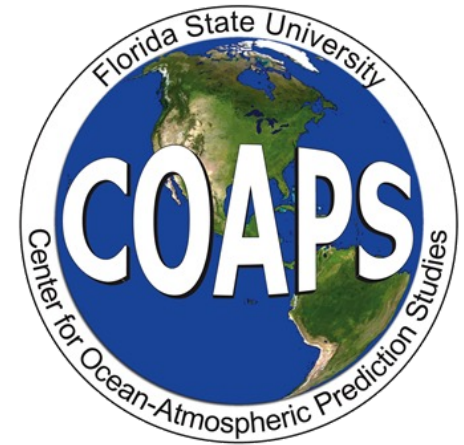


Swell Modulation of Scatterometer Wind Speed Observations

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1. Introduction

- The impact of swell on scatterometer backscatter holds relevance from the perspective of **geophysical applications** and **scatterometer calibration**.
- As scatterometers continue to get more accurate, swell-related effects are likely to become more prominent.

Questions:

- **Do swells impact scatterometer wind retrieval?**
- **How do such effects depend on the mutual alignment between winds and swell?**
- **Are these effects larger than the typical uncertainty?**

Swell
 $\lambda \sim O(100 \text{ m})$

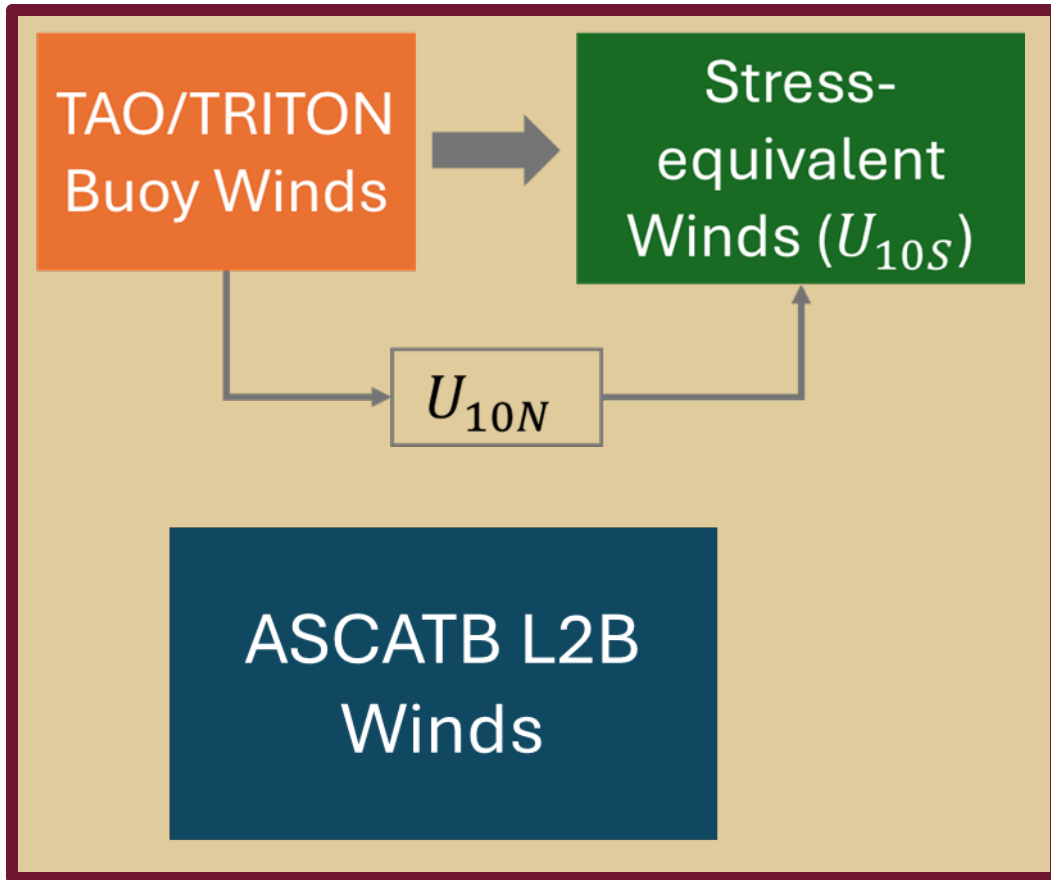


Capillary Gravity Waves
 $\lambda \sim O(1 \text{ cm})$

