Multi-decadal variation of atmospheric aerosols and their effects on surface radiation

Mian Chin[1], Thomas Diehl[1,2], David Streets[3], Martin Wild[4], Hongbin Yu[1,5], Stefan Kinne[6], Qian Tan[1,2], Huisheng Bian[1,7]

[1]NASA Goddard Space Flight Center, USA [2]Universites Space Research Association, USA [3]Argonne National Laboratory, USA [4]ETH Zurich, Switzerland [5]University of Maryland, College Park, USA [6]Max Planck Institute, Hamburg, Germany [7]University of Maryland, Baltimore County, USA [8]NOAA NCEP, USA

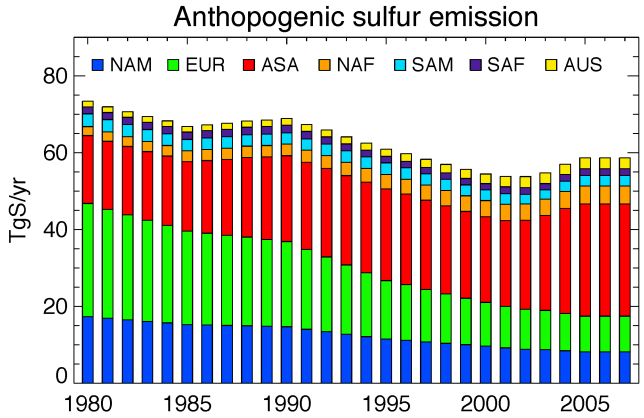
Introduction

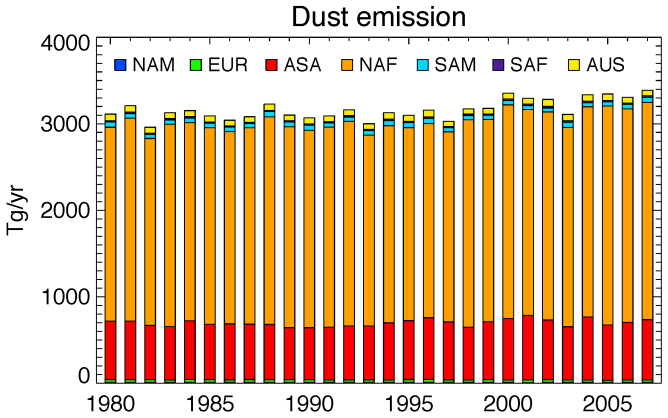
- Long-term observations of downward solar radiation at the surface have shown a wide-spread trends from dimming to brightening in the past 50+ years over different regions of the world
- Various explanations have been given, with special attention given to aerosols since the anthropogenic emission trends of aerosol and precursor gases mirror the change of surface radiation
- **This work attempts to answer one question: What is the role aerosol play in the "dimming/brightening" trend?**

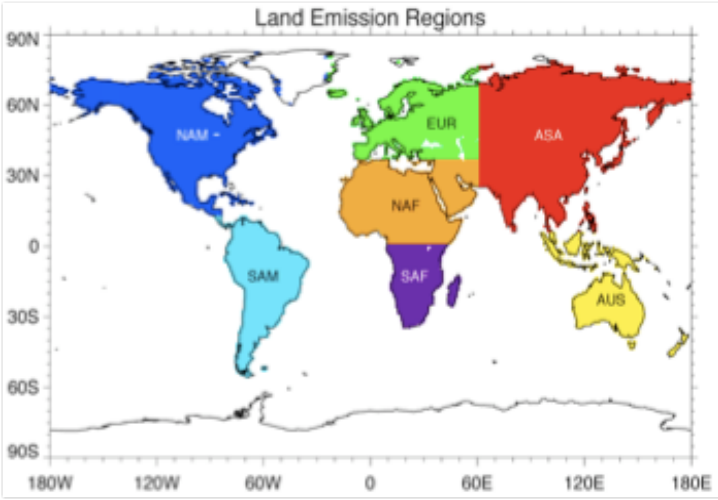
Model and observations used in this study

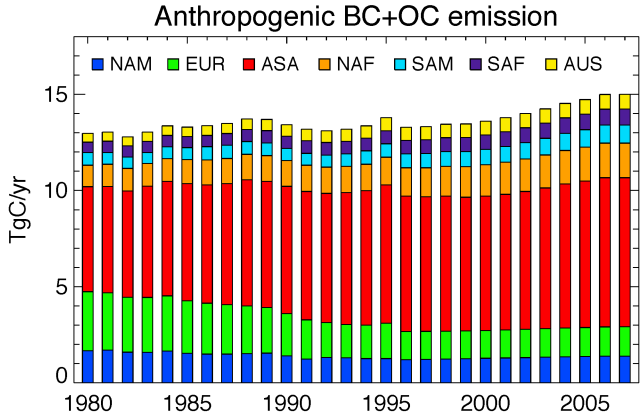
- Model:
  - GOCART – global CTM using assimilated meteorology from GEOS-DAS (version 4), with sulfate, dust, BC, POM, and sea salt and their radiative properties simulated
  - Shortwave radiative fluxes calculated from the Goddard Radiative transfer model
- Satellite-based data products:
  - Global satellite-based surface SW downward radiation data from the International Satellite Cloud Climatology Project (ISCCP) and Surface Radiation Budget (SRB), monthly average, total downward radiation, all sky/clear sky
- Surface radiation measurements:
  - Baseline Surface Radiation Network (BSRN), daily, total/ diffuse/direct radiation, all sky/clear sky)
  - China Meteorological Administration (CMA), daily, total/ diffuse/direct radiation, all sky/clear sky)

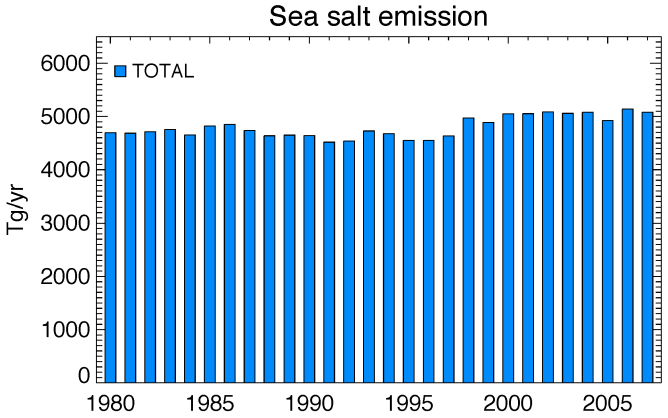
Anthropogenic and natural emissions of aerosols and precursors – 1980 to 2007

