Constraining P deposition to the Amazon from the long-range transport of African dust and biomass burning emissions based on measurements in the Trade Winds at Cayenne, French Guiana

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Background

- Soil in the Amazon is phosphorus (P) depleted, which limits primary productivity and the drawdown of carbon dioxide.[1,2]
- Saharan dust is transported to South America and is thought to replenish P to Amazonian soil.[3-5] However, the amount and solubility of P in mineral transported to the Amazon is poorly constrained.
- Additional sources of P may be transported to the Amazon due to seasonal changes in transport conditions. For example, in boreal Spring, Saharan dust and biomass burning emissions from the Sahel are co-transported to South America (Fig 1). In boreal Fall, the ITCZ shifts north and cuts off dust transport to South America (Fig 2). The effect of aerosol sources on the P cycle during this season is unknown.

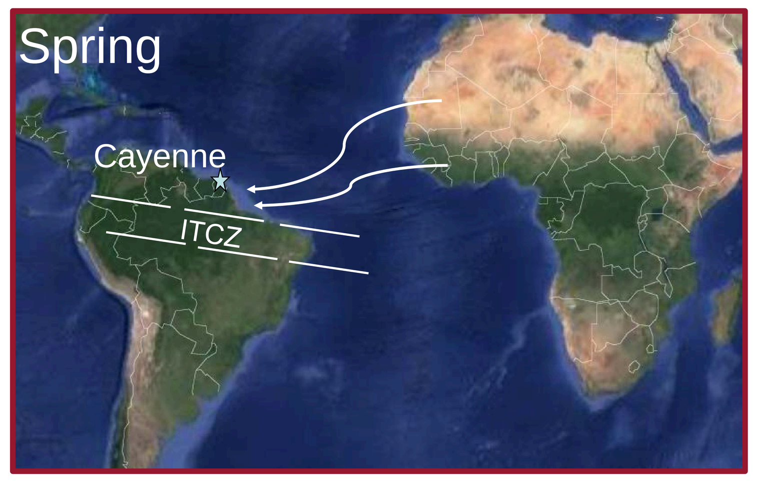


Figure 1. Schematic of spring (Feb – Apr) transport conditions.

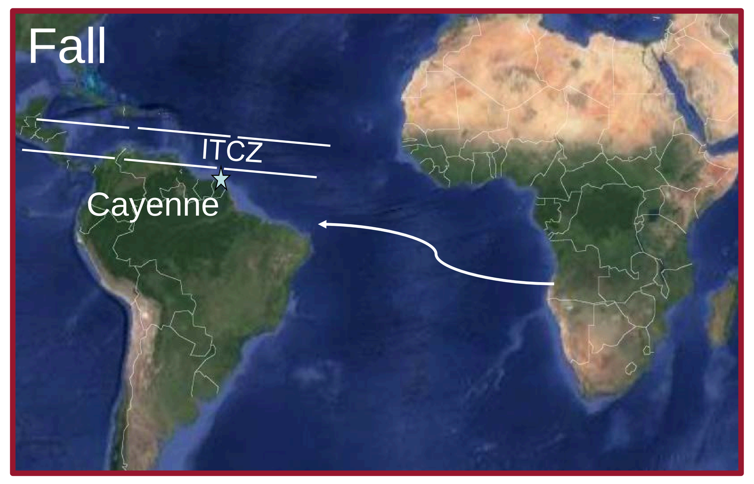


Figure 2. Schematic of climatological transport conditions in Fall (Sept - Nov).

Goal: To investigate the supply and solubility of P from African dust and other aerosol sources transported to the Amazon.

