Met Office
Hadley Centre

Comparing CMIP5 and AeroCom Hindcast simulations by HadGEM2.

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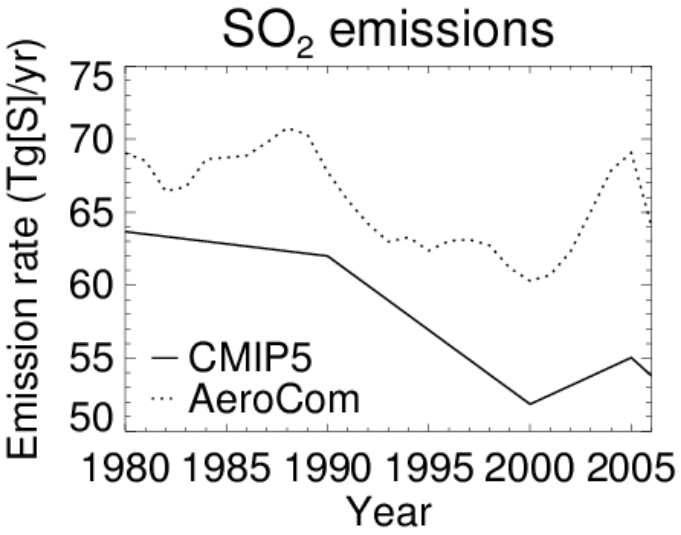
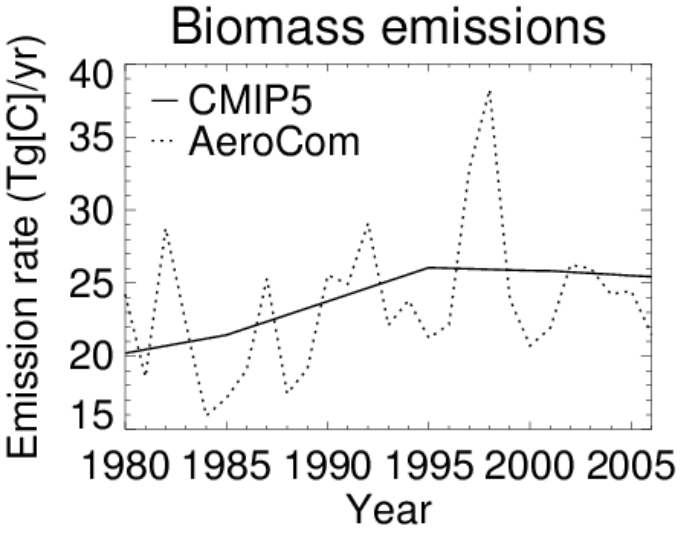
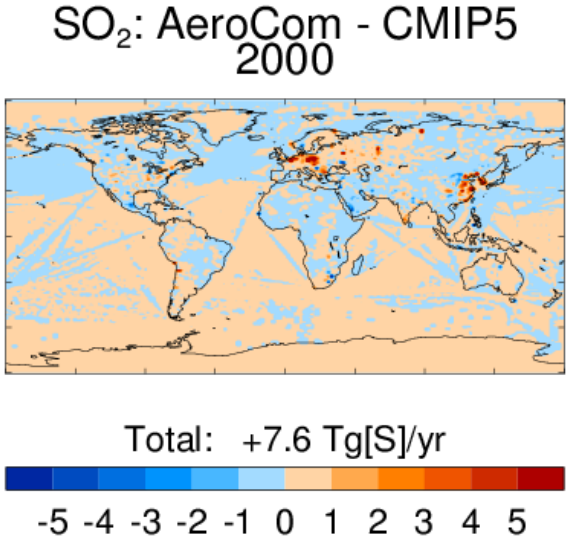
Simulations 1980—2006

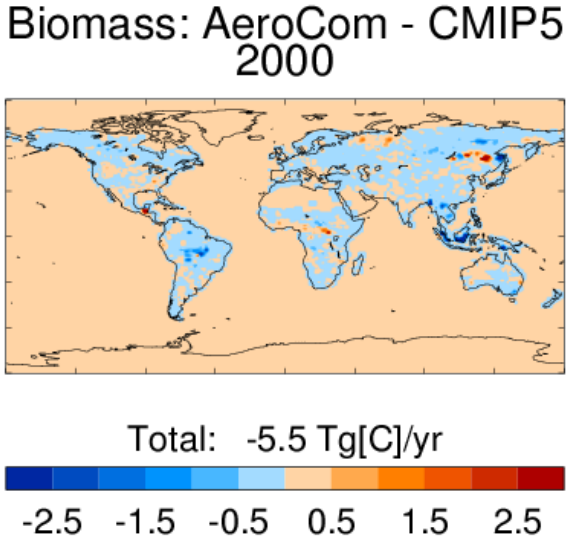
	CMIP5 Historical	AeroCom Hindcast
HadGEM2-ES setup	Atmosphere-ocean coupled	Atmosphere only
Meteorology	**Free running**	**Nudged to ERA40**
Aerosol emissions	**CMIP5**	**AeroCom 2 (v1)**
Sea surface temperatures	From ocean model	AMIP2 climatology
Ocean-based DMS emissions	From ocean model	Climatology from CMIP5 simulation
Volcanic forcing	Prescribed stratospheric AODs	Volcanic SO2 emissions
Vegetation	Interactive	Interactive (reinit 1980)
Trop Chemistry Emis.	CMIP5	CMIP5

