# An approach for volcano-tectonic features extraction using optical and radar remote sensing data

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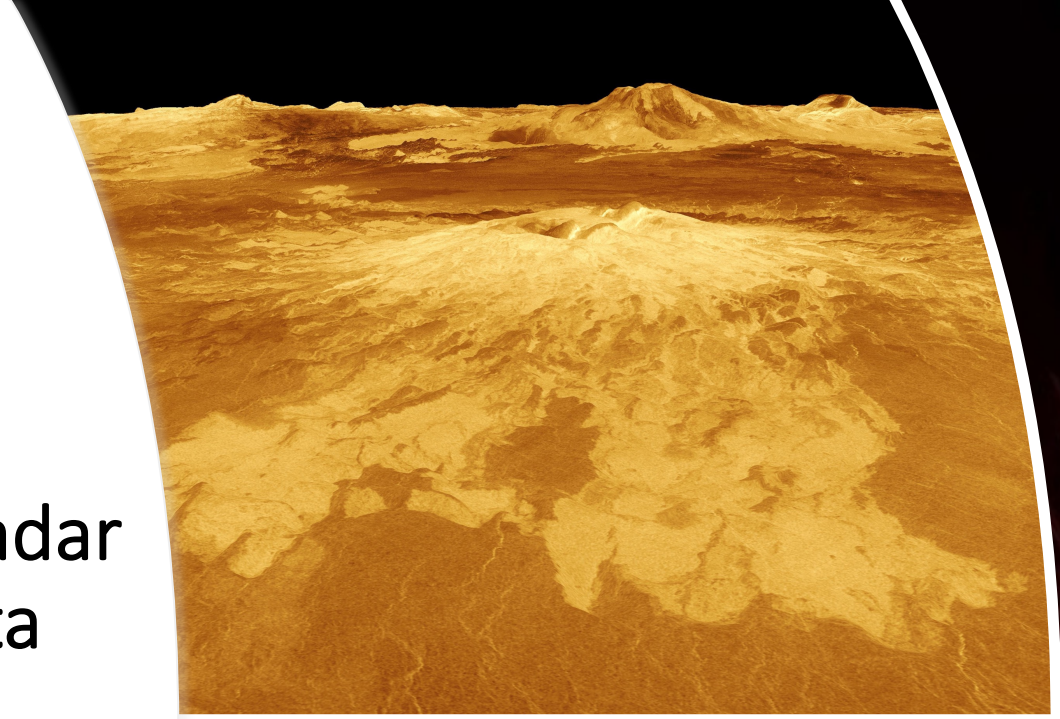

