# Lidar Activities at LMD/IPSL dedicated to Atmospheric Carbon Dioxide Monitoring, Carbon Cycle and Climate

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**Abstract**

Lidar activities at LMD-IPSL dedicated to atmospheric CO2 monitoring and exchanges processes between atmosphere and eco-systems are reviewed. These new activities started in late 2002 to develop a new 2-µm Heterodyne Differential Absorption Lidar to perform accurate CO2 mixing ratio measurements in absolute value. In the meantime, and along the same line, new projects have been submitted to various agencies in France and in Europe. Some of them are already funded while some are still awaiting for approval expected in mid 2006. Among these projects some are dedicated to ground-based Lidar activities, whereas some are aiming at airborne and future space-borne activities. Here, an emphasis is put on Lidar but all the developments are tied to scientific objectives in the broader context of Carbon Cycle and Climate change. Ultimately, the objective is to address some of the major issues raised by the community.

## 1. Introduction

Atmospheric CO2 makes a direct connection between multiple and complex processes combining retroaction from atmosphere, geo-sphere (vegetation, soil) and ocean. Remote sensors are expected to be key partners in the future global observation network combining in situ, ground-, air- and space borne sensors. While several passive vertical sounders are already in space, two dedicated carbon-dioxide passive missions i.e. the "Orbiting Carbon Observatory (OCO)" as proposed by NASA and the "Greenhouse gas Observatory Satellite (GOSAT)" by JAXA, are under development to be launched in 2008. These two CO2 missions will be contemporary with the wind Lidar mission "ADM-ÆOLUS" under development at the European Space Agency (ESA).

It is beyond the scope of the present paper to discuss the various merits and drawbacks of the passive versus active techniques to monitor CO2 from space. However, we know for sure that the two techniques are complementary, and a strong synergism is expected in order to provided coverage and accuracy, at the same time. The basic concept of synergism is currently developed and used by the Lidar community, among others.

## 2. Overview of Lidar activities at LMD-IPSL

According to a strong convergence of scientific interests at IPSL, new Lidar activities dedicated to the monitoring of atmospheric CO2 from ground, air- and space-borne platforms are conducted at LMD in successive steps. (1) At first, a 2-µm Heterodyne Differential Absorption Lidar has been developed and successfully tested in late 2004, and more data collected during 2005 - 2006 (see the F. Gibert et al. at 23 ILRC). (2) LMD/IPSL undertakes the study of a new DIAL based on the Optical Parametric Oscillator technique and direct detection. (3) LMD-IPSL is also contributing to a study funded by ESA to study the feasibility of powerful 2-µm laser transmitters for future DIAL applications from space. The study is led by ONERA (France). In this framework, LMD-IPSL is in charge of the laser metrology and testing units. (4) Now, looking into the future, a new proposal has been submitted recently to the French "Agence Nationale de la Recherche" to develop an airborne payload "AIReS" that combines a multipurpose Lidar and an advanced Vegetation fluorescence radiometer. The result of the review is expected by mid-2006. (5) On a longer term, a proposal "A-SCOPE" has been submitted in August 2005 to ESA in response to a Call for Ideas for the next Earth Explorer Mission. "A-SCOPE" makes use of the findings of the "FACTS" study that has been conducted by IPSL and Alcatel Space in 2004-2005 for ESA. The result of the review is expected by mid 2006.The following sections will present the new activities and projects, some of them are still under review. The 2-µm Heterodyne Differential Absorption Lidar and the main results will be presented in a separate paper.

## 3. New ground-based DIAL

For the current 2-µm HDIAL is a laboratory breadboard that cannot be transported in the field, LMD/IPSL undertakes the study of a new Direct Detection DIAL (D-DIAL) based on the Optical Parametric Oscillator technique for the laser transmitters (on- and off-wavelengths). It is planed to develop the D-DIAL instrument later this year. The new 2-µm system will be tested against the 2-

µm H-DIAL in operation at LMD-IPSL and various *in situ* sensors. The activity is funded as a research activity by the French "Centre National d'Études Spatiales" (CNES is the French Space Agency).

## 4. "AIReS"

An "Advanced Airborne Integrated Remote Sensors (AIReS)" project as been submitted early 2006 to the French "Agence National de la Recherche" (National Research Agency), as a 4 years project. Partners of different expertise and fields of activities are involved in "AIReS". The objective is to develop an integrated platform for Regional Studied of Carbon Cycle and Ecosystems. During the last year of the project, "AIReS" will be deployed in Europe. This project prepares the future of remote sensors to monitor CO2 from space.

For Europe is a region of significant fossil fuel emission, the motivation is to provide scientific information that is critical to reducing uncertainties in our current understanding of sources and sinks at regional scales. "AIReS" will help to assess the scale integration problem, and will be used to link the sparse monitoring stations of the current ground based network. On a longer term (beyond the current project), AIReS could be used to reducing the uncertainties surrounding the magnitude of Europe's contribution to an overall Northern Hemisphere carbon sink.

The airborne payload combines a multipurpose Lidar and a vegetation fluorescence radiometer. The multipurpose Lidar combines three functionalities: (i) a Differential Absorption Lidar (DIAL) to measure $CO_2$ and water vapor ($H_2O$), simultaneously; (ii) an aerosol Lidar and (iii) a canopy Lidar. The Multipurpose Lidar is based on one single mode Nd-YAG laser that is used to pump 3 OPOs, and also used to profile atmospheric aerosols and the canopy structure. The DIAL measurements consider total column content using surface return and boundary layer distributed aerosols. ONERA (France) is a key partner of "AIReS" for its expertise in high performance compact OPOs. All key items that drive the DIAL performance are considered in the project including new spectroscopic data applicable to CO2 and H2O absorption lines for accurate measurements.

The Multi purpose Lidar will provides high resolution measurements at high accuracy on (1) two key greenhouse gases that contributes to the carbon cycle, CO2 and H2O are also the key components of plants biological processes (photosynthesis, respiration) (2) Aerosols burden that links the surface to the lower troposphere; multi-wavelength Lidar remote sensing will provide some information about the atmospheric vertical stratification, (3) the canopy and biomass that are in close interrelation with carbon dioxide and water vapor.

Also, "AIReS" addresses all the necessary techniques and disciplines to fulfill the scientific goals such as: (1) the space segment and satellite data processing,; (2) numerical modeling at the mesoscale; (3) expertise in aerosols science; (4) expertise in basic ecosystems processes and remote sensing of vegetation.

## 5. "A-SCOPE"

The purpose of the "Advanced Space Carbon and Climate Observation of Planet Earth (A-SCOPE)" proposal is to study, develop and fly a CO2 Differential Absorption Lidar to complement the existing and forthcoming passive remote sensing missions. Considering the proposed schedule for a mission in the 2010 – 2015 time frame, we propose two functionalities: (1) CO2 total column content using surface return with high accuracy (1-3 ppm) and (2) ecosystems and canopy profiling. For $CO_2$ measurements call for high accuracy ranging capability (meter) so if improved a bit it could be used to derive information on vegetation and canopy. The pulsed DIAL will be based on OPO technique or Raman shifting technique. "A-SCOPE" considers the main results and conclusion of the "Future Atmospheric Carbon Dioxide Testing from Space (FACTS)" study conducted by IPSL for ESA.

## 6. Discussion

As said before, two main pieces of proposal are still awaiting (hopefully positive) review and significant funding. According to the result of reviews, the various activities and projects will be presented.

## References


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