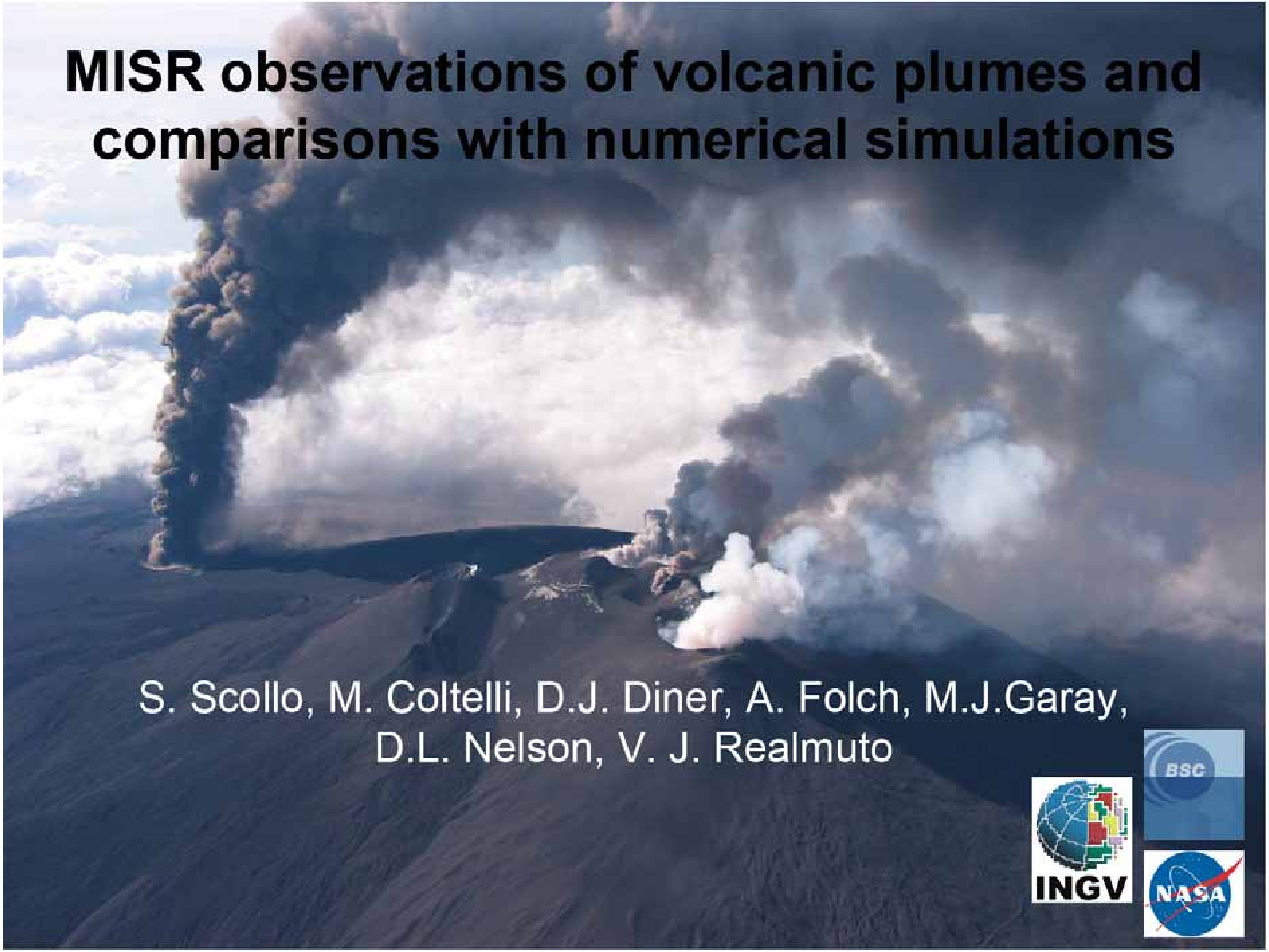


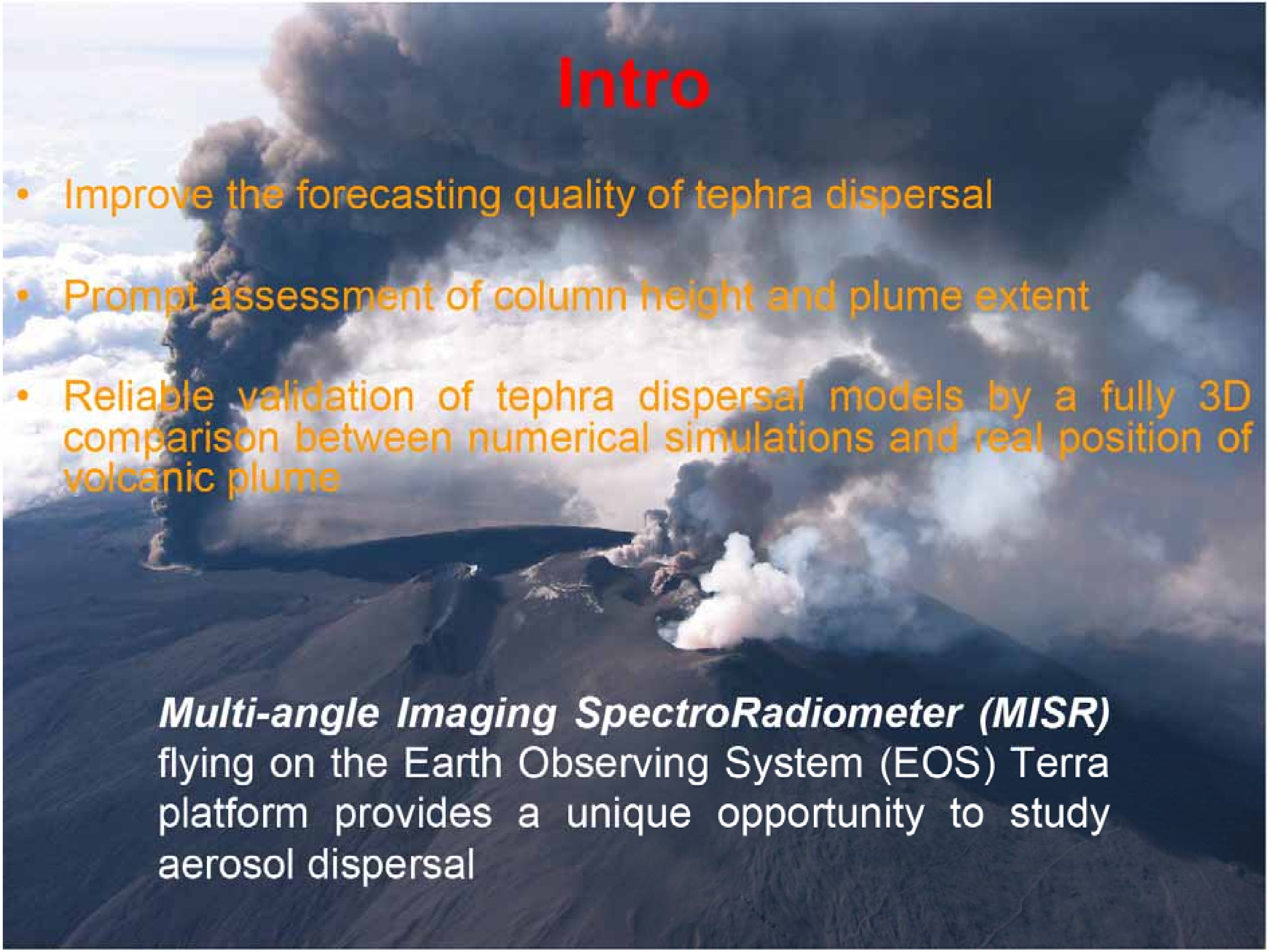
MISR observations of volcanic plumes and comparisons with numerical simulations

S. Scollo, M. Coltelli, D.J. Diner, A. Folch, M.J.Garay,
D.L. Nelson, V. J. Realmuto

BSC

INGV

NASA



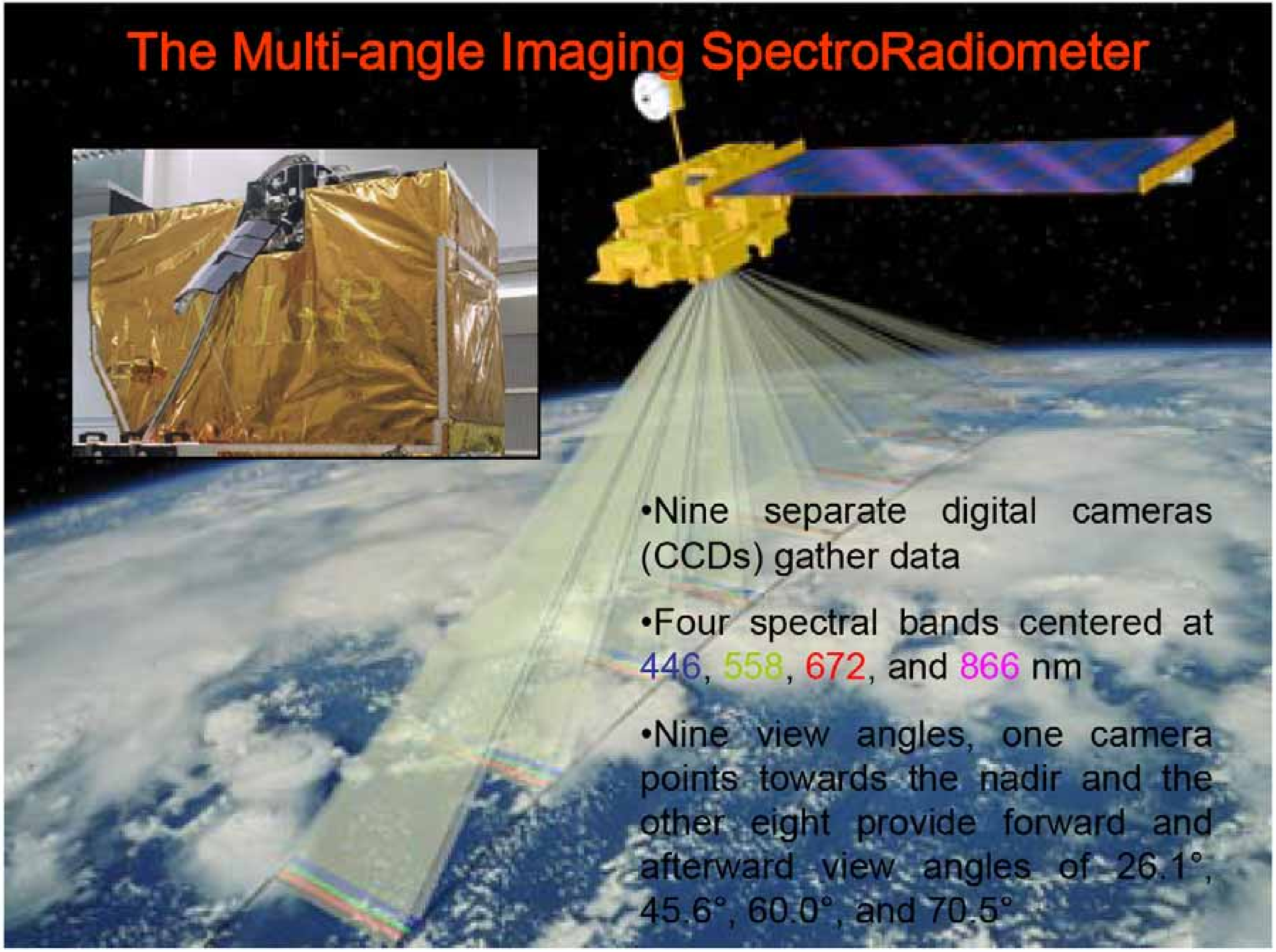
Intro

- Improve the forecasting quality of tephra dispersal
- Prompt assessment of column height and plume extent
- Reliable validation of tephra dispersal models by a fully 3D comparison between numerical simulations and real position of volcanic plume

