From Under the Clouds to in the Cloud:

The Role of Unoccupied Aerial Systems (UASs) and Open Remote Sensing Data Workflows for Characterizing Landscape Change in the Arctic

Shawn P. Serbin

2022-04-11

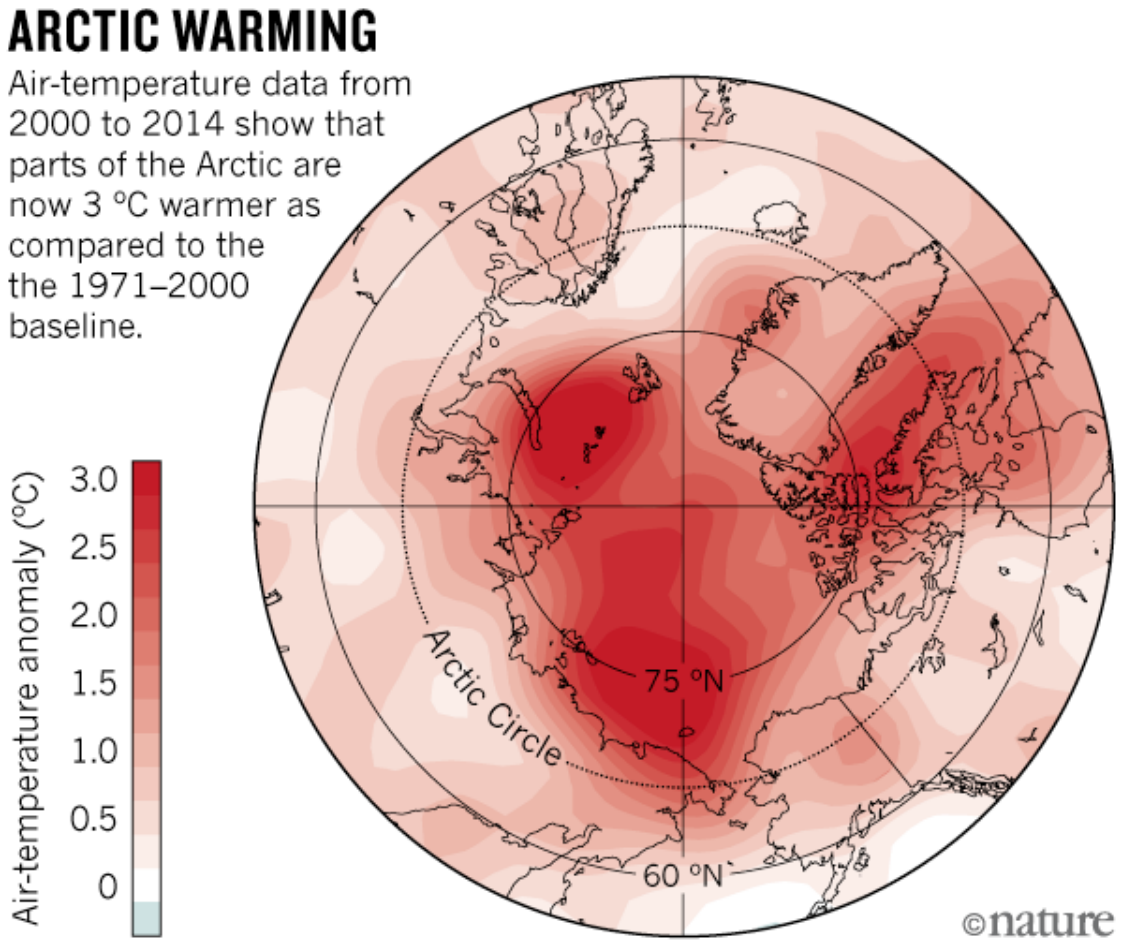
Twitter: @TESTgroup_BNL
web: www.bnl.gov/TESTgroup

Skookum Pass (Mile, 53 Council Road), Seward Peninsula, Alaska

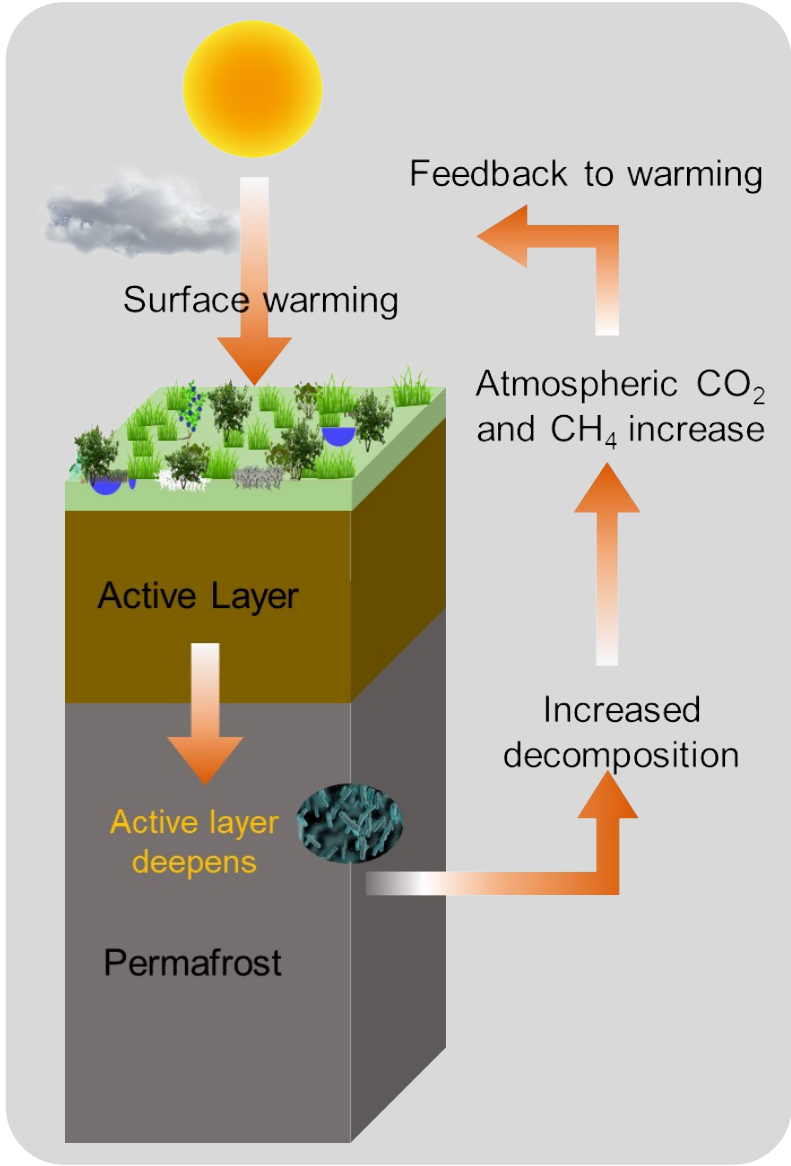
Brookhaven National Laboratory

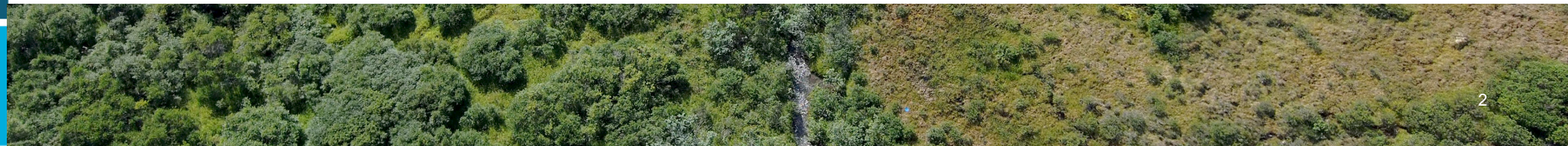
Next Generation Ecosystem Experiment in the Arctic (NGEE Arctic)

Terrestrial Ecosystem Science & Technology (TEST) group

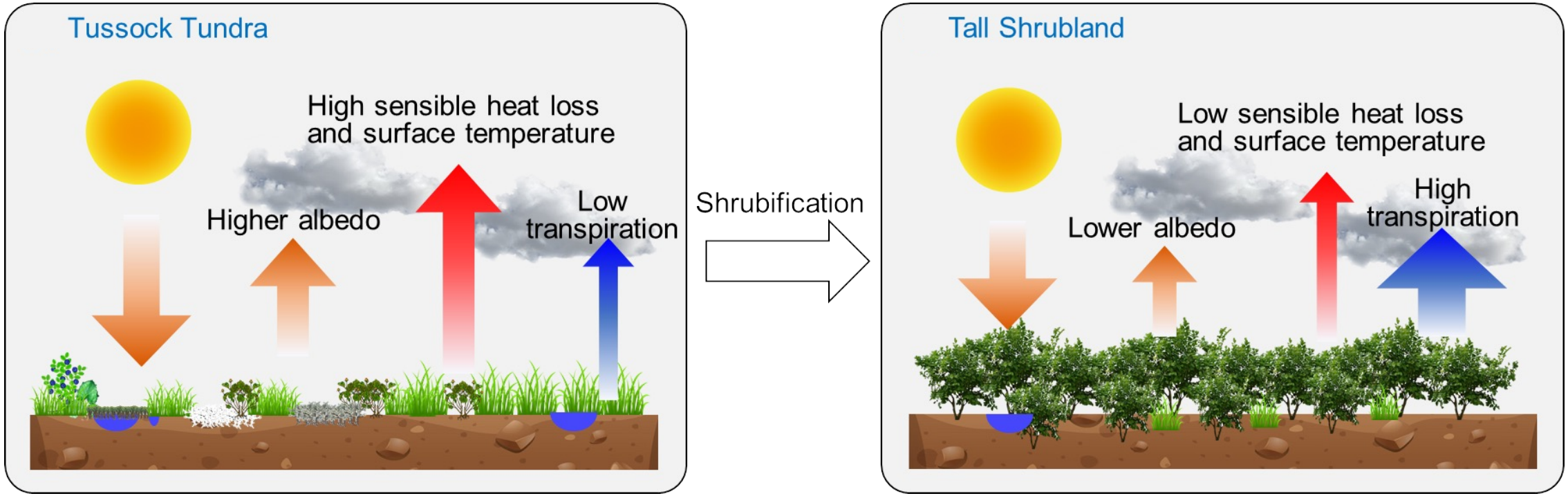


Tollefson, J. Huge Arctic report ups estimates of sea-level rise. Nature (2017) doi:10.1038/nature.2017.21911



