Validation of Model Analysis Offshore Winds Using Two Floating LiDARs in the New York Bight

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1. INTRODUCTION & OBJECTIVES

- Growing offshore wind energy in the New York Bight requires accurate characterization of boundary layer vertical wind profile over various timescales and under warm season low-level jets (LLJs).

Challenges in Offshore Wind Prediction and Mapping

- Lack of long-term, multi-level meteorological observations offshore of the U.S. East Coast → Usage of NWP model reanalysis and forecasts.
- NWP models can have significant limitations in accurately representing the observed marine ABL vertical wind profile.

Utilizing two NYSERDA floating LiDARs, we aim to address:

1. How well do various NWP model analyses depict the marine ABL wind speed resource by season, month, hour of day, and under warm season LLJs?
2. Do NWP model analyses accurately detect and depict observed warm season LLJ characteristics? Is depiction of environmental conditions in model analyses influence warm season LLJ performance?

2. DATA & METHODS

Global and Mesoscale Model Analyses:

1. ECMWF Reanalysis version 5 (**ERA5**)
2. National Renewable Energy Laboratory **NOW-23** model analysis
   a. WRF v. 4.2.1 model initialized and forced at the boundaries with ERA5 on a 2-km nested grid.
3. High-Resolution Rapid-Refresh (**HRRR**) analysis (F00) hours

Study Period: 4 September 2019 – 1 December 2022

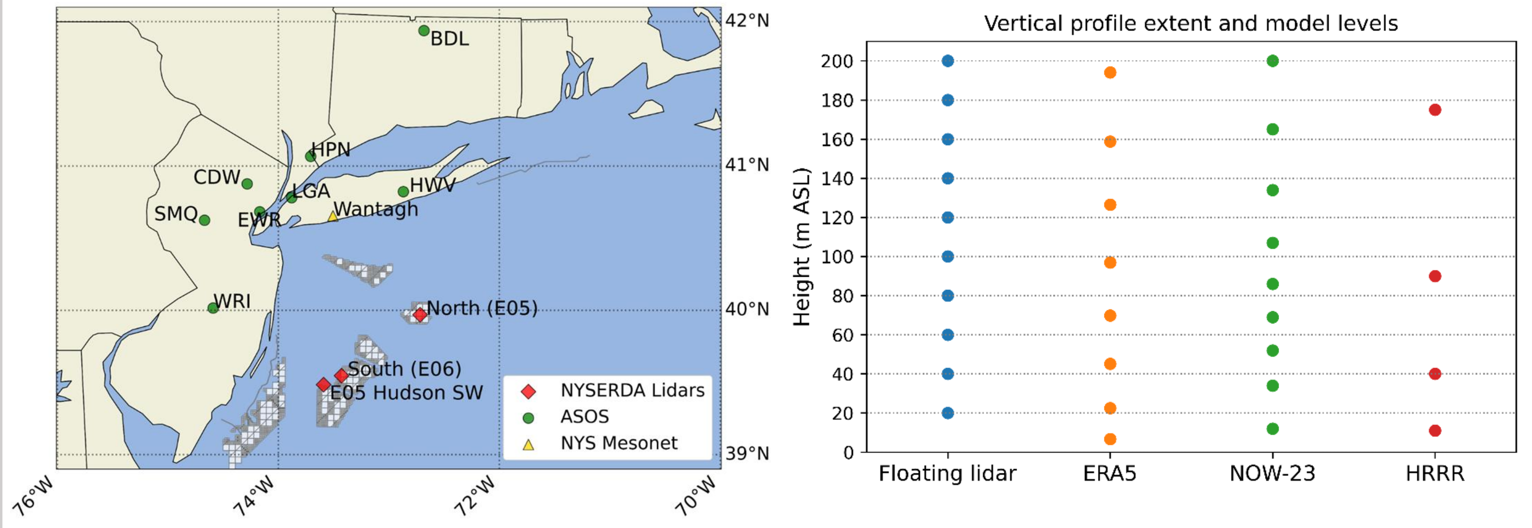

Fig. 1: Study location sites, observed vertical profile, and model levels

Warm Season LLJ Detection Methods:

- 3 different types of algorithms slightly modified from their original usage were used to detect LLJ wind speed profiles
- If **2 or more** of the algorithms detected a LLJ on a given day, that day was counted as an event… **441 hours** or **121 LLJ days** were detected.

