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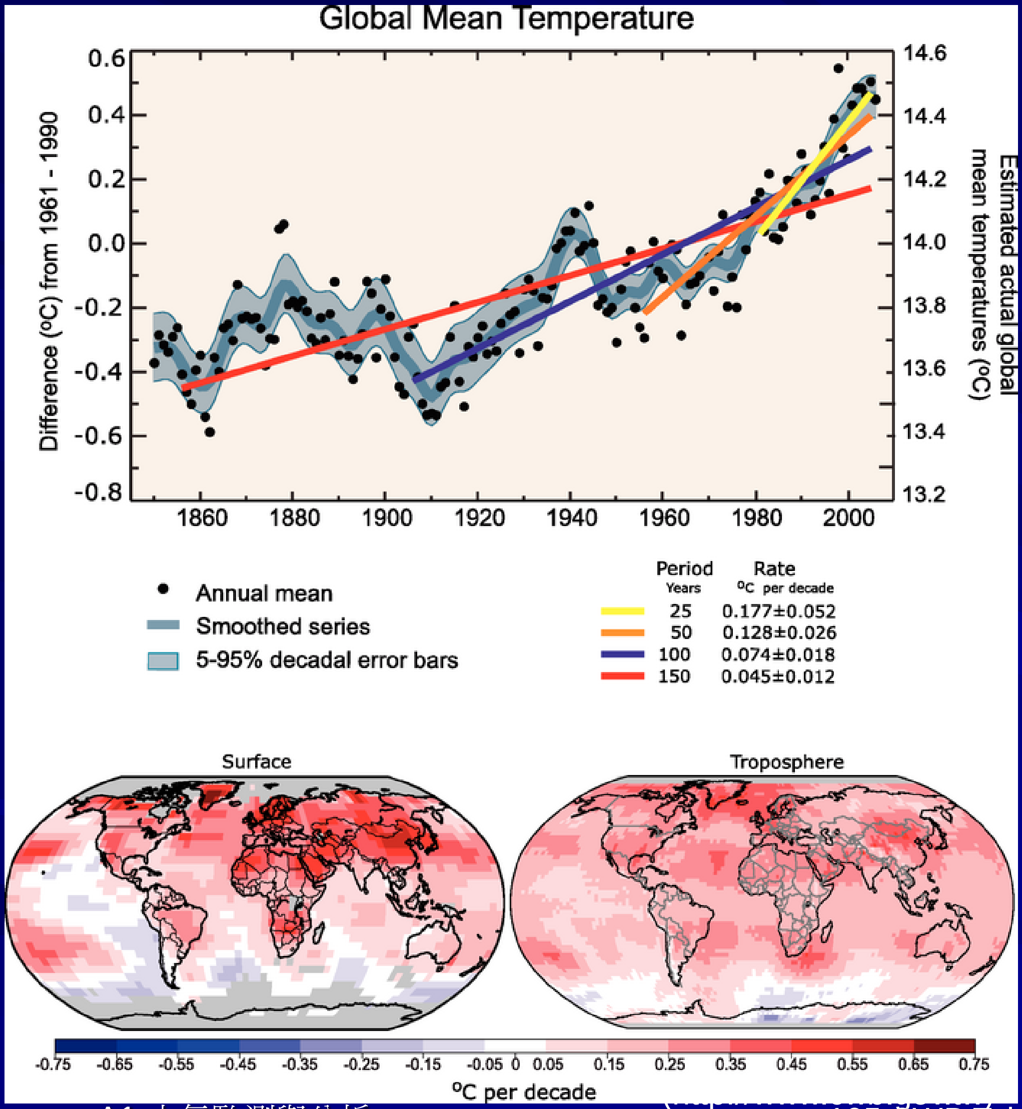
A Novel Index (NGAI) for Aerosol Categorization and AOD Fraction Determination with Satellite Retrievals

Tang-Huang Lin*, Wei-Hung Lien, Kuo-En Chang, Gin-Rong Liu, and Chian-Yi Liu
Center for Space and Remote Sensing Research
National Central University, Taiwan

http://ersl.csrsr.ncu.edu.tw/

Top Issue All Over the World

- **Global Warming and Climate Changes**



Earth Radiance Budget Processes

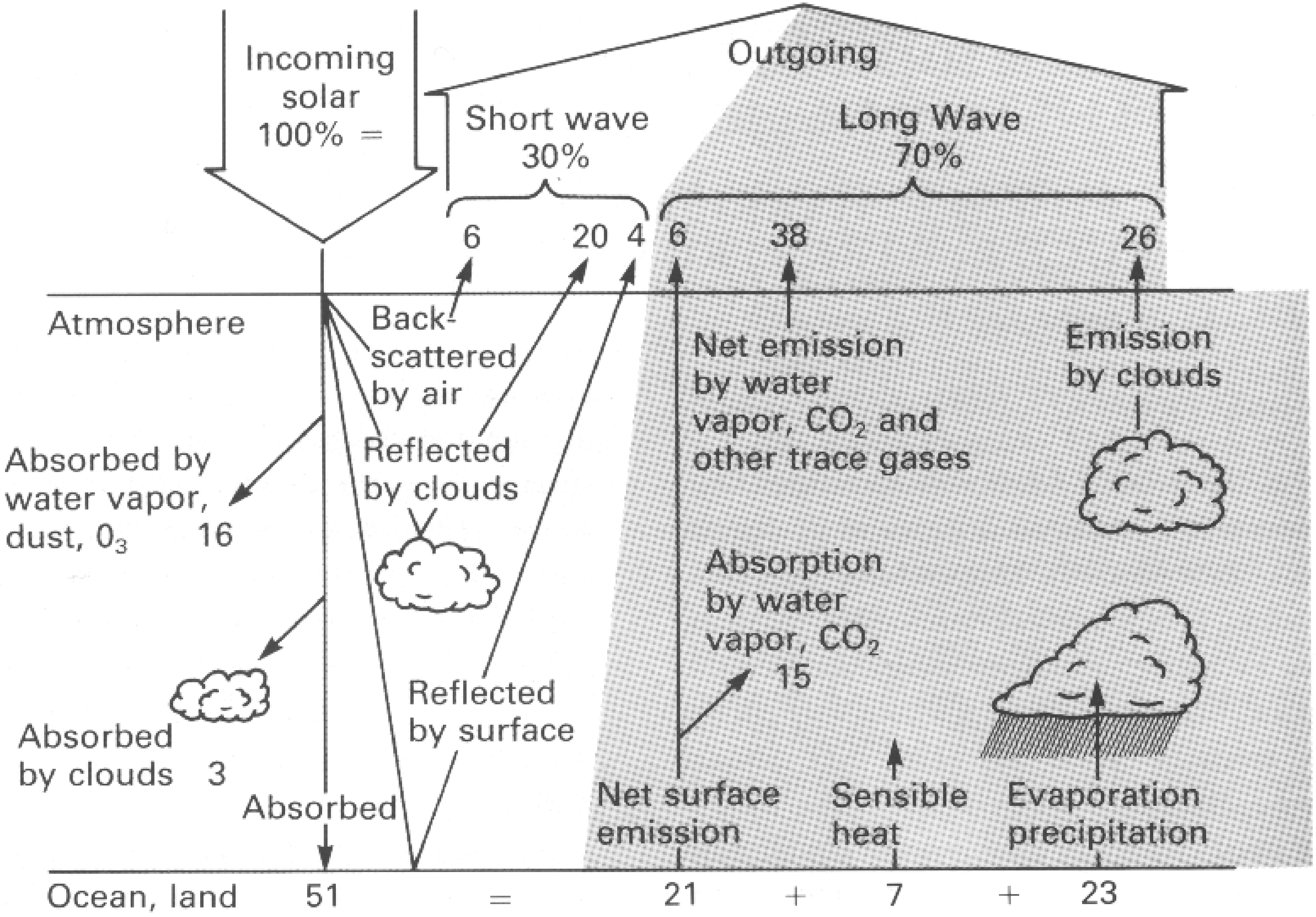
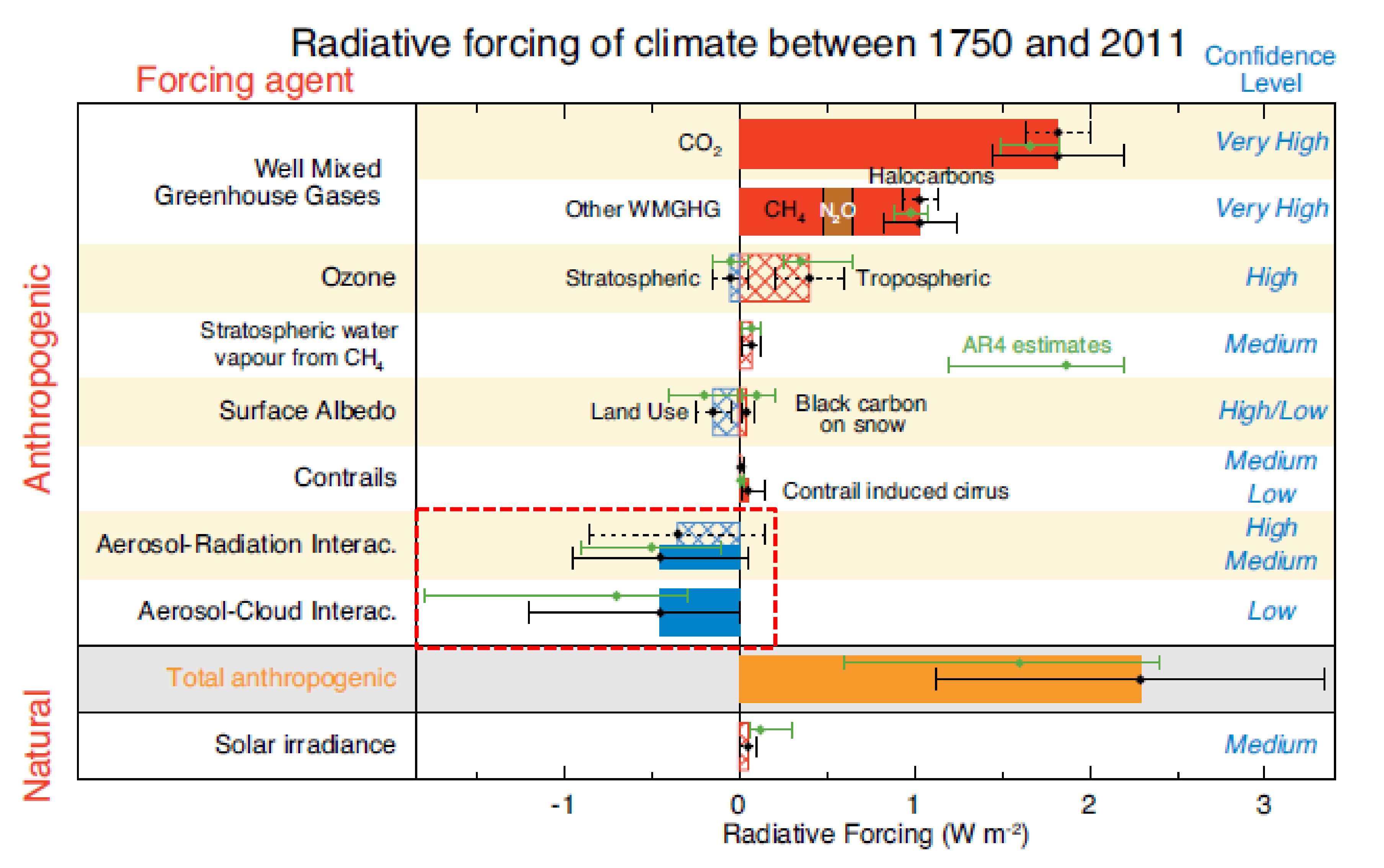
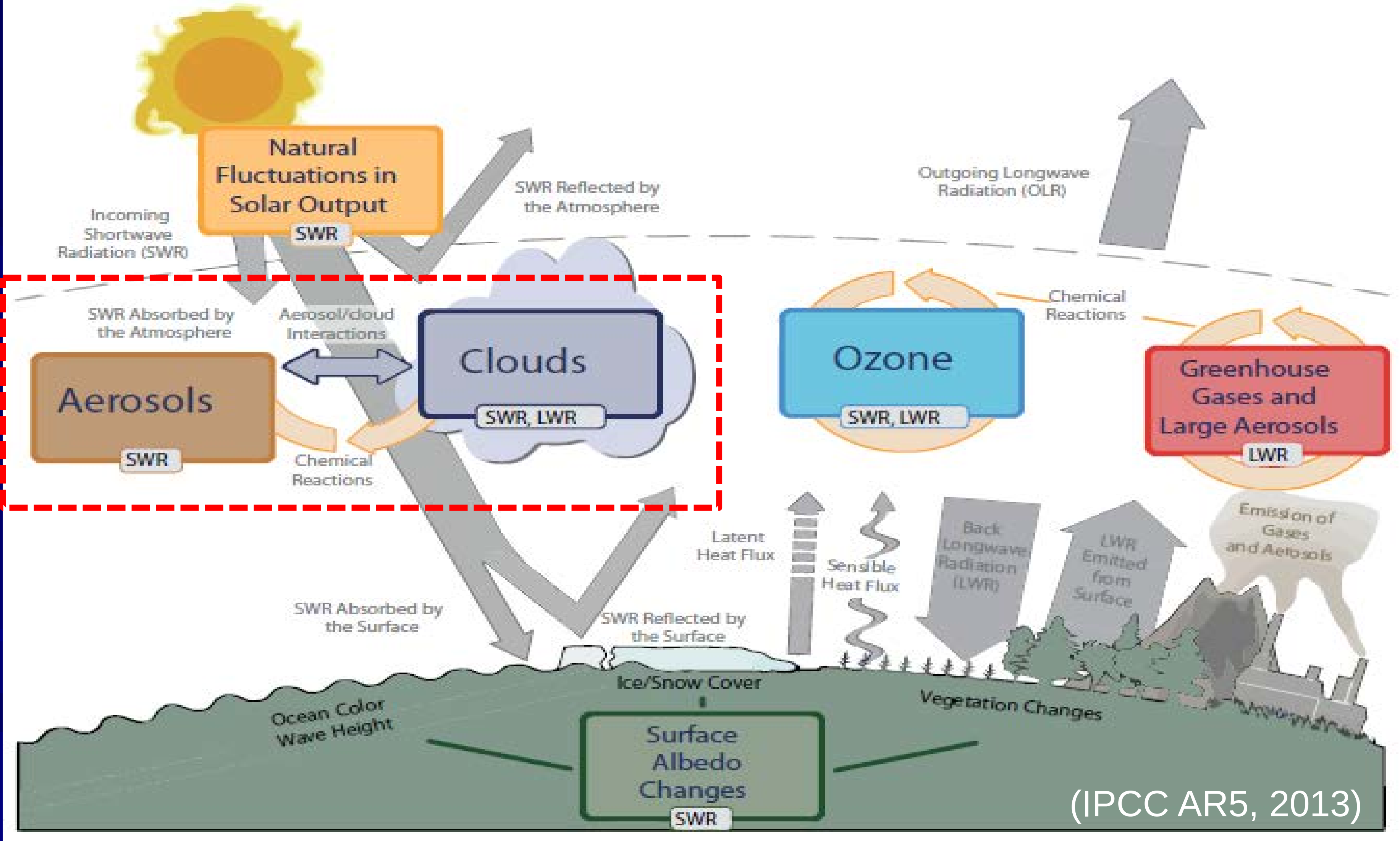


