Impacts of direct radiative forcing of Asian dust on meteorological fields

Soon-Ung Park·Hyun-Ju Ahn·Moon-Soo Park

Center for Atmospheric and Environmental Modeling
Seoul, Korea

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Contents

Introduction

- **Roles of aerosols :**
  - Provide reaction sites for atmospheric chemical species
  - Serve as carriers for many condensed or sorbed species
  - Change the global climate system by
    - changing atmospheric radiation balance,
    - 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
  - 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%

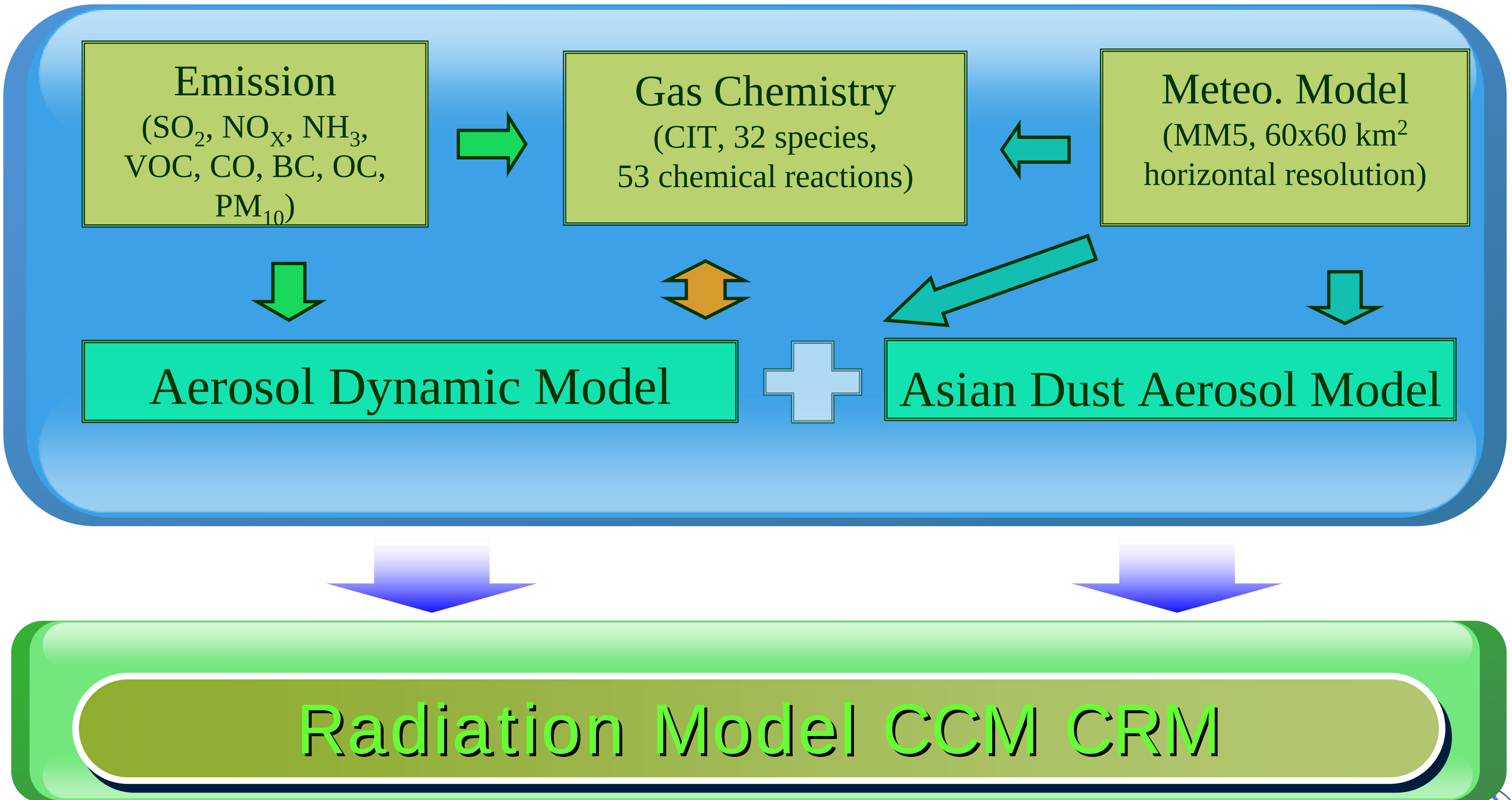
❖Purpose :

- 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

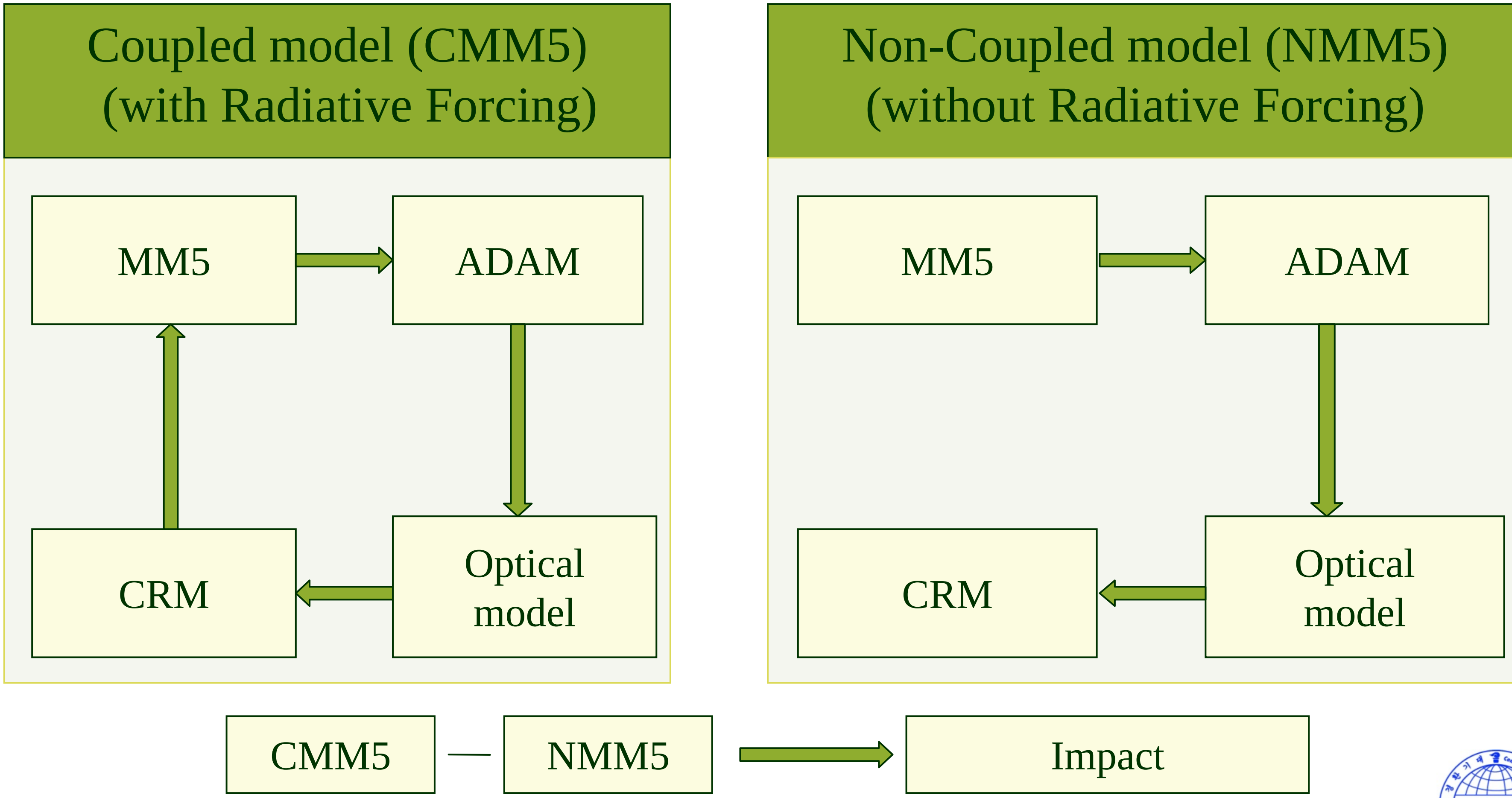
- To estimate impacts of direct radiative forcing of Asian Dust on meteorological fields

