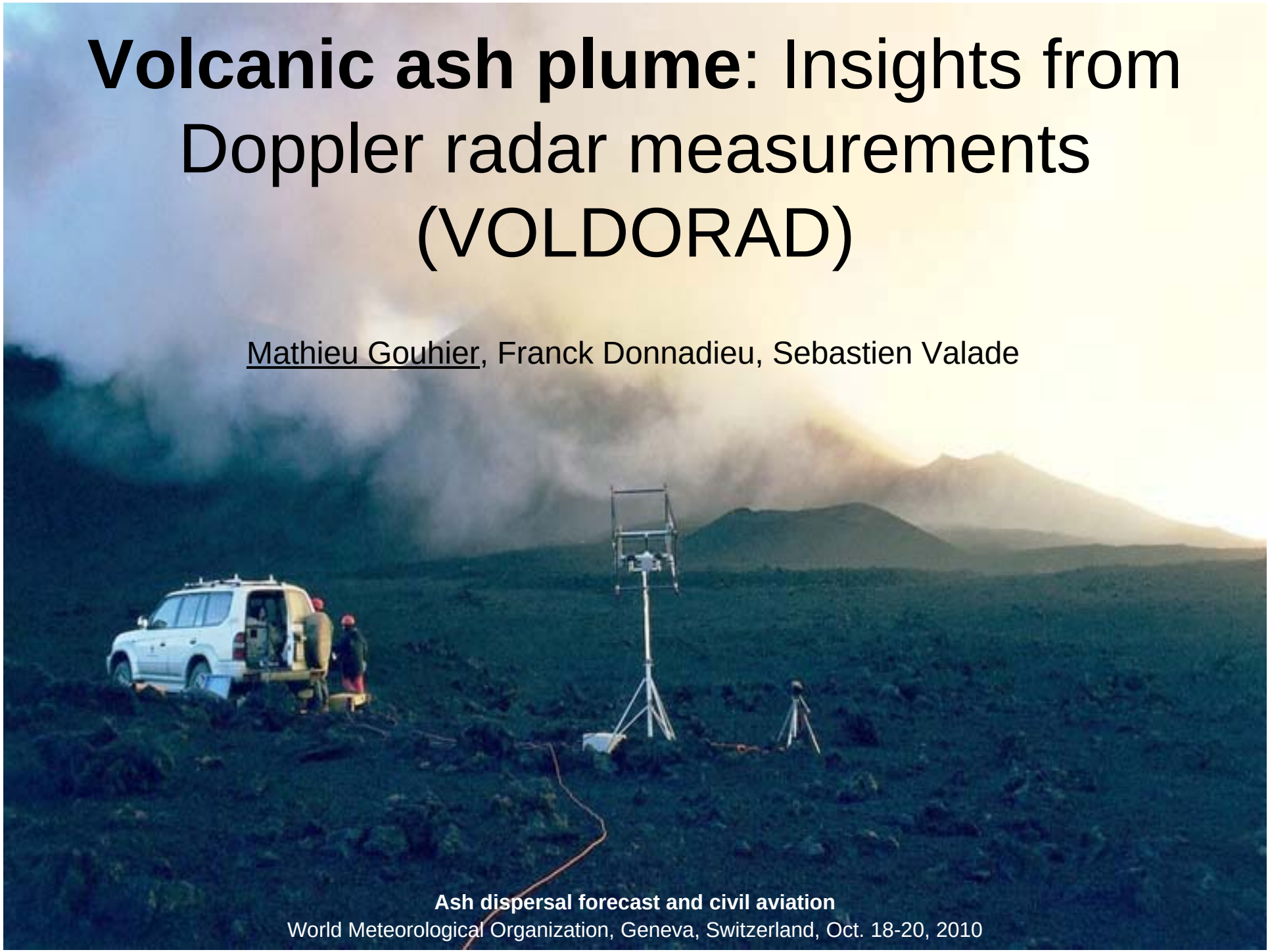
Volcanic ash plume: Insights from Doppler radar measurements (VOLDORAD)

