

# Remote Sensing of Volcanoes Using Smart Sensing Technology

Presented by:



## **Technical Group Leadership:**

**Krishnan Parameswaran, Analog Devices Inc., USA (Chair)**

**Joachim Sacher, Sacher Lasertechnik GmbH, Germany (Member)**

**Amartya Sengupta, Indian Institute of Technology Delhi, India (Member)**

Since 1916



**Technical Group Website:**

[www.osa.org/EnvironmentalSensingTG](http://www.osa.org/EnvironmentalSensingTG)

**Environmental Sensing Technical Group Membership: Over 1,100 Total Members**

Journals & Proceedings

Meetings & Exhibits

Celebrating 100 Years

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Environmental Sensing (IE)

Environmental Sensing (IE)



The group emphasizes sensing for the environment. Environmental sensing involves those tools and processing techniques to characterize the environment including DIAL and LIDAR, hyperspectral monitoring, detection, processing and characterization, surveying applications, atmospheric propagation, pollution monitoring, and remote imaging. Also included in this area is remote sensing for military and commercial applications such as land management, target detection, and disaster monitoring.

Announcements

Computational methods for the analysis of environmental sensing data. The Environmental Sensing Technical Group is a part of the group and has a need for technical and professional people who are interested in the area of environmental sensing.

**Scope of the Environmental Sensing Technical Group:**

This technical group emphasizes sensing for the environment. Environmental sensing involves those tools and processing techniques to characterize the environment including DIAL and LIDAR, hyperspectral monitoring, detection, processing and characterization, surveying applications, atmospheric propagation, pollution monitoring, and remote imaging. Also included in this area is remote sensing for military and commercial applications such as land management, target detection, and disaster monitoring.

# Contact your Technical Group and Get Involved!

[www.linkedin.com/groups/12055528](http://www.linkedin.com/groups/12055528)

**OSA** Environmental Sensing Technical Group  
72 members Member

Start a conversation with your group

Enter a conversation title...

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**Krishnan Parameswaran** · Moderator  
Photonics Engineering Manager at Analog Devices

**Webinar! Volcanoes!**

Hello All. I am happy to announce the first OSA Environmental Sensors Webinar of 2018. The exciting topic is Remote Sensing of Volcanoes using Smart Sensing Technology.

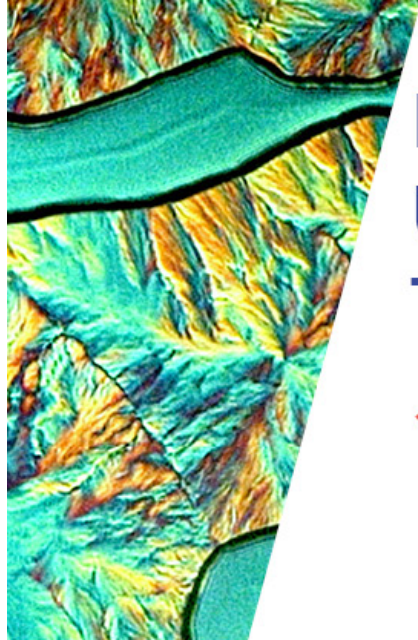
Here are the details

Presenter: Dr. Andrew McGonigle, University of Sheffield  
Date: Wednesday January 17, 2018  
Time: 1000 Eastern Time (United States), 1500 GMT

Registration Link: <https://cc.callinfo.com/registration/#/?meeting=1ee27e6c6b8&campaign=1b7e6d6e6f8>

- **Linked-In site (global reach)**
- **Announce new activities**
- **Promote interactions**
- **Complement the OSA Technical Group Member List**
- **Activities: Webinars, Special Sessions in CLEO/FiO**

**Welcome to Today's Webinar!**



# REMOTE SENSING OF VOLCANOES USING SMART SENSING TECHNOLOGY

17 January 2018 • 10:00 EST



## **Andrew McGonigle, University of Sheffield, UK**

Andrew McGonigle is an environmental scientist with broad research interests in the areas of development and application of remote sensing techniques for environmental, particularly volcanic, remote sensing, for which he was named a Laureate in the 2008 Rolex Awards for Enterprise competition.

Prior to his current association, Andrew was a NERC Post-Doctoral Research Fellow at the University of Cambridge before moving to Sheffield in 2005 as a RCUK Academic Fellow, where currently he is a Reader in Volcano Remote Sensing.

# Recent advances in remote sensing of volcanoes

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*Mt. Etna*



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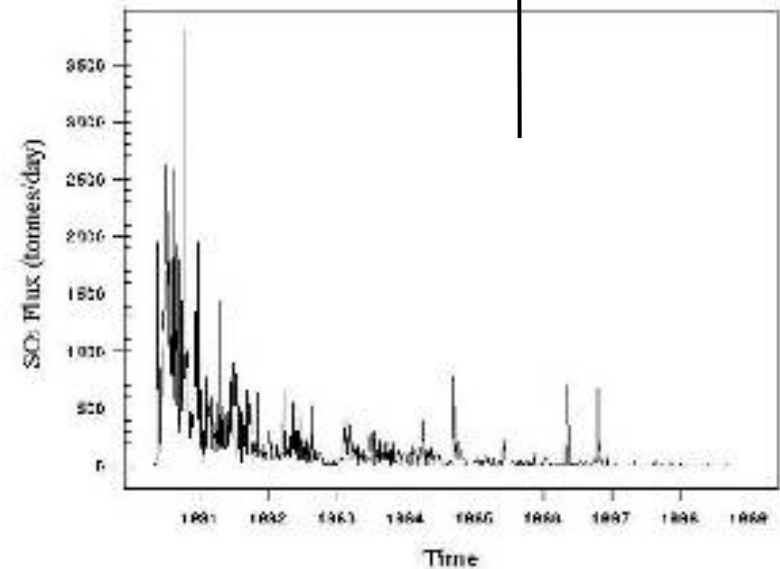
*ANDREW MCGONIGLE*



# Why study volcanic gases?

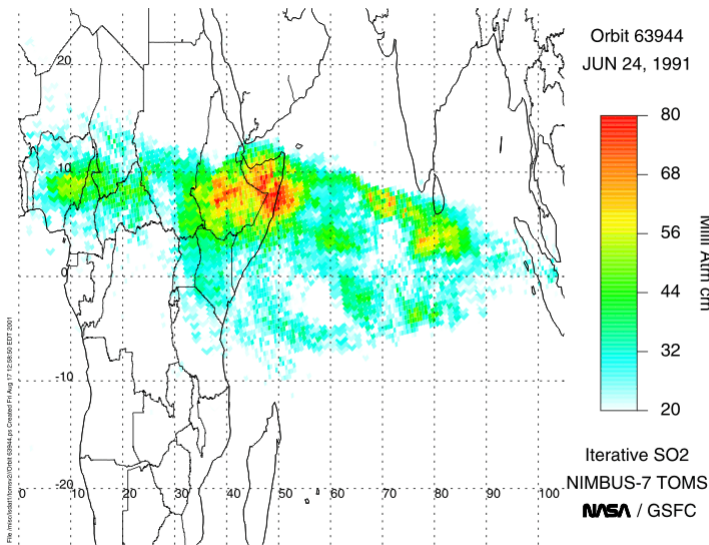
**A** Degassing drives activity

**B** Telegrams into the Earth's interior e.g., monitoring



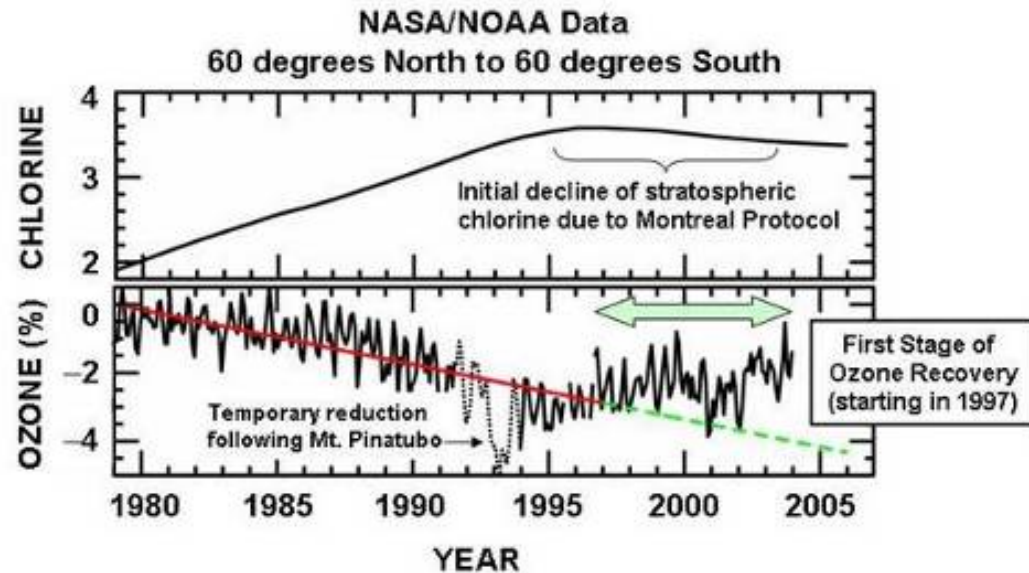


# Why study volcanic gases?



C Impacts on the climate system

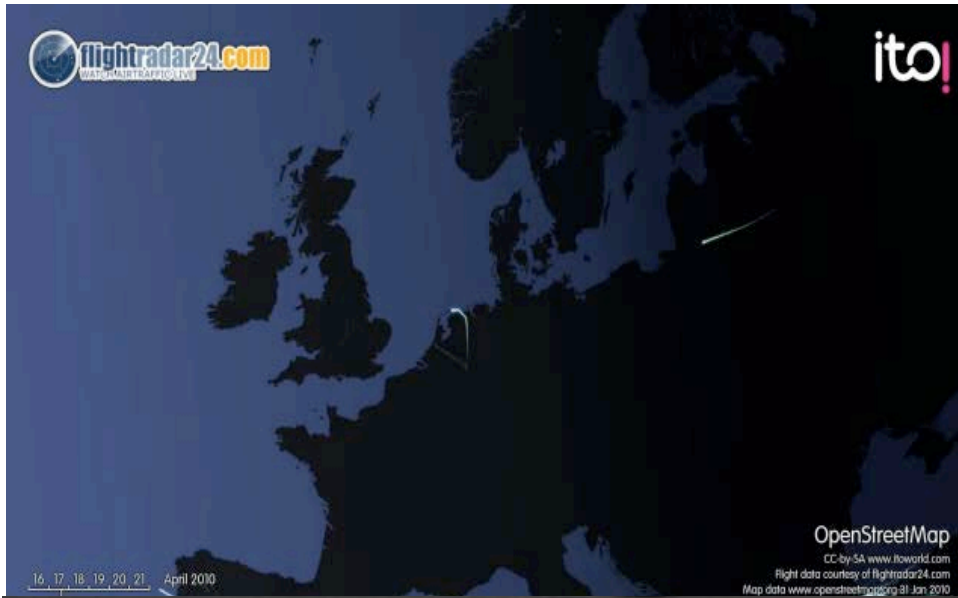
D And on atmospheric chemistry e.g., ozone





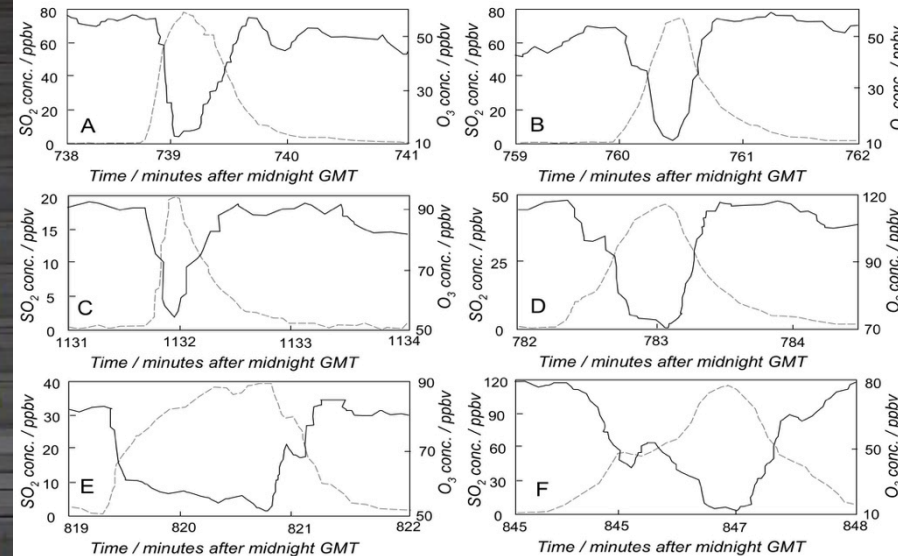


# Why study volcanic gases?



Depletion in tropospheric ozone too

SN	2-01	LONDOL	LHR	4 - 5	CANCELLED
SN	2325	GCNEVA		4 - 5	CANCELLED
SN	3159	MILAN	MXP	4 - 5	CANCELLED
BN	2272	COPENHAGEN		0 - 5	CANCELLED
LS	344	VHENA		8 - 60	CANCELLED
SN	38W9	LISOON		4 - 5	CANCELLED
LF	4609	MUNICH		8 - 57	CANCELLED
BE	W826	SOUTHAMPTON		10 - 37	CANCELLED
BA	397	LONDON	LHR	2 -	CANCELLED
LM	4006	STUTTGART		8 -	CANCELLED





