EVALUATION OF MULTIDECADAL VARIAIBLITY IN CMIP5 SURFACE SOLAR RADIATION AND INFERRED AEROSOL EMISSION HISTORY

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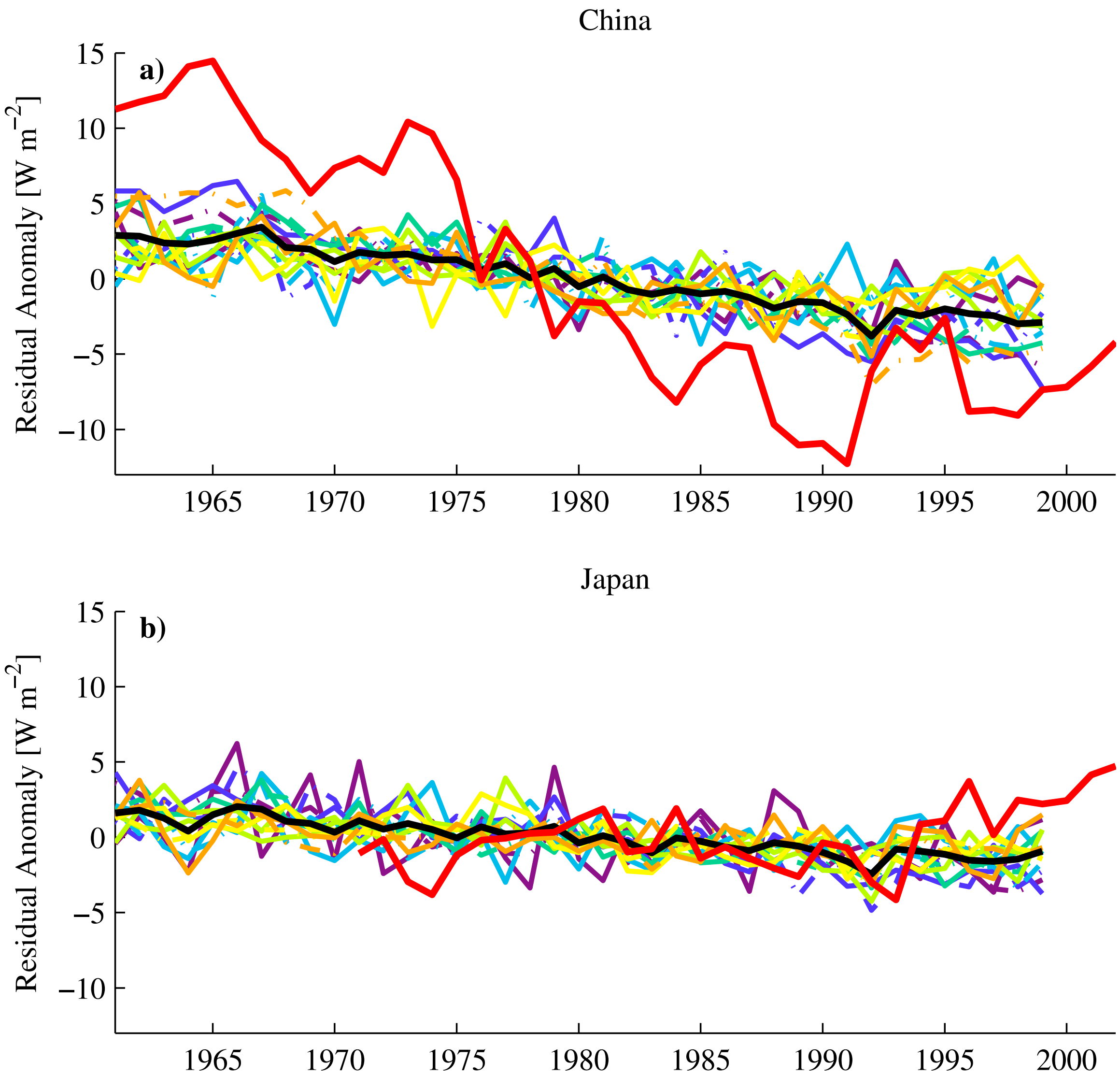
MOTIVATION

- Observations indicate decreases in surface solar radiation (SSR) from ~1950s-1980s ("global dimming"), followed by an increase during the 1990s ("global brightening").
- Anthropogenic aerosol emissions are most likely responsible, esp. for Europe and East Asia (e.g., Wild, 2009 and references therein).
  - Direct aerosol effects, as opposed to indirect effects, appear to be most important (Norris and Wild, 2007, 2009; Ruckstuhl+, 2010).
- Models that exhibit the observed magnitude & timing of dimming/brightening likely have more realistic aerosol radiative forcing (RF).

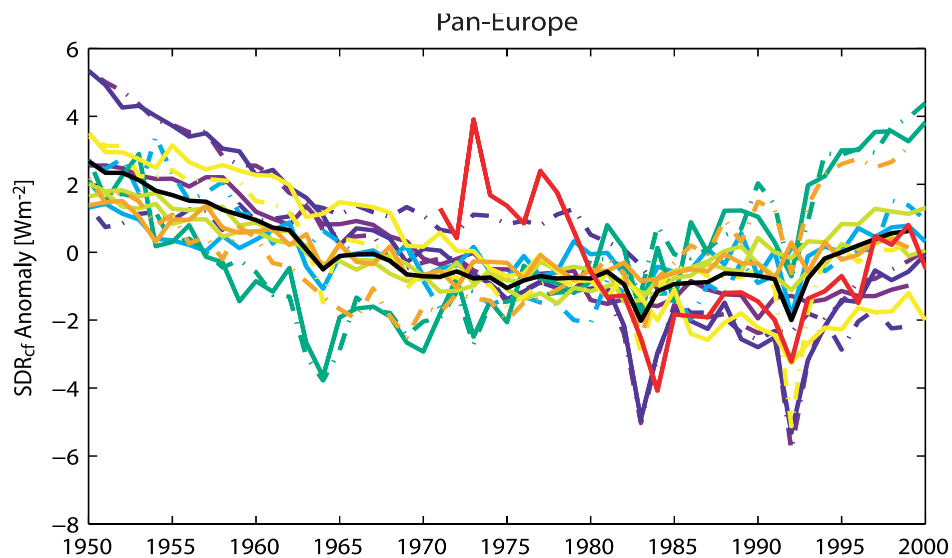
PRIOR WORK: CMIP3

- Only ~50% of CMIP3 models reproduce the observed SSR decadal variations in a qualitative way.
- Nearly all models underestimate the magnitude.
- Attributed to incorrect aerosol emission inventories.