Mathieu Gouhier, Franck Donnadieu, Sebastien Valade

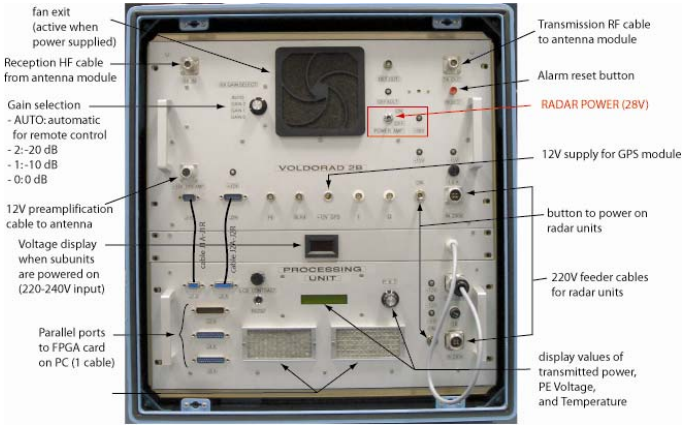


Ash dispersal forecast and civil aviation
World Meteorological Organization, Geneva, Switzerland, Oct. 18-20, 2010

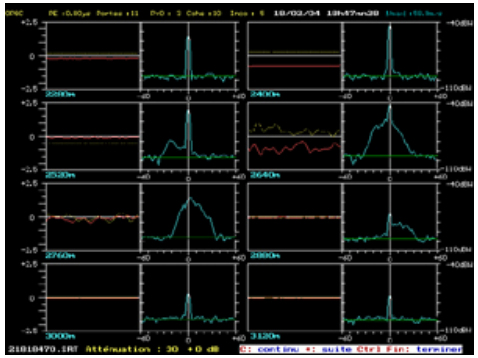
VOLDORAD : instrument

Antenna

Radar core



PC



- Total weigth (PC + Radar + antenna) ~ **70 Kg**
- Power supplied (AC or generator) ~ **300 W**
- 4WD Vehicle (Four Wheel Drive)

VOLDORAD : applications

- **Fields of applications**

Plinian

Pyroclastic flow

Lava fountain

Strombolian

Effusive

VOLDORAD : output parameters

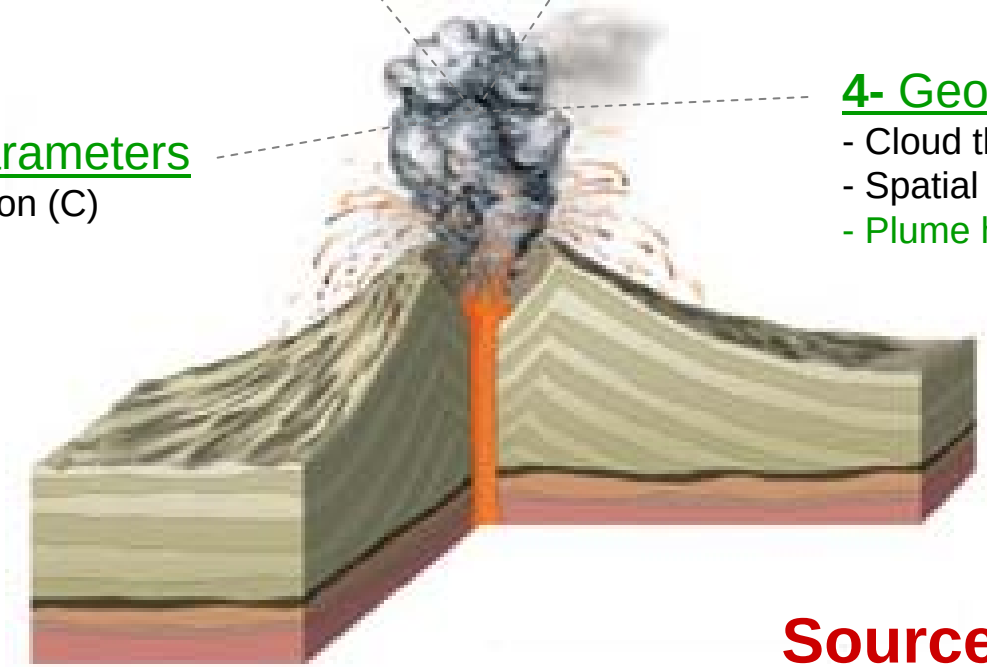
➢ **Output parameters**

3- Particle size parameters
- Ash number (N)
- Ash size (D)
- PSD

2- Kinetic parameters
- Gas velocity (Vg)
- Kinetic energy (Ek)
- Particle velocity (Vp)

4- Geometry parameters
- Cloud thickness (Tc)
- Spatial ejecta distribution (EAD)
- Plume height (Hc)

