

Impact of Swell-induced Tilt on Scatterometer Wind Retrieval

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1. Introduction

- The impact of swell on scatterometer backscatter has been observed, and it holds relevance from the perspective of **geophysical applications** and **scatterometer calibration**.
- Broadly, the underlying mechanisms can be divided into two groups:
 - Swell-induced tilt variations
 - Modification of Capillary-Gravity Wave activityBoth of these are expected to depend strongly on the mutual alignment of winds, swells, and the scatterometer look direction.
- Satellite scatterometers span several swell wavelengths cancelling any symmetric phase dependent effects.

Swell
 $\lambda \sim 10 - 100$
m



Capillary Gravity Waves
 $\lambda \sim 1$ cm

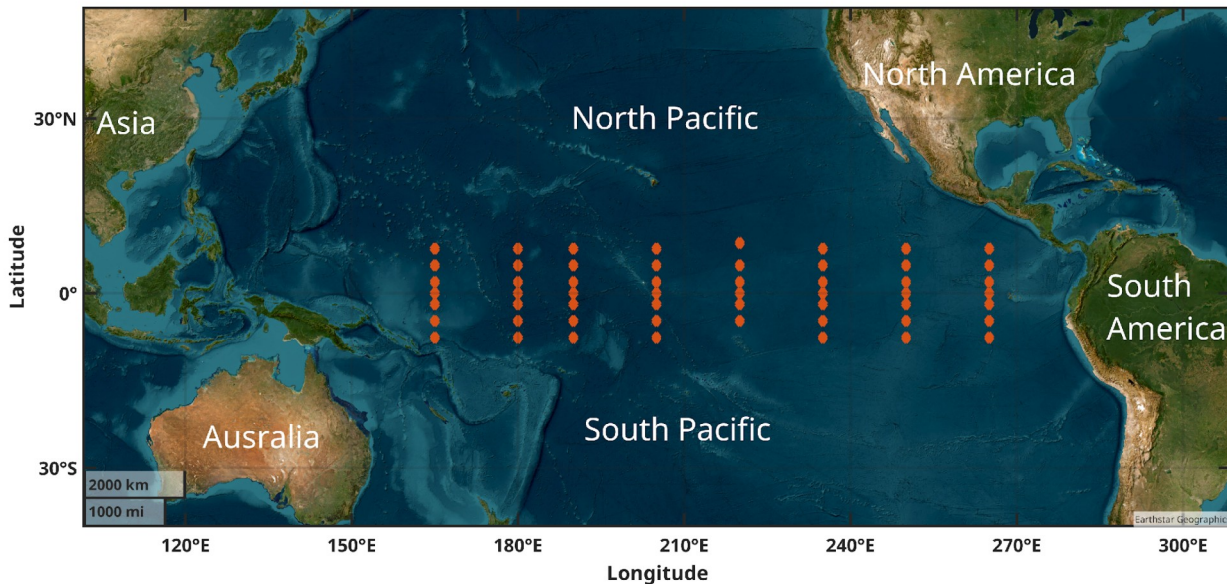
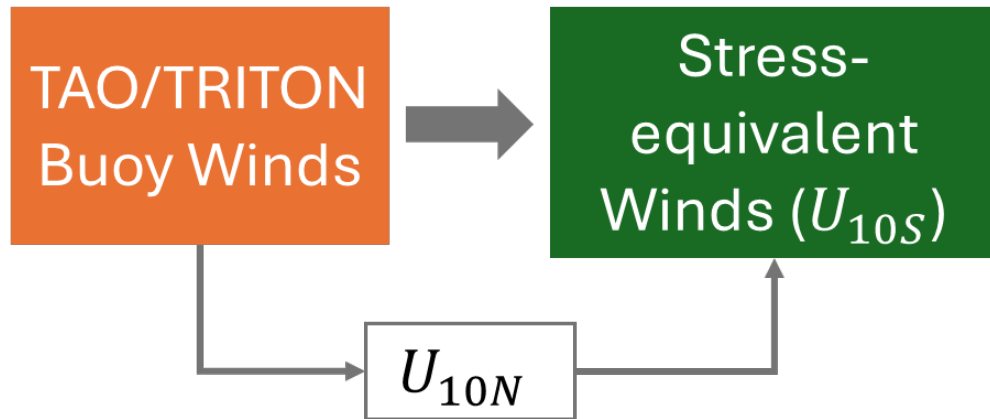


2. Questions

- Do swells impact scatterometer wind retrieval?
- How do such effects depend on the mutual alignment between winds and swell?
- Are wind speed retrieval errors resulting from swells larger than the typical uncertainty in scatterometer measurements for some wind-swell alignments?

