

Winter Storm Elliott: Lessons Learned

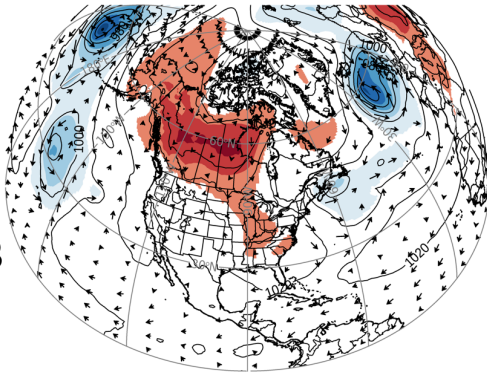
2023 Meteorology & Market Design for Grid Services Workshop

June 14, 2023

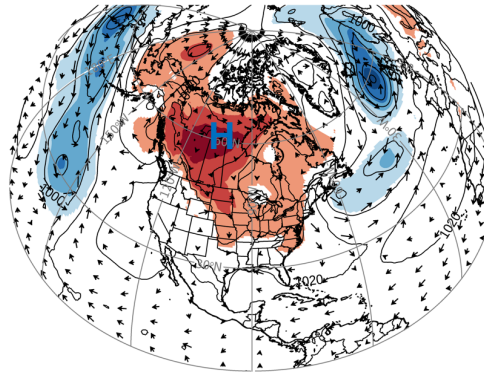


Sea-Level Pressure Anomalies

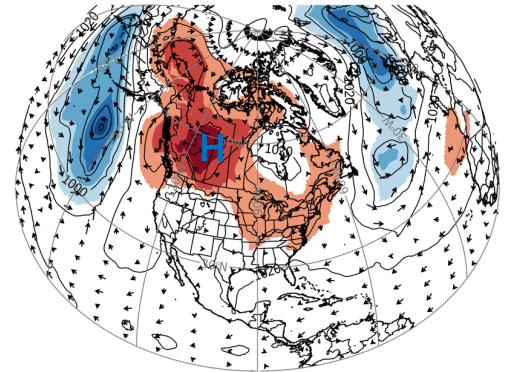
Sea-Level Pressure (mb): 2022-12-19 12:00 EST



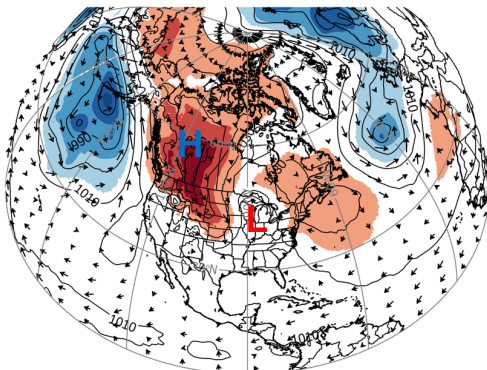
Sea-Level Pressure (mb): 2022-12-20 12:00 EST



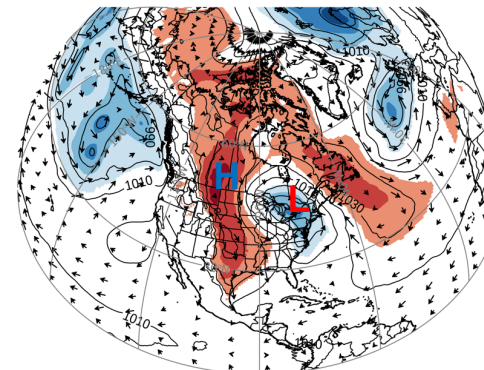
Sea-Level Pressure (mb): 2022-12-21 12:00 EST



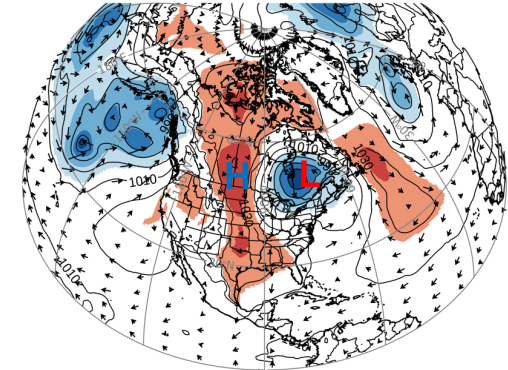
Sea-Level Pressure (mb): 2022-12-22 12:00 EST



Sea-Level Pressure (mb): 2022-12-23 12:00 EST



Sea-Level Pressure (mb): 2022-12-24 12:00 EST

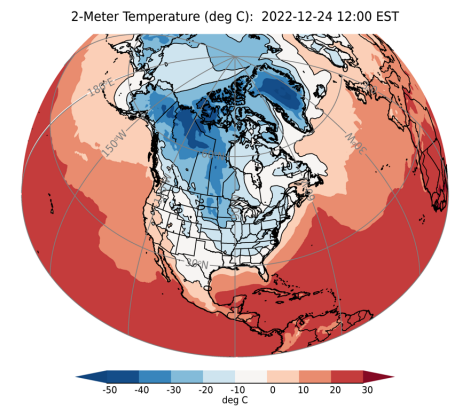
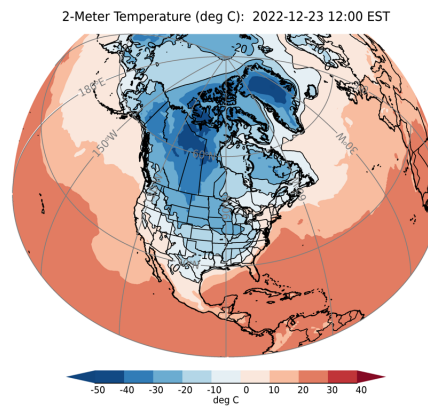
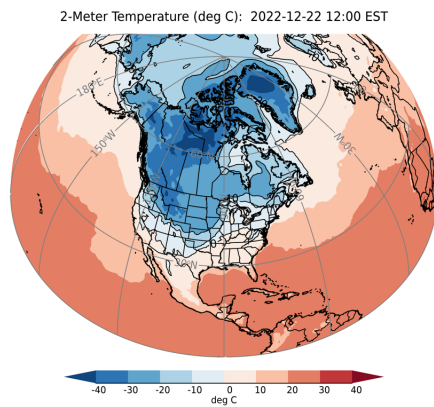
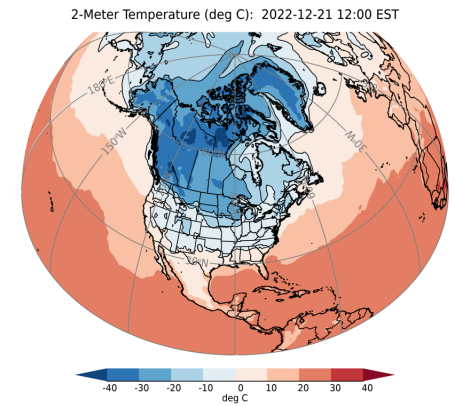
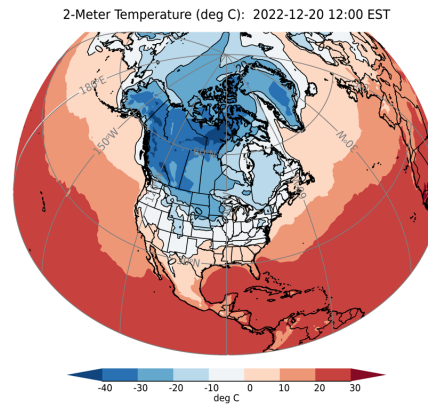
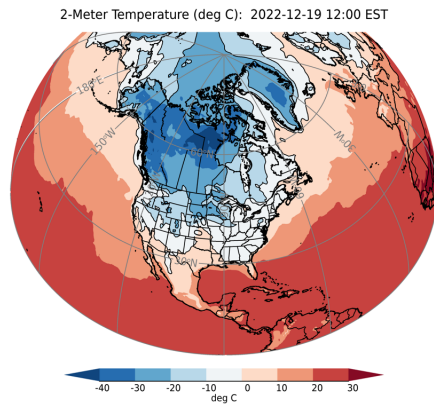