1- Loading parameters
- Ash Concentration (C)
- Ash Volume (V)
- Ash Mass (M)



Source parameters

VOLDORAD : How does it work

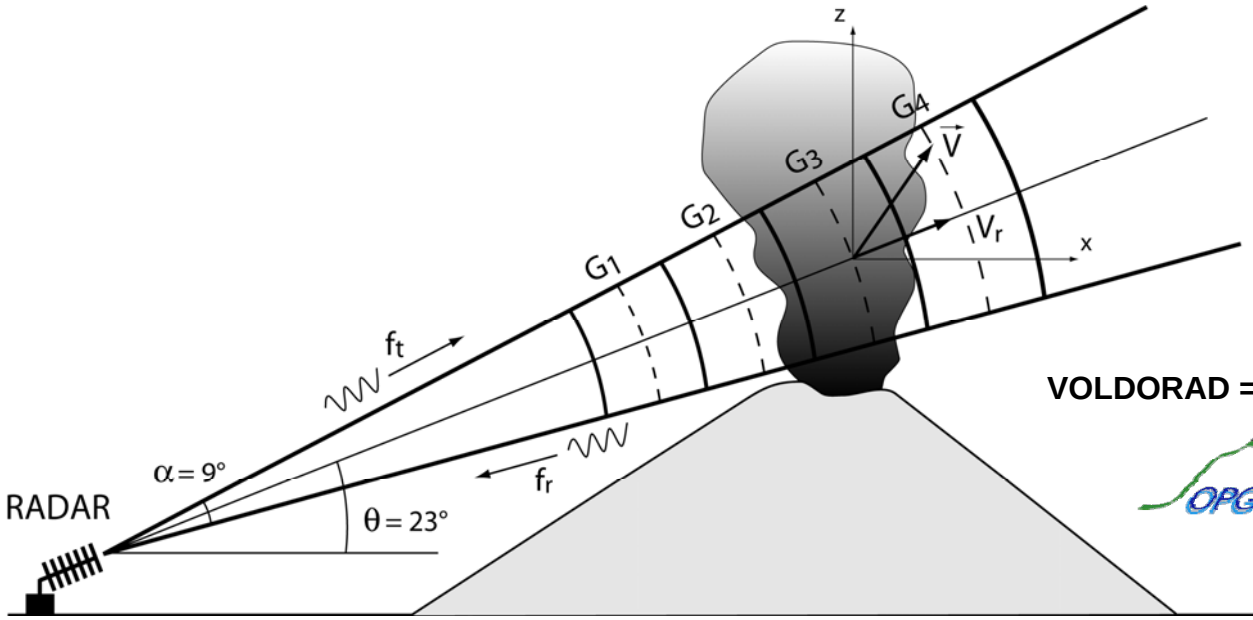
Voldorad properties:

Wavelength = 23.5 cm
Beam width = 9°
Range resolution = 120 m
Sampling rate = 10 Hz
Scale of acquisition = 0.3 – 12 km

