# Observational Evidence for Underestimation of BC Radiative Forcing Trends in CMIP5 Models

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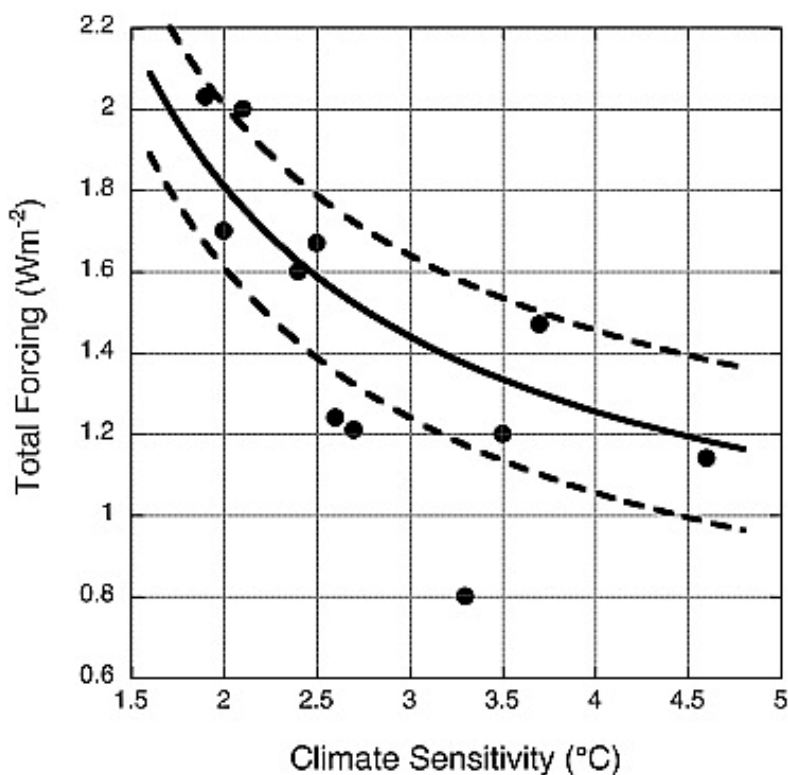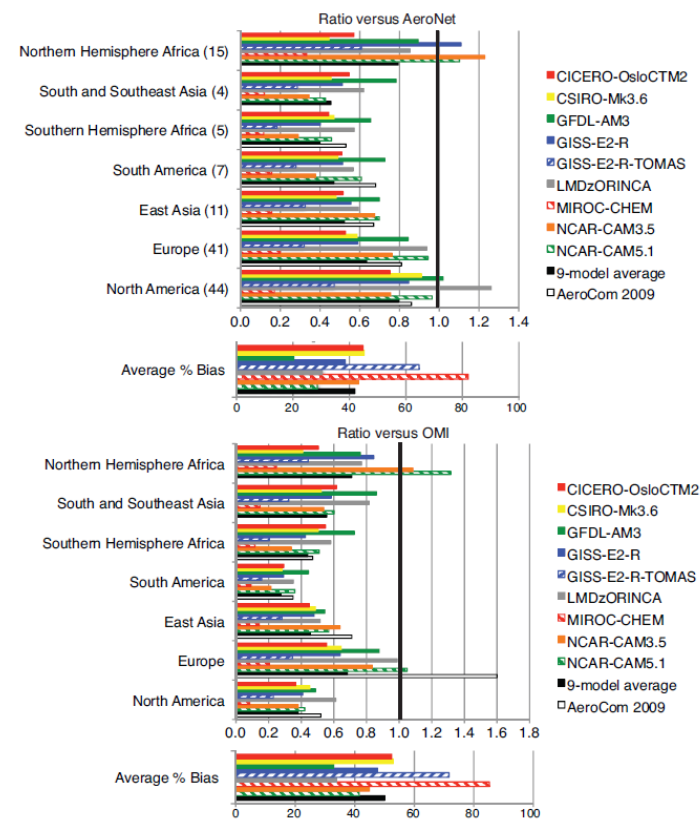Martin Wild (ETH Zürich)