3. SEASONAL, MONTHLY, & DIURNAL VALIDATION: ERA5 & NOW-23

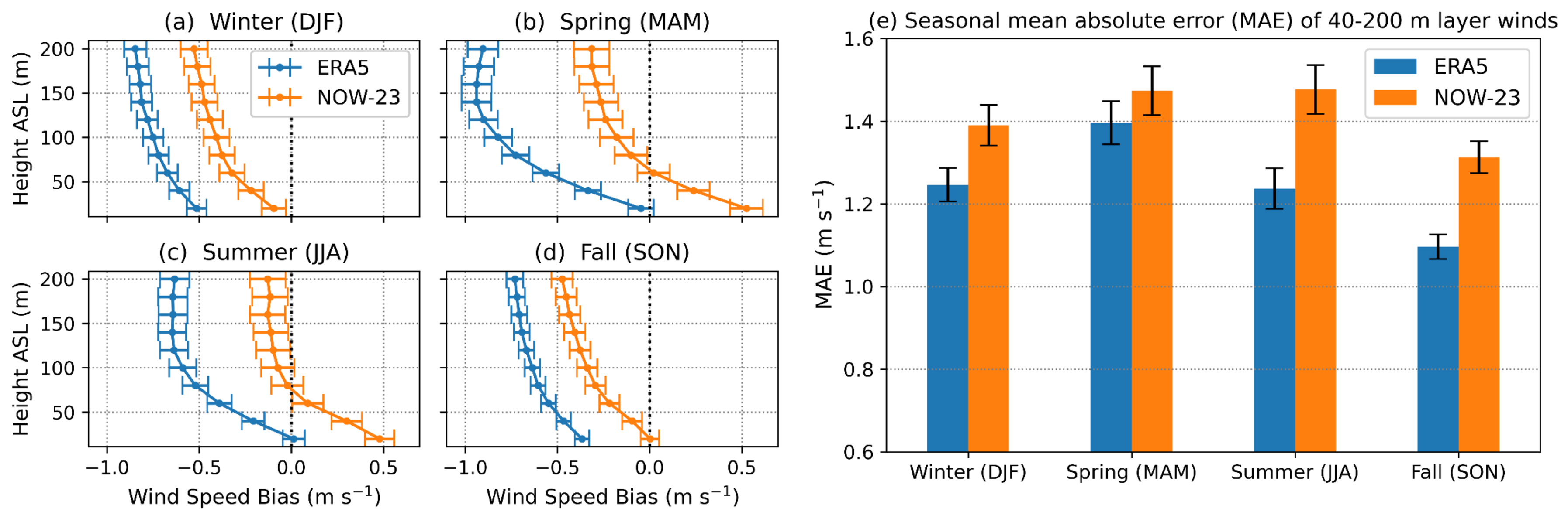

Fig. 2: (a-d) Vertical profile of the seasonal wind speed bias from NOW-23 and ERA5 over 2019-2020 period. (e) Seasonal 40-200 m mean absolute wind speed errors (MAEs) bar plots from NOW-23 and ERA5.