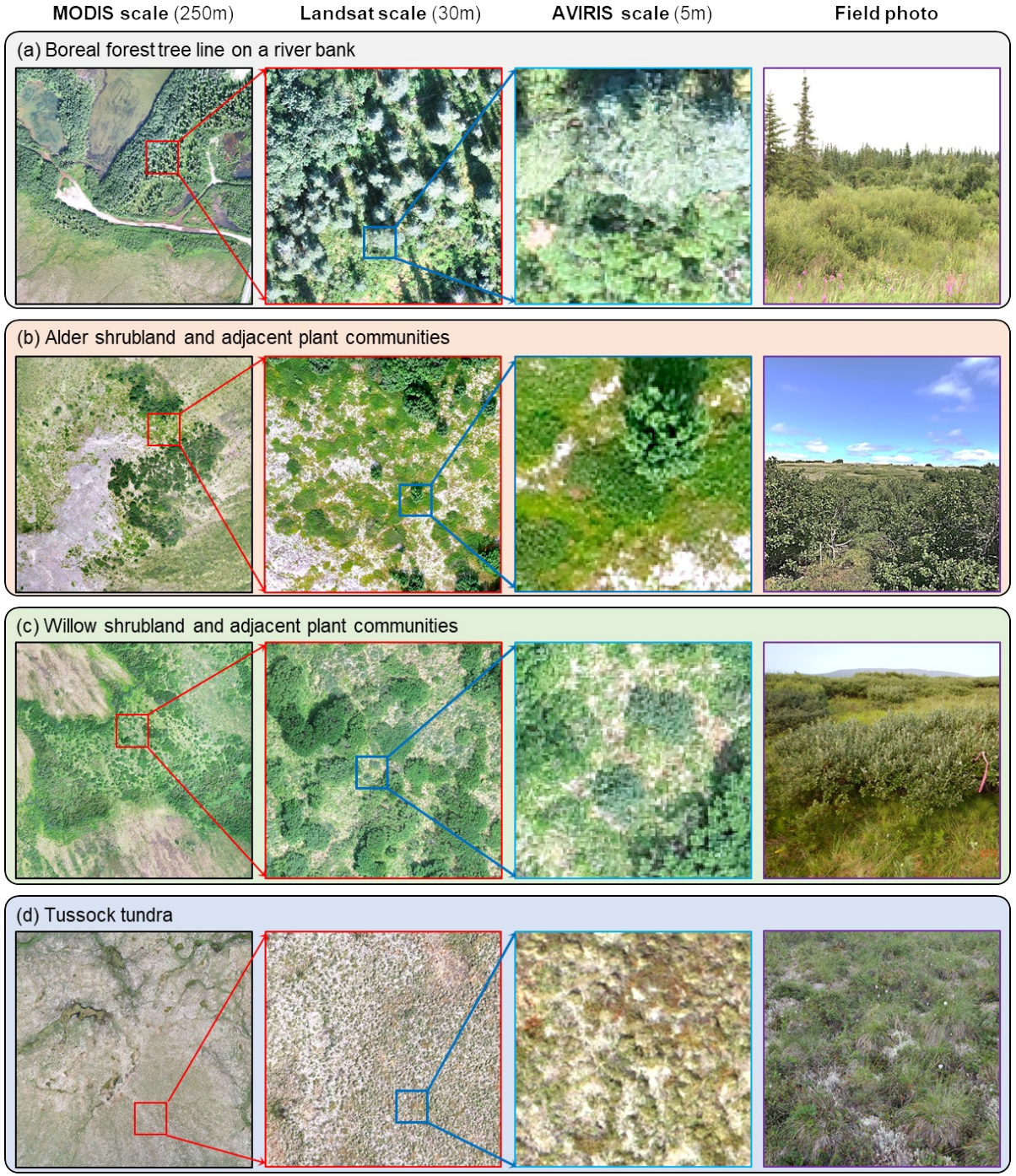


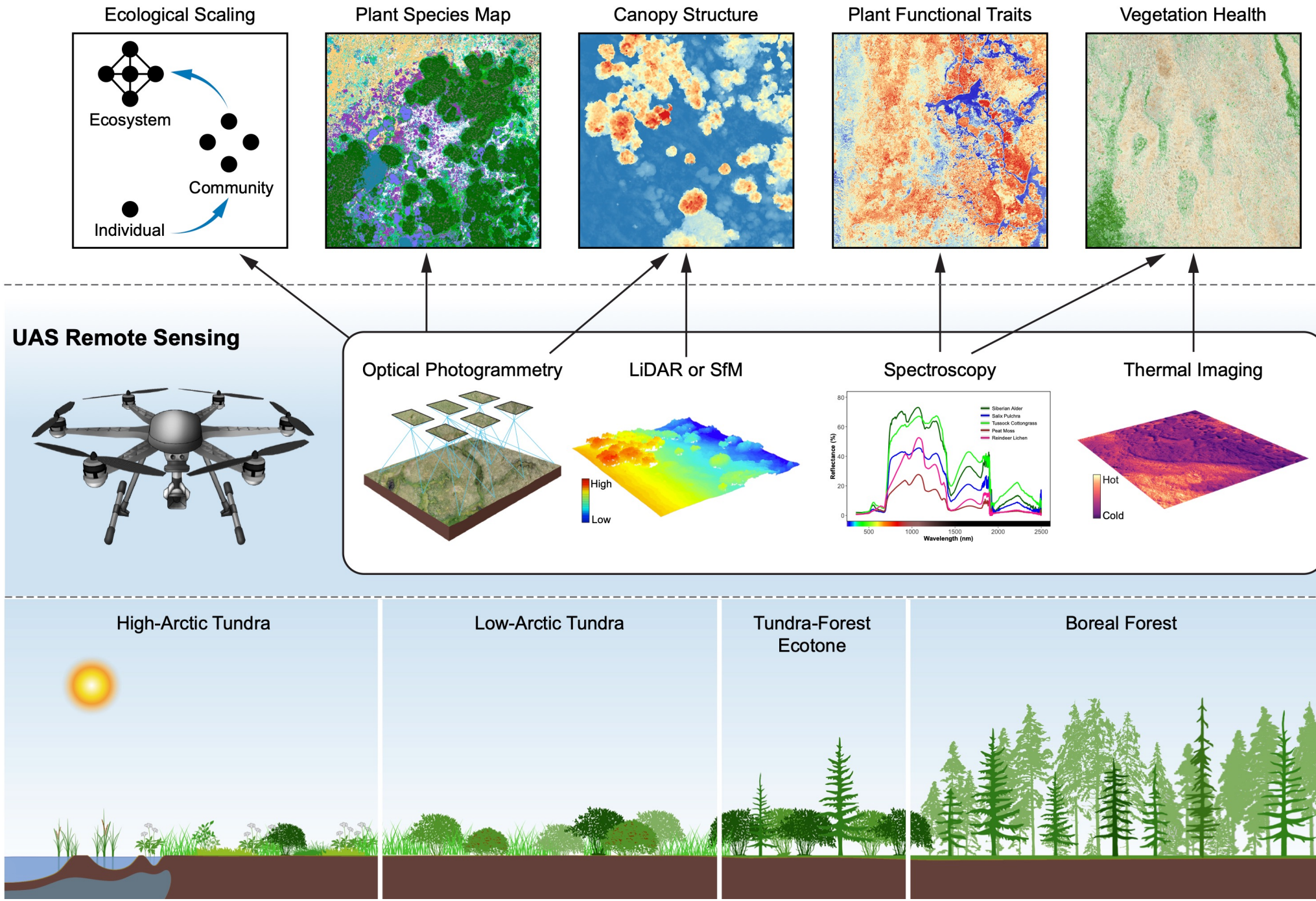
The predicted transition to higher shrub cover in the Arctic will have significant climate feedbacks



Arctic surface heterogeneity

- Species diversity is low, but…
- Contains significant spatial heterogeneity in composition, patch size, and structure related to fine-scale drivers, including soil, permafrost, and moisture and nutrient gradients
- This surface heterogeneity strongly controls the spatio-temporal patterns of vegetation function and dynamics - but is poorly characterized by coarse resolution satellites

