MIPAS-ENVISAT Validation Measurements with the High Resolution FT-FIR Spectrometer SAFIRE-A aboard the Stratospheric Aircraft M-55 Geophysica

U. Cortesi [(1)], G. Bianchini [(1)], L. Palchetti [(1)], E. Castelli [(2)], B.M. Dinelli [(2)], G. Redaelli [(3)]

[(1)] Istituto di Fisica Applicata "Nello Carrara" (IFAC-CNR), Firenze, Italy (u. cortesi@ifac.cnr.it)
[(2)] Istituto per le Scienze della Atmosfera e del Clima (ISAC-CNR), Bologna, Italy
[(3)] Università dell'Aquila, L'Aquila, Italy

SAFIRE — Spectroscopy of the Atmosphere using Far-Infrared Emission

Abstract **The SAFIRE-A Fourier transform Far-infrared spectrometer has been involved in field campaigns carried out with the M-55 Geophysica stratospheric aircraft in 2002-2003, aimed at validating the level-2 products of the ENVISAT chemistry instruments.** The limb sounding observations of volume mixing ratio vertical profiles of Ozone and Nitric Acid were especially focused on the validation of MIPAS products in the altitude range 10-20 km.
Three campaigns have been conducted with the Geophysica platform 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 ESABC (ENVISAT Stratospheric Aircraft and Balloon Campaigns) activities. Here, we report the results of measurements of O_3, HNO_3 acquired by SAFIRE-A during the mid-latitude flight on the 24th of October 2002.
.An attempt to further exploit SAFIRE-A mid-latitude observations, in order to enlarge the dataset useful for MIPAS validation has been made with the support of modelling tools specifically developed by University of L'Aquila. First results from intercomparison based on trajectory calculations are presented, showing the effectiveness of the adopted approach.

1. SAFIRE-A Measurement Products

SAFIRE-A (Spectroscopy of the Atmosphere by using Far Infrared Emission - Airborne)**, is a passive remote-sensor operating aboard the M-55 Geophysica aircraft and capable to perform limb-sounding observations of the atmospheric emission in the Far-Infrared region, in narrow spectral bands** (≈ 2 cm^{-1}) between 20 and 200 cm^{-1}, with a spectral resolution of 0.004 cm^{-1} unapodized [1],[2]. During the 2002-2003 ENVISAT validation campaigns with the M-55, the instrument configuration was set for measurements of O_3, HNO_3, N_2O and ClO in the spectral window 22.0 – 23.5 cm^{-1} (Fig.1) and of H_2O and HCl in the band 124.0-126.0 cm^{-1}.

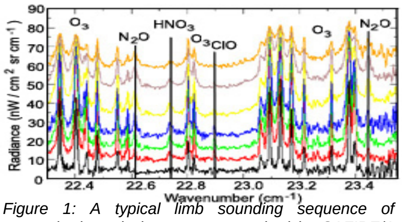

Figure 1: A typical limb sounding sequence of atmospheric emission spectra acquired by SAFIRE/A with the long wavelenght channel.

Figure 2: The SAFIRE-A spectrometer on-board the M-55 Geophysica aircraft during pre-flight operation

2. The Mid-Latitude Validation Flight on 24.10.2002

On October 24th, 2002 the M-55 Geophysica carried out a night-time flight from Forlì, Italy (Lat. 42°N, Lon. 12°E), in coincidence with an overpass of the ENVISAT satellite (orbit 3403) along a route that had been studied to optimize the overlapping between the air masses observed by the airborne limb-sounders and in-situ sensors and those covered by MIPAS scans.
An estimate of the quality of the spatial and temporal overlapping can be attained by looking at Fig. 3, where the geolocation of MIPAS tangent points for three scans of the selected overpass is shown, along with the mean latitude and longitude of the tangent points for each of the limb sequences recorded by SAFIRE-A in the time period 19:05 – 21:55 UT. As evident from the figure, the best overlapping was obtained with the MIPAS scan at 21:23 UT (scan 15), whose tangent points in the altitude range 10-20 km correspond to the latitude and longitude region covered by SAFIRE-A observations during the North-South as well as in the South-North leg of the flight.

