Projection of aerosol radiative forcings along the Representative Concentration Pathways (RCPs) with a global aerosol-climate model

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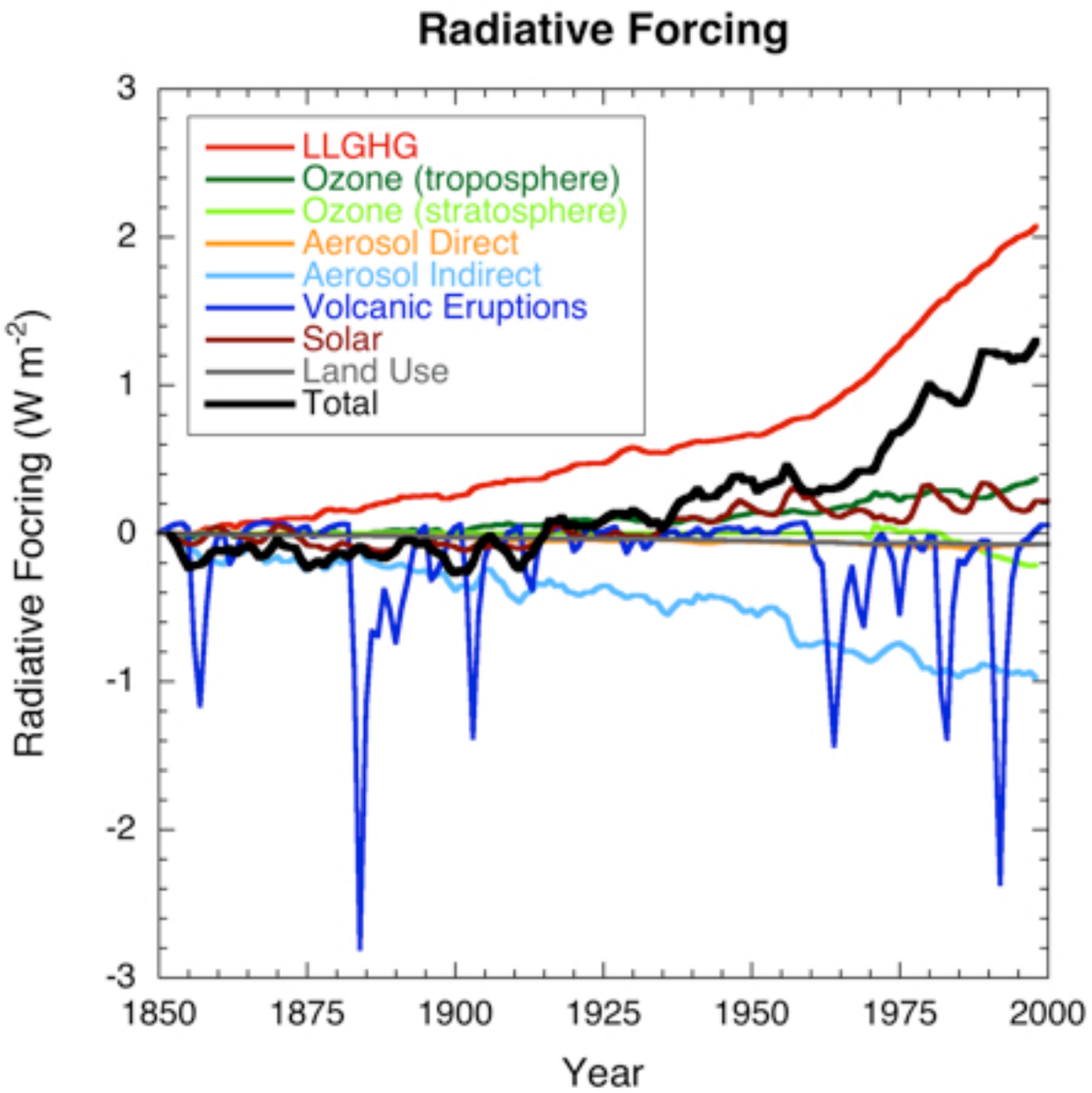
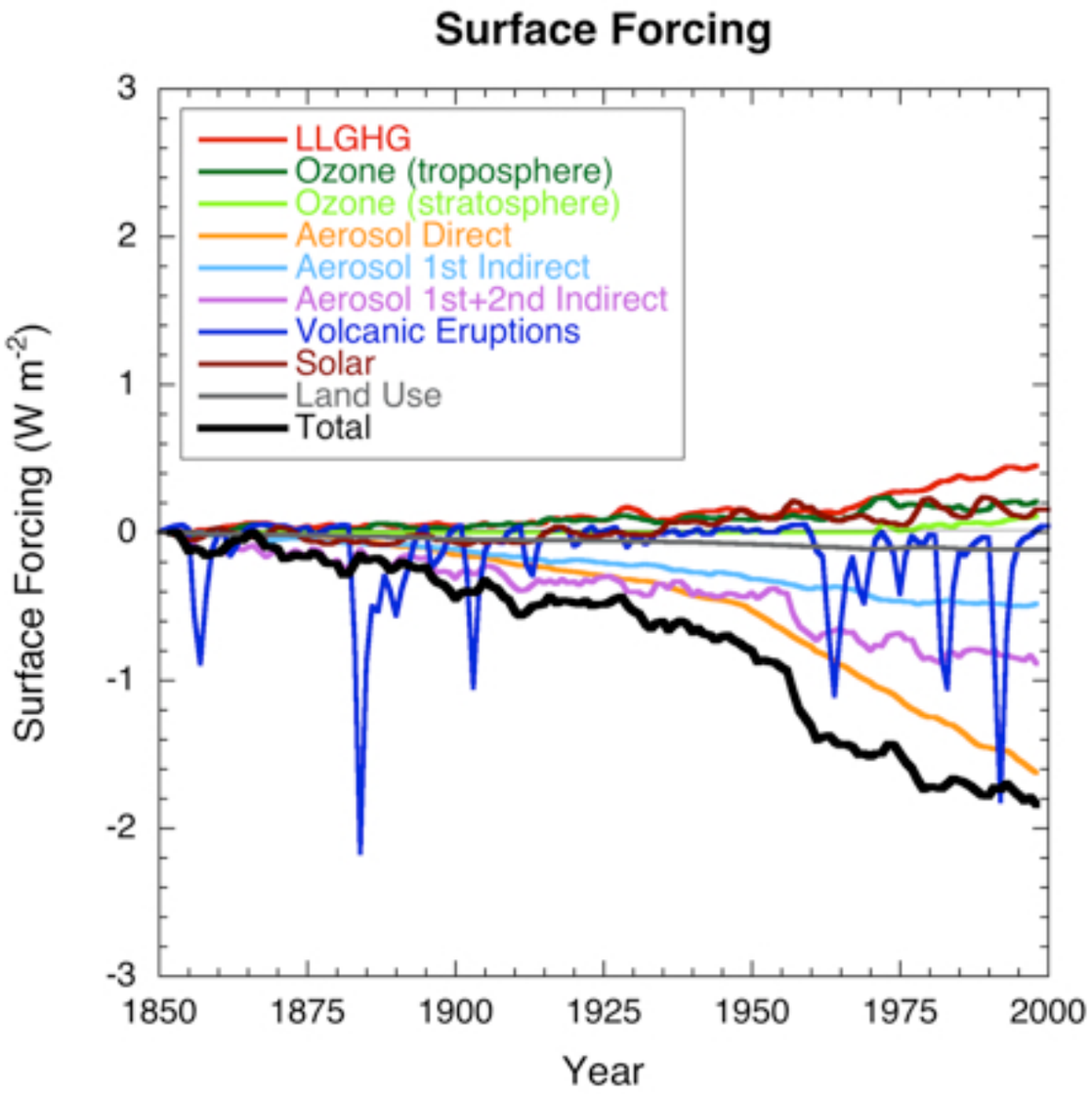
Outline

Projection of radiative forcing and climate change in the 21st century due to the aerosol effects with changes in global aerosol distributions along the emission scenarios of the Representative Concentration Pathways (RCPs).