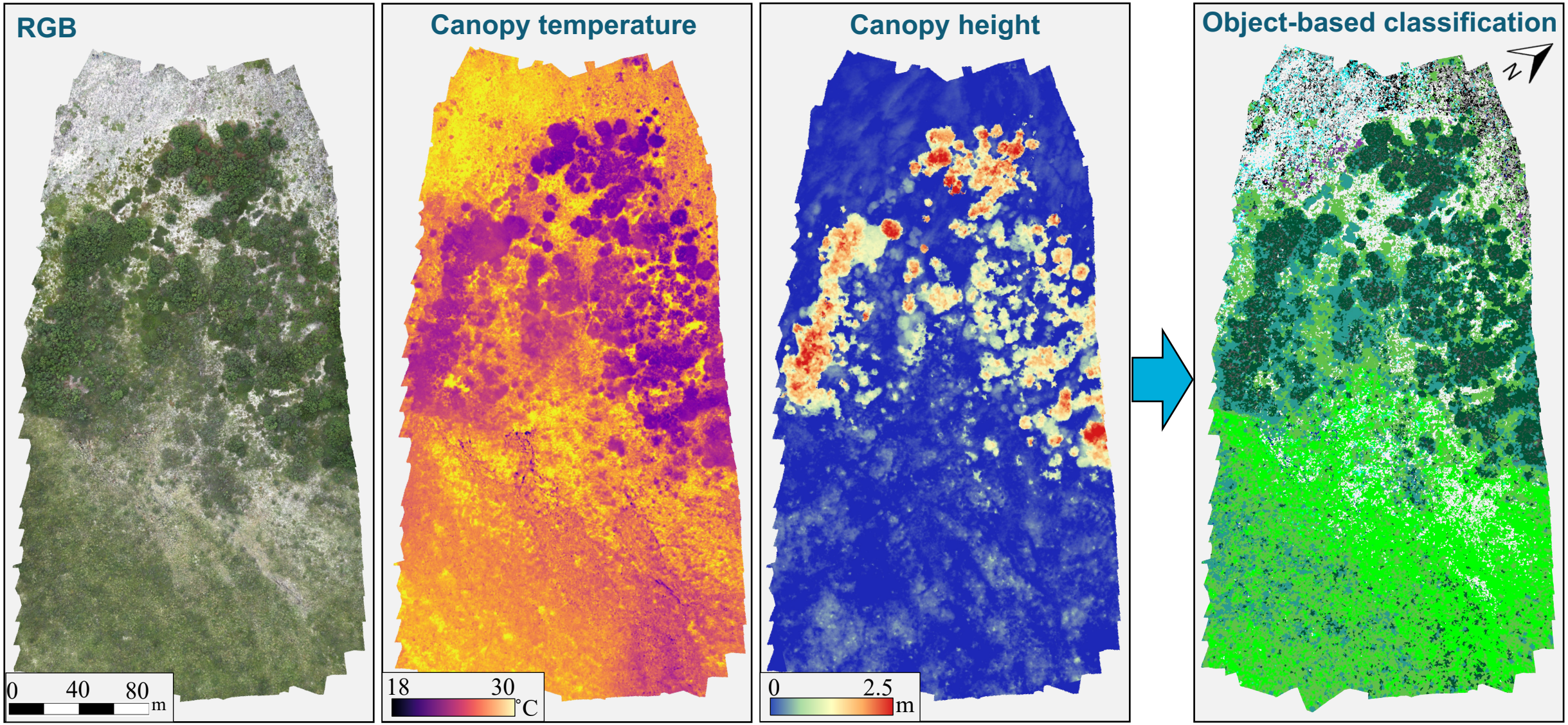




Yang et al., (in review)

Centimeter-scale UAS data

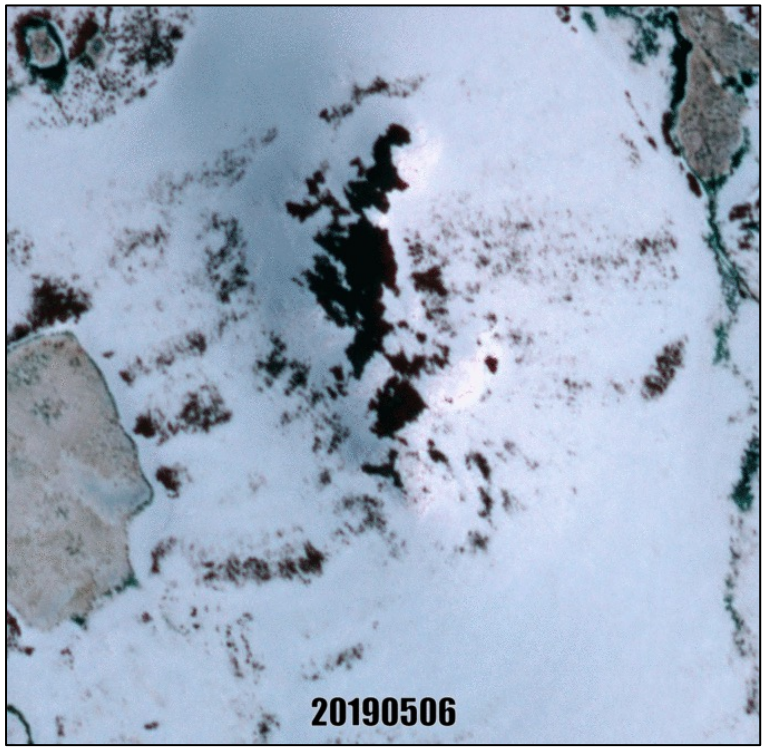
Example data from the *Osprey* platform



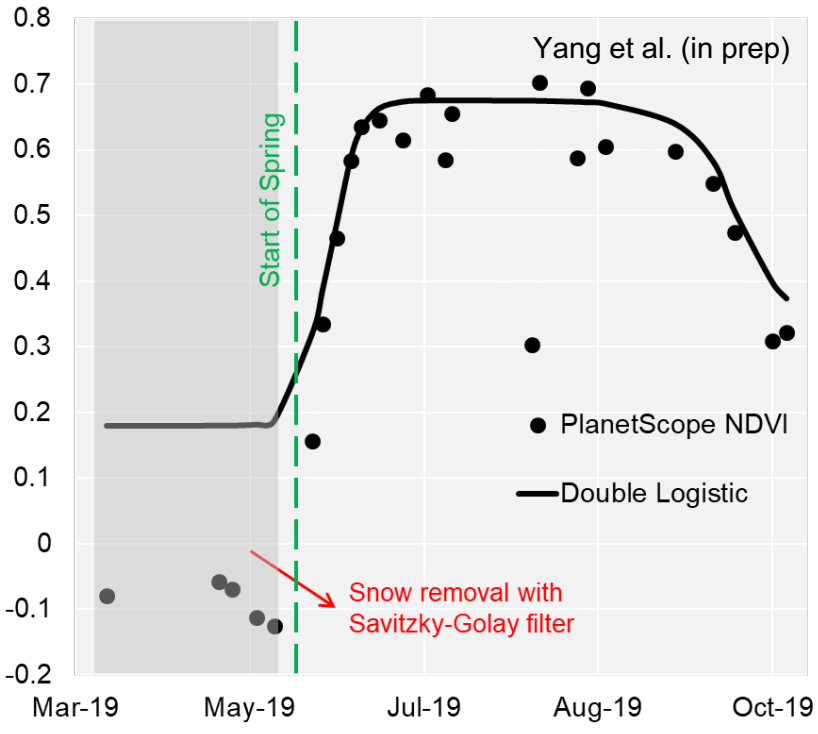
Yang et al., (2020). Remote Sensing

Fine-scale surface heterogeneity drives emergent satellite seasonality in the Arctic

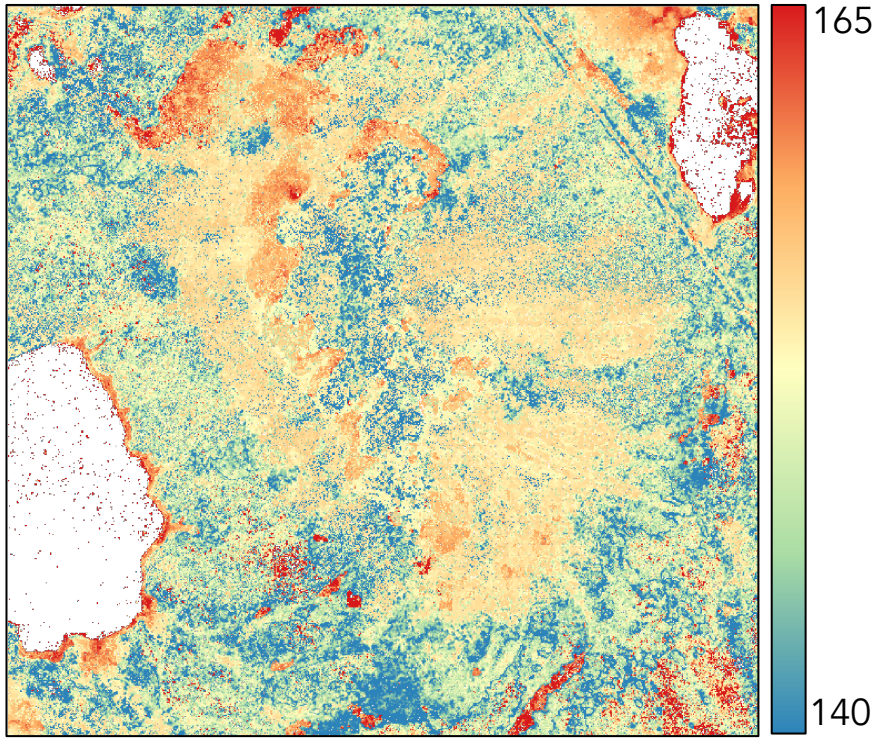
PlanetScope



Phenology modeling

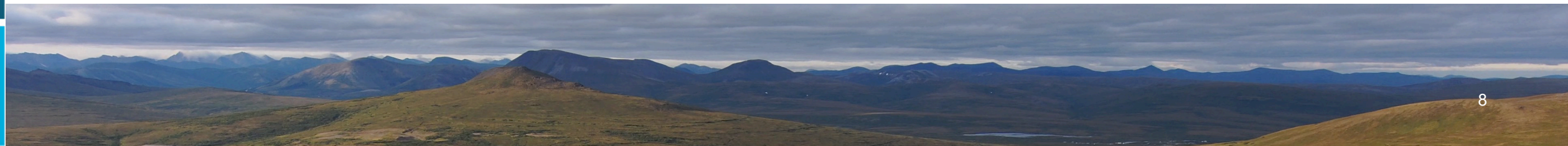


e.g. Start of Spring (day of year)