- Asphyxiation – Mammoth Mountain and Lake Nyos



*Mammoth mountain*



*Kilauea*



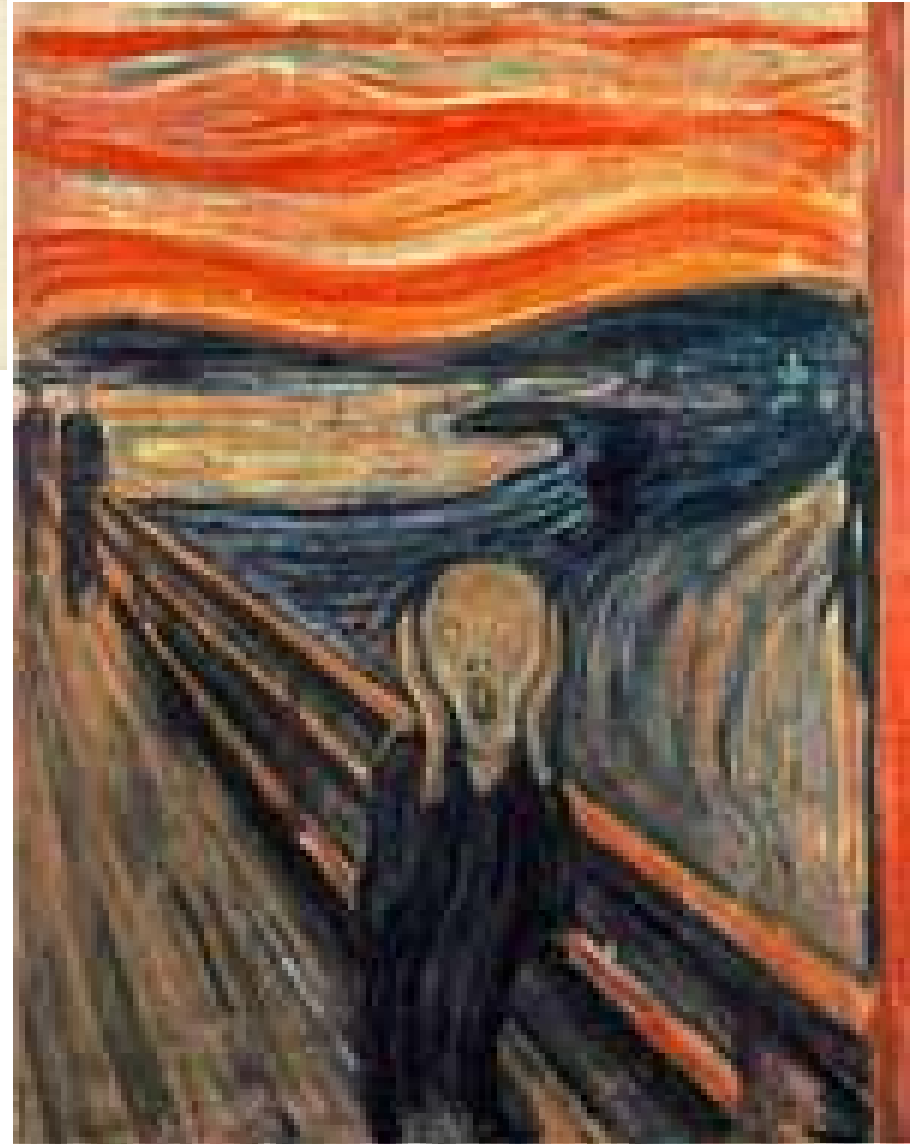
*Masaya, Nicaragua*



*Laki Fissure, Iceland*

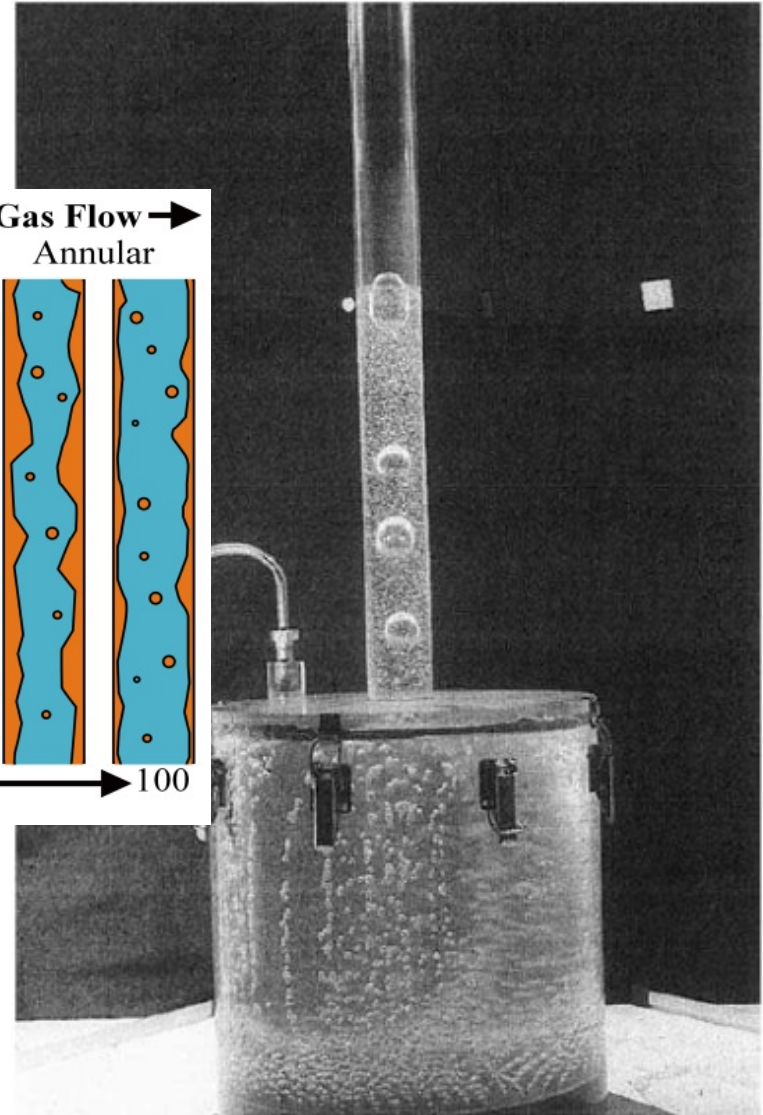
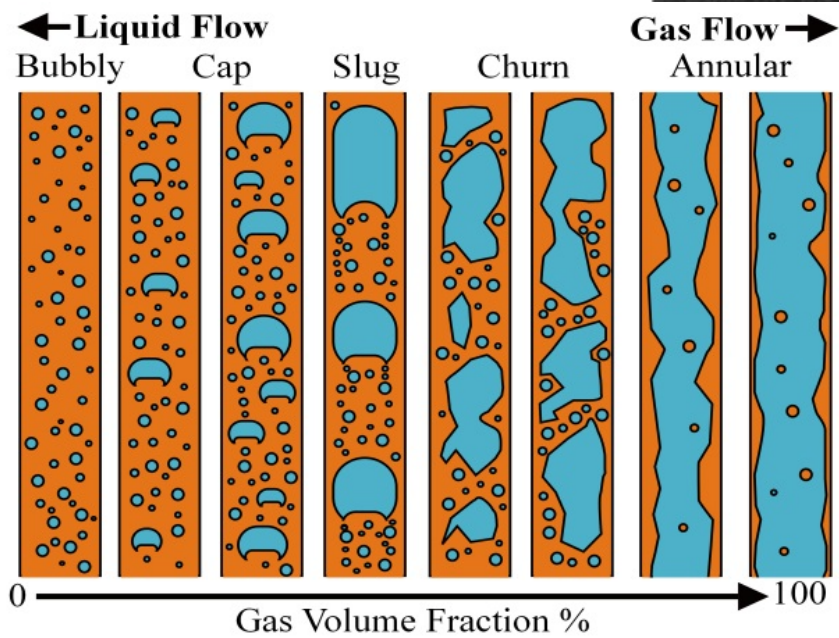
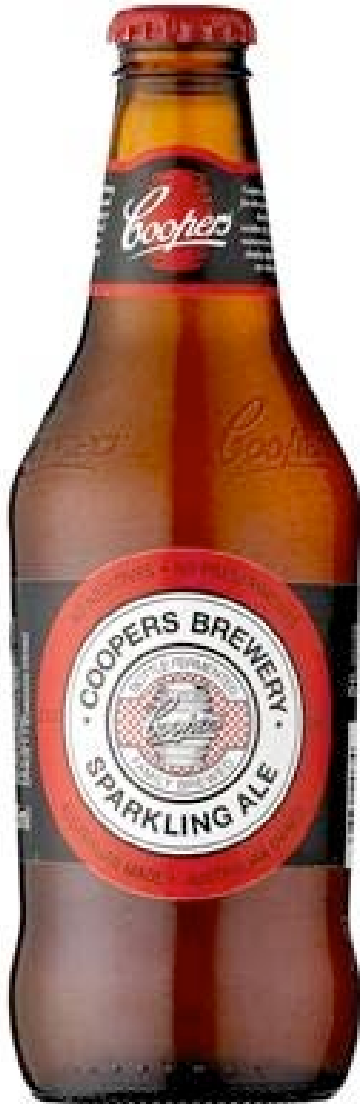


- Laki – affected two continents
- Krakatoa eruption  
1883



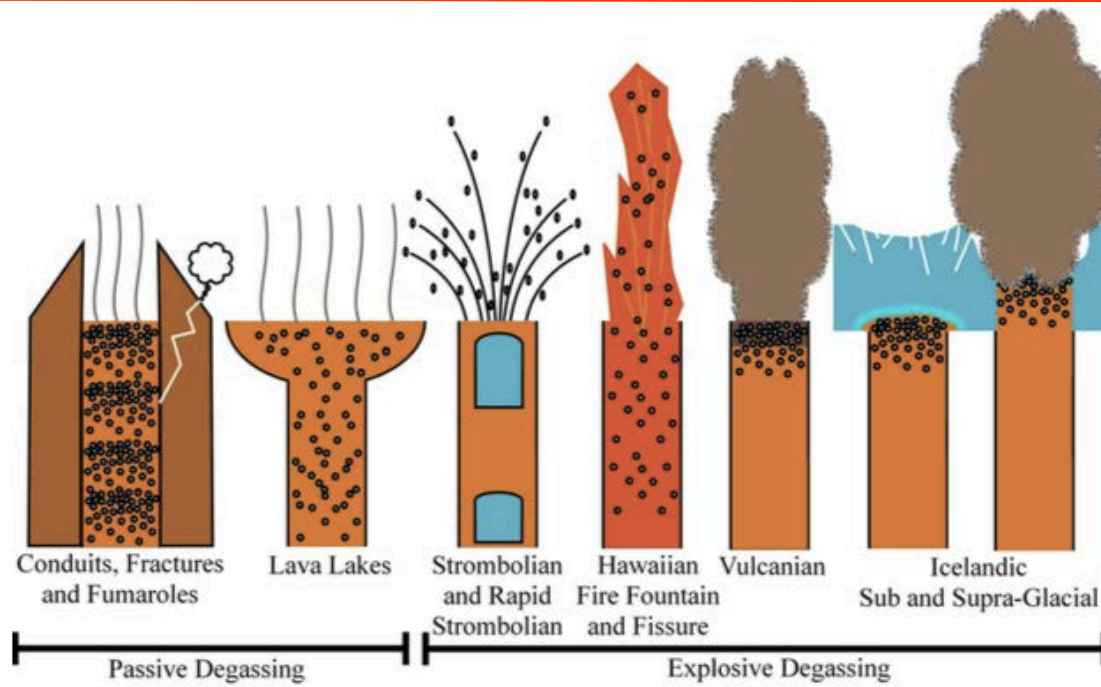


# Bubbles and activity in basalts



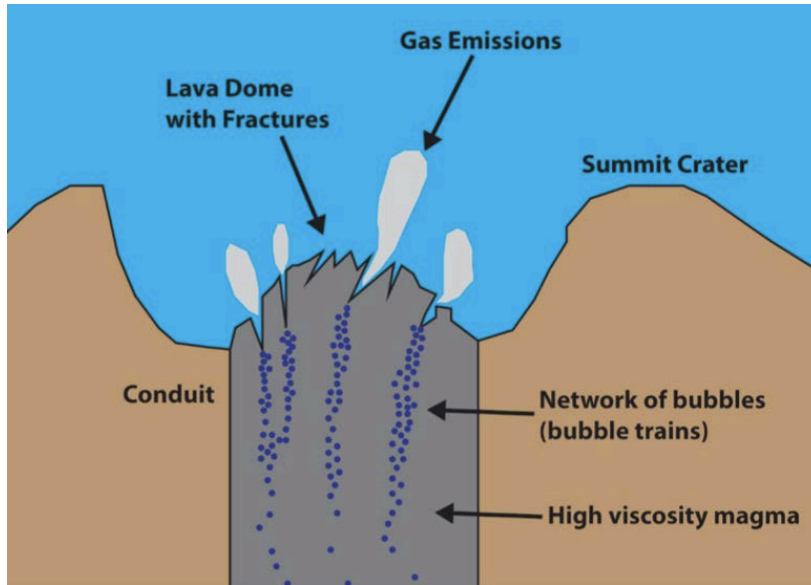


# Bubbles and activity in basalts





# Degassing and silicic volcanism



- Bubbles can't move so readily

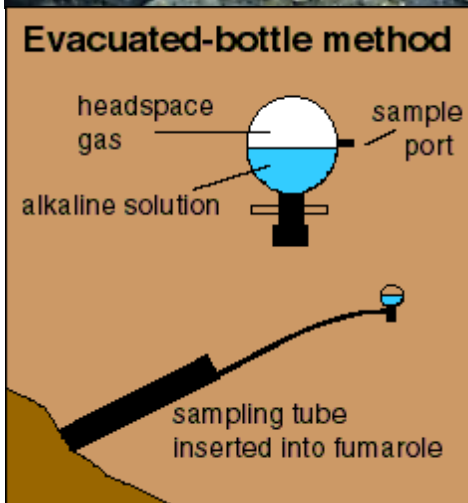
*Dome  
pressurisation  
, explosions  
and  
pyroclastic  
density flows*





# Gas Measurement approaches

- How to measure?

