PHOTONS/AERONET sunphotometer network overview. Description – Activities - Results

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ABSTRACT

PHOTONS is the french component of the AERONET sun-photometer network which provides globally distributed near-real-time observations of aerosol spectral optical depth and sky radiance as well as derived parameters such as particle size distributions, single-scattering albedo and complex refractive index. Now more than 12 years of worldwide distributed data from the network of ground-based radiometers are available. These data are best suited to reliably and continuously derive the detailed aerosol optical properties in key locations. Mid 2007, about 40 sites mainly located in France, Europe, Africa as well as in Asia are managed by PHOTONS. Since 2001, the network also contributes to passive/active sensors synergies. Several sites in France, western as well as eastern Europe, sometimes in connection with EARLINET, are equipped with both lidar system and sun-photometer dedicated to aerosol and cloud observations. These synergies will be enhanced in the future mainly within the context of A-Train experience. In this paper, we provide a general description of PHOTONS network activities and facilities, and present recent results both on instrumental side (development on new sun-photometer, vicarious calibration methods), on scientific side (A-Train mission validation like aerosol retrieval algorithms of PARASOL) and aerosols retrieval from ground-based measurements method.

Keywords: Climate, atmosphere, aerosols monitoring, remote sensing, sunphotometer network, AERONET, PHOTONS, Satellite

1. INTRODUCTION

The lack of detailed knowledge of the optical properties of aerosols results in aerosol being one of the largest uncertainties in climate forcing assessments. Monitoring of atmospheric aerosol is a fundamentally difficult problem. Compared to atmospheric gases, aerosol particles are highly inhomogeneous and variable. Consequently, aerosol observations have to be global and continuous. Although, ground-based aerosol remote sensing does not provide global coverage, its wide angular and spectral measurements of solar and sky radiation are best suited to reliably and continuously derive the detailed aerosol optical properties in key locations. In spite of high temporal and spatial aerosol variability, there are a rather limited number of general categories of aerosol types with distinctly different optical properties.

Only in the last decade have surface-based radiometer networks developed the potential for continuous, long-term aerosol optical depth measurements. Some networks provide routine observations of additional radiometric parameters, such as directional spectral sky radiance and direct and diffuse solar flux. These measurements can be inverted, along with optical depth, to produce integrated radiative microphysical and optical properties[1,2] . The most extensive network of this type is an network of sunphotometers operated as the Aerosol Robotic Network (AERONET) federation[3]. Under cloud-free conditions, AERONET reports daytime aerosol optical depth derived from direct-beam solar measurements[4]. Under a more restrictive set of favorable observing conditions, the column-averaged particle-size distribution, single scattering albedo, and complex index of refraction are derived from sky scans[5] .

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The history of AERONET federation network started at the beginning of the 1990 with a close cooperation between LOA (France), GSFC (USA) and CIMEL (France). PHOTONS is basically the original french component of AERONET. Mid 2007 (Fig. 1), AERONET network managed around is 150 sites and PHOTONS around 43 additionnal ones.

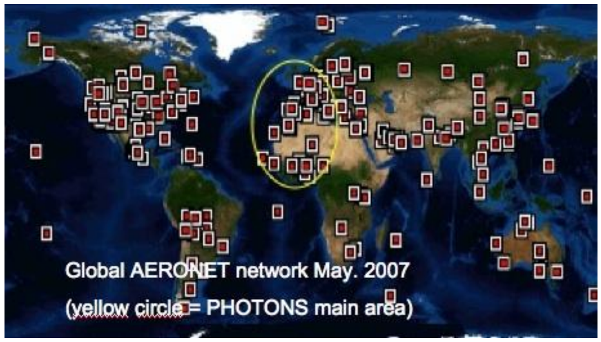

Fig. 1. Map of 2007 AERONET Network. Yellow circle for PHOTONS main area.

The purpose of this paper is to present PHOTONS network, activities (instrumentation and calibration) and some recent results, synergy with lidar.

2. DESCRIPTION OF PHOTONS NETWORK

In this part, we give a general description of the sunphotometer considered in the network.

2.1. Instrumentation

Two types of CIMEL sun-photometer (CE 318) are included in the network, UV-standard type (CE-318-1 Standard Model with 1020-870-675-440-936-500-340-380 nm filters) and Polarized type (CE-318-2 Polar Model) with 1020-870-675-440-936 nm filters. These instruments have Hamamatsu detectors, an ultraviolet (UV) enhanced silicon detector for the sun collimator (model S1336), and a silicon detector for the sky collimator (model S2386). The polarized versions are mainly part of PHOTONS network, french component of AERONET located at LOA.

As shown in Fig. 2, the CE-318 is a solar-powered, weather-hardy, robotically-pointed sun and sky spectral sun photometer. A sensor head fitted with 25 cm collimators is attached robot base which systematically points the sensor head at the sun according to a preprogrammed routine. The controller, batteries, and satellite transmission equipment are usually deployed in a weatherproof plastic case.

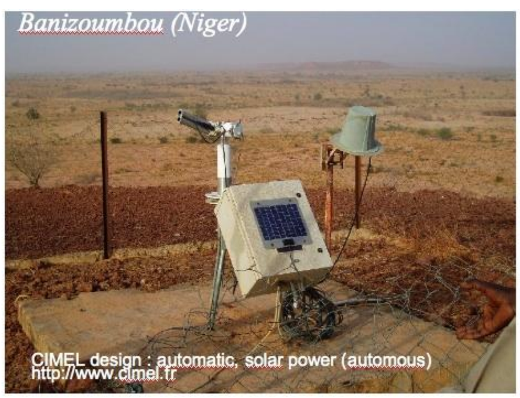

Fig. 2. Example of sunphotometer setup, in Africa.

