Characterization of optical properties of the atmospheric aerosol in Amazonia from long-term Cimel measurements [1993-95; 1999-2004]

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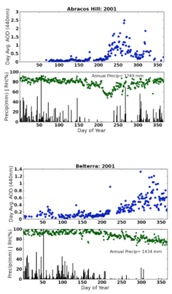
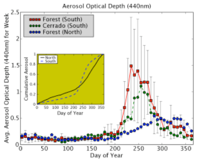
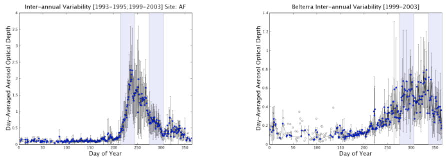
Map depicts every site that has contributed significantly to this study since 1993 The color of the marker indicates the regional group within which the site belongs (open- northern forest; gray- Cerrado; black- southern forest)



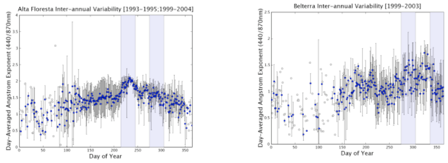
The timing of the onset of fire activity in the Amazon is clearly tied to the local meteorological cycle. The precipitation minimum of the dry season trends is also reflected in the relative humidity and produces the environmental conditions favorable for initiating biomass burning. The dry season is observed to be more pronounced for the southern forest sites (Abracos Hill shown) than for the northern forest site (Belterra), though the clear association of rainfall and AOD is evident ubiquitously.



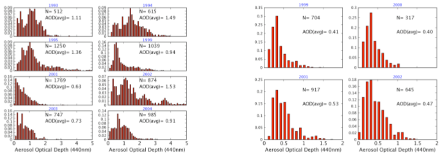
Left: Monthly averages for composite data sets that combine the observations from all sites within a given regional group. These monthly values are an average of all qualifying day averages from the month and so the standard deviation error bars include variation due to both inter-annual and inter-site variation.



These figures depict the inter-annual variability of seasonal trends of day-averaged AOD and Ångström exponent for typical southern (Alta Floresta) and northern (Belterra) forest regions and illustrates the effect of year-to-year variation of factors that influence biomass burning aerosol production. For the day range from 150 to 300, each point is typically based on daily AOD averages from 4-8 different years at Alta Floresta. The shaded bands indicate the approximate starting and ending months of the respective burning seasons.

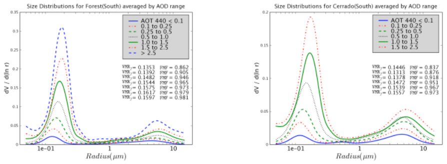


A plot of inter-annual variability of the wavelength dependence of AOD, as characterized by the angstrom exponent (440nm/870nm) is presented in figure 5 for Alta Floresta and Belterra. The salient feature of the left plot is the peak of omega during a week around the middle of August. The Ångström exponent is the wavelength dependence of the AOD (440nm - 870nm) and highly sensitive to the size distribution with larger values encountered when the fine mode aerosol has a large relative contribution to the total aerosol. This peak appears near the start of the dry season when there is a combination of minimal cloud presence and initial fire activity, and may be considered a period of nearly pure smoke aerosol.



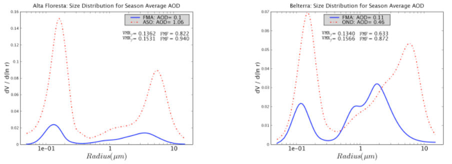
Histograms of the relative frequency of aerosol optical depth (Fig. 6) reflect the greater magnitude and variability of the southern forest sites, with season averages that may vary by almost a factor of three from year to year. By contrast, the northern histograms are fairly uniform in appearance, with negligibly different AOD averages for all four years on record.