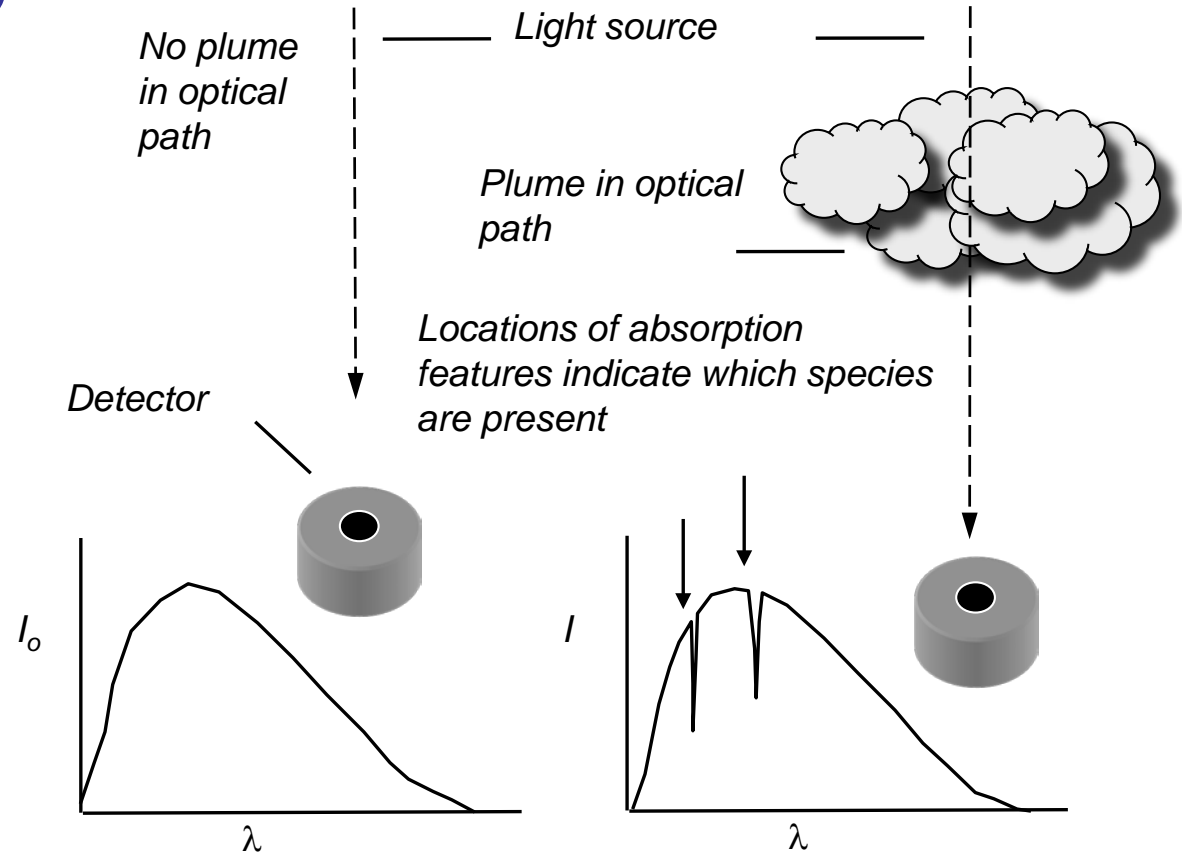


- Detailed but dangerous

*Direct sampling*



- Remote sensing – safe(r)

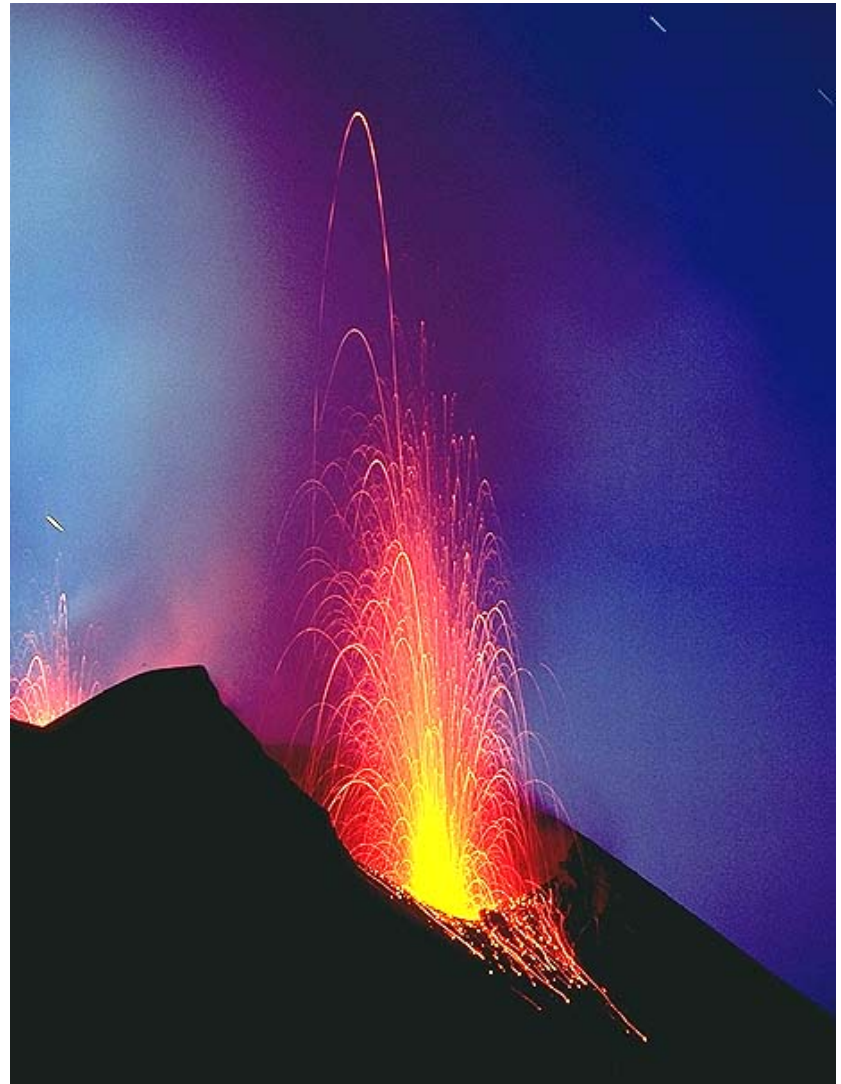


- Fingerprint identification of gas absorption





# Remote sensing



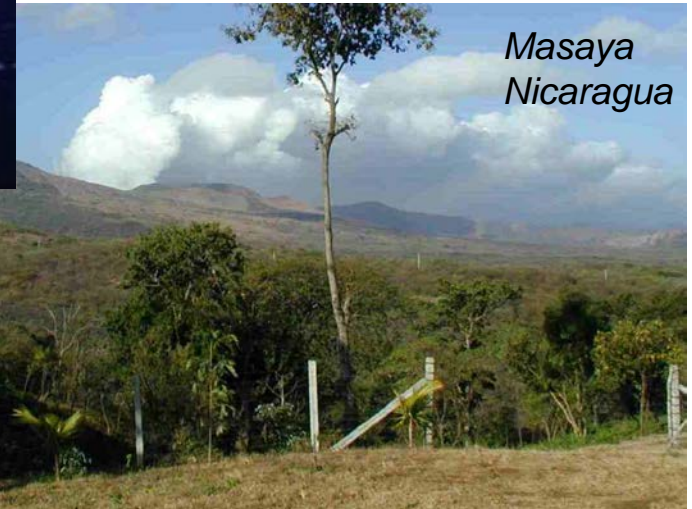


# Ground versus space platforms



*Rabaul plume*

- Ground based better for monitoring

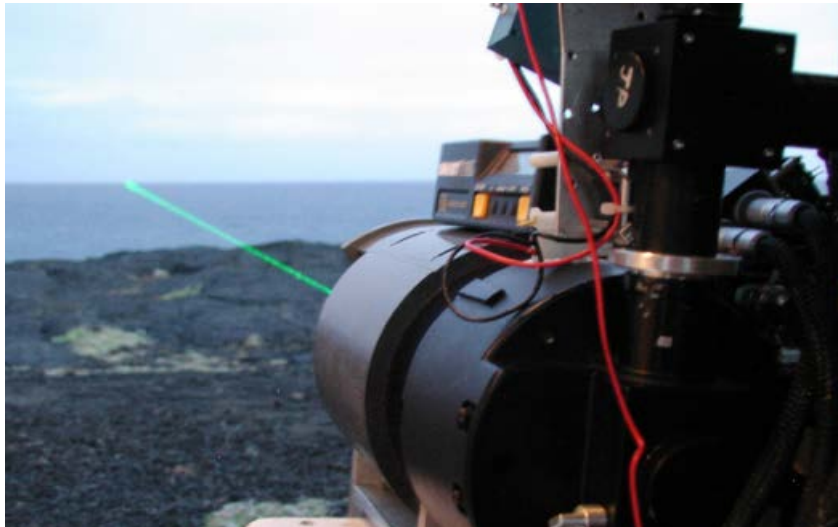


*Masaya  
Nicaragua*

- Satellite good for atmospheric impacts/aviation warning



# Measurement approaches



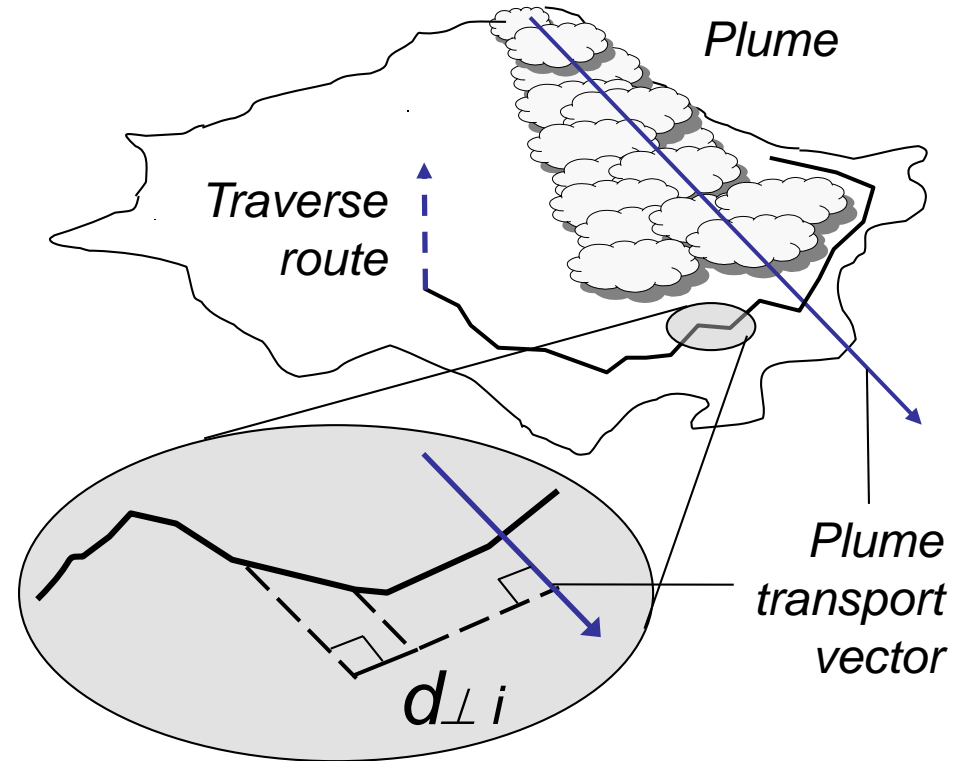
- Lasers and FTIR



# Passive UV RS of gas fluxes

- Sulphur dioxide ~ 310 nm absorption

*Volcano summit - anemometer*

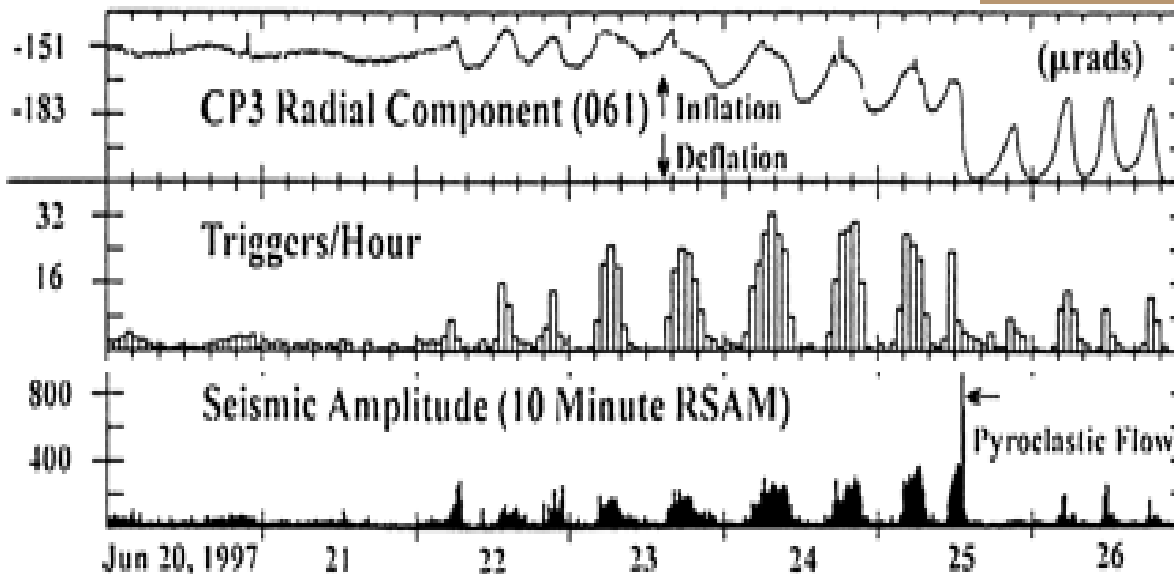
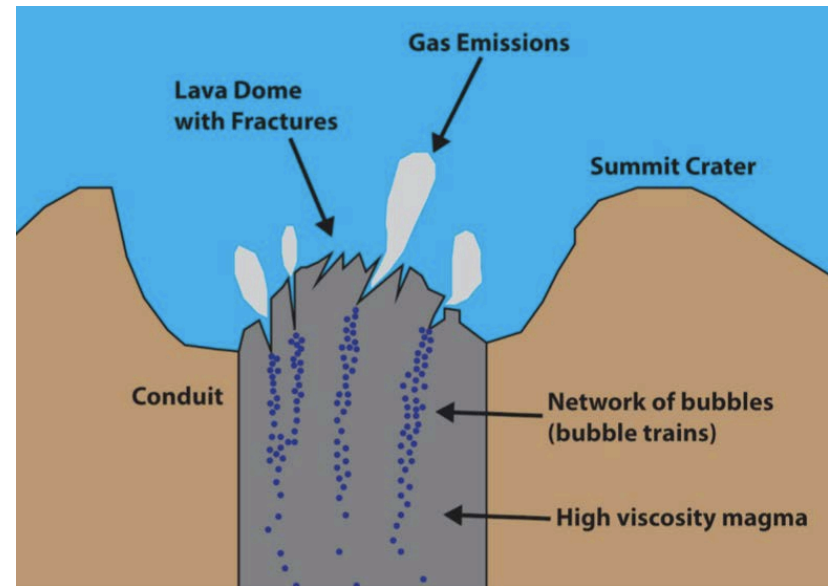


$$\text{Flux} = \text{plume speed} \times \sum_{\text{over plume}} c_i \times d_{\perp i}$$