Fig. 1 The radiation balance of the Earth

IPCC AR5, 2013



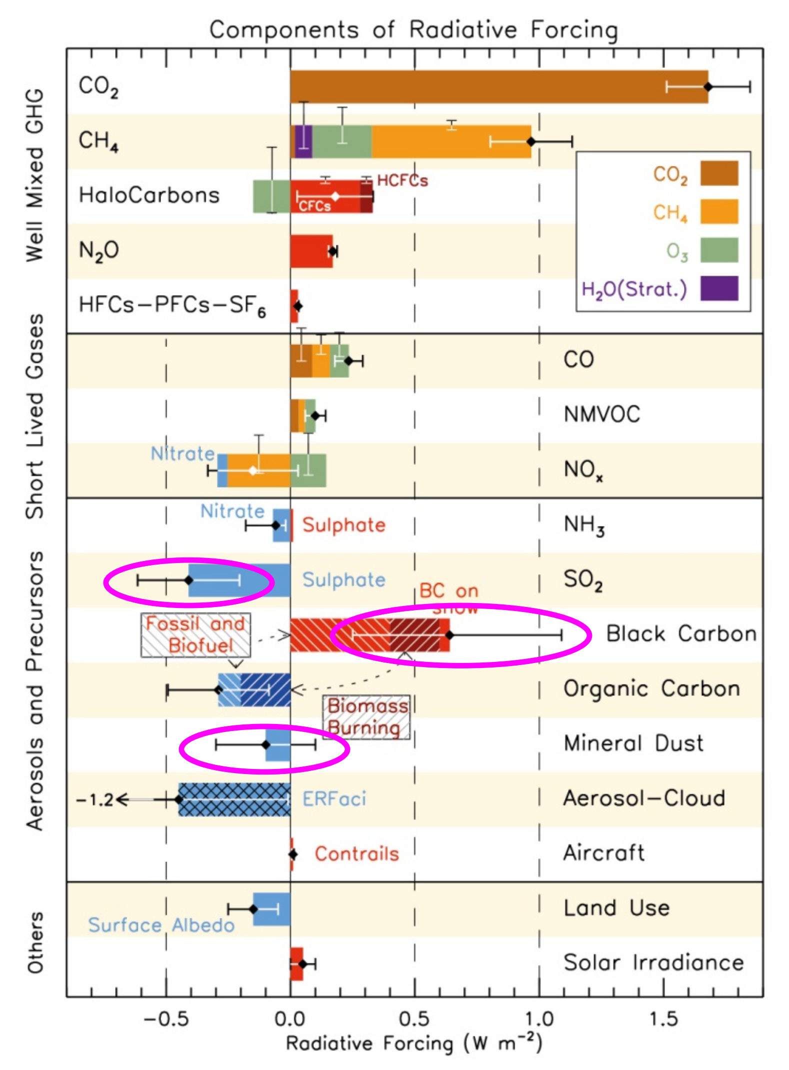
Earth Radiance Budget Processes



(IPCC AR5, 2013)

