COMBINED *In SITU* and *QUASI In SITU* MEASUREMENTS ABOARD M55 GEOPHYSICA STRATOSPHERIC AIRCRAFT DEDICATED FOR ENVISAT SATELLITE DATA VALIDATION

Ivan Kostadinov(1,2), Giorgio Giovanelli(1), Andrea Petritoli(1), Daniele Bortoli(1,3), Fabrizio Ravegnani(1),
Gianluca Radaelli,(4) Aleksey Ulanovsky (5) and Vladimir Yuzhkov(5)

(1) *ISAC-CNR, via Gobetti 101, I-40129,Bologna. E-mail: I.Kostadinov@isac.cnr.it*
(2) *STIL, Bulgarian Academy of Science, Stara Zagora, Bulgaria*
(3) *CGE-UE, University of Evora, Portugal, E-mail: D.Bortoli@isac.cnr.it*
(4) *Unviversity of L'Aquila, L'Aquila, Italy, E-mail: redaelli@aquila.infn.it*
(5) *Central Aerological Observatory, Moscow, Russia, E-mail: v_yushkov@mail.ru*

ABSTRACT

Two field campaigns with stratospheric aircraft M55 Geophysica have been carried out at Forli airport, Italy (44E, 12N), during July and October 2002, dedicated for ENVISAT validation tasks. A part of the scientific payload, composed by *in-situ* and remote sensing instruments, have been deployed to probe the same atmospheric air masses observed from the space by SCIAMACHY and MIPAS-E in order to assess their ability to reproduce the real atmospheric parameters. An newly approach for analysis of the data derived by means of the remote sensing UV/Vis GASCOD/A4π instrument, and the fast *in-situ* zone analyzer FOZAN-II has been developed, allowing an enlargement of the available data sets for validation tasks.

1. INTRODUCTION

The complete understanding of the climate variations and mechanisms controlling them, appear the major reasons for increasing of the efforts of the international scientific community during last decades. The improved knowledge in this field can give important impact for increasing of the confidence level for prediction of the climate changes under different scenarios. In this regard the launch of ENVISAT appear a key event and important contributions in large sectors of the Earth's science are expected.

The obtaining of representative scientific data Earth's climate studies can't be achieved without taking special care regarding the characterization of the scientific payload. For this purpose large variety of tests and calibration procedures are carried out during the pre-flight phase in order to simulate space conditions and geometry of the foreseen in-orbit measurements. Nevertheless sophisticated equipments are deployed for simulation of the space environment, still remain factors which can't be reproduced in the laboratory. Due to this the pre-flight calibration procedures need to be extended after the launch and to quantify the vicinity of the derived satellite geophysical parameters to the same parameters, but obtained by independent measurement manners. In other words, a validation procedures should be applied to adjust the used algorithms for data processing. These independent means are usually based on either different physical methods or exploring different regions of the electromagnetic spectrum. The used instrumentation for the validation procedures can be ground-based, or installed on aircrafts, ships, balloons or sondes. Important issue in this regard is the differences in the fields of view of the satellite instruments and those deployed for the validation procedure. Very often the observed air masses or landscape both from the space and mentioned platforms are not completely the same. It can give different impact on the output results derived by the satellite instruments and those used for validation tasks. Difficulties can arise also due to specificity of the measurements aimed for validation (requirements for low/high Sun elevation, moment of observation, clear sky, etc.) and satellite overpasses. Under certain circumstances CTM assimilation schemes are applied to overcome such limitations. In fact, the validation procedure is a complex activity and comprises large variety of equipments and specialists as an attempt to minimize the influence of unpredicted factors.

The combination of the in-situ and remote sensing instruments appears very good approach and appear a powerful tool for satellite data validation. The scientific payload of the stratospheric aircraft M55 Geophysica, (*www.ape.iroe.fi.cnr.it)*, aimed for probing of the upper troposphere – lower stratosphere region is an example for satellite data validation purposes. In particular, the combined measurements by means of GASCOD/A4π and FOZAN-II aircraft instruments reveal the ability to produce representative data sets, describing better spatial and time variations of the atmospheric ozone along the flight altitude.

Two campaigns carried so far within APE-ENVISAT validation activity demonstrated the advantages of *in situ* and remote sensing approach for SCIAMACHY and MIPAS validation, [1].

2. THE AIRCRAFT, INSTRUMENTAL DESCRIPTION, METHODS OF MEASUREMENTS, SCIENTIFIC PRODUCTS.

2.1 M55Geophysica

M55-Geophysica is a high altitude aircraft built by the Myasishchev Design Bureau to fly up to 21km altitude, with a total range of approximately 3,500 km at 17 km altitude and maximum speed of 750 km/h. The aircraft was completely overhauled to carry scientific instruments for remote and *in-situ* stratospheric measurements, (*http://ape.iroe.fi.cnr.it*).

