Aerosol trends in AeroCom 2 Hindcast experiments

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Motivation for Hindcast simulations

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- **Regional changes in aerosol emissions translate into changes in aerosol concentrations and aerosol radiative effects and forcing, with consequences for:**
  - **Regional air quality**
  - **Global climate (top-of-atmosphere and surface radiative budget)**

- **The ability of models to reproduce observed trends is a more comprehensive measure of model skill than the ability to model one specific year.**

Last year in AeroCom…

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- Model skill defined as the ability to reproduce timeseries of monthly-averaged aerosol optical depth at AERONET sites.

- Comparison between AeroCom 2 Hindcast and CMIP5 experiments showed that:
  - Nudging meteorology improves model skill in general, but not at all sites.
  - The use of Hindcast emission datasets improves model skill over the CMIP5 decadal datasets. Again, the improvement is not systematic.

- Overall, the different Hindcast simulations, and the CMIP5 simulations, have similar skill.

Contents

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- **Trends in anthropogenic emissions**
- **Trends in aerosol burden:**
  - **For species dominated by anthropogenic sources**
  - **For species dominated by natural sources**
- **Trends in total aerosol optical depth:**
  - **Comparison to SeaWIFS and AERONET**
- **Trends in surface radiative fluxes:**
  - **Comparison to BSRN**

Models and simulations

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Institution	Model	Simulation
Met Office Hadley Centre	**HadGEM2-ES**	HCA-0
Kyushu University	**SPRINTARS-v384**	HCA-0
NASA GISS	**GISS-MATRIX**	HCA-IPCC
NASA GISS	**GISS-modelE**	HCA-IPCC
MPI Meteorology	**ECHAM5-HAMMOZ**	HCA-0
NASA GSFC	**GOCART-v4**	HCA-0

Hindcast simulations:

- HCA-0: AeroCom Hindcast emission dataset (Diehl et al., 2012)
- HCA-IPCC: CMIP5 emission dataset (Lamarque et al., 2010)
- *HCA-MET: Free-running meteorology (not used here)*

Simulations cover the period 1980-2006 (except ECHAM5: 1980-2005)

Emissions: “anthropogenic”

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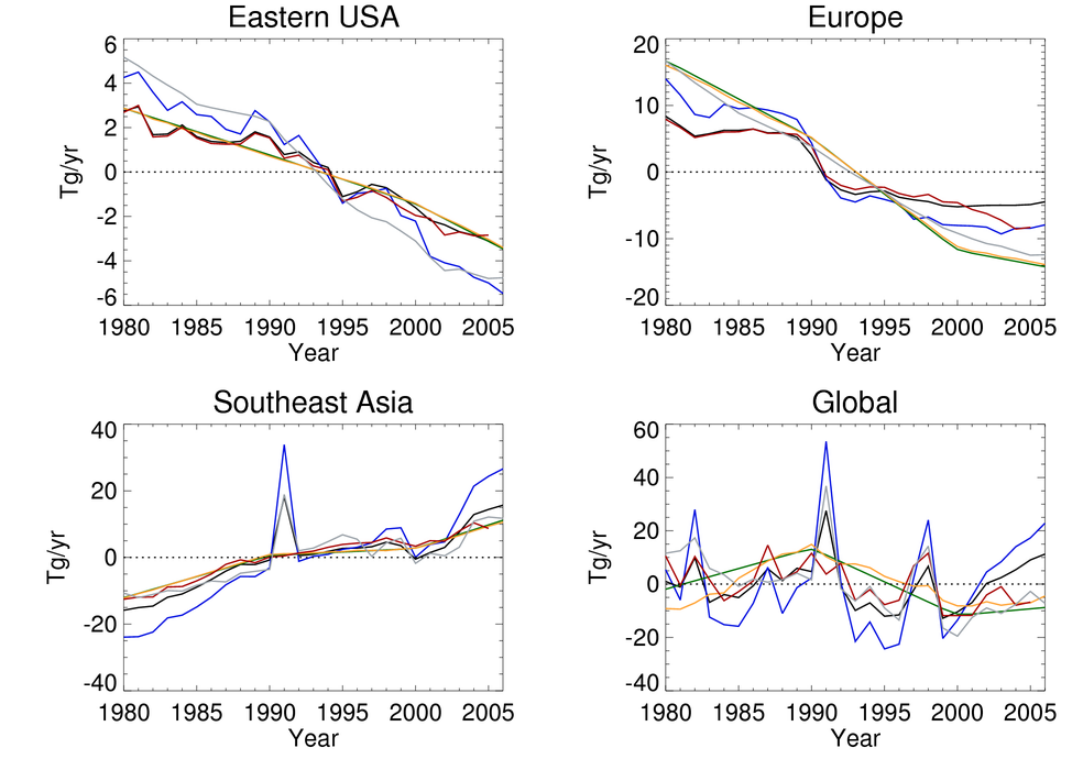
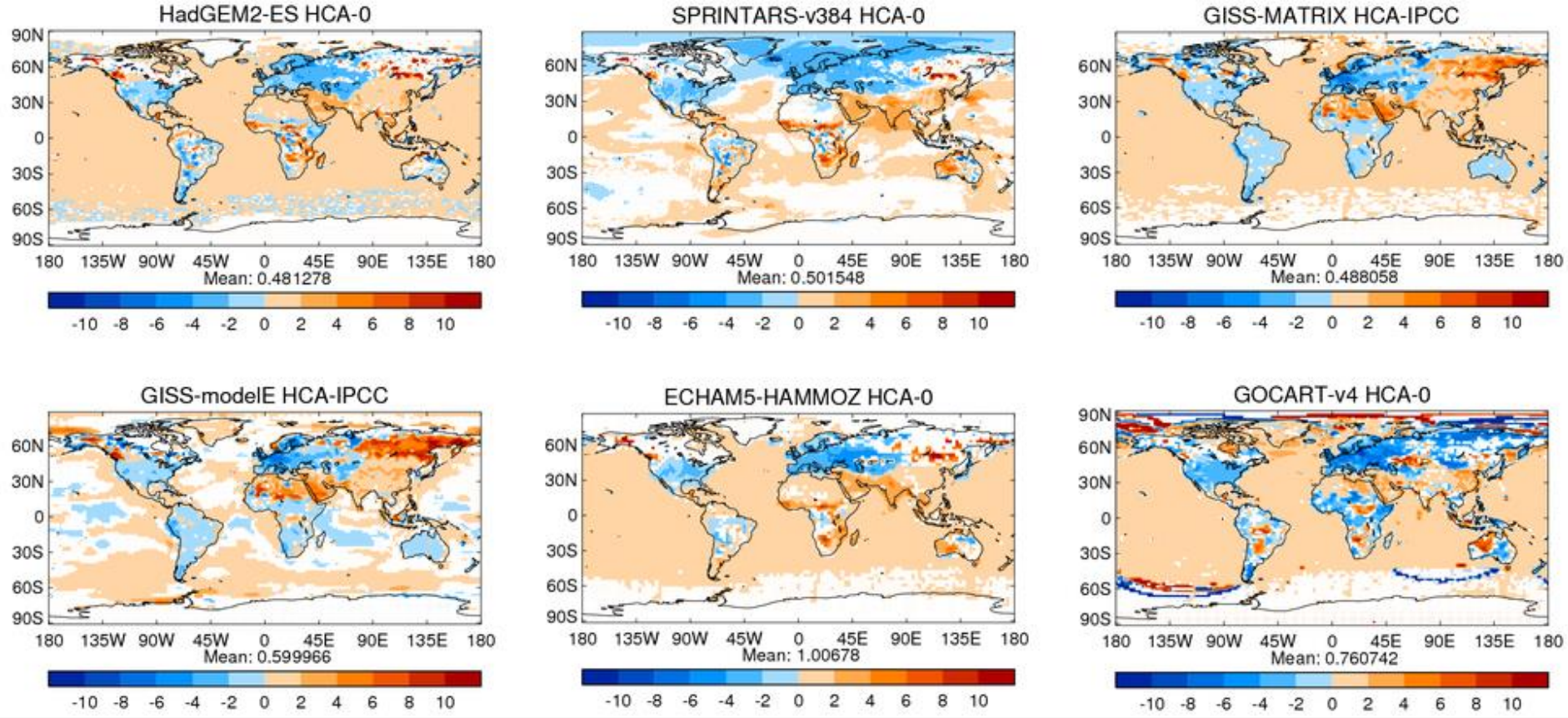
- Annual-averaged anomaly in the sum of emissions of **SO_2, SO_4, BC, OC, NH_3** with respect to Hindcast mean.