- Pre 2000 antiquated technology

# Issues with old technology

- Traverse mode restricts time resolution

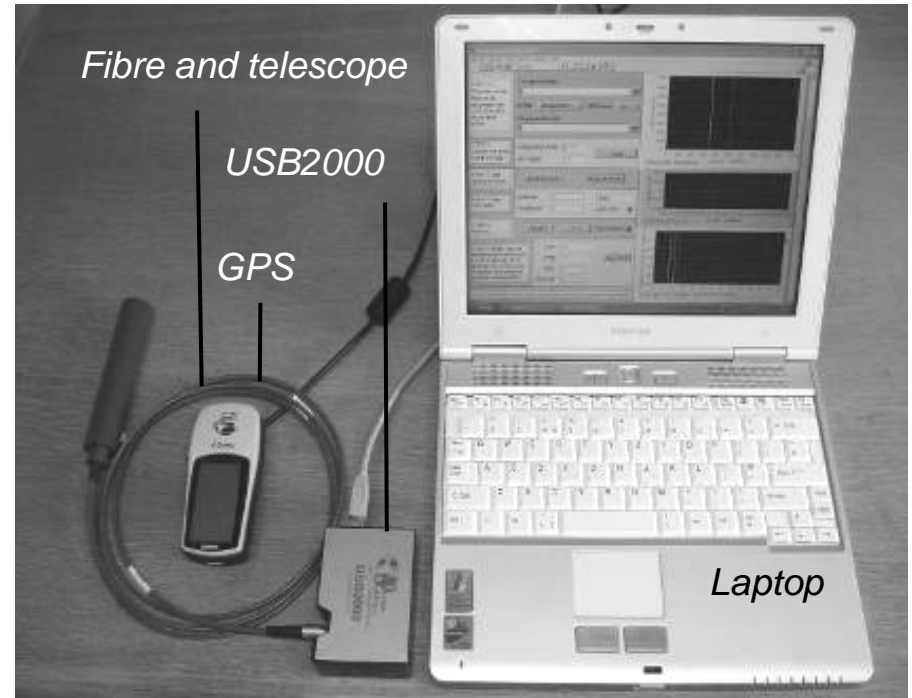
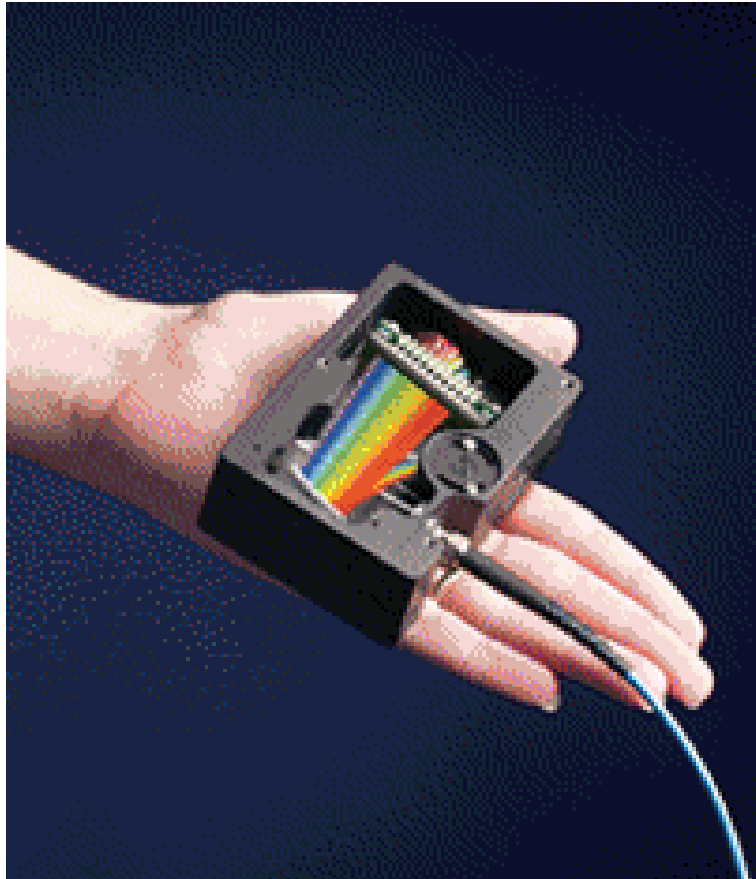


- also large errors; unreliable technology



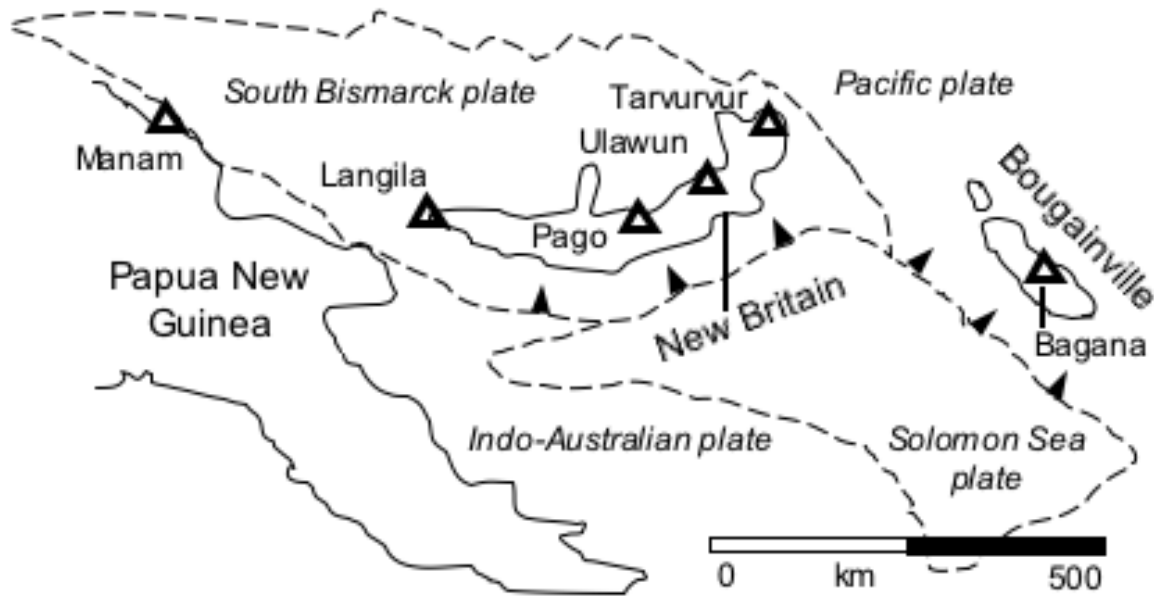
# Hand held spectrometers

- Ocean Optics Inc. USB2000; smaller, lighter and cheaper (\$5k)
- Now used as standard internationally





# Hand held spectrometers



- Broadening gas flux records





# Hand held spectrometers

## Earning a T-shirt the Hard Way!

See Page 114 to find out how.

### Who Needs Hands When You Have a Great Head?

Andrew McGonigle, a Research Fellow with the Volcano Remote Sensing Group at the University of Cambridge, UK, takes a hands-free approach to spectroscopy. Andrew is monitoring sulfur dioxide emissions of a volcano in Nicaragua. Where's the spectrometer, you ask? It's duct-taped to his helmet!

See page 114 for details on how an image like this one, or a paper describing your application earns you a Maxwell's Equations T-shirt. But beware – you, too, could become an Ocean Optics cover model!



For more on the Volcano Remote Sensing Group, visit [www.volcano.geog.cam.ac.uk](http://www.volcano.geog.cam.ac.uk).

727.733.2447 • [OceanOptics.com](http://OceanOptics.com)

Ocean Optics, Inc.



- Measurement flexibility



386 Main Street  
Dunedin, FL 34096

- Scooter measurements the rage in Japan







- User friendly interface

The screenshot displays the Measurement.vi software interface, which is organized into several control panels and three data visualization windows.

**Control Panels:**

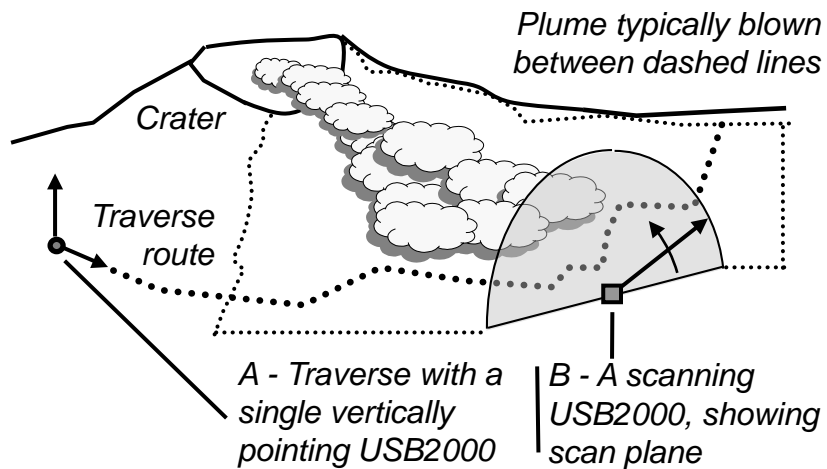
- STEP 1:** Choose mode, file root, fit parameter file, GPS port then press start arrow. Fields include Traverse folder (C:\ssibbo\_02), Mode (Post process), GPS port (1), and Fit parameter file (C:\volp002\fp\fit\_peres\_USB03709.txt).
- STEP 2:** Choose int. time and # averages. Fields include Integration time (300) and Averages (4), with a Test button.
- STEP 3:** get dark and white. Buttons for Acquire dark and Acquire white.
- STEP 4:** log GPS data. Fields include Longitude (0), Latitude (0), Time (-----), and GPS OK? (red indicator).
- STEP 5:** traverse. Buttons for START and STOP, and an Intensity indicator (red).
- STEP 6:** Enter source location (q)dd.ddddd (N, E +ve, S, W -ve), start (green), end (red) limits of plume, and baseline (yellow), and find ICA. Fields include Long (15), Lat (0), ICA (0), and Bearing (319), with a GET ICA button.

**Data Visualization Windows:**

- SPECTRA WINDOW:** A plot of Amplitude vs. pixel number (0 to 2040). The amplitude increases from near zero to approximately 3500, with a green vertical line at pixel 750 and a red vertical line at pixel 1000.
- FITTING WINDOW:** A plot of Amplitude vs. pixel number (700 to 1000). It shows a noisy signal with a fitted curve, with a green vertical line at pixel 750 and a red vertical line at pixel 1000.
- CONCENTRATIONS:** A plot of Concentration /ppm vs. spectrum number (0 to 95). The concentration is mostly zero until spectrum 70, then rises to about 1400 ppm, with a green vertical line at spectrum 15 and a red vertical line at spectrum 20.



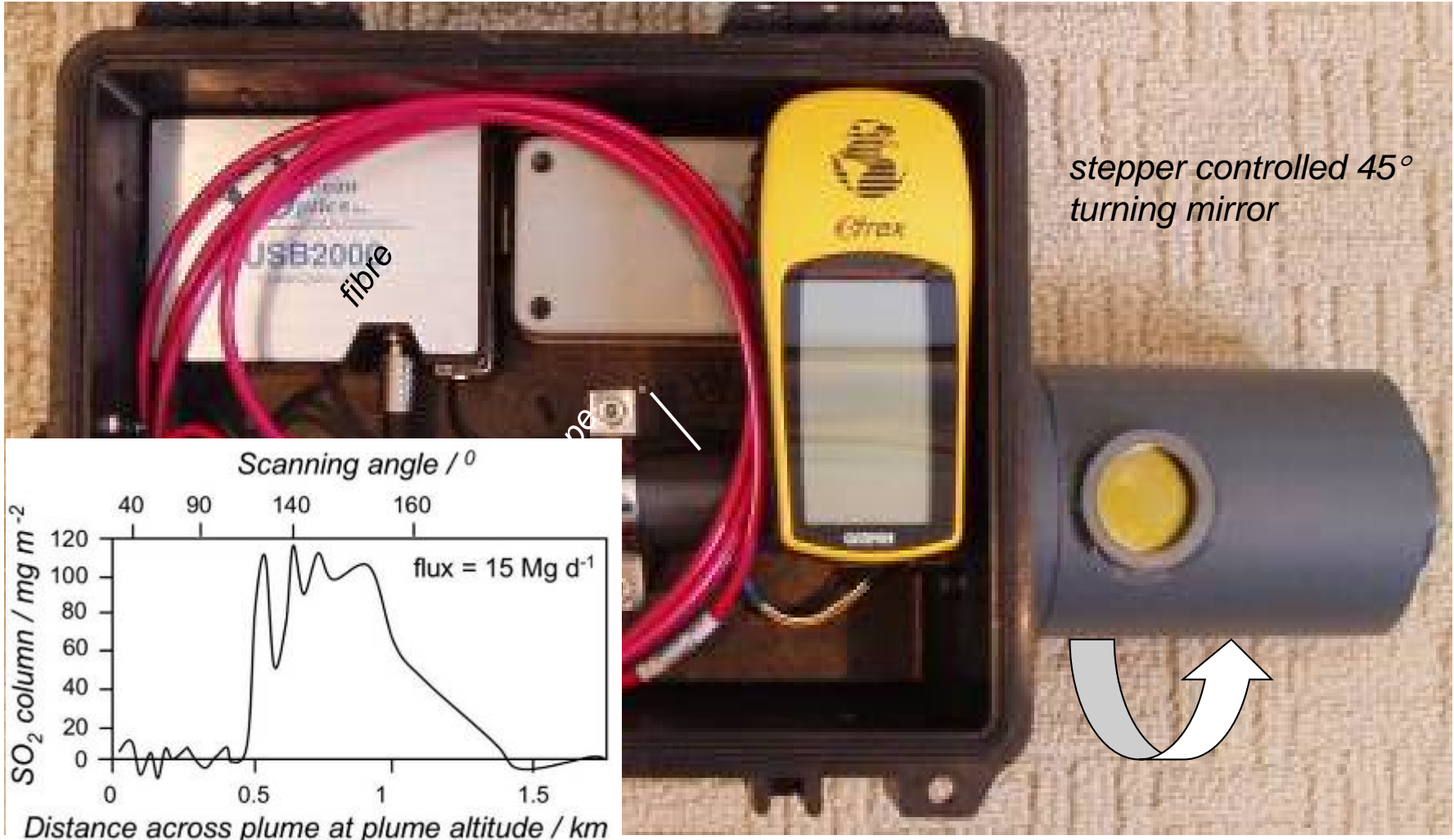
# Scanning Measurements



- Scan plume from below rather than traverse beneath it
- Manual test – Masaya volcano Nicaragua



