Presentation Program

and

Abstracts

IAVCEI

Commission on the Chemistry of Volcanic Gases

The 15th Field Workshop on Volcanic Gases

Hokkaido, Japan,

Oral Presentation Schedule

September 1 (Monday)

Time	Title	Presenter (Affiliation)	Abst#
09:30–09:45	Opening Ceremony		
09:45–9:55	Synthesis of the Activities of the Board	Silvana Hidalgo Tobias Fischer	
09:55 –10:30	Fumarolic and Hydrothermal Activity in Kuttara, Tarumae and Usu Volcanoes	Ryo Takahashi (Hokkaido Research Organization)	
10:30-10:45	Presentation of the Decadal Program	Nicole Bobrowski	
	Session: Geochemistry of Magmatic Gases		
10:45-11:00	Clumped Nitrogen Isotopes Reveal $\delta^{15}N$ Signature of the Icelandic OIB Mantle	Tobias P. Fischer (University of New Mexico)	11
11:00–11:30	Tea Break		
11:30–11:45	Experimental Calibration of Carbon Isotope Fractionation for Volcanic CO_2	Hyunjoo Lee (Columbia University)	23
11:45–12:00	S-bearing Trace Compounds as Potential New Geoindicators in Volcanic and Geothermal Discharges	Matteo Lelli (INGV-Pisa)	24
12:00–12:15	What Do Control Degassing Rates of Open-Vent Volcanoes?	Hiroshi Shinohara (Geological Survey of Japan)	41
12:15–12:30	Spatial and Temporal Variations in Noble Gas Isotopic Compositions of Fumaroles and Hot/Cold Spring Gases at Kusatsu-Shirane Volcano	Hirochika Sumino (University of Tokyo)	43
12:30–14:00	Lunch		
	Session: Quantification, composition, and chemistry of volcanic plumes		

Time	Title	Presenter (Affiliation)	Abst#
14:00–14:15	Simulations of Volcanic Outgassing in the COHS System: Comparison of Modelled Outgassed Compositions with Field Measurements of Volcanic Plumes	Gianluigi Ortenzi (INGV-Catania)	39
14:15–14:30	Comparison of MultiGAS and FTIR Gas Ratios Measured During Icelandic Effusive Eruptions	Celine Mandon (Icelandic Meteorological Office)	27
14:30–14:45	Magmatic Gases in the Plume Can Be Oxidized If Bromine Monoxide Is Observed Near the Source	Alexander Nies (University of Orléans)	33
14:45–15:00	SO_2 Monitoring of Mayon Volcano from 2014–2023: Challenges and Insights in Assessing Eruptive Behavior	Deborah Fernandez (PHIVOLCS)	93
15:00–15:15	Eruptive Column Dynamics Observed via Thermal Infrared Imaging	Freddy Vásconez (Escuela Politécnica Nacional)	88
15:15–15:30	Monitoring Active Volcanoes During Wartime: The Case of Nyiragongo and Nyamulagira Volcanoes and the City of Goma (DR Congo)	Dario Tedesco (University of Campania)	46
15:30–15:45	VGR Processor: A Python-Based Software for Calculating Gas Ratios from multicomponent gas analyzers	Ali Zare (Universidad Nacional Autónoma de México)	57
15:45–16:00	Gas Measurements in the New Era of Eruptive Activity at Kīlauea, 2020–2025	Christine Sealing (USGS Hawaiian Volcano Observatory)	32
16:00–16:45	Flash Talks (30 x 1-minute presentations)		
16:45–18:30	Tea Break and Posters		

September 2 (Tuesday)

Time	Title	Presenter (Affiliation)	Abst#
09:10–09:15	Introduction of the Day		
	Session: Deciphering Volcanic Processes Using Gas Emission Observations		
09:15–09:30	Interpreting Gas Emissions During Current Unrest at Mount Spurr (Alaska) by Combining Airborne Monitoring with Degassing and Thermodynamic Reaction Modeling	Allan Lerner (USGS Cascades Volcano Observatory)	25
0930–09:45	Persistent outgassing of Nyiragongo volcano and the impact on drinking water quality	Sergio Calabrese (Università degli Studi di Palermo, INGV-Palermo)	89
09:45–10:00	Monitoring of Fumarolic Gas Compositions Using a Multi-GAS Station during the 2018 Eruption of Iwoyama Volcano, Kirishima Volcanic Complex, Japan	Masaaki Morita (University of Tokyo)	31
10:00–10:15	Volcanic Gases from Ebinokogen Ioyama Volcano, Japan	Takeshi Ohba (Tokai University)	37
10:15–10:30	Consideration of Sulfur Isotope Ratios in Hakone Volcanic Gas Since 2019	Seiya Toyoshima (Tokai University)	47
10:30–10:45	Studying Copahue Volcano's Plume Using Multigas: A Journey Through Crater Lakes and Phreatic Explosions	Nicolás Nuñez (Comisión Nacional de Energía Atómica)	64
10:45–11:00	Eruptive and Non-Eruptive Degassing in Active Volcanoes of Guatemala	Susana Layana (Universidad Andrés Bello)	79
11:00–11:30	Tea Break		
11:30–11:45	Volcanic Gas Compositions Reveal Different Magma Pathways Through the Crust That Control Eruption Dynamics in the 2023–2025 Sundhnúksgígar Eruptions	Melissa Anne Pfeffer (Icelandic Meteorological Office)	86
	Session: Innovations and Recent Advances in Observational Techniques and Methods		
11:45–12:00	Investigating CO_2 Diffuse Emission: Best Practices and Future Developments	Carlo Cardellini (Università di Perugia)	06

Time	Title	Presenter (Affiliation)	Abst#
12:00–12:15	Enhanced Monitoring of Volcanic Emissions with Geostationary Ultraviolet Satellite Data	Simon Carn (Michigan Technological University)	07
12:15–12:30	Estimating Emission Flux of H_2S from Fumarolic Fields Using Vertical Sensor Array System	Yutaka Miyagi (Nagoya University)	30
12:30–12:45	Development of On-Site Analysis Equipment for Helium Isotopes Using Multi-Turn Time-of-Flight Mass Spectrometer	Shogo Numata (University of Tokyo)	53
12:45–14:00	Lunch		
14:00–14:15	Insights from Simultaneous Measurement of CO_2 Soil Fluxes and Subsoil Gas Pressure Gradients at Stromboli Volcano	Giancarlo Tamburello (INGV-Bologna)	44
14:15–14:30	Development of a Drone-Borne Volcanic Plume Sampler SelPS for Remotely Determined Stable Isotopic Compositions of Fumarolic CO_2, H_2, and H_2O	Urumu Tsunogai (Nagoya University)	49
14:30–14:45	What Is the Future of Multi-GAS Monitoring? Global Network of the Future or Too Specialized to Scale?	Peter Kelly (US Geological Survey)	60
14:45–15:00	CCVG Remote Sensing Group Measurements at Sabancaya: Comparison and Analysis	Santiago Arellano (Chalmers University of Technology)	82
15:00–15:15	sGs UnMix: A Web Application for Spatial Prediction and Mixture Modeling of Volcanic Soil CO_2 Fluxes	Giulio Bini (INGV-Bologna)	84
15:15–15:30	Steam and Fire: Drone-Based Techniques for Volatiles Study of Plumes and the Water Sources Interplay in Active Volcanoes	Felipe Rojas Vilches (University of New Mexico)	40
15:30–16:00	Instructions for the Field		
16:00–16:45	Flash Talks (30 x 1-minute presentations)		
16:45–18:30	Tea Break and Posters		

September 6 (Saturday)

Time	Title
09:10–11:00	Group Meetings
11:00–11:30	Tea Break
11:30–12:30	Discussion of the Decadal Program
12:30–14:00	Lunch
14:00–14:30	Elections: Presentation of Candidates
14:30–14:45	Elections
14:45–15:30	Presentation of Potential Sites for Organizing the Next Workshop
15:30–16:00	Election of the Next Workshop Site
16:00	Closing of the Workshop
18:00–19:30	Dinner
20:00–22:00	Farewell Party

List of Poster presentations

Abst #	Title	Presenter (Affiliation)
02	Chemical Signatures of Ash-Leachates as Indicators of Eruptive Styles at Stromboli Volcano (2019–2024)	Emanuela Bagnato (INGV-Roma1)
03	Wavelet Coherence for Volcanic SO_2 Detection: Applied to UV Spectra from Ruapehu and Iceland	Charlotte Barrington (Nanyang Technological University)
04	Volcanic Degassing Across Asia: Enhanced Characterisation Through Multi-GAS Campaigns and the Development of a Low-Cost Monitoring Instrument	Charlotte Barrington (Nanyang Technological University)
08	Evidence for magma intrusion beneath Trident Volcano, Alaska from multi-GAS and direct gas sampling	Laura Clor (USGS CVO)
09	A cross-comparison of thermal infrared vs ultraviolet ground-based retrievals of SO_2 masses during Strombolian explosions	Elisabetta Del Bello (INGV-Roma1)
10	Drone-based plume CO_2 sampling and flux measurements: changes in $\delta^{13}C$ track magma degassing and volcanic activity	Tobias P. Fischer (University of New Mexico)
12	Temporal and Spatial Variations of $^3He/^4He$ Ratios in the Kirishima Volcanic Group: Implications for Volcanic Activity Assessment	Nanae Fukushima (University of Tokyo)
13	Quantification of Chlorine (Cl_2), Bromine chloride (BrCl) and Bromine (Br_2) in volcanic plumes via drone-based measurements: Studies at Mt Etna (Italy)	Bastien Geil (Johannes Gutenberg-University)
14	$\delta^{13}C$-CO_2 and Soil CO_2 Flux Measurements as Key Indicators of Volcanic Dynamics Prior to the 2024 Eruptive Events at Stromboli Volcano	Giovanni Bruno Giuffrida (INGV)
15	Repetitive observations of soil diffuse CO_2 fluxes at Mt. Usu	Nayuta Izumi (Hokkaido University)
18	Towards continuous remote sensing of volcanic water, carbon dioxide, and hydrogen fluoride emissions	Jonas Kuhn (University of California)
19	How fast do high temperature magmatic gases adapt to changes in temperature and pressure?	Jonas Kuhn (University of California)
20	Evidence of magmatic and hydrothermal signatures in gas emissions from Deception Island volcano, Antarctica	María Clara Lamberti (Universidad de Buenos Aires)
21	What controls CO_2 Diffuse Emissions at Deception Island volcano, Antarctica?	María Clara Lamberti (Universidad de Buenos Aires)
22	Studying Copahue Volcano's Plume Using Multigas: A Journey Through Crater Lakes and Phreatic Explosions	María Clara Lamberti (Universidad de Buenos Aires)

Abst #	Title	Presenter (Affiliation)
26	Assessing the volcanic implications of the 2025 seismic activity in the Santorini region	Marco Liuzzo (INGV)
29	Interdisciplinary Application Of Drone-Mounted And Ground-Based MultiGAS Instruments	Suzanne Mikhail-Lee (McGill University)
34	Fast near-source oxidation of mercury in volcanic gases: Measurements and Model simulations	Alexander Nies (University of Orléans)
35	Evaluation of volcanic activity using geochemical monitoring with multivariate analysis	Nozomi Numanami (Tokai University)
38	Volcanic gas measurement by using drone and Multi-GAS at Mt. Tokachi, Hokkaido in 2023 and 2024	Atsuya Onishi (Hokkaido University)
42	Expansion of a degassing area in the north flank of Fogo Volcano (S. Miguel, Azores)	Catarina Silva (IVAR- CIVISA)
45	Advancing Volcanic Gas Measurement: Open-Source Applications for Data Analysis of Gas Sensors	Giancarlo Tamburello (INGV-Bologna)
48	Geochemical Monitoring of Active Volcanoes in the Philippines	Jerome Peter Traviña (PHIVOLCS)
50	CO_2 fluxes and gas ratios at Campi Flegrei, Italy, measured by drone-based MultiGAS in near-real time and comparison with ground-based measurements	Gustavo Villarruel (McGill University)
51	Diffuse Flux: Towards an Integrated Measurement and Near Real-Time Data Processing Approach	Giorgio Virgili (Independent Advisor)
52	Influence of hydrothermal fluids on the lithium enrichment in evaporitic brines of the Altiplano-Puna region: Evidences from fluid geochemistry	María de Lucia Vitón Albet (Catholic University of the North (Chile))
53	The nature of fumarolic gases collected at Ojigokudani, Iwate volcano, Japan in September 2024	Muga Yaguchi (MRI-JMA)
54	Noble gas geochemistry of the latest eruption in Ioto island (Iwo-jima)	Soho Yamamoto (University of Tokyo)
55	Estimation of Generation Process of Elemental Sulfur Through Groundwater Chemical Analysis at Shiretokoiozan Volcano, Hokkaido, Northeastern JAPAN	Mutsunori Yamamoto (Osaka Museum of Natural History)
56	Gas Measurements Reveal Fractional Degassing and Water Interaction During a Flank Eruption of Pacaya Volcano (Guatemala)	Ali Zare (Universidad Nacional Autónoma de México)

Abst #	Title	Presenter (Affiliation)
59	Continuous monitoring of the CO_2/H_2S ratio in volcanic gas at Hakone volcano	Kotaro Toyama (Hot Springs Research Institute of Kanagawa Prefecture),
61	Monitoring a volcanic fissure zone using diffuse degassing – challenges associated with the 2022 São Jorge seismovolcanic crises	Fátima Viveiros (IVAR- Universidade dos Açores)
62	Geochemistry of Gas Emissions in the Yellowstone Plateau Volcanic Field: New Insights into Peripheral Areas	Sara Peek (USGS CalVO)
63	Decoding mantle degassing at a quiescent basaltic volcano: insights from surface CO_2 fluxes and fluid inclusions on Bioko Island	Christine R. Sealing (University of Hawaii, Hilo)
65	The Chemical Impacts of Volcanic Lightning: A Comprehensive Simulation and Assessment Approach	Chen Xu (Ludwig-Maximilians-Universität München)
66	Gas ratios in the plume as proxies for magmatic degassing dynamic in an open-conduit volcano: insights from monitoring at Stromboli, Italy	Fausto Grassa (INGV-Palermo)
67	SO_2-to-Sulfate Conversion in Volcanic Plumes: Insights from the 2014–2015 Holuhraun Eruption	Julia Schunke (Ludwig-Maximilians-Universität München)
68	Shallow conduit controls on degassing: vesiculation- and sintering-driven permeability evolution	Julia Schunke (Ludwig-Maximilians-Universität München)
69	CO_2 diffuse degassing in volcanic lakes in Ecuador	Daniel Sierra (Instituto Geofísico de la Escuela Politécnica Nacional)
70	Multiparametric evolution of the 2022–2023 mild eruption of Cotopaxi volcano (Ecuador)	Silvana Hidalgo (Instituto Geofísico de la Escuela Politécnica Nacional)
71	Redox state of hydrothermal systems and implications for volcano monitoring	Andrea Ricci (Department of Earth Sciences)
72	Estimation of the SO_2 emission of the 800 BP eruption of Quilotoa volcano (Ecuador)	Diego Narváez (University of Pisa)
74	Evidence of magmatic and hydrothermal signatures in gas emissions from Deception Island volcano, Antarctica	Lucas Guerriero (Escuela Politécnica Nacional)

Abst #	Title	Presenter (Affiliation)
75	Geothermal activity from 2015 to 2024 with the 2018 minor eruption at Ebinokogen-Ioyama in Kirishima Volcano, Japan	Yasuhisa Tajima (Nippon Koei)
76	Geochemistry of the hydrothermal fluids from the Western Cordillera area, Departamento de Potosí, Bolivia	Felipe Aguilera (Universidad Andrés Bello)
77	Geochemistry of fluids emitted from the hydrothermal systems of Moyuta volcano and Ixpaco lake (Tecuamburro volcano), Guatemala	Felipe Aguilera (Universidad Andrés Bello)
80	Calibration of SO_2 Cameras with Long Pass Glass Filters: Towards Simplified Field Measurements	Toshiya Mori (The University of Tokyo)
81	Recent developments for measurements of gas flux and ash in plumes and detection of anomalous soil degassing in volcanic areas	Santiago Arellano (Chalmers University of Technology)
83	NOVAC: 20 years of global collaboration on volcanic gas studies	NOVAC Collaboration (novac-community.org/partners)
85	Geochemistry of Magmatic and Hydrothermal Fluids from Isluga Volcano, Northern Chile	Cristóbal González (Universidad Andrés Bello)
87	Lastarria volcano emits substantial concentrations of B and chalcophiles in northern Chile and the Central Volcanic Zone	Manuel Inostroza (Universidad Andrés Bello)
90	Infrared and Ultraviolet Remote Sensing of Sulfur Dioxide Gas Emitted During the 2018 Lower East Rift Zone Eruption of Kīlauea Volcano, Hawai`i	Allan Lerner (USGS Cascades Volcano Observatory)
91	SO_2 Monitoring by Continuous Scanning DOAS at Sinabung, Gamalama and Merapi Volcanoes, Indonesia	Syegi L. Kunrat (CVGHM)
92	Characterisation of Volcanic Gases at Tangkuban Parahu Volcano, West Java, Indonesia by Multi-GAS Stationary Measurement	Hilma Alfianti (CVGHM)
95	Trace Element Emissions from the Tajogaite Eruption, La Palma, Canary Islands	Nemesio M. Pérez (INVOLCAN)
96	Thirty Years of Geochemical Monitoring at Teide Volcano: Implications for Early Detection of Volcanic Unrest	Gladys V. Melián (INVOLCAN)
97	Soil gas geochemistry as evidence of ^{40}Ar transport	Eleazar Padrón (INVOLCAN)
98	Carbon dioxide hazard monitoring at Puerto Naos and La Bombilla inhabited areas, La Palma, Canary Islands	Pedro A. Hernández (INVOLCAN / ITER)
99	Geochemical Evolution and Activity Indicators of the Hydrothermal System in the Tatun Volcano Group, Northern Taiwan (2014–2022)	Hsiao-Fen Lee (National Center for Research on Earthquake Engineering)

Abstract 02

Chemical Signatures of Ash-Leachates as Indicators of Eruptive Styles at Stromboli Volcano (2019–2024)

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Daniele Cinti, Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma1, Italy
Elisabetta Del Bello, Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma1, Italy
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During volcanic eruptions, ash and gas release triggers complex physical and chemical processes, leading to the deposition of magmatic volatiles as water-soluble salts on ash particle surfaces, known as ‘ash-leachates’. Analyzing these leachates provides crucial insights into volcanic gas compositions and eruptive dynamics. Specifically, molar ratios of S/Cl, S/F, and Cl/F serve as sensitive indicators of eruptive intensity, reflecting changes in the gas plume composition. Stromboli volcano (Italy), renowned for its persistent explosive activity and frequent ash emissions, offers an ideal natural laboratory for investigating gas-ash interactions. This study presents a five-year dataset (2019-2024) of ash-leachates analysis, focusing mainly on chlorine (Cl), fluorine (F), and sulfur (S), obtained from 119 freshly erupted ash samples. These samples encompass a broad range of eruptive scenarios, including ordinary and effusive activity, major and paroxysmal explosions, littoral blasts, and pyroclastic flows from lava front collapses. The research examines how leachates’ composition varies across different eruption styles. Despite the high heterogeneity of ash-leachates’chemistry due to the complex and time-dependent interplay of factors, elevated S/Cl and S/F ratios consistently correspond with high-energy events. These include the paroxysms of July 2019 and 2024, the explosive-effusive phases and associated pyroclastic flows between 2021-2023, and littoral explosions following the 2024 paroxysm. Notably, data associated with similar eruptive styles show a strong year-to-year correlation (r^2 = 0.7-0.8). After these high-energy episodes, S/Cl and S/F ratios return to baseline levels typical of Stromboli’s persistent activity.

