

# Exploring L2A Reflectance

## Summary

In this notebook we will open a Level 2A (L2A) Reflectance product file (netcdf) from Earth Surface Mineral Dust Source Investigation (EMIT). We will inspect the structure and plot the spectra of individual pixels and spatial coverage of a single band. Next, we will orthorectify the imagery using the included geometry lookup table (GLT). Finally, we will take advantage of the `holoviews` `streams` module to build an interactive plot.

## Background

The EMIT instrument is an imaging spectrometer that measures light in visible and infrared wavelengths. These measurements display unique spectral signatures that correspond to the composition on the Earth's surface. The EMIT mission focuses specifically on mapping the composition of minerals to better understand the effects of mineral dust throughout the Earth system and human populations now and in the future. More details about EMIT and its associated products can be found in the **README.md** and on the [EMIT website](#).

The L2A Reflectance Product contains estimated surface reflectance. Surface reflectance is the fraction of incoming solar radiation reflected Earth's surface. Materials reflect proportions of radiation differently based upon their chemical composition. This means that reflectance information can be used to determine the composition of a target. In this guide you will learn how to plot a band from the L2A reflectance spatially and look at the spectral curve associated with individual pixels.

## References

- Leith, Alex. 2023. Hyperspectral Notebooks. Jupyter Notebook. Auspacious. <https://github.com/auspacious/hyperspectral-notebooks/tree/main>

## Requirements

- Set up Python Environment - See **setup\_instructions.md** in the `/setup/` folder

## Learning Objectives

- How to open an EMIT `.nc` file as an `xarray.Dataset`
- Apply the Geometry Lookup Table (GLT) to orthorectify the image.
- How to plot the spectra of pixels
- How to plot specific bands as images
- How to make an interactive plot to visualize spectra

## Tutorial Outline

- 1.1 Setup
- 1.2 Opening The Data
- 1.3 Plotting Data - Non-Orthorectified
- 1.4 Orthorectification
- 1.5 Plotting Data - Orthorectified
- 1.6 Saving Orthorectified Data
- 1.7 Interactive Plots

 Interactive Plot

## 1.1 Setup

Import the required Python libraries.

```
In [ ]: !pip install netCDF4
!pip install earthaccess
!pip install os
!pip install warnings
!pip install csv
#from osgeo import gdal
```

```
!pip install numpy
!pip install math
!pip install rasterio
!pip install xarray
!pip install holoviews
!pip install hvplot
```

Requirement already satisfied: netCDF4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)

Requirement already satisfied: cftime in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.6.3)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (2024.2.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.25.2)

Requirement already satisfied: earthaccess in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.9.0)

Requirement already satisfied: fsspec>=2022.11 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (2024.3.1)

Requirement already satisfied: multimethod>=1.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (1.11.2)

Requirement already satisfied: pqdm>=0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (0.2.0)

Requirement already satisfied: python-cmr>=0.9.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (0.9.0)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (2.9.0.post0)

Requirement already satisfied: requests>=2.26 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (2.31.0)

Requirement already satisfied: s3fs>=2022.11 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (2024.3.1)

Requirement already satisfied: tinynetrc<2.0.0,>=1.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from earthaccess) (1.3.1)

Requirement already satisfied: bounded-pool-executor in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pqdm>=0.1->earthaccess) (0.0.3)

Requirement already satisfied: tqdm in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pqdm>=0.1->earthaccess) (4.66.2)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pqdm>=0.1->earthaccess) (4.10.0)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->earthaccess) (1.16.0)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.26->earthaccess) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.26->earthaccess) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.26->earthaccess) (2.0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.26->earthaccess) (2024.2.2)

Requirement already satisfied: aiobotocore<3.0.0,>=2.5.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs>=2022.11->earthaccess) (2.12.1)

Requirement already satisfied: aiohttp!=4.0.0a0,!4.0.0a1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs>=2022.11->earthaccess) (3.9.3)

Requirement already satisfied: botocore<1.34.52,>=1.34.41 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs>=2022.11->earthaccess) (1.34.51)

Requirement already satisfied: wrapt<2.0.0,>=1.10.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs>=2022.11->earthaccess) (1.16.0)

Requirement already satisfied: aioitertools<1.0.0,>=0.5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs>=2022.11->earthaccess) (0.11.0)

Requirement already satisfied: aiosignal>=1.1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs>=2022.11->earthaccess) (1.3.1)

Requirement already satisfied: attrs>=17.3.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs>=2022.11->earthaccess) (23.2.0)

Requirement already satisfied: frozenlist>=1.1.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs>=2022.11->earthaccess) (1.4.1)

Requirement already satisfied: multidict<7.0,>=4.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs>=2022.11->earthaccess) (6.0.5)

Requirement already satisfied: yarl<2.0,>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs>=2022.11->earthaccess) (1.9.4)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11

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_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm->pqdm>=0.1->earthaccess) (0.4.6)
Requirement already satisfied: jmespath<2.0.0,>=0.7.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundati
on.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from botocore<1.34.52,>=1.34.41->aiobo
tore<3.0.0,>=2.5.4->s3fs>=2022.11->earthaccess) (1.0.1)
ERROR: Could not find a version that satisfies the requirement os (from versions: none)
ERROR: No matching distribution found for os
ERROR: Could not find a version that satisfies the requirement warnings (from versions: none)
ERROR: No matching distribution found for warnings
ERROR: Could not find a version that satisfies the requirement csv (from versions: none)
ERROR: No matching distribution found for csv
Requirement already satisfied: numpy in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qb
z5n2kfra8p0\localcache\local-packages\python311\site-packages (1.25.2)
ERROR: Could not find a version that satisfies the requirement math (from versions: none)
ERROR: No matching distribution found for math
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Requirement already satisfied: rasterio in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.9)

Requirement already satisfied: affine in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2.4.0)

Requirement already satisfied: attrs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (23.2.0)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2024.2.2)

Requirement already satisfied: click>=4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (8.1.7)

Requirement already satisfied: cligj>=0.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (0.7.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.25.2)

Requirement already satisfied: snuggs>=1.4.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.4.7)

Requirement already satisfied: click-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.1.1)

Requirement already satisfied: setuptools in c:\program files\windowsapps\pythonsoftwarefoundation.python.3.11\_3.11.22.88.0\_x64\_qbz5n2kfra8p0\lib\site-packages (from rasterio) (65.5.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from click>=4.0->rasterio) (0.4.6)

Requirement already satisfied: pyparsing>=2.1.6 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from snuggs>=1.4.1->rasterio) (3.1.2)

Requirement already satisfied: xarray in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2024.2.0)

Requirement already satisfied: numpy>=1.23 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from xarray) (1.25.2)

Requirement already satisfied: packaging>=22 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from xarray) (24.0)

Requirement already satisfied: pandas>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from xarray) (2.2.1)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray) (2024.1)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=1.5->xarray) (1.16.0)

Requirement already satisfied: holoviews in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.18.3)

Requirement already satisfied: param<3.0,>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.1.0)

Requirement already satisfied: numpy>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.25.2)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.0.2)

Requirement already satisfied: panel>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.3.8)

Requirement already satisfied: colorcet in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.1.0)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (24.0)

Requirement already satisfied: pandas>=0.20.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.2.1)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: bokeh<3.4.0,>=3.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.3.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2023.10.1)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2.0.0)

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Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_q bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.py thon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.10.0)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (1.2.0)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoview s) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.4)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11 \_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=0.20.0->holovie ws) (1.16.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11 \_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=1.0->holoviews) (0.4.6)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=1.0->holoviews) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=1.0->holoviews) (1.0. 3)

Requirement already satisfied: mdurl~>=0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3. 11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=1.0->holoviews) (0.1. 2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefounda tion.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoview s) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p ython.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (2. 0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p ython.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (202 4.2.2)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh<3.4.0,>=3.2.0->panel> =1.0->holoviews) (2.1.5)

Requirement already satisfied: hvplot in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_q bz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.9.2)

Requirement already satisfied: bokeh>=1.0.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (3.3.4)

Requirement already satisfied: colorcet>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (3.1.0)

Requirement already satisfied: holoviews>=1.11.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.py thon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.18.3)

Requirement already satisfied: pandas in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_q bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (2.2.1)

Requirement already satisfied: numpy>=1.15 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.25.2)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1 1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (24.0)

Requirement already satisfied: panel>=0.11.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.3.8)

Requirement already satisfied: param<3.0,>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p ython.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (2.1.0)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (1.2.0)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (6.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati  
on.pytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (2023.10.1)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p  
ytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews>=1.11.0->hvplot) (3.0.2)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati  
on.pytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2024.1)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (2.0.3)

Requirement already satisfied: mdit-py-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth  
on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (0.4.0)

Requirement already satisfied: requests in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (2.31.0)

Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.11\_q  
bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.py  
thon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (4.10.0)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth  
on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh>=1.0.0->hvplot) (2.1.  
5)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas->hvplot) (1.16.  
0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=0.11.0->hvplot) (0.4.6)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=0.11.0->hvplot) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=0.11.0->hvplot) (1.0.  
3)

Requirement already satisfied: mdurl~=0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=0.11.0->hvplot) (0.1.  
2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefounda  
tion.pytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot  
t) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p  
ytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (2.  
0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p  
ytho.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (202  
4.2.2)

```
In [ ]: import earthaccess
import os
import warnings
import csv
#from osgeo import gdal
import numpy as np
import math
import rasterio as rio
import xarray as xr
import holoviews as hv
import hvplot.xarray
import netCDF4 as nc
```

```
# This will ignore some warnings caused by holoviews
warnings.simplefilter('ignore')
```

Login to your NASA Earthdata account and create a `.netrc` file using the `login` function from the `earthaccess` library. If you do not have an Earthdata Account, you can create one [here](#).

```
In [ ]: earthaccess.login(persist=True)
```

```
Out [ ]: <earthaccess.auth.Auth at 0x1d34f976850>
```

For this notebook we will download the files necessary using `earthaccess`. You can also access the data in place or stream it, but this can slow due to the file sizes. Provide a URL for an EMIT L2A Reflectance granule.

```
In [ ]: #/EMIT_L2A_RFL_001_20231125T000223_2332816_003/EMIT_L2A_RFL_001_20231125T000223_2332816_003
url = 'https://data.lpdaac.earthdatacloud.nasa.gov/lp-prod-protected/EMITL2ARFL.001/EMIT_L2A_RFL_001_20231125T000223_
```

Get an HTTPS Session using your earthdata login, set a local path to save the file, and download the granule asset - This may take a while, the reflectance file is approximately 1.8 GB.

```
In [ ]: import os

# Get requests https Session using Earthdata Login Info
fs = earthaccess.get_requests_https_session()
# Retrieve granule asset ID from URL (to maintain existing naming convention)
granule_asset_id = url.split('/')[-1]
directory = '../data/'
fp = os.path.join(directory, granule_asset_id) #Join one or more path segments intelligently. The return value is the
if not os.path.isdir(directory): #os.path.isdir(path) Return True if path is an existing directory. This follows symb
    os.makedirs(directory)#, exist_ok=True)

# Download the Granule Asset if it doesn't exist
if not os.path.isfile(fp):
    with fs.get(url, stream=True) as src:
        with open(fp, 'wb') as dst:
            for chunk in src.iter_content(chunk_size=64*1024*1024):
                dst.write(chunk)
```

## 1.2 Opening EMIT Data

EMIT L2A Reflectance Data are distributed in a non-orthorectified spatially raw NetCDF4 (.nc) format consisting of the data and its associated metadata. Inside the L2A Reflectance `.nc` file there are 3 groups. Groups can be thought of as containers to organize the data.

1. The root group that can be considered the main dataset contains the reflectance data described by the downtrack, crosstrack, and bands dimensions.
2. The `sensor_band_parameters` group containing the wavelength center and the full-width half maximum (FWHM) of each band.
3. The `location` group contains latitude and longitude values at the center of each pixel described by the crosstrack and downtrack dimensions, as well as a geometry lookup table (GLT) described by the `ortho_x` and `ortho_y` dimensions. The GLT is an orthorectified image (EPSG:4326) consisting of 2 layers containing downtrack and crosstrack indices. These index positions allow us to quickly project the raw data onto this geographic grid.

To access the `.nc` file we will use the `netCDF4` and `xarray` libraries. The `netCDF4` library will be used to explore the data structure, then we will use `xarray` to work with the data. `xarray` is a python package for working with labelled multi-dimensional arrays. It provides a data model where data, dimensions, and attributes together in an easily interpretable way.

```
In [ ]: ds_nc = nc.Dataset(fp)
ds_nc
```



```

Out[ ]: <class 'netCDF4._netCDF4.Dataset'>
root group (NETCDF4 data model, file format HDF5):
  ncei_template_version: NCEI_NetCDF_Swath_Template_v2.0
  summary: The Earth Surface Mineral Dust Source Investigation (EMIT) is an Earth Ventures-Instrument (EVI-4) Mission that maps the surface mineralogy of arid dust source regions via imaging spectroscopy in the visible and short-wave infrared (VSWIR). Installed on the International Space Station (ISS), the EMIT instrument is a Dyson imaging spectrometer that uses contiguous spectroscopic measurements from 410 to 2450 nm to resolve absorption features of iron oxides, clays, sulfates, carbonates, and other dust-forming minerals. During its one-year mission, EMIT will observe the sunlit Earth's dust source regions that occur within +/-52° latitude and produce maps of the source regions that can be used to improve forecasts of the role of mineral dust in the radiative forcing (warming or cooling) of the atmosphere.

This file contains L2A estimated surface reflectances and geolocation data. Reflectance estimates are created using an Optimal Estimation technique - see ATBD for details. Reflectance values are reported as fractions (relative to 1). Geolocation data (latitude, longitude, height) and a lookup table to project the data are also included.

  keywords: Imaging Spectroscopy, minerals, EMIT, dust, radiative forcing
  Conventions: CF-1.63
  sensor: EMIT (Earth Surface Mineral Dust Source Investigation)
  instrument: EMIT
  platform: ISS
  institution: NASA Jet Propulsion Laboratory/California Institute of Technology
  license: https://science.nasa.gov/earth-science/earth-science-data/data-information-policy/
  naming_authority: LPDAAC
  date_created: 2023-11-26T02:23:22Z
  keywords_vocabulary: NASA Global Change Master Directory (GCMD) Science Keywords
  stdname_vocabulary: NetCDF Climate and Forecast (CF) Metadata Convention
  creator_name: Jet Propulsion Laboratory/California Institute of Technology
  creator_url: https://earth.jpl.nasa.gov/emit/
  project: Earth Surface Mineral Dust Source Investigation
  project_url: https://earth.jpl.nasa.gov/emit/
  publisher_name: NASA LPDAAC
  publisher_url: https://lpdaac.usgs.gov
  publisher_email: lpdaac@usgs.gov
  identifier_product_doi_authority: https://doi.org
  flight_line: emit20231125t000223_o32816_s000
  time_coverage_start: 2023-11-25T00:02:23+0000
  time_coverage_end: 2023-11-25T00:02:35+0000
  software_build_version: 010618
  software_delivery_version: 010618
  product_version: V001
  history: PGE Run Command: {python /beegfs/store/emit/ops/repos/emit-sds-l2a/spectrum_quality.py /tmp/emit/ops/emit20231125t000223_emit.L2AReflectance_20231125t123040/output/emit20231125t000223_rfl /tmp/emit/ops/emit20231125t000223_emit.L2AReflectance_20231125t123040/output/emit20231125t000223_rfl_quality.txt}, PGE Input Files: {radiance_file=/beegfs/store/emit/ops/data/acquisitions/20231125/emit20231125t000223/l1b/emit20231125t000223_o32816_s000_l1b_rdn_b0106_v01.img, pixel_locations_file=/beegfs/store/emit/ops/data/acquisitions/20231125/emit20231125t000223/l1b/emit20231125t000223_o32816_s000_l1b_loc_b0106_v01.img, observation_parameters_file=/beegfs/store/emit/ops/data/acquisitions/20231125/emit20231125t000223/l1b/emit20231125t000223_o32816_s000_l1b_obs_b0106_v01.img, surface_model_config=/beegfs/store/emit/ops/repos/emit-sds-l2a/surface/surface_20221020.json}
  crosstrack_orientation: as seen on ground
  easternmost_longitude: -155.2625938202083
  northernmost_latitude: 20.4028015180889
  westernmost_longitude: -156.36603699893
  southernmost_latitude: 19.380150984885393
  spatialResolution: 0.000542232520256367
  spatial_ref: GEOGCS["WGS 84",DATUM["WGS_1984",SPHEROID["WGS 84",6378137,298.257223563,AUTHORITY["EPSG","7030"]],AUTHORITY["EPSG","6326"]],PRIMEM["Greenwich",0,AUTHORITY["EPSG","8901"]],UNIT["degree",0.0174532925199433,AUTHORITY["EPSG","9122"]],AXIS["Latitude",NORTH],AXIS["Longitude",EAST],AUTHORITY["EPSG","4326"]]
  geotransform: [-1.56366037e+02 5.42232520e-04 -0.00000000e+00 2.04028015e+01 -0.00000000e+00 -5.42232520e-04]
  day_night_flag: Day
  title: EMIT L2A Estimated Surface Reflectance 60 m V001
  dimensions(sizes): downtrack(1280), crosstrack(1242), bands(285), ortho_y(1886), ortho_x(2035)
  variables(dimensions): float32 reflectance(downtrack, crosstrack, bands)
  groups: sensor_band_parameters, location