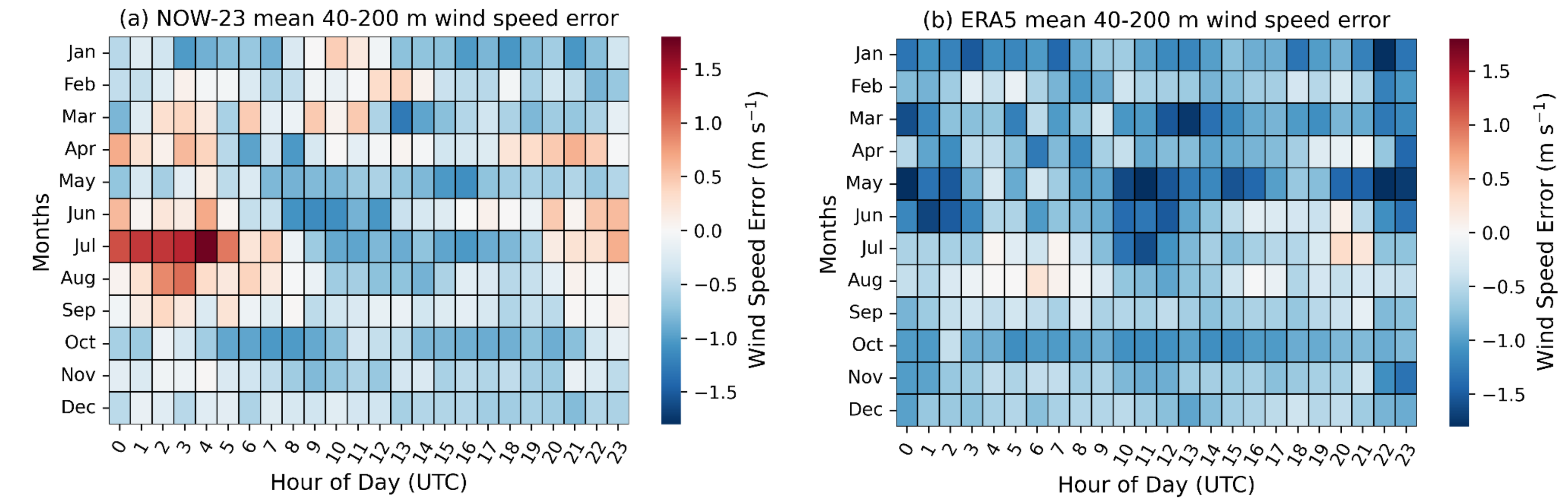

Fig. 3: Monthly and hourly mean 40-200 m layer wind speed error from (a) NOW-23 and (b) ERA5.

4. WARM SEASON LOW-LEVEL JETS (LLJs)

Model Analysis LLJ Forecasting Skill

- **ERA5**: **0 LLJ** events in the lowest 200 m [**Poorest skill**]
- **HRRR** analysis: Exhibited a LLJ **POD** of **9.0%.**

Table 1. NREL NOW-23 LLJ Forecast Skill		
Critical Success Index (CSI)	20%	[accuracy]
Frequency Bias	45%	[i.e., underprediction]
Probability of Detection (POD)	25%	
False Alarm Ratio (FAR)	45%	

Mean LLJ Profiles in Observed, NOW-23, & ERA5

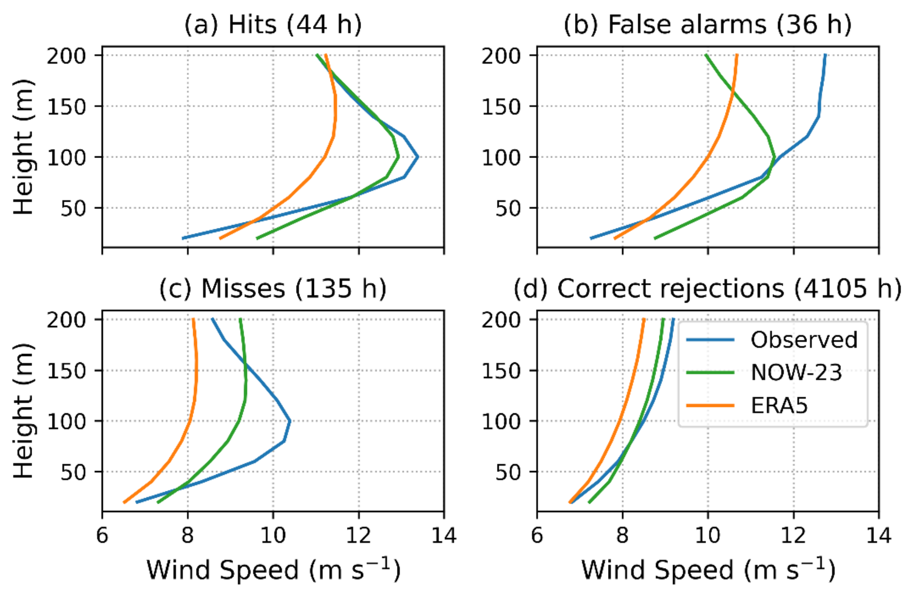

Fig. 4: Mean LLJ Profiles from Observed, ERA5, and NOW-23 on (a) hit, (b) false alarm, (c) misses LLJs

