Large-Scale Aerosol Modeling and Analysis

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LONG-TERM GOALS

The long-term goal of this research is to develop a practical predictive capability for visibility and weather effects of aerosol particles for the entire globe for timely use in planning and executing DoD operations and activities. The fundamental predicted variables are the concentrations of atmospheric aerosol particles responsible for degradation of EO propagation in regions of DoD interest. Post-processors calculate the optical parameters useful in strategic and tactical planning, training, and operational activities. This forecast and simulation capability also is used in theoretical studies of the Earth's atmosphere and has operational usefulness in scientific field campaigns.

OBJECTIVES

The objective of this program is to investigate, develop, and test aerosol initialization, source, and prediction schemes. These will be incorporated into an aerosol data assimilation and prediction system based on observations, aerosol process models, and meteorological models.

APPROACH

The approach to the problem of aerosol and Electro-Optical (EO) extinction prediction follows that used in numerical weather prediction, namely real-time assessment for initialization of first-principles models. The Naval Research Laboratory has developed a new capability for forecasting the global and regional concentration of atmospheric particulate matter and the subsequent effects on visibility. The regional model (COAMPS/Aerosol) became operational during OIF. The global model Navy Aerosol Analysis and Prediction System (NAAPS) became operational in October 2005. These models allow the prediction of the concentration of the dominant visibility reducing aerosol species up to six days in advance anywhere on the globe. NAAPS and COAMPS are particularly useful for forecasts of dust storms in areas downwind of the large deserts of the world: Arabian Gulf, Sea of Japan, China Sea, Mediterranean Sea, and the Tropical Atlantic Ocean. NAAPS also accurately predicts the fate of large-scale smoke and pollution plumes. With its global and continuous coverage, NAAPS is invaluable in

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14. ABSTRACT
The long-term goal of this research is to develop a practical predictive capability for visibility and weather effects of aerosol particles for the entire globe for timely use in planning and executing DoD operations and activities. The fundamental predicted variables are the concentrations of atmospheric aerosol particles responsible for degradation of EO propagation in regions of DoD interest. Postprocessors calculate the optical parameters useful in strategic and tactical planning, training, and operational activities. This forecast and simulation capability also is used in theoretical studies of the Earth?s atmosphere and has operational usefulness in scientific field campaigns.

15. SUBJECT TERMS

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filling the gaps in observations of aerosol particles and visibility and in satellite observations and extends our understanding of aerosol particles and their impact on Navy operations. However, validation studies indicate that the forecasts would benefit from increasing the resolution and the number of species and the implementation of aerosol data assimilation.

WORK COMPLETED

We continued development and improvement of the NRL high-resolution dust source database for east Asia and plan to transition v1.1 to 6.4 in early FY09. A paper describing the NRL high-resolution (1 km) dust source database for the Middle East and SW Asia has been completed and submitted for publication (Walker et al., 2008.)

The collaboration with Scripps Institute of Oceanography and the University of Warsaw has led to the addition of a sea salt component to NAAPS. The physics include emission from the water's surface, vertical and horizontal advection and diffusion, dry and wet deposition, and gravitational sedimentation. This version of the code has been validated for several field campaigns (Witek et al., 2007), has been run on NRL machines in research mode, and transitioned to 6.4 in FY08.

NAAPS is being improved by the addition of an aerosol data assimilation capability. The data assimilation package NAVDAS-AOD is a version of the NRL Atmospheric Variational Data Assimilation System (NAVDAS) modified to assimilate MODIS aerosol optical depths (Zhang et al., 2008). The package has been converted for use in a daily research mode. More extensive validation is underway. Transition to 6.4 and FNMOC occurred in FY08.

RESULTS

In Pratt et al. (2008) we present the first direct, real-time measurements of long-range transported biogenic and dust particles at high altitudes as residues of cloud ice crystals. In this study we applied a novel method of simultaneous real-time measurements of ice-nucleating particle concentrations and size-resolved chemical composition of individual ice residues combined with concurrent cloud phase measurements. Dust simulations using the NAAPS suggested that the measured air mass containing the dust and biogenic particles was lofted from China on October 30 – November 1, 2007. NAAPS was also used to eliminate the possibility of North American sources. This case provides the first evidence for the involvement of biogenic particles in cloud ice formation above 7 km. These results have significant implications on cloud models of radiative forcing and the hydrological cycle. Further, biogenic and dust particles involved in cloud ice formation have been found to be co-transported, pointing to the interconnectedness of processes at the land surface and in the free troposphere that impact cloud processes globally. With increasing dust storms due to climate change and land use changes in desert regions, the impact of the bacteria in large-scale dust storms is expected to significantly impact warm ice cloud formation, human health, and ecosystems globally.