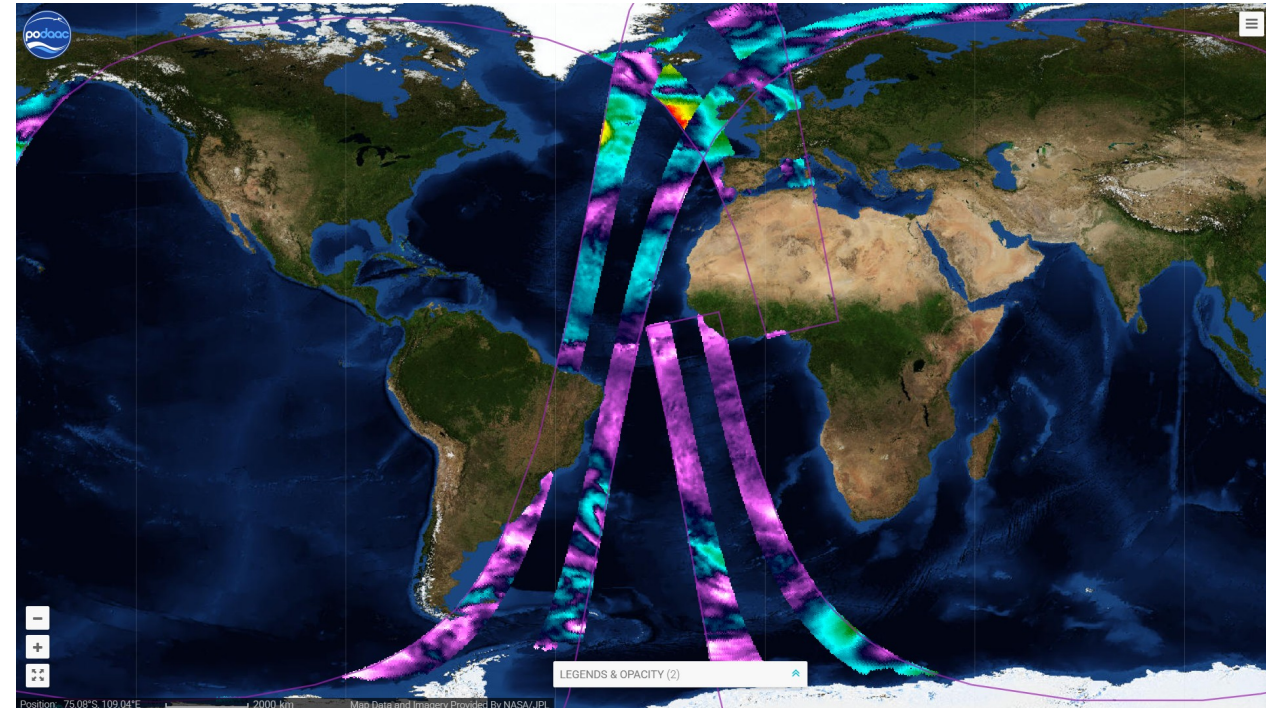
3.Data & Methods

Wind Datasets



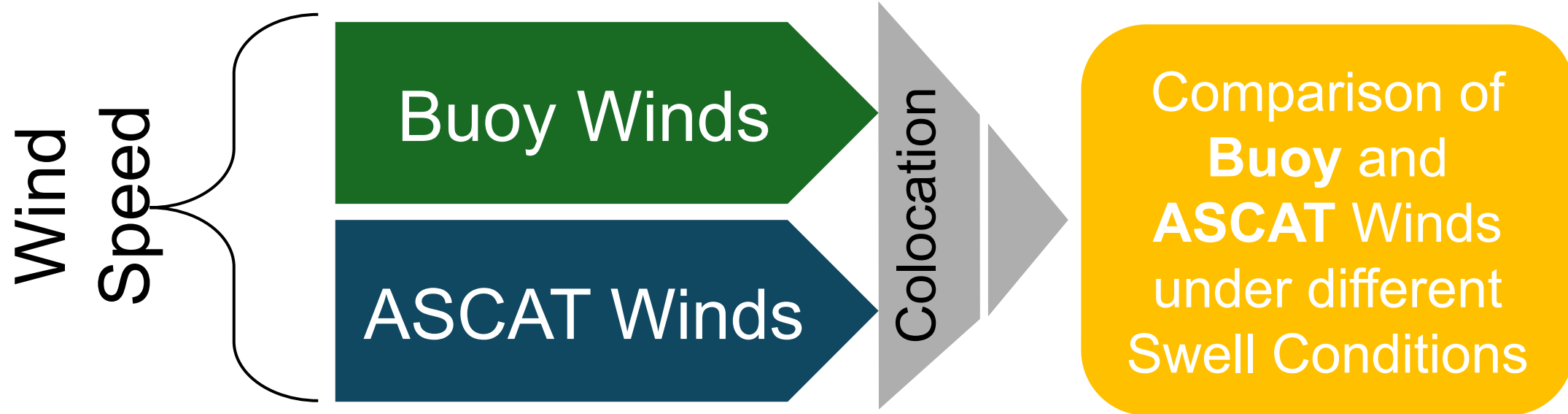
ASCATB L2B Winds

Stress-equivalent Winds (CMOD7)



3.Data & Methods

Methods

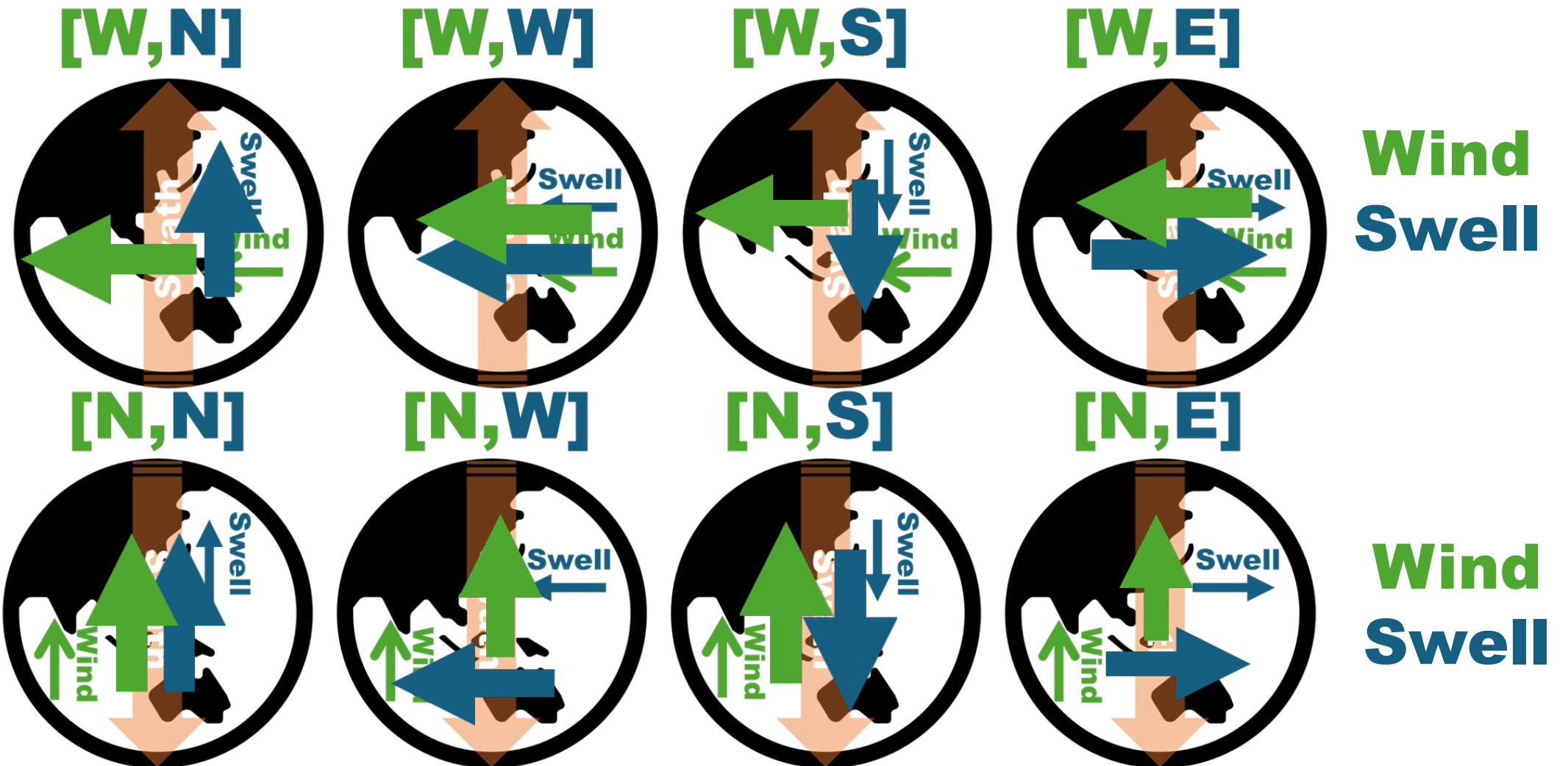


**Swell
Data**

ERA-5 Swell characteristics
(Wave Height, period, direction for
3 swell partitions)

