Limb Sounding Emission Measurements of Lower Stratospheric Constituents From High Altitude Aircraft: an Overview of SAFIRE-A Campaigns at Mid-latitude and in the Polar Regions

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Abstract

The SAFIRE-A instrument has been deployed on the M-55 Geophysica high altitude aircraft in several scientific campaigns carried out, between the end of 1999 and the beginning of 2003, at mid-latitudes as well as in the Polar regions (both Arctic and Antarctica). The measurement capabilities of the spectrometer allowed the observation of the vertical distribution of several minor atmospheric constituents between the tropopause and the flight altitude (approx. 20 km) along the flight route. Recently, an optimised retrieval code, specifically developed for the analysis of the airborne instrument data, has been applied for the re-processing of the data measured during the APE-GAIA campaign (Ushuaia, Argentina, September-October 1999) and during ENVISAT validation flights at mid-latitude (Forlì, Italy, October 2002) and high-latitude flights (Kiruna, Sweden, March 2003). An overview of the main results is presented, highlighting the instrument capability to simultaneously measure Volume Mixing Ratio (VMR) vertical profiles of different species such as Ozone, HNO_3, N_2O, ClO, HCl, H_2O, that play a critical role in lower stratospheric chemistry and transport.

Instrument description

SAFIRE-A (Spectroscopy of the Atmosphere by using Far Infrared Emission - Airborne), **is a passive remote-sensor capable to perform limb-sounding observations of the atmospheric emission in the Far-Infrared region** (20 - 200 cm^{-1}) with a spectral resolution of 0.004 cm^{-1} unapodized[1]. Sequences of individual spectra acquired at different limb angles are processed using an inversion algorithm specifically developed for the airborne measurements, RAS, to retrieve the VMR vertical profiles of minor atmospheric constituents whose spectral features are present in the measured frequency intervals (Fig.1).

APE GAIA Campaign (Ushuaia, 23th September 1999)

SAFIRE-A has been part of the remote-sensing chemistry payload deployed on-board the M-55 Geophysica aircraft during the APE-GAIA campaign (Airborne Polar Experiment – Geophysica Aircraft In Antarctica), aiming at the study of lower stratospheric chemical and transport processes across the border of the Southern Polar vortex in the transition period between the Ozone depletion and recovery phases.

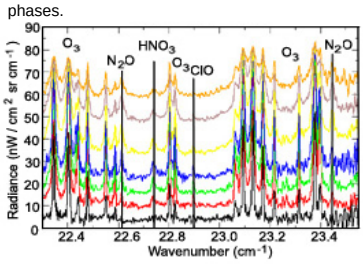

Figure 1. Limb sounding sequence of spectra acquired by SAFIRE/A with the long wavelenght channels.

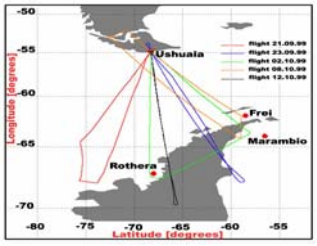

Figure 2. APE-GAIA scientific flights routes over the Antarctic Peninsula.

During the 23.09.1999 flight of the M-55 (Fig.2), SAFIRE-A acquired 35 limb scanning sequences, simultaneously measuring vertical VMR profiles of O_3, N_2O, HNO_3, ClO, H_2O and HCl. The information extracted from individual scans can be combined to reconstruct two-dimensional distributions of the observed species as a function of altitude along the flight route. The maps thus obtained for the six target species listed above are displayed in figure 3.

Most of these measurements show evidence of the perturbed chemistry occurring in the innermost part of the polar vortex (Chemically Perturbed Region), with clear sign of the anti-correlation existing between Ozone and Chlorine Monoxide distributions across the vortex edge that can be noticed also in figure 4.

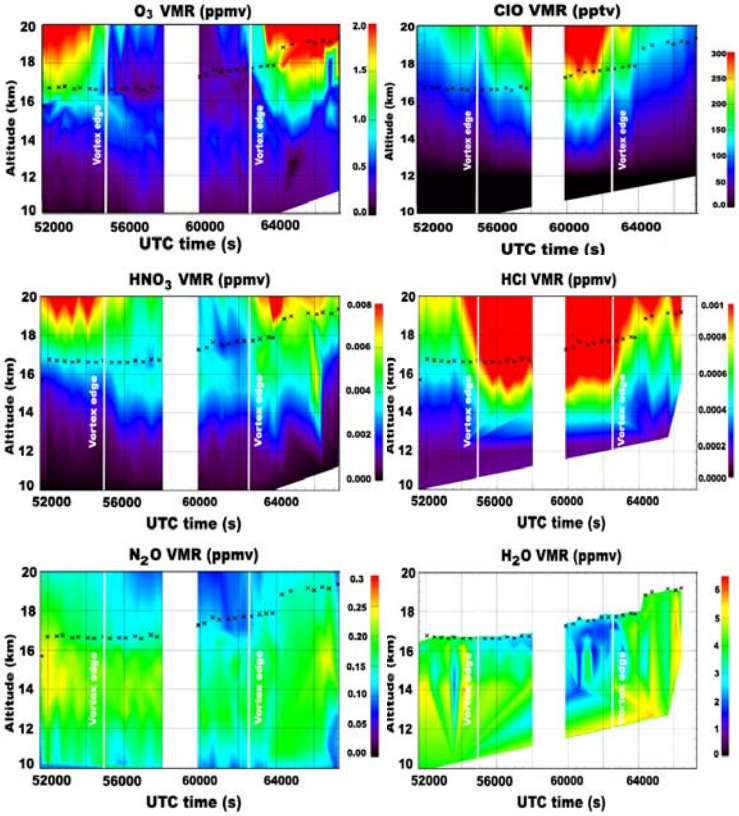

Figure 3. Vertical VMR profiles of O_3, ClO, HNO_3, HCl, N_2O and H_2O along flight route (23th September 1999).

