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# Aerosol Properties Derived From the PREDE POM-01 Mark II Sun Photometer

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## INTRODUCTION

Two PREDE POM-01 MarkII radiometers are part of the instrument pool managed and maintained by the Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project to support ocean and atmospheric measurements. The PREDE is the only sun photometer commercially available that is capable of automatically measuring aerosol properties. The pool also consists of 1 Micropulse (MPL) Lidar, 1 SIMBAD and 2 SIMBADa, 12 MicroTops, and 14 Cimel sun photometers. Because the SIMBIOS Project is dedicated to merger of data products from multiple ocean color missions, measuring the atmospheric contribution is crucial. For this reason, aerosol optical thickness and sky radiance measurements from handheld, and shipboard sun photometers have been made by SIMBIOS investigators on many experiment cruises. During the Asian Regional Aerosol Characterization Experiment (ACE-ASIA) in March and April 2001, two PREDE units were deployed to measure the aerosol properties onboard the National Oceanic and Atmospheric Administration (NOAA) Research Vessel (R/V) *Ron Brown*. Measuring the atmospheric contribution for a ship is not easy since the movements of the vessel need to be taken into account. The PREDE POM-01 MarkII was designed to account for these conditions. In this poster, the PREDE POM-01 MarkII, its features, and its characteristics are described. The calibration techniques and preliminary results obtained during the ACE-ASIA campaign are also presented and discussed.

## FEATURES OF THE PREDE POM01 MARKII

Fig 1.: General View

Fig2.: Optical Head

Fig 3.: Wide FOV Camera

Fig 4.: Narrow FOV Camera

The PREDE POM01 is an automatic sun and sky radiometer produced by PREDE Inc. (Tokyo) for measuring sky radiances and direct solar irradiances. The instrument is mounted on a dual axis robot controlled by servomotors. The PREDE POM01 MarkII tracking the sun is shown in Figure 1.
The main optic element (as shown in Figure 2) consists of seven interference filters placed in front of a silicon photodiode. A collimator is used to stop scattered light, while the instrument measures the sky radiances. Sun tracking is achieved using a four-quadrant silicon detector located below the main optical element. A narrow field of view CCD (Charged Coupled Device) camera is mounted on the optical head (Figure 4) to keep tracking the sun when the sun photometer is onboard a moving ship. A wide field of view CCD camera is also placed on top of the robot (Figure 3) and records the position of the sun while the ship moves.
A computer operates the sun photometer, controls the measurement protocols, and stores the data.

http://www.prede.com

## CHARACTERISTICS OF THE PREDE POM01 MARKII

The PREDE POM01 is equipped with seven channels centered at 315, 400, 500, 675, 870, 940, and 1020 nm whose spectral transmittances are shown in Figure 5. The bandwidths are 10 nm wide.
The field of view (FOV) of the radiometer as given by the manufacturer ranges between 1 and 1.5 degrees. The FOV was chosen to help catch the entire solar disk and measure the direct solar radiation. The effect of the diffuse sky radiance is negligible. The FOV can be determined using a specific protocol to scan the sun. The result is shown in Figure 6 at 870 nm. The solid viewing angles (SVA) are determined for each band and are summarized in Table 1. The FOV was determined in Japan after the ACE-ASIA campaign and at Goddard Space Flight Center (GSFC) in July 2001. Figure 7 shows the comparison at 870 nm.
The determination of the solid viewing angle is essential in the process of analyzing the optical data collected with the sun photometer (Nakajima et al. 1996).

