Convolutional Neural Network Detections of Strombolian Eruptions at Mount Erebus, Antarctica

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Collaborators:

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Leila Honarbakhsh (UL Graduate student)

Machine Learning

1. **Machine Learning (ML)** is a Data-driven broad family of statistical techniques for automatically detecting patterns in data. In ML, **the structure of the data**, rather than on physical models, directs research.

2. ML methods are divided **into supervised and unsupervised learning**. In supervised learning, one builds a mapping from inputs to outputs given labeled I-O pairs. Categorical labels are used for classification. Scalar labels are used in regression. In unsupervised learning, no labels are given.

3. The **features** in the data are fundamental to ML methods. Many techniques are used to determine them (e.g. Principle Component Analysis (PCA), Deep neural networks (NN)). Identifying features, allow **Deep Learning**.

4. However: in ML models often the **interpretation can remain hidden**. ML models require significant amounts of **training data.**

5. **Python and Jupyter Notebooks** have a central role in the development of these techniques.

Machine Learning

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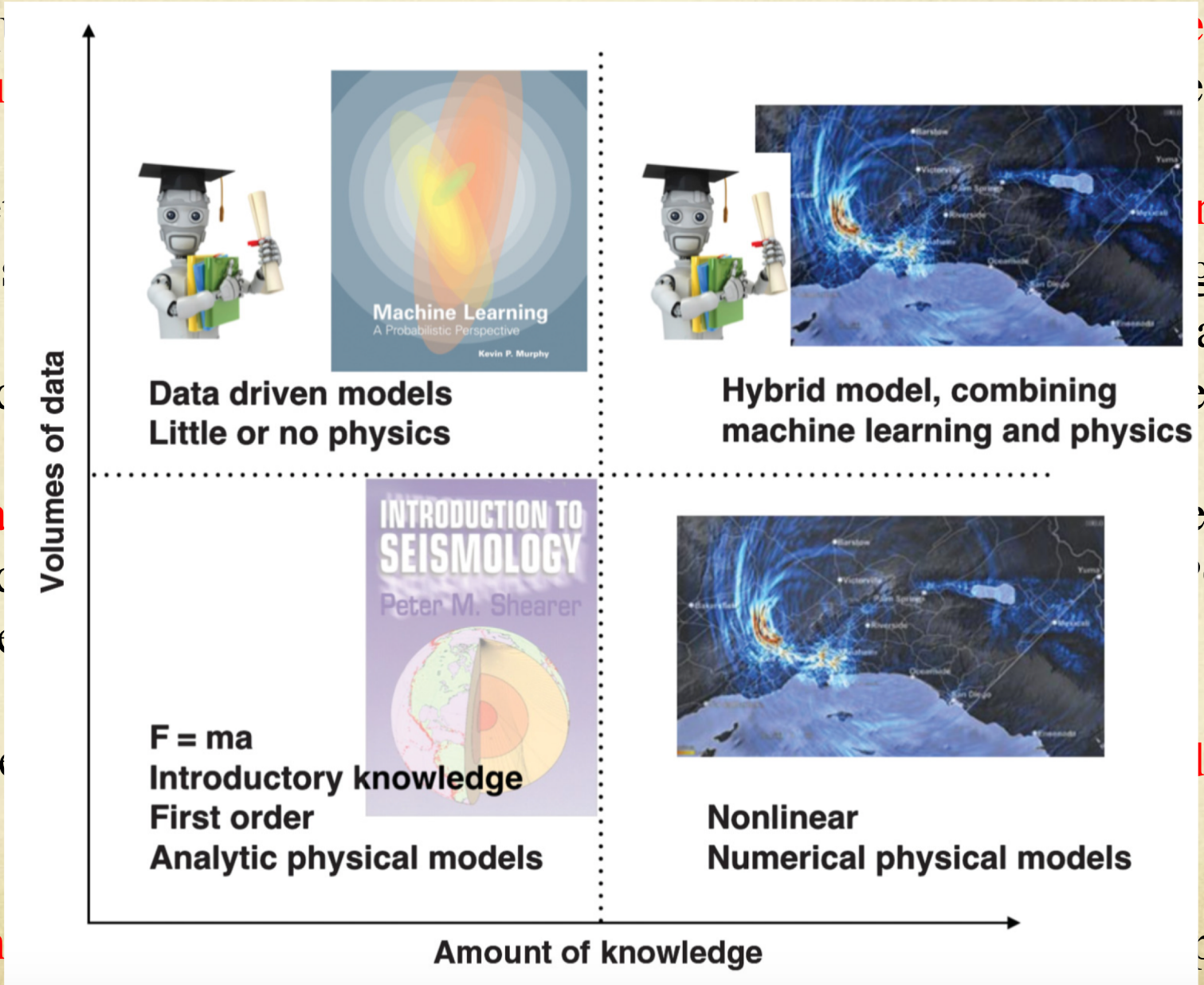
2. ML me… …**ning**. In supervi… …given labeled … …alar labels are used … …n.

3. The **fea**… …chniques are used … …CA), Deep ne…

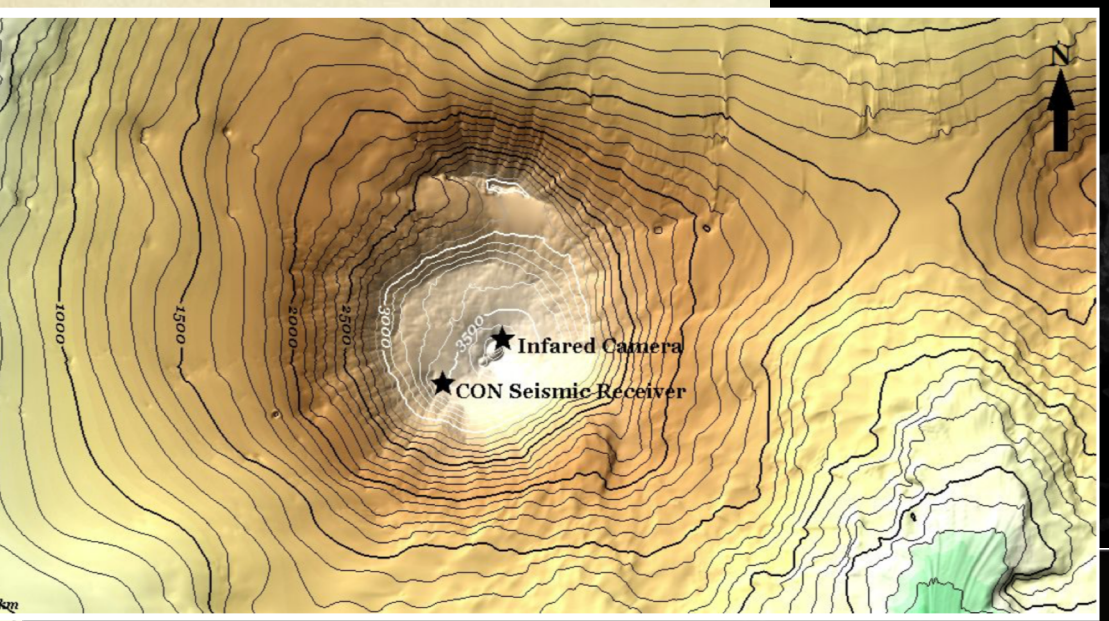
4. Howeve… …**lden**. ML models …

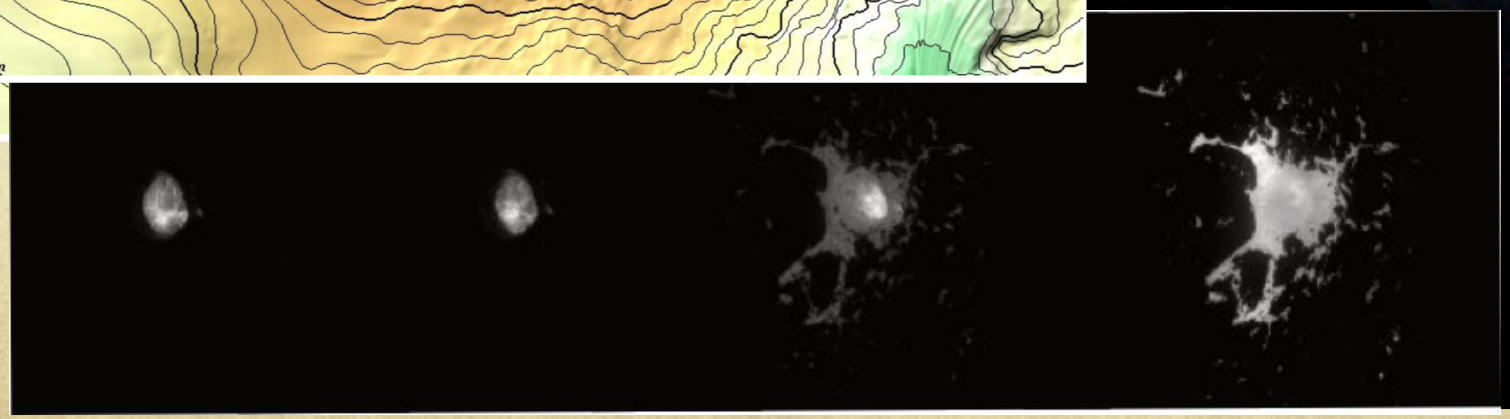
5. **Python** … …oment of these techniques.



Deep Learning of IR images of Erebus

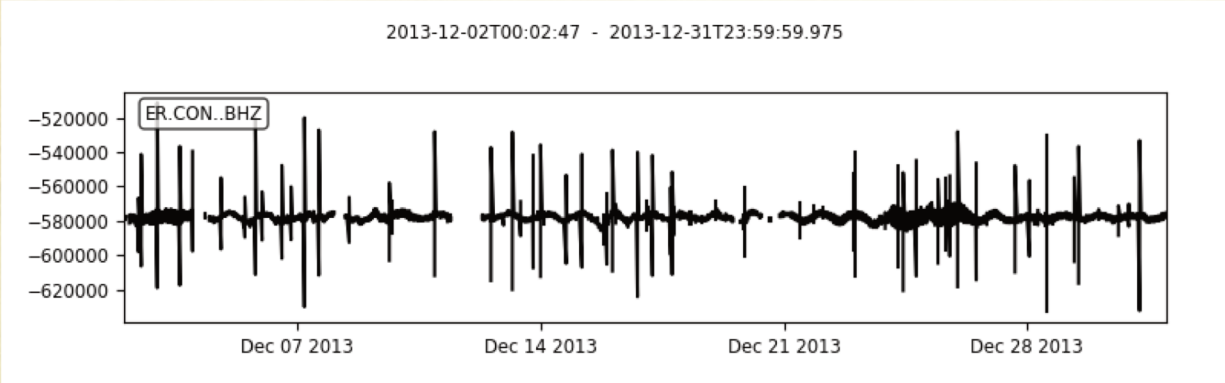
Brian Dye was my first student to ask to work on Machine Learning. We set up a project on detecting eruptions from infrared images taken every 2s from the rim of the Erebus volcano. Camera installed and data collection by Nial Peters (Cambridge).