Proc. of Envisat Validation Workshop, Frascati, Italy, 9 – 13 December 2002 (ESA SP-531, August 2003)

2.2 GASCOD/A4π instrument

GASCOD/A4π instrument appears airborne version, [2] of GASCOD type instruments [3] deployed at number of ground-based stations: Terra Nova Bay, Anctarctica, [4], Mt.Cimone, Italy,[5], Stara Zagora, Bulgaria, [6], for detection of NO_2, O_3 and other gases slant column *(sc)* amounts by means of DOAS techniques. The obtained *sc* are subsequently used for calculation of the vertical column *(vc)* amounts and after that, deploying of an inversion method, profiles are derived also e.g. NO_2, [6]. The acquired experience in the field of the ground-based measurements is currently successfully implemented for carrying out of airborne DOAS measurements for satellite data validation purposes. The 4π index in the instrument's name stands to indicate its ability to measure 2π down-welling (direct and diffused) + 2π up-welling diffused solar radiation, and hence to derive the actinic flux, [7].

GASCOD/A4π contains five optical inputs: three deployed for DOAS measurements – one pointed to the zenith, other two - dedicated for limb measurements in perpendicular left and right directions relatively to the flight direction. All three DOAS channels have narrow field of view, 1.1E-5 *sr*. The optical switching between the DOAS channels and the two new channels for actinic measurements is realised by means of a rotating mirror. At any given moment only one of the five optical channels is selected. The high absorption paint on the internal mechanical parts and walls along the instrumental optical path contributes further to decreasing the S/N ratio.

The radiation entering the instrument via spectroradiometric channels is directed to the entrance slit (0.1 x 8.0mm) of a custom-built monochromator, based on a Jobin-Yvon holographic spherical grating with 1200 grooves/mm.. The entire instrumental spectral interval 285 – 1100nm is sampled in subintervals of 50 - 60nm. A wheel with band-pass filters mounted in front of the input slit and internal baffles reduce the stray light inside the monochromator. The linear spectral dispersion and resolution are about 2.4 nm/mm and 0.7 nm at 350 nm, respectively. In order to avoid temperature effects upon spectral dispersion a special care was taken to keep a constant temperature of the spectrometric unit within a ±0.2°C. For this purpose a TEC system operate in duty cycle, controlling the environmental temperature and the temperature at several points inside the instrument, including the grating temperature.

The incoming radiation, dispersed spectrally inside the instrument, is detected by means of 2D(1100 x330 pixels) SITe manufactured CCD sensor based on the Back Illuminated technology. It is cooled during the flights at a constant operating temperature of -30±0.1°C by means of a Peltier system. After binning procedure, the measured spectra are converted into 1092columns x 11rows. In spite of the binning, the 11 rows still give a possibility to calculate the curvature of the spectral lines and, therefore, to apply corrections for improving the instrumental spectral resolution.

In the SITe manufactured CCD sensor, the spectrum obtained with the binning procedure has the dark current per pixel reduced by a factor of $n_{\mathrm{pix}} \times 0.013$, where n_{pix} is the number of added rows. The signal-to-noise ratio depends on sensor technical characteristics and is measured in the laboratory. We measured dark current and shot noise by using $n_{\mathrm{pix}} = 30$, with a signal integration time of 1 s, a surface sensor temperature of -30°, and an incoming light flux equal to 4/5 of saturation. This is equal to 7 binary units of the 16-bit analog-to-digital converter. The noise that is due to readout, a preamplifier, and an analog-to-digital converter is evaluated to 4 binary units, which leads to a signal-to-noise ratio estimate of $\sim 6\mathrm{x}10^3$, i.e., a detection limit (in optical depth units) of $\sim 2\mathrm{x}10^{-4}$.

The integration time need to achieve sufficient S/N for a single measurement ration depends on available radiation and the selected spectral interval. However, it ranges in 0.1–1.0s, under high Sun elevation, to 15s at solar zenith angle about 94°. Additional information on GASCOD-type instruments can be found in [2,8].

2.2.1 GASCOD/A4π data processing in DOAS mode

The acquired data form narrow FoV zenithal and horizontally looking channels are used to derive so called NO_2 and O_3 ACILA (Average gas Concentration Inside the Layer near the Aircraft) values. The method is schematically depicted in Fig.1.

Assuming that the contribution to the detected signal due to the scattering along V part in the vertical optical path is negligible and that both components of S_V and S_4 weight in the same manner to the zenith and horizontal measurement directions, it is possible to state, [8], that the retrieved horizontal slant column density (*hcd*) can be expressed with first approximation

$$hcd \approx \rho H, \tag{1}$$

where ρ is the average concentration of the absorber along H_4.

This approach, allowing to evaluate the average amounts of atmospheric constituents, (having characteristic absorption structures), along the instrumental optical axis at distance of about 50-70km away the aircraft, depending on the altitude and the solar zenith angle, is actually based on the DOAS method in combination with a single-scattering radiative transfer model (*rtm*) AMEFCO (*Atmospheric Model for Enhancement Factor Computation).* It uses ray tracing in a spherical two-dimensional atmosphere, with optical paths integrated over individual 1-km shells within which the atmosphere is divided for the model calculations. Under such circumstances, it is possible to evaluate the probability density function (for scattering towards the instrument) and to calculate effective absorber optical path under off-axis measurement geometry applied aboard M55 together with classical zenith sky DOAS measurements.

