Electrooptic Propagation

Dr. Steve Doss-Hammel
SPAWARSYSCEN San Diego D858
49170 Propagation Path
San Diego, CA 92152-7385
phone 619-553-4578 fax 619-553-1417 email: hammel@spawar.navy.mil

Dr. Douglas Jensen
phone 619-553-1415 fax 619-553-1417 email: djensen@spawar.navy.mil

Charles McGrath
phone 619-553-1416 fax 619-553-1417 email: mcgrath@spawar.navy.mil

Dr. Jeffrey Reid
phone 619-553-1419 fax 619-553-1417 email: jreid@spawar.navy.mil

Dr. Carl Zeisse
phone 619-553-3602 fax 619-553-1417 email: zeisse@spawar.navy.mil

N0001400WX20267
http://sunspot.spawar.navy.mil

LONG TERM GOALS

Provide the Navy with products describing the electro-optical propagation environment and atmospheric visibility (visible and IR) within marine and coastal environments.

OBJECTIVES

The EO Propagation objectives are: 1) investigate, develop and evaluate ocean and coastal aerosol models and their effects on visibility 2) Integrate and develop simple, realistic models for infrared propagation near the ocean surface, 3) develop and evaluate advanced marine radiance models that are compatible with TAWS and IRTSS 4) develop a consistent chemical/optical model for aerosol particles suitable for inclusion in navy meteorological models.

APPROACH

Remote (surface-based and satellite) and in-situ (surface and airborne) sensors are used to measure the microphysical, optical and meteorological parameters from which models of aerosol-size distributions and sky/sea/terrain backgrounds can be developed and evaluated.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **Electrooptic Propagation**	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) **SPAWARSYSCEN San Diego D858,,49170 Propagation Path,,San Diego,CA,92152**	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

14. ABSTRACT

15. SUBJECT TERMS

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

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

MARINE AEROSOL MEASUREMENTS AND MODELING (Jensen, Reid)

An analysis of the EOPACE/Duck '99 field campaign was competed and several papers were submitted to pear-reviewed journals. Emphasis on the analysis was placed in three areas: 1) Flux of sea-salt particles from both the surf-line and whitecaps, 2) the transition of a continental boundary layer into a marine boundary layer during periods of offshore and along-shore flow, 3) The variability of salt particle size distributions under varying wind speeds.

SeaCluse model runs in conjunction with TNO, Netherlands, addressed two important issues in the near-surface propagation environment. It calculated the distribution of aerosol in the atmospheric surface layer (discussed earlier) with explicit algorithms for the influence of the waves on the airflow and turbulence. These and other ongoing runs are producing profiles that can be used to infer aerosol related extinction and refraction effects close to the sea surface .

This year, the stratus aerosol model has been extended to include the mid-wave infrared (MWIR) wavelength band in the presence of solar multiple-scattering. The model is presently being tested using airborne infrared measurements with the AGEMA 900 of sky radiance backgrounds near the horizon.

IR TRANSMISSION AND RADIANCE (Zeisse, Doss-Hammel)

Design requirements for a new portable transmissometer were completed this year. The transmissometer was designed and built by Mr. R. Dewees, and the primary improvements are portability and improved transmission accuracy. The portable version retains the valuable features of the older design: field lenses, discrete Judson 2 mm low noise detectors, and a beam-splitter for simultaneous two-band operation with a single receiver.

A comprehensive field-test for desert refraction and dust was conducted on the range at China Lake, November and December 1999. An 11.24 km range was defined near the SNORT (Supersonic Naval Ordnance Research Track) facility to measure scintillation and transmission. The site is a relatively homogeneous and flat horizontal path within meters of desert surface. At a point midway along the path a 30 meter meteorological tower was erected to enable wind and temperature measurements at various heights. Two high-speed sonic anemometers were also installed at the mid-path site. The transmissometer receiver was co-located with a complete aerosol survey package at one terminal point. Transmission, scintillation, meteorology, and aerosols were monitored.

An algebraic equation has been derived that gives the grazing infrared reflectivity of the ocean. It applies to circular sources, such as the Sun or an optical transmitter. The result is analogous to the Miller-Brown approximation for grazing radar reflectivity. The parameters required for the infrared formula are wind speed, source diameter, and average grazing angle. The new grazing formula is very close to an exact numerical calculation previously available under the infrared radiance task. It is far superior to the "flat-top" approximation derived previously under this task and to the Cox-Munk approximation. The latter was, however, never intended for grazing geometries.

