The Impact of Wind-Wave Angle on the Momentum Flux Over Shoaling Waves

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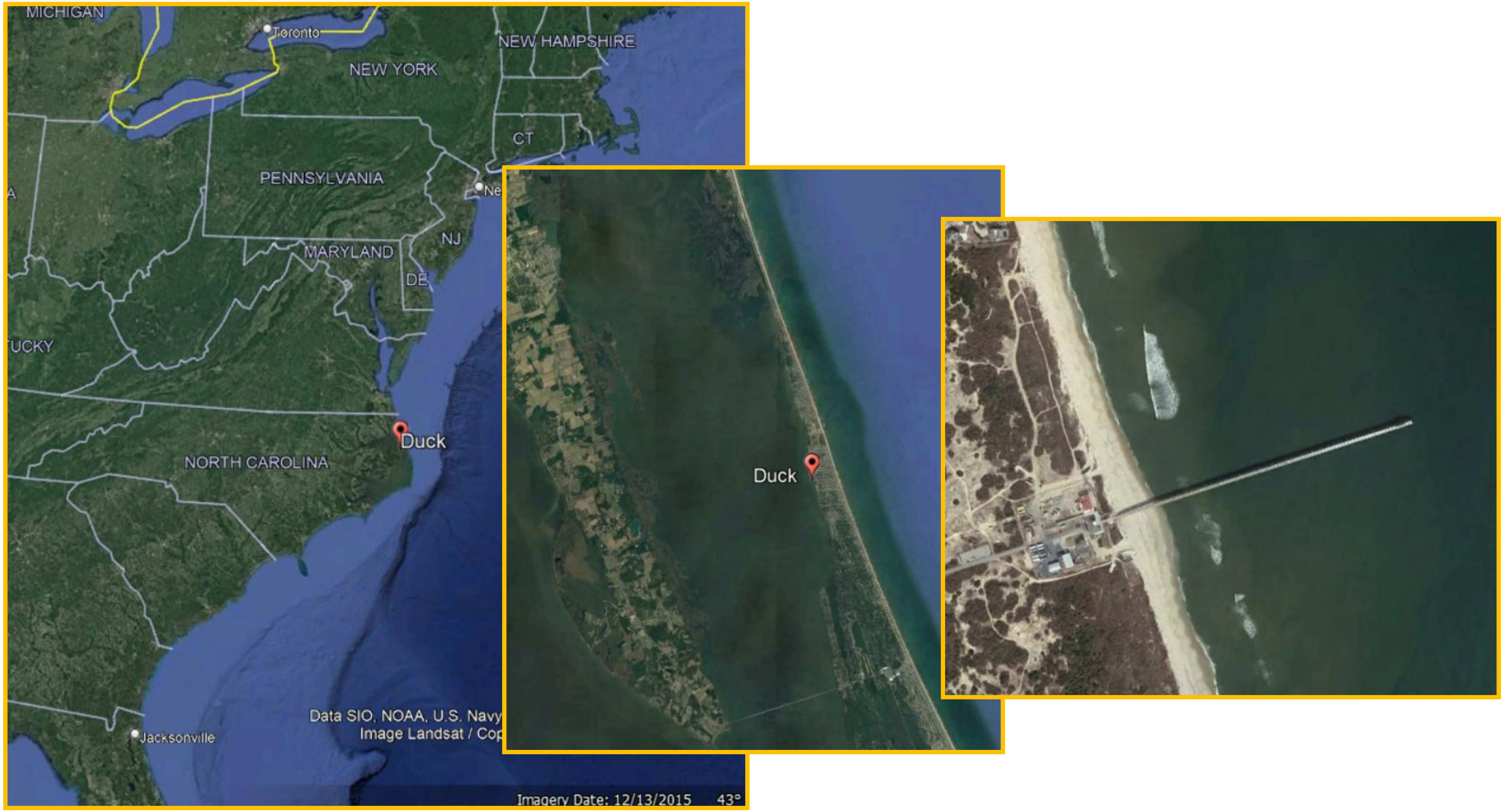
During Nearshore Event Experiment (DUNEX)

Experiment to study nearshore coastal processes during coastal storms.

GOALS

- Improve prediction of storm processes and impacts
- Estimate numerical model accuracy and identify and reduce sources of error for storm processes
- Inform strategies for short- and long-term coastal resilience
- Support more effective communication for coastal communities impacted by storms.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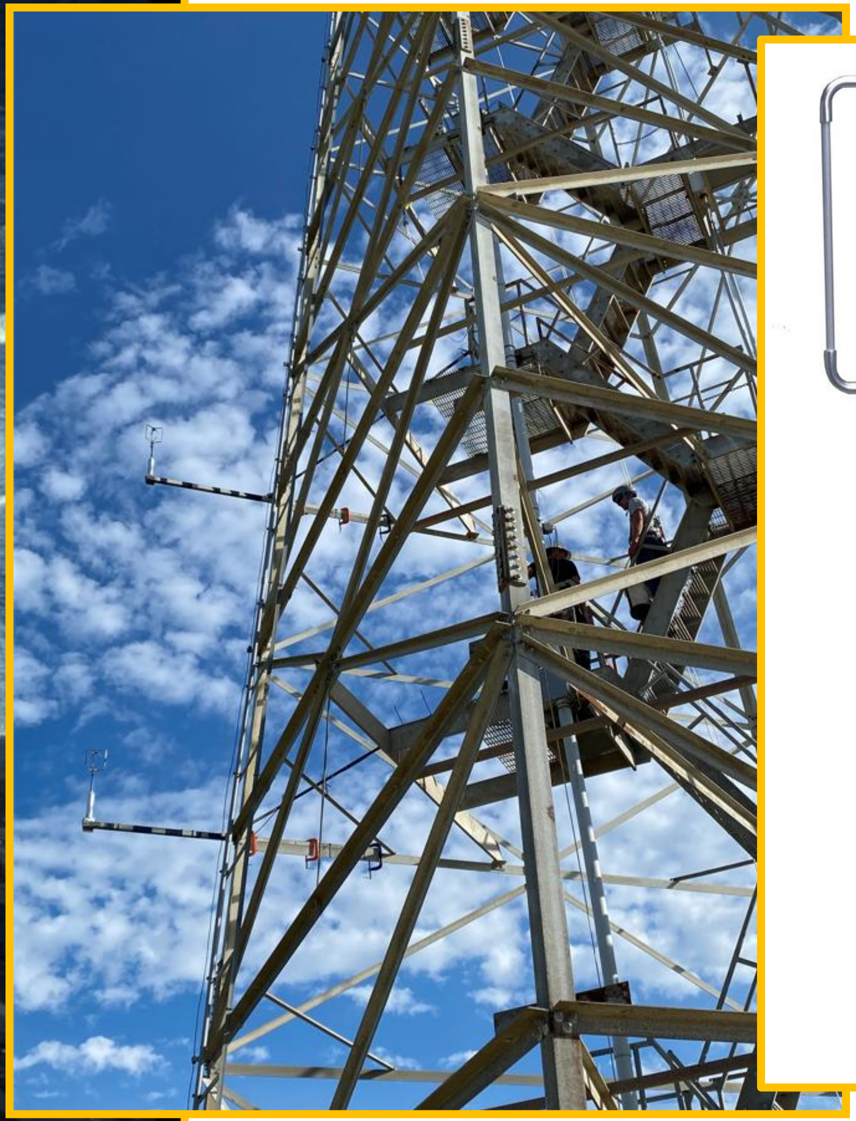
Pier-Based Anemometer, continuously operational since Aug 2021