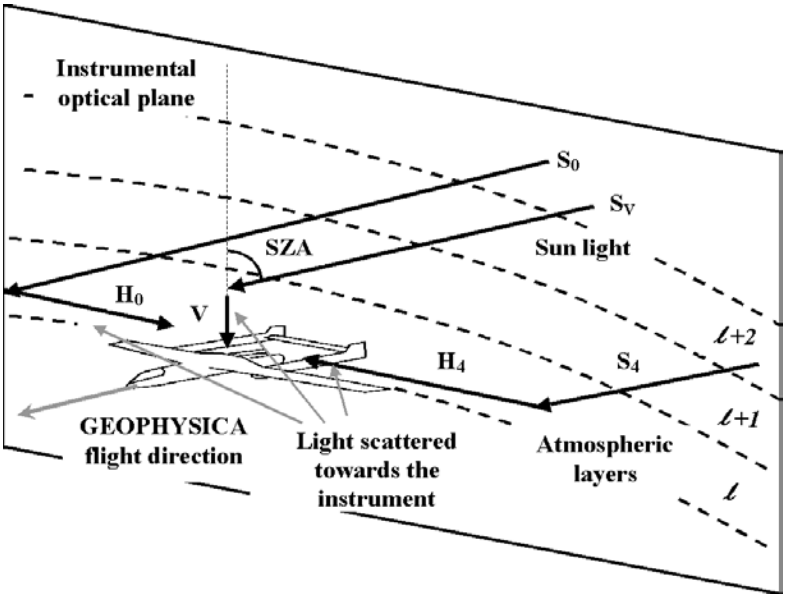

Fig. 1 ACILA scheme

2.2.2 GASCOD/A4π data processing in spectroradiometric mode

While the DOAS method requires an appropriate reference spectrum, calibrated only in wavelength scale, the measurement of the actinic flux, being absolute one, (used subsequently for deriving of J-vales of number photochemical reactions), strongly depend on the good corrections of all factors influencing detected CCD signal, e.g. the sensor's noise and dark current. Two particular measurements - one with 0.0s and 2.0s integration times, together with previously mapped CCD dark current, corresponding to different integration times, allow to draw out the pure output signal, caused by the incoming radiation. The signal is converted into instrumental units/s, (i.u./s) giving a possibility to compare the obtained signals under different environmental and aircraft navigation conditions. The spectral calibration can be performed either using a built-in spectral Hg pencil lamp or relatively to previously selected Fraunhofer lines, far form strong absorption of the atmospheric constituents. The absolute calibration is applied to the measured spectra and convert them from i.u./s into $mW/m^2.nm$ applying the results from previously carried out laboratory calibrations and pre-flight and post-flight calibrations also. Further, all examined spectral intervals through up-faced and down-faced 2π *sr* receivers, undergo a cubic-spline interpolation procedure, creating equidistant time grid for all measurements. The derived actinic flux is converted into photon fluxes used for calculation of the J-values of photochemical reactions under interest. E.g. using the NO_2 absorption cross section [9] and recommended data for primary NO_2 quantum yield [10], we calculate $J(NO_2)$.
These J-values, relate to the available *in situ* photon flux, can be used together with other *in situ* parameters derived aboard Geophysica, e.g. ozone from FOZAN-II and NO from SIOUX, e.g. [11] measurements, in order to evaluate the validity of steady-state conditions approximation along the flights and better understanding of stratospheric photochemistry.

2.3 FOZAN-II

FOZAN-II (Fast Ozone Analyzer) is a fast-response two-channel automated instrument to measure ozone concentration in the atmosphere from board the high-altitude aircraft M-55 Geophysica This instrument makes use of solid-state chemiluminescent sensors, which are durable enough to provide continuous operation of the instrument for at least 40 hours. The instrument has a built-in high-precision ozone generator enabling periodic autocalibration.

The ozone analyzer layout is presented in Fig. 2. A gear-type pneumatic pump provide an airflow of 10L/m which is independent from the pressure in the range 50-800 tor. The chemiluminescence sensor is placed along the air flow inside a chemical reactor; the luminescence light produced by the sensor is recorded by a PTM tube. An internal ozone generator provides a known ozone concentration flow for