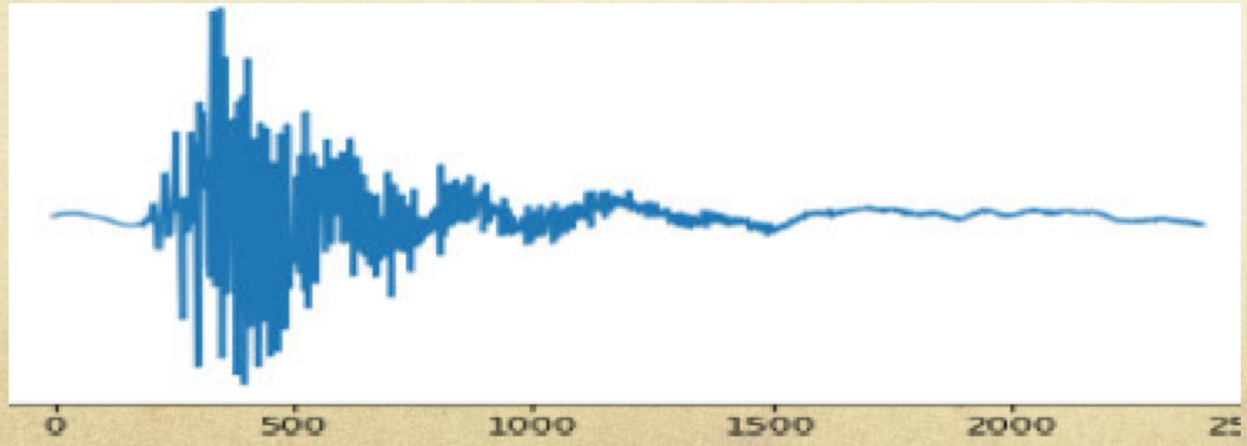


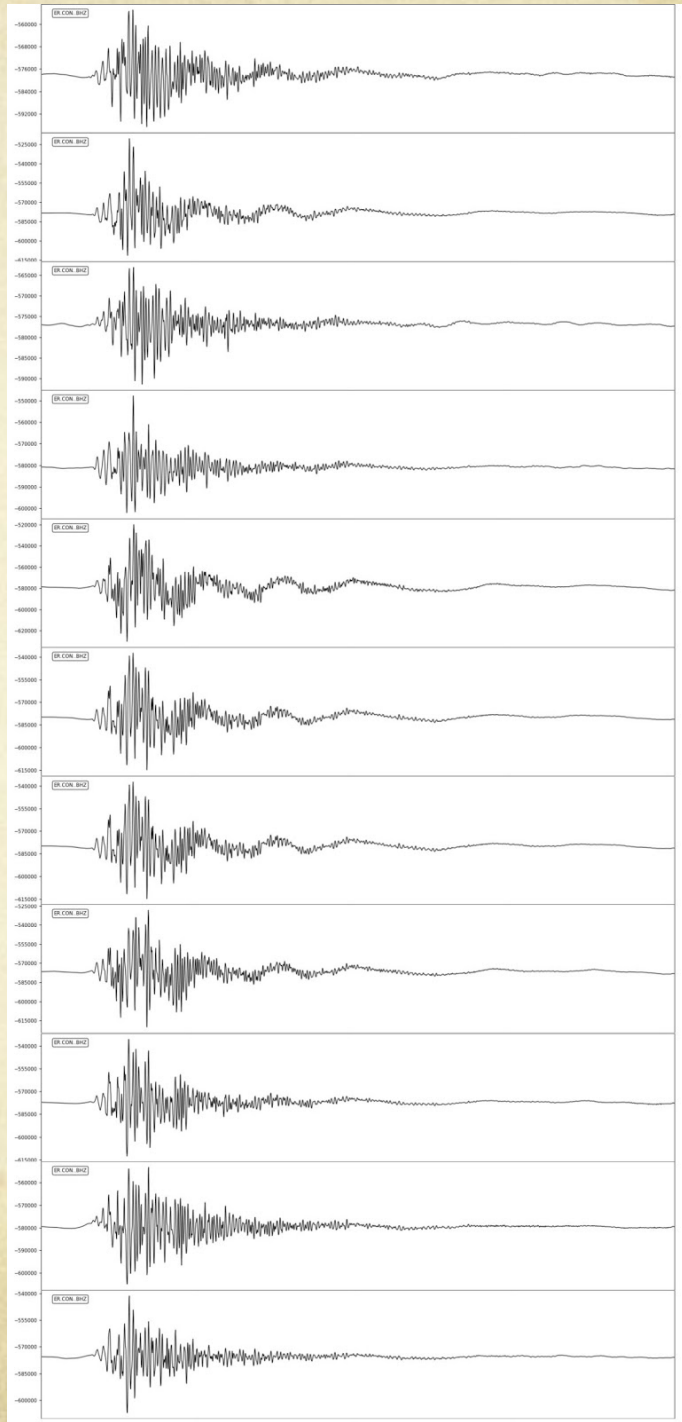
Large eruptions have a seismic signature

- Seismic data gathered using ObsPy. Three-component seismic station at 40Hz



- A master signal is built by stacking 11 manually detected events to be cross-correlated with the seismic signal.

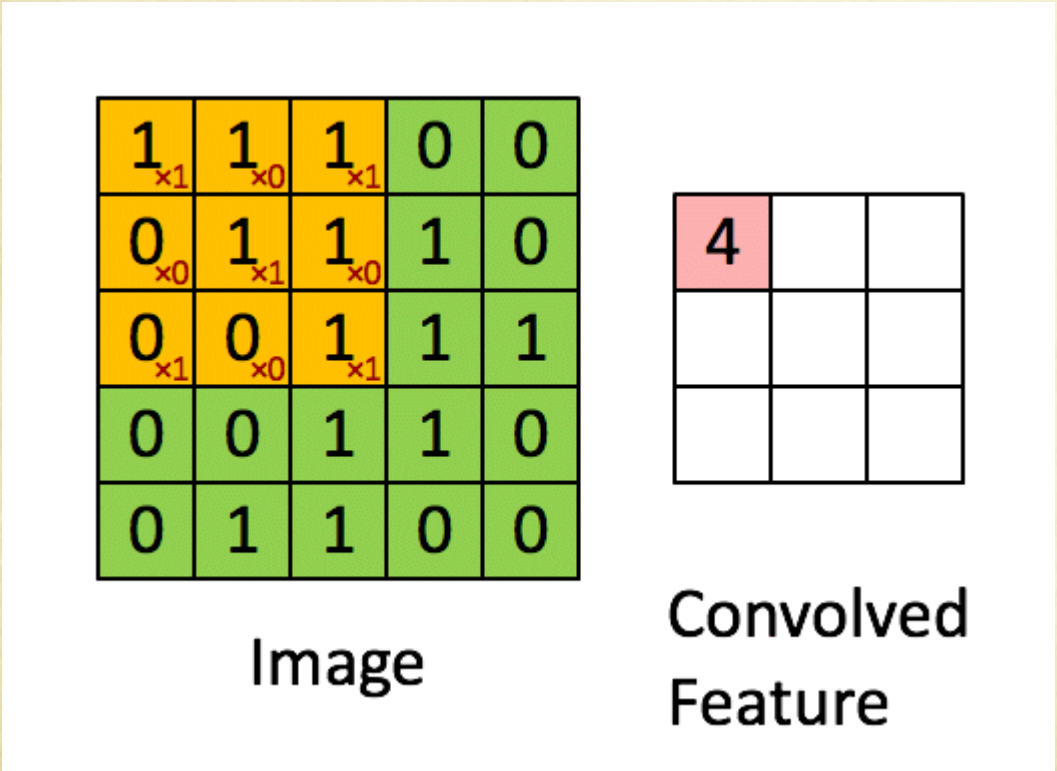


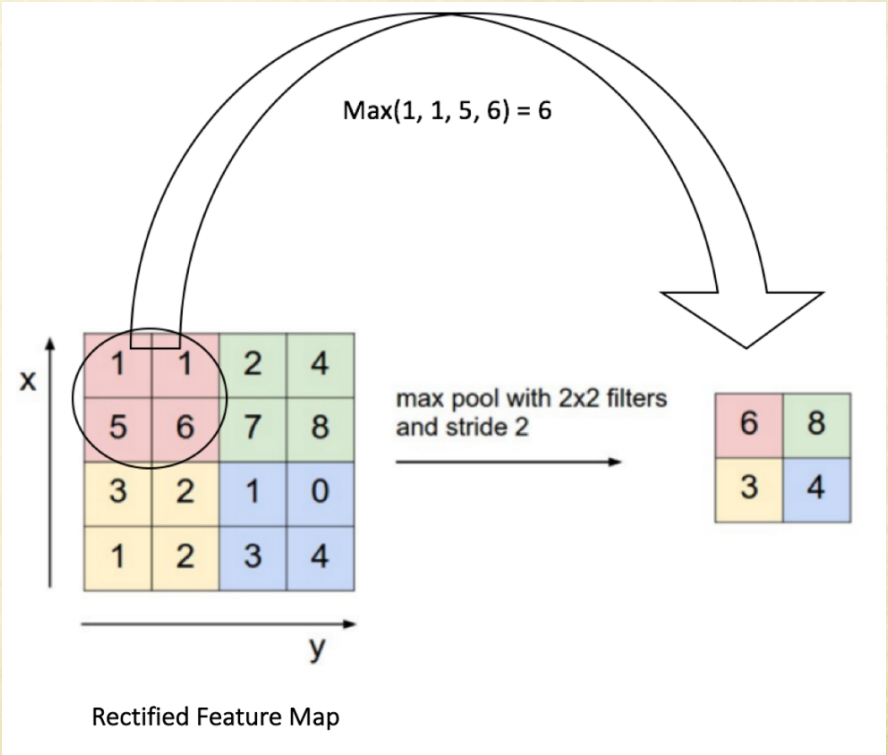


What are Convolutional Neural Networks

CNN is a combination of different algorithms that work well together.

1) Convolution.
2) Rectified Linear Unit (ReLU)
3) Pooling
4) Fully Connected Layers





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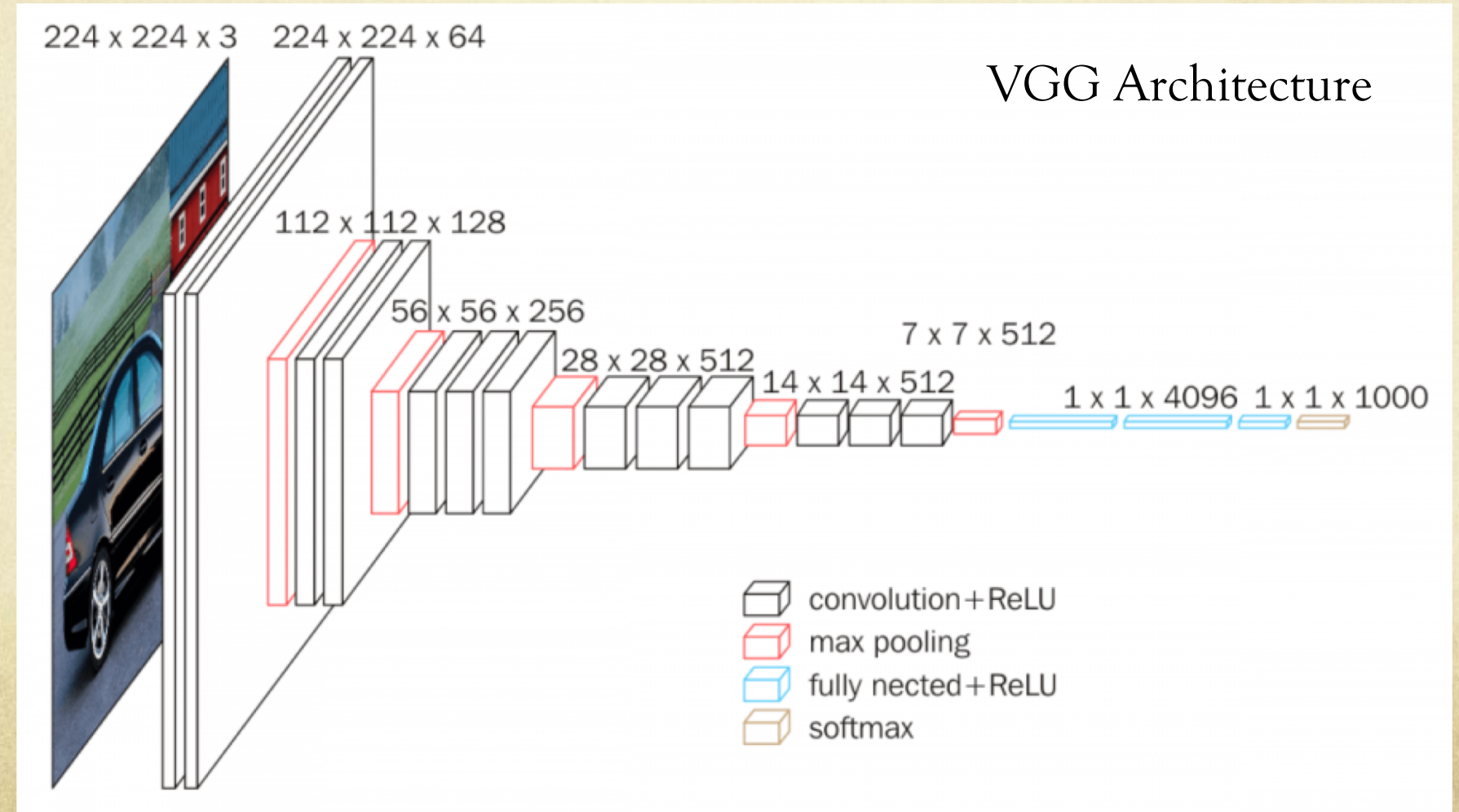