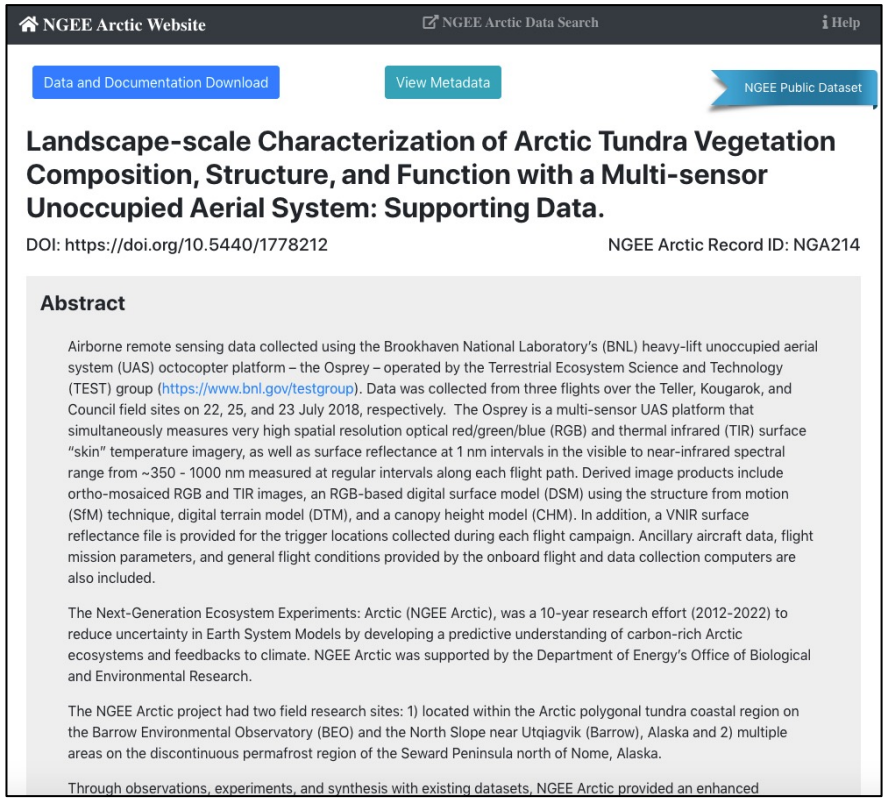
Current challenges with using UAS data in multi-scale synthesis efforts

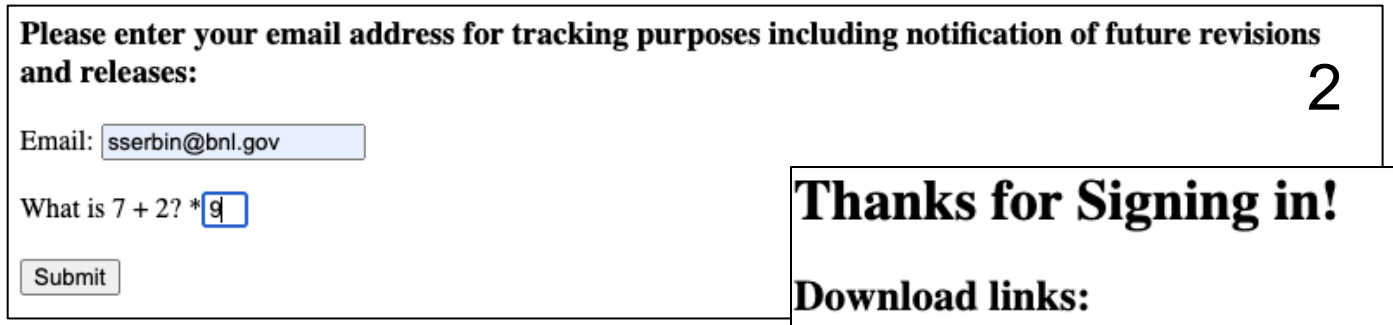
- **Data volume:** The volume of data increases rapidly with resolution and the spatial extent of analysis
- **Discovery:** Many portals lack spatial search or browse – need support for spatial data discovery, e.g. to match novel data with existing field and satellite observations
- **Access:** Complicated, multi-step data access leads to slow and clunky downloads
- **Ease of use:** Commonly compressed (e.g. .zip, .tar.gz), requiring users to download the whole file to access the dataset(s) inside: *need on-the-fly file-level access*



