Consistency of Landsat-8/-9 reflectance products for aquatic science and applications

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Overview

Landsat-9 (L9) was launched on September 27, 2021, and carries the Operational Land Imager 2 (OLI2) and Thermal Infrared Radiometer Suite 2 (TIRS2). L9 is largely identical to Landsat-8 (L8) in spectral and spatial coverage, with improved radiometric resolution (14-bit OLI2 vs 12-bit L8 Operational Land Imager (OLI)).

Our objective is to compare OLI2 and OLI over bodies of water and quantify their consistency for aquatic studies using the L9 underfly maneuver post-launch (**Fig. 1**). More specifically, we

1. Present OLI-OLI2 signal-to-noise ratio (SNR) assessment over aquatic ecosystems.
2. Evaluate OLI-OLI2 standard USGS top-of-the-atmosphere (ρ_t) and aquatic (ρ_w^{AR}) reflectance comparison.
3. Analyze the capability of select atmospheric correction (AC) processors in correcting for variability in OLI's viewing geometry.

The rigor/consistency of corrections for angular variability in SeaDAS (*i.e.*, adopted by USGS to generate ρ_w^{AR}), ACOLITE, and POLYMER was assessed for view azimuth angles (VAA) with the same and opposite signs (**Fig. 6**). Note that aquatic reflectance (ρ_w) is related to remote sensing reflectance (R_{rs}) through $\rho_w = \pi \times R_{rs}$.

