Aerosol effect on Infrared remote sensing of atmospheric structure

Jie Zhang

Institute of Arid Meteorology,
China Meteorological Administration,
Lan zhou ,China
Email: gs-zhangjie@163.com

Outline

- ➢ 1. Aerosol observations

- ➢ 2. Aerosol and optical effect

- ➢ 3. Effect and correction of aerosol on

    atmospheric retrieval

- ➢ 4. Conclusions

1. Aerosol observation

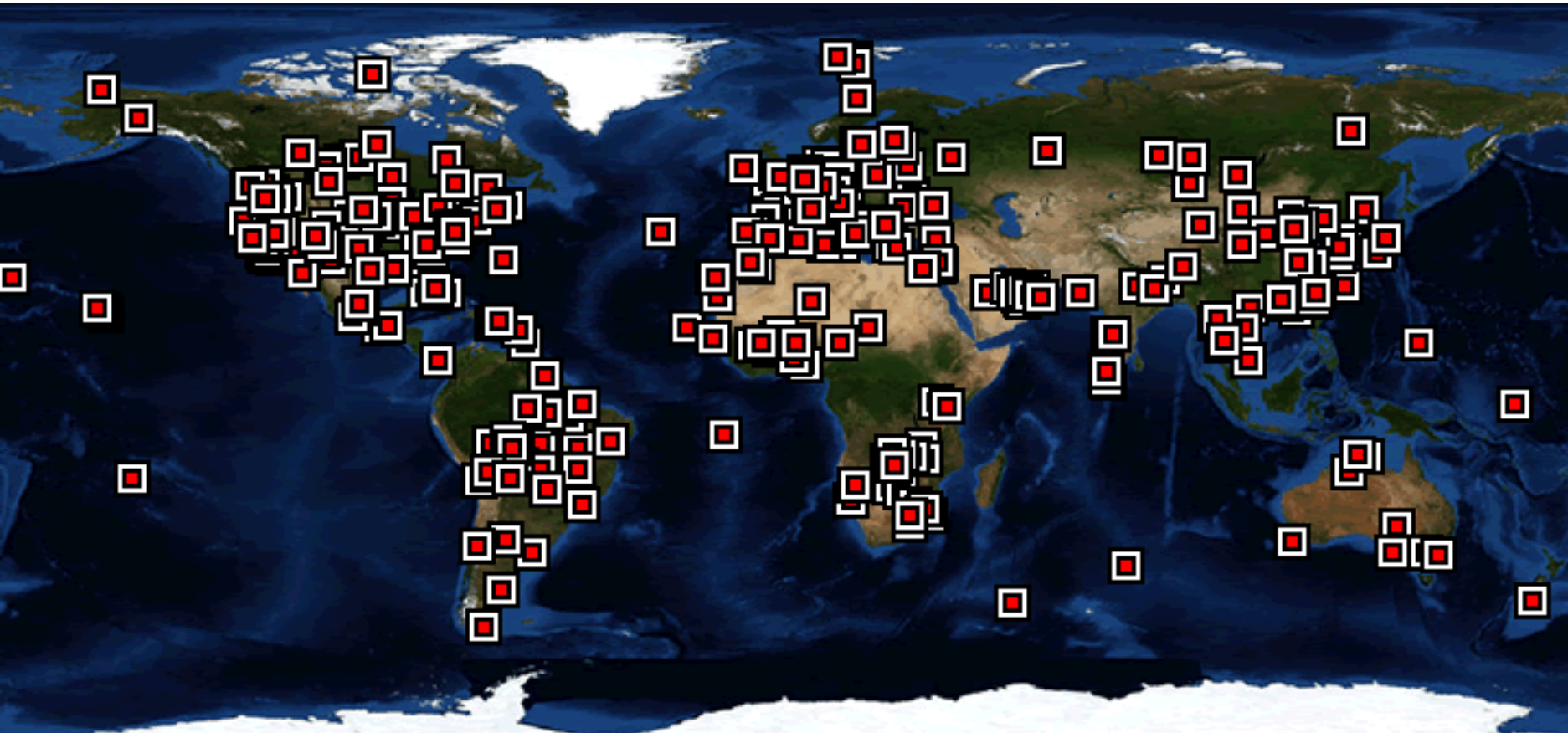## 1.1 Ground-base Measurement

Fig. Distribution of 180 global sun photometers

1. Aerosol observation
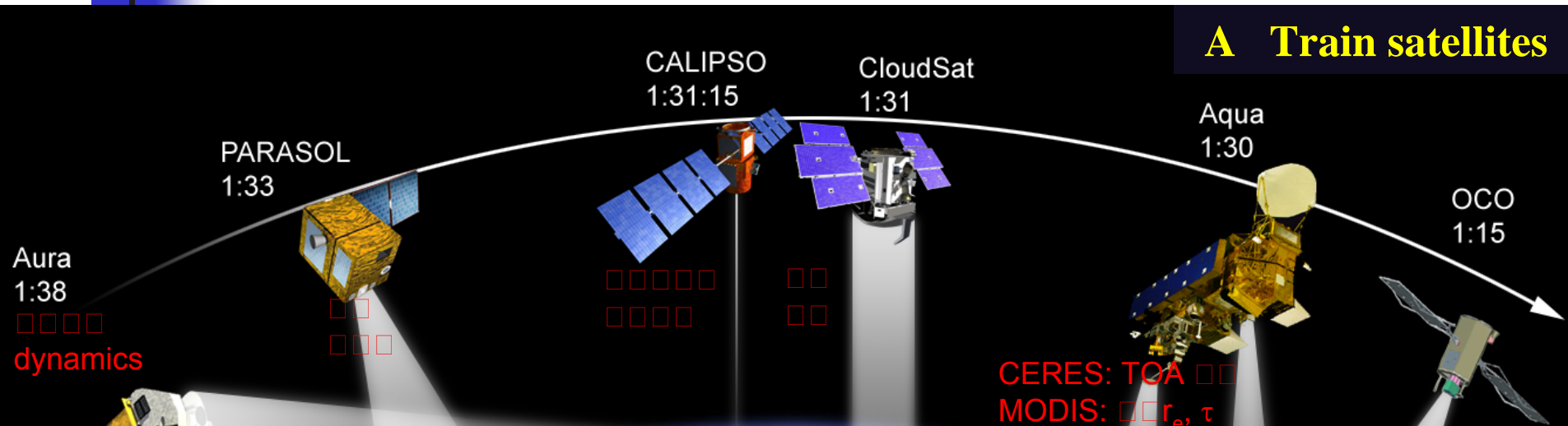
1.1 Ground-base Measurement

Fig. Automatic Sun Tracking Photometer CE-318 and laser radar CAMLTM CE 370-2

1. Aerosol observation

1.2   Airborne Measurement

A   Train satellites

CALIPSO 1:31:15
CloudSat 1:31
Aqua 1:30
OCO 1:15
PARASOL 1:33
Aura 1:38
OCO 1:15

dynamics

CERES: TOA
MODIS: r_e, τ

Ice cloud and water cloud	CloudSat MLS AMSR
Cloud physical property	MODIS CloudSat PARASOL
precipitation	CloudSat AMSR