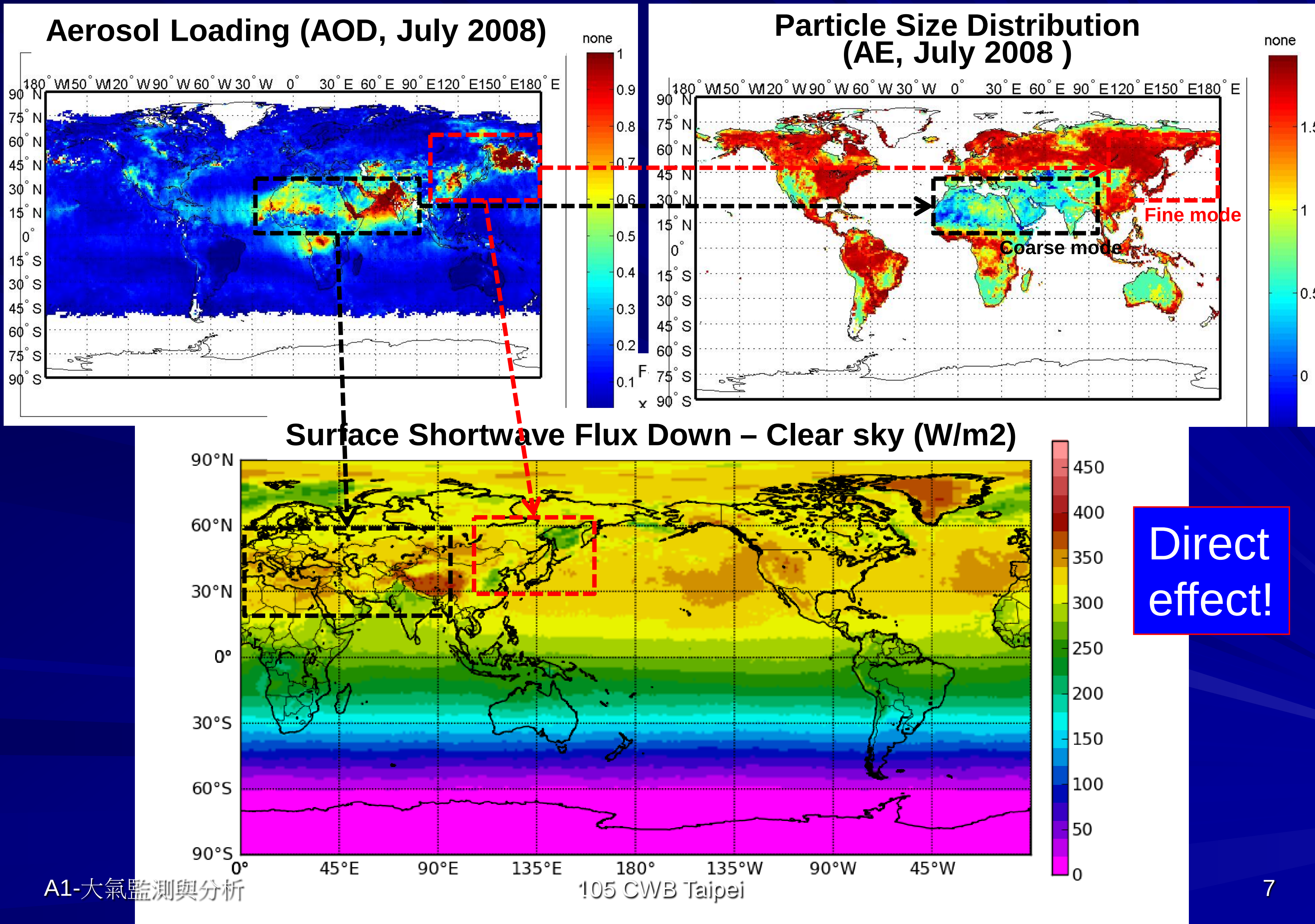
Background

- ◆ Aerosol Radiative Forcing:
  - ➢ Large fluctuation
  - ✓ Complex components (size, shape, material, …) ~ type issue
  - ✓ Aerosol mixture ~ Mixing effect



(Stocker et al., 2013)

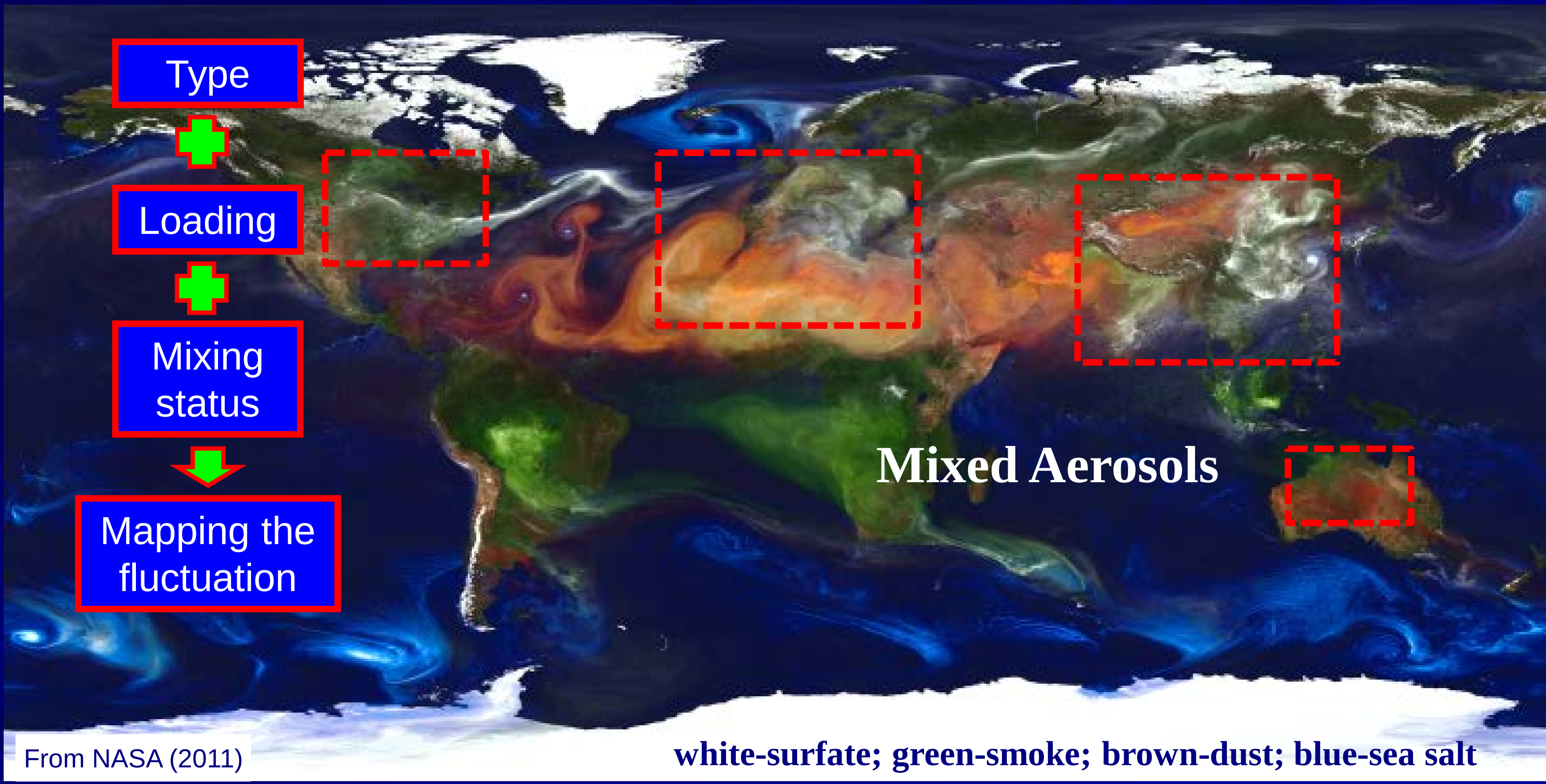
➢ Effect of Aerosol Types on Radiative forcing



Direct effect!

Spatial Distribution of Global Aerosols

(Simulated by NASA & NOAA)



Focal Points of Remote Sensing

- Aerosol categorization – mineral dust(DS), biomass burning(BB) and anthropogenic pollutant(AP)
- Mixing status determination – AOD fractions of dominated aerosols
- Comprehensive information – by means of satellite observations

Discrimination of aerosol type

- Data collection ~ In situ & Satellite

Types	Control dataset	Period	Validation dataset	Period
DS	Beijing (39N,116E)	2001-2012	Beijing (39N,116E)	
	Tamanrasset (22N,5E)	2006-2012	XuZhou-CUMT	
	Solar Village (24N,46E)	1998-2012	(34N,117E)	
AP	Taihu (31N,120E)	2005-2012	Taihu (31N,120E)	
	Taipei (25N,121E)	2002-2012	XuZhou-CUMT	
	Beijing (39N,116E)	2001-2012	(34N,117E)	
	Hong Kong (22N,114E)	2005-2012	Hong Kong (22N,114E)	
BB	Pimai (15N,102E)	2003-2008	Chiang Mai (18N,98E)	2014
	Mukdahan (16N,104E)	2003-2010	Omkoi (17N,98E)	
	Chiang Mai (18N,98E)	2006-2012	Maeson (19N,99E)	
			Vientiane (17N,102E)	
			haTrang (12N,109E)	
			i Ang Khang	
			9N,99E)	
			ang Namtha	
			0N,101E)	
			lpakorn Univ	
			3N,100E)	

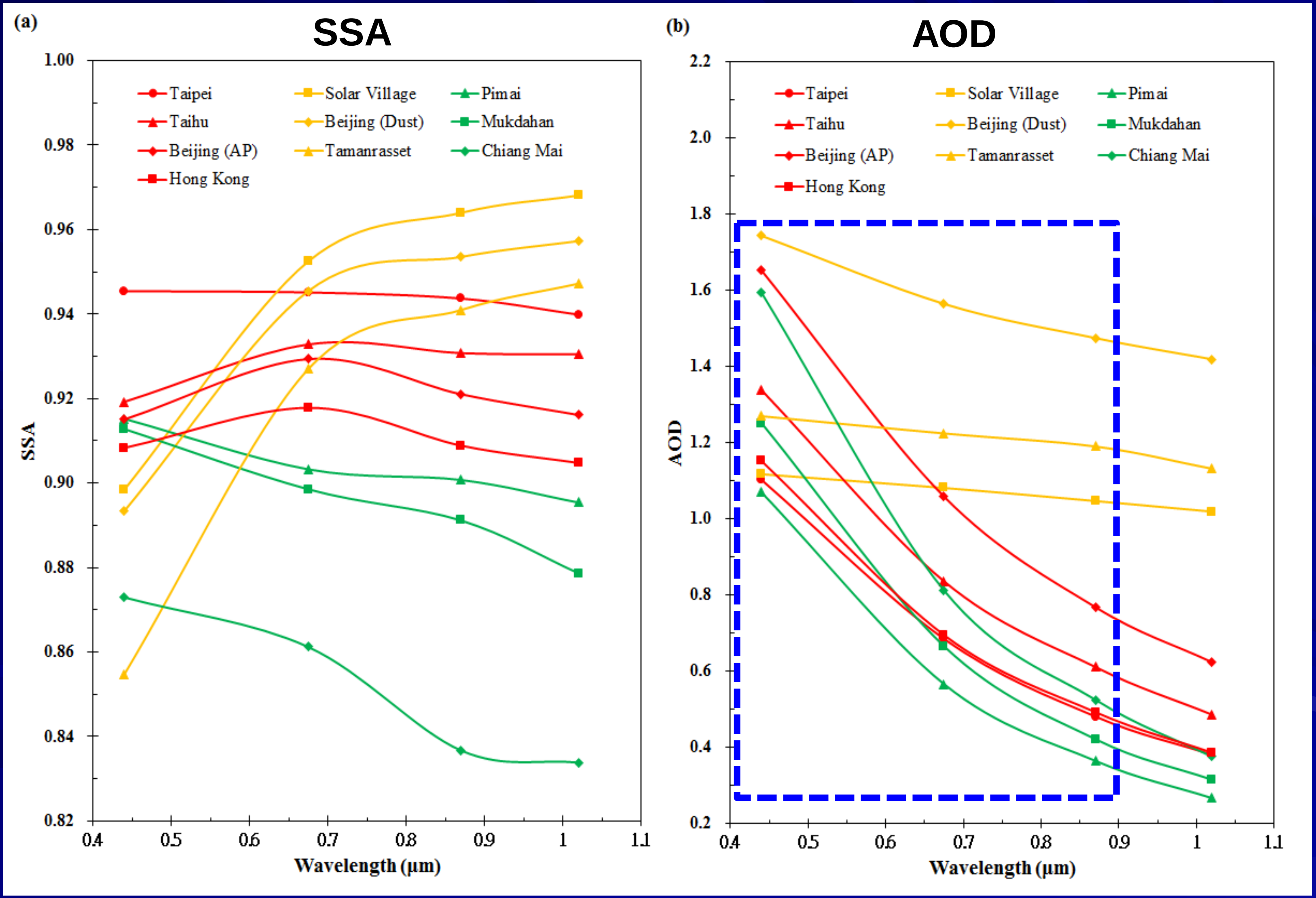
Sensor	Period	Data Product
MODIS	January-December (2014)	MOD04_L2; MYD04_L2
CALIPSO	March-May (2014)	5 km Aerosol Profile_L2 (Extinction); Vertical Feature Mask_L2 (Aerosol Subtype)
CERES	January-April (2014)	SYN1deg_L3 (Upward and Downward Shortwave Flux at Surface and TOA)

