The importance of data sensitivity and effective hazard communication: hazard mapping of Campi Flegrei, Italy

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1. Introduction

Situated immediately west of Naples in southern Italy (Fig.1a), Campi Flegrei is one of the most populated active large calderas on Earth. Since the last episode of caldera formation during the Neapolitan Yellow Tuff (NYT) eruption 15,500 years ago, approximately 60 eruptions have occurred across the caldera floor (Fig.1b, Smith et al., 2011) and the most recent eruption produced Monte Nuovo in 1538. Following more than 400 years of quiescence, the caldera has been in intermittent unrest since the late 1950s (Del Gaudio et al., 2010), raising concern that the volcano is preparing to enter a new phase of eruptive activity.

Pyroclastic Density Currents (PDCs) are the major hazard from future eruptions. Numerous hazard maps have been prepared, but show differences in the expected distribution of PDCs. To avoid confusion when presenting the maps to non-scientific decision makers, it is important to identify uncertainties in preparing each map.

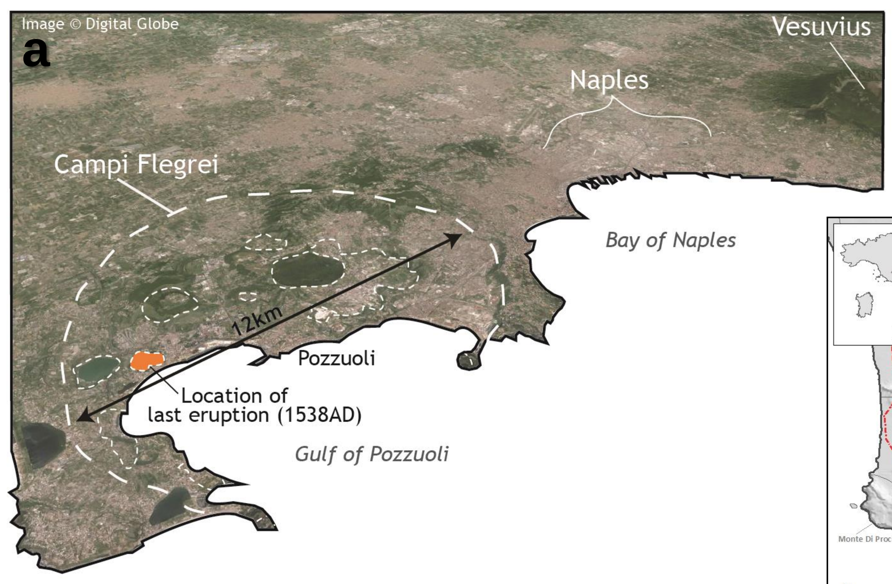
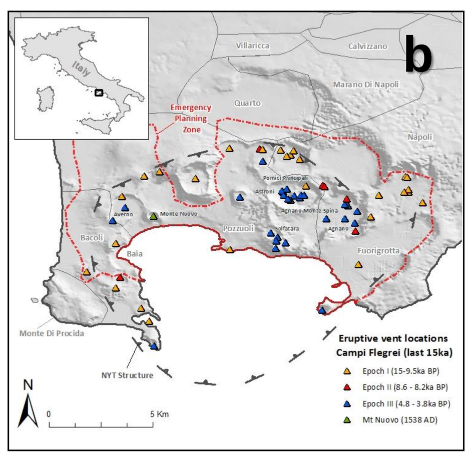


Figure 1. a) Aerial image of Campi Flegrei and Naples. b) Location of vents during the last 15ka. Data modified from Smith et al. (2011)



2. PDC hazard assessments: Campi Flegrei

Four PDC hazard maps have been prepared for Campi Flegrei and show different areas of potential PDC coverage between 67 and 500 km² and different maximum runout lengths between 3 and 20 km (Fig. 2).

The differences in area and runout distance reflect the choice of input data and parameter values, notably the uncertainty surrounding the choice of vent location and eruption size.

