Multitemporal SAR for forest biomass, wetlands and soil moisture over NASA's ABoVE region

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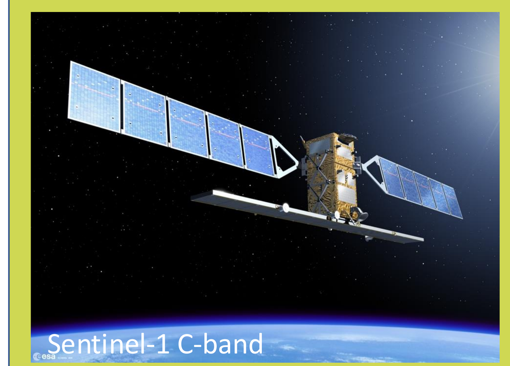
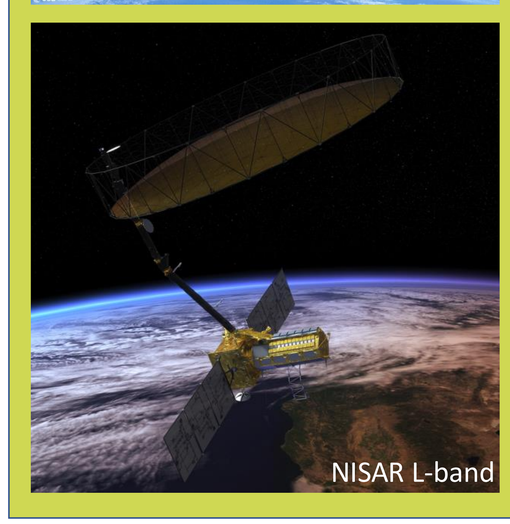
Abstract

The work described here has been part of a multi-year effort between Michigan Tech Research Institute, the University of Massachusetts, JPL, Michigan Tech University (Evan Kane), UCAR (Adriana Foster, Jackie Shuman, now at NASA-Ames), U. Geulph, Wilfred Laurier Univ., Natural Resources Canada, Govt. of NWT, and others for integrating remote sensing and modeling to better undestand the vulnerability of the ABoVE region ecosystems to wildfire. In the efffort described here we focus on the remote sensing aspect of the analysis, where C- and L-band SAR were used for characterizing wetlands and biomass distribution in the Arctic-Boreal region, with an emphasis on learning how satellite resources of Sentinel-1 and the upcoming NISAR mission can be used for creating time-series that would be used to measure the status and state of change for this hydrologically dynamic region.

In this poster there are sections that demonstrate the creation of an Above Ground Biomass (AGB) model for the study region in the NorthWest Territories (NWT), that takes into account seasonal variations, topographic artifacts, and other components (e.g. antenna pattern) that can affect the scaling of estimates over the broader region.

Sections are also included here for describing the importance and mapping of mosses for the ABoVE region using hyperspectral data (bottom), soil mosture measurements using C-band SAR (upper right) and wetlands studies for the Peace Athabasca delta region in the NWT.



