Development of a balloon-borne aerosol profiling system:

Applications in China

Zahra Chaudhry, J. Vanderlei Martins, Zhanqing Li, Si-Chee Tsay, Qiang Ji, Tianxue Wen, Wu Zhang

DOE ARM
Science Team
Meeting

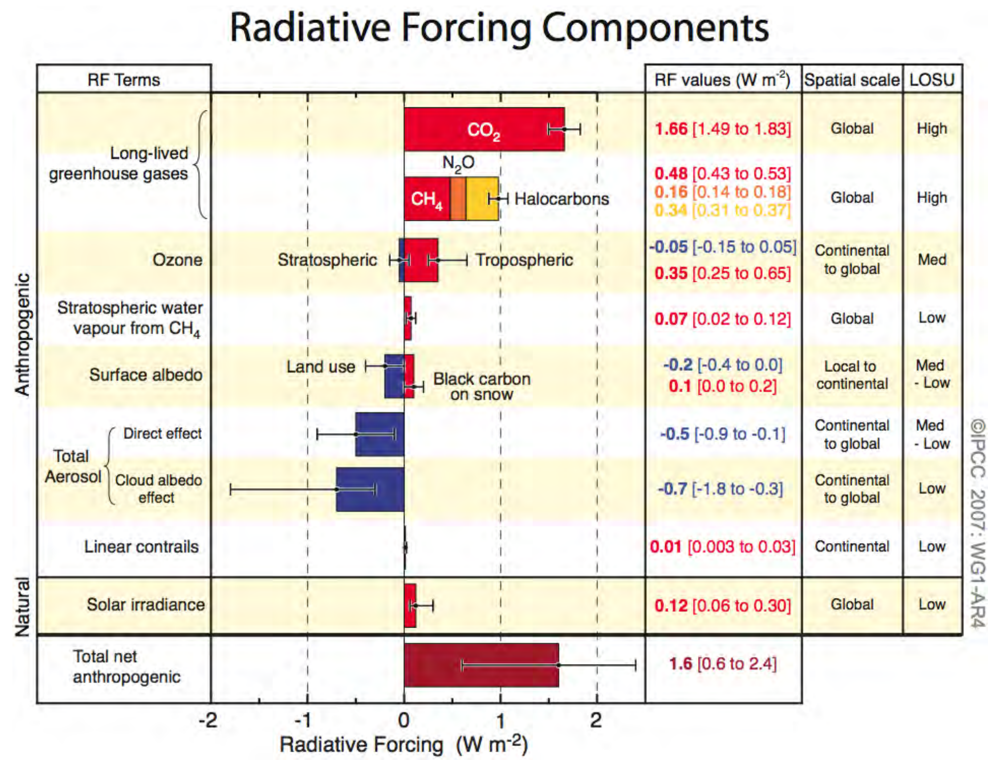
April 2nd, 2009

Outline

- Briefly discuss why we built this instrument
- Show schematics of instrument design
- Validation via Intercomparison
- Experimental Plan
- Results

Motivation

- Aerosol optical and physical properties are highly variable both in time and space, and more accurate information is needed.
- Aerosols form mixtures as different types interact. These mixtures take on different optical properties than those of the originating species.
- Current commercially-available instruments for optical property measurements have inherent biases and involve considerable corrections (eg. Bond et al. 1999 PSAP correction, truncation errors in TSI Nephelometers).
- Optical properties reported as ground concentrations or total column amounts are only telling part of the story.

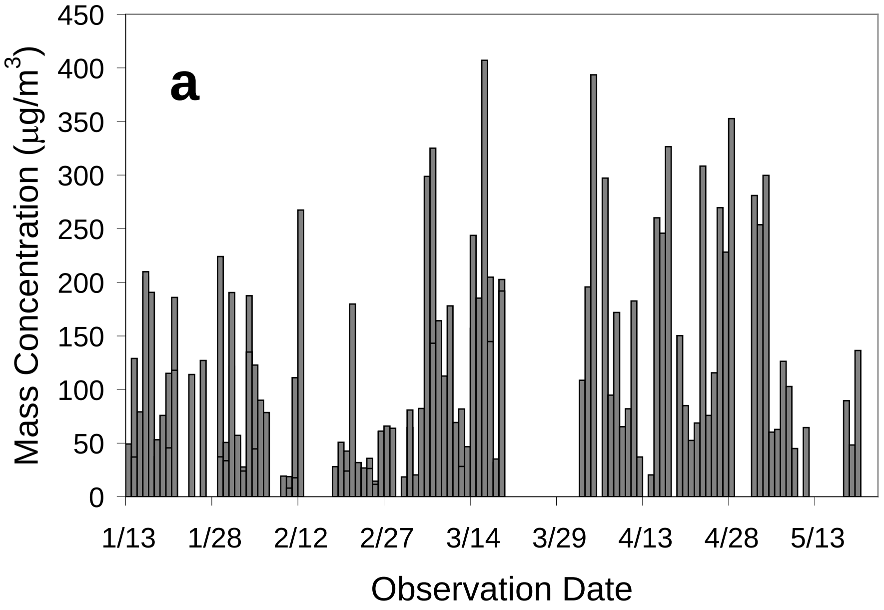


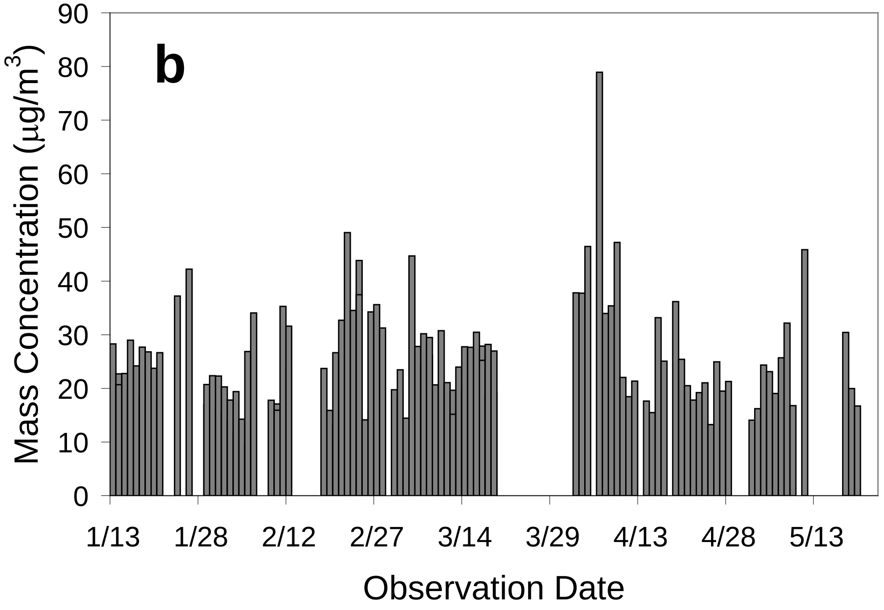
IPCC, 2007

Methodology for EAST-AIRE 2005

Ground-based Aerosol Sampling

- A simple sampling apparatus collects aerosols in 2 size bins, coarse mode (2.5 μm < d < 10 μm) and fine mode (d < 2.5 μm).
- The particles are collected on a smooth polycarbonate substrate, which lends well to optical measurements and chemical speciation.
- The filters are subjected to gravimetric analysis prior to and after field deployment.
- Blank filters are prepared and sent with sampling filters to monitor any contamination, and used to correct for surface reflection in the Optical Reflectance technique.





