Atmospheric aerosols over the Amazon Basin: Composition, microphysics, sources and sinks

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The view pre-1985

It is clear that the high concentrations of CO in the cerrado boundary layer during the dry season [~400 ppb]… are caused by vegetation fires …. The production of CO in the tropical forest boundary layer [~300 ppb!!] can be explained by the rapid oxidation of reactive hydrocarbons emitted by foliage [Crutzen et al., 1985]

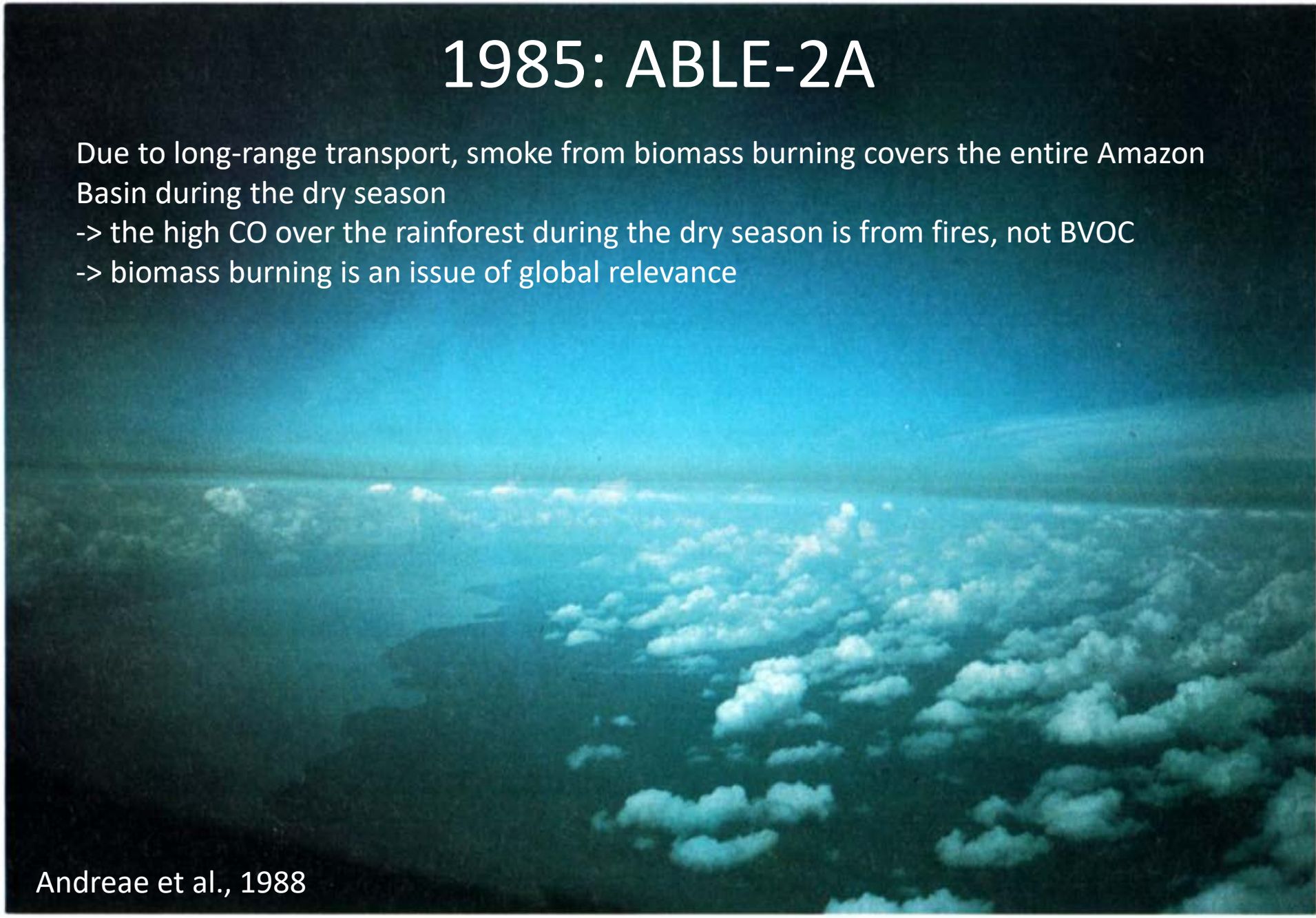
Paul Crutzen in the Amazon forest 1979

1985: ABLE-2A

Due to long-range transport, smoke from biomass burning covers the entire Amazon Basin during the dry season

-> the high CO over the rainforest during the dry season is from fires, not BVOC

-> biomass burning is an issue of global relevance



Andreae et al., 1988

Plate 1. Haze layer, as seen from the cockpit of the NASA Electra aircraft on August 8, 1985, over the Xingu River at an altitude of about 3.7 km.

