28 September 2001

NASA NRA-97-MTPE-16

Integration of Long-Term Oceanic Aerosol Records from Univ. of Miami Network Stations with NASA Satellite Products.

J. M. Prospero (PI), D. L. Savoie and H. Maring (Co-PIs)

Year Three Progress Report and Final Report

Introduction:

The original work statement for this program identified a number of tasks, among them:

- Provide a detailed survey of the types of aerosol data in the UM archive for each station and the time periods for which data are available.
- In response to specific queries from scientists involved in this NASA activity, to examine the aerosol data in detail to ascertain if they would be suitable for use in a satellite validation, algorithm development, and related activities.
- Interact with the users of the data in the interpretation of the data in terms of our understanding of the temporal and spatial distribution of aerosols and the associated meteorological/climatological controlling situations.
- Participate in writing summary reports or scientific papers that might derive from the above activities.
- Participate in the planning of future aerosol/radiation/remote sensing activities.

Accomplishments during Year Three:

1) Prospero, along with Ginoux and Torres from the NASA Goddard/TOMS group and others, used the Total Ozone Mapping Spectrometer (TOMS) sensor on the NIMBUS-7 satellite to map the global distribution of major atmospheric dust sources with the goal of identifying common environmental characteristics. The process is based on the fact that the geographic distribution of the TOMS absorbing aerosol index when averaged over periods of a month often shows characteristic geometric patterns which can be related to topography. Once these sources are identified, we characterized the environmental settings of the source region, i.e., topography, geomorphology, climatology, soil properties, geological history.

TOMS shows that the largest and most persistent sources are located in the Northern Hemisphere, mainly in a broad "dust belt" that extends from the west coast of North Africa, over the Middle East, Central and South Asia, to China. There is remarkably little large-scale dust activity outside this region. In particular the Southern Hemisphere is devoid of major dust activity. Dust sources, regardless of size or strength, can usually be associated with topographical lows located in arid regions with annual rainfall under 200-250 mm. Although the source regions themselves are arid or hyper-arid, the action of water is evident from the presence of ephemeral streams, rivers, lakes, and playas. Most major sources have been intermittently flooded through the Quaternary as evidenced by deep alluvial deposits. Many sources are associated with areas where human impacts are well documented – e.g., the Caspian and Aral Seas, Tigris-Euphrates River Basin, southwestern North America, the loess-lands in China. Nonetheless, the largest and most active sources are located in truly remote areas where there is little or no human activity. Thus on a global scale dust mobilization appears to be dominated by natural sources.

Dust activity is extremely sensitive to many environmental parameters. The identification of major sources will enable us to focus on critical regions and to characterize emission rates in response to environmental conditions. With such knowledge we will be better able to improve global dust models and to assess the effects of climate change on emissions in the future. It will also facilitate the interpretation of the paleoclimate record based on dust contained in ocean sediments and ice cores.

The results of this study have been accepted for publication [Prospero et al., 2002]. Ginoux has adapted his GOCART model (see below) to use the TOMS sources and has obtained much improved results [Ginoux et al., 2001]. Most dust generation models are now being adapted to make use of the findings from our study.

2) We have worked with various modeling groups to develop better global-scale dust generation/transport models, most closely with Paul Ginoux (Georgia Tech & NASA Goddard) who has adapted the Georgia Tech/Goddard Ozone Chemistry Aerosol Radiative Transport (GOCART) model to include mineral dust. GOCART is driven by off-line meteorological data from the GEOS DAS, with a horizontal resolution of 2 latitude by 2.5 longitude and 20-40 vertical layers (vertical resolution depends on GEOS DAS version). The GEOS DAS fields are model-assimilated global analyses constrained by meteorological observations, with extensive diagnostics archived for chemistry transport model applications. We provided to Ginoux the UM ocean network data for dust (also sulfate and sea salt) which were used to test the model. The results were published in a joint paper [Ginoux et al., 2001]. The model yielded excellent results for mineral dust compared to our long-term measurements. Indeed, the GOCART model yields the best overall results for global scale dust generation and transport.