TABLE 1: Solid Viewing Angles in millisteradian

| Date | location | 315nm | 400nm | 500nm | 675nm | 870nm | 940nm | 1020nm |
|---|---|---|---|---|---|---|---|---|
| 04/27/01 | Japan | 0.277 | 0.273 | 0.271 | 0.274 | 0.2728 | 0.277 | 0.273 |
| 05/28/01 | Japan | 0.262 | 0.260 | 0.257 | 0.254 | 0.2607 | 0.255 | 0.256 |
| 07/06/01 | GSFC1 | 0.312 | 0.316 | 0.319 | 0.281 | 0.2958 | 0.301 | 0.298 |
| 07/06/01 | GSFC2 | 0.276 | 0.269 | 0.278 | 0.277 | 0.2826 | 0.289 | 0.285 |
| 07/06/01 | GSFC2 | 0.273 | 0.261 | 0.265 | 0.266 | 0.2664 | 0.264 | 0.259 |

Fig 5.: Filter Spectral Transmission

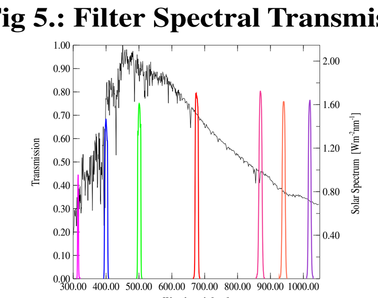


Fig 6.: Normalized Signal channel 5 - 870 nm

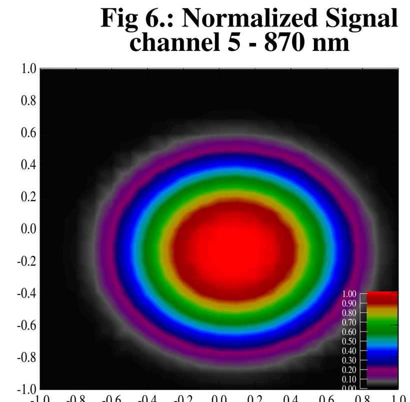
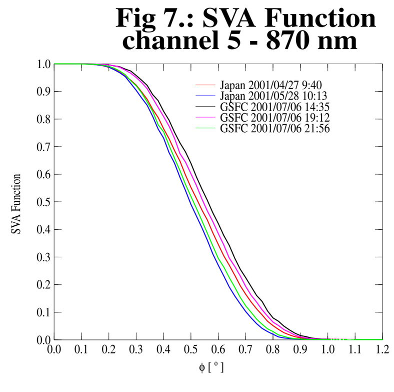


Fig 7.: SVA Function channel 5 - 870 nm



## CALIBRATION OF THE PREDE POM01 MARKII

Fig 8.: Langley Plot for July 6, 2001

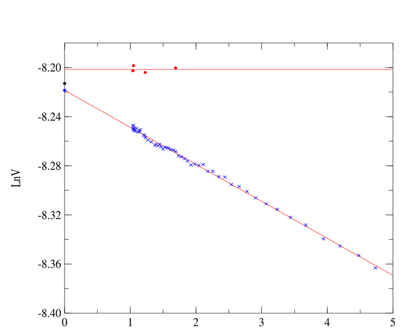


Fig 9.: AOT measured by the Master CIMEL #101 on July 6, 2001

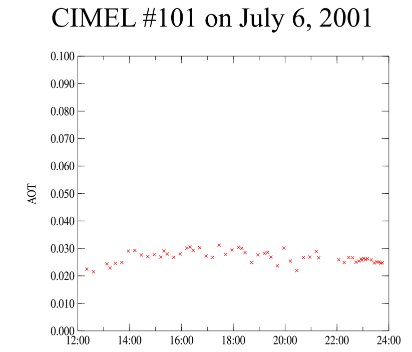
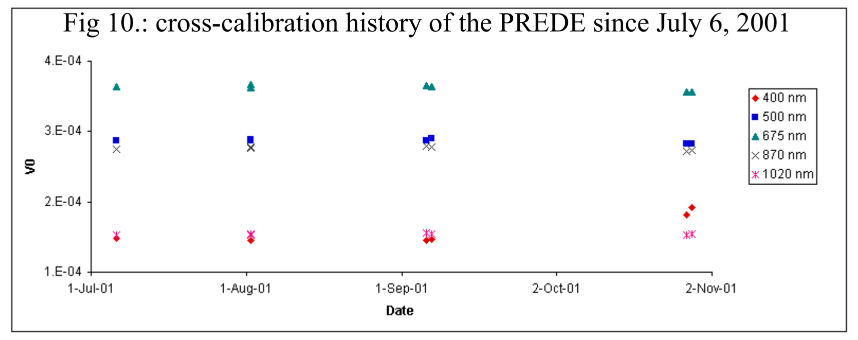