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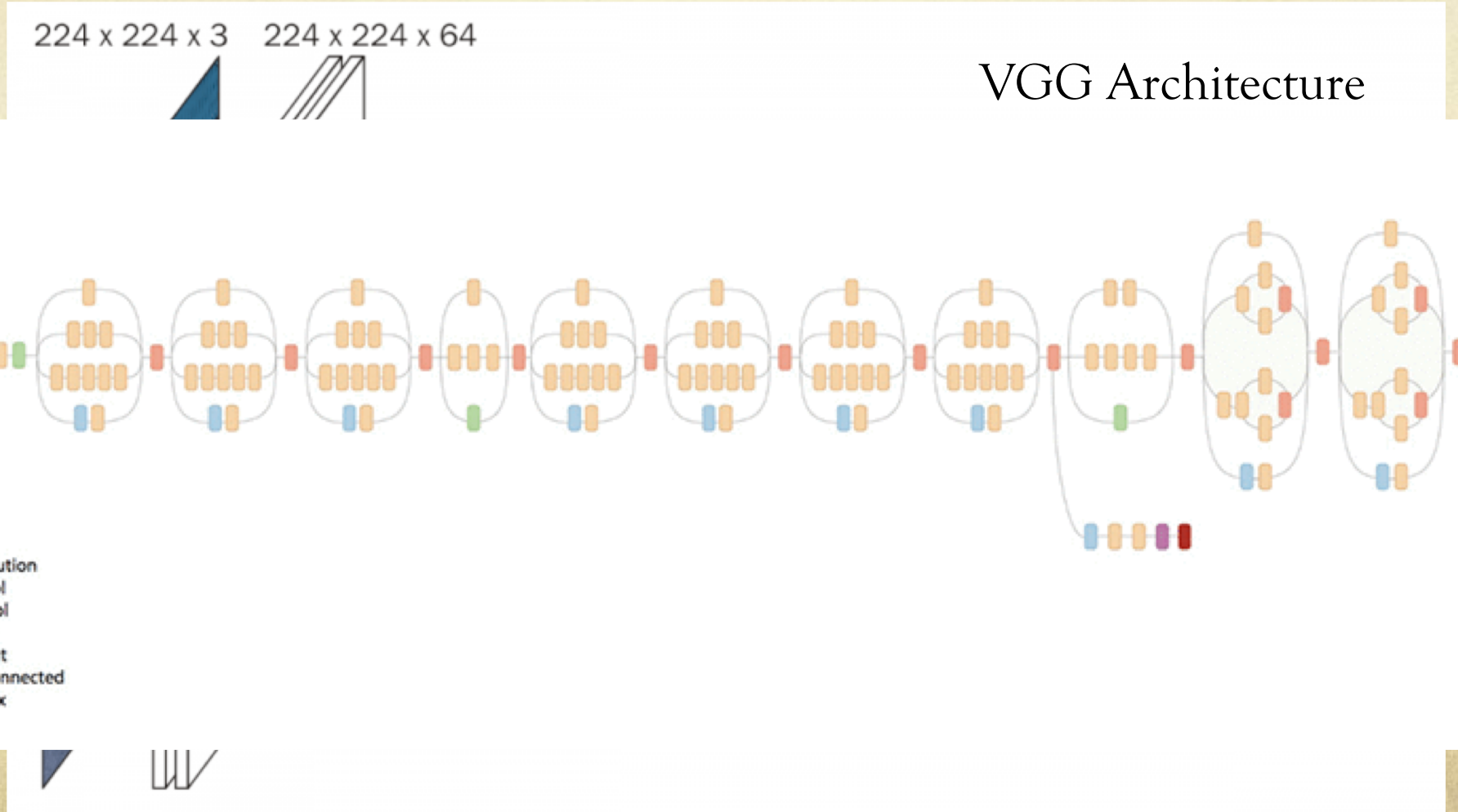
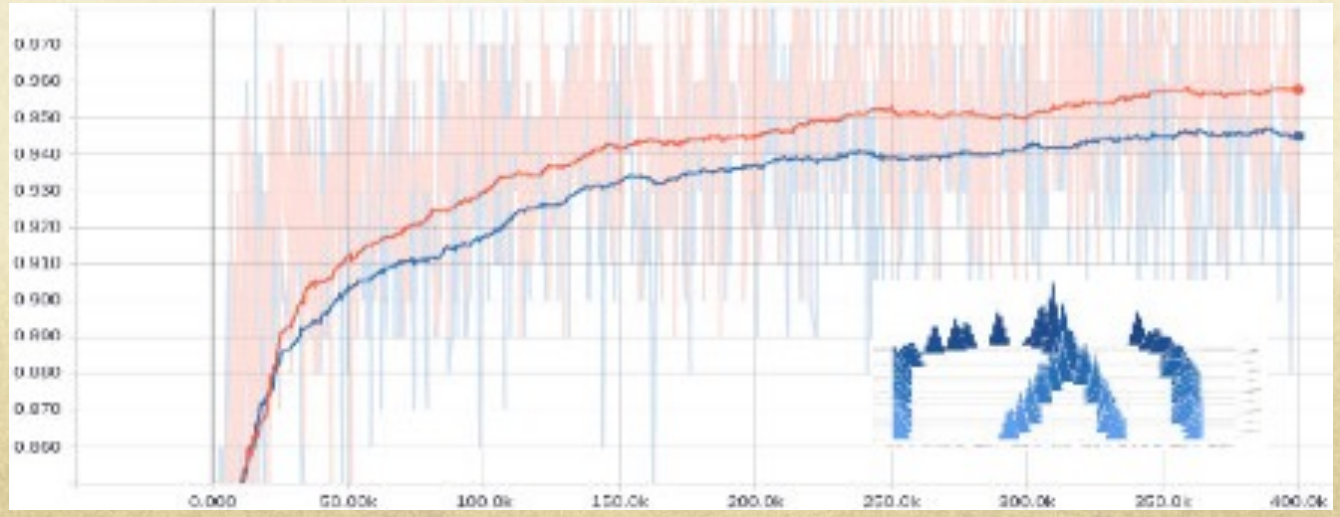
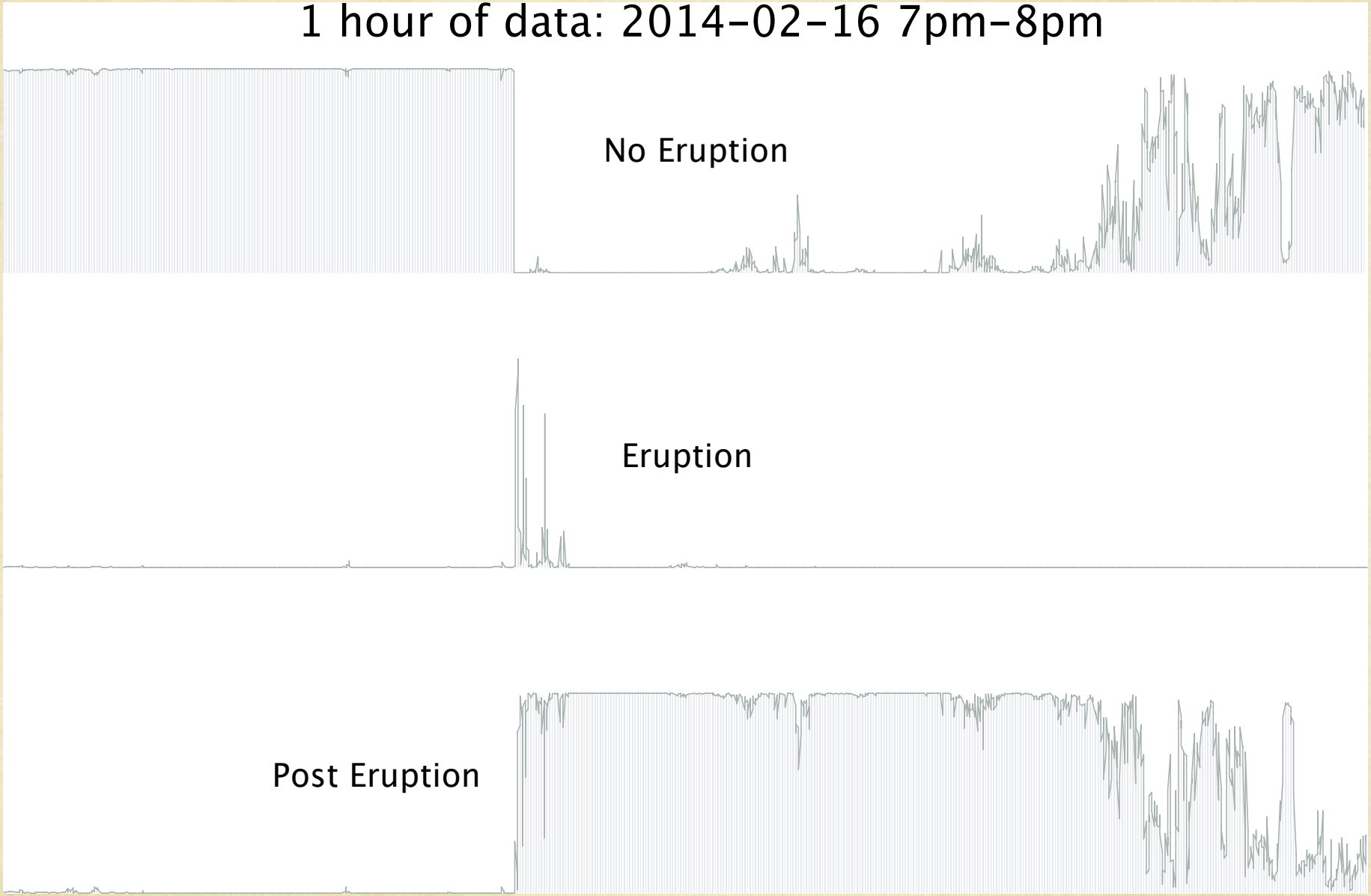


CNN training Images from seismic CC

- Automatic image aggregator to train the Machine Learning tool:
  - No Eruption – From 35 to 30 minutes before the eruption;
  - Pre Eruption – from 5 minutes to 10 seconds before eruption;
  - Eruption – 8 seconds of the eruption (5 images);
  - Post Eruption – 5 minutes from 5 minutes after eruption
- Retrain the final layer of a pre-trained network from the ImageNet set.
- 400,000 training steps were performed with 100 images per training cycle from a cumulative total of approximately 65,000 images.
- We repeated it using PyTorch with only 11 layers, using the VGG architecture.

