

# THE VALIDATION OF THE ENVISAT CHEMISTRY INSTRUMENTS BY USE OF STRATOSPHERIC BALLOONS AND AIRCRAFT

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## ABSTRACT/RESUME

This paper serves as an introduction on the use of Stratospheric Balloons and Aircraft for the Validation of the ENVISAT instruments MIPAS, GOMOS and Sciamachy. Several campaigns have been organised in 2002, during the Commissioning of the satellite, from Northern latitudes to mid-latitudes to validate the level 1b and mainly level 2 data products. The activities performed in these campaigns are presented. This validation will be achieved by using several sensors carried by aircraft and stratospheric balloons. They will provide reference correlative measurements for comparison with Envisat products. The paper concludes by a presentation of the activities planned in 2003 in the frame of the existing flight programme.

## 1 INTRODUCTION

The objective of the ENVISAT Stratospheric Aircraft and Balloon Campaign (ESABC) is to contribute to the validation of the level 1b and level 2 data products of the Atmospheric Chemistry instruments MIPAS, GOMOS and Sciamachy. This validation will be achieved by using several sensors installed on aircraft and stratospheric balloons. The leading scientists in the field of stratospheric flights will participate to this campaign. The bulk of the effort will be provided by French and German teams. Additional flights will be performed by Italian scientists and a US team. The complete list of Principal Investigators is provided in Table 1. It must be emphasized that the PI's listed in this table work in cooperation with many co-PI's, not listed in this publication.

Table. 1. List of Principal Investigators

AO #	Principal Investigator	Institute	Carrier type
114	C. Blom	FZK-IMK, Karlsruhe, Germany	Aircraft (M-55)
144	C. Camy-Peyret	LPMA, Paris, France	Balloon
146	C. Camy-Peyret	LPMA, Paris, France	Balloon
180	C. Camy-Peyret	LPMA, Paris, France	Balloon
240	H. Fischer	FZK-IMK, Karlsruhe, Germany	Balloon
291	M. Pirre	CNRS-LPCE, Orléans, France	Balloon
349	J. Burrows	Univ. Bremen, Germany	Aircraft (Falcon)
362	J.B. Renard	CNRS-LPCE, Orléans, France	Balloon
399	F. Mencaraglia	IROE, Florence, Italy	Balloon
465	K. Pfeilsticker	Univ. Heidelberg, Germany	Balloon
594	K. Labitzke	Institute for Meteorology, Berlin	Support to ESABC
701	F. Goutail	CNRS-Service d'Aéronomie, Verrières, France	Small Balloons
713	J-P. Pommereau	CNRS-Service d'Aéronomie, Verrières, France	Small Balloons
1066	L. Stefanutti	IROE, Florence, Italy	Aircraft (M-55)
1335	K. Strong	Univ. Toronto, Canada	Balloons
2032	V. Mitev	Observatoire Neuchâtel, Switzerland	Aircraft (M-55)
2184	N. Harris	O <sub>3</sub> Research Coordinating Unit, Cambridge, UK	Support to ESABC

The complete flight programme is provided on Figure 1 below. The campaigns take place from mid 2002 until end-March 2003. The site of Kiruna is used in Summer for a balloon campaign and is also used in Winter for a large balloon campaign. This is also the optimum period to organise co-located flights with the two aircraft. Other balloon campaigns have taken place in Aire sur l'Adour, France, where the Balloon Division of the French Space Agency CNES is based. The site of Bauru is used in February 2003 to launch smaller balloons with relatively light payloads while the Italian Space Agency ASI uses the site of Trapani, Sicily, for the launch of balloons. The site of Vanscoy, Saskatchewan, Canada, (52°N, 107°W) is used by Canadian Scientists for the launch a large balloon-borne payload.

As for the aircraft activities, in addition to the flights performed in the Arctic region, the Falcon from the German Aerospace Institute DLR performed also an interesting validation project in co-operation with the M-55 aircraft in the Mediterranean region. During this project the two aircraft were based in Forli, in the North-West of Italy. The Falcon project performed also a transect from the Northern latitudes to the West Africa and the Seychelles.

The current ESABC project is due to complete its task by late 2003 with a workshop dedicated to the review of the validation results.

