Change in surface solar radiation due to aerosols for several decades based on AeroCom Phase II Experiment

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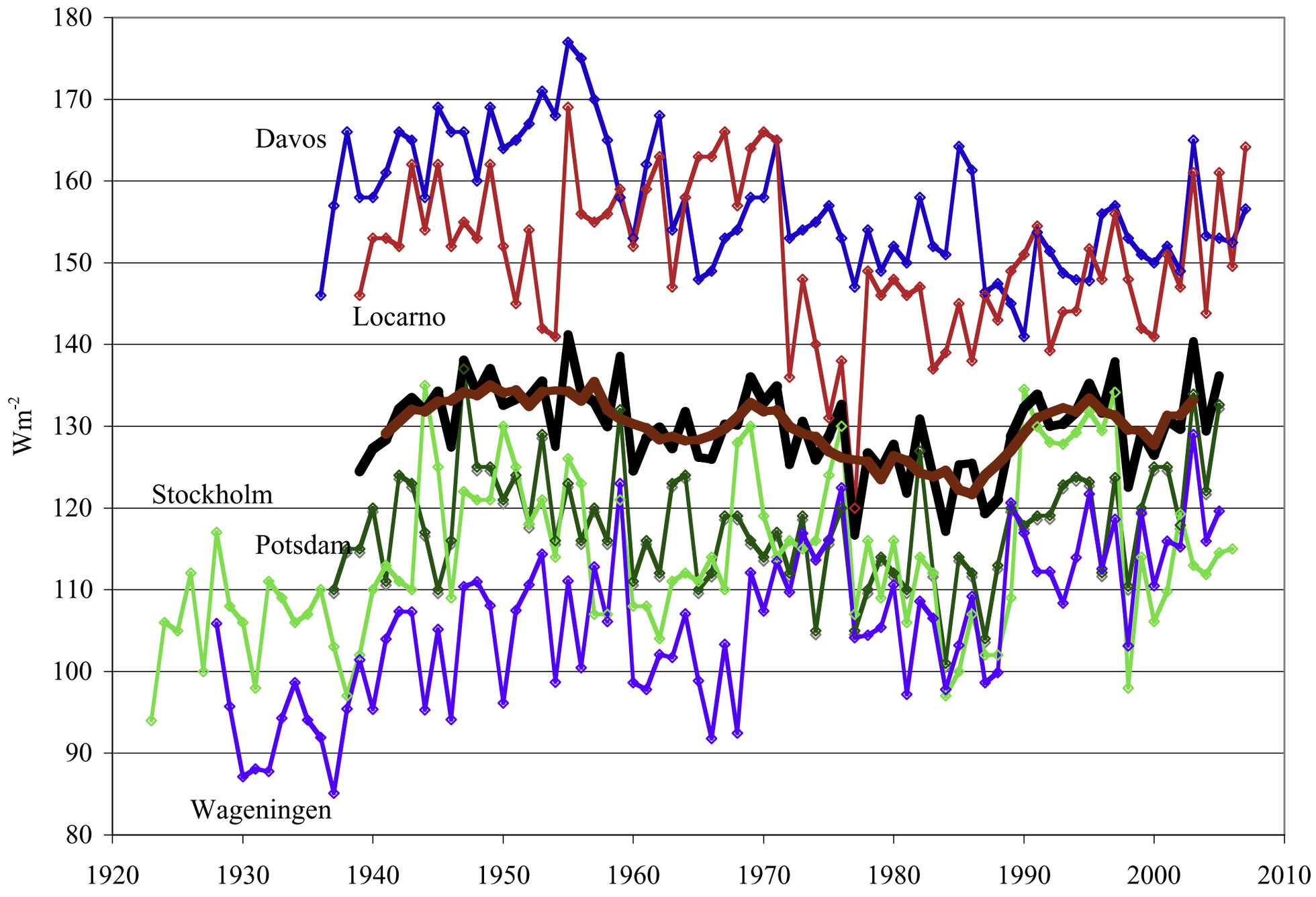
Outline

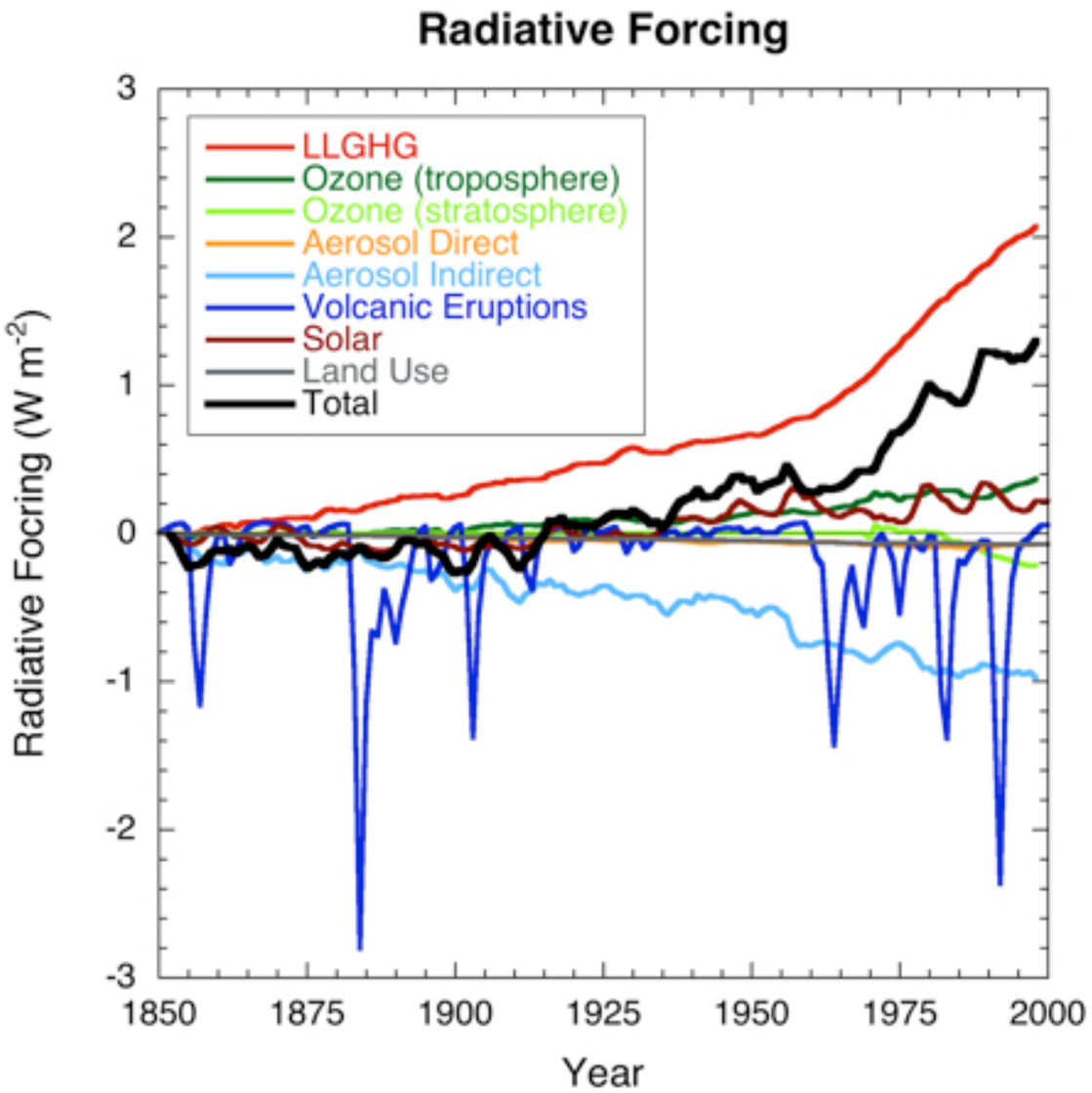
Discussion on changes in the surface solar radiation by the hindcast simulation from the year 1980 to the present based on AeroCom Phase II Experiment, comparing with decadal observations.