12-hour mass concentration of:

a) coarse mode particles with aerodynamic diameter 2.5mm < d < 10mm

b) fine mode particles with d < 2.5mm

From EAST-AIRE 2005

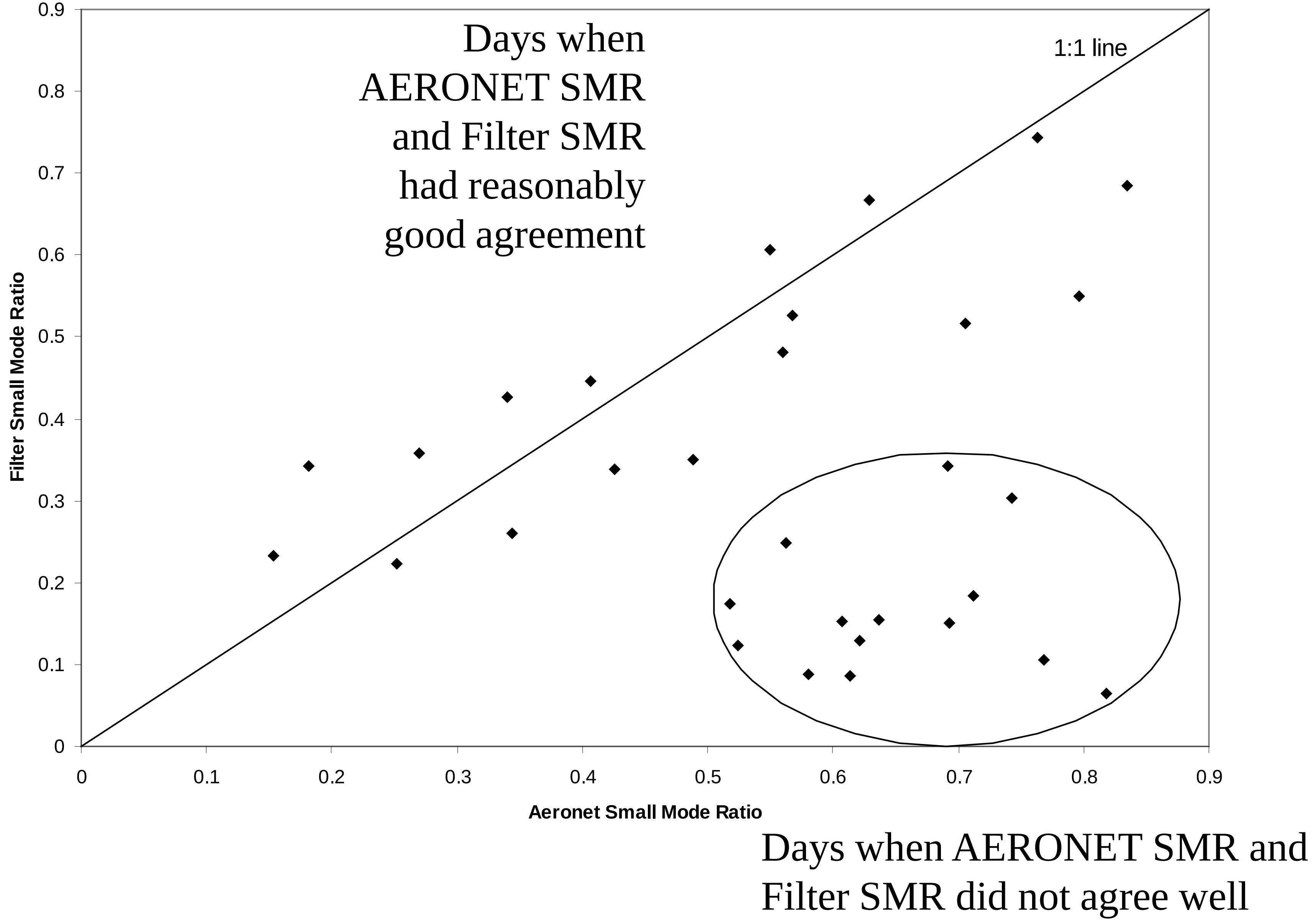
From Chaudhry et al., 2007

Comparison of Mass Concentration as a Proxy for Size Distribution to AERONET

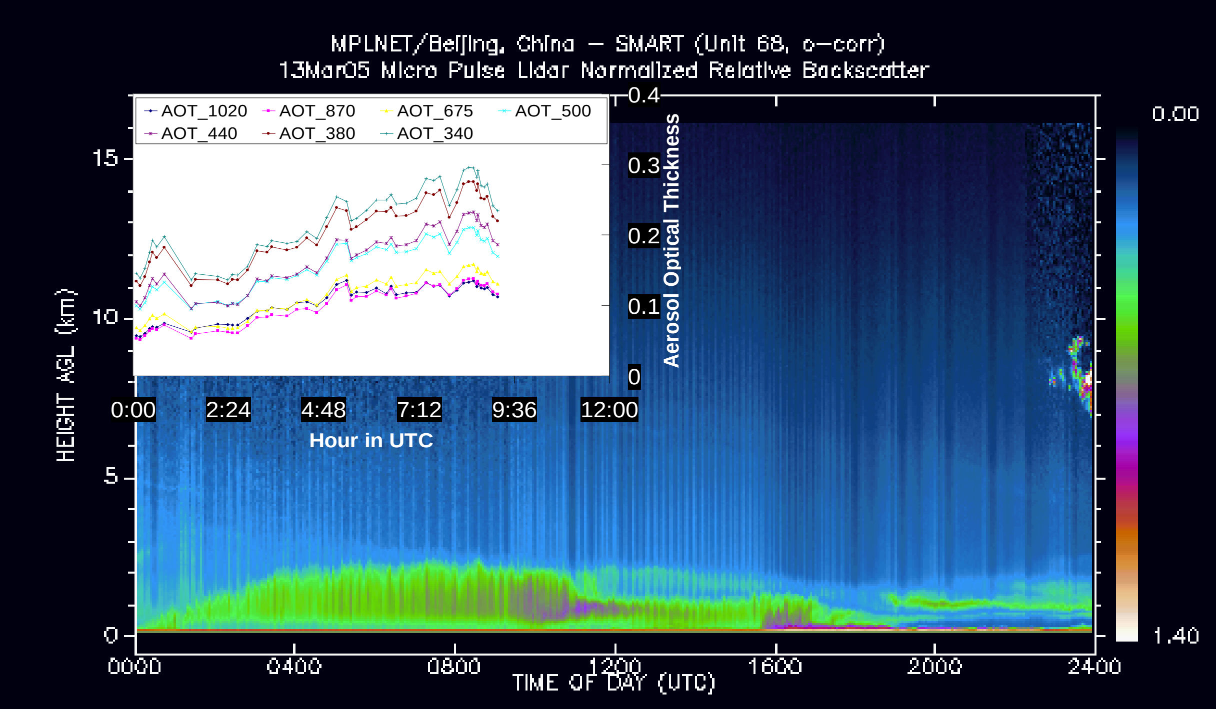
Use co-located AERONET sunphotometer size distribution data to calculate a Small Mode Ratio (SMR)

SMR from Filters = (mass of fine)/(mass of fine + coarse)

