1. General Information

Project title:

Contribution to the POLARCAT experiment with an airborne UV-Vis limb sounder

Project acronym:

POLUVIS

Main scientific field / specific discipline:

Earth Sciences & Environment / Other - Earth Sciences

Scientific theme:

Study of the vertical distribution of several reactive gases involved in the chemistry of the lower atmosphere during the POLARCAT campaign in Spring 2008.

Participants undertaking research:

Name	Institution	Department	Position
MERLAUD Alexis (lead scientist)	Belgian Institute for Space Aeronomy(bira-iasb)	chemisty and physics of atmosphere	reasearch assistant
FAYT Caroline	BIRA-IASB	DOAS UV-Visible	computer scientist
THEYS Nicolas	BIRA-IASB	physics	Research assistant

Lead scientists background:
(scientific background and experience, English level, etc)

3 years of working in the field of Atmospheric Sciences, first at Optical Remote Sensing group in Chalmers, Gotebrorg, Sweden, then in BIRA-IASB, in Brussels, Belgium. Several field camapaigns and measurements in different places/observatories with FTIR and DOAS intruments

Lead scientist considers himself / herself as:

Inexperienced in the use of research aircraft: No

Requiring access to an aircraft he / she has not used before: No

Number of participants on campaign site:

3

Total number of participants:

3

Scientific problems being addressed by the experiments and brief summary of experiments:

Our objective is to study tropospheric profiles of several reactive gases using airborne UV-Visible remote sensing observations during the spring 2008 POLARCAT campaign in Kiruna, Sweden. The target gases are BrO, NO2, O3 and H2CO. For this campaign, we propose to add to the existing instrumentation in the SAFIRE ATR-42, a compact UV-visible grating spectrometer equipped with a CCD detector and adapted input optics. The instrument will look horizontally through a quartz port of the plane. The scattered light will be analyzed using the Differential Optical Absorption Spectroscopy (DOAS) technique, and concentration profiles will be derived using the Optimal Estimation Method. This experiment will provide complementary data to the in-situ measurements performed from the aircraft (CO, NOx, O3) during the campaign. The proposed experiment will contribute to the POLARCAT objectives by providing a better understanding of the chemical processes involved in the oxidation capacity of the arctic troposphere. Furthermore, the measurements will be used to improve the trace gases climatologies in this part of the atmosphere and to support the validation of tropospheric measurements from satellites.

Aircraft:

ATR42 - SAFIRE

Why this aircraft bests suits for this experiments?

We wish to use the ATR-42 from SAFIRE, which will be operated during the campaign. This plane is able to fly up to the upper troposphere (around 7 km), which will enable us to derive a profile covering the entire troposphere. The telescope of our instrument will fit behind a quartz window replacing a port of the plane. It is essential that the window is made of quartz, since the instrument measures the radiance in the UV region down to 320 nm. Moreover, we will need data from the Inertial Measurement Unit of the plane for the data analysis. Finally, data from the in-situ chemical sampler instruments on board the plane will be used for intercomparisons with data from our instrument.

Alternative aircraft:

2. Description of the experiment

Scientific objectives / proposed work / anticipated output:

In the framework of the International Polar Year, the POLARCAT project [1] aims at quantifying contribution of trace gases, aerosols and heavy metals transported to the Arctic to pollutant deposition and climate change in this region. The experiment we propose, i.e., the measurement of vertical distributions of NO2, O3, BrO and H2CO in the troposphere, can help to fulfill two of the 5 main scientific objectives of POLARCAT, which are:

- Determination of chemical processes controlling composition including quantification of sources and sinks of major oxidants such as ozone and nitrogen oxides.
- Quantification of the contribution of summertime boreal forest fires to atmospheric composition in the Arctic compared to contributions from other source regions (e.g. Asia)

NO2 and BrO both play a key-role in ozone chemistry [2]. The latter is currently not well quantified in the troposphere and the processes leading to its formation are poorly understood. H2CO is a direct indicator or volatile organic compounds emissions; in particular it can be used as a tracer of boreal forest fires [3]. All the species targeted by this proposal influence the oxidation capacity of the troposphere.

