DEVELOPMENT OF A SATELLITE ALGORITHM FOR ATMOSPHERIC DUST CONCENTRATIONS OVER FLORIDA

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INTRODUCTION

Summer delivery of Saharan dust to the SE United States has been identified as a major source of iron (Prospero et al., 2001), increasing surface dissolved Fe concentrations on the West Florida shelf (WFS) by over an order of magnitude during deposition events (Lenes et al., 2001). This increase in dissolved iron (dFe) concentrations effectively removes iron limitation of the N_2 fixing cyanobacterium *Trichodesmium*, allowing for an increase in cyanophyte biomass by two orders of magnitude throughout the summer/fall (Lenes et al, 2008). The 'new' nitrogen provided by these diazotrophs has been linked to production of annual red tides on the WFS (Walsh and Steidinger, 2001; Mulholland et al., 2006).

Given the relationship between Fe, *Trichodesmium* and *K. brevis,* any attempt at operational modeling for tracking red tide blooms on the WFS requires explicit concentrations of dust (i.e. Fe) delivery. Current dust collection systems are limited in both time and space. While a few collection towers throughout Florida regularly measure aerosol dust concentrations, it takes approximately weeks to months to process this data. This gives no real time measurements for application to model boundary conditions. Likewise, these measurements are spatially limited and provide no direct data over the WFS and Gulf of Mexico (GOM). Therefore, given the nature of our model and the specific goal of operational red tide modeling, alternative pathways are necessary to calculate proper dust deposition as an atmospheric forcing field constraining the bioavailable iron pool.

Smirnov et al. (2000) demonstrated that ground-based dust concentration measurements were similar to sunphotometry column aerosol optical depth (AOD) retrievals in Barbados by a simple linear regression relationship. Kaufman et al. (2005) used similar methodology to derive dust concentrations from space using MODIS retrievals. This allows for estimation of optical depth for any specific time-period when dust concentrations are unavailable. Therefore, a combination of these methods will be applied to the linear relationship regressed from Miami dust and Dry Tortugas sunphotometry data in order to extract atmospheric dust concentrations from MODIS retrievals specific to our model region.

METHODS

Mineral Dust (after Prospero, 1999)

- Data courtesy of Joseph Propsero, University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS)
- Atmospheric mineral dust measured on Virginia Key at the University of Miami campus of RSMAS, ~4 km east of Miami
- Bulk aerosol samples were collected at 30-m above sea level
- Water-soluble ions extracted with deionized water
- Dust was determined by ashing the filter at 500°C for ~14 hr to destroy organic matter
- Multiplied by a correction factor of 1.3 to compensate for loss of soluble minerals during extraction
- Samples collected every weekday and 3-days over weekend
- Dust concentrations available on 173 days in 1998, 174 days in 1999, 151 days in 2000, and 124 days in 2001 (Table 1)

Optical Properties

- Aerosol optical depth (t) was retrieved from the CIMEL sun and sky radiometer from the AErosol RObotic NETwork (AERoNET) operating at the Dry Tortugas (Holben et al., 1998)
- We obtained level 2 (cloud screened and qualtiy controlled; Smirnov et al., 1999) daily averaged t_a at 870 and 500 nm
- Daily dust (M) was matched to the daily averaged t_a(870) on the same day (tM) and at a one day delay (tM') to allow for transit time between Miami and Dry Tortugas

MODIS - AOD_m(870)

- The MODerate resolution Imaging Spectroradiameter (MODIS) instrument is used by the MODIS team to derive a measure of total column aerosol loading in the atmosphere (t ot AOD)
- The MODIS aerosol algorithm uses the measured 500-m resolution radiance from six MODIS bands (550-2100 nm) to
- The analysis is performed on a grid box of 10 km at a sub-satellite point (Kaufmann et al., 2005)
- Daily AOD_m(870) at Dry Tortugas were extracted from the images obtained from NASA (http://ladsweb.nascom.nasa.gov)
- These were compared to AOD_c(870) from the CIMEL to draw a linear relationship with atmospheric mineral dust

Table 1. The number of days for optical and *in situ* aerosol measurements (tM = where t and M were measured on the same day and tM' = where M was at a one-day delay to t).