Abstract 03

Wavelet Coherence for Volcanic SO_2 Detection: Applied to UV Spectra from Ruapehu and Iceland

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Accurate quantification of volcanic sulphur dioxide (SO_2) emissions is crucial for monitoring volcanic activity. However, Differential Optical Absorption Spectroscopy (DOAS)—the standard technique—can yield uncertain results due to its reliance on user-defined fitting parameters and the need for expertise to visually inspect the fit results. In this study, we apply a recently developed method based on Magnitude-Squared Wavelet Coherence (MSWC) to ultraviolet (UV) spectra from Ruapehu volcano, New Zealand, as well as from an Icelandic volcano, where traditional DOAS analysis produces ambiguous results regarding the presence or absence of small amounts of SO_2. This approach exploits the well-defined spatial frequencies present in sky-scattered UV spectra, which are modified by SO_2 absorption. By comparing spatial frequencies between spectra, we can identify those containing the signature of the volcanic plume, with the resulting MSWC offering a potential method for estimating SO_2 slant column densities (SCDs). This technique has the potential to complement traditional DOAS methods by providing an objective check on the results and assessing the reliability of selected fitting parameters, particularly in cases where DOAS returns uncertain or ambiguous results. This approach is potentially extremely useful for pre-eruptive monitoring at volcanoes around the world where SO_2 leaves the magma at shallow depths. Furthermore, the decrease in uncertainty when detecting low or no SO_2 is crucial in determining the state of a seal below the volcanic edifice before phreatic eruptions.

Abstract 04

Volcanic Degassing Across Asia: Enhanced Characterisation Through Multi-GAS Campaigns and the Development of a Low-Cost Monitoring Instrument

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Volcanic emissions of CO_2, SO_2 and H_2S are sensitive indicators of magma degassing processes and eruption potential. Monitoring temporal variations in the chemical ratios of these three species is of special interest at volcanoes where geophysical precursors are limited. Real-time survey of such chemical gas variations is possible thanks to the recent advent of in situ compact multi-sensors such as Multi-GAS instruments.

Here, we present data from three Multi-GAS field campaigns conducted at Marapi volcano (Sumatra) in 2014 and 2018 and at Gede volcano (Java) in 2017. Marapi, the most active volcano in Sumatra, is characterised by short-lived explosions and prolonged eruptions with minimal geophysical precursors. In contrast, Gede, located 60 km south of Jakarta, has exhibited intermittent seismicity and fumarolic activity since its last eruption in 1957. Our CO_2/SO_2 data for Marapi, the first ones for a Sumatran volcano, further verify a low sulphur content in volcanic emissions along the Sunda Arc, but also allowed us to detect increasing sulphur release (3 times lower CO_2/SO_2 ratio) one month before two explosive eruptions at Marapi in April and May 2018, indicating shallower pre-eruptive magma degassing. At Gede, H_2S-dominated degassing with stable H_2S/SO_2 ratio show that spatially distinct surface emissions are fed by a single source at depth.

To enhance degassing monitoring at volcanoes across Asia, we developed a low-cost Multi-GAS instrument. This instrument will be deployed at the Maruyamasawa Fumarolic Geothermal Area (MFG) at Zao or Azuma volcano in Japan for performance assessment and detailed analysis of fumarolic emissions.

Abstract 06

Investigating CO_2 diffuse emission: best practices and future developments

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Volcanoes and geothermal systems emit volatiles through active plumes, fumarolic vents and diffuse degassing. Diffuse CO_2 degassing may constitute the dominant mode of volatiles emission, particularly from calderas and volcanoes with hydrothermal activity. The measurement, characterisation and quantification of diffuse degassing are key to understanding the state of volcanic activity, volatile budgets and associated energy release. Since the late 1990s, numerous researchers and companies have developed instrumentation and methodologies for data acquisition and processing based on the accumulation chamber method. The worldwide application of this methodological approach and the exponential increase in publications using this method over the last decade recall the need to ensure the reliability and robustness of the achievable results by defining "best practices" for: i) instrument set-up, calibration and maintenance, ii) survey planning and development, iii) collection of field parameters and sampling of emitted gas, iv) statistical and geostatistical methods for flux characterization, mapping and budget estimation. The "best practices" resulting from a round table discussion among gas flux scientists held at the 1st IAVCEI CCVG-CVL Joint Meeting, in Romania in 2024, will be presented along with future challenges in the study of diffuse degassing.

Abstract 07

Enhanced Monitoring of Volcanic Emissions with Geostationary Ultraviolet Satellite Data

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Brad Fisher, Science Systems and Applications, Inc., USA
Nickolay Krotkov, NASA Goddard Space Flight Center, USA

Satellite measurements of volcanic sulfur dioxide (SO_2) and ash emissions support volcanic hazard mitigation, permit assessment of the potential climate impacts of eruptions, and provide insight into volcanic processes. Until recently, a shortcoming of ultraviolet (UV) satellite observations was low temporal resolution. However, since 2020 a new Geostationary UV Air Quality (GEO-AQ) satellite constellation has been deployed, including the South Korean Geostationary Environment Monitoring Spectrometer (GEMS), NASA's Tropospheric Emissions: Monitoring of Pollution (TEMPO), and the forthcoming European Sentinel-4 mission. GEO-AQ satellites have initiated a new era of hyperspectral UV monitoring of volcanic SO_2 emissions (and potentially other volcanic gases such as BrO) in East Asia (including northern Indonesia, the Philippines, and Japan), North America and Europe with unprecedented hourly temporal resolution in daytime. This higher temporal resolution increases the probability of cloud-free observations of volcanic plumes, permits the detection of transient volcanic degassing events, and provides new insights into plume dynamics. Here, we ufse operational SO_2 data products from GEMS and preliminary TEMPO SO_2 retrievals to highlight some volcanological applications of GEO-AQ observations in East Asia and Mexico, including measurement of hourly variations in SO_2 emission rates, improved monitoring of multi-phase eruptions, and enhanced detection of small eruptions. Synergy between geostationary UV measurements of SO_2 degassing and infrared (IR) measurements of volcanic heat flux also has the potential to elucidate volcanic processes and improve satellite-based volcano monitoring.

Abstract 08

Evidence for magma intrusion beneath Trident Volcano, Alaska from multi-GAS and direct gas sampling

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Trident Volcano, on the Alaska Peninsula (USA), last erupted in 1953-1974, producing 0.5 km^3 of lava and tephra. Following a period of apparent quiescence, elevated seismicity in 2022–2023 progressed from a depth of 25 km up to 5 km beneath Trident, and was associated with slight inflation on the southern flank. This was interpreted as the ascent of magma or magmatic fluids, and prompted the Alaska Volcano Observatory to raise the alert level to YELLOW/ADVISORY in September 2022. Geophysical unrest continued through 2023, but no gases were detectable at Trident with airborne techniques. By January of 2024, seismic activity had diminished to background rates, and the alert level was lowered to GREEN/NORMAL. In summer 2024, a ground-based field campaign was undertaken to measure the volcanic gas composition by collecting direct gas samples and multi-GAS measurements from the volcano's SE flank fumarole field to compare with prior measurements collected in 2013 (Lopez et al., 2017). There was good agreement in multi-GAS and direct sampling compositions in both studies. Gas compositions were more CO_2-rich in 2024 (following the unrest), with H_2O/CO_2 ratios decreasing from 8 to 2.2 and CO_2/H_2S increasing from 11.3 to 19.8. This shift to a more CO_2-rich gas composition indicates degassing of a deeper, more volatile-rich magmatic source in 2024, and supports an interpretation of magma intrusion beneath Trident between 2022–2023 as inferred from real-time geophysical data.

Abstract 09

A cross-comparison of thermal infrared *vs* ultraviolet ground-based retrievals of SO_2 masses during Strombolian explosions

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This study explores sulfur dioxide (SO_2) emissions from explosive activity at Stromboli volcano using ground-based remote sensing methods. We analyze the relationship between SO_2 masses measured by ultraviolet (UV) and thermal infrared (TIR) cameras, in conjunction with explosion parameters such as type, duration, frequency, intensity, and pyroclast ejection velocity, the latter determined using a high-frequency (30 Hz) FLIR thermal camera. The dataset comprises 49 explosive events recorded during a field campaign conducted on May 23–24, 2023, involving two active vents. The explosions ranged from gas-dominated (Type 0) to bomb-dominated (Type 1) and ash-rich (Type 2) events. UV cameras operated at 10–30 Hz, while TIR cameras acquired data at 0.5 Hz, allowing for SO_2 mass retrieval from each frame. Both systems detected consistent SO_2 peaks within the volcanic plume; however, the correlation between UV- and TIR-derived SO_2 masses varied depending on explosion type. During non-explosive intervals, UV and TIR SO_2 signals were well correlated. In contrast, explosive events revealed a systematic offset: TIR-derived SO_2 masses were up to 20 times higher than UV values for Type 2b explosions and 2–7 times higher for other types. These discrepancies likely stem from the TIR method overestimating SO_2 due to thermal effects, and the UV method underestimating it because of ash-induced signal attenuation. Our findings underscore the complementary nature and respective limitations of UV and TIR techniques, supporting the need for an integrated UV-TIR approach to enhance the accuracy of volcanic SO_2 measurements.

Abstract 10

Drone-based plume CO_2 sampling and flux measurements: changes in $d^{13}C$ track magma degassing and volcanic activity

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Rapid measurement of volcanic CO_2 emissions is an eruption forecasting tool because of CO_2's low solubility in magmas and its early release from ascending melts. CO_2 emissions from volcanoes during quiescence and eruptions is central to reconstructing the geological carbon cycle. CO_2 emitted from volcanoes during eruptions utilizing currently available remote sensing approaches, remain rare as are C isotope measurements obtained at the same time. Rayleigh-type C isotope fractionation is expected to result in lighter $\delta^{13}C$ values as basaltic magma degasses.

During the 2023 eruption of Litli Hrútur, Reykjanes Peninsula, we utilized a novel method for measuring the CO_2 flux of volcanic plumes (Ericksen et al., 2024). We collected data starting on July 14, 2023, less than a week after eruption initiation. Our CO_2 flux measurements are lower but comparable to emissions using traditional methods. Plume samples collected by UAV and analyzed by IRIS immediately after collection, reach $\delta^{13}C$ values of extrapolated pure CO_2 consistent with Reykjanes thermal fluids (- 3 to - 5 ‰) and distinctly different from lighter values of samples collected from nearby vents prior to eruption. As the eruption progressed, $\delta^{13}C$ values become lighter and months after the end of the eruption (December 2023), $\delta^{13}C$ values were as light as those in samples collected prior to eruption start. Our data implies that plume $\delta^{13}C$ can be used to assess extent of magma degassing, forecast eruption termination, and provide constraints on the CO_2 content of undegassed melts (Fischer et al., 2024).

Ericksen, J., Fischer, T., Fricke, G.M., Nowicki, S., Pérez, N., Hernández Pérez, P., Padrón González, E. and Moses, M., 2024. Drone CO_2 Measurements During the Tajogaite Volcanic Eruption. Atmos. Meas. Tech. Discuss., 2024: 1-17.

Fischer, T.P., Mandon, C.L., Nowicki, S., Ericksen, J., Vilches, F.R., Pfeffer, M.A., Aiuppa, A., Bitetto, M., Vitale, A., Fricke, G.M., Moses, M.E. and Stefánsson, A., 2024. CO_2 emissions during the 2023 Litli Hrútur eruption in Reykjanes, Iceland: $\delta^{13}C$ tracks magma degassing. Bulletin of Volcanology, 86(6): 60.

Abstract 11

Clumped nitrogen isotopes reveal $d^{15}N$ signature of the Icelandic OIB mantle

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The nitrogen isotope composition of the lower mantle that feeds OIB magmatism has remained elusive. Nitrogen's high abundance in air and air-saturated waters circulating at shallow levels in hydrothermal systems often results in contamination of the magmatic or mantle signature. Advances in stable isotope mass spectrometry and the development of large radius gas-source multi-collector sector field instruments have enabled the measurement of $D^{30}N$ and $d^{15}N$ simultaneously in natural and synthetic materials. $D^{30}N$ is an unambiguous and sensitive tracer of air-derived N ($D^{30}N$ = 19.1 ± 0.3‰) and high-temperature N ($D^{30}N$ = 0.0‰). Samples collected from hot springs in Yellowstone National Park have low $D^{30}N$ signatures that extrapolate to a pristine $d^{15}N$ value of +3 ‰. This positive value is significant as it suggests contribution of a subducted N component to the hot spot mantle source region (Labidi et al., 2020).
Here we present the first $D^{30}N$ and $d^{15}N$ values of samples collected from Icelandic hydrothermal systems that show non-air $D^{30}N$. Our samples are from geothermal boreholes at Krafla, Theistareykir, Namasfjall, Reykjanes and Svartsengi and fumaroles at Kerlingafjöll. While most samples have $D^{30}N$ close to 19‰, one borehole sample from Svartsengi, sampled during the 2024 eruptive activity in the region, has a distinctly lower $D^{30}N$ (14.9‰) and a $d^{15}N$ of –1.14‰. Extrapolation to 0.0 ‰ in $D^{30}N$ assuming a negative slope, gives a slightly positive $d^{15}N$. At face value, this result implies that the mantle supplying Iceland's OIB magmas contains surface-derived nitrogen. More work on OIB fluids is needed to confirm data collected in these settings.

Labidi, J., Barry, P.H., Bekaert, D.V., Broadley, M.W., Marty, B., Giunta, T., Warr, O., Sherwood Lollar, B., Fischer, T.P., Avice, G., Caracausi, A., Ballentine, C.J., Halldórsson, S., Stefánsson, A., Kurz, M., Kohl, I. and Young, E.D., 2020. Hydrothermal 15N15N abundances constrain the origins of mantle nitrogen. Nature, 580: 367–371.

Abstract 12

Temporal and Spatial Variations of $^3He/^4He$ Ratios in the Kirishima Volcanic Group: Implications for Volcanic Activity Assessment

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Helium isotope ratios ($^3He/^4He$) in volcanic gases are useful indicators of magmatic fluid contributions and can assess volcanic activity. We investigate temporal and spatial variations of $^3He/^4He$ in gases from Kirishima volcanic group, southern Kyushu, Japan, focusing on Shinmoe-dake and Ebinokogen Iwo-yama (hereafter, Iwo-yama), both of which have erupted since the 20th century. Based on the volcanic subsurface structure inferred from geophysical observations (Nakao et al., 2013), the two volcanoes may share the same magma reservoir.

From 2016 to 2025, gas samples were collected every few months from Iwo-yama fumaroles and Shinyu fumarole on Shinmoe-dake's southwest flank. We examined how temporal $^3He/^4He$ variations relate to volume changes in the pressure source beneath Iwo-yama, estimated through precision leveling surveys. A low-resistivity layer was identified at 200–700 m depth beneath Iwo-yama (Tsukamoto et al., 2018).

Significant variations in the $^3He/^4He$ ratios were observed at Iwo-yama surrounding the 2017 and 2018 eruptions. The $^3He/^4He$ ratio increased before the 2017 Shinmoe-dake eruption, decreased afterward, and increased again during the 2018 eruptions at both Shinmoe-dake and Iwo-yama. Concurrently, the volume of the pressure source beneath Iwo-yama also rapidly expanded. Since then, the $^3He/^4He$ ratio has gradually risen with minor fluctuations, alongside continued the pressure source expansion. Agreement between geochemical and geophysical data indicates that volatile ascent from the magma reservoir influences volcanic activity.

In contrast, the Shinyu fumarole exhibits periodic $^3He/^4He$ fluctuations every 9–12 months, with unknown causes. Clarifying this periodicity is essential for assessing its utility in monitoring Shinmoe-dake activity.

Abstract 13

Quantification of Chlorine (Cl_2), Bromine chloride (BrCl) and Bromine (Br_2) in volcanic plumes via drone-based measurements: Studies at Mt Etna (Italy)

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Halogens are a key component of volcanic emissions, and the ratio of halogens to quasi-inert dilution tracers (e.g., S_{total}) serves as a potential indicator of changes in volcanic activity. Only a limited number of halogen species (e.g., BrO, OClO, HCl, HF) can be reliably quantified by remote sensing. BrO, for instance, forms through the oxidation of HBr via reactions with ambient O_3 and HO_2. Understanding these rapid oxidation processes—occurring within minutes of emission—is essential for linking remote observations to source conditions.

We conducted UAV-based sampling at varying distances (10–5300 m) from the Bocca Nuova crater (Mt. Etna) during field campaigns in 2022 and 2023. Reactive halogen species were collected using in situ derivatization agents on filters, while total halogen and sulfur were collected using aqueous alkaline traps. We present quantitative results for total chlorine, bromine, sulfur, and for the first time, differentiate Cl_2, Br_2, and BrCl in volcanic plumes. The maximum observed molar ratios in 2022 were $Cl_2/S = 7 \times 10^{-5}$, $BrCl/S = 3 \times 10^{-4}$, $Br_2/S = 2 \times 10^{-5}$ and average ratios were Cl/S = 1.4 and $Br/S = 4.0 \times 10^{-3}$. Less than two minutes after emission the proportion of oxidized bromine was 98 % of total bromine. Our data confirm a rapid increase in reactive bromine and reveal a clear chemical distinction between reactive halogen species and total halogen content.

This data set provides novel constraints on reactive halogen chemistry and supports the development of future plume chemistry models.

Abstract 14

$d^{13}C$-CO_2 AND SOIL CO_2 FLUX MEASUREMENTS AS KEY INDICATORS OF VOLCANIC DYNAMICS PRIOR TO THE 2024 ERUPTIVE EVENTS AT STROMBOLI VOLCANO

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Continuous monitoring of these emissions - particularly in terms of fluxes and isotopic composition - is critical for assessing volcanic activity and supporting risk mitigation strategies. Stromboli, a persistently active volcano, is characterized by frequent low-energy Strombolian explosions and occasional higher-energy events, ranging from major explosions to paroxysms. In 2024, a sequence of eruptive episodes provided a clear illustration of the volcano's dynamic explosive and effusive behaviour.
This study presents the results of periodic $\delta^{13}C$- CO_2 measurements obtained from six discrete sampling sites over a two-year period. At two of these sites, continuous CO_2 flux data (recorded hourly) have also been acquired since February 2024. These sites, located between 1 and 2.5 km from the craters, were selected following several field surveys conducted across the island as part of a project aimed at enhancing the geochemical monitoring network of Stromboli volcano. Collectively, these datasets capture the degassing dynamics throughout 2024, encompassing multiple eruptive phases.
Our analysis identifies a magmatic input to the system beginning in April 2024, evidenced by increased CO_2 fluxes and a corresponding shift toward a magmatic isotopic signature. The timing of this magmatic contribution is consistent with ascent rates observed in previous Stromboli eruptions, highlighting the diagnostic value of soil CO_2 monitoring in detecting pre-eruptive magmatic processes, particularly those associated with high-energy explosive events. These findings underscore the importance of soil gas surveillance as a key component of volcanic hazard assessment and mitigation efforts.