The proposed measurements consist of the analysis of the scattered sunlight between 330 and 450 nm at a spectral resolution of 0.7 nm. We will use a compact grating spectrometer with a cooled CCD and a narrow field-of-view telescope, which will be installed behind a quartz port in the ATR-42. Cooling of the CCD will improve the signal to noise ratio and hence the sensitivity of the measurements. Sensitivity studies show that the optimal measurement geometry is obtained with a horizontal-looking instrument. In this configuration (limb viewing geometry), most of the information in the measured signal comes from the altitude of the plane, which makes it easier to derive vertical profiles during the data analysis. The telescope will thus be installed in horizontal position, with a small scanner to optimize the viewing angle. An optical fiber will transmit the light from the telescope to the spectrometer. A rackmounted PC will be connected to the output of the CCD to store the spectra obtained during the flight. Clear sky is preferable for the measurements; however thin clouds can possibly be dealt with in the analysis.

The measurements will be analyzed using the widely used DOAS (Differential Optical Absorption Spectroscopy) technique [5], relying on the discrimination of molecular absorption features in the spectra. Integrated concentrations along the line of sight (slant columns) will be derived using the WinDOAS tool, which has been developed at BIRA-IASB [6]. For the inversion of vertical concentration profiles, the Optimal Estimation Method [7] will be adopted, using the radiative transfer code LIDORT [8, 9] in the forward model. One expects to reach a vertical resolution of approximately 100 m.

Our remote sensing measurements will be compared to available co-located satellite observations (from GOME,GOME-2, SCIAMACHY or OMI) as well as to balloon and ground based observations performed during the POLARCAT campaign.

Results will be exploited as part of the PhD work of two students in the team.

[1] http://www.polarcat.no/

[2] WMO: Global ozone research and monitoring project, in: Scientific Assessment of Ozone Depletion: 2002, Rep. 47, Geneva, 2003

[3] Coheur P et al., ACE-FTS observation of a young biomass burning plume: first reported measurements of C2H4, C3H6O, H2CO and PAN by infrared occultation from space, Atmos. Chem. Phys., 7, 5437-5446

[4] Riedel, Ket al. (2005), Discrepancies between formaldehyde measurements and methane oxidation model predictions in the Antarctic troposphere: An assessment of other possible formaldehyde sources, J. Geophys. Res., 110, D15308, doi:10.1029/2005JD005859.

[5]Platt, U., "Differential optical absorption spectroscopy (DOAS)", Chem. Anal. Series, 127, 27 - 83, 1994.

[6] Fayt, C., and Van Roozendael, M.: WinDOAS 2.1 – Software user manual, Uccle, Belgium, BIRA-IASB, 2001

[7] Rodgers, C. D.: Inverse Methods for Atmospheric Sounding, Theory and Practice, World Scientific Publishing, Singapore-New-Jersey-London-Hong Kong, 2000.

[8] Spurr, R.J.D., T.P. Kurosu, and K.V. Chance, A Linearized discrete Ordinate Radiative Transfer Model for Atmospheric Remote Sensing Retrieval, J. Quant. Spectrosc. Radiat. Transfer, 68, 689-735, 2001.

[9] Spurr, R.J.D. Simultaneous derivation of intensities and weighting functions in a general pseudo-spherical discrete ordinate radiative transfer treatment, J. Quant. Spectrosc. Radiat. Transfer, 75, 129-175, 2002.

Weather conditions:
(e.g. clouds, atmospheric stability, wind speed and direction, weather...)

Clear sky and a maximum visibility offer the best measurement conditions for our experiment, since the radiative transfer computation is simpler in this case. Theoretically however, results can also be derived from measurements taken with a more cloudy sky, using the O4 measurements that are available at the same time from the instrument (as has been done by a group from Heidelberg University during the ASTAR 2007 campaign)

Time constraints:
(night time, under-pass(es) of satellites, weekends...)

The measurements must be made during day-time.
It would be more interesting to make the measurements during the overpasses of the satellite-borne instruments measuring the same species (GOME, SCIAMACHY, OMI, GOME-2); however we will adapt to the flight plans defined for the campaign.

Location(s) and reason for that choice:

Kiruna, Sweden

Number of flights and flight patterns:

If compatible with the requirements and specifications from the other experiments involved in the campaign, we would like to perform vertical sounding of the troposphere, by means of helicoidal flights, between 150 and 7000m.

Other constraints or requirements:

3. Parameters to be measured / Instrumentation

Description of parameter / measurement required for the experiment:

Spectral radiances measured with our UV- visible spectrometer between 320 and 460 nm

Instruments to be provided by hosting Aircraft Operator:
(basic instrumentation described on EUFAR website only)

We will need the attitude of the plane, measured by the IMU of the plane. Data from the in situ chemical sampler for O3 and NO would be interesting for comparison with our data

Own instruments to be added:
(have they already been flown? Do they have their own data acquisition system?)