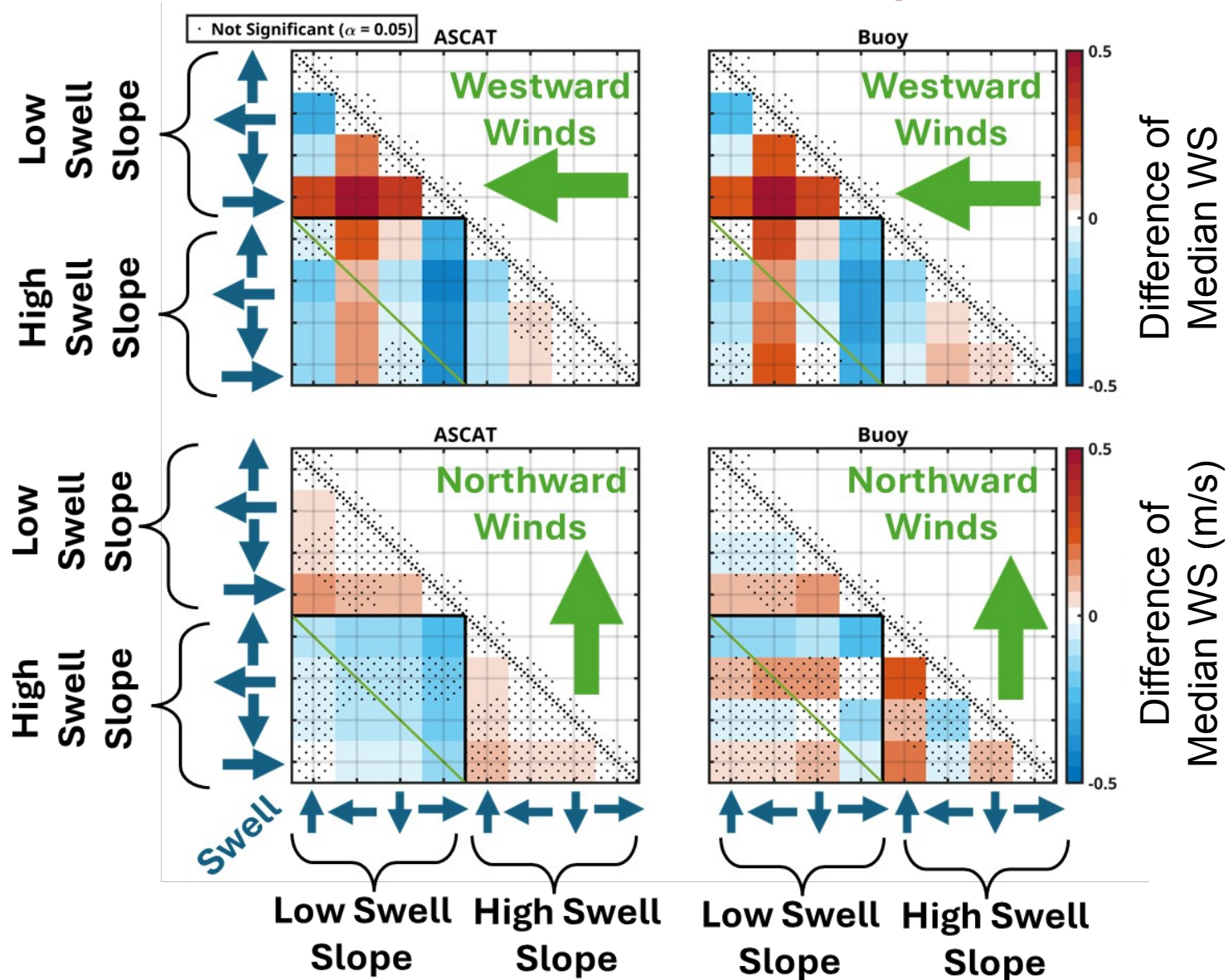
3.Data & Methods

Wind/Swell Configurations



4. Swell Effects on Wind Speed Distributions

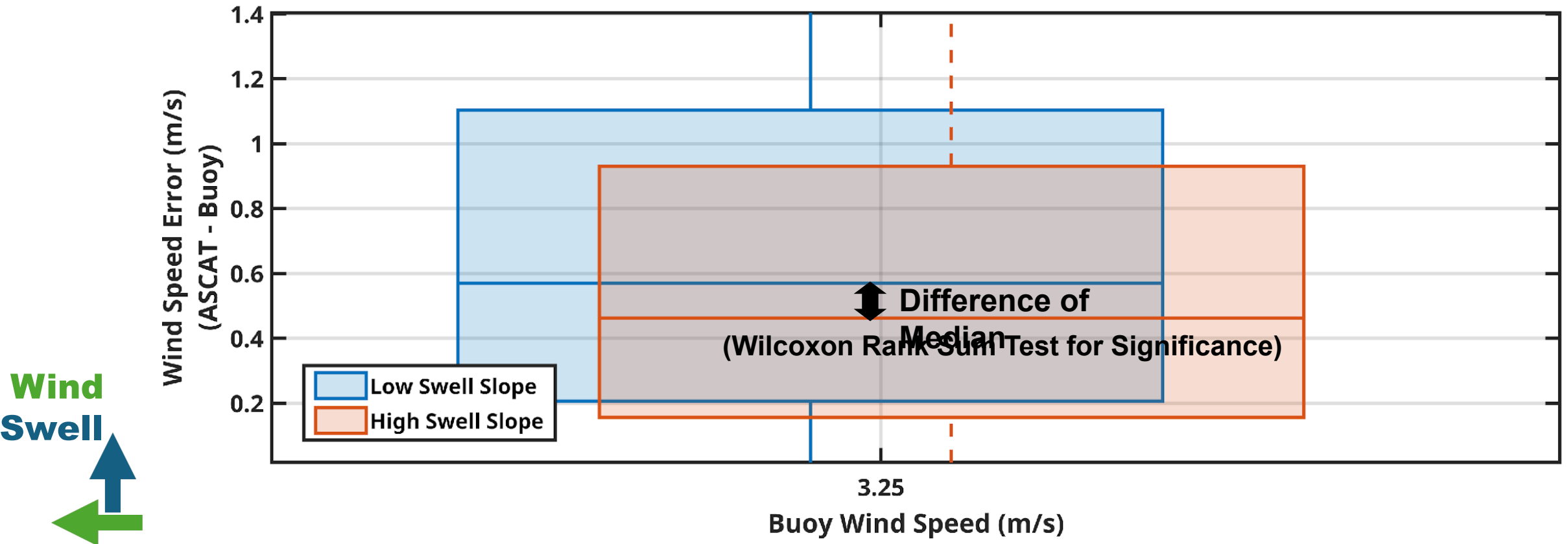
Contrast in Median Wind Speeds



- **Black Box**
 - High vs low slope cases
- **ASCAT**
 - Sharp contrast between high and low swell slope (**Northward Winds**)
 - **Low winds at high slope conditions**
- **Buoys**
 - No such contrast
- **Do these contrasts depend on Wind Speed?**

