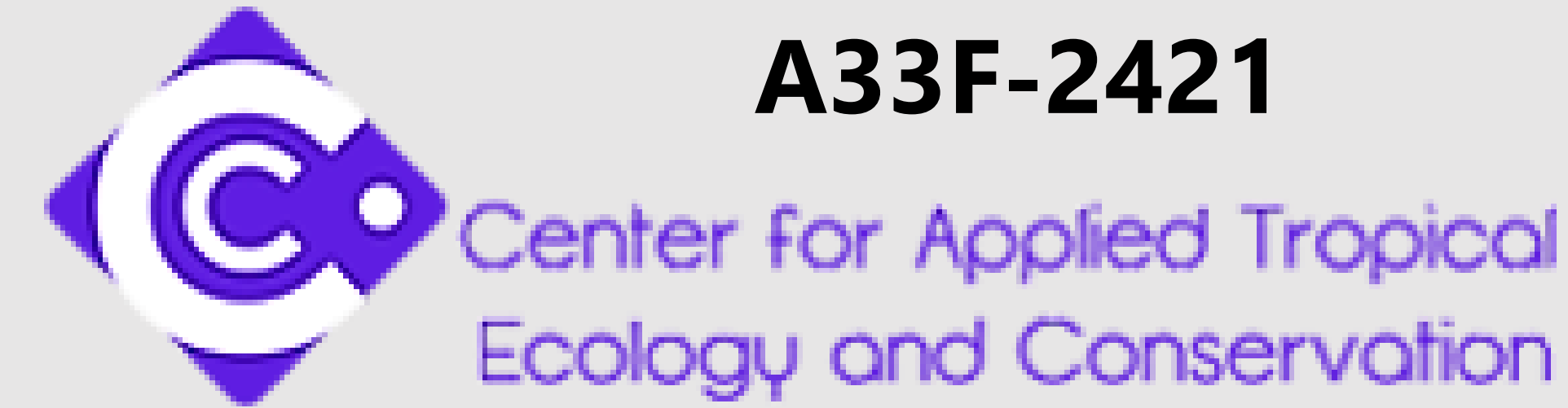




Temporal Relationships Between African Dust and Chlorophyll- α in the Eastern Caribbean Basin



A33F-2421



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Introduction

- Aeolian dust has been shown to increase phytoplankton concentrations in marine areas characterized by high nutrients, but low chlorophyll concentrations (Jickels et al., 2005).
- However, dust deposition is still one of the sources (alongside coastal upwelling and riverine discharges) thought to determine sea surface nutrient availability in oligotrophic tropical regions (Tagliabue et al., 2017).
- Large amounts of mineral dust travel from the African continent to the Caribbean region.
- African dust events reach Puerto Rico primarily during boreal summer months (Prospero et al., 2013), and transport nitrogen and iron, inducing phosphorous limitations on the sea (Chien et al., 2016).
- African dust has been shown to influence chlorophyll- α concentrations in the tropical north Atlantic ocean (Santos, 2010).
- When bioavailable, nutrients in African dust could help increase marine primary productivity in oligotrophic Caribbean waters.

Research Questions:

- Does African mineral dust enhance primary productivity in the eastern Caribbean basin?
 - ❖ Are African dust events directly correlated to peak chlorophyll concentrations?
 - ❖ If so, do these correlations exhibit a reasonable temporal lag-time to account for deposition and bio assimilation time frames?

Methodology

Sampling Locations:

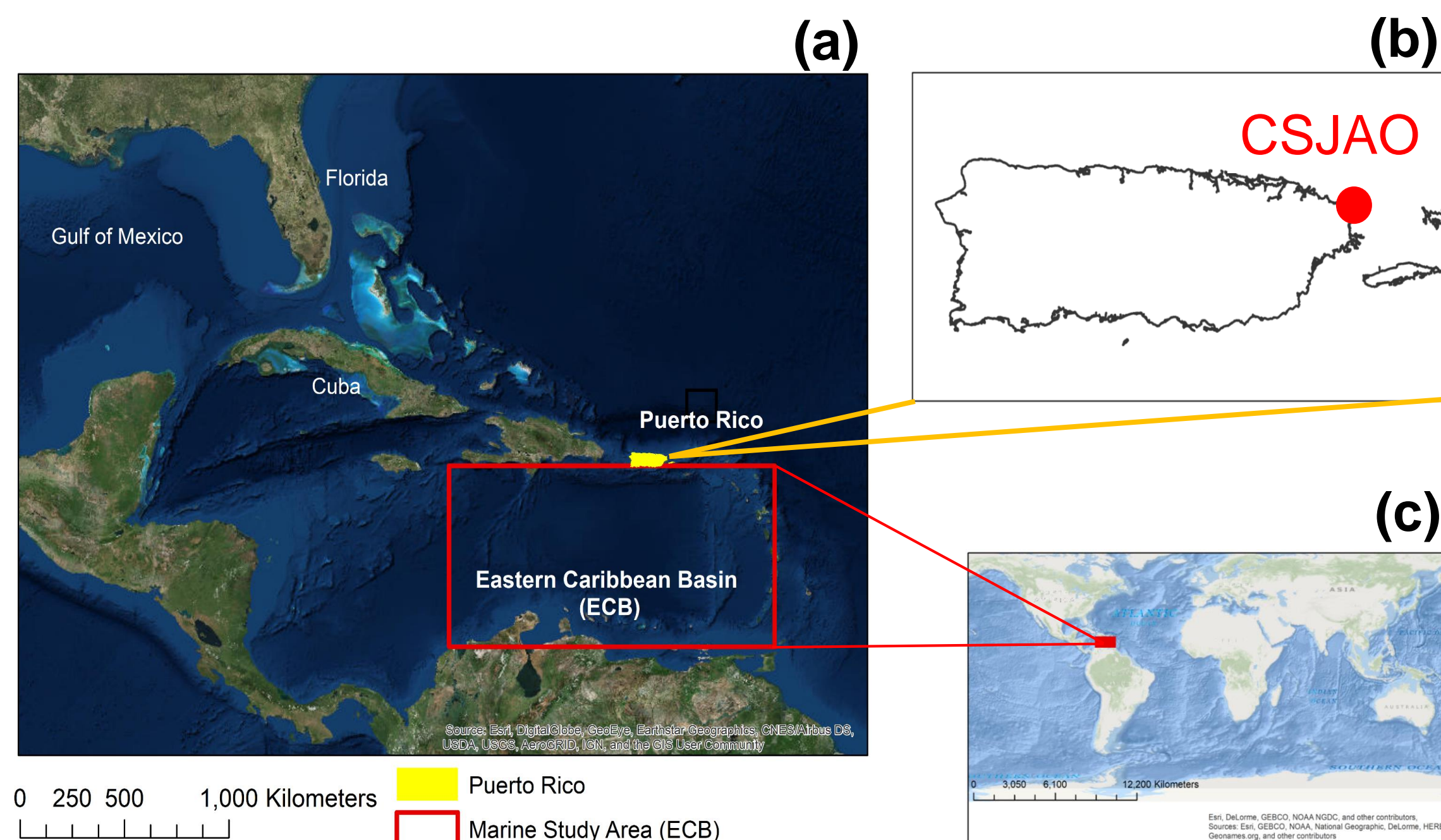


Figure 1. Cabezas de San Juan Atmospheric Observatory (CSJAO) at the most northeastern tip of Puerto Rico (18° 23' N, 65° 37' W, 60 masl).

Figure 2. (a) Extent of marine study area in the Eastern Caribbean Basin (ECB), as delineated in López et al., 2013 (18°N, 75°W, 11°N, 61°W, 116,647 km²). (b) Location of CSJAO sampling site. (c) World location.

- Overall study time frame: January 2005 – December 2015

Part 1: Identification of African dust (AD) events over Puerto Rico

Step 1: Characterized possible events according to aerosol optical properties at CSJAO

• Scattering coefficient (σ_s)

- ❖ TSI Nephelometer Model #3563

• Absorption coefficient (σ_a)

- ❖ Particle Soot/Absorption Photometer (PSAP)
- ❖ Continuous Light Absorption Photometer (CLAP)