Trend of hindcast radiative forcing in IPCC AR4





Global mean instantaneous radiative forcings from the year 1850 to 2000 under all-sky condition due to various climate forcing agents at the tropopause (left) and surface (right) (Takemura et al., GRL, 2006 → Fig. 2.23 of IPCC WGI AR4).

Model description of SPRINTARS

Met. condition

on/off

MIROC
Atmospheric-Ocean GCM

SPRINTARS
(Spectral Radiation-Transport Model for Aerosol Species)

http://sprintars.net/

- **Tracers**
  black carbon, organic matter, sulfate, soil dust, sea salt, SO_2, DMS
- **Aerosol transport processes**
  emission, advection, diffusion, sulfur chemistry, deposition
- **Aerosol optical properties**
- **Aerosol climate effects**
  direct / semi-direct / indirect

Resolution: T213/T106/T85/T42
L56/L40/L20

References: Takemura et al. (JGR, 2000; JCLI, 2002; JGR, 2005; ACP, 2009)

Transport Processes

Emission

- BC, OM: biomass burning, fossil fuel, biofuel, agricultural activities, terpene origin.
- SO_2: fossil fuel, biomass burning, and volcanoes.
- DMS: oceanic phytoplankton, land vegetation.
- soil dust: depending on surface wind speed, vegetation, soil moisture, snow amount, LAI.
- sea salt: depending on surface wind speed.

Advection

- Flux-Form Semi-Lagrangian.
- Arakawa-Schubert cumulus convection.

Diffusion

Sulfur chemistry

- sulfur oxidation (gas/liquid phases).
- simplified SOA chemical scheme (option).
- nitrate thermal equilibrium model (option).

Deposition

- wet deposition (wash out, rain out).
- dry deposition.
- gravitational settling.

Model description of SPRINTARS

Aerosol optical properties

- optical thickness.
- Ångström exponent.
- single scattering albedo.

Aerosol climate effects

Direct effect

- coupled with radiation process in GCM.
- considering refractive index of each aerosol depending on wavelengths, size distributions, and hygroscopic growth.
- semi-direct effect if SPRINTARS is fully coupled with GCM.

Indirect effect

- coupled with radiation and cloud/ precipitation processes in GCM.
- prognostic cloud droplet and ice crystal number concentrations N_l, N_i.
- cloud droplet and ice crystal effective radii depending on N_l, N_i » 1st indirect effect.
- precipitation rates depending on N_l, N_i » 2nd indirect effect.

Period

January 1, 2011 – December 31, 2100.

Resolution

T42 (2.8°in lon. × approx. 2.8° in lat.), 20 layers.

Aerosol-related emission inventories

- according to Representative Concentration Pathways (RCPs) for BC, OM, SO_2 emissions from anthropogenic, biomass-burning, and aircrafts sources.
- calculation inside the model for soil dust, sea salt, and DMS emissions.
- SO_2 from continuous erupting volcanoes.
- OH, O_3, H_2O_2 prescribed by CHASER (Sudo et al.) according to RCPs.