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# Motivation

Trade-off between radiative forcing and climate sensitivity in models

Models underestimate absorbing aerosol optical depth (AAOD)



from Kiehl 2007 (GRL)

from Shindell et al. 2012 (ACPD)

# Change in Forcing over Recent Decades

- Regions: Europe, China, and India

- All-sky monthly surface solar radiation measurements from Global Energy Budget Archive (GEBA)
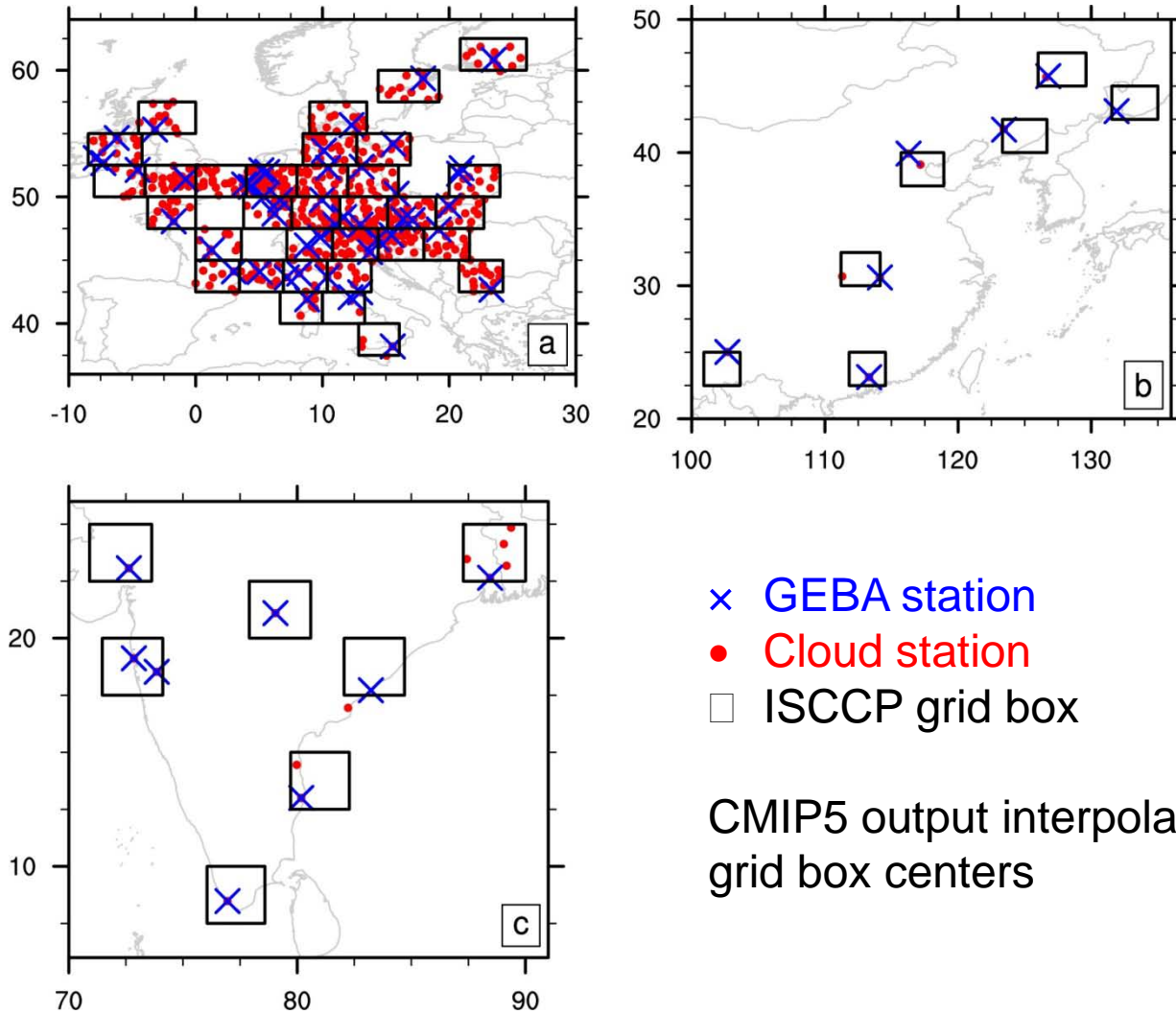
  *Regional multidecadal clear sky record not available from surface stations or satellite*