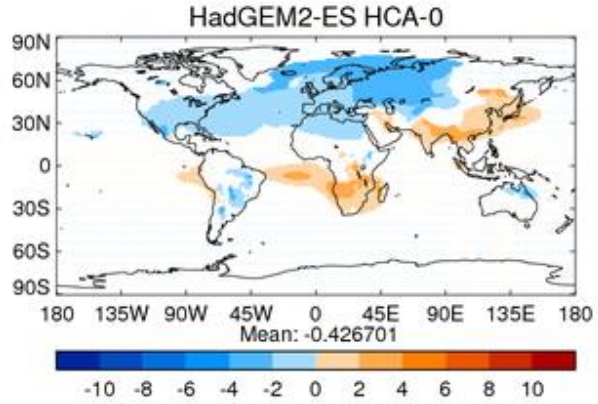
- Monotonous trends over the Hindcast period make the analysis easier, but provide no contrast over a given region.

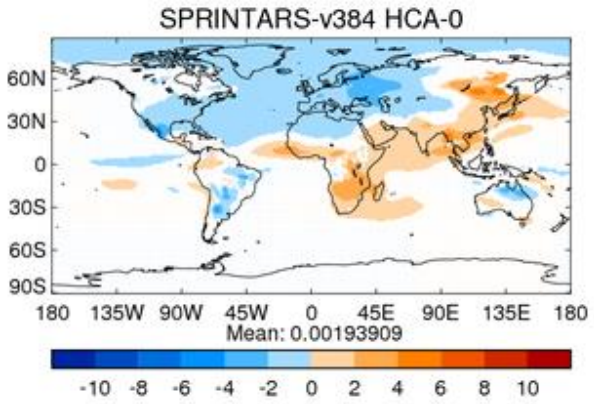
- Deseasonalised **sum of emissions of SO_2, SO_4, BC, OC, NH**
- Linear trends (% yr^{-1}) over Hindcast period, relative to period mean.
- White areas are not significant at the 95% confidence level.

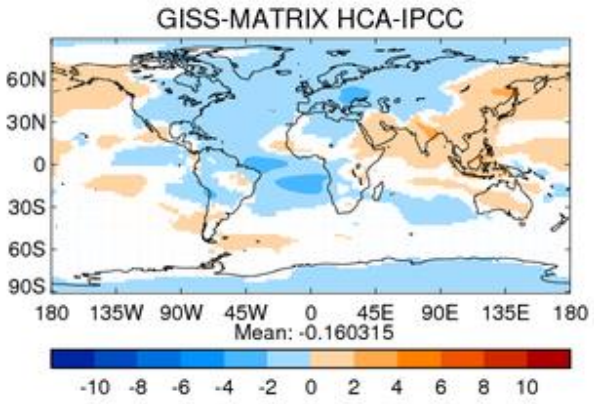


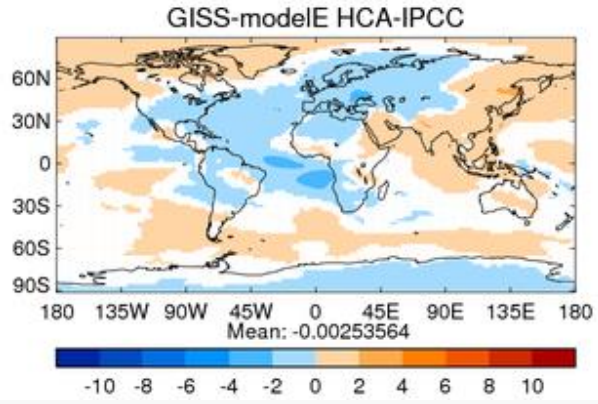
- Negative trends over North America and Europe, positive over Asia.
- Positive trends over Siberia (biomass-burning) in CMIP5 dataset.

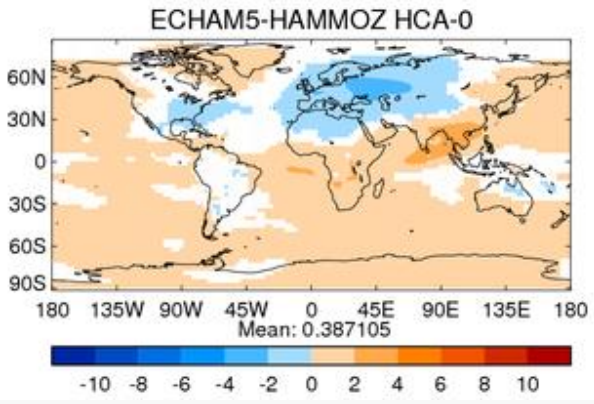
- Deseasonalised **sum of burdens of SO_4, BC, OC, NO_3.**
- Linear trends (% yr^{-1}) over Hindcast period, relative to period mean.
- White areas are not significant at the 95% confidence level.

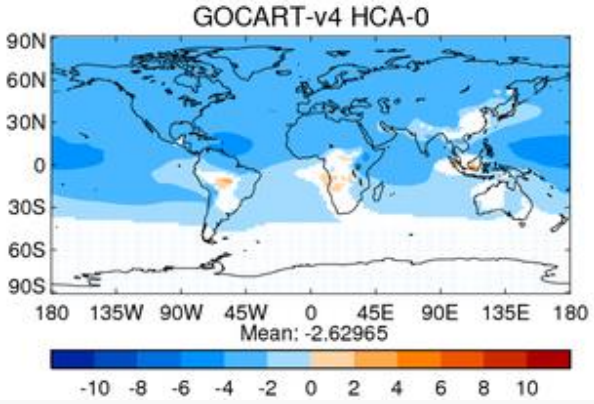












- Same sign as emission trends, but generally smaller.
- Extend to main transport pathways.

