Application of Earth Sciences Products for use in Next Generation Numerical Aerosol Prediction Models

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Award Number: N0001408WX20635

LONG-TERM GOALS

In this project we rapidly devise a forward modeling system to characterize and predict clear sky radiation fields through the harvest of a number of preexisting basic research programs funded by Navy and other government agencies (NASA, NOAA, DOE, etc.). By combining prognostic aerosol and meteorological fields from the NRL Aerosol Analysis and Prediction System (NAAPS) and Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®) with near real time satellite surface and aerosol products via a high resolution radiative transfer model, angular clear sky radiance fields and diabatic heating rates can be generated and predicted. Through this system, we will be able to advance a number of US Navy Applied Science needs in the areas of improved Electro Optical (EO) propagation prediction and aerosol meteorology interaction. Particular focus of these subject areas surrounds the further development of the Navy's atmospheric constituent data assimilation system, including the utilization of a number of satellite based products. Deliverables surround a system for the calculation of atmospheric radiance fields from Navy data feeds. From this project we will deliver quasi-operational computations of aerosol impacts on atmospheric diabatic heating rates and surface fluxes, as well as a significant upgrade to the US Navy's aerosol data assimilation system through the inclusion of a number of additional satellite sensors. With this enhanced capability we will be able to significantly improve source functions for Navy aerosol models, as well as prepare for expected data gaps in the early 2010's.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2008	**Annual**	**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE	
Application Of Earth Sciences Products For Use In Next Generation Numerical Aerosol Prediction Models	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory, Marine Meteorology Division,7 Grace Hopper St., Stop 2,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

OBJECTIVES

Scientific objectives of this project are tightly aligned with the long term goals listed above, and can be broken down into the following categories in order of relative project order a) model data assimilation and initialization; b) source functions; c) radiative transfer; d) synthesis and scale independent integration. In this first year of the project, focus has surrounded the transition of data assimilation and its use for improving source functions. Specific objectives are as follows:

Develop quality assurance and quality control procedures for over land MODIS aerosol product and expand assimilation to all traditional dark target surfaces. This includes the evaluation of the current state of satellite aerosol measurement over land relative to the accuracy requirements of the Navy Aerosol Analysis and Prediction System. This work is tightly integrated with the over waterdata assimilation development and logn term simulation work on a parallel ONR grant to Prof. Jianglong Zhang at the University of North Dakota.

Initiate a program to develop error matrices and spread function for the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) data for use in refining aerosol vertical information.

Based on the assimilation based NAAPS analysis and assimilated satellite data, improve the smoke aerosol source descriptions and model used operationally by the Navy.

Stage the Bond et al., (2004) source function for non-biomass organic and black carbon for use in the Navy Aerosol Analysis and Precition System (NAAPS).

Begin development of unified cross platform analysis and radiaiton tools for the consistent use of NAAPS. NOGAPS, and COAMPS data. This includes the in house impilimantation of advancements in the aerosol data assimilation system developed by Prof. Zhang at UND.

APPROACH

Much of the work performed this year surrounds the development of appropriate error matrices for the satellite products to be assimilated, including MODIS over land and now CALIPSO. High-precision aerosol measurements from the global AERONET monitoring network were used to perform a detailed evaluation of the MODIS version 5 aerosol optical depth retrieval over land areas. Where necessary, additional ancillary observations such as global albedo and snow cover data sets were used to enhance the analysis. After identifying and quantifying uncertainties in retrieved AOD, empirical corrections and bad data screening. A final quality assurance system for MODIS AOD observations generates an aggregated observation field with well-defined uncertainty for use in data assimilation applications.

For CALIPSO similar process is performed. However, the lack of substantive vertical information to validate lidar data makes the process much more complex. In response, we work closely with the CALIPSO project team at NASA Langley. We are combining Navy and NASA field data along with representative CALIPSO data to develop a suitable calibration/validation data set.

Once a suitable product is available, it can be assimilated into the model. An aerosol optical depth data assimilation system has been developed at NRL that incorporates aerosol optical depth retrievals into the NRL Atmospheric Variation Data Assimilation System (NAVDAS).

