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Climatic change and atmospheric composition research via balloons

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Abstract. A brief description of a compact, high sensitive and selective fluorescence technique for the atmospheric composition measurements is given here. This technique that uses a laser as a source has been used at the beginning on balloon platforms, in the last years it is preferred to use an aircraft as flying platform because it allows the measurements of atmospheric species not only as function of the altitude, but also the study of the variation from region to region. A short description of the instrument developed at the CETEMPS-Università di L'Aquila, some results and future improvements and deployment will be also reported.

Key words. High sensitivity – Selective fluorescence – Laser induced fluorescence

1. Introduction

Changes in the atmospheric composition impact the earth ecosystems and the human life. The increase of CO_2 is the source of climate change; the increase of tropospheric ozone affects the air quality, the reduction of the stratospheric ozone layer influences the ultraviolet radiation level on the earth surface. The atmosphere is composed on average mainly of nitrogen and oxygen molecules (together accounts for 99%), but only changes in the abundance of trace species may be origin of climate changes, degradation of air quality and of other atmospheric issues. Trace species in the atmosphere have concentrations that range between ppmv (parts per million by volume) as for CO_2 to pptv (parts per trillion by volume) as for the main tropospheric oxidant: the hydroxyl radical (OH). These very low concentrations require instruments with high sensitivity as well as very selective instruments to discriminate each species. The lifetime of atmospheric trace gasses ranges between few seconds of the very reactive molecules (i.e. OH) to years (i.e. CO, methane). To detect the concentration variations of very reactive species besides sensitivity and selectivity, is needed fast detectors. Finally, since the concentration of most atmospheric molecules changes with altitude and from site to site, a light compact and low power consumption instrument is preferable to be used on flying platforms.

Laser induced fluorescence (LIF) uses the laser radiation to excite molecule and from the detection of fluorescence light it is possible to determine their concentration (Heard, 2006). Since each molecule has its own absorption spectrum LIF is a selective technique as long as the laser wavelength is superimposed to one of the molecule transition. This technique has

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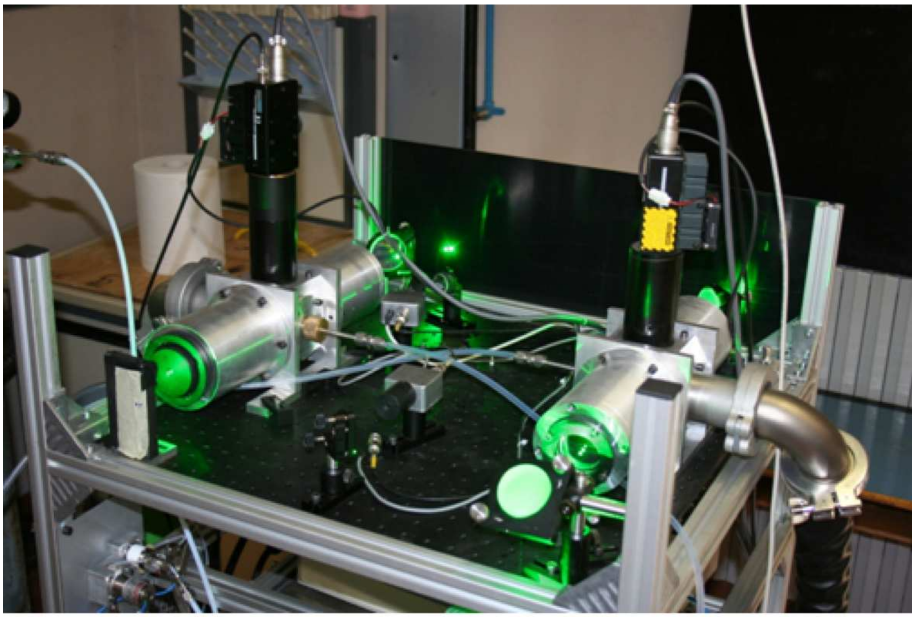

