Geophysical Surveillance Methods of Active Volcanoes

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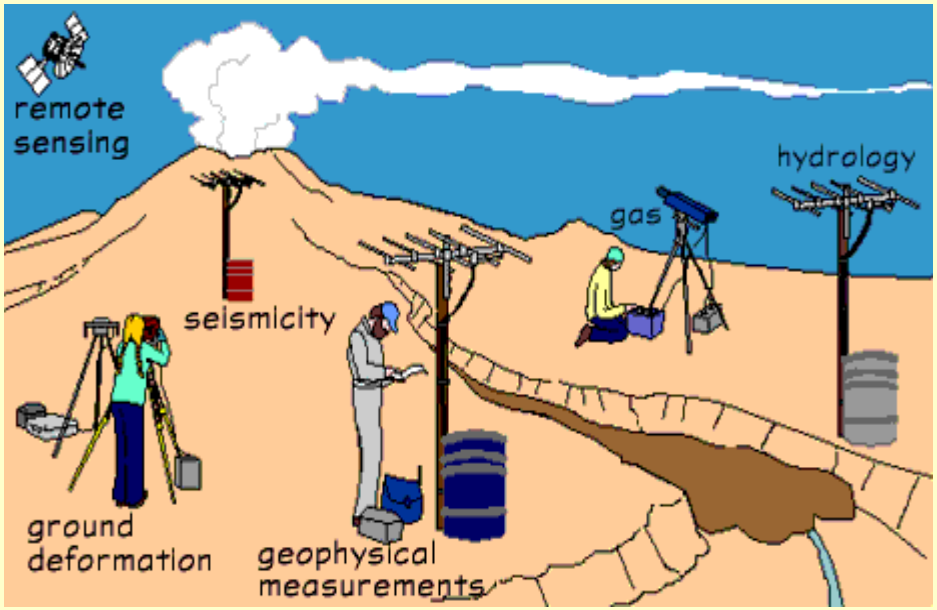


1. Some General Remarks about Monitoring Volcanoes

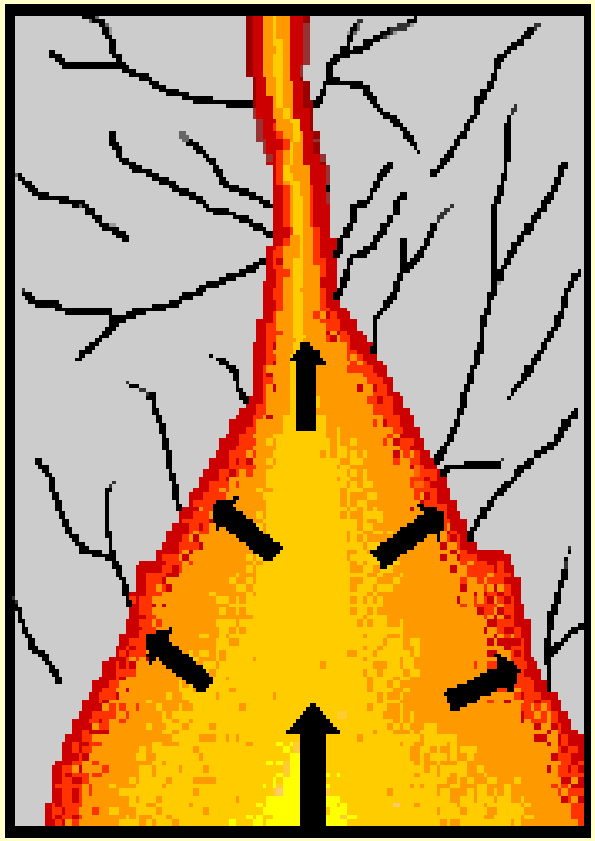
- Why?
  - To predict eruptions and to protect people in this way
  - To understand how volcanoes work
- It's important to survey a volcano for a longer time in order to be able to detect changes of parameters. An absolute value says nothing, but its change in time a lot about processes inside a volcano. That's why it's generally called monitoring and not measuring.
- To have a good chance to predict anything at all it's reasonable to observe as many parameters as possible, since it is not sure that every parameter reflects a forthcoming eruption.
- The time we have to observe a volcano is very short in comparison to its lifetime. This makes it complicated to understand long term activities.
- For predicting eruptions it's profitable to know the “history” of a volcano and its characteristics.