In Niemi et al. (2008), we studied the frequency, strength and sources of long-range transport (LRT) episodes of fine particles ($PM_{2.5}$) in southern Finland using air quality monitoring results, backward air mass trajectories, remote sensing of fire hot spots, transport and dispersion modelling of smoke and chemical analysis of particle samples (Figure 1.) NAAPS was used to show that the daily WHO guideline value (24-h PM2.5 mean 25 μg m^{-3}) was exceeded at Helsinki one to seven time per year due to LRT. The highest particle concentrations (max. 1-h mean 163 μg m^{-3}) and the longest episodes (max. 9 days) were mainly caused by the emissions from open biomass burning, especially during spring and late-summer in 2002 and 2006 and indicated that approximately half of the episodes were caused partly by the emissions from wildfires and/or agricultural waste burning in fields in Eastern Europe, especially in Russia, Belarus and Ukraine.

Cachorro et al. (2008) present the analysis of the strongest North African desert dust intrusion that occurred over the Iberian Peninsula (IP) during the last few decades. NAAPS simulations were used to investigate the origin and transport during the event, including the mixing of dust with smoke from fires in the IP. The intensity and duration of this event were exceptional, which took place from 22 July to 3 August 2004. The AOD at sites on the IP reached maximum of 2.7. In addition, PM_{10} hourly peak concentration levels were nearly 600 mg m^{-3}.

At times, a near-continuous cloud of Saharan dust extends from West Africa to Central America, South America and north to the southeastern U.S. An international team of scientists led by the USGS is examining the contaminants carried with African dust and the role they may play in the degradation of Caribbean coral reefs and other downwind ecosystems (Rothenberger et al., 2008.) NAAPS simulations have been used to predict the long-range transport of Saharan dust for mission planning and post-mission analysis. Thus far, African dust has been found to carry viable microorganisms, including pathogens, nutrients such as iron, persistent organic pollutants and heavy (Griffin et al., 2006).

IMPACT/APPLICATIONS

NAAPS helps to satisfy the Navy's long-term goal of a predictive capability for aerosol particles and EO propagation. The forecasts of aerosol concentration are distributed via NIPRNET and SIPRNET for use by DoD forecasters, operators, planners, and aviators (http://www.nrlmry.navy.mil/aerosol/). The model output is processed by FNMOC and converted into the fundamental optical properties required to calculate EO propagation. These properties are used to populate the Tactical Environmental Data Server (TEDS) and subsequently used by the Target Acquisition Weapons Software (TAWS) to calculate slant-path visibility. The forecasts are used to correct satellite retrievals of sea surface temperature (SST) by NAVO, thus improving tropical forecasts.

NAAPS also provides tools for the 6.1 and 6.2 aerosol research communities and the academic community. NAAPS data continues to be used in interactions with research community appearing in peer-reviewed and conference papers. Over the year, collaborations have occurred between NRL and the University of Valladolid (Spain), University of California at San Diego, University of Helsinki, Scripps Institute of Oceanography, the University of Warsaw, Colorado State University, USGS and others. NAAPS forecasts enhance NRL's continued participation in field programs and will give us further opportunities for collaboration and access to important validation data.

NRL was invited to described the NAAPS system of models and lesson learned at a meeting in Barcelona in November 2007 on the World Weather Research Programme and the Global Atmospheric Watch (WWRP/GAW) Sand and Dust Storm Research Development Project (SDS RDP). Established in September 2004, the purpose of the SDS Project is to achieve comprehensive, coordinated and sustained observations and modeling capabilities of the sand and dust storm, in order to improve the monitoring state of the sand and dust storm, increase the understanding of its the formation processes, and enhance prediction capabilities.

NRL was also invited to present our work in using NAAPS in TAWS for EO propagation calculations at the 30th Anniversary - Review of Atmospheric Transmission Models, in Boston, June 2008. NRL was invited to present our work on dust source inventories and data assimilation at the 3rd International Workshop on Mineral Dust, September 2008, Leipzig, Germany.

The capabilities of NAAPS have been briefed to the IC community (NGA and NASIC) and have been received favorably. Their needs are similar to those of the research community, that is atmospheric correction. Funding has been secured from both agencies for current NAAPS products. The development of IC-specific products is being discussed and may lead to more funding.

TRANSITIONS

NAAPS has been operational at FNMOC since September 2005. Improvements to NAAPS (as developed in this work unit) are transitioned to FNMOC via 6.4 funding provided by PMW-120.

RELATED PROJECTS

ONR 6.2 “Application of Earth Sciences Products” supports improvements in NAAPS physics and model initialization. The implementation of NAAPS, NAVDAS-AOD, FLAMBE and FAROP at FNMOC are supported by PMW 120 6.4 “Large-scale Atmospheric Models”, 6.4 “Small-scale Atmospheric Models.”, and 6.4 “Satellite Aerosol Data Assimilation.” This funding also supports development and generation of products for use by the fleet. The NRL 6.1 “Turbulence-Aerosol-Cloud Interactions” program uses NAAPS data and products for initialization, investigations and validation. NAAPS forecasts and simulations are used for several applications: FAA Volcanic plumes, NASA “Vertical Dust Distribution Analysis and Lidar Data Assimilation”, NASA Biomass-cloud interactions, NASA ARCTAS.

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HONORS/AWARDS/PRIZES

DoN Special Act Award awarded to D. L. Westphal for NAAPS contributions to the investigation of the near-loss of WP-3D aircraft due to severe sea salt fouling (Reid et al., 2007).

