

This work was written as part of one of the author's official duties as an Employee of the United States Government and is therefore a work of the United States Government. In accordance with 17 U.S.C. 105, no copyright protection is available for such works under U.S. Law.

Public Domain Mark 1.0

<https://creativecommons.org/publicdomain/mark/1.0/>

Access to this work was provided by the University of Maryland, Baltimore County (UMBC) ScholarWorks@UMBC digital repository on the Maryland Shared Open Access (MD-SOAR) platform.

Please provide feedback

Please support the ScholarWorks@UMBC repository by emailing scholarworks-group@umbc.edu and telling us what having access to this work means to you and why it's important to you. Thank you.

EOS

VOLUME 79 NUMBER 5

FEBRUARY 3, 1998

PAGES 57–68

New TOMS Instrument Measures Ozone and Aerosols

Jack A. Kaye, Richard D. McPeters, Jay R. Herman, P. K. Bhartia, and Arlin J. Krueger

PAGES 57, 63

New Total Ozone Mapping Spectrometer (TOMS) instruments launched in 1996 have provided new and better information about ozone distribution, sulfur dioxide concentrations following large volcanic eruptions, the distributions of ultraviolet-absorbing aerosols (including ash plumes) in the troposphere, and the flux of ultraviolet radiation reaching the Earth's surface. The instruments gathered important data on ozone depletion in the Antarctic in the austral springs of 1996 and 1997 and in the Arctic in the Northern Hemisphere spring of 1997. Ash clouds associated with forest fires in the United States and in Indonesia, as well as the eruption of the Soufriere Hills volcano in Montserrat in December 1997, were also observed.

NASA's Earth Probe (EP) satellite, launched in July 1996, carries one TOMS instrument. A second TOMS instrument flew on the Japanese Advanced Environmental Orbiting Satellite (ADEOS), known as "Midori," launched in August 1996 from Japan. Unfortunately, because the ADEOS spacecraft failed in June 1997, only 10 months of data are available from the ADEOS TOMS instrument (see <http://mentor.eorc.nasda.go.jp/ADEOS>). The Earth Probe satellite flew in a 500 km Sun-synchronous orbit, which was chosen to complement the 800 km altitude of the ADEOS spacecraft by providing improved horizontal resolution for viewing aerosol sources (26 km x 26 km at nadir instead of the 42 km x 42 km resolution of ADEOS). Because of the lower orbit, data gaps did not allow for full daily maps of the sunlit Earth from EP TOMS. In order to restore the complete global coverage lost with the ADEOS failure, the EP spacecraft was boosted to a 740 km orbit in early December 1997.

The two TOMS instruments follow the 16-year record of the first TOMS instruments: one aboard NASA's Nimbus 7 satellite, gathering data from 1978 to 1993; and one traveling on a Russian Meteor-3 satellite from 1991 through 1994. Though similar to the previous instruments, the new TOMS instruments have improvements in two areas: calibration and wavelength coverage. As TOMS is designed to detect a 1% per decade trend in total ozone [Krueger *et al.*, 1995a], the new in-flight instrument calibration enhances the

long-term accuracy of the data. The wavelength bands used to measure ozone—308.6, 312.5, 317.5, 322.4, 331.3, and 360.0 nm, with a nominal bandwidth of 1.1 nm for each band—have also been modified from the nominal wavelengths for previous TOMS instruments (312.5, 317.5, 331.2, 339.8, 360, and 380 nm). The main benefit of the wavelength changes is to increase accuracy of ozone measurements made at high solar zenith angles.

Tracking Ozone

Both TOMS instruments provided coverage of the 1996 Antarctic hole in stratospheric ozone, which, while similar to those used in previous years, developed more quickly. The lowest ozone value, 111 Dobson Units (DU) as measured by EP TOMS, occurred on October 5, 1996. The average area of the ozone hole (defined as that inside the 220 DU contour) for the time period September 9 to Oct. 13, 1996, was 21.6 million sq km.