Model Description

Aerosol model system



Effects of radiative forcing of Asian dust on Meteorological fields



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 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

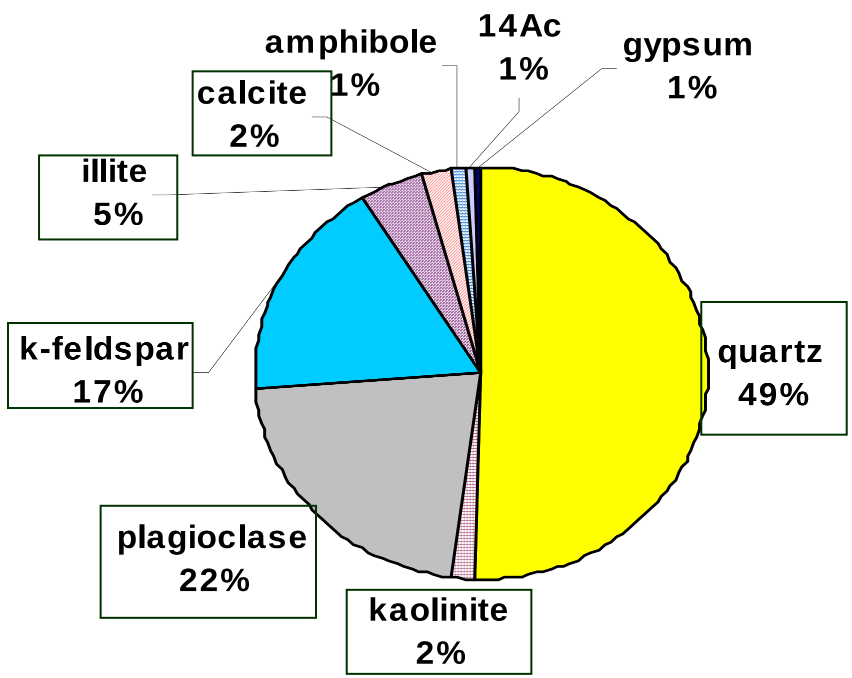
Asian Dust Aerosol Model

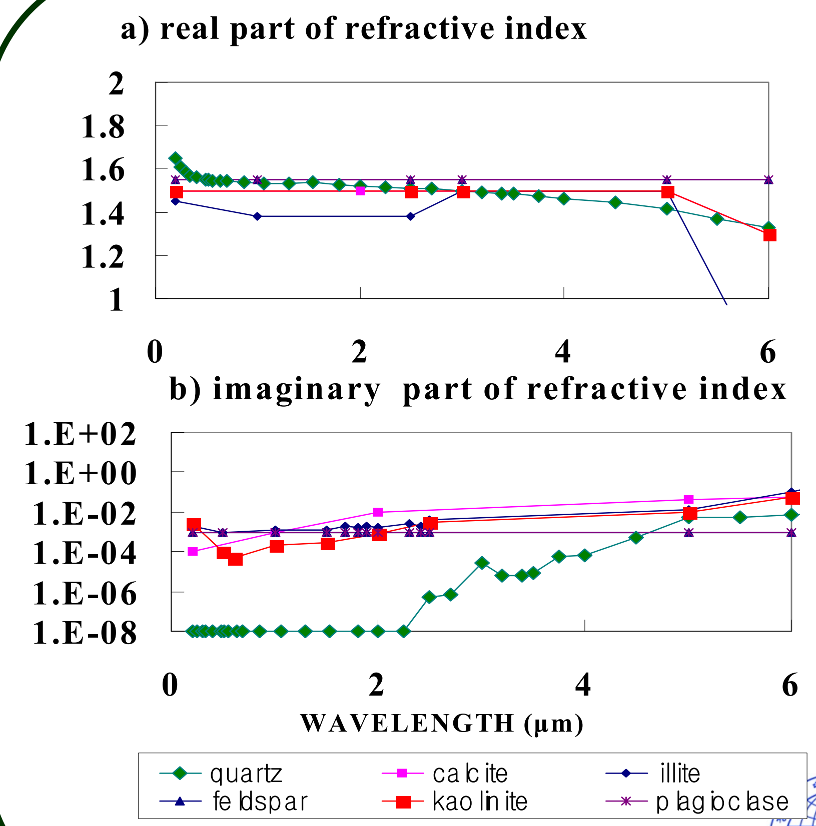
- Specification of Dust source region
- 12 bins (0.02~77 ㎛ in diameter)
- Statistically derived dust emission conditions in Sand, Gobi, Loess, mixed soil surface
- Dust emission flux $\propto u_*^4$
- Dust emission modification by the land-use types
- Log-normal distributions of the suspended particles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

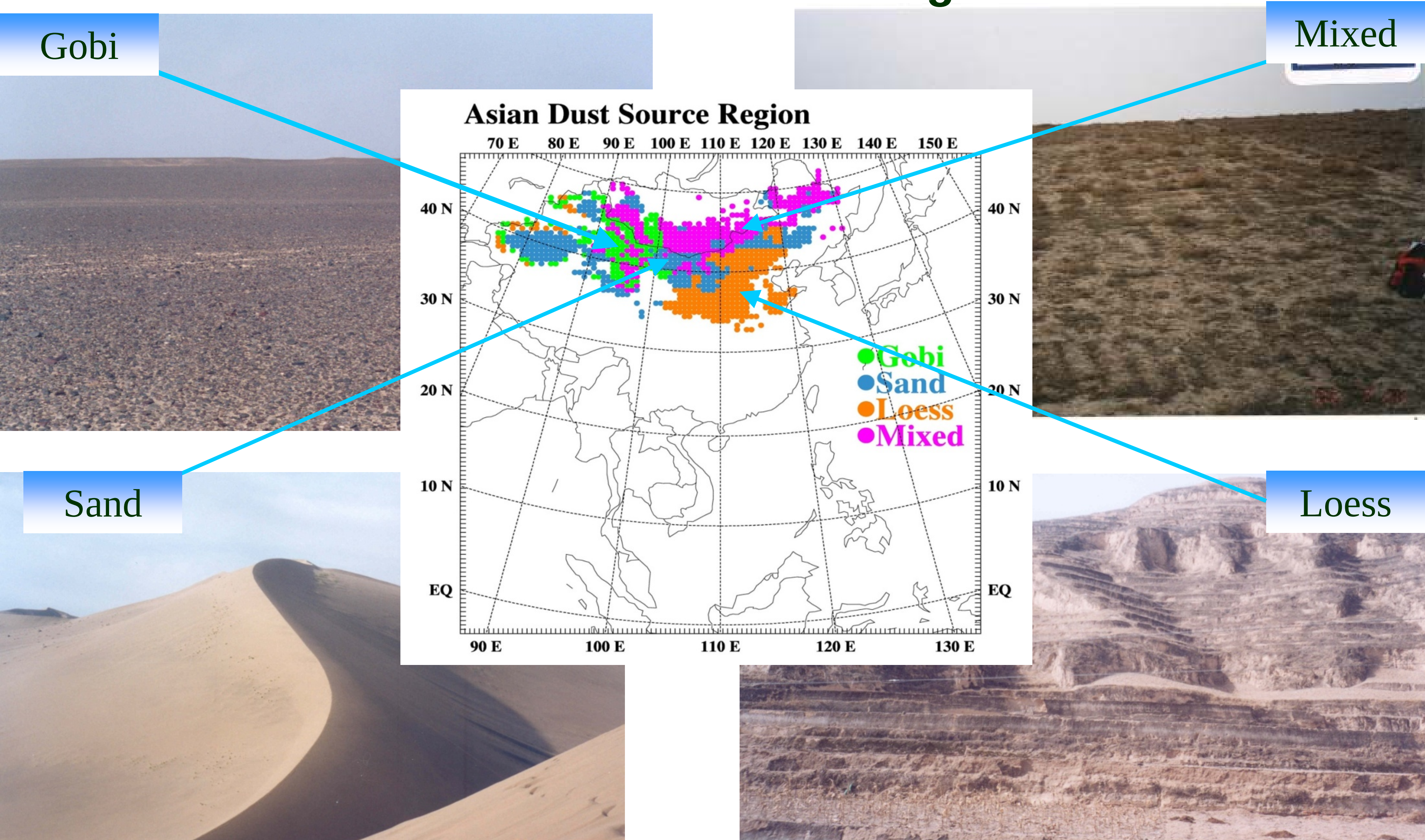
Mineralogical composition in Asian Dust
[from soil samples in the source regions (Park, 2002)]