	1998		1999		2000		2001		Total	
	t_a(870)	M (ug m^{-3})	t_a(870)	M (ug m^{-3})	t_a(870)	M (ug m^{-3})	t_a(870)	M (ug m^{-3})	tM	tM'
Jan	6	12	3	13	18	10	1	4	4	3
Feb	25	10	-	14	27	13	9	12	24	26
Mar	29	10	-	16	30	10	30	6	26	25
Apr	29	10	-	16	29	7	27	9	25	24
May	25	13	-	17	31	16	11	13	27	27
Jun	27	19	19	19	22	20	23	16	56	56
Jul	23	20	26	20	18	14	26	16	57	55
Aug	24	20	18	15	-	20	26	18	40	40
Sep	16	13	22	14	-	18	16	11	23	20
Oct	26	18	21	12	-	4	24	11	35	30
Nov	28	15	15	7	-	11	27	8	26	23
Dec	26	13	-	11	-	8	27	-	12	11
Total	284	173	124	174	175	151	247	124	355	340

RESULTS & DISCUSSION

The daily dust concentration and AOD_c(870) were plotted as a 14-day moving average (Figure 1a). Both showed large increases during summer months coinciding with Saharan dust delivery to the southeast United States (Prospero et al., 2001). Daily AOD_c(870) were as high as 0.7 with the bulk of the measuements below 0.1 (Figure 1b).