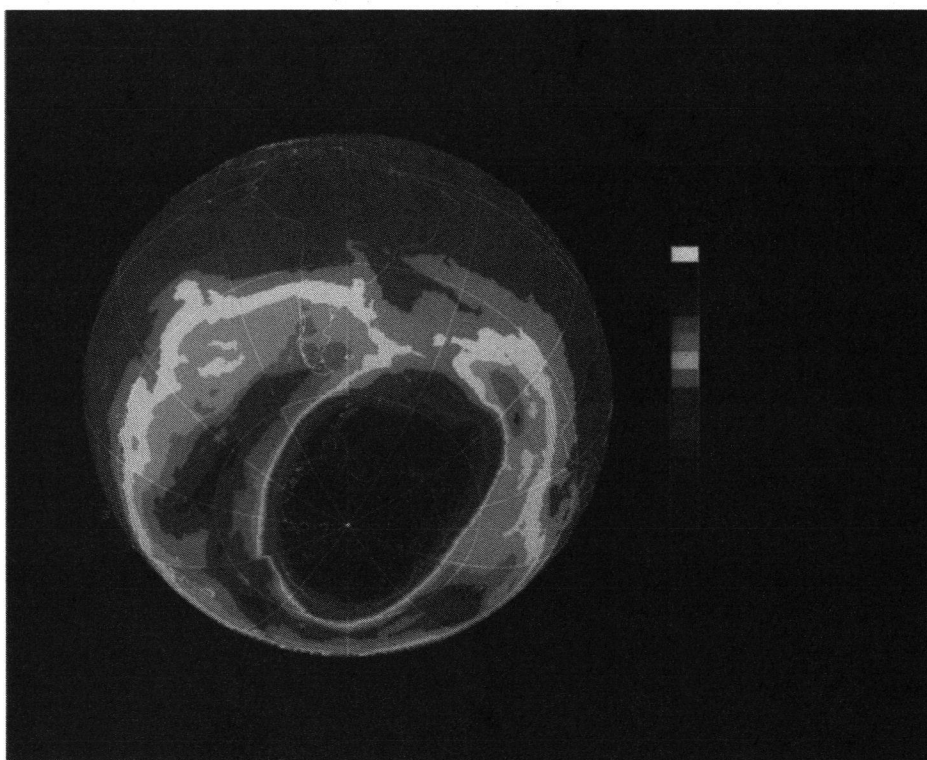


Fig. 1. Map of ozone measured by the Earth Probe Total Ozone Mapping Spectrometer (EP TOMS) instrument on September 24, 1997, when the lowest annual value (104 Dobson Units) was recorded. Original color image appears at the back of this volume.

For more information contact Jack A. Kaye, NASA Headquarters, Office of Mission to Planet Earth, Washington, DC 20546, USA.

