Remote sensing of haze aerosol over eastern China

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WG III/8: Remote Sensing of Atmospheric Environment

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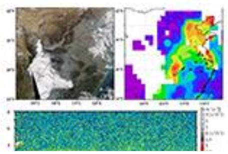

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Terms of Reference:

- Development of satellite observations on atmospheric environment including air pollutants, aerosol and its dynamic process
- Development of new models for estimating atmospheric aerosol optical depth, characteristics and particulate matters (PMs) concentration
- Development of new models for extracting atmospheric parameters through sounders/GPS/LiDAR/radio occultation, etc.
- Development of spatio-temporal methodologies and GIS-based systems for atmospheric environment analysis
- Evaluation and validation of satellite observations on atmospheric components and PMs concentration
- Assessment of the impact of urbanization and fossil energy on atmosphere environment
- Collaborate with GEO to serve for public affairs and human health with data and maps

学科：摄影测量与遥感

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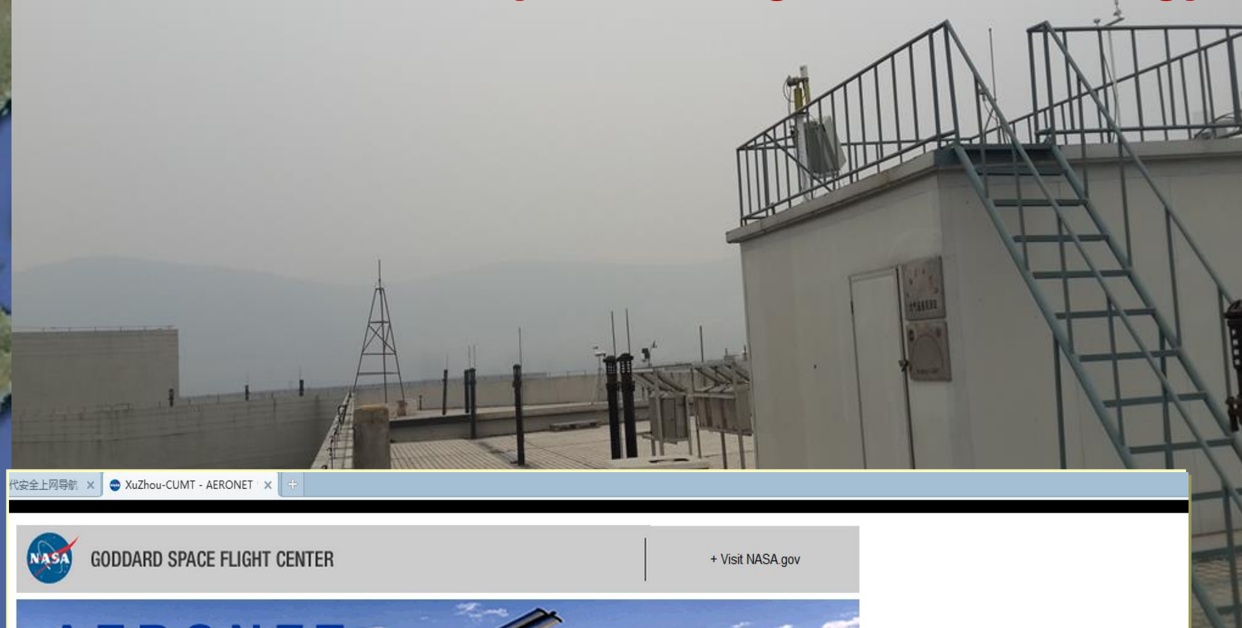

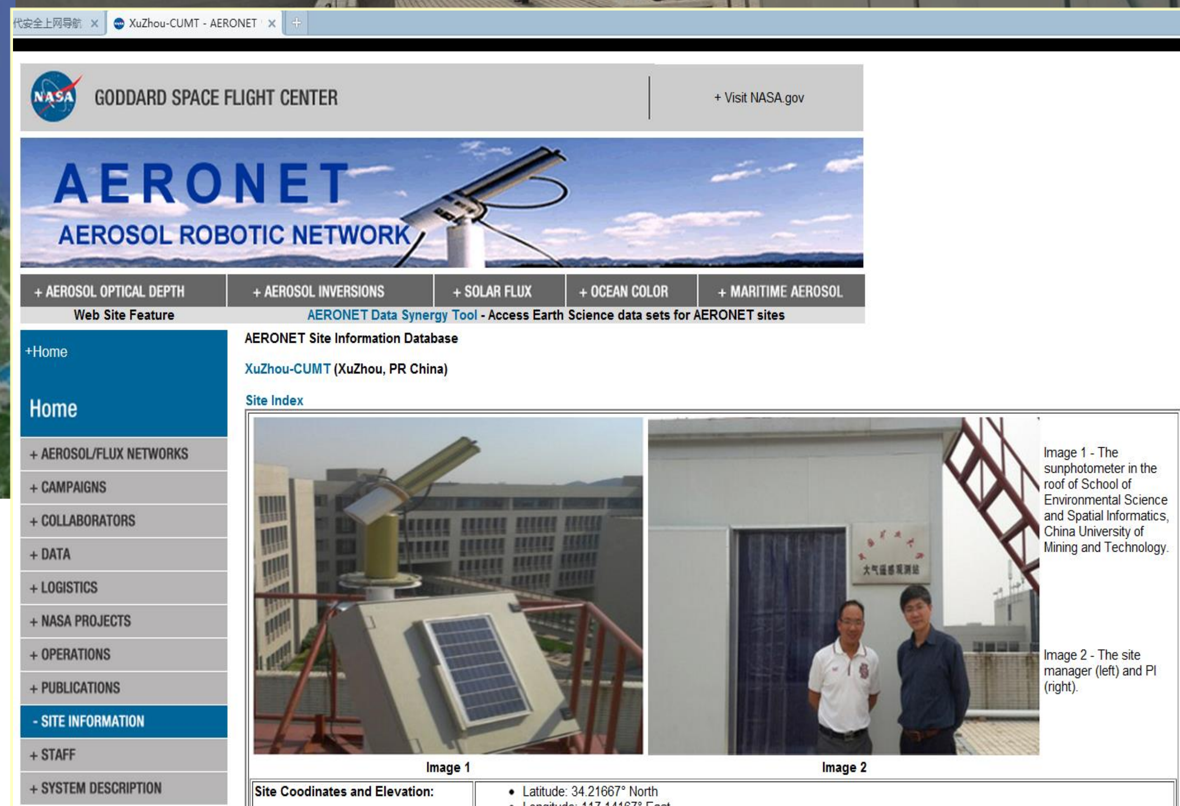

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Part 1

Haze transport revealed by ground LIDAR and CALIPSO satellite

Motivation

The main factors contributing to the formation of recent regional haze in China are:

(a) high secondary aerosol transformation from gaseous pollutants (Huang et al., 2014);

(b) stable weather conditions with weak surface wind, vertical temperature inversion and low planetary boundary layer height (Wang et al., 2014);

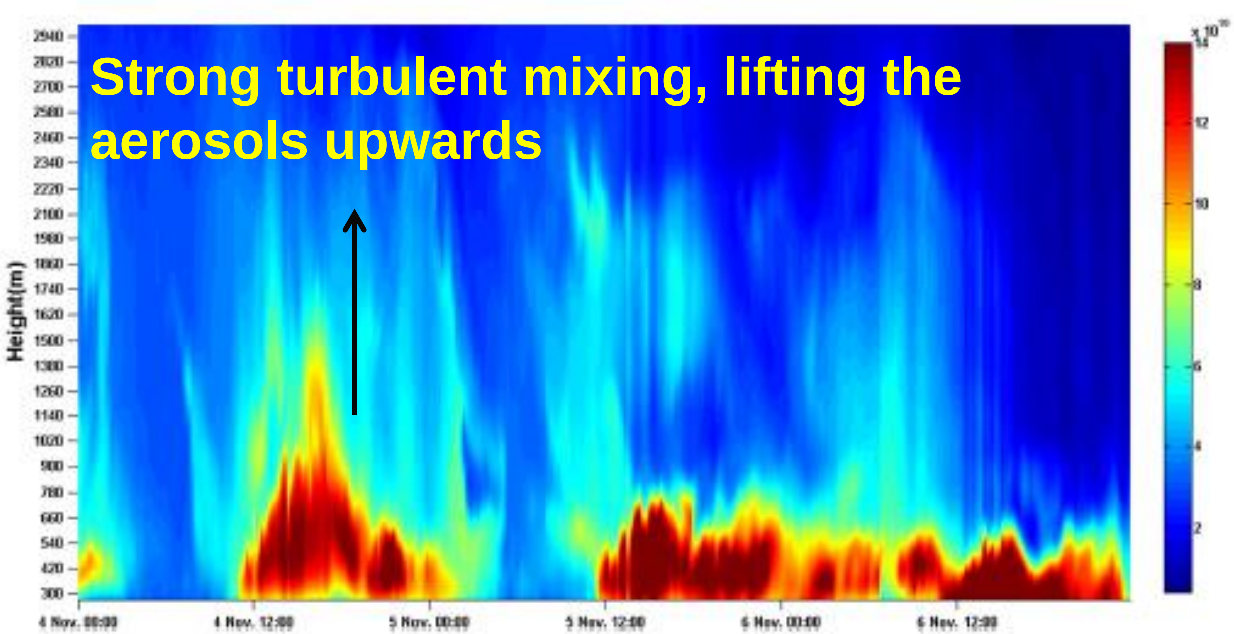
(c) trans-boundary regional transport (Zheng et al., 2015).

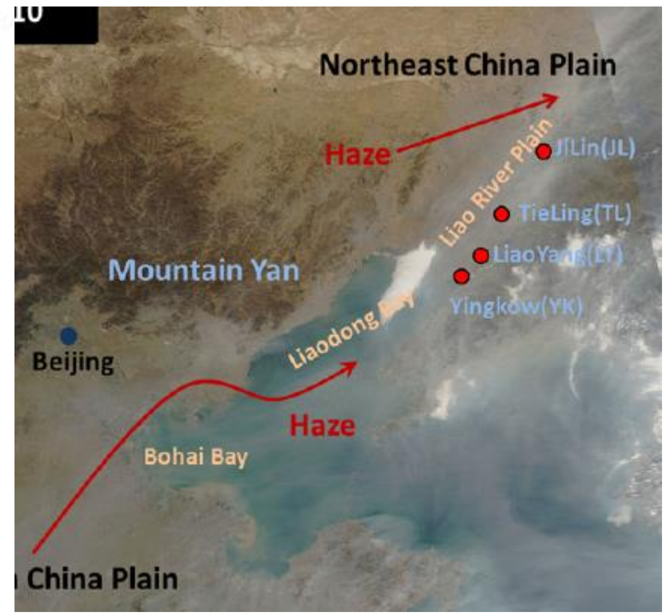
Understanding the haze transport is important for regional joint mitigation of air pollution.