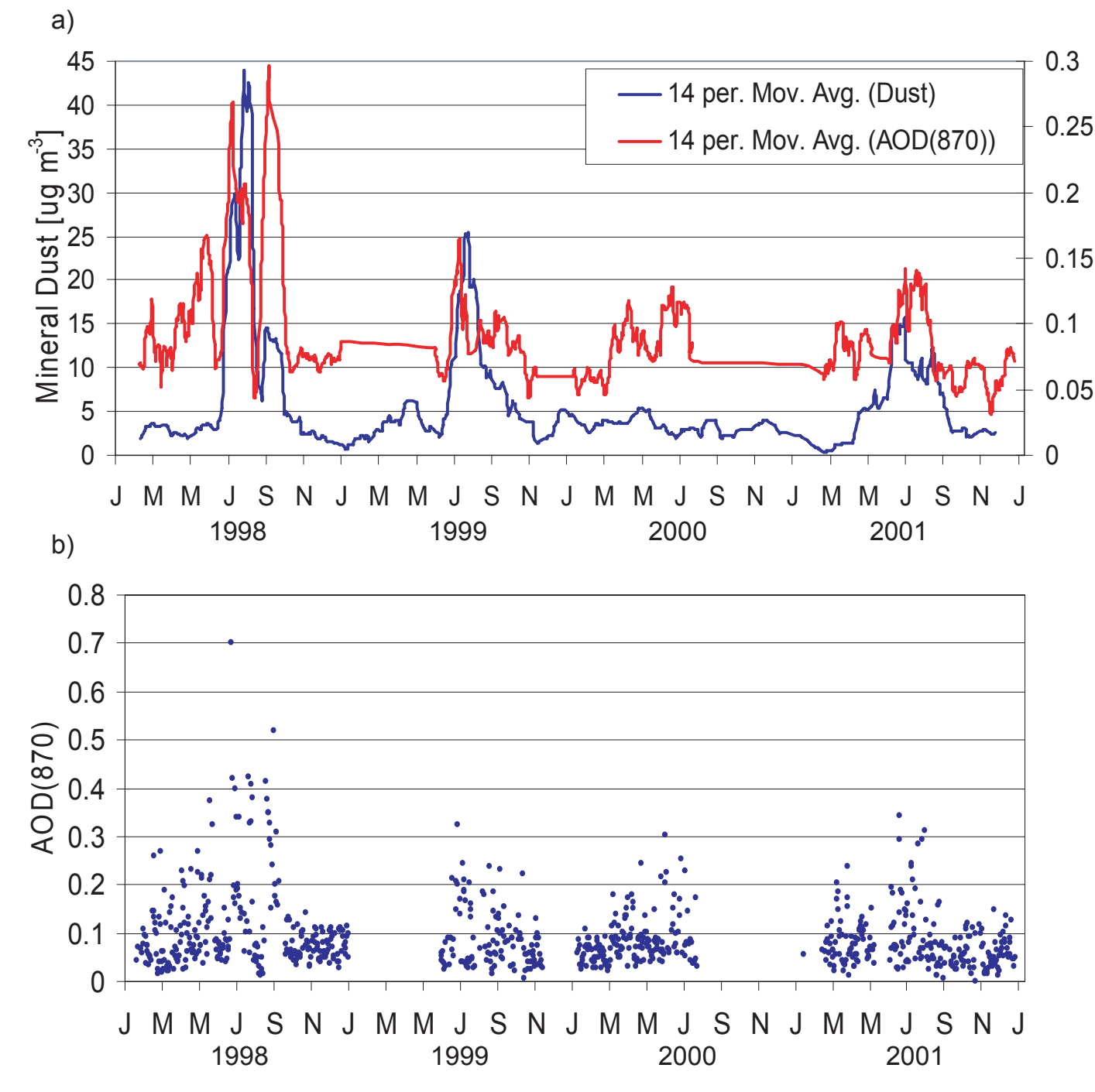

Figure 1. a) The 14-day moving average of dust at Miami and AOD_c(870) at Dry Tortugas from 1998-2001. b) Scatterplot of AOD_c(870) at Dry Tortugas over this period. Significant variability exists in this relationship since AOD is a total air column measurement while dust concentrations were collected at 30-m.

The monthly mean of the dust for this period showed elevated concentrations in the summer, with a maximum dust concetration (~21 ug m^{-3}) in July (Figure 2a). A similar pattern was observed in the AOD_c(870) monthly mean retrievals (Figure 2b).

