Remote Sensing of Volcanoes Using Smart Sensing Technology

Presented by:

OSA Environmental Sensing Technical Group

OSA Environmental Sensing Technical Group

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)

OSA Environmental Sensing Technical Group

Technical Group Website:

www.osa.org/EnvironmentalSensingTG

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

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.

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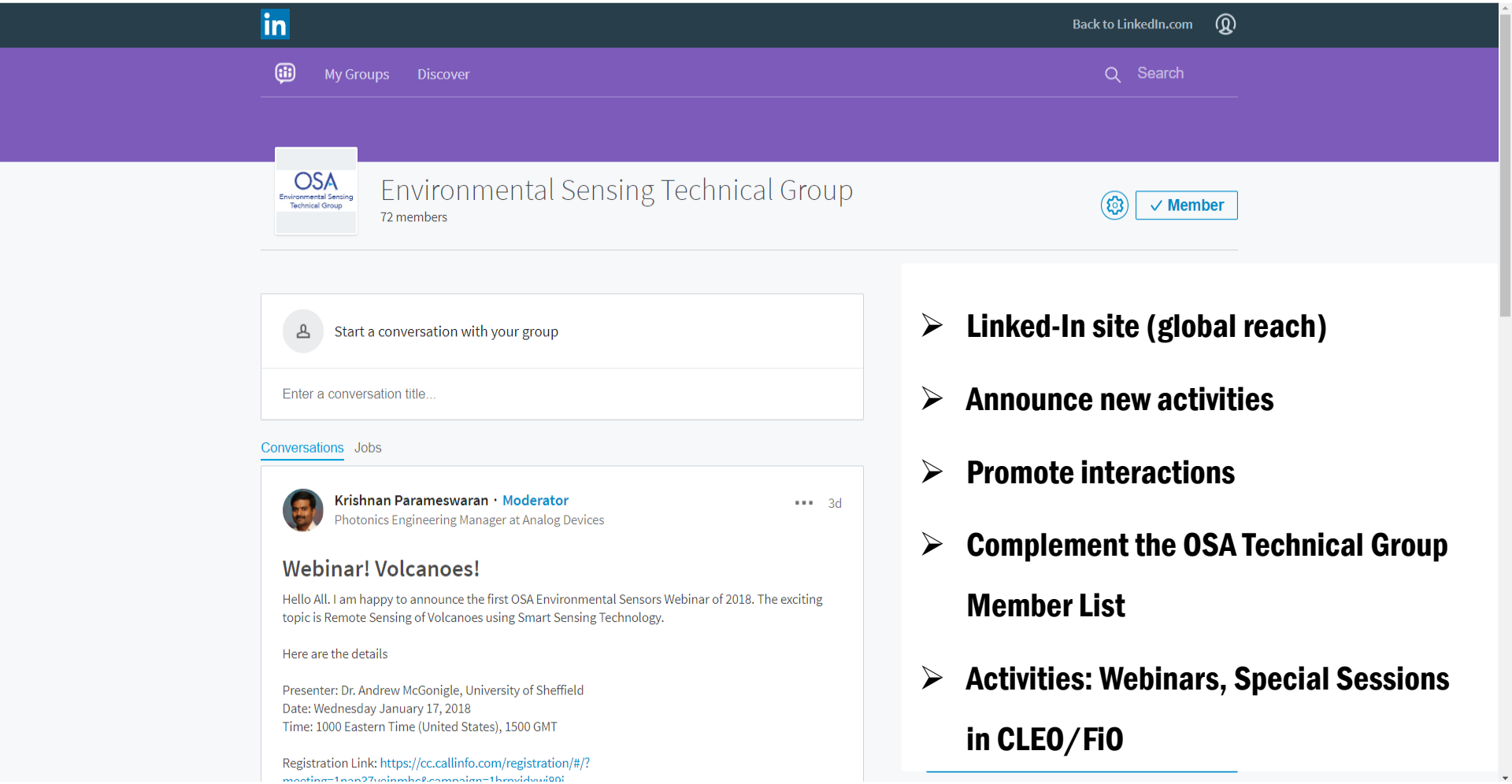
Contact your Technical Group and Get Involved!

www.linkedin.com/groups/12055528



- **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!

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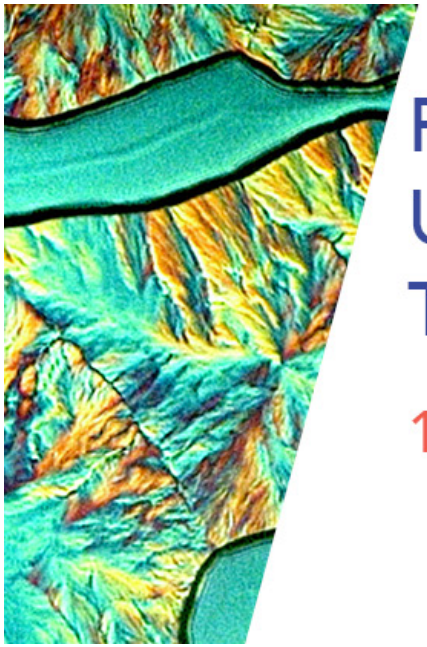

REMOTE SENSING OF VOLCANOES USING SMART SENSING TECHNOLOGY

17 January 2018 • 10:00 EST

OSA Environmental Sensing Technical Group

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

Mt. Etna

ANDREW MCGONIGLE

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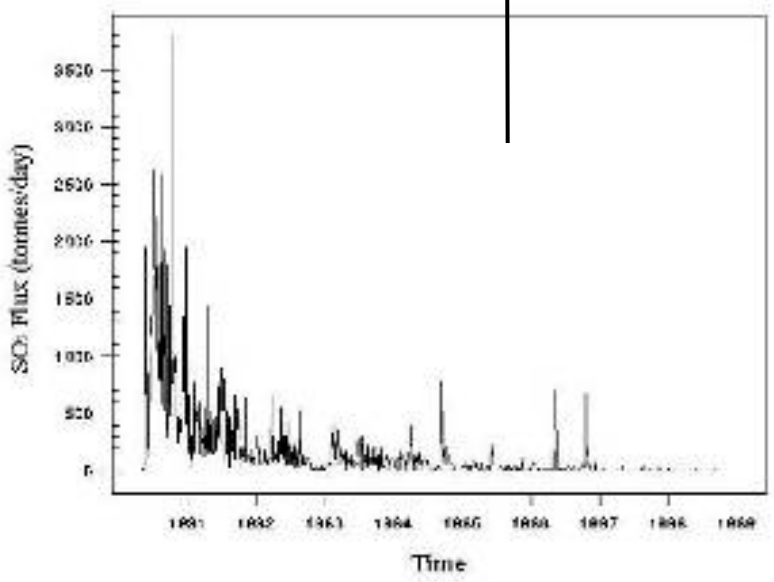
Why study volcanic gases?

A Degassing drives activity

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



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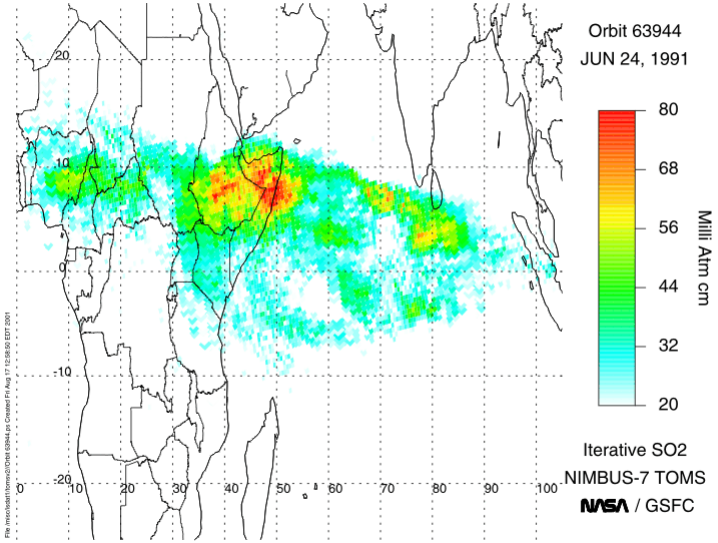
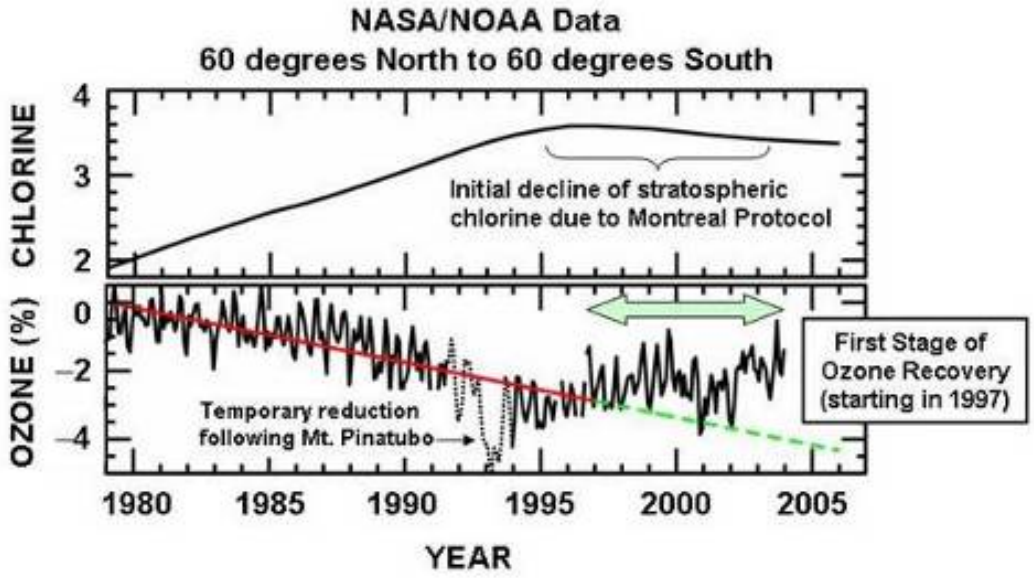
Why study volcanic gases?



C Impacts on the climate system

D And on atmospheric chemistry e.g., ozone



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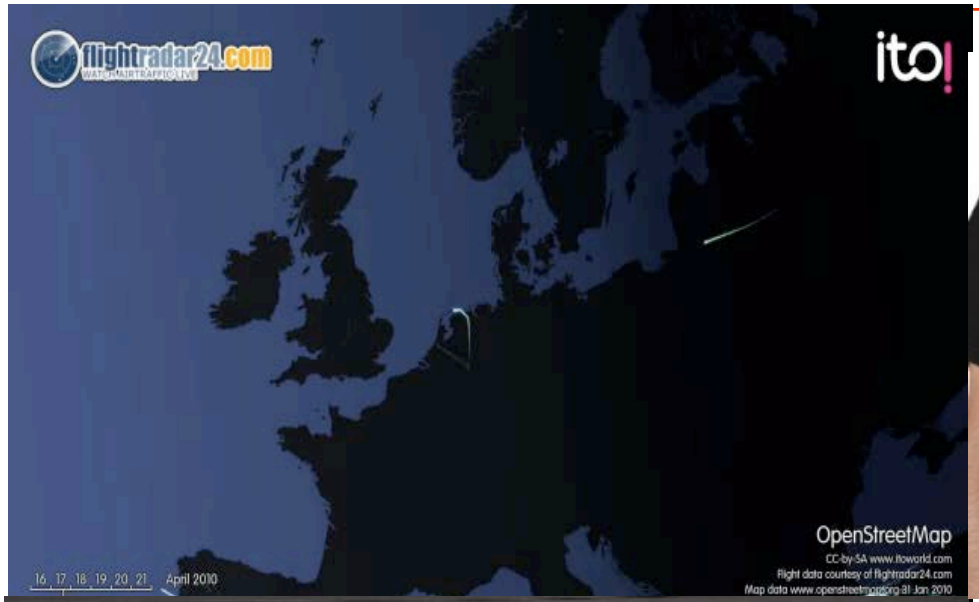
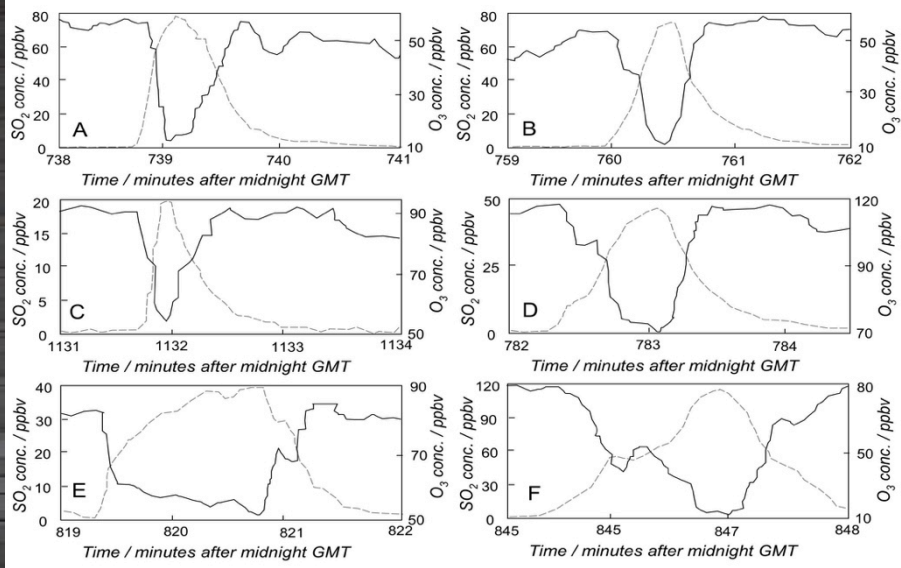
Why study volcanic gases?



