# Impact of aerosol scheme, meteorology, and emissions on model skill in the AeroCom and CMIP5 aerosol simulations

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# 4 aerosol schemes, 11 simulations of 1980−2006

| Model | Simulation | Emissions | Meteorology |
|---|---|---|---|
| HadGEM2-ES | AeroCom HCA-0 | AeroCom | Nudged |
| | CMIP5 Historical | CMIP5 | Free-running |
| GISS-MATRIX | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | AeroCom HCA-MET | CMIP5 | Free-running |
| GISS-modelE | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | AeroCom HCA-MET | CMIP5 | Free-running |
| SPRINTARS, MIROC5, MIROC-ESM | AeroCom HCA-0 | AeroCom | Nudged |
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| | CMIP5 Historical | CMIP5 | Free-running |
| | CMIP5 Historical | CMIP5 | Free-running |
| | CMIP5 Historical | CMIP5 | Free-running |

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# AOD data availability (1980 – 2006)

| | |
|---|---|
| (green) | Available |
| (red) | Missing |
| ? | Unclear |
| | N/A |

| Model: | H2 | H2 | SP | SP | MI | MI | MI | GX | GX | GE | GE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Simulation: | A0 | CH | A0 | AI | CH | CH | CH | AI | AM | AI | AM |
| Total | Available | Available | Available | Available | Available | Available | Available | Available | Available | Available | Available |
| Absorption | Available | Missing | Available | Available | Available | Available | Available | Available | Available | Available | Available |
| Fine-mode | Available | Available | Available | Available | Available | Available | Available | Available | Available | Available | Available |
| Sulphate | Available | Available | Available | Available | Available | Available | Available | | | Available | Available |
| BC | Available | Available | Available | Available | Available | Available | Available | | | Missing | Missing |
| OA | Available | Available | Available | Available | Available | Available | Available | | | Available | Available |
| SOA | Available | Available | Available | Available | ? | ? | ? | | | ? | ? |
| Biomass | Available | Available | | | | | | | | | |
| Nitrate | Available | | | | | | | | | Missing | Missing |
| Sea-salt | Available | Available | Available | Available | Available | Available | Available | | | Available | Available |
| M.Dust | Available | Available | Available | Available | Available | Available | Available | | | Available | Available |

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# Inter-comparison

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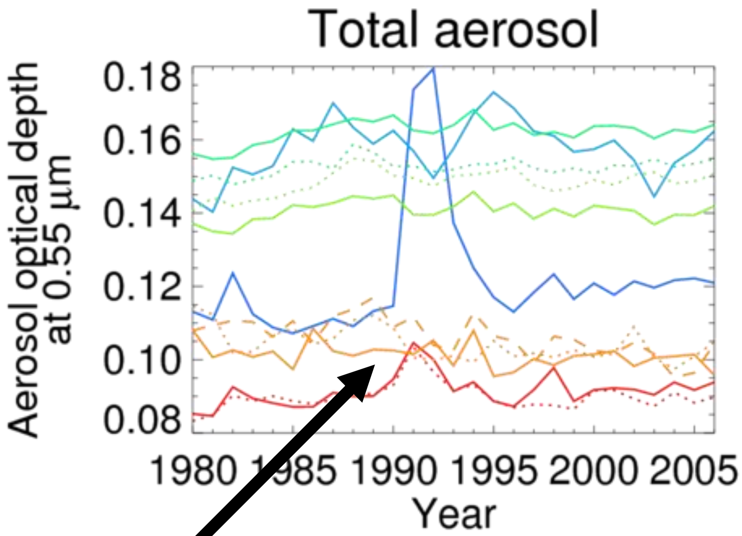


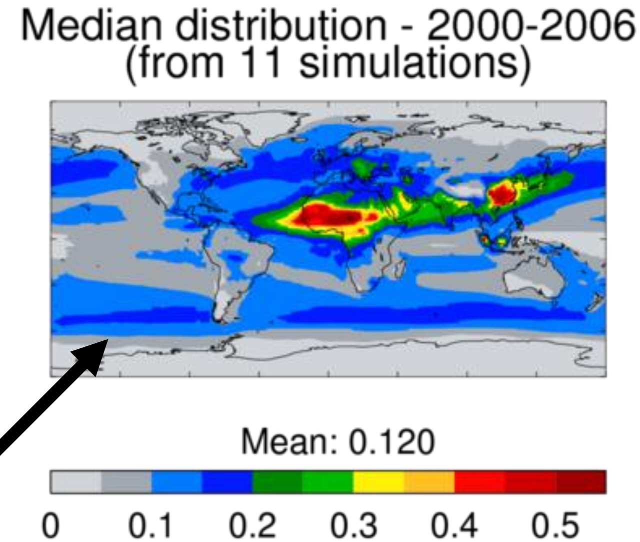


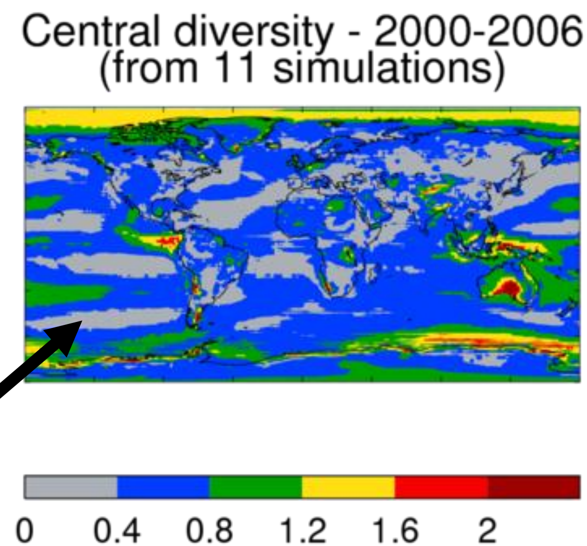


**Time series of global, annual averages for 1980–2006**

**Median distribution for 2000–2006**

**Central diversity with respect to the median: (P75-P25) / P50**

**HadGEM2**
**GISS-MATRIX**
**GISS-modelE**
**SPRINTARS/MIROC**

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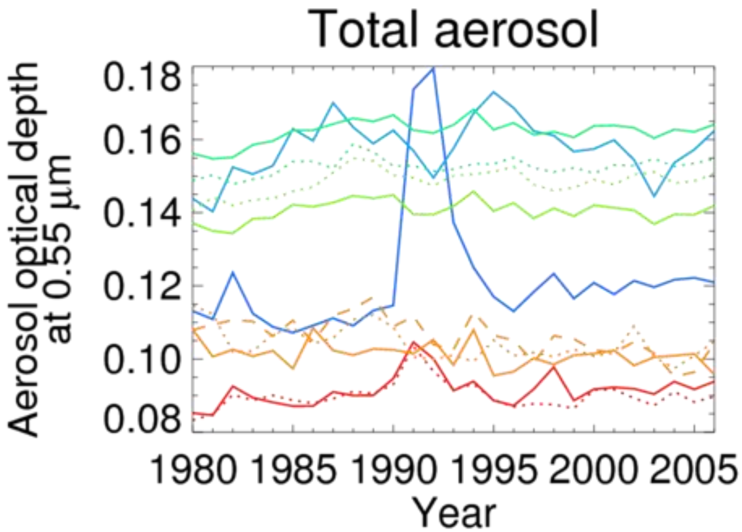


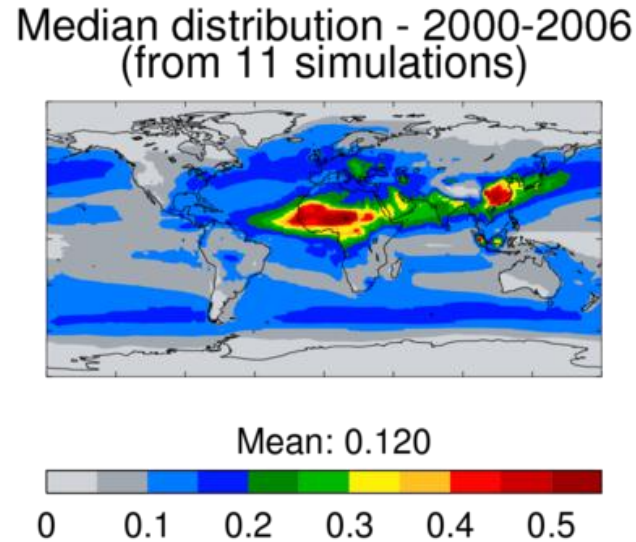


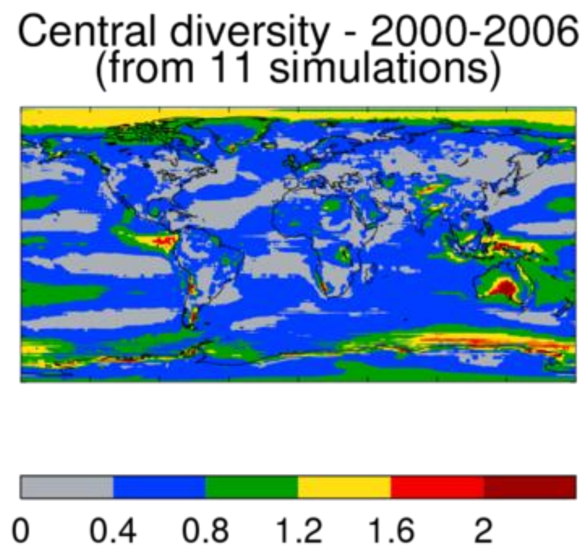


- Total AOD:
  - Factor 2 between max and min globally-averaged time series.
  - Simulations tend to group by aerosol scheme.
  - Diversity is relatively large, and peaks in remote regions.