➢ Optical properties of aerosols ~ In situ & Satellite

AERONET (Surface)	Dusts (DS)	Biomass Burning (BB)	Anthropogenic Pollutants (AP)
Ångström exponent (**AE**) 440_675nm (**Particle Size**)	**0.066 ± 0.055 (Coarse)**	**1.499 ± 0.096 (Fine mode)**	**1.105± 0.269 (Fine mode)**
Single scattering albedo (**SSA**) 675nm **(Absorption; Scattering)**	**0.958 ± 0.002**	**0.903 ± 0.024 (absorptive)**	**0.940 ± 0.031 (scattered)**

MODIS (Satellite)	Dusts (DS)	Biomass Burning (BB)	Anthropogenic Pollutants (AP)
Ångström exponent (**AE**) 440_675nm	**0.523±0.1833**	**1.3395±0.286**	**1.158±0.492**
Single scattering albedo (**SSA**) 675nm	**0.9311±0.0286**	**No information**	**No information**

➢ Spectral variations of optical properties



Approach

Ångström empirical formula:

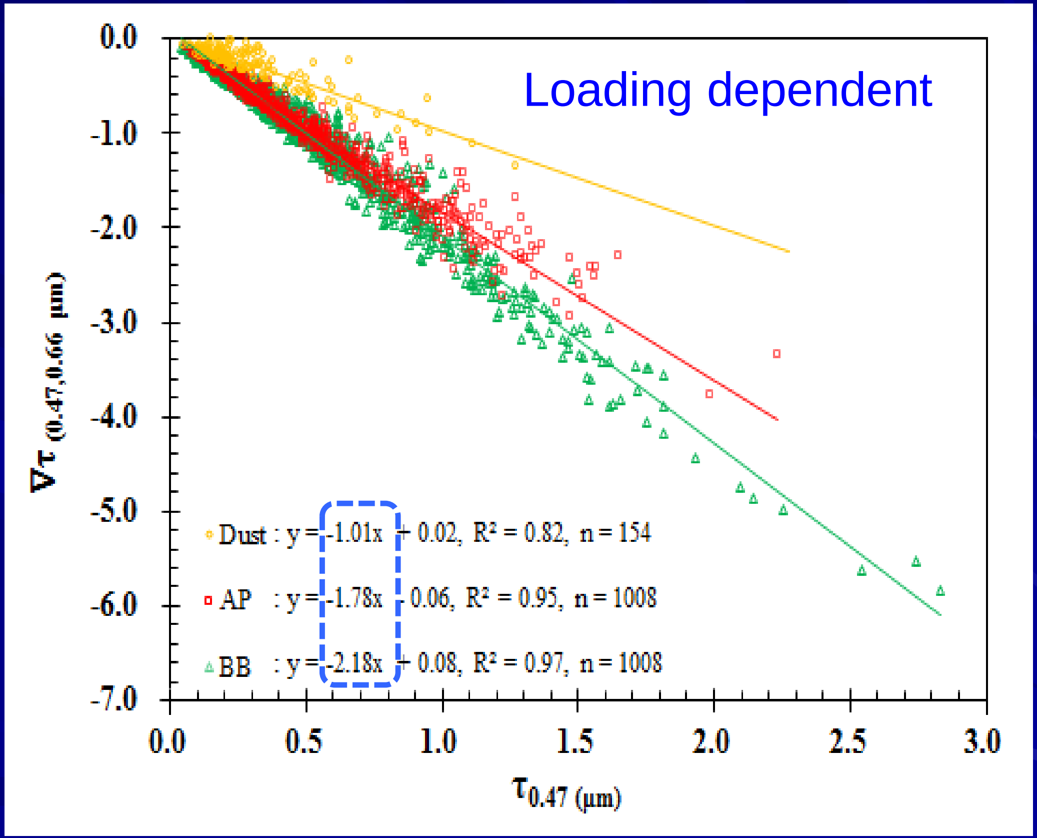
$$\tau_\lambda = \beta\lambda^{-\alpha}$$

$$\nabla\tau_{(\lambda_1,\lambda_2)} = \frac{\tau_{\lambda_1} - \tau_{\lambda_2}}{\lambda_1 - \lambda_2}$$

$$= \tau_{\lambda_2} \times (1 - A^\alpha) \times B$$

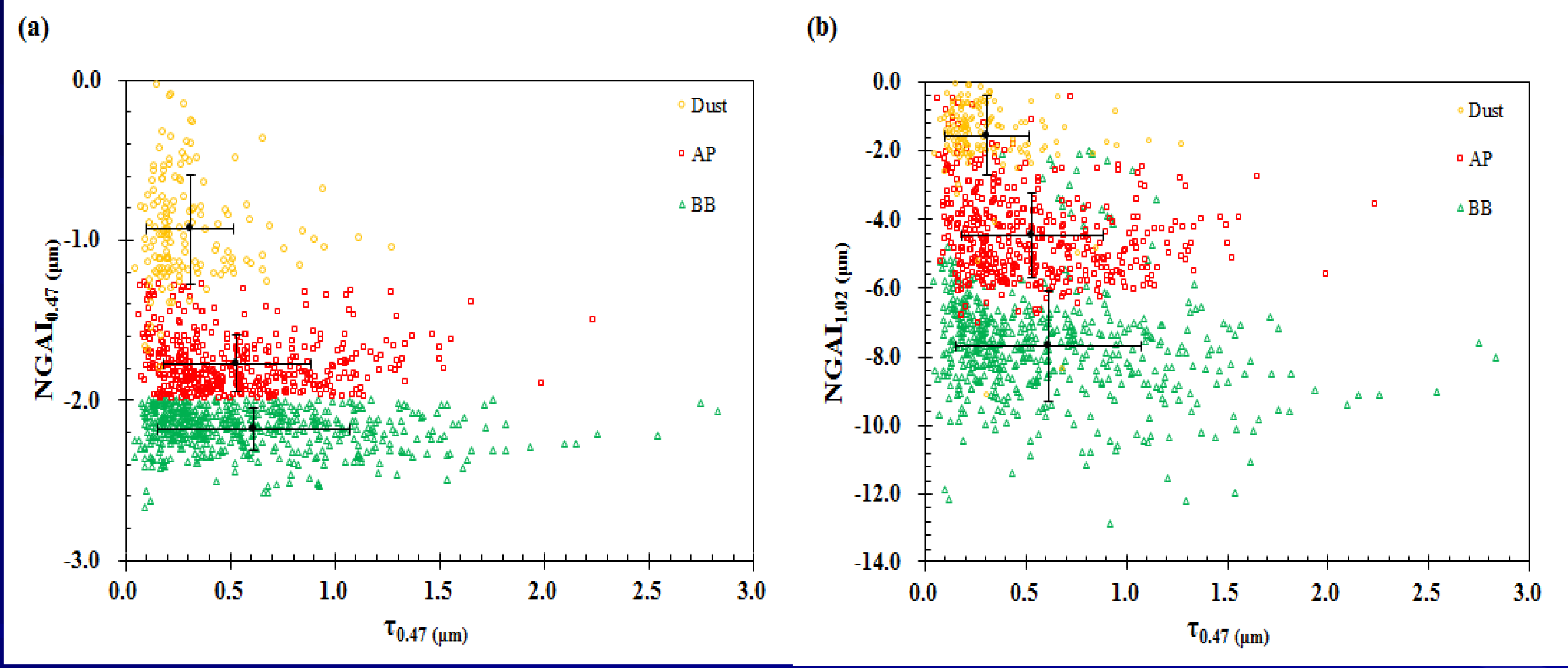
$$A = \lambda_2 / \lambda_1 \quad B = 1/(\lambda_2 - \lambda_1)$$