5. Swell Effects on Wind Speed Error Distributions

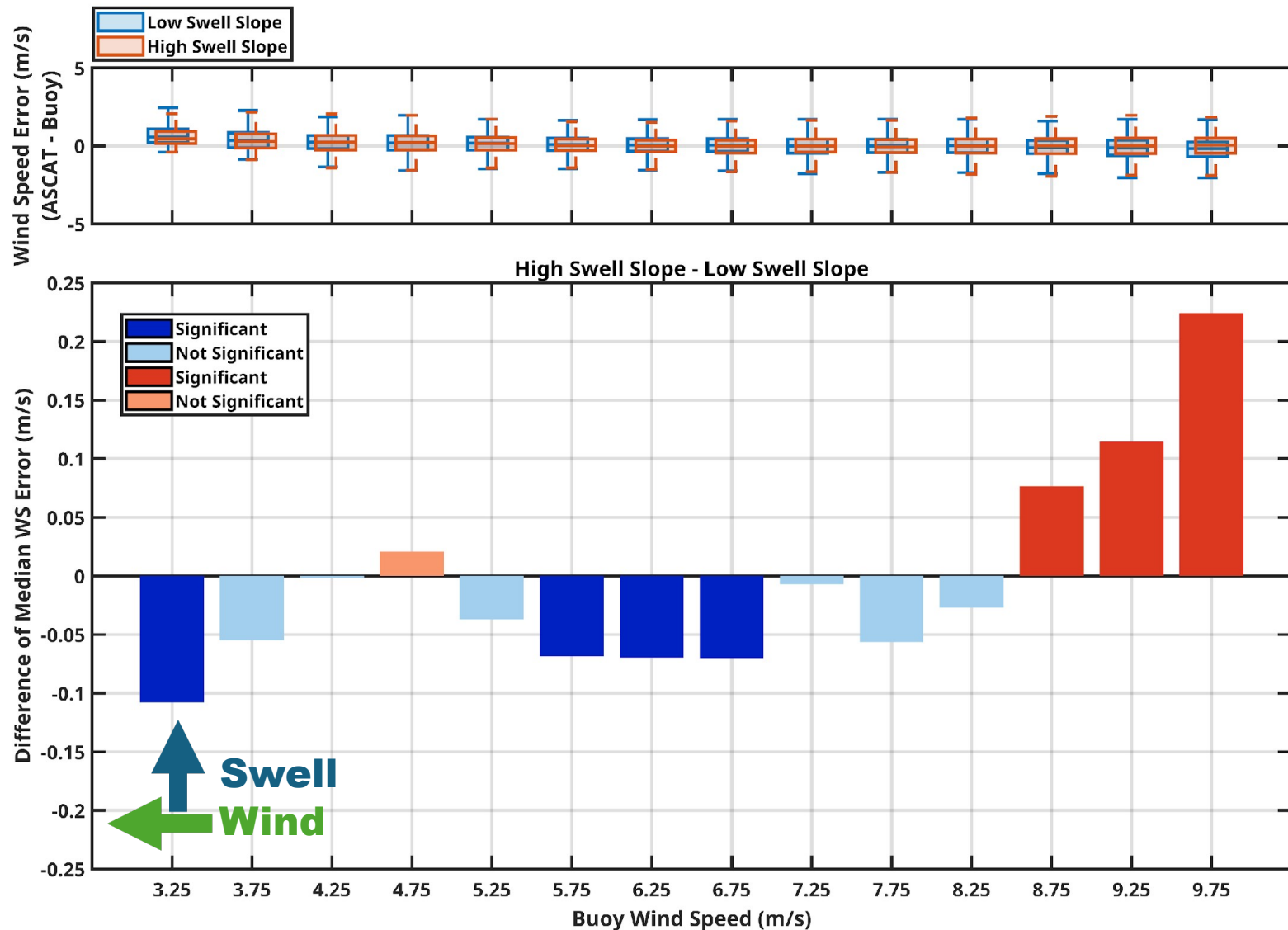
Contrast in Median Wind Speed Errors



- WS Errors are WS Dependent.
- At low WS ($WS < 6$ m/s) ☐ **ASCAT overestimates WS**
- At high WS ($WS > 7$ m/s) ☐ **ASCAT underestimates WS**

6. Contrast in Median Wind Speed Errors

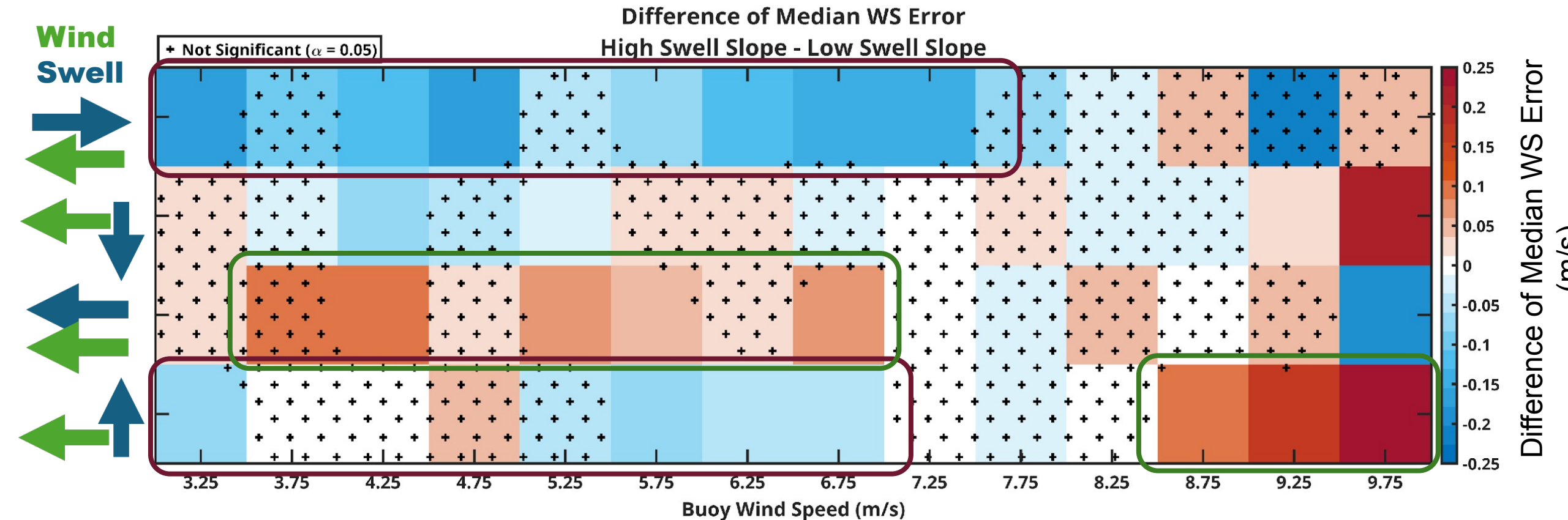
Variation with Wind Speed: Single Case



- **Negative Difference**
- ASCAT WS retrievals are **Low** in high swell slope conditions.
- **Positive Difference**
- ASCAT WS retrievals are **High** in high swell slope conditions.

