Coastal Aerosol Distribution by Data Assimilation

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LONG-TERM GOALS

The long-term goal of this research is to develop an initialization scheme for a multi-dimensional, predictive aerosol model in coastal regions. The initialization scheme will have global coverage and include data gathering, quality control and data assimilation of the available aerosol observations, including satellite aerosol retrievals, ground-based remote sensing, point measurements, and the previous aerosol forecast.

OBJECTIVES

The objectives of this program are to (1) investigate and evaluate the existing and proposed aerosol retrievals from satellites for applicability to aerosol model initialization and (2) develop and test aerosol analysis and data assimilation techniques using satellite and other aerosol measurements.

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 and first-principle modeling. A predictive model requires the initial spatial distribution of the aerosol field including composition, concentration, and size distribution. Sensors and retrieval techniques exist for obtaining the aerosol optical depth (AOD) and some information about particle size. The remotely sensed aerosol properties typically are vertical integrals and are generated at horizontal resolutions ranging from one kilometer to one degree. An objective analysis method is being devised to merge these 2-D distributions with point measurements and model constraints to produce a three-dimensional description of aerosols.

WORK COMPLETED

A global predictive model of tropospheric aerosols has been developed over the past several years. Improvements have been made this year to the source functions, validation techniques, and product distribution. With its global, continuous coverage, the Navy Aerosol Analysis and Prediction System (NAAPS) is invaluable in filling the gaps in observations of aerosols and visibility and in satellite observations and extends our understanding of aerosols and their impact on Navy operations. NAAPS simulations have revealed that inter-continental transport of aerosols is common and occurs nearly every day somewhere in the world. These improvements will make the model's forecasts even more accurate.

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14. ABSTRACT
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NAAPS was utilized during the Asian Dust Above Monterey (ADAM) experiment in April 2003. The goal of ADAM is to study the properties and distribution of the Asian dust and aerosols that cross the Pacific every spring.

A program to retrieve aerosol optical depth from AVHRR and GOES satellite data has been evaluated for the tropical Atlantic using data collected during the ONR-sponsored Puerto Rico Dust Experiment (PRIDE) in 2000. The algorithm was improved in a number of ways and is now used daily over selected areas.

The NASA/GSFC MODIS fire product from both the Aqua and Terra satellites are now received twice daily and used to specify global smoke sources in regions other than the western hemisphere. The Wildfire-ABBA (Automated Biomass Burning Algorithm) product for fire detection in the western hemisphere from GOES data is now received every half hour at NRL/MRY from University of Wisconsin.

Region-specific web pages for the Mediterranean, Persian Gulf, and other strategic regions have been developed and transitioned to SIPRNET. Deployed Navy personnel can now access these developmental pages and products. Feedback from these users will be used to guide further product development.

RESULTS

NAAPS was used to forecast the arrival in North America of Asian dust and pollution events during ADAM. The NAAPS five-day forecasts of the timing, location, and altitude of elevated dust layers were used successfully to choose aircraft flight days and stand-down days for the CIRPAS Twin Otter aircraft. In some cases, clear conditions prevailed at Monterey, but the forecast allowed the mission scientists to redirect the aircraft southward to the dust plume (see Figure 1.) Until recently, such long-range transport was not considered possible in the troposphere, but NAAPS along with several recent satellites, have demonstrated that these event are occurring numerous times each year. Explaining the long tropospheric lifetime and optical properties of these aerosols is the focus of a 6.1 program.

An aerosol optical depth retrieval algorithm in the visible wavelengths for the NOAA POES AVHRR and GOES-8 visible imager (Durkee et al., 2000) is was implemented, validated and improved. The retrieved satellite aerosol optical depth (AOD) was compared to three land-based sun photometer stations located on islands in the western Atlantic during July and September 2001. Additional corrections to the channel 1 GOES-8 radiances were made by applying a linear offset factor obtained during the experimental time period through comparison with AVHRR radiances. The results for the GOES-derived AOD compare favorably to the Aerosol Robotic NETwork (AERONET) AOD values. For both NOAA and GOES data, the comparison dataset has a correlation coefficient of 0.67 with a standard error of 0.07. An example of the retrieval is shown in Figure 2.