Measurement from AERONET



- **AOD gradient normalization to eliminate the effect of aerosol loading;**

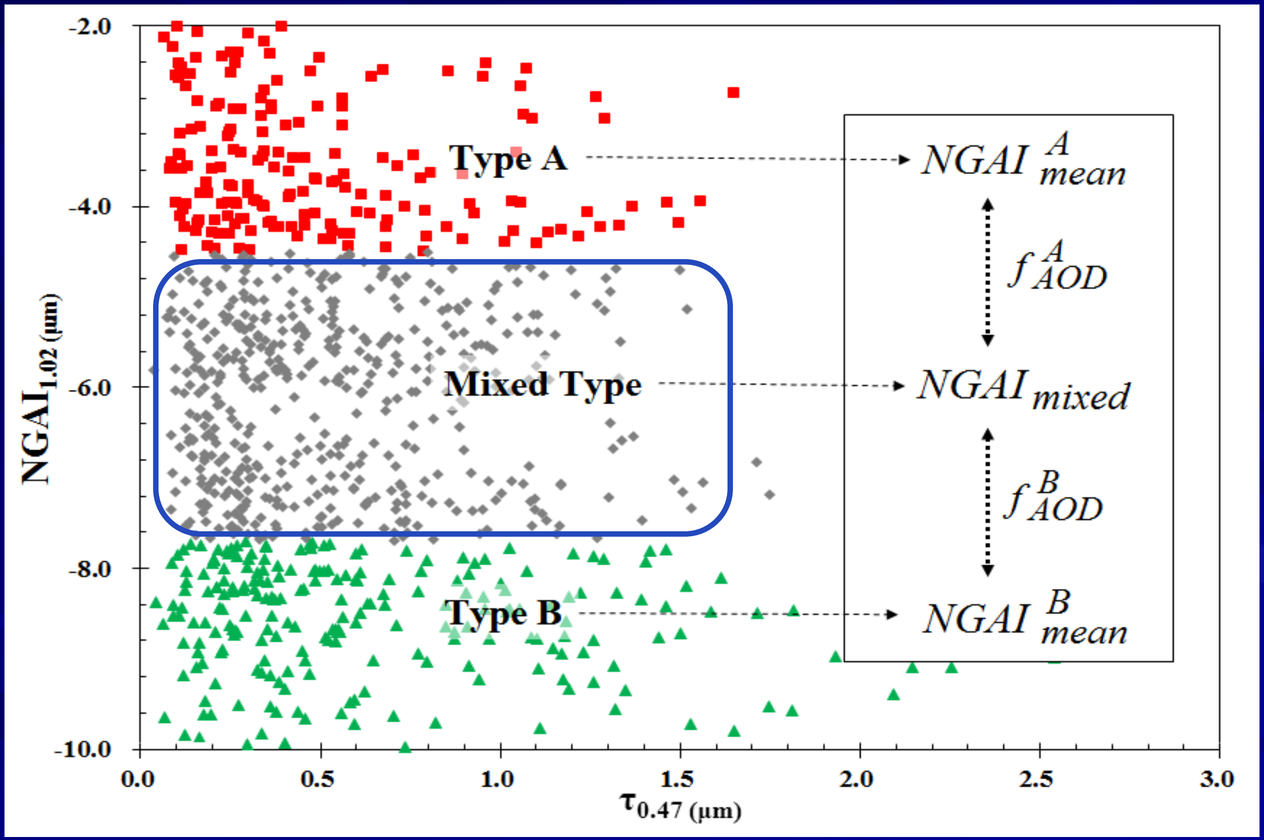
$$\nabla \tau_{(\lambda_1,\lambda_2)} / \tau_{\lambda_{ref}} = (1 - A^{\alpha}) \times B$$



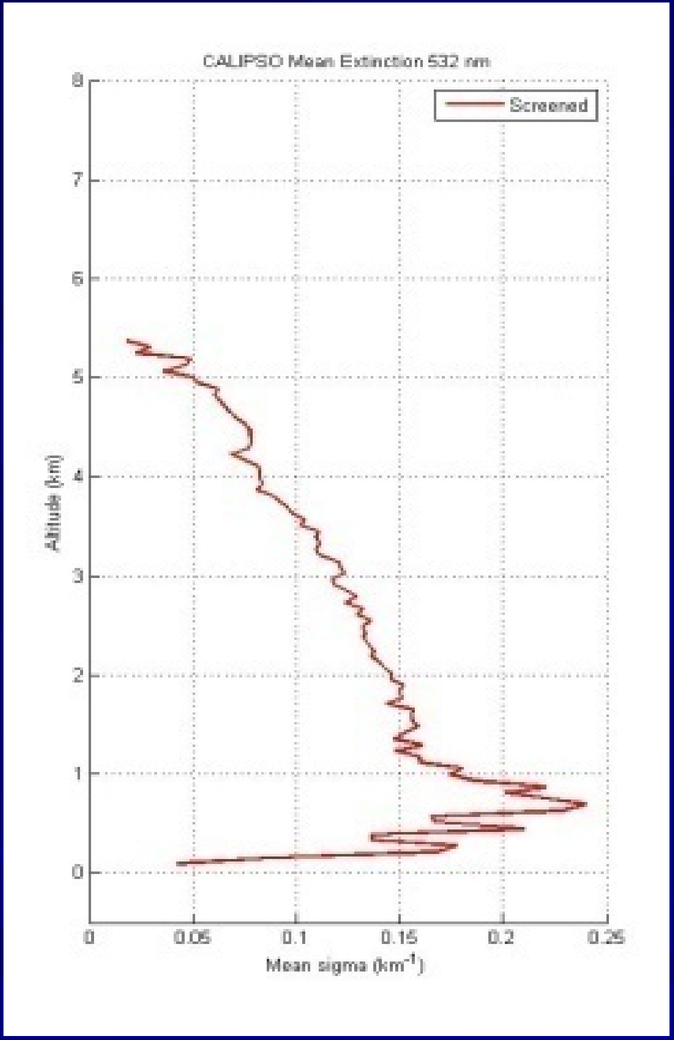
- **A novel index, Normalized Gradient Aerosol Index (NGAI), is defined for aerosol categorization**

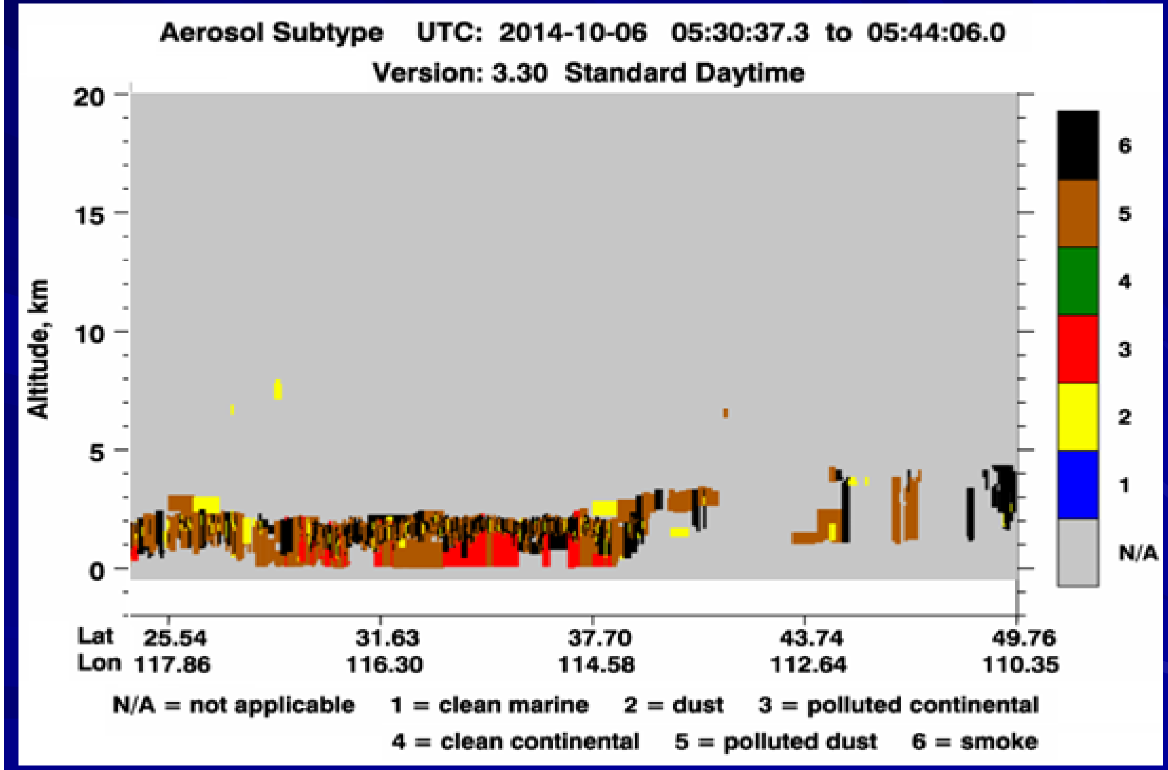
➢AOD fraction of mixed aerosols

$$f_{AOD}^{A} = \frac{NGAI_{mean}^{A} - NGAI_{mixed}}{NGAI_{mean}^{A} - NGAI_{mean}^{B}} \quad ; \quad f_{AOD}^{B} = 1 - f_{AOD}^{A}$$