Since 2004, these models have been improved. They have an improved sensor head optics design with onboard processing. Extended wavelength (1610 nm) versions have a Hamamatsu (model G8421-05) InGaAs or Indium gallium arsenide detector instead of a second silicon detector. They are now named CE 318N (New) (Visible, Extented or Ultraviolet). Let us also mention the “Dual-Polar” prototype performing polarization measurements at several wavelengths. Some preliminary results are presented in section 4.3.

2.2. Site location

Mi-2007, PHOTONS network managed 43 sites which represent approximately 20-25 % of all AERONET sites. In table 1 is given the list of the current sites with their starting date.

Table 1: PHOTONS sites (O means instrument belongs to PHOTONS, P means instrument belongs to other PI, L indicatates that a lidar system is also operational at the corresponding site).

Site name	Country	Start Date	Link
"AFRIQUE"			
Capo_Verde (O)	Capo_Verde	10.1994	
Ouagadougou (O)	Burkina_Faso	11.1994	
Banizoumbou (O)	Niger	10.1995	
Dakar (O, **L**)	Sénégal	12.1996	
Agoufou (O)	Mali	10.2002	
CinZana (O)	Mali	06.2004	
Mainé_Soroa (O)	Mali	11.2005	
Djougou (O)	Benin	02.2004	
Saada (P)	Morroco	06.2004	
Tamanrasset (P)	Algéria	02.2006	GAW
« Calibration sites»			
Lille (O, **L**)	France	10.1994	
Carpentras (O)	France	01.2003	Meteo France
Izaña (O, **L**)	Spain	01.2004	GAW/PFR, INM
« FRANCE»			
Dunkerque (O, **L**)	France	07.2004	
Toulouse (O)	France	07.1999	
Avignon (P)	France	01.1999	
Palaiseau (O, **L**)	France	07.1999	NDSC, EARLINET
Fontainebleau (P)	France	03.2002	
Clermont-Ferrand (P)	France	06.2007	NDSC
Villefranche (P)	France	01.2002	
Toulon (P)	France	06.2003	
Paris (P)	France	02.2002	
OHP (O, **L**)	France	06.2005	NDSC
Lannion (P, **L**)	France	12.2004	
La Réunion (P, **L**)	France	12.2003	NDSC
« EUROPE »			
Minsk (O, **L**)	Belarus	07.2002	EARLINET, CIS-Linet
Bucarest (P, **L**)	Romania	06. 2007	EARLINET
El_Arenosillo (P)	Spain	02.2000	
Palencia (P)	Spain	01.2003	
Caceres (P)	Spain	07.2005	
Barcelone (P)	Spain	06.2006	
SantaCruz (P,**L**)	Spain	10.2005	
The_Hague (P)	Netherlands	01.2002	
Cabaw (P, **L**)	Netherlands	01.2005	EARLINET
Oostende (P)	Belgium	06.2001	
Brussel (P)	Belgium	01.2007	
Evora (P)	Portugal	06.2003	
Cabo_da_Roca (P)	Portugal	08.2003	
Messina (P)	Italy	02.2005	
Davos (P)	Switzerland	10.2005	GAW/PFR
"ASIA"			

Beijing (O, L)	Chine	04.2002	
Xinglong (O)	China	10.2005	
Hefei (P, L)	China	10.2005	

One can notice that 30 sites are located in Europe, half of them in France for historical reasons. West Africa is also well covered with 10 sites. Some of these african sites were set up for the AMMA (African Monsoon Multidisciplinary Analyses) experiment devoted to the study of the the african moonson (http:// science.amma-international.org). Finally, a couple of atmospheric super-sites were equipped with sunphotometers in China. Historically, the core of PHOTONS network is composed of instruments in France and Africa and at present, PHOTONS supports mainly come from french institutions (CNRS, INSU, CNES) for maintaining this original network. Recent additional support came from European Commission within the framework of 6th PCRD but are not sufficient to support all extra-national european sites. Thus, european PI involved with their instrument in PHOTONS are kindly ask to support all shipping costs (every year maintenance and calibration) and, to some extend, repair cost in case of strong problem with one sunphotometer component. Let us mention, the recent participation of PHOTONS to the GEOMON (Global Earth Observing and Monitoring, http://geomon.ipsl.jussieu.fr/) european integrated project, provided PHOTONS additional and necessary but short time additional man power.

In table 1, we also mention when lidar system is operating at the same site (L). Some sites are part of other sun-photometer network like Precision Filter Radiometer (PFR,WMO/GAW), lidar (EARLINET and CIS-Linet). Coincident Lidar-sun-photometer measurements are very valuable for improving knowledge on aerosol properties vertical distribution and will be encouraged in the future.

2.3. Provided Aerosol parameters

AERONET collaboration provides globally distributed observations of spectral aerosol optical Depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. Aerosol optical depth data are computed for three data quality levels: Level 1.0 (unscreened), Level 1.5 (cloud-screened), and Level 2.0 (cloud screened and quality-assured). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

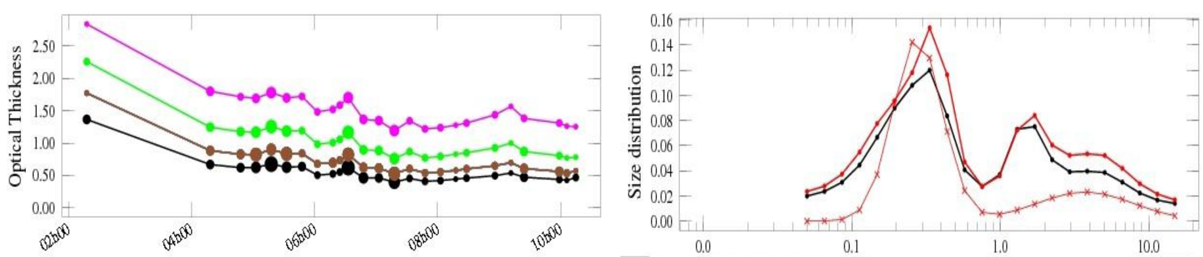

Fig 3. Spectral AOD (440, 670, 870 and 1020nm) and size distribution (volumic) 28th June 2007 at Beijing

Some additional retrievals (polarized phase function), not available in the standard AERONET retrievals are computed and available in the PHOTONS and are presented in section 4.1.