COASTAL RADIANCE MODELING (McGrath)

We replaced the original EOTDA semi-empirical water background with the mathematically rigorous SeaRad model. When TAWS replaced the EOTDA as the fleet strike warfare weather tactical decision aid, we developed a new ocean radiance model, called SeaPlus, that extended the capabilities of SeaRad to the midwave band and included clutter, glint and cloud variance. We are currently finalizing the model with features to handle non-homogeneous conditions.

DUST AEROSOL MEASUREMENTS AND MODELING (Reid)

In FY00 we ramped up the program and completed two field campaigns. The first, Dust Experiment to Study IR Extinction (DESIRE) took place at the Naval Air Weapons Station, China Lake, in November-December, 1999. The purpose of this study was to determine the appropriate means of dust aerosol measurement in a more controlled situation. Because of the difficulties in measuring dust aerosol properties, care must be taken from the onset to ensure future data sets are not biased.

The completion of much larger Puerto Rico Dust Experiment (PRIDE) was the principal objective for the dust program. PRIDE took place at Roosevelt Roads Naval Station, PR, from June 27-July 25 2000. For this study a group of over 35 Navy, NASA, and university scientists conducted a combined surface, airborne, satellite and modeling campaign in an effort to measure the properties of African dust transported into the Caribbean. There were two principal tasks: 1) Determine the extent to which the properties of dust particles and the spectral surface reflectance of the ocean surface need to be known before remote sensing systems can accurately determine optical depth and flux. 2) Evaluate/validate the skill in which the Naval Research Laboratory's Aerosol Analysis and Prediction System (NAAPS) predicts the long-range transport and vertical distribution of African dust.

In addition to the field studies, work on community data sets has been ongoing. In particular, we continue to collaborate closely with scientists at NASA GSFC. We have completed theoretical work relating to the determination of optical depth by satellite systems, and have worked to validate NASA systems that invert particle size distributions from sun-sky radiometric measurements. We, in turn, have been employing these inversions to study the characteristics of dusts globally. In particular, we are exploring ways to determine the coarse/fine partition by using spectroscopic techniques.

RESULTS

MARINE AEROSOL MEAUREMENTS AND MODELING

Open ocean salt particle fluxes were derived from the Duck/EOPACE '99 field study data set and analyzed in the context of 4 commonly used salt microphysics parameterizations. It was determined from this analysis that the NRL Aerosol Analysis and Prediction System (NAAPS) should employ a modified version for the Smith et al., 1994 parameterization for salt fluxes. A subroutine for this parameterization has been coded and is awaiting integration into NAAPS.

A further analysis of the Duck/EOPACE dataset showed are large differences in the literature for sea-salt size distributions. Several manuscripts suggest that only half of the variance in salt particle concentration can be explained by wind speed alone. These differences are likely due to three reasons: 1) natural variability in the ocean's wind and precipitation fields prohibit smaller sea-salt aerosols ever getting into steady state. 2) Variations in the insoluble organic content of the ocean influences the bubble bursting process and hence the salt particle size distribution. 3) Instrumentation/presentation biases. To a certain extent all of these reasons bias the community data set causing great uncertainty in the field.

It was determined that within a certain amount of error (either from the model or from the assumptions made in the model) that the profile function for both unstable and neutral conditions is adequately represented in the Advanced Navy Aerosol Model (ANAM). Data collected from the independent ANICE series of experiments has shown that there does appear to be a wind dependence on the mode radius. Therefore, the linear function of radius with wind speed should be used in all of the equations evolving the mode radius. Secondly, it was found that fetch strongly affects the concentration of aerosols and the amplitude component of the model should include fetch as well as the wind dependence. We suggest that the functional form of Piazzola et al. be used until an improved function can be derived from the existing rotorod databases.

The development of the marine status model produced encouraging results. For high elevation angles of the sun, the MWIR sky radiances calculated using the model with the solar multiple scattering option of MODTRAN agreed with measurements to better than 1 °C for sensor elevation angles within 1 to 2.5 degrees above the horizon. Within 1 degree of the horizon, however, the calculated values over estimate the measured sky radiances by 1 to 2 °C. The LWIR modeled sky radiances agree well with the measured values to within 1 °C for sensor elevations between 0 and 2.5 degrees. For low elevation angles of the sun, the calculated MWIR sky radiances over estimate the measurements within 2.5 degrees of the horizon by about 2 °C. The LWIR modeled and measured radiances are in still good agreement. While the differences encountered between the MWIR measured and modeled radiances may be related to undetermined discrepancies in MODTRAN solar multiple scattering routines, they may also be related to the surface layer stability conditions which were “stable” during the AGEMA measurement periods.