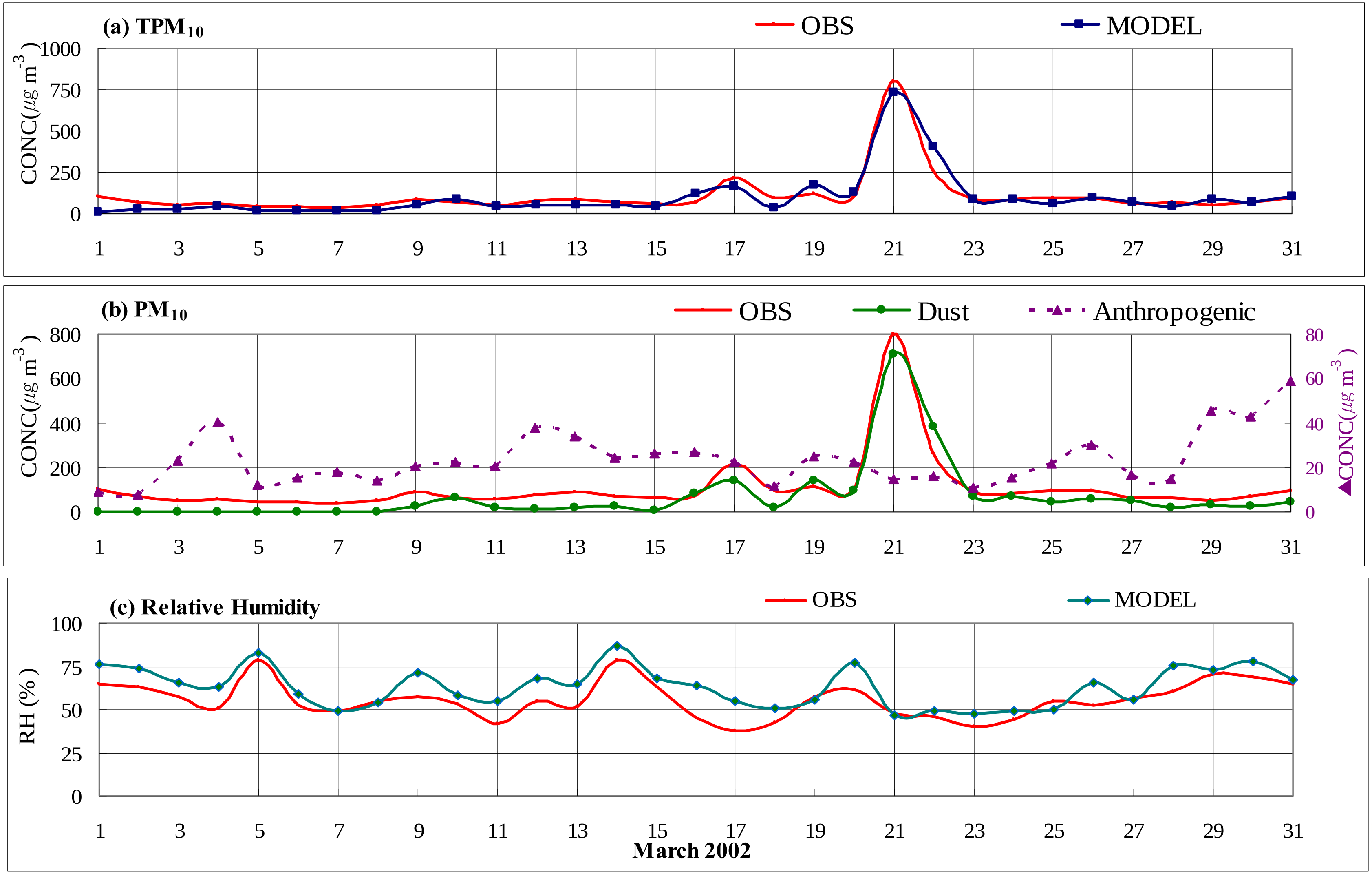
6 mineral component selected

Model Domain & Asian Dust Source Region

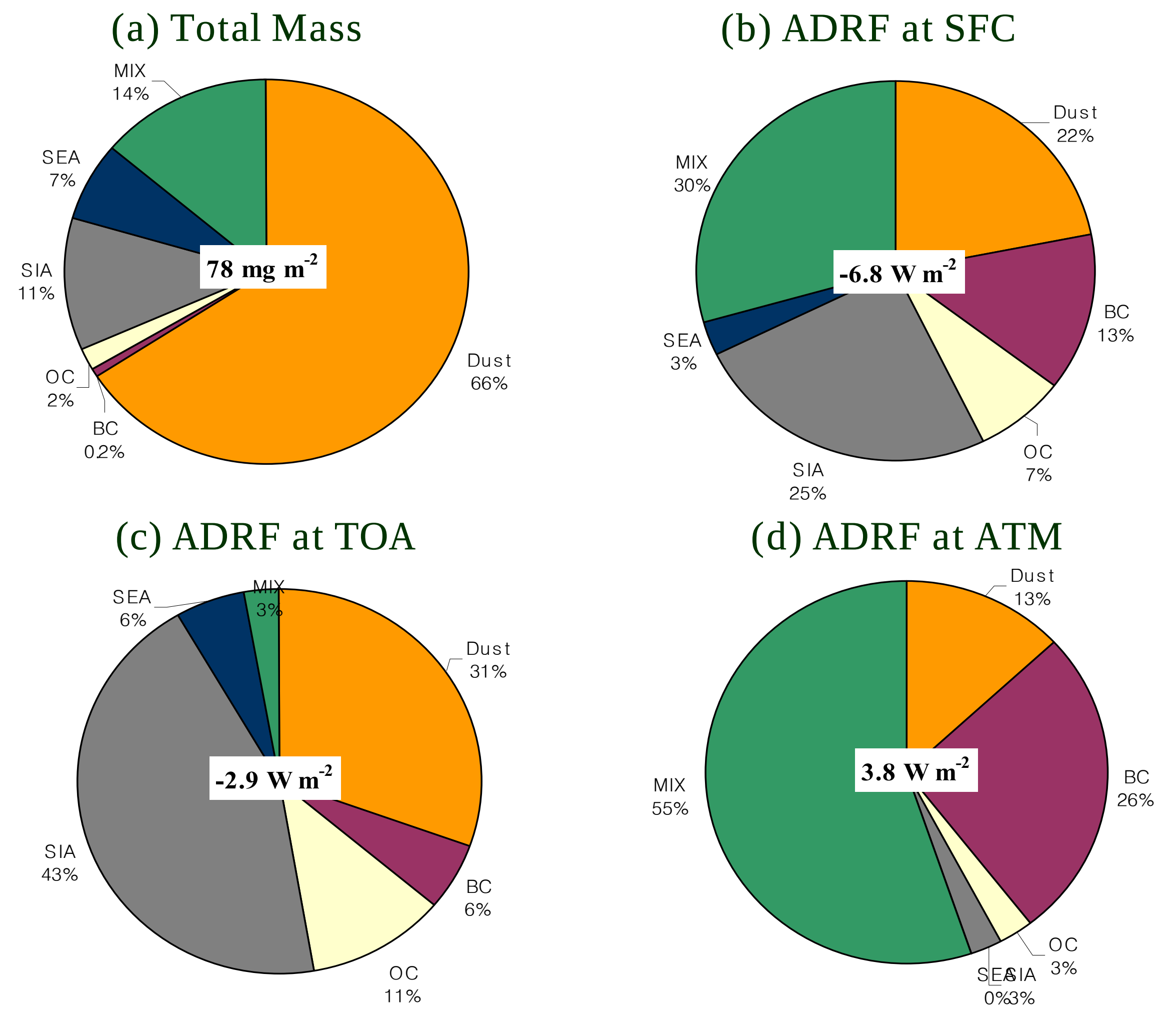


Results

Daily mean surface concentration over South Korea



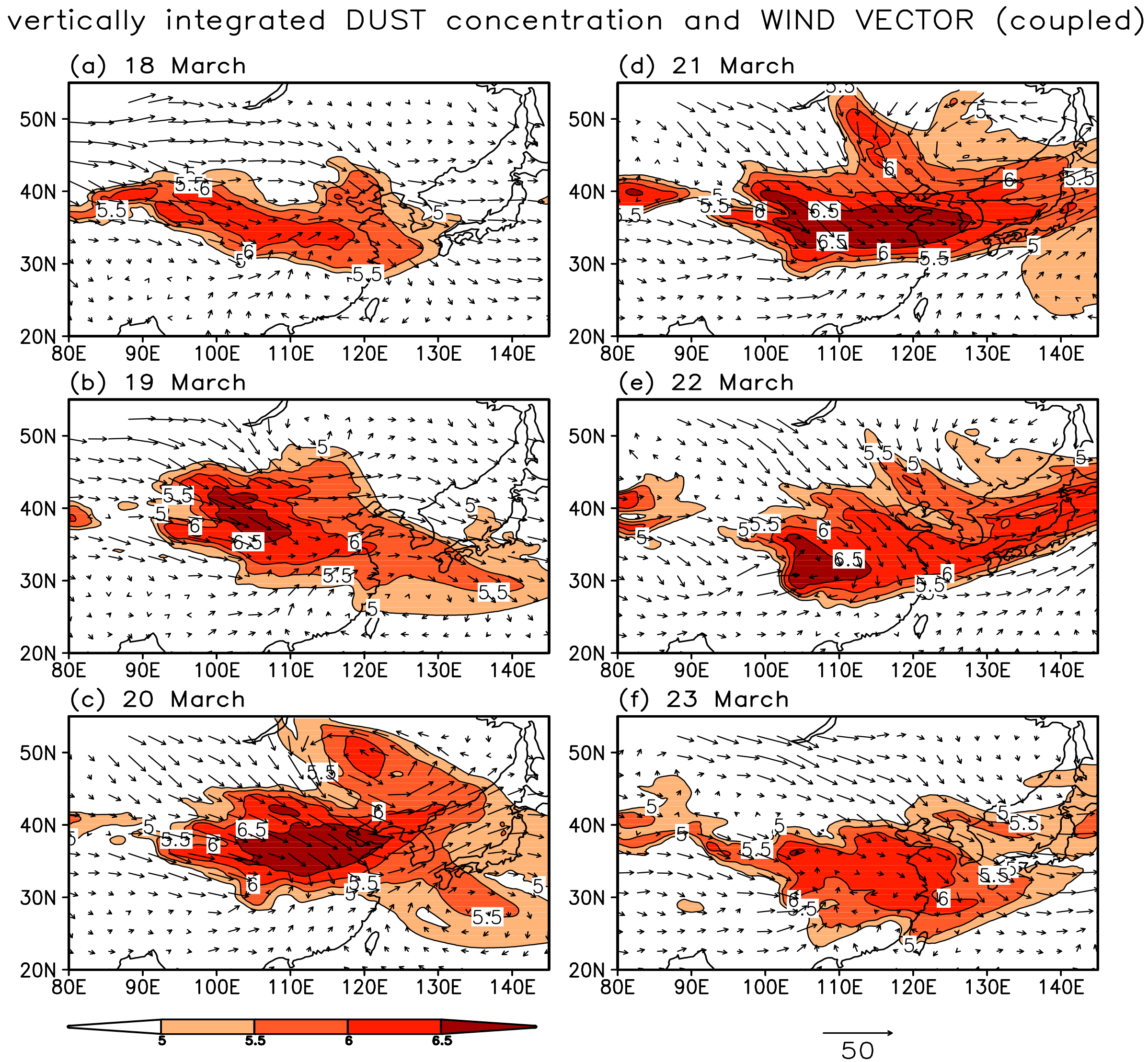
Fractional contributions of each type of aerosols