```

```
In [ ]: ds_nc['location']
```

```

Out[ ]: <class 'netCDF4._netCDF4.Group'>
group /location:
  dimensions(sizes):
    variables(dimensions): float64 lon(downtrack, crosstrack), float64 lat(downtrack, crosstrack), float64 elev(downtrack, crosstrack), int32 glt_x(ortho_y, ortho_x), int32 glt_y(ortho_y, ortho_x)
  groups:

```

From this output, we can see the `reflectance` variable, and the `sensor_band_parameters` and `location` groups. We can also see the dimensions, their sizes, and file metadata.

Now that we have a better understanding of the structure of the file, read the EMIT data as an `xarray.Dataset` and preview it.

```
In [ ]: ds = xr.open_dataset(fp)
        ds
```

```
Out[ ]: xarray.Dataset
```

► Dimensions: (downtrack: 1280, crosstrack: 1242, bands: 285)

► Coordinates: (0)

▼ Data variables:

reflectance (downtrack, crosstrack, bands) float32 ...



► Indexes: (0)

► Attributes: (38)

This `xarray` dataset only contains the `reflectance` variable and attributes metadata, not the data from the other groups in the file. This is because `xarray` only supports reading non-hierarchical (flat) datasets, meaning that when loading a NetCDF into an `xarray.Dataset`, only the root group is added. The other groups will have to be read into `xarray` separately. We can list them using the `netCDF4` library to get the group names, then use that to add them to new `xarray` datasets.

```
In [ ]: ds_nc.groups.keys()
```

```
Out[ ]: dict_keys(['sensor_band_parameters', 'location'])
```

Now that we know the other group names, read the `sensor_band_parameters` and `location` groups into their own `xarray` datasets.

```
In [ ]: wv1 = xr.open_dataset(fp, group='sensor_band_parameters')
        wv1
```

```
Out[ ]: xarray.Dataset
```

► Dimensions: (bands: 285)

► Coordinates: (0)

▼ Data variables:

wavelengths (bands) float32 ...



fwhm (bands) float32 ...



good\_wavelength... (bands) float32 ...



► Indexes: (0)

► Attributes: (0)











```
In [ ]: loc = xr.open_dataset(fp, group='location')
        loc
```

Out [ ]: xarray.Dataset

► Dimensions: (downtrack: 1280, crosstrack: 1242, ortho\_y: 1886, ortho\_x: 2035)

► Coordinates: (0)

▼ Data variables:

lon	(downtrack, crosstrack)	float64	...		
lat	(downtrack, crosstrack)	float64	...		
elev	(downtrack, crosstrack)	float64	...		
glt_x	(ortho_y, ortho_x)	float64	...		
glt_y	(ortho_y, ortho_x)	float64	...		

► Indexes: (0)

► Attributes: (0)





















We could merge all 3 datasets, but since `sensor_band_parameters` and `location` describe various aspects of the `reflectance` variable we can simply add them as coordinates, along with a `downtrack` and `crosstrack` dimension to describe the reflectance data array. This will allow us to utilize some additional features of `xarray`.

```
In [ ]: # Create coordinates and an index for the downtrack and crosstrack dimensions, then unpack the variables from the wvl
ds = ds.assign_coords({'downtrack':(['downtrack'], ds.downtrack.data), 'crosstrack':(['crosstrack'], ds.crosstrack.data)
ds
```



Out [ ]: xarray.Dataset

► Dimensions: (**downtrack**: 1280, **crosstrack**: 1242, bands: 285, ortho\_y: 1886, ortho\_x: 2035)

▼ Coordinates:

<b>downtrack</b>	(downtrack)	int64	0 1 2 3 4 ... 1276 1277 1278 1279		
<b>crosstrack</b>	(crosstrack)	int64	0 1 2 3 4 ... 1238 1239 1240 1241		
wavelengths	(bands)	float32	...		
fwhm	(bands)	float32	...		
good_wavelength...	(bands)	float32	...		
lon	(downtrack, crosstrack)	float64	...		
lat	(downtrack, crosstrack)	float64	...		
elev	(downtrack, crosstrack)	float64	...		
glt_x	(ortho_y, ortho_x)	float64	...		
glt_y	(ortho_y, ortho_x)	float64	...		

▼ Data variables:

reflectance	(downtrack, crosstrack, bands)	float32	...		
-------------	--------------------------------	---------	-----	---	---

► Indexes: (2)

► Attributes: (38)





















Another step we can take is to swap the 'bands' dimension with `wavelengths`. Doing this will allow us to index based on the wavelength of the band, and remove 'bands' as a dimension. We can do this since bands is just a 3rd dimension that will be defined based on the 'sensor\_band\_parameters' group (i.e. 'wavelengths' for reflectance, or 'mask\_bands' for mask data).

```
In [ ]: ds = ds.swap_dims({'bands': 'wavelengths'})
ds
```



Out [ ]: xarray.Dataset

► Dimensions: (downtrack: 1280, crosstrack: 1242, wavelengths: 285, ortho\_y: 1886, ortho\_x: 2035)

▼ Coordinates:

<b>downtrack</b>	(downtrack)	int64	0 1 2 3 4 ... 1276 1277 1278 1279		
<b>crosstrack</b>	(crosstrack)	int64	0 1 2 3 4 ... 1238 1239 1240 1241		
<b>wavelengths</b>	(wavelengths)	float32	381.0 388.4 ... 2.486e+03 2.493e...		
fwhm	(wavelengths)	float32	...		
good_wavelength...	(wavelengths)	float32	...		
lon	(downtrack, crosstrack)	float64	...		
lat	(downtrack, crosstrack)	float64	...		
elev	(downtrack, crosstrack)	float64	...		
glt_x	(ortho_y, ortho_x)	float64	...		
glt_y	(ortho_y, ortho_x)	float64	...		

▼ Data variables:

<b>reflectance</b>	(downtrack, crosstrack, wavelengths)	float32	...		
--------------------	--------------------------------------	---------	-----	---	---

► Indexes: (3)

► Attributes: (38)

Now we have an `xarray.Dataset` containing all of the information from EMIT netCDF file. Since these datasets are large, we can go ahead and delete objects we won't be using to conserve memory.

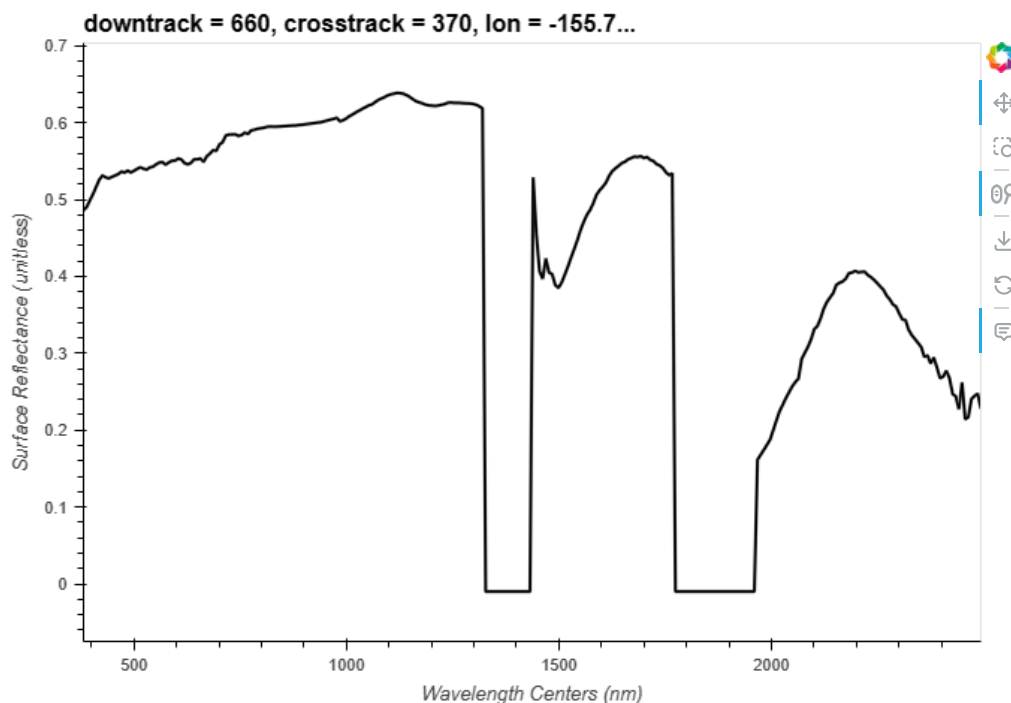
```
In [ ]: del wvl
        del loc
```

## 1.3 Visualizing Spectra - Non-Orthorectified

Pick a random downtrack and crosstrack location. Here we chose 660, 370 (downtrack,crosstrack). Next use the `sel()` function from `xarray` and the `hvplot.line()` functions to first select the spatial position and then plot a line showing the reflectance at that location.

```
In [ ]: example = ds['reflectance'].sel(downtrack=660,crosstrack=370)
        example.hvplot.line(y='reflectance',x='wavelengths', color='black', frame_height=400, frame_width=600)
```

Out [ ]:



We can see some flat regions in the spectral curve around 1320-1440 nm and 1770-1970 nm. These are where water absorption features in these regions were removed. Typically this data is noisy due to the moisture present in the atmosphere; therefore, these spectral regions offer little information about targets and can be excluded from calculations.

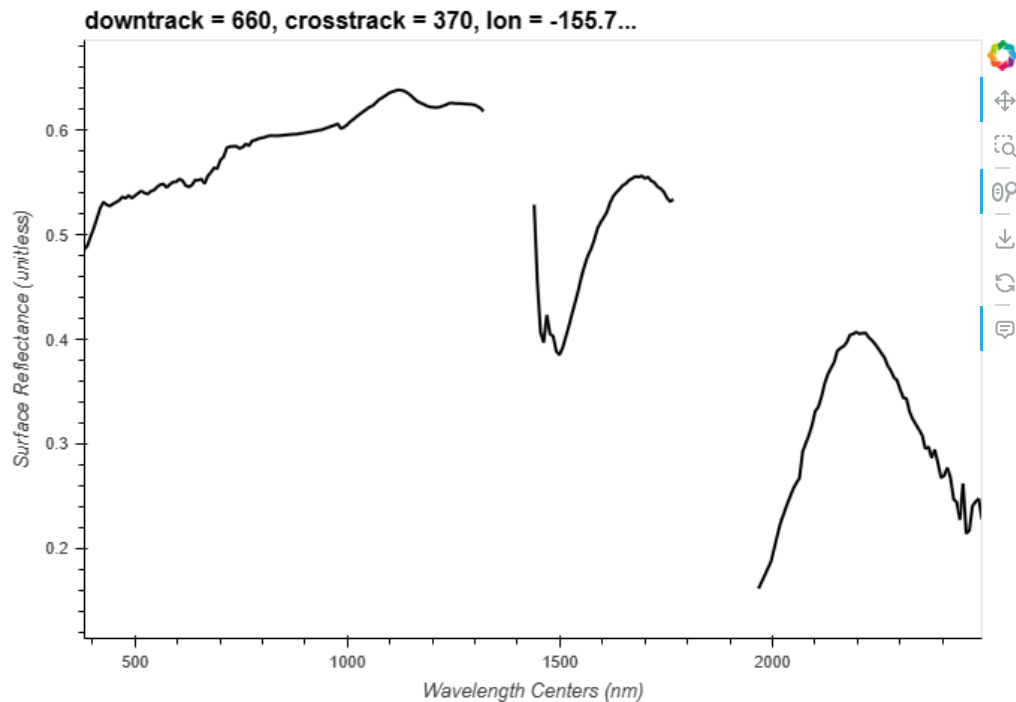
We can set reflectance values where the `good_wavelengths` is 0 (these will have a reflectance of -0.1) to `np.nan` to mask them out and improve visualization.

```
In [ ]: ds['reflectance'].data[:, :, ds['good_wavelengths'].data==0] = np.nan
```

Plot the filtered reflectance values using the same downtrack and crosstrack position as above.

```
In [ ]: ds['reflectance'].sel(downtrack=660, crosstrack=370).hvplot.line(y='reflectance', x='wavelengths', color='black', frame
```

```
Out [ ]:
```



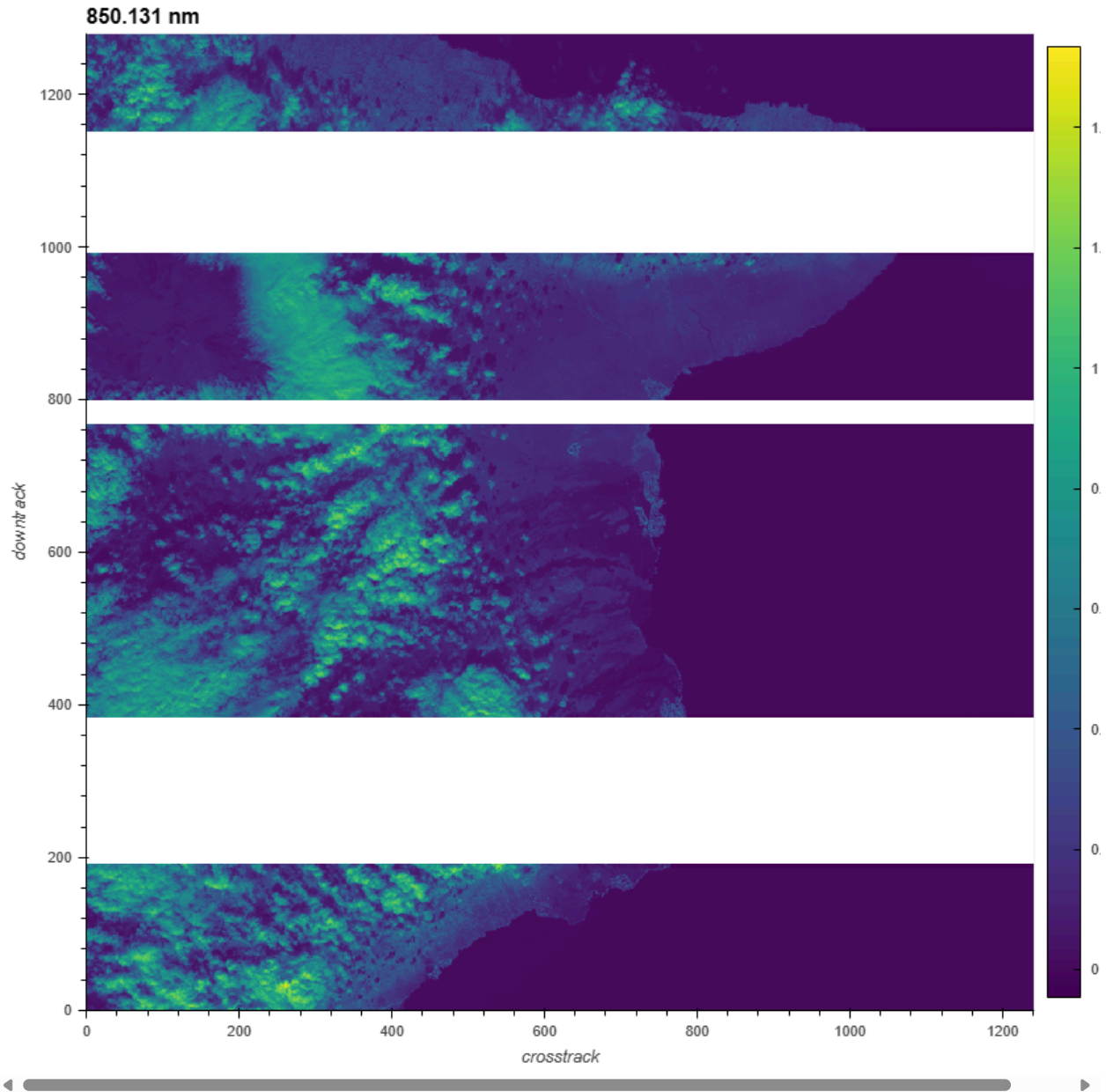
Without these data we can better interpret the spectral curve and `hvplot` will do a better job automatically scaling our axes.