Fig 10.: cross-calibration history of the PREDE since July 6, 2001



The calibration of the PREDE Sun Photometer consists of measuring the top-of-atmosphere voltages (V0) for every channel. Several techniques are used:
- The standard method, known as the Langley Technique (Fig. #8) consists of plotting the measured voltages versus the airmass during a clear day. Extrapolating the straight line to the Y axis gives the V0 (blue dot in Fig. #8), assuming that the total optical thickness is constant during the calibration. The technique gives poor results at ground level because the required conditions rarely occur.
- The improved Langley Technique consists of plotting the measured voltages versus m*τ to account for the variation of the aerosol optical thickness (AOT). The black dot in Figure 8 corresponds to the result of this technique. The method is used in the skyrad code to analyze all PREDE measurements (Nakajima et al. 1996).
- The cross-calibration technique consists of comparing the voltages measured concurrently by the PREDE and a well-calibrated CIMEL (Master) sun photometer. The V0 are retrieved from the averaged ratios for which the standard deviation is not higher than 1% (red dots in Fig. #8).
The last technique is used for the entire SIMBIOS pool of sun photometers. The AOT measured by the Master CIMEL on July 6 is shown on Figure 9. Figure 10 shows the cross-calibration history of the PREDE PS1000111 from July to October 2001 during clear conditions and using different master CIMELs.
The cross-calibration performed on July 6 2001 was used to process data from the ACE-ASIA campaign.

## AEROSOL PROPERTIES RETRIEVED AT GODDARD SPACE FLIGHT CENTER

Fig 11.: AOT retrieved on September 7, 2001

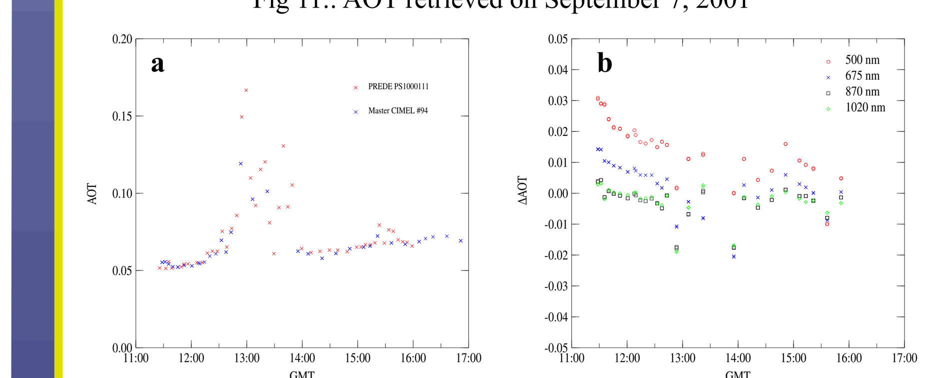
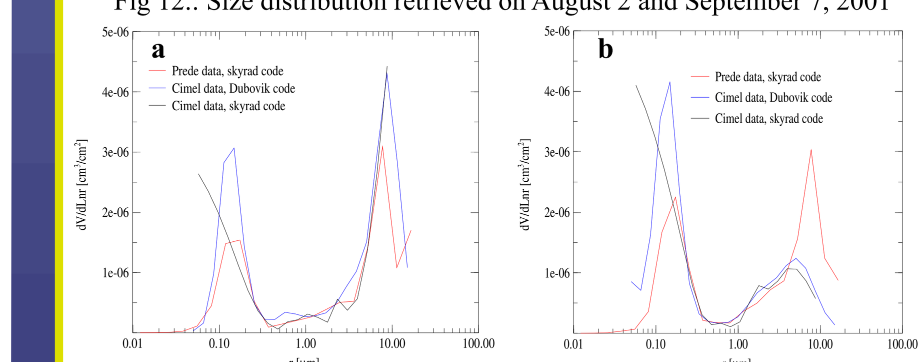