As components of the satellite products/assimilation system are completed, we can begin the feedback process on improving source functions.   Because the assimilation process requires a reasonable first guess by the model, several iterations between model analysis and observations over large time series are required to optimize the system. We are beginning with improvement to the smoke source function. Further, to improve model performance additional species are required, particularly non-biomass black and organic carbon. As a first step, a suitable first guess emissions inventory needs to be generated.

Lastly, we wish to develop data assimilation, radiation, and source function systems that can adapt to future improvements to the core model (including resolution) as well as be applicable to the mesoscale (e.g., COAMPS). Hence, consistent databases and analysis software need to developed. Code and processes developed by partners (such as Prof. Zhang) also need to be integrated into the new experimental framework for long time period test simulations.

WORK COMPLETED

For the over land implementation, errors in MODIS retrieved aerosol optical depth relating to observation geometry, surface boundary conditions, snow and cloud contamination, and aerosol microphysical properties were described, quantified, and, to the extent possible with existing ancillary datasets, corrected. Several observation data sets were compiled for evaluation in the NAVDAS-AOD aerosol data assimilation system. Because appropriate snow and albedo data sets to complete filtering of AOD retrievals are not currently available in real-time, a climatological approach was developed and tested retrospectively.

We have achieved the compulsory proficiency level for accessing, reading, processing and archiving NASA CALIOP Level 1B and Level 2-Aerosol value added datasets. IDL-based programs have been written to read and image the data. A web-archival tool has been built and hosted by NASA co-investigators to ease interaction and data scrutiny. Quick-look products for aerosol attenuated backscatter profile are available within the prescribed research domain for Saharan dust (95º W to 15º E and 0º to 40º N) in July and August 2007 and August 2008.

With regards to revamping NAAPS speciation, we staged and performed initial analysis of non-biomass burning organic and black carbon to complete NAAPS's primary species inventory.

We have begun integration of the NAAPS, NOGAPS and COAMPS analysis tools though the adaptation of the COAMPS-OS IPVS to these systems. We will soon able to run similar radiation post processors across the models with a similar visualization framework.

Lastly, we have finished the final details of our previous studies of the radiation and aerosol environment of SW Asia. Publications for this work appeared in print in FY2008.

RESULTS

This project encompasses a number of sub projects. Key results are as follows:

Collection 5 over land data quality study: We have shown that the fact that AERONET data are used to derive the aerosol models used in the MODIS retrieval creates a problem of tautology when attempting to use AERONET to diagnose uncertainties in MODIS AOD, especially those uncertainties related to the aerosol microphysical properties. Compounding the problem is the fact that aerosol properties, surface properties, and aerosol loading co-vary in both space and time. High optical depths in a given location are often dominated by a single source, and even in areas with multiple sources, these sources do not represent the diversity of global aerosols. Thus, an ideal microphysical model for optical retrieval of aerosol properties requires a wealth of regionally specific data, data which is as yet unavailable for most parts of the globe. This has significantly hampered efforts to assimilate over land data.

Despite the above uncertainties, MODIS retrieved AOD data were compared with AERONET data to evaluate errors and uncertainties. MODIS Collection 5 AOD is greatly improved from Collection 4 (previously deemed unusable), with 40% lower RMS error vs. AERONET. By identifying and filtering retrievals with problematic observation geometry, atmospheric conditions, and surface boundary conditions, we were able to reduce the RMS error by a further 25%, to levels approaching those of the assimilation-quality over-ocean product.

CALIPSO data assimilation: We are in the process of identifying major Saharan dust events during the summer 2007 season that will form the basis for our initial operational tests, which are anticipated to begin in late-October 2008. A large dust plume emerged off of the West African coast on/about 20 July 2007. Data from a nighttime (north-to-south) CALIOP pass is shown in Fig. 1. We have tuned the attenuated backscatter signal scale such that hydrometeor clouds (liquid and ice) are saturated, whereas aerosols and the clear molecular sky aren't. The dust plume is evident below 6.0 km MSL south of 32º N and west of -16º W. It is possible that these particulates are seeding liquid hydrometeors at the top of the layer and to the south end of the plume.

Anthropogenic organic and black carbon: the NAAPS model carries only ammonium sulfate as a representation of pollution. While this was considered acceptable when NAAPS was first constructed, it is now well understood that anthropogenic sources of black and organic carbon from biofuel and industry can account for more than half of the pollution loads in east and southern Asia. An initial source function has been staged (Figure 2), which will provide significant improvements to NAAPS once the species are included (to be complete in FY09), particular in the Pakistan, India, SE Asia, and China.