Surface High builds in Canada over 3 days, and descends into the U.S.

Strong differential thermal advection 22-24 Dec.

2-Meter Temperature

Airmass was Arctic in origin, typically cold, but extremely dry and dense.

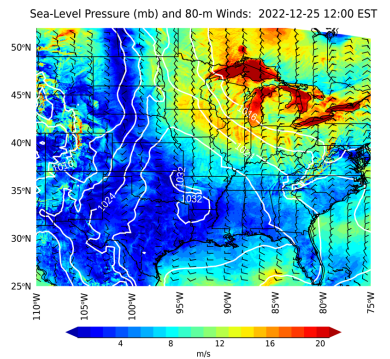
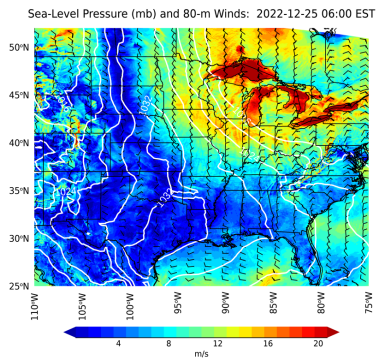
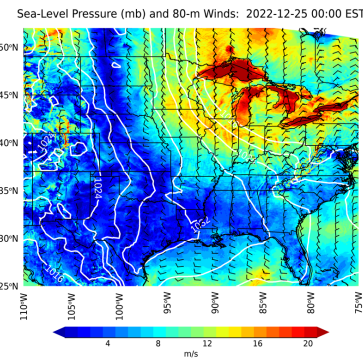
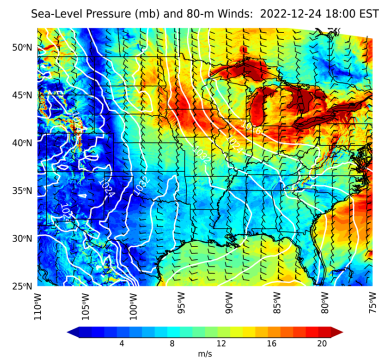
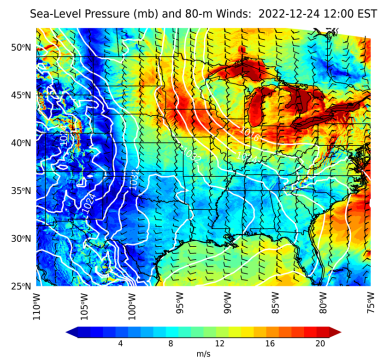
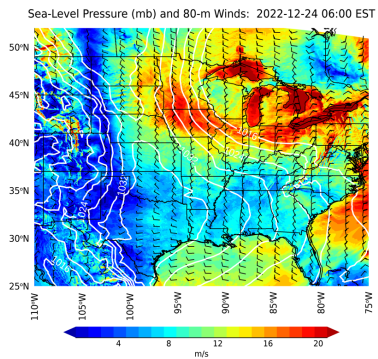
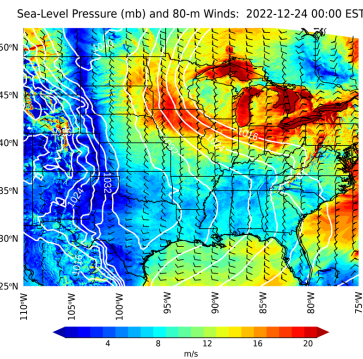
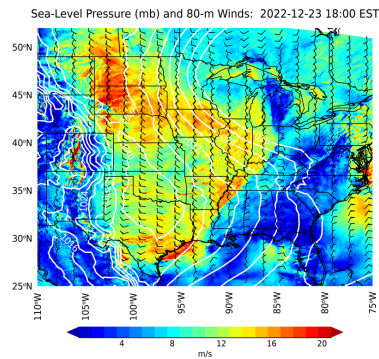