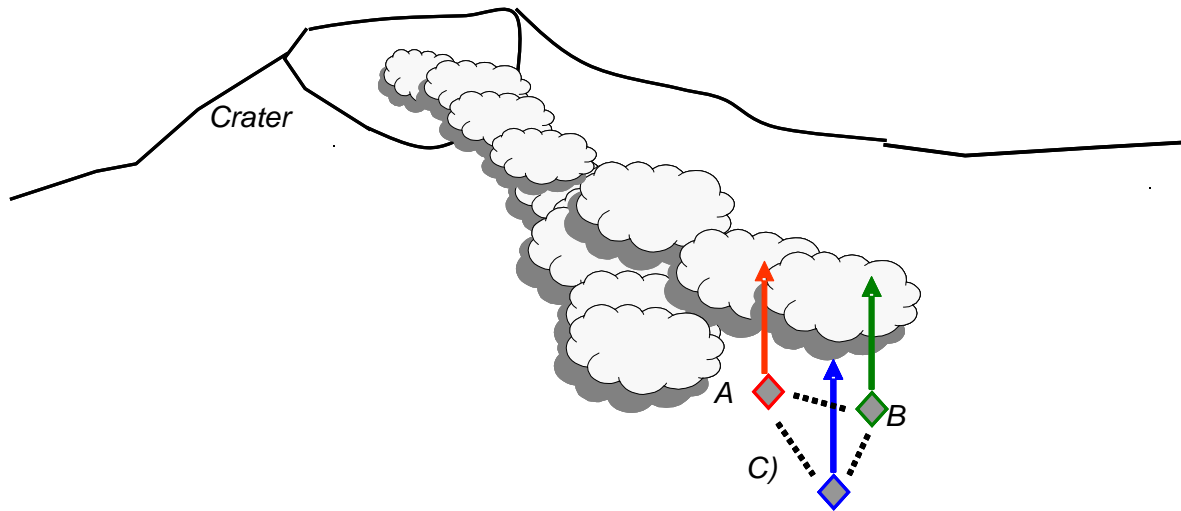
# Solving time resolution problem: Scanning



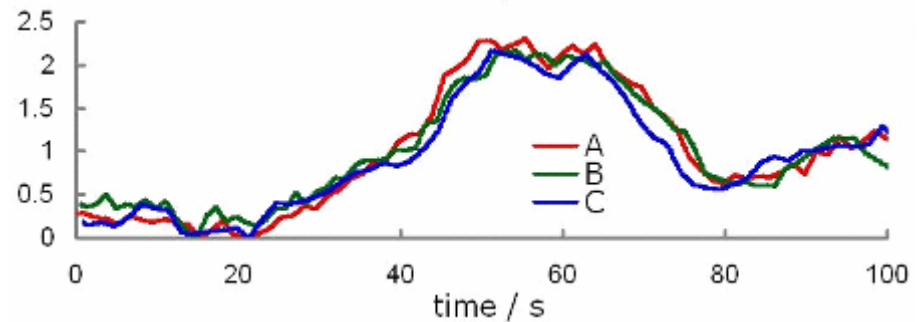
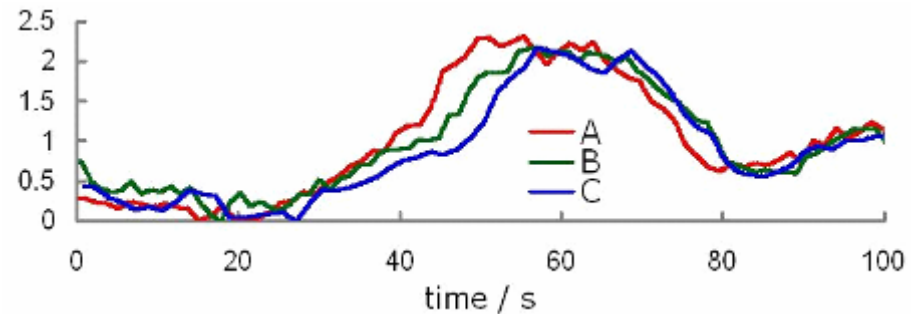
- Now computer automated; time resolution 10s of seconds



# Addressing accuracy problem

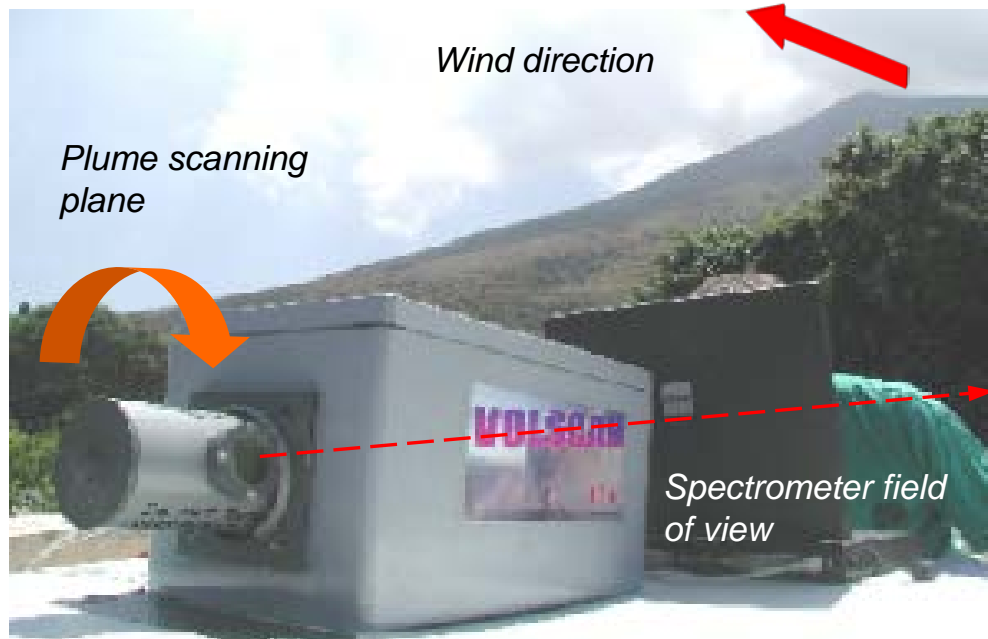


- Cross correlate output from multiple vertically pointing spectrometers



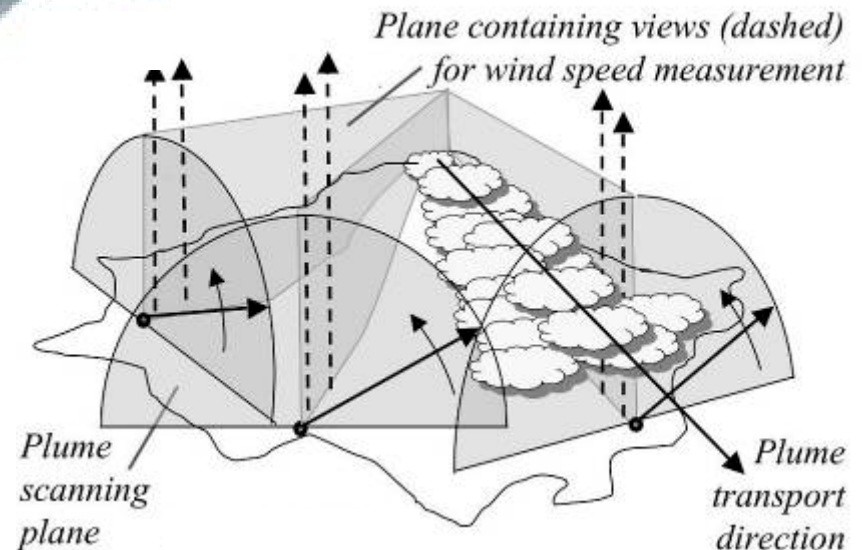


# Putting this all together



- Scanning units used as standard internationally

- But time resolution still far lower than geophysical





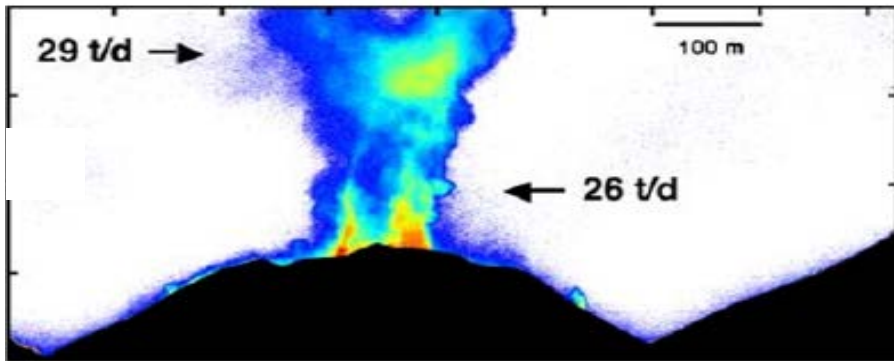
# UV imaging



Visible Image



SO<sub>2</sub> concentrations

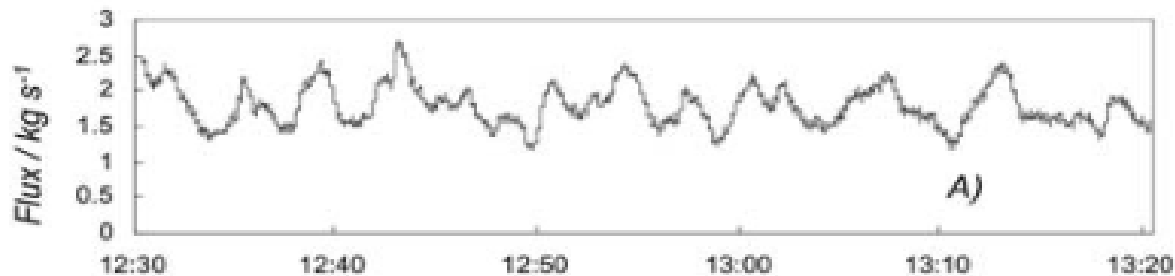
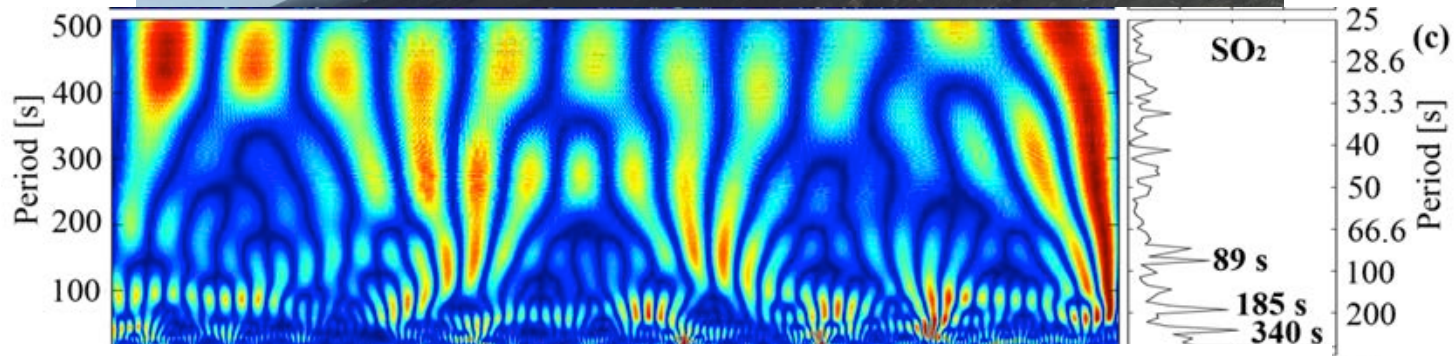


- Contrast on and off resonance – 310 vs 325 nm or so
- 1 Hz data
- £10k instrumentation
- Cell/spectrometer calibrate