7. Contrast in Median Wind Speed Errors

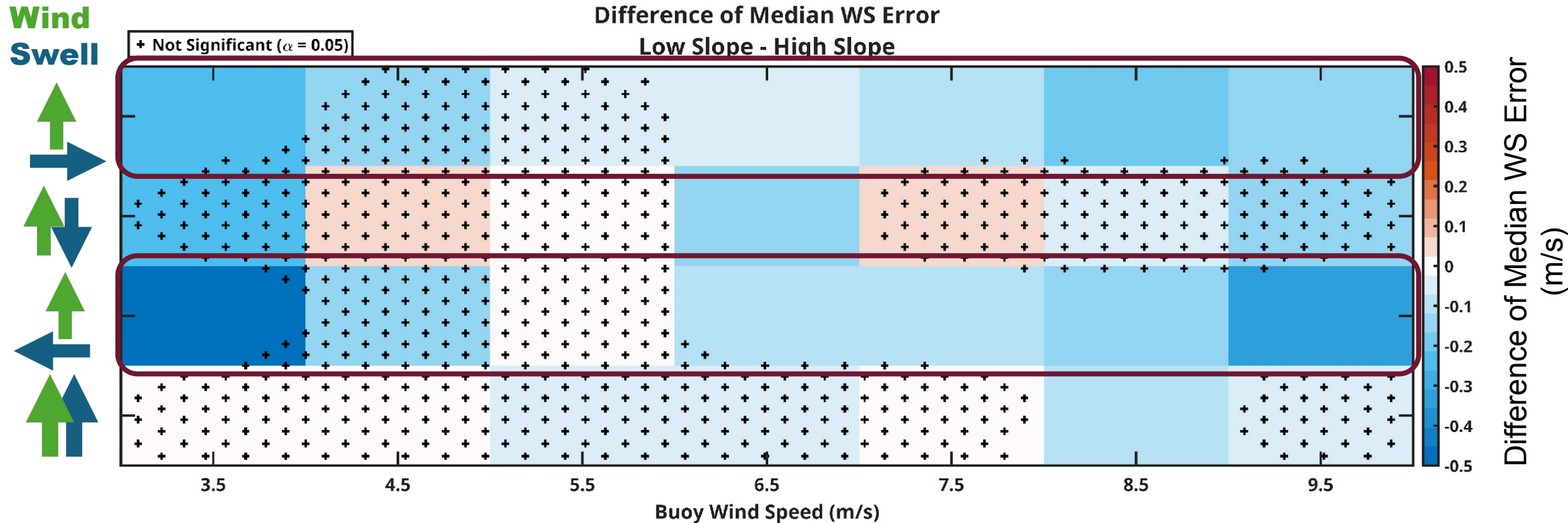
Variation with Wind Speed: 4 Cases (Westward Wind)



- High swell slopes lower ASCAT winds for 2 configurations (at low Wind Speed)
- High swell slopes increase ASCAT winds for 1 configuration

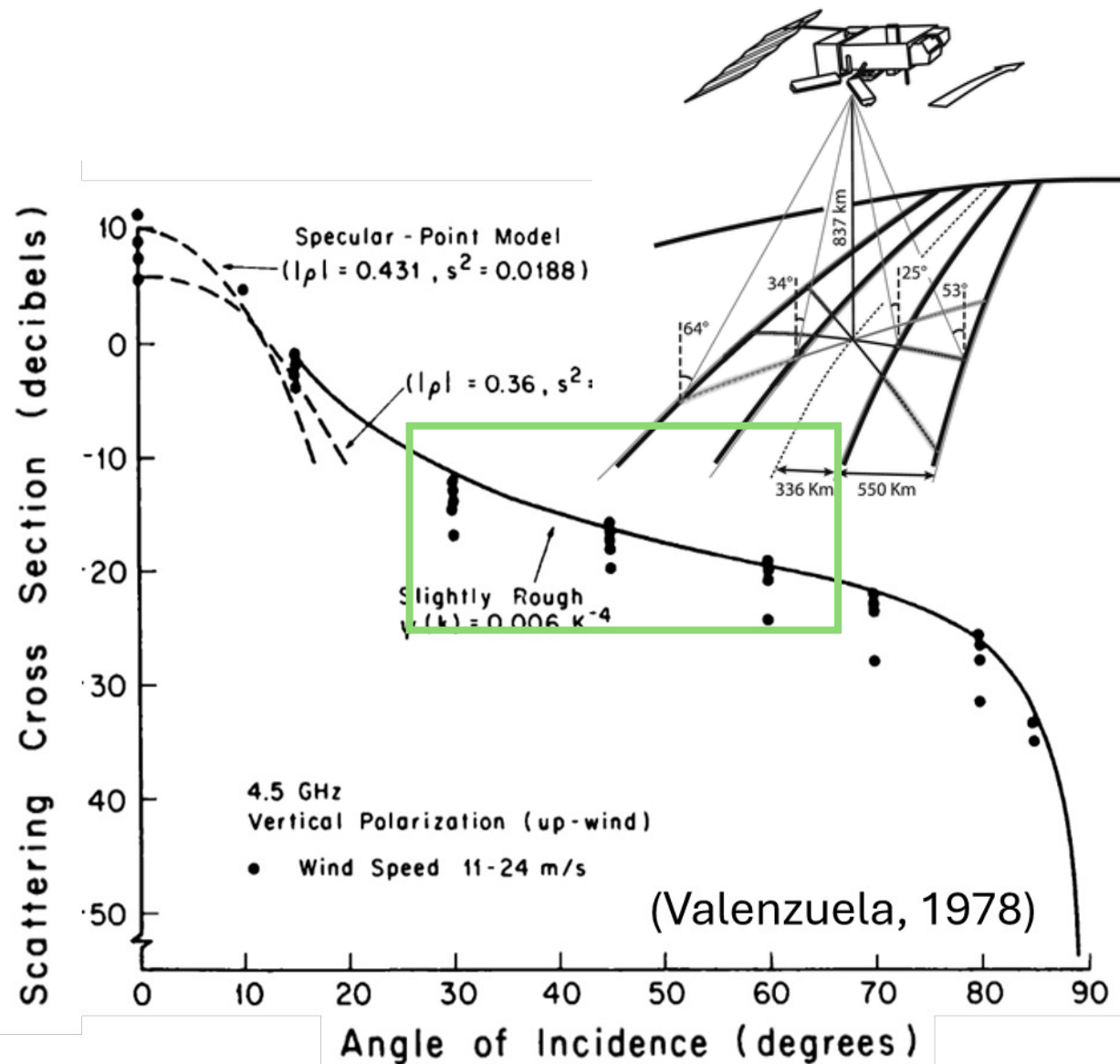
8. Contrast in Median Wind Speed Errors

Variation with Wind Speed: 4 Cases (Northward Wind)