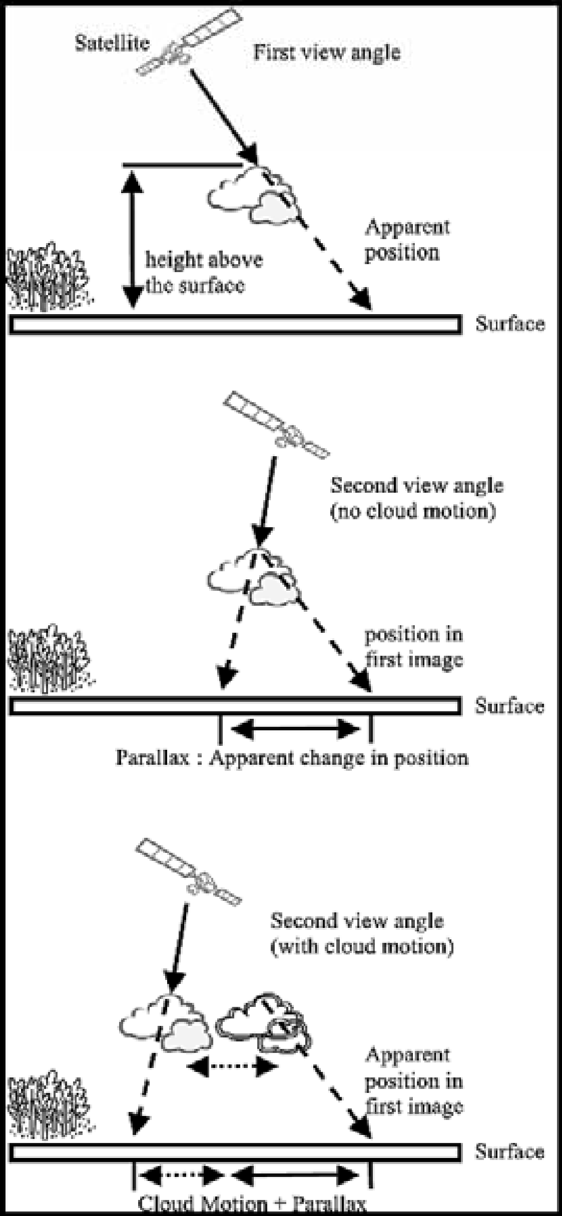
Multi-angle Imaging SpectroRadiometer (MISR) flying on the Earth Observing System (EOS) Terra platform provides a unique opportunity to study aerosol dispersal

Summary

- The Multi-angle Imaging SpectroRadiometer
- MISR observations of Etna volcanic plumes
- MISR versus numerical simulations of tephra dispersal
- Field data and MIRS observations of 2001 and 2002 events
- Ash cloud dispersal modeling
- Comparisons between MIRS data and numerical simulations
- Discussion and Conclusion
- Future Studies


The Multi-angle Imaging SpectroRadiometer
•Nine separate digital cameras (CCDs) gather data
•Four spectral bands centered at 446, 558, 672, and 866 nm
•Nine view angles, one camera points towards the nadir and the other eight provide forward and afterward view angles of 26.1°, 45.6°, 60.0°, and 70.5°

Stereo-imaging technique



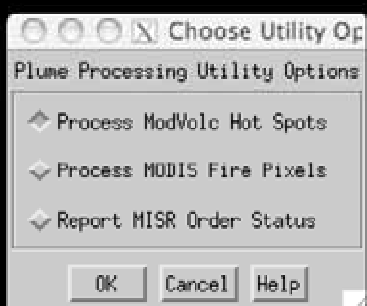
MISR determinates the cloud top height (CTH) using stereo-imaging technique.

The technique is geometric and is not sensitive to the actual value of the observed radiances (i.e., the sensor calibration).

The dominant source of error in the height retrieval comes from errors in the wind correction.

From Marchand et al. (2010)

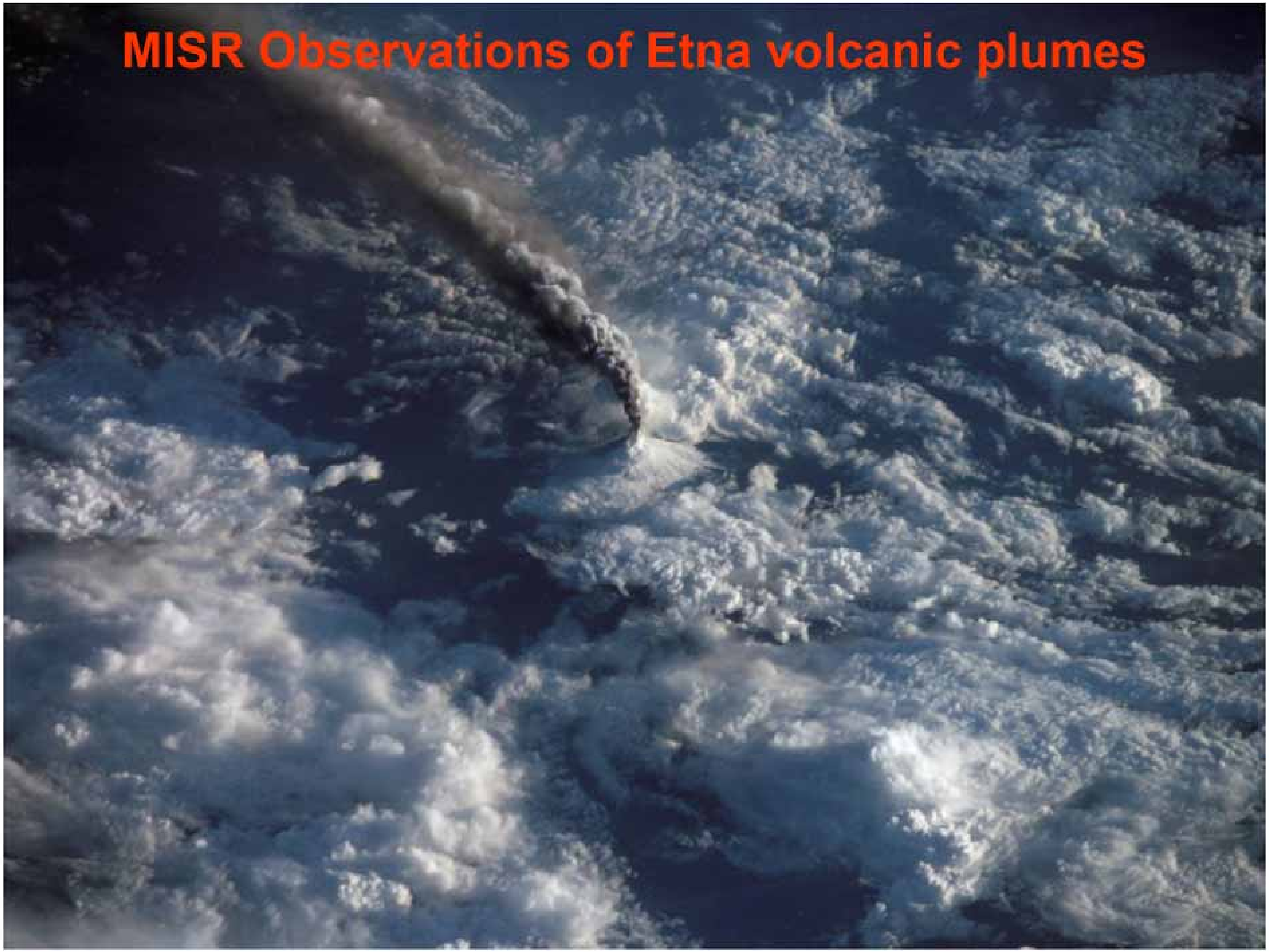
The MINX software (MISR Interactive eXplorer)



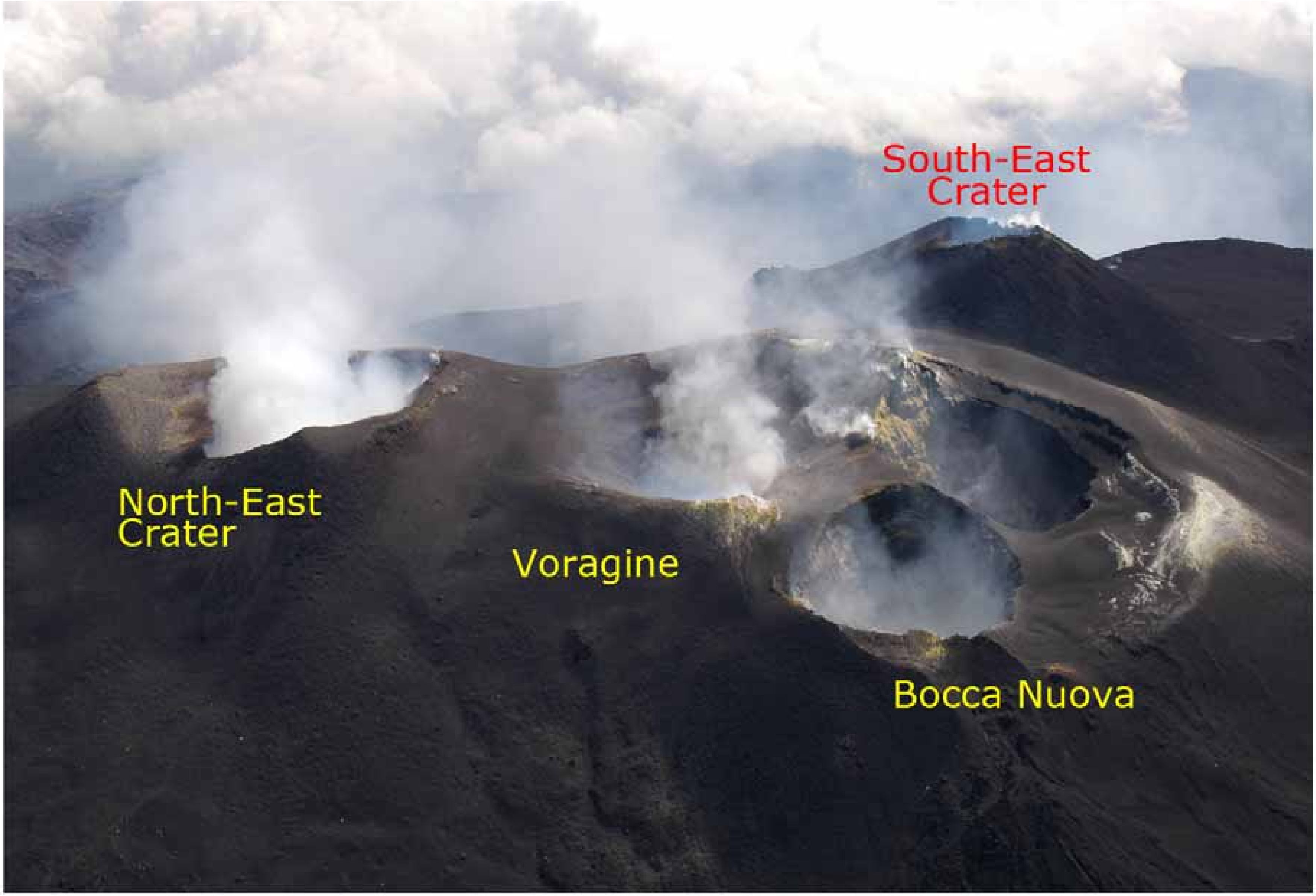
MINX is an interactive application written in IDL and compiled into an IDL Virtual Machine (VM) file.

MINX provides height and wind retrievals at higher resolution and often with greater precision than the standard MISR retrievals. A stereo-matching technique compares red-band data between each of six off-nadir cameras and the nadir or reference camera.