3. BASIC NETWORK SERVICE/ACTIVITIES

This part is devoted to the presentation of standard network activities including monitoring, maintenance and calibration aspect. Recent results in vicarious calibration will be also presented.

3.1. Instrument and data quality monitoring

Thanks to the real time data acquisition, the monitoring of instrument behavior as well as data quality are performed on a weekly basis. Several points, briefly listed below, have to be checked carefully and frequently:

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Fig. 4. View of on PHOTONS web-panel including technical data indicator

(i) *Power supply :* Power for the sun-photometer and data transmission device is supplied by three batteries connected to two separate solar panels. Batteries voltage (BatPH, Batext, BatDCP) should reach the minimum value to have a nominal use of the sunphotometer and must be checked it is; *(ii) Clocks* : Two different clock are used in the global system. One internal clock for sunphotometer and one other in the satellite transmission system . It is important these two clocks provide precise time. Sun-photometer will have somes difficulties to find the sun position in early morning or in late afternoon. Moreover, data collection platform (DCP) are not able to transmit out of its temporal slot which could happen in case of time shift. Then, if transmitter's clock is not correct that could yield lost of data that are never transmitted (Nbtrans) or could also perturb others sites transmissions ; *(iii) Sunphotometer head :* some filter-wheel error may occur sometimes in case of low charge level battery; *(iv) Robot* : specific indicators are available and being analyzed to detect robot error ; *(v) Data* : Several visual inspection of data are performed here. Once processed, the daily spectral AOD and almucantar radiances are analyzed to detect possible (1) “dirty” optics (strong dust event, spider web, etc) (2) filter fast degradation (spectral AOD consistency). If necessary, the local site manager is immediately contacted from cleaning external optics and collimators, at least ; *(vi) Temperature* : temperature (Temp. PH) variation is checked because this information is used for correcting residual temperature effect in the 1020 nm.

3.2. Sunphotometer maintenance and performance improvements – new developments

For several years a collaborative work is existing between GSFC, CIMEL and LOA for improving instruments performances and capabilities. As mentioned previously, new generation of sunphotometer is now available and operating in the network. For two years, PHOTONS, with the support of CNES and INSU/CNRS started an upgrad campaign of the oldest sunphotometers. Versions CE-318-1 and CE-318-2 models can be converted to CE-318N models using an upgrade kit, obtained from CIMEL. Thus, we are working to get a more homogeneous and efficient network. In the meantime, PHOTONS is closely working with CIMEL to developp a specific sunphotometer enabling linear polarization measurements at wavelength ranging from 340 to 1640 nm. Several such instrument (« Dual Polar ») are already in test phase at some sites (Lille, Beijing).

3.3. Calibration

The reliability of aerosol retrievals performed by AERONET is basically firstly depending on sun-photometer calibration accuracy. This calibration mainly include two parts, one devoted to AOD, the second to sky radiance measurements. Since most of PHOTONS sunphotometer are Polarized type, additional polarization calibration is performed in the laboratory, every year.

Within AERONET network direct sun (AOD) and radiance sphere calibration values are measured at distributed calibration sites. The first historical site is NASA GSFC calibration facility that manages direct solar calibrations and radiance sphere calibrations. In addition, NASA GSFC is maintaining "master" instruments that meet high operating standards and determining the apparent extraterrestrial constants at Mauna Loa Observatory in Hawaii.

For several years, PHOTONS developped its own calibration facilities. Direct sun calibration involved Carpentras site in the South of France where all PHOTONS sunphotometers are calibrated versus master instrument. PHOTONS « master » instruments are every 3 month re-calibrated at Izana Observatory site (INM, Tenerife Island, Spain, 2440 m.a.s.l). Finally radiance and polarization calibration are performed at LOA/Lille, North of France.

At present, in order to allow futur network expansion, other distributed calibration sites are under development for example at Arenosillo, Spain (RIMA network) and Canberra, Australia (CSIRO).

3.3.1 Standard AERONET calibration protocol / accuracy

Belonging to the network imposes standardization of instruments, calibration, processing and distribution. Instruments located *initially* at a calibration facility are considered in "pre-deployment" status. Pre-deployment direct sun and radiance calibration data values are obtained at the calibration facility. The instrument is considered as "field-deployed" once the instrument leaves the calibration facility (France or USA). After a determined measurement period (12 month maximum), the instrument is returned from its measurement location to a calibration facility. At this stage, "post-field deployment" calibration direct sun and radiance values are measured and applied to the data and then data can raise to the highest quality (i.e Level 2) . Some window cleaning or filter maintenance may be necessary. After the laboratory maintenance, the instruments are considered in a "pre-deployment" status again.

- *Direct Sun Calibration*

Calibration refers to the determination of the calibration coefficients needed to convert the instrument output digital number (DN) to a desired output, in this case aerosol optical depth (AOD), precipitable water (cm), radiance (W/m2/sr/um) and polarization degree. Field instruments are returned to Carpentras site (Fig. 5b) for intercomparison with reference instruments approximately every 12 months in order to maintain accurate calibration.

Fig. 5 . (a) Izana (INM, 2440 m a.s.l) for Reference or Master instrument ; (b) Carpentras (Météofrance) for inter-calibration against Reference instrument.

PHOTONS reference instruments are typically recalibrated at Izana every 3 months using the Langley plot technique. The zero air mass voltages [Vo, instrument voltage for direct normal solar flux extrapolated to the top of the atmosphere) are inferred to an accuracy of approximately 0.2 to 0.5% for the Izana INM calibrated reference instruments (Fig. 5a). Therefore the uncertainty in AOD due to the uncertainty in zero air mass voltages for the reference instruments is better than 0.002 to 0.005.