OLI-OLI2 Underfly Maneuver

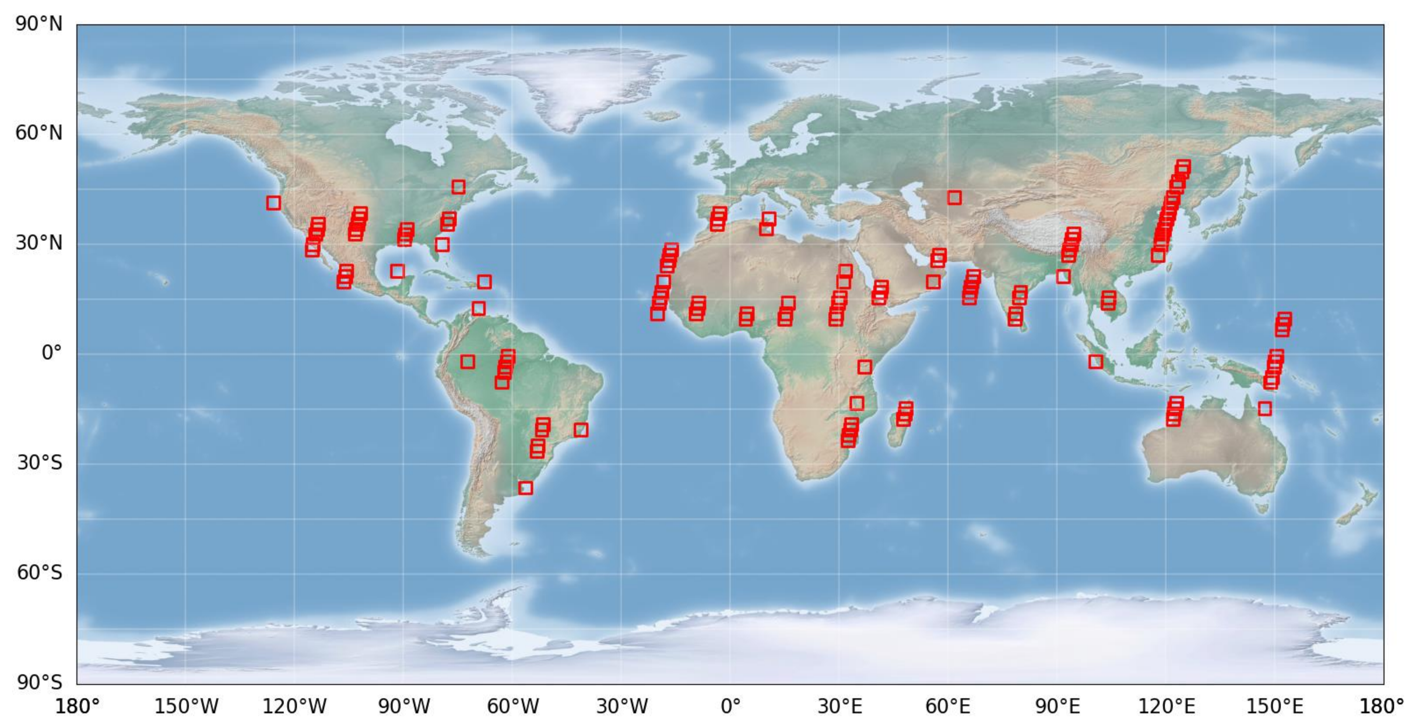

Fig. 1: Geographic distributions of 126 L8/L9 underfly scene pairs (N=126) that passed all the exclusion criteria. The image pairs are distributed over numerous water bodies, including inland, coastal, and open oceans over mid and lower-latitude regions. For ρ_t and ρ_w^{AR} intercomparison, only where view zenith angle (VZA) difference within $\pm1°$ were exploited.

OLI & OLI2 signal-to-noise ratio (SNR)

OLI and OLI2 SNRs computed from ρ_t is illustrated in **Fig. 2**, with data points denoting the average SNRs calculated from five near-simultaneous scene pairs (>50,000 pixels from a scene) and error bars representing 1-σ standard deviation. OLI2 SNRs are 7 to 30% higher than OLI in the ρ_t product.

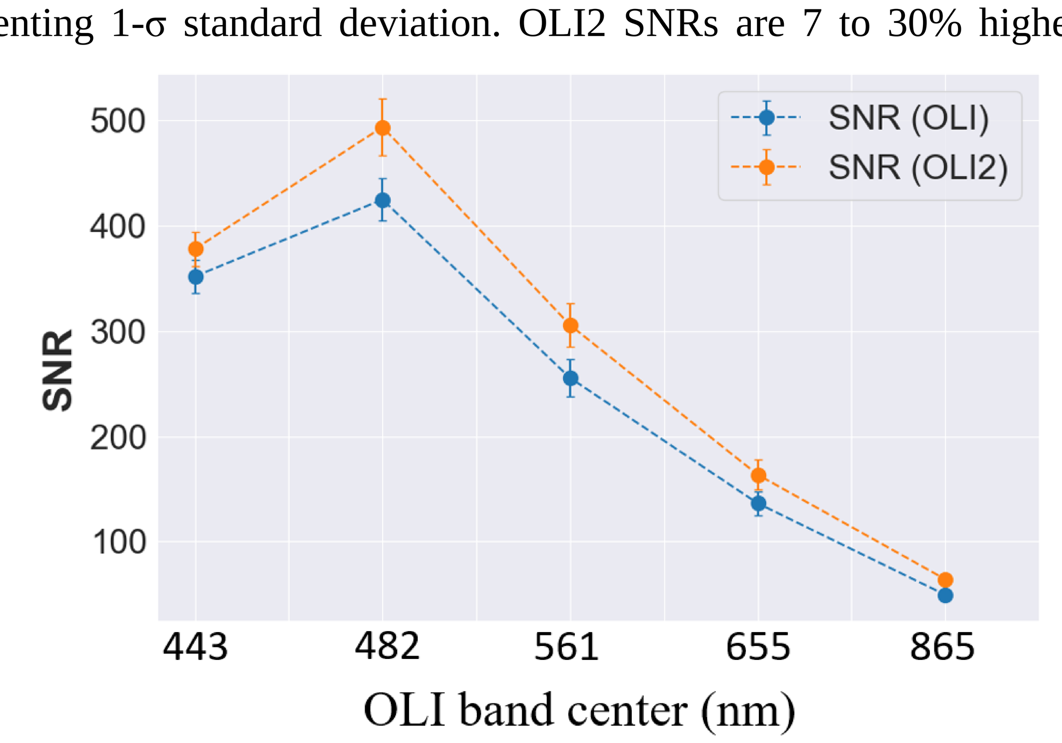

Fig. 2: SNRs estimated from OLI-OLI2 underfly scene pairs where L_{avg} is: 43 (443 nm), 34 (482 nm), 18 (561 nm), 9 (655 nm), 2 (865 nm) $W\,m^{-2}\,sr^{-1}\,\mu m^{-1}$.

OLI-OLI2 Radiometry (ρ_t, ρ_w) Comparison

The differences in unitless ρ_t and ρ_w^{AR} between OLI and OLI2 are illustrated in Fig. 3. ρ_t products are consistent within **0.3%** in the visible-near-infrared (VNIR) bands except in the green band (561 nm), while median differences in the standard ρ_w (ρ_w^{AR}) were estimated to be **~ 2.6%, 0.7%, 3.8%, and 2.8%** in the 443, 482, 561, and 655 nm, respectively.