- Remove radiative effects of cloud cover variations (interannual "noise")

  ➔ "Clear-sky proxy" solar flux anomalies

        includes:      clear sky changes

                               cloud albedo changes

# Station Distribution



× GEBA station
● Cloud station
☐ ISCCP grid box

CMIP5 output interpolated
grid box centers

# CMIP5 Models

| | |
|---|---|
| ——— OBS | ·········· HadCM3 |
| ——— ACCESS1-0 | ·········· HadGEM2-AO |
| ——— ACCESS1-3 | ·········· HadGEM2-CC |
| ——— BCC-CSM1-1 | ·········· HadGEM2-ES |
| ——— BCC_CSM1-1-m | ·········· INM-CM4 |
| ——— BNU-ESM | ·········· IPSL-CM5A-LR |
| ——— CanESM2 | ·········· IPSL-CM5A-MR |
| ——— CCSM4 | ·········· IPSL-CM5B-LR |
| ——— CESM1-BGC | ·········· MIROC-ESM |
| ——— CESM1-CAM5 | ·········· MIROC-ESM-CHEM |
| ——— CESM1-FASTCHEM | ·········· MIROC4h |
| ——— CESM1-WACCM | —·—·— MIROC5 |
| ——— CNRM-CM5 | —·—·— MPI-ESM-LR |
| ——— CSIRO-Mk3-6-0 | —·—·— MPI-ESM-MR |
| — — — FGOALS-g2 | —·—·— MPI-ESM-P |
| — — — FGOALS-s2 | —·—·— MRI-CGCM3 |
| — — — GFDL-CM3 | —·—·— MRI-CGCM3_p2 |
| — — — GFDL-ESM2G | —·—·— NorESM1-M |
| — — — GFDL-ESM2M | —·—·— NorESM1-ME |
| — — — GISS-E2-H | |
| — — — GISS-E2-H_p2 | ——— Circle |
| — — — GISS-E2-H_p3 | — — — X |
| — — — GISS-E2-H_NOIE | ·········· Triangle |
| — — — GISS-E2-H-CC | —·—·— Diamond |
| — — — GISS-E2-R | |
| — — — GISS-E2-R_p2 | |
| — — — GISS-E2-R_p3 | |
| ·········· GISS-E2-R_NOIE | |
| ·········· GISS-E2-R-CC | |