Video Tower-Based Anemometers, intermittently operational since Aug 2021



Site Data Collected at the Field Research Facility

Wave height, directional spectra.	A phased array is moored 800 m offshore which provides directional wave spectra.
Currents (and waves)	Acoustic wave and current profilers (AWAC).
Bathymetry	Monthly (or more frequent) bathymetric surveys
Water temperature	Recorded at the FRF pierhead from a fixed array
Water level	Recorded at the FRF pierhead.
Mean meteorological	Air temperature, humidity, barometric pressure, and wind speed.
Shoreline and surfzone location, shoreline elevation, whitecap coverage.	FRF provides georectified images from the 43 m Beach/Video Tower (Figure right)

Time-averaged image created from video footage from the Video Tower at FRF. Once each image is georectified using ground control points, nearshore characteristics can be quantified.

My Research Questions

- What is the temporal and spatial variability of the momentum flux in the coastal zone?
- How do coastal processes impact the momentum flux?
- How do nearshore conditions and changes to the flux footprint alter the boundary layer flux profile?
- How do heat and momentum flux outside the surfzone compare to those across the surfzone?

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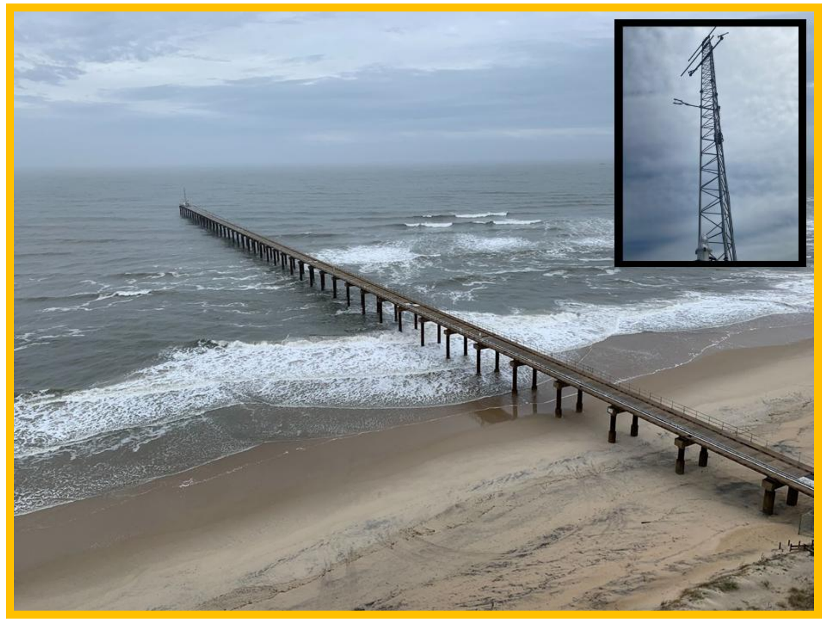
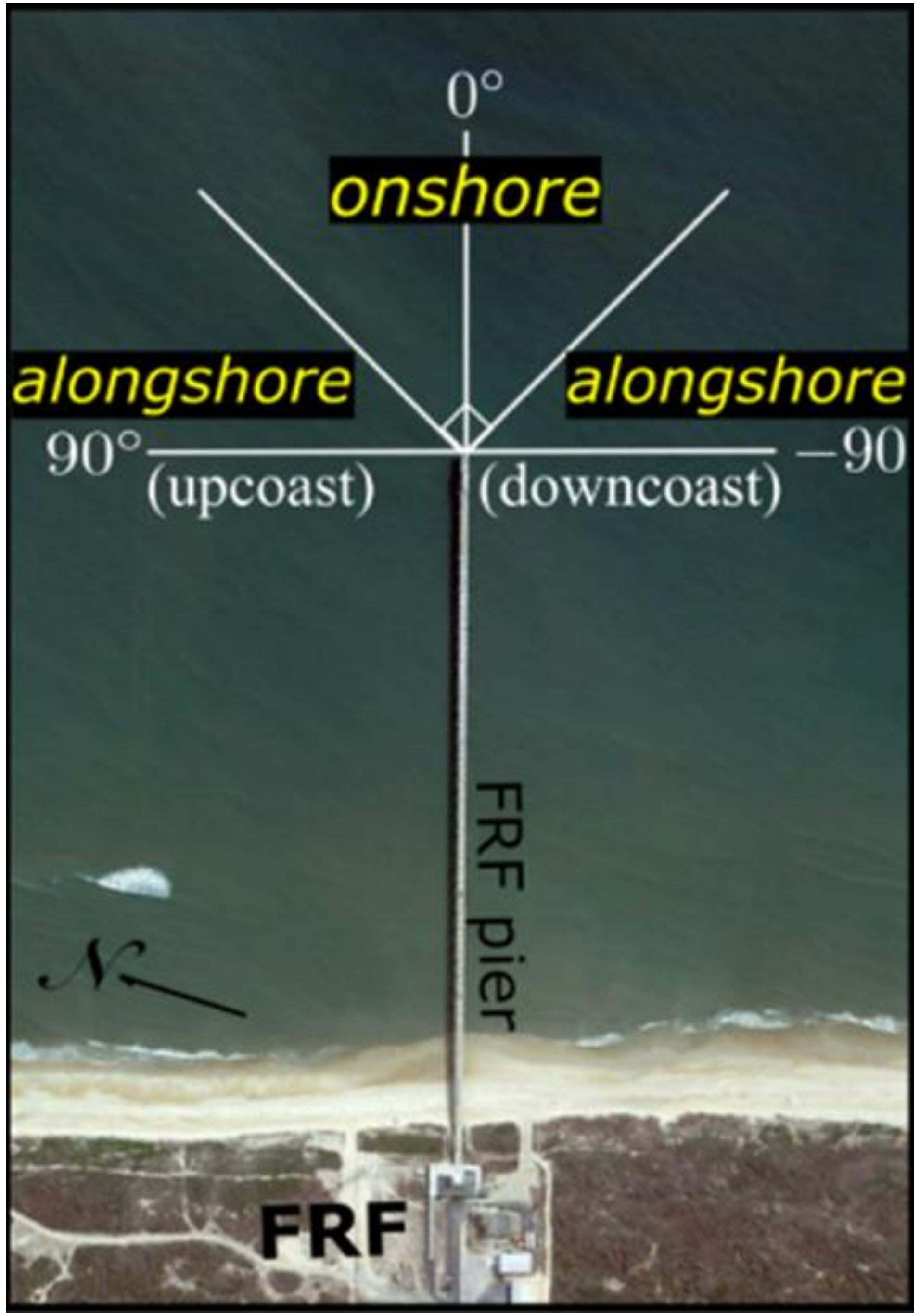
Pier-Based Anemometer, continuously operational since Aug 2021