We can also plot the data spatially. Since we changed our dimension and index to `wavelengths` we can use the `sel()` function to spectrally subset to the wavelength nearest to 850nm in the NIR, then plot the data spatially using `hvplot.image()` to view the reflectance at 850nm of each pixel across the acquired region.

```
In [ ]: ref1850 = ds.sel(wavelengths=850, method='nearest')
```

```
In [ ]: ref1850.hvplot.image(cmap='viridis', aspect = 'equal', frame_width=720).opts(title=f"{ref1850.wavelengths.values:.3f}")
```

Out[ ]:



## 1.4 Orthorectification

The 'real' orthorectification process has already been done for EMIT data. Here we are using the crosstrack and downtrack indices contained in the GLT to place our spatially raw reflectance data into geographic grid with the `ortho_x` and `ortho_y` dimensions. As previously mentioned a Geometry Lookup Table (GLT) is included in the `location` group of the netCDF4 file. Applying the GLT will orthorectify the data and give us Latitude and Longitude positional information.

Before using the GLT to orthorectify the data, examine the `location` group from the dataset by reading it into `xarray`.



```
In [ ]: loc = xr.open_dataset(fp,group='location')
loc
```

Out [ ]: xarray.Dataset

► Dimensions: (downtrack: 1280, crosstrack: 1242, ortho\_y: 1886, ortho\_x: 2035)

► Coordinates: (0)

▼ Data variables:

lon	(downtrack, crosstrack)	float64	...		
lat	(downtrack, crosstrack)	float64	...		
elev	(downtrack, crosstrack)	float64	...		
glt_x	(ortho_y, ortho_x)	float64	...		
glt_y	(ortho_y, ortho_x)	float64	...		

► Indexes: (0)

► Attributes: (0)

We can see that each downtrack and crosstrack position has a latitude, longitude, and elevation, and the ortho\_x and ortho\_y data make up glt\_x and glt\_y arrays with a different shape. These arrays contain crosstrack and downtrack index values to quickly reproject the data. We will use these indexes to build an array of 2009x2353x285 (lat,lon,bands), filling it with the data from the reflectance dataset.

Go ahead and remove this dataset. We will use a function in the provided `emit_tools` module to orthorectify the data and place it into an `xarray.Dataset`.

```
In [ ]: del loc
        del example
```

```
In [ ]: !pip install spectra
        !pip install rioxarray
        !pip install merge
        !pip install scikit-image
        !pip install s3fs
        !pip install fsspec
```

Requirement already satisfied: spectra in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.0.11)

Requirement already satisfied: colormath>=3.0.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spectra) (3.0.0)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from colormath>=3.0.0->spectra) (1.25.2)

Requirement already satisfied: networkx>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from colormath>=3.0.0->spectra) (3.2.1)

Requirement already satisfied: rioarray in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.15.1)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (24.0)

Requirement already satisfied: rasterio>=1.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (1.3.9)

Requirement already satisfied: xarray>=2022.3.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (2024.2.0)

Requirement already satisfied: pyproj>=3.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (3.6.1)

Requirement already satisfied: numpy>=1.23 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (1.25.2)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pyproj>=3.3->rioarray) (2024.2.2)

Requirement already satisfied: affine in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (2.4.0)

Requirement already satisfied: attrs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (23.2.0)

Requirement already satisfied: click>=4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (8.1.7)

Requirement already satisfied: cligj>=0.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (0.7.2)

Requirement already satisfied: snuggs>=1.4.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (1.4.7)

Requirement already satisfied: click-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio>=1.3->rioarray) (1.1.1)

Requirement already satisfied: setuptools in c:\program files\windowsapps\pythonsoftwarefoundation.python.3.11\_2022.0.0\_x64\_\_qbz5n2kfra8p0\lib\site-packages (from rasterio>=1.3->rioarray) (65.5.0)

Requirement already satisfied: pandas>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from xarray>=2022.3.0->rioarray) (2.2.1)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from click>=4.0->rasterio>=1.3->rioarray) (0.4.6)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray>=2022.3.0->rioarray) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray>=2022.3.0->rioarray) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.5->xarray>=2022.3.0->rioarray) (2024.1)

Requirement already satisfied: pyparsing>=2.1.6 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from snuggs>=1.4.1->rasterio>=1.3->rioarray) (3.1.2)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=1.5->xarray>=2022.3.0->rioarray) (1.16.0)

Requirement already satisfied: merge in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.0.0)

Requirement already satisfied: scikit-image in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.22.0)

Requirement already satisfied: numpy>=1.22 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (1.25.2)

Requirement already satisfied: scipy>=1.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (1.9.3)

Requirement already satisfied: networkx>=2.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (3.2.1)

Requirement already satisfied: pillow>=9.0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (10.2.0)

Requirement already satisfied: imageio>=2.27 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (2.34.0)

Requirement already satisfied: tifffile>=2022.8.12 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (2024.2.12)

Requirement already satisfied: packaging>=21 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (24.0)

Requirement already satisfied: lazy\_loader>=0.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image) (0.3)



Requirement already satisfied: s3fs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2024.3.1)

Requirement already satisfied: aiobotocore<3.0.0,>=2.5.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (2.12.1)

Requirement already satisfied: fsspec==2024.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (2024.3.1)

Requirement already satisfied: aiohttp!=4.0.0a0,!4.0.0a1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (3.9.3)

Requirement already satisfied: botocore<1.34.52,>=1.34.41 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs) (1.34.51)

Requirement already satisfied: wrapt<2.0.0,>=1.10.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs) (1.16.0)

Requirement already satisfied: aioitertools<1.0.0,>=0.5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3fs) (0.11.0)

Requirement already satisfied: aiosignal>=1.1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (1.3.1)

Requirement already satisfied: attrs>=17.3.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (23.2.0)

Requirement already satisfied: frozenlist>=1.1.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (1.4.1)

Requirement already satisfied: multidict<7.0,>=4.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (6.0.5)

Requirement already satisfied: yarl<2.0,>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (1.9.4)

Requirement already satisfied: jmespath<2.0.0,>=0.7.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from botocore<1.34.52,>=1.34.41->aiobotocore<3.0.0,>=2.5.4->s3fs) (1.0.1)

Requirement already satisfied: python-dateutil<3.0.0,>=2.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from botocore<1.34.52,>=1.34.41->aiobotocore<3.0.0,>=2.5.4->s3fs) (2.9.0.post0)

Requirement already satisfied: urllib3<2.1,>=1.25.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from botocore<1.34.52,>=1.34.41->aiobotocore<3.0.0,>=2.5.4->s3fs) (2.0.7)

Requirement already satisfied: idna>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from yarl<2.0,>=1.0->aiohttp!=4.0.0a0,!4.0.0a1->s3fs) (3.6)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil<3.0.0,>=2.1->botocore<1.34.52,>=1.34.41->aiobotocore<3.0.0,>=2.5.4->s3fs) (1.16.0)

Requirement already satisfied: fsspec in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2024.3.1)

```
In [ ]: !pip install h5netcdf
```

Requirement already satisfied: h5netcdf in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.0)

Requirement already satisfied: h5py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (3.10.0)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py) (24.0)

Requirement already satisfied: numpy>=1.17.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py->h5netcdf) (1.25.2)

```
In [ ]: !pip install script
```

```
ERROR: Could not find a version that satisfies the requirement script (from versions: none)
ERROR: No matching distribution found for script
```

```
In [ ]: !pip install scipy
```

Requirement already satisfied: scipy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.9.3)

Requirement already satisfied: numpy<1.26.0,>=1.18.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scipy) (1.25.2)

```
In [ ]: !pip install rasterio
```

Requirement already satisfied: rasterio in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.9)

Requirement already satisfied: affine in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2.4.0)

Requirement already satisfied: attrs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (23.2.0)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2024.2.2)

Requirement already satisfied: click>=4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (8.1.7)

Requirement already satisfied: cligj>=0.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (0.7.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.25.2)

Requirement already satisfied: snuggs>=1.4.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.4.7)

Requirement already satisfied: click-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.1.1)

Requirement already satisfied: setuptools in c:\program files\windowsapps\pythonsoftwarefoundation.python.3.11\_3.11.22.88.0\_x64\_\_qbz5n2kfra8p0\lib\site-packages (from rasterio) (65.5.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from click>=4.0->rasterio) (0.4.6)

Requirement already satisfied: pyparsing>=2.1.6 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from snuggs>=1.4.1->rasterio) (3.1.2)

In [ ]: !pip install store

Requirement already satisfied: store in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2020.2.10)

Requirement already satisfied: pony in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from store) (0.7.17)

In [ ]: !pip install netCDF4  
!pip install jupyter\_bokeh  
!pip install h5py  
!pip install h5netcdf  
!pip install jupyterlab  
!pip install seaborn  
!pip install dask  
!pip install ray-default

Requirement already satisfied: netCDF4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)

Requirement already satisfied: cftime in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.6.3)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (2024.2.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.25.2)

Requirement already satisfied: jupyter\_bokeh in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (4.0.1)

Requirement already satisfied: bokeh==3.\* in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3. 11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter\_bokeh) (3.3.4)

Requirement already satisfied: ipywidgets==8.\* in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter\_bokeh) (8.1.2)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (1.2.0)

Requirement already satisfied: numpy>=1.16 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (1.25.2)

Requirement already satisfied: packaging>=16.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (24.0)

Requirement already satisfied: pandas>=1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (2.2.1)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (6.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati on.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh==3.\*->jupyter\_bokeh) (2023. 10.1)

Requirement already satisfied: comm>=0.1.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipywidgets==8.\*->jupyter\_bokeh) (0.2.2)

Requirement already satisfied: ipython>=6.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipywidgets==8.\*->jupyter\_bokeh) (8.22.2)

Requirement already satisfied: traitlets>=4.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipywidgets==8.\*->jupyter\_bokeh) (5.14. 2)

Requirement already satisfied: widgetsnbextension~4.0.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoun dation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipywidgets==8.\*->jupyter\_boke h) (4.0.10)

Requirement already satisfied: jupyterlab-widgets~3.0.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoun dation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipywidgets==8.\*->jupyter\_boke h) (3.0.10)

Requirement already satisfied: decorator in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1 1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyter\_boke h) (5.1.1)

Requirement already satisfied: jedi>=0.16 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3. 11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyter\_boke h) (0.19.1)

Requirement already satisfied: matplotlib-inline in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.py thon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyt er\_bokeh) (0.1.6)

Requirement already satisfied: prompt-toolkit<3.1.0,>=3.0.41 in c:\users\alons\_\appdata\local\packages\pythonsoftwaref oundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets ==8.\*->jupyter\_bokeh) (3.0.43)

Requirement already satisfied: pygments>=2.4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyter \_bokeh) (2.17.2)

Requirement already satisfied: stack-data in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3. 11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyter\_boke h) (0.6.3)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11 \_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython>=6.1.0->ipywidgets==8.\*->jupyter\_bokeh) (0.4.6)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh==3.\*->jupyter\_bokeh) (2.1.5)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati on.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->bokeh==3.\*->jupyter\_ bokeh) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->bokeh==3.\*->jupyter\_bokeh) (20

24.1)  
Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->bokeh==3.\*->jupyter\_bokeh)  
(2024.1)  
Requirement already satisfied: parso<0.9.0,>=0.8.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.  
python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jedi>=0.16->ipython>=6.1.0->ipywide  
ts==8.\*->jupyter\_bokeh) (0.8.3)  
Requirement already satisfied: wcwidth in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from prompt-toolkit<3.1.0,>=3.0.41->ipython>=6.1.0->i  
pywidgets==8.\*->jupyter\_bokeh) (0.2.13)  
Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=1.2->bokeh==3.\*  
->jupyter\_bokeh) (1.16.0)  
Requirement already satisfied: executing>=1.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt  
hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython>=6.1.0->ipywidgets=  
=8.\*->jupyter\_bokeh) (2.0.1)  
Requirement already satisfied: asttokens>=2.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt  
hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython>=6.1.0->ipywidgets=  
=8.\*->jupyter\_bokeh) (2.4.1)  
Requirement already satisfied: pure-eval in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython>=6.1.0->ipywidgets==8.\*->j  
upyter\_bokeh) (0.2.2)  
Requirement already satisfied: h5py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz  
5n2kfra8p0\localcache\local-packages\python311\site-packages (3.10.0)  
Requirement already satisfied: numpy>=1.17.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py) (1.25.2)  
Requirement already satisfied: h5netcdf in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.0)  
Requirement already satisfied: h5py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz  
5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (3.10.0)  
Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (24.0)  
Requirement already satisfied: numpy>=1.17.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py->h5netcdf) (1.25.2)  
Requirement already satisfied: jupyterlab in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (3.0.7)  
Requirement already satisfied: ipython in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (8.22.2)  
Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (24.0)  
Requirement already satisfied: tornado>=6.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (6.4)  
Requirement already satisfied: jupyter-core in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (5.7.2)  
Requirement already satisfied: jupyterlab-server~=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati  
on.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (2.25.4)  
Requirement already satisfied: jupyter-server~=1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.  
python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (1.24.0)  
Requirement already satisfied: nbclassic~=0.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (0.3.7)  
Requirement already satisfied: jinja2>=2.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab) (3.1.3)  
Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth  
on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jinja2>=2.10->jupyterlab) (2.1.5)  
Requirement already satisfied: anyio<4,>=3.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth  
on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (3.7.1)  
Requirement already satisfied: argon2-cffi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (23.1.0)  
Requirement already satisfied: jupyter-client>=6.1.12 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundati  
on.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab)  
(8.6.1)  
Requirement already satisfied: nbconvert>=6.4.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt  
hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (7.16.  
3)  
Requirement already satisfied: nbformat>=5.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyth  
on.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (5.10.  
3)  
Requirement already satisfied: prometheus-client in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.py  
thon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (0.2  
0.0)  
Requirement already satisfied: pyzmq>=17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (25.1.2)  
Requirement already satisfied: Send2Trash in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (1.8.2)  
Requirement already satisfied: terminado>=0.8.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt

hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (0.18.1)

