Direct radiative forcing due to aerosols in Asia during March 2002

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Contents

Introduction

- **Atmospheric aerosol plays a major role in the global climate change,**
  - **Directly : by absorption, scattering and emission of solar and terrestrial radiation**
  - **Indirectly : by changing the albedo and the life time of clouds by acting as cloud condensation nuclei**

- **Wind-blown mineral dust from desert and semiarid regions is important source of tropospheric aerosols**
  - **contributes 1000-3000 Tg yr^{-1} to global atmospheric emission**
  - **plays an important role on the earth-atmosphere radiative system**
  - **a distinct feature in East Asia, West Africa, South America**

- **In East Asia, Asian dust (Hwangsa in Korean)**
  - **frequently occurs in Sand desert, Gobi desert and Loess plateau in northern China and Mongolia**
  - **reported to be transported to the western part of USA**
  - **increases the albedo over the cloudless ocean and land by up to 10-20%**
  - **reduces the direct solar radiation by 30-40%**

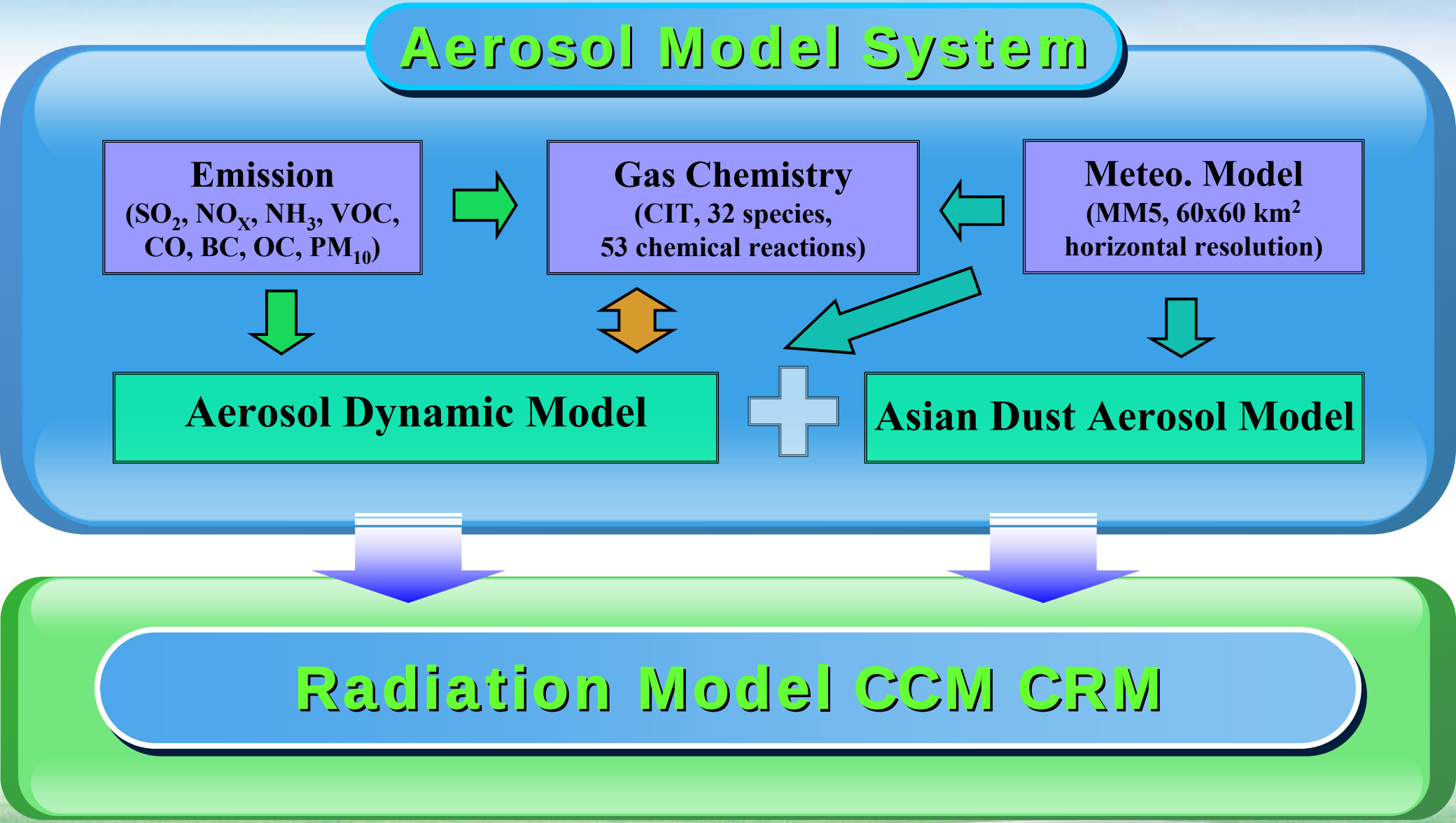
Introduction

- **Radiative effects of mineral aerosols**
  - **The present estimate of global mean radiative forcing due to anthropogenic aerosols and biomass burnings : –0.3 ~ –3.5 W m^{-2}, that of the greenhouse gases forcing : 2.0 ~ 2.8 W m^{-2}**
  - **large uncertainties due to the lack of detailed information on size, chemical composition, surface properties, source strength, transport and removal processes**

•Anthropogenic aerosols are important in Asia

- **Purpose: To estimate direct radiative forcing of Asian dust aerosols and anthropogenic aerosols for the period of March 2002. Using ADAM model, Aerosol dynamic model, NCAR column radiation model (CRM) with the MM5 meteorological model**