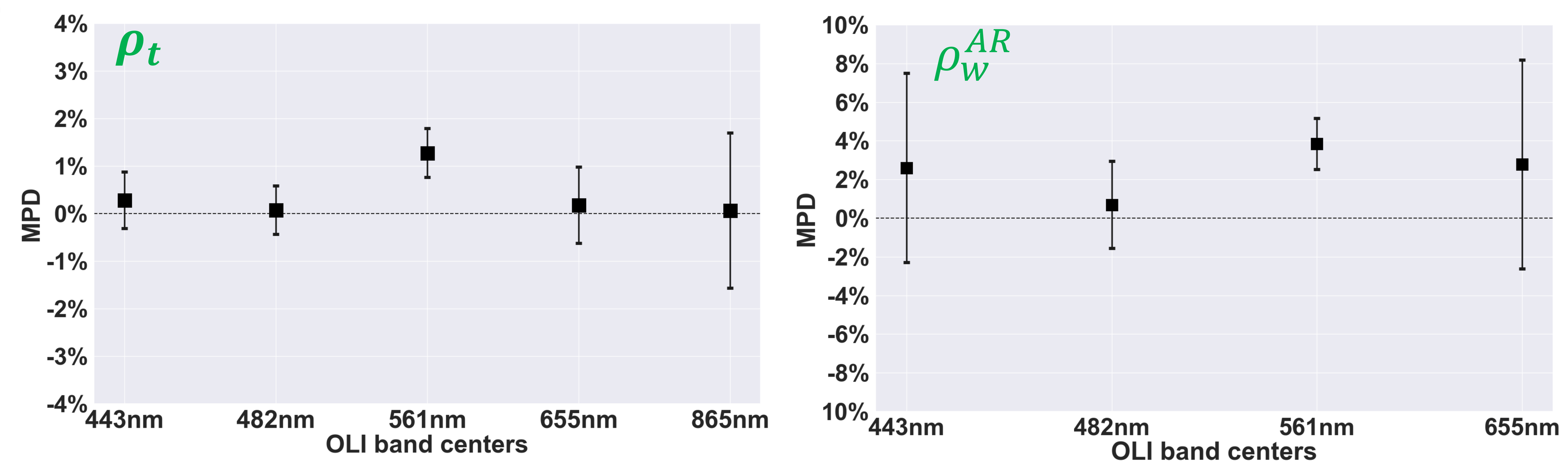

Fig. 3: OLI and OLI2 ρ_t and ρ_w^{AR} product inter-comparison (N = ~ 10000) for the VNIR bands. The data points indicate the median percent difference between OLI-OLI2 ($MPD_{\lambda i} = median([(\gamma^{OLI2(\lambda i)} - \gamma^{OLI(\lambda i)})/\gamma^{OLI(\lambda i)}] \times 100)$).

OLI and OLI2 ρ_w^{AR} is illustrated in **Fig. 4**, and **Fig. 5** shows the percentage difference maps for SeaDAS (ρ_w^{AR}), ACOLITE and POLYMER. The OLI and OLI2 images were acquired, within ~ 1 minute on 14th Nov 2021 over the Atlantic Ocean (east coast of the U.S.). The banding in **Fig. 5** stems from slight differences in VAAs (Fig. 6).

