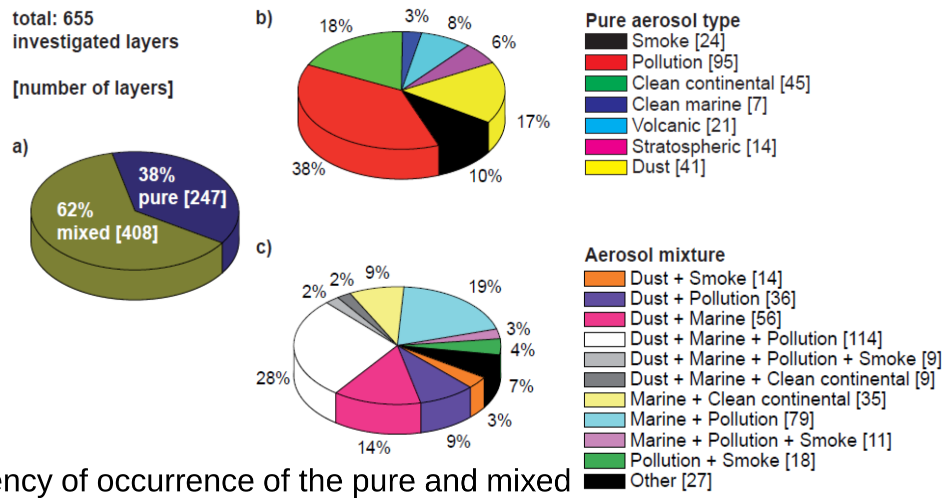
**Draft** (will be updated before the symposium)

# Lidar Observations from ADM-Aeolus and EarthCARE-Validation, Study of Long-range Transport of Aerosol and Preparation of a Future Chinese $CO_2$ Lidar Mission

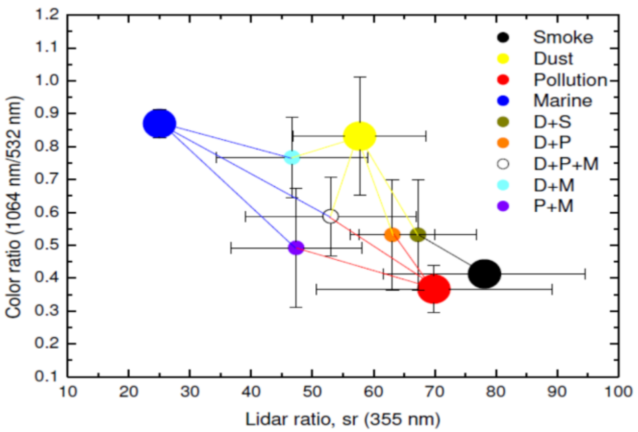
| Topic Nr. | PIs | Title |
|---|---|---|
| 32296_3 | Dietrich Althausen, TROPOS<br>Songhua Wu, OUC | **Height-dependent Identification of Particles, Fluxes and Intercomparisons based on Lidar Techniques （HIP）** |

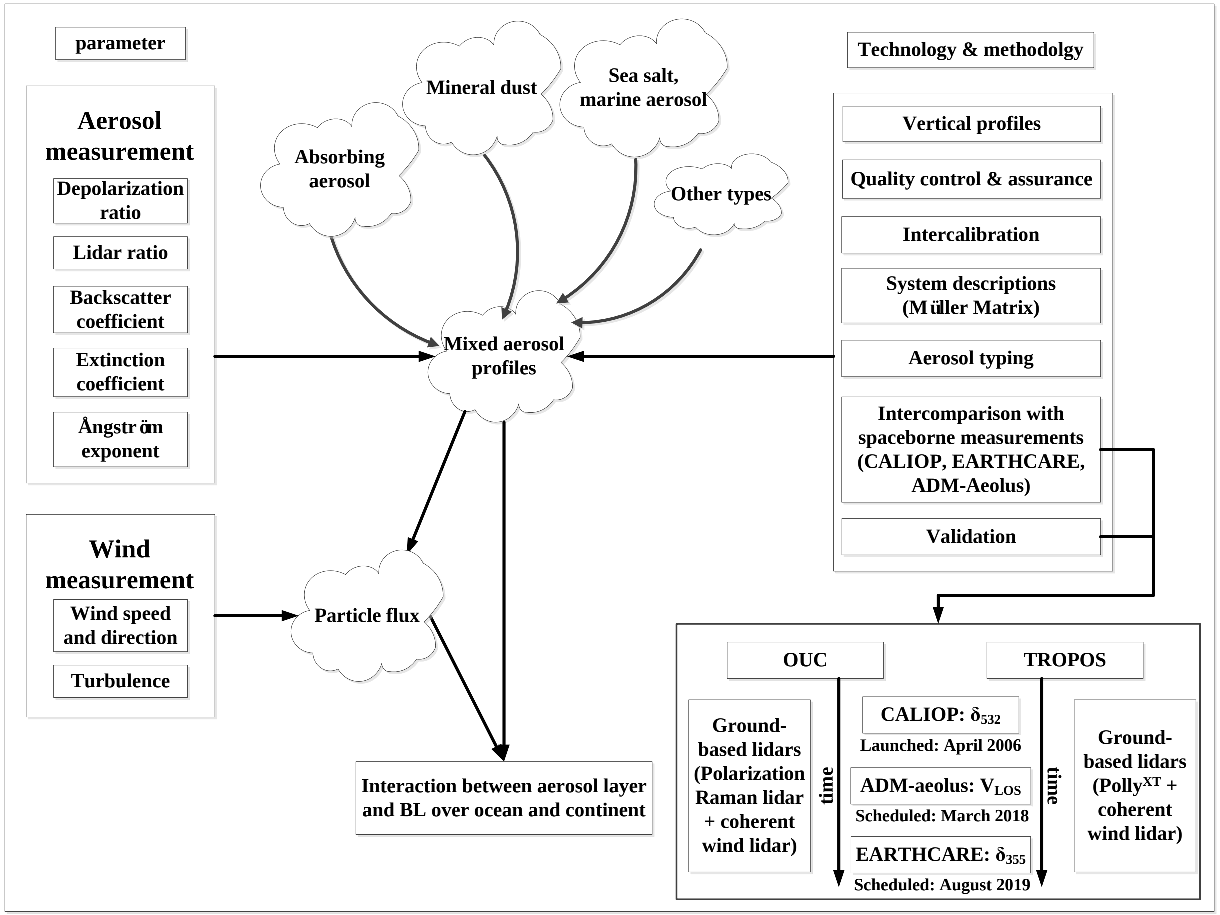
***TROPOS:*** *Dietrich Althausen, Ulla Wandinger,*
***OUC-ORSI:*** *Songhua WU, Xiaoquan Song, Bingyi Liu, Guangyao Dai, Xiaochun Zhai,*
***DLR-IPA:*** *Oliver Reitebuch, Silke Groß*
***LZU:*** *J. Huang, Z. Huang*

# Height-dependent Identification of Particles, Fluxes and Intercomparisons based on Lidar Techniques （HIPs）




Frequency of occurrence of the pure and mixed aerosol types for the EARLINET stations




Research strategy.

Wandinger 2011, Schwarz 2016

# Height-dependent Identification of Particles, Fluxes and Intercomparisons based on Lidar Techniques （HIPs）

- **Task 1:** Intercalibration and intercomparison of ground-based lidars in Europe. The polarization Raman lidar (PRL) and coherent wind lidar (CWL) from OUC/China will be shipped to TROPOS at Leipzig/Germany. The lidars will be operated 24/7 and controlled remotely. Cloud-free measurement cases with (almost) no aerosol and with different aerosol types will be selected for detailed comparison. The properties of particle backscatter coefficient, particle extinction coefficient, particle linear depolarization ratio (at 532 nm and 355 nm), lidar ratio and Ångström exponent ($Å_{b,a}$) measured with PRL and $Polly^{XT}$ will be compared. The wind speed and direction measured with wind lidar and radiosonde station at TROPOS will be compared, too. The intercomparisons and errors of the measurements will be provided.
- **Task 2:** Descriptions of the aerosol lidar systems. The optical elements of the systems will be described by using Müller Matrixes. This will help to understand the possible differences of the lidars and would enable the reduction of errors.
- **Task 3:** The polarization Raman lidar (PRL) and coherent wind lidar (CWL) from OUC/China and $Polly^{XT}$ from TROPOS/Germany will be shipped to Changdao Island / China. The lidars will be operated 24/7 and controlled remotely for at least half a year. Cloud-free measurement cases with (almost) no aerosol and with different aerosol types will be selected for a recapped intercomparison of the aerosol lidar systems.
- **Task 4** Installation and operation of PRL on the research vessel “Dongfanghong II” of China. The plan is to determine aerosol vertical structures and intensive particle properties over the Bohai Sea, especially around Changdao Island. These results will be compared with the results from the PollyXT- system at Changdao Island within Task 5.
- **Task 5:** Aerosol type characterization. Different particle types and characteristics are determined by the lidar ratios, the depolarization ratios, and the wavelength-dependent particle optical parameters. The differences of aerosol types between Leipzig (west of Eurasia) and Changdao Island (Bohai Sea, east of Eurasia) will be investigated.
- **Task 6:** Determination of flux and transport of aerosol. In this part of the project, the multi-wavelength polarization Raman lidars are used to determine the vertical distribution of aerosol. Simultaneous observations of the wind field (especially the vertical velocity) by the coherent Doppler wind lidar will be conducted, too. Combining the data products from all these lidars, the aerosol deposition and vertical transport fluxes can be determined by using the eddy-covariance technique. This method supposes that the changes of aerosol parameters are only related to particle transport and not related to particle changes. But, the optical particle parameters depend on the relative humidity (if the relative humidity is ≥ 50 %) and a change of the optical particle parameters might be caused by a fast change of the relative humidity at small scales, too. Hence, it is only possible to determine the particle flux in case of taking into account the relative humidity or at a relative humidity below ~ 50 %. Since there is no fast measurement of the relative humidity, these particle flux measurements can be only performed at heights where the relative humidity is below ~ 50 %.
- **Task 7:** Intercomparison of aerosol and wind measurements with ground-based lidars ($Polly^{XT}$, PRL and coherent wind lidar) and satellite-based lidars (carried by CALIPSO, EARTHCARE and ADM-aeolus);