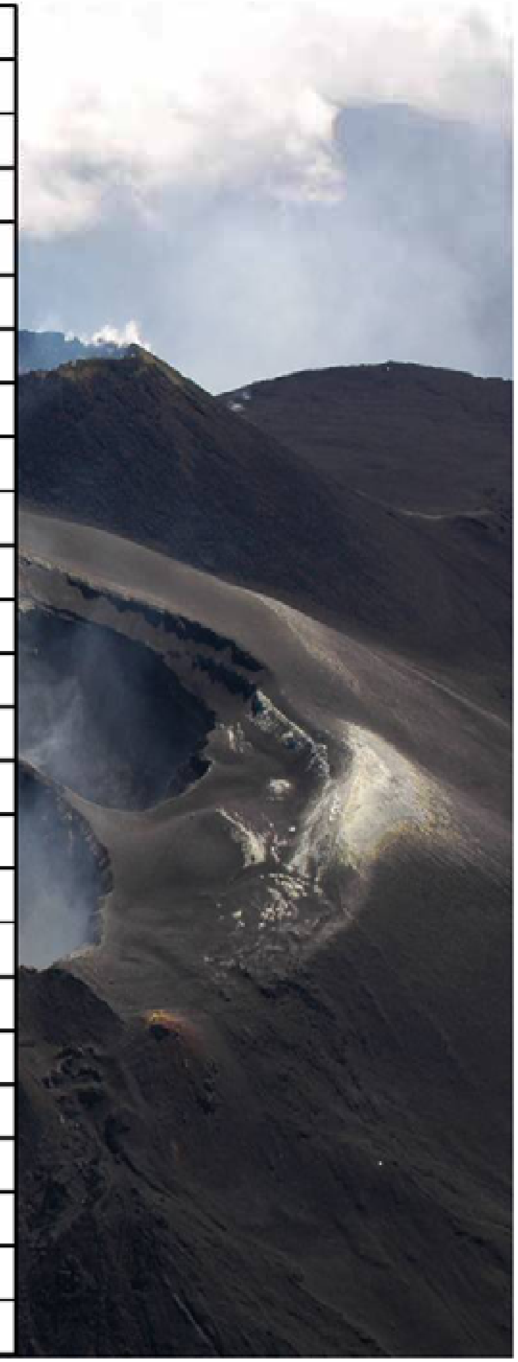
From Nelson et al. (2008)


MISR Observations of Etna volcanic plumes

Mount Etna



ETNA ERUPTIONS	*MISR*
23 May 2000 at 10:08 UTC	*Orbit 2287, path 188, block 60*
1 Jun 2000 at 10:02 UTC	*Orbit 2418, path 187, block 48*
20 Jul 2001 at 10:07 UTC	*Orbit 8447, path 189, block 60*
22 Jul 2001 at 09:07 UTC	*Orbit 8476, path 187, block 60*
29 Jul 2001 at 10:01 UTC	*Orbit 8578, path 188, block 60*
27 Oct 2002 at 10:00 UTC	*Orbit 15204, path 189, block 61*
29 Oct 2002 at 09:48 UTC	*Orbit 15233, path 187, block 60*
05 Nov 2002 at 09:54 UTC	*Orbit 15335, path 188, block 60*
07 Nov 2002 at 09:41 UTC	*Orbit 15364, path 186, block 60*
14 Nov 2002 at 09:47 UTC	*Orbit 15466, path 187, block 60*
23 Nov 2002 at 09:42 UTC	*Orbit 15597, path 186, block 60*
28 Nov 2002 at 10:00 UTC	*Orbit 15670, path 189, block 60*
07 Dec 2002 at 09:54 UTC	*Orbit 15801, path 188, block 60*
16 Dec 2002 at 09:48 UTC	*Orbit 15932, path 187, block 60*
23 Dec 2002 at 09:54 UTC	*Orbit 16034, path 188, block 60*
30 Dec 2002 at 10:04 UTC	*Orbit 16136, path 189, block 60*
01 Jan 2003 at 09:54 UTC	*Orbit 16267, path 188, block 60*
15 Jan 2003 at 10:00 UTC	*Orbit 16369, path 189, block 60*
31 Jan 2003 at 10:00 UTC	*Orbit 16602, path 189, block 60*
22 Sept 2006 at 09:46 UTC	*Orbit 35970, path 187, block 60*
29 Sept 2006 at 09:52 UTC	*Orbit 36072, path 188, block 60*
16 Nov 2006 at 09:52 UTC	*Orbit 36771, path 188, block 60*
25 Nov 2006 at 09:46 UTC	*Orbit 36902, path 187, block 60*
13 May 2008 at 09:53 UTC	*Orbit 44693, path 188, block 60*



The 2000 lava fountaining activity

The Southeast Crater of Mount Etna (Italy) was characterized by a violent eruptive activity between 26 January and 24 June 2000. This activity produced 64 lava fountain episodes with repose periods from 3 hours to 10 days (Alparone et al., 2003).

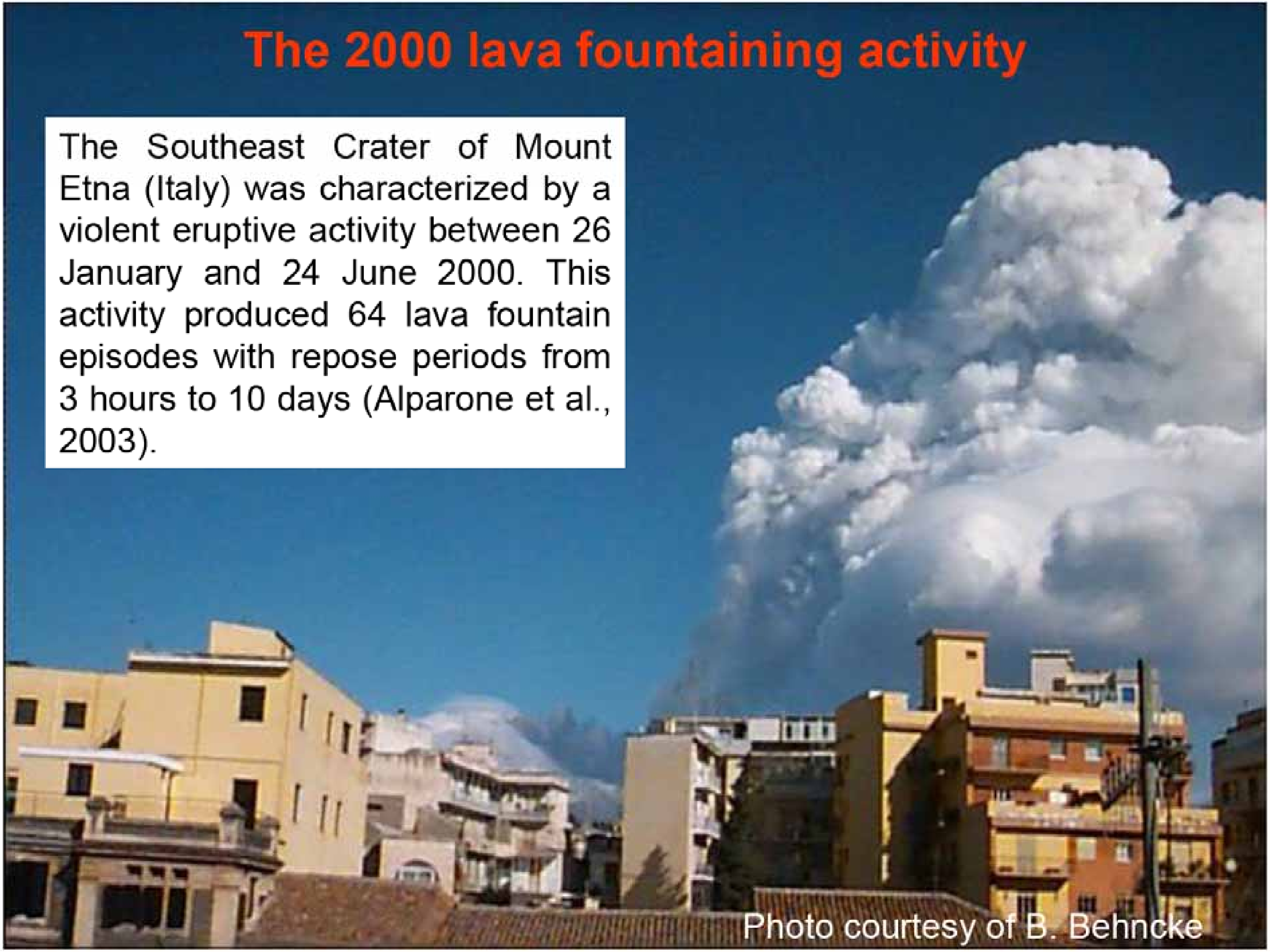
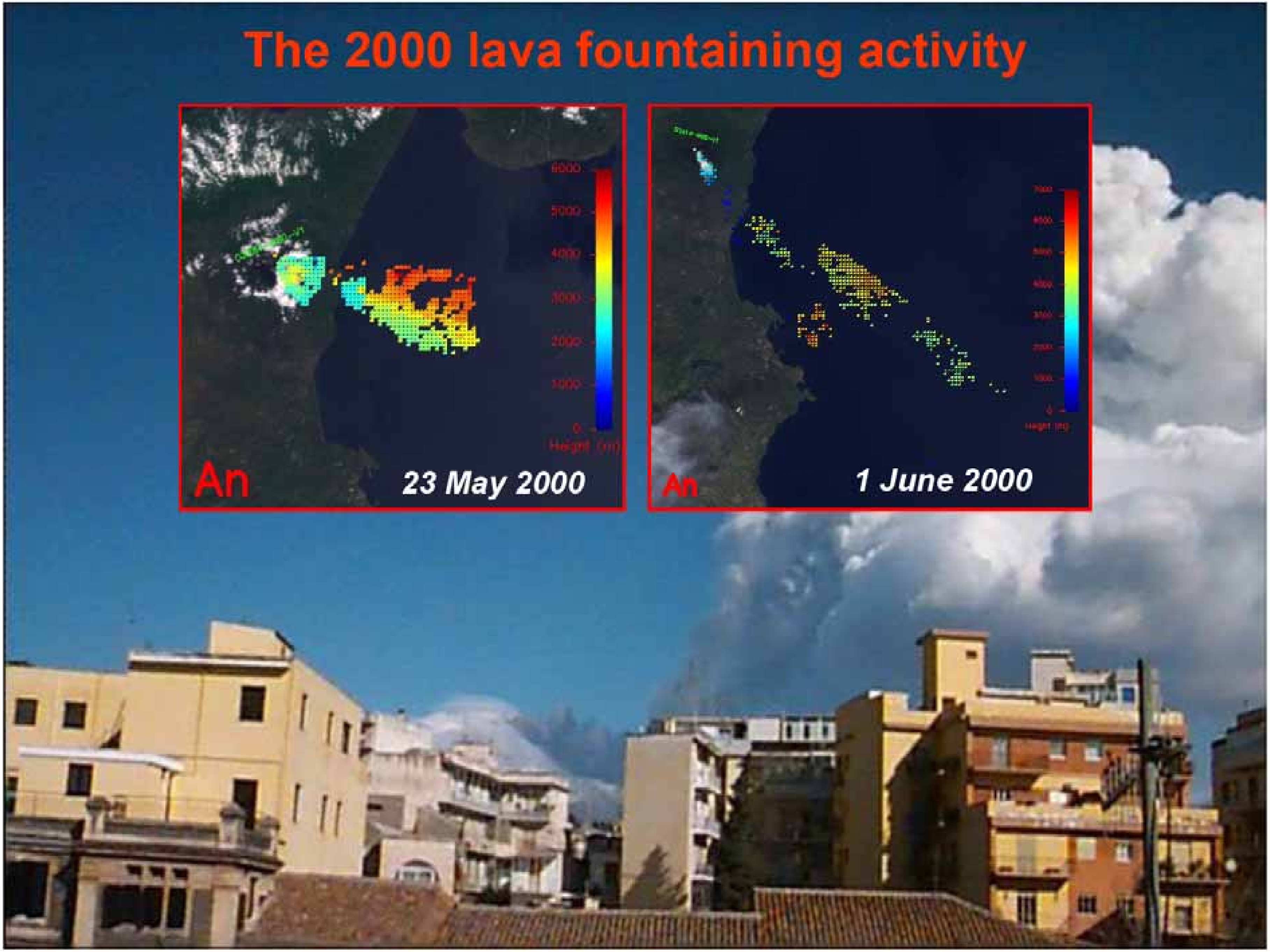
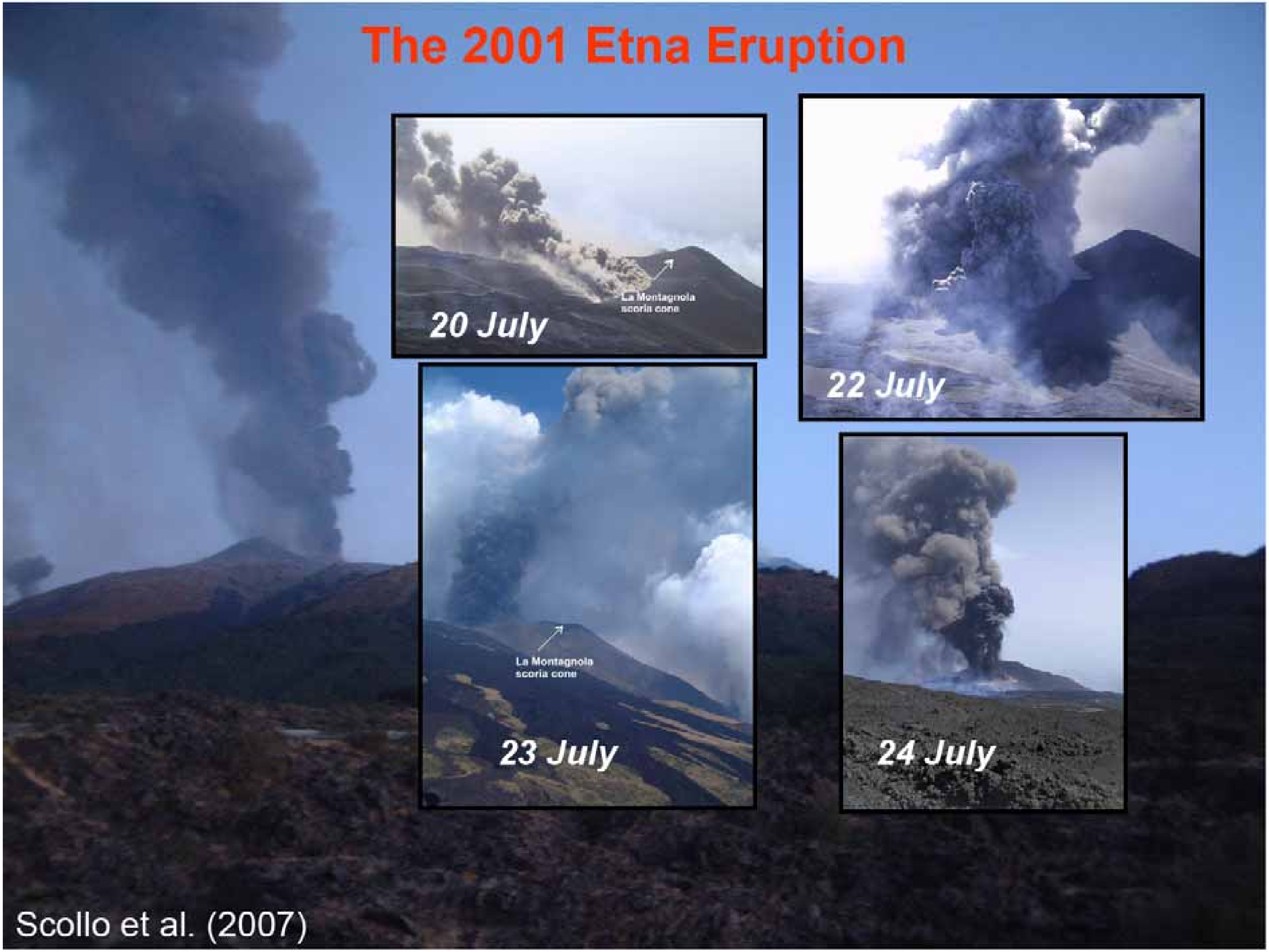


