25PC4 LIDAR MEASUREMENTS OF VOLCANIC GAS FLUXES

Hans Edner, Pär Ragnarson, Sune Svanberg, and Eva Wallinder
Department of Physics, Lund Institute of Technology
P.O. Box 118, S-221 00 Lund, Sweden
Phone: 46-46-107658 Facsimile: 46-46-104250
E-mail: Hans.Edner@fysik.lth.se

Volcanic gases are composed of molecular combinations of a limited number of major elements; H, C, O, S, F, Cl and N, associated with minor quantities of rare gases and metal compounds. Water, carbon dioxide and sulphur species represent by far the predominant components of volcanic fluids. Their relative proportions essentially reflect the nature of magma, as well as the thermodynamic conditions prevailing at depth. Measurements of the composition and flux of emitted gases and particles from active volcanoes are thus of great importance for the monitoring of volcanic activity, but also from an environmental point of view regarding possible effects on the earth's climate. SO_2 is generally the main sulphur-containing species in a high-temperature volcanic gas plume. Ash particles or condensed water in the plume can act as oxidising catalysts converting SO_2 into sulphates. If the sulphur in the plume remains as SO_2 for a long time after its dispersion into the atmosphere, and the total SO_2 flux is known, the flux of other chemical constituents with sufficiently long mean lifetime can also be inferred from their concentration ratio to SO_2.

During a field campaign in Italy the total flux of SO_2 from the volcanoes Etna, Stromboli and Vulcano was determined using the differential absorption lidar (DIAL) technique [1]. The measurements were performed with a mobile DIAL system housed in a truck parked on the aft deck of the Italian CNR research ship "Urania". Different measurement modes were used. At Etna and Stromboli scans through the volcanic plume were obtained in traverses under the plume, with the lidar system pointing in a fixed vertical direction. At Vulcano, with the active area at a lower altitude, vertical lidar scans through the spreading plume near the source could be made with the ship positioned in a fixed position.

Fig 1 shows an example of a measurement of the SO_2 plume from Etna, captured at a distance of 23 km from the source. Wind data were received from observation stations at Etna at 2500 and 3000 metres above sea level. By combining the integrated gas concentration over the plume cross-section with wind velocity data, it was possible to determine the total flux of SO_2. The three volcanoes were all measured within a three-day period in September 1992. We found total fluxes of about 25, 180 and 1,300 tonnes/day for Vulcano, Stromboli and Etna, respectively. The results are in good agreement with the baseline values, typical of "low-level" volcanic activity, from previous measurements with passive UV correlation spectroscopy (COSPEC) techniques. Lidar measurements on atomic mercury were also made for the plumes from Vulcano and Stromboli, but the system sensitivity and range only allowed estimates of upper limits for the Hg fluxes.

The lidar measurements of volcanic gas fluxes are the first, to our knowledge, in which an *active* optical remote sensing technique has been used. DIAL can measure the overhead burden more correctly than passive techniques, which often require correction for scattering within or below the plume. The DIAL technique also gives the height and vertical extension of the plume which are important parameters in the determination of the appropriate wind velocity. During the measurements the lidar data were compared with simultaneous recording with passive differential optical absorption spectroscopy (DOAS) using the

