

A photograph of a volcanic eruption, likely Mount Etna, showing a massive, dark, and dense plume of ash and smoke rising from a crater. The plume is thick and billowing, filling much of the sky. The foreground shows the rugged, dark, and rocky terrain of the volcano's interior, with some lighter-colored ash or sand visible. The sky is a pale blue with some wispy clouds.

**Long-lasting volcanic ash clouds
disrupting air transport;
how to handle them for a
sustainable mobility: the case of
2002 Etna eruption**

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INGV - Sezione di Catania

**In collaboration with UPNV workgroup of Catania:
Michele Prestifilippo, Simona Scollo, Gaetano Spata**

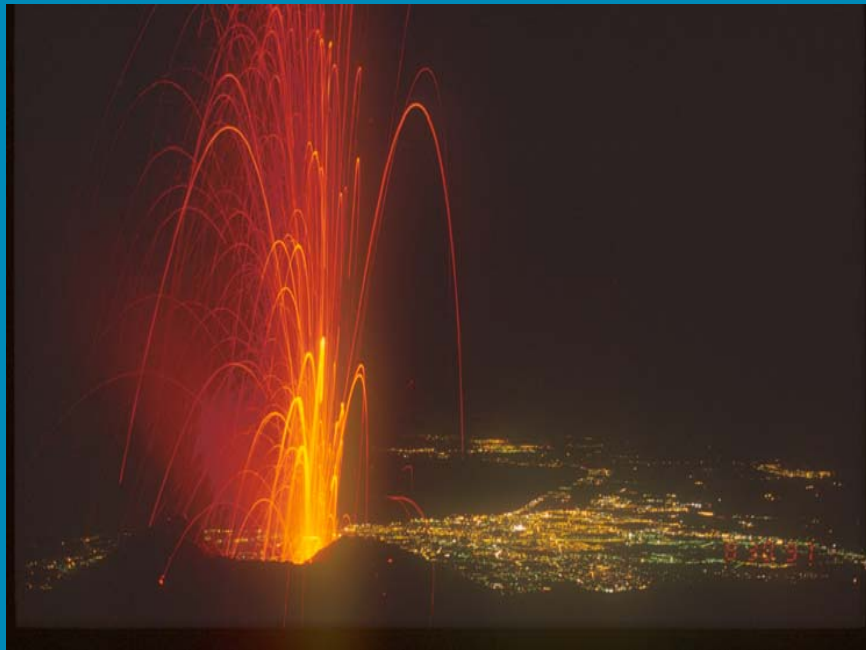


Outline

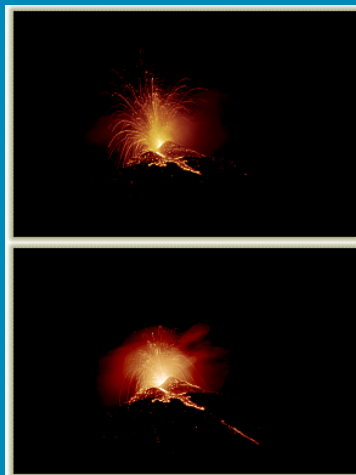
- Etna's explosive activity background
- 2002 long-lasting ash-cloud forming eruption
- Present monitoring and forecasting system operating at Etna
- Interaction between Volcano Observatory (INGV) and aviation organization (in Italy)
- Strategy for managing future eruptive crises of Etna volcano



Etna summit persistent activity



**Strombolian activity
at summit craters**



**Strombolian activity at Bocca
Nuova crater and lava effusion**



Etna summit strong explosive activity



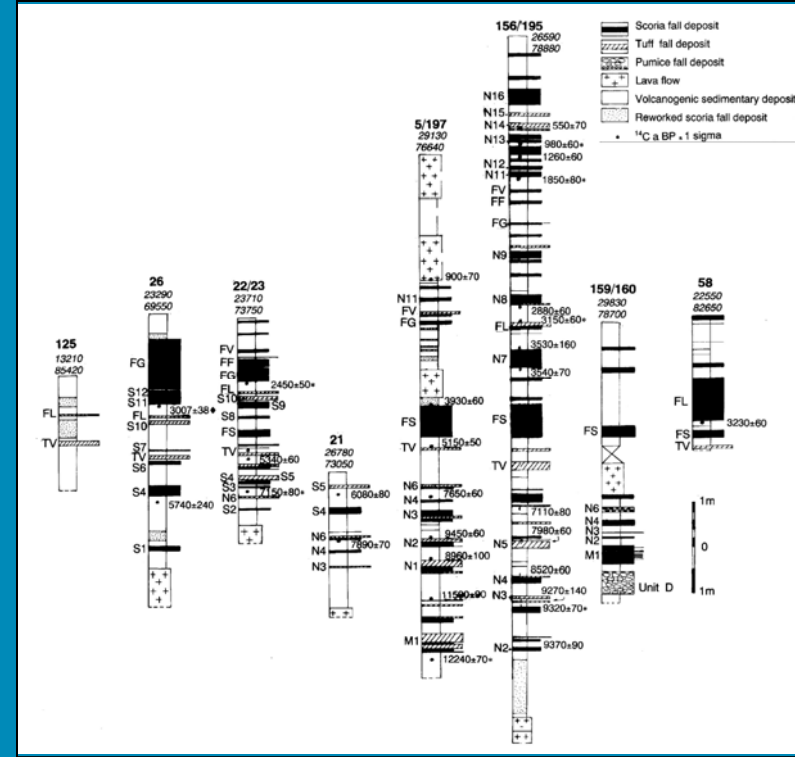
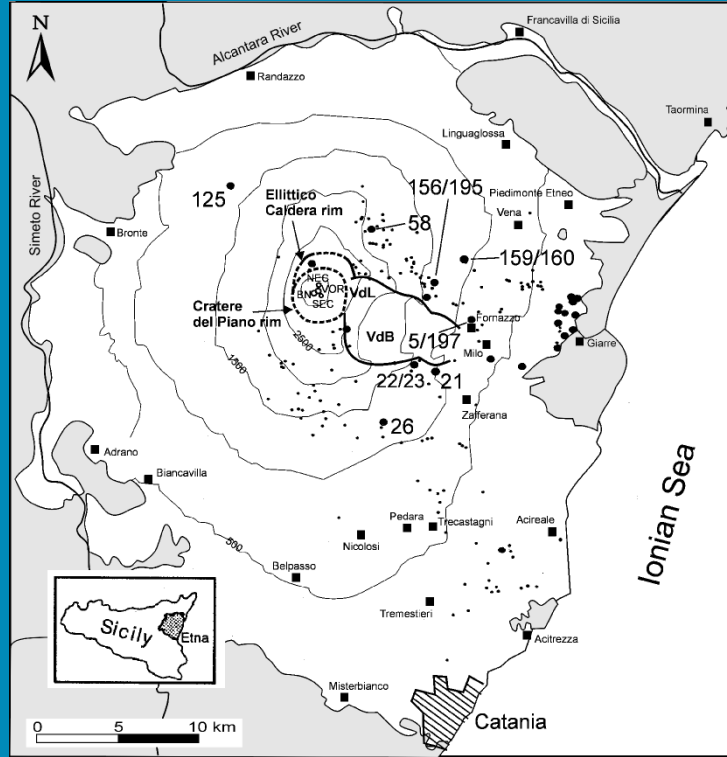
Fire fountain activity
from SE Crater