- *Radiance Calibration*

For the sky radiance measurements, calibration is performed at the LOA/PHOTONS facility using a calibrated integrating sphere (Fig. 6a) to an accuracy of 5% (e.g Labsphere Inc). Therefore, instruments are calibrated on a 12-month rotation and filters are changed when needed

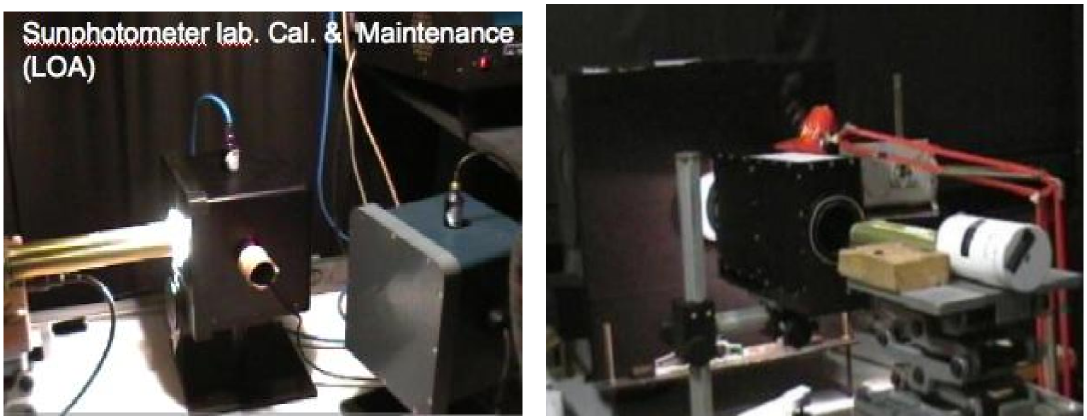

Fig 6. (a) Integrating sphere for radiance calibration ; (b) « Polbox » system for polarization calibration

- *Traveling master.*

Every year a “Travelling master” is moving, for a short period, between USA an France facilities in order to have a link for radiance calibration made in USA and France, and then to normalize calibration to USA sphere. At present maximum observed difference between integrating spheres is 4 %.

- *Polarization calibration.*

As mentioned previously, one specificity of PHOTONS is to deal with “polarized” sunphotometer version. Specific equipment was developed for calibrating polarization degree. A passive polarization box (Polbox) is used to polarized the natural light exiting the integrating sphere. With such a device, polarization degree can be checked accurately (accuracy on polarization degree better than 0.2 %) from 0 to 60% thus enabling full characterisation of each sunphotometer every year.

- *Interpolation and Uncertainty*

The Sun-sky radiometers at sites other than Carpentras are intercalibrated against a Izana calibrated PHOTONS reference instrument both before deployment in the field and post- deployment. A linear rate of change in time of the zero air mass voltages is then assumed in the processing of the data from field sites. The uncertainty is approximately 0.01 - 0.02 in AOD (wavelength dependent) due to calibration uncertainty for the field instruments.

3.3.2 Development of an alternative calibration method

As it has been shown in the previous part, PHOTONS calibration strategy relies on three geographically distinct sites. In order to faster the calibration process as well as, to some extend, improve its accuracy, we are developing a “vicarious” method for radiance channels calibration. This idea is to transfer the very accurate AOD calibration to the radiance calibration, assuming the instrument field of view (solid angle, Ω) is well known.

We propose a vicarious calibration method which computes the radiance calibration coefficient from AOD calibration coefficient given the solid angle Ω[6]. Presently, we consider two approaches for retrieving Ω for CIMEL sunphotometers. The first approach (“semi-vicarious”) uses historical laboratory calibration records (or only the initial record) and the last AOD calibration coefficient for determination Ω with a 3% uncertainty. Meanwhile, another approach (“full-vicarious”) is based on the interpretation of sun-photometer raw sky measurements assuming a pure Rayleigh scattering atmosphere, without need of any laboratory facilities. A sensitivity study shows the accuracy of the vicarious method is very similar to that of current standard laboratory calibration, and can be even better provided the precision of Langley calibration and the solar spectrum at UV wavelengths are improved in the future. Let us finally mention a third possible approach following recent considerations that are indicating a possible important accuracy improvement on Ω determination using geometrical computation of this solid angle, that could reach accuracy better than 1% . Then, we could reach a 1 to 1.5 % accuracy on Ck. This work is currently under investigation.

As example, we present in Table 2 , results of comparison between laboratory calibration and semi-vicarious method.

Table 2 . Comparison of semi-vicarious radiance calibration coefficient, Ck, with laboratory results (Dual Polar # 350). Vo is the direct sun calibration coefficient.

λ (μm)	V_0 (DN)	C_k (μW·cm^{-2}·nm^{-1}·sr^{-1}·DN^{-1}) Lab	Semi-vica.	Diff. %
1.02	9330.8	0.00464	0.00439	-5.5
1.64	21965.1	0.00059	0.00061	2.2
0.87	18129.0	0.00321	0.00311	-3.2
0.68	21304.0	0.00407	0.00409	0.6
0.44	13516.4	0.00838	0.00830	-0.9
0.50	18774.1	0.00584	0.00614	5.3
0.38	33369.9	0.00204	0.00205	0.8
0.34	20258.8	0.00290	0.00291	0.7

With the exception of 1020 nm (temperature effect) and 500 nm (integrating sphere inaccuracy due to interpolation at that wavelength), the results of semi-vicarious are very close to laboratory ones.

Following error analysis, the uncertainties of these two semi-vicarious methods are currently ~3-5% on Ck depending on the wavelength which is similar to that of laboratory calibration but could be used more easily and frequently for some sites.