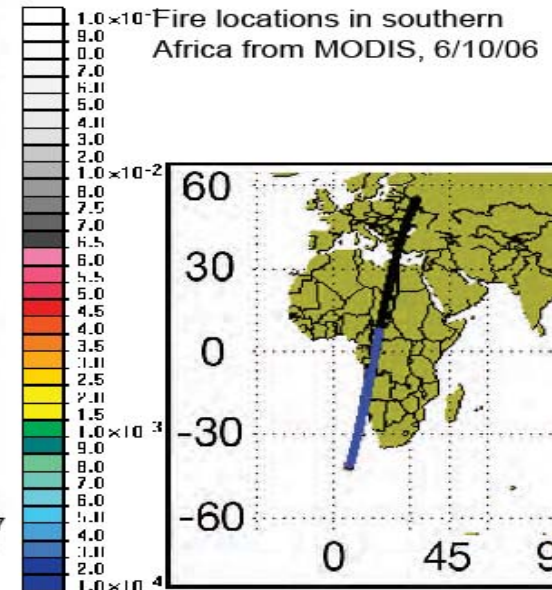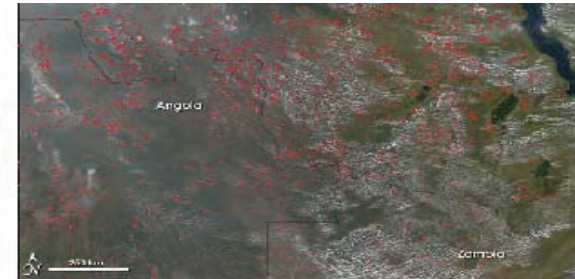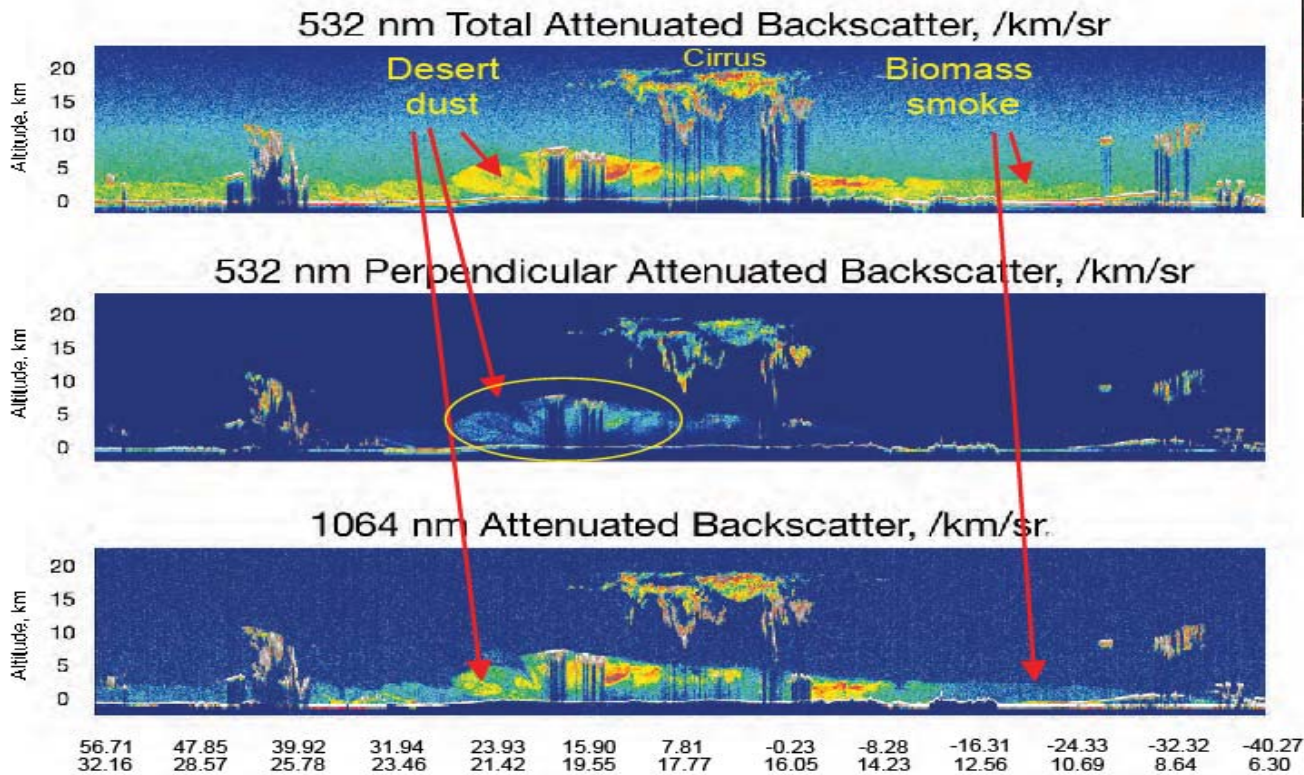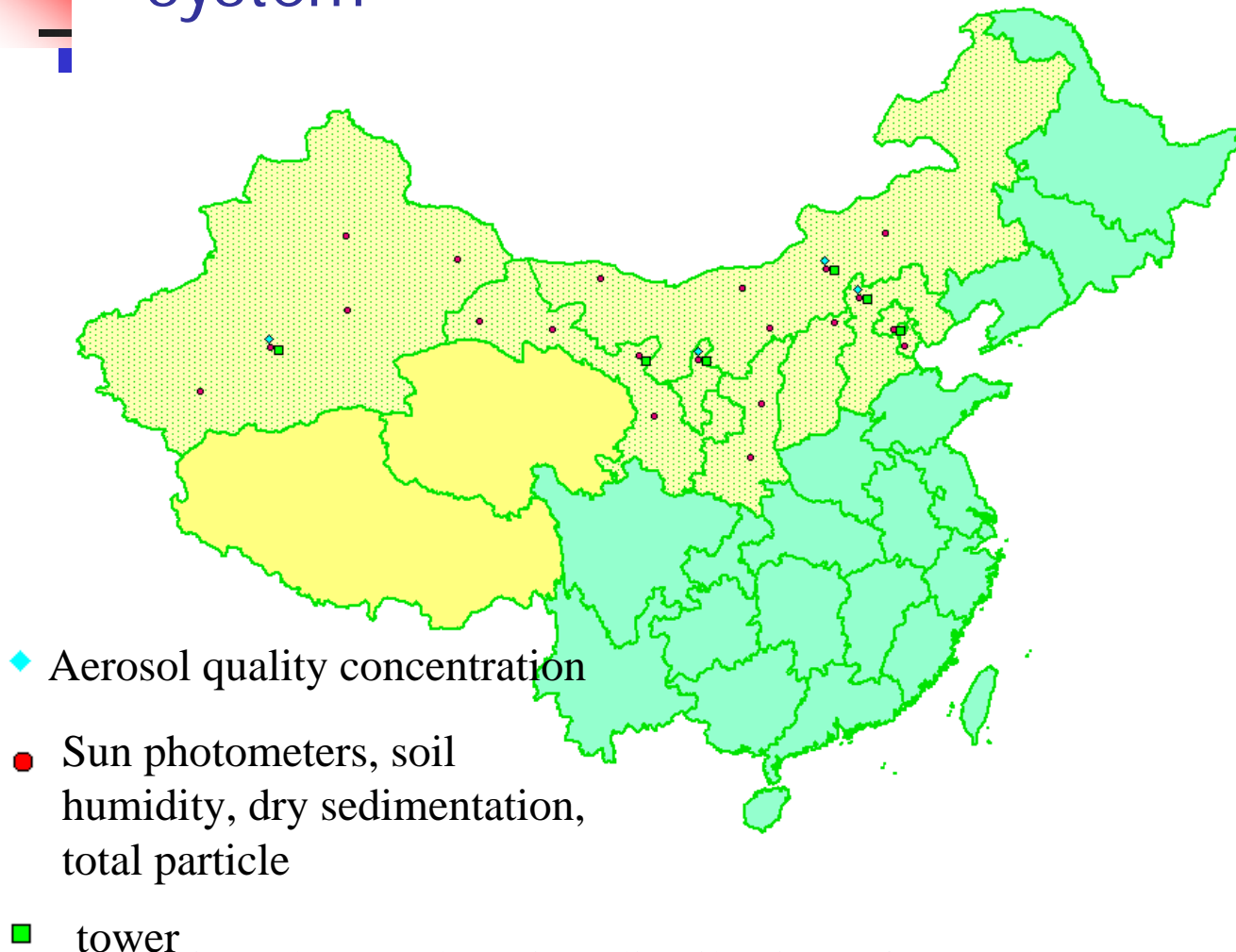| **Aerosol optical property**	**CALIPSO MODIS PARASOL OMI**
Cloud optical property	CALIPSO, MODIS, and PARASOL
Chemical	TES, MLS, OMI
Radiance flux	CERES

1. Aerosol observation

Fig. CALIPSO Level 1 profile data on 9 June 2006 provided by NASA
Langley Dave Winker

1. Aerosol observation in China

## 1.3 sand storm forecast and warning service system

Establish a national dust-storm forecast and warning service system by combining surface and satellite observations, surface physical-chemical parameters into the forecast model.

◆ Aerosol quality concentration

● Sun photometers, soil humidity, dry sedimentation, total particle

■ tower

Fig. Observed station distribution of Sun Photometers and other instrument
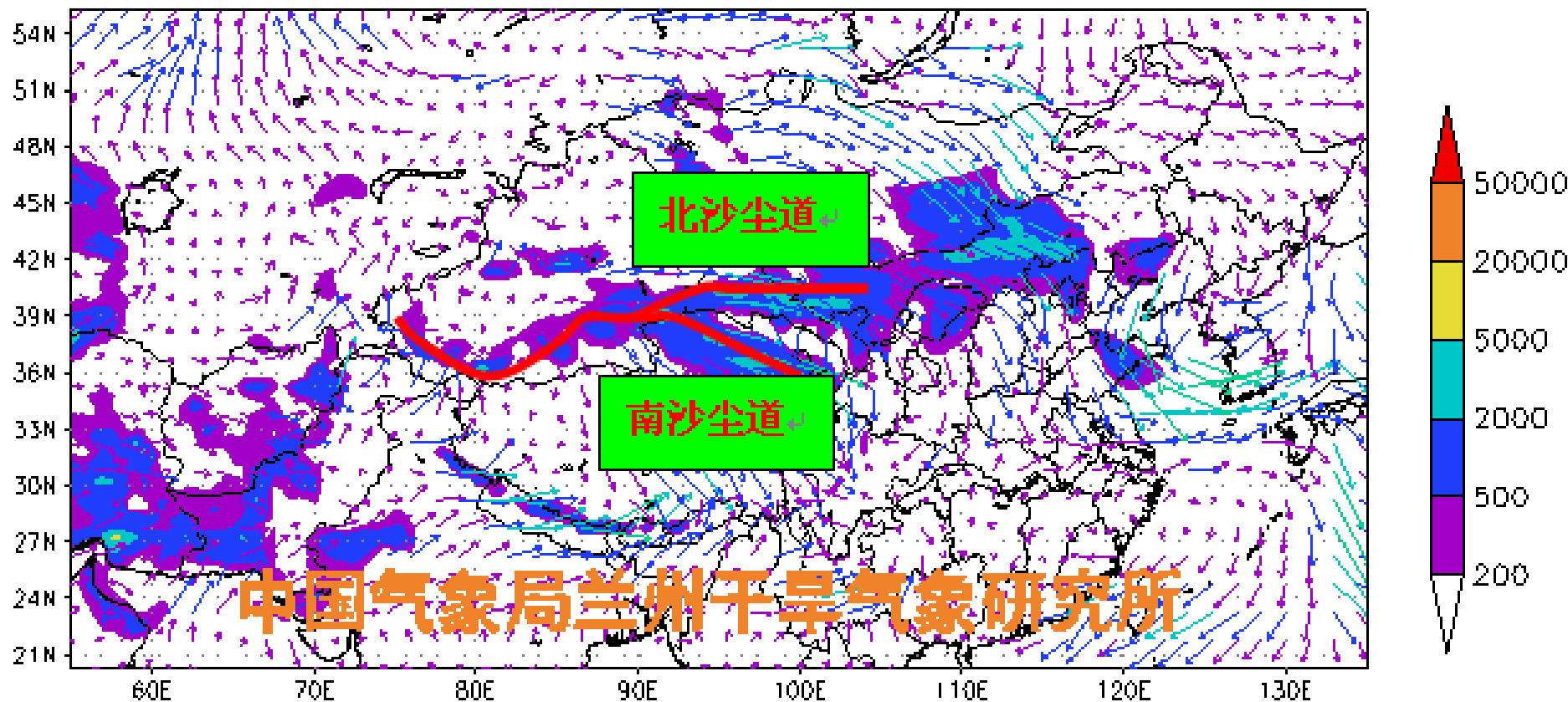
1. Aerosol observation in China