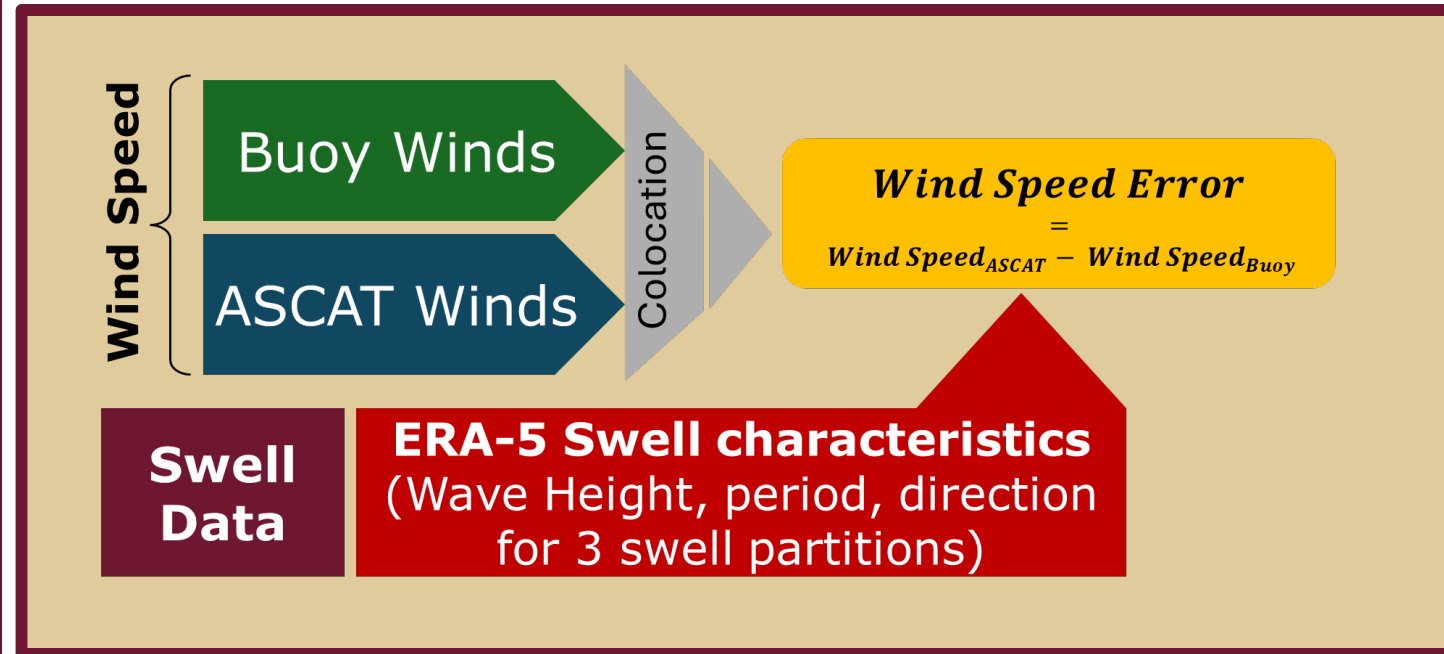


2. Data & Methods

Data



Overview of Methods

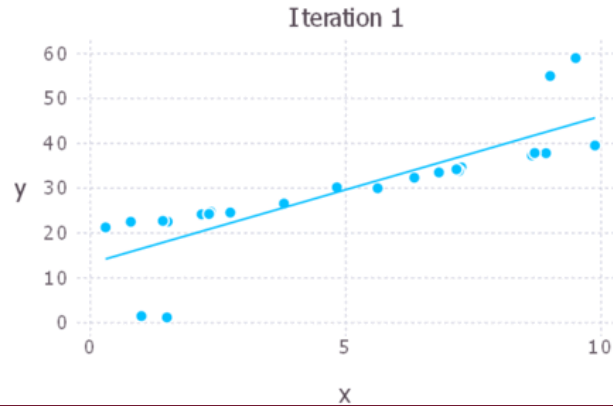


2. Data & Methods

$$U_{10|ASCAT} - U_{10|Buoy} = \text{Wind Speed Error}$$

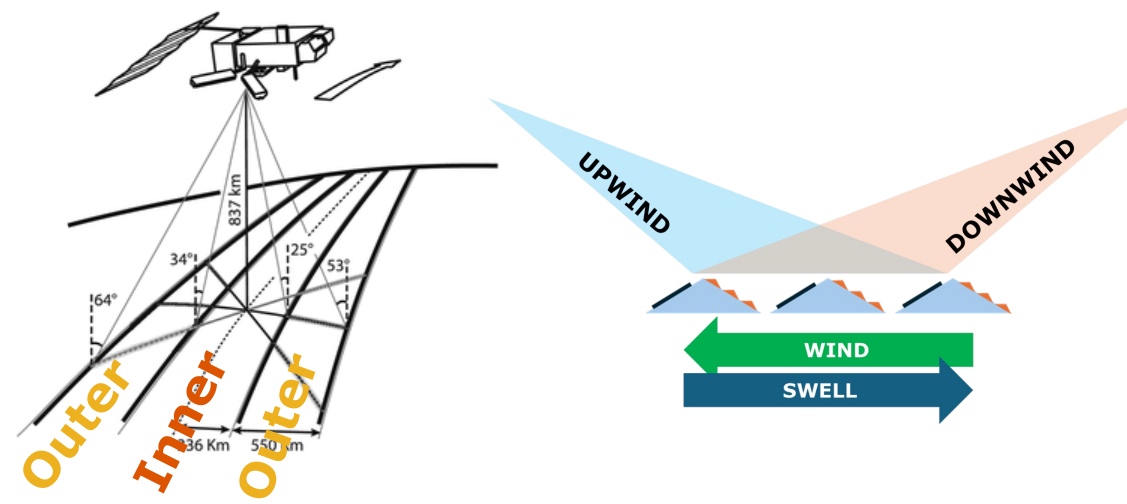
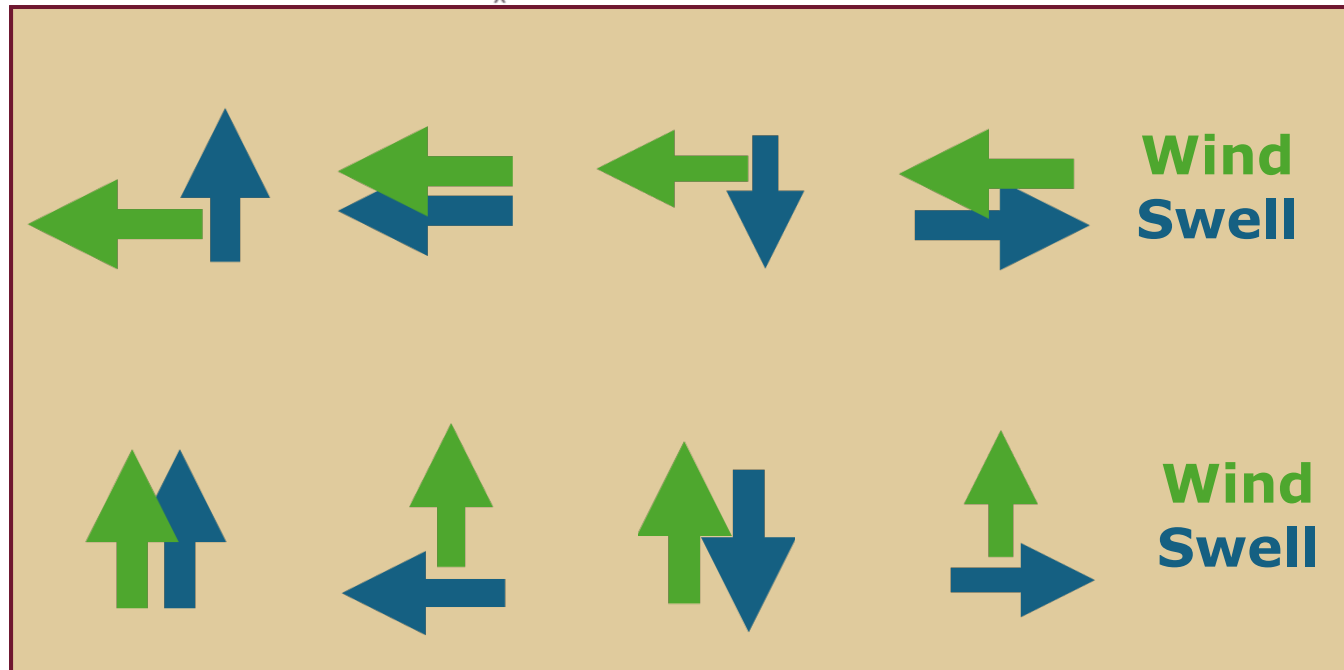
$$= \alpha + \beta_1 \times \text{Swell Slope} + \beta_2 \times U_{10|Buoy}$$