# TROPOS Dust observation

- Portable Raman Lidar System Polly$^{XT}$
  - Aerosol-backscattering ratio (Rb), aerosol extinction coefficient, extinction-to-backscatter (Sa) ratio, water vapor mixing ratio, depolarization ratio

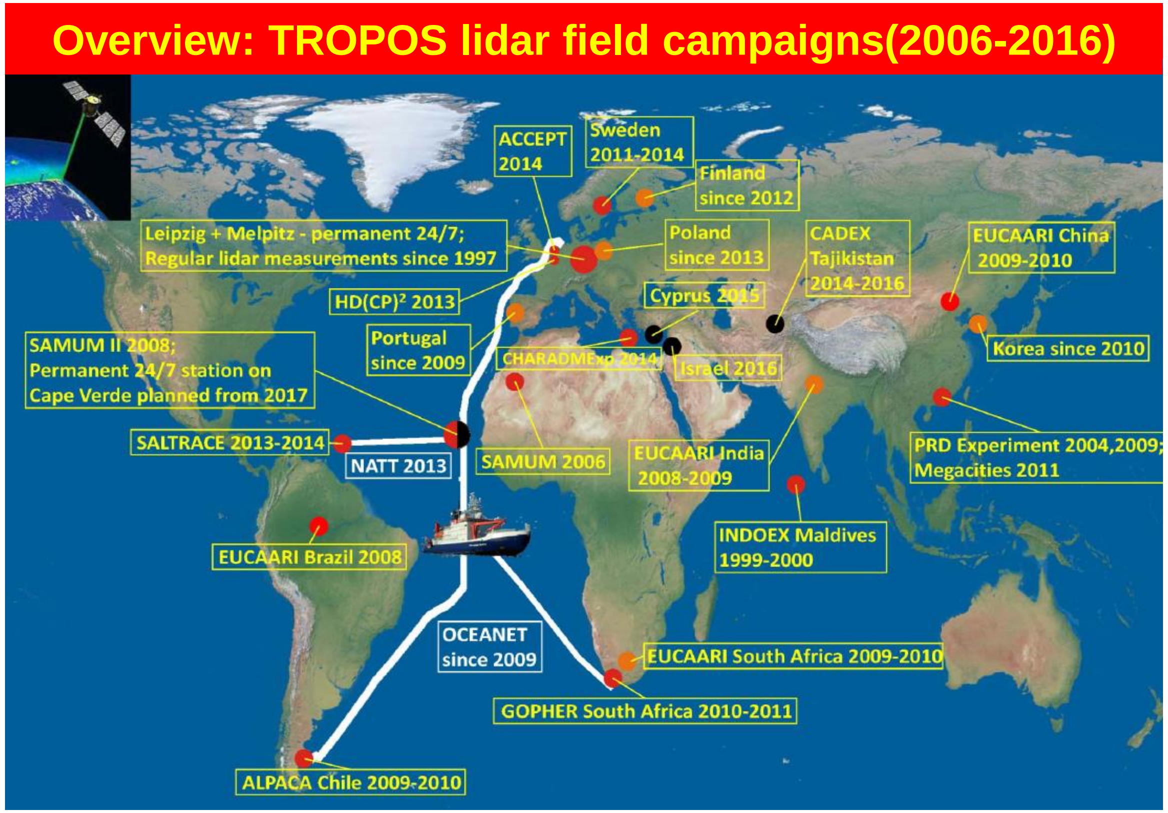
- Multiwavelength-Raman-polarization, lidar MARTHA **(only in Leipzig)**
  - Temperature, Humidity, and Aerosol profiling)


- *BERTHA (only in Leipzig)*
  - Backscatter Extinction Ratio, Temperature, Humidity, depolarization ratio Lidar

- Coherent Doppler lidar
  - wind profile , sea surface wind vector

- Cloud Radar MIRA-35
  - Backscatter ratio, linear depolarization ratio, Doppler velocity

# Description of CAL/VAL techniques applied

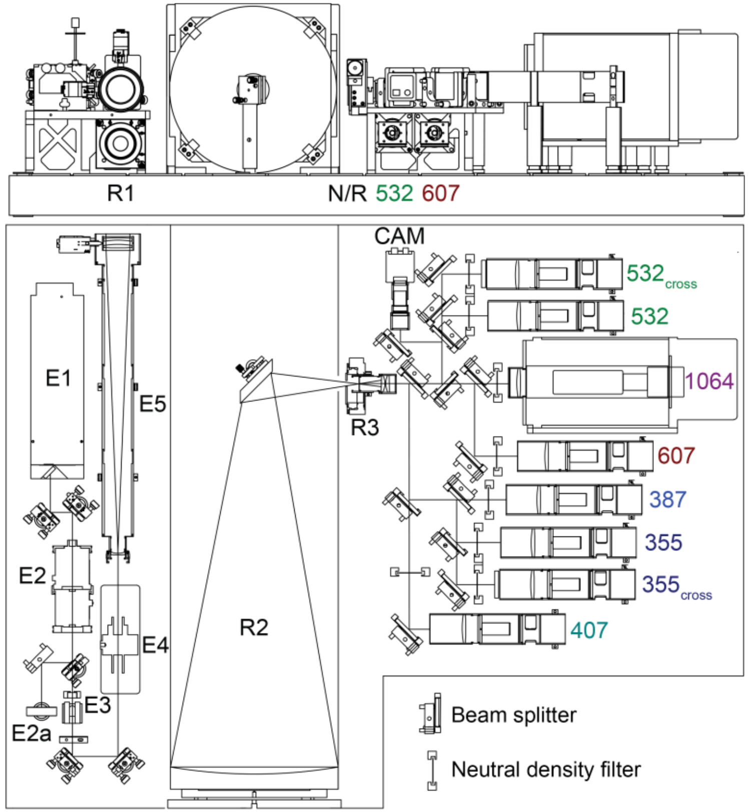



*Dietrich, 2015. Qingdao, China*

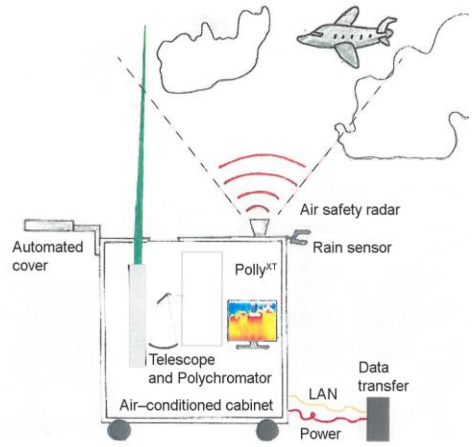
- Saharan mineral dust experiment 1, Morocco 2006 (SAMUM1)
- Convective and orographically-induced precipitation study in the Black Forest, Germany 2007 (COPS)
- Saharan mineral dust experiment 2, Cap Verde 2008 (SAMUM2)
- European Supersites for Atmospheric Aerosol Research 2006 - 2011 (EUSAAR), Leipzig
- Satellite-based aerosol mapping over megacities: Development of methodology and application in health and climate related studies at Leipzig and Guangdong 2007 – 2010 (Megacities)
- Joint experiments with groups in Sweden 2010-2011 (VASA), Chile 2009-2010 (ALPACA), South Africa 2010-2011 (GOPHER)
- OCEANET Autonome Messplattformen zur Bestimmung des Stoff- und Energieaustausches zwischen Ozean und Atmosphäre (Atlantic)
- Saharan Aerosol Long-range Transport and Aerosol-Cloud-Interaction Experiment, Barbados 2013-2014 (SALTRACE)
- Central Asian Dust Experiment 2014-2016 (CADEX)
- Cyprus Clouds Aerosol and Rain Experiment (CyCARE) 2015