Ratio between relative trends in burden and emissions

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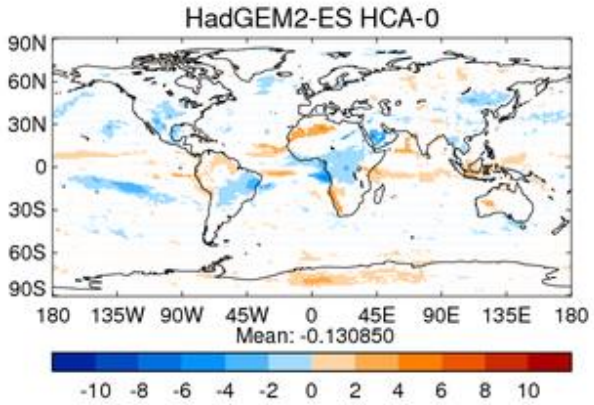
- Reminder: For aerosol species dominated by anthropogenic sources only.

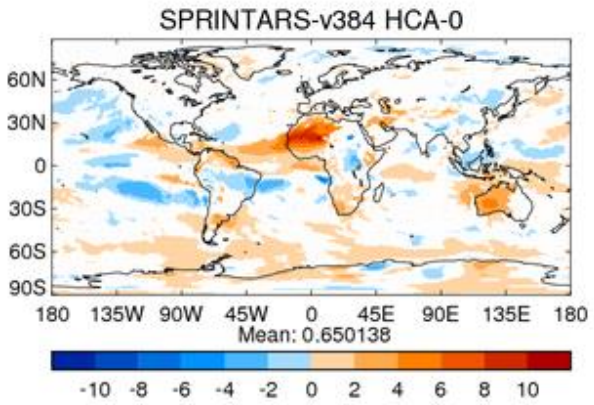
Model	Eastern US	Europe	Southeast Asia
HadGEM2-ES	0.81	0.71	**1.04**
SPRINTARS-v384	0.76	0.84	0.76
GISS-MATRIX	0.28	0.43	**2.12**
GISS-modelE	0.21	0.45	**1.28**
ECHAM5-HAMMOZ	0.45	0.65	**1.68**
GOCART-v4	0.94	0.75	0.57

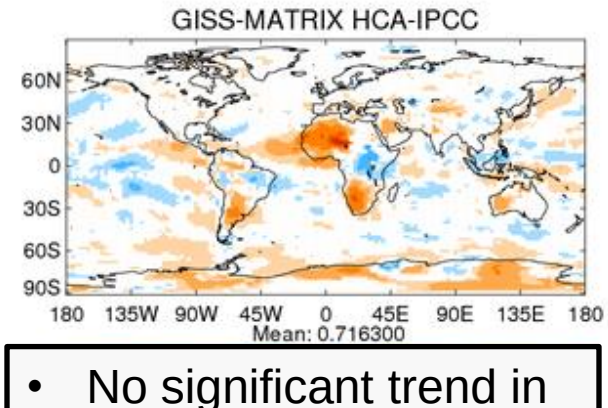
- Models agree that the trend in burden is smaller than that in emissions over Europe and Eastern US: expected because of transport away from the source regions.
- The situation over South-East Asia is less clear, and 4 models suggest that the trend in burden is larger than that in emissions: Trend in import of transported mass, trend in oxidation rates, or trend in deposition rates?

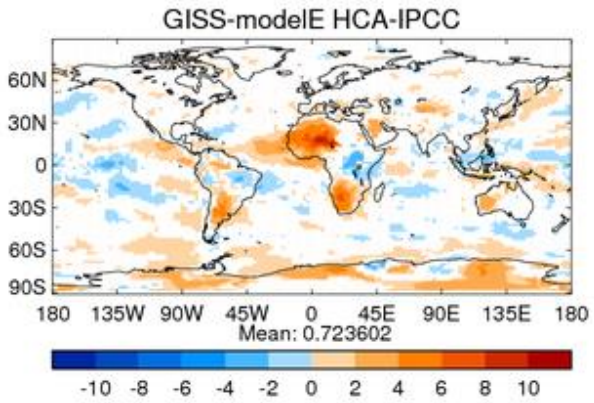
Precipitation rate

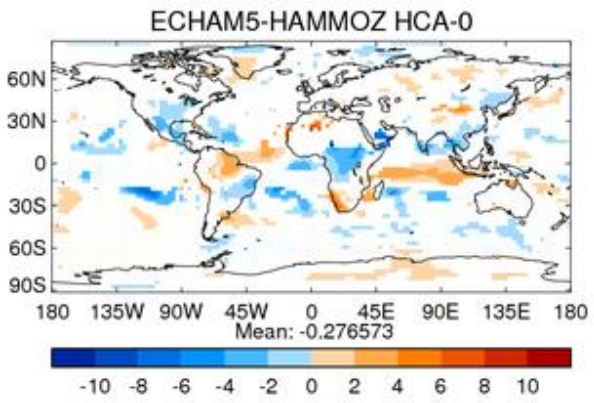
- Linear trends (% yr^{-1}) over Hindcast period, relative to period mean.
- (GOCART did not submit precipitation rates for 1980-1999.)
- White areas are not significant at the 95% confidence level.





