Evaluation of climate model aerosol trends with ground-based observations over the last two decades

an AeroCom and CMIP6 analysis

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Meteorologisk institutt

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Review status
A revised version of this preprint was accepted for the journal ACP and is expected to appear here in due course.

Augustin Mortier[1], Jonas Gliss[1], Michael Schulz[1], Wenche Aas[2], Elisabeth Andrews[3], Huisheng Bian[4], Mian Chin[5], Paul Ginoux[6], Jenny Hand[7], Brent Holben[5], Zhang Hua[8], Zak Kipling[9], Alf Kirkevåg[1], Paolo Laj[10], Thibault Lurton[11], Gunnar Myhre[12], David Neubauer[13], Dirk Olivié[1], Knut von Salzen[14], Toshihiko Takemura[15], and Simon Tilmes[16]

[1]Norwegian Meteorological Institute, Oslo, Norway
[2]NILU, Norwegian Institute for Air Research, Kjeller, Norway
[3]Cooperative Institute for Research in Environmental Sciences,University of Colorado, Boulder, Colorado, USA
[4]Maryland Univ. Baltimore County (UMBC), Baltimore, MD, USA
[5]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA
[6]NOAA, Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
[7]Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO, USA
[8]Laboratory for Climate Studies, National Climate Center, China Meteorological Administration, Beijing, China
[9]European Centre for Medium-Range Weather Forecasts, Reading, UK
[10]Univ. Grenoble Alpes, CNRS, IRD, Grenoble INP, Institute for Geosciences and Environmental Research, Grenoble, France
[11]Met Office Hadley Centre, Exeter, UK
[12]CICERO Center for International Climate and Environmental Research, Oslo, Norway
[13]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[14]Environment Canada, Montréal, Canada
[15]Research Institute for Applied Mechanics, Kyushu University, 6-1 Kasuga-koen, Kasuga, Fukuoka, Japan
[16]National Center for Atmospheric Research (NCAR), Boulder, Colorado, USA

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Abstract. This study presents a multi-parameter analysis of aerosol trends over the last two decades at regional and global scales. Regional time series have been computed for a set of nine optical, chemical composition and mass aerosol properties by using the observations of several ground-based networks. From these regional time series the aerosol trends have been derived for different regions of the world. Most of the properties related to aerosol loading exhibit negative trends, both at the surface and in the total atmospheric column. Significant decreases of aerosol optical depth (AOD) are found in Europe, North America, South America and North Africa, ranging from −1.3 %/yr to −3.1 %/yr. An error and representativity analysis of the incomplete observational data has been performed using model data subsets in order to investigate how likely the observed trends represent the actual trends happening in the regions over the full study period from 2000 to 2014. This analysis reveals that significant uncertainty is associated with some of the regional trends due to time and space sampling deficiencies. The set of observed regional trends has then been used for the evaluation of the climate models and their skills in reproducing the aerosol trends. Model performance is found to vary depending on the parameters and the regions of the world. The models tend to capture trends in AOD, column Angstrom exponent, sulfate and particulate matter well (except in North Africa), but show larger discrepancies for coarse mode AOD. The rather good agreement of the trends, across different aerosol parameters between models and observations, when co-locating them in time and space, implies that global model trends, including those in poorly monitored regions, are likely correct. The models can help to provide a global picture of the aerosol trends by filling the gaps in regions not covered by observations. The calculation of aerosol trends at a global scale reveals a different picture from the one depicted by solely relying on ground based observations. Using a model with complete diagnostics (NorESM2) we find a global increase of AOD of about 0.2 %/yr between 2000 and 2014, primarily caused by an increase of the loads of organic aerosol, sulfate and black carbon.

