UPPER TROPOSPHERIC WATER VAPOUR AND PARTICLES MEASURED IN THE TROPICS BY AIRBORNE H_2O-DIAL DURING TROCCINOX AND SCOUT-O_3

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ABSTRACT

Airborne differential absorption lidar (DIAL) measurements of upper tropospheric water vapour and particle backscatter across tropical and sub-tropical regions are presented. During the SCOUT-O3 tropical field campaign, volume mixing ratios of water vapour as low as 2 ppmv have been observed near the coldest point in the TTL over Darwin (12°S, 130°E) in Australia. During the TROCCINOX campaign which took place in Brazil (22°S, 48°W) the lowest values which have been measured with the DIAL correspond to 3 ppmv. Upper tropospheric water vapour profiles derived from DIAL agree well to data products from in situ observations. From simultaneous measurements of particle backscatter at the wavelengths 1064 nm and 532 nm colour ratio values could be inferred providing information on the size of the particles. Additional microphysical properties are obtained from depolarisation measurements both at 1064 nm and 532 nm. As a result from intense deep convection activity, Cumulonimbus outflow at tropical tropopause level have been frequently observed.

1. INTRODUCTION

The amount of water vapour in the upper troposphere is controlled by upward transport (synoptic systems, convective clouds) and dehydration (sedimentation of ice particles). In the lowermost stratosphere water vapour is also strongly affected by quasi-horizontal transport between the tropics and mid-latitudes (e.g. Monsoon, and subsidence from the stratosphere). Both, water and ice phase critically determine the radiation budget in this sensitive region where the greenhouse potential is high for these components located close to the coldest point of the radiatively relevant atmosphere. Observations are reported on an increase of stratospheric water vapour which cannot be explained by increase of methane which is the primary source of water vapour in the stratosphere. In the tropics an important source of stratospheric water vapour is transport across the tropical tropopause which thus controls the stratospheric water vapor budget, whereby the humidity entering the stratosphere is limited by freeze drying of the air within the coldest layer and possible subsequent sedimentation of ice particles. Hence, knowledge of the amount of water in the tropical tropopause region and in particular its separation into gaseous and ice phases is crucial for a general understanding of the role of water vapour in the climate system. As demonstrated previously, airborne DIAL applied in the infrared spectral region around 935 nm has proven to be a powerful tool for the measurement of low water vapour mixing ratios and particle backscatter with high precision [1]. During two major field campaigns TROCCINOX [2] and SCOUT-O_3 [3] upper tropospheric water vapour and microphysical properties of particles and ice clouds have been obtained from extensive airborne DIAL measurements in the tropical and subtropical tropopause region. Selected results from these measurements which took place in different geophysical locations are presented. The profiles received are compared to each other and to data from collocated measurements with other sensors for validation purposes. Suggestions on instrument improvements are given from which it is expected that water vapour soundings beyond the cold point in the tropics could be possible. As a further topic water vapour and particle backscatter cross sections obtained from ferry flights over extended ranges from Europe to Brazil and Europe to Australia, respectively are presented.

2. AIRBORNE H_2O-DIAL

For the measurements during TROCCINOX and SCOUT the DLR H_2O-DIAL was deployed on the meteorological research aircraft Falcon 20 in zenith viewing arrangement. The key element of this instrument is the transmitter which is based on an injection seeded, narrow-band OPO (Optical Parametric Oscillator) with 100 Hz pulse repetition frequency. The pump source of the OPO consists of a frequency-doubled, diode-pumped Nd:YAG laser which provides a high average output power of the OPO. At 925 nm the output energy of the OPO is about 18 mJ per pulse which degrades to 12 mJ for operation at 935 nm.