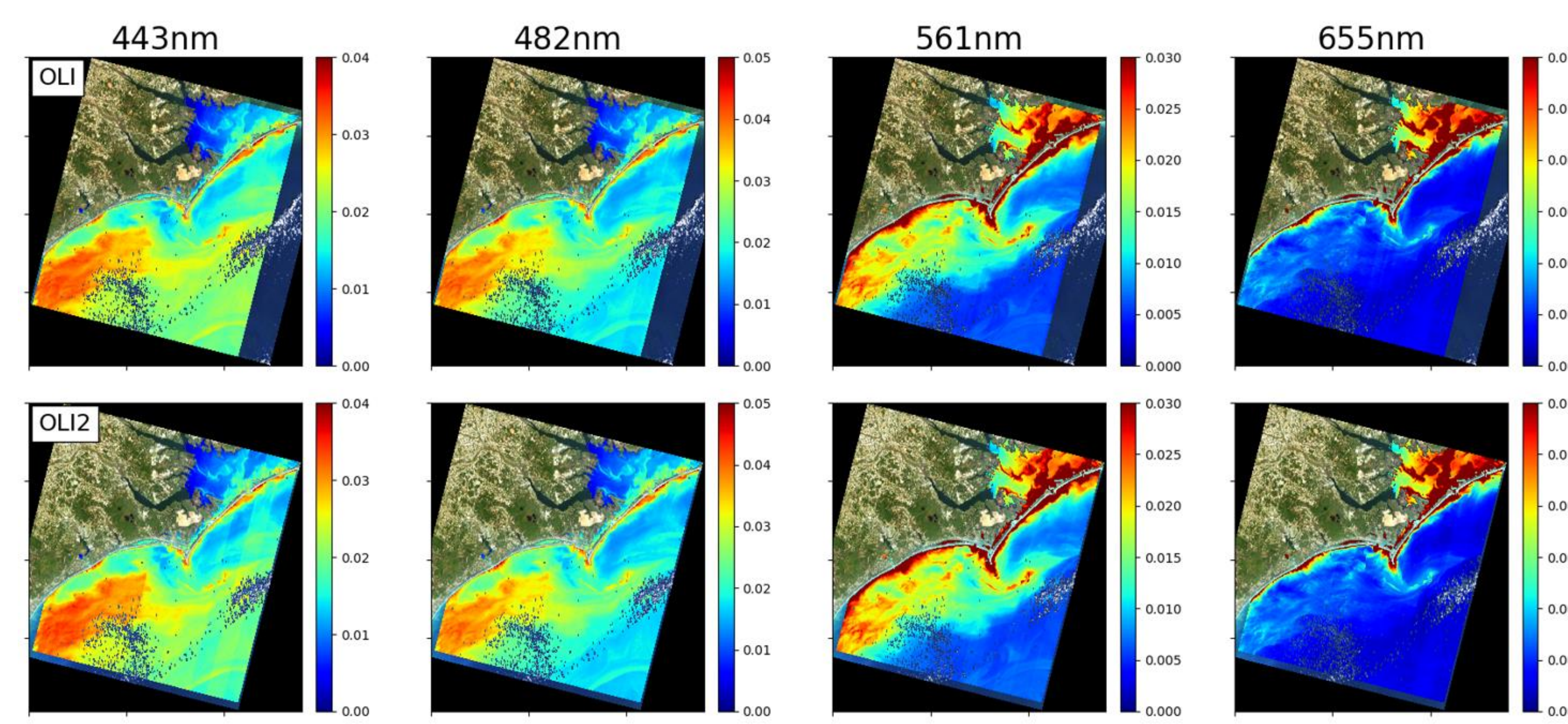

Fig. 4: OLI and OLI2 ρ_w^{AR} product map (overlapping area).