Here we focus on uncertainties inherent in the energy line model that has been used to estimate the runout length of PDCs (Fig. 2C; Alberico et al., 2002).

These maps (Fig. 2C) were chosen as they were the first to simulate PDCs at CF.

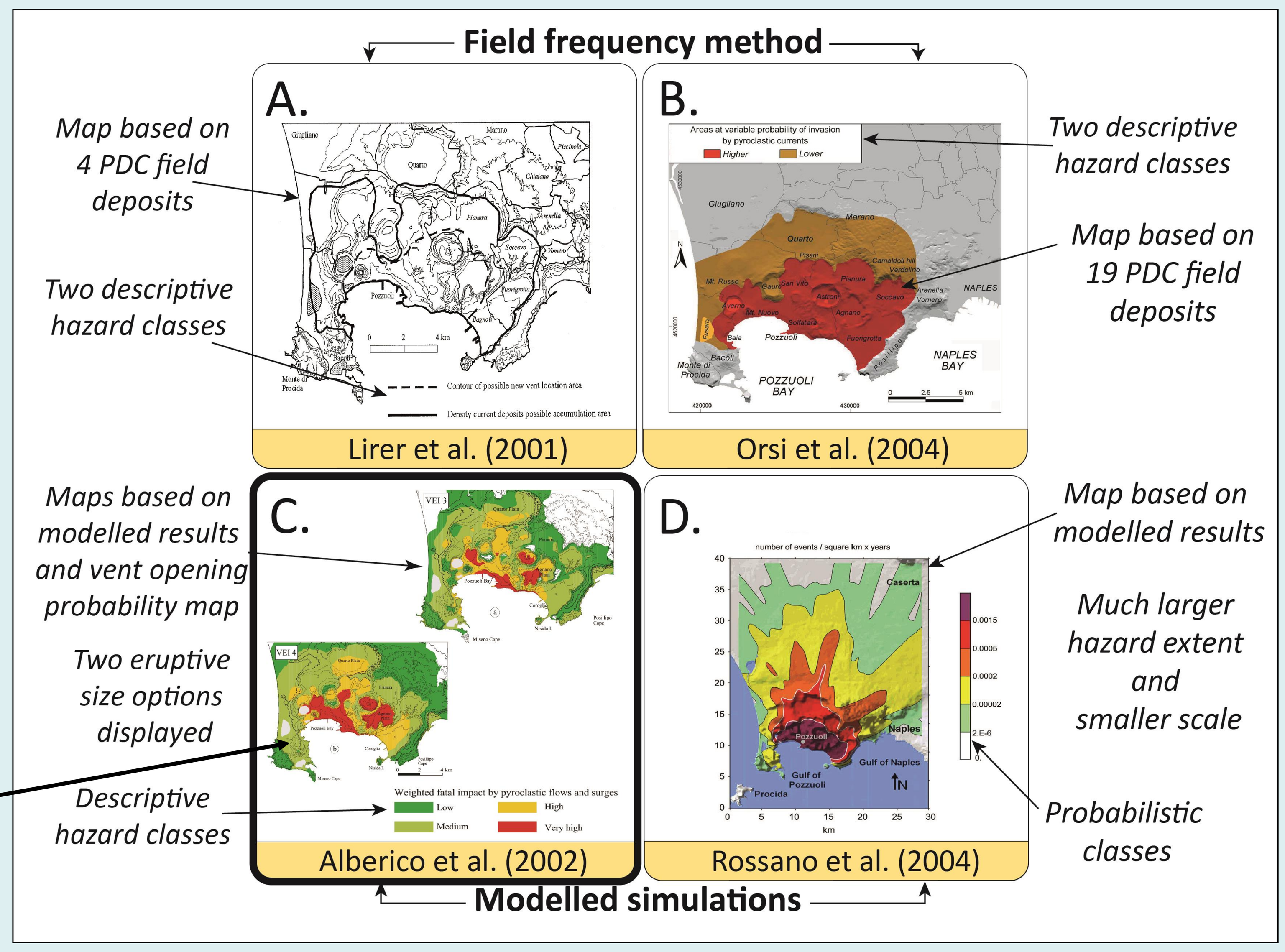


Figure 2. Maps of PDC hazard at Campi Flegrei

3. Preliminary study: data sensitivity and the energy line method

Energy line method

Measured runout lengths for PDCs at Campi Flegrei are on the order of kilometres, with rare events reaching 15 km (de Vita et al., 1999). The distance a PDC can reach depends on numerous factors, most notably initial volume, the physical properties of the flow, and the local topography (Druitt, 1998). The energy line method is useful for estimating PDC runout length because it incorporates both resistance due to friction and topography. By analogy with simple sliding, the energy balance suggests that the ratio H/L is a first-order approximation to a PDC's resistance to motion, where H and L are the vertical and horizontal displacements of the PDC, measured from the highest point of descent to the toe of the deposit (Malin and Sheridan, 1982). The two key input parameters are thus: (i) the height of column collapse and (ii) the value of H/L.