3) We are cooperating with Paul Ginoux and Omar Torres to elucidate the fundamental meteorological data sets necessary for the accurate and consistent modeling of global-scale dust transport. The identification of the major dust sources by Prospero et al. [2002] was the first step. The next step is to use the TOMS AI to analyze the variability of the source strength. Our first objective was to see if a limited number of meteorological surface fields could be used in the modeling effort. Our second objective was to address these problems and provide a framework where the variability of the surface meteorological fields can be used as a proxy to study the variability of the source strength. Our final objective was to analyze the seasonal and interannual variability of the major dust sources. This study is producing interesting results and a paper is in the final stages of preparation. [Ginoux et al., 2002]

4) The UM group continued and completed their participation in the recent IPCC assessment. The UM group had provided data from its ocean network archive for the following species: sulfate (and non-sea-salt sulfate), nitrate, sea salt, methanesulfonate, ammonium, and mineral dust. Dennis Savoie had carried out the statistical characterization of the data sets from 25 stations and conveyed the data to Joyce Penner

who lead the effort. Joseph Prospero served as Review Editor for Chapter 5 of the IPCC report. As previously stated, the UM aerosol archive data were, in effect, the only ocean aerosol data used for model testing. The comparison of the model results dust revealed (among other things) that the models produced extremely poor results for dust and sea salt. It is clear that the future projections of the impact of aerosols of climate forcing will be rather shaky.

General Accomplishments During the Three Years of the Program

As noted above, one of our tasks in GACP was to organize our aerosol data sets and provide them to other groups. Over the three years of the program we have supplied data to a large number of modelers in the community. Following is a partial list of persons/groups who have requested and been directly supplied with the data sets and/or portions of the filter samples in the UM archive. We note that this list is not exhaustive as others have obtained the data sets through third parties and others have not been documented.

- IPCC (Intergovernmental Panel on Climate Change) via Professor Joyce Penner (University of Michigan): our data was the only ocean data used for the current IPCC study of aerosol impacts on climate
- COSAM (Comparison of Sulfur Atmospheric Models) via Len Barrie (Atmospheric Environment Service, Canada), Julian Wilson (Joint Research Commision, Italy) and Francis McGovern (University College Galway, Ireland): Our data set (for a set of 20+ stations) was the prime data set used in the COSAM model comparison
- NAtChem/Particles database via Atmospheric Environment Service, Canada (Len Barrie, Robert Vet, and Peter Liu)
- Betsy Andrews and John Ogren (CMDL, NOAA): INDOEX data - to estimate refractive index based on individual components of the aerosol to constrain my calculations
- Yves Balkanski (CEA-LMCE, 91191 Gif-sur Yvette Cedex, France): AEROCE (Barbados and Izaña) dust data for model comparison, supplied for European Aerosols Assembly
- Carmen M. Benkovitz (Brookhaven National Laboratory, Upton, NY): AEROCE and SEAREX aerosol data for comparison with models
- Kendall L. Carder and Christopher Cattrall (University of South Florida, St. Petersburg, FL): AEROCE (Barbados and Miami) dust data and portions of archived filter samples for comparison with their samples from Fort Jefferson, Florida.
- Mian Chin (NASA Goddard Space Flight Center, Greenbelt, MD): AEROCE, SEAREX, and INDOEX data for comparison with results from global sulfur model.
- Peter Colarco (University of Colorado, Boulder, CO): AEROCE, dust data for validation of dust transport/deposition model
- Frank Dentener (University of Utrecht, The Netherlands): AEROCE, Izaña dust data for model validation and as a preparation to 2 additional experiments at Izaña and at Mt. Cimone, Italy.