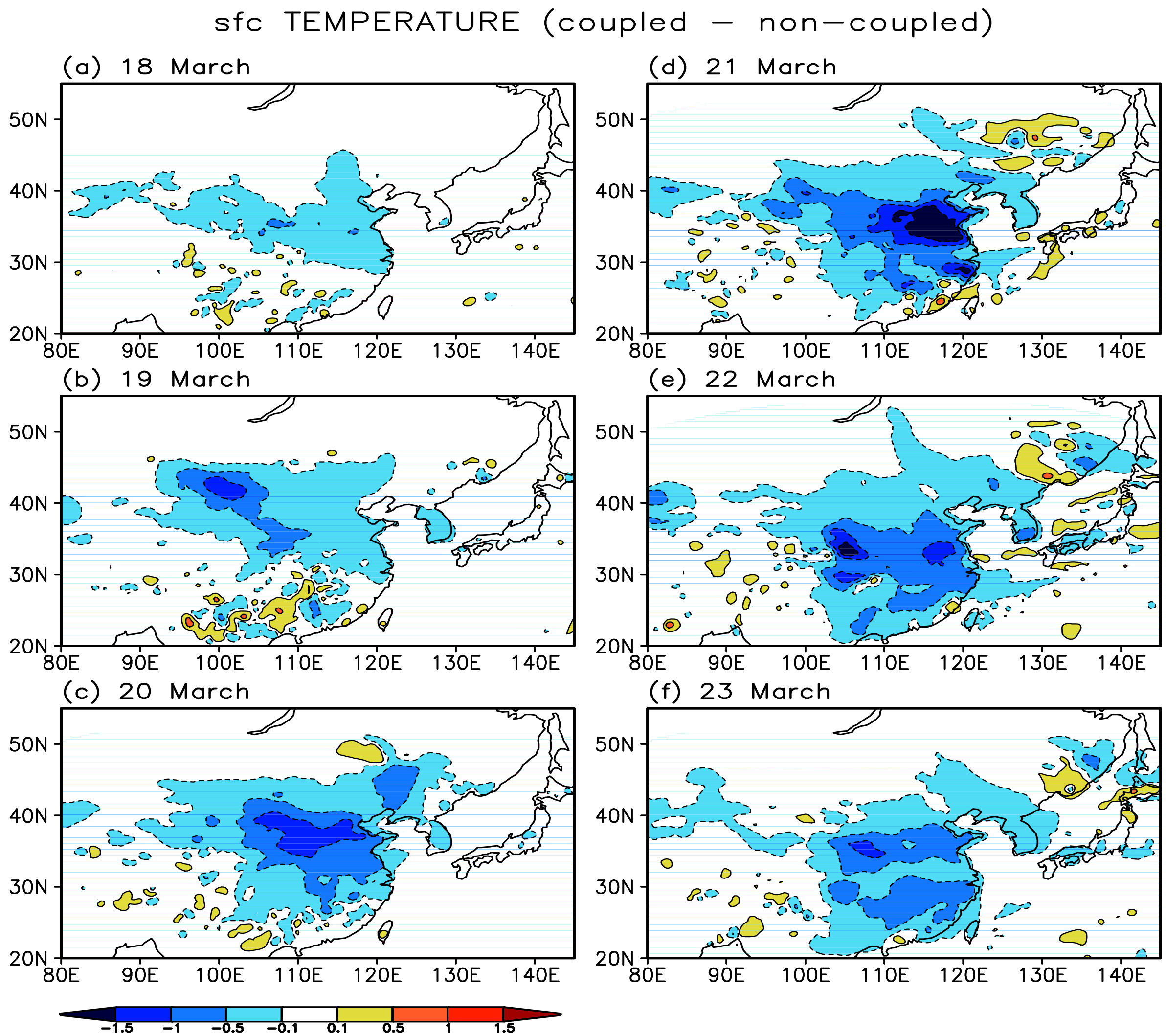
Radiative intensity

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

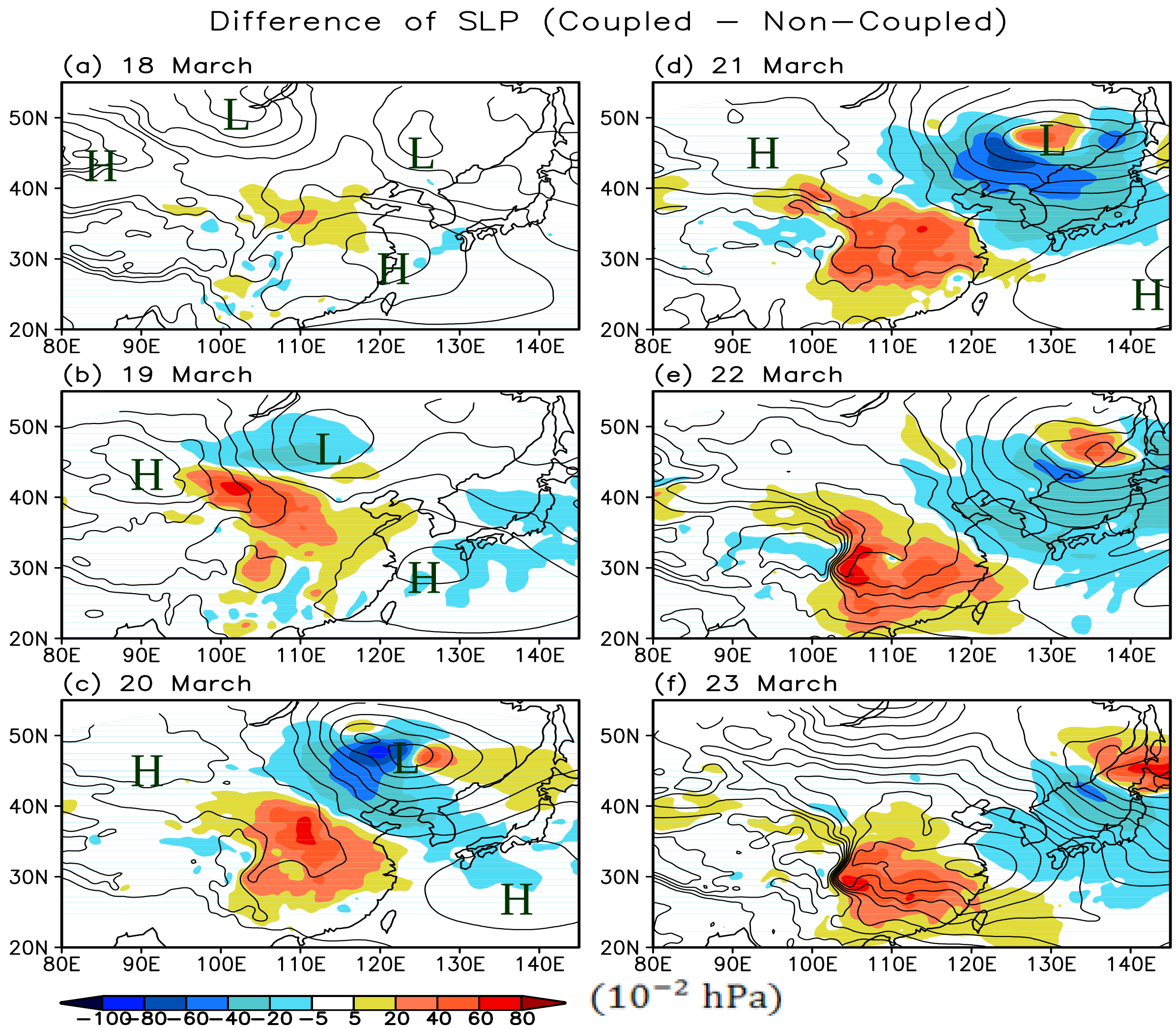
Impacts of Asian dust aerosol radiative forcing on meteorologi



