Poster #

Evaluating Machine Learning Approaches to Plume Tracking

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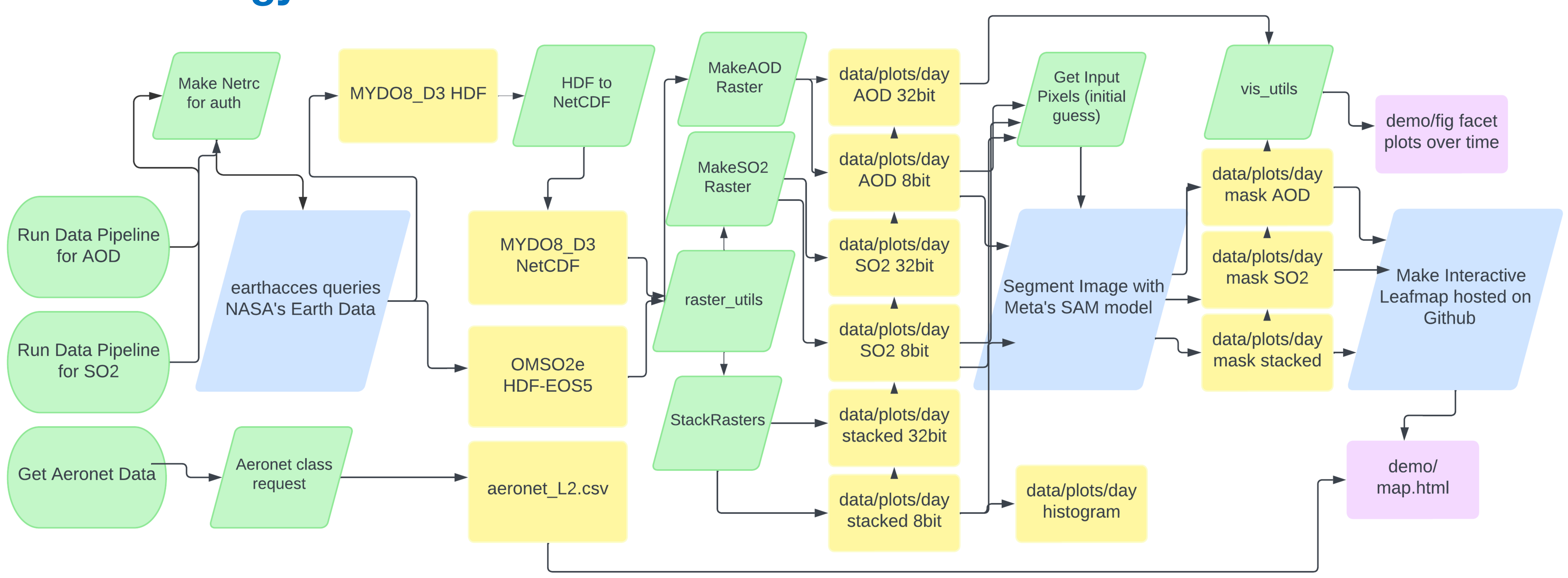
Overview

The Hunga Tonga-Hunga Ha'apai volcanic eruption on January 15, 2022 exploded a plume of gases, water vapor, and dust through the troposphere into the stratosphere. Prior studies have manually tracked and mapped the plume's impact across the planet.

Leveraging open data from NASA's Earth System Observatory, open-source code from NASA's DAACs and OpenScapes program, and open-source machine learning models from Meta, this project explores a synergized approach, and demonstrates an automated, open science methodology for tracking and mapping the Hunga Tonga plume. Furthermore, this project shows how machine learning models can rapidly analyze remote sensing data to help address disasters and accelerate atmospheric research.

