P2.7 CLEAR SKY COLUMN CLOSURE STUDIES OF URBAN-MARINE AND MINERAL-DUST AEROSOLS USING AIRCRAFT, SHIP, SATELLITE AND GROUND-BASED MEASUREMENTS IN ACE-2

Beat Schmid*
Bay Area Environmental Research Institute, San Francisco, CA
Philip B. Russell
NASA Ames Research Center, Moffett Field, CA
John M. Livingston
SRI International, Menlo Park, CA
Santiago Gassó and Dean A. Hegg
University of Washington, Seattle, WA
Donald R. Collins, Richard C. Flagan, and John H. Seinfeld
California Institute of Technology, Pasadena, CA
Elisabeth Öström and Kevin J. Noone
Stockholm University, Stockholm, Sweden
Philip A. Durkee and Haflidi H. Jonsson
Naval Postgraduate School, Monterey, CA
Ellsworth J. Welton, Kenneth J. Voss, and Howard R. Gordon
University of Miami, Miami, FL
Paola Formenti and Meinrat O. Andreae
Max Planck Institute for Chemistry, Mainz, Germany
Vladimir N. Kapustin
University of Hawaii, Honolulu, HI
Timothy S. Bates and Patricia K. Quinn
NOAA PMEL, Seattle, WA

1. INTRODUCTION

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).

2. MEASUREMENTS

Among other quantities, the Pelican measured aerosol optical depth and extinction spectra, water vapor column contents and vertical profiles using AATS-14 (an airborne 14-channel sunphotometer, Schmid et al., 1999); aerosol absorption coefficients 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 (Livingston et al., 1999).

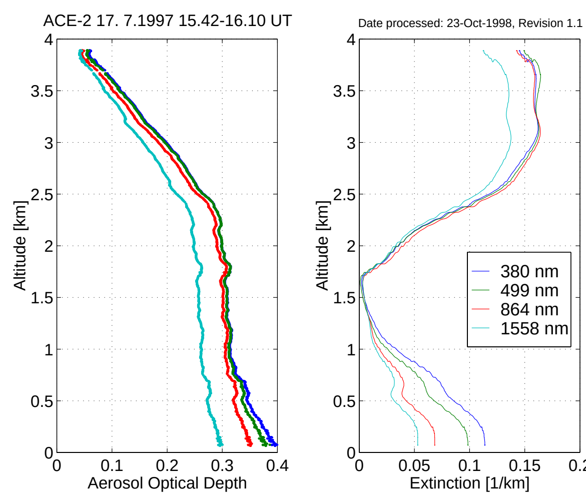

Fig. 1: Aerosol optical depth and extinction profile retrieved from AATS-14 measurements during Pelican flight tf20 on July 17, 1997. Only 4 of 13 aerosol channels are shown. In the right panel a marine boundary (MBL) and an elevated Sahara dust layer with distinctly different extinction spectra can be identified.

* *Corresponding author address*: Beat Schmid, NASA Ames Research Center, MS 245-5, Moffett Field, CA 94035-1000; e-mail: bschmid@mail.arc.nasa.gov

Ground-based measurements included aerosol optical depth spectra from sun/sky radiometers (Smirnov et al., 1998; Formenti et al., 1999) and aerosol extinction profiles from 2 lidars (Welton et al. 1999, Powell 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).

3. METHODOLOGY

A variety of comparisons between properties measured by different techniques or derived from other measurements using models (i.e. closure analysis) have been carried out (items denoted by * are comparisons where results are not available yet):

- Optical depth spectra
  - Measured by sunphotometers,
  - Derived by integrating vertical profiles of humidified scattering coefficients and absorption coefficients
  - Derived by integrating vertical profiles of size distributions using hygroscopic growth factors and model refractive index spectra (combined according to internal and external mixing models)
  - Derived from AVHRR radiances
  - Derived from ground based lidar
- Extinction spectra
  - Derived from ground based lidar,
  - Derived by vertically differentiating sunphotometer optical depth spectra (Fig. 1),
  - Derived from in situ measurements of scattering coefficients, absorption coefficients, and humidification factors,
  - Derived from in situ measurements of size distributions, hygroscopic growth factors, and model refractive index spectra
- Particle size distributions
  - Measured in situ,
  - Derived by inverting optical depth or extinction spectra,
  - Derived by inverting sky radiances*
  - 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
  - Derived from sky radiances*
  - 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