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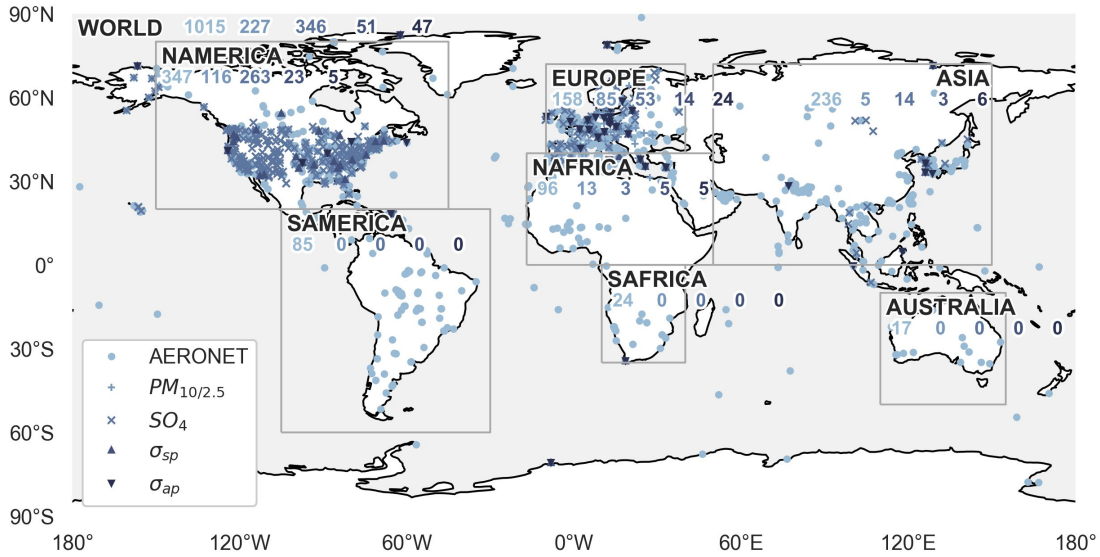
Dataset

Observations

Type	Variable	Total Nb.*
Column	$AOD_{tot,f,c}$, AE	1015
Surface	PM_{10}, $PM_{2.5}$	227
	SO_4	346
	σ_{sp}	51
	σ_{ap}	47

**before time sampling criteria filtering*



Models

- CAMS Reanalysis
- 6 AP3 models
- 4 CMIP6 models

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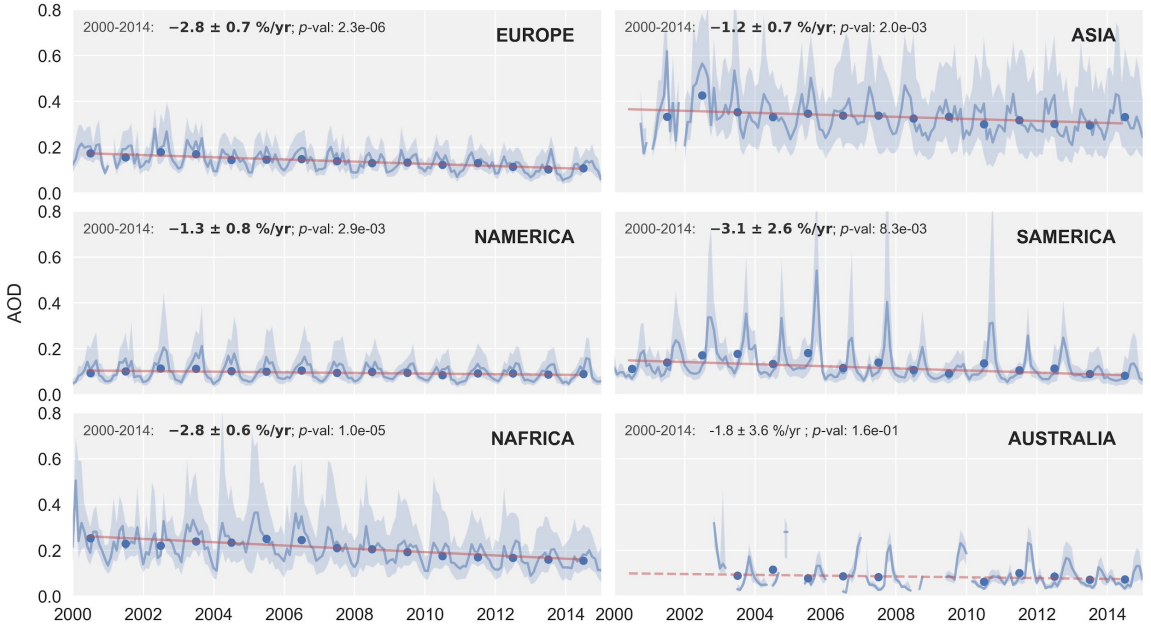
Regional time series

