TRO-PICO: A SMALL BALLOON CAMPAIGN TO STUDY THE IMPACT OF TROPICAL CONVECTIVE OVERSHOOTING ON STRATOSPHERIC WATER BUDGET

E. D. Rivière (1), J.-P. Pommerau (2), N. Amarouche (3), M. Ghysels (1), and J. Cousin (1), and the TRO-pico's team

(1) Groupe de Spectrométrie Moléculaire et Atmosphérique (GSMA)/URCA/CNRS, Faculté des sciences, Campus Moulin de la Housse, B.P. 1039, 51687 Reims Cedex 2, France, emmanuel.riviere@univ-reims.fr

(2) Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Quartier des Garennes, 11 Boulevard D'Alembert, 78280 Guyancourt, France, jean-pierre.pommereau@latmos.ipsl.fr

(3) Division Technique de l'Institut National des Sciences de L'Univers, 1 Place Aristide Briand, 92195 Meudon Cedex, France, amarouche@dt.insu.cnrs.fr

ABSTRACT

The entry of water vapour in the tropical stratosphere is still a highly debated issue but is crucial for the radiative and the chemical balance of the stratosphere. This entry is due to two competing processes. i) The slow ascent leading to dehydration at the global scale (so-called the cold trap) is said to mainly drive the water concentration at the tropical tropopause. ii) Overshooting convection, inject ice in the lower stratosphere leading to a potential hydration. It is a fast and local process, difficult to capture by global scale model. TRO-pico is a project funded by the French ANR dedicated to study the impact of tropical convective overshooting on stratospheric water budget from the local to wider scales. It is based on a small balloon campaign from Bauru, SP, Brazil at two timescales (overall wet season, and intense convective season), followed by the campaign data analysis with a wide set of modeling tools. Here we describe the scientific context of TRO-pico, the objectives of the project, the campaign planned to start in November 2011, as well as the instruments to be flown in Brazil, which have recently participated in the Kiruna 2011 campaign with preliminary results from this campaign.

1. CONTEXT

In the tropical upper troposphere lower stratosphere (UTLS) water vapour is a key species both for the radiative and the chemical balance of the stratosphere. However the entry of water vapour in the tropical stratosphere is still debated. The cross-tropopause water budget is a competition between two processes occurring at different spatial and timescales. On the one hand, the slow radiative ascent in the tropical tropopause layer (TTL) leads to the formation of ice crystal which later sediment, acting as a sink for water vapour. This process is ubiquitous in the Tropical Tropopause Layer (TTL) at the global scale, and is shown to explain rather well the amount of water vapour at the tropopause [1]. On the other hand, overshooting convection across the tropical tropopause, injects ice crystals directly in the lower stratosphere. They often sublimate in a sub-saturated environment and act as a source of water vapour for the stratosphere. Statistically, the overshoots happen preferentially over tropical land of South America, Africa and Indonesia [2] on a short time scale (less than one hour) and penetrate the stratosphere through narrow surface area (a few km^2). Furthermore while it is accepted that overshoots mainly hydrate the stratosphere, some cases lead to dehydration [3]. Quantitatively speaking the estimation of the hydration given by cloud resolving models are of the order of several hundred tons per event. A range from 100 to 1000 tons/event is given according to model case studies [e.g. 3, 4]. This makes difficult an extrapolation of the impact of overshooting convection at a broader scale. The aim of the TRO-pico project is to further study the impact of tropical convective overshooting on the stratospheric water budget from local to regional scales and its relative importance compared to the cold trap mechanism. Four French institutes participate in the project: GSMA in Reims, LATMOS in Guyancourt, DT-INSU in Meudon, and LA in Toulouse. Associated partners of the project are LMD/Polytechnique in Palaiseau, LPC2E in Orléans, and CNRM/GAME in Toulouse. The main Brazilian partner is the Institute of Meteorological Research (IPMet) of the State University of Sao Paulo (UNESP).