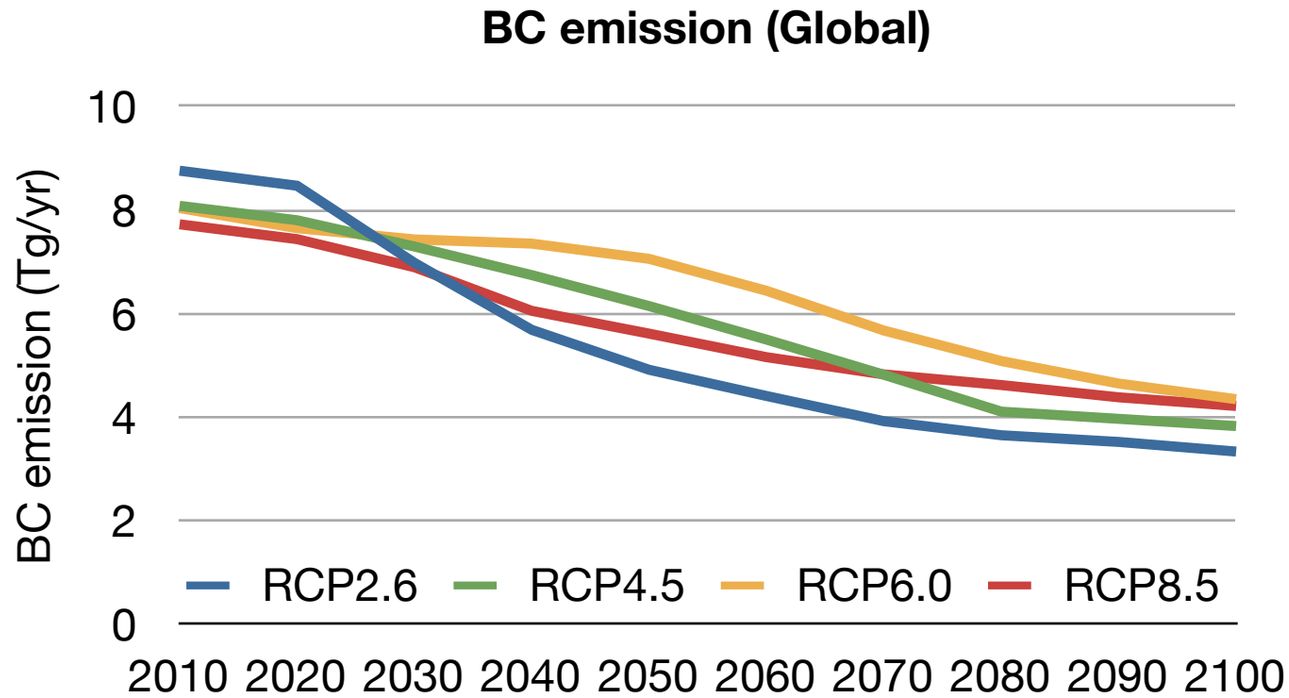
Meteorology

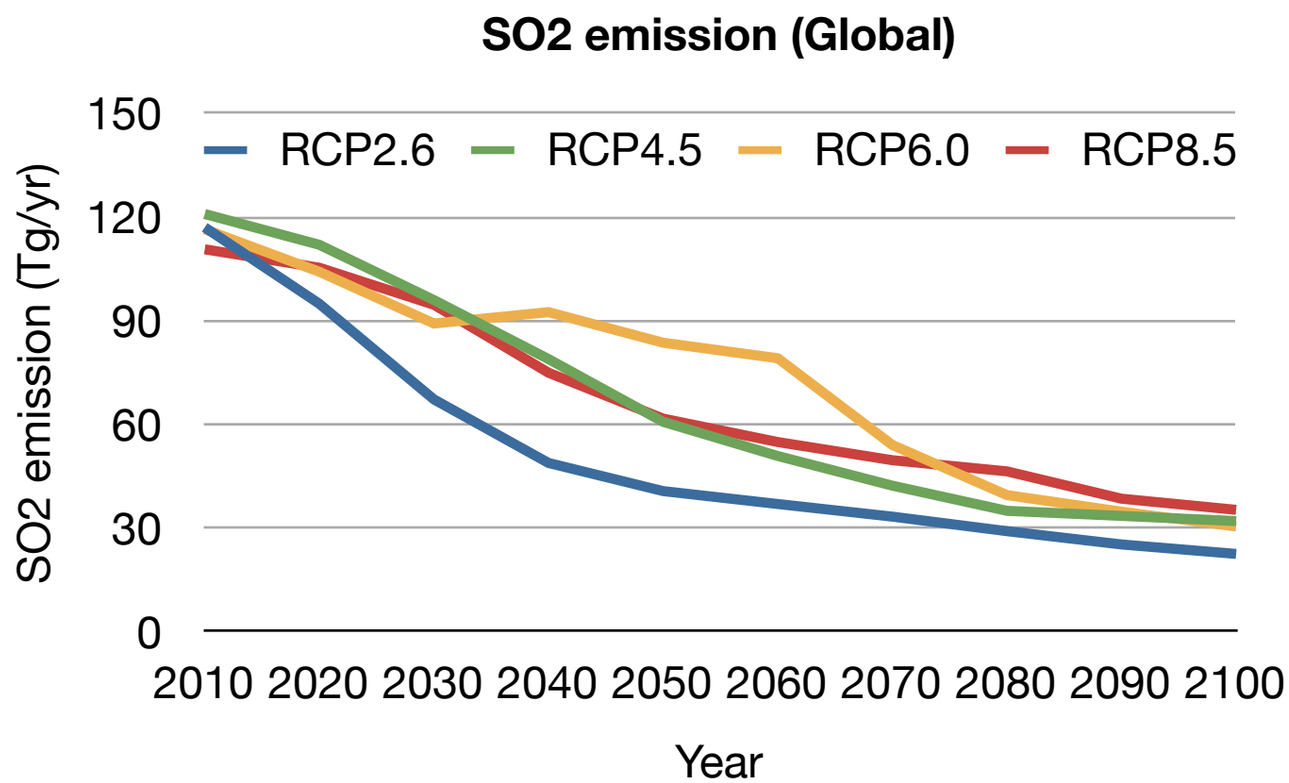
- monthly mean SST and sea ice by MIROC for CMIP5 simulation.
  ➡ including only rapid responses.

Representative Concentration Pathways (RCPs)

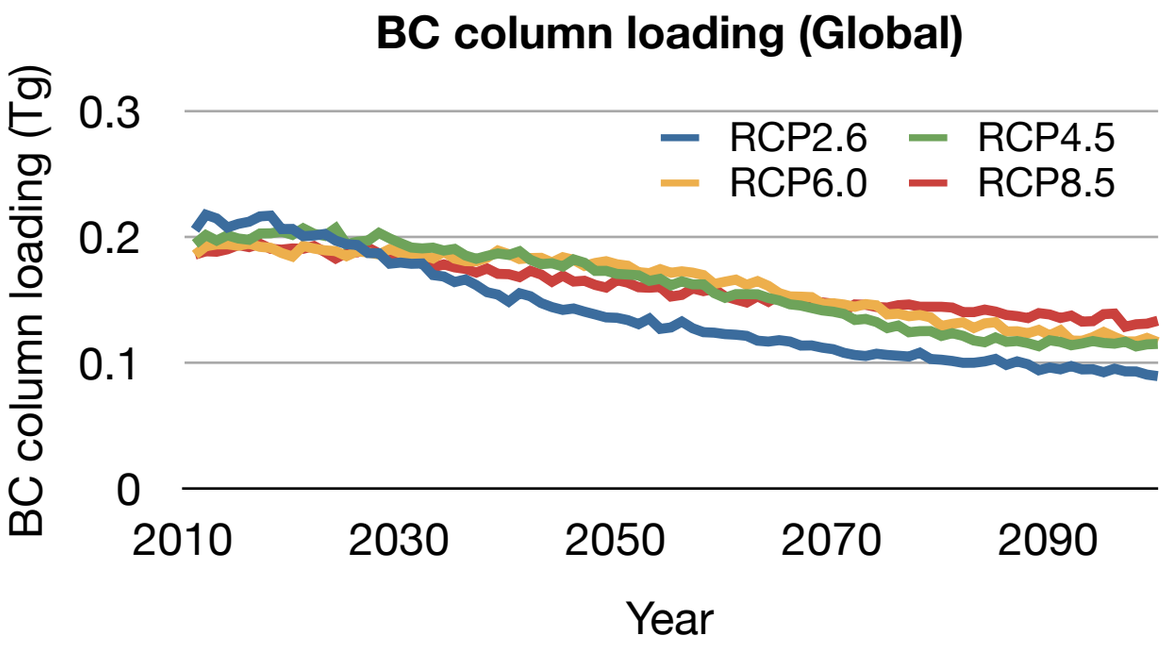
Emission scenarios for greenhouse gases and other atmospheric components used in CMIP5 / 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

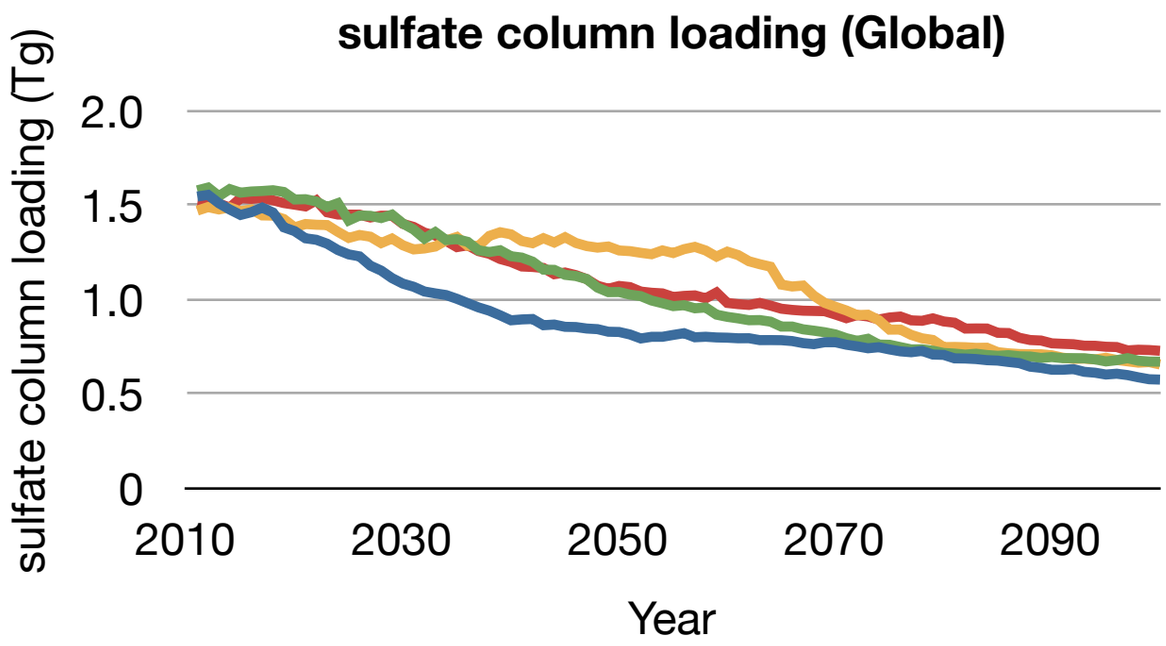
- RCP2.6 (RCP3-PD)
  [IMAGE (PBL, Netherlands)]
  Peak in radiative forcing at 2.6 W m^{-2} before 2100 and decline.
- RCP4.5 [MiniCAM (PNNL, USA)]
  Stabilization without overshoot pathway to 4.5 W m^{-2} at stabilization after 2100.
- RCP6 [AIM (NIES, Japan)]
  Stabilization without overshoot pathway to 6 W m^{-2} at stabilization after 2100.
- RCP8.5 [MESSAGE (IIASA, Austria)]
  Rising radiative forcing pathway leading 8.5 W m^{-2} in 2100.