Requirement already satisfied: traitlets>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (5.14.2)

Requirement already satisfied: websocket-client in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (1.7.0)

Requirement already satisfied: pywinpty in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-server~=1.2->jupyterlab) (2.0.13)

Requirement already satisfied: platformdirs>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-core->jupyterlab) (4.2.0)

Requirement already satisfied: pywin32>=300 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-core->jupyterlab) (306)

Requirement already satisfied: babel>=2.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab-server~=2.0->jupyterlab) (2.14.0)

Requirement already satisfied: json5>=0.9.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab-server~=2.0->jupyterlab) (0.9.24)

Requirement already satisfied: jsonschema>=4.18.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab-server~=2.0->jupyterlab) (4.21.1)

Requirement already satisfied: requests>=2.31 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyterlab-server~=2.0->jupyterlab) (2.31.0)

Requirement already satisfied: notebook<7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbclassic~=0.2->jupyterlab) (6.4.5)

Requirement already satisfied: notebook-shim>=0.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbclassic~=0.2->jupyterlab) (0.2.4)

Requirement already satisfied: decorator in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (5.1.1)

Requirement already satisfied: jedi>=0.16 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (0.19.1)

Requirement already satisfied: matplotlib-inline in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (0.1.6)

Requirement already satisfied: prompt-toolkit<3.1.0,>=3.0.41 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (3.0.43)

Requirement already satisfied: pygments>=2.4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (2.17.2)

Requirement already satisfied: stack-data in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (0.6.3)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipython->jupyterlab) (0.4.6)

Requirement already satisfied: idna>=2.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from anyio<4,>=3.1.0->jupyter-server~=1.2->jupyterlab) (3.6)

Requirement already satisfied: sniffio>=1.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from anyio<4,>=3.1.0->jupyter-server~=1.2->jupyterlab) (1.3.1)

Requirement already satisfied: parso<0.9.0,>=0.8.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jedi>=0.16->ipython->jupyterlab) (0.8.3)

Requirement already satisfied: attrs>=22.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jsonschema>=4.18.0->jupyterlab-server~=2.0->jupyterlab) (23.2.0)

Requirement already satisfied: jsonschema-specifications>=2023.03.6 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jsonschema>=4.18.0->jupyterlab-server~=2.0->jupyterlab) (2023.12.1)

Requirement already satisfied: referencing>=0.28.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jsonschema>=4.18.0->jupyterlab-server~=2.0->jupyterlab) (0.34.0)

Requirement already satisfied: rpds-py>=0.7.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jsonschema>=4.18.0->jupyterlab-server~=2.0->jupyterlab) (0.18.0)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jupyter-client>=6.1.12->jupyter-server~=1.2->jupyterlab) (2.9.0.post0)

Requirement already satisfied: beautifulsoup4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~=1.2->jupyterlab) (4.12.3)

Requirement already satisfied: bleach!=5.0.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~=1.2->jupyterlab) (6.1.0)

Requirement already satisfied: defusedxml in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (0.7.1)

Requirement already satisfied: jupyterlab-pygments in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (0.3.0)

Requirement already satisfied: mistune<4,>=2.0.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (3.0.2)

Requirement already satisfied: nbclient>=0.5.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (0.10.0)

Requirement already satisfied: pandocfilters>=1.4.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (1.5.1)

Requirement already satisfied: tinycss2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (1.2.1)

Requirement already satisfied: fastjsonschema in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from nbformat>=5.2.0->jupyter-server~1.2->jupyterlab) (2.19.1)

Requirement already satisfied: ipython-genutils in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from notebook<7->nbclassic~0.2->jupyterlab) (0.2.0)

Requirement already satisfied: ipykernel in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from notebook<7->nbclassic~0.2->jupyterlab) (6.29.3)

Requirement already satisfied: wcwidth in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from prompt-toolkit<3.1.0,>=3.0.41->ipython->jupyterlab) (0.2.13)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.31->jupyterlab-server~2.0->jupyterlab) (3.3.2)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.31->jupyterlab-server~2.0->jupyterlab) (2.0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests>=2.31->jupyterlab-server~2.0->jupyterlab) (2024.2.2)

Requirement already satisfied: argon2-cffi-bindings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from argon2-cffi->jupyter-server~1.2->jupyterlab) (21.2.0)

Requirement already satisfied: executing>=1.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython->jupyterlab) (2.0.1)

Requirement already satisfied: asttokens>=2.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython->jupyterlab) (2.4.1)

Requirement already satisfied: pure-eval in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from stack-data->ipython->jupyterlab) (0.2.2)

Requirement already satisfied: six>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from asttokens>=2.1.0->stack-data->ipython->jupyterlab) (1.16.0)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach!=5.0.0->nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (0.5.1)

Requirement already satisfied: cffi>=1.0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from argon2-cffi-bindings->argon2-cffi->jupyter-server~1.2->jupyterlab) (1.16.0)

Requirement already satisfied: soupsieve>1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from beautifulsoup4->nbconvert>=6.4.4->jupyter-server~1.2->jupyterlab) (2.5)

Requirement already satisfied: comm>=0.1.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipykernel->notebook<7->nbclassic~0.2->jupyterlab) (0.2.2)

Requirement already satisfied: debugpy>=1.6.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipykernel->notebook<7->nbclassic~0.2->jupyterlab) (1.8.1)

Requirement already satisfied: nest-asyncio in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipykernel->notebook<7->nbclassic~0.2->jupyterlab) (1.4.3)

Requirement already satisfied: psutil in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ipykernel->notebook<7->nbclassic~0.2->jupyterlab) (5.9.8)

Requirement already satisfied: pycparser in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cffi>=1.0.1->argon2-cffi-bindings->argon2-cffi->jupyter-server~1.2->jupyterlab) (2.22)

```

1_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cffi>=1.0.1->argon2-cffi-bindings->argon2-cffi
->jupyter-server~=1.2->jupyterlab) (2.21)
Requirement already satisfied: seaborn in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.13.2)
Requirement already satisfied: numpy!=1.24.0,>=1.20 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundatio
n.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from seaborn) (1.25.2)
Requirement already satisfied: pandas>=1.2 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.
3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from seaborn) (2.2.1)
Requirement already satisfied: matplotlib!=3.6.1,>=3.4 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundat
ion.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from seaborn) (3.8.3)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyt
hon.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (1.2.
0)
Requirement already satisfied: cycler>=0.10 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.
3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.py
thon.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (4.5
0.0)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyt
hon.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (1.
4.5)
Requirement already satisfied: packaging>=20.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyth
on.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (24.0)
Requirement already satisfied: pillow>=8 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.1
1_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (10.2.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyt
hon.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (3.1.
2)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundatio
n.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.
3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->seaborn) (2024.1)
Requirement already satisfied: tzdata>=2022.7 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pytho
n.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->seaborn) (2024.1)
Requirement already satisfied: six>=1.5 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11
_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.7->matplotlib!=3.6.1,>=3.4->
seaborn) (1.16.0)
Requirement already satisfied: dask in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz
5n2kfra8p0\localcache\local-packages\python311\site-packages (2024.3.1)
Requirement already satisfied: click>=8.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.
11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (8.1.7)
Requirement already satisfied: cloudpickle>=1.5.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.p
ython.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (3.0.0)
Requirement already satisfied: fsspec>=2021.09.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyt
hon.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (2024.3.1)
Requirement already satisfied: packaging>=20.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pyth
on.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (24.0)
Requirement already satisfied: partd>=1.2.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.
3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (1.4.1)
Requirement already satisfied: pyyaml>=5.3.1 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pytho
n.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (6.0.1)
Requirement already satisfied: toolz>=0.10.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.pytho
n.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (0.12.1)
Requirement already satisfied: importlib-metadata>=4.13.0 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoun
dation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from dask) (7.1.0)
Requirement already satisfied: colorama in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11
_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from click>=8.1->dask) (0.4.6)
Requirement already satisfied: zipp>=0.5 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.1
1_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from importlib-metadata>=4.13.0->dask) (3.18.1)
Requirement already satisfied: locket in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_q
bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from partd>=1.2.0->dask) (1.0.0)
ERROR: Could not find a version that satisfies the requirement ray-default (from versions: none)
ERROR: No matching distribution found for ray-default

```

```
In [ ]: # Packages used
```

```

!pip install scipy
!pip install rasterio
!pip install store
!pip install netCDF4
!pip install spectral
!pip install rioxarray
!pip install merge
!pip install scikit-image

```

```
!pip install s3fs
!pip install fsspec
!pip install geopandas

import netCDF4 as nc
import os
from spectral.io import envi
#from osgeo import gdal
import numpy as np
import math
from skimage import io
import pandas as pd
import geopandas as gpd
import xarray as xr
import rasterio as rio
import rioarray as rxr
import s3fs
from rioarray.merge import merge_arrays
from fsspec.implementations.http import HTTPFile
```



Requirement already satisfied: scipy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (1.9.3)

Requirement already satisfied: numpy<1.26.0, >=1.18.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundatio  
n.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scipy) (1.25.2)

Requirement already satisfied: rasterio in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.9)

Requirement already satisfied: affine in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_q  
bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2.4.0)

Requirement already satisfied: attrs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (23.2.0)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (2024.2.2)

Requirement already satisfied: click>=4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (8.1.7)

Requirement already satisfied: cligj>=0.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (0.7.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.25.2)

Requirement already satisfied: snuggs>=1.4.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.4.7)

Requirement already satisfied: click-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rasterio) (1.1.1)

Requirement already satisfied: setuptools in c:\program files\windowsapps\pythonsoftwarefoundation.python.3.11\_3.11.22  
88.0\_x64\_\_qbz5n2kfra8p0\lib\site-packages (from rasterio) (65.5.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from click>=4.0->rasterio) (0.4.6)

Requirement already satisfied: pyparsing>=2.1.6 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt  
hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from snuggs>=1.4.1->rasterio) (3.1.2)

Requirement already satisfied: store in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (2020.2.10)

Requirement already satisfied: pony in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz  
5n2kfra8p0\localcache\local-packages\python311\site-packages (from store) (0.7.17)

Requirement already satisfied: netCDF4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)

Requirement already satisfied: cftime in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_q  
bz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.6.3)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_  
qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (2024.2.2)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.25.2)

Requirement already satisfied: spectral in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.23.1)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qb  
z5n2kfra8p0\localcache\local-packages\python311\site-packages (from spectral) (1.25.2)

Requirement already satisfied: rioarray in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.15.1)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.1  
1\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (24.0)

Requirement already satisfied: rasterio>=1.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rioarray) (1.3.9)

Requirement already satisfied: xarray>=2022.3.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt  
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Requirement already satisfied: click>=4.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
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Requirement already satisfied: scikit-image in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python. 3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.22.0)

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Requirement already satisfied: s3fs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz 5n2kfra8p0\localcache\local-packages\python311\site-packages (2024.3.1)

Requirement already satisfied: aiobotocore<3.0.0,>=2.5.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefound ation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (2.12.1)

Requirement already satisfied: fsspec==2024.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pyt hon.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (2024.3.1)

Requirement already satisfied: aiohttp!=4.0.0a0,!4.0.0a1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoun dation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from s3fs) (3.9.3)

Requirement already satisfied: botocore<1.34.52,>=1.34.41 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoun dation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from aiobotocore<3.0.0,>=2.5.4->s3 fs) (1.34.51)

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```

```

In [ ]: !pip install netcdf4
        !pip install store

```

```

Requirement already satisfied: netcdf4 in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)
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Requirement already satisfied: numpy in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netcdf4) (1.25.2)
Requirement already satisfied: store in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2020.2.10)
Requirement already satisfied: pony in c:\users\alons_\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from store) (0.7.17)

```

```

In [ ]: """
        This Module has the functions related to working with an EMIT dataset. This includes doing things
        like opening and flattening the data to work in xarray, orthorectification, and extracting point and area samples.

        Author: Erik Bolch, ebolch@contractor.usgs.gov

        Last Updated: 11/03/2023

        TO DO:
        - Add units to metadata for ENVI header
        - Investigate reducing memory usage
        - Improve conditionals to evaluate which EMIT product is being used/what to use for band dimension indexing
        - Test/Improve flexibility for applying the GLT to modified/clipped datasets
        - Improve envi conversion function
        """

```

```

def emit_xarray(filepath, ortho=False, qmask=None, unpacked_bmask=None):
    """
    This function utilizes other functions in this module to streamline opening an EMIT dataset as an xarray.Dataset.

    Parameters:
    filepath: a filepath to an EMIT netCDF file
    ortho: True or False, whether to orthorectify the dataset or leave in crosstrack/downtrack coordinates.
    qmask: a numpy array output from the quality_mask function used to mask pixels based on quality flags selected in
    unpacked_bmask: a numpy array from the band_mask function that can be used to mask band-specific pixels that hav

    Returns:
    out_xr: an xarray.Dataset constructed based on the parameters provided.

    """
    # Grab granule filename to check product

    if type(filepath) == s3fs.core.S3File:
        granule_id = filepath.info()["name"].split("/", -1)[-1].split(".", -1)[0]
    elif type(filepath) == HTTPFile:
        granule_id = filepath.path.split("/", -1)[-1].split(".", -1)[0]
    else:
        granule_id = os.path.splitext(os.path.basename(filepath))[0]

    # Read in Data as Xarray Datasetsh5netcdf
    engine, wvl_group = "h5netcdf", None

    ds = xr.open_dataset(filepath, engine=engine)
    loc = xr.open_dataset(filepath, engine=engine, group="location")

    # Check if mineral dataset and read in groups (only ds/Loc for minunc)

    if "L2B_MIN" in granule_id:
        wvl_group = "mineral_metadata"
    elif "L2B_MINUNC" not in granule_id:
        wvl_group = "sensor_band_parameters"

    wvl = None

    if wvl_group:
        wvl = xr.open_dataset(filepath, engine=engine, group=wvl_group)

    # Building Flat Dataset from Components
    data_vars = {**ds.variables}

    # Format xarray coordinates based upon emit product (no wvl for mineral uncertainty)
    coords = {
        "downtrack": ([ "downtrack"], ds.downtrack.data),
        "crosstrack": ([ "crosstrack"], ds.crosstrack.data),
        **loc.variables,
    }

    product_band_map = {
        "L2B_MIN": "name",
        "L2A_MASK": "mask_bands",
        "L1B_OBS": "observation_bands",
        "L2A_RFL": "wavelengths",
        "L1B_RAD": "wavelengths",
        "L2A_RFLUNCERT": "wavelengths",
    }

    # if band := product_band_map.get(next((k for k in product_band_map.keys() if k in granule_id), 'unknown'), None)
    # coords['bands'] = wvl[band].data

    if wvl:
        coords = {**coords, **wvl.variables}

    out_xr = xr.Dataset(data_vars=data_vars, coords=coords, attrs=ds.attrs)
    out_xr.attrs["granule_id"] = granule_id

    if band := product_band_map.get(
        next((k for k in product_band_map.keys() if k in granule_id), "unknown"), None