Wind Conditions near the Surface

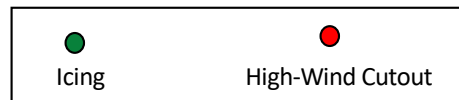
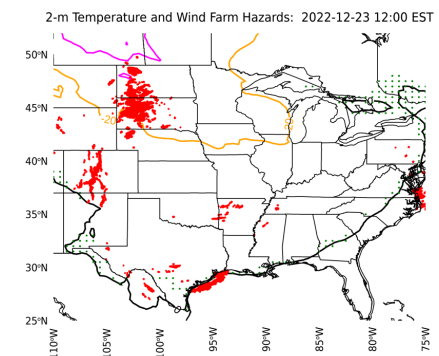
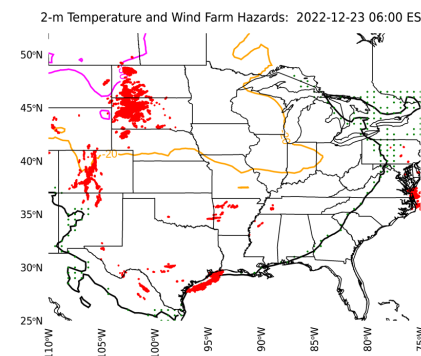
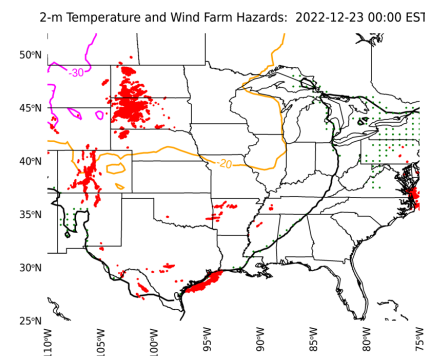
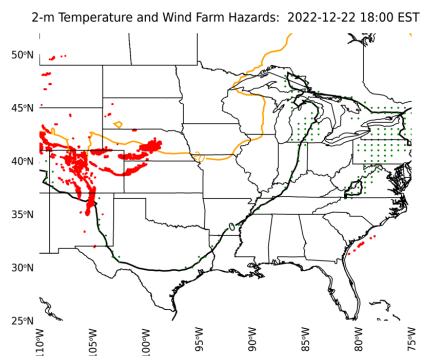
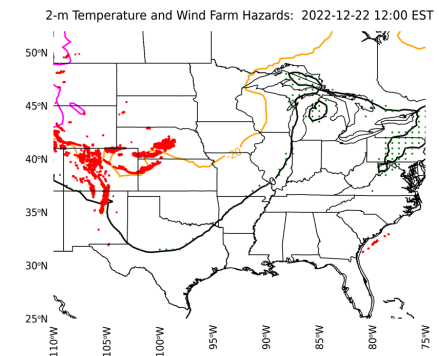
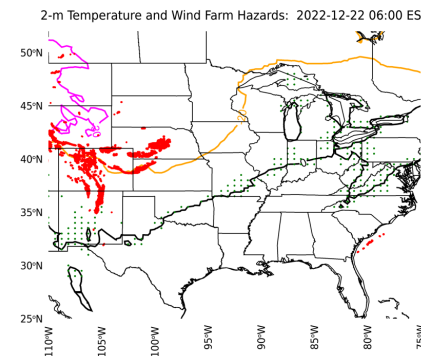
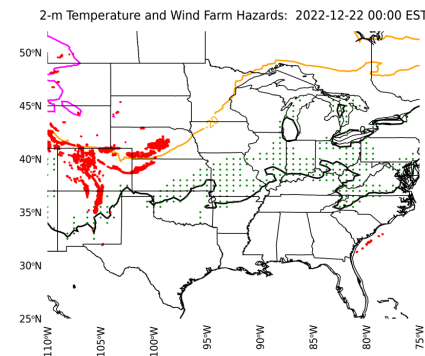
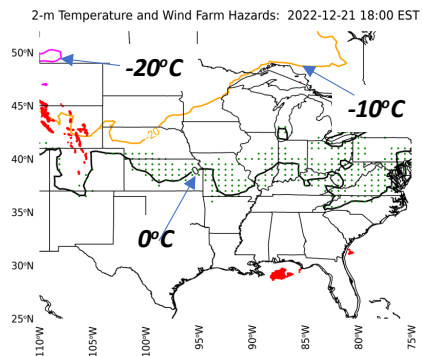


On the 23rd and 24th, surface pressure gradient tightens.

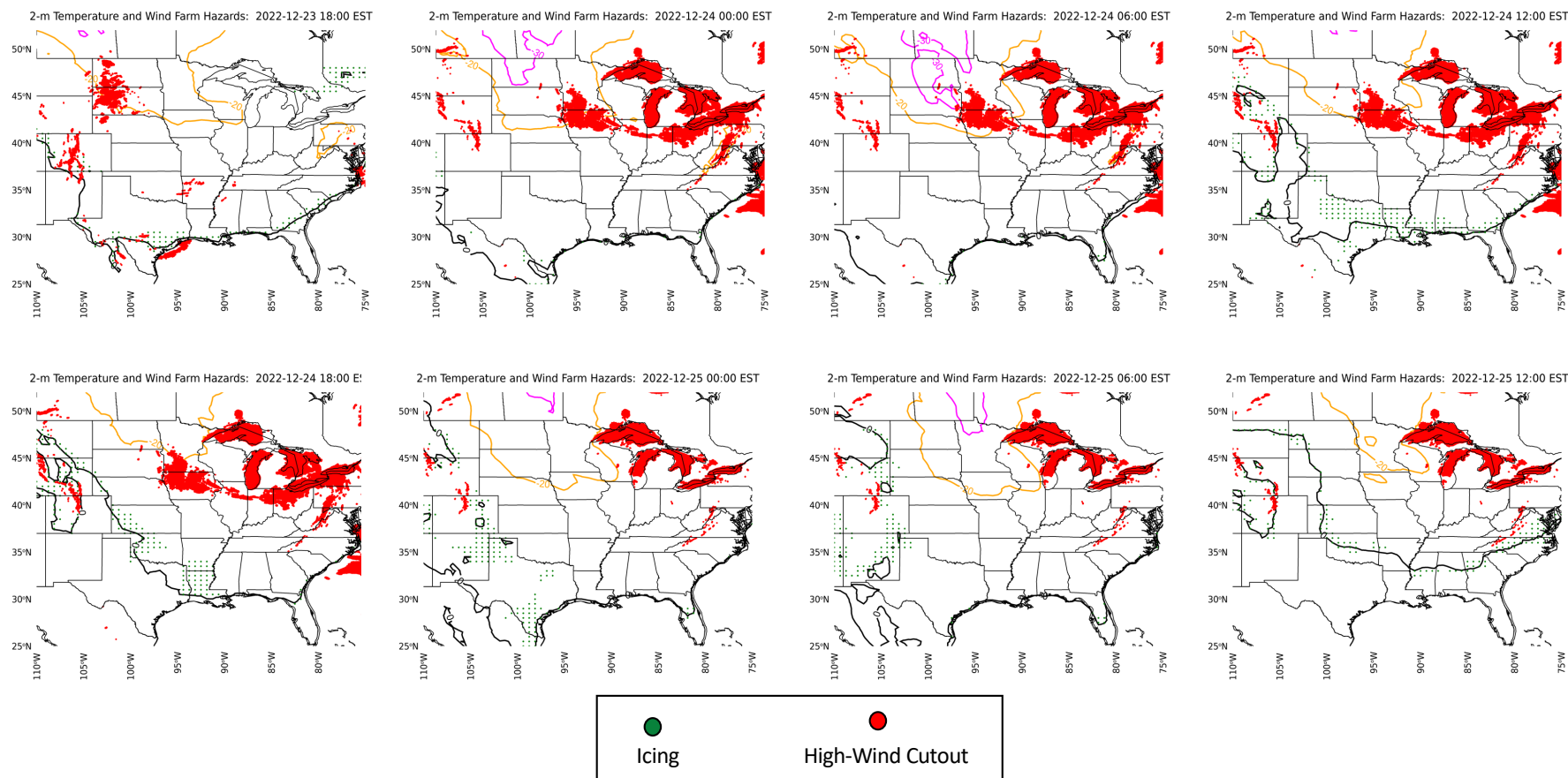
During event peak, pressure gradient across Iowa is 20 mb over 500 km (compare to cat. 3 hurricane)