The high wavelength flexibility of the OPO allows an easy selection of proper water vapour absorption lines around 935 nm to be most sensitive for mixing ratio measurements in the upper troposphere over a large dynamic range. A detailed assessment of the measurement accuracy is given in [4]. Uncertainties in the water vapour retrieval stem both from systematic and statistical errors. Main sources of systematic errors are uncertainty in the determination of the water vapour absorption line cross section (4% estimated uncertainty), laser spectral impurity (1% after correction), atmospheric temperature uncertainty

Tab. 1: Instrument parameter of the DLR H_2O-DIAL

Wavelength (nm)	925-940	1064	532
Pulse energy (mJ)	12 - 18	50	40
Repetition rate (Hz)	50 (on/off)	100	100
Pulse length (ns)	7	15	11
Bandwidth (GHz)	0.14 / 90 on/off	0.05	0.05
Spectral purity (%)	> 99	---	---
Detector	Si:APD	Si:APD p&v pol	PMT p& v pol
Filter FWHM (nm)	1	1	1
Filter trans. (%)	65	40	55
Telescope	Cassegrain, Ø35 cm; field-of-view 1 - 2 mrad		
Data acquisition	14 bit, 10 MHz		

(<1%), and the Rayleigh-Doppler broadening (<1.5% after correction). They sum up geometrically to about 5% in total. The statistical error of a DIAL measurement is controlled by horizontal and vertical data smoothing. Atmospheric backscatter and depolarisation is measured simultaneously both at 1064 and 532 nm. The most important specifications of the current instrument set-up are outlined in Table 1.

3. RESULTS FROM FIELD CAMPAIGNS

A main focus of the Tropical Convection, Cirrus and Nitrogen Oxides Experiment TROCCINOX which took place in Brazil was put on convection and corresponding modification of the humidity field at upper tropospheric levels. Hence, anvils of deep convective Cumulonimbus (Cb) clouds were investigated, with focus on the outflow of air masses at the top transported upward from the low or middle troposphere.

A total of 13 local flights were performed during the first campaign over central Brazil in February and March 2004. Most flight strategies aimed at maximising close encounters with important deep convective systems. While the DIAL was unable to

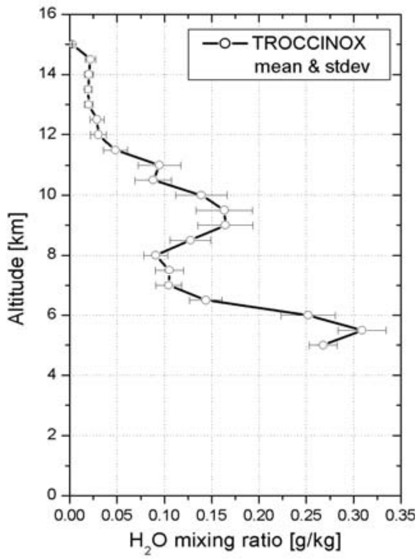

Fig. 1: Mean water vapour profiles in the upper troposphere obtained from airborne H_2O-DIAL measurements during the TROCCINOX field campaign 2004

measure within thunderstorms, it performed well by profiling the anvil and the convective outflow regions further downstream. In contrast, some flights were dedicated to measure air masses not influenced by

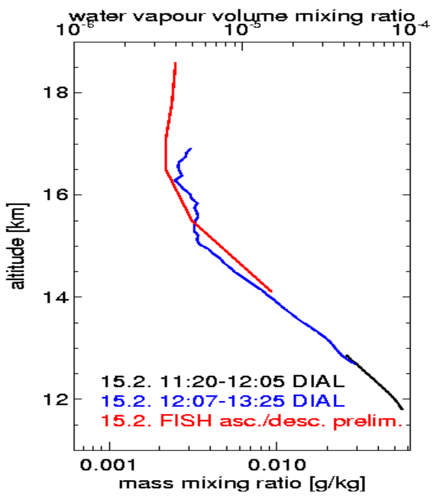

Fig. 2: Water vapour profiles obtained from DLR H_2O-DIAL measurements on the Falcon and FISH (Lyman-alpha hygrometer) sensor on the Geophysika aircraft during the TROCCINOX field campaign 2005