Abstract 15

REPETITIVE OBSERVATIONS OF SOIL DIFFUSE CO_2 FLUXES AT MT. USU

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Volcanic gases are released from fumaroles and are also diffused from the ground surface. At Mt. Usu, diffuse CO_2 fluxes were measured before and after the 2000 eruption (Hernández et al., 2001), and the flux in the summit area increased 6 months before the eruption. This suggests that repetitive observations of the CO_2 fluxes may provide valuable information for eruption forecasting.
Hokkaido University has conducted repetitive observations of the CO_2 fluxes since 2020. We observed the summit area of Mt. Usu in May and October of 2023 and 2024. We used the chamber method, accumulating soil CO_2 in a chamber and measuring the concentration increasing rate with a spectrometer. Spatial interpolation using kriging produced a distribution map of CO_2 emissions for the whole area.
The CO_2 fluxes were low at most sites, except the inner rim of Gin-numa crater, I-crater, and the ridge of Kita-byoubu peak. The spatial distribution did not change significantly between the measurements, but the fluxes tended to be slightly higher in October than in May. The logarithm of the CO_2 fluxes at the same location after 2020 fluctuates within a range of 1, repeatedly increasing and decreasing at some points. However, compared with the values before the 2000 eruption, the maximum flux is 1-2 orders of magnitude lower than that time, so we consider that Mt. Usu is still inactive. We expect that the CO_2 fluxes will increase by several orders of magnitude if the volcano becomes more active in the future.

Abstract 18

Towards continuous remote sensing of volcanic water, carbon dioxide, and hydrogen fluoride emissions

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Continuous long-term records of volcanic gas emissions are invaluable for the interpretation of volcanic activity. The spectroscopic analysis of sunlight, which has traversed the volcanic gas emission plume, can provide accurate plume composition data during most stages of volcanic activity. This remote sensing approach furthermore minimizes maintenance requirements, allowing for autonomous operation from ground-based to space-borne platforms. Thus far, sulfur dioxide is the only major magmatic gas species that is routinely monitored by remote sensing of its strong and specific absorption fingerprint in the ultraviolet spectrum of sunlight. While long continuous records of sulfur dioxide emissions have substantially contributed to the understanding and monitoring of many volcanic systems, data sets remain influenced by meteorology and limited to a single magmatic gas species.

Farby-Perot interferometers can optimize the spectral resolution, light throughput, and mobility of spectrometers for volcanic gas remote sensing applications. This work assesses the feasibility of continuous remote sensing of volcanic hydrogen fluoride, water, and carbon dioxide using customized Fabry-Perot interferometer-based spectrographs. Extending existing sulfur dioxide remote sensing measurements by further magmatic gas species would provide continuous measurements of magmatic plume gas ratios of water, carbon dioxide, sulfur dioxide and halogens.

This would drastically increase the geochemical and geophysical information content of the data and simultaneously minimize the influences of meteorology.

Abstract 19

How fast do high temperature magmatic gases adapt to changes in temperature and pressure?

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Magmatic volatiles, which have exsolved from the silicate melt, can accumulate in gas bubbles traveling upward inside the magma along the gravitational pressure gradient. Decreasing pressure causes bubble expansion and accelerates rising speeds. Magmatic gas bubble diameters can be on the order of meters when leaving the magma body, causing highly dynamic vigorous volcanic degassing conditions. Just before reaching the magma surface, gas pressures are likely to drop rapidly, and recent studies even suggest that magmatic gas temperatures decouple from magma temperatures due to gas cooling by the adiabatic expansion of the bubbles.

Interpretations of volcanic gas composition measurements commonly rely on the well-established assumption that the magmatic gases sustain chemical equilibrium at all times during depressurization to atmospheric pressure.

We use high-temperature chemical kinetics data to calculate the re-equilibration time of magmatic gases after a step-change in temperature or pressure. The time needed for chemical equilibration can then be compared to the timescale of the respective physical degassing process and validate assumption of chemical equilibrium.

First preliminary results show that during vigorous degassing conditions with larger bubble diameters and high rising speeds, the magmatic gas might be quenched at higher pressures. That is to say, chemical kinetics may prevent the gas composition from sustaining chemical equilibrium during depressurization, particularly if the gas is cooler than the melt. These results point to the potential limitation of equilibrium assumptions and imply that chemical kinetics may control the composition of rising magmatic gas bubbles before the gases are released into the atmosphere.

Abstract 20

Evidence of magmatic and hydrothermal signatures in gas emissions from Deception Island volcano, Antarctica

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Deception Island is an active basaltic-andesitic volcanic caldera flooded by seawater, located in the Bransfield Strait region (South Shetland Islands, Antarctica). The volcano forms part of a subaerial-to-submarine volcanic lineament situated within a back-arc basin, generated by the subduction of the Phoenix Plate beneath the South Shetland Plate. Since the Antarctic summer of 2022, we have conducted geochemical surveys at seven hydrothermal sites, most of which are situated along the island's inner coastline. Direct gas sampling, using Giggenbach bottles filled by NaOH or $Cd(OH)_2$ solutions, revealed that the fumaroles at Fumarole Bay (~100 ºC) are dominated by water vapor, with an average gas fraction of approximately 10% and CO_2/H_2S ratios ranging from 20 to 200. The remaining sites are characterized by CO_2-dominated emissions with no detectable sulfur species, except at Whalers Bay, where the use of a MultiGAS instrument allowed the detection of minor H_2S concentrations. The absence of acidic magmatic gases such as SO_2, HCl, and HF in the fumarolic emissions suggests efficient gas scrubbing processes within the hydrothermal system. Furthermore, temporal variations in the CO_2/H_2S ratio detected by MultiGAS monitoring indicate fluctuating contributions of seawater and snowmelt to the emission areas. Overall, the relative abundances of N_2-He-Ar suggest a mantle-derived gas composition modified by interaction with air-saturated water, occasionally enriched in N_2 (N_2/Ar ratios up to 117) and CH_4. Additionally, isotopic signatures of carbon ($\delta^{13}C$-CO_2 between -4.8‰ and -8.8‰) and helium ($^3He/^4He$ ~7 Ra) point to a predominant deep magmatic source with limited atmospheric and/or crustal contamination.

Abstract 21

What controls CO_2 Diffuse Emissions at Deception Island volcano, Antarctica?

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Deception Island, located in the South Shetland Archipelago, is one of the most active volcanoes on the Antarctic continent, with several eruptions in the last centuries. Since 2021 we carried out comprehensive geochemical campaigns during the Antarctic summers. This work focuses on the survey of soil diffuse CO_2 fluxes and temperature. In total, we performed 1,015 and 1,558 measurements of these parameters, performed between 2022-2023. Results reveal active diffuse degassing along the intertidal zones of five inner-shore sites around Port Foster, the flooded caldera bay, and at least three inland sites distributed across different sectors of the island. Inland degassing shows a strong structural control, while intertidal emissions appear to be modulated mainly, though likely not exclusively, by the presence of the sea. In these coastal zones, the lateral displacement of emissions may be driven by the weight of the water column, whereas the dissolution of CO_2 in seawater, supported by acid pH and elevated total alkalinity at hydrothermal sites, likely contributes to masking or attenuating direct emissions. Additional factors may influence the spatial distribution of shoreline degassing, including the thinning of permafrost toward the coast and the presence of the caldera ring fault system inherited from the collapse structure, which may be as recent as 4 ka. The circular arrangement of emissions around the bay suggests that degassing is not localized, but instead occurs in multiple sectors, further supporting the existence of a broad underlying hydrothermal system.

Abstract 22

Studying Copahue Volcano's Plume Using Multigas: A Journey Through Crater Lakes and Phreatic Explosions

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Since 2018, Copahue volcano has exhibited a seasonal pattern characterized by the formation of a crater lake during summer, its displacement or disappearance in winter, and subsequent explosions—presumably phreatic in nature. Over the past five years, we conducted several summer field campaigns to measure volcanic gas ratios (CO_2, SO_2, and H_2S) using a portable Multigas instrument. During the most recent lake–explosion–lake cycle, gas measurements were obtained at three key stages: (1) during the presence of the crater lake (February 2024), (2) immediately after the explosion, when the lake was absent (November 2024), and (3) once the lake had reformed (February 2025). A striking result is the complete absence of SO_2 during the third stage, suggesting effective scrubbing of this gas by the crater lake—a phenomenon not observed in previous years. The CO_2/SO_2 ratios measured with and without the crater lake averaged 1 and 0.3, respectively. CO_2/H_2S ratios varied across the three stages: 20.5 before the explosion, 0.3 immediately after, and 4.5 post-reformation. These trends point to a moderate decrease in the CO_2/H_2S ratio during the explosion phase, likely linked to the sudden removal of the lake and disruption of the mineralogical seal typically precipitated in the vent. Overall, these results demonstrate that both the presence of the crater lake and the opening of the vent due to the explosion are reflected in the volcanic gas ratios measured by the Multigas instrument.

Abstract 23

Experimental Calibration of Carbon Isotope Fractionation for Volcanic CO_2

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Understanding carbon isotopic fractionation between volcanic CO_2 gas and silicate melts is essential for interpreting volcanic degassing processes and the deep carbon cycle. However, the lack of constraints on the appropriate fractionation coefficient has led to inconsistencies in modeling $\delta^{13}C$ evolution during magma degassing. To address this, we conducted high-pressure (350–420 MPa) and high-temperature (1160–1225 °C) experiments across a range of melt compositions from andesite to basanite. Our results reveal a systematic relationship between the fractionation coefficient and the degree of polymerization (NBO/T), with greater fractionation in more depolymerized melts (e.g., basalt) and lower fractionation in polymerized melts (e.g., rhyolite). This calibration provides a quantitative framework for interpreting $\delta^{13}C$–values in volcanic gases and reconstructing volcanic degassing histories and pre-eruptive carbon budgets.

Abstract 24

S-bearing Trace Compounds as Potential New Geoindicators in Volcanic and Geothermal Discharges

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ABSTRACT
The distribution of COS in volcanic and geothermal fluids is linked to the total budget of C and S in the gas phase. Although the chemical speciation of sulphur is dominated by SO_2 and H_2S, trace sulphur-bearing species are expected to occur, sometimes in measurable concentrations as pointed out by geochemical modeling. In line with these expectations, the presence of COS in volcanic gases was highlighted since the late 70's. A direct correlation between the COS concentration and the emission temperature, within the range 100-1100°C, was reported by Belviso et al. (1986).
Recently, the interest in COS and other S-bearing trace compounds in volcanic and geothermal fluids is renewed, thanks to the use of analytical methods based on the coupling of GC and ICP-MS techniques. This GC-ICP-MS methodology is able to measure low levels of S in the gas mixture, permitting to quantify COS, CH_3HS and CS_2 in gas samples of Solfatara, Vulcano and Larderello fumarolic emissions.
This work tackles the distribution of trace S-bearing species in volcanic and geothermal gas mixtures, with two main aims:
1) Investigate the presence, distribution, and evolution of these species in gas samples;
2) develop new geoindicators to estimate T-P-Redox at depth;
3) Simulate the possible changes in gas chemistry upon cooling.

REFERENCES
Belviso, S., Nguyen, B.C., and Allard, P., 1986. Estimate of Carbonyl Sulfide (OCS) volcanic source strength deduced from OCS/CO_2 ratios in volcanic gases. Geophys. Res. Let., vol.13, pp. 133-136.

Abstract 25

Interpreting Gas Emissions During Current Unrest at Mount Spurr (Alaska) by Combining Airborne Monitoring with Degassing and Thermodynamic Reaction Modeling

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Mount Spurr is a 3300-m-tall ice-capped stratovolcano located near Anchorage (Alaska, USA) and along a busy path of trans-Pacific air traffic. Ashfall from past eruptions of Mount Spurr (1953, 1992) significantly affected regional populations. Since April 2024, Mount Spurr has been experiencing unrest, with ice melt forming a summit crater lake, increased seismicity and deformation, and since March 2025, elevated gas emissions.

Airborne gas measurements have identified two distinct gas compositions at Mount Spurr: a sulfur- and halogen-bearing gas emitted from the lake-bearing summit crater, and a nearly pure CO_2 gas (no S) emitted from Crater Peak, a flank vent ~4 km south of the summit, which has been the source of historic eruptions. These distinct gas types were also observed at Mount Spurr's summit and Crater Peak locations during the last episode of unrest (2004–2006), indicating this degassing configuration may be generated by a repeating process at depth.

We apply a petrologic degassing model (Sulfur_X) and gas-water-rock thermodynamic reaction models (CHIM, GASWORKS) to constrain the origins of the two distinct gas compositions. Preliminary results suggest that the summit gases are sourced from shallow magma (<4 km), whereas CO_2-rich Crater Peak gases are likely sourced from deeper magma (>10 km). However, sulfur scrubbing reactions may also be important in producing the nearly pure CO_2 gas at Crater Peak. Constraining what magma depths and scrubbing reactions can generate the Mount Spurr gases has major implications for understanding the current volcanic unrest and how it may progress.

Abstract 26

Assessing the volcanic implications of the 2025 seismic activity in the Santorini region

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Recent seismic activity in the Santorini region has attracted global attention and raised concerns about ongoing volcanic hazards. Santorini, a large volcanic caldera featuring the central islets of Nea Kameni and Palea Kameni, has a complex eruptive history spanning approximately 650,000 years, including the catastrophic eruption (~1560 B.C.) linked to the decline of the Minoan civilization. Since 27 January 2025, the region has experienced a major seismic crisis, with over 2,000 earthquakes recorded, including 14 events with magnitudes ≥5.0 and a maximum magnitude of 5.3. Seismicity has been concentrated approximately 25 km northeast of Santorini and 25 km southwest of Amorgos.

We present the results of two geochemical surveys conducted between March and April 2025, involving water sampling from 10 wells, measurements of soil CO_2 fluxes and $\delta^{13}C$-CO_2 values in Santorini and Nea Kameni, as well as sampling of fumarolic gases at Nea Kameni and bubbling gases at Palea Kameni. These data provide a preliminary assessment of the current degassing dynamics of the area. Comparison and integration with existing literature indicate that the post-seismic volcanic phase following the January–February 2025 seismic crisis is marked by an increased degassing rate in the Nea Kameni region. However, the chemical and isotopic compositions of the gases ($^3He/^4He$ and $\delta^{13}C$ values) exhibit only minor variations relative to pre-crisis measurements reported in previous studies.

Although preliminary, these findings underscore the critical need for continuous monitoring of the Santorini volcanic system, in order to deliver timely and reliable information to the local community and to support effective volcanic risk mitigation strategies.

Abstract 27

Comparison Of MultiGAS And FTIR Gas Ratios Measured During Icelandic Effusive Eruptions

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Volcanic gas composition, and especially CO_2/SO_2 ratio, is extensively used to monitor volcanic activity, both to track magma movements in the subsurface and characterize magma composition and evolution. Various instruments are available to determine gas compositions, the most commonly used being MultiGAS and open-path FTIR, as they allow for simultaneous measurement of multiple species. MultiGAS instruments measures gas composition in-situ, providing H_2O, CO_2, SO_2 and H_2S concentrations from electro-chemical and IR sensors. Open-path FTIR spectroscopy, on the other hand, remotely determines the relative gas composition (H_2O, CO_2, SO_2, HCl, HF, CO, CH_4) by measuring absorption along the path between the instrument and an infrared source. We report the CO_2/SO_2 ratios retrieved from simultaneous measurements made by ground and drone-borne MultiGAS and FTIR during recent effusive eruptions (2022-2025) on the Reykjanes Peninsula, Iceland. Most of the measurements reveal a higher CO_2/SO_2 ratio measured by FTIR compared to MultiGAS. We discuss the potential causes explaining this discrepancy. Factors relevant for each instrument measurements and data processing include path length and source intensity for FTIR, calibration and sensor saturation for MultiGAS. Measurement setup is critical, in particular contributions from the outgassing lava field or burning vegetation, which may be captured by a single instrument despite simultaneous sampling. We also discuss sulfate aerosol formation, as inferred by MultiGAS measurements at increasing distance from the crater. This comparison shows the importance of understanding instruments' limitations and processes that can affect measurements in order to acquire meaningful, high-quality data for monitoring.

Abstract 29

Interdisciplinary Application Of Drone-Mounted And Ground-Based MultiGAS Instruments

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Carbon dioxide (CO_2) is a key emission from both wildfires and volcanoes. In wildfire contexts, carbon monoxide (CO) can indicate combustion efficiency and chemical behavior, while methane (CH_4) may reflect the type of vegetation burned. In volcanic environments, CO is typically below detection thresholds, but CH_4 and hydrogen sulfide (H_2S) can serve as indicators of hydrothermal input and pre-eruption signals. Both wildfires and volcanoes are rapidly-evolving natural hazards that emit large quantities of gases. These gases can thereby be effectively measured using either ground-based or drone-mounted MultiGAS instruments. We used two MultiGAS instruments in a controlled combustion experiment to assess their performance: one drone-mountable unit equipped with CO_2 (0-2000 ppm) and CO (0-2000 ppm) sensors, and a ground-based unit equipped with high-range CO_2 (0-100,000 ppm), CH_4 (0-250 ppm), and H_2S (0-200 ppm) sensors. These instruments successfully captured distinct gas signatures across different combustion phases, providing preliminary validation of sensor behavior. We aim to deploy the ground-based MultiGAS instrument at CCVG15 to characterize in situ gas compositions. In the future, we intend to also validate our CO_2, CH_4 and CO results with satellite measurements. This work contributes to developing portable, adaptable methods for monitoring gas emissions, offering tools for both hazard assessment and interdisciplinary study.

Abstract 30

Estimating emission flux of H_2S from fumarolic fields using vertical sensor array system

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Abstract text
The emission flux of volatiles from fumarolic fields in volcanic and geothermal areas serves as a valuable indicator of magmatic activity and its future trends. However, conventional optical methods, such as the differential optical absorption spectroscopy (DOAS) method, are not applicable in fields where SO_2 is depleted, particularly in geothermal areas. To address this limitation, we developed a vertical sensor array system (VSAS) consisting of seven inlets fixed at 1.5 m intervals along a telescoping pole. All the inlets were connected with respective chemical H_2S sensors. This system enables the determination of the cross-sectional distribution of H_2S concentrations in volcanic plumes and the quantification of H_2S emission fluxes. In addition to the walking traverse (WT) method, a fixed point (FP) method was developed, in which the VSAS was positioned at a single location and the cross-sectional distribution of H_2S was estimated based on natural wind direction variations.
The emission flux of SO_2 was estimated at Kirishima-Iwoyama volcano based on that of H_2S obtained using the VSAS and the SO_2/H_2S ratio in the plume obtained using the Multi-GAS, which corresponded well with the values obtained using the optical method. The emission flux of H_2S was determined at Oyunuma Pond, Kuttara volcano, as well, applying the FP method.
Furthermore, a UAV-mounted VSAS was developed recently to overcome topographic constrains using VSAS. On December 11, 2024, the UAV-mounted VSAS was used successfully to estimate H_2S flux at Kirishima-Iwoyama volcano.

