FORM A: GACP ACCOMPLISHMENT REPORT

Name: Philip A. Durkee
Institution: Naval Postgraduate School
TITLE: Development and Validation of Multiple-Satellite Data Sets for Global Aerosol Radiative Forcing.

ABSTRACT: Aerosol properties can be derived from numerous satellite data sets. Most aerosol retrieval schemes utilize a single sensor system such as NOAA AVHRR, CZCS, or Meteosat. This study proposes to combine the benefits of individual satellite sensors into a "composite" retrieval scheme. In particular retrievals with NOAA AVHRR nominally provide two daytime views per day. Although AVHRR provides high spatial resolution (1 km) and multi-wavelength observations, the temporal resolution is weak. The GOES Imager provides single-wavelength retrievals with similar spatial resolution to AVHRR but with lower signal-to-noise ratio (less accuracy). However, GOES provides observations as often as four times per hour. The first focus of this study will be to develop combined AVHRR-GOES retrievals that exploit the advantages of each system. In addition, collaboration with TNO Netherlands will investigate composite retrievals using AVHRR, GOES and the ERS-2 ATSR. ATSR adds multiple view angles to the mix of tools for retrieval of aerosol properties. ATSR data is available through TNO and this collaboration will make this data set available to the Science Team formed through this NRA.

The second focus of this study will be to advocate the preparation of comprehensive data sets for validation of retrievals prepared by the Science Team. Comparison of retrieval schemes as well as validation of an aerosol climatology will require intercomparison with common in situ, radiation and satellite data sets. Aircraft, surface (including ship), and satellite data will be used to test not only the absolute result of a retrieval (such as aerosol optical depth), but also the individual assumptions imbedded in the retrieval methods (such as aerosol model size distribution, scattering phase function parameterization, surface reflectance, etc.). These data sets would become standard, community data sets that all algorithms could be validated against.

GOALS: The goal of this research is twofold. First, the development of aerosol retrievals that combine the benefits of multiple satellite sensor systems will increase the information content of global and regional climatologies. Second, validation data sets will offer component-level verification of aerosol retrievals and provide the basis for comparison of various aerosol retrieval techniques.

OBJECTIVES: This project will provide two important components for the formation and validation of the aerosol climatology described in NRA-97-MTPE-16: multiple-satellite retrieval techniques and analysis of validation data sets. The aerosol properties important for assessment of radiative forcing vary on all time and space scales. The limitations of remote techniques impose severe constraints on the complete description of aerosol properties, especially when

including single sensor techniques. Further, the assumptions inherent in all retrieval schemes require validation of each component of the retrieval with in situ measurements.

APPROACH: Aerosol properties can be derived from numerous satellite data sets. Most aerosol retrieval schemes utilize a single sensor system such as NOAA AVHRR, CZCS, or GOES/Meteosat. In this project, a retrieval technique will be developed that combines the benefits of individual satellite sensors into a "composite" retrieval scheme. In particular retrievals with NOAA AVHRR nominally provide two daytime views per day. Although AVHRR provides high spatial resolution (1 km) and multi-wavelength observations, the temporal resolution is weak. The GOES Imager provides single-wavelength retrievals with similar spatial resolution to AVHRR but with lower signal-to-noise ratio (reduced accuracy). However, GOES provides observations as often as four times per hour.

The first focus of this study will be to develop combined AVHRR-GOES retrievals that exploit the advantages of each system. The retrieval will incorporate the two-wavelengths of the AVHRR and the temporal resolution of the GOES to provide more accurate retrievals of optical depth than could be performed with either sensor alone. Because of the improved GOES temporal resolution, this technique will provide critical insight into the diurnal variations of optical depth on regional scales.

Other satellite sensors that provide unique retrieval capabilities include CZCS-NIMBUS-7, OCTS-ADEOS, ATSR and others. This project will benefit from an established collaboration with Dr. Gerrit de Leeuw, TNO Physics and Electronics Laboratory, The Hague, Netherlands. We have collaborated on retrievals from AVHRR and ATSR (Along-Track Scanning Radiometer) on the ERS satellites. ATSR provides multiple wavelengths as well as dual views - nadir and forward. Of particular interest is the capability of usable values over land.