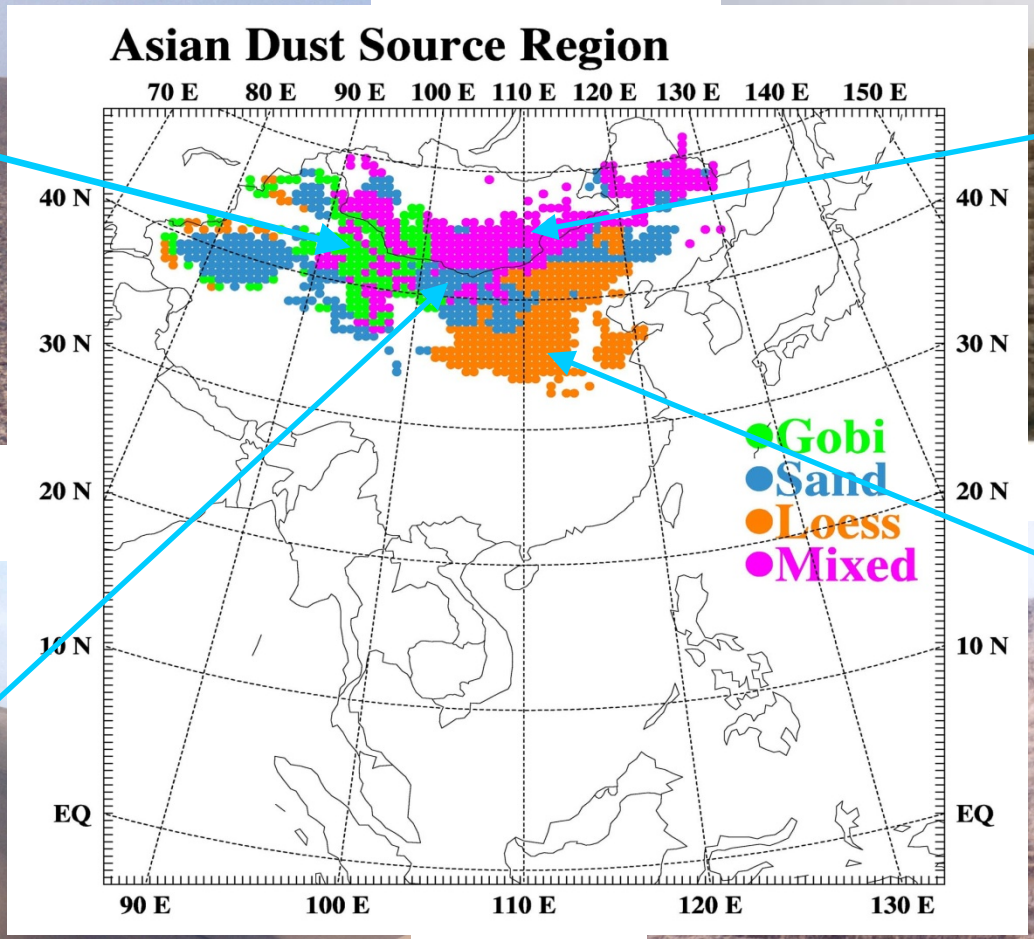
Model Description



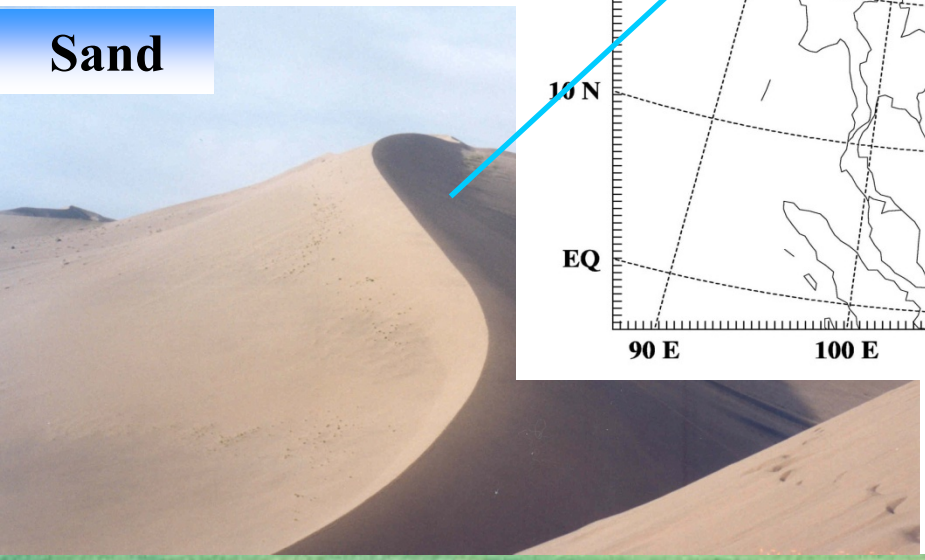
Model Domain & Asian Dust Source Region

Gobi

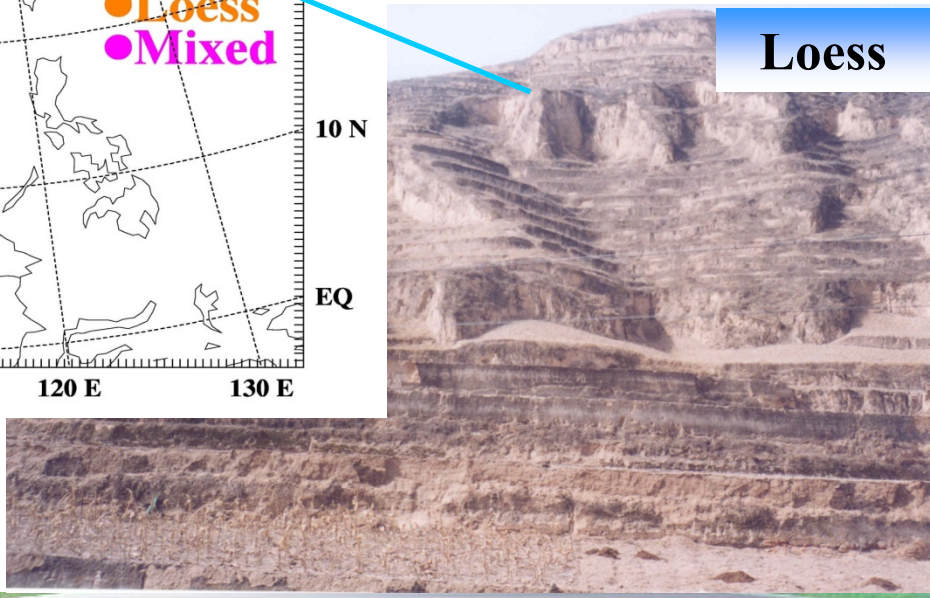
Mixed



Sand



Loess



Aerosol Model System

Meteorological Model

- MM5 version 3 nonhydrostatic model
- 60 km x 60 km horizontal resolution
- 20 Vertical layer in coordinate
- Moisture : simple ice explicit scheme
- Convection : Kain-Fritsch scheme
- PBL : Medium Range Forecasting (MRF)
- Period : March 2002

Gas Chemistry

- CIT (California Institute of Technology, Russel)
- Adds (SO_2+OH) reaction and NH_3 (52 → 53 chemical reactions, 29 → 32 species)
- 8 photolytic reaction (cloud effect)
- SO_2 oxidation : 3 path (O_3, H_2O_2, Fe^+, Mn^+)
- NH_3/HNO_3 dissolution

Aerosol Model System

Aerosol Dynamics Model

- Gas-Aerosol mass transfer (Hybrid scheme)
- Nucleation : critical value of the gas-phase sulfuric acid
- Condensation/evaporation : concentration difference between the particle surface and the bulk gas
- Dry and wet deposition
- Hygroscopic growth
- Coagulation : Brownian motion, Turbulent shear, Sedimentation

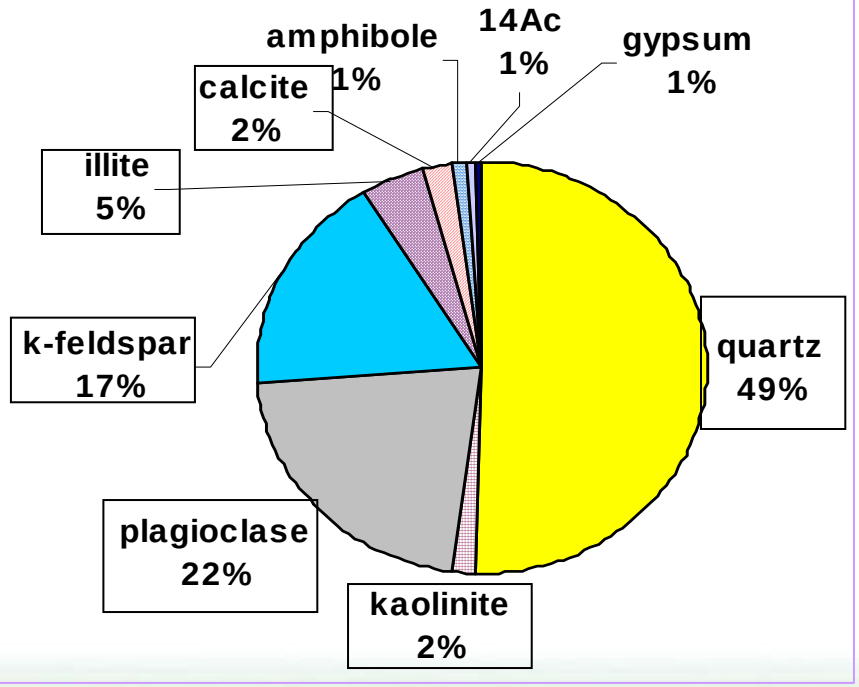
Asian Dust Aerosol Model

- Specification of Dust source region
- 12 bins (0.02~77 ㎛ in diameter)
- Statistically derived dust emission conditions in Sand, Gobi, Loess, mixed soil surface
- Dust emission flux $\propto u_*^4$
- Dust emission modification by the land-use types
- Log-normal distributions of the suspended particles in the source region with minimally and fully dispersed particle-size distribution

