# AOPs and RF over a Loess Plateau region in Northwestern China—Compared with SPRINTARS

**Bi J.[1], J. Huang[1], T. Takemura[2], and SACOL Team[1]**

*1-College of Atmospheric Sciences, Lanzhou University, China*
*2-RIAM, Kyushu University, Japan*

**10th AeroCom Workshop**
**Oct. 3-6, 2011, Kyushu, Japan**

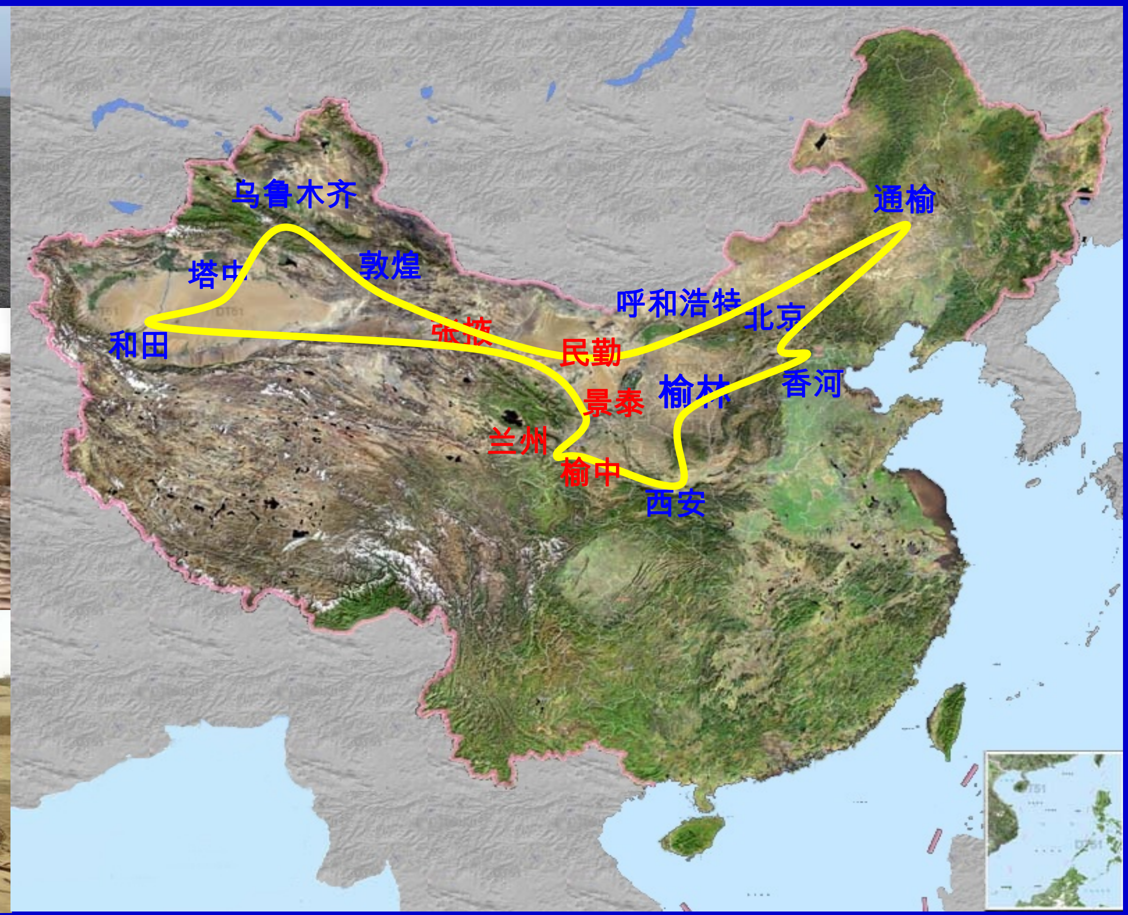
# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary

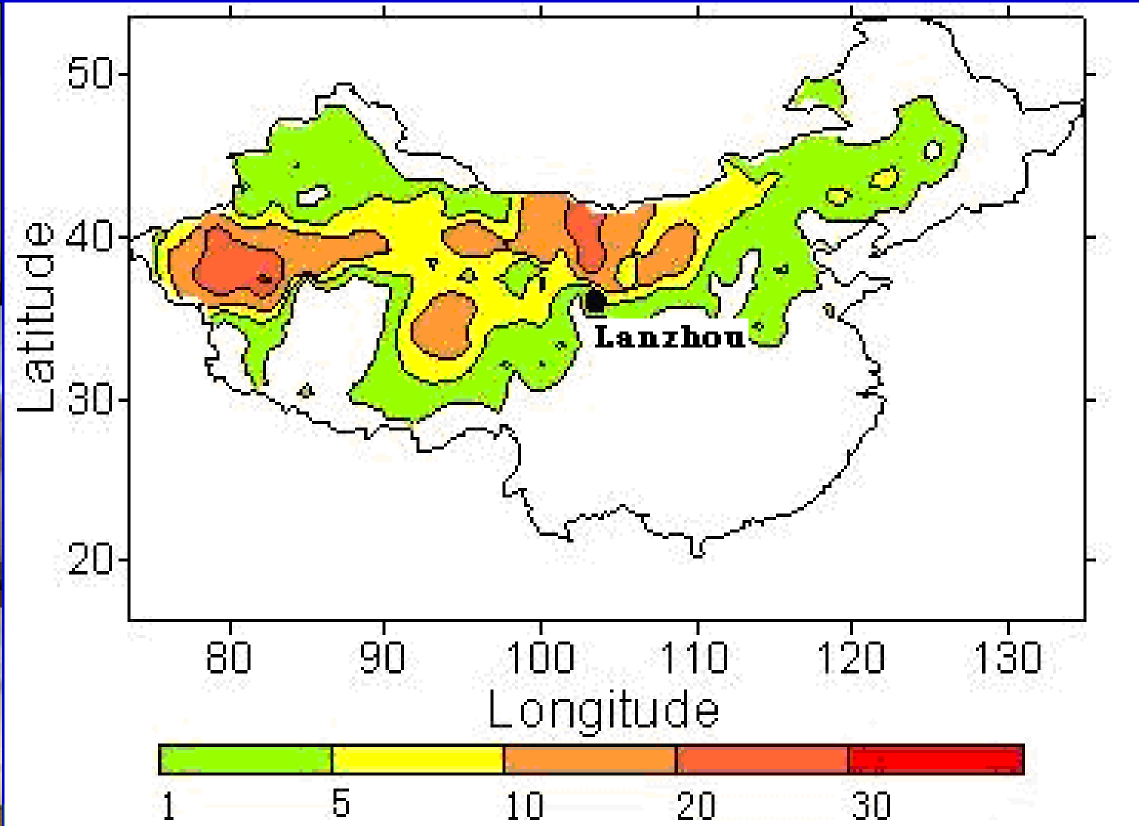
# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary

# Northwest China is arid/semi-arid area

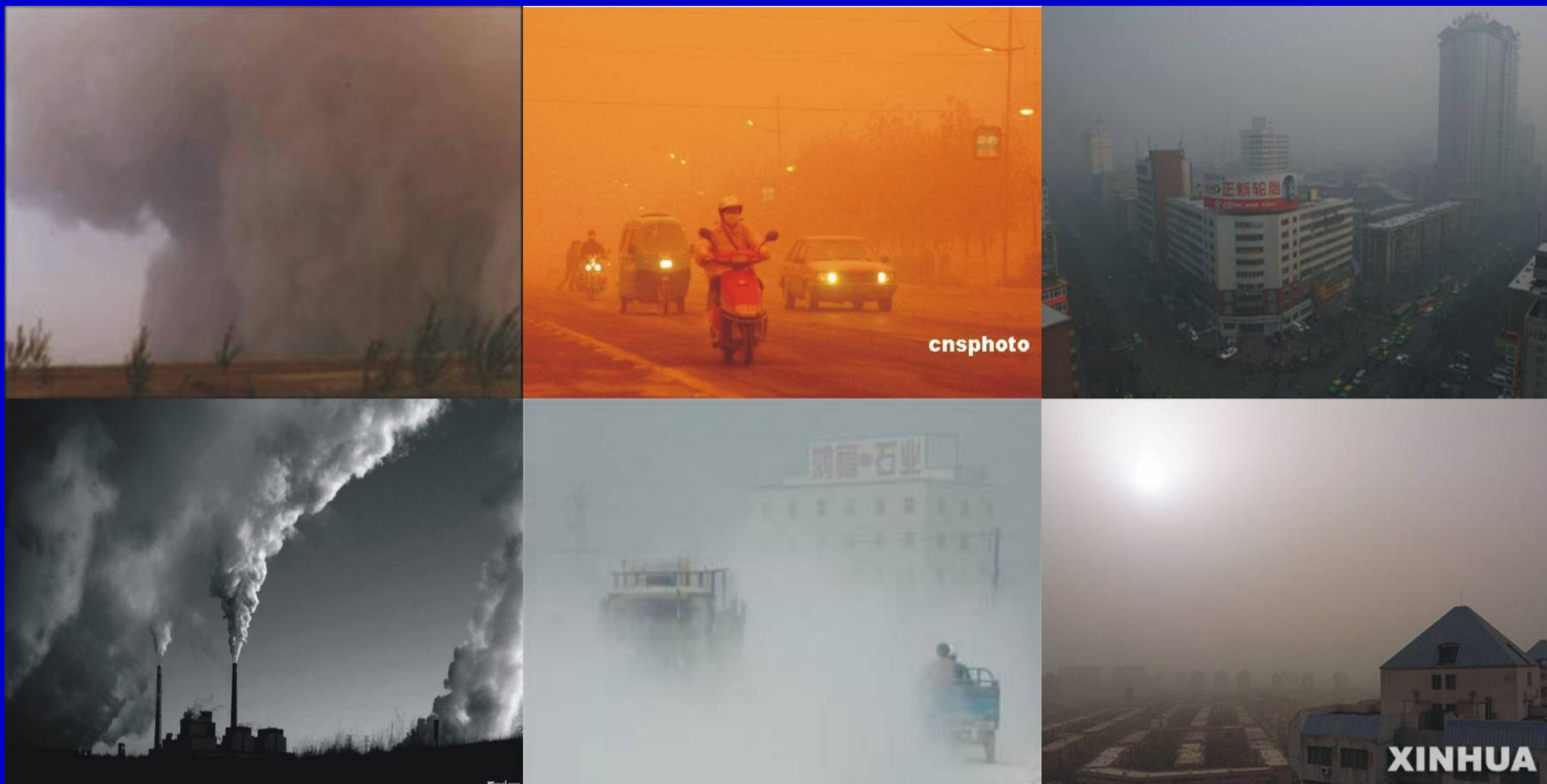


# This area is  a major source region of dust storm

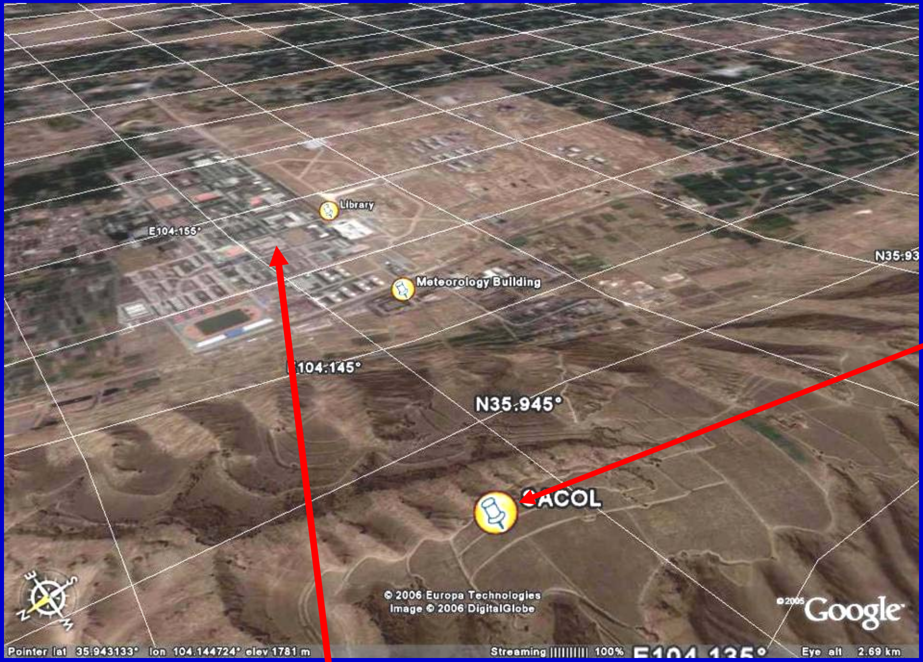


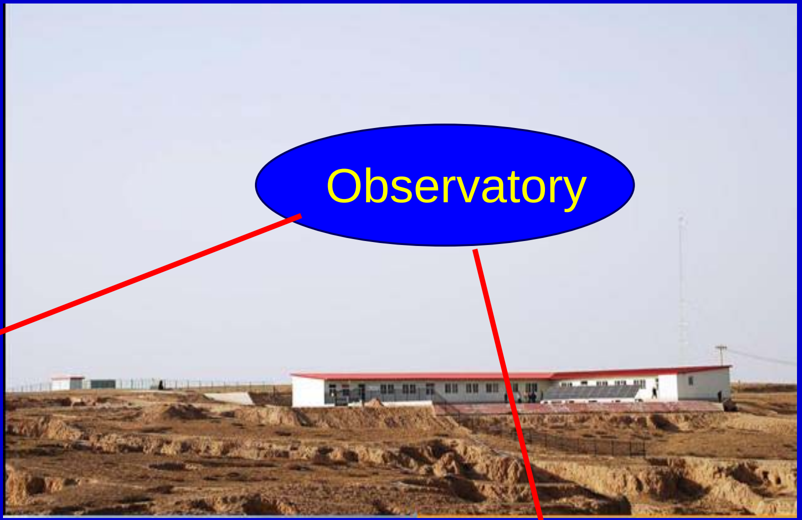

Distribution of  Dust Storm over China

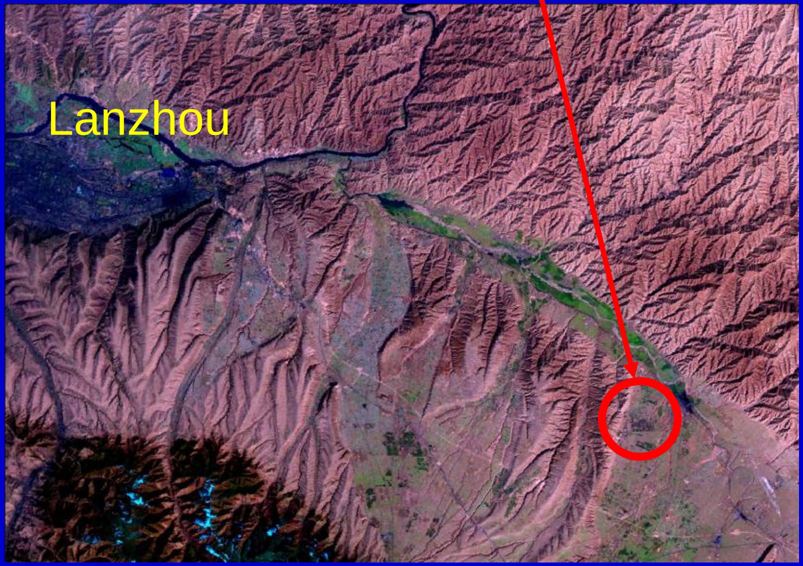
# Many kinds of other aerosols exist in this region