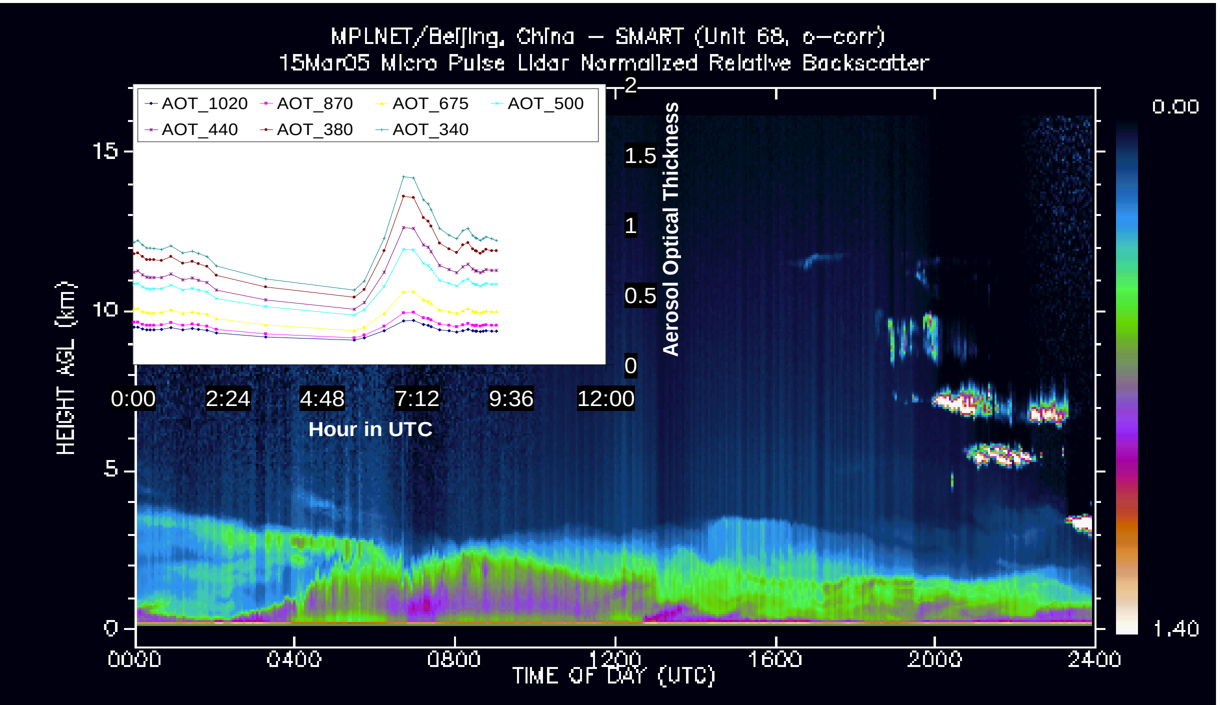
SMR from AERONET = integrated the size distribution of the fine particles, up to 2.24μm, integrated the size distribution of the coarse mode, all particles larger than 2.24μm, then divided fine by total



From Chaudhry et al., 2007



March 13th: a relatively homogenous boundary layer

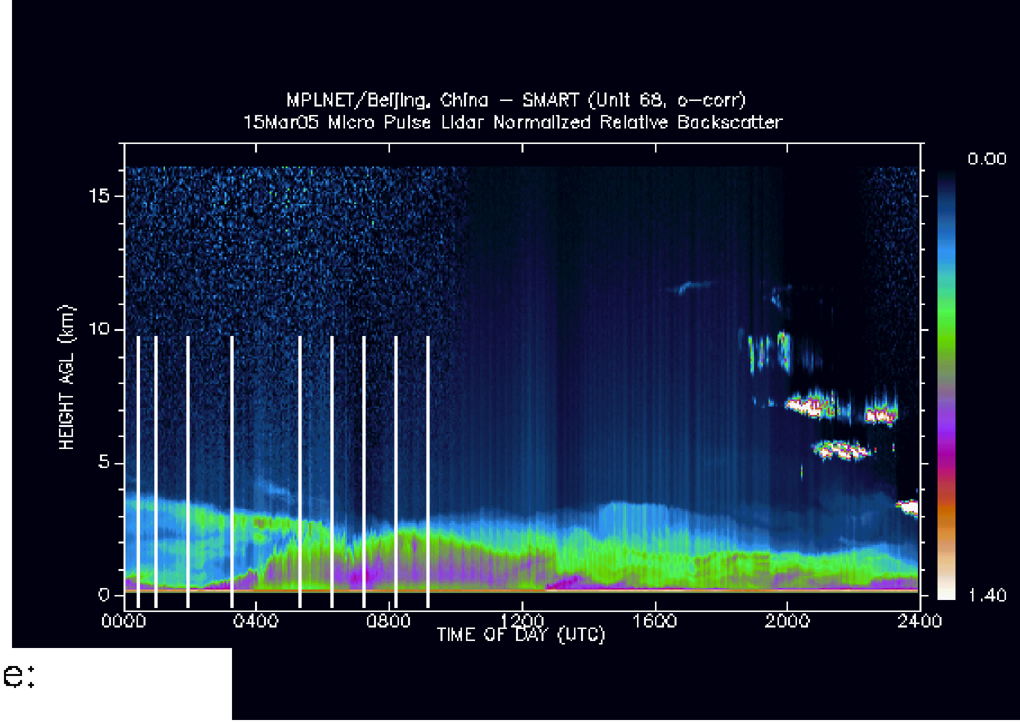


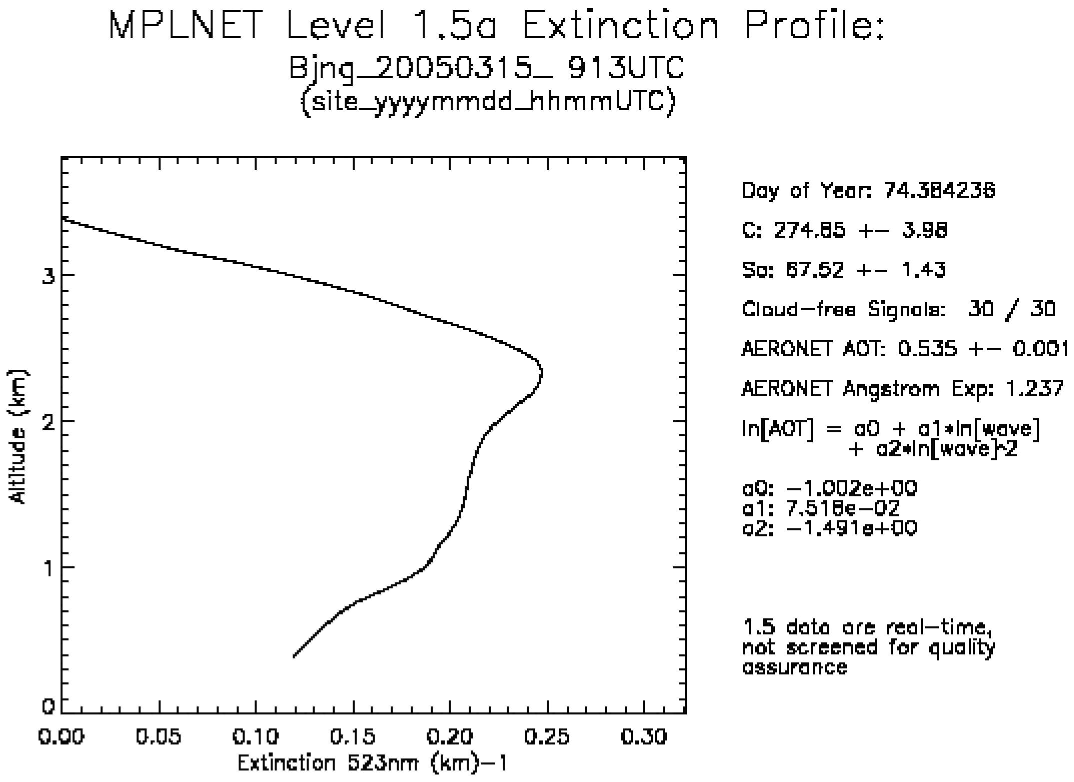
March 15th: a more complex boundary layer with overnight residual