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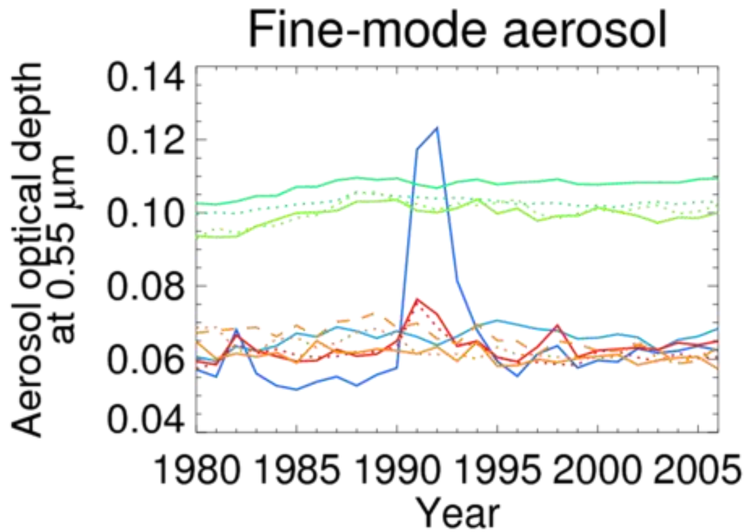
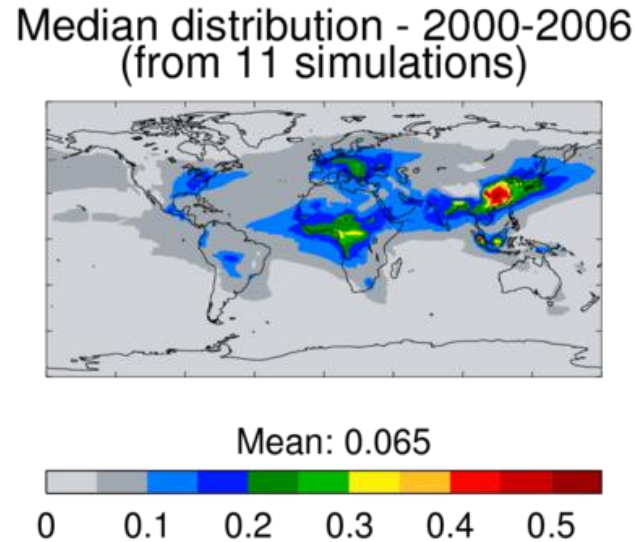
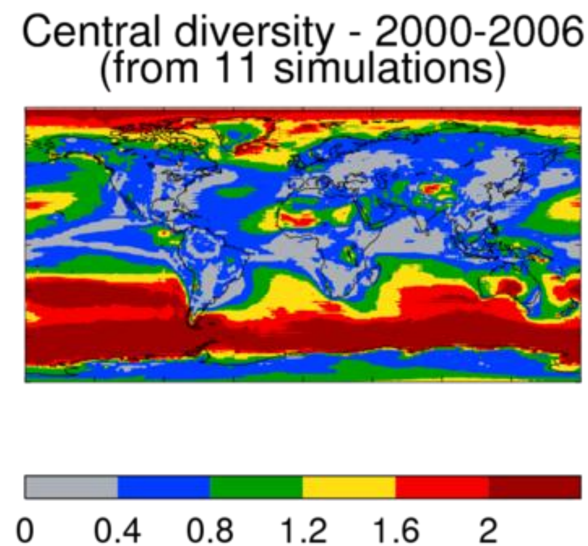



- Fine-mode AOD:
  - Factor 1.5 between max and min globally-averaged time series.
  - GISS models yield larger values than HadGEM and SPRINTARS.
  - Diversity is larger in regions dominated by coarse-mode aerosols. Near anthropogenic source regions, diversity is 20 to 40%.

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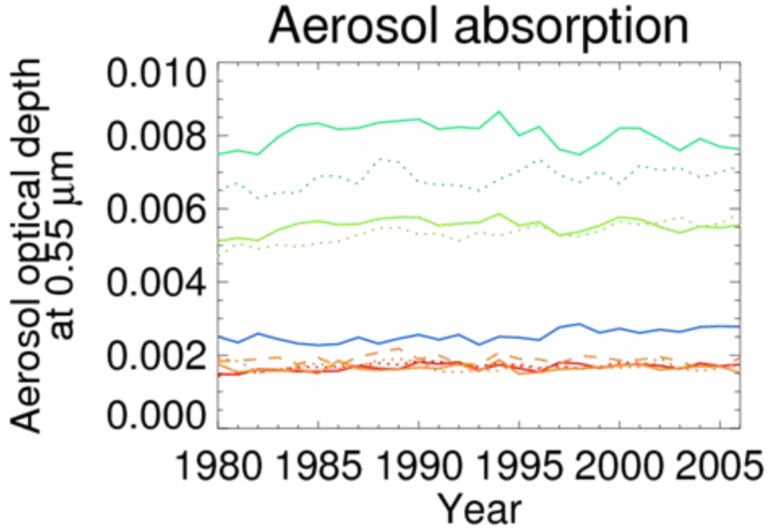
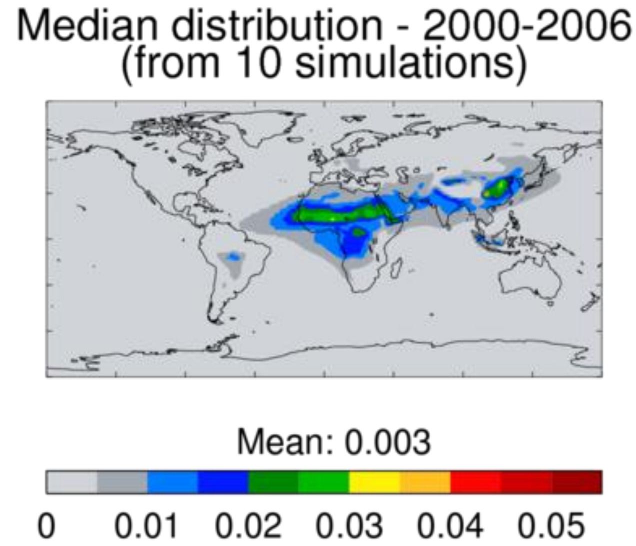
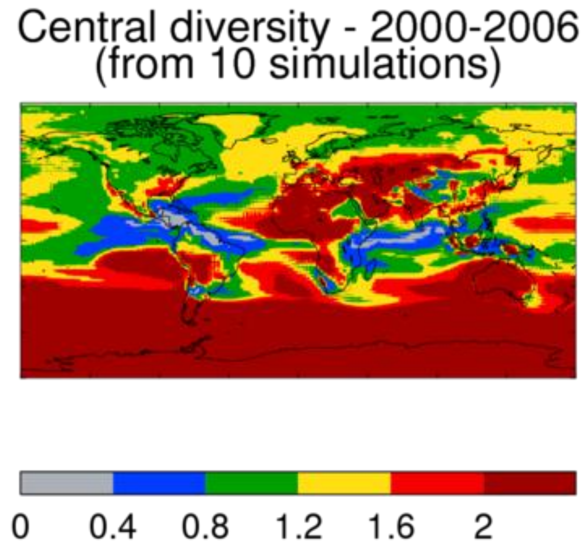



- Absorption AOD:
  - Factor 4 between globally-averaged time series. Magnitudes are strongly dependent on the aerosol scheme.
  - GISS models include enhancement of BC absorption (modelE: globally prescribed factor, MATRIX: internal mixture state).
  - Mineral dust absorption also matters.