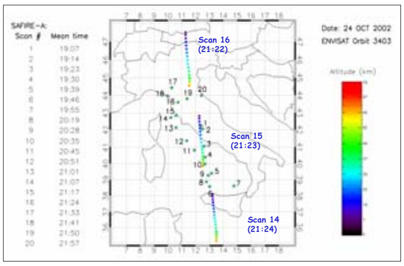

Figure 3: Space-time overlapping between MIPAS and SAFIRE-A measurements for the ENVISAT overpass on 24th October 2002 (orbit 3403). Geolocation of individual tangent points (circles) is shown for MIPAS, with tangent altitudes represented in a false colour scale. Location of SAFIRE measurements (stars) is given by tangent latitude and longitude values averaged over each limb sequence. Mean acquisition time for SAFIRE-A scans is also indicated.

The analysis carried out for validation purposes focused therefore on the intercomparison with MIPAS L2 products from scan 15 (Lat. 42°N, Lon. 12°E) and particularly on O_3 and HNO_3, for which most of SAFIRE scans provided useful results. The choice of profiles to be used in the intercomparison was made by evaluating the distance between the average location of MIPAS tangent points in the range 10-25 km and the one of each SAFIRE-A scan and by calculating the time difference between the corresponding acquisition times. Table 1 summarizes the results of this estimate, whilst a detailed plot reporting latitude and longitude of individual tangent points of both MIPAS and SAFIRE is shown in figure 4.

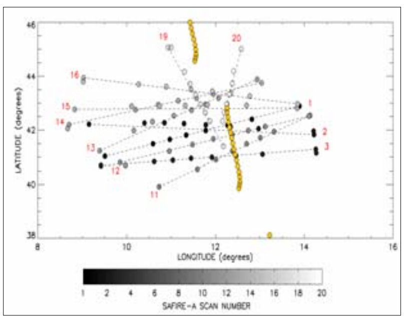

Figure 4: Co-location of SAFIRE scans (B&W dots) and MIPAS scan 15 (yellow dots). SAFIRE scan numbers are placed approximately at the instrument location during the scan and the dashed line represents the line of sight.

Scan number	Distance (km)	Time difference
1	99	2^{h} 16^{min}
2	100	2^{h} 09^{min}
3	183	2^{h} 00^{min}
4	251	1^{h} 53^{min}
5	368	1^{h} 44^{min}
6	No data	No data
7	452	1^{h} 32^{min}
8	392	1^{h} 04^{min}
9	339	0^{h} 55^{min}
10	282	0^{h} 48^{min}
11	179	0^{h} 38^{min}
12	139	0^{h} 32^{min}
13	137	0^{h} 22^{min}
14	157	0^{h} 16^{min}
15	130	0^{h} 06^{min}
16	168	0^{h} 01^{min}
17	283	0^{h} 10^{min}
18	248	0^{h} 18^{min}
19	151	0^{h} 27^{min}
20	135	0^{h} 34^{min}

Table 1: SAFIRE-A scans time delay and distance from MIPAS-ENVISAT scan 15. Best coincidences are highlighted in dark and light gray.