Geographic Distribution of Hazards, by Time



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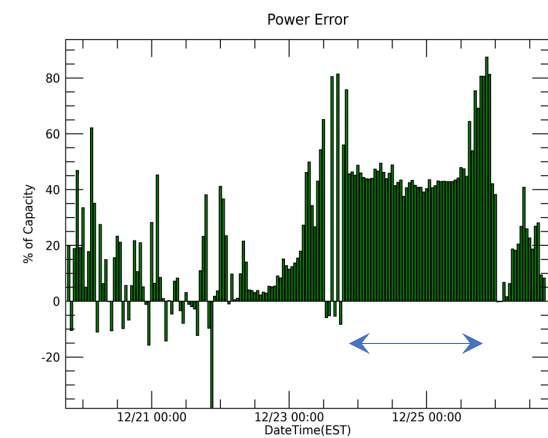
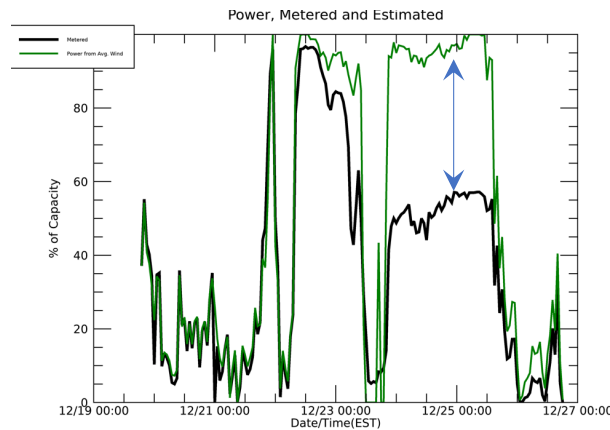
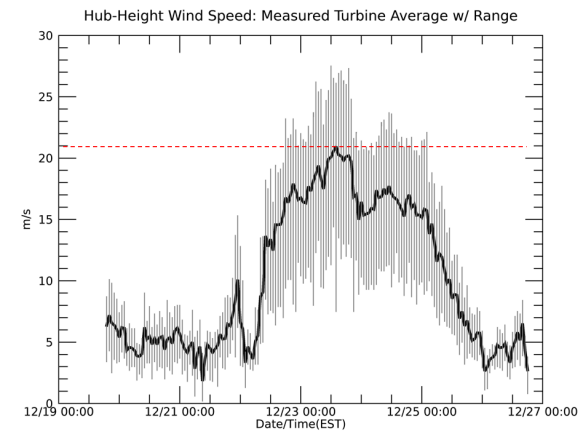
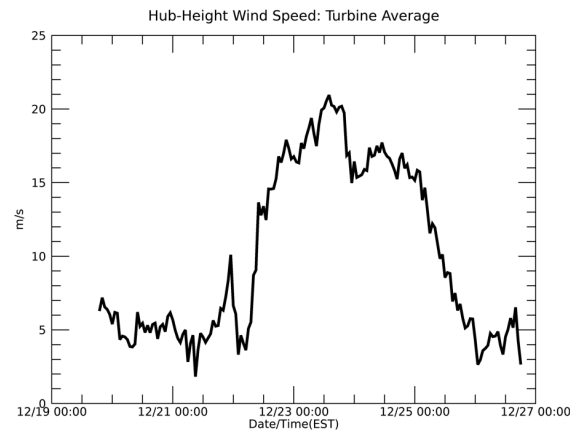
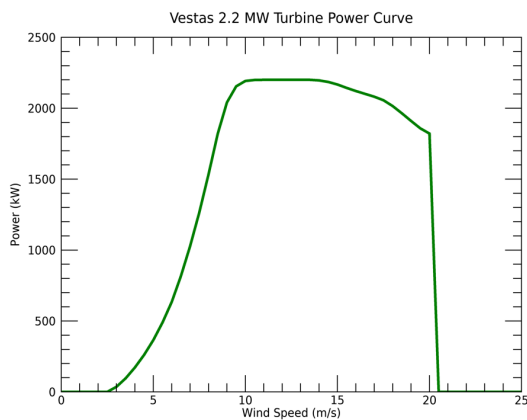


Western Wind Plant during the Elliott Wind Event



Under-sampling or averaging wind across turbines → major over-prediction

Intra-farm variation near cutout as high as 15-20 m/s!

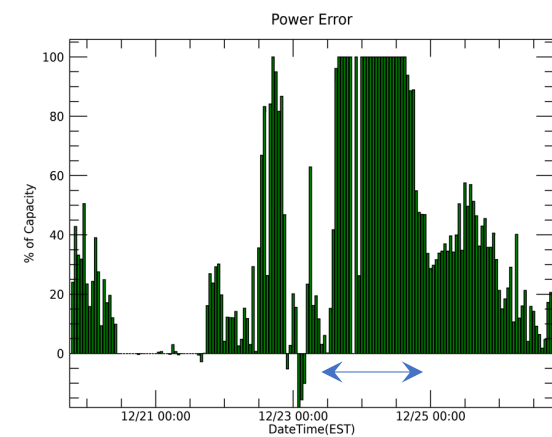
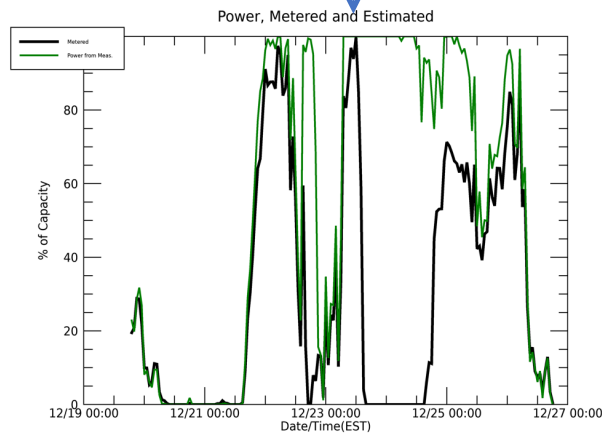
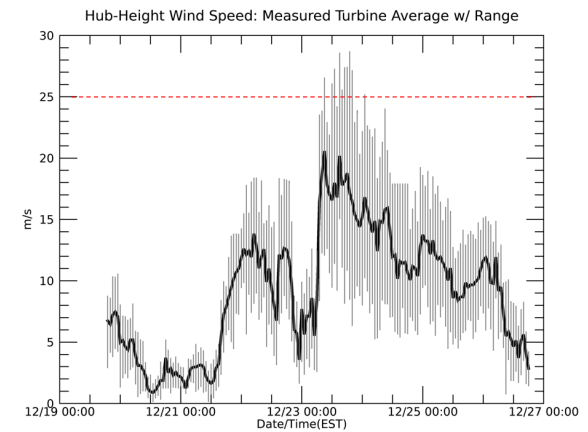
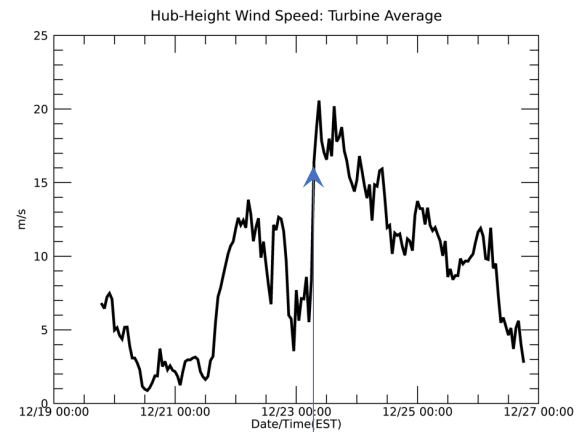
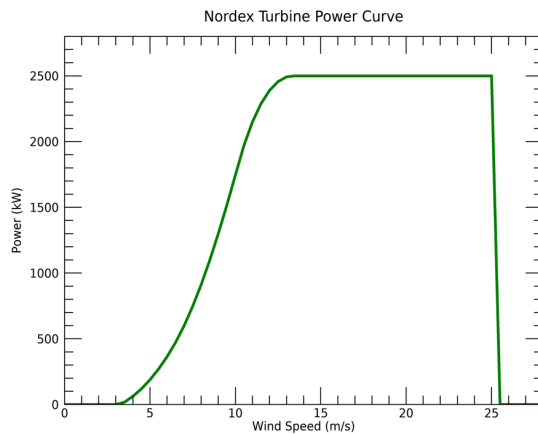


