Propriétés optiques et microphysiques des aérosols déduites de la combinaison LILAS/photomètre pour les sites de Lille et Dakar.

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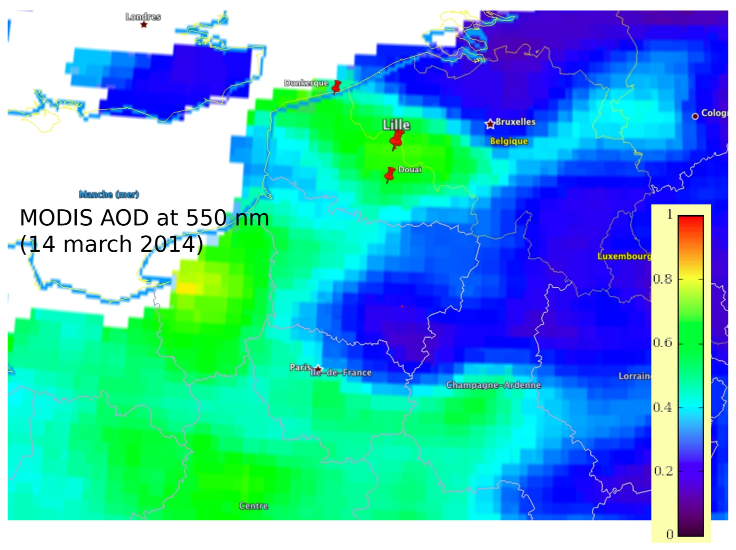
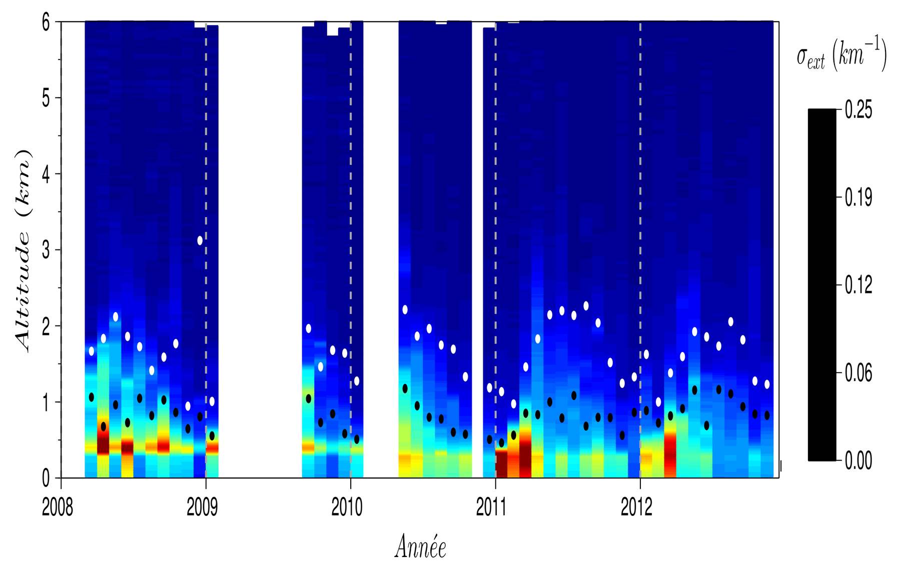
Motivation

Atmospheric aerosols are considered one of the major uncertainties in climate forcing (Boucher et al., 2013) and a detailed aerosol characterization is needed in order to understand their role in the atmospheric processes as well as on human health and environment. One of the uncertainty is due to the spatial variability and especially, vertical variability. At present time, several atmospheric stations have vertical sounding capabilities thanks to LIDAR system. LOA atmospheric station (recently included in EARLINET network), located in the Campus of University of Lille 1, is one of them, thanks to vertical soundings performed, since 2006, on a routine basis.

Several studies have demonstrated the relevance to combine sun/sky photometer and LIDAR observation to monitor aerosol characteristics. In LOA station, both automatic sun/sky photometer and automatic elastic back-scattering CAML (Cloud Aerosol Micro Lidar, one wavelength 532 nm) are operated for long time. Moreover, in December 2013, LILAS, a multiwavelength Elastic and Raman LIDAR, has been assembled in the framework of a cooperation between PIC (Russia), CIMEL-Avanced monitor SME and LOA and started observations dedicated to aerosol, water vapour and cloud characterization.



