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Clear column closure studies of urban-marine and mineral-dust aerosols using aircraft, ship, satellite and ground-based measurements in ACE-2

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Summary

As part of the second Aerosol Characterization Experiment (ACE-2), European urban-marine and African mineral-dust aerosols were measured aboard the Pelican aircraft, the Research Vessel Vodyanitskiy, from the ground and from satellites (Heintzenberg and Russell, 1999).

Among other quantities, the Pelican measured aerosol optical depth and extinction spectra, water vapor column contents and vertical profiles using a 14-channel sunphotometer (Schmid et al., 1999); aerosol absorption coefficient and 3-wavelength scattering coefficients using an absorption photometer and nephelometer (Öström and Noone, 1999); aerosol scattering humidification factors using a passive humidigraph (Gassó et al., 1999); and aerosol size distributions using a differential mobility analyzer and two optical particle sizers (Collins et al., 1999).

The R/V Vodyanitskiy measured various atmospheric parameters, including aerosol optical depth spectra and water vapor column contents using a six-channel tracking sunphotometer (Livingston et al., 1999), plus aerosol size distributions and chemical compositions using the NOAA-PMEL shipboard suite (Quinn et al., 1996 and 1999), and aerosol extinction profiles using a lidar. Ground-based measurements included aerosol optical depth spectra (Smirnov et al., 1998; Formenti et al., 1999) and aerosol extinction profiles from a lidar (Welton et al. 1999).

The AVHRR instruments aboard the NOAA-12 and NOAA-14 satellites measured upward-scattered radiances from which 2-wavelength aerosol optical depths have been derived (Durkee et al., 1999).

The purpose of this paper is to show results of a variety of comparisons between properties measured by different techniques or derived from other measurements using models. Examples include:

- Optical depth spectra
  - Measured by sunphotometer (Fig. 1, Fig. 2),
  - Derived by integrating vertical profiles of humidified scattering coefficient and absorption coefficient
  - Derived by integrating vertical profiles of size distribution using hygroscopic growth factors and model refractive index spectra (combined according to internal and external mixing models)
  - Derived from AVHRR radiances (Fig. 2)
- Extinction spectra
  - Derived by vertically differentiating sunphotometer optical depth spectra (Fig. 1),
  - Derived from in situ measurements of scattering coefficient, absorption coefficient, and humidification factor,
  - Derived from in situ measurements of size distribution, hygroscopic growth factors, and model refractive index spectra
- Particle size distributions
  - Measured in situ,
  - Derived by inverting optical depth or extinction spectra,
  - * Derived from AVHRR spectral radiance ratios using the bimodal model employed in retrieving optical depths
- Single-scatter albedo spectra
  - Calculated from measured size distributions and model refractive index spectra, using various internal and external mixing models
  - Derived from measured aerosol absorption and scattering coefficients
  - * Used in retrieving optical depths from AVHRR spectral radiances
- *Scattering phase functions
  - Calculated from measured size distributions and model refractive index spectra, using various internal and external mixing models, including possible shape effects
  - Calculated as above, but using size distributions retrieved from optical depth or extinction spectra
  - Used in retrieving optical depths from AVHRR spectral radiances
- Water vapor column contents
  - Derived from sunphotometer transmission spectra
  - * Derived from satellite-measured radiances
  - Derived by integrating in situ water vapor profiles

Items denoted by * are comparisons where results are not available yet. Initial comparisons have shown that achieving closure, or mutual consistency, depends critically on the methods used to account for aerosol hygroscopic growth, scattering humidification factors, and the particle-size cutoffs of different sampling instruments.

