From Airborne Hyperspectral to Space-borne Multispectral Optical Simulations: Demonstration of Sentinel-2a simulations of a Northern Ombrotrophic Bog

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Introduction

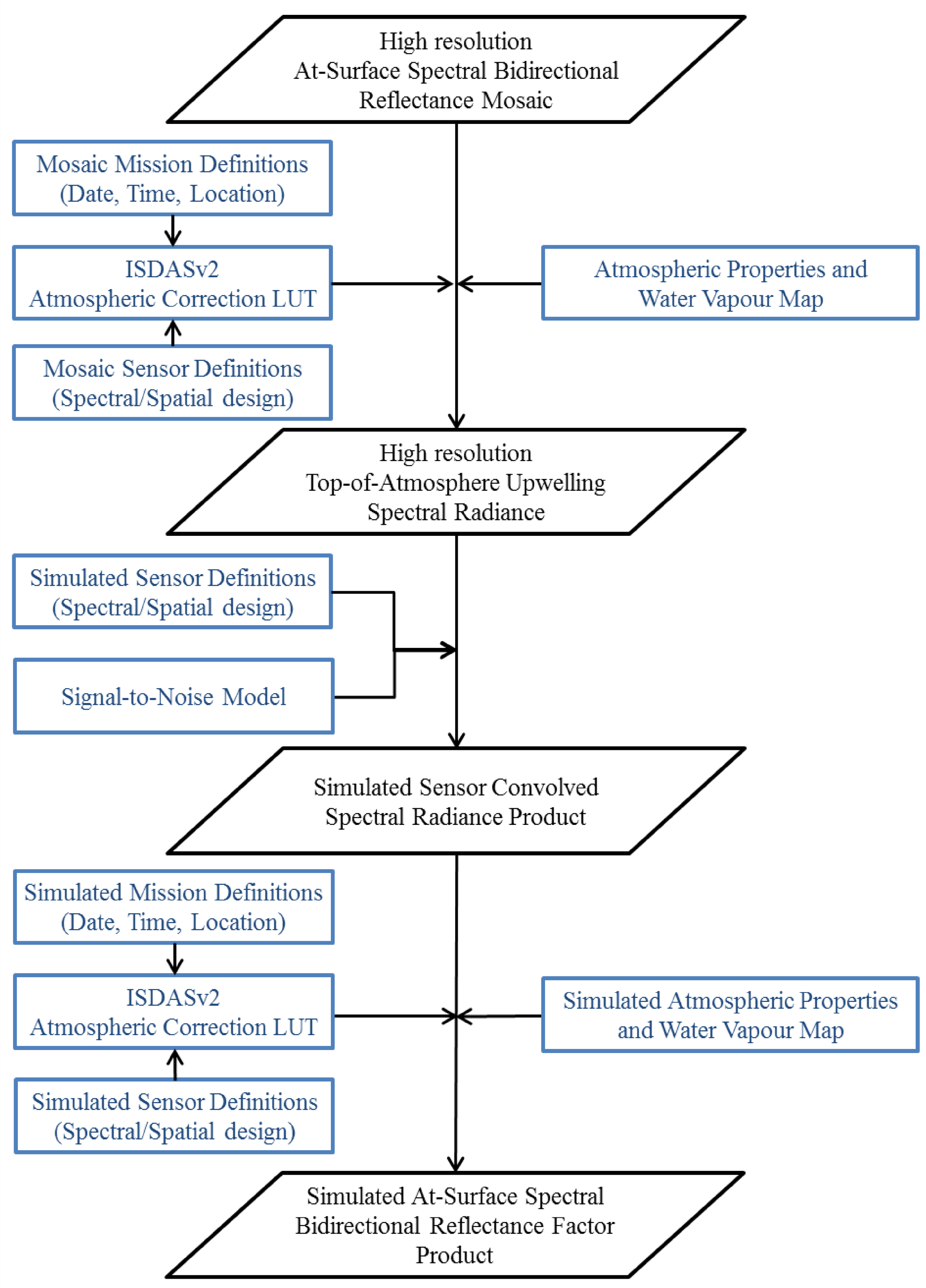
Simulation of space-borne optical (spectral) Earth Observation imagery has become a useful tool to support the design of future systems and to evaluate the impact of system designs on remote sensing applications. To this end, the Imaging Spectrometry Data Analysis System (ISDASv2) was developed allowing for simulations of space-borne imagery from airborne and field data. The processing chain includes simulating impacts of potential (or existing) sensor artefacts (spectral/spatial resolutions, spectral curvature, keystone, noise, etc.), atmospheric influences (atmospheric water vapour, etc.) and a varying view/illumination orientation to the remotely recorded radiance. Simulated at-sensor radiance imagery can then be compared to imagery acquired by a space-borne sensor, or used to evaluate sensitivities of information extraction methods to sensor design and atmospheric influences.