Field Site & Methods

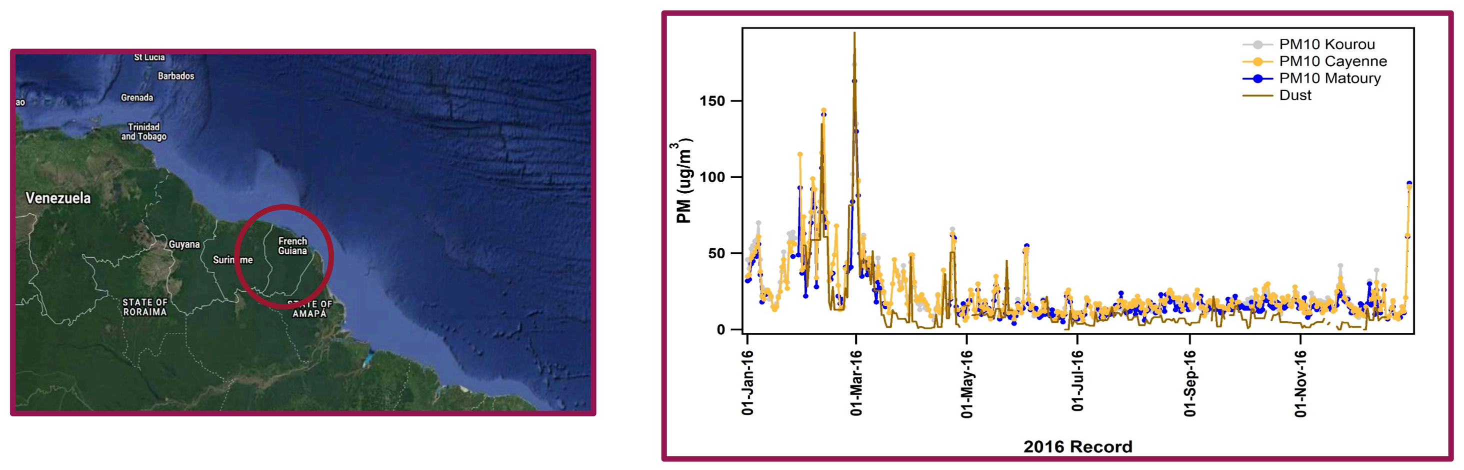


Figure 3 (left to right). Map of aerosol sampling location, located on the coast of Cayenne, French Guiana on a 67 m hill. TEOM PM_{10} concentrations and dust time series showing PM_{10} is dominated by dust (right panel).

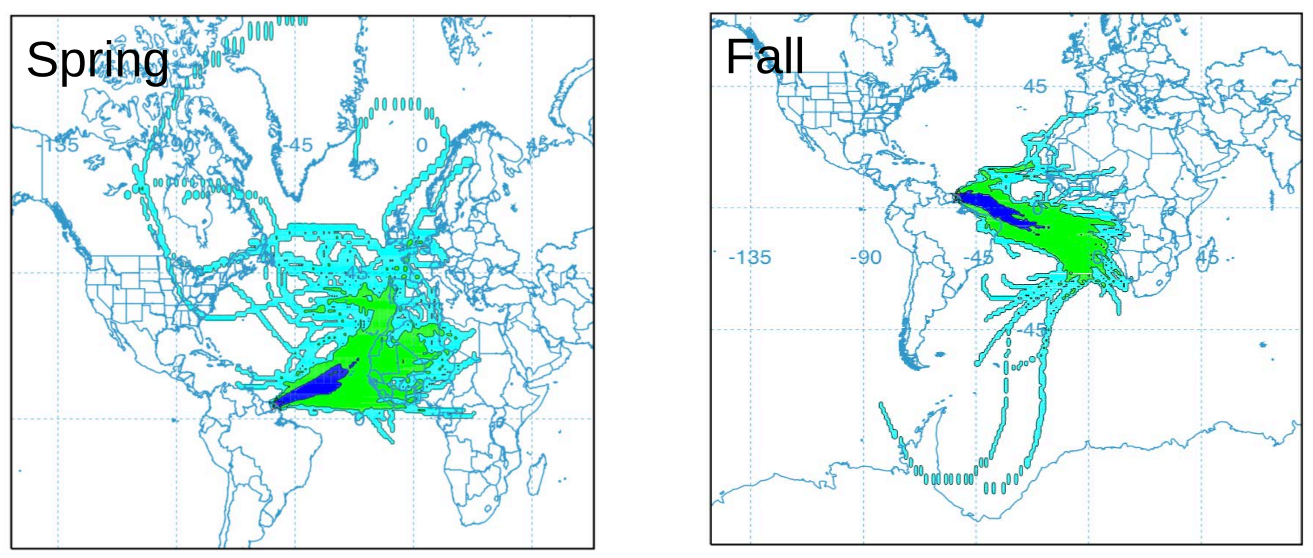


Figure 4. Spring: HYSPLIT air mass back trajectory computed every 6 hours for Feb and Mar. Note all the air masses come from the NE. Fall: air masses computed every 6 hours for Sep and Oct. Note the air masses all come from the SE.

