Observational assessment of metocean conditions in the WFIP3 region

Prakash Mohan, Nicola Bodini, Raghu Krishnamurthy, Andrew Kumler, …

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AVANGRID; Vineyard Wind; ISO new england; equinor; Mayflower; Ørsted; NSF; Ocean Observatories Initiative; RWSC Regional Wildlife Science Collaborative for Offshore Wind; ROSA Responsible Offshore Science Alliance

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WFIP-3: Science Questions

- WFIP-3 Science Questions and testable hypothesis were based on scientific community and industry knowledge gaps : Science Plan
- Some of the Challenges in Offshore Wind Energy Resource Assessment and Forecasting

I. What are the **characteristics** of the **marine atmospheric boundary layer**, **surface layer**, and **coastal ocean** in the study region and how might they affect energy production and turbulence?

II. What are the **effects of mesoscale atmospheric or oceanic processes** on boundary and rotor layer characteristics in the study region?

III. What are the **impacts of a dynamic, coupled, atmosphere-wave-ocean** on the atmospheric **boundary layer** and **wind power forecasts**?

IV. How can air-sea fluxes and **flux profile parameterizations** be improved to better capture the evolving characteristics of winds in the study region?

V. What are the effects of **clouds and precipitation** on boundary layer, rotor layer winds and turbine performance?

VI. How do **atmospheric and oceanic conditions influence** turbine or **wind plant wakes** in offshore conditions and our predictions of turbine wake morphology, evolution and wake interactions?

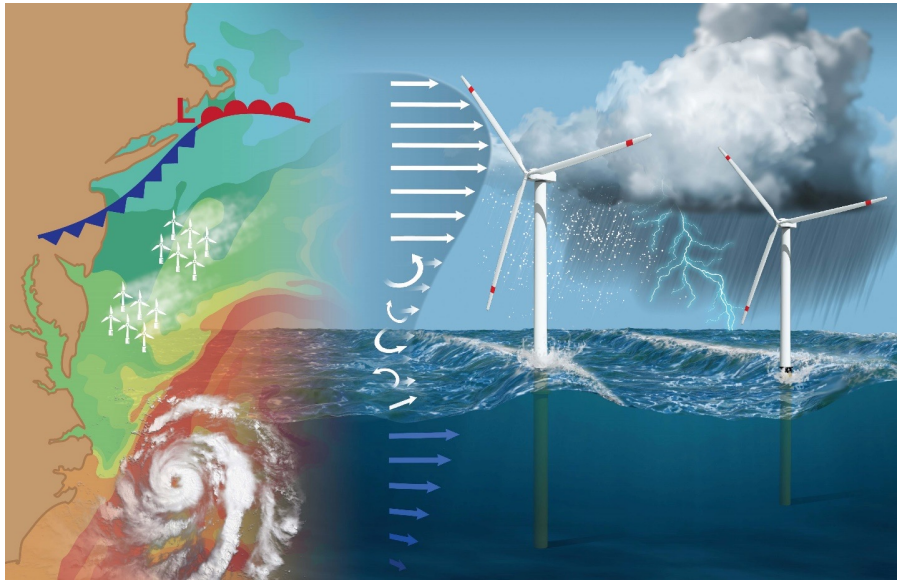
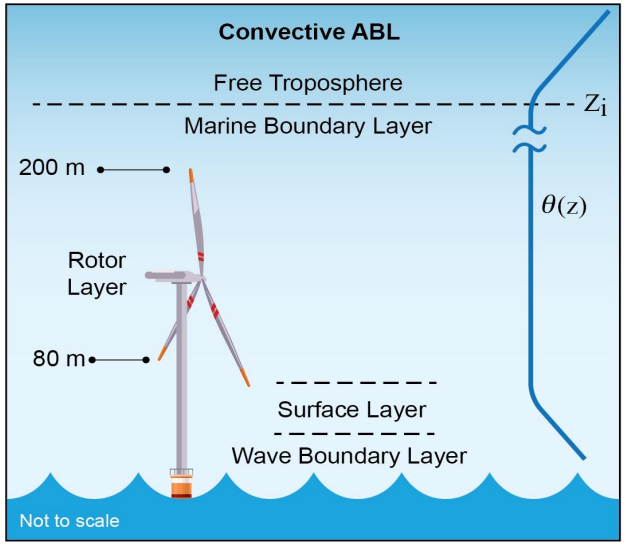
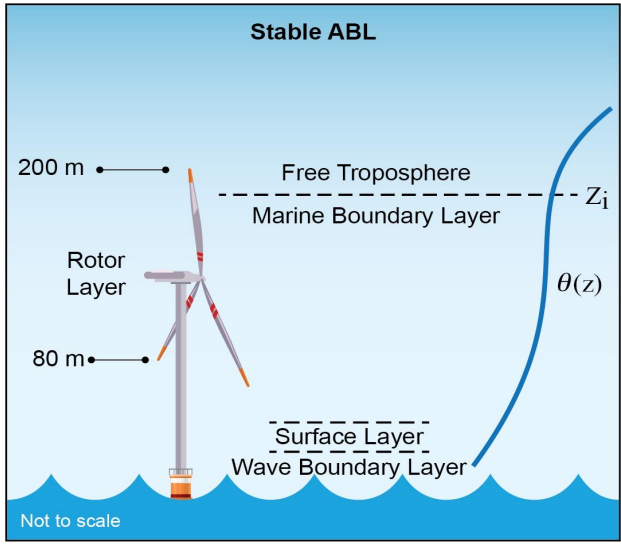


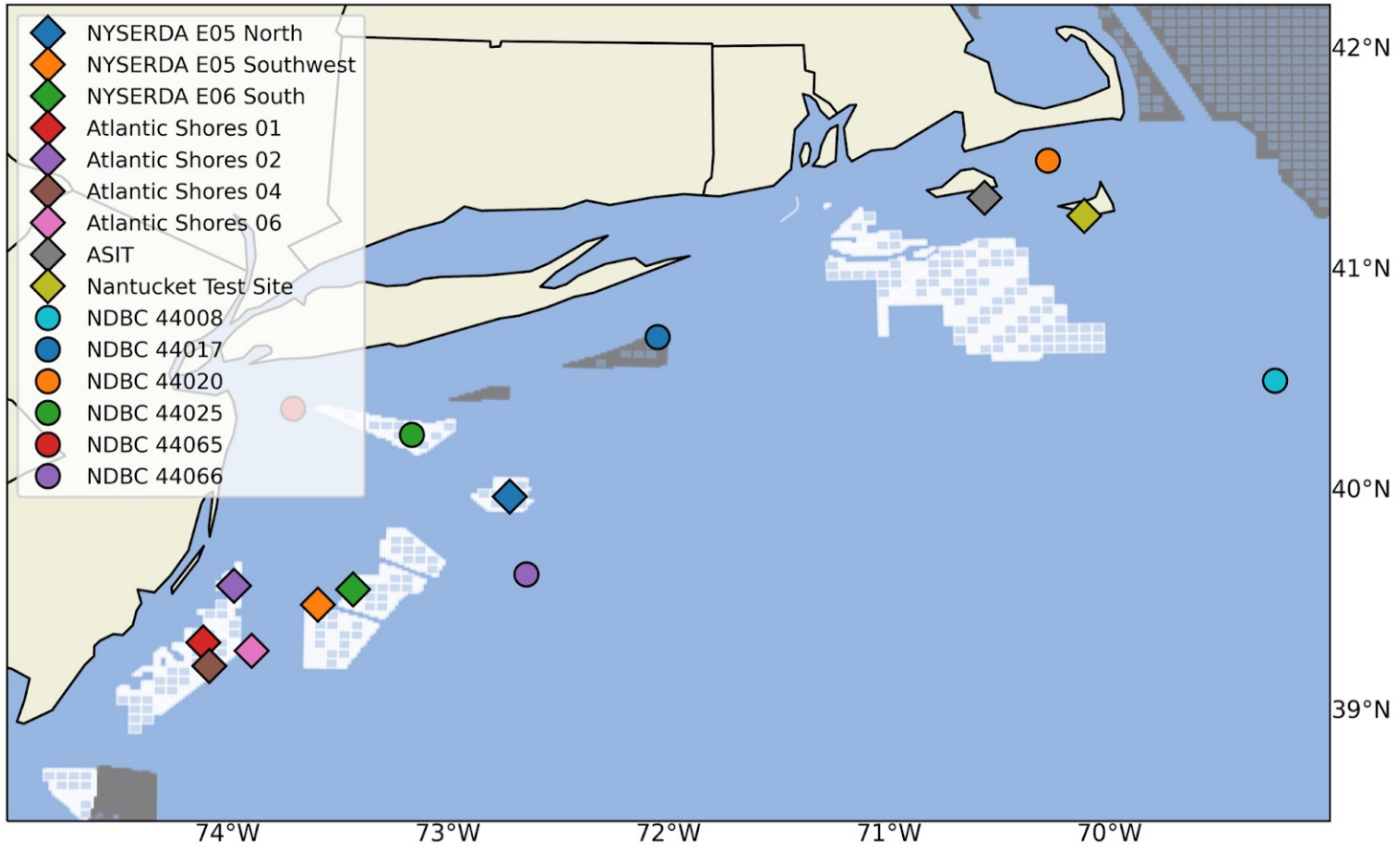
Illustration of phenomena affecting offshore wind plants at varying scales on the U.S. East Coast.





