

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

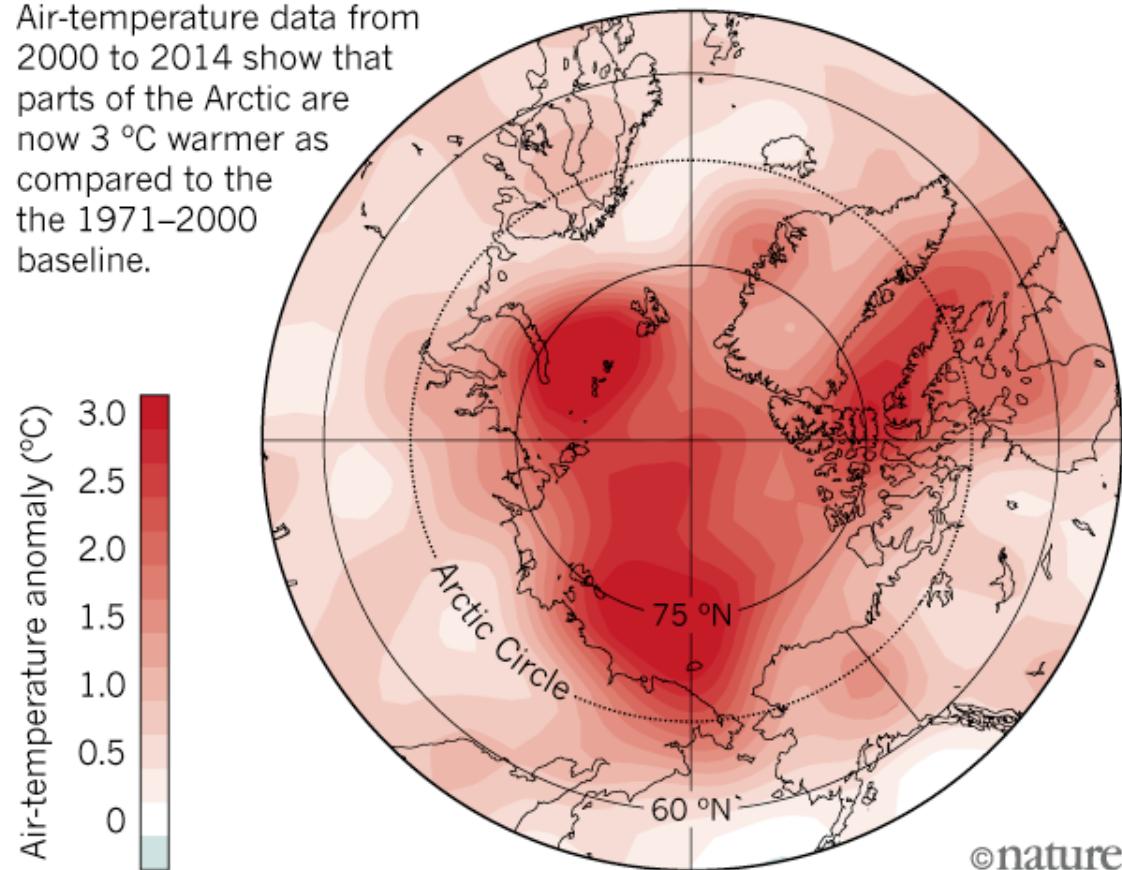
2022-04-11

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

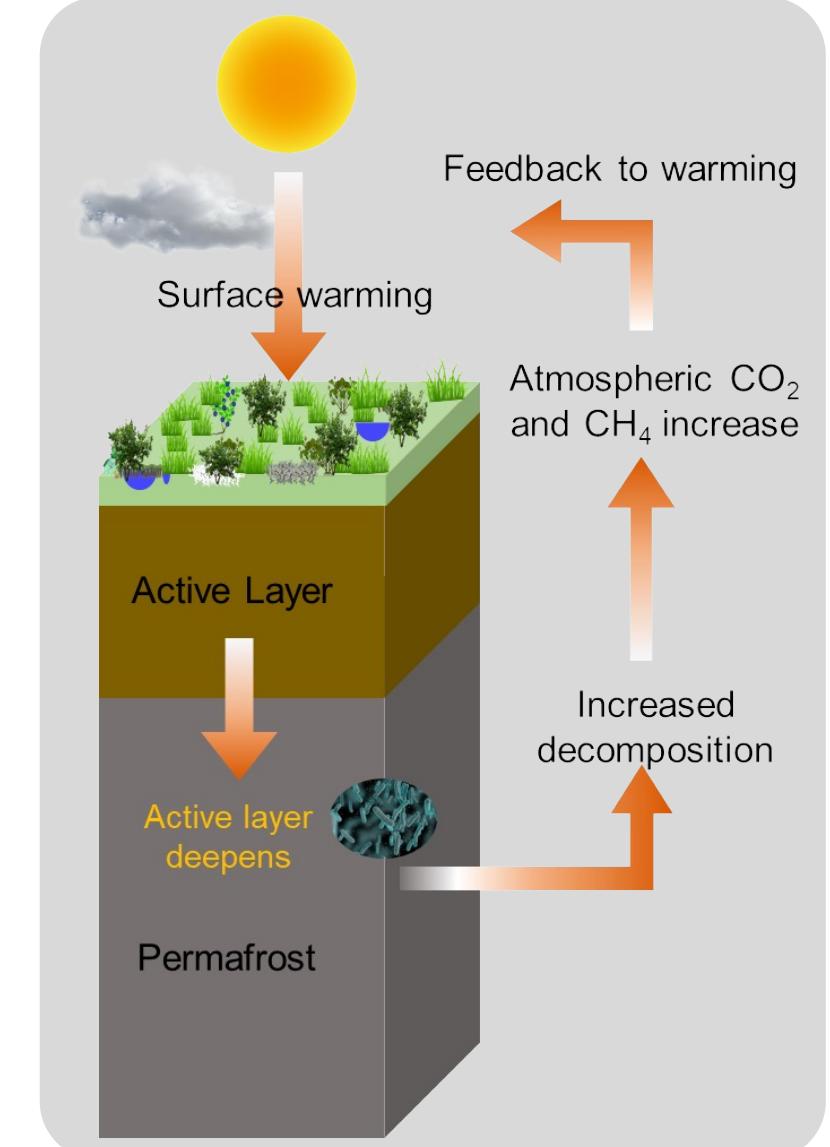
Twitter: @TESTgroup_BNL
web: www.bnl.gov/TESTgroup