Iteratively Reweighted Least-Squares



<https://www.sebastiansylvan.com/post/robustestimation/>

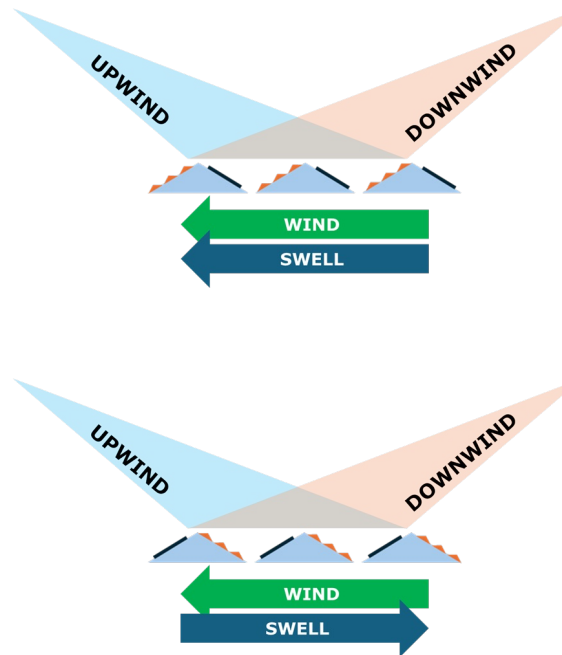
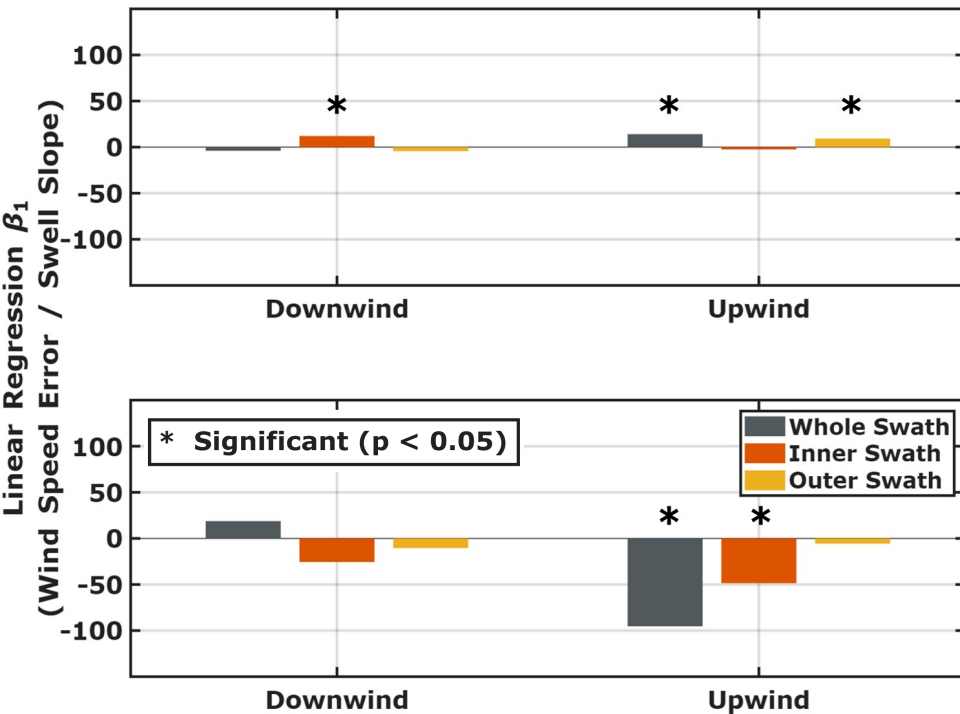
Wind Speed	Linear wind speed dependence removed
Wind-Swell Orientation	Segregation by relative orientations
Incidence Angle	Segregation by inner/outer swath (WVC number)
Upwind/Downwind Asymmetry	Segregated for some wind-swell orientations
Azimuthal Angle	Not segregated as L2B Winds are used