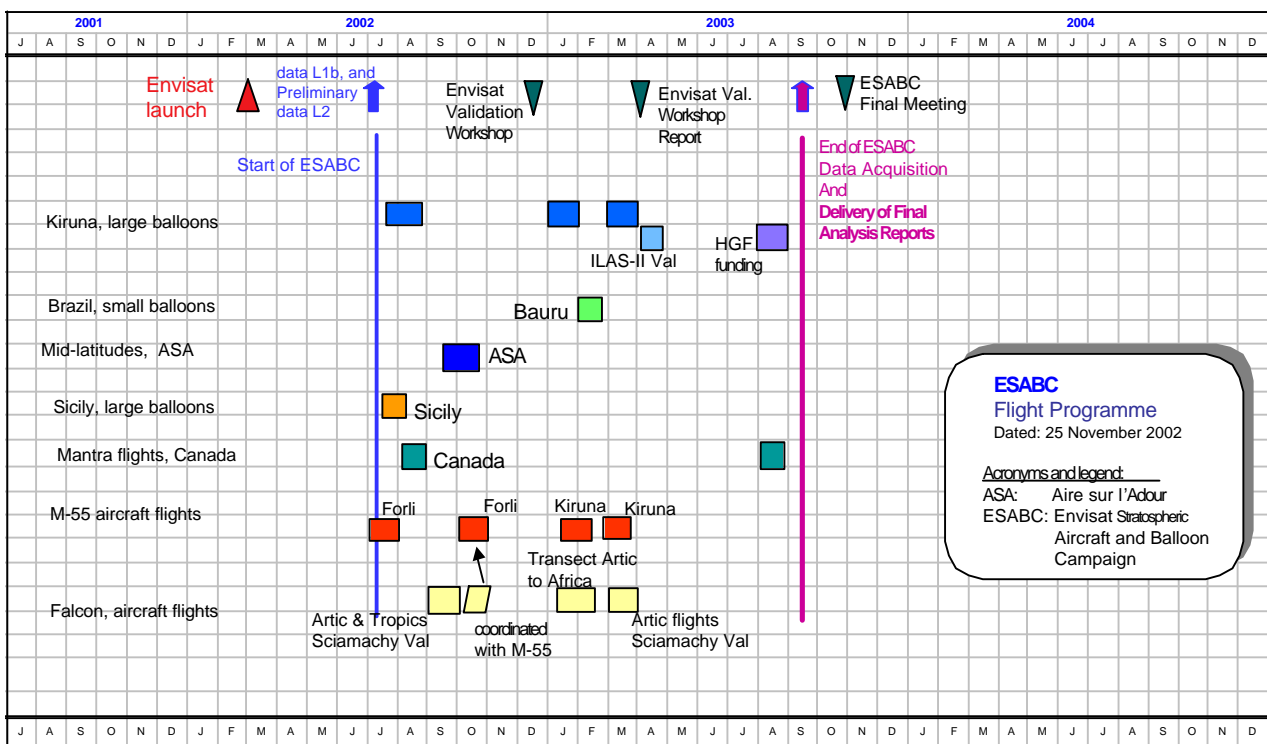


Figure. 1. The ESABC Flight Programme in 2002-2003

## 2 THE BALLOON CAMPAIGNS

The Envisat satellite covers the whole Earth surface and its atmosphere. It is therefore relevant to validate the level 1b and 2 data products over a range of latitudes and seasons in order to test Envisat products under different atmospheric conditions. Existing operational sites in Europe have been used, including CNES mid-latitude range of Aire-Sur-L'Adour, France, the ASI range in Trapani, Sicily, and the Arctic ESRANGE in Kiruna, northern Sweden. They provide convenient logistics and facilitate the recovery of the gondolas. Figure 2 below shows the launch of the SPIRALE payload from Aire sur l'Adour.

The site of Bauru, Brazil, will be used in the frame of a CNES campaign in February 2003 to launch SAOZ payloads from small balloons and from long duration infrared montgolfiere (MIR).



Figure. 2. The launch of the SPIRALE payload from Aire sur l'Adour

The table 2 provides a summary of the balloon flights performed in 2002.

Table. 2. The balloon flights performed in 2002

Date, Time	Flight	Comment
<b>Trapani, Italy</b>		
29 July	IBEX	MIPAS
<b>Kiruna, Sweden</b>		
6 Aug, 20:10 local	LPMA-IASI	Not part of the ESABC, but will be used for the validation
8 Aug, 16:31 local	SDLA-LAMA	GOMOS
12 Aug, 19:50 local	SAOZ + SAOZ BrO	GOMOS-Scia
18 Aug, 17:13 local	LPMA-NIR	GOMOS-Scia
<b>Vanscoy, Canada</b>		
3 Sept, 08:02 UT	MANTRA	
<b>Aire sur l'Adour, France</b>		
16 Sept, 11:00 local	$\mu$ SDLA	Not part of the ESABC, but will be used for the validation of GOMOS
19 Sept, 21:00 local	SALOMON	GOMOS
24 Sept, 09:06 local	TRIPLE	Scia, MIPAS
24 Sept, 21:06 local	MIPAS-B2	MIPAS
02 Oct, 08:45 local	SPIRALE	All
01 Oct, 18:07 local	SAOZ-BUS	All
04 Oct, 06:07 local	SAOZ-DIRAC	All
<b>USA</b>		
20 Oct	FIRS	Scia, MIPAS