It is critical for the integrity and acceptance of the Aerosol Climatology, that satellite retrievals be validated against vertical profiles of measured aerosol absorption, scattering, size/surface area distributions, and compositions. This is necessary so that uncertainties in resultant aerosol radiative forcing are known. Validation cannot be limited to direct comparisons of various methods of optical depth retrieval (such as surface and airborne sunphotometer measurements). All satellite retrievals will contain assumptions about the aerosol properties that cannot be derived directly from the observed radiance. Therefore, validation must include tests of these assumptions.

TASKS COMPLETED:

Extensive validation activities have been conducted using the ACE-2 and TARFOX data sets

1. Comparisons of surface, ship-board, and aircraft sunphotometers with satellite retrievals. (TARFOX, ACE-2, Aerosols99/INDOEX)

2. Tests of aerosol model assumptions against in situ aircraft measurements of aerosol properties such size distribution, composition, and resulting radiative properties.

3. Validation within the context of complete column closure studies is continuing.

4. Tests of the effects of sunglint and cloud screening techniques.

Regional analysis of optical depth including wavelength variation and variation statistics was conducted for the 4 recent aerosol experiments (ACE-1, TARFOX, ACE-2, and Aerosols99/INDOEX).

Development of retrievals from combined NOAA AVHRR and GOES are in progress. Validation of these techniques include observations from TARFOX, EOPACE, and recent observations off the US West Coast.

FUTURE PLANS: The activity for the third year of this study will focus on completion of the component-level validation data sets and the completion/validation of the AVHRR-GOES algorithm. Work will also begin on including ATSR and other satellite systems in the multiple-satellite algorithms. A Ph.D. student (Cristina Gonzalez) from Utrecht University (Netherlands) is visiting NPS for two months to extend joint retrieval work to GMS and Meteosat Second Generation.

RESULTS:

1. Validation of AVHRR optical depth retrieval during ACE-2 shows comparison with surface, ship-board, and aircraft sunphotometers correlates to an RMS error of 0.02 in optical depth for both wavelengths of the AVHRR sensor (0.63 and 0.86 μm - central wavelength).

2. Component-level validation of inherent assumptions about aerosol properties in aerosol retrievals was conducted within the context of column closure experiments during ACE-2.

3. Regional analysis of optical depth and size properties were produced for the ACE-1, TARFOX, ACE-2 and Aerosols99/INDOEX field campaigns. This analysis shows the importance of producing analysis of variability as well as time-averaged properties. INDOEX results show important differences between GAC (4km resolution) and LAC (1km resolution) probably due to partial filling of pixels by clouds.

4. GOES optical depth retrievals provide consistency with AVHRR retrievals and sunphotometer observations when scattering phase function is

parameterized from wavelength variations observed in near-coincident AVHRR data.

