TROCCINOX - Tropical Convection, Cirrus and Nitrogen Oxides Experiment, Overview

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Abstract

The EU project TROCCINOX (Tropical Convection, Cirrus, and Nitrogen Oxides Experiment), http://www.pa.op.dlr.de/troccinox/, is being performed in 2002-2005 in cooperation with the Brazilian project TROCCIBRAS and in coordination with the EU-project HIBISCUS. The project investigates the contributions of tropical continental deep convection to lightning-produced nitrogen oxides (NO_x) and to other trace gases (including water vapour) and particles (ice crystal and aerosols). A first field campaign has been performed with the DLR Falcon aircraft during February and March 2004. Eight transfer flights between Oberpfaffenhofen (Germany) and Gaviao Peixoto (S. P. , Brazil) and 14 local flights have been performed. The aircraft was instrumented with in-situ sensors for NO, NO_y, O_3, CO, H_2O, T, NO_2 photolysis rate, and various aerosols. A differential absorption Lidar measures aerosol properties and H_2O profiles above or below the aircraft (see Flentje et al., this workshop). A second field experiment is now being performed in Brazil between mid-January and end of February 2005 including measurements with the Falcon and the high-flying (up to 21 km altitude) Geophysica aircraft.

Introduction

The project TROCCINOX investigates the impact of tropical deep convection on the distribution and the sources of trace gases, cloud and aerosol particles focusing on processes in the upper troposphere and lower stratosphere. Field observations and model simulations are being performed. TROCCINOX is being co-ordinated with the Brazilian TroCCiBras project which is co-ordinated by the Instituto de Pesquisas Meteorológicas (IPMet), Bauru, S.P. The Brazilian institutions, including the University of São Paulo (USP), and the National Institute for Space Research (INPE), operate a low-flying Bandeirante aircraft to perform chemical and aerosol measurements. Ground based observations mainly from Bauru, include weather radar, radiosoundings, and lightning observations. Weather forecasts are provided by Brazilian and European partners. The field experiment was performed along with the EU-project HIBISCUS, (http://www.aero.jussieu.fr/projet/HIBISCUS/en/many/index.html) with balloon-borne meteorological and chemical measurements in the upper troposphere and lower stratosphere.

General objectives of the experiments are:

1. to improve the knowledge about lightning-produced nitrogen oxides (NO_x) in tropical thunderstorms by quantifying the produced amounts, by comparing it to other major sources of NO_x and by assessing its global impact, and
2. to improve the current knowledge on the occurrence of other trace gases (including water vapour) and particles (ice crystal and aerosols) in the upper troposphere and lower stratosphere in connection with tropical deep convection as well as large scale upwelling motions.

TROCCINOX is a project under the Fifth framework programme of the European Community (CEC) for research, technological development and demonstration activities (1998 - 2002), within the RTD Programme "Energy, environment, and sustainable development", Key Action: 2 (Global Change, Climate and Biodiversity), Contract EVK2-CT-2001-00122. Its duration is from June 2002 until May 2005. An application of prolongation of the project duration until end of November 2005 has been submitted to the CEC.

TROCCINOX provides two aircraft (the Russian M55 Geophysica and the German Falcon), see Figure 1, to probe the atmosphere. The aircraft fly at variable altitude up to about 21 km (Geophysica) or 12.5 km (Falcon). In the tropics, the Falcon measures in the mid-troposphere and the Geophysica reaches the lower stratosphere. The TROCCINOX team has equipped the aircraft with various in-situ and Lidar instruments. The in-situ instruments are used to measure temperature, wind, pressure, position, and several trace gases

[1] See Table 1.

concentrations (O_3, total and gas phase H_2O, NO, NO_y, particle NO_y, ClO, BrO, $ClONO_2$, N_2O, CFC 12, CFC11, Halon 1211, SF_6, CH_4, CO_2, N_2O, CH_4, CO, and isotopes), NO_2 photolysis rate, and properties of aerosol: number density, radiation absorption coefficient, and size spectra over the size range from a few nanometers (volatile and non-volatile condensation nuclei) to 100 μm (cloud particles). The Lidar instruments measure vertical profiles of aerosol backscatter, depolarization, and water vapor concentration, versus time.

