

Geophysical Trends in Volcanic Eruptions

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How do geophysical properties change before and after eruptions?



Geophysical properties such as gas emissions, seismic events, and ground deformation change during eruptive periods.



How can these changes be observed?



What trends and correlations can be seen in the data?

Motivations

Volcanic eruptions are powerful geologic processes that can be dangerous to humans

- Over 500 million people live near active volcanoes

Understanding how geophysical properties change can help with predicting volcanic events

Chosen volcano

- Vulcan Sabancaya, Peru
- Active Stratovolcano since 2016

Data Acquisition

Thermal Data

- MIROVA Database
- Taken from satellite images
- File type: CSV
- Processed in Pandas DataFrame

Deformation Data

- COMET Deformation Collection
- Collected via satellite imagery
- File types: CSV
- Processed in Pandas Dataframes

Sulfur Dioxide Emissions

- NASA GES DISC Database
- File type: hdf5
- Similar to netCDF files.
- Processed in Pandas DataFrame

Seismic Events

- NEIC Earthquake Search Catalog
- File type: CSV
- Processed in Pandas DataFrame

Sulfur Dioxide

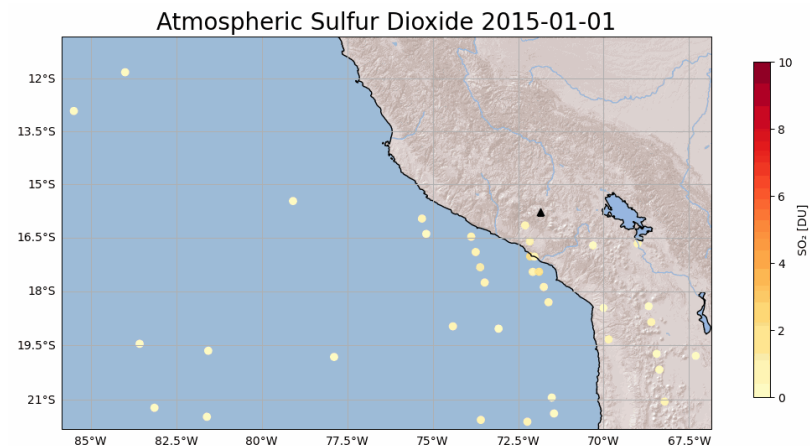
Gas emitted from volcanoes

Heavy aerosol that can eat away the ozone layer

- Only can get there in explosive eruptions

Major cause of climate change in

- Reflects sunlight
- Large amounts cool the atmosphere



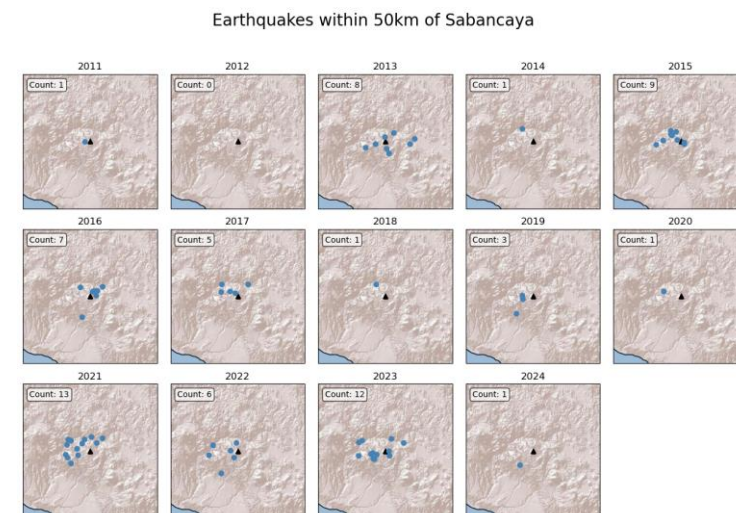
Seismic Events

Evaluated seismic events within 50 km of the volcano shallower than 30 km.