RESULTS

4.1. Comparisons

- Water vapor profiles from sunphotometer measurements agree well with direct in-situ measurements
- Comparisons between aerosol optical depth (AOD) measured with sunphotometers (on the ship and on Pelican) and retrieved from AVHRR radiances show better agreement when African dust is absent than when dust is present. For example, four comparisons made with no dust present yielded a mean difference (AVHRR minus sunphotometer) for AVHRR Channel 1 (wavelength 640 nm) of 0.015, with standard deviation 0.030. For AVHRR Channel 2 (wavelength 840 nm) the mean difference was 0.025, with standard deviation 0.020. In contrast, for the single comparison to date with dust present, the differences were –0.03 and –0.08 in Channels 1 and 2, respectively (Fig. 2). We attribute this to the lack of an appropriate phase function for dust aerosols in the retrieval algorithm.
- Comparisons of AOD profiles from AATS-14 and a ground-based lidar lead to agreement well within 0.02 at all altitudes (Fig. 3). A ground-based sunphotometer AOD spectrum on Teide (3570m) and a simultaneous AATS-14 airborne AOD spectrum at the same altitude near Teide agree within 0.005.

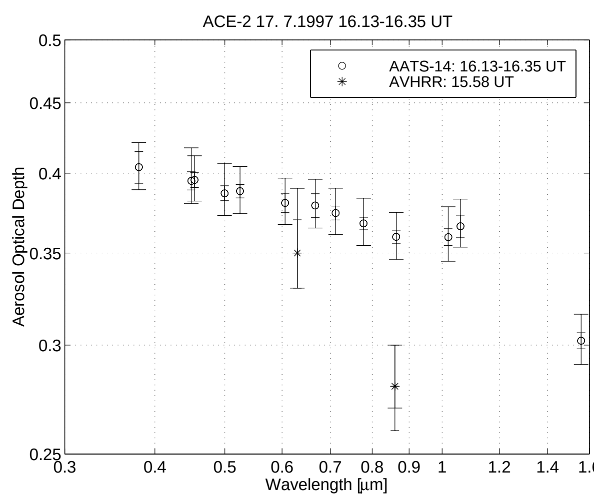

Fig. 2: Comparison of aerosol optical depth as retrieved from AVHRR radiances (Durkee et al., 1999) and measured by AATS-14. The elevated dust layer shown in Fig. 1 is responsible for the disagreement, especially in the AVHRR 860 nm channel. In the absence of such dust layers, AVHRR and AATS-14 values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

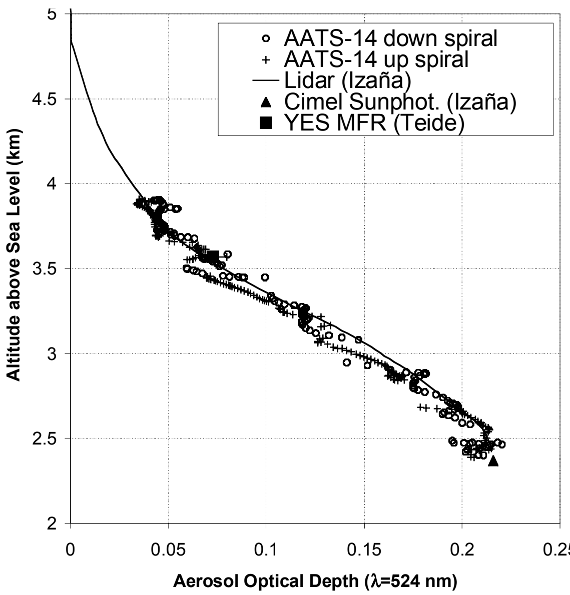

Fig. 3: AOD profile from lidar (λ=524 nm) and AATS-14 AOD profile (λ=524.8 nm) above Izaña. Also shown Cimel AOD at the location of the lidar and the MFR sunphotometer AOD at nearby Teide at 3570 m a.s.l. (for both instruments the AODs are interpolated to λ=524 nm).

4.2. Closure analysis

- Aerosol extinction (or layer AOD) closure in the MBL has not been achieved based on nephelometer[1], optical particle counters, and AATS-14 measurements (Fig. 4). Compared to AATS-14 (at the green wavelength), nephelometer[1] values are lower by 25% (±10%), optical particle counter results are lower by 7%-30%. Similar results have been found during TARFOX (e.g. Hegg et al., 1997)
- Aerosol extinction (or layer AOD) closure in Sahara dust layers has been achieved based on nephelometer[1], optical particle counters, and airborne sunphotometer measurements (Fig. 5). Problems arise at λ>1 µm. What is the spectral dependence of the dust refractive index?
- Aerosol size-distribution closure based on in-situ size distributions and inverted AATS-14 extinction spectra was not achieved in either the MBL (Fig. 6) or the dust (Fig. 7). In the dust layer, the differences between size distributions are rather large. We attribute this to the fact that a wavelength-independent refractive index has been used in the inversion of the AATS-14 spectra. What is the spectral dependence of the dust refractive index?