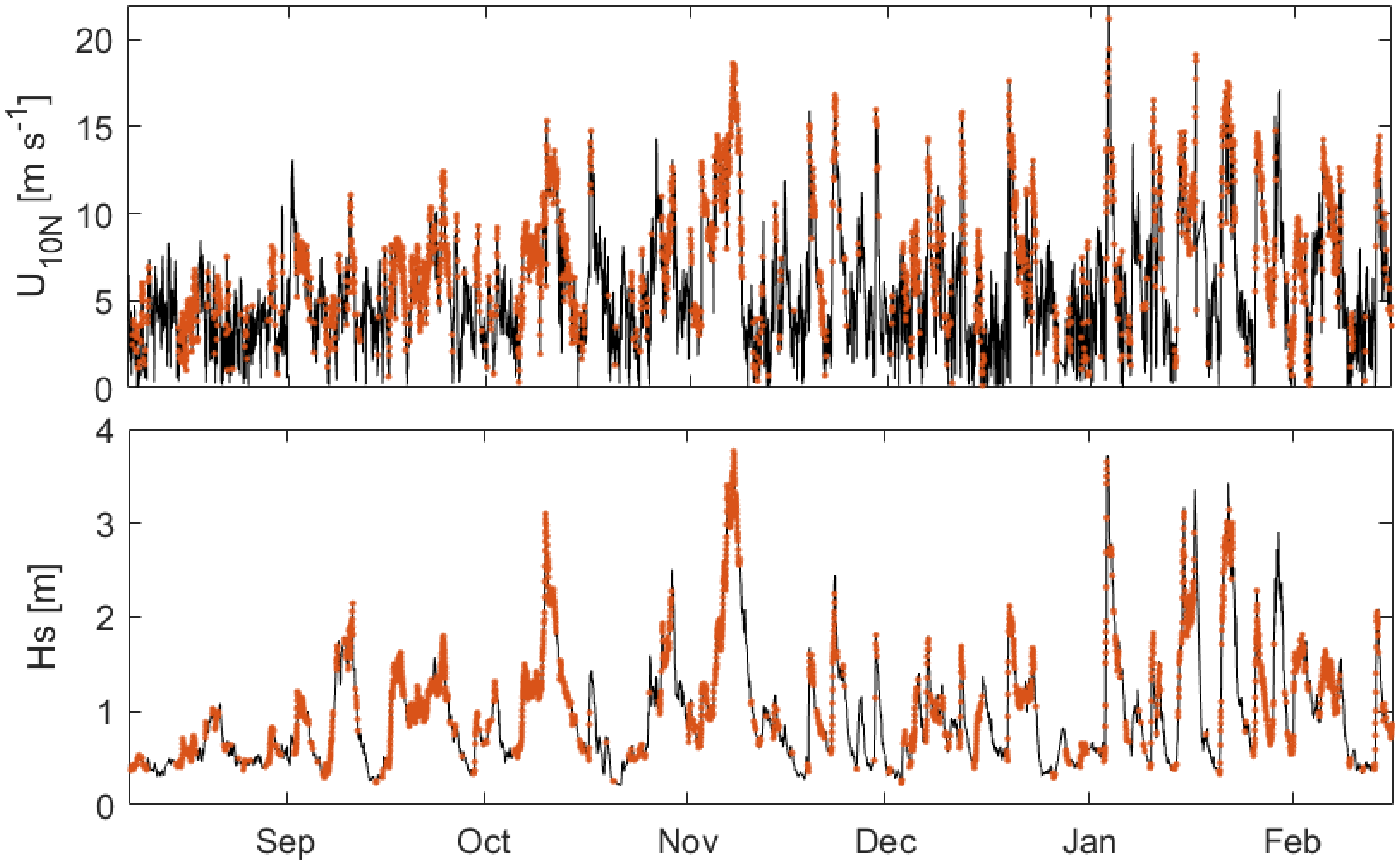
DATA COLLECTION AND PROCESSING

- IRGASON 14.4 m above MWL
- Collected data at 20 Hz for six months which were put into 30 minute blocks.
- Only data during onshore or alongshore wind were used.
- Adjust wind speed to 10 m neutral equivalent conditions (U_{10N})
- Calculate the drag coefficient (C_{D10N})

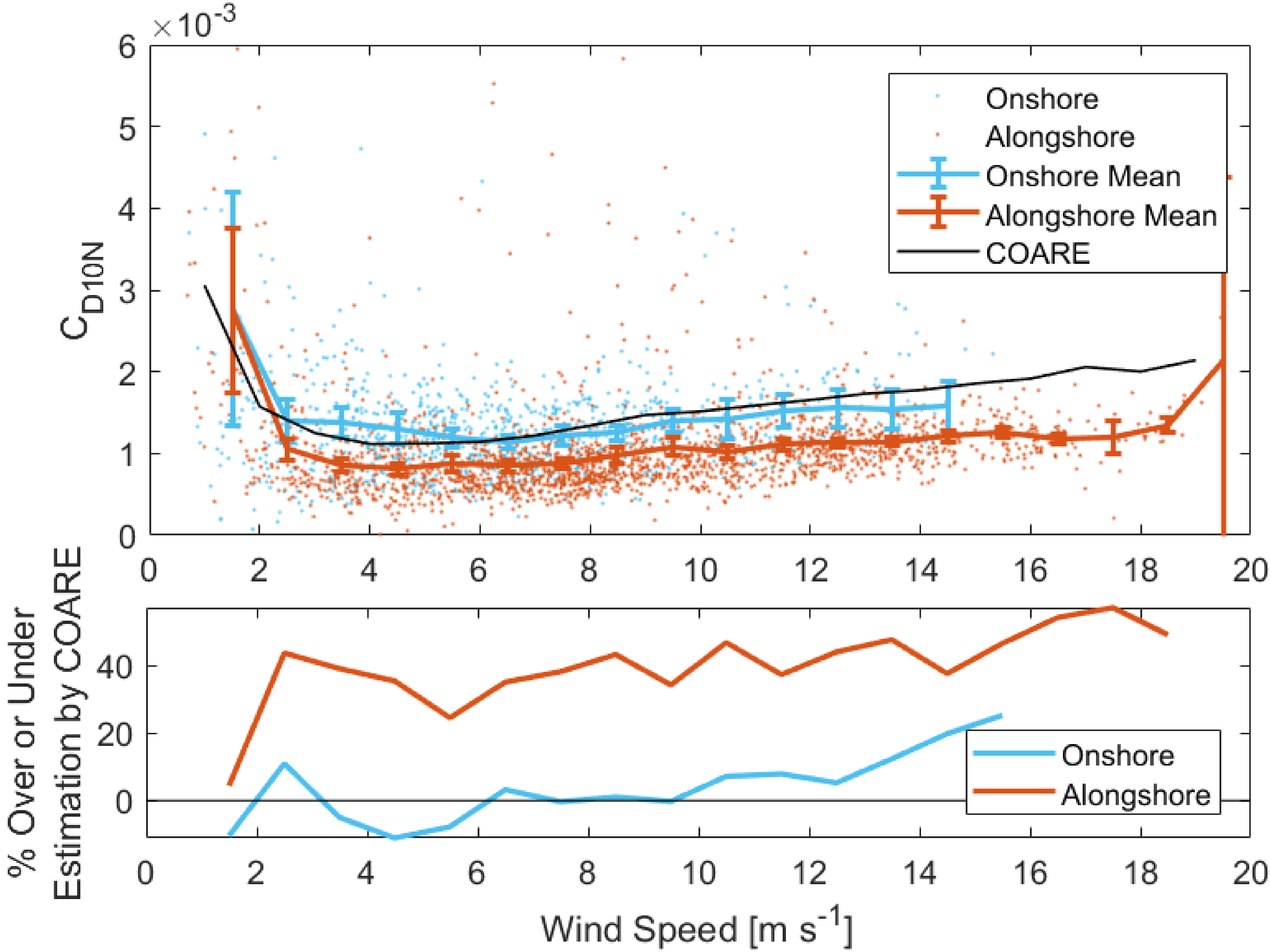
$$C_{Dz} = \frac{\sqrt{\left(\overline{-u'w'}\right)^2 + \left(\overline{-v'w'}\right)^2}}{U_z^2}$$