# Europe Dimming and Brightening



Clear Sky Proxy Anomaly
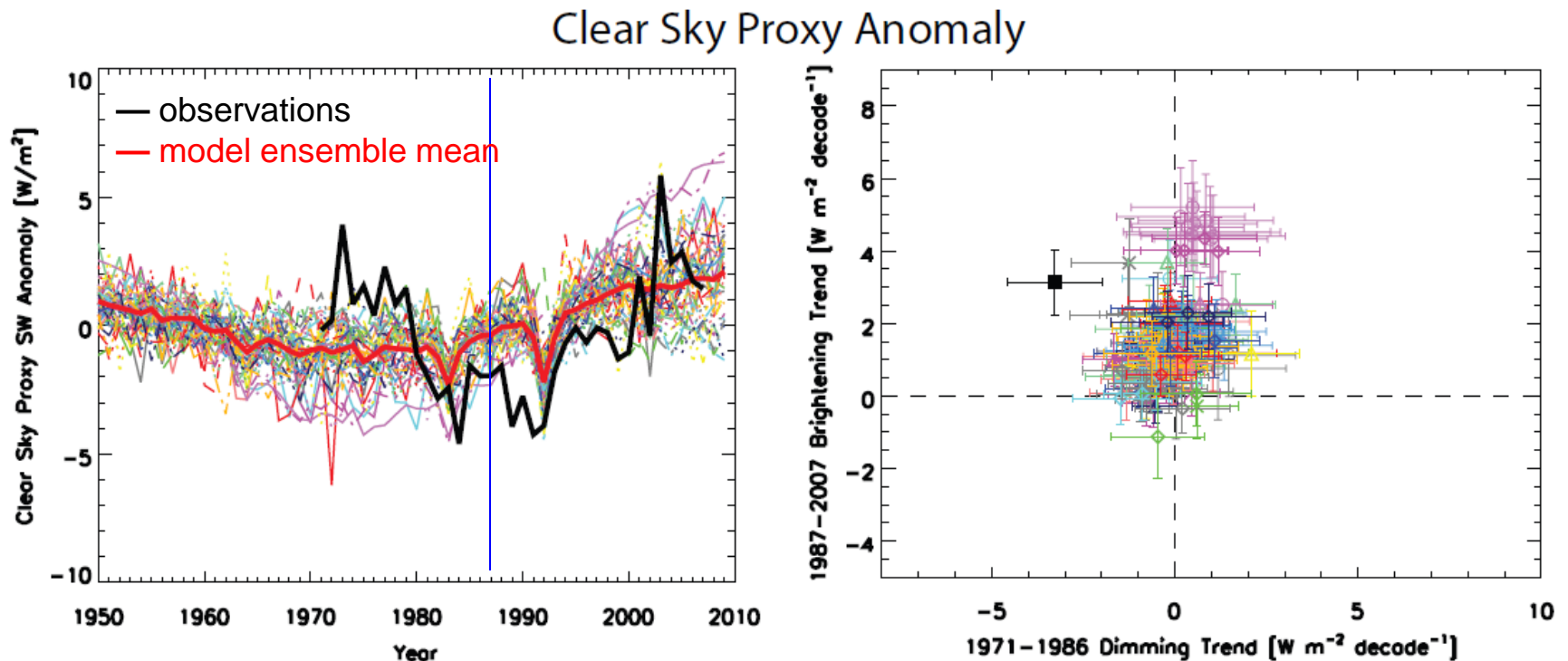
CMIP5 simulations underestimate observed dimming prior to ~1987