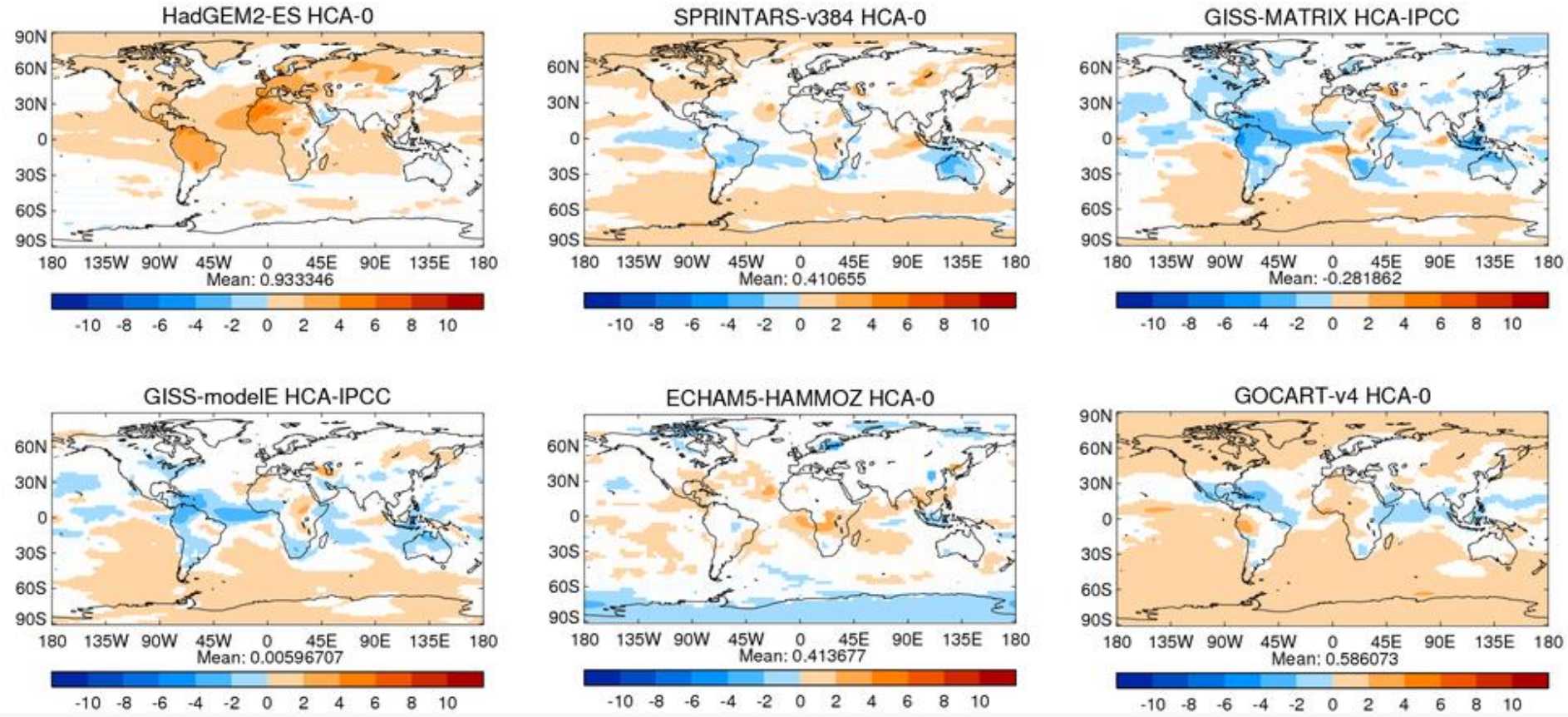






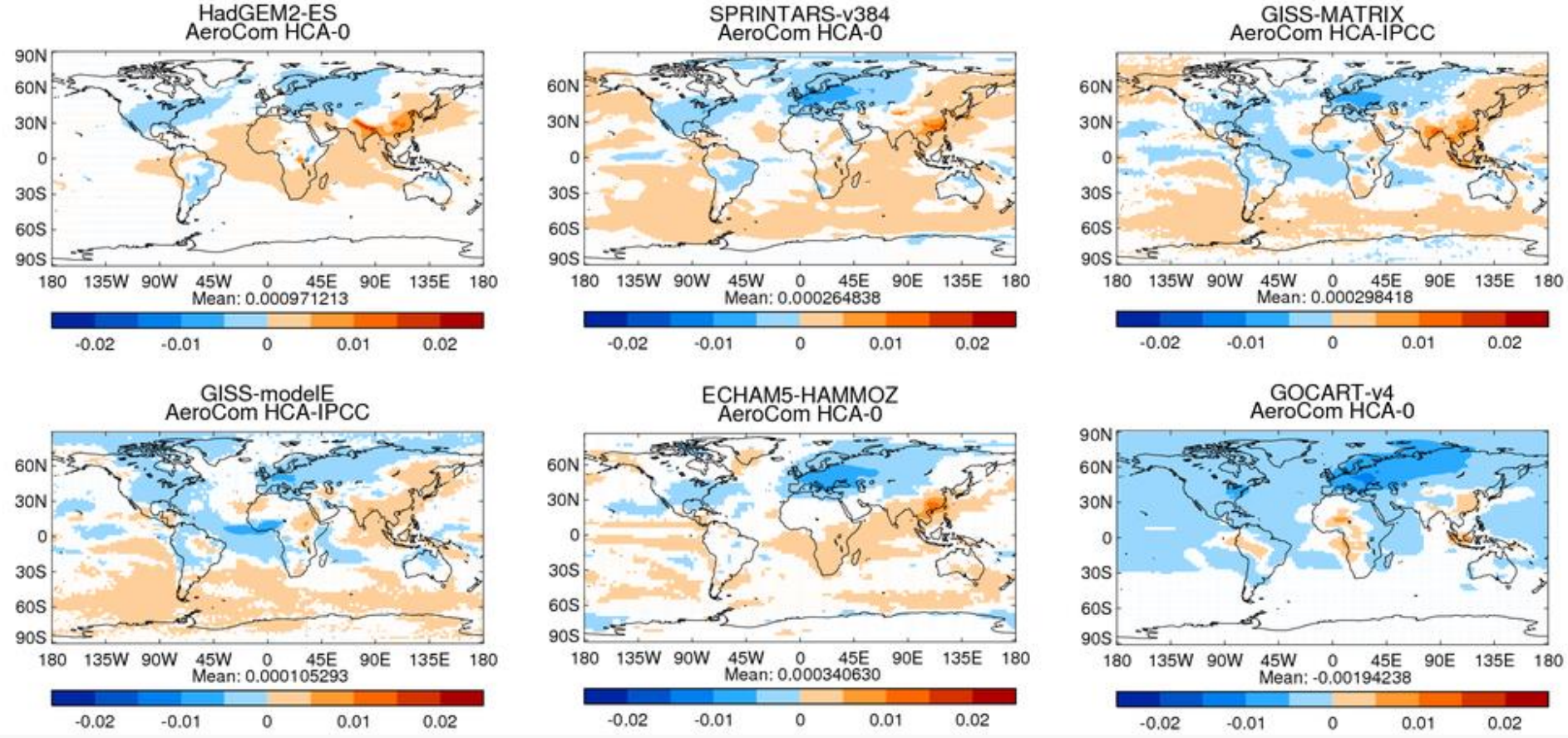
- No significant trend in precipitation over source regions in general, and Southeast Asia in particular.
- Some qualitative agreement between models, most likely

- Deseasonalised **sum of burdens of mineral dust, sea-salt, SOA**
- Linear trends (% yr^{-1}) over Hindcast period, relative to period mean.
- White areas are not significant at the 95% confidence level.