2. Geophysical Parameters

- Seismic activity
- Deformation of the surface
- Thermal variations
- Electrical variations
- Magnetic variations
- Gravitational variations

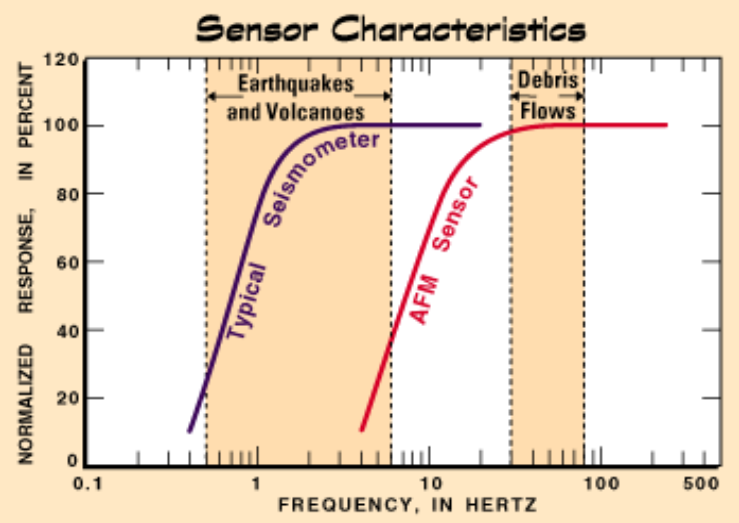
Seismic Activity

- There are different types of seismic events with different causes
  - “normal” earthquakes, not directly related to the volcano
  - earthquakes originating from breaking rocks due to the pressure of ascending magma (picture on the right)
  - surface events, such as tephra events, rockfalls associated with dome growth, and snow and rock avalanches from the crater walls
  - harmonic tremor, which is a long-lasting, very rhythmic signal whose origin is not completely understood but probably comes from the flow of magma through cracks in solid rocks (duration minutes to days)