Eastern Wind Plant during the Elliott Wind Event

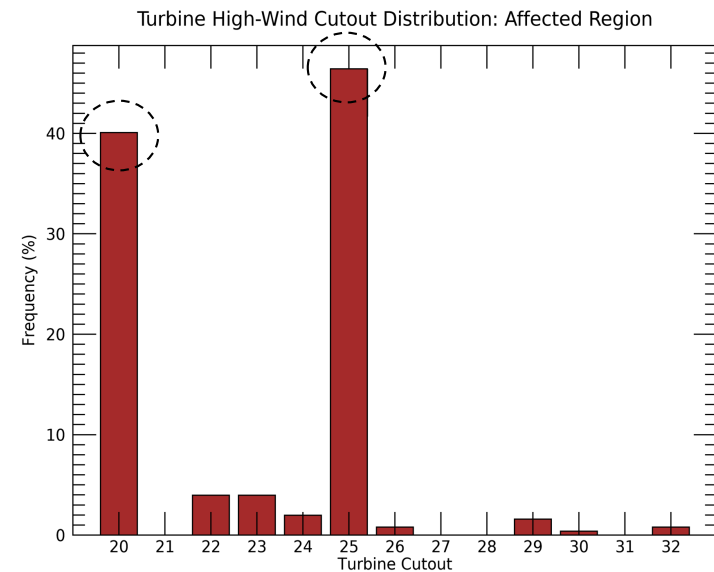
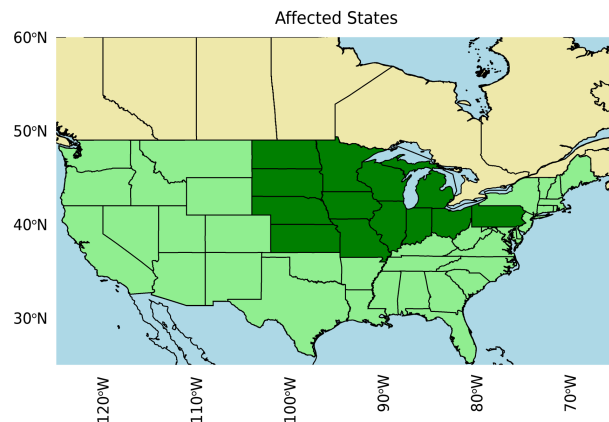
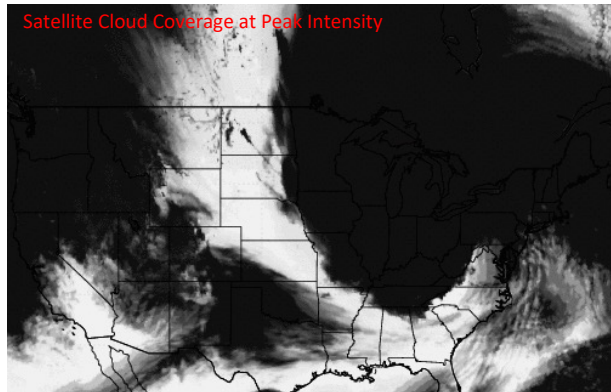


All turbines shut down at the peak of the event.