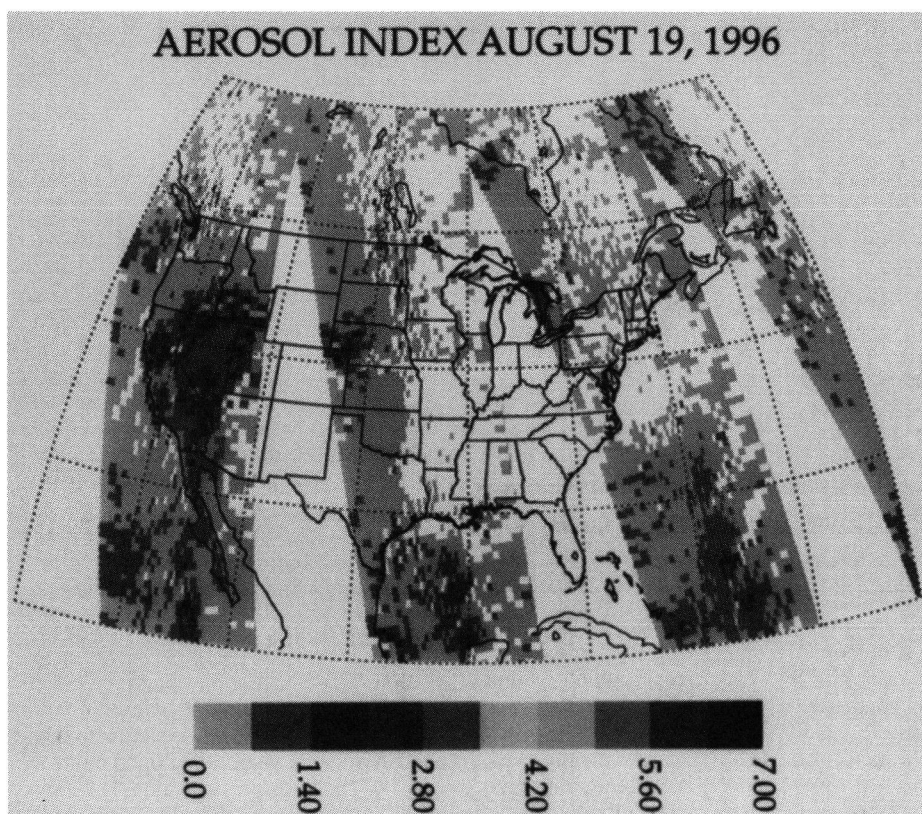


Fig. 2. Image from EP TOMS on August 19, 1996, showing heavy smoke from fires in the western United States. TOMS is sensitive to UV-absorbing aerosols such as smoke and silicate dust. The blank areas are outside the EP TOMS scan pattern. Original color image appears at the back of this volume.

The 1997 Antarctic ozone hole, observed with EP TOMS, had a minimum ozone level of 104 DU, which occurred on September 24, 1997 (see Figure 1). The average area (as defined above) was 20.9 million sq km. Both instruments also measured the low total ozone values over the Arctic in the spring of 1997 [Newman *et al.*, 1997]; the lowest total ozone value observed was 219 DU, and the size of the region of ozone depletion (measured as the area inside the 280 DU contour) was 5–6 million sq km.

Although tropospheric ozone cannot be directly measured by TOMS, information on its distribution can be obtained by subtracting stratospheric ozone as measured by some other instrument (Stratospheric Aerosol and Gas Experiment (SAGE II), Solar Backscatter Ultraviolet (SBUV/2), or Microwave Limb Sounder (MLS)) from the TOMS total column. This tropospheric ozone residual (TOR) technique was originally developed by Fishman *et al.* [1996]. Tropospheric ozone can also be derived directly from TOMS by making assumptions about the variation of stratospheric ozone [Kim *et al.*, 1996].

Ash, Aerosols, and Sulfur Dioxide

The EP and ADEOS TOMS instruments monitored the eruption of the volcano Nyamuragira in Zaire (1.42°S, 29.2°E) and detected elevated SO₂ levels from December 1–13, 1996. Simultaneous TOMS measurements of volcanic ash [Seftor *et al.*, 1997] and sulfur dioxide are valuable to studies of volcanic processes and aviation hazards. The new TOMS observations should also complement the record of volcanic SO₂ from previous TOMS instruments [Krueger *et al.*, 1995b]. Images of volcanic sulfur dioxide and ash plumes are available at <http://skye.gsfc.nasa.gov>.

TOMS measurements of tropospheric aerosols use the wavelength dependence of UV reflectivity measured at channels little affected by ozone [Hsu *et al.*, 1996; Herman *et al.*, 1997]. In earlier TOMS instruments, the 331.3, 360, and 380 nm channels provided excellent long-wavelength information. Although the 380 nm channel was eliminated in the new TOMS instruments, TOMS can clearly observe UV-absorbing materials such as mineral desert dust, volcanic ash, and

smoke from fires using the 360 nm and 331.3 nm channels. Several fires, especially those in the western United States in late summer of 1996 (Figure 2), were observed by EP TOMS.

UV Exposure

With radiative transfer models, scientists can accurately estimate the amount of ultraviolet radiation reaching the Earth's surface from the solar flux entering the atmosphere (determined from spectrally resolved solar irradiance data from instruments aboard NASA's Upper Atmosphere Research Satellite), total ozone measurements from TOMS, and cloud cover data from long wavelength TOMS channels. The results of this technique, validated by comparison with ground-based measurements made in Toronto, showed information on trends in UV radiation over most of the Earth [Herman *et al.*, 1996]. Nimbus 7 TOMS data have also been used to determine the first surface reflectivity climatology of the Earth's surface (oceans and land) in the near UV, and reflectivity data will also be available from the EP and ADEOS TOMS instruments.

Data Calibration and Validation

TOMS data recorded on the spacecraft are downlinked and transmitted to the TOMS Science Operations Center at the Goddard Space Flight Center for rapid processing. In most cases, ozone values are mapped and made available as they are received (within hours), and full global maps are usually available within 24 hrs. These data, along with historical data sets, can be found on the TOMS home page (<http://jwocky.gsfc.nasa.gov>), complete with numerical values of the ozone fields as well as color images (full globe, north polar projection, south polar projection).