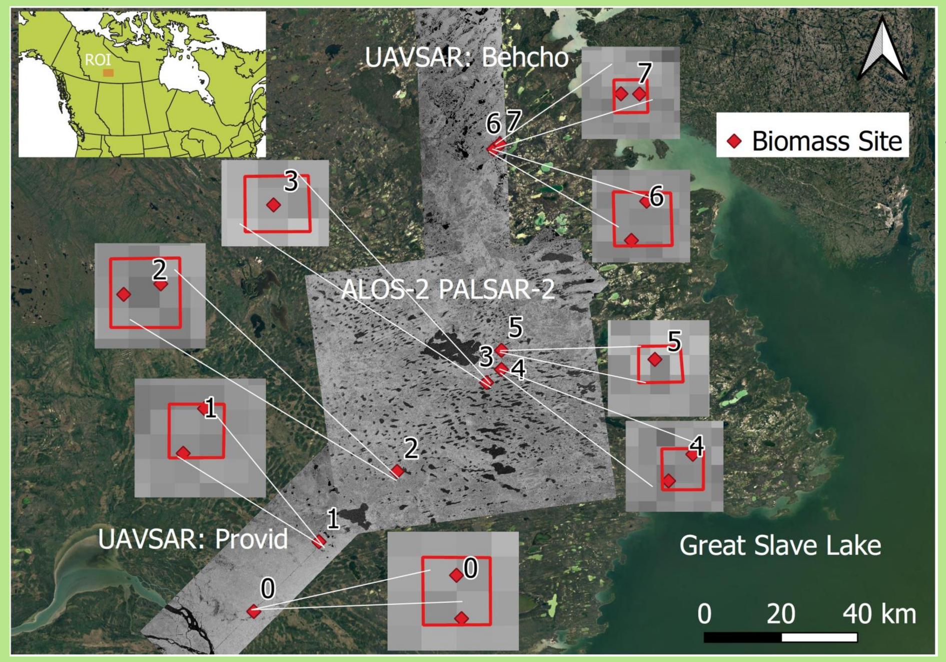


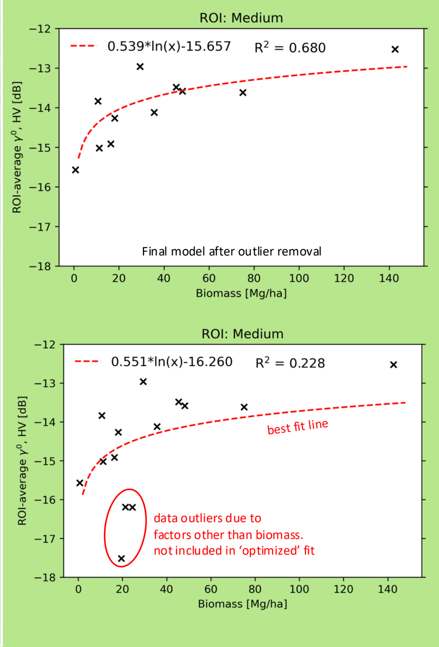
Calculating biomass

Different models were used to relate field observations of AGB to the radar cross-section (γ_0). The simplest of these models was a logarthmic relationship with unknown coefficeints a and b. These were determined using an optimized fit the ground validation regions shown below

$$\gamma^o = a\, ln(AGB) + b$$

Once a relationship between the radar and AGB data was created, this was then expanded to the larger area. Consistency between UAVSAR and ALOS-2 data indicate good calibration and stability of the input data resources.