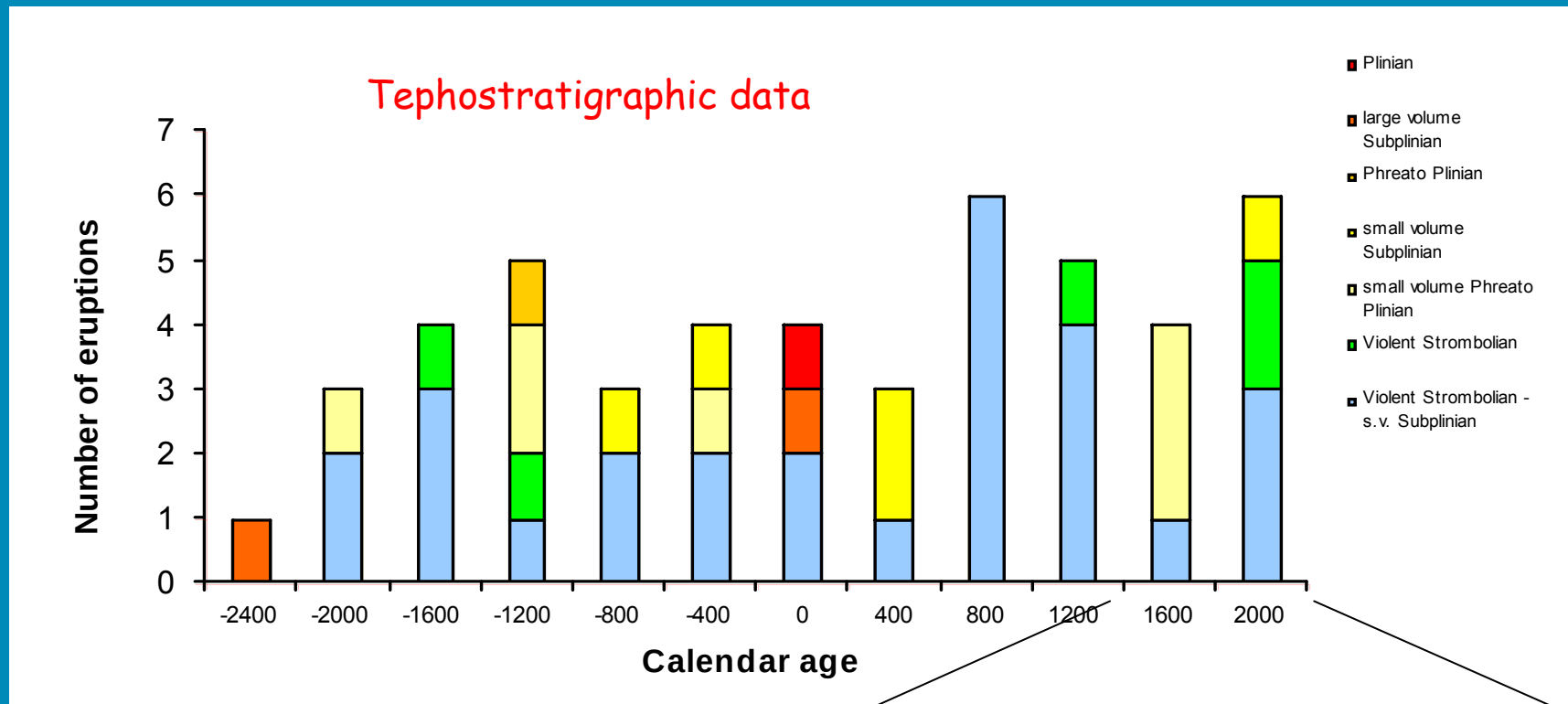


Sustained eruptive column
from SE Crater

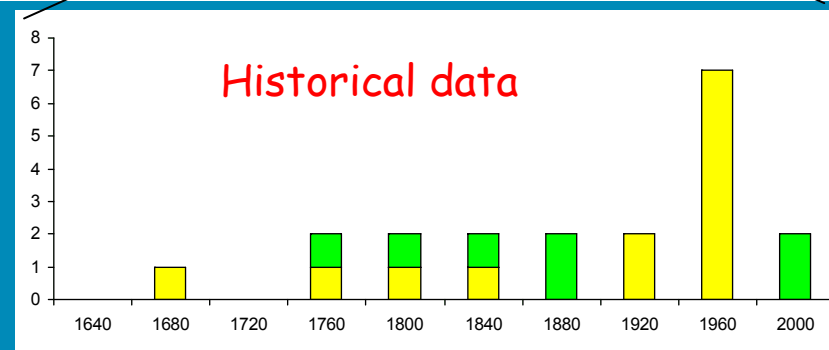


Holocene pyroclastic deposits of Etna



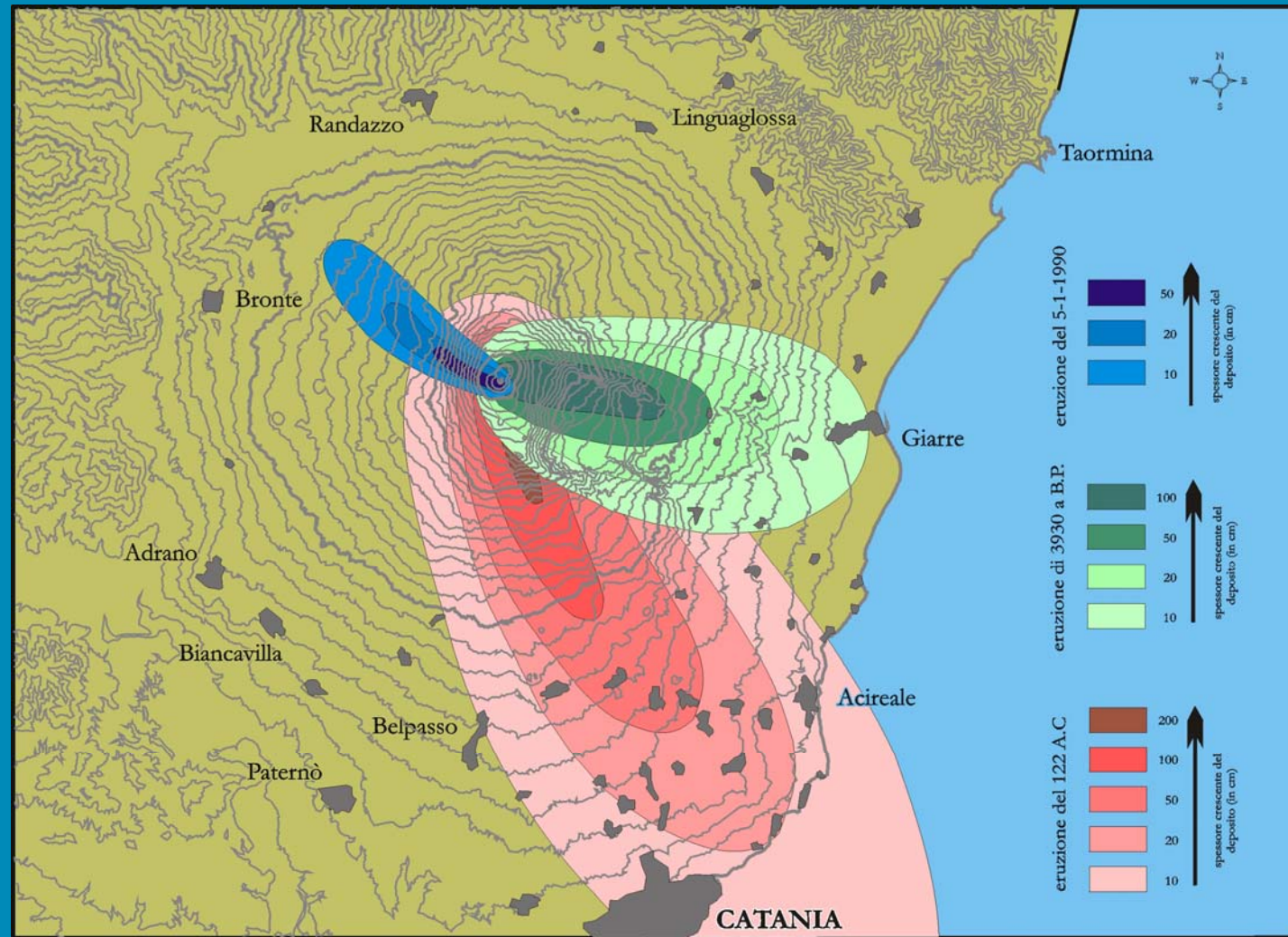


Explosive eruptions
occurred in the last 4000
years

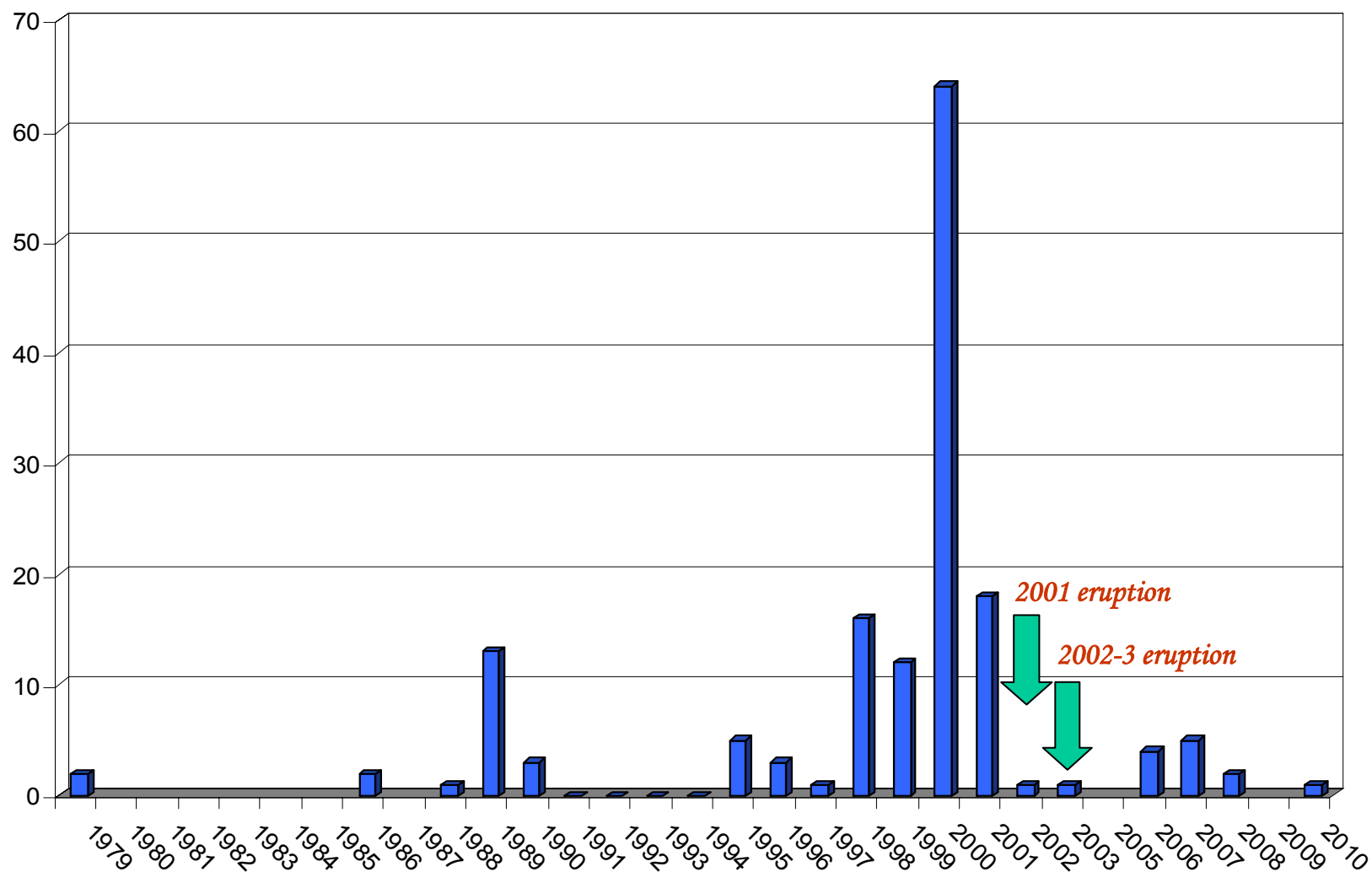




Fallout deposit dispersion of the plinian and sub-plinian historical eruptions

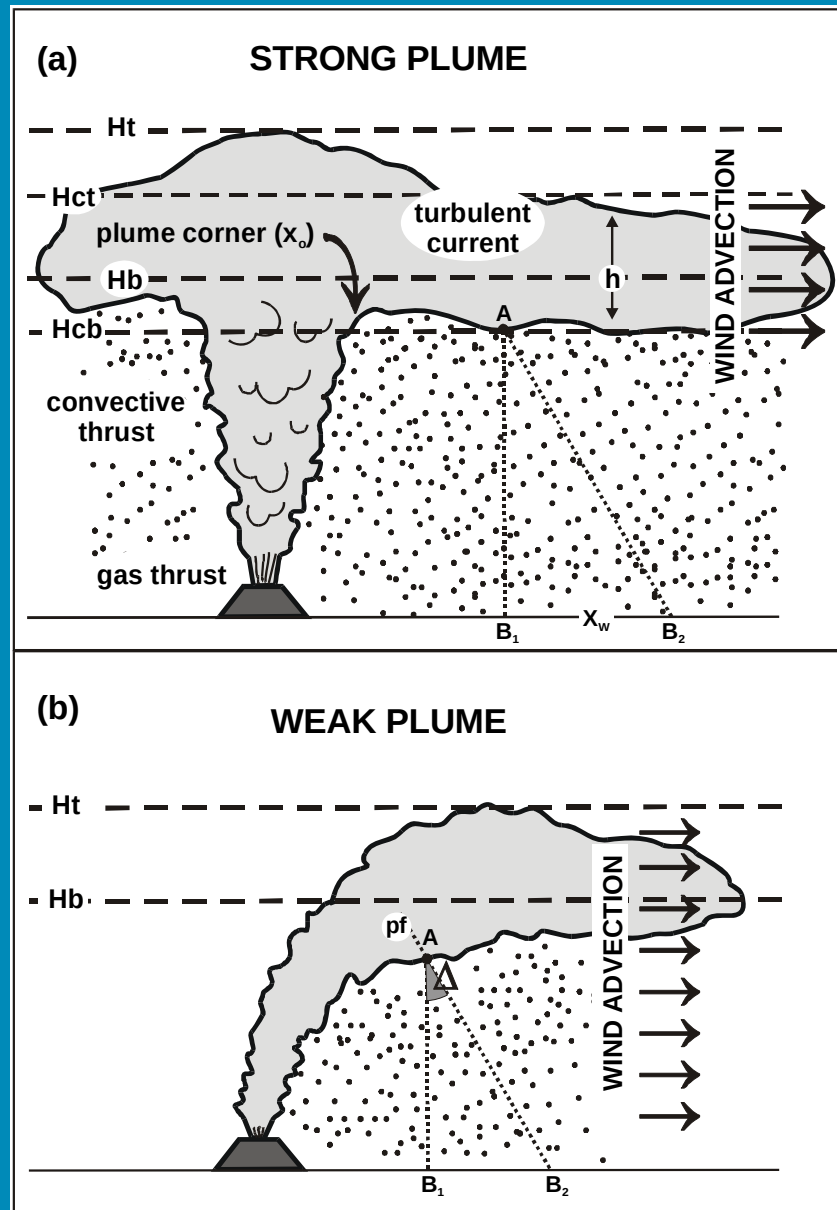


Explosive eruptions occurred in the last 30 years





Main features of Etna's explosive eruptions



Short-lasting eruptions (a)

- Duration from minutes to a few hours
- Magnitude from violent strombolian to subplinian (from 4 to 15 km high eruptive plumes)
- One plinian eruption in historical time (26 km high plume)
- Occurrence more than 150 in the last 25 years
- Frequency up to several tens in a few months

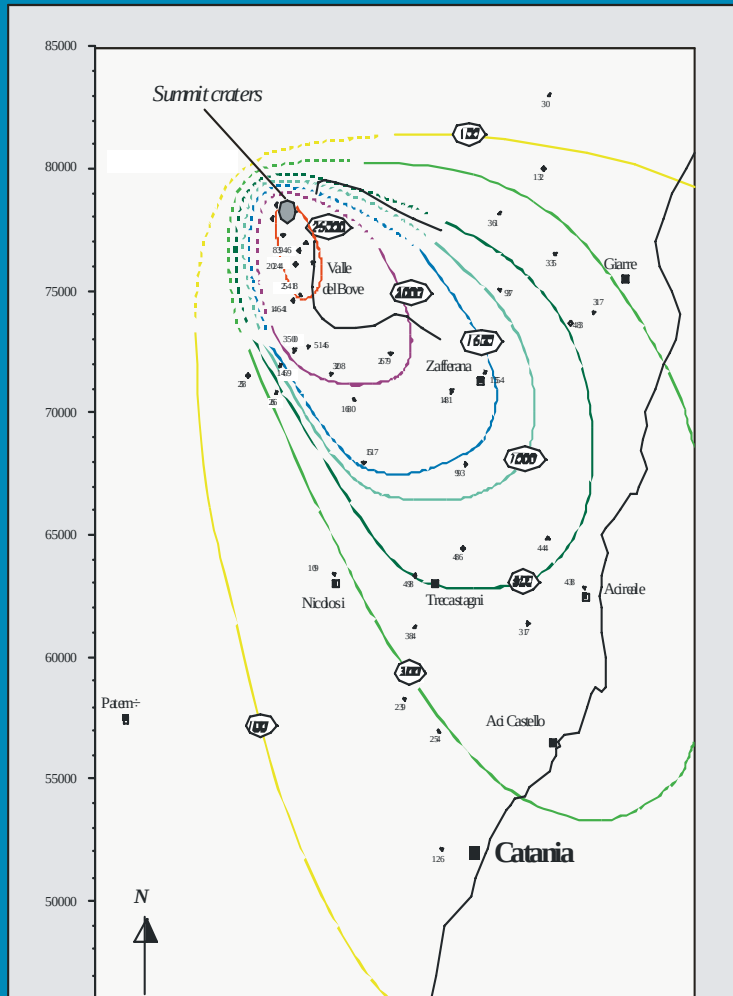
Long-lasting eruptions (b)

- Duration from days to a few months
- Magnitude violent strombolian (low-troposphere plumes)
- Occurrence only two in the last century but at least 8 occurred in the last four century

from Bonadonna and Philips, 2003



Short-lasting eruptive episode: 22 July 1998

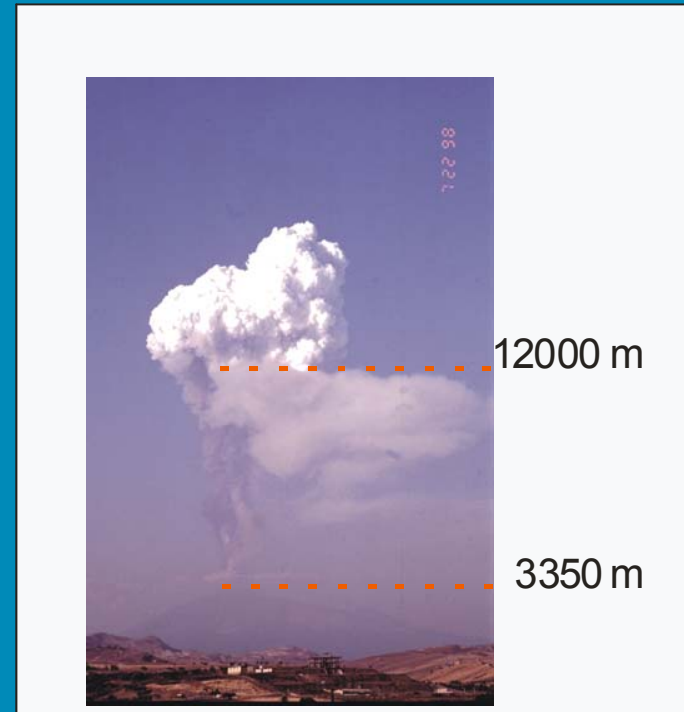


About 3 min long event

Volume: 1.3 Mm^3

Mass rate: $6.7 \times 10^6 \text{ kg s}^{-1}$

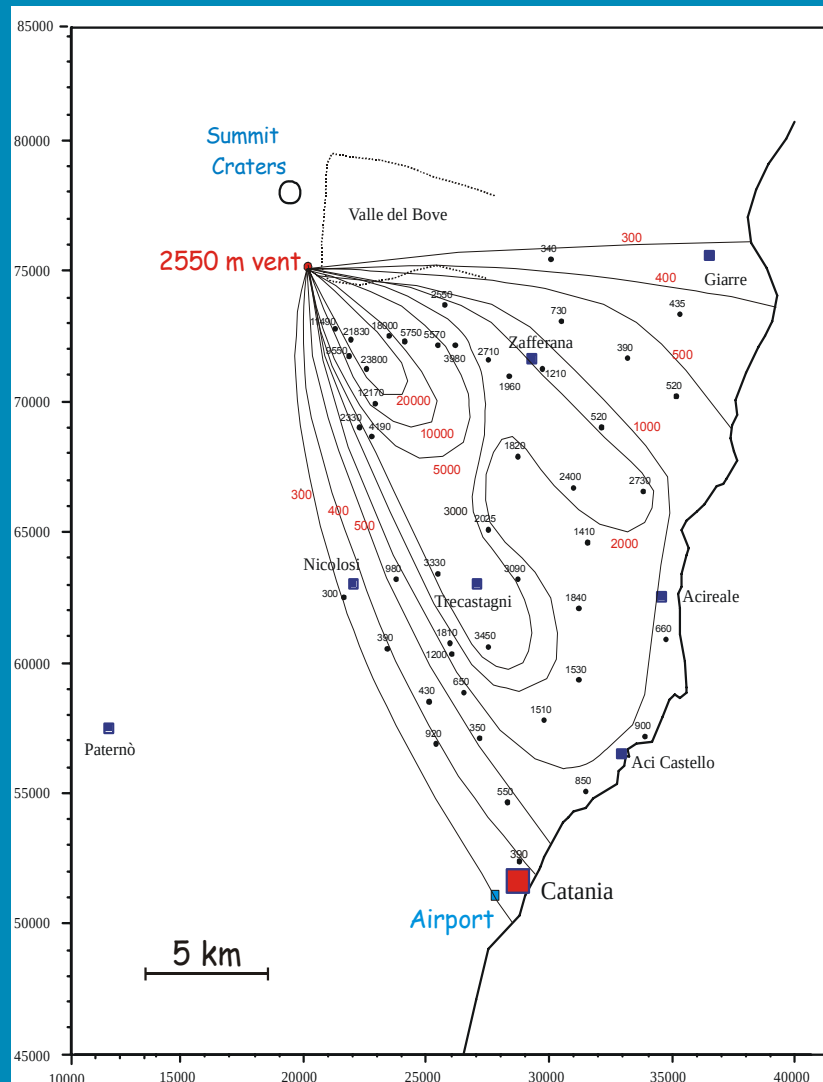
Column height: 12 km



Andronico et al. (1999)



Long-lasting eruptive episode: 21-24 July 2001



5 day long emission
5 km high ash column
Volume $0.41 \times 10^6 \text{ m}^3$



Scollo et al. (2007)



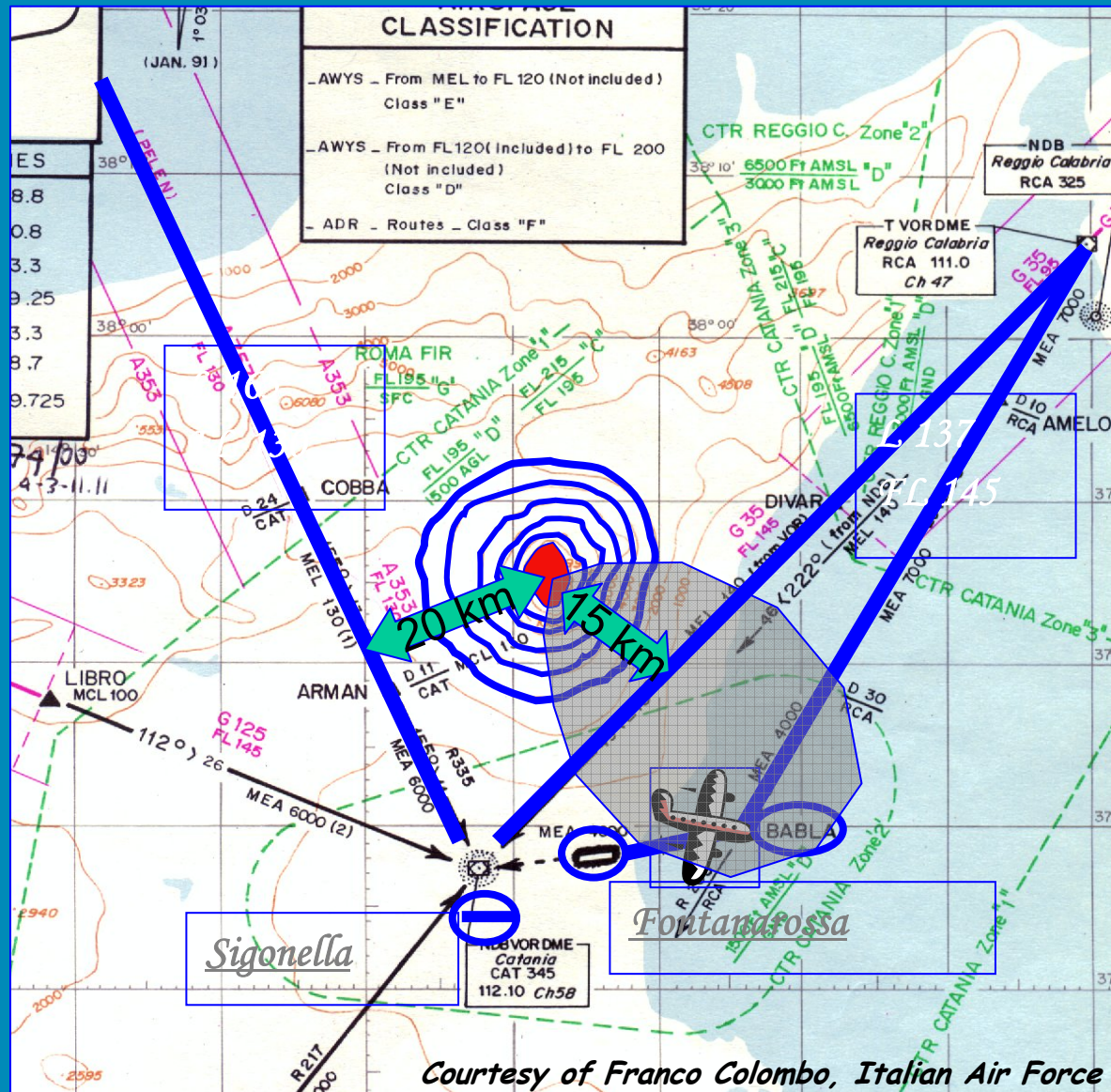
Etna ash fallout: impact and effects



Catania
Via Etnea



Catania
Vincenzo Bellini International Airport





Airports disrupted (≥ 3 events):