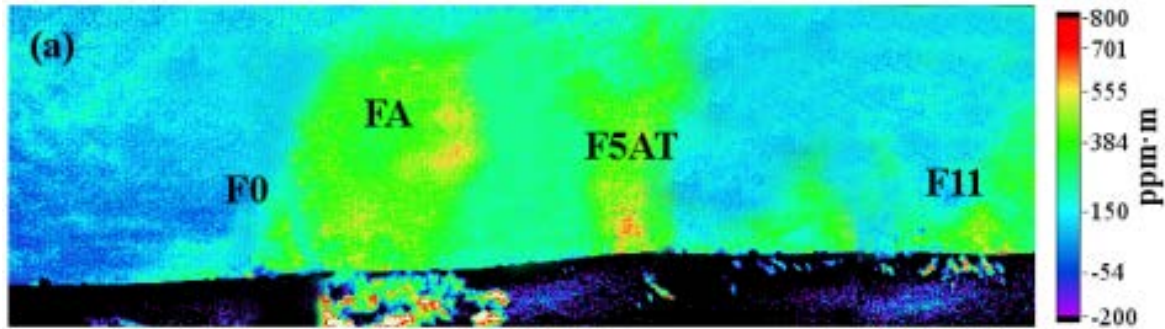
# Passive degassing

- modulation in gas release





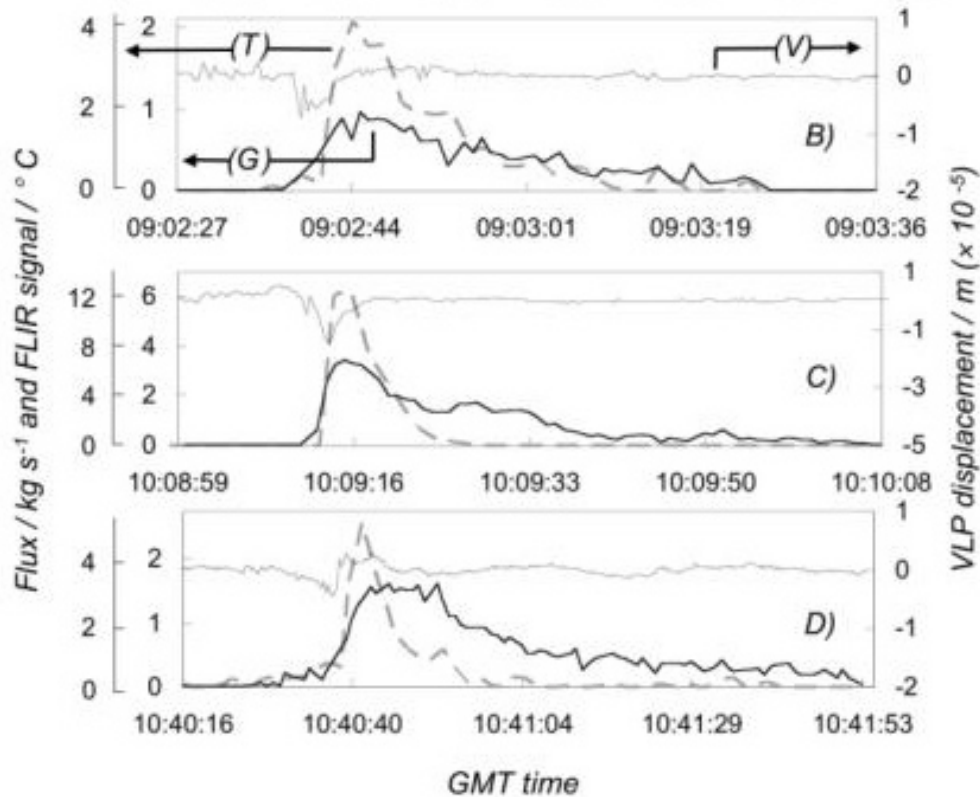
# Resolution of heterogeneous sources



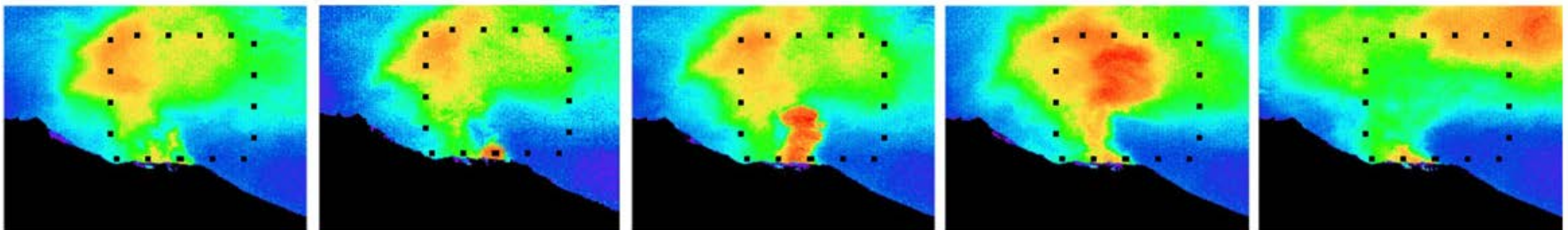
- Gas transference from crater to crater

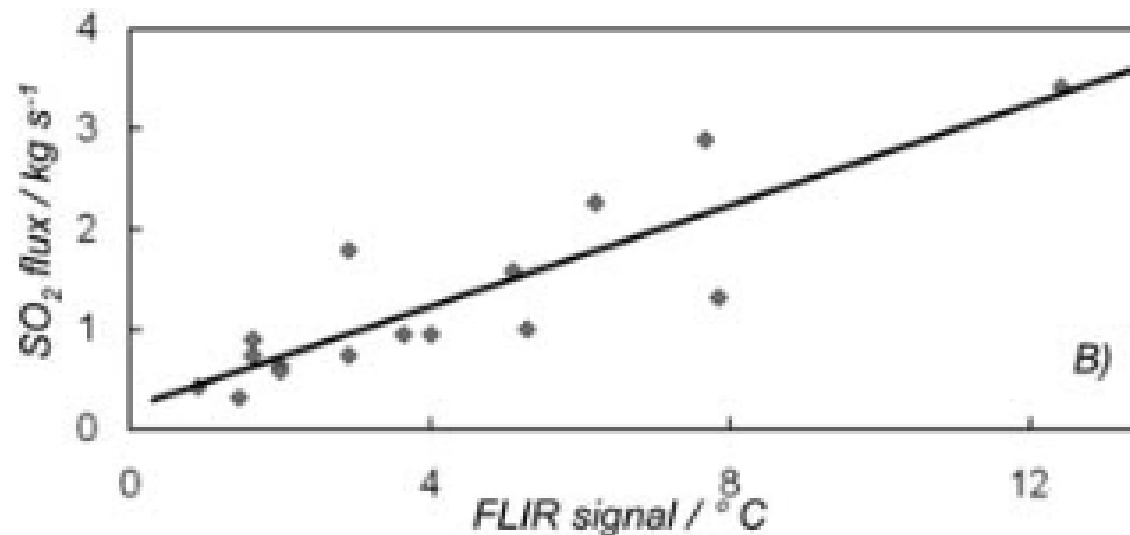
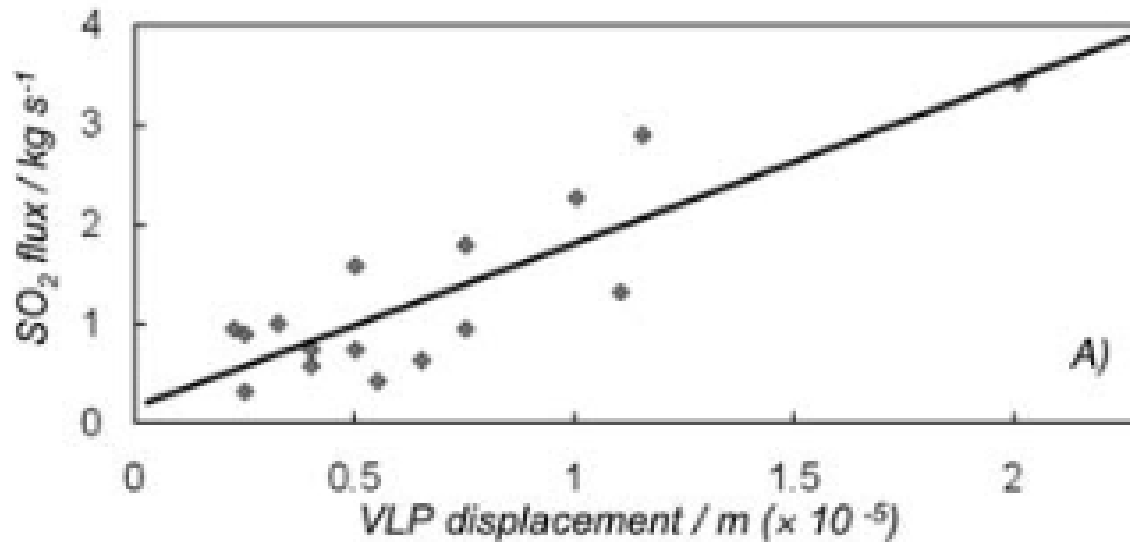


# Explosive dynamics

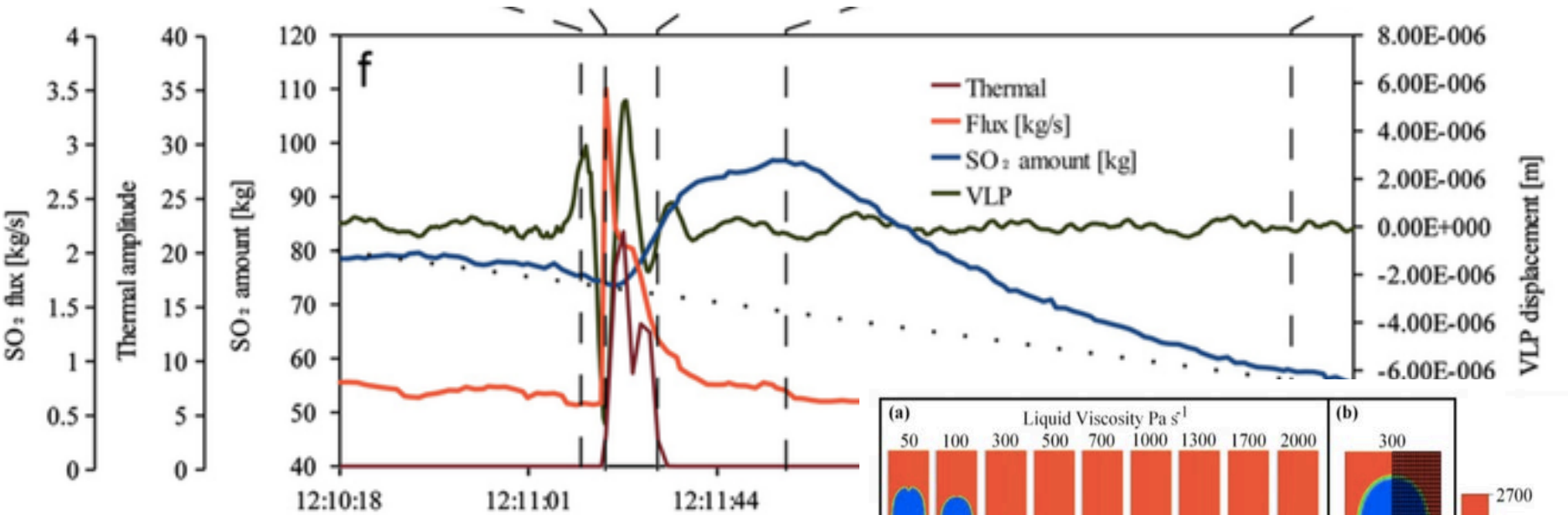


- Resolution comparable to seismic and thermal for first time



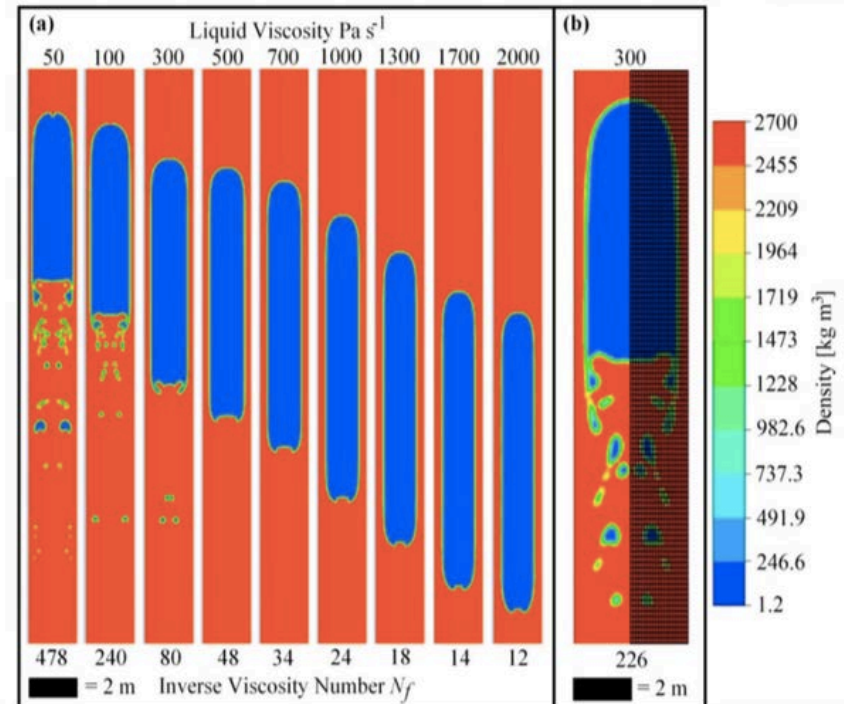


- Unravel degassing processes driving geophysics on volcanoes
- Link seismic to degassing in hazard assessment



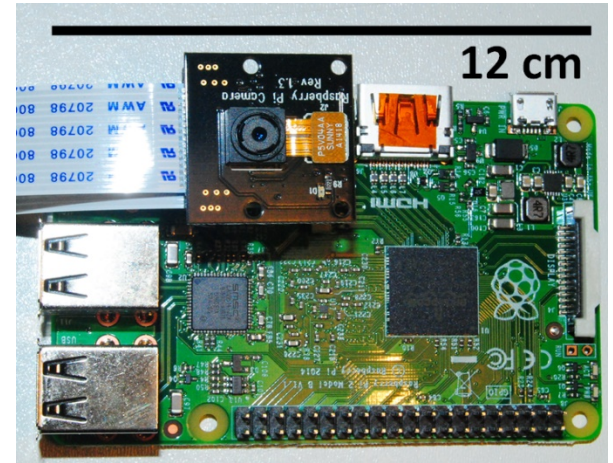
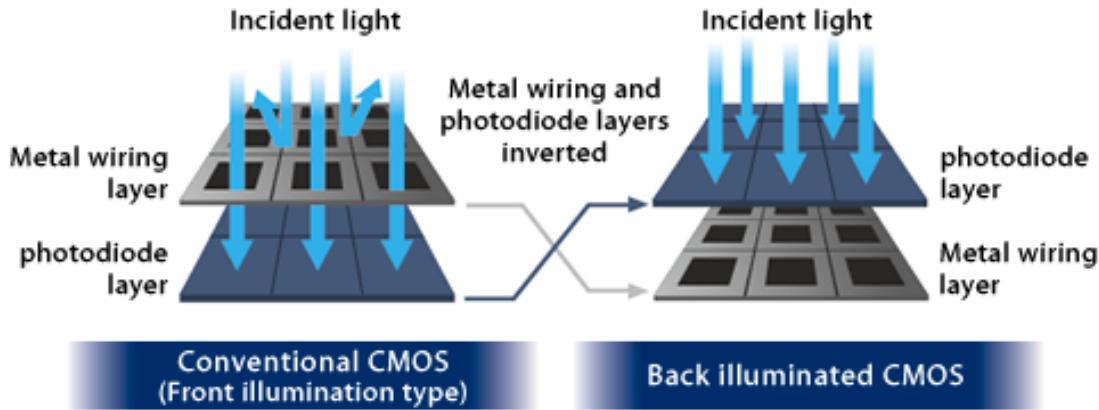
- Daughter bubble production