Depletion in tropospheric ozone too



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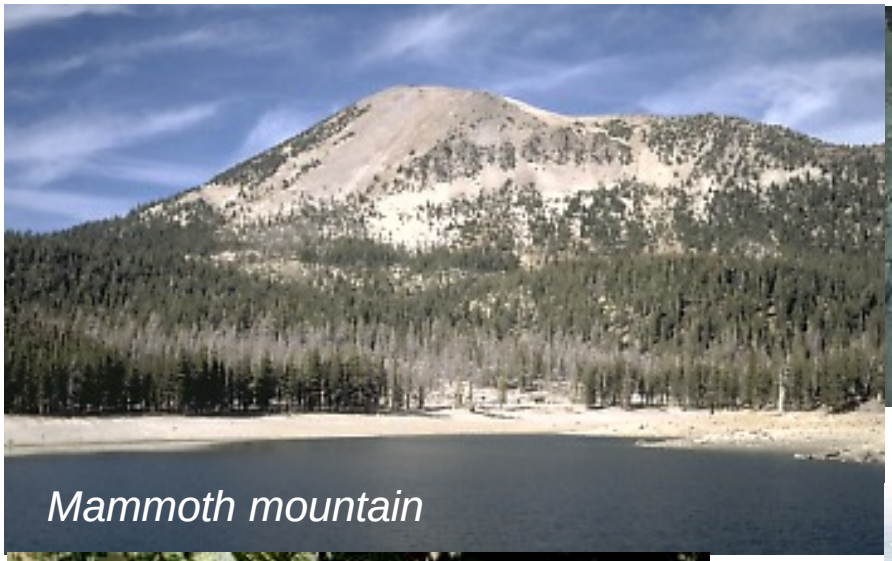
Environmental Impacts

- Asphyxiation – Mammoth Mountain and Lake Nyos



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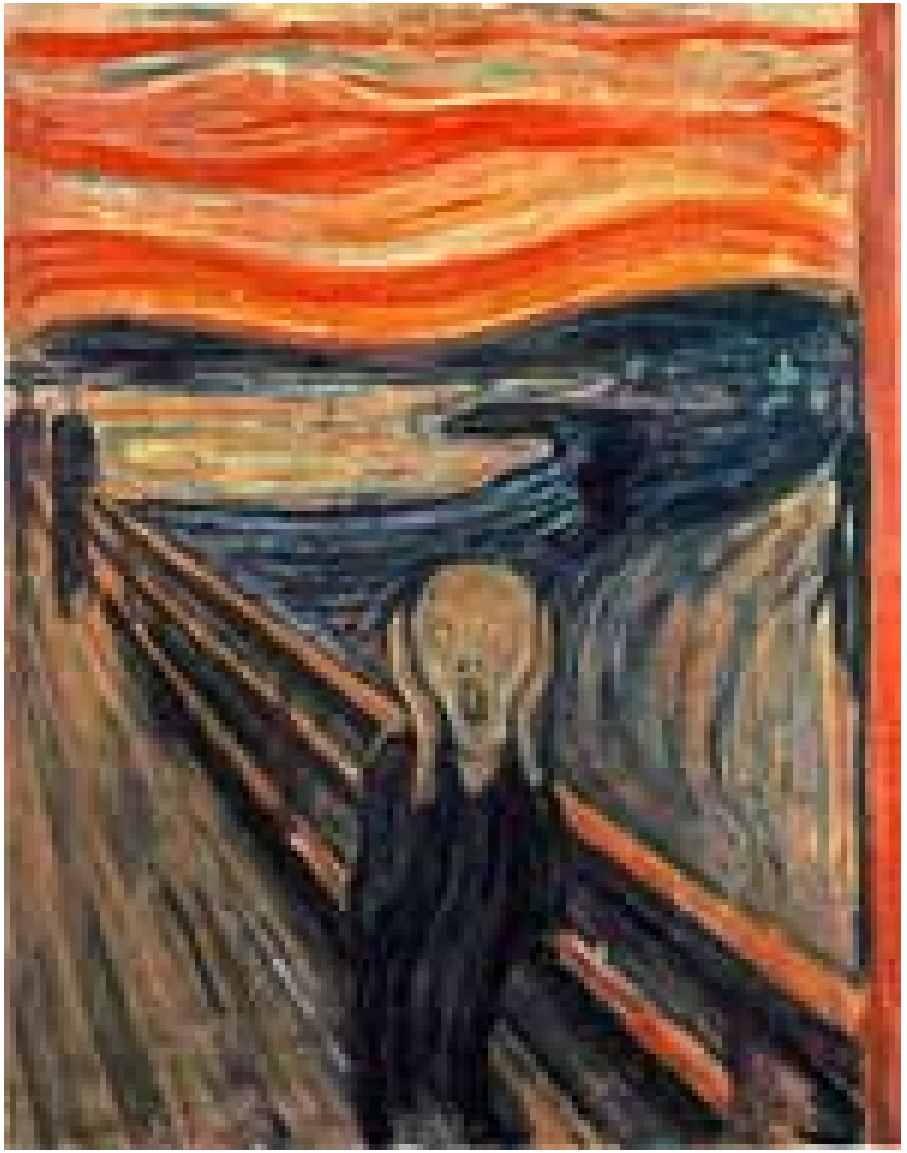
Climatic Impacts

- Laki – affected two continents

- Krakatoa eruption 1883



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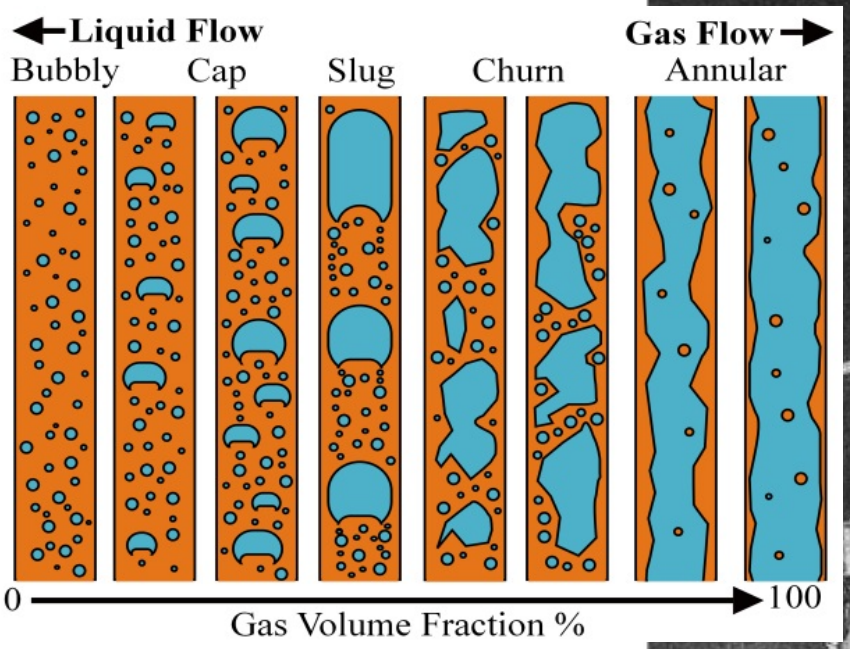
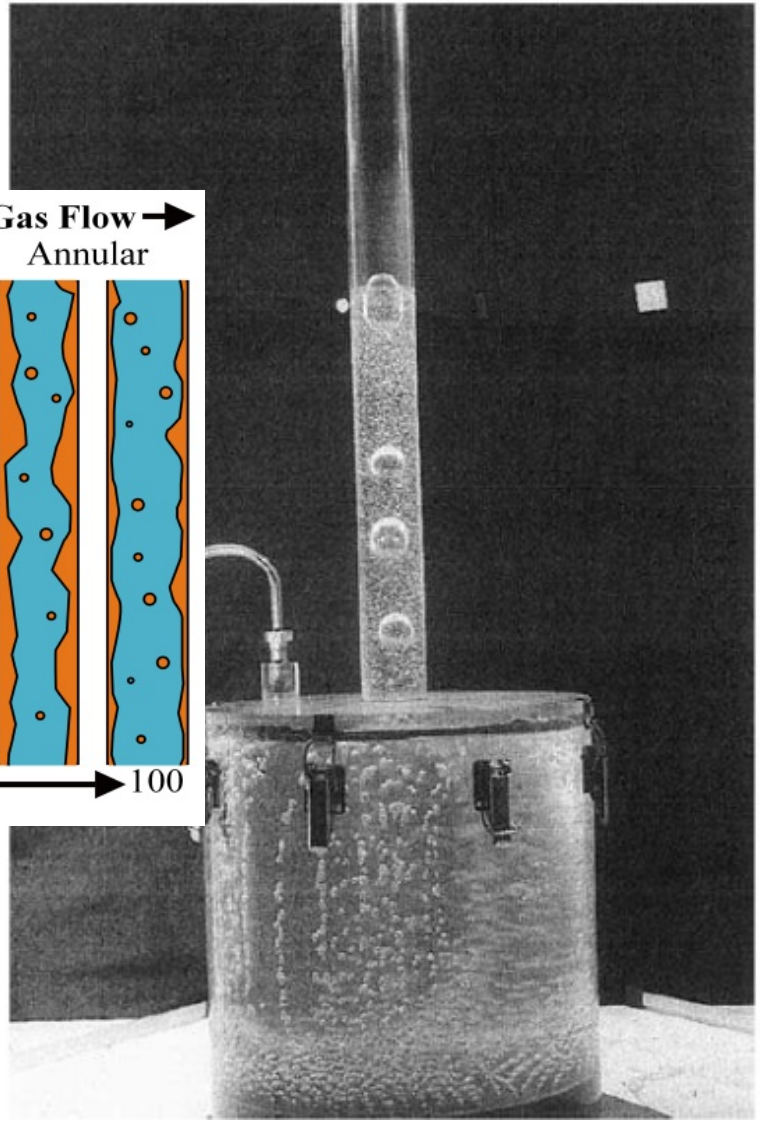
Bubbles and activity in basalts





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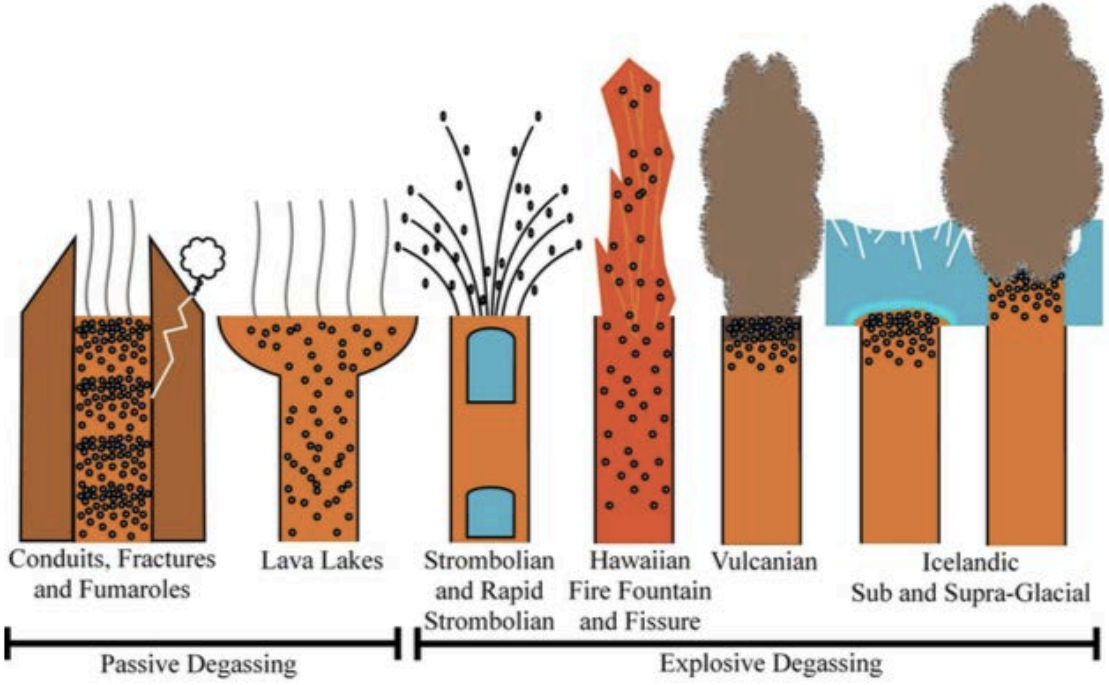
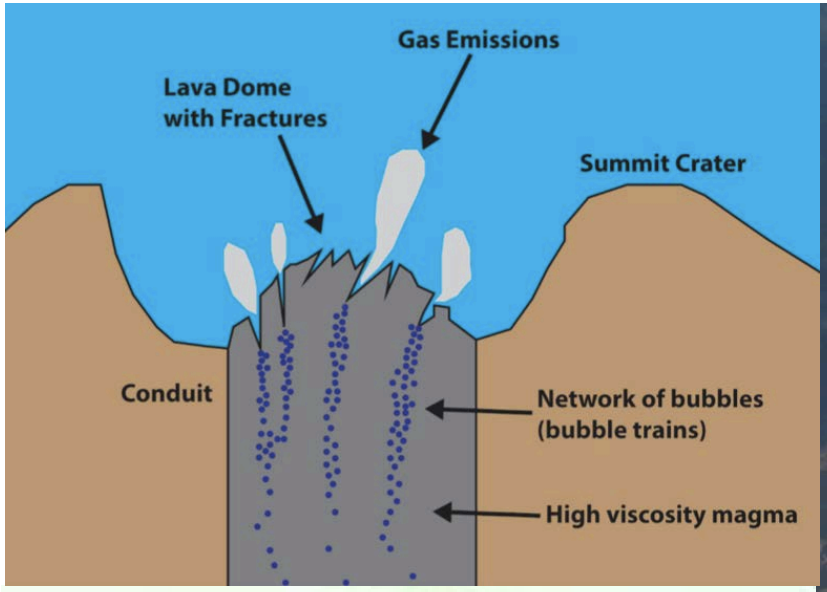
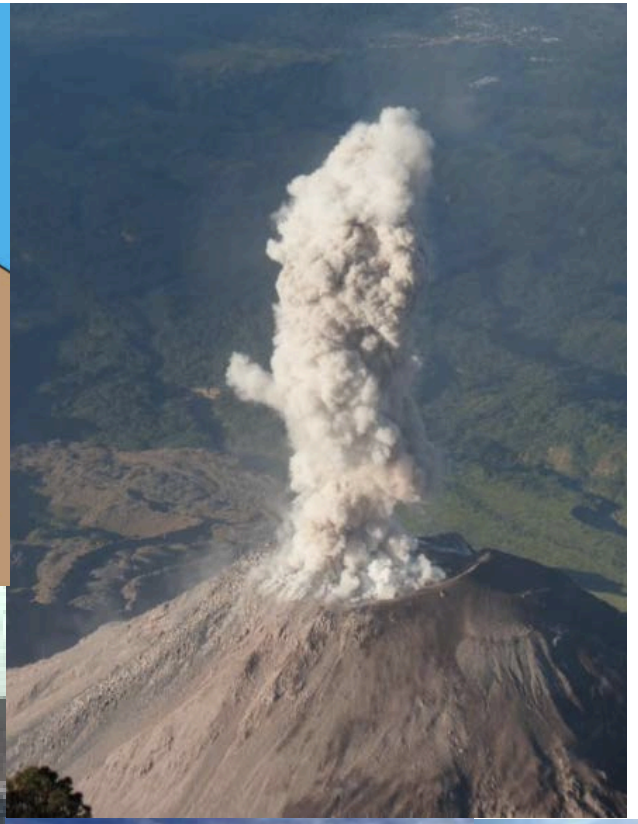
Bubbles and activity in basalts