Partial HWC + partial LTS simultaneously

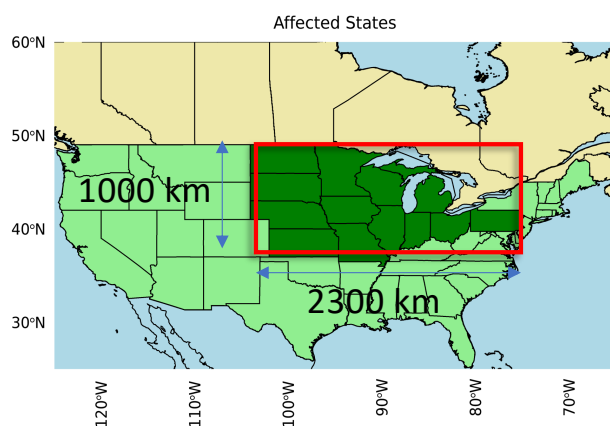


High Wind Cutout Distribution, Event-Affected Region

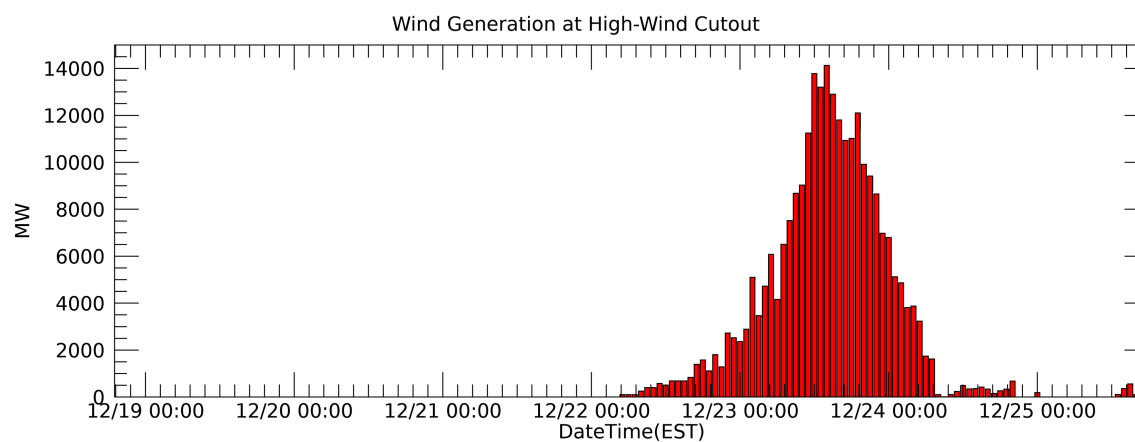
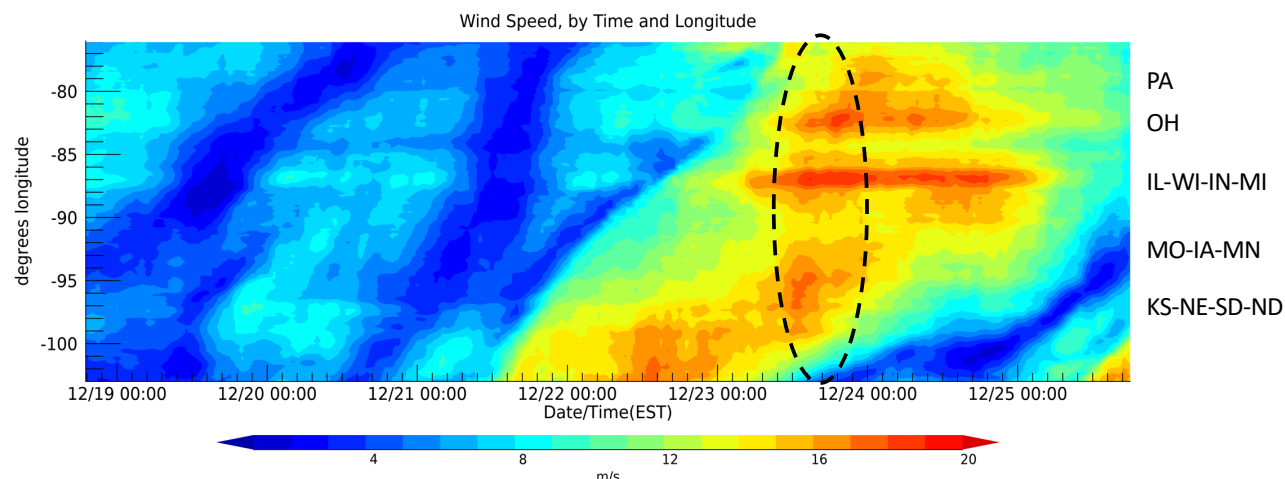


About 45 GW of wind in the “danger zone” – with about 45% at 20-21 m/s cutout and 50% GW at 25-26 m/s cutout.

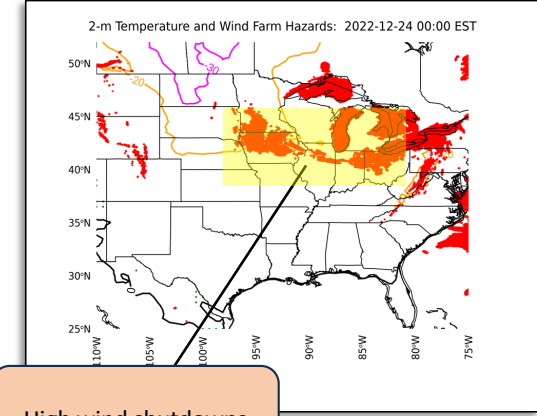
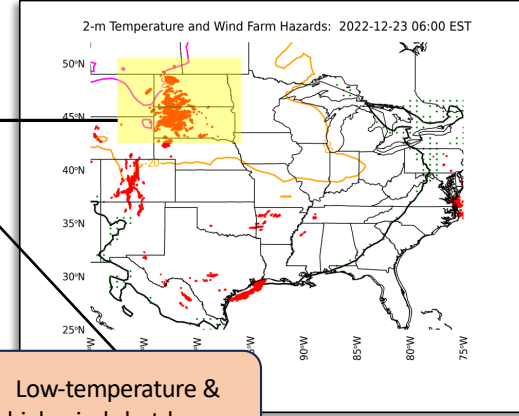
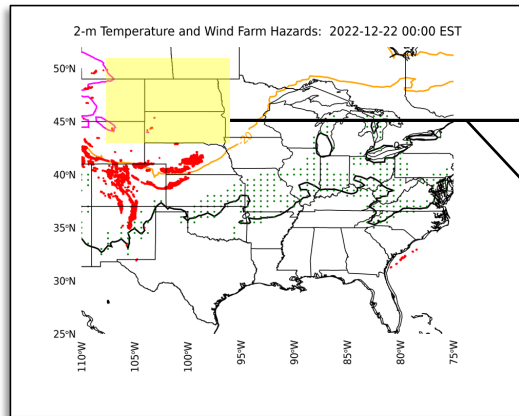
Simultaneous Wind-Cutout



If it was all deliverable, 14 GW of wind would be lost to cutout in one hour.



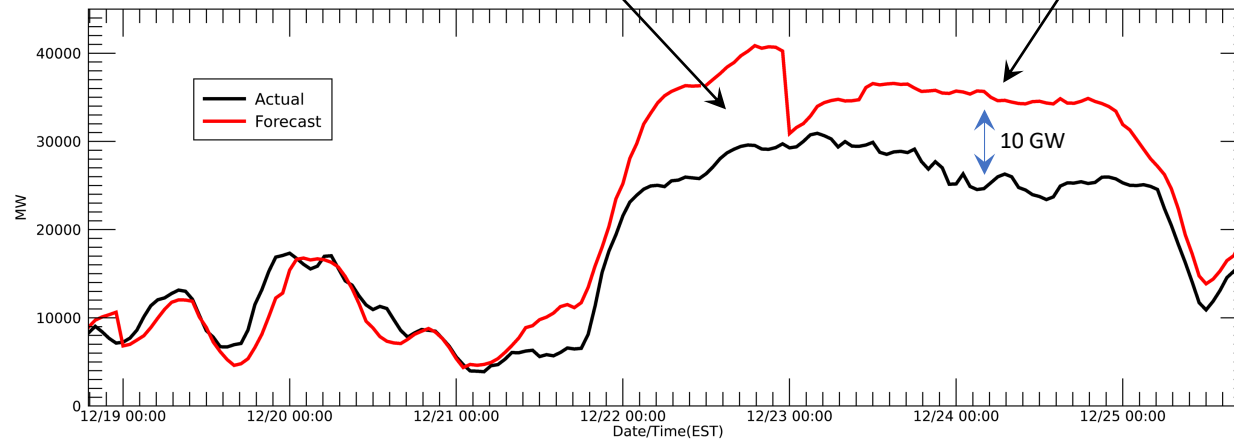
Predictability Challenges



Low-temperature &
high wind shutdowns

High wind shutdowns

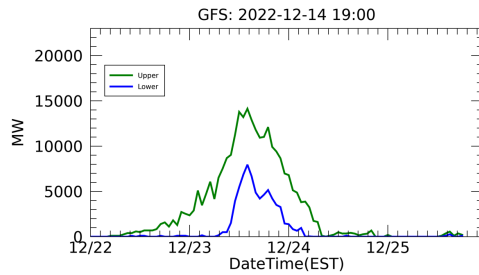
Day-Ahead Forecast: Affected-Area Aggregate