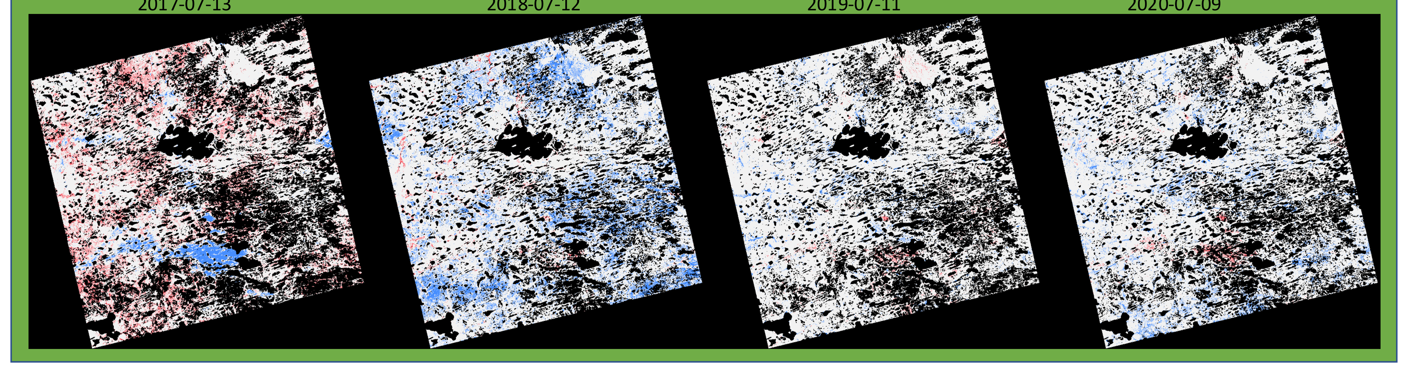


Variability over seasons and years

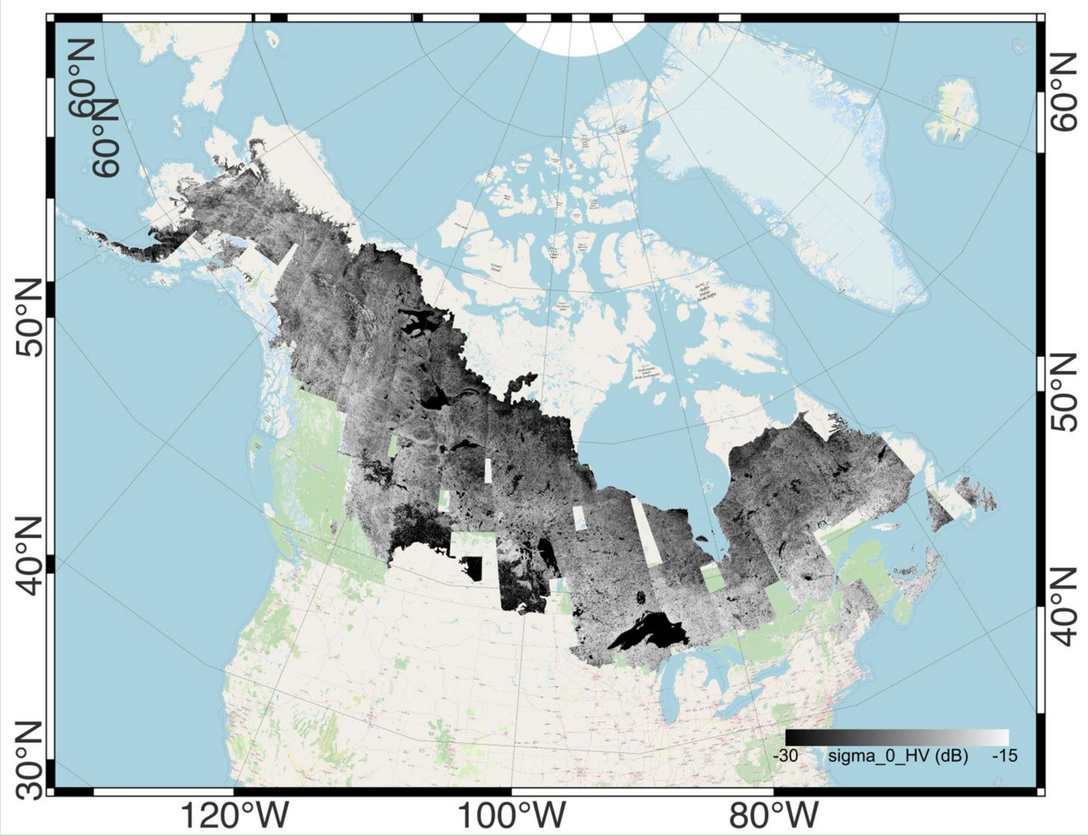
The ABoVE region is marked by strong seasonal and hydrologic cycles throughout the year. In order to undestand the effects of this dynamism over time, ALOS-2 data were compared with one another and a metric created to map the source and severity of these fluctuations.