3. Upwind-Downwind Asymmetry

$$U_{10|ASCAT} - U_{10|Buoy} = \text{Wind Speed Error}$$

$$= \alpha + \beta_1 \times \text{Swell Slope} + \beta_2 \times U_{10|Buoy}$$



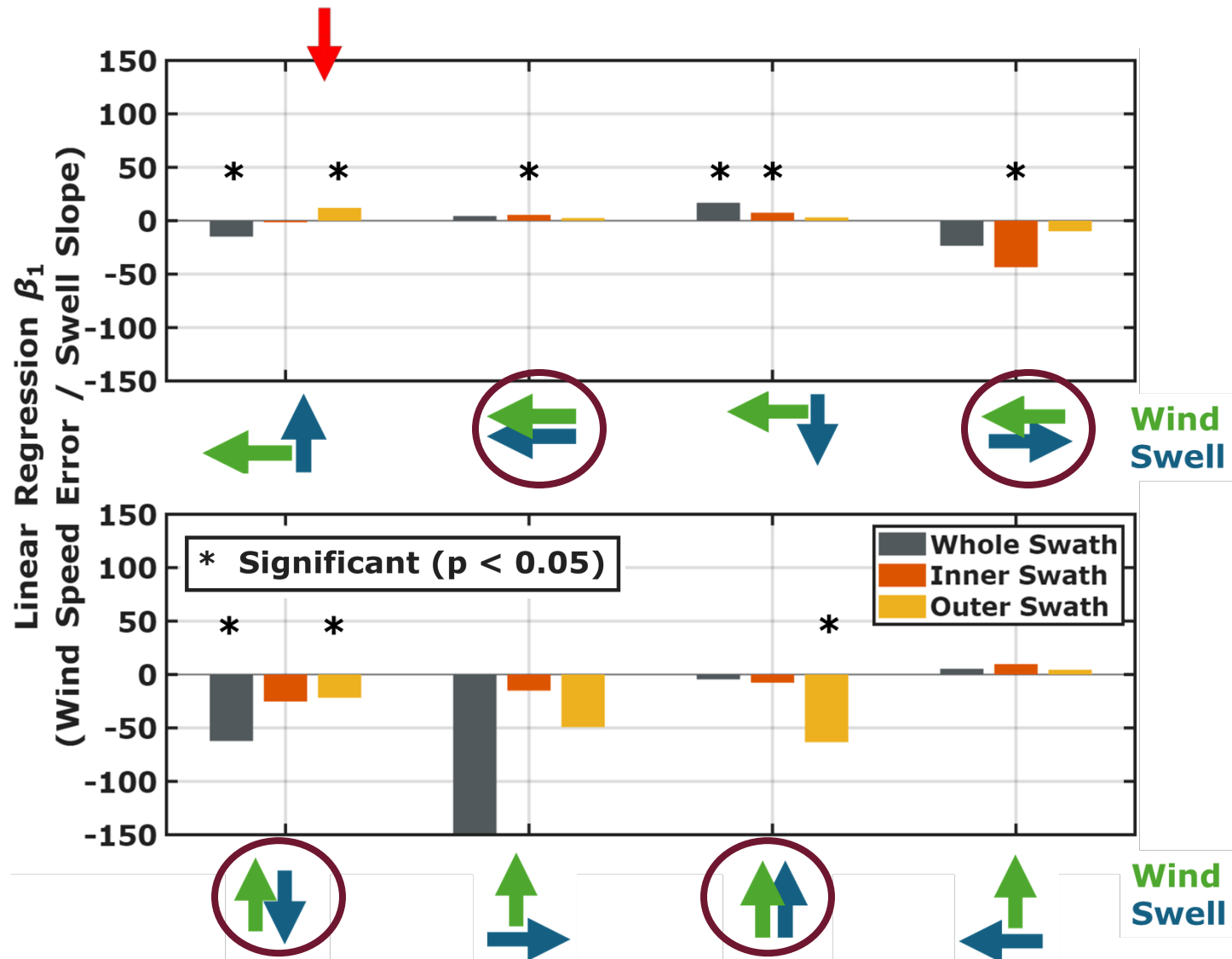
β_1	48.43 m/s / swell slope
Wind Speed Error ($\beta_1 \times \text{Swell Slope}$)	0.58 m/s

- Strongest swell sensitivity: **westward winds + eastward swells (inner swath)**
 - ASCAT wind speed estimates decrease by **0.58 m/s** at moderately high swell slopes
- Large positive sensitivities are absent
 - **Net swell effect can be predominantly negative.**

4. Swell-sensitivity for all Wind-Swell Orientations

$$U_{10|ASCAT} - U_{10|Buoy} = \text{Wind Speed Error}$$

$$= \alpha + \beta_1 \times \text{Swell Slope} + \beta_2 \times U_{10|Buoy}$$



- Largest swell sensitivity:
 - Are **negative**
 - Occur for **Parallel winds and swells**

