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Covering the Period 1 April 1997 through 31 March 1999

CHARACTERIZATION OF ATMOSPHERIC AEROSOL BEHAVIOR AND CLIMATIC EFFECTS BY ANALYSIS OF SAGE II AND OTHER SPACE, AIR, AND GROUND MEASUREMENTS

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FIGURES

1 INTRODUCTION

This report documents the research performed under NASA Ames Cooperative Agreement NCC 2-991, which covered the period 1 April 1997 through 31 March 1999. Previously, an interim technical report (Technical Report No. 1, 20 March 1998) summarized the work completed during the period 1 April 1997 through 31 March 1998.

2 OBJECTIVE

This cooperative agreement provided partial support for Mr. John Livingston of SRI International to perform collaborative research with civil servant and contractor atmospheric scientists at NASA Ames Research Center. The objective of the proposed research was to advance our understanding of atmospheric aerosol behavior, aerosol-induced climatic effects, and the remote measurement and retrieval capabilities of spaceborne sensors such as SAGE II by combining and comparing data from these instruments and from airborne and ground-based instruments. Because this research was (and continues to be) a team effort, Mr. Livingston's role evolved during the course of the cooperative agreement. The focus of his work supported by this cooperative agreement was on the analysis of NASA Ames airborne sunphotometer measurements collected during the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) to investigate aerosol-induced climatic effects and on preliminary analysis of Ames shipboard sunphotometer measurements collected during the North Atlantic Aerosol Characterization Experiment (ACE-2).

3 TECHNICAL SUMMARY

The following tasks were completed with support, wholly or in part, from this cooperative research agreement:

- Calculation of atmospheric layer aerosol optical depths and uncertainties from direct-beam solar transmission measurements taken during TARFOX with the NASA Ames 6-channel (AATS-6) and 14-channel (AATS-14) airborne sunphotometers.
- Inversion of these layer aerosol optical depths to retrieve layer aerosol size distributions and associated uncertainties. This task included the development of MATLAB software routines to perform these inversions (software based on a public FORTRAN source code that uses constrained linear inversion theory) and to quantify the uncertainties associated with the retrieved size distributions by analyzing results for a series of inversion runs.
- Calculation of aerosol layer optical properties—single scattering albedo, asymmetry factor, and optical depth—from the retrieved TARFOX layer aerosol size distributions and an observation-based refractive index model for use in computing direct aerosol-induced radiative flux changes and subsequent comparison with aircraft-measured flux changes.
- Derivation of time-dependent columnar water vapor amounts from AATS-6 measurements acquired during nine TARFOX flights.
- Initial reduction of selected data sets acquired with the AATS-6, lidar, and various in situ instruments from aboard ship during ACE-2; subsequent presentation of initial findings at the 1997 Fall Meeting of the American Geophysical Union.

Thus far, results of the TARFOX research have been described in detail in four separate journal publications on which Mr. Livingston is a coauthor. Figures 1 through 3 of this report were produced by Mr. Livingston and appear in the Russell et al. (1999) Journal of Geophysical Research article. Additional TARFOX-related articles are to appear in a forthcoming special issue of the Journal of Geophysical Research. A list of the journal and conference publications supported by this cooperative agreement is given in Section 4 below. The bulk of the analysis of ACE-2 NASA Ames shipboard sunphotometer measurements and the publication of the results is being conducted under support from a separate cooperative agreement.