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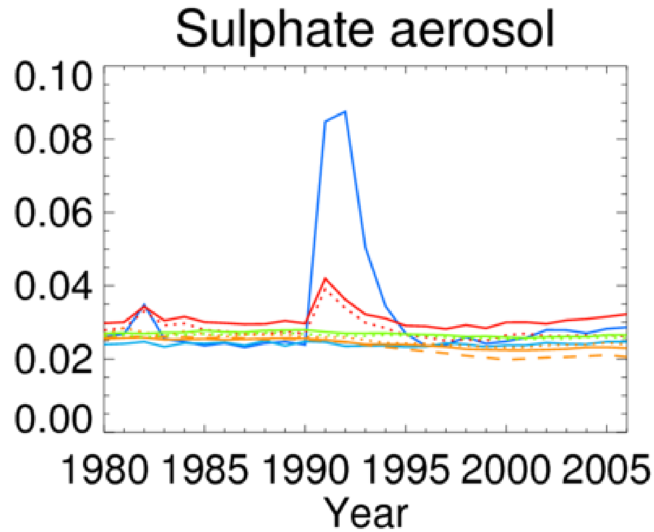


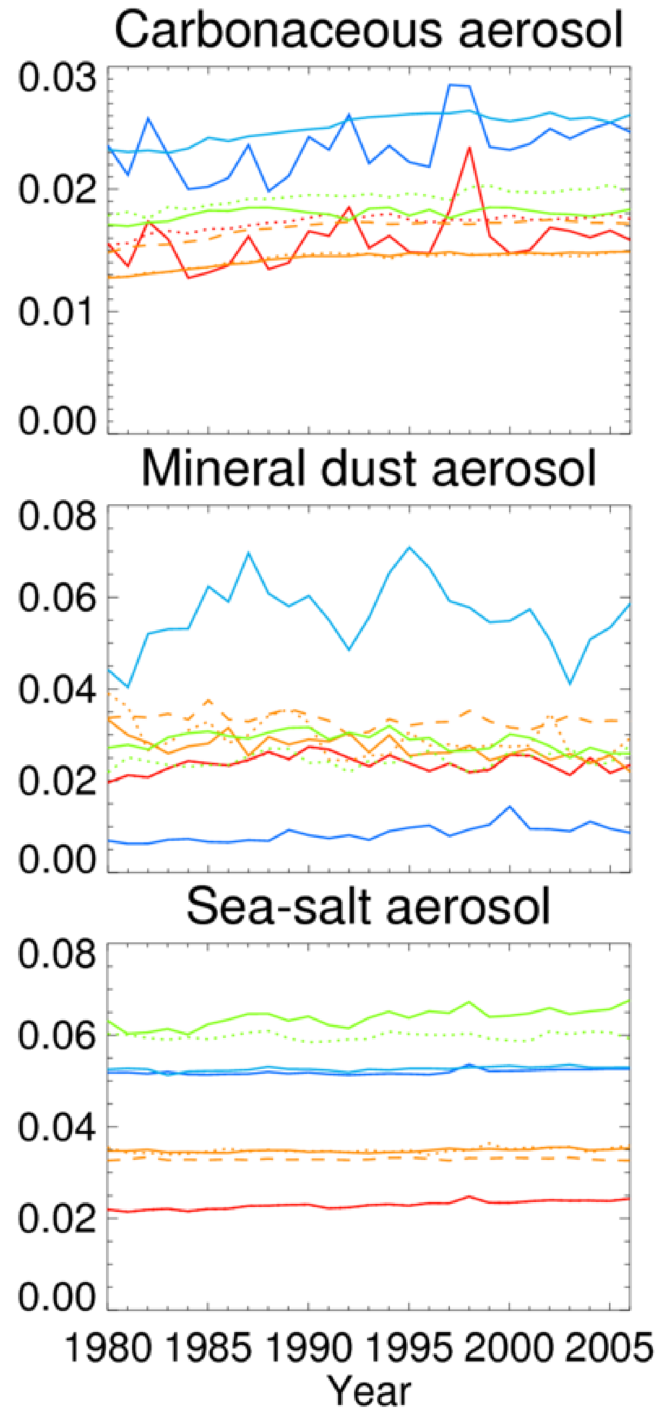


- Sulphate:
  - Good global agreement. Diversity at high latitudes and over the oceans around the Equator (wet removal, DMS emissions).
- Carbonaceous:
  - Global disagreement by a factor 1.4. Diversity 40-80% over source regions, much larger elsewhere.
- Mineral dust:
  - Varies wildly in HadGEM2 simulations. Agreement within a factor 1.5 in GISS and SPRINTARS model. Diversity is larger for transported aerosol, including Atlantic plume.
- Sea-salt:
  - Global disagreement by a factor 3, strongly dependent on the aerosol scheme. Diversity is larger over tropical oceans.
- **(See additional slides at the end of this presentation for more details.)**

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# Assessment of model skill

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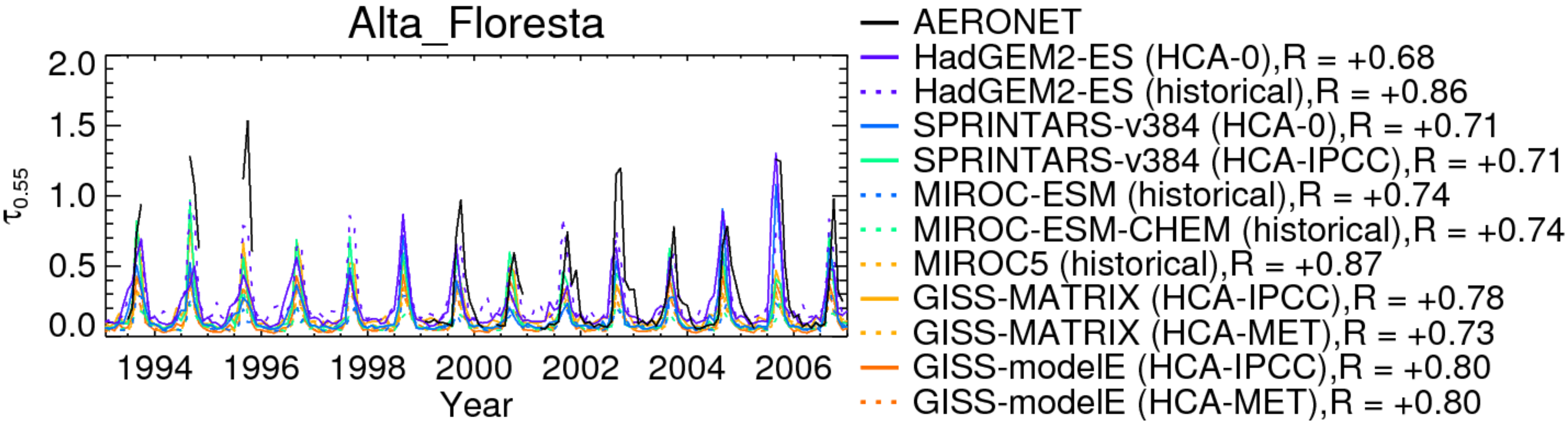
# Method




- Simulated **monthly total AODs** at 0.55 μm are compared against AERONET.
- **135 AERONET sites** with at least 60 valid (L2V2) monthly means over 1990s–2006.
- **RMSE** against AERONET gives a measure of model skill at reproducing the magnitudes of the AODs.
- **Correlation** with AERONET gives a measure of model skill at reproducing seasonal and inter-annual variability.

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# Impact of meteorology

| Model | Simulation | Emissions | Meteorology |
|---|---|---|---|
| HadGEM2-ES | AeroCom HCA-0 | AeroCom | Nudged |
| | CMIP5 Historical | CMIP5 | Free-running |
| **GISS-MATRIX** | **AeroCom HCA-IPCC** | **CMIP5** | **Nudged** |
| | **AeroCom HCA-MET** | **CMIP5** | **Free-running** |
| GISS-modelE | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | AeroCom HCA-MET | CMIP5 | Free-running |
| SPRINTARS, MIROC5, MIROC-ESM | AeroCom HCA-0 | AeroCom | Nudged |
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| | CMIP5 Historical | CMIP5 | Free-running |

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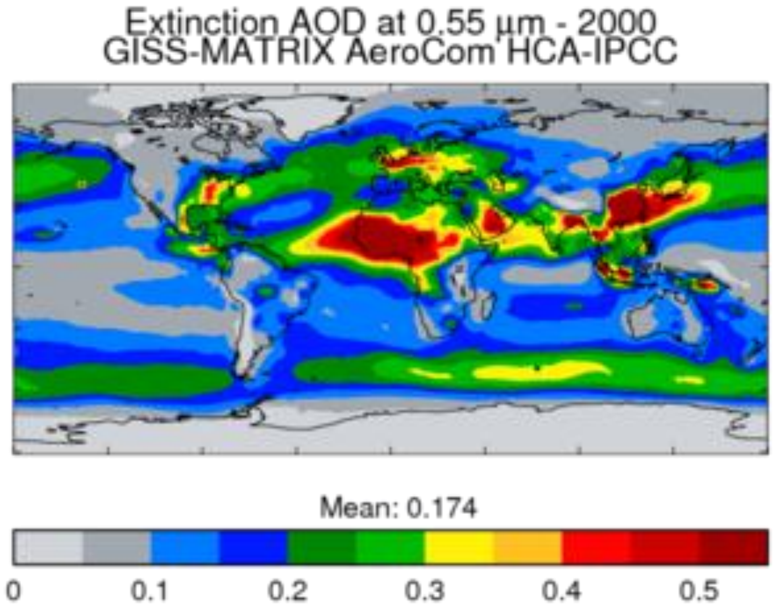
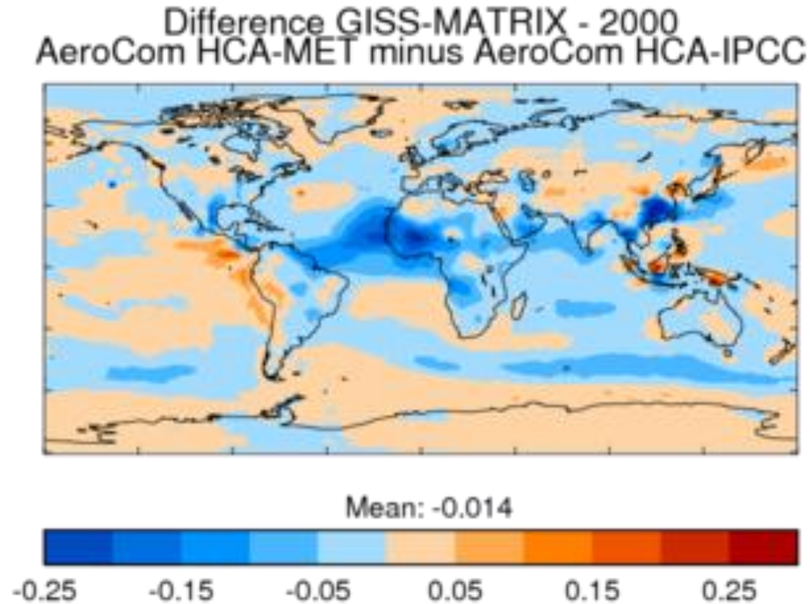
# Impact of meteorology




- Similar simulations of total AOD for the year 2000.
- Mineral dust is sensitive to meteorology, as can be expected.

