Relative contributions of regional emissions to the aerosol radiative forcing based on the AeroCom Phase III / HTAP2 experiment

Toshihiko Takemura[1], Mian Chin[2]

1: Research Institute for Applied Mechanics, Kyushu University, Japan
2: NASA Goddard Space Flight Center, USA

Contents

- Radiative forcing of the aerosol-radiation and aerosol-cloud interactions derived from the AeroCom Phase III / HTAP2 experiment.
- Other information and suggestions related to AeroCom.

Japanese project on SLCPs

Environment Research and Technology Development Fund (ERTDF) of the Ministry of the Environment of Japan S-12:

- Theme 1
- Theme 2
- Theme 3
  Assessment of climate-environment and impacts by SLCPs with numerical models
- Theme 4

Objective of S-12-3

Quantitative assessment of effects of SLCPs on climate, hydrological cycle, health, and agriculture with climate-air quality coupled models.

➡ Contribution to scientific bases for suitable reductions of SLCPs/WMGHGs.

Emission inventories and scenarios [Themes 1 & 2]

Suitable reduction path [Theme 4]

Assessment of effects of SLCPs on climate with climate-aerosol-chemistry models (SPRINTARS/CHASER) [Sub-themes 1 & 2]

Assessment of changes in hydrological cycles by SLCPs with a climate model MIROC-ESM [Sub-themes 5 & 6]

Assessment of impacts on health and agriculture by SLCPs [sub-themes 3 & 4]

Theme 3

Model intercomparison on Fukushima Accident

Report from Science Council of Japan

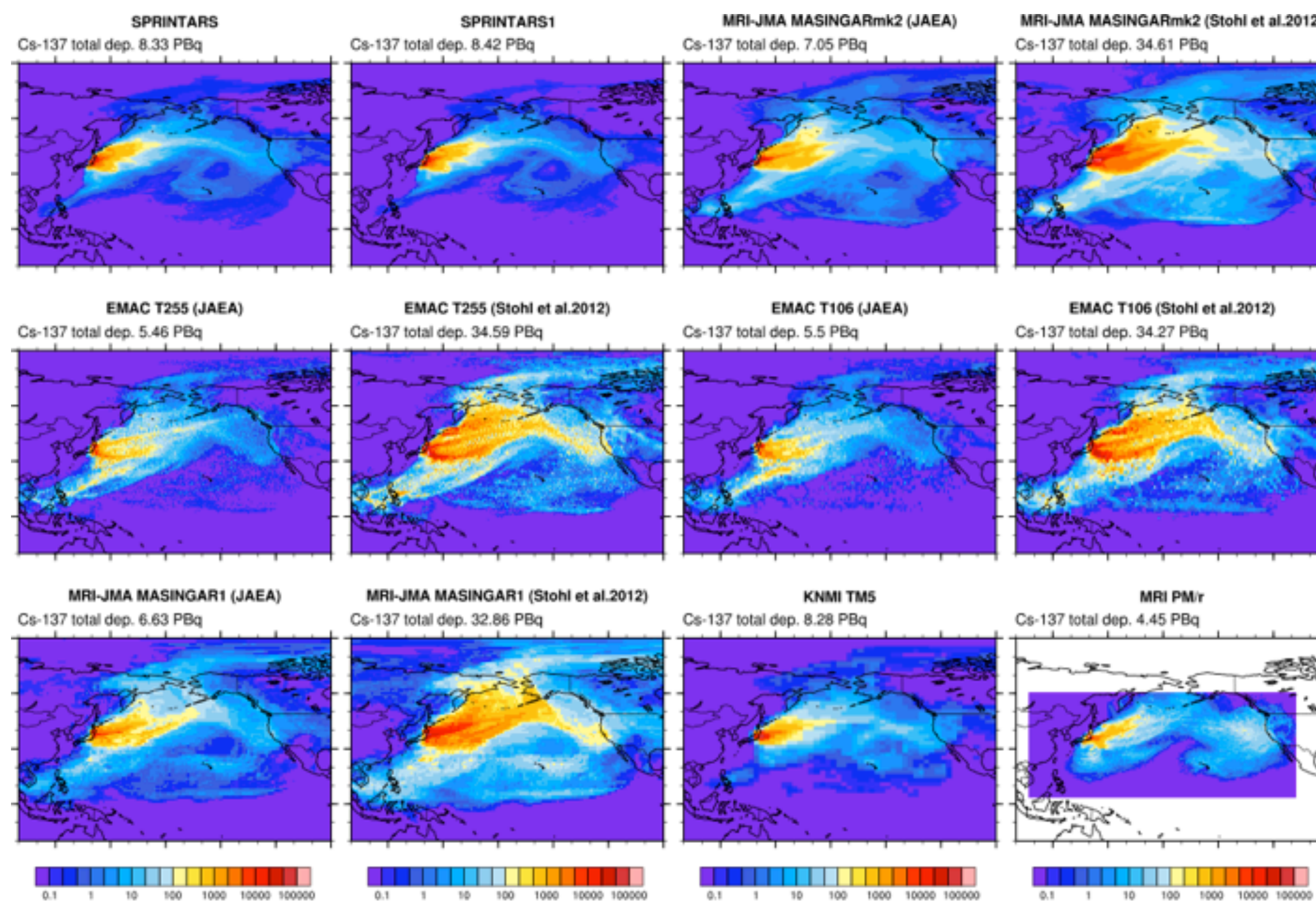
"A review of the model comparison of transportation and deposition of radioactive materials released to the environment as a result of the Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant"

http://www.jpgu.org/scj/report/20140902scj_report_e.pdf

Interactive website: http://cesd.aori.u-tokyo.ac.jp/cesddb/scj_fukushima/index_j.html

Numbers of participation

- Global atmospheric models: 6
- Regional atmospheric models: 9
- Regional ocean models: 11