Voldorad: Raw data

1- **Power** = particle loading

2- **Velocity** = particle velocity

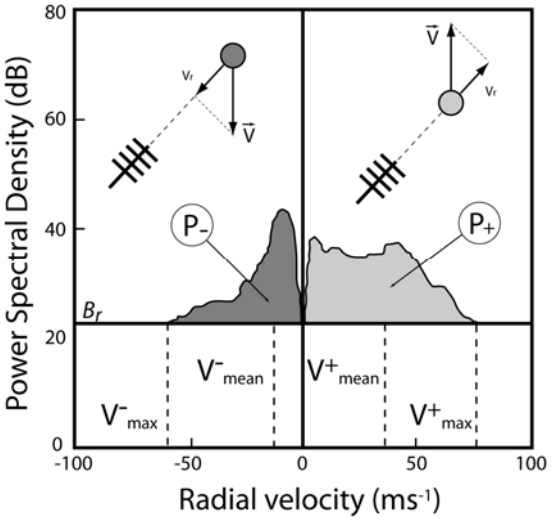


VOLDORAD = Volcano **Do**ppler **Rad**ar

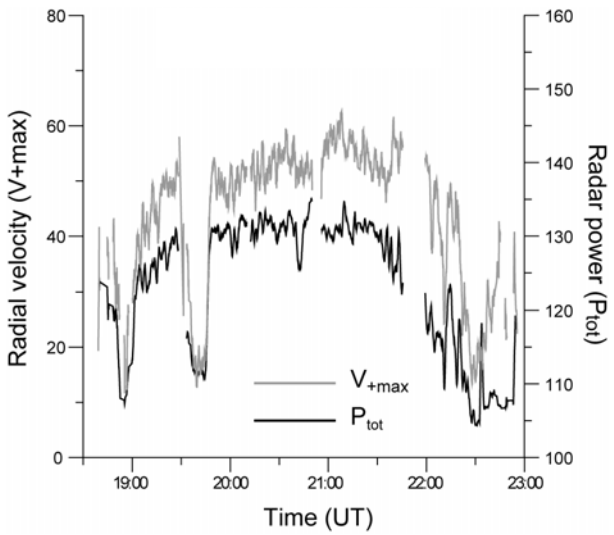
VOLDORAD direct parameters

➢ **Direct parameters :** (1) total power, (2) maximum velocity

Doppler spectrum



Time series : 10 Hz



Power ⇨ $\mathbf{P_{tot}}$

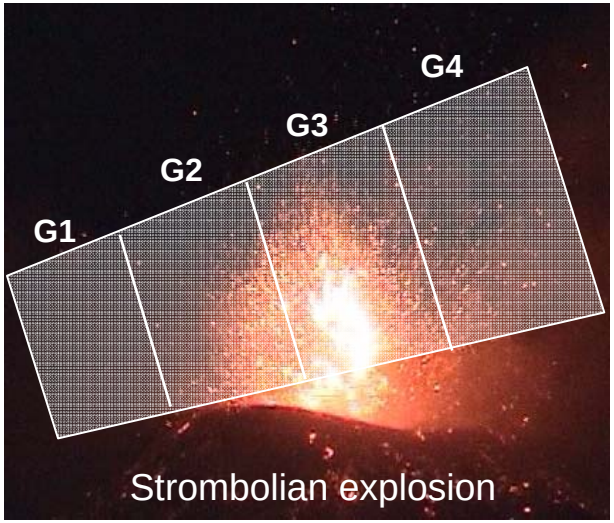
Velocity ⇨ $\mathbf{V^+_{max}}$

VOLDORAD direct parameters

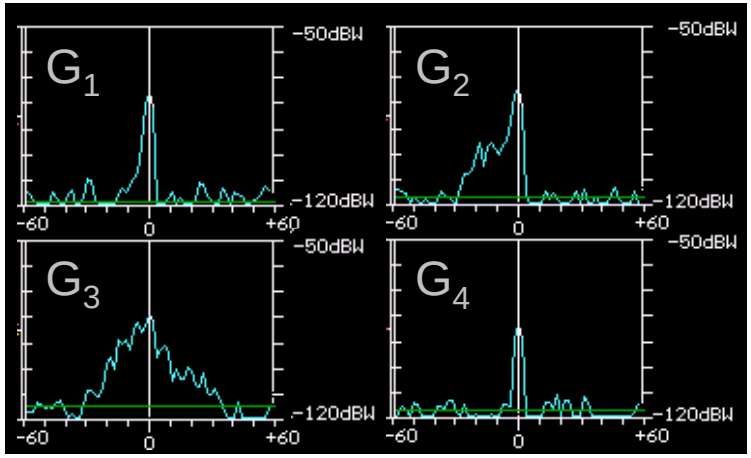
➢ **Example : Strombolian activity**

- 1 explosion
- 04 July 2001
- Etna SEC

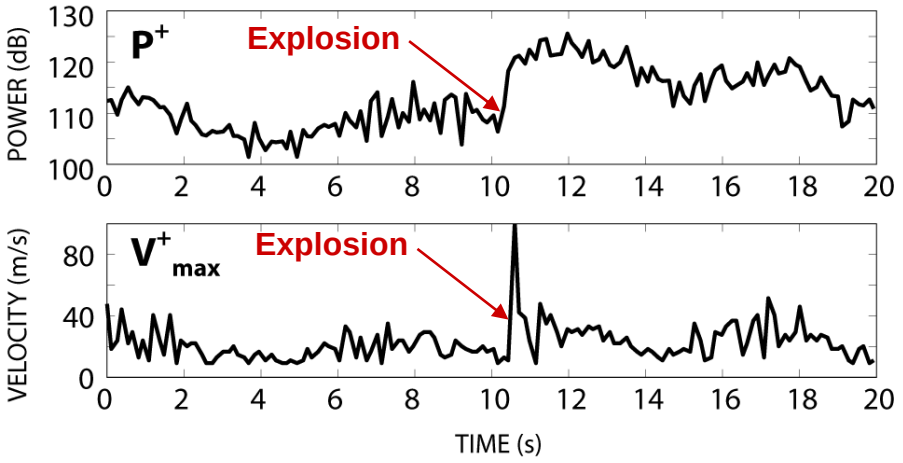
- **No** processing = real-time



