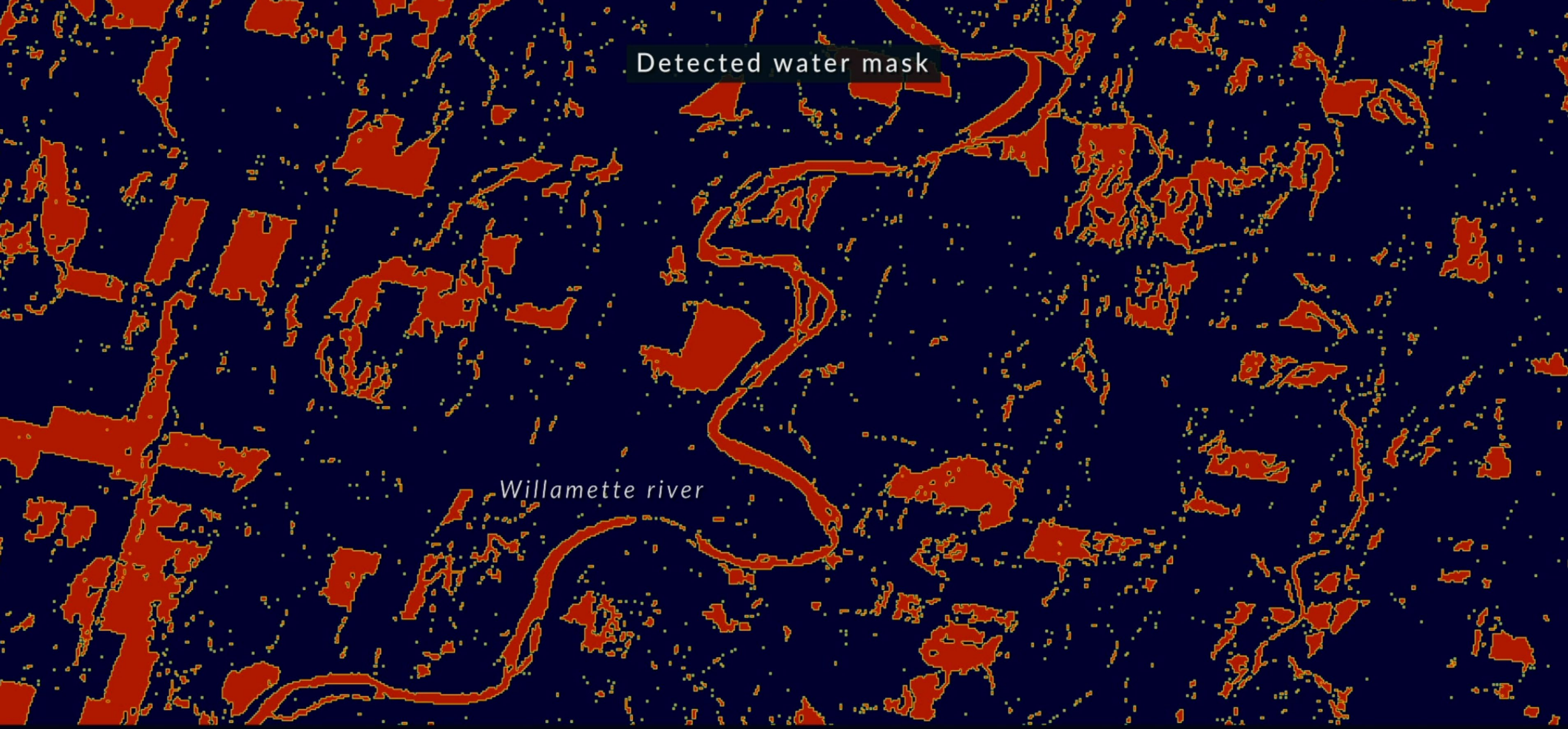
SWOT Ka-band Scattering Phenomenology

Lake Winds, Vegetation and Surface Moisture

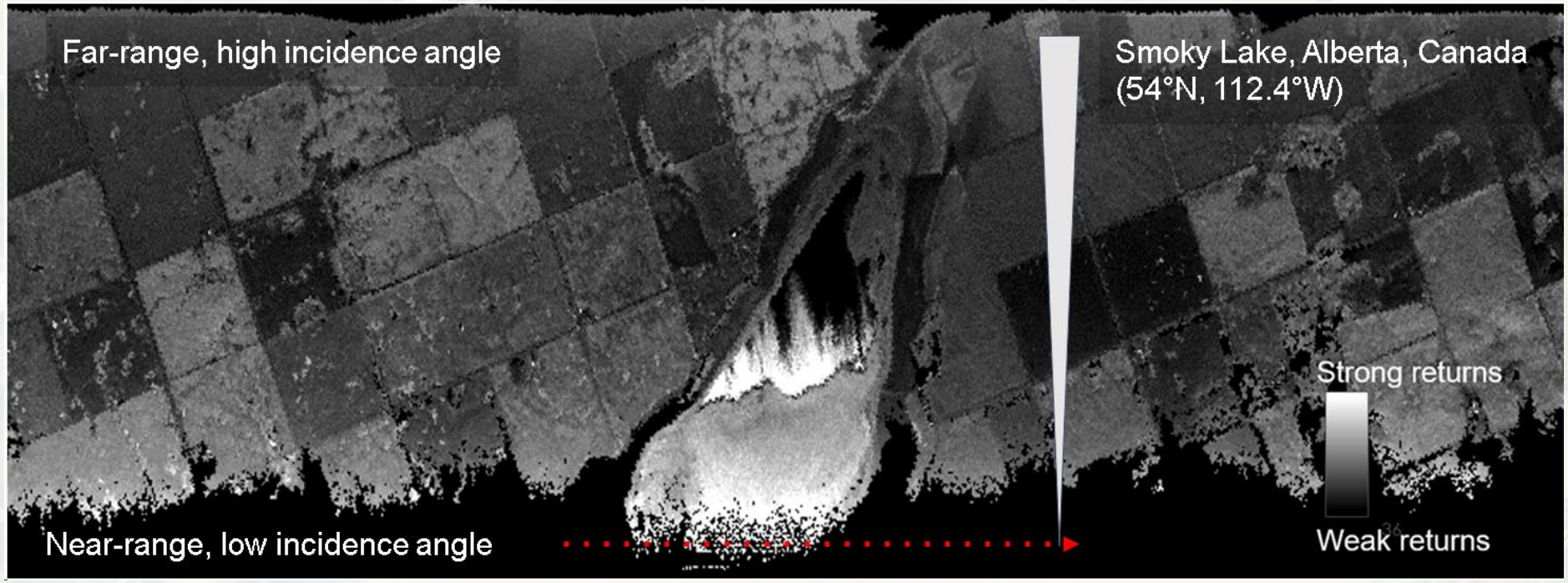
Jessica Fayne
Site suggestions from Clara Chew and Luciana Fenoglio
Waveform analysis by Duncan Jurayj

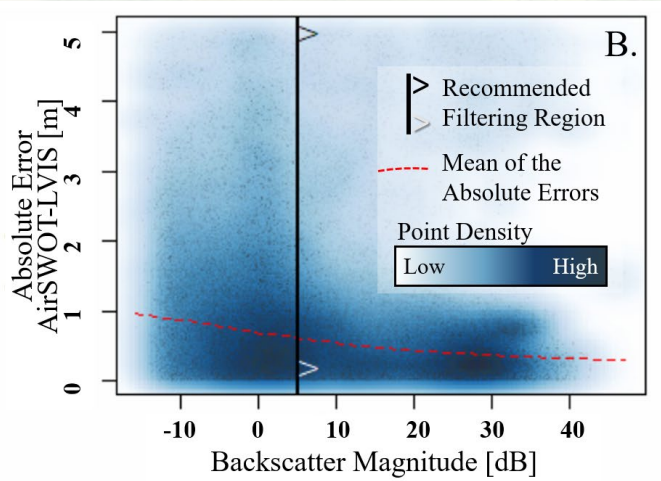


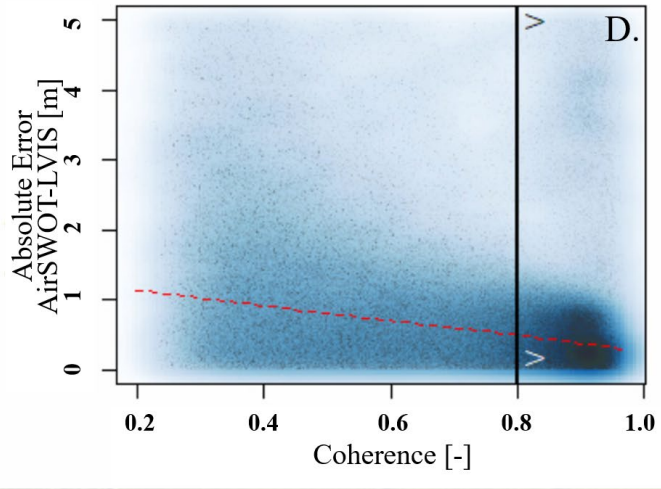
HYDROLOGY - USA

SWOT detects the Willamette River, also bright crop fields due to wet soil.
This may lead to over-detection of water.

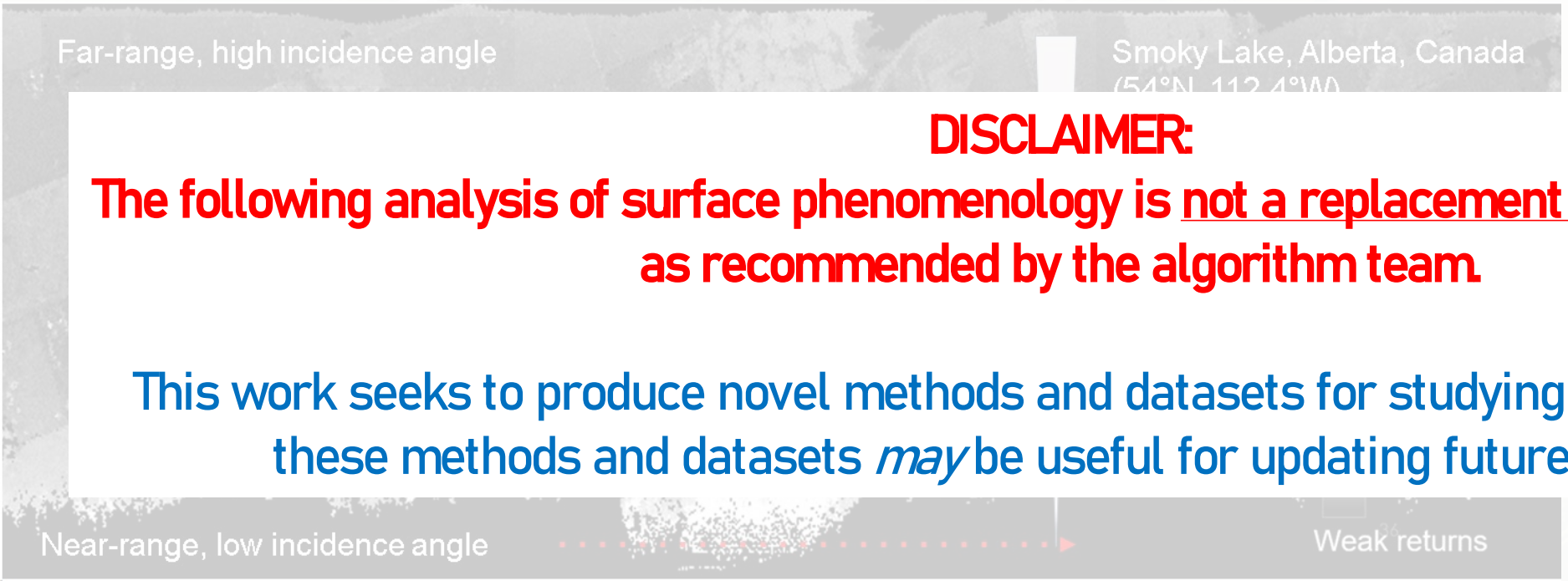
SWOT and AirSWOT SAR backscatter (sigma0) observations can be used to help:
1) Quantify uncertainties in SWOT water surface elevations and water surface extents
2) Produce new and dynamic wind, moisture, and vegetation products for lakes and wetlands