Data accessibility challenges

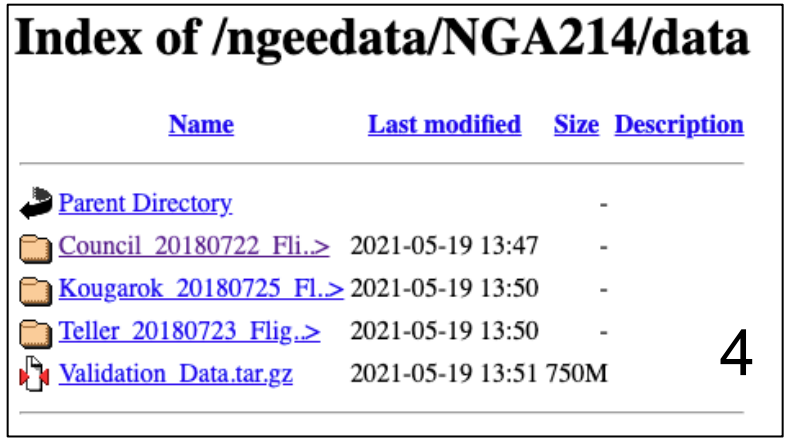
1



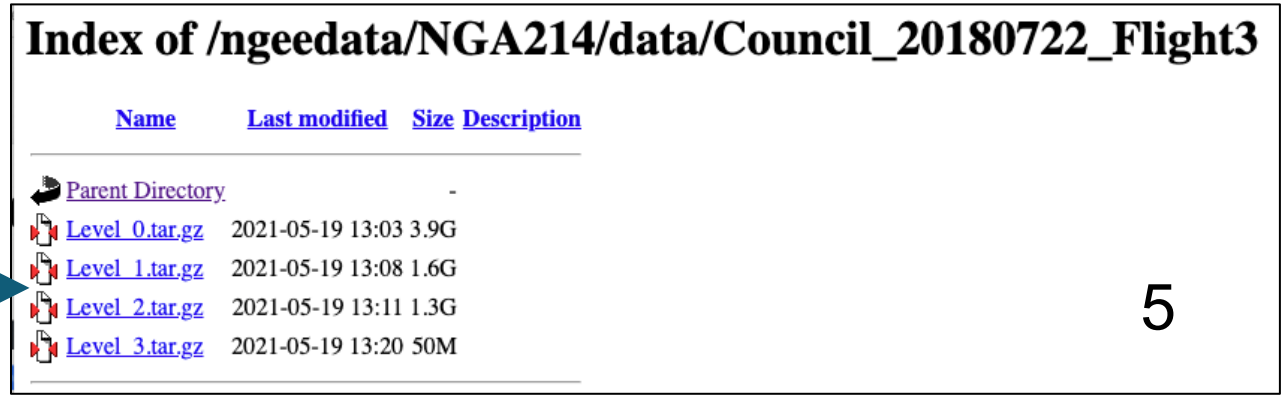


2

3



4



5

Data stored within compressed files

https://github.com/TESTgroup-BNL/meeting_demos

GitHub

Google Cloud Storage

python™

jupyter

R

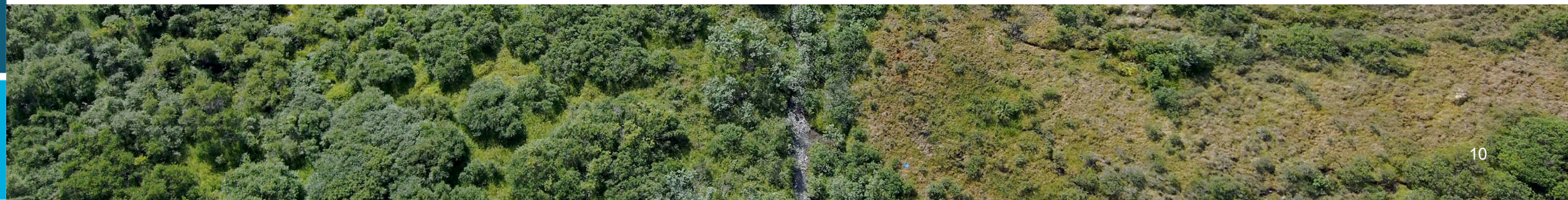
Google Earth Engine

binder

CO

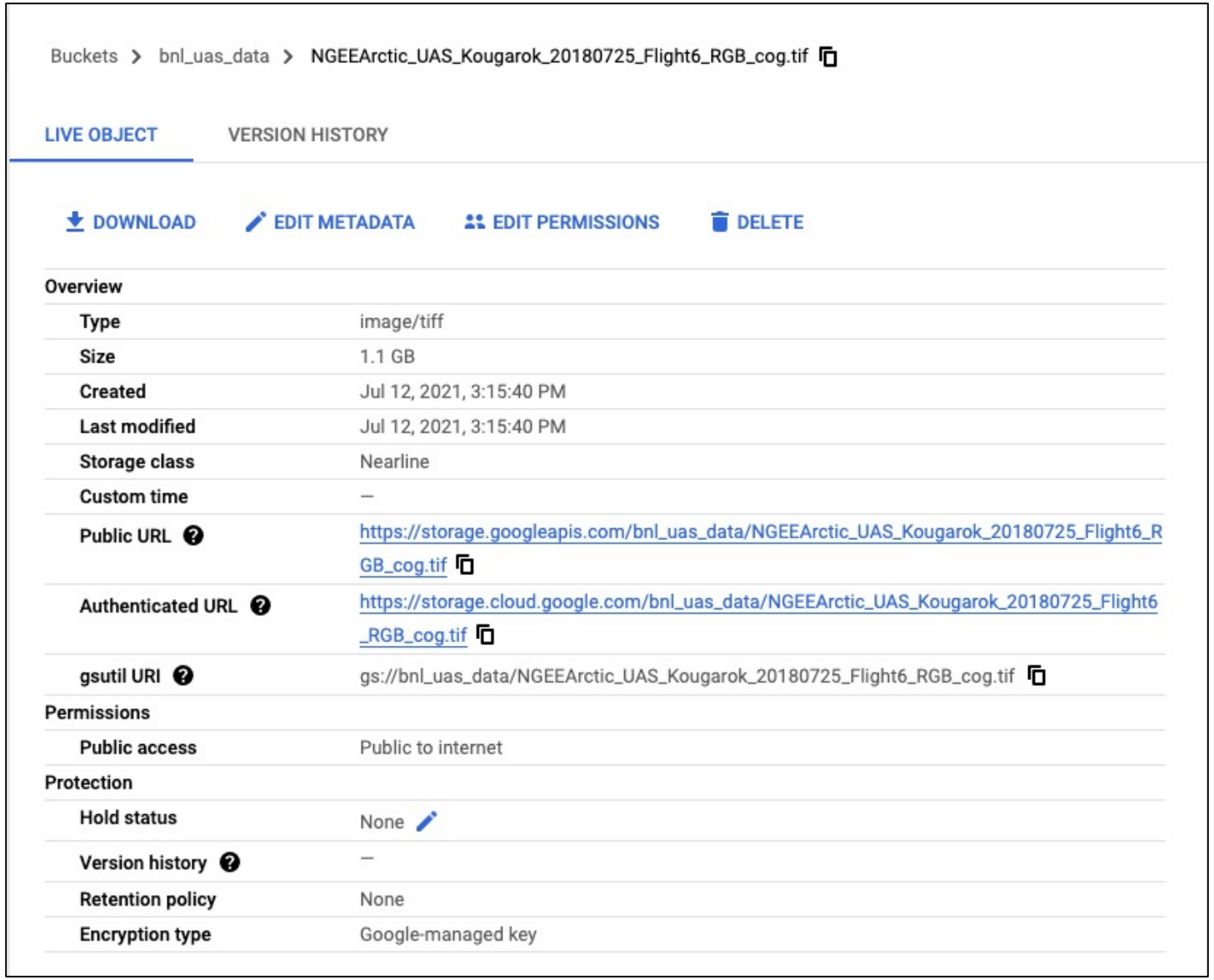
Don’t download, code

- UAS data package volumes can be large (100s Gbs); not feasible to download for local analyses
- However, an “ecosystem” of new tools exist for cloud storage, compute and interactive data analysis
- Storing novel datasets in “the cloud” increases access and accessibility
- Can be linked with Google Earth Engine and related data providers to access petabytes of remote sensing & geospatial data



Cloud Storage

- Datasets are stored with URL (file-level access) or in buckets - accessible containers that hold the data
- Objects in buckets have public, API-key, and cloud bucket addresses (e.g. gs:// for Google Cloud Services)
- Cloud storage objects (i.e. datasets) can be organized into different buckets with specific access controls - can be public *OR* private
- Accessible datasets in public buckets enable scripted (e.g. wget) or *on-the-fly* access to data (e.g. Earth Engine, R, Python)



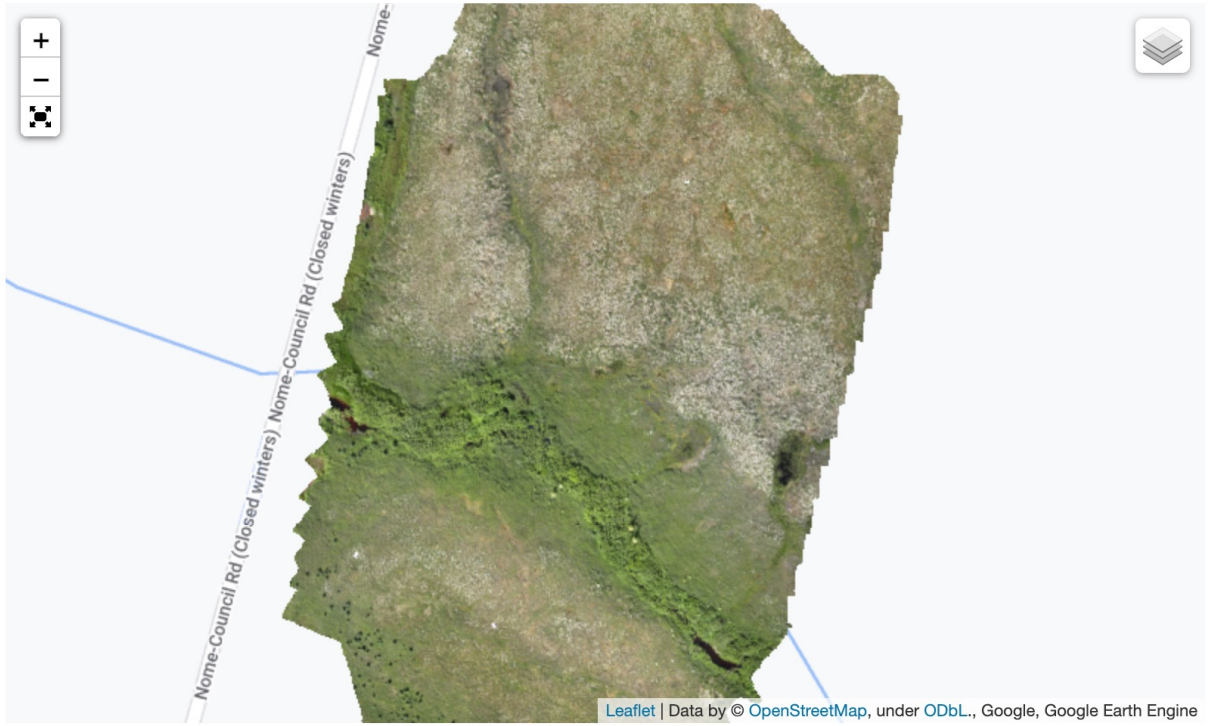
Multi-scale geospatial scientific workflows w/ open-source tools & data

ngee_multisite_uas_examp

Code | Python 3

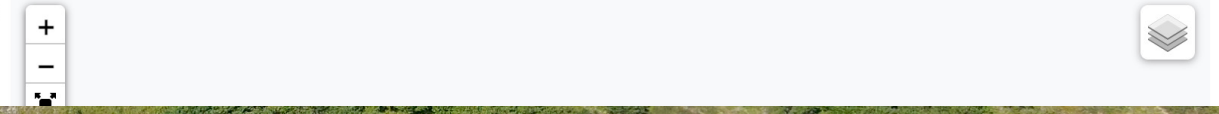
[7]:
```
##### Create a simple map displaying an RGB UAS image (Yang et al., 2021)
# center map over the Council Study Site
uas_map = geemap.Map(center=[64.857595,-163.693854], zoom=17);
uas_map.addLayer(counc_rgb_image, counc_RGB_imageVisParam, 'UAS_Council_20180722_Flight3_RGB')
uas_map
```

[7]:

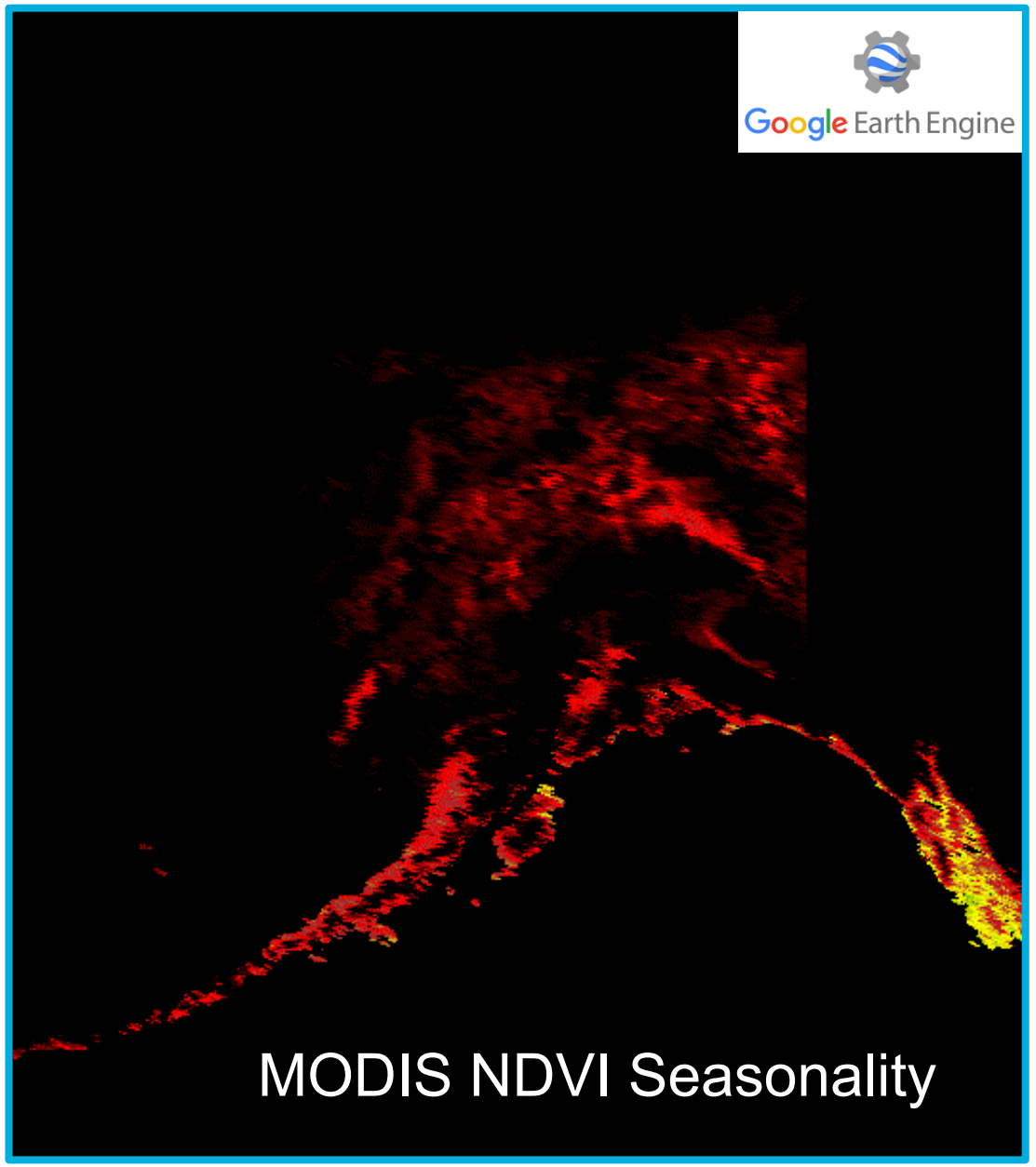


[8]:
```
##### Create a simple map displaying an RGB UAS image (Yang et al., 2021)
# center map over the Kougarok study site
uas_map = geemap.Map(center=[65.164354,-164.823043], zoom=17);
uas_map.addLayer(kg_rgb_image, kg_RGB_imageVisParam, 'UAS_Kougarok_20180725_Flight6_RGB')
uas_map
```

[8]:

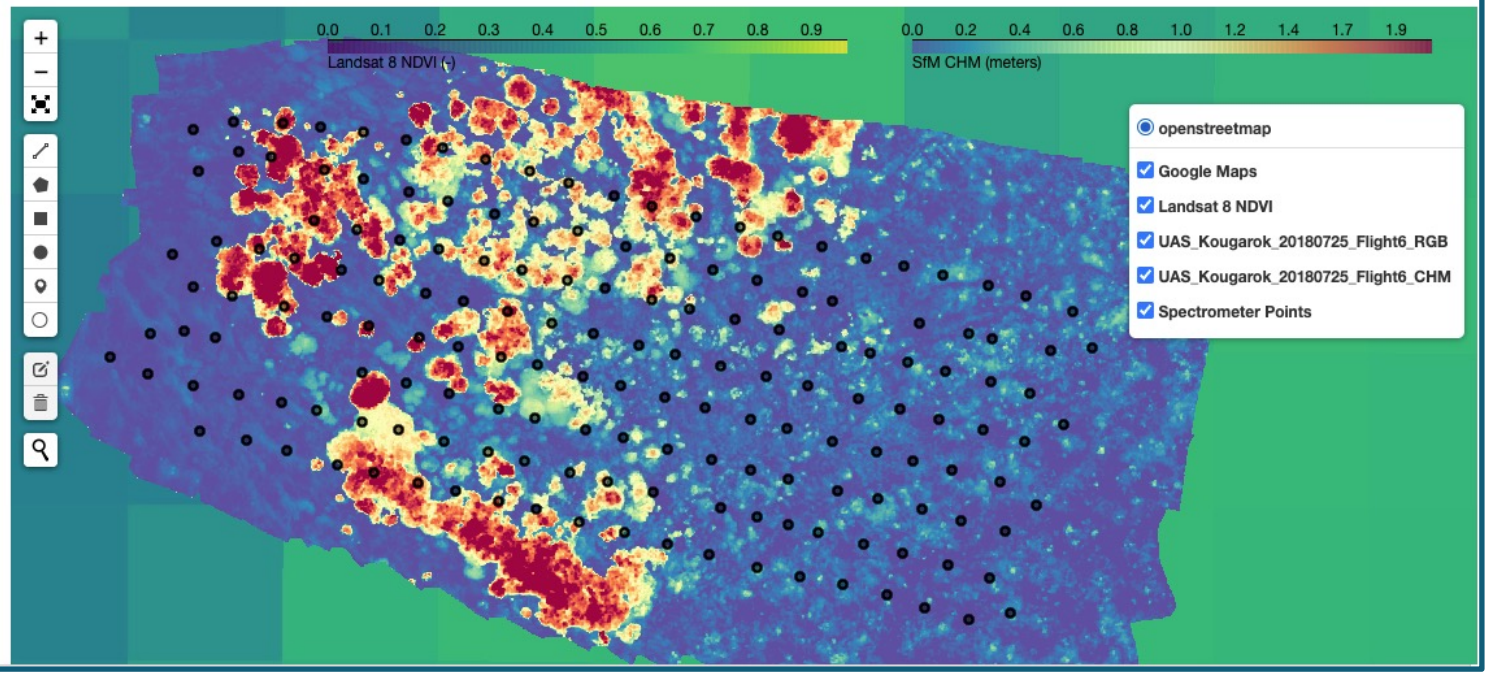


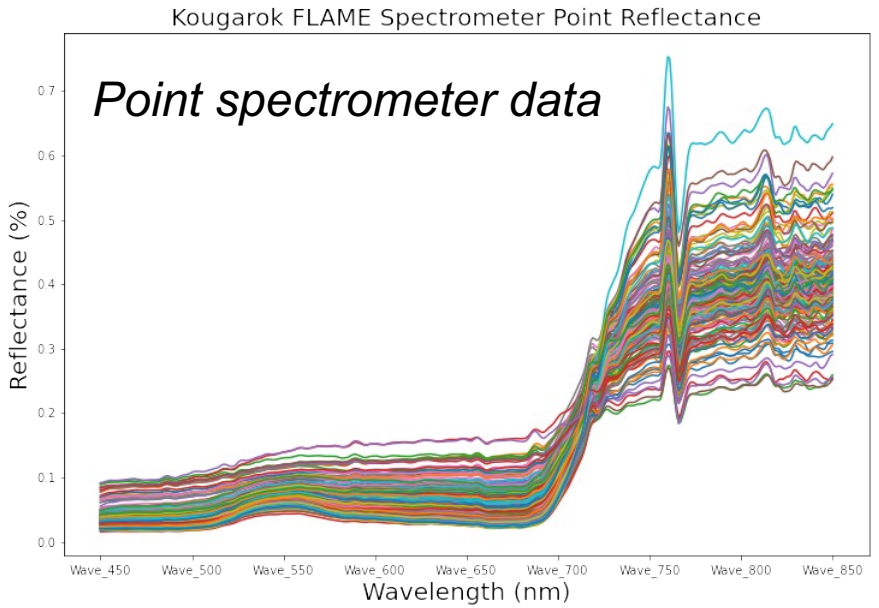
A “firehose” of data available for scripted cloud workflows