At this point, the EP TOMS results are considered preliminary because they are based on preflight calibrations and a first-estimated, in-orbit calibration correction. TOMS data are validated by comparisons with the Dobson network [McPeters and Labow, 1996] as well as with data from other instruments, including ozonesondes, the currently operating SBUV/2 instruments, and the Global Ozone Monitoring Experiment (GOME) aboard the European Space Agency's ERS-2 satellite. Initial validation shows that the current EP calibration gives ozone just 1% higher than an average of 30 ground-based Dobson stations.

EP TOMS data are also directly transmitted to S-band receiving stations in real time

for processing and use in applications requiring rapid access to data. Current real-time users of data include the National Science Foundation's McMurdo station, where ozone data are used by on-site experimenters, and the Federal Aviation Administration (in conjunction with the National Weather Service's Anchorage, Alaska, station), for which sulfur dioxide and ozone data are used in volcanic hazard mitigation and flight level wind forecast validation in the North Pacific region. Data for other atmospheric constituents (sulfur dioxide, volcanic ash plumes, tropospheric aerosols, surface ultraviolet radiation flux, surface ultraviolet reflectivity, tropospheric ozone based on some assumption about stratospheric ozone distributions) are not yet available for immediate access, although they will be made available through the TOMS Web site in 1998.

The TOMS series will continue with the launch of a final TOMS instrument aboard a Russian Meteor-3M spacecraft in the year 2000. An advanced version of the total ozone mapping instrument is also under considera-

tion for inclusion in the National Polar Orbiting Environmental Satellite System (NPOESS) program, to be launched in 2007.

References

- Fishman, J., V. B. Brackett, E. V. Browell, and W. B. Grant, Tropospheric ozone derived from TOMS/SBUV measurements during TRACE A, *J. Geophys. Res.*, **101**, 24,069–24,082, 1996.
- Herman, J. R., P. K. Bhartia, J. Ziemke, Z. Ahmad, and D. Larko, UV-B increases (1979–1992) from decreases in total ozone, *Geophys. Res. Lett.*, **23**, 2,117–2,120, 1996.
- Herman, J. R., P. K. Bhartia, O. Torres, C. Hsu, C. Seftor, and E. Celarier, Global distribution of UV-absorbing aerosols from Nimbus-7/TOMS data, *J. Geophys. Res.*, **102**, 16,911–16,922, 1997.
- Hsu, N. C., J. R. Herman, P. K. Bhartia, C. J. Seftor, O. Torres, A. M. Thompson, J. F. Gleason, T. F. Eck, and B. N. Holben, Detection of biomass burning smoke from TOMS measurements, *Geophys. Res. Lett.*, **23**, 745–748, 1996.
- Kim, J. H., R. D. Hudson, and A. M. Thompson, A new method of deriving time-averaged tropospheric column ozone over the tropics using total ozone mapping spectrometer (TOMS) radiances: Intercomparison and analysis using TRACE A data, *J. Geophys. Res.*, **101**, 24,317–24,330, 1996.
- Krueger, A. J., G. Jaross, and U. Hartmann, Design of the ADEOS/TOMS instrument for ozone trend assessment, *Proc. SPIE*, **2583**, 235–244, 1995a.
- Krueger, A. J., L. S. Walter, P. K. Bhartia, C. C. Schnetzler, N. A. Krotkov, I. Sprod, and G. J. S. Bluth, Volcanic sulfur dioxide measurements from the Total Ozone Mapping Spectrometer (TOMS) Instruments, *J. Geophys. Res.*, **100**, 14,057–14,076, 1995b.
- McPeters R. D., and G. Labow, An assessment of the accuracy of 14.5 years of Nimbus 7 TOMS Version 7 ozone data by comparison with the Dobson network, *Geophys. Res. Lett.*, **23**, 3,695–3,698, 1996.
- Newman, P. A., J. Gleason, R. McPeters, R. Stolarski, Anomalous low ozone over the Arctic, *Geophys. Res. Lett.*, **24**, 2,689–2,692, 1997.
- Seftor, C., N. Hsu, J. Herman, P. K. Bhartia, O. Torres, W. Rose, D. Schneider, and N. Krotkov, Detection of volcanic ash clouds from Nimbus 7/total ozone mapping spectrometer, *J. Geophys. Res.*, **102**, 16,749–16,759, 1997.