Fig. 1. A picture of the LIF developed at the CETEMPS. The detections cells, that include detectors (photomultipliers) are shown, whereas the laser source is below the cells and not shown here.

been used with success on the detection of several species with detection limit well below their typical atmospheric concentrations like for OH that is one of the species more challenging to be detect (Faloona, et al., 2004). The rapid development of the laser technology allowed a reduction of the weight and the power consumption of LIF instruments. The first deployment on atmospheric balloon of a LIF instrument has been done by the Anderson group at the end of the 80's to measure stratopheric OH (Stimpfle and Anderson, 1988). After the firsts observations with balloons more LIF systems have been developed to detect a range of atmospheric species and deployed in several research aircrafts during field campaigns (Brune et al. 1998; Wennberg et al., 1994; Bertram et al., 2007).

2. LIF Instrumentation

The CETEMPS NO2-LIF uses as light source a YAG Q-switched laser that emits at 532 nm. The laser beam and his electric field are perpendicular to the direction of the air fow in order to reduce the amount of Rayleigh and Raman photons emitted in the direction of the phototube. The laser power is monitored before and after the cell by two photodiode detectors. The detection cell is a 8 cm cube where laser scatter is reduced by a sequence of circular baffles mounted along the laser path. Sample gas at atmospheric pressure is drawn in the detection cell by a pump. The fluorescence is emitted perpendicularly both to the gas flow and to the light beam and it is collected with a PMT fixed after filters that cut the non-fluorescence light. In figure 1 it is reported a picture of the detection cells of the instrument. The instrument has a detection limit of 12pptv and a rate of measurements up to 4 hz. The LIF is completely autonomous using custom LabView and Lookout programs, more details of the instrument with a description of an intercomparison campaign could be find in Dari Salisburgo et al. (2008). In figure 2 is reported an example of 1 s. measurements of NO_2 and O_3 to show the chemistry coupling of these two species and the ability of the LIF

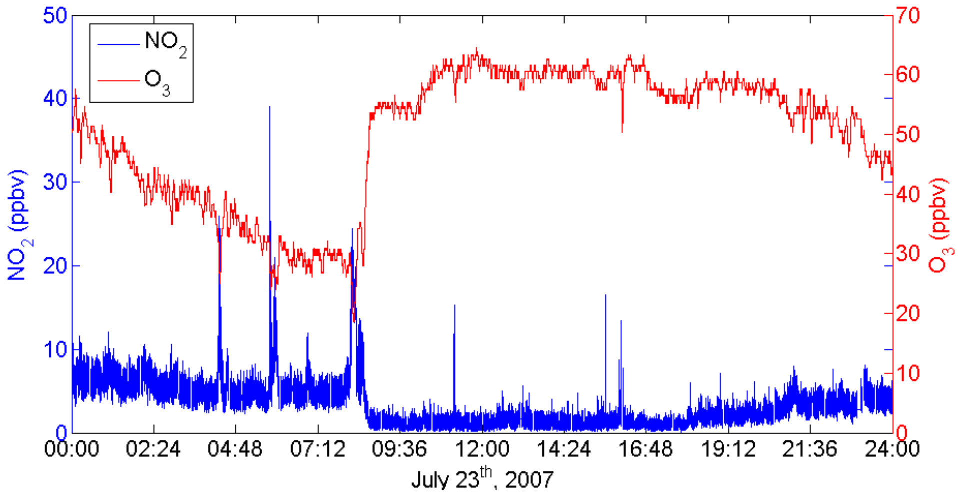

Fig. 2. Diurnal variation of NO_2 and O_3. Here are reported 1 s. data to track the fast variation of these species.

instrument to detect fast variations of the NO_2 concentrations.

3. Conclusion

A short description of a laser induced fluorescence developed for atmospheric trace gases measurements has been reported. The instrument has a very high sensitivity (less than 12 ppt) and the fast response (more than 4 Hz) allows to track fast concentration variations, needed to understand the chemistry of very reactive species. The instrument is so light and compact to be installed on balloons as well as aircraft platforms.

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