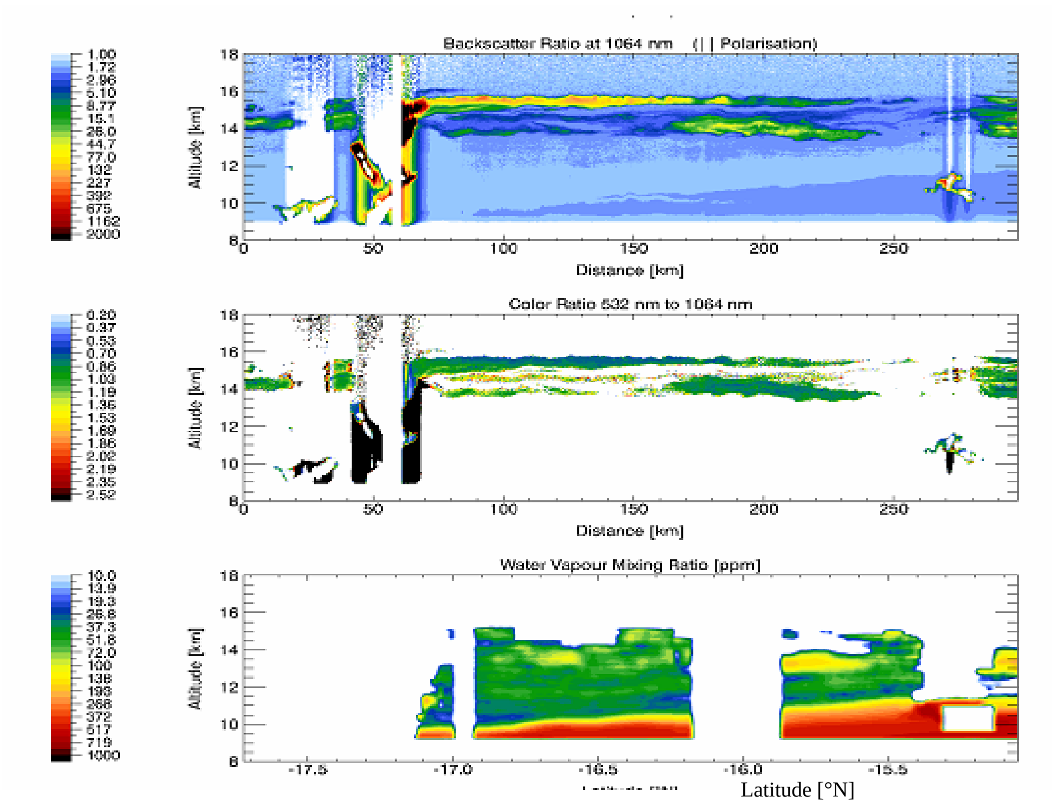

Fig. 3: Cross sections of the backscatter ratio at 1064 nm (upper panel), colour ratio at 1046nm / 532 nm (centre panel) and volume mixing ratio of water vapour (lower panel) from TROCCINOX flight campaign at 16°S, 48°W. More details are shown on the colour plots provided with the proceedings CD.