# Description of HIP techniques applied

*PollyXT*

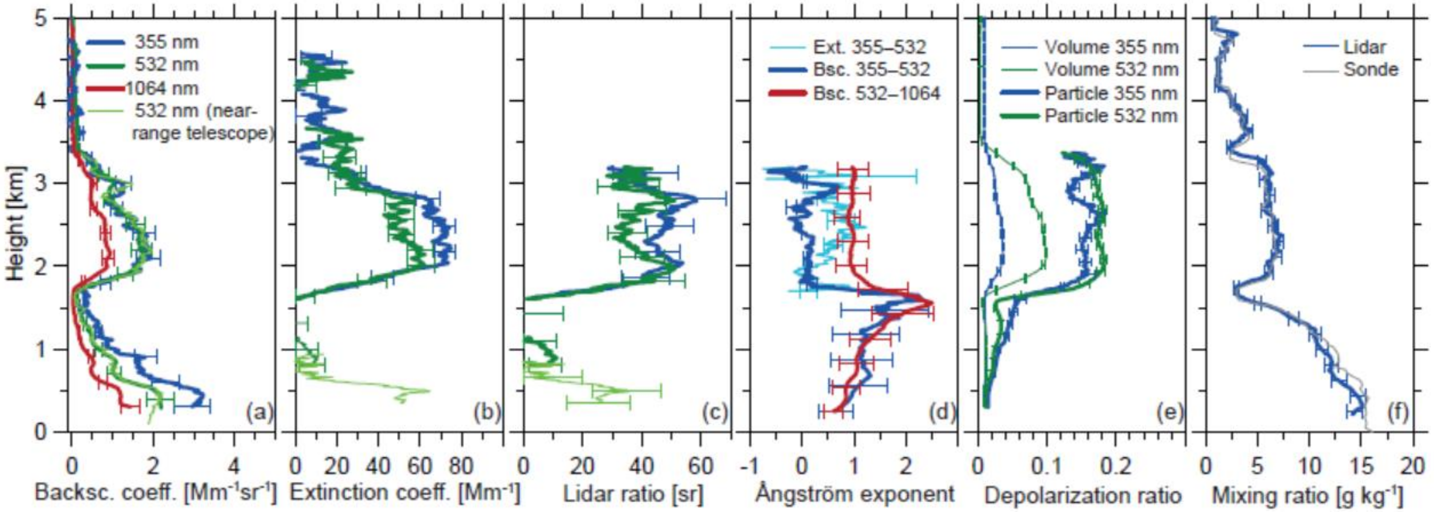



*Engelmann et al, 2016*

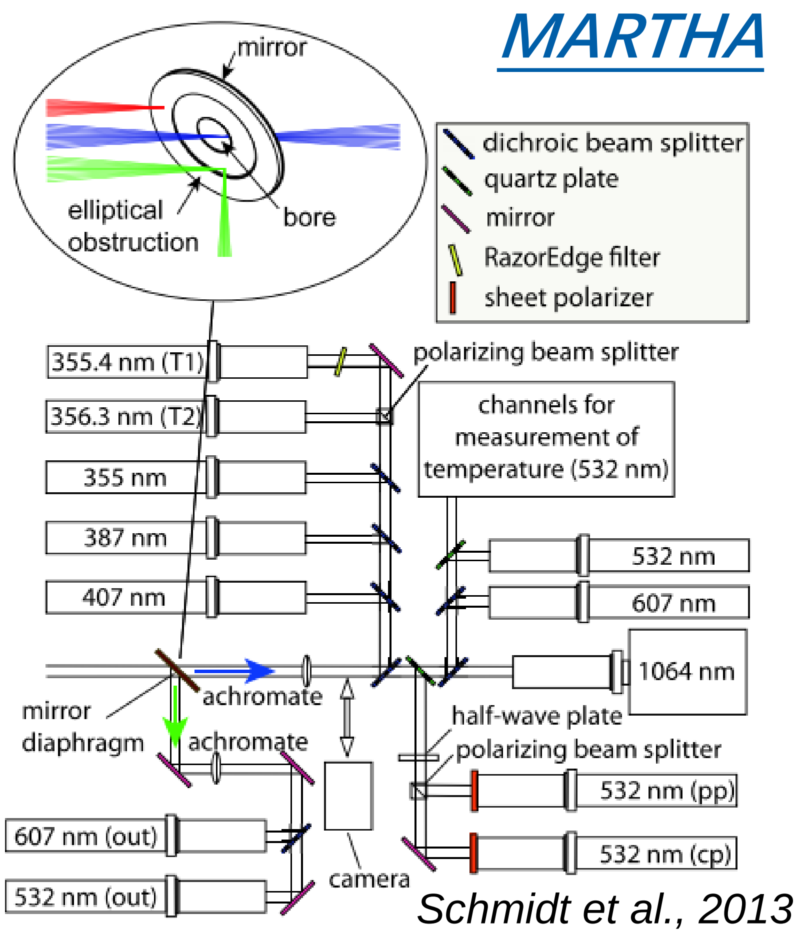




Autonomous measurements of PollyXT

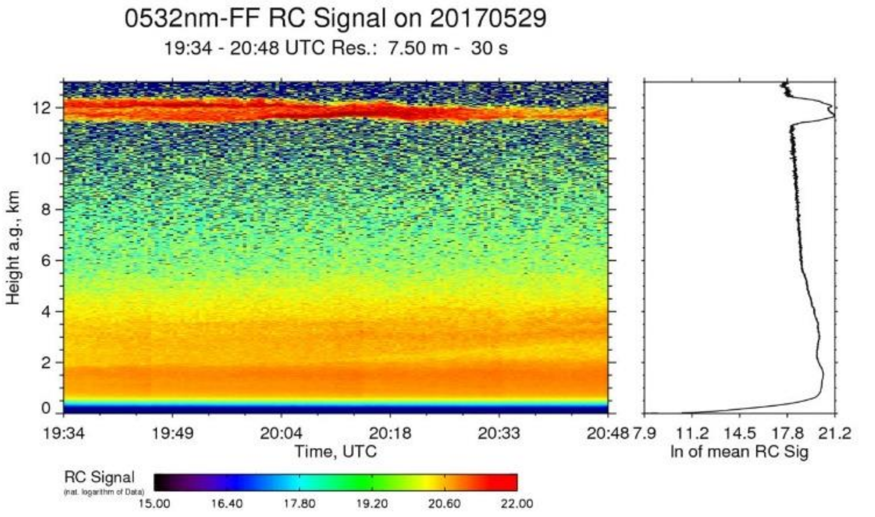


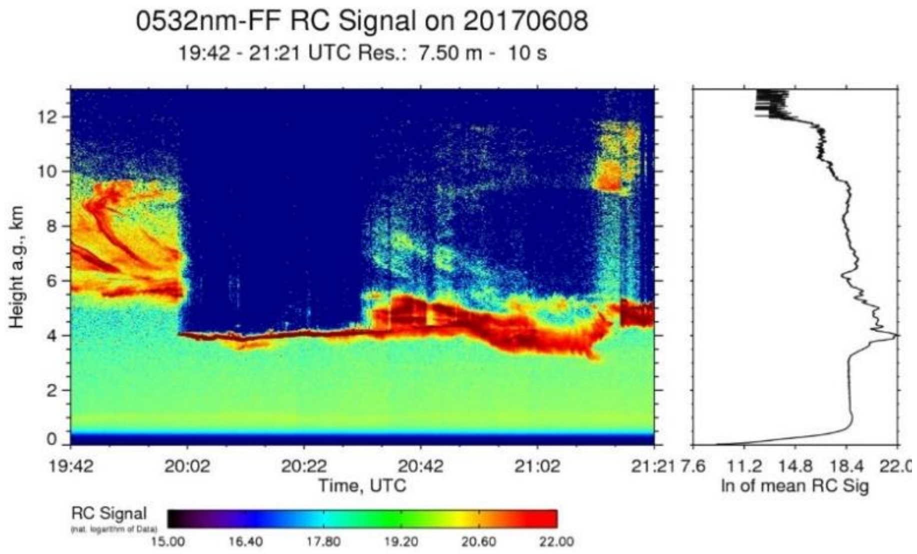
# Description of HIP techniques applied




*Schmidt et al., 2013*

Schematic diagram of MARTHA

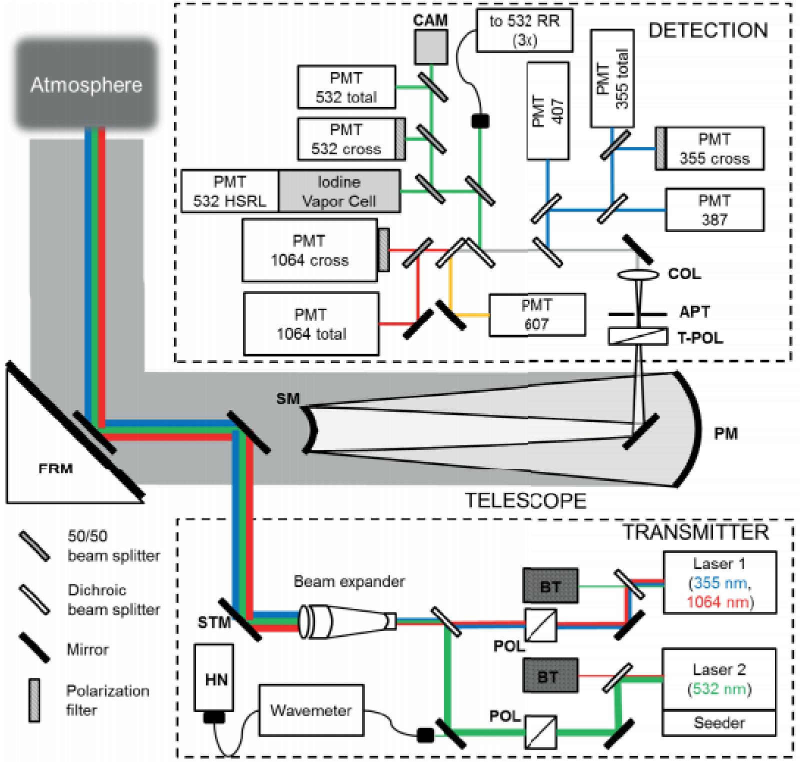



Regular measurement on 29 May and 08 June 2017.

