Volcanic Gas Analytical Monitor (VGAM): Compact and Low Power Mass Spectrometer-based Instrumentation for Volcanic Gas Monitoring

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Stacked Mass Spectra from Field Auto-Run Program

Analyzable Gases: $\text{H}_2$, He, $\text{H}_2\text{O}$, $\text{N}_2$, $\text{O}_2$, Ar, NO, $\text{N}_2\text{O}$, CO, CO$_2$, $\text{H}_2\text{S}$, SO, SO$_2$ and CH$_4$
Vacuum plumbing: Mini-MIMS and Nafion Dryer reduce liquid/vapor water to MS. Diaphragm pump provides rough vacuum (3 Torr).
Stinger™ convection gauge monitors rough vacuum. NEG-Ion Pump provides high vacuum for MS, and Ion Pump provides high-vacuum monitor. A 10-micron aperture cuts pressure from 3 Torr to ~ 10⁻⁶ Torr.

Mass Spec: Granville-Phillips 835 Auto Resonant Ion Trap (ART MS), 1-145 amu mass range.
Power: @ 24V DC, **25 Watt** when measuring, **1 Watt** in sleep mode.
Scientific/Technical Description

NEG-Ion VGAM (early V-CAFÉ version)
Bench Test
Field Layout
Solar panels,
Sample bottles
Each run has two data files for background and sample. Each data file contains 167 averaged spectrums ("scans") containing 15,000 (0.01 amu) responses. Each run also contains high vacuum pressure for the 167 scans.

**Data Post-Processing**

- **MS Input data**
- **Read pressure**
- **Read each scan**
- **Subtract baseline**
- **Subtract background from sample response**
- **Average of scans 50-167, for each gas**
- **Multiply by High Vacuum pressure**
- **Normalized response for each gas, for each scan**
- **Determine the response for each gas**
- **Determine the response for entire spectrum**

**Final Output**

**Peak Width Tolerance = 0.50**
**Slope Tolerance = 1e-8**

**For each gas:** Identify peak and use slope to integrate under the curve.
Kilauea Sulfur Bank Deployment

![Kilauea Sulfur Bank, July 2014](chart.png)

- **Argon**
- **Nitrogen**
- **Oxygen**
- **CO2**
- **Water**
- **Methane**

Absolute PP (Torr)
Kilauea Sulfur Bank Deployment

Kilauea Sulfur Bank, July 2014

Time

Log Absolute PP (Torr)
Kilauea Sulfur Bank Deployment

Kilauea Sulfur Bank, July 2014

Log Absolute PP (Torr)

Time

Night

Night

Night
Instrument Temperature (°C)
Kilauea Sulfur Bank
July, 2014
Kilauea Sulfur Bank
July, 2014

○ = July 16 PM
○ = July 19 PM
Correlation Matrix for Gases
Principal Component Analysis

Normalized Factor Loadings

Atmospheric Factor (Ar, O₂, N₂ dominated)

Volcanic Factor (CO₂ dominated)

Water Factor (Humidity)
Lab Calibration for $\text{CO}_2$

$y = 4.789 \times 10^{-13}x + 1.1486 \times 10^{-9}$

$R^2 = 0.99934$
Kilauea Sulfur Bank Deployment – comparison to gas samples

3 day (72 hours) deployment

CO$_2$(ppm)
Kilauea Sulfur Bank Deployment – comparison to gas samples

The graph shows the CO$_2$/Ar ratio over a 3-day (72 hours) deployment from 7/16/14 to 7/20/14. The data points are represented by diamonds and orange squares, corresponding to CO$_2$/Ar ratios and gas samples, respectively. The graph also includes a dashed green line indicating the CO$_2$/Ar ratio of air.
Discussion & Conclusions

• Weather was a big factor in this short deployment, with increasing rainfall at the site over the deployment period. This apparently affected the signal strength from the fumarole, as seen in the decreasing partial pressures of all gases over time.

• A day-night pattern is clearly displayed that likely reflects the small ambient temperature variation. These partial pressure trends compare well with the internal temperature sensor data, but not with the fumarole temperatures taken manually.

• Although highly correlated, plots of Ar, O$_2$, H$_2$O, CO$_2$ and CH$_4$ versus N$_2$ show slope changes that reflect increasing volcanic signature with respect to nitrogen: higher CO$_2$ and H$_2$O and lower atmospheric Ar and O$_2$ over time. Methane is abundant but shows no trend over time. It is likely sourced from local microbial activity.

• Lab-calibrated CO$_2$ and CO$_2$/Ar trends compare well with bottle sampling, showing a decrease in CO$_2$ concentration over time, but an increase in CO$_2$/Ar, consistent with an increasing volcanic signature of the rainfall-diluted fumarole gas flux over time.
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Hard on the equipment!