The distinguishing characteristic of the highest AOD years at Alta Floresta (1994, 1995, 2002) is the significant frequency of extreme smoke events with AOD values ranging from 3.0 to as high as 5.0, given that such events are all but non-existent in more modest burning years

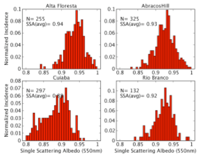


Numerical inversion techniques applied to sky radiance from Cimel protocols provide a means to acquire columnar-averaged aerosol size distributions during favorable conditions (cloud-free, spatially homogeneous sky). These figures were generated by grouping the data from each region by defined AOD ranges and averaging the retrieved size distributions within each aerosol bin. As noted in previous studies of smoke aerosol, all regions exhibit an increase of fine mode (sub-micrometer) particles and a general shift towards larger volume median radius (VMR_f) for the accumulation mode as (smoke) aerosol optical depth increases. This may attributed to the fact that the heaviest smoke conditions have larger aerosol concentrations which are more favorable for coagulation processes associated with aging smoke.

Fine mode fraction of the AOD (FMF) represents the relative contribution of the fine mode to the total aerosol optical depth. For the southern forest and cerrado sites, even at the lowest AOD, this is the dominant influence (84%). For the highest AOD, the coarse mode is essentially optically negligible.

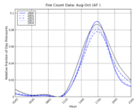


Above: Averaged subsets of size distributions derived for the wet season and the respective peak burning seasons at Alta Floresta and Belterra. The wet season size distributions were derived from observations during the February-April months and are composites of size distributions for all almucantars acquired under low AOD conditions (AOD 440_{nm}: 0.11 +/- 0.04). The aerosol volume concentrations are at minimal levels during this interval at both locations as would be anticipated. Given the known annual transport of Saharan dust into northeastern South America during this part of the year, it is reasonable to speculate that the enhanced coarse mode for the Belterra site may represent a dust signature associated with transport into the Brazilian interior. For the peak months of biomass burning (Aug-Oct in the south, Oct-Dec in the north), average size distributions are shown for almucantars acquired during the respective average AOD conditions during these months (South: average AOD= 1.06 +/- 0.2; North: average AOD= 0.46 +/- 0.1) which may be taken as 'typical' size distributions for the burning season in each region.



We have a substantial record of single-scattering albedo measurements for the southern and cerrado sites derived from numerous years that are composited (the average of SSA_{440nm} and SSA_{670nm} is shown) and presented as histograms. The southern forest sites have comparable values and exhibit a moderately-absorbing average single scattering albedo of 0.92-0.94 while the cerrado site (Cuiabá) averages 0.05 less than this as we expect given the difference in predominant fuel for this ground cover type. Of course, by definition, the cerrado region includes sites that are primarily influenced by savanna and open pasture lands that are flaming phase combustion regimes which explains why the mean single scattering albedo averages substantially less than the mean values in the southern forest region for the corresponding month. The range of SSA is also greater for the Cerrado site (standard deviation= 0.04) than at the three forest sites (0.026-0.027).

The Automated Biomass Burning Algorithm (ABBA) was used to assess fire activity for a region centered on the Alta Floresta site (details of the algorithm can be found in Prins et al., 1998, 2001). Using the 17:45 GMT scan, the count of fire pixels detected in a 10 degree box surrounding the site was tallied and correlated with the day averaged AOD_{440nm} observed at the site on the same day and the following day. Both the same day and next day AOD averages were considered due to the large dimensions of the sampling box and the often significant residence time of smoke aerosol that can advect over the Cimel position.



Year	Flag	r_{same}	r_{next}	AOD_{440nm}	FireCnts	NumDays
2000	0123	0.44	0.52	0.72	4754	40
2001	0123	0.15	0.22	0.75	9294	69
2002	0123	0.55	0.58	1.44	7439	44
2003	0123	0.42	0.36	0.75	6264	49
2004	0123	0.40	0.50	0.89	7184	54

The analysis was based on observations acquired during the biomass burning season (Aug-Oct) for five years from 2000-2004. It was anticipated that the number of instantaneous fire pixels in the study region would be a significant predictor of aerosol optical depth (as smoke is by far the dominant contributor during this season), however the strength of correlations between total identified fire pixel number and AOD (both same day and next day average) determined for the individual year data sets (while uniformly positive) ranged from negligible to moderate at best. These relatively weak correlations between the day-averaged AOD and the regional fire count totals were also found when different sizes of the sampling box surrounding the site were used (ranging from 2 to 10 degrees).