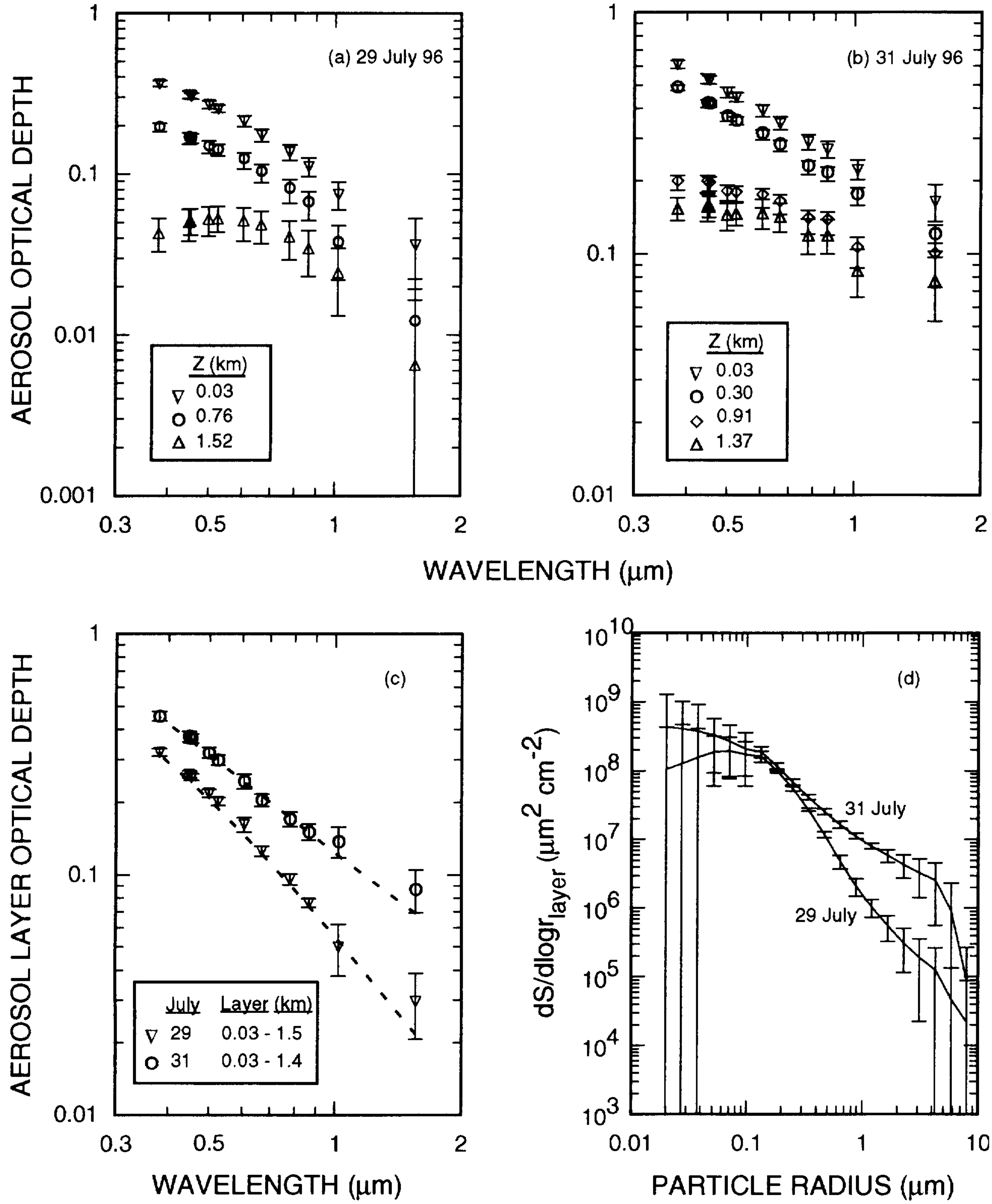

Figure 1 (a,b) Aerosol optical depth spectra measured by the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14) on the Pelican aircraft. (c) Aerosol layer optical depth spectra obtained by differencing spectra for minimum and maximum altitudes in Figures 1a, 1b. (d) Aerosol layer size distributions retrieved from the optical depth spectra in Figure 1c. Dashed lines in Figure 1c are computed from the size distributions in Figure 1d.