FORM B: GACP SIGNIFICANT HIGHLIGHTS

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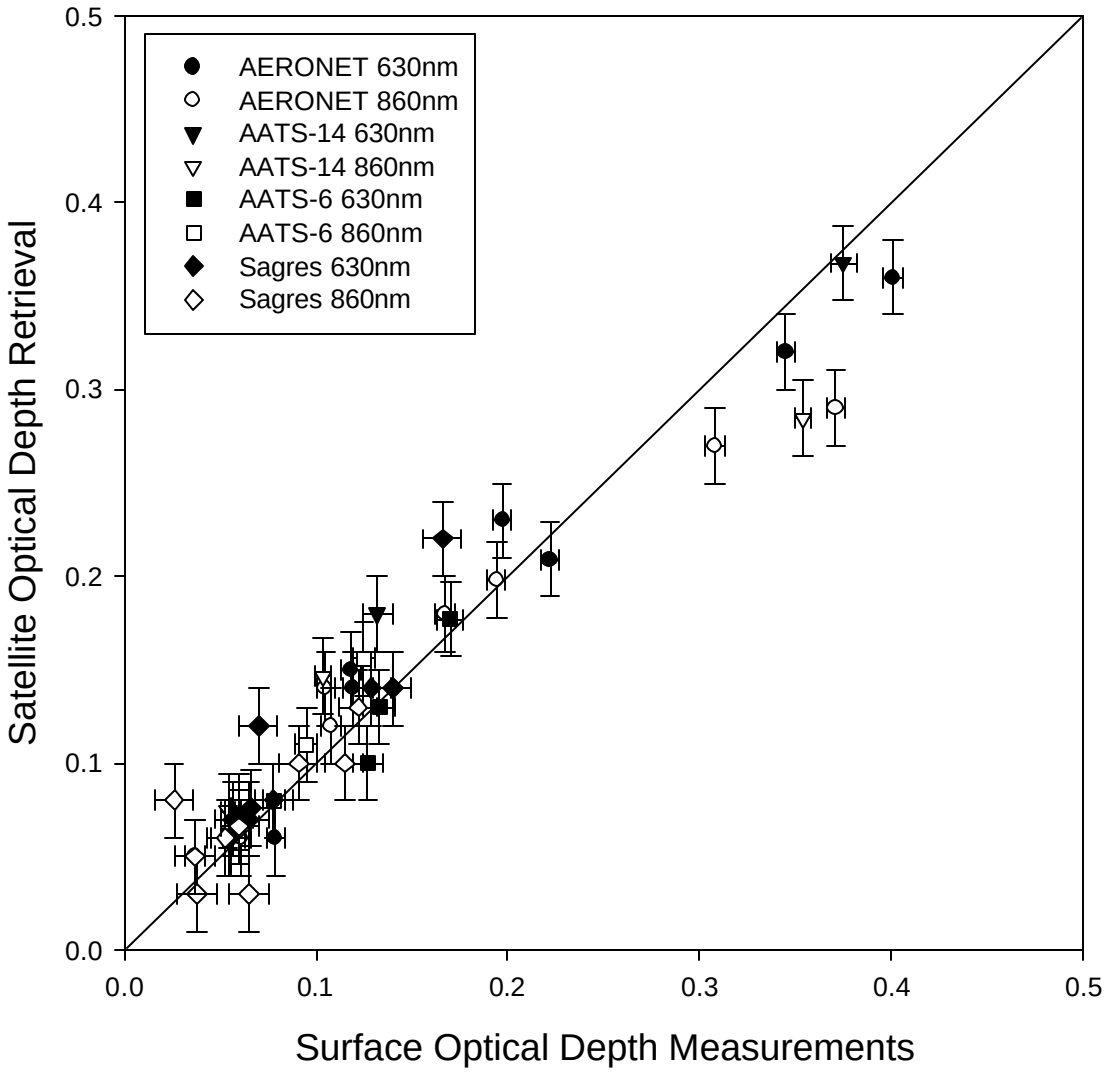