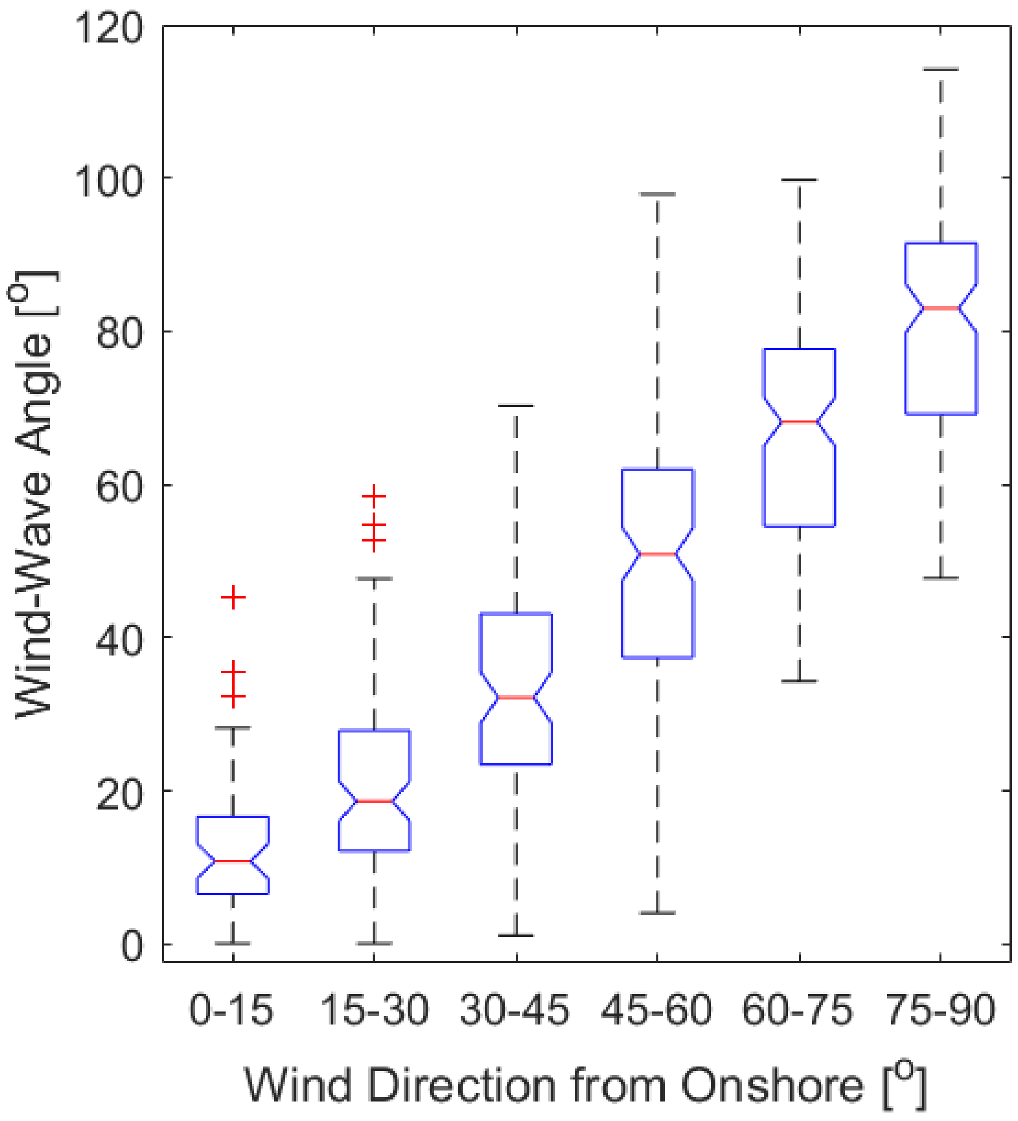


459 onshore hours and 1073 alongshore hours



×10^-3
C_D10N
Onshore
Alongshore
Onshore Mean
Alongshore Mean
COARE
% Over or Under
Estimation by COARE
Onshore
Alongshore
Wind Speed [m s^-1]