Previous studies relied on air quality models to simulate and evaluate the regional haze movement in China but a few studies were based on direct observations.

Motivation

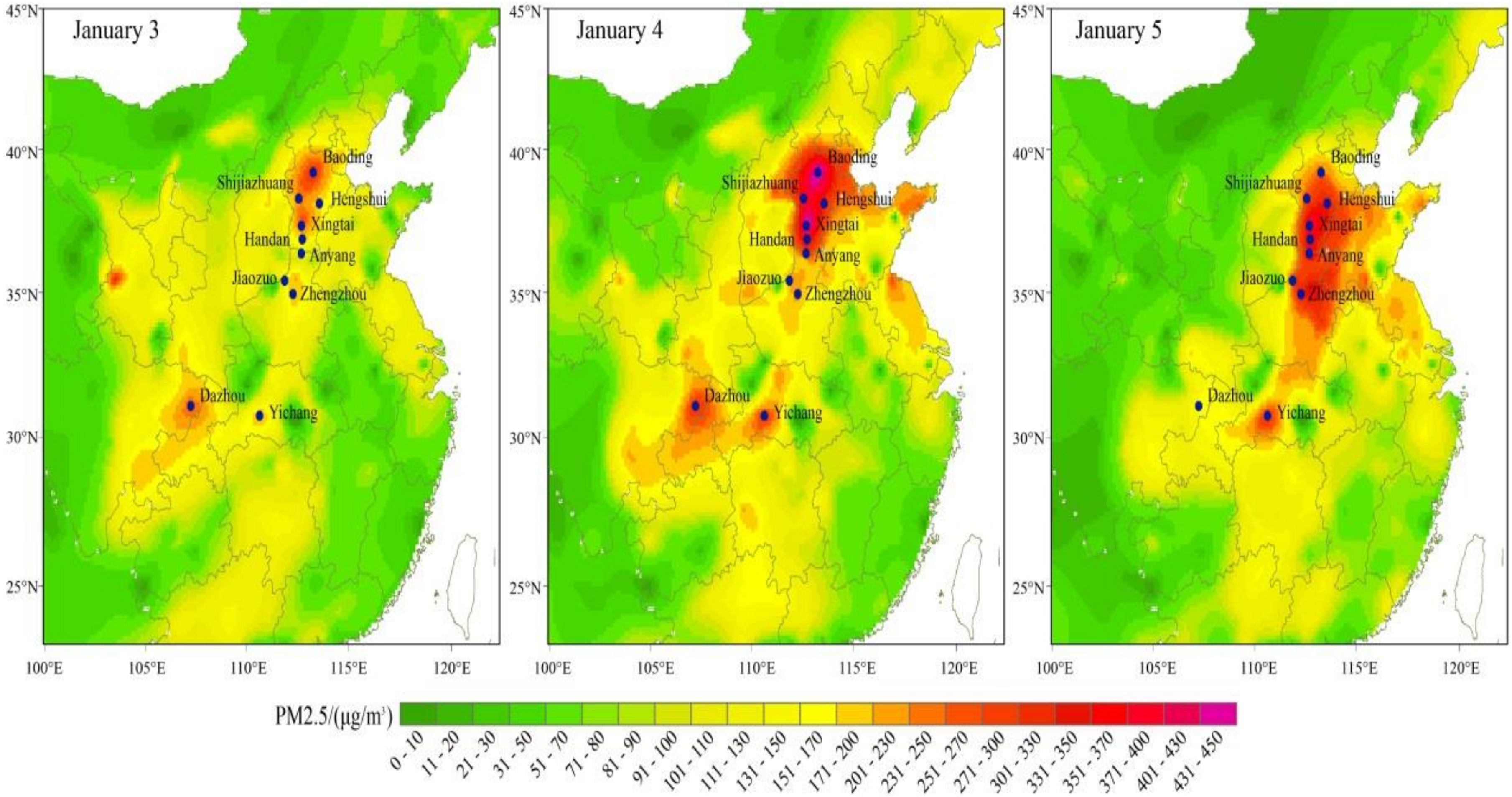
Gravity-Current Driven Transport of Haze from North China Plain to Northeast China in Winter 2010





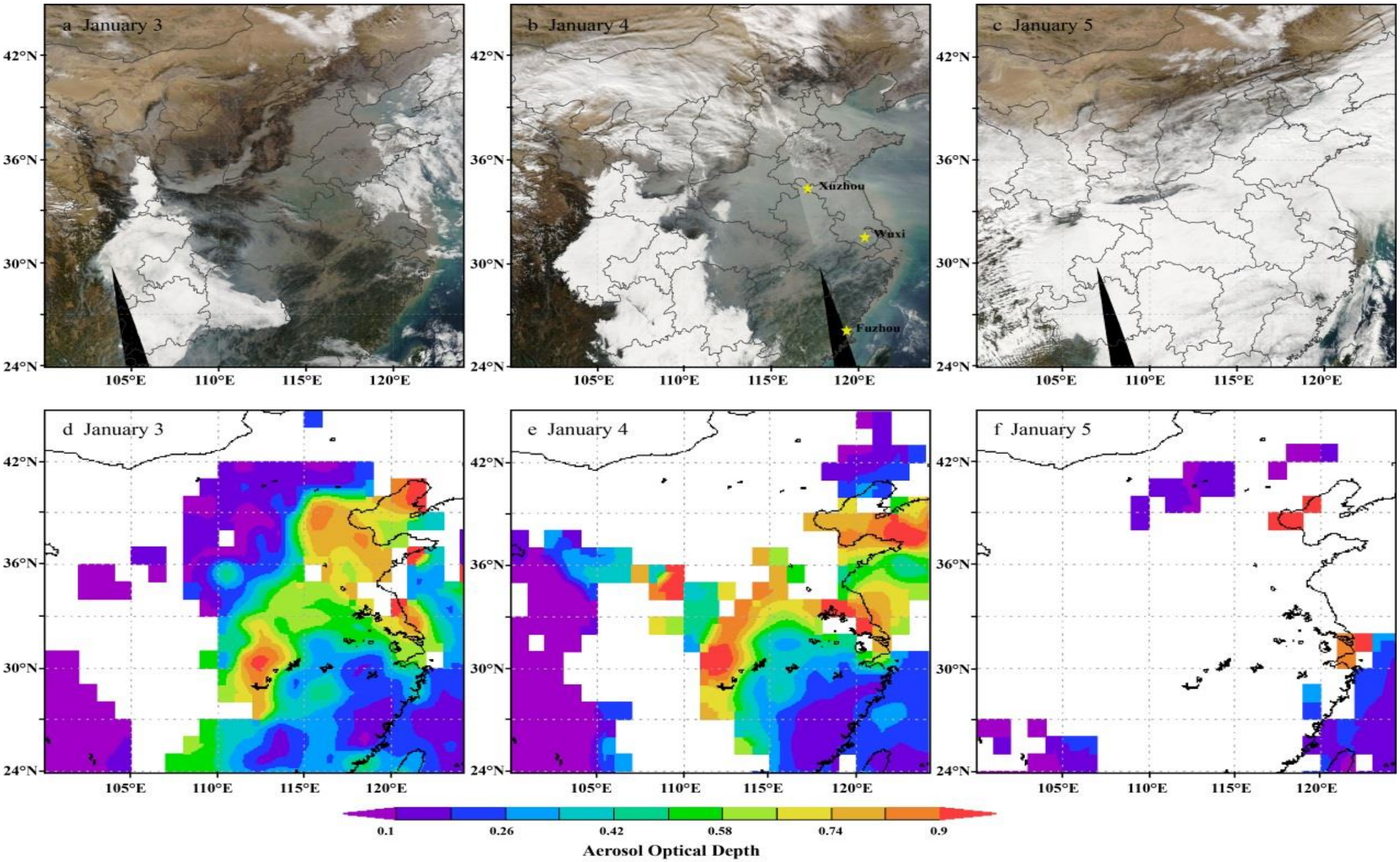
Yang, T., Wang, X., Wang, Z., Sun, Y., Zhang, W., Zhang, B., & Du, Y. (2012). Gravity-current driven transport of haze from North China Plain to Northeast China in winter 2010-Part I: observations. Sola, 8(0), 13-16.

