

Global Aerosol Climatology Project (GACP)

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Project starting date: 1998

URL: gacp.giss.nasa.gov

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Objectives

The Global Aerosol Climatology Project (GACP) was established in 1998 jointly by GEWEX and the NASA Radiation Sciences Program (RSP). Its main objectives have been to:

1. Analyze satellite radiance measurements and field observations in order to infer the global distribution of aerosols, their properties, and their seasonal and interannual variations; and
2. Perform advanced global and regional modeling studies of the aerosol formation, processing, and transport.

To accomplish these objectives, RSP has been funding a satellite-data processing center at the NASA Goddard Institute for Space Studies. In addition, in 1999-2001 NASA funded ~30 individual investigations selected on a competitive basis. The principal investigators of the successful proposals formed the GACP Science Team. Besides pursuing their individual research objectives, the members of the Science Team participated in selecting candidate algorithms to be applied to the full period of satellite measurements in order to estimate parameters of significance to the aerosol climatology. The processing center has been employing the algorithms recommended by the Science Team to produce the satellite component of the combined GACP aerosol product.

A major outcome of this collective research effort is a 25-year global aerosol climatology compiled from channel-1 and -2 AVHRR data and supplemented by data from other satellites, field observations, and chemical-transport modeling. The resulting datasets and analysis products have been documented in numerous peer-reviewed publications, including a special issue of the Journal of Atmospheric Sciences. They have been used to improve the understanding and modeling of the climate forcing due to changing aerosols, including both the direct radiative forcing by the aerosols and the indirect radiative forcing caused by the effects of changing aerosols on cloud properties.

Project Status

A global climatology of the column aerosol optical thickness (AOT) and Ångström exponent over the oceans has been derived from channel-1 and -2 radiances of the AVHRR. The latest version of the climatology covers the period from August 1981 to June 2005 and is based on an adjusted value of the diffuse component of the ocean reflectance as derived from extensive comparisons with ship sun-photometer data.

The project is funded by NASA through 30 September 2006.

Data Products Available-Archived

Complete GACP datasets currently available at the GACP web site are the monthly averages of the aerosol optical thickness and Angstrom exponent for the period from August 1981 to June 2005.

Key results

1. The global monthly mean optical thickness and Ångström exponent of tropospheric aerosols show no significant trends over the entire period and oscillate around the average values 0.145 and 0.75, respectively. The Northern hemisphere means AOT systematically exceeds that averaged over the Southern hemisphere.
2. Initial comparisons of the GACP aerosol product with MODIS and MISR aerosol retrievals have shown general agreement, the GACP global monthly AOT being lower than the MODIS one by approximately 0.03. Larger differences have been observed on regional scales. Comparisons of the GACP and MODIS Ångström exponent records are less conclusive and require further analysis.