From Chaudhry et al., 2007

Extinction Profile from MPLnet

March 15th, 2005
Xianghe, China

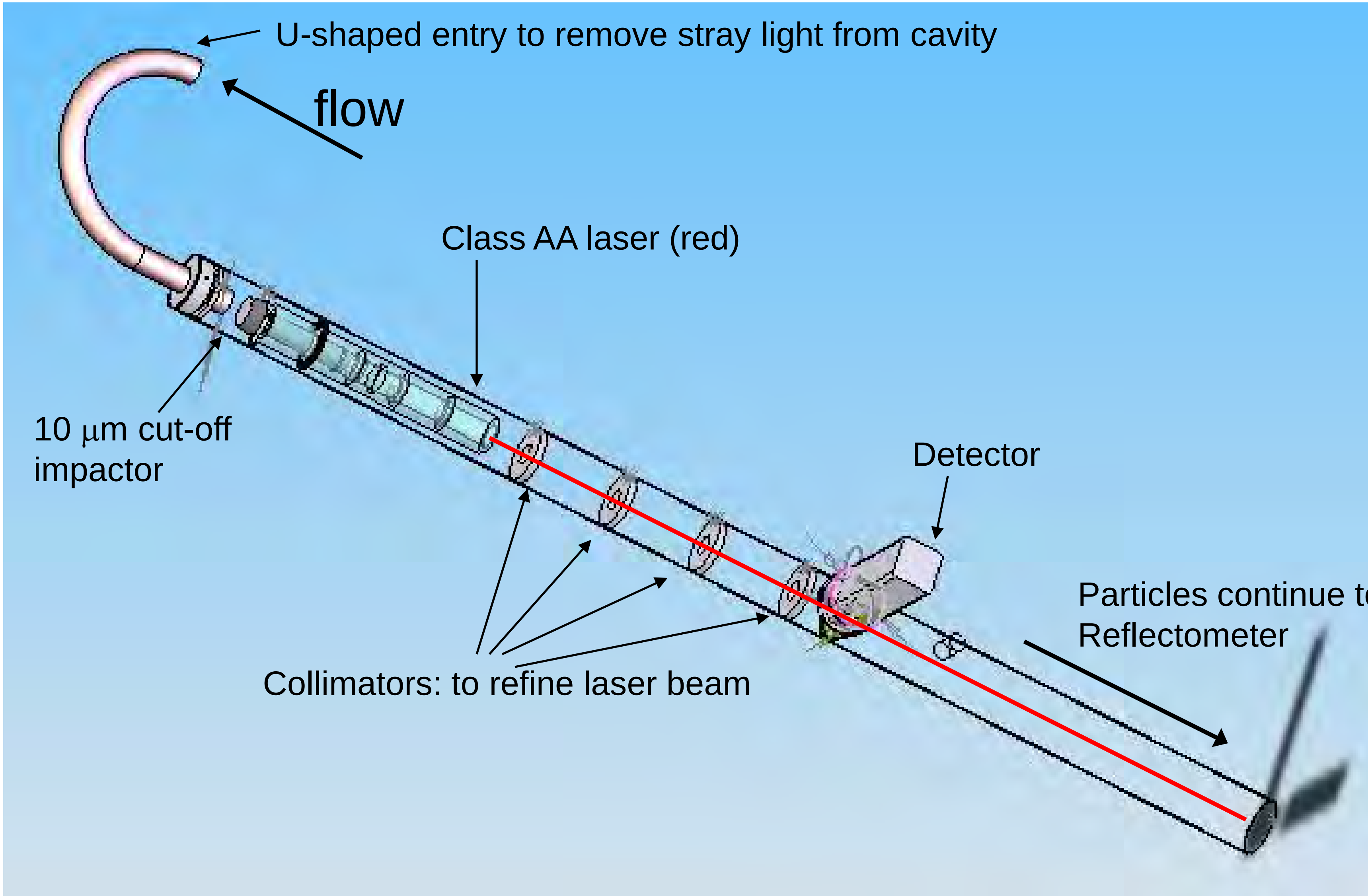




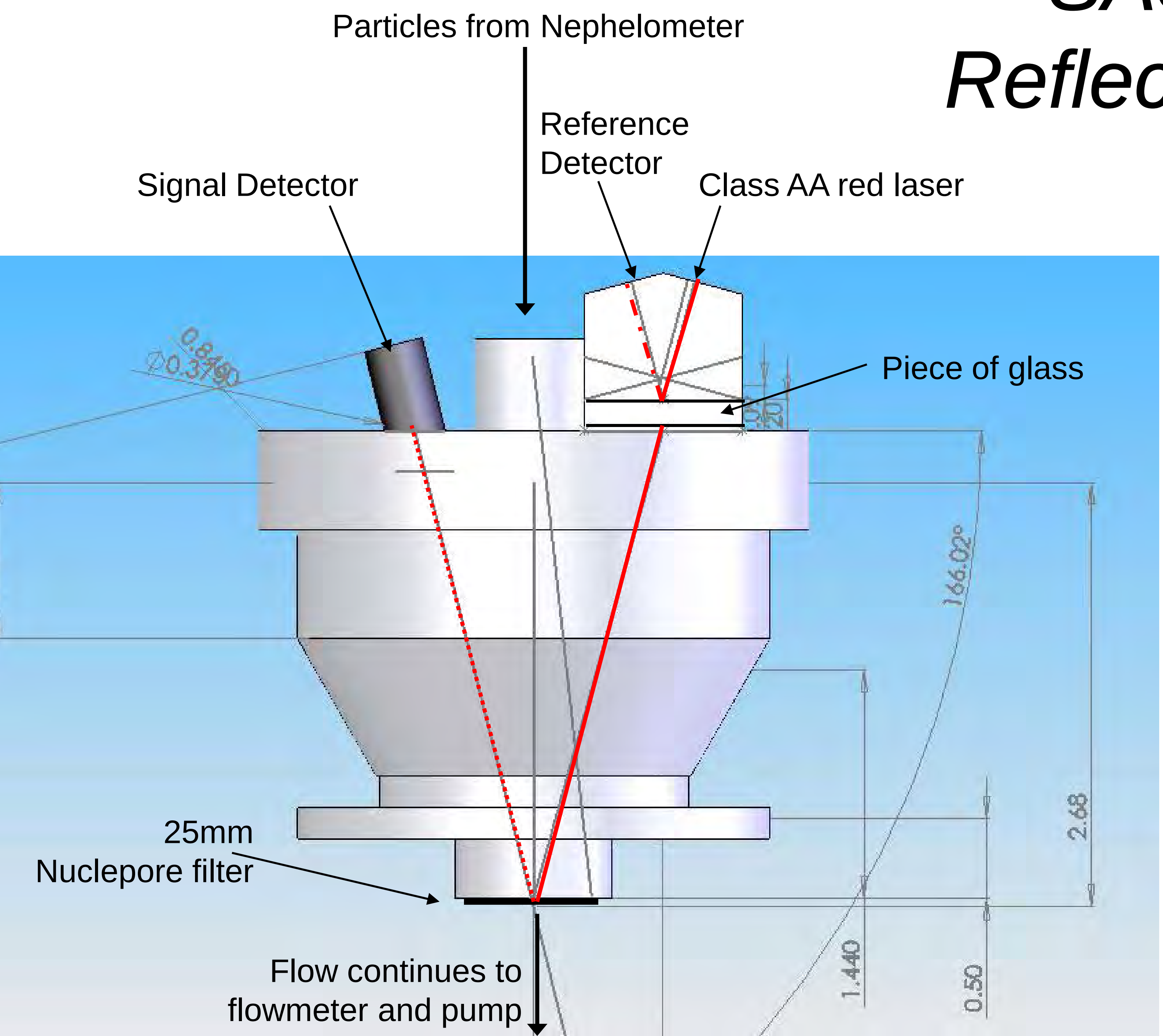
Experiment Objective

To examine the vertical profile of extinction by launching a “scattering and absorption sonde” and modeling how the optical properties of aerosol layers in the atmosphere affect atmospheric stability.