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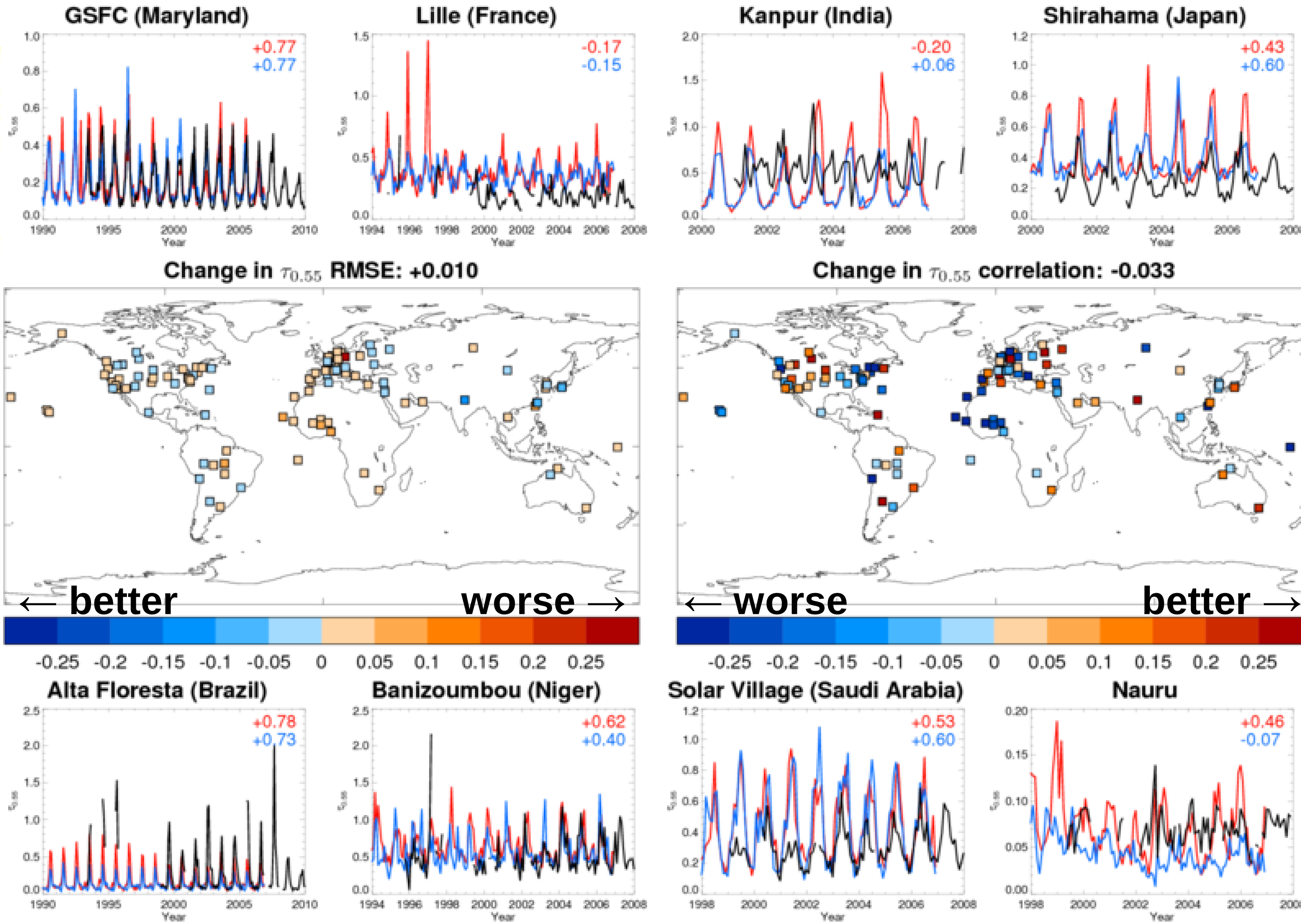


- Across all sites, moving from nudged to free-running meteorology increases RMSE by 9% and decreases correlation by 11%.
- Free-running meteorology improves skill at some sites, however.

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# Impact of emission datasets

| Model | Simulation | Emissions | Meteorology |
| --- | --- | --- | --- |
| HadGEM2-ES | AeroCom HCA-0 | AeroCom | Nudged |
| | CMIP5 Historical | CMIP5 | Free-running |
| GISS-MATRIX | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | AeroCom HCA-MET | CMIP5 | Free-running |
| GISS-modelE | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | AeroCom HCA-MET | CMIP5 | Free-running |
| **SPRINTARS**, MIROC5, MIROC-ESM | **AeroCom HCA-0** | **AeroCom** | **Nudged** |
| | **AeroCom HCA-IPCC** | **CMIP5** | **Nudged** |
| | CMIP5 Historical | CMIP5 | Free-running |
| | CMIP5 Historical | CMIP5 | Free-running |
| | CMIP5 Historical | CMIP5 | Free-running |

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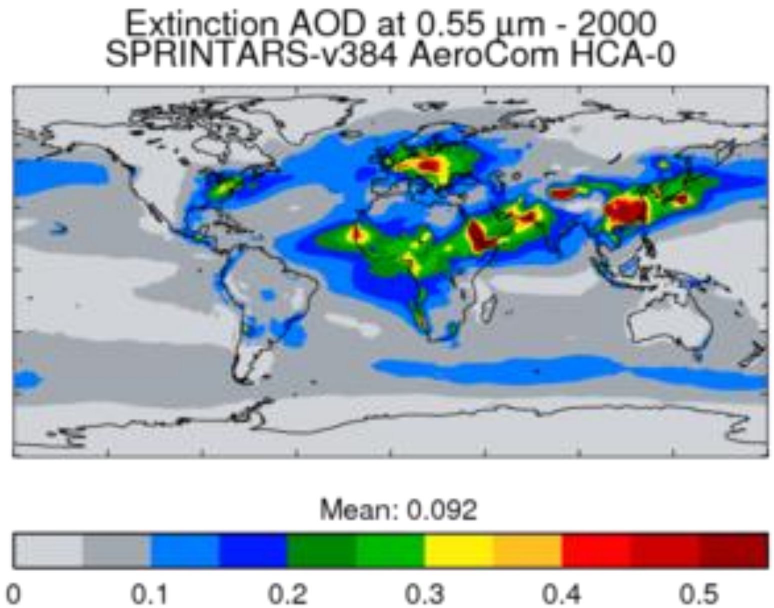
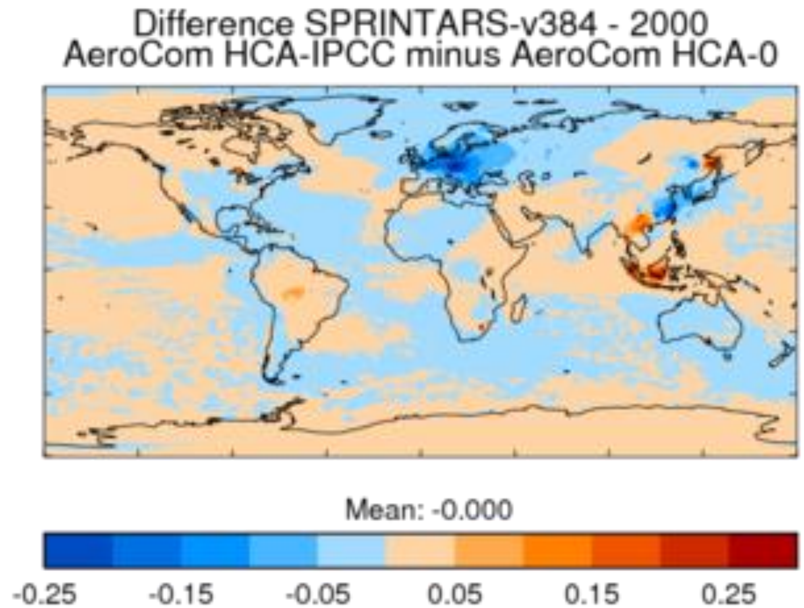
# Impact of emission datasets




- Known errors in AeroCom Hindcast emissions in Eastern Europe cause an overestimation of sulphate AOD there.
- Differences in biomass-burning emissions have more limited impacts.