Measurements:

- Dust mass concentrations were quantified according to the method of Prospero, 1999.
- Total Phosphorus (TP): Whatman-41 cellulose filters were ashed at 500C for 24 hours, then samples were acid digested with 3:1:1 ratio of HCl, HF, and HNO_3 and analyzed by MC-ICP-MS (similar to Baker et al., 2006)
- Soluble Reactive Phosphorus (SRP) was quantified using colorimetric analysis similar to Strickland and Parsons (1972) with leaching time similar to Ridame and Guieu (2002).

The supply of P from African dust

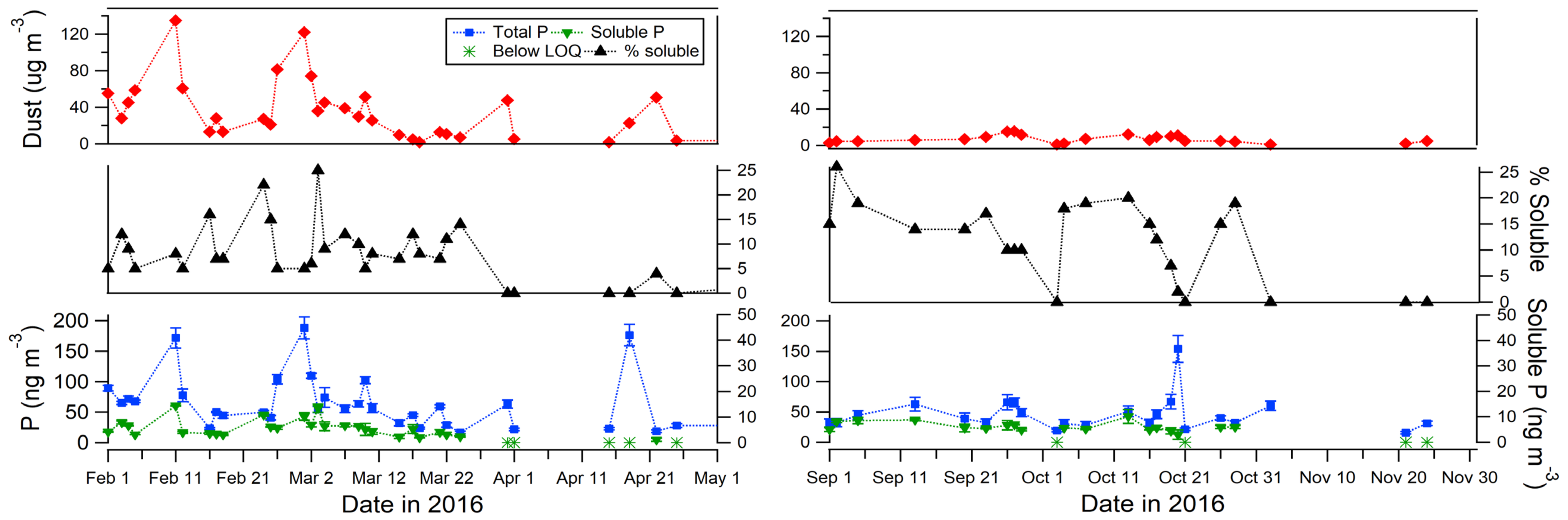


Figure 5. Measurements of dust (top), total P (bottom, blue), and soluble P (bottom, green). All total P measurements have corresponding soluble P values. The absence of a soluble P marker (e.g. in April and November) indicates that the SRP concentration was below the LOQ.

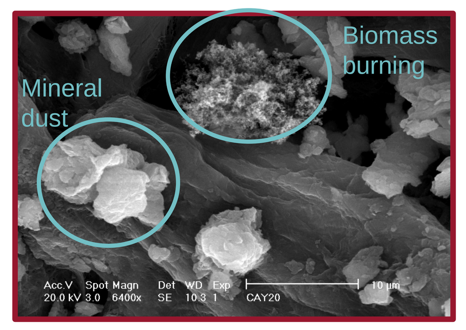


Figure 6. SEM image of a sample from March 2016 showing both biomass burning and mineral dust.

