

## LIDAR OBSERVATIONS FROM ADM-AEOLUS AND EARTHCARE - VALIDATION, STUDY OF LONG-RANGE TRANSPORT OF AEROSOL AND PREPARATION OF A FUTURE CHINESE CO2 LIDAR MISSION.

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### List of Principal Investigators (PIs)

Topic Nr.	PIs	Title
32296_1	Dr. Oliver Reitebuch, Prof. Weibiao Chen	<b>Preparation of Cal/Val of spaceborne Aerosol and Carbon dioxide Detection Lidar (ACDL) by ground-based and airborne sounding instruments observations</b>
32296_2	Dr. Oliver Reitebuch, Prof. Songhua Wu	<b>Validation of ADM-Aeolus by airborne and ground-based wind lidar observations</b>
32296_3	Dr. Dietrich Althausen, Prof. Songhua Wu	<b>Long-range dust transport and validation using ground-based and satellite lidar observations</b>

### EXECUTIVE SUMMARY

ESA decided to implement ADM-Aeolus to demonstrate the potential of the Doppler lidar technology for global wind profiling in order to improve the quality of future numerical weather prediction. ADM-Aeolus will carry the first wind lidar in space and launch is currently scheduled for mid 2017. The second lidar mission of ESA named EarthCARE is related to the observation of the climate impact of aerosols and clouds with a launch planned for end 2018. The Chinese lidar mission ACDL (Aerosol and Carbon dioxide Detection Lidar) to measure CO<sub>2</sub> and aerosol from space is planned for 2020. The proposed activities aim at validating ADM-Aeolus and EarthCARE, the study of long-range transport of aerosol, and the preparation of the Chinese CO<sub>2</sub> lidar mission. The first proposal covers the validation of the ADM-Aeolus wind products by means of ground and airborne observations. An airborne prototype of the lidar instrument on ADM-Aeolus was developed by DLR (Deutsches Zentrum f. Luft- und Raumfahrt) and deployed in several field campaigns on the DLR Falcon aircraft, most recently in 2015 in coordination with the NASA DC-8 aircraft. A ground-based direct-detection wind lidar was developed at OUC (Ocean University of China) and deployed during several field campaigns, including the sailing competition within the Olympic Games in 2008 in Qingdao. Ground-based co-located measurements with wind lidars during overpasses of Aeolus are foreseen in China and in Central Europe. Further airborne campaigns with the ADM-Aeolus airborne demonstrator are planned over Central Europe and the North Atlantic region. The second proposal covers the study of long-range transport of aerosol in Asia and the validation of the aerosol product from the ADM-Aeolus and EarthCARE mission. EarthCARE will carry cloud profiling radar, HSRL (High Spectral Resolution Lidar) and multispectral imager and is scheduled for launch in 2018. As parts of The European Aerosol Research Lidar Network, EARLINET, PollyXT and BERTHA were developed by TROPOS (Leibniz Institute for Tropospheric Research) and deployed worldwide (<http://polly.tropos.de>) for intensive observations of the aerosol and cloud vertical distribution over the lidar stations at 4 continents and 2 oceans. Ground-based WACAL (WATER vapor, Cloud and Aerosol Lidar) was developed by the lidar group at OUC and deployed during several field campaigns, including the third Tibetan Plateau Experiment of Atmospheric Sciences (TIPEX III) in Naqu (31.5N, 92.05 E) with a mean elevation of more than 4500 m above MSL in summer of 2014. The first project objective is the comprehensive observations of vertical profiles of optical properties, flux and the deposition of dust during the long-range transport over continents of Europe and Asia. Based on the ground-based lidar and the missions ADM-Aeolus and EarthCARE, and combining back trajectories, it is possible to determine the dust source region, the main transport route and the main deposition areas. The second project objective is to validate the ADM-Aeolus and EarthCARE wind, cloud and aerosol data products. Ground-based co-located measurements with lidars during overpasses of Aeolus and EarthCARE are foreseen in China (Costal cities, China Seas, inland cities, Tibetan Plateau, Taklimakan desert) and in Central Europe. The third proposal covers the preparation of the Chinese CO<sub>2</sub> lidar mission ACDL building on the experience made with the validation of ADM-Aeolus and EarthCARE. Airborne and ground-based lidars for measurement of CO<sub>2</sub> were developed at SIOM (Shanghai Institute of Fine Mechanics and Optics) and DLR. Their data will be used for preparation of retrieval algorithms for future spaceborne CO<sub>2</sub> lidars. Funding for these activities will be provided by internal sources from the participating institutes in Europe and China and it is planned to apply for external funding on national level and within other ESA programmes.

