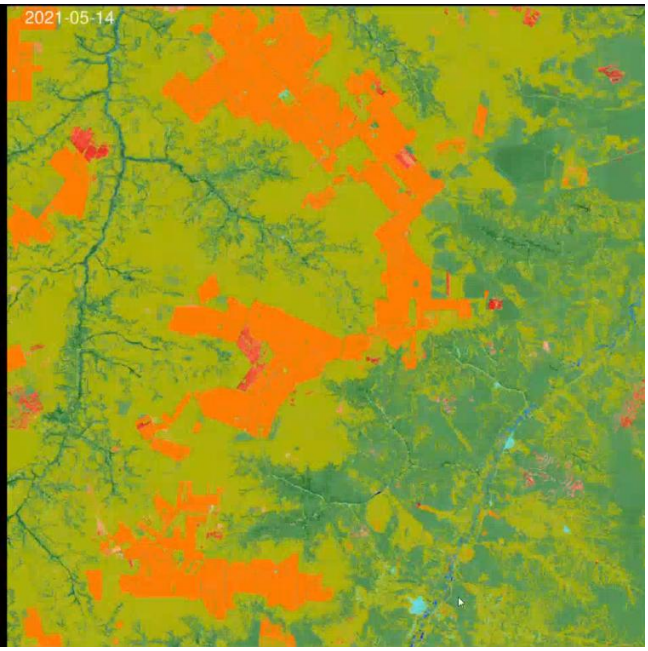
Home grown Landsat to HLS-based ARD compositing



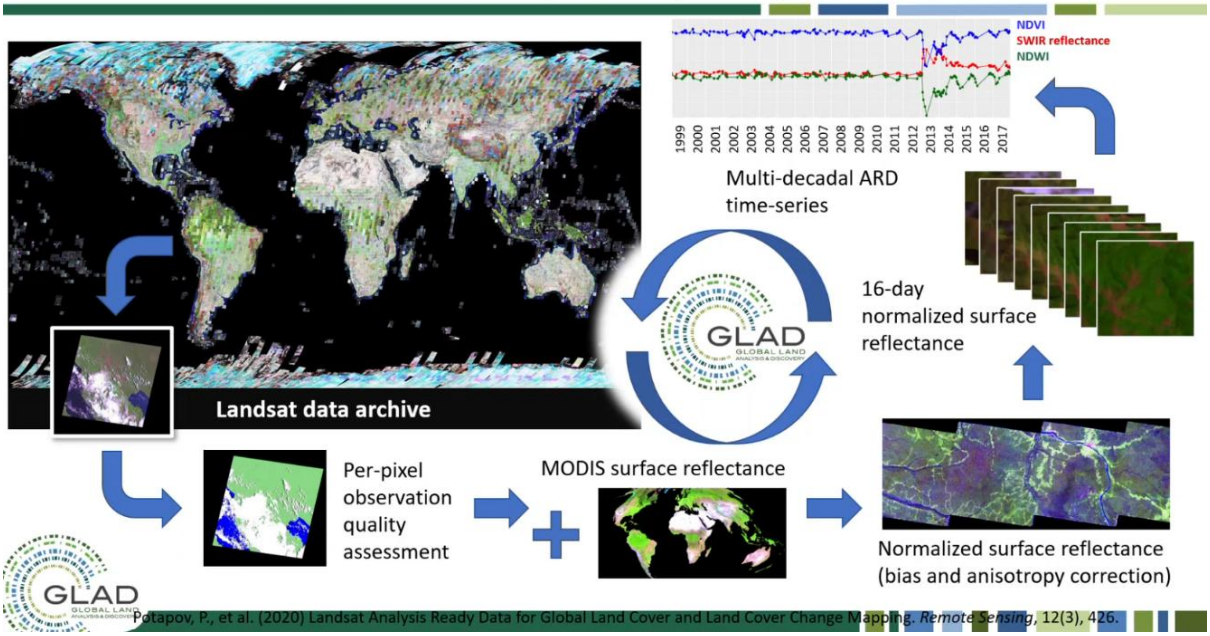
Time-series composite imagery

- While the AVHRR Pathfinder and MODIS Land time-series imagery were delivered as daily data, the key advance in facilitating land monitoring was best-pixel compositing over varying intervals
- Doing so required consideration of view geometry, spatial and spectral resampling, quality assurance tests, observation coverage, and rules for compositing
- When we started creating 16-day composite imagery for Landsats 5 and 7, there was no surface reflectance product

Considerations

- Composite period – tolerance of poor quality or missing data versus coarse temporal resolution and loss of phenological/ephemeral change
- QA – dependent on bands, challenging to implement generically for both clouds and shadows
- Resampling – nearest neighbor is best choice due to spatial degradation of averaging methods, go from L0 to output grid and be done
- Compositing rule – central tendency, maximum value, etc., all a function of how good QA is
- BRDF – critically important for low latitude forest cover, especially during the equinoxes
- Relative normalization is useful

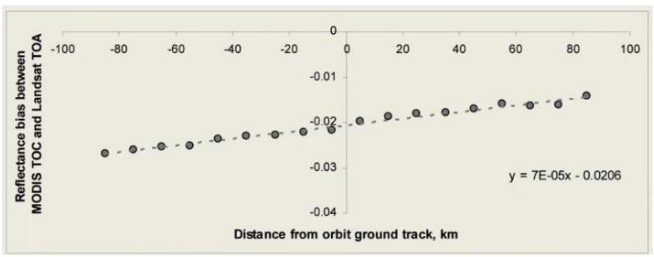
GLAD Landsat Analysis Ready Data (GLAD ARD)

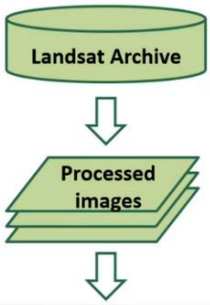


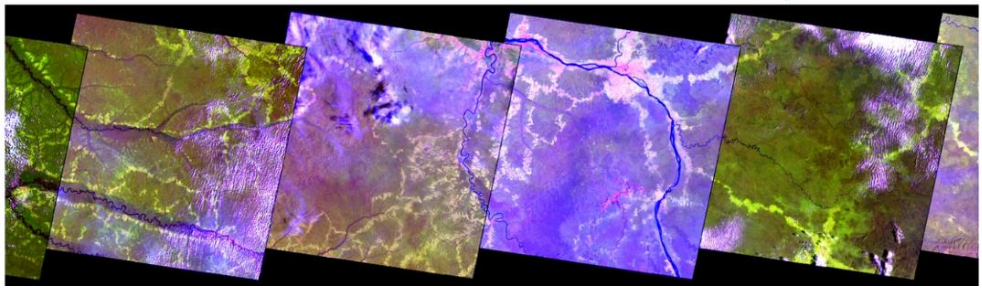
Potapov, P., et al. (2020) Landsat Analysis Ready Data for Global Land Cover and Land Cover Change Mapping. *Remote Sensing*, 12(3), 426.