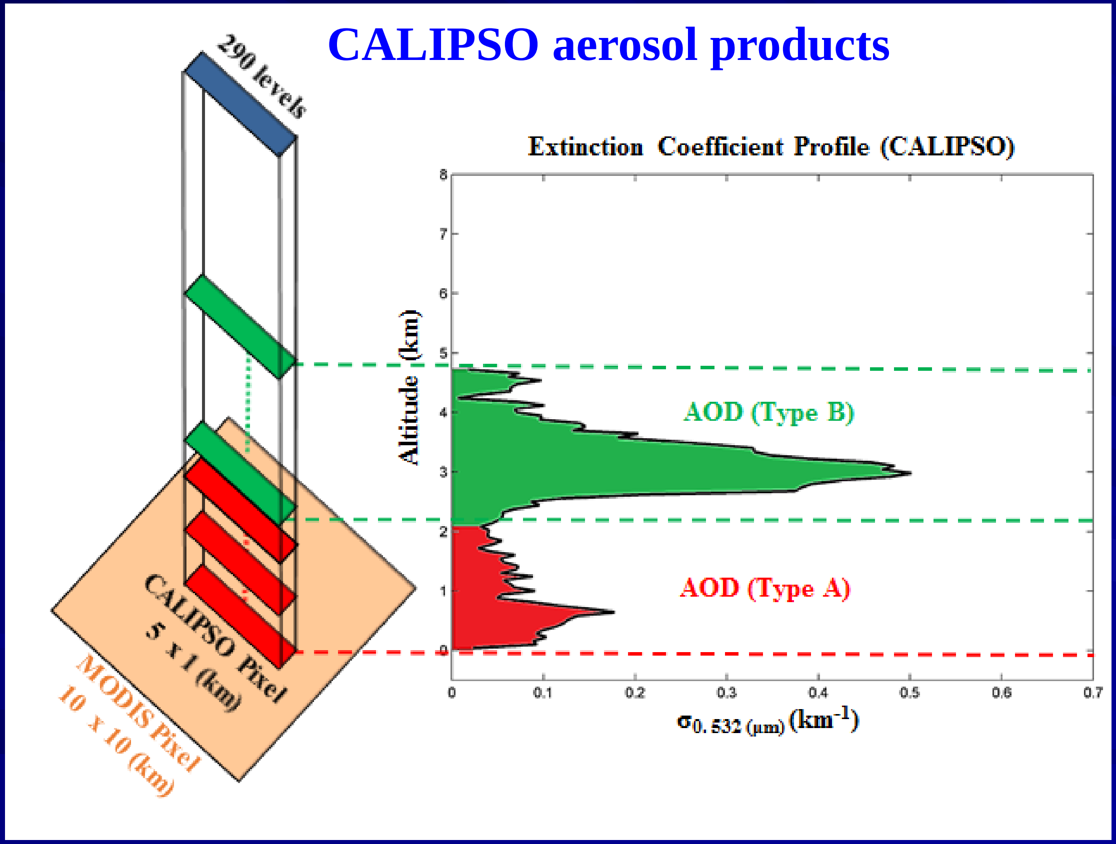
➢ Validation of NGAI AOD fraction ~ CALIPSO





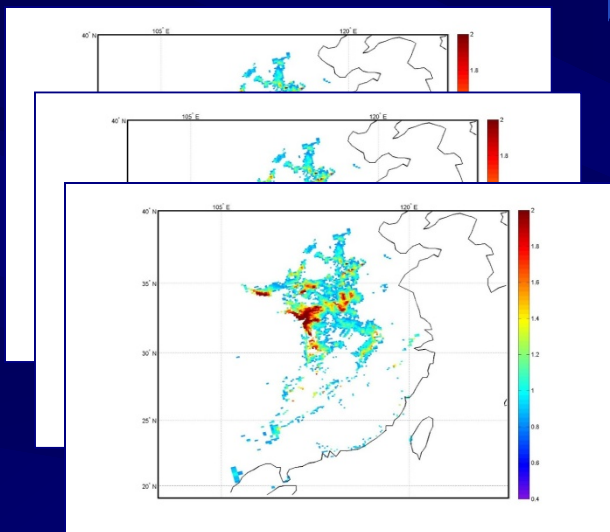
➢ Validation of NGAI AOD fraction ~ the reference

$$f^{A}_{AOD_{CALIPSO}} = \frac{AOD^{A}_{CALIPSO}}{AOD^{A}_{CALIPSO} + AOD^{B}_{CALIPSO}}$$

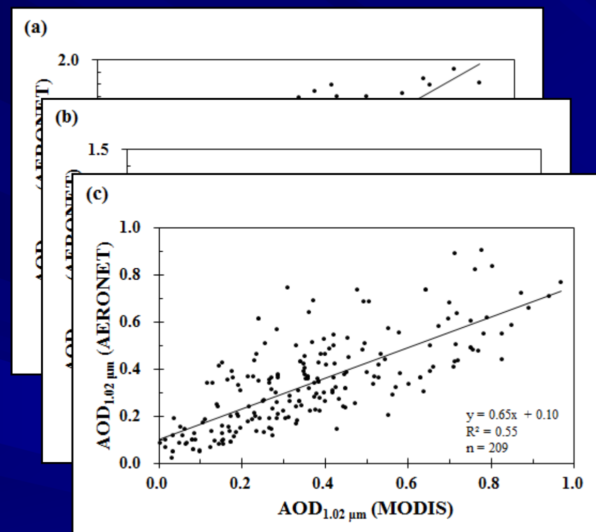


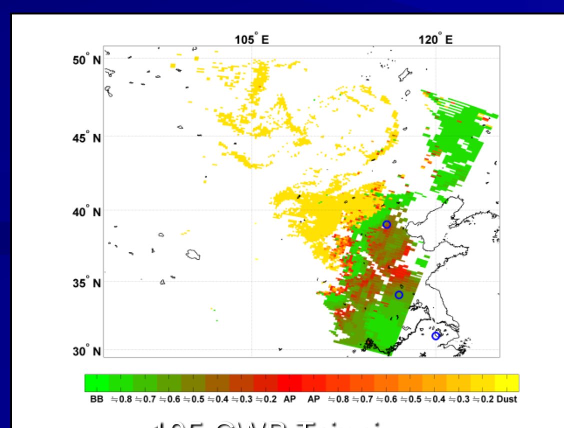
Application to MODIS AOD products

MODIS Multi-spectral AODs



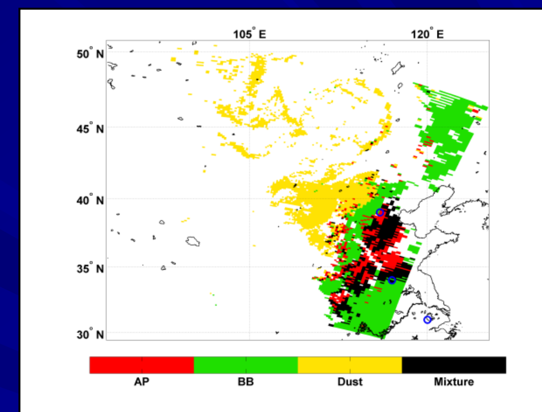
Systemic Calibration





NGAI Calculation

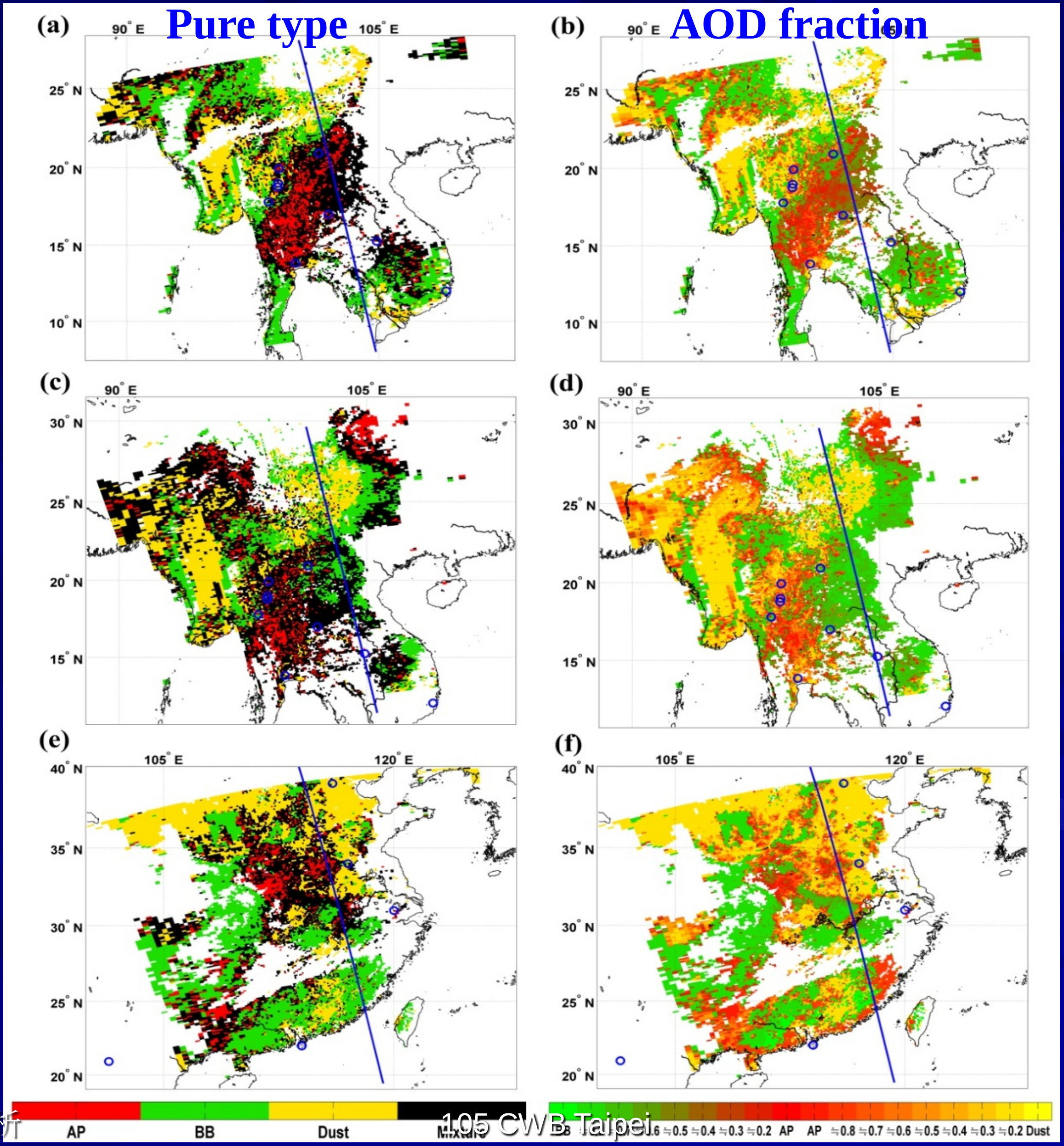
$$NGAI = \nabla \tau_{(\lambda_1, \lambda_2)} / \tau_{\lambda_{ref}}$$