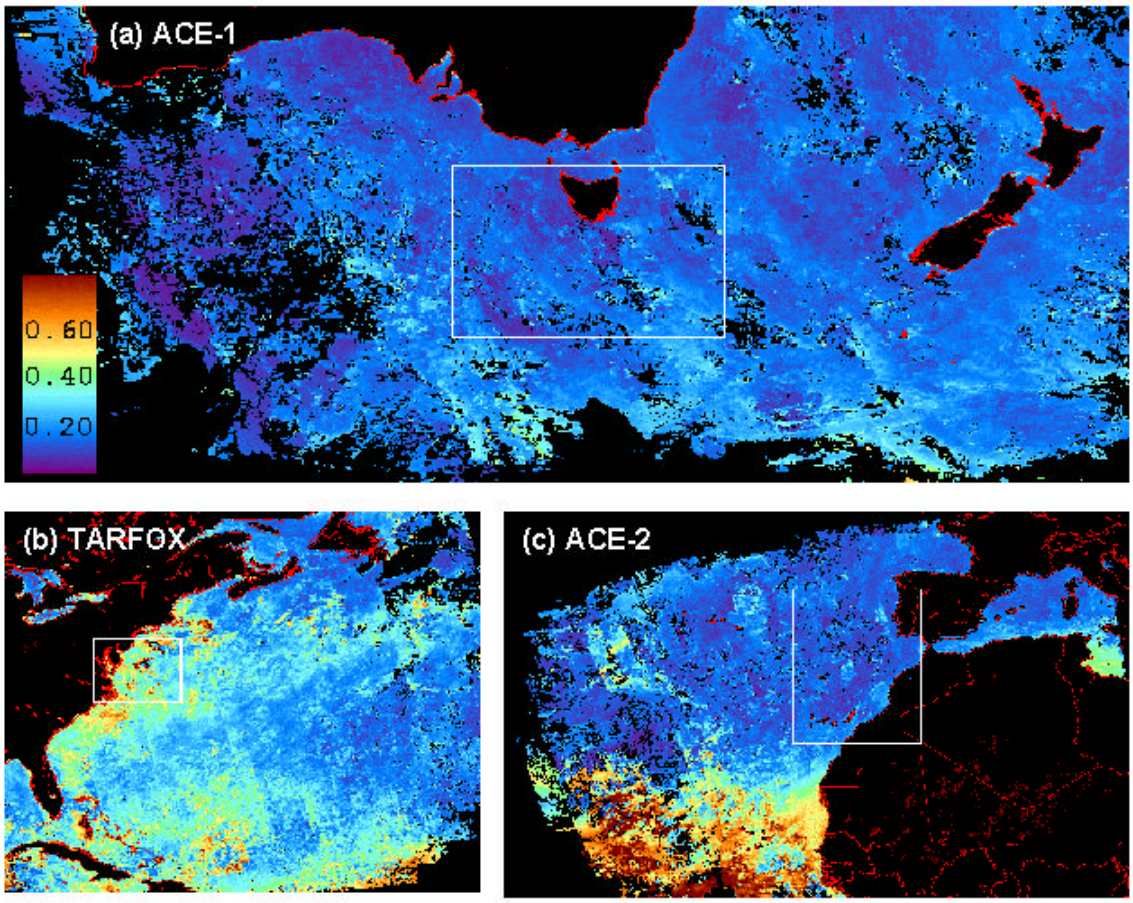
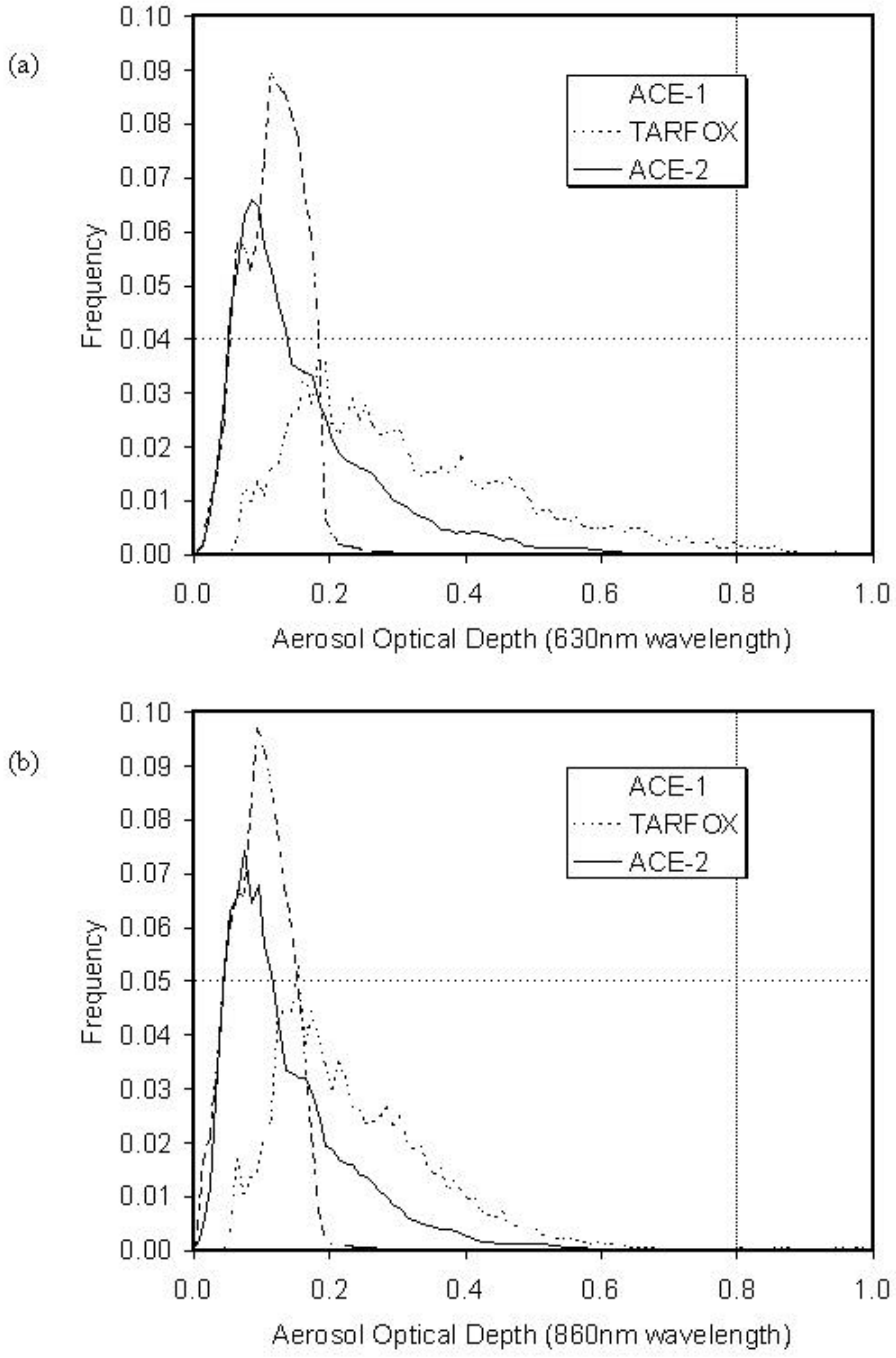
SIGNIFICANT HIGHLIGHTS:



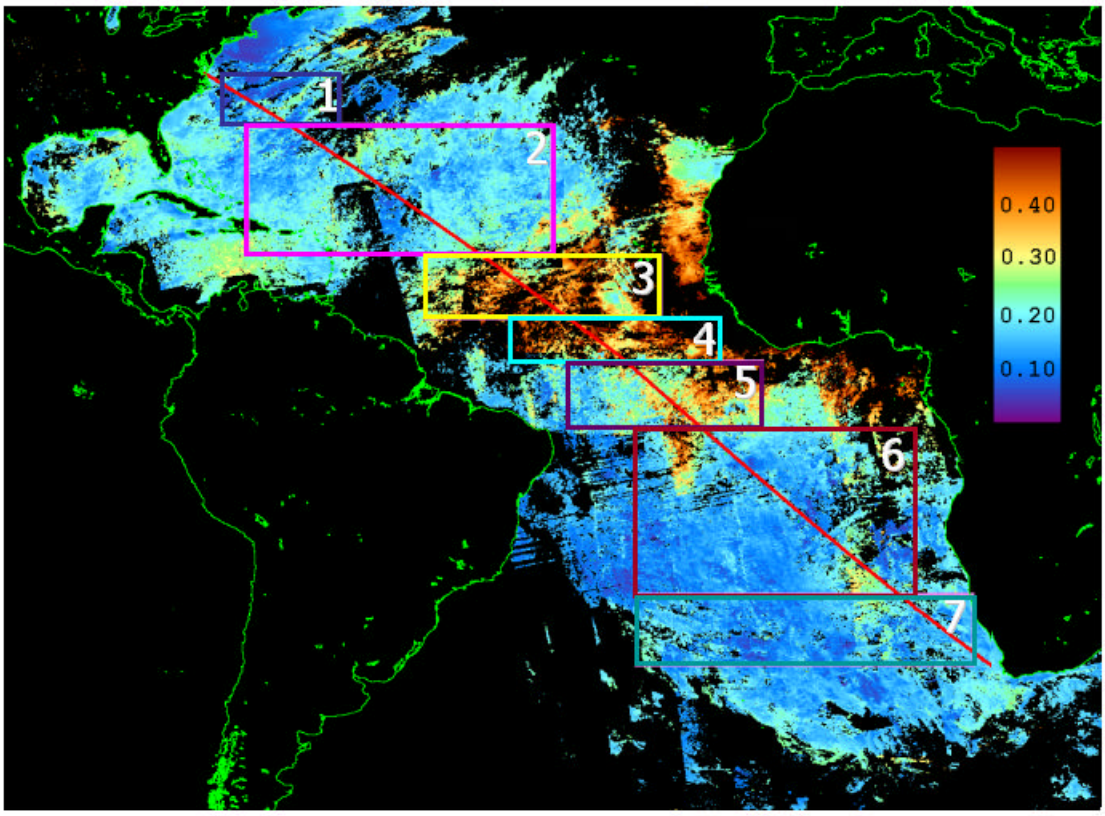
Scatter diagram of surface measured aerosol optical depth from surface (AERONET and Sagres), ship-board (AATS-6), and aircraft (AATS-14) sunphotometers versus aerosol optical depths retrieved from NOAA-14 AVHRR radiance measurements. The correlation is 0.88 and the standard error is 0.02 for both wavelengths.