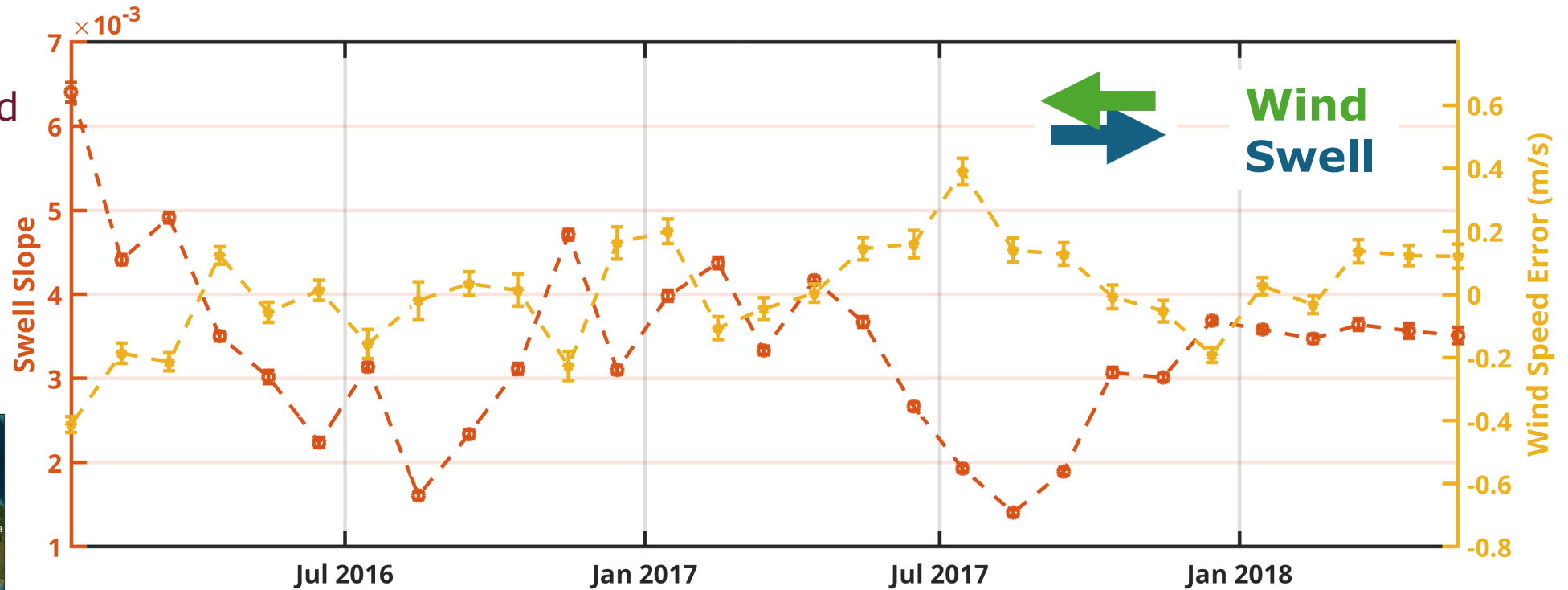
- The three strongest cases:

Wind/Swell Orientation	Wind Speed Error ($\beta_1 \times \text{Swell Slope}$)
	0.75 m/s
	0.52 m/s
	0.26 m/s

- Broadly consistent with theories of swell-driven roughness modulation (cosine dependence, Smith, 1986)

5. Temporal Covariability of Swell and Wind Speed Error

Considering winds and swells of appropriate directions.



- Consistent with the regression-based swell sensitivity** shown earlier:
- Monthly mean variations in **swell slope** and **ASCAT wind speed error** (considering specific directions) are significantly correlated in this configuration with a correlation coefficient of **-0.57** ($p \approx 10^{-4}$).
 - Periods of **steeper swells** coincide with **more negative ASCAT wind speed errors**.

6. Conclusions

- **Swell can measurably affect ASCAT wind speed estimates for specific wind-swell orientations, but these effects disappear when averaged over all orientations.**
- The strongest swell effects occur when **winds and swells are nearly parallel** and lowers ASCAT wind speed estimates by **0.26 – 0.75 m/s**.
- The pattern is most consistent with a swell sensitivity **driven primarily by capillary-gravity wave modulation** following a cosine dependence on the wind-swell relative angle.

Future work:

1. Explore simple swell-dependent adjustments to scatterometer wind speeds and wind vectors
2. Repeat the analysis for other satellite wind sensors (including radiometers like COWVR) to better characterize the swell sensitivity of surface roughness and probe the physical mechanisms underlying swell-driven stress variations.

Sources and References

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