- ANCHORAGE, Alaska (Spurr, Redoubt)
- CATANIA, Italy (Etna)
- KAGOSHIMA, Japan (Sakura-jima)
- MANADO, Indonesia (Lokon, Soputan)
- MEXICO CITY, Mexico (Popocatepetl)
- QUITO, Ecuador (Pichincha, Reventador)

Volcanoes (≥ 3 events):

- ETNA, Italy (Catania AP)
- SAKURA-JIMA, Japan (Kagoshima AP)
- POPOCATEPETL, Mexico (Mexico City AP)
- SOUFRIERE HILLS, Montserrat (8 airports)

Guffanti et al. (2003)



Eruptions causing airports problems in Italy

Eruption Date Y/M/D	Volcano	City/Airport	Occurrence / Damages
1944/03/22	Vesuvius	Naples/Terzigno	abundant tephra fallout / 88 military planes damaged
1979/08/03	Etna	Catania/Fontanarossa	ash fallout / airport open
1986/09/24	Etna	Catania/Fontanarossa	ash fallout / airport closed night of 24th to late morning of 25th
1998/07/22	Etna	Catania/Fontanarossa	coarse ash fallout / airport closed 15 h
2000/06/05	Etna	Catania/Fontanarossa	sky darkened by ash / difficulties for air traffic
2000/06/05	Etna	Catania/Sigonella	sky darkened by ash / difficulties for air traffic
2001/07/21-30	Etna	Catania/Fontanarossa	fine ash fallout / air traffic interrupted by ash plume, airport closed a few days
2002/10/27-2003/01/28	Etna	Catania/Sigonella	fine and coarse ash fallout / air traffic interrupted by ash plume, airport closed for several days
2002/10/27-2003/01/28	Etna	Reggio Calabria	fine and coarse ash fallout / air traffic interrupted by ash plume, airport closed for several days
2002/10/27-2003/01/28	Etna	Catania/Fontanarossa	fine and coarse ash fallout / air traffic interrupted by ash plume, airport closed for several days



Outline

- . 2002 long-lasting ash-cloud forming eruption



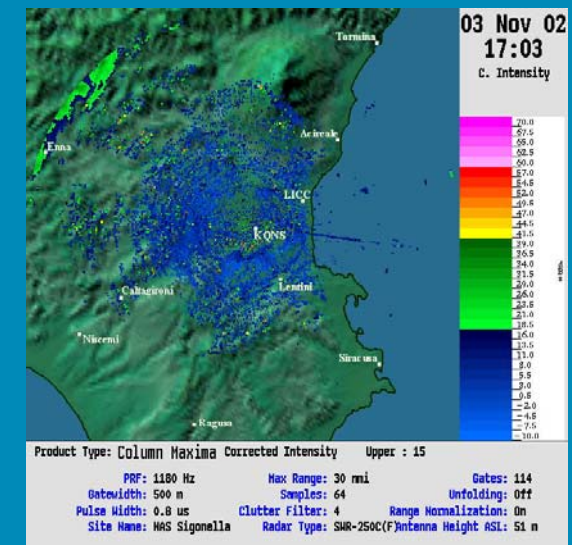
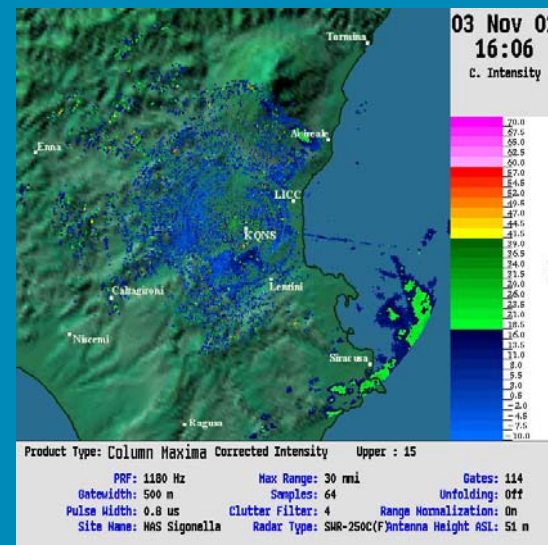
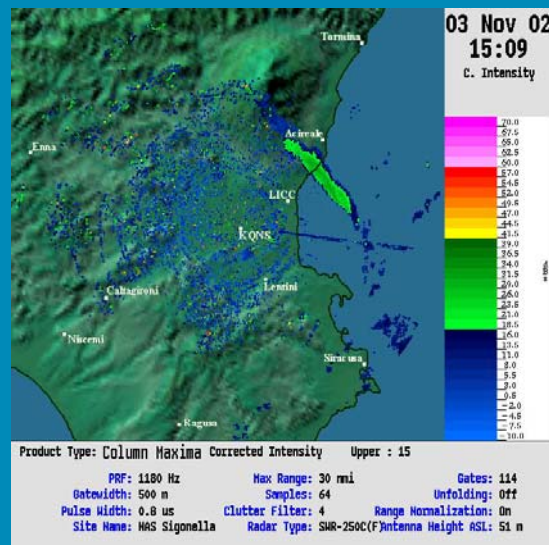
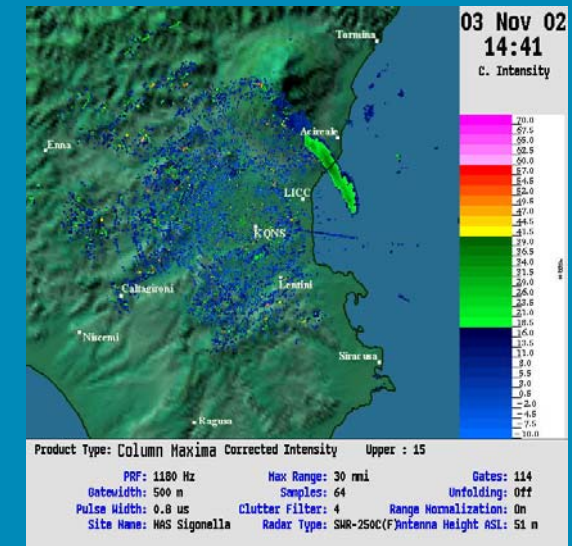
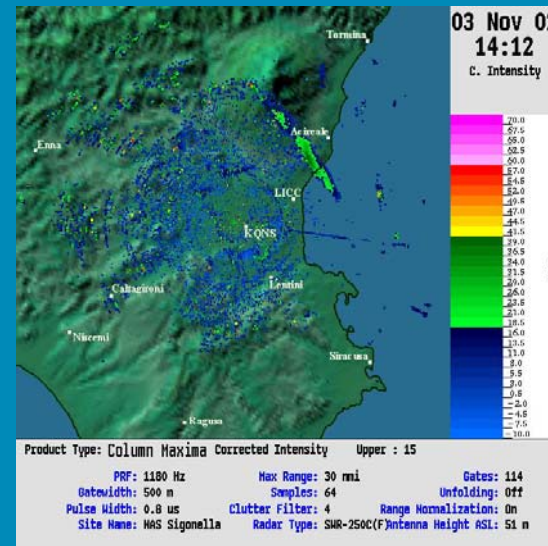
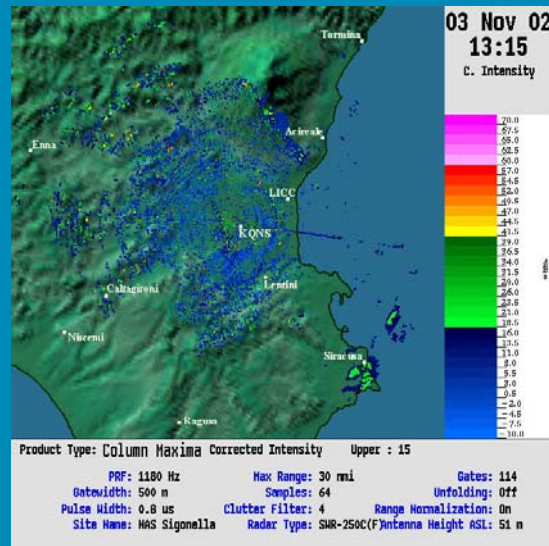
**2002-03 flank
eruption:
started on
October 27
and ended on
January 28**

**58 days of continuous
explosive activity and
ash emission**



The ash plume of the 2002-3 eruption

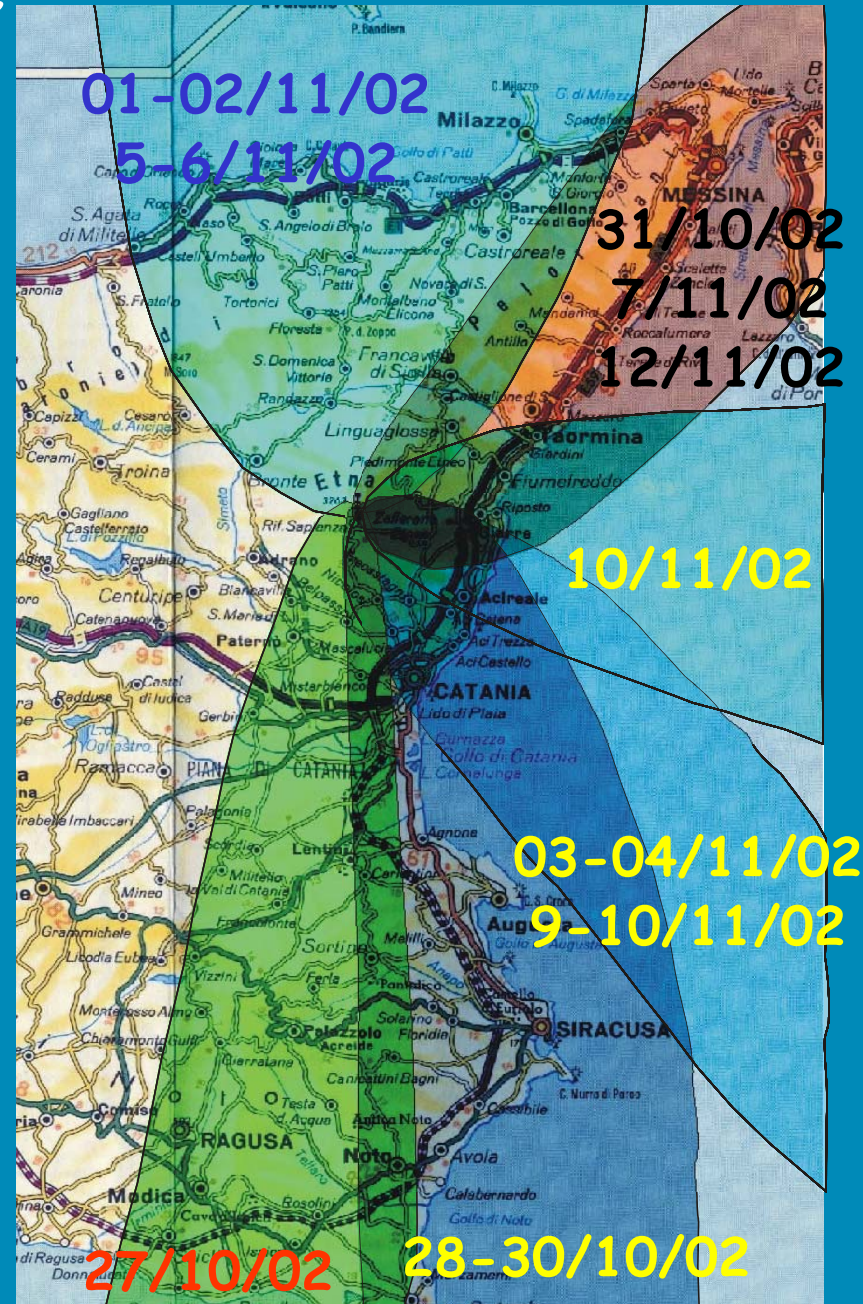




The plume observed by the weather radar of the US Navy Base at Sigonella airport



Ash fallout from October 27 to November 12





Socio-economical and health impact of the eruption

Airports activities were disrupted and often closed without any planning, crisis unit mainly took note of the situation...

Catania and surrounding had damages to houses, roads closed or not viable, plugged drains and so on ...

Respiratory problems for the population: allergies, asthma

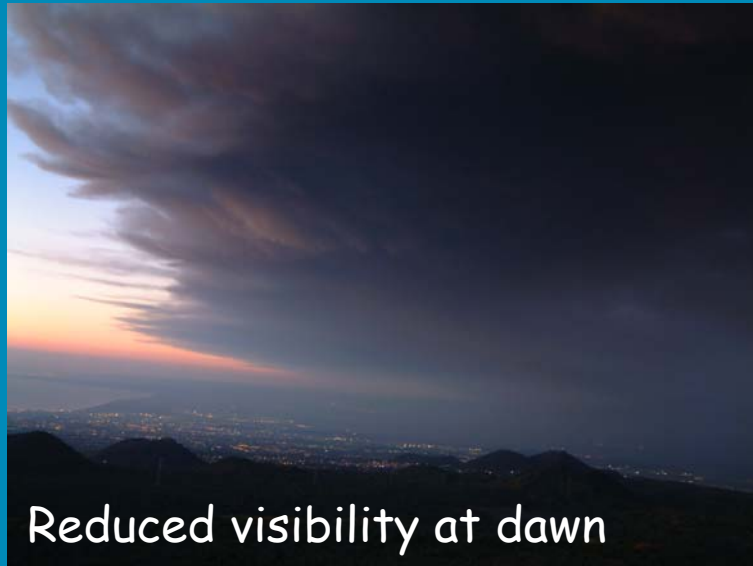
Loss of harvests



Ash fallout on Catania airport

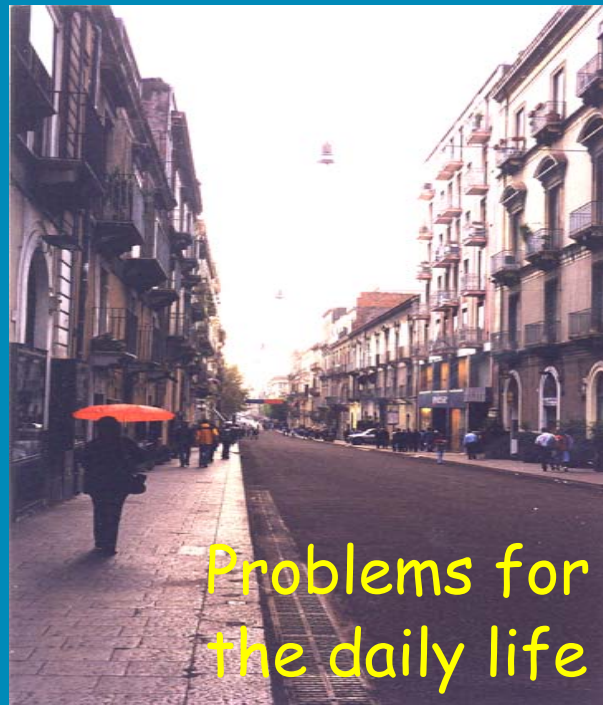


Ash fallout on the Catania-Messina freeway

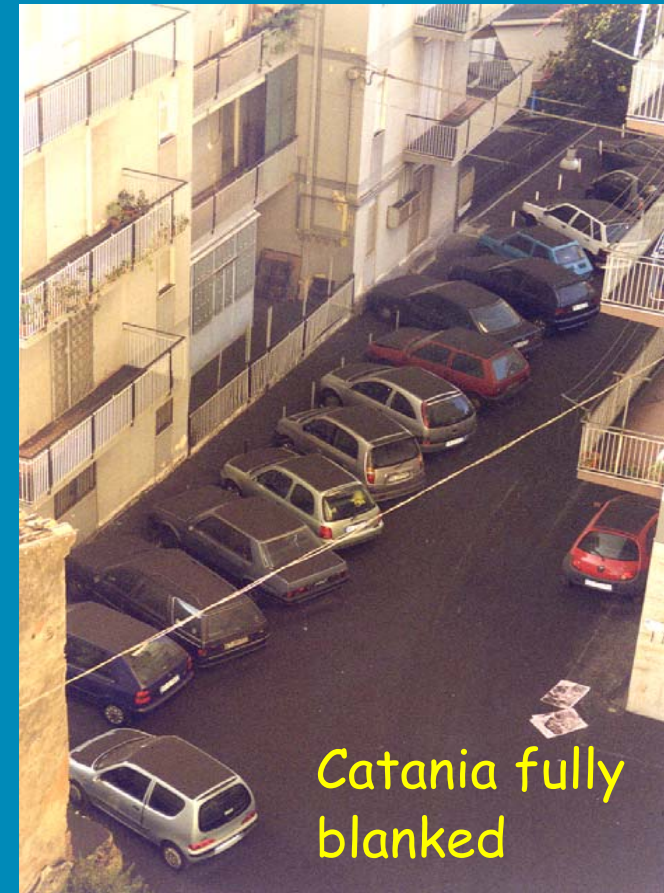


Reduced visibility at dawn

4 kg/m² of coarse ash fell on
Catania 26 km far from the vent
16 kg/m² of coarse ash fell on
Nicolosi 16 km far from the vent