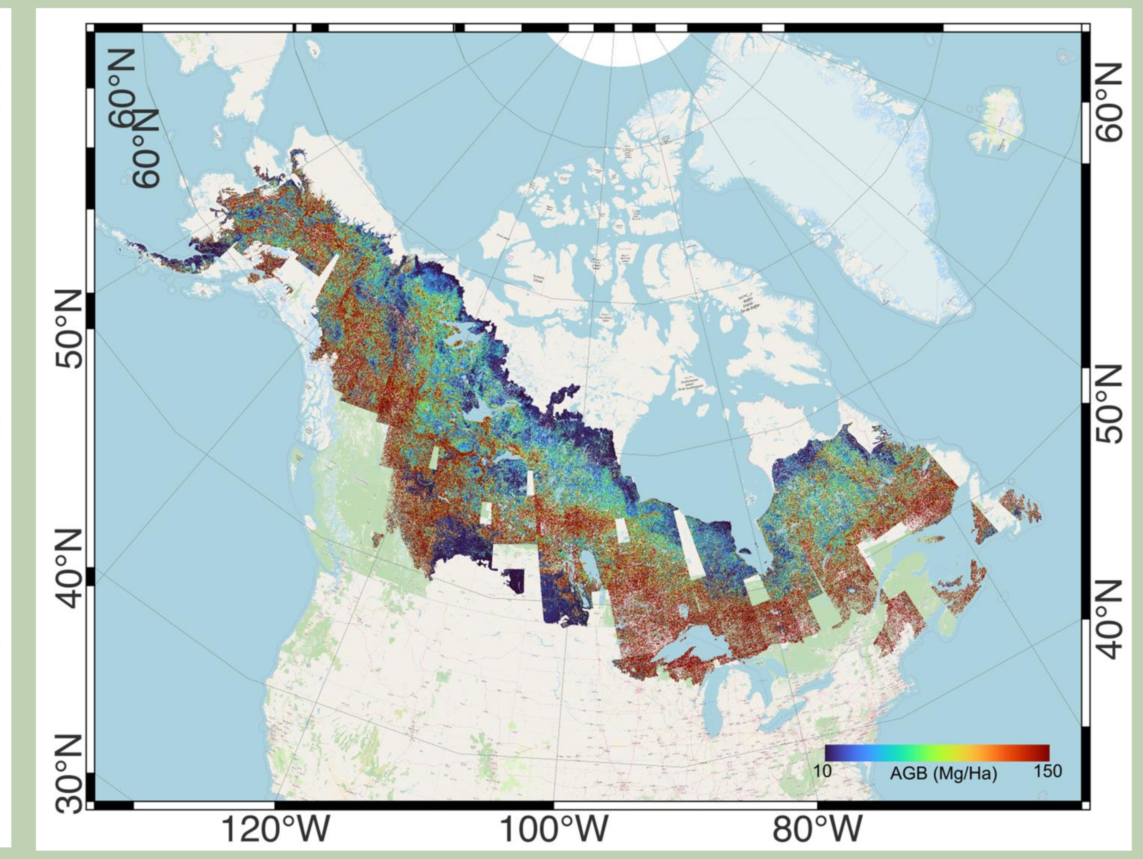
$$\%_{anomaly} = 100 * (\gamma^0(t) - \overline{\gamma^0})/\overline{\gamma^0}$$