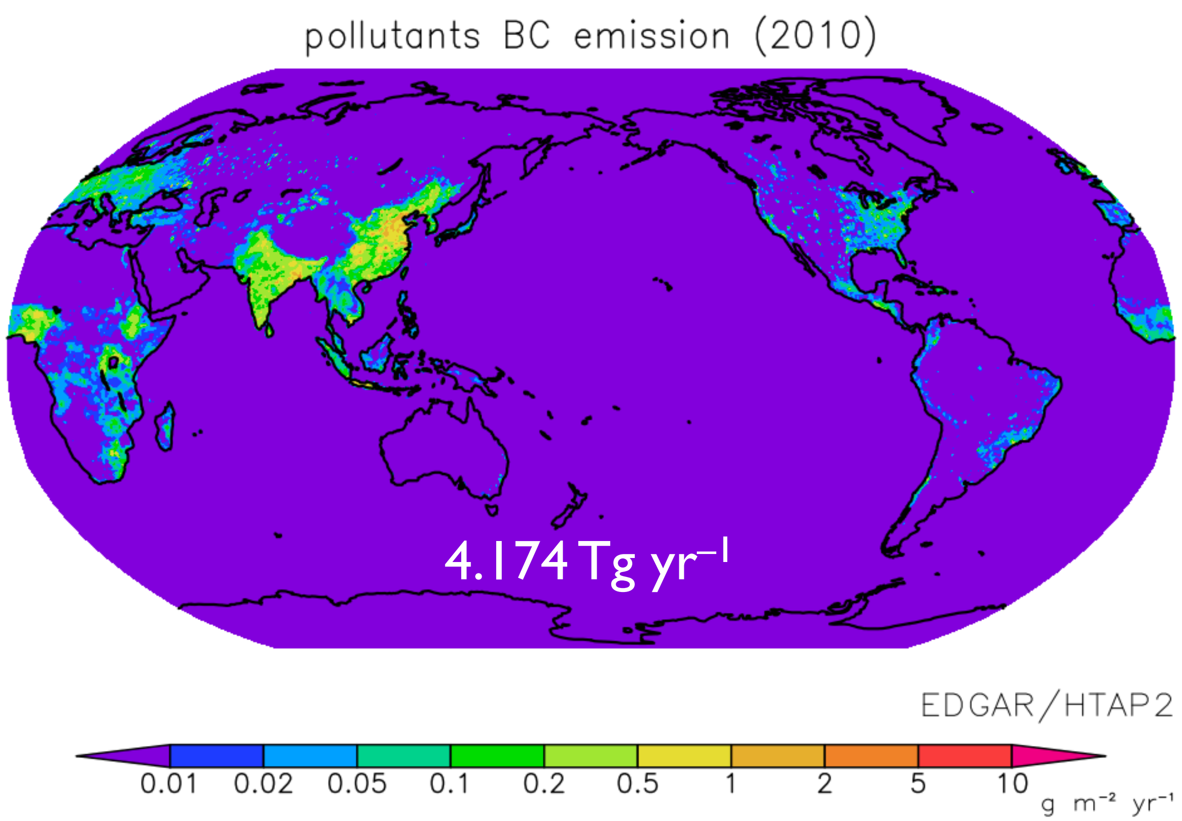
AeroCom Phase III / HTAP2 experiment

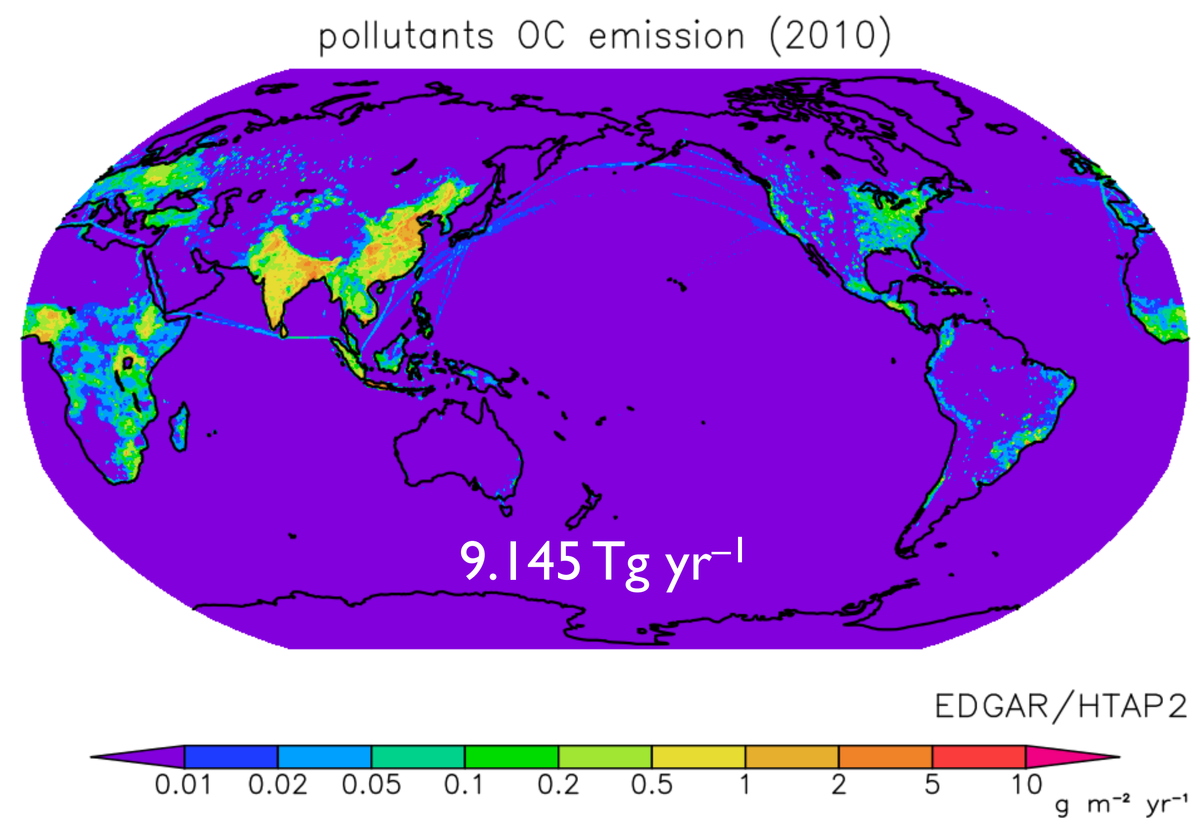
led by M. Chin & M. Schulz

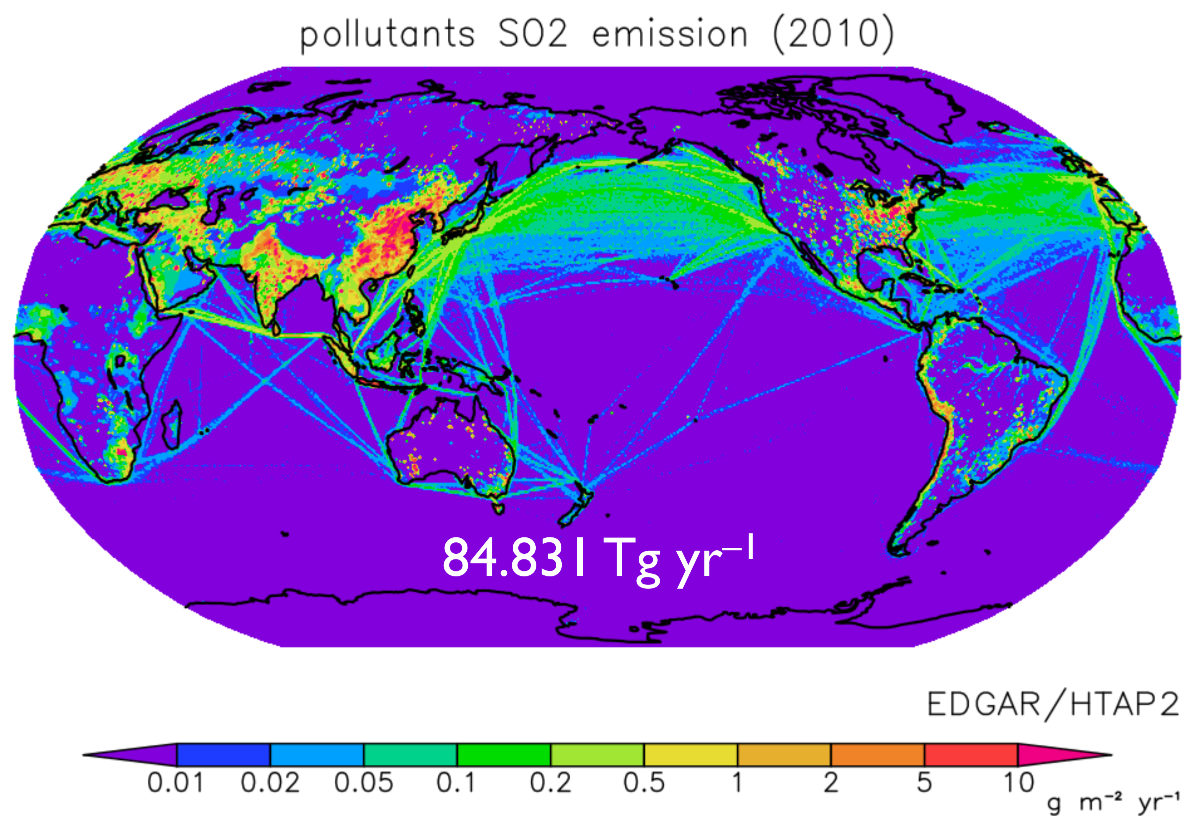
- Primary objectives
  - Estimate the relative contribution of regional aerosol sources for air quality.
  - Evaluate their uncertainties among models.
- Emission inventories
  - Anthropogenic by sectors: HTAP2 (integrating EDGAR, REAS, USEPA, MICS-Asia, and EMEP/TNO database) — 0.1˚x0.1˚
  - Biomass burning: daily GFED3 — 0.5˚x0.5˚
- Experiments — high priority (year 2010 except Base simulation 2008–2010)

	emission perturbation	regions
BASE		
ALL	20% pollutants reduction	Global, North America, Europe, East Asia, South Asia, Russia/Belarus/Ukraine, Middle East
DST	Zero dust	East Asia, Central Asia, Middle East, Sahara, Sahel
FIR	Zero biomass burning	Global
PIN **RES** **TRN**	20% reduction in Power and Industry (PIN), Residential (RES), and Ground Transport (TRN) Sectors	Global