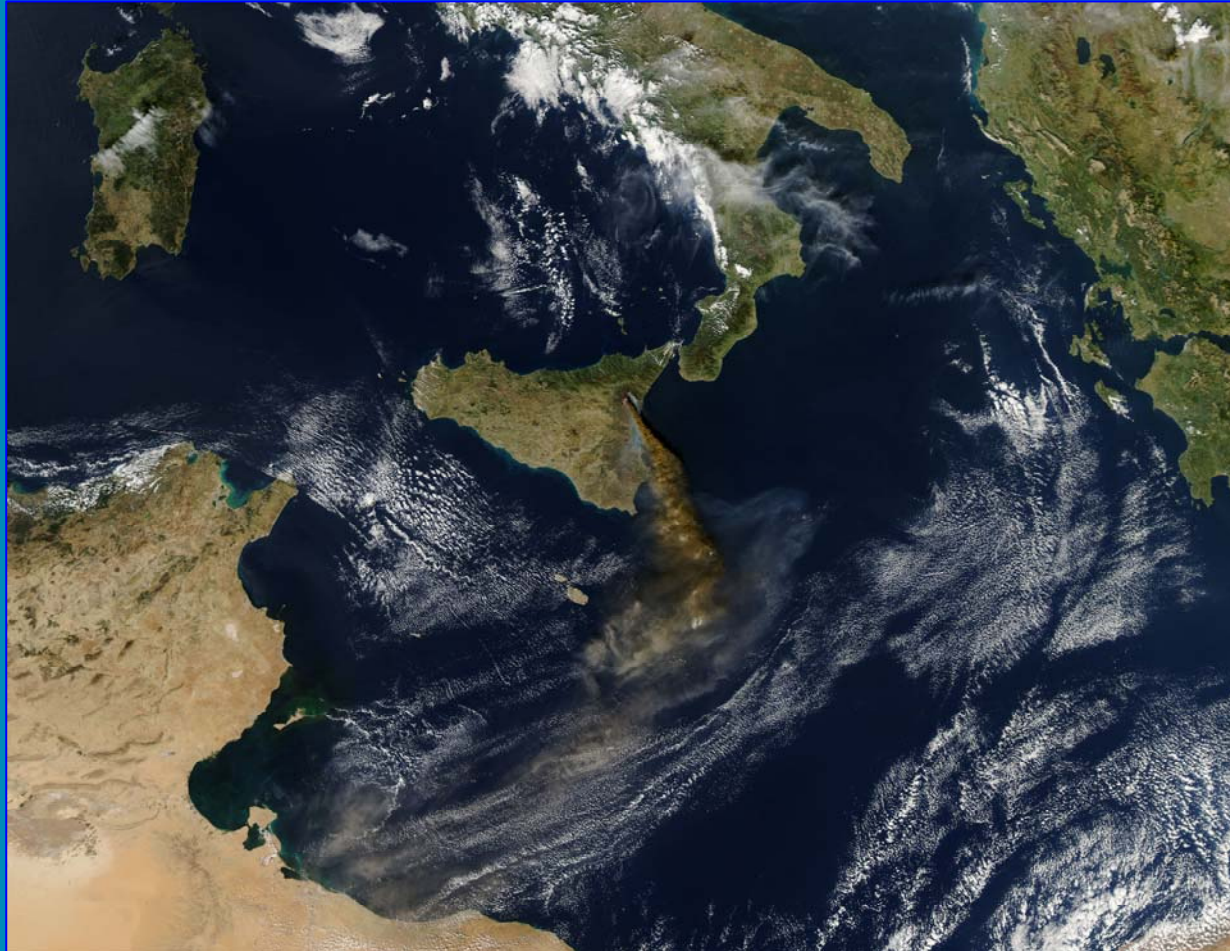
Problems for
the daily life



Catania fully
blanked



Etna's ash cloud threaten aviation on the Central Mediterranean region: how INGV contribute to minimized the risk ?



28 October 2002 - Image courtesy of NASA

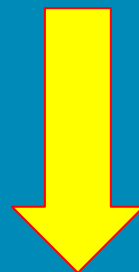


Outline

- . Present monitoring and forecasting system operating at Etna



For an airport close to an active volcano
able to or performing in historical time
explosive eruption and ash emission
it is critical to define in real time
the **safe flight sectors**



Forecasting by using
ash cloud dispersal modelling
real-time monitoring the ash clouds



Ash cloud surveillance at Etna

Monitoring

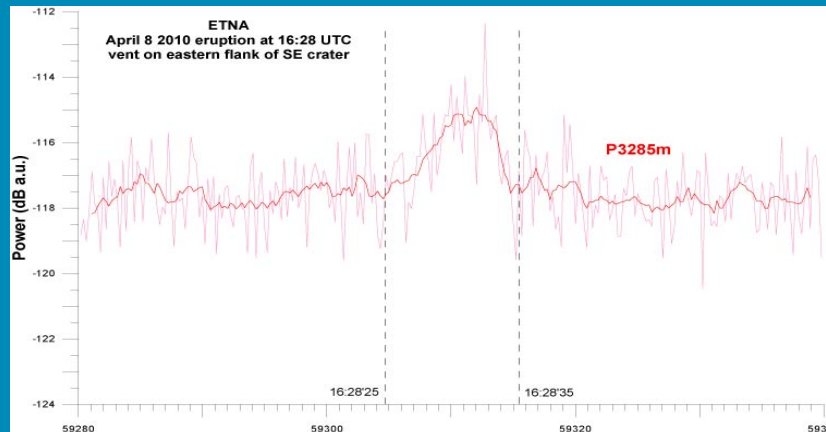
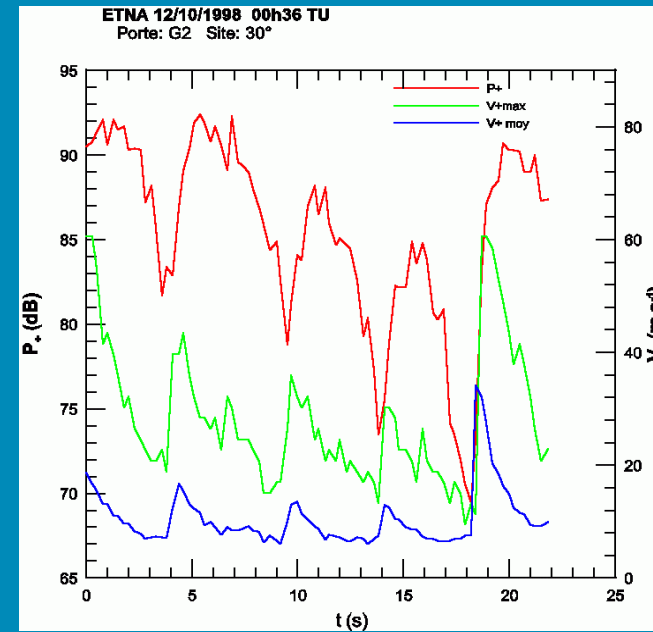
- Multi-parameter geophysical signals real-time analysis (fully operational)
- Radar Sounding near the vent with OPGC, France (fully operational)
- Thermal Cameras network near the vent (fully operational)
- Meteorological Satellite images real-time processes at INGV Rome and Catania (fully operational)
- Atmospheric sounding during the eruption (fully operational)
- Ash fallout on ground real-time monitoring (fully operational)
- Multi-band IR Cameras network on the SE-E-NE volcano flanks (in progress)

Forecasting

- Meteorological forecast data from two LAMs updated 1-2 time for day (fully operational)
- VOL-CALPUFF model running 2 time for day for 2 different scenarios at INGV Pisa (near operational)
- FALL3D model running 2 time for day for 2 different scenarios at INGV Catania (fully operational)
- PUFF// model running 2 time for day for 2 different scenarios at INGV Catania (fully operational)
- Ash clouds dispersal maps compiled 2 time for day from these 3 models outputs and distribute to air traffic controllers via DPC (near operational)



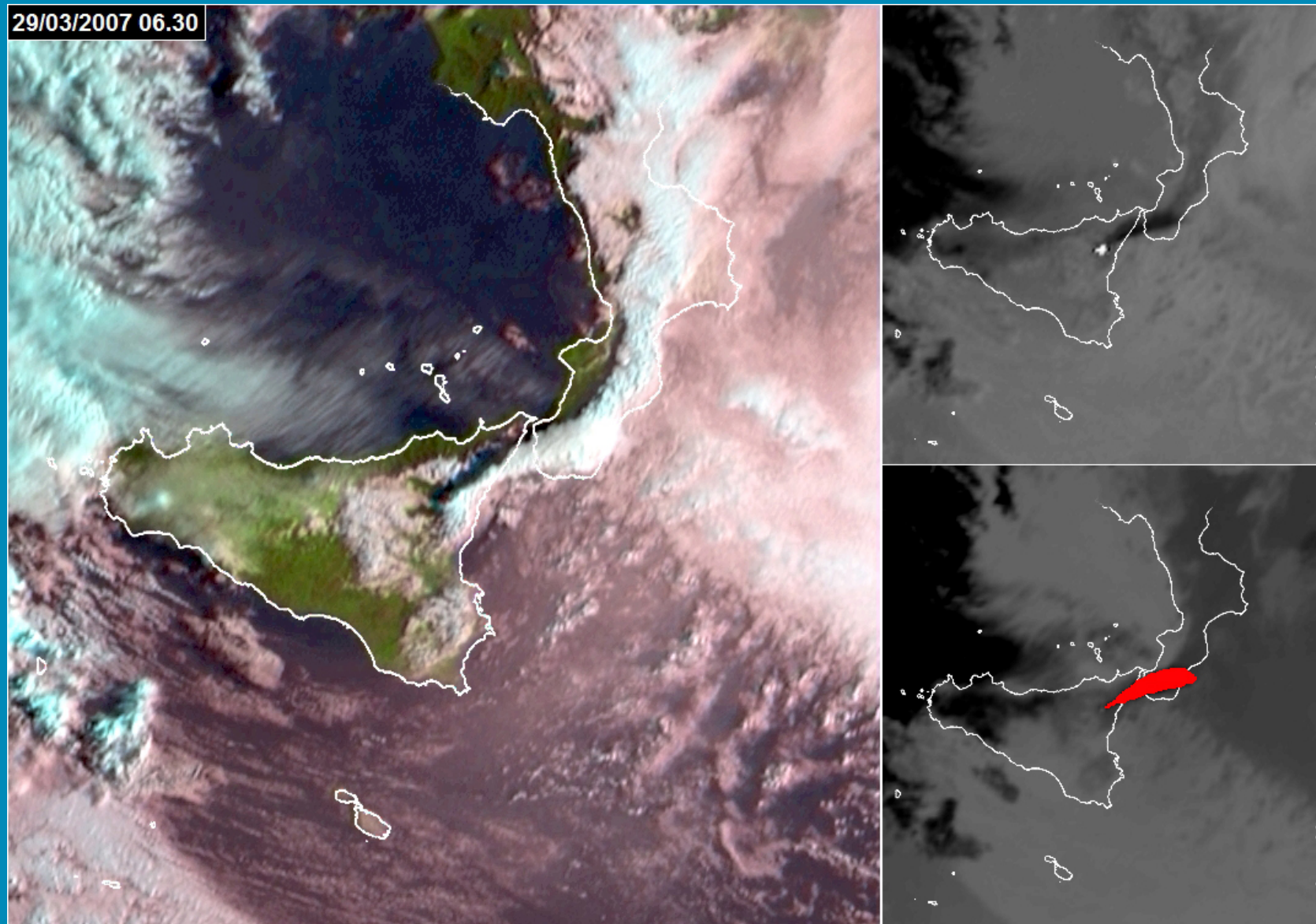
Doppler Radar near Etna summit station



From Donnadieu et al. (2010)



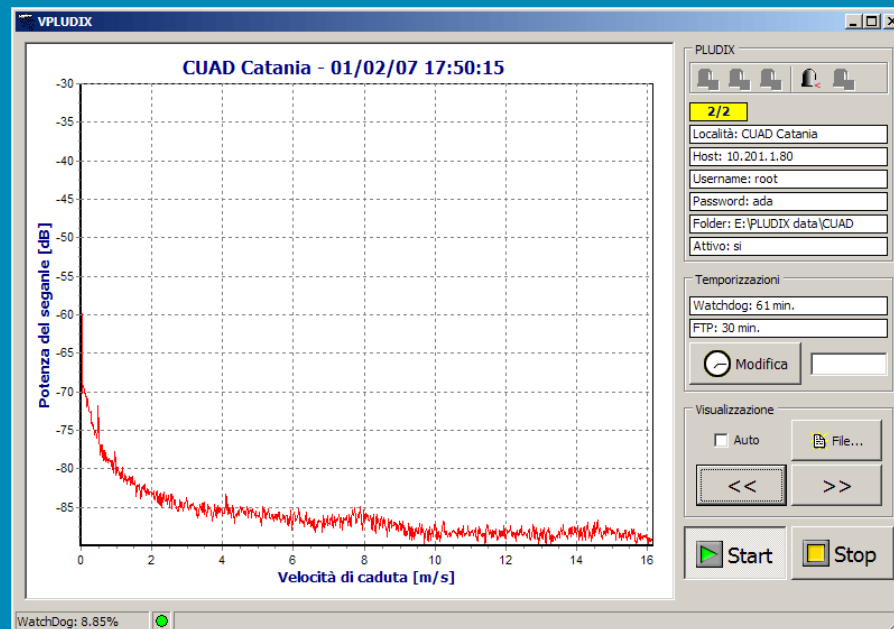
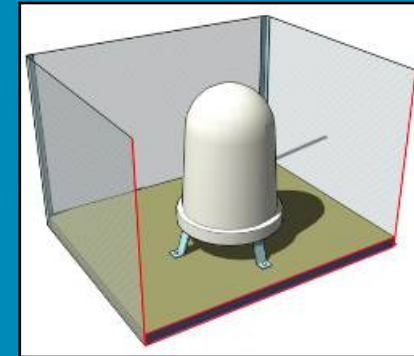
Meteosat real-time images processing