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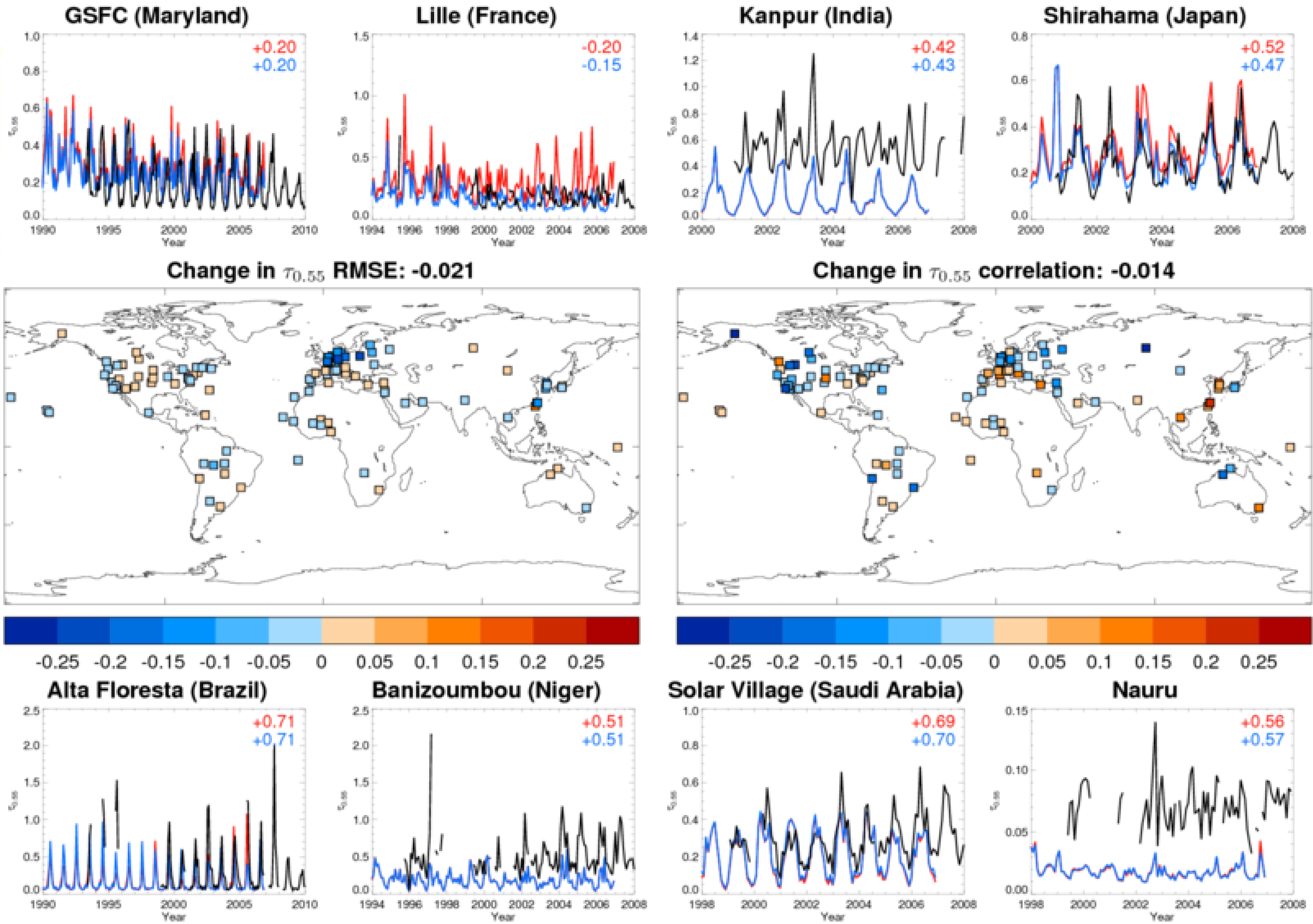


- Across all sites, switching from AeroCom Hindcast (annual) to CMIP5 (decadal) improves RMSE by 14% but decreases correlation by 5%.
- Better RMSE due to European emissions errors in Hindcast dataset. Worse correlation because of decadal resolution, but not everywhere.

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# Impact of meteorology and emissions

| Model | Simulation | Emissions | Meteorology |
|---|---|---|---|
| **HadGEM2-ES** | **AeroCom HCA-0** | **AeroCom** | **Nudged** |
| | **CMIP5 Historical** | **CMIP5** | **Free-running** |
| GISS-MATRIX | AeroCom HCA-IPCC | CMIP5 | Nudged |
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| | AeroCom HCA-IPCC | CMIP5 | Nudged |
| | CMIP5 Historical | CMIP5 | Free-running |
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| | CMIP5 Historical | CMIP5 | Free-running |

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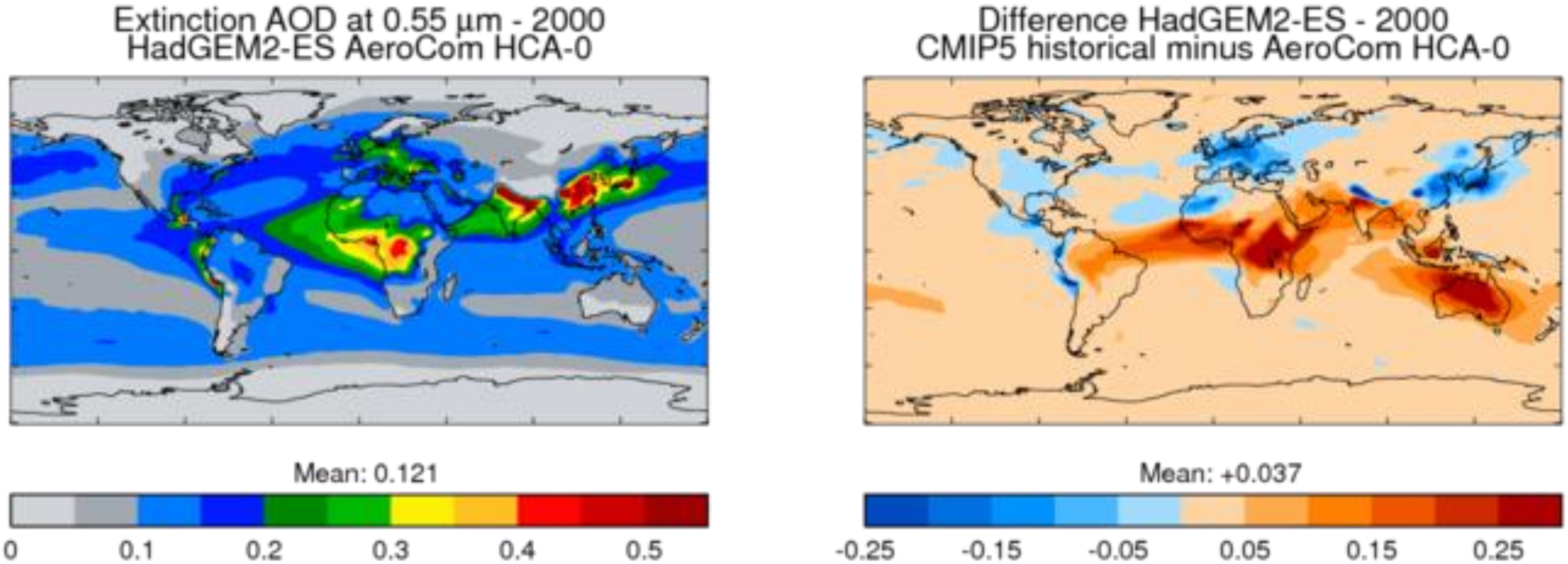
# Impact of meteorology and emissions




- Again, known errors in AeroCom Hindcast emissions in Eastern Europe cause an overestimation of sulphate AOD there.
- Large differences in mineral dust AOD are due to different calibrations of the mineral dust scheme.

