Aerosol Radiative Closure in ACE-2
Based on Transmissometer Measurements

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LONG TERM GOALS

To characterize the radiative properties of aerosols over the oceans so as to understand the factors that affect radiation transmission (UV, visible and IR) in the marine boundary layer (MBL) close to the ocean surface.

OBJECTIVES

To interpret the temporal and spatial variability of aerosol and radiative properties in terms of aerosol sources (both oceanic and continental, natural and anthropogenic); to relate the variability of the aerosol and the consequent radiative behavior of the atmosphere in terms of meteorological conditions and atmospheric transport processes.

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APPROACH

We perform studies that combine measurements of aerosol properties and atmospheric transmission with the development and testing of aerosol radiative models. The program focuses on field studies in which we concurrently measure the spectrally-resolved transmission properties of the atmosphere while making intensive measurements of the aerosol physical, chemical and radiative properties. The aerosol properties are then used in the radiative model to ascertain if the model can duplicate the atmospheric transmission measurements. The degree of agreement between the transmission measurements and the model results is a measure of the adequacy of the characterization of the aerosol properties and the radiative model. This measurement strategy (commonly referred to as “closure” studies) is the ultimate test of the completeness of our knowledge of atmospheric radiative properties.

WORK COMPLETED

The initial effort in our program was on the ACE-2 experiment which was carried out in June-July 1997 in the Canary Islands. The primary objectives of ACE-2 focused on the radiative properties of aerosols in the ocean region between Europe (principally the Iberian peninsula) and the Canary Islands. The emphasis was primarily on pollution aerosol effects (both direct and indirect); there was also a focus on mineral dust transport from Africa and, of course, sea-salt aerosols. Our activities took place at two sites on Tenerife: at the Izaña Observatory (operated by the Spanish Meteorological Service) at an altitude of 2367m; at a 40 m high lighthouse at Punta del Hidalgo on the north coast of Tenerife. There is a strong subsidence inversion layer in this region with the top located at about 1200 m a.s.l. in summer and about 1800 m a.s.l. in winter. Izaña normally lies above the inversion although the inversion level sometimes reaches the station under certain synoptic conditions. Thus, we were able to concurrently measure (and compare) the aerosol and radiative properties in the free troposphere and the MBL. A similar set of aerosol measurements was made at these sites. The UM group was largely responsible for aerosol measurements at Izaña while at Hidalgo measurements were made by the group under F. Raes (Joint Research Centre, Ispra). Hal Maring was responsible for making the aerosol physical property measurements, including the size distribution, aerosol light scatter and absorption. Dennis Savoie is responsible for the aerosol chemical measurements including composition as a function of size. Data will be exchanged between the two groups. Previous research in this region by the UM and JRC groups has show a very dynamic aerosol behavior [Raes *et al.*, 1997] with sharp contrasts between the MBL and the free troposphere.

The UM group deployed transmissometers at the two sites and data was obtained for the entire duration of the ACE-2 program, from 16 June to 26 July, 1997. We used two Optec LPV transmissometers which operate at 550nm; this is the standard transmissometer used by the National Park Service in their visibility program. Our study was carried out as a cooperative effort with Bill Malm (manager of the NPS visibility program) who provided the instruments on loan and John Molenar, vice-president, Air Resources Specialists (ARS) the company that maintains and operates the NPS systems and processes all the data. In addition, we deployed a free-air nephelometer (also on loan from the NPS) at the sea-level site. The free-air nephelometer avoids the problem of the relative humidity changes in the nephelometers and of large particle losses. The instruments were completely checked and calibrated by ARS at their facility at Fort Collins, CO, prior to deployment. Two ARS traveled to Tenerife to install the systems, carry out the preliminary calibrations and instruct the UM technicians who would operate the systems. The instruments deployed without difficulty and they operated successfully throughout the entire program. We had essentially 100% data recovery. We collected nearly 32 MB of raw data at one minute resolution. We used the same QA/QC procedures as that used in the NPS program. Thus all data will be comparable to that obtained in NPS studies.