Doppler spectra



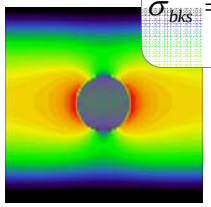
Time series



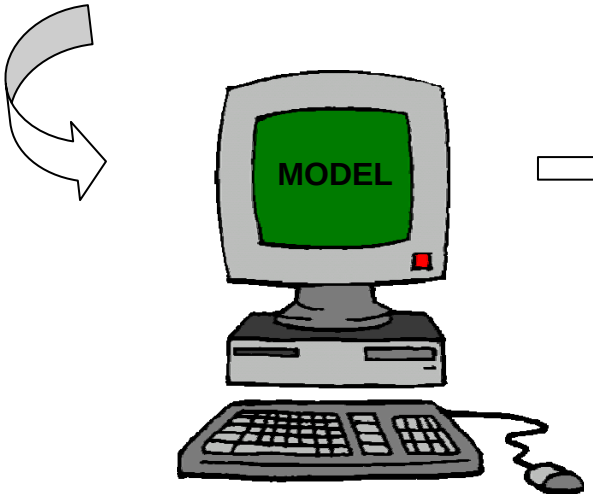
VOLDORAD indirect parameters

Electromagnetic scattering laws

$$\sigma_{bks} = \frac{\lambda^2}{4\pi}\left|\sum_{n=1}^{\infty}(-1)^2(2n+1)(a_n - b_n)\right|^2$$

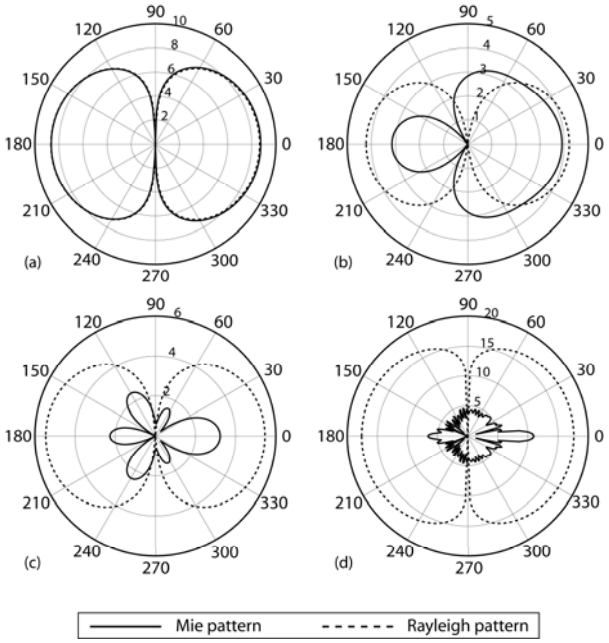


Gouhier and Donnadieu, JGR - 2008



Processing step

Mie vs. Rayleigh

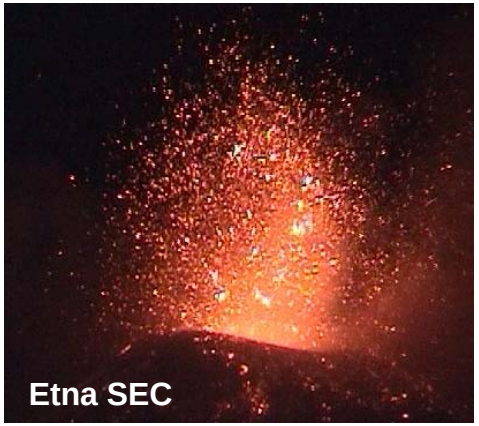


$$P_{synth} = \frac{C_r V_s \eta}{R^4}$$

VOLDORAD loading parameters

➢ Example : loading parameters

Loaded explosion



Total mass = **206 tons**

- Mass flux = 73 t/s
- Volume = 135 m^3
- Mean diameter = 1.6 cm
- Particles number = 23.3×10^6