Regional distribution of Aerosols Optical Depth (AOD) during last pollution spring event in North of France, March 2014, as seen by MODIS satellite (*source ICARE*).



Time series of Aerosol Extinction (Lille, 2008-2013, CAML/CIMEL, Mortier et al., 2013)

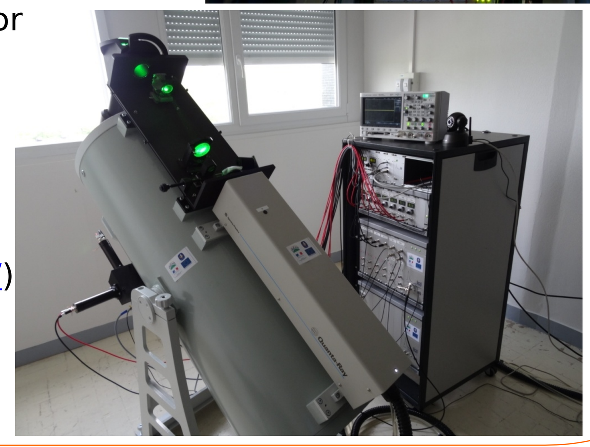
Sites and instrumentation

The atmosphere of Lille is mainly composed of urban and industrial aerosols. However, biomass burning particles (Canada) and mineral dust particles (Sahara region) events are detected several times a year thanks to LIDAR observations. Volcanic ash particles have been rarely detected with the noticeable exception in 2010. Nevertheless the amount and accuracy of the height-dependent aerosol properties remain limited due the reduced amount of information provided by mono-wavelength micro-LIDAR. For this reasons LOA recently setup a new LIDAR system to enable measurement of more relevant aerosol parameters (such as fine/coarse modes, LIDAR ratio, Single Scattering Albedo (SSA), vertical distributions).

For the SHADOW2 (Study of SaHAran Dust Over West Africa, http://labex-cappa.univ-lille1.fr/SHADOW) campaign new LIDAR system have been moved to M'Bour site near to Dakar city, that develops by LOA with IRD support. Main objectives of the campaign are better document physical and chemical aerosol properties over region with such considerable amount of dust particles and study aerosol dynamic.

The new LIDAR system LILAS (Lille Lidar AtmosphereS) is composed of a LASER (Spectra-physics, INDI-40) emitting 1064, 532 and 355 nm (100 mJ/5-8 ns/20 Hz). The range resolution is 7.5 m. Receiving module is designed to measure Raman signals at 387, 608 (530 in SHADOW2 campaign)* and 408 nm (H2O), polarization in 532 and 355 nm (355 total in SHADOW2 campaign), 1064 nm (totally 8 channels and channel for control camera). Channels 355, 532, 530, 387 nm are acquired in Analog and Photons counting. The system can be remotely operated (alignment of laser) and is coupled with a RADAR for safety reasons.

In SHADOW2 campaign have been used multiple instrumentation. Extinction profile of airborne sun-tracking photometer PLASMA presented on the poster for the comparison reason.