Degassing and silicic volcanism



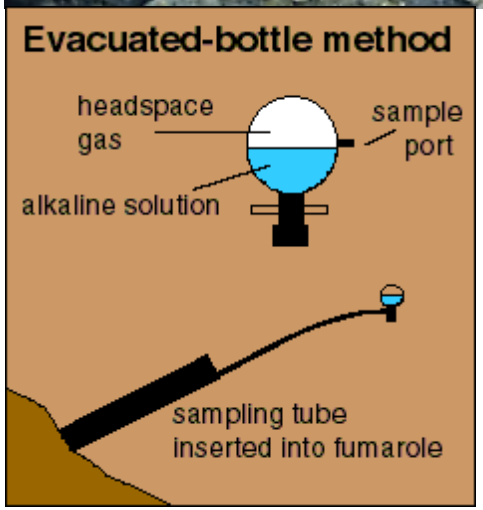


- Bubbles can't move so readily

Dome pressurisation, explosions and pyroclastic density flows

Gas Measurement approaches

- How to measure?



- Detailed but dangerous

Direct sampling

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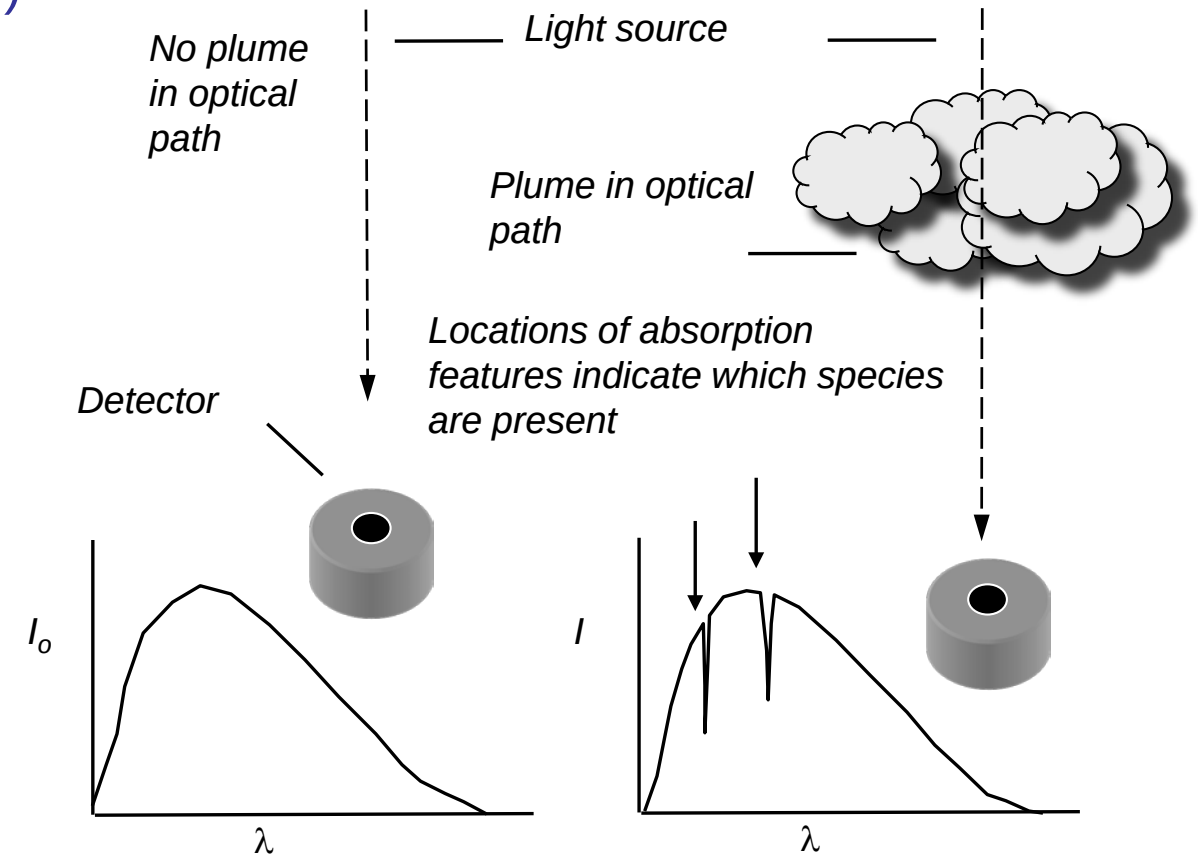
Remote sensing

- Remote sensing – safe(r)



- Fingerprint identification of gas absorption

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Remote sensing

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Ground versus space platforms

Rabaul plume

- Ground based better for monitoring

Masaya Nicaragua

- Satellite good for atmospheric impacts/aviation warning

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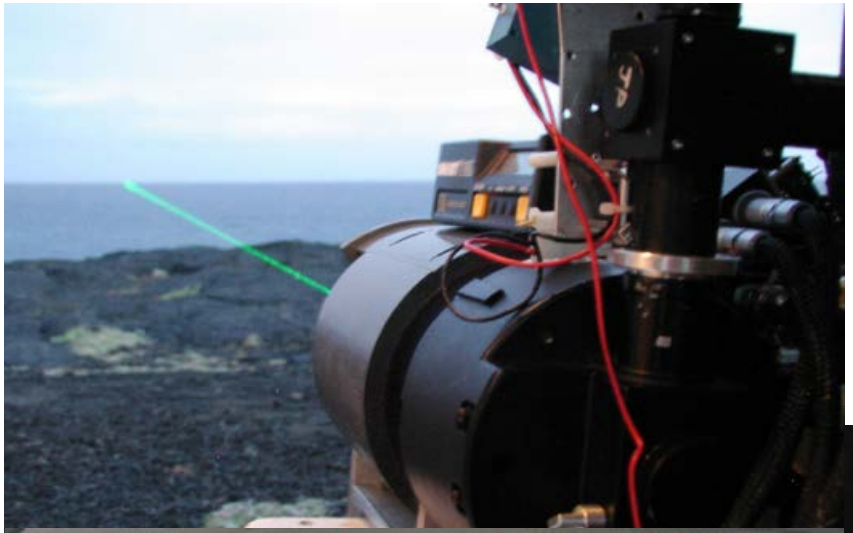
Measurement approaches

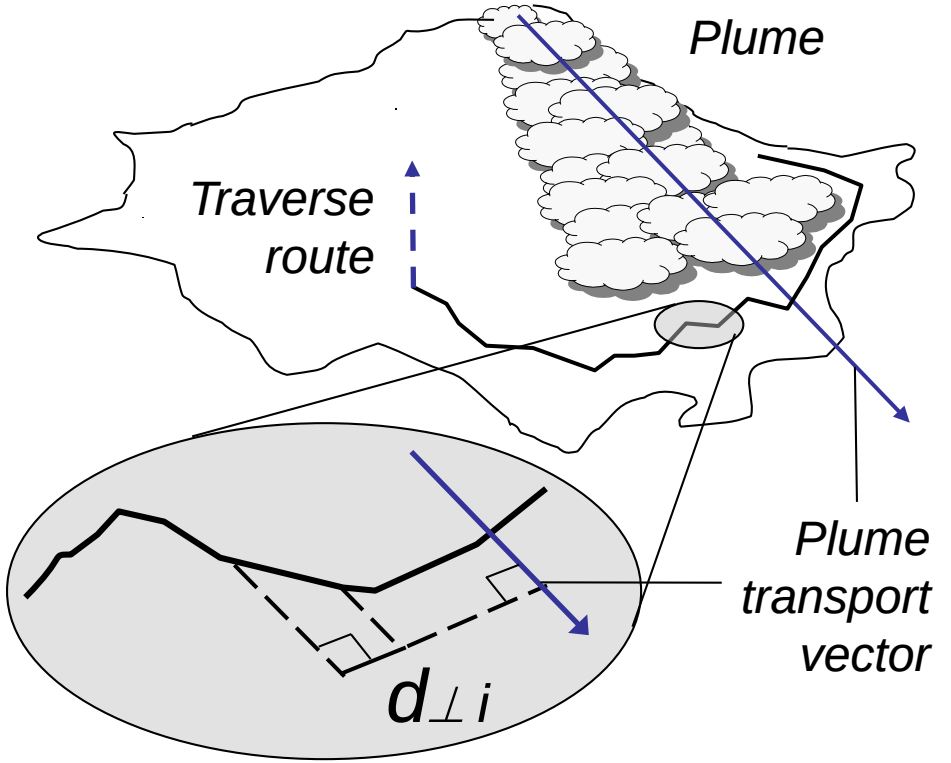


- Lasers and FTIR

Passive UV RS of gas fluxes

- Sulphur dioxide ~ 310 nm absorption

Volcano summit - anemometer



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

- Pre 2000 antiquated technology

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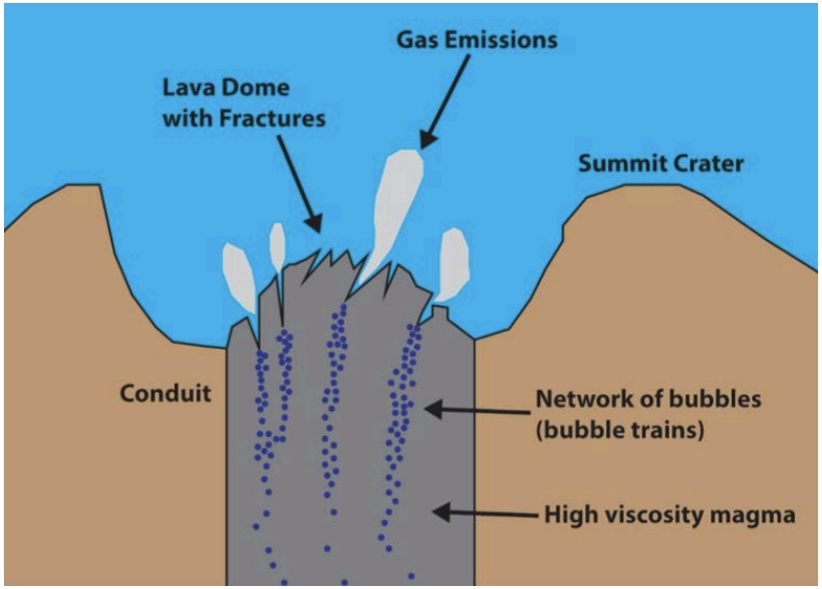
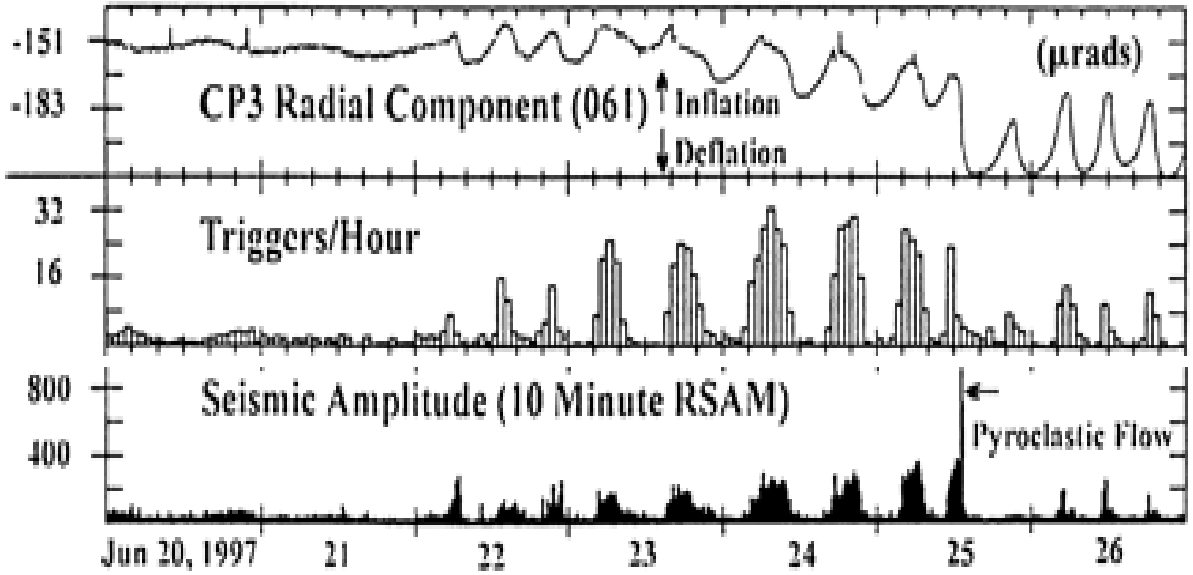
Issues with old technology