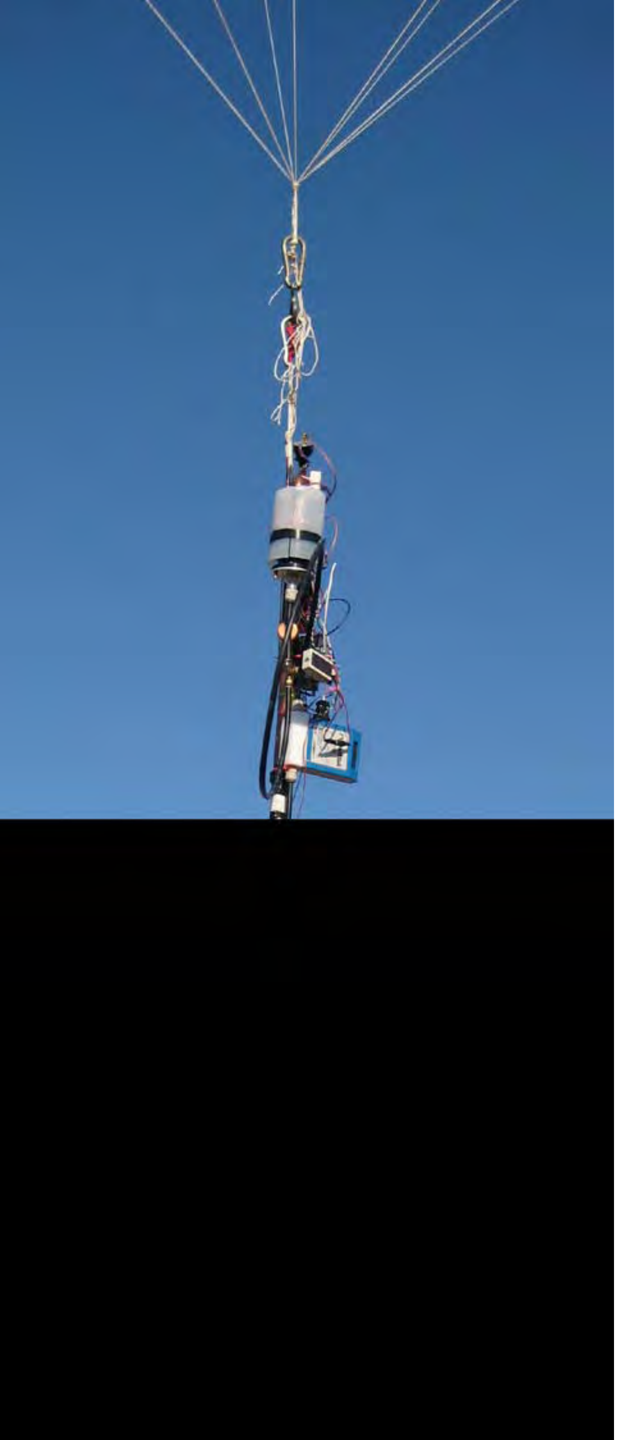
SAS Part I
Inverse Nephelometer



SAS Part II Reflectometer



From Concept to Prototype:

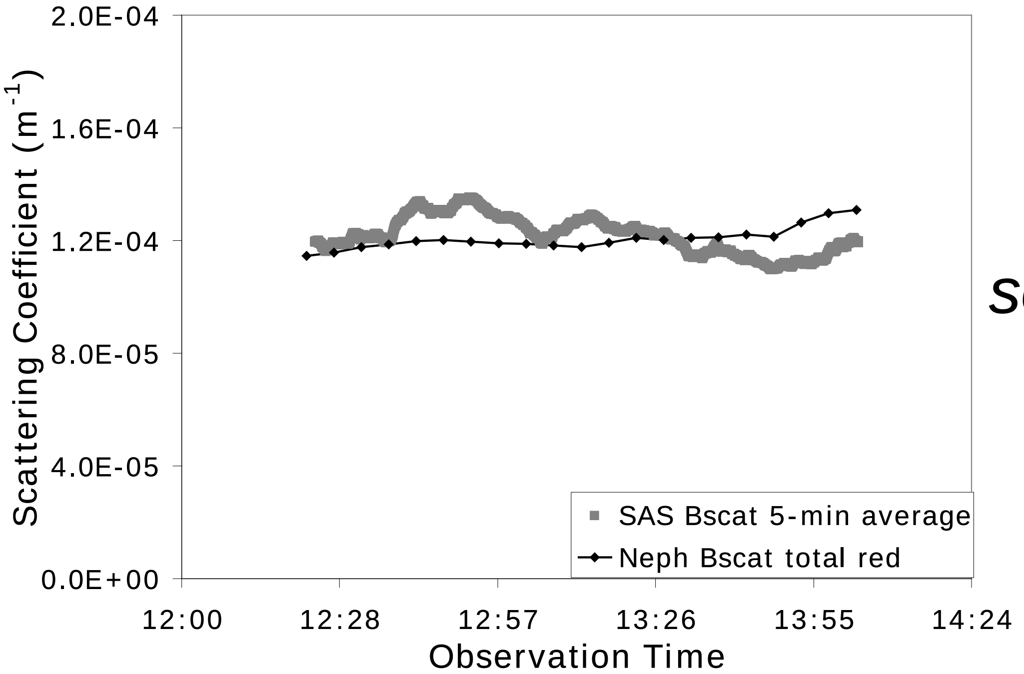


SAS in action

	β_{scat} (m^{-1})
Rayleigh at 595 nm	3.94 E -05
Rayleigh-T/P corrected	3.69 E -05
SAS with HEPA	3.79 E -05

Comparison of the SAS scattering coefficient with theoretical Rayleigh scattering--

Agreement within 2%!