Abstract 31

Monitoring of Fumarolic Gas Compositions Using a Multi-GAS Station during the 2018 Eruption of Iwoyama Volcano, Kirishima Volcanic Complex, Japan

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Continuous observations of fumarolic gas compositions were conducted using Multi-GAS at Iwoyama Volcano, Kirishima Volcanic Complex, Japan, from July 2017 to January 2020. During this period, a phreatic eruption occurred in April 2018. These continuous observations showed that the SO_2/H_2S ratio and the daily maximum values of SO_2 concentration showed a marked increase of approximately 100 times from 0.02 to 1 between February and March 2018, just before the eruption. In contrast to the change in the SO_2/H_2S ratio, the CO_2/H_2S ratio exhibited large fluctuations up to ten times without a clear trend during the same period. After the eruption, the SO_2/H_2S ratio decreased to lower values (0.02–0.7), exhibiting another peak up to 1–10 in June 2019. Based on a CO_2–H_2S–SO_2 ternary diagram, the fluctuations in fumarolic gas composition just before the eruption roughly aligned along a straight line starting from the point of $SO_2/H_2S = 0.5$ on the $CO_2 = 0$ axis. This suggests that the shallow hydrothermal system is supplied with high-temperature magmatic gases and that compositional variations are influenced by sulfur precipitation. The rate at which high-temperature magmatic gases are supplied to the shallow hydrothermal system is estimated to have increased markedly about two months before the eruption. In contrast, compositional variations after the eruption deviate from this linear relationship and align on a straight line toward H_2SO_4, indicating a significant influence of sulfur dioxide disproportionation reactions in the shallow hydrothermal system.

Abstract 32

Gas Measurements in the New Era of Eruptive Activity at Kīlauea, 2020 – 2025

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Since the two-year gap in activity following the 2018 eruption and caldera collapse, Kīlauea has erupted eight times in four years. Activity has varied drastically in location, duration, and style, ranging from an hours-long fissure eruption on the Southwest Rift Zone in 2024, to a 15-month summit lava lake spanning September 2021 to December 2022, to an ongoing summit eruption consisting of episodic lava fountaining that began in December 2024. During each eruption, the Hawaiian Volcano Observatory (HVO) endeavors to constrain SO_2 emission rate, eruptive gas chemical composition, and other information regarding the dynamics of degassing and the role of gas in overall eruption mechanisms.

For much of 2020 – 2025, traditional vehicle-based DOAS traverses served as the primary means of measuring SO_2 emission rate, which ranged from a minimum <100 t/d during intereruptive periods to over 100,000 t/d at some eruption onsets. We have also relied on airborne traverses and SO_2 camera measurements under certain conditions. As of late 2024, a refurbished stationary spectrometer array has also been providing continuous emission rates during trade wind conditions.

Eruptive gas chemistry measurements are made using a combination of station-based, portable ground-based, and UAS-borne multi-GAS, as well as sporadic measurements by FTIR spectrometer. Direct samples are collected at a long-standing fumarolic site near caldera-bounding faults roughly four times per year.

All measurements are leveraged in conjunction with geologic, petrologic, and geophysical observations to better understand current eruptive and intrusive activity, and to place current activity in the context of Kīlauea's long eruptive history.

Abstract 33

Magmatic gases in the plume can be oxidized if bromine monoxide is observed near the source

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Volcanic plume gas compositions are often used to infer magmatic conditions, assuming that magmatic gases remain chemically inert upon release. However, the detection of bromine monoxide (BrO) in many plumes contradicts this, as BrO forms through atmospheric oxidation of emitted hydrogen bromide (HBr). We model the early high-temperature evolution of volcanic plumes using a two-stage box model that couples chemical kinetics with plume cooling and dilution. The first stage simulates the high-temperature plume immediately after gas release, applying combustion chemistry as gases dilute and cool. The second stage models the early downwind plume using photolytic heterogeneous atmospheric chemistry to capture BrO formation. The model is able to reproduce the observations of BrO over minutes in the downwind volcanic plume of Mt Etna. High-temperature oxidation reactions in the first milliseconds after emission are found to be crucial for the formation of BrO. This zone, referred to as the high-temperature atmospheric interface can also oxidize other magmatic gases such as H_2, CO, modifying the magmatic gas redox state. We find that the magmatic gas temperature upon entering the atmosphere critically controls redox changes during cooling. Furthermore, the model explains the observed co-existence of reactive halogens and reduced gases at Mt. Etna, suggesting magmatic gases are released several hundred kelvin below magmatic temperatures.

By linking reactive halogen formation to initial gas conditions, our model both refines and expands interpretations of volcanic gas measurements, emphasizing that significant oxidation of magmatic gases can occur near the vent when BrO is observed.

Abstract 34

Fast near-source oxidation of mercury in volcanic gases: Measurements and Model simulations

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Volcanoes are a natural source of atmospheric mercury and volcanic gases are thought to mainly contain gaseous elemental mercury (Hg^0). Nevertheless, several measurement studies show a varying degree of oxidized mercury in near-source volcanic plumes.
Early-stage high-temperature volcanic plumes are a highly reactive environment where in-mixing of atmospheric oxygen triggers the fast formation of HO_x radicals (OH and HO_2) and subsequent formation of reactive halogen species. These reactive halogen species are well known to react with Hg^0 and form gaseous or particulate oxidized mercury (Hg^{II}) species such as $HgBr_2$ and $HgCl_2$. Furthermore, heterogeneous oxidation on volcanic aerosol can also form particle bound oxidized mercury.
We present speciated mercury (Hg^0, Hg^{II}) measurements performed in near-source fumarolic plumes on La Fossa crater (Vulcano, Italy) in September 2019 and 2023. We find high abundances of oxidized mercury (up to 70% in less than 1 m downwind) close to the emission source and no evidence for further downwind oxidation, indicating rapid near-source processes responsible for the observed pattern.
We compare these field measurements to model studies with a chemical box model which simulates chemical kinetics alongside mixing and dilution of the early stage volcanic plume investigating gas-phase oxidation pathways of mercury. Furthermore, a simplified assessment of aerosol chemistry is included to investigate heterogeneous oxidation pathways alongside the pure gas-phase.

Abstract 35

EVALUATION OF VOLCANIC ACTIVITY USING GEOCHEMICAL MONITORING WITH MULTIVARIATE ANALYSIS

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This study investigates the effectiveness of combining geochemical monitoring with principal component analysis (PCA) for evaluating volcanic activity and predicting phreatic eruptions. The research was conducted in the Hakone volcanic region, where volcanic gas, river water, hot spring water, and riverbed sediment were collected and analyzed for their chemical compositions and stable isotope ratios. PCA was employed to examine the correlation between temporal variations in chemical composition and seismic activity.

In volcanic gases, three principal components were identified, with CO_2 and H_2S showing strong associations with magmatic activity. In river and hot spring waters, variations in the Cl^-/SO_4^{2-} and Cl^-/K ratios, caused by the intrusion of hydrothermal fluids and magmatic HCl, were observed and found to be effective indicators that correspond well with seismic events.

Furthermore, to investigate the influence of altered rock particles derived from geothermal zones, riverbed sediment from rivers flowing through the Hakone caldera was analyzed. The results revealed compositional variations related to the volcanic rocks of Hakone, as well as weathering and acidic alteration processes. Although arsenic (As) did not contribute significantly to any specific principal component, high concentrations were detected in samples derived from geothermal areas, suggesting its potential as an indicator of past geothermal activity.

This study demonstrates that PCA is an effective method for objectively analyzing multivariate geochemical data. When integrated with continuous monitoring, this approach is expected to contribute to the prediction of phreatic eruptions and the enhancement of volcanic disaster mitigation strategies.

Abstract 36

Development of on-site analysis equipment for helium isotopes using multi-turn time-of-flight mass spectrometer

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The helium isotope ratio, $^{3}He/^{4}He$, is useful as an indicator for volcano monitoring. When volcanic activity increases, the contribution of mantle-derived components in volcanic gas increases, and $^{3}He/^{4}He$ becomes higher because helium in the mantle has a higher $^{3}He/^{4}He$ than that in the atmosphere and crust. The conventional method of noble gas analysis uses a large and heavy magnetic field mass spectrometer and requires repeated sampling in the field and analysis in the laboratory, which has hampered frequent data acquisition. To solve this problem, we are developing a portable instrument that can make measurements in the field. To distinguish ^{3}He from HD^{+}, a mass resolution $M/\Delta M$ of 510 is required (Sumino, 2015). Conventional time-of-flight mass spectrometers (TOF-MS) and quadrupole mass spectrometers cannot achieve both compactness and high mass resolution. We used a portable multi-turn TOF-MS (Toyoda et al., 2003) to achieve the requirement. Noble gas measurements require an ultra-high vacuum preparation line to remove active gases and separate noble gas elements. In this study, we aim to make the equipment smaller and lighter, including the preparation line, and to use it for practical use as a portable analyzer. When we measured the $^{3}He/^{4}He$ of hydrothermal fluids collected from submarine volcanoes without separating helium from other noble gases, the helium ion count rate was lower than expected, possibly due to the influence of argon. Nevertheless, magmatic helium was successfully identified in some samples with relatively low $^{40}Ar/^{4}He$ ratios, indicating the capability of the instruments for volcano monitoring.

Abstract 37

Volcanic gases from Ebinokogen Ioyama volcano, Japan

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Ebinokogen Ioyama volcano is an active volcano located on Japan's Kyushu Island, which experienced a phreatic eruption in April 2018. We have repeatedly collected and analyzed the fumarolic gases at the volcano from 2017 to 2024, and measured its chemical composition and stable isotope ratio. As a result, the following points became clear. The SO_2/CO_2 ratio changed in response to the fluctuation in the frequency of volcanic earthquakes during the period from 2017 to 2019 (Period-I), and in particular, it increased just before the phreatic eruption in April 2018, so the SO_2/CO_2 ratio had been thought to be a useful indicator for predicting phreatic eruption. However, during the period from 2020 to 2024 (Period-II), the correlation between the SO_2/CO_2 ratio and the frequency of volcanic earthquakes reduced, and a high SO_2/CO_2 ratio was maintained. The apparent equilibrium temperature (AETS), based on the reaction $SO_2+3H_2=H_2S+2H_2O$, showed changes similar to the SO_2/CO_2 ratio in Periods I and II. The following effects for the magmatic gases (MV) supplied to the hydrothermal reservoir (HR), which causes phreatic eruption, are presumed to explain the SO_2/CO_2 ratio and AETS variations: a) reduction in the cooling effect due to heat transfer, b) reduction in the sulfur sequestration effect, both in the process that MV moves from a degassing magma to HR through a channel developed in crust.

Abstract 38

Volcanic gas measurement by using drone and Multi-GAS at Mt. Tokachi, Hokkaido in 2023 and 2024

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Mt. Tokachi, located in central Hokkaido, is an active volcano that has experienced three magmatic eruptions in the 20th century. Among the volcanoes in Japan during noneruptive periods, some exhibit vigorous fumarolic activity, maintaining SO_2 fluxes ranging from 100 to 2000 t/day (Yamaguchi et al., 2023). Therefore, elucidating the gas supply system at Mt. Tokachi is essential for understanding the mechanisms underlying its volcanic activity. In this study, volcanic gas composition measurements were conducted at Mt. Tokachi in 2023 and 2024 using a multi-gas sensor mounted on a drone, and derived the compositional ratios of H_2O, SO_2, CO_2, and H_2S. To enable observations even when the volcanic alert level is raised from Level 1 to Level 2, drone flights were conducted from Mt. Sandan, and from a mountain hut situated on the middle slope of Mt. Tokachi, located approximately 1.5 km from Crater 62-2.

The observations revealed that the volcanic gas compositions differed among the main fumarolic sources at Mt. Tokachi—Crater 62-2, the Taisho Crater, and the Furikosawa fumaroles. This suggests that the volcanic gas ascent processes differ among the gas emission sources. At the Taisho Crater, the observed higher CO_2/SO_2 and lower SO_2/H_2S ratios and the Furikosawa fumaroles exhibited relatively high SO_2/H_2S and CO_2/H_2O ratios compared to those at Crater 62-2.

Abstract 39

Simulations of volcanic outgassing in the COHS system: comparison of modelled outgassed compositions with field measurements of volcanic plumes

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The investigation of the chemical composition of volcanic plumes provide crucial information on the different processes that influence the volatile components during the magmatic degassing process. In this study we focus on the COHS system, comparing the results of outgassing simulations with field measurements of the volcanic plume of Mt Etna (Italy) and Nyiragongo (D.R.C.). We identify possible melt compositions and volatile contents by using data of melt/fluid inclusions from the literature. Based on that, we calculate the solubility of the species assuming different potential pressures and temperatures of volatiles exsolution. We assume a thermochemical equilibrium speciation of the volatile components in the gas phase before their release into the atmosphere (i.e. chemical equilibrium between the volatiles and the melt). The final step of our simulation is the numerical modelling of chemical kinetics during the mixing process of the hot magmatic gases with the cold, highly oxidized atmospheric air.

The simulated chemical compositions, in particular the CO/CO_2 ratios, are compared with measurements of Mt Etna plume's made from AirCore samples taken with an UAV in 2024 and with previous degassing data from the literature (Gerlach, 1979, La Spina et al., 2015).
The combination of numerical simulations and field measurements give us new insights into the complex processes of volcanic outgassing. We note that the final outgassing composition could mirror the oxidation state of the melt and the gas release temperature into the atmosphere, but also could potentially be mainly determined by chemical kinetics (in the first seconds after gas release).

Abstract 40

Steam and Fire: Drone Based Techniques for Volatiles Study of Plumes and the Water Sources Interplay in Active Volcanoes

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Water vapor (H_2O), the main volatile phase in all volcanic systems, plays a crucial role in the initiation and persistence of eruptions. However, the relative contributions of H_2O from magma versus shallow meteoric-sourced hydrothermal system remains unclear. Identifying and quantifying these H_2O contributions and their temporal variation are key to understanding different eruption mechanisms and have important implication on key redox reactions.

We combined multi-instrument remote sensing and direct sampling techniques, including drone-based Multi-GAS, ultraviolet (UV) and near infra-red (NIR) cameras, and direct- and drone-based sampling of plume gas from 3 volcanoes with varying background humidity, activity levels, and tectonic settings.

In November 2022, we measured the plume of Lascar, Chile, using NIR. H_2O emissions reached up to 35,000 t d^{-1} and SO_2 close to 400 t d^{-1}. Data from December 2024 and January 2025 are currently being processed. In July-August- 2023, measurements at Litli Hrútur, Iceland, showed H_2O emissions up to 45,000 t d^{-1} and SO_2 up to 6,505 t d^{-1}. In February 2024 and March 2025, we measured the plume of Poás, Costa Rica, with data result pending.

A novel pumping system using mesomorphous silica traps H_2O vapor, which is later released by vacuum heating and analyzed for δD and $\delta^{18}O$ values using a Picarro water vapor analyzer, and $\delta^{17}O$ via TILDAS (Perdue et al., 2021). Preliminary results suggest that Lascar's emissions are dominated by meteoric sources. For Poás, pending analysis, we expect prominent arc-type water signature based on the volcano current activity and high magmatic gas emissions.

Perdue, N., Sharp, Z., Nelson, D., Wehr, R., Dyroff, C., 2022. A rapid high-precision analytical method for triple oxygen isotope analysis of CO_2 *gas using tunable infrared laser direct absorption spectroscopy. Rapid Comm Mass Spectrometry 36, e9391. https://doi.org/10.1002/rcm.9391*

Abstract 41

What do control degassing rates of open-vent volcanoes?

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Degassing rate at open-vent volcanoes is considered as a good indicator of volcanic activity reflecting magma supply rate. However, specific conditions of the magma supply (i.e., source, destination, transport process etc) are rarely discussed. At a few volcanoes (e.g., Etna, Soufrière Hills and Asama), a clear coincidence is observed between variation of degassing rate and inflation rate at a deep magma reservoir, and the inflation volume agrees with amount of basaltic magma required to discharge the observed amount of the gases, suggesting that the basaltic magma input to the deep reservoir is the degassing source. Etna is a basaltic volcano and the basaltic magma supplied to a deep chamber can cause both eruption and degassing. Soufrière Hills and Asama, however, are volcanoes of andesitic magma, that formed by mixing of a basaltic and a rhyolitic magmas, and some mechanisms are required to cause both eruption and degassing by basaltic magmas. One mechanism is proposed for Soufrière Hills volcano; crystallization of a water-rich basaltic magma produces the exsolved vapor phase that are transported to the vent by a permeable flow through a volcanic conduit (Edmonds, 2022). This mechanism requires a rapid crystallization of the basaltic magma by a similar rate with the input rate. I propose here another mechanism with an example of Asama; the basaltic magma input to a deep reservoir immediately produces a mixed magma which ascend to the vent by conduit magma convection and erupt. This mechanism can explain the quantitative coincidence of degassing and inflation rates.

Abstract 42

Expansion of a degassing area in the north flank of Fogo Volcano (S. Miguel, Azores)

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Fogo Volcano is an active polygenetic volcano located on the central part of São Miguel Island (Azores), at the intersection of NW–SE, NE–SW and E–W-trending fault systems. The oldest subaerial products of Fogo Volcano are 200 ka and in the last 5 ka there were five trachytic explosive eruptions. The last intracaldera magmatic eruption (1563) occurred after the settlement and it was sub-Plinian type, being followed 4 days later by an Hawaiin type eruption located on the northwestern flank of the volcano. More recently, in Fogo and in the nearby Congro fissural volcanic system several seismic swarms and deformation episodes have occurred.

Hydrothermal manifestations are mainly located on the north flank of the volcano and comprise low-temperature fumaroles, steaming grounds, thermal and cold CO_2-rich springs, and soil diffuse degassing areas. Two geothermal power plants are also located in the northern flank of the volcano. After 2010 a new degassing area expended in the vicinities of Caldeiras da Ribeira Grande fumarolic field, which was associated with the drilling of a geothermal well that caused permeability changes. Three radon (^{222}Rn), carbon dioxide (CO_2) and soil temperature surveys were performed in the area in 2010, 2019 and 2025, showing a degassing expansion from the drilled well to East in direction of the previously existent fumarolic field. With ^{222}Rn, CO_2 and soil temperature maximum values above 300 kBq/m^3, 90 vol.% and 90 ºC, NW-SE diffuse degassing structures (DDS) were identified, in agreement with the tectonic lineaments previously recognized in the area.

Abstract 43

Spatial and temporal variations in noble gas isotopic compositions of fumaroles and hot/cold spring gases at Kusatsu-Shirane volcano

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Helium is present in very small amounts in volcanic gases, and its isotopic ratio ($^{3}He/^{4}He$ ratio) sensitively reflects the state of magma underground. The $^{3}He/^{40}Ar^{*}$ ratio, where $^{40}Ar^{*}$ denotes the magmatic ^{40}Ar, also provides information on the degassing state of the magma. Here we discuss the spatial and temporal variations in the $^{3}He/^{4}He$ and $^{3}He/^{40}Ar^{*}$ ratios of volcanic and hydrothermal fluids in and around the Kusatsu-Shirane volcano to clarify how magmatic fluids are incorporated into the shallow hydrothermal system and how their contributions would reflect variations in magmatic activity. The spatial variation in the $^{3}He/^{4}He$ ratio of the fumaroles and hot/cold spring gases shows systematic $^{3}He/^{4}He$ decreases with increasing distance from the Yugama crater, where most of the recent phreatic eruptions occurred. The spatial $^{3}He/^{4}He$ trend can be explained by a hydrodynamic dispersion model, in which crustal helium with a low $^{3}He/^{4}He$ ratio progressively leaches into an originally ^{3}He-enriched magmatic fluid as it migrates through the local crust. However, the $^{3}He/^{4}He$ distribution is also controlled by the local permeable structure at shallow depths, resulting in a difference in the residence time of migrating fluids underground. The temporal variation in $^{3}He/^{40}Ar^{*}$ ratios observed in some active fumaroles between 2014 and 2021 may reflect changes in magma vesicularity, indicating that the $^{3}He/^{40}Ar^{*}$ ratio of fumaroles is a useful parameter for monitoring the current state of degassing magma, which is essential for understanding the deep processes of volcanic unrest and may contribute to the identification of precursors of future eruptions.