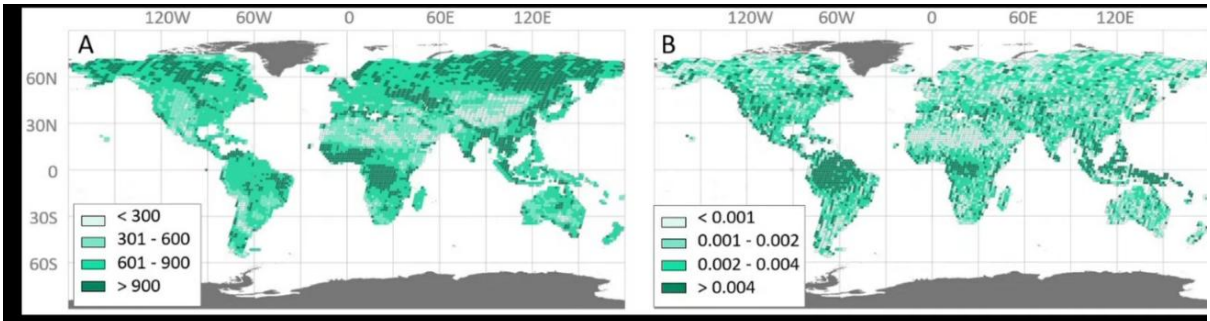
Landsat ARD Processing

3. Reflectance normalization









Gain and bias coefficients are derived for each spectral band and the resulting models appied to the entire Landsat image. The normalized surface reflectance is calculated per-pixel, using the raster layer of distances from the ground path (in meters) calculated for each WRS from the Landsat orbital parameters:

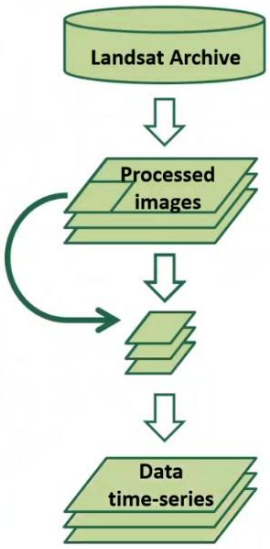
$$\rho^{NORM}=\rho^{TOA}-(G\times d+B)$$

ρ^{NORM} – normalized surface reflectance; ρ^{TOA} – TOA reflectance; G – gain factor; d – distance from the Landsat ground path; B – bias factor.