The combined GOES-ABBA/MODIS product allows, simulations of realistic fire smoke plumes in Siberia, Africa, Southeast Asia, and Indonesia. In particular, NAAPS accurately modeled the large Russian fires of May 2003 (Figure 3). Previously, NAAPS used a historical dataset (1993) for fires, based on AVHRRR data, from ESA, to specify smoke sources in Africa, Australia and Indonesia.

NAAPS forecasts and products were made available to armed forces during Operation Iraqi Freedom via a SIPRNET site hosted at NRL in Monterey. The existing product suite from the NAAPS was

customized for OIF and used by Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the fleet. NRL and FNMOC staff used these and other products to develop a daily 'Dust Discussion' produced by the watch floor of FNMOC. NRL provide training in the interpretation of the dust model forecasts and satellite imagery.

IMPACT/APPLICATIONS

Presently, NAAPS runs in a predictive mode and can help to satisfy the Navy's long-term goal of a predictive capability for aerosols and EO propagation. This research 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. NAAPS will be transitioned to Milestone I early in FY04. Over the past years, collaborations have been initiated between NRL and University of Miami, U. Wisc., U. Alabama, NASA/GSFC, Chinese Academy of Sciences, University of Warsaw, MBARI, Université de Sherbrooke (Quebec) and others. NRL's continued participation in field programs will give us further opportunities for collaboration and access to important validation data.