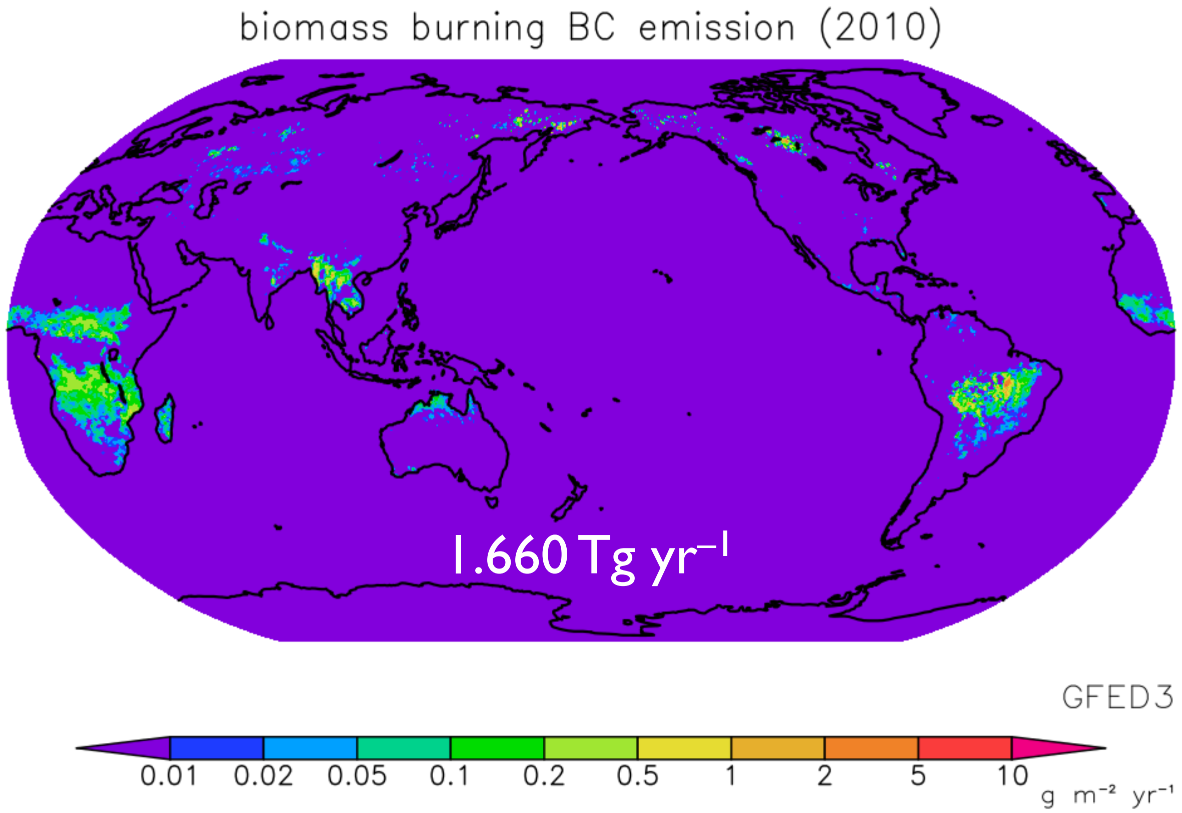
HTAP2 pollutants emission inventory

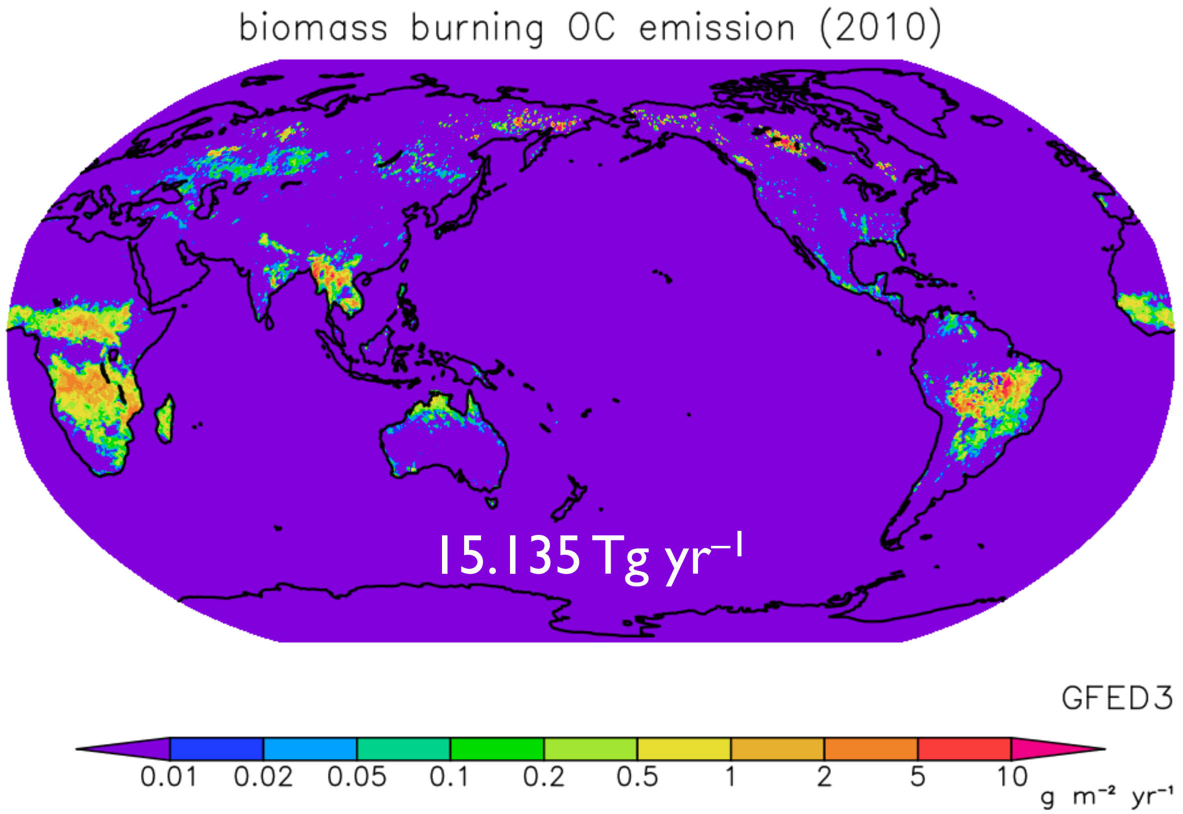


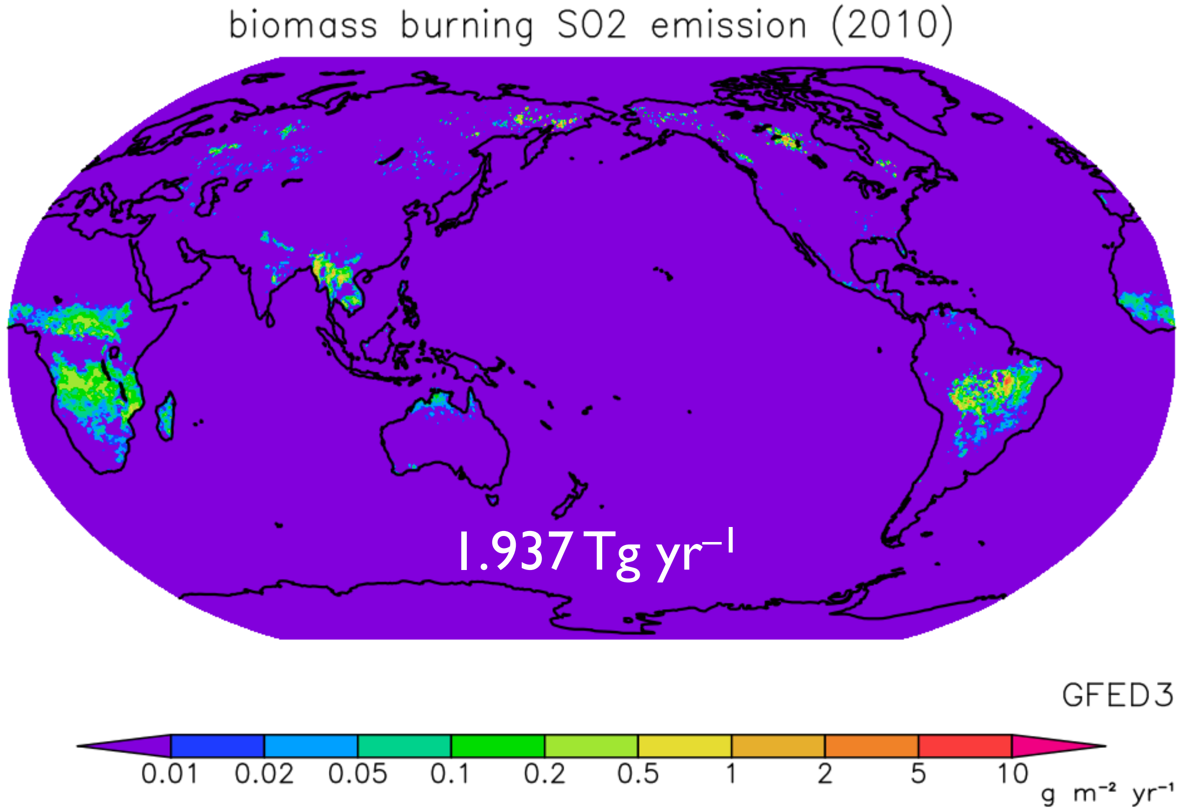




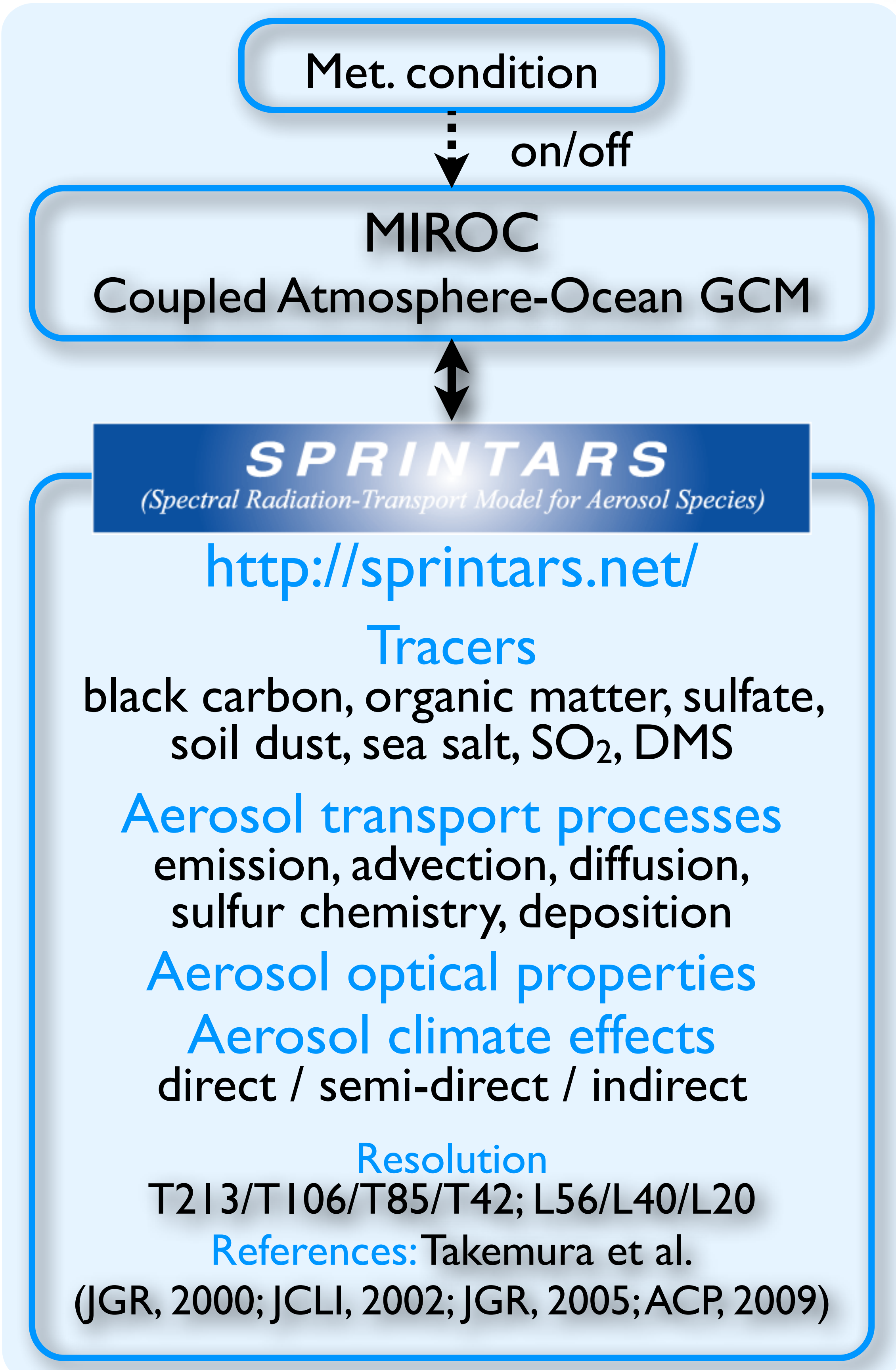
GFED3 biomass burning emission inventory







