Final Report for "Investigations of Desert Dust and Smoke in the North Atlantic in support of the TOMS instrument-NAG5-11069"

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During the initial period of the work we concentrated on Saharan dust storms and published a sequence of papers (Colarco et al 2002, 2003a,b, Toon, 2004). The U.S. Air Force liked the dust model so well that they appropriated it for operational dust storm forecasting (Barnum et al., 2004). The Air Force has used it for about 5 yrs in the Middle East where dust storms cause significant operational problems. The student working on this project, Peter Colarco, has graduated and is now a civil servant at Goddard where he continues to interact with the TOMS team. This work helped constrain the optical properties of dust at TOMS wavelengths, which is useful for climate simulations and for TOMS retrievals of dust properties such as optical depth. We also used TOMS data to constrain the sources of dust in Africa and the Middle East, to determine the actual paths taken by Saharan dust storms, to learn more about the mechanics of variations in the optical depths, and to learn more about the mechanisms controlling the altitudes of the dust.

During the last two years we have been working on smoke from fires. Black carbon aerosols are one of the leading factors in radiative forcing. The US Climate Change Science Program calls this area out for specific study. It has been suggested by Jim Hansen, and Mark Jacobsen among others, that by controlling emissions of black carbon we might reduce greenhouse radiative forcing in a relatively painless manner. However, we need a greatly improved understanding of the amount of black carbon in the atmosphere, where it is located, where it comes from, how it is mixed with other particles, what its actual optical properties are, and how it evolves. In order to learn about these issues we are using a numerical model of smoke. We have applied this model to the SAFARI field program data, and used the TOMS satellite observations in that period (Sept. 2000). Our goal is to constrain source function estimates for black carbon, and smoke optical properties. These goals are similar to those we already met for dust using TOMS data.

We have been very successful with this project and have a paper that will soon be submitted for publication (Matichuk et al., 2006). We have also reported these results at 2 AGU meetings, and have a presentation scheduled for the AAAR meeting this Fall. The student working on this project, Rebecca Matichuk has spent part of a summer at Goddard working with TOMS and other scientists, and is now supported on a Goddard student fellowship. We have found that using Goddard fire carbon emission estimates, we are able to reproduce AERONET optical depths and single scattering properties very well during the SAFARI time period. We are also able to reproduce the vertical distribution of the smoke as observed by lidars. However, our results do not correlate well with TOMS, MODIS and MISR optical depth data. We are trying to understand the reasons for these differences. In some cases we correlate, but the satellite derived optical depths differ in magnitude from those in the model. This may be due to the satellites using inappropriate single scattering albedos in their retrieval algorithms. However, we expect there may be other issues such as techniques for averaging the satellite data onto the model grids. We are continuing to work on this problem and hope to resolve it in the near future. Surprisingly the satellites show a peak monthly average optical depth over the Atlantic Ocean off the coast of Africa, rather than over Africa. Our model does not show this result. We are not sure at the moment is this is a retrieval error, some sort of averaging problem, or a missing aerosol process in the model. Again we are continuing to pursue this issue.

In addition to our work on scientific problems involving dust and smoke, this work has led to new model development. In addition to the Air Force model mentioned above we are now working to move the aerosol modeling capability into global models at Goddard and at NCAR.

Publications resulting from this project.

1. Colarco, P.R., O. B. Toon, O. Torres, and P. J. Rasch, Determining the UV imaginary index of refraction of Saharan dust particles from TOMS data and a three dimensional model of dust transport, J. Geophys. Res., 107, #4289 (2002).
2. Colarco, P. R., O., B. Toon et al., Saharan Dust Transport to the Caribbean during PRIDE: 2. Transport, vertical profiles, and deposition in simulations of in situ and remote sensing observations, J. Geophys. Res. 108 (D19): Art. No. 8590 (2003).
3. Colarco, P. R., O. B. Toon, and B. Holben, Saharan Dust Transport to the Caribbean during PRIDE: 1 Influence of dust sources and removal mechanisms on the timing and magnitude of downwind aerosol optical depth events from simulations of in situ and remote sensing observations, J. Geophys. Res, 108 (D19): Art. No. 8589 (2003).
4. Toon, O. B., Atmospheric Science, African dust in Florida clouds, Nature, 424, (6949): 62-624, (2003).
5. Barnum BH, Winstead NS, Wesely J, Hakola A, Colarco PR, Toon OB, Ginoux P, Brooks G, Hasselbarth L, Toth B, Forecasting dust storms using the CARMA-dust model and MM5 weather data,ENVIRONMENTAL MODELLING & SOFTWARE 19 (2): 129-140 (2004).
6. Matichuk, R. I., P. R. Colarco, J. A. Smith, and O. B. Toon, Modeling the Optical Properties of Aerosols From Biomass Burning Using a Three-Dimensional Transport Model and Comparisons to *In Situ* and Remote Sensing Observations From SAFARI 2000 Part One: Young Smoke Aerosols From Savanna Biomass Burning Fires, in preparation for JGR, (2006).