- Louis A. Derry (Cornell University, Ithaca, NY): AEROCE and SEAREX, portions of archived filter samples for analysis and comparison with sediment trap data.
- Richard C. Easter (Pacific Northwest National Laboratory, Richland, Washington): AEROCE and SEAREX, to evaluate sulfate concentrations simulated by their model.
- Paul Ginoux (NASA Goddard Space Flight Center, Greenbelt, MD): AEROCE, SEAREX, and INDOEX dust data for assessment of his global dust model.
- Laurent Gomes (LISA, University of Paris, France): AEROCE, portions of Barbados samples for mineralogical analysis for comparison with their results from Sal Island, Cape Verde Islands.
- Carolyn Walker and Mike Harvey (National Institute for Water and Atmospheric Research, Wellington, New Zealand): SEAREX, Karamea, NZ, aerosol data for comparison with theirs from Baring Head.
- Jost Heintzenberg (Institute for Tropospheric Research, Leipzig, Germany): pre-INDOEX 1995, 1996, and 1997 shipboard aerosol data for review of marine aerosols.
- Gideon M. Henderson (Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY): AEROCE, portions of archived Barbados filter samples for measurements of U/Th and 234U/238U ratios in Saharan dust.
- Stanley R. Herwitz (Biogeography & Earth Science, Clark University, Worcester, MA): AEROCE, Barbados and Bermuda filter portions for metal analyses for his study of paleosols.
- Ivar Isaksen and Alf Grini (Institutt for geofysikk, Universitetet i Oslo, Norway): AEROCE and SEAREX, sea-salt data for comparison with their model results.
- Anne Jefferson (NOAA CMDL, Boulder, CO): INDOEX, Kaashidoo sulfate data for comparisons with their data on aerosol hygroscopic growth
- Khal Spencer (Dept. of Geology and Geophysics, The University of Hawaii, Honolulu, HI): SEAREX, Data and sample portions from Oahu for measurements of Pb isotopes in aerosols for comparison with those in corals as an indication of sources.
- James Kettle and Meinrat Andreae (Max Planck Institute for Chemistry, Mainz, Germany): SEAREX, Shemya sulfur data for comparison to modeled fluxes of diemthylsulfide from the ocean.
- Ina Tegen and Nilgun Kubilay (NASA Goddard Institute for Space Studies, Columbia University, New York, NY): AEROCE, Saharan dust and sea-salt concentrations for comparison with global dust and sea-salt models.
- Natalie Mahowald (Bren School, Univ. of California, Santa Barbara): AEROCE, INDOEX, and SEAREX, All dust data for comparison with dust generation and transport model.
- Phil Rasch and William Collins (Climate Modeling Section, National Center for Atmospheric Research, Boulder, CO): AEROCE, INDOEX, and SEAREX complete sulfate and dust data sets for model assessment and refinement.

- Simone van Dijk (Institute of Marine and Atmospheric Resesarch, Utrecht, The Netherlands): AEROCE, INDOEX, SEAREX, All sea-salt concentrations for validation of the modeling of sea-salt aerosols on a global scale.
- Alexander Smirnov and Brent Holben (SSAI, NASA Goddard Space Flight Center, Greenbelt, MD): AEROCE, All aerosol data for comparison with AERONET derived optical depths during concurrent periods.
- Charlie Zender (Dept. of Earth System Science, University of California, Irvine CA): AEROCE and INDOEX, All dust concentrations for comparison with model results.
- Peter Adams (Dept. of Civil and Environmental Engineering, Carnegie Mellon Univ., Pittsburgh, PA): All available sea-salt data for comparison with global sea-salt model using GISS GCM.