Results:

- Transported African dust had an average total P concentration of 1080 ppm and an average solubility of 10% (range = 4-25%)
- High P concentrations were also observed in Fall when dust mass concentrations are low.
- P solubility was greater than anticipated especially when dust was low (average solubility = 15%; range = 2-26% in Fall), suggesting that other sources of P are controlling the supply and solubility of P transported to Cayenne. For example, possibly the transport of African biomass burning[6,7] (Fig. 6).

Biomass burning as a source of highly soluble P

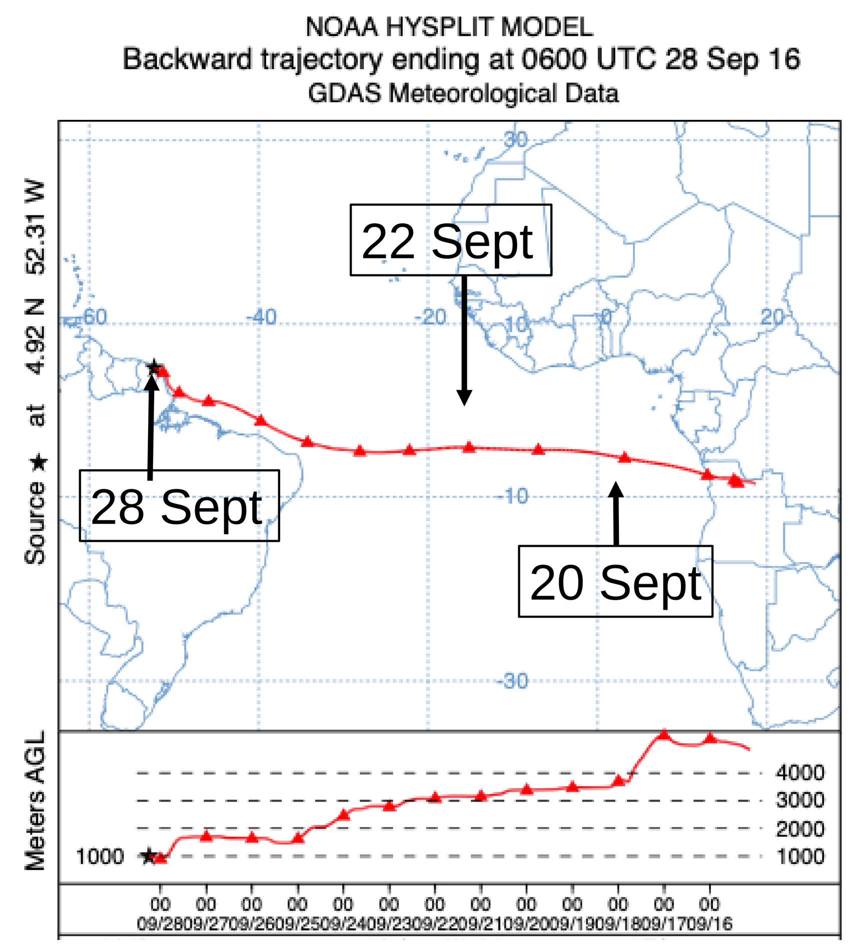


Figure 7. A 315-hour representative air mass back trajectory shown. The black arrows point to specific dates which are shown in the box. These days intersect CALIPSO passes, which give a vertical distribution of aerosol type (shown to the left). The black arrows on the these plots show the intersection of the CALIPSO pass with the air mass back trajectory.