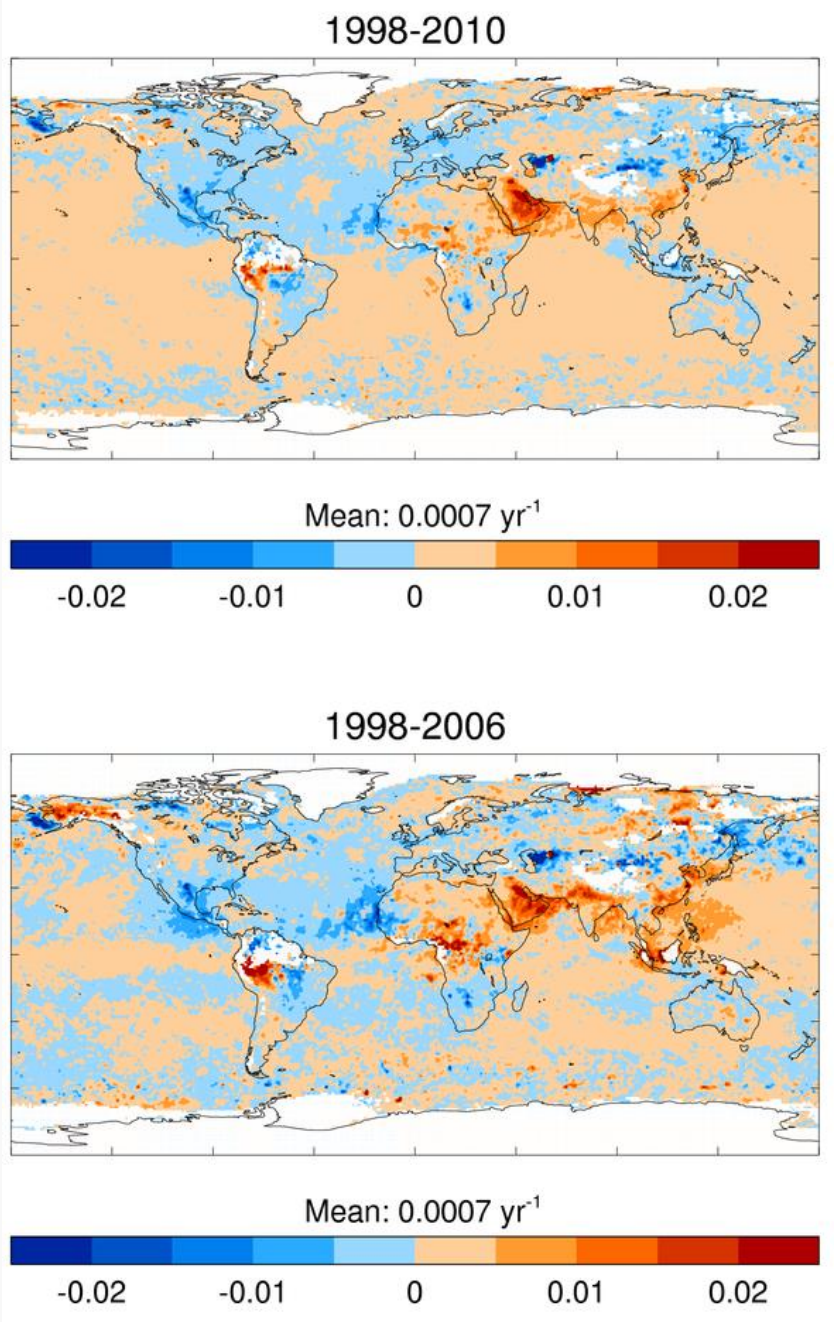


- No significant trends, except Saharan dust in HadGEM2 and GISS models.
- Hindcast setup (fixed SSTs and vegetation) not suited to climate feedbacks

- Deseasonalised **total aerosol optical depth** at 0.55 μm.
- Absolute linear trends (yr^{-1}) over Hindcast period (1980-2006).
- White areas are not significant at the 95% confidence level.



- In agreement with trend in burden: source regions and transport pathways.
- Nitrate opposes trend over Europe in HadGEM2, but not in GISS models.



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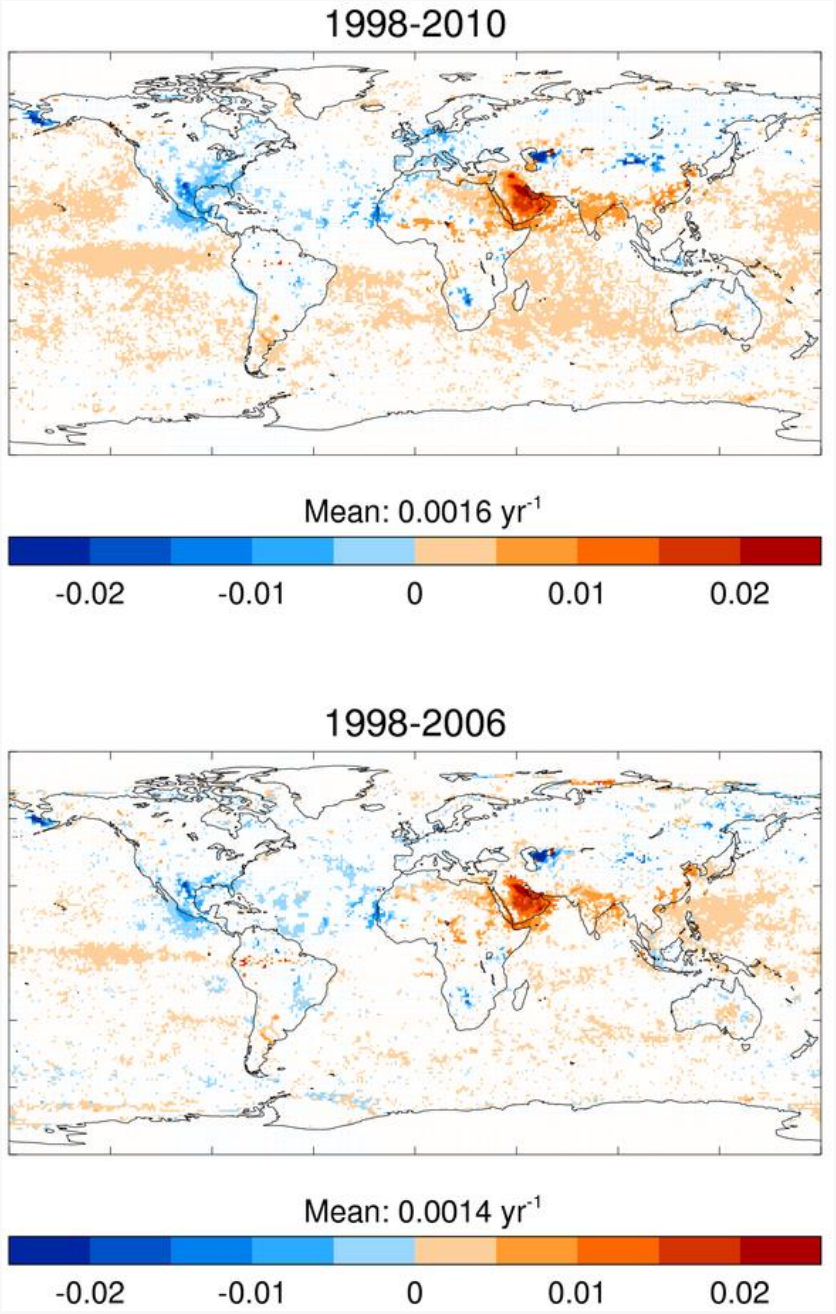
- Linear trends in deseasonalised monthly **total AOD** at 0.55 μm **SeaWIFS** SOAR+Deep Blue (Hsu *et al.*, 2012).
- Trends over anthropogenic source regions follow qualitative expectations.
- Hsu attributes positive trends over the Arabian peninsula, and negative trend off Africa to mineral dust.
- Periods 1998–2010 and 1998–2006 (Hindcast)



