Multidecadal Trends in Aerosol Radiative Effects over Europe in Observations and IPCC AR4 Models

Joel Norris
Scripps Institution of Oceanography

Martin Wild
ETH Zurich

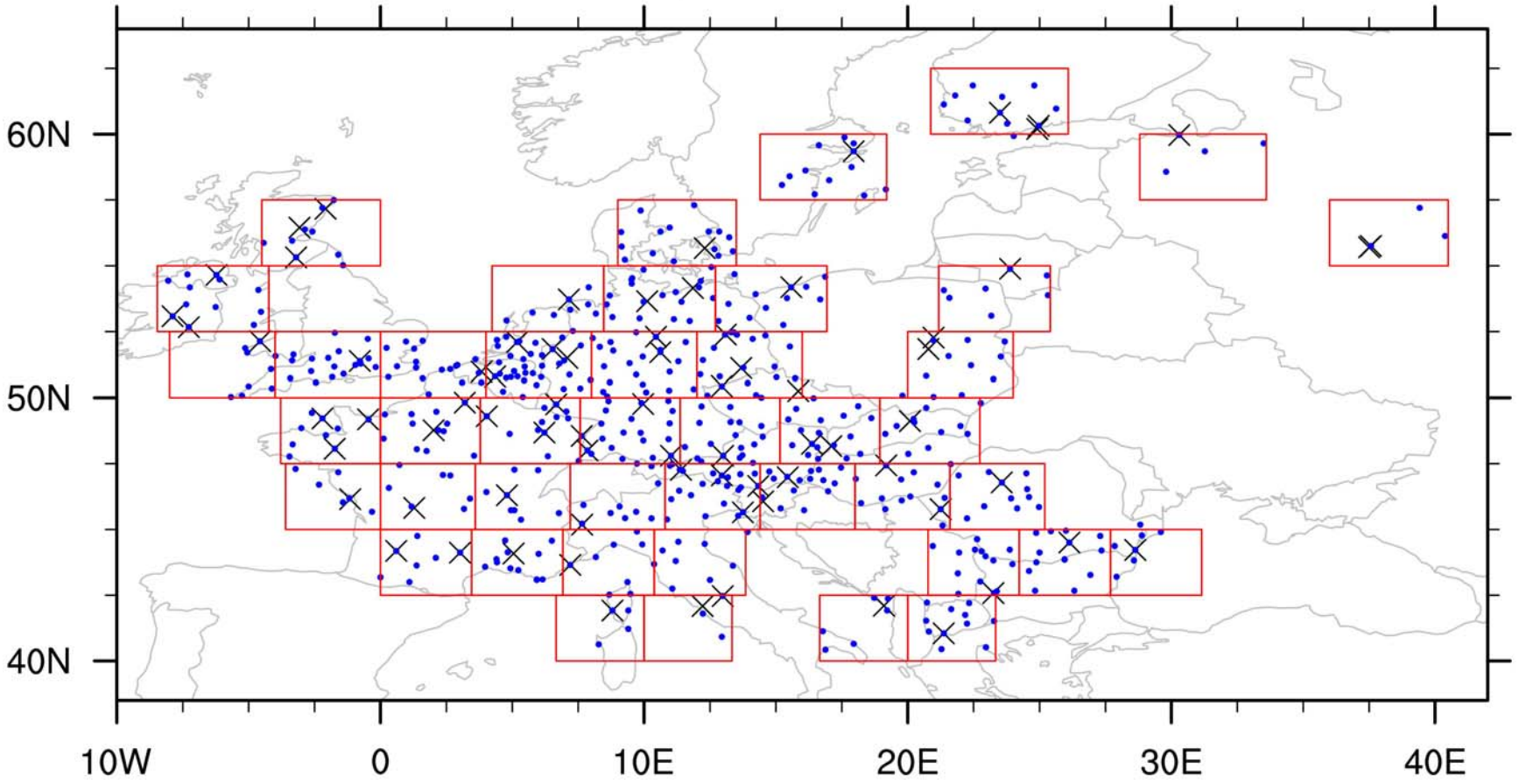
Motivation

- Historical trends in anthropogenic aerosol radiative forcing are highly uncertain.
- The magnitude of aerosol radiative forcing has been estimated by matching GCM temperature records to the observed 20th century temperature record.
- GCMs unfortunately cannot obtain a unique solution due to a trade-off between aerosol radiative forcing and climate sensitivity.
- Quantification of observed changes in regional aerosol radiative forcing would provide additional constraints on estimated emissions and GCM aerosol/cloud parameterizations.

