GACP 3rd Year Progress Report

Remote Sensing of aerosol over land with AVHRR

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Form A. 3rd Year Progress Report

Abstract

This project is designed to retrieve aerosol optical depth over land from AVHRR when and where an aerosol signal is present using the Pathfinder-Atmosphere (PATMOS) data. Research began in the Autumn of 1999 (the second year of GACP work) with the hire of Ken Knapp to perform the research at NOAA/NESDIS. Since then, research status and results have been presented at conferences and in a peer-reviewed journal. Research has shown that there is an aerosol signal in the PATMOS data through comparisons with the Aerosol Robotic Network (AERONET), however, it is convoluted by the contribution of surface reflectance. Research showed that attempts to remove the surface bidirectional reflectance distribution function (BRDF) enhance the aerosol signal. Also, the surface BRDF can be retrieved from temporal composites of observations, allowing correction for the surface and Rayleigh contribution to satellite-detected reflectance. In the past year of work, the first retrievals of aerosol over land have been made and show the likelihood of retrieving aerosol over land for vegetated surfaces around the world.

Goal

The goal of this research is to exploit the 19 years of AVHRR observations to estimate aerosol signal over land for the last two decades when and where an aerosol signal is present.

Objectives

The objectives stated in the 1st year progress report are:

1) Develop an automated algorithm for the retrieval of aerosol optical depth (AOD) over land where an aerosol signal is present in the cloud-free reflectance data
2) Validate this algorithm using regional spectral AOD datasets from NASA's AERONET
3) Explore ways of extending to other grid cells and times away from AERONET
4) Evaluate the performance of the algorithm when implemented into the GACP global AVHRR reprocessing system

These continue to be the primary objectives of the research. During the past year, research has concentrated on the development of a global algorithm to retrieve aerosol information.

Tasks Completed

While research during the first year of the GACP was hindered (i.e., no scientist to do the research prior to Sep. 1999), we feel that we have made significant advances during the past two years of research. We also feel that the remaining work (performed during the no-cost extension) will provide a valuable contribution to the GACP in the 20-year record of aerosol optical depth from NOAA/AVHRR. The following is a summary of our research results during the first year of work followed by a detailed description of results from this past year.

Summary of Year 2 Accomplishments

The following is a short summary of research completed between September 1999 and September 2000.

- *Hire of Ken Knapp* – Ken Knapp was hired as a visiting scientist to perform the GACP research at NOAA/NESDIS/ORA.
- *Signal in PATMOS data found* – With comparisons to AERONET, the PATMOS visible reflectances were found to have an aerosol signal, although it was significantly affected by the surface BRDF.
- *Ocean LUT algorithm not useful over land* – The ocean algorithm proved of little value over land (this research was performed following the original statement of work).
- *Preliminary enhancement of aerosol signal* – The aerosol signal was found to be enhanced by a simplistic removal of the BRDF using a polynomial fit of the data. While this was primitive, it provided a "proof of concept" toward our efforts to remove the BRDF effects and enhance the aerosol signal.
- *Modeled BRDF correction further enhances aerosol signal* – While the above analysis was overly simplistic in its treatment of the surface properties, the ensuing retrieval of the actual BRDF parameters (following the Rahman et al. (1993) surface reflectance model) proved fruitful in its application. Realistic BRDF parameters were retrieved which yielded better aerosol signal (i.e., higher correlation) than the polynomial fits.

Year 3 milestones

The following is a detailed description of research accomplished from October 2000 to September 2001.

Initial retrieval of PATMOS aerosol optical depth over land and comparison with AERONET

Prior to the retrieval of τ, PATMOS observations had been compared to AERONET τ observations in a variety of ways: first, reflectances were compared, then reflectances corrected for the surface BRDF were compared. These comparisons were between deviations in PATMOS cloud-free reflectances and aerosol

optical depth from AERONET. In Year 3, aerosol optical depth was retrieved from PATMOS at AERONET sites by estimating the parameters of the surface BRDF then using the deviation from the top-of-the-atmosphere reflectance to retrieve an aerosol optical depth. The retrieval results were highly correlated at some sites and less at others, with correlation generally depending on the surface cover at the site. That is, areas with higher surface albedo generally had lower correlation than sites with darker surfaces. An example of two sites showing high correlations is provided in Figure 1. Both Concepcion and Los Fieros (Fig. 1a and 1b, respectively) have correlations larger than 0.8 and are located in the biomass burning region of South America.

Initial global results of PATMOS Aerosol over Land

The initial retrieval was extended to the entire globe which allowed the mapping of global aerosol optical depth over land. Again, the testbed for such maps was South America. Three examples are provided.