1.4   sand aerosol monitor from satellites
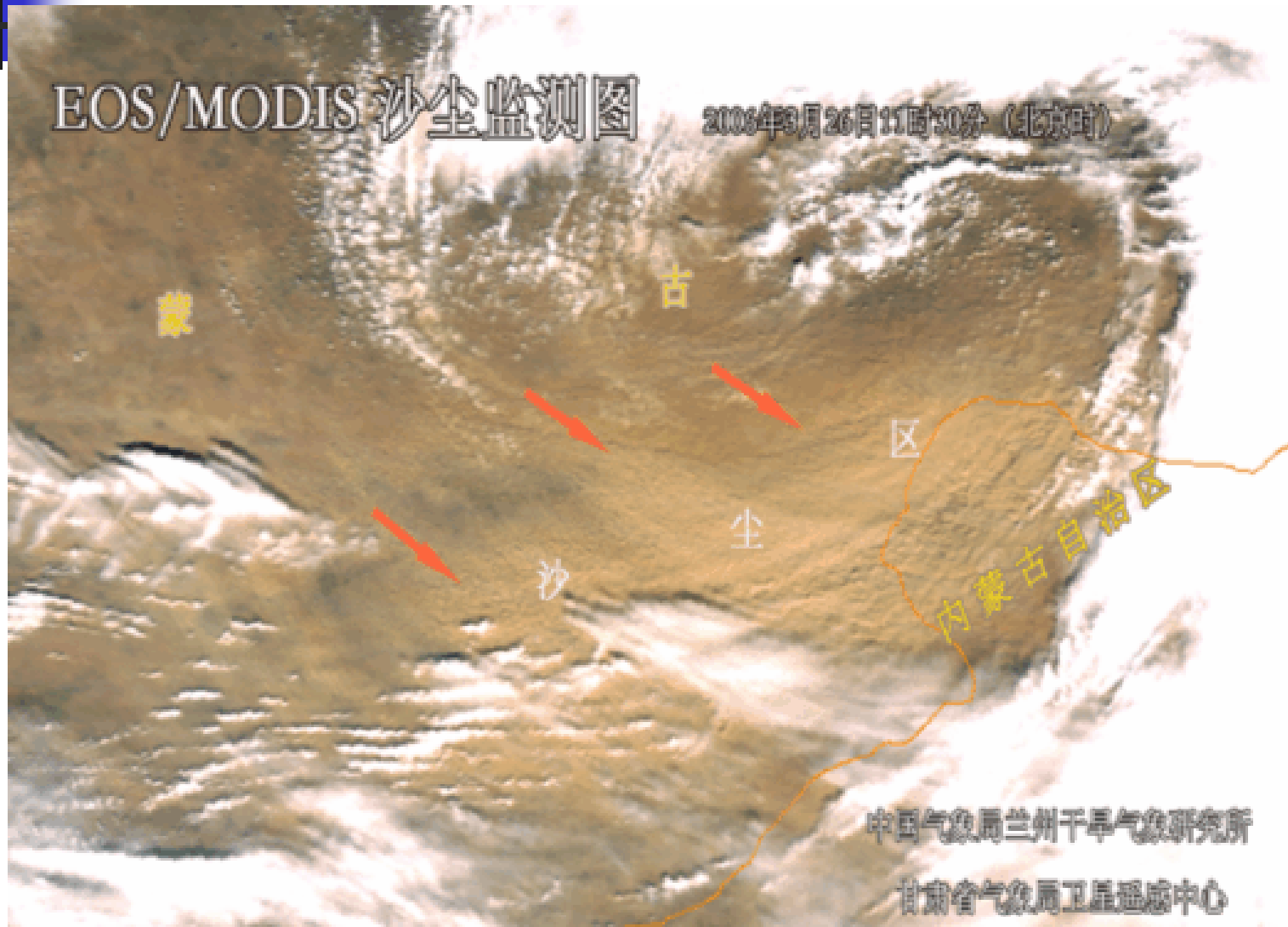
1.4 sand storm forecast model

duststorm concentration(ug/m^3) at 2006030417

Sand model GRAPES_SDM show sand storm region and sand aerosol effect region

2. Aerosol and optical effect
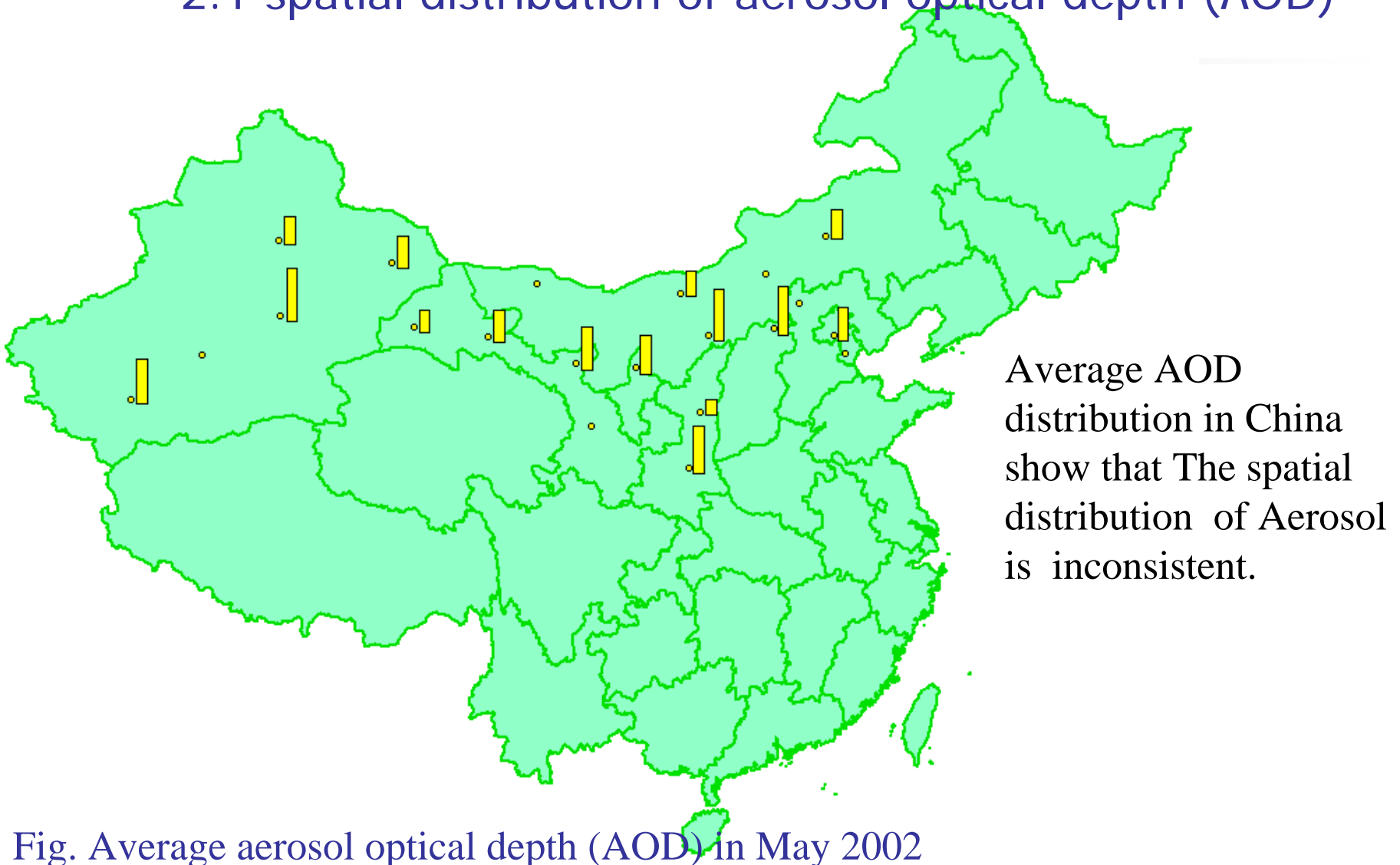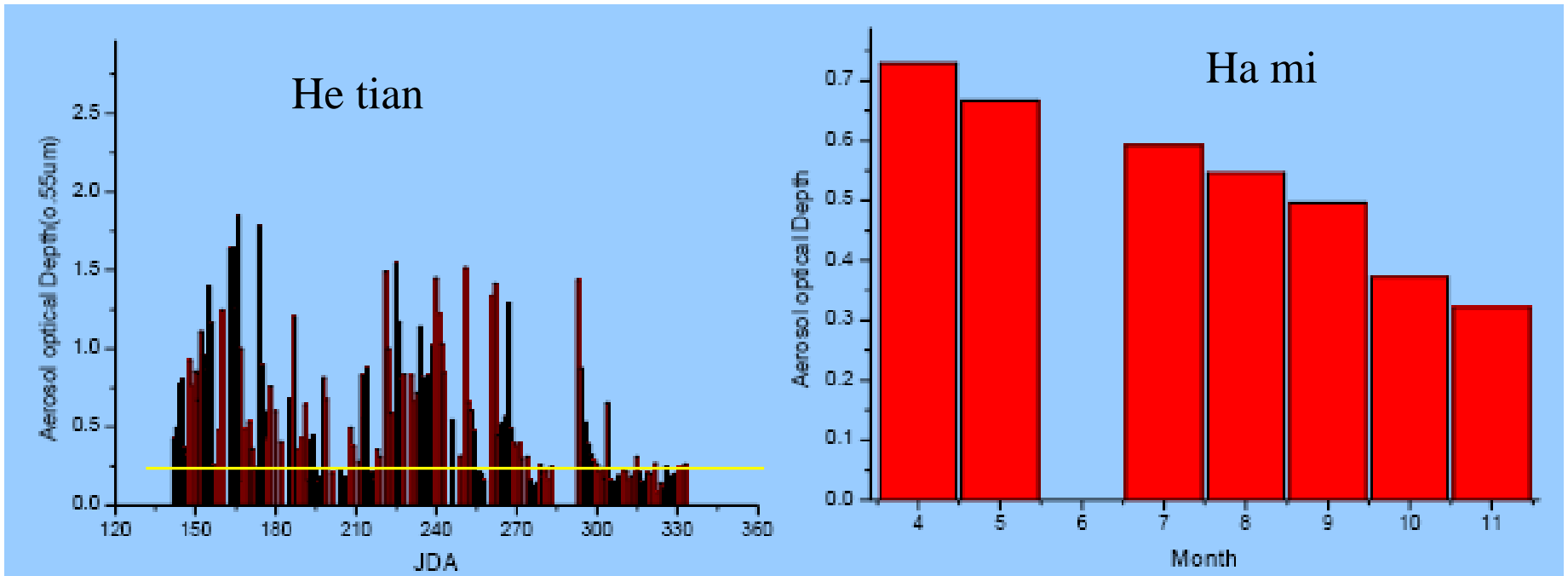
2.1 spatial distribution of aerosol optical depth (AOD)