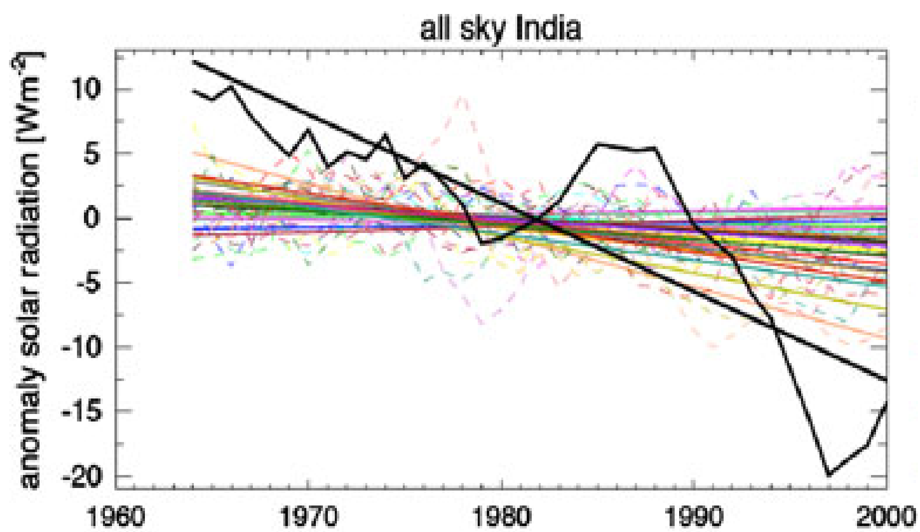


Dwyer+, 2010

Similar CMIP3 Underestimation For Europe & India



Ruckstuhl+Norris, 2009



Wild+Schmucki, 2011

Do CMIP5 models yield improved dimming/brightening trends?

14 CMIP5 MODELS*

1.	BCC-CSM1.1	Beijing Climate Center	3 runs
2.	CanESM2	Canadian Centre for Climate Modeling and Analysis	5 runs
3.	CNRM-CM5	Centre National de Recherches Meteorologiques	1 run
4.	CSIRO-Mk3.6	Commonwealth Scientific & Industrial Research Org.	10 runs
5.	GISS-E2-H	NASA Goddard Institute for Space Studies	5 runs
6.	GISS-E2-R	NASA Goddard Institute for Space Studies	5 runs
7.	HadCM3	Met Office Hadley Centre	4 runs
8.	HadGEM2-CC	Met Office Hadley Centre	1 run
9.	HadGEM2-ES	Met Office Hadley Centre	4 runs
10.	INM-CM4	Institute for Numerical Mathematics	1 run
11.	IPSL-CM5A-LR	Institut Pierre-Simon Laplace	4 runs
12.	MIROC4H	Atmosphere & Ocean Research Institute	3 runs
13.	MRI-CGCM3	Meteorological Research Institute	5 runs
14.	NorESM1-M	Norwegian Climate Centre	3 runs

* All available model-runs (54 total) with necessary variables as of early October, 2011

OBSERVATIONAL DATA

- Global Energy Balance Archive (GEBA) (Gilgen+Ohmura, 1999).
  - Monthly mean global (direct+diffuse) downward solar radiation.
- International Satellite Cloud Climatology Project (ISCCP) Flux Data (Zhang et al., 2004).
  - Monthly mean surface daytime all-sky and clear sky shortwave radiation.
- ISCCP monthly mean daytime total cloud cover (Rossow et al., 1996; Rossow and Schiffer, 1999).
- NDP026-D and NDP-039 monthly mean surface daytime total cloud cover (Hahn and Warren, 2003; Shiyan+, 1997).

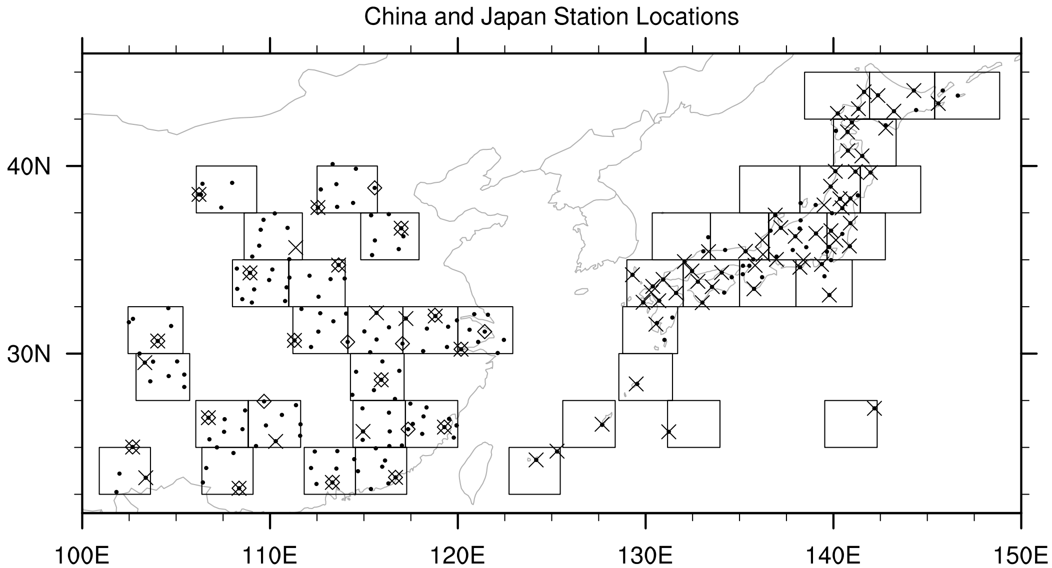
METHODOLOGY

- Estimate surface radiative impact of cloud cover anomalies:

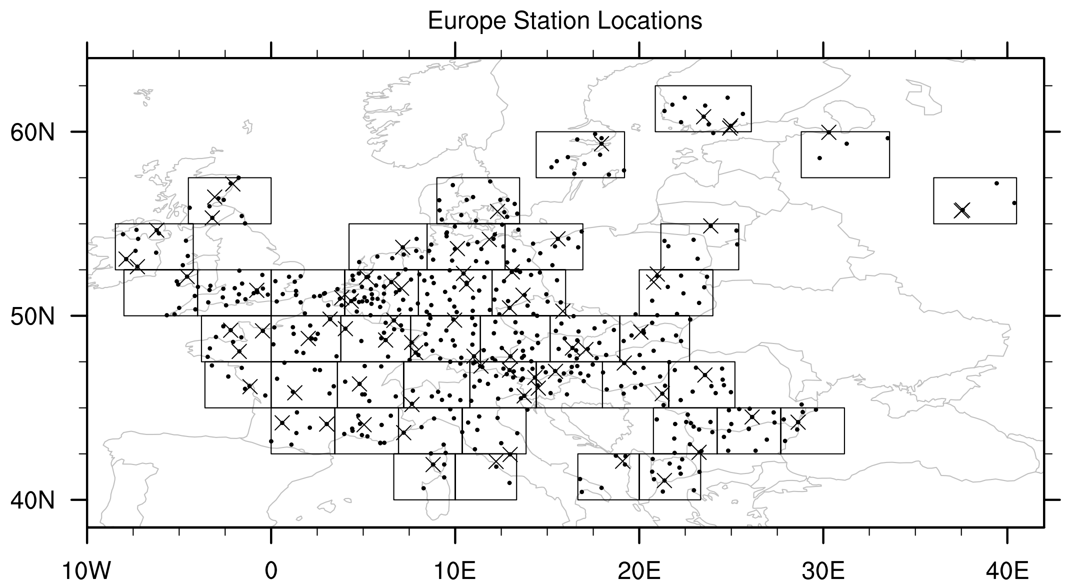
$$CCRE'(x,yr,mn) = CC'(x,yr,mn) \times \frac{\overline{SW}_{all}(x,mn) - \overline{SW}_{clr}(x,mn)}{\overline{CC}(x,mn)}$$

- Remove from global radiation anomalies via linear regression (Norris and Wild, 2007).
- Resulting "Residual Anomalies":
  1. Exhibit more distinct dimming/brightening trends.
  2. Enables aerosol contribution to be better identified.
  3. Allows a more accurate observation-model comparison.