Aerosol emissions

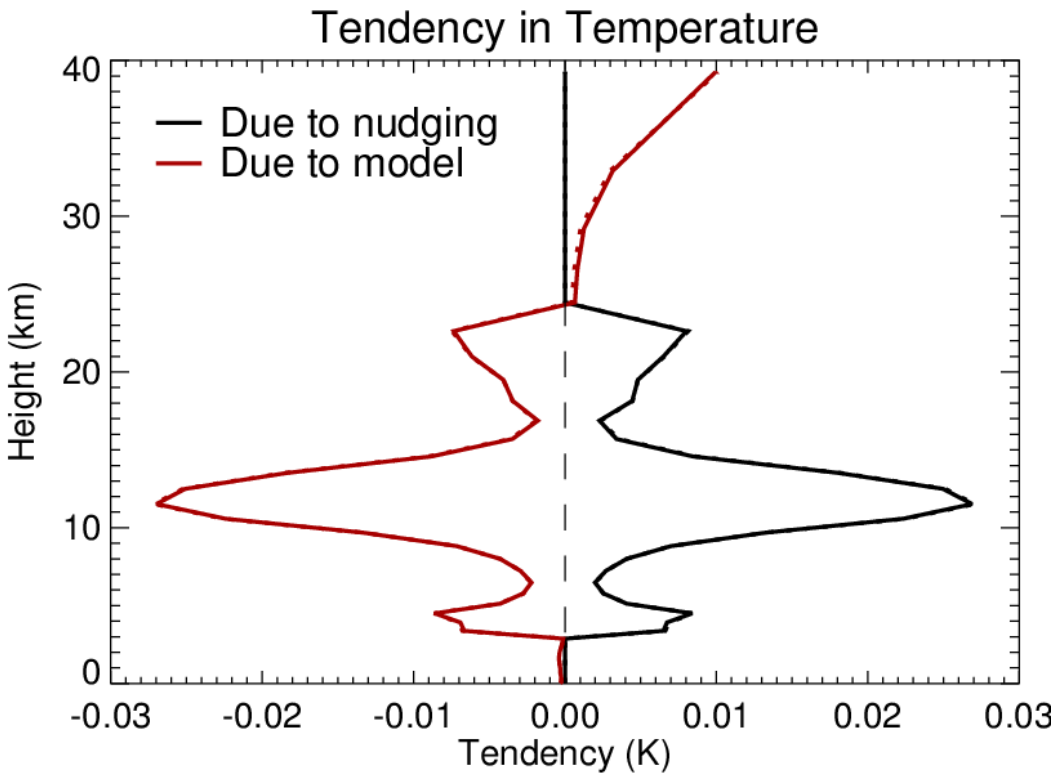


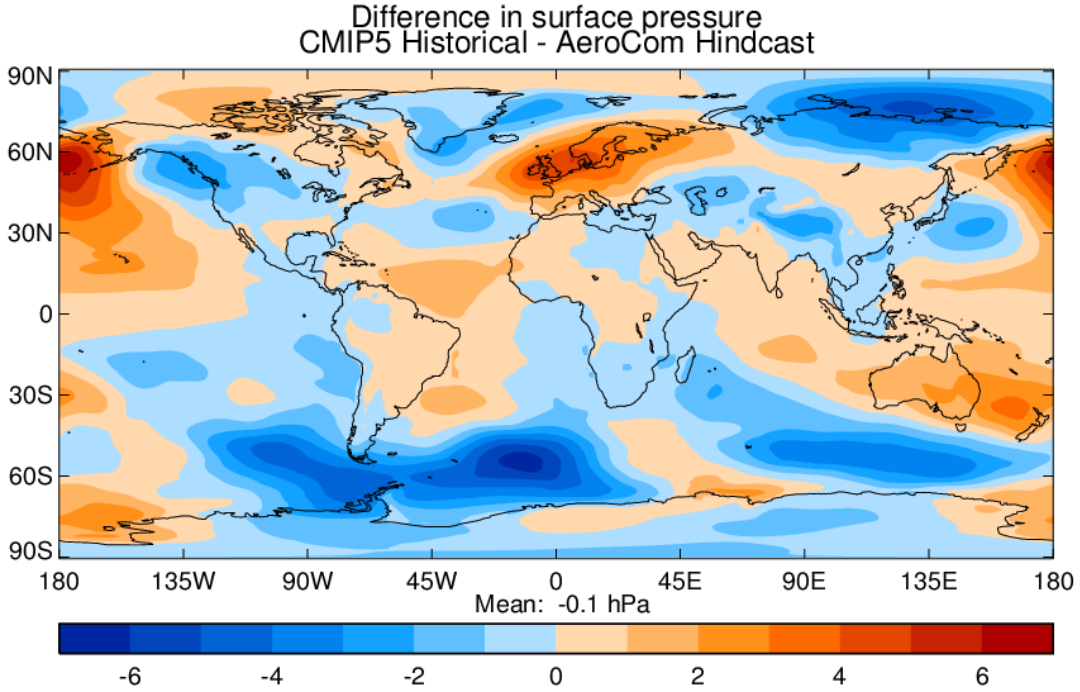






Nudging

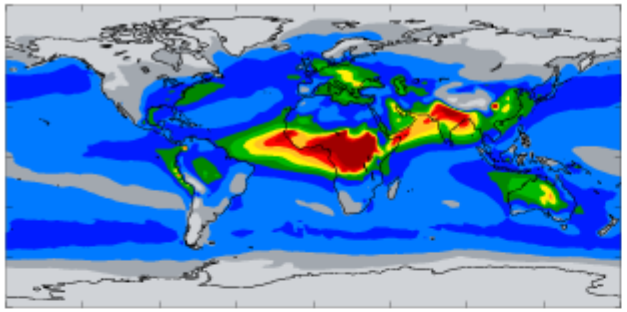




- Free-running model evolution opposes nudging.
- Differences in circulation may impact aerosol transport.
- Can the large scale impact on aerosols be diagnosed?