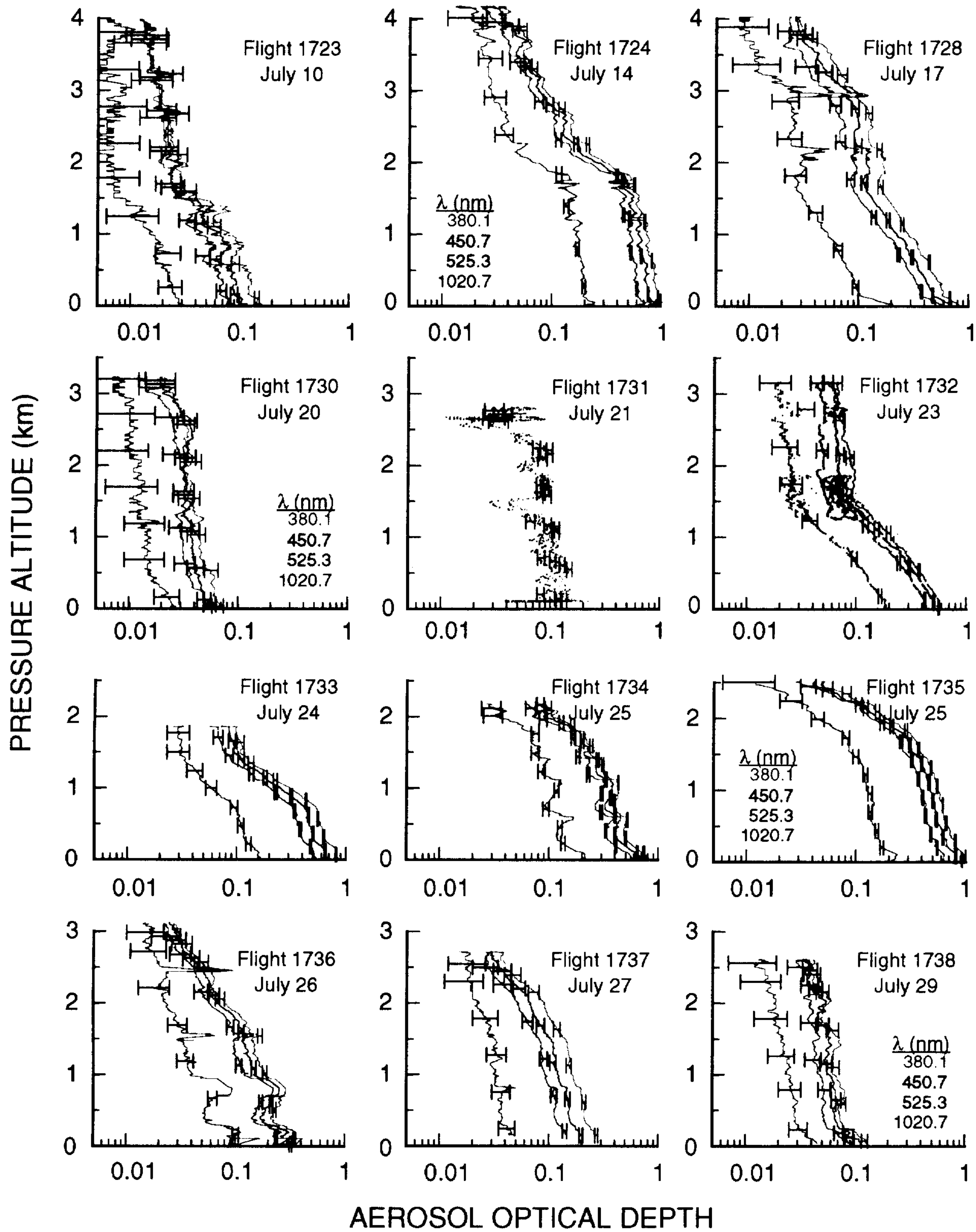

Figure 2 Vertical profiles of aerosol optical depth measured by the six-channel Ames Airborne Tracking Sunphotometer (AATS-6) on C-131A ascents.