# SACOL is located at the top of Tsuiying mountain in Yuzhong Campus of Lanzhou University




*Semi-Arid Climate Observatory & Laboratory (SACOL)*

*http://climate.lzu..edu.cn Email: hjp@lzu.edu.cn*

# SACOL is established since 2005

## (35.95ºN, 104.14ºE)

**Climatic Conditions:**

Elevation: 1965.8 m

Surface Type: loess tableland, ridge, hillock and gully

Land Cover: moderation

**Annual Mean Parameters:**

Precipitation: 381.8 mm

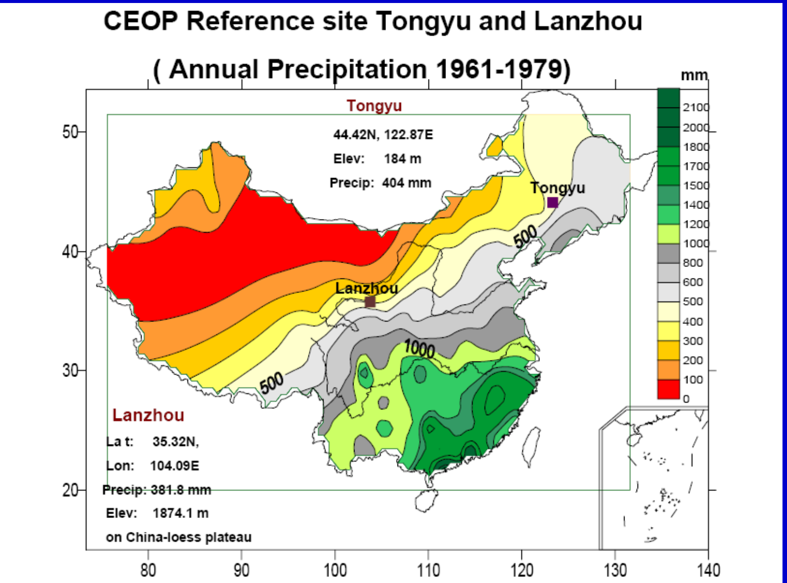
Evaporation: 1326.3 mm

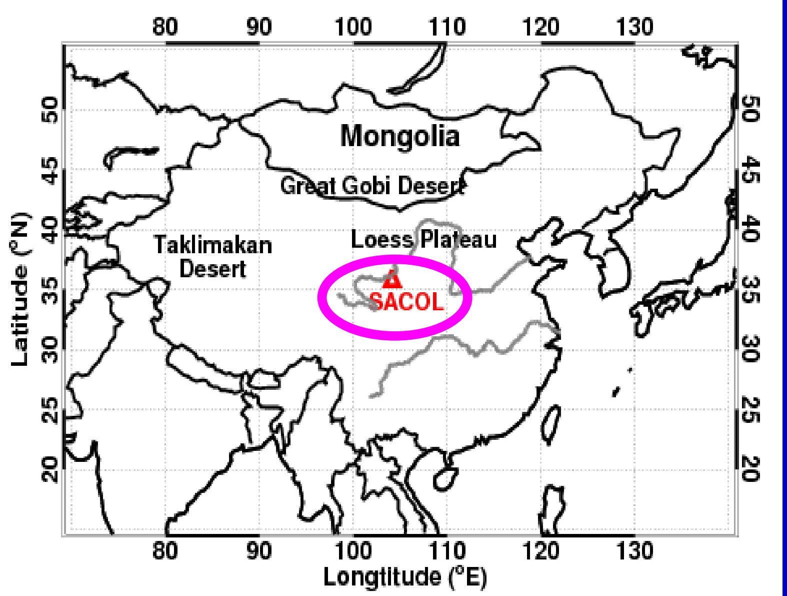
Relative Humidity: 63%

Wind Speed: 1.6m/s

Sunshine hours: 2607.2h

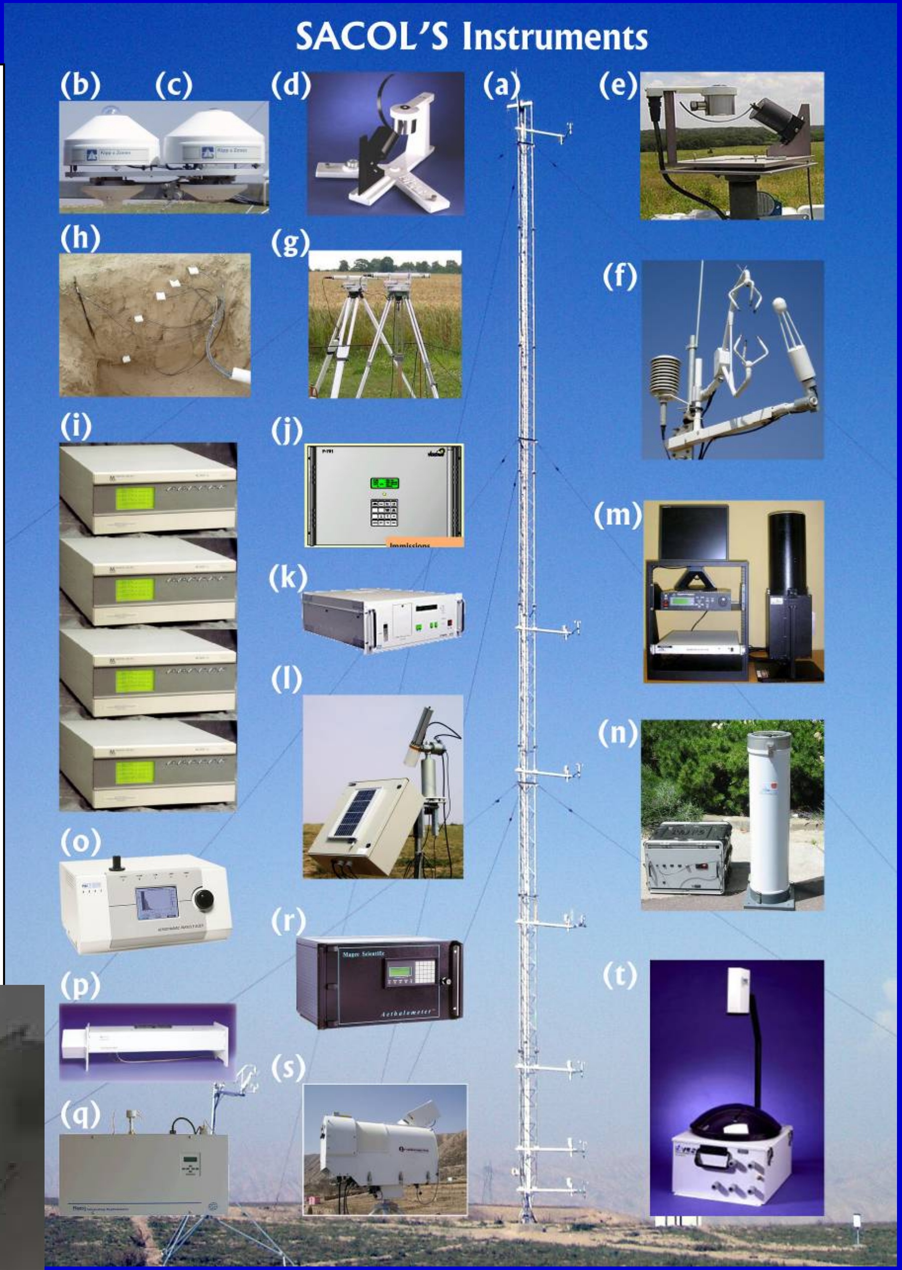
- **J. Huang et al. [*AAS*, 2008]**



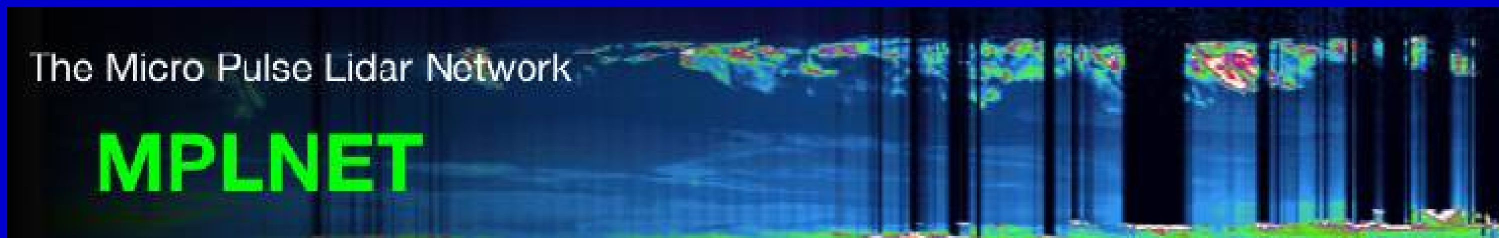



# Major Instruments

- 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




# Join in networks





***Semi-Arid Climate Observatory & Laboratory (SACOL)***
***http://climate.lzu..edu.cn Email: hjp@lzu.edu.cn***

# Sun photometer, CE318 (Cimel, France)

## Specifications

| | |
|---|---|
| Wavelengths | 340, 380, 440, 500, 675, 870, 940, 1020 nm |
| Monochromator | Narrow-bandpass interference filter |
| FWHM of filter | 2 nm for 340, 4 nm for 380, 10 nm for other channels |
| Detector | Silicon photodiode |
| FOV angle | 1.2$^{o}$ |
| Measurement | 30s for triplet measurements |
| Operating Temp. | -30 to +20 ℃ |

**A sun photometer is deployed at SACOL since Aug. 1$^{th}$, 2006.**

**The calibration is carried out at Mauna Loa Observatory (19$^{0}$ 32' N, 155$^{0}$ 34' W) annually.**

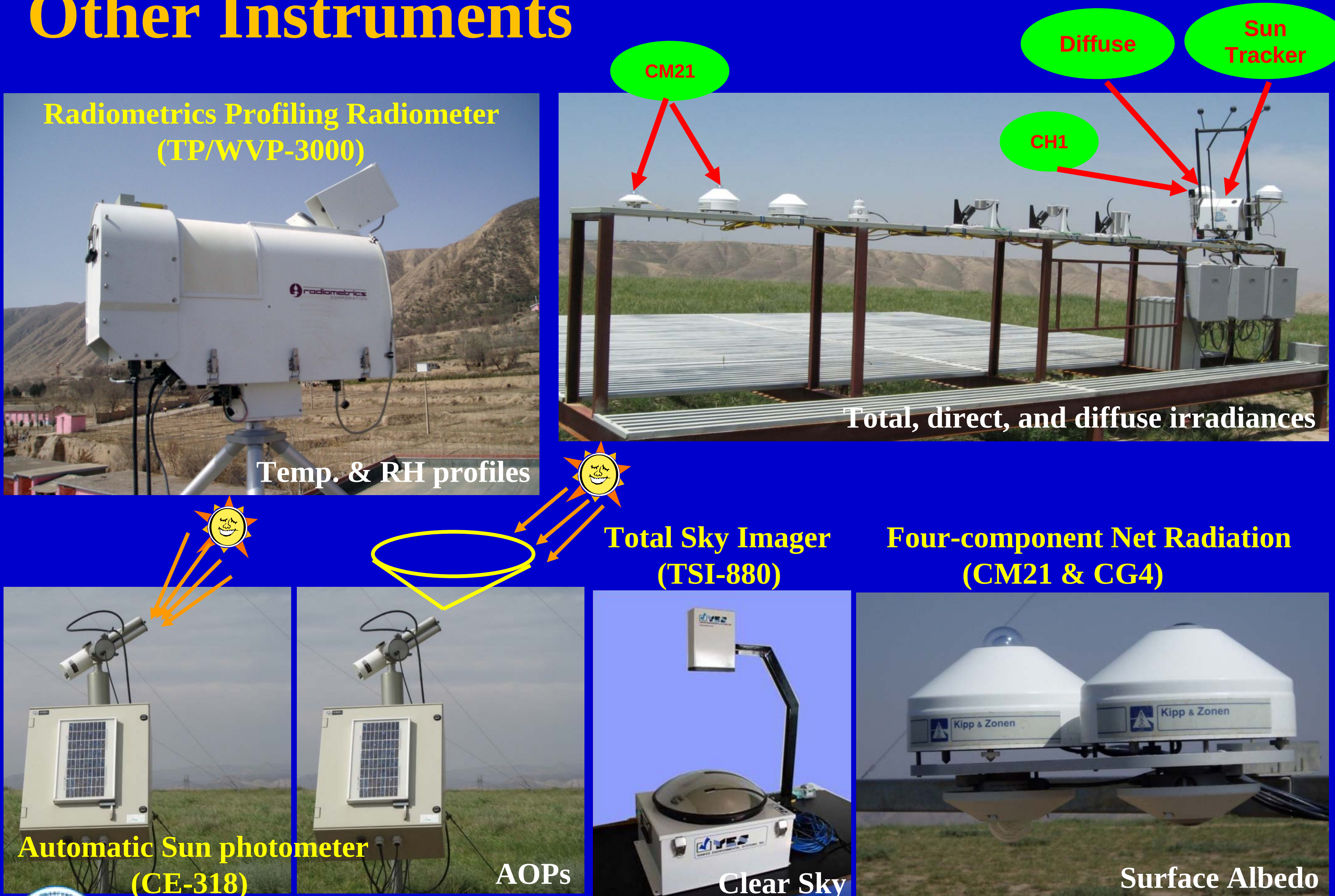
# Retrieved products of sun photometer

**Level 2.0 quality-assured data sets. They are pre- and post-field calibrated, automatically cloud screened and manually inspected.**

**Retrieval accuracy:**

| | |
|---|---|
| **AOD: 0.01-0.02** | **Holben et al. [*RSE*, 1998], Eck et al. [*JGR*, 1999]** |
| **WVC: ~10%** | **Schmid et al. [*AO*, 2001]** |
| **SSA: 0.03-0.05** | **Dubovik et al. [*JGR*, 2000a]** |
| **dV/dlnR: 15-35%** | **Dubovik et al. [*JGR*, 2000b]** |