Comparison of ALOS-2 HV signature over 4-years



Calculating Biomass for the ABoVE region and beyond

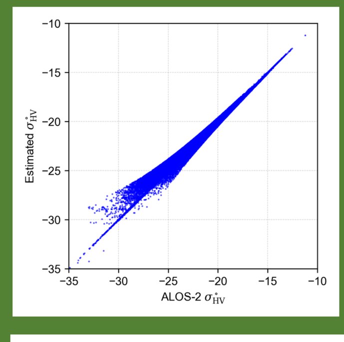




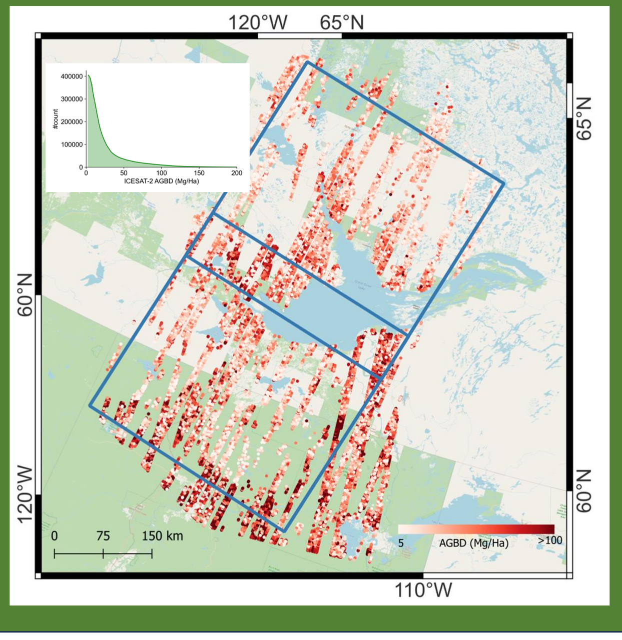
132 ScanSAR scenes from ALOS-2 collected August – October, 2023 of some 8 TB of 50 m resolution cross-polarized (HV) data were assembled and processed using AWS cloud resources and Earth Big Data's SEPPO processing suite. Data were corrected for incidence angle and other radiometric effects in order to make a consistent estimate of the radar cross-section. These data were combined with ICESAT-2 to create a boreal-wide estimate of AGB. Although there remain some artifacts in the derived AGB map, of note is a latitudinal gradient of biomass that is well known for this study area.

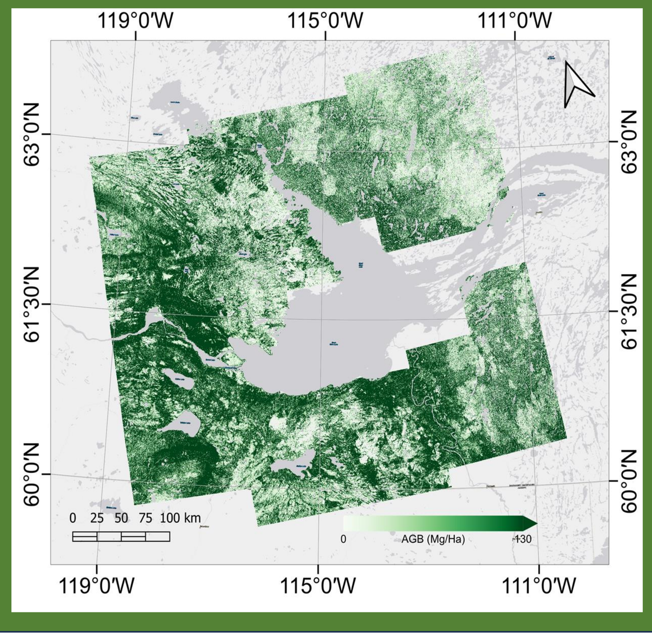
Combining with ICESAT-2 derived Above Ground Biomass