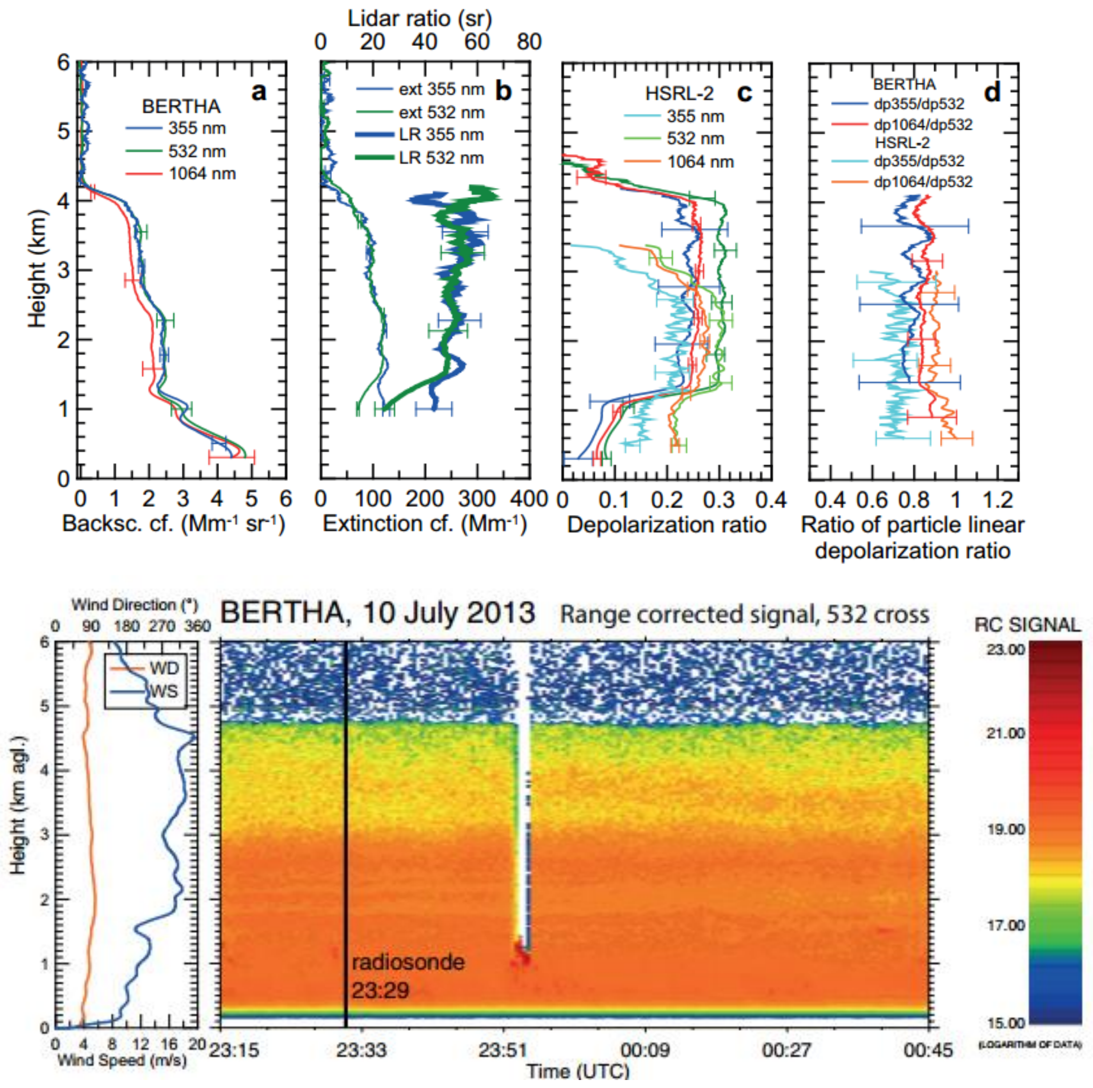
# Description of HIP techniques applied

*BERTHA*



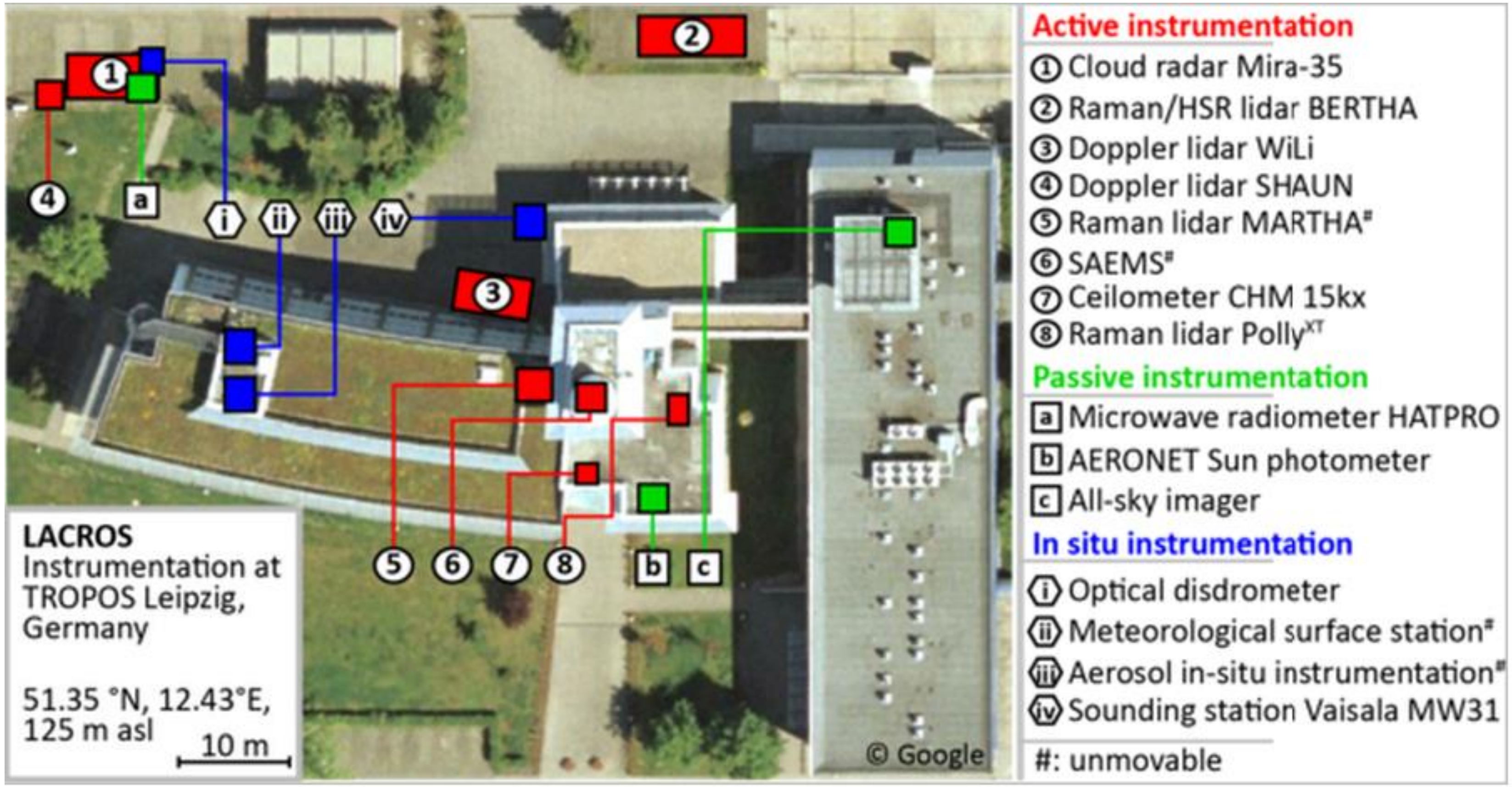

*Haarig et al., 2017*

Schematic diagram of BERTHA




Data products from BERTHA

# Description of HIP techniques applied

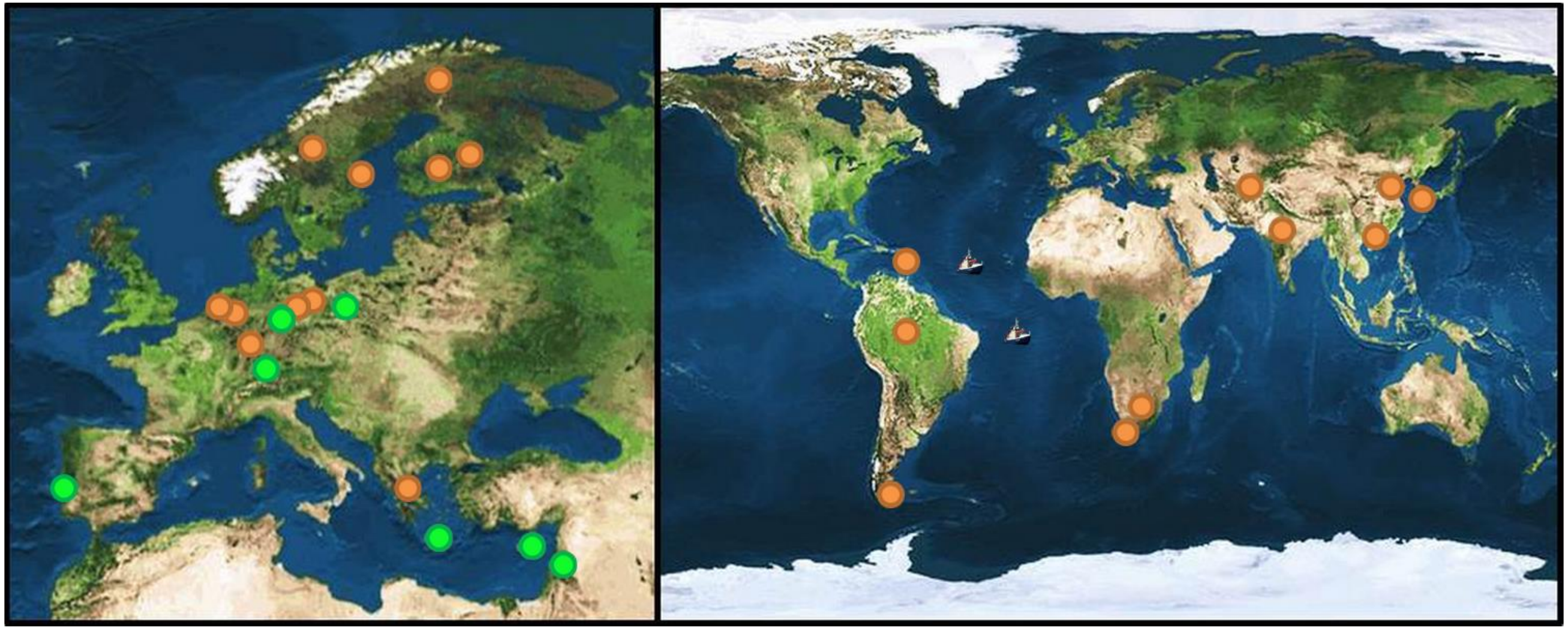


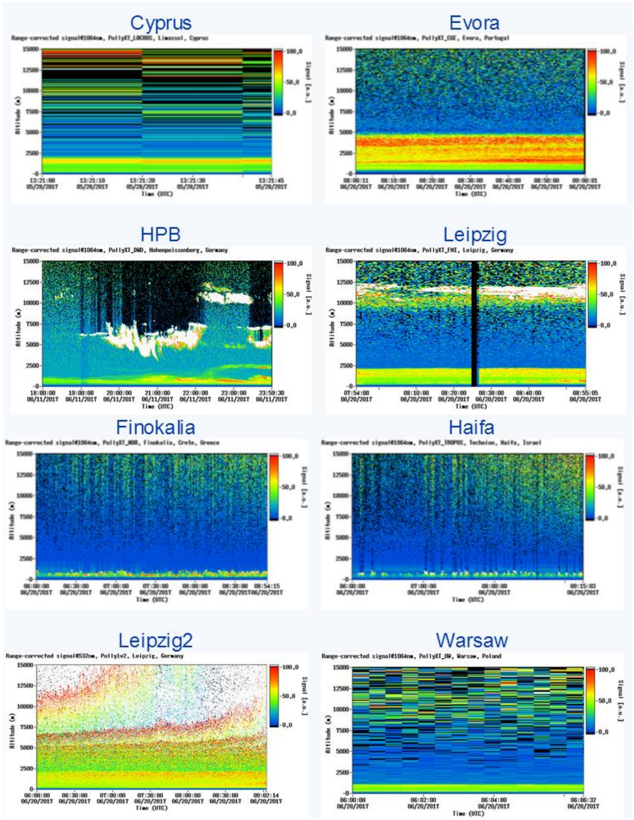



***LACROS*** (The Leipzig Aerosol and Cloud Remote Observations System) comprises a unique set of active and passive remote-sensing instruments which are to a large extent containerized and available for application in field campaigns.

http://www.tropos.de/en/research/projects-infrastructures-technology/coordinated-observations-and-networks/lacros/

# Description of HIP techniques applied






*Green dots: on-going measurements* *Gray dots: archive measurements*

[***Polly<sup></sup>***]

**_Polly$^{NET}$_** (Worldwide observations with the portable Raman lidar systems). This network consists of portable, remote-controlled multiwavelength-polarization-Raman lidars (Polly) for automated and continuous 24/7 observations of clouds and aerosols.

http://polly.rsd.tropos.de/lidar/?p=home

# OUC ground and shipborne dust observations

- Direct detect Doppler wind lidar / HSRL (High Spectral Resolution Lidar) CHiPSDWiL
  - radial wind speed, wind profile, 3D wind vector, aerosol- backscattering ratio (Rb), aerosol extinction coefficient, extinction-to-backscatter (Sa), sea surface wind vectors