- Traverse mode restricts time resolution





- also large errors; unreliable technology

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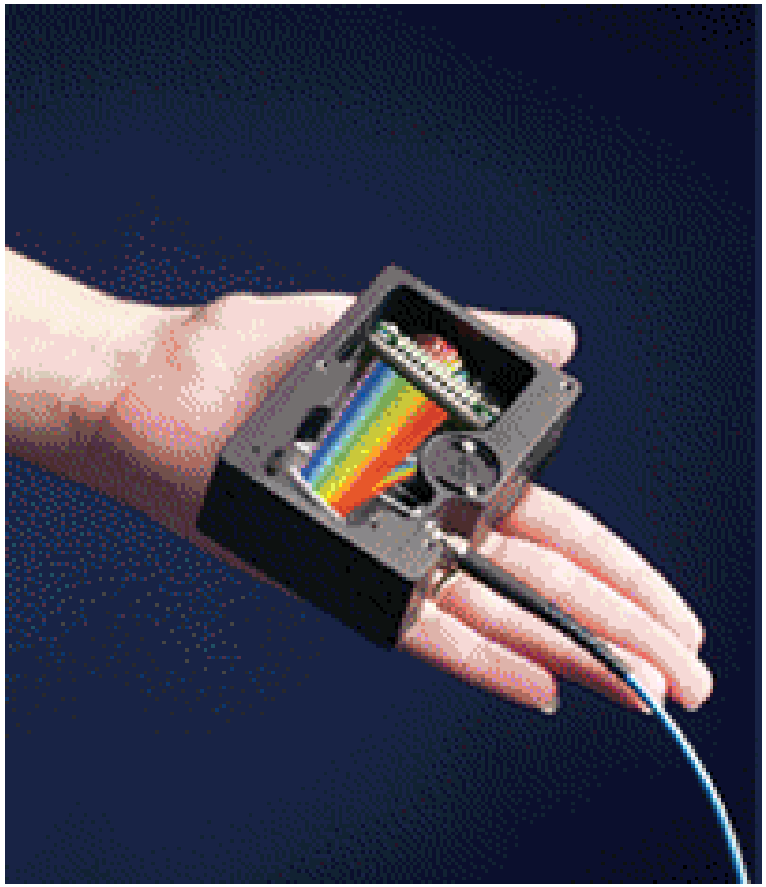
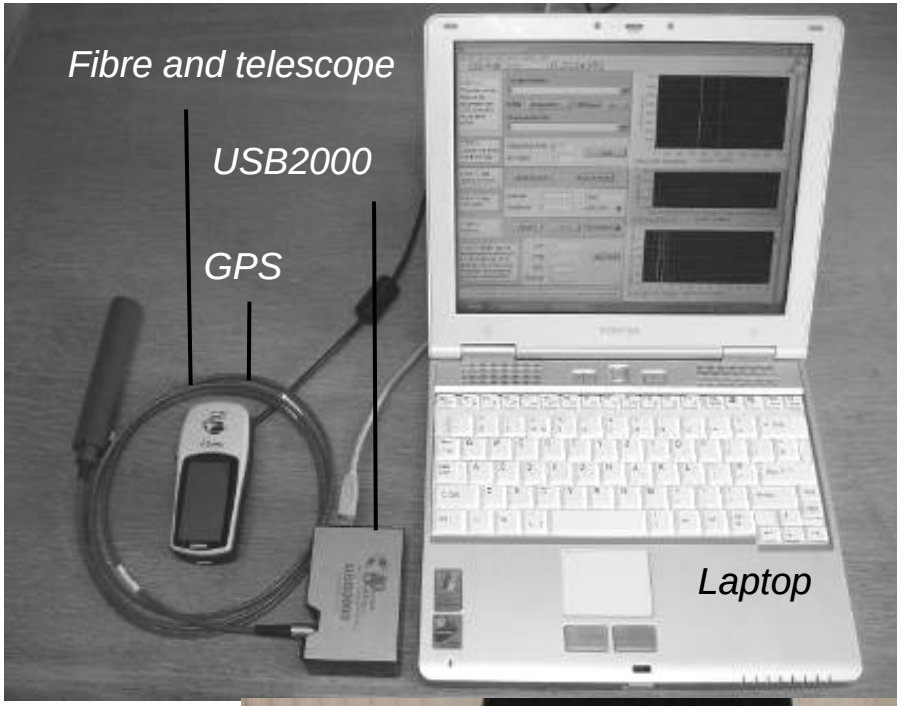
Hand held spectrometers

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





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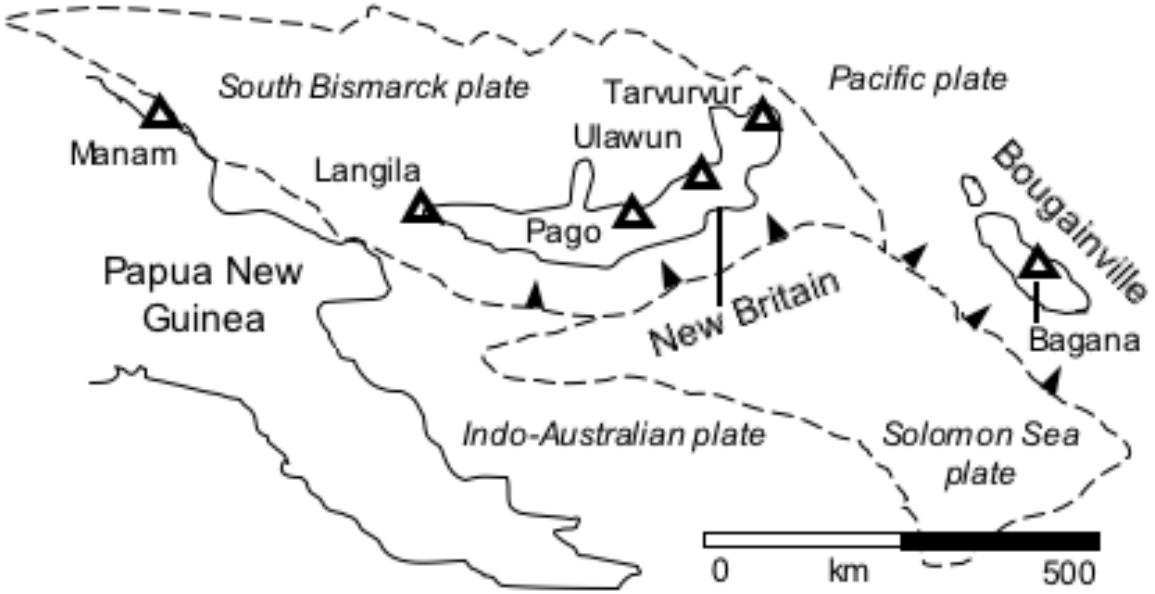
Hand held spectrometers



- Broadening gas flux records

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Hand held spectrometers

- Measurement flexibility

- Scooter measurements the rage in Japan

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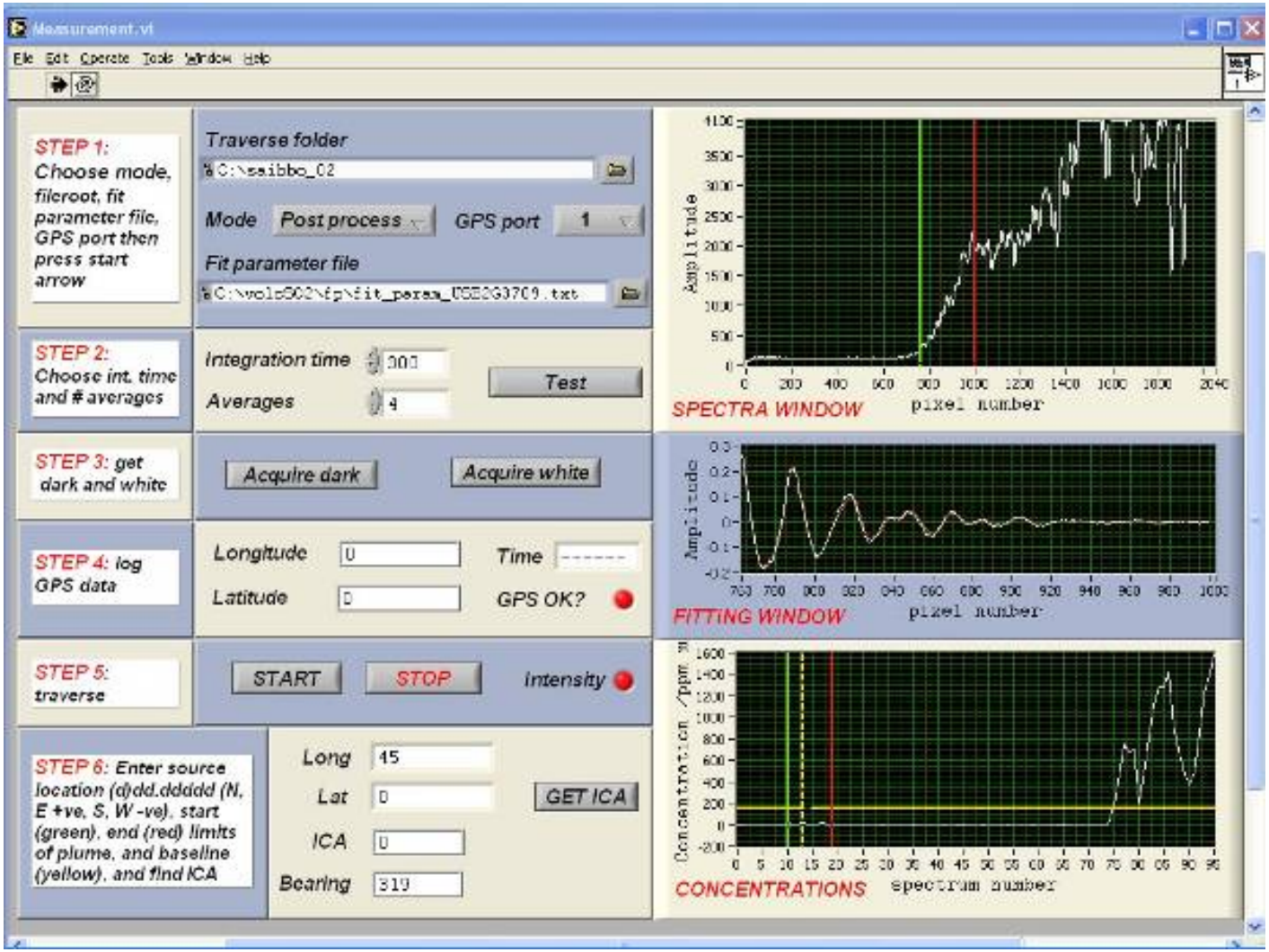
Software Interface

- User friendly interface



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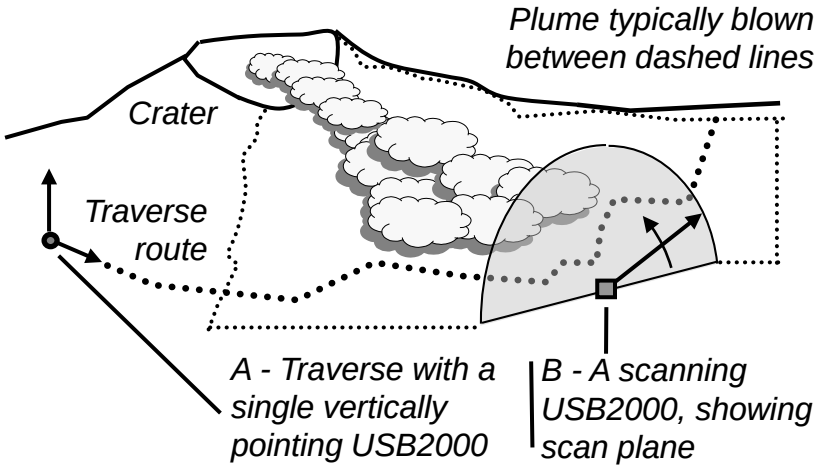
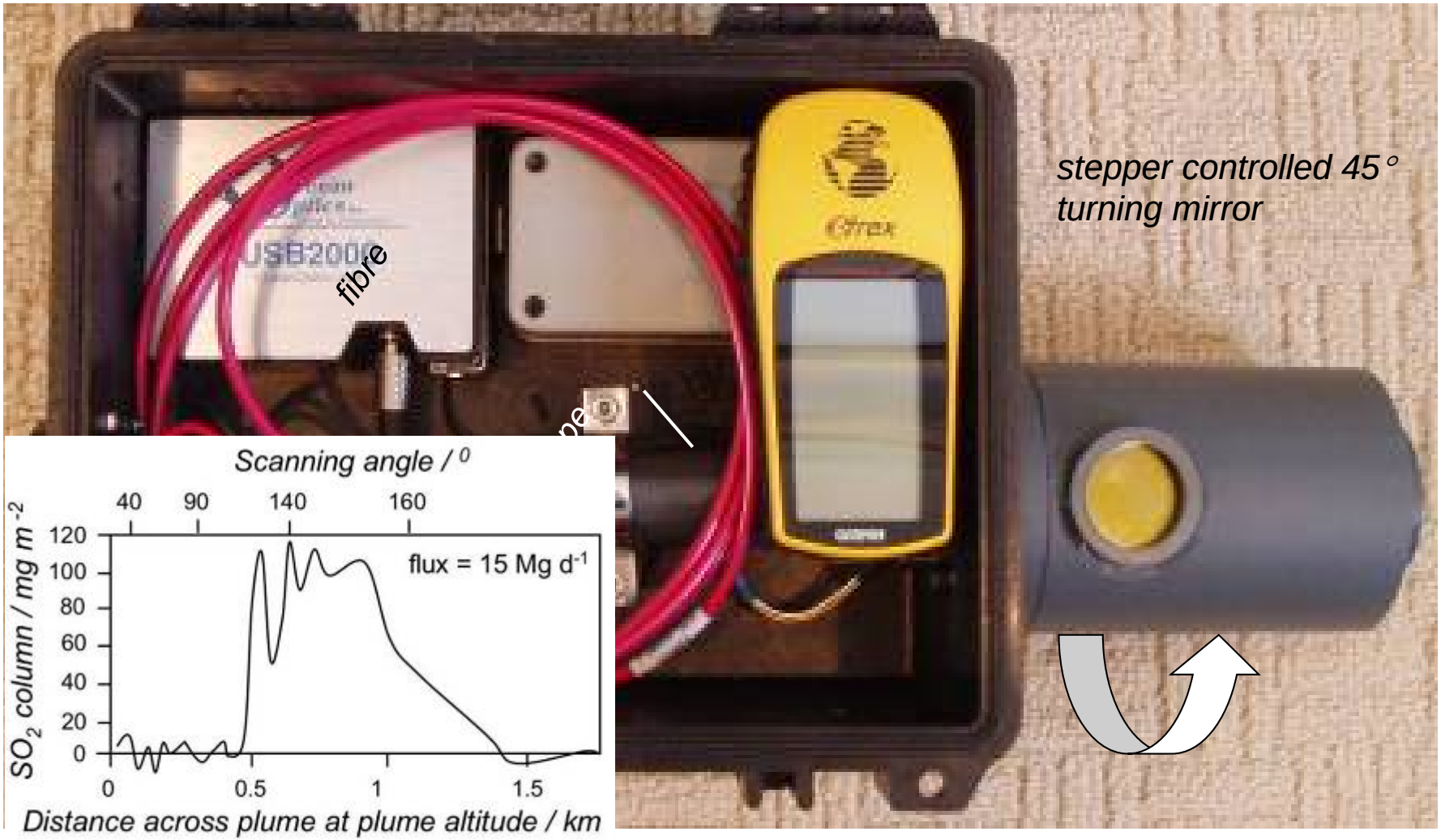
Scanning Measurements