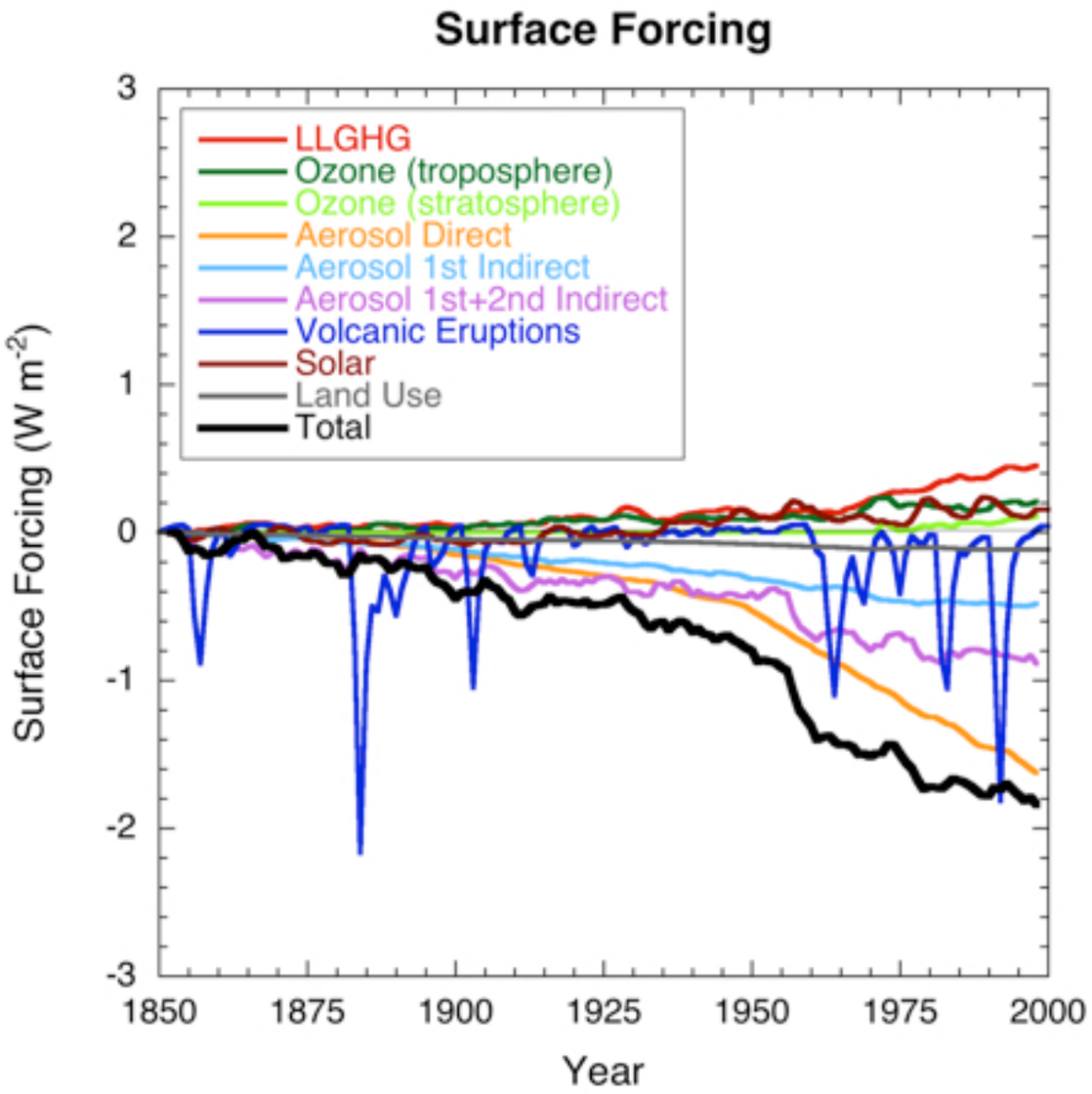
“Global dimming” and “Global brightening”



Annual mean global solar irradiance in Western Europe. The black line represents the mean of the five sites, and the 5-year running mean is indicated by the brown line (Ohmura, JGR, 2009).

Trend of hindcast surface 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: T106/T42, L56/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.

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- 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.

Hindcast aerosol simulation with SPRINTARS

Period

January 1, 1980 – December 31, 2008.

Resolution

T106 (1.125°in lon. × approx. 1.125° in lat), 56 layers.

Aerosol-related emission inventories

- provided by AeroCom from 1980 to 2006.
  - annual mean BC, OC, SO_2 from human activities.
  - monthly mean BC, OC, SO_2 from biomass burning.
  - daily mean SO_2 from continuous/sporadic volcanoes.
  - annual mean SO_4 from ships.
  - monthly mean BC, OC, SO_2 from aircrafts.
- interpolated by increase rates of SRES A2 after 2007.
- OH, O_3, H_2O_2 prescribed by CHASER (Sudo et al.)

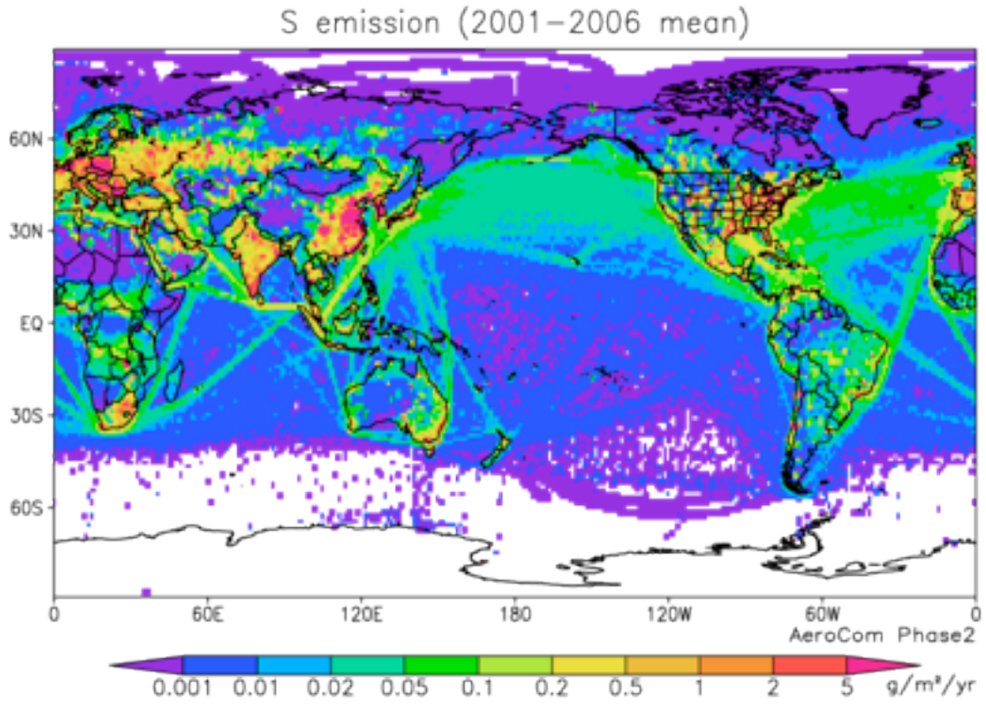
Meteorology

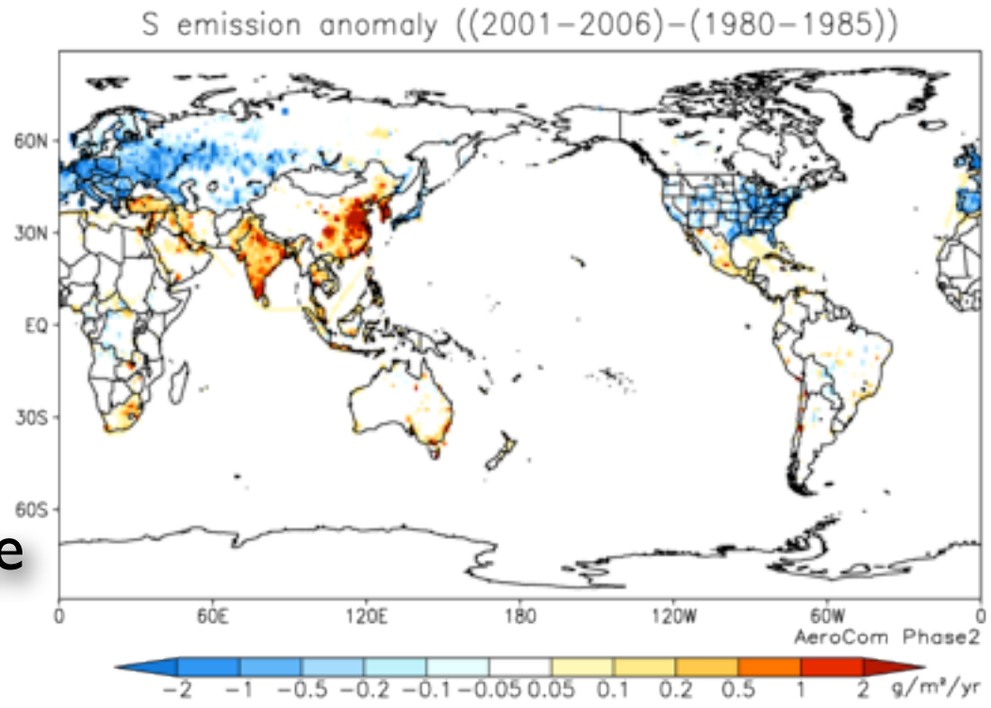
- wind and temperature nudged by 6-hourly NCEP/ NCAR reanalysis data.
- SST and sea ice prescribed by monthly HadISST data.

Comparison with observations of solar irradiance

Provided by Prof. A. Ohmura (ETH)

- Global Energy Balance Archive (GEBA).
- etc.