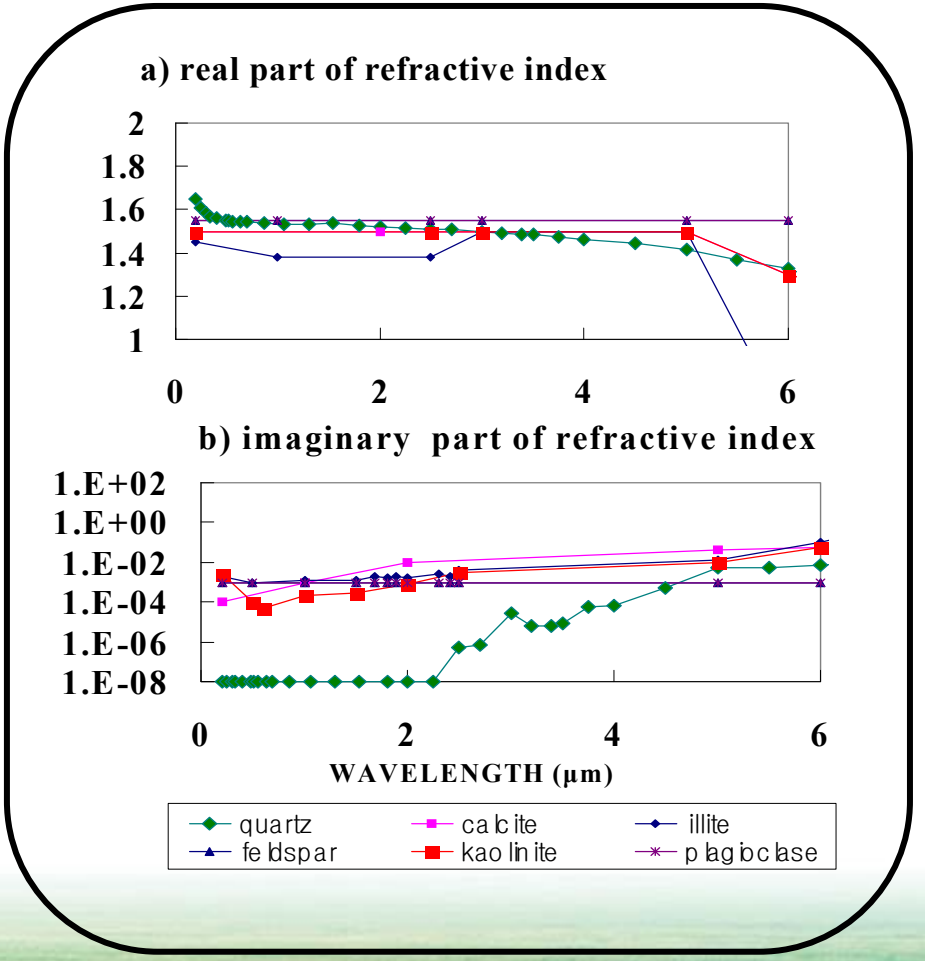
Radiation Model

National Center for Atmospheric Research (NCAR) column radiation model (CRM) of the community climate model (CCM)

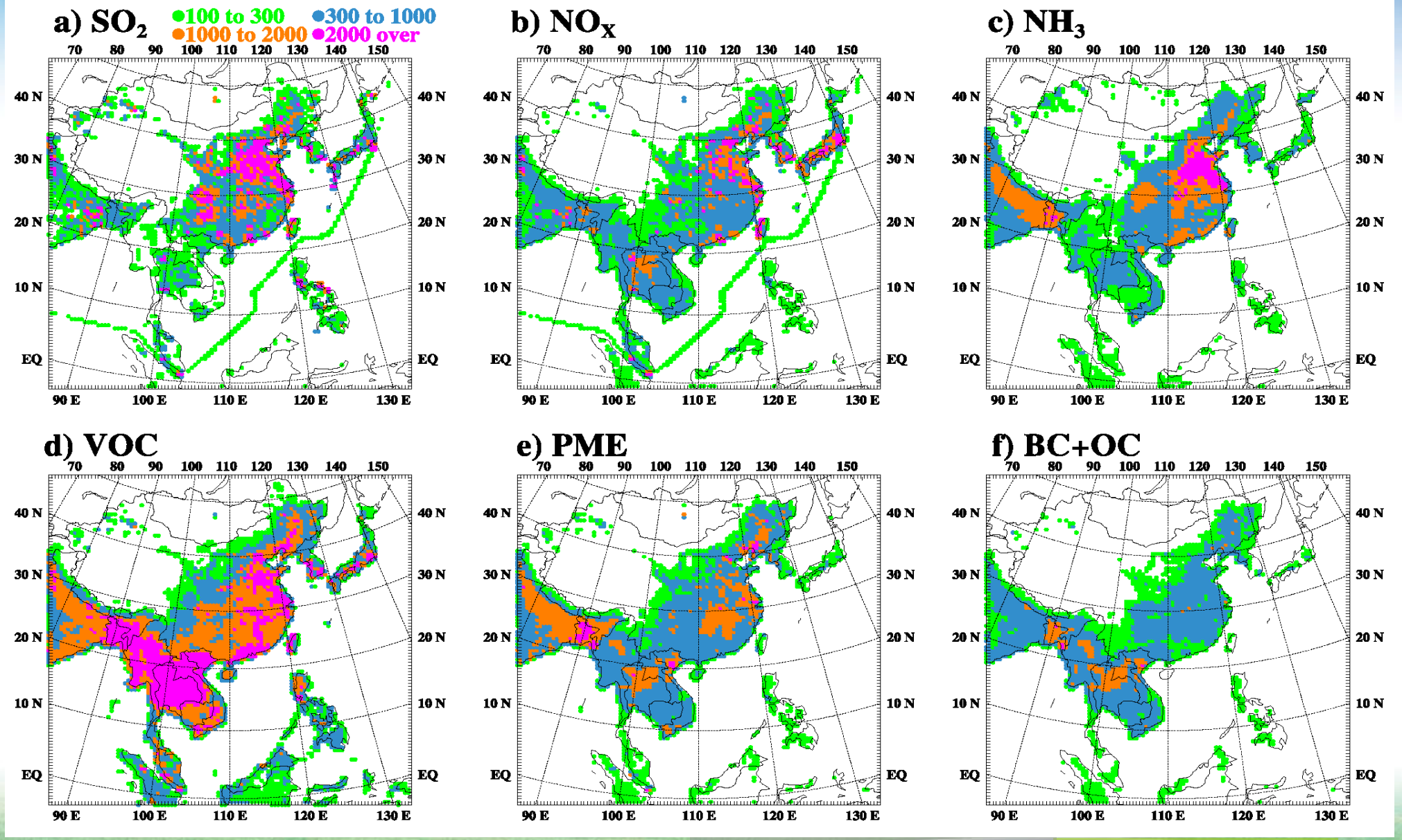
Mineralogical composition in Asian Dust
[from soil samples in the source regions (Park, 2002)]