Key parameter

Collapse height

Most of Campi Flegrei's post-caldera eruptions have been explosive and either magmatic or phreato-magmatic (Di Vito et al., 1999). PDCs are thus generated by the collapse of eruption columns. From the volumes and distributions of pyroclastic deposits from a small number of eruptions, Alberico et al (2002) have estimated magma discharge rates of between 10^3 and 10^4 m^3s^{-1} and inferred corresponding column collapse heights of between 100 and 300 m.

Key parameter

Energy gradient, H/L

An energy gradient of 0.1 has been assumed to characterize the PDCs in Campi Flegrei (Alberico et al., 2002). However, values for H/L tend to decrease with increasing PDC volume. Thus, among PDCs produced by column collapse, those with volumes less than 0.1 km³ have H/L values of 0.35 ± 0.15, whereas larger PDCs have smaller H/L values of 0.13 ± 0.07 (Sheridan, 1979; Hayashi & Self, 1992; Druitt, 1998). Within each category, the full range of H/L can vary by a factor of three.

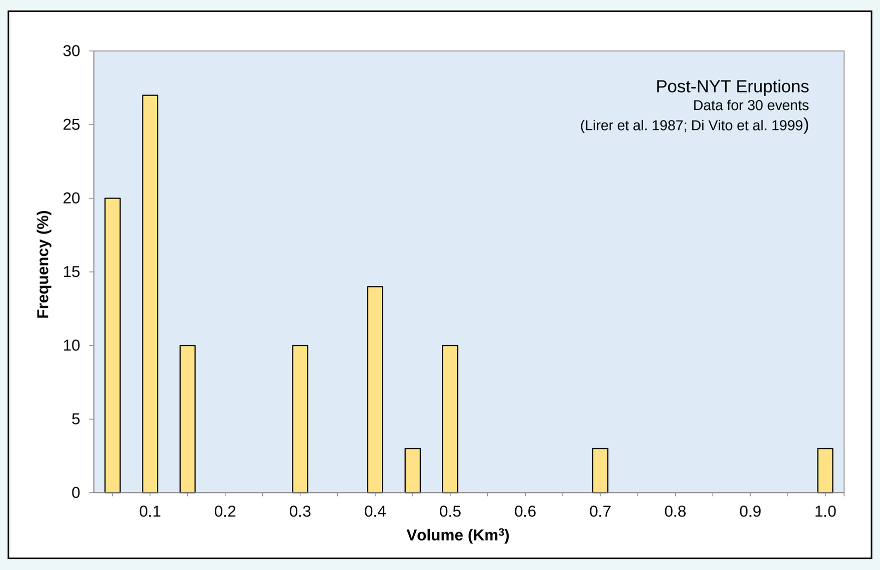


Figure 3. Estimated total volumes from 30 eruptions at CF (Lirer et al., 1987 Di Vito et al., 1999)