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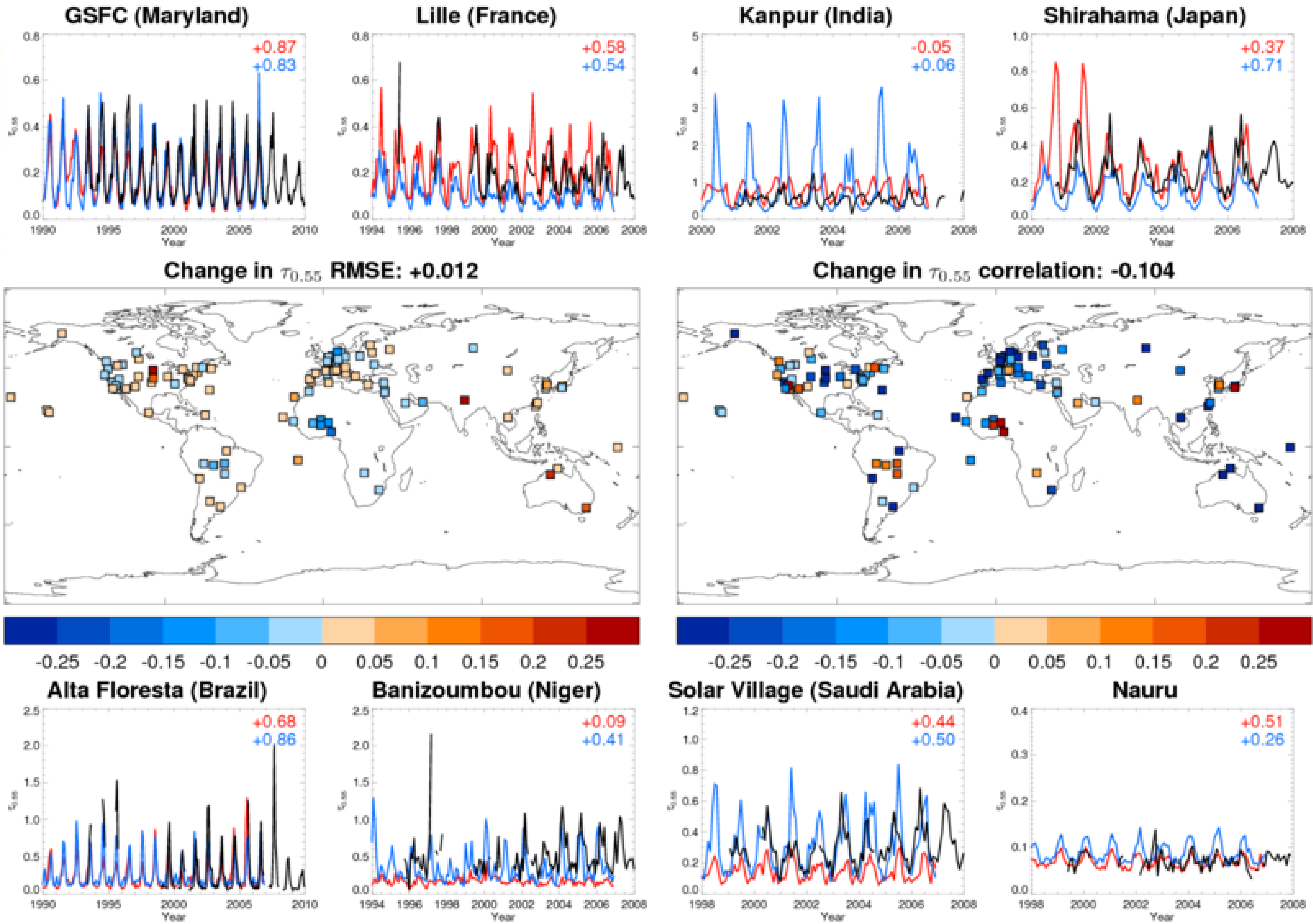


- Across all sites, switching from AeroCom Hindcast (annual emissions, nudged) to CMIP5 (decadal emissions, free-running) degrades skill: RMSE increases by 12%, and correlation decreases by 20%.

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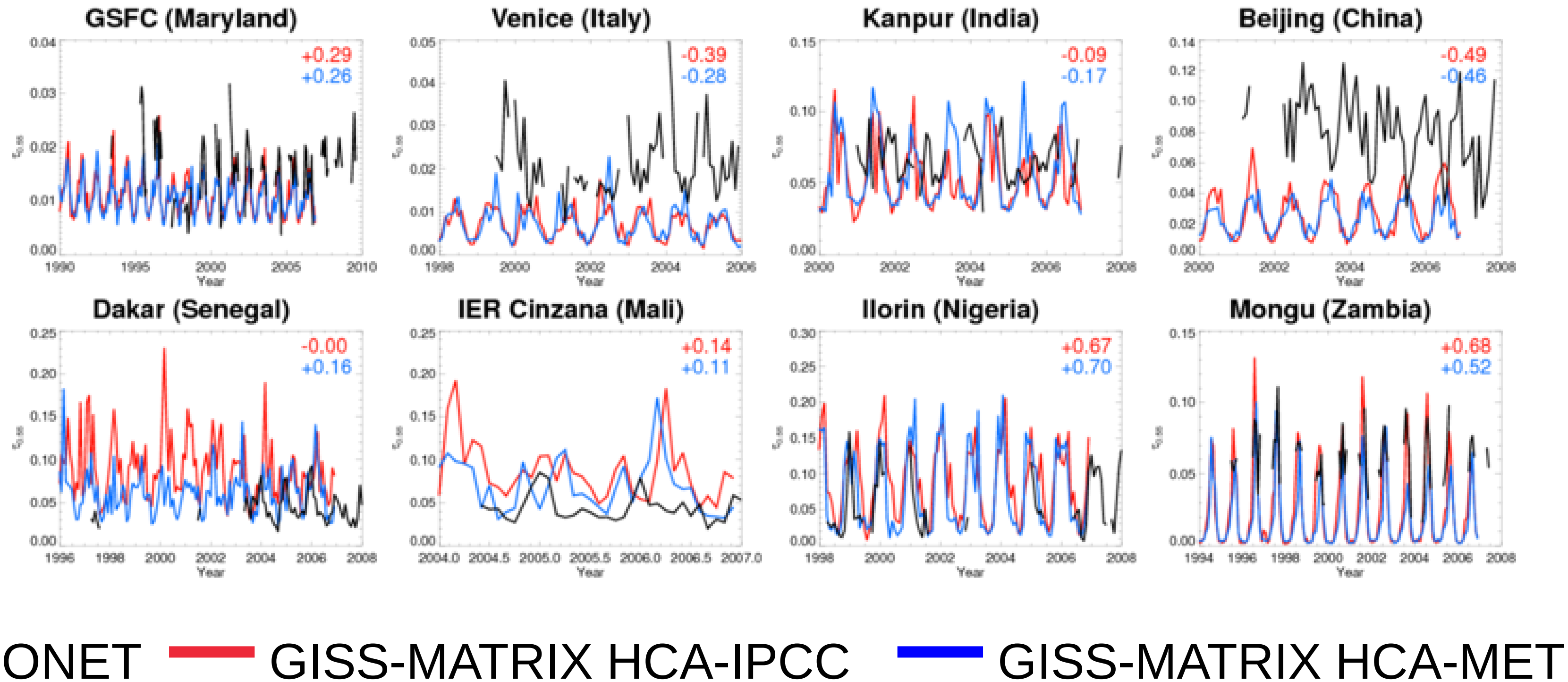
# Absorption optical depth




- Interestingly, GISS-MATRIX simulates the magnitude of absorption AOD reasonably well when compared against Oleg Dubovik’s retrieval at 28 AERONET sites.

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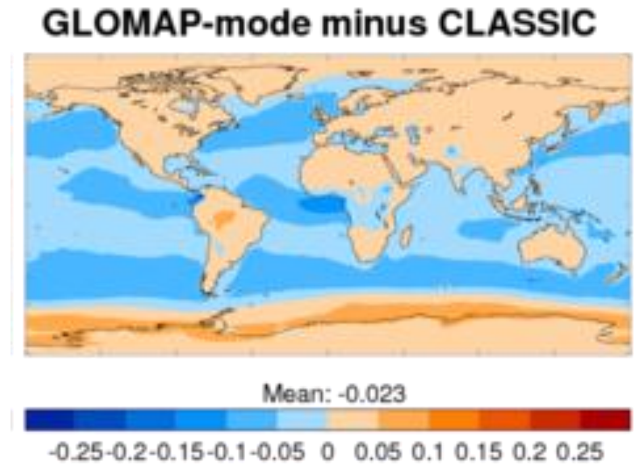
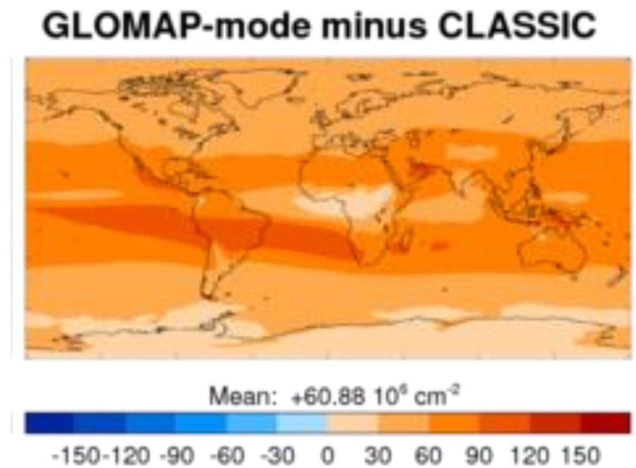
# Relevance to aerosol forcing?

Difference in simulated AOD (0.55 µm) for 1850




Difference in simulated column-integrated CDNC for 1850




- Bellouin et al., ACPD [2012] compare the CLASSIC mass-based and the GLOMAP-mode microphysical scheme in HadGEM.
- Similar skill in simulating present-day AODs.
- But 1850 baseline is different (see above), especially for the background cloud droplet number concentration (CDNC).