### 3 THE M-55 GEOPHYSICA CAMPAIGNS

Unlike the stratospheric balloons, which acquire a limited data set over a limited geographic area, aircraft have the ability to fly for many hours at the optimum altitude and are able to perform flights over several thousand kilometres. In addition, aircraft possess high flexibility to achieve close temporal and spatial coincidence with satellite overpasses almost everywhere on the globe and under most weather conditions. As for the large balloon campaigns several campaigns have taken place in 2002 and will be performed in 2003. In some cases the aircraft activities are co-ordinated with balloon flights to optimise the validation return.

The Russian high-altitude plane M-55 is one of the two aircraft used in the ESABC project. It is shown at lift-off on figure 3. Scientific activities are co-ordinated by the ERS-Srl in Firenze, Italy. The aircraft can carry a payload of 2000 kg to an altitude of 22 km. Its endurance of over 6 hours makes it possible to perform long flights over large areas. The payload of the M-55 is composed of over a dozen sensors well adapted to the validation of GOMOS, MIPAS and Sciamachy. Some of the key sensors are the airborne version of MIPAS, i.e. MIPAS-STR, SAFIRE-A, ECOC, FOZAN and FISH. Additional details on the aircraft, the payload and the campaign record can be retrieved from the Airborne Polar Experiment home page <http://ape.iroecfi.cnr.it/>.



Figure. 3. The aircraft M-55 Geophysica is lifting off the airport of Forli, Italy, for an ENVISAT Validation flight (courtesy Dino Freccchia)

Two campaigns have taken place in 2002 from Forli, Italy. The flights have taken place over the Mediterranean area. A summary of the flights is provided in Table 3 below.

Table. 3. The flights performed by the M-55 in 2002

Date	Payload configuration	Comment
<b>Forli, Italy, July</b>		
13 July	“Chemical” sensor package	Test flight
15 July	“Aerosol” sensor package	Test flight
18 July	“Aerosol” sensor package	Validation flight
22 July	“Chemical” sensor package	Validation flight
<b>Forli, Italy, October</b>		
8 October	“Chemical” sensor package	Test flight
11 October	“Aerosol” sensor package	
14 October	“Aerosol” sensor package	
17 October	“Aerosol” sensor package + NERC	Flight co-ordinated with the Falcon
22 October	“Chemical” sensor package	Flight co-ordinated with the Falcon
24 October	“Chemical” sensor package	Flight co-ordinated with the Falcon
28 October	“Chemical” sensor package	Flight co-ordinated with the Falcon

#### 4 THE FALCON CAMPAIGNS

The meteorological research aircraft Falcon 20 operated by the German Aerospace Centre (DLR) has been in the frame of the ESABC project mainly to validate Sciamachy but has also been involved in the validation of MIPAS. It is a well-established research platform that can carry a payload of 1100 kg at a maximum altitude of 13.000 metres. The payload is composed of a radiometer (ASUR), an Ozone Lidar (OLEX) and a spectrometer (AMAXDOAS). The aircraft is depicted on Figure 4. More details on the carrier can be found at [http://www.dlr.de/FB/s\\_falcon.html](http://www.dlr.de/FB/s_falcon.html).



Two campaigns have been executed in 2002, first in September for a very ambitious programme of thirty days to perform flights from its home base in Munich, Germany, to Kiruna and Greenland and to the Seychelles. In October, the aircraft was active in the Mediterranean region for co-located flights with the M-55, as reported earlier and summarised in Table 3.

The first main campaign provided extended longitudinal and latitudinal atmospheric cross sections at various geophysical locations. Starting in Oberpfaffenhofen near Munich on 3 September the campaign consisted of 14 legs to high and low latitudes each, while instruments collected data along 18 ENVISAT orbits. Missions in the east west direction at high latitudes have been flown, where more than one adjacent orbit of SCIAMACHY could be linked. The aircraft flight plan could be organised in order to obtain very good temporal and spatial coincidence with the SCIAMACHY observations in most

cases. About 54 flight hours within a period of 3-4 weeks have been used in total. A summary of the flight legs, orbits crossed, as well as the Falcon departure and arrival times are given in table 4.

