Distributions and climate effects of atmospheric aerosols from 1850 to 2100 along Representative Concentration Pathways (RCPs) simulated by SPRINTARS

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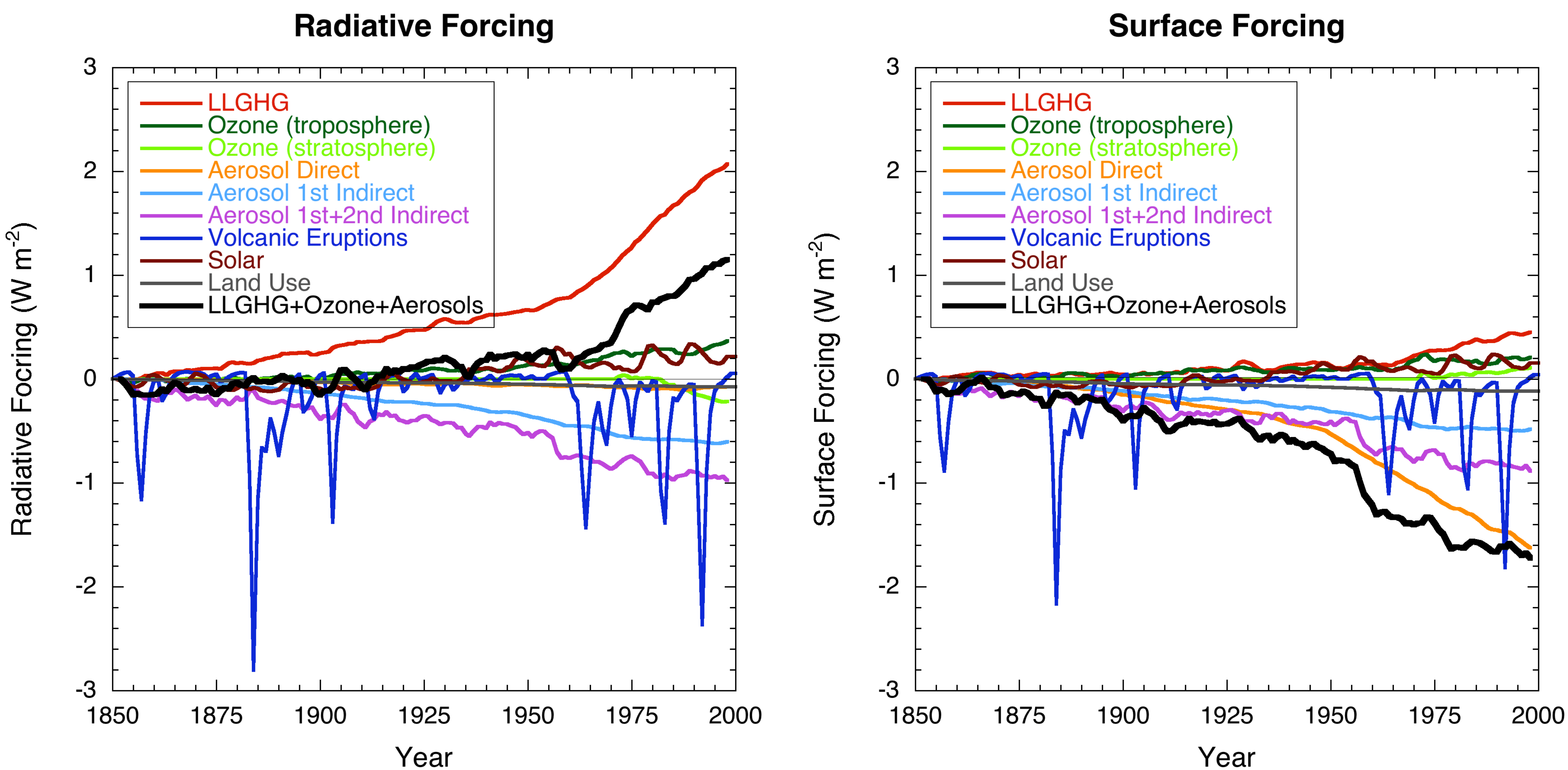
Outline

Global distributions and associated climate effects of atmospheric aerosols are simulated using a global aerosol climate model, SPRINTARS, from 1850 to the present day and projected forward to 2100 along the emission scenario in Coupled Model Intercomparison Project Phase 5 (CMIP5) that includes Representative Concentration Pathways (RCPs) for the future projection.

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)