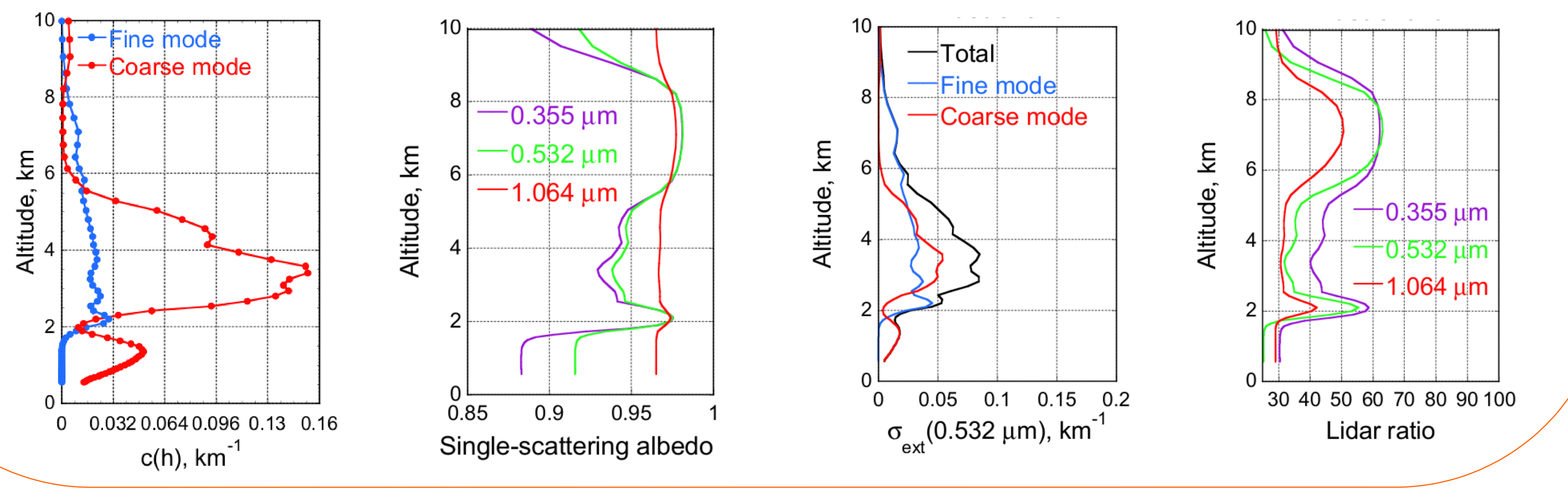
Contributing to ORAURE (http://oraure.univ-lille1.fr/) and EARLINET (http://www.earlinet.org/) networks

*have been used narrow filter for rotational Raman

GARRLiC algorithm

The retrieval of the microphysical aerosol properties profiles is performed with GARRLIC (Generalized Aerosol Retrieval from Radiometer and Lidar Combined data) algorithm (Lopatin et al., 2013). This algorithm combines LIDAR vertical information with sun photometer column-integrated values (spectral AOD + spectral total and polarized radiances) and simultaneously performs the inversion of both datasets. As retrieved aerosol parameters GARRLIC provides both columnar and vertical aerosol properties, including aerosol size distribution, shape, spectral complex refractive index for both fine and coarse aerosol modes, as well as vertical profiles of mode concentrations. Such synergetic retrieval results in additional enhancements derived aerosol properties because the backscattering observations (LIDAR) improve sensitivity to the columnar properties of aerosol. Besides, sun/sky-photometer observations provide enough information about aerosol properties, such as amount or type, required for the LIDAR retrievals without the need of making assumptions based on climatological data.

GARRLIC has been designed to provide two independent vertical concentration profiles for fine and coarse modes since in most cases, aerosols are described as a two modal mixture of fine and coarse aerosol modes. Algorithm works with mono and multi wavelength lidar systems, in case of mono wavelength inversion there are no spectral dependencies between channel and algorithm can not distinguish aerosol modes.



Dust event over Lille

Dust event over Lille on March 30, 2014 characterized with moderate aerosol load (AOD440 =0.52, AE ~ 0.27). Sun-photometer sky-radiance measurements have been checked on cloud contamination. The back-trajectory analysis show that aerosols transported from Saharan region in altitude range from 3 to 6 km, as well as transported from south and south-east of France in lower altitude up to 2 km. Aerosol parameters obtained by GARRLiC method and presented on Table 1 and Figures below.

