Estimating wind direction with SWOT backscatter

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Wind over lakes

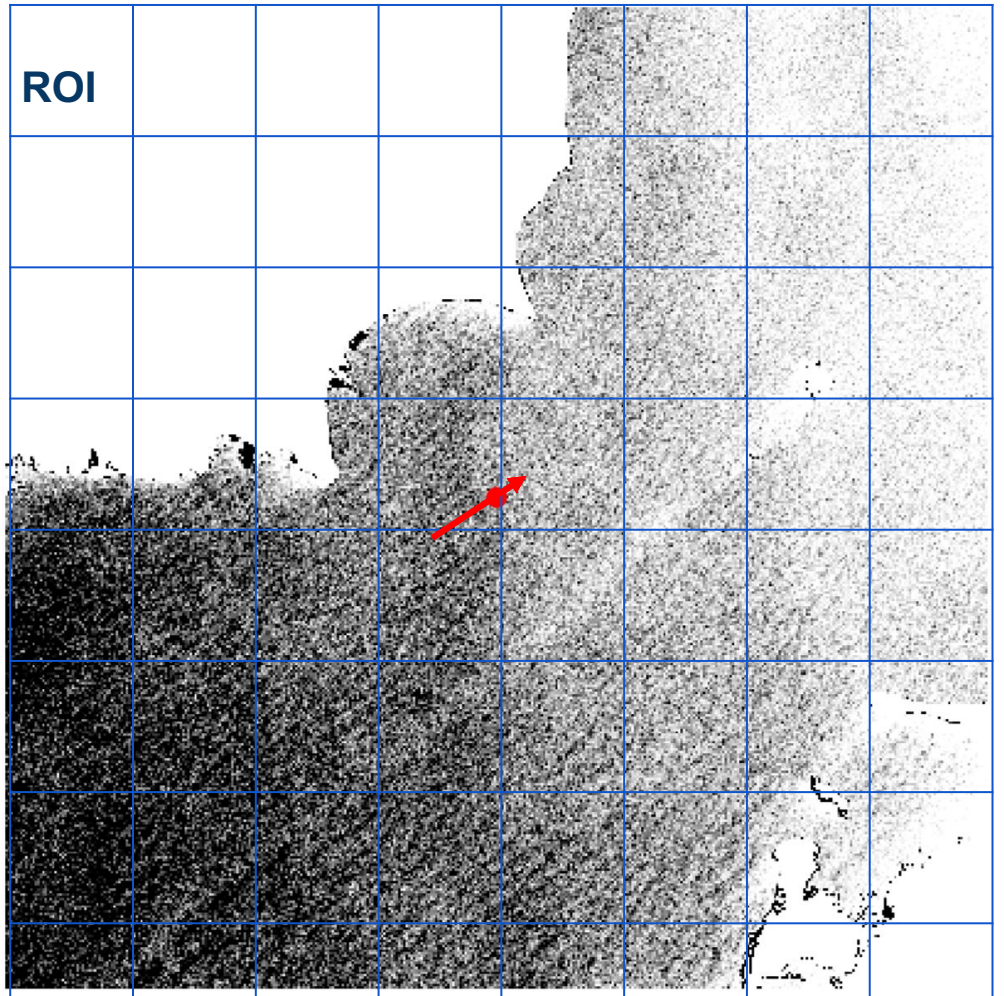
- Wind is an important driver of lake evaporation [1].
- While wind can be extracted from reanalysis datasets, the resolution is often coarser than lake size.
- SWOT KaRIn backscatter (sigma0) observes wind-driven surface water roughness, and could be used to develop a wind speed model for lakes (ongoing work from Jessica Fayne's group) [2].
- Wind direction is required to estimate wind speed from SAR [3].

https://www.tahoedailytribune.com/news/wind-warmth-have-led-to-more-than-expected-evaporation-at-lake-tahoe/