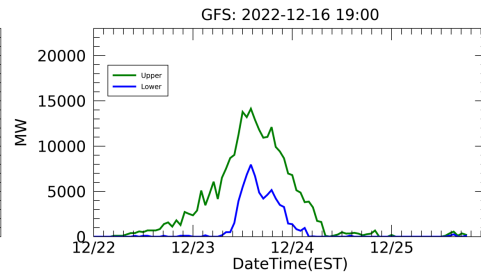
Did any model do well with cutout?



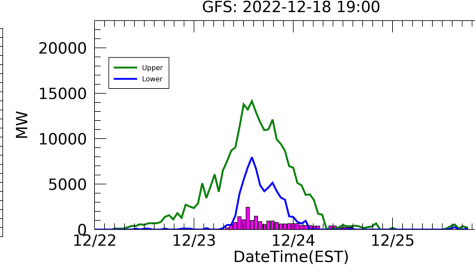
7 Days Ahead



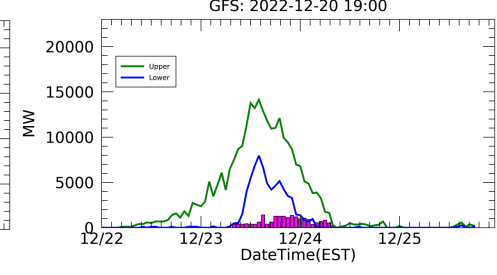
5 Days Ahead



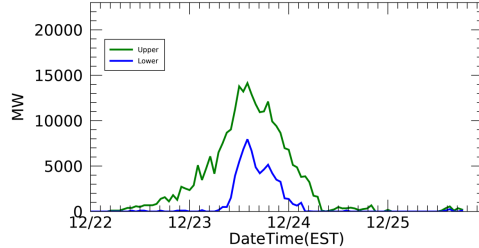
3 Days Ahead



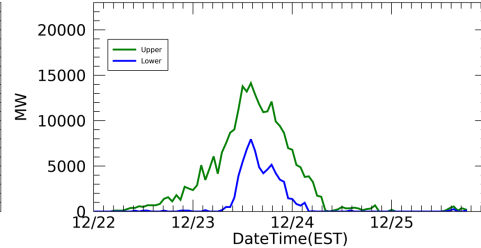
1 Day Ahead



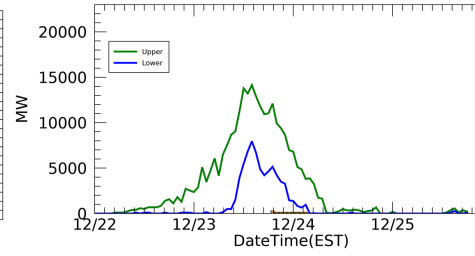
GFS ENS: 2022-12-14 19:00



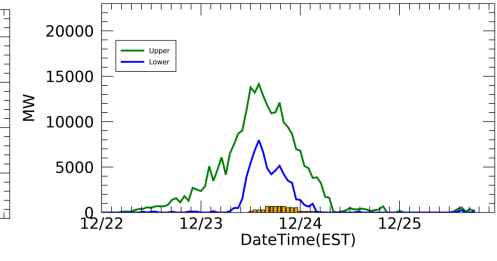
GFS ENS: 2022-12-16 19:00



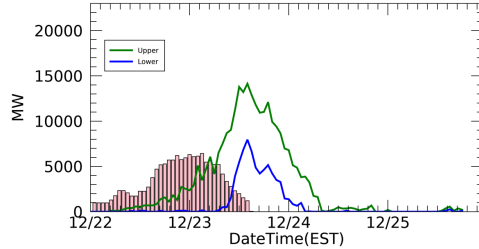
GFS ENS: 2022-12-18 19:00



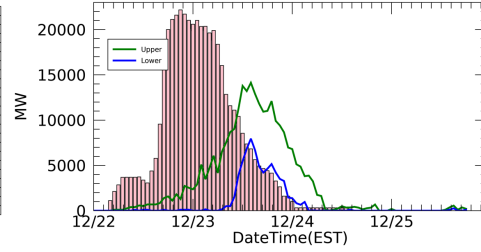
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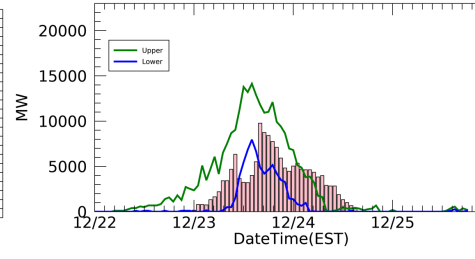
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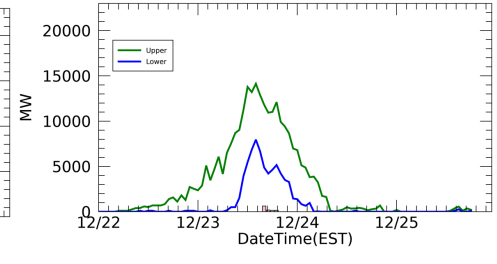
ECMWF: 2022-12-16 19:00