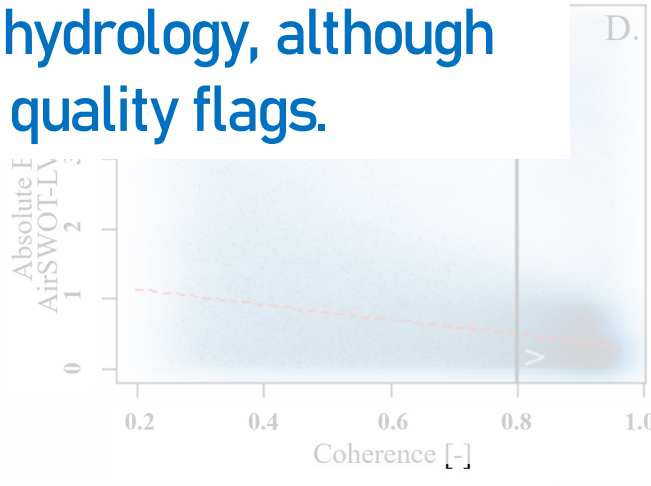






^^ **Fayne, & Smith** 2023. *MDPI RS.*
Fayne, JV et al. 2020. *ERL. >>*



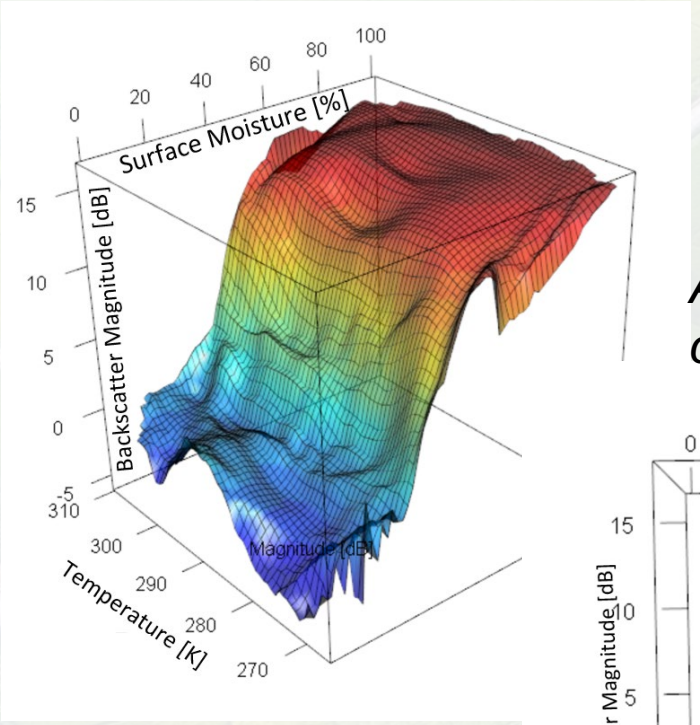


DISCLAIMER:

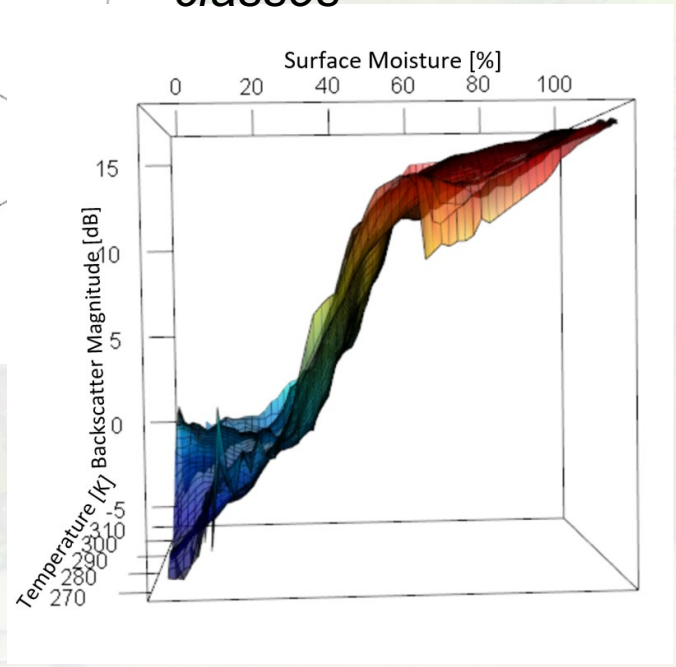
The following analysis of surface phenomenology is not a replacement for using quality flags as recommended by the algorithm team.

This work seeks to produce novel methods and datasets for studying hydrology, although these methods and datasets *may* be useful for updating future quality flags.

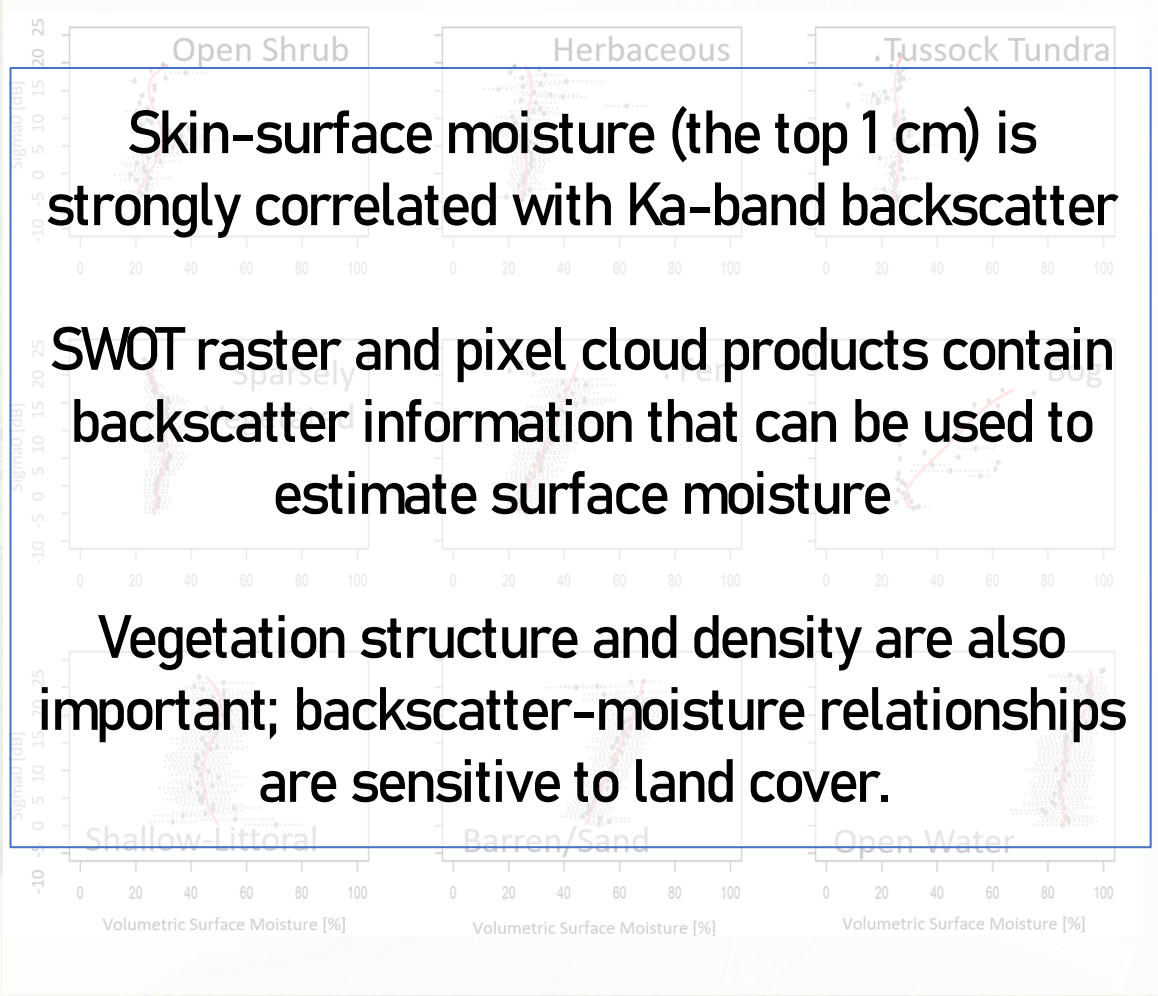
^^ **Fayne, & Smith** 2023. *MDPI RS.*
Fayne, JV et al. 2020. *ERL.* >>



All land cover classes



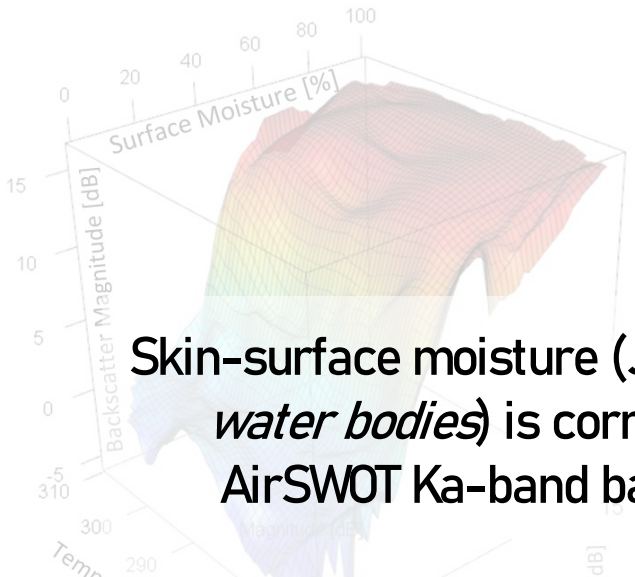
Fayne, JV et al. 2021. *IEEE IGARSS Proceedings 2021.*