Support for U.S. Graduate Education in the Ocean Sciences: Are Research Assistantships Overutilized as a Source of Funding?

S. E. Schoedinger, R.W. Spinrad, and A. R. M. Nowell

PAGES 57, 61, 64

The ocean sciences offer graduate students a unique and exciting educational experience, but is that experience ideally suited to the next step of a student's career, namely postgraduate employment? To begin to answer this question one must consider first whether the requirements of the career that is sought would be met better by a master's or a Ph.D. Often the master's degree is looked upon as a stepping stone along the path to a Ph.D., and then a career in research. Consequently, most of the graduate experiences in ocean sciences are exclusively focused on research. The financial support of students encourages this focus since most of the funding is provided within a specific research project in the form of a research assistantship.

Data from an alumni survey conducted by the Consortium for Oceanographic Research and Education (CORE) show that 58% of the respondents were funded by a research assistantship (RA) for at least part of their graduate education. Similarly, between 1987 and 1994, 61.9% of the graduate students in ocean-

ography programs in the United States were supported by an RA (Figure 1) [*National Science Foundation (NSF)*, 1994]. In comparison, 53.2% of the students in agricultural sciences were funded through an RA during the same time period. Other disciplines showed even lower percentages of support: 41.1% in the physical sciences, 38.3% in the biological sciences, 21.0% in computer science, and 9.6% in mathematics. Thus, the ocean sciences community appears to be utilizing the research assistantship to a higher degree than much of the rest of the scientific community. Given the current and projected trends in the job market, should the RA be the primary means of graduate student support in our community? Probably not.

Focus on the Future

Since 1982 the oceanographic community has conducted a biennial meeting (the Ocean Science Educators Retreat, or OSER) dealing with various subjects, the most recent (1995) focusing on "Advising the Next Generation of Graduate Students" for tomorrow's career opportunities. Originally the retreat involved only Joint Oceanographic Institution members, but with the establishment of CORE (in 1994) the retreat has

been expanded to include the institutions that represent the majority of oceanographic graduate education in the United States. The 1995 OSER was conducted to deal with the issue of graduate education reform in the ocean sciences. In preparation for the retreat, representatives of 35 U.S. institutions of higher learning with graduate programs in the ocean sciences were asked to complete a survey regarding the characteristics of their particular graduate program. These surveys were also used in the 1993 OSER and comparisons of the data from each year show key trends in graduate education in marine science. Subsequent to the 1995 OSER, CORE conducted a survey of its institutions' alumni with respect to their educational backgrounds and job histories. Some preliminary data from this survey were presented at the 1996 AGU Fall Meeting [*Schoedinger et al.*, 1996].

As in many science disciplines these days [*Committee on Science, Engineering, and Public Policy (COSEPUP)*, 1995; *Magner*, 1996], the U.S. oceanographic community is having to deal with the realities of limited federal research dollars and a dearth of available tenure track positions within academia [*National Research Council (NRC)*, 1992; *CORE*, 1996]. This is occurring at a time when student interest in graduate education in the ocean sciences remains high, as reflected by a 79% increase in the number of applications to graduate schools of oceanography between 1984 and 1995. Thus more than ever, students entering graduate school are faced with the need to consider additional career options outside academia.

While there have always been people with advanced degrees in ocean sciences who have chosen to work outside academia—between 1992 and 1995, 65% of mas-

For more information, contact Richard Spinrad, Consortium for Oceanographic Research and Education (CORE), 1755 Massachusetts Avenue, NW, Washington, DC 20036U USA.