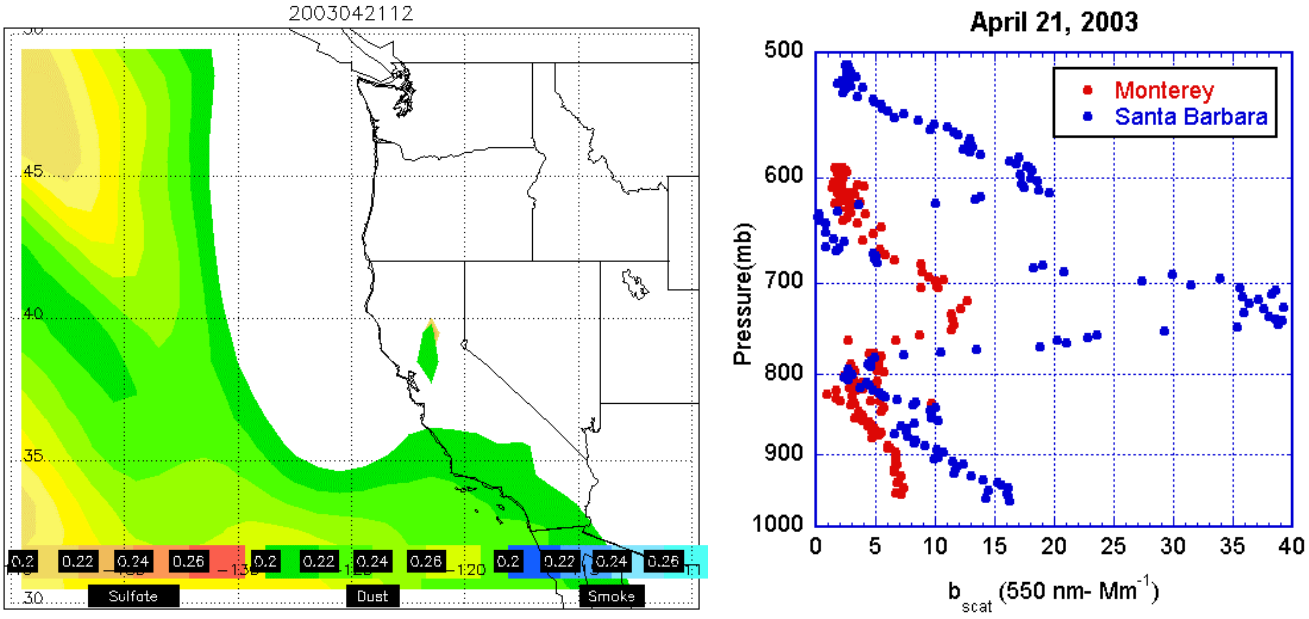

Figure 1. Left frame: The NAAPS simulation of dust optical depth over the east Pacific Ocean on April 12, 2003 showing little dust over Monterey but much dust to the south and west. Right frame: data from the Twin Otter aircraft during ADAM showing vertical profiles of scattering with a weak layer over Monterey, but strong layers over Santa Barbara. (The Twin Otter did not sample the heavies dust concentrations to the west since these were out of the range of the aircraft.)

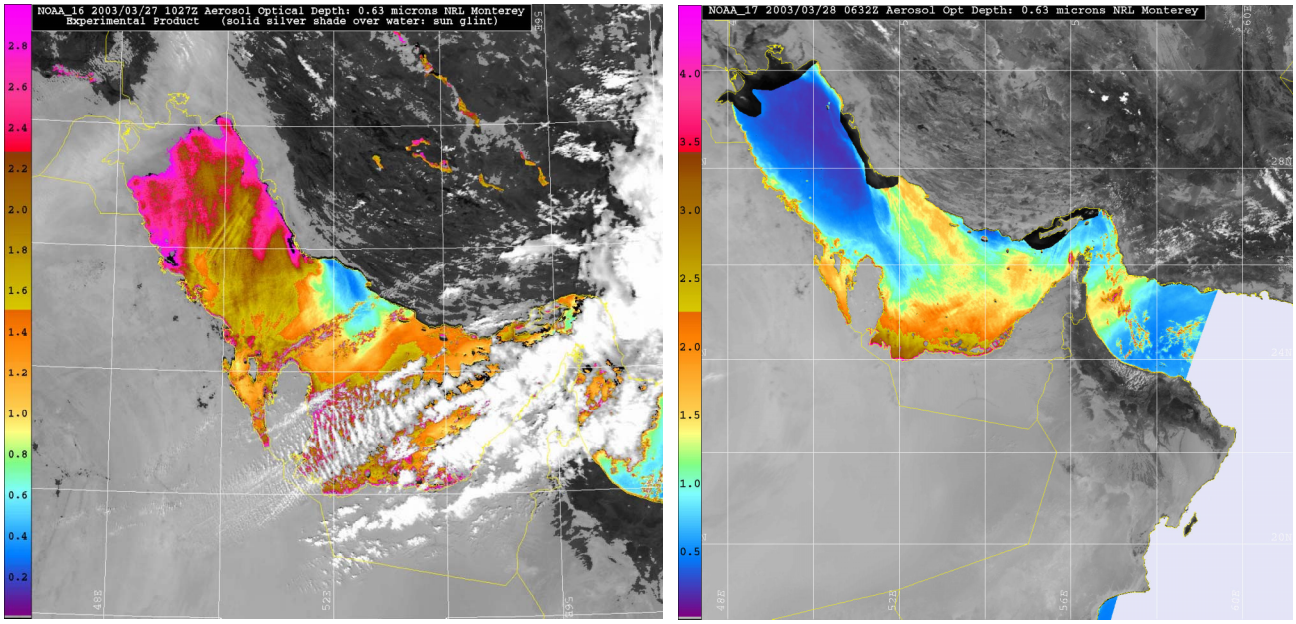

Figure 2. Two examples of aerosol optical depth retrieval over the Persian Gulf from NOAA AVHRR satellite using the technique developed by the Naval Postgraduate School and subsequently improved by the Naval Research Laboratory. The image on the left is valid at 1027 UTC on March 27th or towards the end of the massive dust storm that impacted troops during Operation Iraqi Freedom. It shows extremely high values of optical depth over much of the gulf. The image on the right shows a much clearer atmosphere over the gulf a day later, or at 0632 UTC on March 28th.