In this demonstration, the ISDASv2 Optical Satellite Simulation processing chain is applied with a focus on utilizing field and airborne data of the Mer Bleue Peatland (a northern ombrotrophic bog located near Ottawa, Canada) acquired as part of the MBASSS (Mer Bleue Arctic Surrogate Simulation Site) S2/L8 Validation Project to simulate coincident Sentinel-2a acquisitions. Initial comparisons to the Sentinel-2a acquisitions are used to demonstrate the validity of the simulation, followed by an evaluation of the simulated data set with the initial airborne imagery investigating the impact of spatial scaling and atmospheric contributions.

Field/Airborne/Space-borne Data

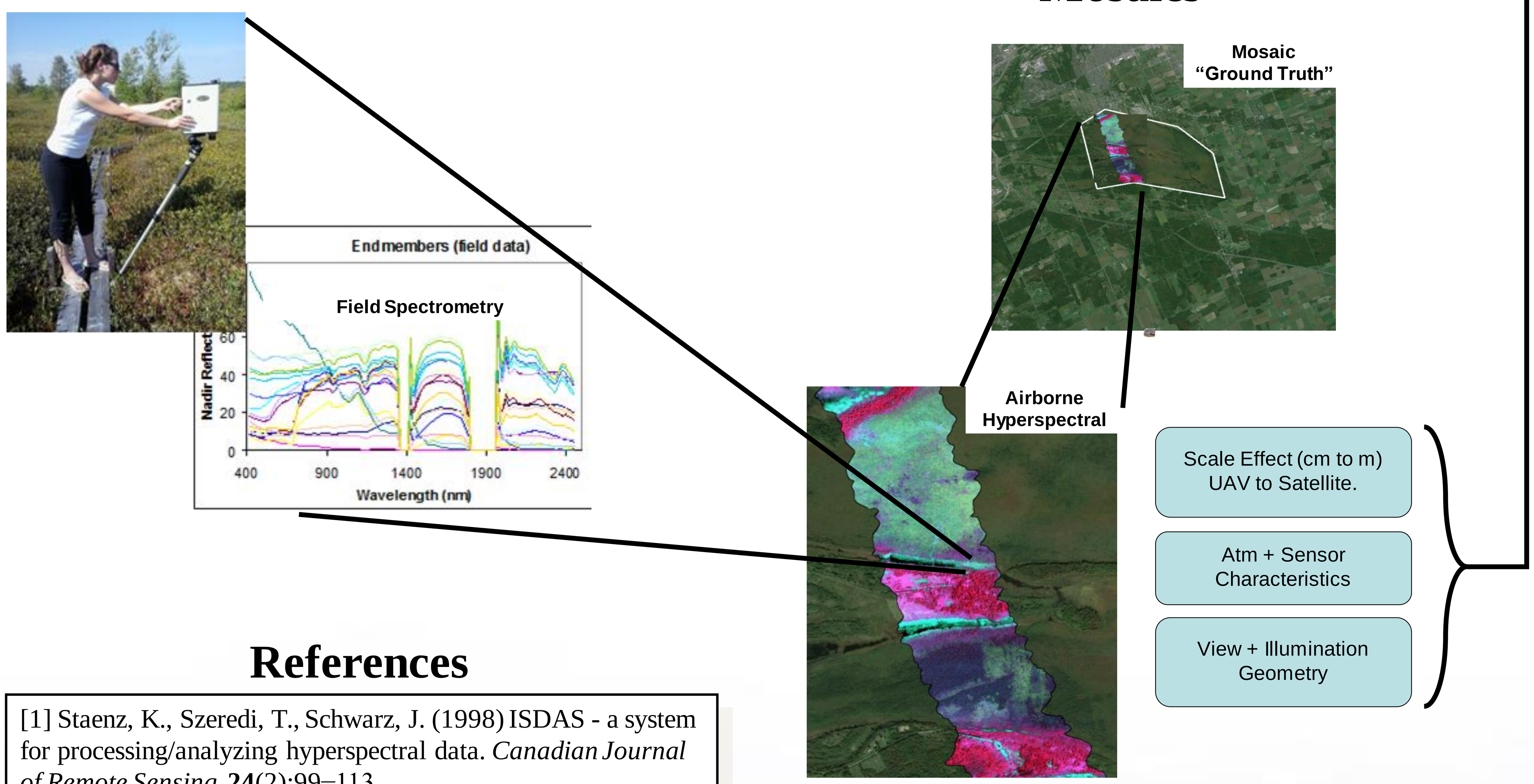
Several field campaigns were accomplished during the summer 2016 growing season at the Mer Bleue Bog. This included Field Spectrometry campaigns to capture surficial BRF due to biochemistry and structure of various land cover types at various periods during the growing period. Airborne campaigns were undertaken coincident with Sentinel-2a overpasses using complimentary CASI and SASI hyperspectral pushbroom sensors from which mosaics images were generated of the peatland. This preliminary investigation focuses on the results of the June 23, 2016 acquisitions. UAV campaigns were also flown, and were used in this part of the study to aid in validation and visualization of the field acquired data only.