6 mineral component selected



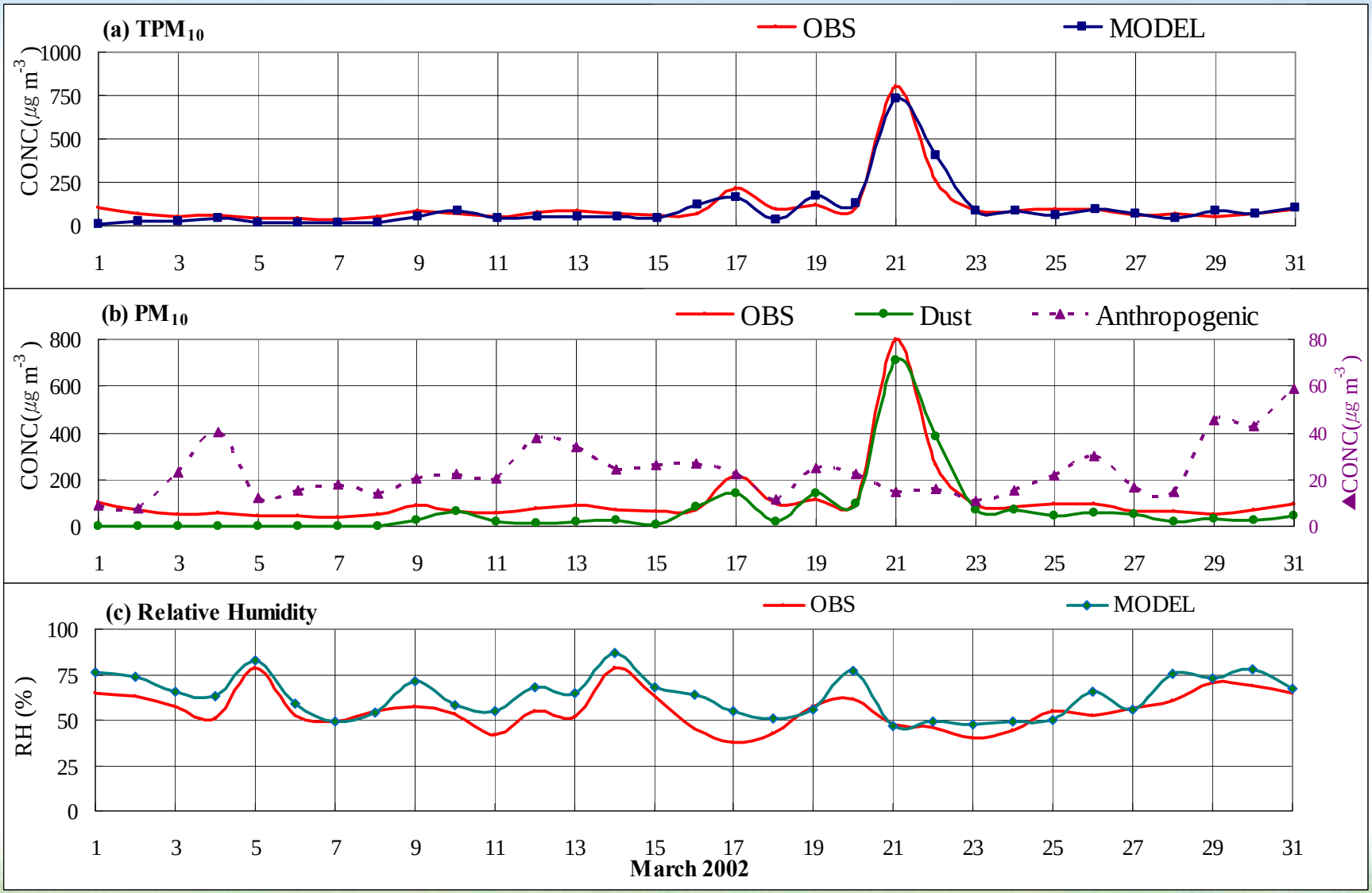
Anthropogenic emissions over Asia



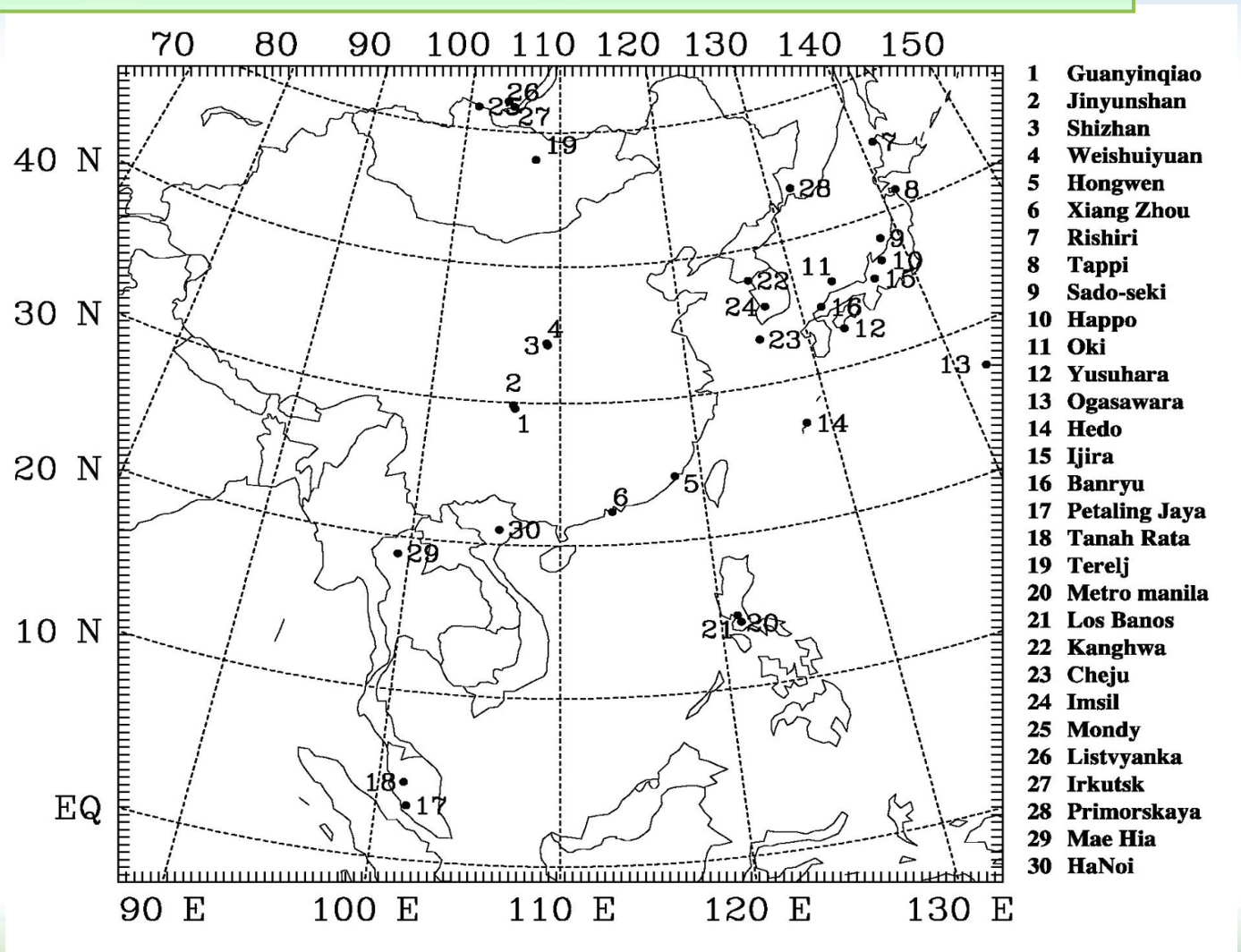
(unit : t grid^{-1} month^{-1}) Streets et al., 2000