Observational Datasets

- Monthly downward all-sky SW flux from Global Energy Budget Archive (GEBA) stations during ~1965-2003 (clear-sky not available)
- Monthly gridded daytime total cloud amount from ISCCP D2 during 1990-2004
- Monthly gridded downward all-sky SW flux and SW cloud effect at the surface from ISCCP Flux Dataset (FD) during 1983-2004
- Monthly daytime total cloud cover from synoptic reports at WMO stations during 1971-1996

Europe Station Locations



× = GEBA station ● = cloud station − = ISCCP grid box

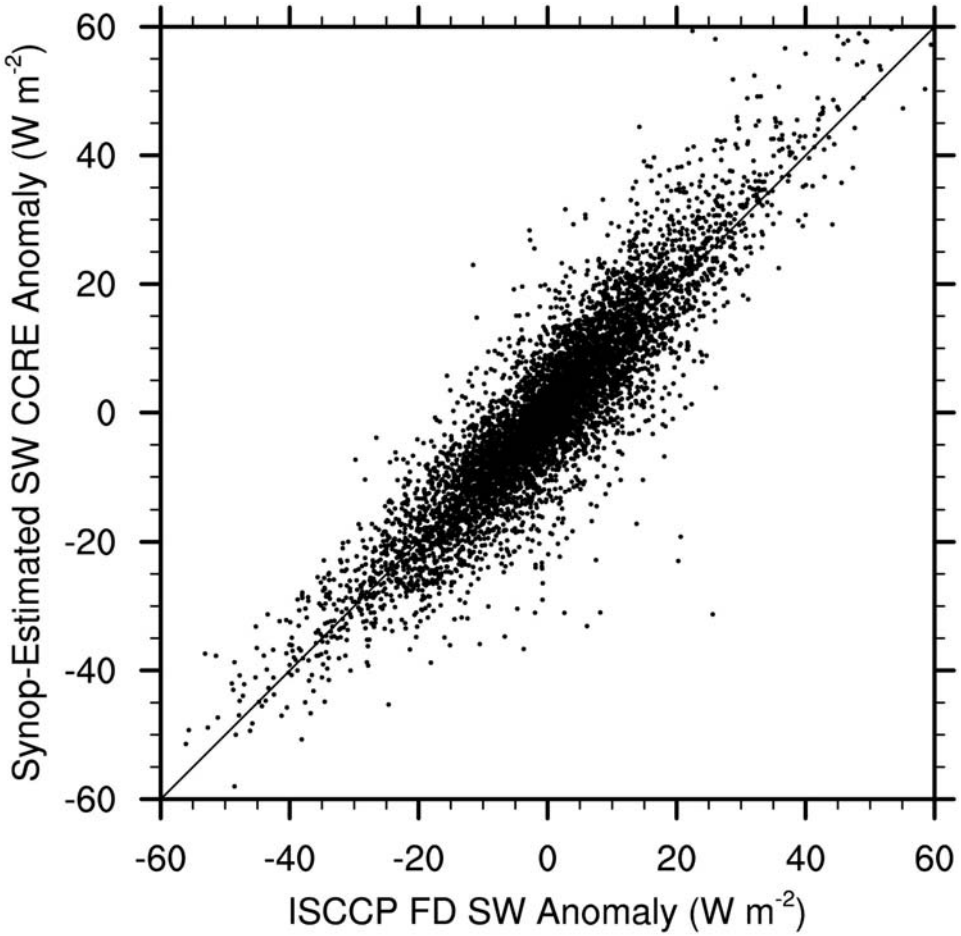
SW Cloud Cover Radiative Effect (CCRE)

- Estimate the radiative effects of variations in cloud cover using the following method:

  SW Cloud Cover Radiative Effect anomaly =
  (mean SW cloud effect / mean cloud cover) ×
  total cloud cover anomaly

