

Analysis of Mt. Etna's Eruptions: 2024 vs 2025

Francesca Saiu

Alma Mater Studiorum - Università di Bologna

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Outline

1 Introduction

2 Data Gathering

3 Data Output

4 Data Analysis

- Difference Vegetation Index (DVI)
 - SO_2 Analysis: Statistics
 - SO_2 Analysis: Concentration

5 Conclusions

Introduction

- **Focus:** Comparison of Mt. Etna's eruptions in August 2024 and June 2025.

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- **Parameters:** NDVI, Sulfur Dioxide Emissions.

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- **Parameters:** NDVI, Sulfur Dioxide Emissions.
- **Data gathering sites:** Google Earth, Earth Observatory, Copernicus.

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R script for dowloading images

R packages used:

```
library(terra)
library(imageR)
library(viridis)
library(patchwork)
library(ggplot2)
```

Image processing function:

```
fplot <- function(x, y){
  x = rast(y)
  x = flip(x)
  plot(x)
  return(x)
}
```

Setting Working Directory for Importing Data

- **Image examples:** Italy base map, true and false color eruption imagery.

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- **Data:** Sentinel-2, Sentinel-5P, NASA.

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- **Image examples:** Italy base map, true and false color eruption imagery.
- **Data:** Sentinel-2, Sentinel-5P, NASA.
- **Comparison:** Images compared side-by-side to highlight differences.

Setting Working Directory for Importing Data

All images are imported with the same procedure as the second line of code:

```
setwd("C:/Users/fsaiu/UNI/MAGISTRALE/TELERILEVAMENTO")
gview = flot(gview, "Italy.jpg")
```

Image Example

The images will look like this one, it shows Italy in a typical setting:

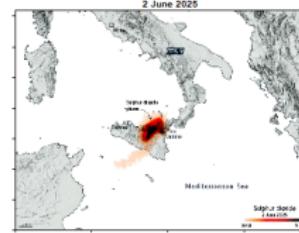
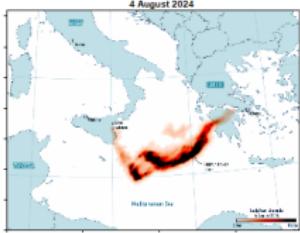
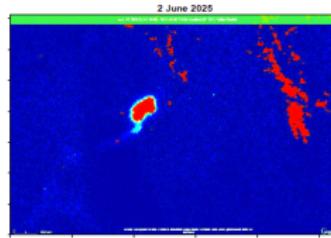
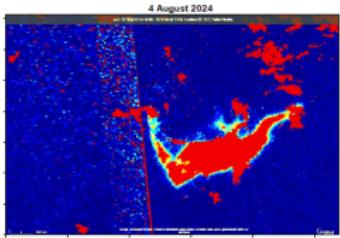
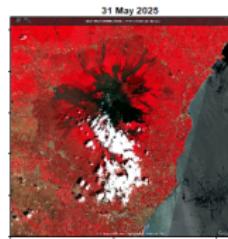
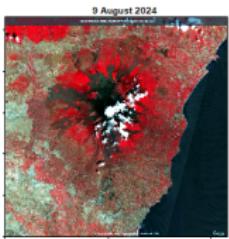


Mt.Etna Eruptions

During the eruptions Mt. Etna looks like these two images in true colors, respectively in 2024 and 2025:



Images Analysed



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Output Collage Creation

All following outcome images are made by generating a png file:

```
png("images.png", width=1000, height=800)
im.multipage(3,2)
im.plotRGB(fc24, r=1, g=2, b=3, title="9\u2014August\u20142024")
im.plotRGB(fc25, r=1, g=2, b=3, title="31\u2014May\u20142025")
im.plotRGB(so2.24, r=1, g=2, b=3, title="4\u2014August\u20142024")
im.plotRGB(so2.25, r=1, g=2, b=3, title="2\u2014June\u20142025")
...
dev.off()
```

This script, for example, produced the previous picture.