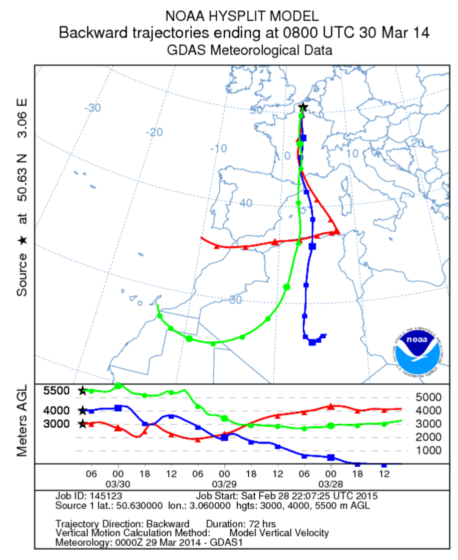
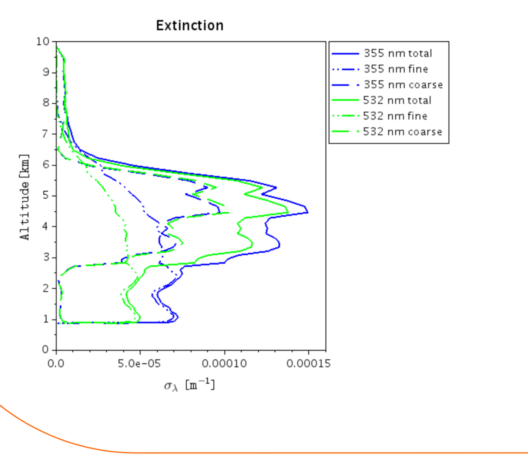
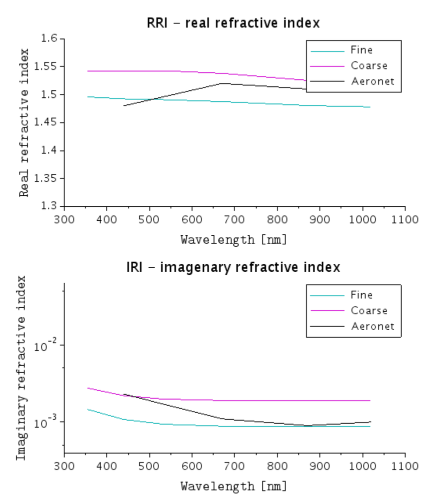


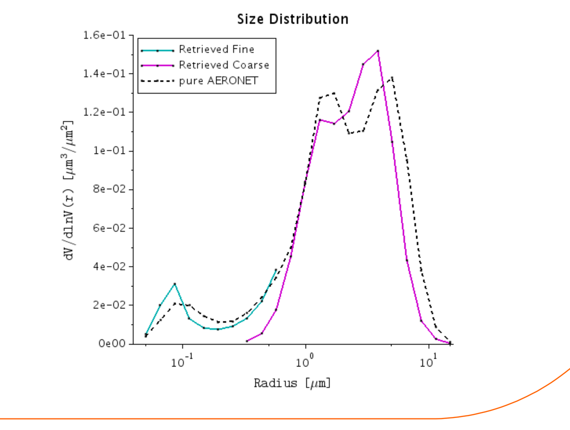
Table 1 Aerosol parameter over Lille, 30.03.2015

λ [nm]	GARRLiC								LR pure AERONET [sr]
	Volume concentration [µm³/µm²]	Effective radii [µm]	Sphericity in %	Real CRI		Imaginary CRI *1e-2		LR [sr]	
				fine	coarse	fine	coarse		
355	fine 0.05 / coarse 0.26	fine 0.14 / coarse 1.86	0.1	1.59	1.54	0.15	0.27	51	63**
440				1.49	1.54	0.11	0.22	44	57
532				1.49	1.54	0.09	0.20	42	52**
675				1.49	1.54	0.09	0.19	43	43
870				1.48	1.53	0.09	0.19	45	43
1020				1.48	1.52	0.09	0.19	46	43

**LR pure have been calculated from AERONET products and have been linearly interpolated/extrapolated to lidar wavelengths.







Dust event over Dakar

The 29 of March 2015 characterized with hight aerosol load over Dakar (AOD440=1.34, AE ~ -0.03). The back-trajectory analysis show transportation of aerosols from Saharan region in boundary layer. Aerosol retrievals obtained by GARRLiC and Raman techniques are presented on Table 2. Day time Raman measurements have been averaged for 3 hours providing extinction, backscatter and LR profiles. Extinction profile measured by the airborne sun-photometer have been added on the Figures.