- Earthquakes within this range can be easily attributed to the volcano

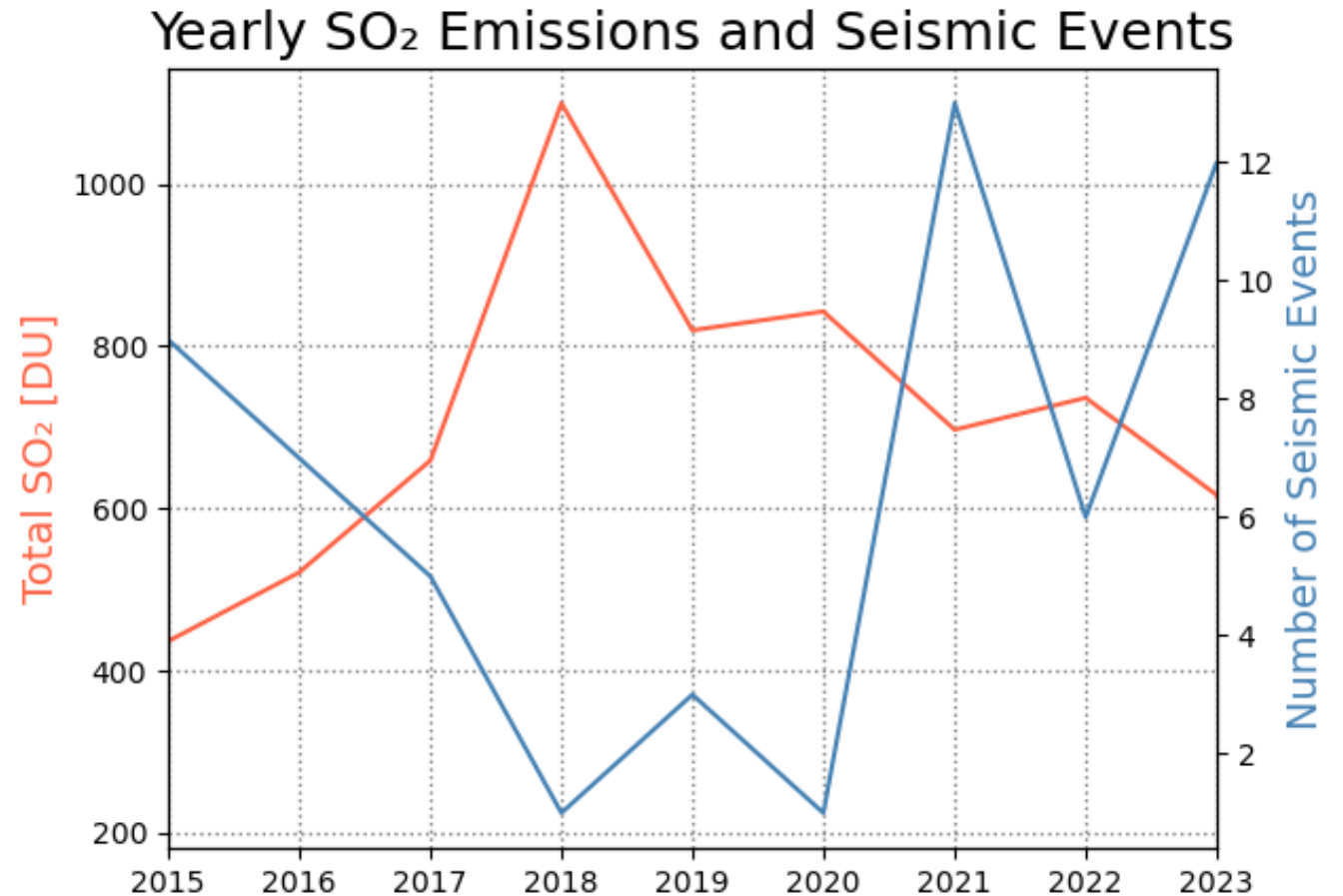
Earthquakes can indicate volcanic unrest. These events release the pressure built up in the volcanic core.

Can cause landslides, damage to homes and infrastructure, injury, and death.