Additional recipients of AEROCE meteorological and/or aerosol data:

- Nicolas Gruber (Climate and Environmental Physics, Physics Institute, University of Bern)
- Mario Blumthaler (Institute of Medical Physics, Innsbruck, Austria)
- Anthony S. Headley (Environmental Engineering Division of the Ministry of Health, Barbados)
- Kamazima Lwiza (State University of New York - Stony Brook)
- Olivier Marchal (Centre des Faibles Radioactivites CNRS/CEA)
- Malgorzata Stramska (University of Southern California)

Some other modeling papers that used our Barbados data:

- Moulin, C., C. E. Lambert, F. Dulac, and U. Dayan, Control of atmospheric export of dust from North Africa by the North Atlantic Oscillation. Nature 387, 691-694 (1997).
- Alpert, P., Y. J. Kaufman, Y. Shay-El, D. Tanre, A. da Silva, S. Schubert, and Y. H. Joseph, Quantification of dust-forced heating of the lower troposphere. Nature, 395, 367-370, 1998.

Publications:

Barrie, L.A., Y. Yi, W.R. Leaitch, U. Lohmann, P. Kasibhatla, G.J. Roelofs, J. Wilson, F. McGovern, C. Benkovitz, M.A. Mélières, K. Law, J. Prospero, M. Kritz, D. Bergmann, C. Bridgeman, M. Chin, J. Christensen, R. Easter, J. Feichter, C. Land, A. Jeuken, E. Kjellström, D. Koch, P. Rasch. A comparison of large scale atmospheric sulphate aerosol models (COSAM): Overview and highlights. *Tellus 53B,* 615-645. 2001.

Chuang, C.C., J.E. Penner, J.M. Prospero, K.E. Grant, and G.H. Rau, Effects of anthropogenic aerosols on cloud susceptibility: A sensitivity study of radiative forcing to aerosol characteristics and global concentration. Submitted, *J. Geophys. Res*., June 2000.

Diaz, J.P., F.J. Expósito, C.J. Torres, F. Herrera, J.M. Prospero, and M.C. Romero, Radiative Properties of Aerosols in Saharan Dust Outbreaks Using Ground-based and Satellite Data: Applications to Radiative Forcing *J. Geophys. Res*., *106* (D16) 18403-18,417, 2001.

Diaz, J.P., M. Arbelo, G. Podesta, R. Evans, and J.M. Prospero, Relationship between errors in AVHRR-derived sea surface temperature and the TOMS aerosol index. *Geophys. Res. Ltrs, 28* (10), 1989-1992, 2001

Ginoux, P., M. Chin, I. Tegen, J. M. Prospero, B. Holben, O. Dubovik, S-J. Lin. Sources and distributions of dust aerosols simulated with the GOCART model. *J. Geophys. Res. 106* (D17) 20,255-20,274, 2001.

Prospero, J. M., Long-term measurements of the transport of African mineral dust to the Southeastern United States: Implications for regional air quality. *J. Geophys. Res., 104,* D13, 15,917-15,927, 1999

Prospero, J.M. Long-range transport of mineral dust in the global atmosphere: Impact of African dust on the environment of the southeastern United States. *Proc. Natl. Acad. Sci. USA, 96*, 3396-3403.

Prospero, J.M., P. Ginoux, O. Torres, and S.E. Nicholson. Environmental Characterization of Global Sources of Atmospheric Soil Dust Derived from the NIMBUS-7 TOMS Absorbing Aerosol Product. *Rev. Geophys.*, accepted for publication in issue February 2002.

Smirnov, A., B.N. Holben, D. Savoie, J.M. Prospero, Y.J. Kaufman, D. Tanre, T.F. Eck, I. Slutsker. Relationship between column aerosol optical thickness and in situ ground based dust concentrations over Barbados. *Geophys. Res. Lett., 27*, 1643-1646, 2000.

Smirnov, A., B.N. Holben, O. Dubovik, N.T. O'Neil, L.A. Remer, T.F. Eck, I. Slutsker, and D. Savoie, Measurement of atmospheric optical properties on U.S. Atlantic coast sites, ships, and Bermuda during TARFOX, *J. Geophys. Res.105 (D8)*, 9887-9902, 2000.