- 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

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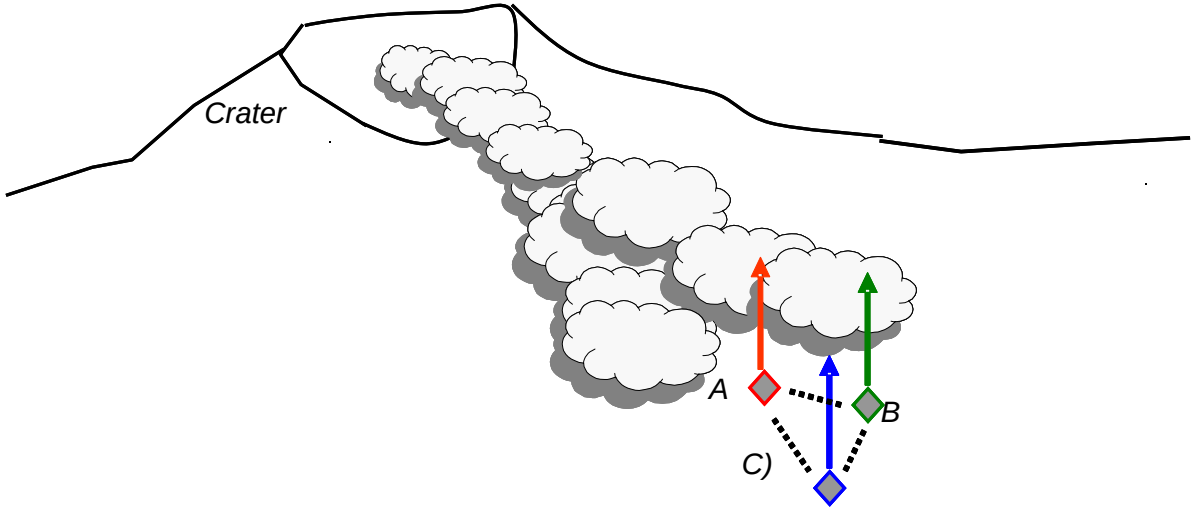
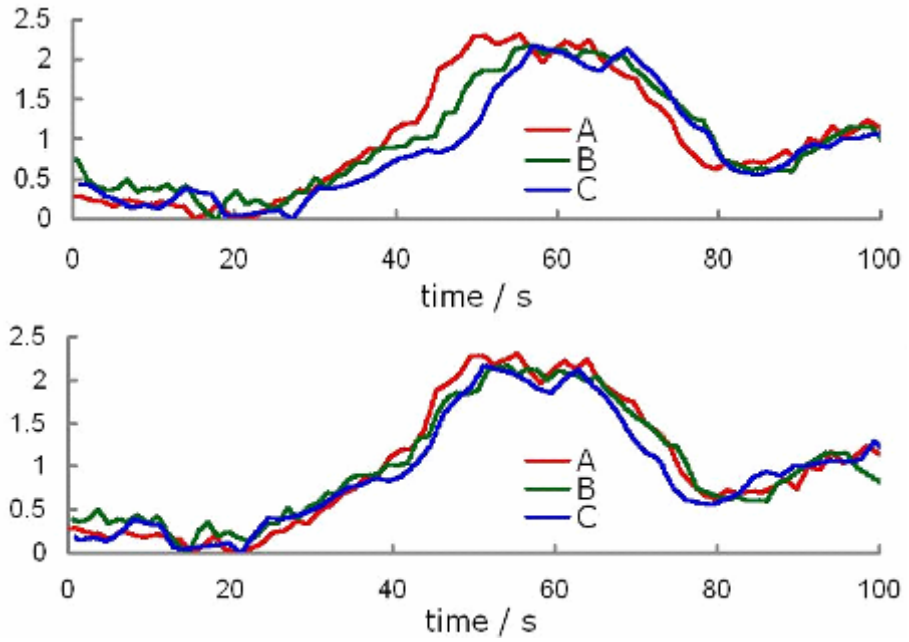
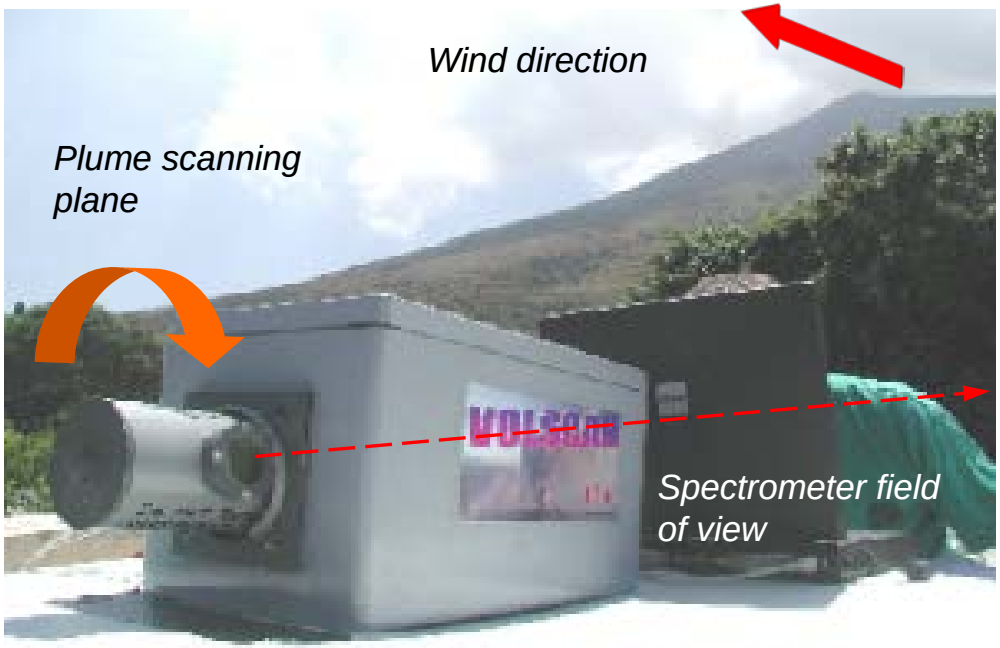
Addressing accuracy problem



- Cross correlate output from multiple vertically pointing spectrometers

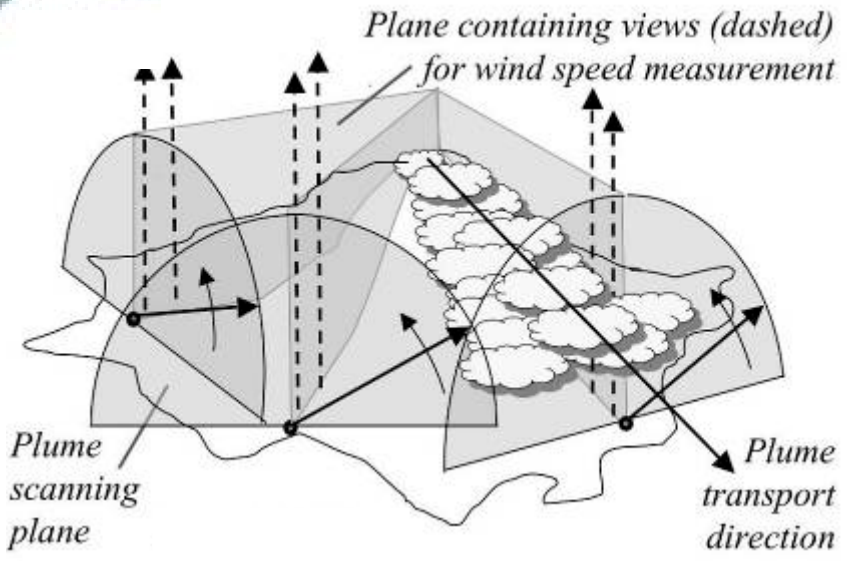


Putting this all together



- Scanning units used as standard internationally

- But time resolution still far lower than geophysical



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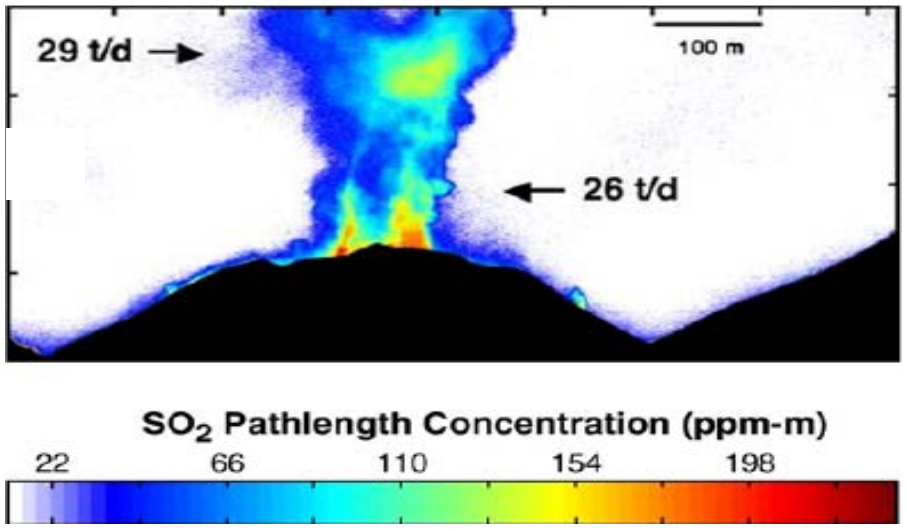
UV imaging

Visible Image



SO_2 concentrations

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

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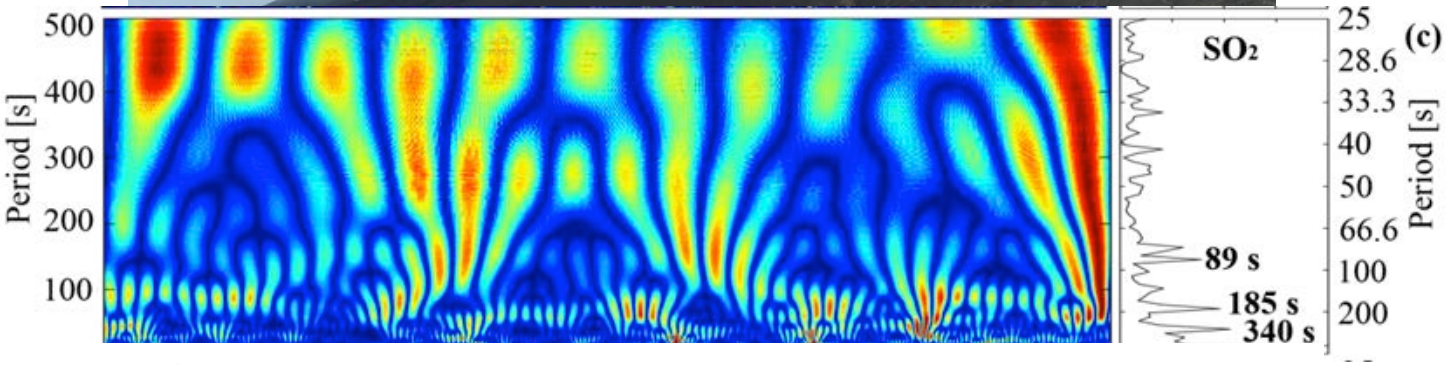
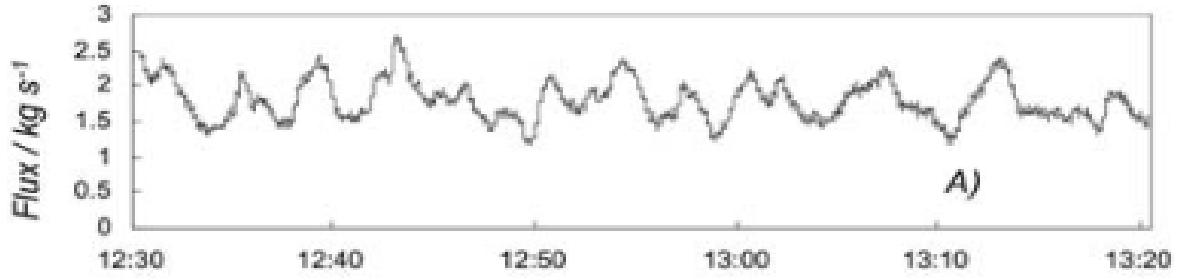
Passive degassing