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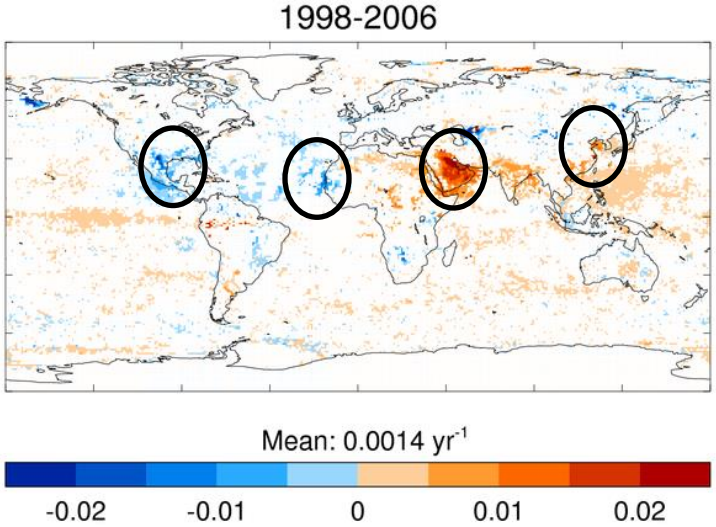
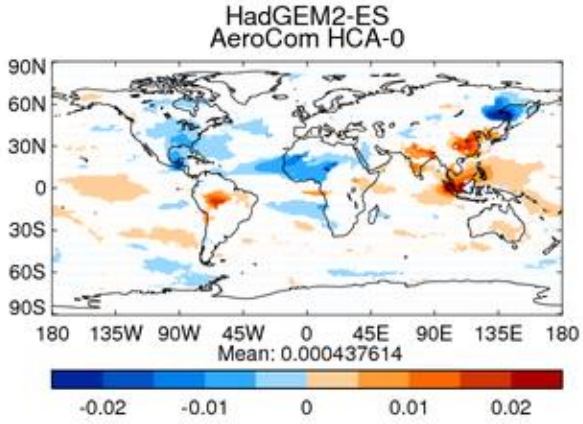
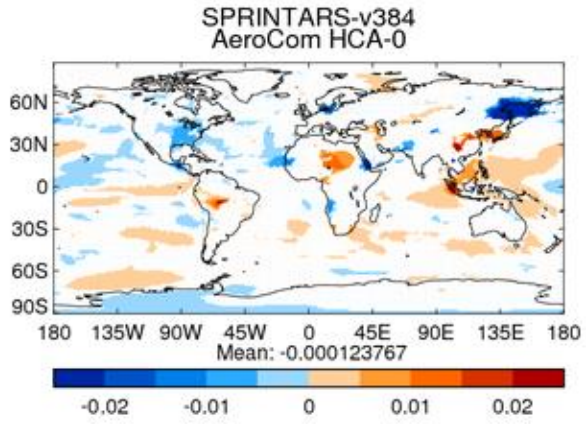
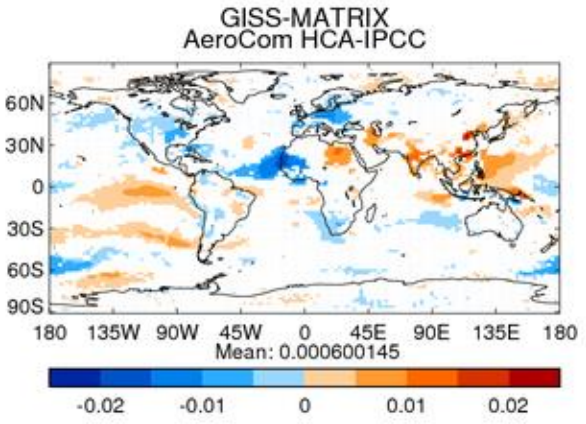
- Linear trends in deseasonalised monthly **total AOD** at 0.55 μm SeaWIFS SOAR+Deep Blue (Hsu et al., 2012).
- White areas are not significant at the 95% confidence level.
- Hints of negative trends over North America and Europe, and positive trends over India and around China.
- Positive trends over Arabian peninsula remain.