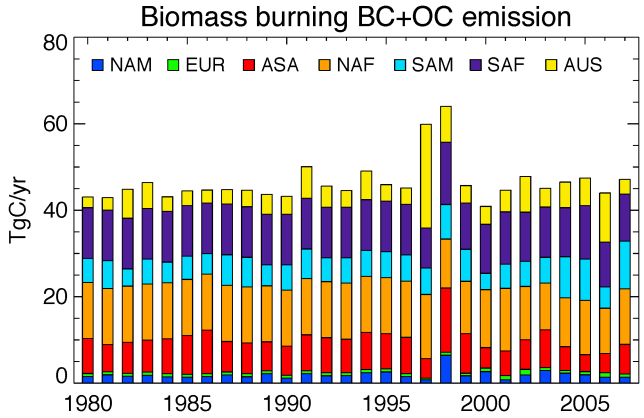


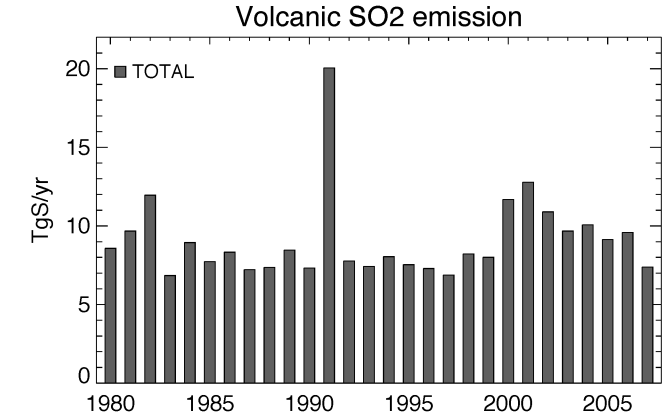












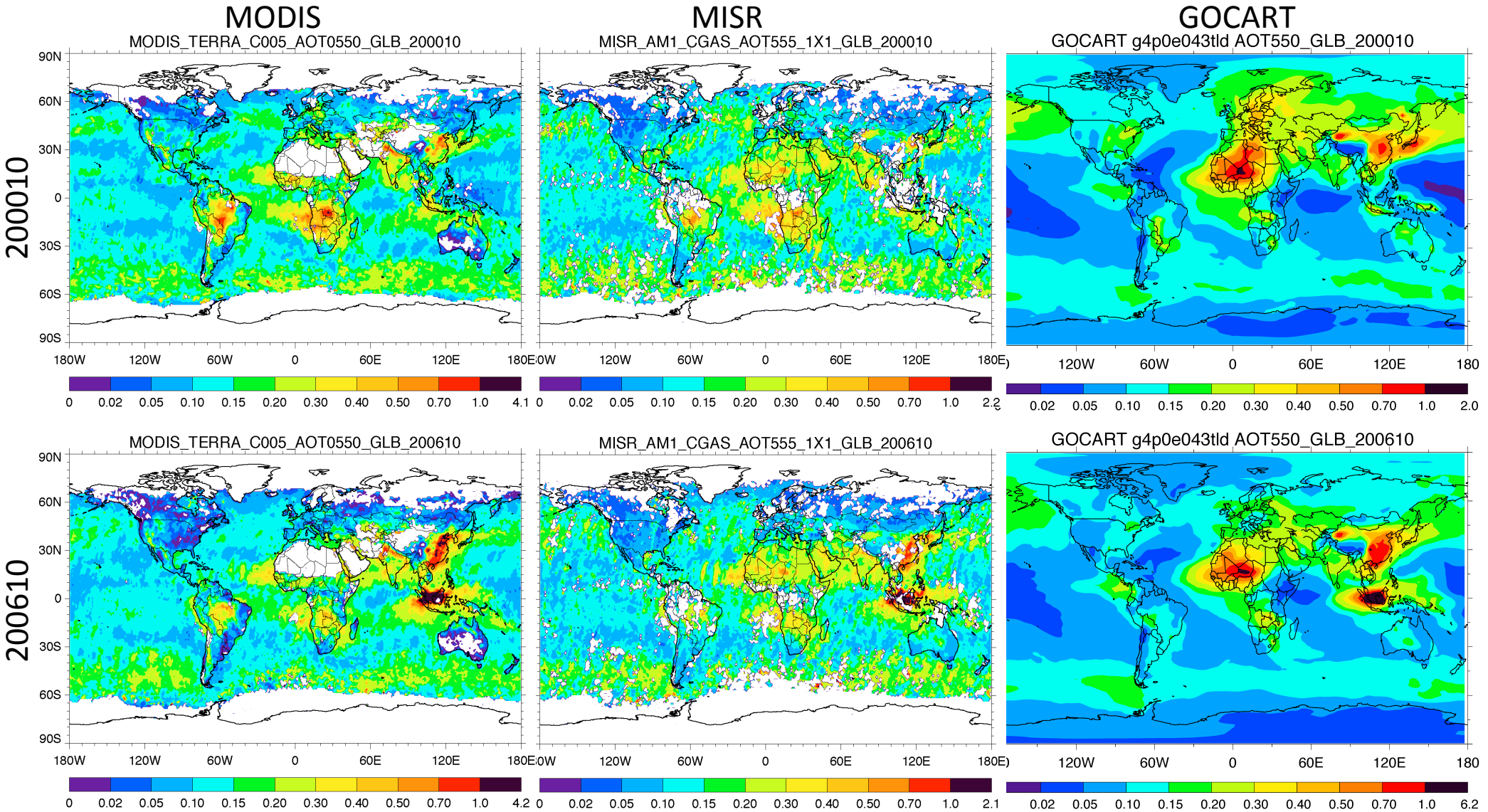
Anthropogenic emission:

- Decreased over North America and Europe, increased over Asia and other regions

Biomass burning and natural emissions:

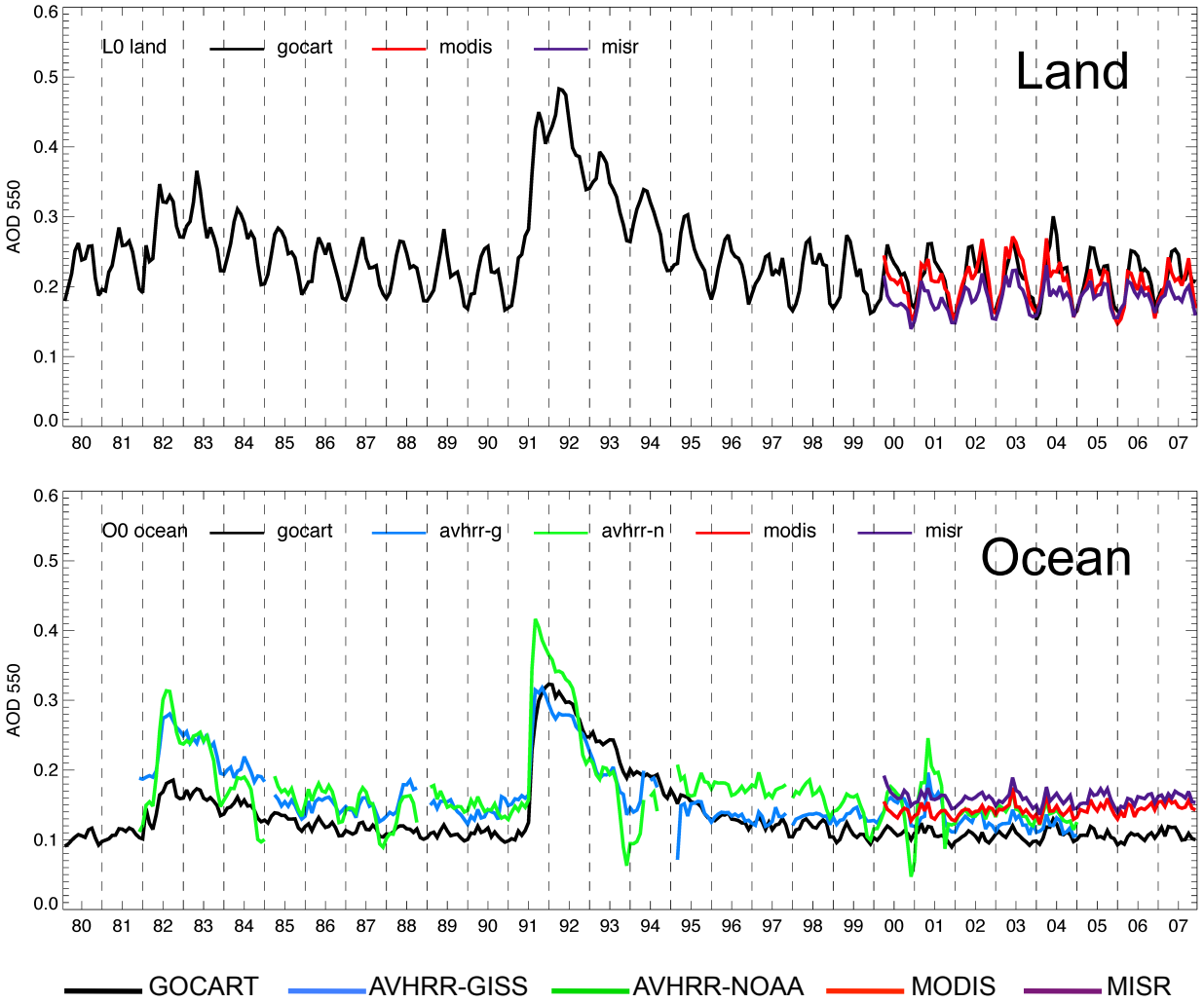
- Varying from year to year (and place to place)

Global distribution of AOD



Multi-year variation of AOD

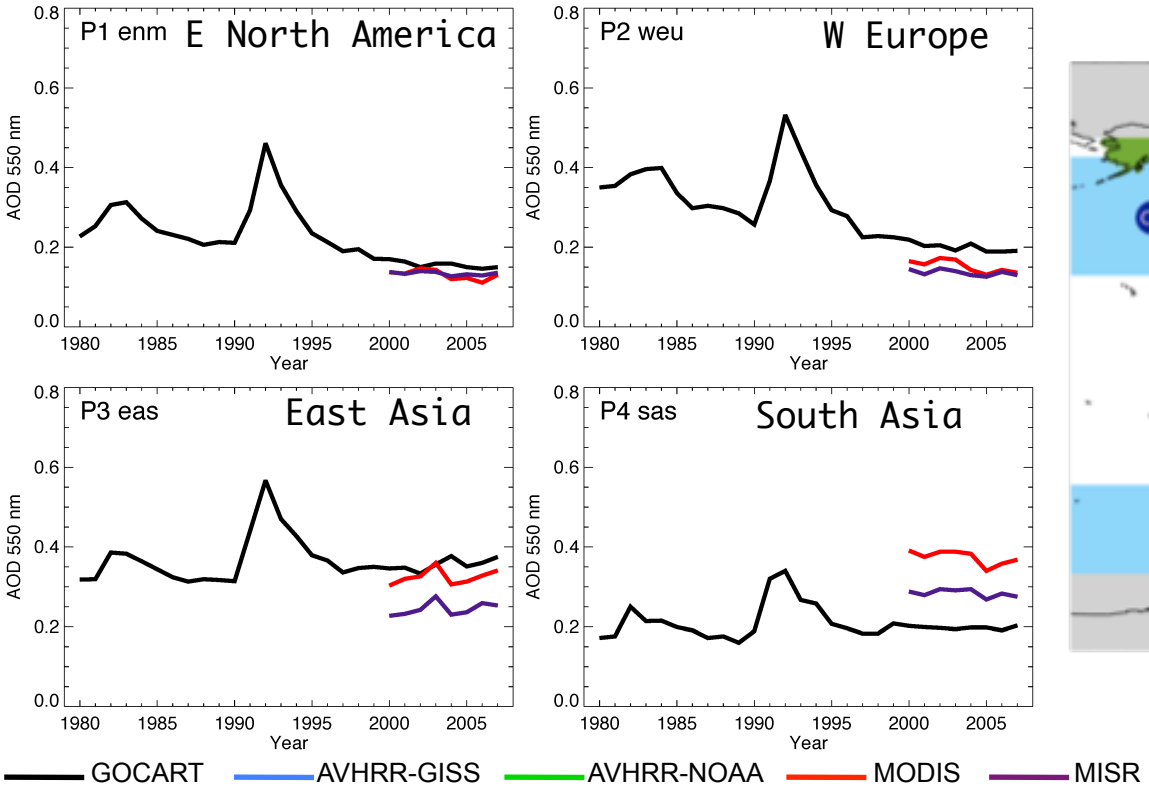
Comparison of monthly average AOD over land and ocean