# Other Instruments

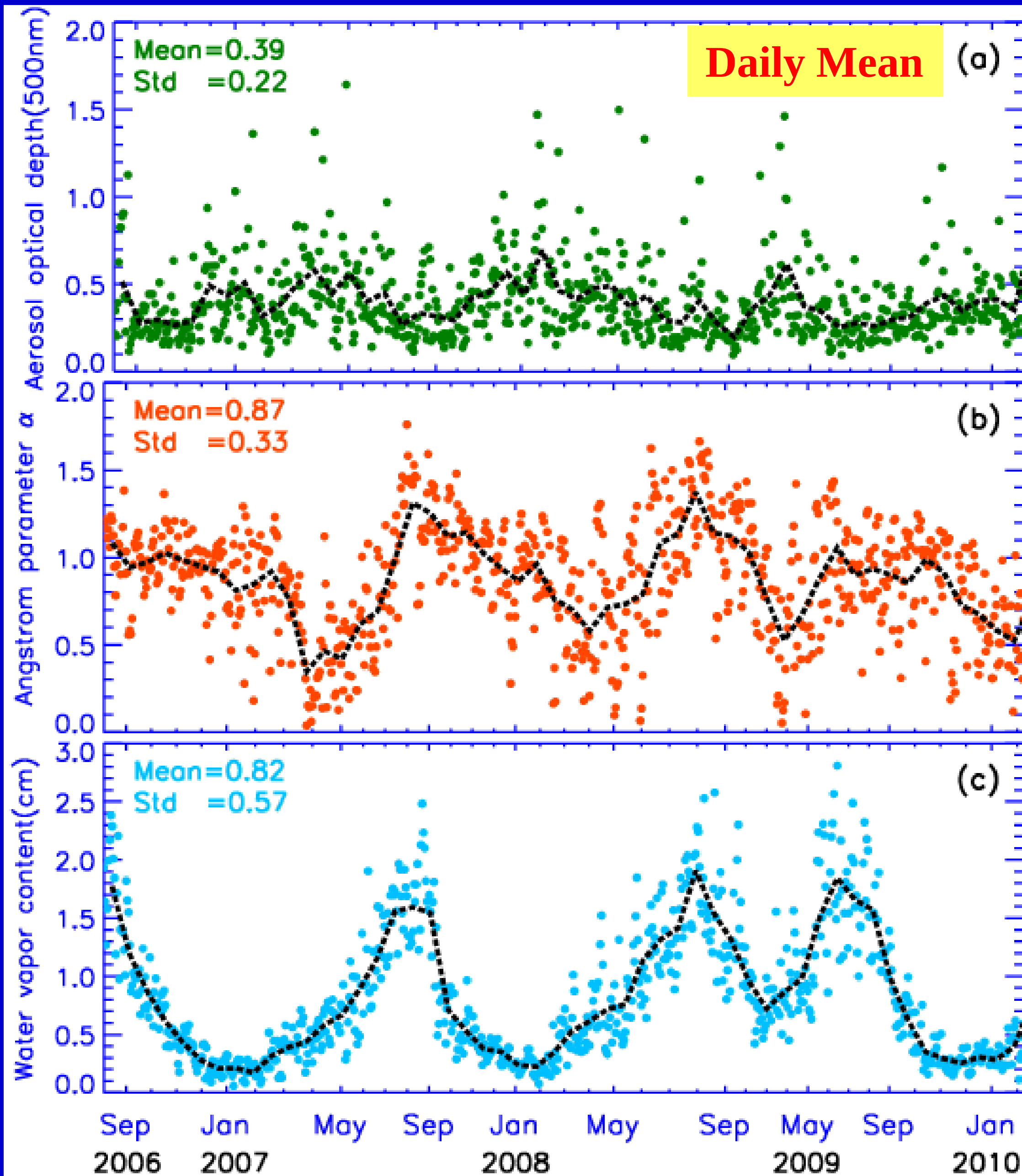


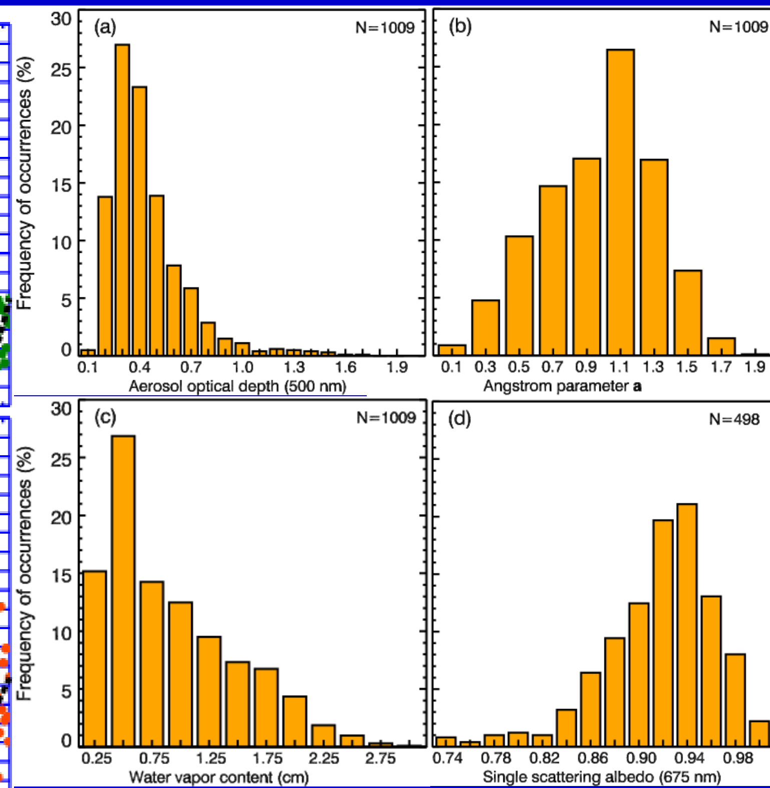

*Semi-Arid Climate Observatory & Laboratory (SACOL)*

*http://climate.lzu..edu.cn  Email: hjp@lzu.edu.cn*

# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary



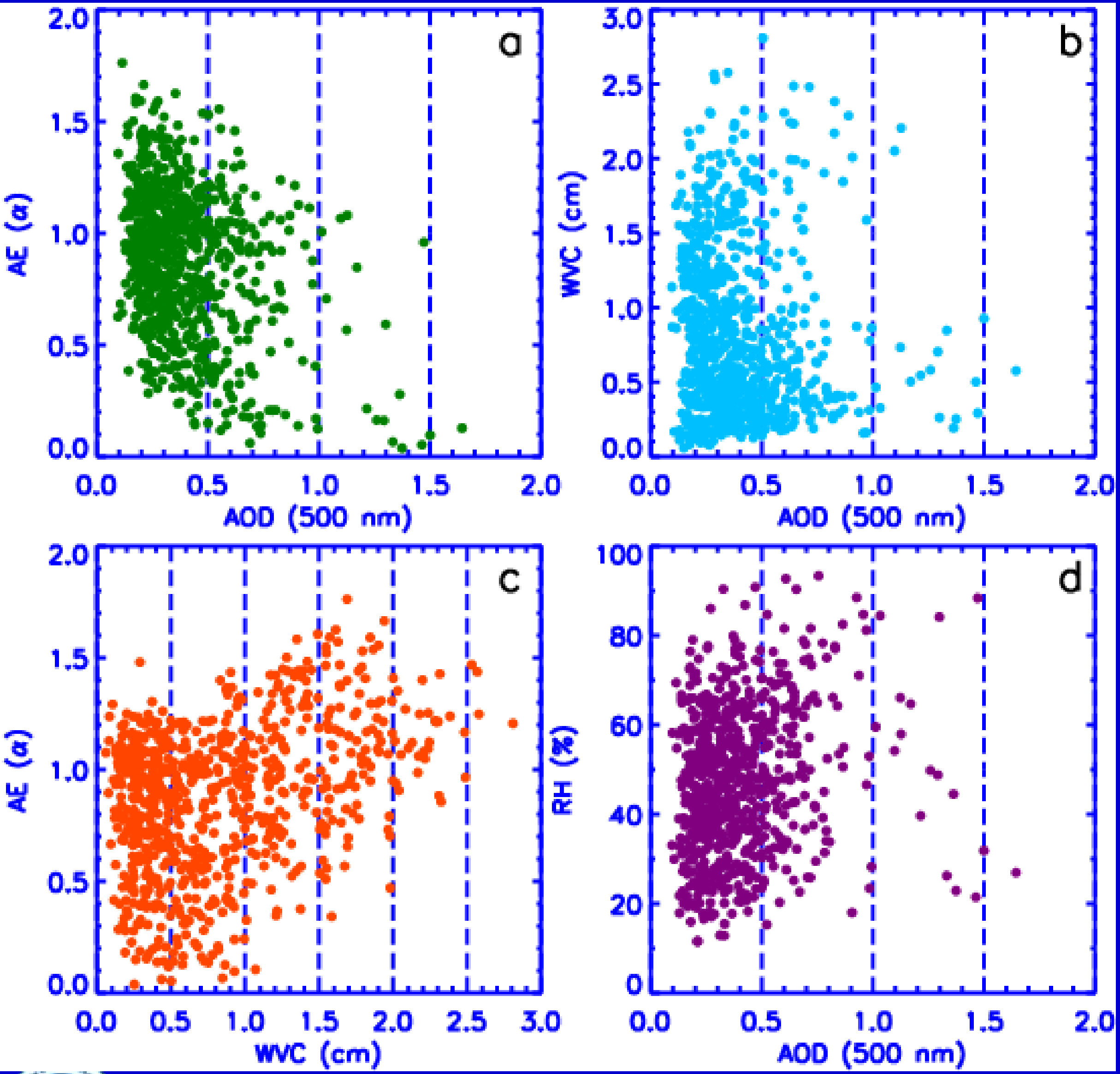

**$AOD_{500}$ < 0.5 : 78.5%**

**$AE_{440\text{-}870}$ > 0.9 : 69.4%**

**WVC at 0.5cm : 27%**

**$SSA_{675}$ at 0.92 and 0.94 : 40%**

# Scatterplots among $AOD_{500}$, AE and WVC




**According to AOKI et al. [*JMSJ*, 2003], aerosols are classified into four types:**

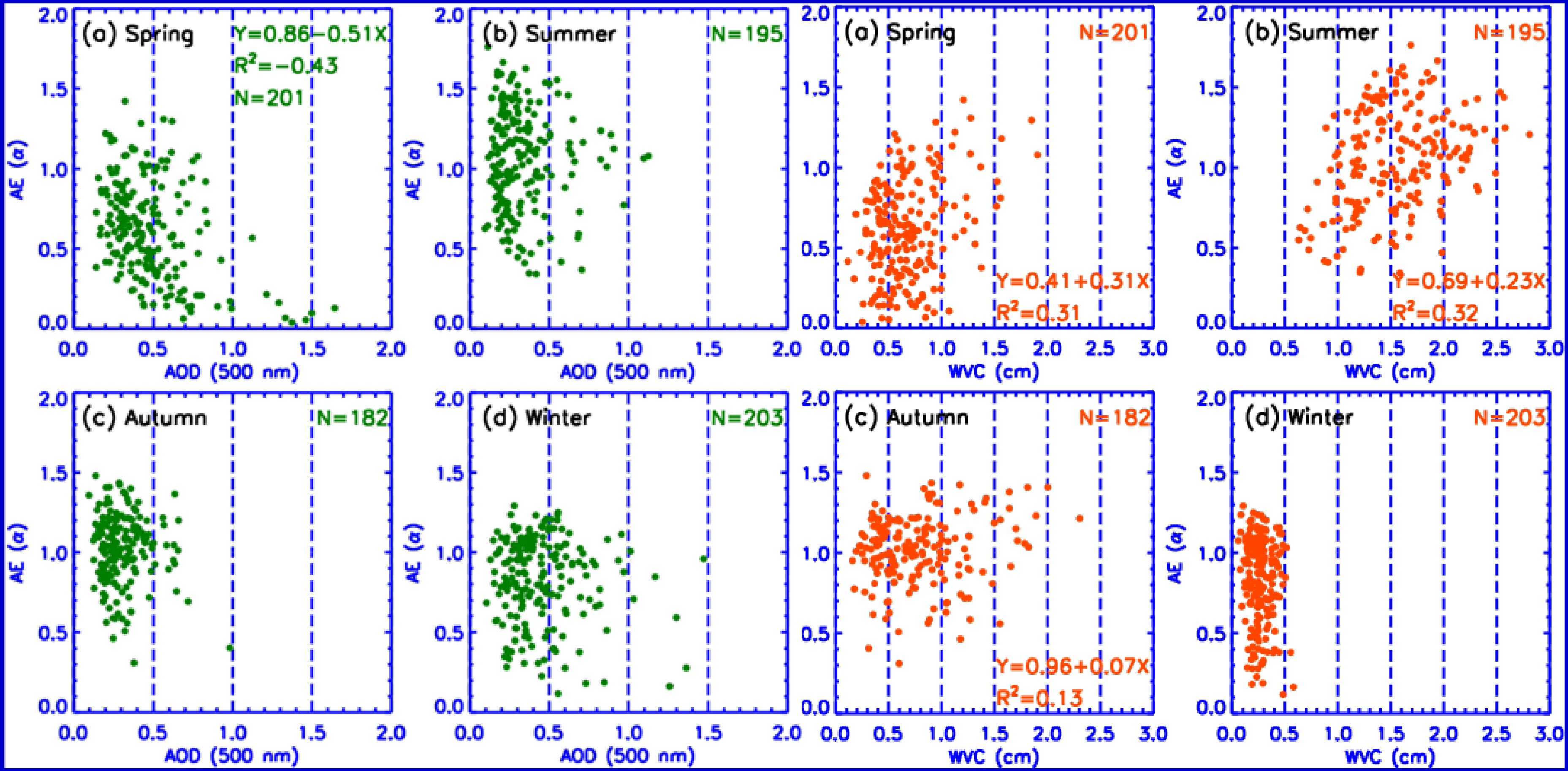
**I.** $\tau_{500} < \overline{\tau_{500}}$ , $\alpha > \overline{\alpha}$
**background, ~38%**

**II.** $\tau_{500} \geq \overline{\tau_{500}}$ , $\alpha \geq \overline{\alpha}$
**local, ~17% (sum.)**

**III.** $\tau_{500} < \overline{\tau_{500}}$ , $\alpha < \overline{\alpha}$
**large particles, ~25% (spr., win.)**

**IV.** $\tau_{500} > \overline{\tau_{500}}$ , $\alpha < \overline{\alpha}$
**dust, ~20% (spr., win.)**

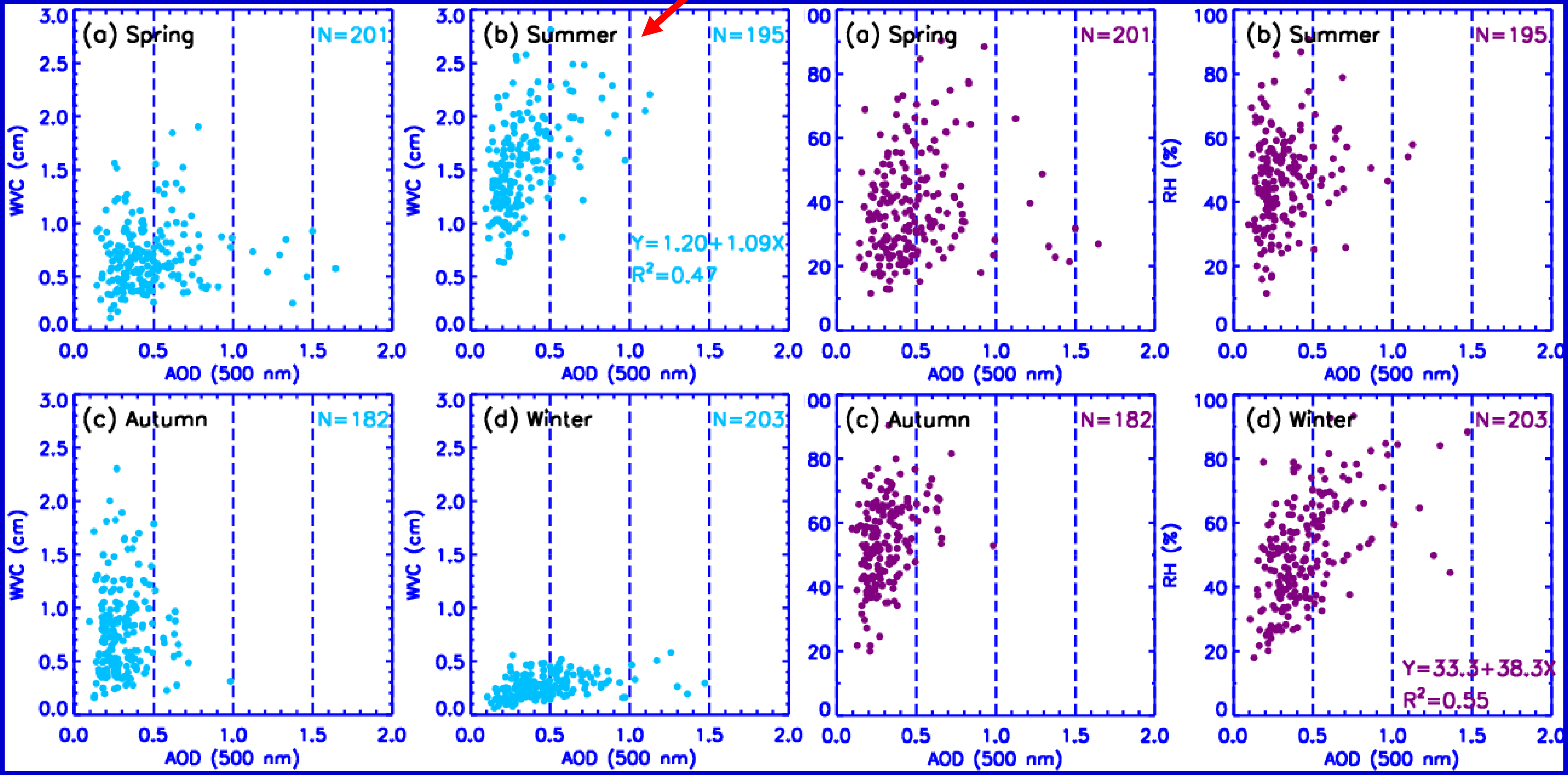
# Scatterplots: AE vs. $AOD_{500}$, AE vs. WVC — four seasons

