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S2.9-171 Databases: advancing volcanology

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Multi-variate analysis of the monitoring data at Vulcano and Campi Flegrei

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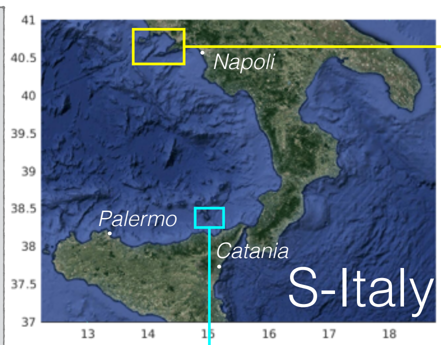
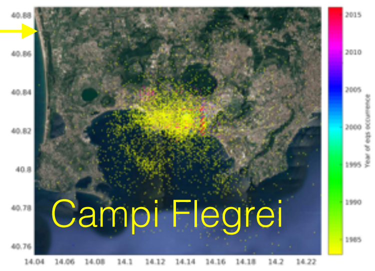
ABSTRACT *This contribution describes the work-in-progress within the project FREAPROB, funded by INGV. The ultimate goal is to seek signals or recurrent patterns within data of different nature (from geochemistry, geodesy, gravity and seismology), which are recorded at two of the best monitored volcanoes in the world, Vulcano and Campi Flegrei (Italy). In fact, despite the strong monitoring effort, the multivariate and objective analysis of the monitoring observations from different disciplines is still uncommon. The first step of our work has been the collection, collation and homogeneization of some of the available data.*

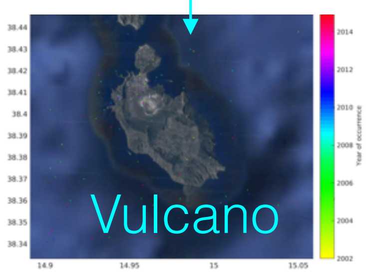
At Campi Flegrei, the dataset features all published geochemical data from the two main fumaroles (Bocca Grande and Bocca Nuova), gravity residuals, ground displacement and seismic activity, all recorded by Osservatorio Vesuviano in the last decades. This dataset is being analysed in search for recurrent patterns describing periods of higher fumarolic temperature or characterized by greater deformation rate.

For the case of Vulcano, data from the continuous monitoring of the crater rim's fumaroles were collated with the records from the monthly surveys that have been carried out in the last 25 years to monitor the largest and most persistent fumaroles at the La Fossa crater. The fumarole observations (consisting of temperature and geochemical variables) were further merged with the observations from the seismic network to constitute the base for a multivariate analysis. Aim of the analysis is the identification of patterns capable of discriminating periods of high and low temperature at the fumaroles, or periods characterized by more intense seismic activity.

This contribution underlines and encourages the development of multivariate datasets and databases that allow searching, through objective statistical analysis, signals and patterns that are difficult to extract "by eye".