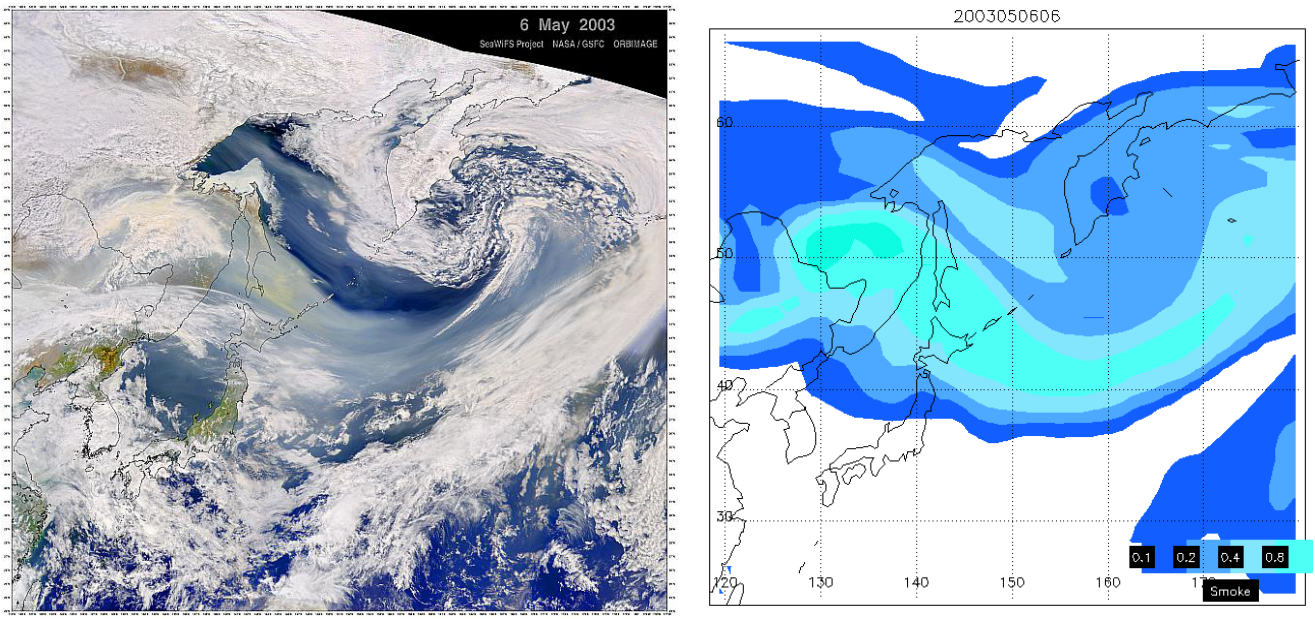

Figure 3. An example of forest fire smoke plume simulation by NAAPS using smoke sources detected by MODIS and converted to smoke flux by FLAMBE. The left image shows the SEAWIFS image for May 6, 2003 for East Asia and the Northwest Pacific Ocean with a heavy smoke plume emerging from Russia, crossing Japan, and then heading northeast over the ocean. At right we show the NAAPS simulation of this event. The model correctly shows the location, shape, and timing of the multiple plumes contained in this event.

TRANSITIONS

NAAPS forecasts and products were made available to armed forces during Operation Iraqi Freedom via a SIPRNET site hosted at NRL in Monterey (Figure 4.) The existing product suite from the NAAPS was customized for OIF and used by Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the fleet. This developmental SIPRNET site will be improved based on feedback from the users and then made permanent at FNMOC when NAAPS becomes operational.