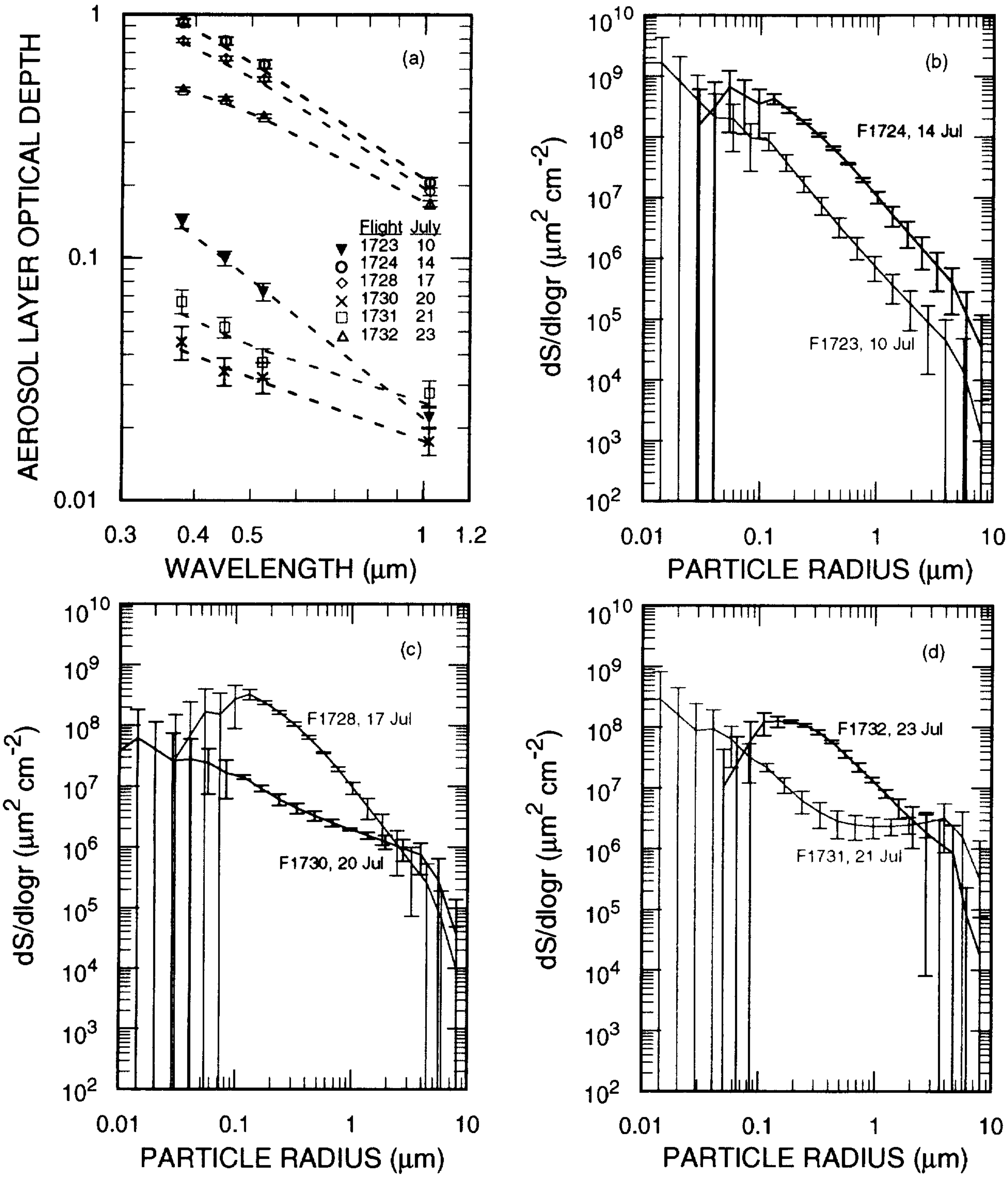

Figure 3 (a) Aerosol layer optical depth spectra obtained by differencing profile bottom and top values in Figure 2. (b-d) Aerosol layer size distributions retrieved from the optical depth spectra in Figure 3a. Dashed lines in Figure 3a are computed from the size distributions in Figures 3b-3d..