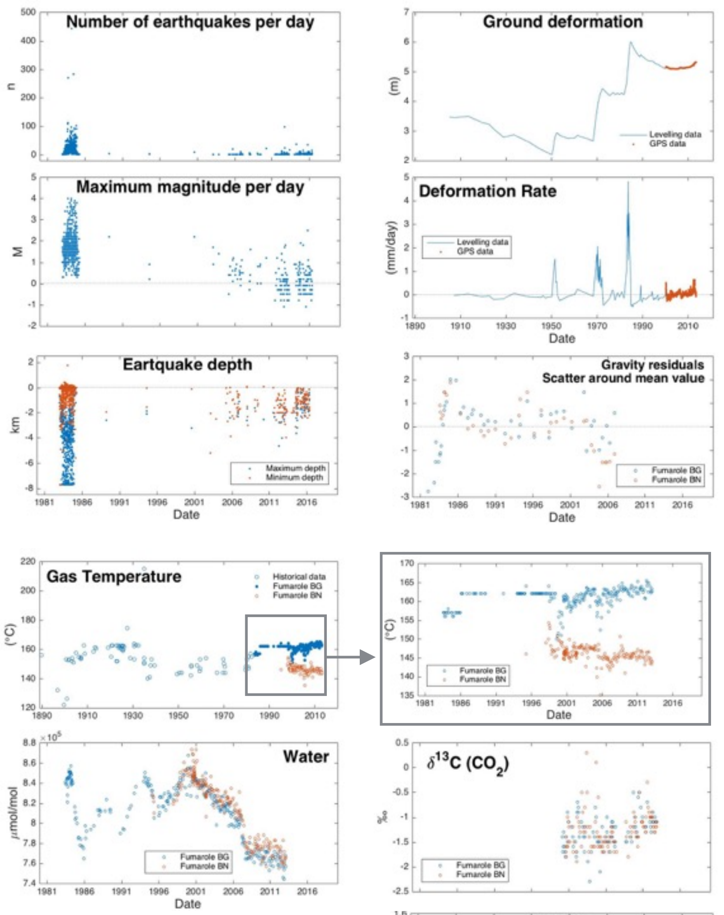


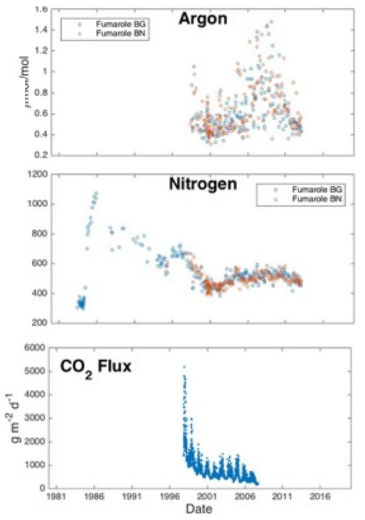




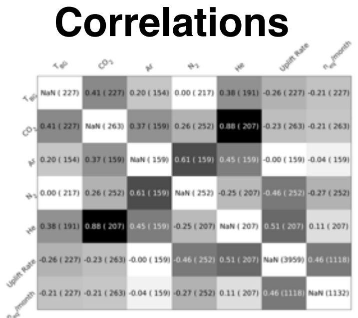
pictures by R. Mora-Amador (CCVG-2005)

Time series monitoring data Campi Flegrei

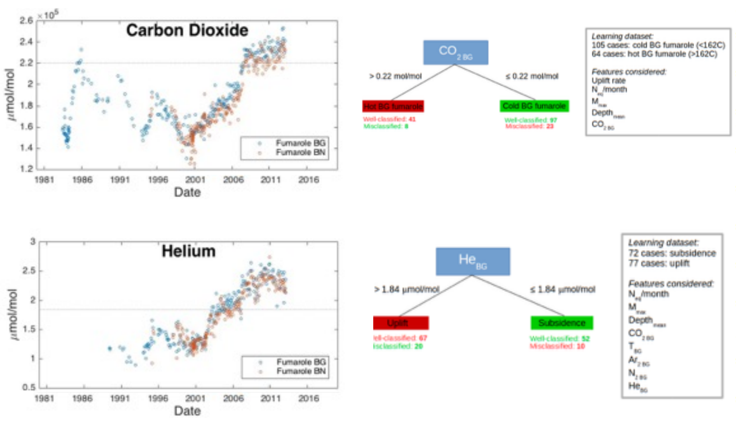




Correlations



seeking thresholds
Pattern Recognition



SOME THEORY: PATTERN RECOGNITION

Binary decision tree (BDT)

This method was developed by Rounds (1980) and, slightly modified, successfully applied to volcanic data by Mulargia et al. (1992). It can be used only in the 2-class problem and it was originally designed for hierarchically ordered datasets, even though tests on synthetic data have shown very good behavior also on different types of datasets.
Once the data have been collected, and objects and classes have been defined, BDT integrates feature selection and binary decision tree according to the following steps:

1. The fixing of a level alpha for the decision rule. This level represents the risk we accept of a wrong attribution at each step. We use α=0.01.