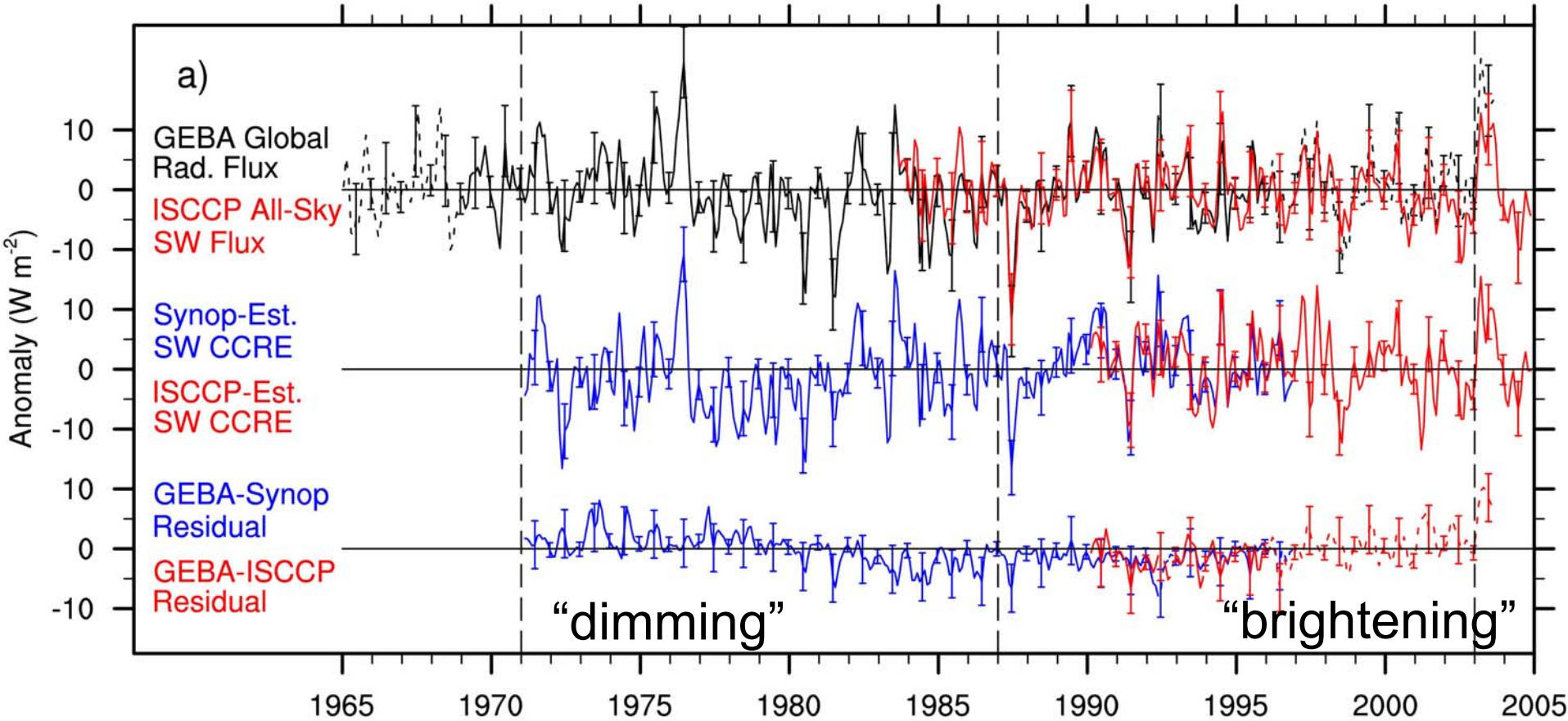
- Do separately for each calendar month and grid box

SW Cloud Cover Radiative Effect (CCRE)



- Residuals comprise variability in clear sky flux and variability in cloud albedo that is uncorrelated with cloud cover.
- On multidecadal time scales, these likely correspond to the direct aerosol effect and the first indirect aerosol effect.

Observed Pan-European Time Series



Note that residual SW radiation flux decreases until the mid 1980s and increases thereafter.

IPCC AR4 Model Output

- Monthly cloud and radiation output from 13 modeling centers with 57 simulations collectively
- Coupled atmosphere-ocean models constrained by prescribed historical variations in anthropogenic greenhouse gases and estimated aerosol emissions ("20th Century simulation")
- Some models included volcanic aerosol and aerosol indirect effects on clouds
- Monthly output processed for the same grid boxes and in the same way as were the observations

IPCC AR4 Model Output

CCSR/NIES/FRCGC MIROC3.2 [T42]

CCCMA CGCM3.1 [T47]

LASG/IAP FGOALSg1.0

GISS Model E-R (solid)
GISS Model E-H (dash)

UKMO HadCM3 (solid)
UKMO HadGEM1 (dash)