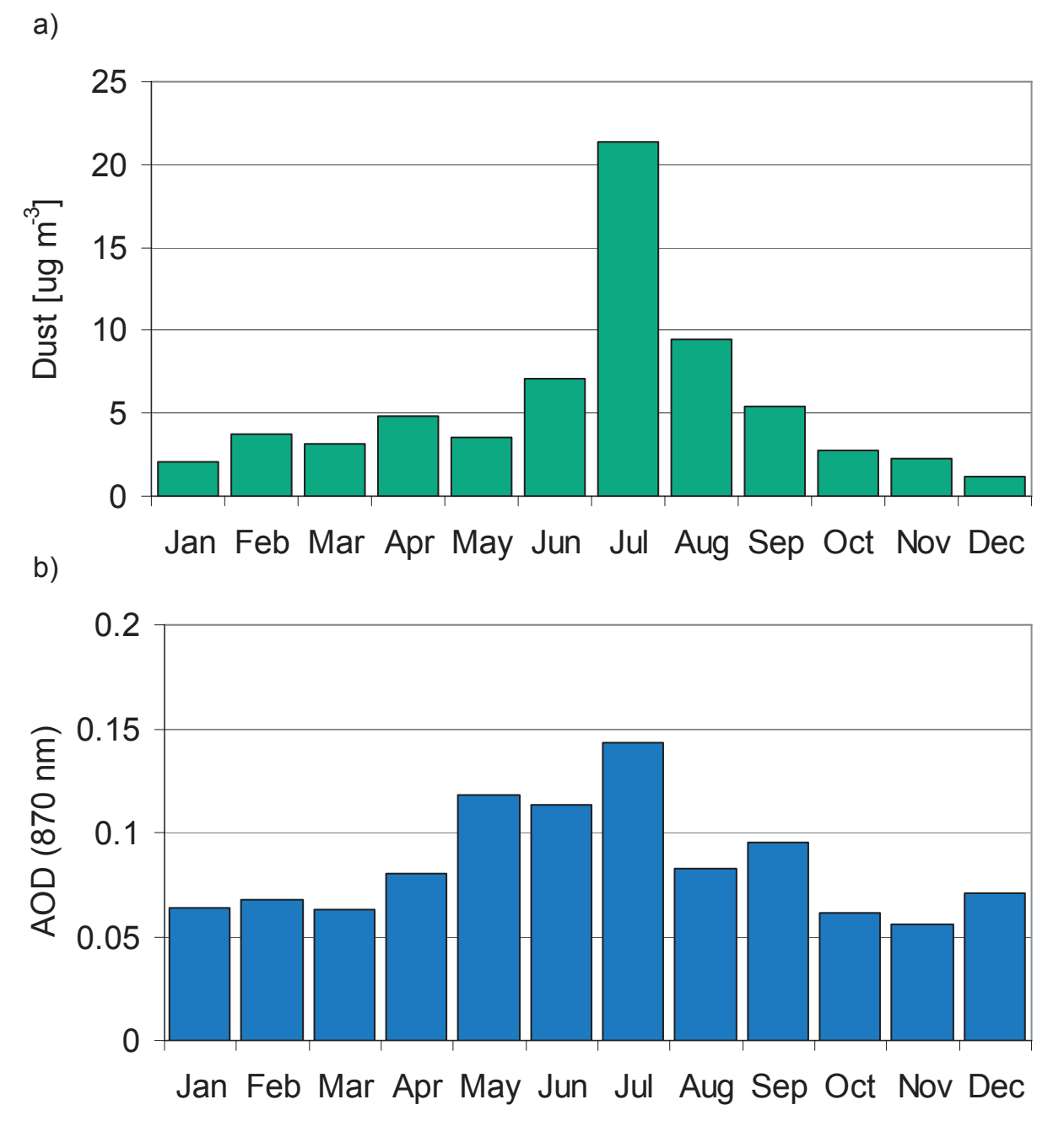

Figure 2. The monthly mean a) dust concentration (ug m^{-3}) at Miami and AOD_c(870) at Dry Tortugas from 1998-2001.

A linear correlation of daily dust concentrations and AOD_c(870) yielded a modest relationship of r=0.55 (Figure 3a). A linear correlation with a one-day delay in AOD_c(870) retrievals increased the statistical significance to r=0.67 (Figure 3b). Comparison of the duts concentrations to AOD_c(500) drastically reduced the fecundity of this relationship to r=0.41 (Figure 3c).