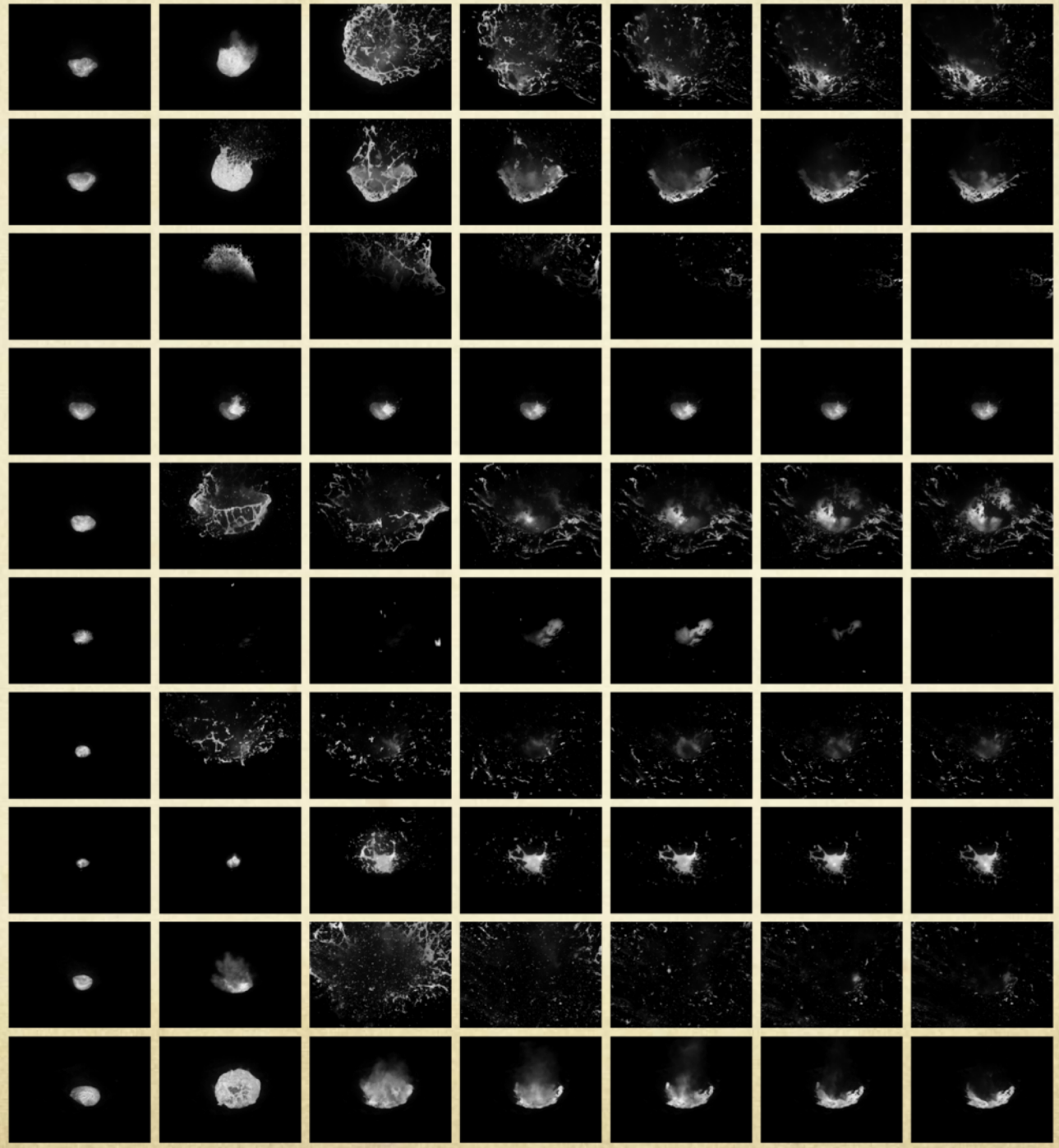


Machine Learning from Images

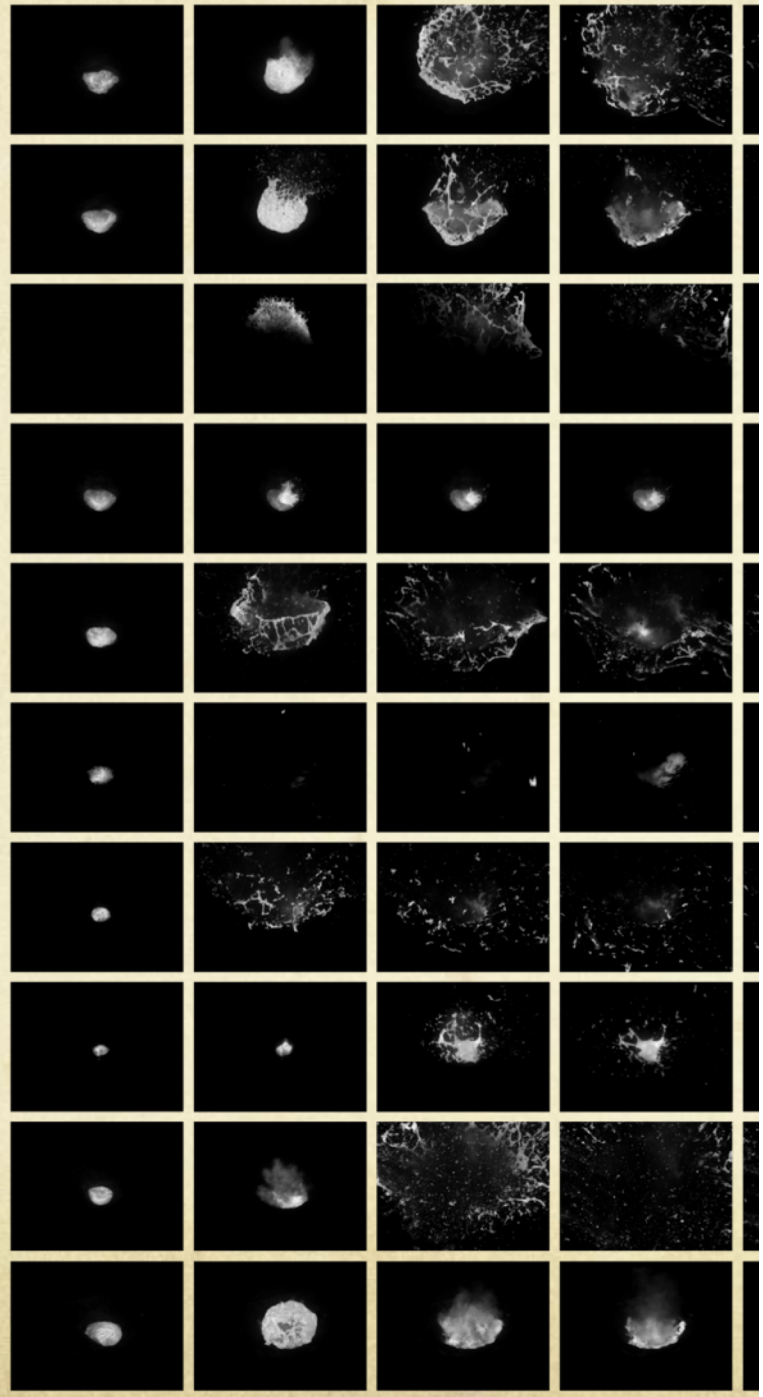


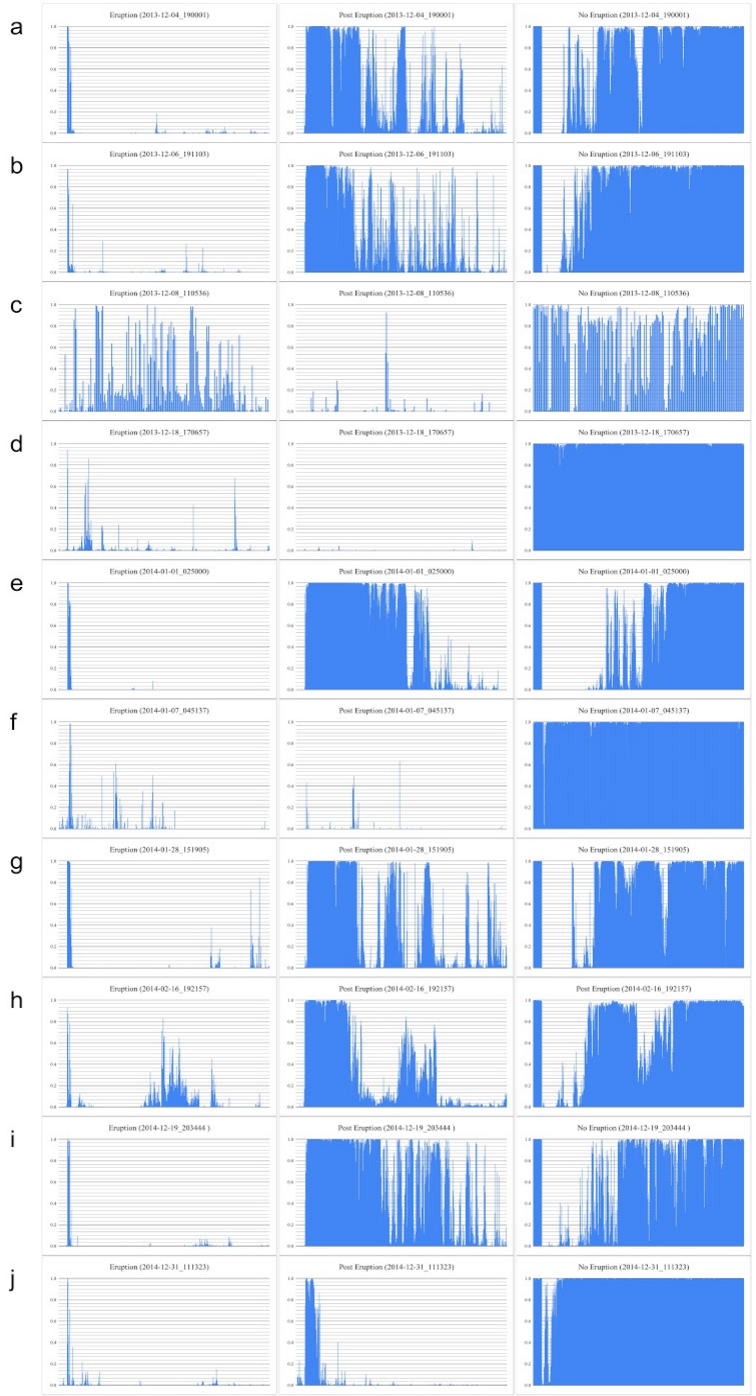
Pre-eruption was not successful. No-eruption and pre-eruption are interchangeable. Instead Eruption and Post-eruption is very clear.