- modulation in gas release





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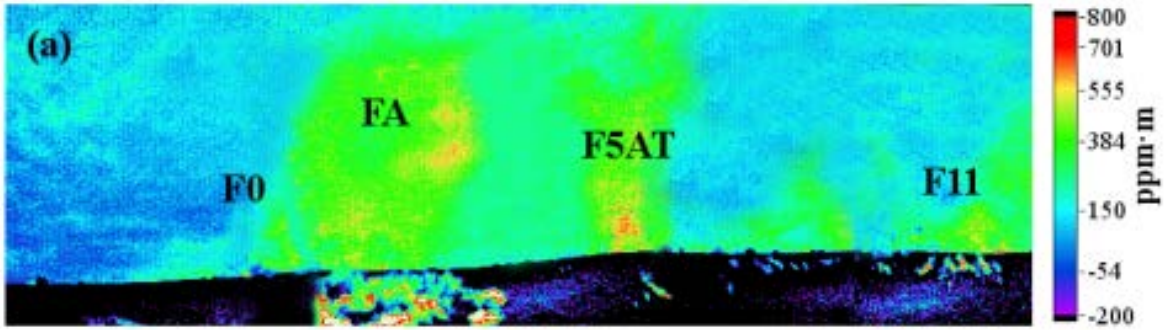
Resolution of heterogeneous sources



- Gas transference from crater to crater

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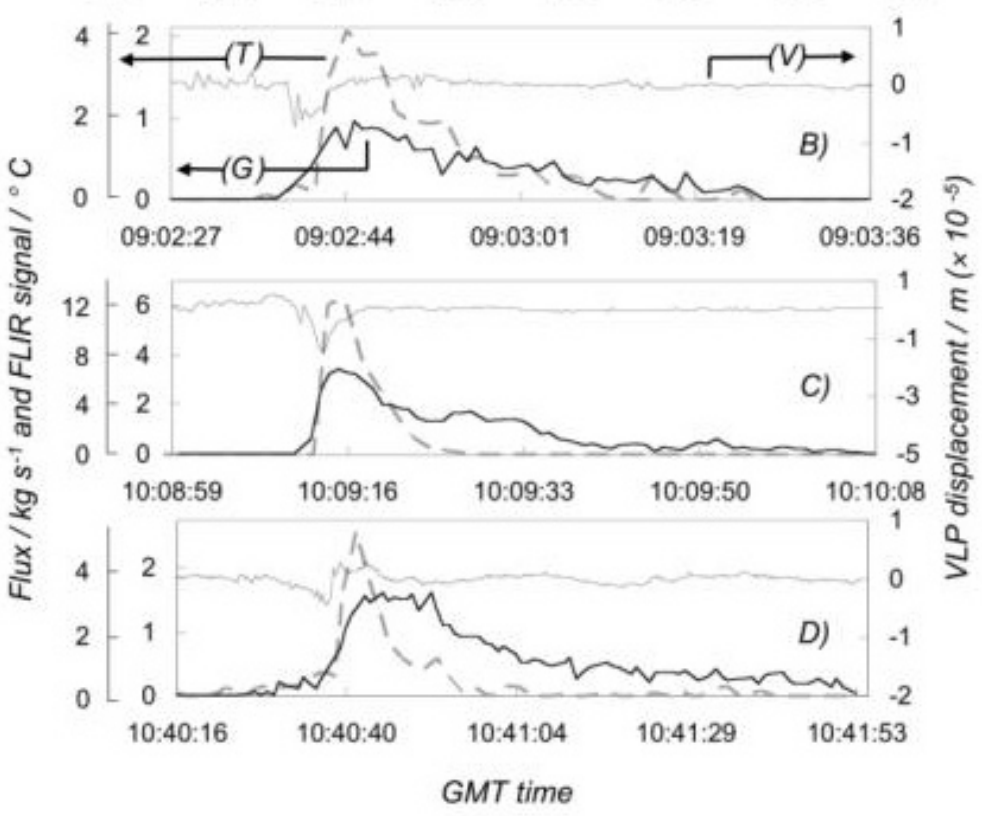
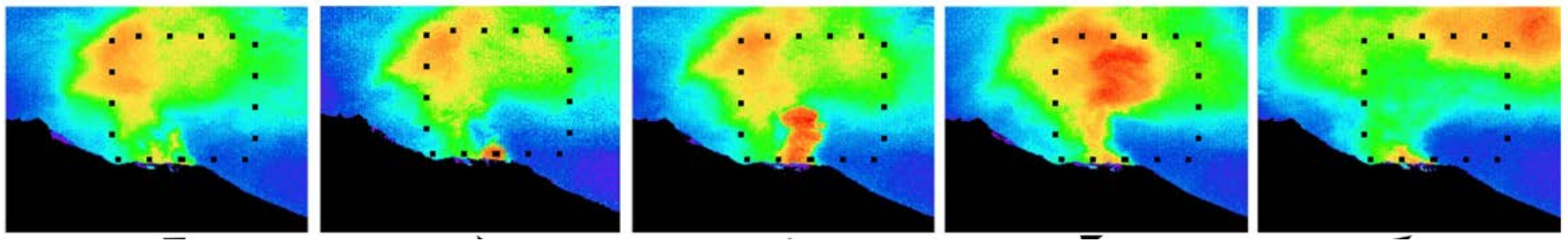
Explosive dynamics



- Resolution comparable to seismic and thermal for first time



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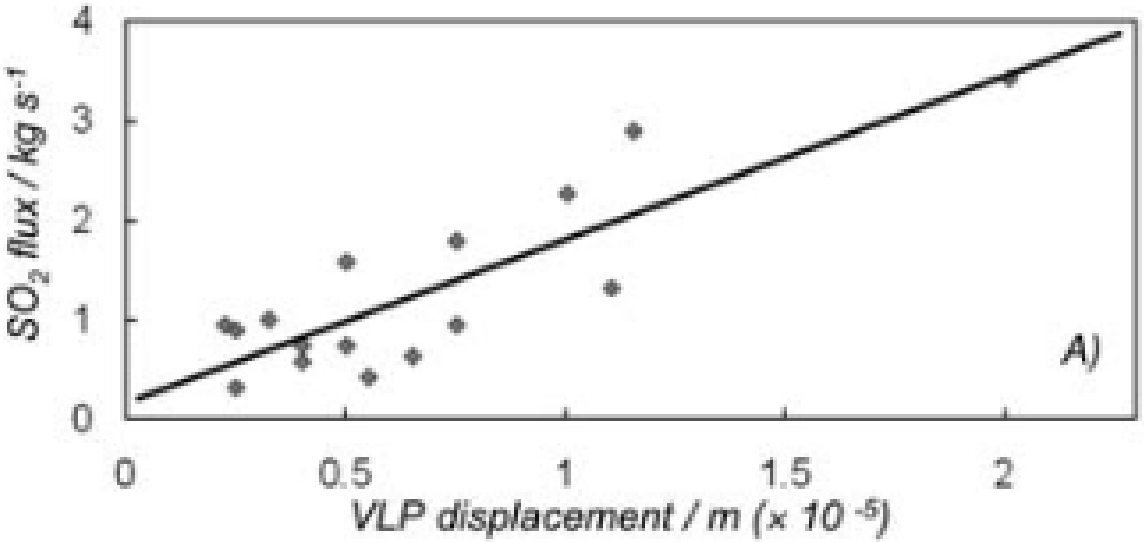
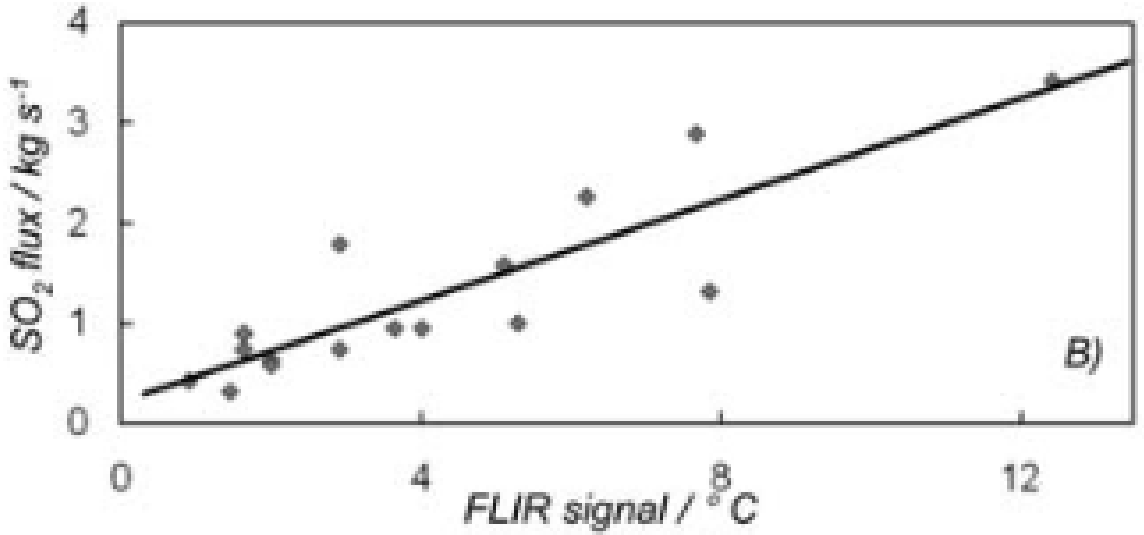
Linking to geophysics





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

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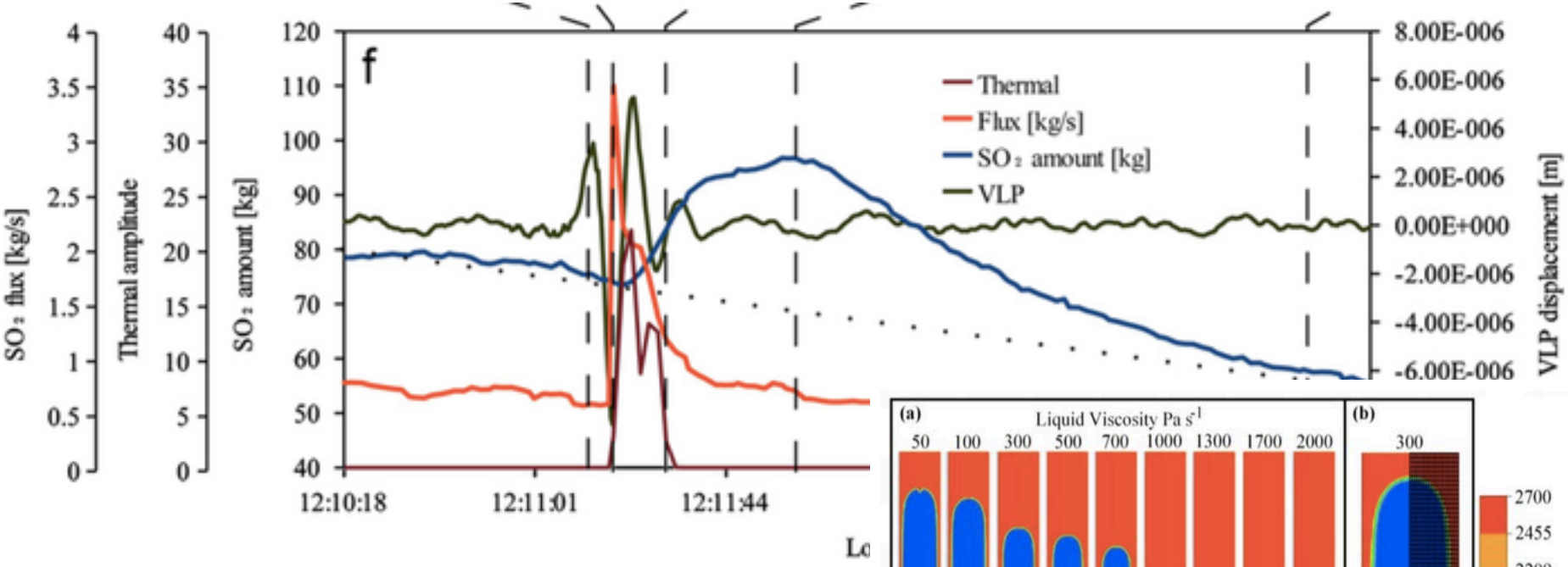
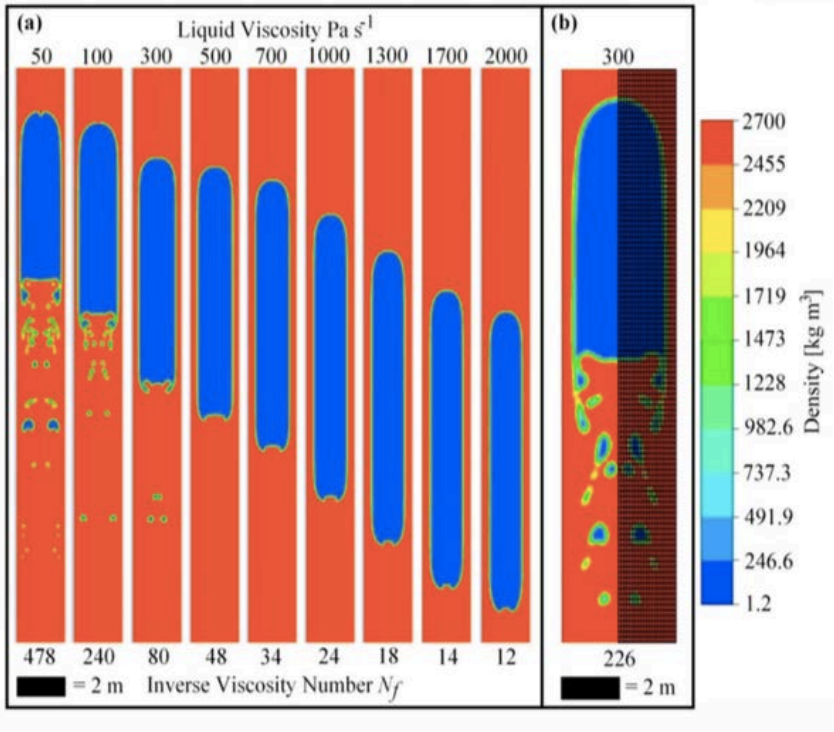
Coupling to models