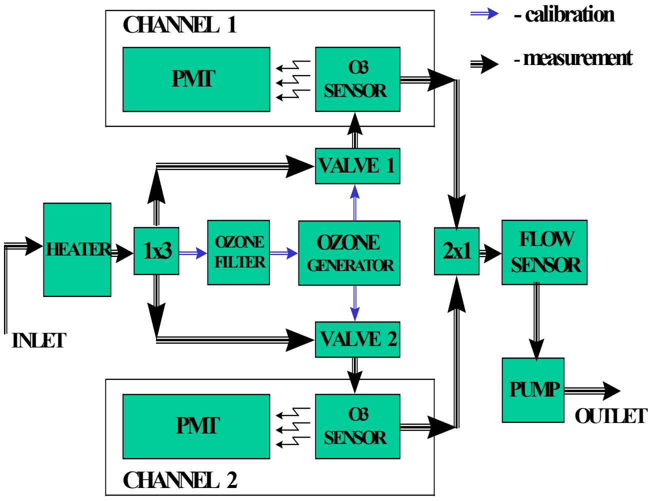

Fig.2 FOZAN-II layout

periodically (every 15 min) in-flight calibration. Two independent measurements channels are used in order to increase reliability and avoid data loss during calibration period. A more detailed description of the instrument is given by [12, 13]. The temporal resolution of the ozone sensor is 1 sec, which corresponds to a vertical resolution of about 10 m during standard ascent and descent or 200 m on horizontal plane at cruise speed. The instrument operated successfully during flights over mid-latitudes, tropical and polar regions [14,15,16] .

3. IMPLEMENTATION OF LAGRANGIAN TRAJECTORIES FOR ENVISAT VALIDATION TASKS BY MEANS OF GEOPHYSICA AIRCRAFT

Important issue during the validation tasks is providing appropriate conditions to get, as much as it is possible, closest temporal and spatial coincidence of the observed atmospherics air masses both form the ENVISAT and Geophysica aircraft. This requirement is difficult to be satisfied completely because the scientific payload of the platforms consists different type of instruments, aimed to probe the Earth's atmosphere not only for large number of physical parameters and chemical species, but also to draw out information regarding their altitude distribution. This is very important specially for the species having short life time or participating in chemical reactions, which take place under particular environmental temperature and/or pressure.
Other restrictions to obtain exact coincidence of the satellite and aircraft measurements appear the time and spatial resolution of the deployed instruments. Finally, the substantial difference of ENVISAT and M55 Geophysica speeds contribute additionally for creation of sophisticate validation geometry. Due to this, very short time and spatial cross/tracking coincidences can be obtained for the validation tasks. Under these circumstances it is possible, for instance, to compare *(a)* columnar amounts of O_3, NO_2, BrO, OClO, SO_2, H_2CO etc., derived trough SCIAMACHY nadir cannel and GASCOD/A4π DOAS measurements related to zenith and nadir (foreseen to be in operation mode during next Arctic campign, March 2003) looking channels, or *(b)* to compare the ACILA values to a given point of O_3, NO_2, BrO, etc. profiles derived by the satellite measurements, corresponding to the Geophysica altitude.

For this purpose a trajectory model with Lagrangian code operating in forecast mode was tested and is ready to be employed during the validation campaigns. This approach gives the possibility to foresee the evolution of the air masses sampled by GASCOD/A4π and SCIAMACHY, allowing the choice of appropriate flight paths with a view to extend the comparison to the air masses sampled by both instruments, even at different times and positions.
The model trajectory also allows the filling in of spatial and temporal gaps in the satellite data, through the use of special "intelligent interpolation" techniques. Among the latter are MATCH-type techniques, which select the appropriate air masses sampled by different instruments at different times and positions. They also include so-called "trajectory maps" (TM), with which a large number of measurements performed at different times are made to converge on the same moment.
A variant of the TM technique, i.e. "Reverse Domain Filling" (RDF), [17], already successfully employed during the APE-GAIA campaign, is under use. This technique can also amplify the horizontal resolution of the fields of trace chemical species, thus increasing the possibilities of intercomparison with SCIAMACHY data.

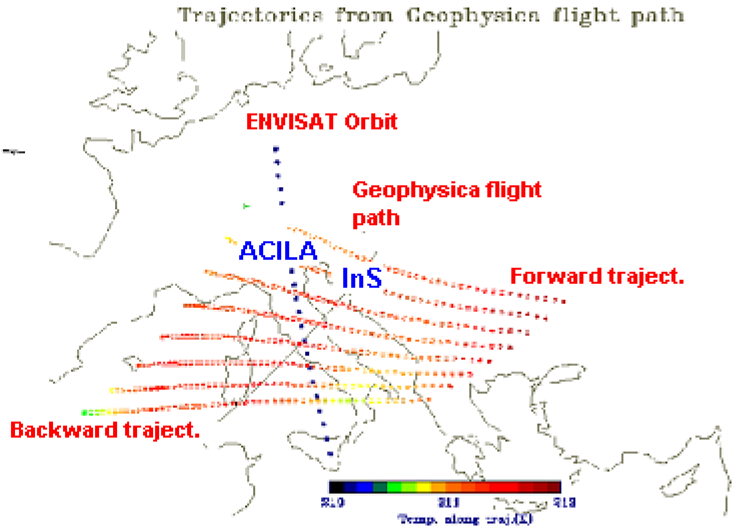

Fig. 3 A simulation of trajectories forwards and backwards from a potential M55 flight path and opportunity for both ACILA and In-Situ measurements

4. FORLI CAMPAIGNS, ENVISAT OVERPASSES, SCIAMACHY AND MIPAS VALIDATION

Both campaigns carried out at Forli airport (42N, 12E) Italy, during July and October, 2002 have been dedicated to validation of the atmospheric ENVISAT scientific payload. Depending on the goal of given flight, aerosol or chemistry aspects of the validation, the Geophysica flight paths were previously planned [18], in order to achieve appropriate conditions for spatial and time matching of the aircraft and satellite measurements.