A typical winter haze in China in January 2015



Spatial interpolation of daily $PM_{2.5}$ of 367 cities in central and eastern China

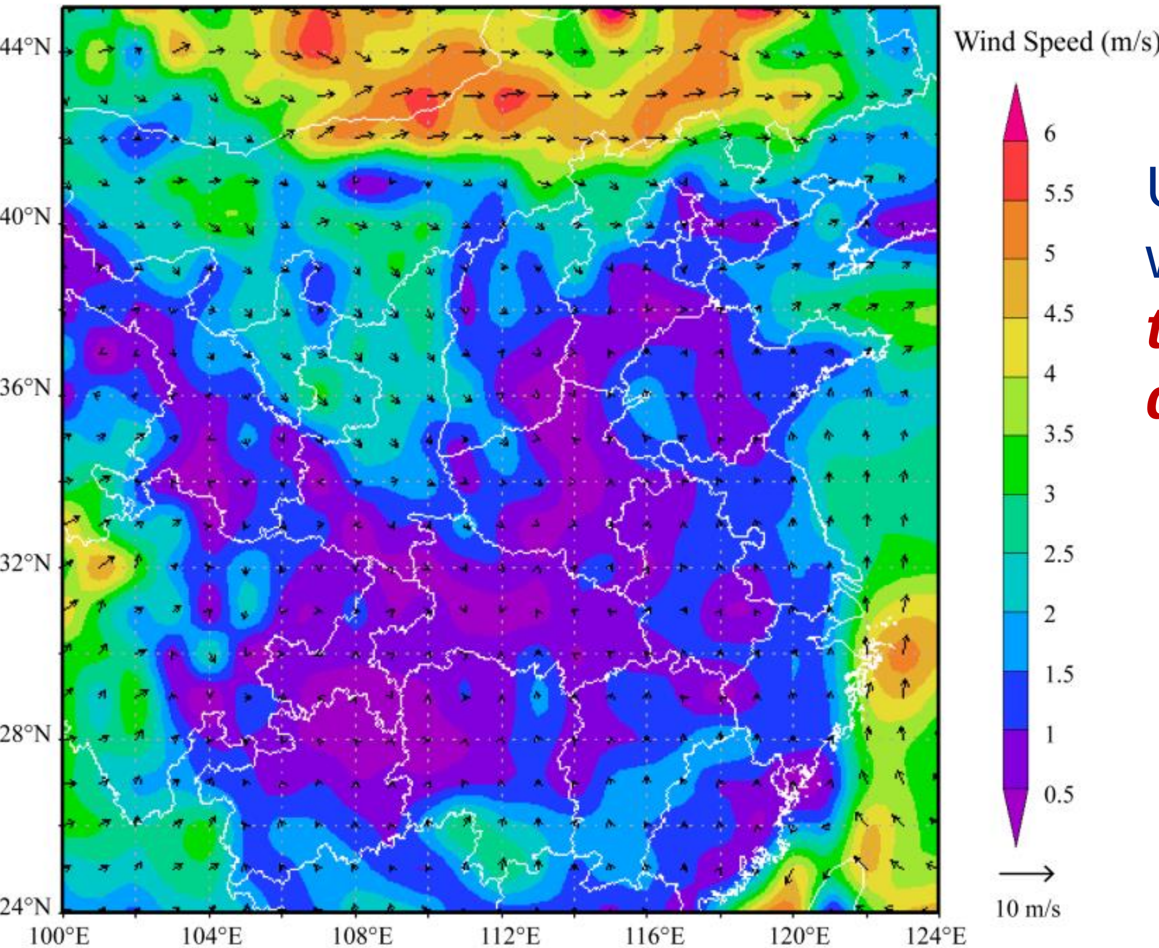
A typical winter haze in China in January 2015



Aqua MODIS true color images and AOD

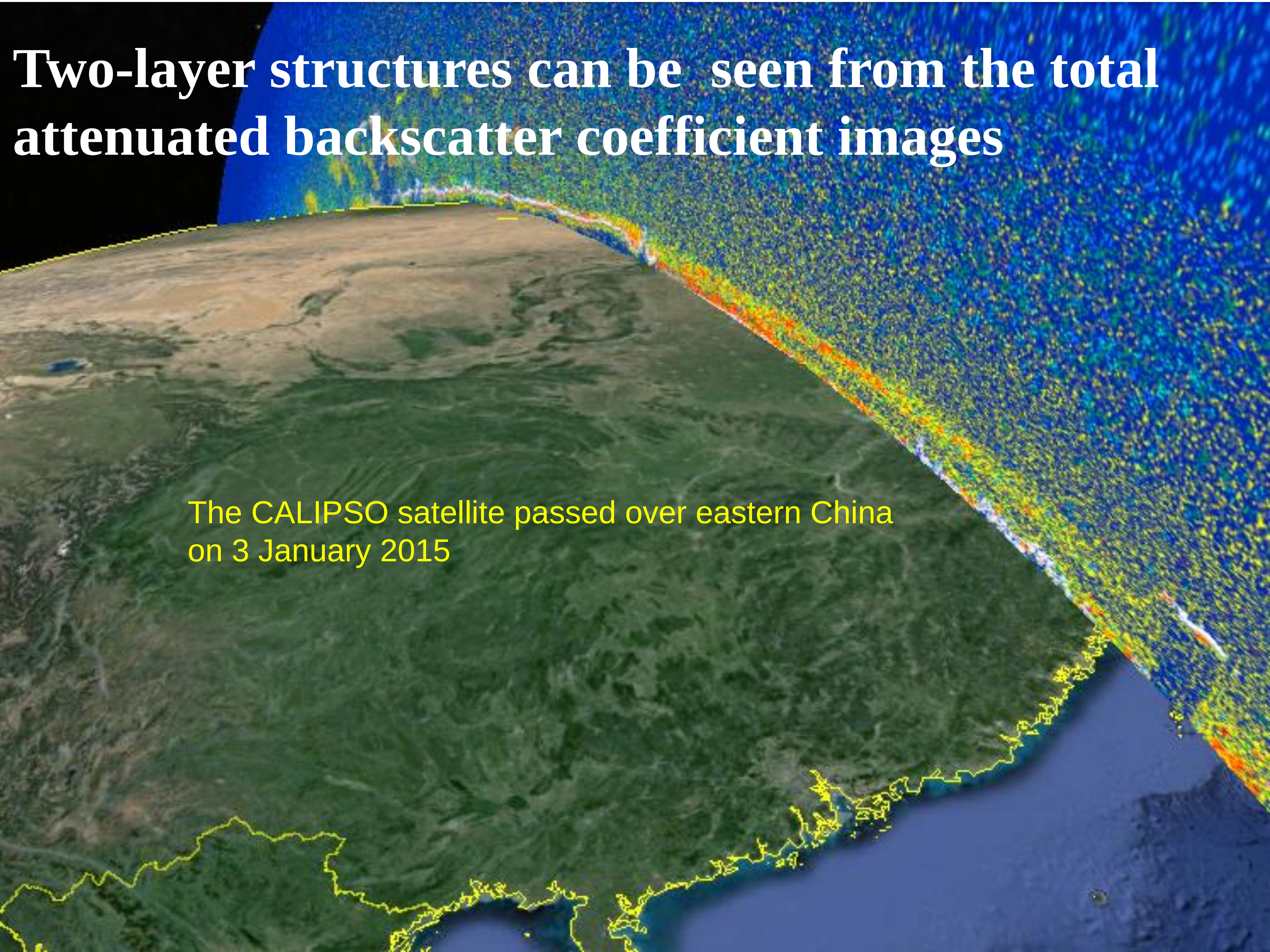
Weak ground wind

The average surface wind speeds from NCEP data were very weak (less than 1 ms^{-1}) in most of the regions with haze, probably leading to the accumulation of surface pollutants

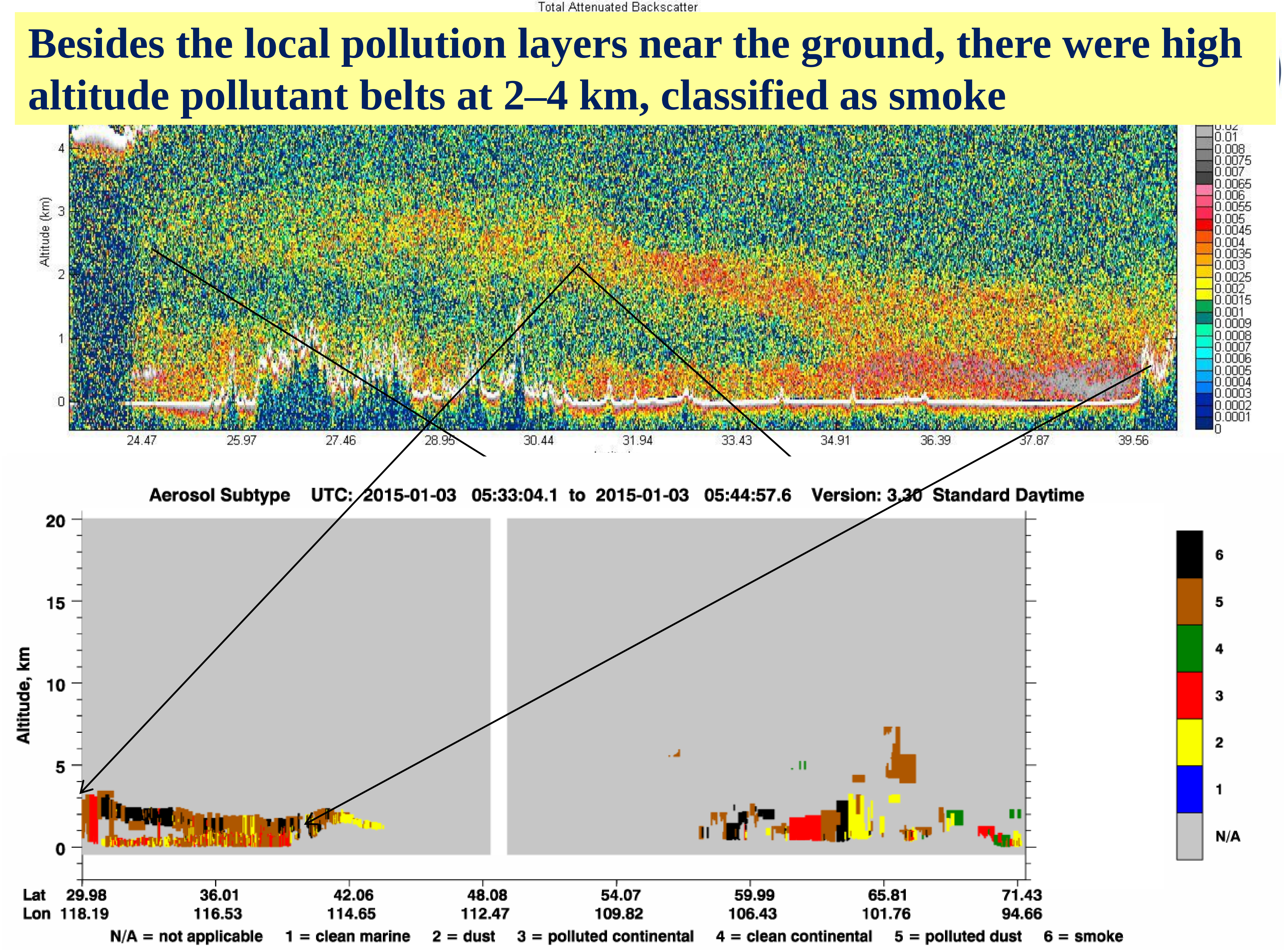


Under the stable surface weather condition, ***are there aerosol transport during this haze episode?***

