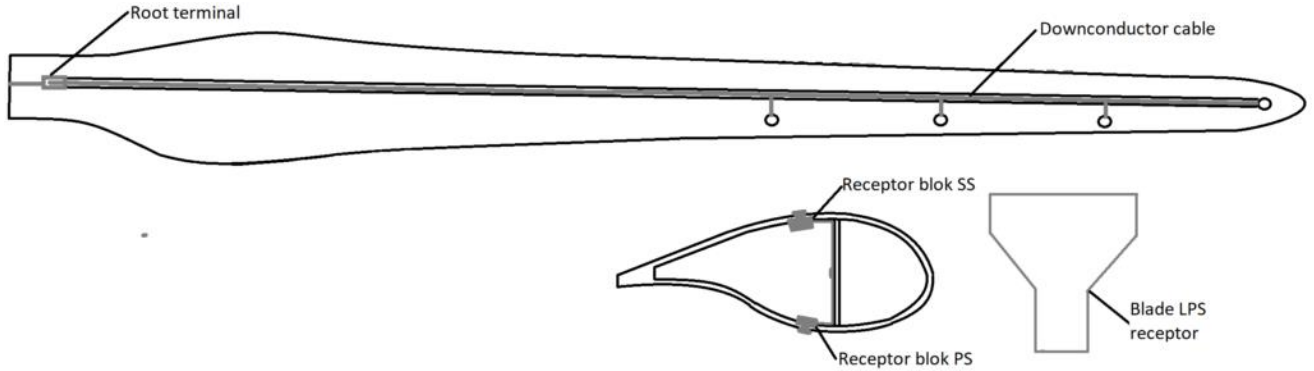




- *Sensor and processor upgrades led to misclassification problems with IC versus CG in 2015-2018.*
- *Hard to discern trend from increased detection offshore, even given the filtering to the dataset.*

TURBINE LIGHTNING PROTECTION SYSTEMS

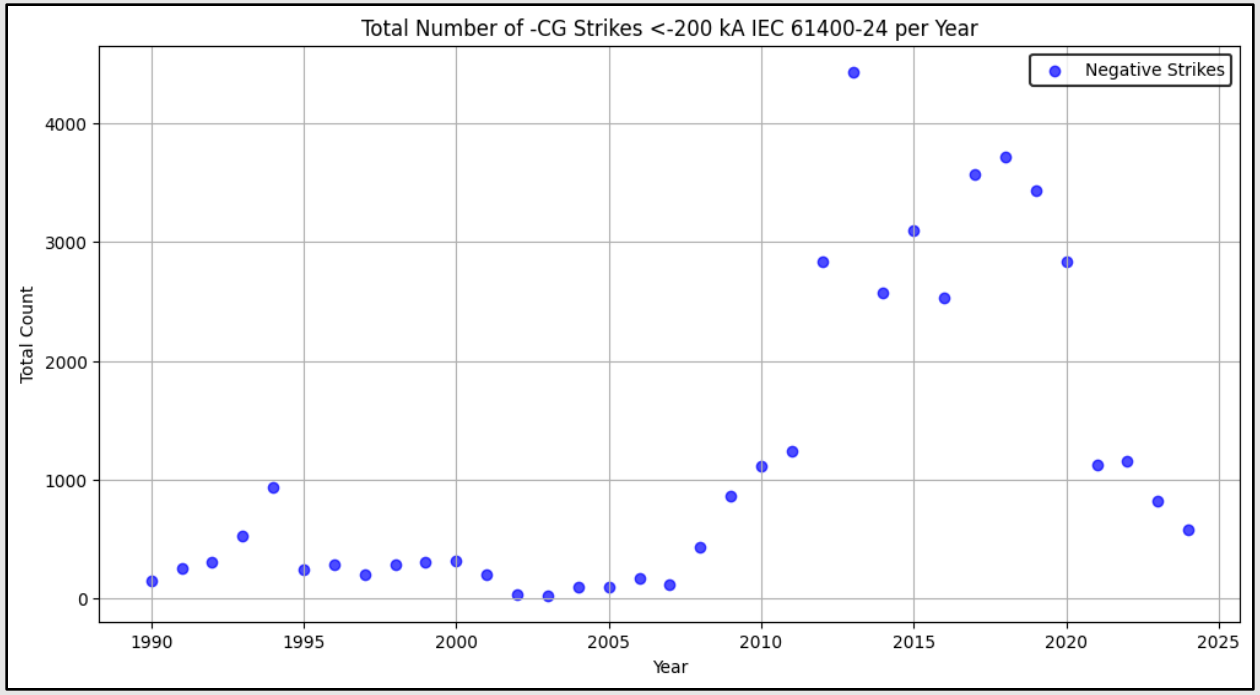
- A metal (typically copper) or metal alloy is placed on blade tips to transfer the load from lightning strikes to the grounding.
- Designed to handle lightning strikes up to 100-200 kiloamperes (kA) without system wear (IEC 61400-24 Standard)
- These do get replaced, so how often/intense can lightning be expected offshore?