Lc

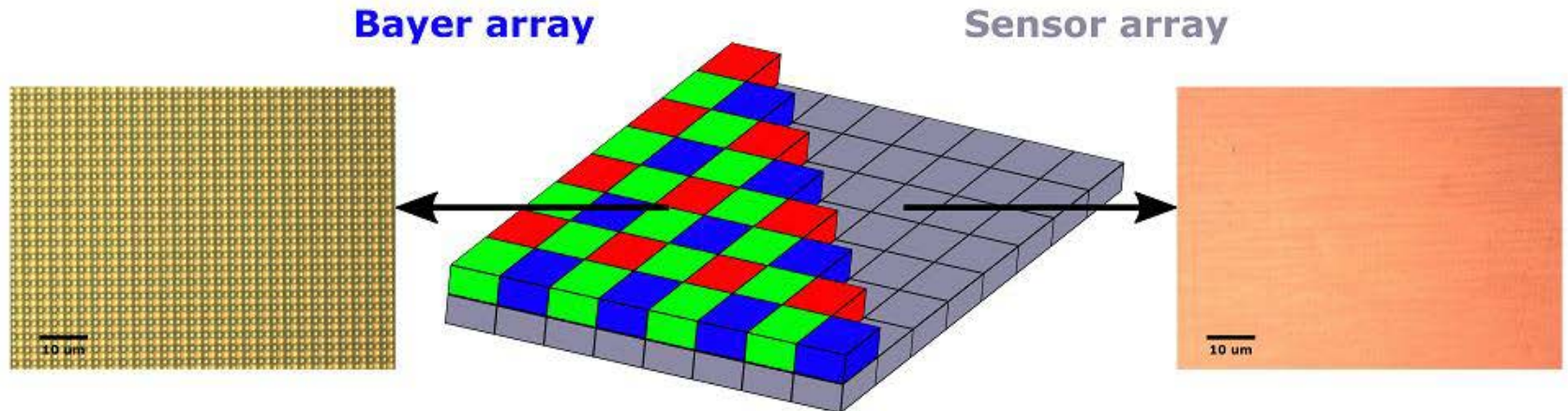




# Still too expensive? Smartphone sensors?

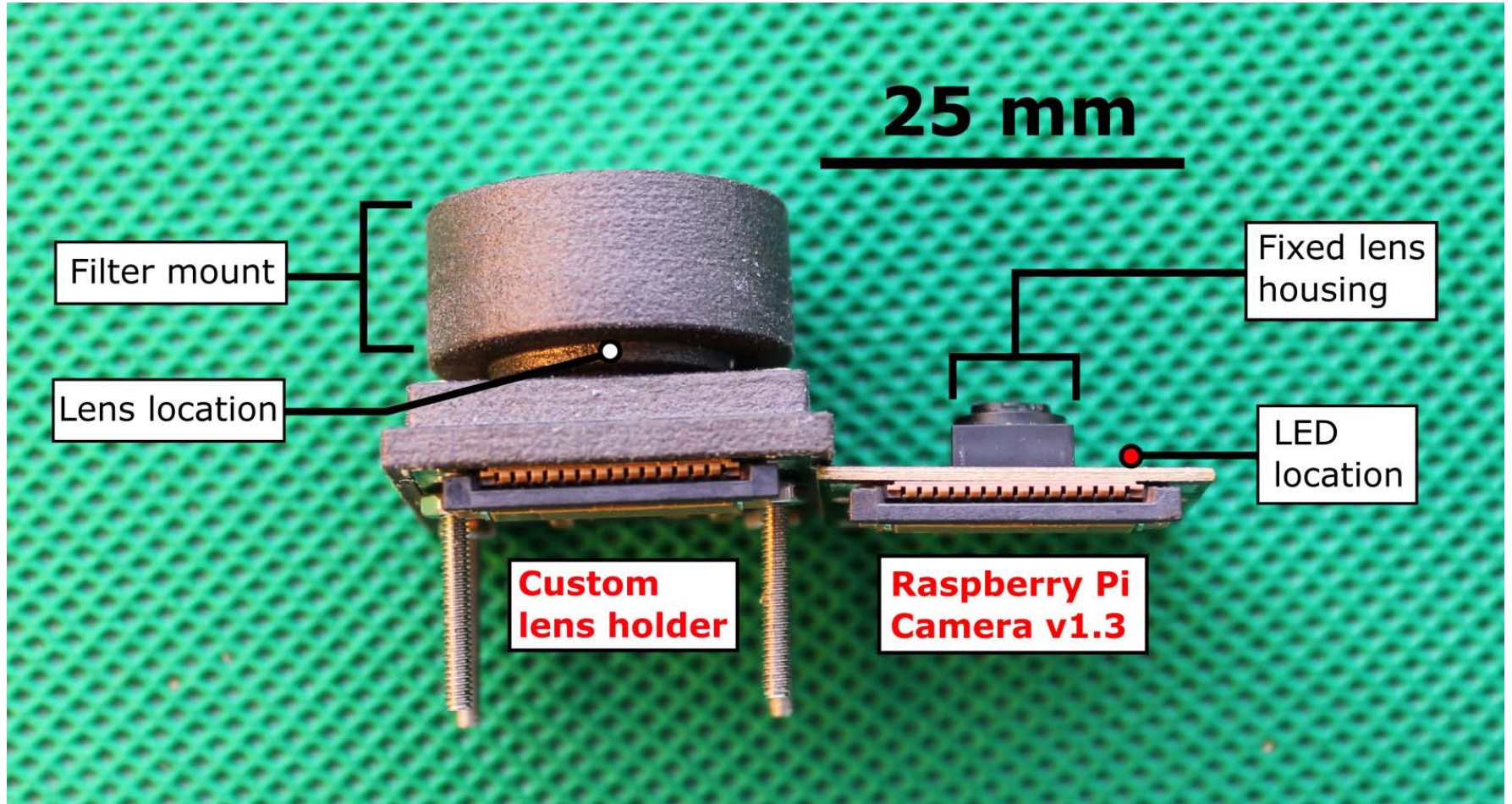


- Remove Bayer layer from Raspberry Pi camera - £20



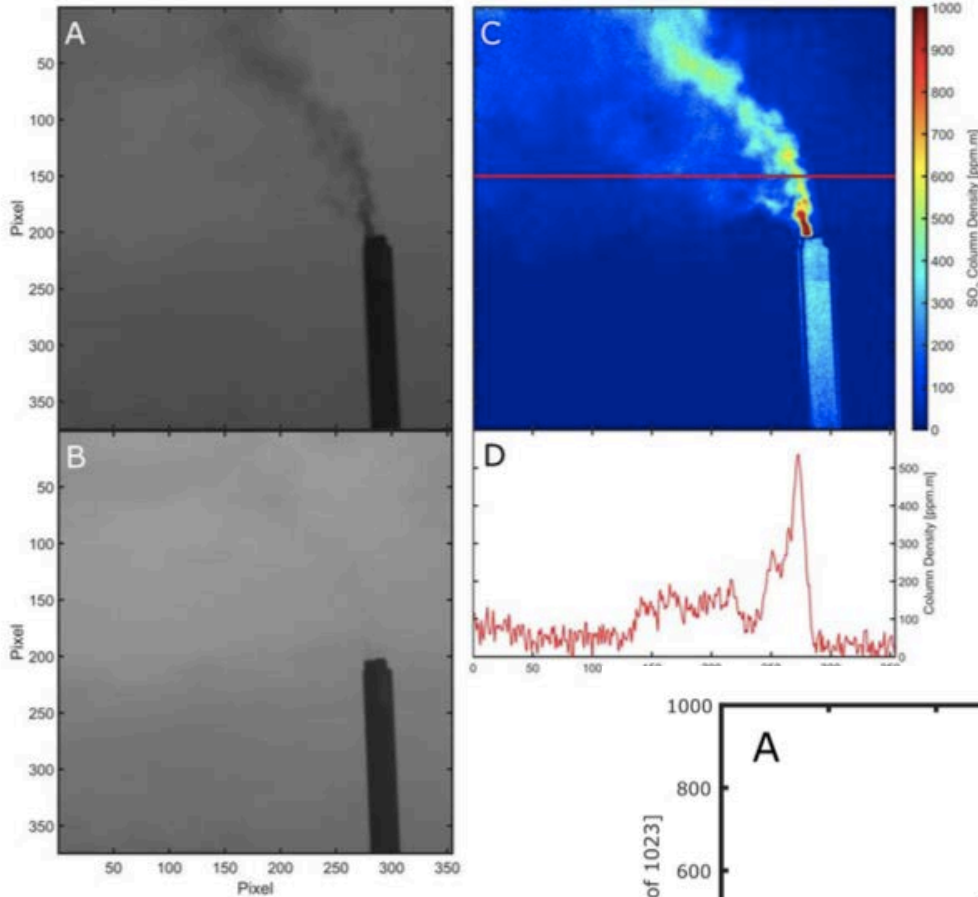


# Smartphone sensor UV camera

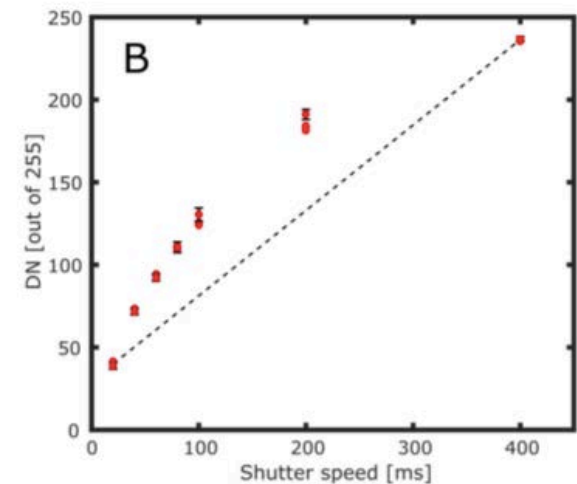
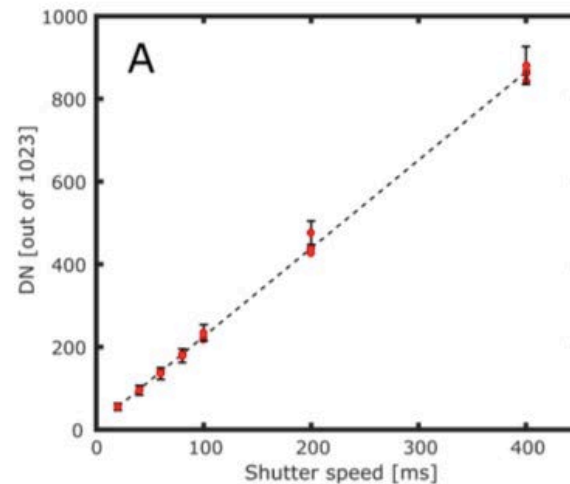




