Forecasting the evolution of volcanic unrest

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Motivations

Volcanic activity poses a unique set of challenges due to its sudden onset and potential for catastrophic consequences. In densely populated areas, like in the case of Campi Flegrei, the need for accurate forecast of volcanic unrest evolution becomes paramount to safeguard human lives and minimize the socio-economic impact of potential eruptions.

The Bayesian Event Tree for Eruption Forecasting

Through the introduction of the Bayesian Event Tree for Eruption Forecasting (BET_EF) (Figure 1), Marzocchi et al. (2008) have proposed a method to decompose the calculation of the probability for each specific volcanic event of interest into a chain of conditional probabilities (easier to compute). Within the event tree, individual probabilities are represented as random variables. This approach is employed to consider both aleatory and epistemic uncertainties.

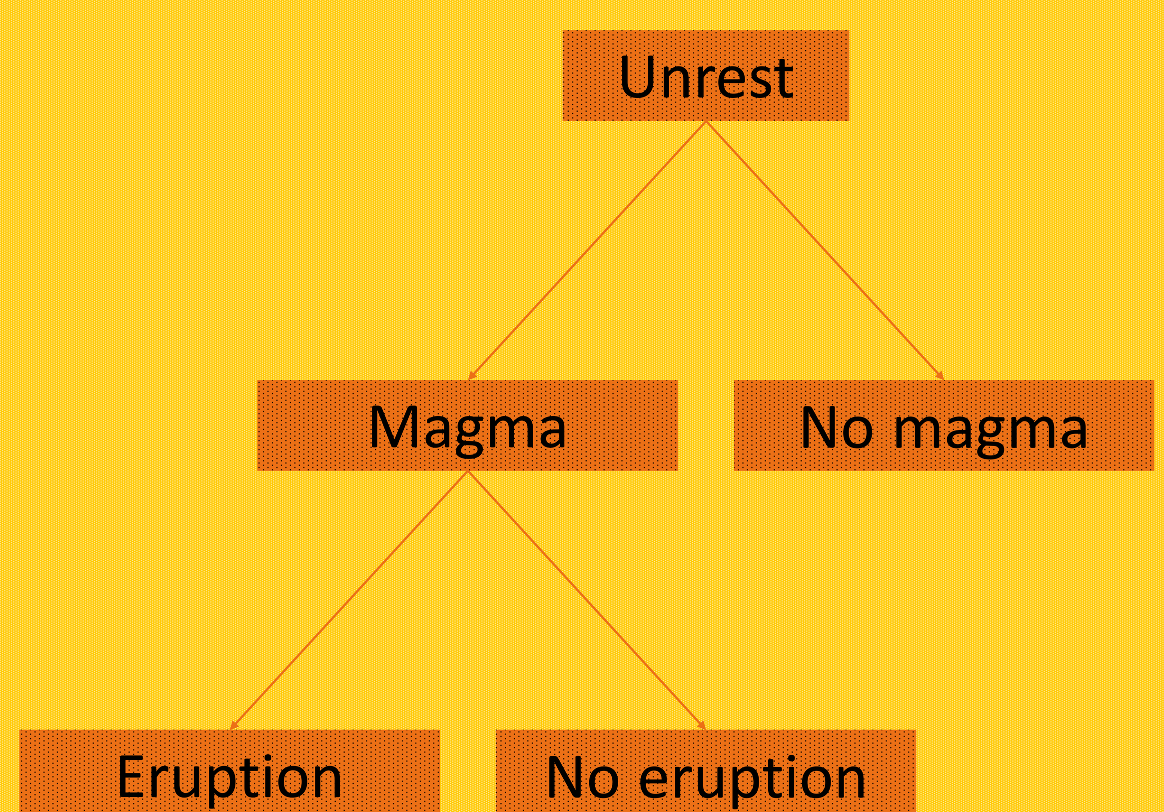

Figure 1 – Simplified structure of the Bayesian Event Tree for Eruption Forecasting (BET_EF).

Details on BET_EF can be found in Marzocchi et al., 2008.

Expert Elicitation

Expert elicitation is a procedure for extracting a collective opinion in a relatively short time despite the incomplete knowledge of the problem. This approach has been employed in calibrating the BET_EF model for Campi Flegrei through seven elicitation sessions held over the years (Selva et al., 2012). In this work, we use data from the VI elicitation conducted within the framework of the INGV/DPC V2 project from 2012 to 2015.

The current unrest of Campi Flegrei

Presently, the Campi Flegrei caldera is undergoing an uplift phase initiated in November 2005. The ongoing activity is characterized by frequent volcano-tectonic earthquakes (VTs) and continuous gas emissions. Since the beginning of the ongoing uplift phase the year 2023 has been the period in which the most significant signs of unrest have been observed (Figure 2).