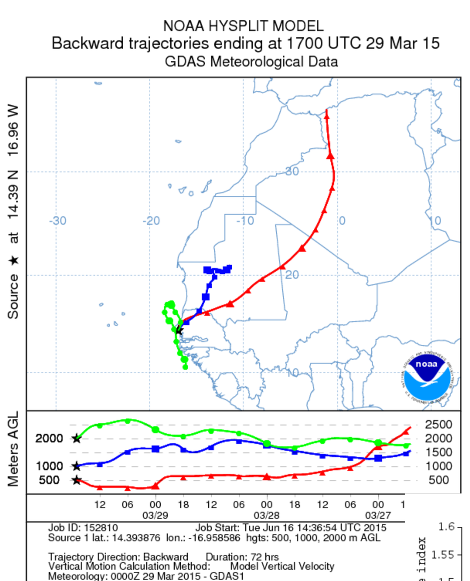
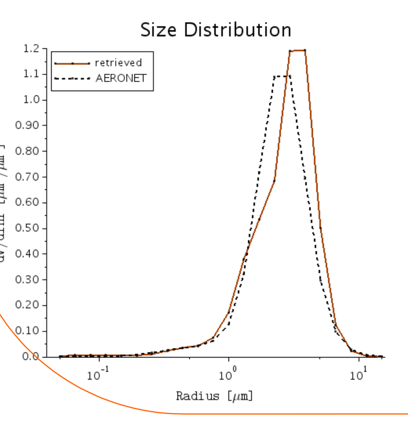
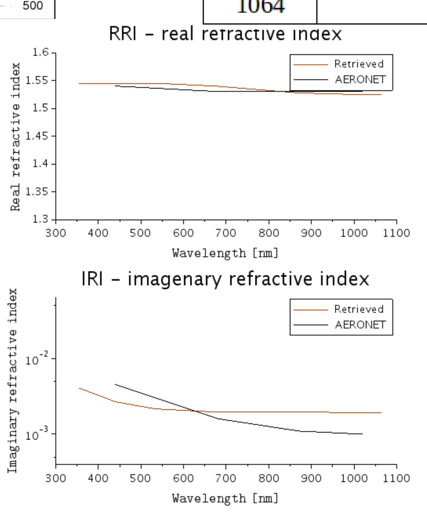


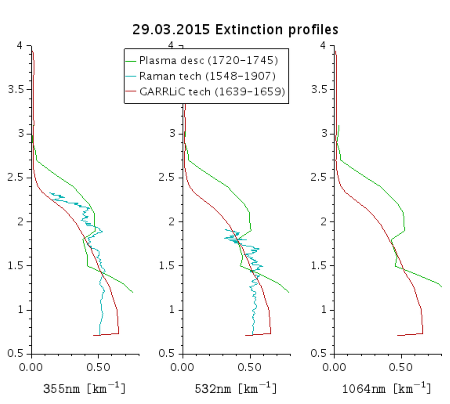
Table 2 Aerosol parameters over Dakar

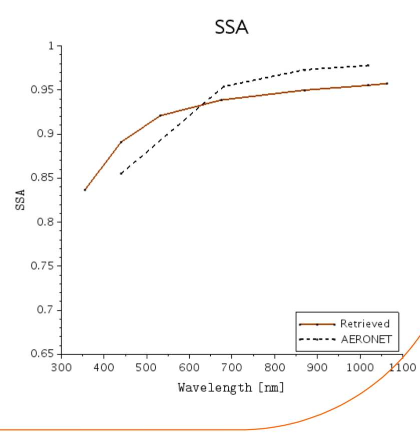
Wave [nm]	GARRLiC						LR Raman technique [sr]	LR pure AERONET [sr]
	Volume concentration [µm³/µm²]	Effective radii [µm]	Sphericity in %	Real CRI	Imaginary CRI *1e-2	LR [sr]		
355	1.37	1.9	3.7	1.55	0.40	72	~60	85**
440				1.55	0.27	53		74
532				1.55	0.22	46	~50	62**
675				1.54	0.20	41		43
870				1.53	0.19	39		37
1020				1.52	0.19	37		35
1064				1.52	0.19	38		34**

**LR pure have been calculated from AERONET products and have been linearly interpolated/extrapolated to lidar wavelengths.