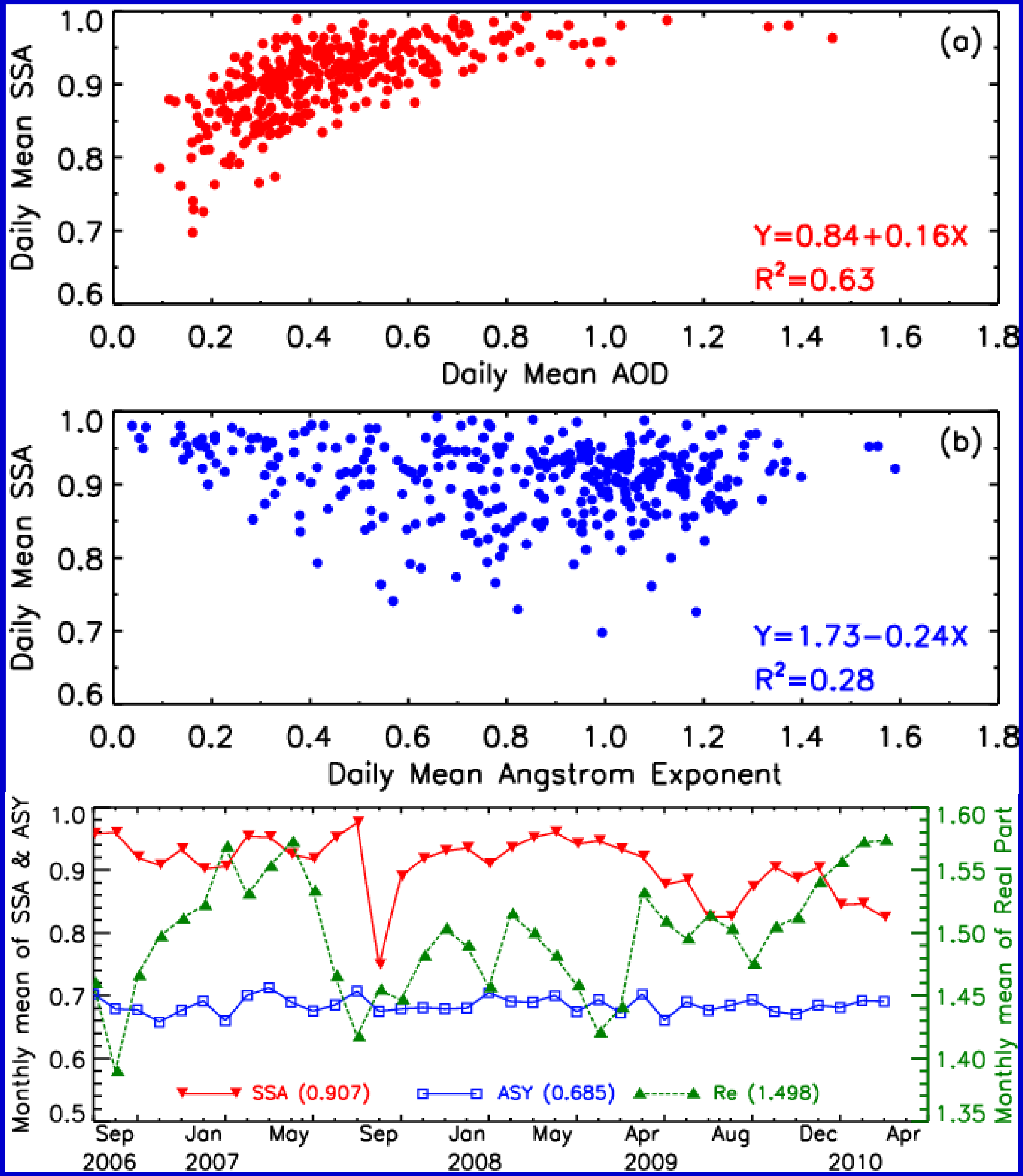



**Four types of aerosol are distinct in the left panel.**

# Scatterplots: WVC vs. $AOD_{500}$, RH vs. $AOD_{500}$ — four seasons

hygroscopic growth??



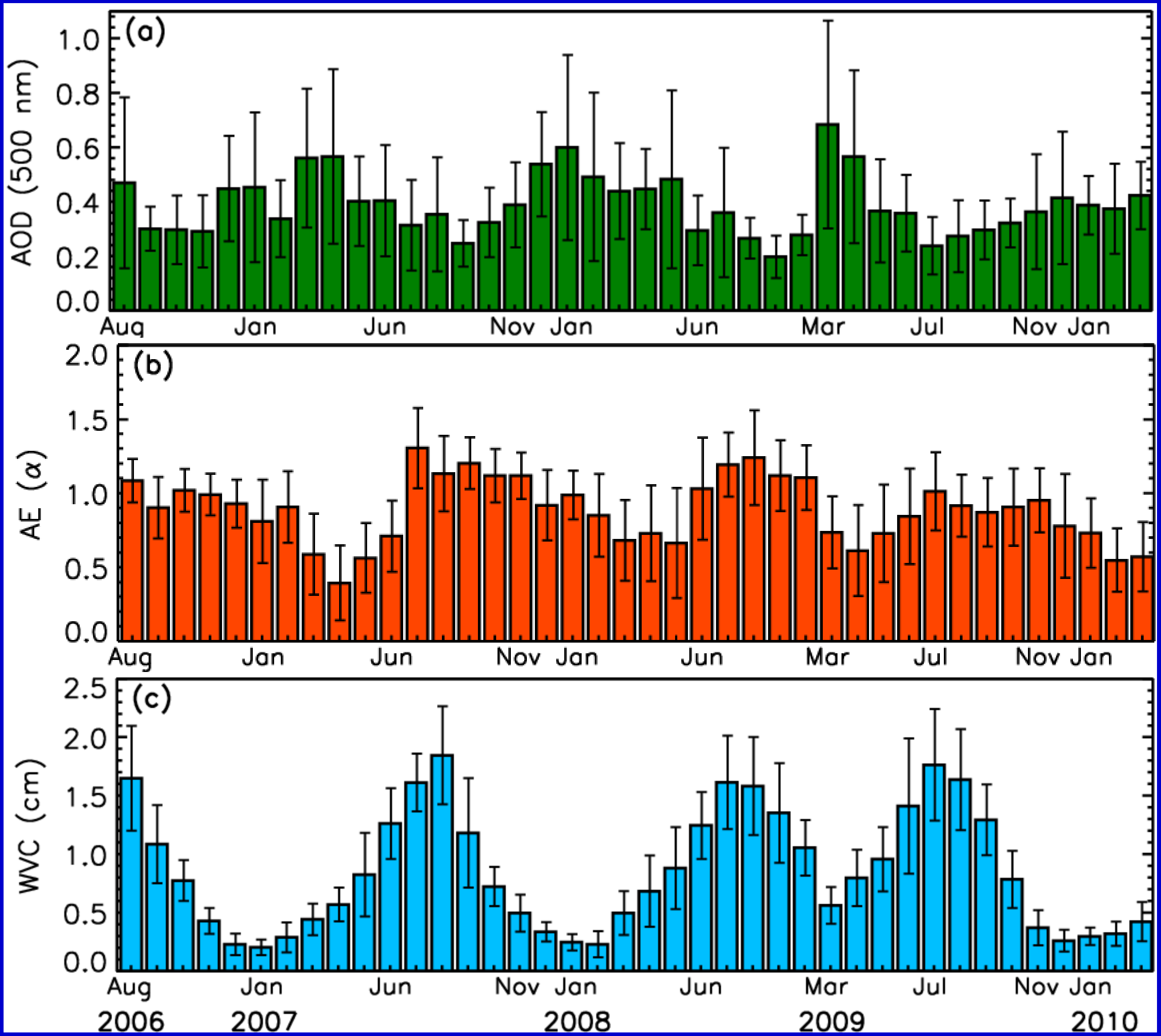


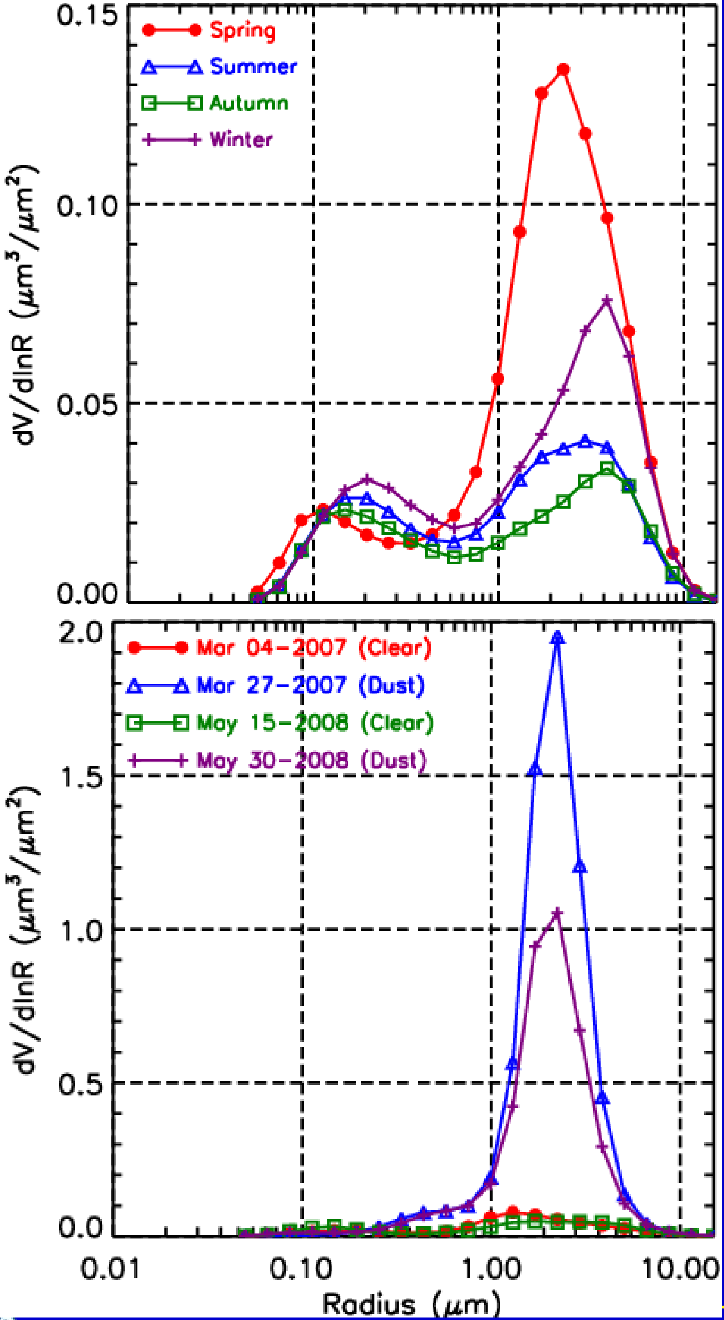

**SSA tends to increase with AOD, but decrease with $AE_{440\text{-}870}$.**

**Reasons:**

**Mixed of hygroscopic, coagulation growth and variable species of aerosol emissions from various sources.**

# Monthly mean AOPs at SACOL






**The variation of magnitude and shape of coarse particle in spring are distinct attributed to injecting dust particles.**