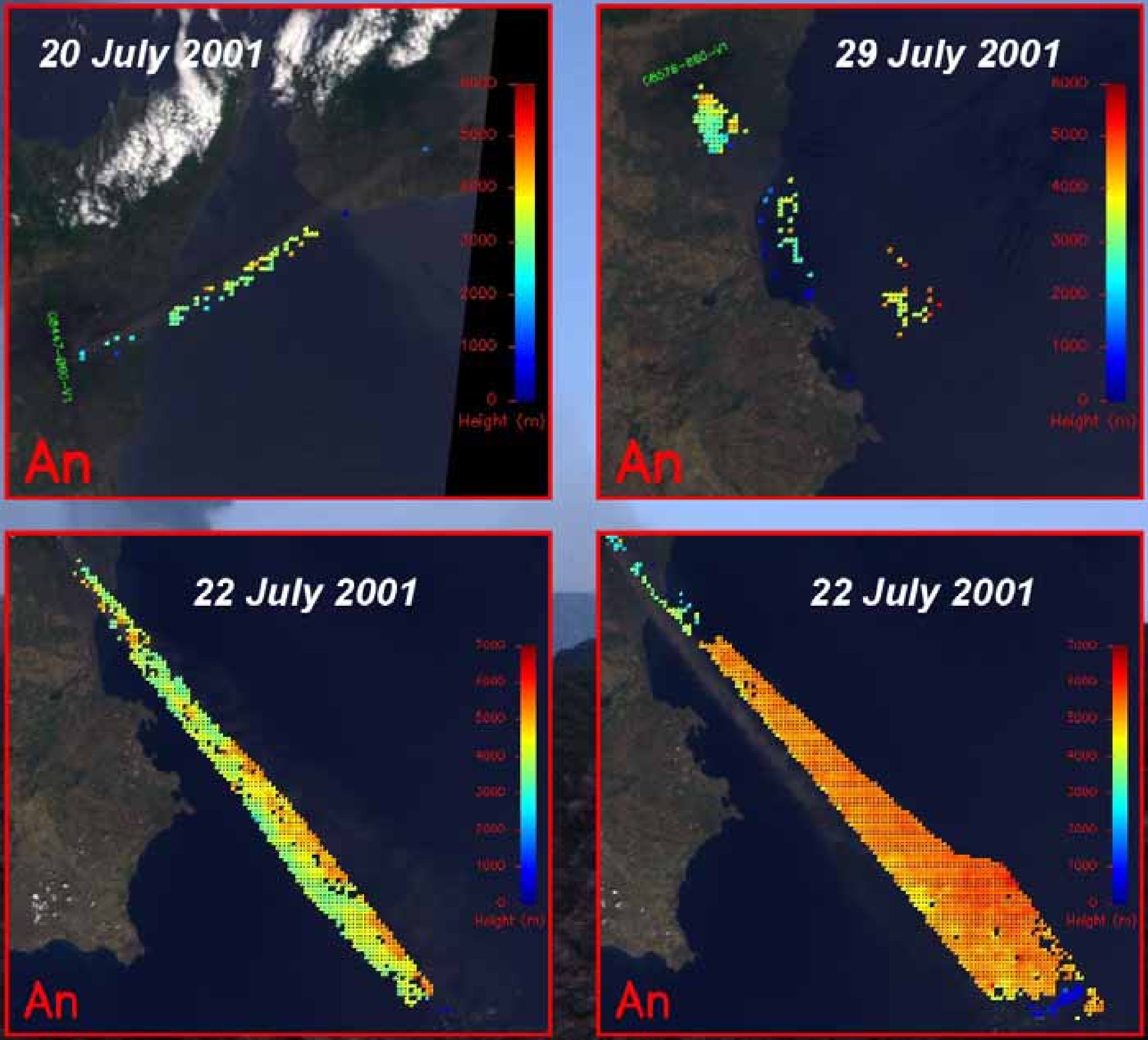
Photo courtesy of B. Behncke

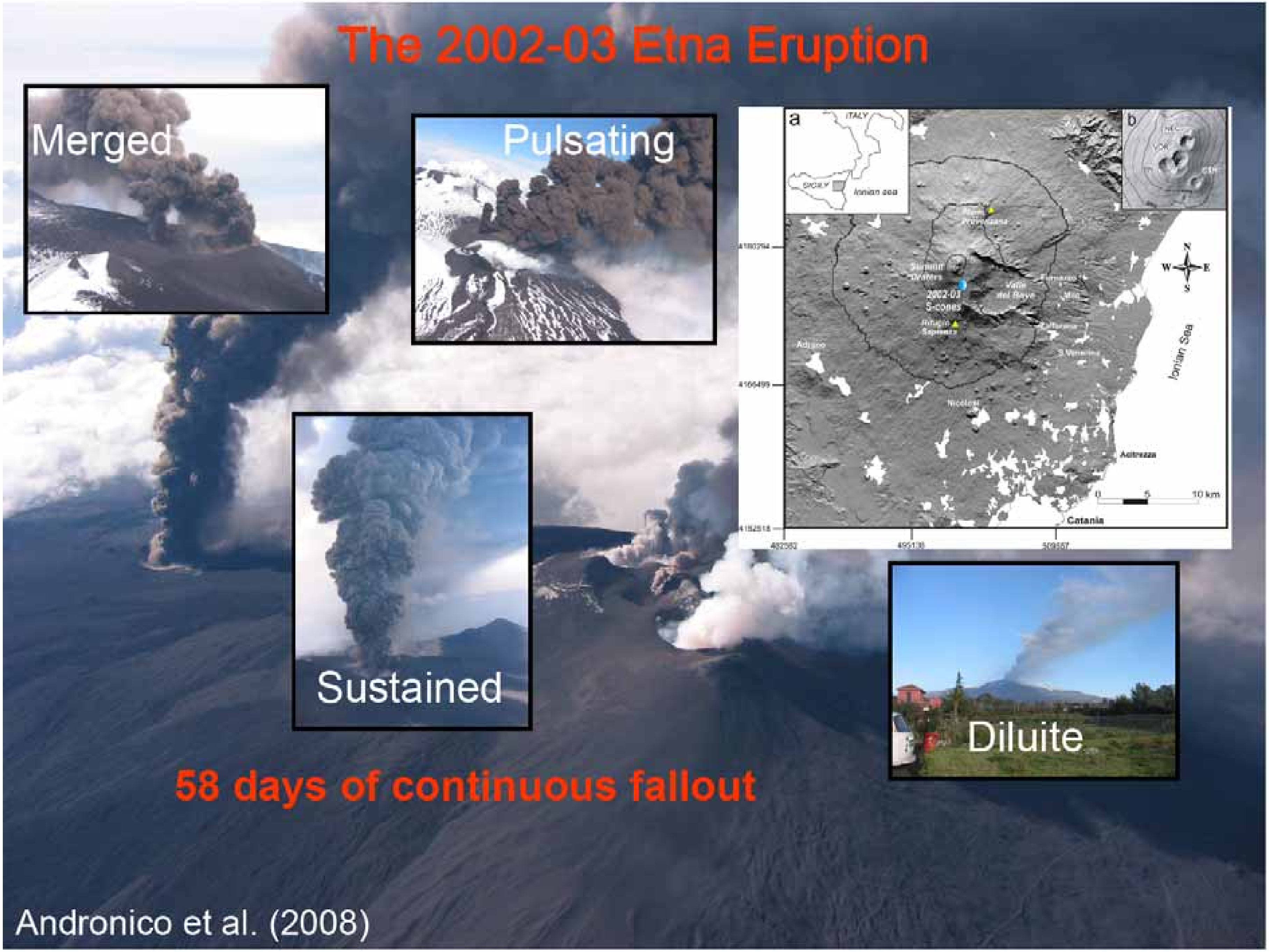


The 2000 lava fountaining activity
6000
5000
4000
3000
2000
1000
0
Height (m)
An
23 May 2000
An
1 June 2000

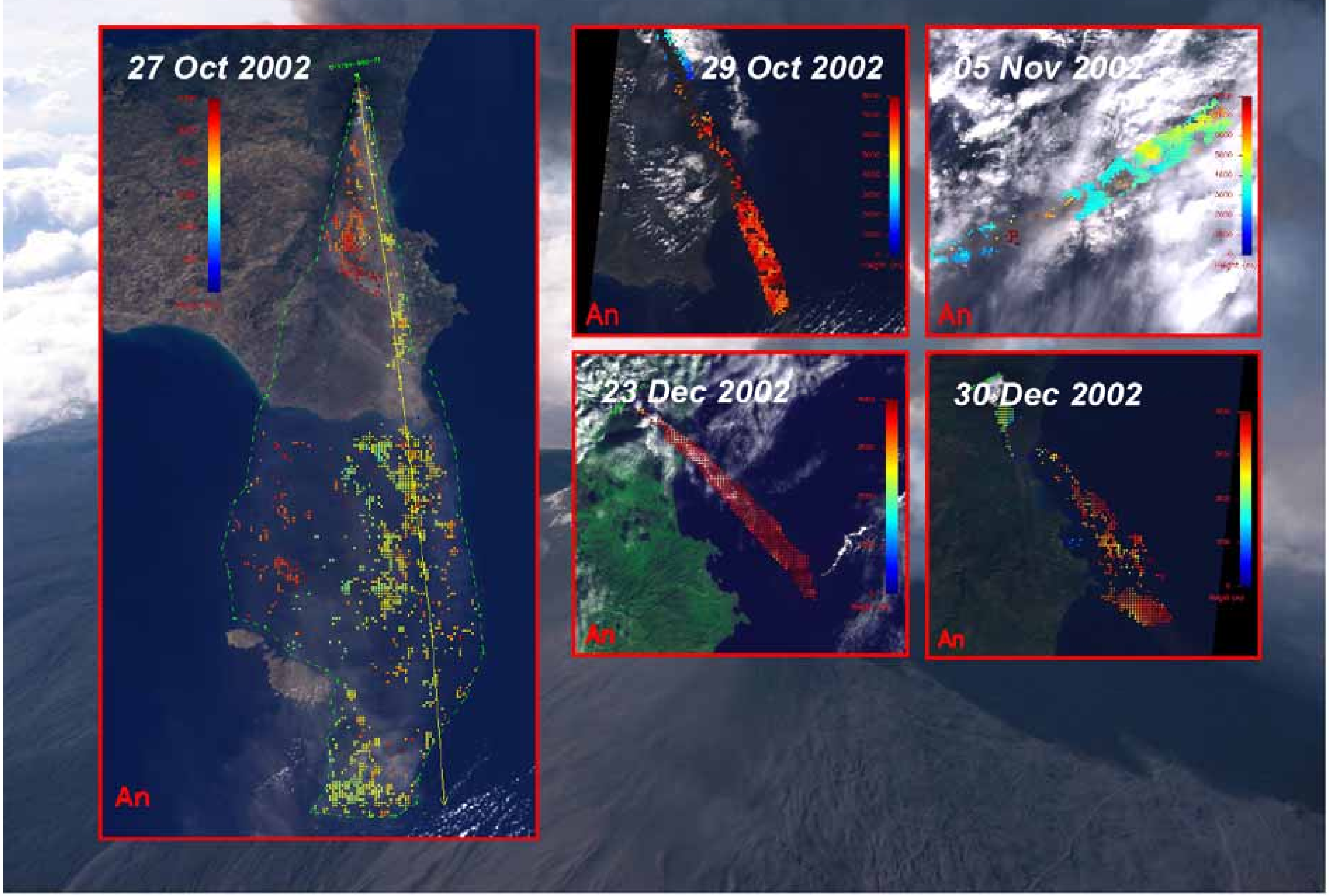

The 2001 Etna Eruption
La Montagnola
scoria cone
20 July
22 July
La Montagnola
scoria cone
23 July
24 July
Scollo et al. (2007)