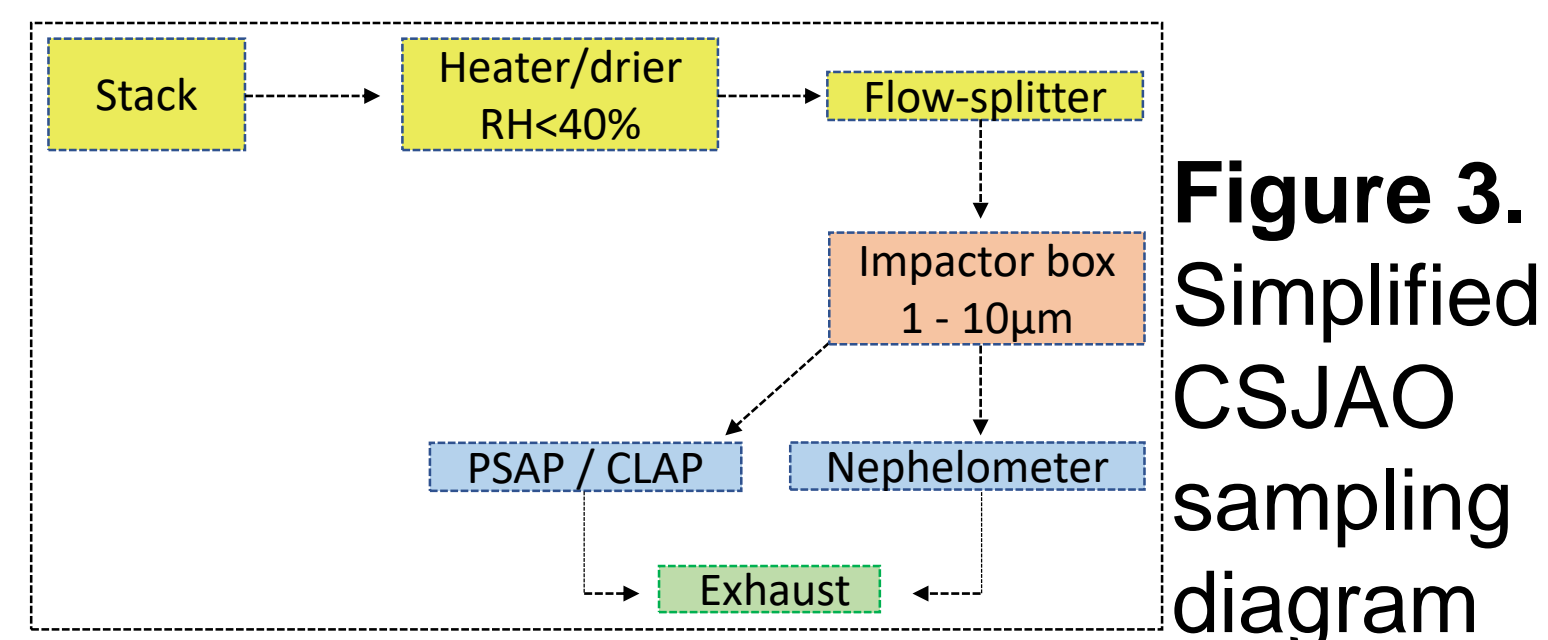


Figure 3. Simplified CSJAO sampling diagram

Step 2: Data processing:

- Averaged to daily values
- Calculated the **Scattering Ångström Exponent (SAE)**, whose values are inversely proportional of particle size

$$SAE = -\log \left(\frac{\sigma_s 700nm}{\sigma_s 500nm} \right) \frac{\lambda_{700}}{\lambda_{500}}$$

Figure 4. SAE equation

Step 3: Confirmed AD events with supporting modeled products:

- NAAPS surface dust forecast (<https://www.nrlmry.navy.mil>)
- SKIRON dust concentration forecast (<http://forecast.uoa.gr/>)
- NESDIS daily Aerosol Optical Depth (AOT) (<https://www.nesdis.noaa.gov/content/imagery>)
- Ten-day air mass back trajectories using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPPLIT) model for three elevations (500m, 1500m, 3000m) starting 12:00 UTZ (<https://ready.arl.noaa.gov>)

Part 2: Identification of peak Chlorophyll- α (CHL- α) concentrations, plus relationships to AD and nutrient availability using modelled and remotely sensed products

- **Dataset acquisition:** (<http://giovanni.gsfc.nasa.gov/giovanni/>)

- ❖ **Instrument:** NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua satellite
- ❖ **NASA's Models:** Ocean Biogeological Model (OBM) and Modern-Era Retrospective analysis for Research and Applications (MERRA-2)
- ❖ **Primary productivity proxies:** diatom, coccolithophore, cyanobacteria, total CHL and CHL- α concentrations
- ❖ **Dust variables:** wet and dry deposition, surface mass concentration, dust column mass density
- ❖ **Sea surface nutrient concentrations:** nitrate and iron

Dust Events suggested by Aerosol Optical Data:

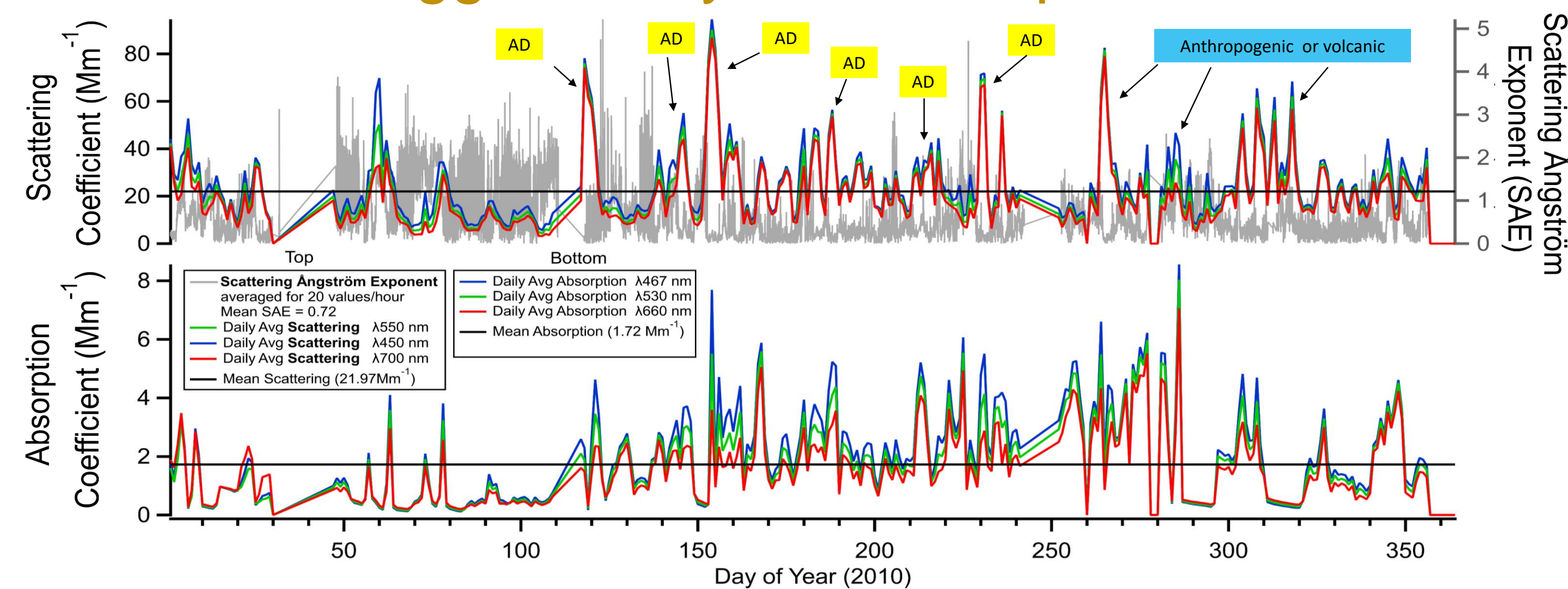


Figure 5. Annual distribution of optical variables for 2010. Greatest scattering & absorption, plus minimum SAE values are indicative of mineral dust influence (Rivera et al., 2017).

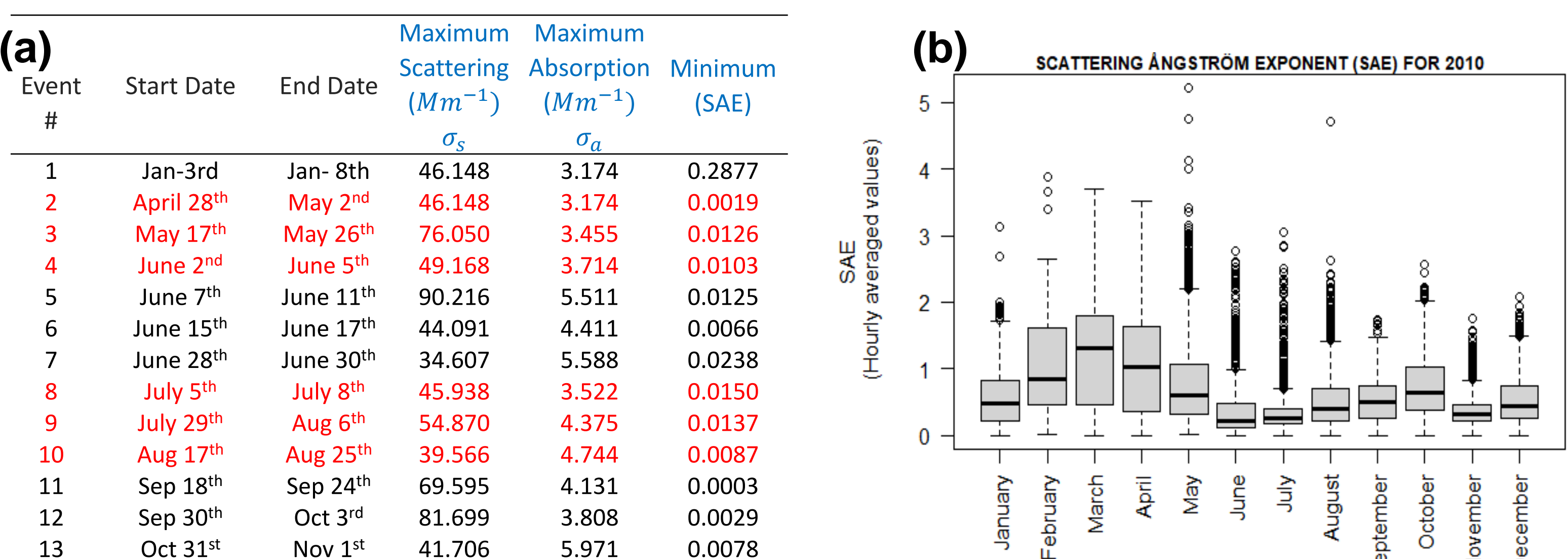


Figure 6. (a) Possible African dust events in 2010. Dates were selected for exhibiting the following criteria: 1 standard deviation (SD) above average σ_s , 1 SD above average σ_a and 1 SD below average SAE. Red rows indicate events in which significant AD influence was posteriorly confirmed. (b) Distribution of monthly SAE values across 2010.