⇨ KINETIC ENERGY

$\frac{1}{2} M \times V^2 = 3.9 \times 10^8$ J

Diluted explosion

Total mass = **58 tons**

- Mass flux = 26 t/s
- Volume = 38 m^3
- Mean diameter = 1.3 cm
- Particles number = 13.9×10^6

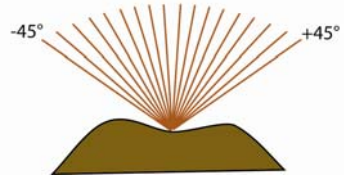
⇨ KINETIC ENERGY

$\frac{1}{2} M \times V^2 = 4.2 \times 10^7$ J

VOLDORAD Geometry parameters

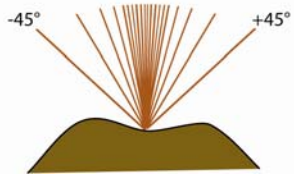
TOP - HAT

Explosion 1 :
Hemispherical and isotropic



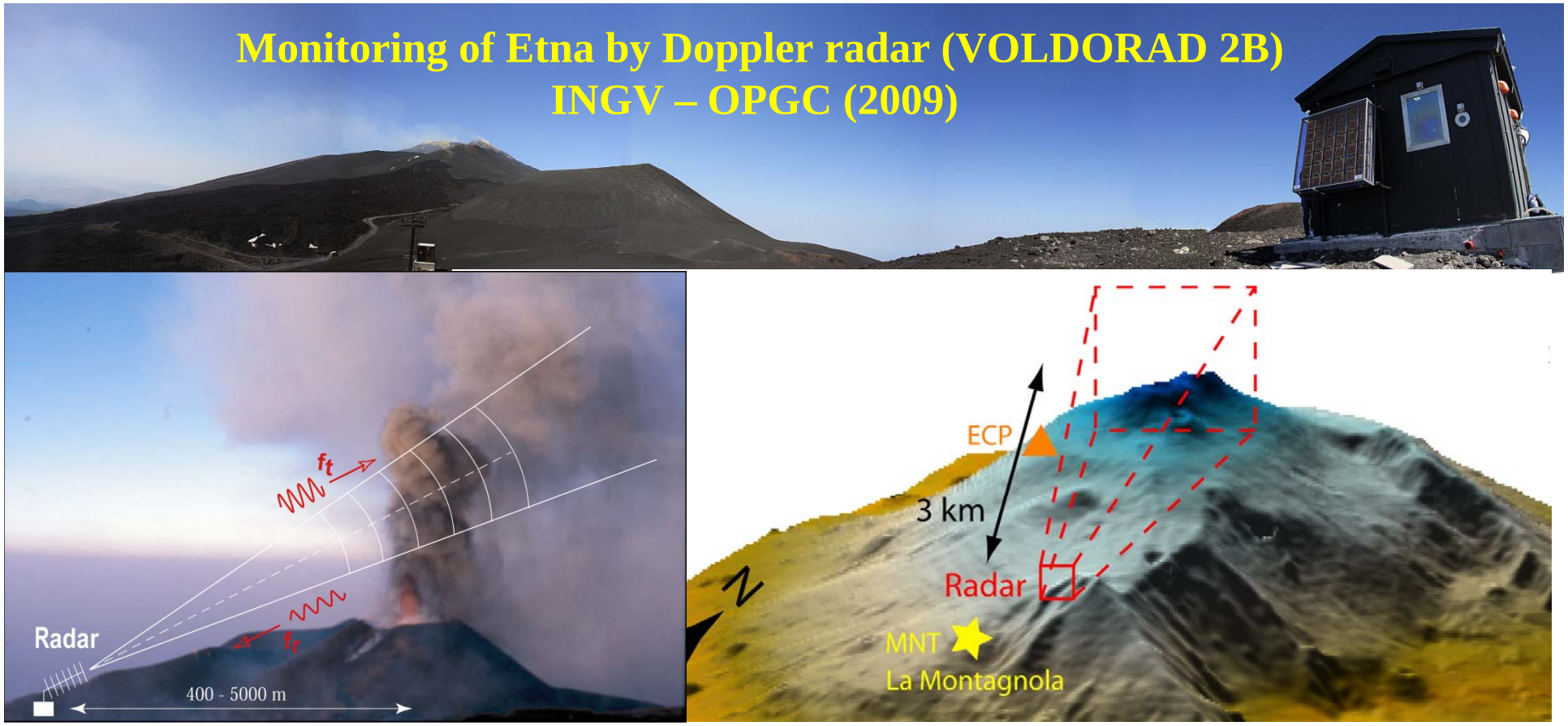
TRIANGULAR

Explosion 2 :
Vertical and anisotropic

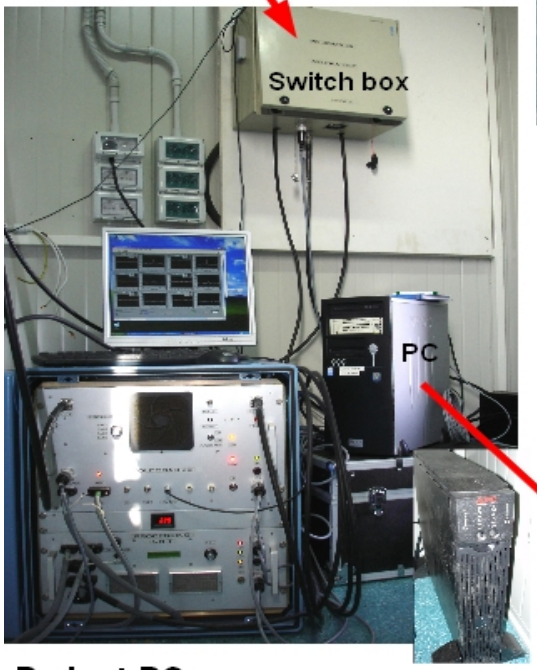


VOLDORAD : Operational

- **Real-time Monitoring at Etna**

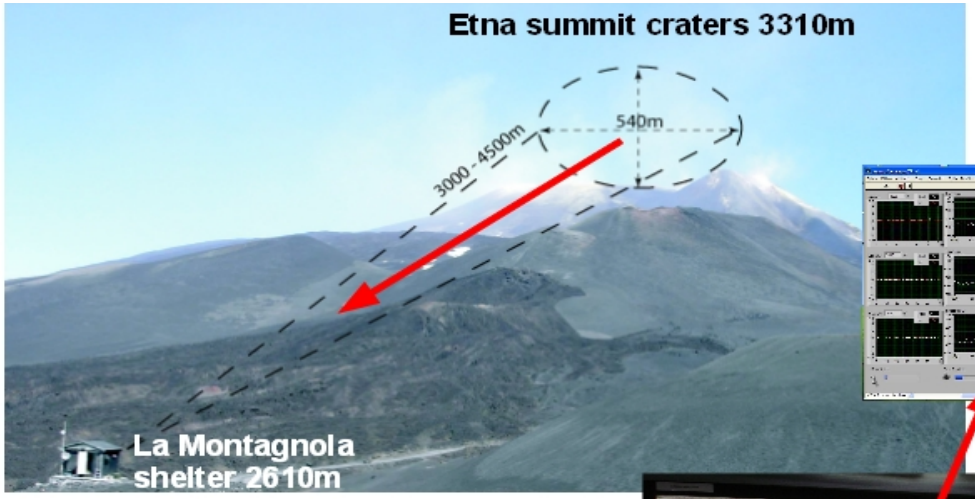


VOLDORAD : Operational



Radar + PC

Onduleur 2KW
+ batteries



FTP transfer
to OPGC