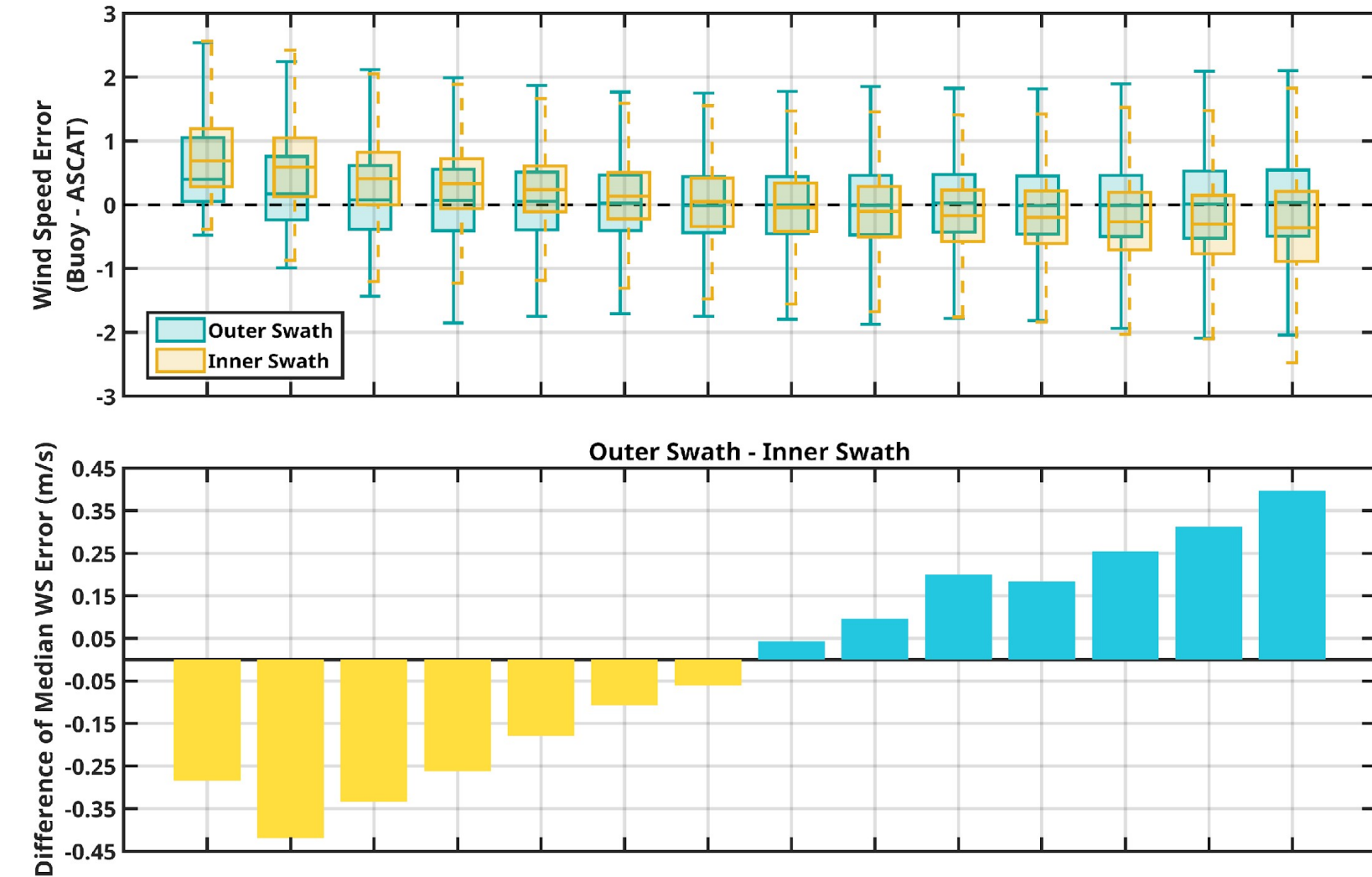
- High swell slopes lower ASCAT winds for 2 configurations

9. Swath Index Dependence of Swell Effects



- The tilting effect of swells travelling perpendicular to the swath (in the range direction) are akin to small local variations in the incidence angle.
- The rate of change of backscatter w.r.t incidence angle (slope) decreases with increasing angle.
- These effects may be larger for the **inner ASCAT swath**.
- The impact of swells travelling along the swath (through tilting or CGW modulation) are more complicated.

10. Swath Index Dependence of Median Wind Speed Errors



- **Inner Swath: Larger Wind Speed Errors** are observed over the inner swath (smaller incidence angles).