Fig 12.: Size distribution retrieved on August 2 and September 7, 2001



The cross-calibration performed on July 6 was used to process the data collected at Goddard from July to October, 2001. The skyrad code (Nakajima et al. 1996) was used to retrieve the aerosol optical thickness (Fig. #11) and the volume size distribution (Fig. #12) from data collected with the PREDE POM01 Mark II.
Figure 11 a shows the AOT at 870 nm derived from data collected by the PREDE and from data collected by the Master CIMEL at the same time on September 7. A good agreement is retrieved in all common channels as shown in Figure 11 b. The maximum AOT difference between sun photometers is 0.03 at 500 nm. The agreement in other channels is better.
Doing a cross-calibration of the PREDE every three months is recommended to accurately derive the AOT. A modification of the protocol of measurements is also considered to acquire more direct solar measurements and increase the number of simultaneous measurements with the Master CIMEL.
The volume spectrum distributions are derived after inversion of the diffuse sky radiances measured in the almucanthar of the sun. The inversion of the measurements collected on August 2 and September 7 are presented in Figures 12 a and 12 b (red lines). Only size distributions for which the original signal was reconstructed better than 5% were used and averaged. The blue and black lines correspond to the size distributions derived from the CIMEL data collected on the same days and analyzed using Dubovik's code (Dubovik et al. 2000) and the skyrad code, respectively.

## ACE-ASIA EXPERIMENT

ACE-ASIA was the fourth experiment organized by the International Global Atmospheric Chemistry (IGAC) Program. The experiment took place off the coasts of China, Japan and Korea during the spring of 2001 to measure aerosol particle properties.
The SIMBIOS Project dedicated significant effort to this program. Four SIMBIOS Principal Investigators (PIs) participated: Robert Frouin from Scripps Institute, David Siegel from the University of California, Mark Miller from the Brookhaven National Laboratory and Judd Welton from the NASAGoddard Space Flight Center. The SIMBIOS Project provided one PREDE POM01 Mark II and a second PREDE was borrowed from the Center for Climate Research in Tokyo. The SIMBIOS Project also provided real-time SeaWiFS data. Finally, the SIMBIOS project provided a Cimel for a station at Anmyon (Korea).
Two PREDE sun photometers were onboard the R/V *Ron Brown* (Fig. #13) and collected measurements between March 16 and April 22 (Fig. #14). The Blue circle corresponds to the Cimel station. The AOT is first derived from the direct solar irradiances measured by the PREDE. Figure 15 shows the AOT retrieved by MicroTops #3772 (a) and by PREDE #PS100011 (b) during the whole campaign. The size distribution of the particles is then retrieved from the sky radiances measured by the PREDE for several scattering angles.
The region is known to be the largest source of aerosols emitted by human activities or natural processes, such as wind borne dust. Different particle types vary in composition and size and have different radiative effects on the atmosphere. ACE-ASIA helps scientist understand the influence of aerosols on climate.
Many research organizations and groups participated to the ACE-ASIA activities. A global description can be viewed at