Ancillary information useful for achieving of the validation tasks have been also used: e.g. TM3 /DAM assimilated ozone fields based on GOME/ ECMWF data by KNIM (*http://www.schiamachy-validation.org/sv/*); ozone climatological mean [19], calculated PV fields from UKMO and NCEP etc.

5. SOME EXAMPLES

Below we report some results derived during Forli APE/ENVISAT campaigns by means of GASCOD/A4π and FOZAN-II instruments as attempt to contribute to better understanding of the obtained so far experimental results within the validation activity. A part of these results are presented more in details in many publications in this issue, e.g. [1,18], where only preliminary assessments are expressed, due to the limited satellite data sets. Here we would like to stress on existing possibility to apply largely simultaneous *in situ* and *quasi in siti* aircraft measurements to improve further evaluations of satellite measurements during validation campaigns. An example of this approach is the common analysis of GASCOD/A4π, FOZAN-II and SIOUX instruments, [1].

One step of this approach appears the verification of the aircraft measurements and their consistency with former similar measurements carried out by other platforms, with the existing climatological data and model simulations, corresponding to onboard Geophysica measurements during a given flight. For instance the comparison of ozone profile derived by FOZAN-II *in situ*, and GASCOD/A4π ACILA (*quasi in situ*) measurements during the flight of 22 October 2002, to the TM3-DAM model output for WMO ozone station San Pietro Capofiume (SPC), Italy. The model was initialized using GOME observation nearest in time to the aircraft measurements. This station was selected due to its vicinity to the Forli airport and appropriate conditions arisen for profiling during descent phase of the flight.

As it is seen, Fig. 4 the coincidence between three data sets is very good, except the region around 160-125hPa, where FOZAN-II detects higher ozone content. The analysis of the Geophysica navigation parameters and GASCOD/A4π system for roll and pitch angles control, shows that during the descent the air mass probed by GASCOD/A4π is actually just above San Pietro Capofiume, while in the same moment FOZAN-II performs *in-situ* measurements at the altitude of the flight. Here we would like to remember that GASCOD/A4π ACILA values appear averaged O_3 concentrations along approx. 50-70 km away the aircraft and due to this the coincidence between TM3-DAM assimilated data and ACILA values in 160-125hPa interval is better. We consider described example as an demonstration of the usefulness to perform both type of measurements aboard the aircraft: while in-situ measurements supply information at given point, the ACILA values, averaging the measured parameter in larger area, represent better the air masses observed from the space.The ozone detected in *in-situ* and *quasi in-situ* modes alongtime of all the flight is shown in Fig. 5. At a first glance there are evident differences between both data sets, which we explain as follow: in the beginning of the flight the optical axis of the channel used to derive ACILA is towards and above