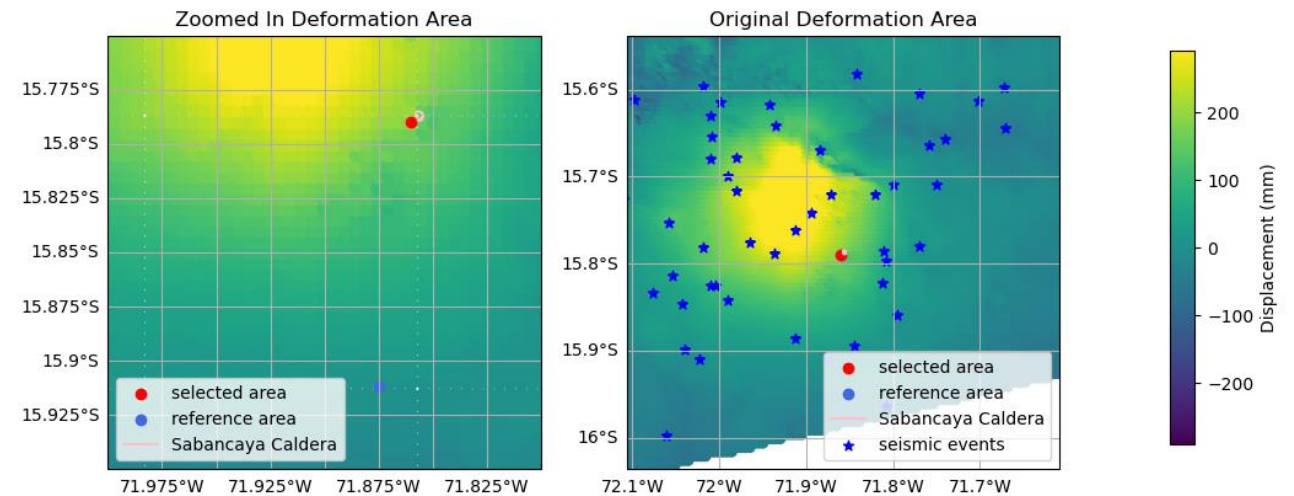
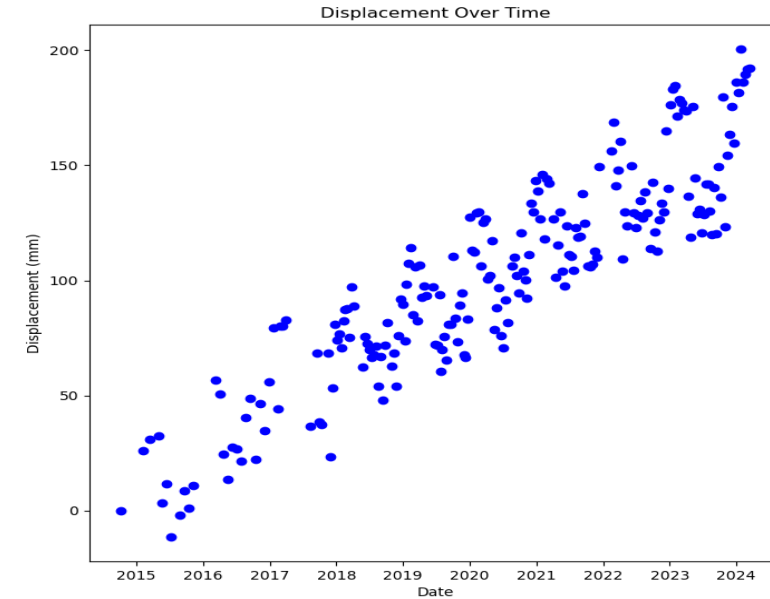
Sulfur Dioxide and Seismic Correlation

- Seismic events and Sulfur Dioxide emissions have a negative correlation
- In full years of data collection (2015-2023)
- Interior pressure must be released in some fashion
 - If not released by degassing, more earthquakes will occur and vice versa