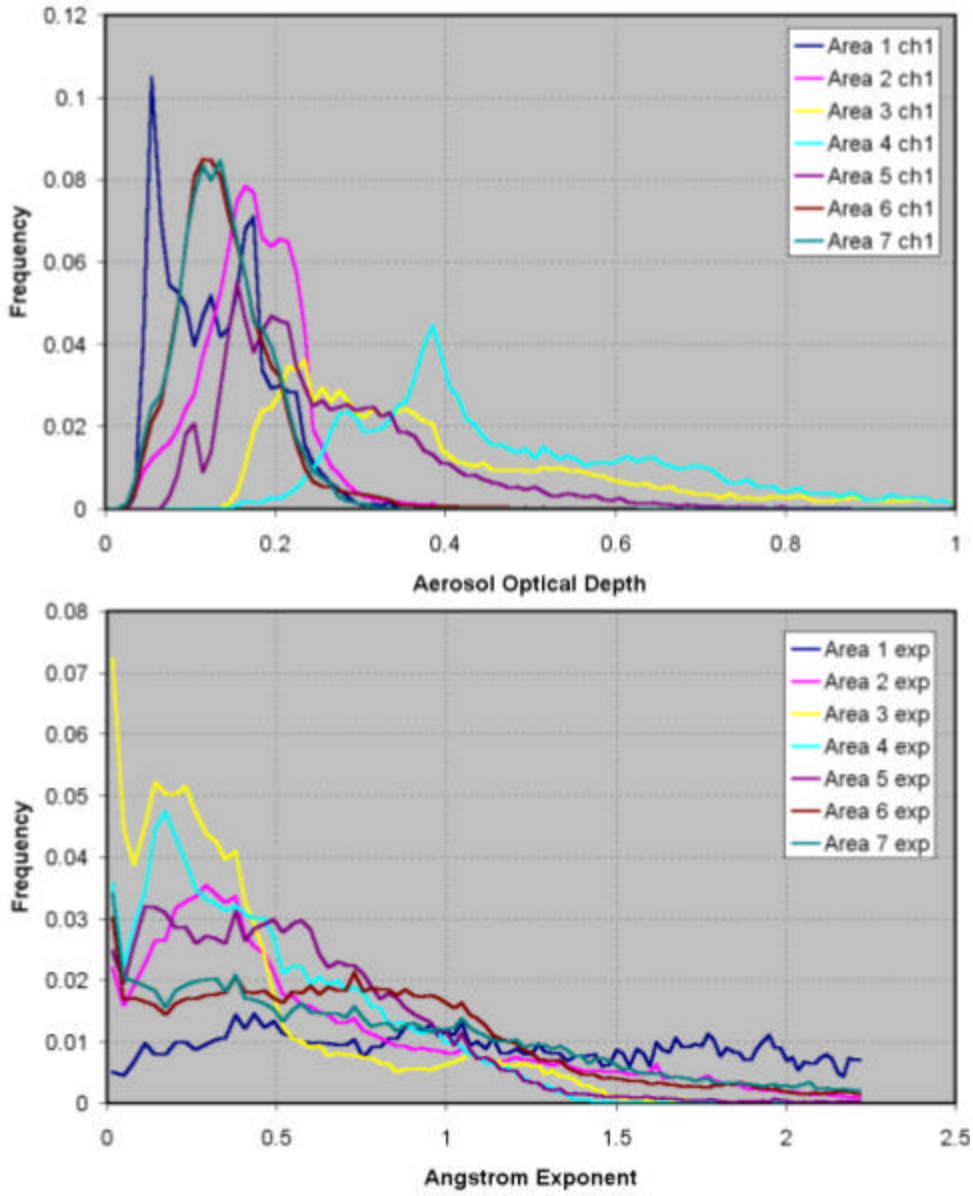
Composite of aerosol optical depth at 630 nm wavelength retrieved from NOAA-14 AVHRR on 10km grid for (a) ACE-1, (b) TARFOX and (c) ACE-2. The white boxes outline the area of operations for each experiment and define the region used for statistical analysis.