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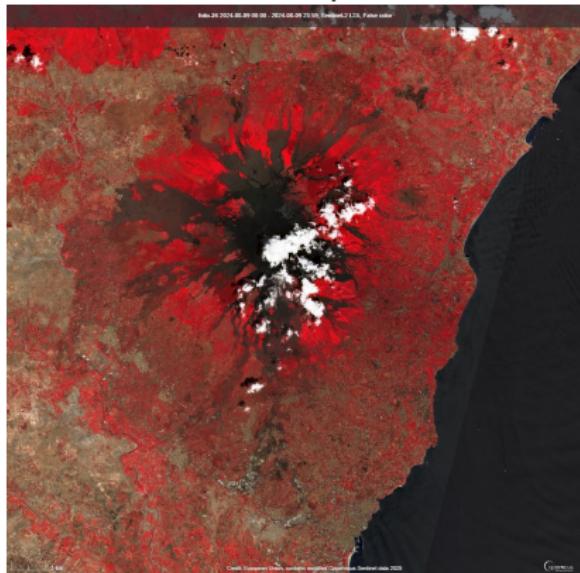
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NDVI Analysis

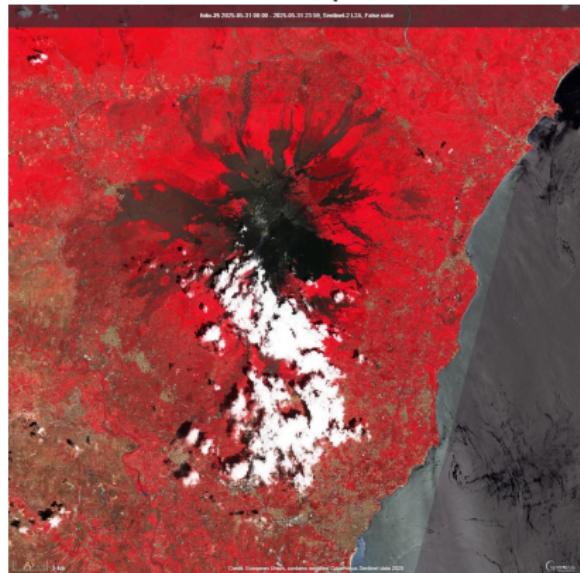
- DVI = NIR - Red
- NDVI = $(\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$
- $\text{NDVI} \in [-1;+1]$
- Clear difference between spring (2025) and summer (2024).

Analysed Images

2024 Eruption



2025 Eruption

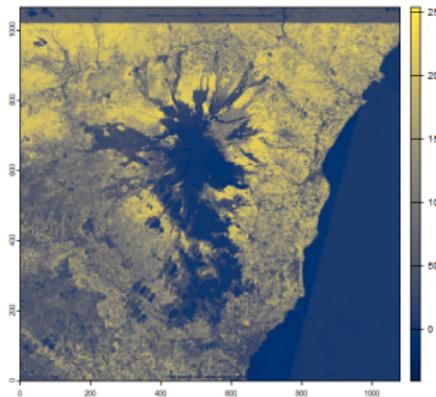
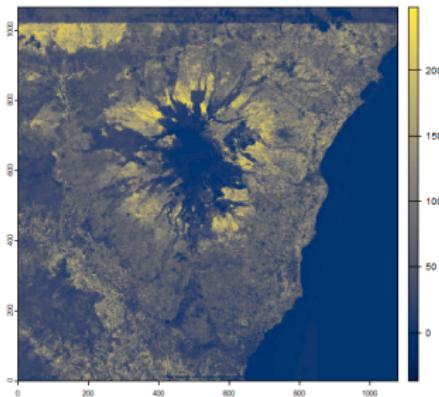


DVI R Code

With false color images it is possible to calculate the DVI:

```
dvi24 = fc24[[1]] - fc24[[2]]  
dvi25 = fc25[[1]] - fc25[[2]]
```

The result is:



NDVI R Code and Graph

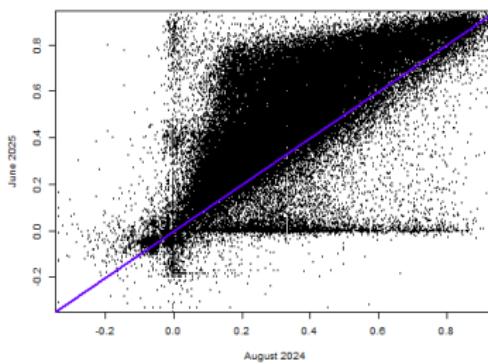
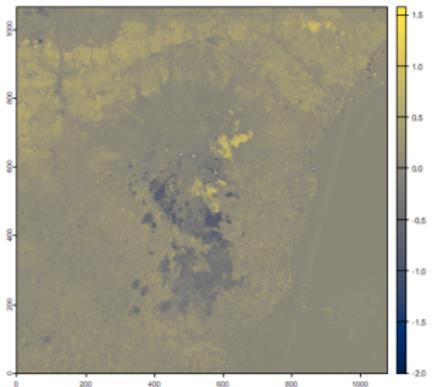
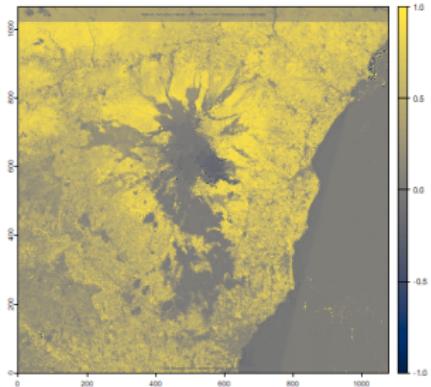
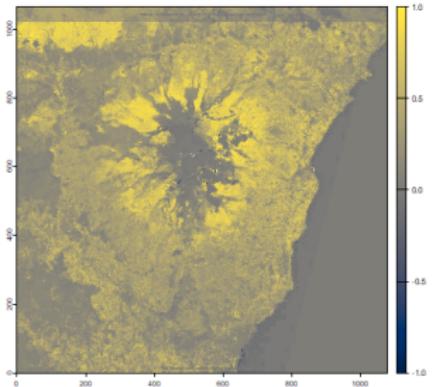
With false color images it is possible to calculate the NDVI:

```
ndvi24 = dvi24 / (fc24[[1]] + fc24[[2]])
ndvi25 = dvi25 / (fc25[[1]] + fc25[[2]])
```

To analitically compare NDVI values between the two dates, results are plotted in a cartesian graph and it is added a bisector for reference:

```
ndvidiff = ndvi25 - ndvi24
plot(ndvi24, ndvi25, xlim=c(-0.3,0.9), ylim=c(-0.3, 0.9), ylab="June
    \u2025", xlab="August\u20252024")
abline(0, 1, col="#6600ff", lwd=2)
dev.off()
```

NDVI Comparison Images



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Sulfur Dioxide Analysis

- **Importance:**

- Monitoring, helps with predictions of new eruptions;
- Health, irritation eyes and mucous membranes and cause damage to the respiratory system;
- Climate, reaction with the water in the atmosphere and generation of sulfuric acid that contributes to acid rain, vegetation damage and soil contamination;

Sulfur Dioxide Analysis

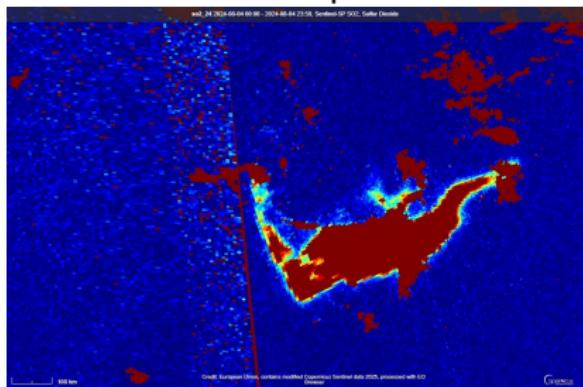
- **Importance:**

- Monitoring, helps with predictions of new eruptions;
- Health, irritation eyes and mucous membranes and cause damage to the respiratory system;
- Climate, reaction with the water in the atmosphere and generation of sulfuric acid that contributes to acid rain, vegetation damage and soil contamination;

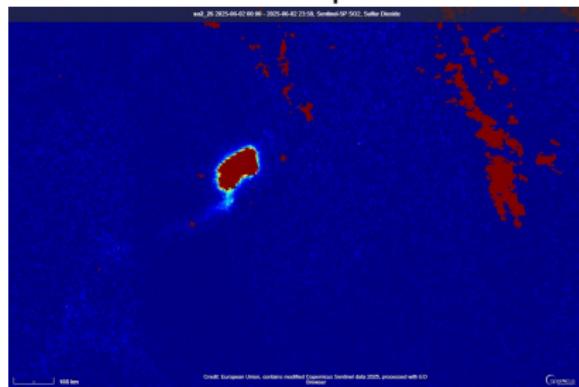
- **Analysis:** Emission extent, standard deviation, variance.