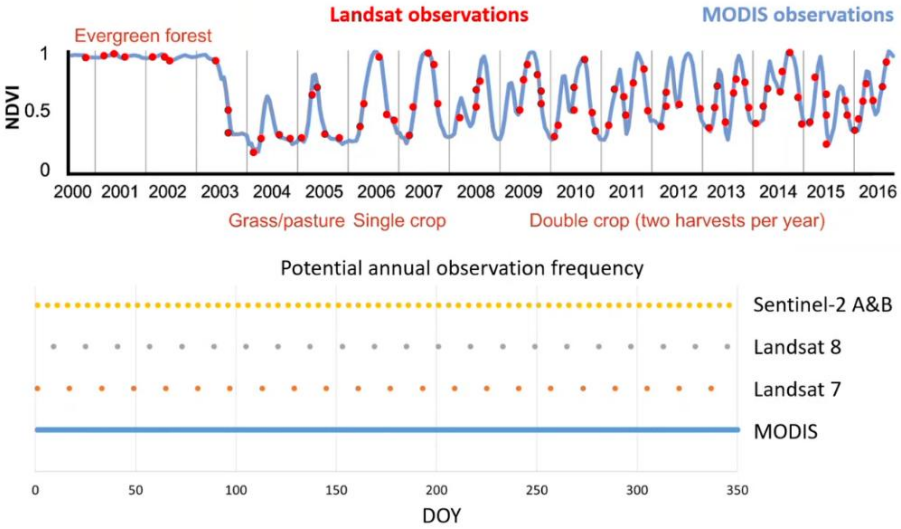
Landsat ARD Processing

5. **16-day Landsat data time-series**





Time-series data sets



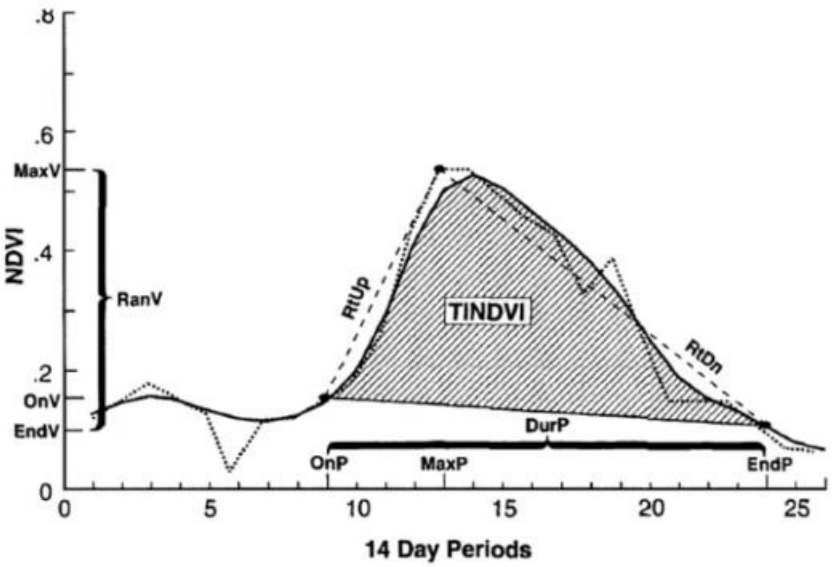
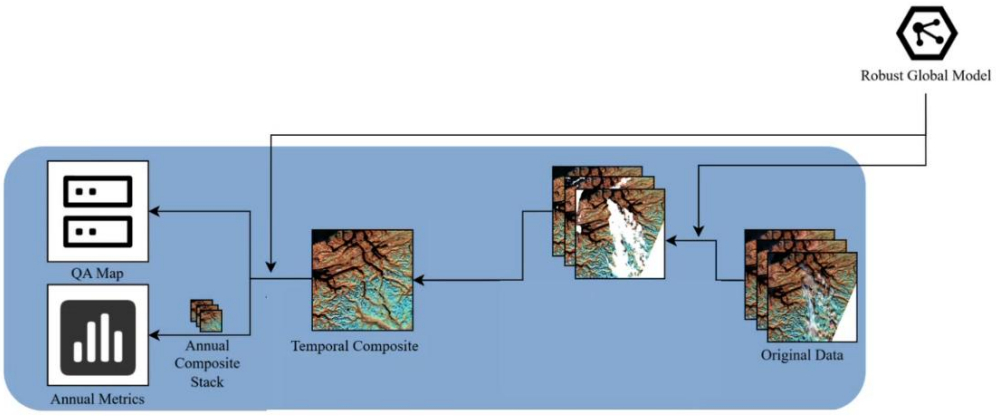
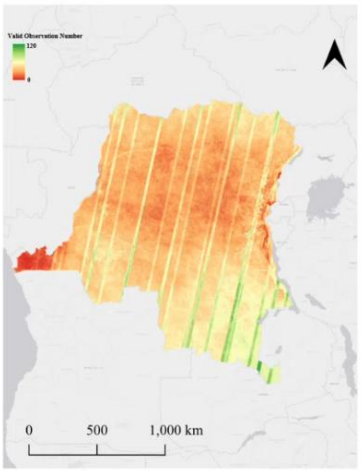


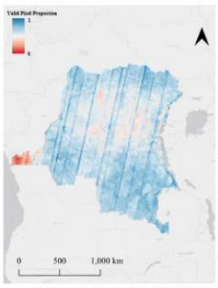
Fig. 3. Derivation of phenological metrics from actual temporal NDVI profile. OnP = Time of onset of greenness; OnV = NDVI value at onset; EndP = Time of end of greenness; EndV = NDVI value at end; DurP = Duration of greenness; MaxP = Time of maximum NDVI; MaxV = Maximum NDVI value; RanV = Range of NDVI values; RtUp = Rate of greenup; RtDn = Rate of senescence; TINDVI = Time-integrated NDVI.

Harmonized Landsat Sentinel 2 16-day composites of HLS data for Red, NIR, SWIR1, and SWIR2 bands

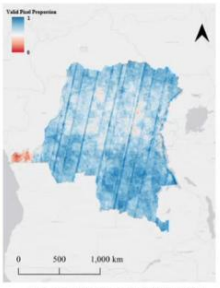


Methodology | Composite Time Window

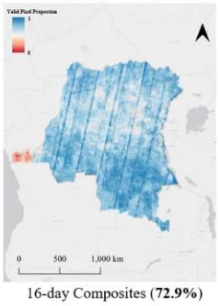




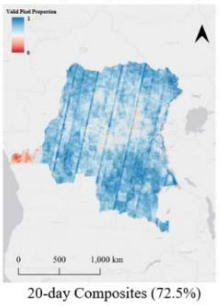
10-day Composites (63.3%)



15-day Composites (72.1%)



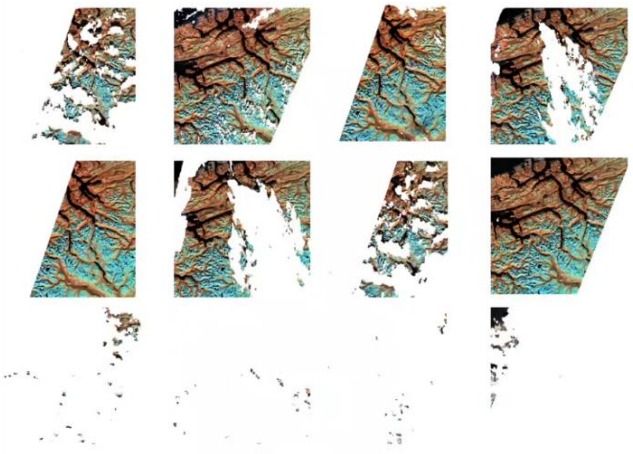
16-day Composites (**72.9%**)



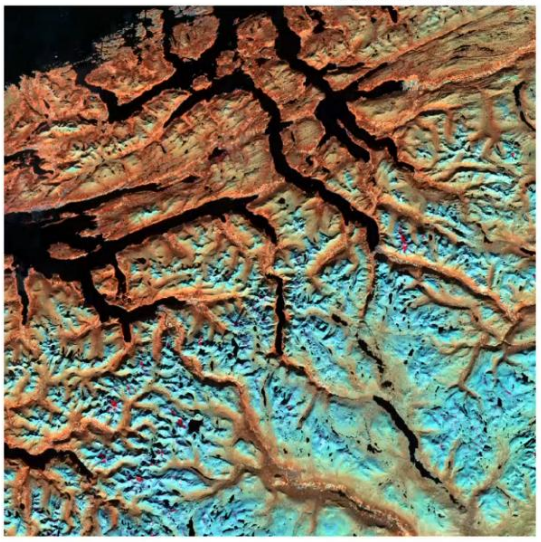
20-day Composites (72.5%)

Left: The HLS valid observation number in 2023 in DRC.
Right: The proportion of valid pixel in pixelwise. The ratios after captions are the mean annual proportion of valid pixels across DRC.