Confirmation of Air Masses:

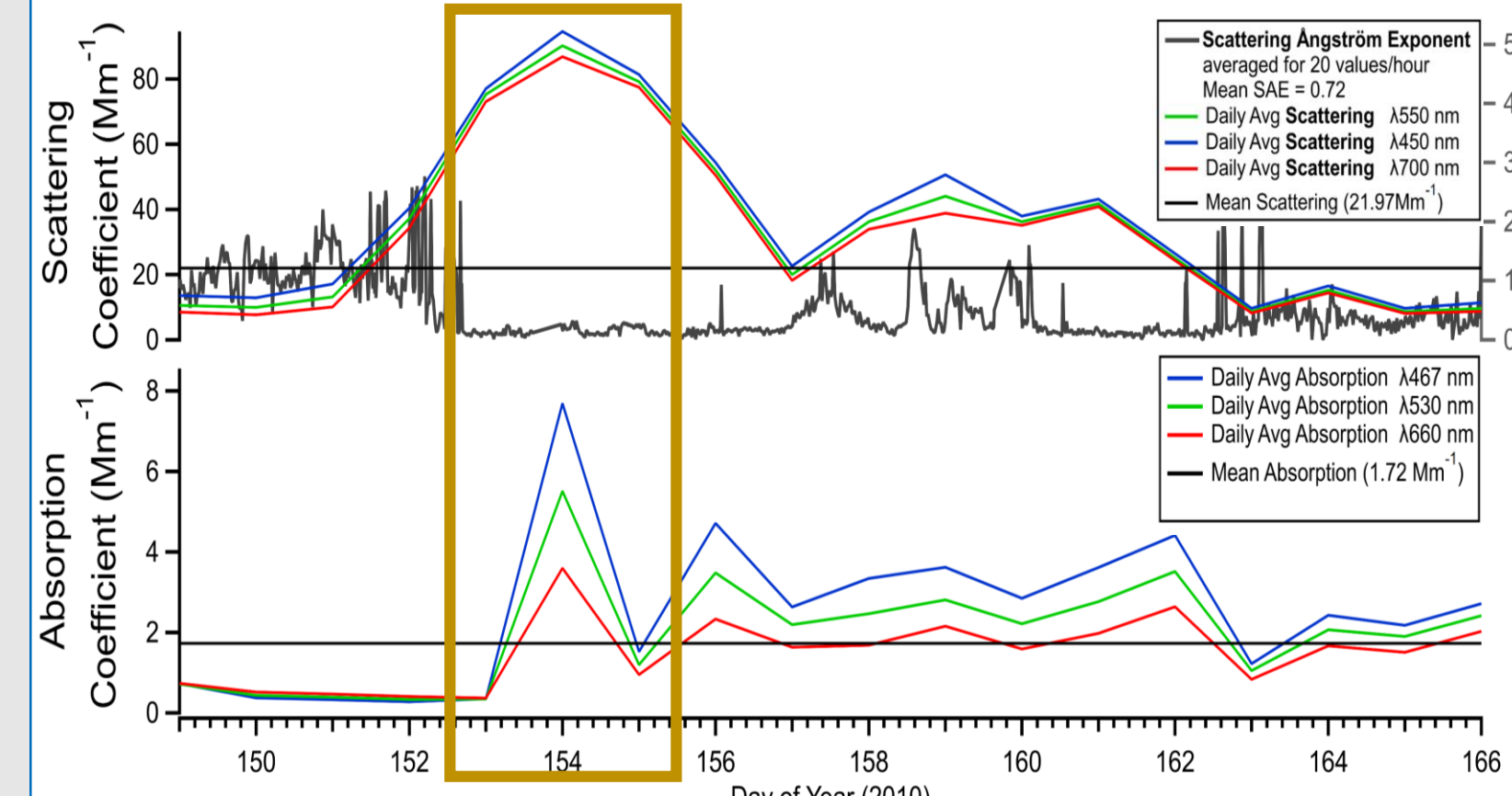


Figure 7. Confirmation of differences in SAE

Figure 8. Example of aerosol optical properties indicating dust event #4 from June 2nd - 5th.