Simulation Workflow



Demonstration of a simulation can be pursued by obtaining field data of a site coincident to a space-borne acquisition. To this end, the field and airborne campaigns were performed on mornings of a Sentinel-2a overpass. This information was compiled to produce a validated high resolution at-surface spectral reflectance (BRF) mosaic of the Mer Bleue Bog that could be used as the foundation for comparison between actual and simulated acquisitions.

Field Spectrometry and Airborne Mosaics



References

[1] Staenz, K., Szeredi, T., Schwarz, J. (1998) ISDAS - a system for processing/analyzing hyperspectral data. *Canadian Journal of Remote Sensing*, **24**(2):99−113.

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[4] White, H.P., Khurshid, S., Hitchcock, R., Neville, R., Sun, L., Champagne, C.M., Staenz, K. (2004) From at-sensor observation to at-surface reflectance – calibration steps for earth observation hyperspectral sensors, *IGARSS Conference Proc.*

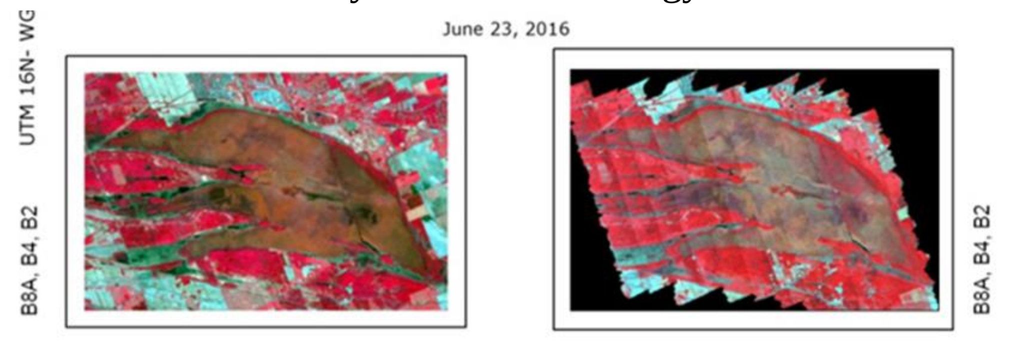
Future Directions

Understanding the relationship between field acquired surface reflectance and surface reflectance derived from space-borne acquired imagery requires detailed understanding of the influences impacting the space-borne acquisition.