IMPACT/APPLICATIONS

The AOD datasets were have produced will allow us to directly test the forecast impact of different choices balancing aggressive data filtering with avoiding unnecessary reduction in data volume and coverage. Once the tradeoffs have been quantified, we can begin to incorporate over-land AOD observations in the NAVDAS-AOD system, thereby improving forecast skill over both land and ocean. Once fully implemented, it will be considerably easier to add additional sensors and sustain long term support of the system. Further, with the substantially improved model efficacy data assimilation provides, it will be possible to predict higher level radiation fields and EO propagation in both the global, and eventually mesoscale models.

TRANSITIONS

Code for optical depth data assimilation and NAVDAS-AOD has been delivered to FNMOC for implementation. The algorithm for constructing a data assimilation quality MODIS collection 4 over water product has been delivered as well.

RELATED PROJECTS

This project is tightly coupled to a number of ONR 32 programs, particularly Professor Jianglong Zhang at the Our primary transition partner is Douglas Westphal who is principal investigator on the Large Scale Aerosol Modeling Development (PI: Doug Westphal). New data processing and visualization systems are being adaped for aerosol research through the COAMPS-On Scene IVPS charts program (PI: John Cook). We have also begun working with Jim Hansen on his ONR 32 grant on the use of ensemble data assimilation for the prediction of atmospheric constituents.

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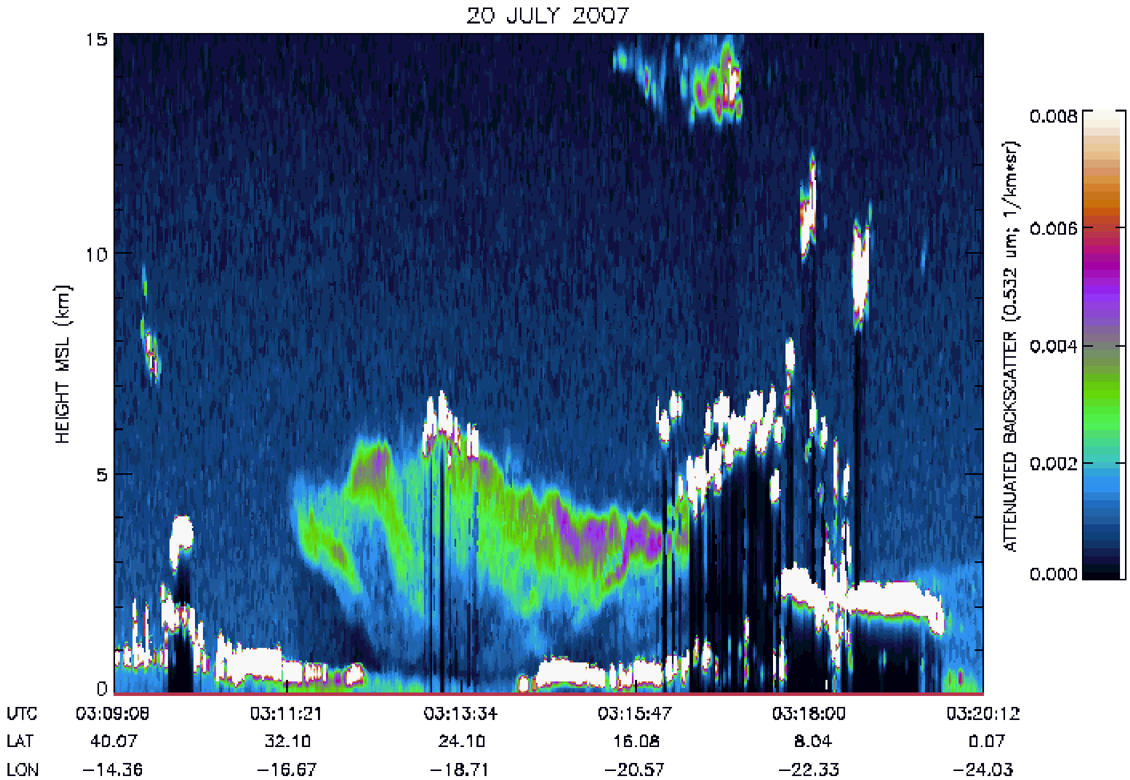