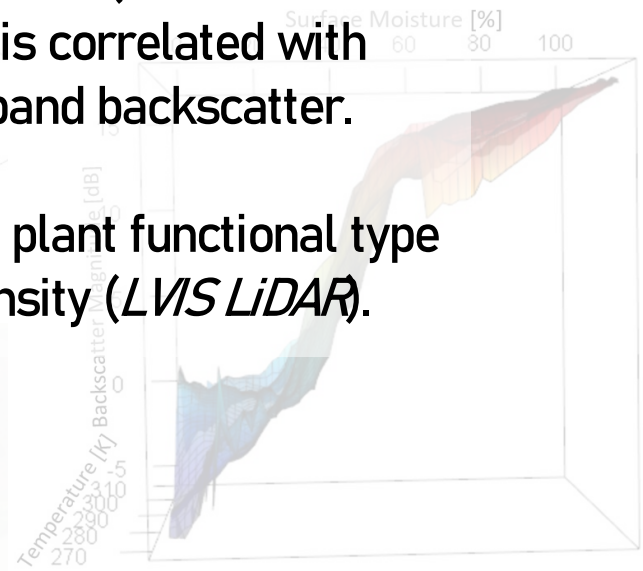
Skin-surface moisture (the top 1 cm) is strongly correlated with Ka-band backscatter

SWOT raster and pixel cloud products contain backscatter information that can be used to estimate surface moisture

Vegetation structure and density are also important; backscatter-moisture relationships are sensitive to land cover.



All land cover classes

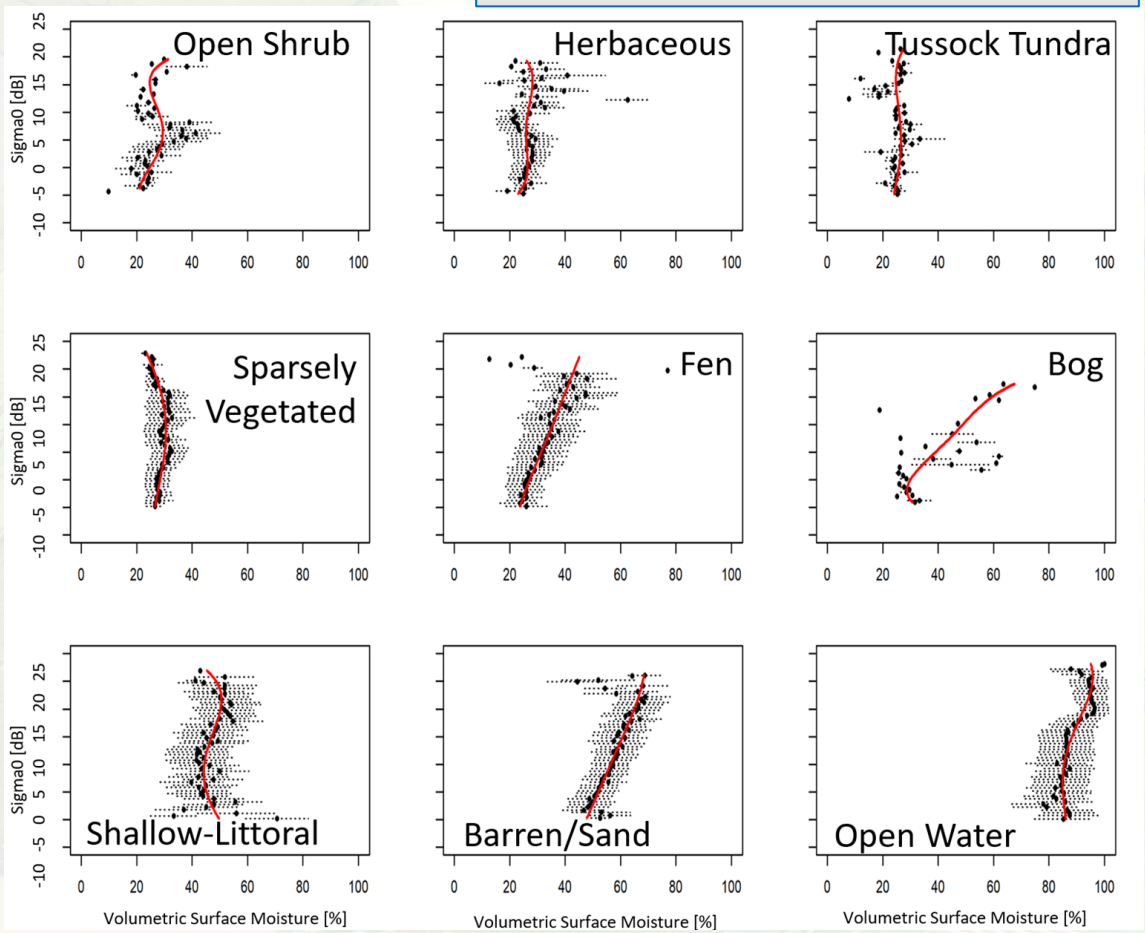


Skin-surface moisture (*SMOPS + added water bodies*) is correlated with AirSWOT Ka-band backscatter.

Trends depend on plant functional type and foliage density (*LVIS LiDAR*).