http://saga.pmel.noaa.gov/aceasia/

Fig 13.: Two PREDE POM01 Mark II onboard the R/V *Ron Brown*

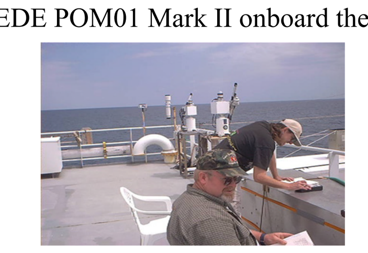


Fig 14.: Data collected with both PREDE during ACE-ASIA

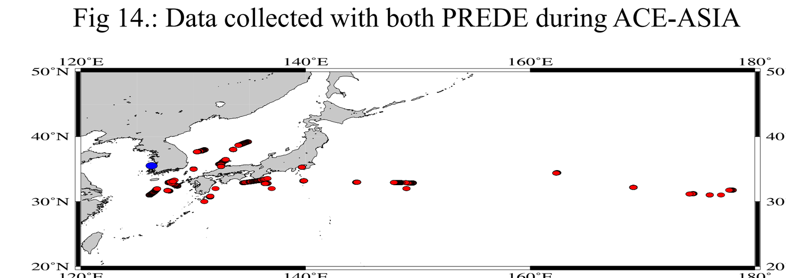
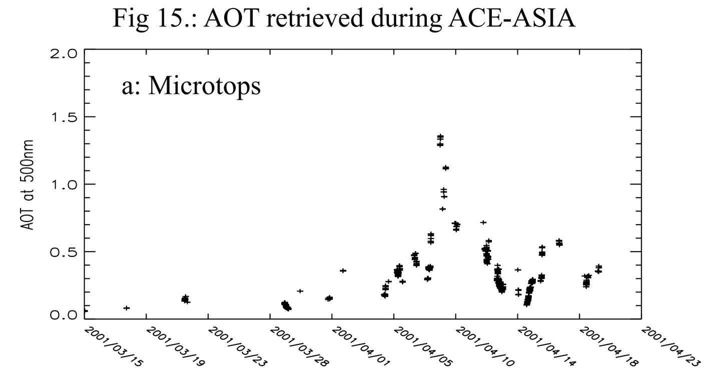
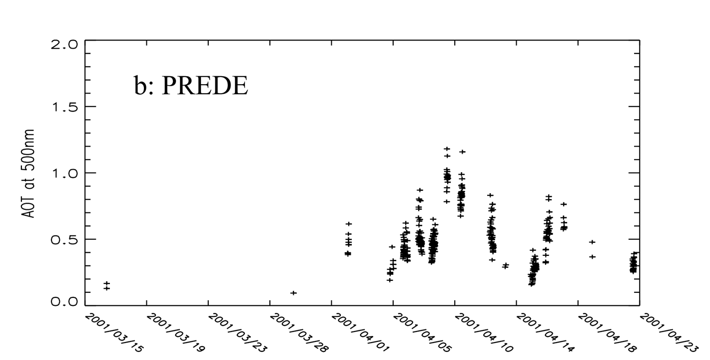


Fig 15.: AOT retrieved during ACE-ASIA




## AOT RETRIEVED DURING ACE-ASIA

Fig 16.: AOT at 870 nm measured a) on April 7 and b) on April 9 2001

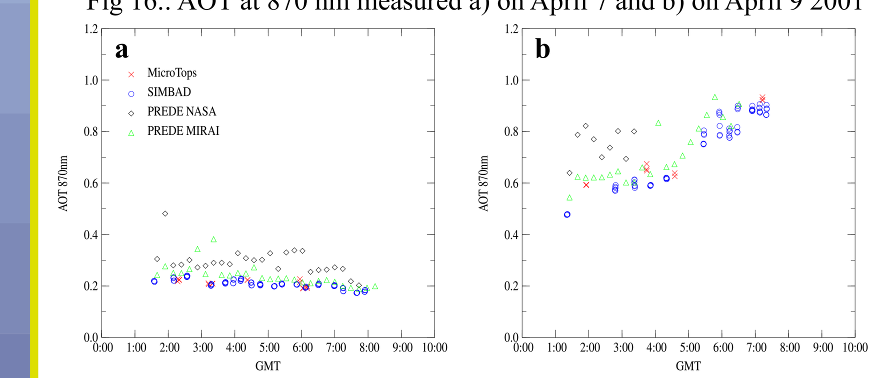
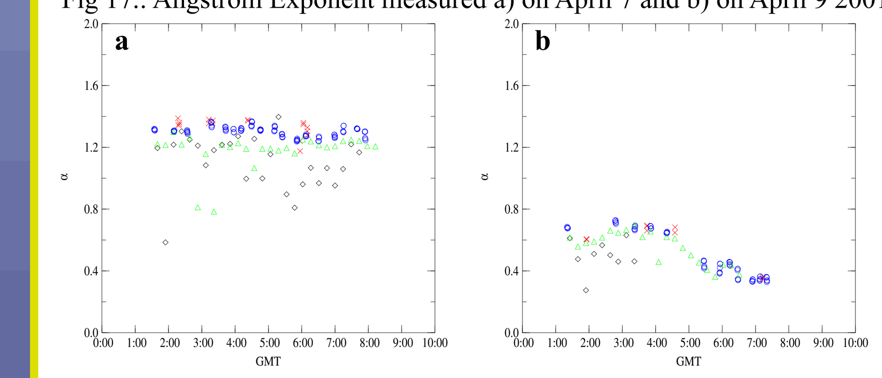