Results | Composite Showcase

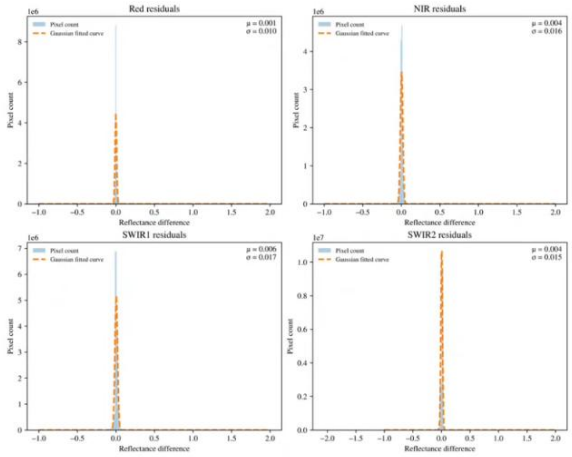


RGB: NIR-SWIR1-SWIR2

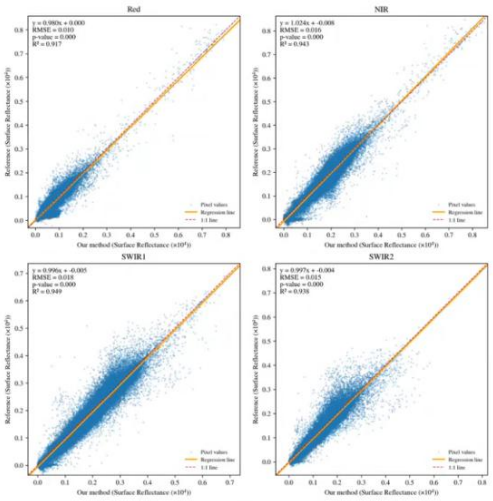


Tile 32VMQ (Norway) in the time period from 2024/08/28 to 2024/9/12. **Left**: 12 HLS granueles after cloud mask, **Right**: The 16-day cloudless and shadowless composite using our method.

Results | Validation Result



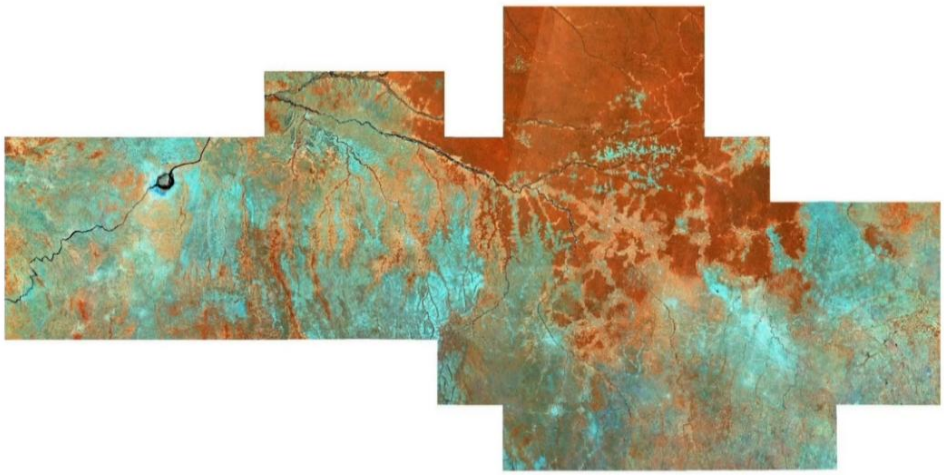
Histograms and the Normalized Gaussian Fitted Curves of reflectance difference between composite and reference images for 4 bands.



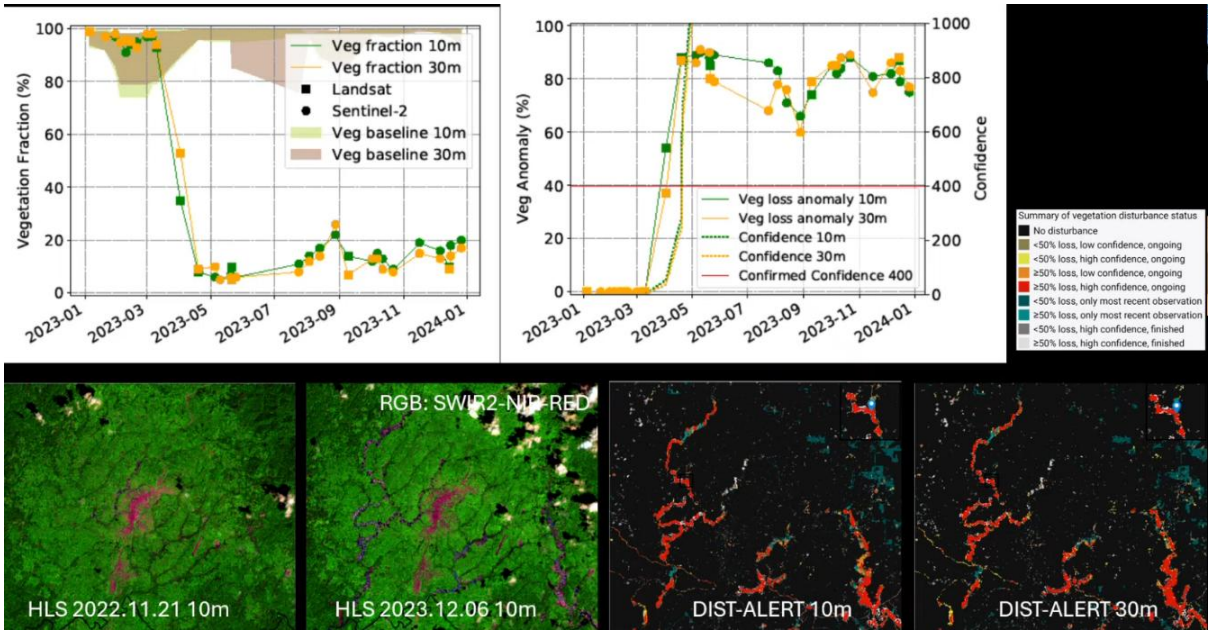
The linear regression result from pixel values in the composite image of our method and the reference image