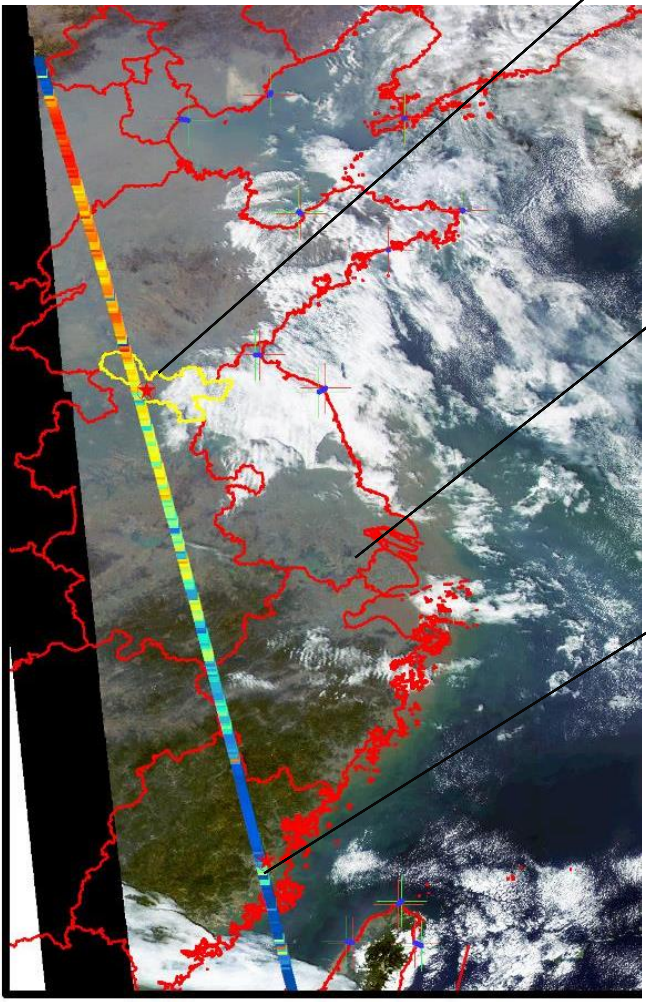
Two-layer structures can be seen from the total attenuated backscatter coefficient images

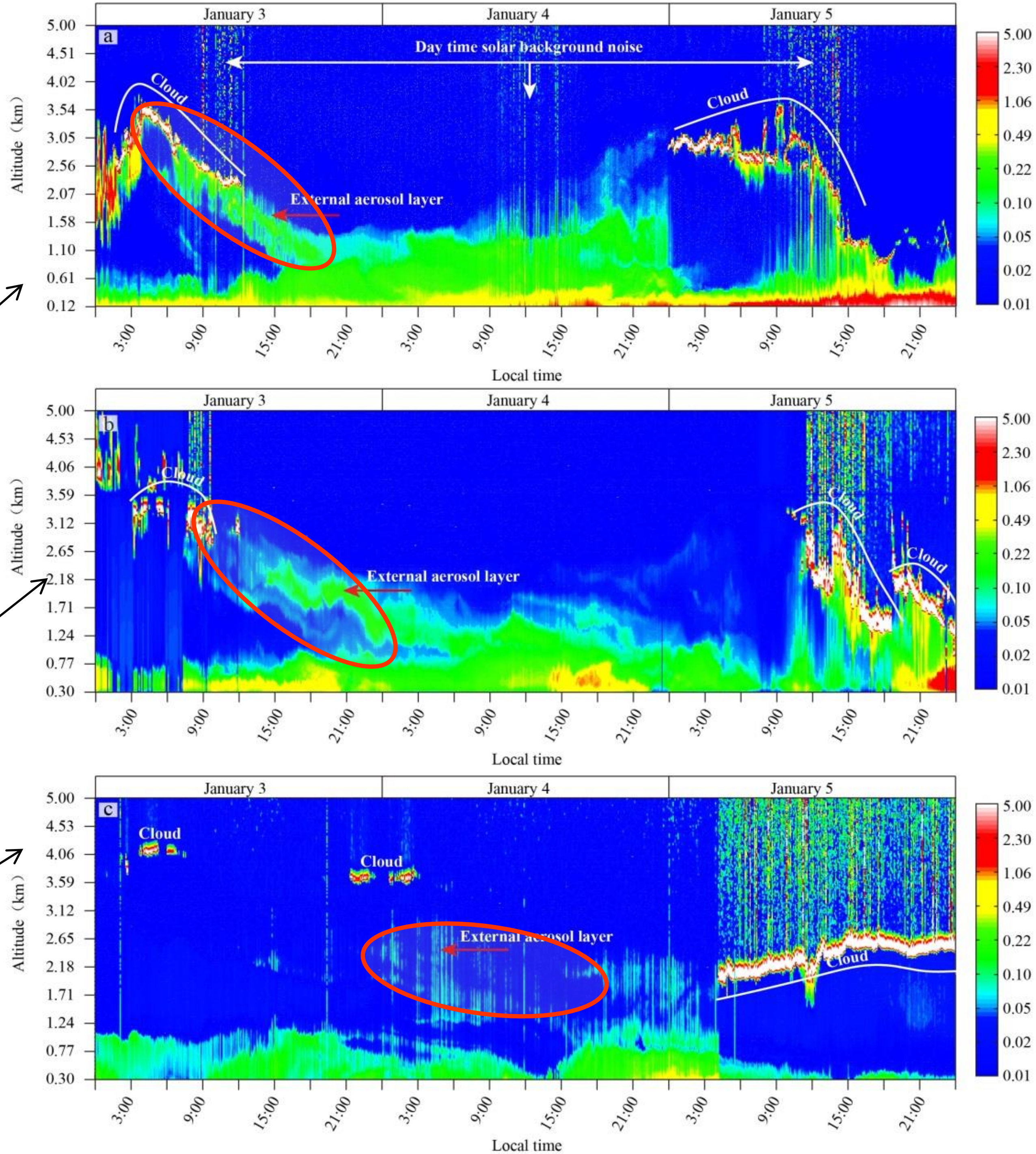


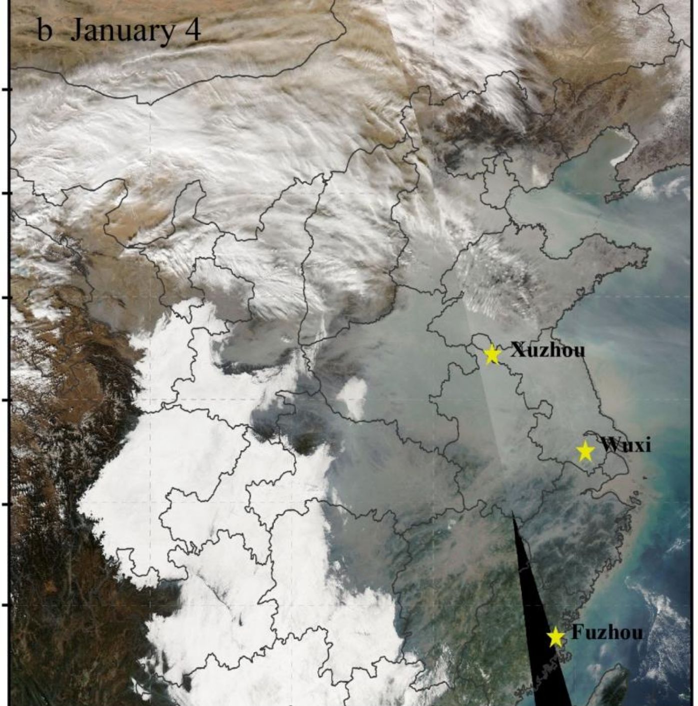
Besides the local pollution layers near the ground, there were high altitude pollutant belts at 2–4 km, classified as smoke



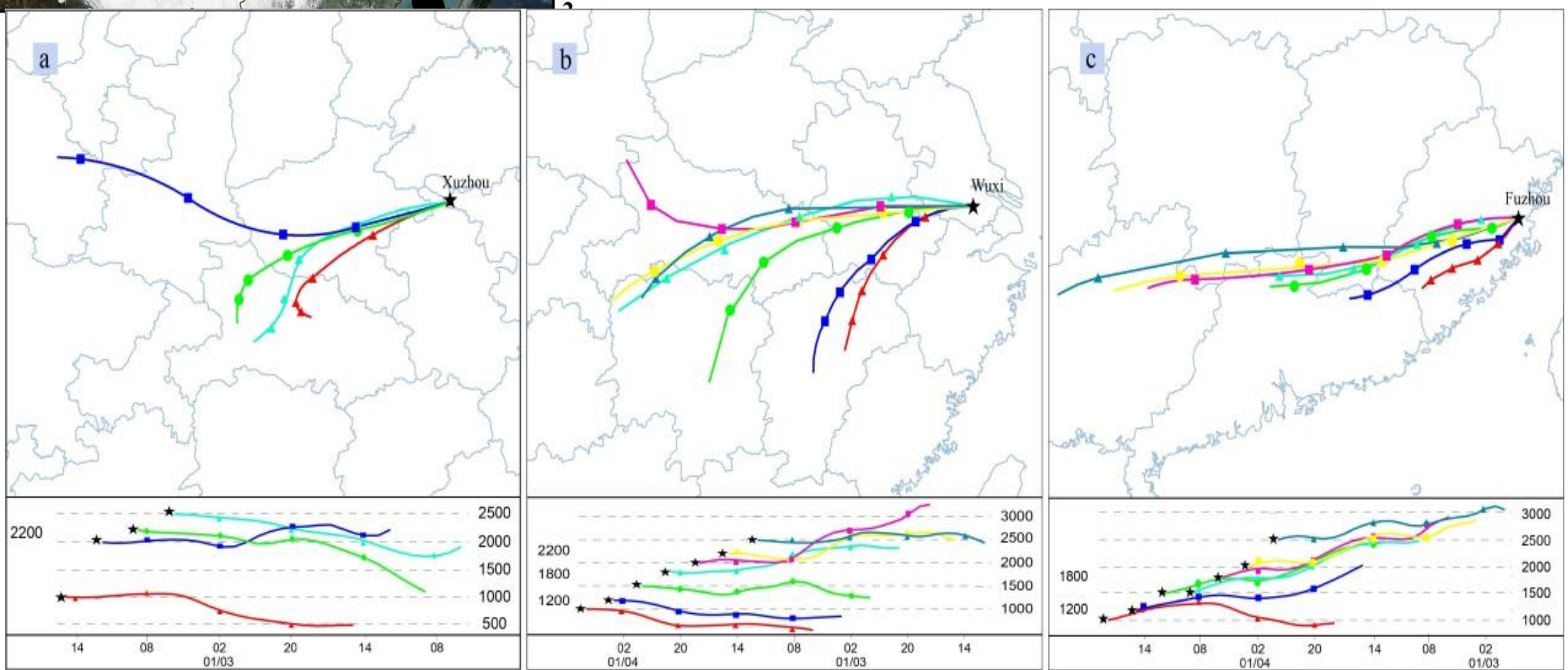
Similar episodes of external aerosol passing through and into the area were seen by ground LIDAR in three cities in eastern China