Fig 17.: Angstrom Exponent measured a) on April 7 and b) on April 9 2001



The skyrad code (Nakajima et al. 1996) was used to derive the AOTs from data collected by both PREDE instruments during ACE-ASIA. They are compared with the AOTs derived from the data collected with two handheld sun photometers, a MicroTops and a SIMBAD, carried and maintained by two SIMBIOS PIs.
The AOT at 870 nm retrieved on April 7 and April 9 are shown in Figure 16 a and 16 b.
The Angstrom exponent is computed from the AOT measured from 400 nm to 870 nm and are shown in Figure 17 a for April 7 and in Figure 17 b for April 9. A screening algorithm was applied to remove the outliers and account for the clouds.
The AOT and Angstrom exponent retrieved by the two handheld sun photometers agree very well; however because of the moving ship, the retrieval of the optical thickness from both PREDE instruments is quite noisy. The correction for the ship's movement is not perfect and needs further investigations. Nonetheless, using a screening algorithm similar to the one applied to a handheld sun photometer, provides a reasonable comparison. The retrieval from the PREDE Mirai appears to be better.
The two days show the different aerosol properties that occurred in the region. April 7 was clearer than April 9 and show higher Angstrom exponent. The size distribution should be quite different as well.

## AEROSOL SIZE DISTRIBUTION RETRIEVED DURING ACE-ASIA

Figure 18 shows the volume size distribution for April 7 retrieved from both PREDE instruments compared to the volume size distribution derived from the CIMEL data collected in Anmyon Island off the coast of Korea. The research vessel cruised on April 7, 400 km off the coast of Korea (132$^{o}$ longitude 36$^{o}$ latitude) while the CIMEL station is located at 126$^{o}$ longitude and 36$^{o}$ latitude. Both the PREDE and the CIMEL show good agreement. A fine mode (0.15 µm) and a coarse mode (2 µm) are well observed.
The volume size distributions were also retrieved by both PREDE instruments on April 9 (Fig. #19). The red lines correspond to the data averaged from the morning and the blue lines the data averaged from the afternoon. Only size distributions for which the original signal was reconstructed better than 20% were used and averaged. The retrievals from both PREDE agree very well on the morning and on the afternoon. A coarse mode (2.5 µm) is clearly observed on April 9 and the fine mode is reduced compared to April 7. The significant coarse mode and most probably the reduced fine mode explain the small Angstrom exponent retrieved on April 9 compared to April 7. The Anmyon CIMEL station retrieved the significant coarse mode as well, but also observed a significant fine mode. It has to be noted that on April 9 the ship cruised farther from the coast than April 7 and 1000 km from Anmyon, and measured mainly sea salt particles.