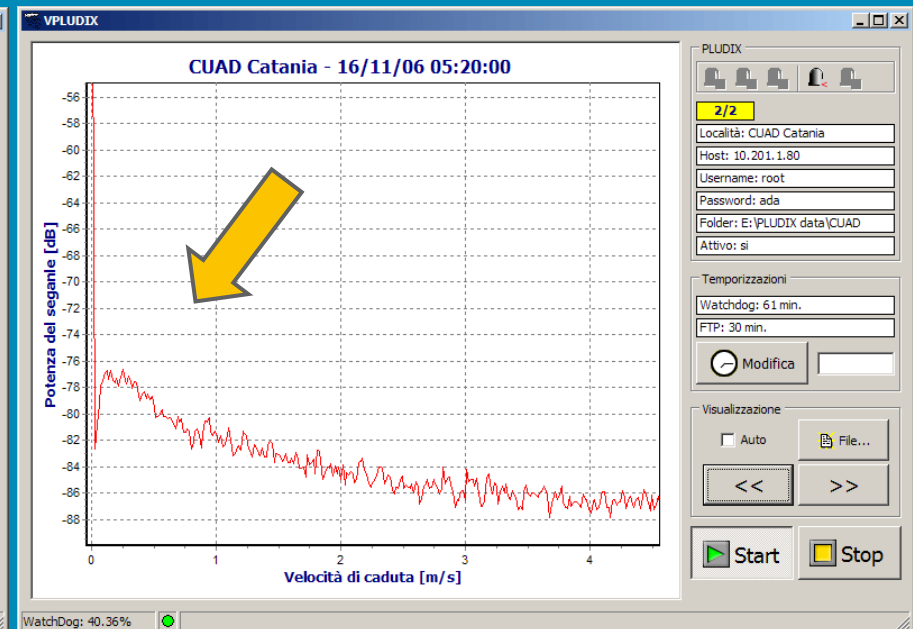
From Coltelli et al. (2007)



On-line Radar Disdrometer network



rain

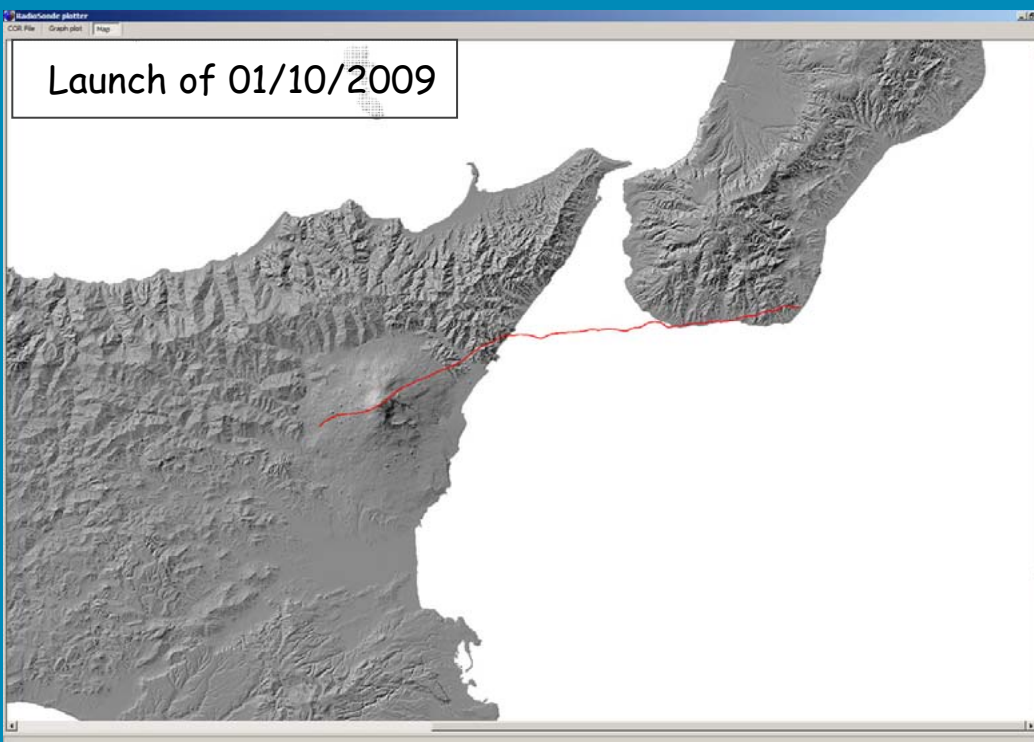
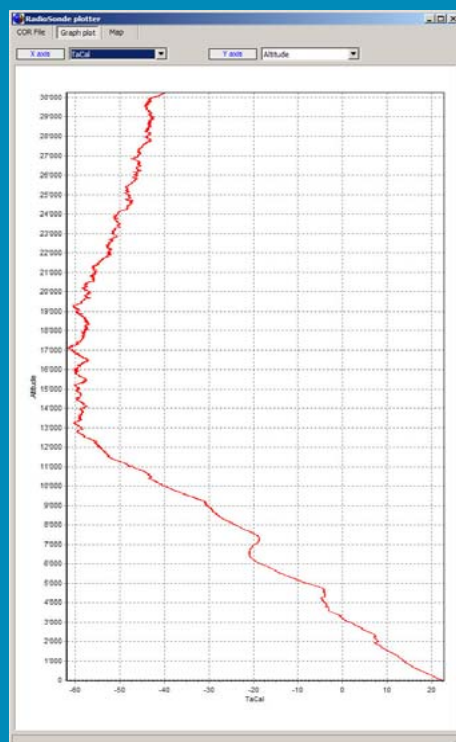
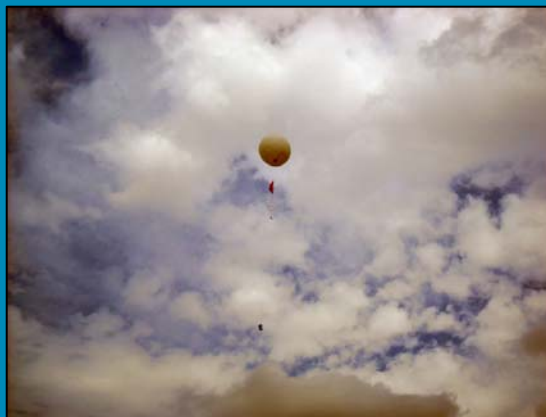


volcanic ash

Scollo et al. (2005)

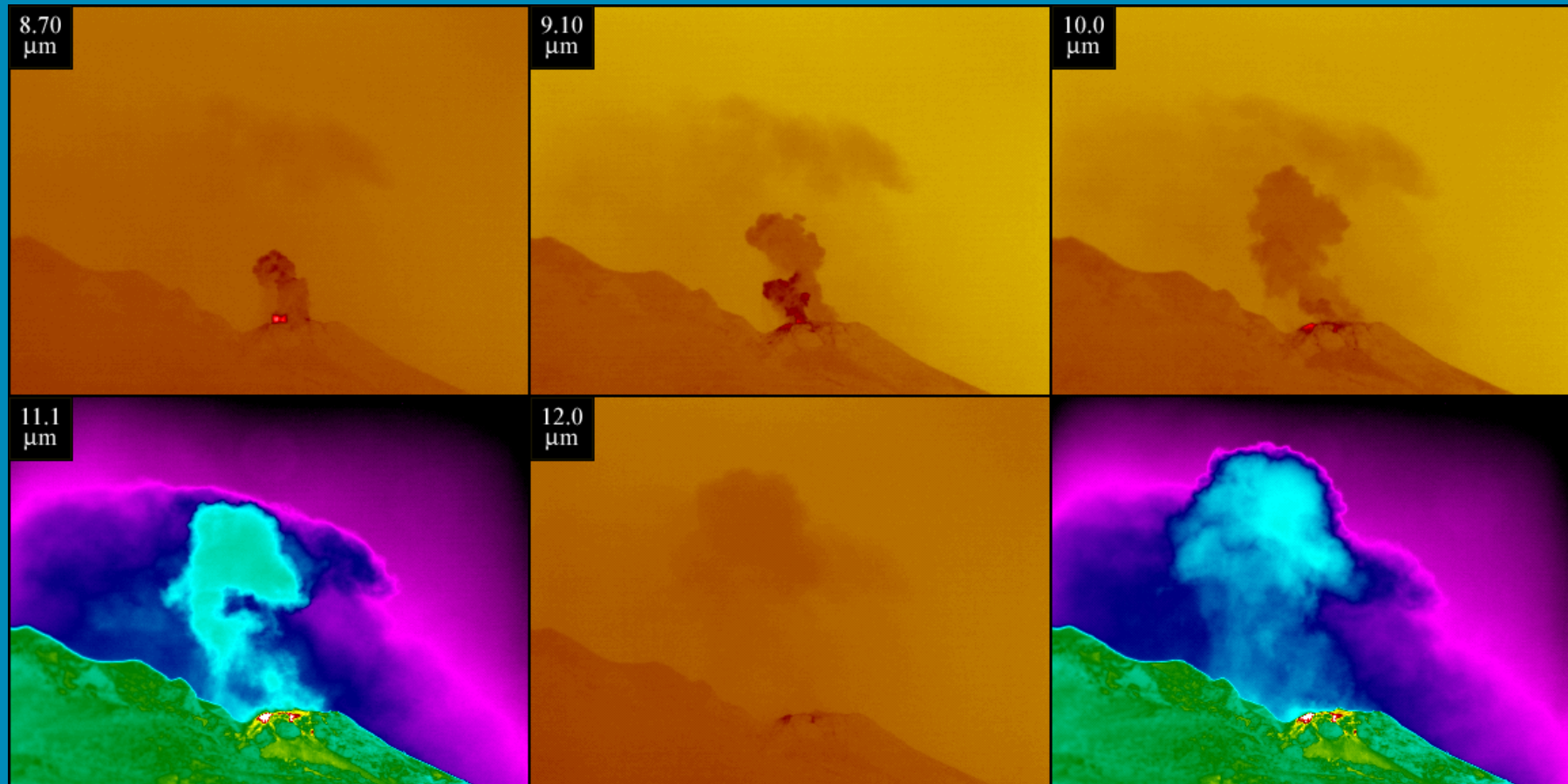


Atmospheric sounding for model validation



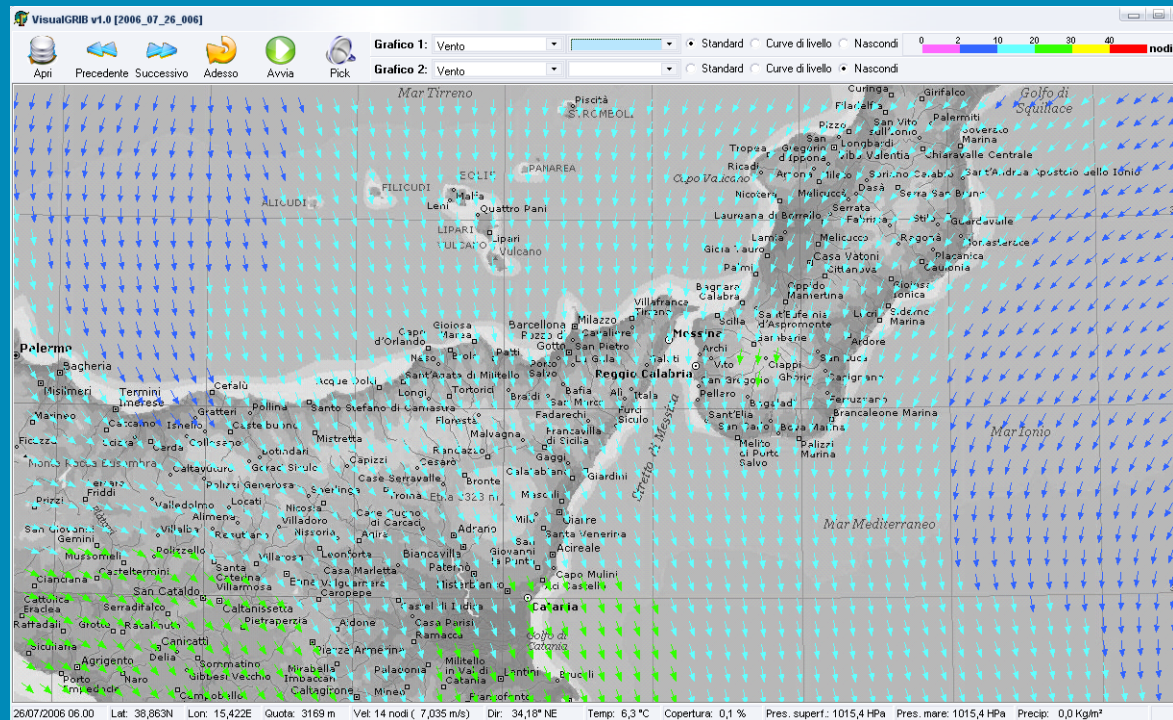


Development of a multi-band IR camera





Meteorological forecast data daily collection

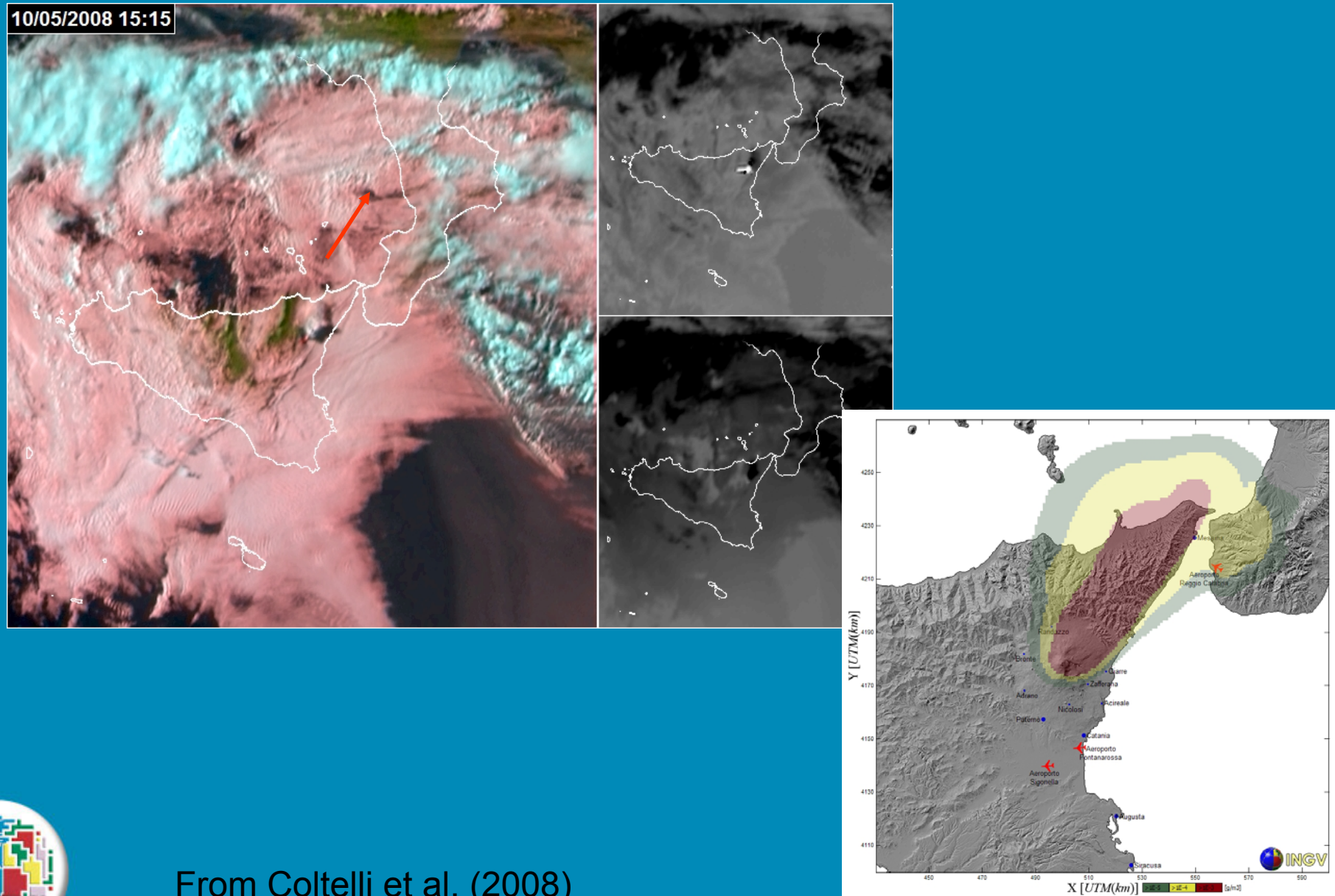


Eruption scenarios input parameters

Eruption Scenarios	Time	MER (kg/s)	CH (km)	TGS (ϕ)	Sigma	Etna Eruptions
Scenario 1	5 min	1.E+06	8	2	1.5	1998
Scenario 2	3 hours	5.E+03	2	2	1.5	2001
Scenario 3	3 hours	1.E+05	4	0.5	1.5	2002-03