Variety of detected eruptions

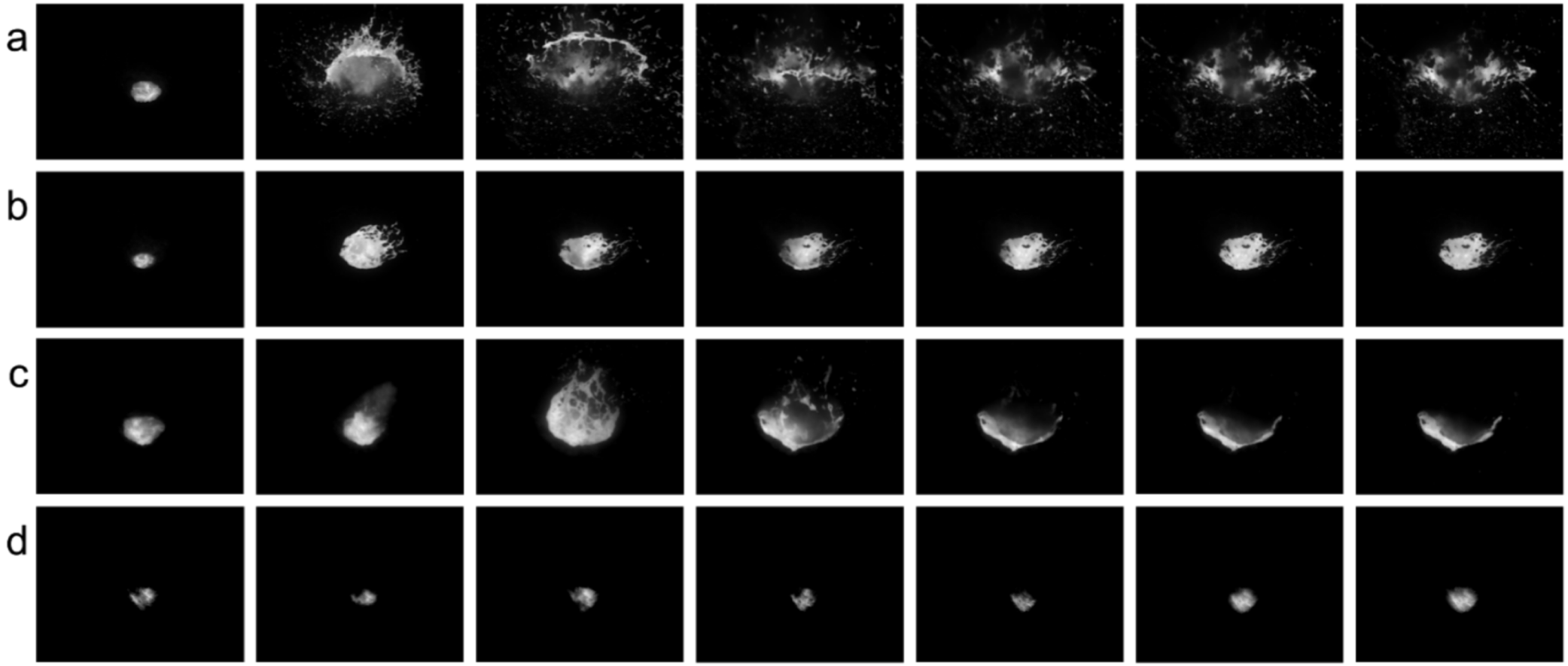


Variety of detected eruptions



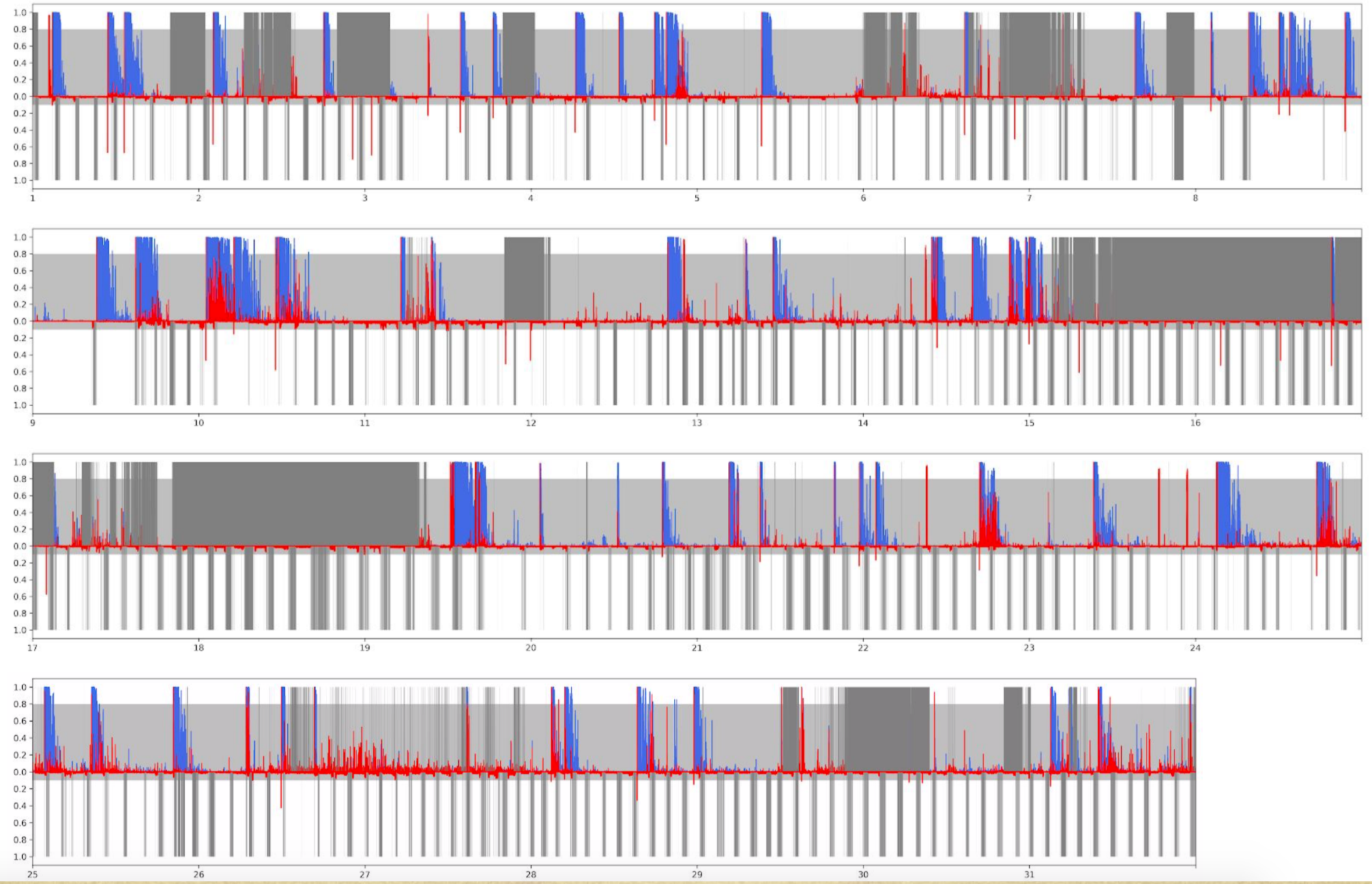


Fundamental cases



Time sequence of detection examples:
a – Typical large eruption
b – Small eruption detected by neural network but not within seismic cross-correlation threshold
c – Plume obscured image likely causing missed detected
d – Plume caused false positive

Comparison seismic and ML



Clustering of the ML outcome

Including Instrument Downtime

Machine Learning of Infrared Images

	Predicted Event	Predicted Non-Event
Actual Event	69	3
Actual Non-Event	18	---

Seismic Cross-Correlation

	Predicted Event	Predicted Non-Event
Actual Event	47	5
Actual Non-Event	0	---

Only Instrument Uptime

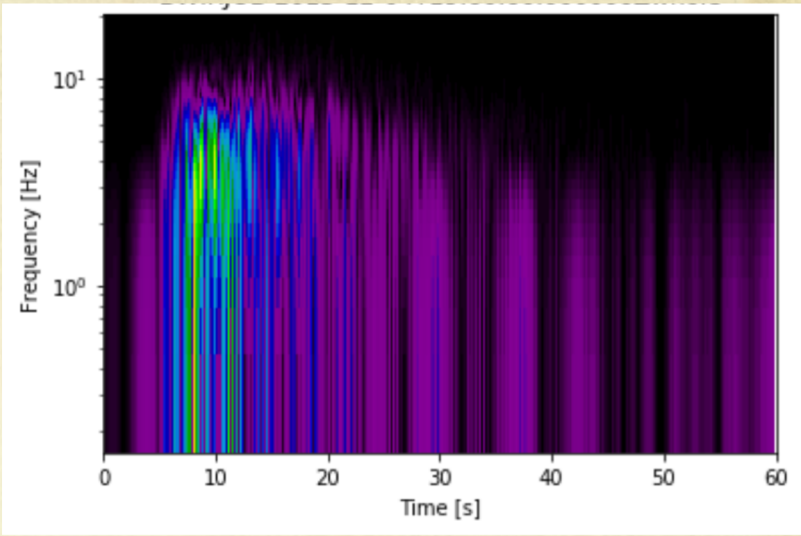
Machine Learning of Infrared Images

	Predicted Event	Predicted Non-Event
Actual Event	39	3
Actual Non-Event	18	---

Seismic Cross-Correlation

	Predicted Event	Predicted Non-Event
Actual Event	37	5
Actual Non-Event	0	---

Discussion and Conclusion

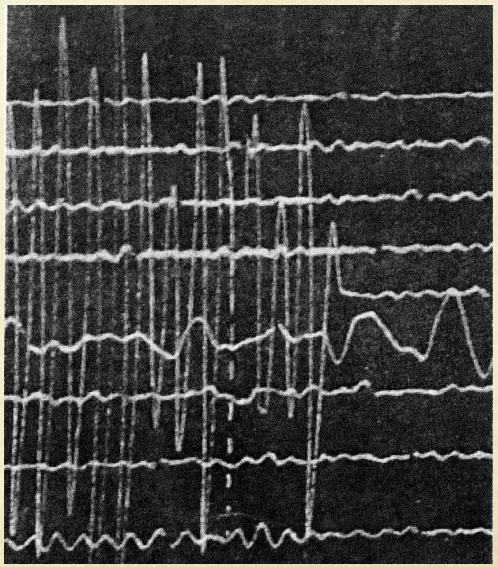


1. **Deep Learning (NN)** is able to categorize IR images, identify eruptions. However deep learning requires large training datasets.

2. We experiment NN of **spectrograms**.

3. **Legacy seismic data can help to create large training datasets** that are necessary for training NN.

4. NN are particularly effective on images and might allow to analyze **Legacy Seismic Data** avoiding digitization altogether.



Unsupervised and Supervised Machine Learning in Seismology and Volcanology

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Taylor Privat (UL Undergraduate student)

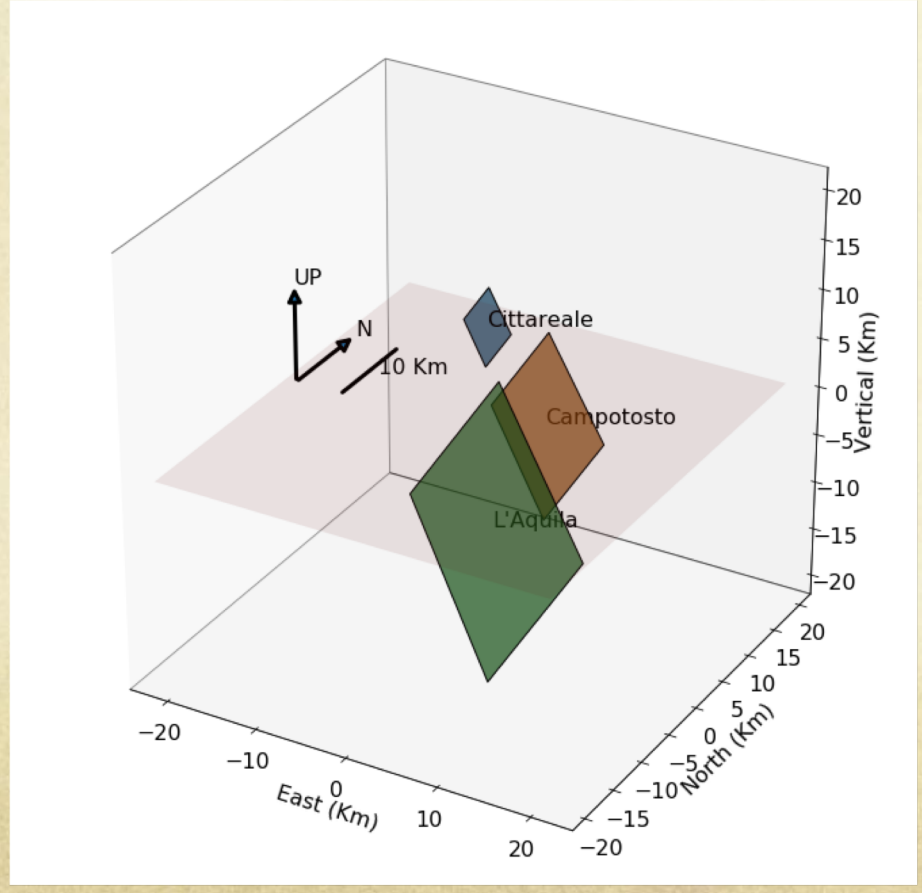
Brian Dye (Former UL master student, now at EPA)