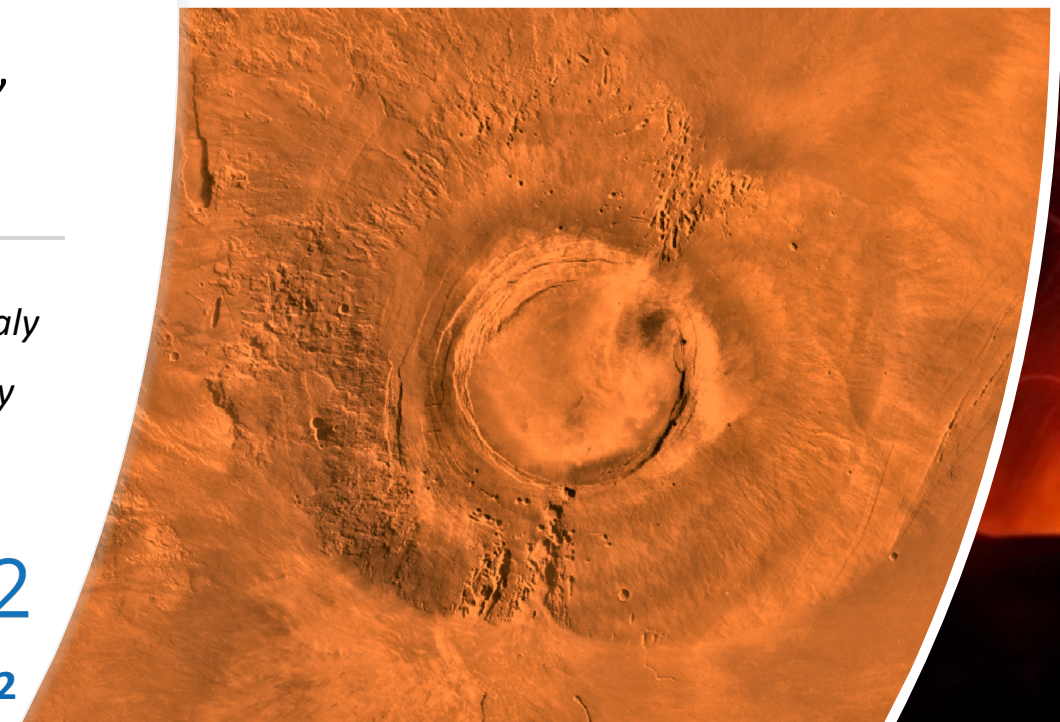

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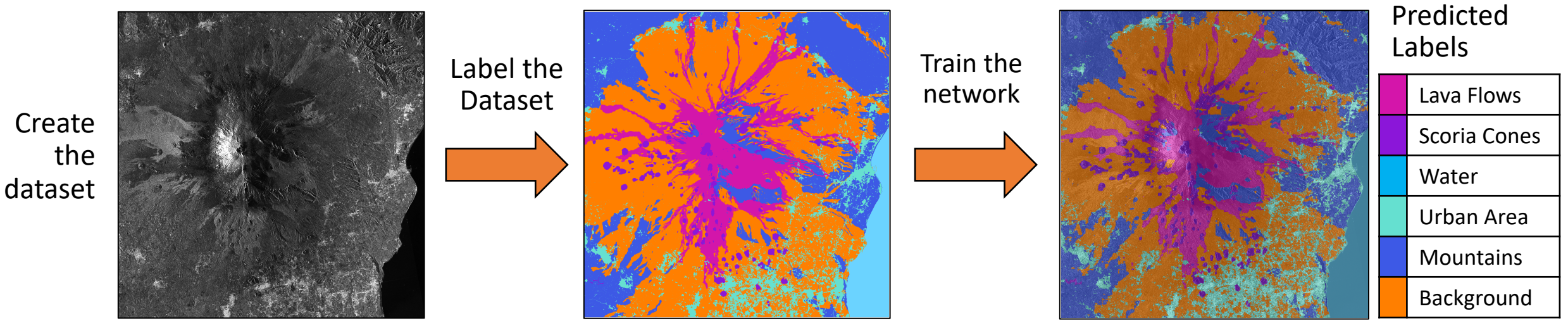
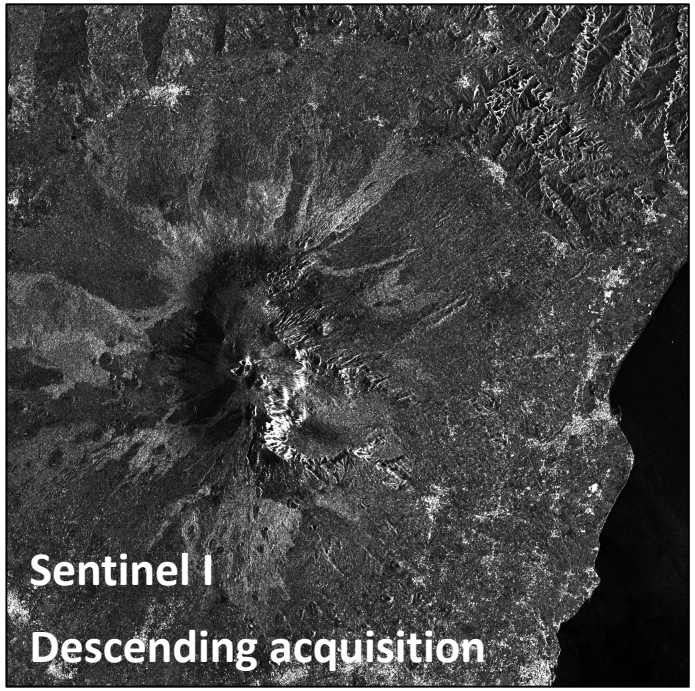
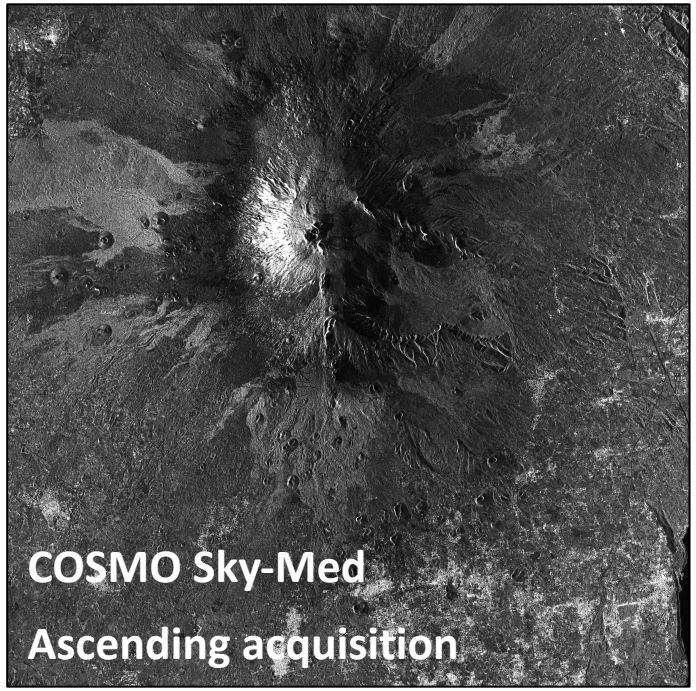
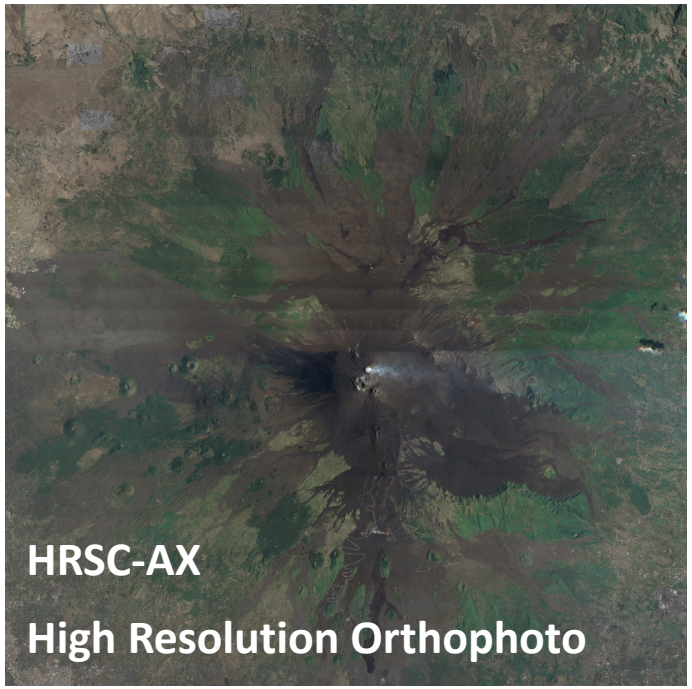
# Objectives