IR TRANSMISSION AND RADIANCE

The results from the Nov/Dec 99 test have proved valuable; it was possible in this desert environment to essentially ignore the signal attenuation due to aerosol. It is also possible to separate the other two effects on the signal, refraction and scintillation. We observed regular quiet scintillation periods near sunrise and sunset when the heat flux changed direction. We also observed strong refractive signal enhancement and (as might be expected on such a path) severe image distortion. A strong dust storm event occurred during the test, and we recorded unexpectedly high transmission in the visible and infrared during this event. We installed an imaging camera (visible wavelength) for the last part of the 1999 test, and recorded data that provided insight into the very large transmission measurements. We recorded a signal that was 400% of the free-space value at certain points in the day. Imagery from the camera revealed a mirage and looming effect that briefly concentrated the transmissometer source beam at the receiver, leading to abnormally large transmission values. These episodes were only 10 or 20 minutes in duration. This type of information is impossible to acquire without the use of an imaging camera, either in optical or infrared wavelengths.

COASTAL RADIANCE MODELING

The SeaRad and SeaPlus models showed marked improvement over the current models in the EOTDA and TAWS respectively. Average errors in test data were reduced from 14.9 percent (original EOTDA) to 5.5 percent (EOTDA with SeaRad) and from 12.6 percent (original TAWS) to 3.5 percent (TAWS with SeaPlus), which is better than a 3-to-1 improvement with both models.

DUST AEROSOL MEASUREMENTS AND MODELING

The DESIRE and PRIDE field missions were completed and the collected data is under analysis. The PRIDE mission was particularly successful with high data recovery rates (>95%) and favorable meteorological conditions. The year 2000 dust season showed higher concentrations in the Caribbean than in pervious years. However, during the PRIDE study period, dust concentrations were more typical. Mid-visible optical depths in Puerto Rico averaged 0.3, with a maximum of 0.6-thus indicating that large quantities of African dust is transported across the Atlantic Ocean in the Northern Hemisphere. African dust was almost always present at the surface. Dust particle volume median diameters ranged from 4-10 microns-very similar to sizes reported near the source in Africa (5-10 microns). This suggests that dust particle size may be more static during transport than was previously thought. The vertical distribution of the dust during the study period was similar to those found in BOMEX in 1969, with a principal Saharan Air Layer (SAL) being clearly visible up to as high as 5.5 km. A preliminary analysis of the data indicates that the NAAPS model qualitatively reproduces dust transport over several thousand kilometers.

IMPACT/APPLICATIONS

Radiative transfer models originally developed for open water use are simply not applicable during coastal actions where the atmospheric structure and constituents varies considerably. This directly impacts the performance of the MODTRAN based models, which the navy heavily uses to predict EO performance. The products from the EO propagation project are applicable to the Navy's meteorology, sensor performance assessment systems and sensor/system development projects. They are directly applicable to TAWS that will be integrated into Navy NITES-2000 package. Also, the SeaPlus model relates directly to IRTSS.

The marked improvement gained by the SeaPlus model will give the warfighter better mission planning, more effective weapons selection and delivery, and with greater safety to the aircrews by providing times of maximum thermal contrast and best angles of approach for given strike warfare scenarios.

TRANSITIONS

Parameterizations for the determination of dust concentration and slant path visibility from remote sensing systems will be transitioned to the Marine Meteorology Division of NRL Monterey for further development and possible implementation. This work will also lead to the development of dust aerosol models that will be made available for inclusion in the Air Force MODTRAN propagation and TAWS (Target Acquisition Weather Software) codes.

SeaPlus was transitioned to TAWS in FY00. The finalized version that handles variable conditions will transition in FY01.

RELATED PROJECTS

This project is related to NRL Monterey's mesoscale and data assimilation model projects and their program for improving the current WIN-EOTDA used by the fleet in the TESS(NC) and TAWS, the COVAMP project. The Coastal Radiance Modeling task is directly tied to the tri-service Target Acquisition Weather Software (TAWS) and can be used in other electrooptical scene and target simulation software, such as IRTSS and TOPSCENE. Tri service coordination is conducted under the Technology Area Review and Assessment.

PUBLICATIONS

Peer Reviewed Manuscripts Related to FY00 Work:

Frederickson, P. A., K. L. Davidson, C.R. Zeisse, C. S. Bendall, "Estimating the Refractive Index Structure Parameter (C_n^2) Over the Ocean Using Bulk Methods," *Journal of Applied Meteorology*, Vol. 39, pp. 1770-1783, October 2000.

Zeisse, C. R., B. D. Nener and R. V. Dewees, "Measurement of low-altitude infrared propagation," *Applied Optics*, Vol. 39, No. 6, Feb 2000.