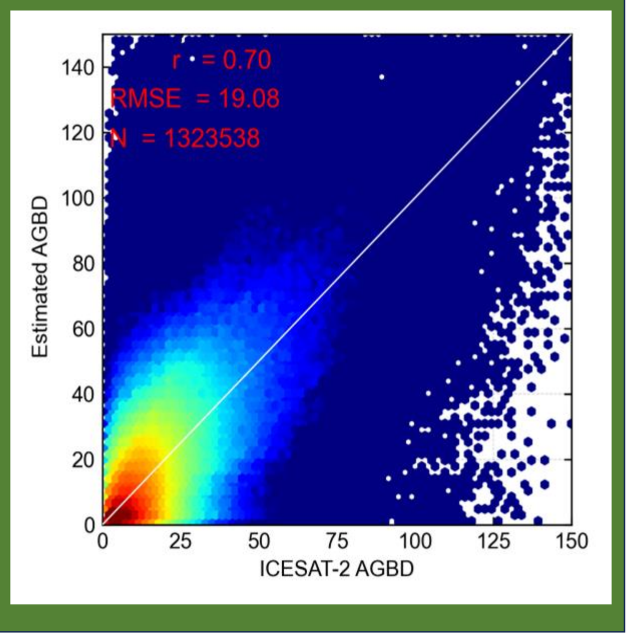
To scale ground validation measures of biomass to larger regions, AGB density estimates derived from ICESAT-2 (center left) were used to create a mapping relationship through the fitting of coefficients of the logarthmic model between the observed radar cross section and the biomass. When combined with ALOS-2 observations, an AGB map was made of the Great Slave Lake study region (center right) . A density map of the two types of AGB estimates is shown at right. Of note is the RMSE of 19 t/ha of biomass, which is common for both lidar- and radar-derived estimates of AGB.



The plot at left shows a strong relationship between the mesaured RCS and the estimated RCS that would come from "known" values of AGB. This plot effectively shows that the model is doing as good as it can, but would still be limited by saturation effects that are well known for this type of analysis.