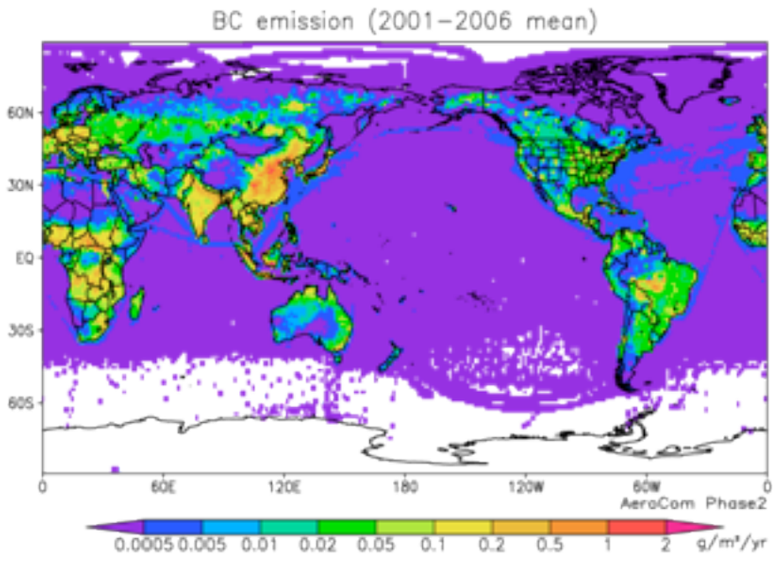
Global emission inventories in AeroCom Phase II

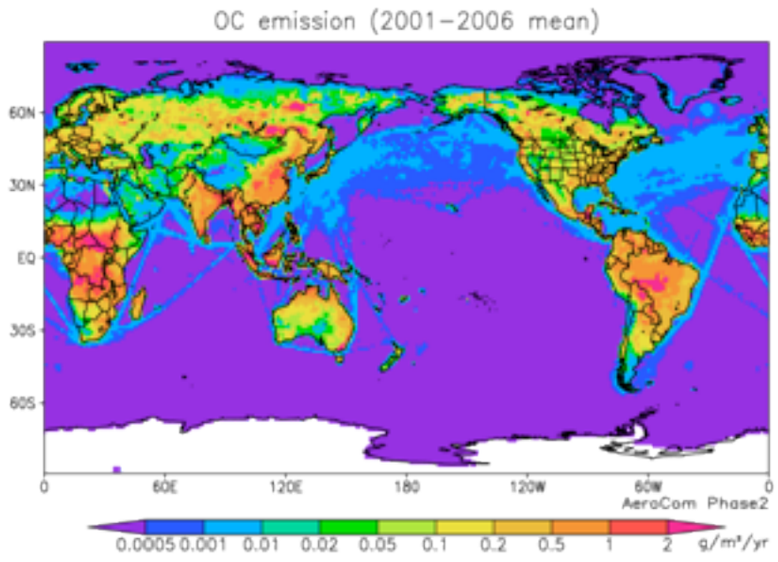
BC

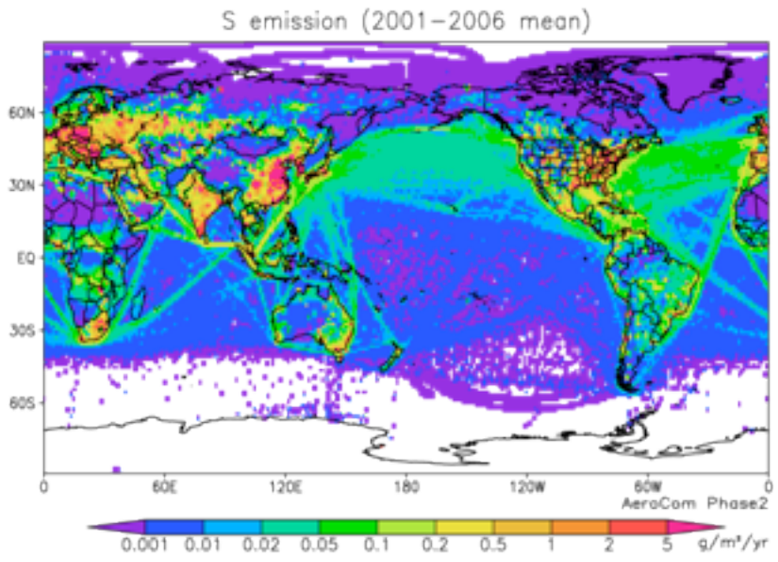
OC

S

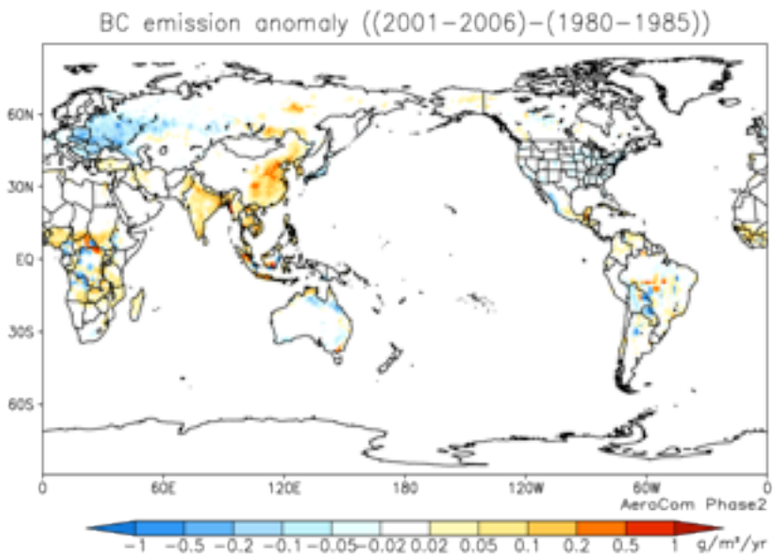
Annual emissions

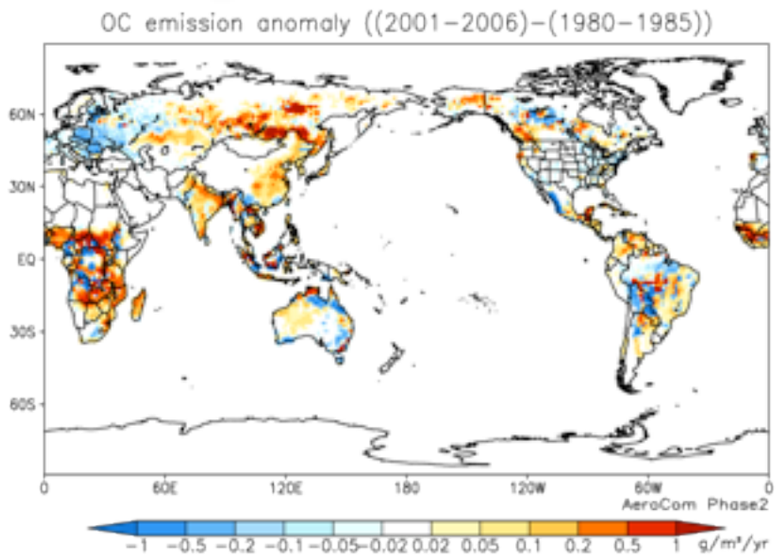


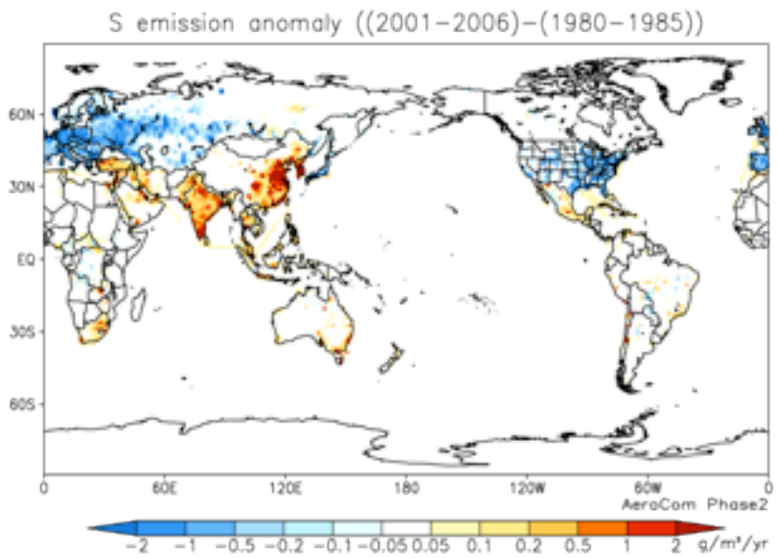




Anomaly of annual emissions







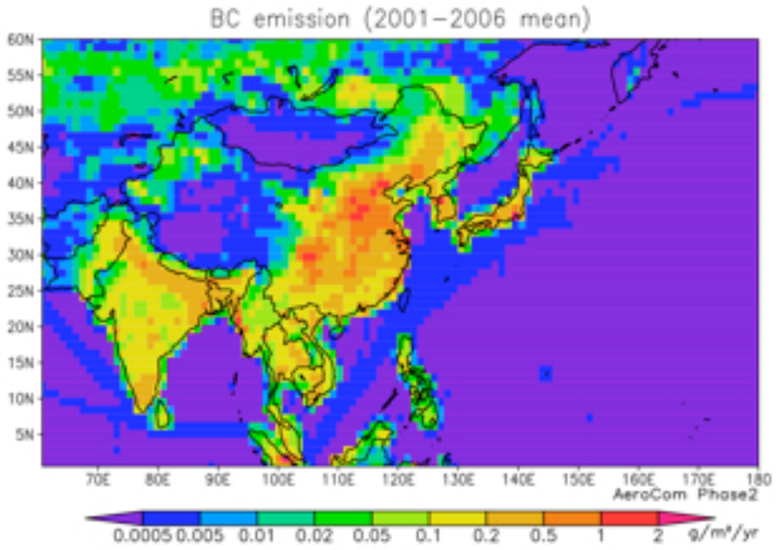
Asian emission inventories in AeroCom Phase II