Frequency distributions of aerosol optical depth within the area of operations at (a) 630 nm and (b) 860 nm wavelength for ACE-1, TARFOX and ACE-2.

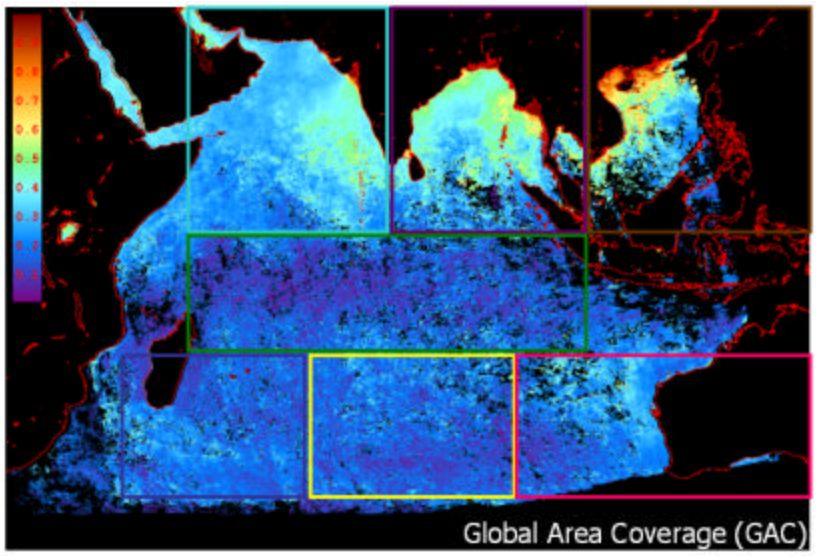


Composite of aerosol optical depth at 630 nm wavelength retrieved from NOAA-14 AVHRR on 10km grid for Aerosols99. The boxes outline the area of coherent aerosol regions and define the regions used for statistical analysis.

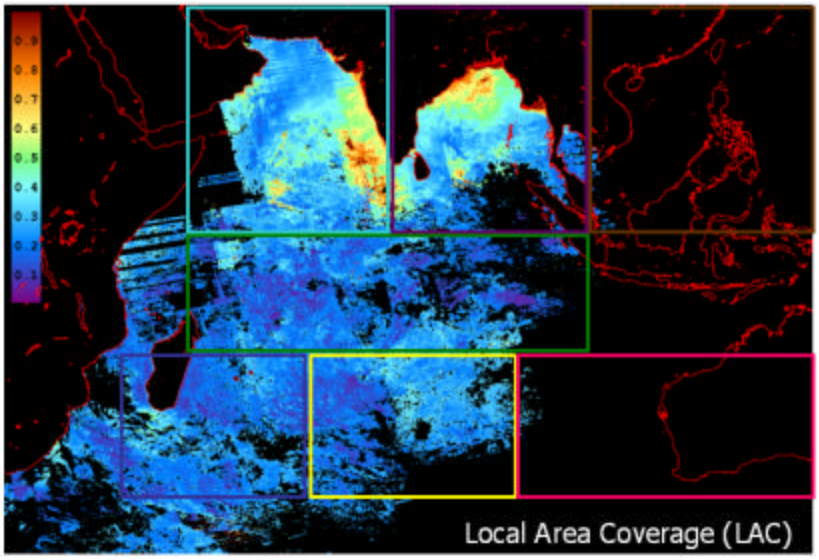


Frequency distributions of (a) aerosol optical depth at 630 nm and (b) Angstrom exponent within the boxed areas for Aerosols99.