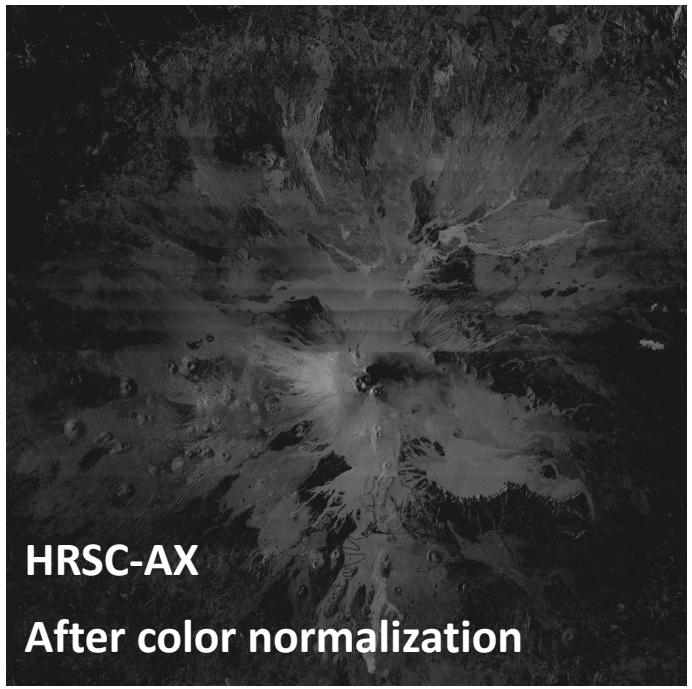
- The objective is to build a robust **method to identify volcano-tectonic morphologies** in **remote areas** and on other **terrestrial planets** (*e.g.*, Venus and Mars) based on an automatic **feature extraction algorithm** that **identifies** the most common **structures** originating from **volcano-tectonic** activities **on Earth**.
- We focus on **optical** and **Synthetic Aperture Radar** (SAR) **images** representing one of the **most tectonically** and **magmatically active zones** in the Mediterranean Sea Area, *i.e.*, **Mt. Etna**.
- We **trained** a **Machine Learning** (ML) **model** for the task of **Semantic Segmentation**, which involves assigning a class label (*e.g.*, scoria cones, lava flows) to every pixel in the image.