```

```

):
    if "minerals" in list(out_xr.dims):
        out_xr = out_xr.swap_dims({"minerals": band})
        out_xr = out_xr.rename({band: "mineral_name"})
    else:
        out_xr = out_xr.swap_dims({"bands": band})

# Apply Quality and Band Masks, set fill values to NaN
for var in list(ds.data_vars):
    if qmask is not None:
        out_xr[var].data[qmask == 1] = np.nan
    if unpacked_bmask is not None:
        out_xr[var].data[unpacked_bmask == 1] = np.nan
    out_xr[var].data[out_xr[var].data == -9999] = np.nan

if ortho is True:
    out_xr = ortho_xr(out_xr)
    out_xr.attrs["Orthorectified"] = "True"

return out_xr

# Function to Calculate the Lat and Lon Vectors/Coordinate Grid
def coord_vects(ds):
    """
    This function calculates the Lat and Lon Coordinate Vectors using the GLT and Metadata from an EMIT dataset read

    Parameters:
    ds: an xarray.Dataset containing the root variable and metadata of an EMIT dataset
    loc: an xarray.Dataset containing the 'location' group of an EMIT dataset

    Returns:
    lon, lat (numpy.array): longitude and latitude array grid for the dataset

    """
    # Retrieve Geotransform from Metadata
    GT = ds.geotransform
    # Create Array for Lat and Lon and fill
    dim_x = ds.glt_x.shape[1]
    dim_y = ds.glt_x.shape[0]
    lon = np.zeros(dim_x)
    lat = np.zeros(dim_y)
    # Note: no rotation for EMIT Data
    for x in np.arange(dim_x):
        x_geo = (GT[0] + 0.5 * GT[1]) + x * GT[1] # Adjust coordinates to pixel-center
        lon[x] = x_geo
    for y in np.arange(dim_y):
        y_geo = (GT[3] + 0.5 * GT[5]) + y * GT[5]
        lat[y] = y_geo
    return lon, lat

# Function to Apply the GLT to an array
def apply_glt(ds_array, glt_array, fill_value=-9999, GLT_NODATA_VALUE=0):
    """
    This function applies the GLT array to a numpy array of either 2 or 3 dimensions.

    Parameters:
    ds_array: numpy array of the desired variable
    glt_array: a GLT array constructed from EMIT GLT data

    Returns:
    out_ds: a numpy array of orthorectified data.
    """

    # Build Output Dataset
    if ds_array.ndim == 2:
        ds_array = ds_array[:, :, np.newaxis]
    out_ds = np.full(
        (glt_array.shape[0], glt_array.shape[1], ds_array.shape[-1]),
        fill_value,
        dtype=np.float32,
    )
    valid_glt = np.all(glt_array != GLT_NODATA_VALUE, axis=-1)

```

```

# Adjust for One based Index - make a copy to prevent decrementing multiple times inside ortho_xr when applying t
glt_array_copy = glt_array.copy()
glt_array_copy[valid_glt] -= 1
out_ds[valid_glt, :] = ds_array[
    glt_array_copy[valid_glt, 1], glt_array_copy[valid_glt, 0], :
]
return out_ds

def ortho_xr(ds, GLT_NODATA_VALUE=0, fill_value=-9999):
    """
    This function uses `apply_glt` to create an orthorectified xarray dataset.

    Parameters:
    ds: an xarray dataset produced by emit_xarray
    GLT_NODATA_VALUE: no data value for the GLT tables, 0 by default
    fill_value: the fill value for EMIT datasets, -9999 by default

    Returns:
    ortho_ds: an orthorectified xarray dataset.

    """
    # Build glt_ds
    glt_ds = np.nan_to_num(
        np.stack([ds["glt_x"].data, ds["glt_y"].data], axis=-1), nan=GLT_NODATA_VALUE
    ).astype(int)

    # List Variables
    var_list = list(ds.data_vars)

    # Remove flat field from data vars - the flat field is only useful with additional information before orthorectif
    if "flat_field_update" in var_list:
        var_list.remove("flat_field_update")

    # Create empty dictionary for orthorectified data vars
    data_vars = {}

    # Extract Rawspace Dataset Variable Values (Typically Reflectance)
    for var in var_list:
        raw_ds = ds[var].data
        var_dims = ds[var].dims
        # Apply GLT to dataset
        out_ds = apply_glt(raw_ds, glt_ds, GLT_NODATA_VALUE=GLT_NODATA_VALUE)

        # Mask fill values
        out_ds[out_ds == fill_value] = np.nan

        # Update variables - Only works for 2 or 3 dimensional arrays
        if raw_ds.ndim == 2:
            out_ds = out_ds.squeeze()
            data_vars[var] = (["latitude", "longitude"], out_ds)
        else:
            data_vars[var] = (["latitude", "longitude", var_dims[-1]], out_ds)

    del raw_ds

    # Calculate Lat and Lon Vectors
    lon, lat = coord_vects(
        ds
    ) # Reorder this function to make sense in case of multiple variables

    # Apply GLT to elevation
    elev_ds = apply_glt(ds["elev"].data, glt_ds)
    elev_ds[elev_ds == fill_value] = np.nan

    # Delete glt_ds - no longer needed
    del glt_ds

    # Create Coordinate Dictionary
    coords = {
        "latitude": (["latitude"], lat),
        "longitude": (["longitude"], lon),
        **ds.coords,
    } # unpack to add appropriate coordinates

```

```

# Remove Unnecessary Coords
for key in ["downtrack", "crosstrack", "lat", "lon", "glt_x", "glt_y", "elev"]:
    del coords[key]

# Add Orthorectified Elevation
coords["elev"] = ([ "latitude", "longitude"], np.squeeze(elev_ds))

# Build Output xarray Dataset and assign data_vars array attributes
out_xr = xr.Dataset(data_vars=data_vars, coords=coords, attrs=ds.attrs)

del out_ds
# Assign Attributes from Original Datasets
for var in var_list:
    out_xr[var].attrs = ds[var].attrs
out_xr.coords["latitude"].attrs = ds["lat"].attrs
out_xr.coords["longitude"].attrs = ds["lon"].attrs
out_xr.coords["elev"].attrs = ds["elev"].attrs

# Add Spatial Reference in recognizable format
out_xr.rio.write_crs(ds.spatial_ref, inplace=True)

return out_xr

def quality_mask(filepath, quality_bands):
    """
    This function builds a single layer mask to apply based on the bands selected from an EMIT L2A Mask file.

    Parameters:
    filepath: an EMIT L2A Mask netCDF file.
    quality_bands: a list of bands (quality flags only) from the mask file that should be used in creation of mask.

    Returns:
    qmask: a numpy array that can be used with the emit_xarray function to apply a quality mask.
    """
    # Open Dataset
    mask_ds = xr.open_dataset(filepath, engine="h5netcdf")
    # Open Sensor band Group
    mask_parameters_ds = xr.open_dataset(
        filepath, engine="h5netcdf", group="sensor_band_parameters"
    )
    # Print Flags used
    flags_used = mask_parameters_ds["mask_bands"].data[quality_bands]
    print(f"Flags used: {flags_used}")
    # Check for data bands and build mask
    if any(x in quality_bands for x in [5, 6]):
        err_str = f"Selected flags include a data band (5 or 6) not just flag bands"
        raise AttributeError(err_str)
    else:
        qmask = np.sum(mask_ds["mask"][ :, :, quality_bands].values, axis=-1)
        qmask[qmask > 1] = 1
    return qmask

def band_mask(filepath):
    """
    This function unpacks the packed band mask to apply to the dataset. Can be used manually or as an input in the emit_xarray function.

    Parameters:
    filepath: an EMIT L2A Mask netCDF file.
    packed_bands: the 'packed_bands' dataset from the EMIT L2A Mask file.

    Returns:
    band_mask: a numpy array that can be used with the emit_xarray function to apply a band mask.
    """
    # Open Dataset
    mask_ds = xr.open_dataset(filepath, engine="h5netcdf")
    # Open band_mask and convert to uint8
    bmask = mask_ds.band_mask.data.astype("uint8")
    # Print Flags used
    unpacked_bmask = np.unpackbits(bmask, axis=-1)
    # Remove bands > 285
    unpacked_bmask = unpacked_bmask[ :, :, 0:285]
    # Check for data bands and build mask

```

```

return unpacked_bmask

def write_envi(
    xr_ds,
    output_dir,
    overwrite=False,
    extension=".img",
    interleave="BIL",
    glt_file=False,
):
    """
    This function takes an EMIT dataset read into an xarray dataset using the emit_xarray function and then writes an

    Parameters:
    xr_ds: an EMIT dataset read into xarray using the emit_xarray function.
    output_dir: output directory
    overwrite: overwrite existing file if True
    extension: the file extension for the envi formatted file, .img by default.
    glt_file: also create a GLT ENVI file for later use to reproject

    Returns:
    envi_ds: file in the output directory
    glt_ds: file in the output directory

    """
    # Check if xr_ds has been orthorectified, raise exception if it has been but GLT is still requested
    if (
        "Orthorectified" in xr_ds.attrs.keys()
        and xr_ds.attrs["Orthorectified"] == "True"
        and glt_file == True
    ):
        raise Exception("Data is already orthorectified.")

    # Typemap dictionary for ENVI files
    envi_typemap = {
        "uint8": 1,
        "int16": 2,
        "int32": 3,
        "float32": 4,
        "float64": 5,
        "complex64": 6,
        "complex128": 9,
        "uint16": 12,
        "uint32": 13,
        "int64": 14,
        "uint64": 15,
    }

    # Get CRS/geotransform for creation of Orthorectified ENVI file or optional GLT file
    gt = xr_ds.attrs["geotransform"]
    mapinfo = (
        "{Geographic Lat/Lon, 1, 1, "
        + str(gt[0])
        + ", "
        + str(gt[3])
        + ", "
        + str(gt[1])
        + ", "
        + str(gt[5] * -1)
        + ", WGS-84, units=Degrees}"
    )

    # This creates the coordinate system string
    # hard-coded replacement of wkt crs could probably be improved, though should be the same for all EMIT datasets
    csstring = '{ GEOGCS["WGS 84", DATUM["WGS_1984", SPHEROID["WGS 84", 6378137, 298.257223563, AUTHORITY["EPSG", "7030"]]',
    # List data variables (typically reflectance/radiance)
    var_names = list(xr_ds.data_vars)

    # Loop through variable names
    for var in var_names:
        # Define output filename
        output_name = os.path.join(output_dir, xr_ds.attrs["granule_id"] + "_" + var)

        nbands = 1

```



```

if len(xr_ds[var].data.shape) > 2:
    nbands = xr_ds[var].data.shape[2]

# Start building metadata
metadata = {
    "lines": xr_ds[var].data.shape[0],
    "samples": xr_ds[var].data.shape[1],
    "bands": nbands,
    "interleave": interleave,
    "header offset": 0,
    "file type": "ENVI Standard",
    "data type": envi_ttypemap[str(xr_ds[var].data.dtype)],
    "byte order": 0,
}

for key in list(xr_ds.attrs.keys()):
    if key == "summary":
        metadata["description"] = xr_ds.attrs[key]
    elif key not in ["geotransform", "spatial_ref"]:
        metadata[key] = f"{{ {xr_ds.attrs[key]} }}"

# List all variables in dataset (including coordinate variables)
meta_vars = list(xr_ds.variables)

# Add band parameter information to metadata (ie wavelengths/obs etc.)
for m in meta_vars:
    if m == "wavelengths" or m == "radiance_wl":
        metadata["wavelength"] = np.array(xr_ds[m].data).astype(str).tolist()
    elif m == "fwhm" or m == "radiance_fwhm":
        metadata["fwhm"] = np.array(xr_ds[m].data).astype(str).tolist()
    elif m == "good_wavelengths":
        metadata["good_wavelengths"] = (
            np.array(xr_ds[m].data).astype(int).tolist()
        )
    elif m == "observation_bands":
        metadata["band names"] = np.array(xr_ds[m].data).astype(str).tolist()
    elif m == "mask_bands":
        if var == "band_mask":
            metadata["band names"] = [
                "packed_bands_" + bn
                for bn in np.arange(285 / 8).astype(str).tolist()
            ]
        else:
            metadata["band names"] = (
                np.array(xr_ds[m].data).astype(str).tolist()
            )
    if "wavelength" in list(metadata.keys()) and "band names" not in list(
        metadata.keys()
    ):
        metadata["band names"] = metadata["wavelength"]

# Add CRS/mapinfo if xarray dataset has been orthorectified
if (
    "Orthorectified" in xr_ds.attrs.keys()
    and xr_ds.attrs["Orthorectified"] == "True"
):
    metadata["coordinate system string"] = csstring
    metadata["map info"] = mapinfo

# Replace NaN values in each layer with fill_value
# np.nan_to_num(xr_ds[var].data, copy=False, nan=-9999)

# Write Variables as ENVI Output
envi_ds = envi.create_image(
    envi_header(output_name), metadata, ext=extension, force=overwrite
)
mm = envi_ds.open_memmap(interleave="bip", writable=True)

dat = xr_ds[var].data

if len(dat.shape) == 2:
    dat = dat.reshape((dat.shape[0], dat.shape[1], 1))

mm[...] = dat

```

```

# Create GLT Metadata/File
if glt_file == True:
    # Output Name
    glt_output_name = os.path.join(
        output_dir, xr_ds.attrs["granule_id"] + "_" + "glt"
    )

    # Write GLT Metadata
    glt_metadata = metadata

    # Remove Unwanted Metadata
    glt_metadata.pop("wavelength", None)
    glt_metadata.pop("fwhm", None)

    # Replace Metadata
    glt_metadata["lines"] = xr_ds["glt_x"].data.shape[0]
    glt_metadata["samples"] = xr_ds["glt_x"].data.shape[1]
    glt_metadata["bands"] = 2
    glt_metadata["data type"] = envi_ttypemap["int32"]
    glt_metadata["band names"] = ["glt_x", "glt_y"]
    glt_metadata["coordinate system string"] = csstring
    glt_metadata["map info"] = mapinfo

    # Write GLT Outputs as ENVI File
    glt_ds = envi.create_image(
        envi_header(glt_output_name), glt_metadata, ext=extension, force=overwrite
    )
    mmglt = glt_ds.open_memmap(interleave="bip", writable=True)
    mmglt[...] = np.stack(
        (xr_ds["glt_x"].values, xr_ds["glt_y"].values), axis=-1
    ).astype("int32")

def envi_header(inputpath):
    """
    Convert a envi binary/header path to a header, handling extensions
    Args:
        inputpath: path to envi binary file
    Returns:
        str: the header file associated with the input reference.
    """
    if (
        os.path.splitext(inputpath)[-1] == ".img"
        or os.path.splitext(inputpath)[-1] == ".dat"
        or os.path.splitext(inputpath)[-1] == ".raw"
    ):
        # headers could be at either filename.img.hdr or filename.hdr. Check both, return the one that exists if it
        # does, if not return the latter (new file creation presumed).
        hdrfile = os.path.splitext(inputpath)[0] + ".hdr"
        if os.path.isfile(hdrfile):
            return hdrfile
        elif os.path.isfile(inputpath + ".hdr"):
            return inputpath + ".hdr"
        return hdrfile
    elif os.path.splitext(inputpath)[-1] == ".hdr":
        return inputpath
    else:
        return inputpath + ".hdr"

def raw_spatial_crop(ds, shape):
    """
    Use a polygon to clip the file GLT, then a bounding box to crop the spatially raw data. Regions clipped in the GLT
    used to orthorectify the data at a later point in a workflow.
    Args:
        ds: raw spatial EMIT data (non-orthorectified) opened with the `emit_xarray` function.
        shape: a polygon opened with geopandas.
    Returns:
        clipped_ds: a clipped GLT and raw spatial data clipped to a bounding box.
    """
    # Reformat the GLT
    lon, lat = coord_vects(ds)
    data_vars = {
        "glt_x": ([ "latitude", "longitude"], ds.glt_x.data),