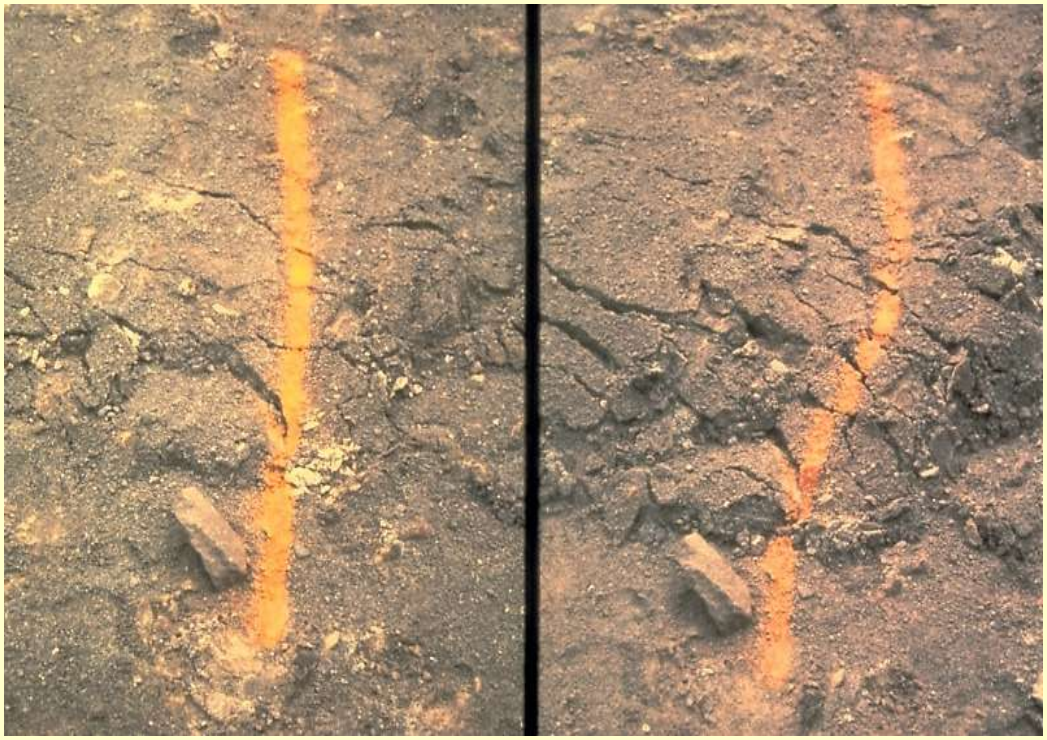
Seismic Activity

- Measuring instruments
  - Seismometers
  - Acoustic flow monitors (AFM)
- Benefit
  - Volcanic tremors are one of the important indicators for an eruption in the near future
  - With multiple seismometers it's possible to locate the source position of the signals and probably to track the way over time
  - Since no S-Waves propagate through magma, you can locate magma chambers



Deformation of the Surface

- Deformations have reasons similar to seismic events. The ascending magma expands the volcano. This leads to an increase in the tilt of the slopes, which is used to predict eruptions.
- After an eruption a volcano normally deflates
- Measuring methods
  - Tilt Meters
  - EDM
  - GPS
  - InSAR

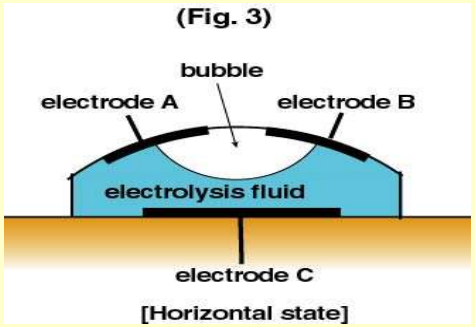


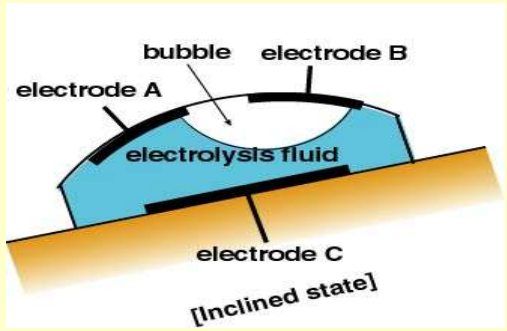
Mount St. Helens 1982: line is about 1m long, deformation in 2 days

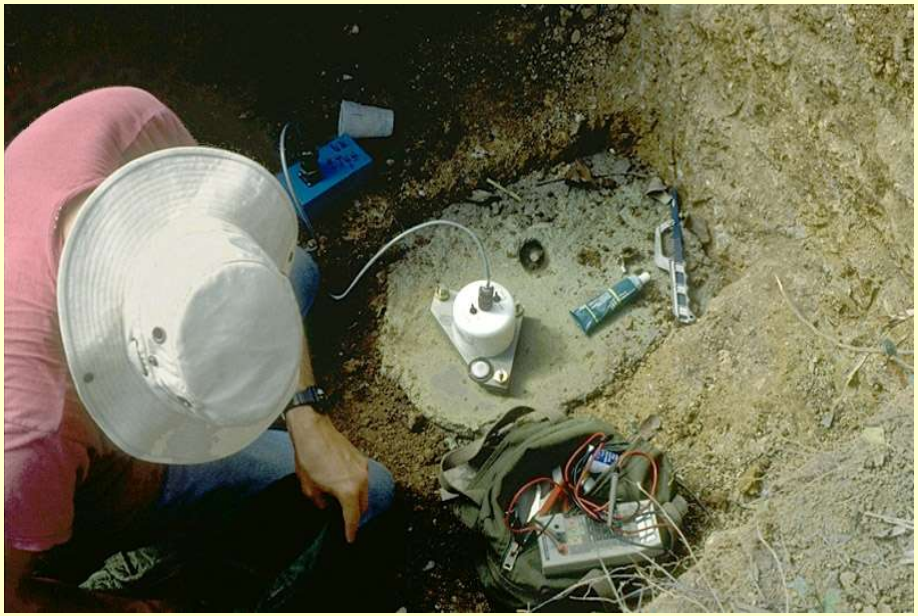
Tilt Meters

- An often used construction works like a spirit-level with a conductive fluid and electrodes to determine the tilt. Basically it's like a voltage divider.