ARCTIC WARMING

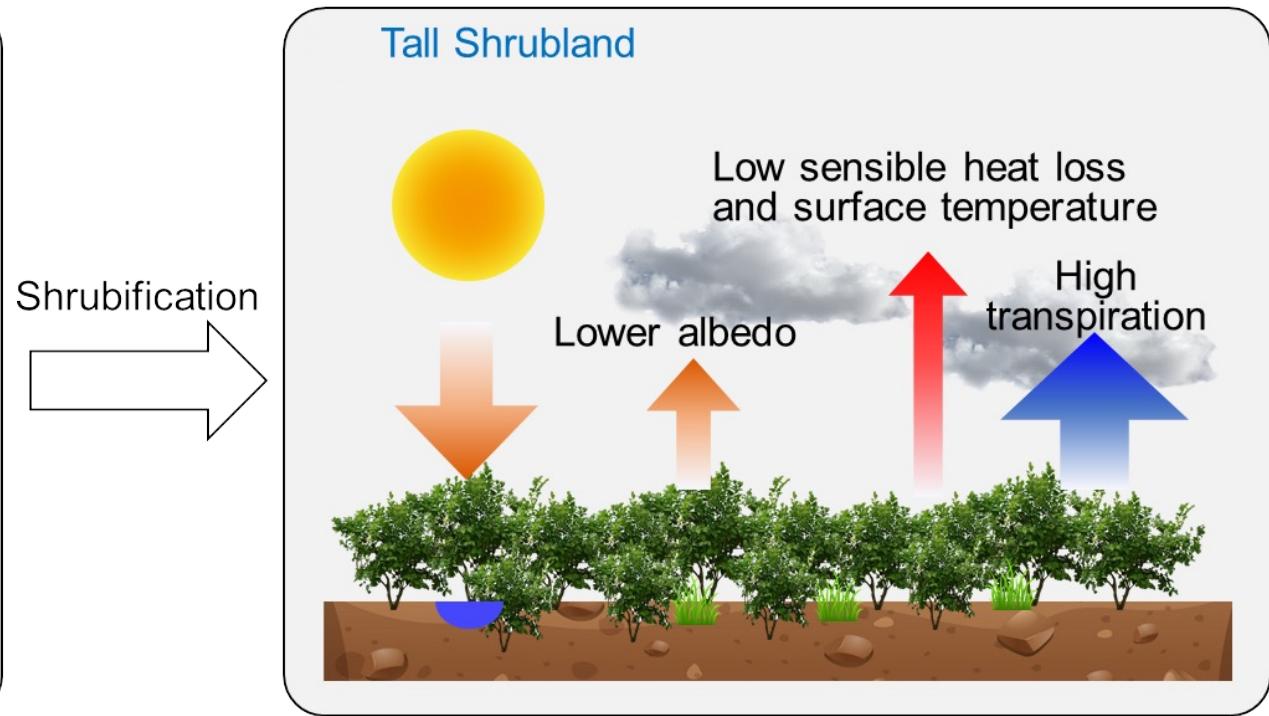
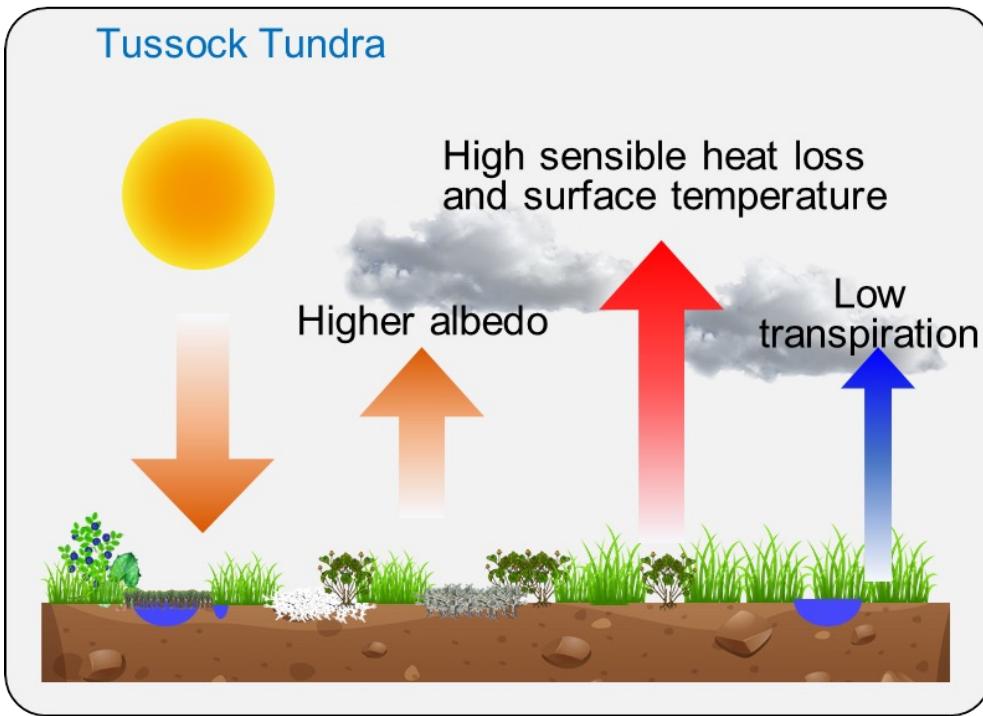
Air-temperature data from 2000 to 2014 show that parts of the Arctic are now 3 °C warmer as compared to the the 1971–2000 baseline.



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

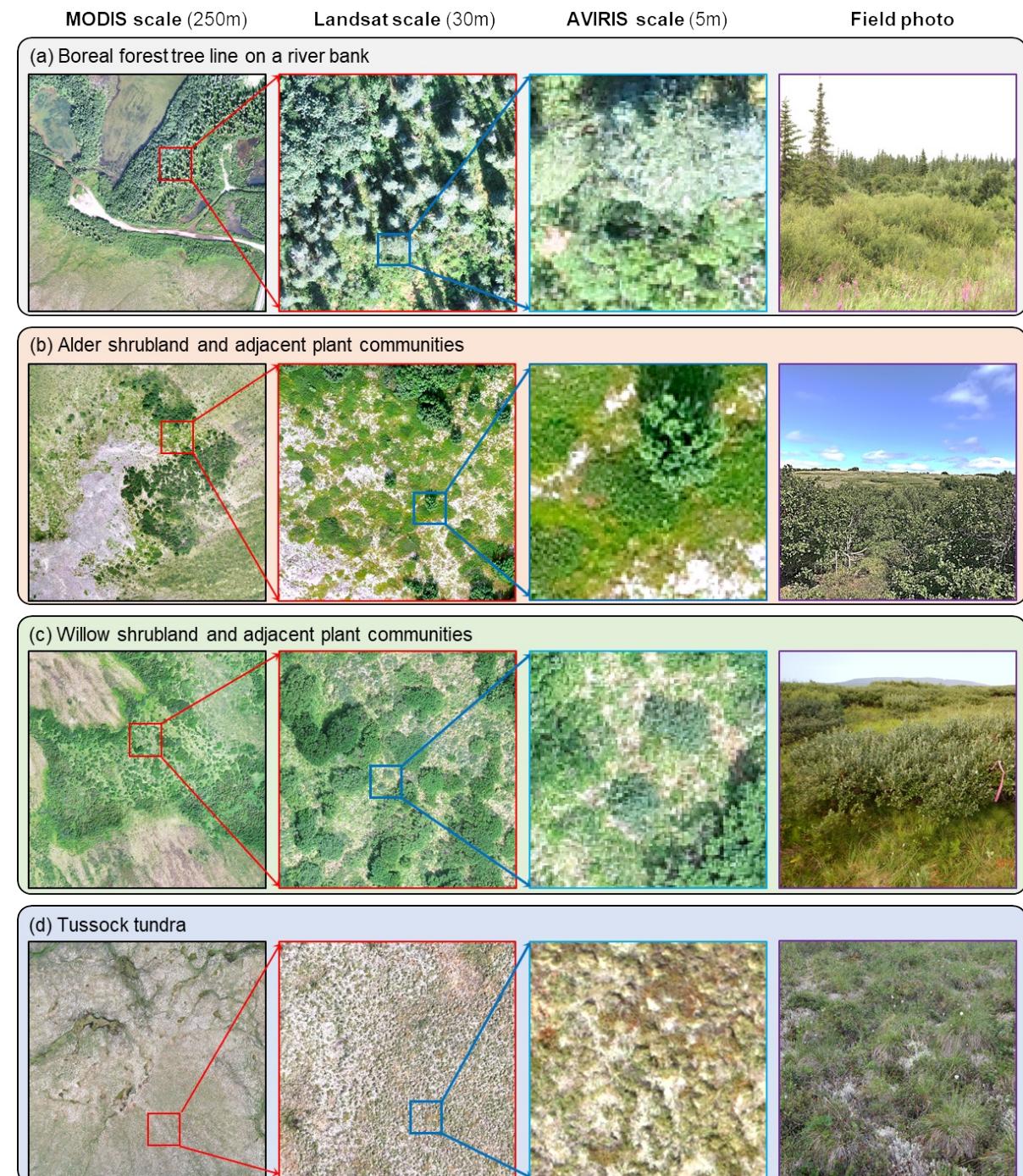


The predicted transition to higher shrub cover in the Arctic will have significant climate feedbacks

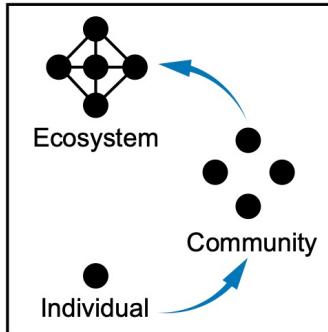


Arctic surface heterogeneity

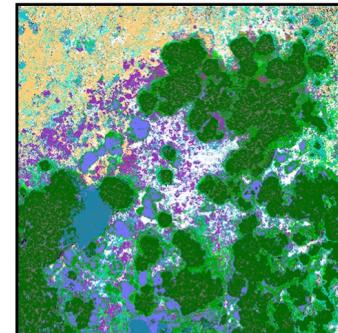
- Species diversity is low, but...
- Contains significant spatial heterogeneity in composition, patch size, and structure related to fine-scale drivers, including soil, permafrost, and moisture and nutrient gradients
- This surface heterogeneity strongly controls the spatio-temporal patterns of vegetation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