A compact grating spectrometer will be added to the instrumentation of the ATR-42. This system has not been on an airplane yet, but it is pretty small and receives the incoming light via an optical fiber. Therefore it can be arranged in different ways to fit the configurations inside the plane. A rackmount computer will be used to store the data. The telescope (a cylinder of 3cm diameter by 5 cm long) needs to be installed behind the quartz window of the plane. The spectrometer itself will be put inside a rack. Beside power for the PC, we need power for the CCD (80W), the motor of the scanner (20W) and a small heater for stabilizing the temperature(20W). Everything can work on DC and adapted to the 28V standard of the plane.

Number of instrument operators needed onboard:
(in addition to those provided by the Aircraft Operator)

0

If applicable, plans for simultaneous field work / ground equipment to be used:

4. Data processing and analysis

Methodology for handling the data and analysis of output:
(airborne data acquisition, ground-truthing / observations, data processing and interpretation)

The data will be acquired automatically during the flight, with a software calculating the integration time of the CCD and triggering the measurements. Such software has already been used at BIRA-IASB for automatic ground-based experiments. If none of us can be present in the plane during the flights, an operator can be trained quickly to verify the quality of the spectra. The spectra obtained will then be analyzed after the flight using WinDOAS, which will provide the slant columns. Vertical profiles will then be obtained after radiative transfer calculations which will be performed after the campaign. The data will be compared with data from the other instruments recording similar parameters and to satellite data.

What resources are available to support the project beyond flying / data acquisition:

(funding, cooperation with other projects, manpower for analysis of results and preparation of user report, availability of laboratory facilities, etc)

Alexis Merlaud has received a grant from the Belgian Science Policy, to support this work. The salary of Nicolas Theys is also assured (PRODEX funding). Both of them will be involved in the analyses of the data, together with Michel Van Roozendael, leader of the BIRA-IASB team specialized in UV-visible remote sounding. The institute has extensive know-how in DOAS analysis and interpretation of UV-visible ground-based and satellite data, and has all the software tools that are needed to carry out the data analysis of the proposed experiment. The team has already built several UV-visible spectrometers of similar type as the one proposed here. It has support from a mechanical and electronics workshop, and an engineering division at the institute.
Senior scientists will also be involved in the instrumental part and the data analysis, beside Michel Van Roozendael, Christian Hermans, Caroline Fayt and Martine De Mazière will support the two students.

5. Planning

Primary / preferred dates:

Starting date: 03-03-2008

Ending date: 13-04-2008

Acceptable dates:

(season / time windows)

Two weeks during the campaign whenever it fits with the other experiments and the availability of the plane.

Agree to share aircraft time:

No

6. Other useful comments

Training benefit of the project:

(e.g. spread potential of airborne research to a wide scientific community; training of research students in experimental planning, methodology, data analysis and applications, etc)

This experiment will first allow two students and the associated senior scientists to deal with airborne data, from the instrument design and testing to the data analysis. Development of the instruments in cooperation with the operator will give us some knowledge about the requirements of airborne instrumentations. Regarding the radiative transfer calculations that are necessary for the derivation of the vertical profiles, we consider cooperation with a Phd student from Heidelberg who has been doing similar measurements last year during the ASTAR campaign.
Up to now, our institute has developed a strong expertise in ground-based and satellite observations. Remote sensing from aircraft is a new research direction for our institute, in which it wants to carry on after the campaign, since this approach offers promising perspectives to improve the link between ground-based and satellite observations. Belgium teams have a particular interest in Eufar since there is no national aircraft scientific operator in this country.

Scientific reviewers suggested by applicant:

Klaus Pfeilsticker, university of Heidelberg, Germany
Jean-Pierre Pommereau, Service D'Aéronomie, France
Johan Mellqvist, Chalmers Institute of Technology, Sweden

Other European funding:

The proposed work is scientifically connected to several EU project dealing with atmospheric sciences, e.g. GEOMON or ACCENT. Our institute is involved in these project, however our funding for this experiment does not come from the European Commission but from the ESA(Prodex) and from the Belgian Science Policy

Is the applicant agreeing to host a student during campaign and data analysis:
(in the frame of Education & Training "Join an existing campaign" activity)
No

Where does the applicant know EUFAR Transnational Access and Education&Training opportunities from?
Advertisement at conferences/scientific events