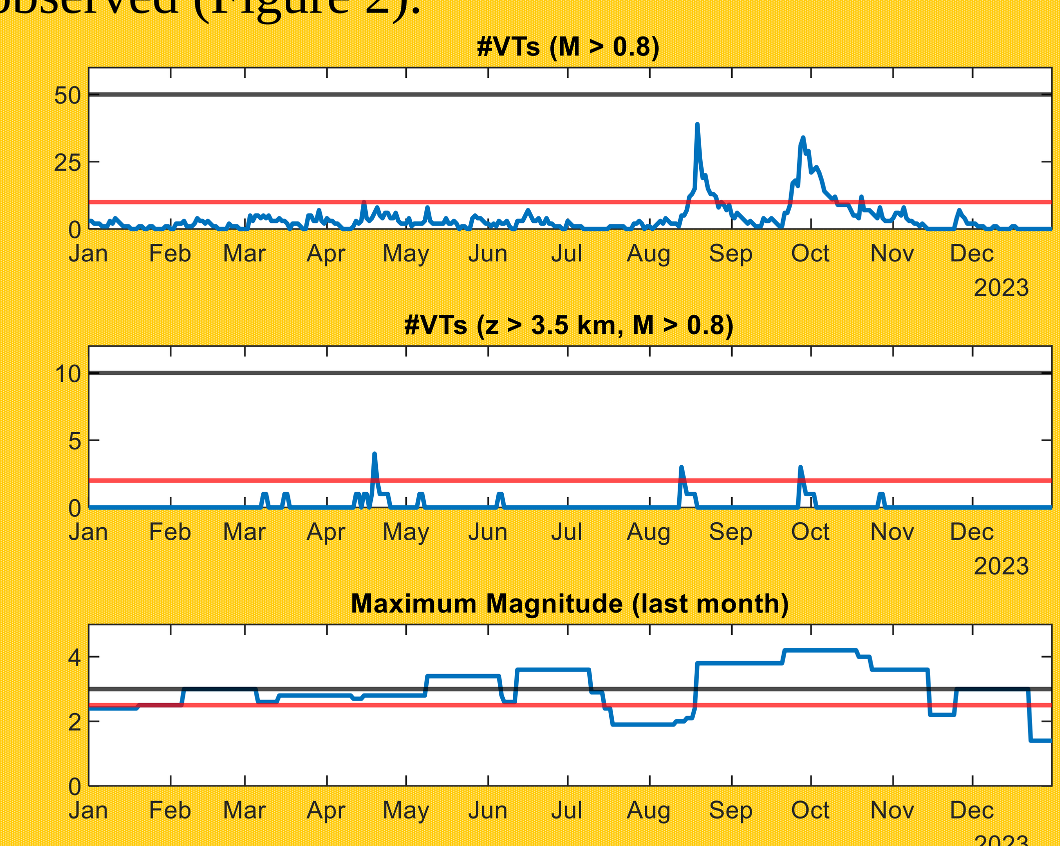

Figure 2 – Variation of parameters related to node 2 of the BET_EF (Magmatic Unrest). The red and black horizontal lines represent the minimum and maximum value of the monitoring variable which defines when the parameter is certainly anomalous or not.

The monitoring information shown in Figure 2 is then translated into probability through an entropy-based model (Marzocchi et al., 2024).

Details on the method can be found in Marzocchi et al., 2024.

Forecasting the evolution of the 2023 unrest at Campi Flegrei

Figure 3 illustrates the variation of the expected value of the probability of magmatic unrest and eruption within 1 month throughout the entire year. The figure highlights that the probability of magmatic unrest was lower than that of unrest of another nature for most of the year. The probability of magmatic unrest surpassed the probability of unrest of another nature on two different occasions, firstly in August, secondly in September.