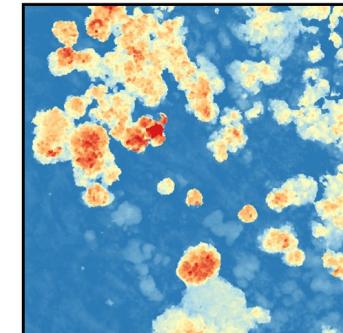
Ecological Scaling



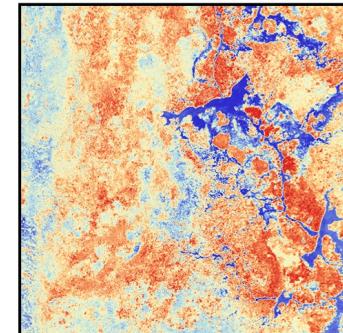
Plant Species Map



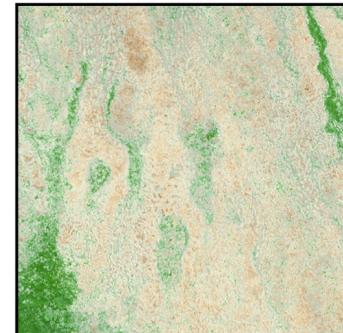
Canopy Structure



Plant Functional Traits



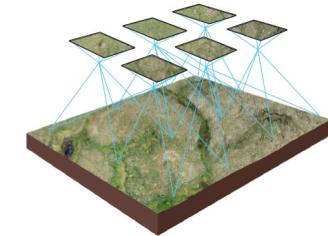
Vegetation Health



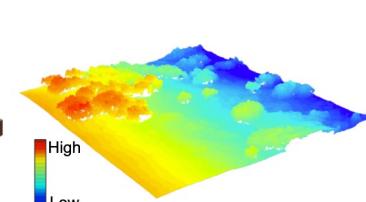
UAS Remote Sensing



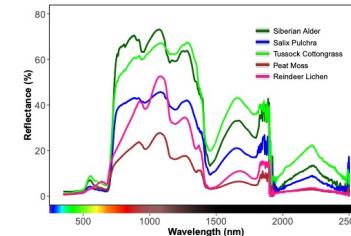
Optical Photogrammetry



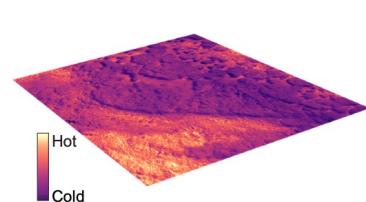
LiDAR or SfM



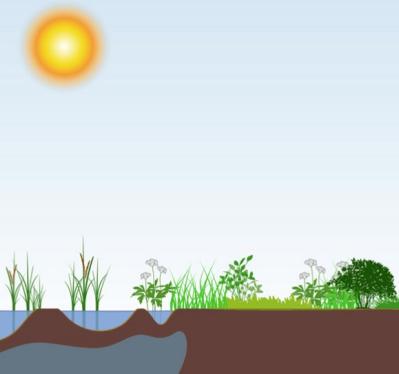
Spectroscopy



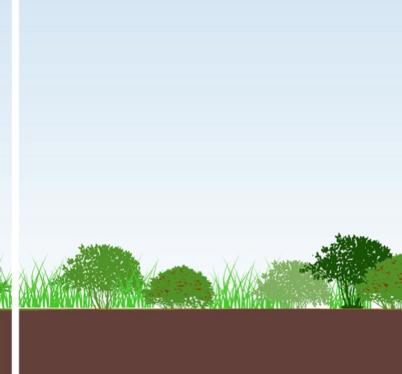
Thermal Imaging



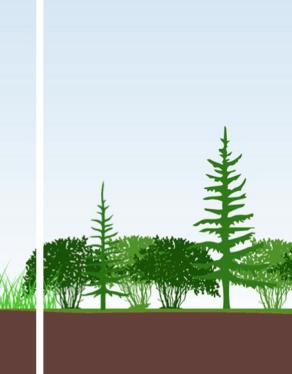
High-Arctic Tundra



Low-Arctic Tundra



Tundra-Forest Ecotone

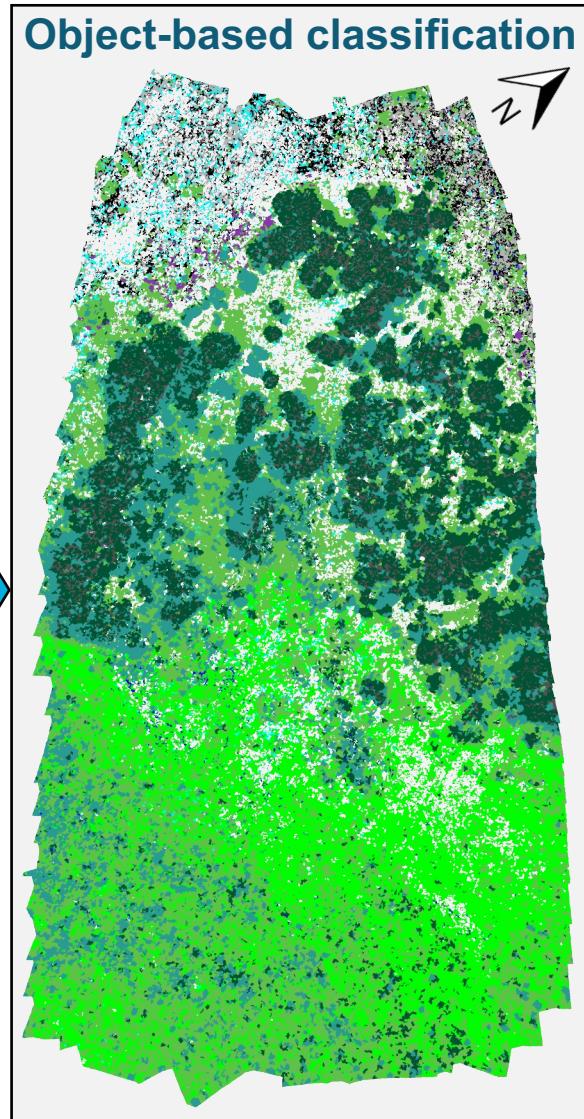
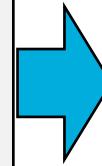
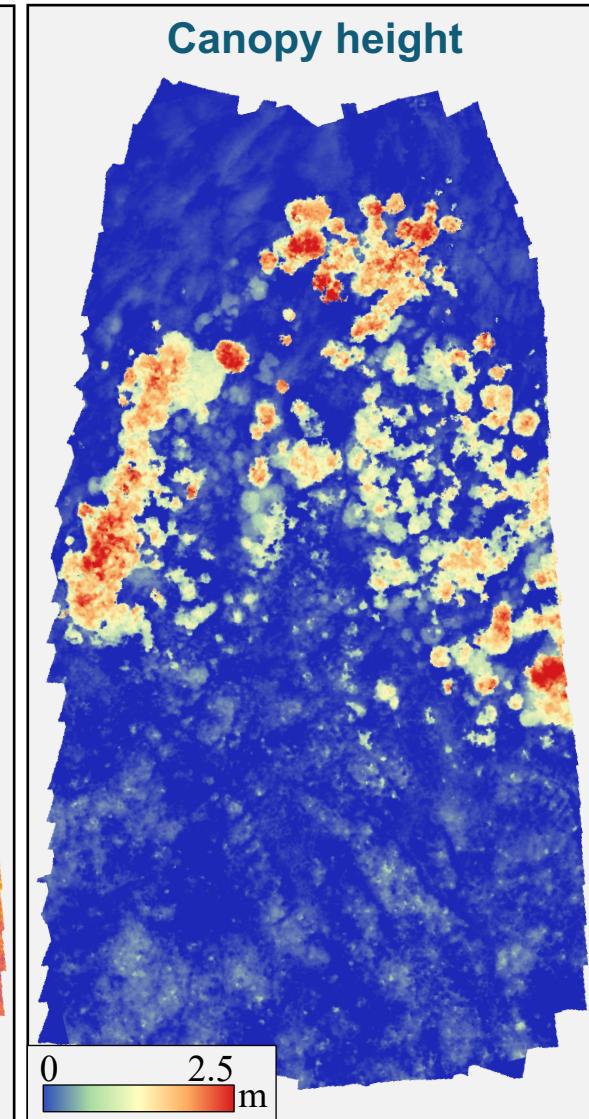
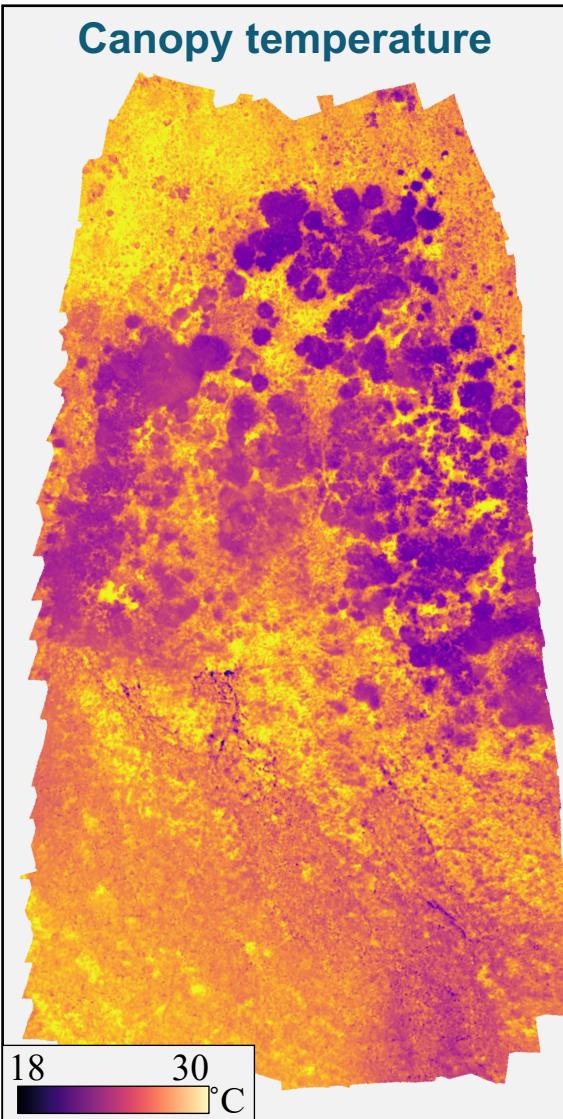