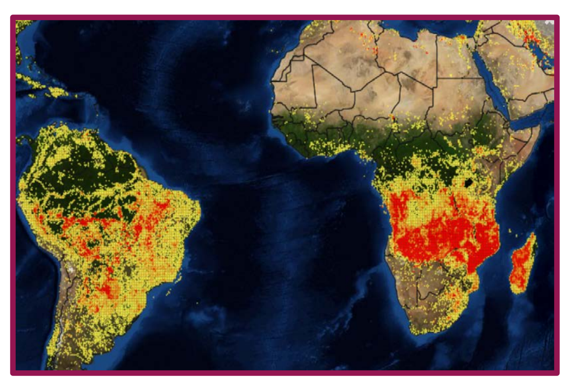
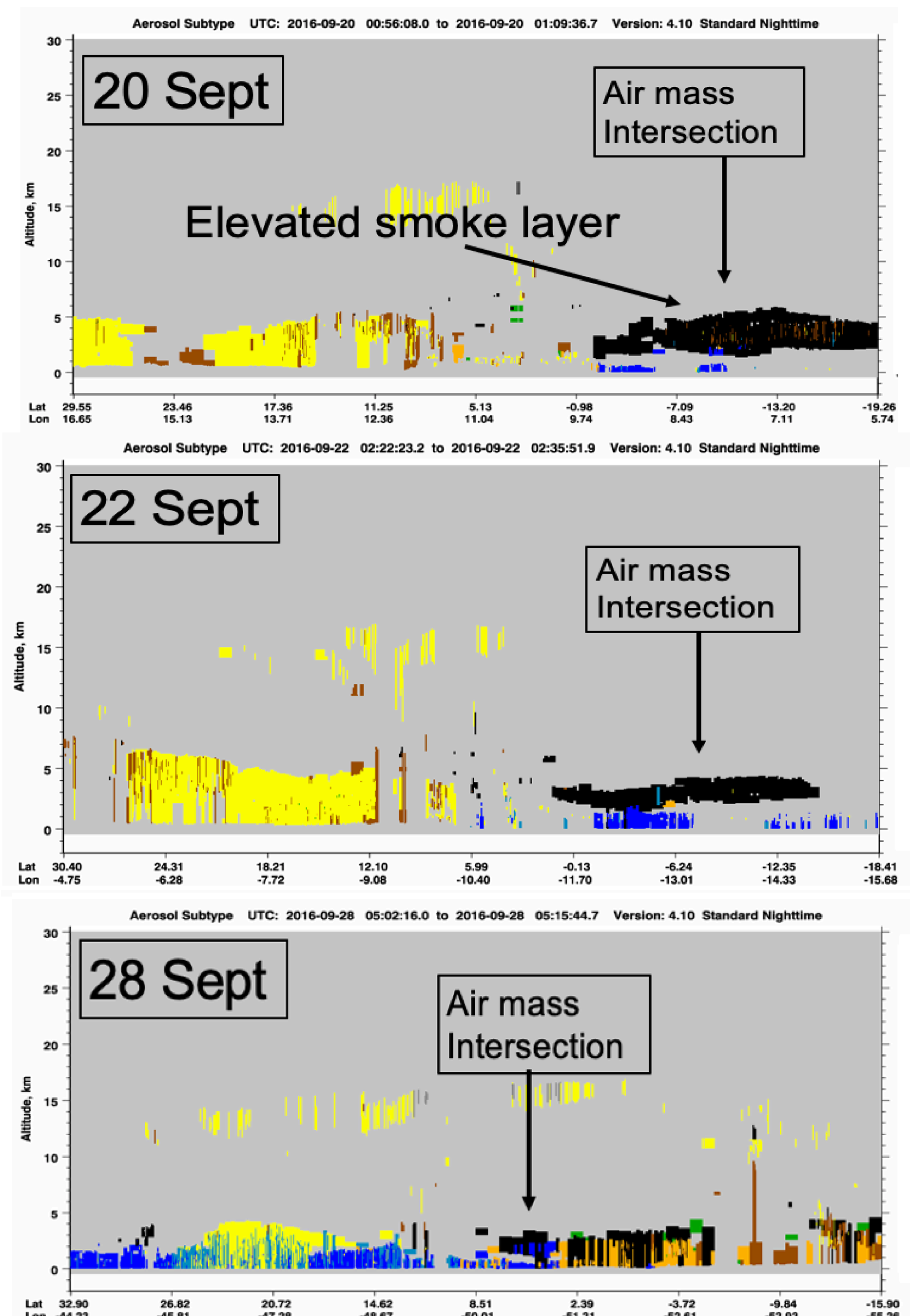


Figure 8. Thermal anomalies indicate fire and are shown for September 2016 from VIIRS.