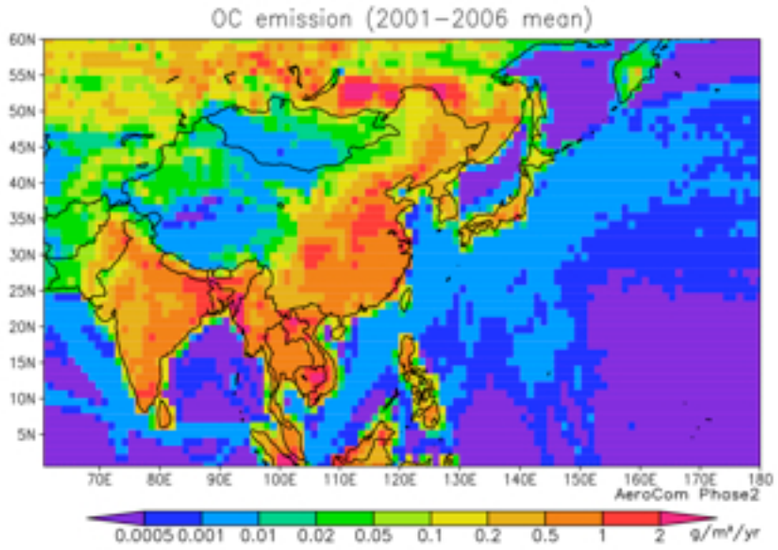
BC

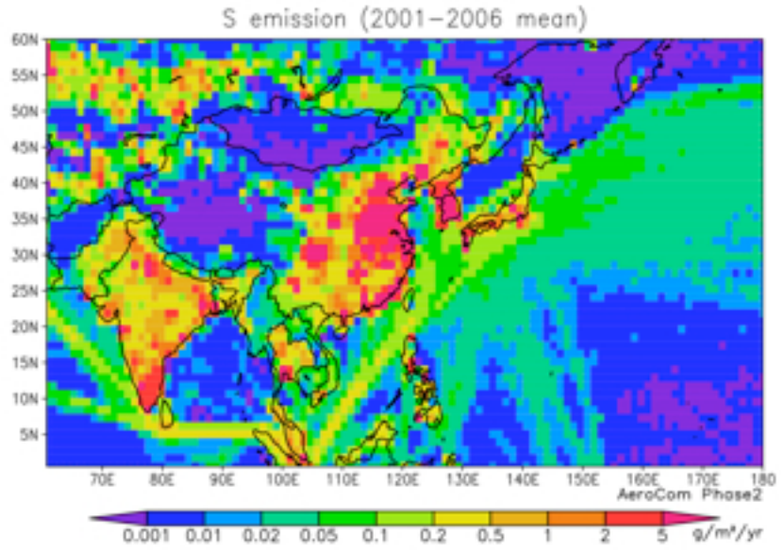
OC

S

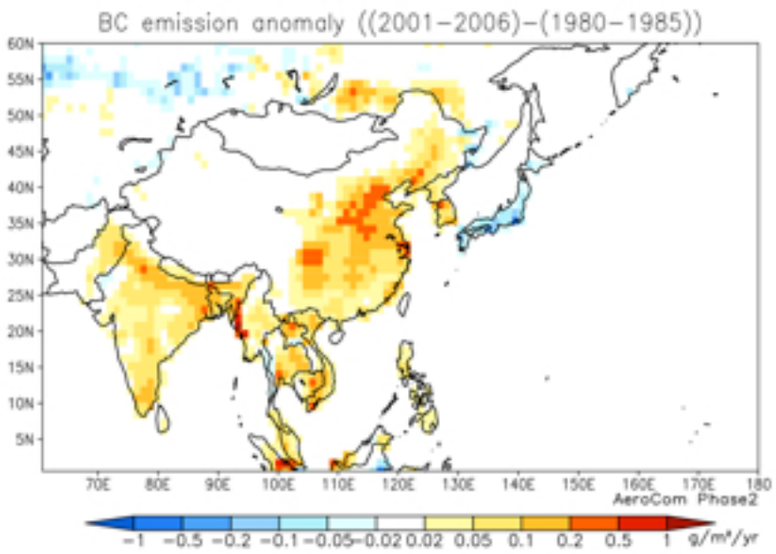
Annual emissions

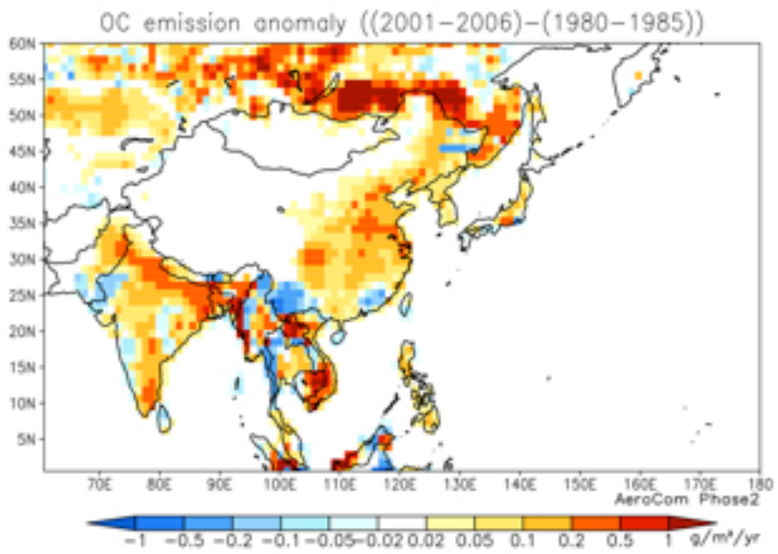


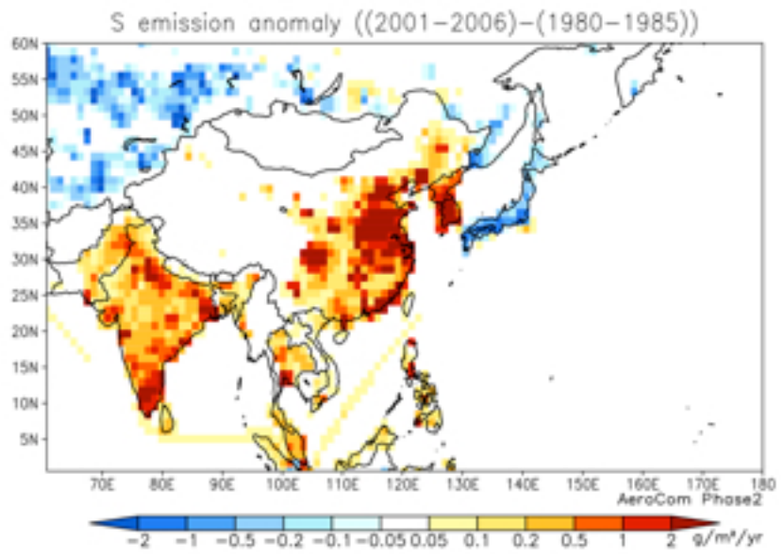




Anomaly of annual emissions







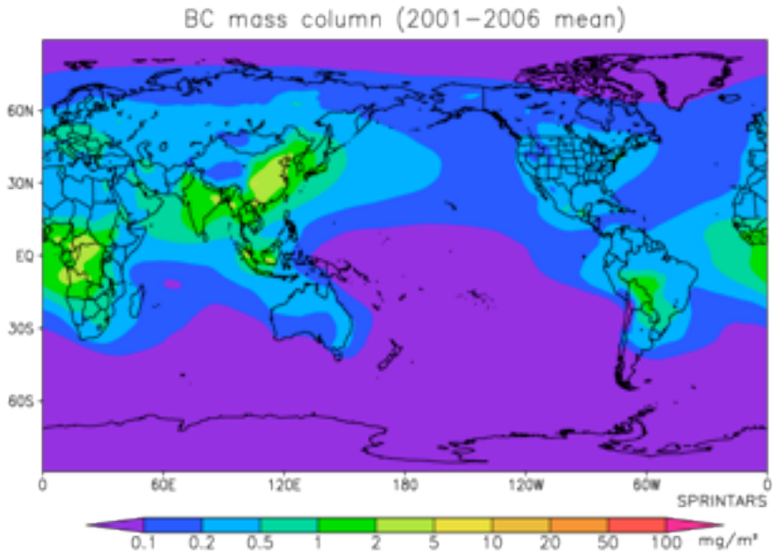
Global distributions of each aerosol component