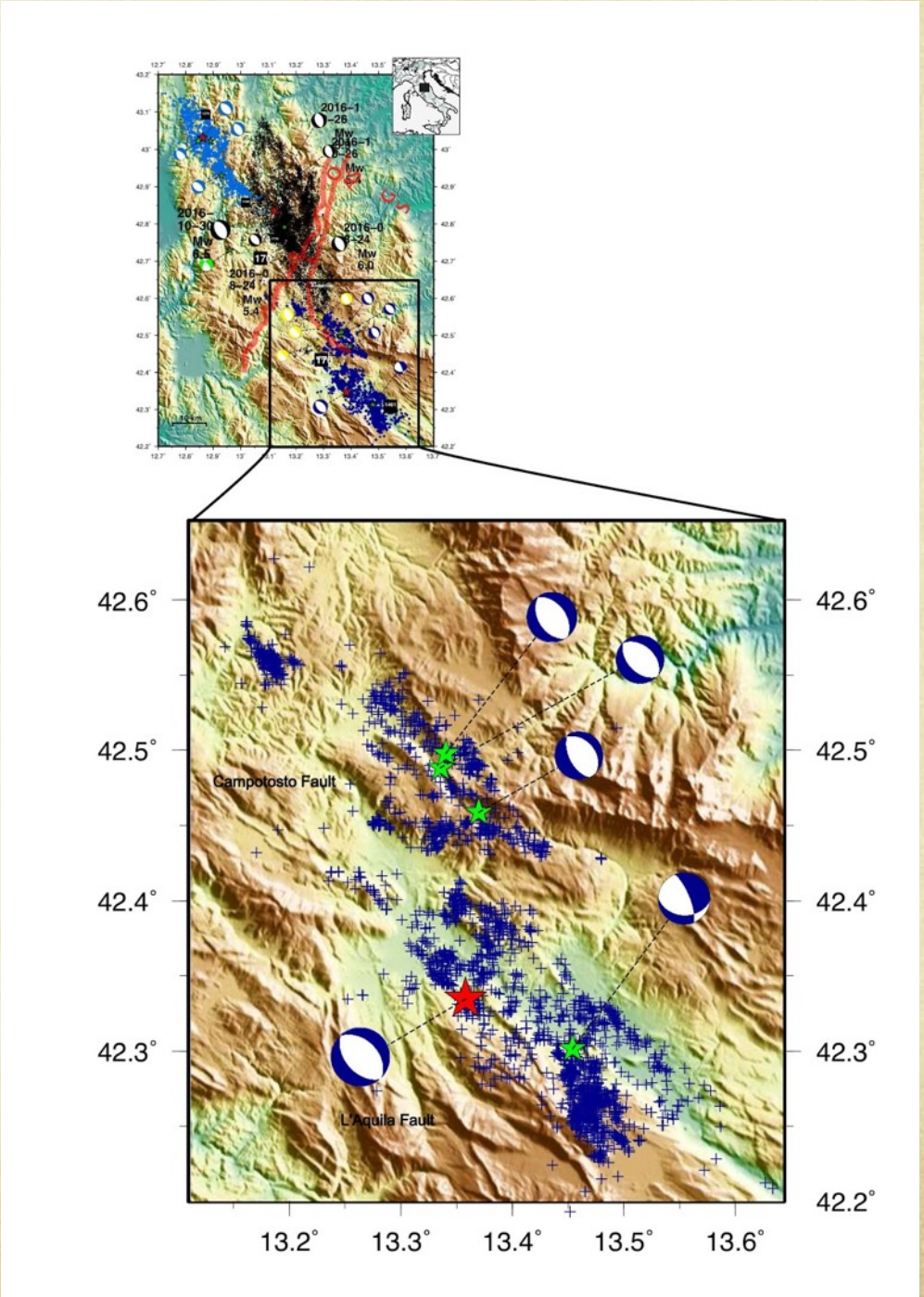
Leila Honarbakhsh (UL Graduate student)

Brennan Brunsvik (Former UL master student, now at UCSB)

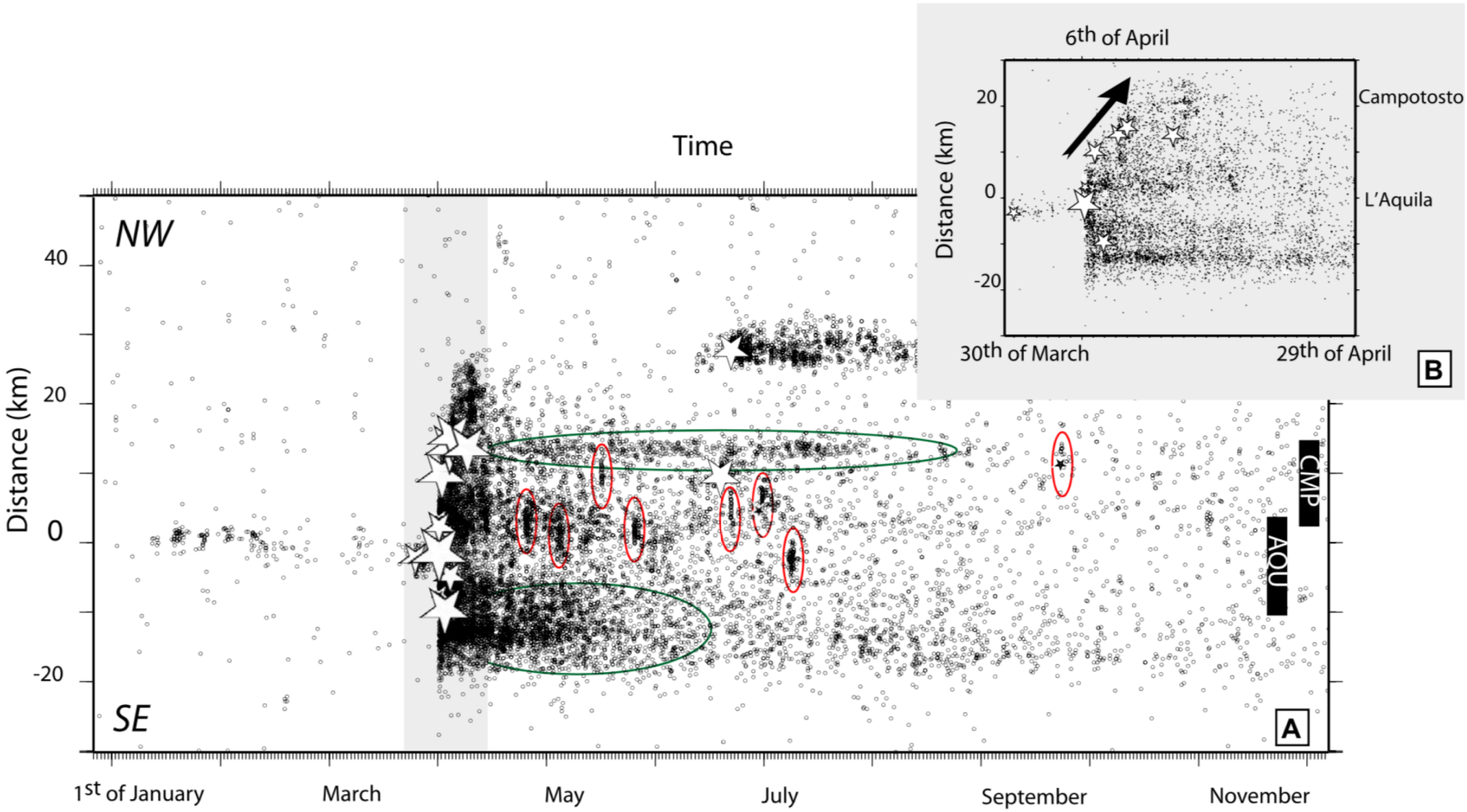
Automatic 3D Fault Reconstruction

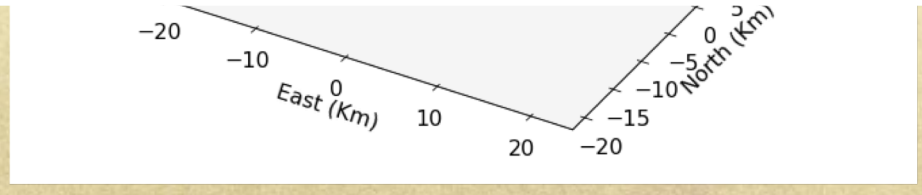
Brennan and I started to work in the Fall 2017 on the seismicity in central Italy in 2009, the year of L'Aquila earthquake.