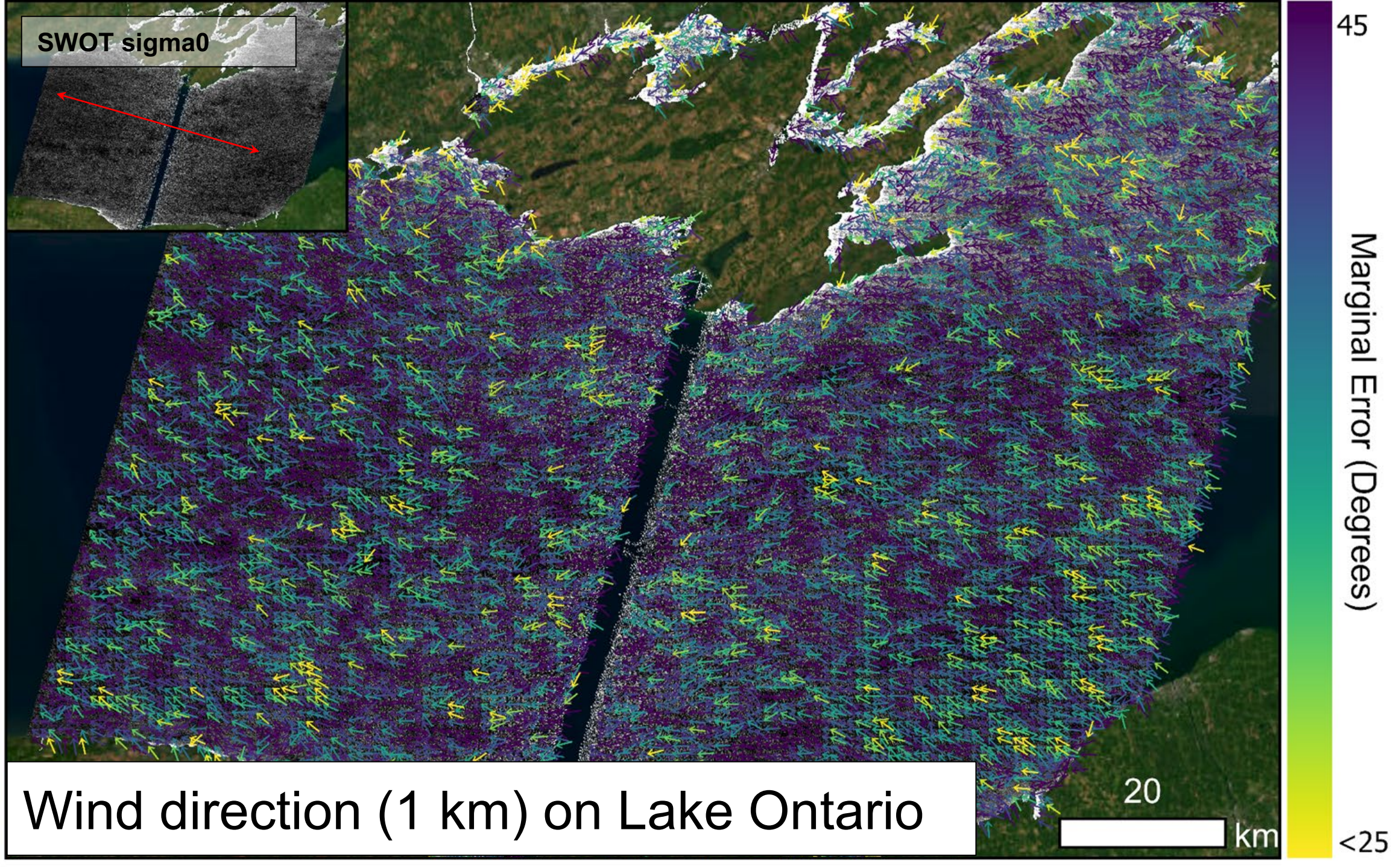
Use wind streaks to estimate wind direction from SWOT

- Estimate wind direction and marginal error (ME) from wind streaks using the Modified Local Gradient method [3] at 1 km resolution.
  - Subset the lake into ROIs of desired size (1 km)
  - Calculate local gradients within each ROI and use to estimate wind direction and ME
  - ME is a function of the local directions alignment within the ROI.
  - **Smaller ME = more reliable wind direction estimate**
- Test method using sigma0 from SWOT Level 2 Water Raster Image Data Product 2.0 (100m)