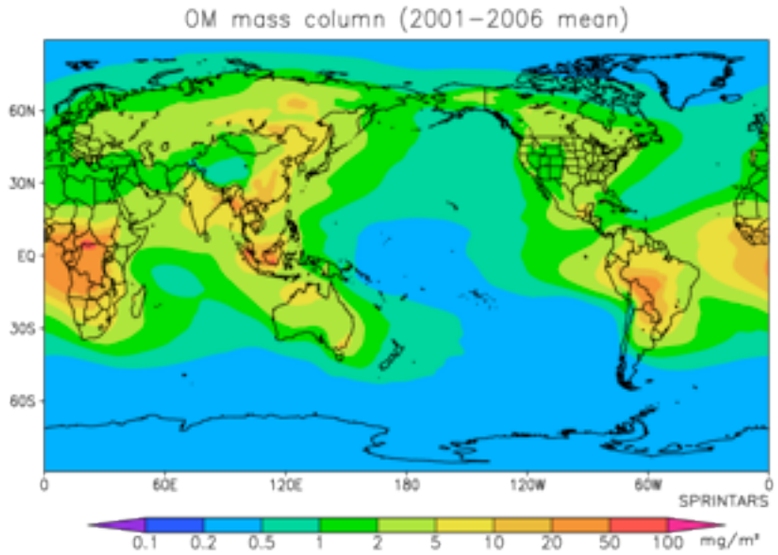
BC

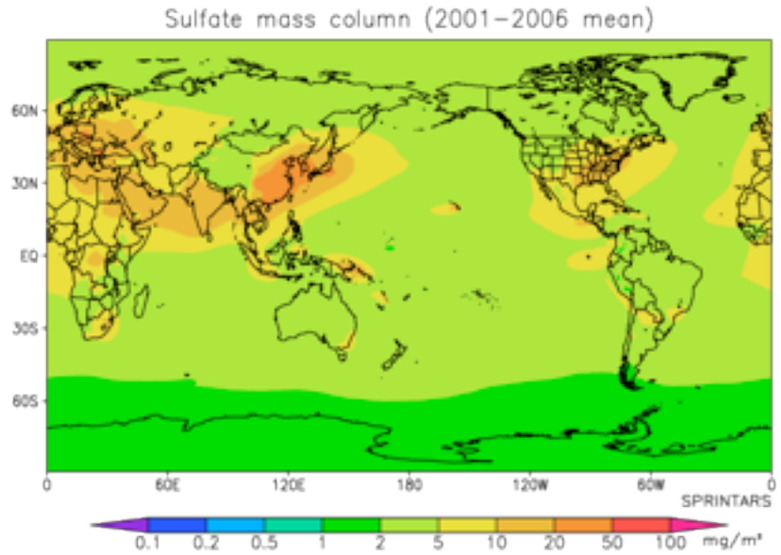
OC

Sulfate

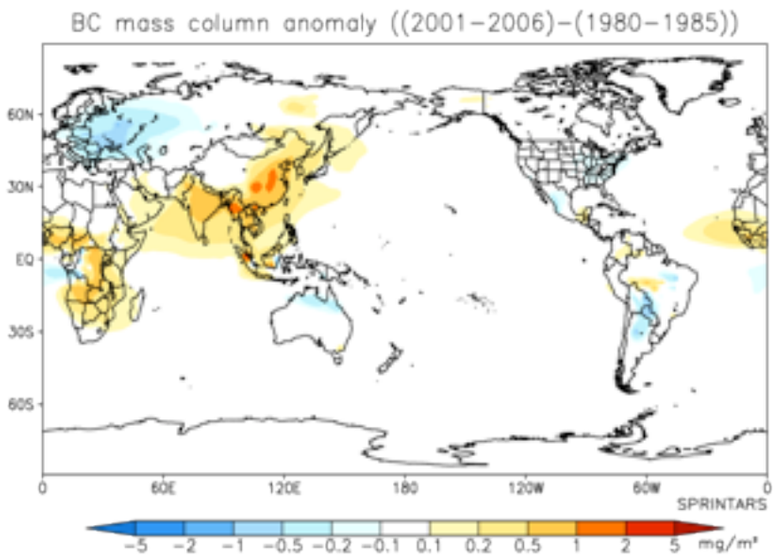
Annual mean mass column loading

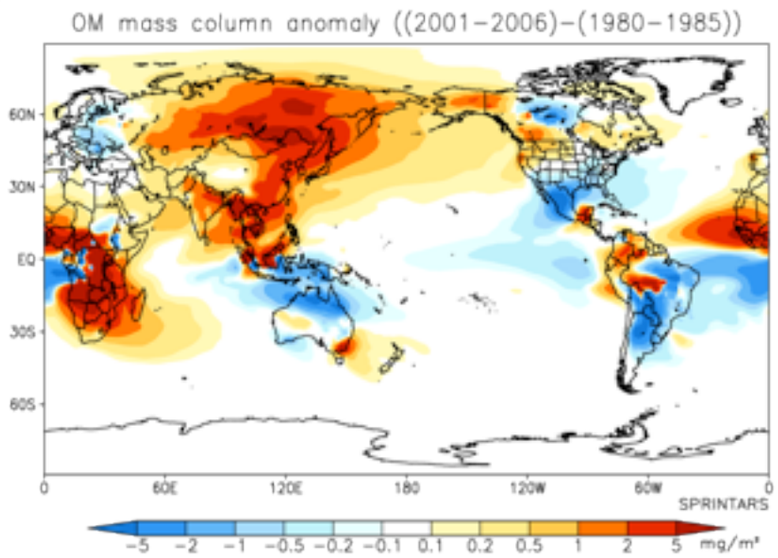


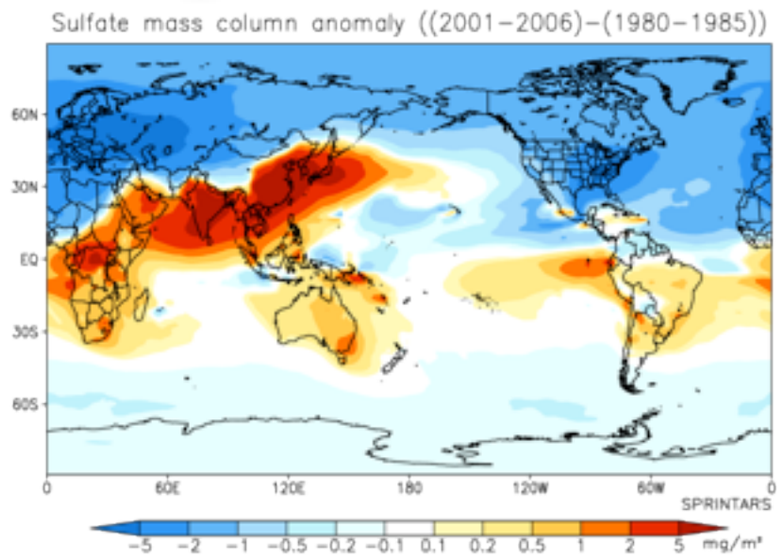




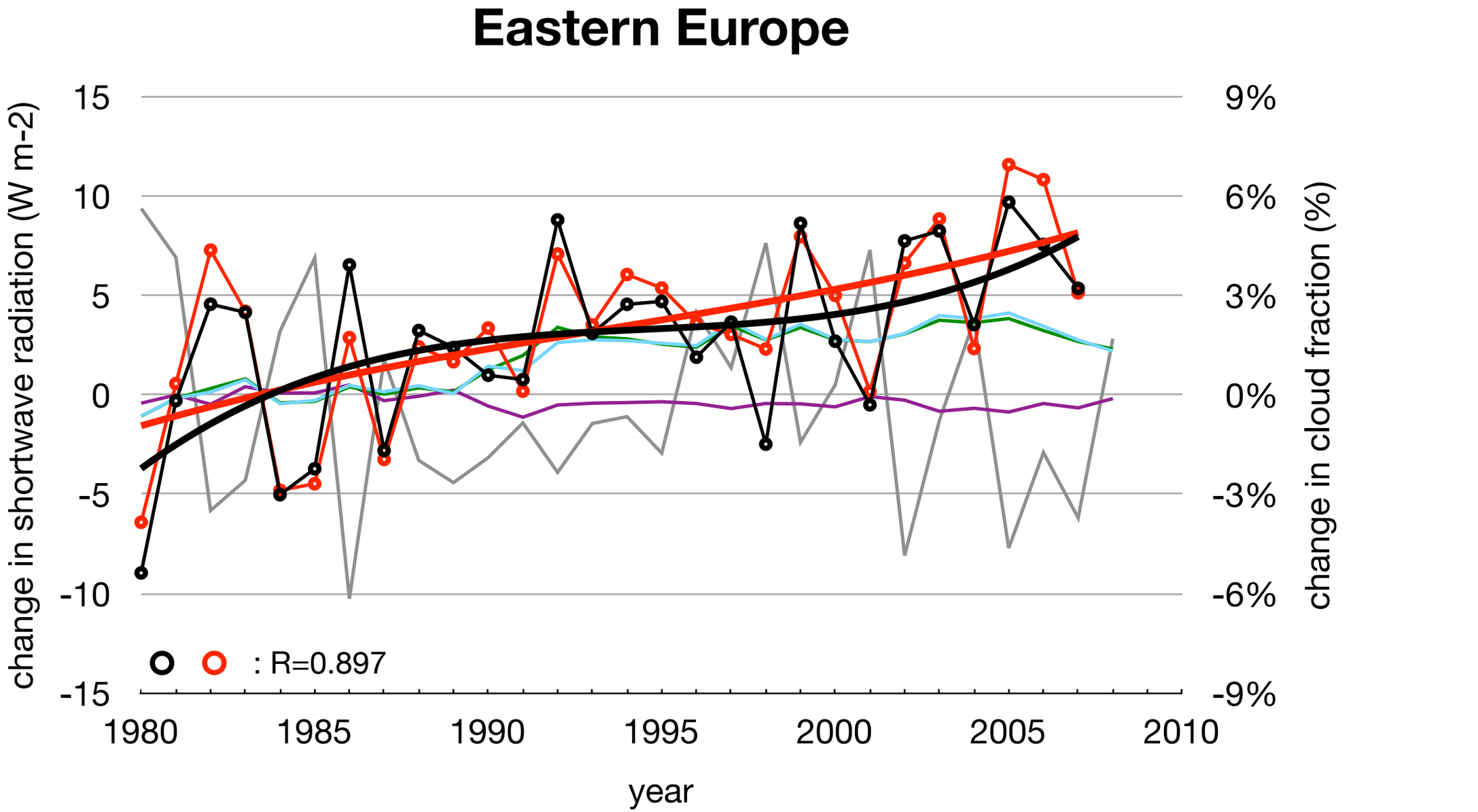
Anomaly of annual mean mass column loading