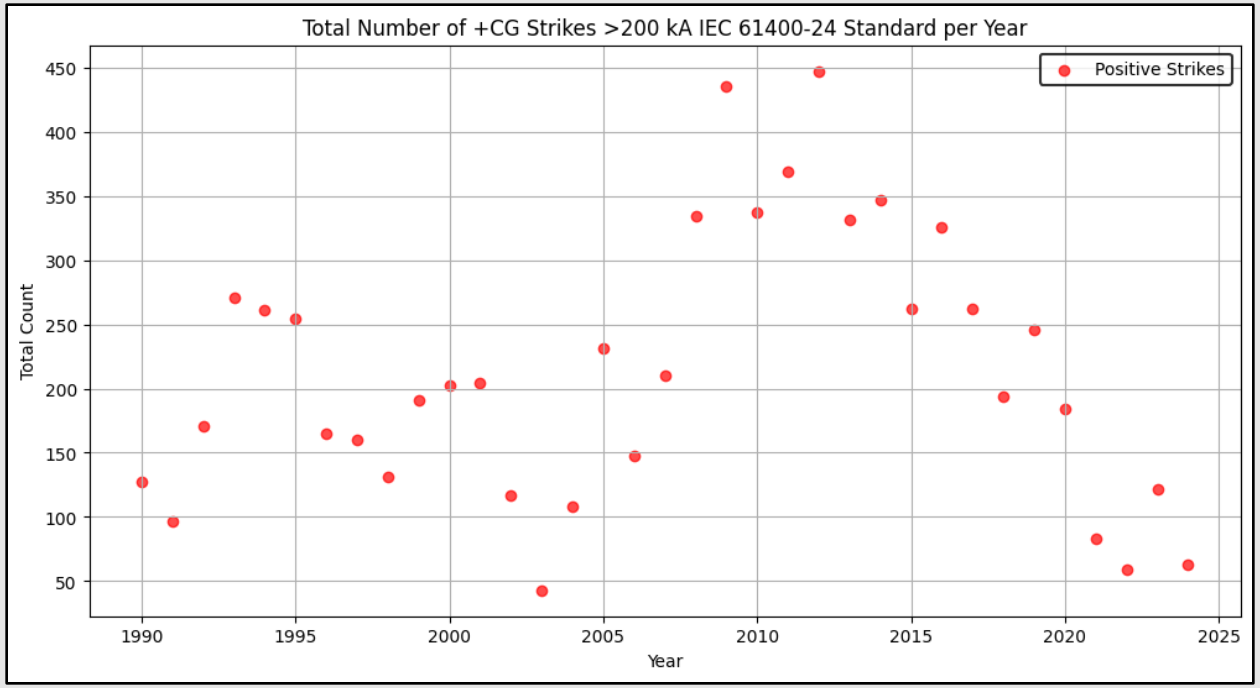


(Wind Power Lab, 2023)

ARE CG STRIKES OFFSHORE MORE INTENSE THAN IEC 61400-24 PROTECTION STANDARDS?

