

Volcanic SO2 measurements by UV-TIR satellite retrievals: validation by using the groundbased FLAME network at Mt. Etna





C. Spinetti (1)*, G. Salerno (2), T. Caltabiano (2), E. Carboni (3), L. Clarisse (4), S. Corradini (1), P. Hedelt (5), M.E.Koukouli (6), L. Merucci (1), R. Siddans (7) L. Tampellini (8), N. Theys (9), P. Valks (5), J. Vira (10), C. Zehner (11)



(1) Istituto Nazionale di Geofisica e Vulcanologia, CNT, Roma, Italy ; (2) Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy ; (3) University of Oxford, Atmospheric, Oceanic & Planetary Physics Clarendon Laboratory, Oxford, UK; (4) Spectroscopie de l'Atmosphère, Service de Chimie Quantique et Photophysique, Université Libre de Bruxelles, Brussels, Belgium; (5) German Space Agency, Munich, Germany; (6) Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece; (7) Rutherford Appleton Laboratory, Chilton, U.K; (8) Compagnia Generale per lo Spazio, Milano, Italy; (9) Belgian Institute of Aeronomie, Brussels, Belgium; (10) Finnish Meteorological Institute, Helsinki, Finland; (11) European Space Agency, Rome, Italy

*corresponding author : claudia.spinetti@ingv.it

ABSTRACT Monitoring active volcanoes is crucial for social, environment and economic aspects, especially in a densely populated area as Mt. Etna in Italy. Since the '80s surveillance approach has displayed an intense and rapid growth also thanks to fast technological advances. Thought, satellite-based observation nowadays still lie beyond ground-method, in the next decade this technique is a potential ability for large-scale tracking volcanic SO₂ cloud at high temporal and spatial resolution. The European Space Agency project 'Study on an End-to End system for retrieving quantitative measurement of volcanic SO₂ and ash clouds parameters. Here, we present the Mt. Etna SO₂ measurements retrieved by MODIS, IASI, GOME-2 and OMI and their comparison with the ground-based DOAS monitoring network (FLAME). Case-studies were selected in the range of the paroxysmal episodes a selection has been performed in order to have contemporaneous detection of the Volcanic clouds and their respective uncertainty. The agreement between the satellite and the ground measurements has been investigated. For all the sensors retrieval is a promising volcano monitoring tool for SO₂ volcanic cloud observation providing day-night integration in the day-light ground-based SO₂ measurements records

Mt. Etna 2011 Lava fountains events

Between 12 January 2011 and 27 April 2013 Etna produced thirtyeight basaltic lava fountains from a new volcanic vent opened on the eastern flank of the South East Crater.



The eruptive episodes were characterized by a paroxysmal phase which lasted on average about one hour and were preceded by mild strombolian activity and often by la∨a flow. E∨ery paroxysm formed an eruption column ranging from 5 to 11 km of height above sea level and tephra fallout was mainly spread out on the eastern sectors of the volcano (Fig 1). Most of them have been preceded by intense strombolian activity (Behncke et al., 2014).

Figure 1. Picture taken on 20-8-2011 courtesy of B. Behncke

From these eruptive episodes the most energetic lava fountains have been chosen as suitable to be measured by space sensors.

Mt. Etna SO₂ FLAME network

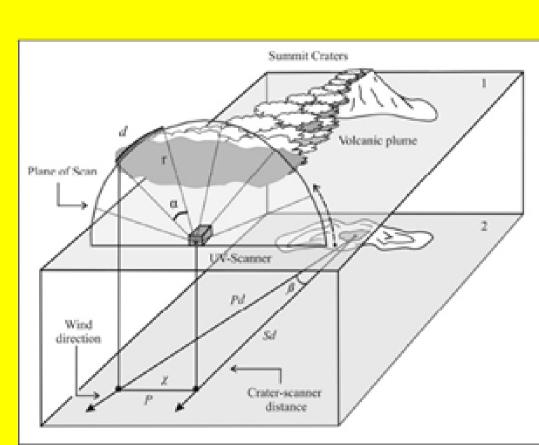


Figure 2. Scheme of UV-Scanner recorded spectra over a plume cross section.