Regional trend of surface shortwave radiation



* *Observational data provided by Global Energy Balance Archive (GEBA) from Prof. A. Ohmura (ETH).*

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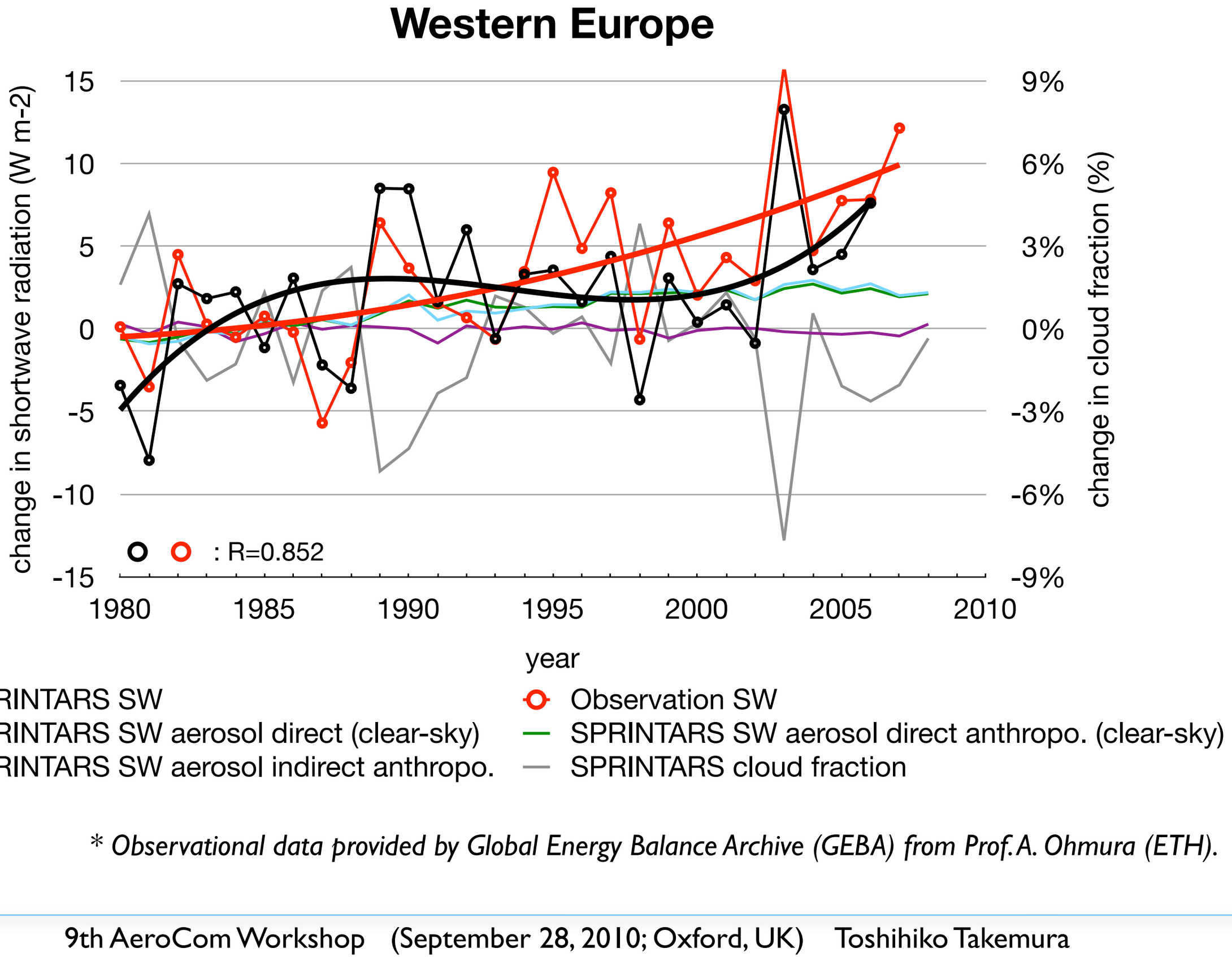

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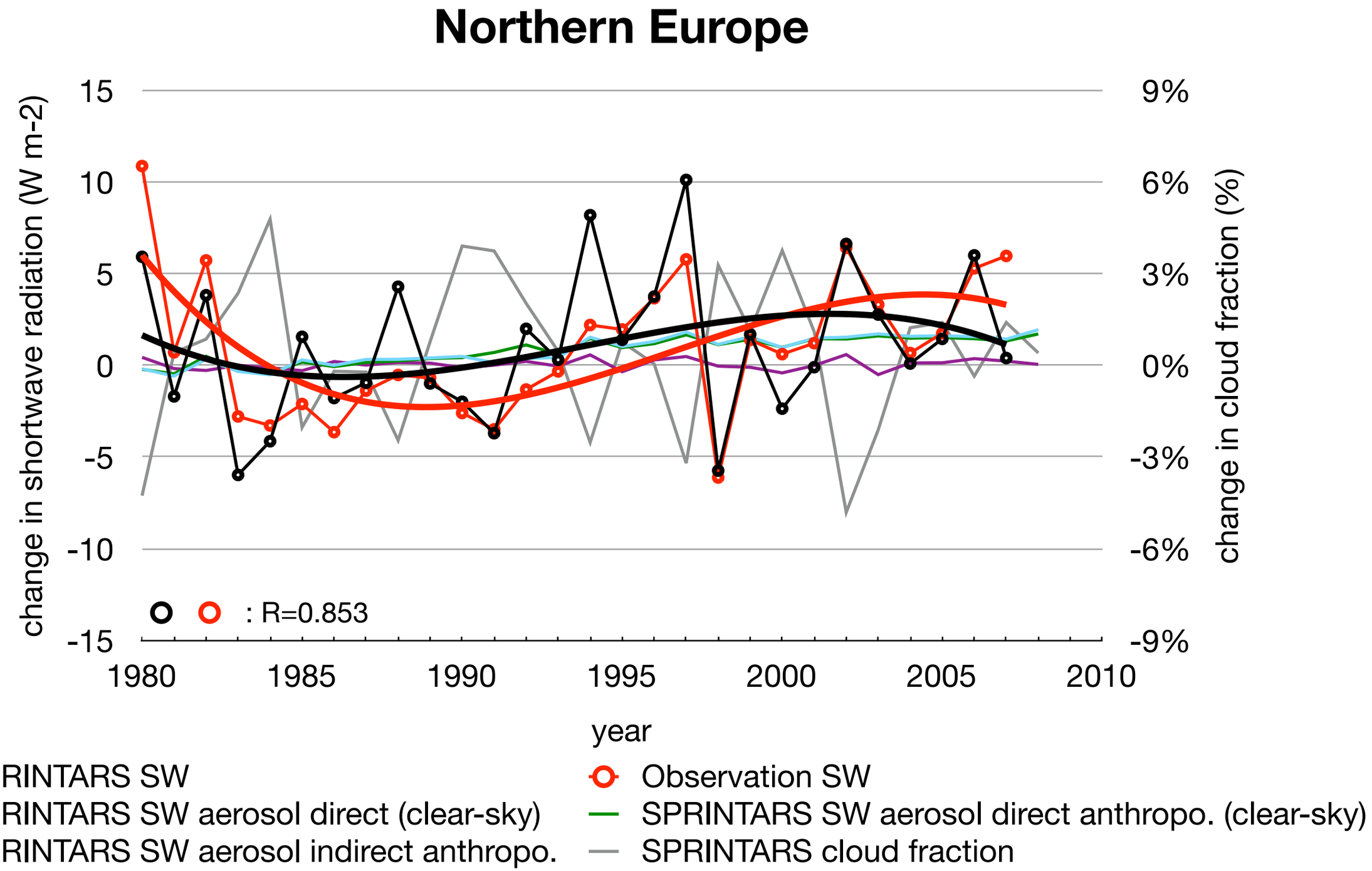