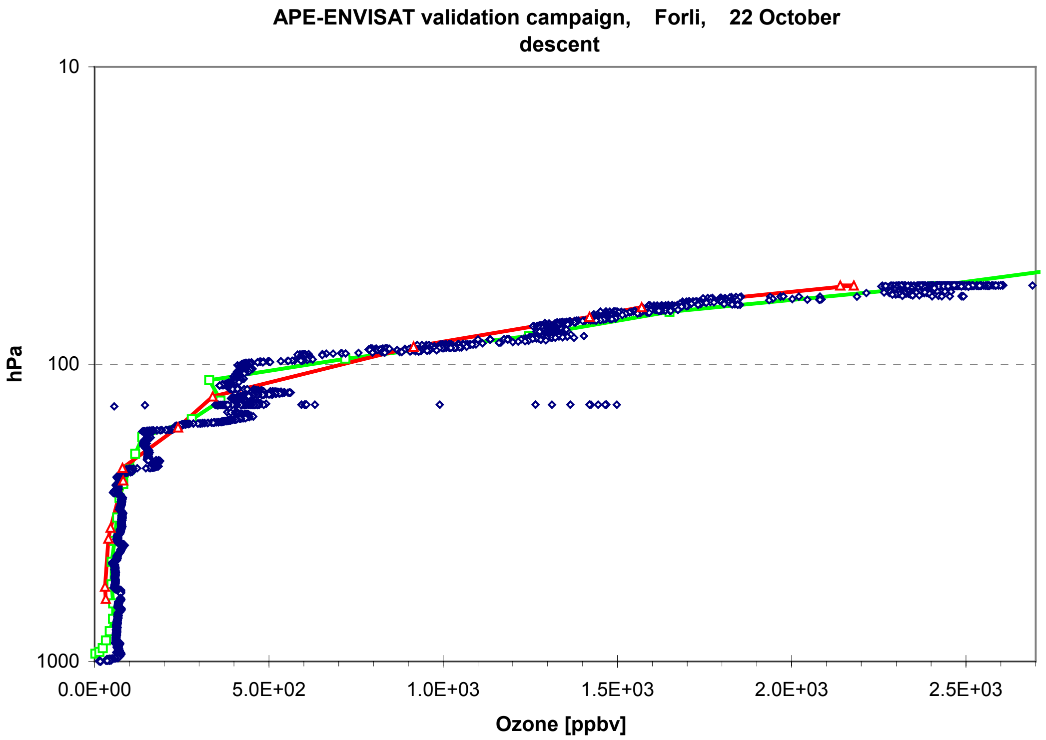

Fig 4. Assimilated TM3-DAM ozone profile above San Pietro Capofiume using GOME data (green), GASCOD/A/4π ACILA values (red) and FOZAN-II data (blue).

urban and industrial areas, and nevertheless the airport is at several kilometres of these zone GASCOD/A4π can probes the air masses there. During descent the axis is pointed in opposite side, above the Apennine mountain (air masses less affected by urban and industrial pollution), so better correlation between *in situ* and *quasi in situ* measurements can be seen.

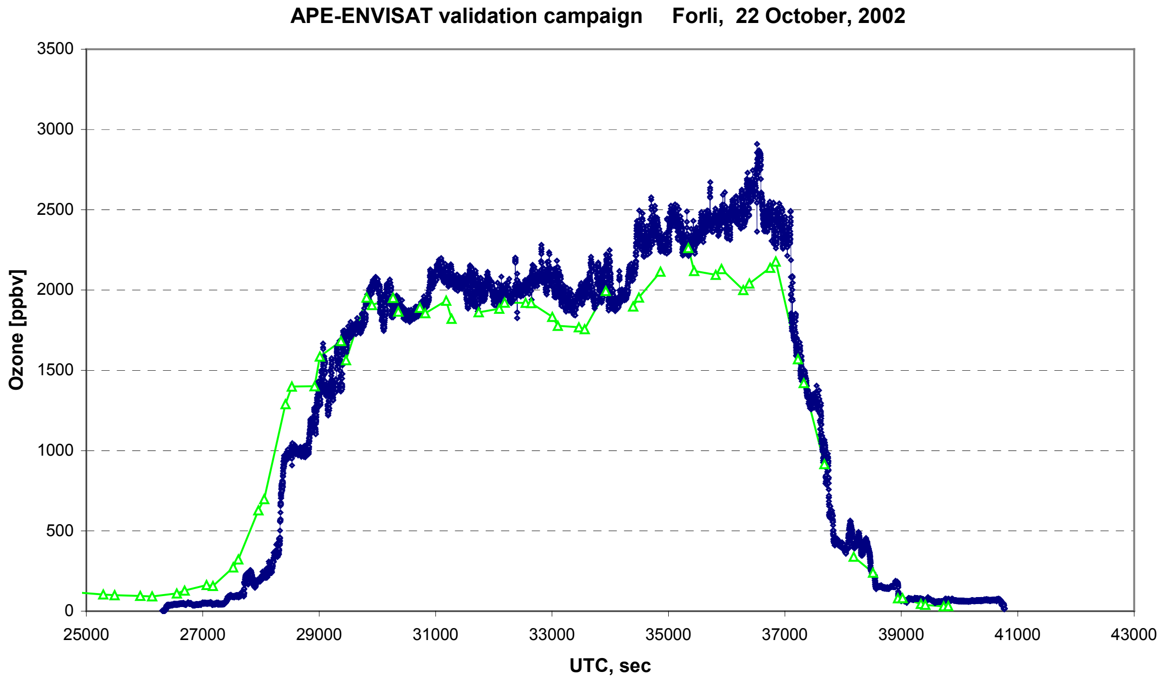

Fig. 5. In situ (blue) and quasi in situ (green) ozone content along the flight of 11 October, 2002

Another example, similar to that above described is the flight of 11 Oct 2002, Fig.6, but the conditions for comparison of *in-situ*, *quasi in-situ* data arisen during the accent phase of the flight. Unfortunately, due to unravelled still reasons GASCOD/A4π data are available during only the first part of the flight. Here, around take-off period *in-situ* and quasi *in-situ* measurements are better correlated in comparison to the results derived during the initial part of flight of 22Oct. In

33000 – 35000 UTC the ozone detected by GASCOD/A4π is higher of about 15% relatively FOZAN-II data. This due the fact that in the mentioned period, when the aircraft is near to position 1 in Fig.7, the GASCOD/A4π observes air masses with higher ozone content, as it can be seen from the plotted assimilated ozone data derived by TM3-DAM and GOME. After the take-off the aircraft flew towards position 1, but the optical axis, shown with black arrow, of the channel used for ACILA values deriving was pointed in south-east direction.