HRRR LLJ Profile Detection & Performance

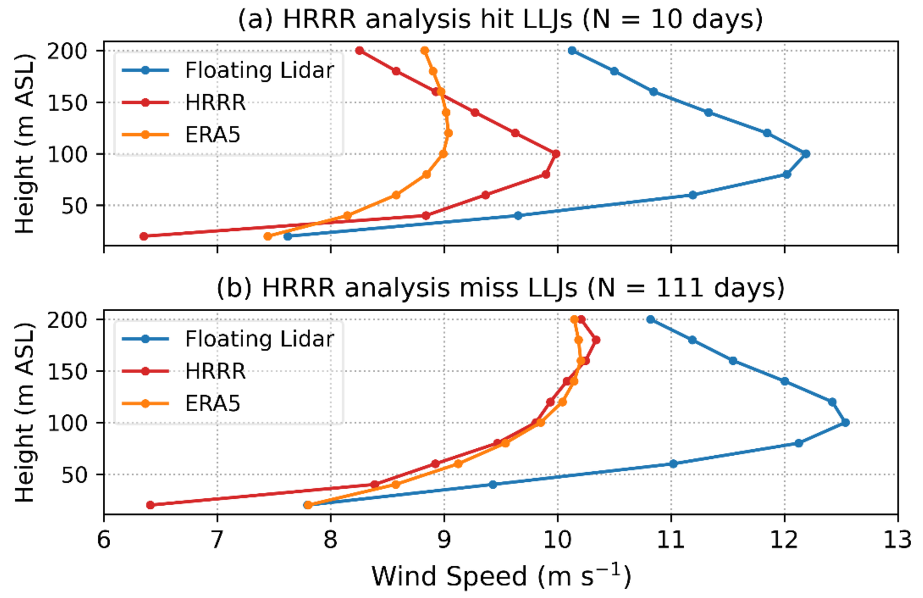

Fig. 5: Average wind speed profiles on HRRR hit LLJ events (top) and HRRR miss LLJ events (bottom).

Analysis Mean Error in Jet Core Speed & Height

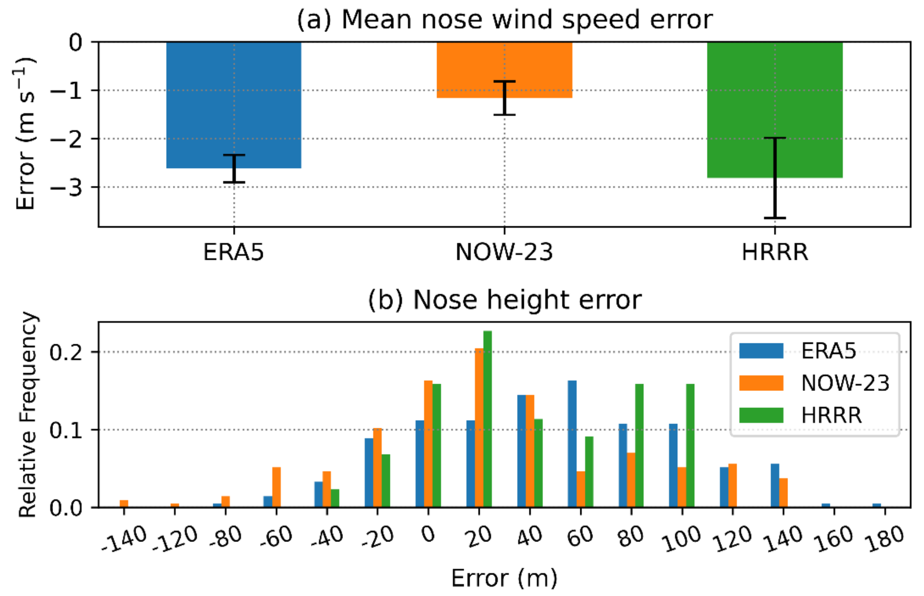

Fig. 6: (a) Mean nose wind speed error of analyses; (b) Model analysis jet nose height error frequency distributions