The retrievals were qualitatively compared to aerosol signals in existing data sets. Figure 2 provides a comparison of PATMOS Aerosol over Land (PAL) with the Automated Smoke Aerosol Detection Algorithm (ASADA). ASADA is a decision tree which determines areas of a GOES-8 image over South America which are covered by smoke (which was developed at CIMSS). You can see that the smoke plume in the PAL data on 28 Aug. 1995 (Fig 2a) closely corresponds with the GOES-8 visible image (Fig 2b) and the ASADA data (Fig 2c) as well. Also, TOMS has shown the ability to detect absorbing aerosols. Corresponding TOMS and PAL data are shown in Fig 3 for 31 Aug. 1998. Again, a smoke plume emanating from South America has very similar spatial pattern in both data sets.

Last, temporal averaging has been applied to PAL data and merged with the PATMOS-2/Aerosol Optical Depth (AOD) (derived using the NESDIS ocean algorithm: the 2nd generation aerosol retrieval algorithm). The average AOD for 27 August through 1 September 1995 is shown in Fig 3. Another smoke plume, originating in Brazil, is transported south, then east off the continent. The plume is continuous between the PAL and PATMOS/AOD data. The result shows the possibility for creating an aerosol climatology from PATMOS data set.

Retirement of Dr. Larry Stowe

Unfortunately, Larry Stowe retired on September 21, 2001. He leaves ORA to pursue his retirement career in providing golf travel packages in Southern France (visit www.stoweawaytours.com). Ken Knapp will continue the GACP research with Dr. Istvan Laszlo (NESDIS/ORA) as government supervisor.

Current Status

In light of the recent milestones, the project is poised to perform a full global retrieval. However, this requires massive look up tables and significant computing time. Work is currently underway to perform these calculations and produce aerosol optical depths over land over the past 20 years.

Form B. Significant Highlights

While the research performed during this period represents progress toward the end goal, significant highlights include:

1. The acceptance for publication in the *Journal of Atmospheric Science* of the initial efforts to quantify the aerosol signal in the PATMOS dataset.
2. The demonstration of the ability to merge the PATMOS/AOD with optical depth values derived in this research.

Form C. Statement of Work for No-Cost Extension

Further research will be toward the production and validation of the aerosol optical depth data.

October 2001 – January 2002

This time period will consist of production of the global aerosol over land climatology. It will primarily consist of processing the large amount of data.

February 2002 – October 2002

After production of the final climatology, the product will be analyzed. Analysis will likely consist of:

- Climatology consistency analysis– checking the data and looking for discontinuities and regions with significant problems (i.e., noise or bias).
- Consistency check with ancillary data– In addition to the AERONET comparisons that will be ongoing through the algorithm development, further checks will be compared to:
    - Global surface weather observations – This dataset is in-hand and consists of 1500 observation stations world-wide from 1982 through 1997, most of which report visibility and current weather observations (e.g., haze, smoke)
    - Surface flux measurements – Surface flux measurements were made in the U.S. (and possibly elsewhere in the world). Results could be compared to these observations, given that the downward solar flux at the surface should be inversely proportional to the aerosol optical depth.

Form D. GACP Bibliography

Conference Presentations

Knapp, K. R., 2001: Aerosol optical depth over land from the AVHRR pathfinder atmosphere data set. 11th AMS Conference on Satellite Meteorology and Oceanography, Madison, WI.

Knapp, K. R. and L. Stowe, L., 1999: An approach to deriving an aerosol optical thickness climatology over land with AVHRR data. Fall Meeting of the AGU, San Francisco, CA.

——, 2000: Aerosol optical depth signal over land in the AVHRR Pathfinder Atmosphere Data set. AGU Spring Meeting, Washington, DC.

——, 2000: Deriving an aerosol optical depth climatology over land with AVHR data. International Radiation Symposium, St. Petersburg, Russia.

——, 2000: Satellite remote sensing of aerosol over land from geostationary and polar orbiting satellites. AAAR 19th Annual Meeting, St. Louis, MO.

——, 2001: Inference of aerosol optical depth over land through the retrieval of surface BRDF parameters from the AVHRR Pathfinder Atmosphere data set. AMS Annual Meeting, Albuquerque, NM.

Peer Reviewed Publications

Knapp, K. R. and L. Stowe, L., 2001: Evaluating the potential for retrieving aerosol optical depth over land from AVHRR Pathfinder Atmosphere data. Journal of Atmospheric Science, In press.