The 2001 Etna Eruption



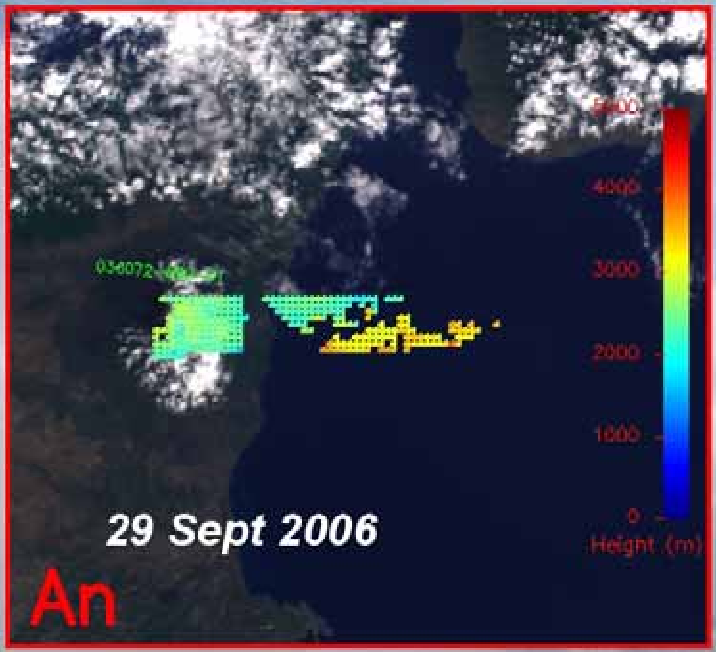

The 2002-03 Etna Eruption
Merged
Pulsating
Sustained
Diluite
ITALY
SICILY
Ionian sea
Ionian Sea
Acitrezza
Catania
10 km
58 days of continuous fallout
Andronico et al. (2008)

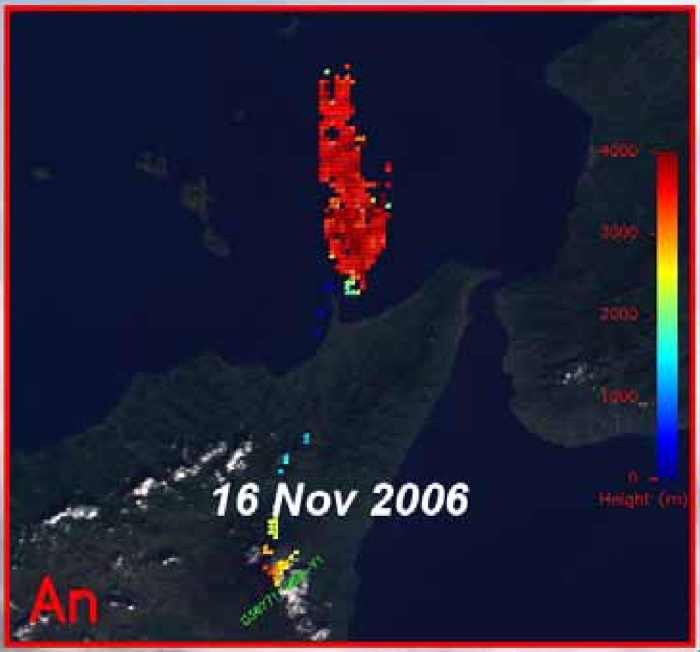
The 2002-03 Etna Eruption



The 2006 Etna Eruption

The 2006 Etna Eruption



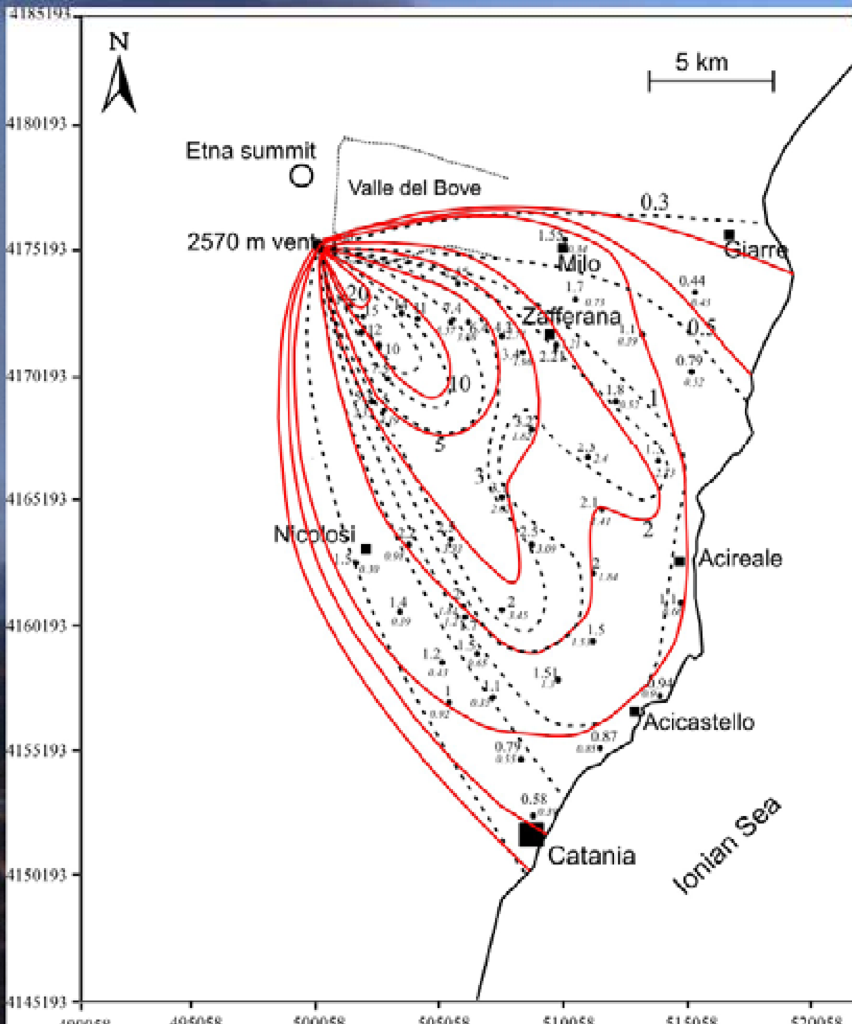


3D Comparison aerosol dispersal: a comparison between MISR data and numerical simulations

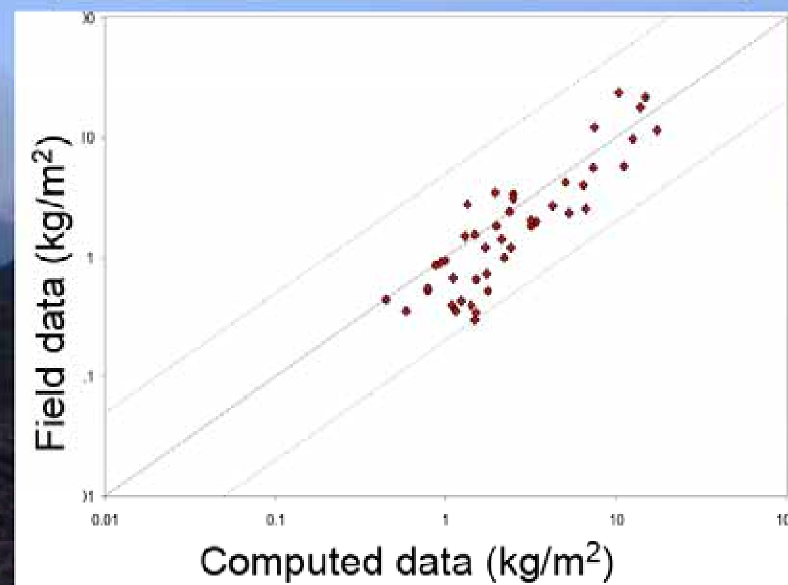
Scollo et al. (2010, JGR, in press)

The 2001 Etna Eruption

TEPHRA DEPOSIT



DATA COLLECTION

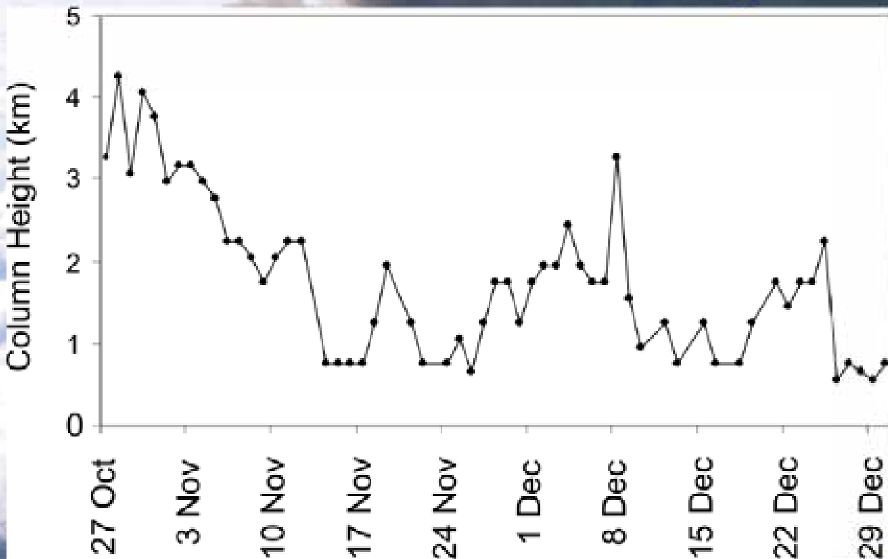


Scollo et al. (2007)

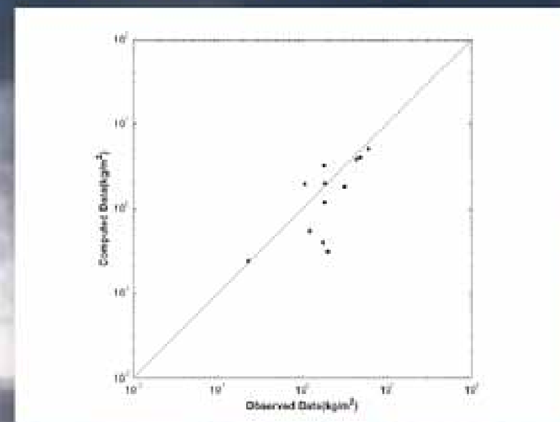
http://www.ct.ingv.it/Progetti/lavcei/index.htm