# Dataset and Method

The dataset includes:

- **SAR images** acquired by **COSMO Sky-Med** X-band sensor (5m resolution) and **Sentinel I** C-band sensor (2.7×22 m resolution).
- **High resolution orthophoto map**, from airborne sensor **HRSC-AX** survey of Mt. Etna [1].

Dataset preprocessing:

- **SAR data** were prepared for **backscatter intensity analysis** (multi-look registration, speckle filtering, geocoding and radiometric calibration).
- The **orthoimage** required RGB to grayscale conversion and **normalization** to be compliant with SAR colormap.

[1] Gwinner, K., Coltelli, M., Marsella, M. et al. (2006). The HRSC-AX MT. ETNA project: High-resolution orthoimages and 1 m dem at regional scale. Revue Francaise de Photogrammetrie et de Teledetection.

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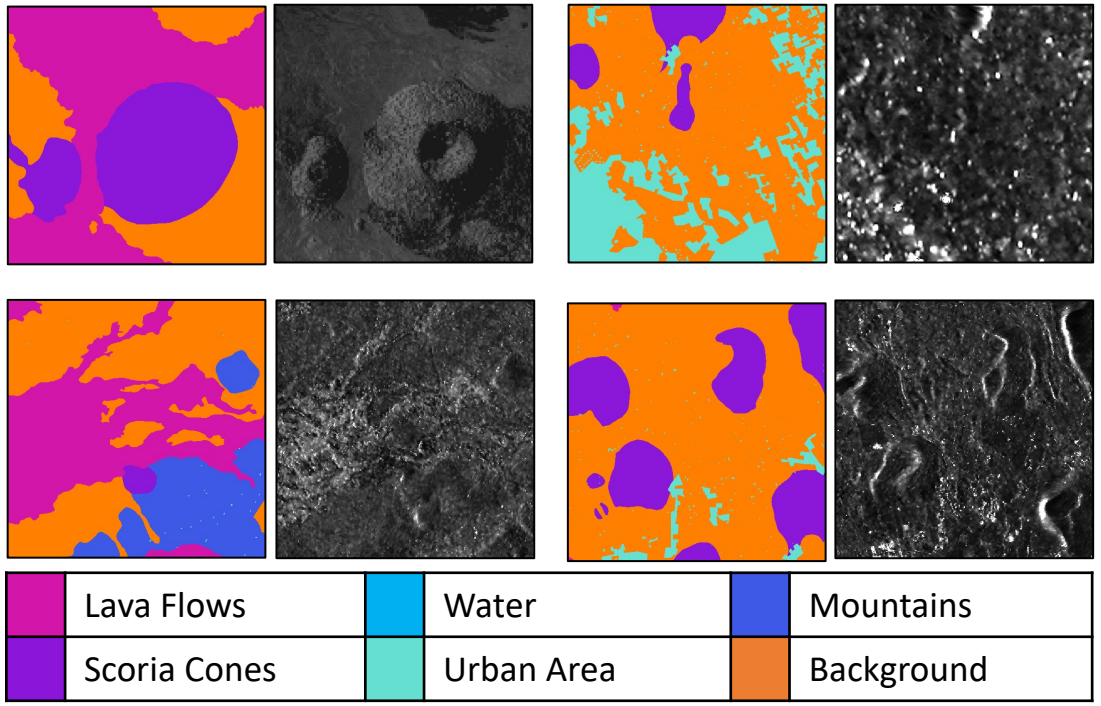
# Dataset and Method