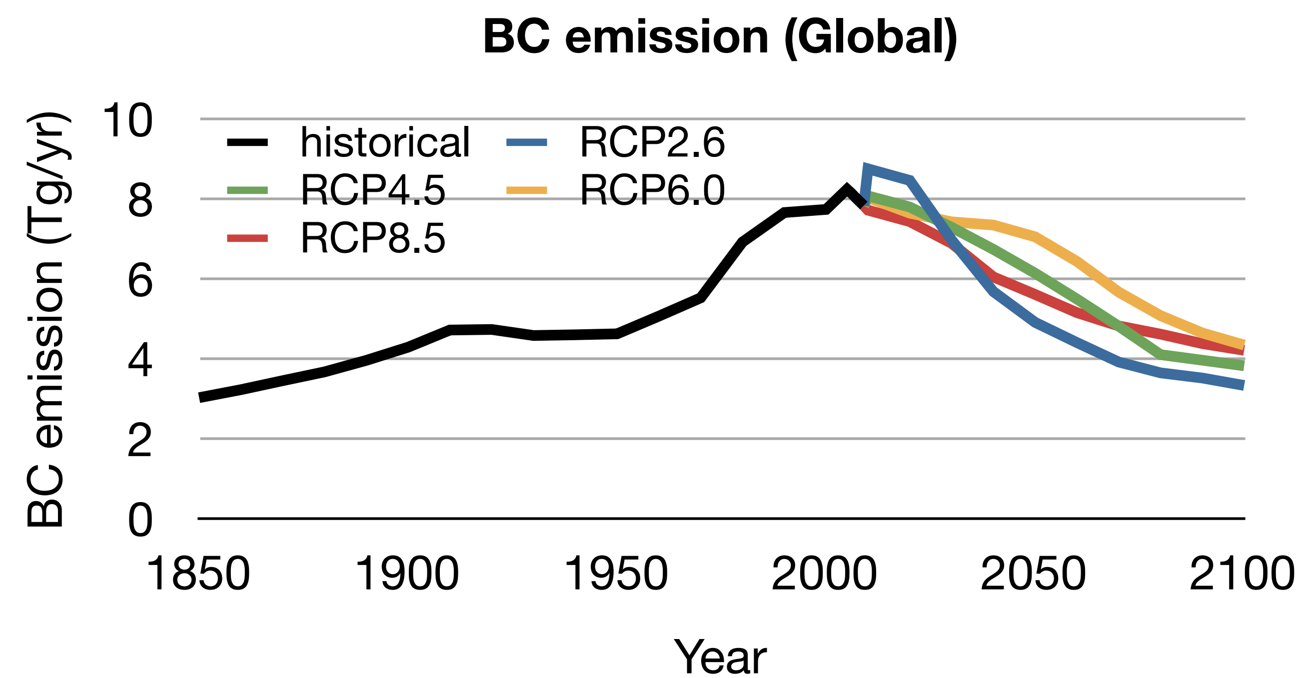
- **Period:** 1850 – 2100
- **Resolution:** T42 (2.8°in lon. × approx. 2.8° in lat.), L20.
- **Aerosol-related emission inventories**
  - BC, POM, SO_2 from anthropogenic sources and biomass burning along the emission scenario in Coupled Model Intercomparison Project Phase 5 (CMIP5) that includes Representative Concentration Pathways (RCPs) for the future projection.
  - Emissions of soil dust, sea salt, and DMS calculated with internal parameters.
  - SO_2 from continuously erupting volcanoes with past sporadic erupting volcanoes.
  - OH, O_3, H_2O_2 prescribed from time slice simulations by CHASER (Sudo et al.) along the RCPs.
- **Adjusted forcing (AF)**

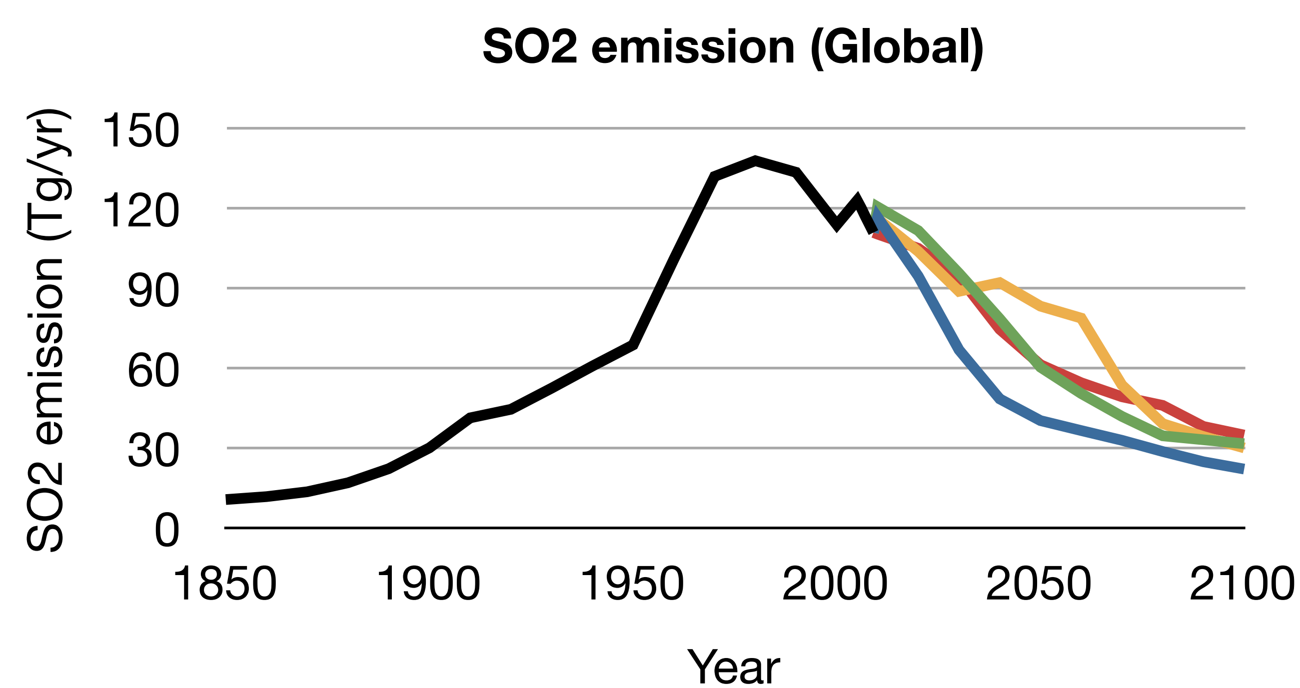
  AF including rapid responses to the climate system calculated as a difference in the radiation budget from simulations with the aerosol-related emissions between 1850 and a concerned year with the same sea surface temperature, sea ice cover, and concentrations of greenhouse gases in a concerned year.

Representative Concentration Pathways (RCPs)