- How sensitive are tilt meters? Good tilt meters measure the amount of tilt in microradians, which is the angle turned by raising one end of a beam one kilometer long about 1 mm (equivalent to 0.00006 degree!).





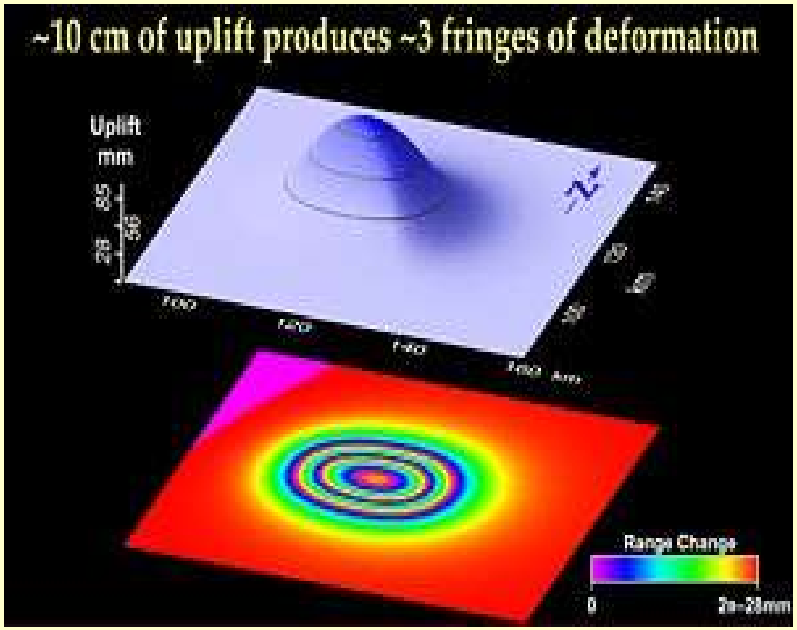


Satellite Radar Interferometry

- Satellite images of the area recorded before and after the deformation can be combined to generate a colorful pattern of fringes representing the phase shift. One fringe corresponds to the the half of the used wavelength (~3cm).