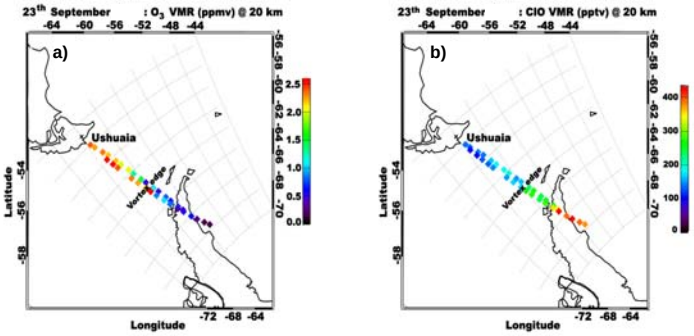

Figure 4. VMR values of O_3 (a) and ClO (b), retrieved by SAFIRE-A for the 23th September 1999, at 20 km along the flight track. O_3 values decrease entering the vortex region while ClO values tend to increase.

In figure 5, Ozone VMR values at flight altitude measured by SAFIRE-A are compared with the time series obtained by the in-situ sensor ECOC (Electro-Chemical Ozone Cell), **displaying a very good agreement between the two instruments.** A more extensive comaparison is shown in figure 6, where measurements from the FOZAN (Fast OZone ANalyzer) in-situ sensor, as well as from MIPAS-STR (Michelson Interferometer for Passive Atmospheric Sounding –Stratospheric aircraft) and GASCOD-A (Gas Absorption Spectrometer Correlating Optical Differences) spectrometers are included.

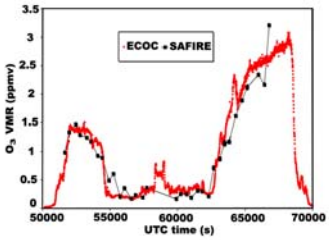

Figure 5. Ozone VMR values at flight altitude from SAFIRE and ECOC (23th September 1999).

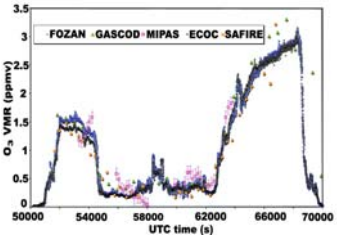

Figure 6. O_3 values at flight altitude from SAFIRE, FOZAN, MIPAS, GASCOD and ECOC (23th September 1999).

ENVISAT Validation Campaign (Forlì 2002 and Kiruna 2003)

Three ENVISAT validation campaigns with the stratospheric aircraft M-55 Geophysica have been conducted from Forlì, Italy (Lat. 44°N, Lon. 12°E) in July and October 2002 and from Kiruna, Sweden (Lat. 68°N, Lon. 20°E) in February-March 2003, as part of the ENVISAT Stratospheric Aircraft and Balloon Campaigns activities.
The M-55 Geophysica flight of 24th October 2002 was planned in coincidence with the night-time ENVISAT overpass, aiming at the validation of MIPAS observations along the orbit 3403. **In figure 7, the result of the comparison for SAFIRE sequence 1 and MIPAS scan 15 is shown together with FOZAN in-situ measurements (24th October 2002).**
On 2nd of March 2003, the limb sequences performed by the SAFIRE-A instrument were planned to sound the same air masses explored by MIPAS scans 19, 20 and 21 of the orbit 5250. In figure 8, we have plotted VMR profiles of O_3 retrieved from SAFIRE-A data for sequences 2, 3, 4 and 19 and corresponding profile from MIPAS scan 20 data.

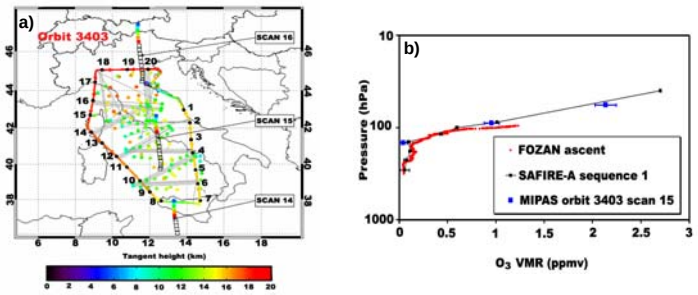

Figure 7. a) Map of 24th October 2002 Flight, b) Comparison between O_3 profile from MIPAS scan 15 of orbit 3403, SAFIRE-A sequence 1 and FOZAN ascent.

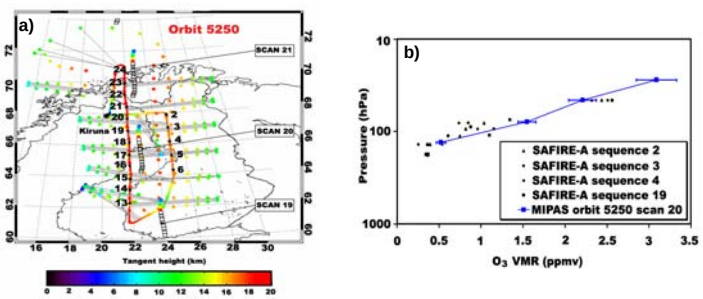

Figure 8. a) Map of 2nd March 2003 Flight, b) Comparison between Ozone VMR profiles measured by SAFIRE-A and MIPAS (orbit 5250 scan 20).

References

[1] Bianchini, G., U. Cortesi, L. Palchetti, E. Pascale, SAFIRE-A: optimised instrument configuration and new assessment of spectroscopic performances, in press *Applied Optics*, Vol. 43, 2004.