The large range of scales addressed in the field studies requires the use of a variety of models, each applied for a special aspect of the project. Modeling covers the growth of ice crystals and aerosol particles, the effects of clouds on the radiative transfer, chemistry and transport of trace gases, precipitation formation, lightning and the related NO_x-production, and the global scale climatic impacts of deep tropical convection. Weather prediction and model based computational predictions of the chemical composition of the atmosphere are used for local flight planning and analysis.

First Field Experiment

A first field experiment has been performed with the Falcon in South America during February/March 2004 based at the facilities of EMBRAER in Gavião Peixoto and of IPMet in Bauru in the State of São Paulo, Brazil. In addition to transit flights from and to Europe, see Figure 2, a total of 14 local flights were performed with the Falcon, instrumented with a Differential Absorption H_2O/aerosol Lidar (DIAL) and in situ chemical/aerosol probes. Falcon missions included measurements in fresh and aged outflow from deep convective events and large-scale survey flights across the Intertropical Convergence Zone (ITCZ).

Results

Quality controlled data are available from the TROCCINOX data bank. Some preliminary results were presented in Schumann et al. (2004). Lightning induced NO_x has been measured in or near tropical and subtropical thunderstorms at altitudes up to 12.5 km. In addition several model studies (see Huntrieser et al., this workshop) and studies with satellite data are being performed. Data are available for validation of ENVISAT (MIPAS and SCIAMACHY) and ICESAT (GLAS) observations. The in-situ data show high NO and CO background mixing ratios in the mid troposphere. In the anvil outflow of thunderstorms, spiky NO structures (maximum 65 nmol/mol) above background were observed. Some of the spikes were notably wide (order several 10 km) indicating outflow from a thunderstorm anvil, others were narrow (order 200 m) clearly originating from fresh lightning events. Model studies and some preliminary analysis indicate global lightning-NO_x production rates between 2 and 9 Tg(N) yr^{-1}. These are lower limit estimates because of missing data above 12.5 km altitude.

Outlook

The second field experiment in 2005 uses both TROCCINOX aircraft, the Geophysica and the Falcon. The second TROCCINOX campaign will be extended by additional Geophysica and Falcon flights for validation of the ESA ENVISAT satellite observations in the tropics. Some Falcon flights will be dedicated to investigate particle and cirrus interaction according to the project PAZI ("Particles and Cirrus") of DLR. Most of the experiment will be performed from the airport of Araçatuba (21°08'29" S/ 050°25'29" W) about 500 km west of São Paulo.

References

Schumann, U., H. Huntrieser, H. Schlager, L. Bugliaro, C. Gatzen, and H. Hoeller, Nitrogen Oxides from thunderstorms- Results from experiments over Europe and the Continental tropics. DACH - Deutsch-Österreichisch-Schweizerische Meteorologen-Tagung, 7. -10. September 2004, Karlsruhe, Deutschland, Proceedings on CD (2004), http://imk-msa.fzk.de/dach2004/

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Table 1. The TROCCINOX Team

N°	Institution/Organisation	City, Country	PI
1	Deutsches Zentrum für Luft- und Raumfahrt	Oberpfaffenhofen, D	Ulrich Schumann
2	Swiss Federal Institute of Technology	Zürich, CH	Thomas Peter
3	Lancaster University	Lancaster, UK	Rob MacKenzie
4	Central Aerological Observatory	Dogoprudny, RU	Vladimir Yushkov
5	Stratosphere-M, Ltd.	Dogoprudny, RU	Slava Khattatov
6	Consiglio Nazionale delle Ricerche, IFA	Rome, I	Francesco Cairo
7	Forschungszentrum Jülich	Jülich, D	Cornelius Schiller
8	Université Paul Sabatier	Toulouse, F	Jean-Pierre Cammas
9	Johannes Gutenberg Universität Mainz	Mainz, D	Stephan Borrmann
10	Johann Wolfgang Goethe-Universität Frankfurt	Frankfurt/Main, D	Michael Volk
11	University of Leeds	Leeds, UK	Kenneth Carslaw
12	Instituto Nazionale di Ottica Applicata	Firenze, I	Piero Mazzinghi
13	Observatoire Cantonal de Neuchatel	Neuchatel, CH	Valentin Mitev
14	Centre National de la Recherche Scientifique	Toulouse, F	

Table 2: Falcon Flights during the first TROCCINOX campaign: 23 flights, 45 days, 82 flight hours.