2. TRO-PICO OBJECTIVES

Among the above general goal, TRO-pico aims at making significant progress in the following fields: a) water vapour variability during the wet season, b) frequency of occurrence of convective overshooting and its impact on the LS hydration at the local scale as well as on the thermal structure of the TTL, c) cirrus clouds formation and impact of electrically charged ice particles and on their lifetime in the

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TTL. Indeed, these parameters could have an impact on the lifetime of the cirrus in the TTL, and consequently on their dehydration potential, d) upscaling of the impact of overshooting convection currently unknown, and its importance compared to the cold trap, and e) validation of water vapour satellite measurements IASI/Metop as well as SAPHIR/Megha-tropiques.

To make the link between the convective scale and broader scale (regional and global) processes, an approach of observation and modelling at different time scales and spatial scales will be adopted. At the convective scale, the TRO-pico small balloon campaign will take place from Bauru, SP, Brazil (see section 3), regularly during the full wet season (six month) and the shorter most intense convective season (2 months). The observations will be associated with cloud resolving model or mesoscale model simulations and analyses. At a the broad scale, the objective is to use satellite observations as well as global chemical transport model simulations. The approach of the TRO-pico project is summarized in Fig. 1.

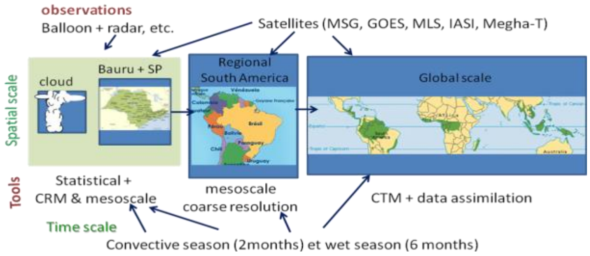

Figure 1. Different spatial and time scales under the scope of the TRO-pico project. The different types of observation and modeling tools are also displayed in this figure.

3. THE TRO-PICO CAMPAIGN

The TRO-pico field campaign is based on measurements by light payloads flown on small balloon o 500 m3 to 1500 m3 volume from Bauru, SP, Brazil, in order to sample the vicinity of deep convective systems with maximum flexibility, as well as water vapour trend during the summer season The campaign will be divided into two different periods of observation, corresponding to different objectives: a) a six month observation period (so-called SMOP) from November 2011 to April 2012, when regular water vapour soundings will be performed using pico-SDLA (once every ten days) to get the variability of water vapour during the wet season;. b) an intensive observation period (so-called IOP) in January and February 2012, with frequent measurements of water vapour next and above convective systemsn, but also measurements of CO_2 and methane O_3, NOx, which are species strongly linked to deep convection, electric discharges and lightning.

3.1 Instrumentation

Water vapour will be the most measured species. The main hygrometer used will be the pico-SDLA H_2O infrared laser spectrometer measuring the water wapour absorption in the 2.65 µm spectral region. It is based on the same concept of the former versions SDLA [5] and micro-SDLA but uses a one-meter long path for the open cell. Two different spectral lines are used (the more intense line is chosen for the stratosphere) to perform measurement up to 25 km. A picture of the instrument is shown in Fig. 2.

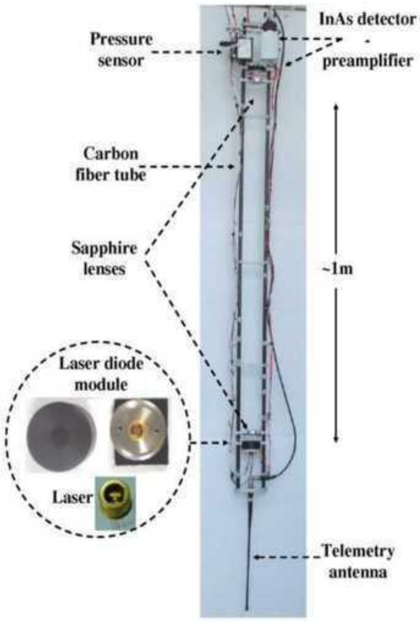

Figure. 2. Picture of the Pico-SDLA hygrometer with the different parts of the instrument.