Introduction: Data Sources

- NYSERDA lidars
- Atlantic Shores lidars
- ASIT lidars
- NDBC Buoys
- Satellite observations



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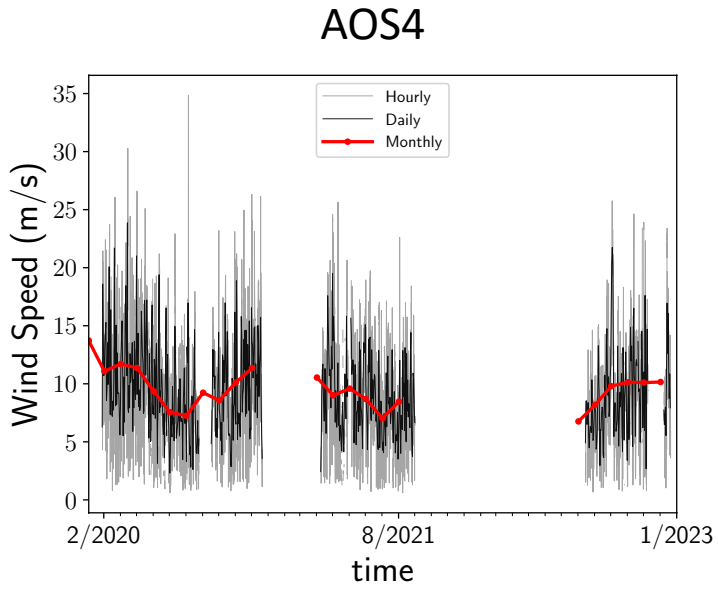
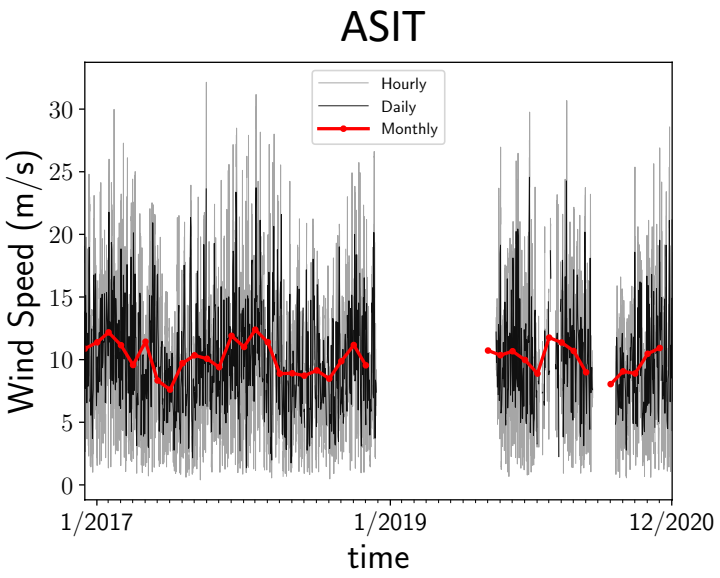
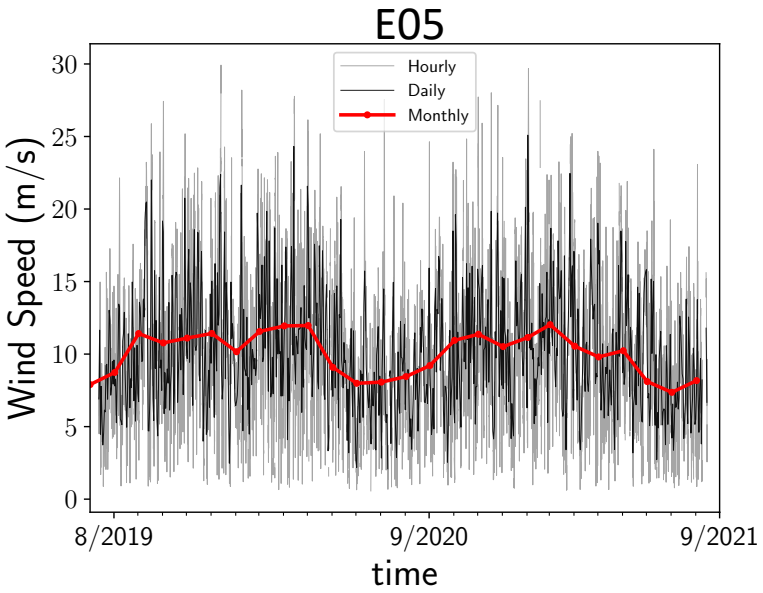
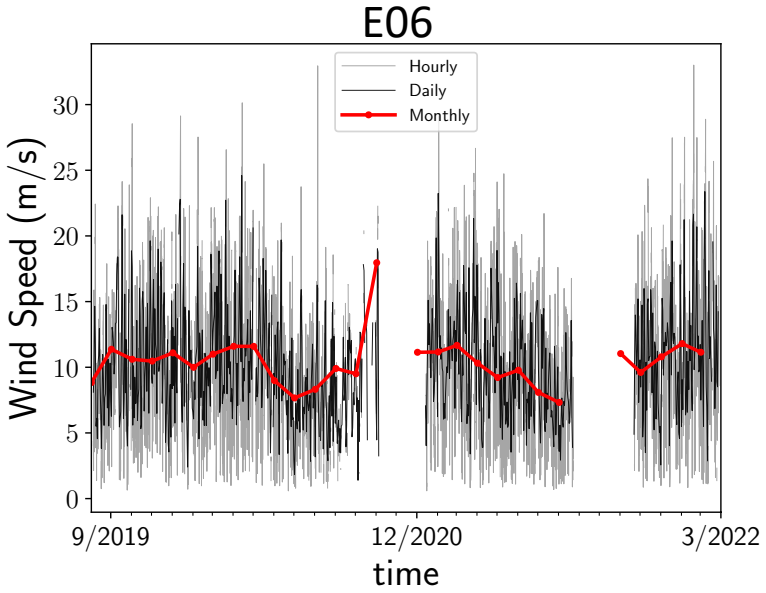
Inter-annual Variability: Wind Speed at 140(m AMSL)









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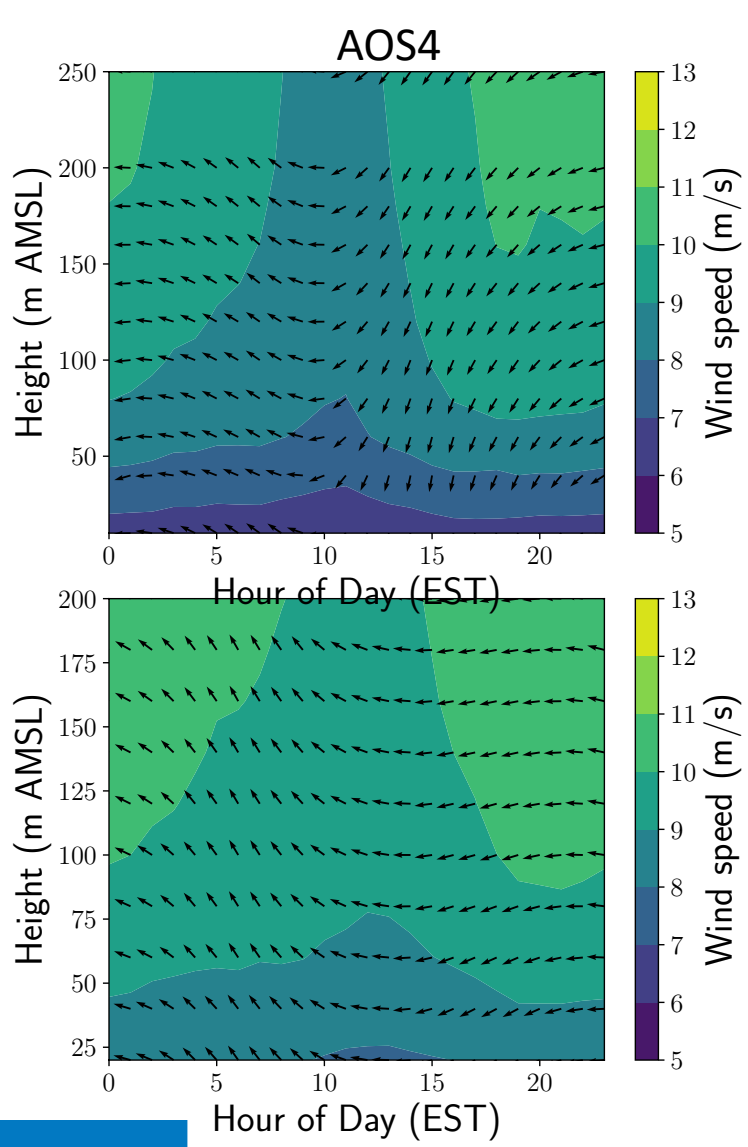
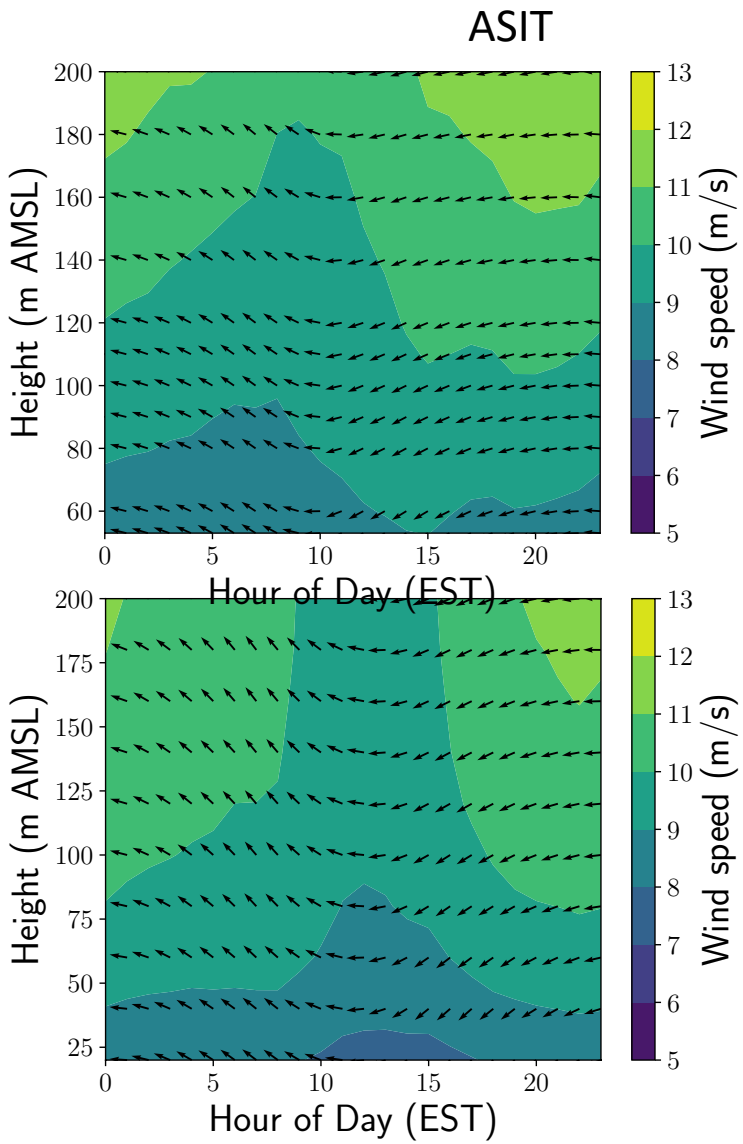
Mean hourly wind profiles