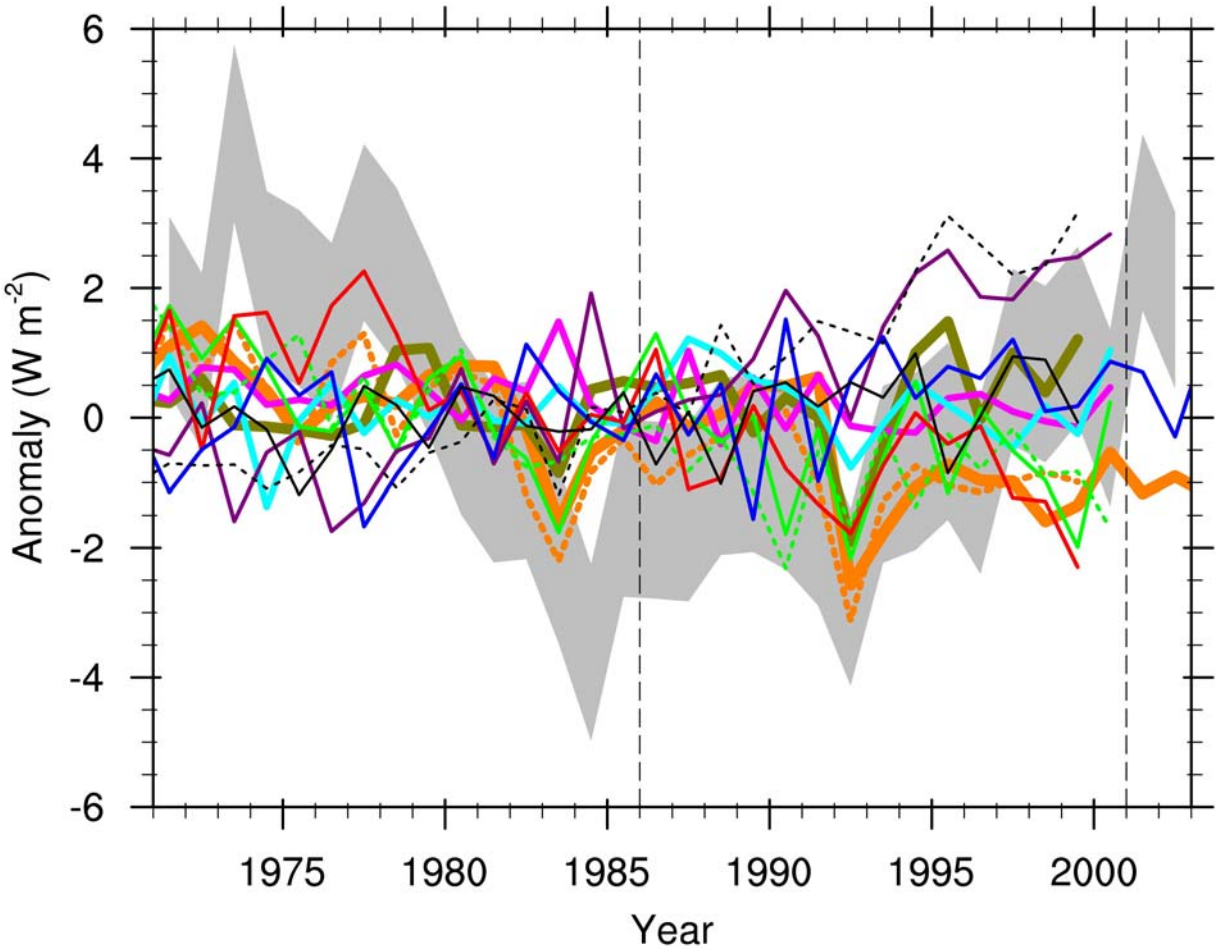
MIUB/KMA ECHO-G

GFDL CM2.0 (solid)
GFDL CM2.1 (dash)

MPI ECHAM5

NCAR CCSM3

Observed/Model Time Series Comparison



Observations
[95% confidence]

line thickness proportional to number of runs in ensemble

Observed/Model Time Series Comparison

- Agreement is not expected for interannual anomalies since the observations and the models experienced different year-to-year “weather”.
- However, none of the model ensemble mean time series have multidecadal changes that resemble those in the observations.
- The vertical dashed lines indicate starting and ending points for trend calculations.

IPCC AR4 Model Output

○ CCSR/NIES/FRCGC MIROC3.2 [T42]
⊗ CCSR/NIES/FRCGC MIROC3.2 [T106]

○ CCCMA CGCM3.1 [T47]
⊗ CCCMA CGCM3.1 [T63]