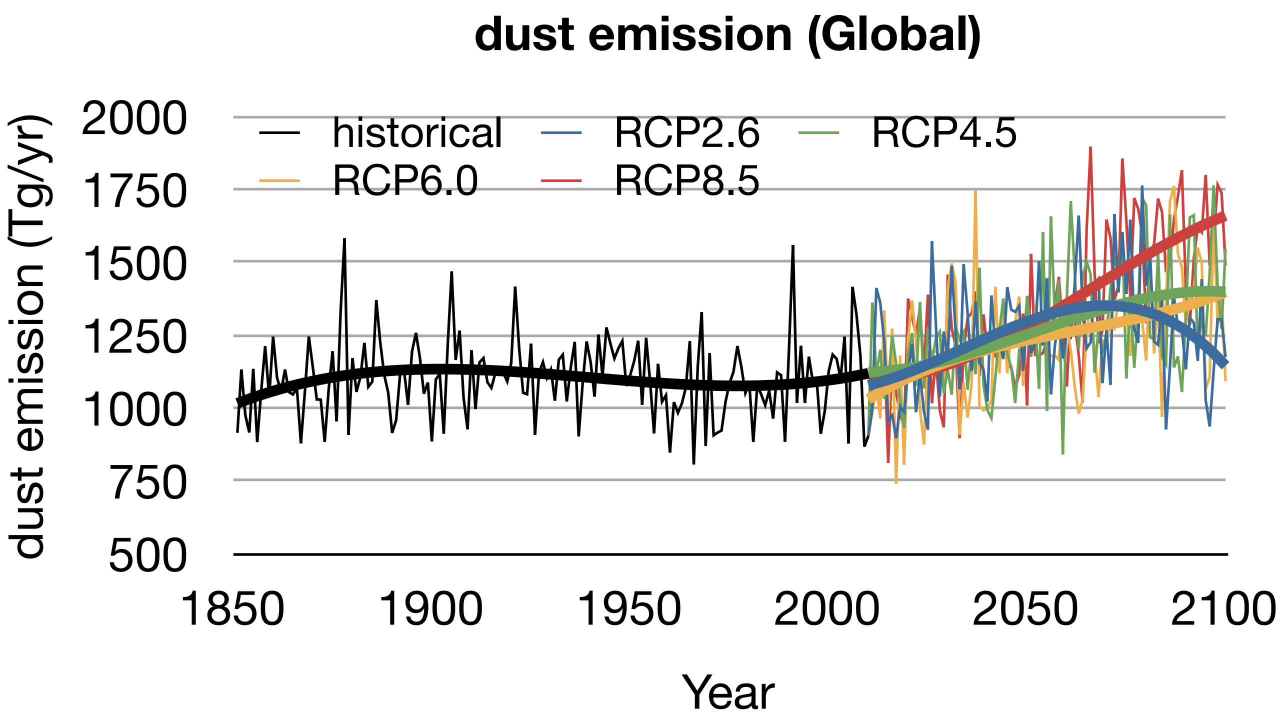
Emission scenarios for greenhouse gases and other atmospheric components used in CMIP5 / 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)
(Emissions from preindustrial to the present day by Lamarque et al. (2010)).

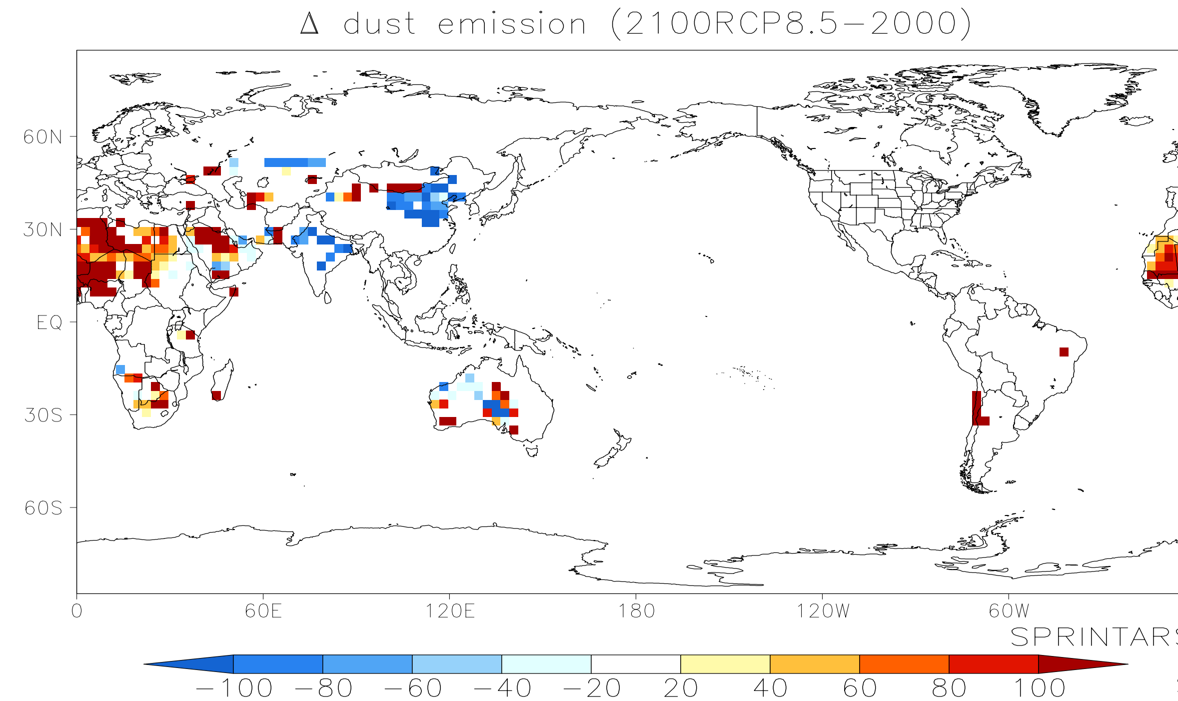
- RCP2.6 (RCP3-PD) [IMAGE (PBL, Netherlands)]
  Peak in radiative forcing at 2.6 W m^{-2} before 2100 and decline.
- RCP4.5 [MiniCAM (PNNL, USA)]
  Stabilization without overshoot pathway to 4.5 W m^{-2} at stabilization after 2100.
- RCP6 [AIM (NIES, Japan)]
  Stabilization without overshoot pathway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