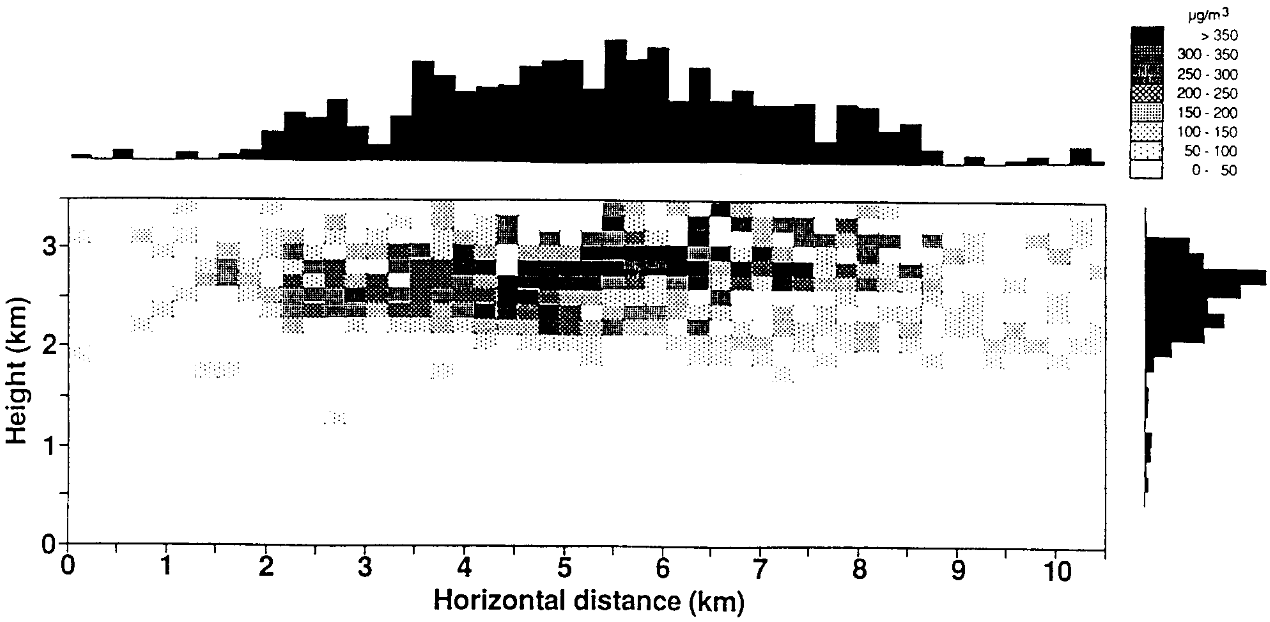

Fig. 1. SO_2 distribution in a cross-section of the spreading plume from Etna obtained from range-resolved DIAL measurements.

sky radiation as the light source. A distinct difficulty with passive optical measurements, compared with active ones, is establishing the effective path through the plume. In an ideal passive measurement all detected photons are scattered above the plume and penetrate the plume in vertical beams. The actual conditions are of course more complicated and a thorough investigation of this subject has been made by Millån [2]. In a horizontally extended plume, photons can penetrate at a slanting angle before they are scattered within or below the plume. This light has a longer absorption path through the plume and will therefore indicate a larger overhead burden. If, on the other hand, the base of the plume is high enough compared with its horizontal extension, light can be scattered into the telescope without passing the plume at all. Fig 2 shows the result from simultaneous DIAL and DOAS measurements, evaluated as the integrated vertical SO column content, during a traverse under the plume from Etna. Several such measurements gave as a mean a DOAS overestimation of about 30% for the Etna plume. Measurements at Stromboli, with a plume 2-2.5 km wide at an altitude of 1 km, gave a difference of only 5%. Our results agree rather well with the estimates of Millån, although differences in meteorological conditions, horizontal extension of the plumes as well as the distances to them make it difficult to obtain a general correction factor.

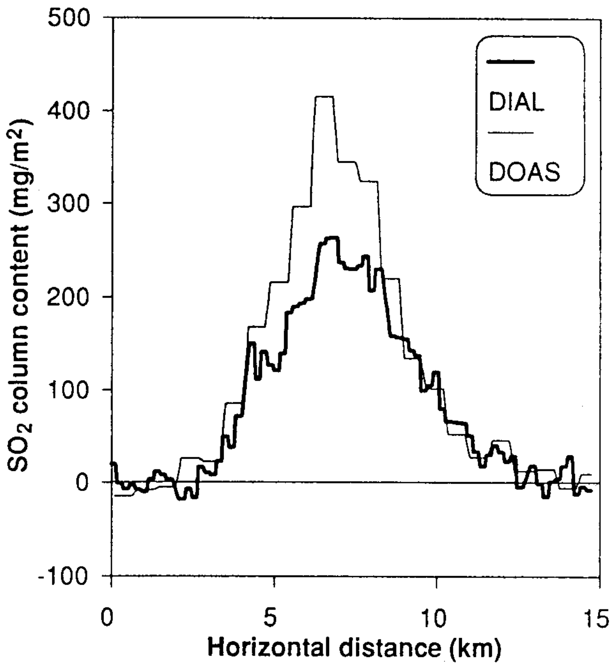

Fig. 2. SO_2 vertical column content for the Etna plume as measured by DIAL and DOAS.

References:

1. H. Edner, P. Ragnarson, S. Svanberg, E. Wallinder, R. Ferrara, R. Cioni, B. Raco, and G. Taddeucci, J. Geophys. Res., in press.
2. M.M. Millån, Atm. Environ. 14, 1241 (1980).