In late 2004, an automated network of UV scanning spectrometers was developed and installed by the Geochemistry group of INGV-OE migrating from discrete to automatic, real-time, high-resolution SO2 flux measurements. The FLux Automatic MEasurement FLAME network consists of 9 UV scanning spectrometers (Fig 3) spaced ~7 km apart installed at an altitude of ~900 m a.s.l. on the flanks of Mt. Etna. Processed data are transmitted via GSM modem to the INGV Observatory, where the SO2 flux is computed and displayed in real-time in the INGV 24-hour operational room, providing near instantaneous information on degassing rates and plume location. Fig 2 shows a measurement scheme.





Figure 3. (a) and (b) shows the inner and outer components of one UV-scanner stations.

SO₂ SATELLITE PRODUCTS

The validation of satellite SO₂ products has been performed selecting a subset of eruptive episodes following the criteria of availability of correlative data and SO2 products from both SMASH and SACS-2. The satellite SO₂ products contains column load (DU) and the cloud altitude (km a.s.l.) derived using different algorithm developed by SMASH and SACS-2 project partner using MODIS, IASI, GOME-2 and OMI data capturing the Mt. Etna SO₂ cloud (figs 4 to 7). They are briefly described in the following table 1:

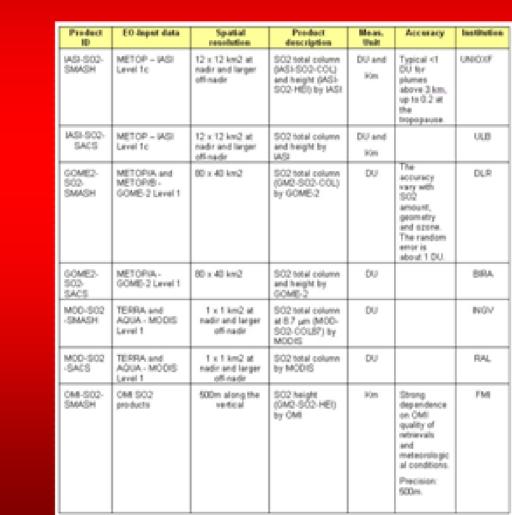


Table1: Satellite SO₂ products



Figure 4. MODIS SO₂ product (10 April 12:27 GMT): a) SMASH produced by INGV and b) SACS-2 produced by RAL

IASI MetOp-A and MetOp-B

Figure 5. IASI SO₂ product (10 April 19.43 GMT): a) SMASH produced by UNIOX and b) SACS-2 produced by ULB.

GOME-2 MetOp-A and MetOp-B

Figure 6. GOME-2 SO₂ product (20 August 09.12 GMT): a) SMASH produced by DRL and b) SACS-2 produced by BIRA.