- Coherent Doppler lidar WindPrint
  - wind profile , sea surface wind vector

- Multi-wavelength Raman-Polarization lidar WACAL
  - Aerosol-backscattering ratio (Rb), aerosol extinction coefficient, extinction-to-backscatter (Sa) ratio, cloud base height

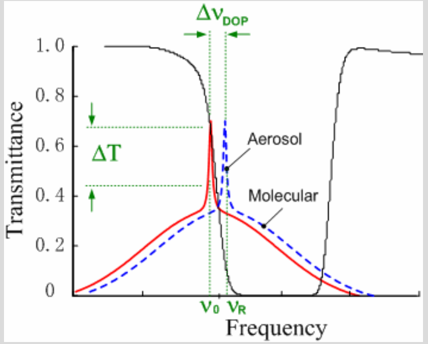
Co-located ground observations by OUC lidar facilities can be compared with the data products of ADM-Aeolus, and we will analyze the comparison results and present assessment reports to ADM-Aeolus community.

# Field campaigns

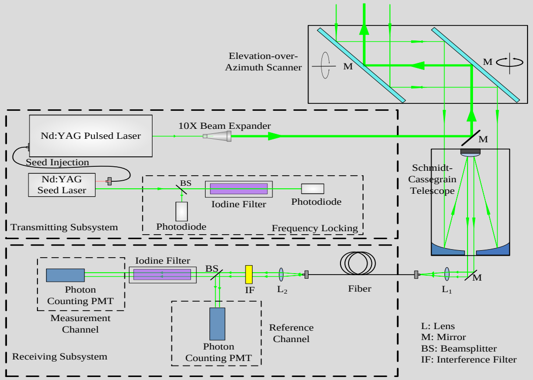
## Atmospheric lidar campaigns of last 10 yrs

- 2014-2017 MABL dynamics and structure observation by Doppler Lidar
- 2014-2016 Wind turbine wake research
- 2015-2017 UAV wind lidar for MABL and SSW
- 2015-2016 Aviation hazard weather monitoring
- 2013-2017 Tibetan Plateau atmospheric experiment
- 2011-2012 CMA Lidar and radiosonde campaign
- 2010 Sea surface wind observations for Asia Game
- 2013 MABL lidar observation in Indian Ocean
- 2010 WMO radiosonde validation campaign at Yangjiang
- 2009 Storm observation : lidar, radars
- 2008 Spacecraft landing area : wind profile
- 2008 Olympics: operational SSW monitoring
- 2007 International Sailing Games
- 2007 Ground anemometer validation campaign
- 2005~2006 : radiosonde validation