Ex. of wind streaks on Lake Huron

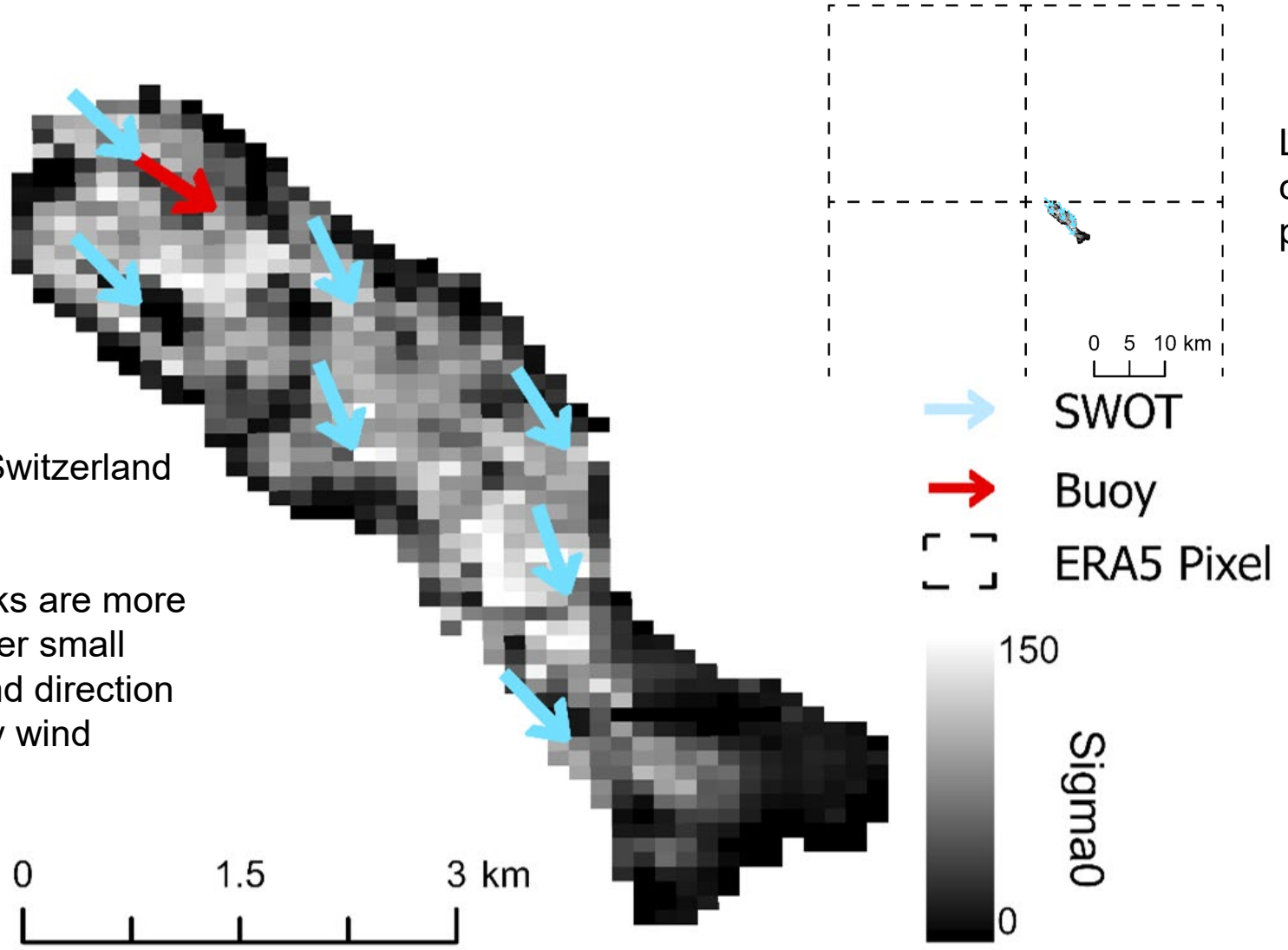


Example of wind streaks oriented NE-SW visible in Sentinel-1 radar backscatter over Lake Huron. The red arrow represents buoy wind direction at 56 degrees, aligning with the wind streaks.