The 2002 Etna Eruption

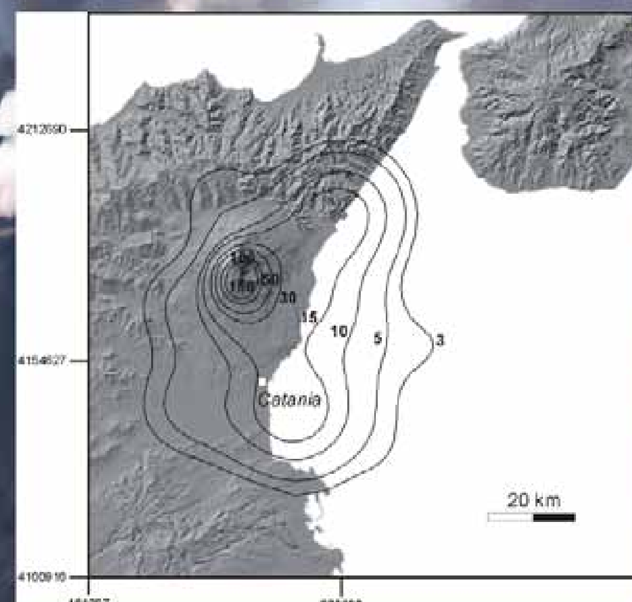
Variation of the column height



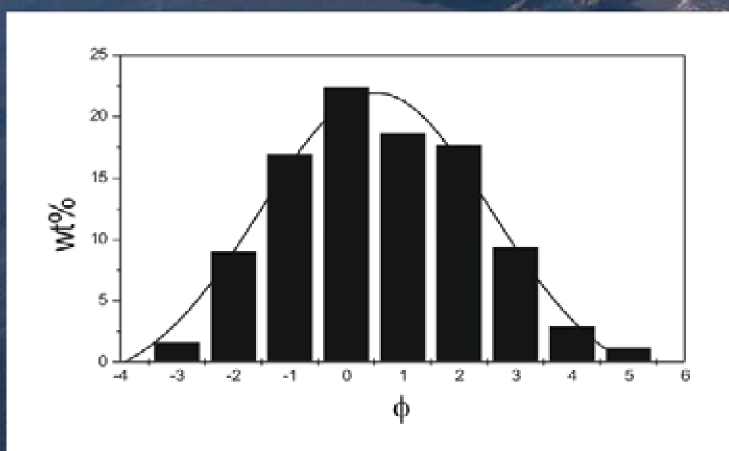
Model Calibration



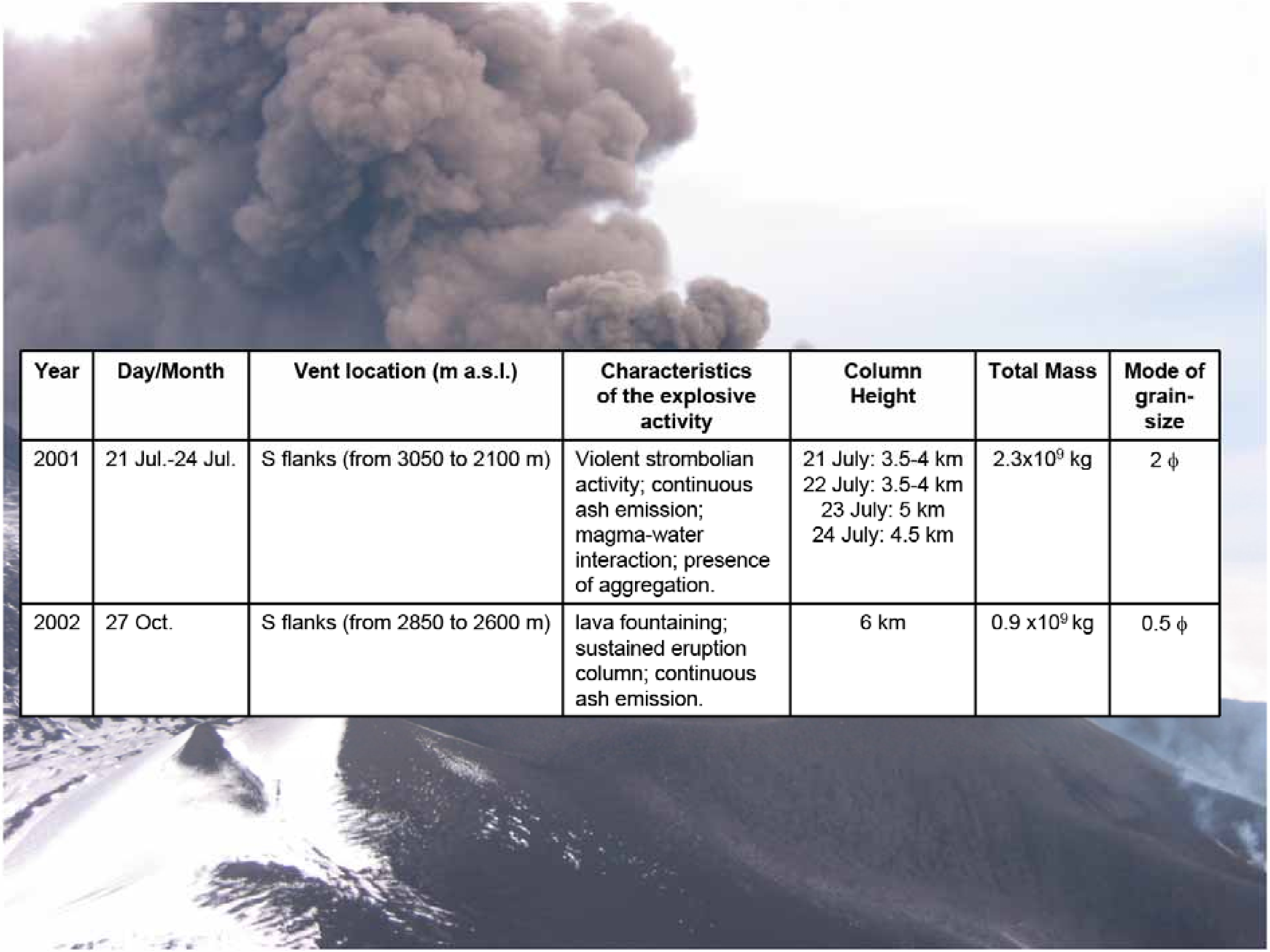
Hazard Evaluation



Total Grain-size Diistribution



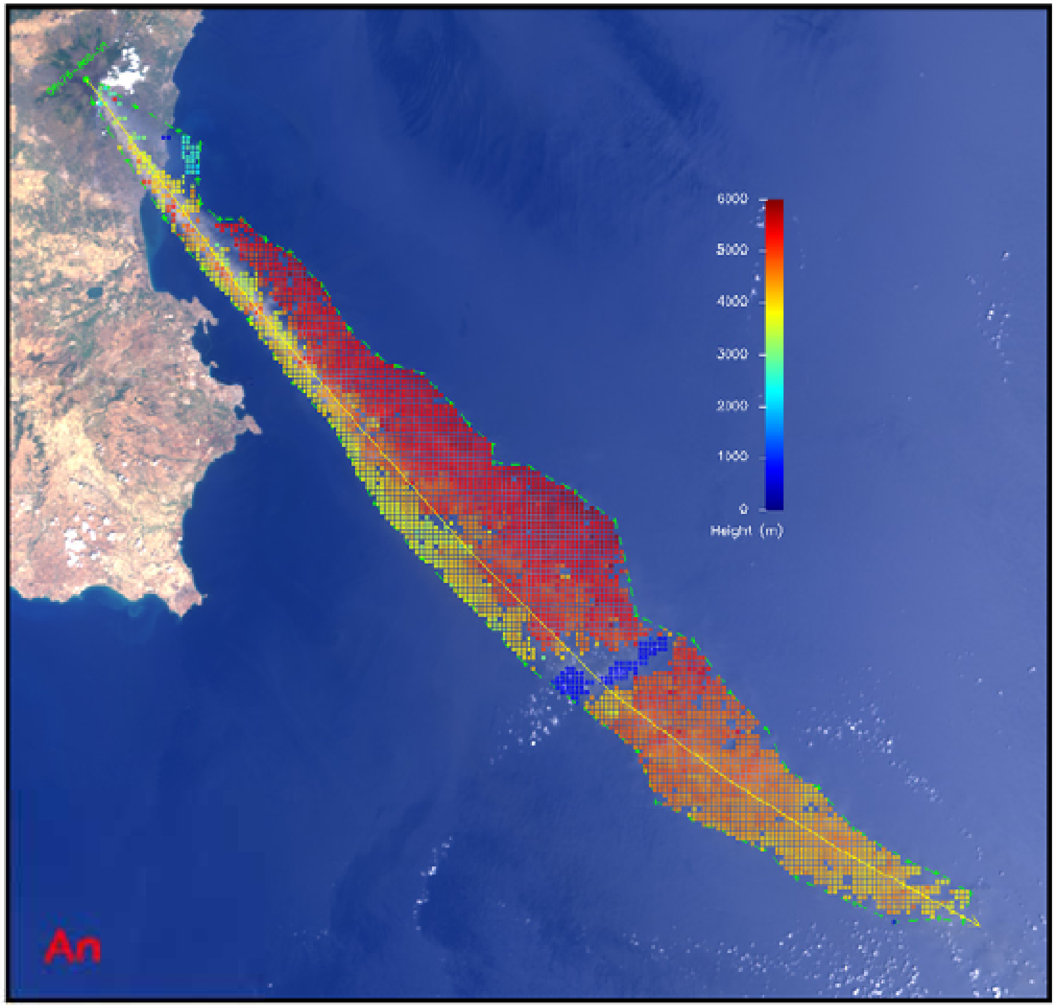
Andronico et al. (2008)



Year	Day/Month	Vent location (m a.s.l.)	Characteristics of the explosive activity	Column Height	Total Mass	Mode of grain-size
2001	21 Jul.-24 Jul.	S flanks (from 3050 to 2100 m)	Violent strombolian activity; continuous ash emission; magma-water interaction; presence of aggregation.	21 July: 3.5-4 km 22 July: 3.5-4 km 23 July: 5 km 24 July: 4.5 km	2.3×10^9 kg	2 ϕ
2002	27 Oct.	S flanks (from 2850 to 2600 m)	lava fountaining; sustained eruption column; continuous ash emission.	6 km	0.9×10^9 kg	0.5 ϕ

MISR data of the 2001 Etna eruption

Wind-corrected stereo heights

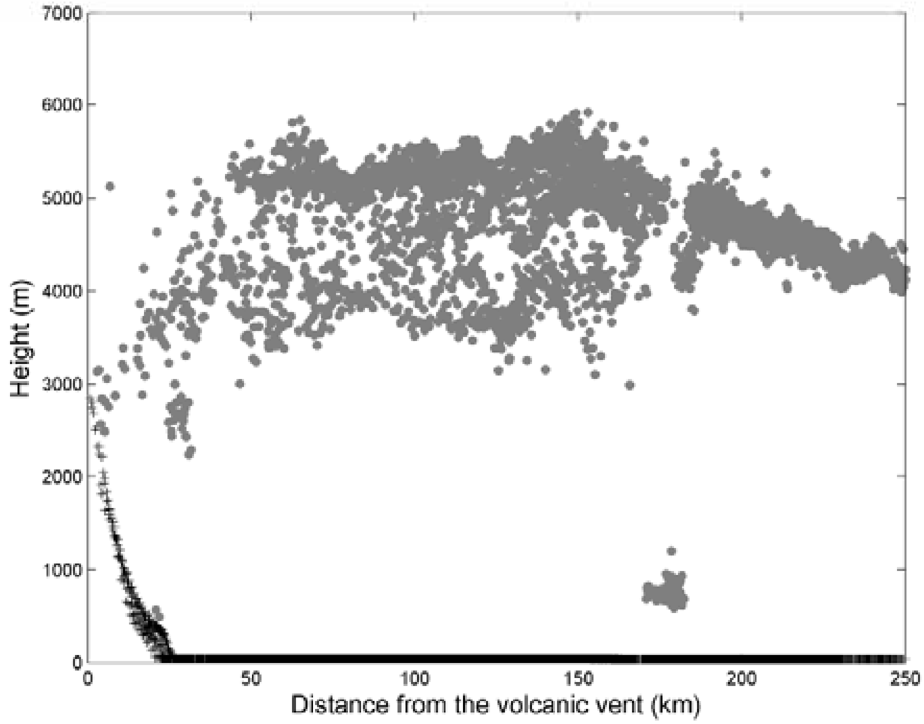


MISR detected the plume directed toward SE

The most of particles belong to the medium class (between 0.35 and 0.7 μm diameter).