# Direct detect Doppler wind lidar DDWL and HSRL
# For tropospheric wind and aerosol measurement

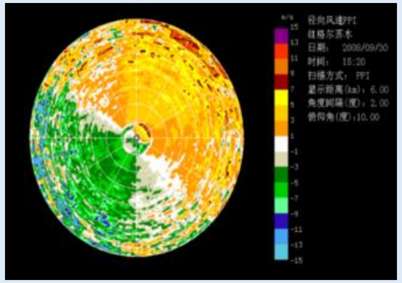


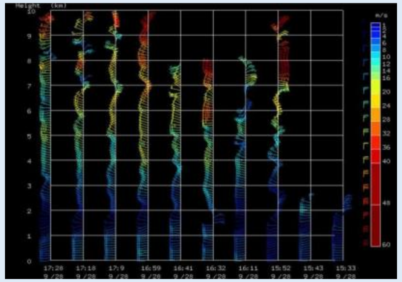

Theory




Schematics

**CHiPSDWiL**

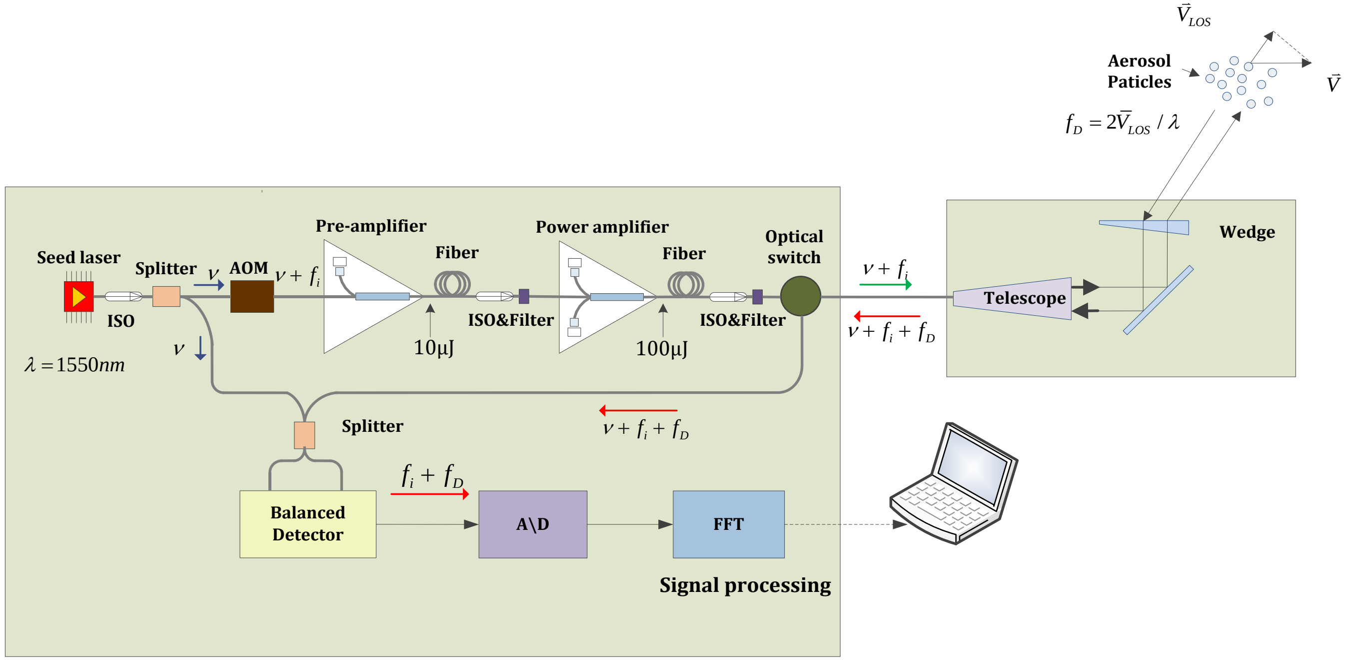


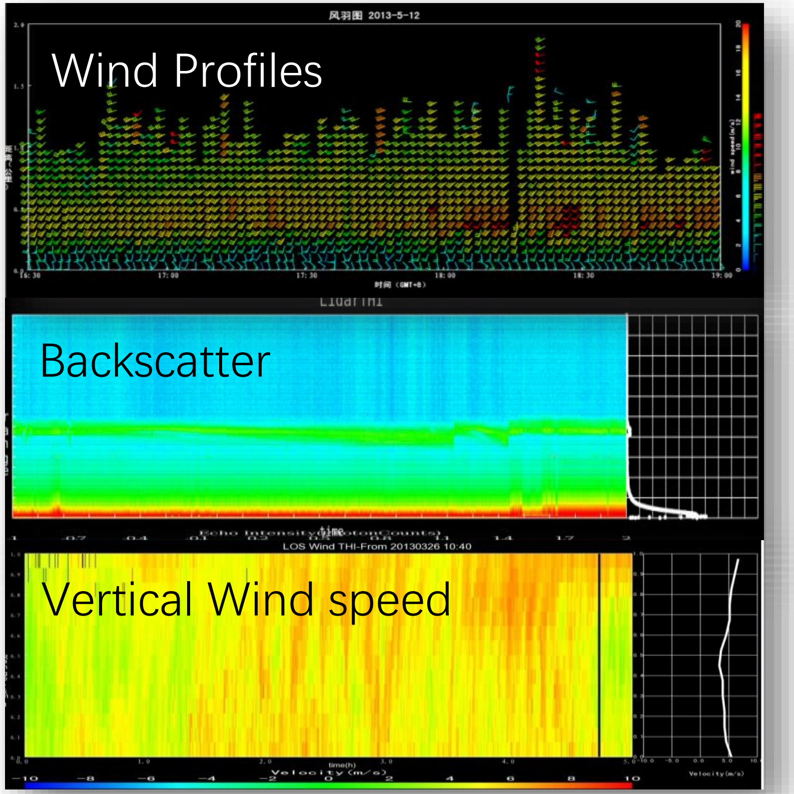
3D wind and wind Profile

High precision scanner enables the observation at specified azimuth and elevation angle pointing to the ADM-Aeolus laser path.

Z. Liu, S. Wu, B. Liu, Z. Li, et.al. 2003,2006,2007,2008, 2014, 2016

# Coherent Doppler lidar
# For boundary wind measurement and direct detect DWL Cal/Val

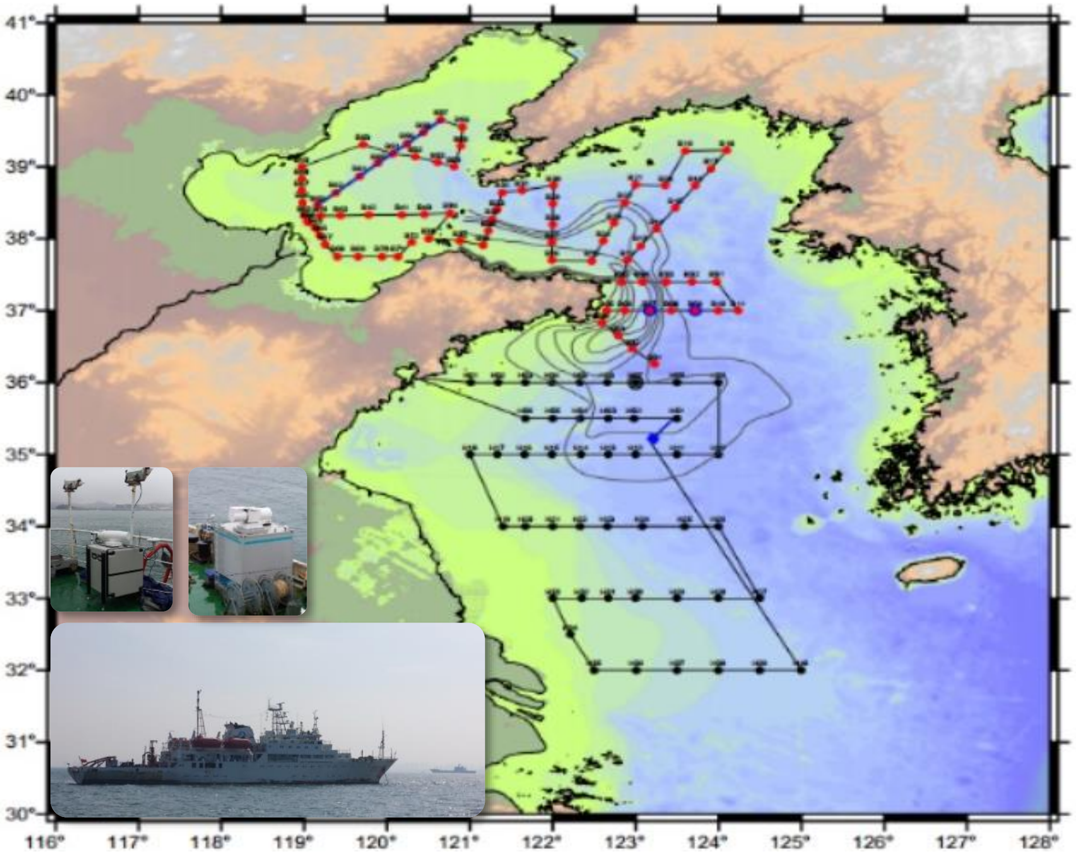


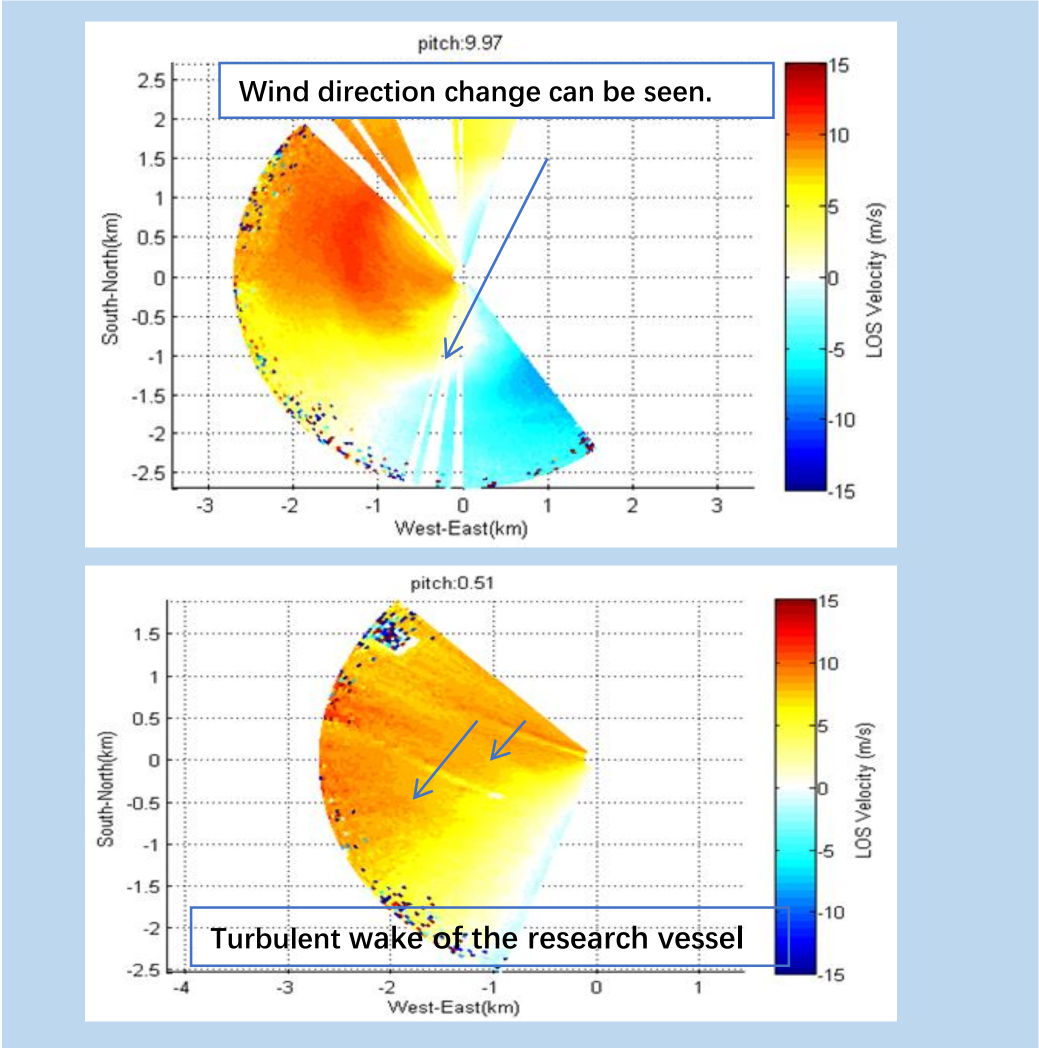

- Boundary layer wind profile measurement with high accuracy of 0.3 m/s.
- Better understanding of the vertical wind under and within clouds.
- Easy to transport for remote area campaign
- Deployed in the Tibetan Plateau campaign.