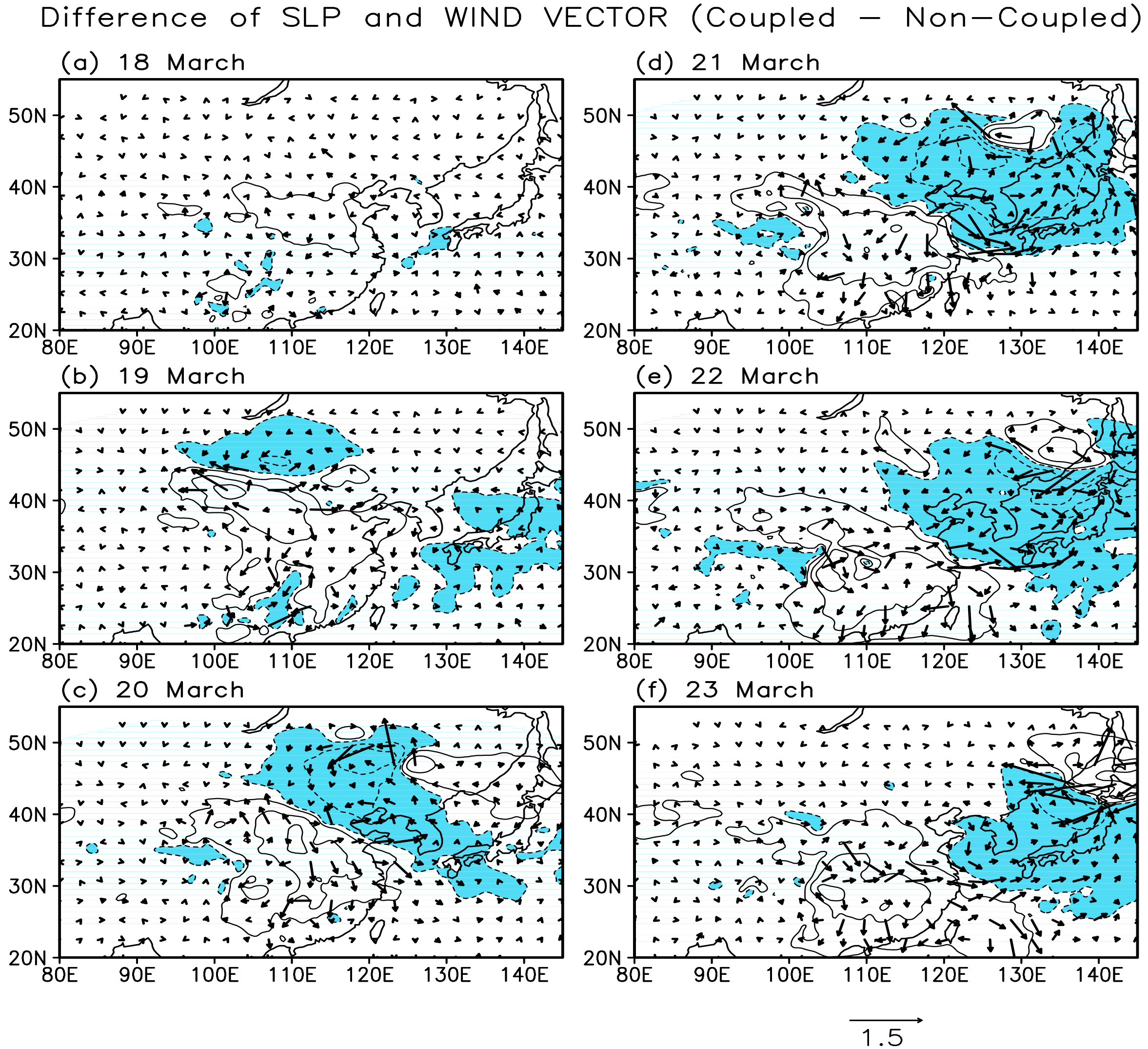
Affected temperature



Pressure anomaly

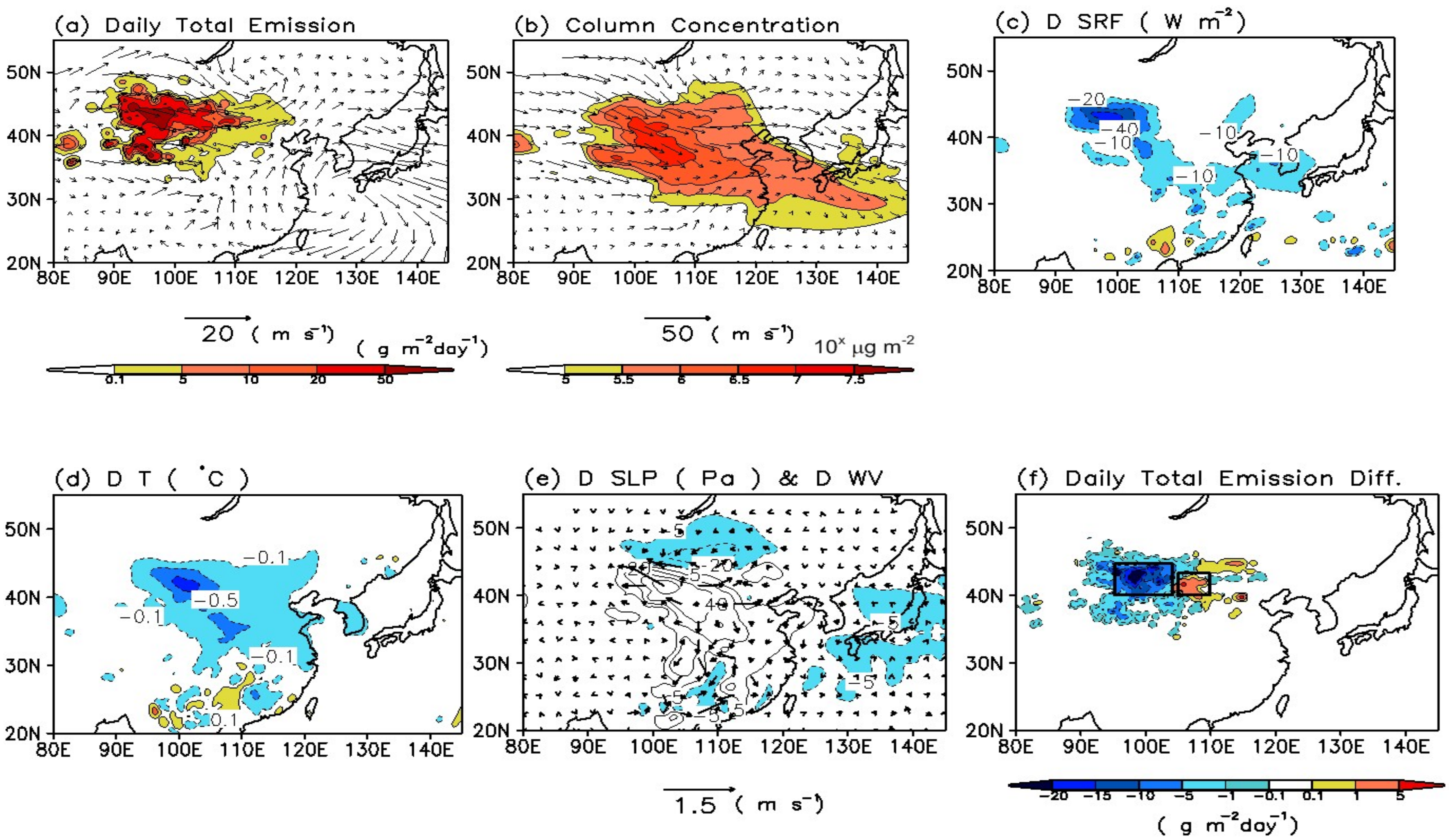


Wind affected by radiative forcing

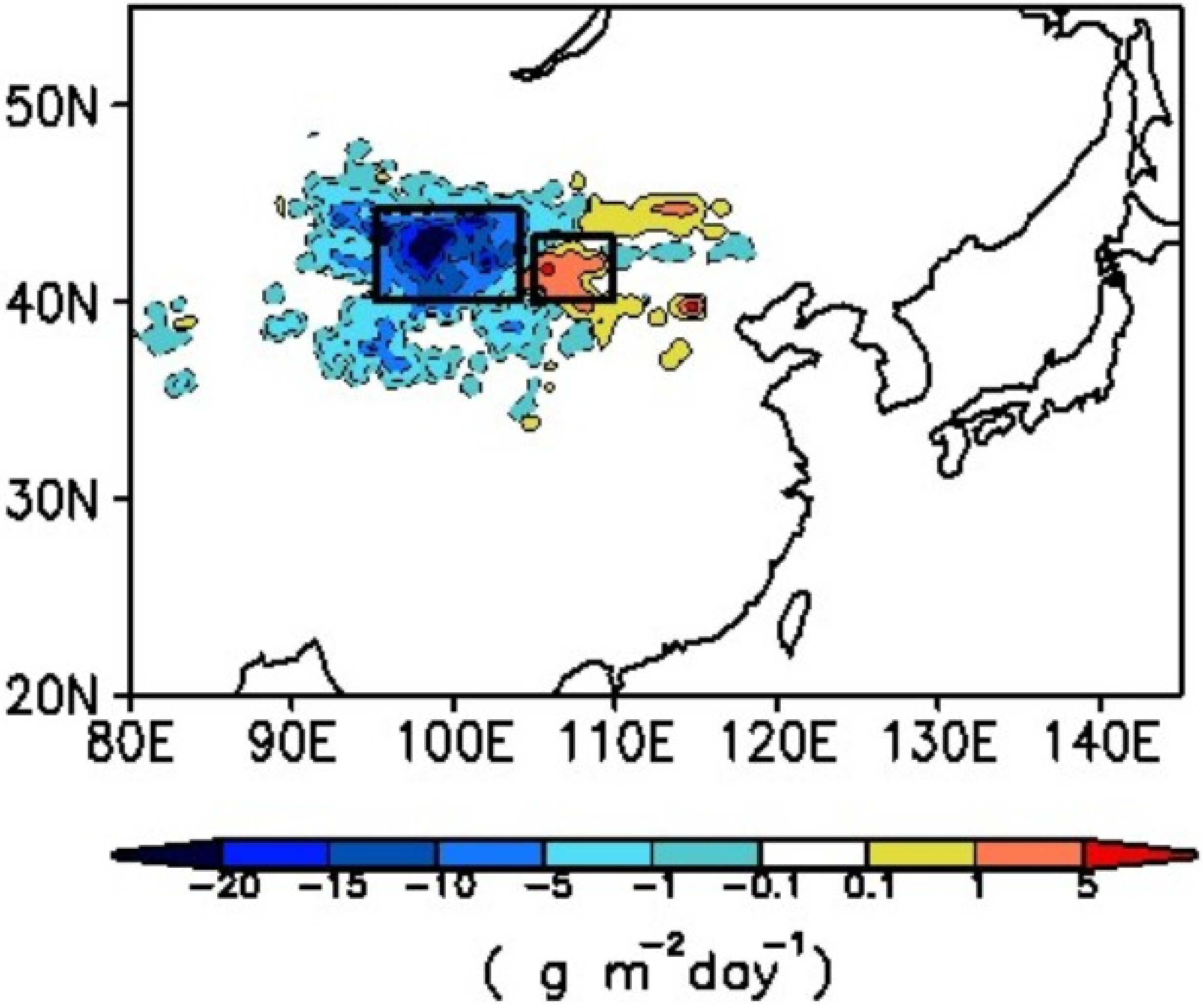