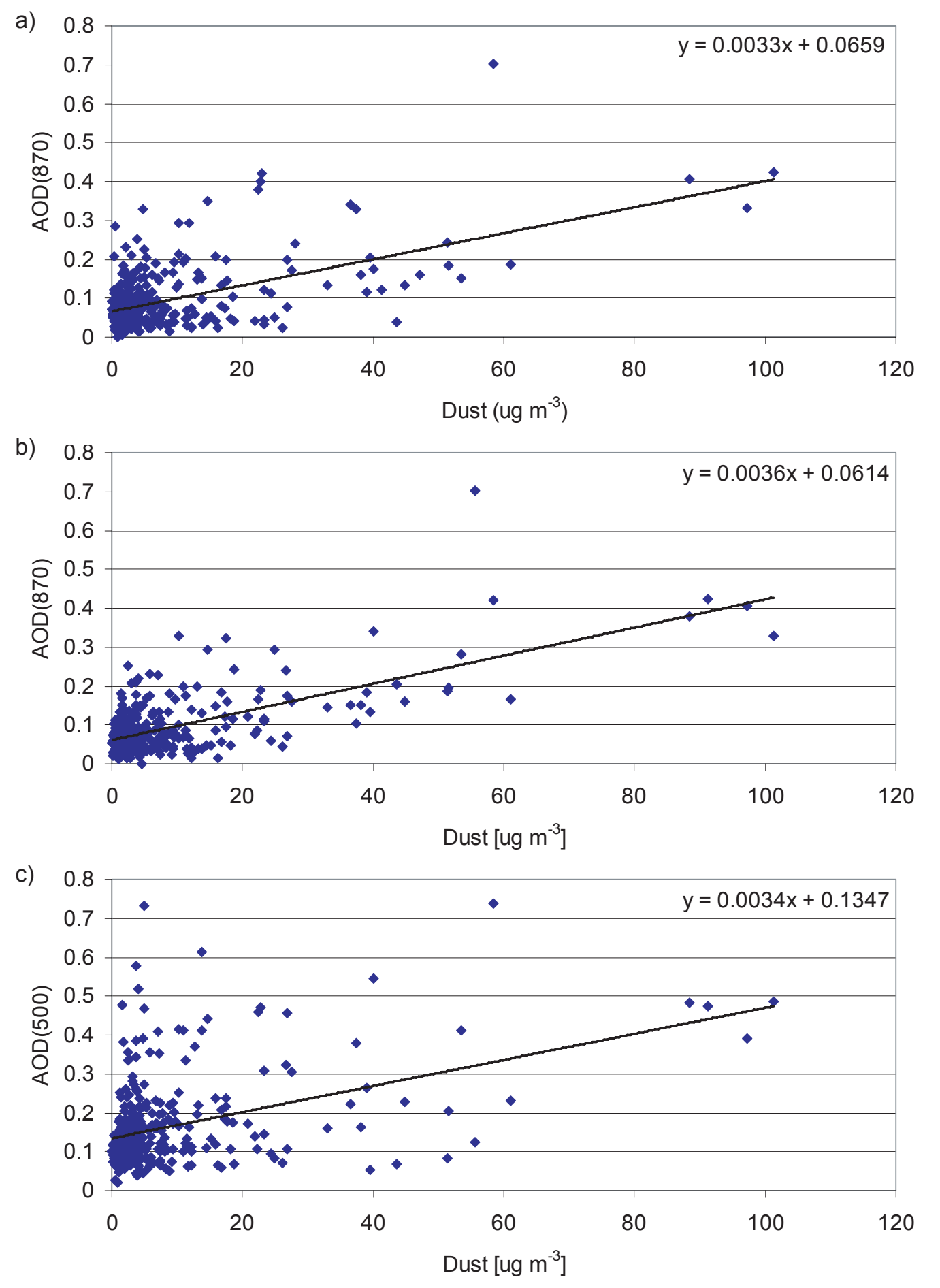

Figure 3. Linear correlation of Miami mineral dust concentration (ug m^{-3}) versus AOD at Dry Tortugas. a) Dust vs. AOD_c(870) on the same day. b) Dust vs. AOD_c(870) at a one-day delay. c) Dust vs. AOD_c(500) on the same day. This indicates that utilizing AOD_c(870) at a one-day delay to allow for dust transport from Miami to Dry Tortugas provided the closest relationship.

In order to improve upon the relationship between AOD and mineral dust concentration (Figure 4a), we applied an Angstrom exponent filter (a > 0.8) to the data (Figure 4b). A linear correlation of the filtered data to dust concentration yielded a statistical significance of r=0.71 (Figure 3c).