Average AOD distribution in China show that The spatial distribution of Aerosol is inconsistent.

Fig. Average aerosol optical depth (AOD) in May 2002

2. Aerosol and optical effect

2.2 temporal variation of aerosol optical depth(AOD)

He tian

Ha mi

- AOD at He tian station is high in June , August and September, and low in July and winter, the low AOD is about 0.25.

- AOD at Ha mi station is high in April and decreased with month increased.

2. Aerosol and optical effect
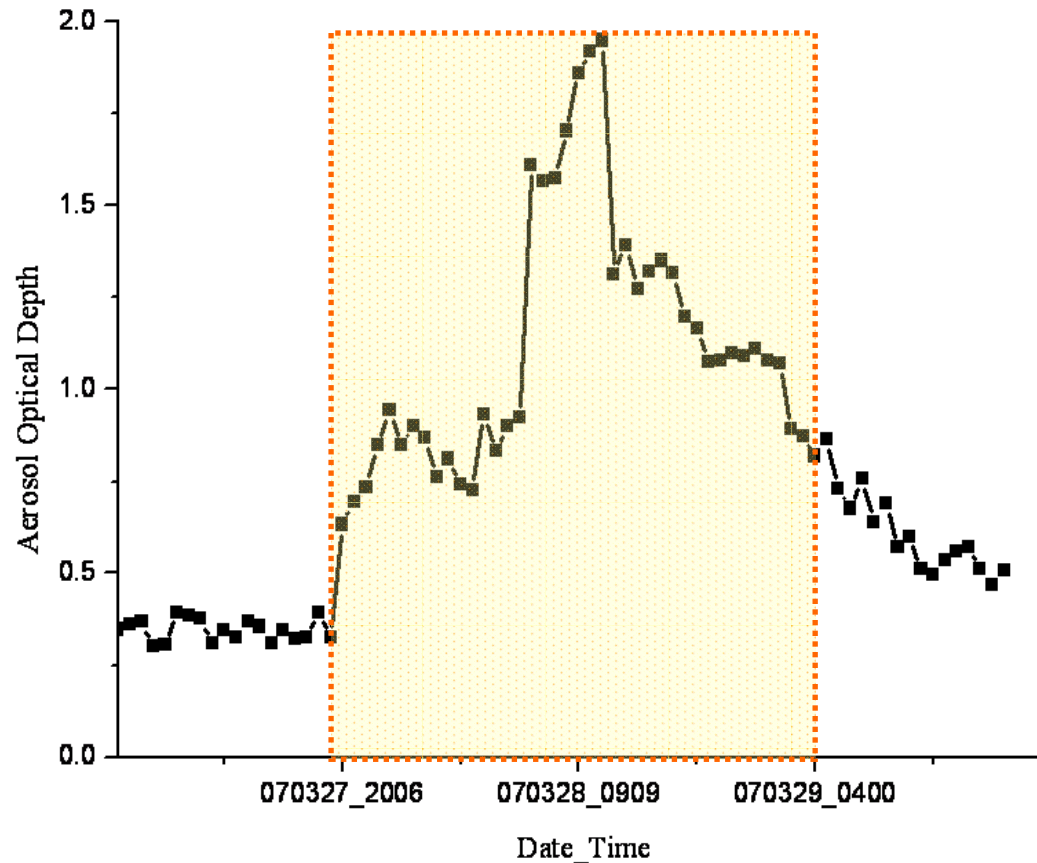
2.3 temporal variation of sand strom AOD

Fig. AOD variation when sand storm happened between 20:00 on 27 March 2007 and 4:00 on 29 March 2007

2. Aerosol and optical effect

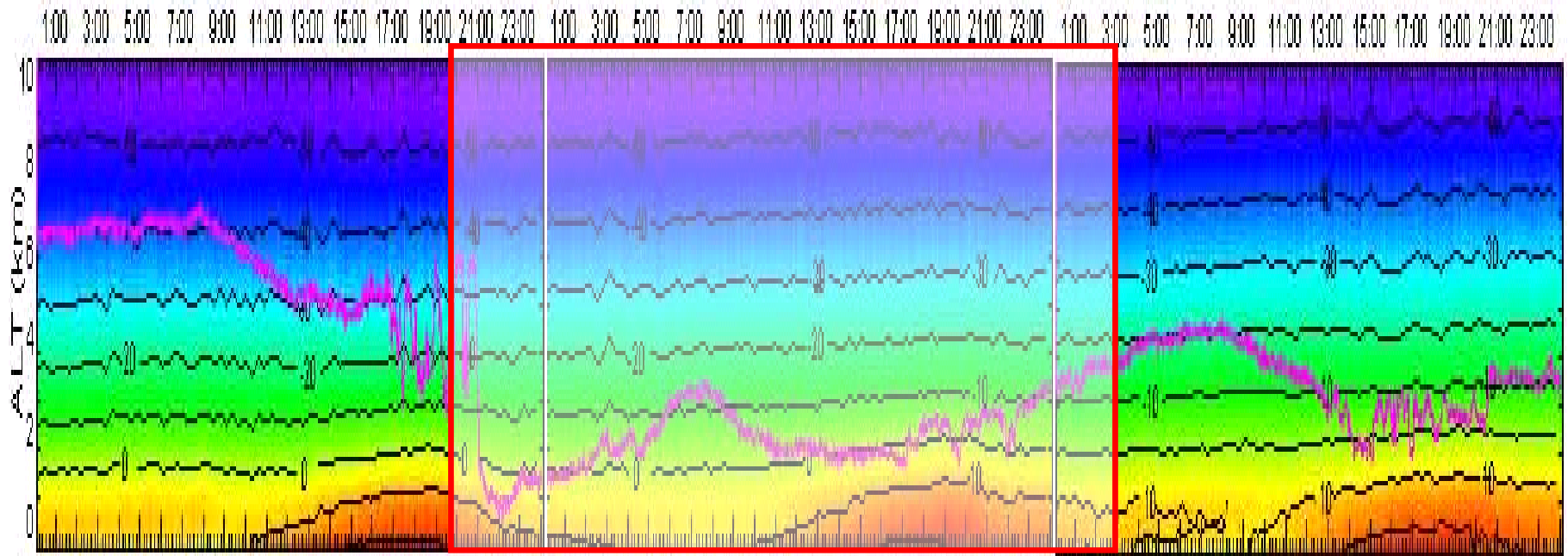## 2.4 Aerosol change vertical structure of atmospheric temperature

Fig. Temporal variable of atmospheric temperature from TP/WVP-3000 level

The reason is: though aerosol attenuate short-wave from Sun, it can hold back sensible heat transportation from surface, and increase downward long-wave radiance, the total effect is warming atmosphere .