Physical Mechanisms

Radiative forcing

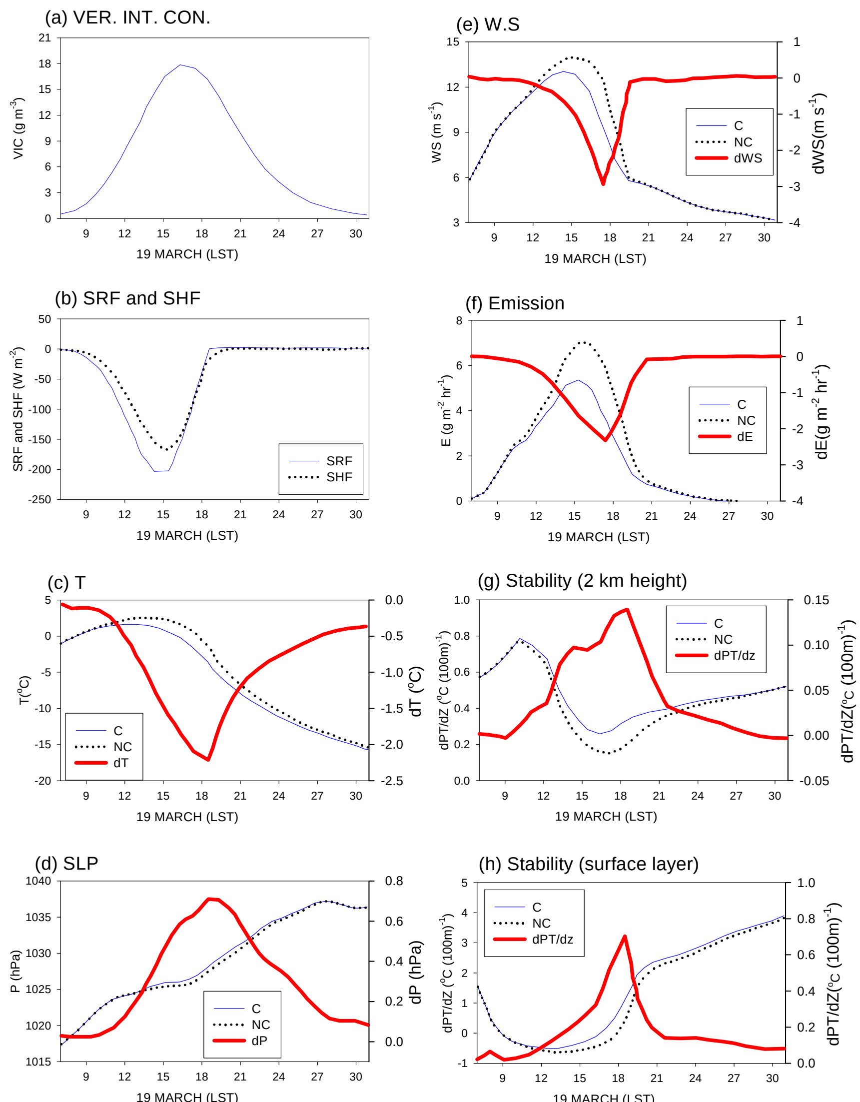


Daily total emission difference

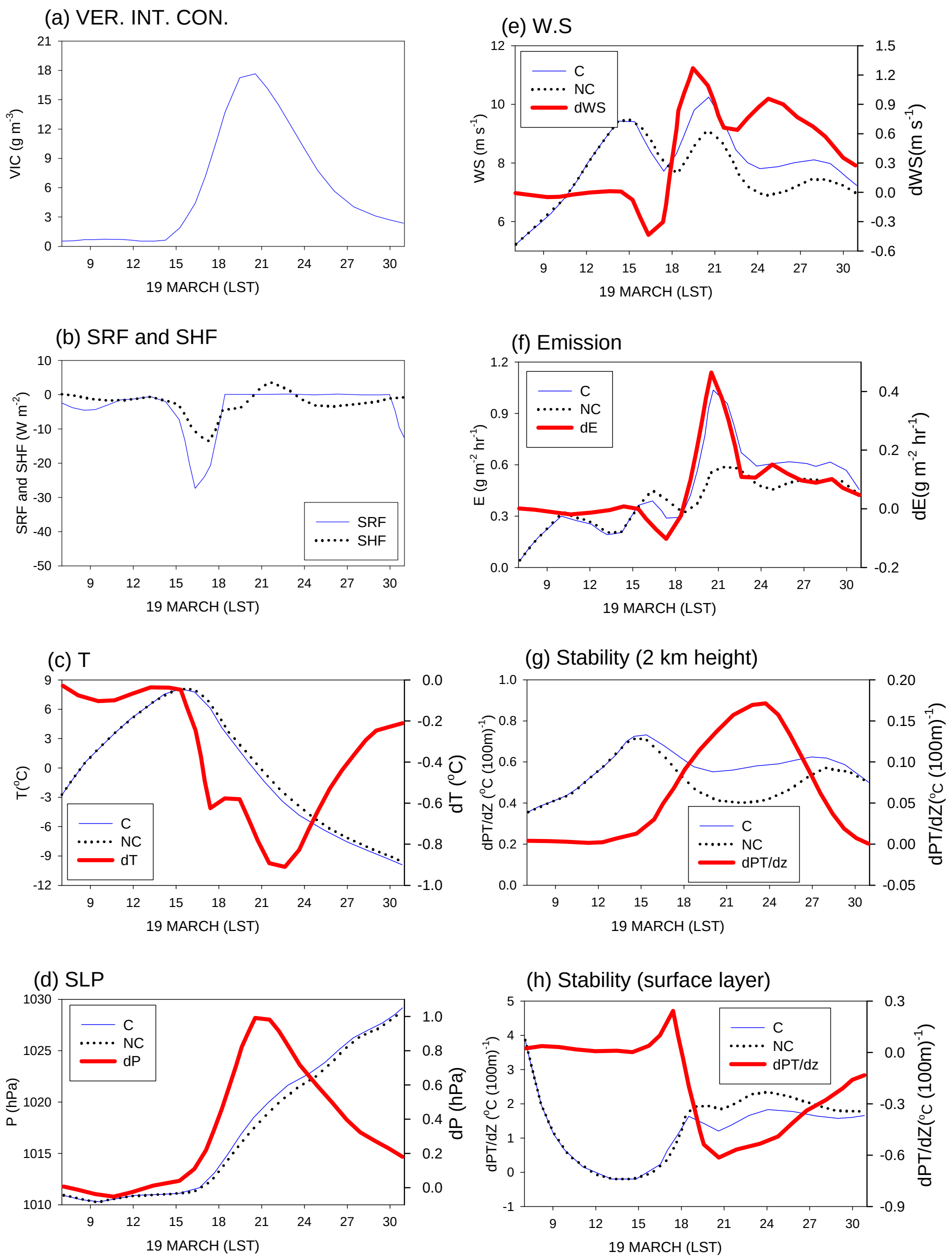