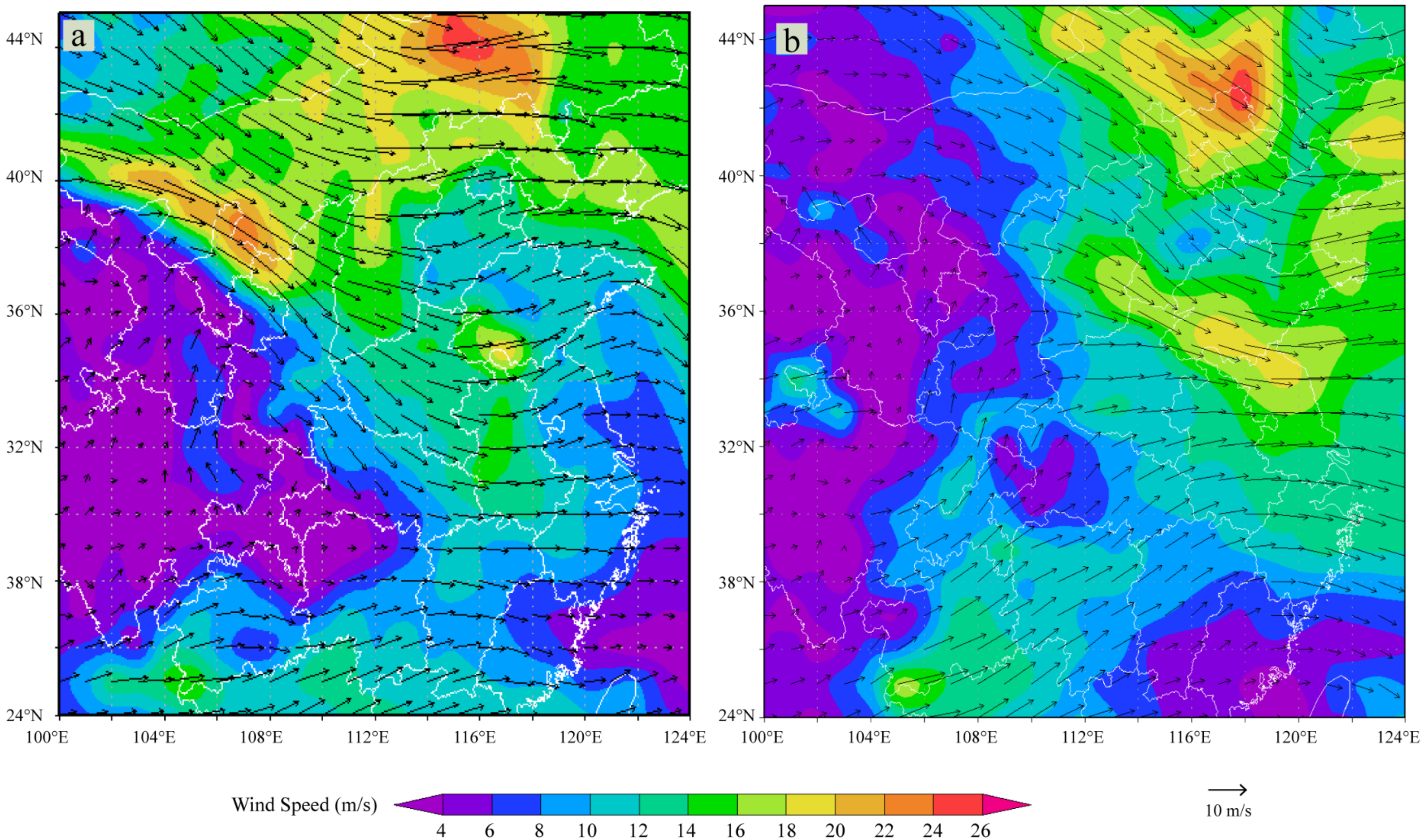




The backward trajectories terminating at Xuzhou and Wuxi show the airflows passed through severely polluted regions in central China, While terminating at Fuzhou the airflows passed through slightly polluted regions.



The high altitude wind fields (700 and 750 hPa) at 2:00am on 3 January show north-westerly prevailed in most polluted provinces, which favours the transport of pollutants from Hebei and Henan to Shandong and from Henan and Hubei by way of Anhui to Jiangsu.



Summary

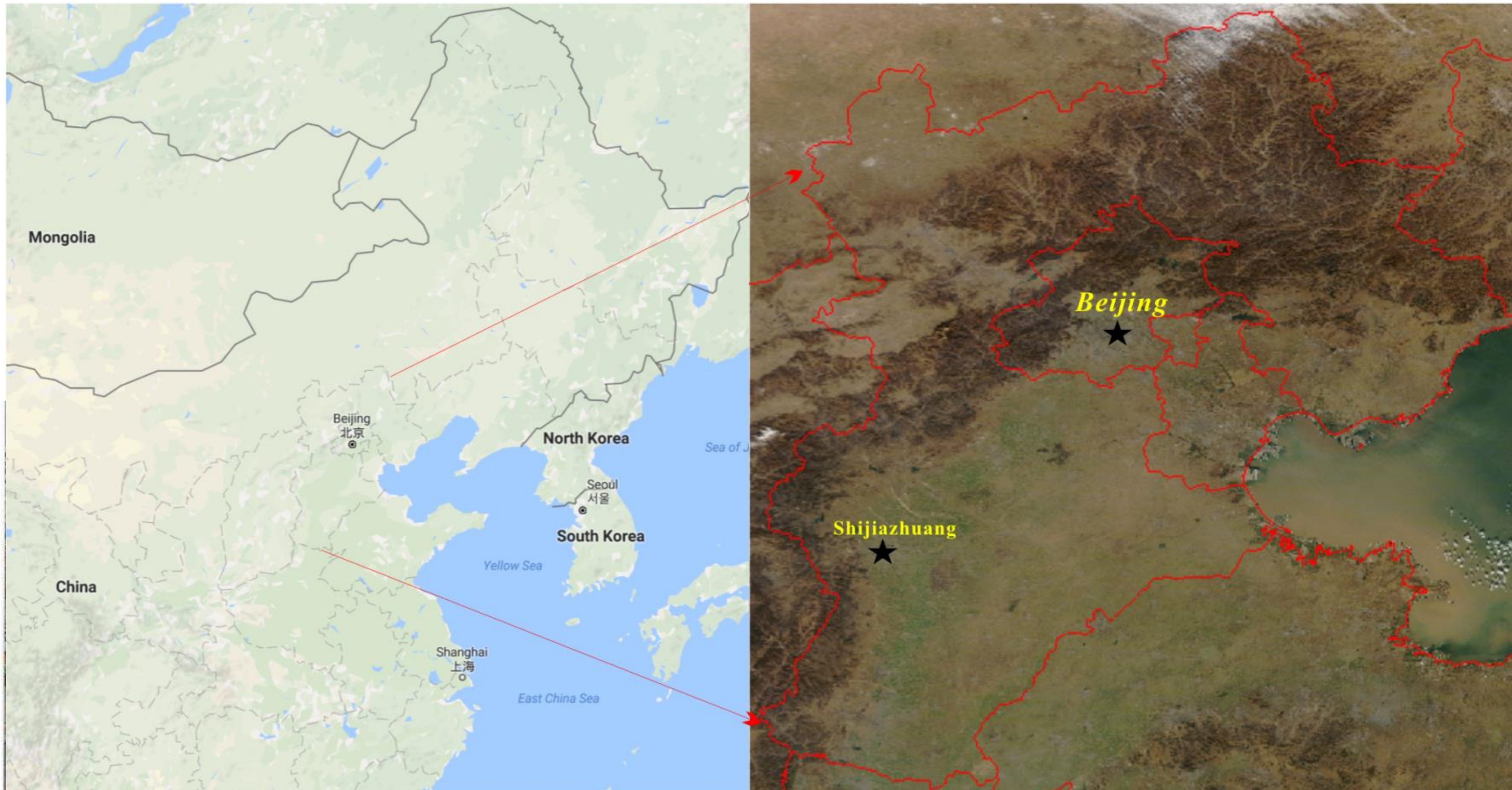
- In this case, LIDAR with the ability to detect aerosol vertical properties made it possible to reveal the haze's movement
- Under the influence of winter monsoons in northern China, the trans-boundary aerosol transport across the two major haze areas (the North China Plain and East China) is possibly a universal phenomenon during the frequent haze events.

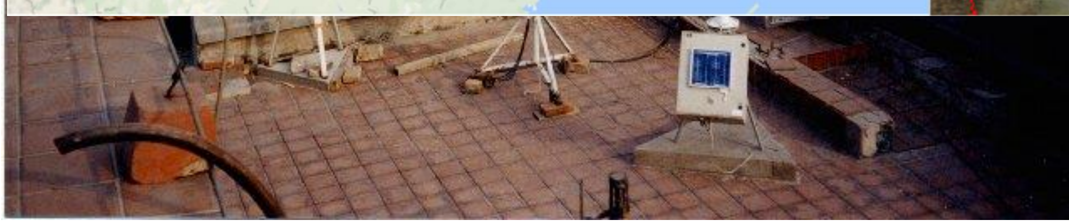
Reference: Qin K, Wu L, Wong M S, et al. Trans-boundary aerosol transport during a winter haze episode in China revealed by ground-based Lidar and CALIPSO satellite[J]. Atmospheric Environment, 2016, 141: 20-29.