Figure 1. CALIPSO/CALIOP 0.532 µm attenuated backscatter (1/km·sr) data profile a nighttime (north-to-south) pass over the sub-tropical eastern Atlantic on 20 July 2007 at 0.100 km/1s resolution

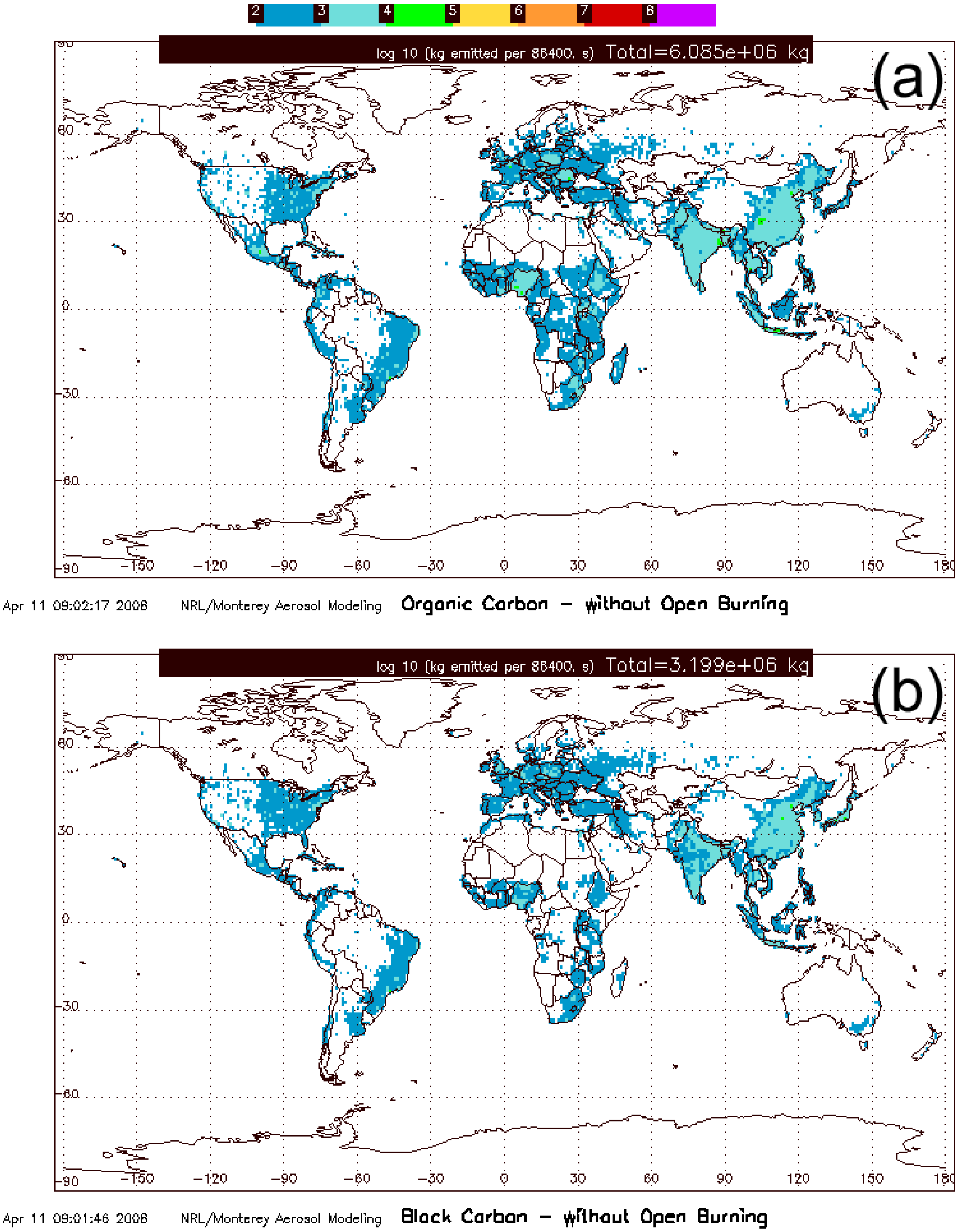

Figure 2: Anthropogenic organic (a) and black carbon (b) emissions (excluding open burning) staged for use in NAAPS based on the inventory of Bond et al., [2004].