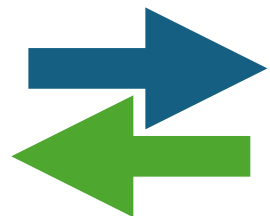
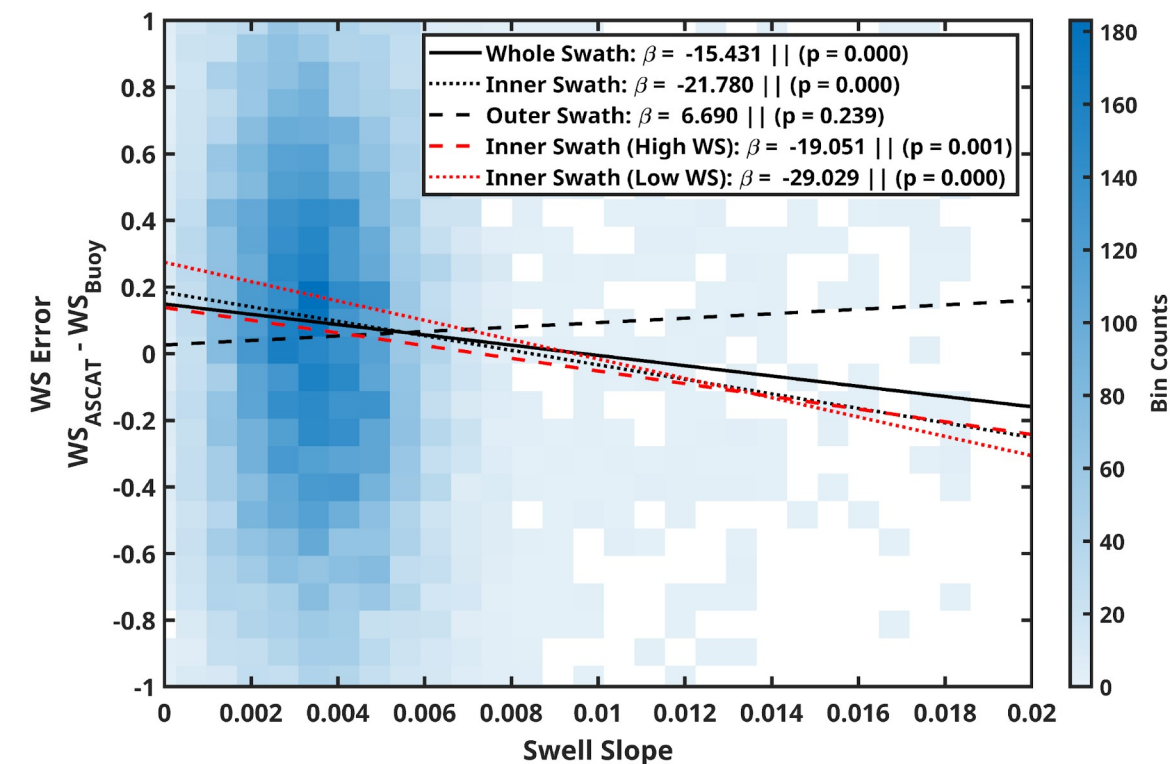
- **Negative Difference**
ASCAT WS are **Low** in the Inner swath for low WS.

- **Positive Difference**
ASCAT WS are **High** in the Inner swath for high WS.

11. Wind Speed Error – Swell Slope Linear

Regression

Swath Index and Wind Speed Dependence (Single Case)



- Assuming a linear relation between Swell Slope and WS Error.

- Negative Regression Slope:**

- Wind Speed Error more negative

- **ASCAT Wind Speed decrease**

- Positive Regression Slope:**

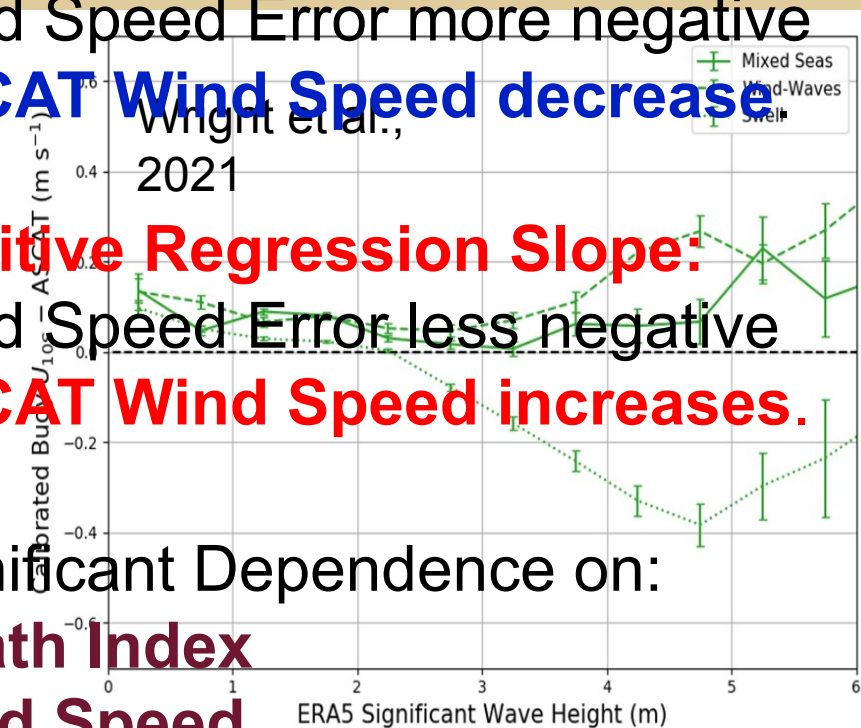
- Wind Speed Error less negative

- **ASCAT Wind Speed increases.**

- Significant Dependence on:

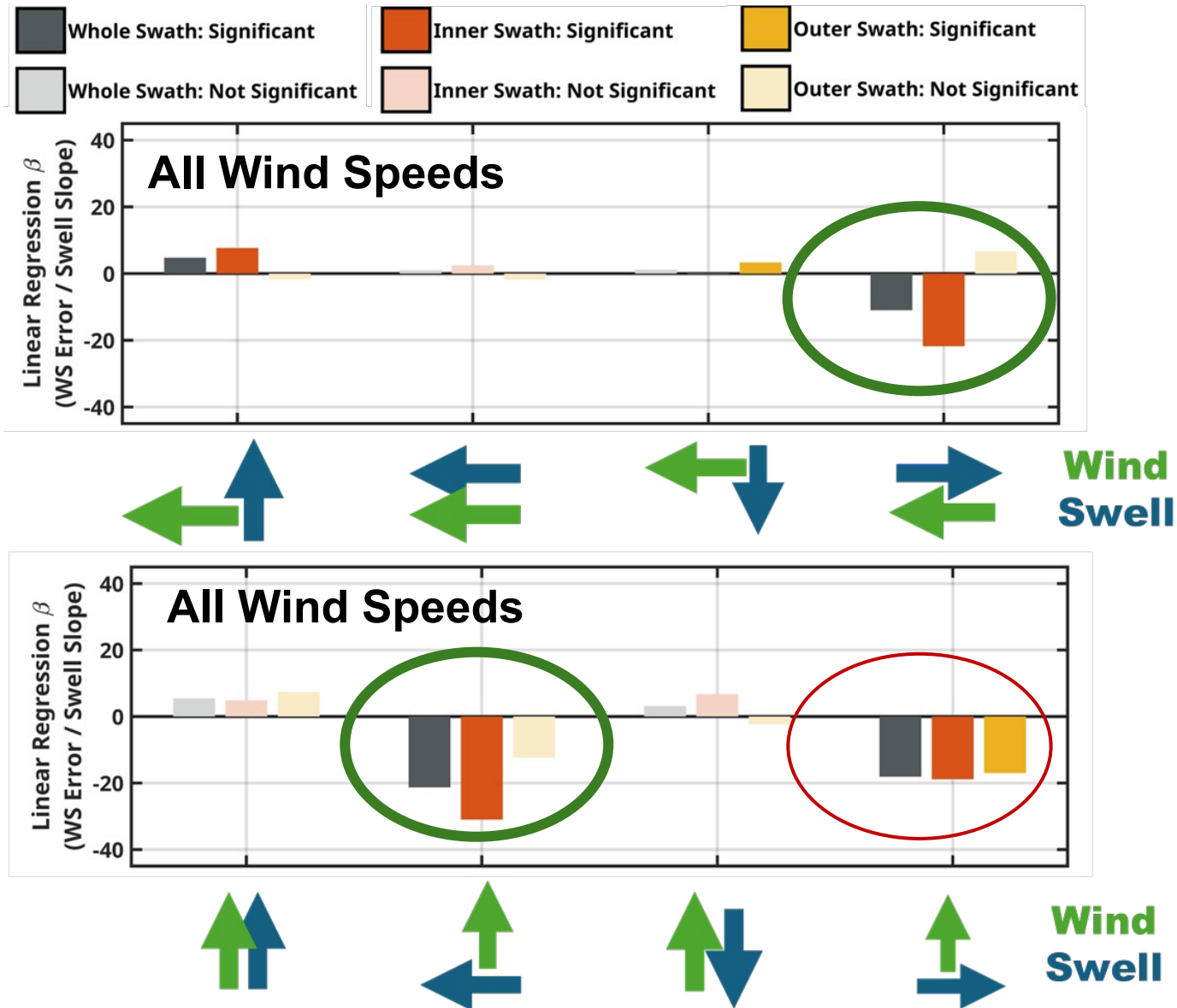
- **Swath Index**

- **Wind Speed**



12. Linear Regression Slope

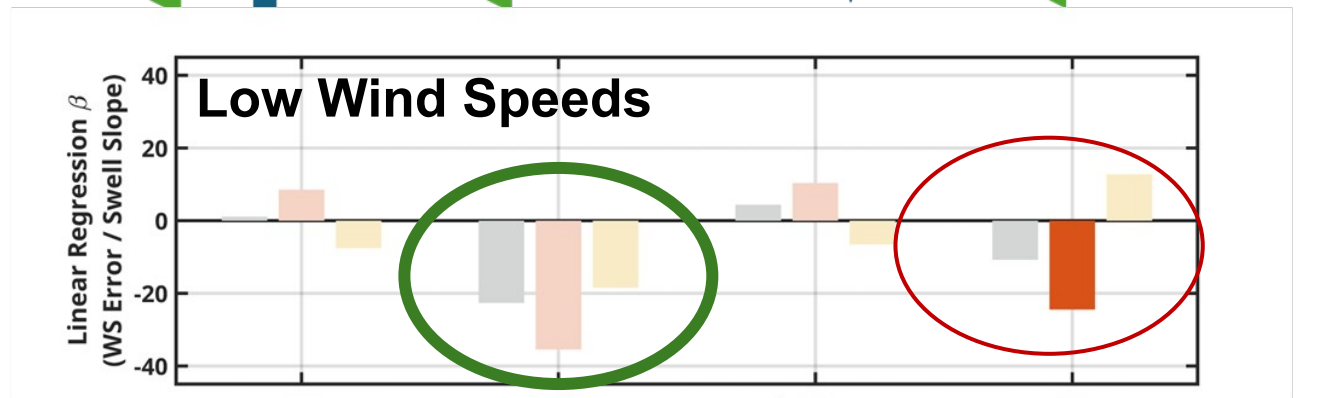
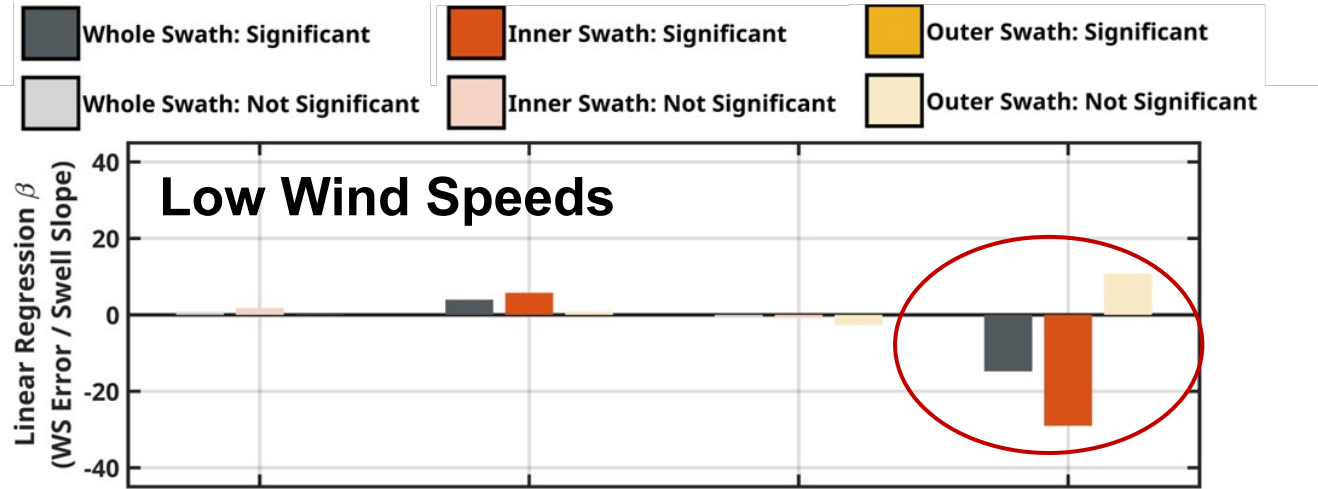
All 8 Cases (All Wind Speeds)



- **Strongest effect:**
 - Swells propagate across the swath.
 - ASCAT Wind Speeds decrease with increasing Swell slope.
- The regression slope (β):
 - **~ 20 m/s / slope**
 - Median **Wind Speed Error** change of **0.2 m/s** at a swell slope of 0.01 (inclination of **0.5 °**)
- **Restricted to the inner swath**
 - In 2 of the 3 cases.
- For all other orientations:
 - The slope is too small/ not significant.

13. Linear Regression Slope

All 8 Cases (Low Wind Speeds)



- **Low Wind Speed (< 6 m/s),**
 - Similar to previous case
 - Except in 1 case (high wind speed effect)
- Stronger Inner Swath effects.
- Selective appearance over the inner swath
 - association with the swell-induced tilt

14. Conclusions

High swell slopes appear to decrease ASCAT retrieved WS selectively at

- ▢ **Low WS**
- ▢ **Swells propagating perpendicular to the swath**
- ▢ **Low Incidence Angles**

A bias of around **0.2 m/s** in Wind Speed errors can be introduced due to reasonably high swell slopes (of around 0.01), depending on the Wind-Swell alignment.

- ▢ This error is small enough to neglect for geophysical applications (e.g., while investigating swell-wind feedback).
- ▢ This error is larger than scatterometer retrieval accuracies, and eliminating it can improve the accuracy of scatterometers.

Hypothesis:

Swells propagating perpendicular to the ASCAT swath lowers ASCAT observed WS likely through local changes in the incidence angle. It may be possible to account for this error in wind retrieval.