○ LASG/IAP FGOALSg1.0

○ GISS Model E-R
⊗ GISS Model E-H

○ UKMO HadCM3
⊗ UKMO HadGEM1

○ GFDL CM2.0
⊗ GFDL CM2.1

○ MIUB/KMA ECHO-G

○ MPI ECHAM5

○ NCAR CCSM3

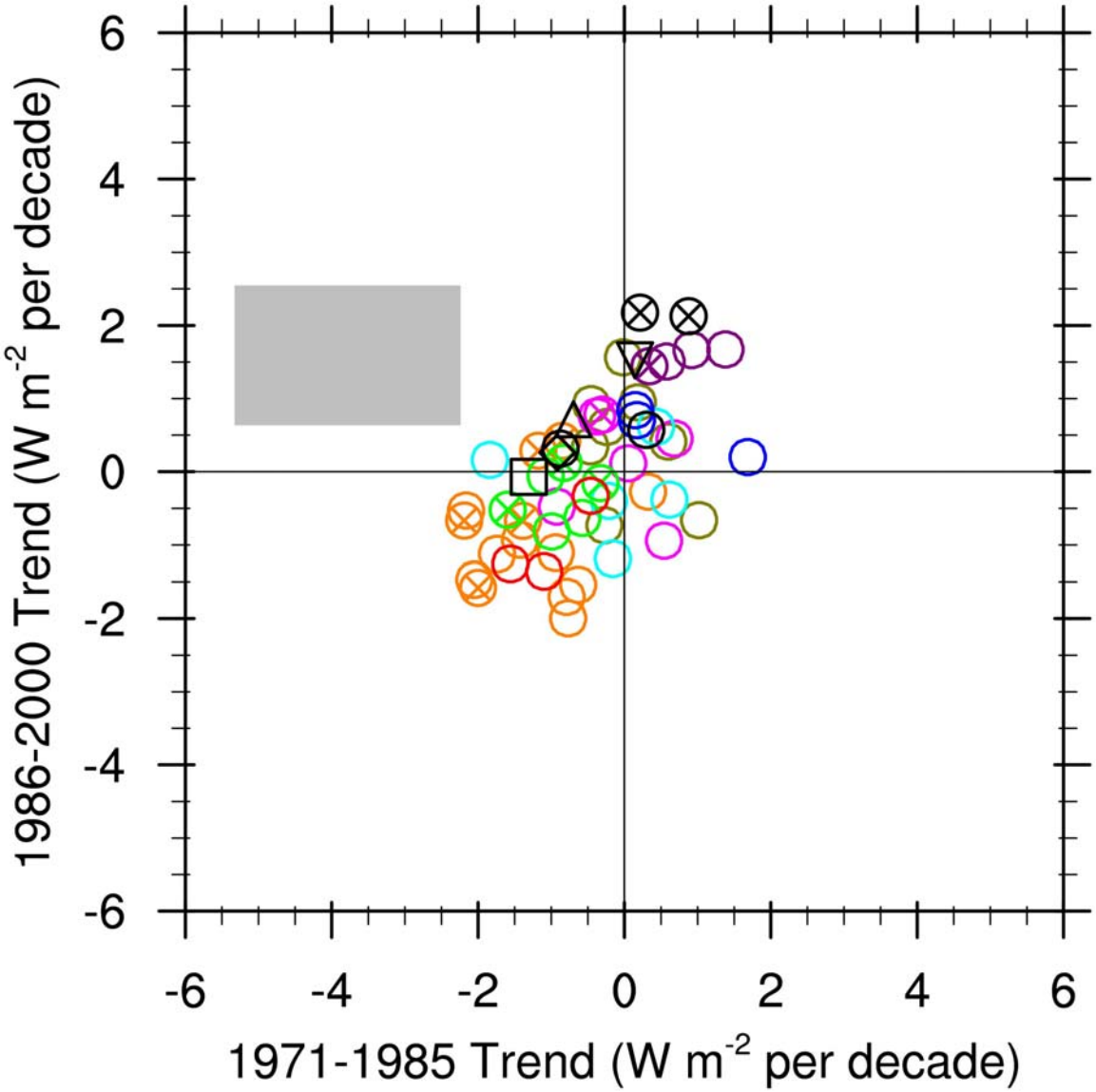
◇ MRI CGCM2.3.2

□ CNRM CM3

△ INM CM3.0

▽ IPSL CM4

Observed/Model Trend Comparison



Observations
[95% confidence]

symbols indicate trend pairs from individual model runs

Conclusions

- After removal of the radiative effects of cloud cover anomalies, observed surface SW residual flux over Europe exhibits a distinct decrease until the mid 1980s followed by a distinct increase.
- The most likely explanation of the observed solar dimming and brightening are the direct and first indirect aerosol effects.
- None of the IPCC AR4 model "20th Century" simulations reproduces the magnitudes of observed solar dimming and solar brightening over Europe.

Conclusions

- One possible reason for the failure is that the models use an incorrect history of aerosol emissions.
- Another possible reason is that the models incorrectly simulate the transport and processing of aerosol particles.
- A third possible reason is that the models do not correctly represent the radiative effects of aerosols on clear sky flux and cloud albedo.