Abstract 44

Insights from Simultaneous Measurement of CO_2 Soil Fluxes and Subsoil Gas Pressure Gradients at Stromboli Volcano

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We present our findings on the simultaneous measurement of CO_2 soil fluxes and subsoil gas pressure gradients near the crater area of Stromboli volcano(Eolian Islands, Italy). The installed pressure sensors recorded the pressure difference between ground level and depths of 50 cm and 100 cm (ΔP). Analysing the pressure gradient data showed a median ΔP of about 0.02 mbar, translating to a gradient of approximately 0.04 mbar·m^{-1}. The values ranged from 0 mbar (no gradient) to 1.14 mbar (0.57 mbar·m^{-1}). The median ΔP calculated each minute (ΔP_m) shows two main traits: i) sustained low values (< 0.1 mbar) with hour-long fluctuations, and ii) short, sharp spikes (> 0.1 mbar) that last just a few minutes. We compared pressure gradients and CO_2 soil fluxes from the accumulation chamber next to the pressure station. Our observations show periods of strong correlation between ΔP_m and the diffusive CO_2 flux with low and stable pressure gradients. The higher frequency of the pressure gradient recordings (1 minute against 60 minutes of the accumulation chamber) better captures the sharp variations of the diffusive degassing. Throughout several months, the comparison shows that both signals exhibit similar variations over weeks, indicating a significant level of correlation. Pressure gradients are exceptionally responsive to rapid increases and decreases, with some important changes occurring weeks before major strombolian eruptions. Our findings indicate that due to the low cost of installation and maintenance, pressure gradients may offer additional insights into the monitoring of diffusive soil CO_2 fluxes.

Abstract 45

Advancing Volcanic Gas Measurement: Open-Source Applications for Data Analysis of Gas Sensors

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Volcanic gas sensors have a successful history of applications in research and monitoring spanning over a decade. The integration of drone technology has enhanced the utility of these gas sensors, enabling safe and effective measurements of volcanic gas emissions. The data collected typically consists of time series readings of gas concentrations from which molar ratios are derived. Previous studies have shown that volcanic gas fluxes can also be quantified through specialized data processing techniques. In this paper, we introduce open-source applications developed in R and Python that facilitate the analysis of gas sensor data through intuitive user interfaces. These applications can be executed both locally and online as a web app, providing accessibility to a broader audience of researchers and practitioners. The development of these user-friendly applications marks a significant advancement in the analysis of volcanic gas sensor data. By leveraging open-source tools and modern programming languages, we aim to enhance the accessibility and usability of data analysis techniques in the volcanology community. This increased accessibility allows researchers to conduct more comprehensive studies and fosters collaboration across disciplines, ultimately contributing to improved monitoring and understanding of volcanic activity and its implications for public safety and environmental health.

Abstract 46

MONITORING ACTIVE VOLCANOES DURING WAR TIME: THE CASE OF NYIRAGONGO AND NYAMULAGIRA VOLCANOES AND THE CITY OF GOMA (RDCONGO)

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Monitoring active volcanoes requires different strategies and few (but necessary) measurements still bring scientists in the field going in or next to the volcano looking for critical points to be collected for further analysis in the laboratory, or for visual observations that can help understanding dynamics of the volcano that geophysical data, such as seismicity or deformations, or remote measurements (gas fluxes) and/or observations (satellite) cannot explain or to make clear(er) what those remote and geophysical data, exactly meant.
Recently in the eastern DRCongo, the security situation quickly deteriorated, and field works to volcanoes or in their vicinities during the last three and half years were stopped. Even the UNITED NATIONS helicopters used to allow visual observations of the most recent events and landing within the crater(s) to collect samples and making measurements, have been grounded after a series of very serious accidents. Then, we have decided to explore a new monitoring tool that just happen to be present in Goma: water wells.
The drilling of water wells is very recent in Goma, the first dated only three years back.
To explore local superficial and deep systems and possible presence of dikes, we started collecting samples for water chemistry, dissolved gases (CO_2, N_2, O_2, Ar, CH_4, He, Ne …), O and D, TDIC and $^{13}CO_2$-CH_4 and Noble Gas isotopes. Results striking highlight the dynamics of the area and allow to revise the model of what happened in the past (2021 eruption) and what it could happen in the future.

Abstract 47

CONSIDERATION OF SULFUR ISOTOPE RATIOS IN HAKONE VOLCANIC GAS SINCE 2019

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Hakone Volcano is an active volcano located on Honshu, Japan. A small phreatic eruption occurred at Hakone volcano on June 29, 2019. Prior to that, a swarm of earthquakes occurred in May 2019. In 2021, crustal deformation was observed. Even now, volcanic gases are being emitted from Owakudani in Hakone Volcano. This study reports the measurement results of the sulfur isotope ratios in the volcanic gas from Hakone volcano since 2019.

Volcanic gas was collected once a month from a fumarole in Owakudani. This fumarole was formed during the phreatic eruption in 2015. For volcanic gas sampling, a titanium tube was inserted into the fumarole, and the gas was collected by absorbing it into an absorption tube containing KI-KIO_3 solution or by drawing it into a vacuum container filled with KOH. The SO_2 and H_2S in the collected volcanic gas were oxidized and precipitated as $BaSO_4$. The sulfur isotope ratio was then determined using a continuous-flow stable isotope ratio mass spectrometer.

Regarding the temporal variation of sulfur isotope ratios, SO_2 showed a decreasing trend after peaking around May 2019. In 2021, it decreased by 0.3‰, and the declining trend continued until March 2022. On the other hand, the temporal variation of H_2S was smaller compared to SO_2. During the active periods of Hakone Volcano in 2019 and 2021, the increase in the number of earthquakes coincided with the decreasing trend of the sulfur isotope ratio of SO_2, suggesting a correlation between earthquake frequency and the sulfur isotope ratio of SO_2.

Abstract 48

Geochemical Monitoring of Active Volcanoes in the Philippines

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Various geochemical monitoring strategies utilizing campaign and continuous methods have been implemented across several active volcanoes in the Philippines based on the level of volcanic activity. These are directly applied to early warning and pre-, syn- and post-assessment of unrest and volcanic hazards. Nine active volcanoes in the Philippines—Mayon, Taal, Kanlaon, Bulusan, Pinatubo, Hibok-Hibok, Matutum, Parker, and Leonard Kniaseff– are regularly monitored in terms of the physico-chemistry and gas concentrations in volcanic plumes, fumaroles, soil, crater lake, or spring discharges. At Kanlaon, Mayon, and Taal volcanoes, temporal sulfur dioxide flux measurements using remote UV spectrometers and DOAS systems have proven crucial for evaluating developing and ongoing unrest and post-eruption hazards. For volcanoes with crater lakes—Pinatubo, Parker, and Taal— campaign measurements of dissolved and diffused carbon dioxide and hydrogen sulfide provide long-term data for assessing degassing behavior. Routine ionic and physicochemical analyses of spring water and other effluents further establish long-term geochemical trends for monitoring pre-eruptive changes. Specifically for Taal, which exhibited excessive post-eruptive SO_2 degassing with significant health impacts on communities, campaign remote surveys utilized Remotely Piloted Aircrafts (RPAs) for sampling and physico-chemical monitoring of its Main Crater Lake. Lastly, continuous real-time SO_2 and multigas monitoring stations provide critical precursory warning of volcanic unrest. Geochemical monitoring strategies continue to evolve as technologies develop to ensure comprehensive long-term decision-support and effective early warning.

Abstract 49

Development of a drone-borne volcanic plume sampler SelPS for remotely determined stable isotopic compositions of fumarolic CO_2, H_2, and H_2O

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Stable isotopic compositions of CO_2, H_2, and H_2O ejected from fumaroles are highly useful in evaluating the present status of each active volcano. In 2019, we developed a drone-borne automatic sampler SelPS (SO_2-Selective Plume Sampler), in which an output signal from a SO_2 sensor triggered a pump when its SO_2 concentration exceeded a predefined threshold, to collect concentrated volcanic plume ejected from active volcanoes wherein fumaroles are inaccessible (Shingubara et al., 2020; Tsunogai et al., 2021). By using SelPS, we successfully obtained significant linear correlation between the reciprocal of the concentration and isotopic ratios for the $^2H/^1H$ ratios of H_2, $^{18}O/^{16}O$ ratios of CO_2, and $^{13}C/^{12}C$ ratios of CO_2 within the plume samples taken in each volcano. Based on the isotopic ratios of fumarolic H_2 and fumarolic CO_2 determined from the linear correlations, we estimated the apparent equilibrium temperatures (AETs) with magmatic H_2O simultaneously and precisely, assuming both hydrogen isotope exchange equilibrium between H_2 and H_2O and oxygen isotope exchange equilibrium between CO_2 and H_2O. In Nakadake central cone, Aso volcano (Japan), the estimated AET_{18O} was always lower than the AET_D. While the temperature of the magmatic gases was originally 600°C or more, most of the gases cooled just beneath the crater to temperatures around the boiling point of water. Simultaneous and precise determination of both the AET_{18O} and AET_D using SelPS can provide novel information on each volcano having inaccessible fumaroles, such as the physicochemical conditions of magma degassing and the development of fluid circulation systems beneath each volcano.

Abstract 50

CO_2 fluxes and gas ratios at Campi Flegrei, Italy, measured by drone-based MultiGAS in near-real time and comparison with ground-based measurements

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Abstract
Determination of CO_2 gas flux and its concentration relative to other gas species in volcanic plumes is an essential tool to assess volcanic unrest and the risk of eruption. This is particularly important at Campi Flegrei, the largest restless caldera in Europe, which has experienced increasing activity since 2004. This unrest is characterized by ground uplift, seismicity, variations in volcanic gas flux and composition, opening of new fumaroles and expansion of mud pools in the crater. Although direct CO_2 fluxes have been monitored periodically through ground-based MultiGAS techniques (Aiuppa et al., 2013), the escalating level of activity could render such measurements unfeasible in the near future. This highlights the need for another approach to safely and reliably measure CO_2 fluxes in Campi Flegrei. Here we present the first drone-based direct CO_2 flux measurements at the Pisciarelli vent at Campi Flegrei, as well as H_2S fluxes, and volcanic gas ratios (CO_2/H_2S and CO_2/H_2O) with simultaneous ground-based measurements for comparison. Ground-based measurements indicate a decline from approximately 600 tons/day for CO_2 and 1.4 tons/day for H_2S in 2019, to around 260 tons/day for CO_2, and 0.7 tons/day for H_2S in 2024. These ground-based measurements from 2024 align closely with drone-based MultiGAS results. The decline in gas fluxes may be linked to the expansion of a bubbling pool system that enclosed the Pisciarelli vent between 2019 and 2024, diluting its gas output. CO_2/H_2O increased from 0.16 in 2004 to 0.23 in 2024, which may reflect an increased CO_2 emission from diffuse soil degassing.

Abstract 51

Diffuse Flux: Towards an Integrated Measurement and Near Real-Time Data Processing Approach

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The present work reports the results related to the development and validation of an integrated system for the acquisition and near real-time treatment of diffuse fluxes of CO_2 and other gaseous species. The objectives of the team, which is highly multidisciplinary, are:

- Design and development of a new class of instrumentation characterised by small size, low mass and instrumental performance identical to or better than actual instrumentation;
- Upward expansion of the measurement range of CO_2 fluxes to enable characterisation of high and very high emission areas;
- The implementation of a mobile (Android – IOS) based application and a remote data processing platform that with conventional and AI-based procedures allows:

  - Robust statistical analysis based on multiple approaches, for partitioning of datasets with polymodal statistical distribution, to obtain statistical parameters of the combined populations and to estimate of total output and its uncertainties.
  - Real-time generation of distribution gas maps using a stochastic approach operating on unstructured meshes executed on remote calculation nodes. The two-way exchange of data with the field instrumentation allows for gradual updates. The probabilistic method allows for the assessment of local and regional variability, which pushes incremental sampling towards variance minimization, leading one or possibly several sampling units to collaborate during a survey.
  - Live data visualization through heat maps, depicting emission point distributions, also available off-line when no connectivity is available in the field.

The Technology Readiness Level (ISO-TRL) of the various components ranges from TRL7 to TRL5 with few parts in TRL4.

Abstract 52

Influence of hydrothermal fluids on the lithium enrichment in evaporitic brines of the Altiplano-Puna region: Evidences from fluid geochemistry

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The Altiplano-Puna plateau hosts over 50% of the world's lithium reserves, primarily within evaporitic brine systems. This study investigates the contribution of Neogene Volcanic Arc-derived hydrothermal fluids to lithium enrichment in the endorheic salars, specifically Pujsa and La Isla salars, Altiplano-Puna region. Both salars are situated within active volcanic settings, in proximity to hydrothermal surface manifestations and extensive ignimbrite exposures conditions that allow isolation of primary volcanic variables.
We hypothesize that high-temperature, low-pH hydrothermal fluids act as geochemical catalysts, enhancing the leaching, mobilization, and concentration of lithium from volcanic source rocks into basin brines. This hypothesis was tested through integrated major element, mineralogical, and isotopic analyses of thermal waters, brines, ignimbrites, and saline crusts.
Our results demonstrate that hydrothermal fluids exhibit significantly higher lithium concentrations and lower $\delta^{7}Li$ values than meteoric counterparts, consistent with isotopic fractionation during high-temperature fluid-rock interaction. Brines in hydrothermally influenced zones show negative $\delta^{11}B$ and $\delta^{37}Cl$ signatures, indicative of deep fluid contributions. Laboratory leaching experiments on ignimbrite samples confirm increased lithium release under hydrothermal conditions compared to cold water leaching.
These findings confirm the central role of hydrothermal systems in the genesis and geochemical evolution of lithium-rich brines in the Altiplano-Puna region. The application of multiple isotopic tracers allows discrimination between hydrothermal and meteoric contributions and provides a robust framework for evaluating lithium metallogenesis in other volcanic and geothermal environments.

Abstract 53

The nature of fumarolic gases collected at Ojigokudani, Iwate volcano, Japan in September 2024

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Direct sampling and analysis of fumarolic gases is a useful technique for assessing volcanic activity. In this presentation, we report the chemical and stable isotope properties of fumarolic gases collected from Iwate volcano, an active volcano in northern Japan, where a failed eruption occurred in 1998 unrest, and unrest has been observed since 2024 again. The fumarolic gases we newly analyzed were collected at two locations at Ojigokudani on Iwate volcano in September 2024, before the volcanic alert level was raised and access was restricted in October 2024. The characteristics of δD and $\delta^{18}O$ indicate that the fumarolic gases are a mixture of local meteoric water and magmatic gas, with the meteoric water component predominant. The fumarolic gases were poor in HCl, and the SO_2/H_2S ratio, which is generally high in high-temperature gases, was low at 0.01 to 0.02. The apparent equilibrium temperature, which is useful for estimating the temperature of the gas source, was estimated to be 212 to 227°C. Comparing these geochemical characteristics with those of the fumarolic gases reported during the 1998 unrest, the contribution of magma to the hydrothermal system of Iwate volcano is not as intense as observed during the 1998 unrest, when a magmatic intrusion was suspected but failed to erupt, as of September 2024.

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Abstract 54

Noble gas geochemistry of the latest eruption in Ioto island (Iwo-jima)

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Ioto Island (Iwo-Jima) is one of the active volcanic islands of the Izu-Bonin-Mariana island arc, located about 1,250 km south of Tokyo. In July 2022, a magmatic eruption spewing pumice occurred off the coast of Okinahama in the southern part of the island for the first time in recorded history. Variations in helium isotope ratios ($^3He/^4He$) are correlated with volcanic activities and it is expected to be a useful proxy for volcanic monitoring (Padron et al., 2013). Volatiles in volcanic rocks directly supply information about magma owing to melt inclusions, which are enclosures of magma in the mineral crystals. In this study, $^3He/^4He$ of the volcanic rocks and the volcanic gases in Ioto were compared to reveal the relationship between them. Noble gas isotopes of mafic minerals in pumices from the latest eruptions in Ioto were measured with a magnetic sector mass spectrometer (modified VG-5400) at the University of Tokyo.
$^3He/^4He$ of olivines, pyroxenes were 3.3 - 4.7 and 2.0 - 4.5 Ra (where atmospheric $^3He/^4He$ of 1.4×10^{-6} ≡ 1Ra), respectively. These values were lower than the volcanic gas values collected in 1997-2002, ranging from 4.7 to 5.6 Ra (Sumino et al., 2004) and also lower than the highest value of the volcanic gases of 6.0 Ra in 2024. This indicates that minerals of the pumice may have trapped low $^3He/^4He$ magma in the shallow magma chamber where crustal contamination occurs.

[1] Padron *et al., Geology*, 41, 539-542 (2013)
[2] Sumino *et al., Chemical Geology*, 209, 153-173 (2004)

Abstract 55

Estimation of Generation Process of Elemental Sulfur Through Groundwater Chemical Analysis at Shiretokoiozan Volcano, Hokkaido, Northeastern JAPAN

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Shiretokoiozan Volcano, Hokkaido, Japan, is notable for large-scale molten sulfur eruptions, e.g. in 1936, 116,523 tons of molten sulfur was expelled at a crater on the northwestern mountain flank and flowed for 1400 meters down the slope. Our study elucidates the sulfur generation mechanism through geochemical analyses of water and gas, focusing on aquifer structure, groundwater–magmatic water interaction, and subsurface flow systems. Water isotopic data reveal mixing of meteoric and andesitic waters with volcanic gases, predominantly within a high self-potential (SP) zone at ~700 masl. The recharge elevation was estimated at 860 masl by the altitude effect of water isotope. The temperature of magmatic fluid entering into the aquifer was also estimated as 176℃. Based on these results, a schematic model is produced from the recharge area at 860 masl, through the mixing zone with high SP around 700 masl, eruption point of molten sulfur at the crater located on the northwestern mountain flank of the volcano (Crater I) at 600 masl, and a discharge area around hot spring (Kamuiwakka) at 330−500 masl. High H_2S and SO_2 concentrations in fumarolic gases and high SO_4^{2-} condensation in the hot spring waters suggest intense magmatic gas input. Results indicate that elemental sulfur forms by the reaction of H_2S and SO_2 dissolved in groundwater within the aquifer. Molten sulfur eruption likely occurs when high-temperature volcanic gases intrude into the aquifer during periods of intensive volcanic activity.

Abstract 56

Gas measurements reveal fractional degassing and water interaction during a flank eruption of Pacaya Volcano (Guatemala)

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Abstract

SO_2 flux and gas composition were measured during the 2021 flank eruption of Pacaya Volcano (Guatemala). The SO_2 flux, measured with Tropomi, gradually rose from ~1 to ~30 kg/s over a 5-month period before the eruption. Field UV camera data showed that >95% of the SO_2 was emitted from the summit crater. The Multigas composition measurements evidenced a depletion in CO_2 and a significant enrichment in H_2O over SO_2 in the plume from the flank eruptive fissure compared to the central crater plume, and punctual amounts of H_2S. We explained these variations by a combination of 1) Fractional degassing between a vertical conduit and an almost horizontal dyke diverging at a calculated pressure of 10-20 MPa, 2) SO_2 scrubbing by a local and temporary hydrothermal system, and 3) Inclusion of groundwater in the magma dyke, even if visually the activity looked purely magmatic (lava spattering and effusion).