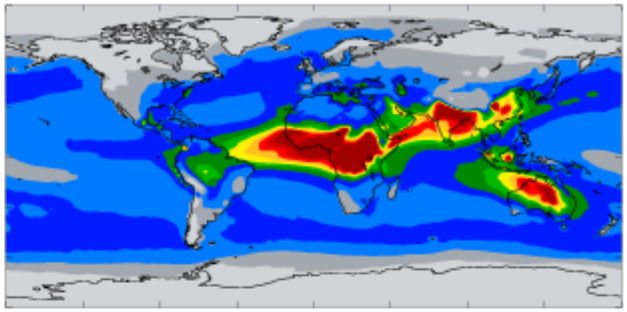
Total aerosol optical depth at 0.55 µm

CMIP5 Historical - 1980



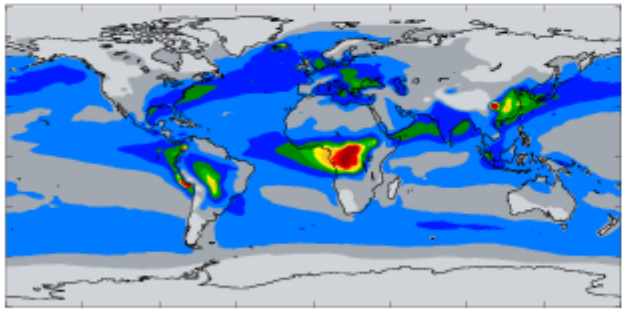
Mean: 0.146

CMIP5 Historical - 2000



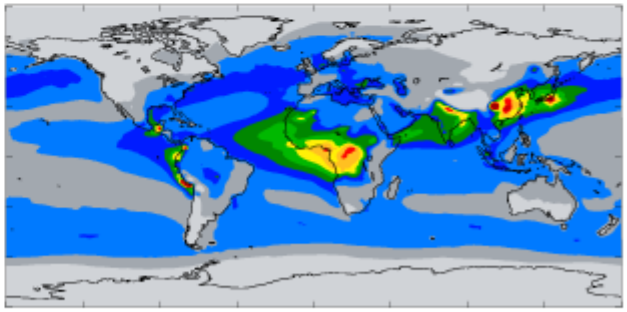
Mean: 0.159

AeroCom Hindcast - 1980



Mean: 0.108

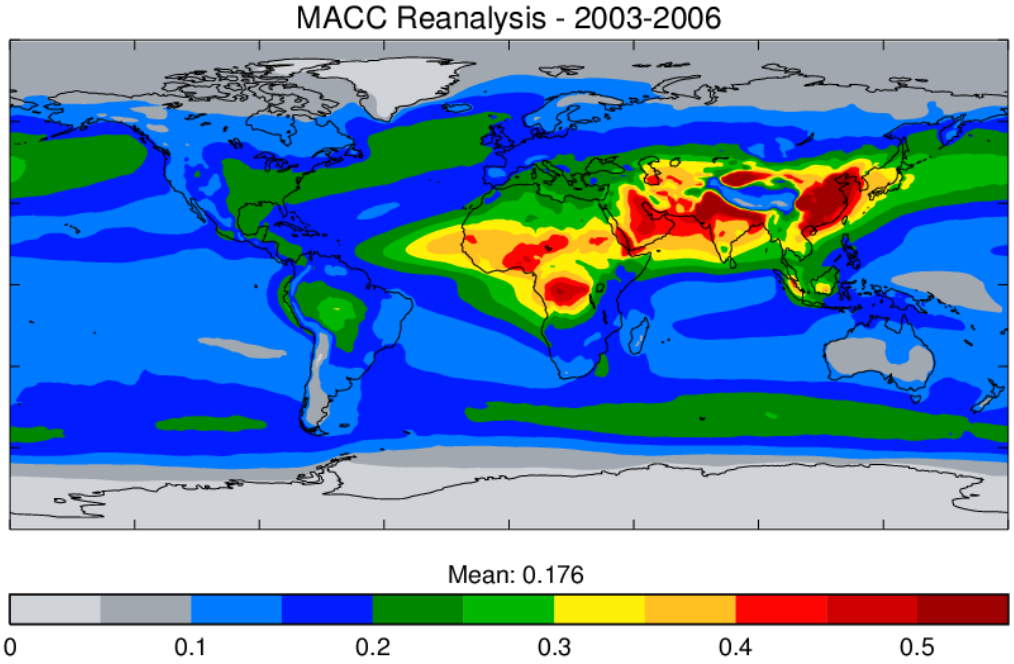
AeroCom Hindcast - 2000

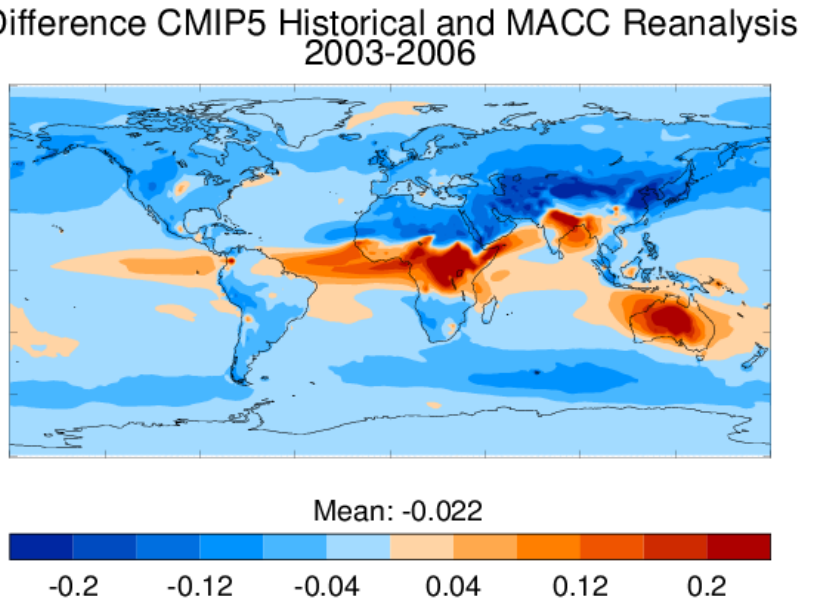


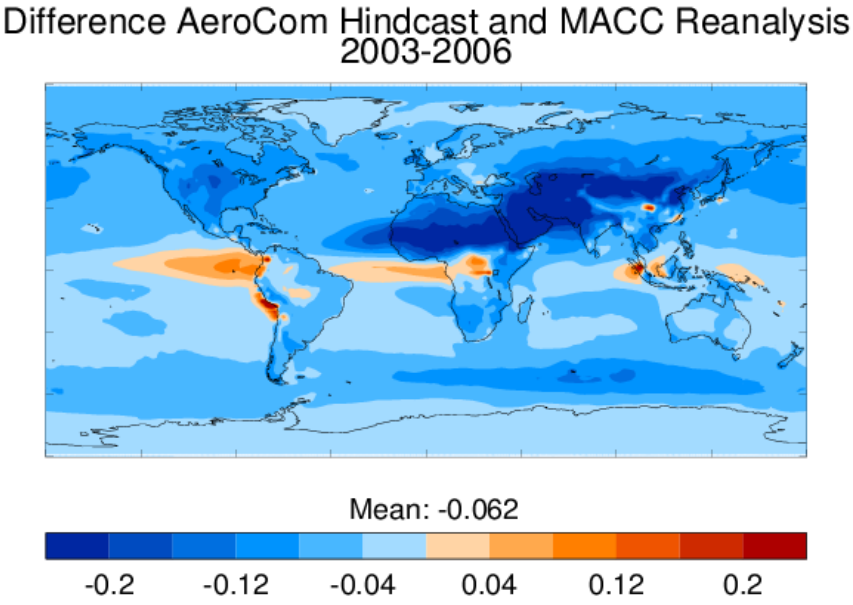
Mean: 0.114

- **Mineral dust larger in CMIP5 over Sahara, Arabian Sea, India, and Australia**
- **Non-dust AOD is ~0.1 for both simulations.**

Total aerosol optical depth at 0.55 μm: MACC Re-analysis

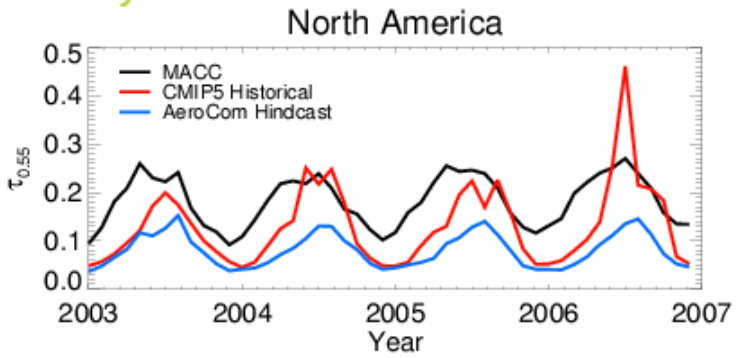


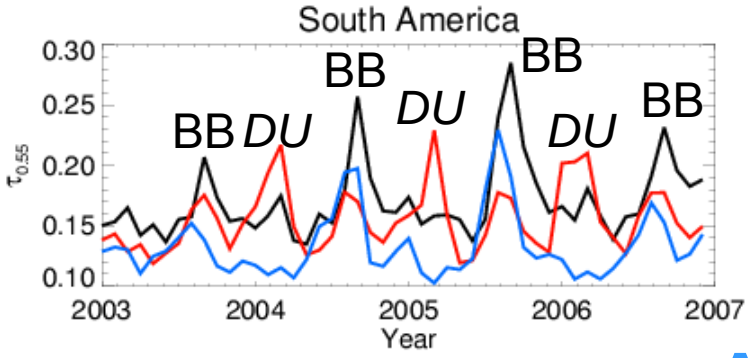


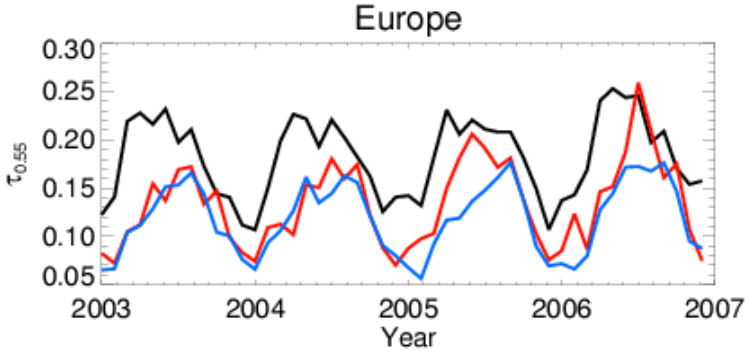


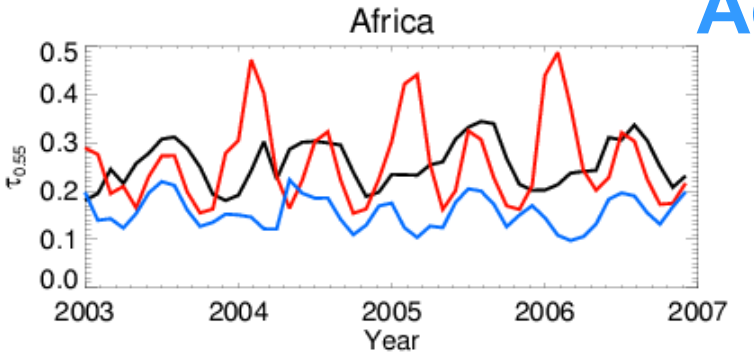
- MACC Re-analysis: ECMWF aerosol product with assimilation of MODIS aerosol optical depth.
- Differences dominated by differences in mineral dust. Generally, lower background in HadGEM.

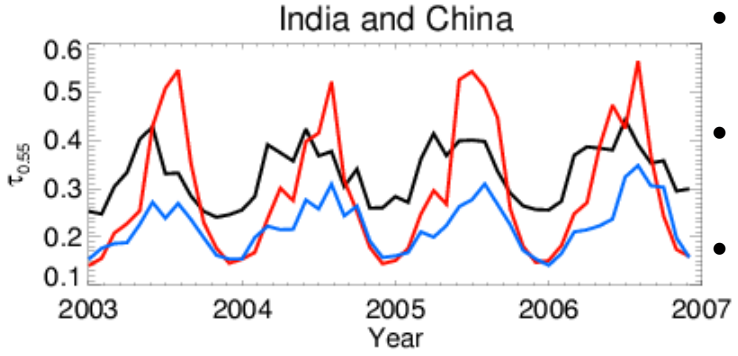
Regional time series of total aerosol optical depth