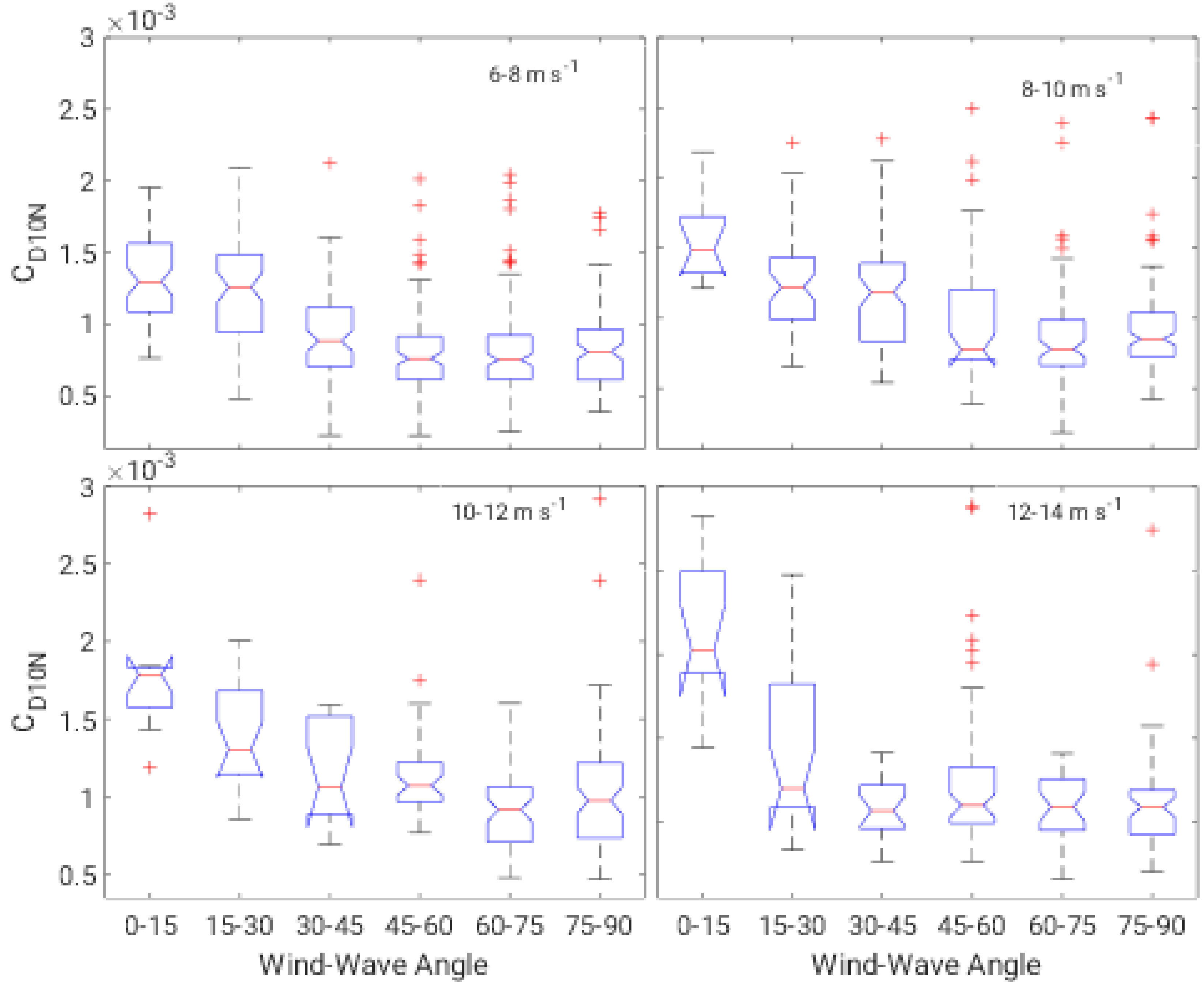
Waves



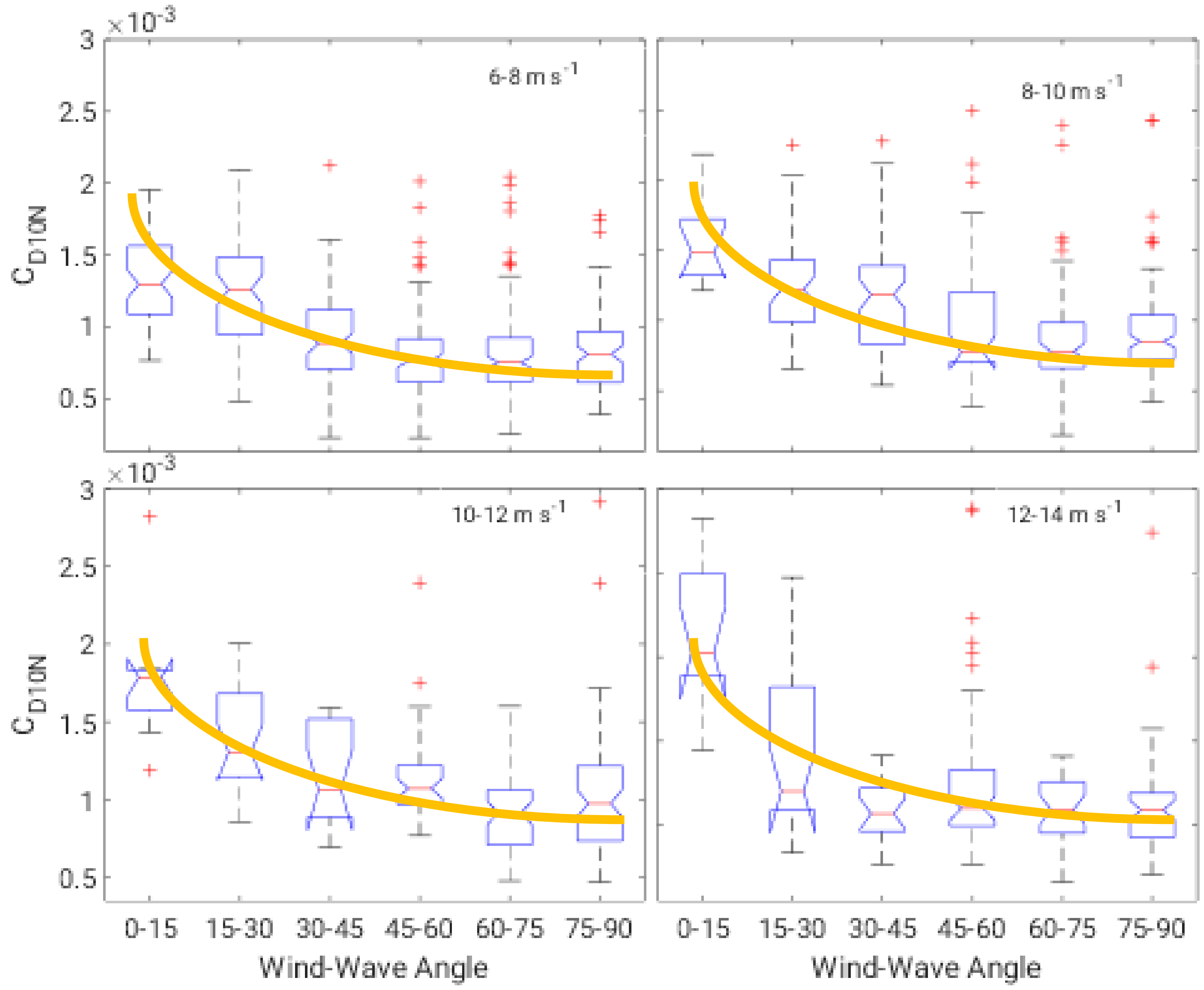
- When the wind is perpendicular to shore (0-15°), the wind and peak wave directions are approximately aligned.

- When the wind is parallel to shore (75-90°), the wind and peak wave directions are approximately perpendicular.