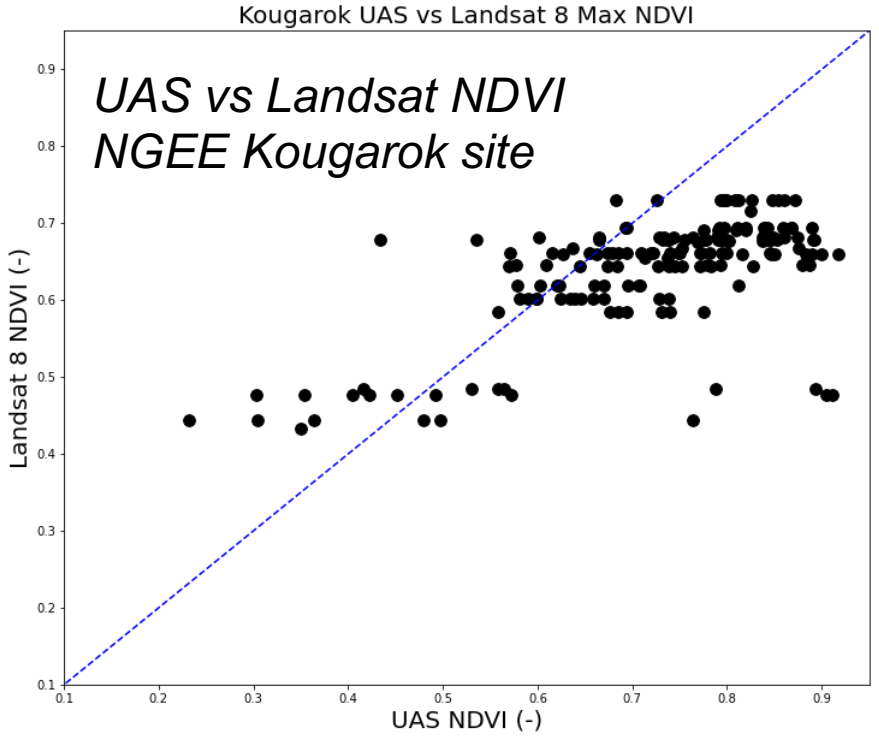


Combining NGEE-Arctic UAS & GEE remote sensing data

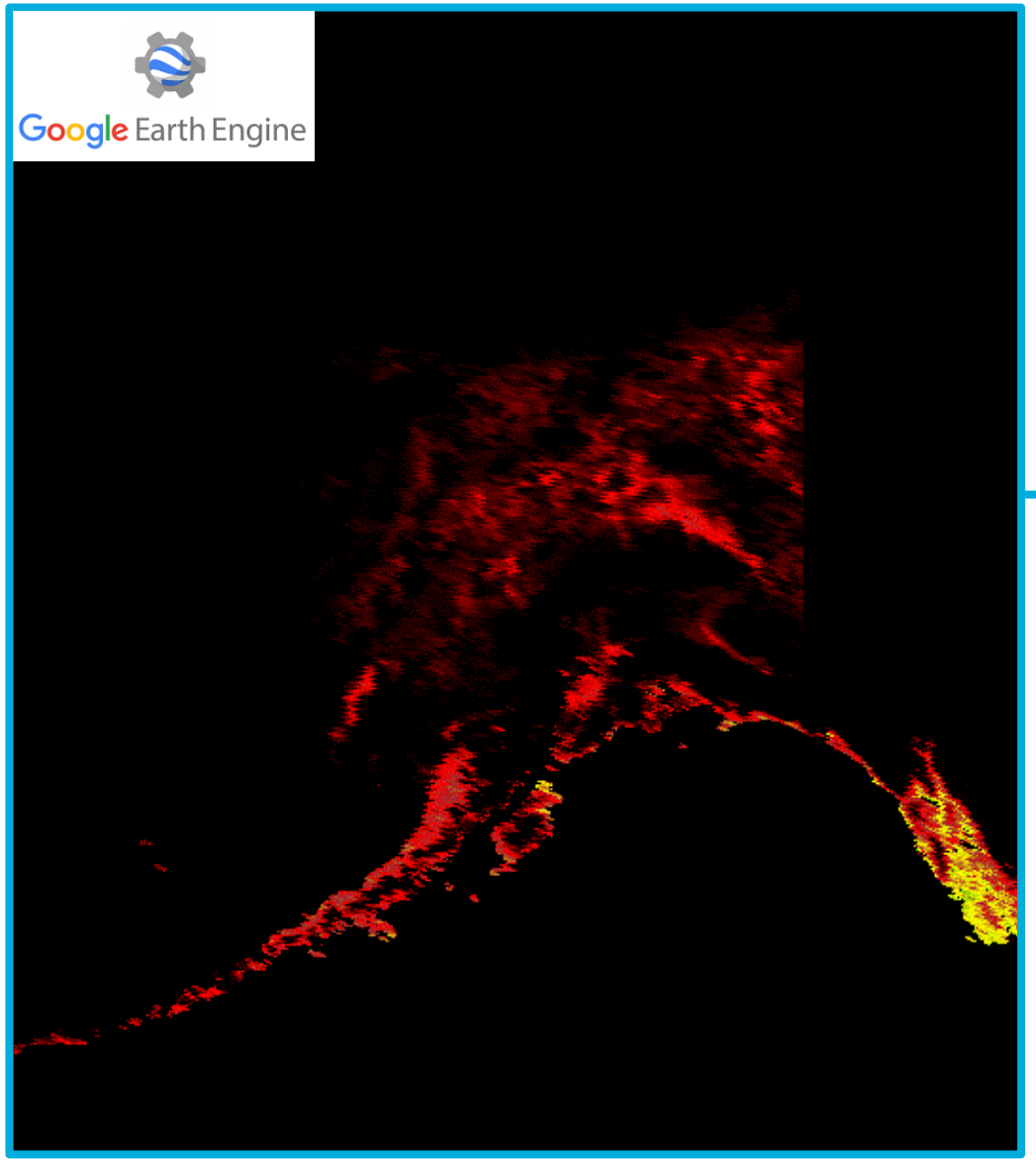
```
#### Create map and overlay spec points
uas_map = geemap.Map(center=[65.164354,-164.823043], zoom=18);
uas_map.addLayer(l8_maxval_ndvi_composite, ndviViz, 'Landsat 8 NDVI');
uas_map.add_colorbar(vis_params=ndviViz, label='Landsat 8 NDVI (-)')

uas_map.addLayer(kg_rgb_image, RGB_imageVisParam, 'UAS_Kougarok_20180725_Flight6_RGB')
uas_map.addLayer(chm_uas_image_masked, demViz, 'UAS_Kougarok_20180725_Flight6_CHM')
uas_map.add_colorbar(vis_params=demViz, label='SfM CHM (meters)')
uas_map.addLayer(pt_refl_data_gee,{},'Spectrometer Points')
uas_map
```

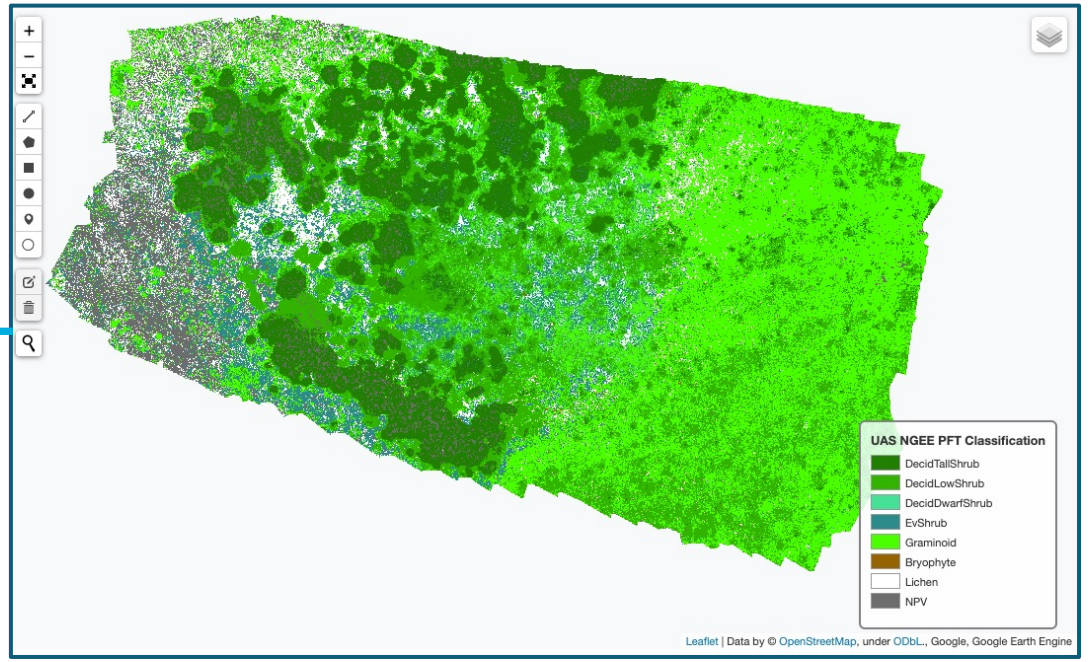


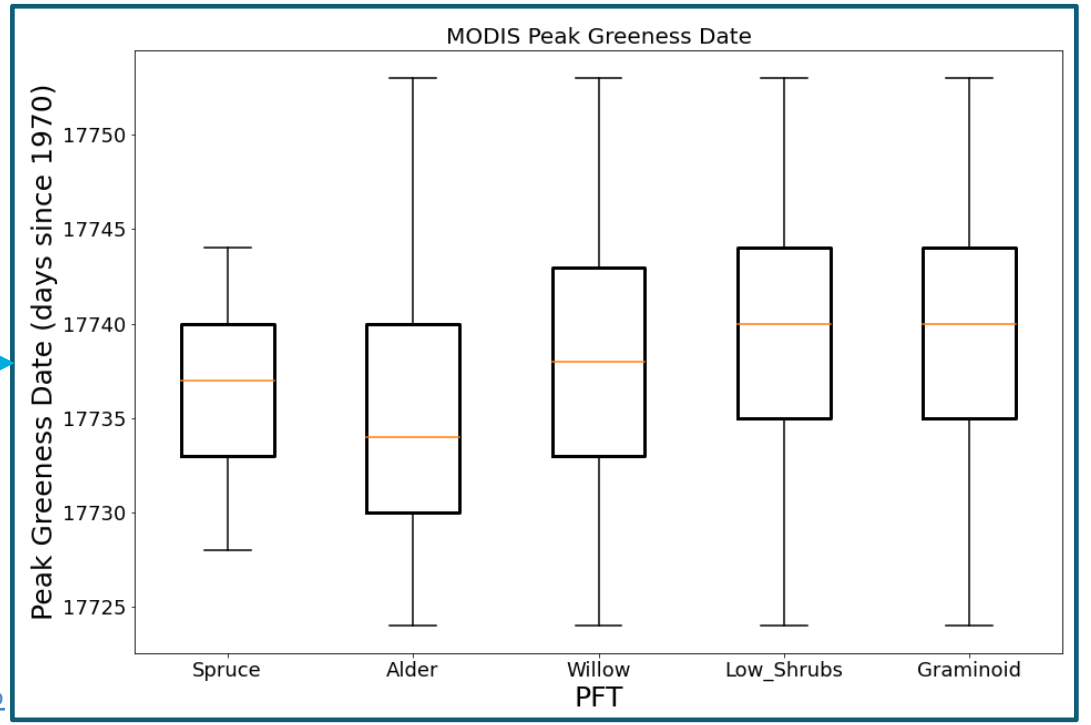




Example:
https://github.com/TESTgroup-BNL/meeting_demos/blob/main/us_iale_2022/python/ngee_multisite_uas_example.ipynb