2. Aerosol and optical effect
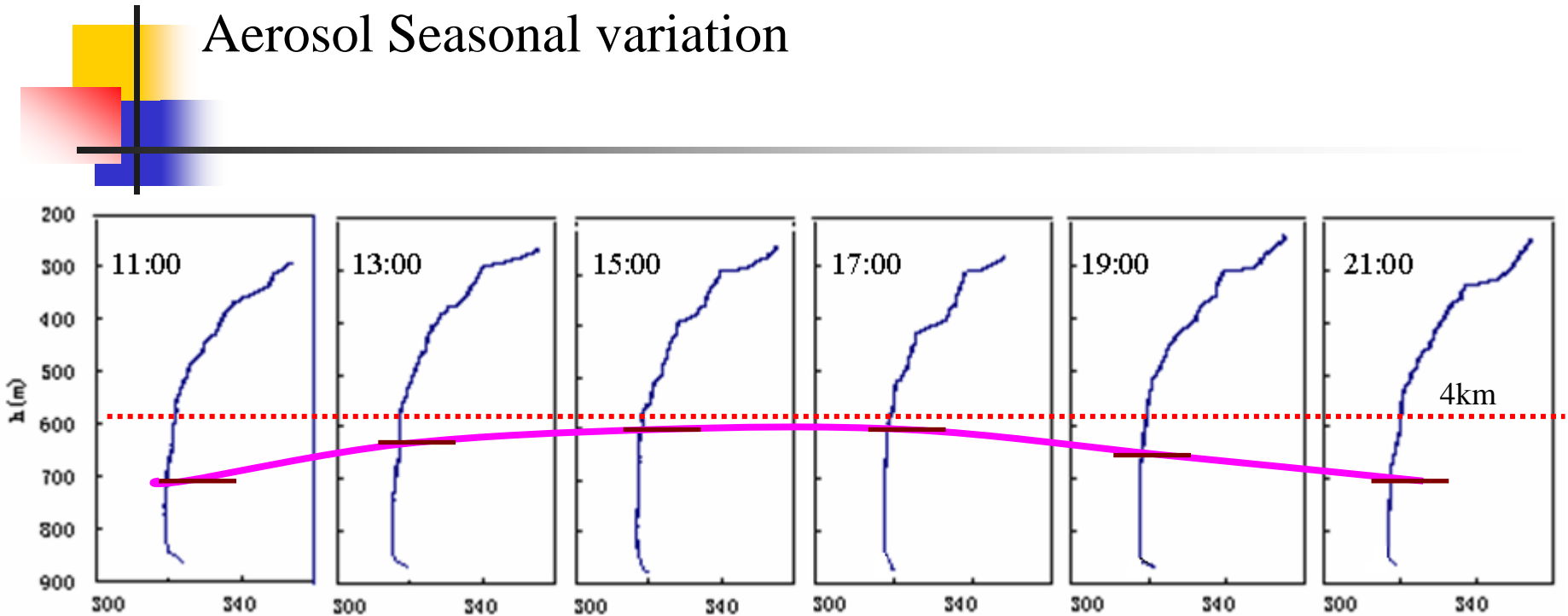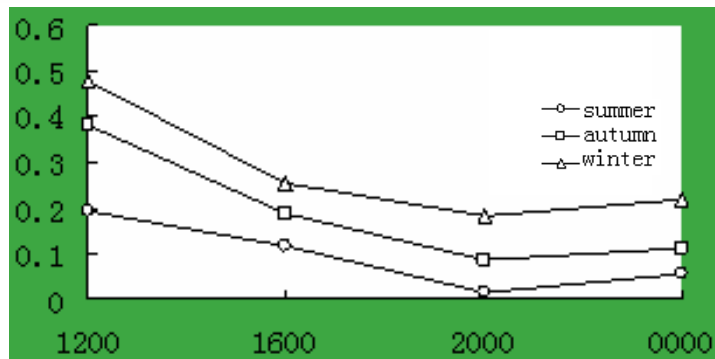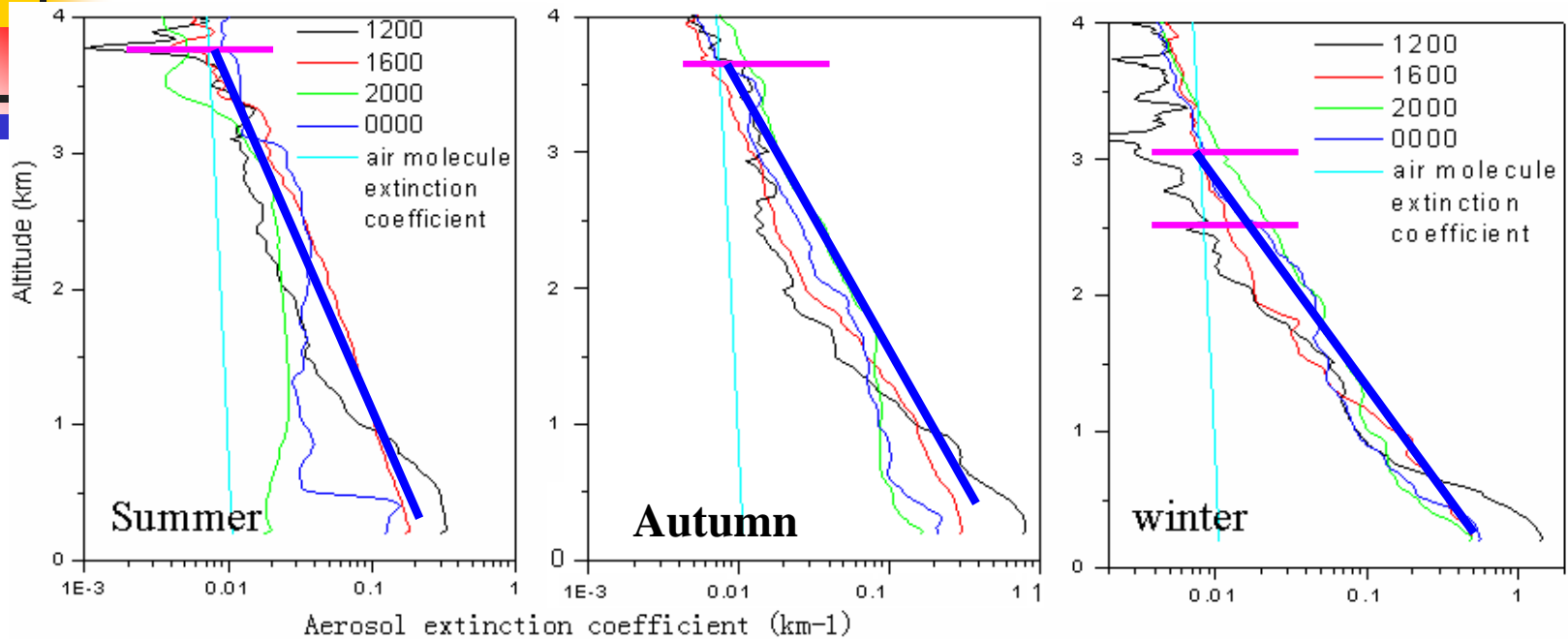
Aerosol Seasonal variation

Fig. Potential temperature and the top of boundary layer diurnal variation on July 9 2006

The top of boundary layer is high at noon, and reach 600hpa or 4km level , which may effect aerosol vertical distribution

2. Aerosol and optical effect

Aerosol Seasonal variation

a. aerosol extinction coefficient is larger than air molecule within boundary layer.

b. Aerosol distributing level is higher in summer and autumn, and lower in winter.

c. Aerosol extinction coefficient deduce with altitude increase.

d. AOD is lower in summer and higher in winter due to burning carbon and biomass in winter.

2. Aerosol and optical effect

aerosol diurnal variation
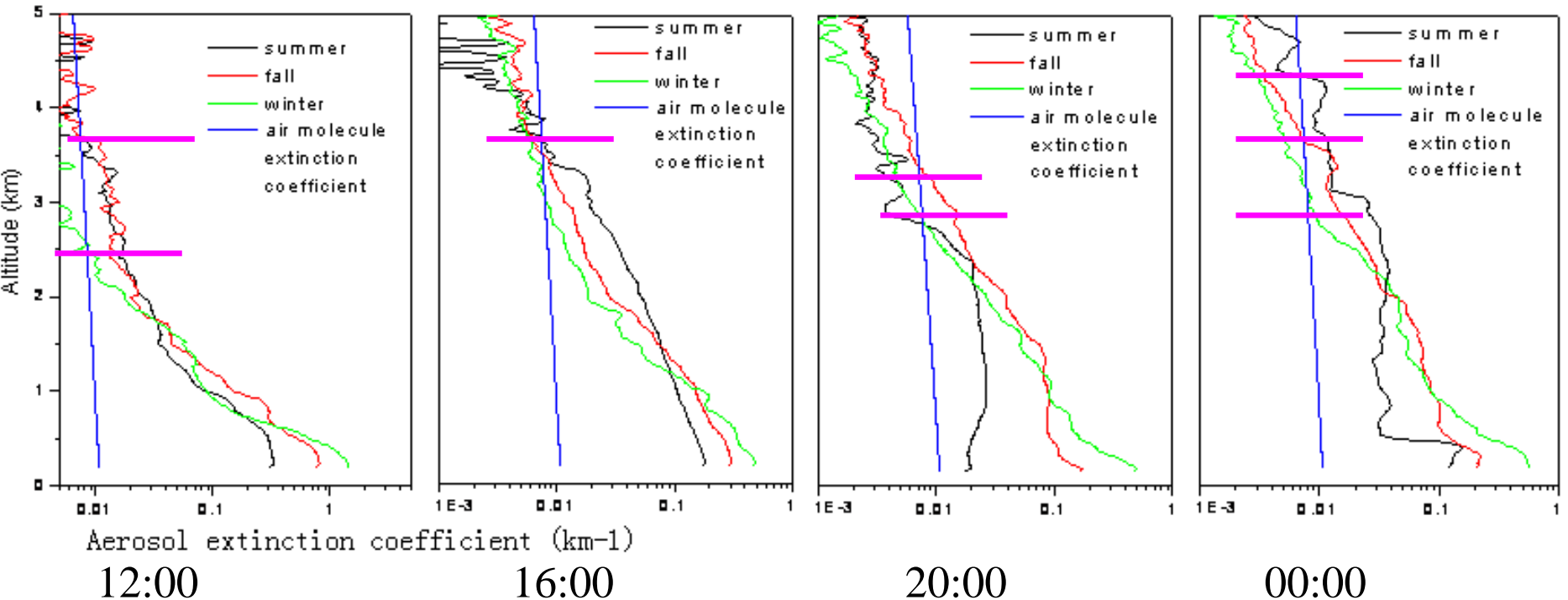
a. Aerosol is large at 12:00 , and decrease with time variable

b. There is a steady value at night , and the level is higher in summer and

    lower in autumn and winter.

c. Aerosol level is higher between 12:00 and 16:00, lower at night, but it is increased late at night.