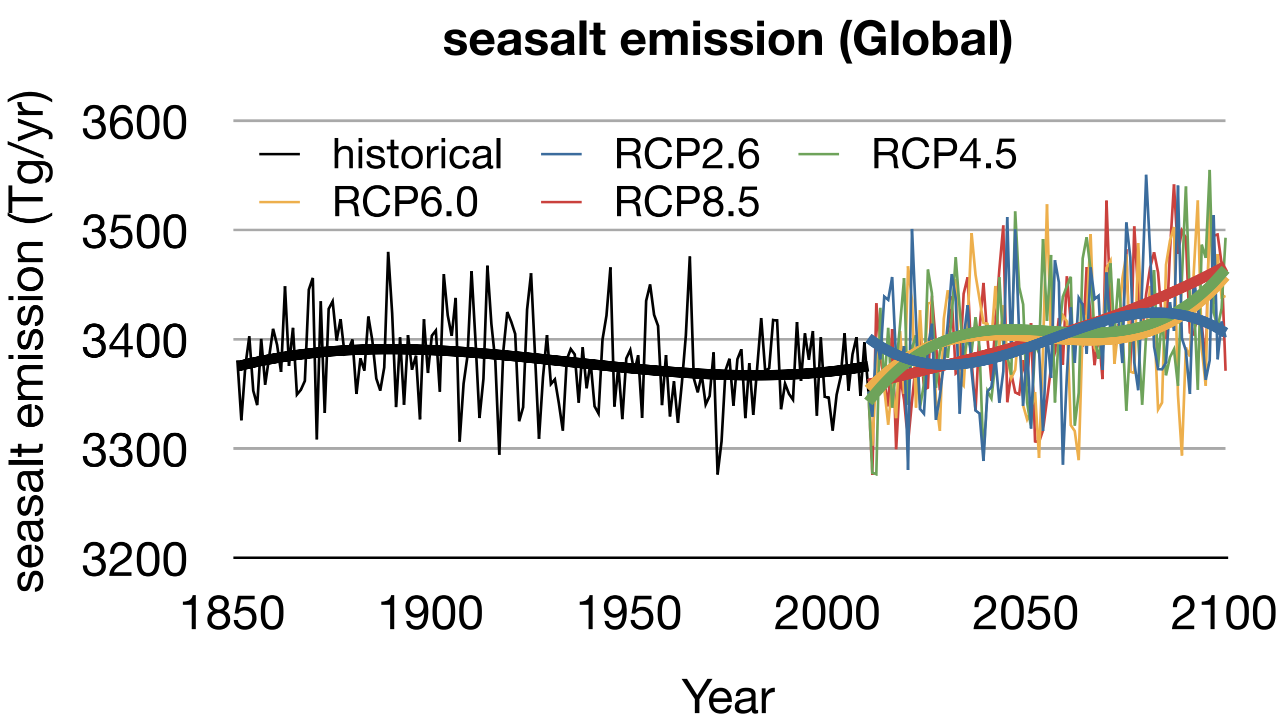


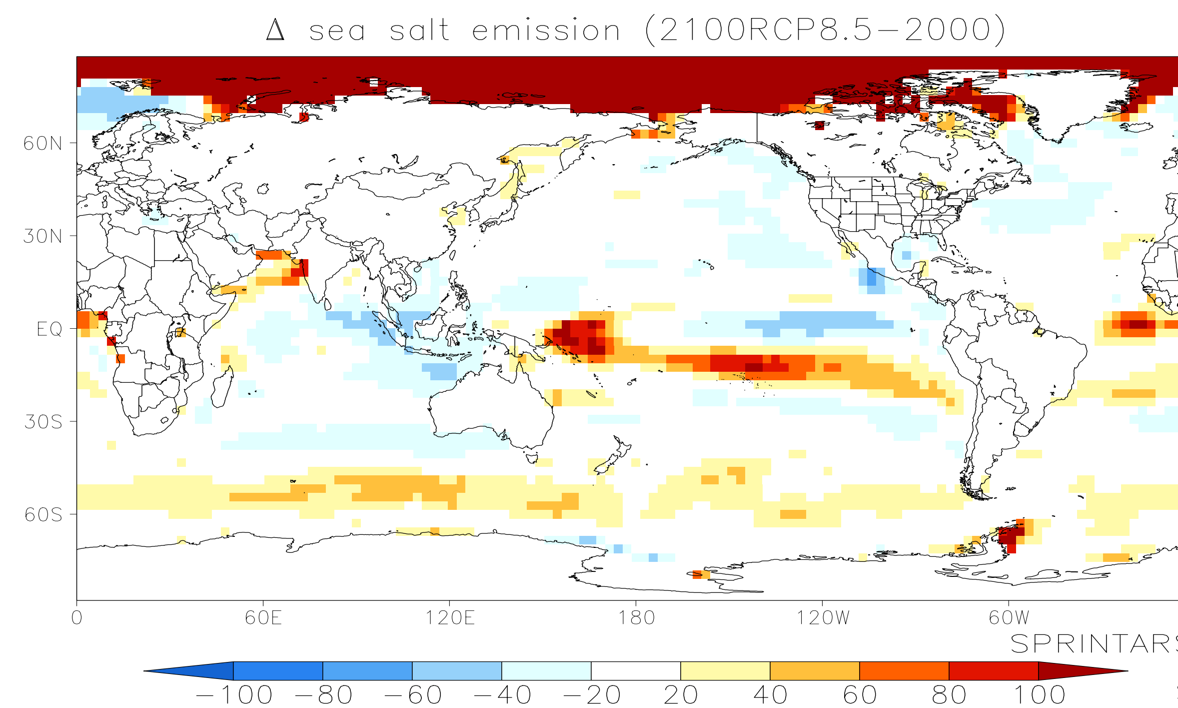


Temporal trends of natural aerosols



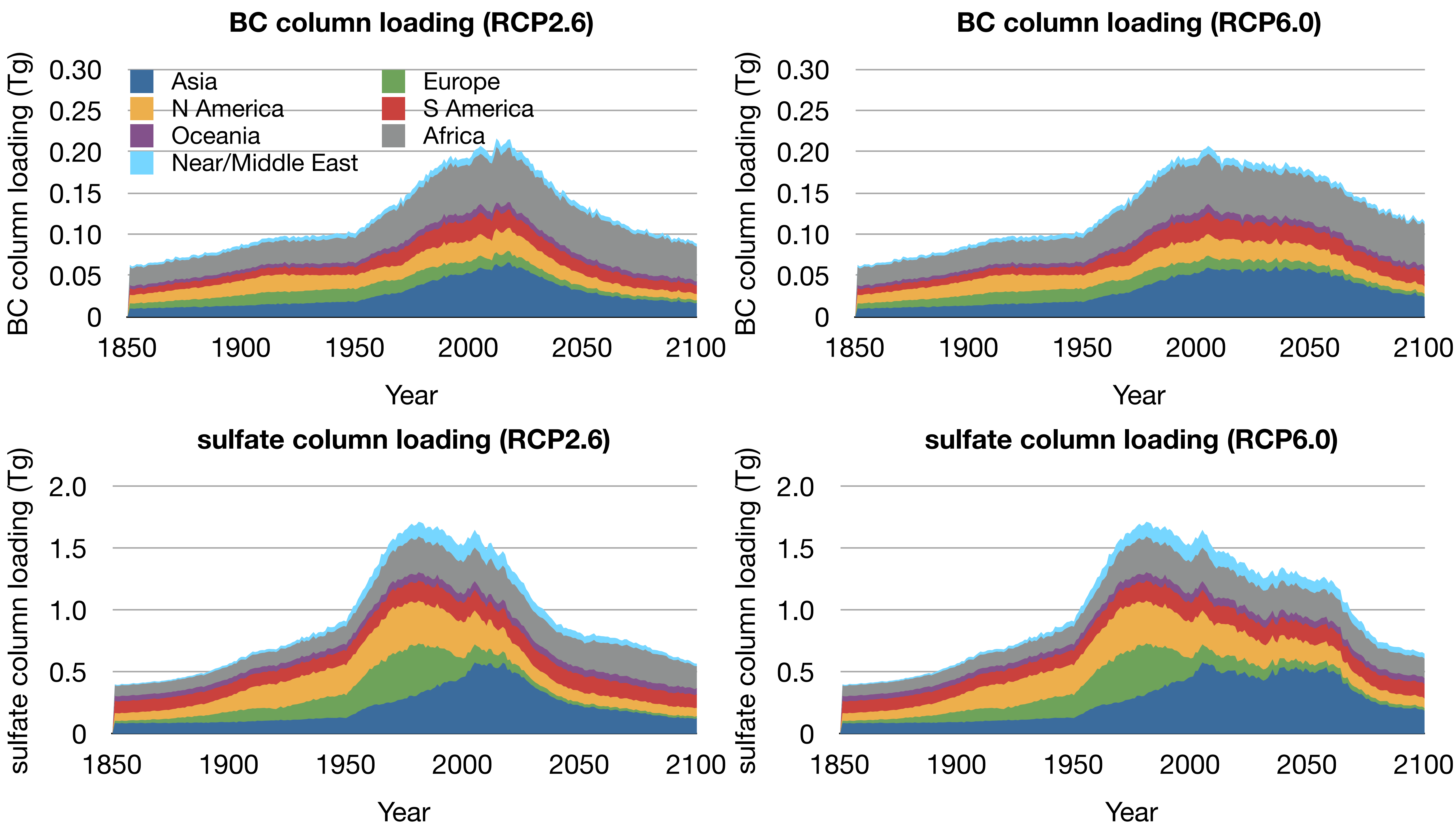






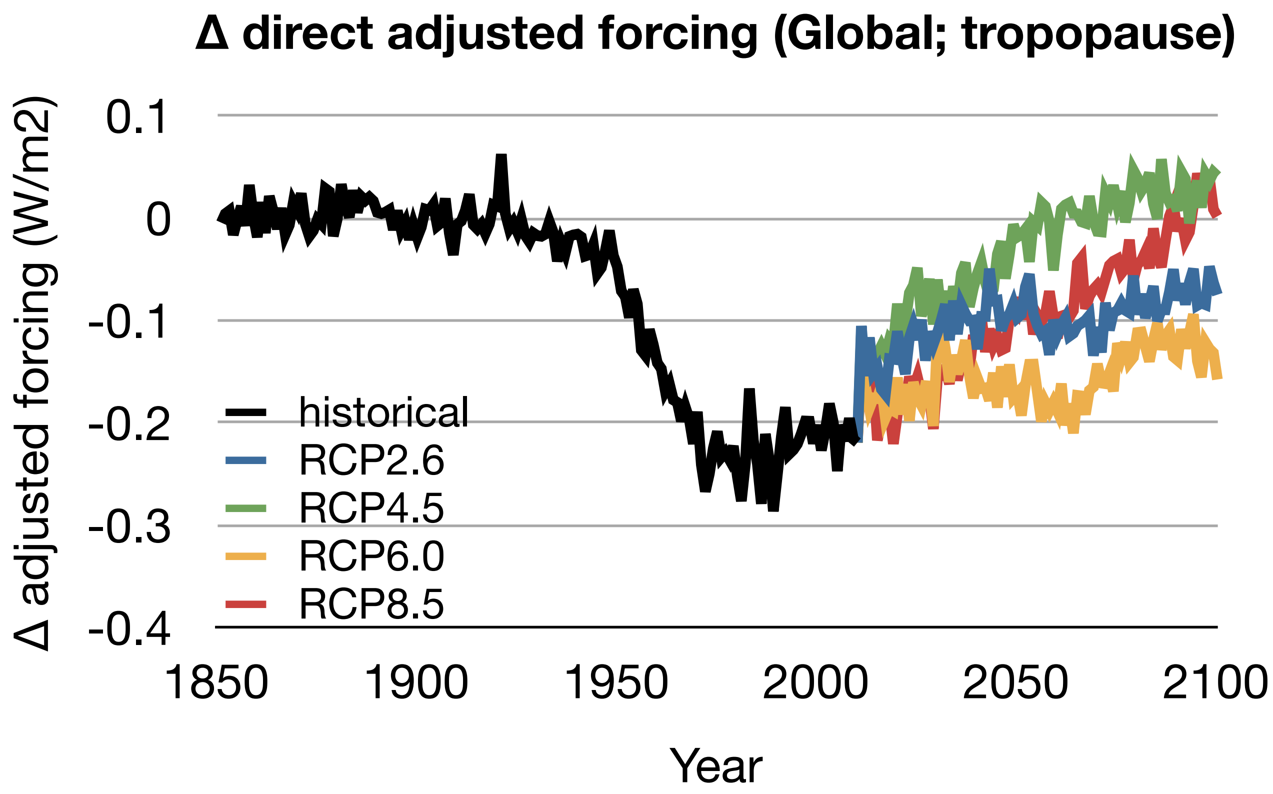
Time series of annual and global total emissions (left) and distributions of differences between 2100 for RCP8.5 and 2000 (right) of soil dust (top) and sea salt (bottom).