Hughes, H. G. and C. R. Zeisse, "Infrared Propagation Modeling Beneath Marine Stratus Clouds," *Journal of Atmospheric and Oceanic Technology*, vol. 17, no. 4, pp. 504-511, 2000.

Jensen, D. R., S. G. Gathman, C. R. Zeisse, C. P. McGrath, G. de Leeuw, M. H. Smith, P. A. Frederickson, and K. L. Davidson, "Electrooptical Propagation Assessment in Coastal Environments (EOPACE) Summary and Accomplishments," Submitted for publication in *Optical Engineering*, August 2000.

Reid, J.S., H. Jonsson, M. Smith, and A. Smirnov, Sea-salt particles in a coastal zone, *J. Geophys. Res.* (submitted), 2000.

Eck, T.F.,B.N. Holben, D. E. Ward, O. Dubovik, J.S. Reid, A. Smirnov, M. M. Mukelabai, N.C. Hsu, N. T. O'Neill, and I. Slutsker, Characterization of the optical properties of biomass burning aerosols in Zambia during the 1997 ZIBBEE experiment, *J. Geophys. Res.* (in press), 2000.

Christopher, S.A., X. Li, R.W. Welch, J.S. Reid, P.V. Hobbs, T.F. Eck, and B. Holben Estimation of downward shortwave irradiances in biomass burning regions during SCAR-B, *J. Atmos. Sci.,* (in press), 2000.

Conference Proceedings and Abstracts Related to FY00 Work:

Reid, J.S., and H. Jonsson, Evolution of the vertical profile and flux of large sea-salt particles in a coastal zone, AGU Fall Meeting, San Francisco, CA. December 10-15, 1999.

Pilewskie, P., J.S. Reid, and S. Tsay (1999), Measurements of the Sea-Surface Spectral reflectance in a Coastal region and estimates of solar spectral radiative forcing of a marine boundary layer aerosol, AGU Fall Meeting, San Francisco, CA. December 10-15, 1999.

Eck, T, B. Holben, O. Dubovik, A. Smirnov, J.S. Reid, I. Slutsker, AERONET remote sensing retrievals of aerosol optical properties for accumulation mode dominated aerosol types AGU Fall Meeting, San Francisco, CA. December 10-15, 1999.

Jensen, D. R., "Surf Generated Aerosols," J. Aerosol Science, vol. 31, sup. 1, pp. S538-S539, Abstracts of the 2000 European Aerosol Conference, Dublin, Ireland, 3-8 September 2000.

De Leeuw, M. M. Moerman, A. N. de Jong, C. Zeisse and K. L. Davidson, "Effect of Aerosols on Coastal Transmission," J. Aerosol Science, vol. 31, sup. 1, pp. S727-728, Abstracts of the 2000 European Aerosol Conference, Dublin, Ireland, 3-8 September 2000 .

Jensen, D. R., S. G. Gathman, C. R. Zeisse, and K. M. Littfin, "EOPACE (Electrooptical Propagation Assessment in Coastal Environments) Overview and Initial Accomplishments," Proceedings of Millennium Conference on Antennas and Propagation, AP2000, Davos, Switzerland, 9-14 April 2000.

Zeisse, C. R., A. Barrios, K. M.. Littfin, S.G. Gathman, "Low Altitude Infrared Propagation," Proceedings of Millennium Conference on Antennas and Propagation, AP2000, Davos, Switzerland, 9-14 April 2000.

Potvin, G., D. Dion, J.L. Forand, C.R. Zeisse, P.A. Frederickson, and K.L. Davidson, "Scintillation in the Littoral Battlespace," Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) Conference, April 2000.

Potvin, G., D. Dion, and J.L. Forand, C.R. Zeisse, P.A. Frederickson, and K.L. Davidson, "Scintillation in the Coastal Atmospheric Surface Layer," Boundary Layer and Turbulence Conference, Aspen, Colorado, Sept. 2000.

Doss-Hammel, S., and C. Zeisse, "Time-Frequency Analysis of Propagation in the Marine Surface Layer," presented National Radio Science Meeting of the International Union of Radio Science (URSI), January 4 – 8, 2000 at Boulder, Colorado.

Zeisse, C., A. Barrios, and S. Doss-Hammel, "Refractive Effects in Infrared Transmission," presented National Radio Science Meeting of the International Union of Radio Science (URSI), January 4 – 8, 2000 at Boulder, Colorado.

Barrios, A. and C. Zeisse," Applying the Parabolic Equation Method to Model Refractive Effects on Infrared Transmission," presented National Radio Science Meeting of the International Union of Radio Science (URSI), January 4 – 8, 2000 at Boulder, Colorado.