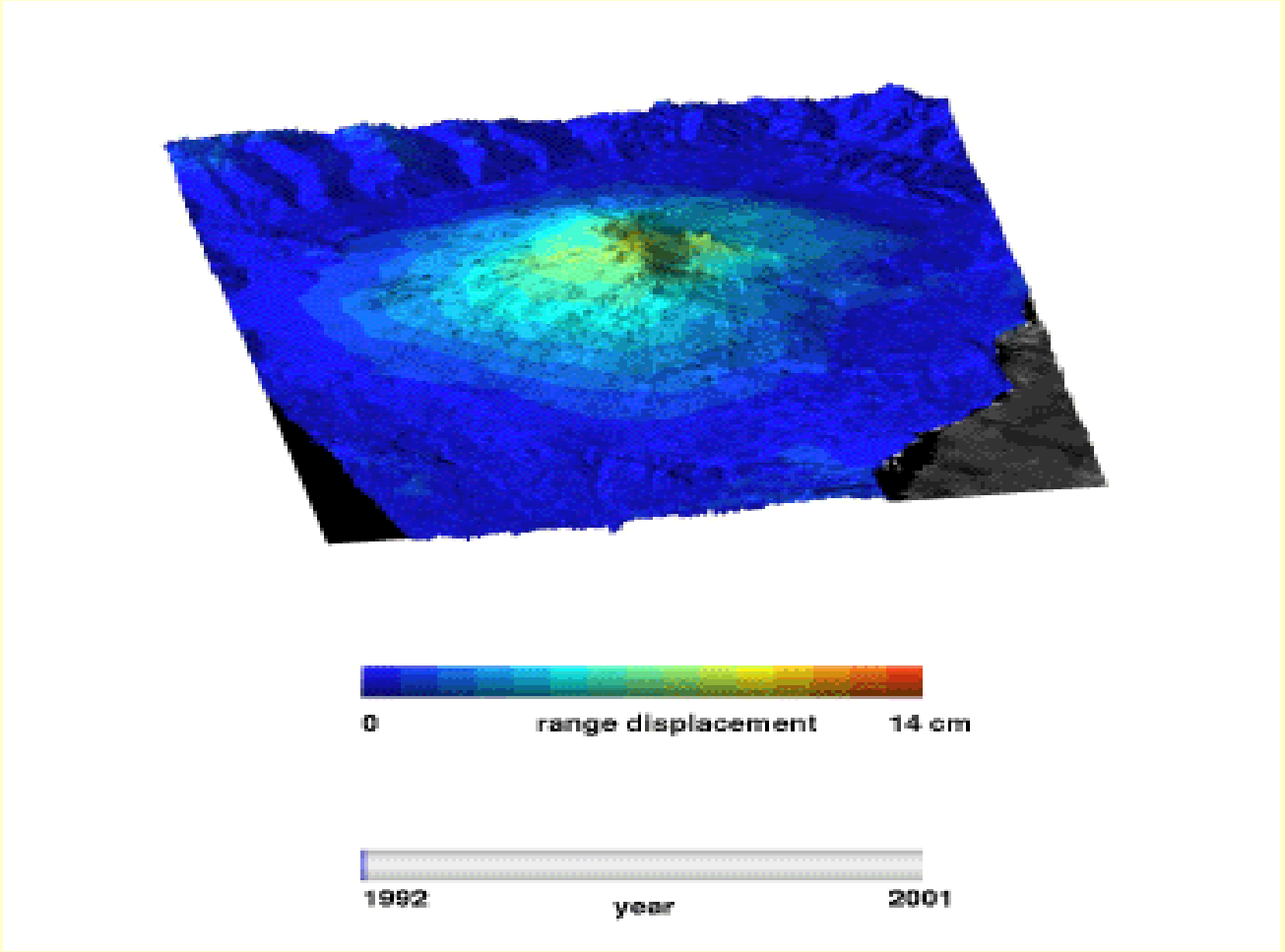
- Advantage over other techniques is that you get a continuous picture and not only data from some selected points and that you don't have to install any equipment on the ground.

- With multiple pictures like this it's possible to calculate an animation of the ground deformation over time.