S. Wu, et. al. 2012

# Coherent Doppler lidar
# Marine boundary layer structure and wind measurement




2013 Cruise, April 27th to May 21th




S. Wu, et. al. 2012

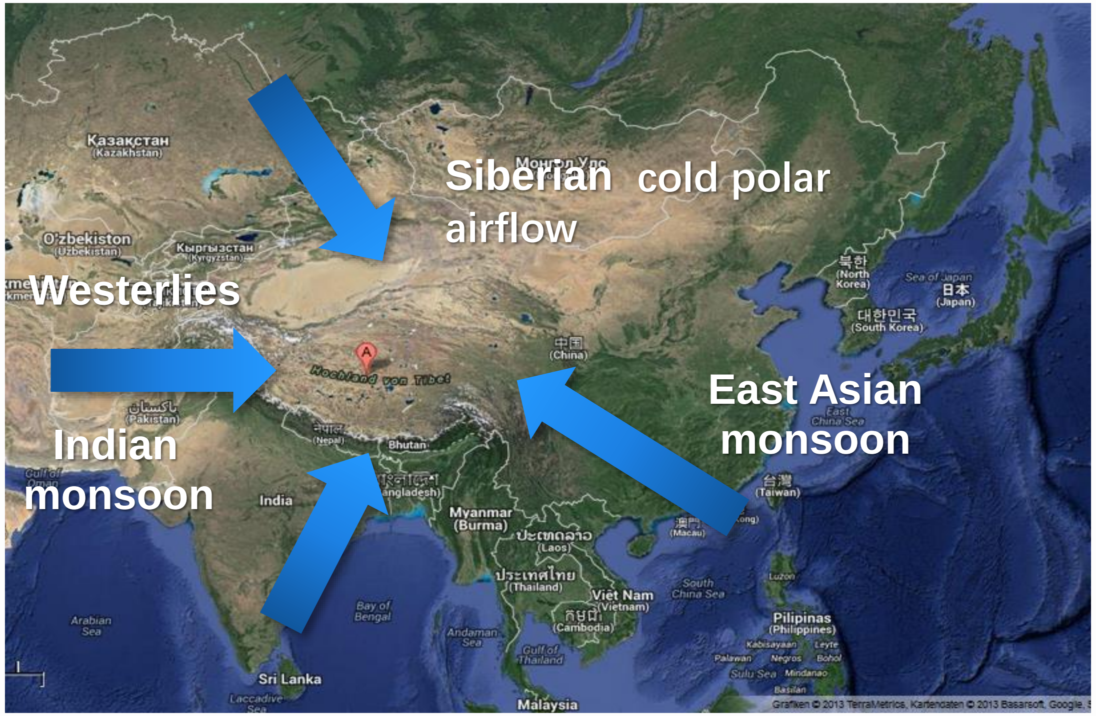
# Atmospheric campaign in the Tibetan Plateau

CMA

OUC

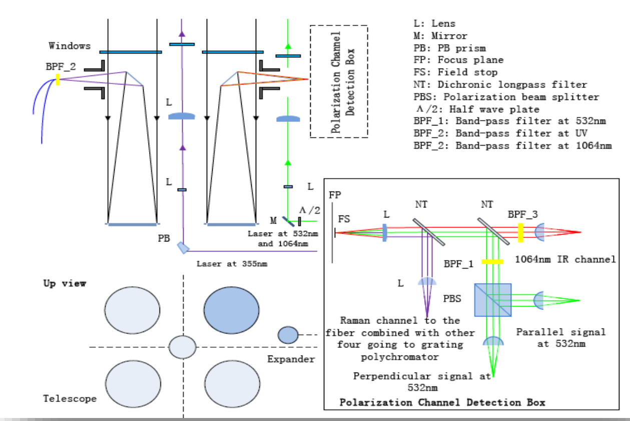
CAMS

LaSW




The Tibet lidar campaign is a joint experiment organized by OUC/ORSI and CAMS/LAWS ( Chinese Academy of Meteorological Sciences/  Laboratory of Severe Weather.

**OUC lidar facilities: Wind, Humidity, , Temperature, Aerosol and Cloud profiling**




**Multi-wavelength Raman-Polarization lidar**

WACAL diagram

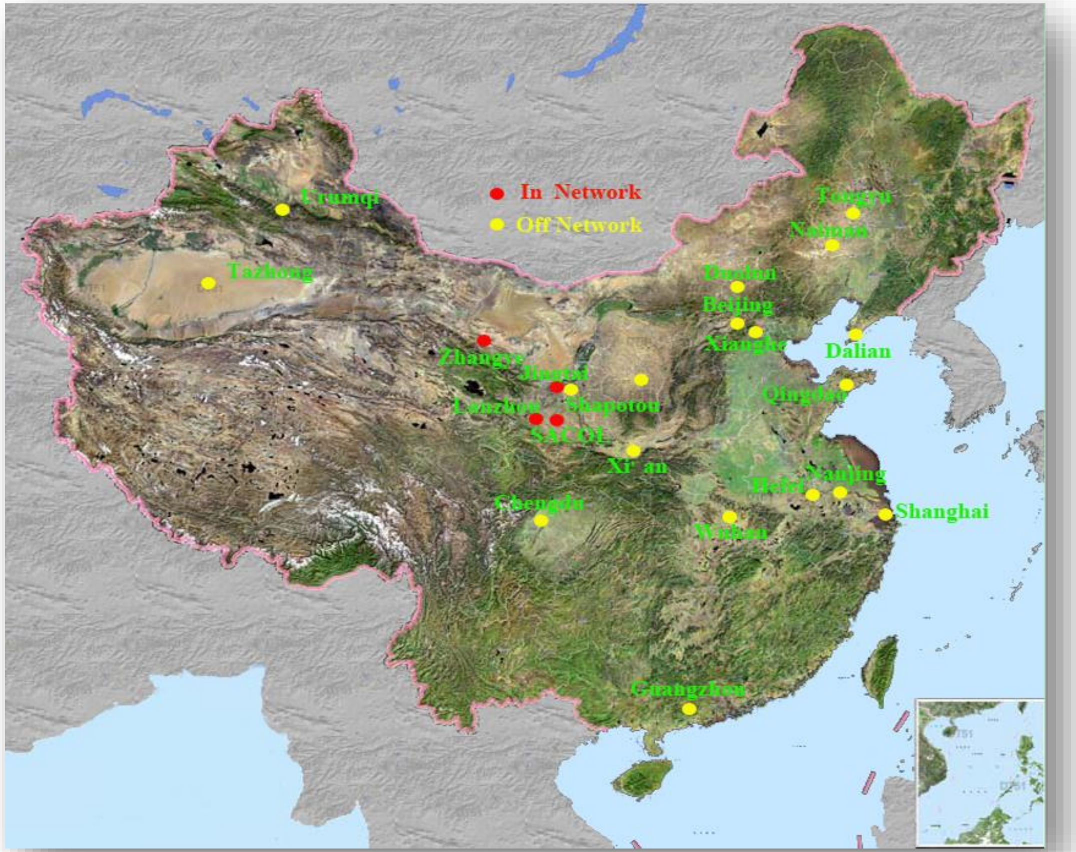
## To study cloud/aerosol effect on semi-arid climate, we developed a supper site for cloud/aerosol & climate parameters measurements in 2005.

### MOTIVATION

**Fill the gap of global climate monitoring network.**

**There is no any international network (such as CEOP,BSRN, Aeronet) site in Loess Plateau yet.**

**Loess Plateau is a special semi-arid land surface; & part of dust aerosol source and close to the desert.**

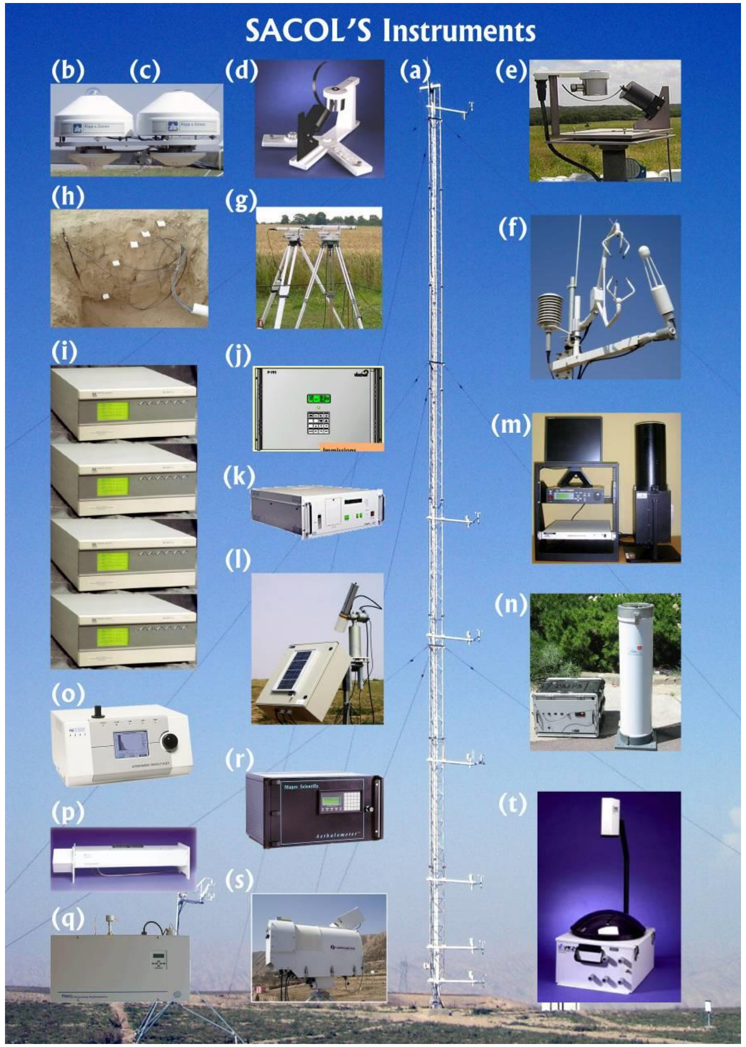


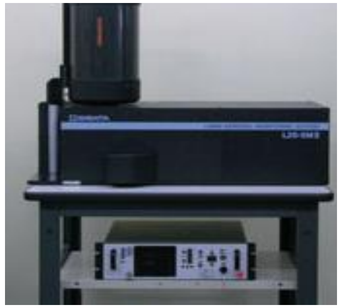
# LZU SACOL Mobile Facility Instrument and Measurement