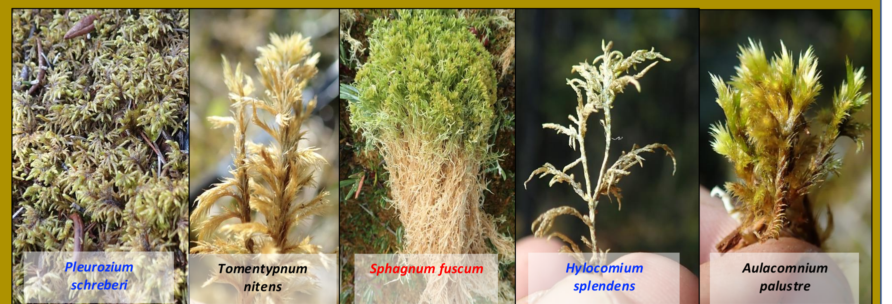




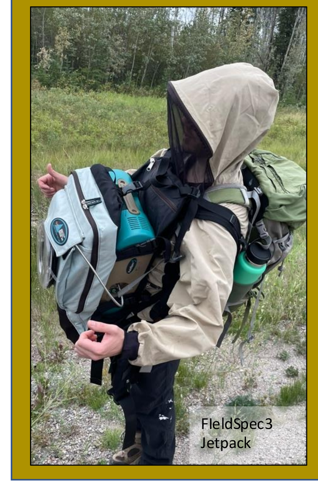
Working with Hyperspectral Data

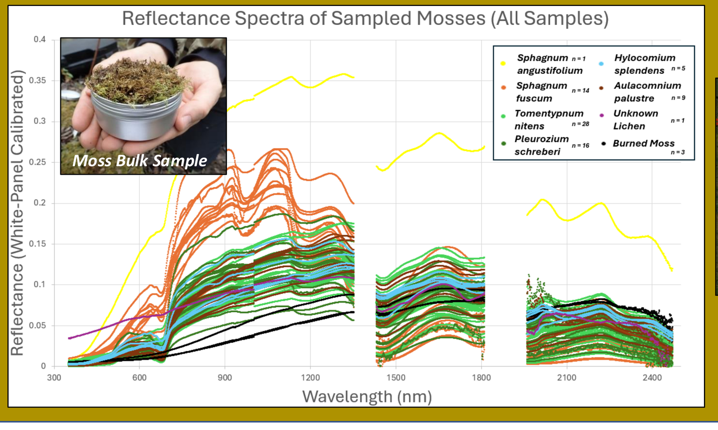
Not all biomass can be seen with SAR

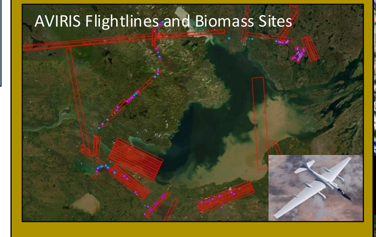
Our team has also been using AVIRIS data for mapping Plant Functional Types (PFTs) focused on mosses. Mosses are important and often overlooked parts of the ecosystem. Different mosses contribute to the carbon and water cycle in their own way. Certain moss types (e.g. sphagnum) excel at water retention and affect local hydrology. These differences have impacts on wildfire progression and emissions. Mapping of these mosses, and their types, through the combination of their spectral mapping and PFTs are important for integration into carbon, fire and emission modeling.



Spectral signatures for different moss species make up MTRI's spectral library.