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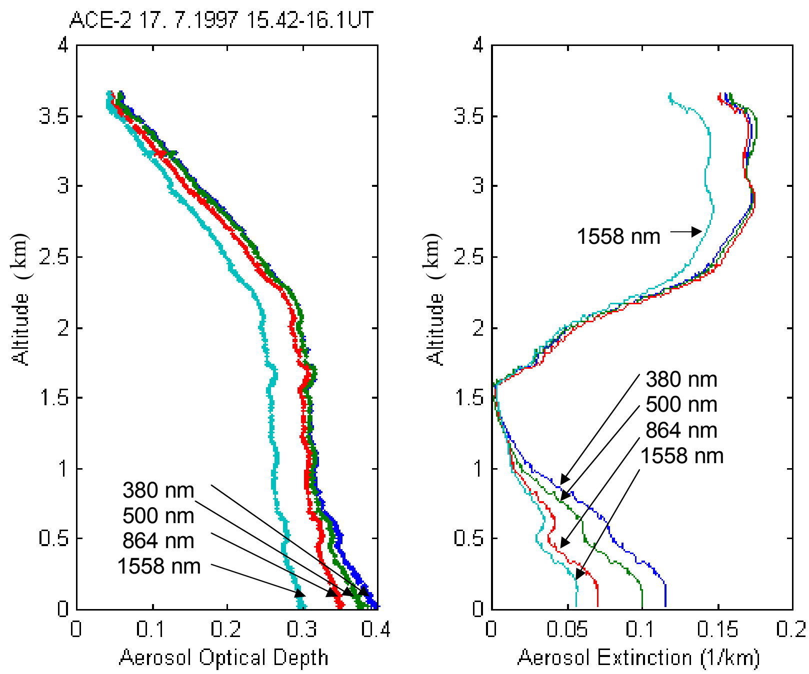

Fig. 1: Left panel: Profiles of aerosol optical depth at four selected AATS-14 wavelengths measured in ACE-2 south of the coast of Tenerife. Right panel: Aerosol extinction profiles derived by differentiating the profiles in the left panel. The marine boundary layer and an elevated Sahara dust layer can be characterized.

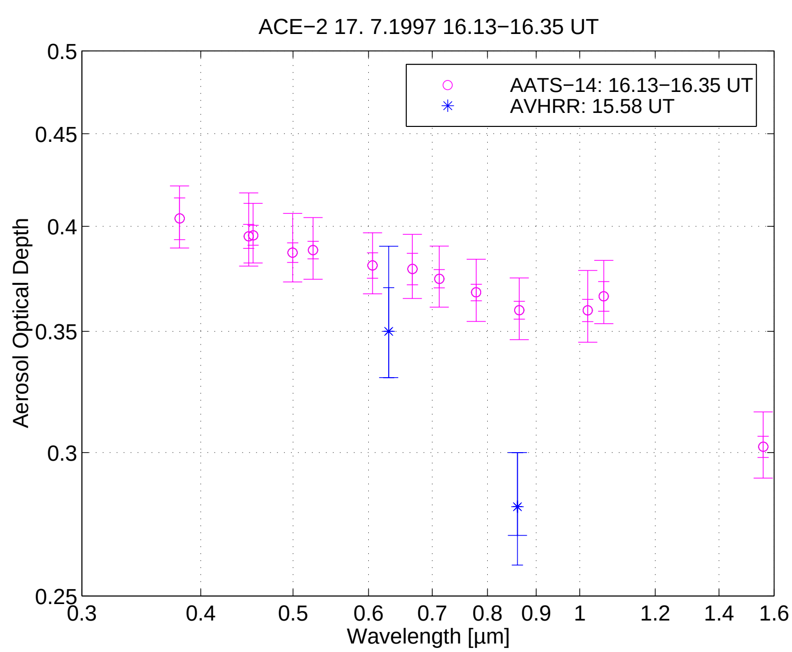

Fig. 2: Comparison of aerosol optical depth as retrieved from AVHRR radiances (Durkee et al., 1999) and measured by AATS-14. The elevated dust layer shown in Fig. 1 is responsible for the disagreement, especially in the AVHRR 860 nm channel. In the absence of such dust layers, AVHRR and AATS-14 values typically agree within error bars (Durkee et al., 1999; Livingston et al., 1999).