```

```

    "glt_y": ([ "latitude", "longitude"], ds.glt_y.data),
}
coords = {
    "latitude": ([ "latitude"], lat),
    "longitude": ([ "longitude"], lon),
    "ortho_y": ([ "latitude"], ds.ortho_y.data),
    "ortho_x": ([ "longitude"], ds.ortho_x.data),
}
glt_ds = xr.Dataset(data_vars=data_vars, coords=coords, attrs=ds.attrs)
glt_ds.rio.write_crs(glt_ds.spatial_ref, inplace=True)

# Clip the emit glt
clipped = glt_ds.rio.clip(shape.geometry.values, shape.crs, all_touched=True)

# Pull new geotransform from clipped glt
clipped_gt = np.array(
    [float(i) for i in clipped["spatial_ref"].GeoTransform.split(" ")]
) # THIS GEOTRANSFORM IS OFF BY HALF A PIXEL

# Create Crosstrack and Downtrack masks for spatially raw dataset -1 is to account for 1 based index. May be a mo
crosstrack_mask = (ds.crosstrack >= np.nanmin(clipped.glt_x.data) - 1) & (
    ds.crosstrack <= np.nanmax(clipped.glt_x.data) - 1
)
downtrack_mask = (ds.downtrack >= np.nanmin(clipped.glt_y.data) - 1) & (
    ds.downtrack <= np.nanmax(clipped.glt_y.data) - 1
)

# Mask Areas outside of crosstrack and downtrack covered by the shape
clipped_ds = ds.where((crosstrack_mask & downtrack_mask), drop=True)
# Replace Full dataset geotransform with clipped geotransform
clipped_ds.attrs["geotransform"] = clipped_gt

# Drop unnecessary vars from dataset
clipped_ds = clipped_ds.drop_vars(["glt_x", "glt_y", "downtrack", "crosstrack"])

# Re-index the GLT to the new array
glt_x_data = clipped.glt_x.data - np.nanmin(clipped.glt_x)
glt_y_data = clipped.glt_y.data - np.nanmin(clipped.glt_y)
clipped_ds = clipped_ds.assign_coords(
    {
        "glt_x": ([ "ortho_y", "ortho_x"], np.nan_to_num(glt_x_data)),
        "glt_y": ([ "ortho_y", "ortho_x"], np.nan_to_num(glt_y_data)),
    }
)
clipped_ds = clipped_ds.assign_coords(
    {
        "downtrack": (
            ["downtrack"],
            np.arange(0, clipped_ds[list(ds.data_vars.keys())[0]].shape[0]),
        ),
        "crosstrack": (
            ["crosstrack"],
            np.arange(0, clipped_ds[list(ds.data_vars.keys())[0]].shape[1]),
        ),
    }
)

return clipped_ds

def is_adjacent(scene: str, same_orbit: list):
    """
    This function makes a list of scene numbers from the same orbit as integers and checks
    if they are adjacent/sequential.
    """
    scene_nums = [int(scene.split(".")[2].split("_")[-1]) for scene in same_orbit]
    return all(b - a == 1 for a, b in zip(scene_nums[:-1], scene_nums[1:]))

def merge_emit(datasets: dict, gdf: gpd.GeoDataFrame):
    """
    A function to merge xarray datasets formatted using emit_xarray. This could probably be improved,
    lots of shuffling data around to keep in xarray and get it to merge properly. Note: GDF may only work with a
    single geometry.
    """

```

```

nested_data_arrays = {}
# Loop over datasets
for dataset in datasets:
    # create dictionary of arrays for each dataset

    # create dictionary of 1D variables, which should be consistent across datasets
    one_d_arrays = {}

    # Dictionary of variables to merge
    data_arrays = {}
    # Loop over variables in dataset including elevation
    for var in list(datasets[dataset].data_vars) + ["elev"]:
        # Get 1D for this variable and add to dictionary
        if not one_d_arrays:
            # These should be an array describing the others (wavelengths, mask_bands, etc.)
            one_dim = [
                item
                for item in list(datasets[dataset].coords)
                if item not in ["latitude", "longitude", "spatial_ref"]
                and len(datasets[dataset][item].dims) == 1
            ]
            # print(one_dim)
            for od in one_dim:
                one_d_arrays[od] = datasets[dataset].coords[od].data

            # Update format for merging - This could probably be improved
            da = datasets[dataset][var].reset_coords("elev", drop=False)
            da = da.rename({"latitude": "y", "longitude": "x"})
            if len(da.dims) == 3:
                if any(item in list(da.coords) for item in one_dim):
                    da = da.drop_vars(one_dim)
                da = da.drop_vars("elev")
                da = da.to_array(name=var).squeeze("variable", drop=True)
                da = da.transpose(da.dims[-1], da.dims[0], da.dims[1])
                # print(da.dims)
            if var == "elev":
                da = da.to_array(name=var).squeeze("variable", drop=True)
            data_arrays[var] = da
            nested_data_arrays[dataset] = data_arrays

    # Transpose the nested arrays dict. This is horrible to read, but works to pair up variables (ie mask) fr
    transposed_dict = {
        inner_key: {
            outer_key: inner_dict[inner_key]
            for outer_key, inner_dict in nested_data_arrays.items()
        }
        for inner_key in nested_data_arrays[next(iter(nested_data_arrays))]
    }

    # remove some unused data
    del nested_data_arrays, data_arrays, da

    # Merge the arrays using rioxarray.merge_arrays()
    merged = {}
    for _var in transposed_dict:
        merged[_var] = merge_arrays(
            list(transposed_dict[_var].values()),
            bounds=gdf.unary_union.bounds,
            nodata=np.nan,
        )

    # Create a new xarray dataset from the merged arrays
    # Create Merged Dataset
    merged_ds = xr.Dataset(data_vars=merged, coords=one_d_arrays)
    # Rename x and y to Longitude and Latitude
    merged_ds = merged_ds.rename({"y": "latitude", "x": "longitude"})
    del transposed_dict, merged
    return merged_ds

def ortho_browse(url, glt, spatial_ref, geotransform, white_background=True):
    """
    Use an EMIT GLT, geotransform, and spatial ref to orthorectify a browse image. (browse images are in native resol
    """
    # Read Data

```

```

data = io.imread(url)
# Orthorectify using GLT and transpose so band is first dimension
if white_background == True:
    fill = 255
else:
    fill = 0
ortho_data = apply_glt(data, glt, fill_value=fill).transpose(2, 0, 1)
coords = {
    "y": (
        ["y"],
        (geotransform[3] + 0.5 * geotransform[5])
        + np.arange(glt.shape[0]) * geotransform[5],
    ),
    "x": (
        ["x"],
        (geotransform[0] + 0.5 * geotransform[1])
        + np.arange(glt.shape[1]) * geotransform[1],
    ),
}
ortho_data = ortho_data.astype(int)
ortho_data[ortho_data == -1] = 0
# Place in xarray.Dataset
da = xr.DataArray(ortho_data, dims=["band", "y", "x"], coords=coords)
da.rio.write_crs(spatial_ref, inplace=True)
return da

```

Import the `emit_tools` module and call use the help function to see how it can be used.

Note: This function currently works with L1B Radiance and L2A Reflectance Data.

```

In [ ]: #import sys
        #sys.path.append('../modules/')
        #from emit_tools import emit_xarray
        help(emit_xarray)

```

Help on function emit\_xarray in module \_\_main\_\_:

emit\_xarray(filepath, ortho=False, qmask=None, unpacked\_bmask=None)

This function utilizes other functions in this module to streamline opening an EMIT dataset as an xarray.Dataset.

Parameters:

filepath: a filepath to an EMIT netCDF file

ortho: True or False, whether to orthorectify the dataset or leave in crosstrack/downtrack coordinates.

qmask: a numpy array output from the quality\_mask function used to mask pixels based on quality flags selected in that function. Any non-orthorectified array with the proper crosstrack and downtrack dimensions can also be used.

unpacked\_bmask: a numpy array from the band\_mask function that can be used to mask band-specific pixels that have been interpolated.

Returns:

out\_xr: an xarray.Dataset constructed based on the parameters provided.

```

In [ ]: !pip install netCDF4
        !pip install store
        !pip install h5netcdf

```

Requirement already satisfied: netCDF4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)  
 Requirement already satisfied: cftime in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.6.3)  
 Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (2024.2.2)  
 Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.25.2)  
 Requirement already satisfied: store in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2020.2.10)  
 Requirement already satisfied: pony in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from store) (0.7.17)  
 Requirement already satisfied: h5netcdf in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.0)  
 Requirement already satisfied: h5py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (3.10.0)  
 Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (24.0)  
 Requirement already satisfied: numpy>=1.17.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py->h5netcdf) (1.25.2)

We can see that the `emit_xarray` function will automatically apply the GLT to orthorectify the data unless `ortho = False`. The function will also apply masks if desired during construction of the output `xarray.Dataset`. EMIT L2A Masks files provides a quality mask and a band\_mask indicating if values were interpolated. For more about masking, see the [How\\_to\\_use\\_EMIT\\_Quality\\_data.ipynb](#).

Use the `emit_xarray` function to read in and orthorectify the L2A reflectance data.

**For a detailed walkthrough of the orthorectification process using the GLT see section 2 of the [How\\_to\\_Orthorectify.ipynb](#) in the how-tos folder.**















```
In [ ]: !pip install netCDF4
        !pip install store
        !pip install h5netcdf
        ds_geo = emit_xarray(fp, ortho=True)
        ds_geo
```

Requirement already satisfied: netCDF4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.6.5)  
 Requirement already satisfied: cftime in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.6.3)  
 Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (2024.2.2)  
 Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from netCDF4) (1.25.2)  
 Requirement already satisfied: store in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (2020.2.10)  
 Requirement already satisfied: pony in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from store) (0.7.17)  
 Requirement already satisfied: h5netcdf in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.3.0)  
 Requirement already satisfied: h5py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (3.10.0)  
 Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5netcdf) (24.0)  
 Requirement already satisfied: numpy>=1.17.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from h5py->h5netcdf) (1.25.2)



Out [ ]: xarray.Dataset

► Dimensions: (latitude: 1886, longitude: 2035, wavelengths: 285)

▼ Coordinates:

<b>wavelengths</b>	(wavelengths)	float32	381.0 388.4 ... 2.486e+03 2.493e+03		
fwhm	(wavelengths)	float32	...		
good_wavelength...	(wavelengths)	float32	...		
<b>latitude</b>	(latitude)	float64	20.4 20.4 20.4 ... 19.38 19.38		
<b>longitude</b>	(longitude)	float64	-156.4 -156.4 ... -155.3 -155.3		
elev	(latitude, longitude)	float32	nan nan nan nan ... nan nan nan nan		
spatial_ref	()	int32	0		

▼ Data variables:

<b>reflectance</b>	(latitude, longitude, wavelengths)	float32	nan nan nan nan ... nan nan nan nan		
--------------------	------------------------------------	---------	-------------------------------------	---	---

► Indexes: (3)

► Attributes: (40)

```
In [ ]: refl850 = ds.sel(wavelengths=850, method='nearest')
non_ortho_fig = ds.sel(wavelengths=850, method='nearest').hvplot.image(cmap='Viridis', aspect = 'equal', frame_height=
title=f"Reflectance at {refl850.wavelengths.values:.3f} {refl850.wavelengths.units}")
```

```
In [ ]: !pip install ENVI
```

Requirement already satisfied: ENVI in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.2.2)

```
In [ ]: !pip install cartopy
```

Requirement already satisfied: cartopy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.22.0)  
Requirement already satisfied: numpy>=1.21 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (1.25.2)  
Requirement already satisfied: matplotlib>=3.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (3.8.3)  
Requirement already satisfied: shapely>=1.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (2.0.3)  
Requirement already satisfied: packaging>=20 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (24.0)  
Requirement already satisfied: pyshp>=2.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (2.3.1)  
Requirement already satisfied: pyproj>=3.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy) (3.6.1)  
Requirement already satisfied: contourpy>=1.0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (1.2.0)  
Requirement already satisfied: cycler>=0.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (0.12.1)  
Requirement already satisfied: fonttools>=4.22.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (4.50.0)  
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (1.4.5)  
Requirement already satisfied: pillow>=8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (10.2.0)  
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (3.1.2)  
Requirement already satisfied: python-dateutil>=2.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy) (2.9.0.post0)  
Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pyproj>=3.1.0->cartopy) (2024.2.2)  
Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.7->matplotlib>=3.4->cartopy) (1.16.0)

```
In [ ]: !pip install geoviews
```

Requirement already satisfied: geoviews in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.11.1)

Requirement already satisfied: bokeh<3.4.0,>=3.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (3.3.4)

Requirement already satisfied: cartopy>=0.18.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (0.22.0)

Requirement already satisfied: holoviews>=1.16.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (1.18.3)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (24.0)

Requirement already satisfied: numpy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (1.25.2)

Requirement already satisfied: shapely in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (2.0.3)

Requirement already satisfied: param in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (2.1.0)

Requirement already satisfied: panel>=1.0.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (1.3.8)

Requirement already satisfied: pyproj in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (3.6.1)

Requirement already satisfied: xyzservices in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from geoviews) (2023.10.1)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (1.2.0)

Requirement already satisfied: pandas>=1.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (2.2.1)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->geoviews) (6.4)

Requirement already satisfied: matplotlib>=3.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy>=0.18.0->geoviews) (3.8.3)

Requirement already satisfied: pyshp>=2.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from cartopy>=0.18.0->geoviews) (2.3.1)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews>=1.16.0->geoviews) (3.0.2)

Requirement already satisfied: colorcet in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews>=1.16.0->geoviews) (3.1.0)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (2.0.3)

Requirement already satisfied: mdit-py-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (0.4.0)

Requirement already satisfied: requests in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (2.31.0)

Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0.0->geoviews) (4.10.0)

Requirement already satisfied: certifi in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pyproj->geoviews) (2024.2.2)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh<3.4.0,>=3.2.0->geoviews) (2.1.5)

Requirement already satisfied: cyclicalr>=0.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy>=0.18.0->geoviews) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy>=0.18.0->geoviews) (4.50.0)

Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy>=0.18.0->geoviews) (1.4.5)

Requirement already satisfied: pyparsing>=2.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy>=0.18.0->geoviews) (3.1.2)



Requirement already satisfied: python-dateutil>=2.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundatio  
n.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib>=3.4->cartopy>=0.18.0->  
geoviews) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->bokeh<3.4.0,>=3.2.0->geoviews)  
(2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.pytho  
n.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=1.2->bokeh<3.4.0,>=3.2.0->geoview  
s) (2024.1)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11  
\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=1.0.0->geoviews) (0.4.6)

Requirement already satisfied: six>=1.9.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=1.0.0->geoviews) (1.16.0)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=1.0.0->geoviews) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=1.0.0->geoviews) (1.  
0.3)

Requirement already satisfied: mdurl~=0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.  
11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=1.0.0->geoviews) (0.1.  
2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefounda  
tion.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0.0->geoview  
s) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.  
3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0.0->geoviews) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.p  
ython.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0.0->geoviews) (2.  
0.7)

```
In [ ]: !pip install gdal
```

```
Collecting gdal
  Using cached GDAL-3.8.4.tar.gz (802 kB)
  Installing build dependencies: started
  Installing build dependencies: finished with status 'done'
  Getting requirements to build wheel: started
  Getting requirements to build wheel: finished with status 'done'
  Installing backend dependencies: started
  Installing backend dependencies: finished with status 'done'
  Preparing metadata (pyproject.toml): started
  Preparing metadata (pyproject.toml): finished with status 'done'
Building wheels for collected packages: gdal
  Building wheel for gdal (pyproject.toml): started
  Building wheel for gdal (pyproject.toml): finished with status 'error'
Failed to build gdal
```

error: subprocess-exited-with-error

× Building wheel for gdal (pyproject.toml) did not run successfully.