# China Dimming and Brightening

## Clear Sky Proxy Anomaly
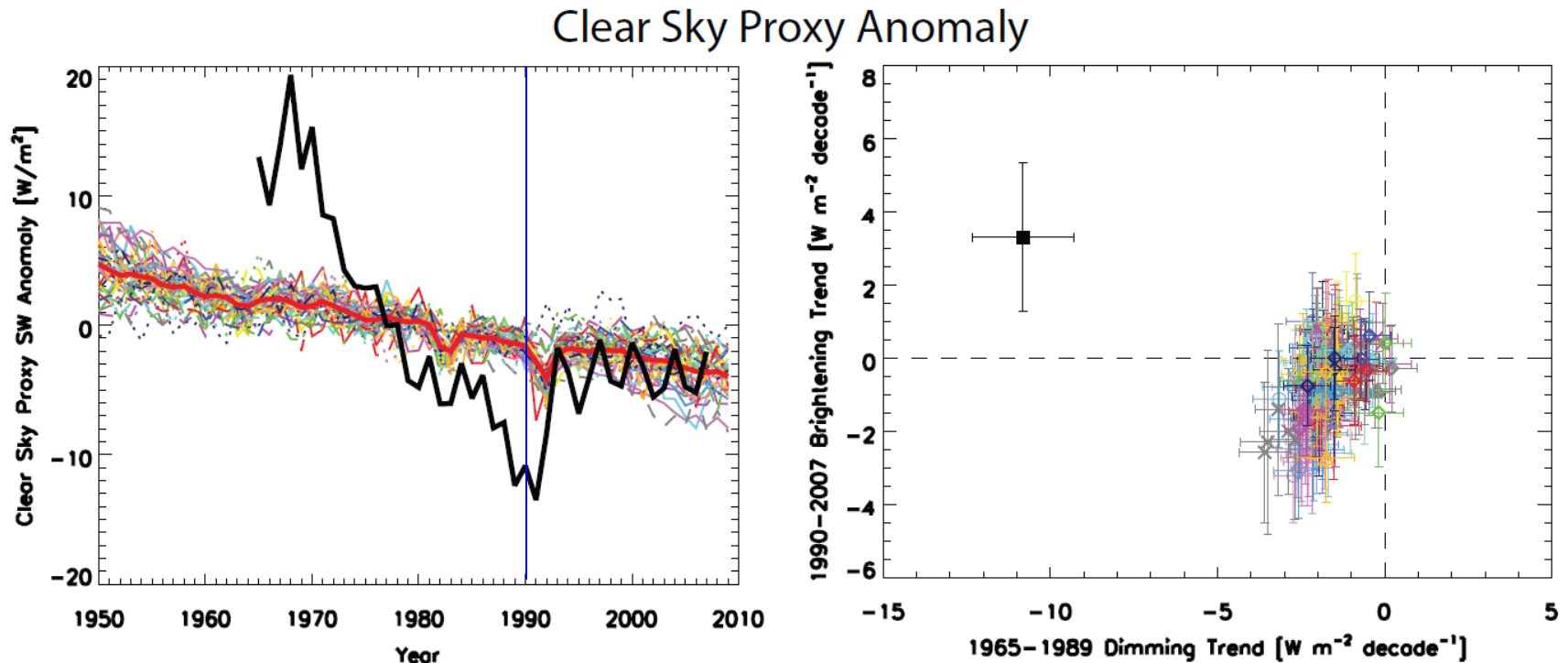


CMIP5 simulations *severely underestimate* observed dimming prior to ~1990

# India Dimming



Clear Sky Proxy Anomaly
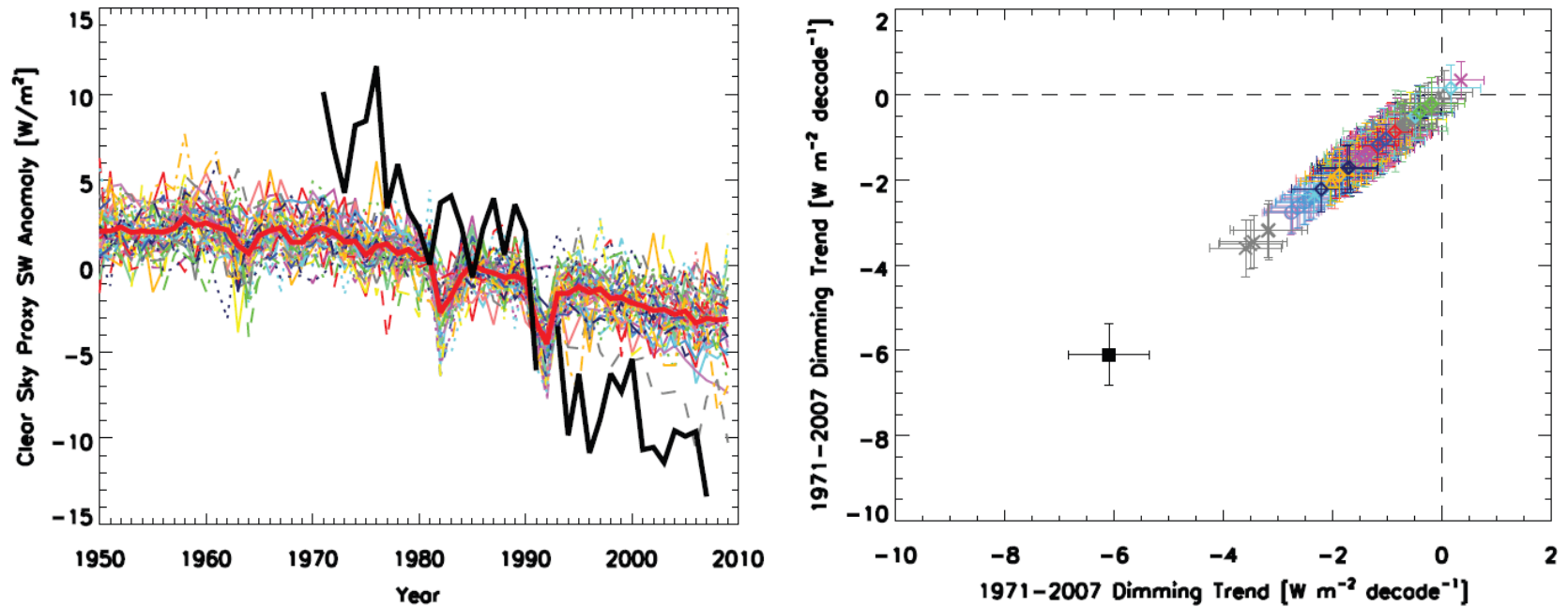
CMIP5 simulations *severely* underestimate observed dimming

