Network for Observation of Volcanic and Atmospheric Change


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The Consortium

The consortium encompasses observatories of 15 volcanoes from five continents, including some of the most active and strongest degassing volcanoes in the world. Table 1. As these observatories are to expand the network, additional observatories are invited to join. Contact: bo.galle@chalmers.se

Introduction

NOVAC is a recently started project funded by European Union, with the aim to establish a global network of stations for the quantitative measurement of volcanic gas emissions. The network is based on a novel type of instrument, the Scanning Dual-beam mini-DOAS, developed within the EU-project DEFIELD/A. Normally such instruments will be used to provide data which can be exploited for risk assessment, volcanic gas emissions and geophysical research on the local scale. In addition, the data are explored for other possible purposes, such as: volcanic plume height measurement: by comparing high time resolution concentration data from different geographical sites, or with other geophysical event (earthquakes, tilt sensor) mechanisms of volcanic tectonics may be revealed. The data recorded by the instrument will also be used to derive data that complement global observation systems related to climate change and atmospheric composition and depletion research.

The Dual-Beam Scanning mini-DOAS instrument

The basic mini-DOAS system consists of a pointing telescope fiber-coupled to a spectrophotometer. Ultraviolet light from the Sun, scattered from aerosols and molecules in the atmosphere, is collected by a telescope with a quartz lens defining a field-of-view of 12 mrad. Light is transferred to the spectrometer by means of a optical fiber. The spectrometer uses a 2400 lines gratings covering a 0.6 nm resolution over a wavelength range of 245-380 nm.

In the Scanning mini-DOAS the telescope is attached to a scanning device consisting of a motor attached to a computer-controlled stepper-motor, providing a means to scan the field-of-view of the spectrometer over 180°. In Figure 1 a typical measurement technique is shown. The instrument is located under the plume, and scans are made, from horizon to horizon, in a plane perpendicular to the wind-direction. Typically 3-4 second integration time is used, with 10° angular resolution, providing a full emission measurement every 5 minutes. By adding a second spectrometer and fiber, simultaneous measurements can be made in two viewing directions. In Figure 2 a time resolved measurement of the gas emission from San Cristobal volcano in Nicaragua is shown. A 30-60 second in gas emission is seen over a time scale of 1 hour. Further studies of the gas emissions from this volcano using the scanning mini-DOAS system have revealed cyclic degassing behavior involving fluctuations of SO2 fluxes on three superimposed time scales in the course of a day. Correlating these gas data with other geophysical data, e.g. seismic data, is likely to substantially increase our understanding of the status and behavior of this volcano.

Plume speed and plume height

The main source of error in both mobile and scanning mini-DOAS measurements is determination of wind-speed and wind height. In the scanning measurements, also knowledge of the plume height is crucial in order to accurately calculate the number of gas molecules in a cross-section of the plume. For the wind measurements the wind speed and wind direction is calculated from observations of SO2 in different viewing directions. As a result from different viewing directions, one beam pointing upwind and the other downwind the plume. A time series of total column variations are registered in both directions, and from the temporal delay in variations in the total column, the wind speed can be calculated. In Figure 2 the plume height measurement is the plume simultaneously monitored by 2 scanning mini-DOAS instruments separated by some distance, and a vertical cross section of the gas concentration is derived from these measurements. Besides giving the plume height, these data can be used to study the plume dynamics and in combination with a dispersion model assess the impact of the gas emissions on the local environment.

Measurement of additional molecules

The dual-beam mini-DOAS instrument measures SO2 concentration in the sky. In the scanning measurements, also knowledge of the plume height is crucial in order to accurately calculate the number of gas molecules in a cross-section of the plume. For the wind measurements the wind speed and wind direction is calculated from observations of SO2 in different viewing directions. As a result from different viewing directions, one beam pointing upwind and the other downwind the plume. A time series of total column variations are registered in both directions, and from the temporal delay in variations in the total column, the wind speed can be calculated. In Figure 2 the plume height measurement is the plume simultaneously monitored by 2 scanning mini-DOAS instruments separated by some distance, and a vertical cross section of the gas concentration is derived from these measurements. Besides giving the plume height, these data can be used to study the plume dynamics and in combination with a dispersion model assess the impact of the gas emissions on the local environment.

Studies of stratigraphic and tephrochronological composition

The instrument is an all-sky spectrometer which is also used for studies of atmospheric gas composition. Among others, this is the same instrument where the instrument can simultaneously measure SO2 and BrO from volcanic gas sources. This opens up the possibility to measure time resolved measurements of the ratio BrO/SO2, another parameter that may be used to understand volcanic degassing and eruptive style. An important problem when using scanned sunlight to study volcanic emissions is multiple scattering of the Solar light in aerosols and clouds. Depending on the conditions this effect may result in serious over- or underestimation of the measurements. During the past decade significant improvements in radiative transfer modeling and understanding of multiple scattering processes in clouds have been achieved. In combination with the measurements of column densities by the mini-DOAS, precision of errors due to multiple scattering may be reduced.

Satellite validation

Many volcanoes with strong gas emission are located in remote places with no regular gas measurements. Therefore, the use of satellite-borne DOAS measurements can play an important role in monitoring volcanic gas emissions. This is especially true for those volcanoes that are active in remote areas where active volcanoes are frequently found. Table 1. As one of the aims of the project is to expand the network, additional observatories are invited to join. Contact: bo.galle@chalmers.se

Table 1. Institutes and volcanoes presently contributing to the NOVAC network.

| Institute Volcanoes |
|----------------------|-----------------|
| Institut de Physique de Globe de Paris | Piton de Fournaise |
| Instituto Nacional de Geofísica y Volcánologia, Chile | Antuco Volcano |
| Instituto Nicaragüense de Electricidad | Fuego de Colima |
| Instituto Nicaragüense de Estaciones Terrestres | San Cristobal |
| Observatorio Volcánologico y Geológico de Costa Rica | Arenal |
| Instituto Colombiano de Geología y Minería | Nevado del Ruiz |
| Instituto Nacional de Geofísica y Volcánologia, Italy | Stromboli |
| Instituto de Física de Globus de París | Piton de Fournaise |

Figure 3. Measurement of plume speed during the flank campaign at Mt. Etna in May 2005 using a dual-beam mini-DOAS system.

Figure 4. Time resolved measurement of emissions from San Cristobal (13 December 2002), calculated using plume height and wind speed from Dual Beam mini-DOAS measurements.

Figure 5. The relationship between BrO and SO2 measured on 5 different volcanoes measured with a scanning mini-DOAS instrument (Hoefer et al. 2003).

Figure 6. Measured concentrations of SO2 at Piton de Fournaise during the period 1996-2002. Note that few of these volcanoes are part of the NOVAC network. [Karlovsh et al. 2004].