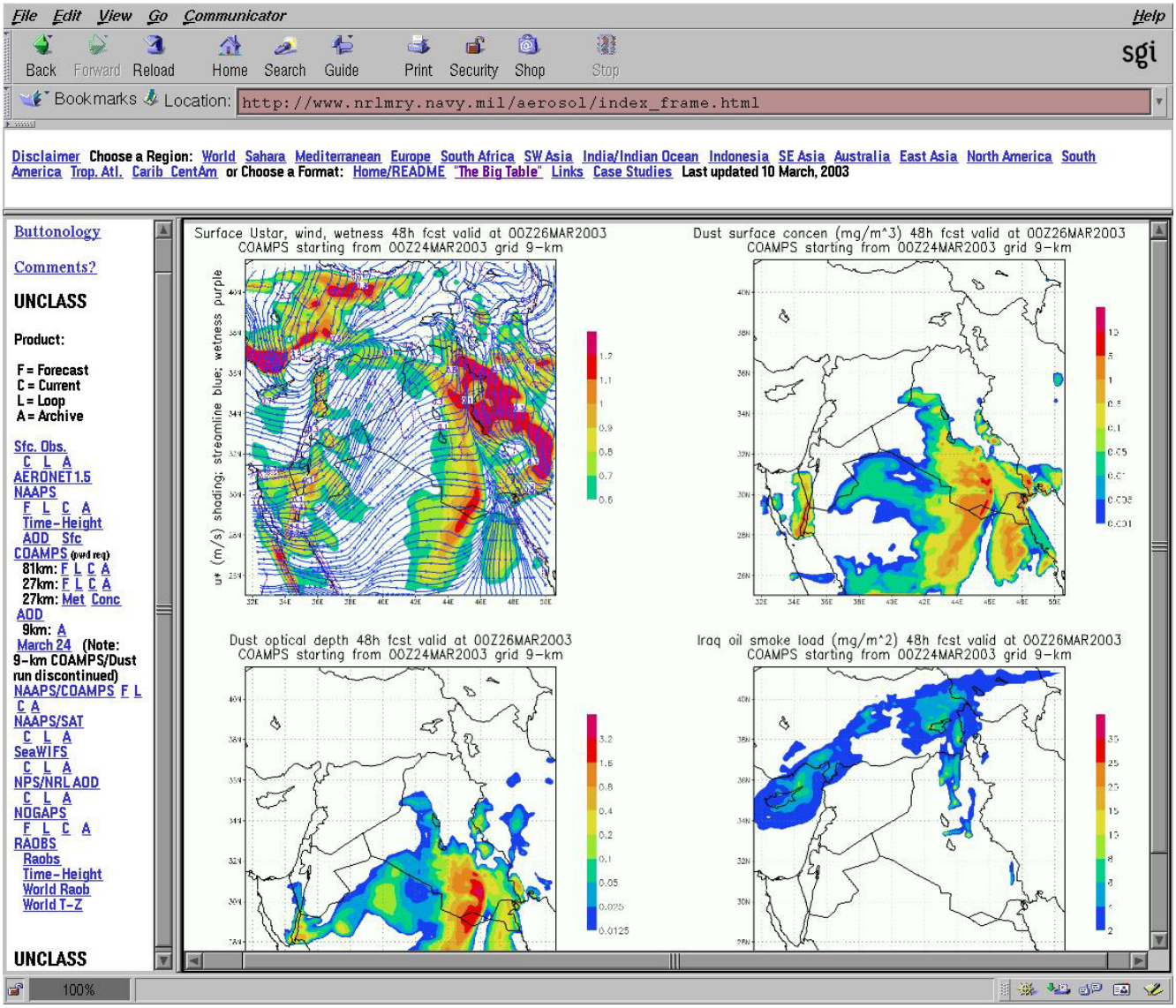

Figure 4. An example of one of the regional SIPRNET web pages, shown here for Southwest Asia. The left panel lists the various model, satellite, and other products that are available either as images or animated loops. The product is displayed in the right frame. This sample shows the COAMPS weather and dust forecast for the severe dust storm of March 26, 2003 during OIF.

RELATED PROJECTS

The NRL 6.1 base *Atmospheric Physics* and the NRL 6.2 base *Improved COAMPS Land Boundary Layers* (includes COAMPS aerosol modeling) use NAAPS data and products and the satellite retrievals for investigations and validation. The SPAWAR 6.4 *Improvement of Aerosol Prediction Capability* will transition NAAPS to operations and use it to generate products for use by the fleet.

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HONORS/AWARDS/PRIZES

An NRL Technology Transfer Award for "Real-time Dust Forecasting for Operation Iraqi Freedom" was received on September 2, 2003.