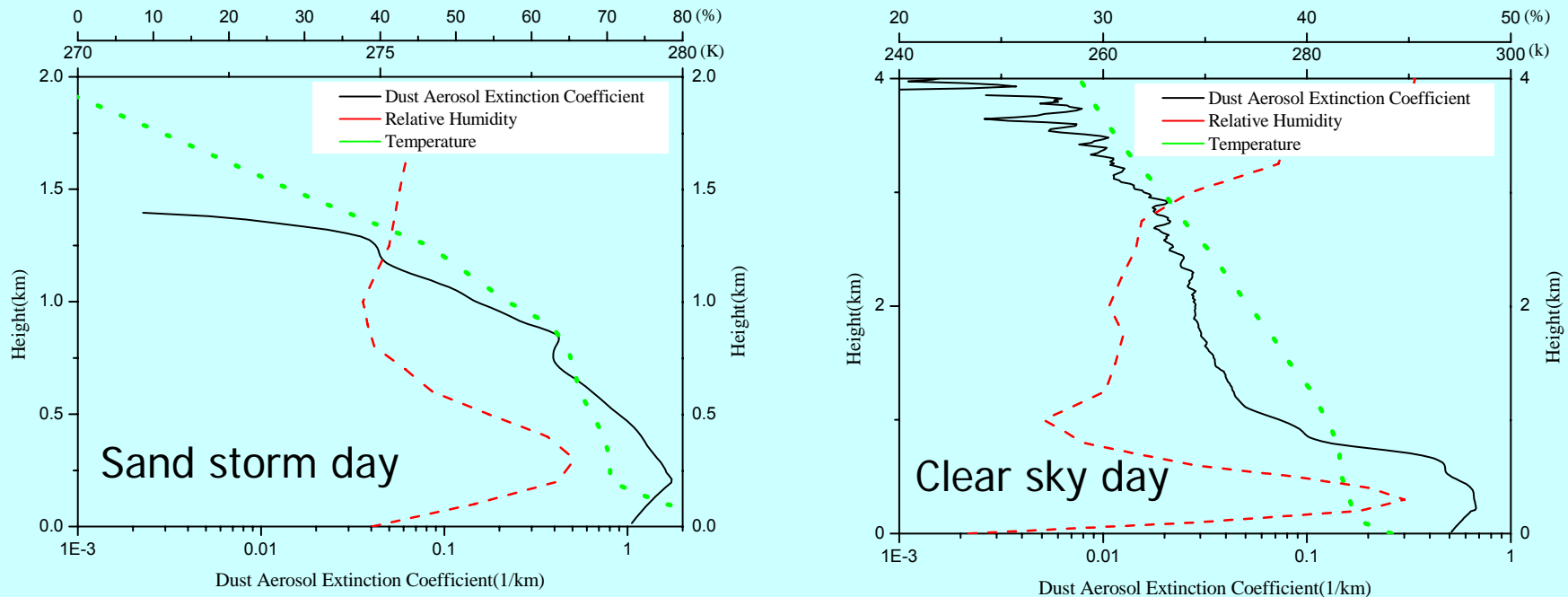# 2. Aerosol and optical effect

Fig. aerosol extinction coefficient change with atmospheric temperature and humidity from Profiling Radiometer TP/WVP-3000

Aerosol profile are in consistent with atmospheric temperature and relativity humidity profile

2. Aerosol and optical effect

■**Summary**

- Sand aerosol change the day-night variable of atmospheric temperature under boundary layer.

- Aerosol exist main in boundary layer, and the distributing is change with seasonal variable due to atmospheric environment change.

- Synchronous aerosol correction is necessary for remote sensing .

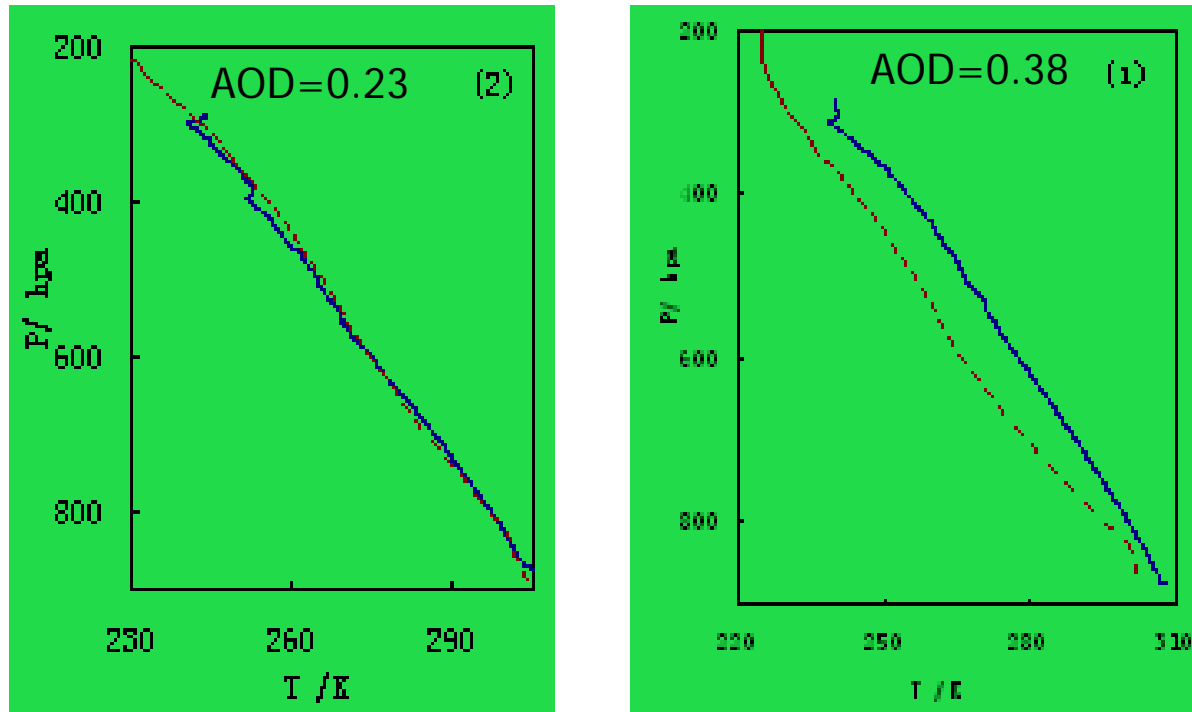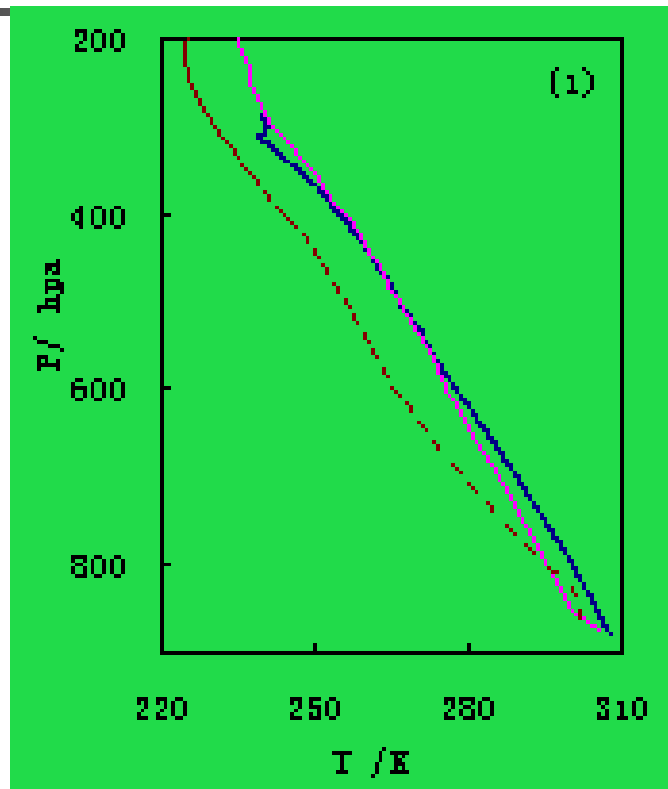# 3.Effect and correction of aerosol on atmospheric temperature retrieval

Fig. Statistical retrieval of atmospheric temperature from MODIS
(dashed line indicates statistical retrieval, thick line is observed result)

3.Effect and correction of aerosol on atmospheric retrieval

the nonlinear iterative approach based on 1D-Var method used, the result is good for above the top of the boundary layer, but poor for within the boundary layer.

Fig. Physical retrieval of atmospheric temperature from MODIS (dashed line indicates statistical retrieval, thin line is physical retrieval value, thick line is observed result)