Aggregation of the observations in 7 main regions in the world

Trends derived from *yearly* averages (no seasonal cycles) computed step by step:

- month → **5** days
- season → **1** month
- year → **4** seasons



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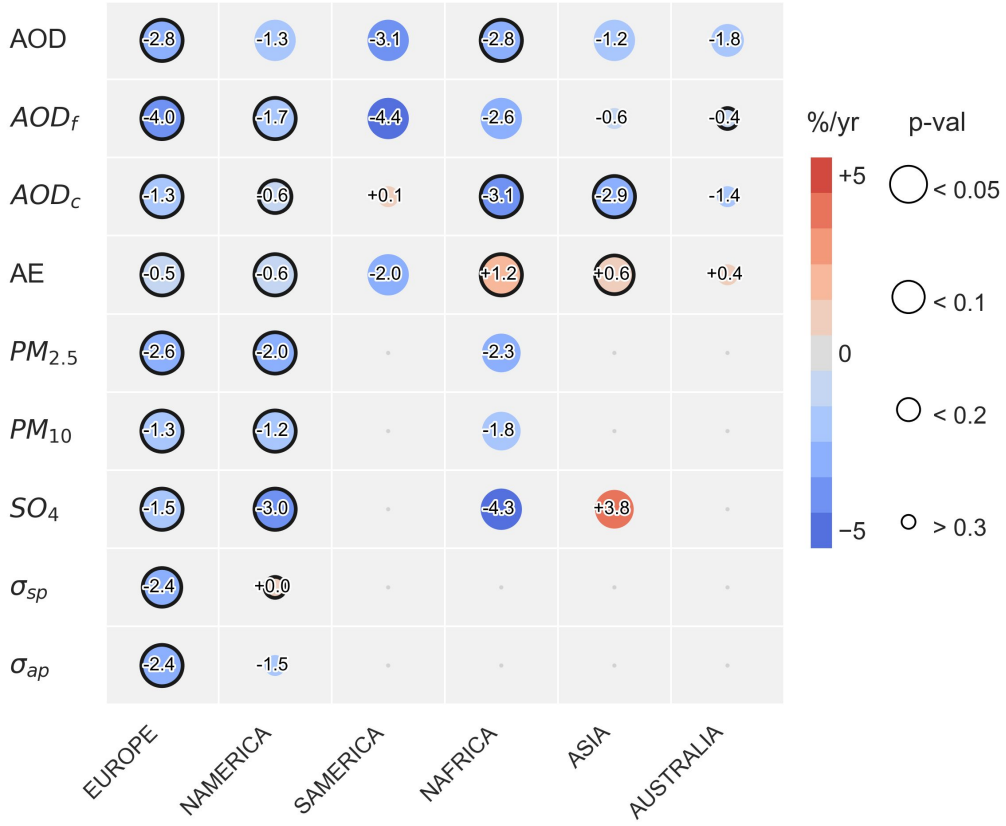
Observed trends

- Mostly *negative* trends regarding the *extensive properties* (aerosol load*)*, both in the total *column* and at the *surface*.
- *Significant decreases* are found in *Europe, North America, South America, North Africa and Asia*. In Asia, AE is increasing in time and is consistent with increases in AOD f and SO 4 , which reflects the regional *increase of the anthropogenic* aerosols.
- Representativity study based on subset model data shows that some of these trends are *not representative* of the actual trends in the considered region and time period [2000-2014] due to the *lack of observation.*



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Model trends evaluation

Various performances depending on regions and variables. In summary:

- *Good* performances: AOD, AOD_f, AE, $PM_{2.5}$, SO_4
- *Medium/poor* performances: AOD_c, PM_{10}
- σ_{sp}, σ_{ap}: *large uncertainties* due to lack of observations

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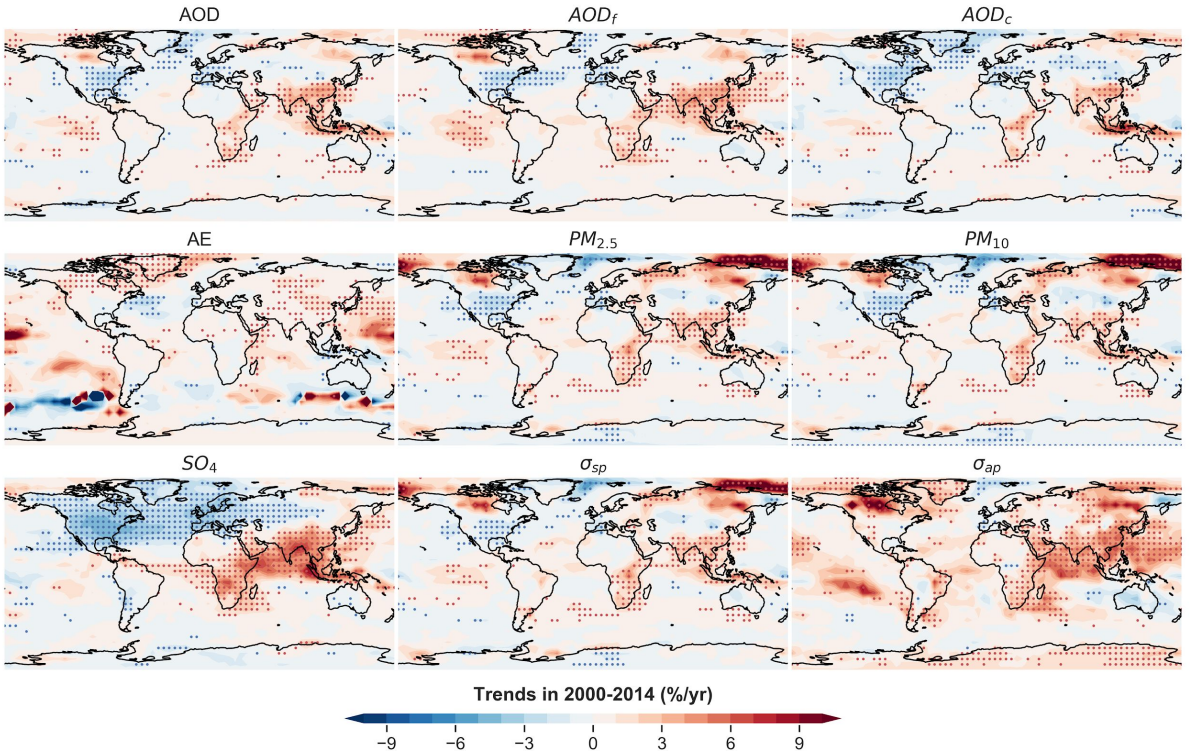
Global trends

NorESM2	$Mean_{2000}$	Trend (%/yr)
AOD	0.14	+0.2
AOD_f	0.05	+0.6
AOD_c	0.09	+0.1
AE	0.43	+0.3
$PM_{2.5}$	9.1	+0.2
PM_{10}	18.7	+0.1
SO_4	0.64	+0.4
σ_{sp}	21.2	+0.2
σ_{ap}	0.9	+1.5