Intercomparison of the SAS scattering coefficient with a TSI Nephelometer in Zhangye

Experiment Plan

EXPERIMENT 1

- Xianghe, Hebei Province
- IAP-UMD Joint Lab
- Max altitude: 450m
- Launches:
  - March 19, am
  - March 19, pm
  - March 26th, pm
  - March 27th, am
  - March 27th, pm

EXPERIMENT 2

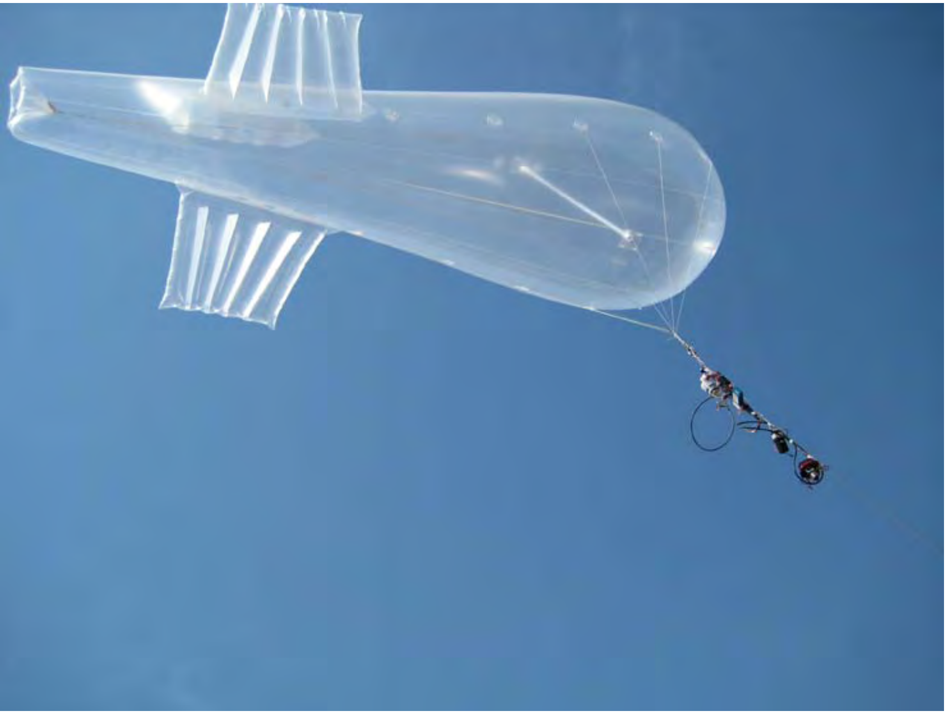
- Zhangye, Gansu Province
- Co-located with NASA SMART/COMMIT trailers
- Max altitude: 800m
- Launches:
  - April 14th, pm
  - April 21st, pm
  - April 23rd, am***

*** Launch ended in balloon crashing into a gate, cutting the line and **sending the balloon and instrument off into the wild blue**

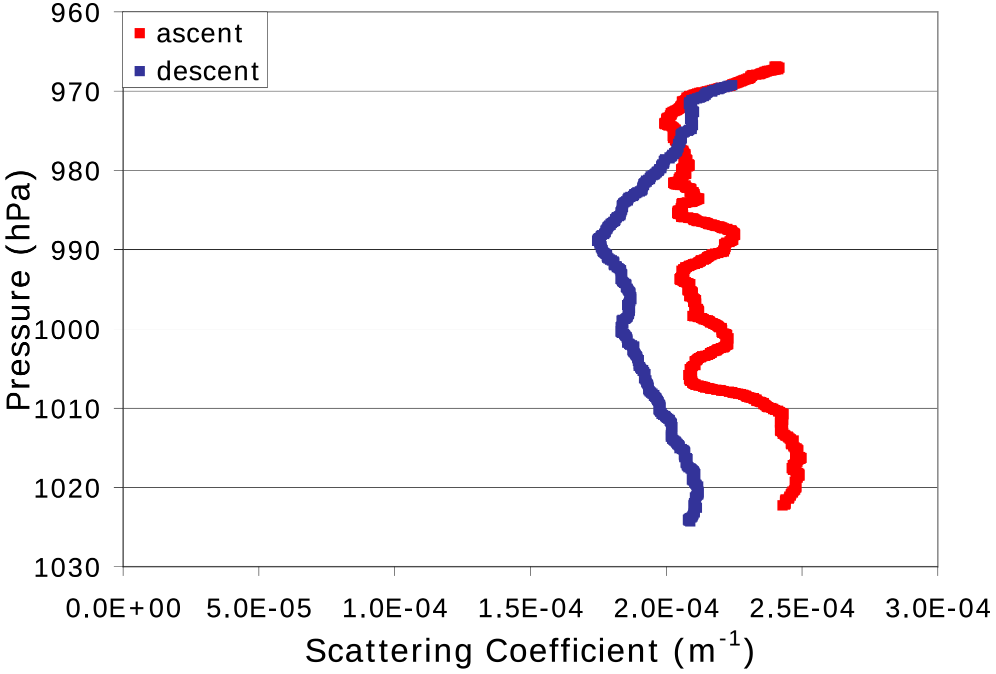

Zhangye
Xianghe
HEILONGJIANG
Harbin
JILIN
Changchun
Shenyang
LIAONING
INNER MONGOLIA A. R.
Urumqi
XINJIANG UYGHUR A. R.
GANSU
NINGXIA
HUI A. R.
Yin-
chuan
Hohhot
TIANJIN
HEBEI
Shijiazhuang
Taiyuan
SHANXI
Jinan
SHAN-
DONG
QINGHAI
Xining
Lanzhou
Xi'an
SHAANXI
Zhengzhou
HENAN
JIANG-
SU
Nan-
jing
Hefei
ANHUI
TIBET A. R.
Lhasa
SICHUAN
Chengdu
CHONGQING
HUBEI
Wuhan
Hangzhou
ZHE-
JIANG
Nanchang
Changsha
HUNAN
JIANGXI
GUIZHOU
Guiyang
Fuzhou
FUJIAN
Kunming
YUNNAN
GUANGXI
ZHUANG A. R.
Nanning
GUANGDONG
Guangzhou
HONG KONG
MACAU
HAINAN
Haikou