Part 2

Investigating haze aerosol optical properties

Sites and Measurements



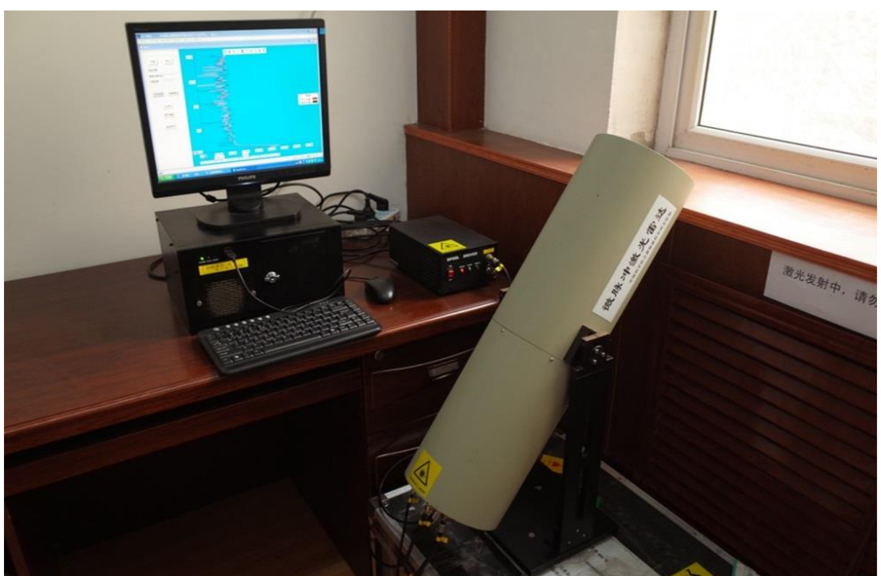


Level 1.5 (cloud-screened)
Level 2.0 (cloud screened and quality-assured)

Sites and Measurements

A single channel **aethalometer** (model: AE-16, Magee Scientific) is used to measure black carbon (BC).

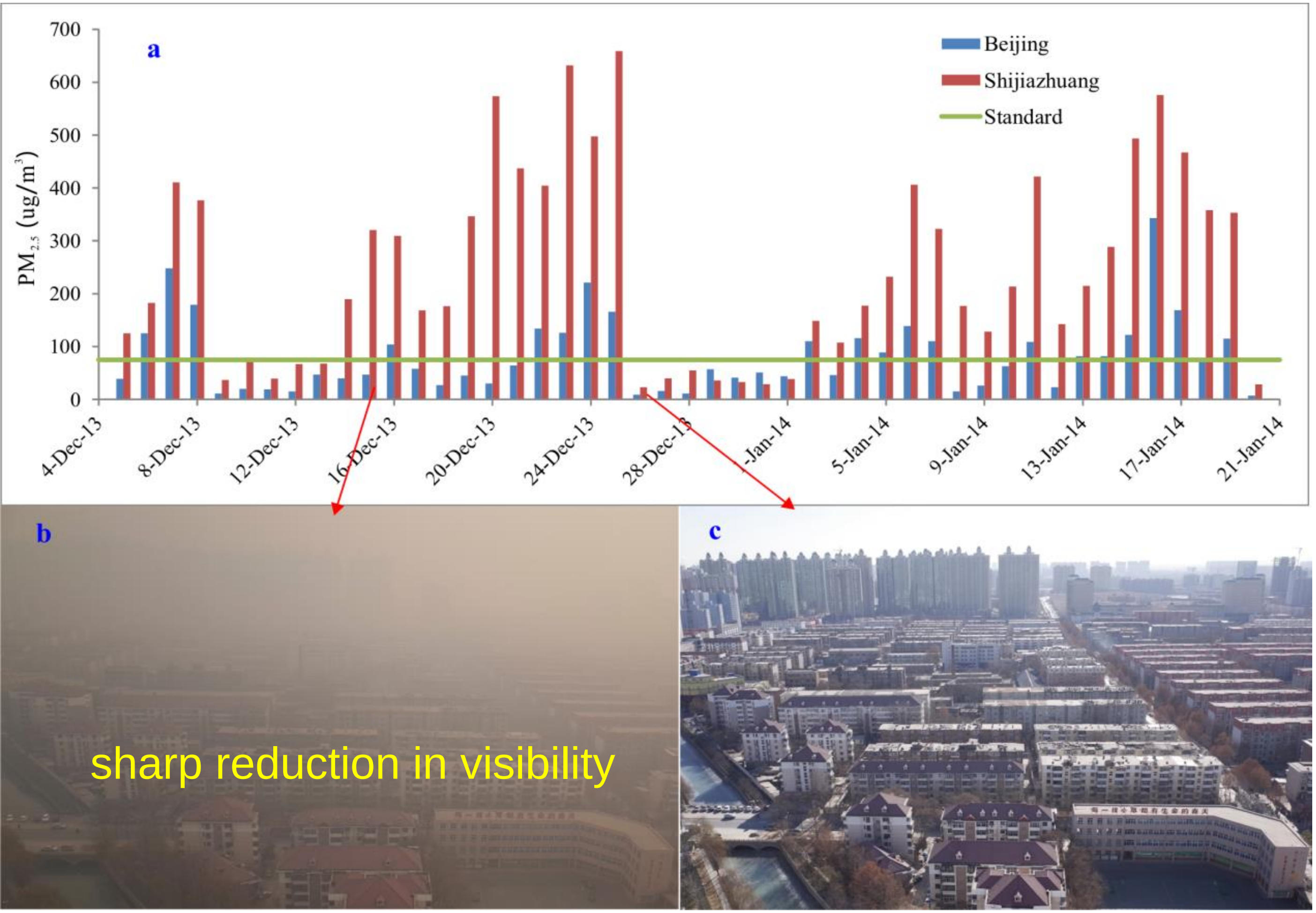
The attenuation of light at 880 nm wavelength is converted to the BC mass concentration using wavelength dependent calibration factors.



A **micro pulse lidar (MPL)** is used to obtain vertical aerosol distribution.

Aerosol extinction profiles are derived by solving lidar equation using a Fernald algorithm assuming a constant Lidar Ratio (the ratio of the volume backscattering coefficient to the volume extinction coefficient).

Results and Analysis



More than 70% and about 45% of the total days were polluted ($PM_{2.5}$>75 μg/m^3) in Shijiazhuang and in Beijing, respectively

More frequent hazes over Shijiazhuang than Beijing

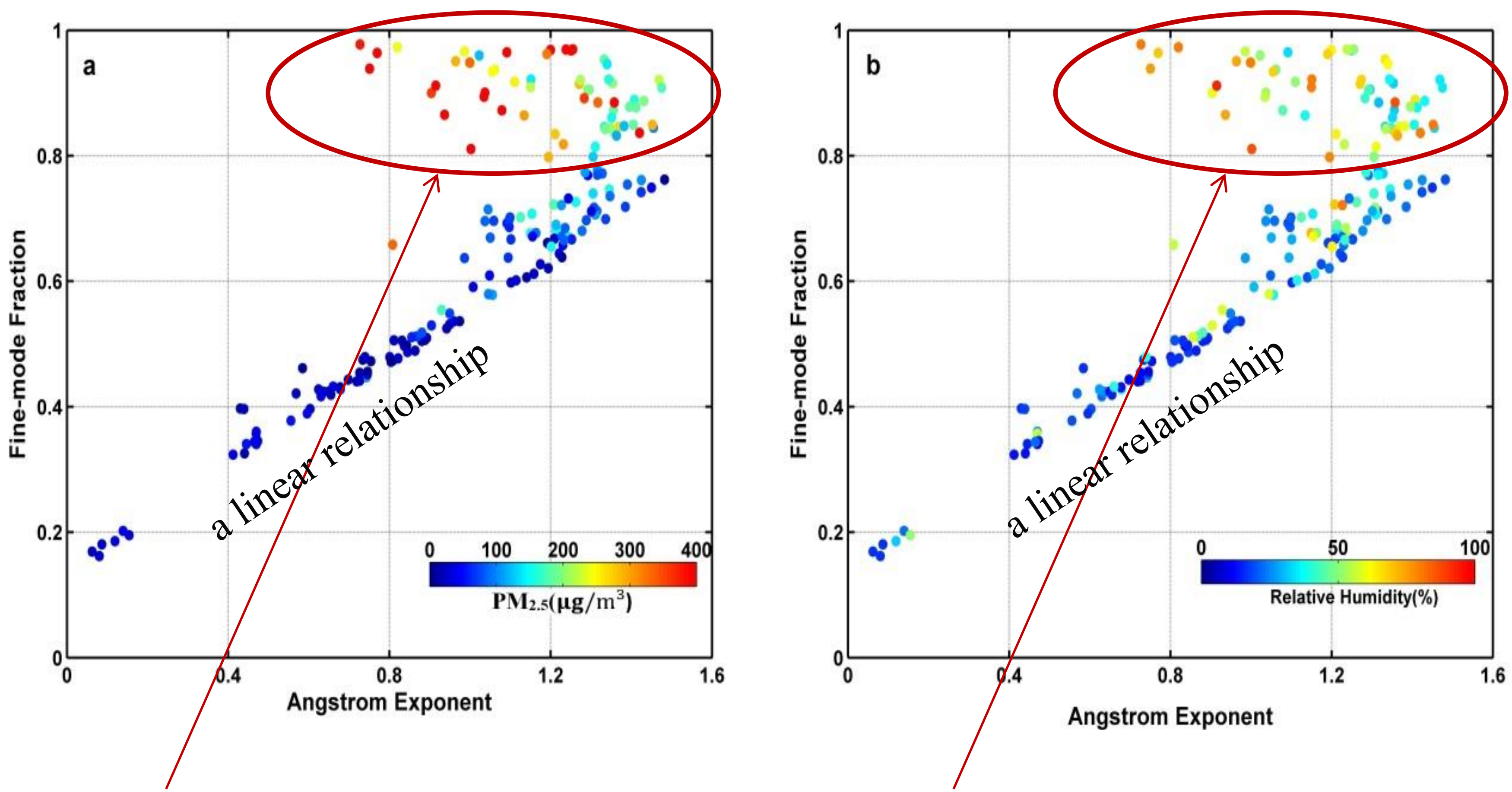
Daily mean value of $PM_{2.5}$ over Shijiazhuang and Beijing in 2013-2014 winter

Results and Analysis

- **Total and fine-mode** (anthropogenic aerosol) AODs show dramatic daily variations.
- **Coarse-mode AOD** (natural aerosol) is generally small and nearly constant.

