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Improved quantification of CO_2 emission at Campi Flegrei by combined Lagrangian Stochastic and Eulerian dispersion modelling

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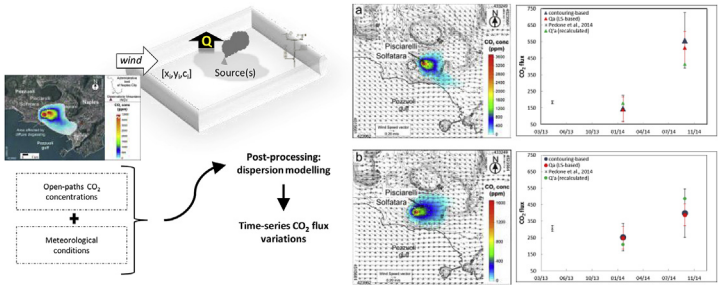
HIGHLIGHTS

- Fumarolic carbon dioxide dispersion modelling.
- Novel approaches to estimate CO_2 emissions and dispersions.
- Comparison between novel and previous approaches.
- Time-series variations of CO_2 emissions at Campi Flegrei caldera.
- Atmospheric dispersion of fumarolic + soil CO_2 plume over a highly populated area.

GRAPHICAL ABSTRACT



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ABSTRACT

This study investigates fumarolic CO_2 emissions at Campi Flegrei (Southern Italy) and their dispersion in the lowest atmospheric boundary layer. We innovatively utilize a Lagrangian Stochastic dispersion model (WindTrax) combined with an Eulerian model (DISGAS) to diagnose the dispersion of diluted gas plumes over large and complex topographic domains. New measurements of CO_2 concentrations acquired in February and October 2014 in the area of Pisciarelli and Solfatara, the two major fumarolic fields of Campi Flegrei caldera, and simultaneous measurements of meteorological parameters are used to: 1) test the ability of WindTrax to calculate the fumarolic CO_2 flux from the investigated sources, and 2) perform predictive numerical simulations to resolve the mutual interference between the CO_2 emissions of the two adjacent areas. This novel approach allows us to a) better quantify the CO_2 emission of the fumarolic source, b) discriminate "true" CO_2 contributions for each source, and c) understand the potential impact of the composite CO_2 plume (Pisciarelli "plus" Solfatara) on the highly populated areas inside the Campi Flegrei caldera.

1. Introduction

Campi Flegrei (CF) is a typical example of a large collapse caldera in which post-caldera volcanic activity is polygenetic (De Natale et al., 2006, 2016, 2017). The CF caldera has been active for the last six decades, following four centuries of quiescence, raising

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concern about an increased potential for eruption (Chiodini et al., 2016, 2017; De Natale et al., 2017; Kilburn et al., 2017; Moretti et al., 2017). Following the maximum ground uplift attained in 1984, the ground subsided until 2005 and then started a new slow uplift phase that is still ongoing (Gaeta et al., 2003; Kilburn et al., 2017). CF is one of the most dangerous volcanoes on Earth in terms of its proximity to a densely populated urban area; the Neapolitan district (Southern Italy) is home to about three million people living between CF, Vesuvius and Ischia (De Natale et al., 2016, 2017) (Fig. 1).

In cities located near active volcanoes, natural sources can increase urban CO_2 levels (Idso et al., 1998). This is the case in Naples, where much of the city lies downwind of the CF volcanic area (Fig. 1a).

The most active volcanic sites in CF are Solfatara, whose crater hosts three main high-temperature fumaroles (Aiuppa et al., 2013; Fedele et al., 2017; Pedone et al., 2014) and Pisciarelli, a NE-SW fault-related fumarolic field located a few hundred metres east of Solfatara (Fig. 1b). Intense and persistent outgassing occurs at these fumarolic areas that affects humans, vegetation (Bartiromo et al., 2012) and fauna. For example, fish-kill episodes have occurred at the nearby Lake of Averno (Fig. 1b) due to paroxysmal output stages