Methodology

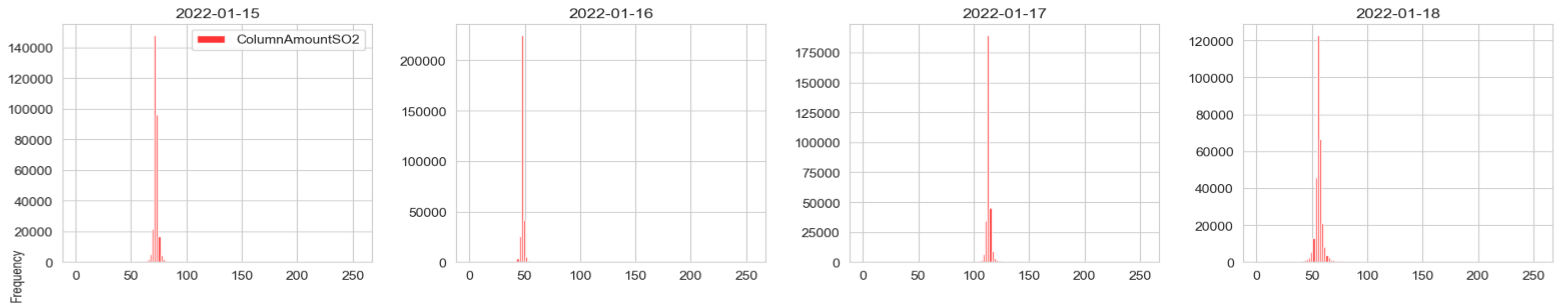


Data & Model Selection

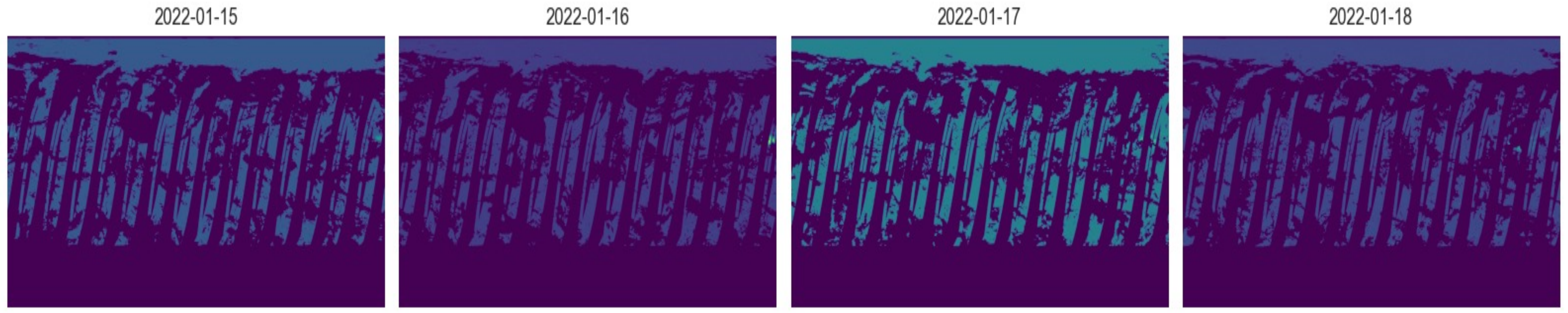
- MODIS/Aqua Aerosol Cloud Water Vapor Ozone Daily L3 provides grided global coverage of aerosol optical depth (AOD).
- OMI/Aura Sulfur Dioxide Daily L3 products shows global gridded Total Column Density of SO2.
- Segment Anything Model (SAM) from Meta takes points in a scene as input and returns feature masks showing the boundaries of an object. This model helps predict and map the plume's location.