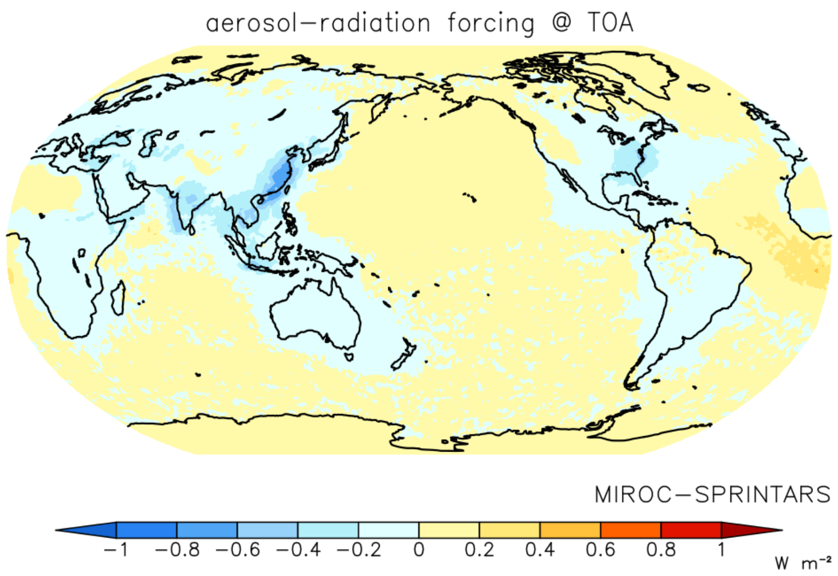
Model description of SPRINTARS



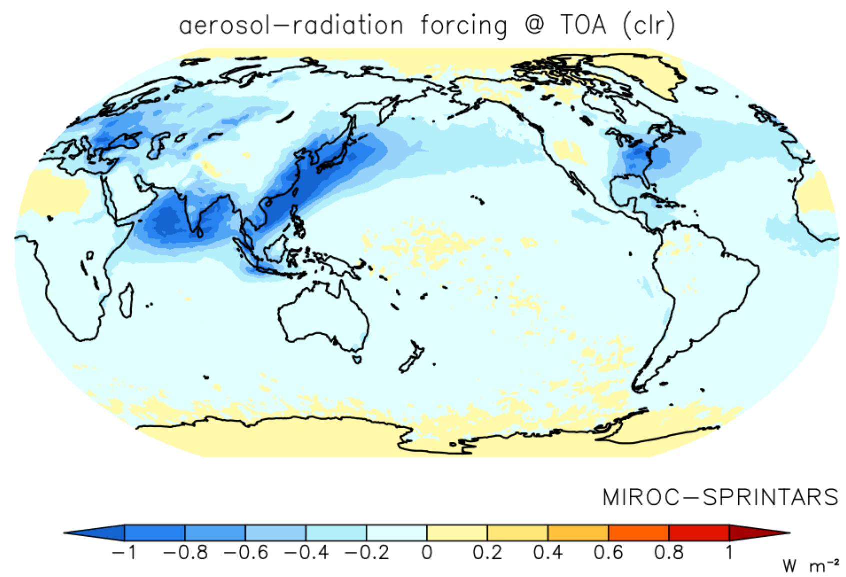
- GCM: MIROC5.2.
- Resolution: T106 (1.125°x approx. 1.125°), L56.
- Period: year 2010 (also 2008 and 2009 for BASE).
- Aerosol-related emissions
  - Pollutants: HTAP2 inventories for BC, POM, SO_2.
  - Biomass burning: GFED3 for BC, POM, SO_2.
  - Natural emissions:
    - Calculated with internal parameters for soil dust, sea salt, DMS.
    - Volcanic SO_2, Terpene/Isoprene.
- Meteorology
  - atmospheric temperature and horizontal wind nudged by 6-hourly ECMWF ERA-interim (0.75°x0.75°).
  - sea surface temperature and sea ice prescribed by monthly HadISST.

Radiative forcing in ALL (20% pollutants reduction)