Boreal Forest



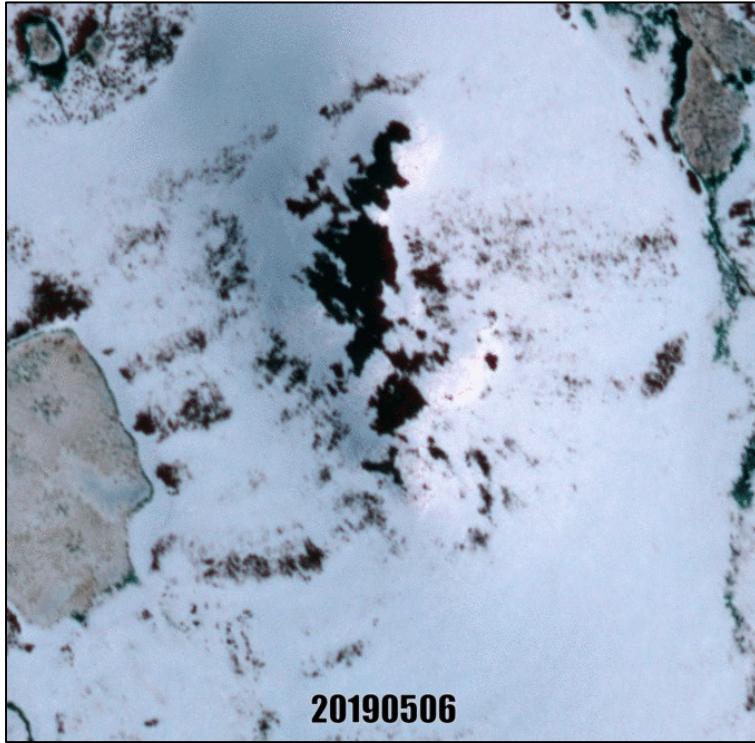
Centimeter-scale UAS data

Example data from the Osprey platform

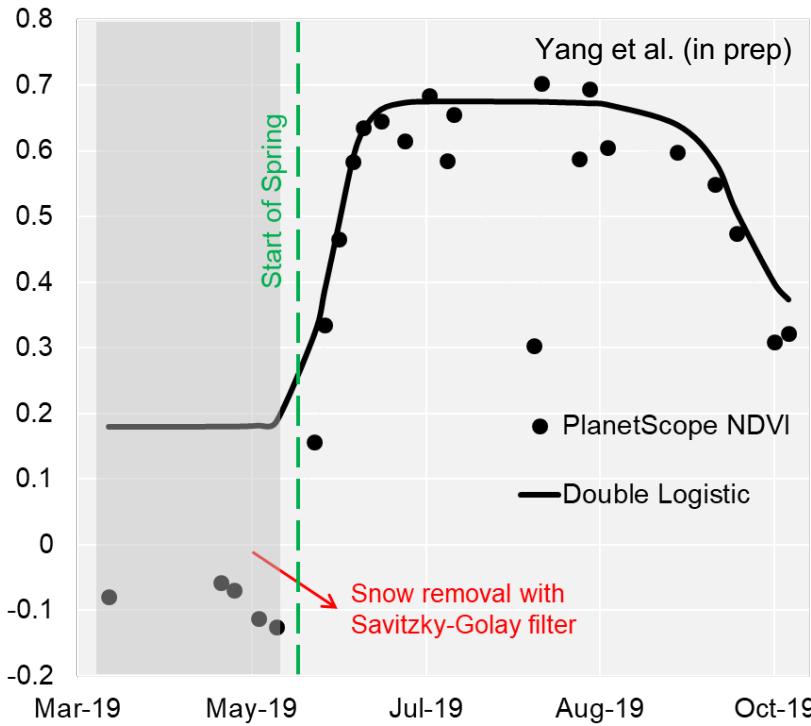


Fine-scale surface heterogeneity drives emergent satellite seasonality in the Arctic

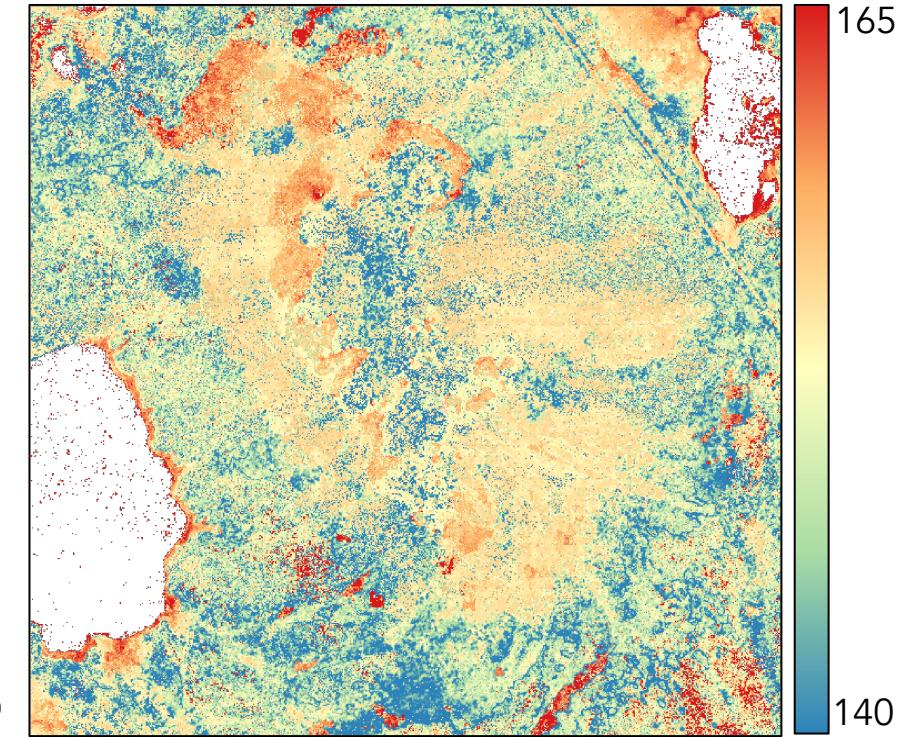
PlanetScope



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

The screenshot shows a dataset page from the NGEET Arctic Website. At the top, there are navigation links for "NGEE Arctic Website", "NGEE Arctic Data Search", and "Help". Below these are buttons for "Data and Documentation Download" and "View Metadata". A large blue button labeled "NGEE Public Dataset" is prominent. The main content area features a title: "Landscape-scale Characterization of Arctic Tundra Vegetation Composition, Structure, and Function with a Multi-sensor Unoccupied Aerial System: Supporting Data." Below the title is the DOI: <https://doi.org/10.5440/1778212>. To the right, it says "NGEE Arctic Record ID: NGA214". A section titled "Abstract" contains detailed text about the dataset, mentioning the use of a heavy-lift unoccupied aerial system (UAS) to collect optical and thermal infrared data over three field sites in July 2018. Another section at the bottom discusses the Next-Generation Ecosystem Experiments: Arctic (NGEE Arctic) project and its support by the Department of Energy's Office of Biological and Environmental Research.

Data stored within compressed files

Please enter your email address for tracking purposes including notification of future revisions and releases:

Email:

What is $7 + 2$? *

2

Thanks for Signing in!