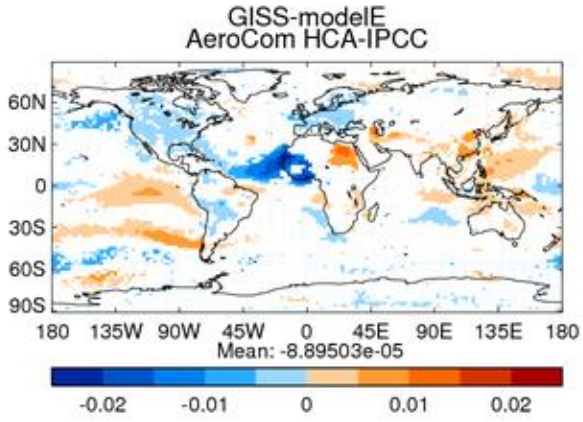
Trends in total AOD 1998–2006

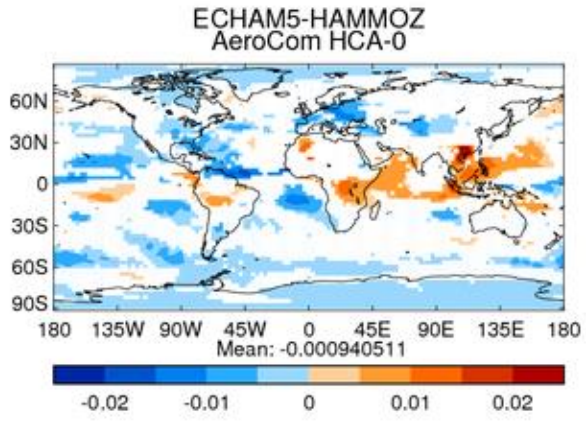


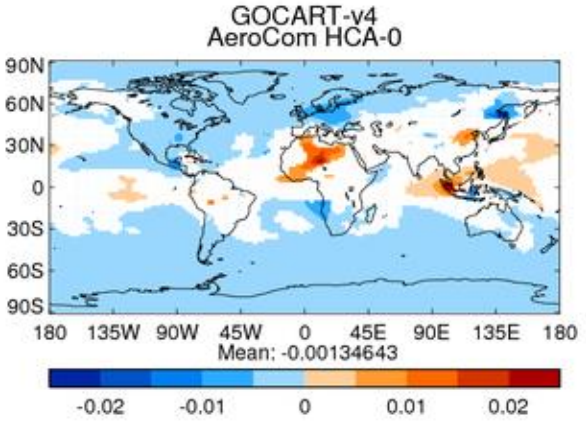




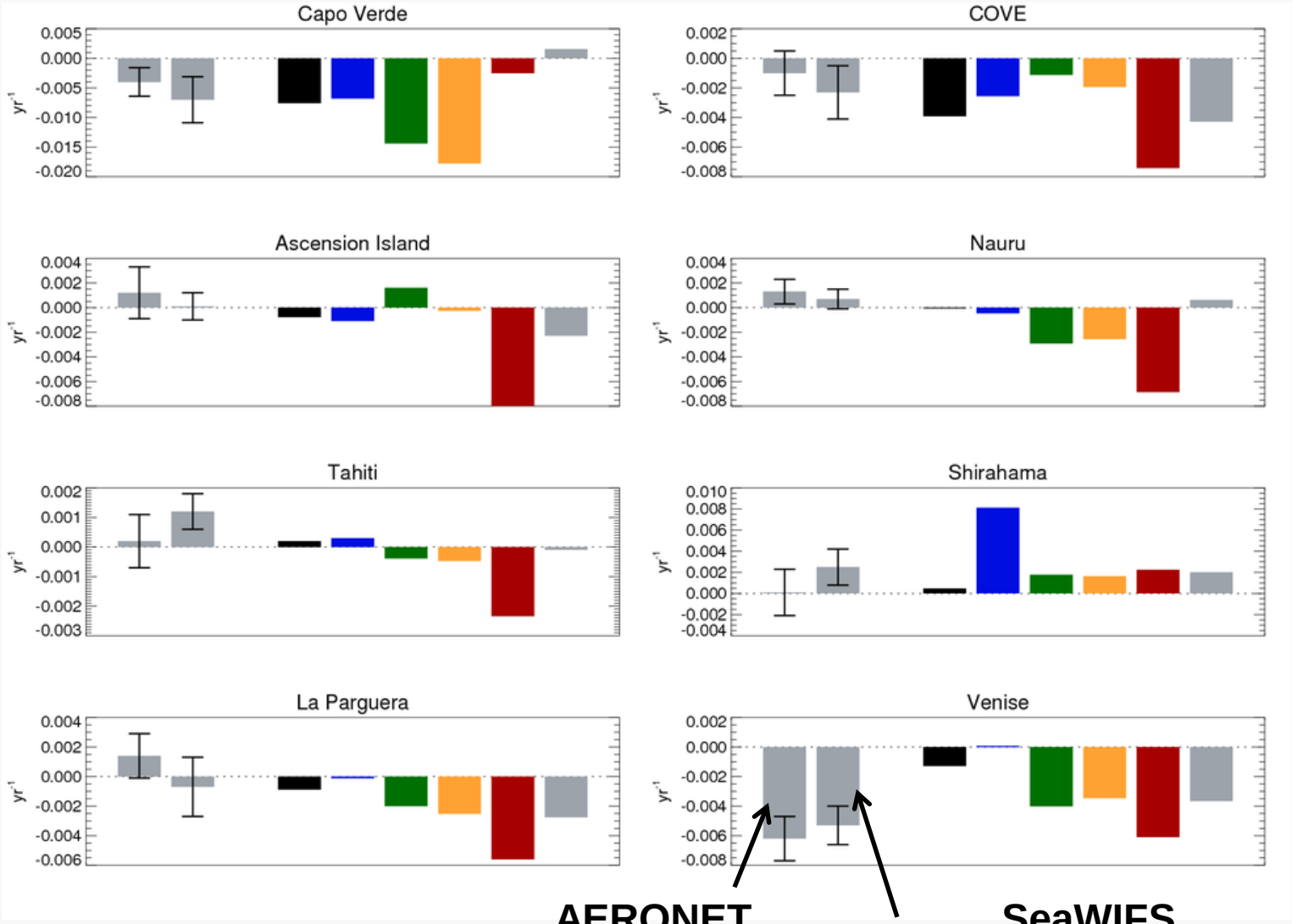








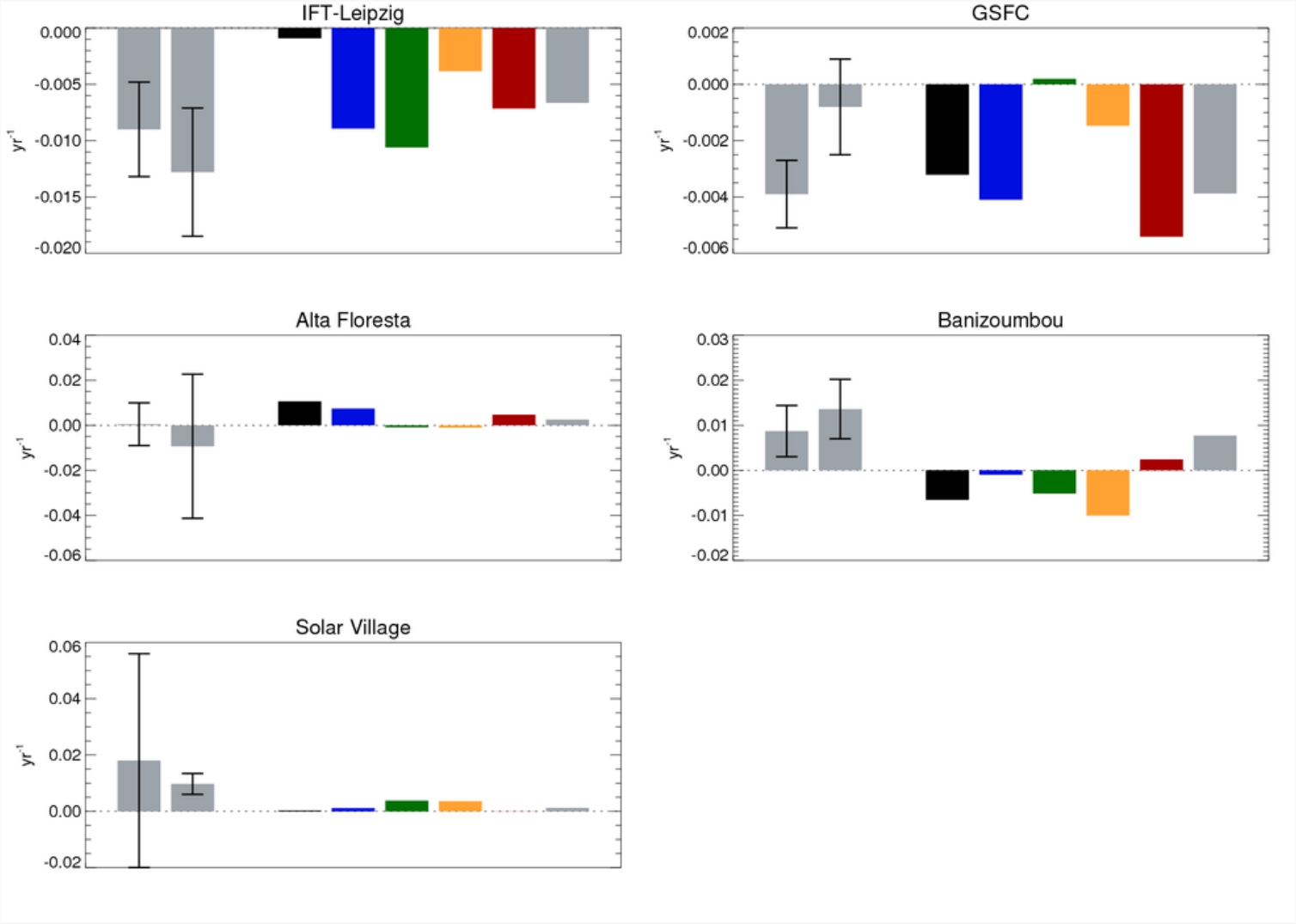
Trends in total AOD: AERONET. Coastal and



HadGEM2
SPRINTAR
G-MATRIX
G-modelE
ECHAM5
GOGART

AERONET and SeaWIFS trends from Table 2 of Hsu *et al.* (2012).