[1] taking into account cut-off effects and measured absorption and hygroscopic growth

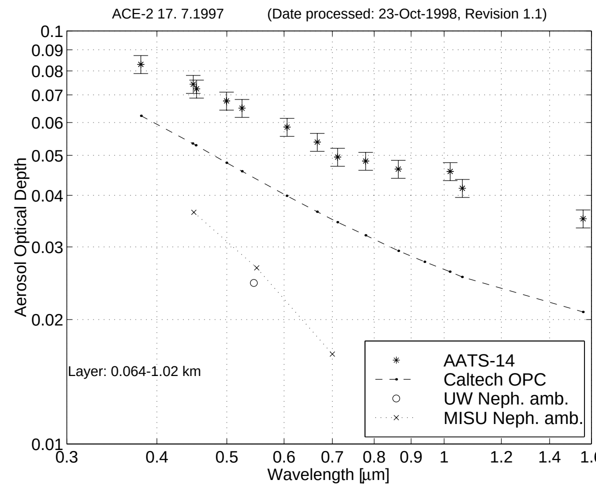

Fig. 4: Spectral aerosol optical depth for the MBL (64-1020m) during Pelican flight tf20 on July 17, 1997. UW-PH and MISU nephelometer results do not include absorption and inlet cut-off correction

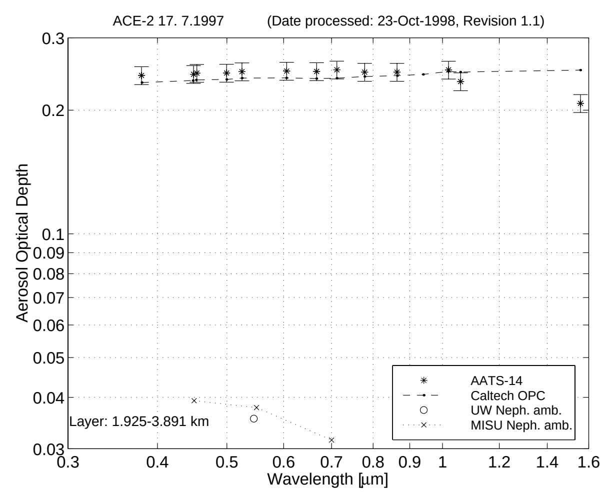

Fig. 5: Spectral aerosol optical depth for part of the dust layer (1925–3891 m) during Pelican flight tf20 on July 17, 1997. UW-PH and MISU nephelometer results do not include absorption and inlet cut-off correction

5. CONCLUSION

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. Important yet unresolved issues are also the spectral dependence of the complex refractive index, and the scattering phase function of dust aerosols.

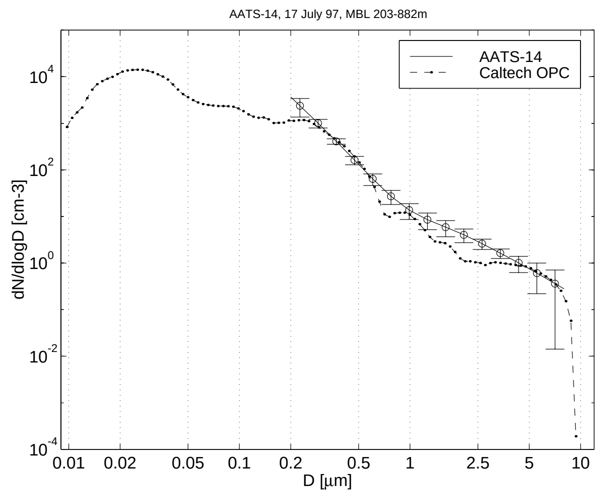

Fig. 6: Comparison of MBL size distributions from in-situ measurements and from inverted AATS-14 spectral extinction measurements during Pelican flight tf20 on July 17, 1997.

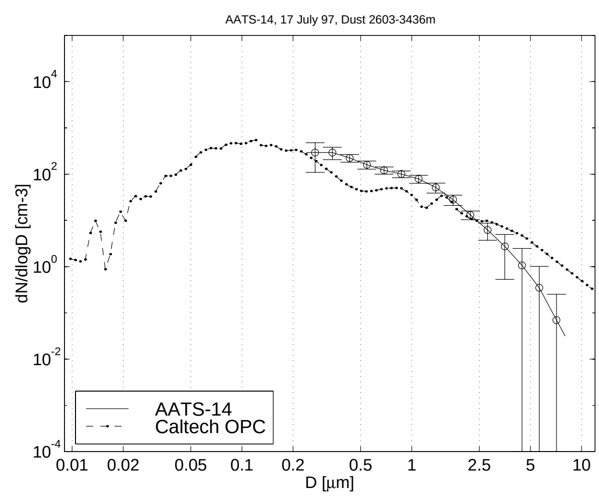

Fig. 7: Comparison of dust size distributions from in-situ measurements and from inverted AATS-14 spectral extinction measurements during Pelican flight tf20 on July 17, 1997.

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