3

Download links:

- <https://ngee.ornl.gov/ngedata/NGA214/data>
- <https://ngee.ornl.gov/ngedata/NGA214/documentation>

4

Index of /ngedata/NGA214/data

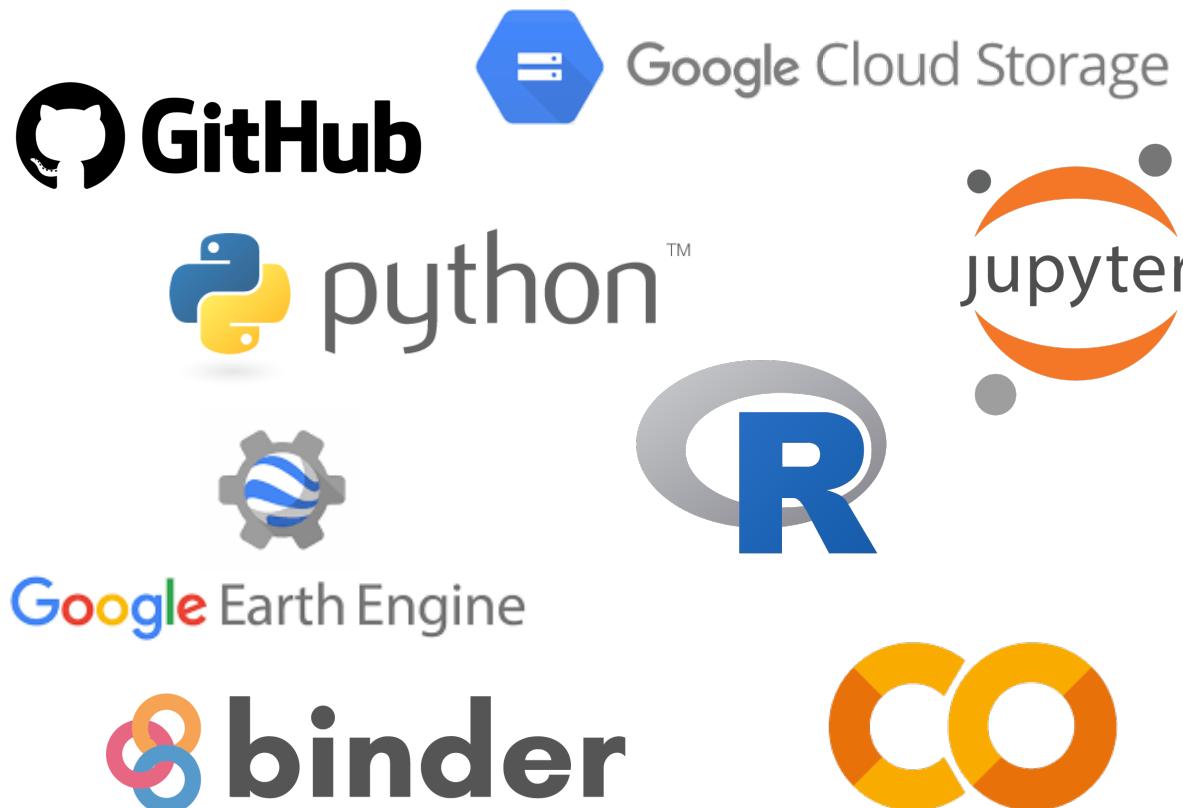
Name	Last modified	Size	Description
Parent Directory		-	
Council_20180722_Fli.>	2021-05-19 13:47	-	
Kougarok_20180725_Fl.>	2021-05-19 13:50	-	
Teller_20180723_Flig.>	2021-05-19 13:50	-	
Validation_Data.tar.gz	2021-05-19 13:51	750M	

Index of /ngedata/NGA214/data/Council_20180722_Flight3

Name	Last modified	Size	Description
Parent Directory		-	
Level_0.tar.gz	2021-05-19 13:03	3.9G	
Level_1.tar.gz	2021-05-19 13:08	1.6G	
Level_2.tar.gz	2021-05-19 13:11	1.3G	
Level_3.tar.gz	2021-05-19 13:20	50M	

5

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



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)

Buckets > bnl_uas_data > NGEEArctic_UAS_Kougarok_20180725_Flight6_RGB_cog.tif 

LIVE OBJECT VERSION HISTORY

 DOWNLOAD  EDIT METADATA  EDIT PERMISSIONS  DELETE

Overview

Type	image/tiff
Size	1.1 GB
Created	Jul 12, 2021, 3:15:40 PM
Last modified	Jul 12, 2021, 3:15:40 PM
Storage class	Nearline
Custom time	—
Public URL 	https://storage.googleapis.com/bnl_uas_data/NGEEArctic_UAS_Kougarok_20180725_Flight6_RGB_cog.tif 
Authenticated URL 	https://storage.cloud.google.com/bnl_uas_data/NGEEArctic_UAS_Kougarok_20180725_Flight6_RGB_cog.tif 
gsutil URI 	gs://bnl_uas_data/NGEEArctic_UAS_Kougarok_20180725_Flight6_RGB_cog.tif 

Permissions

Public access	Public to internet
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Protection

Hold status	None 
Version history 	—
Retention policy	None
Encryption type	Google-managed key