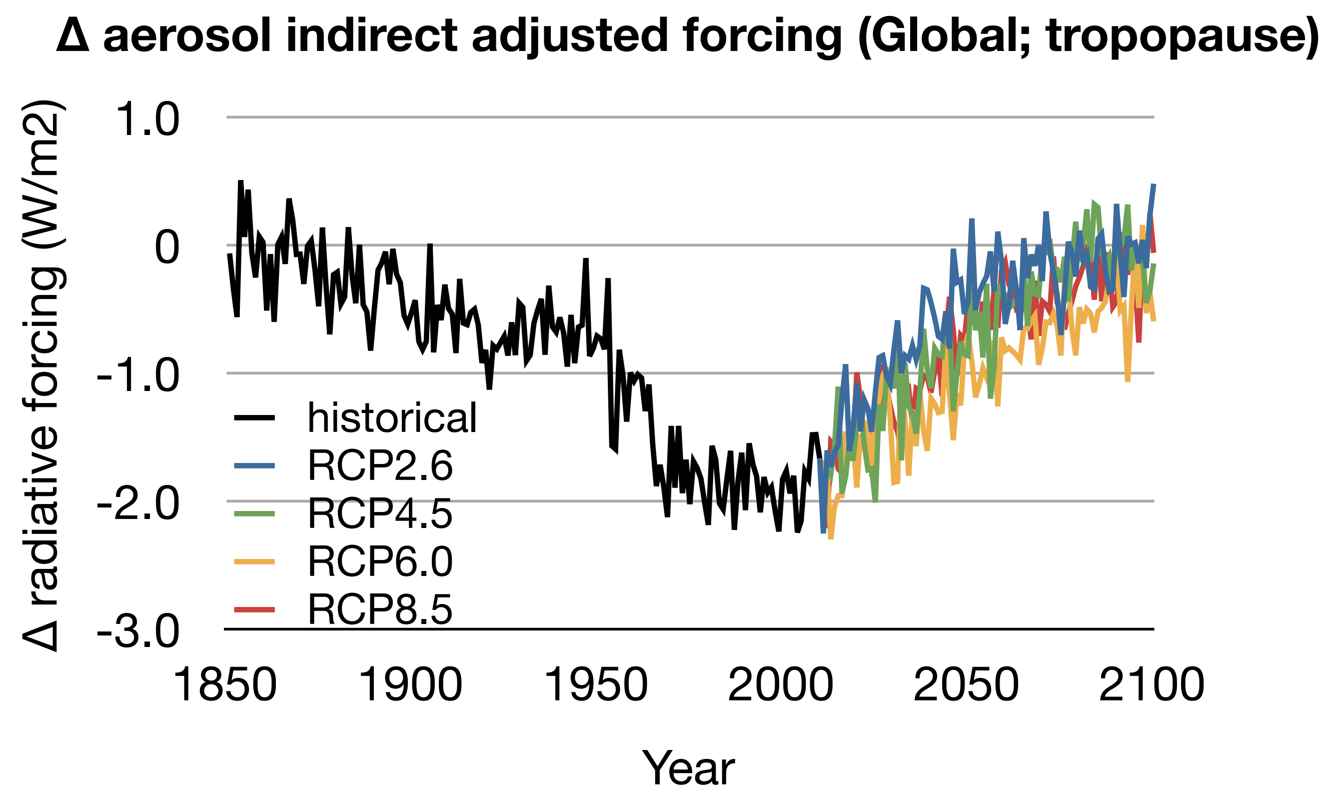
Temporal trends of aerosol column loading

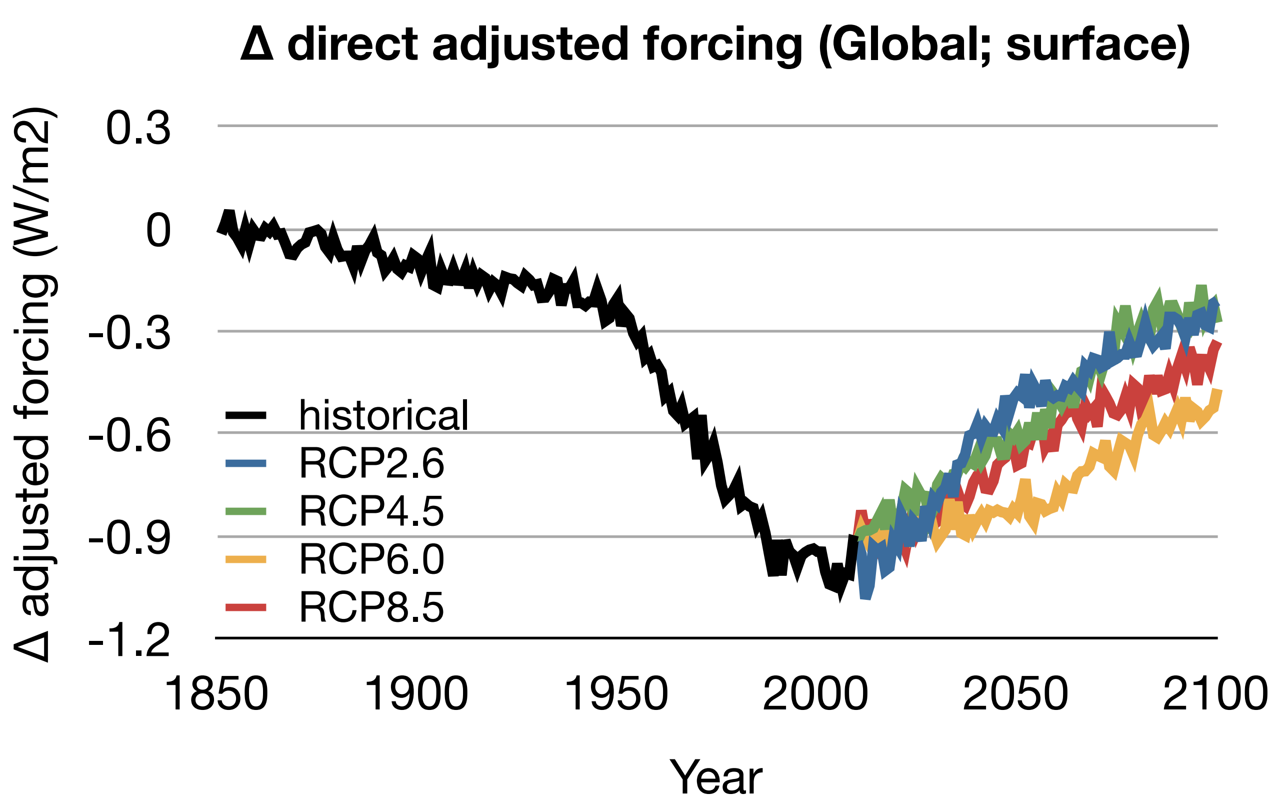


- Aerosol loading has already peaked and is now reducing in Europe and North America.
- In Asia, aerosol loading is estimated to reach a maximum in the first half of this century.
- Aerosols from biomass burning will maintain high loadings throughout the 21st century in Africa.