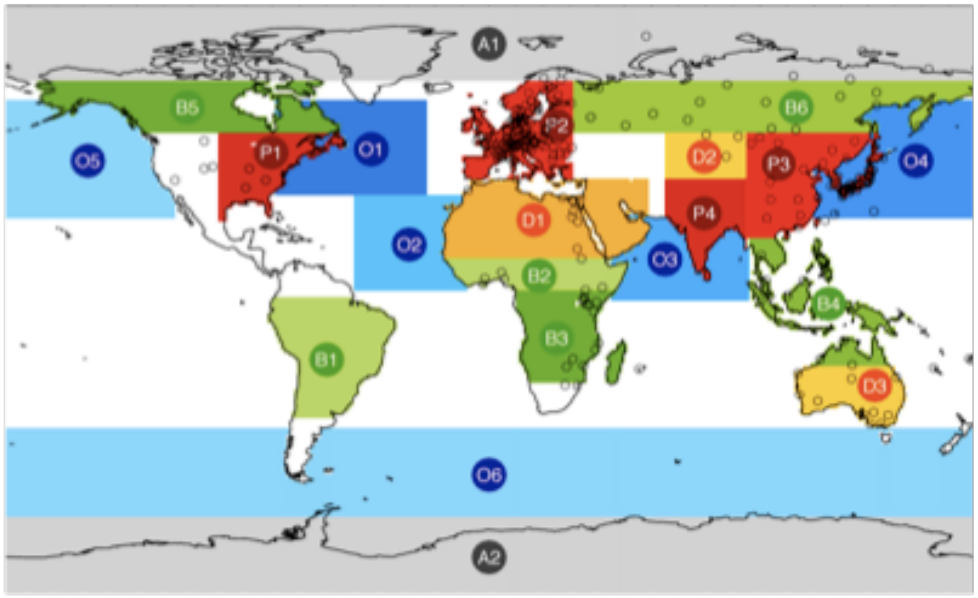


- Over land: Model simulated AOD agrees with MODIS and MISR
- Over ocean: model is in general lower than satellite data
- There are also differences among different satellite datasets

AOD trends over pollution source regions

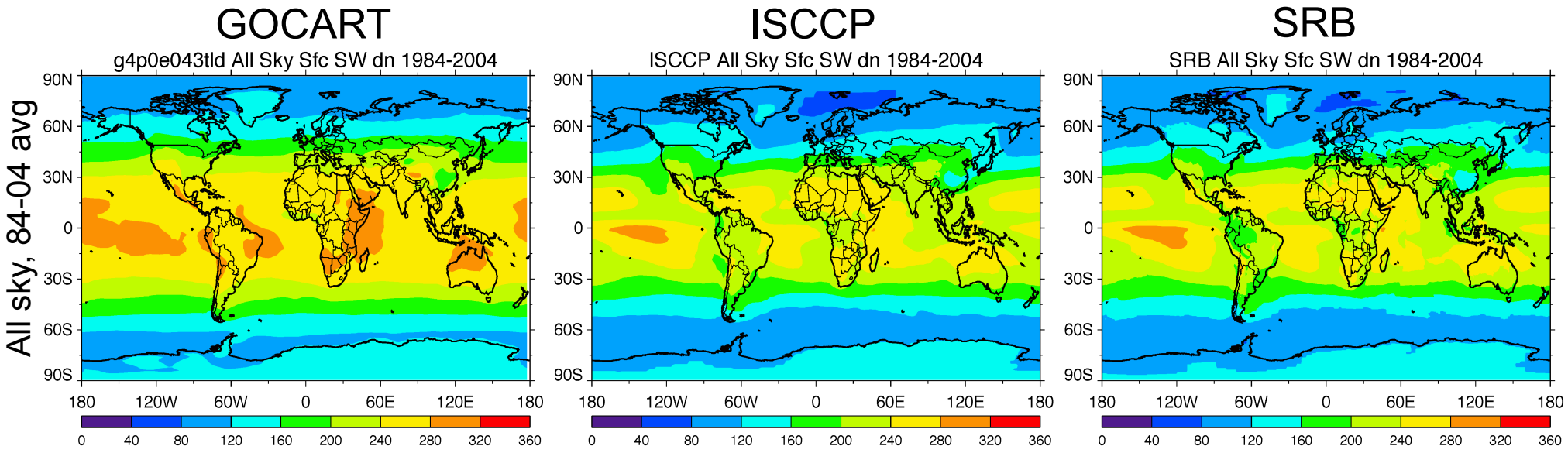
AOD trends over pollution regions (de-seasonalized)





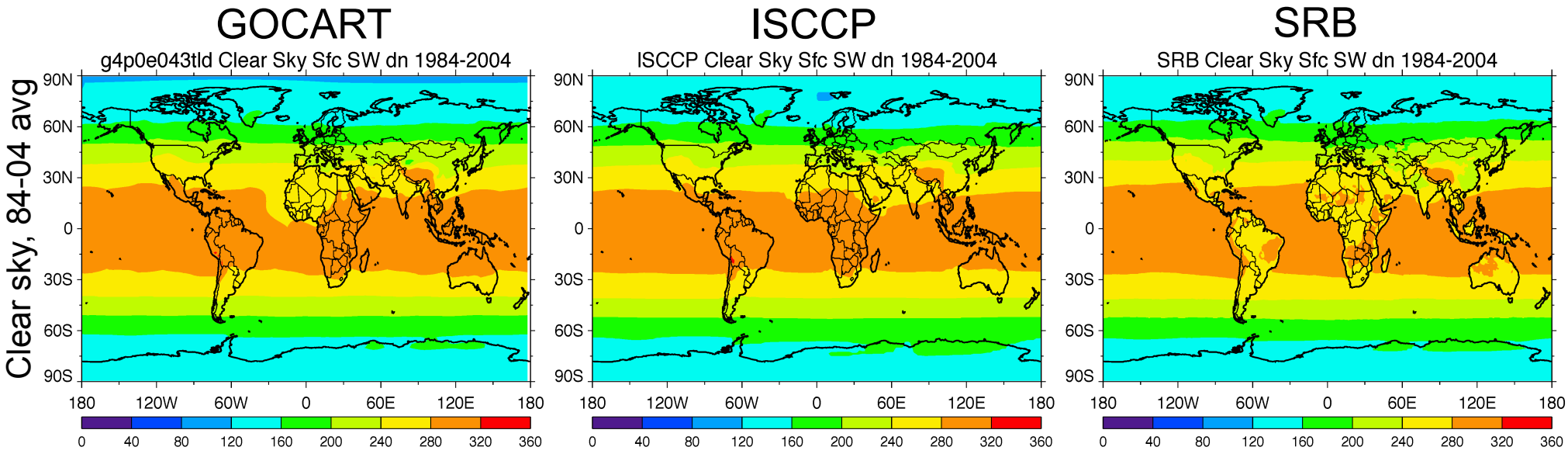
- Over E North America and Europe: AOD decreasing
- Over E Asia: AOD increasing
- El Chichon and Pinatubo volcanoes have large global influences
- Modeled AOD is much lower than MODIS and MISR over S Asia