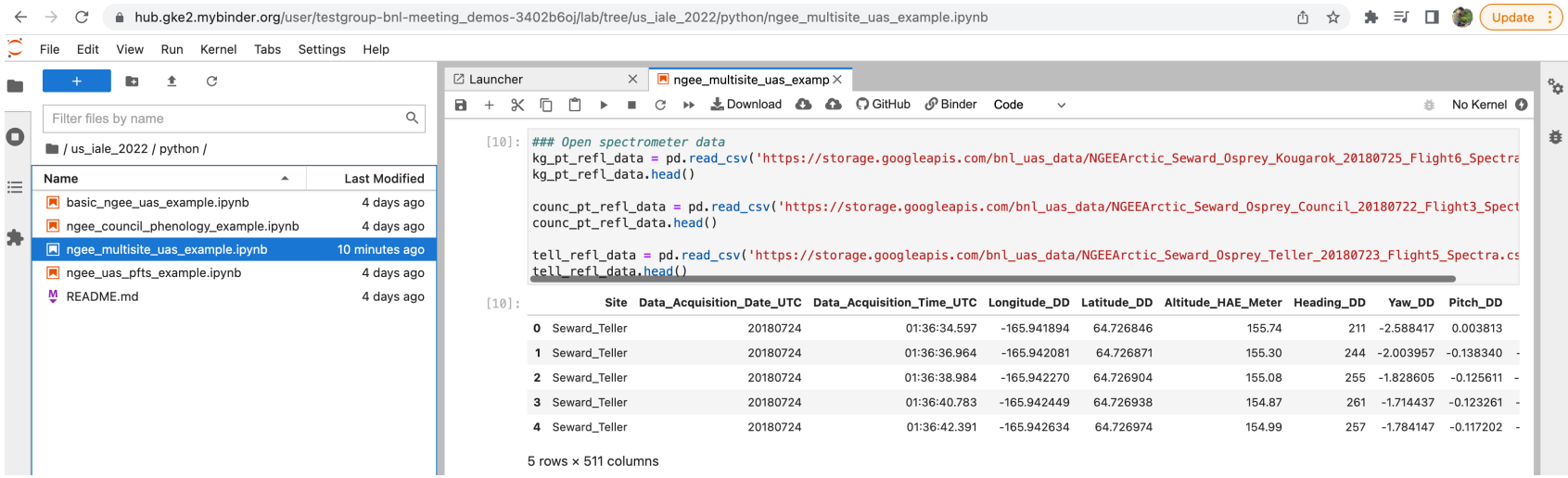


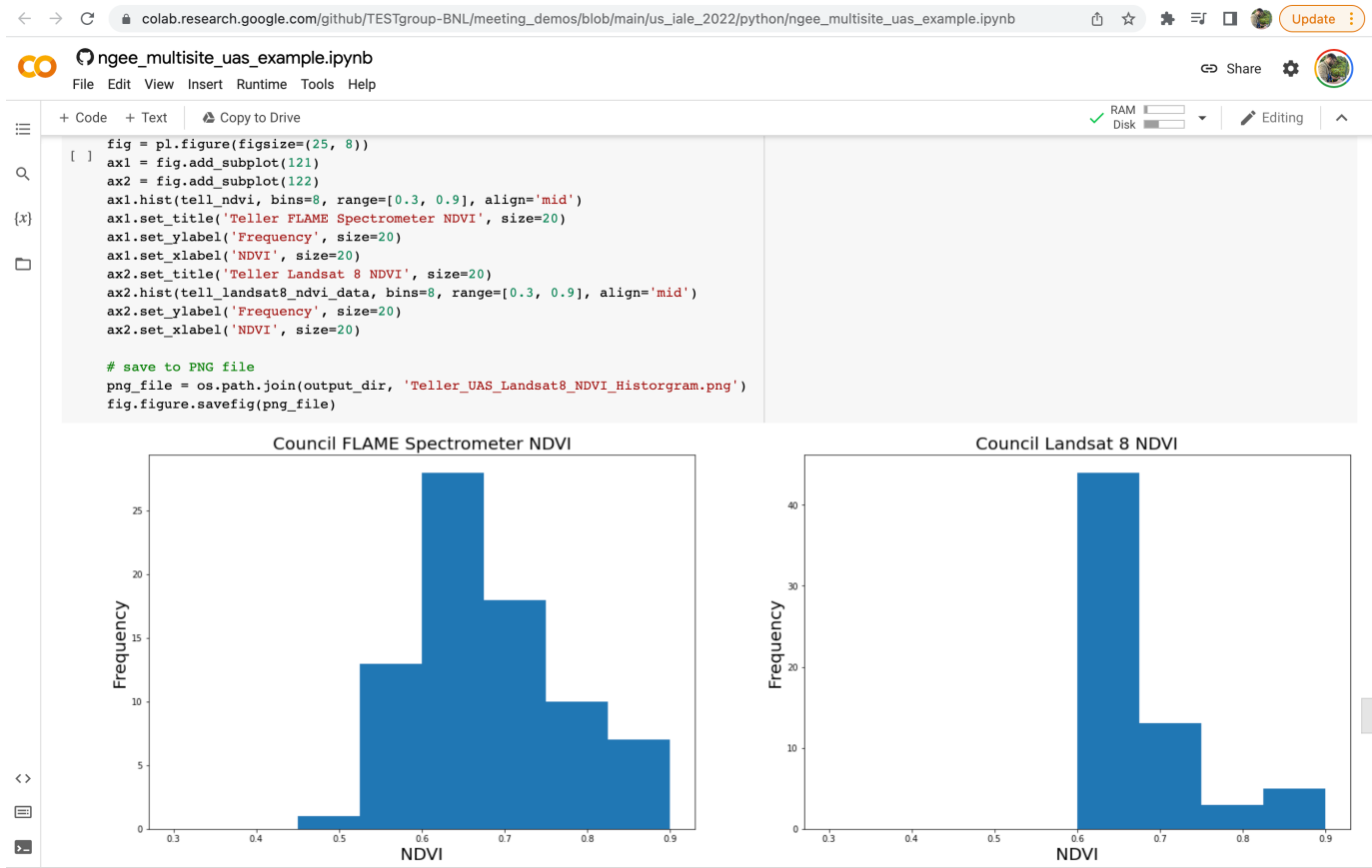




Examples:
https://github.com/TESTgroup-BNL/meeting_demos/blob/main/us_iale_2022/python/ngee_uas_pfts_example.ipynb

https://github.com/TESTgroup-BNL/meeting_demos/blob/main/us_iale_2022/python/ngee_council_phenology_example.ipynb





https://github.com/TESTgroup-BNL/meeting_demos

Image file format considerations

- File format is an important decision for enabling cloud-storage and accessibility
- Preference should be on the creation of Cloud-Optimized GeoTiffs (COGs)
- A **Cloud Optimized GeoTIFF (COG)** is a GeoTIFF file that can be hosted on a HTTP file server and contains an internal organization that facilitates remote (cloud) access. A remote client issues a **HTTP GET** range requests to obtain the file or just the parts of a file they need (e.g. pixels or spatial subset)
- Overviews stored in the COG allow for fast previews at pre-defined zoom levels
- Doesn’t require a complicated backend to manage remote data requests like standard netCDF, which requires a THREDDS service

CYVERSE

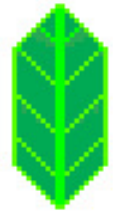
OSF

DOE ESS-DIVE

Other cloud resources

- The availability and diversity of UAS data for ecological research and resource management applications is rapidly growing
- These novel data are highly useful for developing new methods to characterize and map landscapes across scales, but data volume and access challenges currently limit broader applications
- Existing tools and resources can help address these challenges, but moving beyond one-off examples to large-scale implementation will require new community efforts and agency investments – costs can be high for paid use (e.g. Amazon or Google Cloud Services)
- The ecological and remote sensing communities also require new UAS metadata and data standards to facilitate cross-site syntheses.
  - E.g. https://github.com/ess-dive-community/essdive-uas

Try out these demos yourself @:
https://github.com/TESTgroup-BNL/meeting_demos



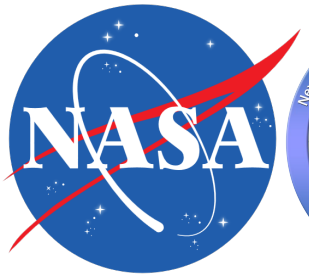
Research Team & Collaborators

Daryl Yang
Wouter Hantson
Daniel Hayes
Angela Erb
Kim Ely
Jeremiah Anderson
Andrew McMahon
Terri Velliquette &
The larger NGEE-Artic Team

Standardizing UAS metadata for synthesis studies
https://github.com/ess-dive-community/essdive-uas

U.S. DEPARTMENT OF ENERGY | Office of Science

Brookhaven National Laboratory



Contact: sserbin@bnl.gov