Table 4 Summary of validation activity during the first VAP- Campaign.  
The orbit index is related to limb observation

<i>Date</i>	<i>Orbit</i>	<i>Crossed Orbit Index</i>	<i>Flight Leg</i>	<i>Departure [UTC]</i>	<i>Arrival [UTC]</i>
<b>Northern Route</b>					
02/09/03	2667	10,11,12	Munich - Kiruna	08:00	10:30
02/09/04	2685, 2686	7,5	Kiruna - Kiruna via Longyear	16:00	19:30
02/09/05	2696,2697	10,11	Kiruna - Keflavik	10:00	13:00
02/09/06	2712, 2713	10. Nov	Keflavik - Sondre	12:50	15:00
02/09/07	2726, 2727	10	Sondre - Keflavik	12:30	14:30
02/09/08	2730	<b>Occultation 61.8° lat., 351.9° lon.</b>	Keflavik - Munich	18:20	22:00
<b>Southern Route</b>					
02/09/15	2839	12	Munich - Palma de Mallorca	09:15	11:00
02/09/17	2867	<b>13-17</b>	Palma de Mallorca - Yaounde	05:45	15:30
02/09/18	2880, 2881	17,18	Yaounde - Nairobi	08:30	11:30
02/09/19	2894	18,19	Nairobi - Seychelles	05:00	07:30
02.09.24	2966	17,18	Seychelles - Nairobi	06:30	08:30
02/09/25	2981	17,18	Nairobi - Yaounde	06:30	09:45
02/09/26	2996	13,16	Yaounde - Palma de Mallorca	05:30	15:00
02/09/28	3025	11,12	Palma de Mallorca - Munich	09:30	11:00



Figure. 4. The Falcon aircraft from the DLR, in Tunisia, during the flight from Europe to the Seychelles.

## 5 THE ACTIVITIES IN 2003

The existing ESABC Validation project includes balloon and aircraft flights in 2003, mainly in Kiruna and in the Arctic region from January to March. In addition, the tropics are also investigated with a campaign in Bauru, Brazil, in February. The Canadian team has planned a flight of the MANTRA payload in August. The Falcon team will again perform a transect from the Arctic to Africa. The list of balloon flights is summarised in Table 5.

Table. 5. The balloon flights planned in 2003

<b>Payload</b>	<b>Sensors validated</b>
<b>Kiruna, Sweden, January</b>	
AMON+RA	GOMOS
SPIRALE	MIPAS-GOMOS
SDLA	MIPAS-GOMOS
ELHYSA	GOMOS-MIPAS
<b>Bauru, Brazil, February</b>	
SAOZ+	All
SAOZ+	All
MIR	All
MIR	All
<b>Kiruna, Sweden, March</b>	
MIPAS-B2	MIPAS-Scia
TRIPLE	MIPAS-Scia
LPMA/DOAS	Scia-MIPAS
SALOMON	GOMOS-Scia
LPMA/CAESR	MIPAS-Scia
SAOZ+	All
SAOZ+	All
<b>Vanscoy, Canada, August</b>	
MANTRA	All

The year 2003 will be quite important for the ESABC team as it will give the opportunity to analyse in depth the data acquired to contribute to the validation of the three Chemistry instruments. This first phase of the validation, performed in the frame of the satellite commissioning phase, will be concluded by the organisation of workshops in late 2003. During these meetings whose frame is yet to be defined the Scientists and ESA will have the opportunity to review the results achieved and consider the recommendations to update the ground-based processing chains. A first opportunity to review the results will be the symposium to be held on 2-5 June in St-Gallen, Switzerland, dedicated to sounding rockets and balloons. A special session on the ESABC will be held. Further details on the organisation of the symposium will be provided via the web page at <http://www.estec.esa.nl/conferences/>.

## **6 RECOMMENDATIONS AND CONCLUSIONS**

The first results shown during the ENVISAT Validation workshop in Frascati demonstrate clearly that Stratospheric campaigns using Aircraft and Balloons demonstrate clearly that they can provide a significant contribution to the overall validation effort. It is recommended to pursue the effort and to consider the implementation of additional campaigns for the long-term monitoring of the data products. In addition the sensitivity of the sensors can be used to validate atmospheric species which have not been given yet the full attention. In this respect it is also essential to consider the organisation of campaigns in the Tropics. The campaign planned in Bauru in February 2003 is a start but must be complemented with larger projects involving a larger range of sensors.