Xianghe launch site 360°

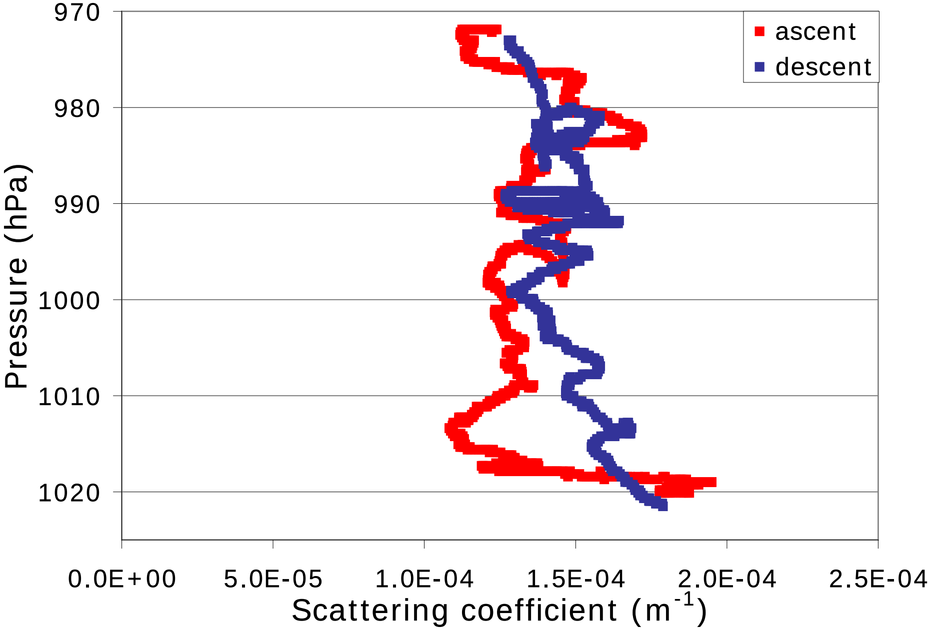
Xianghe launches



SAS Scattering Profiles

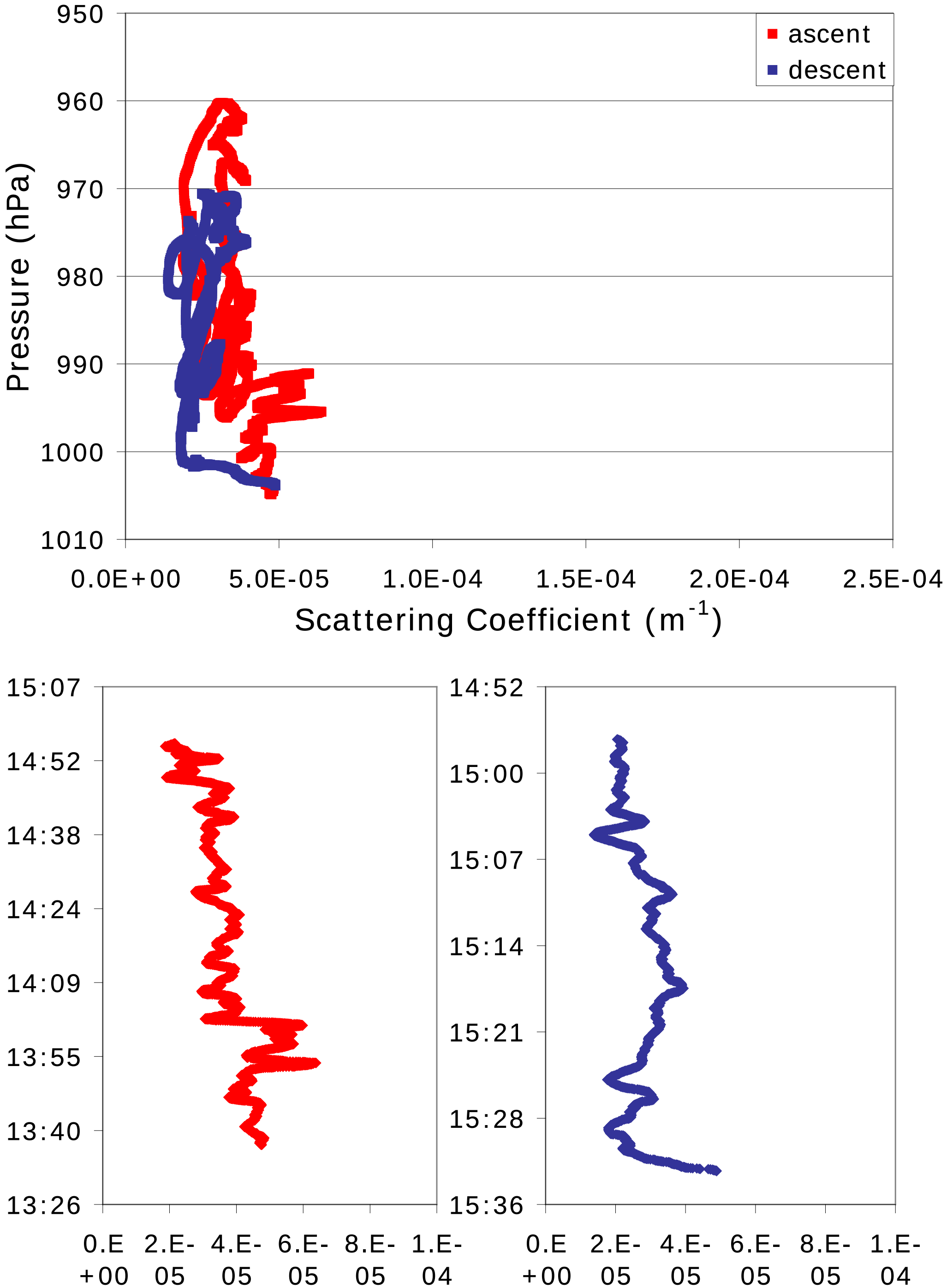


March 19th, morning launch



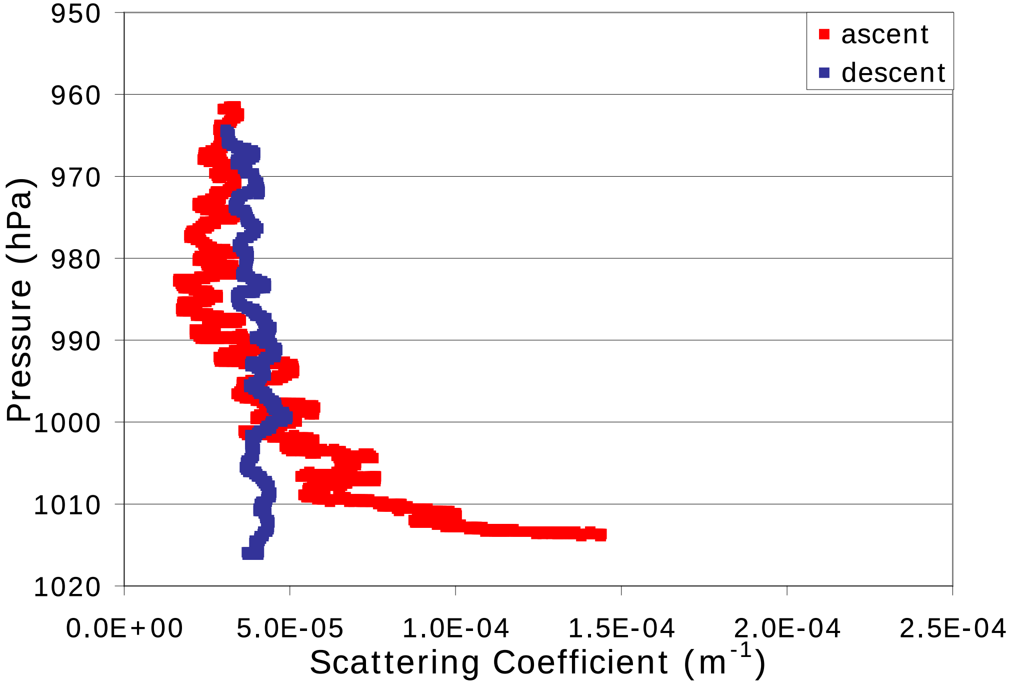
March 19th, afternoon launch

SAS Scattering Profiles

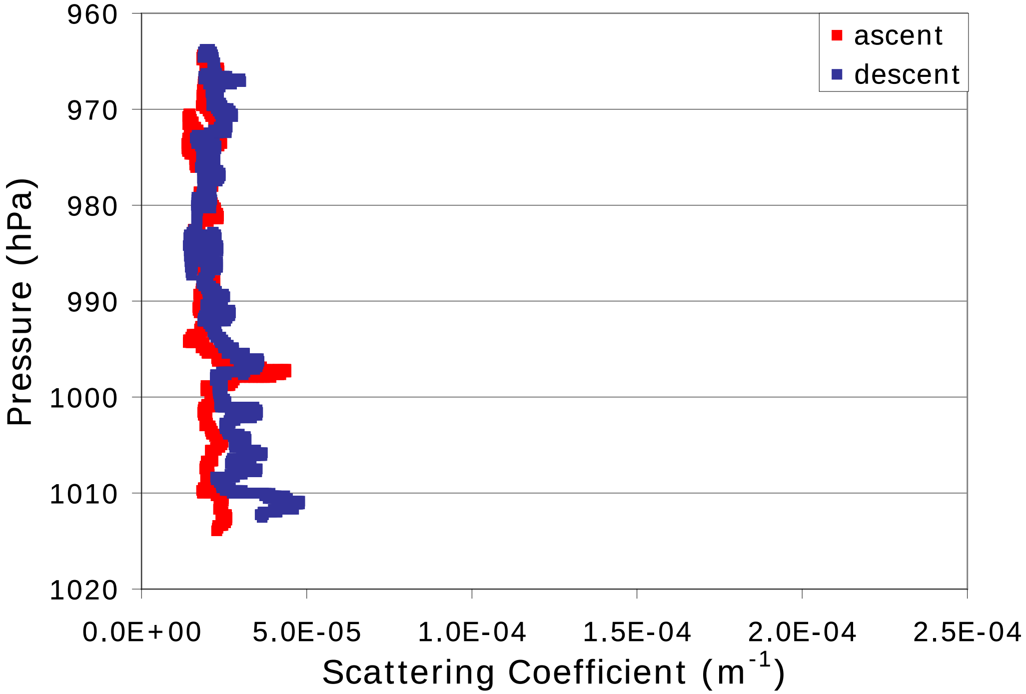


March 26th, afternoon launch

SAS Scattering Profiles



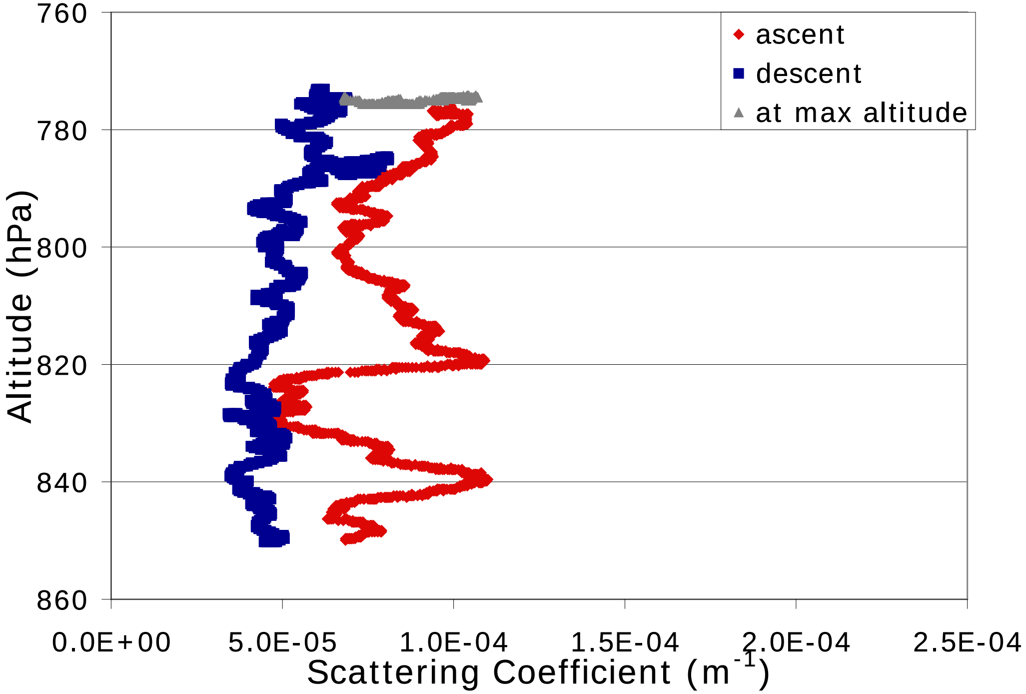
March 27th, morning launch



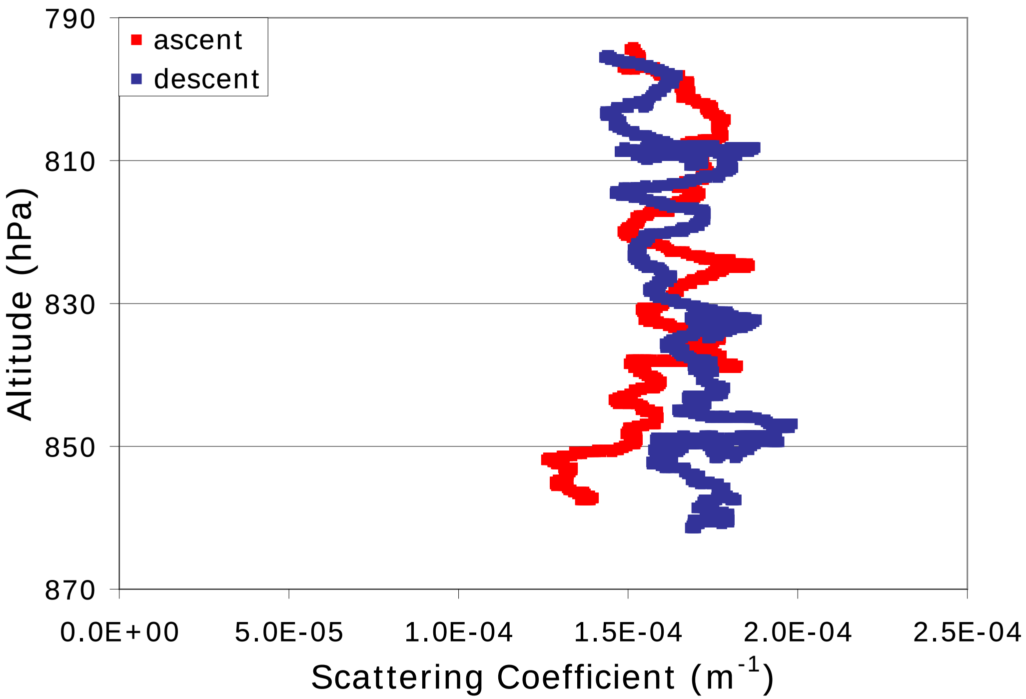
March 27th, afternoon launch

Zhangye measurement site

SAS Scattering Profiles



April 14th, afternoon launch



April 21st, afternoon launch

Conclusions

- In cases where aerosol are well-mixed through the column, ground-based instruments are able to represent well the total column aerosol loading. When aerosols are not well-mixed, more information is needed on where the aerosols are located.
- Balloon-borne instruments have the advantage of measuring closer to the ground than lidar in measuring vertical profiles of aerosol optical properties.
- The Inverse Nephelometer on the SAS, through intercomparison, was determined to measure β_{scat} within an acceptable range of uncertainty, and was able to discern numerous aerosol layers when launched in China.

Future Work

- The scattering profiles can be used in a radiative transfer model to calculate the heating rate based on the strength of the scattering.
- The SAS is currently undergoing redesign to improve the resolution of the Reflectometer.

THANK YOU!

References:

Bond, T.C., T.L. Anderson, and D. Campbell (1999), Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols, *Aerosol Sci. Technol*., *30*, 582-600.

Chaudhry, Z., J.V. Martins, Z. Li, S.-C. Tsay, H. Chen, P. Wang, T. Wen, C. Li and R.R. Dickerson (2007), In situ measurements of aerosol mass concentration and radiative properties in Xianghe, southeast of Beijing, *J. Geophys. Res.*, *112*, D23S90, doi:10.1029/2007JD009055.

Forster, P. et al. (2007), Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007: The Physical Science Basis. Contributions of Working Group I to the Fourth Assessment of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.