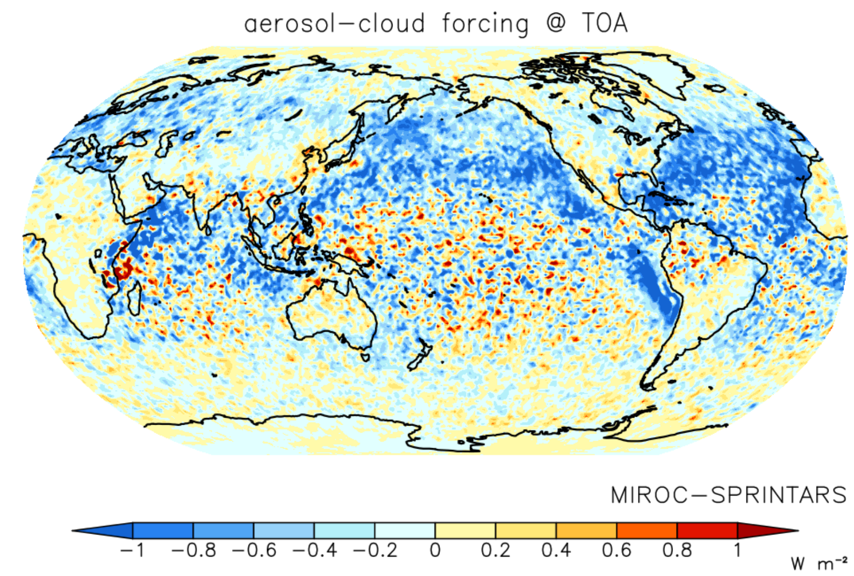
AVG. –0.017 W m^{-2}



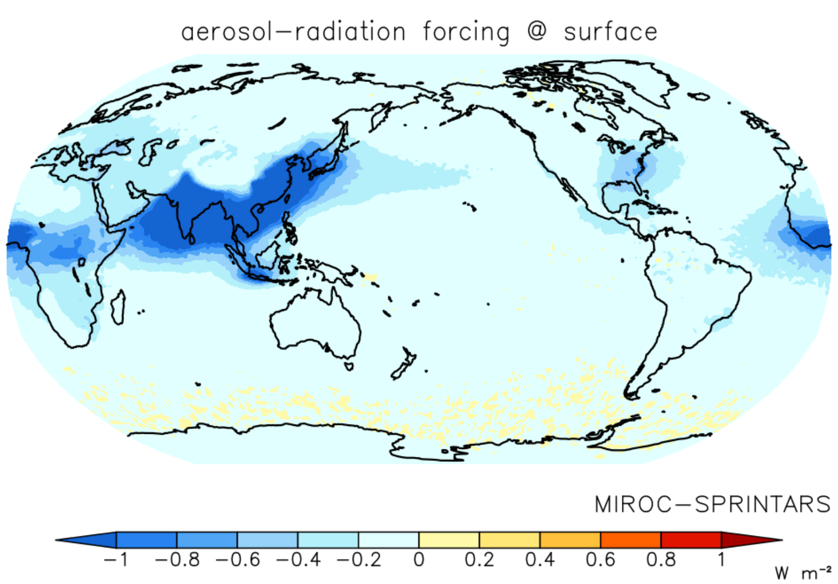
AVG. –0.142 W m^{-2}



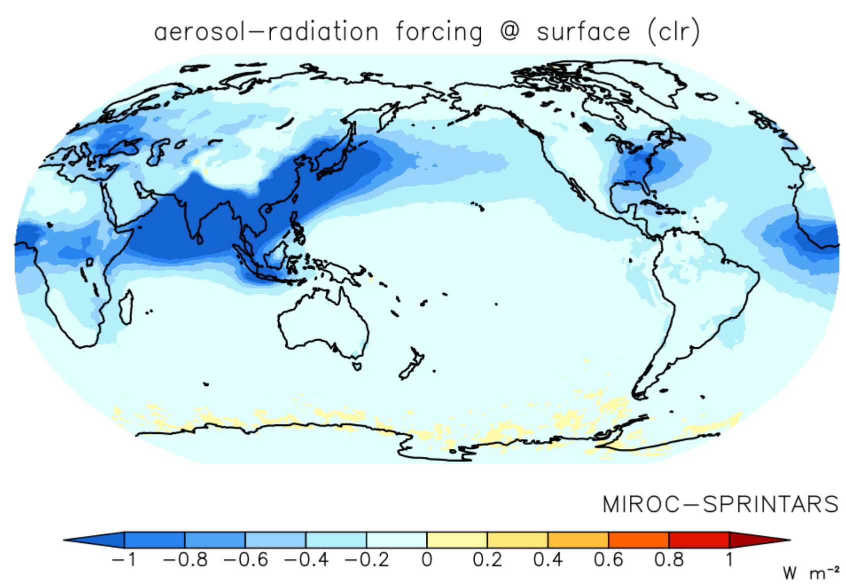
AVG. –0.186 W m^{-2}



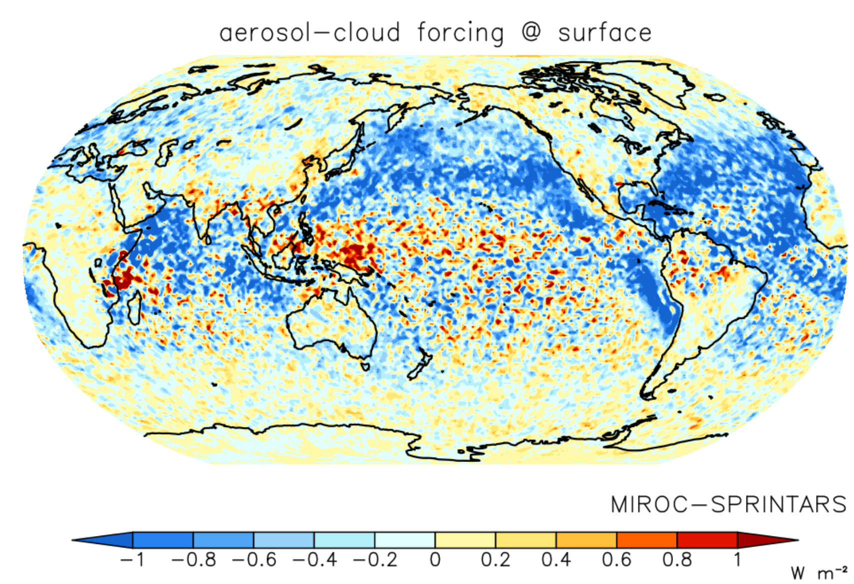
AVG. –0.185 W m^{-2}



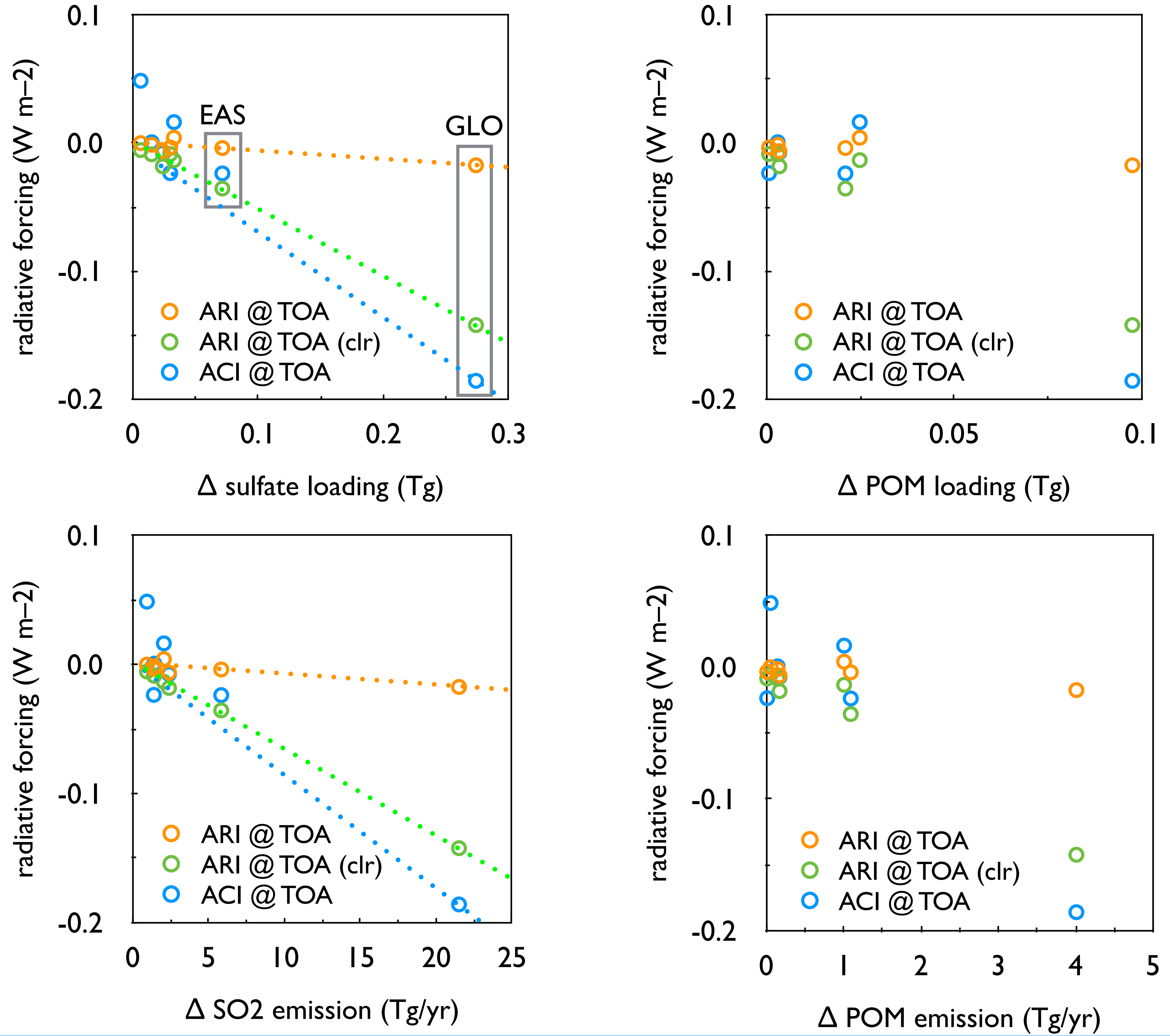
AVG. –0.297 W m^{-2}



AVG. –0.186 W m^{-2}

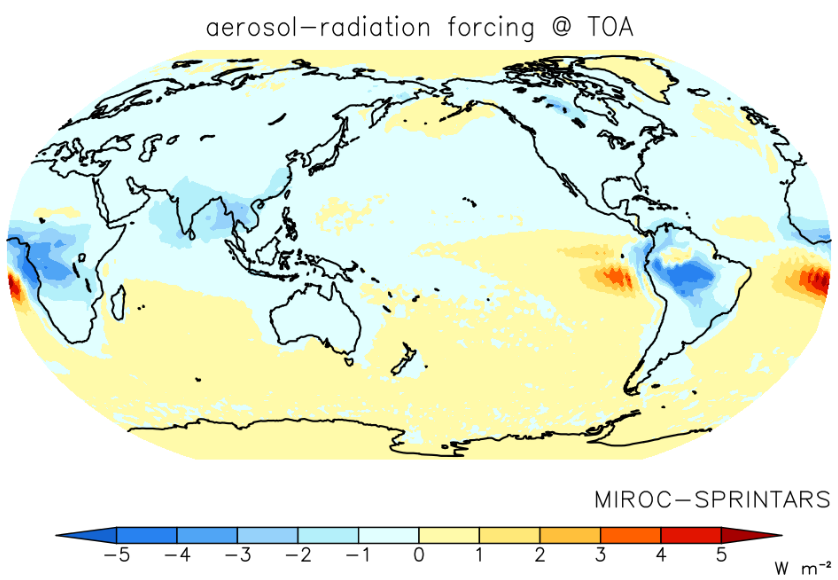


Radiative forcing in ALL (20% pollutants reduction)

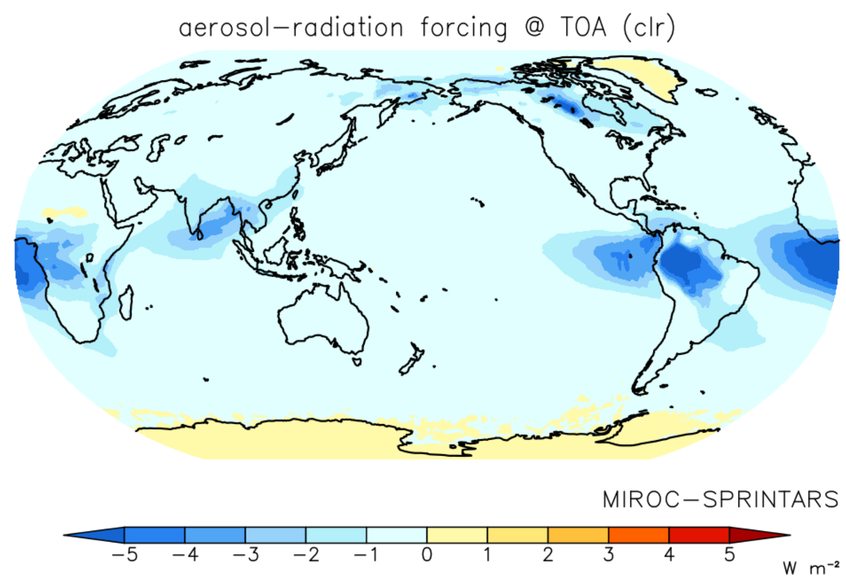


Radiative forcing in FIR (zero biomass burning)