Fayne, JV et al. 2021. *IEEE IGARSS Proceedings 2021.*

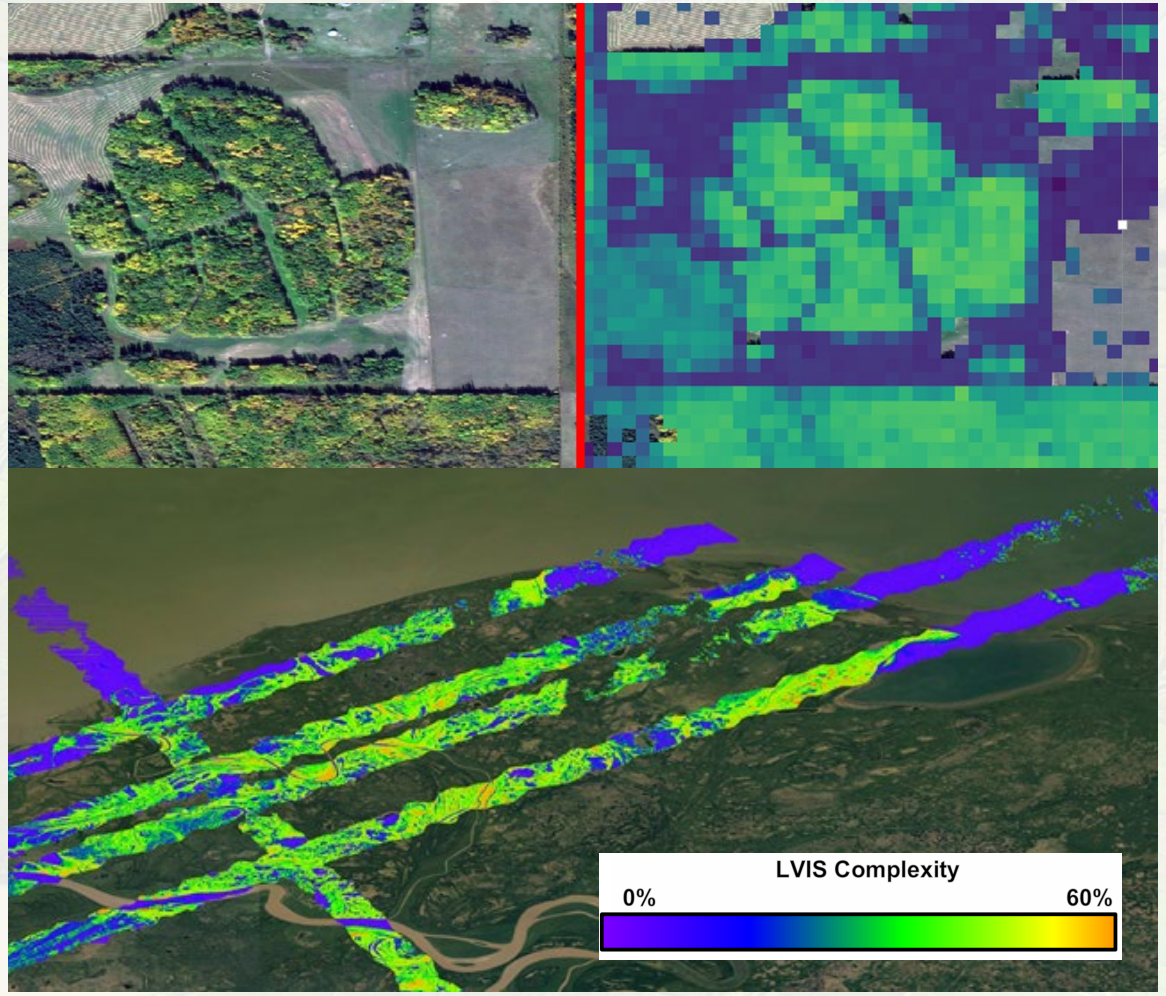
Fayne, JV et al. 2023. *IEEE JSTARS*



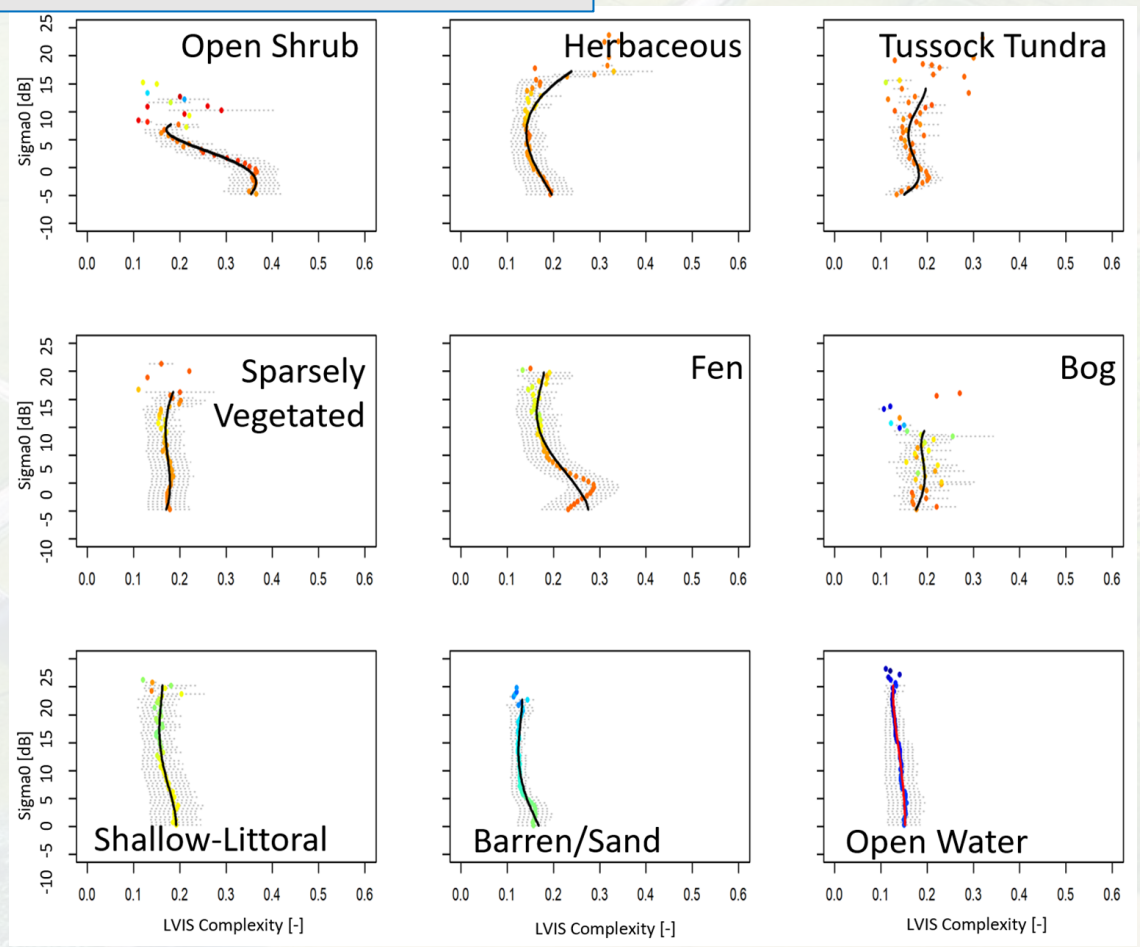
Vegetation structure maps from LiDAR are useful for quantifying vegetation health and change.

An example vegetation structure metric is “Complexity” from LVIS LiDAR.

LiDAR data at the resolution necessary to quantify small branches and leaves is not globally available.



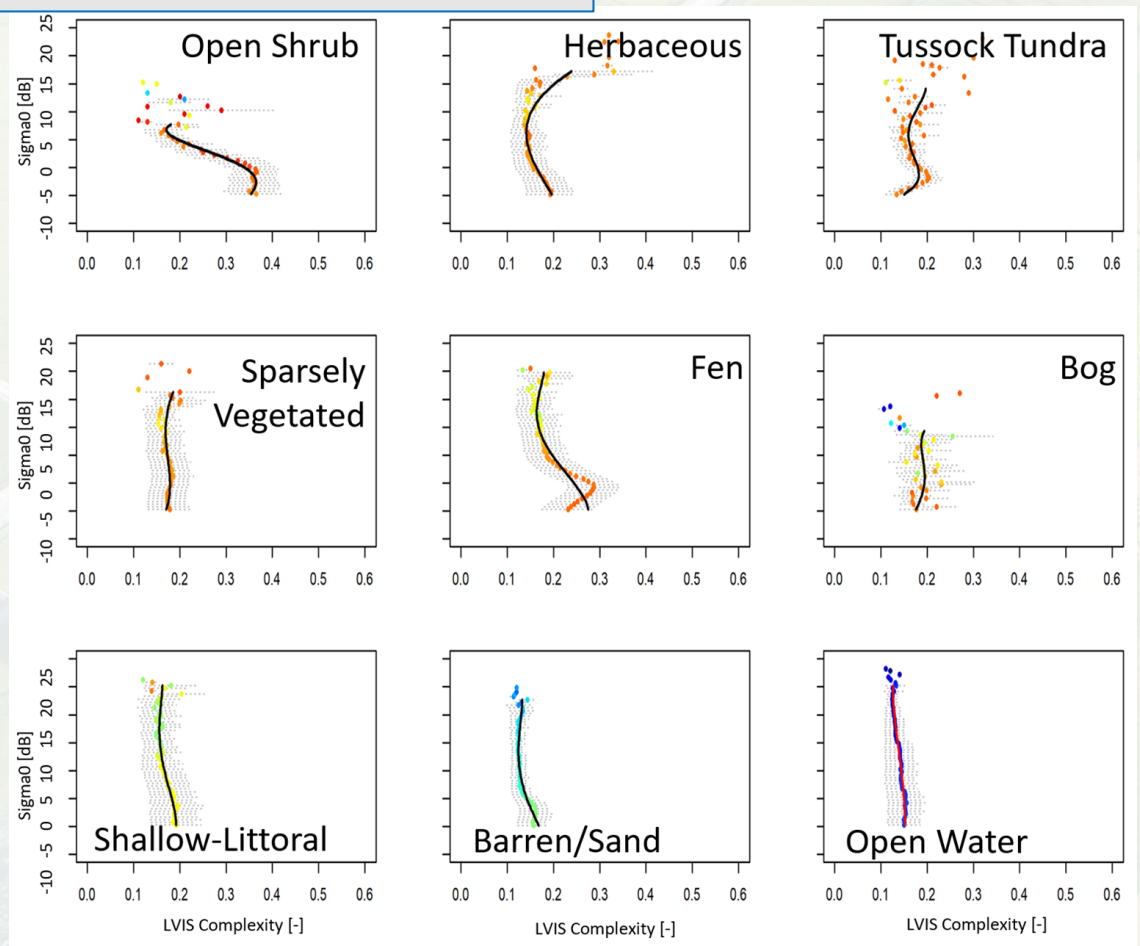
Fayne, JV et al. 2023. *IEEE JSTARS*



The Ka-band signal is sensitive to variations in vegetation structure (LVIS LiDAR Complexity).

Decreases in backscatter with increasing vegetation structure suggests some of the radar signal is lost in dense canopies.

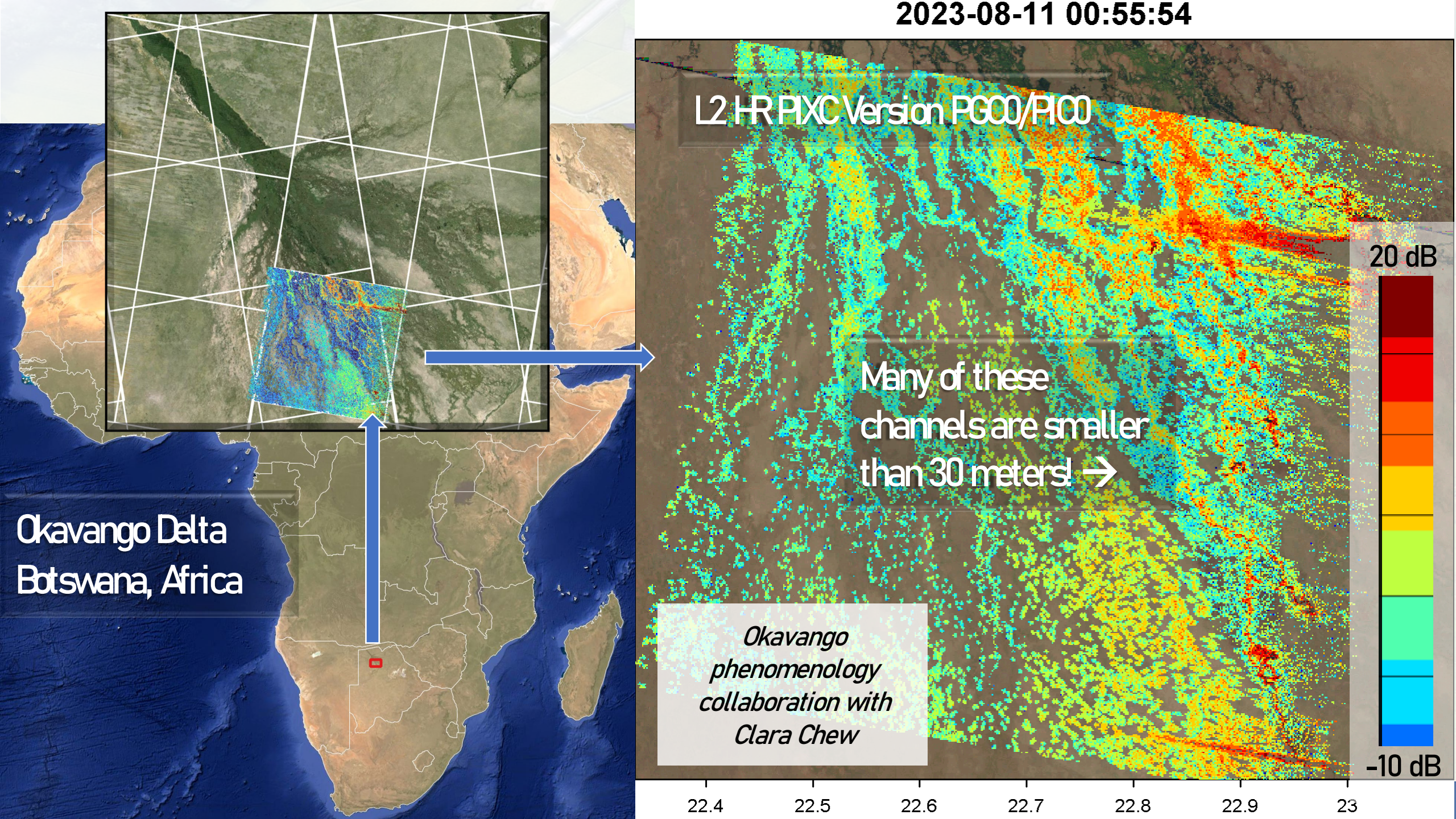
Fayne, JV et al. 2023. *IEEE JSTARS*



SWOT raster and pixel cloud products contain backscatter information that can be used to estimate surface moisture and vegetation structure.

Polynomial equations have been defined to describe the relationships between backscatter and moisture, and backscatter and vegetation structure.