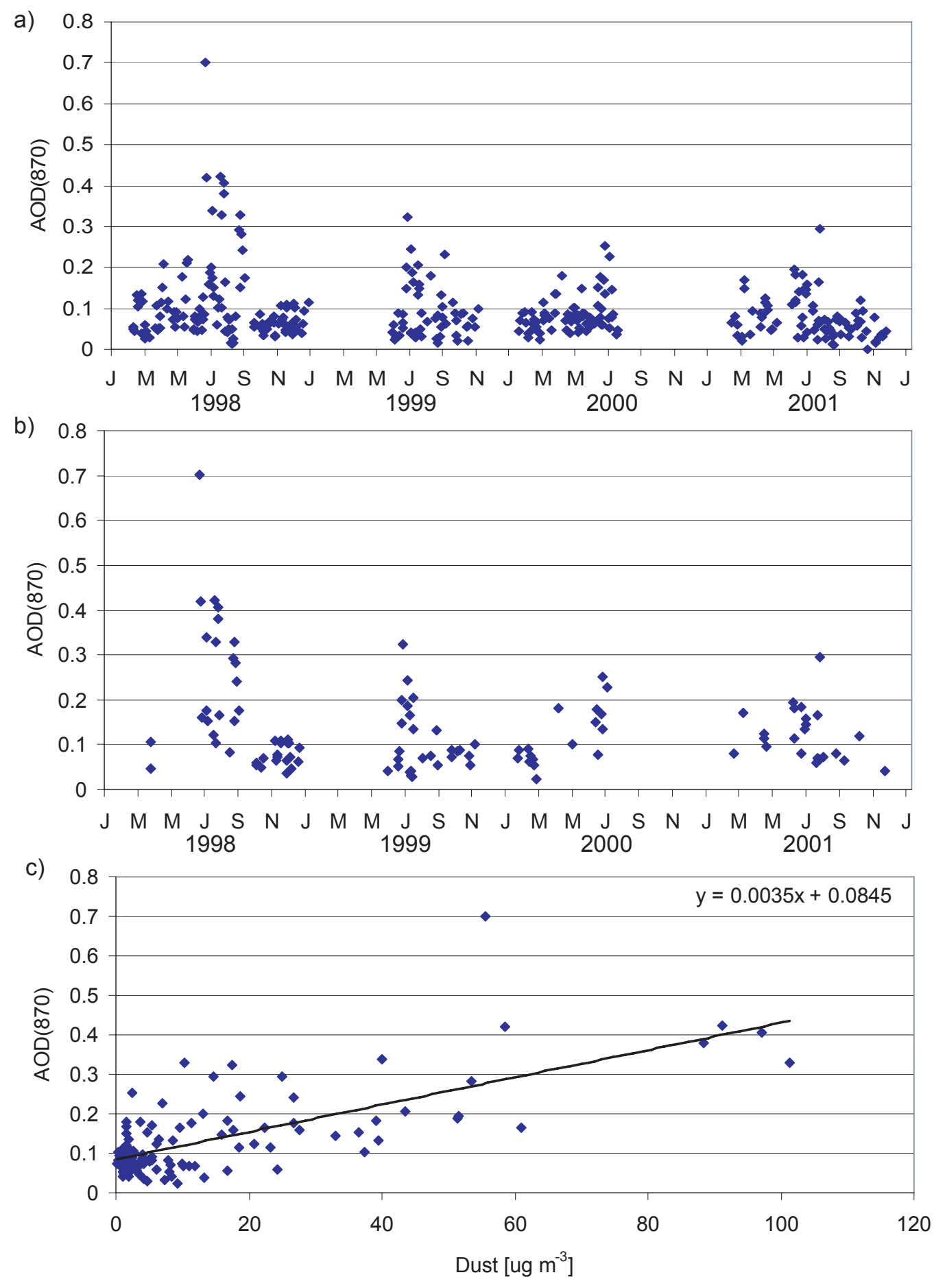

Figure 4. Scatterplot of AOD_c(870) at Dry Tortugas for a) days corresponding to available dust data (340 points) and b) filtered to remove any data with an Angstrom exponent (a) > 0.8 (107 points). c) Linear correlation of the filtered AOD_c(870) versus Miami mineral dust (ug m^{-3}).

The MODIS AOD_m(870) values were extracted from the images during 2000-01 and plotted versus CIMEL AOD_c(870) at Dry Tortugas for the same day to derive a linear relationship (Figure 5a). The Angstrom filtered CIMEL AOD_c(870) was also plotted against Miami dust for this period (Figure 5b).