# Aerosol Indirect Effects in GISS Model
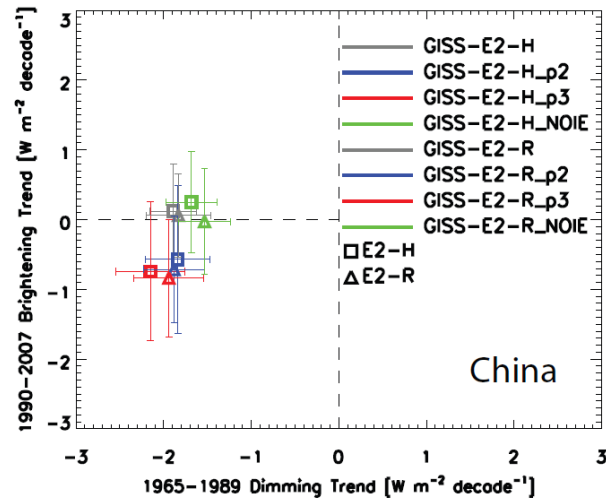


prescribed aerosol no indirect effect
prescribed aerosol w/ indirect effect
prognostic aerosol w/ indirect effect v1
prognostic aerosol w/ indirect effect v2

*Aerosol indirect effects appear to have small impact on clear-sky proxy trends in the GISS model*
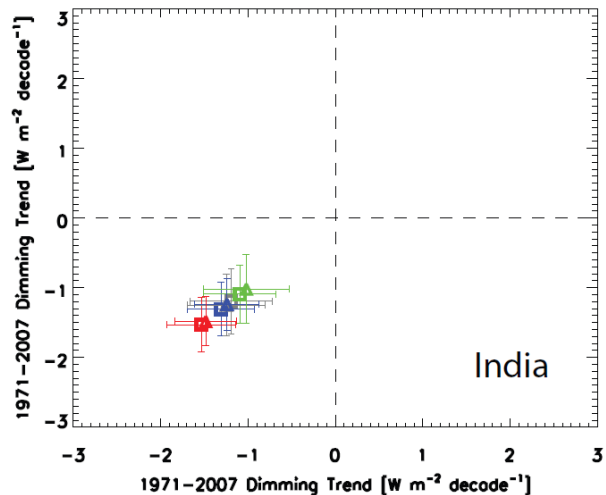
*Prognostic rather than prescribed aerosol appears to have small impact on dimming in the GISS model*