Climatology (1984-2004) of SW downward radiative flux at surface – All sky



– Under all sky condition, model calculated surface SWDF is about 20 – 60 W m^{-2} higher than that from ISCCP and SRB, most likely because of the difference in cloud fields

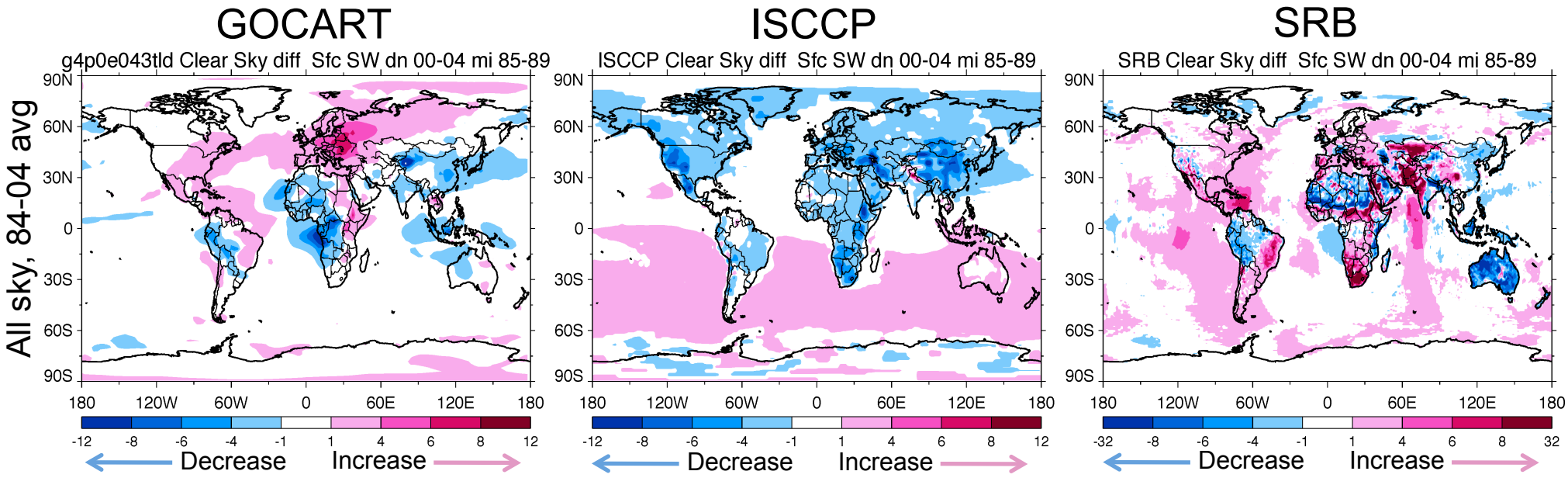
Climatology (1984-2004) of SW downward radiative flux at surface – Clear sky



– Under clear sky condition, the model agrees with ISCCP and SRB in most location (Note: clear sky data from ISCCP and SRB are extracted with cloud fraction < 10%)

- In this presentation we will concentrate on clear sky only to isolate the aerosol effects, because the cloud forcing is much larger than aerosols under all sky conditions

Clear sky trend of SW downward radiative flux at surface, [2000-2004] – [1984-1989]

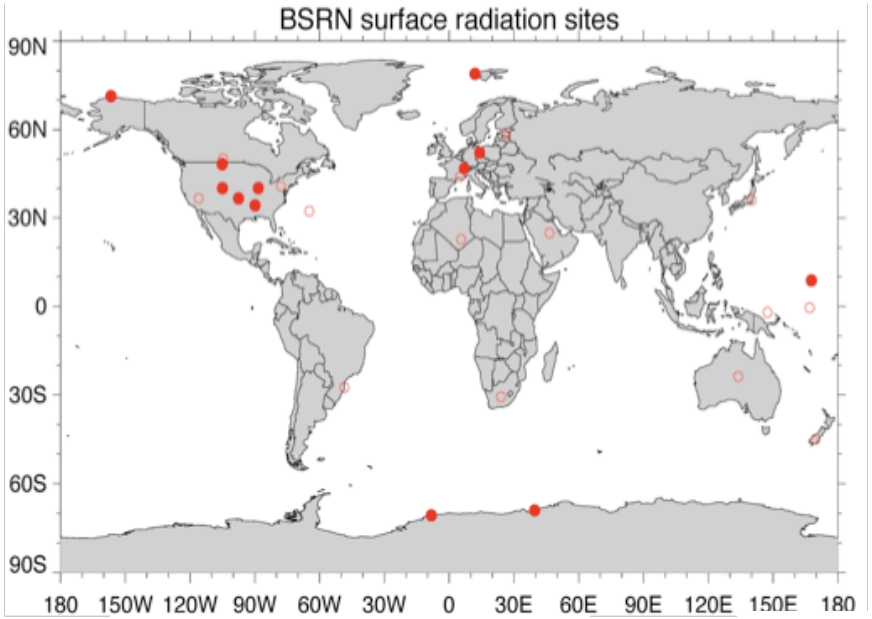


- Model shows brightening over eastern US, Europe, and Eurasia, dimming over Asia, Africa, and NW South America
- SRB shows similar trends as model over land (except in S Africa), but the pattern is quite different over ocean
- ISCCP shows dimming almost everywhere over land and brightening over SH ocean