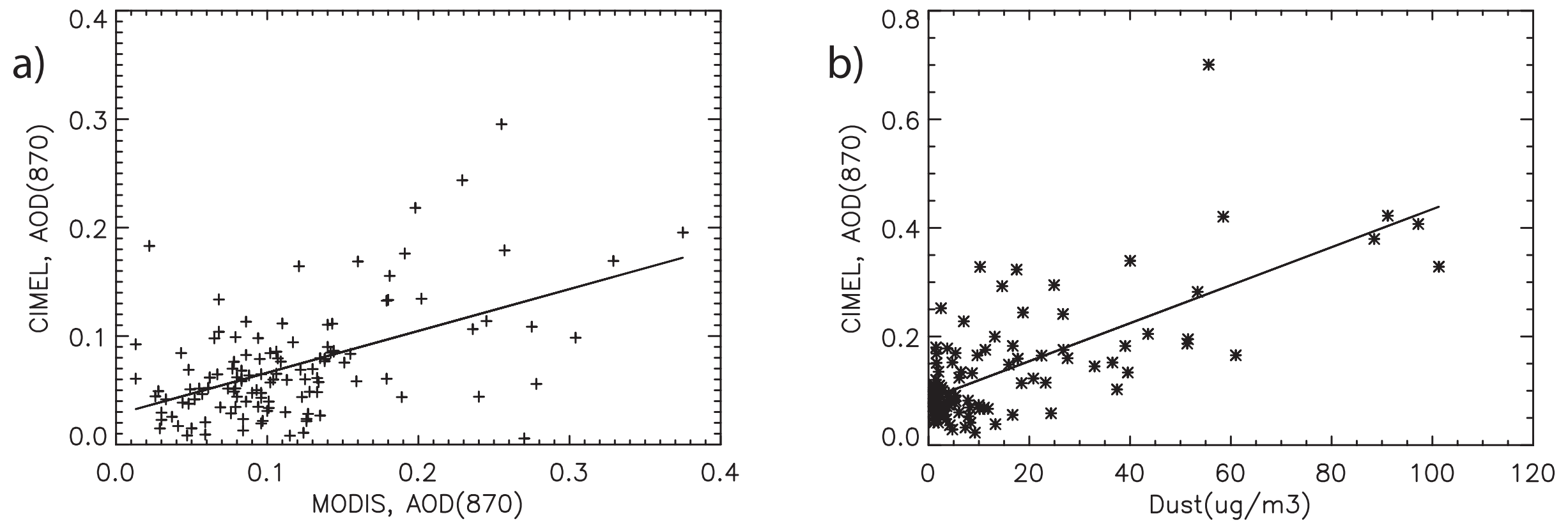

Figure 5. a) The daily AOD(870) of MODIS and CIMEL at Dry Tortugas from 2000-01 and b) the linear correlation of the filtered AOD_c(870) versus Miami mineral dust (ug m^{-3}). The linear correlation of (b) yielded a linear relationship with an r=0.71.

The two linear equations from Figure 5 were combined to reveal a new relationship for the dust concentration and MODIS AOD_m(870): **DUST = 110.19*MODIS - 4.51**

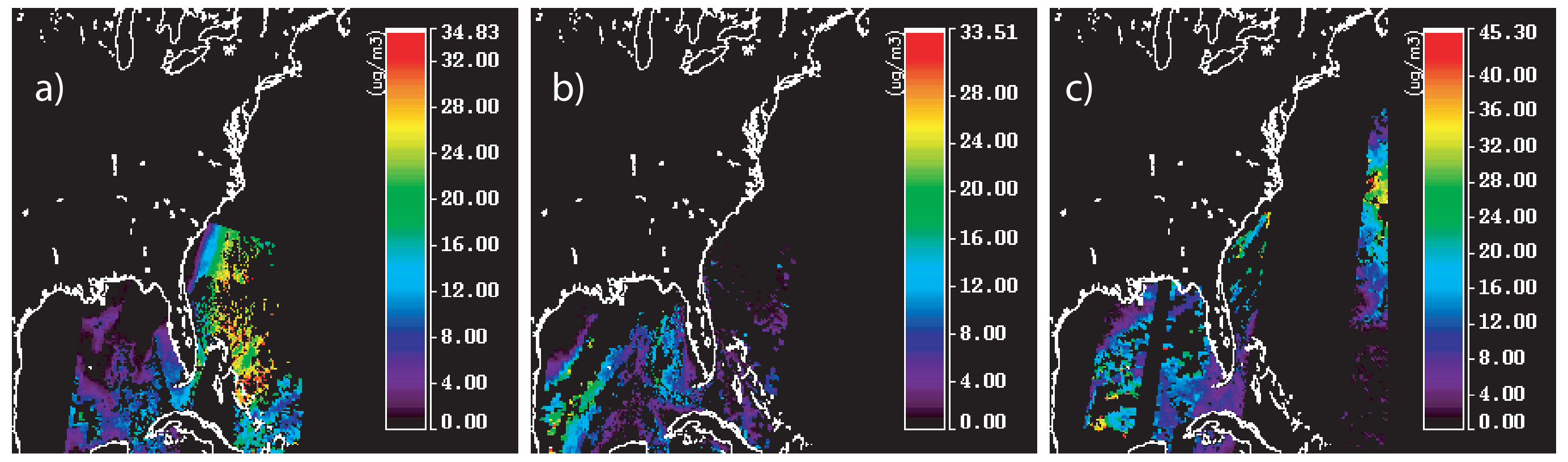

Figure 6. Three images of dust concentration derived from the MODIS/dust equation .

CONCLUSION

The daily dust concentration distribution was made possible by using the relationship between CIMEL estimated aerosol optical depths, the station measured mineral dust concentration and MODIS images of estimated aerosol optical depth. This algorithm could provide a real time, large spatial data field to serve as a proxy for dust concentration, and therefore, dust/iron loading to the surface ocean.

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