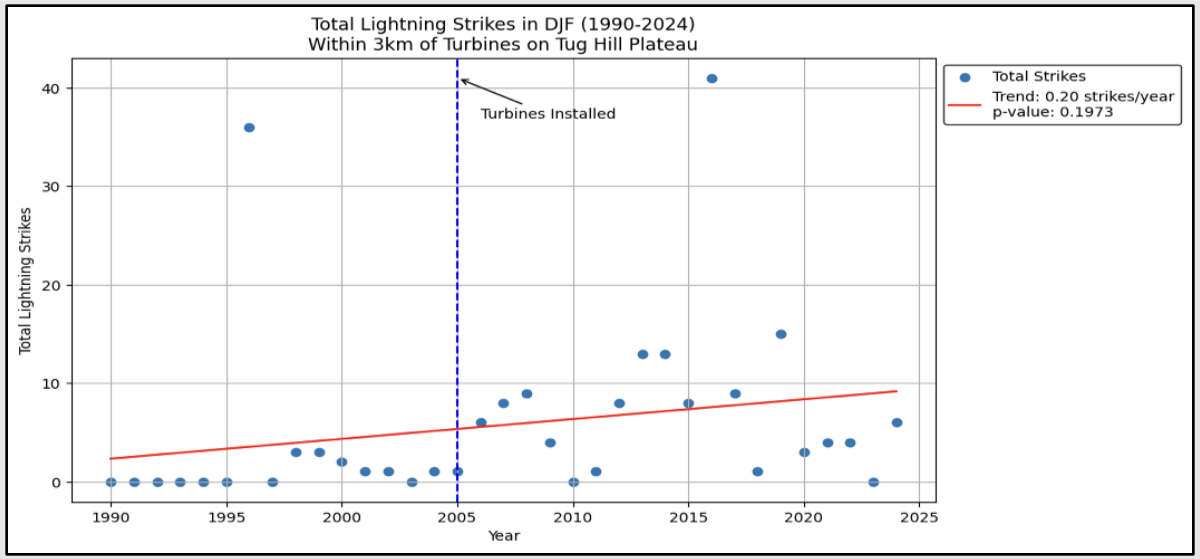
- Strikes within -67° to -76° W and 36° to 42° N to focus on the offshore waters from NC/VA border through the NYB.