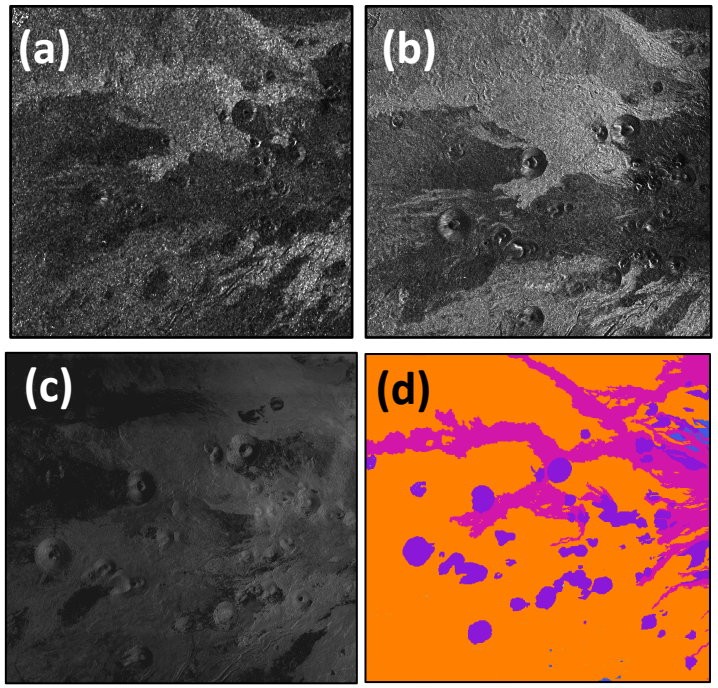
**Dataset labels** were retrieved from accurate **vector maps** representing **geological features** and **land cover maps** [2,3].

The classification algorithm recognizes 6 classes: **recent lava flows**, **scoria cones**, **urban area**, **water**, **mountains**, **background**

**Training** and **validation dataset** were created splitting the full-size images into smaller patches (512×512)

The **classification algorithm architecture** is based on a pre-trained deep learning model, **DeepLabv3+** [4] and **ResNet18** [5]. This solution leads to **high pixel accuracy** even with a small dataset (~5k patches) **using transfer learning**.




Same features represented in (a) Descending Sentinel I acquisition, (b) Ascending COSMO Sky-Med acquisition, (c) HRSC-AX product, (d) labeled image


[2] Branca, S., Coltelli, M., Groppelli, G., Lentini, F. (2011) Geological map of Etna volcano. INGV Osservatorio Etneo.

[3] CORINE Land Cover. https://land.copernicus.eu/pan-european/corine-land-cover

[4]Chen, L.-C., Zhu, Y., Papandreou, G., Schroff, F., Adam, H. (2018) Encoder-decoder with atrous separable convolution for semantic image segmentation. Proceedings of the European Conference on Computer Vision (ECCV).

[5] He, K., Zhang, X., Ren, S., Sun, J. (2015) Deep Residual Learning for Image Recognition. Computer Vision and Pattern Recognition (CVPR).

# Results

The **trained network** achieves **84.45%** of overall **pixel accuracy**.

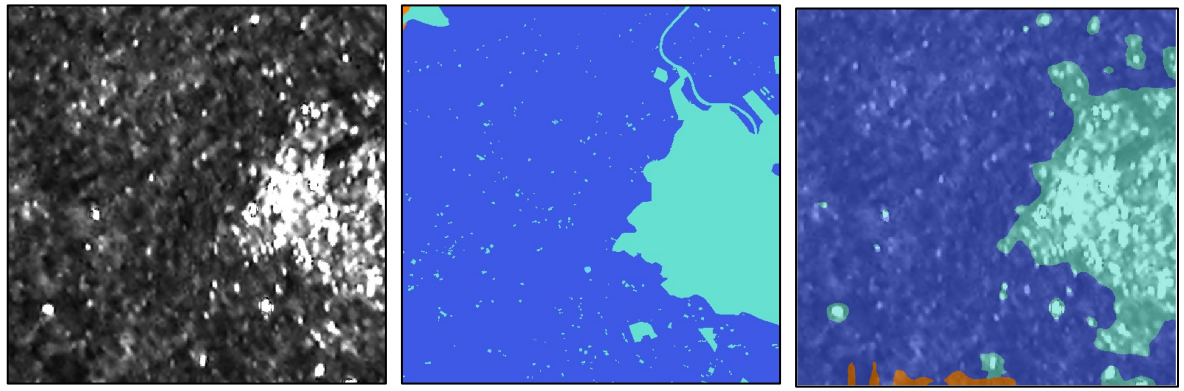
The **confusion matrix** shows that the different **classes** are **identified** with **homogeneous accuracy**.

The **predicted labels** on the validation set patches and the **ground truth match**.