**ABSTRACT 32296\_1: "Preparation of Cal/Val of spaceborne Aerosol and Carbon dioxide Detection Lidar (ACDL) by ground-based and airborne sounding instruments observations"**

***European Principal Investigator***

Dr. Oliver Reitebuch  
 DLR-IPA, Germany

***Chinese Principal Investigator***

Prof. Weibiao Chen  
 CAS-SIOM, CHINA

The global observations of column carbon dioxide concentrations and aerosol extinction profiles are important for climate study and environment monitoring. China decided to implement the Aerosol and Carbon dioxide Detection Lidar (ACDL) in one dedicated atmosphere and environment monitoring satellite to improve the quality of future climate and air quality prediction. The atmosphere and environment monitoring satellite will carry the ACDL lidar in space and is currently scheduled in 2020. A spaceborne engineering prototype of the ACDL lidar is being developed and an airborne prototype of integrated path differential absorption (IPDA) lidar for column carbon dioxide concentrations measurements was developed by Shanghai Institute of Optics and Fine Mechanics (SIOM) of the Chinese Academy of Sciences (CAS). SIOM also developed a ground based direct-detection wind lidar in 355 nm and an airborne coherent Doppler wind lidar. SIOM is responsible for several ground validation stations for future spaceborne atmospheric lidar validation in China. A ground-based direct-detection and a coherent Doppler wind lidar and a Raman polarization lidar were developed by the Ocean University of China (OUC) and deployed during several field campaigns, including the sailing competition within the Olympic Games in 2008 in Qingdao and the atmospheric explorer in Tibetan Plateau Experiment of Atmospheric Sciences (TIPEX III). Several atmosphere sounding lidars have been built for the scientific research in troposphere, stratosphere and upper atmosphere in Anhui Institute of Optics and Fine Mechanics (AIOFM), Chinese Academy of Sciences (CAS), including multi-function stratospheric lidar for aerosol, ozone, temperature and gravity wave measurement, and dual-wavelength tropospheric lidar for the aerosol vertical profile measurement from the ground, and mobile DIAL lidar for O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO<sub>2</sub> profiling, multi-wavelength Raman lidar (TMPRL) for vertical aerosol microphysics research, and multi-function Raman lidar for water vapor and temperature profiling in the troposphere, and airborne dual-wavelength polarization lidar for the atmosphere and environmental monitoring. OUC and AIOFM also participated in the ACDL lidar and airborne lidar prototype validation in China. DLR-IPA developed an airborne IPDA lidar for measurement of CO<sub>2</sub> and CH<sub>4</sub>, which serves as an airborne demonstrator for the future French-German lidar mission MERLIN (planned launch 2020). This airborne demonstrator named CHARM-F was flown in May 2015 on the German research aircraft HALO for the first time; further airborne campaigns on HALO are planned for the future.

The first project objective is to analyze the column carbon dioxide concentrations and aerosol extinction profiles measurements requirements of the ACDL lidar for science applications, such as climate study and air quality prediction. Also the data products applications need to be analyzed. The second project objective is to study the retrieval algorithms of ACDL lidar for carbon dioxide and aerosol for the future spaceborne lidar. The atmosphere auxiliary data from satellite and observation stations and model are important for data products. The third project objective is to define a validation plan for the spaceborne ACDL lidar in China and in Europe.

Funding for these activities will be provided by DLR, CAS-SIOM, OUC, CAS-AIOFM and it is planned to apply for external funding on national level and within other ESA programs.

<b>ABSTRACT 32296_2: "Validation of ADM-Aeolus by airborne and ground-based wind lidar observations"</b>	
<b>European Principal Investigator</b> Dr. Oliver Reitebuch (DLR-IPA, Germany)	<b>Chinese Principal Investigator</b> Prof. Songhua Wu (OUC, CHINA)
<p>The global observation of atmospheric wind profiles remains one of the highest priority needs for weather forecasting. ESA decided to implement the Atmospheric Dynamics Mission ADM-Aeolus to demonstrate the potential of the Doppler lidar technology for global wind profiling in order to improve the quality of future numerical weather prediction. ADM-Aeolus will carry the first wind lidar in space and launch is currently scheduled for mid 2017.</p> <p>An airborne prototype of the lidar instrument on ADM-Aeolus was developed by DLR (Deutsches Zentrum f. Luft- und Raumfahrt) and deployed in several field campaigns on the DLR Falcon aircraft, most recently in 2015 in coordination with the NASA DC-8 aircraft. A ground-based direct-detection and a heterodyne Doppler wind lidar and a Raman polarization lidar were developed by the Ocean University of China (OUC) and deployed during several field campaigns, including the sailing competition within the Olympic Games in 2008 in Qingdao and the atmospheric explorer in Tibetan Plateau Experiment of Atmospheric Sciences (TIPEX III). The Shanghai Institute of Optics and Fine Mechanics (SIOM) of the Chinese Academy of Sciences (CAS) developed a ground based direct-detection wind lidar in 355nm and a airborne coherent Doppler wind lidar. SIOM is responsible for several ground validation stations for future space-borne atmospheric lidar in China, which may provide useful aerosol and wind profiles data for ADM-Aeolus validation. The University of Science and Technology of China (USTC) developed a ground based direct detect Doppler lidar based on the Fabry-Perot etalon for troposphere and stratosphere wind observation. The National Satellite Meteorological Center (NSMC), China Meteorological Administration is responsible for receiving, processing the data of Chinese FY meteorological satellites, and distributing the data and information products to users for application.</p> <p>The first project objective is to validate the ADM-Aeolus wind, cloud and aerosol data products and to exploit the Aeolus wind observations for the study of atmospheric dynamics. Ground-based co-located measurements with wind lidars during overpasses of Aeolus are foreseen in China and in Central Europe. Further airborne campaigns with the ADM-Aeolus airborne demonstrator are planned over Central Europe and the North Atlantic region. The second project objective is to use the ground return from ADM-Aeolus to derive high-resolution reflectance's of different surfaces (sea, ice, land, etc.) in the UV. The data obtained will be compared to the data set being developed by the ESA-ADAM project in which a global spectral reflectance data set is created for 10 years (including the UV region). In addition, data from various airborne campaigns performed with the ADM-Aeolus airborne demonstrator will be used for this purpose.</p> <p>Funding for these activities will be provided by DLR, OUC, CAS-SIOM, USTC, and CMA-NSMC internal sources and it is planned to apply for external funding on national level and within other ESA programs.</p>	