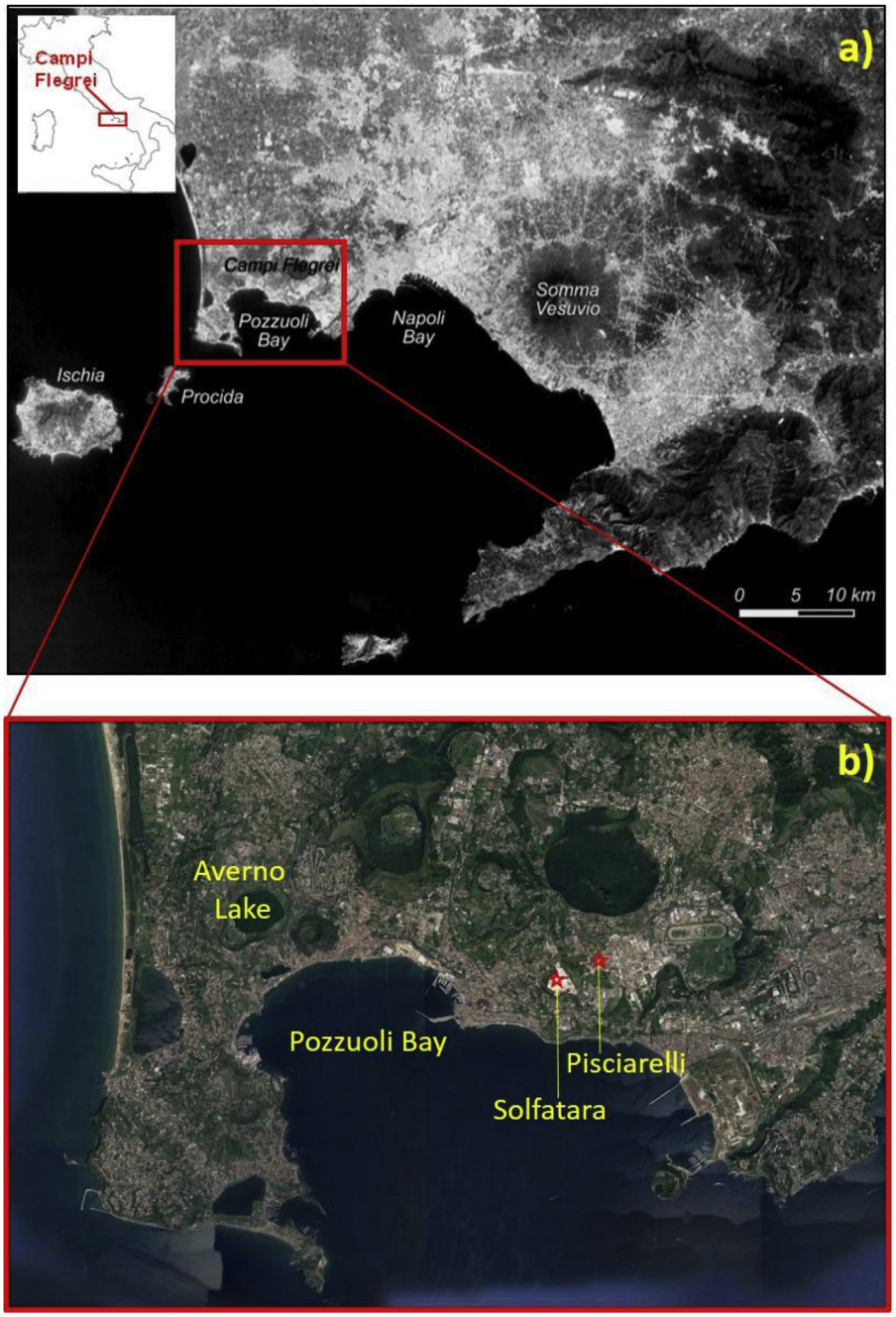

Fig. 1. The Campi Flegrei volcanic area, adjacent to Naples (Southern Italy). a) Urbanized areas are represented by the lighter shades of the satellite imagery; darker areas indicate lower population density. A large portion of Naples lies downwind of Campi Flegrei. b) A detailed picture of the Campi Flegrei area (red square in a) with the locations of the most active volcanic sites, Solfatara and Pisciarelli. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)