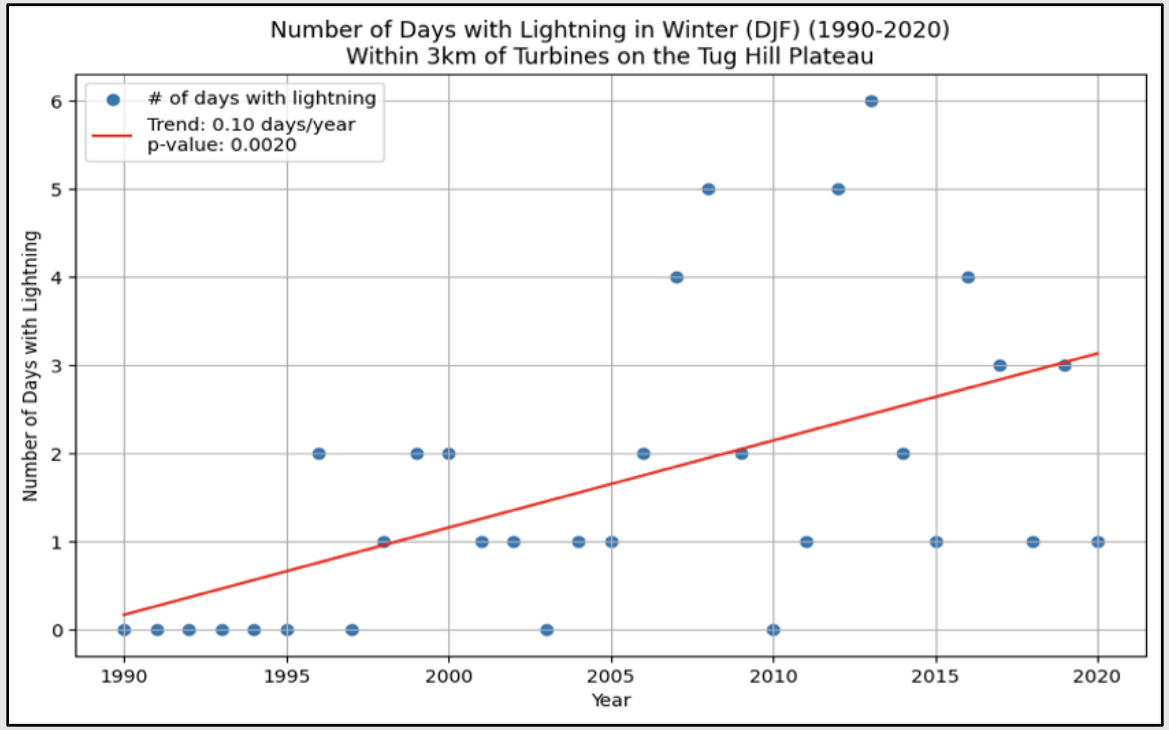




- Possible decadal variability.
- No clear, statistically significant annual trend.

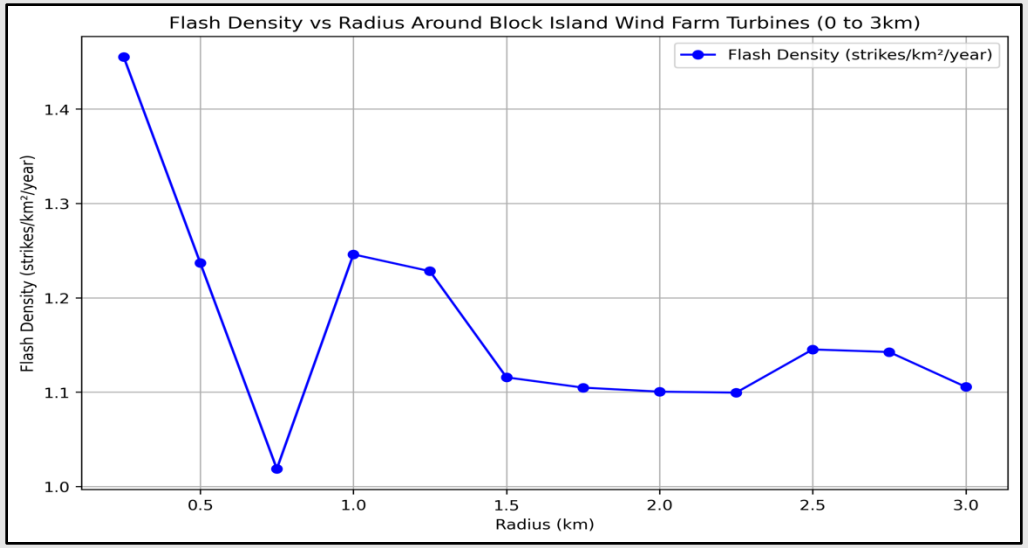
HAVE WIND FARMS CHANGED LIGHTNING CLIMATOLOGY ONSHORE?

