Biennial update of ACTRIS-2 trends report on trend assessment December 2018

Augustin Mortier, Michael Schulz, Jonas Gliss
Norwegian Meteorological Institute

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Table of content

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1 Introduction

A workup of long term data sets from the ACTRIS and collocated data is needed to provide an assessment of trends in aerosol concentrations and properties. The ultimate goal is to compute trends for parameters of relevance for atmospheric and climate research and make them available via a harmonized and easy to use trend portal. A regular trend update may be used to monitor recent changes in emissions or climate. Trends may also become only apparent when the time series becomes longer and interannual variations become less important. Methods also improve to deal with the specific problem of trend analysis for atmospheric data, linked to the characteristics of the data itself. Measurements at any set of stations in a network start and end at different times, are done slightly irregular in time and are interrupted for weeks to months due to individual maintenance schedules. Some parameters are prone to seasonal variation in magnitude and regional averages are uncertain due to limited observational coverage. Of further interest is the comparison to model and satellite data. These global fields may produce different regional trends, because their coverage may be different than that of the ground data network. While we have included some pilot data from CAMS, EMEP and cci-aerosol we expect to use the trend product for the forthcoming CMIP6 and AeroCom 2019 analysis. Here we report an update of both the measured in-situ and sun photometer derived aerosol trends and the ACTRIS infrastructure efforts associated to trend assessments.

2 Updated aerosol trends

For a systematic comparison of most recent data on aerosol optical properties, trends are computed for the period 1995-2015, representing the measurements at the start of the ACTRIS-2 project and the a period extended to 2017. To link the European ACTRIS trends to global aerosol trends, both Aeronet and NOAA are added to the ACTRIS data. Note that all data can be inspected in detail via the trend web interface actris-trends.met.no (also available under aerocom-trends.met.no).

2.1 Updated aerosol optical depth trends

In order to capture the most recent trends, the period [1995-2017] was added to the ACTRIS trend product. Aeronet data including the European ACTRIS component are retrieved using the latest data version 3, level 2. A global comparison with trends computed over the earlier period [1995-2014] is presented in Figure 1 and Table 1. The maps with the trends show rather similar patterns, with e.g. generally negative AOD trends in Europe and North America. With 3 additional years, one increases the number of stations which satisfies the time criteria (> 7 years) required to compute trends. One

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can also observe a reduction of the diversity of the trends within a region, e.g. the standard deviation in AOD trends in Europe decrease from +-1.5%/y to +-1.0%/y by extending the time series. This could be the result of both an increase of the number of stations where trends can be computed, and the extension of the time series that gives more statistically robust trends. Standard deviations for all regions can be found on the web interface. The largest increase towards more negative trends is found for East Asia, while the positive trends in Africa increased. Trends in the other regions seem to be rather unchanged.

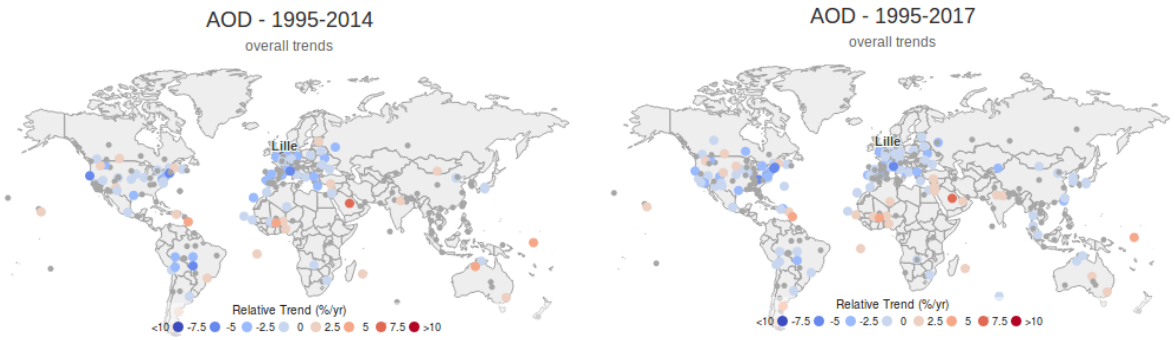

Figure 1: *Global maps of relative trends in AOD for [1995-2014] (left) and for the updated [1995-2017] time period (right). The color of the dots indicate the value and sign of the trend. Smaller gray dots correspond to stations where no trends were computed since the time coverage (<7 years) was too short.*

Table 1: Regional statistics of relative trends in AOD over the period [1995-2014] and the updated [1995-2017] time period. N is the number of stations with at least 7 years of data available.