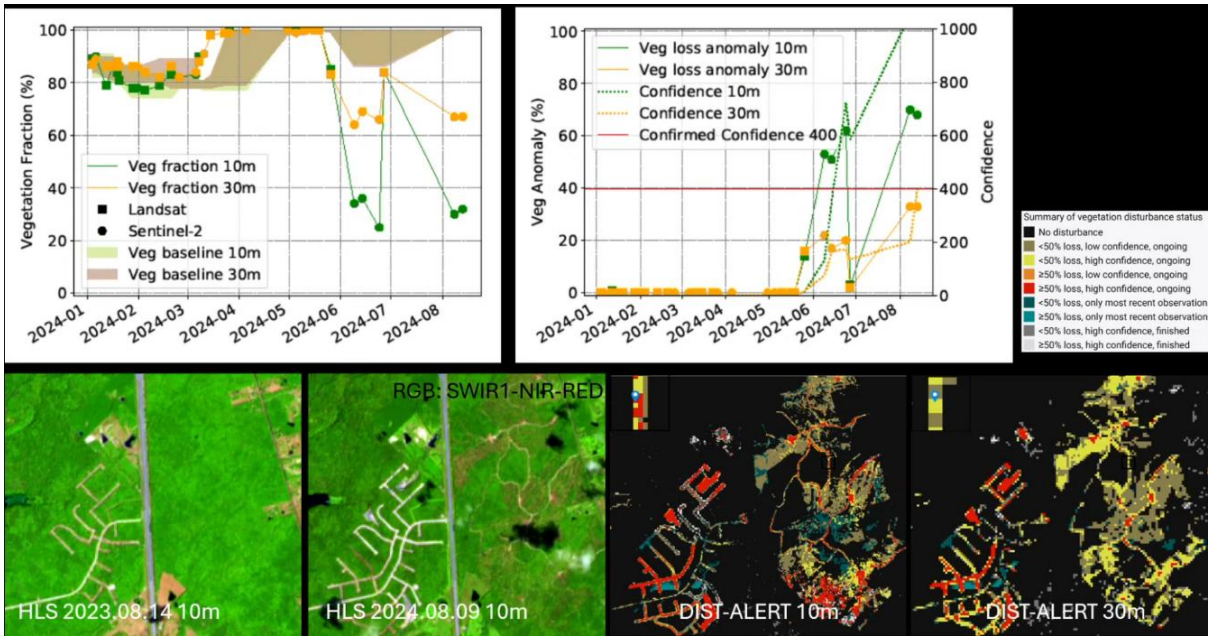
BRDF present in composites

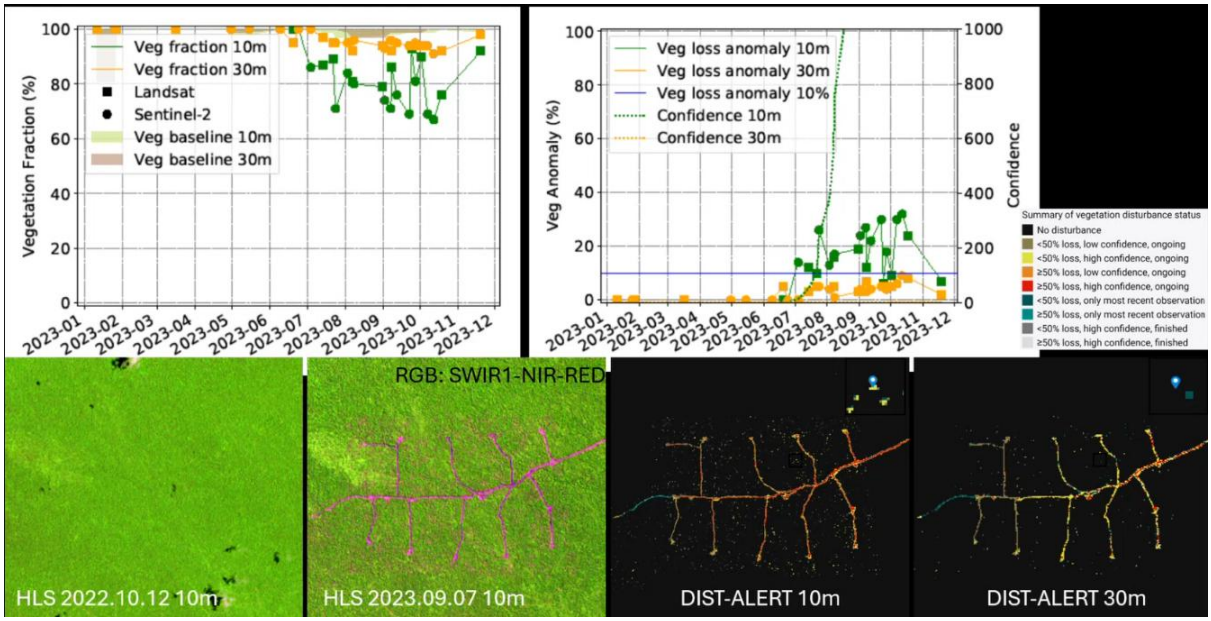
RGB: NIR-SWIR1-SWIR2



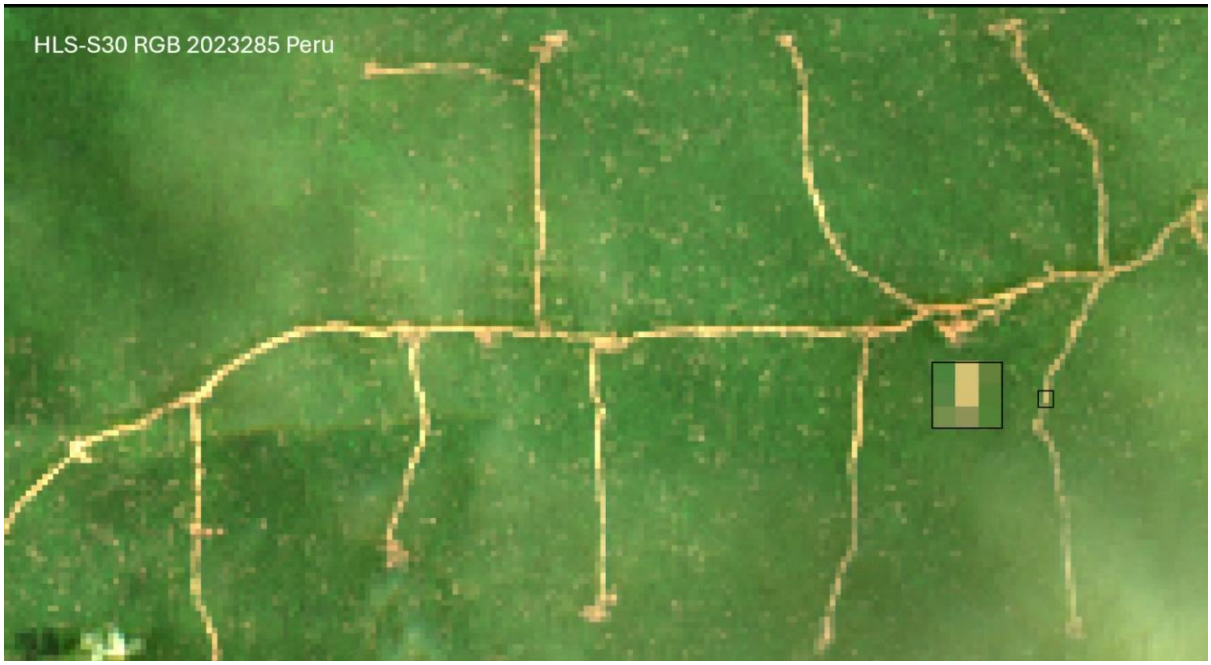
Subregion of the Congo Basin shown in a 2018 composite of mean NIR, SWIR1, and SWIR2 reflectance values computed from the 25th–75th percentile range for each band (Potapov et al., 2020).

