Spatial and temporal variability of stratospheric HNO_3 from IASI global measurements

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Nitric acid (HNO_3) plays a crucial role in the stratospheric ozone cycles but its spatial distribution was until recently only accessible from limb satellite measurements, with medium coverage and sampling. IASI provides since 2007 HNO_3 concentration distributions with unprecedented spatial and temporal sampling, which have not yet been exploited.

In this presentation, we will first briefly review the characteristics of the HNO_3 profiles retrieved from IASI and we will show results from a validation exercise, in which the HNO_3 profiles and total columns from IASI are compared with those retrieved from ground-based measurements at several sites.

We will then show and discuss the spatial distributions of HNO_3 IASI total and stratospheric columns and assess the seasonal and inter-annual variability of HNO_3 using the 8 years of IASI observations available. Preliminary results from a simple multivariable regression model applied to these time series will be shown to support the analysis and to identify the principal processes driving the variability of stratospheric HNO_3. In this discussion focus will be given onto the polar regions, where the relation of HNO_3 to ozone will be investigated in greater details.

With these results, the potential of using IASI for studying stratospheric chemistry will be more generally highlighted.

Worldwide spatial and temporal ammonia (NH_3) variability revealed by IASI

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As a short-lived species, ammonia (NH_3) is highly variable in time and space, and while ground based measurements are possible, they are sparse and their coverage is largely heterogeneous. Consequently, spatial and temporal patterns of NH_3 emissions and their strength are poorly known and account for the largest uncertainties in the nitrogen cycle.

IASI is measuring since 8 years NH_3 columns at a high spatiotemporal resolution. The aim of this work is to assess distributions and to investigate, from a global to a local scale, the variability of NH_3 using this remarkable time series. We first look at yearly distributions (2008-2015) to identify the main source processes and areas. Seasonal patterns and inter-annual variability are then investigated at subcontinental scale by looking at global composite seasonal means and monthly time series over various regions around the world, considering separately but simultaneously measurements from IASI morning and evening overpasses. The relations between the NH_3 atmospheric abundance and emission processes is emphasized at smaller regional scale by extracting at high spatial resolution the global climatology of the month of maxima columns. Finally, IASI observations are exploited to identify and track industrial NH_3 emissions.

Measuring volcanic SO_2 emission using IASI

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ABSTRACT

Sulphur dioxide (SO_2) is an important atmospheric constituent that plays a crucial role in many atmospheric processes. Volcanic eruptions are a significant source of atmospheric SO_2 and its effects and lifetime depend on the SO_2 injection altitude. Measurements of volcanic SO_2 emissions can offer critical insight into the current and near-future activity of volcanoes, however, the majority of active volcanoes lack regular ground-based monitoring.

Here we exploit the spectral range of IASI, from 1000 to 1200 cm^{-1} and from 1300 to 1410 cm^{-1} (the 7.3 and 8.7 μm SO2 absorption bands), to study volcanic SO_2 in 3 ways:

1) The IASI-A dataset was analysed using a rapid linear retrieval algorithm as a global survey tool to show that IASI observations detect SO_2 emissions from anthropogenic sources, volcanic eruptions and certain persistently degassing volcanoes over the IASI time series.

2) We apply the iterative optimal estimation retrieval scheme to measure both the SO_2 amount and altitude of volcanic plume from explosive and effusive eruptions, from 2008 up to the more recent Calbuco and Bárðabunga eruptions. Comparison with Brewer ground measurements over Europe (Eyjafjallajökull, 2010) and CALIPSO backscatter profiles show that IASI SO_2 measurements are not affected by underlying cloud and are consistent (within the retrieved errors) with the other measurements. The series of analysed eruptions (2008 to 2012) show that the biggest emitter of volcanic SO_2 was Nabro (2011), followed by Kasatochi (2008) and Grimsvoton (2011). Our observations also show a tendency for volcanic SO_2 to be injected to the level of the tropopause during many of the moderately explosive eruptions observed.

3) The iterative retrieval is used over Ecuador and Northern Kamchatka to explore how trends in SO_2 emissions observed by IASI compared to reported changes in the level of volcanic activity. The IASI retrieval is able to quantify tropospheric SO_2 from multiple volcanoes in both regions across the period sampled. Over Ecuador, Tungurahua showed the most persistent signal, with a strong correlation in relative emission rates between quiescent and active periods when comparing IASI with ground-based and OMI datasets. Over Kamchatka, IASI detected clear peaks in SO_2 emissions coincident with reports of elevated volcanic activity. This is the first long-term satellite survey over the Kamchatka region and highlights the value of infrared satellite spectrometers, such as IASI, in regions where short wavelength observations are limited.

Reconstruction of flux and altitude of volcanic SO_2 emissions from IASI satellite observations: implications for volcanological and atmospherical studies.

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Volcanic SO_2 degassing is a crucial indicator of the sub-surface volcanic activity, which is widely used today for volcano monitoring and hazard assessment purposes. Volcanic SO_2 is also important regarding atmospherical studies. More easily detectable from space, SO_2 can be used as a proxy of the presence of ash to anticipate air traffic issues caused by explosive eruptions. Moreover, volcanic SO_2 strongly impacts air quality but also climate following its conversion to radiatively-active sulphate aerosols. However, the accurate assessment of these various impacts is currently hampered by the poor knowledge of volcanic SO_2 emissions, which can substantially vary with time, in terms of flux and altitude.