		N-America	S-America	Europe	East-Asia	Africa	India
1995-2014	*(%/yr)*	-1.9	-2.1	-2.3	-1.0	+0.1	+0.8
	N	28	10	28	5	16	1
1995-2017	*(%/yr)*	-2.1	-1.6	-2.1	-1.6	+0.7	+0.6
	N	44	10	40	14	19	2

2.2 Updated dry aerosol scattering coefficient

In order to use most reliable in-situ dry aerosol scattering data, a level 3 data set has been constructed from the ACTRIS/EBAS data by removing obvious outliers (eg negative values, factor 1000) and by selecting the data associated with dry conditions (relative humidity < 50%). For these

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data the trends have been also computed for both the [1995-2014] and the [1995-2017] time periods.

Figure 2 and Table 2 summarizes the differences obtained with Level 3 data for these two time periods for dry aerosol scattering coefficient. European long time series have become more numerous due to ACTRIS activities (6 -> 10). The negative trends are larger in Europe (ca. - 3.7%/year) than in North America (-1.8 %/y). Trends in the other continents can not be established. Note that in Europe the dry aerosol scattering coefficient (surface aerosol) is larger than the column AOD trend (-2.1 %/year). For North America AOD and surface aerosol trends are almost equal.

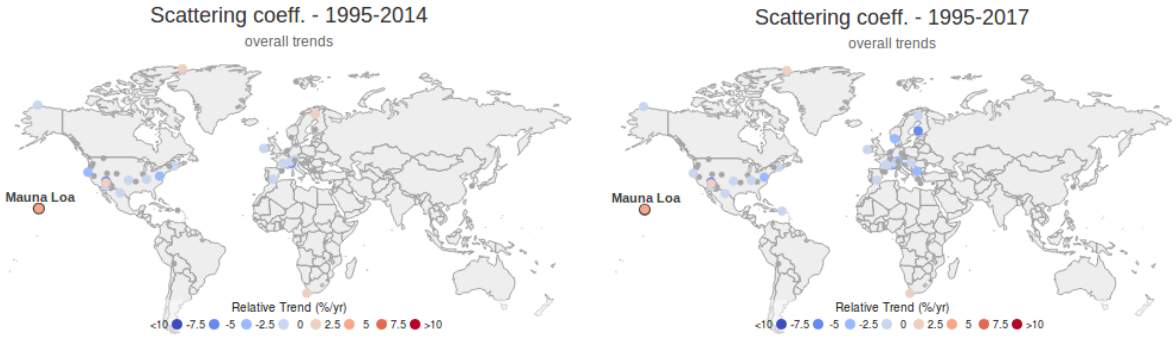

***Figure 2**: Same as Figure 2 but for dry aerosol scattering coefficient.*

Table 2: Mean regional trends of dry aerosol scattering coefficient and number of stations (N) with significantly long records.

		N-America	S-America	Europe	East-Asia	Africa	India
1995-2014	*(%/yr)*	-1.9	-	-4.1	-	+0.71	-
	N	13	0	6	0	1	0
1995-2017	*(%/yr)*	-1.8	-	-3.7	-	+0.71	-
	N	14	0	10	0	1	0

2.3 Updated aerosol absorption coefficient

There appear less long-term absorption coefficient data in the database, with only half of the sites reporting sufficient long trend data. Figure 3 and table 3 show the respective data in the same way as shown above for AOD and scattering coefficient. Interestingly absorption trends in Europe and North America are very similar to the aerosol scattering trends. Trends are larger in Europe than in North America, and again - European surface absorption coefficient trends are smaller than AOD trends.

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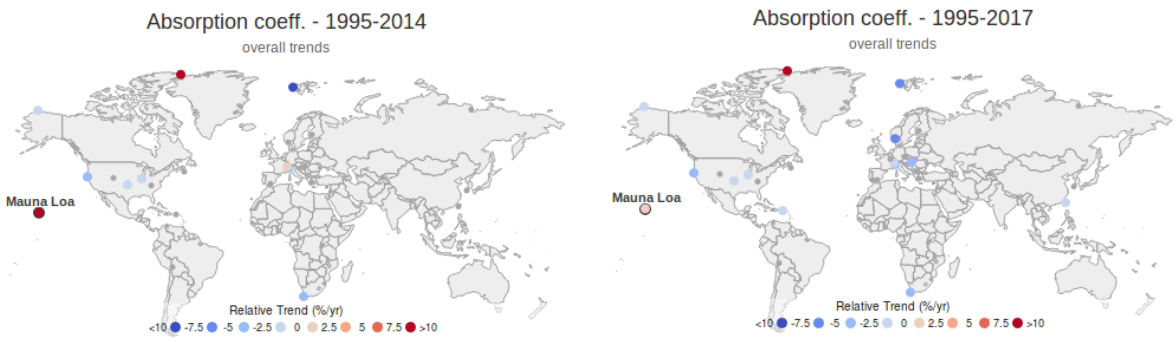

***Figure 3**: Same as Figure 1 but for aerosol absorption coefficient.*

Table 3: Mean regional trends of aerosol absorption coefficient and number of stations (N) with significantly long records.