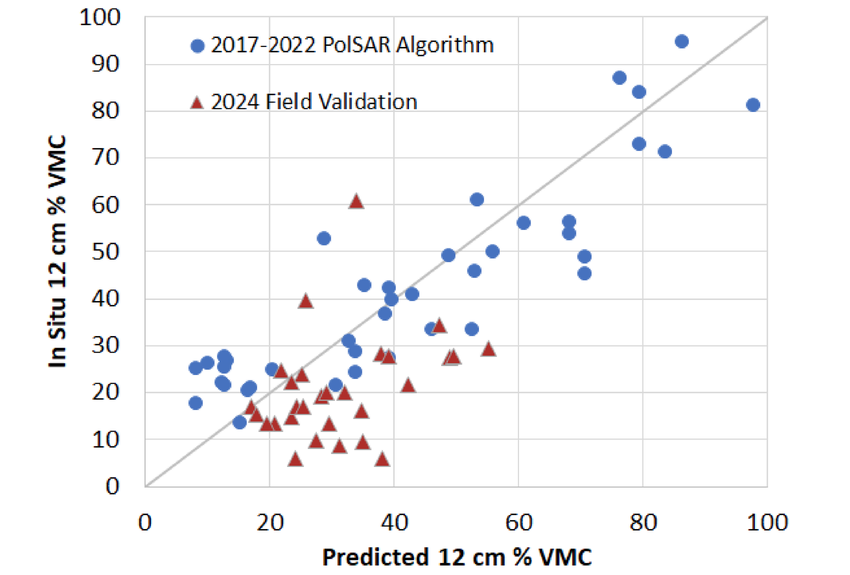




Spectral Information Divergence classification from AVIRIS

Soil Moisture from SAR

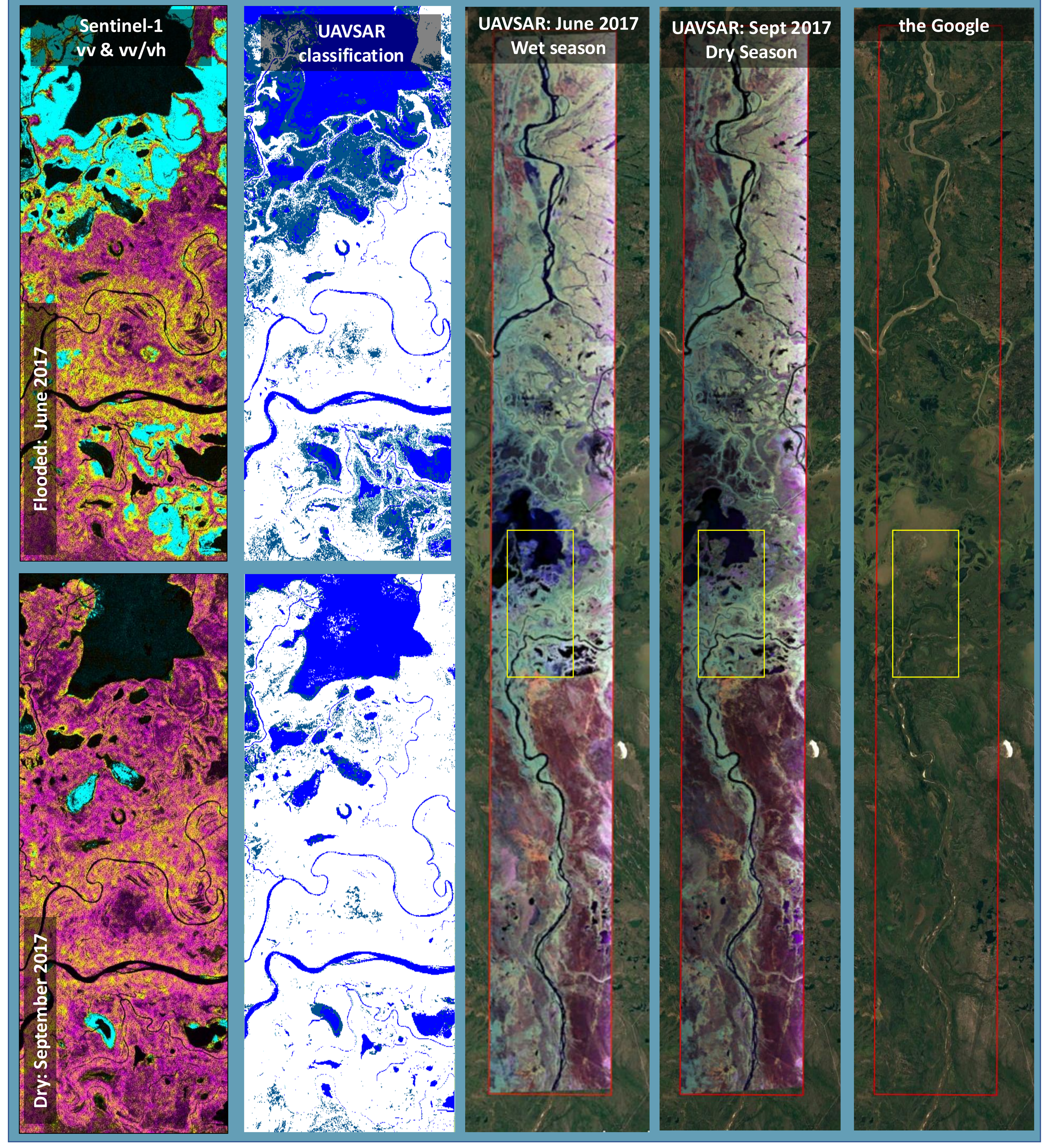
Using fully polarimetric L-band observations from UAVSAR, a Multiple Linear Regression (MLR) algorithm is combined with ground validation measurements to estimate volumetric moisture content (VMC).



Shown in the graph above are plots of two sets of points. The first set (blue dots), compare results from the MLR algorithm applied to concurrent UAVSAR that was used to make the model. The red triangles show the results when the same algorithm, trained on the 2017-2022 data, is applied to 2024 UAVSAR observations. The comparison is imperfect because soil moisture in 2024 was collected in regions of high biomass and also during an anomoulsly dry year. This also shows the challenges in applying such an algorithm over varying years and landcovers.

Flooding and Inundation Mapping using Sentinel-1 C-band and UAVSAR L-band

Because of the relatively low biomass range for the ABoVE region (0 – 150 t/ha), both the longer wavelength L-band (24 cm) and C-band (5.4 cm) sensors will have sensitivity to soil moisture and flooding beneath vegetation. The seasonal flooding, and lack thereof, are important for mapping and monitoring.
Shown below are signatures for Sentinel-1 and L-band UAVSAR (as a proxy for NISAR) for the wet (June) and dry (September) of 2017 over the Peace–Athabasca delta area. The nearly-coincident in time collections between C- and L-band observations indicates the sensitivities that the different instruments have for the soil moisture and flooding dynamics. The false color imagery shown at left are from NASA's OPERA project using Sentinel-1 data, and a UAVSAR-based classification of open water, flooding and dry land.



References

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Acknowledgements

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