**Volume concentration ratio of coarse to fine particles ($C_{vc}/C_{vf}$)**

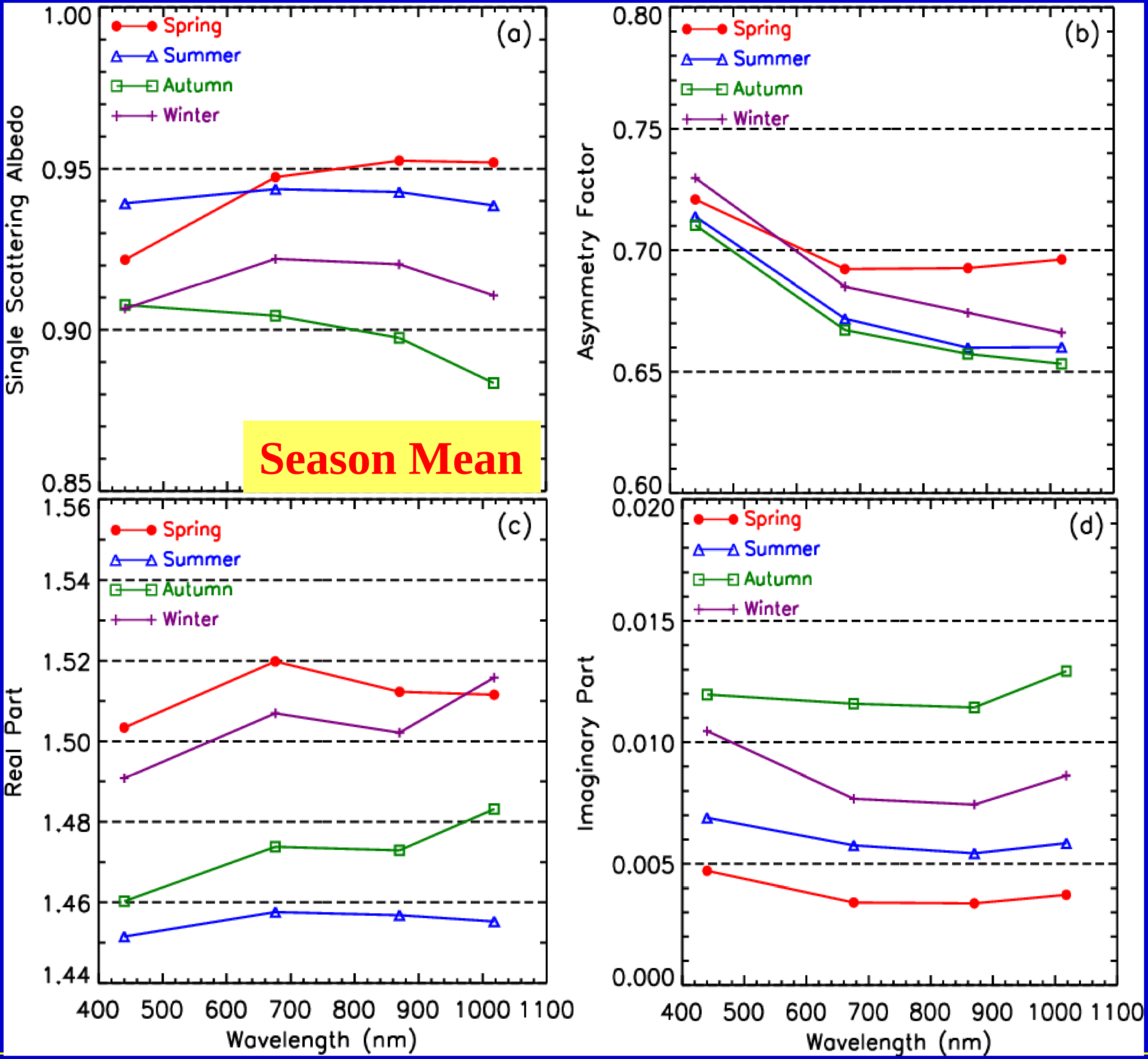
**SACOL: ~ 7 [Mean of Spring]**

**SACOL: ~ 20 [Heavy dust, Mar27,2007]**

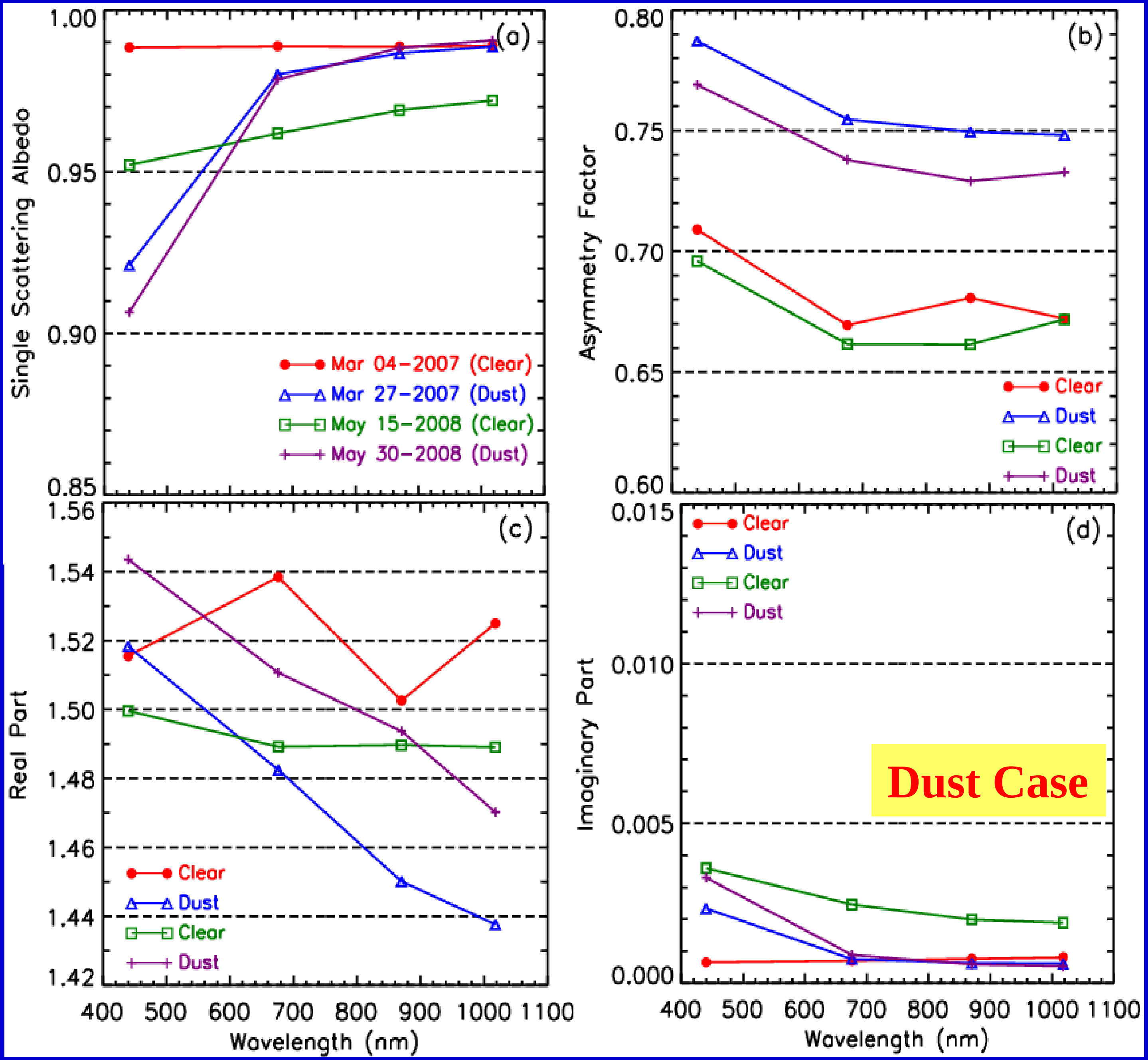
**ZhangYe: ~ 10 [*Ge et al.*, 2010]**

**DunHuang: ~ 30 [*Xia et al.*, 2004]**

**Sahara: ~ 50 [*Dubovik et al.*, 2002]**



Spring
Summer
Autumn
Winter
(a)
(b)
(c)
(d)
Single Scattering Albedo
Asymmetry Factor
Real Part
Imaginary Part
Season Mean
Wavelength (nm)



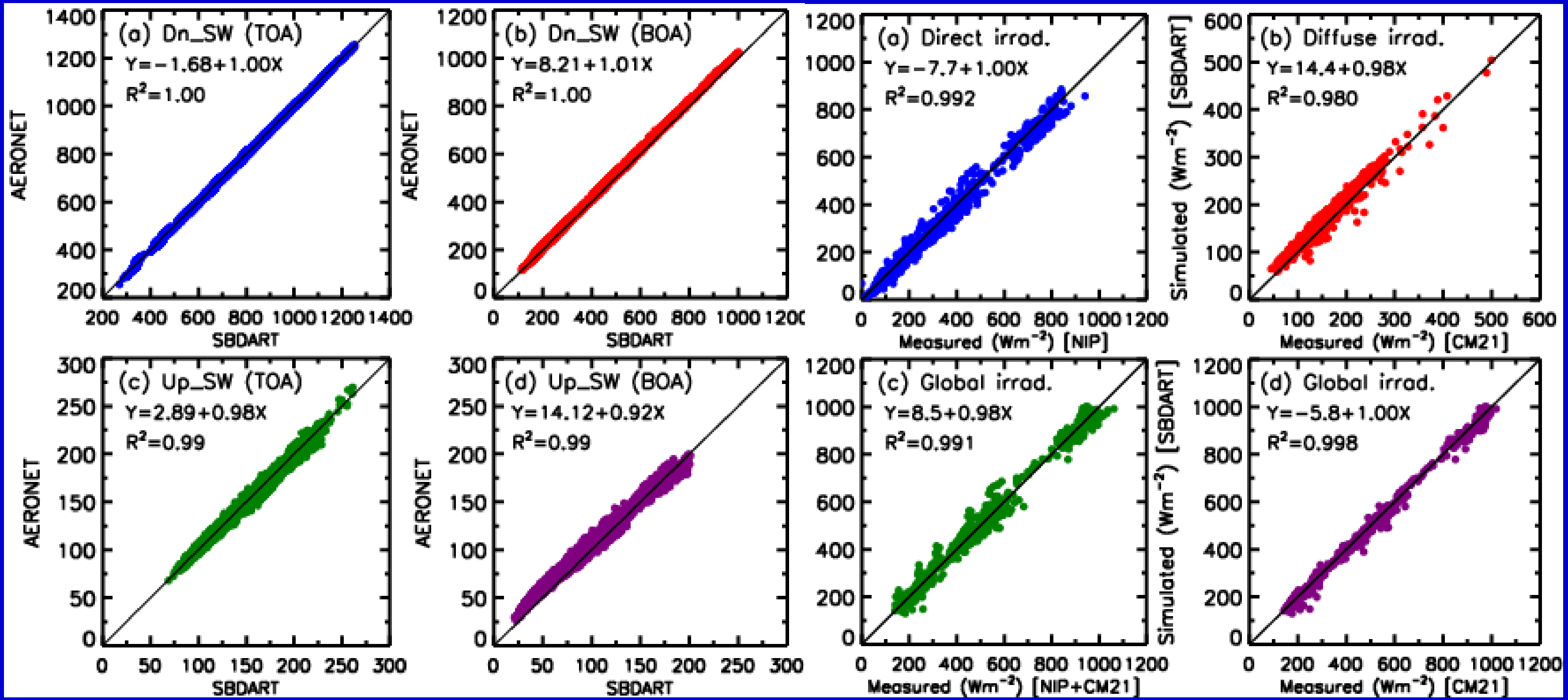

**Spectral behaviors are more apparent under dust events!!**

# Radiative Transfer Calculations—SBDART

## Input parameters

1. AOPs, Angstrom Exponent and WVC are retrieved from CE318.
2. Daily mean of Temp. & RH profiles are acquired from TP/WVP-3000 [0-10km height].
3. Daily total ozone amount is derived from TOMS.
4. Spectrally-dependent surface albedo is obtained from MODIS/BRDF, determined by mixing fraction of ‘Soil, Vegetation, and Water’ at a fixed site, Snow is also considered during the wintertime.
5. Broadband surface albedo is also taken into consideration.

# Radiative Closure Experiment at SACOL




**Good agreements among model, ground-based observations, and AERONET!**

# Direct Aerosol Radiative Forcing (ARF)

**ARF can be determined from mentioned above parameters and SBDART in 30-minute intervals. It is defined as:**

$$ARF=(F_{net})_{aerosol}-(F_{net})_{without\ aerosol}$$

$$ARF^{TOA}=(F_{net})^{TOA}_{aerosol}-(F_{net})^{TOA}_{without\ aerosol}$$

$$ARF^{BOA}=(F_{net})^{BOA}_{aerosol}-(F_{net})^{BOA}_{without\ aerosol}$$

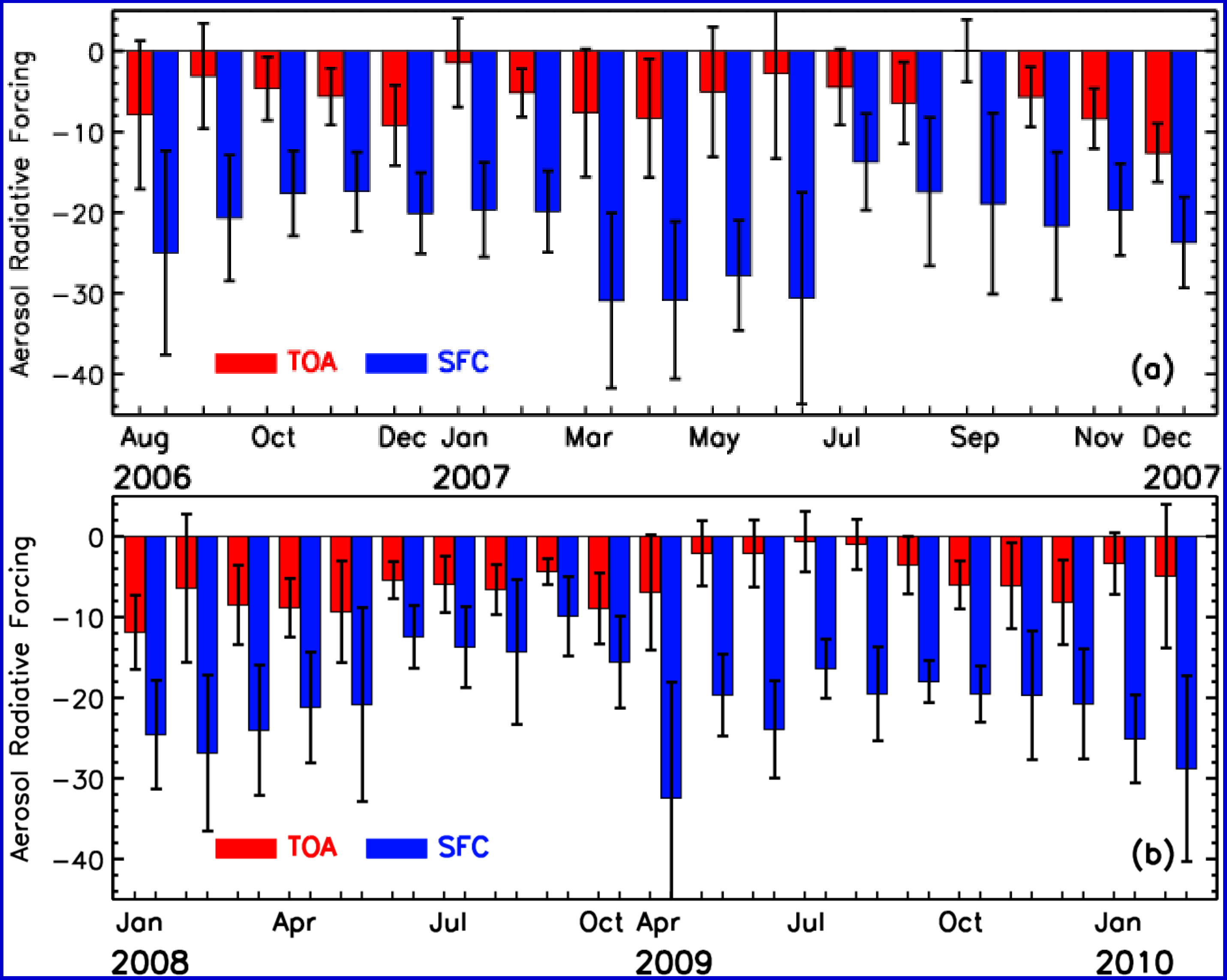
$$ARF^{Atmos}=ARF^{TOA}-ARF^{BOA}$$

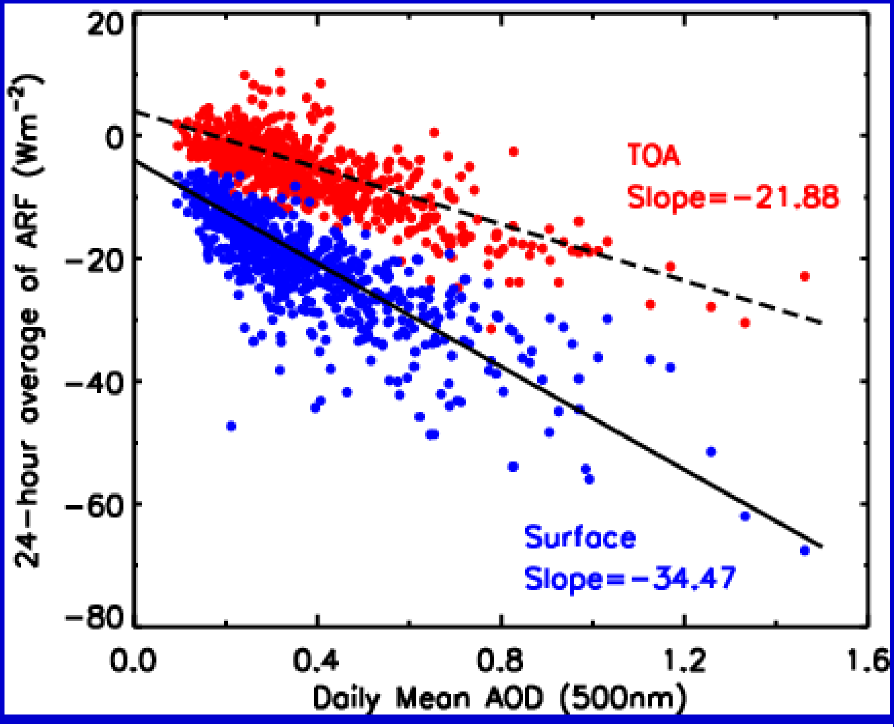
$$F_{net}=F^{sw}_{\downarrow}-F^{SW}_{\uparrow}$$

