Source Strength and Scattering Properties of Organic Marine Aerosols

Lynn M. Russell
Department of Chemical Engineering
Princeton University
Princeton, NJ 08544
phone: (609) 258-1144 fax: (609) 258-0211 email: lrussell@princeton.edu
Award #: N00014-97-1-0673
http://www.princeton.edu/~aerosol

LONG-TERM GOAL

My long term goal is to quantify the role played by sea salt in radiative scattering in the marine environment. This project studies the number of aerosol particles produced from sea salt under different marine conditions. Studying the chemical composition of those particles provides important information about their behavior in the atmosphere.

OBJECTIVES

I would like to see whether the number of sea salt particles observed in field projects can be predicted by current parameterizations of particle flux based on wind speed. I will test whether other parameters are also important determinants of sea salt particle concentrations.

I also want to establish what the compositions of sea salt particles are. To this end, I will need to design and build an accurate instrument for measuring sea salt aerosol.

APPROACH

We have completed analyses of the chemical composition of aerosol samples collected as part of the Aerosol Characterization Experiment (ACE) 2 in Tenerife in 1997.

We have also studied the role of sea salt particles in layers other than the boundary layer by quantifying the rate of entrainment of particles to and from the marine boundary layer.

We have designed and built a new salt particle counter to make direct measurements of sea salt more accurately.

WORK COMPLETED

Collection of filter samples aboard Pelican flights during the Aerosol Characterization Experiment (ACE2) was completed. All organic and elemental carbon analyses have been completed. All ionic analyses are completed. Extraction of samples for trace metal analysis was performed. Our samples provide important data on the composition of the aerosol measured for the limited samples that were allowed by the aircraft constraints.

The ACE2 project has provided a wealth of data on the distribution of and scattering by aerosol particles over the North Atlantic.

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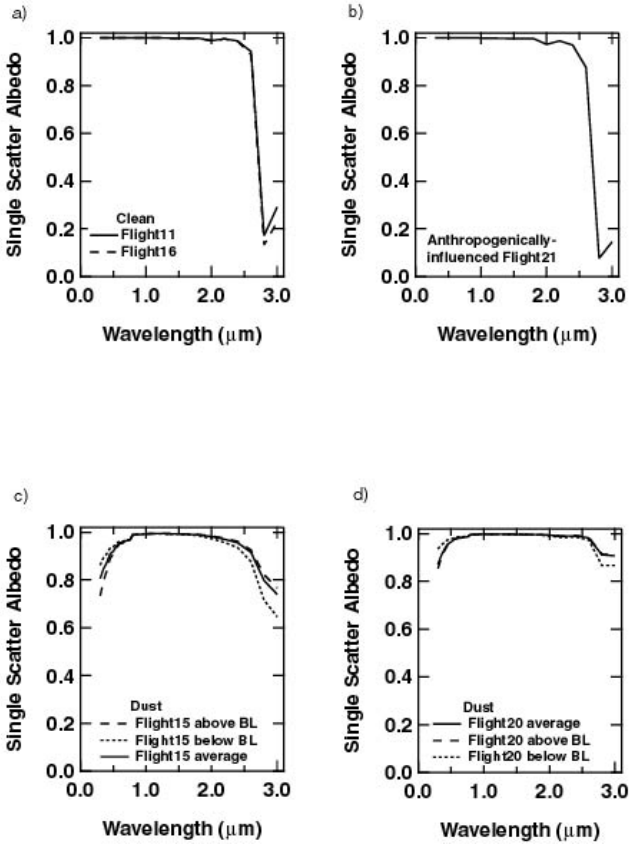
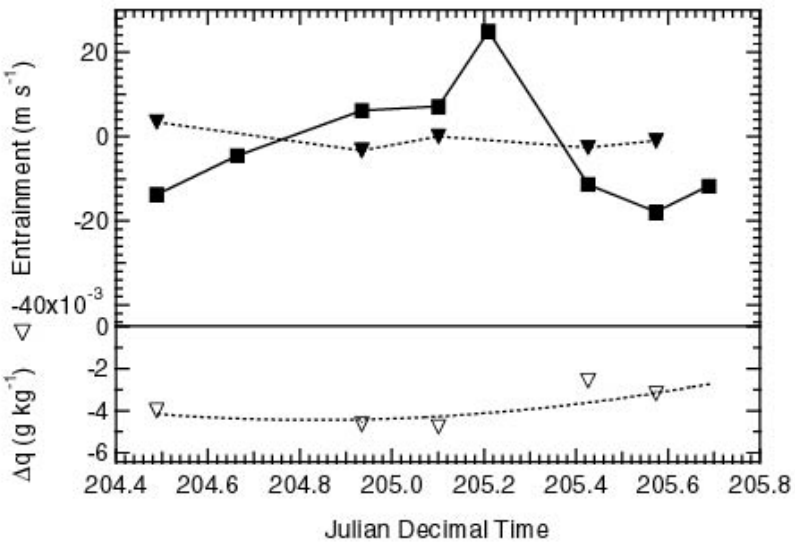
The prototype salt particle counter has been constructed and is being calibrated. A provisional patent application for its design was filed.