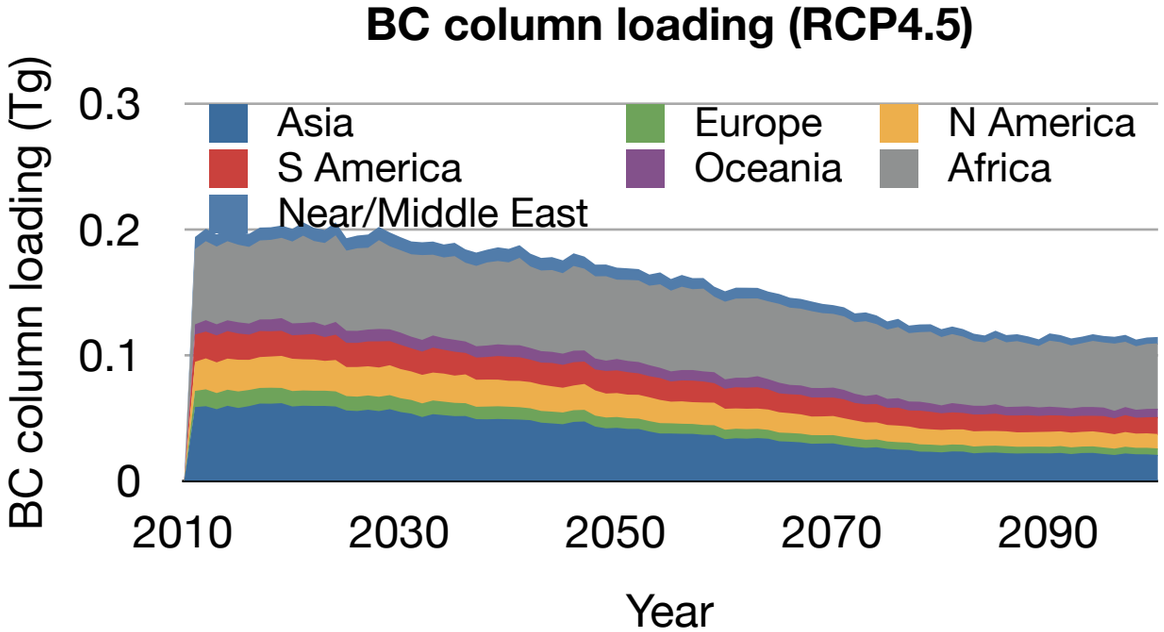


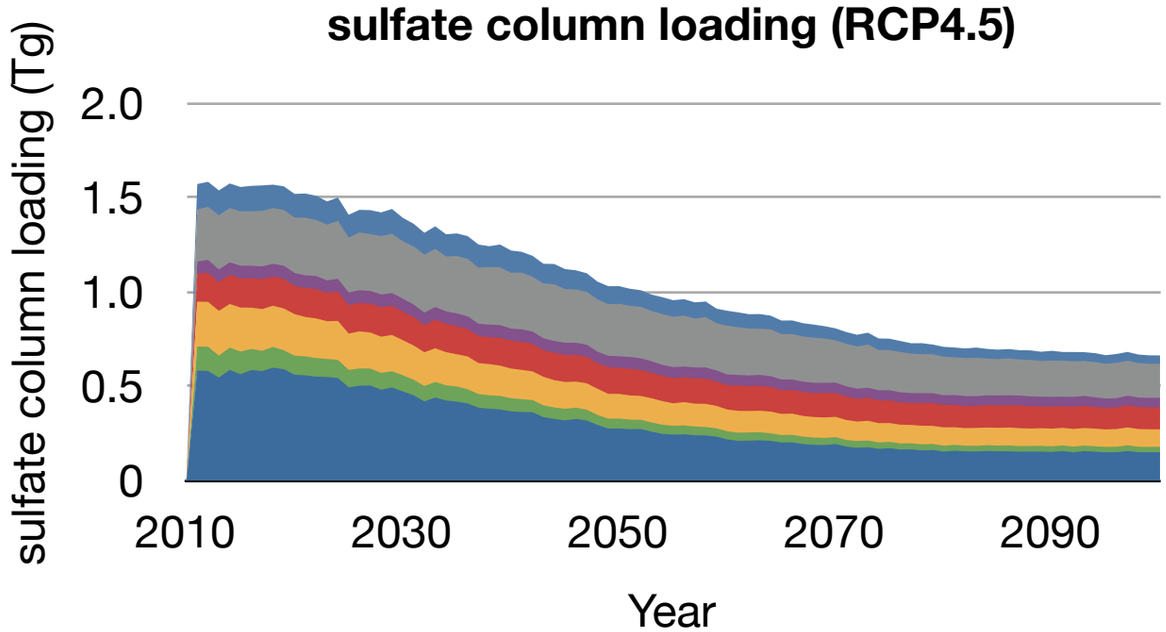


Temporal trends of aerosol column loading



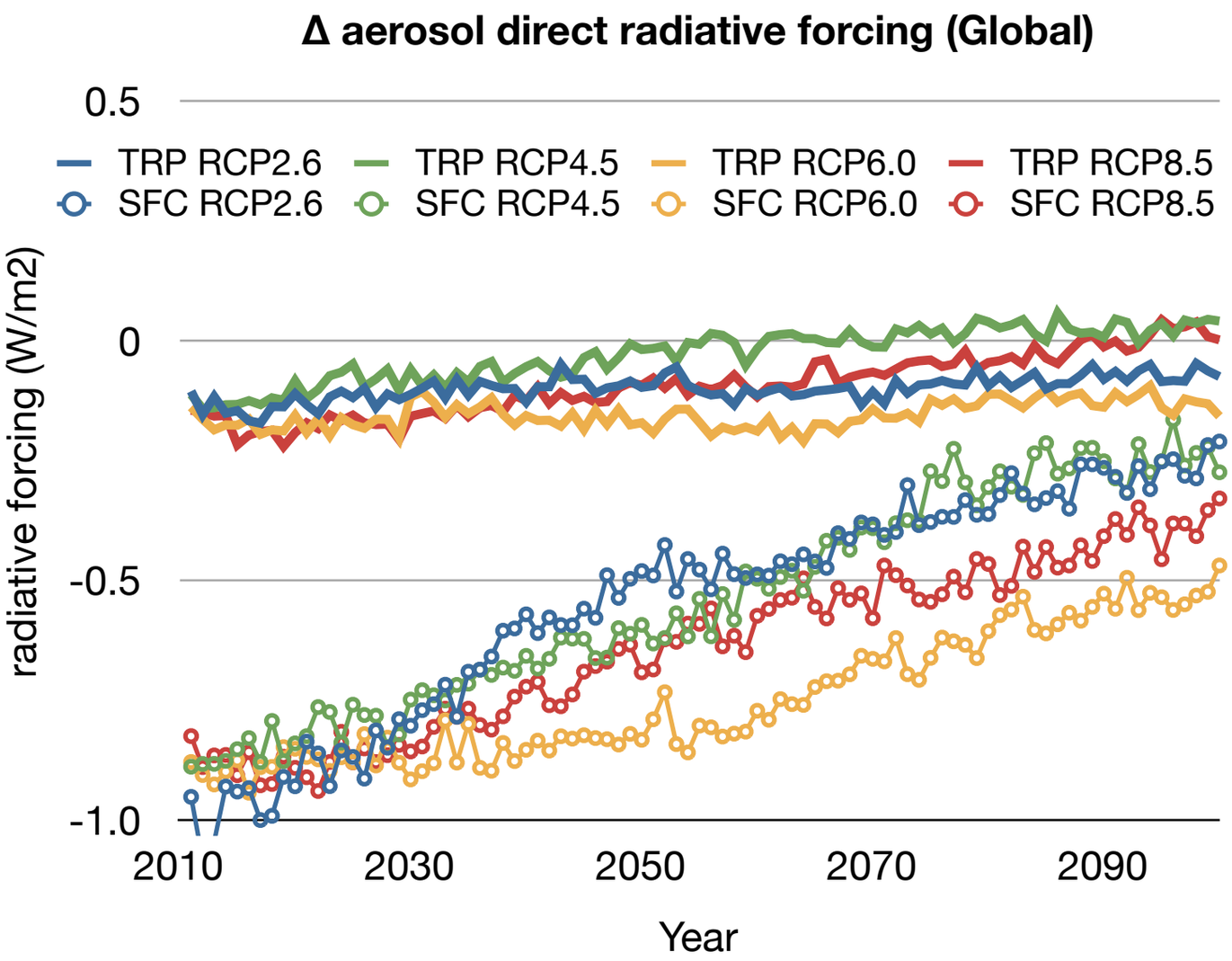


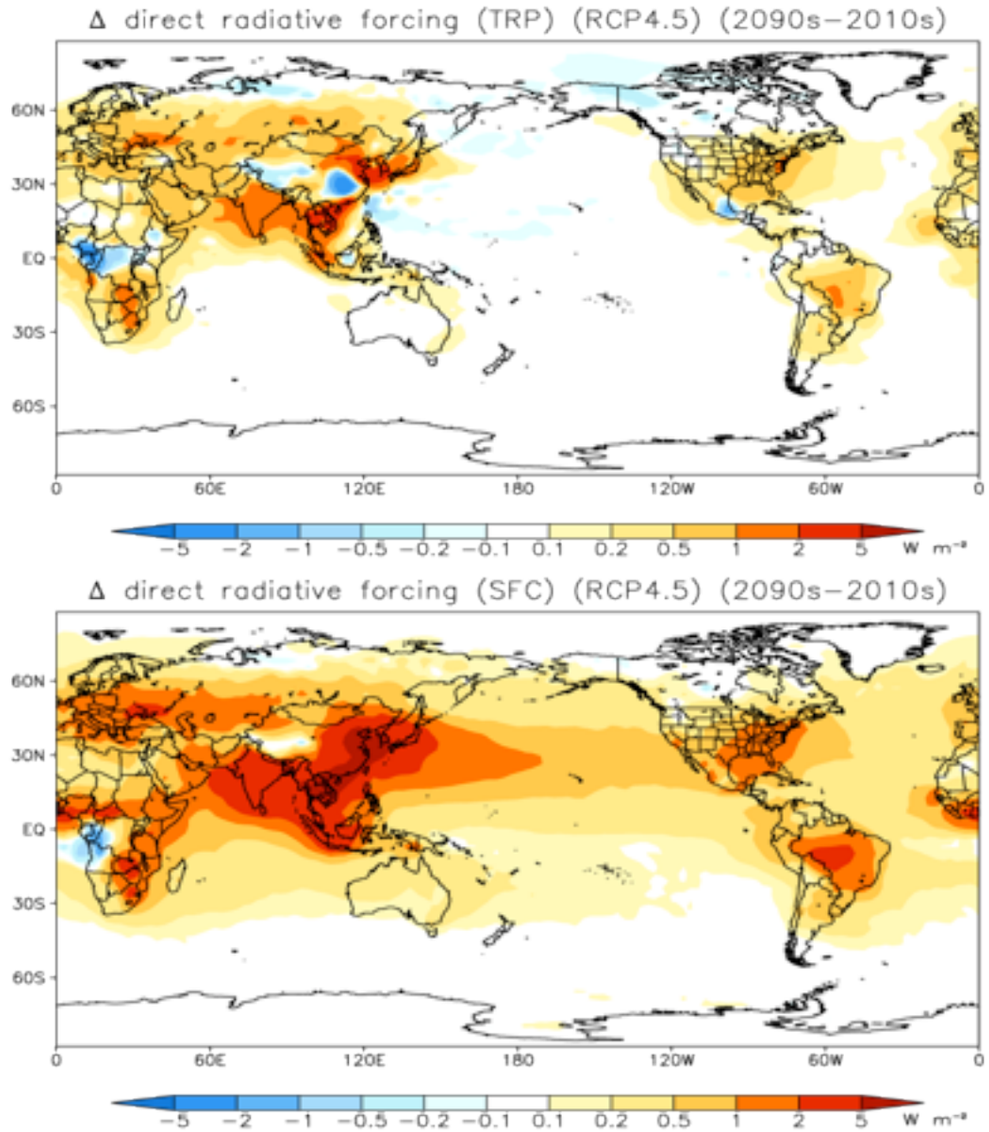




- It is expected that BC, OM, and sulfate aerosols in the atmosphere originating from anthropogenic sources will largely decrease in the end of the 21st century relative to the present.
- Aerosol concentrations from biomass burning in Africa will not vary much, and then their relative contributions to the total aerosol concentrations will gradually increase.