# SACOL Major Instruments

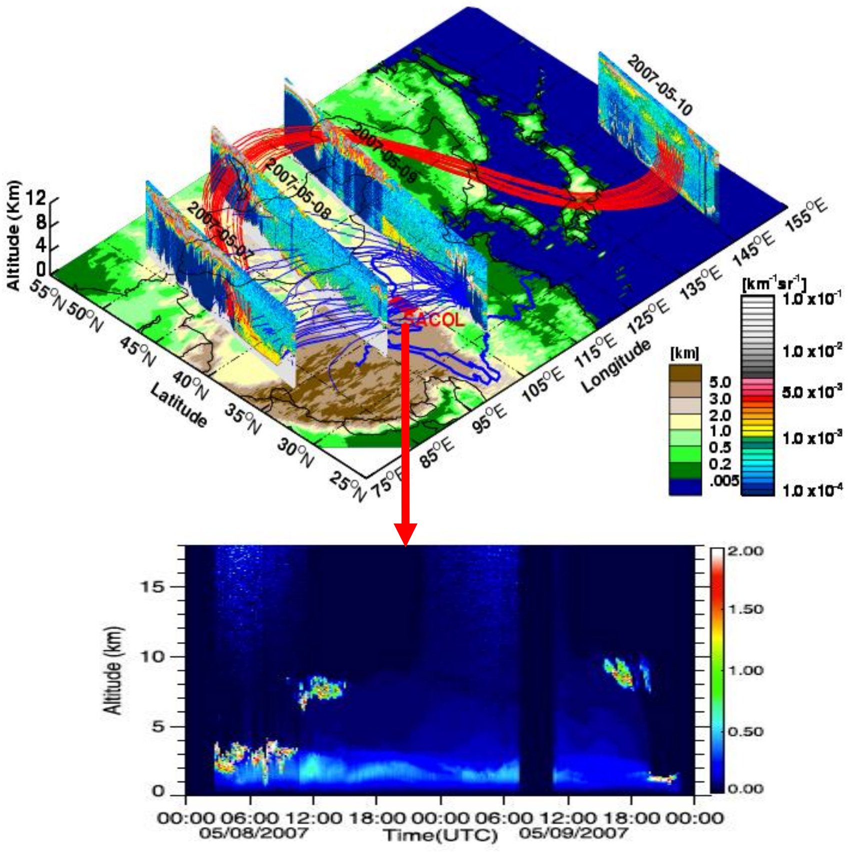
**Huang et al., AAS, 2008**

- **Boundary layer**
- **Surface radiation**
- **Surface fluxes**
- **Soil parameters**
- **Ambient air analyzers**
- **Aerosol optical properties**
- **Aerosol vertical profile**
- **Temperature and water vapor vertical profiles**
- **Sky condition**



# Long-range transportation of Asian dust was investigated using ground-based and space borne lidar measurements





JGR Journal of Geophysical Research AGU

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D23212, doi:10.1029/2008JD010620, 2008


## Long-range transport and vertical structure of Asian dust from CALIPSO and surface measurements during PACDEX


Jianping Huang,[1] Patrick Minnis,[2] Bin Chen,[1] Zhongwei Huang,[1] Zhaoyan Liu,[3] Qingyun Zhao,[4] Yuhong Yi,[5] and J. Kirk Ayers[5]



Received 17 June 2008; revised 12 September 2008; accepted 29 September 2008; published 11 December 2008.

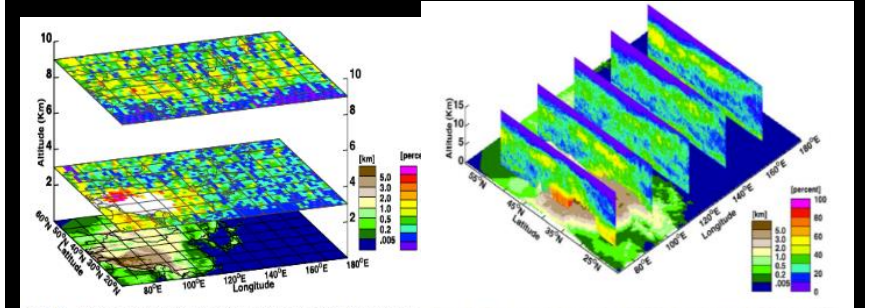
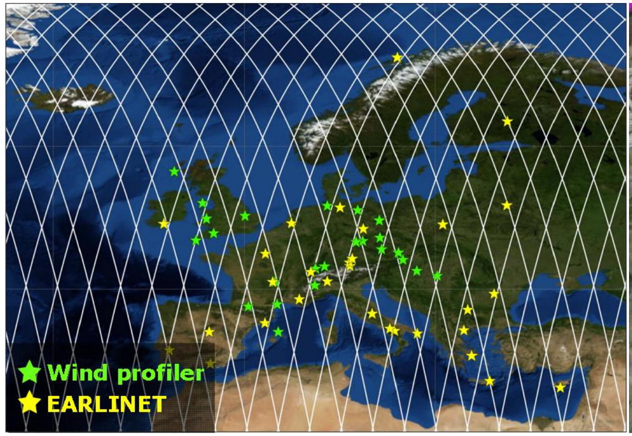



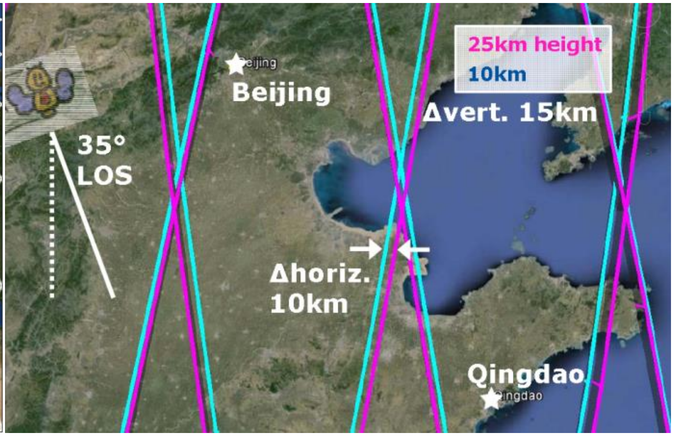
Figure 13. Horizontal distribution of dust event frequency of occurrence over eastern Asia and ad Pacific Ocean determined from CALIPSO measurements near the surface, at 3 km, and at 9 km. scales on the left represent topographical elevation, and those on the right represent dust event freq of occurrence in percent.

Figure 12. Dust event vertical structure from CALIPSO observations over the Taklamakan (80°E), Gobi (102°E), eastern China (124°E), Japan/China Yellow Sea (146°E), and the Pacific Ocean (168°E) superimposed on a regional map. Color scales on left represent topographical elevation, and those on the right represent dust event frequency of occurrence in percent.

**Huang et al., JGR, 2008a, 2010.**

# Summary of ground based measurement for dust long range transportation and Cal/Val




*Kanitz , 2015. Frascati, Italy.*


*Marksteiner et al., 2015. Frascati*

OUC lidar facilities

TROPOS Lidars


*Lanzhou Univ. SACOL station*

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.

# Young scientists contributions

Chinese YS

- **Mr. DAI Guangyao**
  joint-Ph.D student (2016.11-2018.4) working on aerosol and cloud laser remote sensing with TROPOS/Germany and OUC/China.

- Research experience:
  - ✓ Construction of lidar system, calibration and validation;
  - ✓ Water vapor calibration;
  - ✓ Depolarization ratio calibration;
  - ✓ Quality control (QC) and Quality assurance (QA);
  - ✓ Lidar products retrieval.

# Young scientists contributions

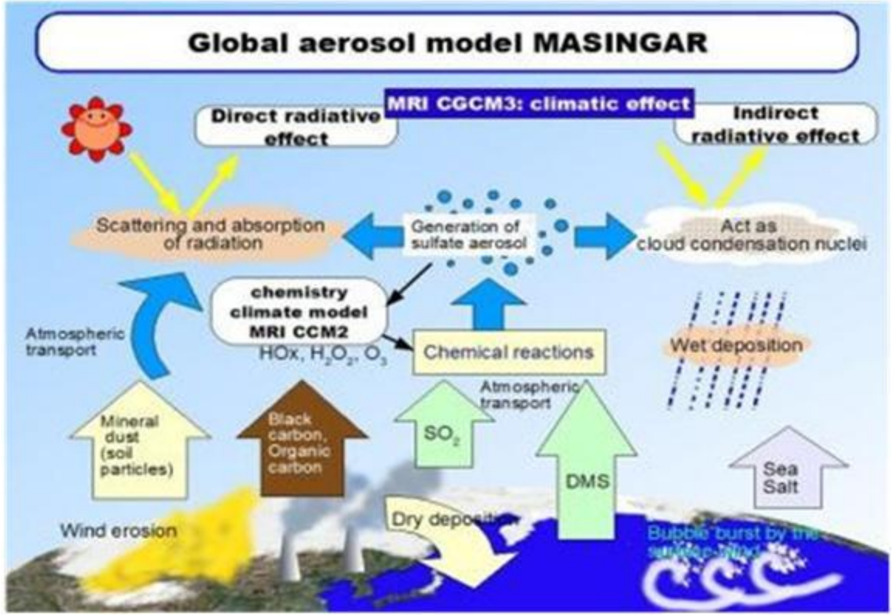
Chinese YS

- Ms. Zhai Xiaochun
  joint-Ph.D student (2018.3-2019.5) working on ADM-Aeolus Cal/Val with DLR-IPA/Germany and OUC/China.

- Research experience:
  - ✓ Data analysis of DWL and coherent lidar system, calibration and validation;
  - ✓ Marine boundary layer dynamics lidar observation;
  - ✓ Wind and turbulence lidar observation and products retrieval.

# Summary on progress and collaboration

- **Joint proposal to NSFC and DFG for**
- **Height-dependent Identification of Particles, Fluxes and Intercomparisons based on Lidar Techniques （HIP）**
- (in review)




- **联合向中国自然科学基金委与德国科学联合会申请课题：**
- 吸收性海洋性及矿物性等多类气溶胶光学特性鉴别与通量廓线的激光雷达探测与校准技术研究
- （评审中）