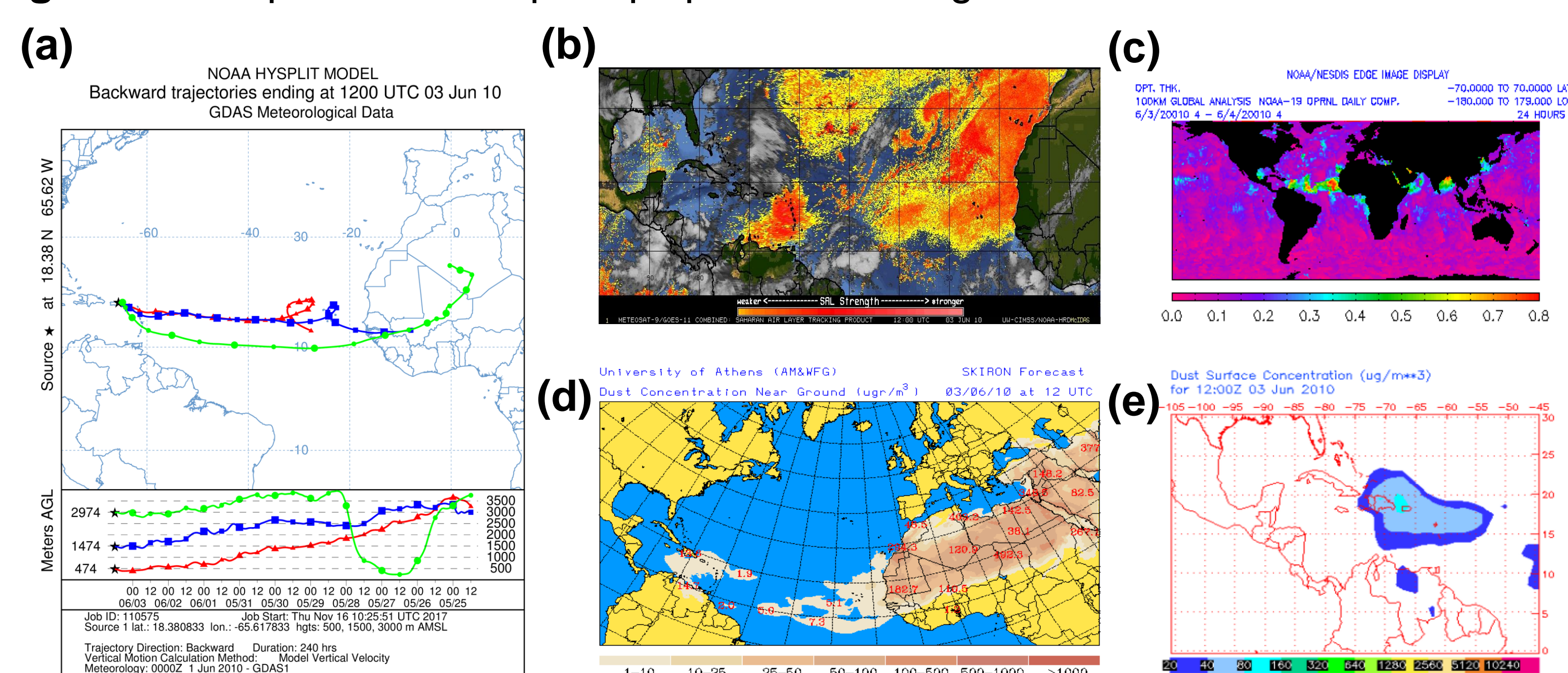


Figure 9. Products of modeling tools confirming the presence of African dust over the ECB during Event #4 of 2010. (a) Ten-day HYSPLIT back trajectories starting June 3rd, 12:00 UTZ, showing the air mass sourced to Saharan Africa. (b) Saharan Air Layer forecast illustrating a dry air mass over the ECB. (c) Aerosol Optical Depth imagery displaying an African dust plume crossing the Atlantic Ocean. (d) SKIRON forecast predicting the presence of AD. (e) NAAPS surface forecast also indicating dust over the study area.

Conclusions

- Periods influenced by African dust were successfully characterized 77% of all possible dates, using values of scattering and absorption coefficients, plus the Scattering Ångström Exponent.
- Moderate correlations between dust deposition and chlorophyll- α (CHL- α) were obtained, confirming the seasonal coincidence. Further analysis shows that high magnitude three African dust periods were followed by increases in CHL- α concentrations after 1.0-1.5 months, suggesting a link between mineral dust particles and primary productivity. This temporal lag-time is similar to previous observations in the Tropical North Atlantic and ECB (Santos, 2010).
- This study coincided with the unprecedented bloom of *Sargassum spp.* in the Caribbean region. This macro-algae lives in the air-sea interface and has caused harmful algal blooms during summer and fall seasons of 2010 and posterior years. However, we have not been able to link African dust events in the ECB to these harmful algal blooms.

2010 Case Study Results

Links between primary productivity proxies and dust events:

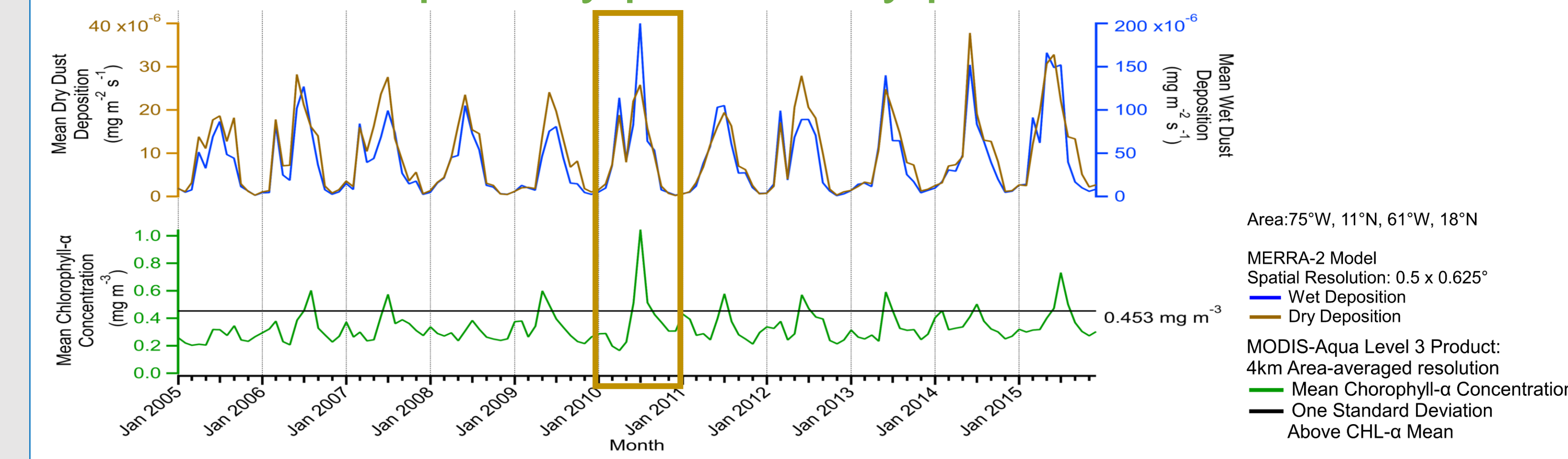


Figure 10. Monthly averages from 2005-2015 of modeled dust deposition and remotely sensed CHL- α . All three variables exhibit summer maxima. This is especially notable for CHL- α during 2010, where June-August surpasses one standard deviation above the decadal average (0.34 mg m⁻³). Overall, wet deposition in this model contributes ~400% more dust than dry deposition.

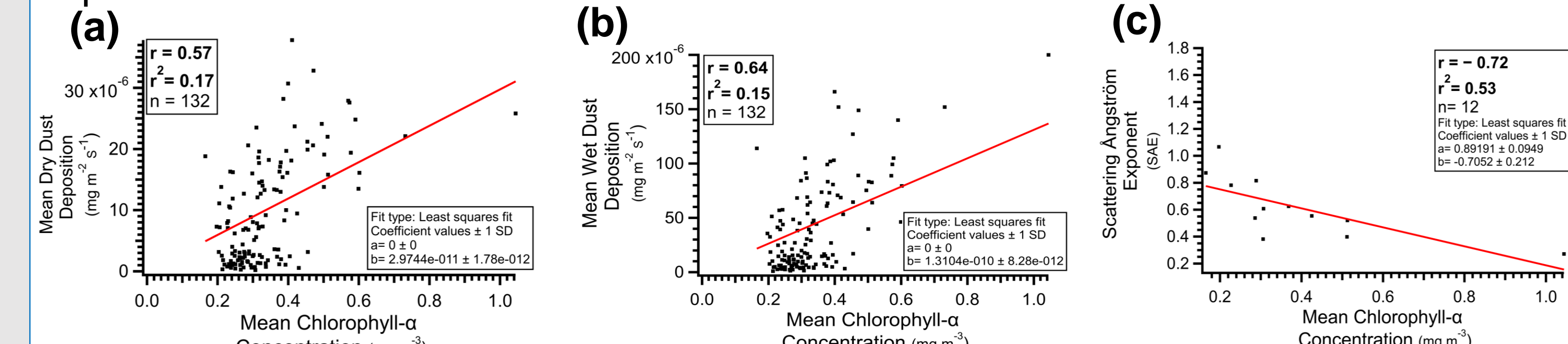


Figure 11. Scatter plots exhibiting coefficients of correlation (r) and of determination (r²), using monthly averaged values. (a) A weak, positive relationship between dry deposition and CHL- α from 2005-2015. (b) A slightly stronger positive relationship between wet deposition and CHL- α . (c) An inversely proportional relationship between SAE and CHL- α only using 2010 values, suggesting the influence of dust over the ECB.