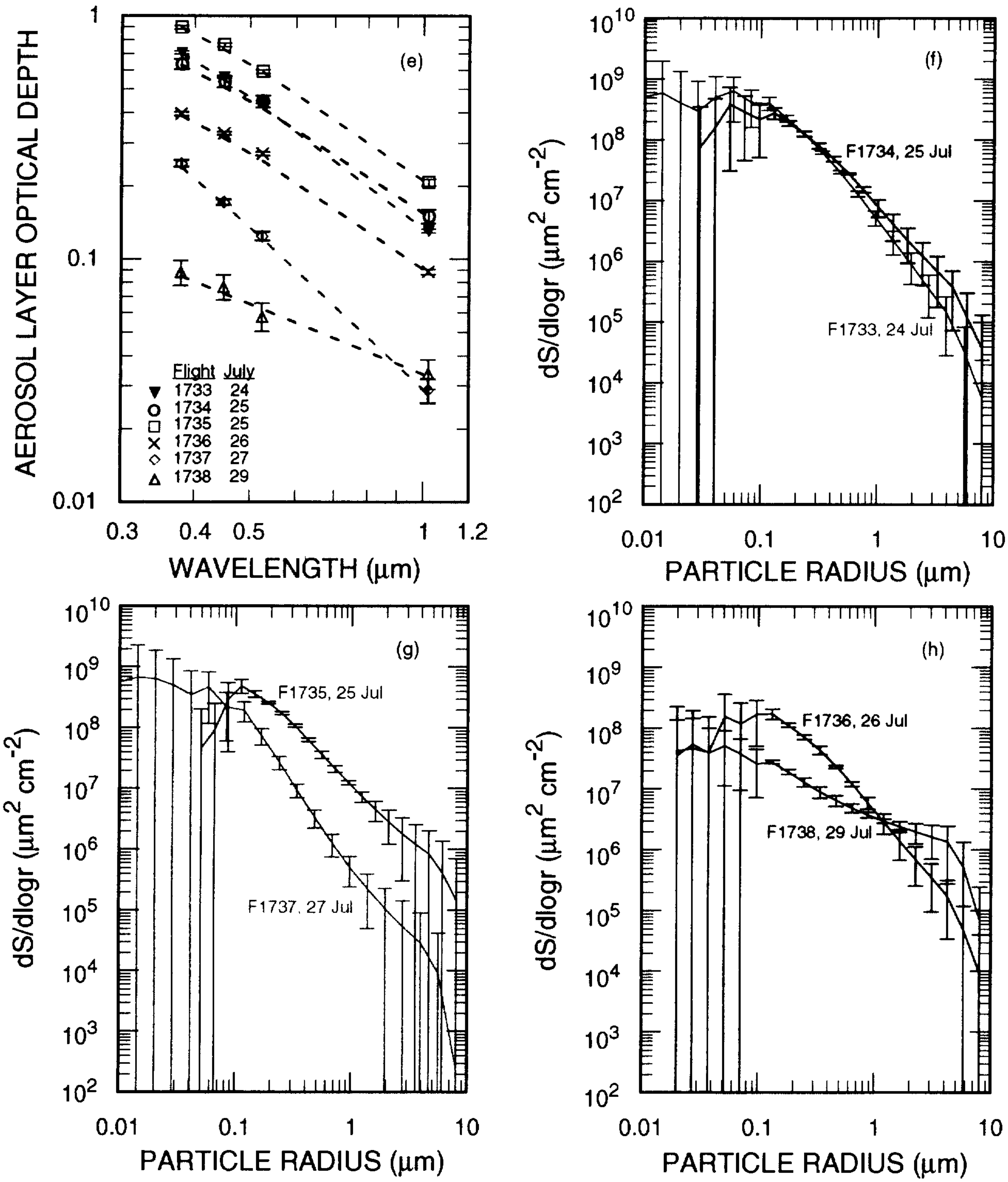

Figure 3 (e) Aerosol layer optical depth spectra obtained by differencing profile bottom and top values in Figure 2. (f-h) Aerosol layer size distributions retrieved from the optical depth spectra in Figure 3e. Dashed lines in Figure 3e are computed from the size distributions in Figures 3f-3h.

4 SUPPORTED JOURNAL AND CONFERENCE PUBLICATIONS

Hegg, Dean A., John Livingston, Peter V. Hobbs, T. Novakov, and Philip Russell, "Chemical apportionment of aerosol column optical depth off the mid-Atlantic coast of the United States," *J. Geophys. Res.*, **102**, 25,293–25,303, 1997.

Livingston, J. M., and P. B. Russell, Aerosol optical depth spectra, vertical profiles, and horizontal transects derived from TARFOX airborne sunphotometer measurements, Poster A51B-08, 1997 Spring Meeting of the American Geophysical Union, Baltimore, MD, May 27–30, 1997, *EOS Trans. Amer. Geophys. Union*, **78**, S92, 1997a.

Livingston, J. M., V. Kapustin, B. Schmid, P. B. Russell, P. A. Durkee, T. S. Bates, P. K. Quinn, and V. Freudenthaler, Shipboard sunphotometer measurements of aerosol optical depth spectra obtained during ACE-2, Paper A31D-09, 1997 Fall Meeting of the American Geophysical Union, San Francisco, CA, December 8–12, 1997, *EOS Trans. Amer. Geophys. Union*, **78**, F97–98, 1997b.

Russell, P., J. Livingston, D. Hegg, P. Hobbs, T. Novakov, and J. Wong, Direct aerosol radiative forcing off the U.S. Mid-Atlantic coast: Calculations from sunphotometer and in situ measurements in TARFOX, Paper A42D-04, 1997 Spring Meeting of the American Geophysical Union, Baltimore, MD, May 27–30, 1997, *EOS Trans. Amer. Geophys. Union*, **78**, S87–88, 1997.

Russell, P. B., J. M. Livingston, P. Hignett, S. Kinne, J. Wong, A. Chien, R. Bergstrom, P. Durkee, and P. V. Hobbs, "Aerosol-induced radiative flux changes off the United States mid-Atlantic coast: Comparison of values calculated from sunphotometer and in situ data with those measured by airborne pyronmeter," *J. Geophys. Res.*, **104**, 2289–2307, 1999.

Tanre, D., L. A. Remer, Y. J. Kaufman, S. Mattoo, P. V. Hobbs, J. M. Livingston, P. B. Russell, A. Smirnov, "Retrieval of aerosol optical thickness and size distribution over ocean from the MODIS airborne simulator during TARFOX," *J. Geophys. Res.*, **104**, 2261–2278, 1999.

Veefkind, J. Pepijn, Gerrit de Leeuw, Philip A. Durkee, Philip B. Russell, Peter V. Hobbs, and John M. Livingston, "Aerosol optical depth retrieval using ATSR-2 and AVHRR data during TARFOX," *J. Geophys. Res.*, **104**, 2253–2260, 1999.