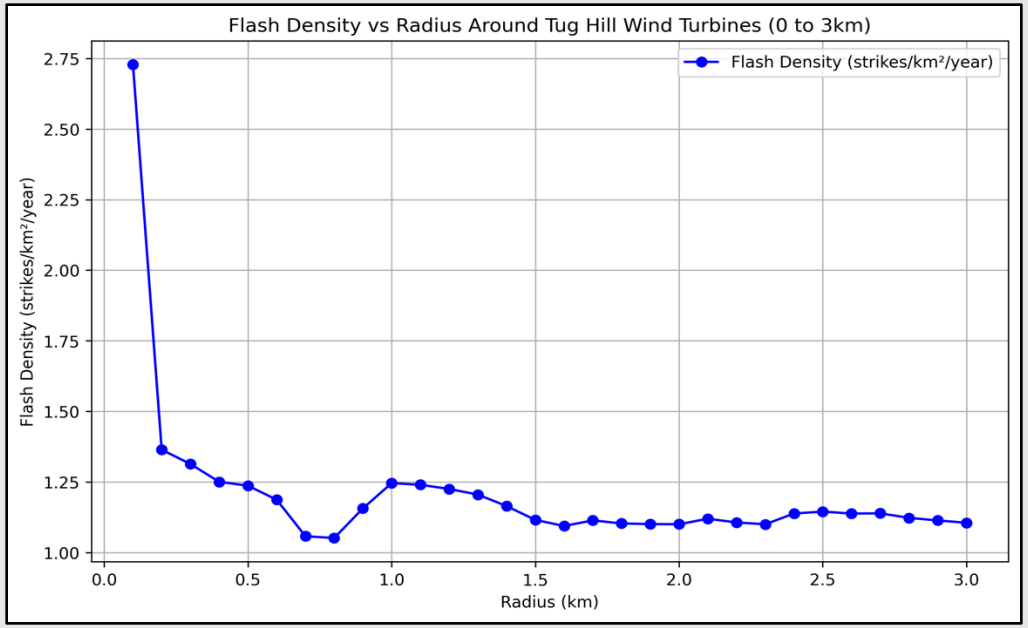




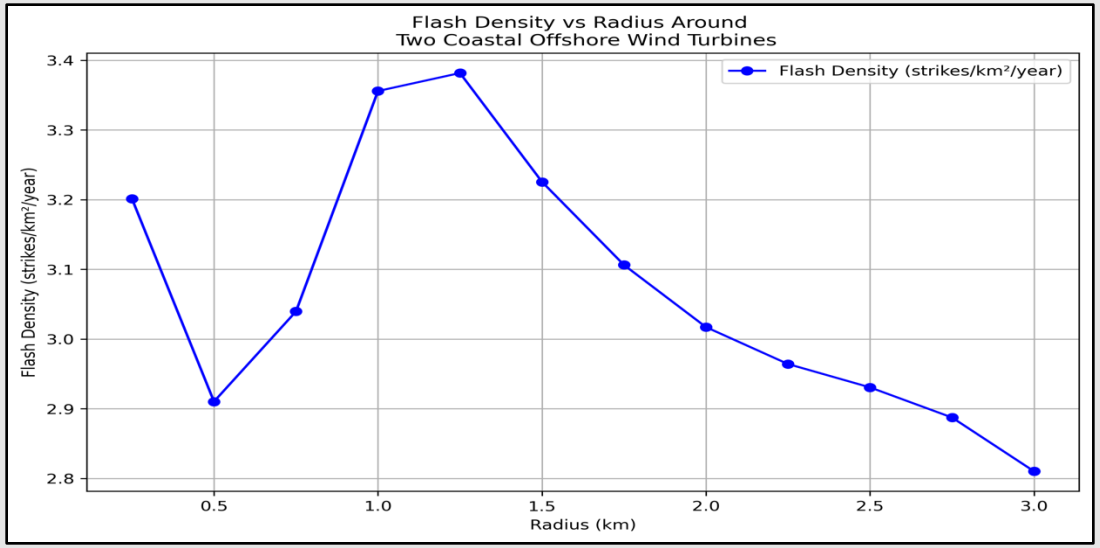
- Lake-effect lightning previously expected to be predominantly over the lake waters, or just inland, closer to higher instability (Moore and Orville 1990, Steiger et al. 2009).
- Supports previous field campaigns that have shown new secondary maximum of lake-effect lightning away from Lake Ontario (Steiger et al. 2024), over higher terrain.