**Where TOA and BOA is the top and bottom of atmosphere, and Atmos represents the atmosphere.**

**To calculate the daily average ARF, we postulate that aerosol concentration remains relatively constant during the entire day and interpolated AOPs across periods when clouds present and missing data (including nighttime) to create a continuous time series.**

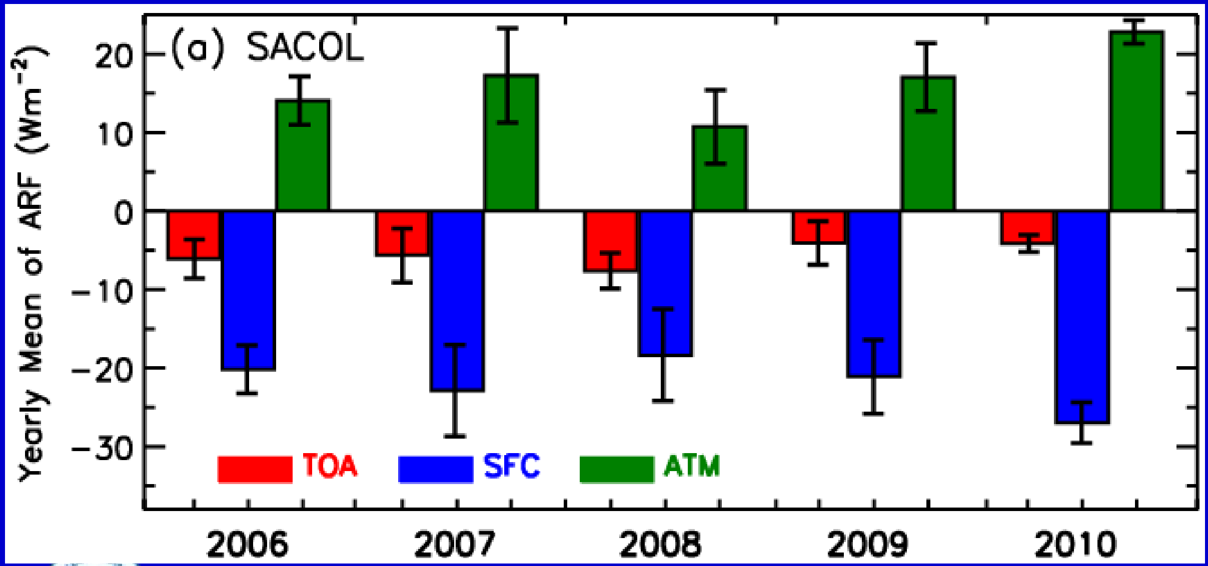
# Monthly mean ARF at SACOL






# TOA: slope=-21.88

# SFC: slope=-34.47




## Overall Average ARF:

**TOA: -5.5±1.5**

**SFC : -21.9±3.3**

**ATM: 16.4±4.5**

# Overall Average of ARF and ARFE

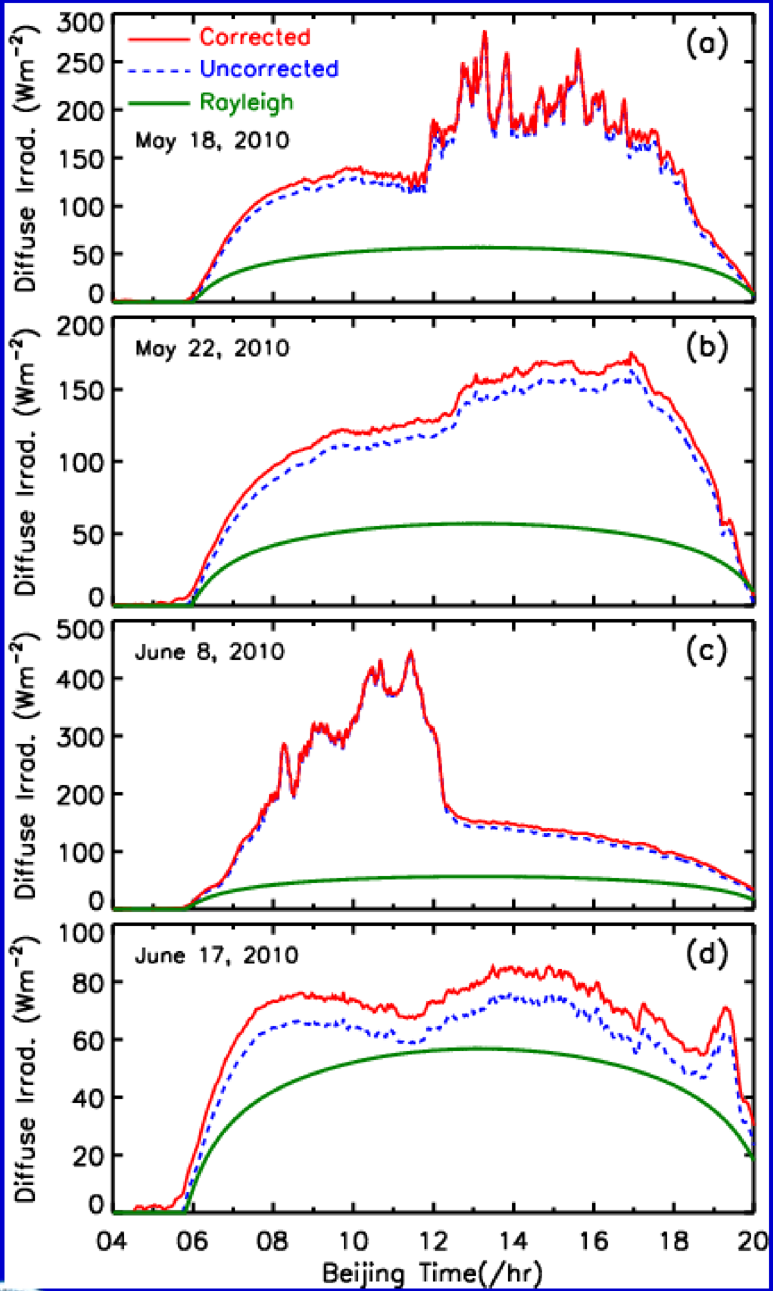
## Total average of ARF and ARFE at diverse locations.

| SACOL | 2006 | 2007 | 2008 | 2009 | Total |
|---|---|---|---|---|---|
| $ARF_{TOA}$ | -6.3±5.9 | -6.2±6.8 | -7.7±5.1 | -4.6±5.2 | -5.5±1.5 |
| $ARF_{SFC}$ | -19.8±7.5 | -23.5±9.7 | -18.9±9.3 | -21.4±8.5 | -21.9±3.3 |
| $ARF_{ATM}$ | 13.6±7.9 | 17.3±10.5 | 11.2±6.9 | 16.8±7.0 | 16.4±4.5 |
| $ARFE_{SFC}$ | -66.1±5.8 | -65.9±7.4 | -59.1±9.1 | -76.0±10.8 | 67.0±10.5 |

| | $ARF_{TOA}$ | $ARF_{SFC}$ | $ARF_{ATM}$ | $ARFE_{SFC}$ | |
|---|---|---|---|---|---|
| Global | -4.9±0.7 | -11.8±1.9 | | -80 ~ -48 | *Yu et al.*, 2006 |
| INDOEX | -7.0±1.0 | -23.0±3.0 | 16.0±2.0 | -72.2±5.5 | *Ramanathan*, 2001 |
| East Asia | | -43 ~ -13 | | -76.0±9.6 | *Kim et al.*, 2005 |
| ZhangYe | 0.52±1.69 | -22.4±8.9 | | -95.1±10.3 | *Ge et al.*, 2010 |
| China | 0.30±1.60 | -15.7±8.9 | 16.0±9.2 | -65.4±4.7 | *Li et al.*, 2010 |
| Yangtze | | -38.4 | | -51.4 | *Xia et al.*, 2007 |

# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary

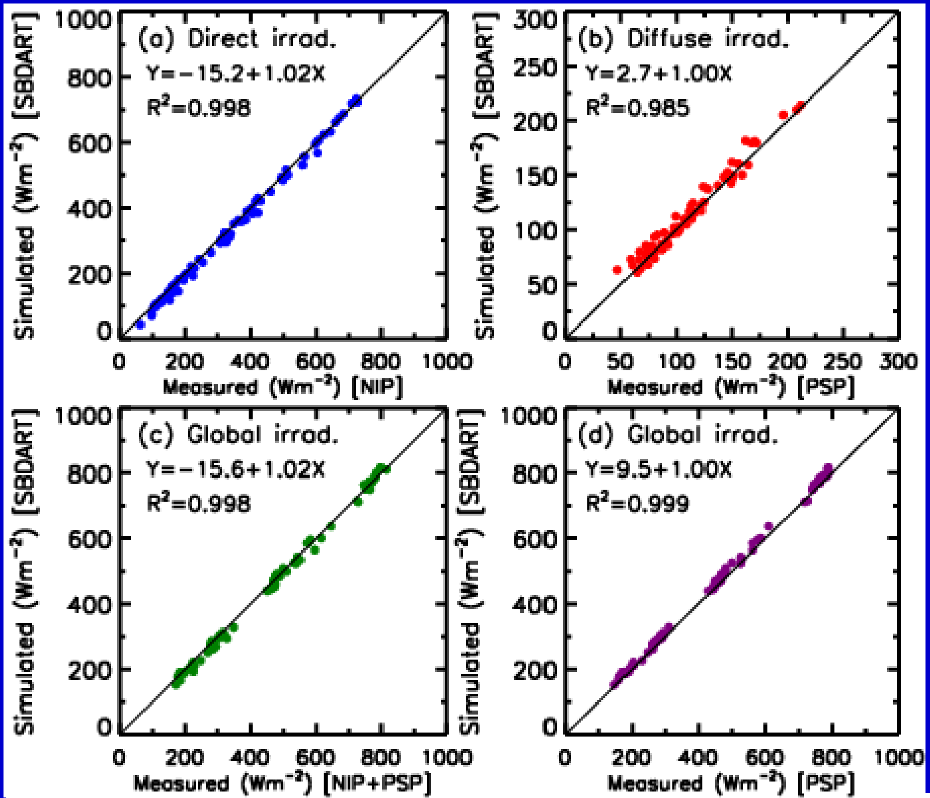




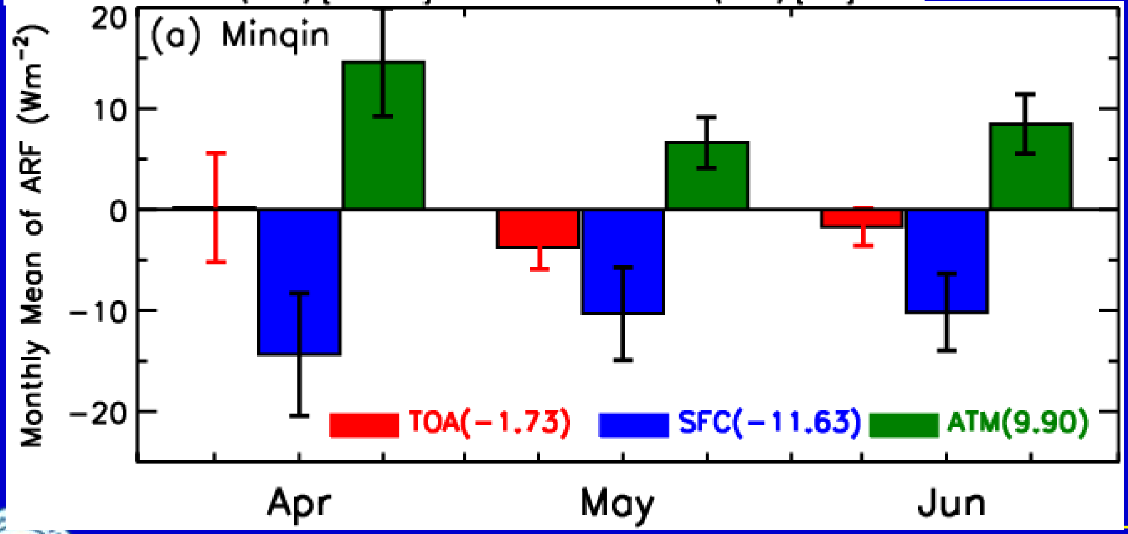
**SACOL Mobile Facility is deployed at Minqin (38.61ºN/102.96ºE, 1373 m), where locate in the Southeast border of Badain Jaran Desert.**