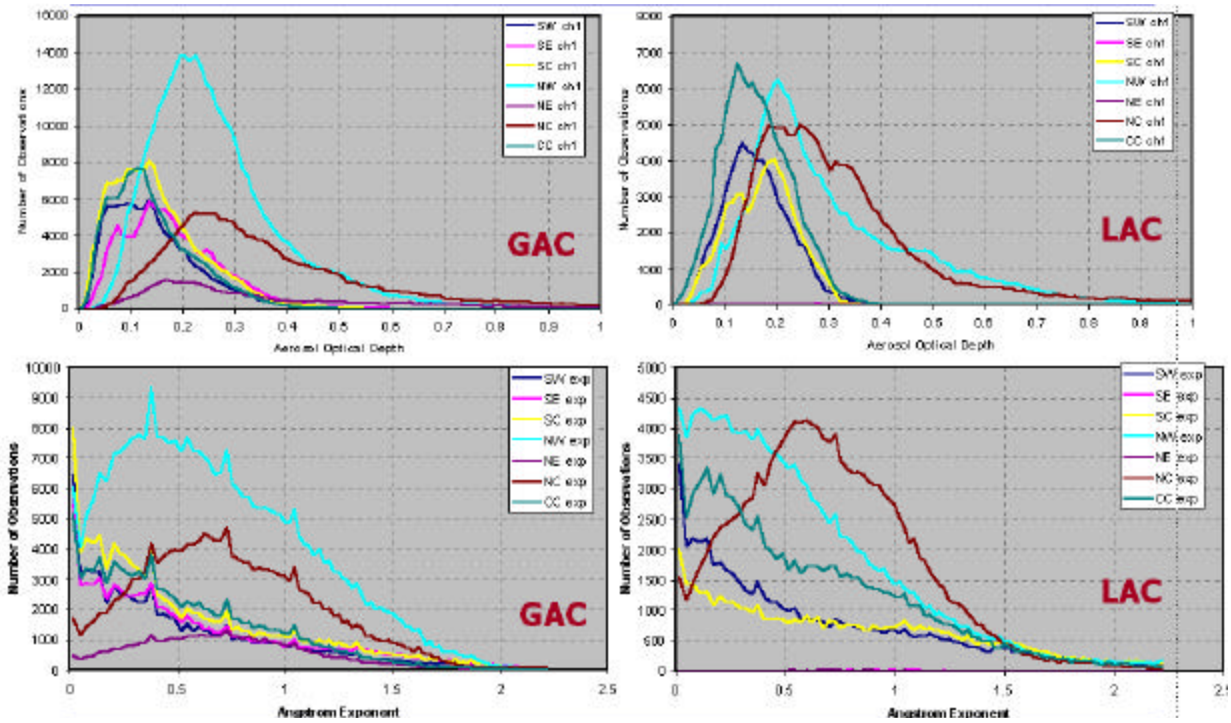
(a)



(b)



Composite of aerosol optical depth at 630 nm wavelength retrieved from NOAA-14 AVHRR on 10km grid for INDOEX. (a) is derived from NOAA GAC data (4km resolution) and (b) is derived from LAC data (1km resolution). LAC data was collected aboard the *R/V Brown* so does not cover as much area as the GAC data. The boxes outline the area of coherent aerosol regions and define the regions used for statistical analysis.



Number distributions of (a) aerosol optical depth at 630 nm and (b) Angstrom exponent within the boxed areas for INDOEX GAC data (4km resolution) and LAC data (1km resolution).

FORM C: FUTURE PLANS

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The activity for the third year of this study will focus on the completion/validation of the AVHRR-GOES algorithm. Work will also continue on including ATSR and other satellite systems in the multiple-satellite algorithms.

FORM D: GACP BIBLIOGRAPHY

Name: Philip A. Durkee
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