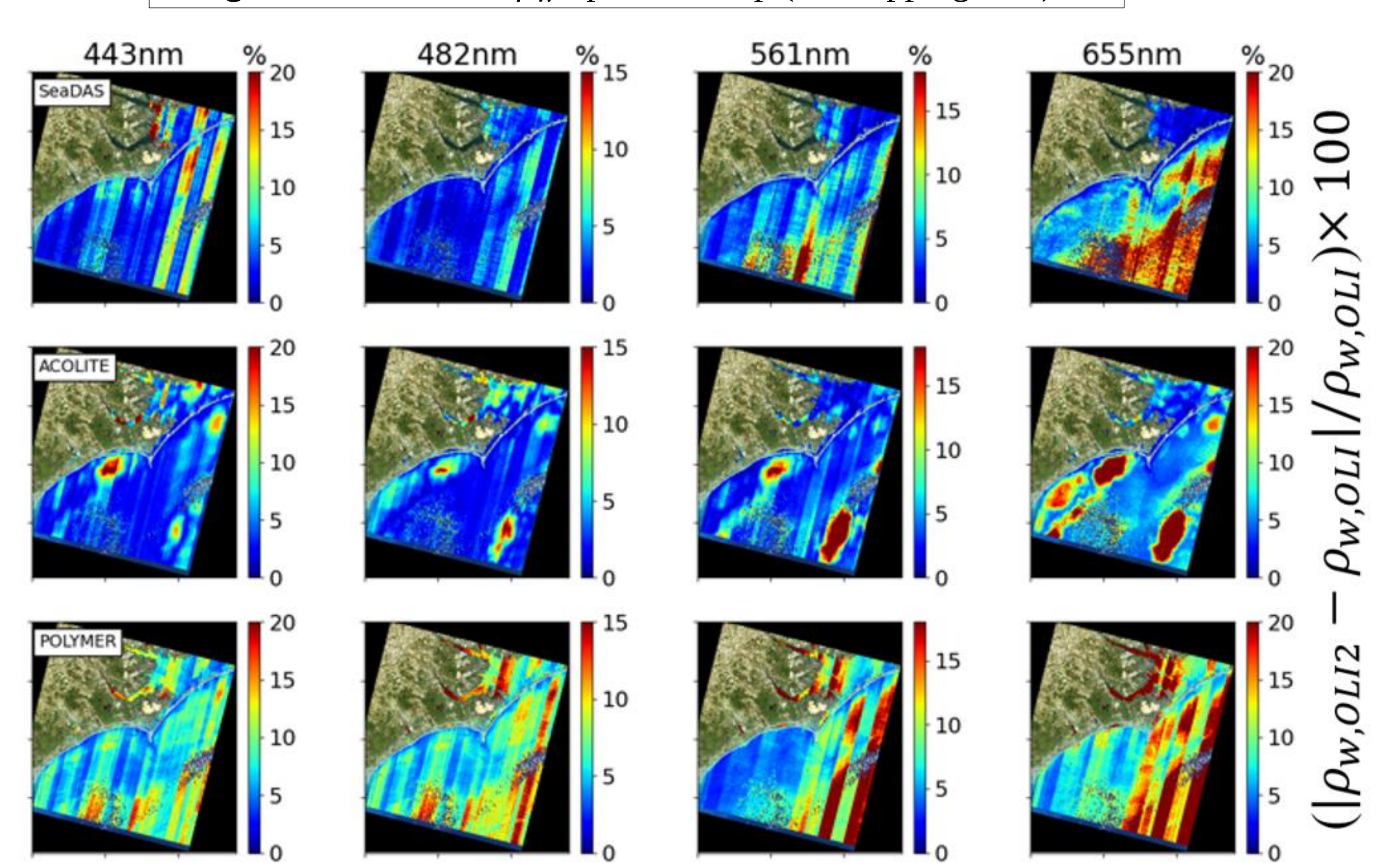

Fig. 5: OLI-OLI2 ρ_w difference maps for SeaDAS, ACOLITE and POLYMER.