Simulations allow the opportunity to assess impacts of spatial resolution on derived image products. Future work includes further evaluating of the influences of atmospheric and sensor design on acquired imagery, and how to better identify pixels that include a wide diversity of sub-pixel constituents.

Sensor Simulation - Imagery

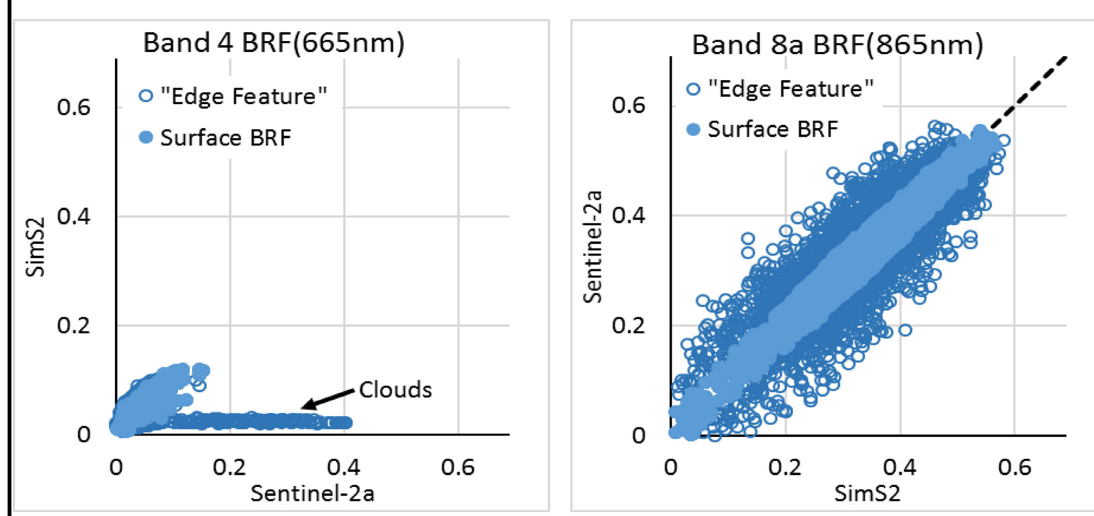
Imagery simulated to match the spectral and spatial characteristics of an actual sensor acquisition can be compared to demonstrate efficacy of the methodology.



The above example provides a visual comparison of the June 23, 2016 acquired Senitnel-2a Level-2A imagery with the equivalent derived SimS2 simulation imagery. Sentinel-2a (B8A: 865 nm, B4: 664.5 nm, B2: 560 nm) bands are used in this 3-band composite. Note the cross-track illumination effects in the originally provided 1m resolution CASI mosaics used to derive the 20 m resolution SimS2 simulation remain (these were not removed so that the impact of such artefacts could be evaluated in a separate study).