Fraction Determination

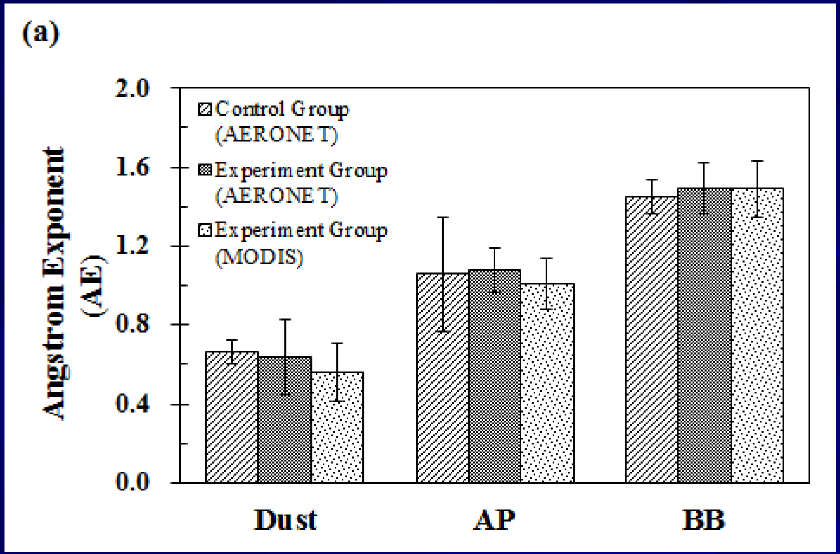
$$f_{AOD}^{A} = \frac{NGAI_{mean}^{A} - NGAI_{mixed}}{NGAI_{mean}^{A} - NGAI_{mean}^{B}}$$

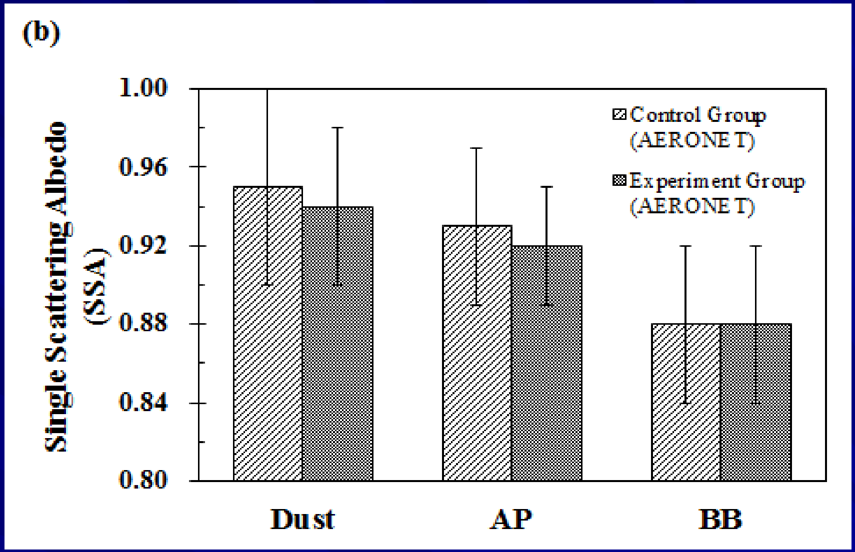
Results from MODIS



➢ Validations with AERONET

Aerosol Category -- Compare to AERONET





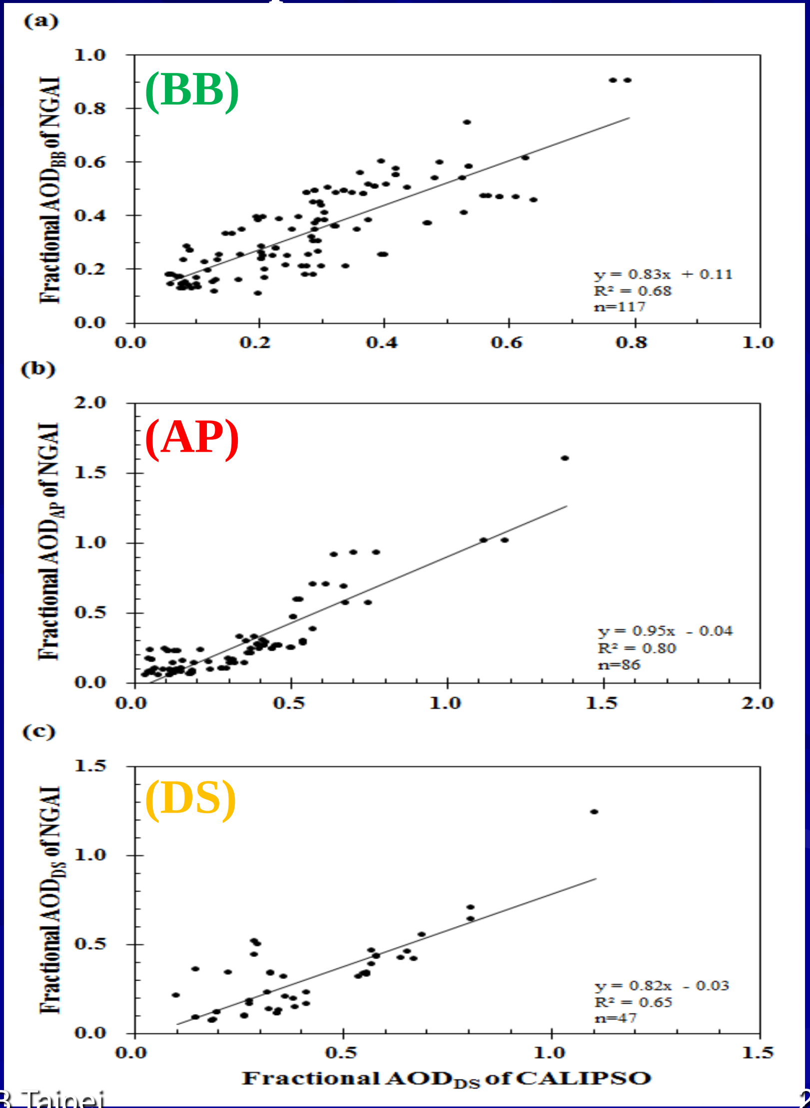
158 Cases	AERONET Dust	AERONET BB	AERONET AP
MODIS Dust	**0.64±0.19 (2.53%)**	1.50±0.09 (1.27%)	1.29±0.13 (1.27%)
MODIS BB	0.87 (0.63%)	**1.49±0.13 (86.08%)**	1.16±0.05 (1.90%)
MODIS AP	0.65 (0.63%)	1.37 (0.63%)	**1.08±0.11 (5.06%)**

➢ Validations with COLIPSO

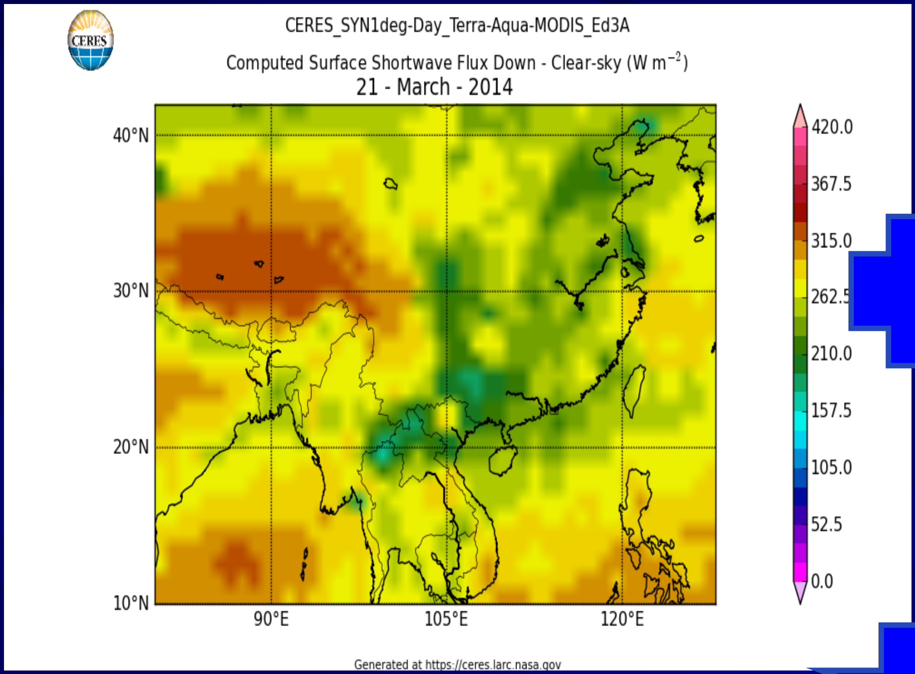
Aerosol Category -- Compare to CALIPSO (pure column)

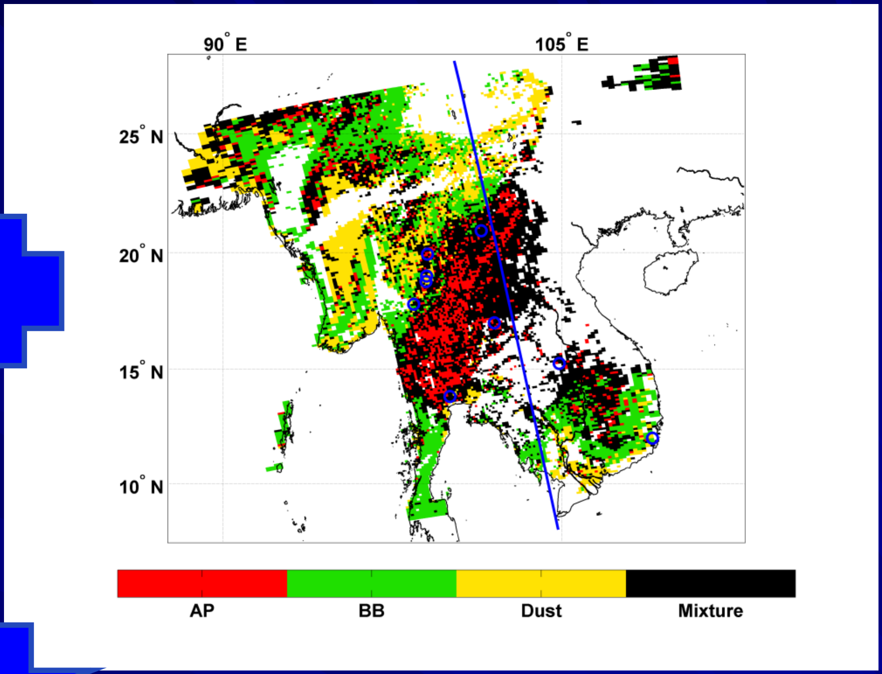
(Percentage of Cases)	CALIPSO Dust	CALIPSO BB	CALIPSO AP
MODIS Dust	**0.59±0.04 (13%)**	0.59±0.04 (11%)	0.57±0.03 (7%)
MODIS BB	1.70±0.11 (3%)	**1.71±0.03 (35%)**	1.70±0.03 (7%)
MODIS AP	1.01±0.13 (1%)	1.20±0.16 (10%)	**1.02±0.17 (14%)**