Abstract 57

VGR Processor: A Python-Based Software for Calculating Gas Ratios from multicomponent gas analyzers

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The multi-gas analyzer, which has gained widespread use among the volcanology community since the early 2000s, has proven to be an efficient tool for gas measurements in recent years. This small, lightweight, and portable device is equipped with various infrared and electrochemical sensors, enabling the measurement of concentrations of different volcanic gases (most commonly CO_2, SO_2, H_2S, H_2O, H_2) and determination of their mutual molar ratios in diluted plumes an fumarolic fields. However, Multigas data processing needs to address instrumental problems such as the sensitivity of sensors to environmental conditions such as humidity, temperature, and pressure, differences in sensor response times, cross-sensitivities to other gases, and instrumental drift. Today, the use of Python-based software has become common across many scientific disciplines. In this context, we introduce VGR Processor, a simple yet powerful Python software designed specifically for processing multi-gas analyzer data. This tool addresses many of the aforementioned challenges and, with features such as the ability to generate chemical maps, contributes to more effective interpretation of fumarolic fields.

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Abstract 59

Continuous monitoring of the CO2/H2S ratio in volcanic gas at Hakone volcano

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Hakone volcano, located in central Japan, has been active every few years since 2001, with a very small phreatic eruption occurring at Owakudani in 2015. Some researchers reported the temporal variation of the CO_2/H_2S concentration ratio in volcanic gases linked to volcanic activity (e.g., Ohba et al., 2019). They have pointed out that CO_2 and H_2S in volcanic gases are derived from magma and hydrothermal systems, respectively. The present study aims to construct and operate a continuous monitoring system for volcanic gas composition (CO_2 and H_2S).

The monitoring system was installed in the Kamiyu fumarolic area, about 300 m north of Owakudani. It introduced volcanic gas into the measurement section for 10 minutes every hour and measured CO_2 and H_2S concentrations using a non-dispersive infrared absorption analyzer and a controlled potential electrolysis sensor, respectively.

The CO_2/H_2S ratios ranged from 20 to 95 between June 2022 and October 2024, corresponding to those obtained by the detector tube method, indicating that the values measured by the developed monitoring system are valid. The CO_2/H_2S ratios increased from 45 to 95 between early April and mid-April and decreased to 40 in late April 2023. Moreover, The CO_2/H_2S ratios increased from 40 to 85 between July and October and decreased to 50 in December 2023. During these periods of fluctuation, there was no significant change in H_2S concentration and an increase in CO_2 concentrations, indicating the possibility of involvement of magma-derived gases.

Abstract 60

What is the future of multi-GAS monitoring? Global network of the future or too specialized to scale?

Peter Kelly, US Geological Survey

Instrumenting volcanoes with sensors to monitor gas compositions is not a new idea (e.g. Sato and McGee, 1981) but it is one that has proven to be difficult to achieve at scale. This is because developing small, low-cost, low-power instruments that can survive in harsh high-mountain volcanic environments is an exceptional challenge and such highly specialized instruments lack broader commercial applications. Nevertheless, over the past two decades many technical obstacles have been overcome and multi-GAS instruments that measure major volcanic gas species (H_2O, CO_2, SO_2, H_2S) are now an important tool for modern volcano monitoring and research. However, despite considerable community effort, acquiring and maintaining multi-GAS instruments remains difficult for many institutes, data formats lack standardization, analysis methods and software vary, and scant data are archived according to FAIR (Findable, Accessible, Interoperable, Reusable) standards, all of which limit the impact and long-term viability of multi-GAS monitoring networks and the data they produce.

In this contribution I will review a decade of work at the US Geological Survey to implement and support multi-GAS monitoring on volcanoes, including efforts to i) engineer rugged field installations, ii) standardize, scale, and commercialize instrument production, iii) automate data processing and quality control, and iv) make data more openly available. By sharing some successes and failures in these areas, I will highlight present challenges that could be addressed with modest international coordination, with the goal of helping to sustain multi-GAS networks long-term and with FAIR data that is available to address grand challenges in volcano science.

Abstract 61

Monitoring a volcanic fissure zone using diffuse degassing – challenges associated with the 2022 São Jorge seismovolcanic crises

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Volcanic unrest is commonly detected using a holistic approach accomplishing geophysical and geochemical methodologies. In March 2022, thousands of seismic events together with ground deformation affected the Manadas Fissural Volcanic System in the island of São Jorge (Azores, Portugal), where two subaerial volcanic eruptions occurred in the past 450 years.
No visible gas emissions are recognized, and only some weak soil CO_2 diffuse emissions were previously detected from associated tectonic structures. The strategy applied to set up a geochemical monitoring programme during the unrest is discussed and accounted with regular surveys (soil CO_2 flux/concentration, temperature, ^{222}Rn) and the installation of a permanent soil CO_2 flux station. About 20 sites were selected from a grid of 100 and more than 50 surveys were carried out in the period March 2022-February 2023. During the same period, two surveys were done to evaluate carbon isotopic imprint of the soil CO_2 emissions ($\delta^{13}C_{CO2}$). No thermal anomalies were identified and even if some maximum soil CO_2 fluxes and concentrations would be compatible with a deep-derived CO_2 source, $\delta^{13}C_{CO2}$ showed a clear biogenic signal compatible with the local vegetation.
Physico-chemical characterization of a drilled water well showing $^{3}He/^{4}He$ around 7.79 Ra was also done regularly, and the chemical and isotopic compositions suggested a deep-origin for the dissolved gases. However, temporal variations on the geochemical data did not show changes that could be associated with the magmatic intrusion. Carbon isotopic data showed once again to be crucial to discriminate potential deep-derived sources of the gas.

Abstract 62

Geochemistry of Gas Emissions in the Yellowstone Plateau Volcanic Field: New Insights into Peripheral Areas

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The Yellowstone Plateau volcanic field (YPVF) hosts over 10,000 thermal features driven by heat from underlying magma bodies. Despite extensive previous characterizations, knowledge gaps remain regarding gas compositions in peripheral areas of the volcanic system. This study builds upon previous research (Lowenstern et al., JVGR 2015) by analyzing new gas samples from previously under-studied locations, including remote sites outside the caldera boundary.

Throughout the YPVF, magma-derived gases transfer upward into groundwater, driving the hydrothermal system that feeds hot springs and fumaroles. Typical emissions contain >99% H_2O, with dry gas fractions dominated by CO_2 (>90%), H_2S (1-6%), and various minor components including nitrogen, argon, methane, hydrogen, and helium. These gases typically exhibit $\delta^{13}C$ values from -1 to -6‰ VPDB and helium isotopic ratios (R/Ra) as high as 16.

Our September 2024 sampling campaign revealed anomalous gas compositions at Wahb Springs, 10 km north of the caldera. Despite temperatures <30°C, these emissions showed CO_2 concentrations similar to those at boiling-temperature sites within the caldera, but with significant enrichment in CH_4 and higher-order hydrocarbons. While H_2S concentrations were <3%, associated waters contained remarkably high dissolved sulfide concentrations. In contrast, samples from thermal areas ~15 km southwest of the caldera resembled typical YPVF compositions but contained higher levels of gas derived from dissolution in meteoric water.

This study of peripheral hydrothermal features reveals complex mixing between magmatic gases and contributions from organic-rich sediments or meteoric water, broadening our understanding of the spatial heterogeneity of the YPVF hydrothermal system.

Abstract 63

Decoding mantle degassing at a quiescent basaltic volcano: insights from surface CO_2 fluxes and fluid inclusions on Bioko Island

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Quiescent volcanoes are notoriously challenging to study from a gas geochemistry perspective. These systems lack active degassing features such as volcanic plumes and fumaroles from which to draw samples, and although diffuse surface degassing may be present, the absence of thermal features means these areas are not visually obvious. In this situation, we must search for structural features that may be pathways for gas escape in the present, as well as examine gases trapped in minerals for clues to degassing in the past. In this study, we employed soil CO_2 flux measurements to delineate degassing structures on Bioko Island, using the accumulation chamber and dynamic concentration probe techniques. We then compared chemistry and noble gas isotopic ratios from surface gases and fluid inclusions (FI) in crystals to reveal the source features and the style of degassing on Bioko Island. Our results show that mantle-derived CO_2 is the dominant surface gas species followed by thermogenic CH_4. Helium isotopic ratios from surface emissions are isotopically similar to those of FI (~5 to 6.8Ra) indicating a lower than MORB isotopic signature, more typical of Sub Continental Lithospheric Mantle (SCLM) environments, with variable ingrowth in the magma of radiogenic ^4He. CO_2 densimetry in FI from olivine and pyroxene crystals through Raman spectroscopy reveals a main zone of magma storage and degassing beneath the Moho at 12-14 km. The outcome of this study reveals the absence of crustal storage and a rapid ascent of magma from the mantle, which has implications for volcano monitoring.

Abstract 64

Studying Copahue Volcano's Plume Using Multigas: A Journey Through Crater Lakes and Phreatic Explosions

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Since 2018, Copahue volcano has exhibited a seasonal pattern characterized by the formation of a crater lake during summer, its displacement or disappearance in winter, and subsequent explosions—presumably phreatic in nature. Over the past five years, we conducted several summer field campaigns to measure volcanic gas ratios (CO_2, SO_2, and H_2S) using a portable Multigas instrument. During the most recent lake–explosion–lake cycle, gas measurements were obtained at three key stages: (1) during the presence of the crater lake (February 2024), (2) immediately after the explosion, when the lake was absent (November 2024), and (3) once the lake had reformed (February 2025). A striking result is the complete absence of SO_2 during the third stage, suggesting effective scrubbing of this gas by the crater lake—a phenomenon not observed in previous years. The CO_2/SO_2 ratios measured with and without the crater lake averaged 1 and 0.3, respectively. CO_2/H_2S ratios varied across the three stages: 20.5 before the explosion, 0.3 immediately after, and 4.5 post-reformation. These trends point to a moderate decrease in the CO_2/H_2S ratio during the explosion phase, likely linked to the sudden removal of the lake and disruption of the mineralogical seal typically precipitated in the vent. Overall, these results demonstrate that both the presence of the crater lake and the opening of the vent due to the explosion are reflected in the volcanic gas ratios measured by the Multigas instrument.

Abstract 65

The Chemical Impacts of Volcanic Lightning:
A Comprehensive Simulation and Assessment Approach

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Abstract
Volcanic lightning (VL) is a form of electrical discharge that can be both powerful and far-reaching. It is a common phenomenon during volcanic explosive eruptions of all scales, making it a significant source of nitrogen oxides (NO_x) at various altitudes. Volcanic lightning may also modify sulfur or halogen speciation in volcanic plumes. This study aims to develop a comprehensive chemical model framework that incorporates electric field-driven and high-temperature processes within the volcanic eruption plume environment, to simulate the impacts of VL. This project builds on recent chemical box modelling of (nonvolcanic) lightning impacts (Xu C. et al., JGR-A, 2020, 2023), with small time steps and hundreds of chemical species, to provide new insights into the mechanisms underlying the chemical impacts of VL. We will seek to assess the chemical impacts of HTHH (Hunga Tonga-Hunga Ha'apai) eruption in the stratosphere, with particular attention to NO_x fixation, greenhouse gas production, and interactions with volcanic plume water vapor, halogens, ozone, and sulfate. The findings are expected to provide a deeper understanding of the role of VL in atmospheric chemistry and its broader implications for volcanic systems.

Abstract 66

Gas ratios in the plume as proxies for magmatic degassing dynamic in an open-conduit volcano: insights from monitoring at Stromboli, Italy

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We present our findings on the correlation between the CO_2/SO_2 molar ratio of volcanic gas in the plume and the hourly frequency of Strombolian explosions recorded at Stromboli between April and December 2024. In general, high CO_2/SO_2 ratios were associated with a higher frequency of explosions, although, at times, CO_2/SO_2 ratios and hourly frequency of explosions showed disjoined phases. In the period preceding the paroxysm, occurred on 11 July 2024, the CO_2/SO_2 ratios declined sharply, coinciding with an increase in the frequency of explosions until June 28, when a lava overflow occurred, after which the frequency decreased rapidly. After the paroxysm, we observed a gradual increase in the CO_2/SO_2 ratio until the end of December, and the frequency of explosions also increased moderately though it still varied. It is known that at Stromboli the volcanic gases causing the explosions originate from deeper magmatic sources that exhibit a higher CO_2/SO_2 ratios in the plume. Therefore, the relationship between changes in gas composition and the frequency of explosions hints at a possible cause and effect, although we have yet to fully understand exactly the link between these factors. To truly grasp the relationship between the gas composition and explosion frequency long-term data collection and further investigation is required. These insights deepen our knowledge on how gases are released at Stromboli, the interaction between gas and eruption frequency, and the styles of volcanic activity. Furthermore, they emphasize the importance of real-time monitoring of plume gas emissions to improve our understanding of the magmatic dynamics of Stromboli and similar basaltic volcanoes.

Abstract 67

SO_2-to-Sulfate Conversion in Volcanic Plumes: Insights from the 2014–2015 Holuhraun Eruption

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The emission of SO_2 during volcanic eruptions, and its subsequent in-plume conversion to sulfate particles, represents a key volcanic atmospheric process with direct implications for air quality as well as the formation of other components e.g. metals, halogens. However, the rates of this in-plume oxidation process remain poorly constrained and vary widely across eruptions and conditions. In 2014–2015, the Holuhraun (Bardarbunga) eruption in Iceland released vast amounts of SO_2 into the troposphere, impacting air quality stations across Europe. Several studies reported on SO_2, sulfate, and metals from this eruption but a systematic analysis to quantify SO_2-to-sulfate oxidation is still missing. This eruption provides a unique dataset to analyze SO_2 decay in the troposphere. Here, we assess the oxidation of volcanic SO_2 by combining data from European air quality stations with satellite observations (IASI, OMPS) and FLEXPART back-trajectory modelling to estimate plume ages. We determine a notably slow SO_2 decay rate - among the lowest reported in volcanic plumes - likely driven by inefficient gas-phase oxidation under the cold, low-light conditions of the Icelandic autumn and winter. Further analysis of the local gas and aerosol composition during distinct "volcanic events" suggests that the background atmospheric composition - specifically the abundance of neutralizing species - changes aerosol acidity and thus the extent of aqueous-phase SO_2-to-sulfate conversion. These observations indicate that plume age, climatic conditions and the local atmospheric composition may control sulfate particle formation. The results can be used for modeling air quality and particle exposure hazards from volcanic eruptions.

Abstract 68

Shallow conduit controls on degassing: vesiculation- and sintering-driven permeability evolution

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In active volcanoes, degassing has a key control on eruption style. In silicic systems the permeable structure of the shallow conduit comprises fractures in the magma and surrounding rock, which are often infilled with fragmental material. Magma fragmentation during decompression produces a wide range of melt fragment sizes, and rigid particles such as crystals or lithic fragments. These fragments deposit as polydisperse suspensions of melt and crystals with a complex pore structure that governs degassing. If the temperatures remain high following deposition, these fragmental systems undergo changes as they sinter (weld), a process by which loose particles evolve into a cohesive but porous structure, progressively reducing permeability. In hydrous fragments, residual volatiles, primarily H_2O, in the melt may be mobile enough to result in vesiculation and diffusive outgassing which contribute to the complex evolution of porosity and permeability. We perform high-temperature sintering experiments on hydrous pyroclasts interspersed with variable fractions of crystals to map the porous-permeable evolution through time. Our results show that higher crystal fractions inhibit sintering, promoting sustained permeability and extended degassing potential. Furthermore, we posit that these fragmental systems are not inert: they provide significant surface area for 1) direct outgassing of hydrous pyroclasts, 2) gas–particle interactions including salt formation, and 3) can act as filter for ascending, deeper-derived volatiles. These processes can shape the composition and flux of emitted gases. We will discuss how the vesiculation- and sintering-driven clogging of shallow systems has the potential to affect the volatile ratio of gas emissions.

Abstract 69

CO_2 diffuse degassing in volcanic lakes in Ecuador

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Cuicocha and Quilotoa, Ecuador, are volcanic lakes associated with large explosive eruptions (VEI 5-6) occurred ≈3000- and 800-years BP, respectively. Both are surrounded by inhabited areas and display a high touristic frequentation. Despite their long recurrence eruptive periods, both lakes pose the potential hazard of limnic eruptions, as water can retain volcanic gases and suddenly release them during quiescent periods. Indeed, some historical chronicles at Quilotoa probably suggest the occurrence of unrest periods (CE1725, 1740, 1797), probably related to large regional earthquakes such as the February 4 earthquake, whose epicenter was some 100 km from the volcano and had a Mic 7.6.
To identify degassing patterns, we perform periodic diffused CO_2 surveys using the accumulation chamber method at both lakes. The diffused CO_2 emissions at Cuicocha have been measured for more than a decade, revealing strong spatial and seasonal control in the degassing process. CO_2 for Cuicocha ranges from 34 g/m2/d to 63 g/m2/d. For Quilotoa, CO_2 emissions have been measured three times between 2014 and 2018, showing values ranging from 46 to 180 g/m2/d (Melian et al., 2021). However, recent measurements during 2024 and 2025, reveal fluxes of up to 600 g/m2/d which are significantly higher than the average reported for Cuicocha, and for other active crater lakes. These fluxes are quite high and if stratification of the lake is confirmed, a better understanding of the CO_2 -degassing dynamics at both lakes, especially at Quilotoa, is necessary to enhance the ability to forecast these hazardous limnic eruptions in the future.

Abstract 70

Multiparametric evolution of the 2022-2023 mild eruption of Cotopaxi volcano (Ecuador)
(Centered, Title case capitalization, Bold, 12 pt font, Times New Roman)

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On October 22, 2022, Cotopaxi Volcano began a new moderate eruptive episode. Only few early signs of degassing and deformation were recorded but no clear seismic precursors. The activity lasted until July 2023 and was characterized by periodic seismicity patterns (LPs and tremor episodes), slight inflation and SO_2 degassing above background levels, with fluctuating SO_2/H_2S and CO_2/SO_2 ratios. Thermal anomalies recorded by MIROVA since September 2022 were more frequent, but of low intensity. The height of visible gas and ash plumes was less than 3 km above the crater and generally about 1 km.

Sustained tremor episodes were associated with ash emissions that produced regular light ash fallout near the volcano, and, occasionally, at distances of 60 km from the vent. Routinely collected ash samples showed an increasing content of juvenile material and an andesitic composition. The analyzed juvenile fragments display a dacitic glass. S-Cl-F were measured in melt inclusions and matrix glass. Based on the composition of plagioclases and glass, we calculated a pre-eruptive temperature to be 938 ± 18 ºC considering 5% wt.% H_2O and a pressure of 2kbar.

Compared to the last eruptive activity in 2015, the current reactivation reached lower intensity and magnitude, and did not show long-lived precursors, leading us to consider an open-vent dynamics. Nevertheless, both phases are related to a magmatic source. Determining the size and location of this source would improve the proposed eruptive scenarios and the monitoring of Cotopaxi's future activity, specially now, as it can be considered a primed volcano.