Study Area

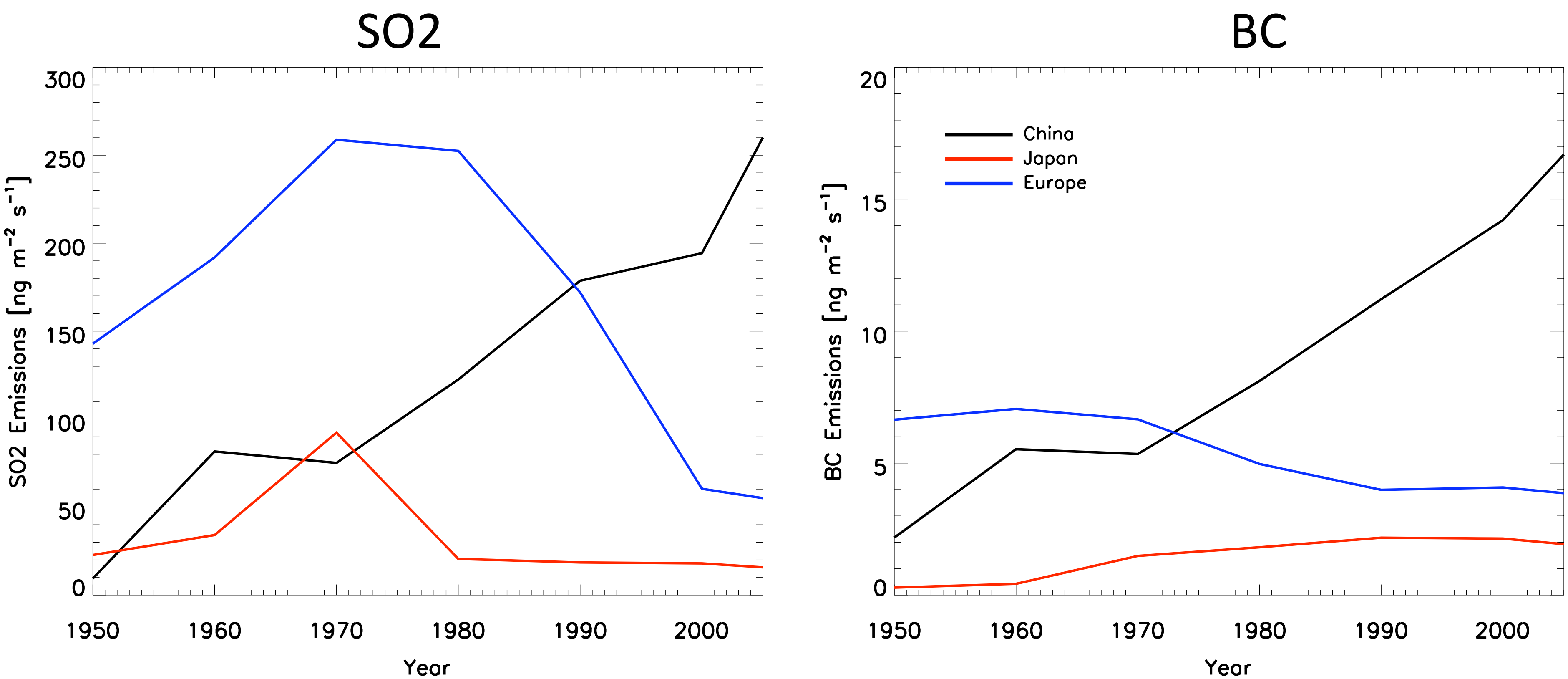


China and Japan: 83 GEBA stations

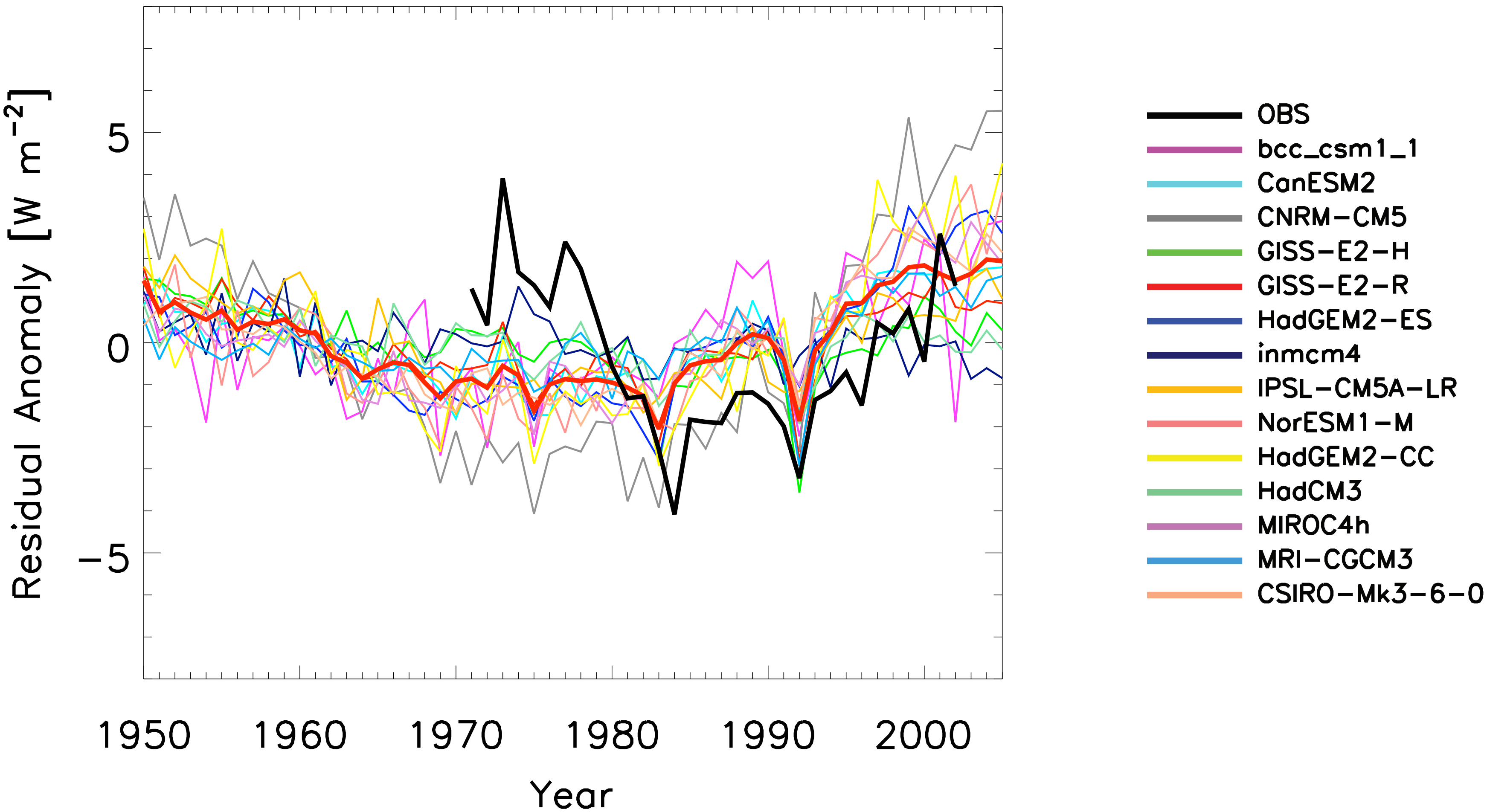


Europe: 75 GEBA stations

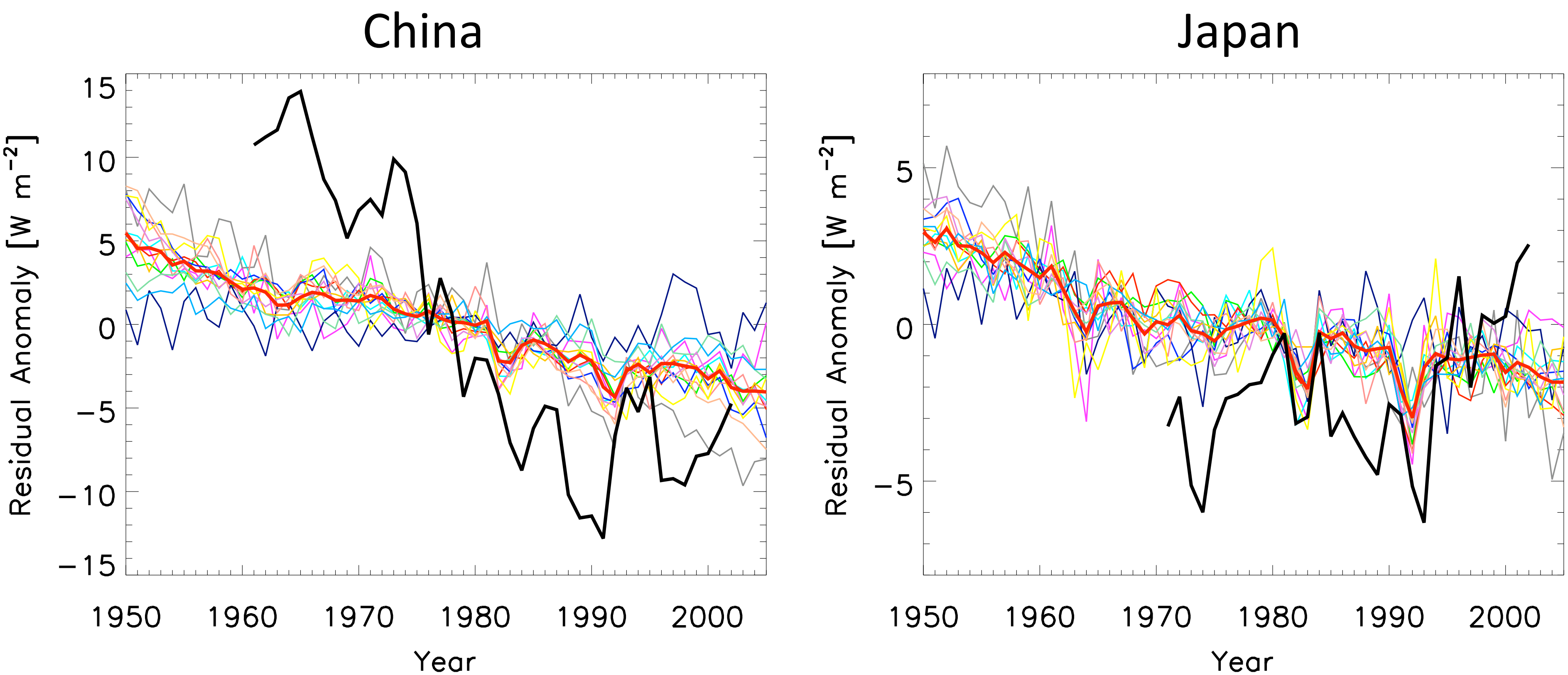
CMIP5 SO2 & BC Historical Emission Inventories