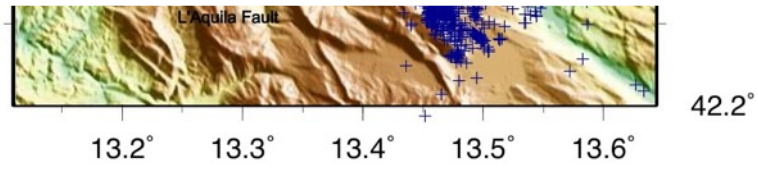


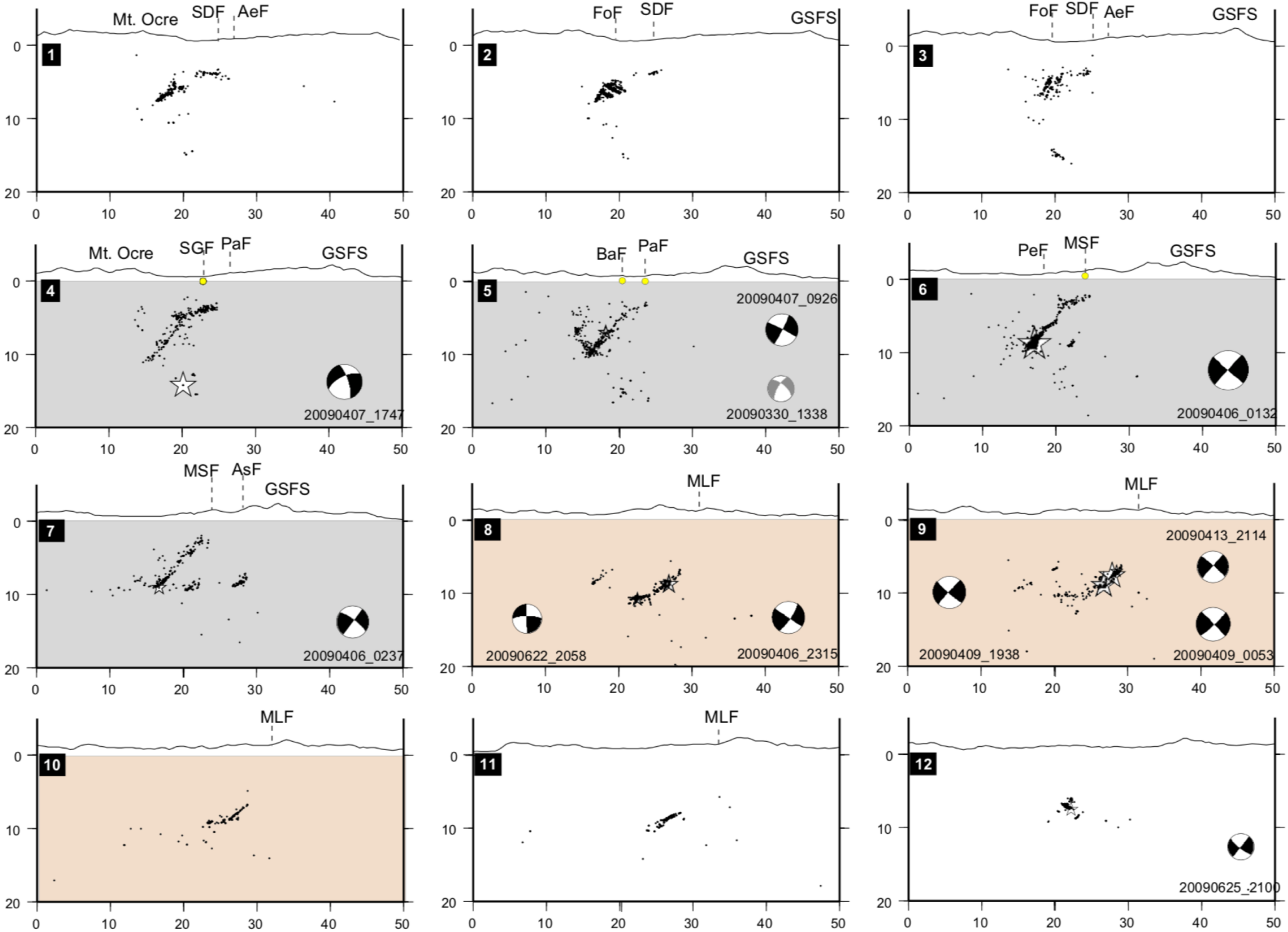


The data challenge





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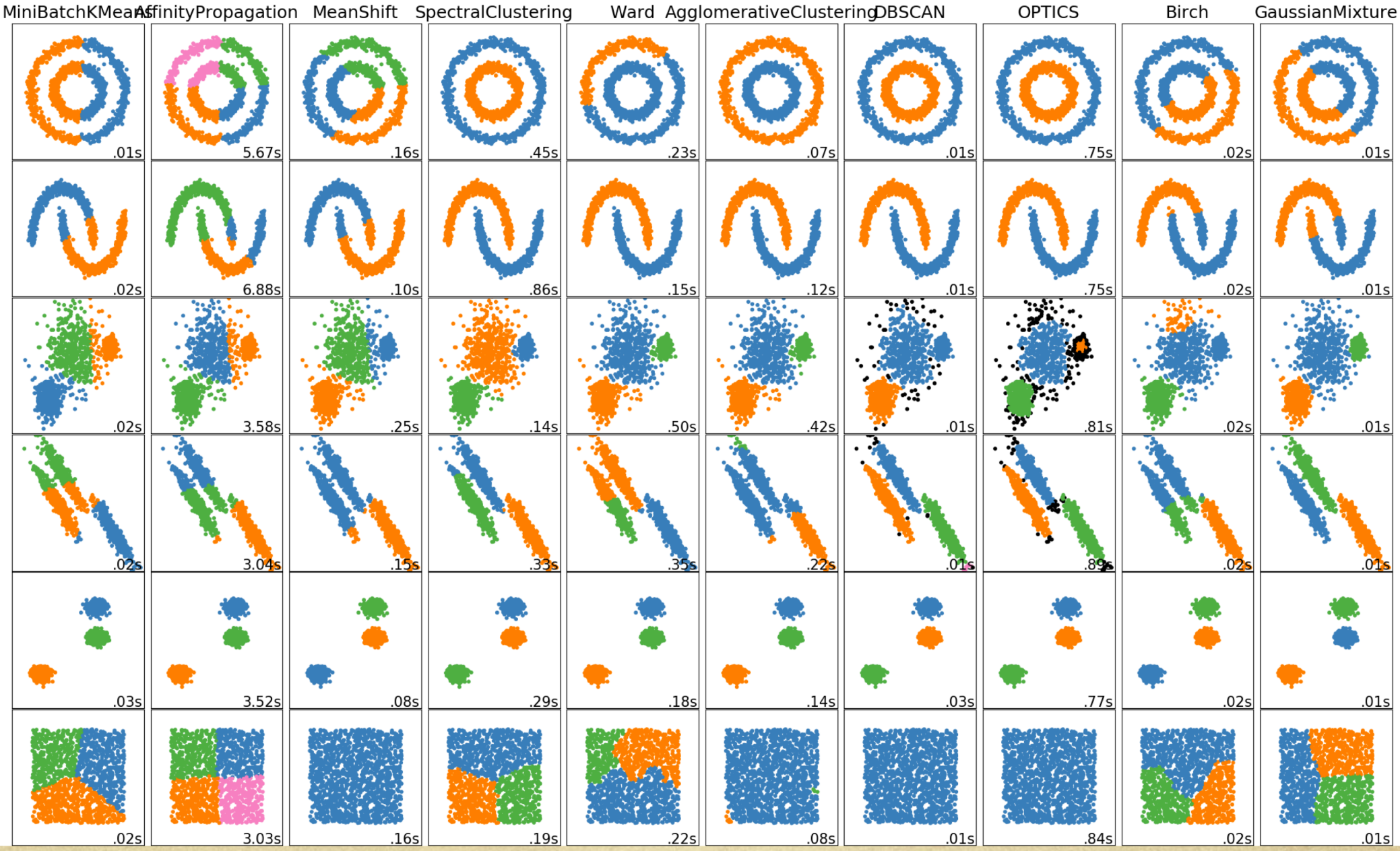
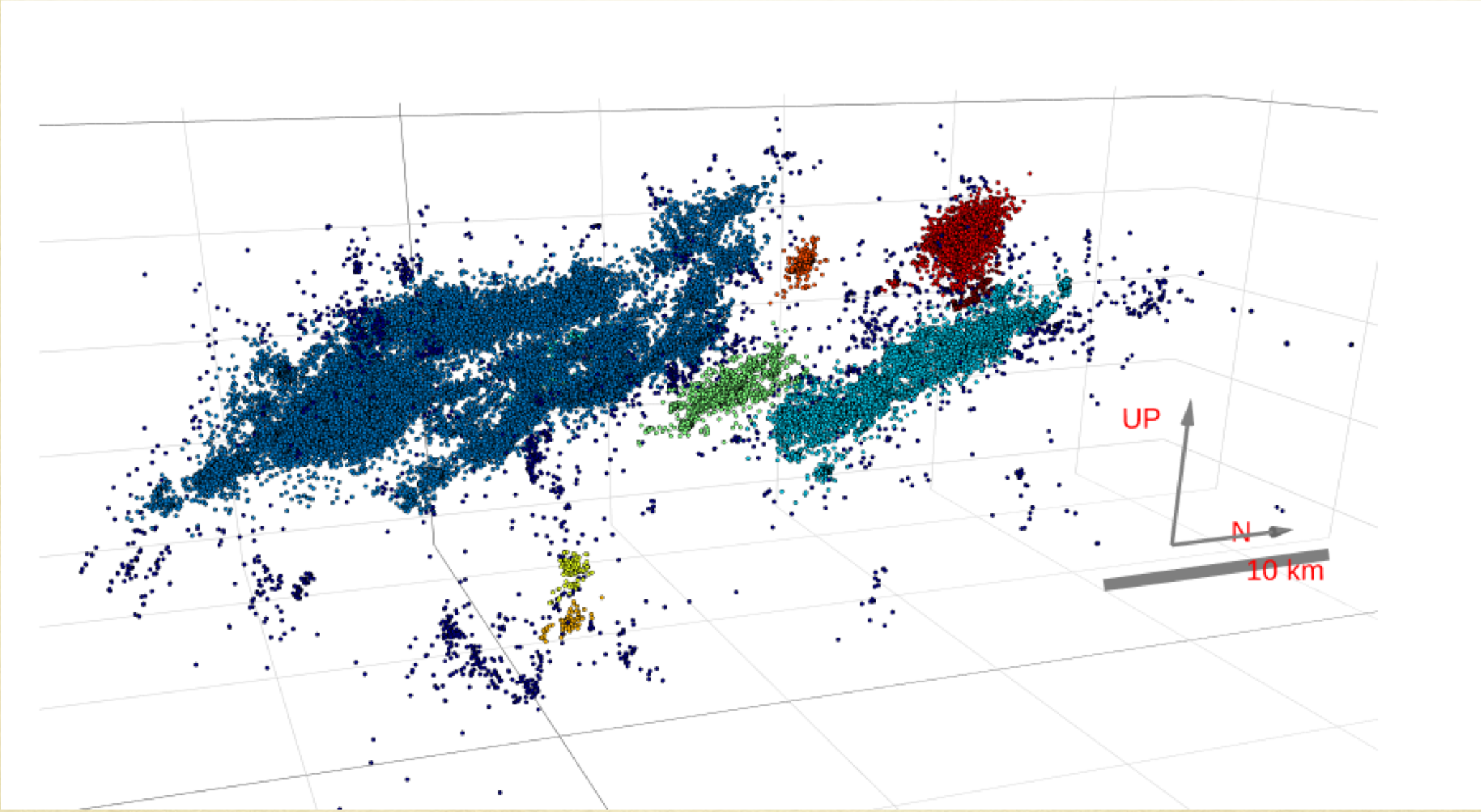
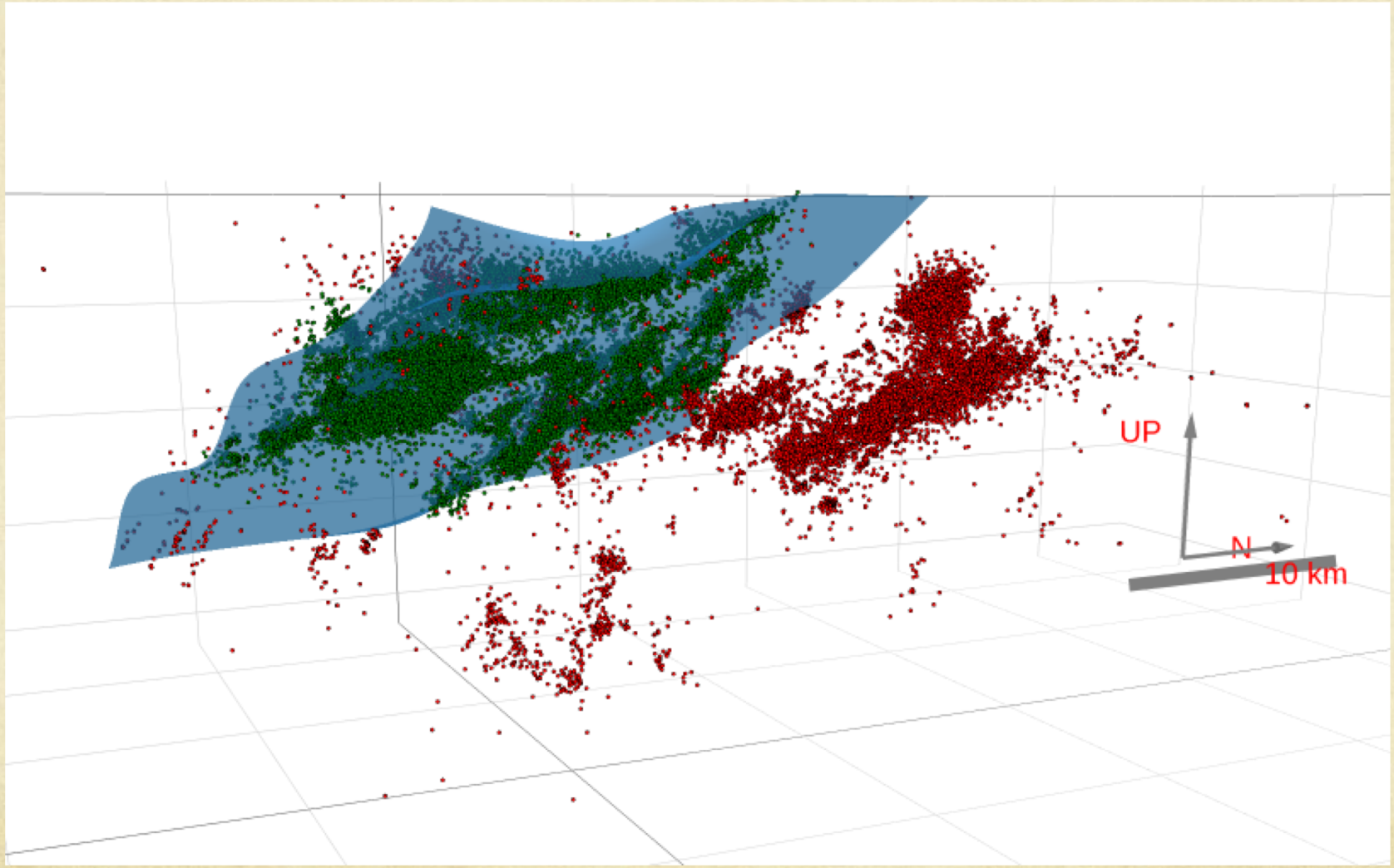
Hypocenters clustering