Diurnal variation of affected meteorological fields

REGION I [95-103E, 40-45N]



REGION II [105-110E, 40-43N]



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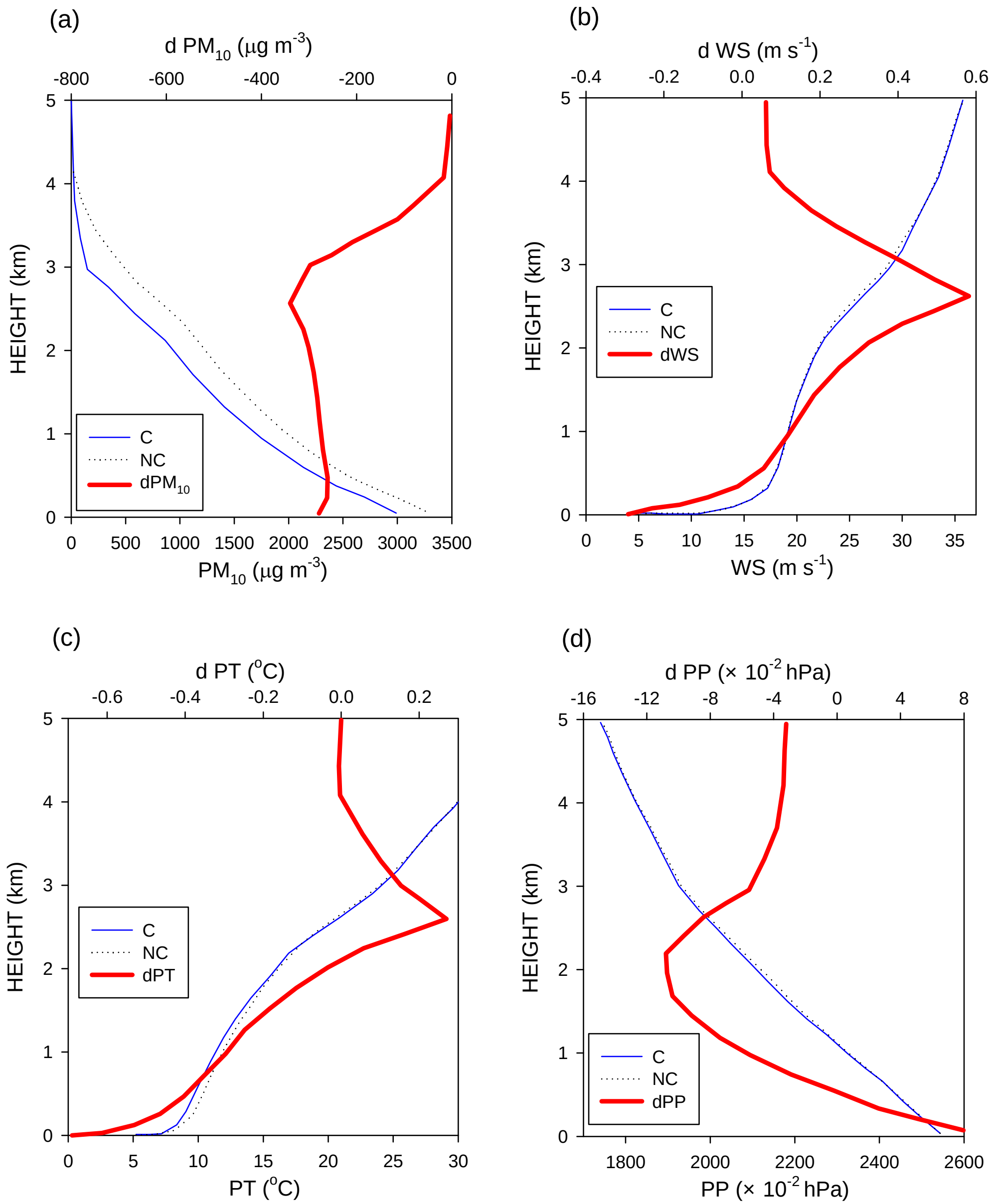