OMI

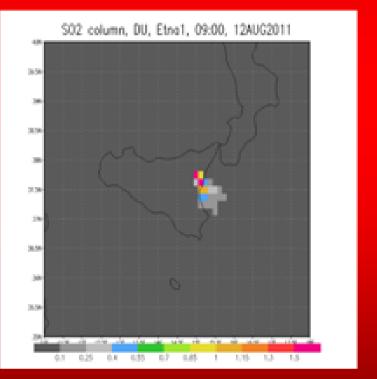
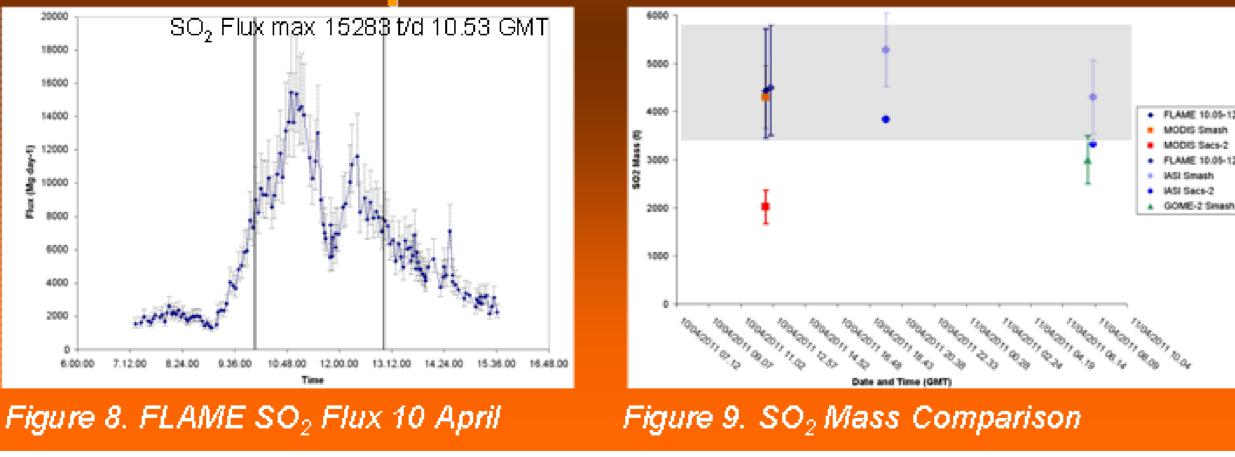
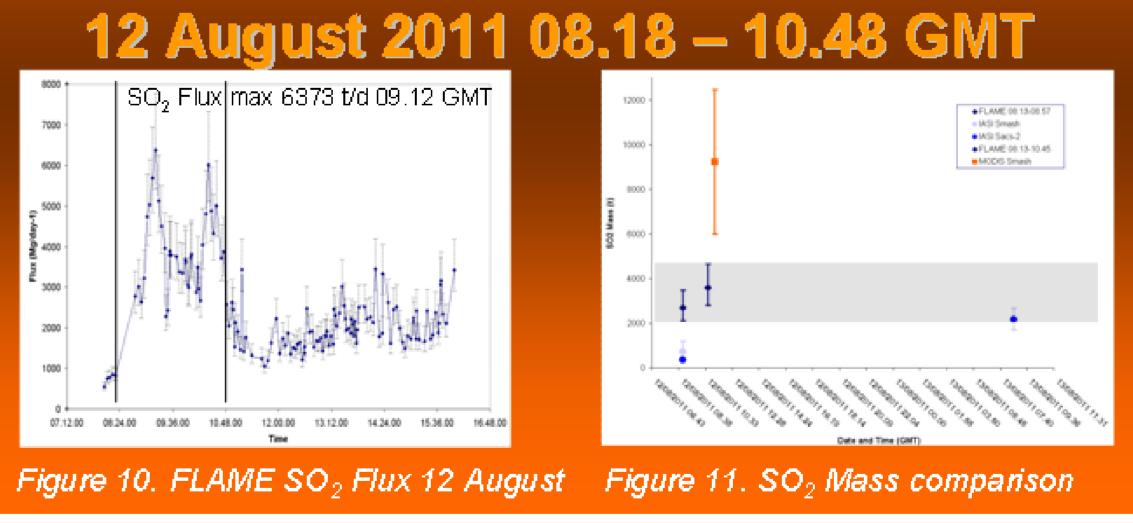


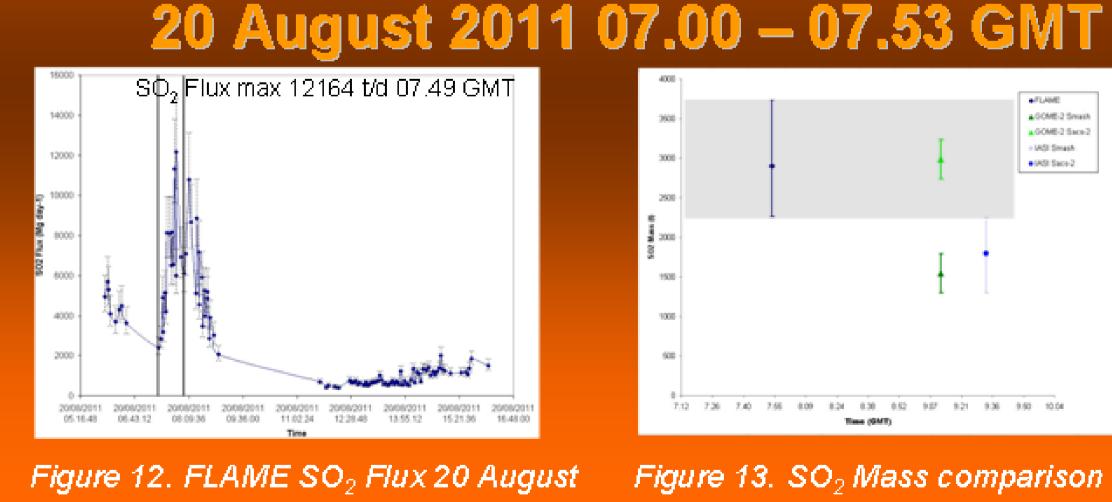
Figure 7. OMI SO₂ products (12 August) SMASH produced by FIMI