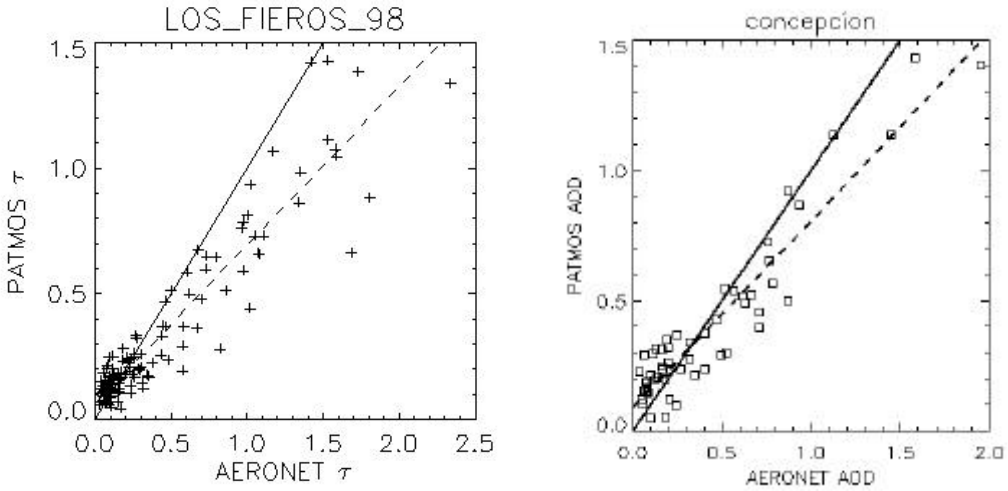
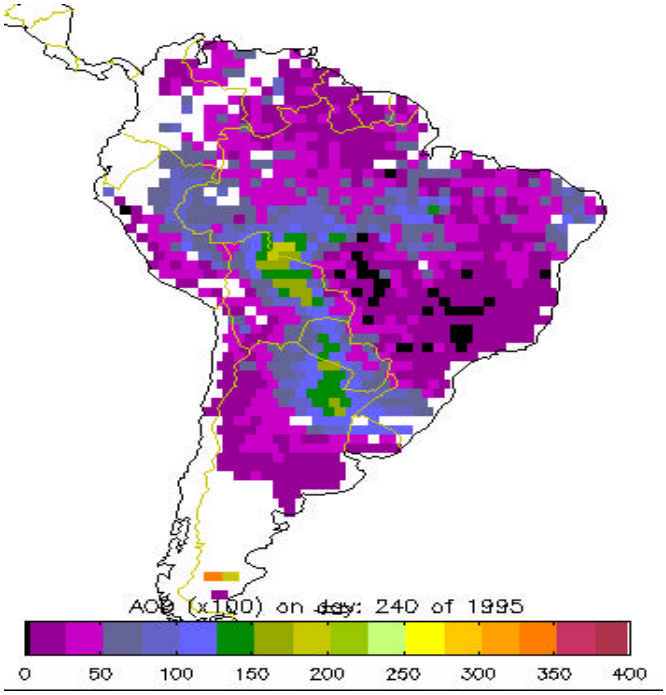


Figure 1 – Examples of PATMOS – Aerosol over land validation at AERONET sites Los Fieros '98 (a) and Concepcion (b). The solid line represents the one-to-one relationship and the dashed lines are the linear regressions.

A



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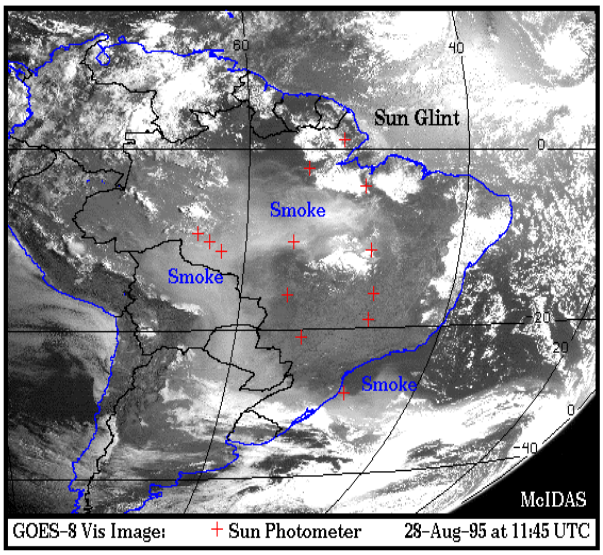