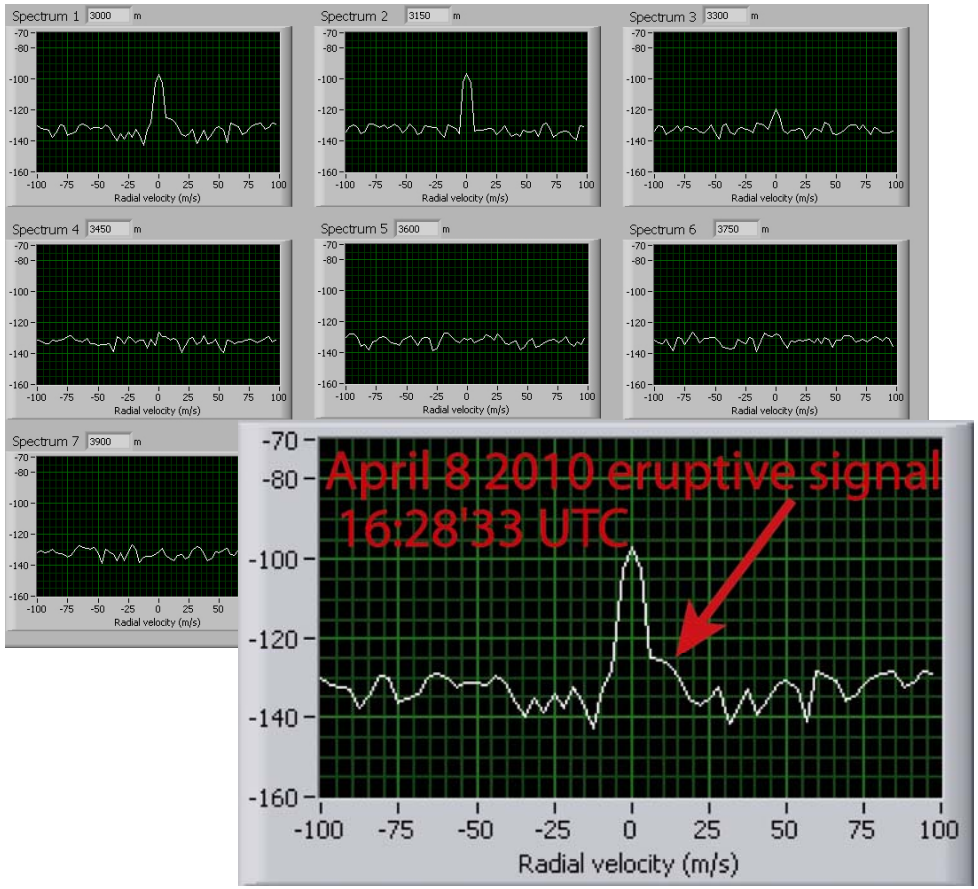
Control / backup server in shelter

Wifi transmission
to Catania (25km)

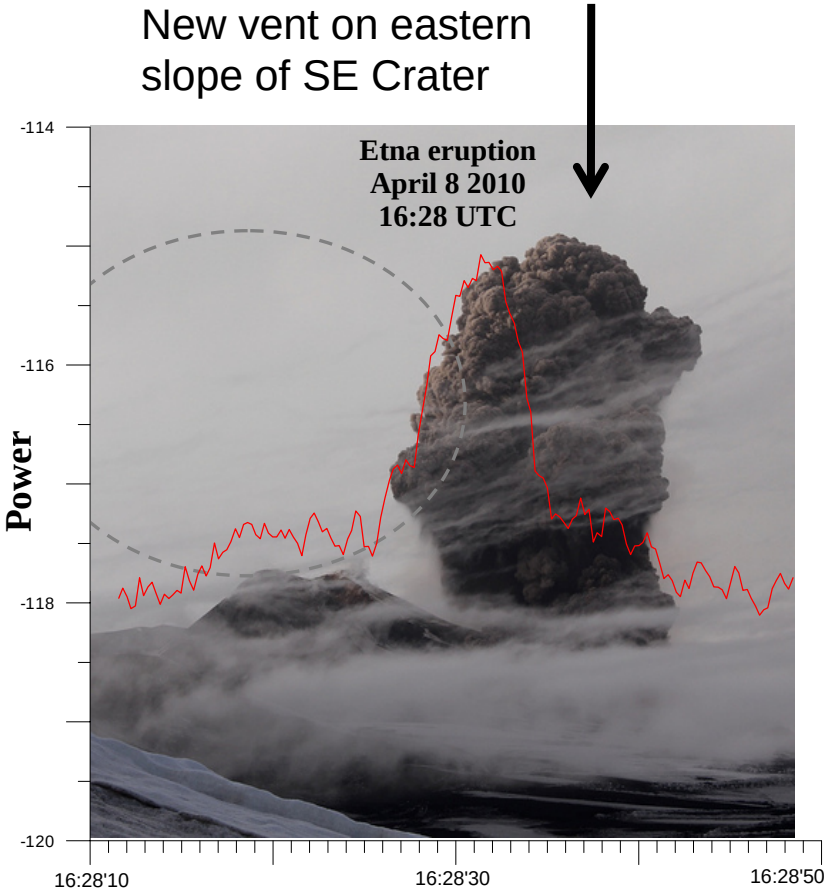
VOLDORAD : Operational

- First eruption detected by VOLDORAD 2B on April 8 2010

Doppler spectra in real-time



New vent on eastern slope of SE Crater



VOLDORAD : Operational

- Bocca Nuova (W vent) eruption on August 25 2010