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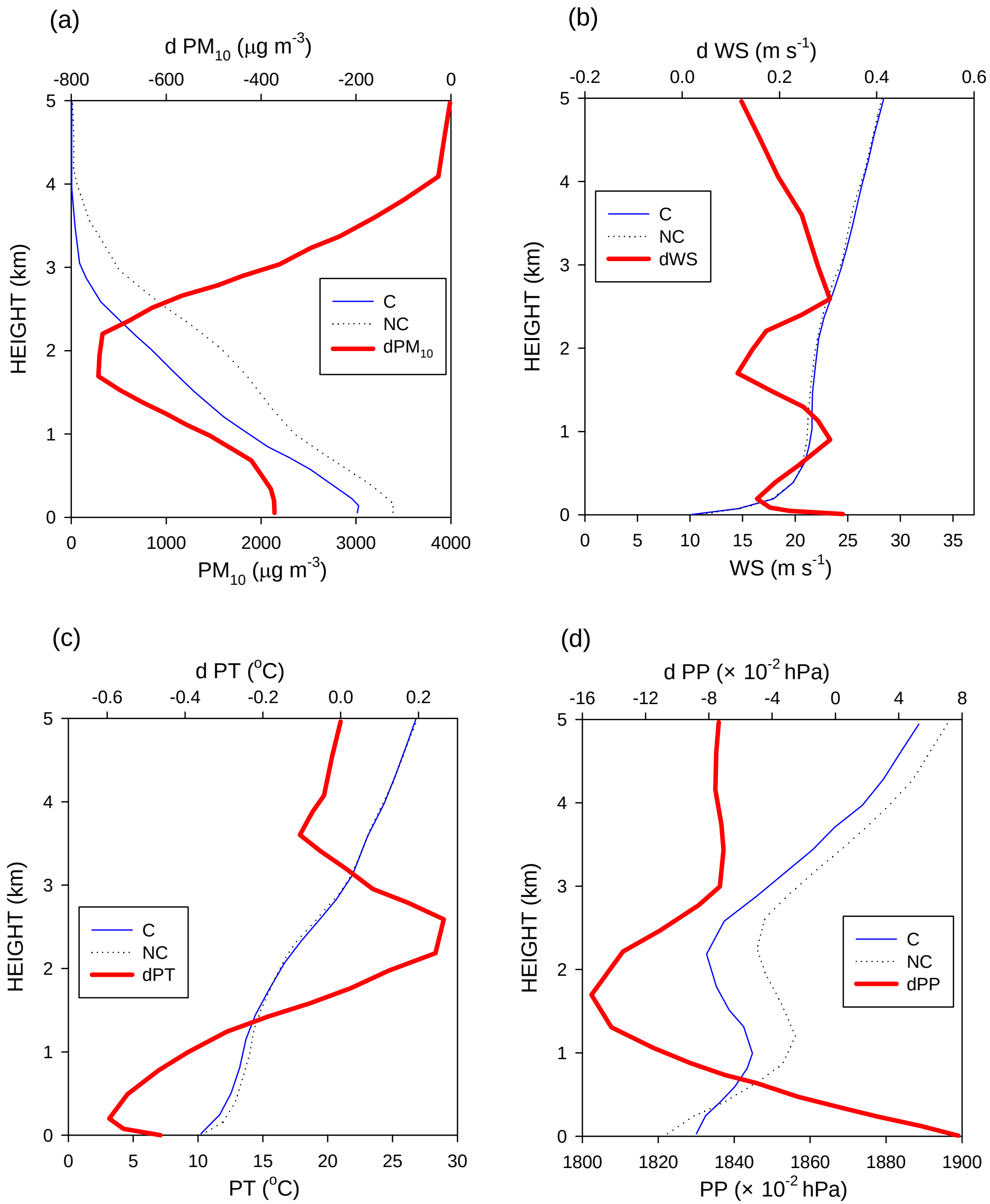

Conclusion

❖ Time-area averaged column integrated total aerosol concentration in the analysis domain is

78 mg m^{-2}
- 66 % by Asian dust
- 14 % by mixed type aerosol
- 11 % by SIA
- 7 % by Sea salt

❖ Time-area averaged direct radiative forcing at the surface is

-6.8 W m^{-2}

	Radiative intensity
- 30 % by mixed type	-0.19 W mg^{-1}
- 25 % by SIA	-0.20 W mg^{-1}
- 22 % by Asian dust	-0.03 W mg^{-1}
- 13 % by BC	-5.67 W mg^{-1}
- 7 % by OC	-0.31 W mg^{-1}

❖ Time-area averaged direct radiative forcing at the top of atmosphere is -2.9 W m^{-2}

		Radiative intensity
-2.9 W m^{-2}	- 43 % by SIA	-0.18 W mg^{-1}
	- 31 % by Asian dust	-0.02 W mg^{-1}
	- 11 % by OC	-0.25 W mg^{-1}
	- 6 % by Sea salt	-0.04 W mg^{-1}
	+ 6 % by BC	+1.35 W mg^{-1}
	+ 3 % by mixed aerosol	+0.01 W mg^{-1}

❖ Time-area averaged direct radiative forcing in the atmosphere is +3.8 W m^{-2}

		Radiative intensity
+3.8 W m^{-2}	+ 55 % by mixed aerosol	+0.19 W mg^{-1}
	+ 26 % by BC	+6.21 W mg^{-1}
	+ 13 % by Asian dust	+0.01 W mg^{-1}

❖Effects of radiative forcing of Asian dust on meteorological fields

- **With vertically integrated Asian dust aerosol concentration of 15 g m^{-2} produces -200 W m^{-2} surface radiative forcing, which in turn reduces the surface temperature of -2 ^{o}C.**

- **In the mean time it produces a positive pressure anomaly (about 0.8 hPa) with the negative pressure anomaly toward the synoptic low pressure center forming a dipole shape of pressure anomaly.**

- **The associated secondary circulation reduces the mean wind speed (about 3 m s^{-1}) in the upstream part of the high dust concentration region resulting in dust emission reduction, while in the downstream region it enhances the low-level wind speed, which in turn, enhance the dust emission.**

- **However, the contribution of the enhanced dust concentration in Region II is much smaller than dust concentration reduction due to transport by enhanced wind, resulting in overall dust concentration reduction in Region II.**

- **Lower level cooling due to Asian dust aerosol enhances stable stratification in the lower layer. Reduction of turbulence intensity reduces dust emission.**

Thank you!