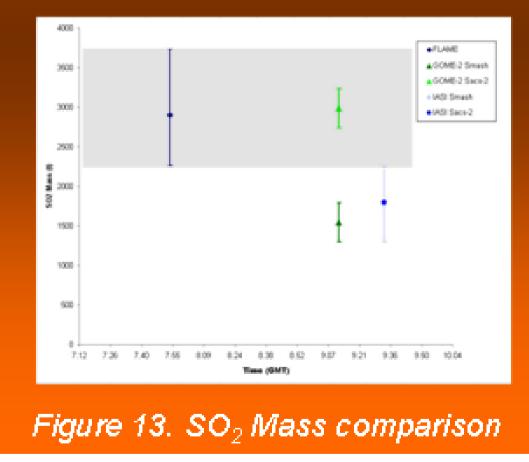
SO, MASS COMPARISON BETWEEN SATELLITE AND GROUND DATA

The Lava fountain events selected has been: 10 April, 12 August and 20 August 2011. The comparison has been between the SO2 mass calculated from the SO2 satellite product and the ground independent SO₂ mass obtained by the re-analysis of Flame SO₂ flux data shown in figs 8, 10, 12. For each of the satellite product MODIS, IASI and GOME-2 the SO₂ mass has been calculated as cumulative mass and averaged over the detected area. In figs 9, 11, 13 the results of comparison are reported for the selected events. In the case of satellite passes during the lava fountain event, the SO2 amount from Flame network has been recalculated considering the amount of SO2 in the time lapse from the start time of lava fountain and time of satellite pass.









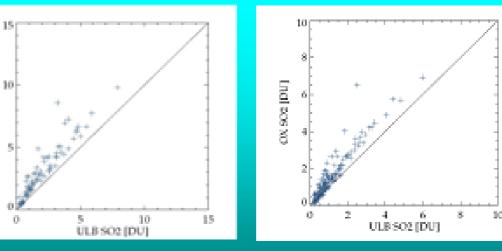
CONCLUSIONS

Mt. Etna 2011 Lava Fountains events have been selected when ground data have been available and satellite SO₂ product has been retrieved. From the comparison each of SO₂ product IASI, MODIS and GOME-2 can be considered validated if the product SO₂ mass values are within the ground Flame errors. The Cross-correlation on Cloud detected area evidence small difference in retrieval algorithm for IASI, MODIS and GOME-2 while a difference of 50% on Colum Amount for MODIS is derived. Cloud altitude crosscorrelation shows large difference.

CROSS-CORRELATION

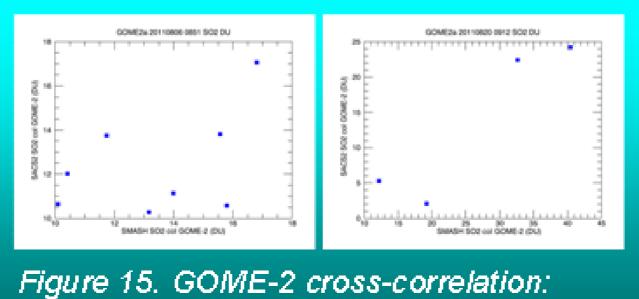
The cross-correlation is between products derived using same instrument but different retrievals algorithms. The test cases for cross-comparison of MODIS, IASI and GOME-2 sensors in terms of cloud detected area, SO2 Column Content and cloud altitude are in the following figures 14,15 and table 2 and 3 for:

10/04 (ET2) MODIS and IASI; 05/08 (ET6) GOME-2; 12/08 (ET7) MODIS and IASI; 20/08 (ET8) MODIS, IASI, GOME-2.

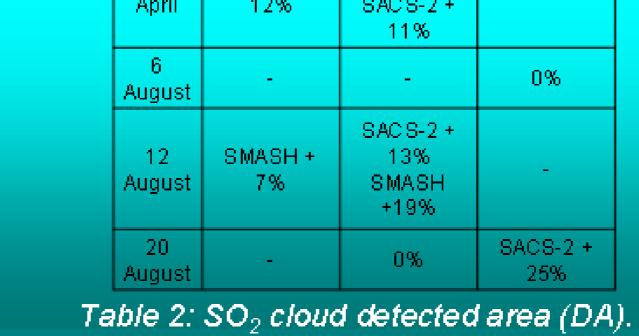


a) 10 April 19.42 b)11 April 08.03 GMT.

Figure 14. IASI cross-correlation:



a) 10 April 19.42 b) 11 April 08.03 GMT.



background made after the fountaining.