Analysed Images

2024 Eruption



2025 Eruption



SO_2 Standard Deviation

Taking a look at the images it is possible to see that the sulfur dioxide plume of year 2024 was spreading much more than this year's plume. The difference is calculated like this:

```
so2d = so2.25[[1]] - so2.24[[1]]
```

Then, the extent to which the values deviate from their average can be extrapolated using the latter variable:

```
sd = focal(so2d, w=c(3,3), fun="sd")
sd24 = focal(so2.24[[1]], w=c(3,3), fun="sd")
sd25 = focal(so2.25[[1]], w=c(3,3), fun="sd")
```

SO_2 Variance and Comparison Plots Code

From total standard deviation can be evaluated the variance index:

```
var = sd^2
```

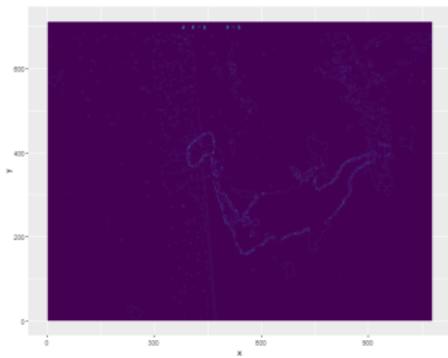
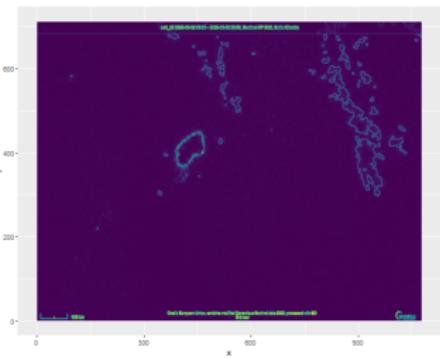
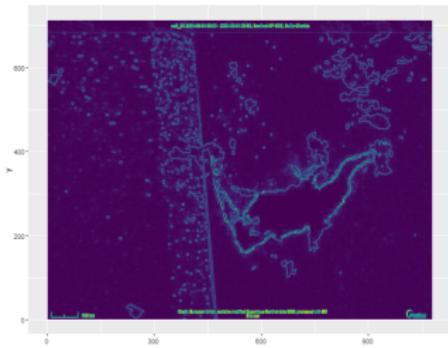
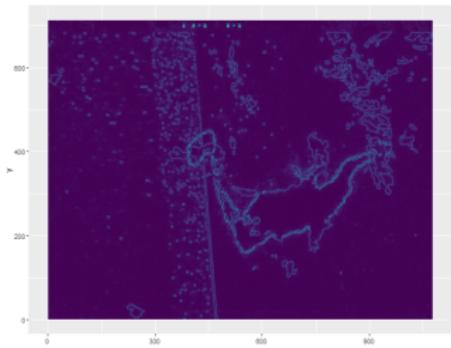
Plotting ggplot graphics:

```
# Changing names to distinguish the graphics
names(sd)="Total_standard_deviatio"
names(sd24)="Standard_deviatio_year_2024"
names(sd25)="Standard_deviatio_year_2025"
names(var)="Total_variance"

p0 = im.ggplot(sd)
p1 = im.ggplot(sd24)
p2 = im.ggplot(sd25)
p3 = im.ggplot(var)

p0+p1+p2+p3
```