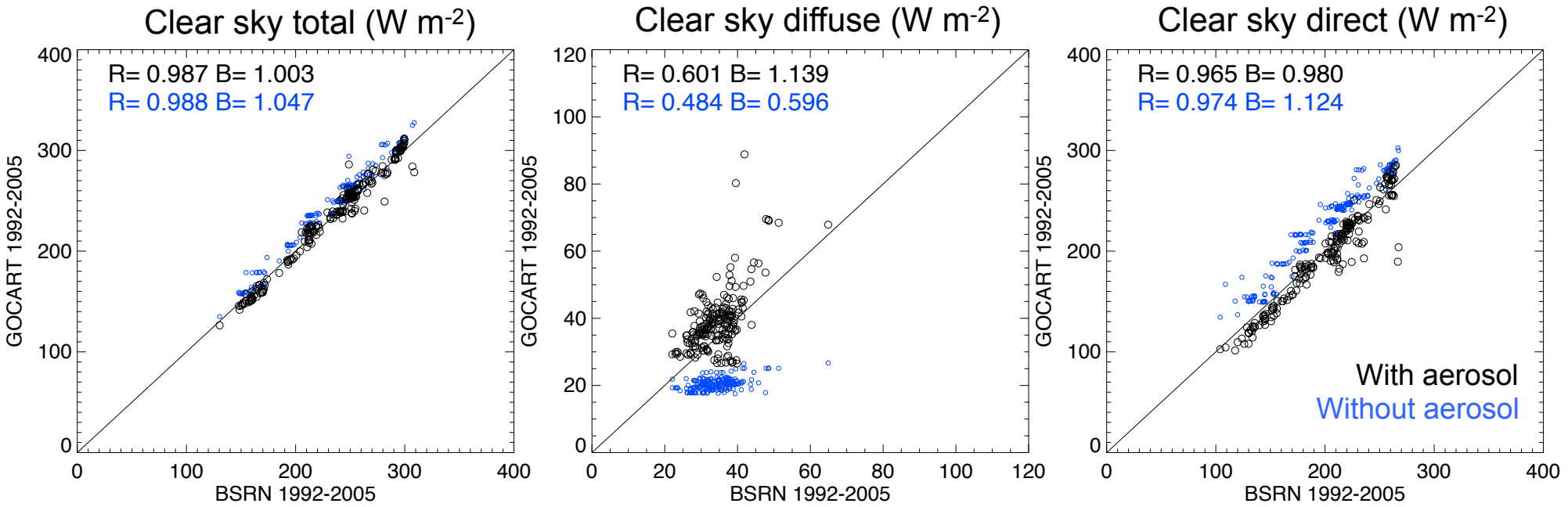
Comparisons with clear sky surface radiative flux data

- Baseline Surface Radiation Network (BSRN):
  - started in 1992, high quality, high frequency (sub-hourly)
  - Separated clear/all and diffuse/direct sky data, but only a few dozens of stations
- China Meteorological Administration (CMA) data:
  - long-term record, daily
  - Separated diffuse/direct data; clear sky data extracted at cloud fraction < 10%
  - Needed data screening to remove suspicious data

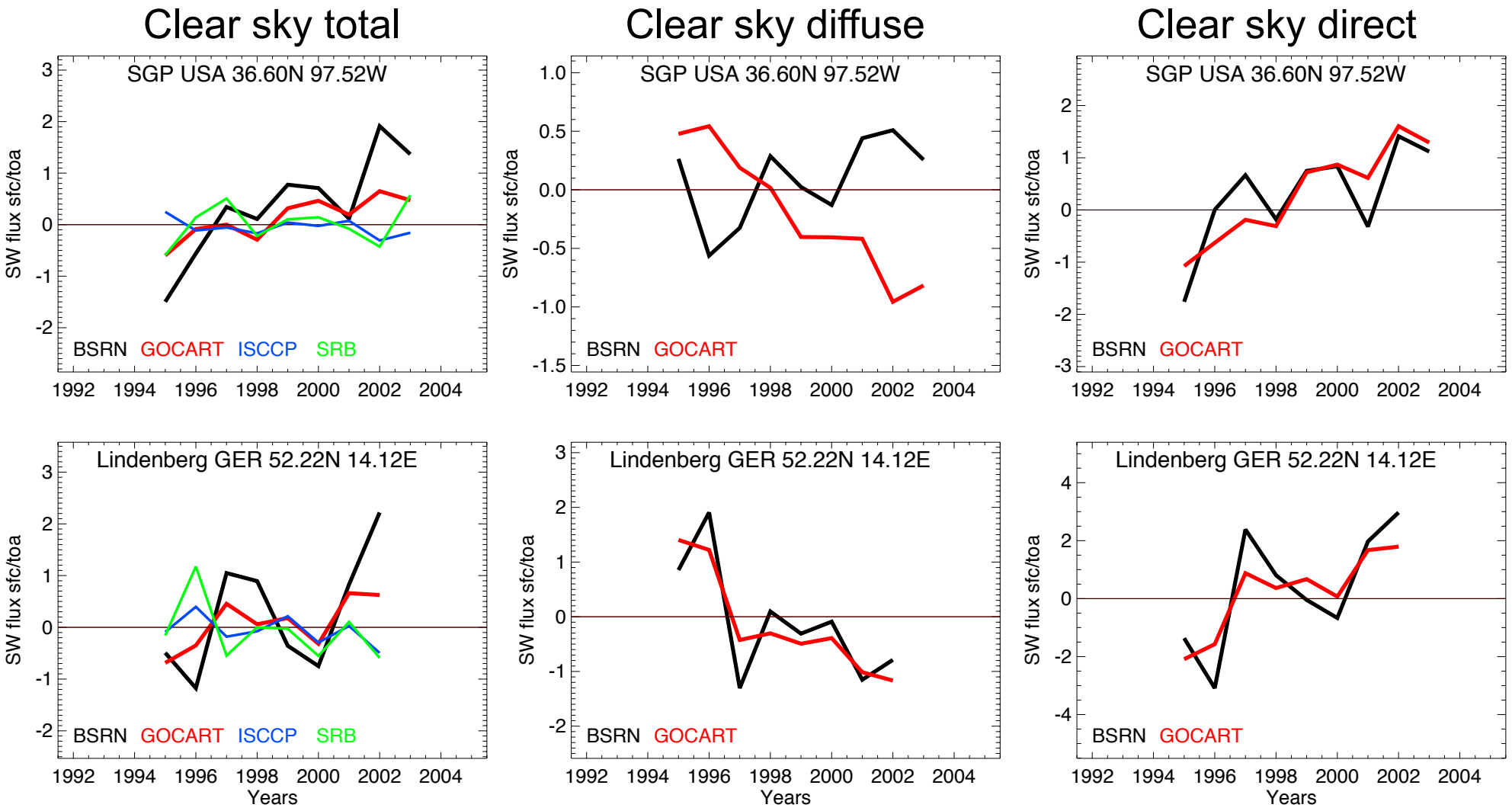
Comparisons with clear sky surface measurements - BSRN