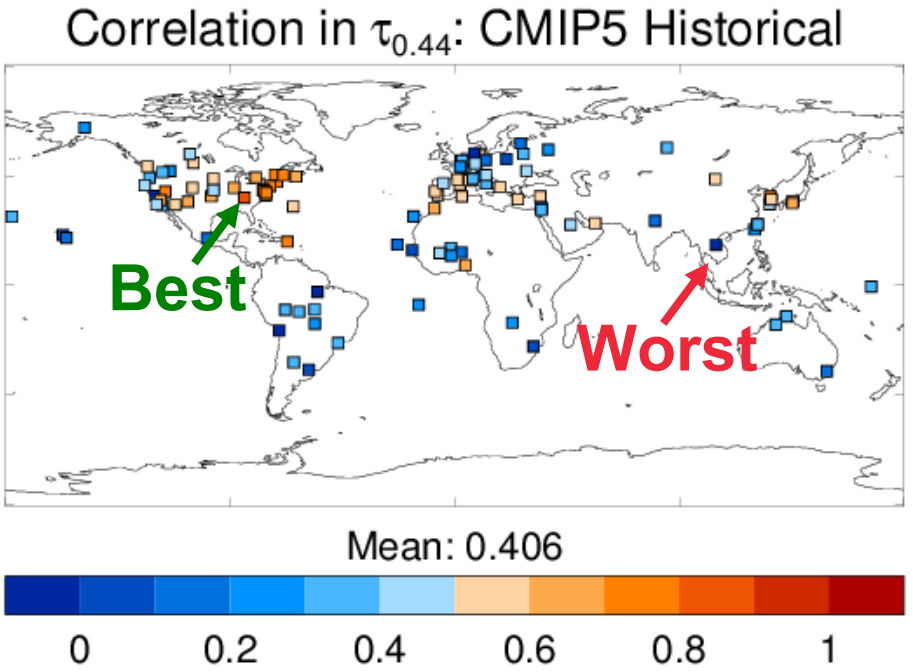


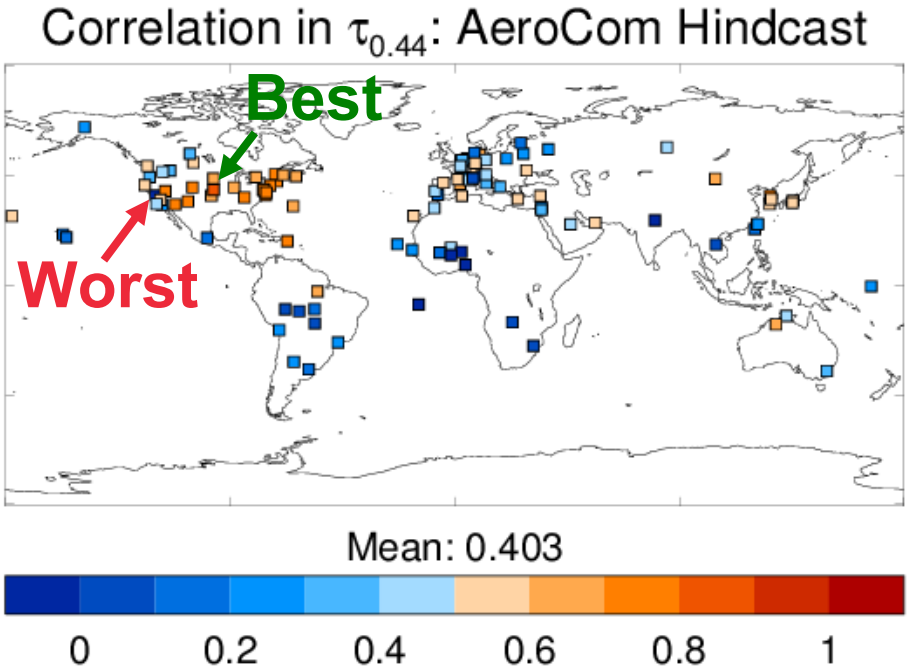
MACC
CMIP5
AeroCom

- AOD underestimated, except for CMIP5 dust events in Africa, India, and transport to South Am.
- Seasonality in North America, Europe, India and China skewed towards the summer.
- AeroCom Hindcast better represents year-to-year variability in South American biomass-burning.

Temporal correlations with AERONET

- 113 AERONET sites with at least 60 valid monthly means of AOD at 0.44 μm (version 2, level 2) in the hindcast period
- Correlations from –0.4 to +0.8
- Best performance in North America, poor performance in Southern Hemisphere

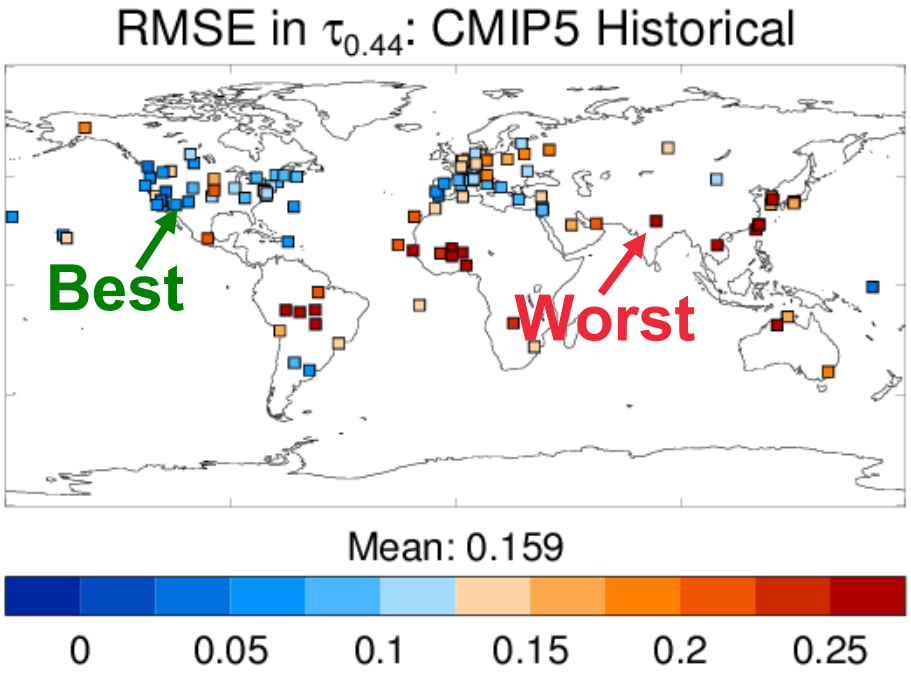


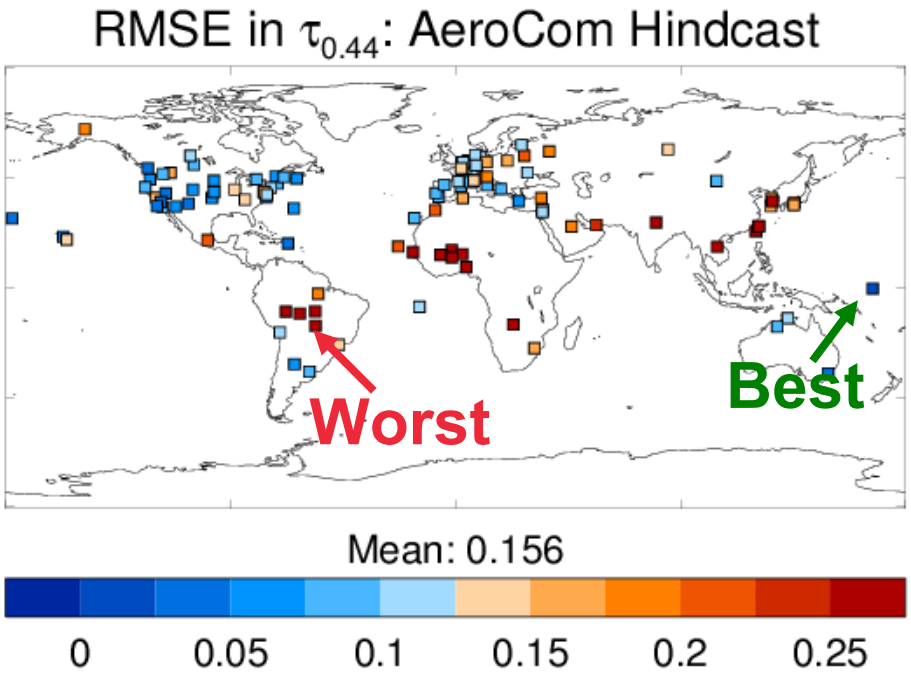


Root mean square errors against AERONET

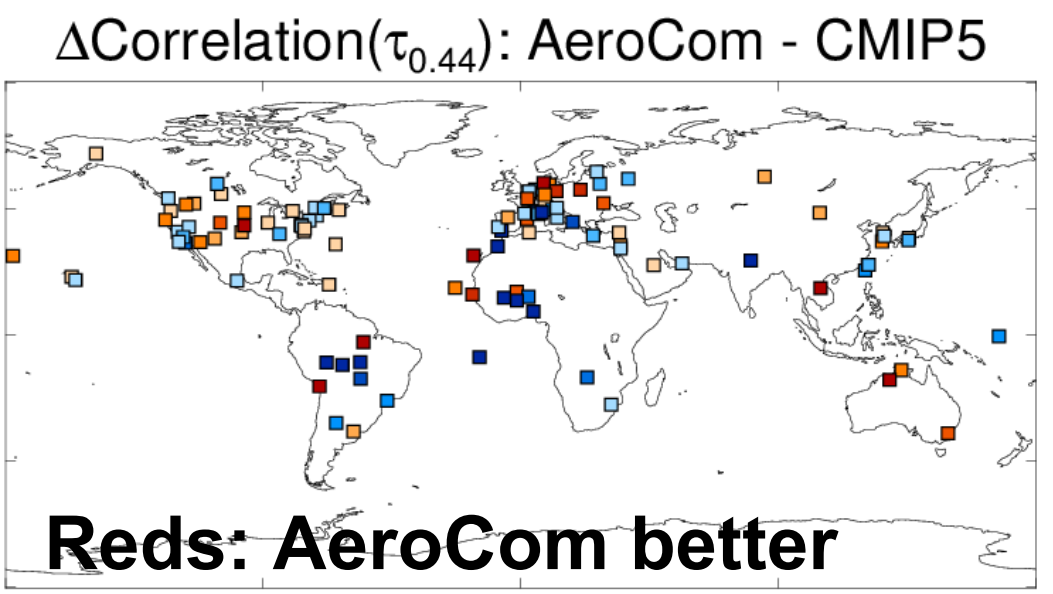
- RMSE from 0.02 to 0.97.