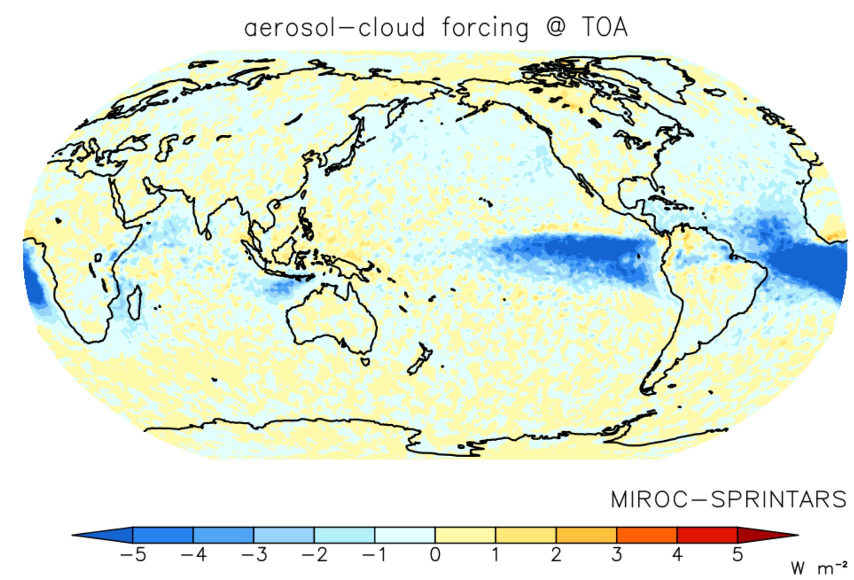
AVG. –0.178 W m^{-2}



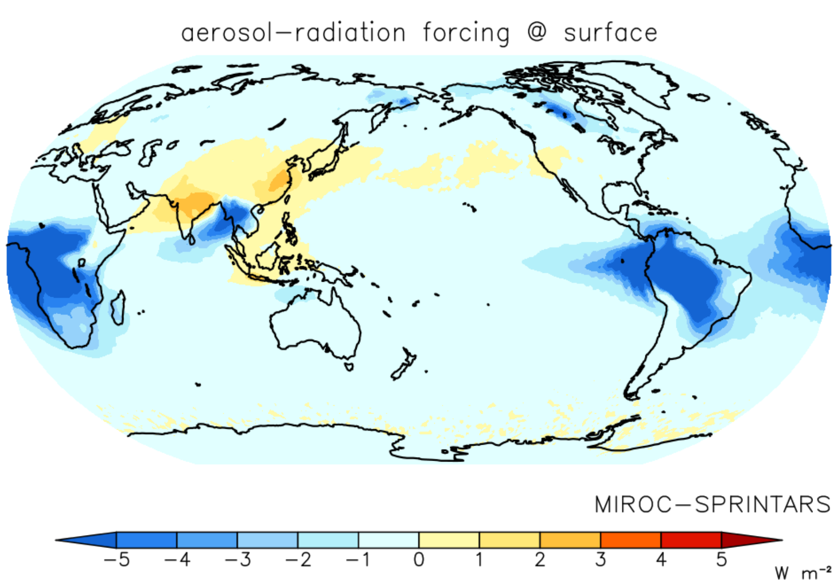
AVG. –0.635 W m^{-2}



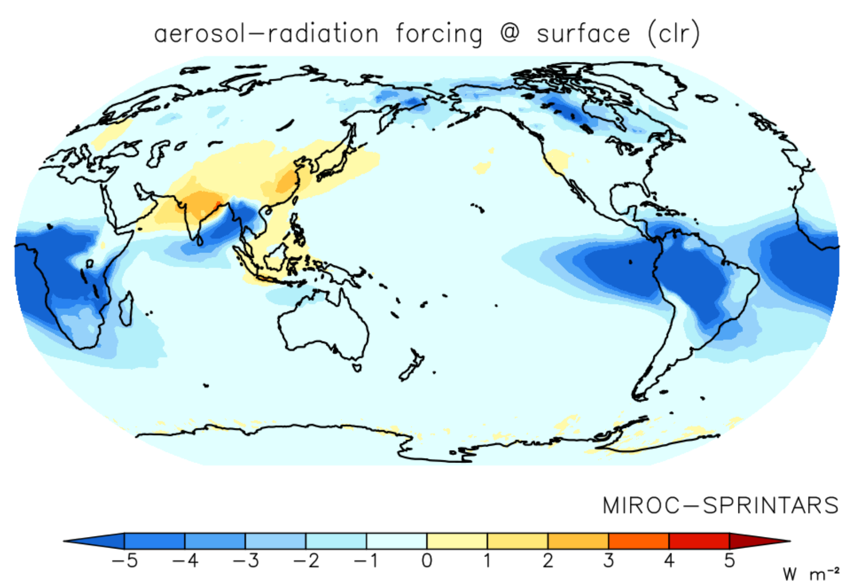
AVG. –0.454 W m^{-2}



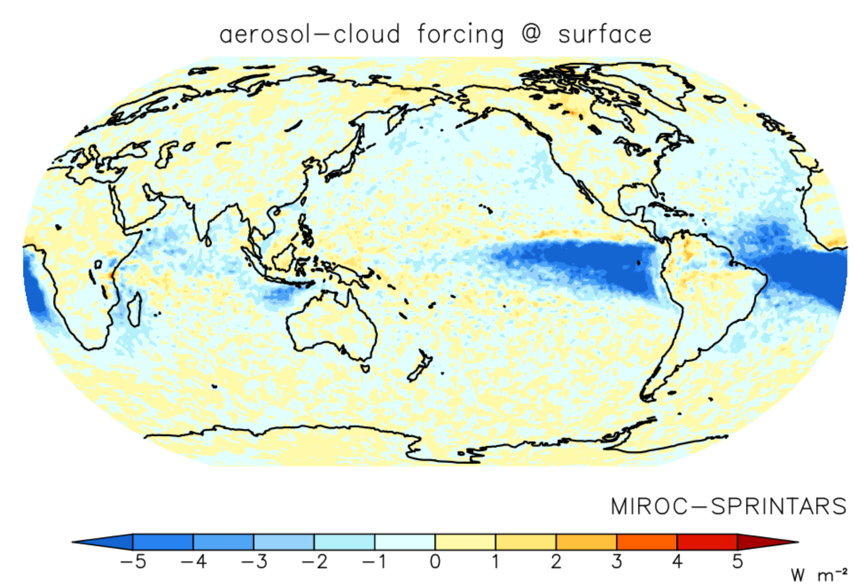
AVG. –0.800 W m^{-2}



AVG. –1.183 W m^{-2}



AVG. –0.549 W m^{-2}



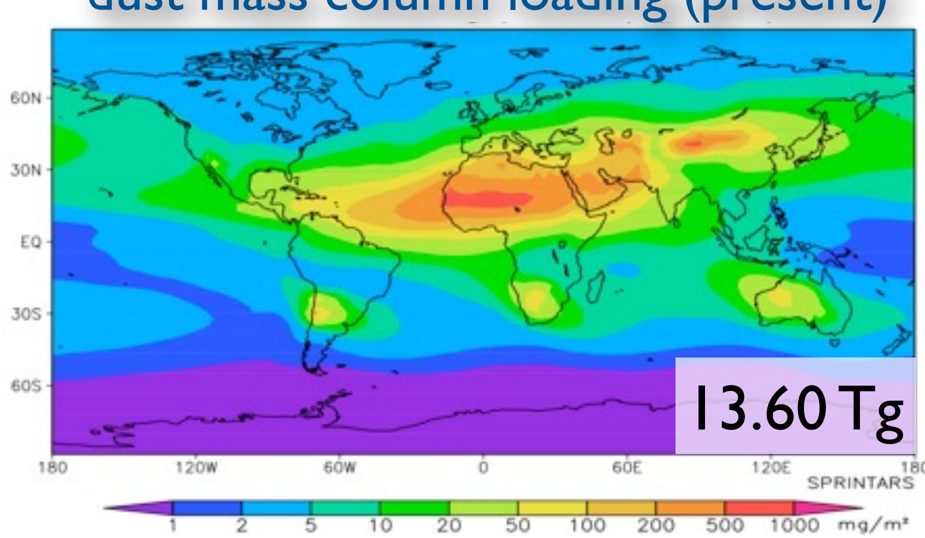
Model intercomparison for natural aerosols?

- Global total mass of natural aerosols is larger than anthropogenic aerosols.
  - Sea salt, mineral dust, POA, precursor gases (DMS, VOC, etc.).
- Their distributions are affected by seasonal, year-to-year, decadal, and glacial-interglacial variations of meteorology and their variations affect climate change.
- Their sources are related to the earth system (land surface, vegetation, oceanic biogeochemistry, etc.).