- 28 high frequency measurement sites since late 1992
- 12 sites with the most continuous and longest data records
- Monthly average data (from Stefan Kinne) used here

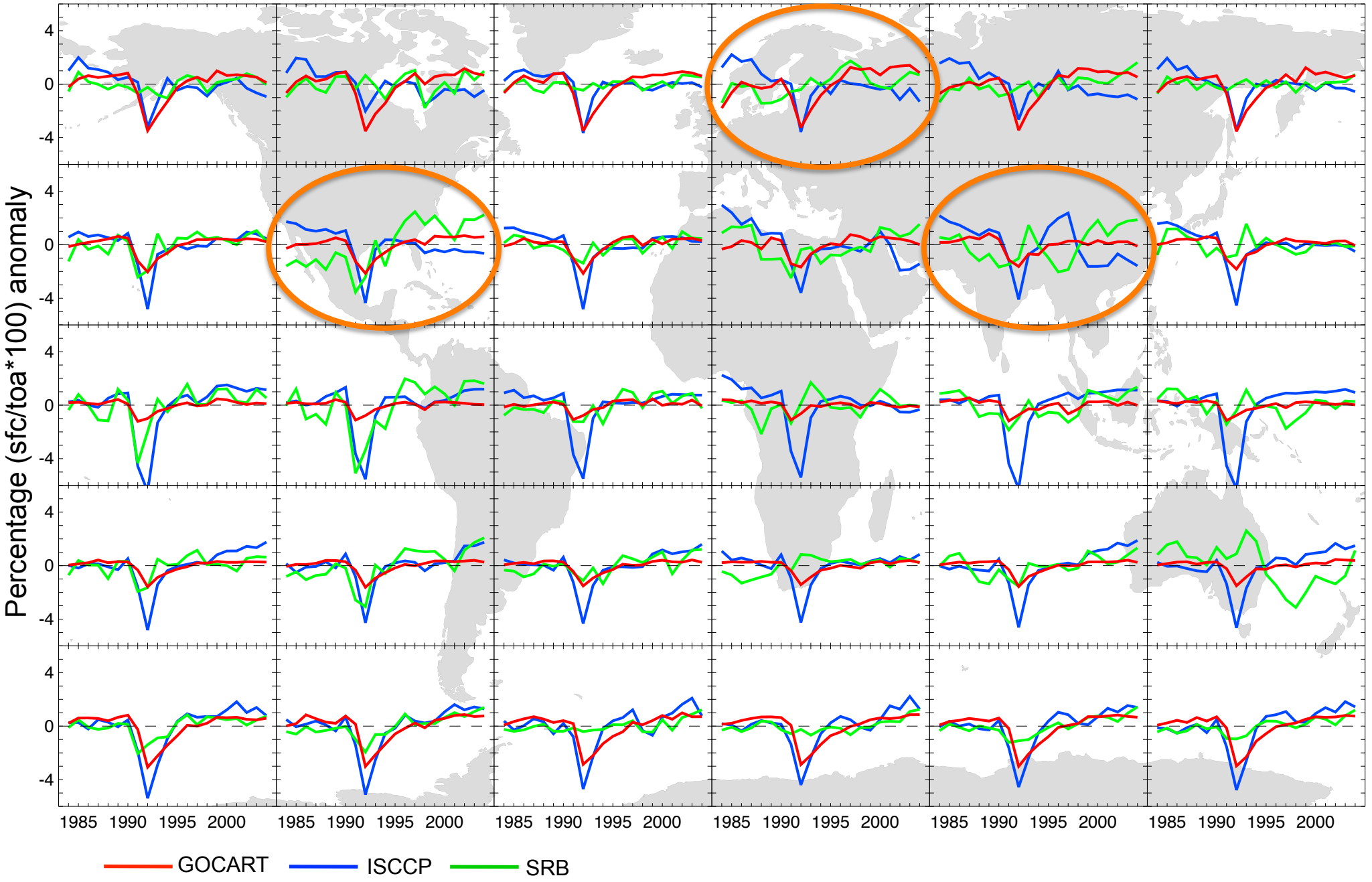


Anomaly of downward surface radiation at Oklahoma, USA and Lindenberg, Germany

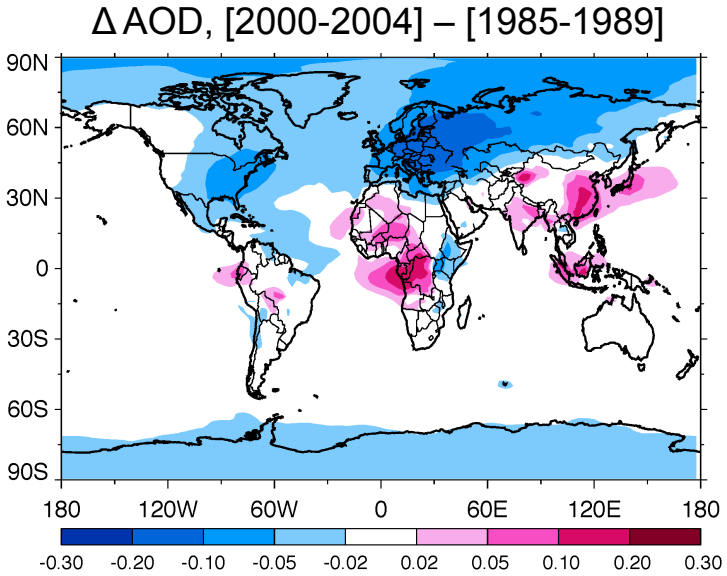


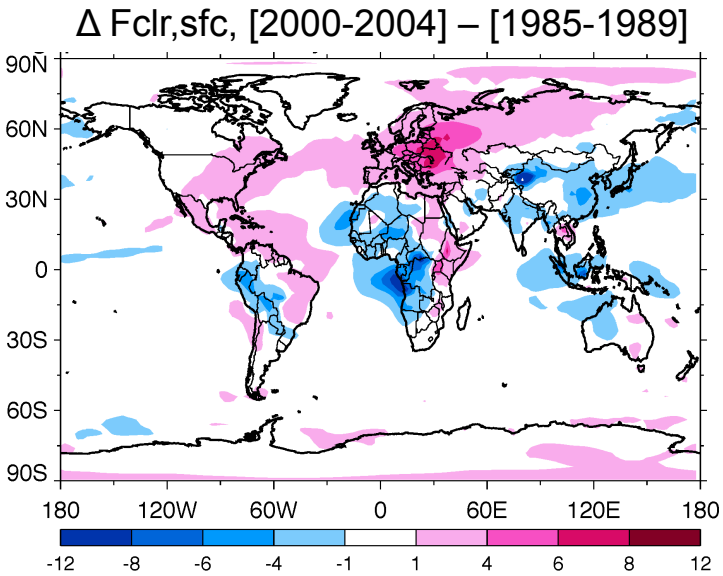
- Clear brightening trends from BSRN and model
- Trends unclear from satellite-based products

Trends of SW downward radiation at the surface

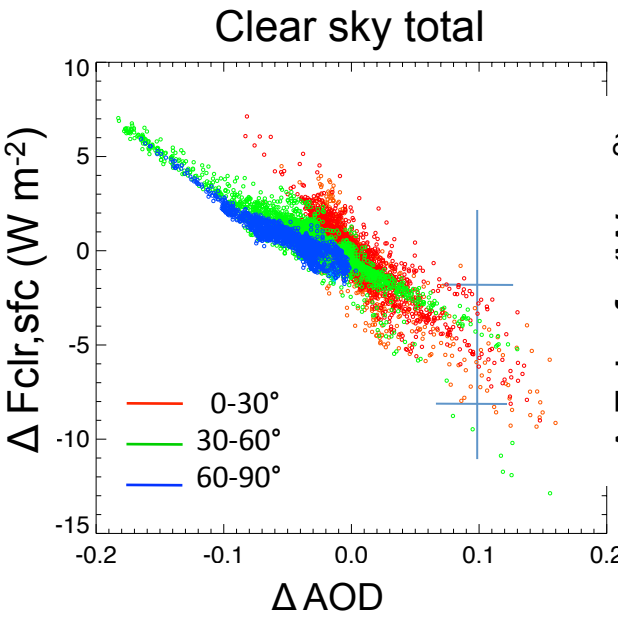


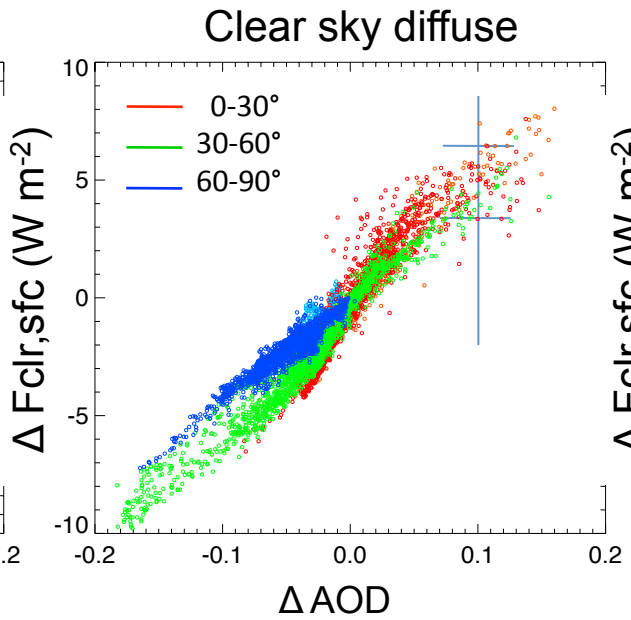
Relationship between AOD and clear sky SW downward radiative flux

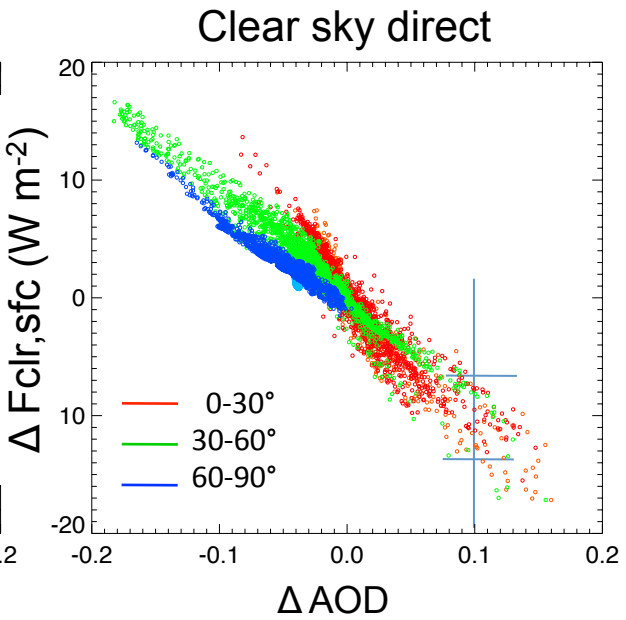




- Under clear sky conditions, aerosols control the change of solar radiation reaching the surface
- "Dimming " efficiency dep. on location, season, and aerosol type







Concluding remarks

- Aerosol controls the clear sky radiation reaching the surface, thus the corresponding dimming/brightening trends. It attenuates the direct radiation but amplifies the diffuse radiation
- Model simulation suggests a dimming trends between 1985 and 2004 over Asia, Africa, and South America but a brightening trends over North America, Europe, North Atlantic Ocean, and the Arctic, in line with the change of anthropogenic emissions in different regions
- The BSRN data over North America and Europe show the same characteristics
- There are some difficulties in using satellite-based products in deriving clear sky surface radiation trends, e.g., ISCCP showing a uniform global dimming over land

Acknowledgements

- NASA MAP program for funding
- ISCCP and SRB projects for providing surface radiation data
- BSRN