5. WARM SEASON LLJ ENVIRONMENTAL CONDITIONS

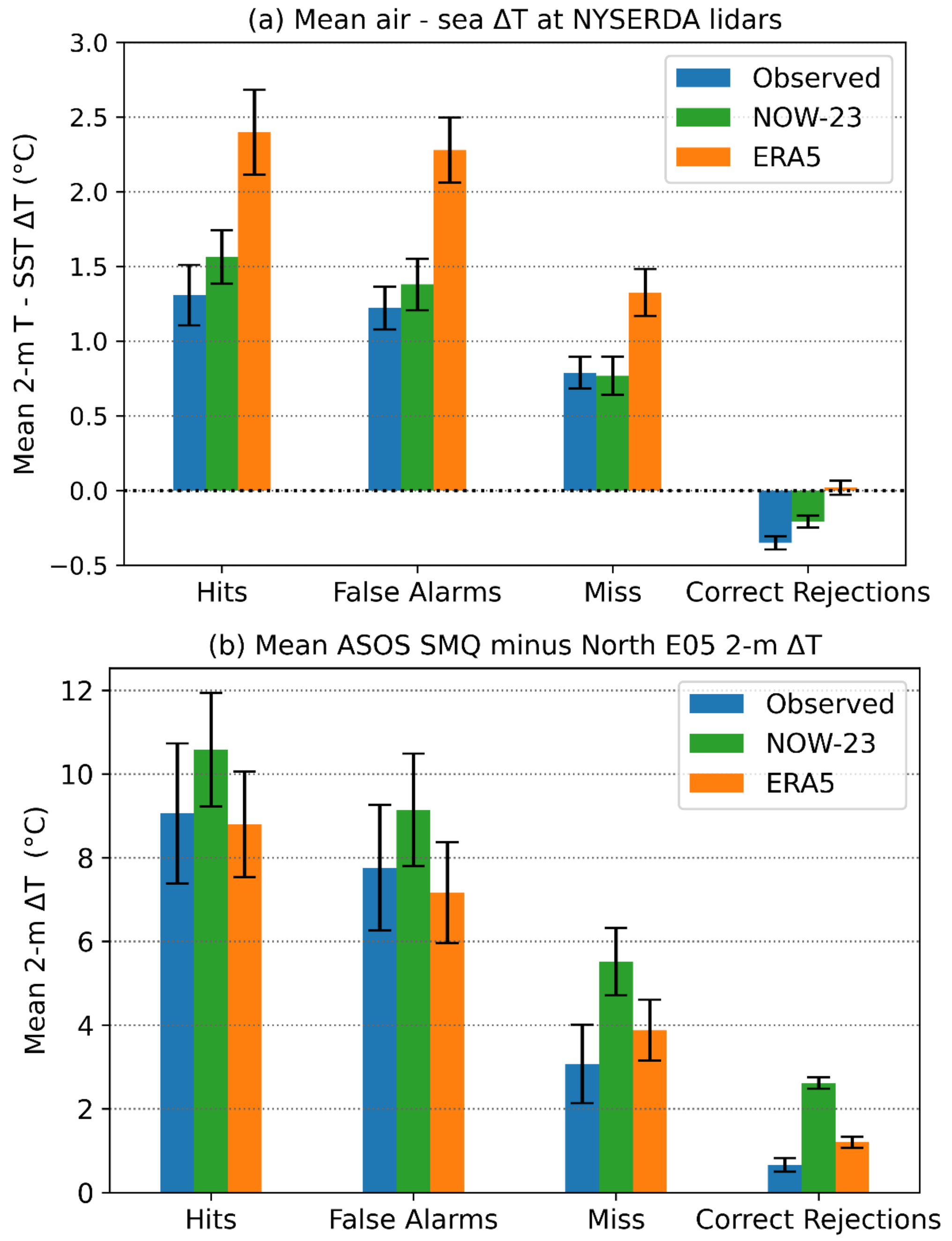

Fig. 7: (a) Mean air-sea temperature difference at floating lidars, and (b) mean land-sea 2-m air temperature difference between ASOS SMQ (Somerset, NJ) and North E05 lidar from observed, NOW-23, and ERA5 on NOW-23 hit, false alarm, and miss LLJs

DISCUSSION & CONCLUSIONS

- During **Spring and Summer (i.e., warm season)** months is when model analysis **wind speed profile performance** more **strongly deteriorates**… **Varies per model analysis**.
- ERA5 and NOW-23 both struggle in accurately depicting wind speeds in the warm season from ~ 2000 – 0600 UTC and 1000 – 1300 UTC.
- ERA5 underestimates by 1.3 – 1.8 m s^{-1} in May-June. NOW-23 overestimates by 0.5 – 1.8 m s^{-1} in June-August
- **All model analyses underestimate** warm season LLJ **frequency occurrence** and exhibit **poor 1:1 correspondence**.
- **Best performing** model analysis, in terms of **LLJ detection** and **depiction**, is **NOW-23, followed** next by the **HRRR**.
- **ERA5**: **Worst performing** in terms of LLJ detection and depiction of structural features → Misrepresentation of turbulence during stable conditions.
- Significantly larger observed air-sea ΔT and land-sea ΔT are associated with NOW-23 LLJ detection.