# Trends in Sulfate Load and Clear-Sky Proxy
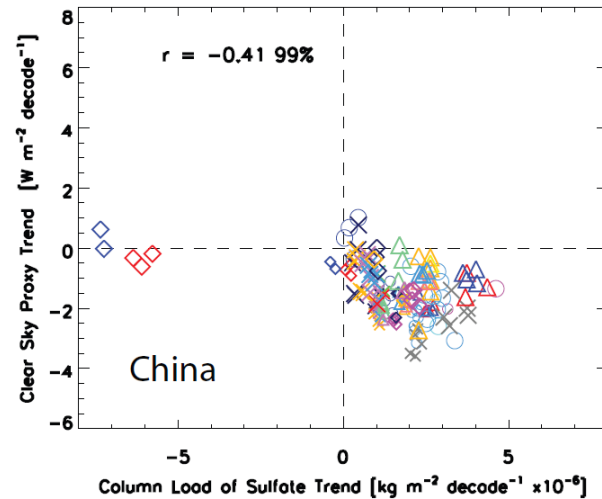


CMIP5 simulations with the biggest trends in sulfate load tend to have the biggest trends in clear-sky proxy flux
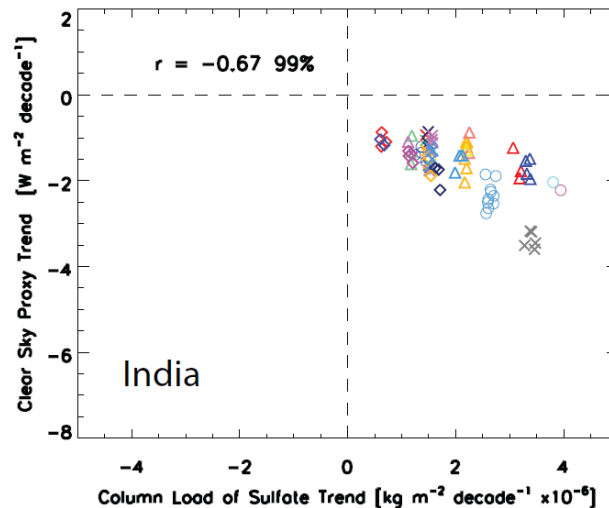
# Trends in AAOD and Clear-Sky Proxy



CMIP5 simulations with the biggest trends in exp(–AAOD) tend to have the biggest trends in clear-sky proxy flux

Clear-sky proxy trends are more highly correlated to AAOD trends than they are to sulfate trends or AOD trends

# Conclusions

- CMIP5 simulations <u>severely underestimate</u> observed decreases in surface solar radiation over Europe, China, and India

- Comparison of GISS model versions suggests that aerosol indirect effects have small impact on surface solar radiation trends

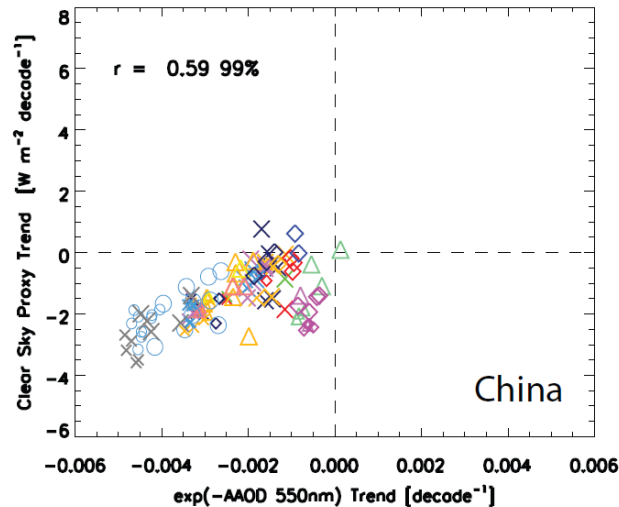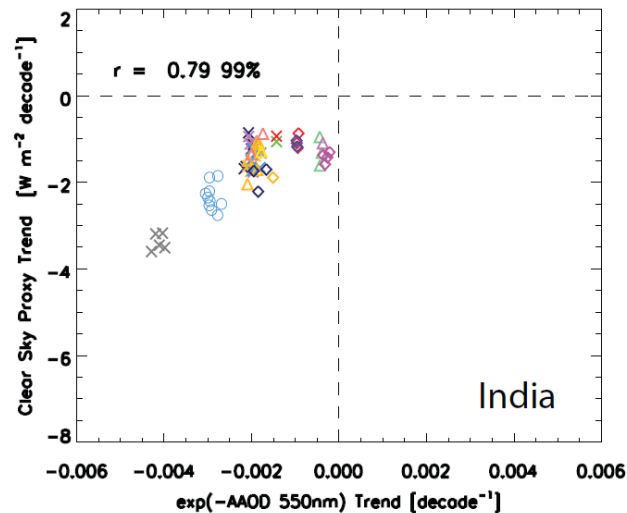- CMIP5 solar radiation trends over China and India appear to be more related to trends in absorbing aerosol than trends in sulfate