Abstract 71

Redox state of hydrothermal systems and implications for volcano monitoring: new insights from hydrocarbon geochemistry in Mediterranean fumarolic emissions

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In closed-conduit volcanoes, hydrothermal aquifers act as intermediate buffers between the magmatic plumbing system and the surface, effectively retaining a substantial fraction of magmatic volatiles. These aquifers can significantly modulate volcanic degassing and obscure early warning signals of unrest, for example, by delaying the detection of SO_2, HCl, and HF at the surface. Although, early degassing of such volatiles may not be directly detectable, it can induce a decrease in pH and promote more oxidizing conditions within the hydrothermal system. Redox-sensitive parameters could therefore be used as tracers of magmatic degassing. Hydrocarbons constitute a broad group of redox-sensitive gas species. However, the effect of the redox state of the magmatic-hydrothermal system on their chemical and isotopic composition remains poorly constrained. We investigated the geochemistry of hydrocarbons in low-temperature (≤100 °C) fumarolic emissions from active volcanoes (Vulcano Island), dormant calderas (Nisyros and Campi Flegrei) and non-volcanic areas (Larderello geothermal field). It was revealed that hydrocarbons from Vulcano fumaroles, in contrast to those from the other sites, are characterized by (1) CH_4 with ^{13}C- and ^{2}H-enriched isotopic compositions, (2) peculiar carbon isotope patterns, (3) extremely high $CH_4/(C_2H_6+C_3H_8)$ ratios, and (4) elevated alkenes/alkanes ratios and iso-C_4H_{10} and benzene concentrations. Such features are attributed to the influence of highly oxidizing conditions within the hydrothermal system, likely driven by a substantial influx of magmatic volatiles. Consequently, we suggest a set of hydrocarbon-based parameters that can be used for tracing the evolution from hydrothermal to magmatic-hydrothermal systems following the persistent or transient injection of magmatic gases.

Abstract 72

Estimation of the SO_2 emission of the 800 BP eruption of Quilotoa volcano (Ecuador)

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Quilotoa is an active dacitic crater-lake volcano in central Ecuador. The last eruption occurred 800 yBP (VEI=5-6), and its deposit comprises a wide dispersed fallout, PDCs, and a co-ignimbrite. The primary fallout covers an area of ~40000 km^2, and the PDCs show a proximal distribution with a corresponding volume of 2.5 km^3 (DRE) and 2.8 km^3 (DRE), respectively. The co-ignimbrite accounts for most of this eruption volume (9 km^3, DRE) and reaches the furthest from the vent. Juvenile eruptive products are mainly highly vesiculated pumices containing plagioclase, hornblende, biotite, quartz, and Fe-Ti-oxides. We analyzed major and volatile elements of plagioclase and quartz-hosted melt-inclusions sampled from the fallout deposit to estimate the SO_2 emitted mass during this event. Melt inclusions display a rhyolitic sub-alkaline composition (75 to 82 wt.% SiO_2), with average water and CO_2 contents of 5.5 and 0.26 wt.%, respectively. Pressure calculation based on magma's CO_2 and H_2O solubility is 5±3 kbar. Sulfur in melt inclusions reaches up to 351 ppm, while it is less than 216 ppm in the matrix glass. Considering the total mass of the emitted magma (14.3 km^3, DRE), the concentration of sulfur in melt-inclusions and the matrix glass, we calculated that the emitted SO_2 mass is 4700 kt (4.7 Tg). Compared to a smaller dacitic eruption that occurred at Pinatubo in 1991 (5.3 km^3 DRE), Quilotoa would have emitted only one quarter of SO_2. Such a difference could be related to the absence of a basaltic recharge in Quilotoa, as identified for Pinatubo.

Abstract 74

Evidence of magmatic and hydrothermal signatures in gas emissions from Deception Island volcano, Antarctica

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Deception Island is an active basaltic-andesitic volcanic caldera flooded by seawater, located in the Bransfield Strait region (South Shetland Islands, Antarctica). The volcano forms part of a subaerial-to-submarine volcanic lineament situated within a back-arc basin, generated by the subduction of the Phoenix Plate beneath the South Shetland Plate. Since the Antarctic summer of 2022, we have conducted geochemical surveys at seven hydrothermal sites, most of which are situated along the island's inner coastline. Direct gas sampling, using Giggenbach bottles filled by NaOH or $Cd(OH)_2$ solutions, revealed that the fumaroles at Fumarole Bay (~100 ºC) are dominated by water vapor, with an average gas fraction of approximately 10% and CO_2/H_2S ratios ranging from 20 to 200. The remaining sites are characterized by CO_2-dominated emissions with no detectable sulfur species, except at Whalers Bay, where the use of a MultiGAS instrument allowed the detection of minor H_2S concentrations. The absence of acidic magmatic gases such as SO_2, HCl, and HF in the fumarolic emissions suggests efficient gas scrubbing processes within the hydrothermal system. Furthermore, temporal variations in the CO_2/H_2S ratio detected by MultiGAS monitoring indicate fluctuating contributions of seawater and snowmelt to the emission areas. Overall, the relative abundances of N_2-He-Ar suggest a mantle-derived gas composition modified by interaction with air-saturated water, occasionally enriched in N_2 (N_2/Ar ratios up to 117) and CH_4. Additionally, isotopic signatures of carbon ($\delta^{13}C$-CO_2 between -4.8‰ and -8.8‰) and helium ($^3He/^4He$ ~7 Ra) point to a predominant deep magmatic source with limited atmospheric and/or crustal contamination.

Abstract 75

Geothermal activity from 2015 to 2024 with the 2018 minor eruption at Ebinokogen-Ioyama in Kirishima Volcano, Japan

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Geothermal activity in Ebinokogen-Ioyama restarted from late December 2015. Subsequently, in April 2018, hydrothermal eruption occurred, forming the Ioyama-south craters and Ioyama-west crater. Temperature observations in the geothermal area indicated three hydrothermal liquids supply events prior to the eruption. The last supply event triggered the eruption. The oxygen-hydrogen isotope values of the hydrothermal liquids suggested that magmatic water and groundwater mixed just before the eruption (Tajima et al., 2020). After this eruption, an open geothermal environment with a large amount of volcanic gas release was constructed, and high Cl/SO_4 ratio water was produced until May 2019. However, the Cl/SO_4 ratio decreased after the event (Ishibashi et al., 2024; Ishibashi et al., submitted), when pools of water in the Ioyama-south craters disappeared in May 2019. This environmental change might have been caused by a decrease in the supply rate of magmatic water to the groundwater system. Hydrothermal water producing activity stopped at the Ioyama-west crater in July 2021. Since then, the fumarole-H temperature has been increasing in the summit area. During this increase in fumarole-H temperature, five small hydrothermal blowout events and two small molten sulfur blowout events occurred around the Ioyama-south craters from Nov. 2022 to Dec. 2023. The fumarole-H temperature had been decreasing for several months before these blowouts, and rainfall was observed just before blowouts in some cases. Lastly, gypsum mineral was observed in three cases. Therefore, the blowout events may have been a result of progressive blockage by sulfur and gypsum.

Abstract 76

Geochemistry of the hydrothermal fluids from the Western Cordillera area, Departamento de Potosí, Bolivia

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The Central Volcanic Zone of the Andes (CVZA) is characterized by its intense magmatic activity, which includes the presence of several types of volcanic structures, including giant calderas, occurrence of eruptions (from freatic to plinian) and presence of persistent passive degassing volcanoes. Because of the high thermal flux from the magmatic activity, several hydrothermal systems are hosted along the CVZA, such as Tutupaca (Perú), Sajama (Bolivia), El Tatio (Chile), Cerro Blanco (Argentina), among others. One of the most interesting hydrothermal areas in the Western Cordillera, where the active volcanism of the CVZA is focused, is the western part of the Departamento de Potosí, Bolivia. In this area, at least 6 hydrothermal zones have been recognized, from north to south corresponding to Laguna Colorada, Huayllajara, Agüita Brava, Sol de Mañana, Salar de Chalviri and Laguna Blanca. Gas and water are emitted from fumaroles, steaming ground, bubbling pools and springs, with outlet temperatures ranging from 18.1°C and 103.9°C. Thermal waters have a pH range of 1.86-8.66, whereas its compositions include sulfate-(chlorine)-sodium, sulfate-calcium and chlorine-sodium waters. Gas composition is dominated by H_2O, CO_2 and H_2S, whilst relatively high concentrations of N_2 have been also observed. R/Ra ratios range 2.29-2.76, suggesting a limited contribution from a magmatic source. Water geothermometry based on Na-K-Ca-Mg ions cannot be applied due to the area is dominated by immature waters, whereas silica geothermometry provides reservoir temperatures between 124 and 235°C. Gas geothermometry based on the H_2/Ar pair indicates that reservoir temperature varies from 213 and 305°C.

Abstract 77

Geochemistry of fluids emitted from the hydrothermal systems of Moyuta volcano and Ixpaco lake (Tecuamburro volcano), Guatemala

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Several areas with geothermal potential are located along the Central American Volcanic Arc (CAVA). Guatemala has 27 areas of interest (the most important Zunil II, Tecuamburro, San Marcos, Moyuta, and Tetonicapán). Here we present the chemical composition of water and gas emitted from Moyuta Volcano and Laguna Ixpaco (Tecuamburro Volcano), with the aim to estimate the hydrothermal reservoirs temperature. The hydrothermal emissions correspond to fumarolic gases, bubbling and mud pools, and hot spring emissions. At Moyuta volcano, outlet temperatures range 22-97°C, waters have a sulfate (bicarbonate)-calcium composition with increasing bicarbonate content toward the peripheral zones, and the gas phase is dominated by CO_2 and H_2S. According to the He and $\delta^{13}C$-CO_2 isotopic data, these emissions are fed by deep magmatic fluids (inputs from both upper mantle and subducted sediments in the slab), whereas crustal inputs are related to the interaction of deep fluids with organic-rich sedimentary rocks, especially in the peripheral emissions. On the other hand, the acid Ixpaco lake (pH 2.4 and calcium-sulfate composition) presents fumarolic emissions with temperatures of 88 °C, dominated by CO_2 and H_2S, and relatively high CH_4 concentrations. He and $\delta^{13}C$-CO_2 isotopic compositions are similar than Moyuta volcano, i.e., signature related to mantle and subducted carbonate sediments. According to the gas-phase geothermometers, reservoir temperatures of 290°C were estimated under relatively oxidizing conditions (RH = -3.4) for Moyuta volcano, whereas in the case of Ixpaco lake, similar temperatures were estimated (280°C), albeit under more oxidizing conditions (RH = -3).

Abstract 79

Eruptive and non-eruptive degassing in active volcanoes of Guatemala

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Degassing from active volcanoes can occur non-eruptively (passive degassing) and during eruptions, injecting volcanic gases into the atmosphere. These gases are dominated by H_2O, CO_2, SO_2, HCl, HF. The study of volcanic gases (directly or remotely) allows a better understanding of the internal dynamics of volcanoes, and the evolution of magmatic/hydrothermal systems. In this work we present discrete measurements carried out during February 2024, using UV camera and DOAS instruments at Santiaguito, Fuego and Pacaya volcanoes (MultiGAS measurements were also done at Pacaya) with the aim of linking degassing patterns and the last eruptive episodes at each volcano, and to identify the deep/shallow processes that control such degassing. Santiaguito volcano records 94±74 t/d, Fuego 117±47 t/d and Pacaya 13 t/d of SO_2. Pacaya volcano average plume composition was ~92.6% mol H_2O, ~7% mol CO_2, 0.33% mol SO_2 and 0.07% mol H_2S. Santiaguito has exhibited persistent lava dome extrusion accompanied by low-intensity explosions over the past 50 years. Our measurements are consistent with a shear fracturing model at the conduit margins, where weak and continuous degassing permeates through the surface seal, which is interrupted by small explosions, and consequently, increasing degassing rates. Pacaya volcano exhibits lower SO_2 emission rates (accompanied by decreasing CO_2 and increasing H_2O) than those observed during previous years, probably related to decreasing eruptive activity in recent years. Fuego volcano exhibits a range of 4-to-8 explosions per hour. This activity produces columns of gases and ash, generating pulsatile gas emissions, whose concentrations are consistent with previously reported results.

Abstract 80

Calibration of SO_2 Cameras with Long Pass Glass Filters: Towards Simplified Field Measurements

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This study introduces and evaluates a simple calibration method for SO_2 cameras, eliminating the need for SO_2 gas cells in the field. SO_2 cameras, combining UV-sensitive cameras with specific UV bandpass filters, enable high-frequency visualization of SO_2 column amounts in volcanic plumes, crucial for understanding volcanic activity or degassing behavior of the volcanoes . Conventional calibration using the SO_2 gas cells poses logistical challenges. Our approach utilizes a specific long-pass glass filter whose UV transmission properties resemble spectral trends of SO_2 transmission within the camera's spectral range.

Fundamental experiments with an Alta U260 (Apogee Inc.) camera involved imaging gas cells (94-5616 ppm_m) and glass filters of varying thicknesses (1-8 mm) against a clear sky. Pseudo-absorbance was calculated for both. A linear correlation was found between filter thickness and pseudo-absorbance. Plotting pseudo-absorbance against SO_2 column amount (with 1 mm filter equivalent to ~300 ppm_m SO_2) showed that data from both gas cells and glass filters aligned on a single trend.

These initial results suggest that the glass filter can potentially calibrate SO_2 cameras without requiring gas cells. This approach simplifies field operations SO_2 cameras. The presentation will further validate this technique under various observational conditions.

Abstract 81

Recent developments for measurements of gas flux and ash in plumes and detection of anomalous soil degassing in volcanic areas

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We present three recent developments on methods and instruments for the remote sensing of volcanic emissions. The first deals with the integration of ground- and satellite-based observations of volcanic gas emissions from NOVAC's scanning-DOAS and ESA's Sentinel-5P/TROPOMI. Enabled by tools from the Volcano Space Observatory, this approach provides daily global estimates of gas emission rates from volcanoes, leveraging the complementary strengths of both measurement platforms. The second is the development of a channeled spectropolarimeter that can be easily integrated with existing scanners. In addition to enabling trace gas spectroscopy, the instrument can detect volcanic ash plumes through measurements of light polarization. And the third is the development of a portable instrument to measure Solar-Induced Fluorescence (SIF) to assess photosynthetic activity in plants affected by anomalous soil degassing in tectonic areas. This method uses the Fraunhofer Line Depth method to detect stress-related changes in vegetation's photosynthetic activity. Each of these techniques will be demonstrated with examples and through field applications during the Field Workshop of CCVG.

Abstract 82

CCVG Remote Sensing Group measurements at Sabancaya: comparison and analysis

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CCVG Remote Sensing Group participants in the 14th Field Workshop of CCVG

We present the results of an intercomparison exercise conducted at Sabancaya volcano (Peru), on 10-11 November 2022, during the 14th Field Workshop of CCVG. Measurements were taken by 12 groups with a variety of established and novel remote sensing techniques, using scattered light, solar-occultation and thermal emission methods. Measurements conditions were good, and the volcano showed passive degassing and pulses of ash emission.
We found SO_2 fluxes between 22 and 45 kg/s, molar ratios of 10-22 for SO_2/HCl and of 34-53 for SO_2/HF. Good agreement is found for measurements with the same technique, while some bias is observed between the results of measurements from different techniques. We analyze the results in relation to natural emission variability, varying choices of evaluation parameters and ancillary information, and physical effects caused by radiative transfer through the atmosphere and ash.
This study shows the large variety, versatility and complementarity of remote sensing tools for volcanic gas measurements and its widespread use in the community. It also signals the importance of refining measurement protocols and of careful interpretation of measurement conditions.

Abstract 83

NOVAC: 20 years of global collaboration on volcanic gas studies

The NOVAC Collaboration, novac-community.org/partners

The Network for Observation of Volcanic and Atmospheric Change (NOVAC) was initiated in 2005 as a European project aimed at providing volcano observatories with automatic tools for the continuous monitoring of volcanic gas emissions. Over the past two decades, this collaboration has expanded and is now active in 23 countries, covering nearly 50 volcanoes.

Sustained efforts from multiple fronts have contributed to maintaining and strengthening this community, including continuous instrument and method development, training activities, exchanges of expertise in data analysis and interpretation, support with installations, and the organization of workshops.

The value of consistent, long-term observations has been demonstrated through numerous research contributions highlighting the role of magmatic degassing in volcanic activity changes, the correlation between gas emissions and other geophysical signals, the estimation of regional and global volcanic emission budgets, or the validation and complementing of satellite observations.

Looking ahead, we aim to further strengthen and expand this community and enhance the observational capabilities of the network. This contribution provides an overview of NOVAC's achievements during its first 20 years.

Abstract 84

sGs UnMix: a web application for spatial prediction and mixture modeling of volcanic soil CO_2 fluxes

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Spatial analysis and prediction of soil CO_2 fluxes are fundamental in volcanology for mapping the extent of degassing and quantifying the emission of CO_2 into the atmosphere. However, traditional geostatistical tools (e.g., GSLIB; Deutsch and Journel, 1998) often require programming skills or involve numerous manual steps that can be time-consuming and prone to user subjectivity. Here, we developed sGs UnMix, an interactive web application that simplifies spatial prediction workflows and reduces subjectivity in statistical analysis, making it accessible to the entire geoscience community. sGs UnMix (available online at https://apps.bo.ingv.it/sgs-unmix) is built with the shiny package for R studio and is organized into four main panels, which allow data loading and coordinate projection, identification of biogenic and volcanic soil CO_2 fluxes through mixture modeling, variogram modeling, and spatial prediction using sequential Gaussian simulation (sGs). Automated variogram fitting and mixture modeling reduce user bias, while dynamically updated heat maps of soil CO_2 fluxes enable real-time visualization of spatial patterns. sGs UnMix provides not only a standardized approach for estimating volcanic volatile fluxes (e.g., soil CO_2 emissions) but also applications in diverse geoscience fields, including ore deposit mapping, hydrocarbon exploration, environmental monitoring, and climatology. Compared to existing geostatistical tools, it offers automation, interactivity, dynamic and responsive outputs (tables and plots), and a platform-independent, standalone web-based solution for geoscientists.

References

Deutsch, C.V., Journel, A.G., 1998. GSLIB: Geostatistical Software Library and Users Guide. Oxford Univerity Press, New York (369 pp.).

Abstract 85

Geochemistry of Magmatic and Hydrothermal Fluids from Isluga Volcano, Northern Chile

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Isluga volcano is located in the Central Volcanic Zone of the Andes (19.15°S - 68.83°W). It is a stratovolcano characterized by continuous passive degassing over time of both its main crater and the flank of the volcanic edifice. This volcano has a long eruptive history and presents a bimodal system: the crater emits magmatic gases while the flank shows emissions of hydrothermal origin. Using direct sampling, remote sensing and MultiGAS techniques, the total volatile flux and the evolution of volcanic fluids were calculated. The total volatile flux at Isluga is ~ 2,900 t/d, of which ~ 2,000 t/d come from the crater and are dominated by H_2O, with an enrichment in acidic species (~ 16% SO_2 and H_2S). On the other hand, hydrothermal emissions from the flank are composed of ~900 t/d of CO_2 and ~ 4 t/d of HCl. Furthermore, Isluga presents a stable system over time, where magmatic emissions from the crater have not shown significant variation between 2015 and 2022, while the flank has evolved into a mature hydrothermal system. This pattern evidences a volcanic system dominated by hydrothermal processes recorded in the flank fumaroles, as well as magmatic emissions evidenced by emissions from the main crater, which largely control the emissions Isluga volcano.