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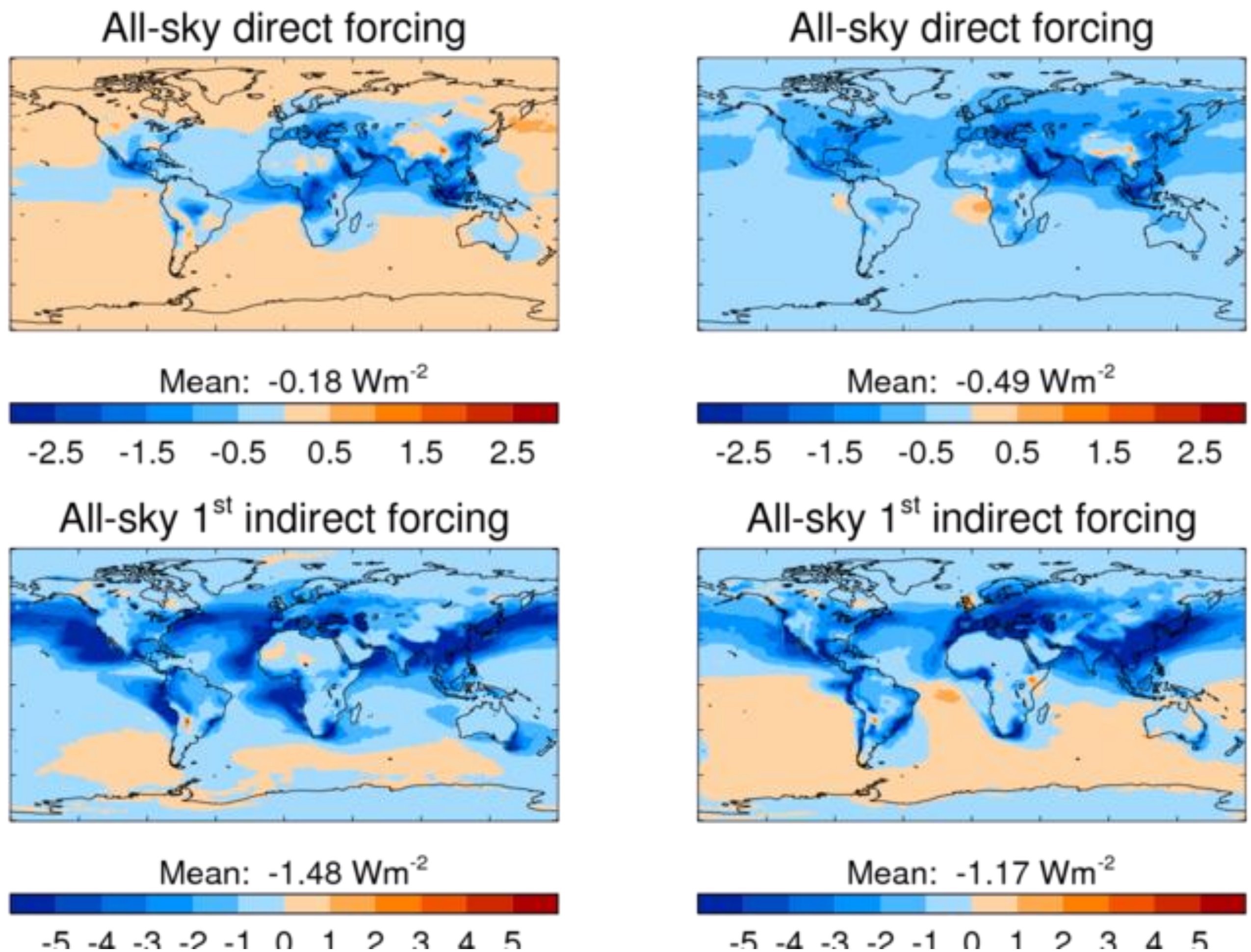
# Relevance to aerosol forcing?

**CLASSIC** | **GLOMAP-mode**




- Direct forcing is 72% stronger in the microphysical scheme, but 1st indirect forcing is 20% weaker.
- Need to validate the simulated contrast in aerosols in polluted and unpolluted regions to assess skill in forcing estimates.

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# Conclusion

- The magnitude of extinction and absorption aerosol optical depth is primarily determined by the aerosol scheme used. Model diversity is large.

- Free-running meteorology typically worsen model skill, as measured against AERONET, although some locations see improvements over nudged meteorology.

- Using decadal emission datasets over annual ones typically worsen model skill, although not necessarily in biomass-burning regions where time resolution of emissions would be expected to have a large impact.

- Analysis to be extended to metrics more relevant to total aerosol forcing, such as comparison of aerosols in polluted and unpolluted regions.

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# Questions and answers

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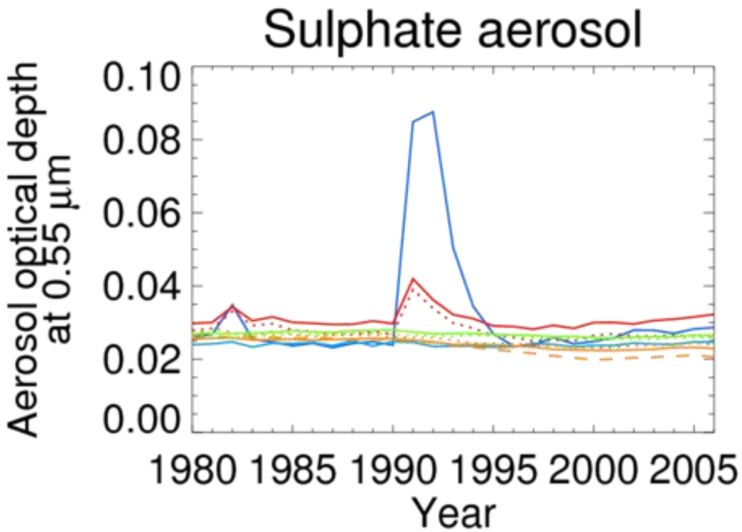


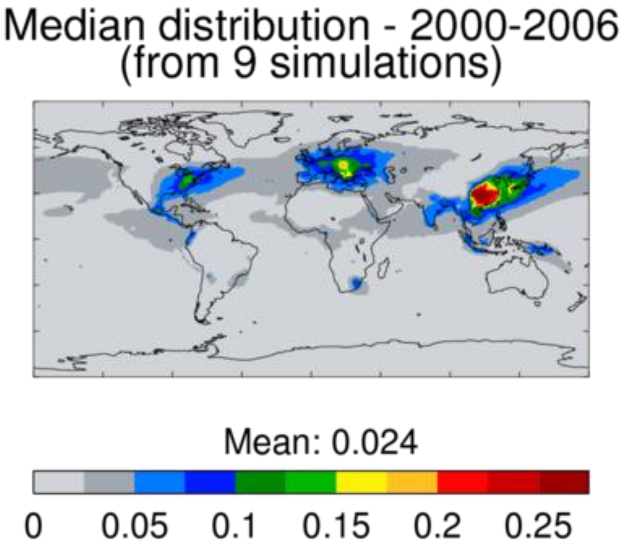


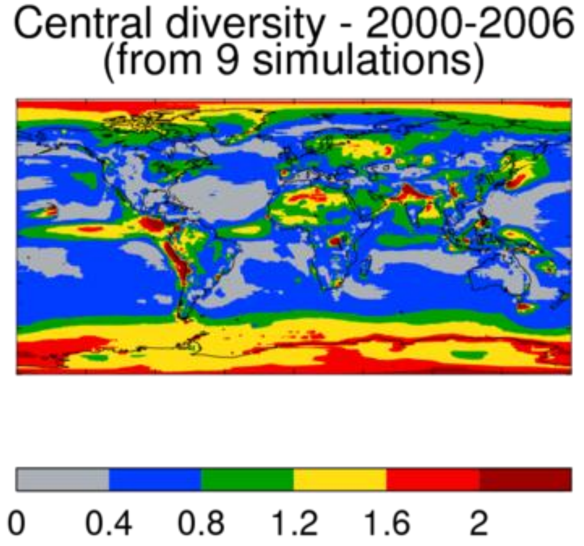


- Sulphate AOD:
  - Good agreement among models (AeroCom Hindcast emissions include $SO_2$ from volcanic eruptions).
  - Diversity is larger in high-latitudes regions, and around the Equator where wet removal (and, for some models, DMS emissions) are important processes.

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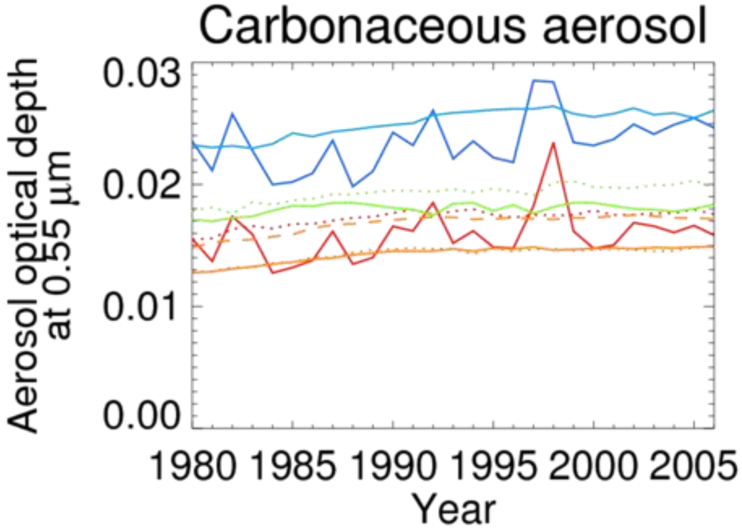