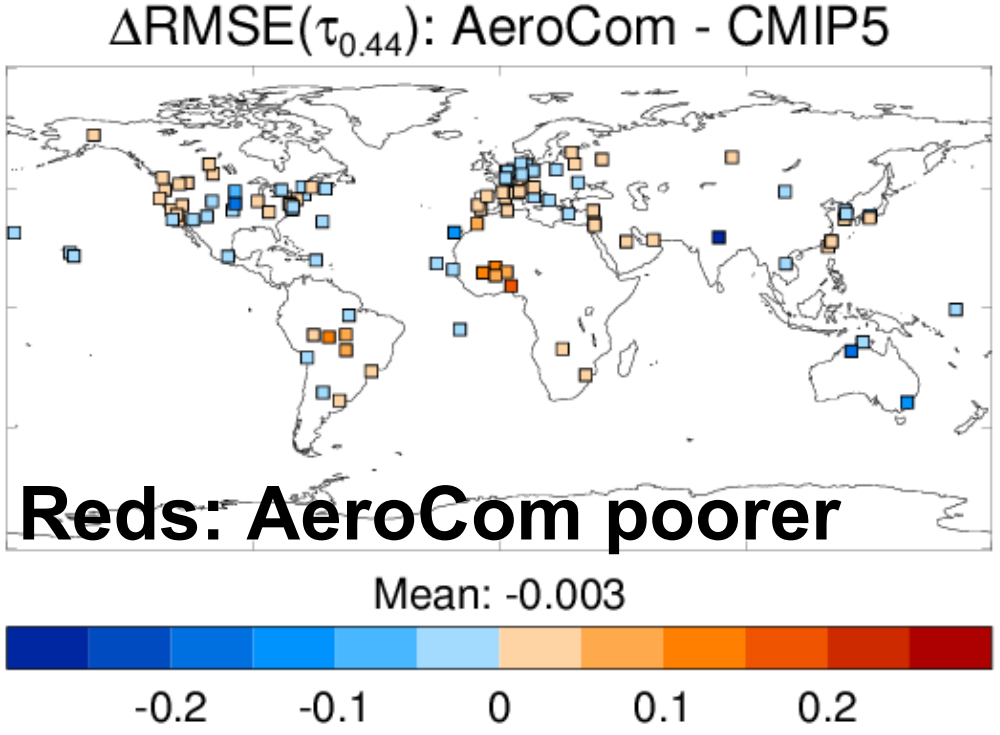
- Again, performance is better in the Northern Hemisphere.





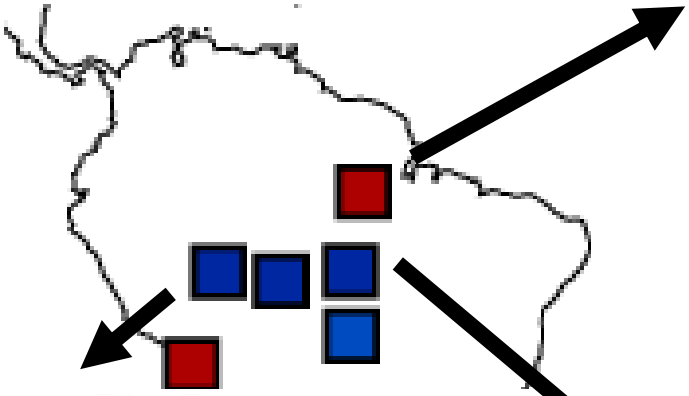
- Regional patterns in differences between the two simulations.
- Northern Europe: different emissions benefit AeroCom?
- Equatorial Africa: underestimate of mineral dust in AeroCom is detrimental.
- Australia: overestimate of mineral dust in CMIP is detrimental.
- South America: Hindcast is poorer – surprising.