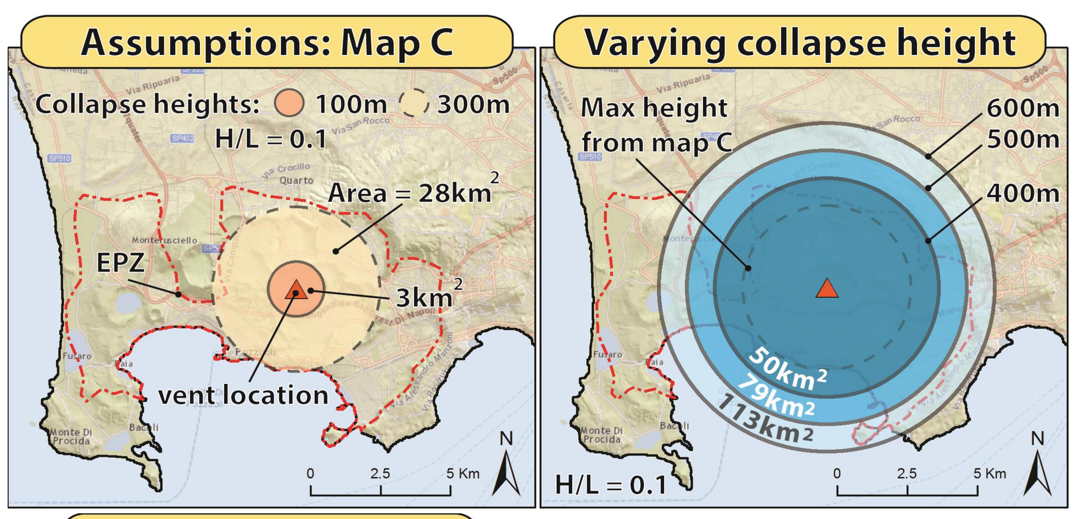
Using published field data (Lirer et al., 1987; Rossano et al., 2004; Isaia et al., 2004; Orsi et al., 2009), the maximum volumes of PDCs at Campi Flegrei are estimated to be about 0.01 – 0.2 times the total volume erupted. About 84% of the eruptions have had volumes less than 0.5 km³ (Fig. 3), and so are associated with maximum PDC volumes of 0.1 km³. The preferred value for H/L is thus expected to be 0.35 ± 0.25 or between 0.1 – 0.6. Hence the choice of 0.1 represents a worst case scenario and so may overestimate the most likely run out length of PDCs.

Data sensitivity

Figure 3 illustrates that the choices of height and H/L do have an implication on the extent of hazard area. The heights used by Alberico et al. (2002) of 100 and 300 m are conservative, when compared to gas thrust heights of 500-600 m estimated by Sheridan (1979). Therefore, if the height values are increased to 400, 500 and 600 m, the PDC hazard coverage and run out will increase to 4, 5, and 6 km respectively (Fig.4).

PDC volume estimates from Campi Flegrei suggest that H/L values could range between 0.1 – 0.6. Another example shows that if H/L values are increased to 0.2, 0.4 and 0.6, the PDC hazard coverage and run out will decrease to less than 1.5 km (Fig.4). Choosing values as accurate as possible and communicating the uncertainties are both important at Campi Flegrei.

The discharge rates used by Alberico et al. (2002) represent order-of-magnitude estimates. They may therefore include values to at least 3 x 10^4 m^3s^{-1}. The maximum collapse height may thus reach 600 m. The worst-case scenarios, using H/L = 0.1, thus involves runout lengths twice as far as those shown on Fig. 2C. However, such lengths may be offset by using larger H/L values of 0.2 for small-volume PDCs.