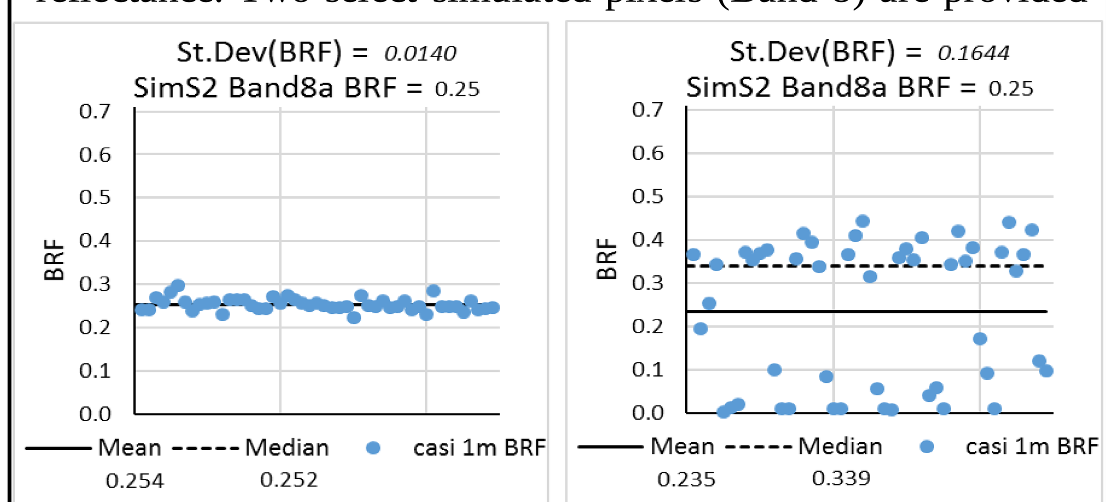
Sensor Simulation - Pixels

Pixel-to-pixel comparison of the Sentinel-2a and SimS2 derived surface BRF for 23 June 2016 are compared (Bands 4 and 8a are shown here). Dark blue pixels represent mixed pixels, such as water shorelines or clumps of trees in the bog. Bright blue represent pixels over relatively homogenous (spectrally) surfaces. Cloud/Haze pixels were identified and masked.

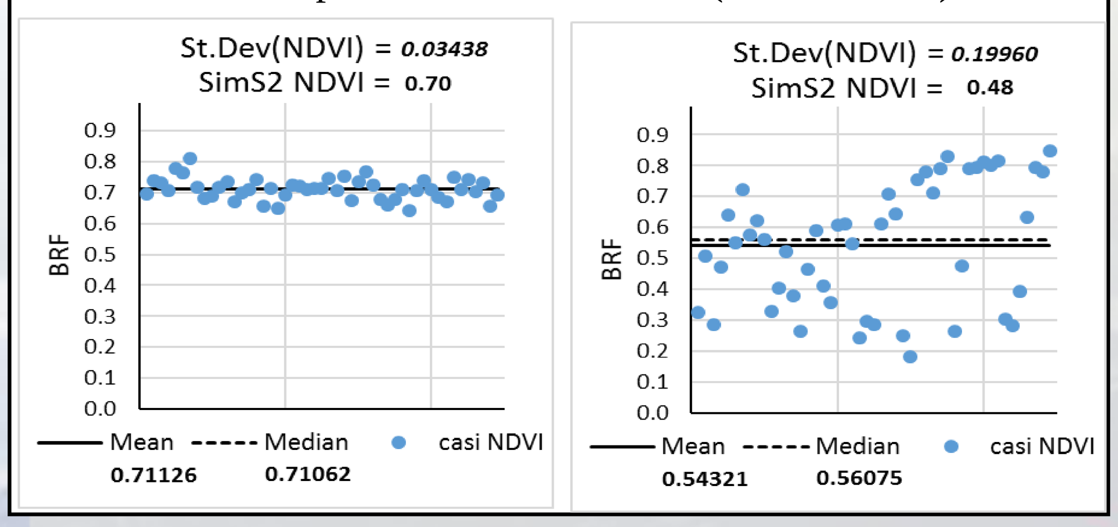


Given the SimS2 reproduced a validated Sentinel-2a at-surface reflectance product, the opportunity exists to examine aspects such as scale. To this end, individual pixels from the SimS2 20m at-surface reflectance were matched to the provided CASI 1m at-surface reflectance mosaic. The 400 CASI pixels directly contributing to each SimS2 pixel were mapped, and convolved to match the SimS2 spectral characteristics.

As expected, some SimS2 pixels well represented the mean of the contributing CASI pixels, while others did not. SimS2 pixels in homogeneous regions mapped to CASI pixels that were spectral similar, while SimS2 pixels in heterogeneous regions mapped to CASI pixels with a wide range of spectral reflectance. Two select simulated pixels (Band 8) are provided



Here, a simulated SimS2 pixel located in an exposed peatland region (left) shows good agreement with the contributing CASI pixels. The other SimS2 pixel (right) with the same at-surface reflectance is located near water and trees. In this case a diverse mixture of land covers results in a reflectance value similar to the open bog. Similar examples could be identified for all bands. It was also noted that SimS2 pixels with larger magnitude reflectance values had contributing CASI pixels more closely aligned with the SimS2 reflectance (mean close to the SimS2 value, small standard deviation). This effect translates to data products such as NDVI (shown below).



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