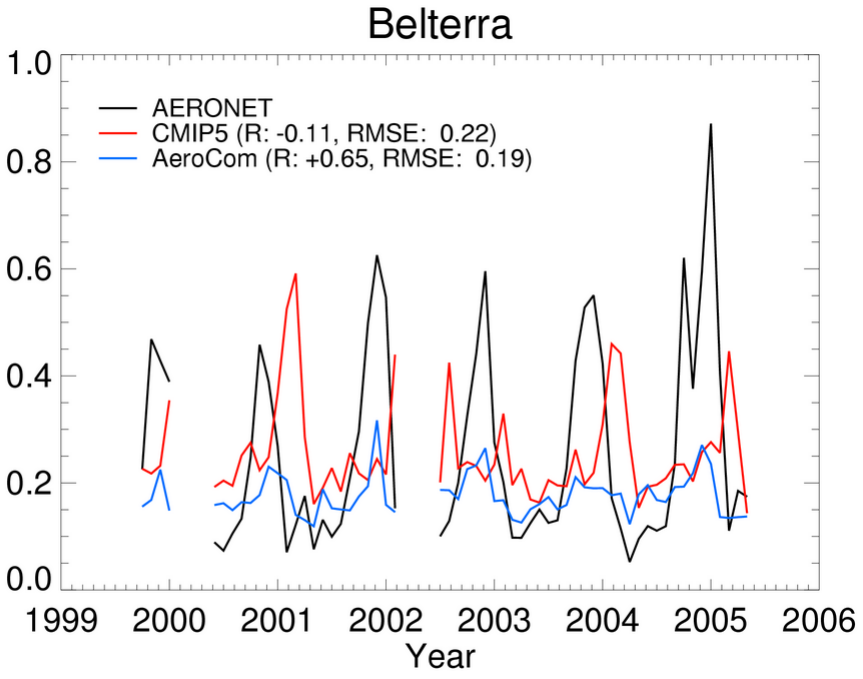


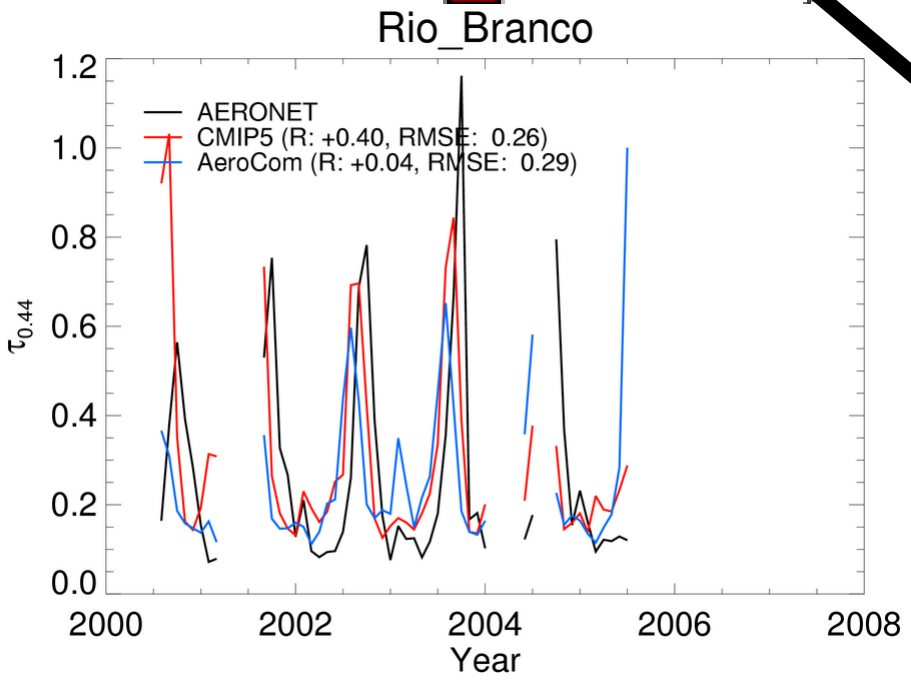


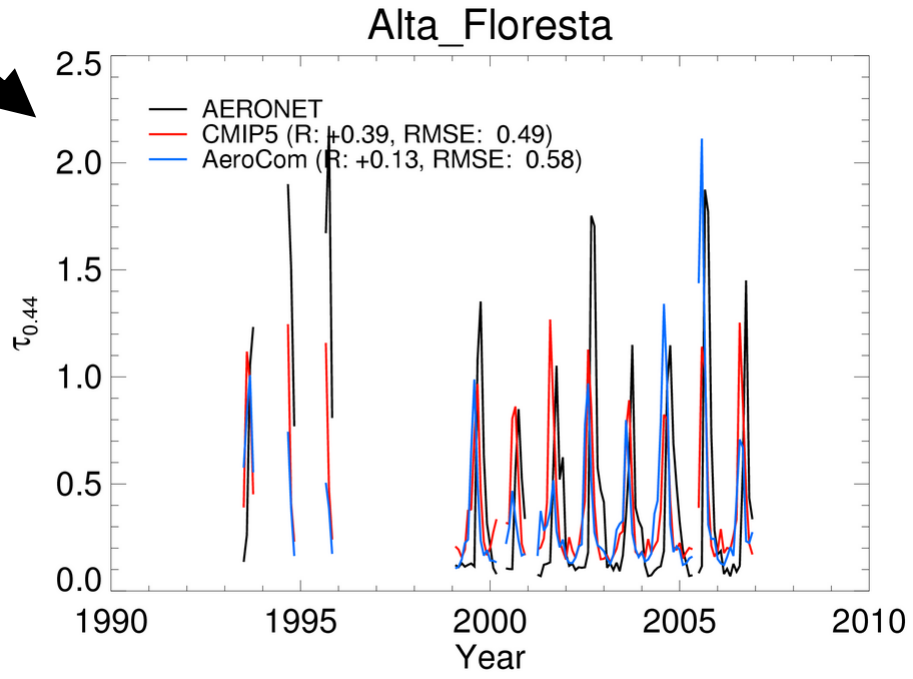
S. America

- AOD peaks one month too early, yearly emissions not always better



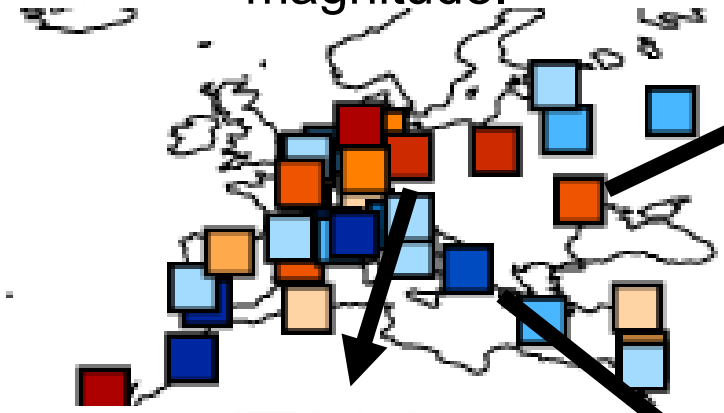


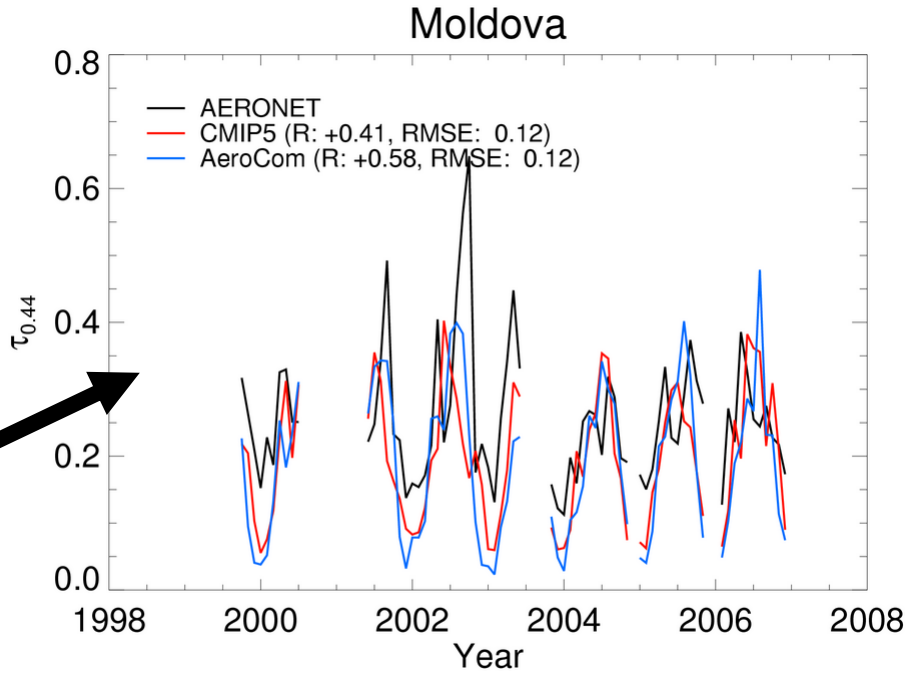


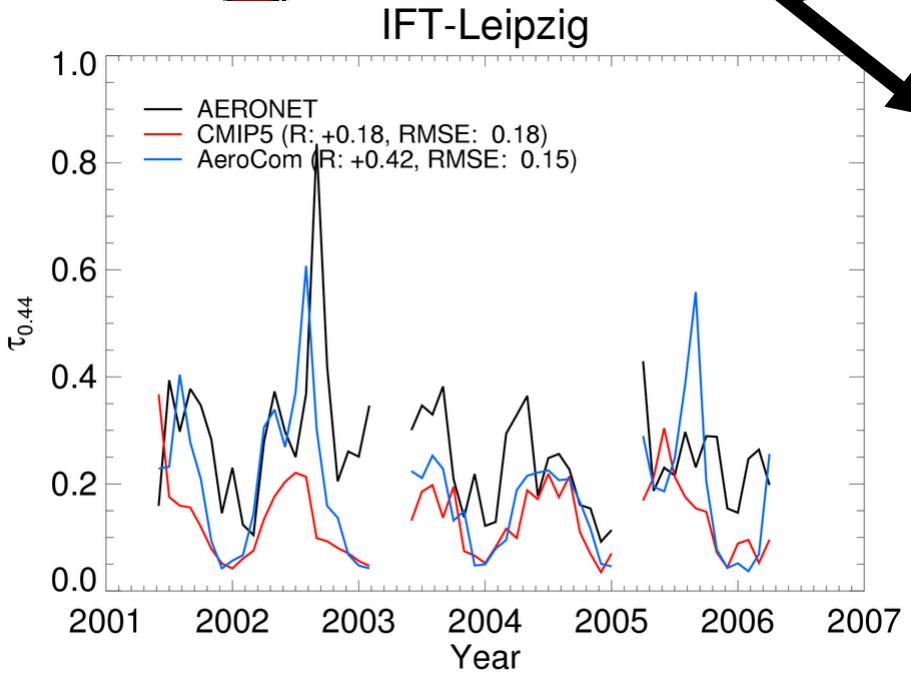


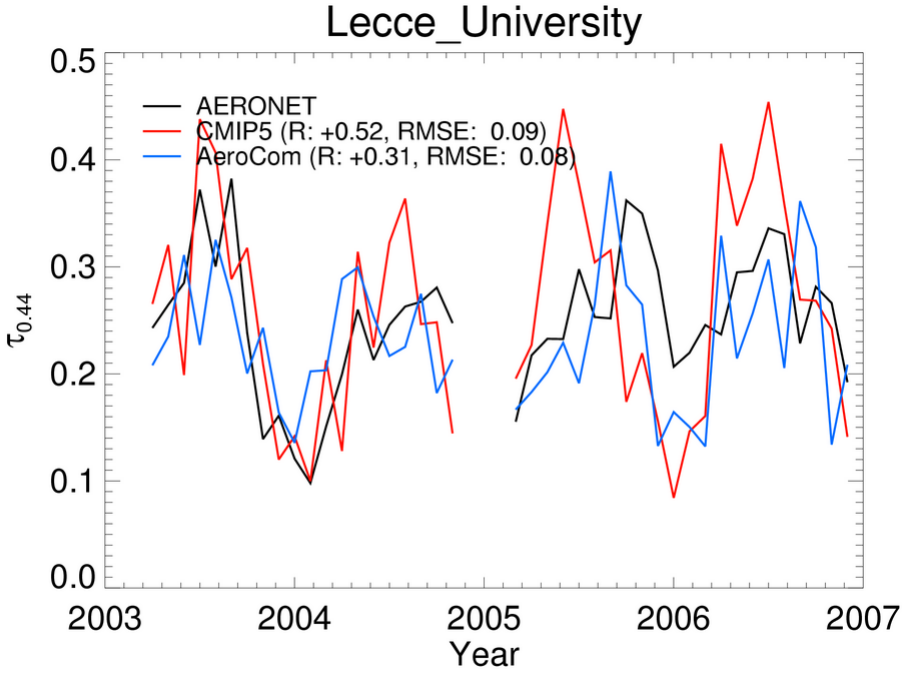
Europe

- Differences have more to do with timing than magnitude.