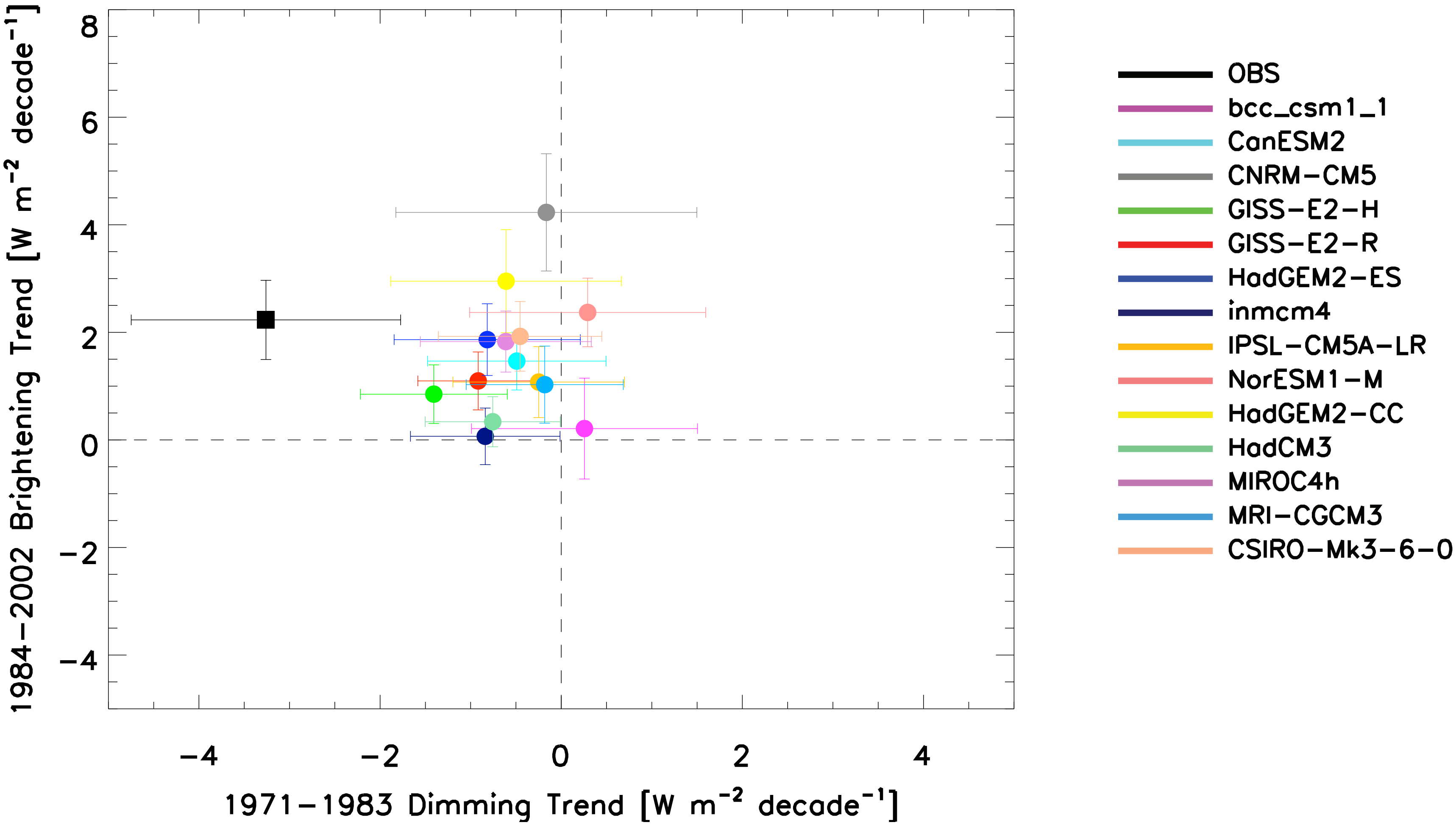
EUROPEAN RESIDUAL FLUX ANOMALIES



EAST ASIA RESIDUAL FLUX ANOMALIES



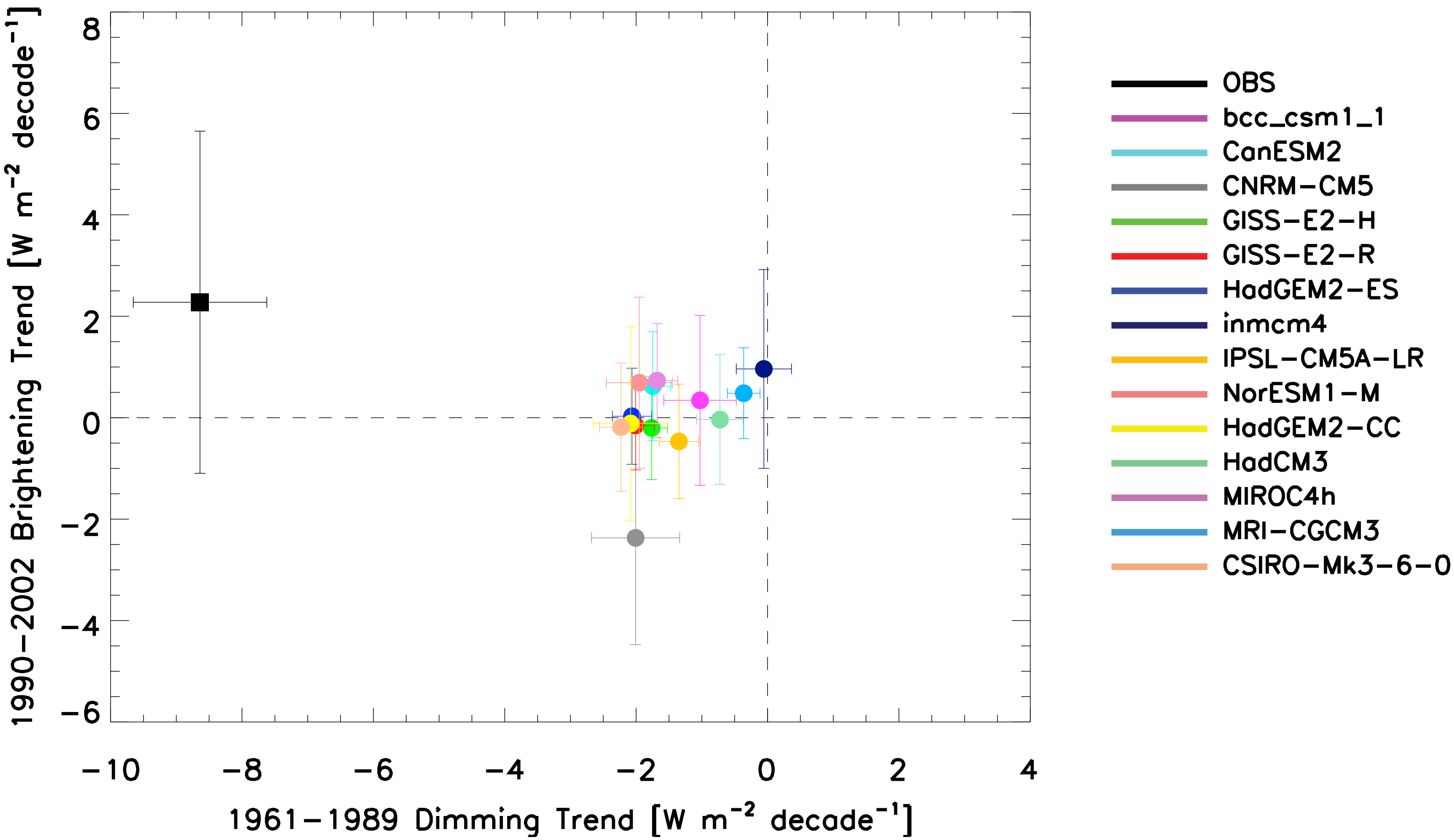
EUROPEAN RESIDUAL FLUX TRENDS



CMIP5 underestimates 1971-1983 European dimming trend:

$-3.3 \pm 1.5 \;\; vs. \;\; -0.5 \pm 1.1 \quad Wm^{-2} decade^{-1}$

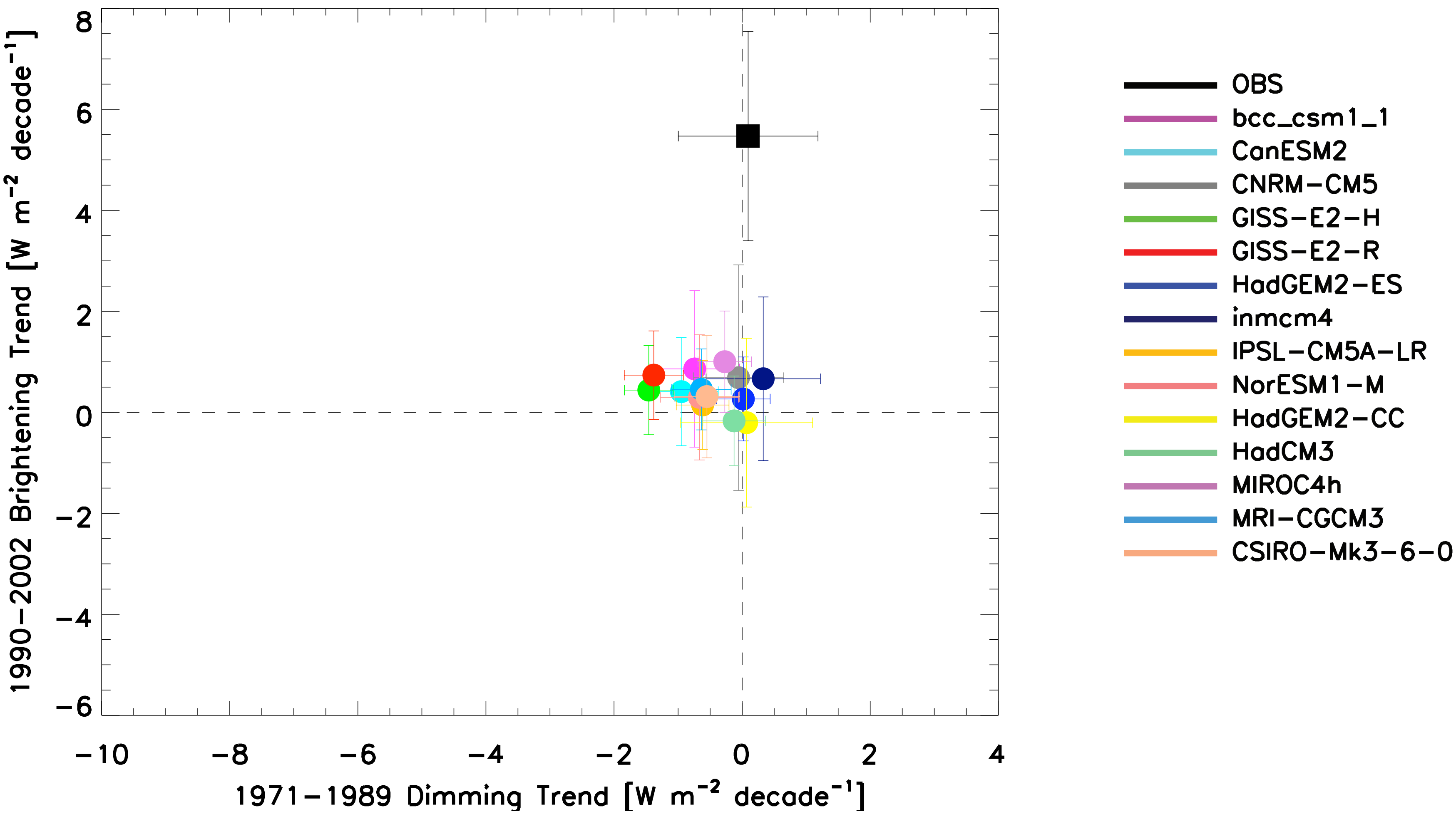
CHINA RESIDUAL FLUX TRENDS



CMIP5 underestimates 1961-1989 China dimming trend:

$$-8.6 \pm 1.0 \quad vs. \quad -1.5 \pm 0.2 \qquad Wm^{-2} decade^{-1}$$

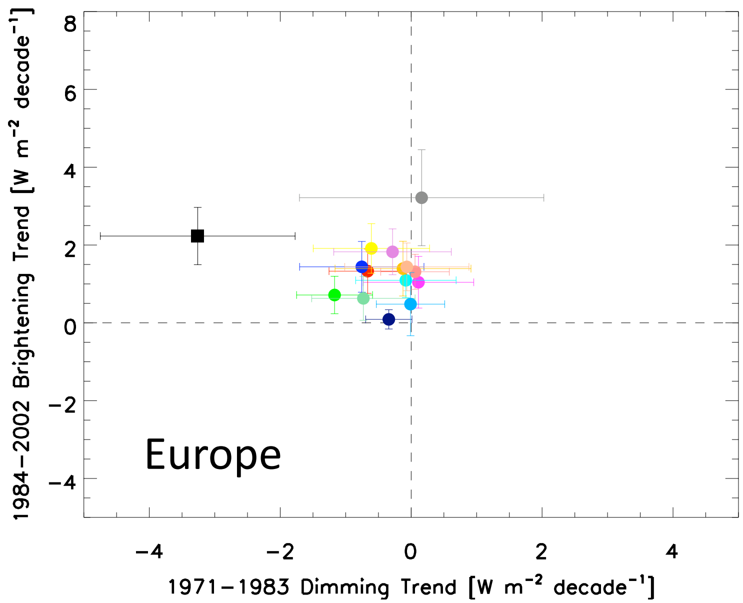
JAPAN RESIDUAL FLUX TRENDS

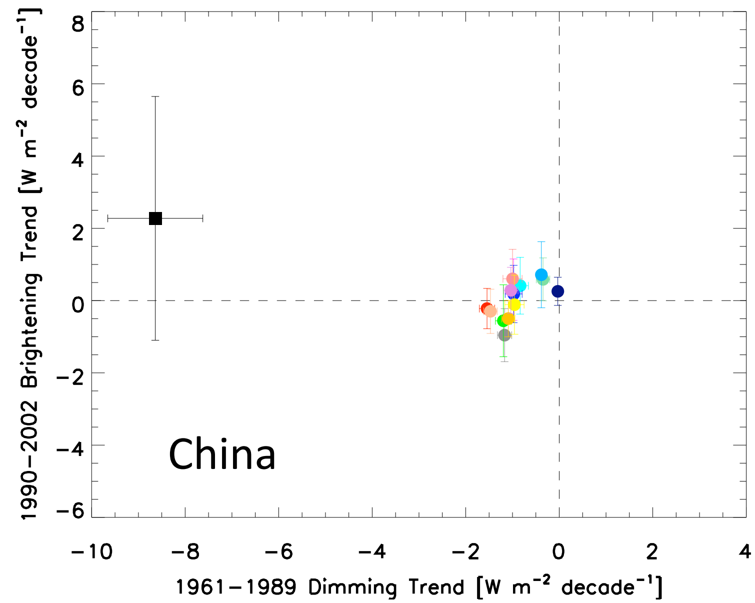


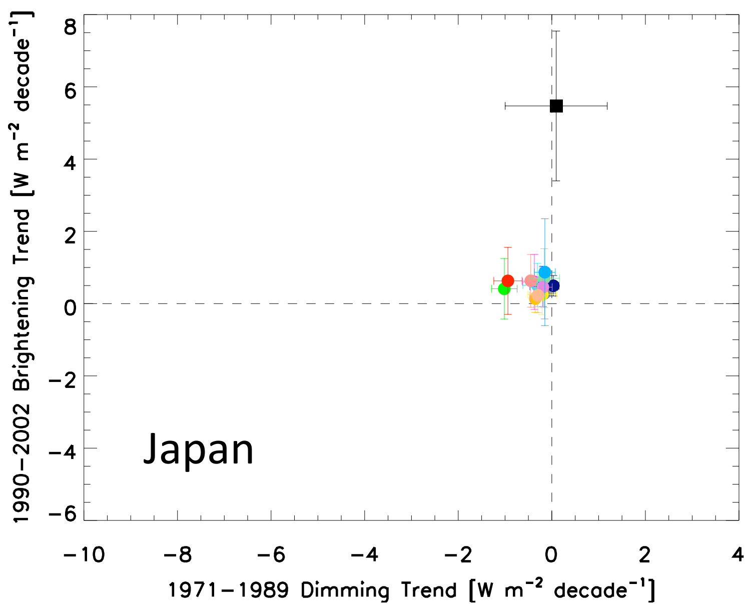
CMIP5 underestimates 1990-2002 Japan brightening trend:

$+5.5 \pm 2.1 \;\; vs. \;\; +0.4 \pm 0.7 \quad Wm^{-2} decade^{-1}$

Similar Conclusions Using Model $SW_{clr} \times \left(1 - \overline{CC}\right)$

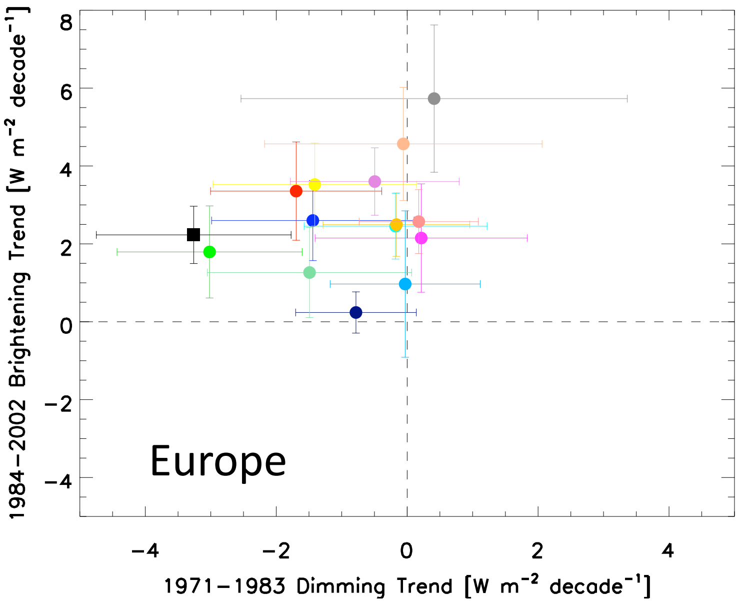


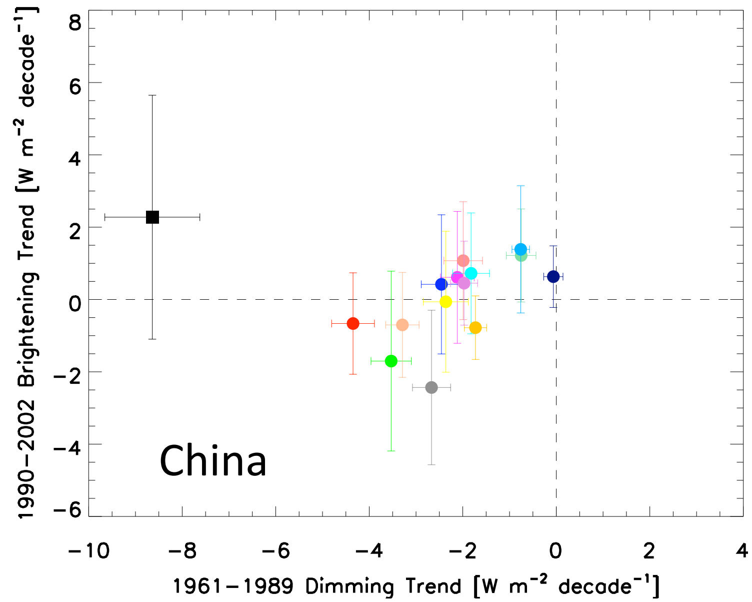


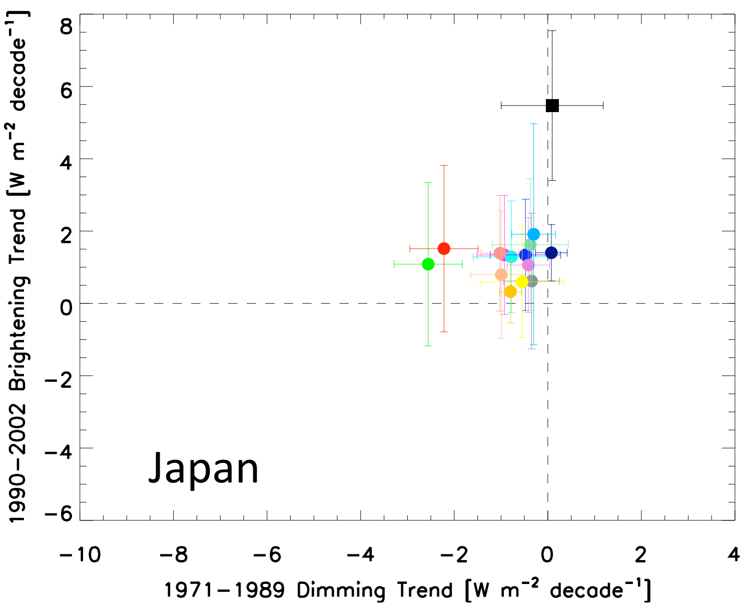


- Suggests residual flux is a good proxy for clear sky fluxes → Improves confidence in observed brightening/dimming trends.