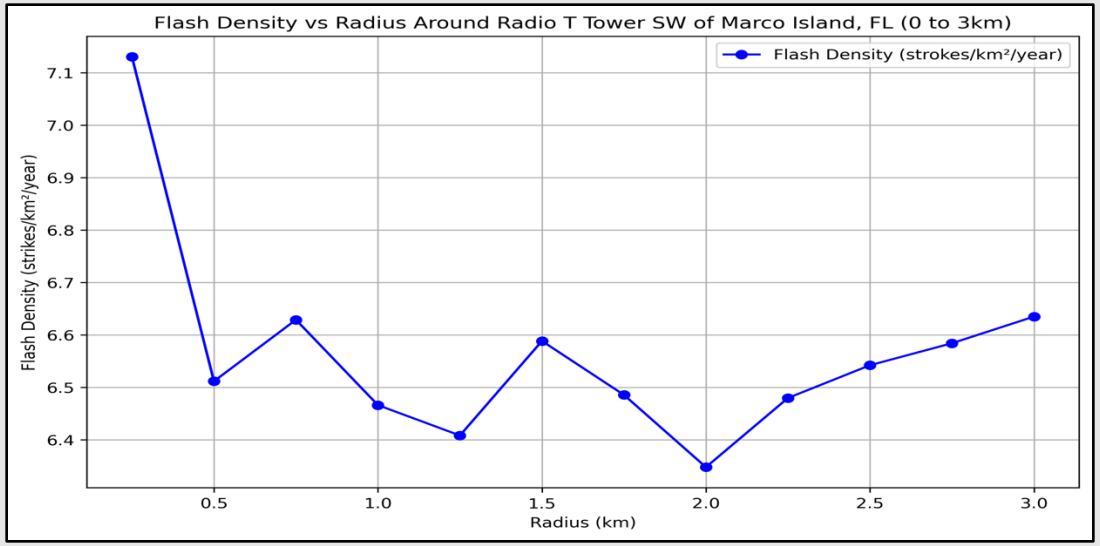
TURBINES AND TALL METAL TOWERS ATTRACTING LIGHTNING





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



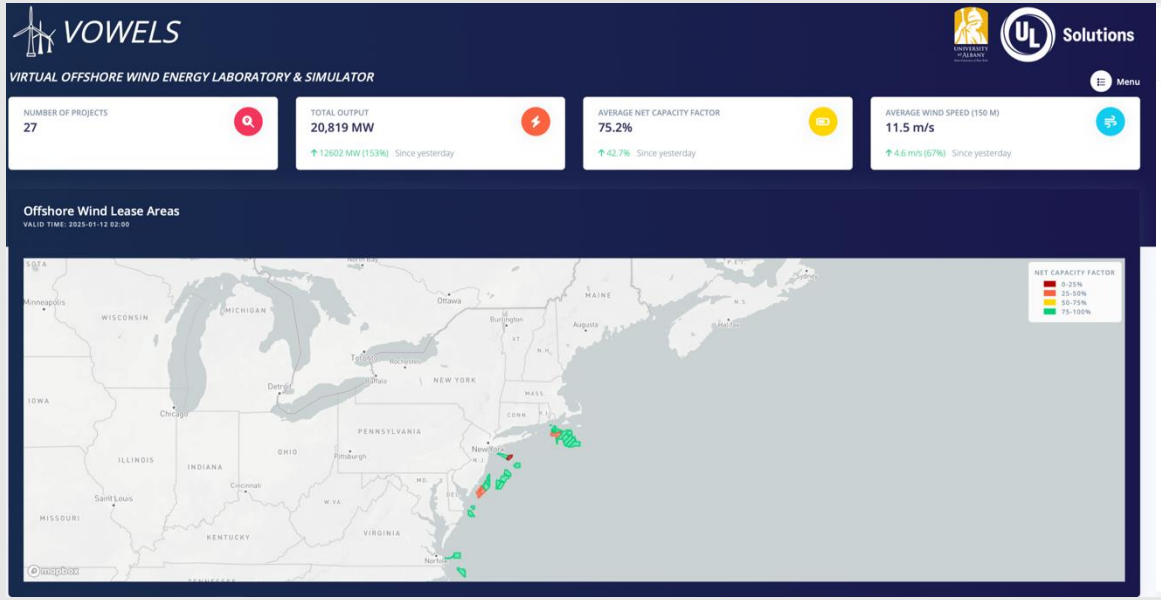


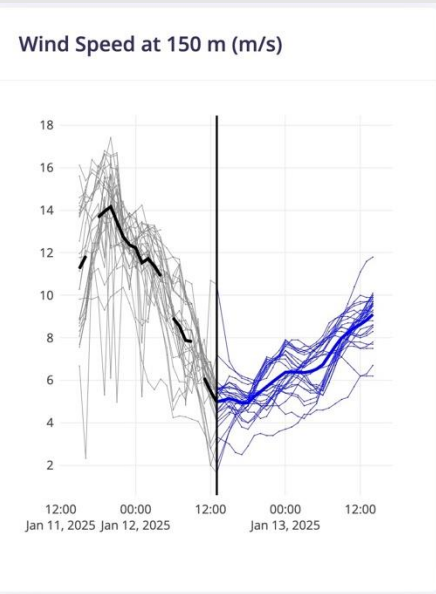
CONCLUDING REMARKS & FUTURE WORK

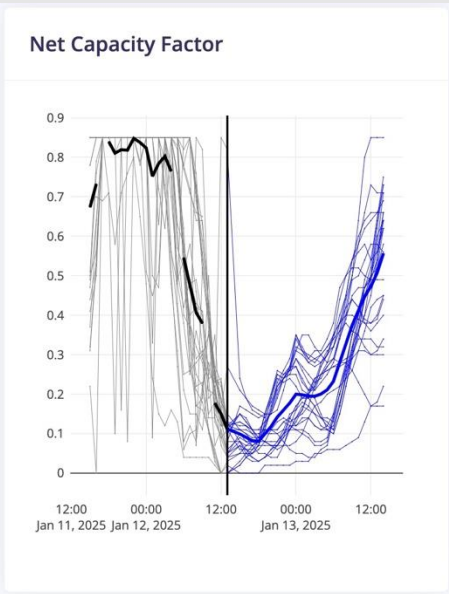
- The NLDN data supports the hypothesis that lightning is attracted to offshore wind turbines, and tall metal towers.
  - Also confirms other studies that show the same increased frequency onshore near wind farms.
- Varying risk across the East Coast, including increased exposure to positive CG strikes near the Gulf Stream.