| exit code: 1

↳ [147 lines of output]

WARNING: numpy not available! Array support will not be enabled

running bdist\_wheel

running build

running build\_py

creating build

creating build\lib.win-amd64-cpython-311

creating build\lib.win-amd64-cpython-311\osgeo

copying osgeo\gdal.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\gdalconst.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\gdalnumeric.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\gdal\_array.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\gnm.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\ogr.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\osr.py -> build\lib.win-amd64-cpython-311\osgeo

copying osgeo\\_\_init\_\_.py -> build\lib.win-amd64-cpython-311\osgeo

creating build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal2tiles.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal2xyz.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdalattachpct.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdalcompare.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdalmove.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_calc.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_edit.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_fillnodata.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_merge.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_pansharpen.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_polygonize.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_proximity.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_retile.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\gdal\_sieve.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\ogrmerge.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\ogr\_layer\_algebra.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\pct2rgb.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\rgb2pct.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

copying gdal-utils\osgeo\_utils\\_\_init\_\_.py -> build\lib.win-amd64-cpython-311\osgeo\_utils

creating build\lib.win-amd64-cpython-311\osgeo\_utils\auxiliary

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building 'osgeo._gnm' extension
building 'osgeo._gdalconst' extension
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```

```

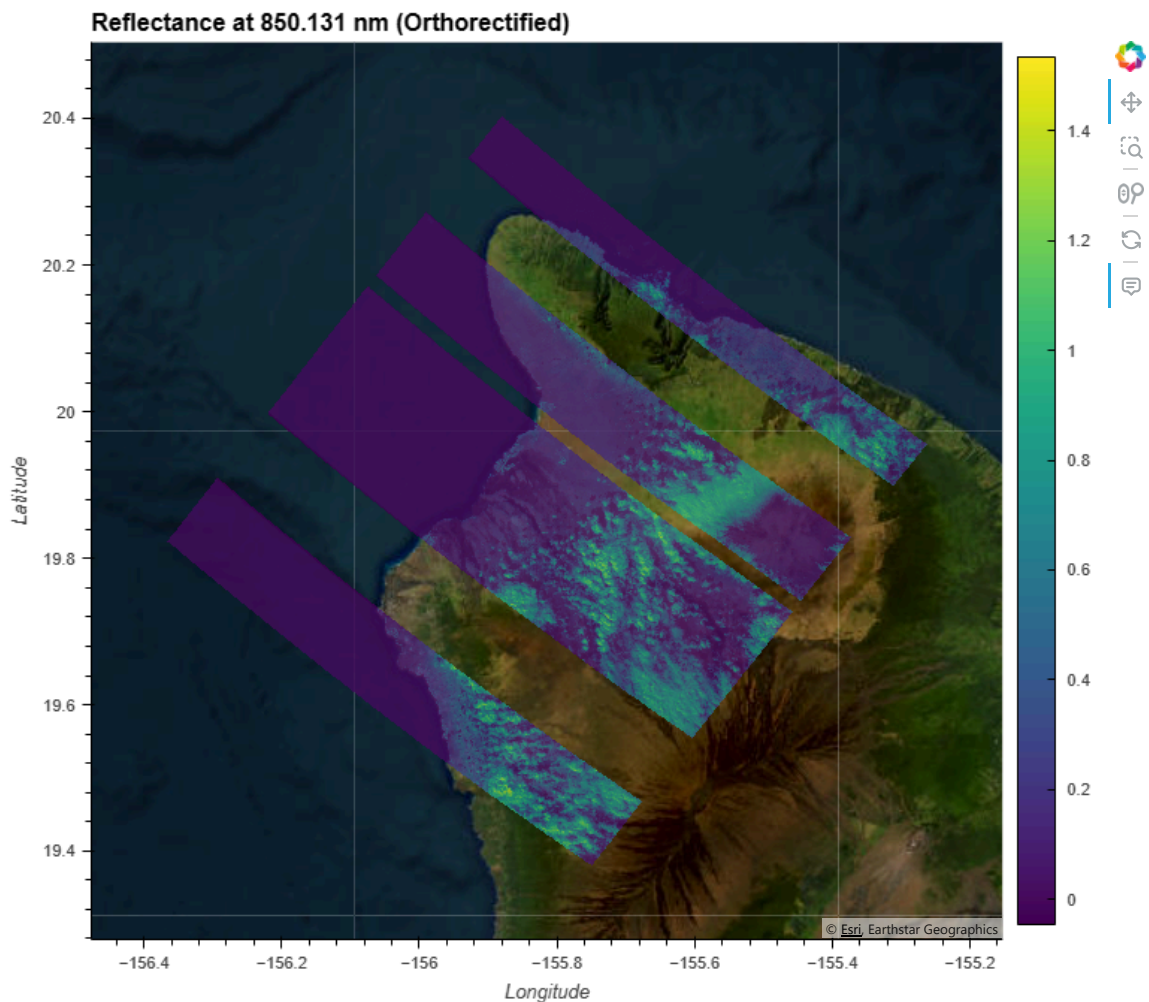
"C:\Program Files (x86)\Microsoft Visual Studio\2022\BuildTools\VC\Tools\MSVC\14.39.33519\bin\HostX86\x64\cl.exe" /c /nologo /O2 /W3 /GL /DNDEBUG /MD "-IC:\Program Files\WindowsApps\PythonSoftwareFoundation.Python.3.11_3.11.2288.0_x64__qbz5n2kfra8p0\include" "-IC:\Program Files\WindowsApps\PythonSoftwareFoundation.Python.3.11_3.11.2288.0_x64__qbz5n2kfra8p0\include" "-IC:\Program Files (x86)\Microsoft Visual Studio\2022\BuildTools\VC\Tools\MSVC\14.39.33519\include" "-IC:\Program Files (x86)\Microsoft Visual Studio\2022\BuildTools\VC\Auxiliary\VS\include" "-IC:\Program Files (x86)\Windows Kits\10\include\10.0.22621.0\ucrt" "-IC:\Program Files (x86)\Windows Kits\10\include\10.0.22621.0\um" "-IC:\Program Files (x86)\Windows Kits\10\include\10.0.22621.0\shared" "-IC:\Program Files (x86)\Windows Kits\10\include\10.0.22621.0\winrt" "-IC:\Program Files (x86)\Windows Kits\10\include\10.0.22621.0\cppwinrt" "-IC:\Program Files (x86)\Windows Kits\NETFXSDK\4.8\include\um" /EHsc /Tpextensions/osr_wrap.cpp /Fobuild\temp.win-amd64-cpython-311\Release\extensions/osr_wrap.obj
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osr_wrap.cpp
gnm_wrap.cpp
gdalconst_wrap.c
extensions/gdalconst_wrap.c(3013): fatal error C1083: Cannot open include file: 'gdal.h': No such file or directory
extensions/ogr_wrap.cpp(3181): fatal error C1083: Cannot open include file: 'gdal.h': No such file or directory
extensions/gnm_wrap.cpp(3153): fatal error C1083: Cannot open include file: 'gdal.h': No such file or directory
extensions/osr_wrap.cpp(3213): fatal error C1083: Cannot open include file: 'cpl_string.h': No such file or directory
extensions/gdal_wrap.cpp(3222): fatal error C1083: Cannot open include file: 'cpl_port.h': No such file or directory
error: command 'C:\\Program Files (x86)\\Microsoft Visual Studio\\2022\\BuildTools\\VC\\Tools\\MSVC\\14.39.33519\\bin\\HostX86\\x64\\cl.exe' failed with exit code 2
[end of output]

note: This error originates from a subprocess, and is likely not a problem with pip.
ERROR: Failed building wheel for gdal
ERROR: Could not build wheels for gdal, which is required to install pyproject.toml-based projects

```

```
In [ ]: ds_geo.sel(wavelengths=850, method='nearest').hvplot.image(cmap='Viridis', geo=True, tiles='ESRI', alpha=0.8, frame_h
        title=f"Reflectance at {refl850.wavelengths.values:.3f} {refl850.wavelengths.units} (Orthorectified)")
```

Out[ ]:



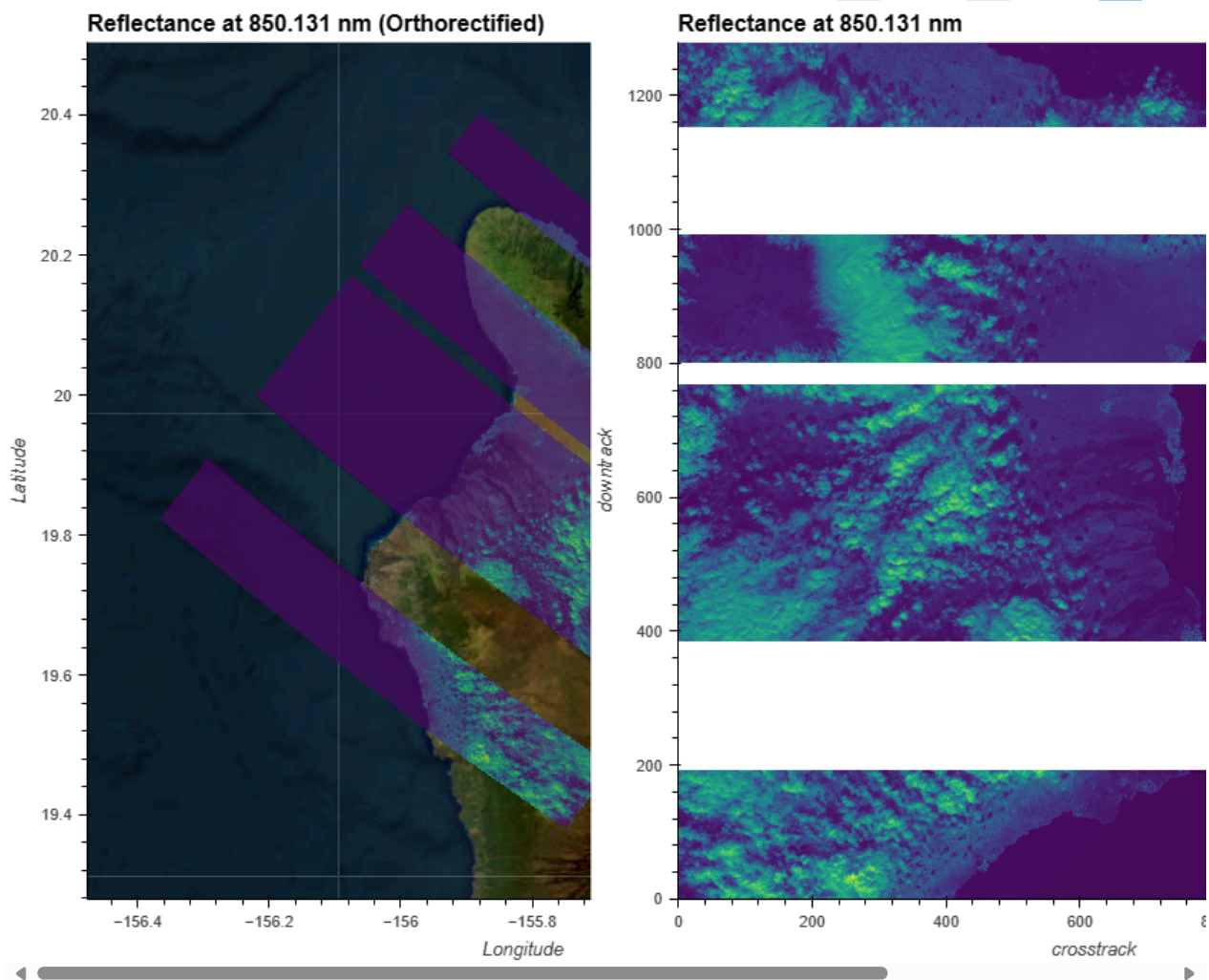
## 1.5 Plotting Data - Orthorectified

Now that the data has been orthorectified, plot the georeferenced dataset using the same single wavelength (850nm) as above alongside the uncorrected image. We can also plot the orthorectified data against an imagery tile using the `geo=True` and `tiles=` parameters instead of `aspect='equal'`. Any tile source available in `geoviews` should work here. This will change the axis names, but that can be fixed by adding them manually in the `opts`, like below.

```
In [ ]: (ds_geo.sel(wavelengths=850, method='nearest').hvplot.image(cmap='Viridis', geo=True, tiles='ESRI', alpha=0.8, frame_
title=f"Reflectance at {refl850.wavelengths.values:.3f} {refl850.wavelengths.units} (Orthorectified)") + \
ds.sel(wavelengths=850, method='nearest').hvplot.image(cmap='Viridis', aspect = 'equal', frame_height=600).opts(
title=f"Reflectance at {refl850.wavelengths.values:.3f} {refl850.wavelengths.units}"))
```



Out [ ]:



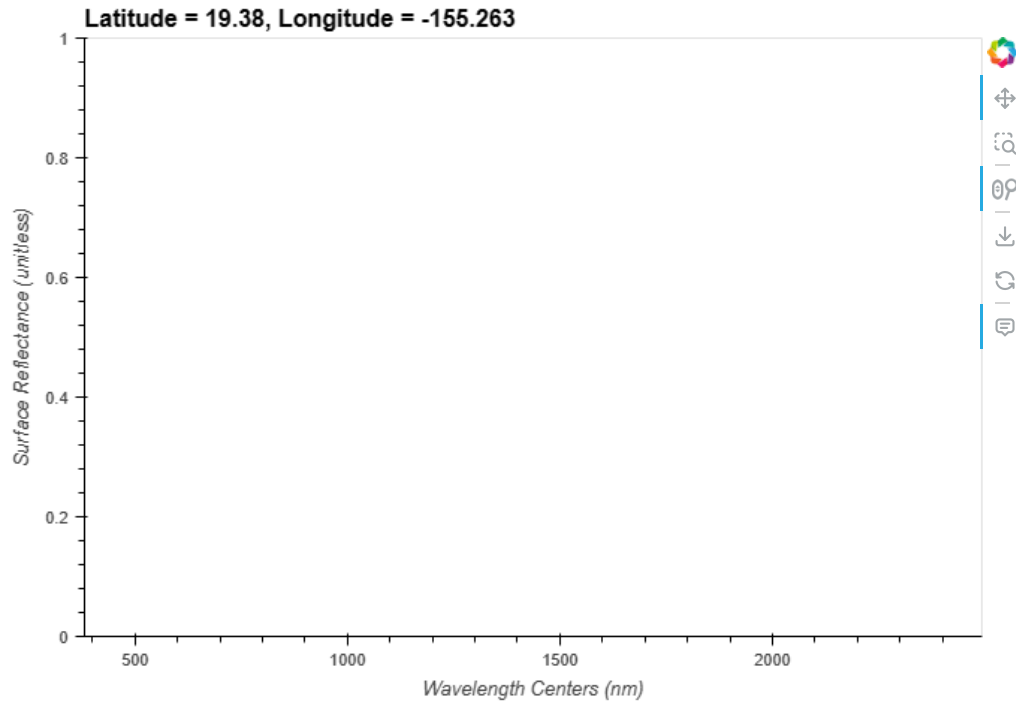
We can see that the orthorectification step placed the data on a geographic grid that matches pretty well with ESRI tiles. Now that we have a better idea of what the target area looks like, we can also plot the spectra using the georeferenced data. First, filter out the water absorption bands like we did earlier. By limiting the third dimension of the array to `good_wavelengths`.

```
In [ ]: ds_geo['reflectance'].data[:, :, ds_geo['good_wavelengths'].data==0] = np.nan
```

Now, plot the spectra at the Lat/Lon coordinates provided below.

```
In [ ]: point = ds_geo.sel(longitude=-155.263, latitude=19.38, method='nearest')
point.hvplot.line(y='reflectance', x='wavelengths', color='black', frame_height=400, frame_width=600).opts(
    title = f'Latitude = {point.latitude.values.round(3)}, Longitude = {point.longitude.values.round(3)}')
```

Out [ ]:



## 1.6 Writing an Orthorectified Output

At this point, the `ds_geo` orthorectified EMIT data can also be written as a flattened netCDF4 output that can be read using the `xarray.open_dataset` function, if desired. Before doing this, we can transpose the dimension order so the bands are the first dimension so that the data is readable by software like QGIS. This file will be larger than the original EMIT granule since it has been orthorectified. If we do write an output file, the format will be such that it can be read in using `xarray`.