Daily mean surface concentration over South Korea

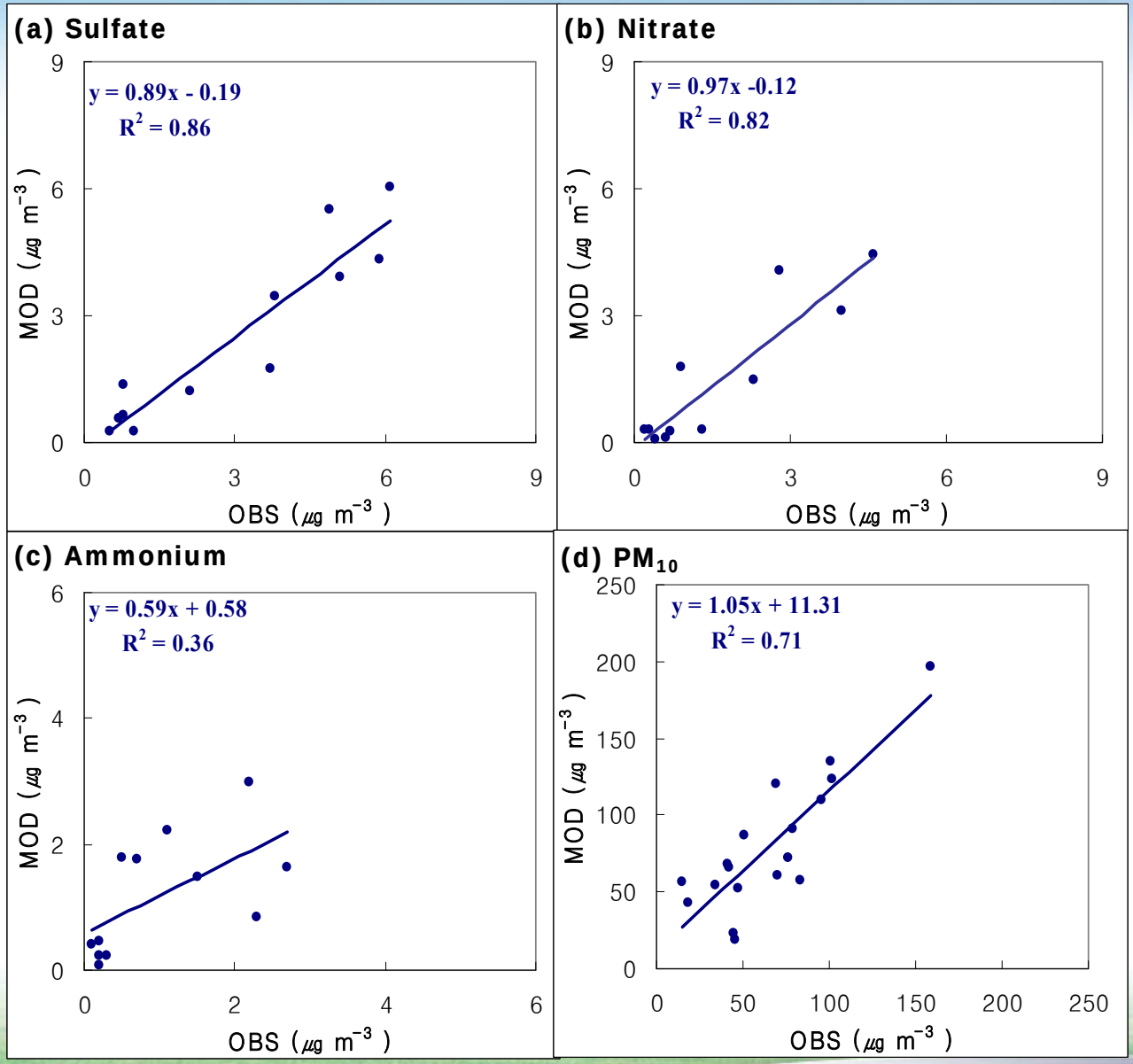
Results



Location of monitoring sites of EANET



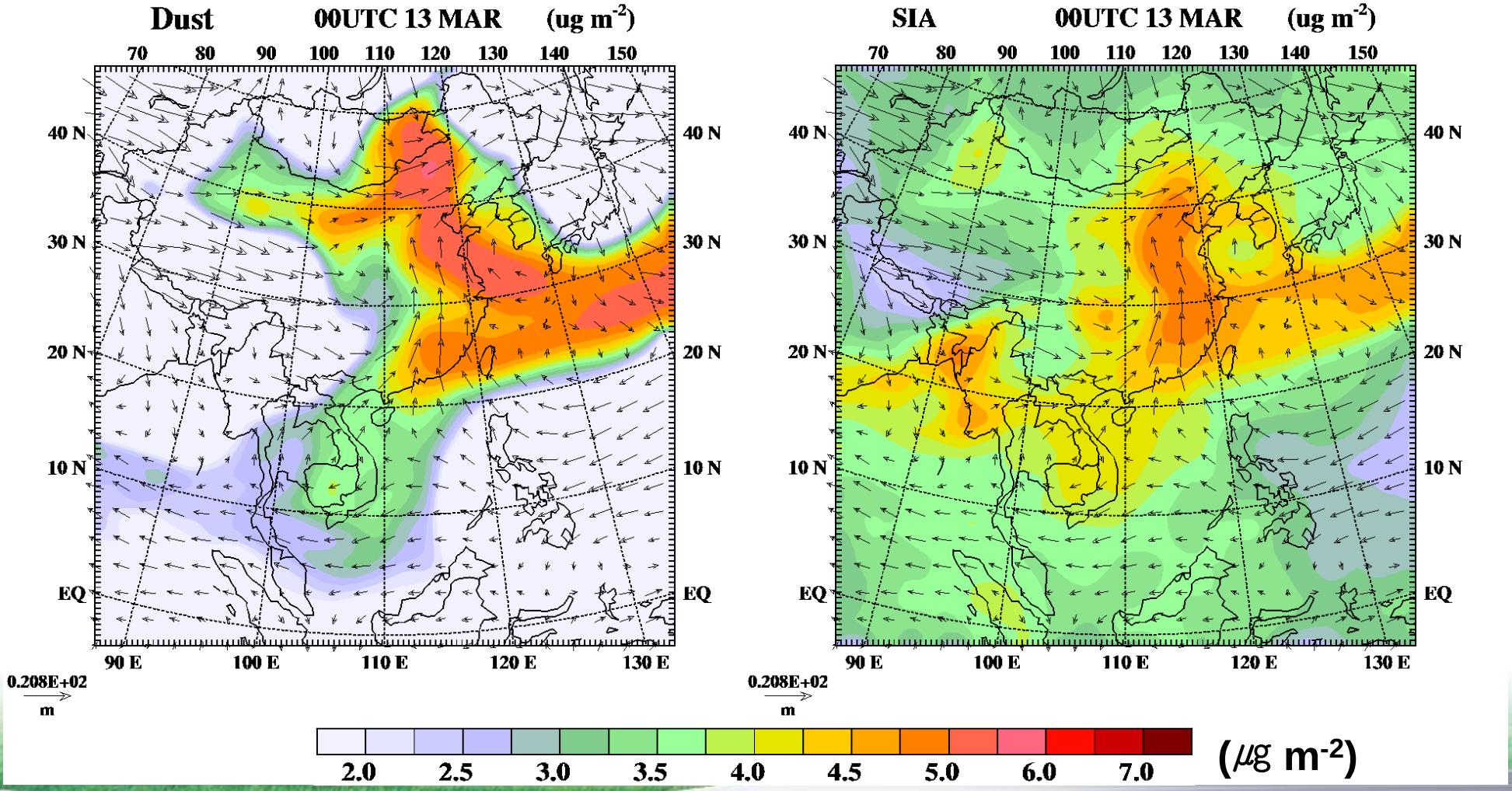
Comparison of observed and modeled aerosol concentration in Asia