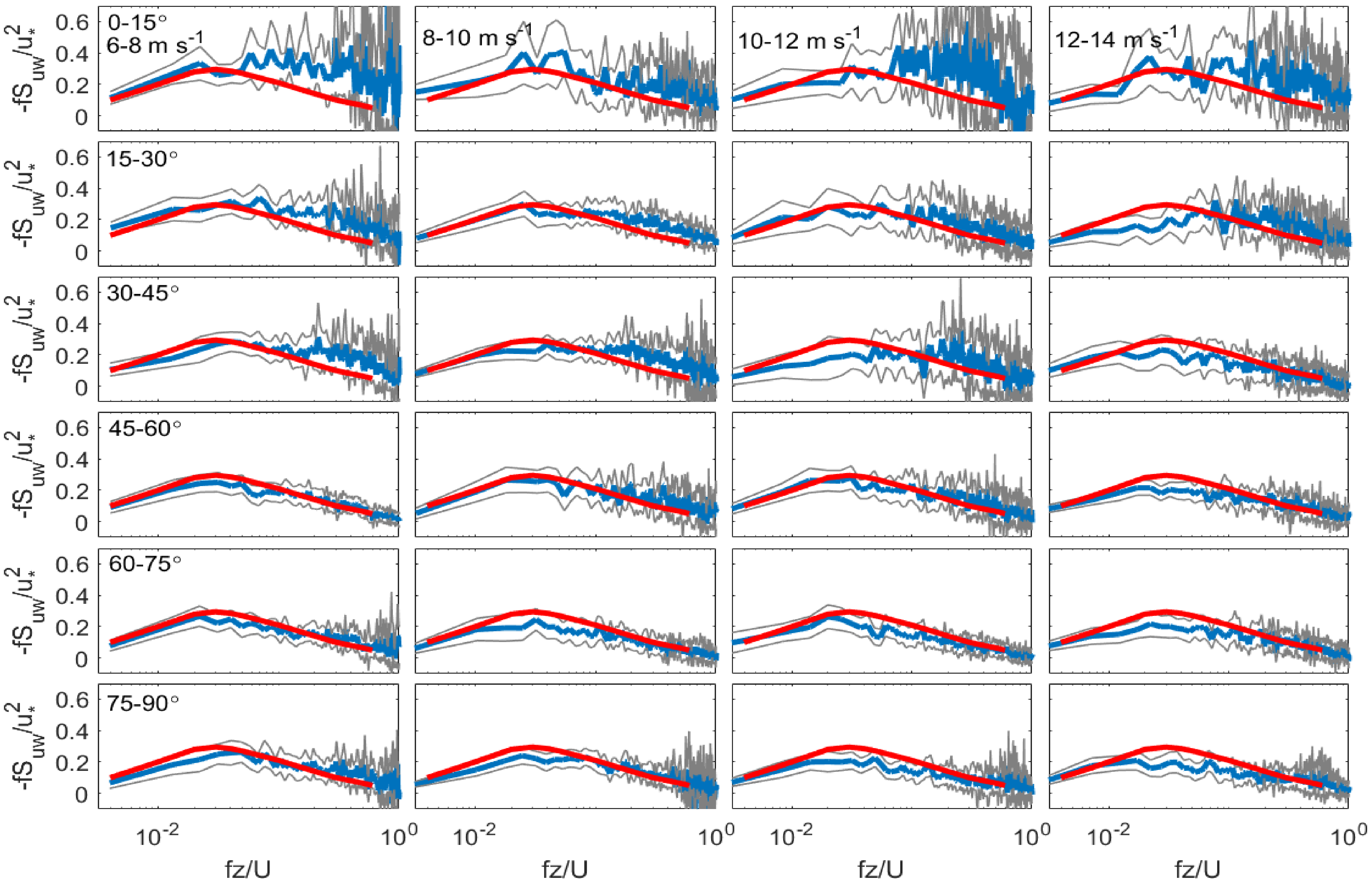
Drag Coefficient Binned by Wind-Wave Angle and Wind Speed



Drag Coefficient Binned by Wind Speed and Wind-Wave Angle



u-w Cospectra in the Scaling of Miyake et al. (1970)



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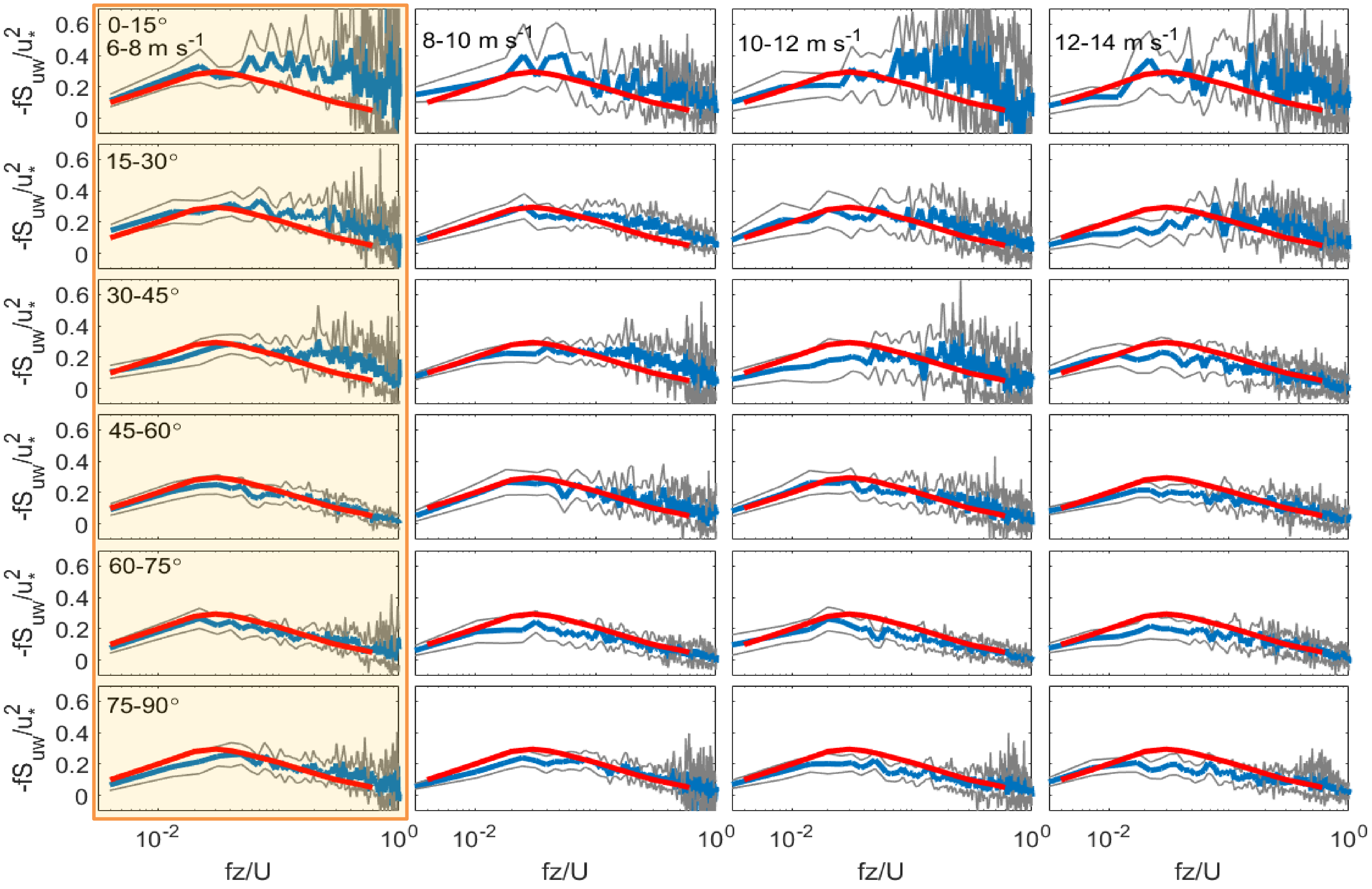