Presently, for a demonstration purpose, a routinely application of this vicarious method is running in PHOTONS (http://www-loa.univ-lille1.fr/photons), in parallel with AERONET/PHOTONS standard calibration protocols, and will be compared with standard laboratory calibration systematically in the future. Moreover, the vicarious method could useful to re-calibrate the historical data for a consistent precision within the whole measurement period. For example, when processing long-time historical records we should make the radiance calibration accuracy consistent which can be done with the use of the constant Ω and the accurate AOD calibration series. Finally, considering other progress in calibration studies, e.g. in situ V_0 calibration and the vicarious polarimetric calibration a fully in situ sun-photometer calibration is possible in the near future for the new generation CIMEL instruments or equivalent instrumentations.

4. RESEARCH ACTIVITIES AND RESULTS

In this part, we intend to give a brief overview of some remarkable results that were recently obtained in the field of remote sensing from ground –based network and spaceborne polarimeter.

4.1. Retrieval of aerosol properties from polarized sunphotometer

In this work[7], we have considered sunphotometer measurements at five african sites (table 1) and derive dust optical properties with the use of a polarimetry-based algorithm[8.] Retrieved single-scattering albedo shows an increasing trend versus wavelength with an average of 0.95 at 0.87 μm. Phase function F11 exhibit strong forward scattering as well as weak and flat backward scattering. Retrieved polarized phase function, -F12, and linear polarization degree –F12/F11 for single scattering of unpolarized incident light increase when the size of the particle decreases, while the maximum values observed at scattering angles of around 100° range between 0.14 and 0.21 (Fig. 7). Compared with the results of Mie theory for spheres, the retrieved angular behavior of the scattering matrix elements differs significantly. Since accurate modeling of polarized optical properties of natural mineral dust from its microphysical properties remains a difficult task, we choose an alternative strategy to validate our retrievals. For that purpose, we perform the comparison with the existing laboratory measurements of linear polarization degree of silicate samples, in order to check the reliability and efficiency of our method in the assessment of optical properties for nonspherical particles.

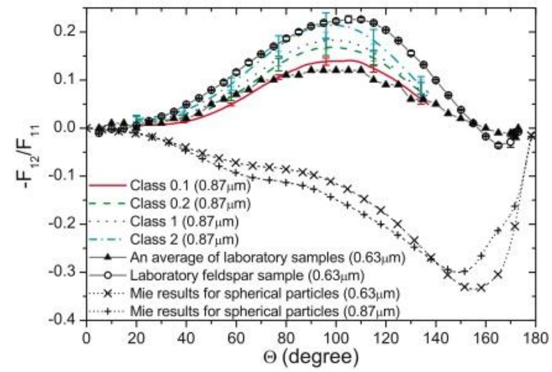

Fig. 7. (Color online) Retrieved linear polarization degree for single scattering of atmospheric total column dust aerosols compared with that for laboratory feldspar sample and an average of seven silicate samples [9]. Error bars present the standard deviation of the retrieved values or experiment errors of the laboratory measurements, respectively. Mie results at two wavelengths for spherical coarse particles corresponding to a lognormal size distribution fitting the laboratory measured size of the feldspar sample and an estimated refractive index (Nousiainen et al., 2006) are also shown.

Although experimental limitations restrict the quantitative aspect of the comparison, the reliability of our retrievals is confirmed by the good consistency with laboratory results as well as the significant difference from Mie results for spherical particles. Furthermore, our results provide valuable information for the spaceborne remote sensing based upon multi-angular, spectral, and polarized observations (POLDER1/2 and PARASOL[10], sect. 4.3). Over the ocean, in dust situations, nonspherical particles model has greatly improved the interpretation of angular radiance and polarized radiance, and consequently the retrieval of aerosol optical properties (i.e AOD).

4.2. Dual Polar sunphotometer

One prototype of CIMEL multi-wavelength polarized sun-photometer (# 350) is operating in Xianghe (near Beijing, China) for about one year up to now. The 8 wavelengths ranging from 340 to 1640nm all have polarization capabilities when scanning sky in the solar principle plane. To investigate the potentials use of these multi-polarization measurements, we made efforts in both calibration (from UV to infrared, including polarization calibration) and inversion aspects. Based on recent improvements in the aerosol inversion algorithm[11] , we have developed a sophisticated program to fit the multi-wavelength polarization measurements with mixture of sphere and spheroid particles and to deduce aerosol properties as soon as comprehensive. We show below an inversion case at Xianghe on 03/07/2007. Spectral AOD are 1.17, 1.04, 0.50 and 0.39 at 440, 500, 870 and 1020 nm, respectively.

The fraction of spheroid particles assumed to obtain the best agreement with measurements is 42 % when considering polarization information whereas only 12% when applying the standard AERONET inversion (without use of polarization information). The next step will be to process the one year data set available and analyze the differences with standard AERONET retrievals which do not make use of polarization information.

4.3. Retrieval of aerosol from PARASOL spaceborne polarimeter

As mentioned previously sunphotometer network is a powerful tool for calibration/validation of satellite retrievals. In this section we focus on POLDER spaceborne polarimeter instruments developed by LOA and CNES and present some results of validation of AOD over oceanic and continental surfaces. The properties of the aerosols over the ocean and land surfaces are investigated by using the observations of the Polarization and Directionality of the Earth's Reflectance (POLDER) wide field of view imaging spectroradiometer developed by the Centre National d'Etudes Spatiales (CNES) and operated since february 2005 aboard PARASOL microsatellite platform (http://132.149.11.177/PARASOL/Fr/, Myriade serie).