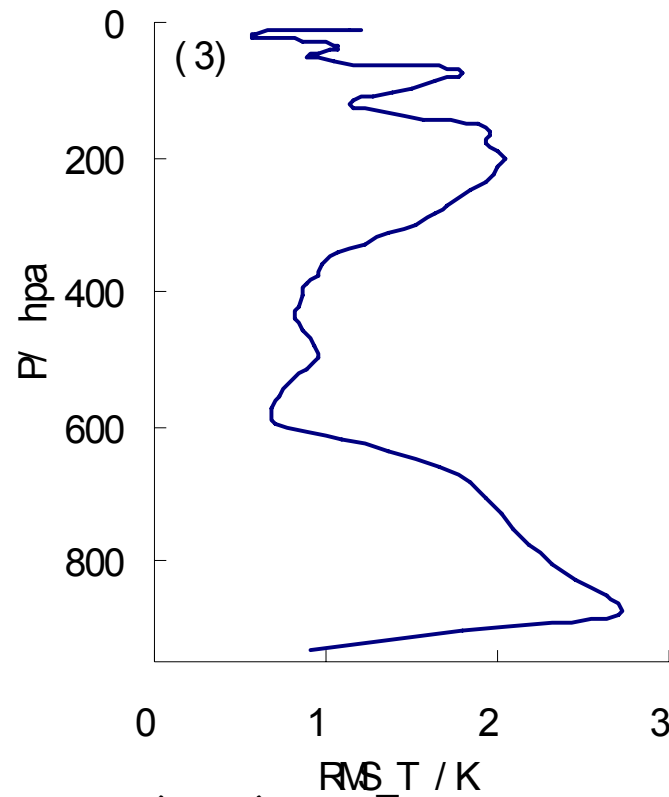# 3.Effect and correction of aerosol on atmospheric retrieval

fig. the root mean square error (rmse) of physical retrieval of cloud-free cases

3.Effect and correction of aerosol on atmospheric retrieval
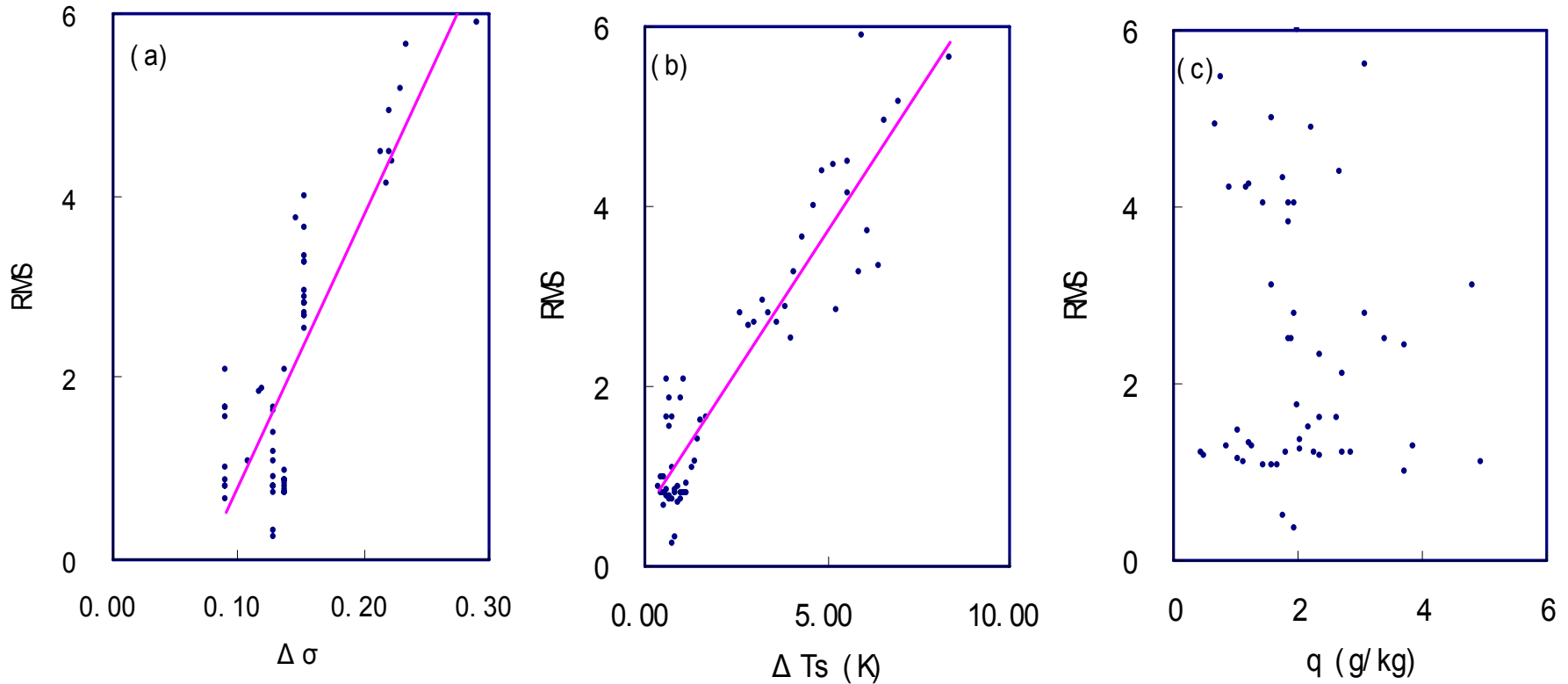

Fig. relations of temperature retrieval error at 2000m level with AOD increment (a), estimated error of skin temperature (b) and water vapor mixing ratio(c)

3.Effect and correction of aerosol on atmospheric retrieval
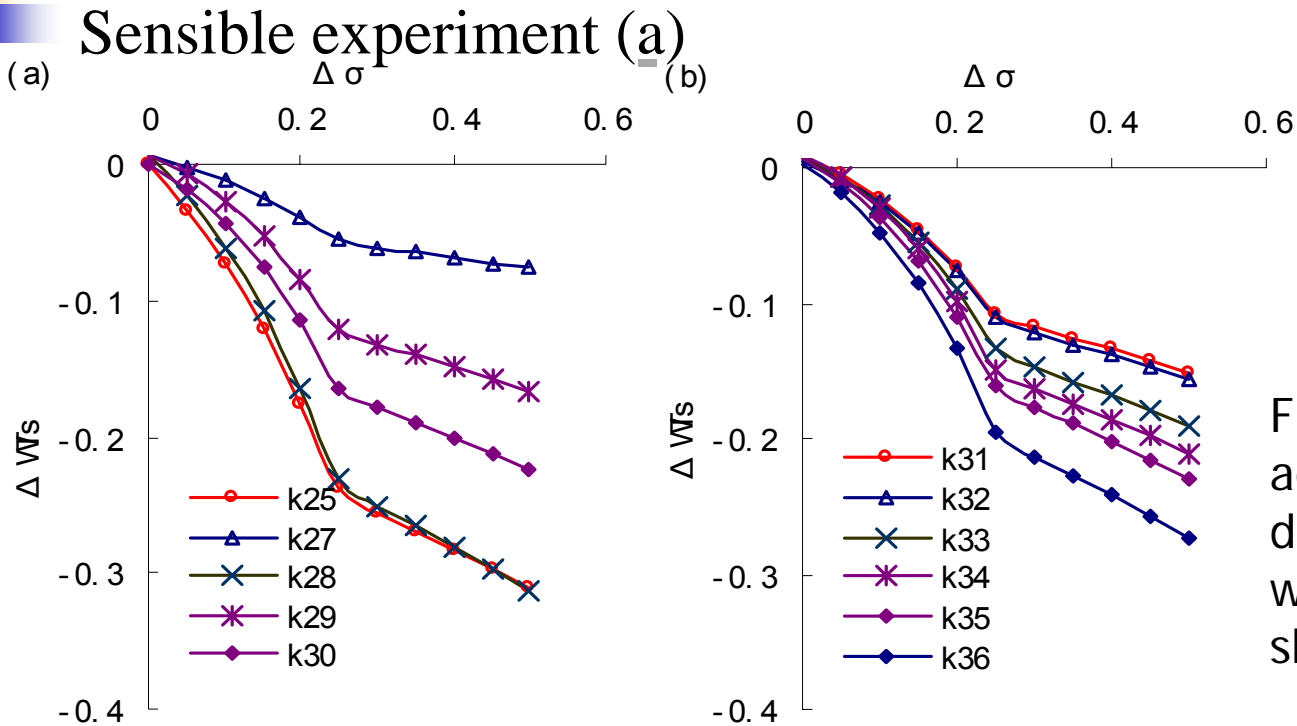
Sensible experiment (a)

Fig. effect of aerosol optical depth (AOD) on the weighting of the skin temperature

Weighting of IR band are decreased with AOD increase . If AOD is underestimated, atmospheric transmittance and weighting of skin and air temperature will be overestimated, and resulting in an underestimation of the retrieval temperature profile, ultimately leading to an increase in the absolute error.

3.Effect and correction of aerosol on atmospheric retrieval
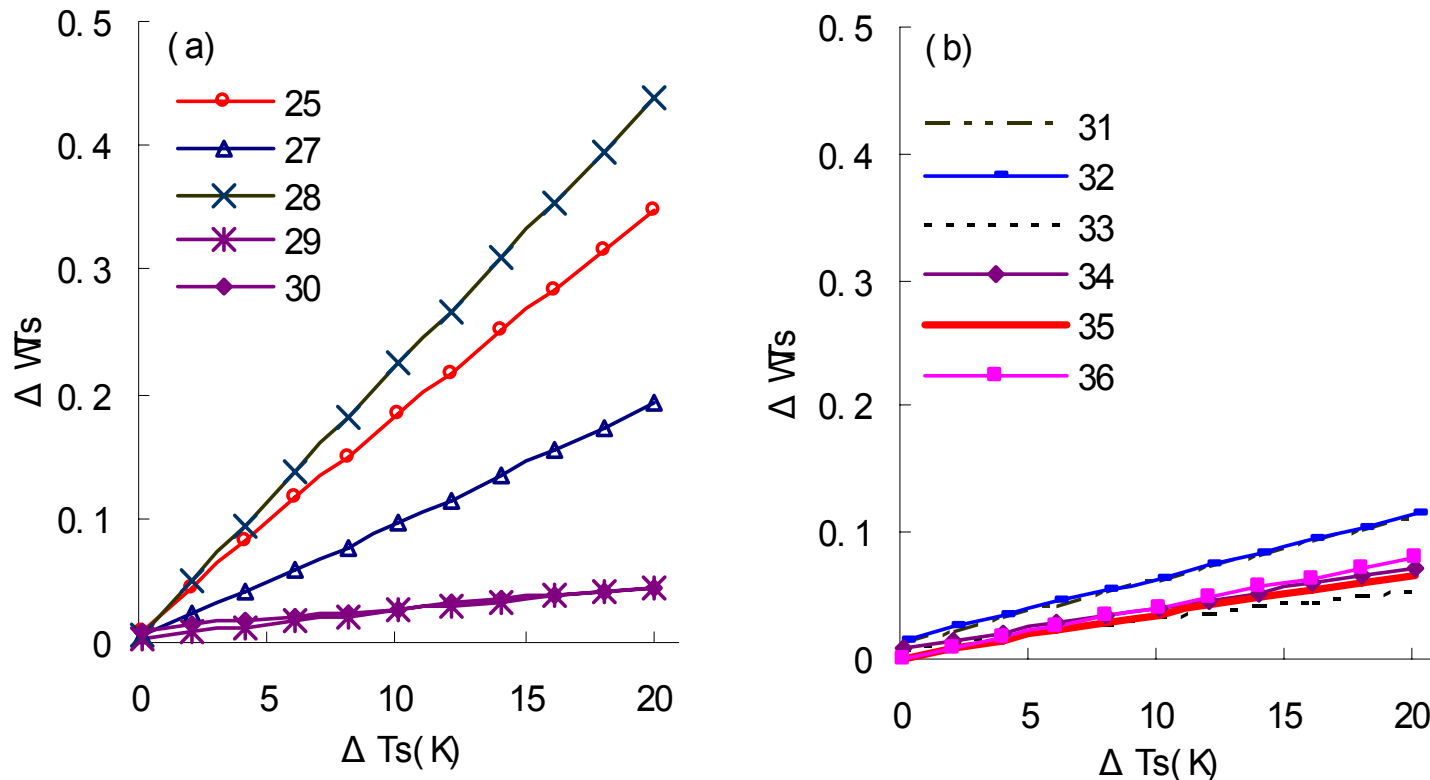
Sensible experiment (b)