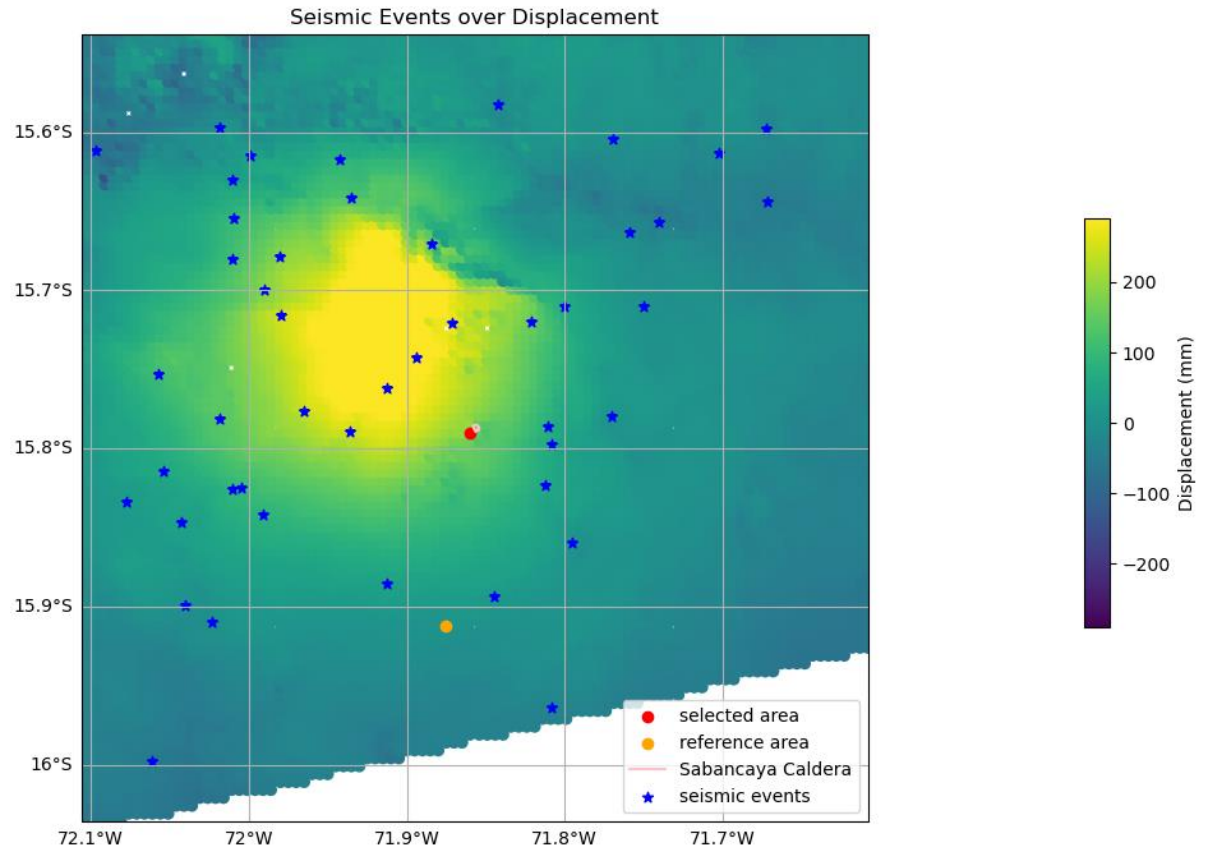
Ground Deformation

- The ground displacement has increased over time since 2015 as Sabancaya has been actively erupting since 2016.
- The graph on the right shows the ground displacement from the selected area over time.
- The selected area (red dot) is near the Volcano's caldera (orange line) and the reference area (blue dot) is around 15-20 kilometers away.



Ground Deformation and Seismic Events

- After plotting the deformation data with associated latitude and longitudes, we plotted the seismic events (blue stars) occurring from 2011 until February of 2024.
- What was interesting was that we found that most of the seismic events occurred outside the area with the most deformation.
- This low seismic activity in the area of highest displacement could possibly be attributed to subsurface magma movement causing the floor to rise and seismic events to occur on the outer sections of the volcano