  - CG strikes with currents more intense than IEC 61400-24 standards do occur but they are a small number of overall strikes.
  - Do wind farms closer to the Gulf Stream, and closer to higher hurricane risk areas need different standards than areas such as the NYB?
- This climatology can eventually be expanded to the Gulf of Mexico, and the Pacific coast (when floating turbines become more prominent).

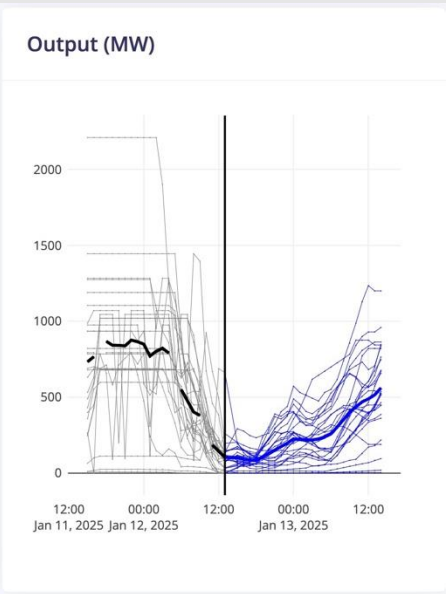
ACKNOWLEDGEMENT AND THANKS

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Thank you and feel free to contact me with any comments/questions:

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