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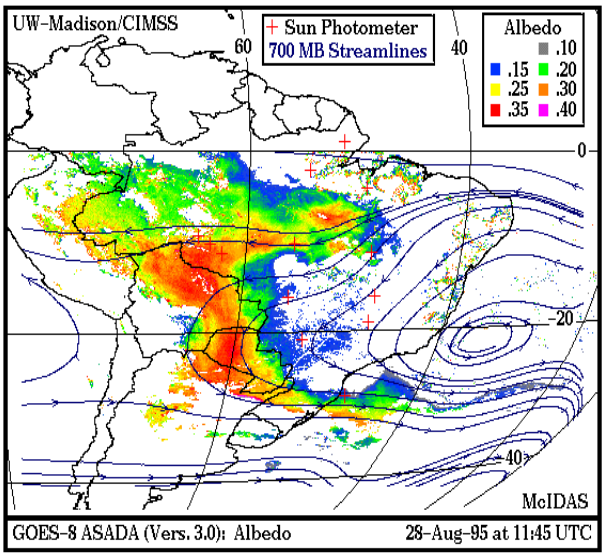

Figure 2 – a) PATMOS over land over South America on 28 August 1995. b) GOES8 visible image for the same day (from CIMSS) and c) the ASADA albedo product (from CIMSS), which identifies smoke and aerosol in the region.

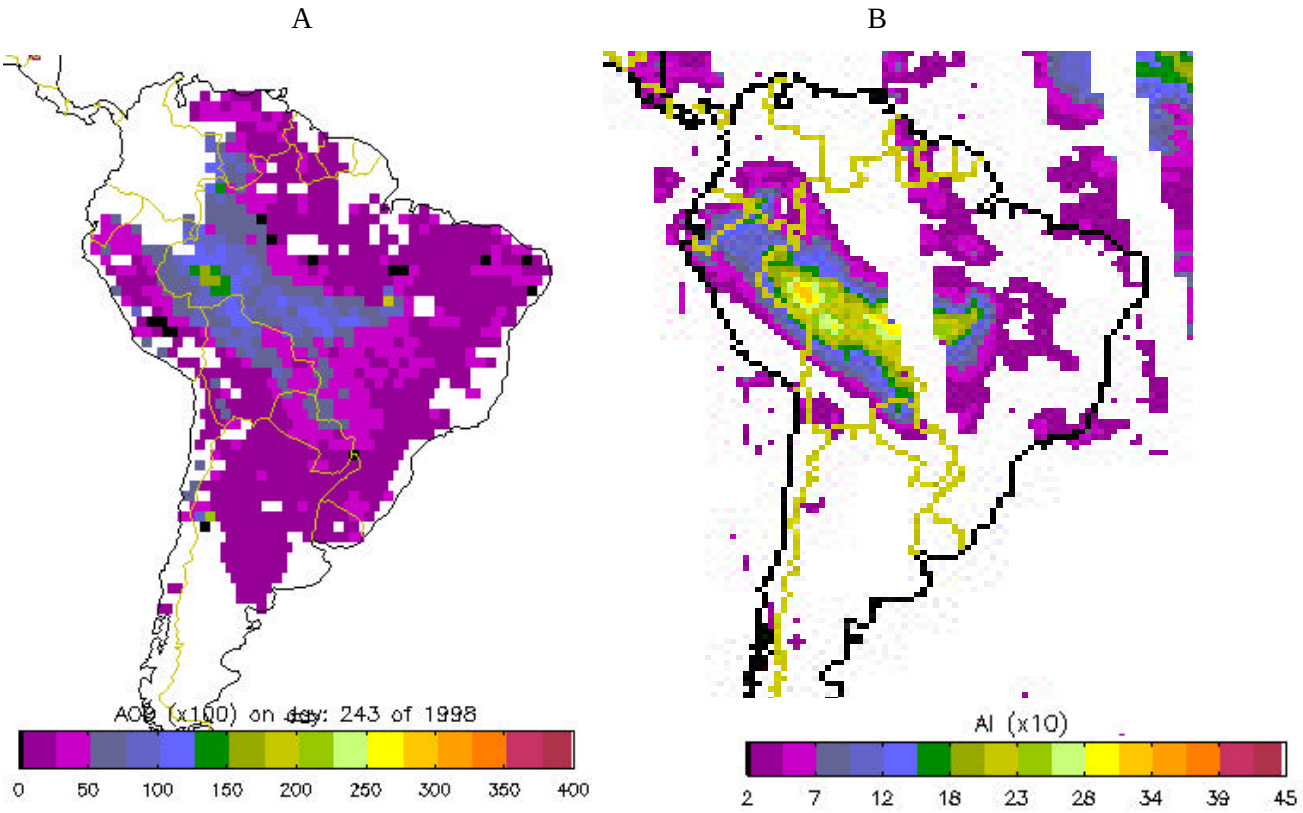

Figure 3 – a) PATMOS – aerosol over land for South America for 31 August 1998. b) correspond TOMS aerosol index (AI) image for the same day.