CMIP5 SW_{clr} Trends → Larger Variability

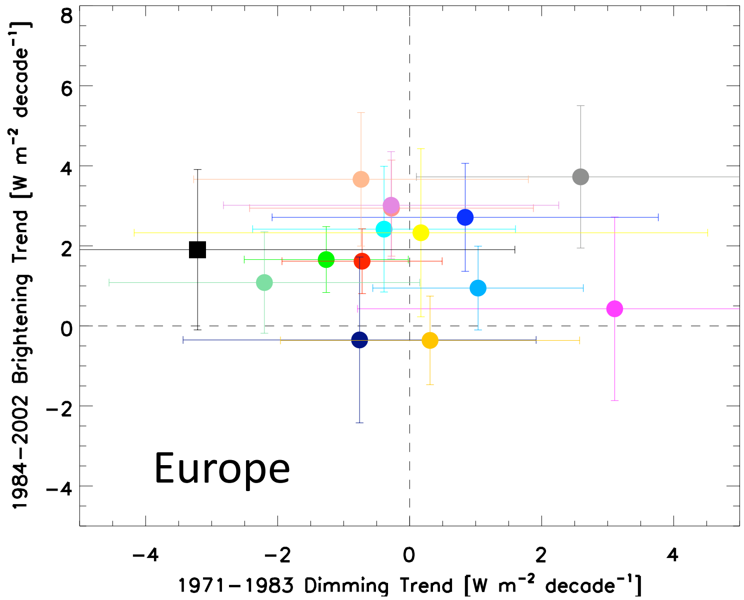


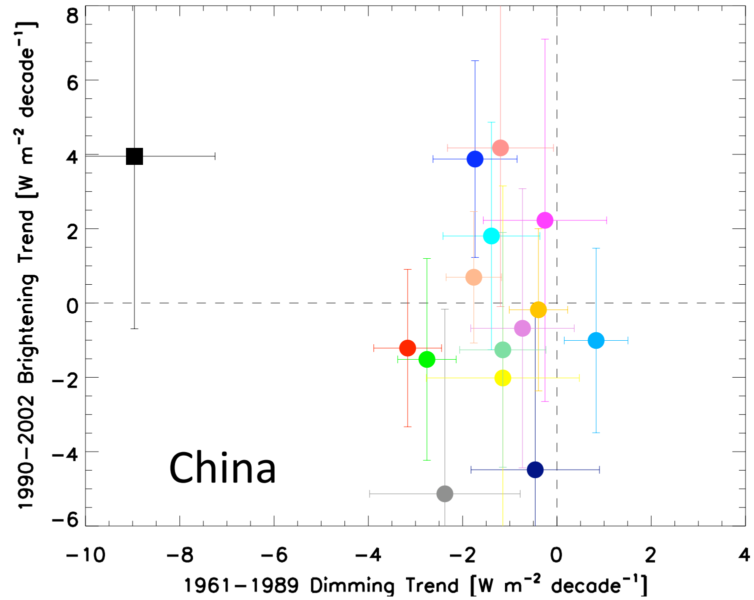


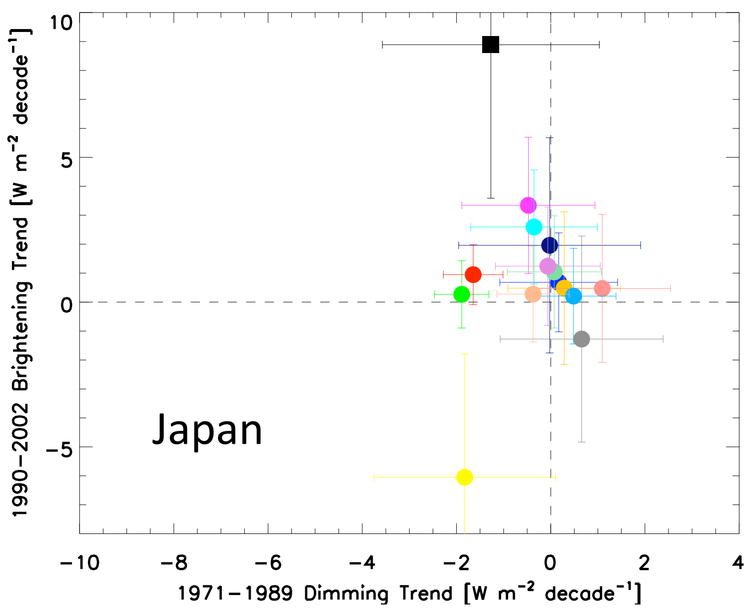


- Use of the same aerosol emissions does not guarantee identical dimming/brightening trends.

All-Sky SW Trends







- SW_{all} trends → larger uncertainty & model spread due to clouds, but similar CMIP5 underestimation.

CONCLUSIONS

- CMIP5 models qualitatively reproduce observed dimming and brightening trends in Europe, China, and Japan.
- Magnitude of trends, however, is underestimated by models, particularly for:
  - 1961-89 Dimming in China → $-8.6 \pm 1.0 \;\; vs. \;\; -1.5 \pm 0.2$
  - 1971-83 Dimming in Europe → $-3.3 \pm 1.5 \;\; vs. \;\; -0.5 \pm 1.1$
  - 1990-02 Brightening in Japan → $+5.5 \pm 2.1 \;\; vs. \;\; +0.4 \pm 0.7$
- The uniformity of the above underestimation suggests:
  1. Deficient aerosol emission histories (temporal variation or mixture of absorbing/scattering).
  2. Deficient model aerosol processing/transport.
- Identical aerosol emissions in CMIP5 does not lead to identical dimming/brightening trends; however, CMIP5 residual flux trends are more uniform relative to CMIP3.

Thank-you