Column integrated Asian dust and Secondary inorganic aerosol

Asian dust concentration ($\mu g\ m^{-2}$) expressed in common logarithm scale

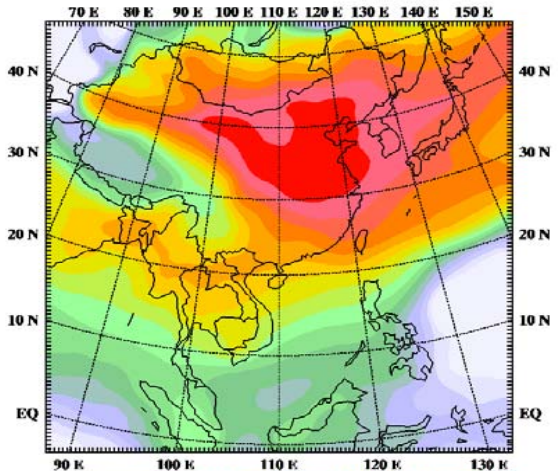
SIA concentration ($\mu g\ m^{-2}$) expressed in common logarithm scale



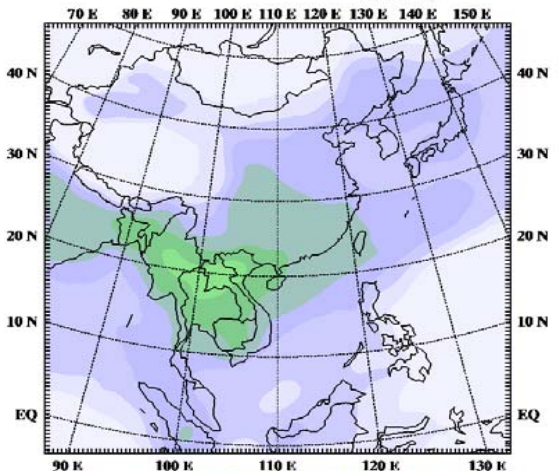
Spatial distribution of aerosol concentrations

Column integrated monthly mean concentration ($\mu g\ m^{-2}$) expressed in common logarithm scale