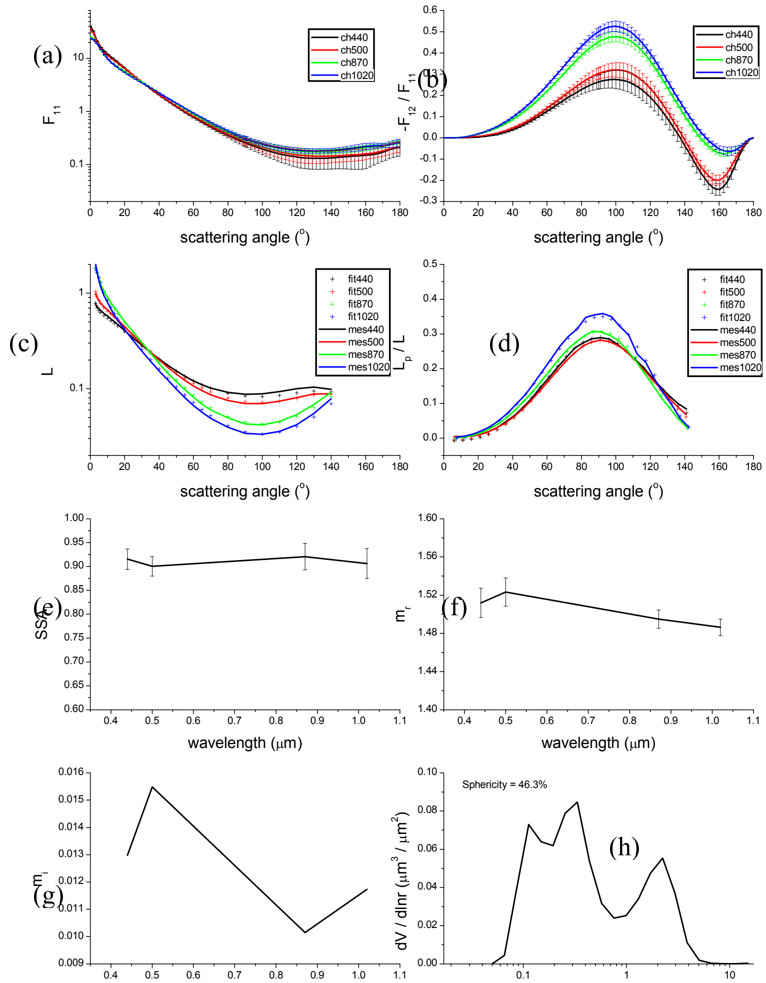

Fig 8. Example of measurements and aerosol retrievals over Beijing. In the figure, F_{11} (a) and F_{12} (b) are the first two elements of aerosol scattering matrix, L (c) is the sky radiance in reflectance units (i.e. $\pi I/E_0$, where I is the intensity of diffuse radiation, E_0 is the extraterrestrial solar irradiance), L_p/L (d) is the degree of linear polarization of the light, SSA (e) is the spectral aerosol single-scattering-albedo, (f, g) m_r and m_i are spectral refractive indices of aerosols, (h) dV/dlnr is the volume size distribution of the total atmosphere column.

4.2.1 Global AOD distribution over ocean and validation

According to Herman[10], aerosols size distributions consist of particles with a bimodal size distributions, in which the large particle mode generally consists of nonspherical particles. In all observations where there is evidence for the occurrence of nonspherical particles from the spectral, directional, and polarization characteristics of the solar radiation scattered by the aerosols, the average aerosol scattering matrix for irregular particles derived from laboratory measurements[9], recently confirmed[11,7], prove to provide a very efficient model of these particles.

The spectral, directional and polarized characteristics of the aerosol scattering are generally consistent only with aerosol models including three modes of particles: a fine mode of spherical particles, a coarse mode of spherical particles, and a coarse mode of nonspherical particles (Fig. 9 b).

The ability to fit both the radiance and polarized radiance directional measurements gives confidence in this aerosol modeling for the monitoring of nonspherical particles. Preliminary results of the processing of the PARASOL measurements by this improved algorithm are presented.

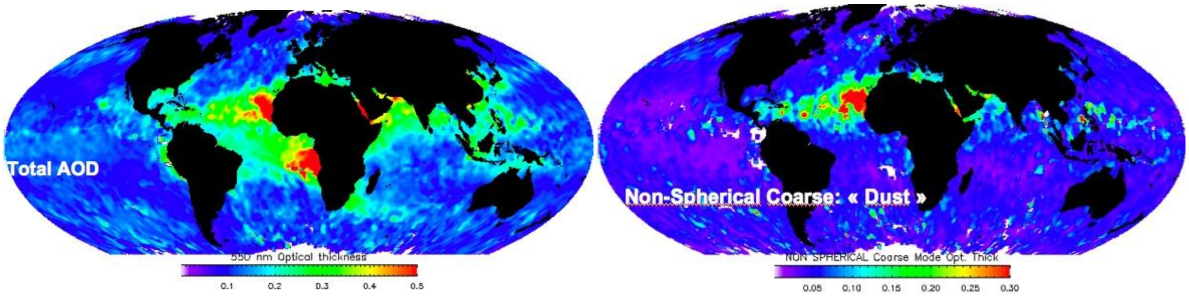

Fig. 9. Monthly averaged PARASOL AOD over ocean (a) total AOD, (b) Non spherical particle contribution to AOD for June 2005 (courtesy from D. Tanré, LOA).

Nonspherical particles appear as a very important component of the continental aerosols over the oceans. Large spherical particles are mainly observed over the open oceans. They correspond to oceanic models of hydrated particles (Tanré, personnal communication).

In the context of satellite products validation, sunphotometer network is a very powerful tool. A validation exercise was performed using AERONET level 2.0 (Quality assured data) over oceanic and coastal sites.

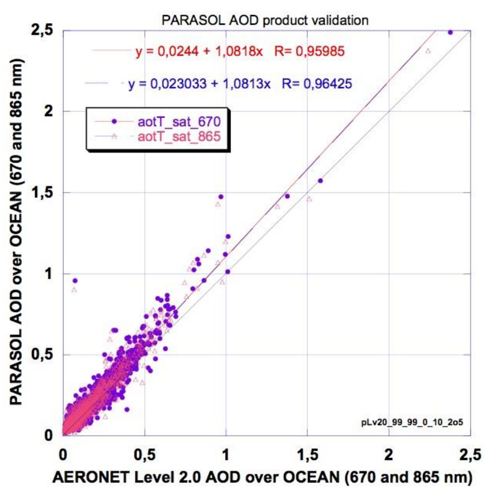

Fig. 10. Validation of total AOD of PARASOL versus AERONET over ocean and coastal sites [13]

Around 350 match-up were available for this comparison showing a good agreement between ground-based and satellite measurements. However, fine mode AOD is currently under-investigation.