- Daughter bubble production

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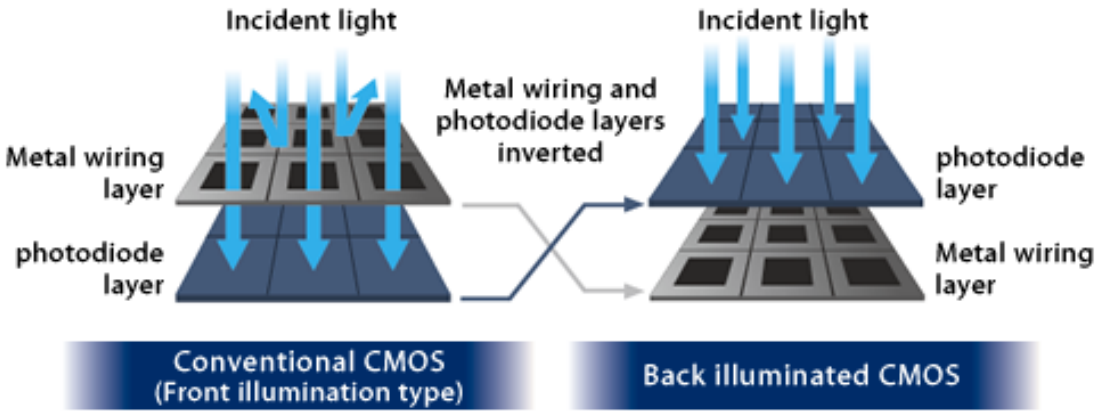
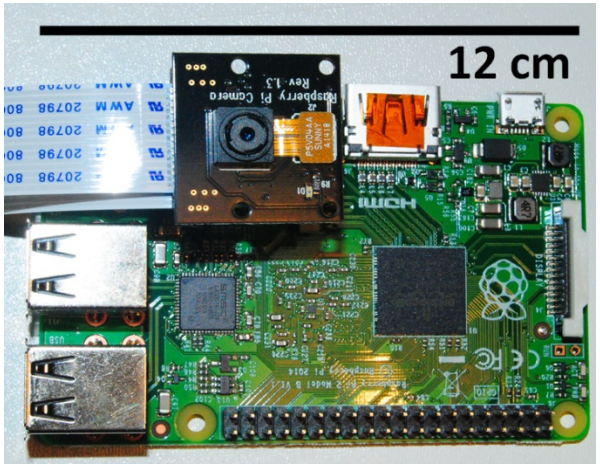
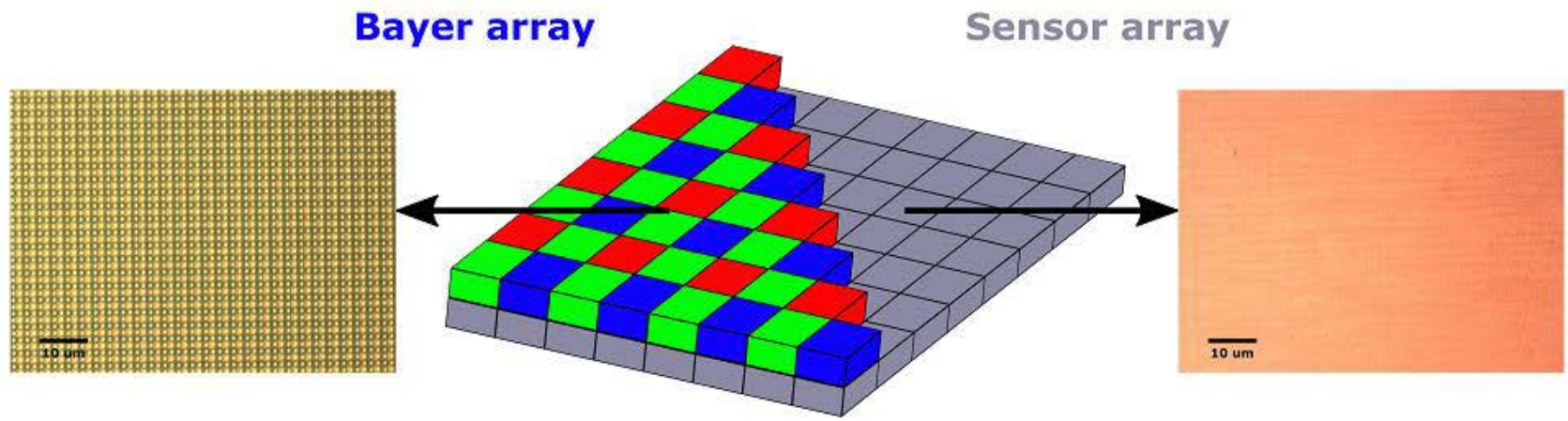
Still too expensive? Smartphone sensors?





- Remove Bayer layer from Raspberry Pi camera - £20



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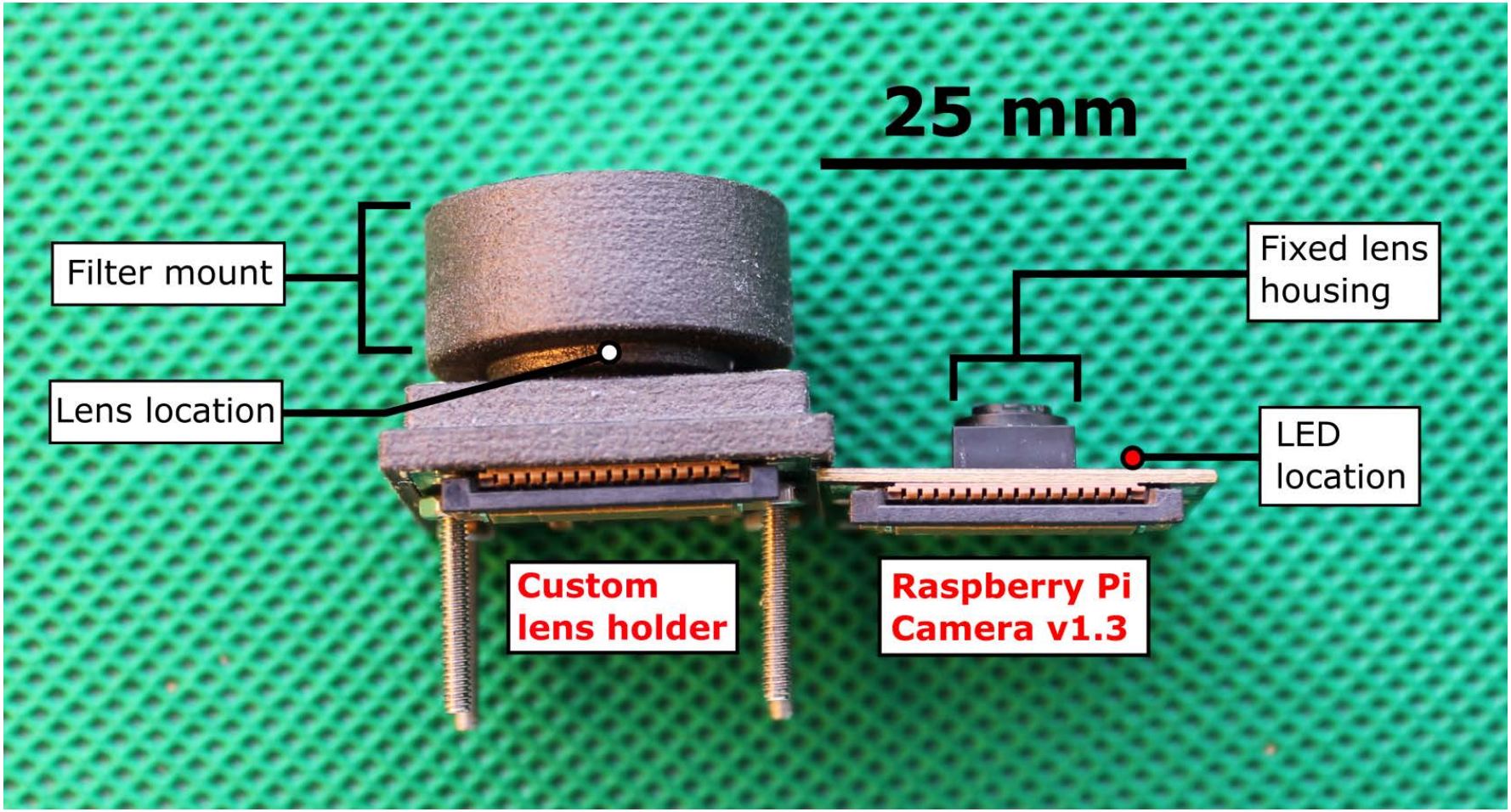
Smartphone sensor UV camera



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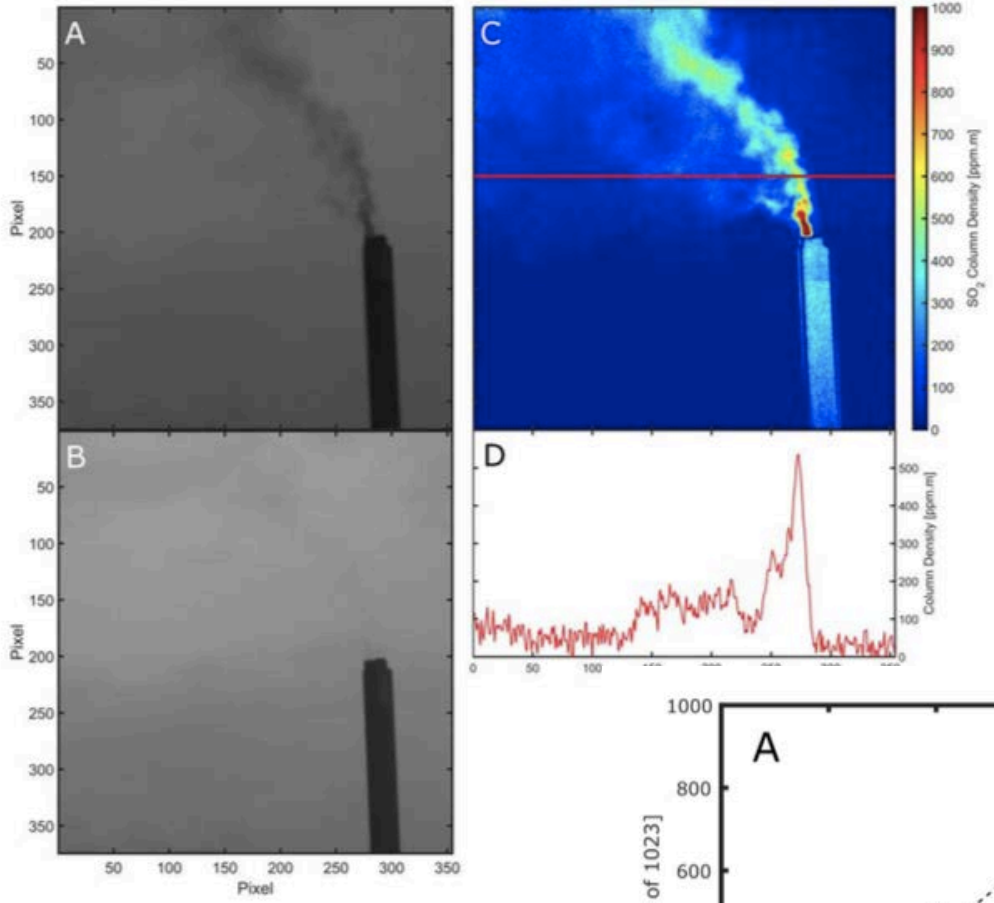
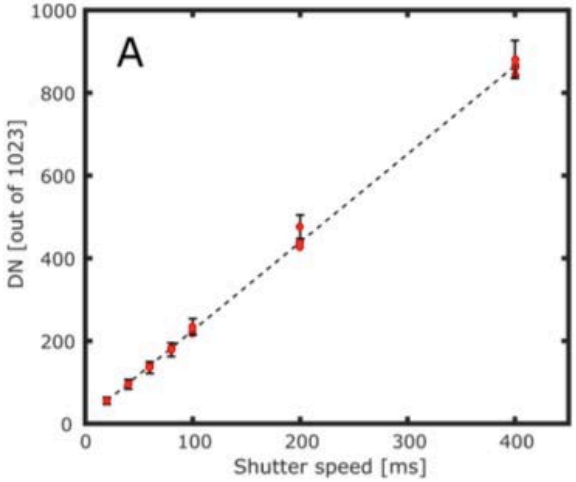
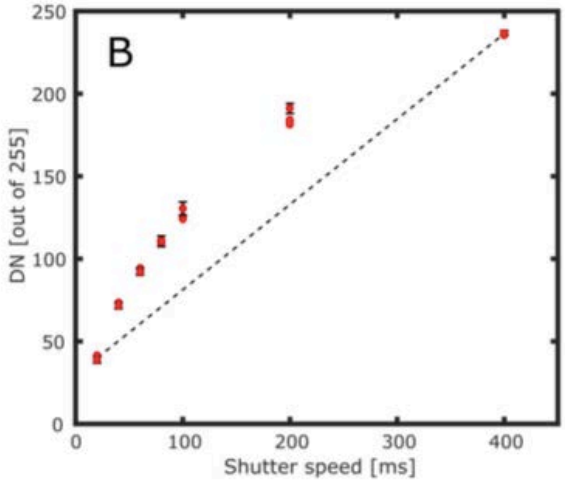
Smartphone sensor UV camera