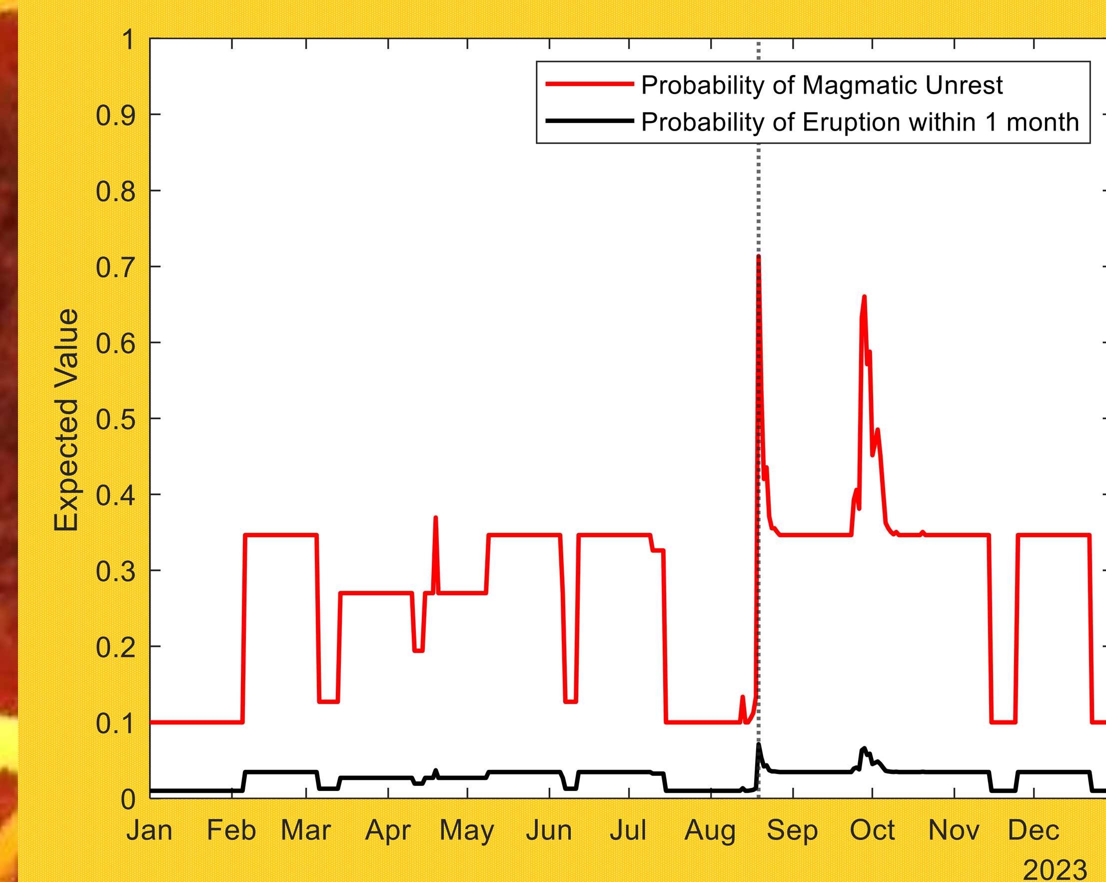

Figure 3 – Variation of the expected value of the probability of Magmatic Unrest (red line) and Eruption within 1 month (black line) throughout the entire examined period.