Date	Flight rational
3101	Transfer Oberpfaffenhofen - Seville
0202	Seville - Sal - Fernando de Naronha, Recife
0402	Recife - Gaviao Peixoto
1302	Cross-section 2: Air masses north and south of convergence zone (CZ)
1402	Radar box: Probing of thunderclouds
1602	Radar box: Air masses unaffected by convection, Comparison with HIBISCUS SP1 balloon
1702	Cross-section 4: Contrast of air masses affected / unaffected by previous tropical convection
1902	Cross-section 2: Contrast of air masses affected / unaffected by previous tropical convection
2002	N-E - triangle: Contrast of air masses affected / unaffected by tropical convection, coordinated with Bandeirante
2702	Stacked profile radar box: Comparison with HIBISCUS MIR-SAOZ balloon, and with Bandeirante
2802	Radar box: Probing of isolated thunderclouds coordinated with Bandeirante
0303a	N-W - triangle: Probing of air masses affected by previous tropical convection
0303b	Radar box: Probing of thunderclouds
0403	N- E-triangle: Lagrangian-Experiment: 2^{nd} probing of air masses measured on 0303b
0503	Profile in radar box: Air masses unaffected by convection
0703	ENVISAT validation, Constant level and profile through MIPAS limb and SCIA limb/nadir measurements
1003	Test flight before transfer to Germany and GLAS comparison
1203	Gaviao Peixoto - Recife
1403	Recife - Sal - Seville
1503	Seville - Oberpfaffenhofen

Figure 1. The Geophysica (after arrival at Oberpfaffenhofen, Germany, Jan 15, 2005), and the Falcon (in the Hangar of EMBRAER at Gavião Peixoto, S.P., Brazil).

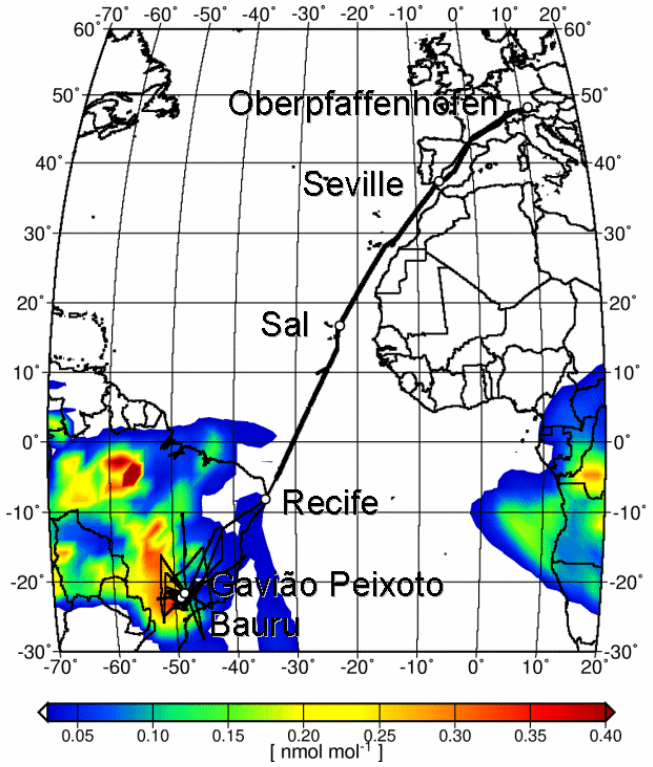

Figure 2. Map of locations and flight routes of the first TROCCINOX field campaign. The Falcon was instrumented at its DLR home base in Oberpfaffenhofen (Germany). Transfer flights to and from Recife via Seville (Spain) and Sal (Cape Verde Islands) provided meridional cross-sections**.** Gavião Peixoto, about 300 km northwest of Sao Paulo (Brazil) was selected as base for the Falcon and Bandeirante aircraft. At Bauru, in the centre of the State of Sao Paulo, the IPMET (Instituto de Pesquisas Meteorológicas) of the UNESP (University of the State of São Paulo) provided radar and other observations and hosted the HIBISCUS balloon operations. A variety of models were run in real time for supporting the flight planning during the campaign. The NO_x field at 200 hPa analyzed by the ECHAM model for 14 February 2004, 00:00 UTC is shown color-coded.