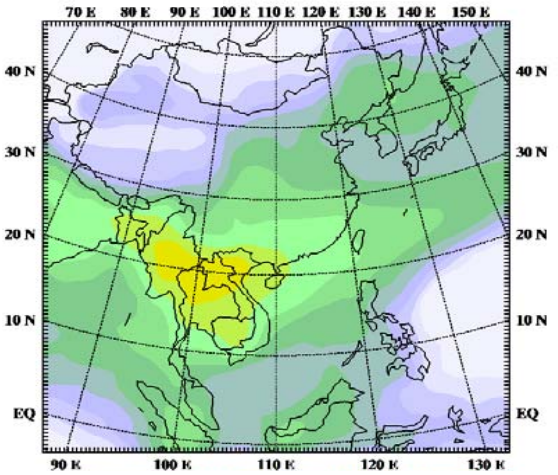
Dust + PM



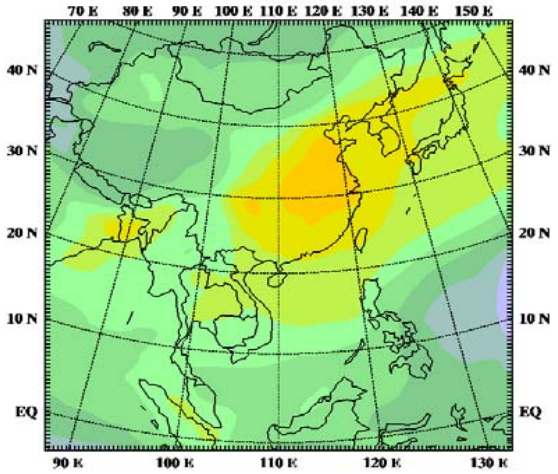
BC



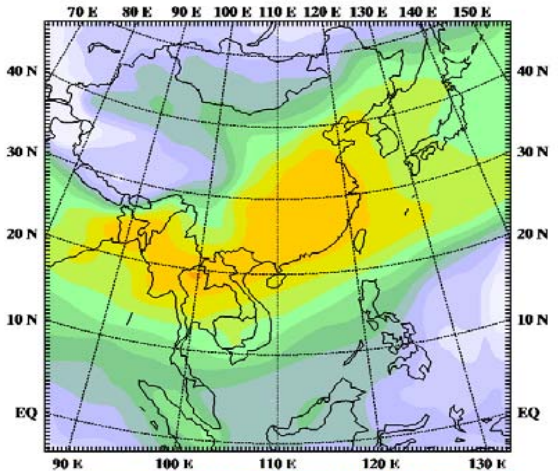
OC



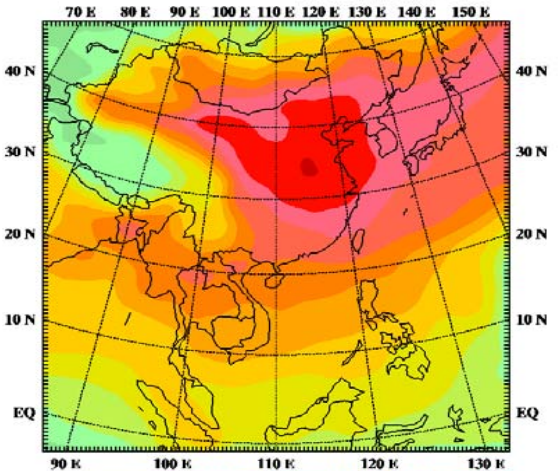
SIA

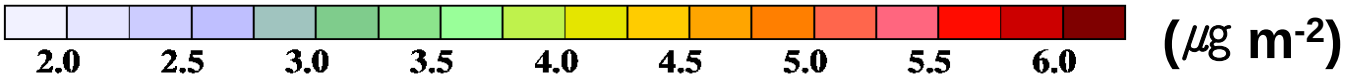


MIX

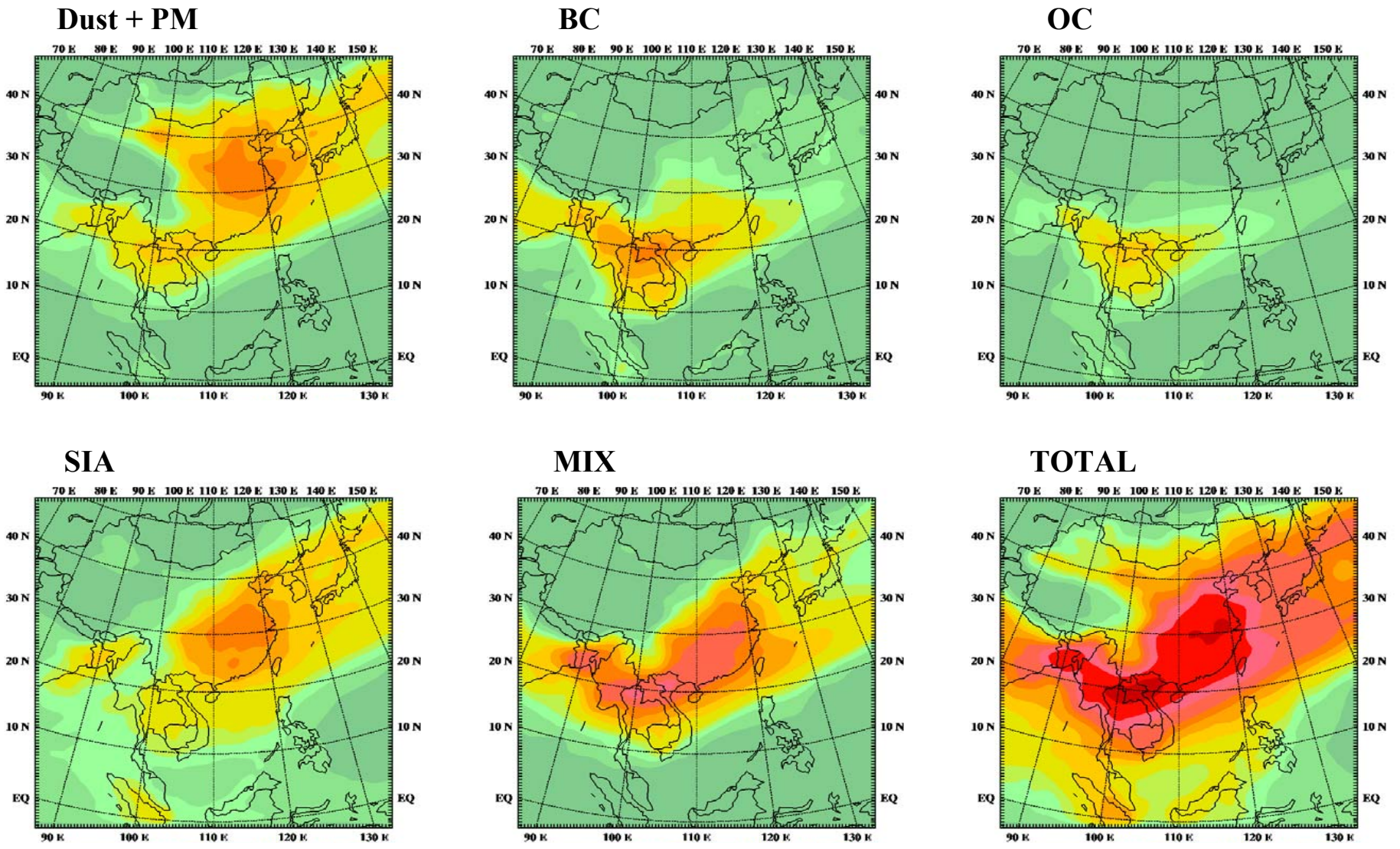


TOTAL

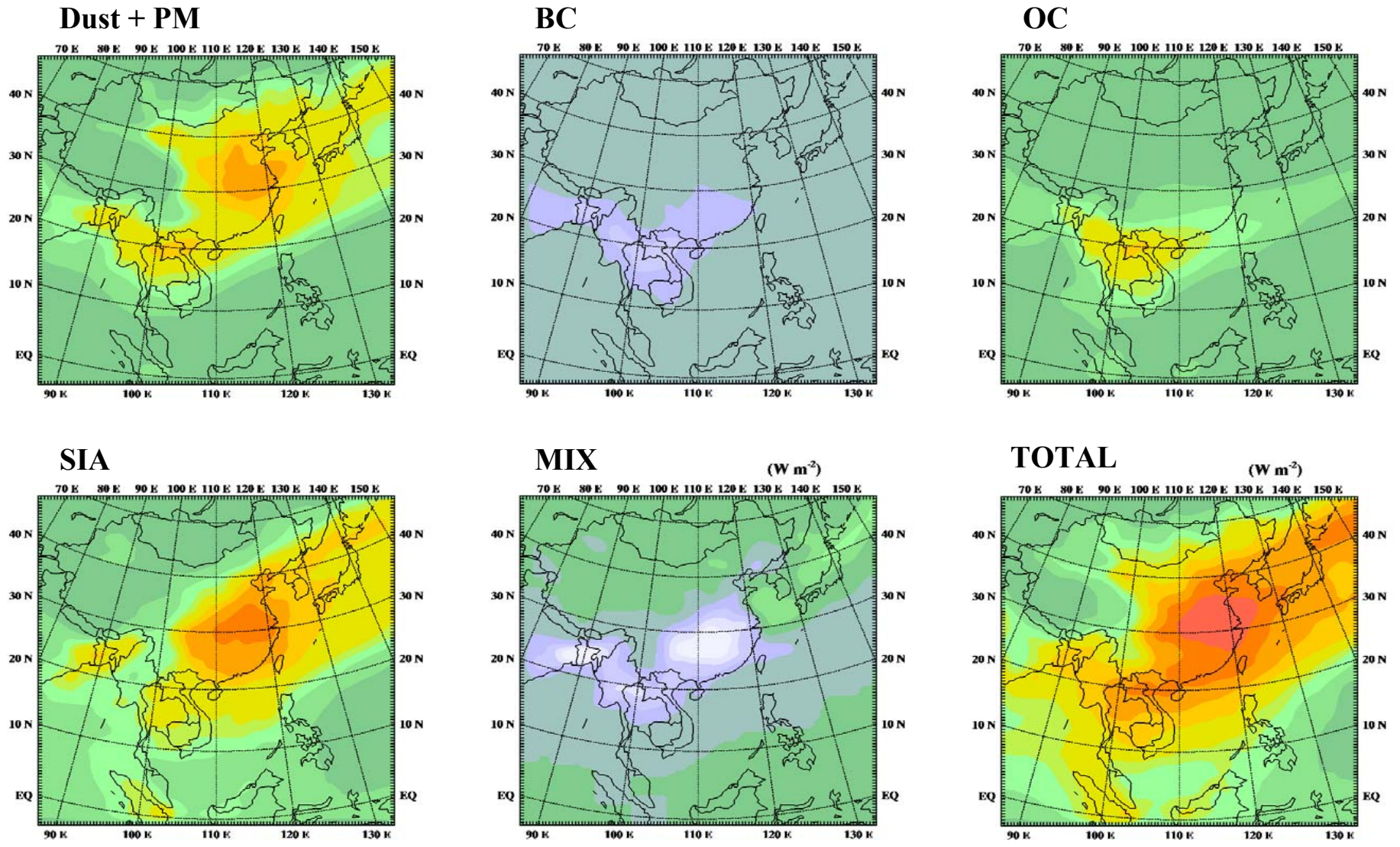




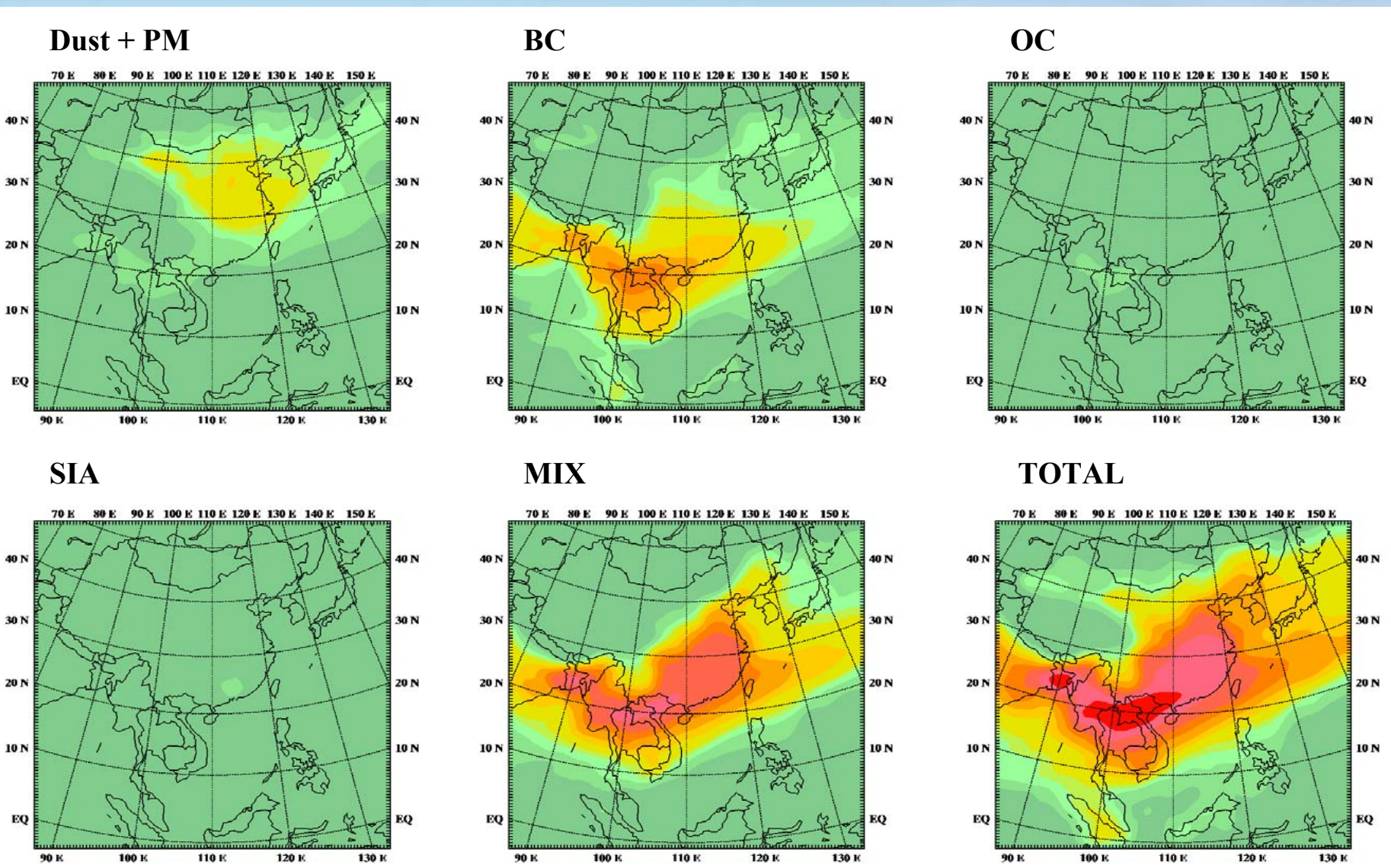
Direct radiative forcing (W m^{-2}) at the surface