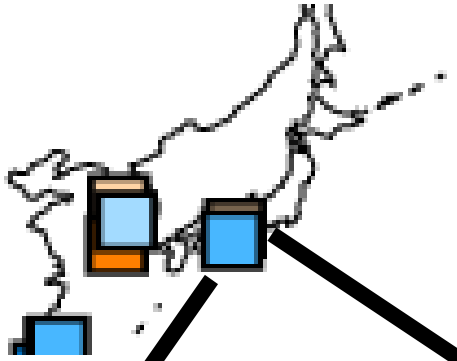


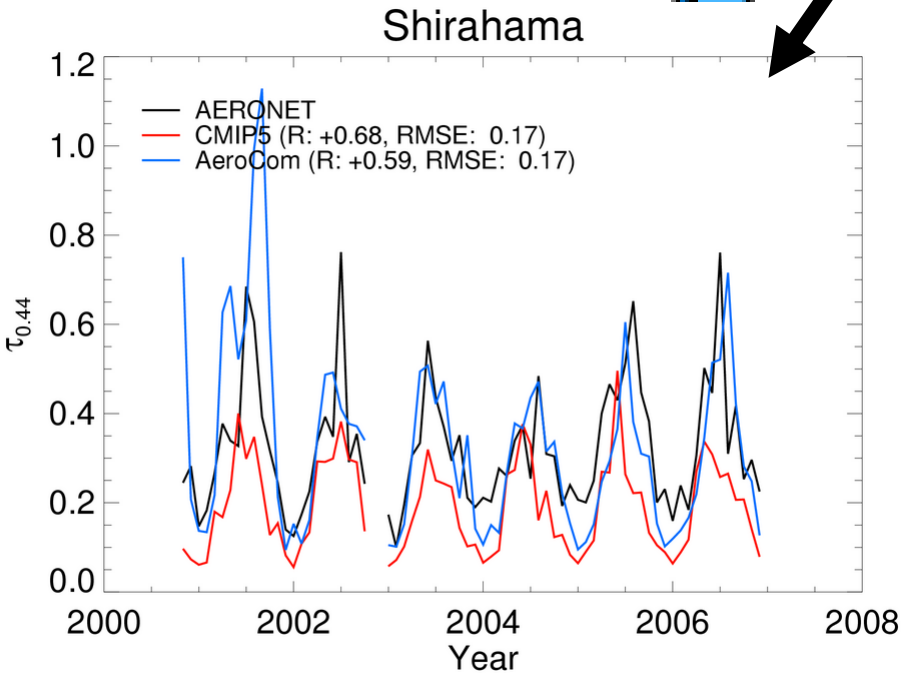


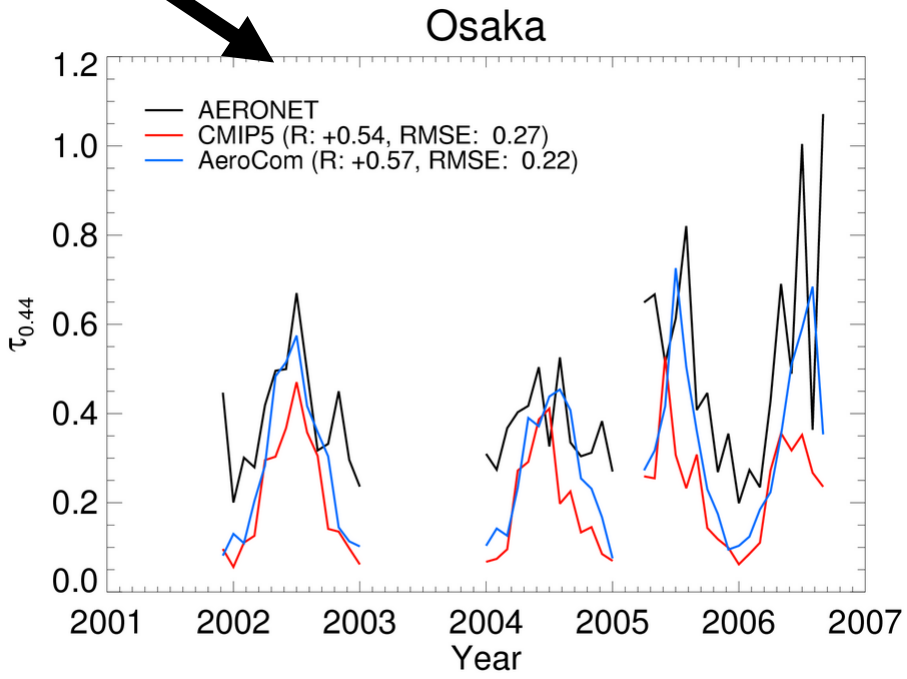


Japan

- AeroCom Hindcast better, winters underestimated

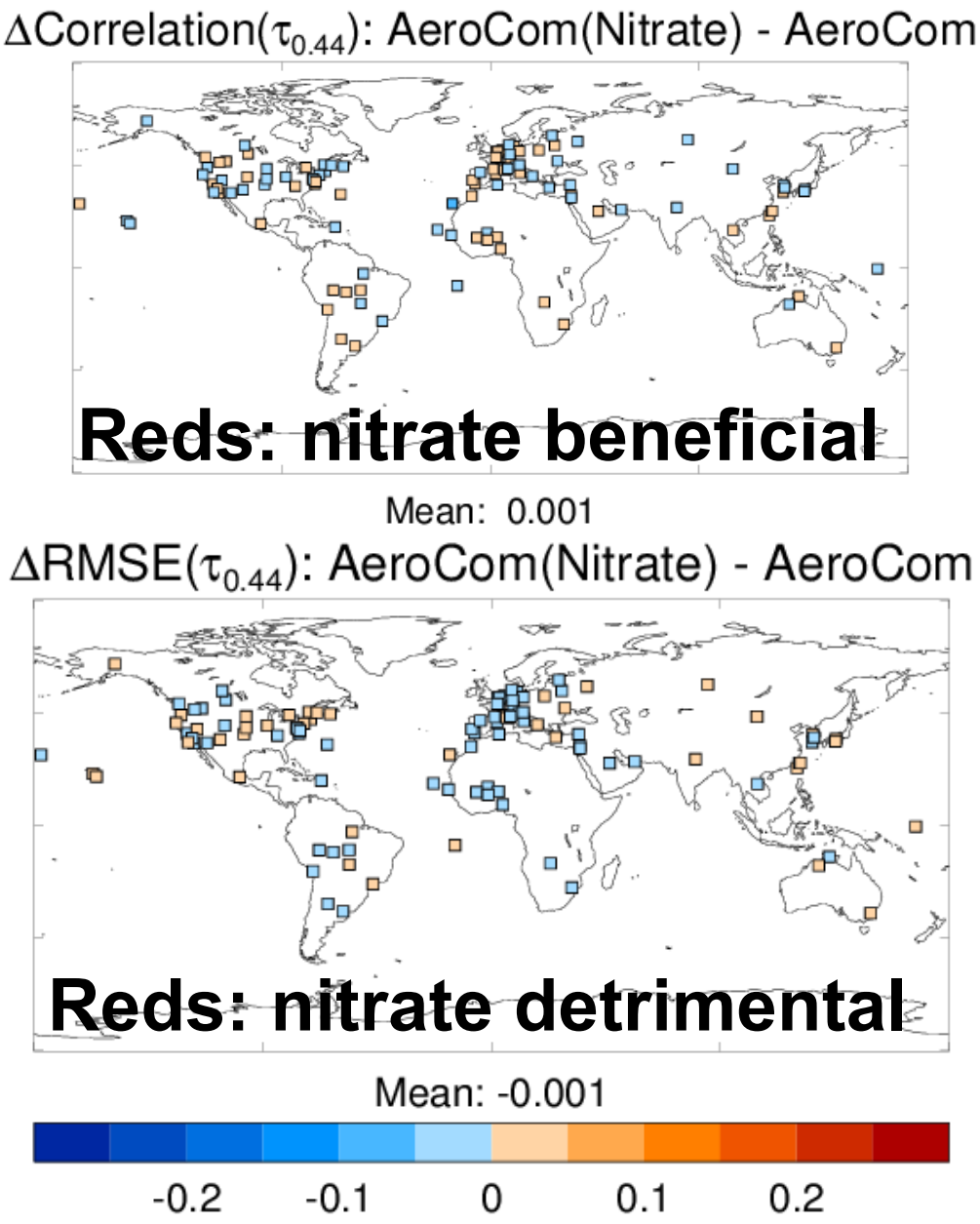






Effect of adding nitrate to AeroCom Hindcast

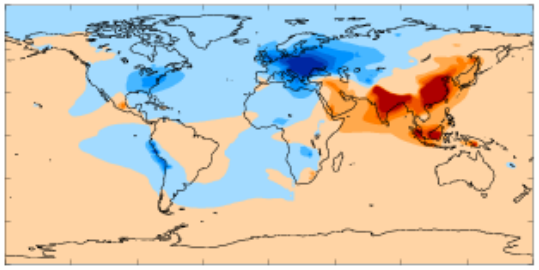
- Adding nitrate optical depth improves RMSE slightly where optical depths are underestimated (Europe).
- Nitrate does not do much to improve seasonality.