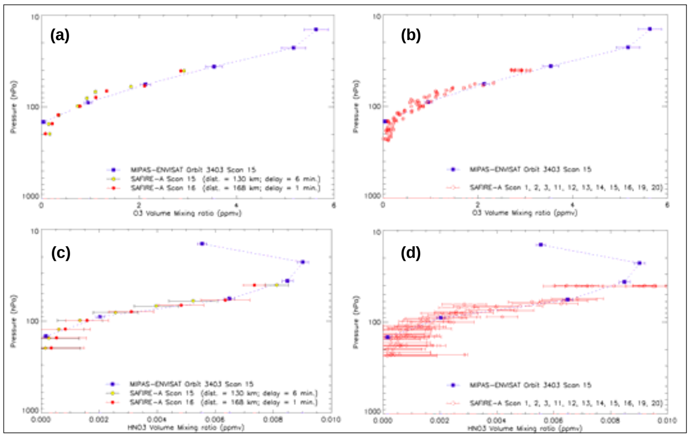

Figure 5:
(a) Comparison between O_3 profiles obtained by SAFIRE-A scans 15, 16 (distance < 200 km, delay < 10 minutes) and MIPAS scan 15 orbit 3403.
(b) Comparison between O_3 profiles obtained by SAFIRE-A scans 1, 2, 3, 11, 12, 13, 14, 15, 16, 19, 20 (distance < 200 km, delay < 2^{h}30^{min}) and MIPAS scan 15 orbit 3403.
(c) Comparison between HNO_3 profiles obtained by SAFIRE-A scans 15, 16 and MIPAS scan 15 orbit 3403.
(d) Comparison between HNO_3 profiles obtained by SAFIRE-A scans 1, 2, 3, 11, 12, 13, 14, 15, 16, 19, 20 and MIPAS scan 15 orbit 3403.

In figure 5.a and 5.c a comparison between the O_3 and HNO_3 profile retrieved by MIPAS and O_3 and HNO_3 VMR data obtained from SAFIRE for the best coincidences of scan 15 and 16 are shown, highlighting a substantially good agreement (with error bars for both instruments representing only the random error), with the largest differences corresponding for O_3, as well as for HNO_3, to MIPAS lowest tangent pressure. In figure 5.b and 5.d, a similar intercomparison is made, considering a larger number of SAFIRE-A profiles, as derived from the relaxed time-matching requirements. These plots provide an indication of the variability of the VMR vertical distribution measured by SAFIRE-A over a wider region that can still be considered, however, in close proximity with the location of MIPAS measurements.

3. Modelling Support

Modeling tools can be used to support MIPAS validation. In particular, the number of MIPAS and SAFIRE-A data points useful to perform intercomparison can be extended beyond those that are simply co-located in space and time, by using a lagrangian approach. Backward and forward isentropic trajectories, starting from all the available SAFIRE-A tangent points, are calculated and used for selecting those air masses sampled by both satellite and the airborne instrument, even if at different times and locations. Trajectory calculations are based on United Kingdom Met Office (UKMO) meteorological fields, and performed using the University of L'Aquila Global Trajectory Model (GTM) [3]. The GTM was also routinely operated during the airborne validation campaigns to fine-tune the flight pattern, using forecasts of the direction and intensity of the winds from the NCEP (National Center for Environmental Prediction) Aviation Model, and therefore a number of lagrangian correspondences between SAFIRE-A and MIPAS tangent points are expected to be found. For the show comparison, 5 days backward and forward trajectories are launched from the location of SAFIRE-A measurements for 24th October 2002. Air parcels sampled at least once also from MIPAS within a prescribed match criterion (Δtime ≤ 1h, Δlatitude ≤ 1° Δlongitude ≤ 1° Δaltitude ≤ 1km) are then selected and their O_3 content measured by satellite compared to the correspondent SAFIRE-A measurements at the trajectory starting points.

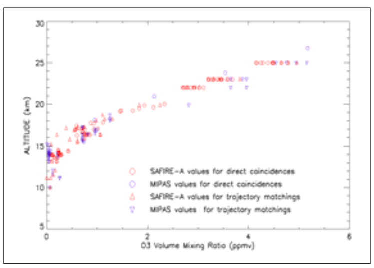

Figure 6: Plot of the two MIPAS validation datasets derived by SAFIRE-A measurements of 24th October 2002. O_3 values from direct coincidences are marked with circles. Triangles represent additional data obtained by trajectory matching.

In Fig. 6, couples of O_3 VMR values by MIPAS and SAFIRE-A associated to the same air parcel, as defined by the matching criteria and derived by trajectory calculations, are plotted as a function of the retrieval altitude of the SAFIRE-A measurement and superimposed to couples of O_3 data resulting from direct coincidences that satisfy similar criteria for geographical and vertical overlapping. By combining the two dataset, we obtained a total number of useful matches more than a factor of 2 larger than the original one. Preliminary results for the comparison of the additional MIPAS and SAFIRE-A O_3 values show that points with large relative differences concentrate around the 15 km altitude level.

References

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2. 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.
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