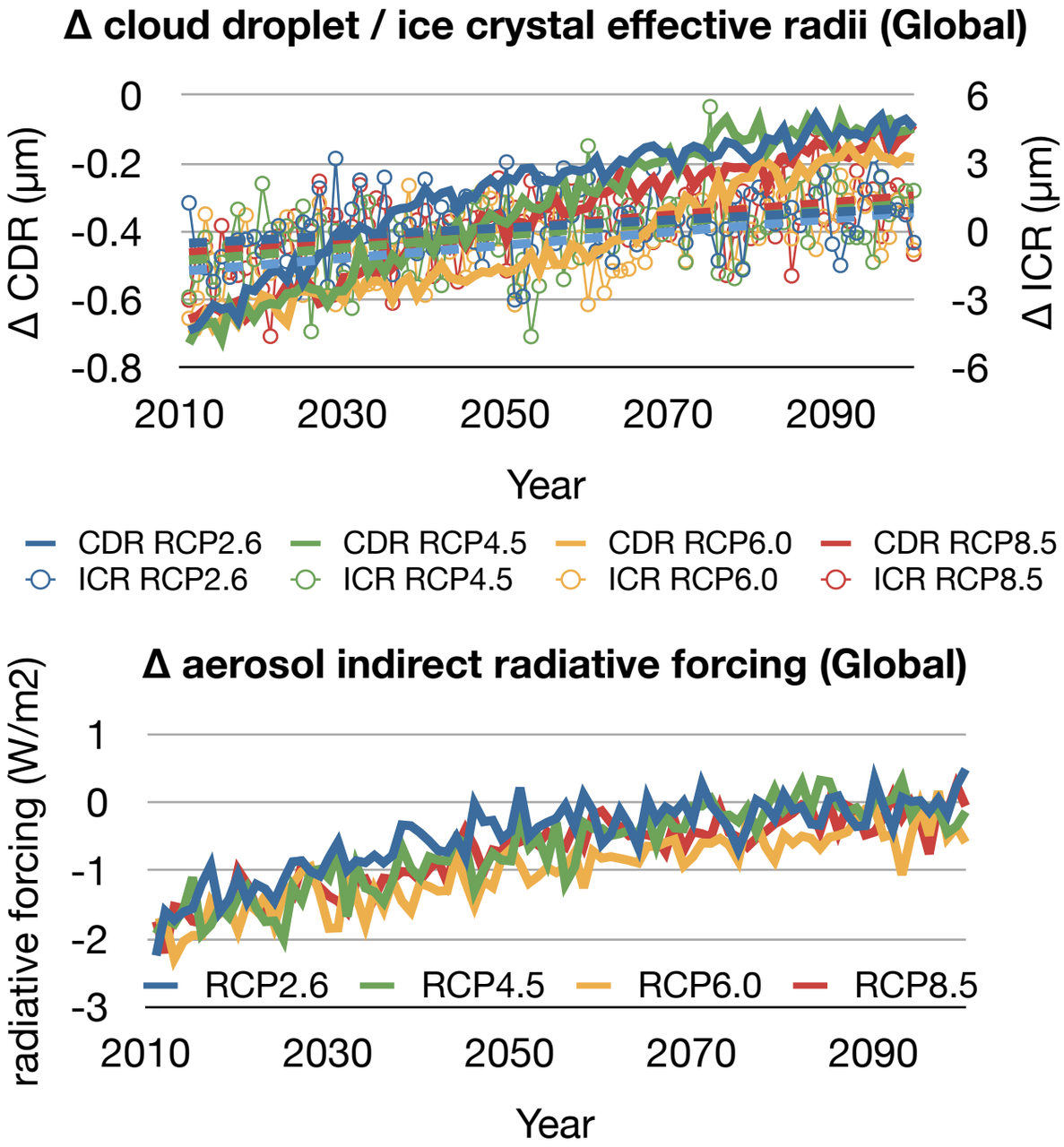
Temporal trends of aerosol direct radiative forcing

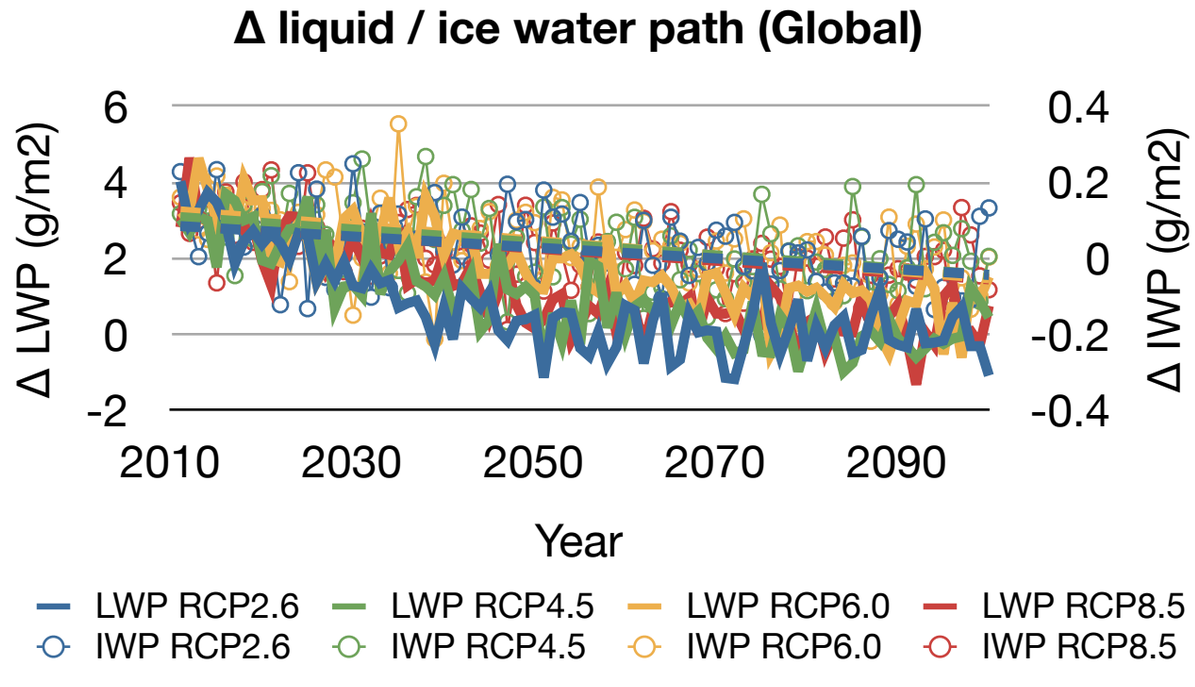


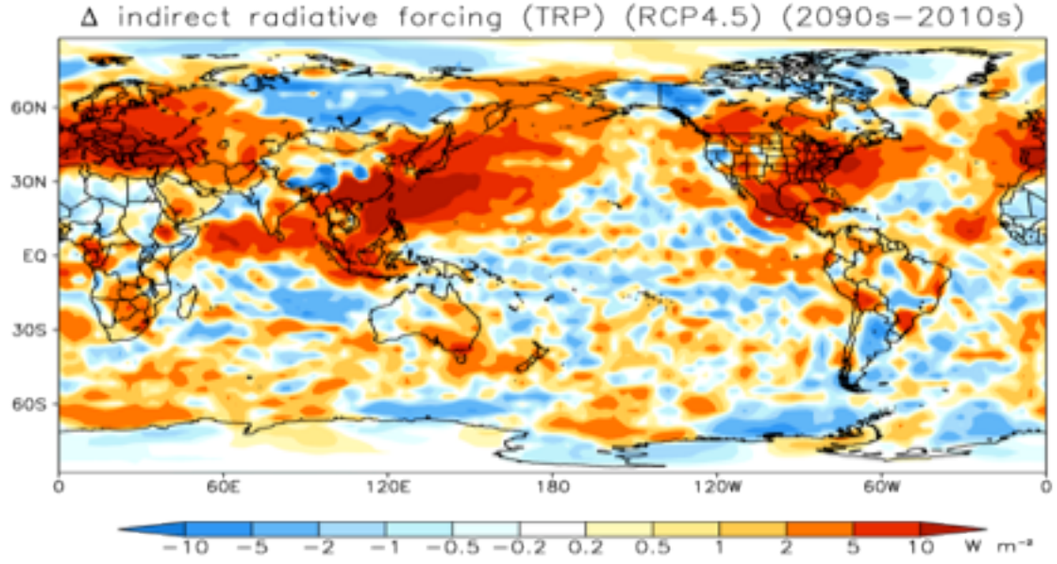


- Negative radiative forcing of the aerosol direct effect relative to the preindustrial era is expected to decrease both at TOA and surface.
- In RCP6.0, the negative aerosol direct radiative forcing keeps in high level due to high sulfate concentration in Asia in comparison with the other pathways.