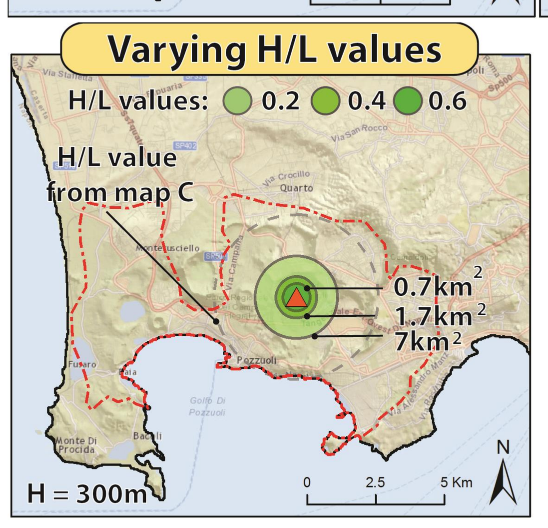


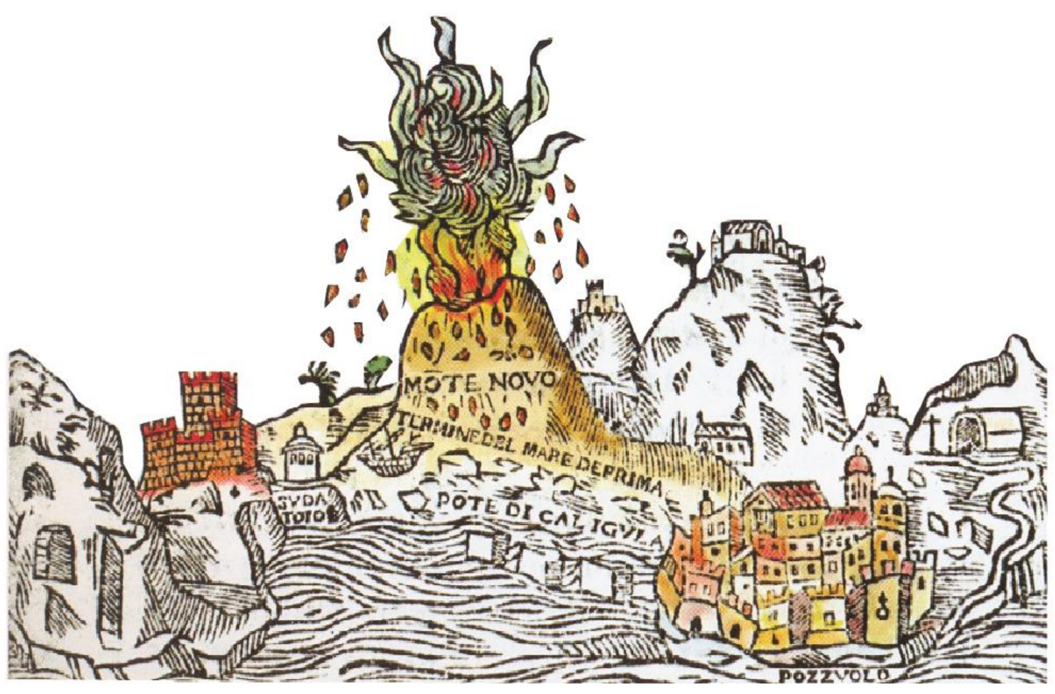
Figure 4. The sensitivity of maximum PDC run out to collapse height and H/L values used within the energy line method. Top left represents PDC maximum extent by using the assumed values used by Alberico et al., (2002) and one possibility of vent location. These results do not take into account topography.

Base map © ESRI and OpenStreetMap contributors

4. Conclusions and further work

To design mitigation strategies, decision makers need to know the most-likely, as well as worst-case, scenarios. To evaluate the PDC hazard at Campi Flegrei, additional models are required that incorporate the full range of potential heights of column collapse, values for the energy line and their corresponding probabilities of occurrence.

I will be focusing on improving the effectiveness hazard mapping and risk communication at Campi Flegrei by: 1) Investigating the uncertainty around future vent locations. 2) Gathering information on the type of hazard information currently available and what is required from different audiences (e.g businesses, local government). 3) Developing better ways of communicating uncertainty and assumptions in hazard and risk maps.



The birth of Monte Nuovo in 1538, as described by Pietro Giacomo de Toledo, 1539
Print published by Kraft (1991)

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