E05

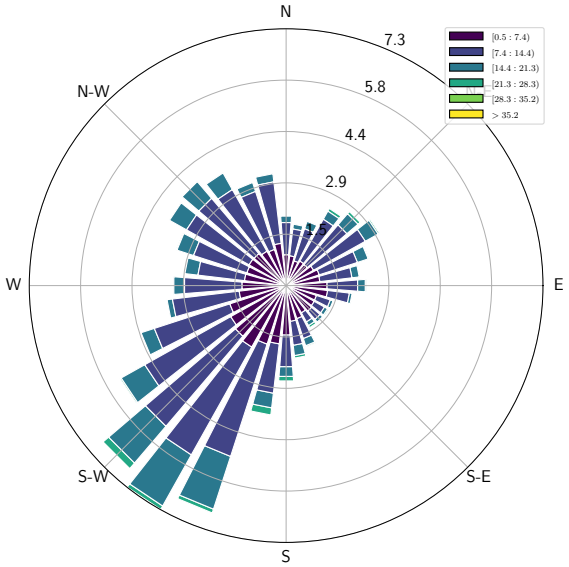


E06

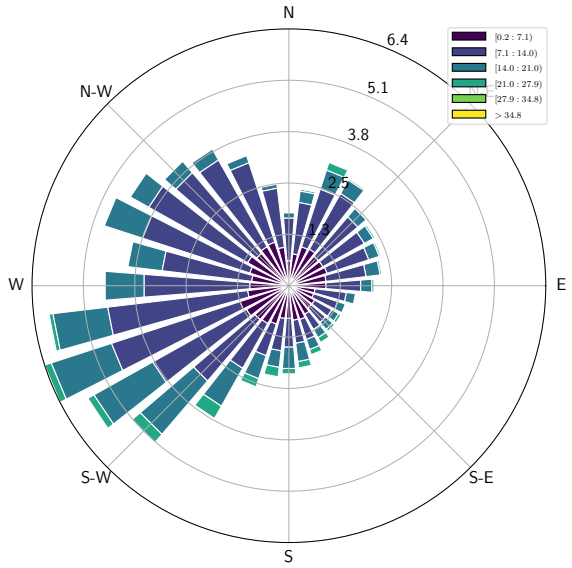
- Higher speeds in the evening/night times
- Strong diurnal cycle in wind direction

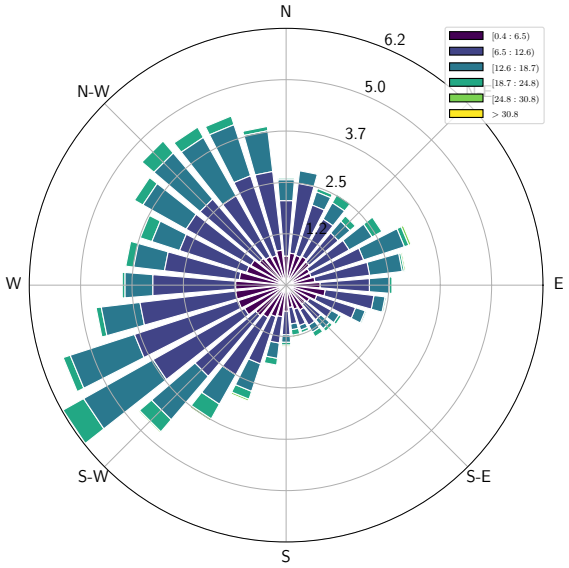
Wind Roses: 140 m AMSL

AOS4



ASIT





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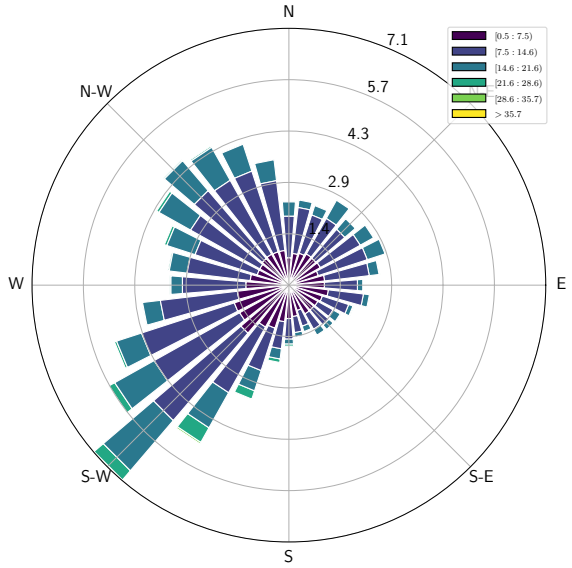

E06

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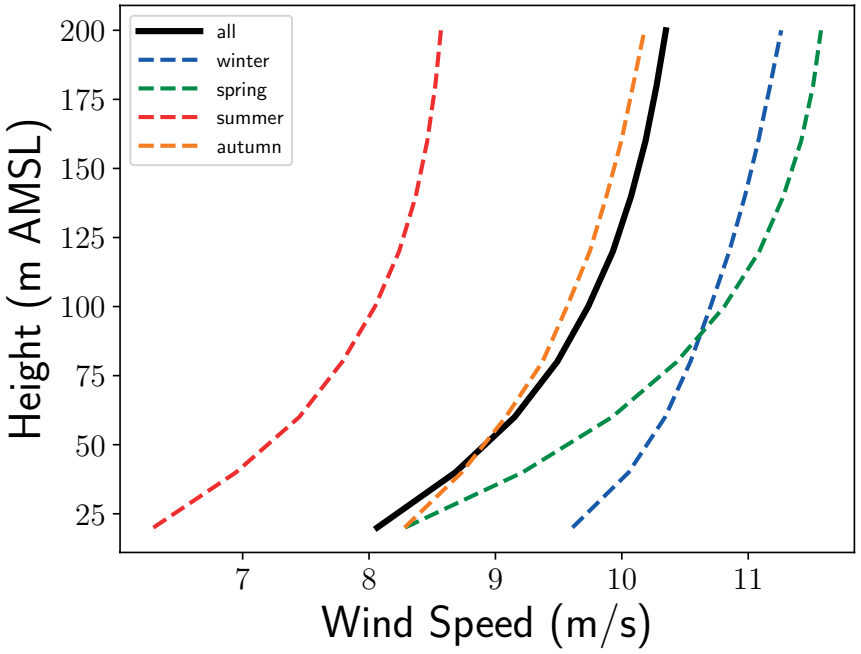
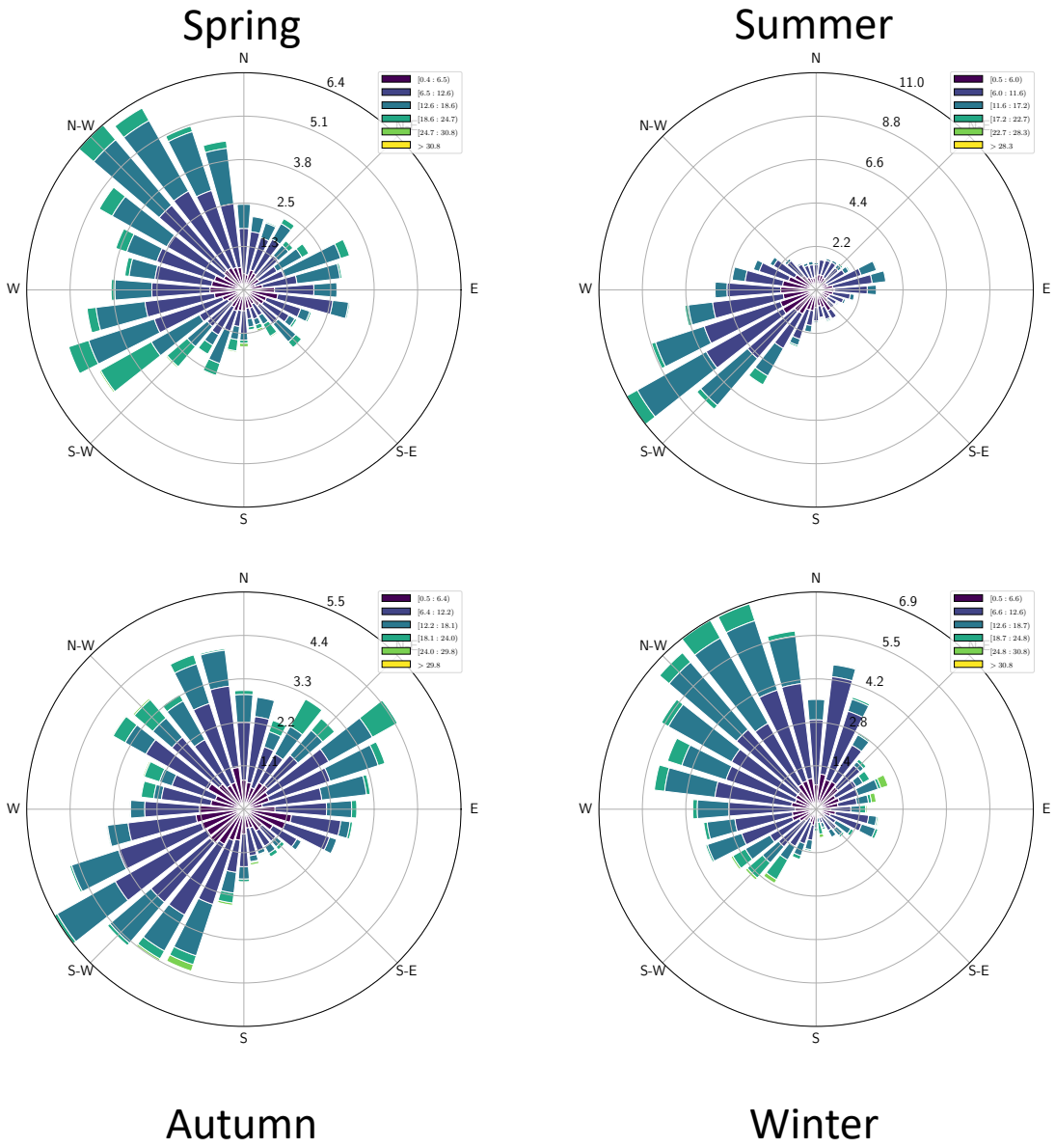
Large Seasonal Variation: E05 at 140 (m AMSL)