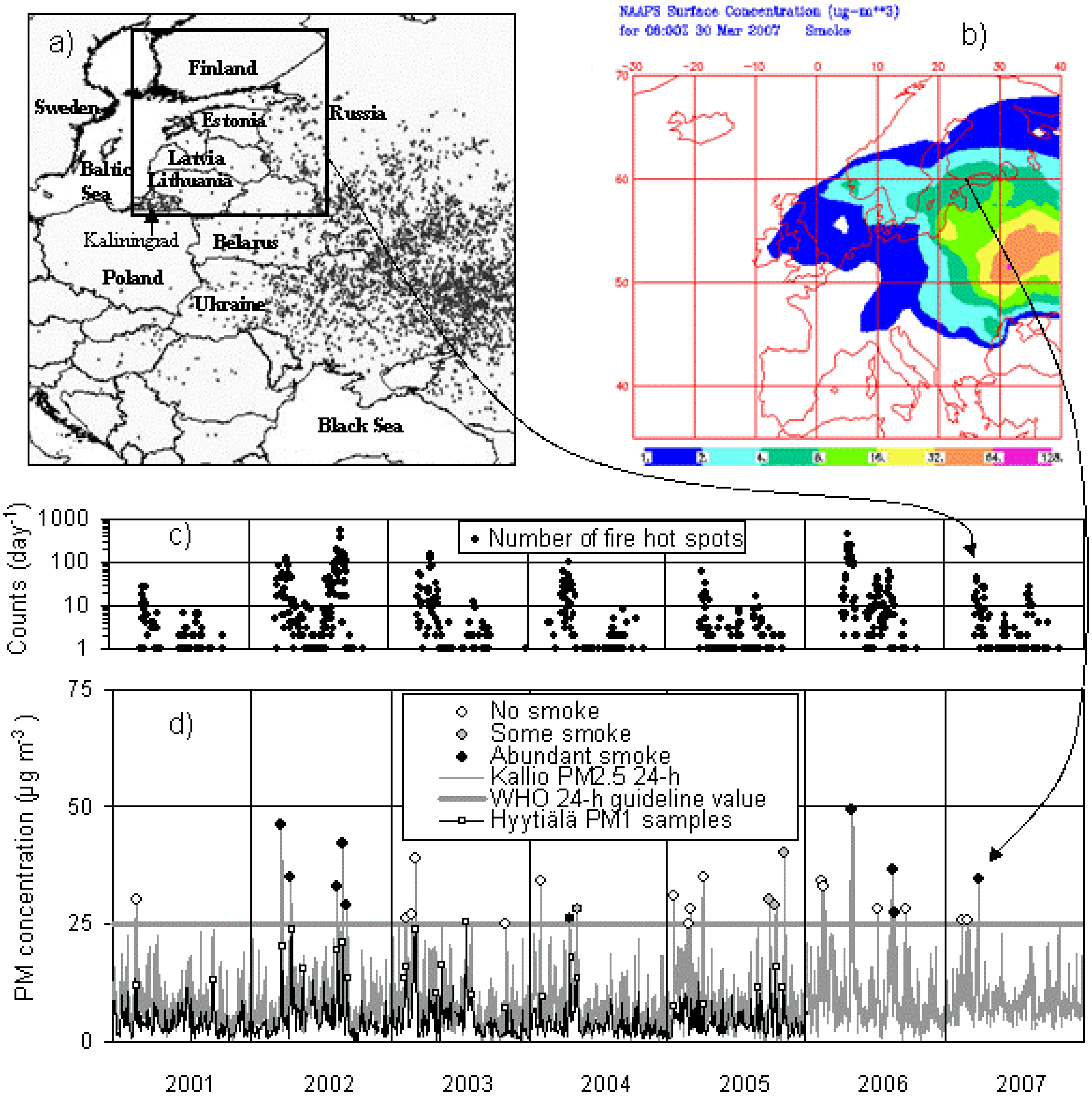

Figure 1. (a) MODIS Aqua and Terra fire detections in Eastern Europe in March 26-30, 2007 (Web Fire Mapper); (b) NAAPS model results showing surface smoke concentrations in March 30, 2007 (UTC 06:00); (c) Daily MODIS Terra fire counts located in rectangle near Finland during 2001-2007; (d) 24-h moving average $PM_{2.5}$ concentrations and different LRT episode types (no, some and abundant smoke as determined by NAAPS) at Kallio in Helsinki in 2001-2007. Also,, 2-3 days PM1 concentrations and sampling periods for chemical analysis in Hyytiälä in 2001-2005 are also shown. [graph. A-panel shows hundreds of individual fires detected by MODIS distributed all over Eastern Europe, with most in Russia. B-panel: NAAPS smoke is distributed over Eastern Europe including Finland, with maximum values in Russia. C-panel: shows fire counts are seasonal, with highest counts in spring and a secondary peak in fall. D-panel: Of the 5 to 10 high daily average PM2.5 values that occur each year, many of the highest are associated with LRT of smoke as simulated by NAAPS.