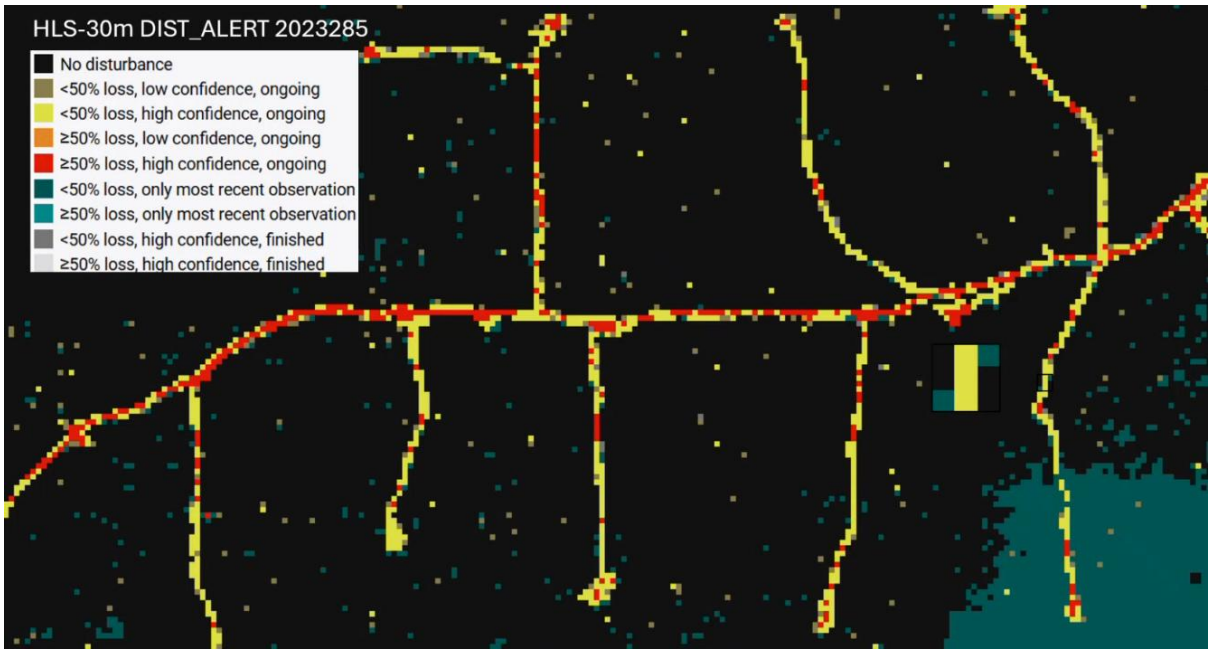

Vegetation Fraction (%)
Veg fraction 10m
Veg fraction 30m
Landsat
Sentinel-2
Veg baseline 10m
Veg baseline 30m
Veg Anomaly (%)
Confidence
Veg loss anomaly 10m
Veg loss anomaly 30m
Confidence 10m
Confidence 30m
Confirmed Confidence 400
Summary of vegetation disturbance status
No disturbance
<50% loss, low confidence, ongoing
<50% loss, high confidence, ongoing
≥50% loss, low confidence, ongoing
≥50% loss, high confidence, ongoing
<50% loss, only most recent observation
≥50% loss, only most recent observation
<50% loss, high confidence, finished
≥50% loss, high confidence, finished
HLS 2022.11.21 10m
RGB: SWIR2-NIR-RED
HLS 2023.12.06 10m
DIST-ALERT 10m
DIST-ALERT 30m