Eos, Vol. 79, No. 5, February 3, 1998

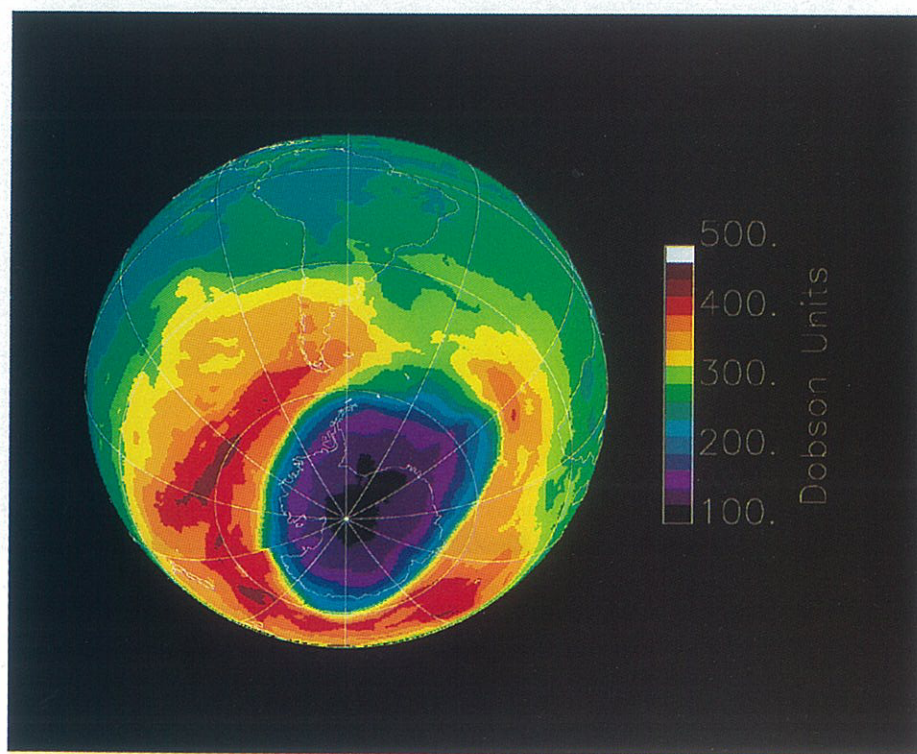


Fig. 1. Map of ozone measured by the Earth Probe Total Ozone Mapping Spectrometer (EP TOMS) instrument on September 24, 1997, when the lowest annual value (104 Dobson Units) was recorded.

AEROSOL INDEX AUGUST 19, 1996

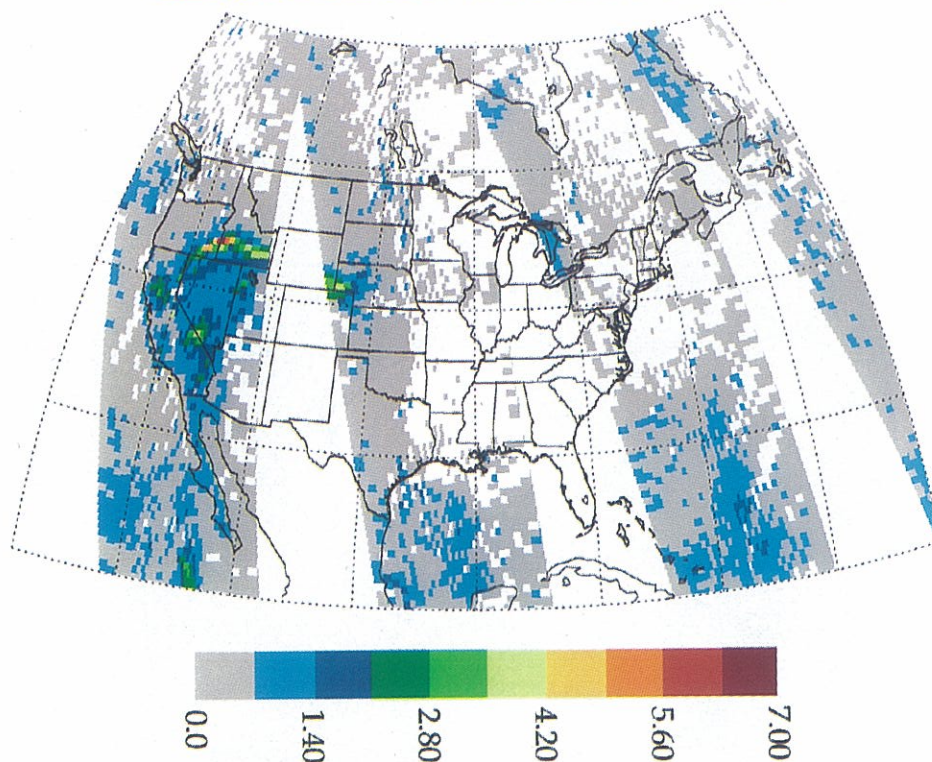


Fig. 2. Image from EP TOMS on August 19, 1996, showing heavy smoke from fires in the western United States. TOMS is sensitive to UV-absorbing aerosols such as smoke and silicate dust. The blank areas are outside the EP TOMS scan pattern.