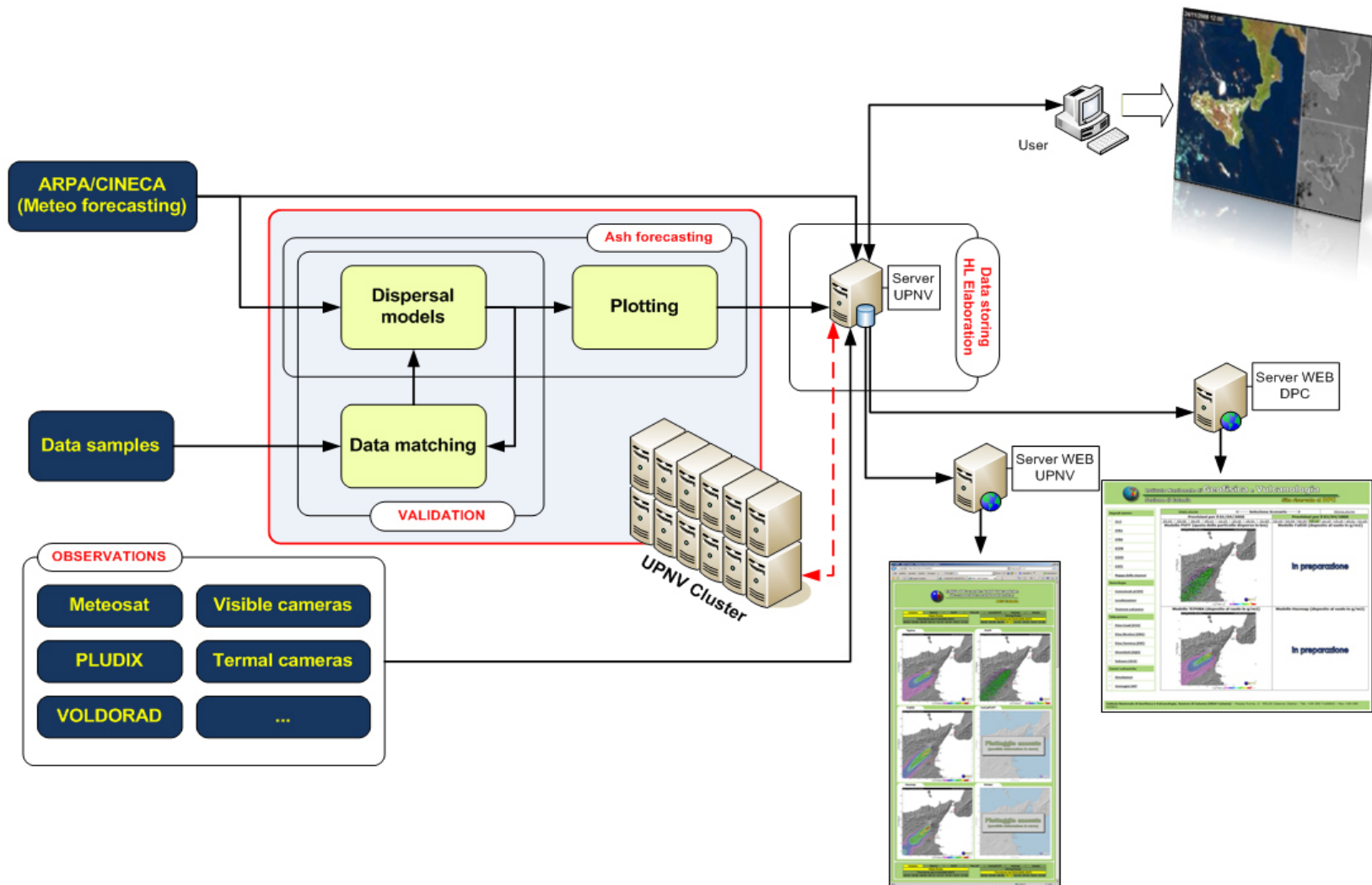
Example of modeling validation: 10 May 2008 eruption



From Coltelli et al. (2008)



Ash dispersal computer simulation flow-chart



For more detail see Scollo S., Prestifilippo M., Spata G., D'Agostino M., Coltelli M. (2009), *Monitoring and forecasting Etna volcanic plumes*, Natural Hazards and Earth System Sciences, 9, 1573-1585



Numerical simulations using multiprocessors computers cluster supervised by an expert system

UPNV Scheduler

Prodotto	Ultima esecuzione	Prossima esecuzione	Stato	Processamento	Progress
DPC_Blanks	01/04/2008 10:50:49	01/04/2008 16:50:49	Play	Control Time	35%
DPC_ZIPS	01/04/2008 07:19:11	01/04/2008 13:29:33	Play	Control Time	38%
DPC_ZIPW	01/04/2008 06:59:52	01/04/2008 13:10:14	Play	Control Time	13%
MSG_Process	01/04/2008 12:59:52	01/04/2008 13:09:52	Play	Control Time	32%
MSG_ier	01/04/2008 11:03:41	01/04/2008 14:23:41	Play	Control Time	85%
MSG_oggi	01/04/2008 13:06:05	01/04/2008 13:11:05	Play	Control Time	12%
Meteo	01/04/2008 06:12:51	01/04/2008 13:25:09	Play	Control Time	24%
Meteo_AM	01/04/2008 10:33:29	01/04/2008 13:07:20	Play	Control Time	69%
Meteo_ARPA	01/04/2008 05:45:52	01/04/2008 13:29:05	Play	Control Time	48%
PLUDIX_ier	01/04/2008 12:49:56	01/04/2008 13:29:56	Play	Control Time	25%
PLUDIX_oggi	01/04/2008 13:01:32	01/04/2008 13:41:32	Play	Control Time	100%
Plot_Fall3D_SP	01/04/2008 10:58:14	01/04/2008 13:32:00	Play	Control Time	91%
Plot_Fall3D_WP	01/04/2008 09:27:28	01/04/2008 13:21:51	Play	Control Time	88%
Plot_Hazmap_SP	01/04/2008 10:58:46	01/04/2008 13:32:32	Play	Control Time	80%
Plot_Hazmap_WP	01/04/2008 09:26:34	01/04/2008 13:21:59	Play	Control Time	85%
Plot_PUFF_SP	01/04/2008 06:50:29	01/04/2008 13:31:49	Play	Control Time	95%
Plot_PUFF_WP	01/04/2008 06:52:58	01/04/2008 13:34:20	Play	Control Time	46%
Plot_Tephra_SP	01/04/2008 07:17:59	01/04/2008 13:28:22	Play	Control Time	61%
Plot_Tephra_WP	01/04/2008 06:58:54	01/04/2008 13:09:30	Play	Control Time	27%
RAR_Folders	01/04/2008 11:28:24	01/04/2008 17:28:24	Play	Control Time	6%
SaveLog	01/04/2008 12:53:46	01/04/2008 13:08:46	Play	Control Time	50%
Simulatori	01/04/2008 10:40:07	01/04/2008 13:13:53	Play	Control Time	42%
Sito_DPC	01/04/2008 12:48:16	01/04/2008 13:48:16	Play	Control Time	57%
Sito_UPNV	01/04/2008 12:52:23	01/04/2008 13:52:23	Play	Control Time	78%
VolcalPuff_Weak	10/03/2008 13:20:28		Stop		

UPNV Scheduler Log

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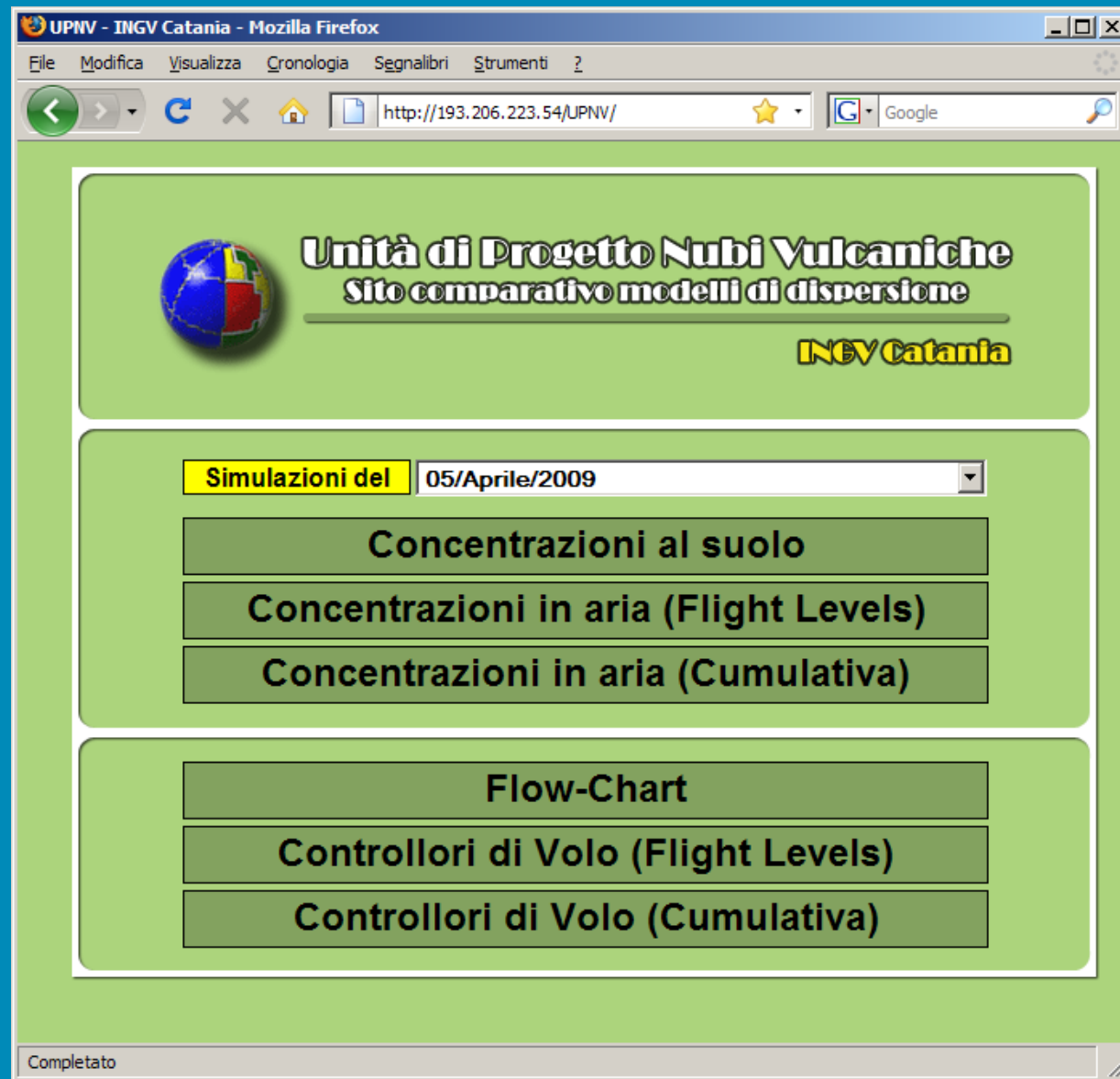
01/04/2008 13:05:57 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.ListShare [Info]: Creazione lista di files \\ctmeteosat\MSG\20080401*.xpf
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.ListShare [Info]: Creazione lista terminata. 624 files
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.SubList [Info]: Lista 1 = lista 1 - lista 0
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.SubList [Info]: Sottrazione completata: 0 files
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.BreakIfEmpty [Info]: Controllo lista 1
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.BreakIfEmpty [Info]: Lista vuota. Esecuzione interrotta
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSG_Backup_oggi.Execute [Warning]: Esecuzione interrotta
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi.RunMacro [Info]: Esecuzione Macro: MSGNC_Backup_oggi
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.Execute [Info]: Esecuzione programma
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.MakeDir [Info]: Creazione directory: D:\Archivio\MSG_NC\20080401
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.ReadListFromFile [Info]: Caricamento lista da file D:\Archivio\MSG_NC\20080401\MSG.f
01/04/2008 13:06:00 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.ReadListFromFile [Info]: Caricamento completato
01/04/2008 13:06:01 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.ListShare [Info]: Creazione lista di files \\ctmeteosat\MSG\20080401*.xpf
01/04/2008 13:06:04 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.ListShare [Info]: Creazione lista terminata. 624 files
01/04/2008 13:06:04 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.SubList [Info]: Lista 1 = lista 1 - lista 0
01/04/2008 13:06:04 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.SubList [Info]: Sottrazione completata: 0 files
01/04/2008 13:06:05 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.BreakIfEmpty [Info]: Controllo lista 1
01/04/2008 13:06:05 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.BreakIfEmpty [Info]: Lista vuota. Esecuzione interrotta
01/04/2008 13:06:05 - TgvpCmds.MSG_oggi->MSGNC_Backup_oggi.Execute [Warning]: Esecuzione interrotta
01/04/2008 13:06:05 - TgvpCmds.MSG_oggi.Execute [Info]: Processamento ok
01/04/2008 13:06:05 - TgvpProduct.MSG_oggi.Pause [Info]: Richiesta di messa in pausa...
01/04/2008 13:06:05 - TgvpProduct.MSG_oggi.Pause [Info]: Prodotto in pausa
01/04/2008 13:06:05 - TgvpProduct.MSG_oggi.SaveConfig [Info]: File di configurazione salvato
01/04/2008 13:06:05 - TgvpProduct.MSG_oggi.Play [Info]: Prodotto riavviato
  
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Unità di Progetto Nubi Vulcaniche - INGV Catania