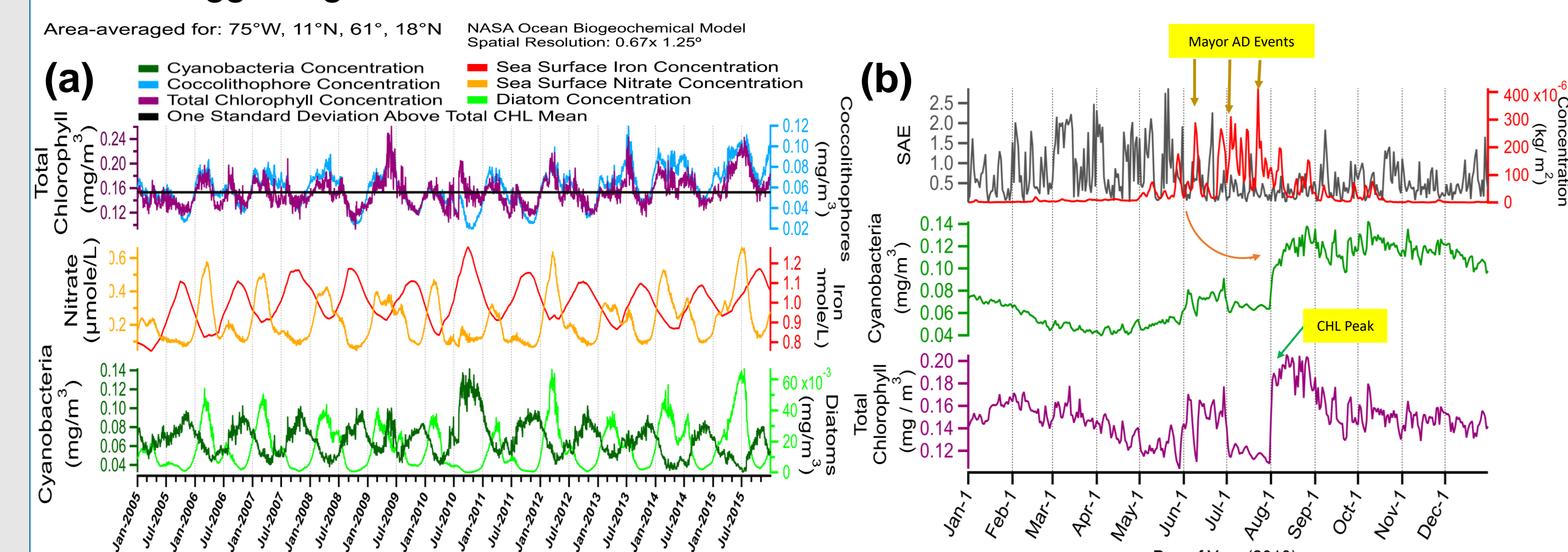


Figure 12. (a) Modeled daily-averaged proxies for marine primary productivity and sea surface nutrient concentrations from 2005-2015. These show direct correlations between CHL and coccolithophores (r=0.83), plus CHL and diatoms (r=0.68). Coccolithophores and diatoms peak when sea surface nitrate concentrations are also maximum (r=0.73 & r=0.96 respectively), but coincide when sea surface iron concentrations are minimum (r=-0.45 & r=-0.55). (b) A 1 to 2 month temporal lag-time between major dust events and peak total CHL, plus cyanobacteria values for 2010.

Influence of the Orinoco River Plume:

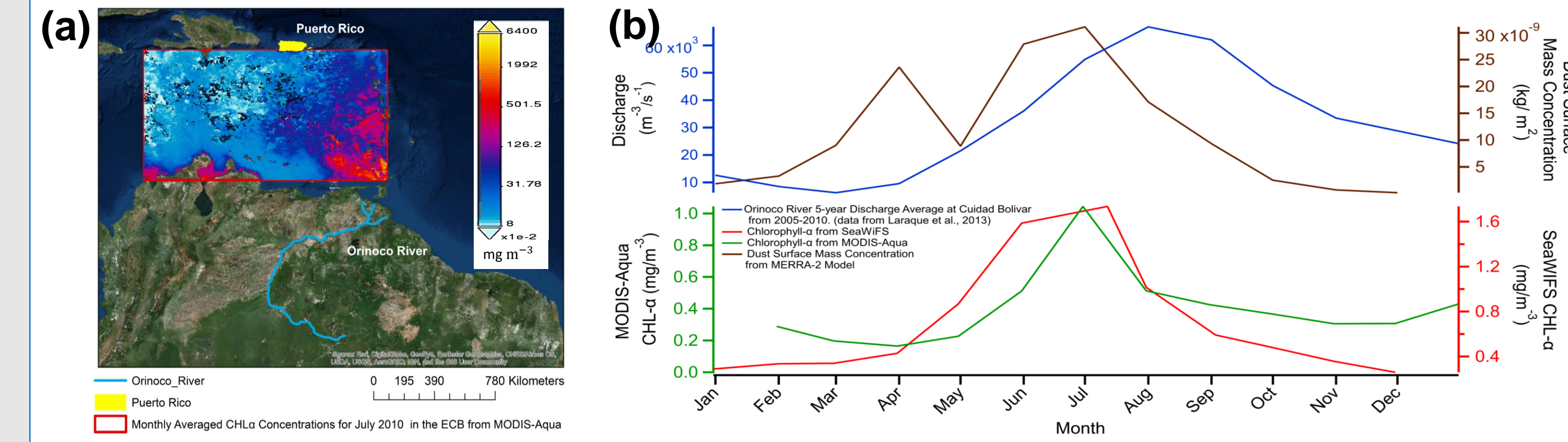


Figure 13. (a) Sediment plumes from the Orinoco River are known to influence the ECB's marine production (López et al., 2013), as depicted here with CHL- α concentrations. (b) However, this simplified schematic shows how CHL- α peaks for 2010 occur 1 month before mean peak river discharges. Also peak CHL- α coincides with the African dust season.

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Acknowledgements

We acknowledge the Center for Applied Tropical Ecology and Conservation, the Department of Particle Chemistry at the Max Plank Institute, and the Department of Environmental Science at the University of Puerto Rico, for their support. We also thank laboratory members, family, and friends for their assistance throughout the project.