Abstract 86

Volcanic Gas Compositions Reveal Different Magma Pathways Through the Crust That Control Eruption Dynamics in the 2023-2025 Sundhnúksgígar Eruptions

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We report gas measurements from eight 2023–2025 Sundhnúksgígar eruptions on the Reykjanes Peninsula made using open-path Fourier Transform Infrared Spectroscopy (FTIR). We focus on CO_2, SO_2, HCl and H_2O as tracers for distinguishing magma pathways. A representative composition for the initial dissolved gas content of diverse mantle sources is used to calculate pre-eruptive CO_2 and SO_2 loss required to achieve the measured compositions.

The magma can follow different pathways to the surface. It can ascend with little residence time in the mid-crust and/or accumulate within a reservoir zone at ~4 km depth and/or stall in previously intruded dykes (surface to ~2 km). Direct ascent preserves initial gas ratios, residence in the accumulation zone allows for the loss of CO_2 and stalling in a dyke allows for the loss of CO_2 and SO_2.

Gas compositions measured at eruption onset indicate which pathway dominated each event. Eruptions showing minimal CO_2 and SO_2 loss indicate rapid ascent from the deep crust; those with CO_2 loss but minimal SO_2 loss point to residence in the accumulation zone; and those with substantial CO_2 and SO_2 loss indicate residence in previously emplaced dykes. Less SO_2 loss, i.e. less magma contributed from previously emplaced dykes, appears to herald longer eruption duration. Less CO_2 loss, i.e. greater contribution from fresh magma, presages larger total erupted volume of lava. These findings demonstrate that early FTIR gas measurements can provide insight into magma pathways and forecast eruption behavior, offering a valuable tool for real-time eruption assessment.

Abstract 87

Lastarria volcano emits substantial concentrations of B and chalcophiles in northern Chile and the Central Volcanic Zone

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Abstract
This work presents the trace element chemistry of fumarolic deposits and volcanic plumes at Lastarria volcano (northern Chile). Fumarolic deposits were manually collected, while volcanic plumes were sampled using the filter pack technique. The research focuses on chalcophile elements (As, Cd, Sb, Te, Cu, Zn, Tl, Pb, and Bi) and B, with the findings revealing significant enrichment of As and Pb in fumarolic deposit samples, especially in medium- and high-temperature fumarolic vents, respectively. On the other hand, filter pack measurements in the volcanic plume indicate a notable enrichment in Te, B, As, and Tl, with Sc-normalized enrichment factors within the range of 10^4 – 10^6. From these elements, B, Tl, and Te appear to be less scavenged at the vent, presenting more significant enrichments in volcanic plumes than in fumarolic deposits. By comparing our results with subduction-related volcanoes such as Etna, Stromboli, Lascar, Masaya, or La Soufrière de Guadeloupe, Lastarria volcanic plumes can be regarded as the one with the highest concentrations of B and As ever recorded. Moreover, Lastarria has chalcophile enrichments comparable to those volcanoes with shallower magma chambers and high-temperature magmatic emissions such as Stromboli. The higher abundance of chalcophiles suggests a significant magmatic influence feeding Lastarria fumaroles and the presence of ligands, such as Cl, which can transport significant amounts of chalcophiles at shallower levels of the crust during late-stage magma crystallization. Large amounts of chalcophiles released by Lastarria and Lascar volcanoes could be responsible for the naturally elevated concentrations of these elements in the Altiplano-Puna area.

Abstract 88

Eruptive Column Dynamics Observed Via Thermal Infrared Imaging

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The ash columns generated during volcanic eruptions provide critical insights into the dynamic processes occurring within a volcano's crater. In this study, we investigate the convective region of a series of explosions at Reventador Volcano, Ecuador, spanning 2017 to 2022. Using IR thermal video recordings, we measured key eruption parameters, including ejection velocity, maximum temperature, ascent rate of the column head, and the spatial volume of the ash plume. By applying theoretical models of volcanic plume dynamics, we further estimated the bulk density of the ash column, the gas mass fraction at the origin of the explosion, as well as the total mass of ejected pyroclasts and volcanic gases.
To identify patterns among eruption characteristics, we conducted a principal component analysis (PCA) on the derived dataset, reducing dimensionality while preserving variance. This statistical approach allowed us to classify the explosions into distinct groups based on their physical and thermal properties, revealing that Reventador Volcano exhibits two predominant types of explosions. We also examine in detail the evolution and characteristics of a typical Reventador explosion. Our observations indicate that the resulting volcanic plumes consist of multiple smaller plumes produced in rapid succession. This suggests a complex vent geometry, where different sections activate sequentially rather than simultaneously. Furthermore, these segments may exhibit varying degrees of gas permeability, implying localized and independent degassing behavior within the conduit.

Abstract 89

Persistent outgassing of Nyiragongo volcano and the impact on drinking water quality

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Nyiragongo (D.R. Congo) is an active volcano known for its impressive persistent lava lake within the crater, and it is recognized as one of the most dangerous volcanoes in the world because more than two million people live on its slopes. Unexpectedly, on 22 May 2021, Nyiragongo produced three different lateral lava flows in the lower flanks, and significant amounts of volcanic gas and ash were emitted from the summit crater. For several weeks, the ash fallout impacted the main city of Goma and the numerous villages located in the vicinity of the volcano. 22 samples of volcanic ashes and 135 samples of drinking water (springs, rivers, rainwater, roof runoff) were collected before, during and after the eruption. From the leaching of the ashes and their direct observation through the electron microscope, large quantities of soluble salts (e.g. sulfates, chlorides) on their surface were identified. The alarming results showed that most of the drinking waters were heavily contaminated by volcanic emissions. Fluoride, chloride, sulphur, and many potentially toxic elements (PTEs), including Al, As, Cd, Cr, Cu, Fe, Mn, Mo, Pb, Sb, Se, Te, Tl, and V, exceeded the suggested World Health Organization (WHO) drinking water limits during the eruptive period, exposing the population, often unaware, to high health risks.

Abstract 90

Infrared and Ultraviolet Remote Sensing of Sulfur Dioxide Gas Emitted During the 2018 Lower East Rift Zone Eruption of Kīlauea Volcano, Hawai`i

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Ultraviolet (UV) remote sensing techniques are commonly used and highly effective for detecting volcanic sulfur dioxide (SO_2) by measuring its characteristic absorption of radiation between 300 and 400 nm. However, significant discrepancies exist between ground-based and satellite UV measurements of SO_2, particularly for dense SO_2 plumes emitted into the lower troposphere. This was evident during the 2018 Kīlauea lower East Rift Zone (LERZ) eruption, where SO_2 fluxes and cumulative emissions from ground-based mobile DOAS instruments (Kern et al., 2020) differed markedly from those retrieved by TROPOMI satellite measurements (Delbrel et al., 2024). To investigate these inconsistencies, we employed spaceborne thermal infrared (IR) imaging interferometry and a newly adapted version of the SO_2 Amenable Lookup Table Algorithm (SO_2-ALTA; Gabrieli et al., 2017) to process multispectral IR imagery from the MODIS instrument. We found that SO_2 column densities of the 2018 Kīlauea plumes retrieved from MODIS align more closely with ground-based observations than with the TROPOMI results. The IR and ground-based results are also consistent with petrologic measurements of sulfur in erupted products. We attribute the lower columns retrieved from TROPOMI to backscattering of UV radiation at the top of dense volcanic plumes. Although the SO_2 detection limit of IR measurements is significantly higher than that of UV methods, IR radiation is less susceptible to scattering and IR measurements thus provide a viable tool for investigating dense plumes. SO_2-ALTA's computational efficiency enables near real-time processing and scalability, and we hope to set up operational SO_2 retrievals for active volcanoes around the globe.

Abstract 91

SO_2 Monitoring by Continuous Scanning DOAS at Sinabung, Gamalama and Merapi Volcanoes, Indonesia

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Indonesia is home to more than 120 active volcanoes. The Center for Volcanology and Geological Hazard Mitigation (CVGHM) monitors 69 of these continuously, mainly using seismic and geodetic methods. Over the last decade, however, CVGHM has begun installing continuous gas-geochemical monitoring on volcanoes where gas measurements are deemed particularly useful for monitoring activity. As part of this effort, scanning Differential Absorption Optical Spectroscopy (DOAS) instruments have been installed on Sinabung (2016), Gamalama (2017), and Merapi volcanoes (2023). Part of the Network for Observation of Volcanic and Atmospheric Change (NOVAC), these instruments continuously measure the sulfur dioxide (SO_2) emission rate from the active vents by scanning through overhead volcanic plumes.

The continuous time series of SO_2 emission rates has provided the local observatories with situational awareness of degassing activity at each of the monitored volcanoes. At Sinabung, a detailed analysis of the time series between October 2016 and 2021 found that SO_2 emissions tended to decrease slightly during the five days leading up to explosions, an observation that allowed us to develop a statistical method for forecasting daily explosion probabilities (Kunrat et al., 2022). At Gamalama, issues with local data telemetry and internet access have made real-time data analysis and interpretation challenging. Data from recent installations on Merapi have yet to be fully analyzed but preliminary results look promising. Overall, the addition of scanning DOAS systems for monitoring SO_2 output now provides CVGHM with an important additional parameter for tracking volcanic unrest and forecasting events.

Abstract 92

Characterisation of Volcanic Gases at Tangkuban Parahu Volcano, West Java, Indonesia by Multi-GAS Stationary Measurement

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Tangkuban Parahu volcano located in West Java is one of Indonesia's active volcanoes with at least 18 phreatic eruptions in almost last two centuries. Despite its eruptive history, the volcano has never caused fatalities. However, its activity poses potential hazard. Sudden eruptions could lead to inevitable casualties, particularly the popularity of Tangkuban Parahu as a tourist destination. Since the eruptions of Tangkuban Parahu are typically short-lived, minor, and often preceded by limited geophysical precursors, this study represents initial efforts to characterize Tangkuban Parahu volcanic gases, which remain poorly understood. To gain deeper insights into the volcano's activity, we installed a stationary Multiple Gas Analyzer System (Multi-GAS) on the southern rim of Ratu Crater. This station is part of ongoing efforts to enhance the volcano monitoring system and improve the interpretation of volcanic activity data. Ratu Multi-GAS station is equipped with sensors for CO_2 (0-5000 ppm), SO_2 (0-100 ppm), and H_2S (0-100 ppm), as well as meteorological sensors measuring wind speed, wind direction, ambient temperature, air pressure, and relative humidity. The sensors are also calibrated with standard gases of CO_2 (1085 ppm), SO_2 (24.7 ppm), and H_2S (26 ppm) periodically. Continous data collection began in May 2024 and preliminary results show that Tangkuban Parahu's volatiles are primarily dominated by H_2O, CO_2, and H_2S. The CO_2/H_2S ratios are 5-28 and the sulfur gases proportion are strongly dominated by H_2S over SO_2, reflecting hydrothermal fluid-rock interactions. The gas data have shown us that Tangkuban Parahu is in a quiescent state.

Abstract 93

SO_2 Monitoring of Mayon Volcano from 2014-2023: challenges and insights in assessing eruptive behavior

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Mayon Volcano, the Philippines' most active volcano, has significantly erupted three times in the last fifteen years: in 2014, 2018, and 2023. Sulfur dioxide (SO_2) emission has been monitored using both ground-based campaign (e,g. FLYSPEC) and continuous (ScanDOAS) systems regularly and at higher temporal resolutions during eruptive unrest to capture rapid changes in degassing behavior. During lava dome extrusion in 2014, SO_2 flux significantly increased from June to October, with a peak average of 2360 t/day on 6 September 2014. This increase followed a peak in average soil temperature recorded in May 2014. In 2018, eruption initiated with summit dome collapses on 13 January which was forewarned by slight increases in SO_2 flux in December 2017. On 6 March 2018, ScanDOAS and FLYSPEC systems detected 4459 t/day and 4316 t/day, coinciding with lava fountaining and sporadic ash emissions. In 2023, no above-baseline SO_2 emissions marked the onset of the June–December effusive eruption. It was characterized by lava dome growth, lava flow and lava collapse-driven pyroclastic density currents (PDC), ash emissions and short-lived lava bursts. The highest SO_2 flux during this period was 4756 t/day on 16 August 2023 during pronounced swarm of volcanic tremors. In every eruptive episode of Mayon, elevated SO_2 flux has consistently either preceded, coincided with, or followed increased seismicity, ground deformation, lava dome growth, and soil temperature anomalies. In sum, the application of SO_2 monitoring has been best complemented by other techniques for effective early-warning and assessment of the eruptive behavior of Mayon Volcano.

Abstract 95

Trace Element Emissions from the Tajogaite Eruption, La Palma, Canary Islands

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During volcanic eruptions, a variety of metals and metalloids are emitted along with gases and particulate matter. These elements are released in trace amounts, often bound to volcanic ash, gases, and aerosols, and can be transported over long distances by wind currents. Some of these elements are of concern because several of them, such as As, Cd and Pb are toxic and pose significant risks to both human health and the environment.

During the Tajogaite eruption (2021) at La Palma (Canary Islands), a substantial amount of CO_2 and SO_2 was released into the atmosphere. Throughout this eruption observations of SO_2 emissions were made using ground-based instruments, in transverse mode, as well as satellite instruments. Air particulate matter sampling followed EN 12341:2014, the European reference method for PM_{10} and $PM_{2.5}$ in ambient air. PM_{10} was collected using a low-volume sampler on 47 mm quartz filters (24 h). Filters were analyzed for Pb, Cd, As, and Ni according to EN 14902:2005, the reference method for metal determination in PM_{10}. Cd, As, Pb, and SO_2 immission levels recorded at air quality monitoring stations during the syneruptive and posteruptive phases of the Tajogaite eruption exceeded typical background levels on La Palma. In this study, we estimate trace element emission rates from the Tajogaite by combining observed Xi/SO_2 ratios (Xi represents a trace metal in PM_{10}) with measured SO_2 emission rates. Estimated Pb, Cd and As average emission rates from Tajogaite during syneruptive and posteruptive degassing stages were 1314, 264 and 115 $kg \cdot d^{-1}$, respectively.

Abstract 96

Thirty Years of Geochemical Monitoring at Teide Volcano: Implications for Early Detection of Volcanic Unrest

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Teide volcano, the only active stratovolcano on Tenerife (Canary Islands), has been the focus of continuous geochemical monitoring over the past 30 years. As part of this long-term program, fumarole emissions at the summit crater, characterized by low-temperature (~83 °C), low-flux gas release, have been systematically studied. Temporal variations in gas composition have provided valuable insights into subsurface processes. Notably, significant shifts in fumarole chemistry were detected approximately one year before the seismic crisis that occurred on the island between April and June 2004. These geochemical anomalies, together with increased seismic activity, suggest a strong link between fluid emissions and underlying magmatic dynamics, highlighting the value of fumarole monitoring as a tool for early detection of volcanic unrest.

From 1991 to 2024, the average air-corrected $^{3}He/^{4}He$ ratio was 7.03 R_A (where R_A is the atmospheric ratio), with a peak of 7.57 R_A recorded in August 2016. This maximum coincided with a magmatic intrusion event, marked by the injection of fresh magma and enhanced convective mixing beneath the volcano. Since then, continued changes in fumarole gas composition indicate a persistent disequilibrium in Teide's volcano-hydrothermal system, likely driven by sustained pulses of magmatic heat and fluid input. These findings underscore the critical role of volcanic gas geochemistry—both chemical and isotopic—in the long-term monitoring of volcanic activity.

Abstract 97

Soil gas geochemistry as evidence of ^{40}Ar transport to the atmosphere during volcanic unrest.

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Transport of ^{40}Ar to the atmosphere involves volcanic degassing, hydrothermal circulation through the crust, and erosion of continental crust. Almost 70% of Ar released to the atmosphere in the Earth would come from the mantle, so only one-quarter of the whole mantle would be outgassed. About one-half of the terrestrial ^{40}Ar inventory is still retained in the deep Earth. Therefore, volcanic eruptions represent an important source of Ar to the atmosphere. We report herein the results of extensive soil gas geochemistry studies performed El Hierro island (Canary Islands, Spain) prior and during the 2011-2012 submarine volcanic eruption. These types of studies offer an important geochemical tool for volcanic monitoring, especially in those volcanic systems that, like El Hierro, do not present visible gas emissions. Our results represent that the average ^{40}Ar/^{36}Ar ratio in the soil atmosphere of El Hierro island increased from an average value of ~290 in the pre-eruptive phase up to ~300 in the eruptive phase. The ^{40}Ar/^{36}Ar ratio showed a declining trend during the eruption until it reached pre-eruptive values. These results show that soil gas geochemistry studies are sensitive to strain-stress changes during volcanic eruption.

Abstract 98

Carbon dioxide hazard monitoring at Puerto Naos and La Bombilla inhabited areas, La Palma, Canary Islands

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The 2021 Tajogaite volcano eruption on La Palma, Canary Islands, Spain, had the most substantial impact on urban centers in Europe over the last 75 years. Following the eruption, an unusual emission of carbon dioxide (CO_2) has emerged as the primary volcanic hazard, directly affecting the residential communities of Puerto Naos and La Bombilla, both situated 6 km from the eruption site. INVOLCAN first detected elevated outdoor CO_2 concentrations in these areas three weeks before the Tajogaite eruption ended on December 13, 2021.

To understand and manage this ongoing volcanic threat, continuous studies of diffuse CO_2 emissions have been conducted in La Bombilla. Additionally, both outdoor and indoor air CO_2 levels have been regularly monitored at La Bombilla and Puerto Naos since December 2021. Diffuse CO_2 emissions in La Bombilla showed significant variations, from 4.0 to 170 td^{-1} (average of 14.4 td^{-1}). These emissions have $\delta^{13}C-CO_2$ values ranging from -8.63 to -4.28‰ vs. VPDB (average = -5.5‰). The highest diffuse CO_2 emission rate (170 td^{-1}) occurred during the initial assessment, with subsequent values typically between 4.0 and 70 td^{-1}.

Notably, outdoor air CO_2 concentrations, measured 15 cm above ground, reached up to 87% (average = 0.67%) in La Bombilla and 30% (average = 0.23%) in Puerto Naos. These are the highest recorded levels during the post-eruptive period. Given these findings, continuous monitoring of both inhabited areas is vital to lessen the danger from gas emissions. Furthermore, innovative solutions are actively being explored to mitigate the risks associated with CO_2.

Abstract 99

Geochemical Evolution and Activity Indicators of the Hydrothermal System in the Tatun Volcano Group, Northern Taiwan (2014–2022)

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This study compiles and analyzes geochemical monitoring data from the Tatun Volcano Group (TVG) between 2014 and 2022, complemented by ground deformation and seismic observations, to investigate the progressive activation of its hydrothermal system. The 2014 Shilin earthquake may have facilitated fracture opening, followed in 2016 by localized anomalies in soil CO_2 flux and a slight increase in sulfate concentrations in thermal waters, suggesting early signs of gas release and conduit development. Since 2019, fumarolic compositional anomalies (e.g., elevated SO_2/H_2S ratios, increased He and HCl) have coincided with seismic activity. In 2020–2021, notable vertical ground displacement and rising concentrations of major cations in hot spring waters were observed, indicating the sustained ascent of deep hydrothermal fluids. Between late 2021 and 2022, suspected hydrothermal rupture events resulted in new vent formation and repeated mud eruptions, exhibiting characteristics akin to small-scale phreatic eruptions. Overall, the shallow hydrothermal system appears to have entered a stage of pressure release and reconfiguration of fluid pathways. Although no clear evidence of magmatic intrusion has been detected, the evolving deep fluid dynamics pose a potential hazard, underscoring the importance of continued geochemical monitoring to track system evolution and support hazard assessment.