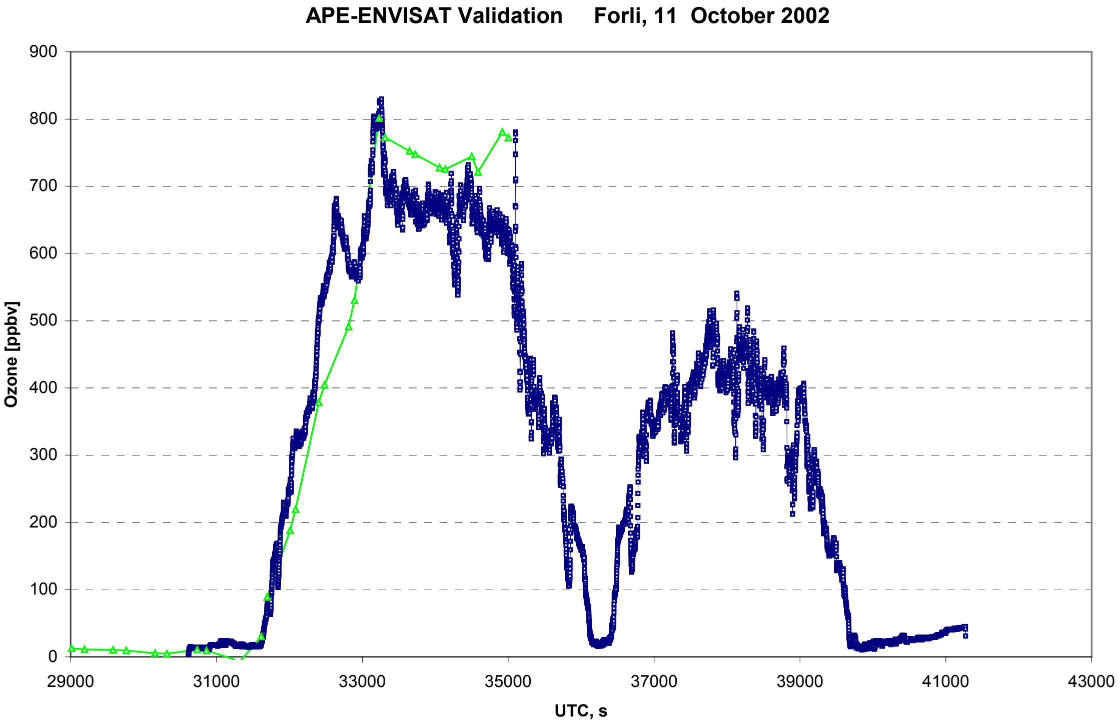

Fig.6 *In-situ* (blue) and *quasi in-situ* (green) ozone content along the flight of 11 October, 2002

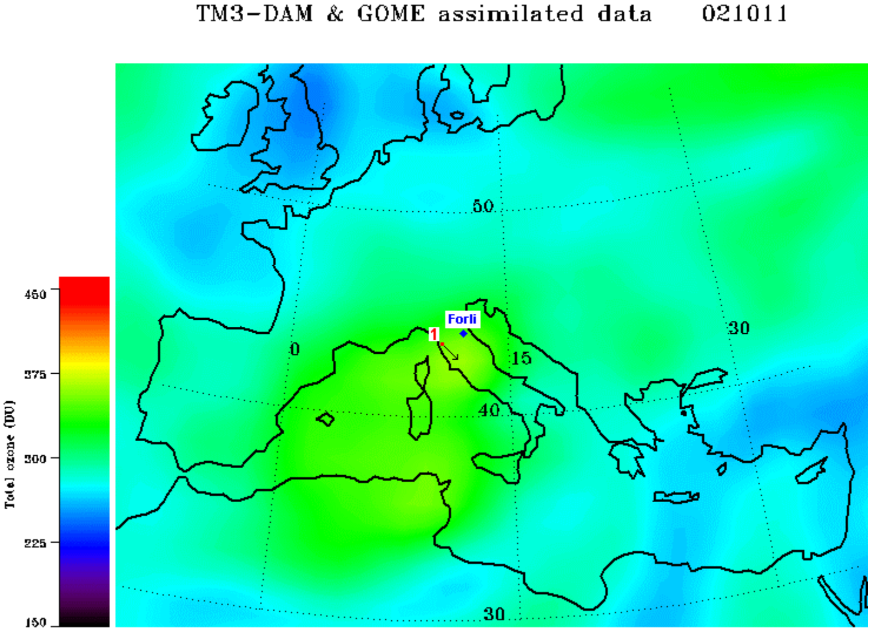

Fig.7 Assimilated ozone data derived by TM3-DAM and GOME

6. CONCLUSIONS

Simultaneous ozone measurements of by means of FOZAN-II and GASCOD/4Aπ instruments aboard Geophysica aircraft during July and October 2002 campaigns carried out at Forli airport demonstrated the advantage to have both *in-situ* and *quasi in-situ* (ACILA) type of measurements. The recent fill the gap in the spatial scale, created by *in-situ* measurements

(0km away from the aircraft) and measurements carried out by means of classical remote sensing techniques, which probe the atmosphere a few hundreds kilometres away form the aircraft, e.g. MIPAS-A and SAFIRE-A instruments installed on the same aircraft. In this regard much more observational geometries satellite –aircraft coincidences can be used and hence a better tuning of the algorithms deployed for satellite data processing can be achieved. All this reveals additional opportunities to improve the analysis of the obtained results and to assess adequately the satellite instrument's operational performances during the validation campaigns.