RESULTS

During the Aerosol Characterization Experiment (ACE-2) filter samples were collected aboard the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) Pelican aircraft near Tenerife in June and July of 1997 (Schmeling et al., 2000). The flights included constant altitude measurements in the boundary layer as well as profiles up to 3800 m providing detailed chemical information about the composition of the aerosol distribution in the lower troposphere. Three cases with different air mass origin -- clean marine air, anthropogenically-influenced air from the European continent, and dust-laden air from the Sahara -- were identified. The samples were analyzed by ion chromatography (IC) for ionic species, combined thermal and optical analysis (TOA) for organic carbon, and by total reflection X-ray fluorescence (TXRF) for elemental composition. Particle composition and size distributions for the range of air masses encountered illustrate links in the chemical and microphysical characteristics of aerosol from different sources. Clean marine air masses were characterized by low particle number and mass concentrations with no detectable metals, while anthropogenically-influenced and dust-laden air had high number, mass, and trace metal concentrations. Anthropogenic sources were characterized by high concentrations of submicron particles and some Fe and Cu, whereas dust particle loadings included a significant mass of micron-sized particles and significant loadings of Fe, in addition to small amounts of Mn, Cu, and Ni. These results showed similar tracers for air mass origin as those found in other measurements of oceanic and continental air masses. Aerosol optical properties were estimated with a simplified model of the aerosol based on the measured compositions. The real and imaginary refractive indices and single scattering albedos differed significantly among the three types of aerosol measured, with clean marine aerosol properties showing the least absorption and dust-containing aerosols showing the most. There were only small differences in optical properties for the two different cases of clean marine aerosol, but some significant differences between the two dust cases. Since measurement uncertainties affect these calculations, we studied the type of mixing and the fraction of absorbing species and found the calculation was sensitive to these variations only for the dust-containing aerosol case, probably due to the small amount of water present. While the optical properties varied little with composition for clean marine and anthropogenically-influenced cases, they showed a strong dependence on variations in particle composition and mixing state for the dust-containing cases. The calculated single scatter albedos for the different cases are shown below.



Exchange rates of aerosol particles and vapor species between layers in the atmosphere allow us to estimate the lifetime of particles in the lower troposphere (Sollazzo et al., 2000). This work analyzes data obtained during the ACE-2 campaign to calculate exchange using two independent methods, divergence and flux. The net entrainment rates obtained from the divergence method are based on spatially-integrated horizontal winds as well as on the average boundary layer height change. The flux method is based on an eddy correlation approach, but relies in this case on a point measurement of concentration change across an atmospheric interface. The thermodynamic structure in these three experiments included well-mixed layers in addition to overlying, more-stratified buffer layers, between which we have studied the net entrainment of air between adjacent layers. The range of entrainment rate magnitudes reported from both methods was from 0.000 m s^{-1} to 0.050 m s^{-1} (with the exception of a few outlying values). Since both methods have significant uncertainties, we believe the best estimates are the average net entrainment rates for both methods, which were 0.007, 0.007, and 0.006 m s^{-1} at the subsidence inversion, for Lagrangians 1, 2, and 3, respectively. The uncertainties were high for both methods, involving a factor of two uncertainty for entrainment rates below 0.020 m s^{-1}. This high uncertainty suggests that continued use of multiple independent methods for measuring entrainment, preferably with the aid of improved instrumentation for fast measurement of conserved tracers and well-designed sampling strategies, is essential for improving models of the sources and sinks for chemical evolution. In some cases, net entrainment rates calculated from the two methods were comparable, but in others the spatial inhomogeneity and sampling limitations led to significant discrepancies in the predicted rates. An example comparing the predicted rates from the covariance (triangle) and divergence (square) methods during Lagrangian 3 is shown below.



IMPACT/APPLICATION

The primary application of our instrument development work is that we will now be able to measure simultaneous mass and sodium distributions. This technique provides us with an unambiguous way to measure the ambient concentrations of sea salt particles. With vertically-resolved measurements of this type, we can obtain the flux of particles.

TRANSITIONS

Our filter data have been made available to other ACE2 investigators for use in their analyses. Our estimates of the entrainment rates during ACE2 have also been made available to several ACE 2 investigators.

RELATED PROJECTS

1 – The particle compositions determined from our ACE2 data were compared with size-resolved compositions used to assess the inversion methods of optical particle data by Don Collins, Richard Flagan and John Seinfeld (California Institute of Technology).

2 – Our entrainment rates were incorporated in studies of the Lagrangian experiments carried out during ACE 2. This work has contributed to publications in press by D.W. Johnson, R. Wood, and S. Osborne (U.K. Meteorological Research Office).

3 – Our entrainment rates have been used by F. Raes and R. Van Dingenen (E.C. Joint Research Center) to assess the role of entrainment in N. Atlantic aerosol evolution models.

PUBLICATIONS

Russell, L.M., and J.H. Seinfeld: Size- and Composition-Resolved Externally Mixed Aerosol Model, Aerosol Science and Technology, 28, 403-416.

Sollazzo, M.J., L.M. Russell, D. Percival, S. Osborne, R. Wood, and D.W. Johnson: Entrainment Rates during ACE 2 Lagrangian Experiments Calculated from Aircraft Measurements, Tellus, in press (2000).

Schmeling, M., L.M. Russell, C. Erlick, D.R. Collins, H. Jonsson, Q. Wang, P. Kregsamer, and C. Streli: Aerosol Particle Chemical Characteristics Measured from Aircraft in the Lower Troposphere during ACE 2, Tellus, in press (2000).

PATENTS

Russell, L.M.: Submicron Salt Particle Counter, patent application filed August 13, 1999.