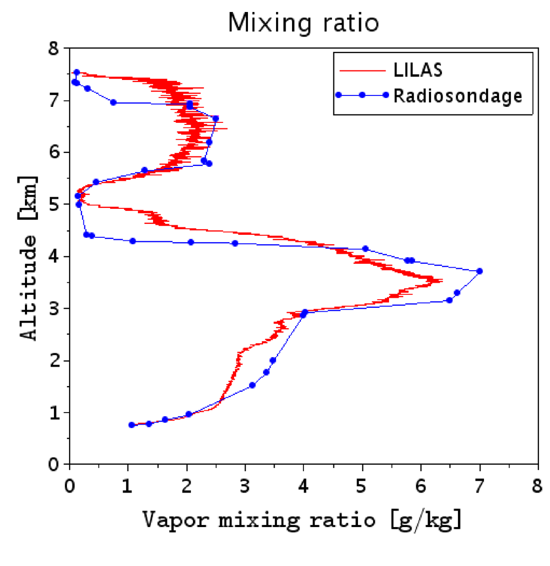


Vapor mixing ratio

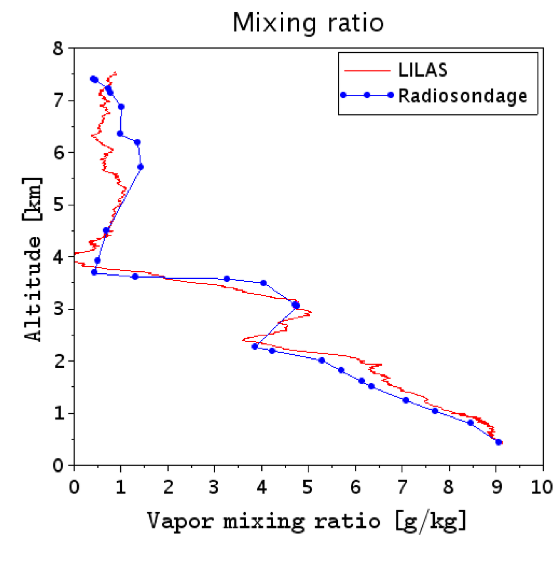
There are multiple methods to calibrate vapor mixing ratio that was obtained by LIDAR measurements. Radiosonde measurements are the most common technique for water vapor profiling. We use it as the reference for the calibration of Raman signal ratio. We use two different ways to calibrate mixing ratio: integration and normalization. Normalization consist of Raman signal shifting to radiosonde measurements. It take place in altitude range where profiles seems to be the same. And integration assumes the equality of water vapor content in some altitude range.

This work presents a few examples of obtained vapor mixing ratio over Lille and Dakar. The calibration have been done by integration method. Radiosonde measurements has been chosen nearest in space and time for both sites. For Lille site we use Beauvecchain(Belgium) radiosonde site (100km from Lille). For SHADOW2 we use Dakar radiosonde observation that situated in 60km from M`Bour observational site.

Dakar, 21.03.2015
Altitude range for calibration: 750 – 7500 m
Without smoothness



Lille, 07.09.2014
Altitude range for calibration: 400 – 7500 m
Moving mean have been used to smooth Raman signal ratio



Conclusions/ Perspectives : A new multi-wavelength, polarized and Raman LIDAR (LILAS) have been designed, set up and started observation at Lille University thanks to a fruitful partnership between University and Industry. Following EARLINET calibration/characterization protocols, analysis show the high quality of the instrument and data (comparisons with Rayleigh profiles, N/S ratio, etc) and show the possibility to use Raman signals during night time up to 10 km and during daytime (up to 2-3km). Several approaches have been considered to retrieve aerosols properties. The core of this work is devoted to application of GRASP/GARRLiC algorithm to data obtained with LILAS at different locations and various aerosols properties since it combined sunphotometer and LIDAR data to retrieve added-value aerosol properties. Raman inversion technique (Daytime and Nightime) has also be considered and results compared with GARRLIC and with vertical profiles of spectral extinction measured by the PLASMA airborne sunphotometer.

Future R&D activity will focus on developing GARRLIC to invert together Elastic (including polarization), Raman, sun/lunar photometer and optical in situ measurements. This activity will be supported by SOERE ATMOS, ACTRIS-2, LOA/CNRS/Lille 1, GRASP-SAS and Labex CaPPA and will therefore involved regional, national and european partners. In the very near future and in the frameworks of ORAURE/ATMOS SOEREs and ACTRIS-2/EARLINET), LILAS data will be processed (aerosols) at ICARE/Pôle de Données Atmosphère. Water vapor profiles will possibly contribute to NDACC SNO. LILAS is currently set up temporarily at Dakar/IRD center in the framework of SHADOW2 field campaign. The second Intensive Observation Period will be organized in Dakar in Dec 2015-Jan 2016.

Once bask in Lille, LILAS will be one component of the Lille Atmospheric Observation Platform and will contribute to the regional observation program supported by CLIMIBIO (Changement climatique, dynamique de l'atmosphère, impacts sur la biodiversité et la santé humaine, CPER project).

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