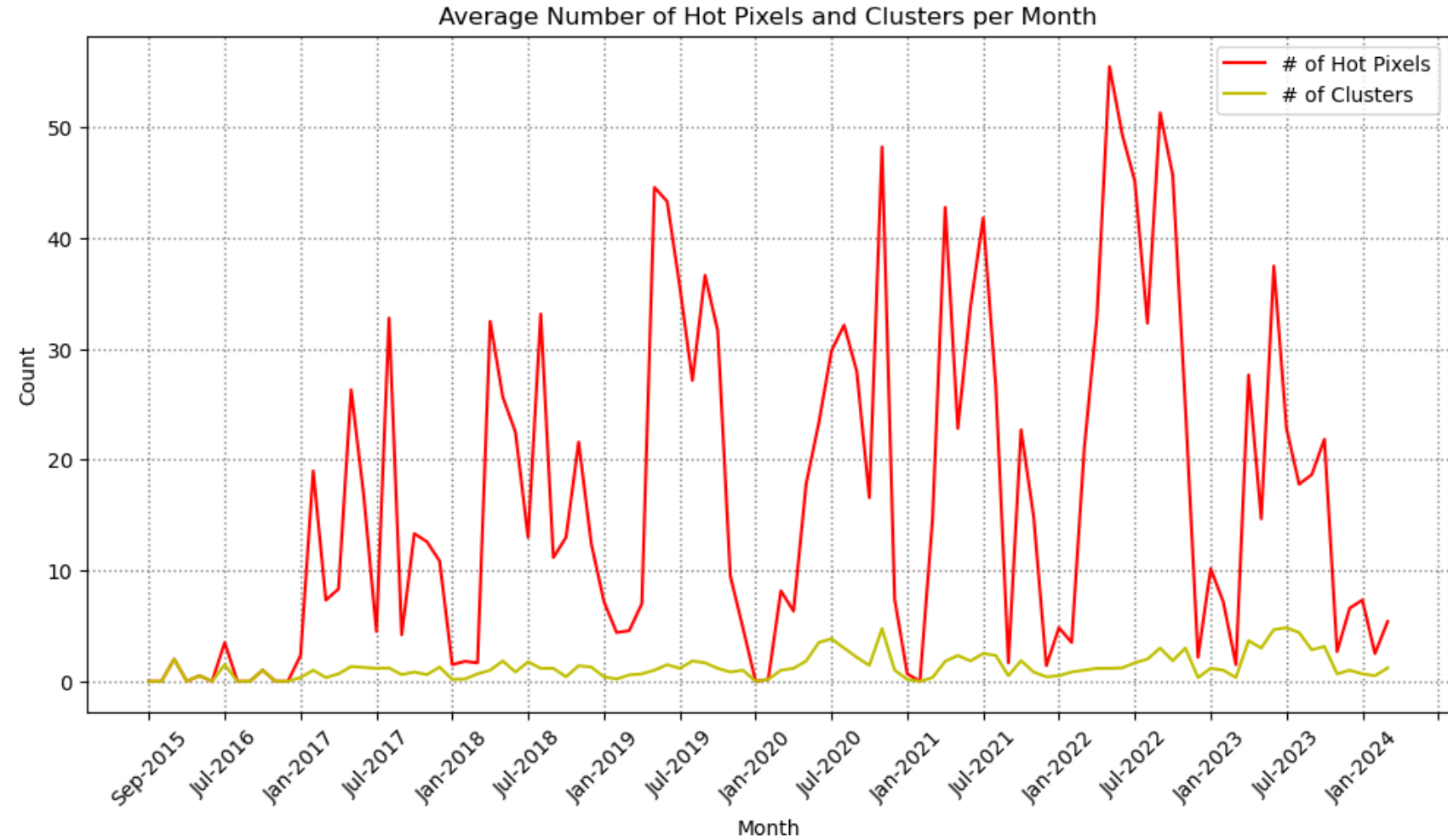


Thermal

Satellite images of a 10 x 10 km area.