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





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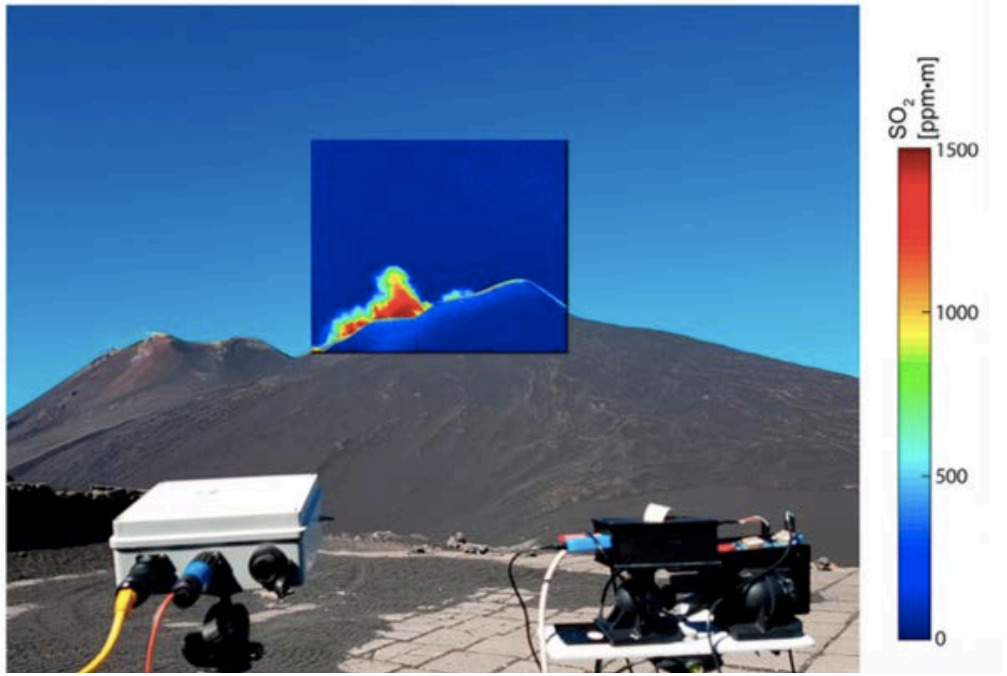
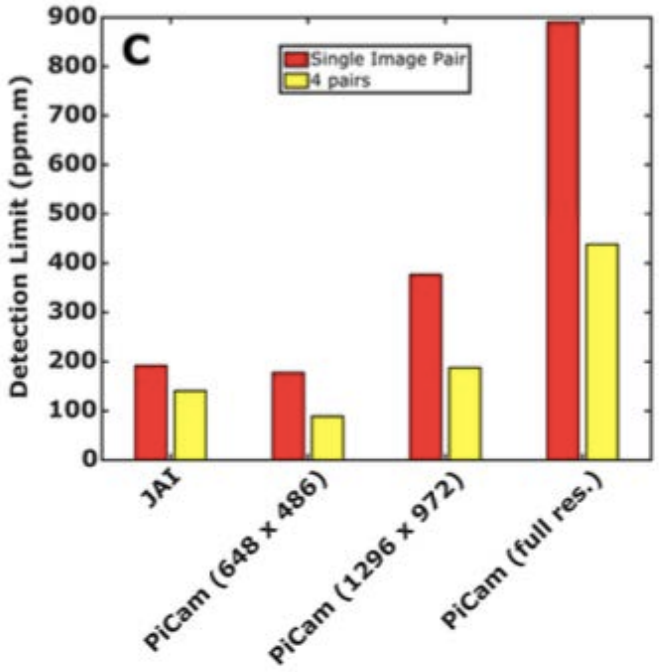
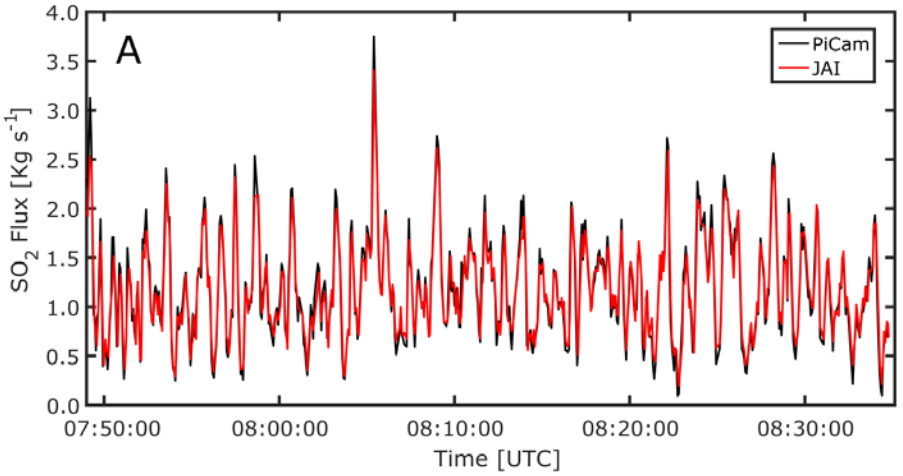
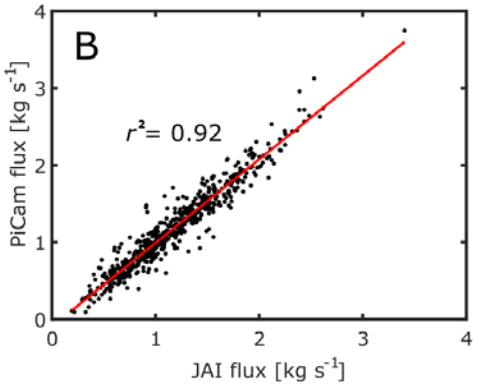
Field test on Mt. Etna









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

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Inexpensive thermal imaging

- Masaya volcano, Nicaragua; dynamics of lava lake behaviour

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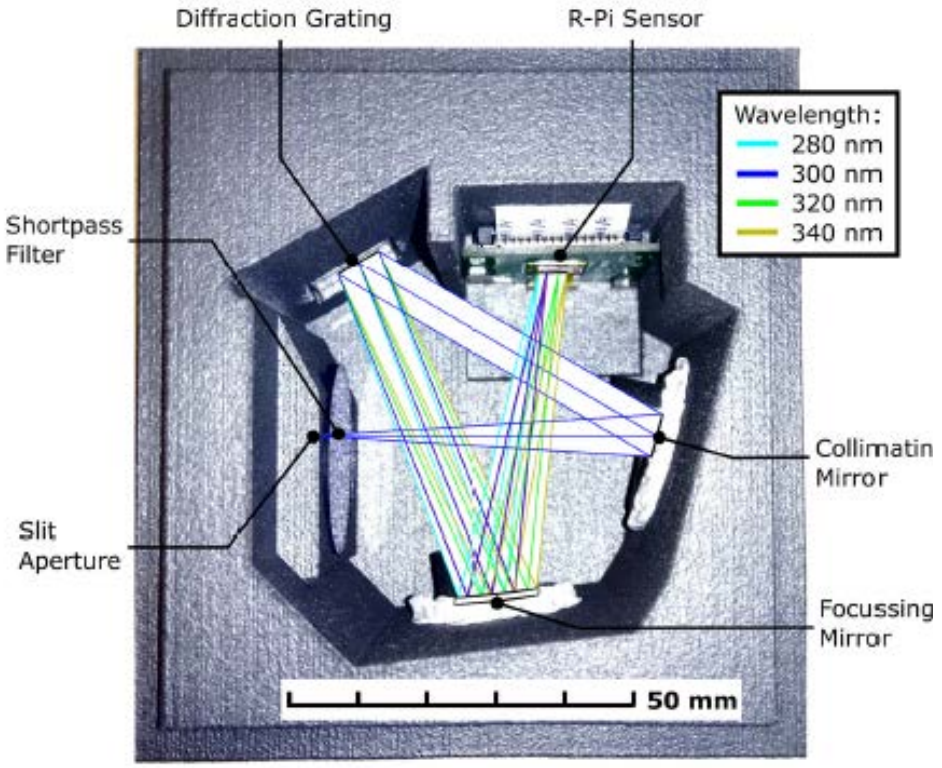
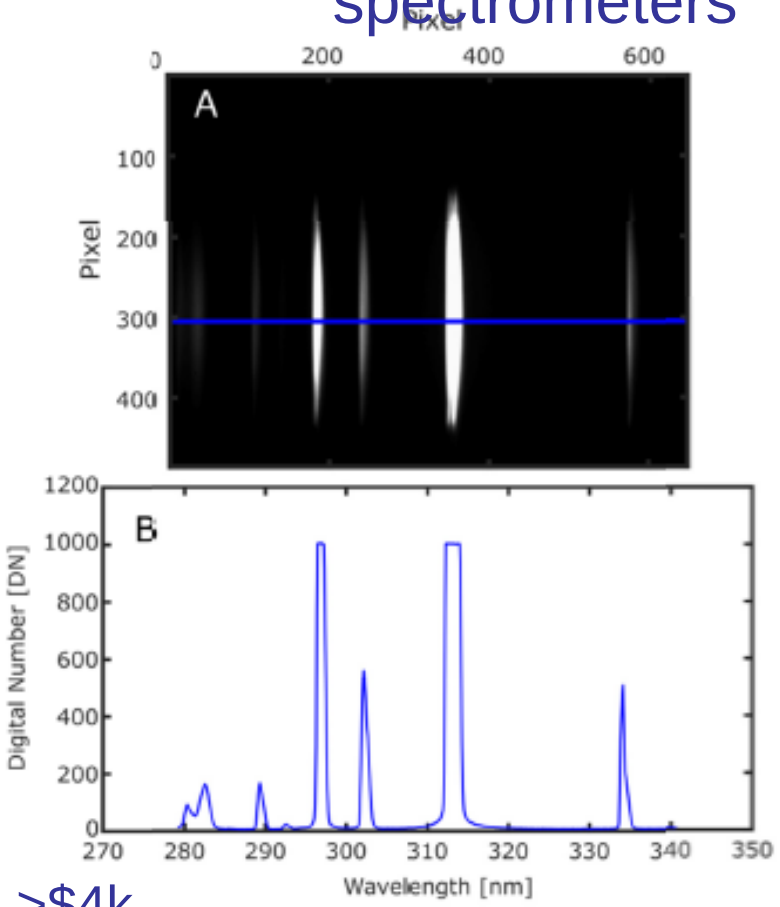
3D printed smartphone sensor spectrometers





- 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

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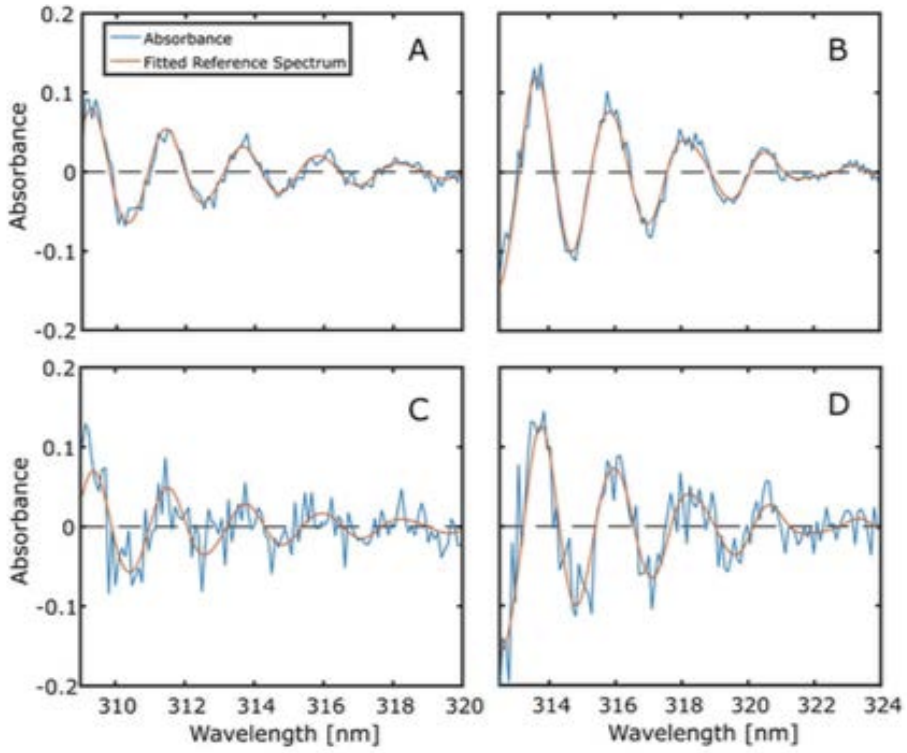
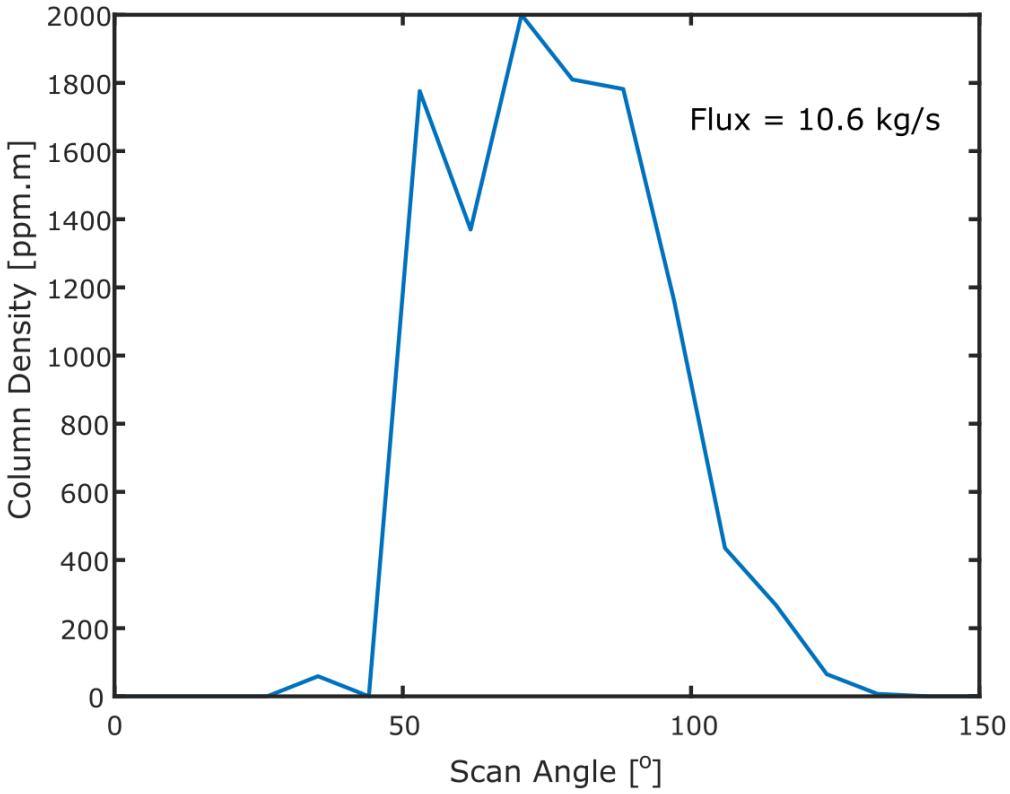
3D printed smartphone sensor spectrometers



- 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

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The future

- low cost and weight – drone and widespread operation

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

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References

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- 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.