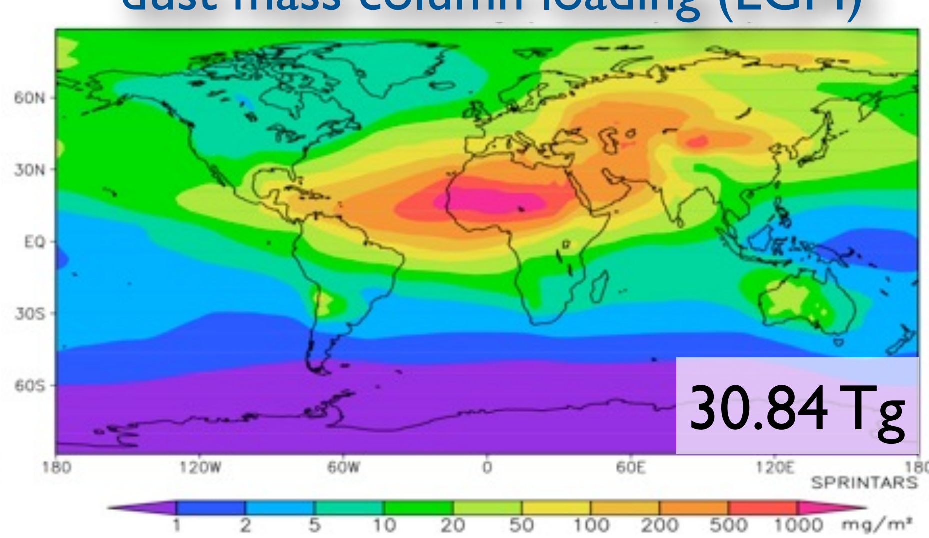
➡ Natural aerosols makes possible to study PURELY scientific aspects of aerosol-climate interaction.

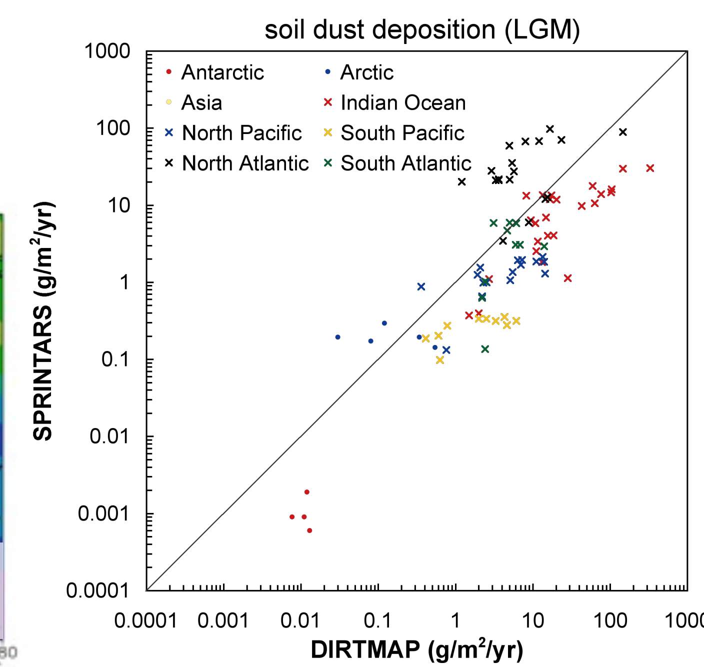
➡ We should do detailed global model intercomparisons for natural aerosols in AeroCom/AerChemMIP to understand uncertainties in their distributions and climate effects.

dust mass column loading (present)



dust mass column loading (LGM)



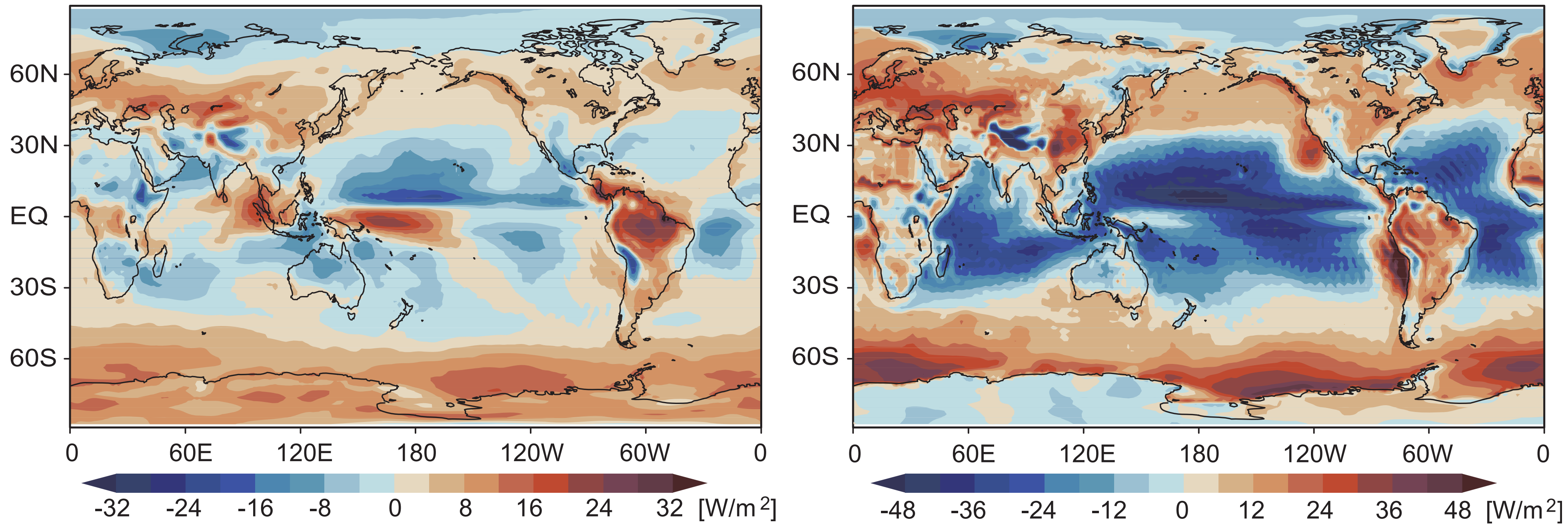


(Takemura et al., ACP, 2009)

Problems in cloud-precipitation process in GCM

Main remaining problems in cloud-precipitation process in GCM

- Uncertainties in parameters and parameterizations for microphysical aerosol-cloud interaction, autoconversion, and accretion.
  - Aerosol-cloud interaction for water: Parameterizations by Abdul-Razzak and Ghan (2000), NENES (Barahona et al., 2010), etc.
  - Aerosol-cloud interaction for ice.
  - Autoconversion: Parameterizations by Berry (1968), Kessler (1969), etc.
- Treatment of drizzle particles both for mass and radiation.



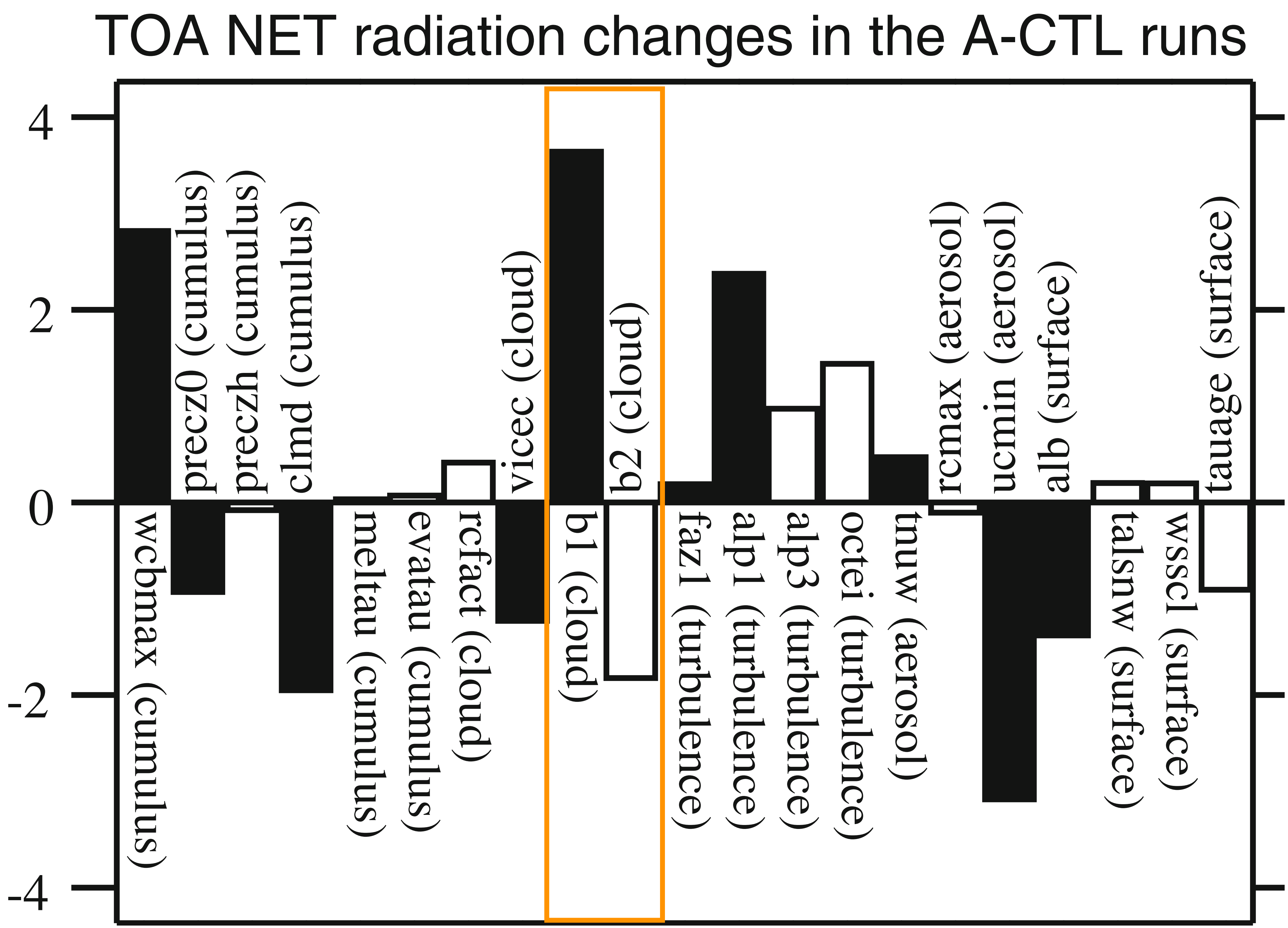
Biases in annual mean radiation budget in MIROC5 relative to ERBE for (a) longwave and (b) shortwave (Watanabe et al., 2010).