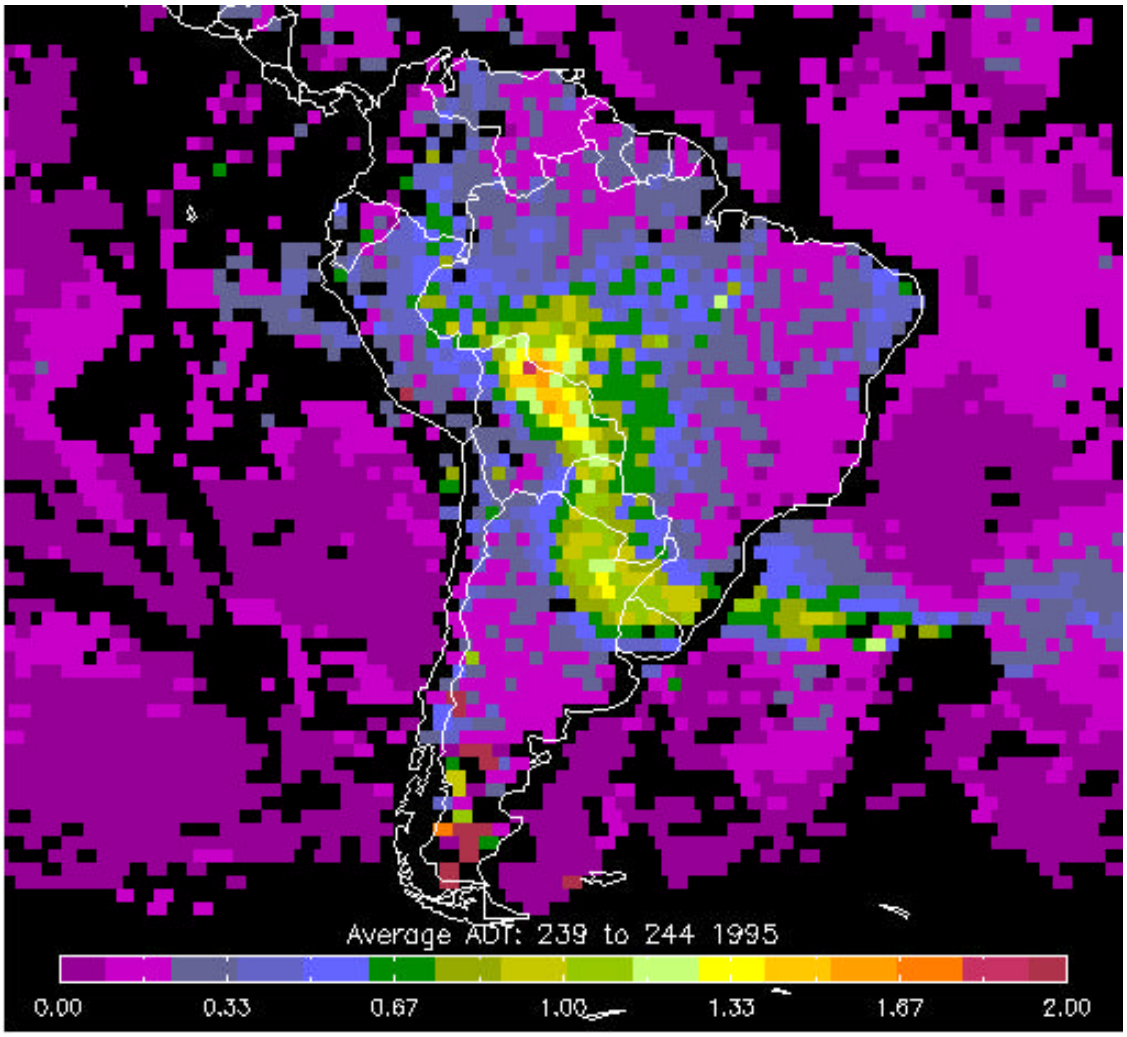

Figure 4 – PATMOS aerosol optical depth average for 27 August to 1 September 1995. The AOD over ocean is from PATMOS-2 data while the values over land were derived during this research project.