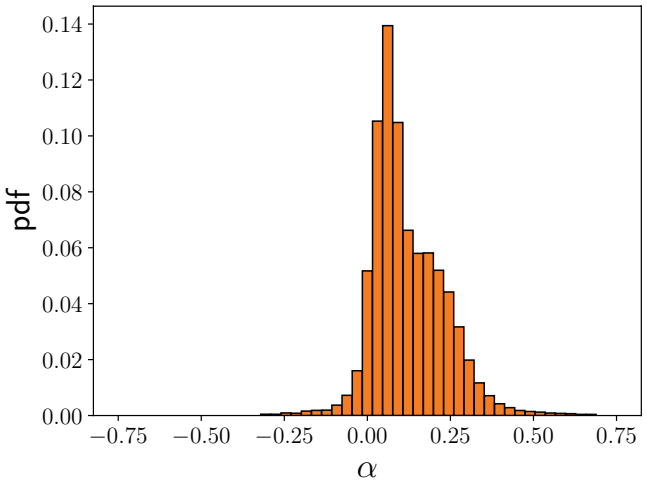


Higher speeds in spring/winter and lower in summer



Wind Shear Exponent $\frac{v_h}{v_{h0}} = \left(\frac{h}{h_0}\right)^{\alpha}$

AOS4



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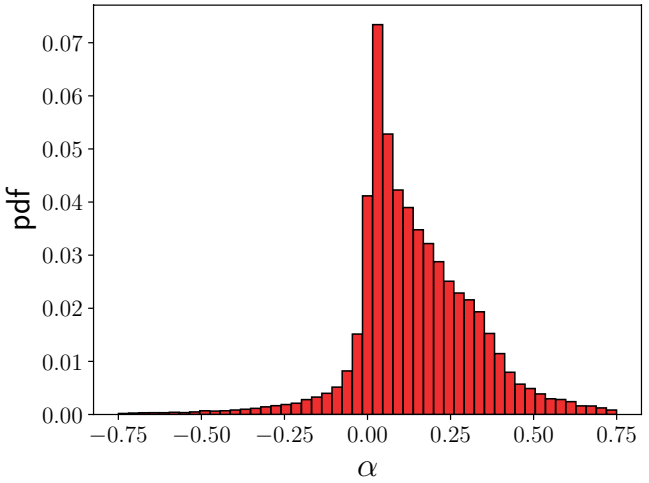

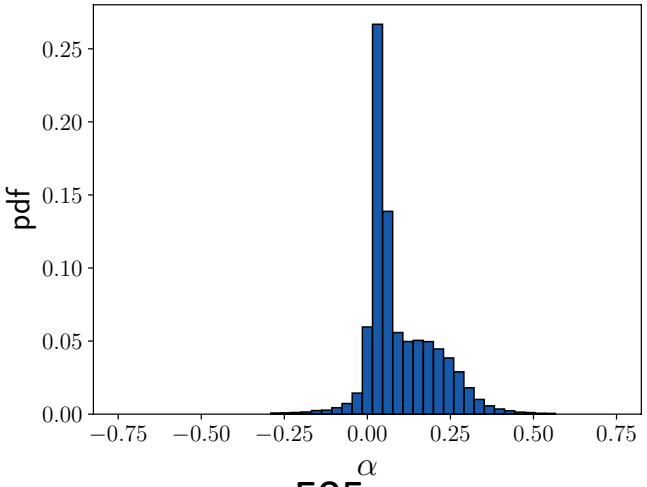

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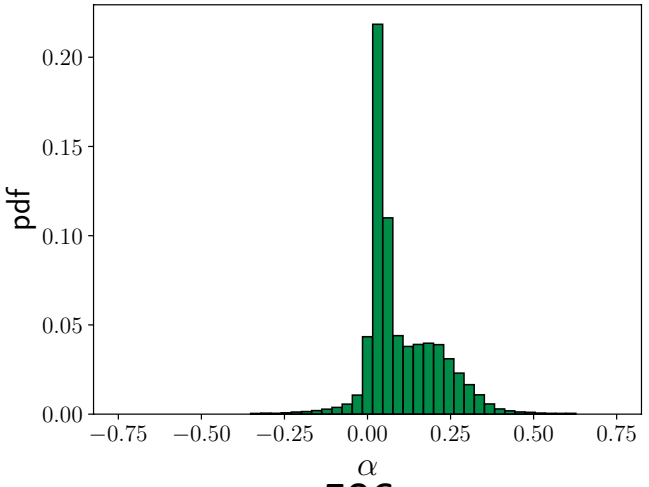

E06

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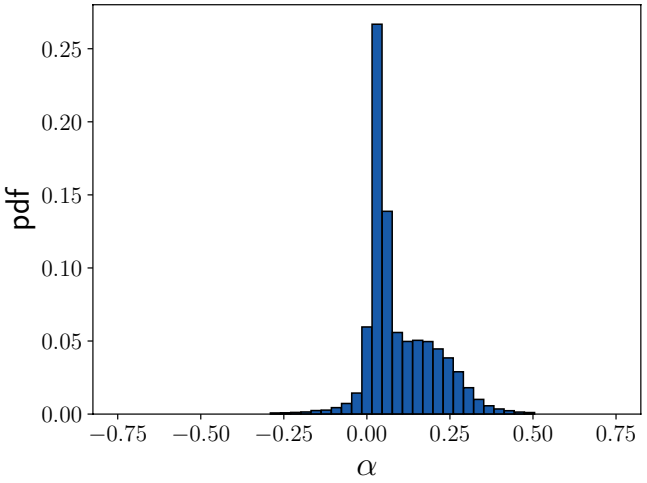
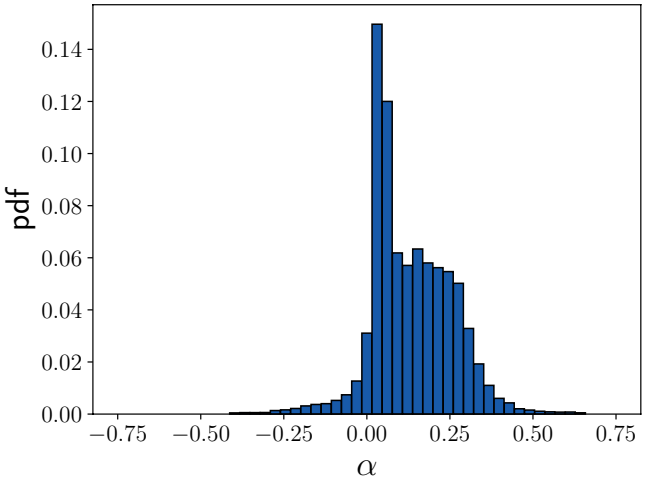
Shear Seasonality E05: higher in spring/summer

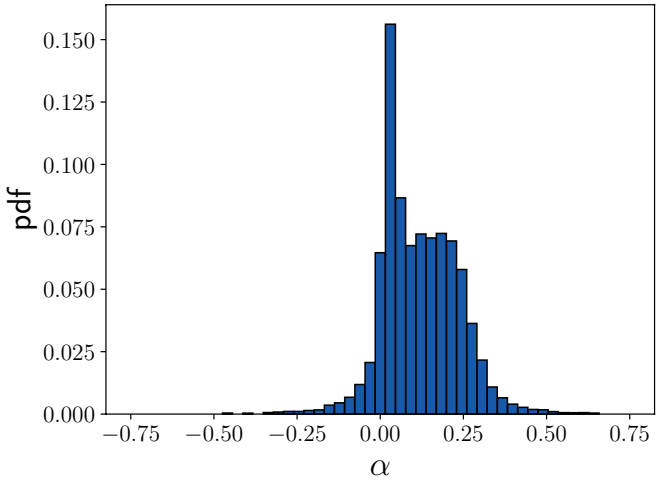


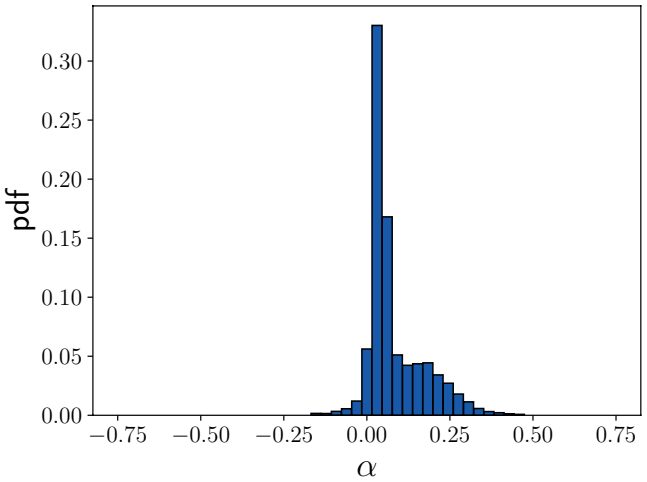
Overall

Spring

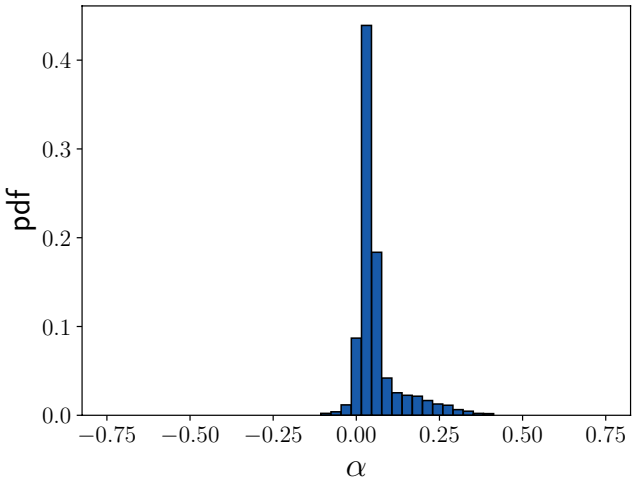


Summer





Autumn



Winter

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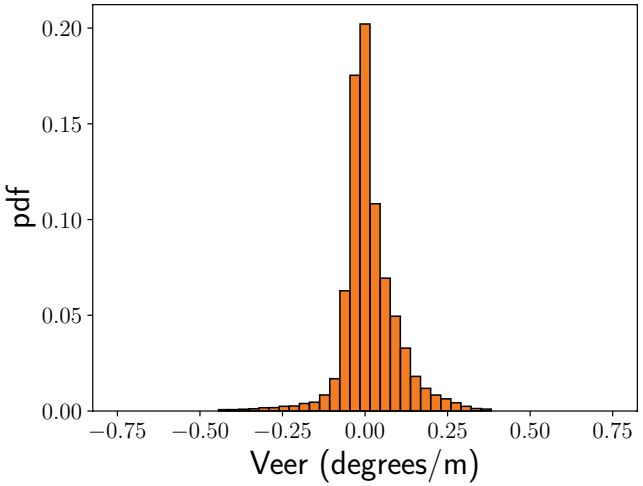
Wind Veer $(\frac{\Delta WD}{\Delta h})$