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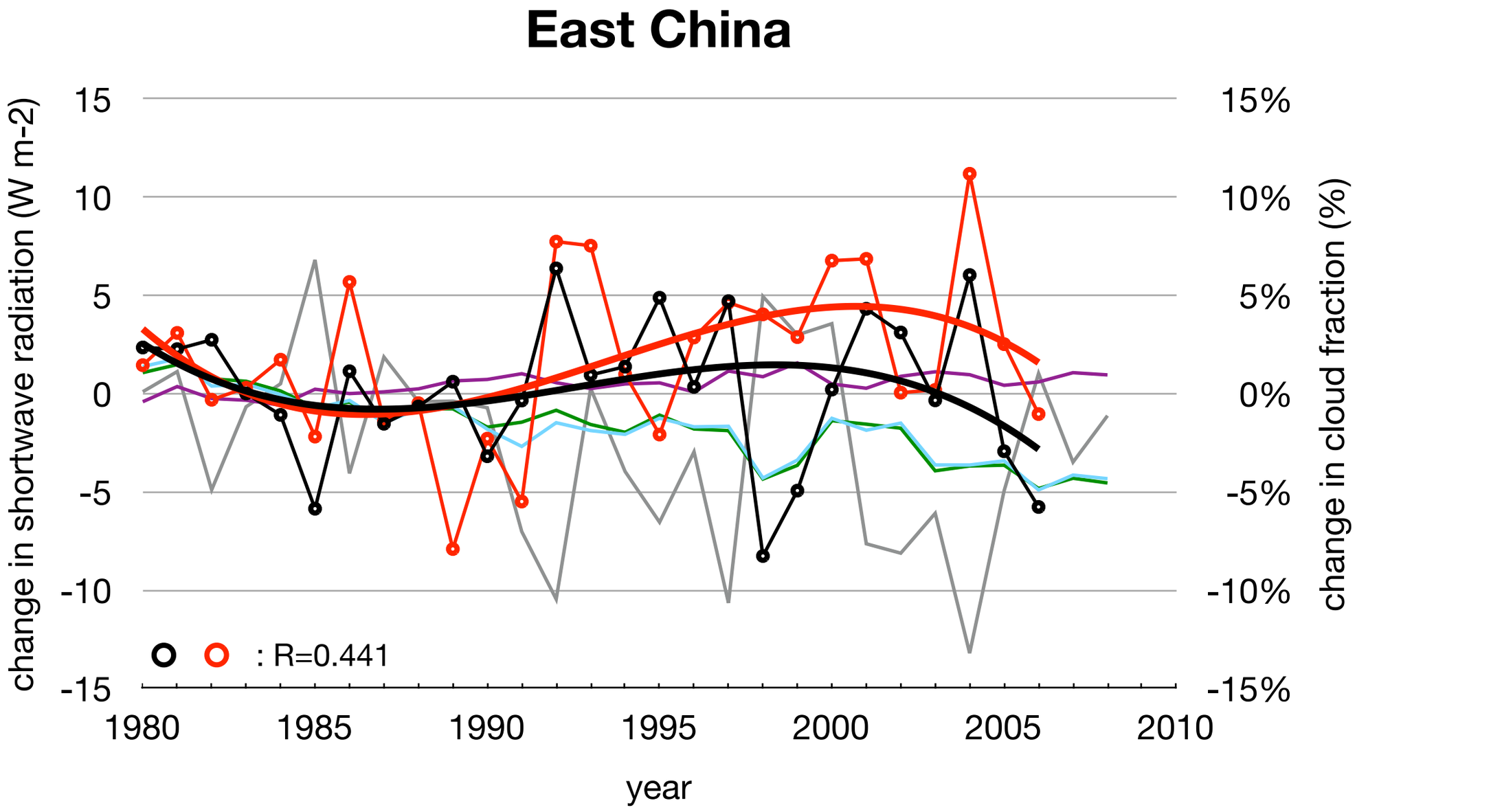

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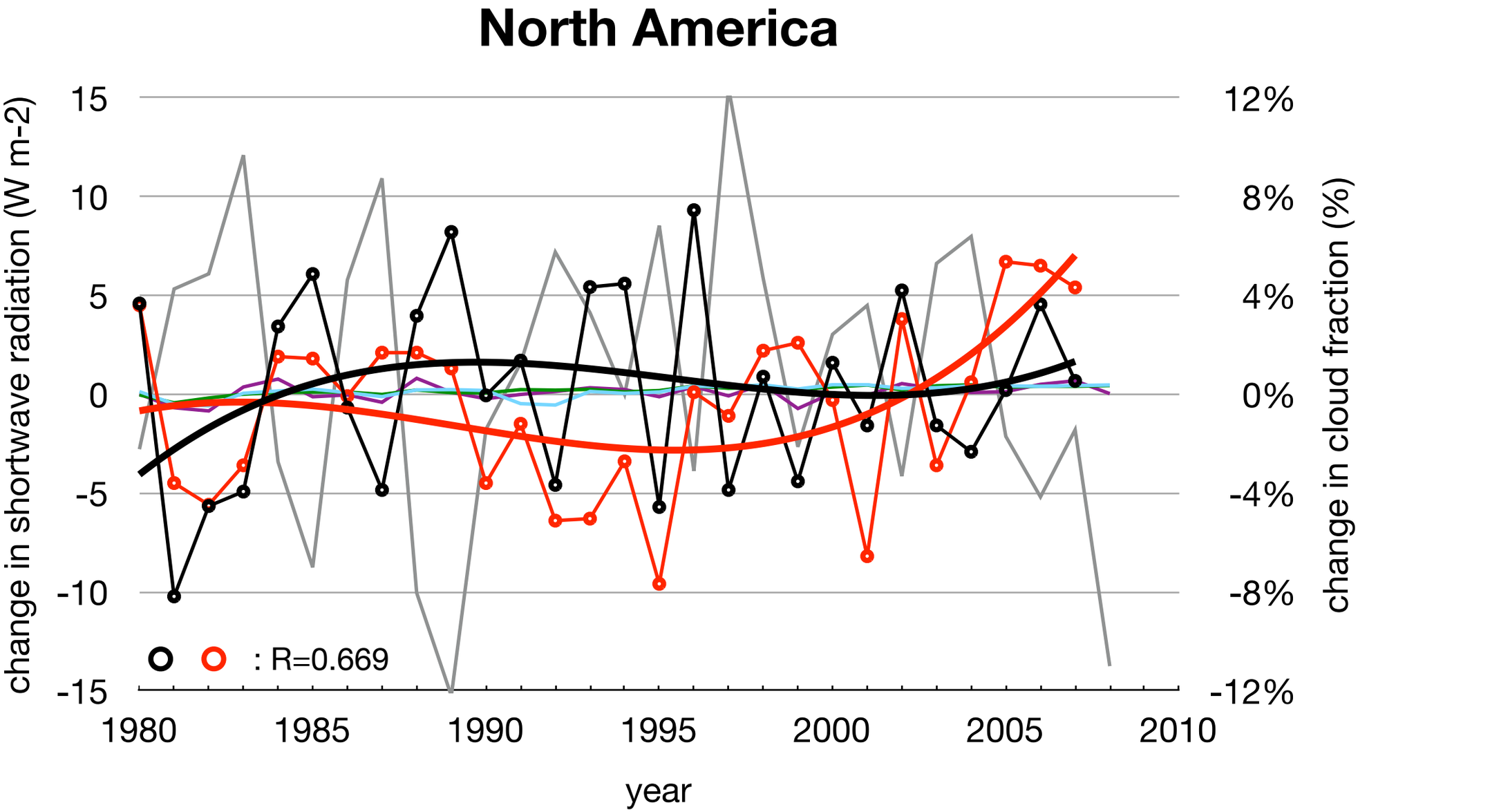

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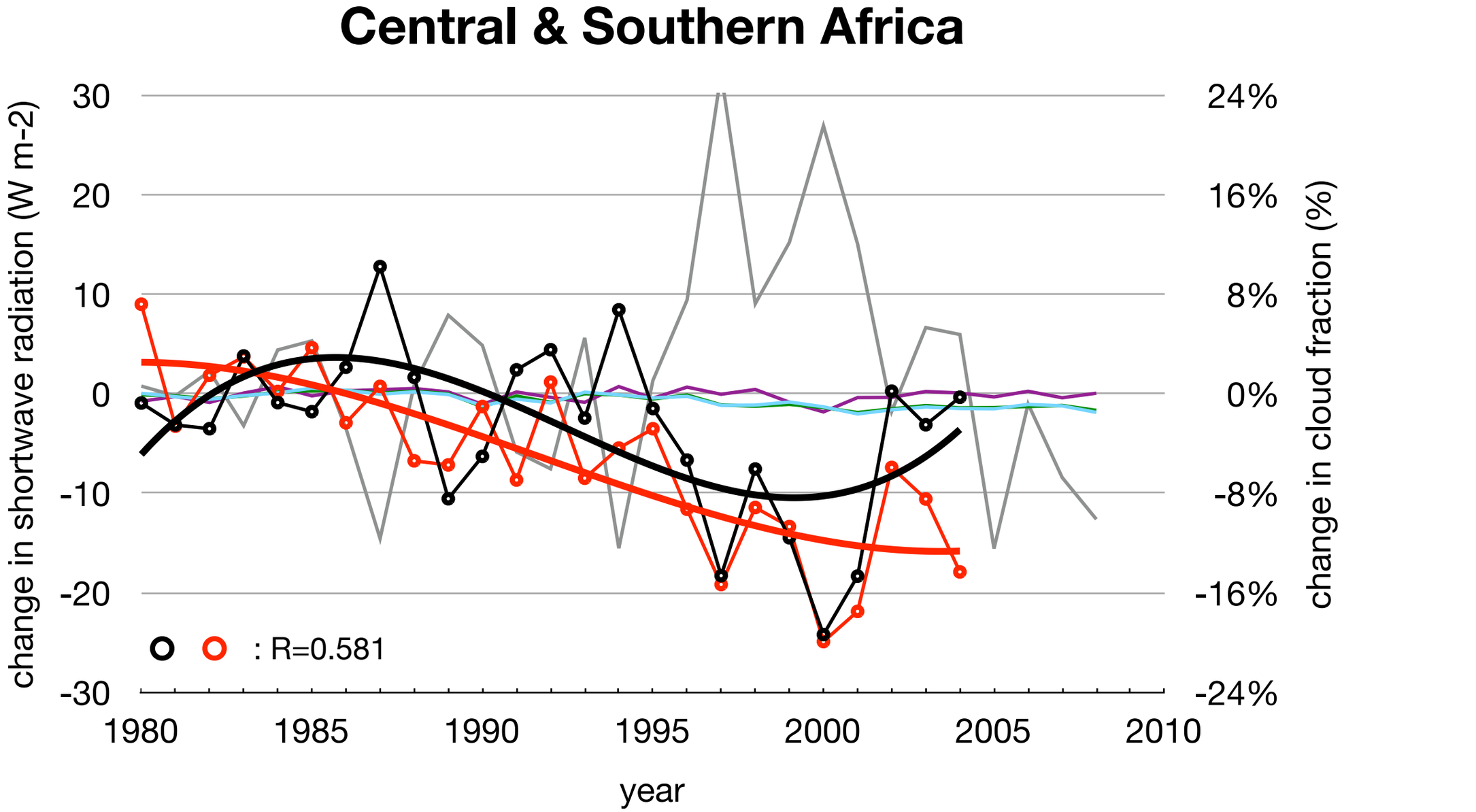