MISR data of the 2001 Etna eruption

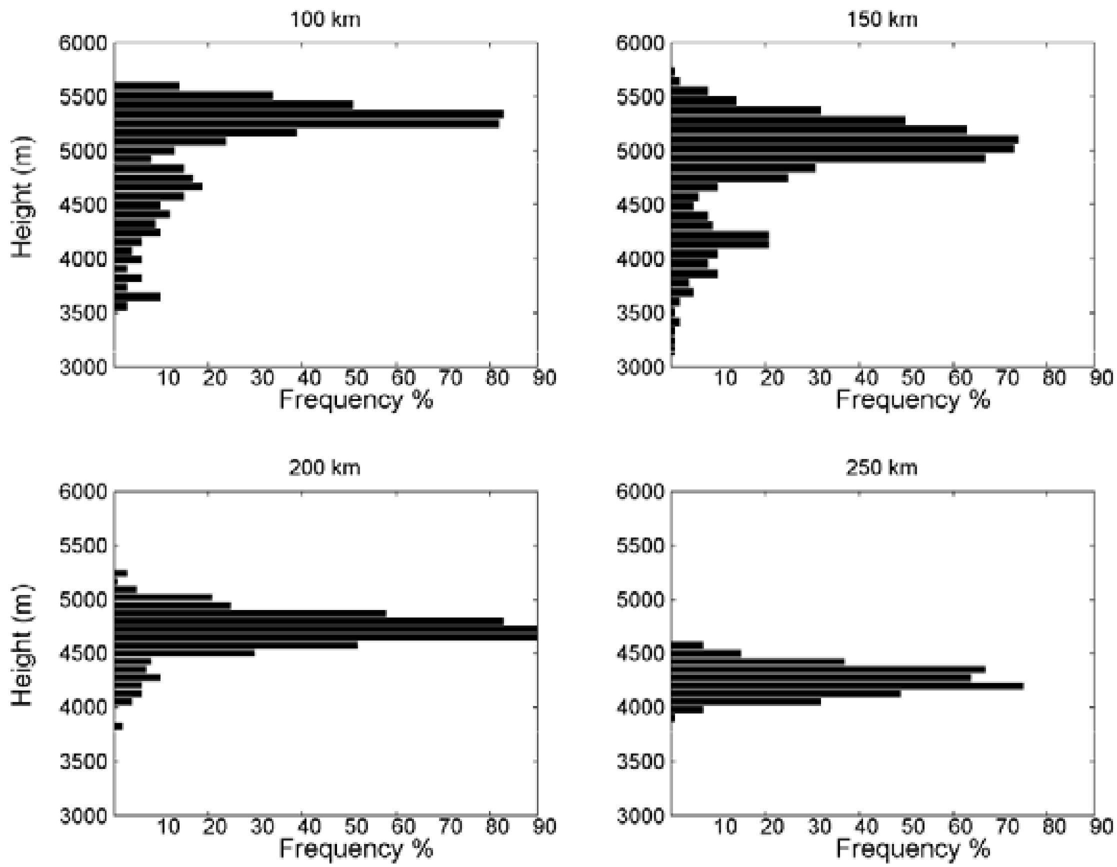
Corrected heights retrieved by MISR in function of the distance from the vent



1) bent-over shape due to wind action near the source
2) increase of fine ash concentration in the lower layers
3) small fingers of particle-laden fluid

MISR data of the 2001 Etna eruption

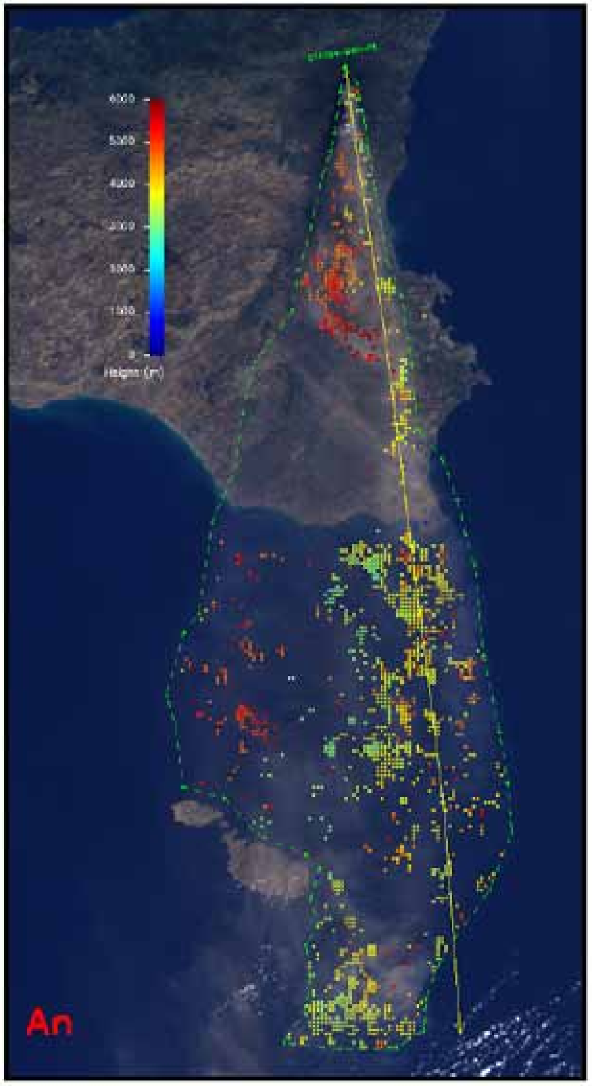
Stereo-height histograms of the volcanic plume at four selected patches



The height of the volcanic plume decreased approximately 1 km along the main plume axes (SE) in about 250 km

MISR data of the 2002 Etna eruption

Wind-corrected stereo heights

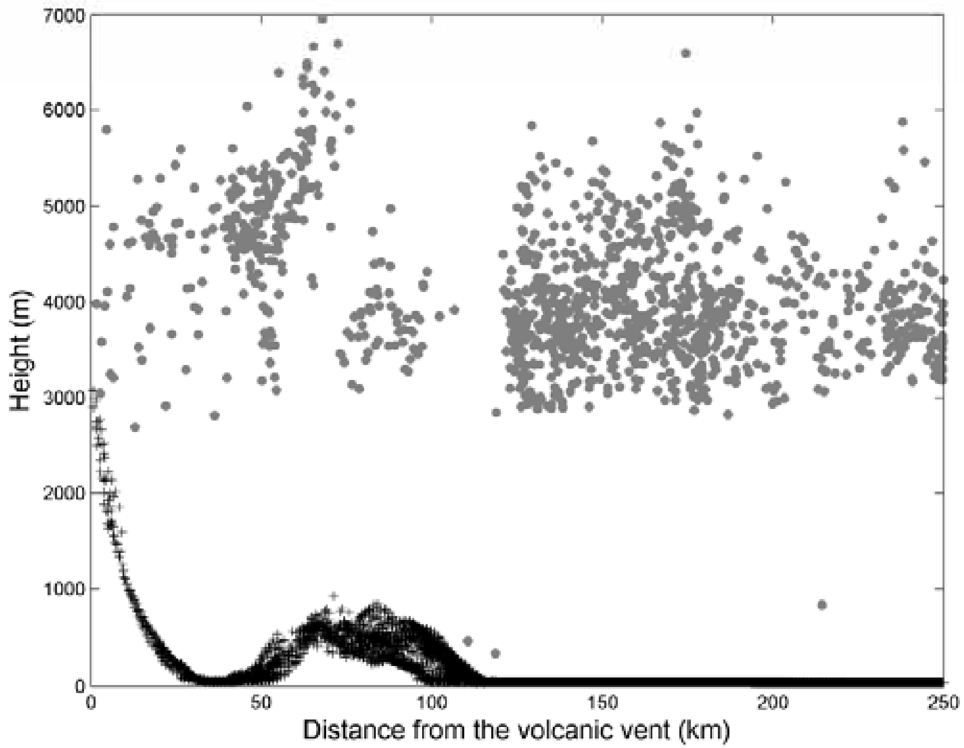


MISR retrieved aerosol above 4500 m toward SSW and below 4500 m towards SSE

the majority of the 2002 plume particles belongs to the large-class interval (larger than 0.7 μm).

Multiple source?!!

MISR data of the 2002 Etna eruption

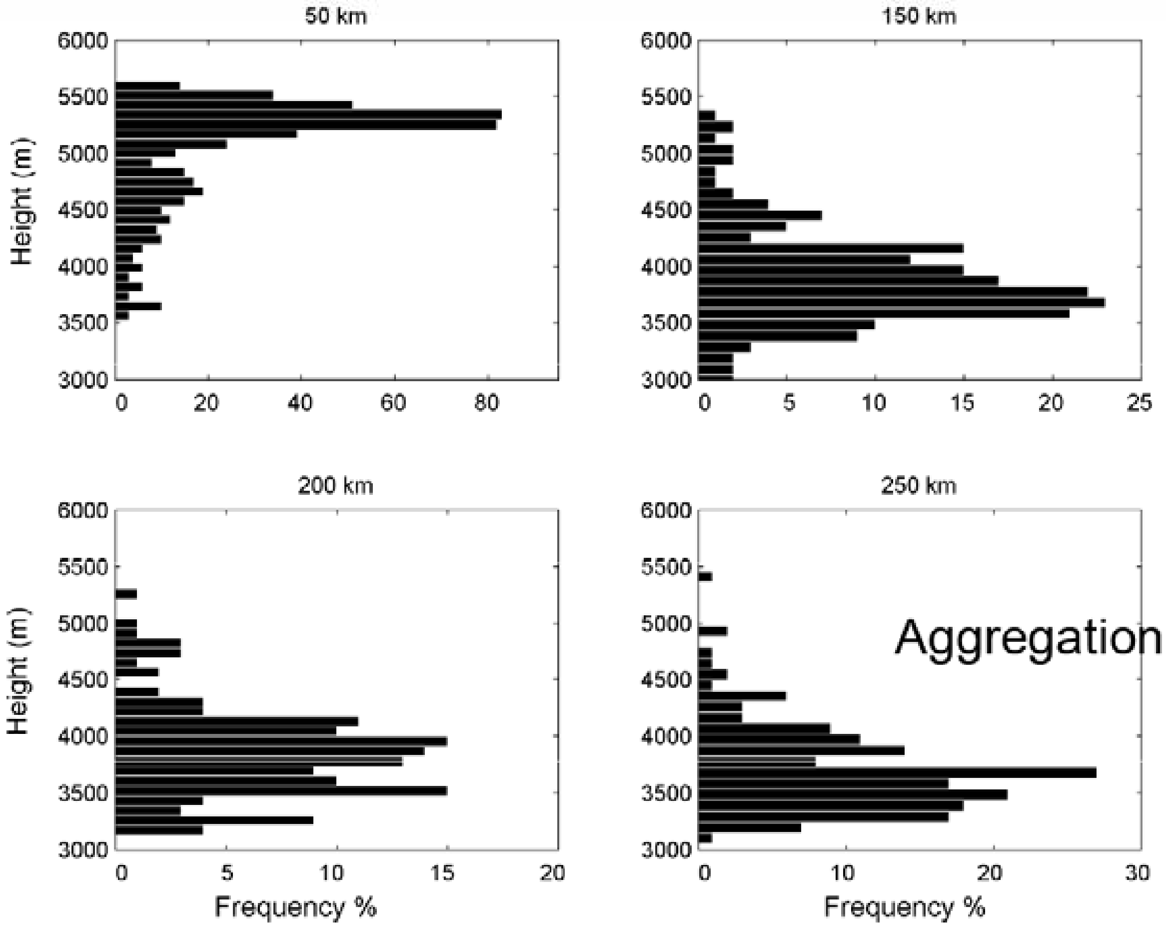


1) two "holes" in MISR data from 75 to 125 km from the vent related to the presence of light and tin clouds

2) a light bent-over shape due to the minor effect of wind on the eruption column