**Daytime thermal offset of diffuse irradiance (PSP) is corrected according to Dutton et al. [*JAOT*, 2001].**

$$corr = b_0 + b_1 NetIR + b_2 \times \sigma \times (T_d^4 - T_c^4)$$




# Model simulated surface irradiances coincide excellent with ground-base observations, as well!

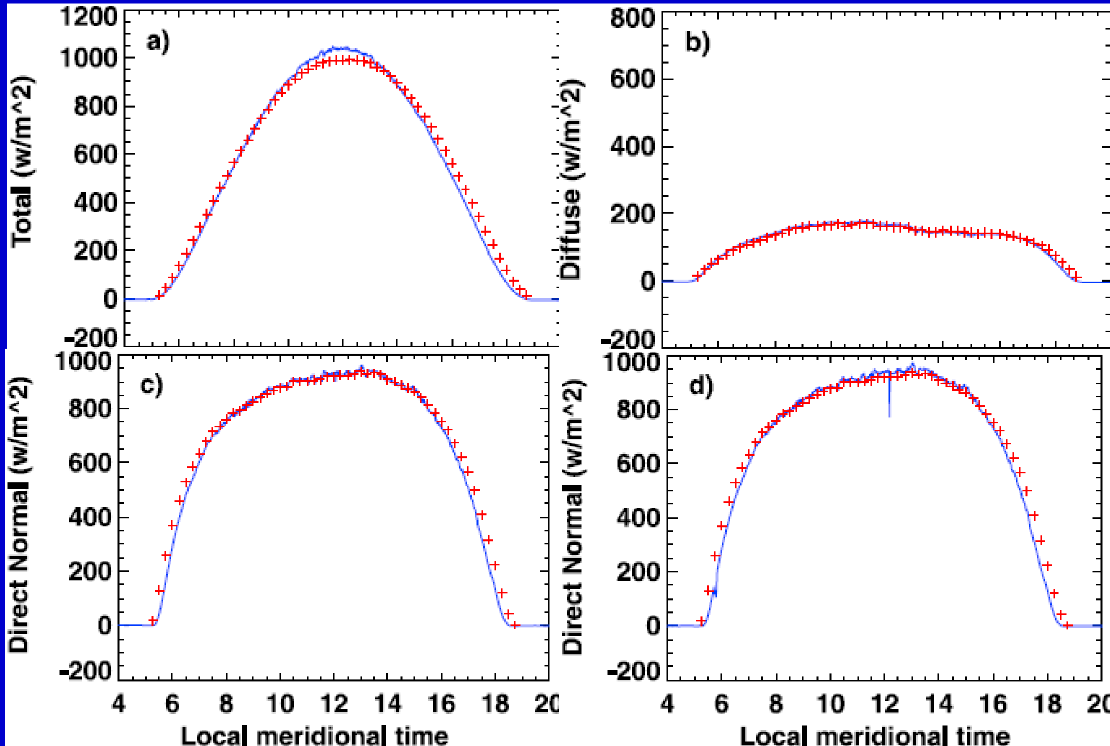



## Total Average ARF:

**TOA: -1.73±1.96**

**SFC: -11.63±2.37**

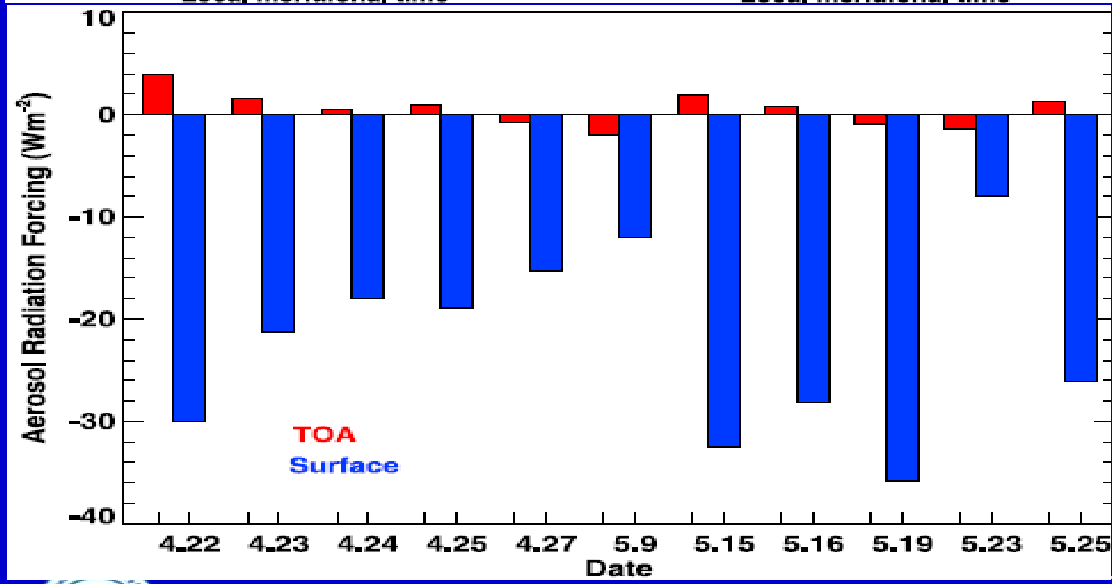
**ATM: 9.90±4.16**



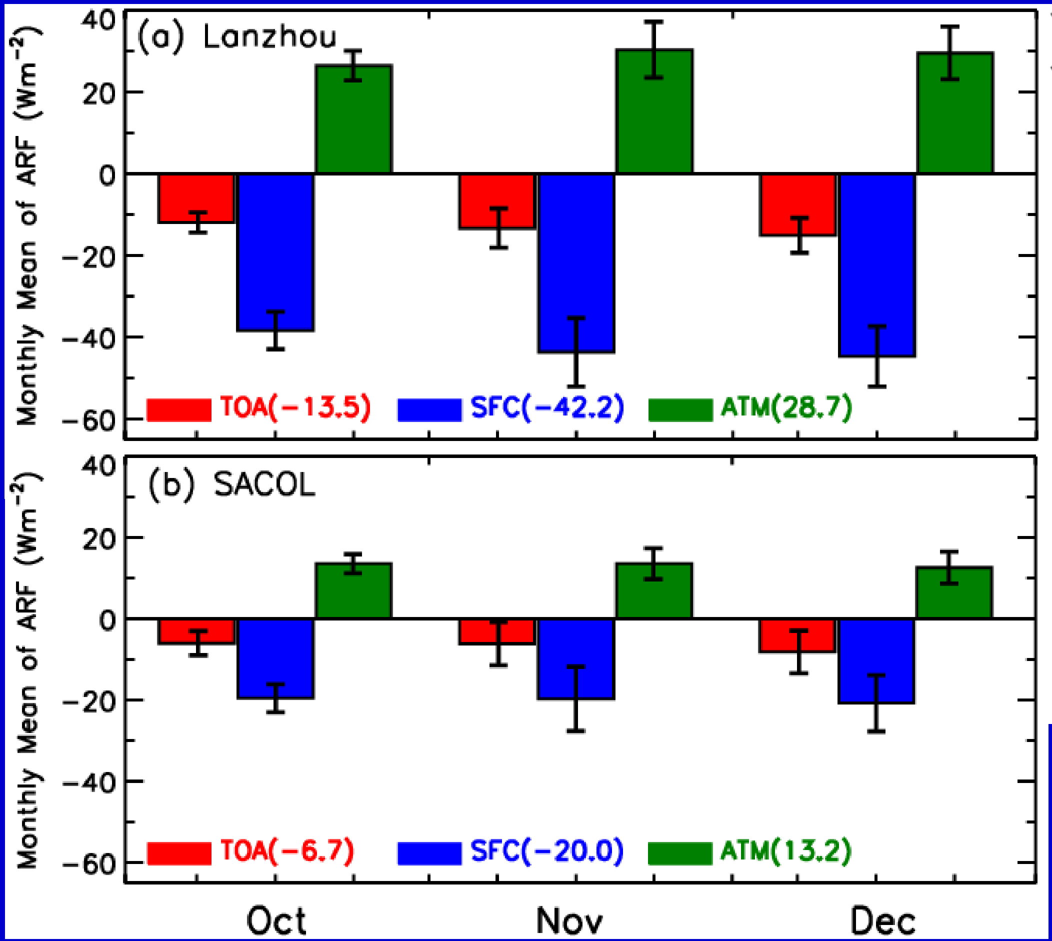


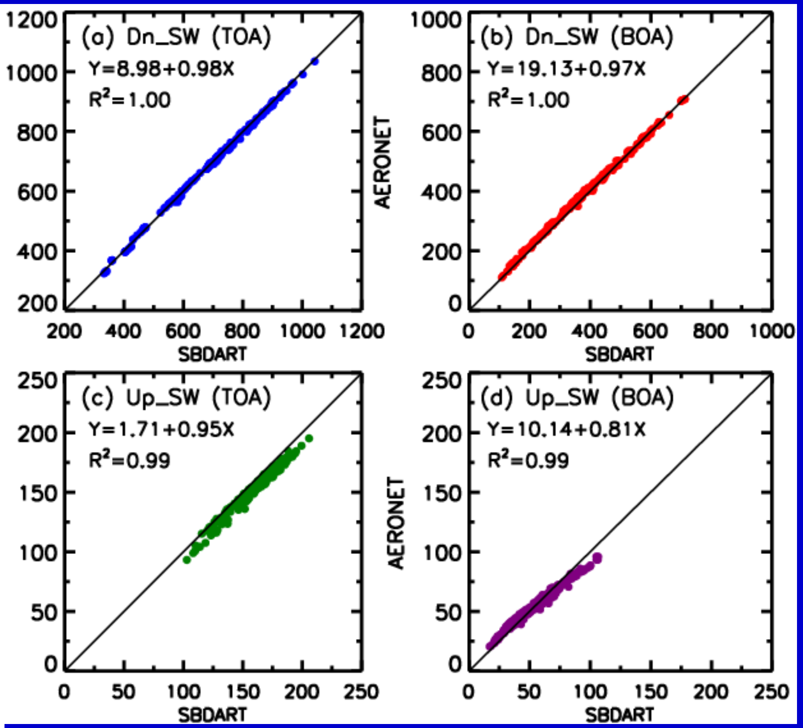
Apr. 16—Jun. 20, 2008

**NASA Mobile Facility is deployed at Zhangye (39.08ºN, 100.27ºE), where locate in the east edge of Taklimakan Desert.**




**Ge et al. [*JGR*, 2010] indicated that moderately strong absorbing aerosols exist in Gobi desert area of northwest China.**



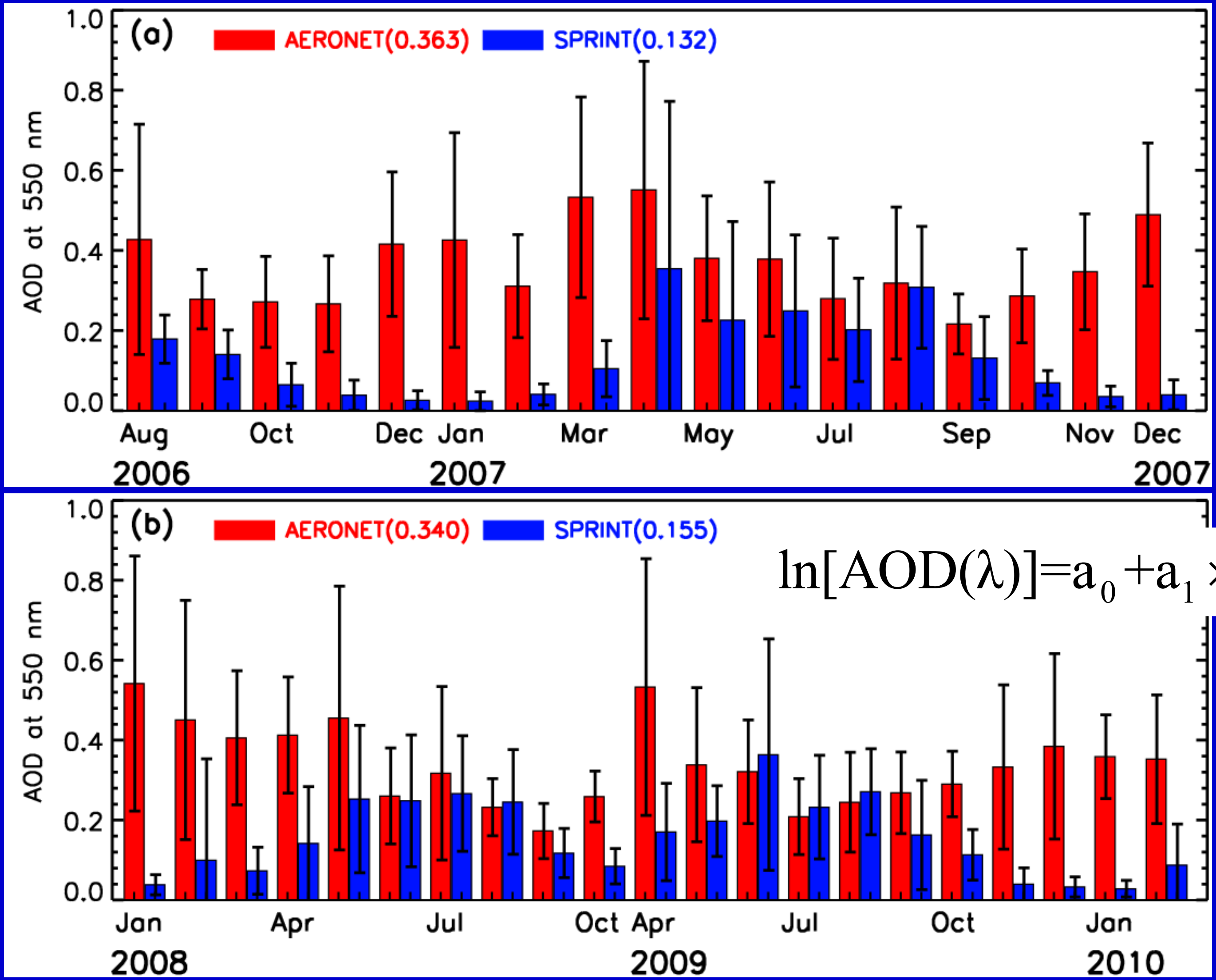




**ARFs in Lanzhou city are twice for SACOL during the same period of 2009.**

# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary

# Comparisons—AOD at 550 nm

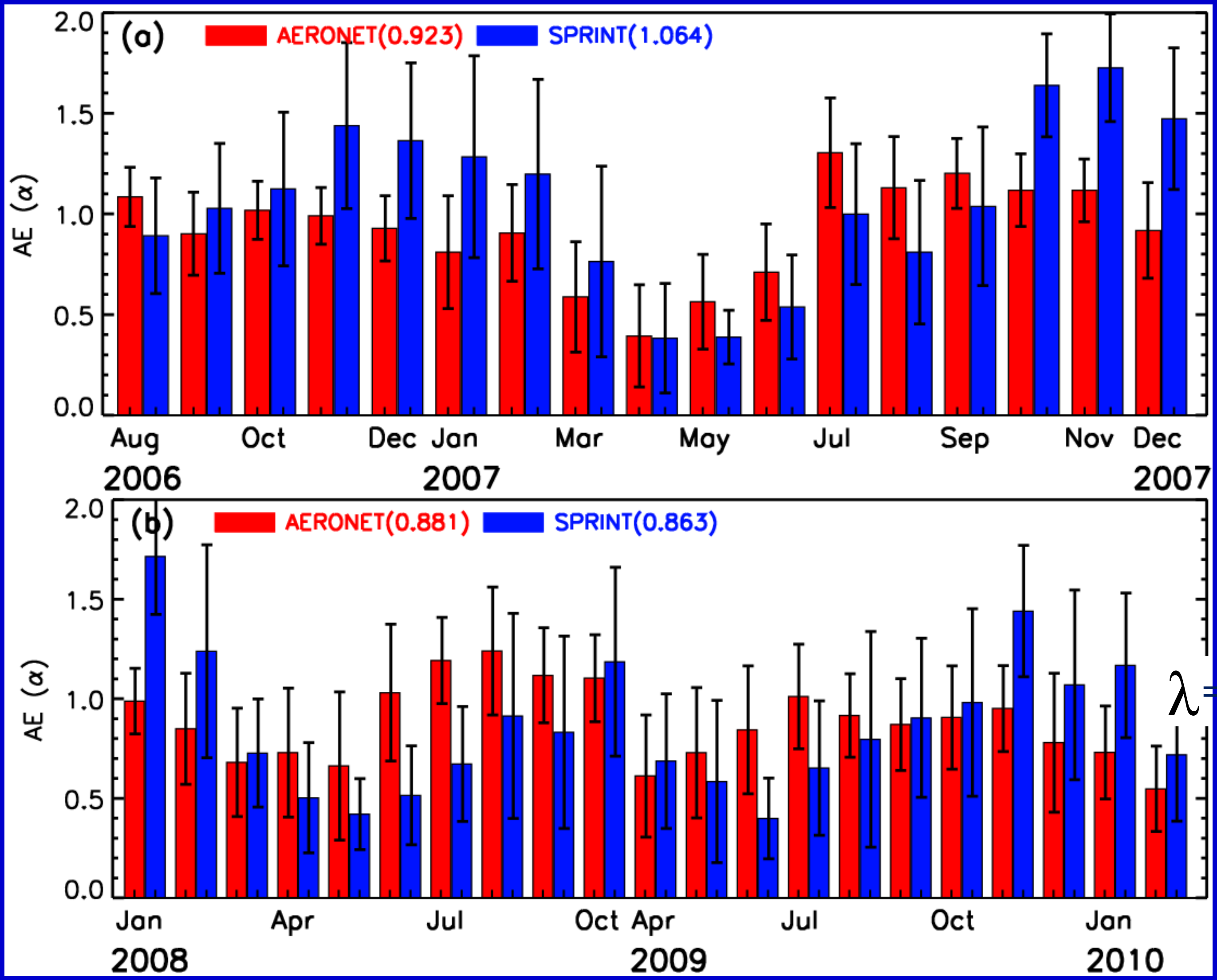



**$AOD_{550}$ is simulated from SPRINTARS seems to be small!**

$$\ln[AOD(\lambda)] = a_0 + a_1 \times \ln(\lambda) + a_2 \times \ln^2(\lambda)$$