Perturbed physical ensembles in MIROC5

Name	Category	Description	Standard	Min	Max
wcbmax[a]	Cumulus	Maximum cumulus updraft velocity at cloud base (m/s)	*1.7*	*0.7*	*2.8*
precz0[a]	Cumulus	Base height for cumulus precipitation (m)	*500*	*200*	*1,000*
preczh[a]	Cumulus	Reference height for cumulus precipitation (m)	4,500	3,000	6,000
clmd[a]	Cumulus	Entrainment efficiency (ND)	*0.51*	*0.4*	*0.6*
meltau[a]	Cumulus	Timescale of ice melting (s)	10	1	15
evatau[a]	Cumulus	Timescale of liquid evaporation (s)	2	0.1	4
rcfact[b]	Cloud	Random overlapping factor in ice cloud falling (ND)	0.2	0	1
vicec[b]	Cloud	Factor for ice falling speed ($m^{0.474}/s$)	*38*	*25*	*40*
b1[c]	Cloud	Berry parameter (m^3/kg)	*0.09*	*0.07*	*0.11*
b2[c]	Cloud	Berry parameter (s)	0.095	0.07	0.12
faz1[d]	Turbulence	Factor for PBL overshooting (ND)	*1.5*	*1*	*3*
alp1[d]	Turbulence	Factor for length scale L_T (ND)	*0.23*	*0.16*	*0.3*
alp3[d]	Turbulence	Factor for length scale L_B (ND)	5	2	8
octei[d]	Turbulence	Switch for cloud top entrainment instability	OFF	ON	
tnuw[c]	Aerosol	Timescale for nucleation (s)	*18,000*	*14,400*	*21,600*
rcmax[c]	Aerosol	Maximum radius of cloud droplet (liquid, ice) (m)	30×10^{-6}, 185×10^{-6}	25×10^{-6}, 150×10^{-6}	35×10^{-6}, 200×10^{-6}
ucmin[c]	Aerosol	Minimum cloud droplet number (liquid) (m^{-3})	2.5×10^7	2.2×10^7	3.0×10^7
alb[e]	Surface	Albedo of ice and snow[f]	*Medium*	*Low*	*High*
talsnw[e]	Surface	Temperature thresholds for albedo function[g] (K)	268.15, 273.15	253.15, 271.15	258.15, 273.15
wsscl[e]	Surface	Lifetime of puddle over land ice (s)	216,000	108,000	432,000
tauage[e]	Surface	Snow aging time scale (s)	2×10^6	2×10^5	2×10^7

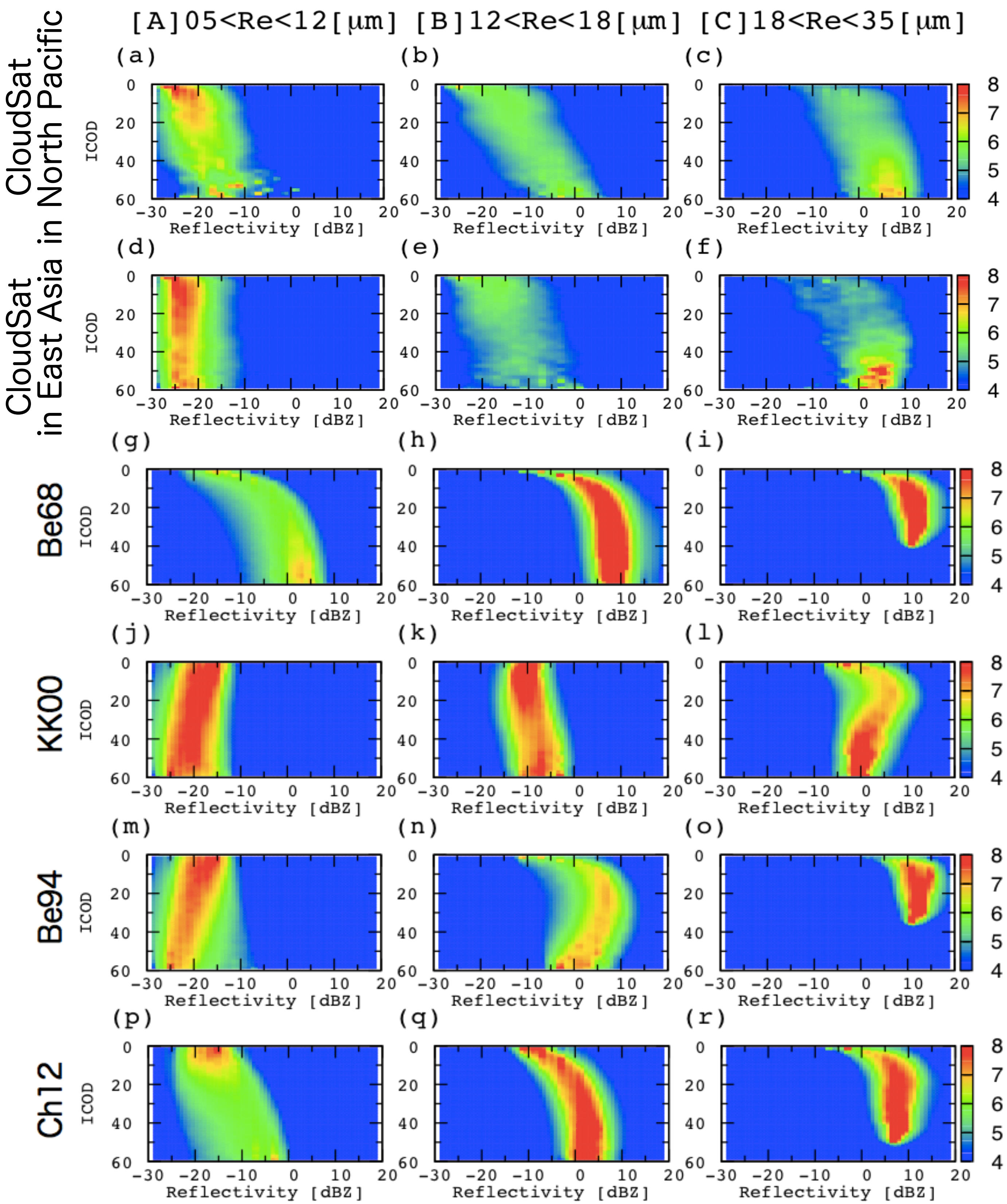
(Shiogama et al., 2012)

Uncertainties in parameters for climate sensitivity



Differences in net radiative flux at TOA (W/m^2) between maximum and minimum values of each physics parameter under the preindustrial condition (Shiogama et al., 2012).

CFODD from satellite and models



CFODD (Nakajima et al., 2010) from (a-f) CloudSat and (g-r) single column models for each autoconversion parameterization. Figures are classified (A, B, and C) by the cloud droplet effective radius at cloud top.

Berry 1968

$$\left(\frac{\partial q_r}{\partial t}\right)_{aut} = \frac{1}{\tau_{aut}} = \frac{c_1(\rho q_c)^2}{c_2 + c_3 \frac{N_c}{(\rho q_c)}}$$

Khairoutdinov and Kogan 2000

$$\left(\frac{\partial q_r}{\partial t}\right)_{aut} = \frac{1}{\tau_{aut}} = 1350 q_c^{2.47} N_c^{-1.79}$$

Beheng 1994

$$\left(\frac{\partial q_r}{\partial t}\right)_{aut} = \frac{1}{\tau_{aut}} = 6.0 \times 10^{25} n^{-1.7} q_c^{4.7} N_c^{-3.3}$$

Chuang et al. (2012)

※ based on Berry (1968)

Summary

- Simulated results from the AeroCom Phase III / HTAP2 experiment provide useful information on efficiency of emission reduction of anthropogenic aerosols from each region for the radiative forcing and climate change by aerosols.
  ➡ Recommendation to output parameters related to radiative forcing and climate additionally (enough for monthly mean data).
- Detailed model intercomparisons for natural aerosols (sea salt, mineral dust, POA, precursor gases (DMS, VOC, etc.)) should be promoted in order to understand relationship with climate system.

Acknowledgments

- MIROC (AORI/NIES/JAMSTEC GCM) developing group
- NIES supercomputer system (NEC SX-9)
- Environment Research and Technology Development Fund S-12-3