AOS4



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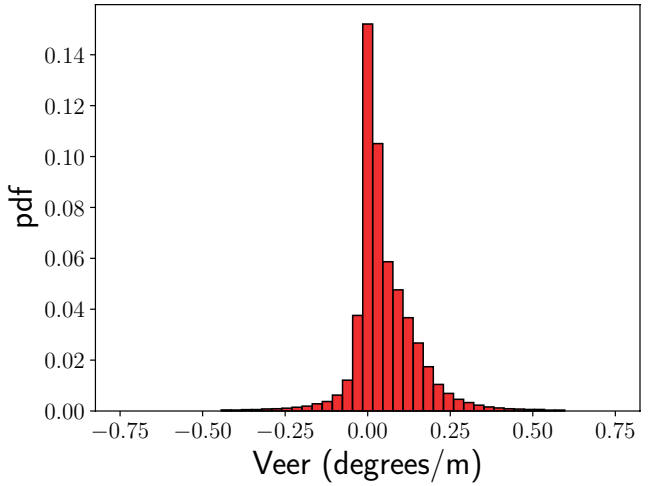
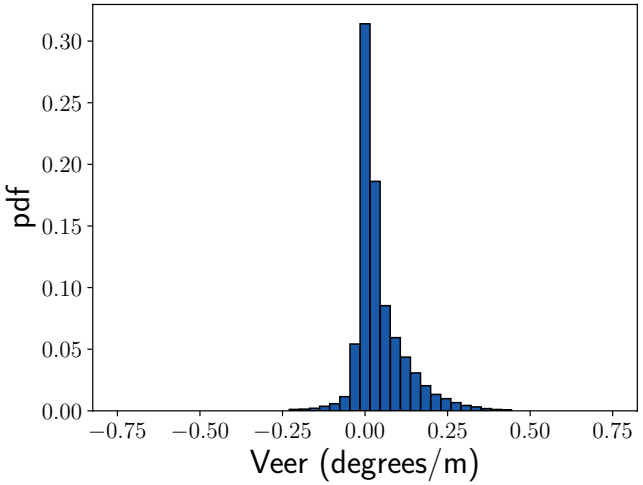
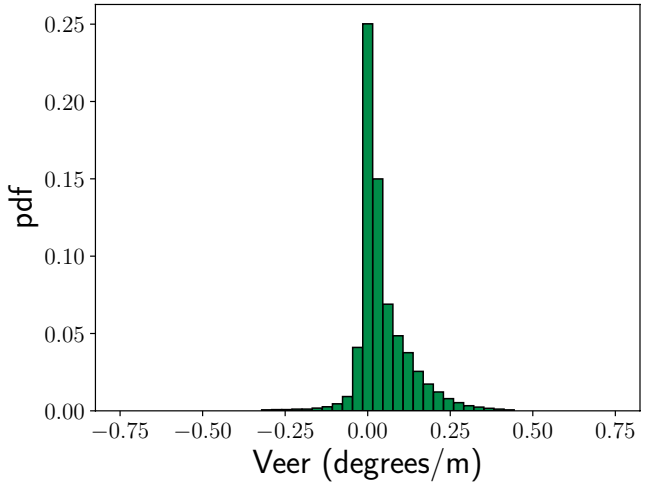




E05



E06

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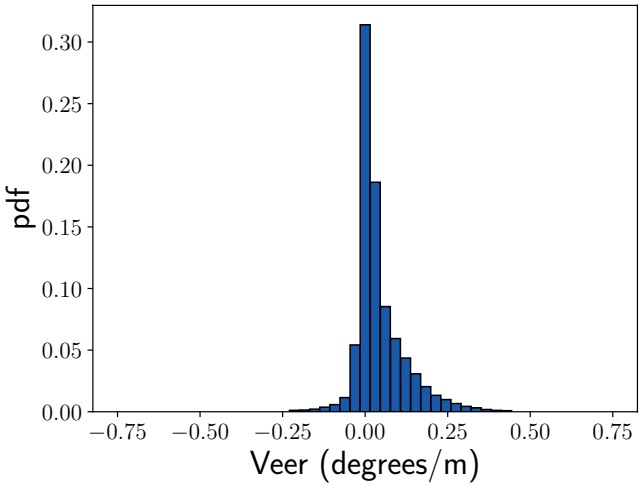
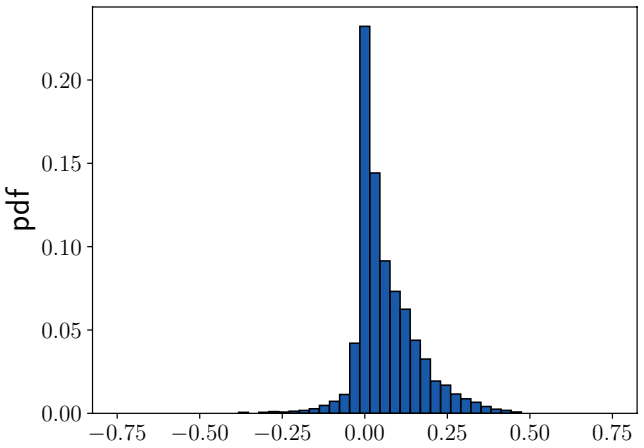
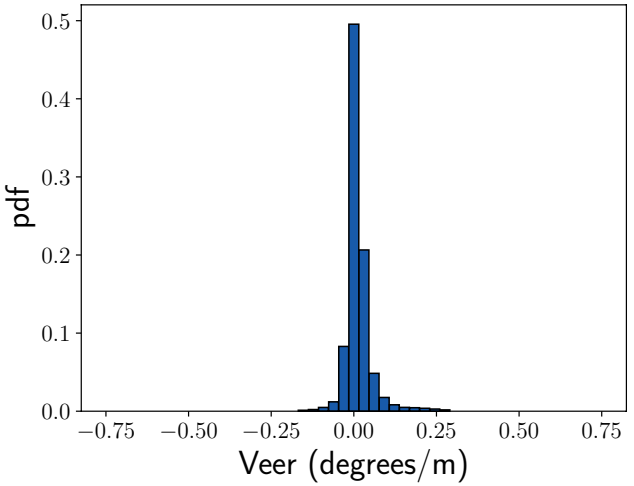
Veer Seasonality E05: Higher veer in spring/summer

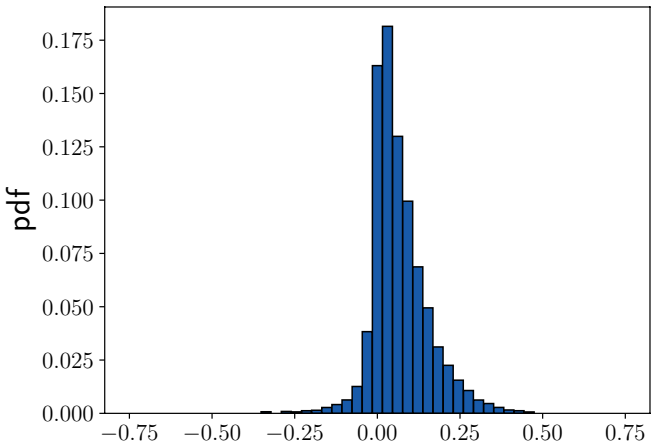


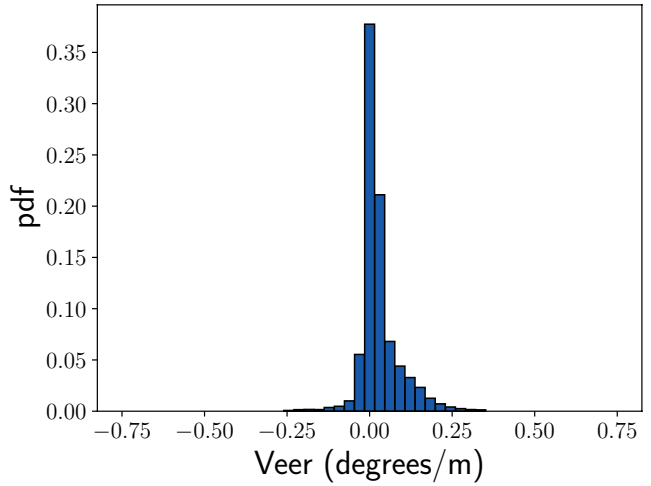
Spring





Summer





Autumn

Winter

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Extreme Events: Low-Level Jets

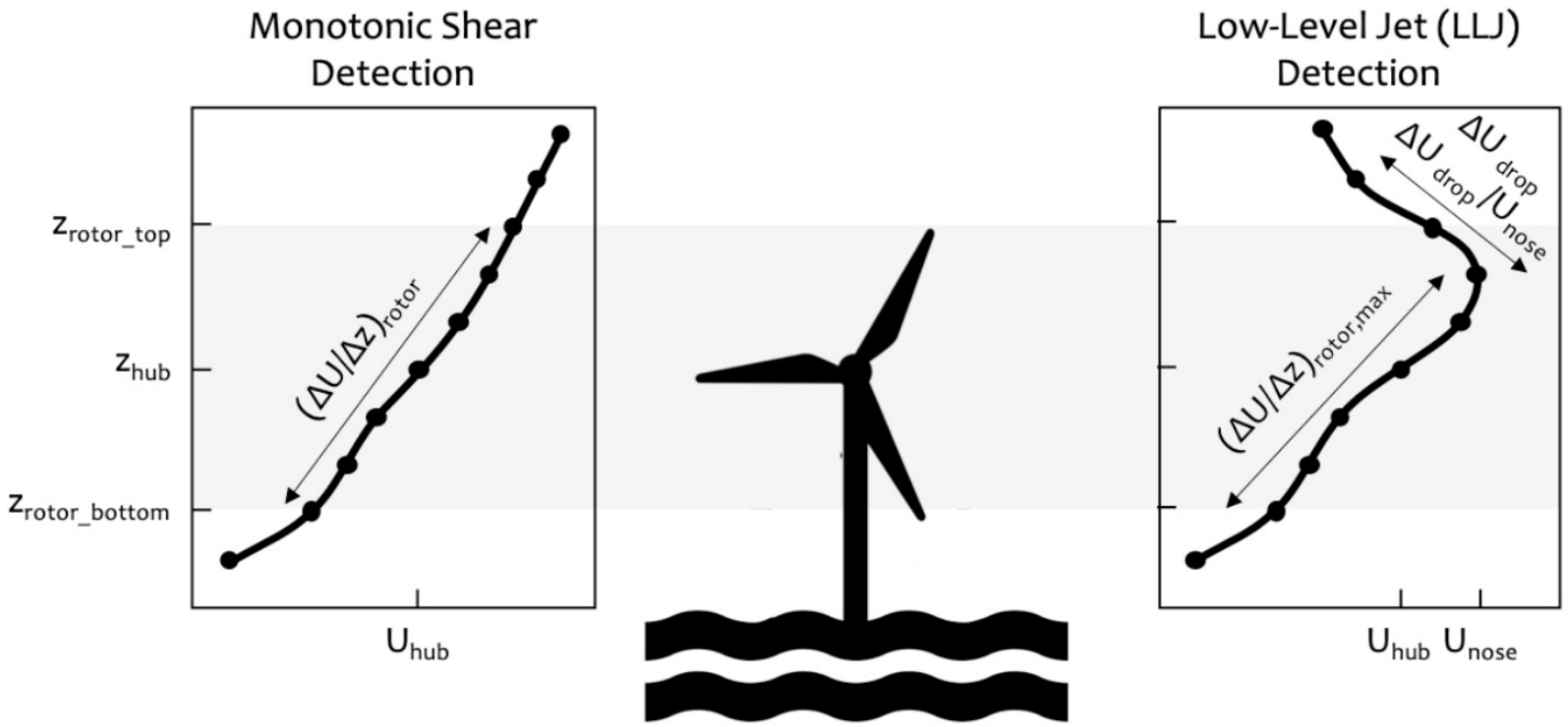

Figure citation: Debnath et al., “Extreme Wind Shear Events in US Offshore Wind Energy Areas and the Role of Induced Stratification.” (2021)