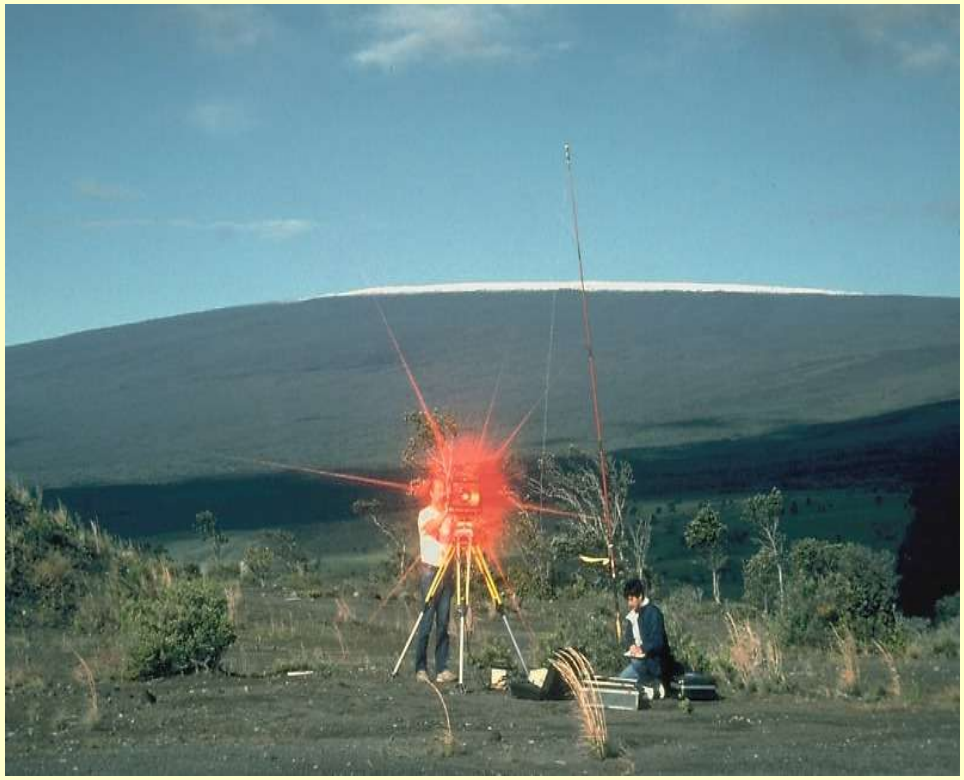
Satellite Radar Interferometry

- Movement of Mt. Etna
- Visualized with data from the ERS (Earth Remote Sensing) satellites of the ESA (European Space Agency)



Electronic Distance Measurement (EDM)

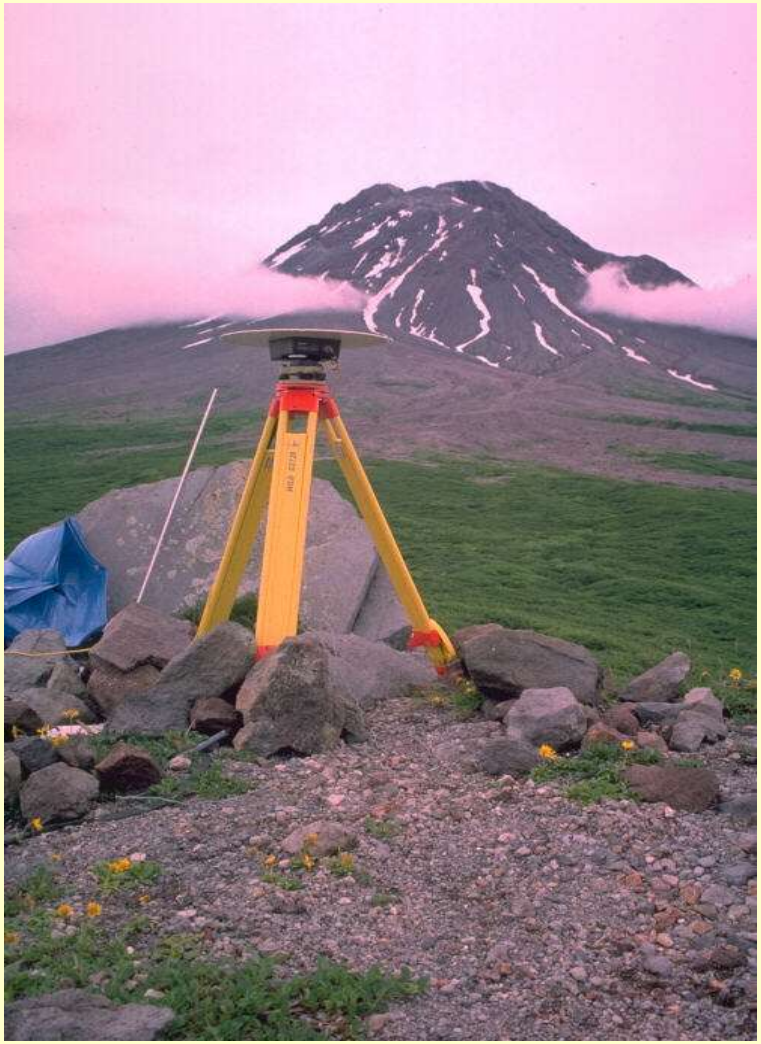
- Works with infra-red laser beam near the visible spectrum
- Reflectors are positioned on the volcano
- From the round-trip travel time of the light the distance can be calculated
- Measuring Distance: ~ 1-50km
- Accuracy: a few millimeters