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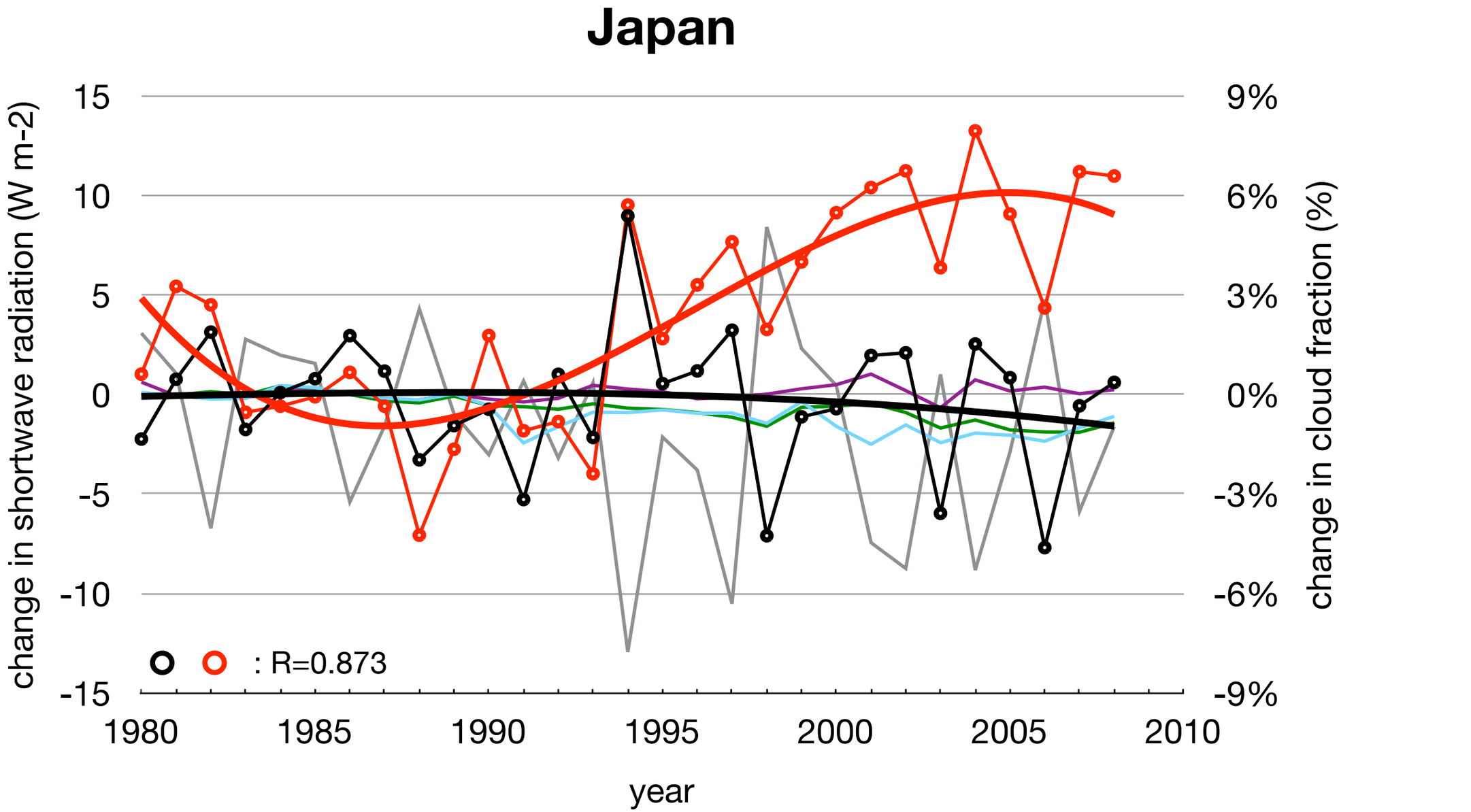

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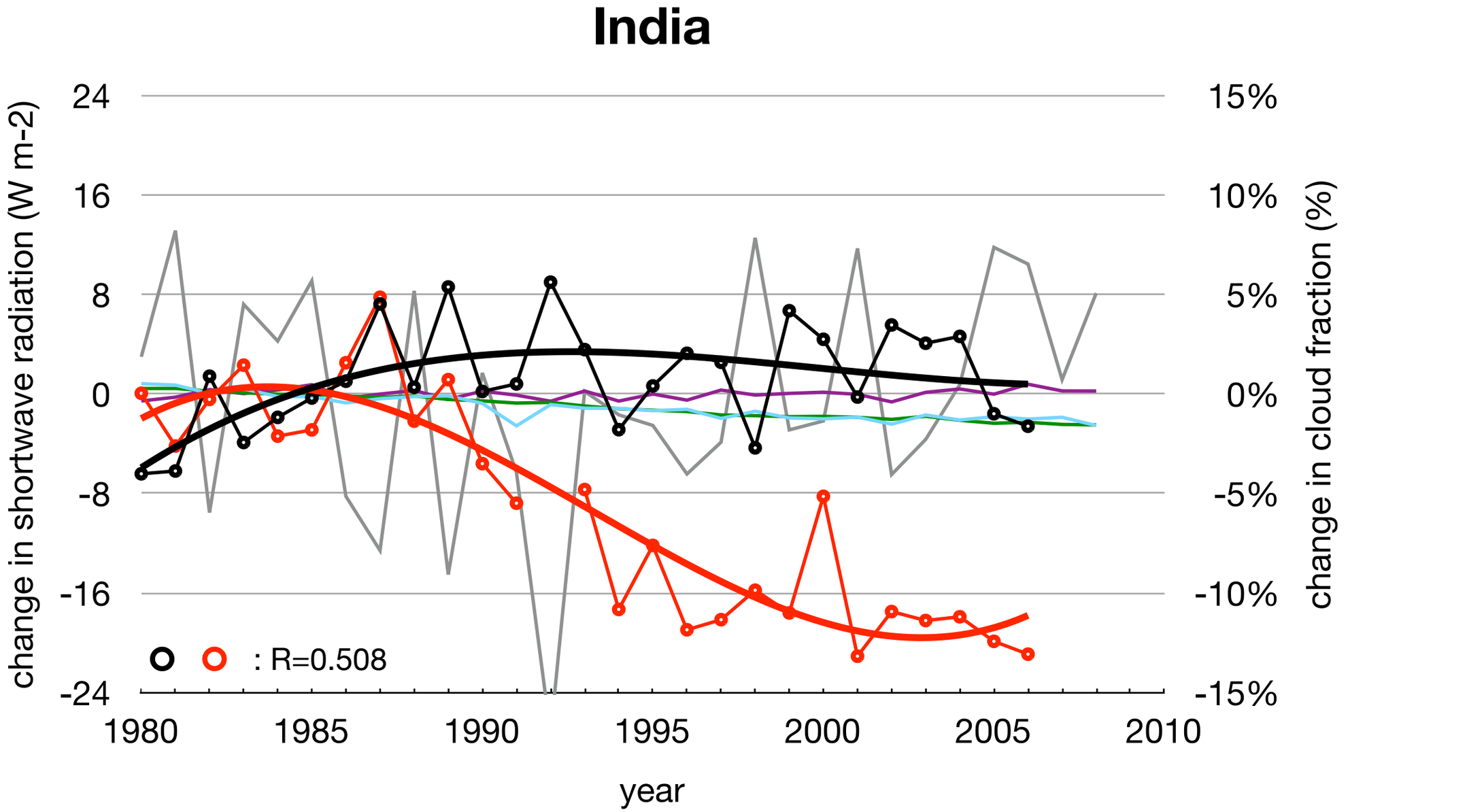

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Conclusions

- Hindcast simulation from the year 1980 to the present with an aerosol climate model, SPRINTARS, based on the AeroCom phase II protocol, comparing with observed long-term data of the surface solar irradiance.
- Year-to-year variations of the surface solar radiation strongly related to cloud fraction.
- Decadal trends of the surface solar radiation related to aerosol direct radiative forcing.
- Significant differences between the simulation and observations in some regions/ periods.
  - ➡ problems in emission inventories? model physics / parameterization?
  - ➡ need of multi-model / multi-inventory intercomparisons

Acknowledgments

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