Science AAAS

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Science **315**, 1543 (2007);
DOI: 10.1126/science.1136709

Long-Term Satellite Record Reveals Likely Recent Aerosol Trend

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Recent observations of downward solar radiation fluxes at Earth's surface have shown a recovery from the previous decline known as global "dimming" (*1*), with the "brightening" beginning around 1990 (*2*). The increasing amount of sunlight at the surface profoundly affects climate and may represent certain diminished counterbalances to greenhouse gas warming, thereby making the warming trend more evident during the past decade.

It has been suggested that tropospheric aerosols have contributed notably to the switch from solar dimming to brightening via both direct and indirect aerosol effects (*1*, *2*). It has further been argued (*3*) that the solar radiation trend mirrors the estimated recent trend in primary anthropogenic emissions of SO_2 and black carbon, which contribute substantially to the global aerosol optical thickness (AOT). A similar increase of net solar flux at the top of the atmosphere (TOA) over the same period appears to be explained by corresponding changes in lower-latitude cloudiness (*4*), which confounds the interpretation of the surface radiation record. Therefore, it is important to provide a direct and independent assessment of the actual global long-term behavior of the AOT. We accomplish this by using the longest uninterrupted record of global satellite estimates of the column AOT over the oceans, the Global Aerosol Climatology Project (GACP) record (*5*). The record is derived from the International Satellite Cloud Climatology Project (ISCCP) DX radiance data set composed of calibrated and sampled Advanced Very High Resolution Radiometer (AVHRR) radiances. A detailed discussion of the sampling resolution, calibration history, and changes in the corresponding satellite sensors can be found in (*6*).

The global monthly average of the column AOT is depicted for the period August 1981 to June 2005 (Fig. 1, solid black curve). The two major maxima are caused by the stratospheric aerosols generated by the El Chichon (March 1982) and the Mount Pinatubo (June 1991) eruptions, also captured in the Stratospheric Aerosol and Gas Experiment (SAGE) stratospheric AOT record (*7*). The quasi-periodic oscillations in the black curve are the result of short-term aerosol variability.

The overall behavior of the column AOT during the eruption-free period from January 1986 to June 1991 (Fig. 1, red line) shows only a hint of a statistically significant tendency and indicates that the average column AOT value just before the Mount Pinatubo eruption was close to 0.142. After the eruption, the GACP curve is a superposition of the complex volcanic and tropospheric AOT temporal variations. However, the green line reveals a long-term decreasing tendency in the tropospheric AOT. Indeed, even if we assume that the stratospheric AOT just before the eruption was as large as 0.007 and that by June 2005 the stratospheric AOT became essentially zero (compare with the blue curve), still the resulting decrease in the tropospheric AOT during the 14-year period comes out to be 0.03. This trend is significant at the 99% confidence level.

Admittedly, AVHRR is not an instrument designed for accurate aerosol retrievals from space. Among the remaining uncertainties is radiance calibration, which, if inaccurate, can result in spurious aerosol tendencies. Similarly, substantial systematic changes in the aerosol single-scattering albedo or the ocean reflectance can be misinterpreted in terms of AOT variations. However, the successful validation of GACP retrievals using precise sun photometer data taken from 1983 through 2004 (*8*, *9*) indicates that the ISCCP radiance calibration is likely to be reliable. This conclusion is reinforced by the close correspondence of calculated and observed TOA solar fluxes (*4*). Furthermore, the GACP AOT record appears to be self-consistent, with no drastic intrasatellite variations, and is consistent with the SAGE record.

The advantage of the AVHRR data set over the data sets collected with more advanced recent satellite instruments is its duration, which makes possible reliable detection of statistically significant tendencies like the substantial decrease of the tropospheric AOT between 1991 and 2005. With all the uncertainties, the tropospheric AOT decrease over the 14-year period is estimated to be at least 0.02. This change is consistent with long-term atmospheric transmission records collected in the former Soviet Union (*5*).

Our results suggest that the recent downward trend in the tropospheric AOT may have contributed to the concurrent upward trend in surface solar fluxes. Neither AVHRR nor other existing satellite instruments can be used to determine unequivocally whether the recent AOT trend is due to long-term global changes in natural or anthropogenic aerosols. This discrimination would be facilitated by an instrument like the Aerosol Polarimetry Sensor (APS), scheduled for launch in December 2008 as part of the NASA Glory mission (*10*). It is thus imperative to provide uninterrupted multidecadal monitoring of aerosols from space with dedicated instruments like APS in order to detect long-term anthropogenic trends potentially having a strong impact on climate.

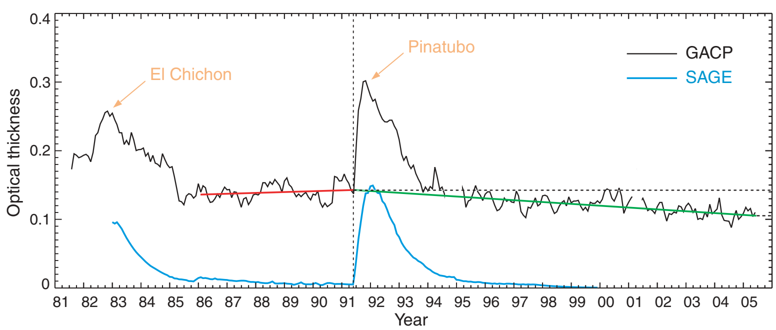

Fig. 1. GACP record of the globally averaged column AOT over the oceans and SAGE record of the globally averaged stratospheric AOT.

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11. This research is part of NASA/Global Energy and Water Cycle Experiment GACP and was funded by the NASA Radiation Sciences Program, managed by H. Maring and D. Anderson.

24 October 2006; accepted 20 December 2006
10.1126/science.1136709

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