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

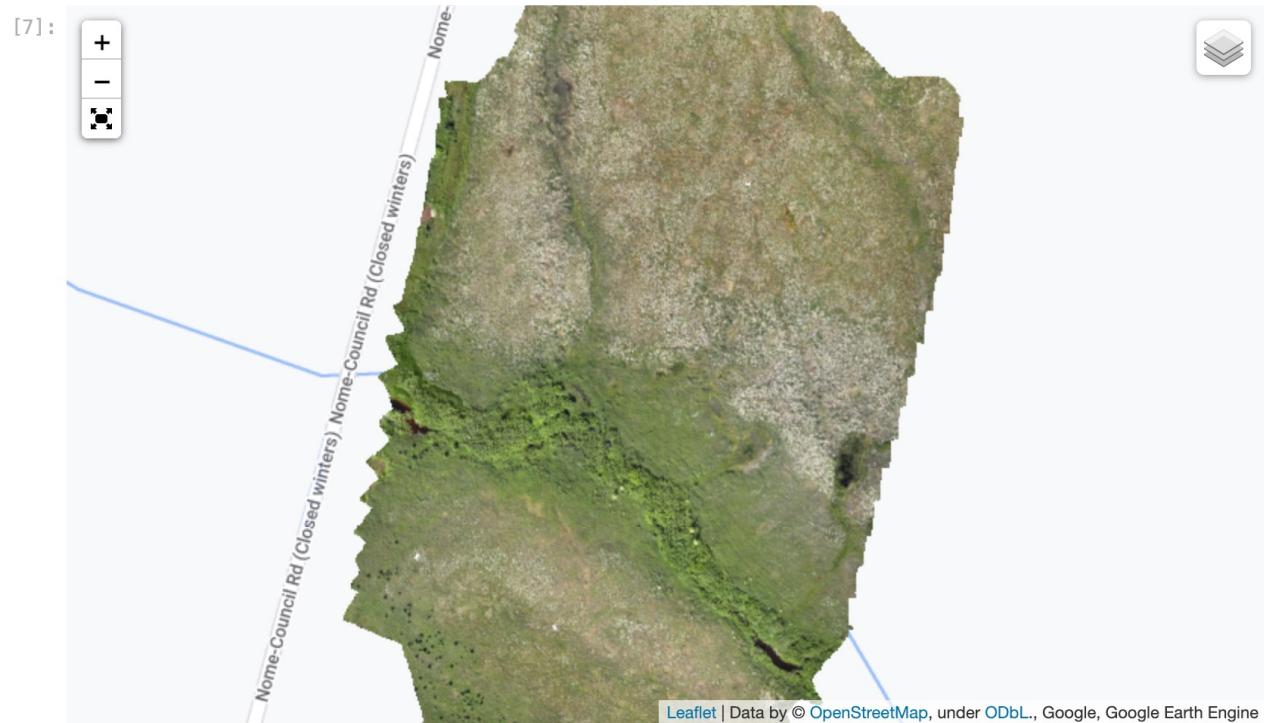


Google Earth Engine

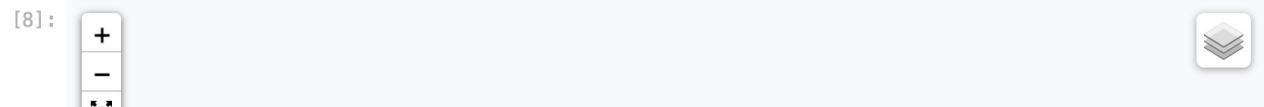


ngee_multisite_uas_exampl Python 3

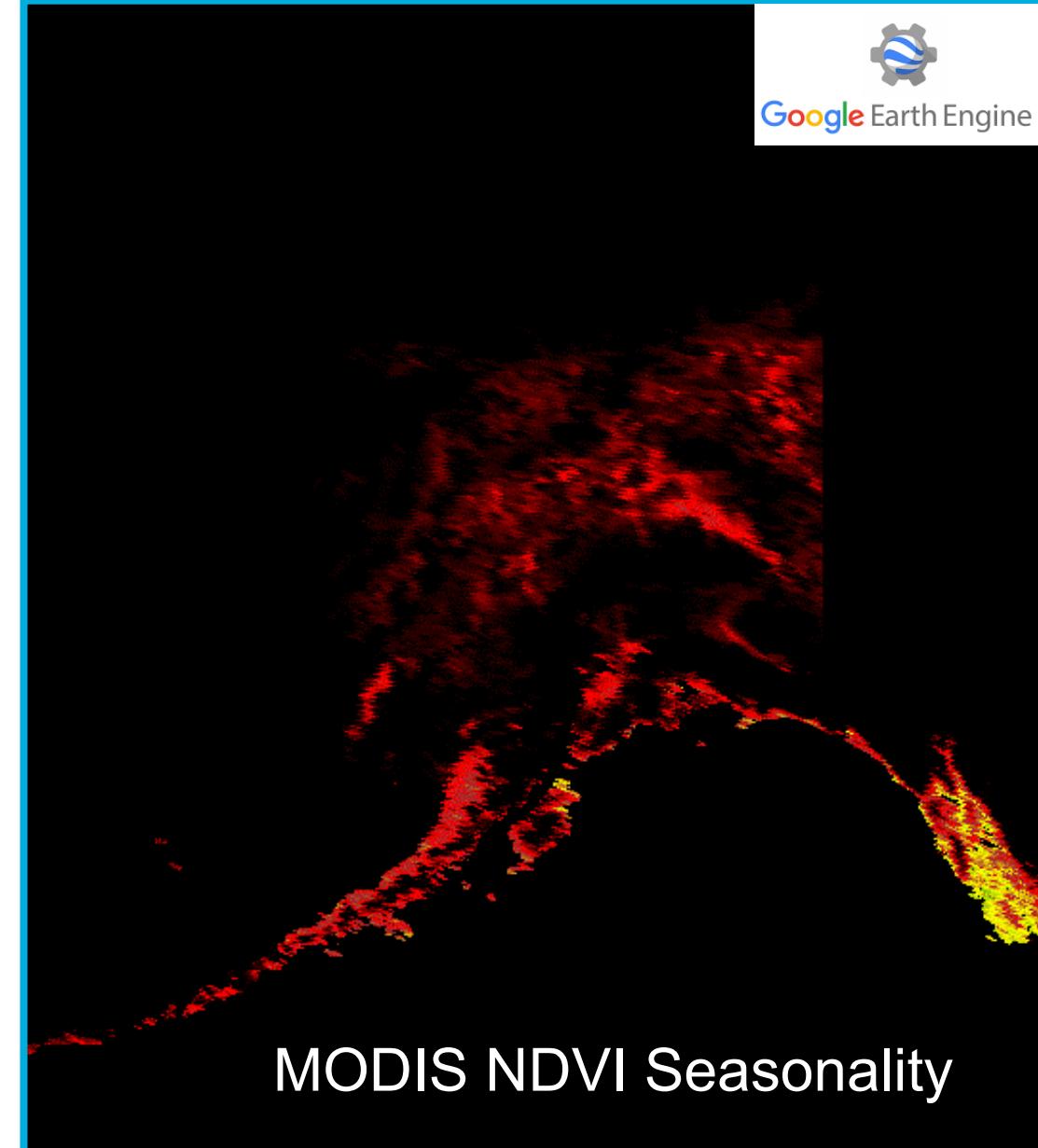
```
[7]: ##### Create a simple map displaying an RGB UAS image (Yang et al., 2021)
# center map over the Council Study Site
uas_map = geemap.Map(center=[64.857595,-163.693854], zoom=17);
uas_map.addLayer(counc_rgb_image, counc_RGB_imageVisParam, 'UAS_Council_20180722_Flight3_RGB')
uas_map
```



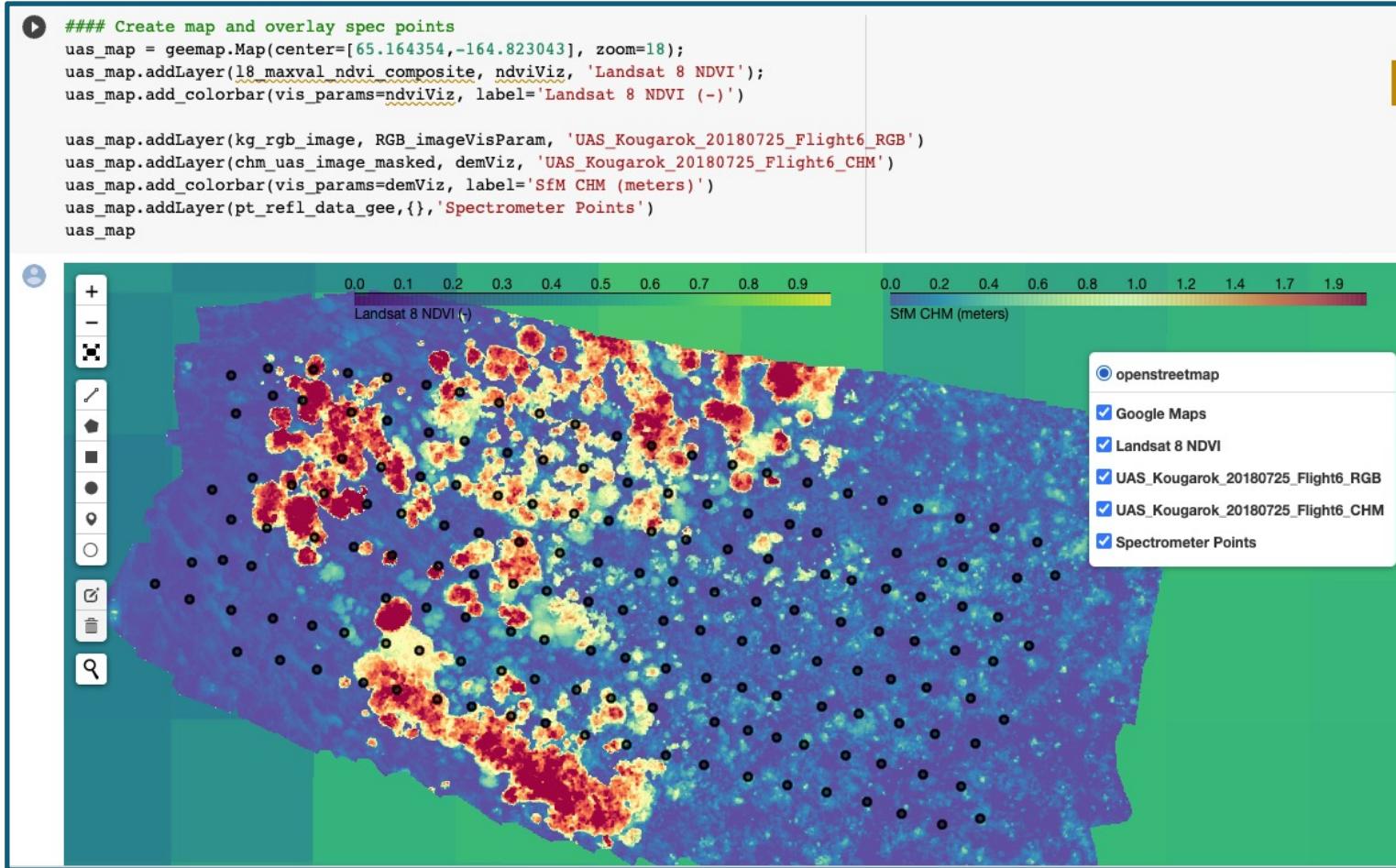
```
[8]: ##### Create a simple map displaying an RGB UAS image (Yang et al., 2021)
# center map over the Kougarok study site
uas_map = geemap.Map(center=[65.164354,-164.823043], zoom=17);
uas_map.addLayer(kg_rgb_image, kg_RGB_imageVisParam, 'UAS_Kougarok_20180725_Flight6_RGB')
uas_map
```