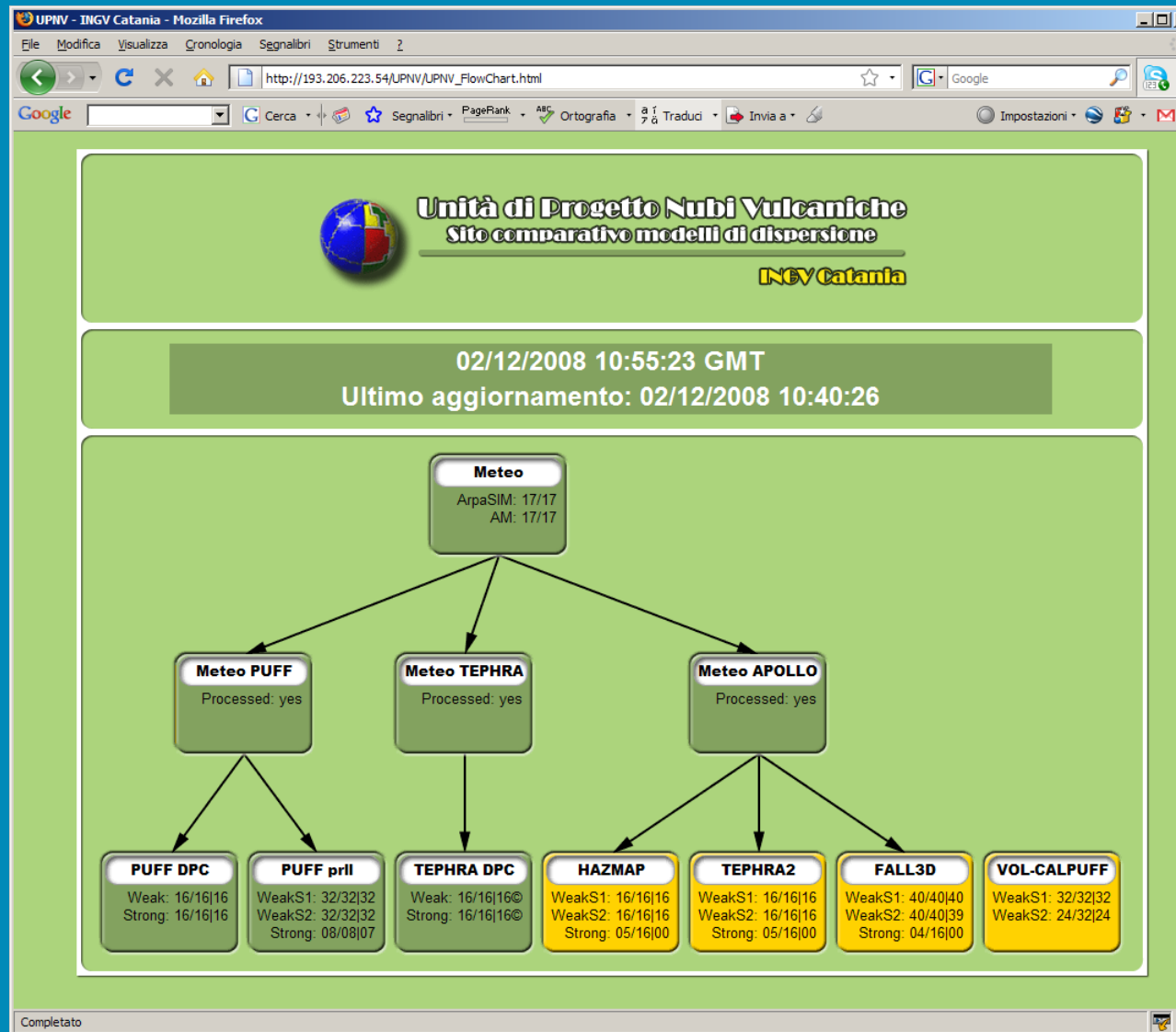


Working web site





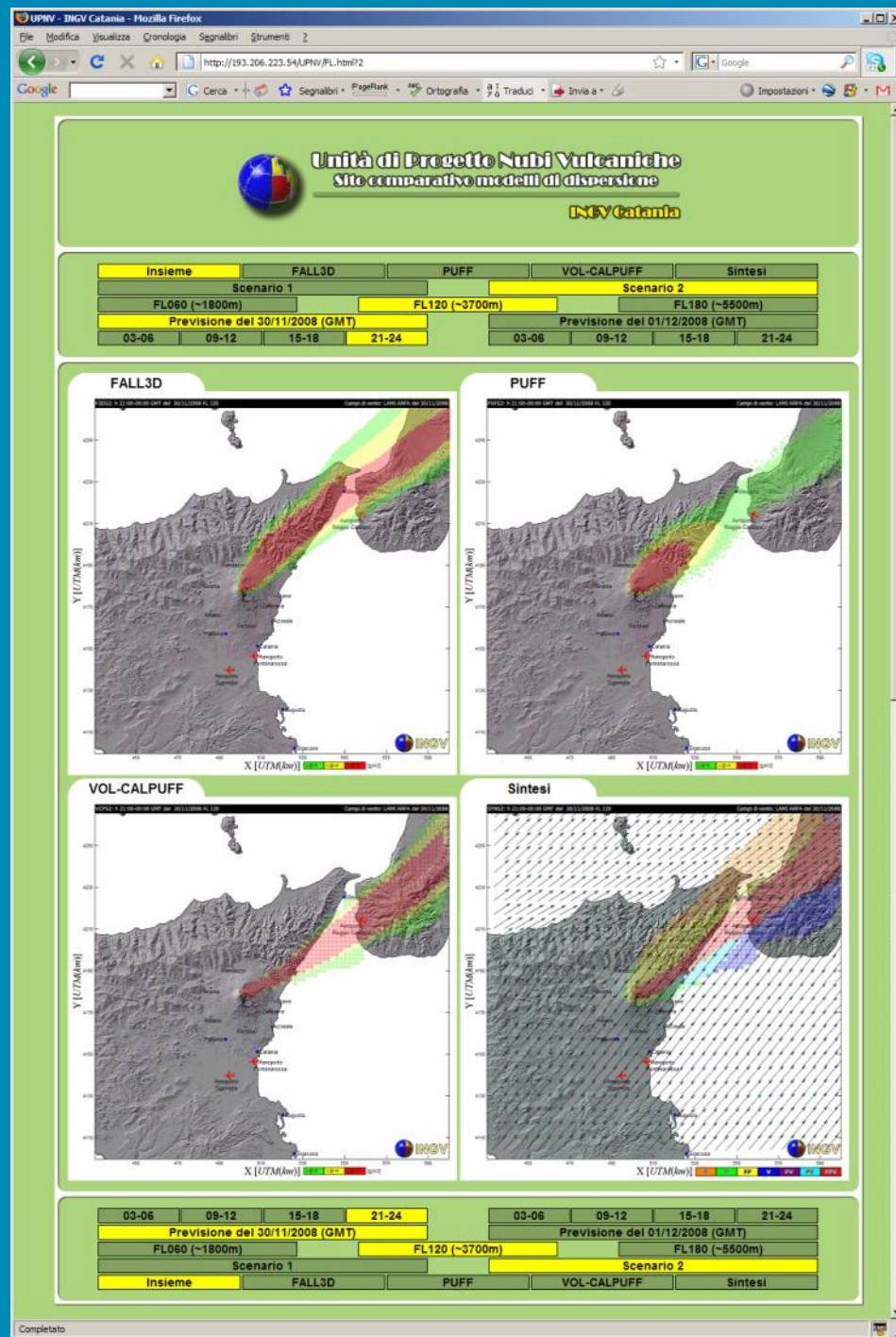
Real-time automatic processes control





Ash dispersal from 3 models plotted on flight levels and synthesis map

For multi-modeling approach
see Neri et al. (2009)





EVR "ETNA VOLCANIC REPORT" VONA compliant

EVR-1: advisory message for eruption forecasting or first observation

AIM: we intent report the forecasting or the first observation of an eruption phenomenon potentially able to emit volcanic ash in atmosphere

EVR-2A: advisory message for volcanic ash emission noticing

AIM: we intent confirm that the reported eruption emit a significant amount of volcanic ash in atmosphere

EVR-2B: advisory message for no volcanic ash emission occurring

AIM: we intent exclude a volcanic ash emission associated to the reported eruption

EVR-3: advisory message for volcanic ash clouds details

AIM: we intent report the available details on the observed ash clouds as height, extension and direction useful to input data for VAAC wide scale dispersal /trajectory models

EVR-4: advisory message for volcanic ash emission stopping

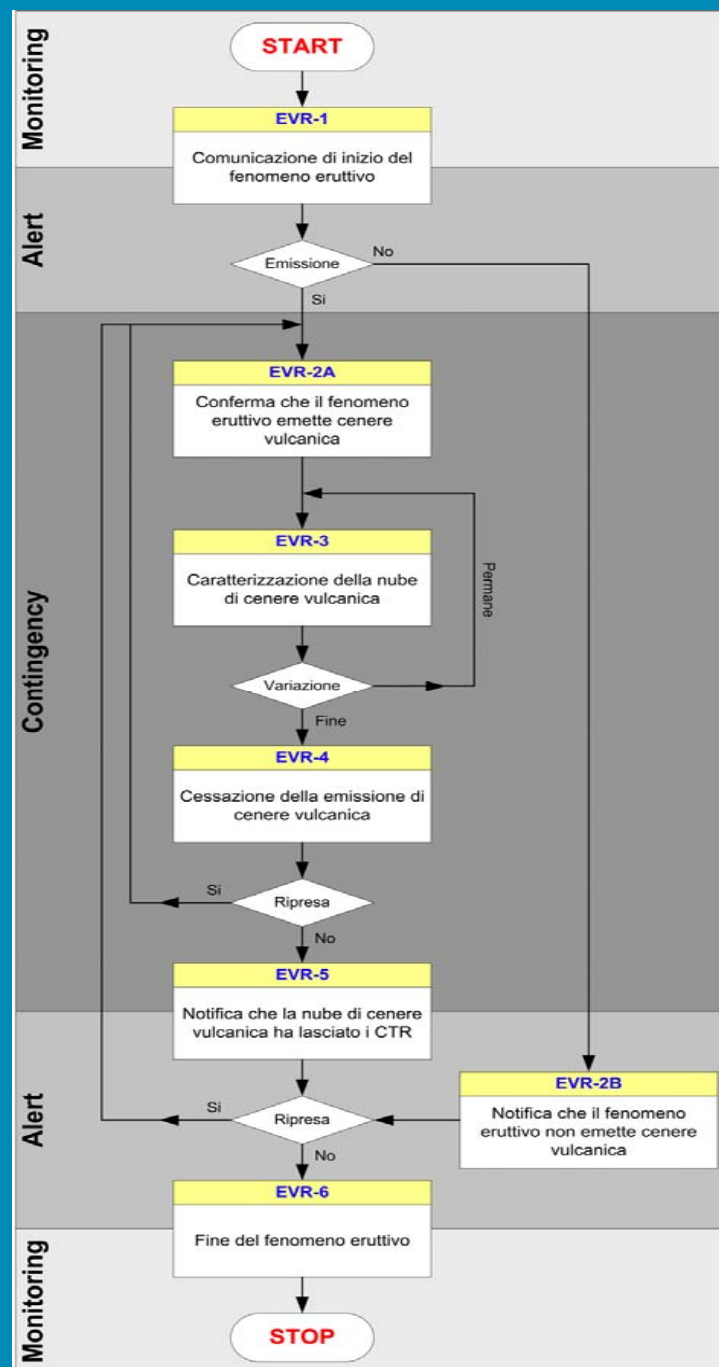
AIM: we intent communicate the end of the emission of volcanic ash in atmosphere

EVR-5: advisory message for volcanic ash cloud leaving CTR

AIM: we intent communicate the volcanic ash cloud is observed or forecasted out of the Catania and Reggio Calabria CTR

EVR-6: advisory the end of the eruption phenomenon

AIM: we intent communicate the definitive conclusion of the eruption phenomenon object of this EVR message set





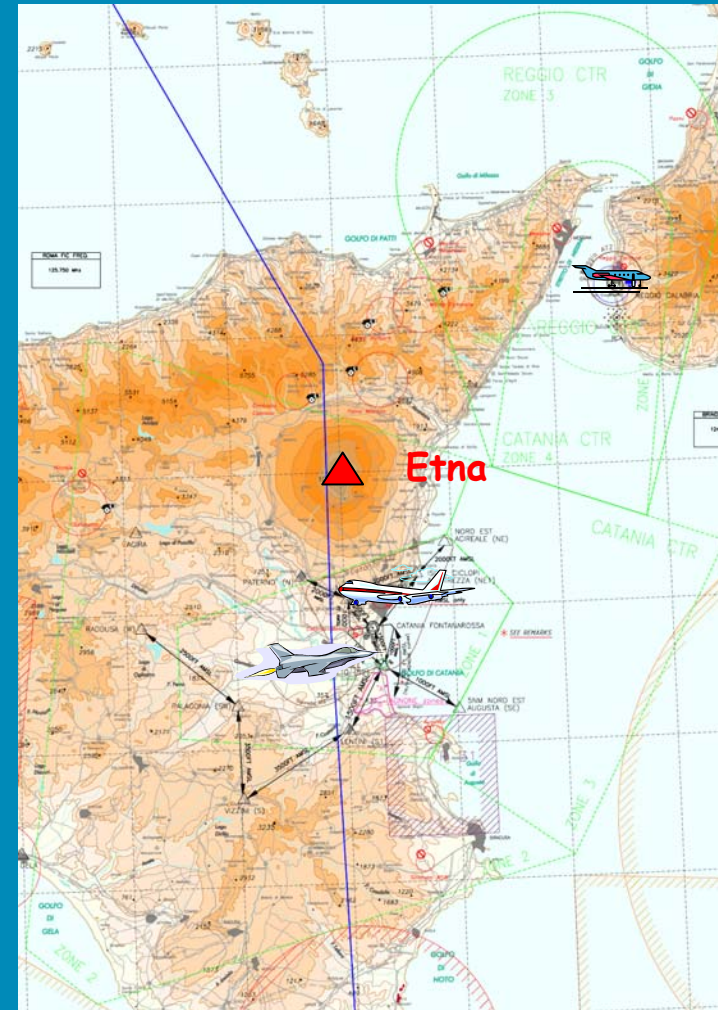
Outline

- Interaction between Volcano Observatory (INGV) and aviation organization (in Italy)



There are 3 large airports located within 37 NM from Etna volcano

- **Catania Fontanarossa International airport**
 - 100,000 mov/year
 - 6 million pax/year
- **Catania Sigonella Military airport**
- **Reggio Calabria Domestic airport**
 - 8,000 mov/year
 - 0.5-0.6 million pax/year





Italian regulatory framework

- In 2003 the Italian regulatory authority ENAC adopted a specific circular to manage flight operations on Catania airport and immediately adjacent airspace that is presently in force
- In 2007 ENAC decides to revise the circular due to some weaknesses of the procedure and a commission that included Civil Protection formulate a new procedure that presently is waiting to be officially put in operation
- At present state no specific regulations are being adopted by ENAC to introduce the ICAO EUR/NAT volcanic ash contingency plan for the whole Italian airspace



The local procedure: ENAC new circular

 ENAC		
CIRCOLARE		
SERIE GENERALE	Data XX/XX/XX	GEN-XX
DISCIPLINA DELLE ATTIVITÀ AERONAUTICHE CONNESSE ALLA CONDUZIONE DI OPERAZIONI DI VOLO SU AEROPORTI E SPAZI AEREI LIMITROFI IN PRESENZA DI NUBE DI CENERE VULCANICA.		
L'appartenenza di una Circolare ad una serie specifica è rappresentativa delle materie in essa prevalentemente trattate. L'applicabilità o meno della Circolare ai diversi soggetti (operatori, gestori aeroportuali, etc.) deve essere tuttavia desunta dal contenuto di essa.		

 ENAC
Allegato alla Circolare GEN-XX
Aeroporti, CTR e ATZ di Catania e di Reggio Calabria
PROCEDURE PER LA CONDUZIONE DELLE OPERAZIONI DI VOLO IN PRESENZA DI NUBE DI CENERE VULCANICA



Institutions, agencies and organisms involved in the application of the procedures described in the ENAC circular

- Aeronautical organisms: Airport Directions, ATS organisms (APP, ARO, ACC, FIC), meteorological organisms (MWO, MET), Airport Operators
- Non aeronautical organisms: INGV Catania (volcano observatory), National Italian Department of Civil Protection
- Special organisms for the contingency plan management: Crisis Unit, Operative Coordination Unit, Airport facilities Operability Evaluation Unit



Main phases of the procedure and related activities

- Continuous aeronautical surveillance: for monitoring the normal volcanic activity
- Alerting phase when an eruptive phenomena is approaching
- Volcanic eruption ongoing with ash emission in the atmosphere



Information dissemination

→ ATS – METEO Messages

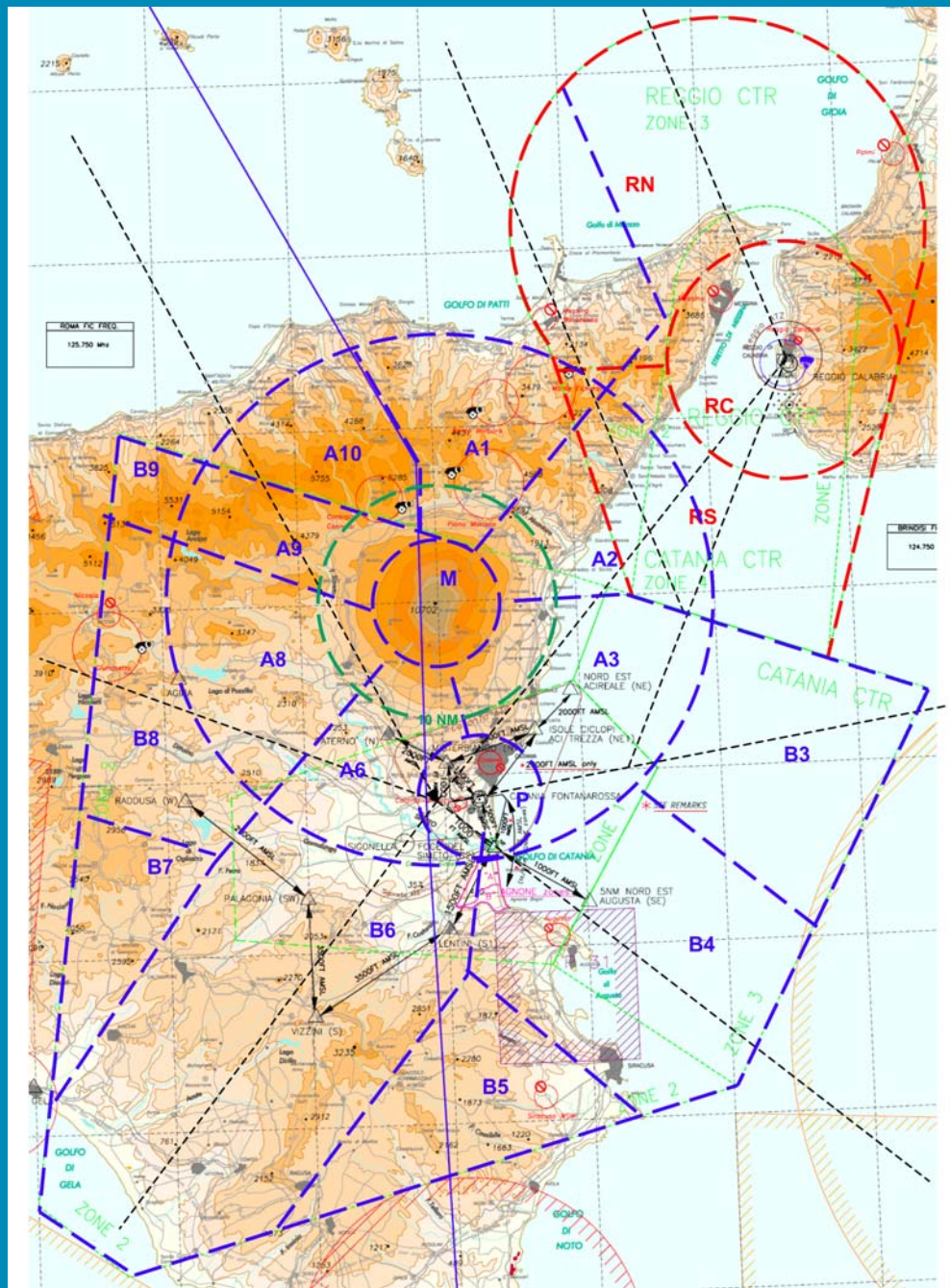
- ✉ ASHTAM (Sigonella ARO - according to color code)
- ✉ AIREP SPECIAL (Report from pilots to ATS UNITS)
- ✉ VAR (from Crews post flight Report on the volcanic activity)
- ✉ VAA / VAG (issued from VAAC Toulouse)
- ✉ SIGMET (AMI MWO /CMR Milano)
- ✉ WARNINGS (locally from ARO)