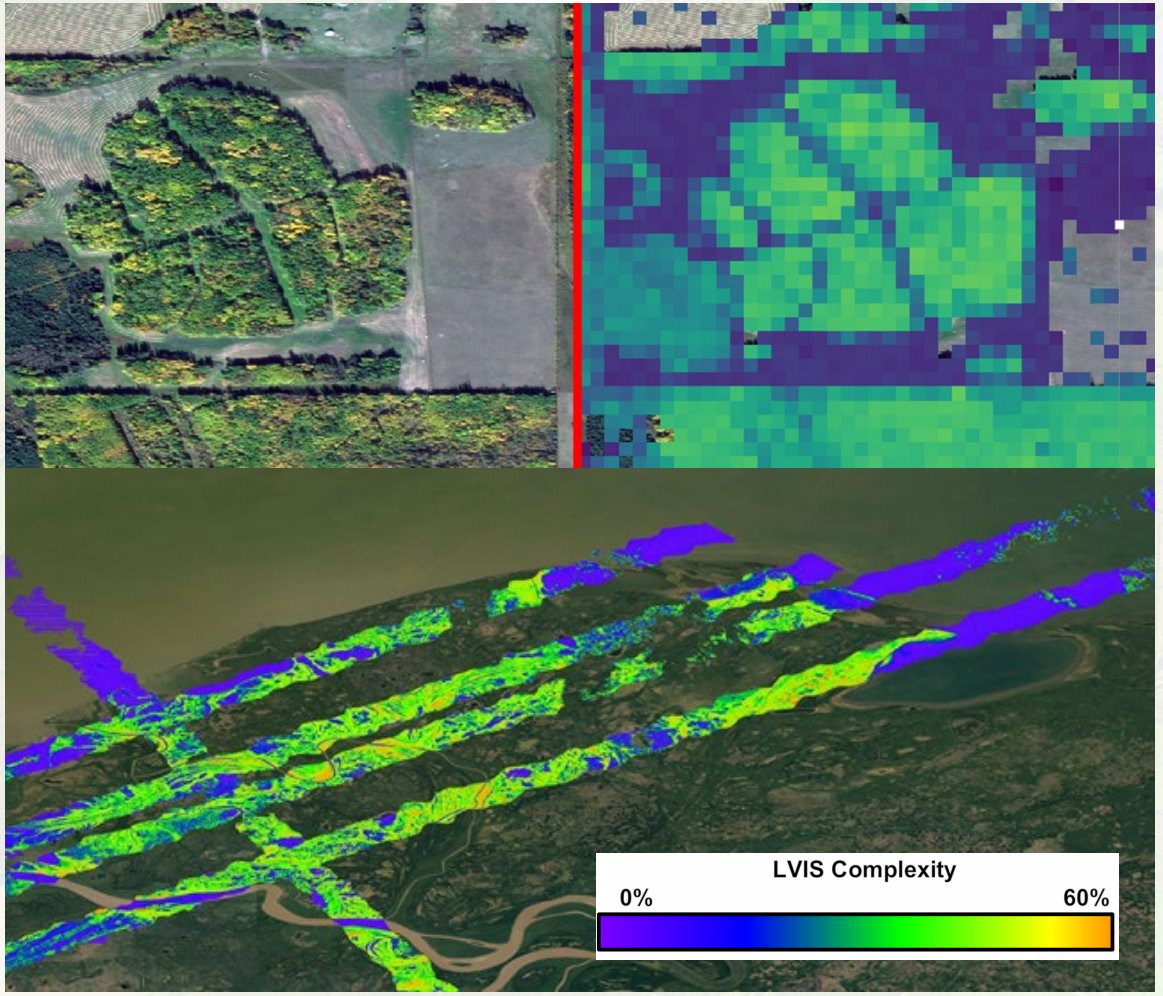
These equations, combined with land cover and incidence angle comprise the **Ka-band Phenomenology Scattering Model (KaPS)**


2023-08-11 00:55:54
L2 HR PIXC Version PGC0/PIC0
20 dB
-10 dB
Many of these channels are smaller than 30 meters! →
Okavango phenomenology collaboration with Clara Chew
Okavango Delta Botswana, Africa
22.4
22.5
22.6
22.7
22.8
22.9
23

The vegetation structural metric of interest is “Complexity” from LVIS LiDAR.

Research on AirSWOT vegetation structure relied on near-coincident airborne LIDAR from LVIS.

LiDAR data at the resolution necessary to quantify small branches and leaves is not globally available.



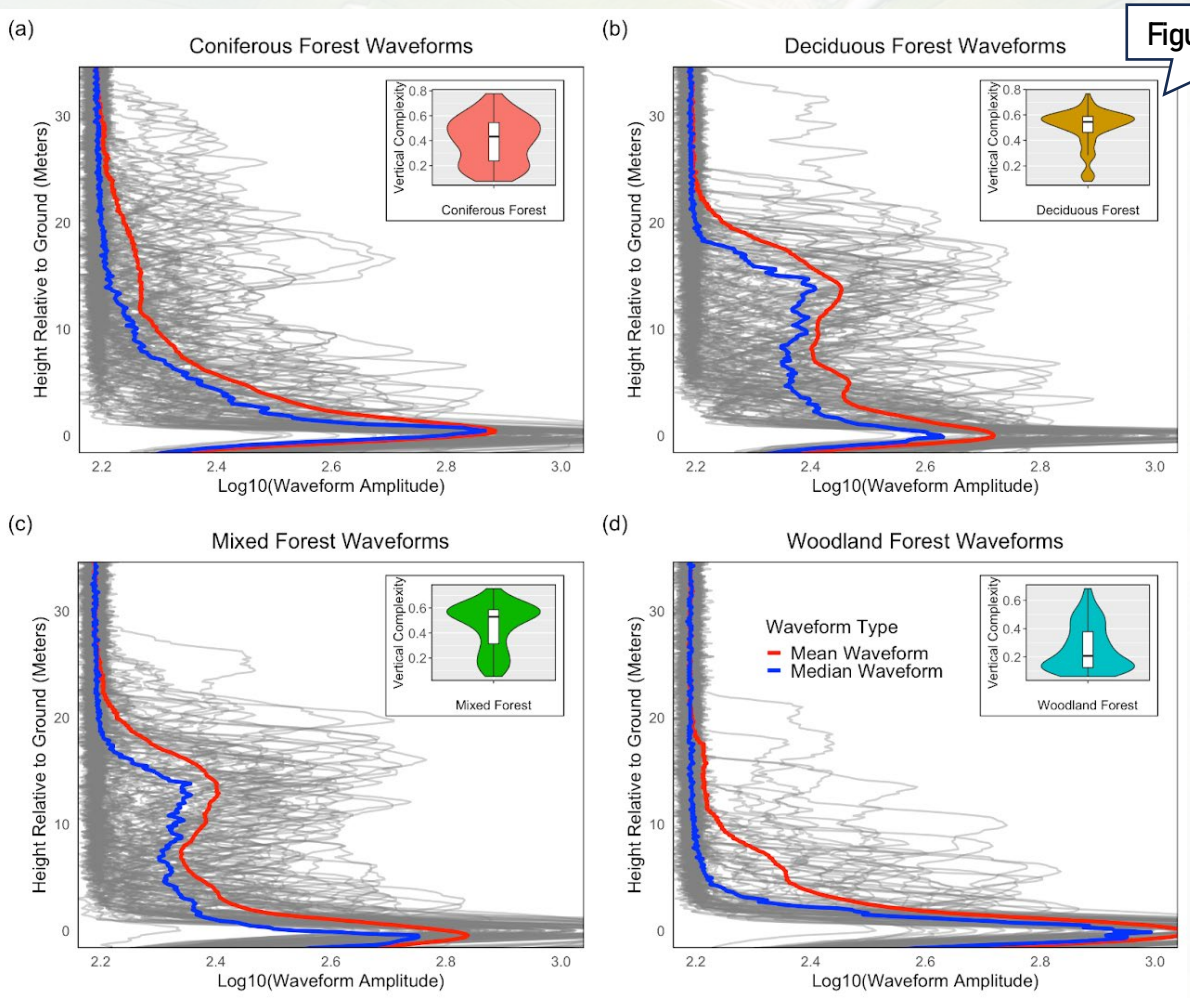


Figure by D. Jurayj

Vegetation structure can be estimated as a function of phenology, land cover, and hydroclimatic variability.

Reference estimates of vegetation structure can be used to study SWOT backscatter sensitivities to vegetation structure and moisture, particularly in wetlands.

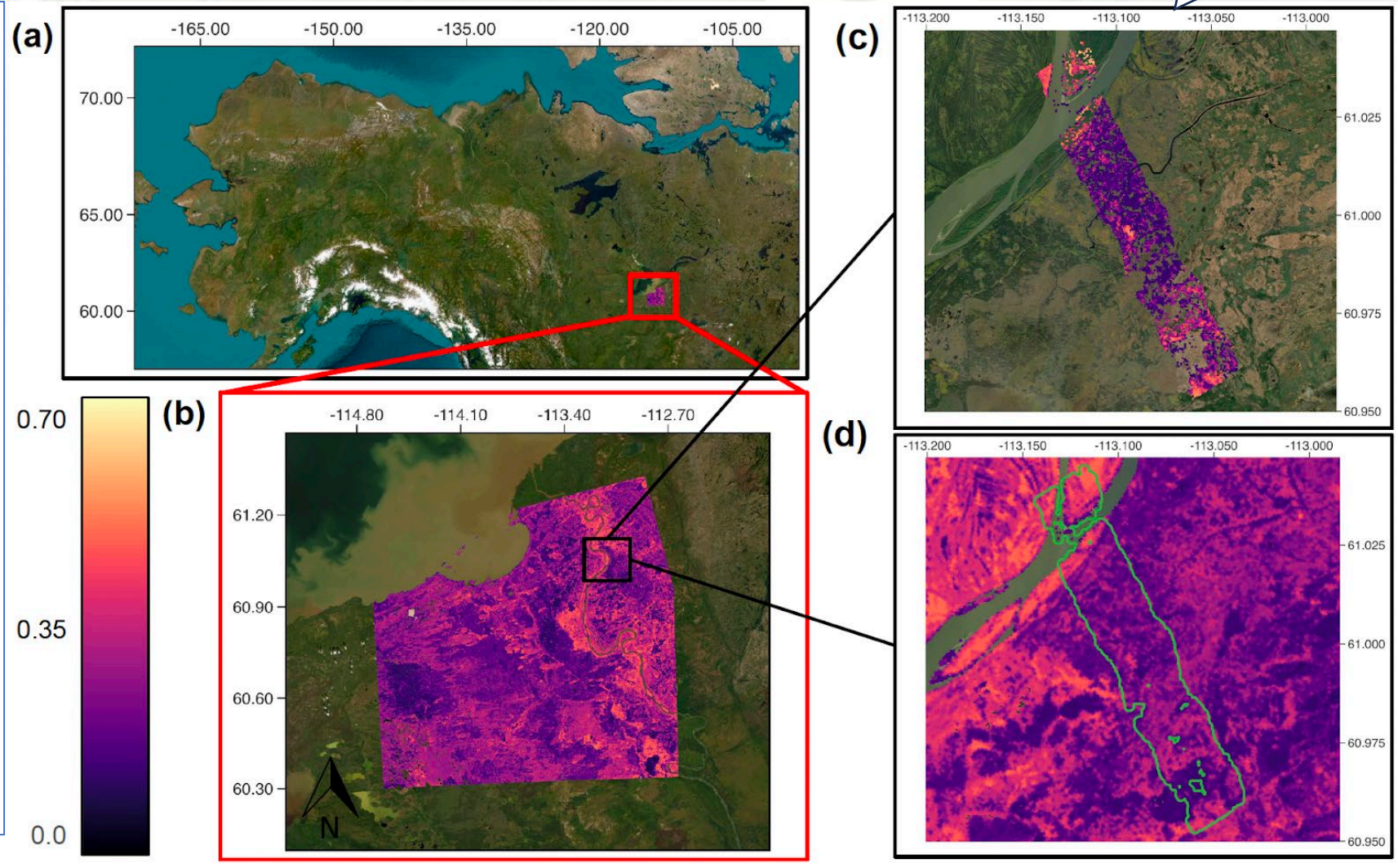
Jurayj, Bowers, and Fayne *in revision*

We are currently working to produce global vegetation complexity maps.