OLI Focal Plane and Viewing Geometry

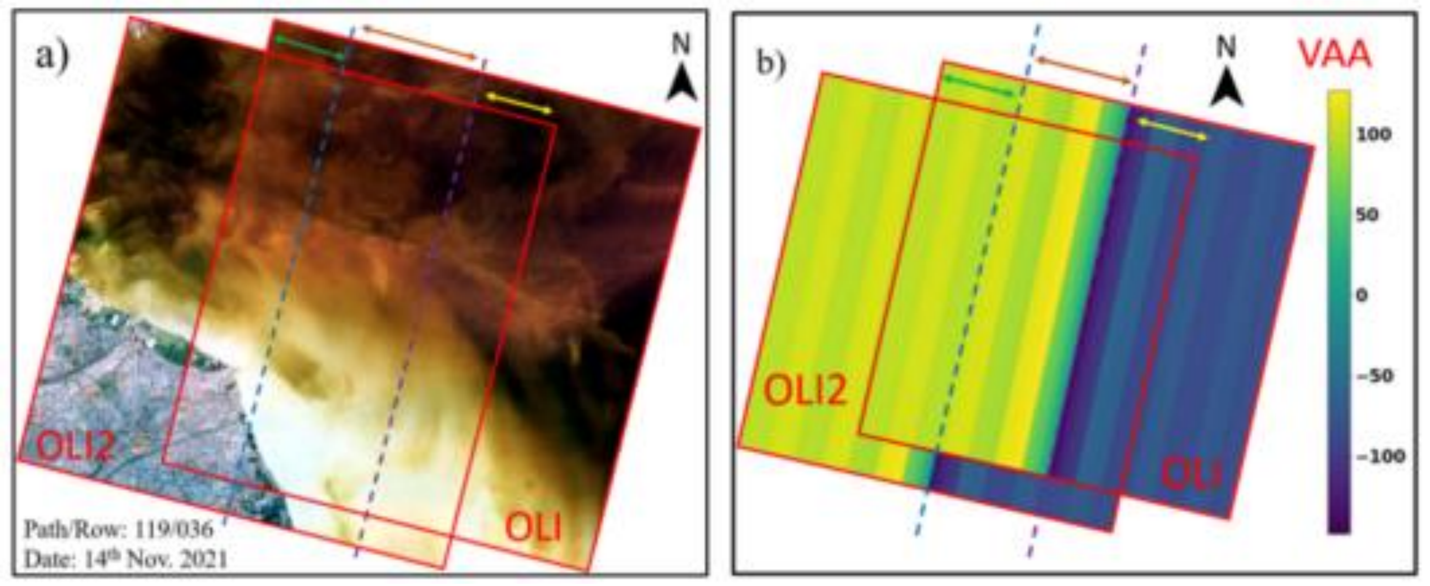

Fig. 6: a) OLI-OLI2 underfly scene pair over the yellow sea (east coast of China) and b) show the corresponding VAAs (in degrees).

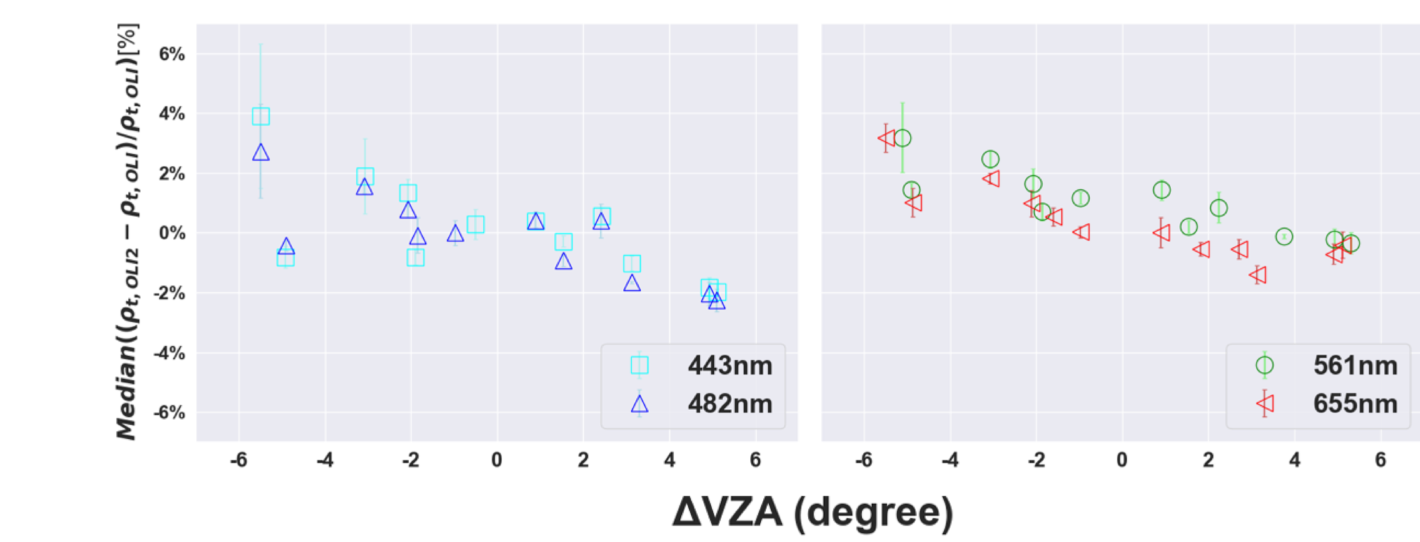

Fig. 7: OLI-OLI2 ρ_t difference as a function of view zenith angle difference (ΔVZA).