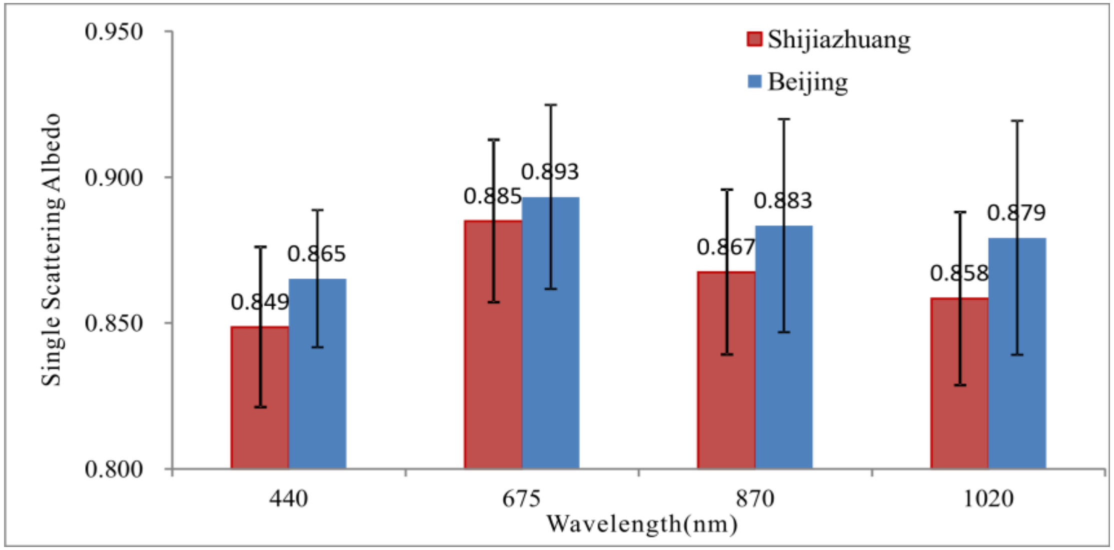
Daily values of total, fine-mode, and coarse-mode AOD_{500nm} over Shijiazhuang and Beijiing.

Results and Analysis

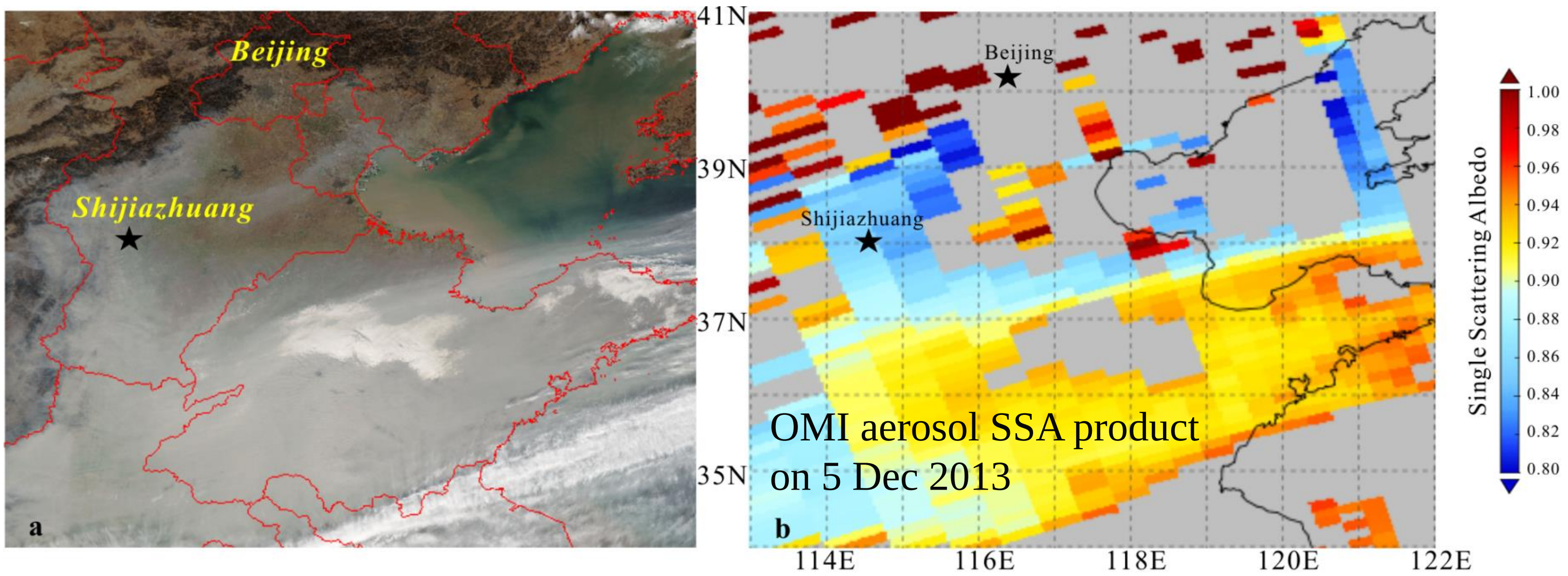


During heavy hazes with higher relative humidity, FMF values are larger than 0.80, the angstrom exponent displays more dispersiveness. This could be attributed to **fine-mode particles augment from hygroscopic growth in the presence of water.**

Results and Analysis



- The presence of spectrally-dependent absorbing aerosols.
- Smaller SSA over Shijiazhuang indicates more absorbing particles (black carbon and brown carbon).



Results and Analysis

High black carbon aerosol during hazes over Shijiazhuang

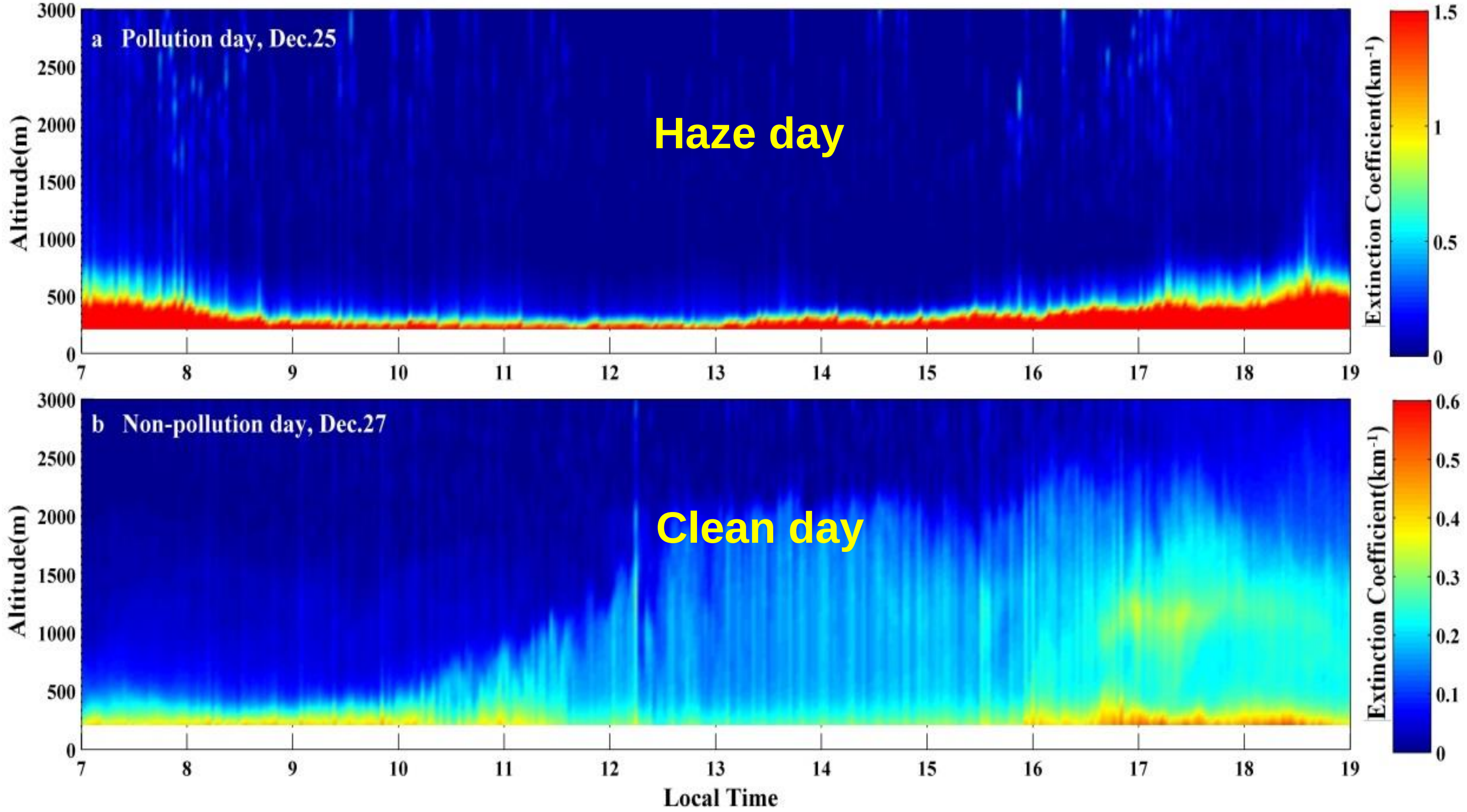
Table 1 Daily concentrations of BC (μg/m^3), $PM_{2.5}$ (μg/m^3) and their ratios during pollution days

Date	BC	$PM_{2.5}$	BC/ $PM_{2.5}$(%)
Dec.16	40.83	309.67	13.18
Dec.17	19.10	168.63	11.33
Dec.18	21.67	176.57	12.27
Dec.19	42.82	346.39	12.36
Dec.20	68.40	573.67	11.92
Dec.21	44.05	437.04	10.08
Dec.22	55.16	404.38	13.64
Dec.23	74.77	632.04	11.83
Dec.24	69.84	497.91	14.03
Dec.25	69.01	658.92	10.47
Means	50.56	420.52	12.11
Std. deviations	20.16	173.94	1.28

Much larger than 6.60% in Nanjing, 8.33% in Shanghai, and those in other 14 cites in China (Cao et al., 2007).