Yellow = dust; blue = sea salt; black = elevated smoke

Results:

- Our measurements, in combination with the CALIPSO aerosol speciation product, suggest that biomass burning from southern Africa (Fig. 7) can provide an additional, unaccounted for supply of highly soluble P during the Fall.

Estimate of P and soluble P deposition to the Amazon

- The MERRA-2 model was used to estimate P deposition because it showed skill at predicting dust mass concentrations (see Fig 9). We applied this model to the area for the Amazon prescribed in Yu et al., 2015. We then used our dust:P and dust:soluble P ratios to estimate the deposition of P to the Amazon.

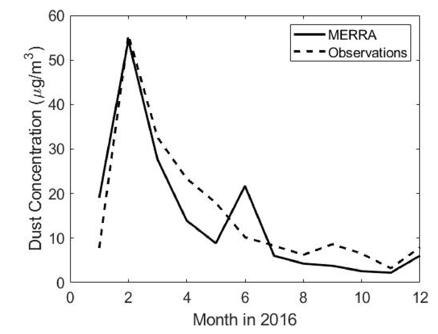


Figure 9. This figure shows monthly dust concentration averages (hashed line) compared to what the MERRA-2 model predicts (solid line) for a 1° x 1° area over Cayenne. MERRA-2 seems to capture to seasonal dust record.

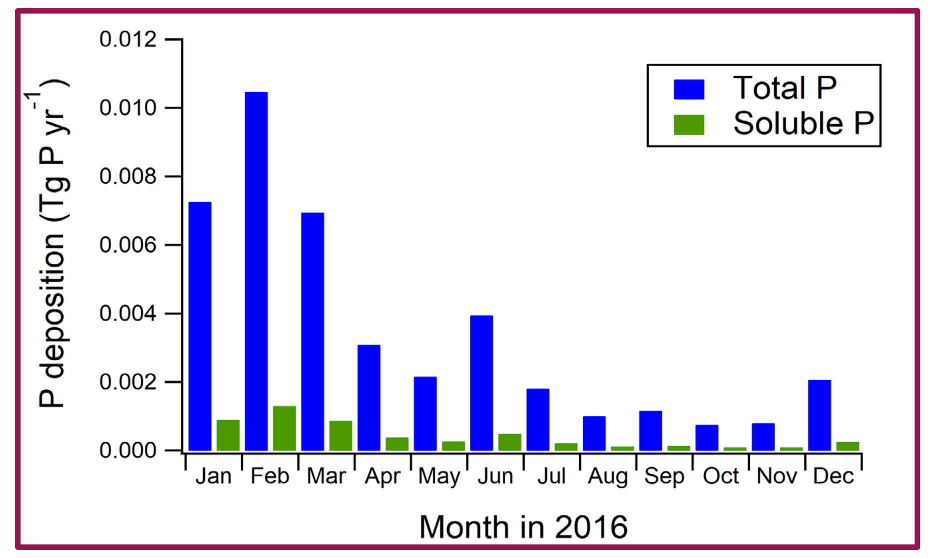


Figure 10. Monthly deposition rates of total P (blue) and soluble P (green) associated with dust. The ratio of dust:P was 1080 ppm based on our results.

Results:

- Total P deposition = 0.042 Tg P yr^{-1} for the Amazon Basin
- Soluble P deposition = 0.005 Tg soluble P yr^{-1} for the Amazon
- Total and soluble P deposition due to southern African biomass burning are not captured in Fig. 10 because our estimates are based on dust deposition only. Therefore, the deposition of P and soluble P is likely even higher.

Conclusions

- Dust dominates total P deposition in spring.
- In the spring, P solubility was 10%, on average. In the Fall, P solubility was higher and ranged from 2-26% with an average of 15%.
- This work suggests that biomass burning from southern Africa also plays a role in supplying P to the Amazon, particularly during the Fall.
- Biogeochemical models should incorporate the supply of P from African biomass burning aerosol.

References: [1]Vitousek and Sanford, 1986; [2]Mahowald et al., 2008; [3]Prospero et al., 1981; [4]Swap et al., 1992; [5]Yu et al., 2015; [6]Adebiyi and Zuidema, 2016, [7]Baker et al., 2006

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