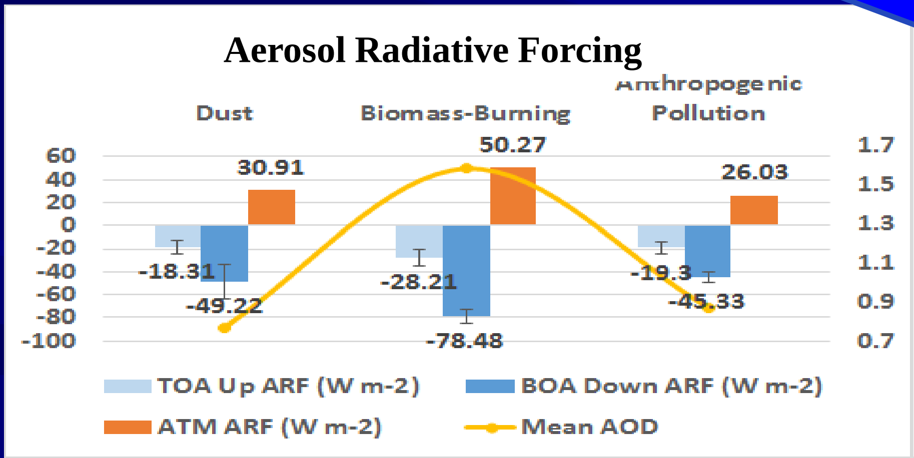
AOD Fraction -- Compare to CALIPSO

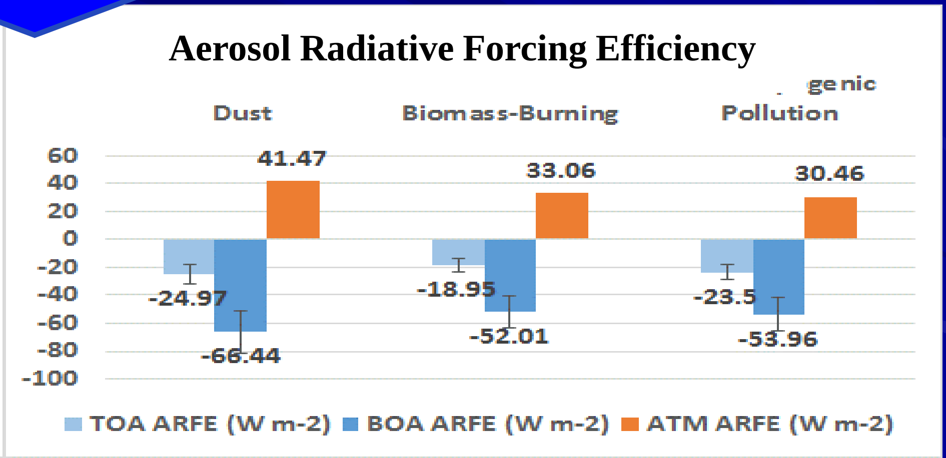


Potential of NGAI for ARF assessment

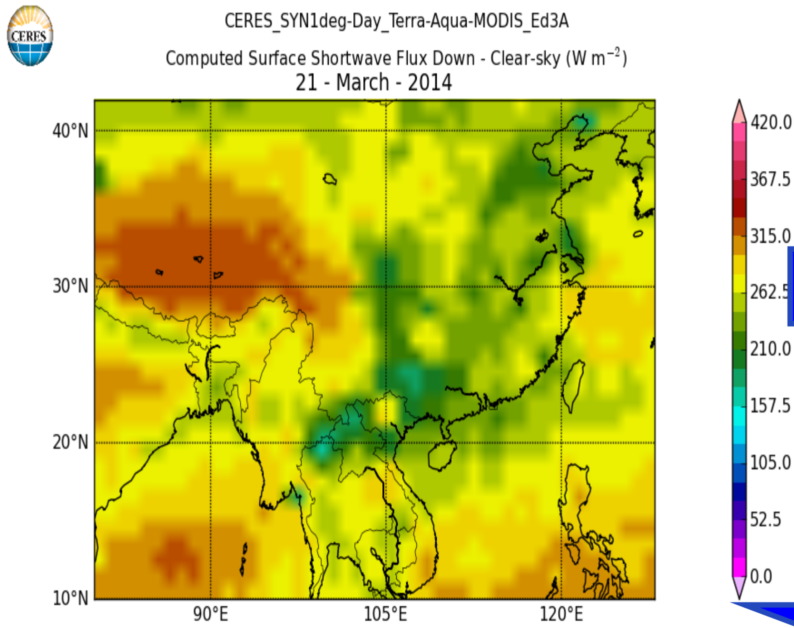


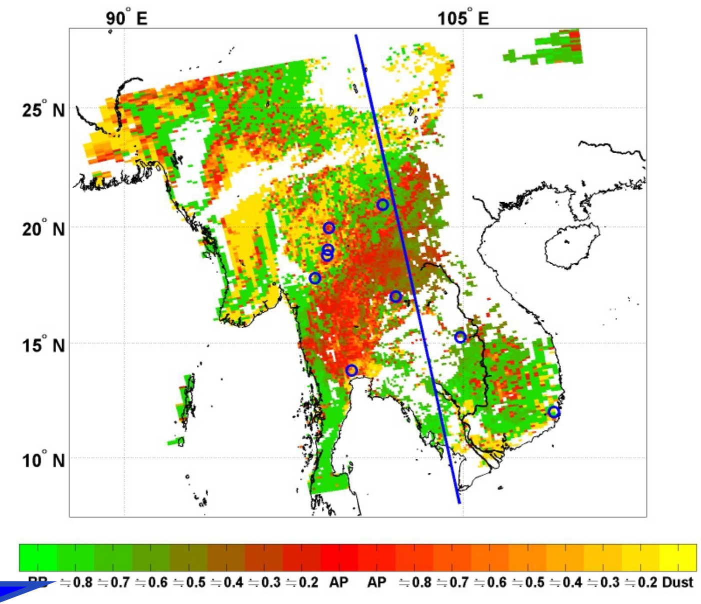


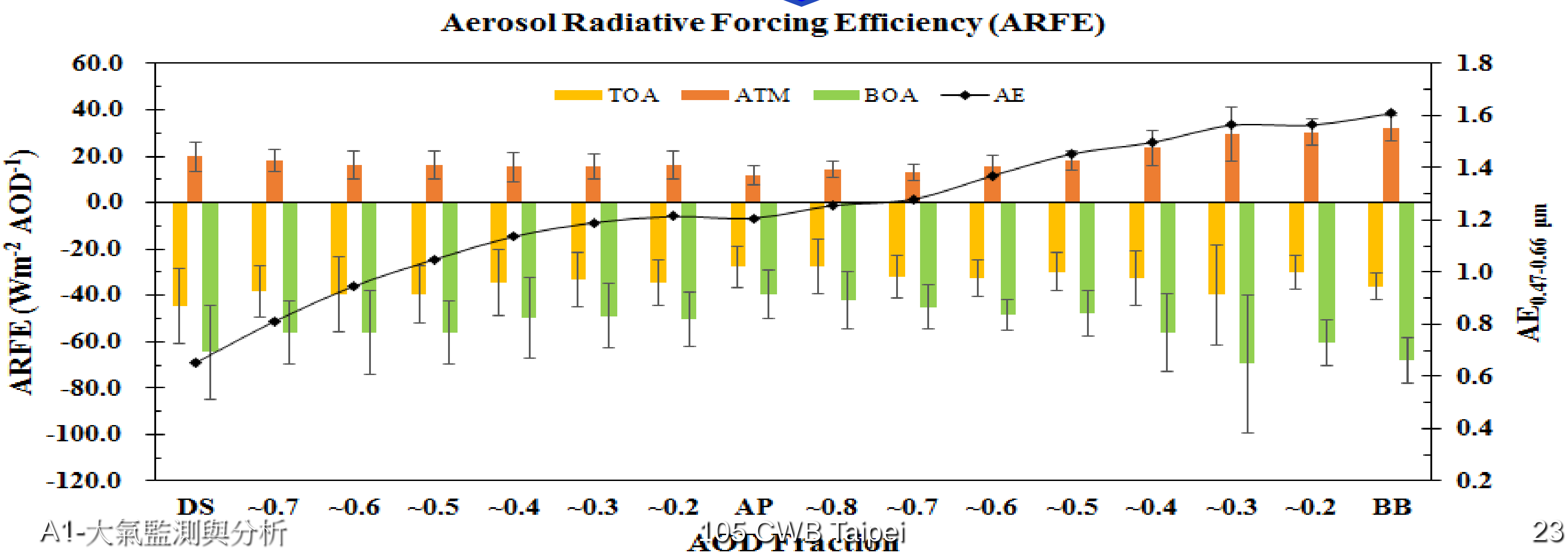




Potential of NGAI for ARFE assessment







◆ Discussions

- A new data product (NGAI) of satellite was proposed to categorize aerosols and determine AOD fraction for mixed aerosols
- Biomass burning aerosol can be discriminated from anthropogenic source using NGAI
- NGAI facilitates the evaluation of aerosol radiative forcing with satellite data
- NGAI also can be applied to geostationary satellite observations, such as Himawari-8, for the continuous monitor during the daytime.

Investigation of aerosol retrievals with Himawari-8 data

◆ Application of $PM_{2.5}$ Monitoring