Transpose the dimensions order and write an output.

```
In [ ]: # Transpose dimensions
# ds_geo = ds_geo.transpose('wavelengths', 'Latitude', 'Longitude')
# ds_geo.to_netcdf('../data/geo_ds_out.nc')

# Example for Opening
# ds = xr.open_dataset('../data/geo_ds_out.nc')
```

## 1.7 Interactive Spatial and Spectral Plots

Combining the Spatial and Spectral information into a single visualization can be a powerful tool for exploring and inspecting imaging spectroscopy data. Using the `streams` module from `Holoviews` we can link a spatial map to a plot of spectra.

We could plot a single band image as we previously have, but using a multiband image, like an RGB may help infer what targets we're examining. Build an RGB image following the steps below.

Select bands to represent red (650 nm), green (560 nm), and blue (470 nm) by finding the nearest to a wavelength chosen to represent that color.















Note that if subsetting by bands like this example, it is more memory efficient to subset before orthorectifying. Instead of using `ortho=True` in the `emit_xarray` function, select bands first, then apply the orthorectification using the `ortho_xr` function from `emit_tools.py` (requires a separate import).

```
In [ ]: rgb = ds_geo.sel(wavelengths=[650, 560, 470], method='nearest')
rgb
```



Out [ ]: xarray.Dataset

► Dimensions: (latitude: 1886, longitude: 2035, wavelengths: 3)

▼ Coordinates:

<b>wavelengths</b>	(wavelengths)	float32	648.7 559.3 470.0		
fwhm	(wavelengths)	float32	...		
good_wavelength...	(wavelengths)	float32	1.0 1.0 1.0		
<b>latitude</b>	(latitude)	float64	20.4 20.4 20.4 ... 19.38 19.38		
<b>longitude</b>	(longitude)	float64	-156.4 -156.4 ... -155.3 -155.3		
elev	(latitude, longitude)	float32	nan nan nan nan ... nan nan nan nan		
spatial_ref	()	int32	0		

▼ Data variables:

<b>reflectance</b>	(latitude, longitude, wavelengths)	float32	nan nan nan nan ... nan nan nan nan		
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► Indexes: (3)

► Attributes: (40)

Next, write a function to scale the values using a gamma correction. Without applying this scaling the majority of the image would be very dark, with the reflectance data being skewed by the few pixels with very high reflectance.

Note: This has no impact on analysis or data, just visualizing the RGB map.

```
In [ ]: # Function to adjust gamma across all bands - adjust brightness
def gamma_adjust(rgb_ds, bright=0.2, white_background=False):
    array = rgb_ds.reflectance.data
    gamma = math.log(bright)/math.log(np.nanmean(array)) # Create exponent for gamma scaling - can be adjusted by cha
    scaled = np.power(array,gamma).clip(0,1) # Apply scaling and clip to 0-1 range
    if white_background == True:
        scaled = np.nan_to_num(scaled, nan = 1) # Assign NA's to 1 so they appear white in plots
    rgb_ds.reflectance.data = scaled
    return rgb_ds
```

```
In [ ]: rgb = gamma_adjust(rgb, white_background=True)
```

Now that we have an RGB dataset, use it to build our spatial plot.

```
In [ ]: map = rgb.hvplot.rgb(x='longitude', y='latitude', bands='wavelengths', aspect = 'equal', frame_height=500)
```

```
In [ ]: !pip install ClickPoints
```



Requirement already satisfied: ClickPoints in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.10.0)

Requirement already satisfied: Pillow in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (10.2.0)

Requirement already satisfied: PyQt5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (5.15.10)

Requirement already satisfied: QtAwesome in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (1.3.1)

Requirement already satisfied: QtPy in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2.4.1)

Requirement already satisfied: imagecodecs in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2024.1.1)

Requirement already satisfied: imageio>=2.0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2.34.0)

Requirement already satisfied: imageio-ffmpeg in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (0.4.9)

Requirement already satisfied: matplotlib in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (3.8.3)

Requirement already satisfied: natsort in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (8.4.0)

Requirement already satisfied: peewee>=3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (3.17.1)

Requirement already satisfied: psutil in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (5.9.8)

Requirement already satisfied: python-dateutil>=2.8.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2.9.0.post0)

Requirement already satisfied: qasync in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (0.27.1)

Requirement already satisfied: qimage2ndarray in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (1.10.0)

Requirement already satisfied: scikit-image>=0.14 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (0.22.0)

Requirement already satisfied: scipy==1.9.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (1.9.3)

Requirement already satisfied: sortedcontainers in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2.4.0)

Requirement already satisfied: tifffile>=2020.2.16 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from ClickPoints) (2024.2.12)

Requirement already satisfied: numpy<1.26.0,>=1.18.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scipy==1.9.3->ClickPoints) (1.25.2)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.1->ClickPoints) (1.16.0)

Requirement already satisfied: networkx>=2.8 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image>=0.14->ClickPoints) (3.2.1)

Requirement already satisfied: packaging>=21 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image>=0.14->ClickPoints) (24.0)

Requirement already satisfied: lazy\_loader>=0.3 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image>=0.14->ClickPoints) (0.3)

Requirement already satisfied: setuptools in c:\program files\windowsapps\pythonsoftwarefoundation.python.3.11\_3.11.22.88.0\_x64\_qbz5n2kfra8p0\lib\site-packages (from imageio-ffmpeg->ClickPoints) (65.5.0)

Requirement already satisfied: contourpy>=1.0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib->ClickPoints) (1.2.0)

Requirement already satisfied: cycler>=0.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib->ClickPoints) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib->ClickPoints) (4.50.0)

Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib->ClickPoints) (1.4.5)

Requirement already satisfied: pyparsing>=2.3.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib->ClickPoints) (3.1.2)

Requirement already satisfied: PyQt5-sip<13,>=12.13 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from PyQt5->ClickPoints) (12.13.0)

Requirement already satisfied: PyQt5-Qt5>=5.15.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from PyQt5->ClickPoints) (5.15.2)

```
In [ ]: !pip install holoviews
```

Requirement already satisfied: holoviews in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.18.3)

Requirement already satisfied: param<3.0,>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.1.0)

Requirement already satisfied: numpy>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.25.2)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.0.2)

Requirement already satisfied: panel>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.3.8)

Requirement already satisfied: colorcet in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.1.0)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (24.0)

Requirement already satisfied: pandas>=0.20.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.2.1)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: bokeh<3.4.0,>=3.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.3.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2023.10.1)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2.0.3)

Requirement already satisfied: mdit-py-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (0.4.0)

Requirement already satisfied: requests in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2.31.0)

Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.10.0)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (1.2.0)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.4)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=0.20.0->holoviews) (1.16.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=1.0->holoviews) (0.4.6)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=1.0->holoviews) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=1.0->holoviews) (1.0.3)

Requirement already satisfied: mdurl~0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=1.0->holoviews) (0.1.2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (2.0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (2024.2.2)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (2.1.5)

In [ ]: `!pip install holoviews`

Requirement already satisfied: holoviews in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (1.18.3)

Requirement already satisfied: param<3.0,>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.1.0)

Requirement already satisfied: numpy>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.25.2)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.0.2)

Requirement already satisfied: panel>=1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (1.3.8)

Requirement already satisfied: colorcet in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (3.1.0)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (24.0)

Requirement already satisfied: pandas>=0.20.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews) (2.2.1)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas>=0.20.0->holoviews) (2024.1)

Requirement already satisfied: bokeh<3.4.0,>=3.2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.3.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2023.10.1)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2.0.3)

Requirement already satisfied: mdit-py-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (0.4.0)

Requirement already satisfied: requests in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (2.31.0)

Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=1.0->holoviews) (4.10.0)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (1.2.0)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (6.4)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas>=0.20.0->holoviews) (1.16.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=1.0->holoviews) (0.4.6)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=1.0->holoviews) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=1.0->holoviews) (1.0.3)

Requirement already satisfied: mdurl~0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=1.0->holoviews) (0.1.2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (2.0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=1.0->holoviews) (2024.2.2)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh<3.4.0,>=3.2.0->panel>=1.0->holoviews) (2.1.5)

In [ ]: `!pip install hvplot`

Requirement already satisfied: hvplot in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.9.2)

Requirement already satisfied: bokeh>=1.0.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (3.3.4)

Requirement already satisfied: colorcet>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (3.1.0)

Requirement already satisfied: holoviews>=1.11.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.18.3)

Requirement already satisfied: pandas in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (2.2.1)

Requirement already satisfied: numpy>=1.15 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.25.2)

Requirement already satisfied: packaging in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (24.0)

Requirement already satisfied: panel>=0.11.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (1.3.8)

Requirement already satisfied: param<3.0,>=1.12.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from hvplot) (2.1.0)

Requirement already satisfied: Jinja2>=2.9 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (3.1.3)

Requirement already satisfied: contourpy>=1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (1.2.0)

Requirement already satisfied: pillow>=7.1.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (10.2.0)

Requirement already satisfied: PyYAML>=3.10 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (6.0.1)

Requirement already satisfied: tornado>=5.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (6.4)

Requirement already satisfied: xyzservices>=2021.09.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bokeh>=1.0.0->hvplot) (2023.10.1)

Requirement already satisfied: pyviz-comms>=0.7.4 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from holoviews>=1.11.0->hvplot) (3.0.2)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas->hvplot) (2024.1)

Requirement already satisfied: markdown in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (3.6)

Requirement already satisfied: markdown-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (3.0.0)

Requirement already satisfied: linkify-it-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (2.0.3)

Requirement already satisfied: mdit-py-plugins in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (0.4.0)

Requirement already satisfied: requests in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (2.31.0)

Requirement already satisfied: tqdm>=4.48.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (4.66.2)

Requirement already satisfied: bleach in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (6.1.0)

Requirement already satisfied: typing-extensions in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from panel>=0.11.0->hvplot) (4.10.0)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from Jinja2>=2.9->bokeh>=1.0.0->hvplot) (2.1.5)

Requirement already satisfied: six>=1.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from python-dateutil>=2.8.2->pandas->hvplot) (1.16.0)

Requirement already satisfied: colorama in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm>=4.48.0->panel>=0.11.0->hvplot) (0.4.6)

Requirement already satisfied: webencodings in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from bleach->panel>=0.11.0->hvplot) (0.5.1)

Requirement already satisfied: uc-micro-py in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from linkify-it-py->panel>=0.11.0->hvplot) (1.0.3)

Requirement already satisfied: mdurl~>=0.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py->panel>=0.11.0->hvplot) (0.1.2)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (3.6)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (2.0.7)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\alons\_\appdata\local\packages\pythonsoftwarefoundation.python.3.11\_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests->panel>=0.11.0->hvplot) (2024.2.2)

To visualize the spectral and spatial data side-by-side, we use the `Point Draw` tool from the `holoviews` library.

Define a limit to the quantity of points and spectra we will plot, a list of colors to cycle through, and an initial point. We use the input from the `PointerXY` to show the spectra where our mouse cursor is. Then use the input from the `Tap` function to provide clicked x and y positions on the `map`. These retrieve spectra from the dataset at those coordinates.

Click in the RGB image to add spectra to the plot. You can also click and hold the mouse button then drag previously place points. To remove a point click and hold the mouse button down, then press the backspace key.

```
In [ ]: # Set Point Limit
POINT_LIMIT = 10

# Set up Color Cycling
color_cycle = hv.Cycle('Category20')
colors = [color_cycle[i] for i in range(5)]

# Get center coordinates of image
xmid = ds_geo.longitude.values[int(len(ds_geo.longitude) / 2)]
ymid = ds_geo.latitude.values[int(len(ds_geo.latitude) / 2)]

#
first_point = ([xmid], [ymid], [0])
points = hv.Points(first_point, vdims='id')
points_stream = hv.streams.PointDraw(
    data=points.columns(),
    source=points,
    drag=True,
    num_objects=POINT_LIMIT,
    styles={'fill_color': color_cycle.values[1:POINT_LIMIT+1], 'line_color': 'gray'}
)

posxy = hv.streams.PointerXY(source=map, x=xmid, y=ymid)
clickxy = hv.streams.Tap(source=map, x=xmid, y=ymid)

# Function to build spectral plot of clicked location to show on hover stream plot
def click_spectra(data):
    coordinates = []
    if data is None or not any(len(d) for d in data.values()):
        coordinates.append(clicked_points[0][0], clicked_points[1][0])
    else:
        coordinates = [c for c in zip(data['x'], data['y'])]

    plots = []
    for i, coords in enumerate(coordinates):
        x, y = coords
        data = ds_geo.sel(longitude=x, latitude=y, method="nearest")
        plots.append(
            data.hvplot.line(
                y="reflectance",
                x="wavelengths",
                color=color_cycle,
                label=f"{i}"
            )
        )
        points_stream.data["id"][i] = i
    return hv.Overlay(plots)

def hover_spectra(x,y):
    return ds_geo.sel(longitude=x,latitude=y,method='nearest').hvplot.line(y='reflectance',x='wavelengths',
                                                                              color='black', frame_width=400)

# Define the Dynamic Maps
click_dmap = hv.DynamicMap(click_spectra, streams=[points_stream])
hover_dmap = hv.DynamicMap(hover_spectra, streams=[posxy])

# Plot the Map and Dynamic Map side by side
hv.Layout(hover_dmap*click_dmap + map * points).cols(2).opts(
    hv.opts.Points(active_tools=['point_draw'], size=10, tools=['hover'], color='white', line_color='gray'),
```

```
hv.opts.Overlay(show_legend=False, show_title=False, fontsize=1.5, frame_height=480)
)
```

Out [ ]: BokehModel(combine\_events=True, render\_bundle={'docs\_json': {'ed8c4f9a-675c-4720-a0bd-66023a3128fd': {'version...

After selecting a number of points we can build a dictionary of points and spectra, then export the spectra to a `.csv` file.

```
In [ ]: data = points_stream.data
wavelengths = ds_geo.wavelengths.values

rows = [{"id", "x", "y"} + [str(i) for i in wavelengths]]

for p in zip(data['x'], data['y'], data['id']):
    x, y, i = p
    spectra = ds_geo.sel(longitude=x, latitude=y, method="nearest").reflectance.values
    row = [i, x, y] + list(spectra)
    rows.append(row)

In [ ]: with open('../data/interactive_plot_data.csv', 'w', newline='') as f:
    writer = csv.writer(f)
    writer.writerows(rows)
```

## Contact Info:

Email: LPDAAC@usgs.gov

Voice: +1-866-573-3222

Organization: Land Processes Distributed Active Archive Center (LP DAAC)<sup>1</sup>

Website: <https://lpdaac.usgs.gov/>

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