4.2.2 Global AOD distribution over land and preliminary validation

Over land surfaces, aerosol retrieval is based, at present, on the analysis and interpretation *of the polarized fraction* of the scattered light in both the visible (670nm) and near-infrared (865nm) part of the electromagnetic spectrum[12]. The main advantage of this method is that polarized light reflected by land surface is small and independent of the wavelength within the considered spectrum. Moreover, spatial variability of surface polarized reflectance is smaller than that of the surface reflectance. Thus the atmosphere is mainly contributing to Top Of Atmosphere (TOA) polarized signal. Monthly average PARASOL AOD, for June 2005, is shown Fig. 11.

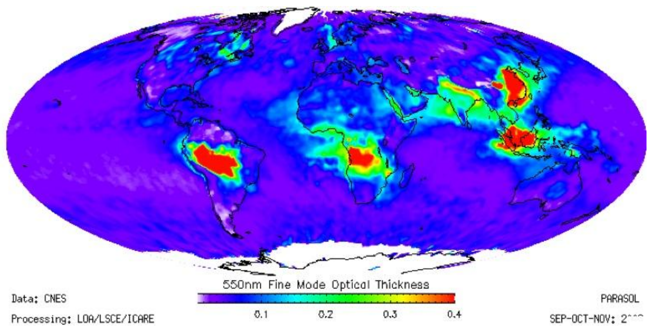

Fig. 11. PARASOL monthly average of AOD at 865nm (level 3), June 2005 (courtesy from D. Tanré, LOA). The information provided over ocean is fine mode AOD (sect. 4.2.1).

The main result is that PARASOL retrieval over land is mainly sensitive to the anthropogenic aerosols which are known for influencing the climate, environment as well as human health. Global validation of PARASOL AOD over land is under progress[14] . However, a region regional validation exercise was conducted over North China[15]. In this part of China, aerosols are a complicated mixture of both fine- and coarse-mode particules, mainly coming from anthropogenic and dust sources, respectively [16,17,18,19]. A regional evaluation of the PARASOL algorithm over land has demonstrated its capability to retrieve fine-mode AOD (r≤0.3 μm) over the northeast part of China.

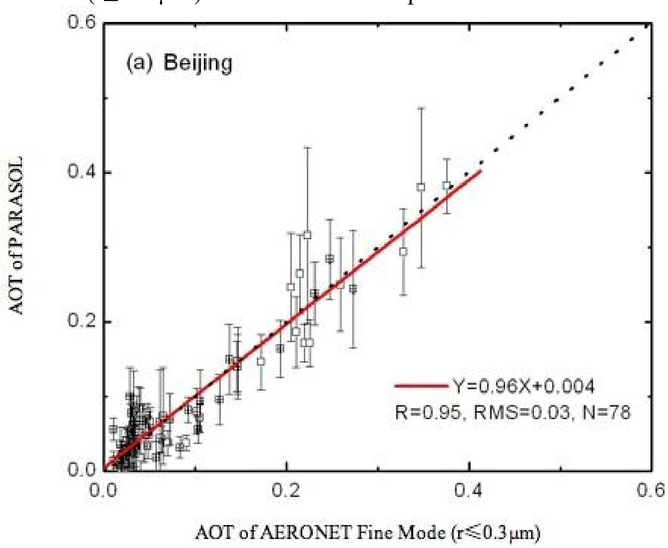

Fig. 12. PARASOL AOD versus AERONET fine mode for Beijing site (λ=865 nm).

Thanks to AERONET/PHOTONS data records over Beijing and Xianghe, this work clearly demonstrates the capability of PARASOL retrieval (slope and correlation are both close to one, with a 0.03 r.m.s on AOT), for determining anthropogenic contribution (particle radii less than or equal to 0.3 μm) of regional aerosols, which is also shown contributing to not less than 30% of total AOT at 865 nm.

5. SYNERGY BETWEEN SUNPHOTOMETER AND LIDAR

In this last part, we want to emphasis the importance of performing joint sunphotometer and lidar measurements at the same location. Within PHOTONS network, several sites (table 1) already include lidar various lidar systems. In the following we will briefly mention some results that were obtained at Minsk, Beijing sites as well as some future project to develop regional lidar network in the North of France.

5.1. Lidar – sun-photometer combination.

In this section, we'll present two examples of synergies between, at least lidar and sunphotometer.

- The first study we report here was performed after intense fires that occurred summer 2002 in Russia and Belarus. During this very dry summer 2002, many fires emitted a lot of aerosol particles in east Europe and Russia. Combination of multi-wavelength lidar data (located at Minsk site) with aerosol column integrated products retrieved from AERONET is a powerful approach to determine vertical distribution of fine and coarse mode AOD (Fig. 13).

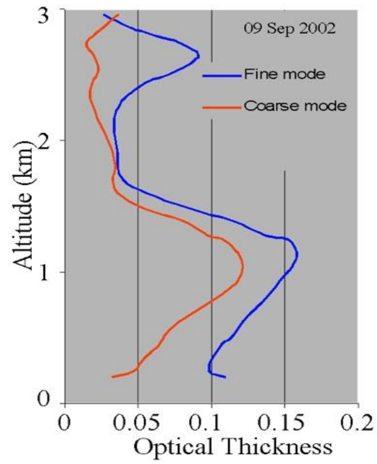

Fig. 13. Vertical profile of fine and coarse mode [20]

Most of this results were obtained within the project "Atmosphere aerosol and ozone monitoring in CIS regions through lidar stations network (CIS-LiNet)" (Chaïkowsky et al.,) aiming at creating scientific, engineering and methodological foundations to develop a lidar network CIS-LiNet in CIS regions, as well as a technology for atmospheric lidar monitoring and its demonstration while tracking atmospheric aerosols and ozone in CIS, and to perform joint atmospheric investigations with the AERONET/PHOTONS/AEROCAN, EARLINET and AD-Net at the Eurasian continent.