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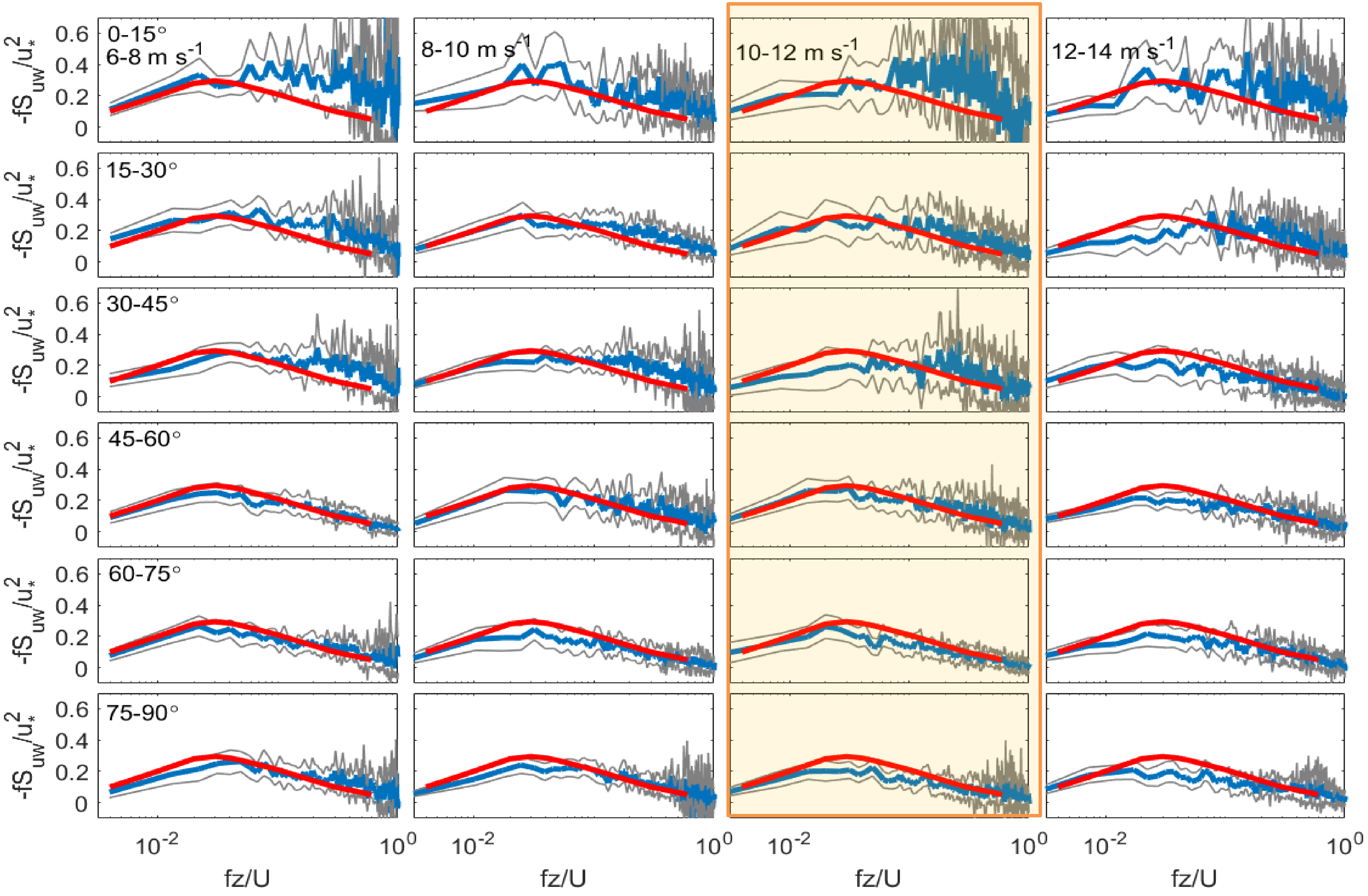
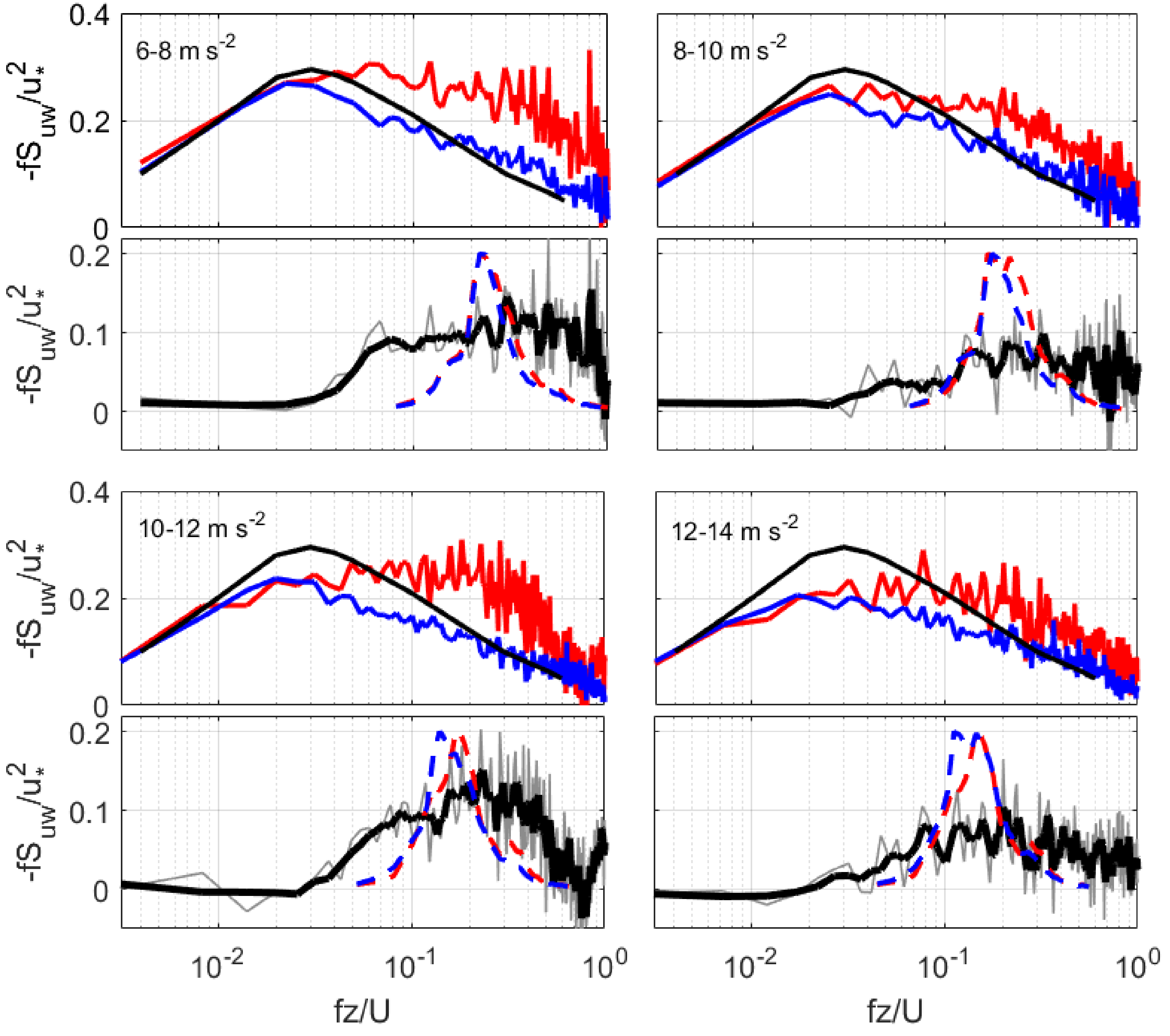