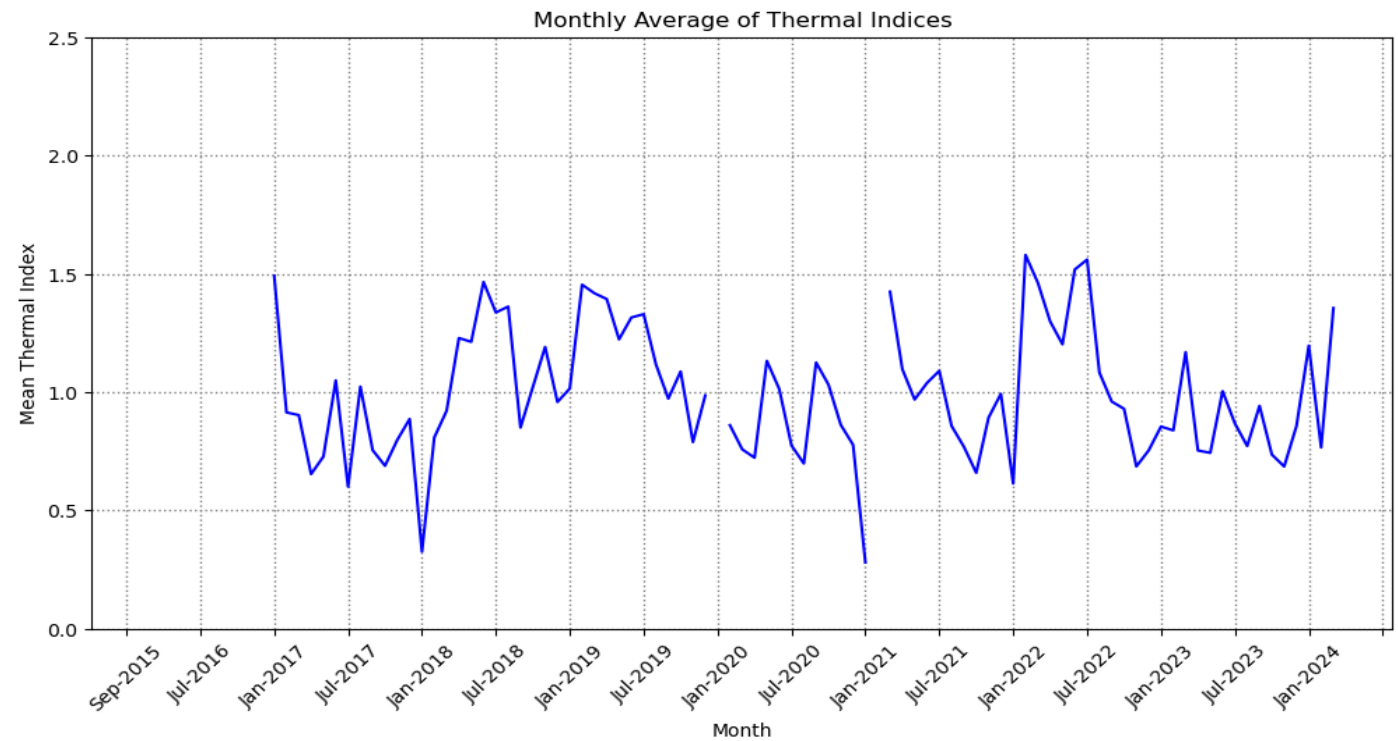
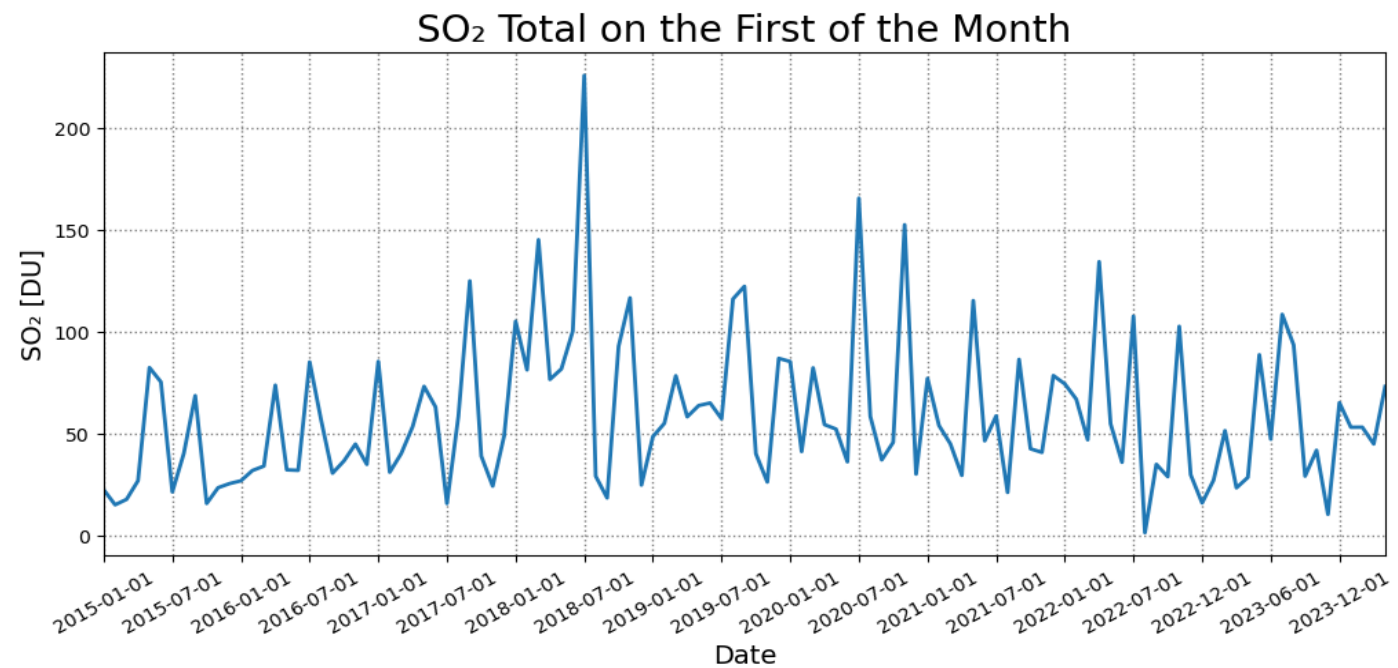
Measured:

- # of Hot Pixels in image
- # of Clusters of Hot Pixels
- Mean Thermal Index of pixels in image



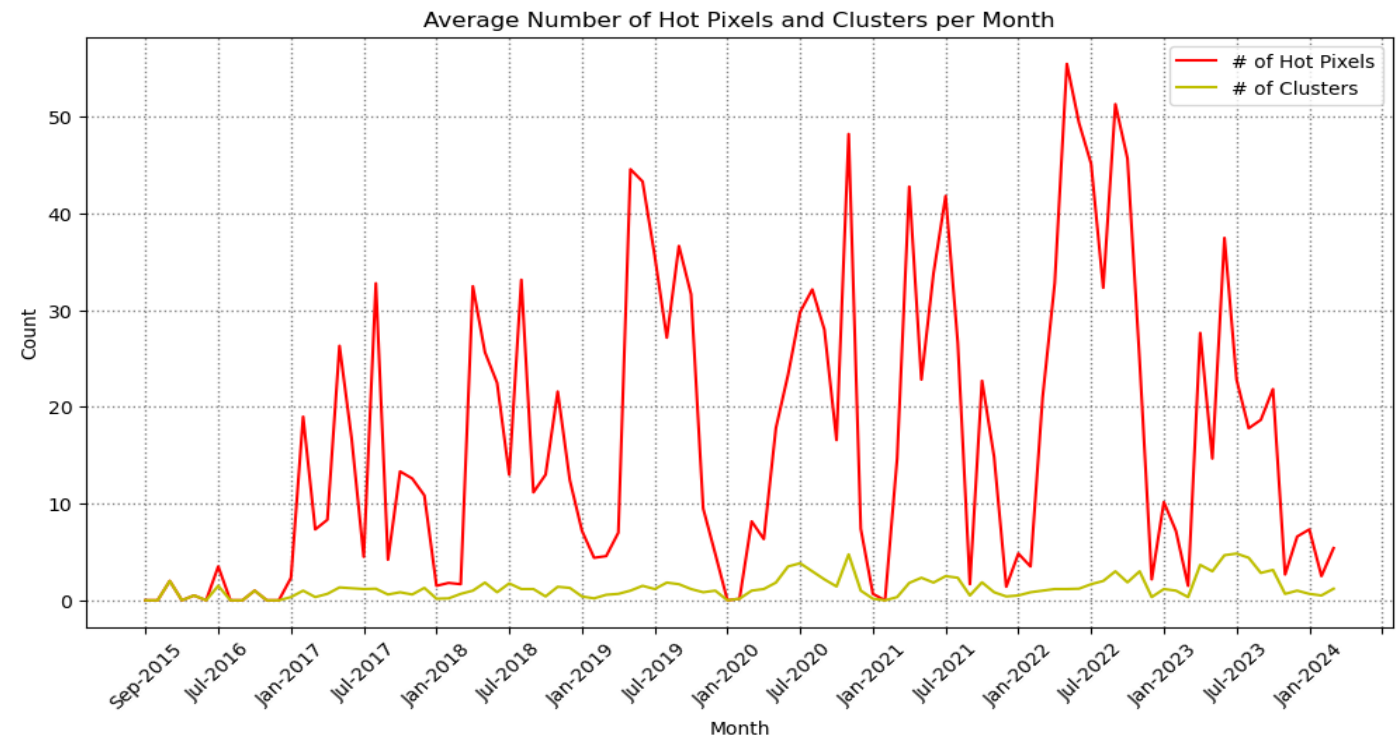
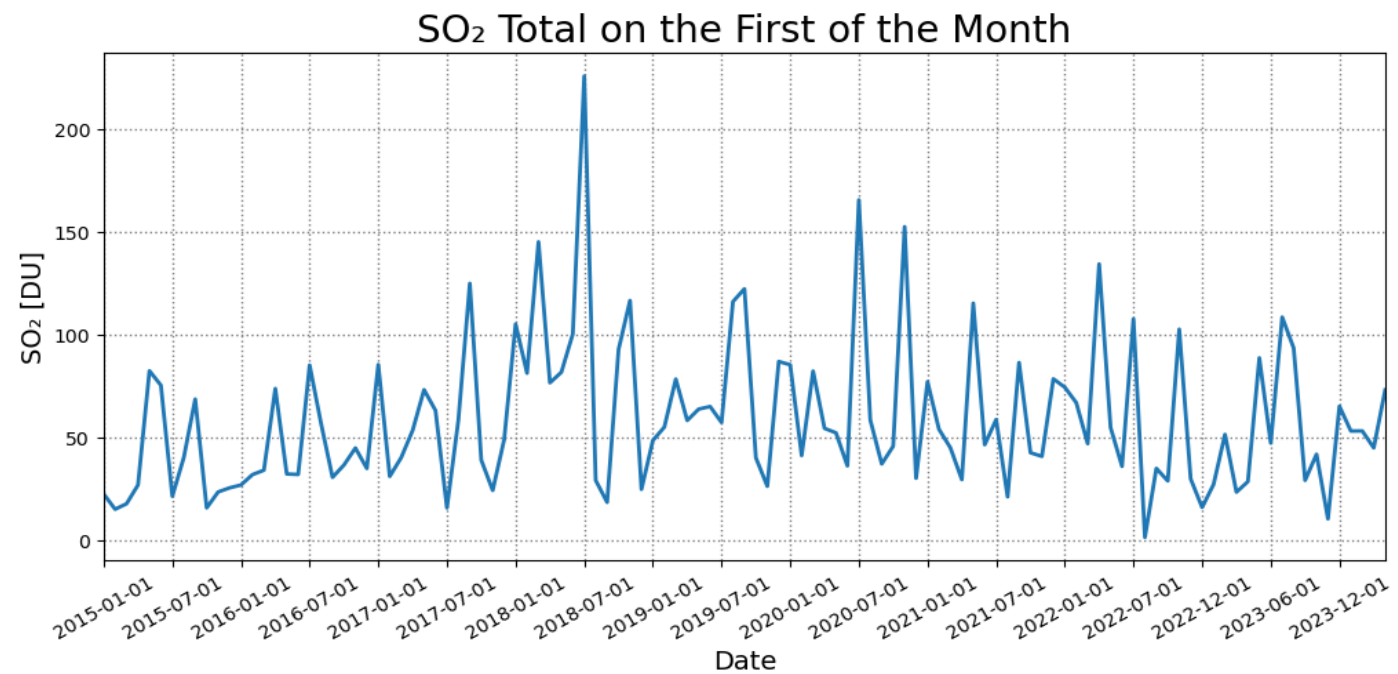
Sulfur Dioxide and Thermal Indices

- Not much association visible
- Limitations on thermal data may introduce hidden variables



Sulfur Dioxide and Thermal Indices

- Possible association
- Limitations on thermal data may introduce hidden variables



Limitations

Satellite Imagery for Thermal Indexing

- Cloud cover can obstruct measurements
- Left out spatial variations

Sulfur Dioxide file size

- Limited to only the first of every month

USGS has few seismic stations in South America

- Source location accuracy is lower

Summary and Implications

Summary and Implications

- Seismic events tend to happen around/near deformation
- Seismic events have a reverse correlation to Sulfur Dioxide emissions
- Hot pixels in thermal images occurs in clusters

Future Steps

- Add singular eruption events and look at a closer time frame pre-eruption
- Model spatial trends in thermal data
- Look at other stratovolcanoes to look for similarities
- Create machine models to predict an eruption

Acknowledgements

Databases

- Smithsonian eruption databases
- MIROVA Heat Database
- USGS National Earthquake Information Center
- NASA GES DISC
- COMET Volcanic and Magmatic Deformation

Programs and Packages

- Jupyter
- Github
- Pandas
- Matplotlib
- Cartopy
- h5py

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