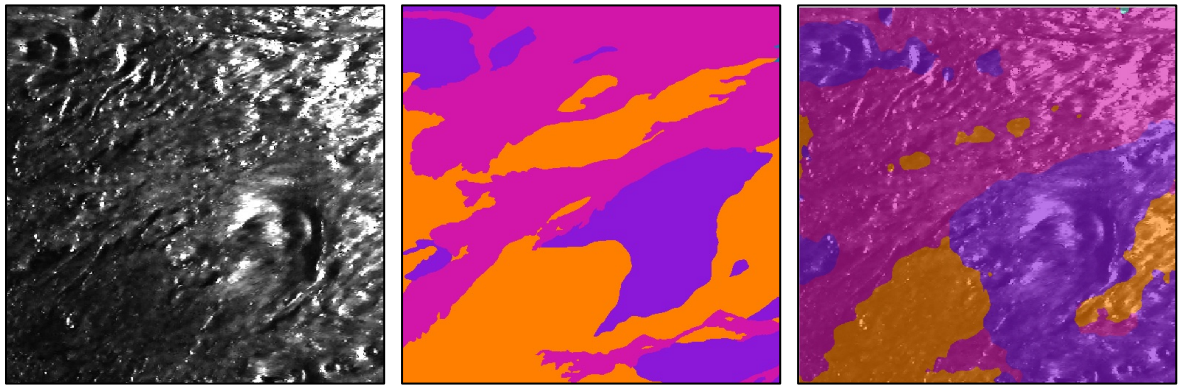
CONFUSION MATRIX

| | Lava Flows | Scoria Cones | Water | Urban Area | Mountains | Background |
|---|---|---|---|---|---|---|
| **Lava Flows** | 85.025% | 3.321% | 0.0020% | 0.703% | 2.534% | 8.417% |
| **Scoria Cones** | 2.602% | 88.971% | 0.0001% | 0.393% | 3.405% | 4.628% |
| **Water** | 0.007% | 0.048% | 97.916% | 0.431% | 1.276% | 0.320% |
| **Urban Area** | 0.376% | 0.202% | 0.077% | 88.719% | 4.234% | 6.394% |
| **Mountains** | 0.992% | 1.329% | 0.098% | 3.593% | 86.144% | 7.873% |
| **Background** | 3.694% | 2.113% | 0.021% | 6.695% | 5.424% | 82.053% |

