Monitoring volcanic SO_2 plumes using the GOME-2 satellite instrument

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Introduction

Space based atmospheric sensors like GOME-2 make it possible to detect the emission of volcanic gases such as **sulphur dioxide** (SO_2) and monitor volcanic activity and eruptions on a global scale and on a daily basis (D. Loyola et al., 2008). Large increases in SO_2 are an important indicator for new episodes of volcanic unrest The GOME-2 SO_2 retrieval is carried out in near real-time (NRT), i.e. within 2-3 hours after the actual GOME-2 measurement. The daily volcanic activity maps for different volcanic regions are provided at:
http://wdc.dlr.de/data_products/SERVICES/GOME2NRT/so2.php

Ensembles of backward trajectories and dispersion modelling are applied to study the motion of volcanic plumes, to relate exceptional SO_2 values to particular sources or regions and hence attribute to a volcanic or anthropogenic origin. Trajectory density maps give an overview of the most probable location of the emission source. Additionally, the moment of the eruption as well as the emission and the plume height can be estimated. Forward dispersion modelling can provide a forecast of the plume motion and the transport of SO_2 for several days. All data are supplied to a database daily and visualised in a GIS-system.

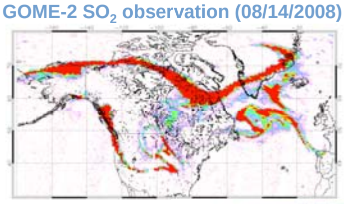
Volcanic SO_2 retrieval and eruption charactristics determination

The slant column density is calculated using the **Differential Optical Absorption Spectroscopy** (DOAS) method in the UV wavelength region 315-326 nm (W. Thomas et al., 2005). A correction is applied for the strong interference of Ozone and SO_2 absorption signals in the wavelength region used for the retrieval. The corrected slant column densities of SO_2 are converted to geometry-independent vertical column amounts through division by an appropriate air mass factor. The SO_2 column is computed for three different assumed volcanic plume heights: 2.5 km, 6 km and 15 km above ground level.

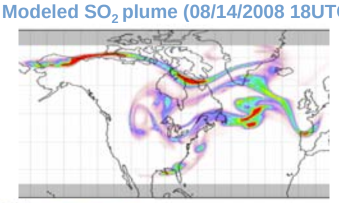
For the determination of the SO_2 plume height the state-of-the-art **3D kinematic trajectory model FLEXTRA** is applied. Input data are wind and temperature fields of the numerical weather prediction models of the European Center for Medium Range Weather Forecast (ECMWF) or the National Oceanic and Atmospheric Administration (NOAA).
In order to forecast the three dimensional transport of volcanic ash and SO_2 plumes the **Lagrangian particle dispersion model FLEXPART** is utilized (A. Stohl et al., 2005). The calculations are based on meteorological data of numerical weather prediction models (ECMWF, GFS, MM5).

Case studies: Explosive eruption and passive degassing

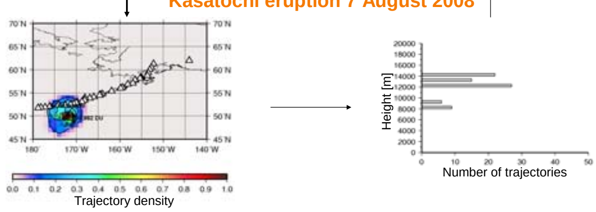
GOME-2 SO_2 observation (08/14/2008)



Modeled SO_2 plume (08/14/2008 18UTC)

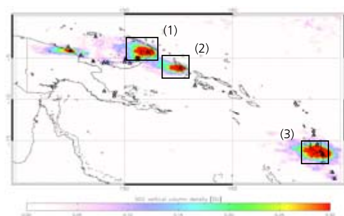


Kasatochi eruption 7 August 2008

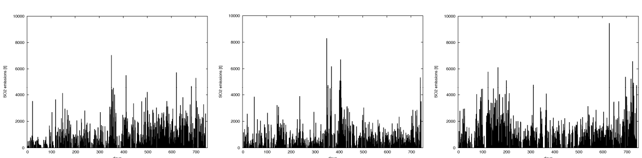


Determination of emission source and plume height

Passive degassing Papua New Guinea 2007 - 2008

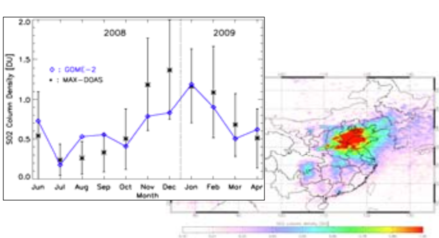


Daily SO_2 emissions 2007 - 2008 in tons estimated from GOME-2 measurements

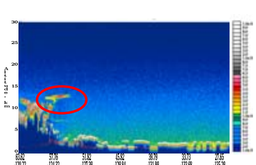


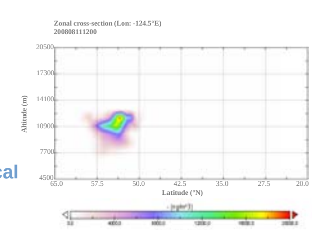
Rabaul(1) **Bagana(2)** **Ambrym(3)**

Validation of results



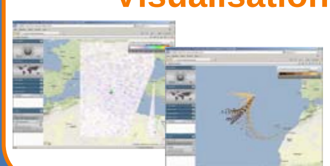
Comparison of SO_2 pollution over China measured by GOME-2 with MaxDOAS instrument, Beijing (2008-2009)





Comparison of modeled vertical SO_2 distribution (right) with CALIPSO observations of volcanic areosol distribution (left) (Kasatochi eruption)

Visualisation in Exupéry-GIS



GOME-2 SO_2 observation on 27 May 2009 for the volcanic region „Italy" (left) and hypothetical trajectories on 16 June 2009 for Agua de Pau volcano, Azores. (right)

Outlook

In order to warn humans and air traffic the early-warning system can be improved by hypothetical dispersion forecasts of volcanic ash and gasses. To enhance the accuracy of these forecasts the source-receptor relationship of emissions should be estimated by using a combination of independent observations (e.g. ensembles of satellite data using advanced retrieval techniques) and a particle dispersion model (PDM) in the future. In contrary to a simple trajectory model a PDM considers important processes as diffusion and deposition of particles that allows a qualitative and a quantitative determination of the emission source strength. With regard to a best possible forecast of the dispersion and chemical conversion of SO2 the PDM could be additionally linked to a chemical module. Furthermore, numerical investigations of the emission characteristics and transport of volcanic ash should be carried out for the integration into the early-warning system.