Acknowledgments:

This work is funded by the Italian Space Agency (ASI) through the VISONE project. The author Daniele Bortoli was financially supported by the " Subprograma Ciência e Tecnologia do 3° Quadro Comunitário de Apoio"

7. REFERENCES

1. Heland J., et al. Validation of MIPAS on Envisat by in situ instruments on the M55-Geophysica, *in this issue, 2003.*
2. Giovanelli G., et al. An airnborne spectroradiometer for atmospheric trace –gases detection and j-values calculations, *Atmos.Ozone, Proc. Quadrennial Ozone Symp. Hokakaido Univ. Sapporo, 2000.*
3. Giovanelli G., et al., Ozone ground-base measurements by the GASCOD near-UV and Visible DOAS system, in *Proceedings of the Quadrennial Ozone Symposium 1992*, Ozone in the troposphere and stratosphere - Part. 2" NASA Conference Pubblication 3266, (Washington, D. C.,), pp. 707-711, 1994.
4. Bortoli D., et al. Stratospheric nitrogen dioxide in antarctic regions from ground based and satellite observation during, *Proc. SPIE*, in press, 2001.
5. Petritoli A., et al. Tropospheric and stratospheric NO_2 amount deduced by slant column measurements at Mt. Cimone station, *Adv. Space Res.*, **29**, 11, 1691-1695, 2002 .
6. Werner R., et al. Spectrometric mesurements of NO_2 slant column amount at Stara Zagora station (42°N, 24°E), Adv. Space. Res, in press, 2002.
7. Kostadinov I., et al. UV-Vis spectroradiometric system for actinic measurements on board of Geophyisica aircraft, Conf. Proc., **69**, 8th Workshop Italian Research on Antarctic Atmopshere, Ed. M.colacino, G.Giovanelli, Italian Phys. Soc., Bologna, pp. 293-303, 1999.
8. Petritoli A., et al. Off-axis measurements of atmospheric trace gases by use of an airborne ultravilolet-visible spectrometer, *Appl. Opt.*, **41**, 27, 5593-5599, 2002.
9. Harder, J. W., et al. Temperature dependent NO_2 cross section at high spectral resolution. *JGR*, **102**, 3861-3879. 1997.
10. Gardner E.P.et al., , Primary Quantum Yelds of NO_2 Photodissotiation, *JGR*, **92**, 6642-6652, 1987.
11. Ziereis, H. et al. Aircraft measurements of tracer correlations in the Arctic subvortex region during the Polar Stratospheric Aerosol Experiment (POLSTAR), *J. Geophys.Res.*, Vol. 105, No. 19, 24305-24313, 2000.
12. Yushkov,V., et al. A chemiluminescent analyzer for stratospheric measurements of the ozone concentration (FOZAN). *J. Atmos. Oceanic Tech*. Vol 16, n. 10 , pg 1344-1349, 1999.
13. Ulanovsky A. E. et al. *FOZAN-II, Fast - response Chemiluminescent Airborne Ozone Analyzer*. Instrument and Experimental Techniques, 44, 2, pg 249-256, 2001.
14. Georgiadis T., et al. Some results of insitu ozone measurements with Fast Ozone Analyzer (FOZAN) onboard high-altitude aircraft Gheophysica during APE. In: *Polar Stratospheric Ozone*, pg 197-200, N.R.P Harris, I. Kilbane, and G.T. Amanatidis Eds., Report EUR 18031 EN, 1998.
15. Ravegnani F., et al. 1999. In situ stratospheric ozone measurements by means of a Fast Ozone Sensor (FOZAN) on board of M55-Geophysica aircraft. *Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research III*. Proc. SPIE 44th annual meeting, Denver, CO, A. M. Larar Ed. SPIE vol 3756, pg 502-510, 1999.
16. Yushkov, V., et al. Measurements of the O*zone and Water vapor content in the Stratospheric Antarctic Cyclone from the Hight Altitude M55 Geophysica aircraft* . Izvestia, Atmospheric and Oceanic Physics, v37, n3, 2001.
17. Radaelli, G. et al., http://apegaia.iroe.fi.cnr.it/
18. Cortesi et al., 2002 *in this issue*
19. Fortuin G.P. and H.M.Kelder, *J.Geophys. Res.*, **103**, 31709-31734, 1998.