Hypocenters clustering

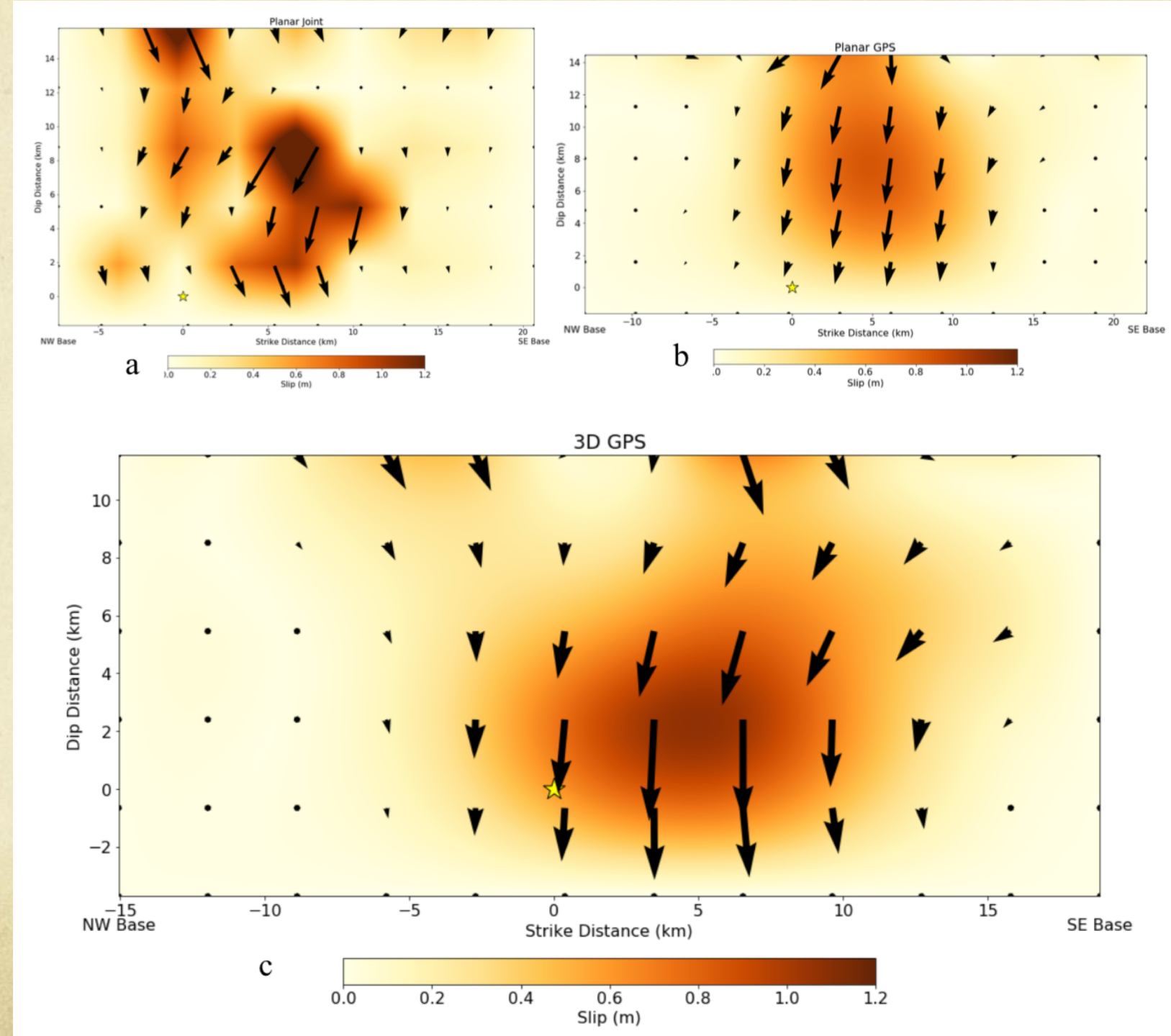


Extrapolation of the main fault morphology using Splines

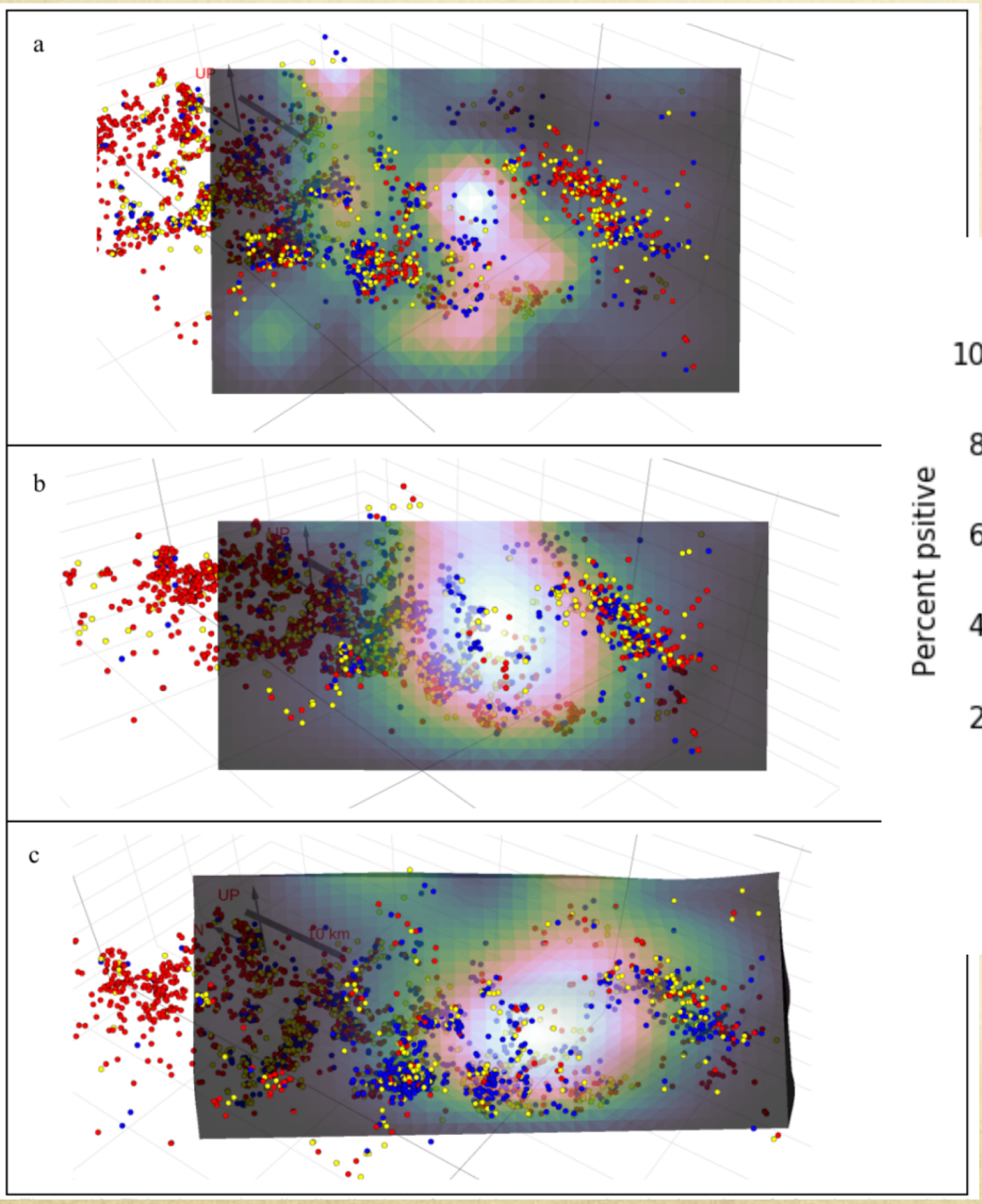


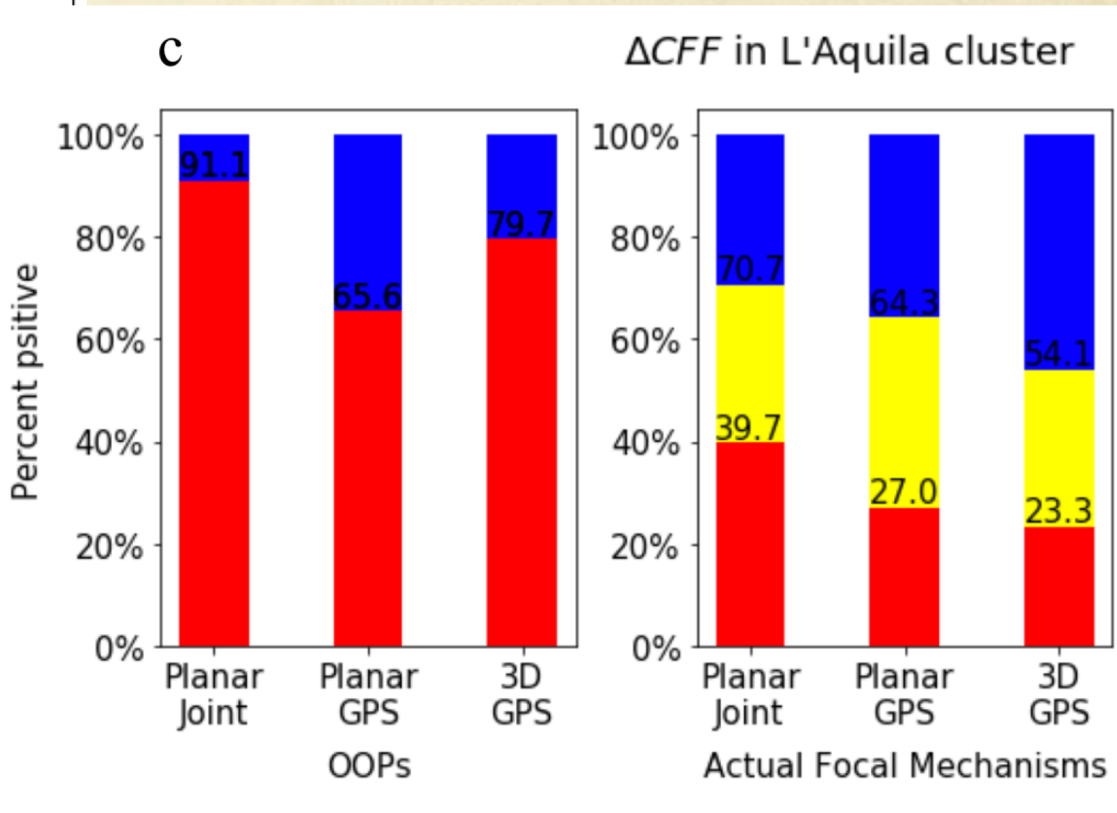
Spline fitting of the surface that best fits the position of the aftershocks

Joint inversion vs. 3D slip GPS based



Joint inversion vs. slip on 3D surface





Jupyter and Binder: the full experience

binder

Loading repository: brennanbrunsvik/Fault-Morphology-Obtained-From-Clus/master

Build logs show

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Fault morphology obtained from clusters of aftershocks with applications to earthquake triggering

21 commits 1 branch 0 releases 1 contributor

Branch: master New pull request Find file Clone or download

brennanbrunsvik Update README.md Latest commit f73c7e8 22 hours ago

stored_variables	Add files via upload	22 hours ago
Calculation_Functions.ipynb	Add files via upload	a day ago
Fault_Splitting.ipynb	Add files via upload	a day ago
Figure_Making_Functions.ipynb	Add files via upload	a day ago
GPSdata.csv	Add files via upload	a day ago
INGV_data	Add files via upload	a day ago
INGV_event_times	Add files via upload	a day ago
LAquila_2009_ALLinONE_unpub.out	Add files via upload	a day ago
Load_Data.ipynb	Add files via upload	a day ago
Old_Functions_Backup.ipynb	Add files via upload	a day ago
README.md	Update README.md	22 hours ago
Supplementary_Notebook.ipynb	Add files via upload	a day ago
clustering_base_file.ipynb	Add files via upload	a day ago
environment.yml	Update environment.yml	23 hours ago
homogenousTests	Add files via upload	a day ago
notebook.tex	Add files via upload	a day ago
stress_base_file.ipynb	Add files via upload	a day ago

README.md

Fault-Morphology-Obtained-From-Clus

Fault morphology obtained from clusters of aftershocks with applications to earthquake triggering

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