**ABSTRACT 32296\_3: "Long-range dust transport and validation using ground-based and satellite lidar observations"**

**European Principal Investigator**

Dr. Dietrich Althausen  
 (TROPOS, Germany)

**Chinese Principal Investigator**

Prof. Songhua Wu  
 (OUC, CHINA)

The atmospheric particles have a remarkable impact on the global environment and climate change. The long-range transport of dust is an important part of the global biogeochemical cycles. It is significant and urgent to investigate dust on its optical properties, long-range transport, aging, and deposition. ESA decided to implement the Atmospheric Dynamics Mission ADM-Aeolus and the Earth Clouds, Aerosol and Radiation Explorer (EarthCARE) to provide global profiles of wind, clouds, aerosols, and properties together with derived radiative fluxes and heating rates. ADM-Aeolus will carry the first wind lidar in space and launch is currently scheduled for mid 2017. EarthCARE will carry cloud profiling radar, HSRL (High Spectral Resolution Lidar) and multispectral imager and is scheduled for launch in 2018. As parts of The European Aerosol Research Lidar Network, EARLINET, PollyXT and BERTHA were developed by TROPOS (Leibniz Institute for Tropospheric Research) and deployed worldwide (<http://polly.tropos.de>) for intensive observations of the aerosol and cloud vertical distribution over the lidar stations at 4 continents and 2 oceans. Ground-based WACAL (WATER vapor, Cloud and Aerosol Lidar) was developed by the lidar group at OUC (Ocean University of China) and deployed during several field campaigns, including the third Tibetan Plateau Experiment of Atmospheric Sciences (TIPEX III) in Naqu (31.5°N, 92.05°E) with a mean elevation of more than 4500 m above MSL in summer of 2014. Moreover, HSRL and CDL (Coherent Doppler Wind Lidar) developed by OUC were also deployed in several field campaigns. Lanzhou University (LZU), Atmospheric Science College carries out basic research and inter-discipline communication on dust aerosol physical optical characteristics. LZU has a Semi-Arid Climate and Environment Observatory of Lanzhou University (SACOL) and conducted lidar observations of dust aerosol physical optical characteristics near the resource area in the northwest of China (Lanzhou, Zhangye, Jingtai, Dunhuang and Wuwei). German Aerospace Center's (Deutsches Zentrum für Luft- und Raumfahrt; DLR) Institute of Atmospheric Physics (IPA) is a member of ESA's ADM-Aeolus Mission Advisory Group, Head of ESA funded pre-launch campaign study and contributor to algorithm and processor studies for Aeolus data products. DLR-IPA conducted series of DLR-led technology demonstration campaigns for ESA's meteorological satellite mission, ADM-Aeolus and EarthCARE, respectively.

The first project objective is the comprehensive observations of vertical profiles of optical properties, flux and the deposition of dust during the long-range transport over continents of Europe and Asia. Based on the ground-based PollyXT, WACAL, CDL and HSRL, ADM-Aeolus and EarthCARE satellites, combining back trajectory model from NOAA, it is available to determine the dust source region, the main transport route and the main deposition areas. The second project objective is to validate the ADM-Aeolus and EarthCARE wind, cloud and aerosol data products. Ground-based co-located measurements with PollyXT, BERTHA, WACAL, CDL and HSRL lidars during overpasses of Aeolus and EarthCARE are foreseen in China (Coastal cities, China Seas, inland cities, Tibetan Plateau, Taklimakan desert) and in Central Europe.

Funding for these activities will be provided by OUC, TROPOS, LZU and DLR-IPA internal sources and it is planned to apply for external funding on national level and within other ESA programs.