Pico-SDLA was already successfully flown in Brazil, Teresina during the SCOUT-O3 campaign, and more recently in Kiruna (67°N, 21°E) during the CNES 2011 campaign. Measurements showed a similar profile than the one obtained by the frost point hygrometer Elhysa on the same day (G. Berthet, personal communication). Pico-SDLA CO_2 is a similar version of pico-SDLA H_2O except that it uses a 0,5 m path, and absorption at 2.68 µm. It was also demonstrated during the Kiruna 2011 campaign. The spectra are currently being processed. A third version of pico-SDLA is dedicated to the measurement of methane. In contrast to the H_2O and the CO_2 sondes, the Pico-SDLA-CH_4 is based on the use of a Compact Difference Frequency Generation (CDFG) laser source (size of approximately 20 cm × 12 cm × 2.5 cm), light weight (980 g), provided by Novawave Technologies, Inc. (USA), within a collaborative agreement. The CDFG emits at 3086 cm^{-1} (3.24 µm) where strong absorption lines in the ν_3 band region without overlapping with water vapor lines, allow measuring CH_4 in the middle atmosphere with a short optical path length of 3.6 m instead of 56 m for the former SDLA spectrometer [5]. The weight of this prototype (including lithium batteries and electronics) is of ~ 14,5 kg. The Pico-SDLA-CH_4 was also tested in flight during the campaign from Kiruna in very cold conditions similar to the temperature of the tropical tropopause. Preliminary results of this flight are shown, adapted from [6]. Fig. 3 shows spectra recorded during the descent at 19.6 km and 15.7 km on April 1st 2011 in Kiruna. It shows that for its first flight, the instrument was performing correctly in a range of altitudes and temperature corresponding to the tropical UTLS. A precision of about 5% is expected when elementary spectra are averaged on a 1s period.

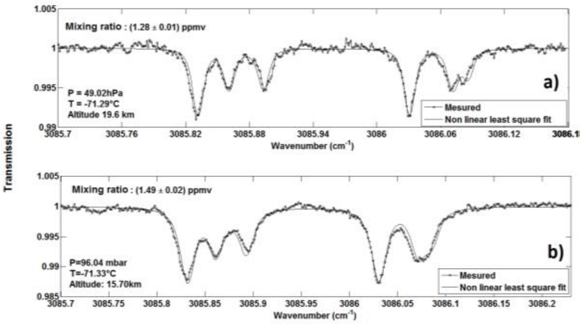

Figure 3. 10-ms elementary spectra of CH_4 recorded by PicoSDLA-CH_4, on April 1st 2011during from Kiruna, during the descent (19.6 km of altitude (a) and 15,7 km (b)).

During the IOP, CO_2 and methane measurements will help studying cross tropopause transport by overshooting convection.

Mini-Saoz is a UV visible NIR spectrometer performing measurements of several species by solar occultation, in a lighter version of the well-known SAOZ spectrometer. Two versions of the instrument will be flown during the TRO-pico IOP: a NIR version measuring O_3, H_2O, and aerosol, and a UV visible version measuring O_3, NO_2, CH_2O, and BrO. Mini SAOZ was also demonstrated during the Kiruna 2011 campaign. For preliminary data, references and details about this instrument could be found in [7] in the same issue. The two versions of the mini SAOZ will be used during the IOP for better characterising the impact of convective transport on the composition of the TTL in complement to, water vapour, and information about aerosol layers, as well as proxies of deep convection by lightning NO_x.

LOAC is a particle counter developed by Environment SA, based on the scattering of the light emitted by a laser diode at two different scattering angles. The first low angle (12°) is used for measuring the aerosol number density, whilst a higher scattering angle (60°) is used to discriminate the nature of aerosols. It can measures sized up to 30 µm, compatible with the presence of ice crystals in the lower stratosphere after an overshooting convective event. LOAC has successfully flown during the Kiruna 2011 campaign. Details on the first version of the instrument can be found in [8] while preliminary data of from the Kiruna's flight where presented by [9].