Temporal trends of aerosol adjusted forcing

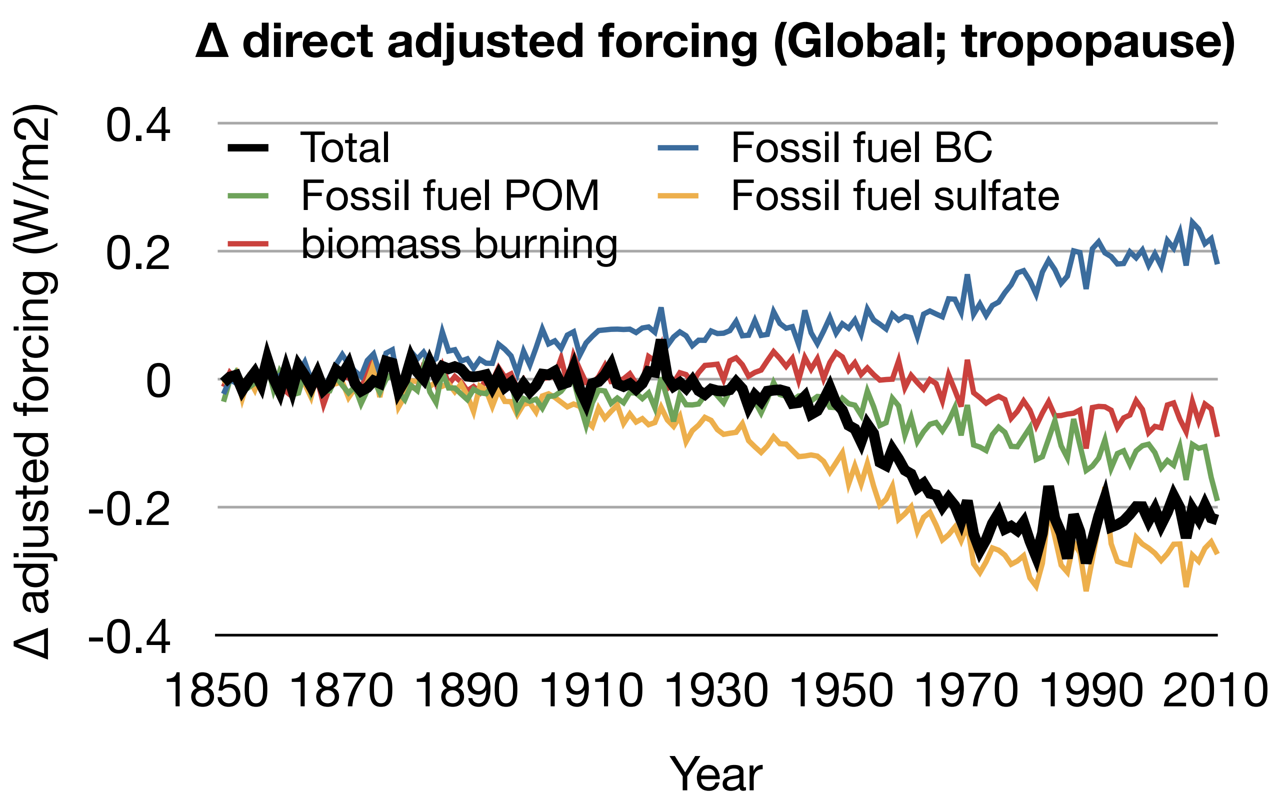


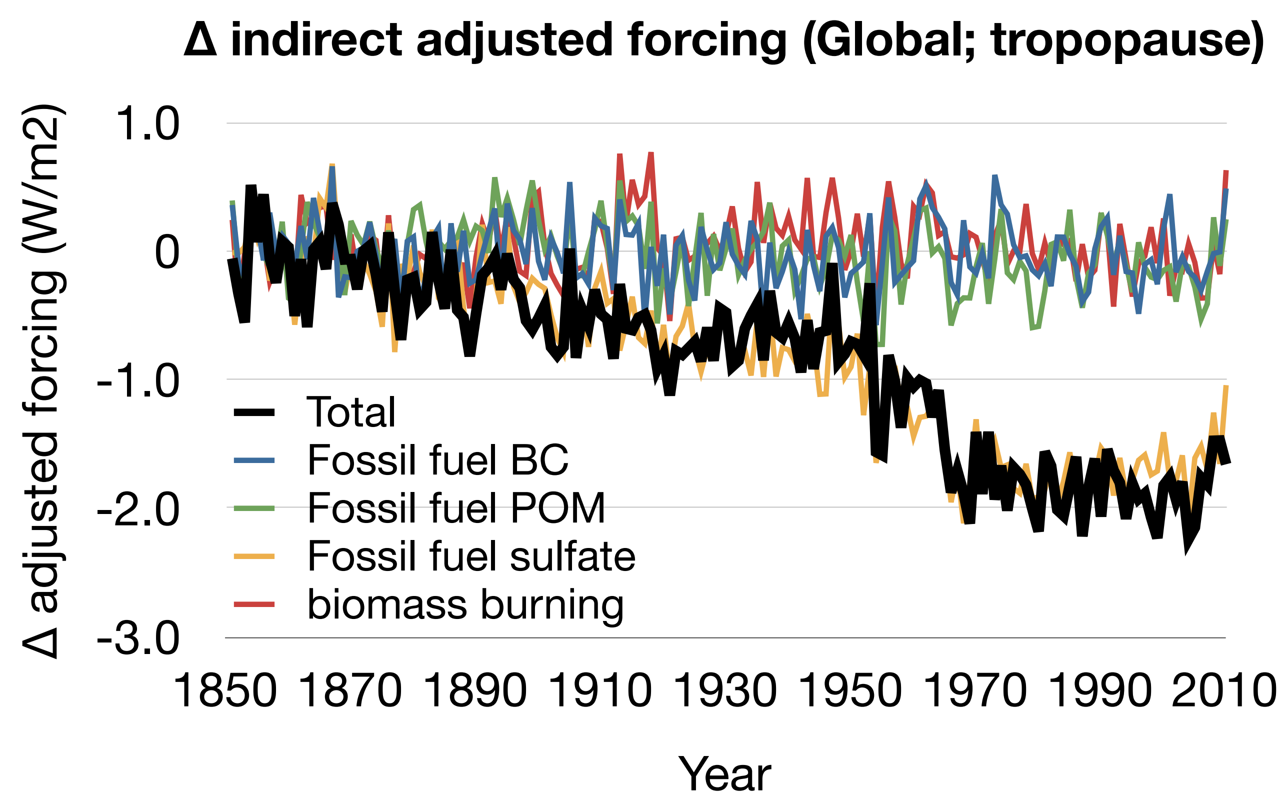


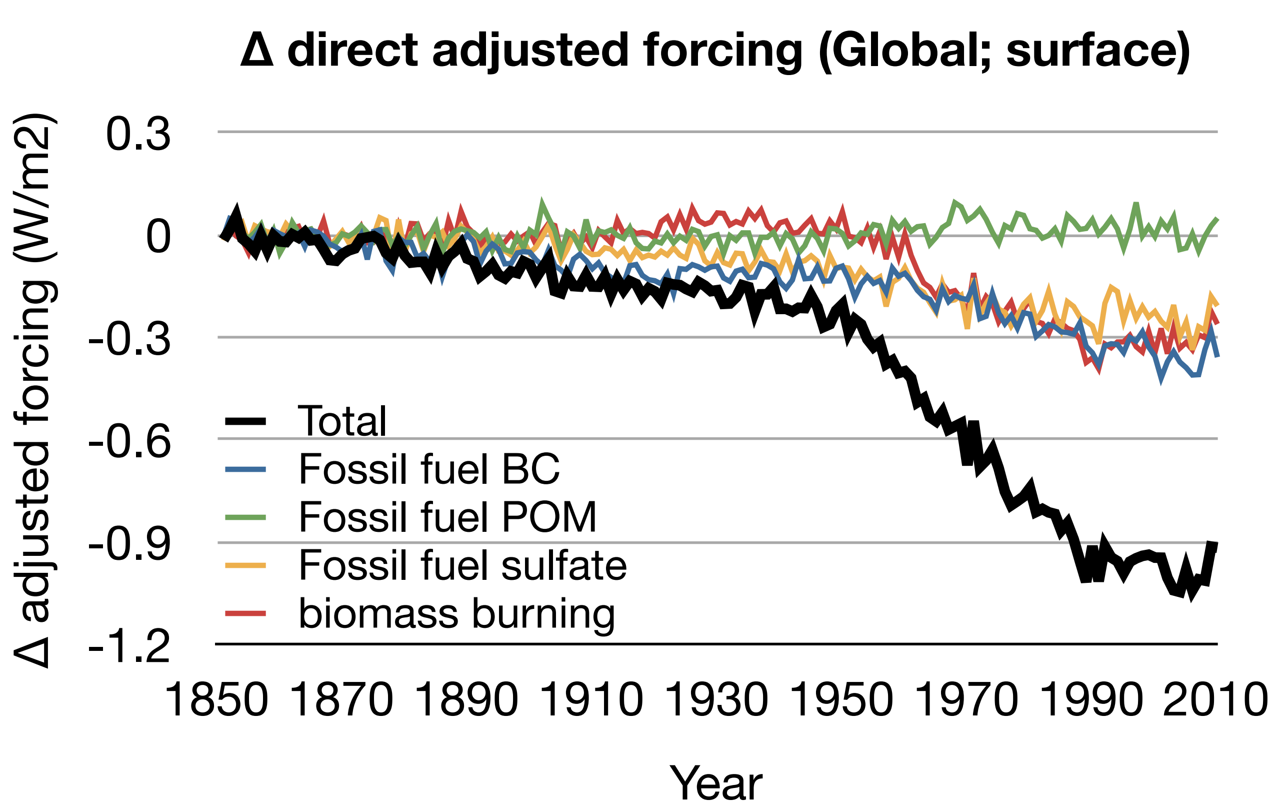


- Evolution of the adjusted forcing by the direct and indirect aerosol effects generally correspond to the aerosol loading.
- The global mean negative AF, both at the tropopause and the surface, rapidly increase after the 1950s and peaked in the 1970s to 1990s, a similar temporal variation to that in Europe and North America.
- It is predicted to retain a high negative AF due to the direct effect until the mid-21st century in Asia in RCP6.0, which affects the time series for the global mean.

Temporal trends of aerosol adjusted forcing







- Components that have the largest negative and positive AF of the direct effect at the tropopause are sulphate and BC from fossil fuel consumption, respectively.
- The contribution towards the negative AF of the direct effect at the surface is estimated to be almost equal among sulphate and BC from fossil fuel consumption and aerosols from biomass burning.
- The total AF of the indirect effect is almost equal to the AF due to sulphate particles which act as cloud condensation nuclei.

Conclusions

Global distributions and associated climate effects of atmospheric aerosols were simulated using a global aerosol climate model, SPRINTARS, from the preindustrial era to the present day and projected forward to the end of the 21st century along the emission scenario in Coupled Model Intercomparison Project Phase 5 (CMIP5) that includes Representative Concentration Pathways (RCPs) for the future projection.

➡ Because aerosol forcing will be close to the preindustrial level by the end of the 21st century for all RCPs despite the continuous increases in greenhouse gases, global warming will be accelerated with reduced aerosol negative forcing.

Acknowledgments

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