Fig 18.: Size distribution retrieved on April 7, 2001

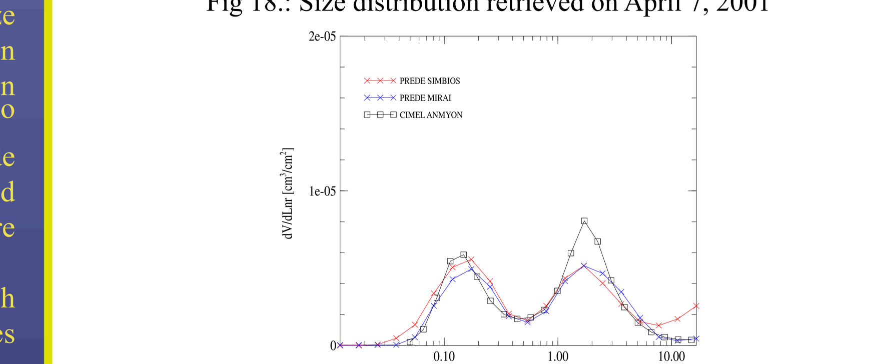
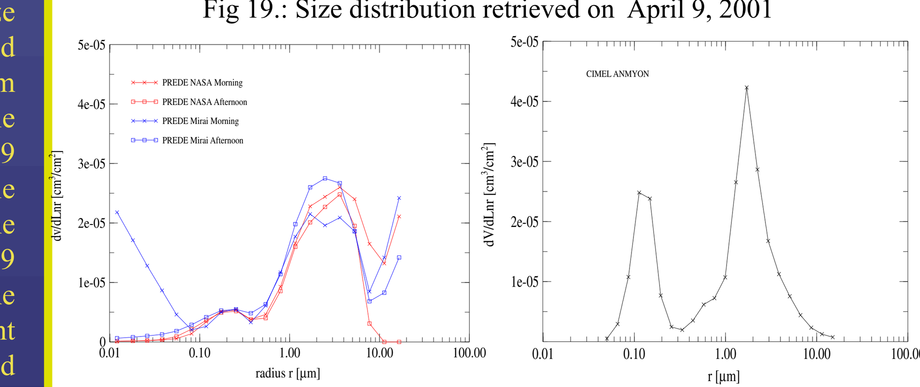


Fig 19.: Size distribution retrieved on April 9, 2001



## Conclusions and Outlook

Two new radiometers specifically designed to collect atmospheric measurements onboard research vessels were used during the ACE-ASIA international campaign. The PREDE POM01 Mark II is the only sun photometer that is commercially available and capable of automatically measuring aerosol properties. Two PREDE were deployed onboard the R/V *Ron Brown*, one maintained by the SIMBIOS Project and one maintained by the Center for Climate Research in Tokyo. Both instruments have successfully collected AOT and volume spectrum distribution during March and April 2001. Although the retrieval of the AOT with both PREDE instruments showed some issues which need investigation, the preliminary retrievals of the aerosol size distribution were in good agreement with the retrieval from the CIMEL measurements. The data were processed using the skyrad package using preliminary input parameters; further analysis needs to be done.

The calibrations of one of the PREDE were performed at GSFC using a master instrument and the stability of the PREDE radiometer was demonstrated over a three month period. The AOT was not as noisy as onboard the research vessel. The size distributions retrieved from the data were reasonable and also compared well with the CIMEL retrieval.
The Angstrom exponent is easy to compute and is commonly used to determine whether small or large particles were present in the atmosphere; however the retrieval is often poor and is unable to estimate the proportions of fine and large particles. Measuring the size distribution helps gather significant knowledge of the aerosol properties. AOT measurements tell scientists how the aerosols scatter and absorb the radiation, whereas the size distribution gives more information on the nature of the aerosols. The preliminary results show clearly that the PREDE radiometers are able to provide such information onboard the ship and is a good complement to the coastal CIMEL stations.

Future analysis
- Continue working with the skyrad code to refine the preliminary results obtained during ACE-ASIA by tuning different input parameters.
- Analyze the retrieval of the single scattering albedo, the refractive index, and the phase function.
- Work with the PREDE company to improve the protocols in order to refine cross-calibration and enable sphere calibration.
- Use the sphere calibration to derive the calibrated diffuse sky radiances. Furthermore, be able to use other radiative codes to invert the measurements and derive the aerosol size distribution.
- Combine the sun photometer measurements with the LIDAR retrievals which give vertical aerosol distribution.

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