Fig. effect of skin temperature estimated error on the weighting of the skin temperature

the weighting of the skin temperature is increased with increasing of skin temperature error , if skin temperature is overestimated, the weighting will be overestimated.

3.Effect and correction of aerosol on atmospheric retrieval

$$\tau_{a\lambda\,j} = \frac{p_j - p_t}{p_0 - p_t}\,\tau_{a\lambda}$$

$$\tau_\lambda = \tau_{ms\lambda} \cdot \tau_g \cdot \tau_o \cdot (\tau_r \cdot \tau_{a\lambda})$$

Considering the combined effects of continuum attenuation $\tau_{c\lambda}$ and molecular absorption $\tau_{ma\lambda}$ the spectral transmittance can be described as formula (2)

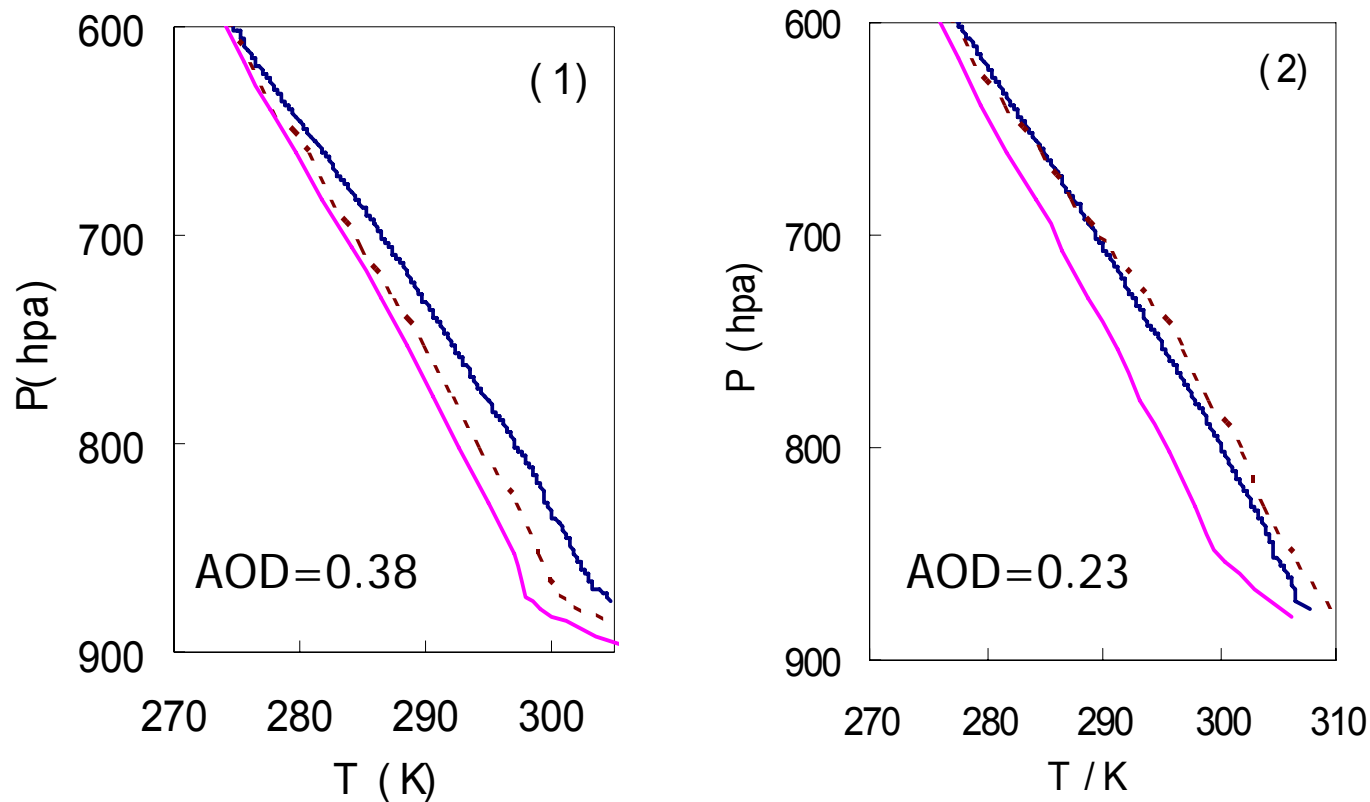# 3.Effect and correction of aerosol on atmospheric retrieval

Fig. The contrast of no physical retrieval (thin line) with AOT correction profile (dash line) and observed value(thick line) of one case on 29 June 2006(left panel), another case with 0.23 AOD (middle panel)

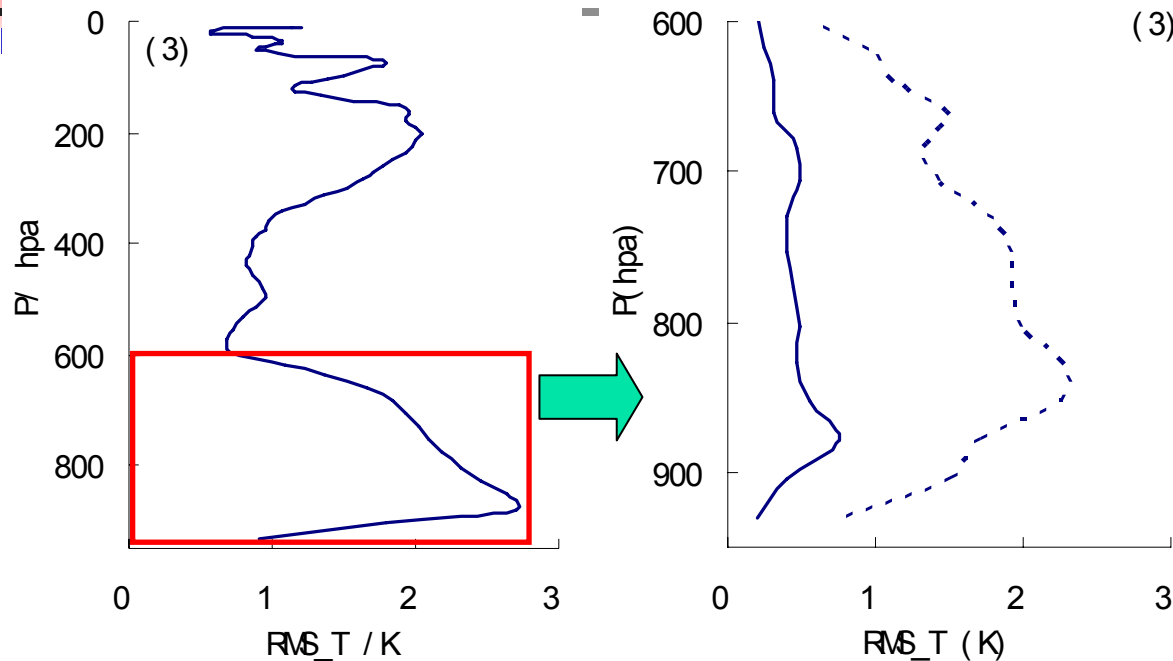# 3.Effect and correction of aerosol on atmospheric retrieval

Fig. The right panel is the RMSE after AOD correction (dashed line) and the RMSE improvement (thick solid line) due to AOD correction from all 32 cases.

After AOD correction, the largest rmse of 32 cases is 2.34 K , the average rmse is 2.02K. Improvement rmse is in 0.15-0.58K, average improvement is 0.38K .

retrieval error : a) MODIS has low spectral resolution. b) better handling emissivity in retrieval should be studied; and c) the radiosonde error should also be considered.
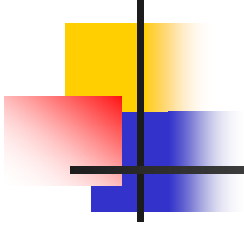
4. Conclusions and future work

Aerosol leads to notable optical effect.

When aerosol effects at infrared spectral are considered, atmospheric transmittance can be better estimated. Moreover, the weighting of skin temperature and atmospheric temperature can be realistically estimated.

lessons learned from MODIS and the techniques tested on MODIS can be applied to both current (AIRS, IASI) and future (CrIS, HES) sounding instruments.

Considering aerosol size distribution in transfer model , to improve regional retrieval precision of IR sounding.

Thank you for your attention!