2. The computation of the cumulative distribution in both classes for each feature taken one at a time, and the identification of the feature and the relative threshold value for which the statistical difference between the cumulative of the two classes is the largest. This means that the significance level of this statistical difference must be (a) lower than the level α and (b) lower than the significance level of the statistical difference calculated for any other feature. The feature (if any) for which both the (a) and (b) conditions are satisfied is the first-order feature, often called the "root" of the pattern. On the basis of the root feature and its threshold value, each object is assigned to either one of two subsets formed respectively by data with a value of the root feature lower/higher than the threshold.

3. The identification of the second-order features and their thresholds for which the statistical difference again satisfies the (a) and (b) conditions. These features, which are at most two (i.e., one for each subset), are found by reanalyzing all the features in the two subsets separately, as in step 2.

4. The repeating of step 3 for each second-order feature in order to identify progressively higher orders, as long as it is possible to find a feature for which the cumulatives in the two classes are statistically different at a significance level lower than α. The progressive branching of the tree gives all the possible patterns. The procedure automatically terminates when no further branching is possible at the given level α.

Steps 2–4 are performed by means of non-parametric Kolmogorov-Smirnov two-sample statistics (Hollander and Wolfe 1973). Note that the use of an a priori fixed level α reduces the possibility of obtaining overfitting patterns.

Data sources and references

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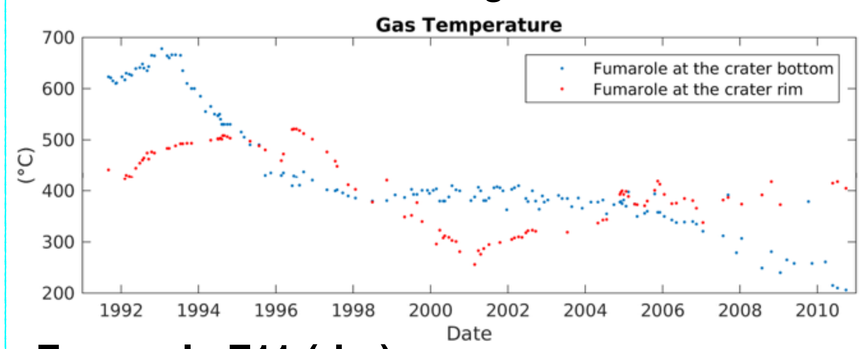
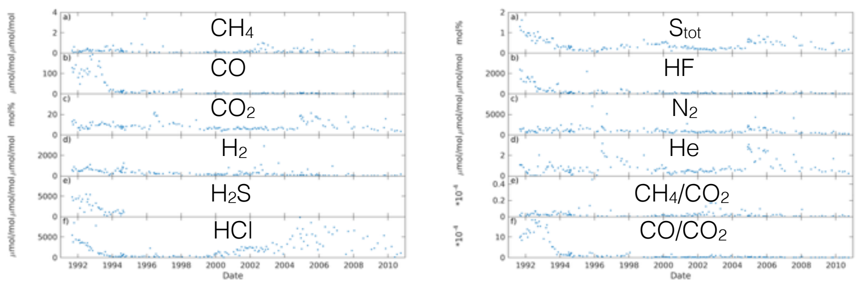
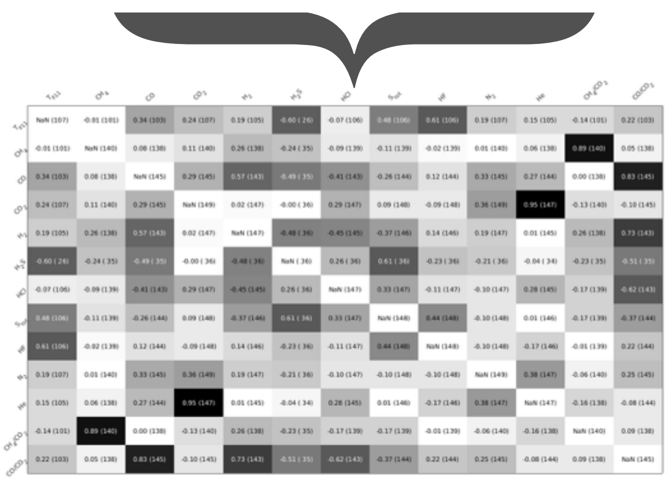
Time series monitoring data Vulcano



Fumarole F11 (rim)





Fumarole FA (bottom)