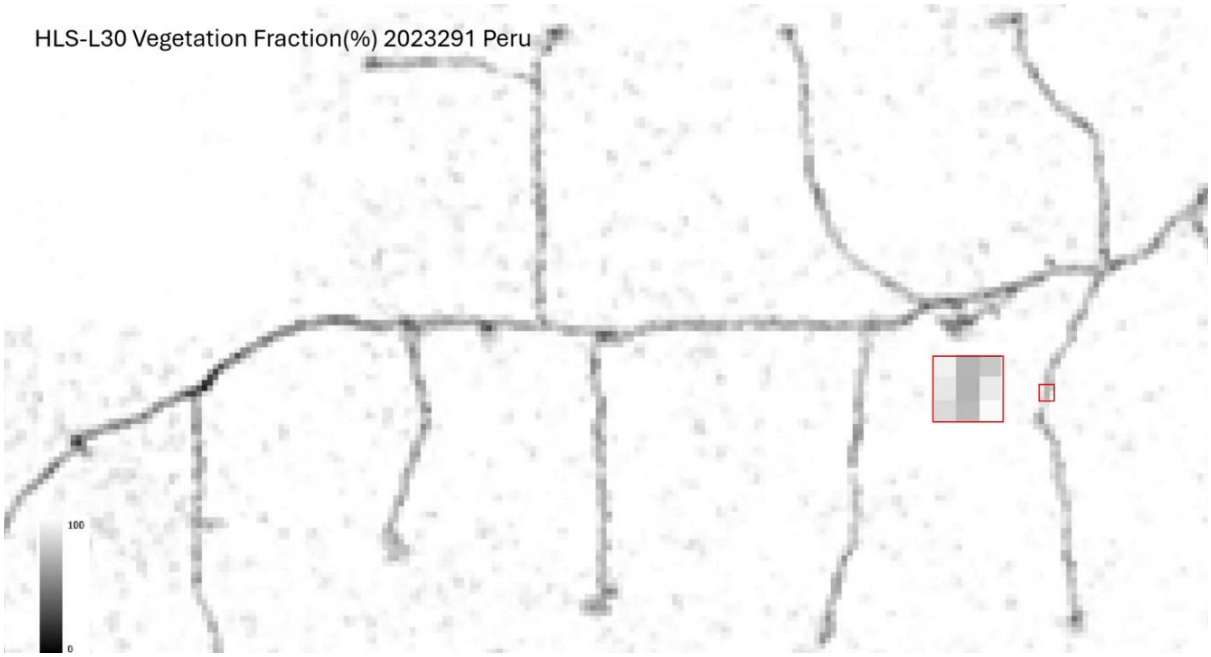

Vegetation Fraction (%)
Veg fraction 10m
Veg fraction 30m
Landsat
Sentinel-2
Veg baseline 10m
Veg baseline 30m
Veg Anomaly (%)
Confidence
Veg loss anomaly 10m
Veg loss anomaly 30m
Confidence 10m
Confidence 30m
Confirmed Confidence 400
Summary of vegetation disturbance status
No disturbance
<50% loss, low confidence, ongoing
<50% loss, high confidence, ongoing
≥50% loss, low confidence, ongoing
≥50% loss, high confidence, ongoing
<50% loss, only most recent observation
≥50% loss, only most recent observation
<50% loss, high confidence, finished
≥50% loss, high confidence, finished
HLS 2023.08.14 10m
RGB: SWIR1-NIR-RED
HLS 2024.08.09 10m
DIST-ALERT 10m
DIST-ALERT 30m

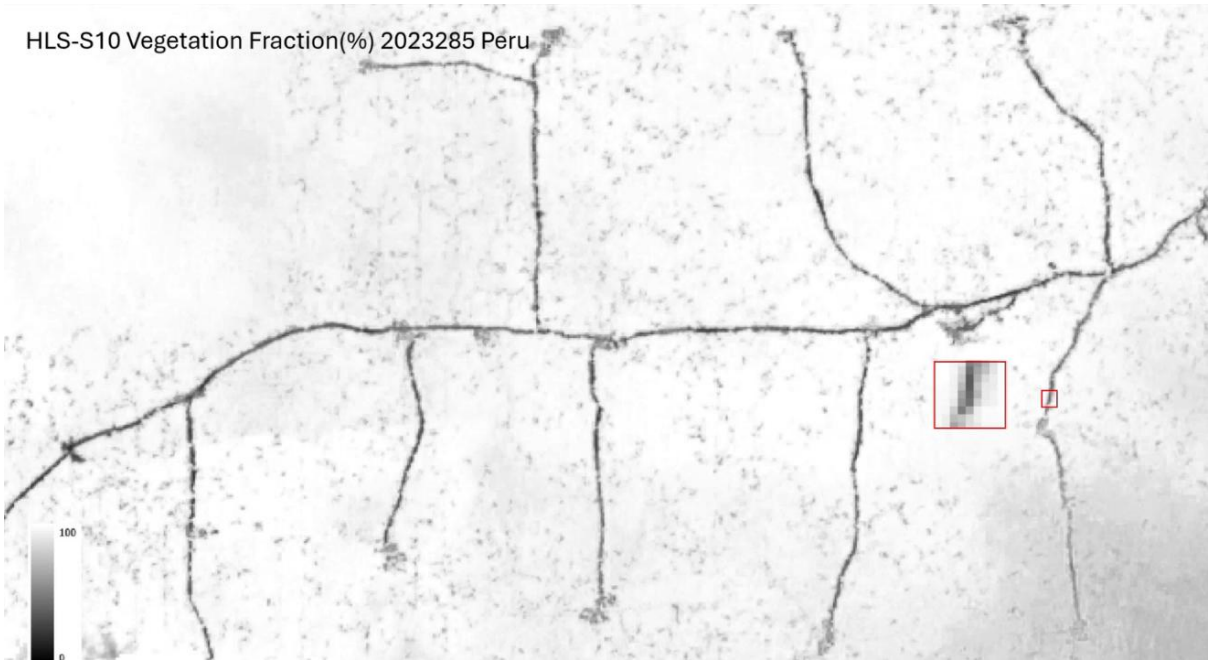

Vegetation Fraction (%)
Veg fraction 10m
Veg fraction 30m
Landsat
Sentinel-2
Veg baseline 10m
Veg baseline 30m
Veg Anomaly (%)
Veg loss anomaly 10m
Veg loss anomaly 30m
Veg loss anomaly 10%
Confidence 10m
Confidence 30m
Confidence
Summary of vegetation disturbance status
No disturbance
<50% loss, low confidence, ongoing
<50% loss, high confidence, ongoing
≥50% loss, low confidence, ongoing
≥50% loss, high confidence, ongoing
<50% loss, only most recent observation
≥50% loss, only most recent observation
<50% loss, high confidence, finished
≥50% loss, high confidence, finished
RGB: SWIR1-NIR-RED
HLS 2022.10.12 10m
HLS 2023.09.07 10m
DIST-ALERT 10m
DIST-ALERT 30m