The second study reported hereafter is related to 2006 strong spring dust events in Beijing that were recently investigated with lidar system, sunphotometer, MODIS satellite and transport model [21]

An extraordinary dust event over Beijing (April 2006) was followed by a synergy of lidar, Sun photometric and satellite measurements. Extreme aerosol optical depth (AOD) values (1 – 4) were measured by sunphotometer and MODIS over Beijing. Coarse particles contributed to more than 60 – 80% to the AOD values, indicating the presence of very large particles. Coarse particle contribution to total AOD is associated with the free tropospheric aerosols calculated by lidar profiles (65%). Lidar vertical profiles with AOD values from Beijing sunphotometer (table 1) were used to estimate a typical lidar ratio for the dust particles (84 sr) during the most intense dust period. The lidar system used (LB10-D200 model, Raymetrics S.A.) is designed to perform continuous measurements of aerosol particles at 532 nm in the Planetary Boundary Layer (PBL) and the free troposphere (FT). The DREAM forecast model was applied for the accurate description of the dust event evolution. Ground-truth data were used for the validation of DREAM over the Beijing area.

5.2. Development of a regional lidar network

CIMEL company recently developed a portable single wavelength (532 nm) lidar system CAML^{TM} (Fig. 14a). The CAML^{TM} CE 370-2, has been designed to be a portable, eye safe, unattended backscattering lidar that features the ability to profile atmospheric cloud and aerosol structures, and to retrieve aerosol optical and dynamic properties. Eye-safety, necessary for fulltime, long-term unattended operation, is realized by transmitting low power pulses using an expanded beam (4 µJ with a 200 mm exit-lens width), with a pulse repetition frequency of approximately 4 kHz. Signal acquisition is managed via photon counting to provide an accurate detection of low-level lidar signals. The lidar featured 150 m maximum vertical resolution and its design allows for up to 30 m vertical resolution. It is designed for outdoor operation developed in collaboration with the National Center for Scientific research (CNRS). The patented optical design based on an optical fiber link between the telescope and the opto-electronics rack assures the alignment of the emission and reception axis of the telescope. Simplicity and practicality are key characteristics of the CAML™. The use of an optical fiber to link the telescope to the opto-electronics part of the lidar contributes to a manageable system that can be easily mounted on a robot to be tunable to various pointingangles. The system is compact allowing for easy deployment and operation. Two such lidar are operating at Lille University and Dakar (Senegal).

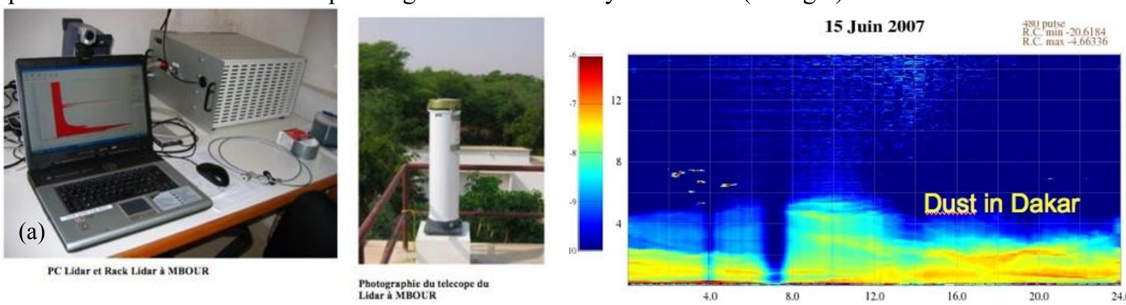

Fig 14. (a), and (b) Lidar operating in Dakar in 2006-2007; (c) Lidar quick-look the 15th June 2007.

In Dakar the system is operating continuously and automatically for almost one year. An example of quick-look is shown in Fig 14b. Every day, the data are transferred automatically via email to LOA for preliminary processing. In the near future, a regional network of about 10 such lidar system will be set up in the North of France to focus on air quality and aerosol studies. The original dataset recorded at Dakar during the A-TRAIN (PARASOL/CALIOP) mission will be used to investigate more deeply the effect of aerosol altitude and shape on PARASOL retrievals (sect 4.2.1).

6. CONCLUSION

In this brief overview, we gave a general description of PHOTONS network activities and facilities, and present results and projects both on instrumental side (development on new sun-photometer, vicarious calibration methods), on scientific side (A-Train mission) as well as aerosols retrieval from ground-based measurements algorithm. Mid 2007, about 40 sites are managed by PHOTONS thus contributing to AERONET effort to provide valuable aerosol data. Development of additional calibration center is very important to allow the network expansion and preserve high quality data. In the present and in the future synergy between lidar and sunphotometer should be supported to provide missing vertical information on aerosol and are extremely important in the A-Train context (Caliop). PHOTONS is collaborating and partner is numerous international projects, like AMMA project. Several other cooperations are existing with Chinese Academy of Sciences, Belarus Academy of Sciences (IPY for example). At european level, PHOTONS is contributing to the GEOMON (Global Earth Observing and Monitoring) integrated project and is also partner in the CIMPAQE project recently submitted to European Commision and aiming at characterizing impact of metropolitan pollution on climate and air quality in Europe using synergy of measurements and modeling.

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This paper is dedicated to the memory of François LAVENU who strongly contributed to AERONET/PHOTONS developpement in Africa and recently died in Bamako. Thank you François.

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