		N-America	S-America	Europe	East-Asia	Africa	India
1995-2014	*(%/yr)*	-1.5	-	-3.8	-	-4.8	-
	N	5	0	2	0	1	0
1995-2017	*(%/yr)*	-1.8	-	-3.5	-2.4	-4.8	-
	N	6	0	4	1	1	0

3. Technical update of the ACTRIS trend product

3.1 Revision of ACTRIS/NOAA data

The homogenization of global scale aerosol measurements was significantly advanced in ACTRIS and NOAA recently. However, additional quality control is required when older data in the ACTRIS/EBAS database are investigated to identify potential issues (units, flags, data overlap, level marking). Outliers can largely affect the assessment of trends. An important work has been done together with Betsy Andrews/NOAA and NILU colleagues to scan the ACTRIS/EBAS database with respect to global aerosol scattering and absorption coefficient erroneous data. The errors and outliers, more easily spotted with our interactive trend visualization interface, have been signalled to NILU, through a specific feedback mechanism developed for that purpose.

3.2 Revision of Aeronet/ACTRIS data versions

The systematic computation of global trends from different observational datasets is raising several challenges. AERONET delivers observations in a homogeneous way since the instruments are very standardized and the measurement protocol is well defined. Different versions and quality levels are available and can be inspected with the ACTRIS trend interface. The recently released version 3 (level

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2), which involved in particular a better automated cloud-screening, was incorporated into the ACTRIS trends product. It appears, that more observations are available, as compared to version 2, when using the same data quality (level 2). For the period [1995-2014], in N-America, the number of stations where at least 7 years of observations are available (minimum period defined to compute the trends), increases from 18 to 28. In S-America, it increases from 4 to 10, making the regional analysis more robust.

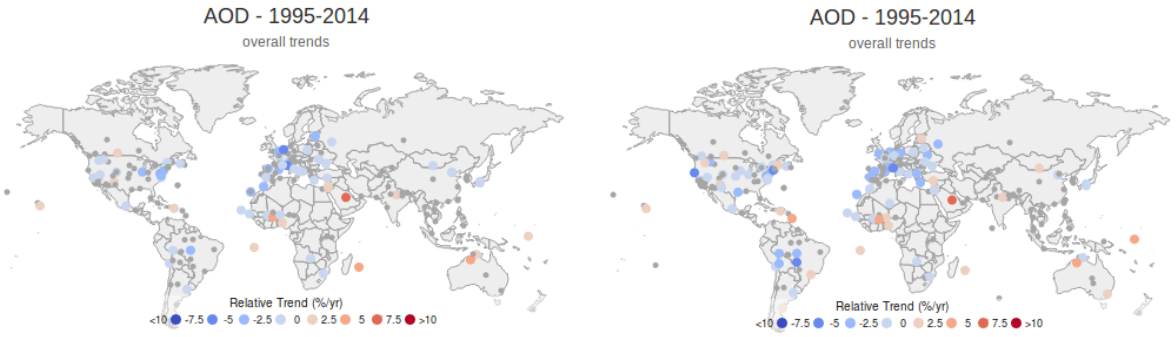

Figure 1: Global maps of relative trends in AOD for [1995-2014] using version 2 level 2 data (left) and version 3 level 3 data (right). The color of the dots indicate the value of the trend. The smaller gray dots correspond to the stations where no trends can be computed since the time criteria (>7 years) was not satisfied.

3.3 Revision of ACTRIS/EBAS and Aeronet post-processing infrastructure

In order to facilitate a more easy update of the trend data, a substantial post-processing software rewrite was performed in 2018. The observation post-processing is now performed using the pyaerocom tool (https://pyaerocom.met.no), which has been updated in order to read the complex, multi-annual ACTRIS/EBAS and Aeronet data. Data from different years and instruments are combined into continuous time series and filtered for major errors. The result is output on MetNo's lustre file system, formatted in json format, and is directly readable and accessible by the trend web interface. Any reprocessing of the ACTRIS/EBAS database and thus update is now possible within a few hours.

3.4 Update of trend web interface

The web interface has been entirely redesigned, enhancing both robustness and access to the data with a user-friendly dynamic interface. Most significant changes are listed hereafter:

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- The interface has been moved to a new web server, for a gain in speed and robustness: actris-trends.met.no (also available under aerocom-trends.met.no for backward compatibility and liaison with modelling community).
- Menus for selecting parameter, data version, period and co-located model or satellite data have been made easy to understand and concise
- The plots visible in the web interface are now entirely dynamic (using highcharts library):
    - dynamic time series with daily, monthly and yearly granularity, allowing for detailed inspection of any part of the time series
    - dynamic maps with colored dots indicating values and sign of relative trends, allowing for a zoom in into regions of interest
    - regional statistics computed in the web client for selected regions
    - meta-data documentation via info box (PI, revision date, instruments, granularity, data overlap)
    - search bar for finding specific stations
    - model/satellite time series are co-located with observations and are shown on top of observed time-series, accompanied with a scatter plot, generated in the web client

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