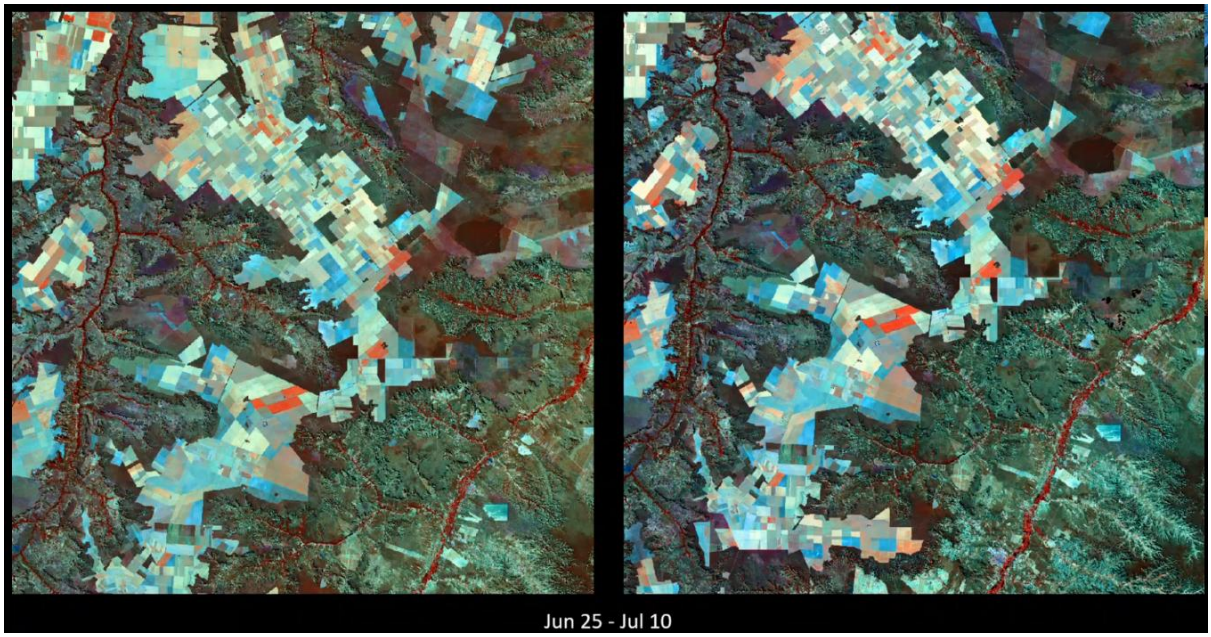

HLS-L30 RGB 2023291 Peru


HLS-S30 RGB 2023285 Peru

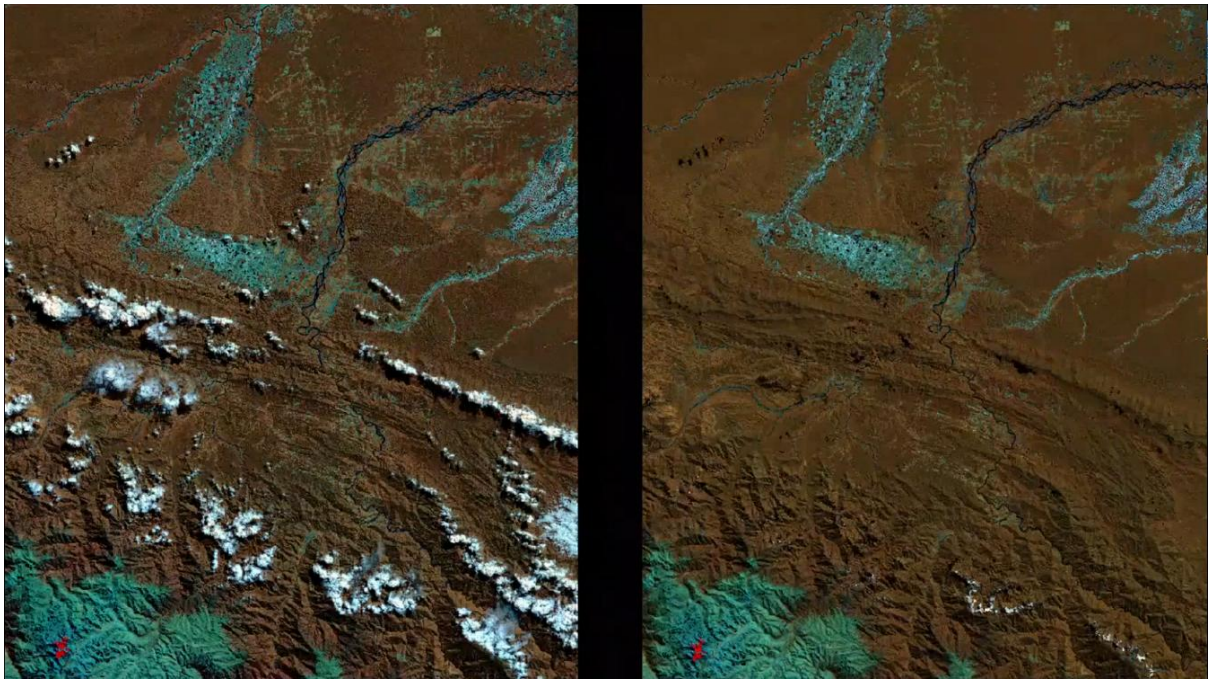

HLS-30m DIST_ALERT 2023285
No disturbance
<50% loss, low confidence, ongoing
<50% loss, high confidence, ongoing
≥50% loss, low confidence, ongoing
≥50% loss, high confidence, ongoing
<50% loss, only most recent observation
≥50% loss, only most recent observation
<50% loss, high confidence, finished
≥50% loss, high confidence, finished


HLS-L30 Vegetation Fraction(%) 2023291 Peru
100
0


HLS-S10 Vegetation Fraction(%) 2023285 Peru
100
0

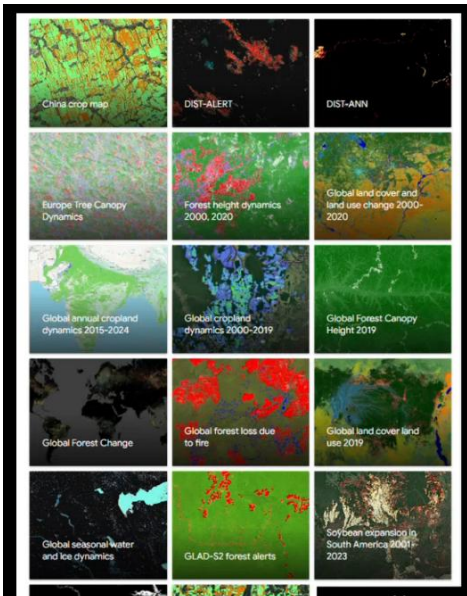


Jun 25 - Jul 10



Some thoughts

- Robust composites reduce data volumes and processing overhead while providing a clean(ish) time series for land characterization
- Given all of the options, the possible permutations of ARD composites are endless
- Could go for one size fits all or ambitious on-demand versioning
- Very much need to improve resampling to retain finest spatial resolution spectral response - nearest neighbor should be assessed due to spatial degradation of averaging methods, , especially for Landsat, and should go from L0 to output grid
- BRDF is tricky, but bulk empirical per scene adjustments work well in humid tropics



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