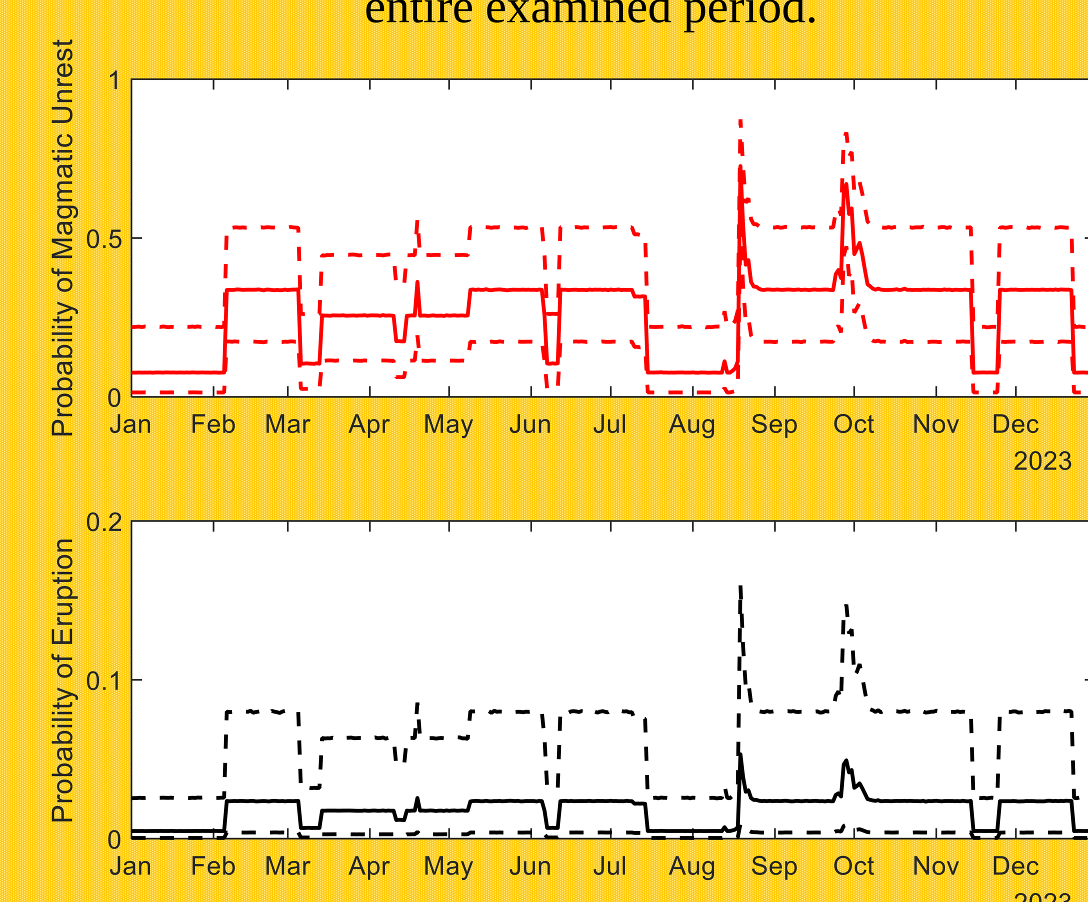

Figure 4 – Variation of the median (solid lines) and 10th and 90th percentiles (dashed lines) of the probability distributions of Magmatic Unrest (upper panel) and Eruption within 1 month (lower panel).

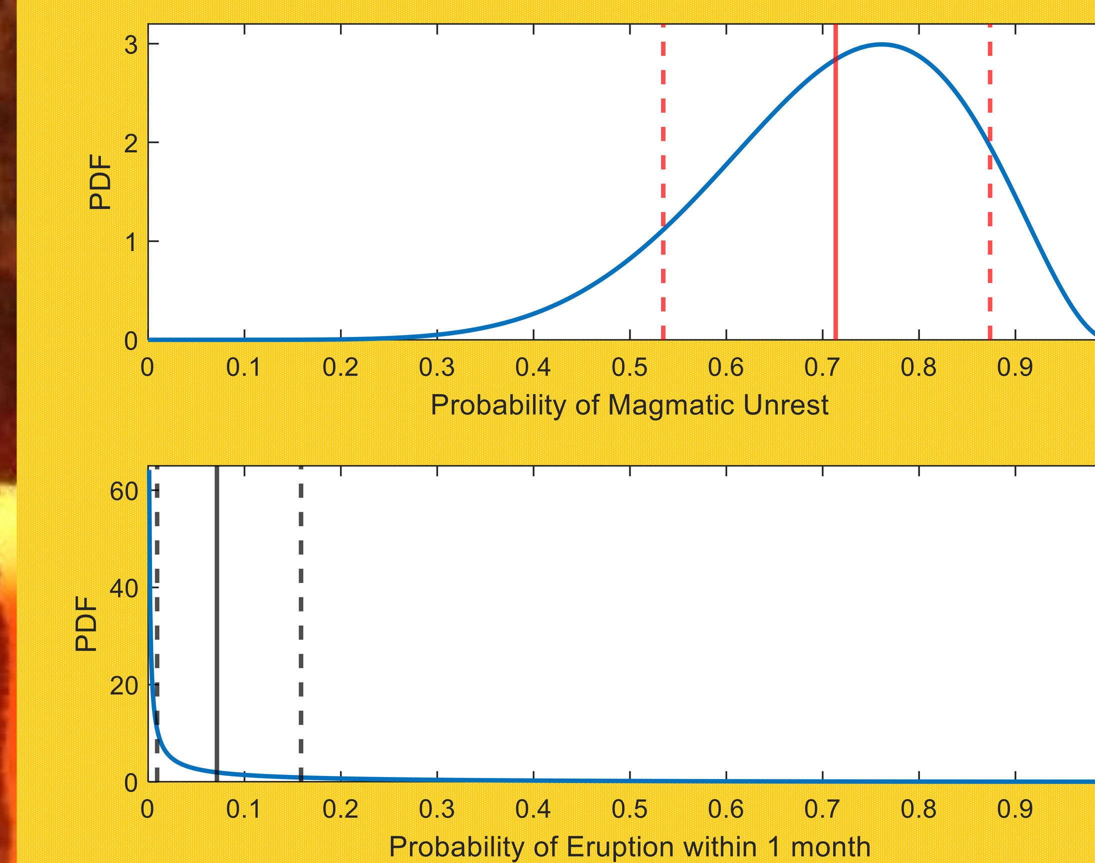

Figure 5 – Probability Density Function of Magmatic Unrest (upper panel) and Eruption within 1 month (lower panel) related to August 18 (dotted vertical line in Figure 3). The vertical solid line depicts the expected value of the distribution, while the dashed lines represent the 10th and 90th percentiles.

The variations of the probability of eruption are simply a consequence of the variations of the probability of magmatic unrest, as no anomalies related to the pre-eruptive phase were observed.

Conclusions

The obtained results show that:

- The probability of magmatic unrest was lower than that of unrest of another nature for most of the year.
- There has never been evidence of anomalies characteristic of a pre-eruptive phase.

It is important to note that the obtained results do not represent the opinions of the work's authors or individual researchers but rather reflect the perspective of the scientific community that participated in the elicitation process, involving more than 100 researchers across all elicitation phases.

References

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