AICEP is a light weighted instrument dedicated to the measurement of electric field, electric conductivity by the well-known relaxation technique, and lightning. It is made of four electrodes measuring electric field in the range ± 10 mV/m to ± 200 V/m for DC large signals, and possibly extended to ±10 KV/m. It includes a simple diode lightning detector. The instrument was flown for the first time during the Kiruna's campaign but the gondola couldn't be retrieved. A schematic of the instrument is shown in Fig. 4.

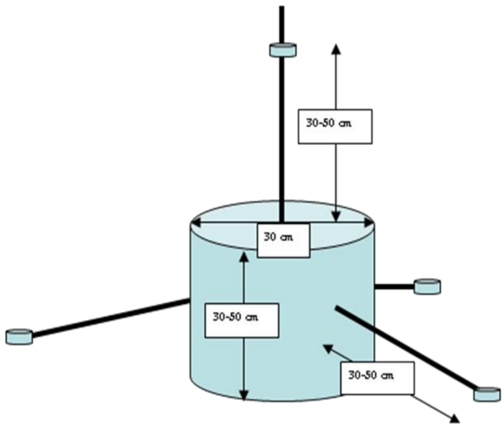

Figure 4. Schematic of the AICEP instrument. With the four electrodes. The size of each part is provided.

During the TRO-Pico IOP AICEP will be flown with the COBALD aerosol backscatter sonde for measuring electric charges of ice particles and the impact of electric field variations on the chemical composition of the UTLS. It will also be flown on the same balloon with a pico-Lidar of the Italian ISAC/CNR, for the remote measurement of cirrus clouds and ice particles below the balloon.

Additional water vapour measurements will be provided by the Russian FLASH-B Lyman-a hygrometer.

The balloon-borne measurements will be complemented by satellite observations (MSG brightness temperatures, GPS COSMIC constellation temperature profiles, MLS water vapour and CALIPSO cloud tops and cirrus), as well as ground based IPMet radar measurements in Bauru and Presidente Prudente, and aerosol Lidar.

3.2 Planned flight

Tab. 1 shows the number of flights scheduled for each instrument during each part of the campaign. The flights of the SMOP are performed with pico-SDLA H2O while all other instruments will be used during the IOP.

Table 1. Number of flights scheduled for each instrument during the IOP and the SMOP periods.

Instrument	SMOP (Nov. 2011-Apr. 2012)	IOP Jan-Feb 2012
Pico-SDLA H_2O	18	6
FLASH		1
Pico-SDLA CH_4		2
Pico-SDLA CO_2		2 with pico-SDLA H_2O
Mini-SAOZ (NIR)		2
Mini SAOZ UV-Vis		2
AICEP		4
LOAC		2 to 6 under pico-SDLA H_2O
COBALD		2 with AICEP
Pico lidar		2 with AICEP

3.3 Flight management

The flights will be managed both by the scientists of IPMET and of the TrO-pico consortium. Flight decisions will be made from radar and satellite images and balloon trajectory forecast. All gondolas will be equipped with a TM/TC system that can control the separation of the payload. The TM/TC will allow positioning the balloon during the flight and the payload at landing to allow a fast and safe recovery of the instruments, which is mandatory.

4. CONCLUDING REMARKS

TRO-pico is a project aiming at better understanding the role of overshooting convection on the humidification of the lower stratosphere from the local scale to the global scale. It is based on a small balloon campaign from Bauru, SP, Brazil during the wet summer season of 2011-2012, involving a relatively large panel of light instrument measuring not only water vapour but also ice particles, aerosols, atmospheric tracers, chemical species linked to deep convection, and electric fields and lightning. The relatively large number of flights planned should help to characterize the impact of overshooting convection. The information collected during the project will help understanding the impact of land overshooting convection at a larger scale (continental and global). Information and current status about the project will be available on www.univ-reims.fr/TRO-pico.

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