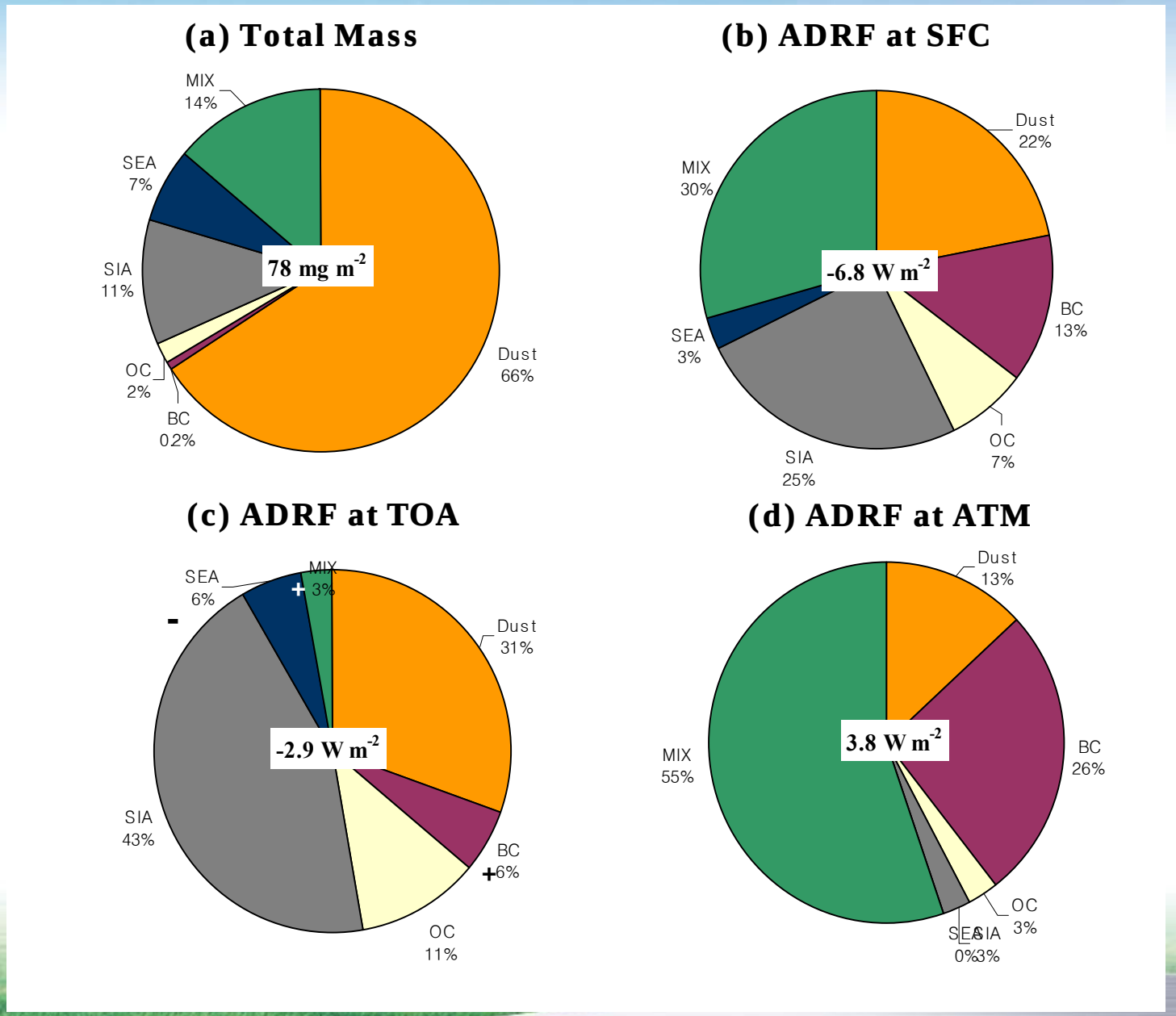
Direct radiative forcing (W m^{-2}) at the top of Atmosphere (TOA)



Direct radiative forcing (W m^{-2}) in the Atmosphere



Fractional contributions of each type of aerosols



Conclusions

- ADAM, aerosol dynamic model and CRM model together with the output of MM5 model in the grid of 60x60 km^2 can be reasonably estimates the direct radiative forcing of aerosols in Asia for the period of March 2002.
- The vertically integrated monthly mean total aerosol mass in the analysis domain is about 78 mg m^{-2}, of which 66%, 14% and 11% are, respectively contributed by the Asian dust, mixed aerosol (Dust+BC+OC+SIA) and SIA aerosol.
- The mean radiative forcing at the surface (-6.8 W m^{-2}) and at the top of atmosphere (-2.9 W m^{-2}) by the Asian dust is about 22% (-0.03 W m^{-2} mg^{-1}) and 31% (-0.02 W m^{-2} mg^{-1}) respectively. The contribution due to SIA aerosol is 25% (-0.20 W m^{-2} mg^{-1}) and 43% (-0.15 W m^{-2} mg^{-1}) respectively, the contribution due to mixed aerosol is 30% (-0.19 W m^{-2} mg^{-1}) and 3% (-0.01 W m^{-2} mg^{-1}) respectively, suggesting more effectiveness of the anthropogenic aerosol on radiative forcing in Asia.
- The atmospheric warming is found to be about 3.8 W m^{-2}, of which 55% and 26% are, respectively contributed by the mixed aerosol and BC due to their strong absorptivity.

Table 1. The radiative intensity of the aerosols

Aerosol	Surface (W $mg^{-1)}$	TOA (W mg^{-1})	**Atmosphere** (W mg^{-1})	Total mass con. (mg m^{-2})
Asian dust	-0.03	-0.02	0.01	51.48
SIA	-0.20	-0.18	0.01	8.58
Mixed type	-0.19	+0.01	0.19	10.92
BC	-5.67	+1.35	6.21	0.16
OC	-0.31	-0.25	0.07	1.56
Sea salt	-0.04	-0.04	0.00	5.46


Thank You !