→ INGV-DPC Messages

- ✉ Report on the volcanic activity – criticism.
- ✉ Forecast ash dispersal maps and info dispatched via reserved internet access.
- ✉ Contact Sigonella Met office and Catania Radar

→ Airport Operators

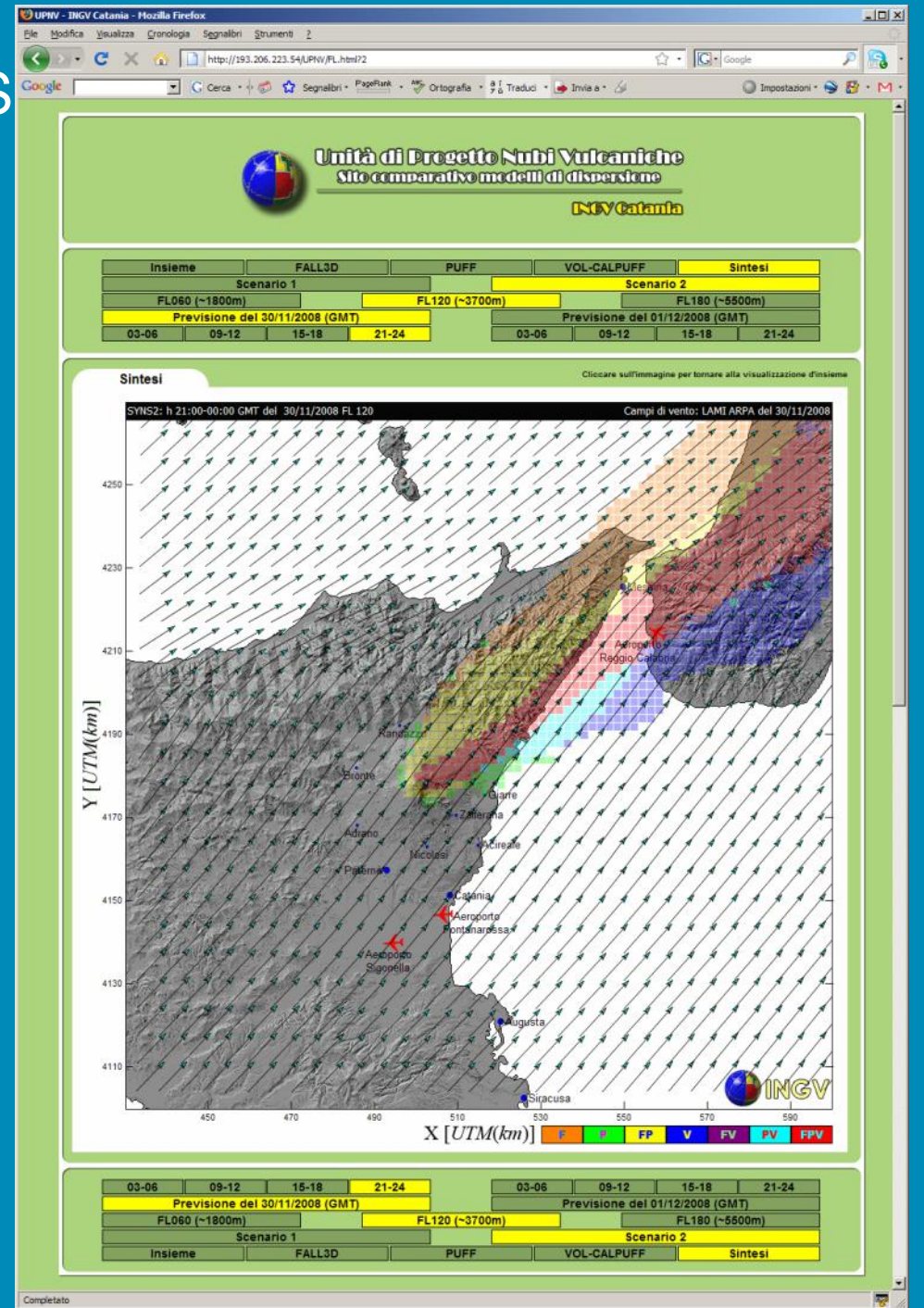
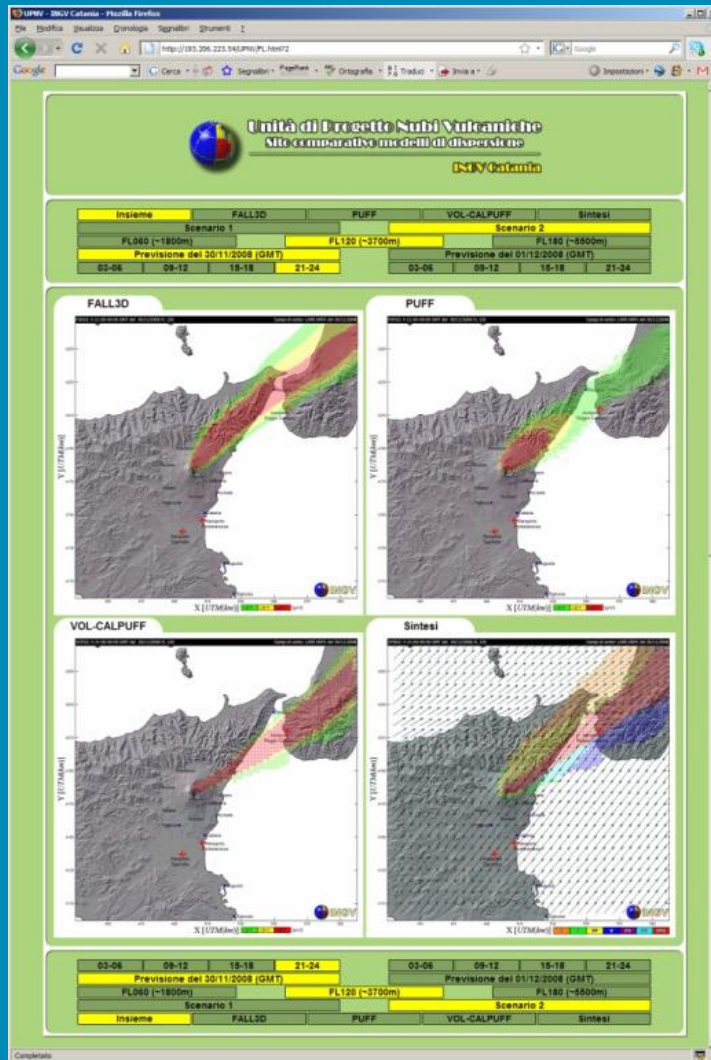
- ✉ Report on RWY and Movement area condition



The map of new
flight sectors for
the contingency
plan

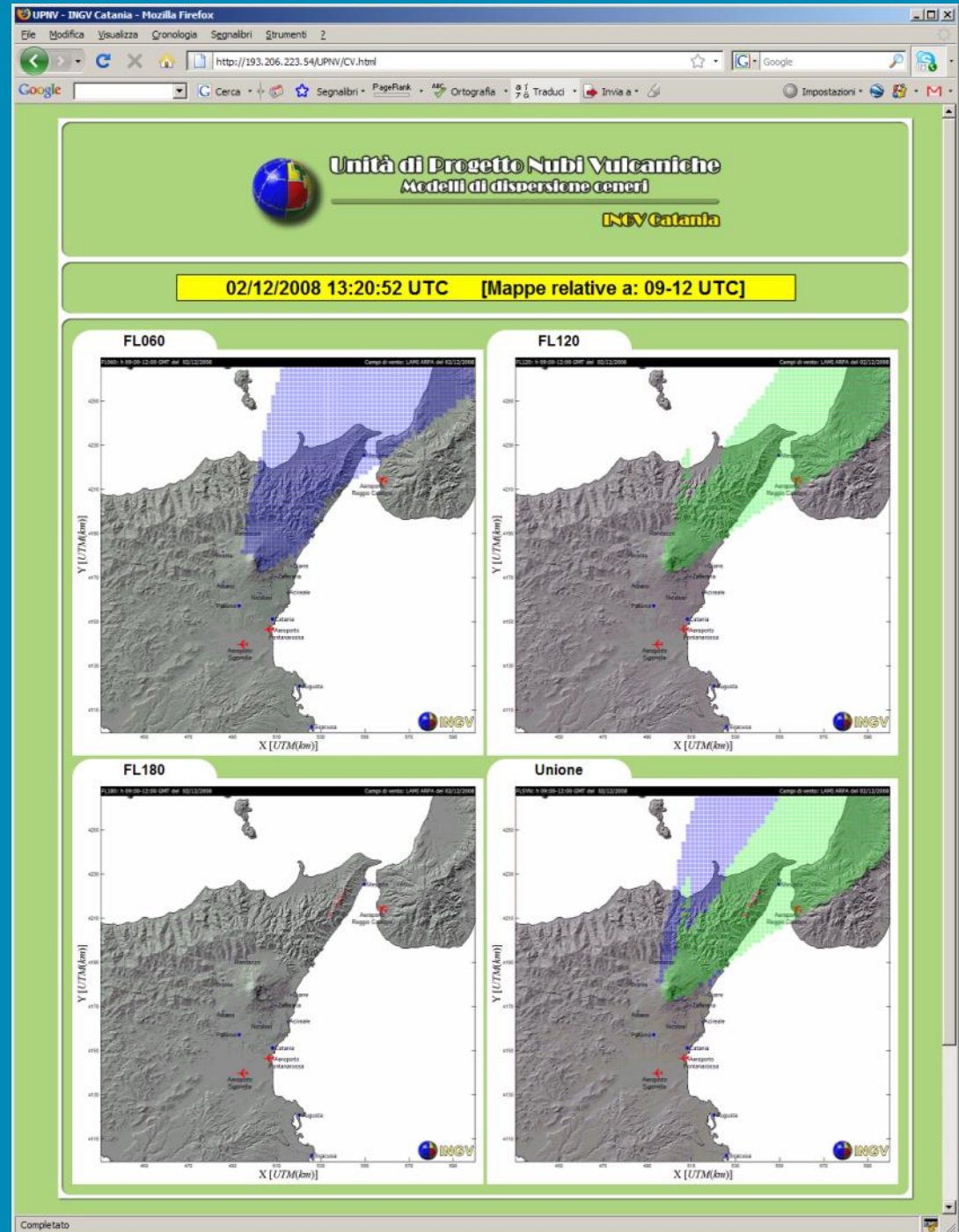


INGV ASH DISPERSAL MAPS



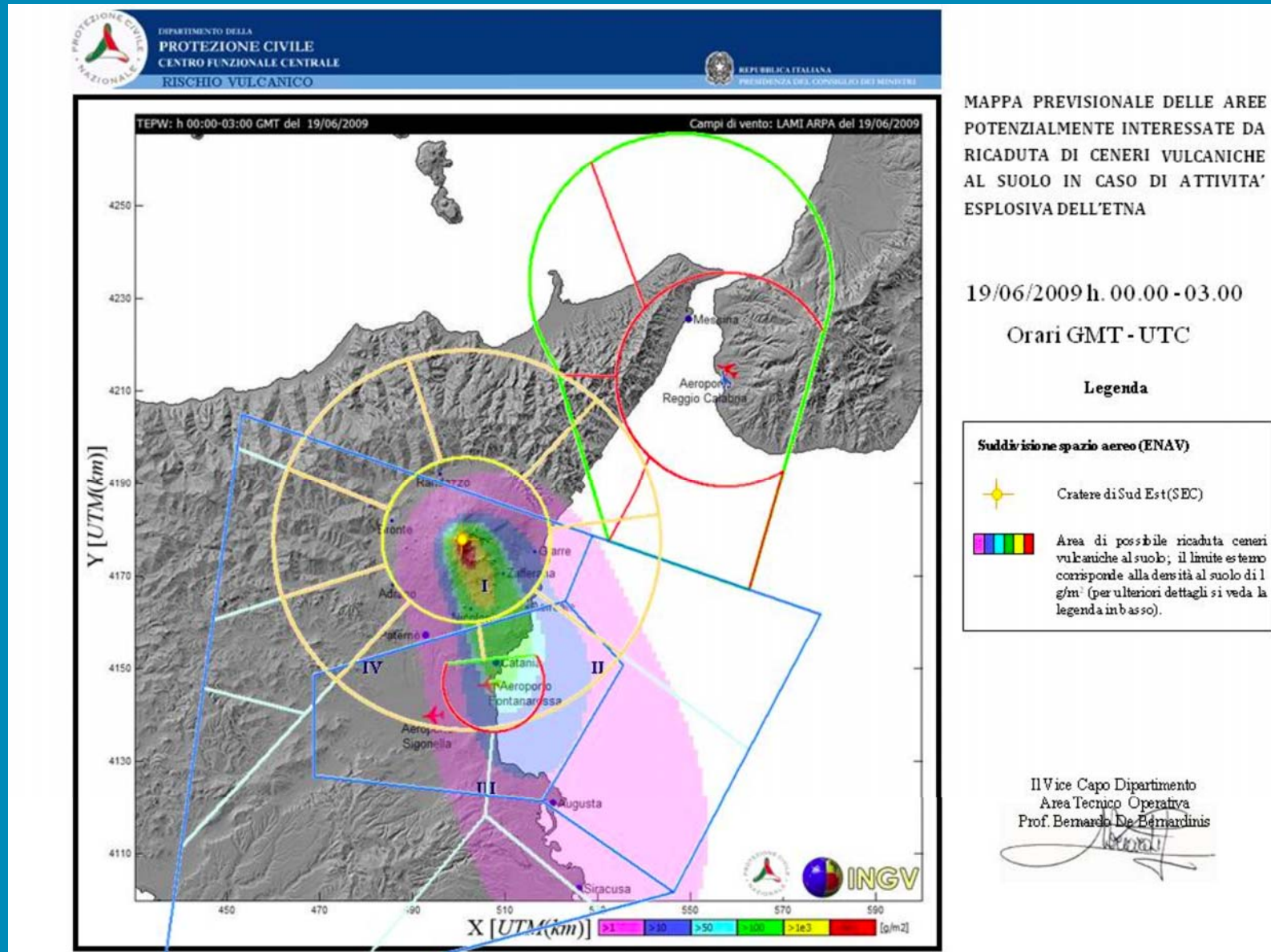


SYNTHESIS FL MAP for air traffic controller





Example of Italian Civil Protection formalized ash dispersal map





Outline

- Strategy for managing future eruptive crises of Etna volcano



Operational strategies

- Long-term ash dispersal forecasting based on medium-range weather forecasts (7-10 days) and reliable scenarios for transport emergency planning
- Real-time and continuous quantitative observation of ash source, dispersal and fallout
- Real-time forecasting based on nowcasting (up to 6 hours) meteorological modeling
- Systematic updating of the "long-term" forecasting for managing the emergency
- Robust background on the airplane vulnerability to the ash impact and ingesting
- Fast control of the airplanes operating near the contaminated airspace



Thank you for your attention

For any additional information you can contact:

coltelli@ct.ingv.it

and visit the UNVP working web site:

<http://193.206.223.54/UPNV/>