This is critical for SWOT retrievals of vegetation and ground moisture characteristics and additionally useful for ecology, agriculture, and agronomy studies.

This study produced Complexity maps for Canada and Alaska, enabling SWOT comparisons of vegetation structure in these regions.

Figure by D. Jurayj



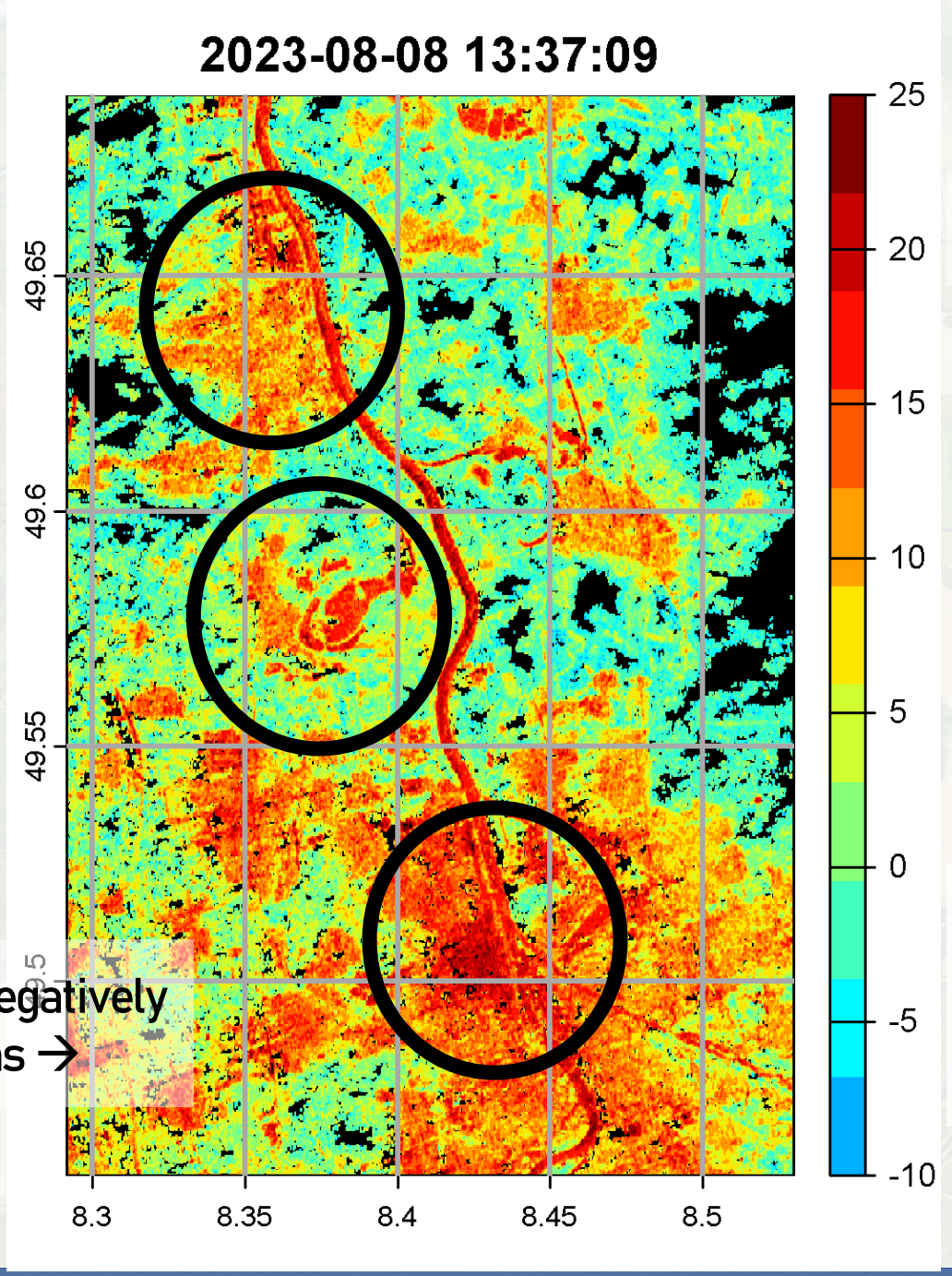
Jurayj, Bowers, and Fayne *in revision*

L2 HR PIXC Version PGC0/PIC0

Urban areas near waterbodies can negatively impact water extent observations →

Surface water phenomena can make water bodies bright or dark (or disappear!)

Urban areas near waterbodies can negatively impact water extent observations →



Worms, Germany

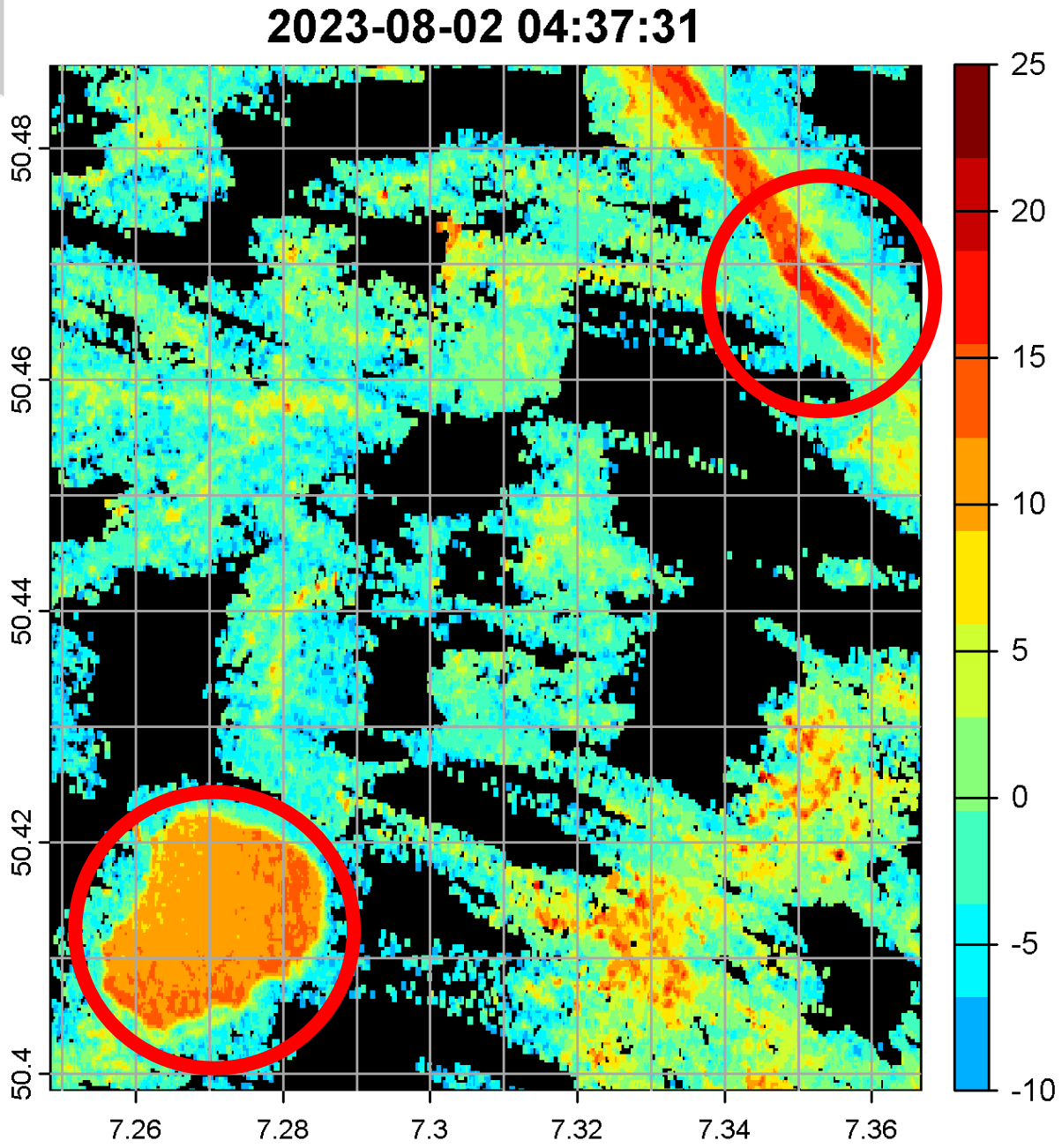
Germany phenomenology collaboration with Luciana Fenoglio

L2 HR PIXC Version PGC0/PIC0

The Laacher See (~1.5km wide) disappears completely in the May 20th observation!

Wind streaking is evident in some observations, but not consistently.

Check out two posters on wind retrievals over lakes!
Katie McQuillan
Jessica Fayne

