GPS Solut (2013) 17:485–497
DOI 10.1007/s10291-012-0294-4

ORIGINAL ARTICLE

Volcanic ash detection by GPS signal

Massimo Aranzulla · Flavio Cannavò · Simona Scollo · Giuseppe Puglisi · Giuseppina Immè

Received: 11 January 2012 / Accepted: 17 September 2012 / Published online: 4 October 2012

Abstract We investigate the ability of GPS to detect volcanic plumes at Mt. Etna, Italy. We use a robust statistical approach to highlight whether the presence of a volcanic plume in the atmosphere may really affect the GPS undifferenced post-fit phase residuals. The proposed method has been tested for the September 4–5, 2007 activity of Mt. Etna. This eruption produced powerful lava fountains forming a weak, a few kilometers high plume for several hours, representing typical activity at Etna over the last 5 years. We analyzed data from nineteen Etna permanent GPS stations located on the volcano flanks at different heights and applied a statistical test based on four main steps: (a) realization of a simplified model representing the volcanic plume in atmosphere; (b) evaluation of the GPS satellite and station couples intersecting the plume; (c) calculation of the volcanic plume region crossed by the GPS signal; (d) application of a robust statistical test in order to see whether the volcanic plume affected the GPS signals. Results show that during the September 4–5, 2007 explosive activity, the GPS residuals definitely include the contribution of the volcanic plume. Our analysis shows that values of the GPS residuals are ten times smaller than those found for the Miyakejima eruption (Japan), highlighting a likely relationship between residuals and eruption intensity. In the future, data derived from the GPS stations located on Etna's flanks could be used to improve the alerting system of volcanic ash, already operating at the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo.

Keywords Volcanic plume · GPS signal · LC residual · Etna · Statistical approach

M. Aranzulla · G. Immè
Dipartimento di Fisica e Astronomia, Università degli studi di Catania, Viale Andre Doria, 6, 95125 Catania, Italy

F. Cannavò · S. Scollo (✉) · G. Puglisi
Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione Catania, Piazza Roma 2, 95123 Catania, Italy
e-mail: simona.scollo@ct.ingv.it

Introduction

Mt. Etna, Italy, is one of the most active volcanoes in the world. Explosive activity usually forms weak plumes that rise some kilometers above the vent and may cause difficulties for aviation operations and the population living on the volcano's flanks. Due to the persistent activity, the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo (INGV-OE) has improved the monitoring of Etna volcanic plumes over recent years with the use of new instruments and volcanic ash dispersal models. Observations of volcanic plume dispersal and fallout are carried out by analyzing multispectral infrared measurements from the Spin Enhanced Visible and Infrared Imager on board the Meteosat Second Generation geosynchronous satellite, visual and thermal images from the video surveillance system, and data collected from a network of radar disdrometers (Scollo et al. 2009). Furthermore, mapping of tephra deposits and prompt analysis of samples collected shortly after the end of the explosive event are also routinely carried out (Andronico et al. 2009). Volcanic ash forecasts are performed using four different models: PUFF (Searcy et al. 1998; Scollo et al. 2011), FALL3D (Costa et al. 2006), HAZMAP (Macedonio et al. 2005) and TEPHRA (Bonadonna et al. 2005). Every day, an automatic procedure downloads wind data of two high-resolution meteorological models, runs these models and transfers hazard maps to the INGV-OE control room and to