Difference in u-w Cospectra with Wave Frequency Spectra

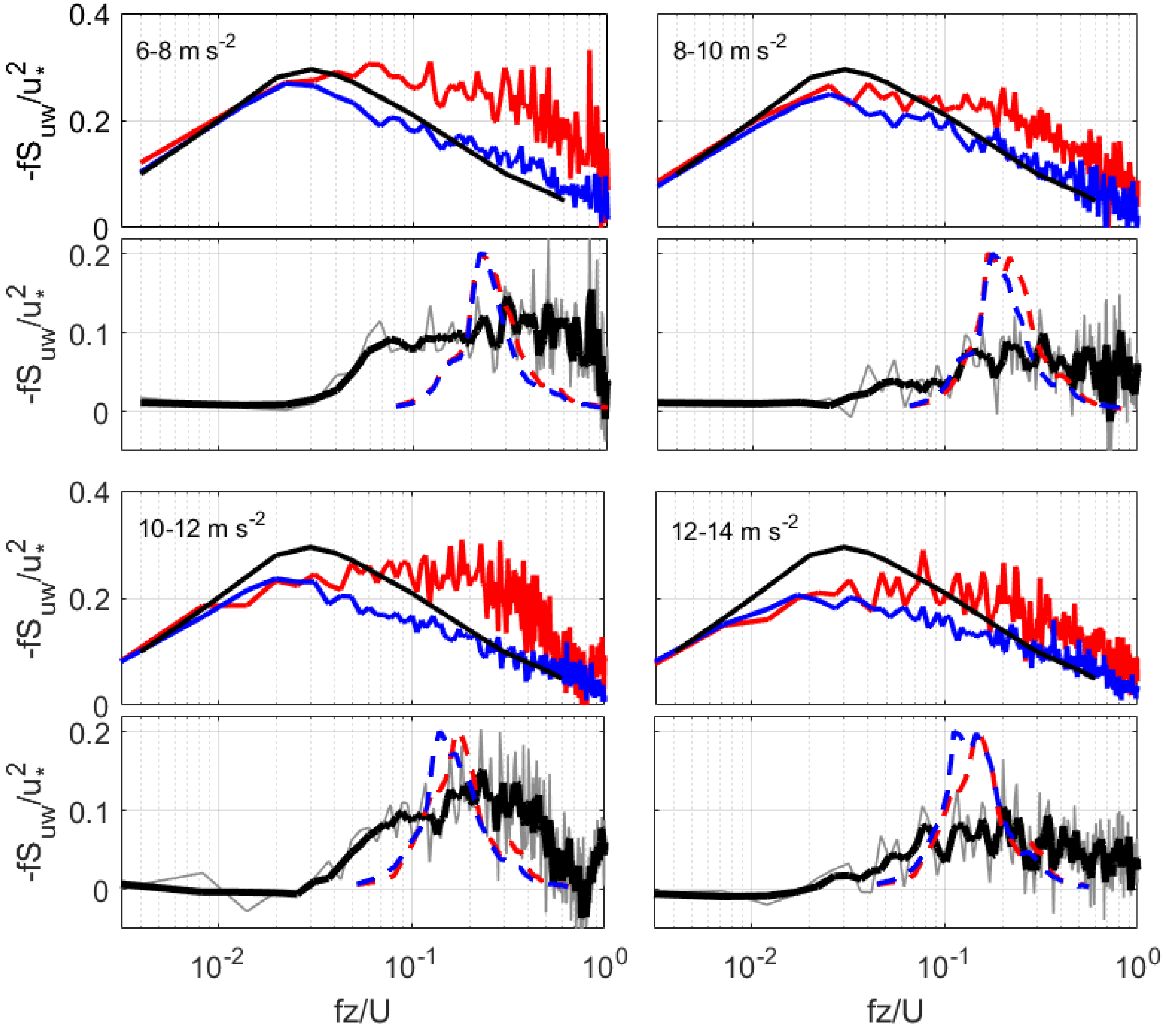


Wind-Wave Angle 0-45 (red)

Wind-Wave Angle 45-90 (blue)

Difference (black)

Difference in u-w Cospectra with Wave Frequency Spectra



Possible Mechanisms:

- Slanting Fetch
  - (e.g., Ardhuin et al., 2007; Husain et al., 2022)
- Wave Shoaling
  - (e.g., Anctil & Donelan, 1996)

Summary

- Approximately 1500 hours of direct flux measurements recoded from a pier at the Field Research Facility, Duck, NC.
- For winds above 3 m s^{-1} the drag coefficient is between 15 and 50% higher for onshore winds when compared to alongshore.
- The COARE 3.5 algorithm does not accurately predict C_{D10N} near shore.
- Controlling for wind speed, C_{D10N} is well correlated to wind-wave angle with highest values when the wind and waves aligned and lowest at greatest wind-wave angles
- Increased fluxes during onshore conditions are coincident with the wave frequency. This indicates that waves may be modulating the momentum transfer near shore by increasing the downwind component of the flux relative to alongshore winds.
- For alongshore winds, slanting-fetch-like conditions are may be associated with decreased flux around the wave frequency because wind-wave coupling is reduced.

Coming Soon

Pier-Based Measurements of Air-Sea Momentum Flux over Shoaling Waves during DUNEX. *JGR – Oceans.* Potter et al. (2022)

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