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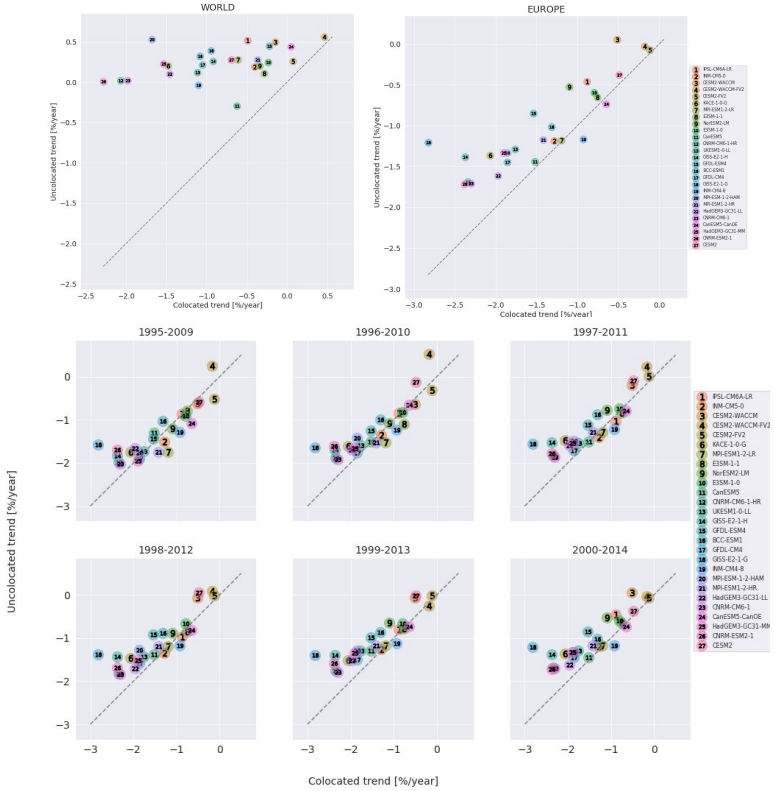
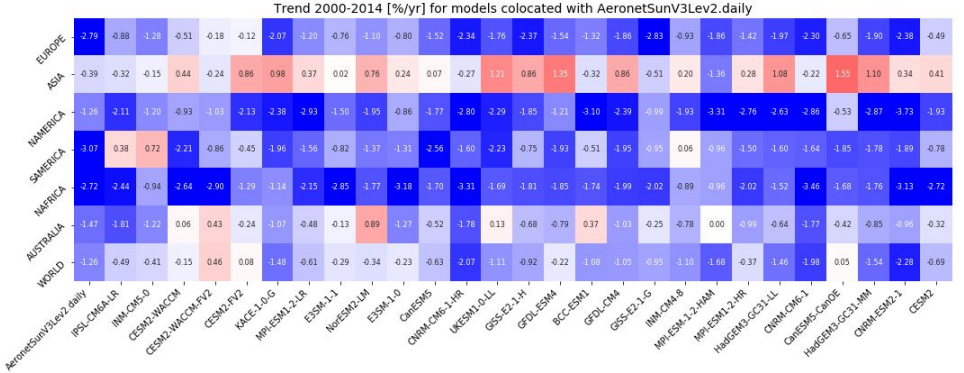
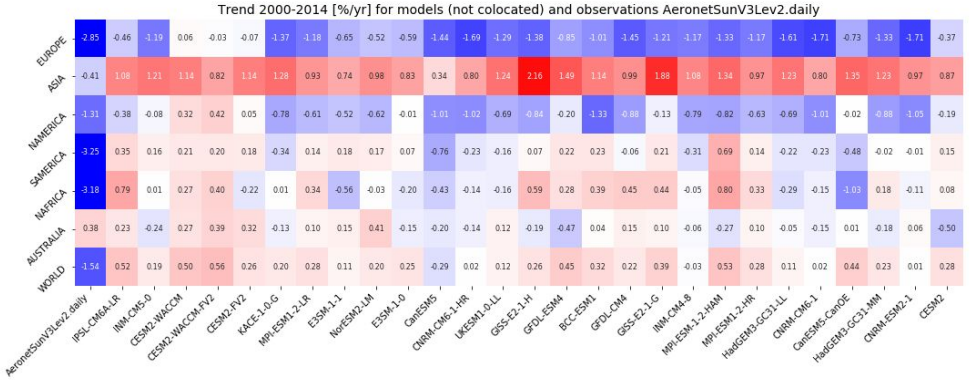
CMIP-6 AOD trends







Figures provided by A. L., Sjur