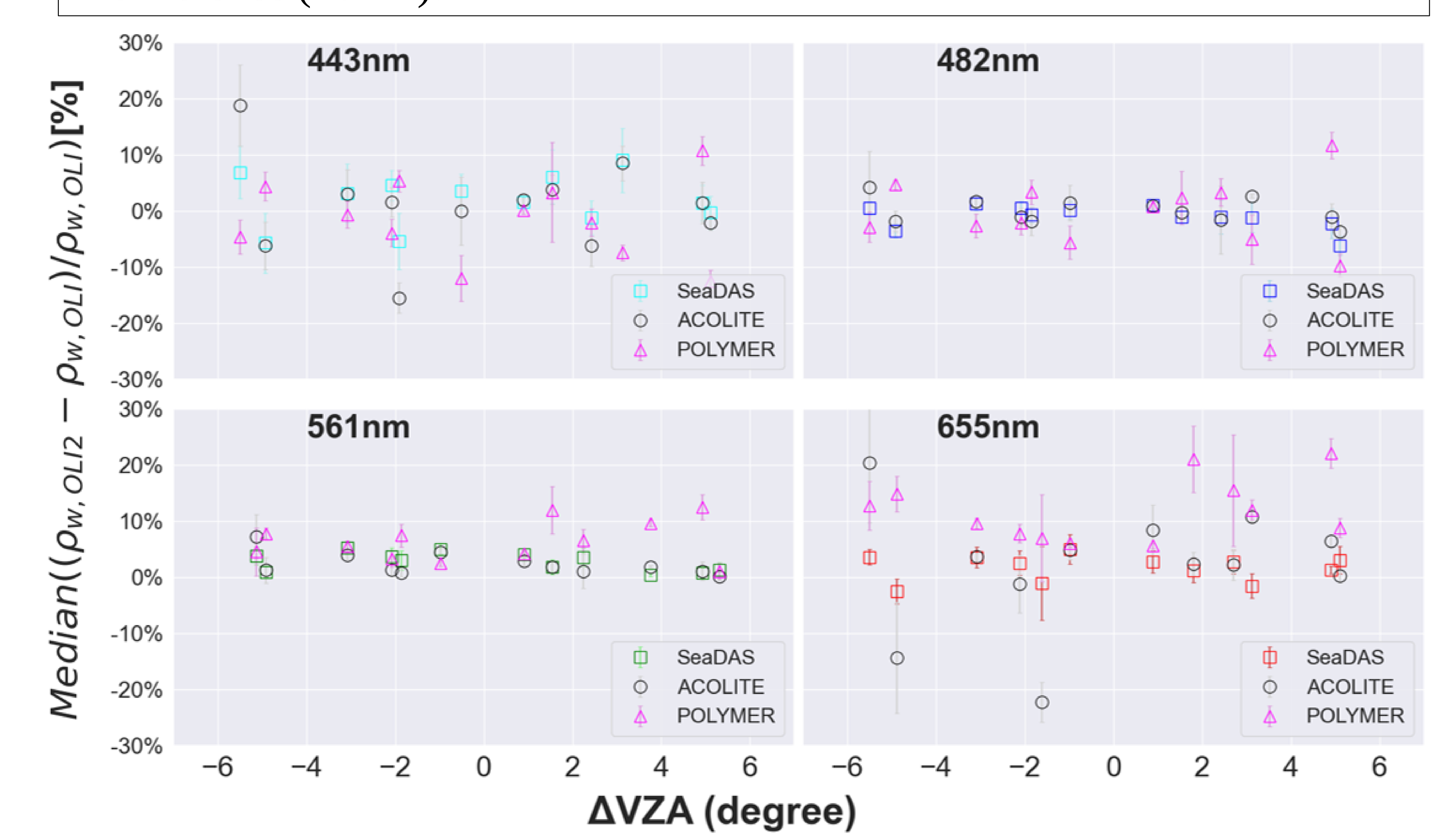

Fig. 8: Performance of the angular variability corrections of the AC processors for the four visible spectral bands, when **VAA signs are the same**. The data points and error bars denote the MPD and 1-σ standard deviation, respectively. SeaDAS-derived products show the lowest differences (~ 5%), followed by ACOLITE and POLYMER.

Conclusions & Future Work

- OLI2 SNRs are 7 to 30% higher than OLI for the VNIR bands.
- OLI-OLI2 ρ_t products are consistent within **0.3%** in the VNIR bands except for the green band (561 nm) showing **~ 1.3%** difference, while median differences in the standard ρ_w (ρ_w^{AR}) were estimated to be **~ 0.7 – 4%** for the visible bands.
- SeaDAS processor (*i.e.*, USGS AR products) is found the most optimal (< **5%** difference) processor in correcting for angular variability.
- **Future work:** Update the analysis with reprocessed Landsat 9 collects. Include SWIR and panchromatic bands.

References

Kabir, S., Pahlevan, N., O'Shea, R.E., & Barnes, B. (*in revision*). **Leveraging Landsat-8/-9 underfly observations to evaluate consistency in reflectance products over aquatic environments.** *Remote Sensing of Environment*

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