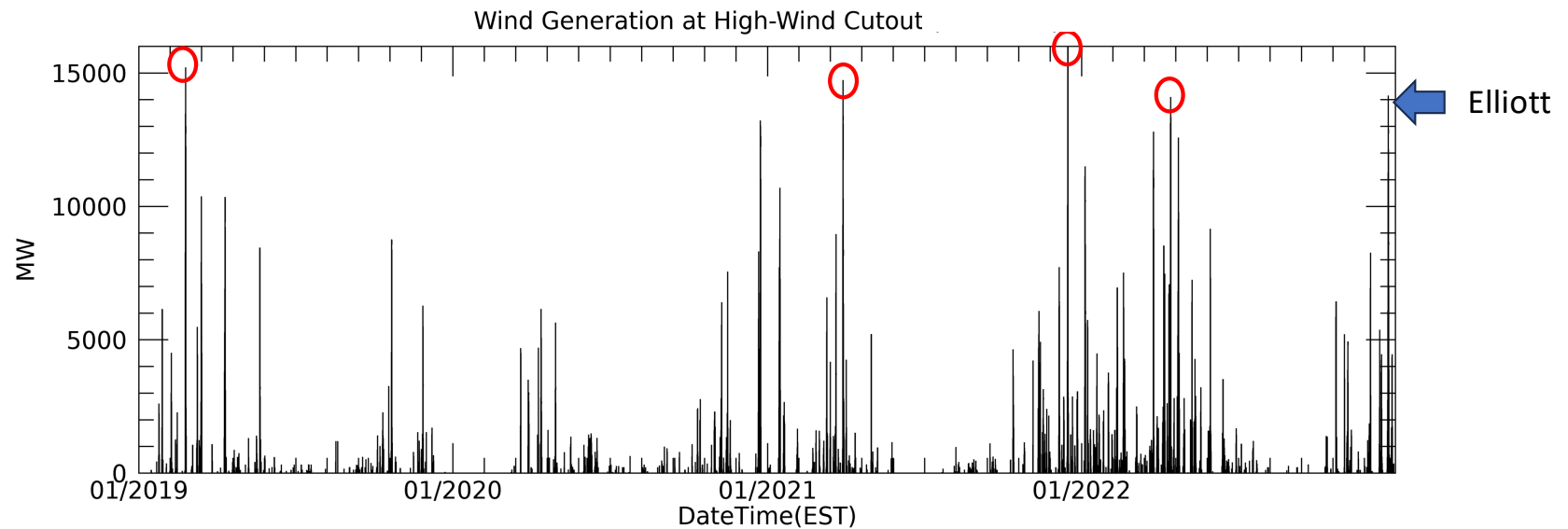
ECMWF: 2022-12-18 19:00



ECMWF: 2022-12-20 19:00



How common is this kind of event?



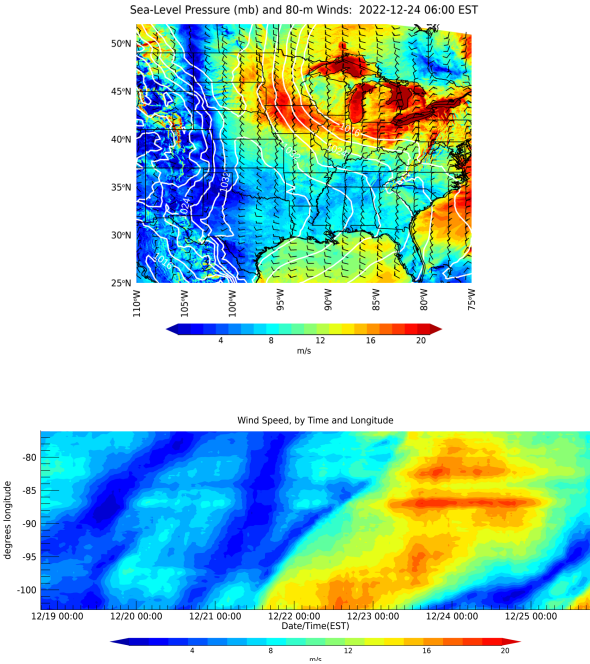
In past 4 years, there have been **4** events that put at least as much generating capacity simultaneously at risk for high-wind cutout:

- February 22, 2019
- March 29, 2021
- December 15, 2021
- April 14, 2022

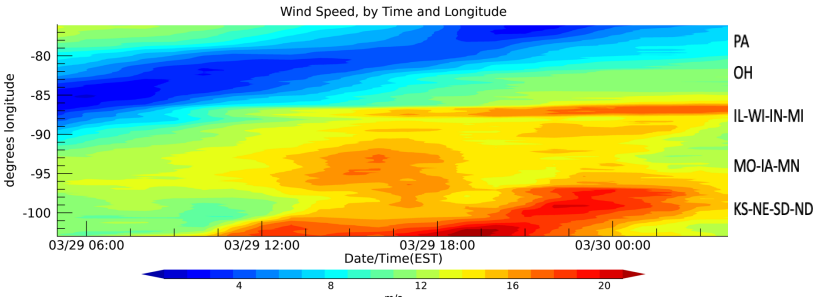
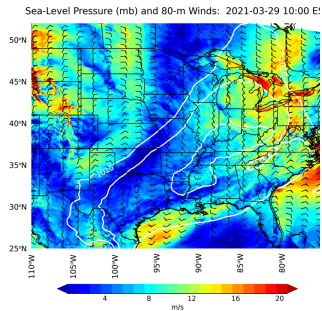
But Elliott was different ... Similar Magnitude, Greater Breadth



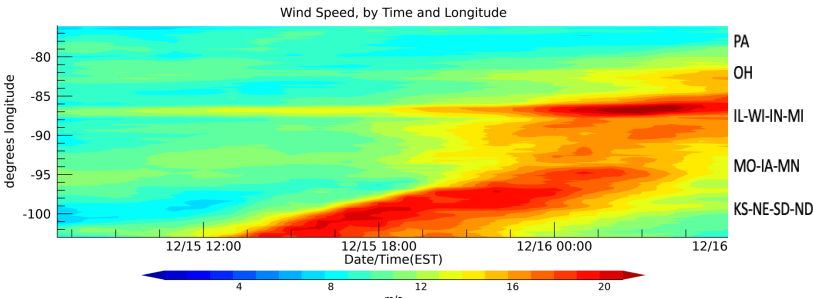
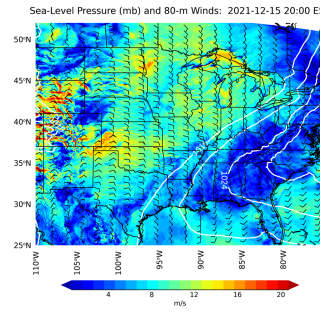
Elliott



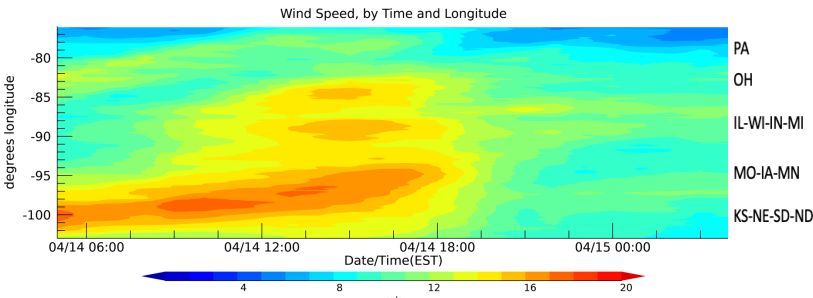
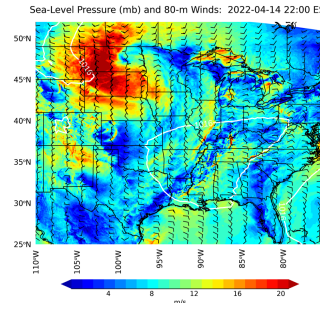
29 Mar '21



15 Dec '21



14 Apr '22



Thank You