Temporal trends of aerosol indirect effects

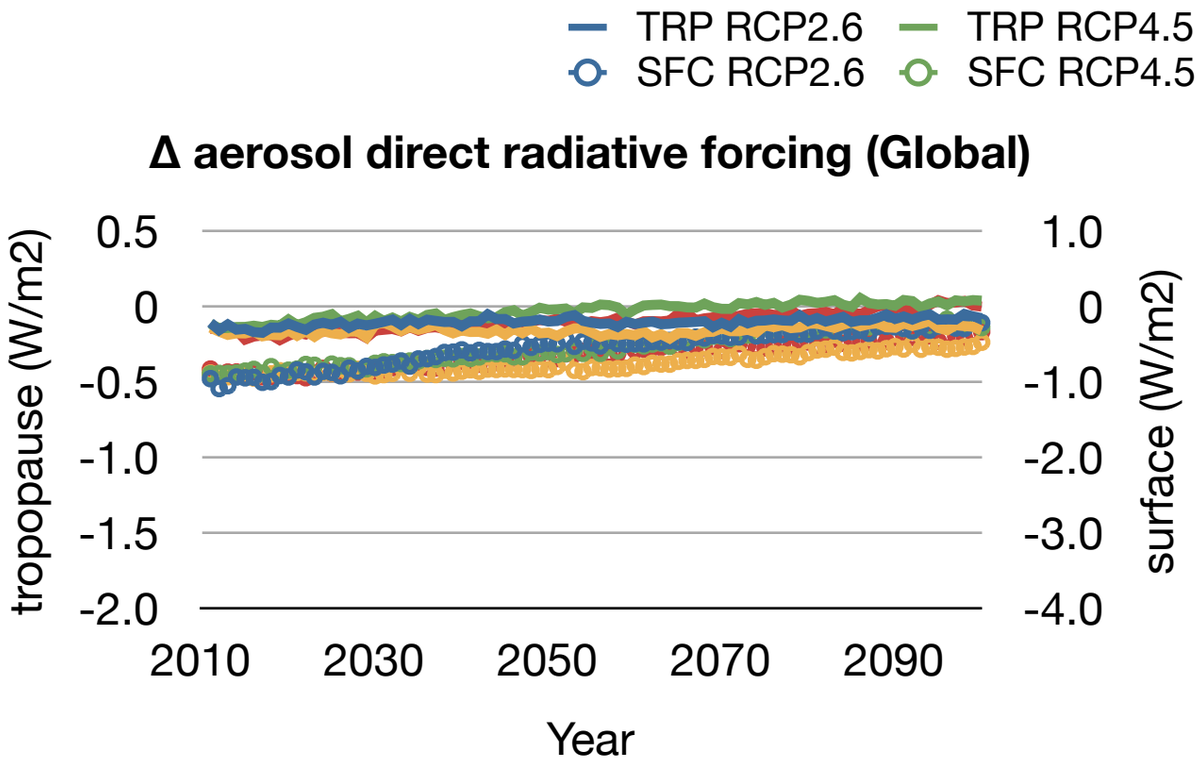


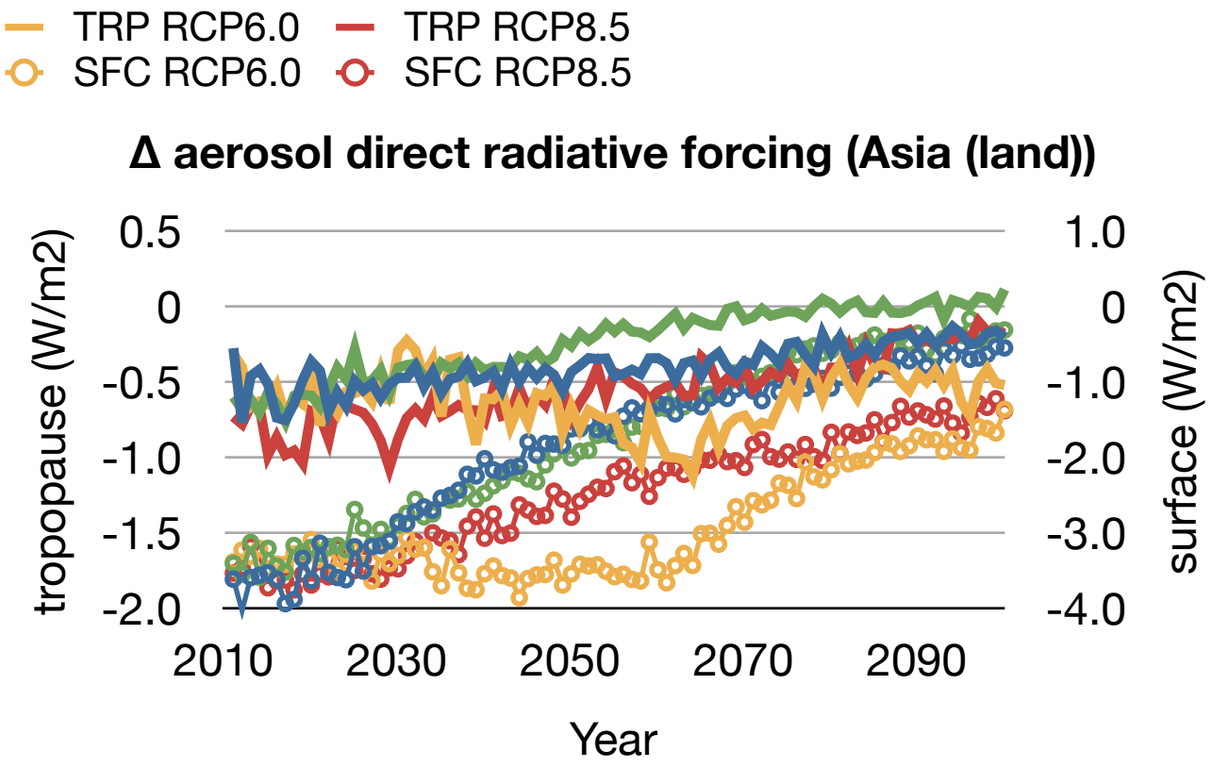


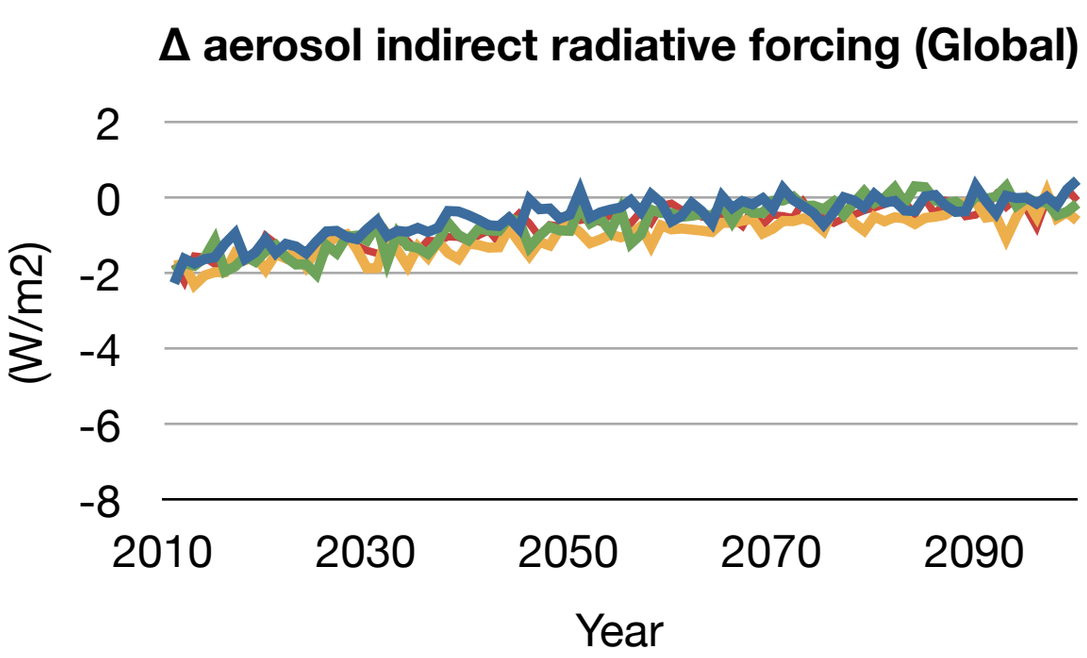


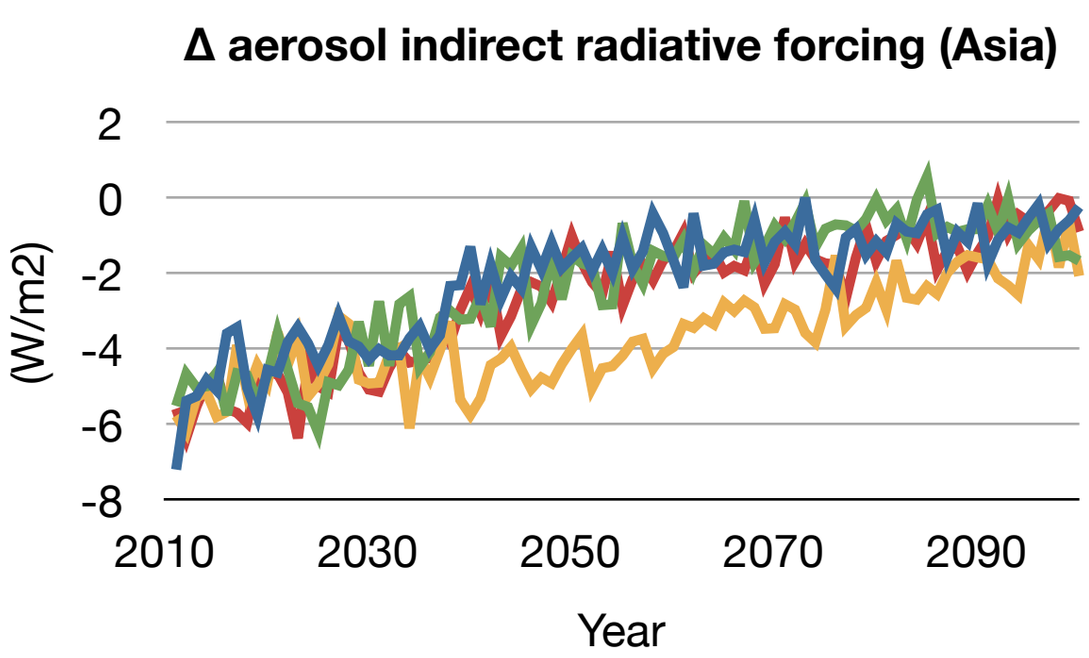
- Both the 1st and 2nd aerosol indirect effects will be reduced due to decreases in anthropogenic aerosols.
- Aerosol indirect radiative forcing relative to the preindustrial era is expected to be close to zero in the end of the 21st century.

Aerosol forcing in Asia









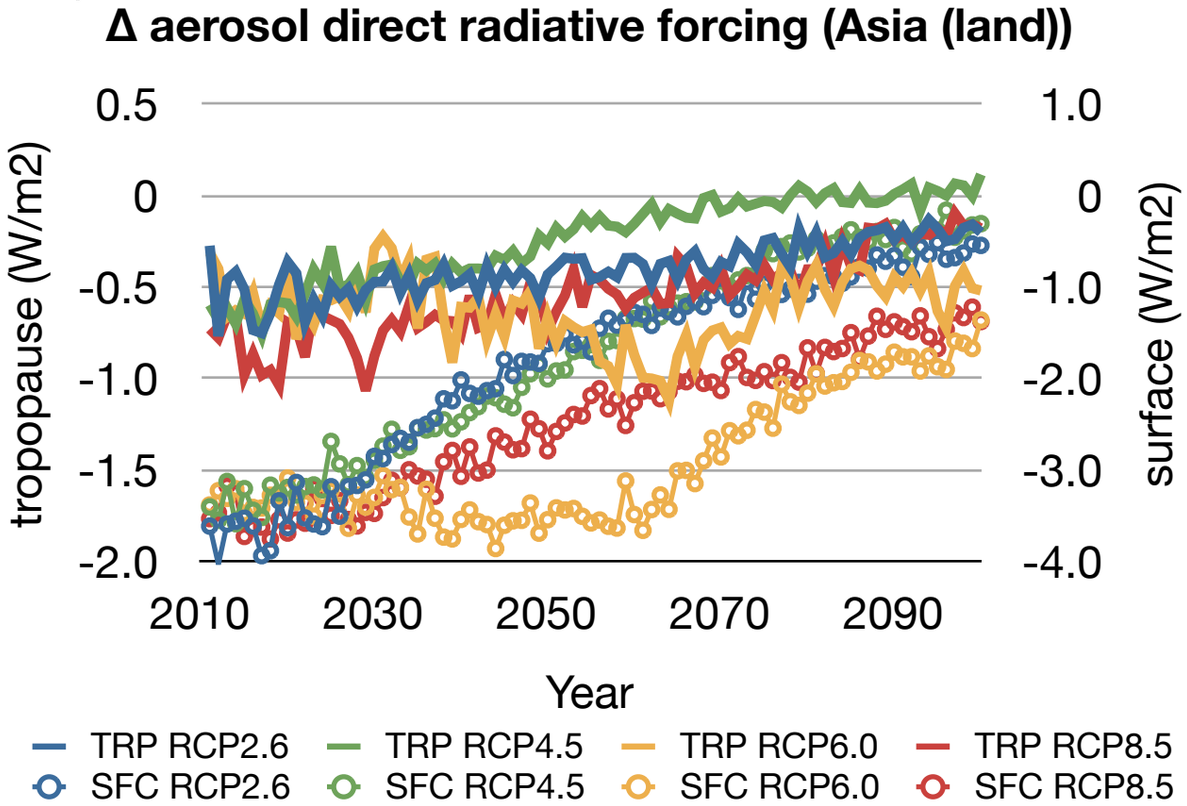
- Aerosol direct forcing in Asia much depends on the pathways.
  - ➡ It is essential to continue monitoring aerosols and clouds and to estimate more reliable emission inventories.

Projection of aerosol radiative forcings along the Representative Concentration Pathways (RCPs) with a global aerosol-climate model

Toshihiko Takemura (Kyushu University, Japan)

Projection of climate change in the 21st century due to the aerosol direct and indirect effects is simulated by the aerosol global climate model, SPRINTARS, along the emission scenarios of the Representative Concentration Pathways (RCPs).

- Radiative forcing of the aerosol direct and indirect effects relative to the preindustrial era will be close to zero in the end of the 21st century due to decreases in anthropogenic aerosols.
- Aerosol direct forcing in Asia much depends on the pathways.
  ➡ It is essential to continue monitoring aerosols and clouds and to estimate more reliable emission inventories.
- It is suggested that falling temperature due to the aerosol effects (including only rapid responses) will weaken.
  ➡ acceleration of the global warming?



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