EDM at Kilauea Volcano

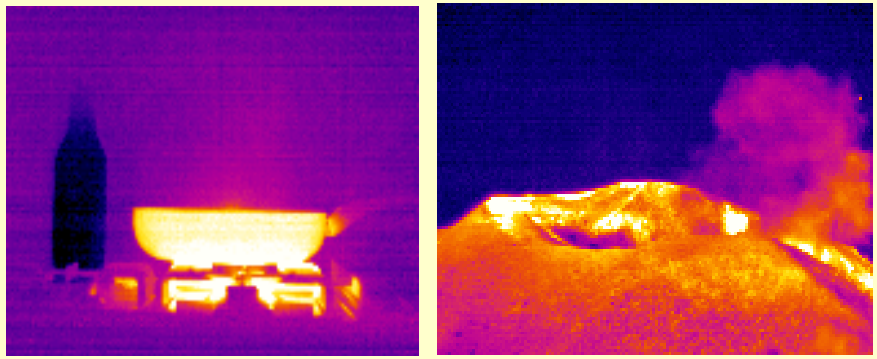
Global Positioning System (GPS)

- The absolute positions given by the GPS-System aren't enough adequate
- By comparing the signals (especially their phase shift) from receivers in different locations it's possible to determine the relative positions very accurately (~ 3 mm)
- In contrast to EDM you don't need a direct line of sight between the stations.



Thermal Variations

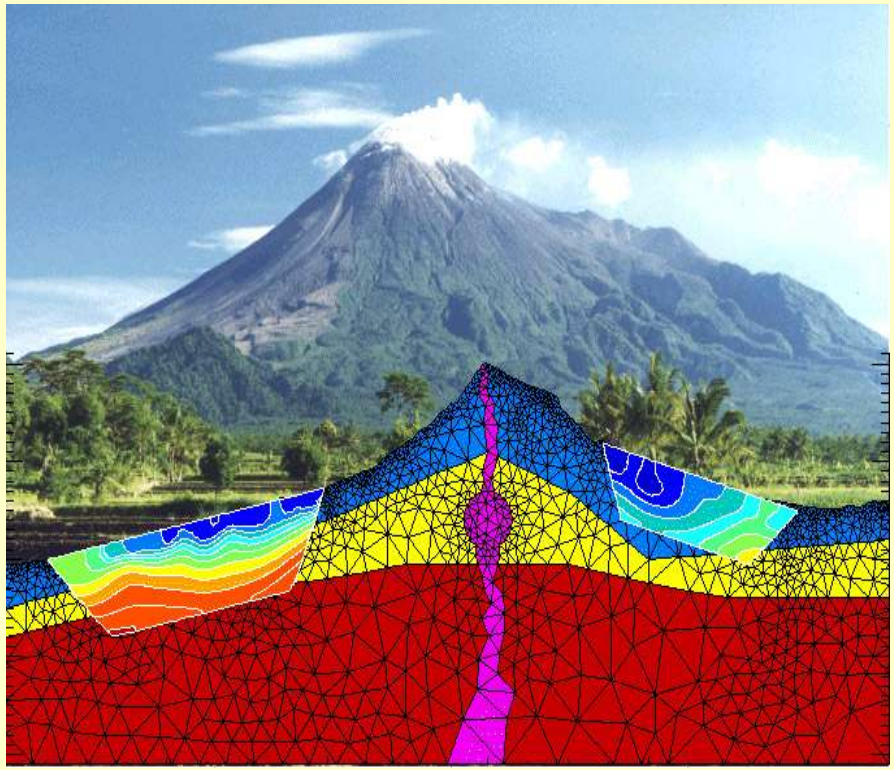
- Sources
  - Magma near the surface
  - Hot gases
- Measuring
  - Directly with sensors at the ground
  - Indirectly through the temperature of water sources or changes in the coverage of snow
  - Infra-red pictures taken from satellites, aircrafts or from the ground
- Benefit
  - An increase in temperature normally is a hint of magma approaching the surface. So it is common that a eruption will occur at a “hot point”.



A hot pan and Stromboli in infra-red

Electrical, Magnetic and Gravitational Variations

- Sources
  - Movement of magma generates magnetic anomalies
  - Filling or deflating of holes in the ground influences gravity
  - Changes of the conductivity affects the results of geoelectrical measurements
- Measuring
  - With magnetometers, gravimeters and voltmeters
- Benefit
  - With numerical models (finite elements) one can try to reconstruct the internal structure and processes of the volcano



Merapi: numerical model, measuring data and reality

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