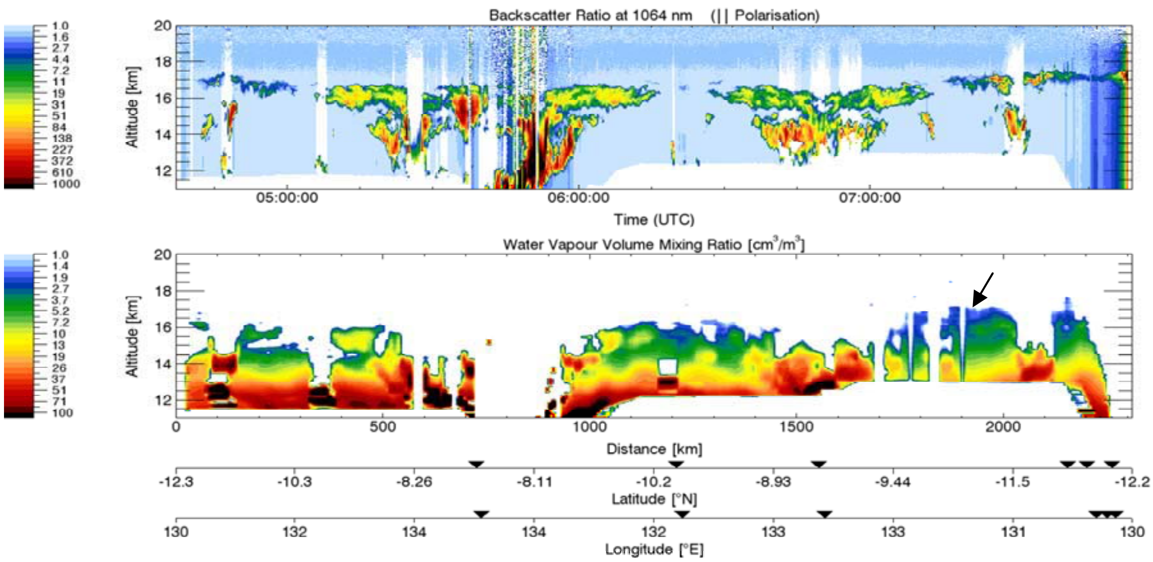

Fig. 4: Cross sections of the backscatter ratio at 1064 nm (upper panel) and water vapour mixing ratio (lower panel) obtained from tropical SCOUT-O3 Campaign. Very low water vapour mixing ratio values around 2 ppmv are indicated by the arrow in the lower panel. More details are shown on the colour plots provided with the proceedings CD.

convection. Here the DIAL obtained reference H_2O profiles, and profiles of background tropospheric and stratospheric aerosol layers.

Preliminary results from TROCCINOX campaign can be summarised as follows. Upper level clouds extended up to 16 km height. Cb outflow have been observed at tropopause level between 15 km and 16 km and around 10 km as indicated by higher mixing ratio values in Fig 1 which is a sum of all DIAL profiles measured during the first phase of TROCCINOX in 2004. Particle backscatter at the tropopause region show colour ratios close to unity and depolarisation ratios in the range between 10% and 20% indicating the existence of ice particles. Water vapour profiles obtained from DIAL measurements agree well with collocated in-situ observations as shown in Fig. 2. The cross sections in Fig. 3 show a measurement example from 17 February 2004 where convective outflow associated to the formation of cirrus clouds at tropopause level is clearly visible. In this example, the water vapour mixing ratios between 10 and 16 km are surprisingly constant with a value around 40 ppmv while a very humid layer with sharp vertical gradient at 10 km height entering the scene from the north.

The second tropical campaign, SCOUT-O3, aimed at a better understanding on the quantification of exchange processes at the tropical tropopause which are relevant for stratospheric ozone chemistry. This campaign took place in November - December 2005 and comprised 9 local flights around Darwin in Australia and two long-range ferry flights between Europe and Australia. Similar to the TROCCINOX campaign the DLR H_2O-DIAL has been operated on the Falcon aircraft to sound the upper troposphere and UTLS in zenith viewing configuration. Fig. 4 depicts a typical measurement example from 23. November 2005 exhibiting Cb outflow at the tropopause region around 17 km height. In agreement to in-situ observations from high-flying Geophysika aircraft, water vapour mixing ratio values down to 2 ppmv have been observed close to the coldest point in the TTL (Tropical Tropopause Layer). This was different to the TROCCINOX campaign where the lowest values observed by the DIAL where always larger than 3 ppmv.

4. SUMMARY

During the two tropical field campaigns, TROCCINOX and SCOUT upper tropospheric water vapour and particle backscatter have been measured across the tropics and sub-tropics by airborne H_2O-DIAL. Volume mixing ratio values as low as 2 ppmv have been observed near the coldest point in the TTL over Darwin in Australia. Upper tropospheric water vapour profiles obtained from DIAL measurements agree well with data products measured by collocated in situ observations using the high-flying Geophysika aircraft which sounded the atmosphere above the Falcon aircraft. From particle backscatter measurements at 1064 nm and 532 nm colour ratios have been computed. Additional information on microphysical properties could by derived from depolarisation measurements both at 1064 nm and 532 nm.

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4. REFERENCES

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