Zero-Shot Predictions of the So2 Trace Gas Plume

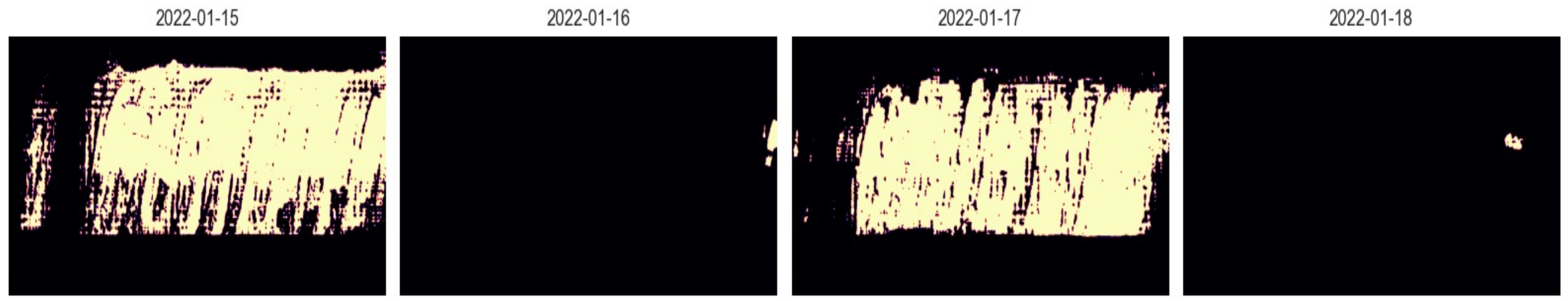
Daily Histograms of So2 Input Images



So2 Input Images



So2 Feature Masks



Input images are 8bit raster files that have been normalized and scaled from 1-255. Pixels without retrievals due to cloud cover or orbital paths are stored as 0s and illustrated in the darkest shades. Brighter pixels represent higher detected concentrations of SO2. The feature masks accurately predict plume locations as bright values against dark backgrounds on January 16 and 18.

Results

- The Segment Anything model better predicted the location of the sulfur dioxide trace gas plume than aerosol optical depth retrievals or the combined plumes due to noise in input images.
- The model performed best on images with high contrast between the plume and background scene, especially when the input pixels were spatially clustered. The input images on January 16, and January 18 show distinct plumes and high-quality feature masks for locating the plume over time.
- Increasing the number of input coordinates generally reduced accuracy because the pipeline selects pixels based on brightness values, potentially introducing coordinates outside of the plume.
- Open-source tools, like *leafmap* and *folium*, can help researchers create interactive and accessible maps that overlay inputs, masks, and ground retrievals from Aeronet to help with disaster tracking.

Future Work and Applications

- Model performance depends on the availability and quality of the input data. Going forward, this project aims to integrate additional datasets and preprocessing techniques to enhance accuracy.
- Adding CALIPSO Lidar data would add a vertical dimension and could improve the process for identifying input coordinates. Incorporating higher resolution datasets like TROPOMI, or future synergy datasets like the GEO-LEO aerosol products might make aerosol retrievals more useable for machine learning modeling by improving spatial and temporal coverage.
- Exploring spatial clustering of the brightest pixels could help generalize filtering and selecting input points for the model to delineate a shifting plume object across multiple images.
- We hope to evaluate how this approach, codebase, and model can be adapted to study other disasters and extreme events including additional volcanic eruptions and large-scale wildfires such as the 2020 California/Oregon wildfires.

References

[1] A. Kirillov et al., "Segment Anything," arXiv preprint arXiv:2304.02643, 2023.
[2] W. Wu et al., "samgeo: A Python package for segmenting geospatial data with the Segment Anything Model (SAM)," Journal of Open Source Software, vol. 8, no. 89, p. 5663, 2023, doi: 10.21105/joss.05663.
[3] Boichu, M., "Growth and Global Persistence of Stratospheric Sulfate Aerosols From the 2022 Hunga Tonga-Hunga Ha'apai Volcanic Eruption", Journal of Geophysical Research (Atmospheres), vol. 128, no. 23, 2023. doi:10.1029/2023JD039010.

Acknowledgements

Dr. Amir Jafari in the Data Science Department at George Washington University.

View Interactive Online Map

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