3. We have used the updated GACP climatology and SAGE data to analyze how stratospheric aerosols from a major volcanic eruption can affect the GACP aerosol product. One possible retrieval strategy based on the AVHRR channel-1 and -2 data alone is to infer both the stratospheric and the tropospheric AOT while assuming fixed microphysical models for both aerosol components. The second approach is to use the SAGE stratospheric aerosol data in order to constrain the AVHRR retrieval algorithm. We have demonstrated that the second approach yields a consistent long-term record of the tropospheric AOT and Ångström exponent. The GACP retrieval results during the period affected by the Mt. Pinatubo eruption have been found to be consistent with the retrievals of the stratospheric AOT based on SAGE data.
4. We have used the GACP data set of the retrieved AOT and Ångström exponent to construct and analyze regional aerosol climatologies for a number of areas affected by different aerosol types (such as dust, biomass burning, anthropogenic, or clear maritime aerosols) which exemplify the range of natural aerosol variation. We have found that variations in the number of individual pixels used to calculate monthly means associated with short- and long-term satellite orbit changes and instrument degradation have little effect on global and hemispherical values of the AOT and Ångström exponent. Aerosol loads are found to be higher and aerosol particles smaller over the Northern Atlantic Ocean off the coast of Europe and Eastern US than off the US West Coast, thereby indicating a significant impact of anthropogenic aerosols. The smallest background levels of maritime aerosols are found in the Southern Pacific Ocean, with seasonal mean optical thicknesses as low as 0.1. We have analyzed time series of AOT in the regions affected by dust outflows from the Sahara and Asian deserts and by biomass burning. An influence of anthropogenic aerosols associated with the high regional industrial activity is apparent in the Eastern China Sea. Two distinct periods have been identified in satellite and sun-photometer aerosol time series over the Black Sea with transition time around 1993. During the first period the aerosol loads in the region significantly exceeded the hemispherical mean, whereas in the second period they became very close. This change has been linked to the reduction in the industrial output in that region.
5. The GACP AOT dataset has been compared with ship-borne sun-photometer results. The comparison of spatial and temporal statistics of the AVHRR results and the ship measurements has shown a strong correlation. The satellite retrieval results obtained with the original algorithm for a wavelength of 0.55 μm were systematically higher than the sun-photometer measurements in the cases of low aerosol loads. The ensemble averaged satellite-retrieved optical thickness overestimated the ensemble averaged sun-photometer data by about 11% with a random error of about 0.04. Increasing the diffuse component of the ocean surface reflectance from 0.002 to 0.004 in the AVHRR algorithm produces a better match, with the ensemble-averaged AVHRR-retrieved AOT differing by only about 3.6% from the sun-photometer truth and having a small offset of 0.03.

New Directions/Future

A number of satellite instruments have been used to develop global climatologies of aerosol properties, most notably MODIS, MISR, and AVHRR. The outcome of these efforts are several climatologies which all purport to represent the same aerosol characteristics such as optical thickness and size. However, the quantitative differences between these climatologies on both local and global scales and over both short and long time periods have been found to far exceed the corresponding individual uncertainty claims. These differences are alarming and necessitate a detailed critical assessment and integrated analysis which would go far beyond simple intercomparisons of various satellite products and comparisons of satellite AOTs with AERONET data. The former reveal the differences but do not help to identify their causes, whereas the latter appear to involve too much human selectivity as well as a priori information not contained in the operational satellite products.

To address this critical issue, we have re-proposed GACP to NASA for another 3-year term as part of a comprehensive research effort focusing on integrated analysis and synthesis of multi-instrument satellite data. This proposal is intended to develop the framework for a global long-term satellite climatology of aerosol properties based on a consistent combination of previous, current, and near-future satellite retrievals and implement it by integrating MODIS, MISR, GACP, and Glory APS datasets. Consistent with this primary objective, we proposed to:

- perform a detailed analysis of the potential uncertainties in the retrieved aerosol characteristics contributed by all components of the MODIS, MISR, and GACP retrieval procedures by examining the full range of spatial and temporal scales from daily pixel-level retrievals to multi-year global averages

- as well as the full range of aerosol type scenarios;
- use RSP data to provide a detailed step-by-step analysis of the MODIS and MISR retrieval procedures and identify the specific cases in which they fail;
- perform a global analysis of the MODIS and MISR retrievals using the benchmark distribution of aerosol characteristics derived with the EOS Glory APS; and
- integrate the MODIS, MISR, and GACP aerosol products into a coherent and consistent climatology.

This proposal thus follows the integrated strategy of utilizing data from multiple sensors and platforms and is expected to yield the following results:

- the quantification of the accuracy and likely limits of applicability of each satellite dataset;
- the clarification of the meaning, accuracy, and utility of various spatial and/or temporal averages (including global and annual averages) of aerosol characteristics;
- the clarification of the extent to which the various satellite datasets are coherent, complimentary, and/or contradictory;
- the rationalization of specific improvements in the existing MODIS, MISR, and GACP aerosol retrieval algorithms and in the future VIIRS algorithms;
- a meaningful synthesis of the MODIS, MISR, and GACP aerosol products in order to infer the three-decade-long pattern of the global distribution of aerosols; and
- an improved framework for the formulation of future NASA satellite missions for aerosol, cloud, and ocean color research.

Key Publications

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