Determining Low-Level Jets (<250m AMSL)

Criteria used (all needs to be satisfied)[1]

- Minimum Speed: **Wind speed at 140m > 3.0 m/s**
- Peak selection: Peak with highest WS is chosen
- Peak location: Cannot be at lowest/highest altitudes
- Dropoff Criteria: Drop in WS above the **nose >1.5 m/s (and >10%)**

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1. Debnath et al., "Extreme Wind Shear Events in US Offshore Wind Energy Areas and the Role of Induced Stratification." (2021)

LLJ Seasonality: frequent in warmer months

Overall

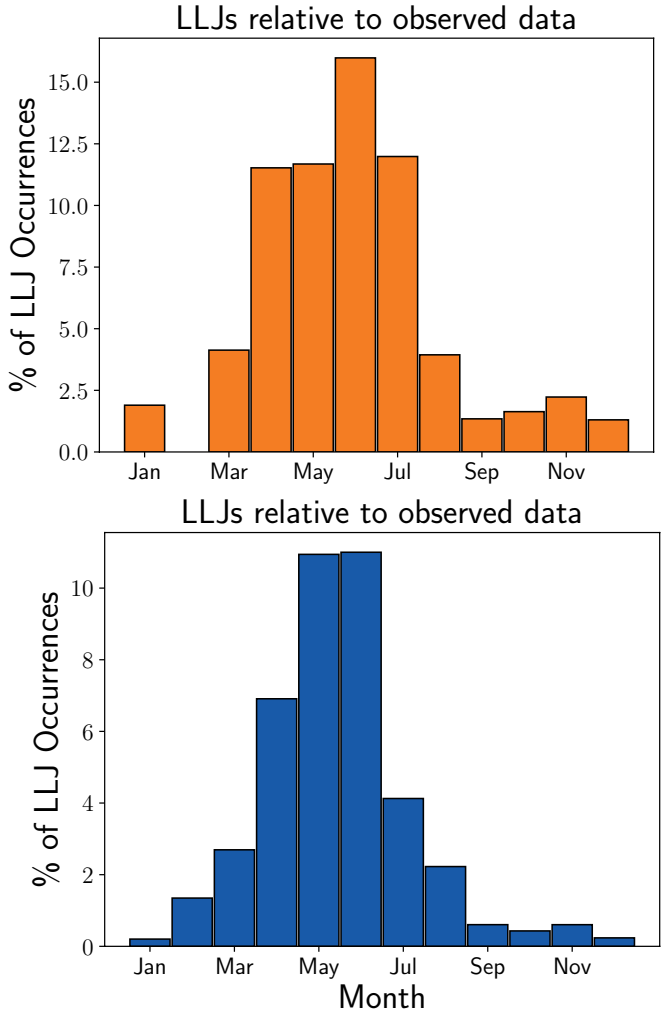
AOS4: 5.7%

ASIT: 3.1%

E05: 3.0%

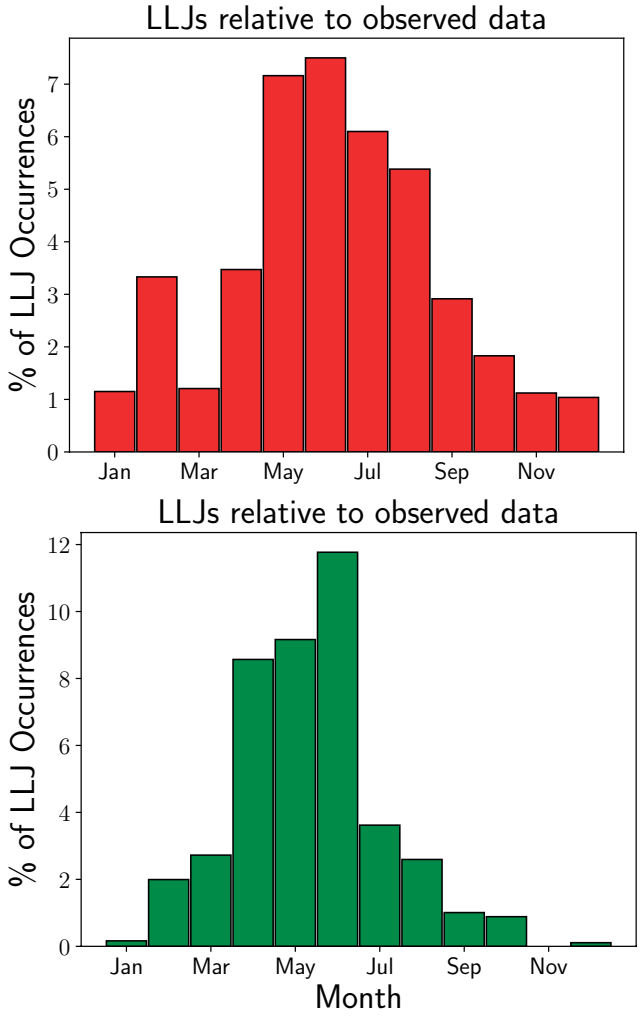
E06: 3.3%

AOS4



E05

ASIT



E06

10-15% occurrence in summer months across all buoys

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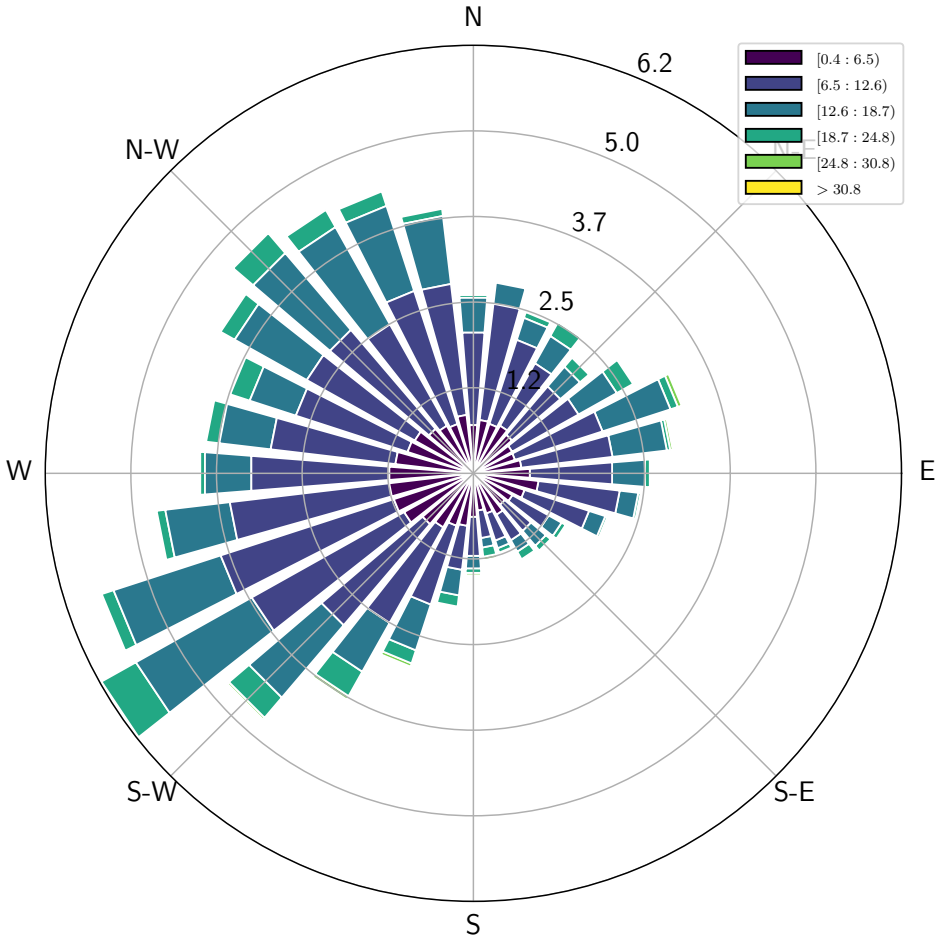
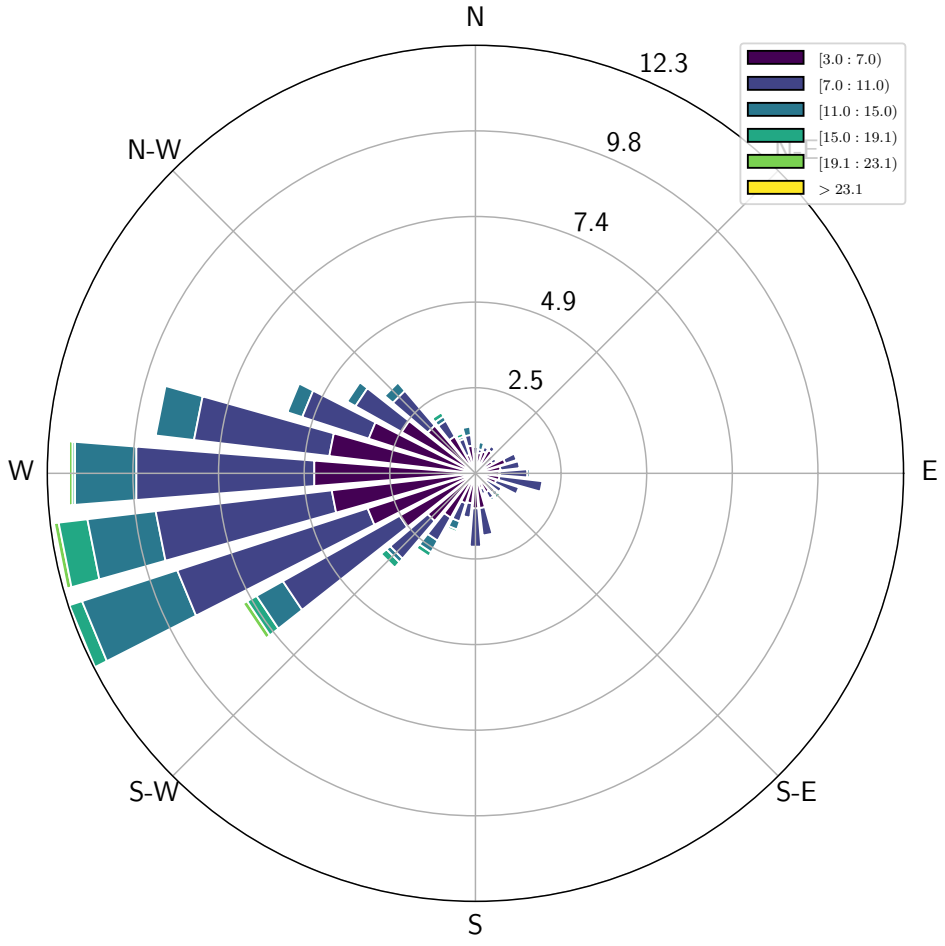
LLJ Wind Roses E05: mostly parallel to coast