Results and Analysis

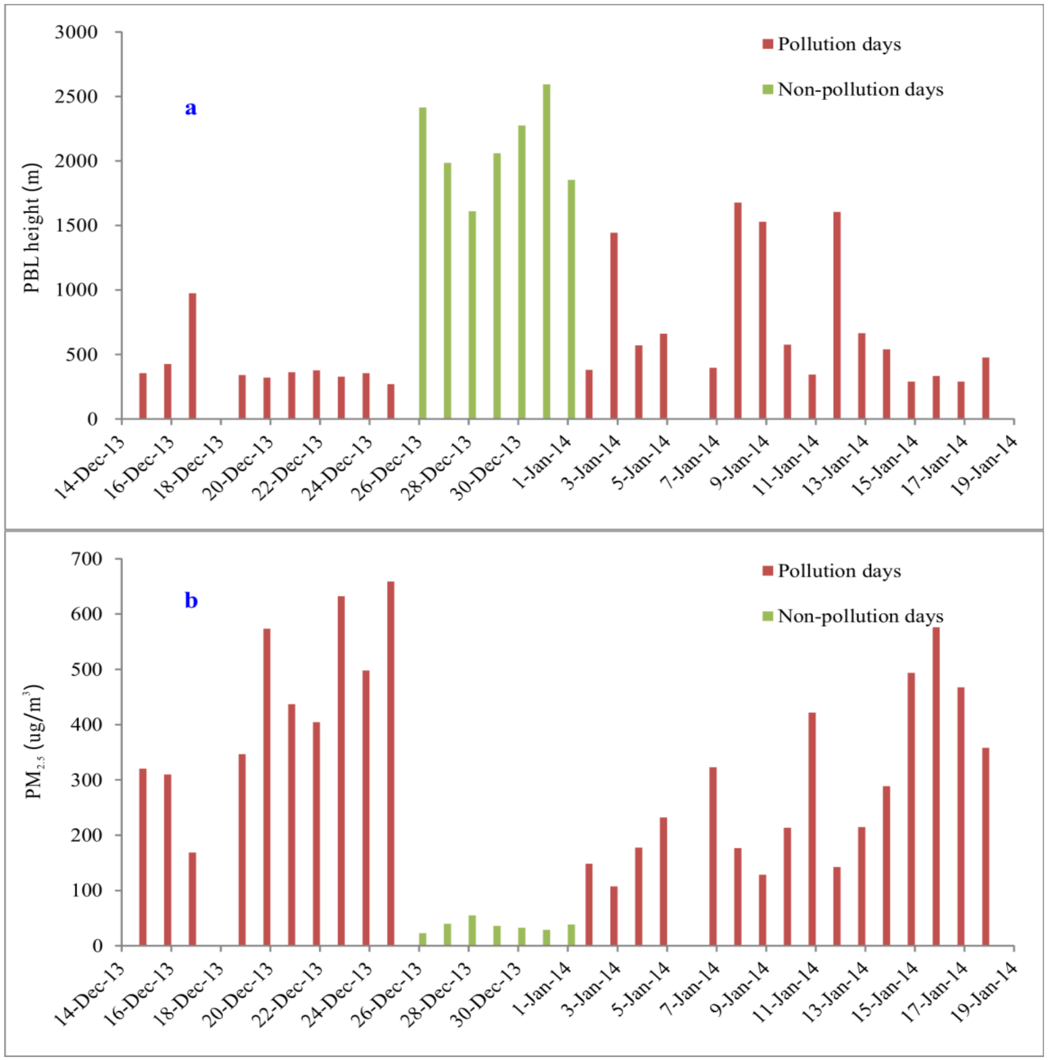
Low boundary layer heights during hazes over Shijiazhuang



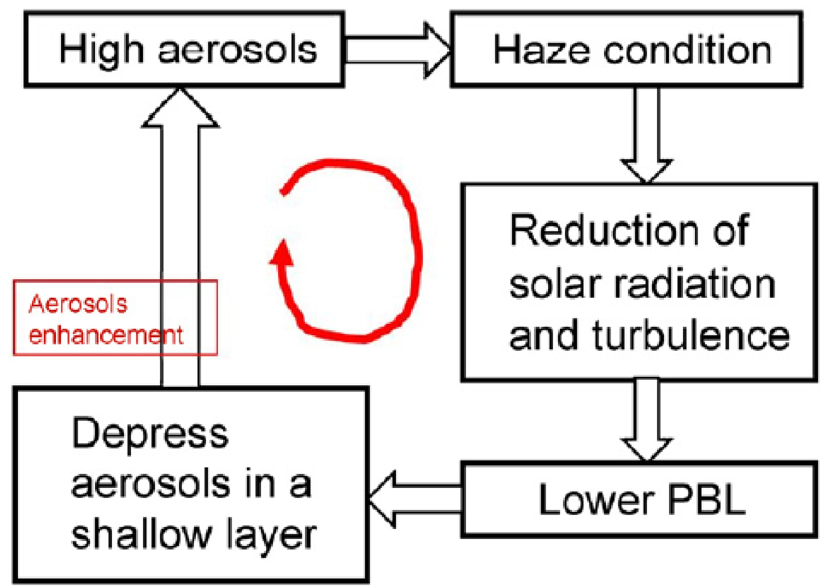
Under fair-weather conditions, the boundary layer is fully developed and actively mixed in the afternoon.

Results and Analysis

Daily max boundary layer height is defined as the averaged afternoon values



Negative correlation between the daily max boundary layer height and the daily means of $PM_{2.5}$

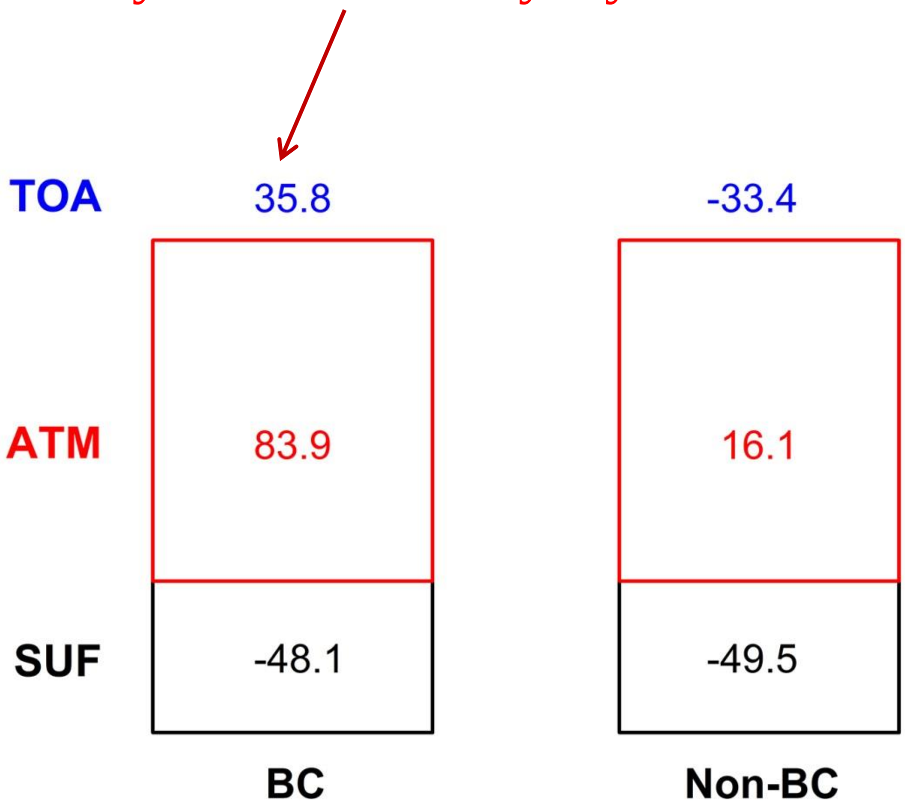


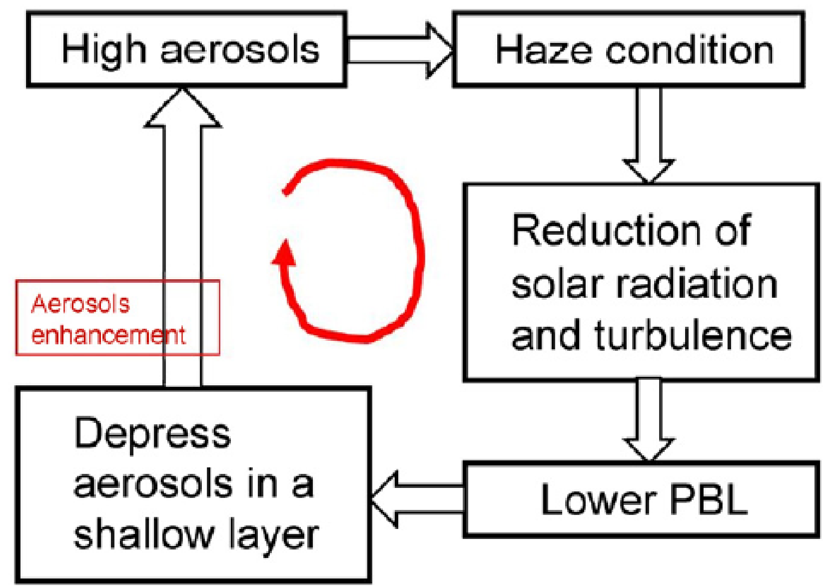
Aerosol-BL feedback loop

Results and Analysis

High BC and low boundary layer height during hazes

The radiative forcing analysis (Ding et al. 2016) suggests that BC plays a key role in heating the atmosphere and cooling the surface, further enhance the stability of the boundary layer.





Aerosol-BL feedback loop

Conclusions

- The winter hazes are dominated by fine-mode particles.
- High carbon aerosols (BC and BrC) are retrieved from the aerosol optical measurments and verified by in-situ measurements over Shijiazhuang.
- BC could affect the boundary layer development and further enhance the surface aerosol loading by accumulating air pollutants into a lower boundary layer.

Reference: Qin K, Wang L, Wu L, et al. A campaign for investigating aerosol optical properties during winter hazes over Shijiazhuang, China [J]. Atmospheric Research, Under Revised.

Developments, Technologies and Applications in Remote Sensing

May 7-10,2018 Beijing,China

Deadline for submission of abstracts 12 January 2018

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- Information Extraction from LiDAR Intensity Data (WG III/5)
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- Landuse and Landcover Change Detection (WG III/7)
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