Aerosol forcing and radiative flux perturbation

- CMIP5: Forcing due to changing emissions from 1980 to 2000.
- AeroCom: Difference for year 2000 between Hindcasts with 1980 emissions and with actual time series.
- Similar, differences due to episodic emissions (volcanic, biomass-burning).

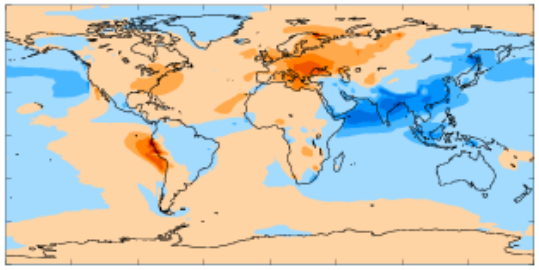
$\Delta\tau_{0.55}$ - 2000-1980
CMIP5 Historical



Mean: +0.003

-0.1 -0.06 -0.02 0.02 0.06 0.1

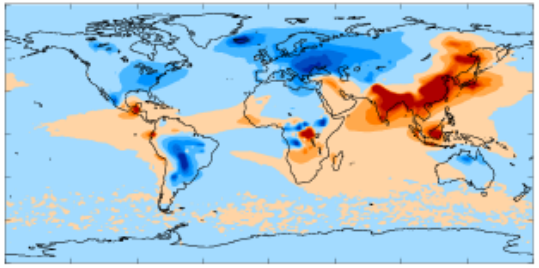
Forcing at TOA 2000-1980
CMIP5 Historical



All-sky, SW+LW, direct and 1st indirect
Mean: -0.06 Wm^{-2}

-5 -4 -3 -2 -1 0 1 2 3 4 5

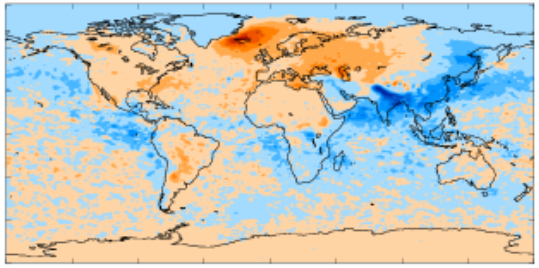
$\Delta\tau_{0.55}$ - 2000-1980
AeroCom Hindcast



Mean: +0.001

-0.1 -0.06 -0.02 0.02 0.06 0.1

Perturbation at TOA 2000-1980
AeroCom Hindcast



All-sky, SW+LW, all radiative effects
Mean: -0.09 Wm^{-2}

-5 -4 -3 -2 -1 0 1 2 3 4 5

Main results

- AeroCom Hindcast is not “better” than CMIP5 Historical.
- It is really easy to introduce diversity in aerosol simulations!
- Attribution of changes in performance to emissions or transport would require additional simulations, where components are changed one at a time. Is it even useful?
- Nitrate aerosols do not affect the comparison significantly.
- Climate forcing is similar in both simulations, suggesting radiative impacts are consistent on continental scales.

- Did other models contribute to both CMIP5 and AeroCom?

Notes on indirect effect discussion

- Natural aerosols are important.
  - Clouds formed from large natural aerosol number are less sensitive to anthropogenic additions;
  - Pre-industrial state scales the indirect forcing.

- Scales: Was it a good idea to introduce parameterizations of cloud microphysical processes in models that do not resolve clouds?

- Why are modelled and satellite-derived cloud susceptibilities so different, in spite of model parameterizations being based on observations?

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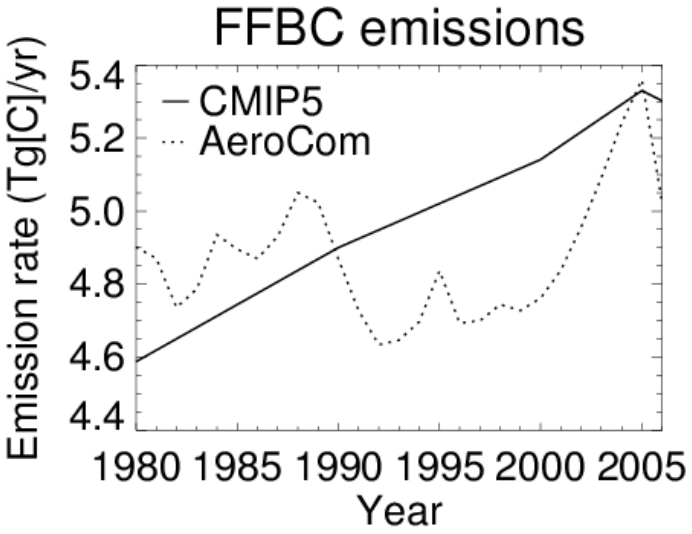
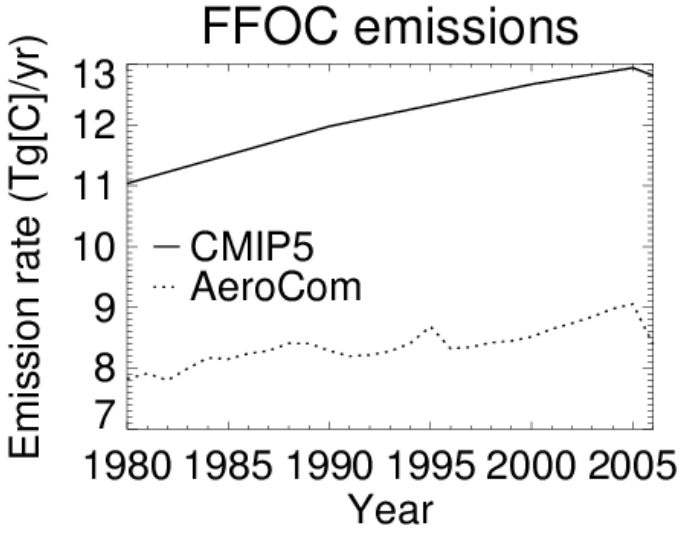
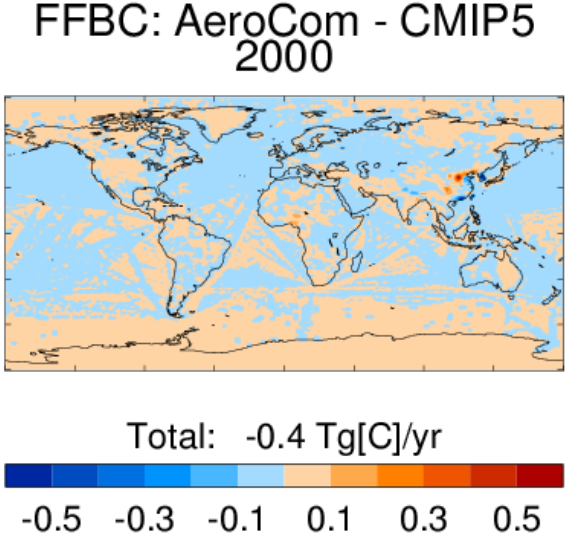
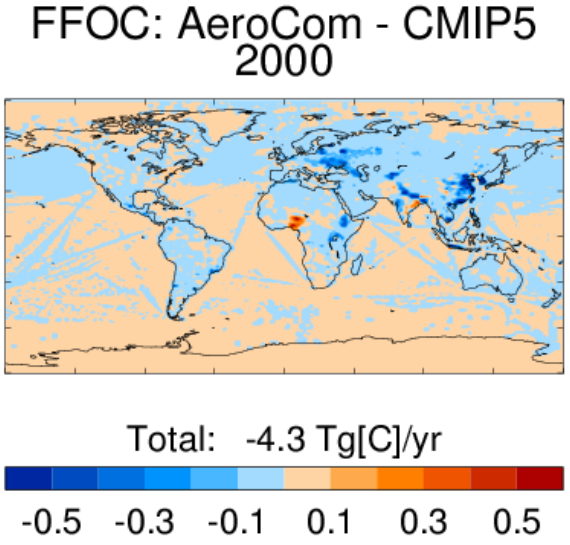
Questions and answers

Aerosol emissions









Africa

- AeroCom poor near sources