Graphic Outcome



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Analysed Images

2024 Eruption



2025 Eruption



SO₂ Classification

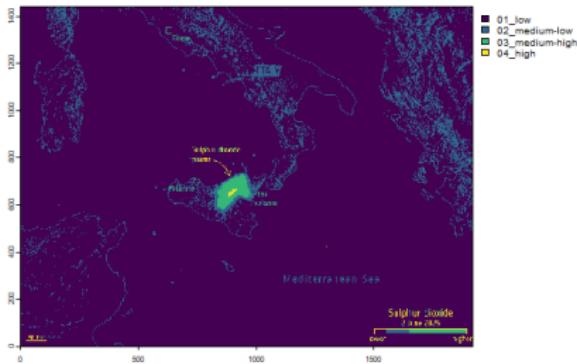
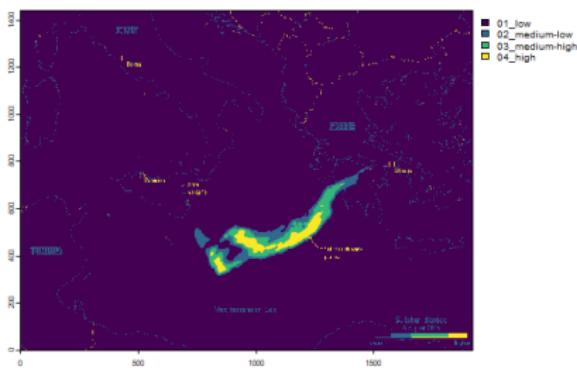
As last analysis, the previous pictures are employed for sulfur dioxide concentration calculation through a function taken from package imageRy that permits an unsupervised (automatic) classification:

```
so2d24c = im.classify(so2d24, num_clusters=4)
so2d25c = im.classify(so2d25, num_clusters=4)
```

Making a correct legend:

```
so2d24cs = subst(so2d24c, c(3,2,4,1), c("01_low", "02_medium-low", "03
      _medium-high", "04_high"))
so2d25cs = subst(so2d25c, c(2,1,3,4), c("01_low", "02_medium-low", "03
      _medium-high", "04_high"))
```

Resulting Images



Determining SO_2 Concentration Percentages Classes

Calculating the percentages of both years:

```
perc24 = freq(so2d24cs)$count*100/ncell(so2d24cs)
perc25 = freq(so2d25cs)$count*100/ncell(so2d25cs)
```

And put in a dataframe:

```
class = c("01_low", "02_medium-low", "03_medium-high", "04_high")
perc_24 = c(95.33, 2.71, 1.04, 0.91)
perc_25 = c(92.20, 6.74, 0.74, 0.32)
tabso2 = data.frame(class, perc_24, perc_25)
```

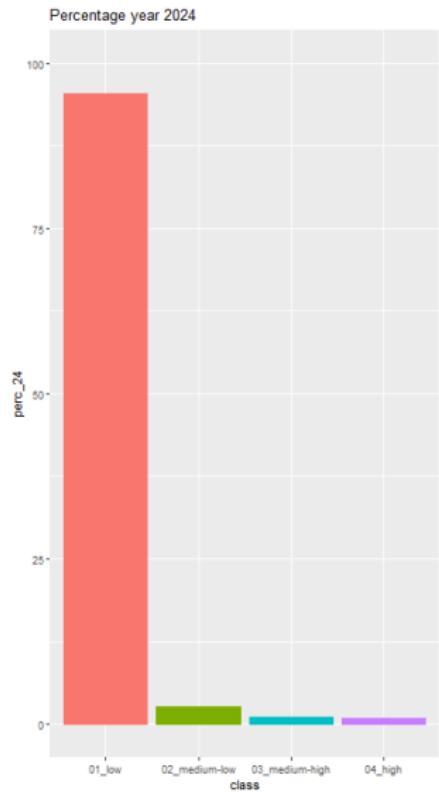
It is a table 3x4, where the rows correspond to the names stored in the variable called "class", while the columns contain percentage values.

Histogram of SO_2 Concentration Classes

The last outputs are two ggplot graphics that show the percentages of various classes in the form of histograms:

```
gso24 = ggplot(tabso2, aes(x=class, y=perc_24, fill=class)) +  
    geom_bar(stat="identity") + ggtitle("2024") + ylim(c(0,100))  
gso25 = ggplot(tabso2, aes(x=class, y=perc_25, fill=class)) +  
    geom_bar(stat="identity") + ggtitle("2025") + ylim(c(0,100))  
gso24 + gso25
```

Histogram Comparison



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Conclusions

- NDVI increased in 2025 — healthier vegetation.
- SO_2 plume smaller in 2025 — weather likely influenced spread.
- Classified results confirm more concentrated SO_2 in 2025.

Introduction
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Data Gathering
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Data Output
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Data Analysis
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Conclusions
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Conclusions

Thanks for the attention!