Overall



LLJs

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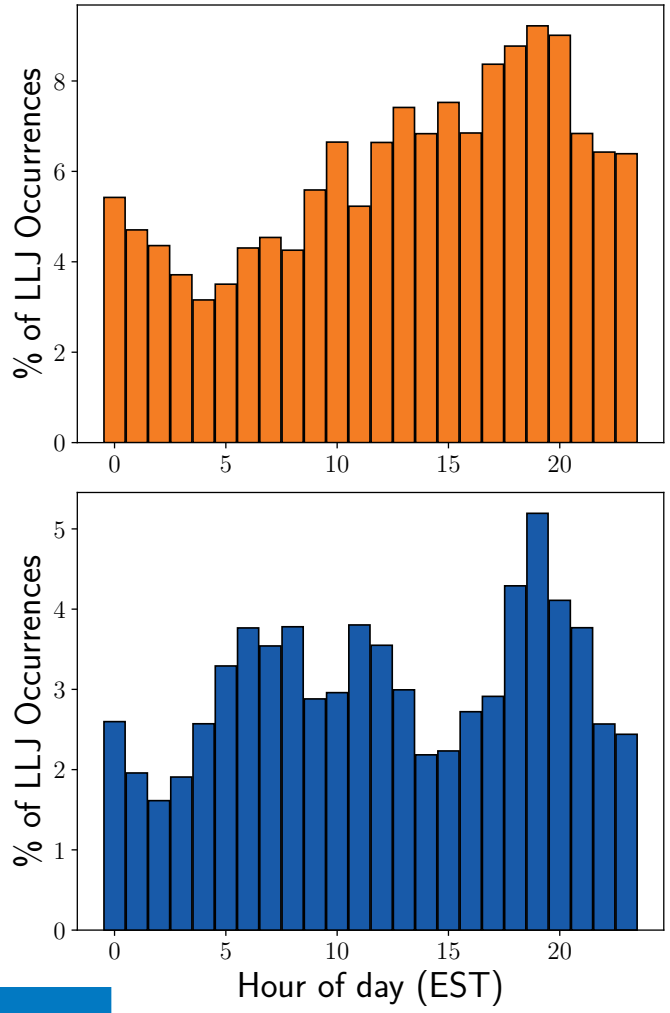
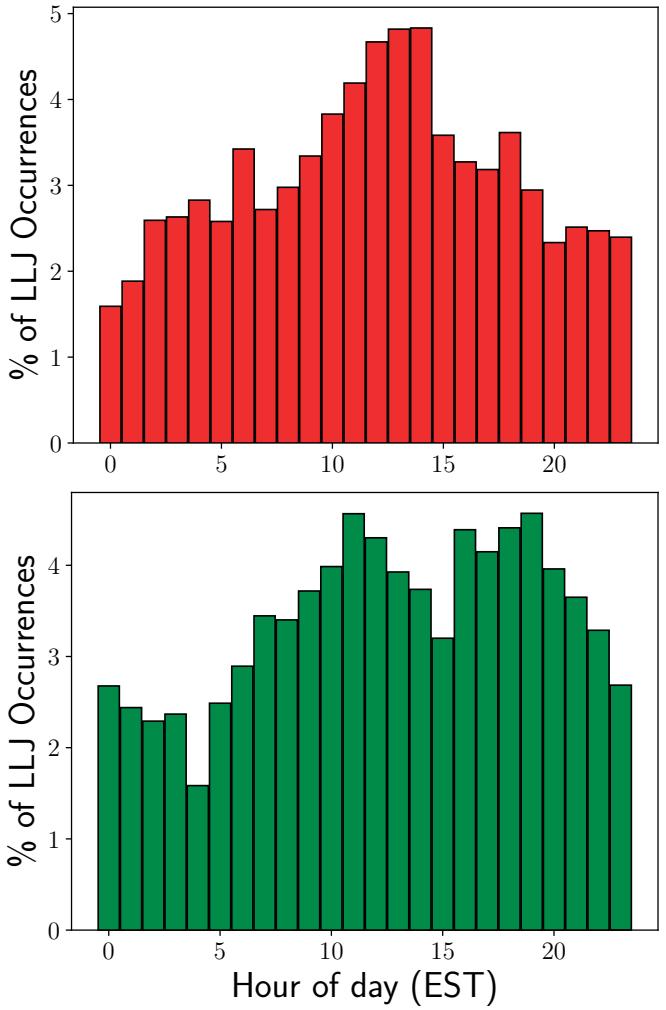
LLJ Hourly Occurrences

AOS4



E05

ASIT



E06

LLJs are more likely to occur in the afternoon/evening hours

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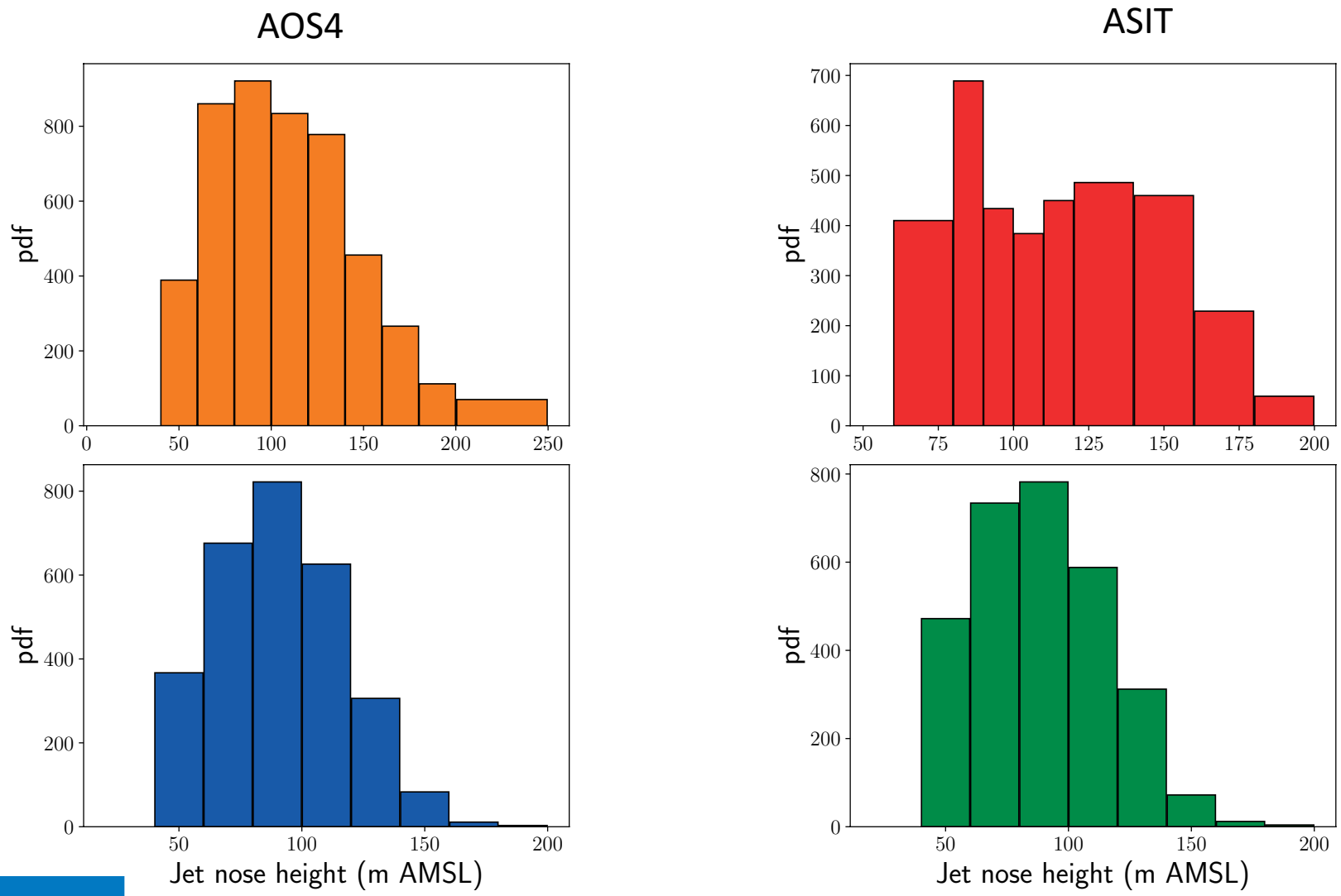
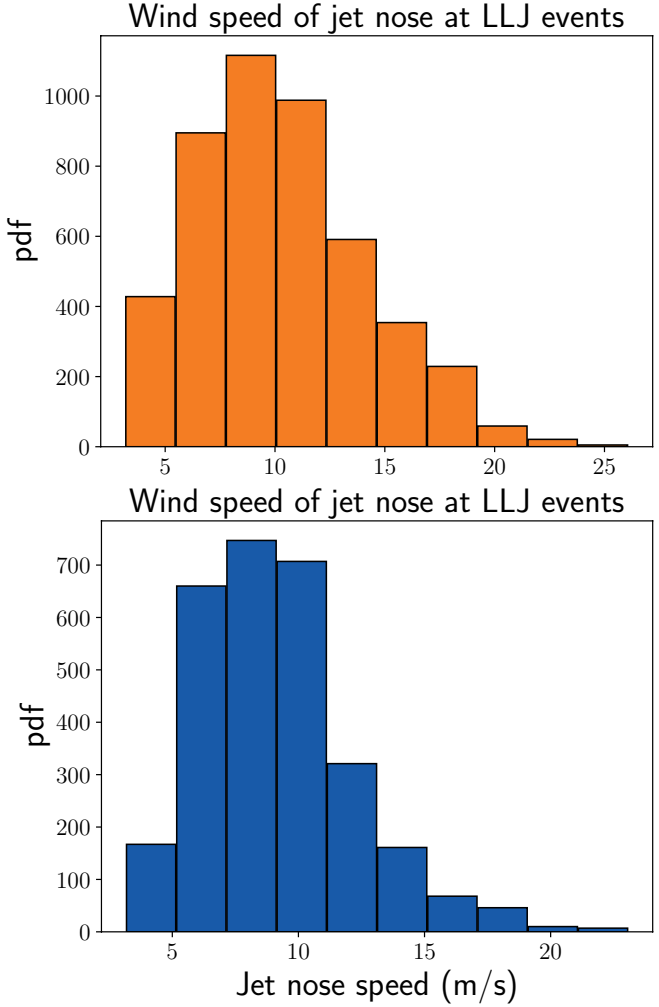
LLJ Statistics: Jet nose heights