RESULTS

All transmissometer data was processed by ARS in the same manner as the data from the NPS network. We received the processed data early this year. We started the project by comparing the transmissometer data against the aerosol measurements made at the Izaña site. During periods when aerosol concentrations were high, we found acceptable (although not good) agreement. However, under extremely clear (aerosol-free conditions) when our integrating nephelometers were yielding scattering coefficients close to Raleigh, the transmissometer was yielding extinction values that were much larger. After consultation with ARS, they agreed to take another look at the data. They found an error in the calibration constants. They subsequently reset the calibration of the instrument using our value for the scattering coefficient during extremely clear periods. We received the data a few months ago. The aerosol extinction data generated by the transmissometers has been compared to scattering data collected with nephelometers and to aerosol absorption data obtained using a Particle/Soot Absorption Photometer. The results have been quite satisfactory. These have been conveyed to Bill Malm who was quite satisfied with the result.

We are now in the process of selecting interesting time periods (i.e., high aerosol concentrations, low concentrations, large variability in concentrations, strong contrasts between the free troposphere site and the MBL site). The aerosol data will be used in the aerosol radiative model NEPH-3 by Chris Pilinis. The model incorporates gaseous, liquid and solid phases; it uses the chemical composition data to calculate the thermodynamically favored species in the aerosol In this way, the model can effectively deal with the role of relative humidity in aerosol composition and growth. Once the composition of each aerosol size bin is calculated, the scattering and backscattering and extinction coefficients can be calculated from the equations. The results obtained with the model will then be compared with the transmissometer measurements made at the time; the degree of "closure" provides a figure of merit for the model and the aerosol measurement protocol.

IMPACT/APPLICATIONS

At present we have no final quantitative results to report with respect to the work sponsored by this program (i.e., the transmissometer study) other than the validated data itself. Nonetheless, it is clear that there are very strong changes in aerosol properties and optical transmission in the eastern North Atlantic. There were several impressive pollution episodes that could be traced from European sources to the Canary Islands even after a 2-3 day transit time from the sources. Despite that fact that the dust season was late in starting, we did record a number of impressive dust events, especially at very end of the program. These produced dramatic changes in visibility at the two sites. These episodes demonstrate the impact of long range transport from sources on continents on the radiative properties of the MBL. Previous work carried out with the involvement of the UM group has shown the dramatic impact that such transport can have on the composition of the MBL even at great distance from the sources [Arimoto *et al.*, 1996; Li *et al.*, 1996; Rhoads *et al.*, 1997]. In particular, the effects of mineral dust and biomass burning are the most evident aerosol features over the oceans [Husar *et al.*, 1997; Herman *et* *al.*, 1997]. This work will increase our understanding of the radiative properties of the atmsophere over the ocean, especially in those regions of the world where there are frequently very high concentrations of mineral dust (the tropical Atlantic, the Indian Ocean and Arabian Sea, the western North Pacific).

TRANSITIONS

We expect that we will be able to provide information that will enable some degree of predictability for radiation propagation in the eastern North Atlantic for Naval operations based on meteorological analyses. It should be possible to extrapolate this information to other similar ocean regions, especially where mineral dust is a major aerosol component.

RELATED PROJECTS

There is a large degree of integration between this ONR activity and the NSF-funded AEROCE program in this region. We also are carrying out some NASA-funded research using the TOMS aerosol product [Herman *et al.*, 1997]; this will enable us to integrate the site-specific measurements made in the ONR (and AEROCE) work into the large-scale picture for the eastern North Atlantic. During the ACE-2 program, there were a number of periods when the Pelican aircraft few in the vicinity of our sampling sites; we intend to compare our data with theirs for these periods. We are working with Doug Westphal (NRL, Montery) to interpret the meteorological conditions associated with large dust events in the eastern Atlantic in conjunction with our ACE-2 measurements.

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