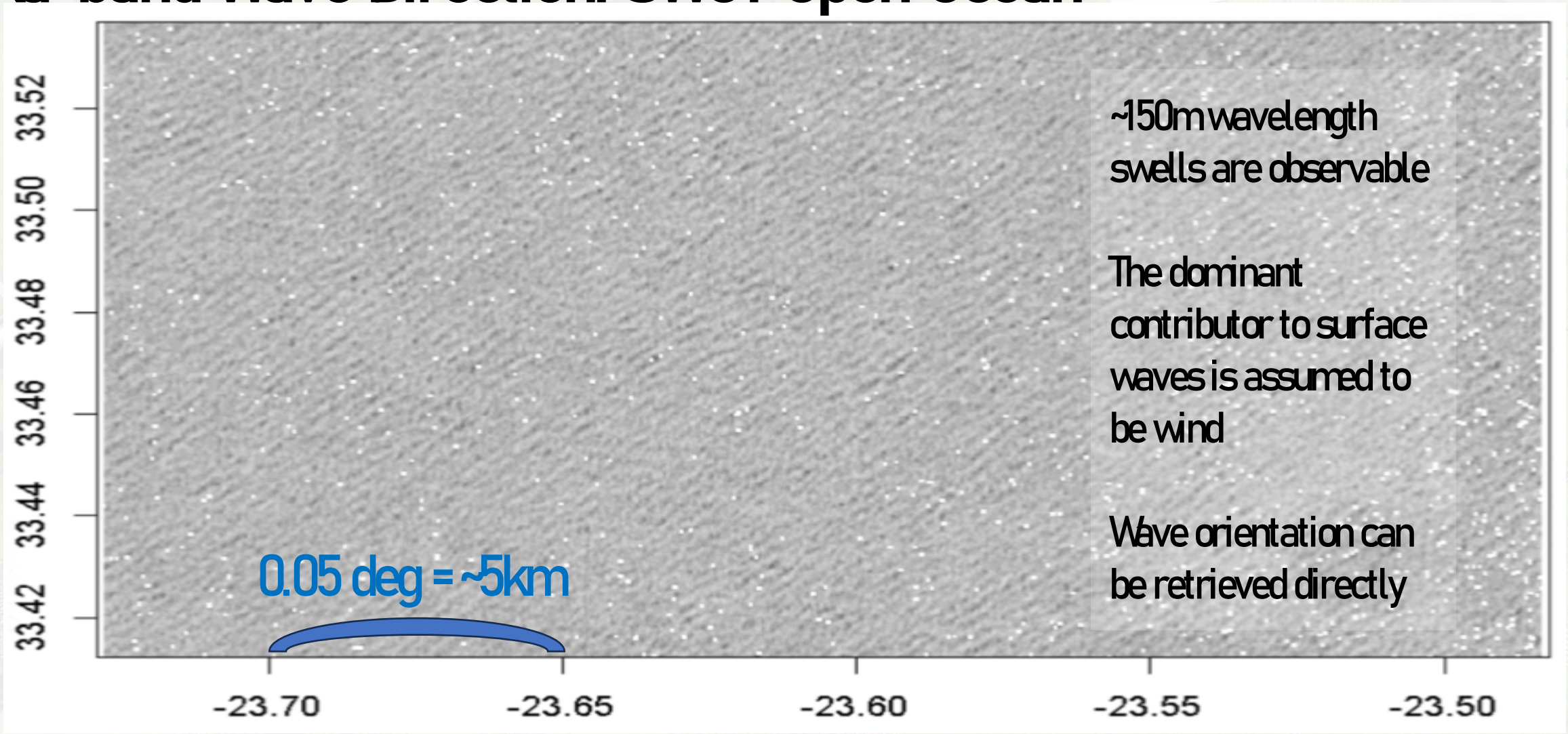


Koblenz, Germany

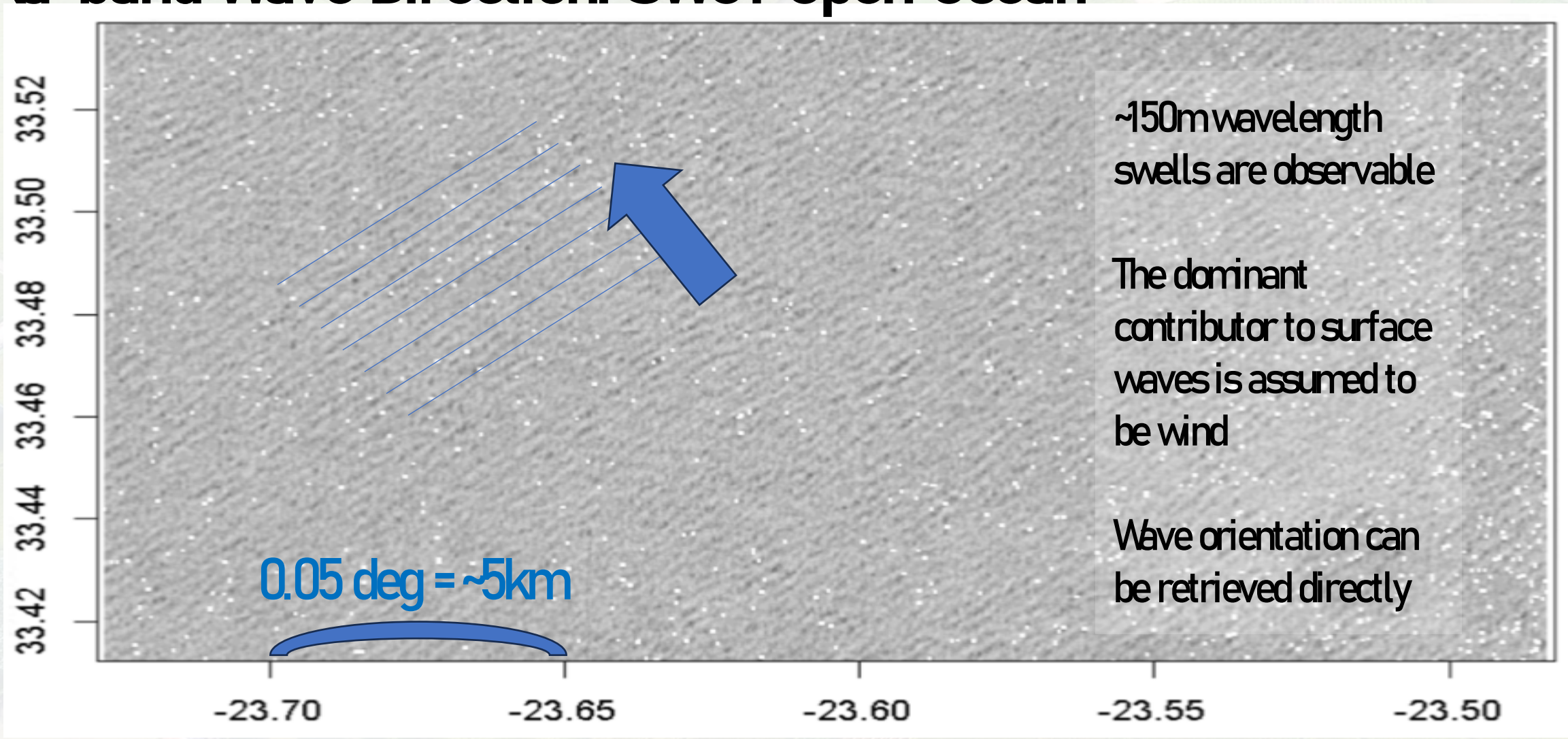
← Surface water phenomena can make water bodies bright or dark (or disappear!)