A “firehose” of data
available for scripted
cloud workflows

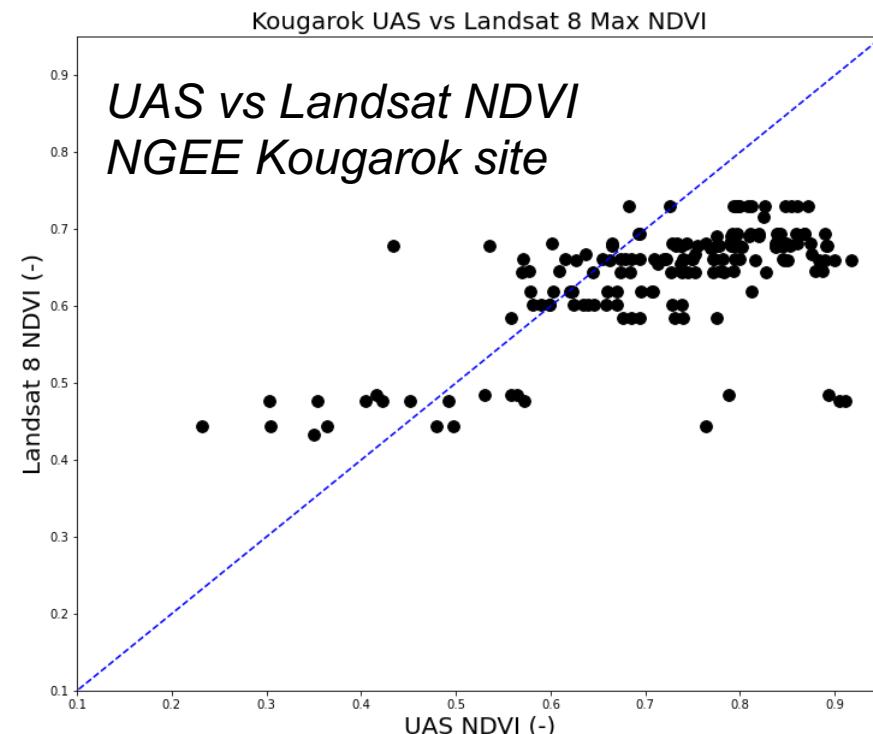
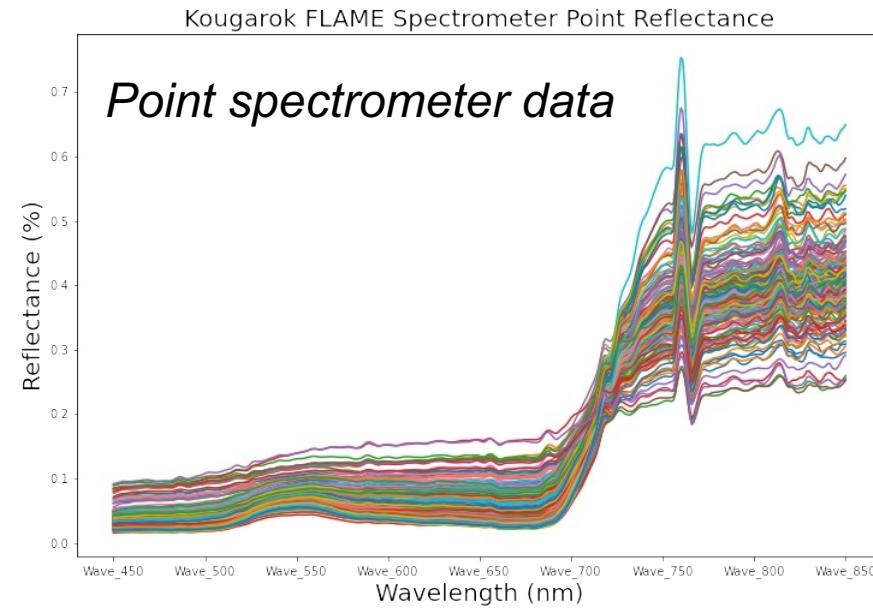


Combining NGEE-Arctic UAS & GEE remote sensing data



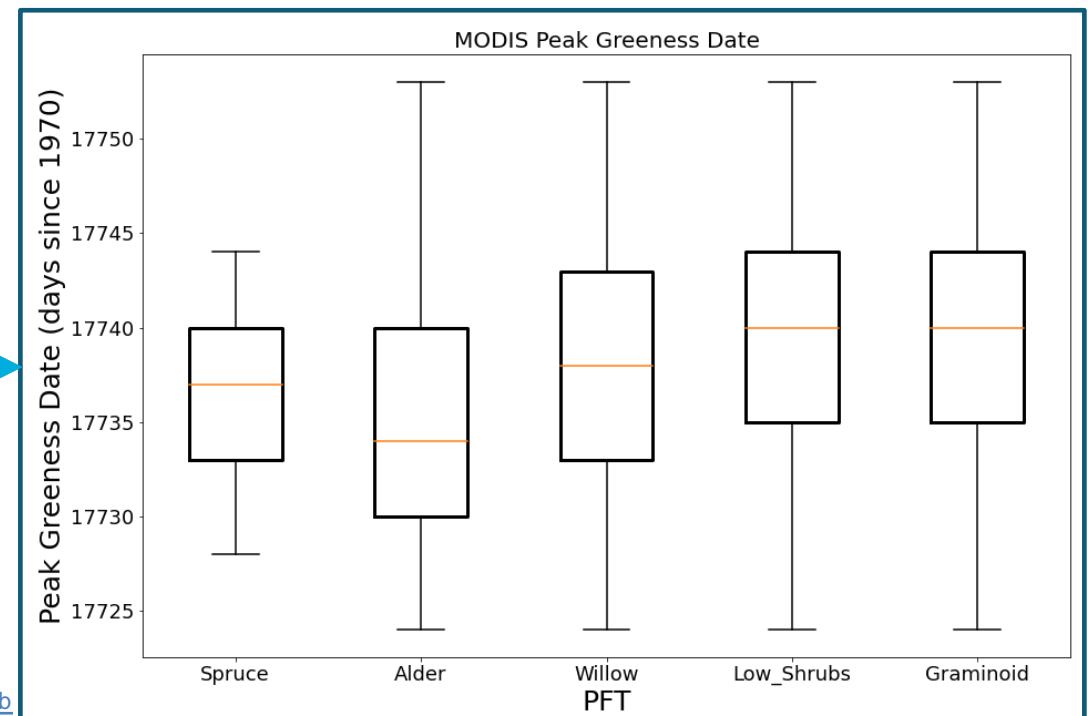
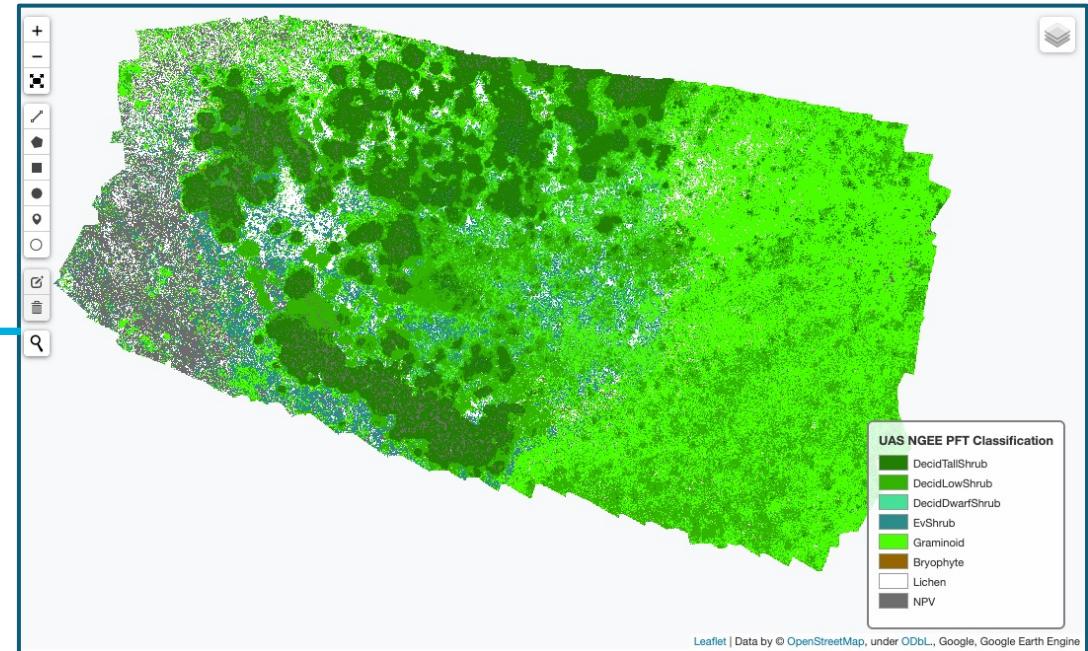
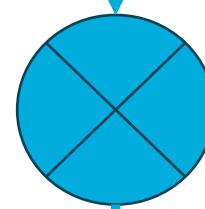
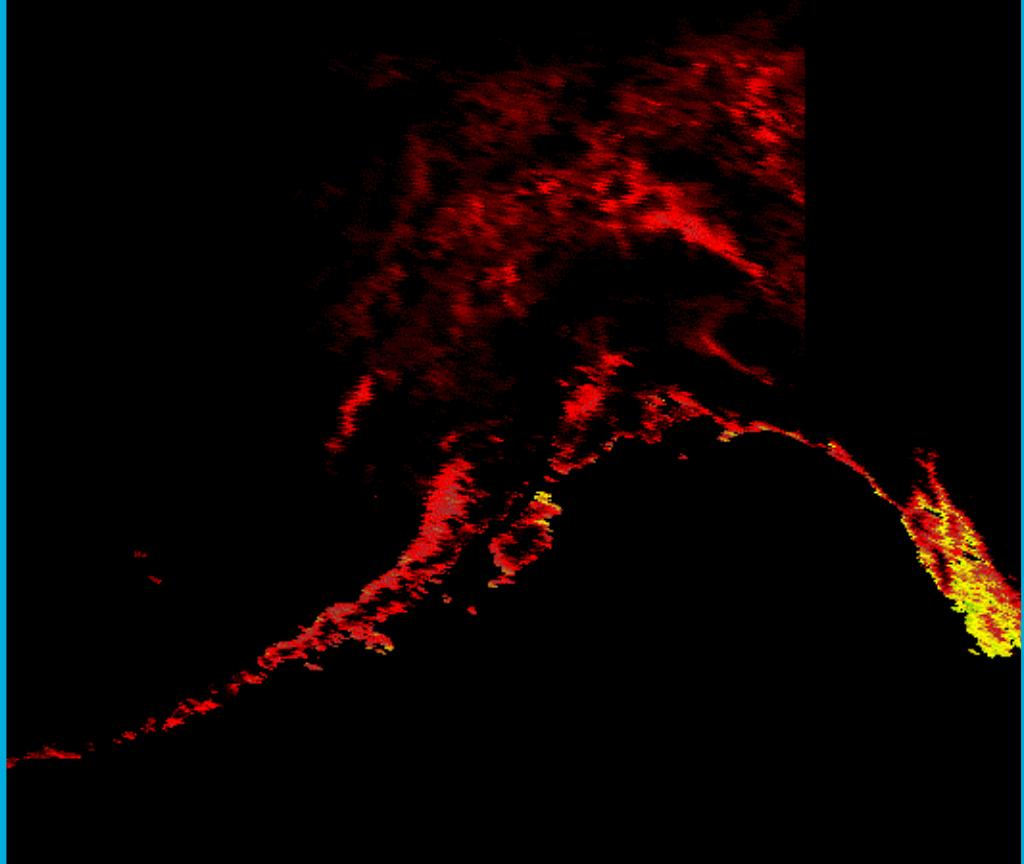
Example:

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





Google Earth Engine



Examples:

https://github.com/TESTgroup-BNL/meeting_demos/blob/main/us_iiale_2022/python/ngee_uas_pfts_example.ipynb

https://github.com/TESTgroup-BNL/meeting_demos/blob/main/us_iiale_2022/python/ngee_council_phenology_example.ipynb



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

hub.gke2.mybinder.org/user/testgroup-bnl-meeting_demos-3402b6oj/lab/tree/us_iale_2022/python/ngee_multisite_uas_example.ipynb

File Edit View Run Kernel Tabs Settings Help

Launcher ngee_multisite_uas_exam

File Edit View Run Kernel Tabs Settings Help

Filter files by name / us_iale_2022 / python /

Name	Last Modified
basic_ngee_uas_example.ipynb	4 days ago
ngee_council_phenology_example.ipynb	4 days ago
ngee_multisite_uas_example.ipynb	10 minutes ago
ngee_uas_pfts_example.ipynb	4 days ago
README.md	4 days ago

```
[10]: ### Open spectrometer data
kg_pt_refl_data = pd.read_csv('https://storage.googleapis.com/bnl_uas_data/NGEEArctic_Seward_Osprey_Kougarok_20180725_Flight6_Spectra.csv')
kg_pt_refl_data.head()

counc_pt_refl_data = pd.read_csv('https://storage.googleapis.com/bnl_uas_data/NGEEArctic_Seward_Osprey_Council_20180722_Flight3_Spectra.csv')
counc_pt_refl_data.head()

tell_refl_data = pd.read_csv('https://storage.googleapis.com/bnl_uas_data/NGEEArctic_Seward_Osprey_Teller_20180723_Flight5_Spectra.csv')
tell_refl_data.head()
```

Site	Data_Acquisition_Date_UTC	Data_Acquisition_Time_UTC	Longitude_DD	Latitude_DD	Altitude_HAE_Meter	Heading_DD	Yaw_DD	Pitch_DD	
0	Seward_Teller	20180724	01:36:34.597	-165.941894	64.726846	155.74	211	-2.588417	0.003813
1	Seward_Teller	20180724	01:36:36.964	-165.942081	64.726871	155.30	244	-2.003957	-0.138340
2	Seward_Teller	20180724	01:36:38.984	-165.942270	64.726904	155.08	255	-1.828605	-0.125611
3	Seward_Teller	20180724	01:36:40.783	-165.942449	64.726938	154.87	261	-1.714437	-0.123261
4	Seward_Teller	20180724	01:36:42.391	-165.942634	64.726974	154.99	257	-1.784147	-0.117202

5 rows x 511 columns

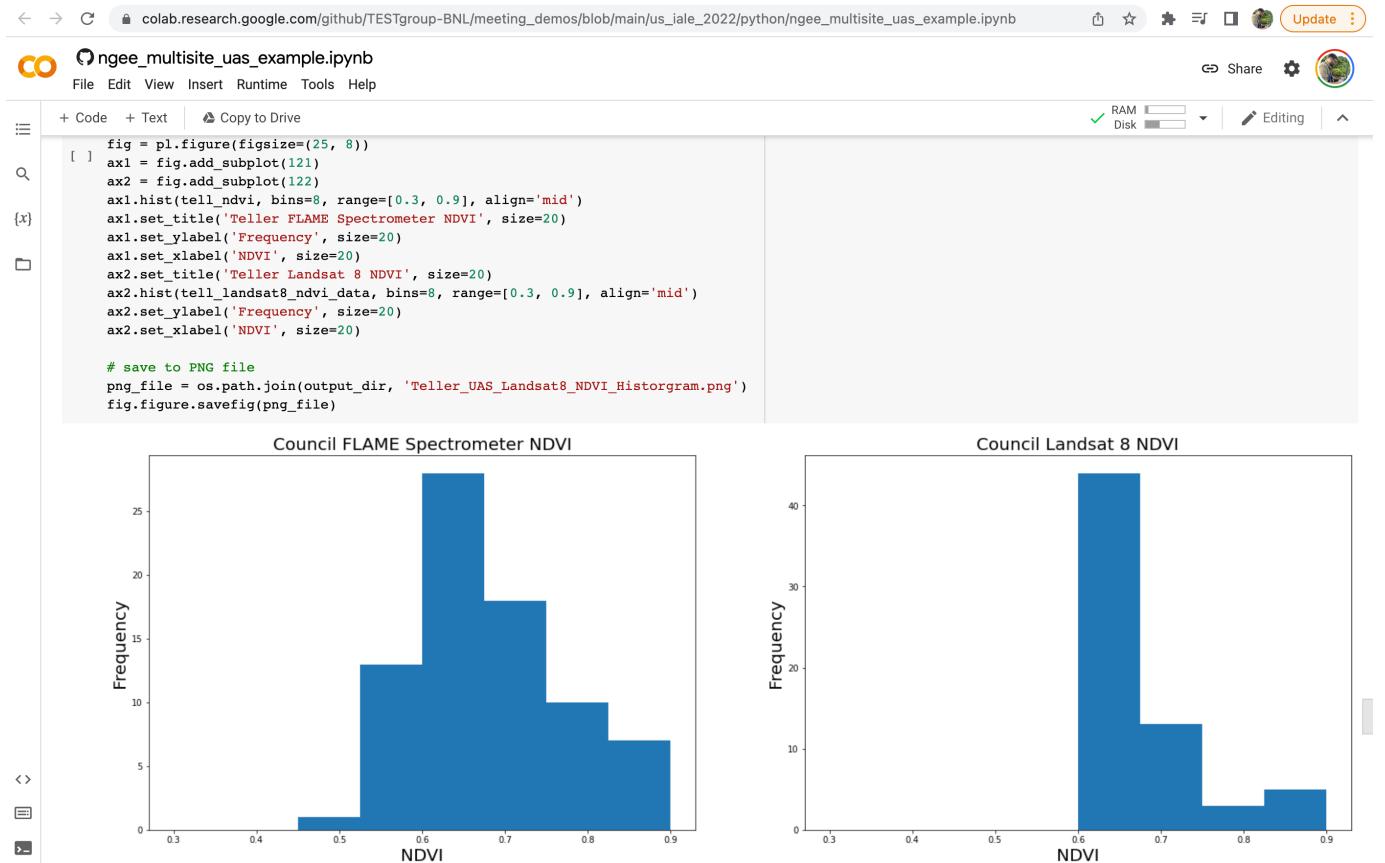


Image file format considerations

- 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



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



Google Cloud Storage



Google Earth Engine



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>

Contact: sserbin@bnl.gov