# Smartphone sensor UV camera

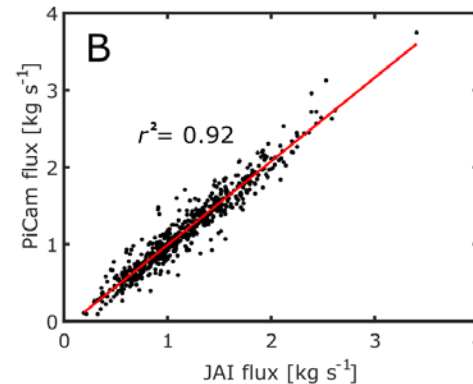
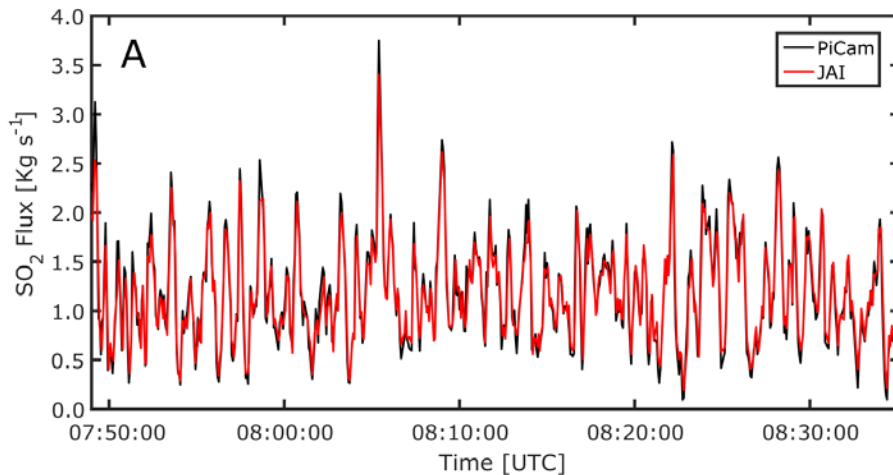
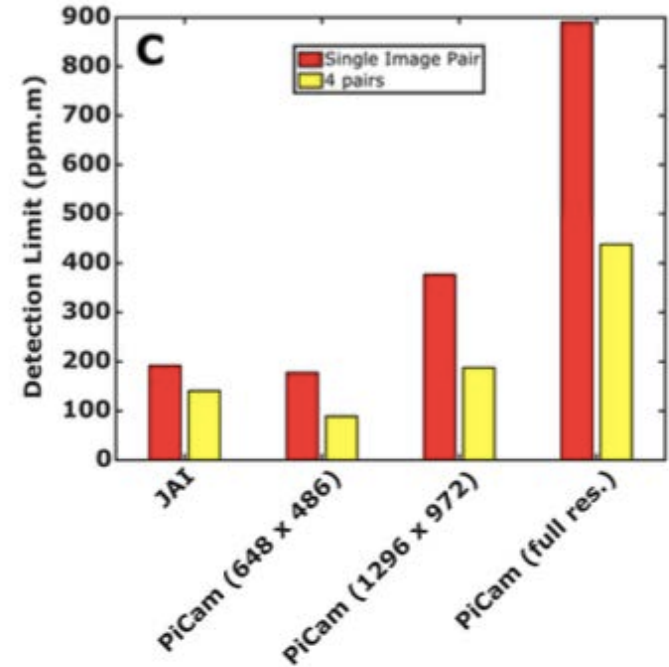
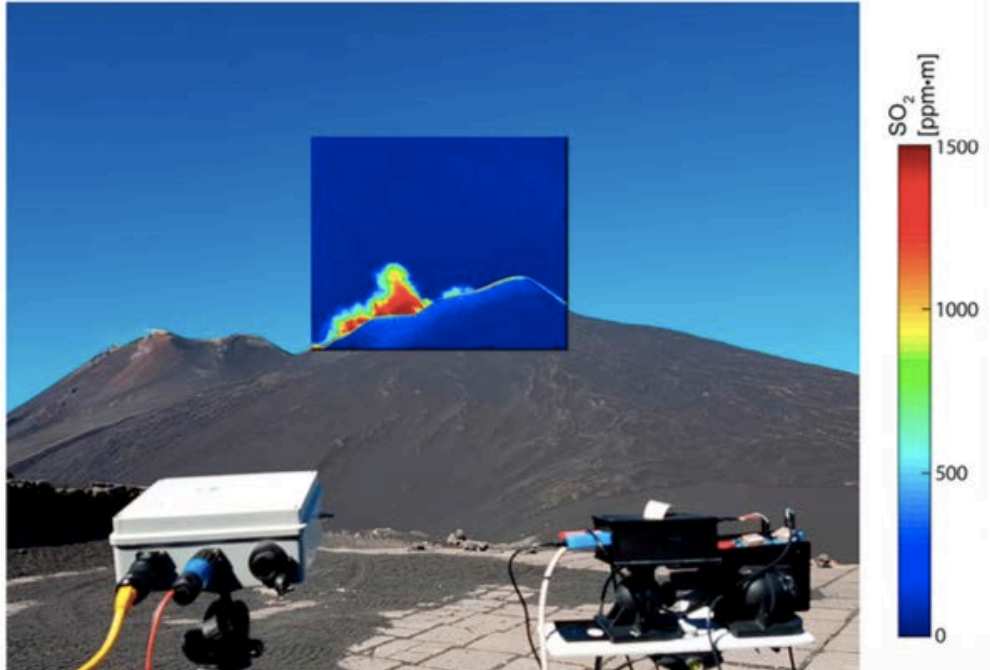


- Obtained RAW data to ensure linearity
- Tests on power station emissions





# Field test on Mt. Etna



- few \$100s
- vs.
- >>\$10k



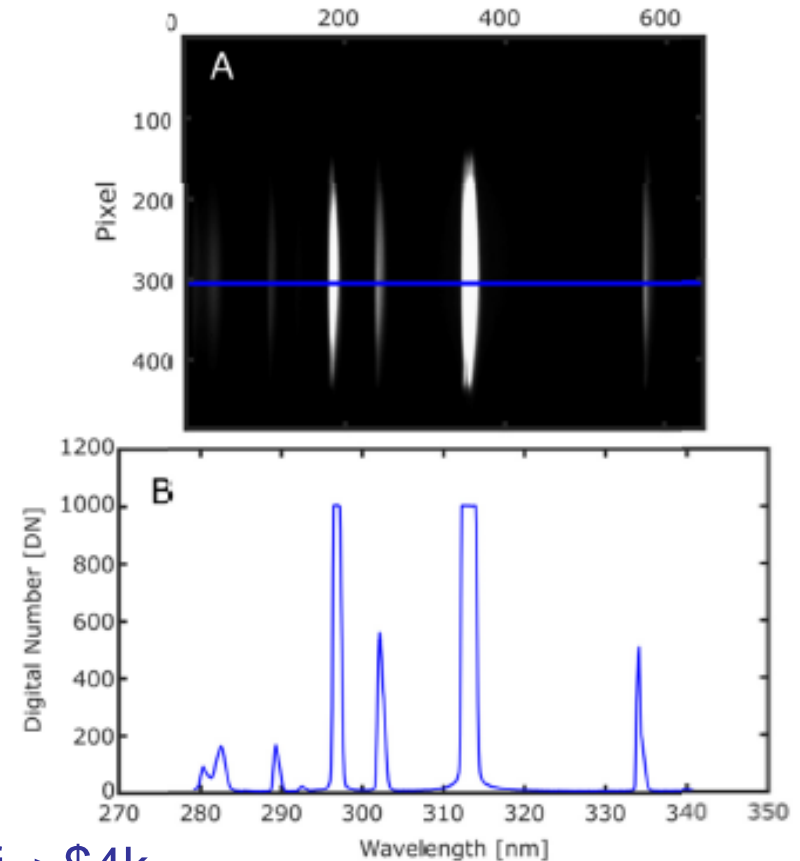
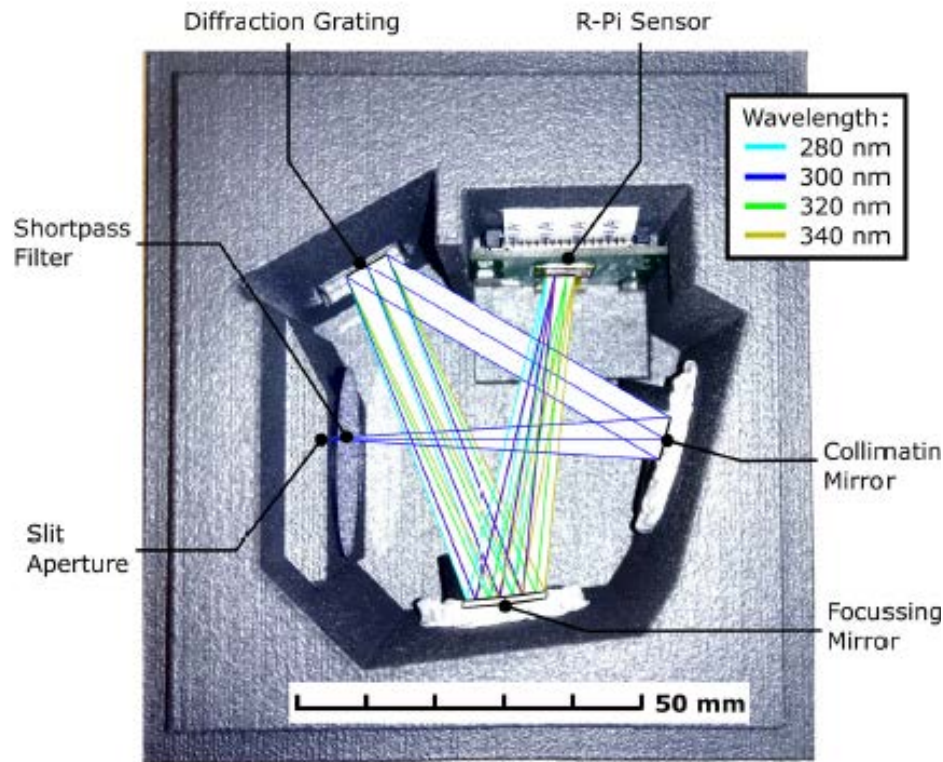
# Inexpensive thermal imaging



- Masaya volcano, Nicaragua; dynamics of lava lake behaviour



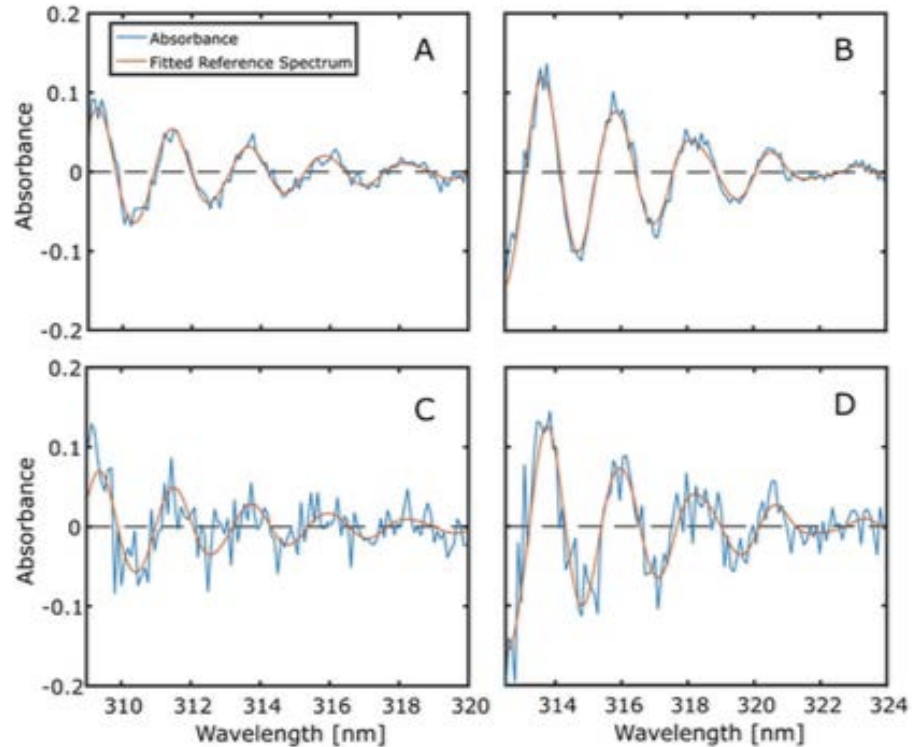
# 3D printed smartphone sensor spectrometers



- 1 nm resolution; few hundred dollars cf. >\$4k
- Optical configuration OpticStudio; SolidWorks used for CAD
- SLS graphite reinforced nylon; 0.2 mm tolerance far better than fused filament fabrication



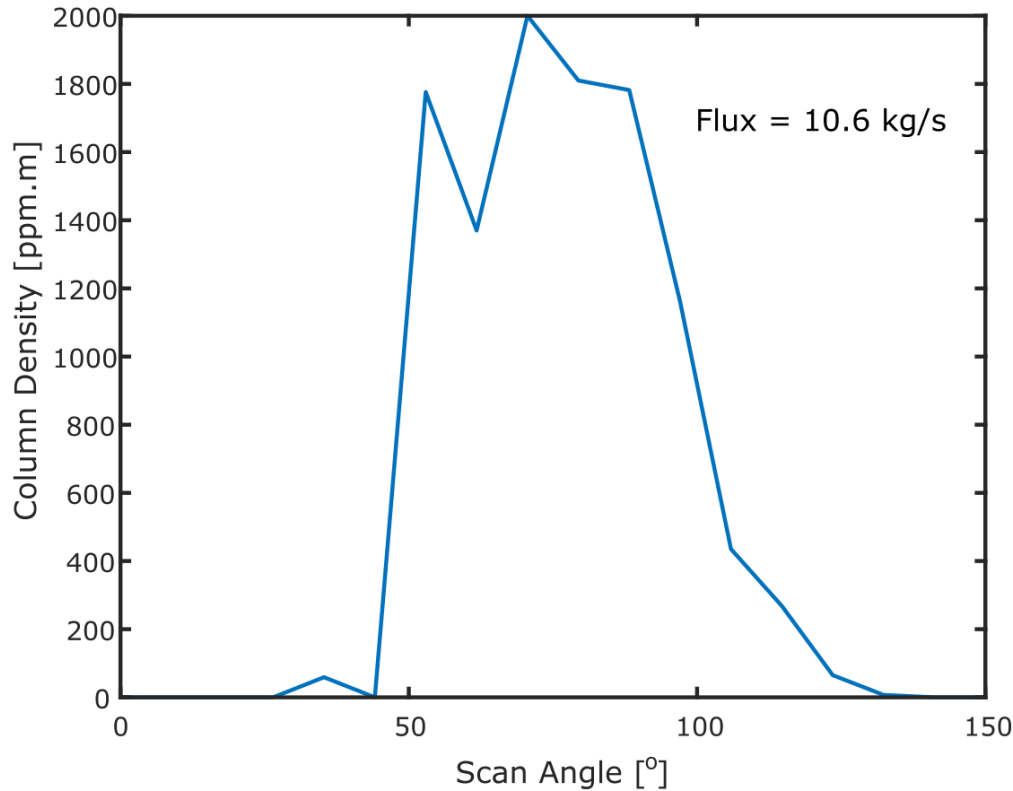
# 3D printed smartphone sensor spectrometers



- Cell concentration S.D. factor of 2/3 larger cf. OO spectrometer
- Co-add ten rows
- Could co-add more rows to reduce noise



# Smartphone sensor spectrometers



- Fieldwork Masaya volcano
- Essentially equivalent gas concentrations to OO unit; slightly noisier



- low cost and weight – drone and widespread operation



- EPSRC Latin America sensor network
- Philippines government – pollution sensor network
- Rolex – UV exposure



- Wilkes et al., 2016 Ultraviolet Imaging with low cost smartphone sensors: development and application of a Raspberry Pi-Based UV camera, *Sensors*, 16, 1649.
- McGonigle et al., 2017 Ultraviolet imaging of volcanic plumes: a new paradigm in volcanology, *Geosciences*, 7, 68.
- Wilkes et al. 2017 Low cost 3D printed 1 nm resolution smartphone sensors based spectrometer: instrument design and application in ultraviolet spectroscopy, *Optics Letters*, 42, 4323-4326.
- McGonigle et al., 2018 Smartphone spectrometers, *Sensors*, 18, 223.