Wind direction (1 km) on Lake Ontario

SWOT estimated wind direction at much higher resolution than global reanalysis dataset, ERA5



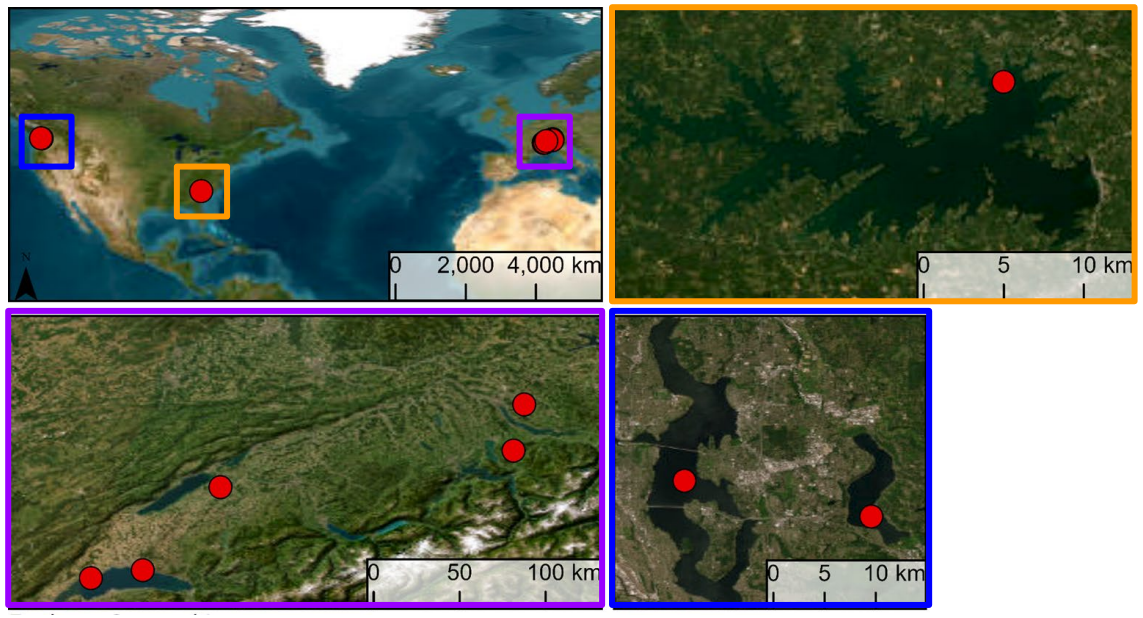
Lake Greifen in Switzerland (7.86 km^2).

While wind streaks are more difficult to see over small lakes, SWOT wind direction aligned with buoy wind direction

Lake Greifen compared to ERA5 pixels (0.25 degrees)

Wind direction validation using over-water buoys

Buoy locations in US and Switzerland (N=8, 7-58 km^2)



Compare performance stats of SWOT with ERA5 (180 degree ambiguity)

Image Subset	Number of images	LG-Mod MAE (degrees)	ERA5 MAE (degrees)
SWOT	70	37.72	39.58
SWOT (ME < 40)	32	36.48	40.99
SWOT (ME < 30)	24	34.78	40.32
SWOT (ME < 20)	10	28.13	50.38

- Wind direction estimated using SWOT had lower error compared to ERA5
- SWOT wind direction error improved after discarding estimates with high marginal error

Preliminary takeaways

- Wind direction from SWOT was more accurate and higher resolution compared to frequently used global ERA5 dataset.
- Expand analysis to include additional buoys for more robust validation.

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Citations

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2. Fayne, J. V., & Smith, L. C. (2023). How Does Wind Influence Near-Nadir and Low-Incidence Ka-Band Radar Backscatter and Coherence from Small Inland Water Bodies? Remote Sensing, 15(13), Article 13. https://doi.org/10.3390/rs15133361
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