**$AOD_{550}$:440, 675, and 1020 nm**

# Comparisons—Ångström Exponent (440-870)

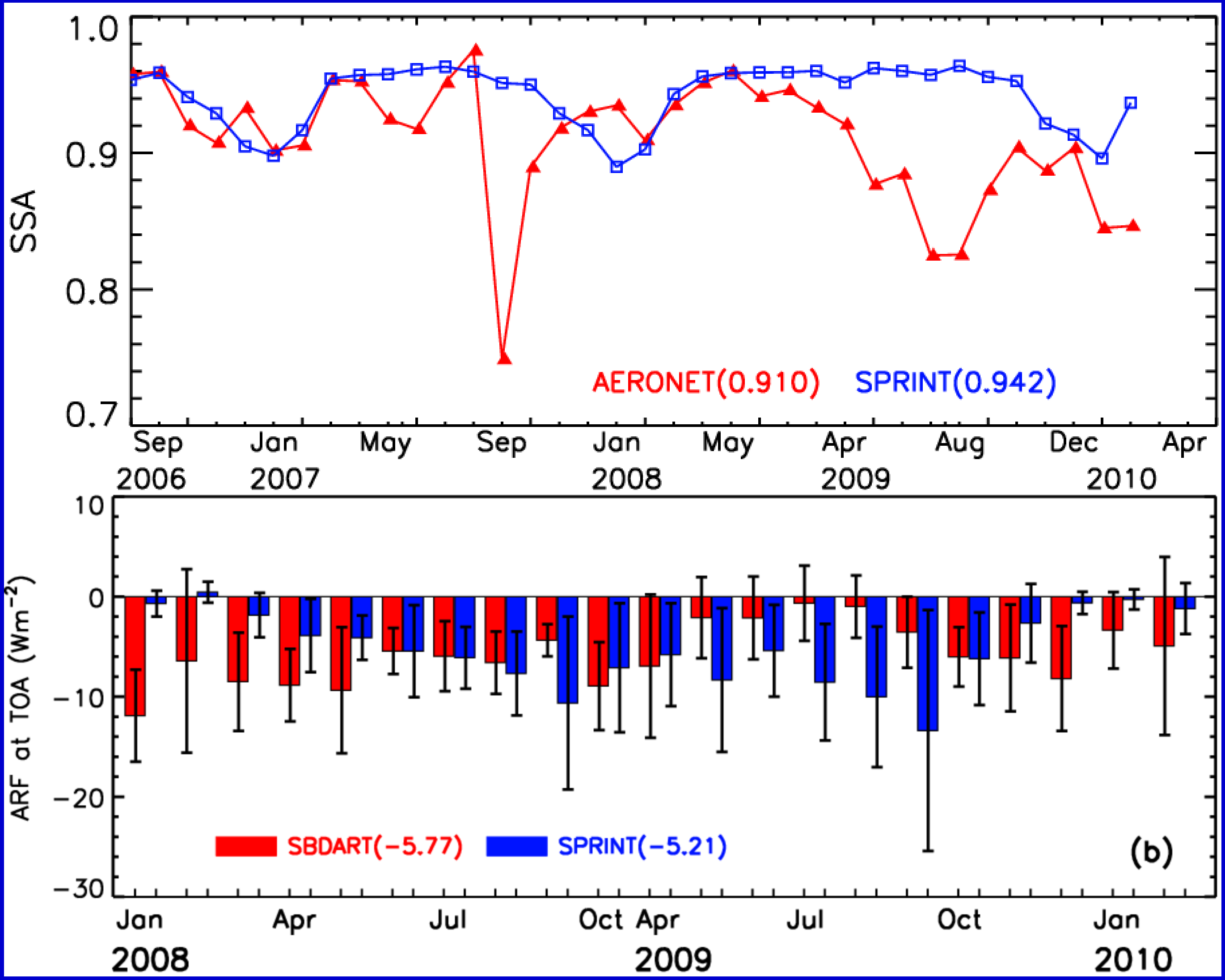



**Simulated $AE_{440\text{-}870}$ from SPRINTARS seems to be good!**

$$\tau(\lambda) \sim \lambda^{-\alpha}$$

$\lambda$ = 440, 500, 675, and 870 nm

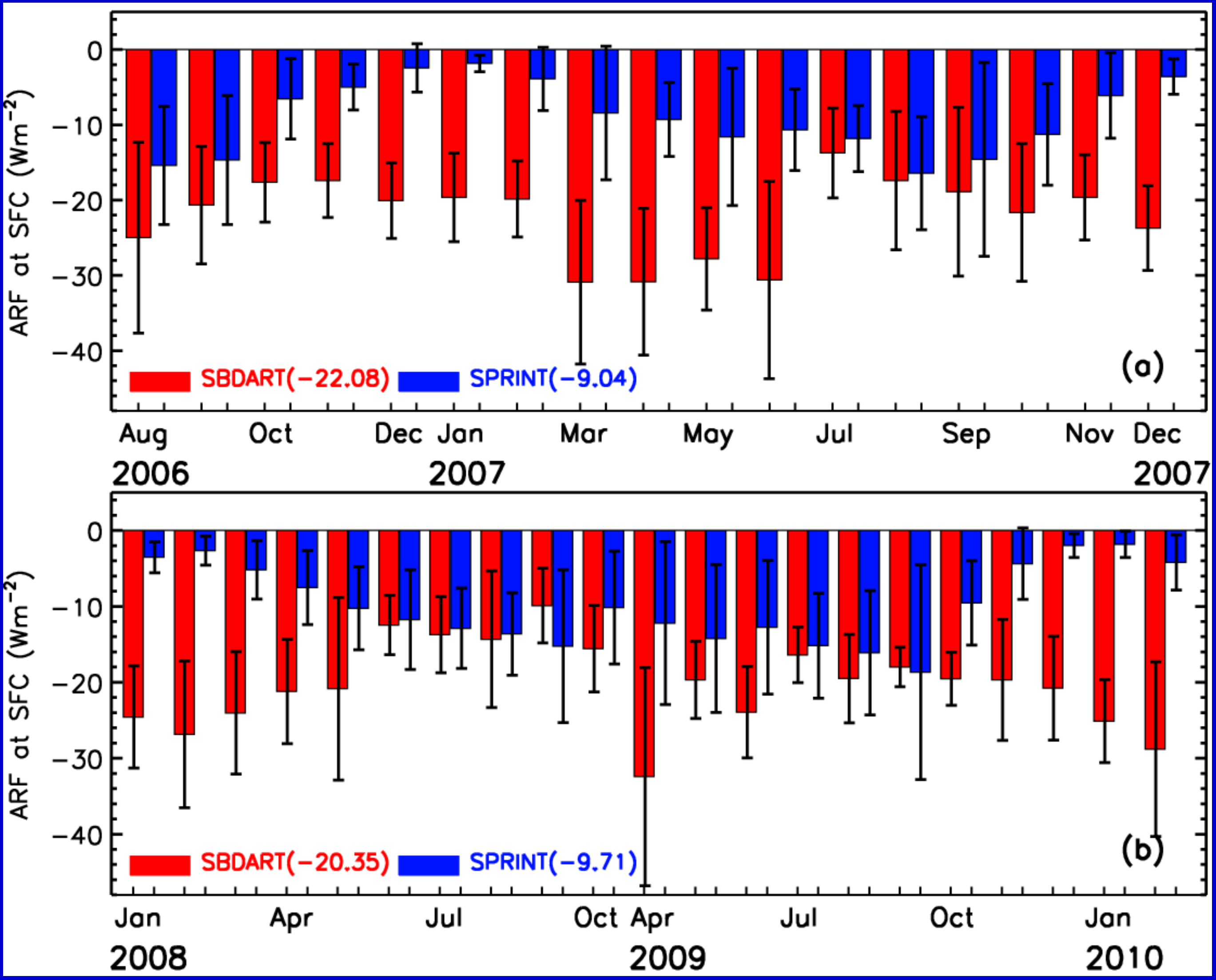
# Comparisons—SSA & ARF at TOA




**Simulated $SSA_{550}$ seems to be large.**

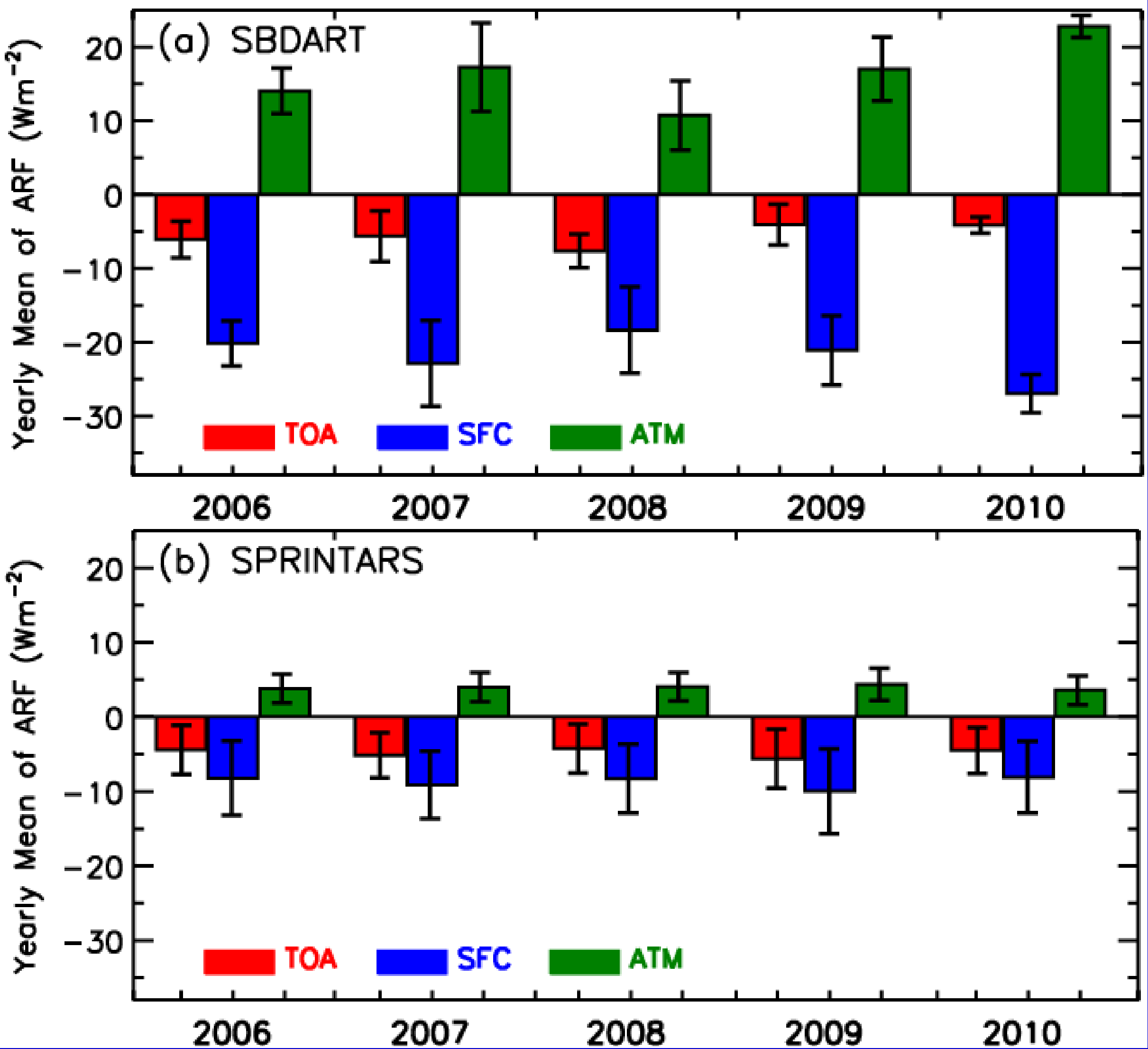
**Simulated $ARF_{TOA}$ is reasonable!**

# Comparisons—ARF at surface




**$ARF_{SFC}$ is simulated from SPRINTARS seems to be large!**

# Yearly mean ARF at SACOL




**$ARF_{TOA}$ simulated from SPRINTARS are comparable to SBDART's**

**$ARF_{SFC}$, $ARF_{ATM}$ are twice and four times for SBDART, respectively!**

*Semi-Arid Climate Observatory & Laboratory (SACOL)*
*http://climate.lzu..edu.cn Email: hjp@lzu.edu.cn*

# Outline

- Site and Instrument
- Results Analysis
- Field Campaigns
- Compared with AeroCom
- Summary

# Summary

1. **Aerosol optical features exhibit remarkable day-to-day variations.**
2. **Coarse mode particles are dominant in spring attributed to injecting dust particles.**
3. **Hygroscopic growth of aerosol exist in summer.**
4. **The overall average of ARF at TOA, SFC and ATM are -5.5±1.5, -21.9±3.3 and 16.4±4.5, respectively.**
5. **SPRINTARS can simulate $AE_{440\text{-}870}$ and $ARF_{TOA}$ well, but need to further improve in $AOD_{550}$, $SSA_{550}$ and $ARF_{SFC}$.**

# Acknowledgements


-AERONET
-SKYNET
-NASA/GSFC, B. Holben, T. –S. Tsay
-Kyushu Univ., T. Takemura
-Univ. of Maryland, Z. Li, Q. Ji
-IAP/LASG, G. Shi (CAS)
-Univ. of Washington, Q. Fu
-Chiba Univ., T. Takamura
-Tokyo Univ., T. Nakajima
-NIES/Japan, N. Sugimoto, I. Matsui

# Thank you for your attention!