Germany phenomenology collaboration with Luciana Fenoglio

Ka-band Wave Direction: SWOT Open Ocean

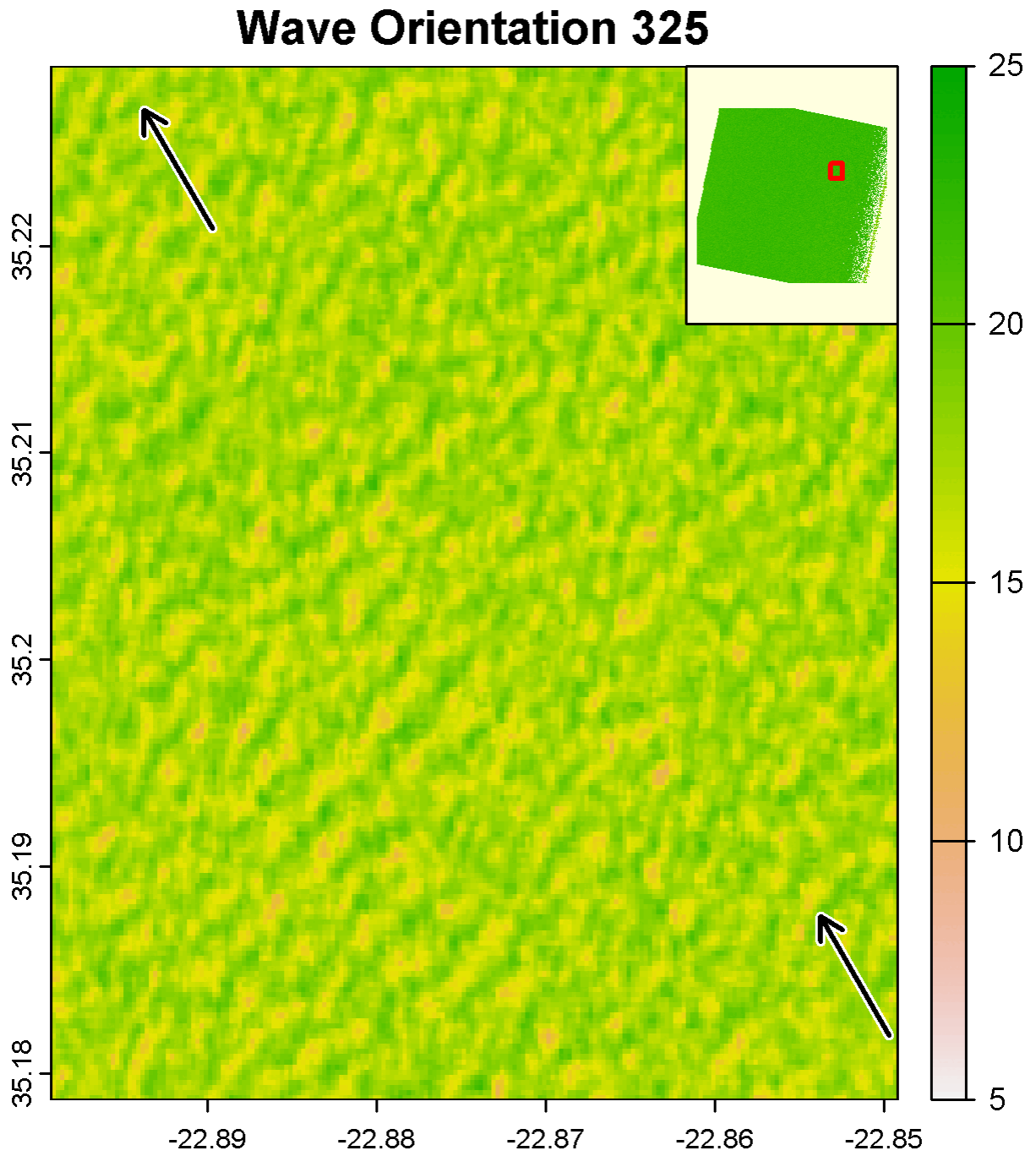


Ka-band Wave Direction: SWOT Open Ocean

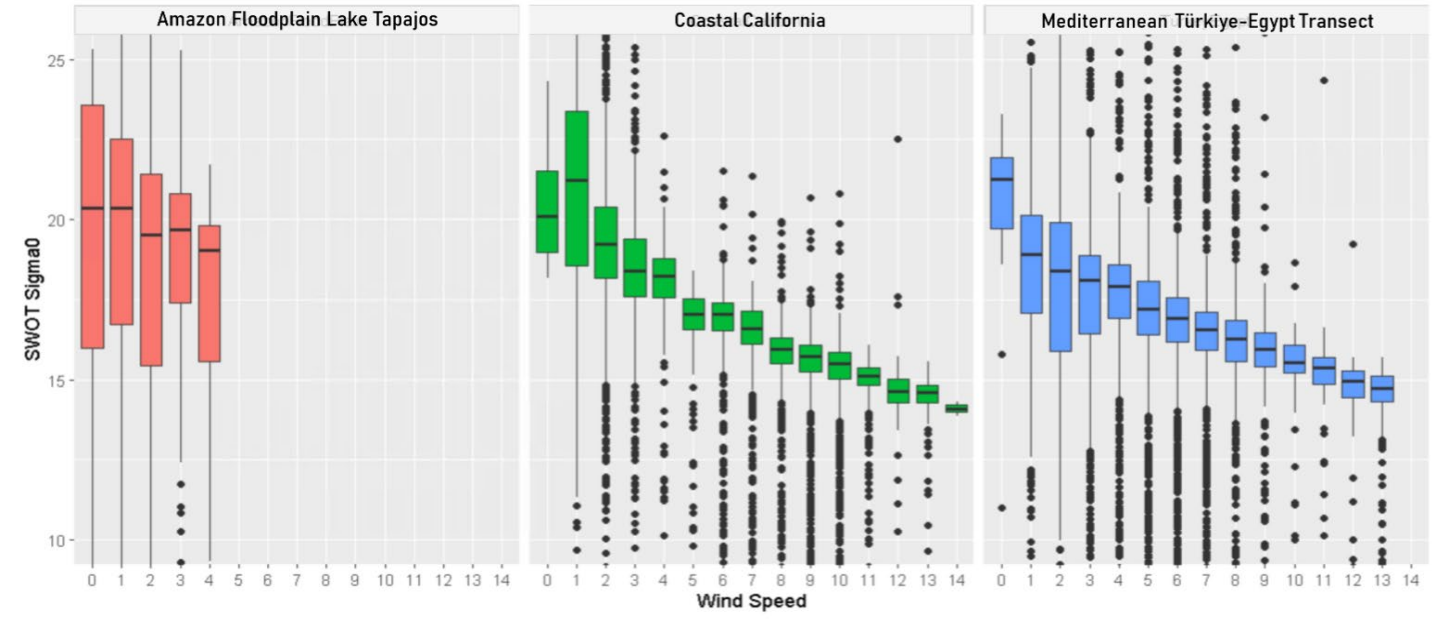


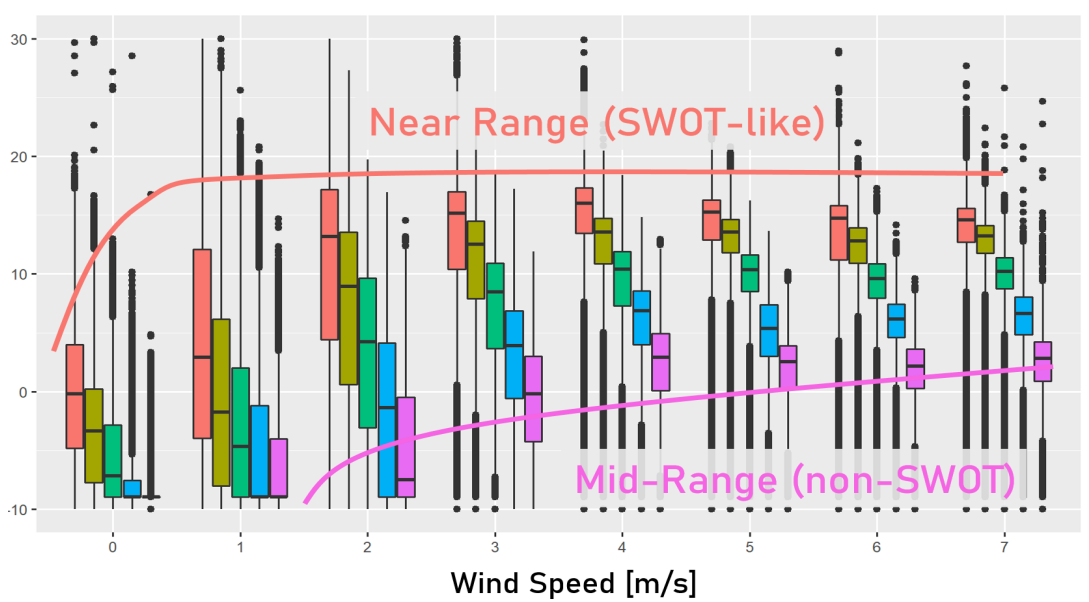
We can analyze the directionality of the Fourier spectrum to retrieve the wave direction.

Technically, this method retrieves surface wave geometry, which is often correlated with wind speed and wind direction, but in some cases, wave formation is not directly tied to wind speeds.



SWOT Backscatter Sensitivity to Wind Speed

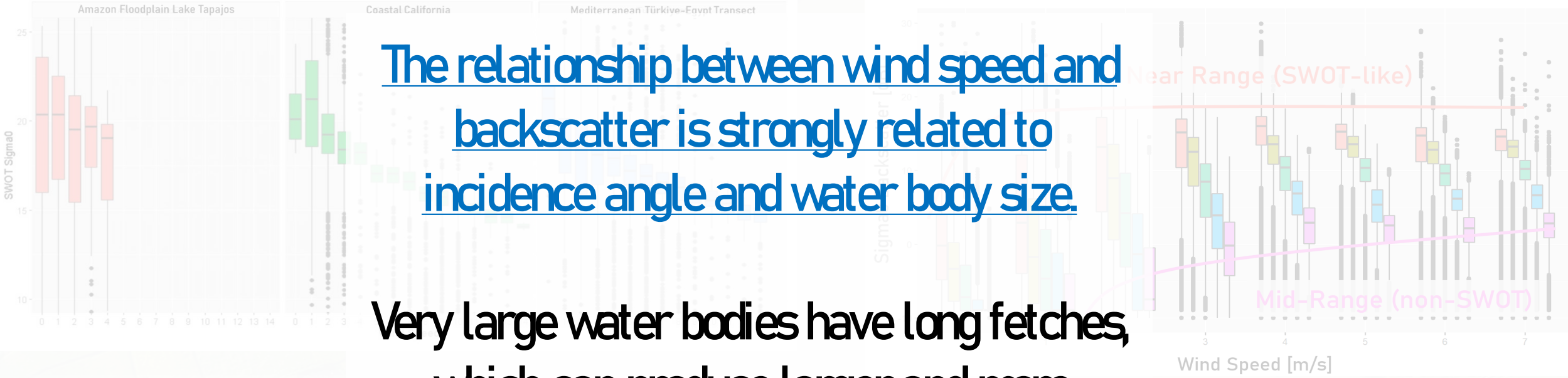




The nadir scattering geometry from SWOT results in a decreasing scattering trend when compared with increasing reference wind speeds

The oblique scattering geometry from AirSWOT results in an increasing scattering trend when compared with increasing reference wind speeds

SWOT Backscatter Sensitivity to Wind Speed



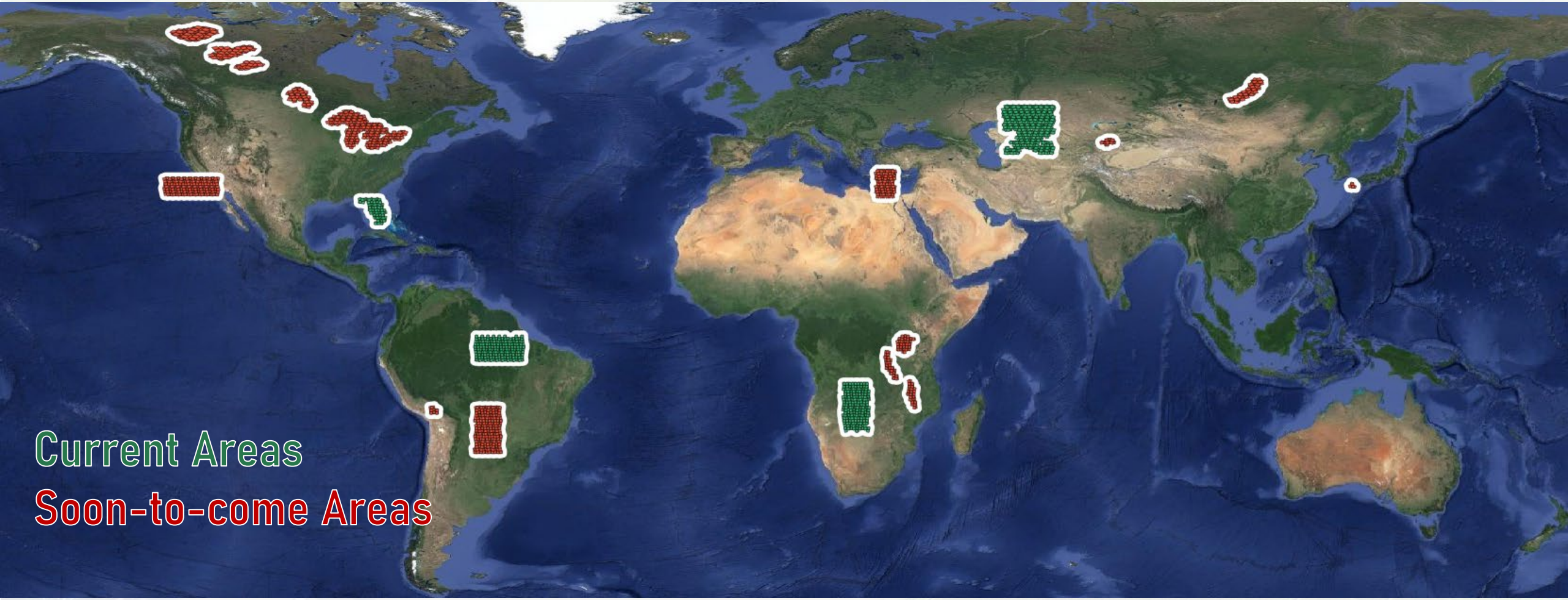
The relationship between wind speed and backscatter is strongly related to incidence angle and water body size.

Very large water bodies have long fetches, which can produce larger and more diverse wave shapes, changing the dominant scattering regime.

The *nadir scattering geometry from SWOT* results in a decreasing scattering trend when compared with increasing reference wind speeds

The *oblique scattering geometry from AirSWOT* results in a decreasing scattering trend when compared with increasing reference wind speeds

Focus areas in progress...



...on the way to global studies!

Vegetation Water and Surface Water Studies from SWOT

- The Ka-band is sensitive to very fine and surficial spatial and structural details.

- Ka-band does not penetrate canopies, but the high-resolution observations work well to see through sparse canopies and short grasses.

- The Ka-band frequency and 25m spatial resolution are ideal for studying surface moisture in croplands and wetlands to where water bodies are not present or are obscured by vegetation.

- **The Ka-band Phenomenology Scattering Model (KaPS) was produced to simulate new Ka-band backscatter images under diverse and changing surface conditions.**

- **Work is ongoing to develop reference datasets for more global studies of vegetation structure and surface moisture and inverse modeling with KaPS.**

- Important datasets/algorithms to consider:
  - Vegetation Complexity (Jurayj et al in review)
  - Multi-Resolution Index of Valley Bottom Flatness (Gallant & Dowling 2003)
  - Plant Health Indicators-- ECOSTRESS/(TRISHNA coming soon)
  - NISAR/SMAP Soil Moisture


Thank You!