To fulfil this need, we propose a strategy relying on satellite observations, which consequently allows for monitoring the eruptive activity of any remote volcano. The method consists in assimilating snapshots of the SO2 load, provided every ~12 hours by IASI, in an inversion scheme that involves the use of a chemistry-transport model to describe the dispersion of SO_2 released in the atmosphere. Applied on Eyjafjallajökull (Iceland) and Etna (Italy) eruption case-studies, this procedure allows for retrospectively reconstructing both the flux and altitude of the SO_2 emissions with an hourly resolution. We show the improvement gained in the simulations and forecasts of the location and mass load of volcanic SO_2 clouds using such a detailed reconstruction of emissions.

For calibration-validation purpose, we compared our satellite-derived time-series of the SO_2 flux with ground-based observations available on Etna. This comparison indicates a good agreement during ash-poor phases of the eruption. However, large discrepancies are observed during the ash-rich paroxysmal phase as a result of enhanced plume opacity affecting ground-based ultraviolet spectroscopic retrievals. Therefore, the SO_2 emission rate derived from the ground is underestimated by almost one order of magnitude. This result calls for the necessity to revisit currently available inventories of the global budget of sulfur released by volcanoes, because they heavily rely on ground-based observations. It also shows that volcano observatories cannot rely solely on ground-based spectroscopical observations for the monitoring of ash-rich explosive eruptions.

Moreover, we will discuss the assimilation procedure of recently-developed IASI products which deliver snapshots of the volcanic SO2 cloud altitude. Such improvement renders the inversion procedure, used for the reconstruction of the altitude of emissions, independent of the wind shear prerequisite.

Eventually, building on our accurate source of precursory SO_2 gas emissions, we can explore the formation and lifecycle of sulphate aerosols in volcanic plumes. Remote sensing of tropospheric sulphate aerosols from moderate eruptions is not straightforward. However, we will show how a combination of chemistry-transport modelling and space-borne CALIOP lidar observations allows for tracking these aerosols despite their small concentration. The latest promising developments from high-resolution infrared sounders will bring further constraints on sulphate aerosol load and characteristics in dispersed volcanic clouds.

Impact of boreal wildfires on air quality: from regional to hemispheric scales

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ABSTRACT

Wildfires are a significant source of atmospheric pollutants, including greenhouse gases and aerosols. Among the emitted species, most have long enough lifetimes to be transported over thousands of kilometres. Boreal wildfires are particularly intense and have been shown to strongly influence the interannual variability of several atmospheric pollutants (carbon monoxide, CO, and aerosols) in the remote Northern Hemisphere. With a fire risk increasing and fire seasons lengthening as a result of climate change, it is all the more critical to better estimate the large-scale impact from these large events.

Here, the impact of boreal fires on regional air quality in Canada and in Europe (after long-range transport) is estimated using a combination of satellite data analysis (IASI for CO, MODIS AOD and CALIOP lidar profiles for aerosols) and modelling with the CHIMERE regional chemistry-transport model. The fire emissions are calculated using the APIFLAME emission model, including in particular a better representation of the potential burning of the ground organic layer. Their variability will first be described for the time period 2013-2015. The performance of the model to simulate the local pollution levels and the influence from long-range transport (in the mid and high latitudes) will be discussed, focusing on the summer of 2013. The chemical evolution of the main plumes will then be evaluated using observations of more reactive trace gases (NH_3 from IASI, NO_2 from GOME-2).

High spectral resolution infrared sounders (IASI, TANSO-fts, IASI-NG, IRS) capabilities to measure aerosols and trace gases emitted by volcanic eruptions.

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Volcanic activity is an important source of aerosols (Ash , H_2SO_4) and trace gases (SO_2, H_2S) which have a significant impact on climate, and affect the regional air quality or air traffic.
In this context, spatial remote sensing represents an efficient tool for the spatio-temporal monitoring of volcanic emission. In particular, some recent works have demonstrated the potential of high spectral resolution infrared sounders to study the volcanic ash plumes distributions and to measure the SO2 concentrations from local to continental scale. However, this kind of studies remains quite challenging. The applications are particularly sparse and concern often only the very large eruptions.

Here, we present a sensitivity study and analysis of the information content (degrees of freedom and errors budget) of simulated IASI, TANSO-fts, IASI-NG, MTG-IRS observations to concentration and altitude of SO_2, H_2S and OCS, but also to volcanic ash and sulphate aerosols parameters (Height, thickness, size distribution).

An algorithm based on channels selection has been performed. The latter allows detecting these volcanic species from the IASI spectra in near real time. Then, the geophysical parameters are retrieved using a line-by-line radiative transfer code (ARAHMIS) developed at LOA combined with an optimal estimation method. The results obtained for aerosols and gas will be illustrated by some case studies corresponding to recent volcanic eruptions.

Monitoring of atmospheric composition with IASI/MetOp Sounders : ULB/LATMOS data in open access via Ether website

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ABSTRACT

The IASI remote sensor flying onboard the MetOp-A and -B satellites has been providing twice daily observation of the atmospheric composition since the end of 2007.

Global distributions of several reactive species are retrieved from IASI radiance spectra in near-real-time both at ULB and LATMOS, using dedicated radiative transfer models and retrieval schemes. Among the different algorithms set up, the FORLI software series provides vertical profiles for CO, O_3, and HNO_3, while alternative methods using brightness temperature differences or so-called "hyperspectral range indices" coupled with look-up tables allow retrieval of SO_2, NH_3 and VOCs columns.

The FORLI software package is now implemented in the EUMETSAT operational processing chain, in the framework of the Ozone and Atmospheric Composition Satellite Application Facility (O3MSAF). CO products are now operationally distributed by EUMETCAST, and SO_2, O_3 and HNO_3 should follow in 2016-2017.

In this presentation, we will review the methods and the products available from our processing chains. Global scale distributions of CO, O_3 profiles as well as SO_2 and NH_3 columns can be downloaded from the Ether (AERIS) website for further scientific analysis.