Ground Truth Predicted Labels

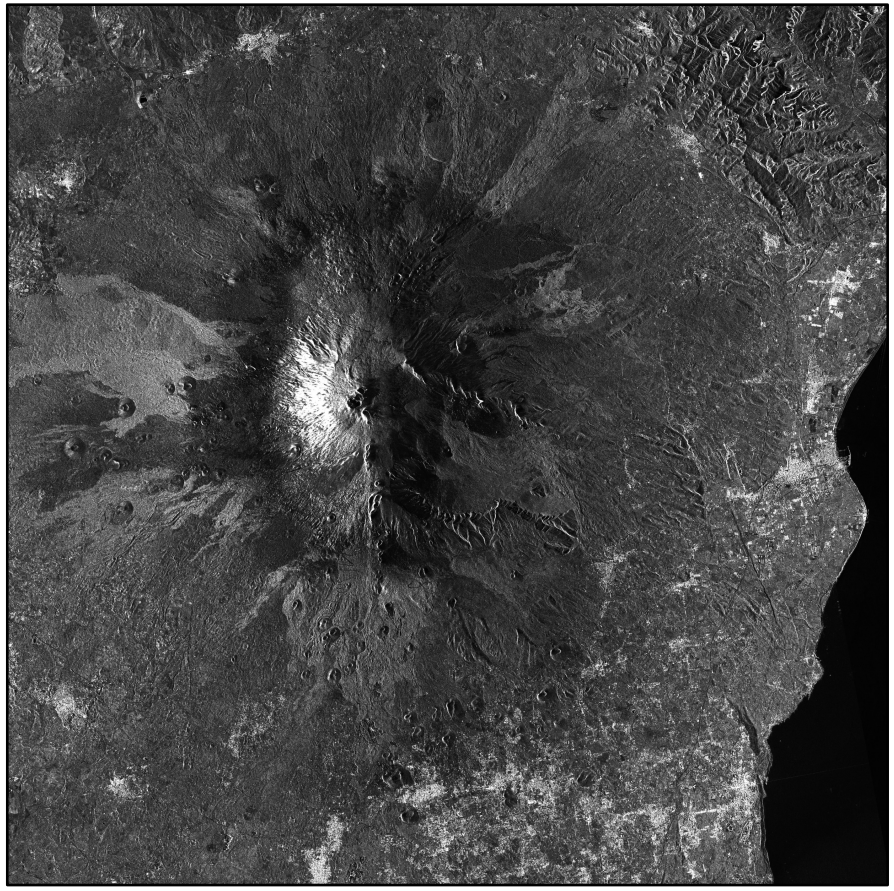


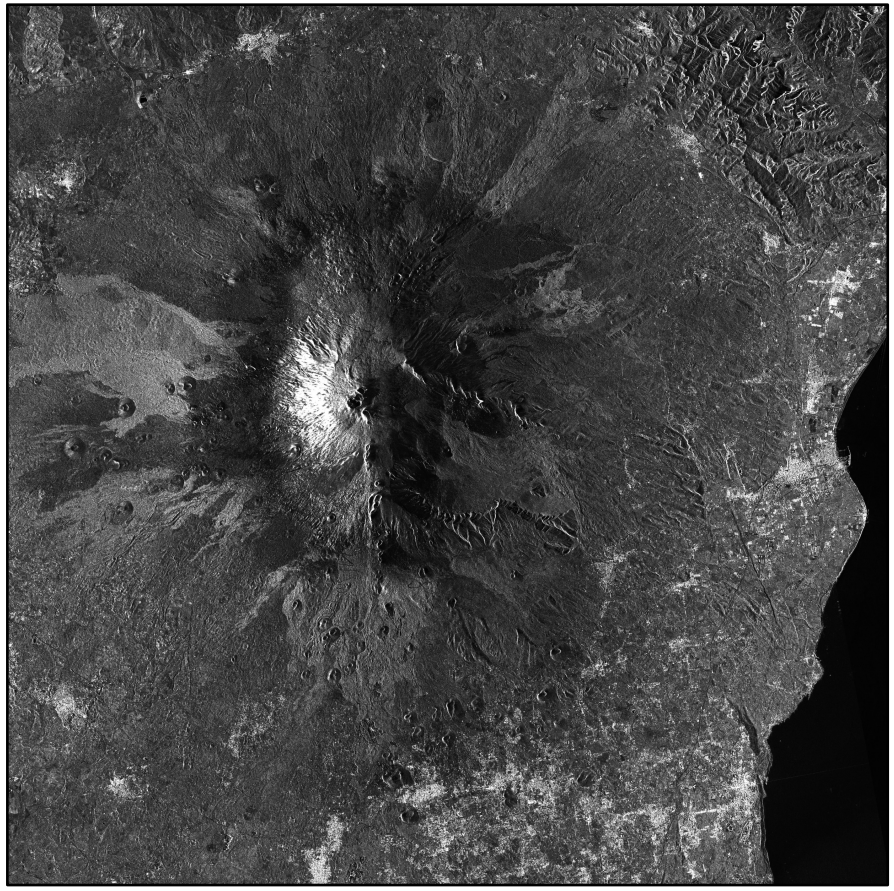
Ground Truth Predicted Labels



# Results

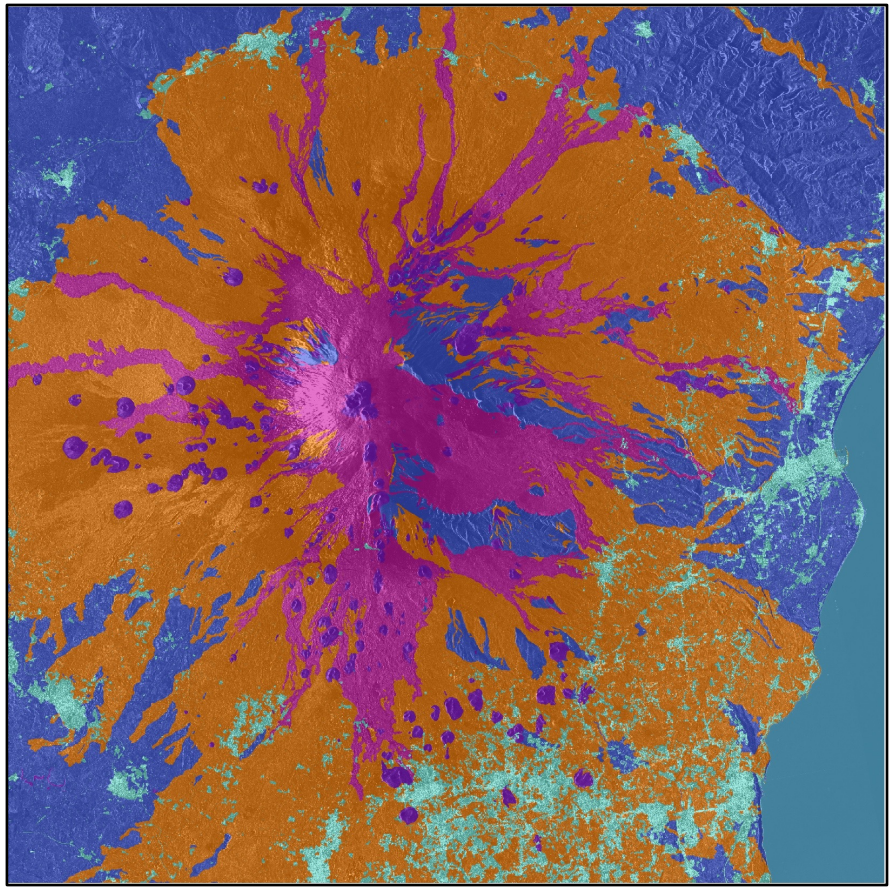
COSMO Sky-Med Descending Acquisition



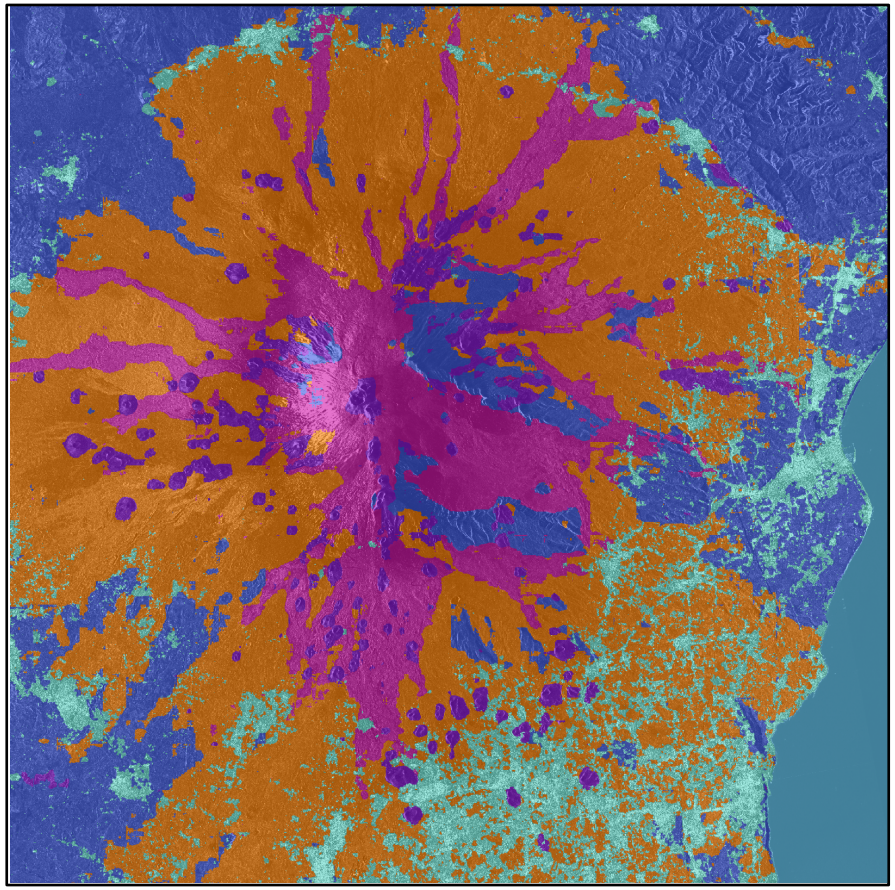


# Results

Ground Truth



Predicted Labels



| Lava Flows | Water | Mountains | Scoria Cones | Urban Area | Background |
|---|---|---|---|---|---|

# Summary and Future Work

**Remote sensing** data is **fundamental** for the monitoring and **survey** of harsh and **remote regions**, *e.g.*, extremely **active volcanic areas**.

Our work suggests that **Machine Learning** models are a valuable **instrument** for **processing** large amount of **data** and **detecting volcano-tectonic features**.

The **results** show that the selected **algorithm DeepLabv3+** achieves **overall pixel accuracy of 84.45%** for the segmentation task.

The **next objective** is to **extend** the **training set, compare** different **architectures** and **validate** the method processing **different regions** of interest.

The **network** trained to recognize Earth's features **will be adapted to detect volcano-tectonic morphologies** on **Venus** and **Mars** exploiting data from space missions, *e.g.*, **Magellan** and **MRO**.