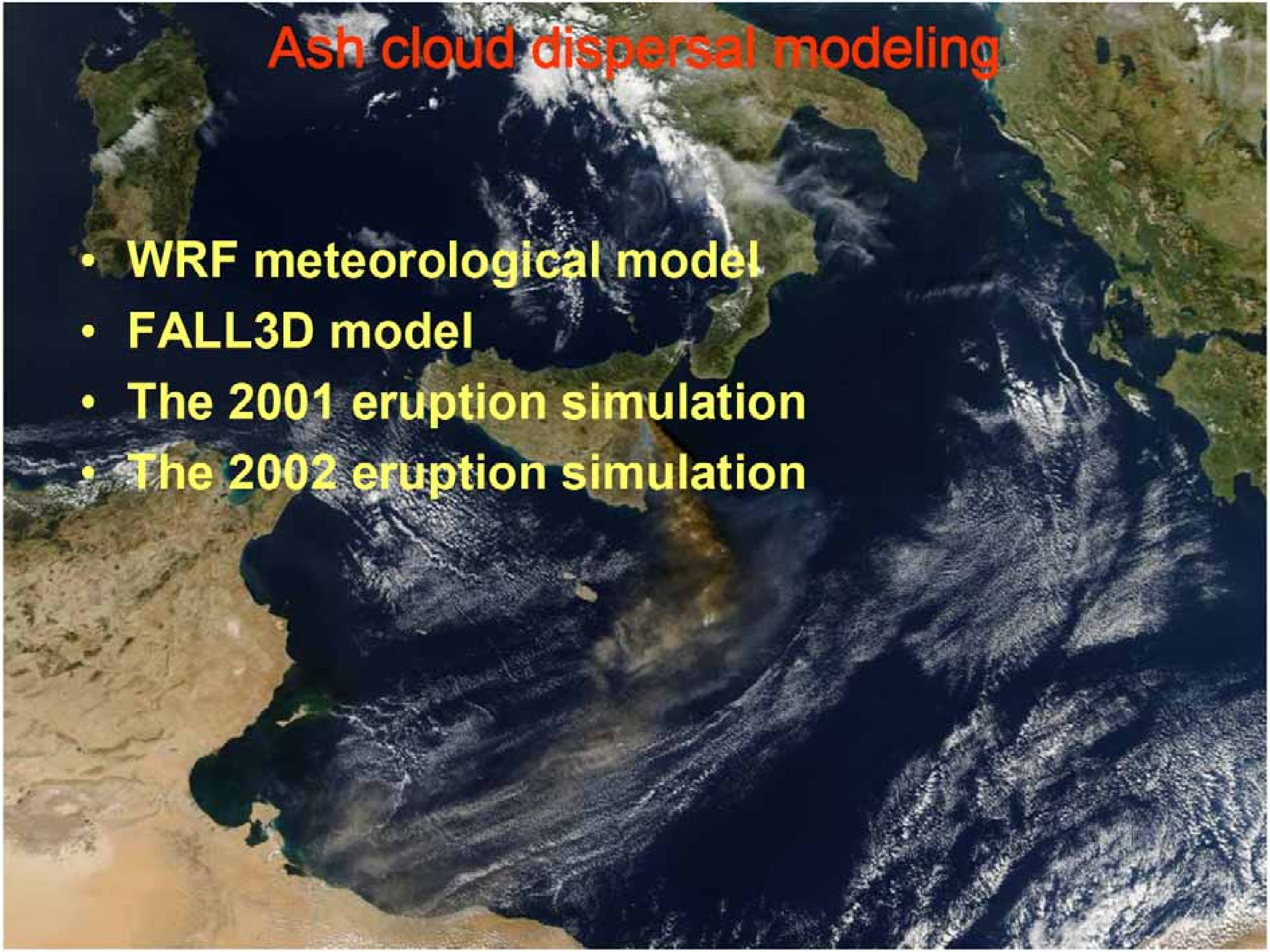
MISR data of the 2002 Etna eruption

Stereo-height histograms of the volcanic plume at four selected patches



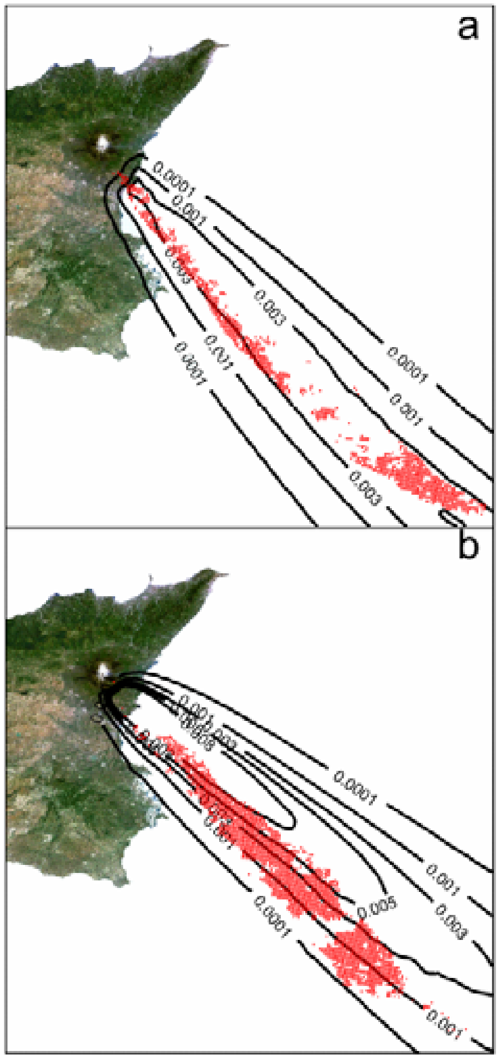
Aggregation phenomena?

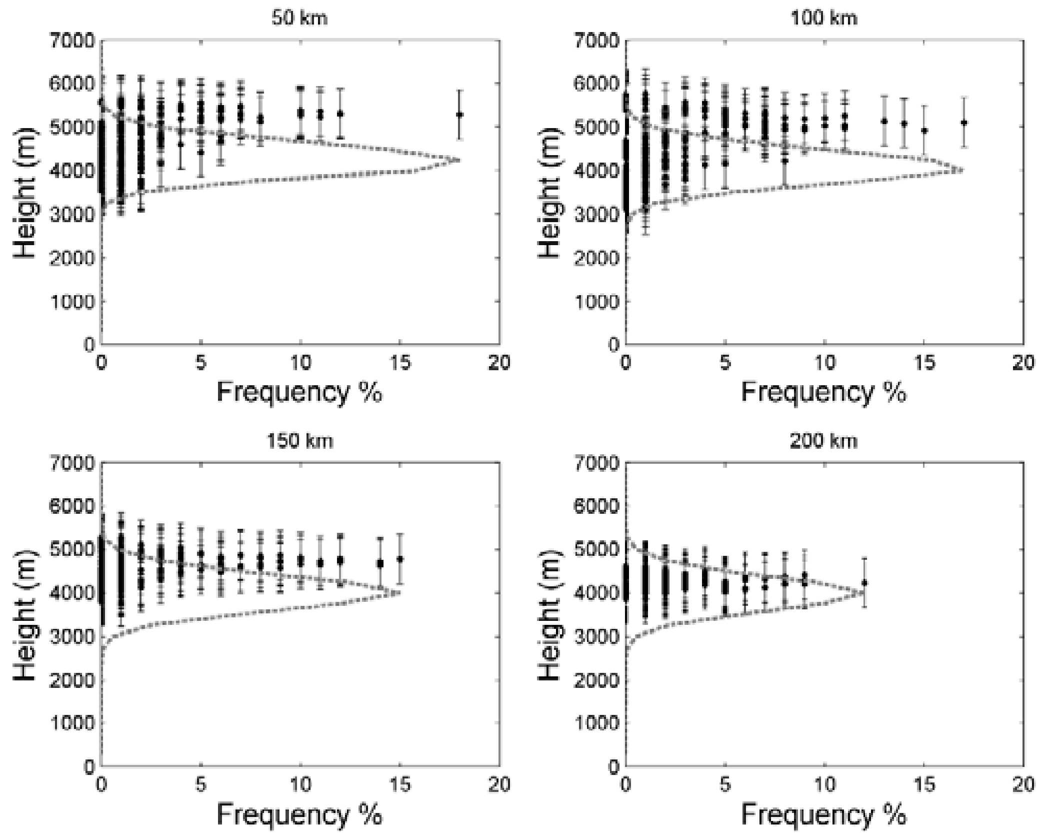
The maximum height retrieved by MISR is about 6 km at the first patch and keeps constant at about 4.5-5 km in the next patches


Ash cloud dispersal modeling
• WRF meteorological model
• FALL3D model
• The 2001 eruption simulation
• The 2002 eruption simulation

Comparison between 2001 MISR observations and numerical simulations

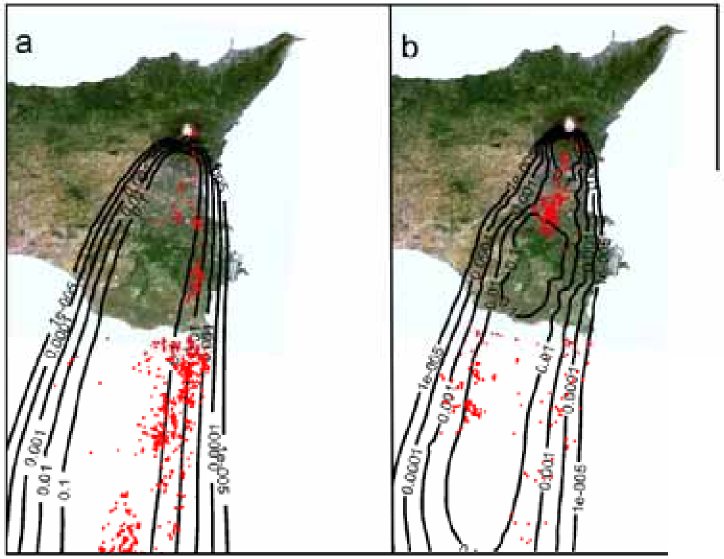
Ash concentration values up to 10^{-5} g/m^3 fit the MISR data

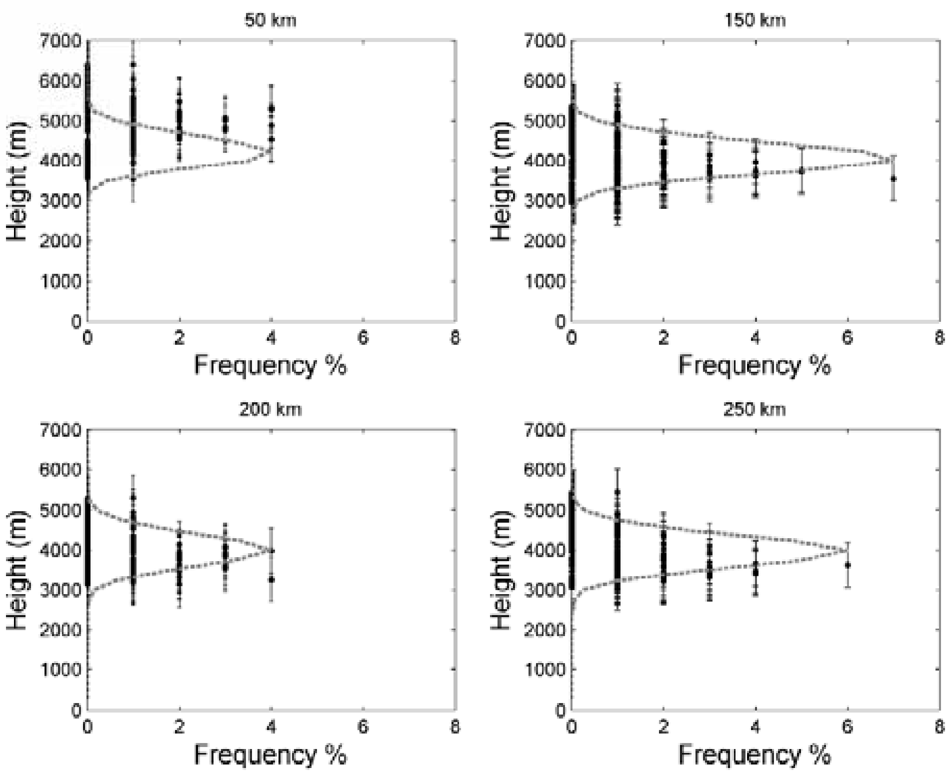




Comparison between 2002 MISR observations and numerical simulations

Ash concentration values up to 10^{-5} g/m^3 fit the MISR data





Discussion and Conclusion

1) MISR has been used successfully to reconstruct volcanic plumes in three-dimension during volcanic eruptions.
2) MISR imaging is an alternative, novel, and powerful mechanism to study volcanic plumes. MISR heights reach a precision of ±0.5 km.
3) Numerical models are able to simulate tephra dispersal properly if input parameters is known with a reasonable precision.
4) MISR takes the phreatomagmatic nature of the investigated phase of 2001 eruption. MISR in fact showed that the phase of 2001 eruption has produced finer particles than 2002 eruption.
5) The ash concentration of 10^{-5} g/m^3 is in agreement with the ash concentration threshold used by VAACs.
6) MISR was able to retrieve some dynamics of volcanic plumes as the bent over shape of the eruption column and aggregation phenomena.
7) Some differences between simulations and MISR data could be due to weather prediction. Using realistic wind fields becomes crucial to improve the forecasting of volcanic ash dispersal

Future Studies

1) Concentration profiles could be extracted from optical depth measurements directly from MISR;
2) Comparisons with other satellite and remote sensing observations;
3) Improvements of the MISR algorithm including the ash particle shape.

Limitations

1) MISR standard algorithm can fail in presence of cloud; low optical density of the plume; bright scenes;
2) MISR spectral range is sensitive mainly to aerosol particles of about 2.5 μm in size.


Thanks
Additional Information
• NASA's MISR page http://www-misr.jpl.nasa.gov
• NASA's Earth Observing System http://eospso.gsfc.nasa.gov
• Atmospheric Science Data Center http://eosweb.larc.nasa.gov/
• http://eosweb.larc.nasa.gov/PRODOCS/misr/FAQ.html
• http://eosweb.larc.nasa.gov/PRODOCS/misr/imagery.html