- CMIP5 simulations with the largest increases in AAOD exhibit the largest decreasing solar radiation trends

  *Black carbon appears to have had a greater radiative impact in recent decades than is currently implemented in climate models*
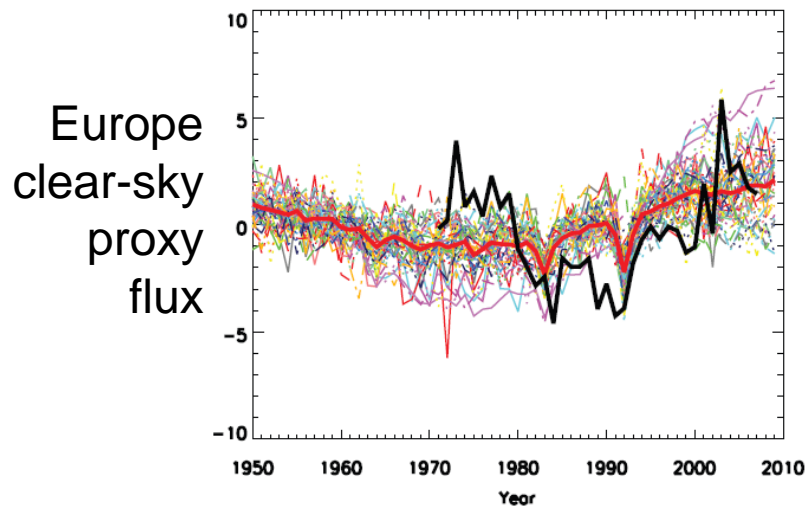
# Thank You!

# Extra Slides

# All-Sky and Clear-Sky Proxy Flux



Europe all-sky flux

Europe clear-sky proxy flux
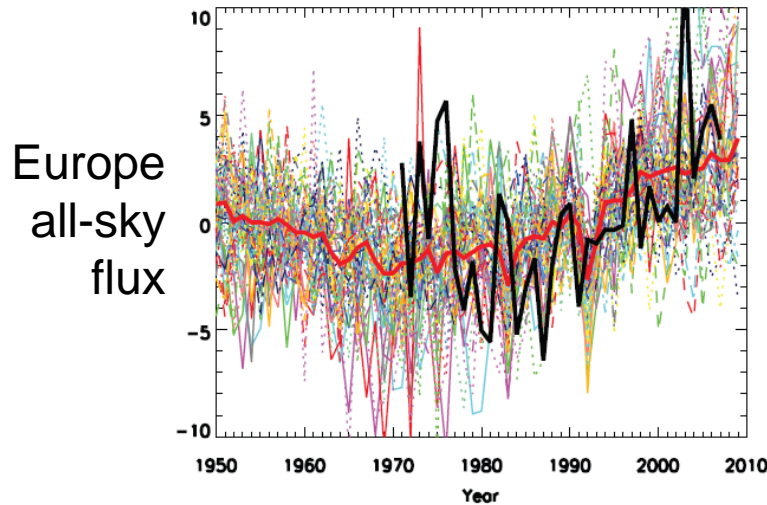
—— observations
—— model ensemble mean

all-sky flux has much greater interannual variability than clear-sky proxy flux due to month-to-month changes in cloud cover