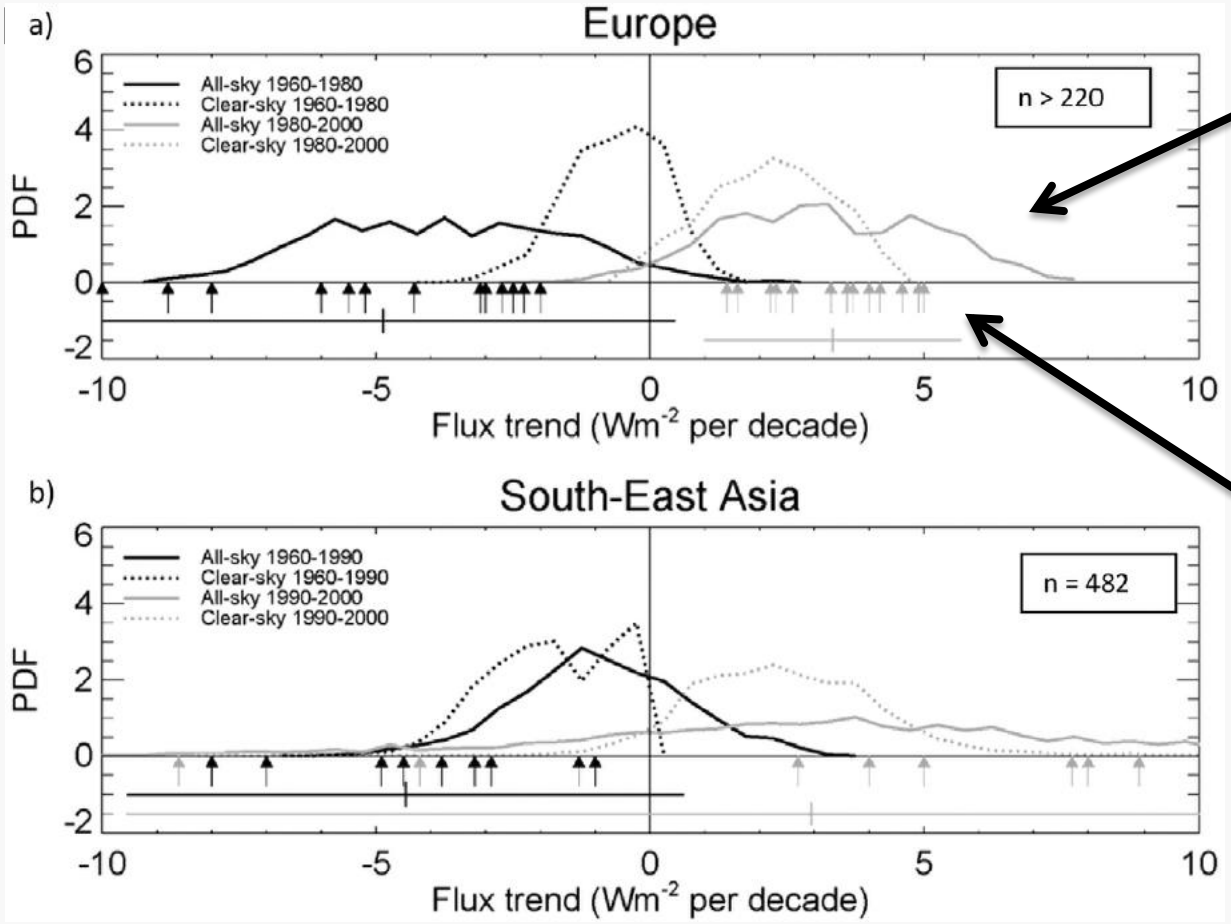
Trends in total AOD: AERONET. Continental sites.



HadGEM2
SPRINTAR
G-MATRIX
G-modelE
ECHAM5
GOGART

AERONET and SeaWIFS trends from Table 2 of Hsu *et al.* (2012).

Trends in surface radiative fluxes: Comparison to BSRN.

- Haywood et al. (2011), using HadGEM2-ES CMIP5 Historical simulation.
- 

PDFs: Modelled trends over the region for dimming (black) and brightening (grey) periods, in all- (solid) and clear-sky (dashed).

Arrows: Trends reported by BSRN sites located in the region.

Trends in surface radiative fluxes: Comparison to BSRN.

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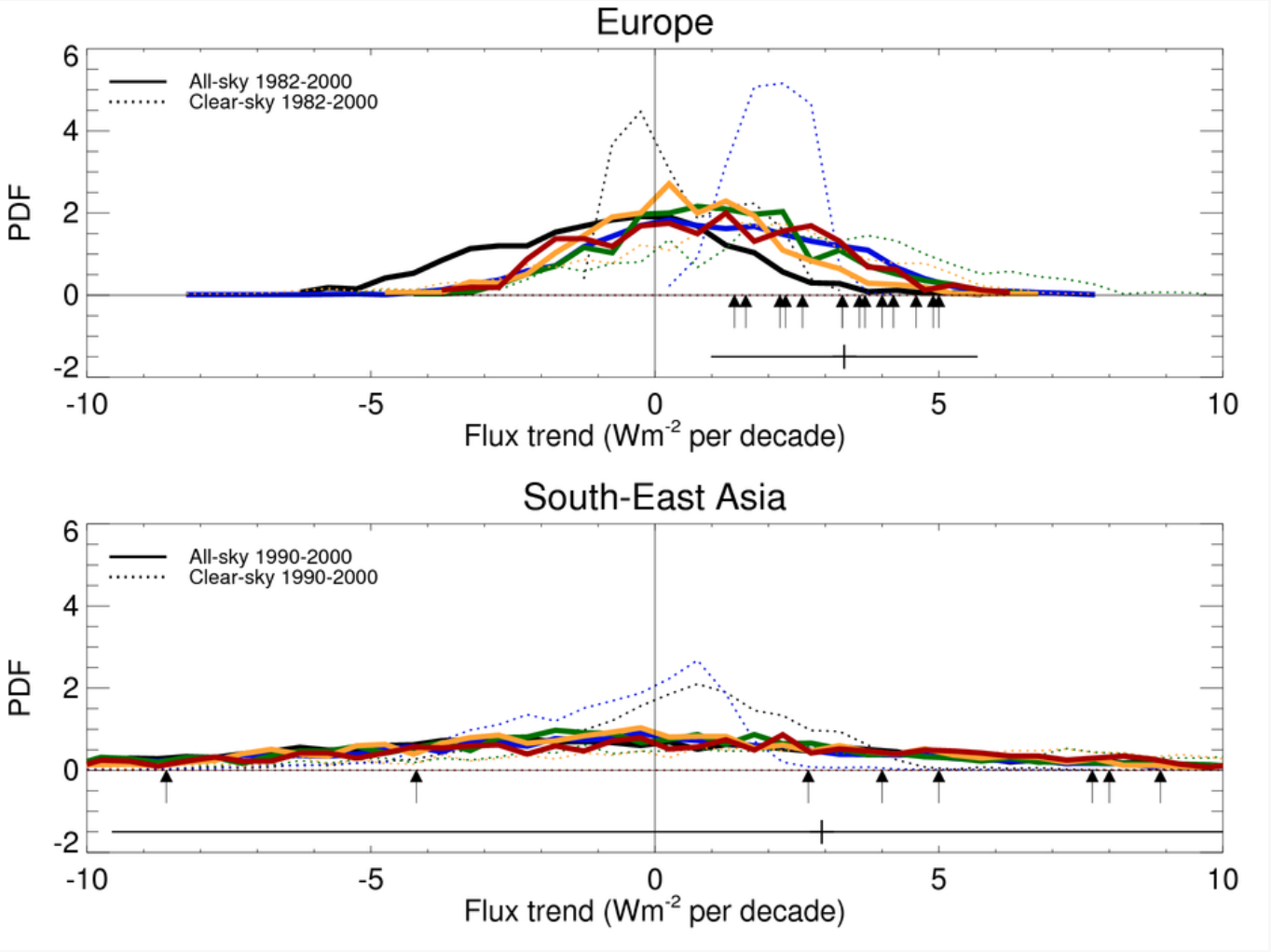

- AeroCom 2 Hindcast simulations fail to reproduce the clear brightening trend seen in European BSRN sites: Need of another forcing?
- The situation is better over Southeast Asia, where both dimming and brightening trends coexist.

HadGEM2
SPRINTARS
G-MATRIX
G-modelE
ECHAM5

Summary

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- No surprises: Anthropogenic emissions impose their trends on to aerosol mass and optical depth over the source regions and transport pathways.
- Trends in aerosol mass are smaller than those in emissions, except over Southeast Asia in 4 out of 6 models.
- No strong trends in aerosol species dominated by natural sources in the Hindcast simulations: *aerosol* v. *climate* Hindcast. (The latter wouldbe more adequate.)
- Hindcast simulations are in qualitative agreement with SeaWIFS and AERONET trends over the anthropogenic source regions.
- Brightening period over Europe is not as clear in Hindcast simulations as in BSRN: Not due to aerosols only?