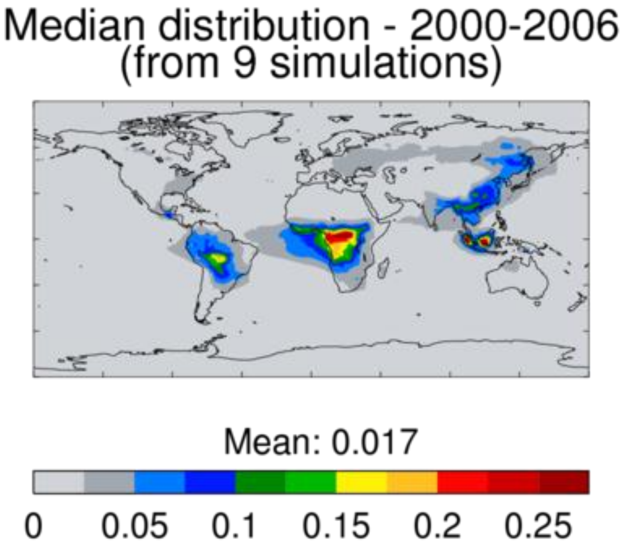


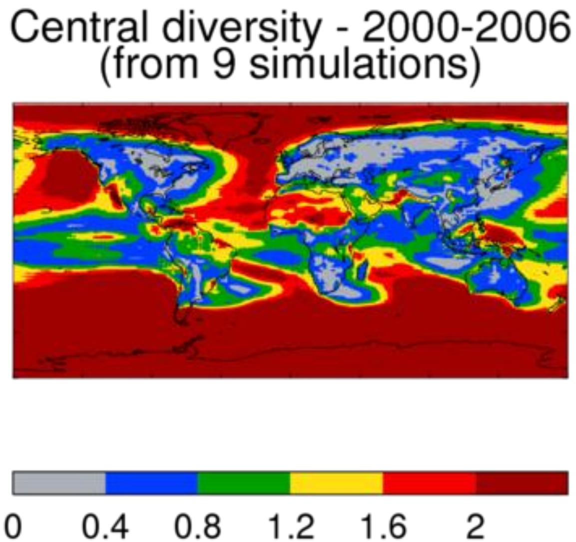


- Carbonaceous AOD:
  - Note that some components (BC, SOA) may be missing for some models.
  - Note that AeroCom Hindcast emissions include the large inter-annual variability in carbonaceous emissions.
  - Diversity is relatively small over source regions, and large everywhere else.

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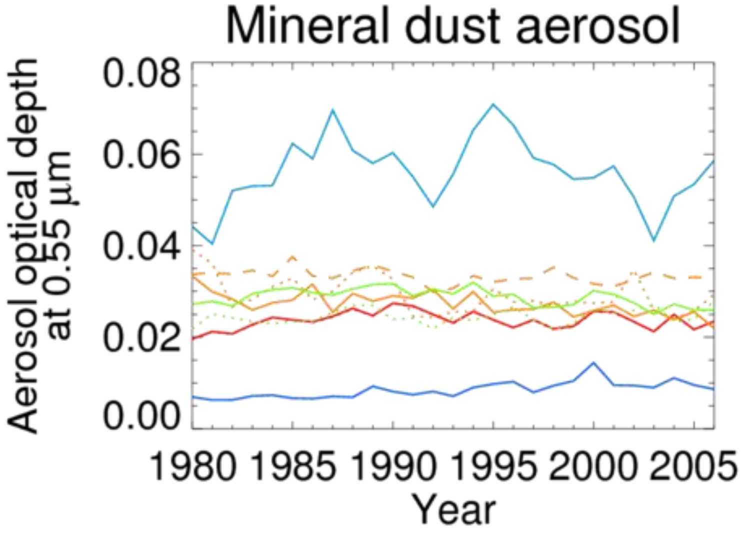
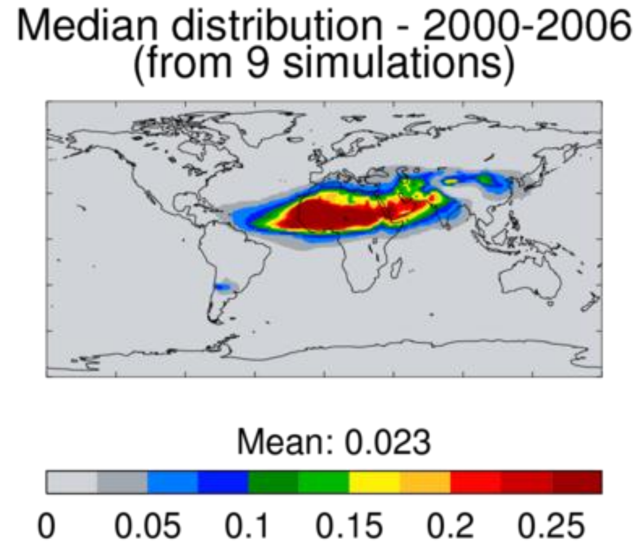
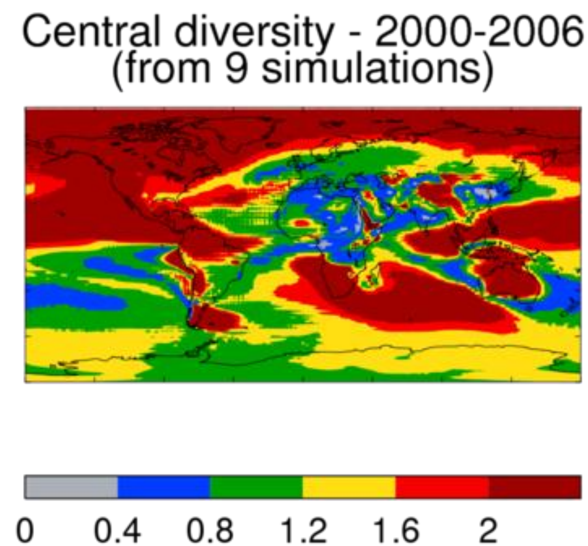



- Mineral-dust AOD:
  - HadGEM2 mineral dust is all over the place, as usual.
  - SPRINTARS/MIROC and GISS-modelE agree within a factor 1.5 on a global average.
  - Diversity is large over transported regions, including the Atlantic plume where diversity is 80 to 120%

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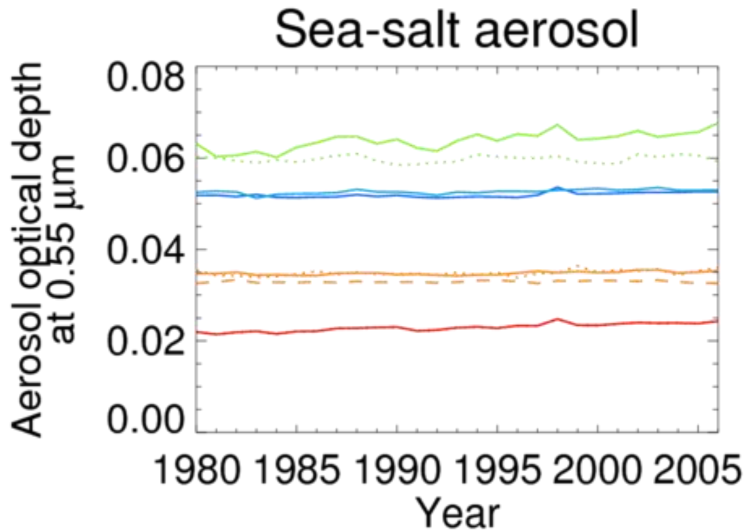
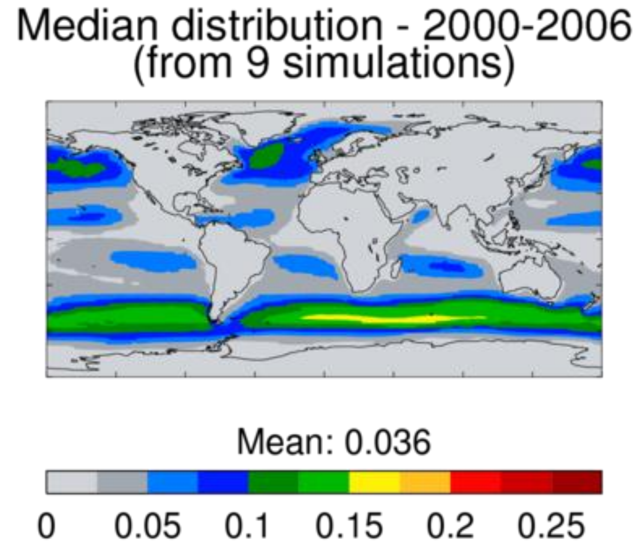
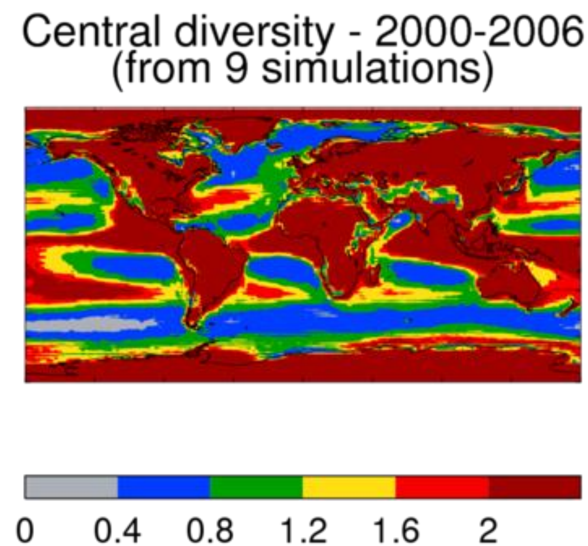



- Sea-salt AOD:
  - Factor 3 between globally-averaged time series.
  - Magnitude of sea-salt AOD strongly depends on the aerosol scheme.
  - Diversity is larger over continents (transported sea-salt) and over tropical oceans.

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