Peak occurrences are around 75-100m AMSL

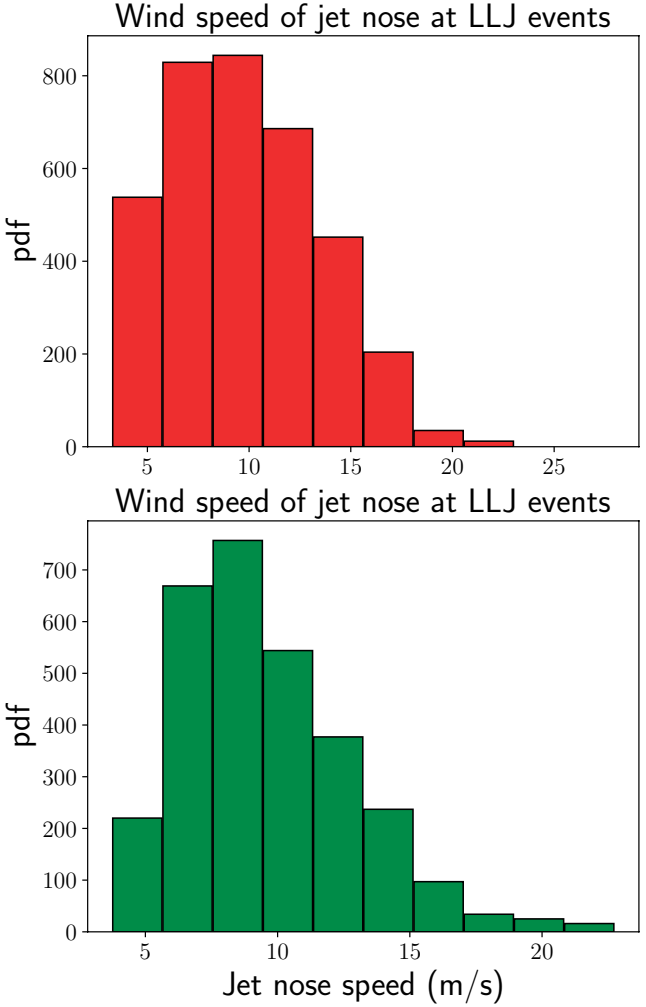
LLJ Statistics: Jet nose speeds

AOS4



E05

ASIT



E06

Peak occurrences are between 7-12 m/s

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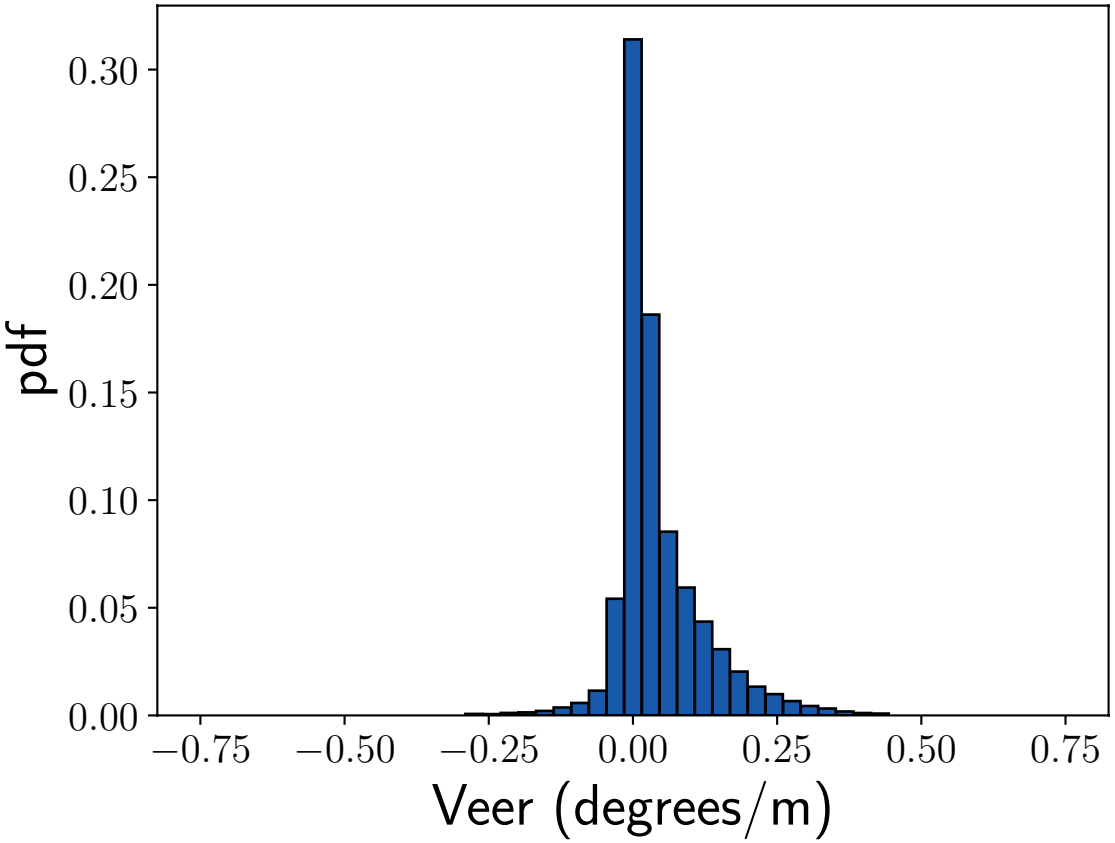
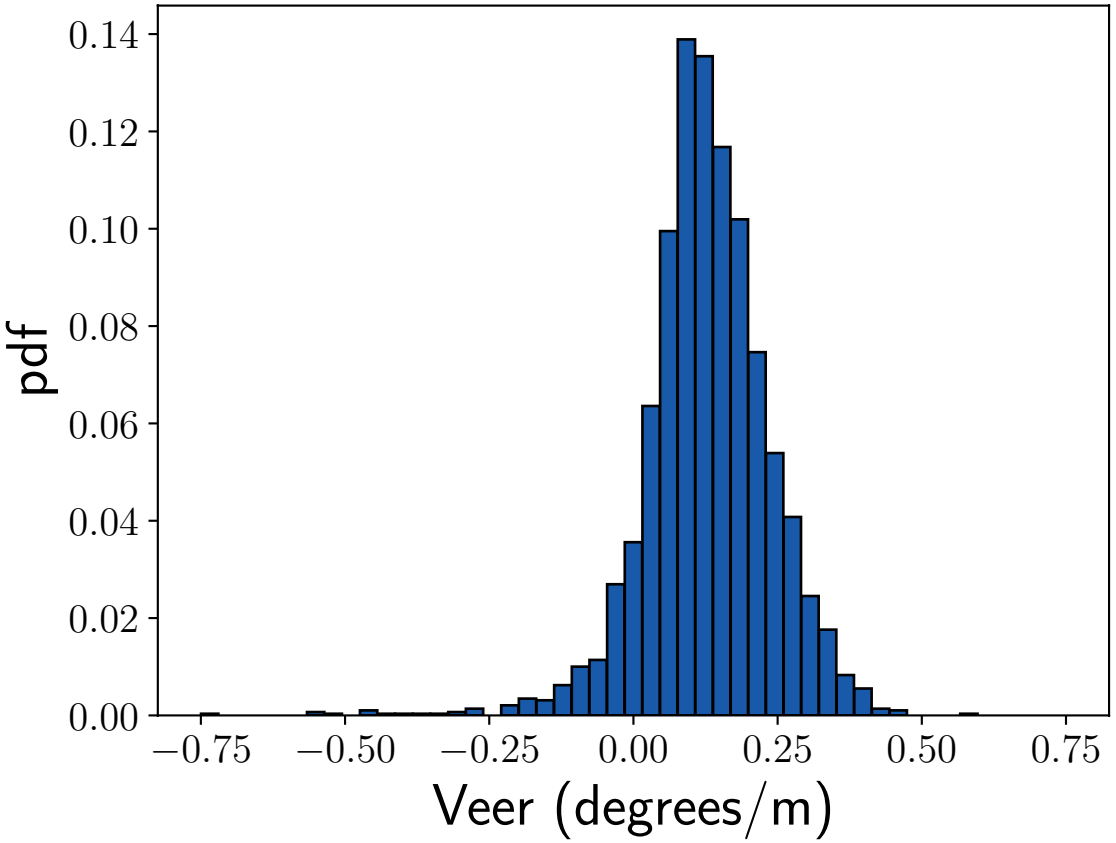
LLJs: Significantly higher veer (E05)



Overall



LLJs

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Summary

- Extensive analysis from lidar observations
  - Paper to follow with an open source python package for the analysis
- Strong seasonal variation in wind speed/direction
  - Higher veer and shear in summer months
- LLJs are frequent offshore, can occur 10-15% times in summer
  - Associated with high non-monotonic shear and veer
- LLJs are highly dependent on shore geometry, occur parallel to coast
- This analysis will provide a metocean guide for the extensive observations that will be collected during the WFIP3 campaign starting in early 2024

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Thank you!

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