1987: ABLE-2B

The Amazon is an "open system" subject to LRT of dust and smoke from North Africa and marine aerosol from the Atlantic

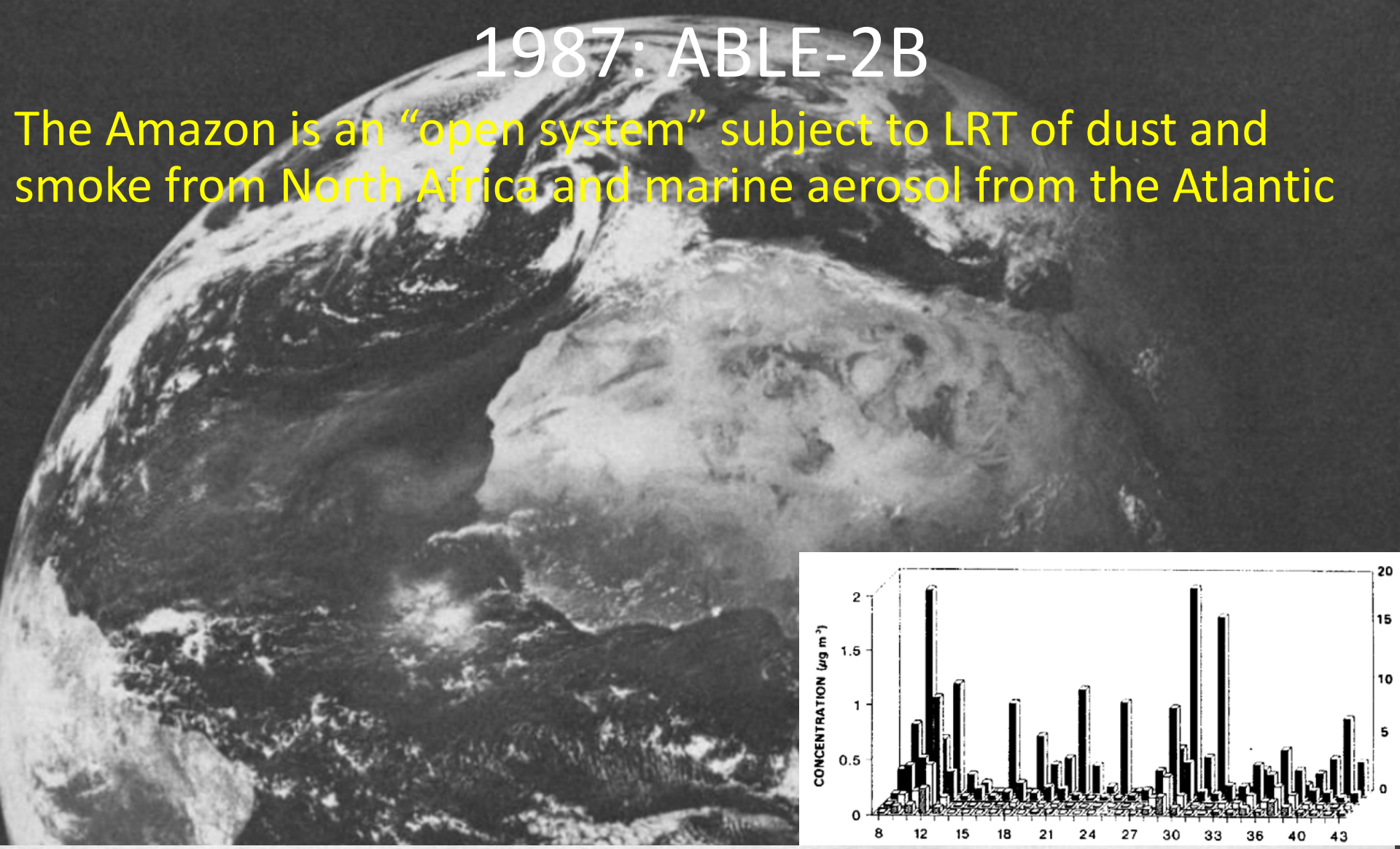


Fig. 12. Meteosat image obtained with the visible channel on April 23, 1987, showing large-scale intrusion of Saharan dust over the tropical Atlantic between west Africa and South America. An intense plume of Saharan dust can be seen leaving the African coast heading west out over the Atlantic. The Meteosat image was supplied by the European

1989: CITE-3

The Amazon is an "open system" also in the dry season, subject to LRT of biomass smoke from southern Africa

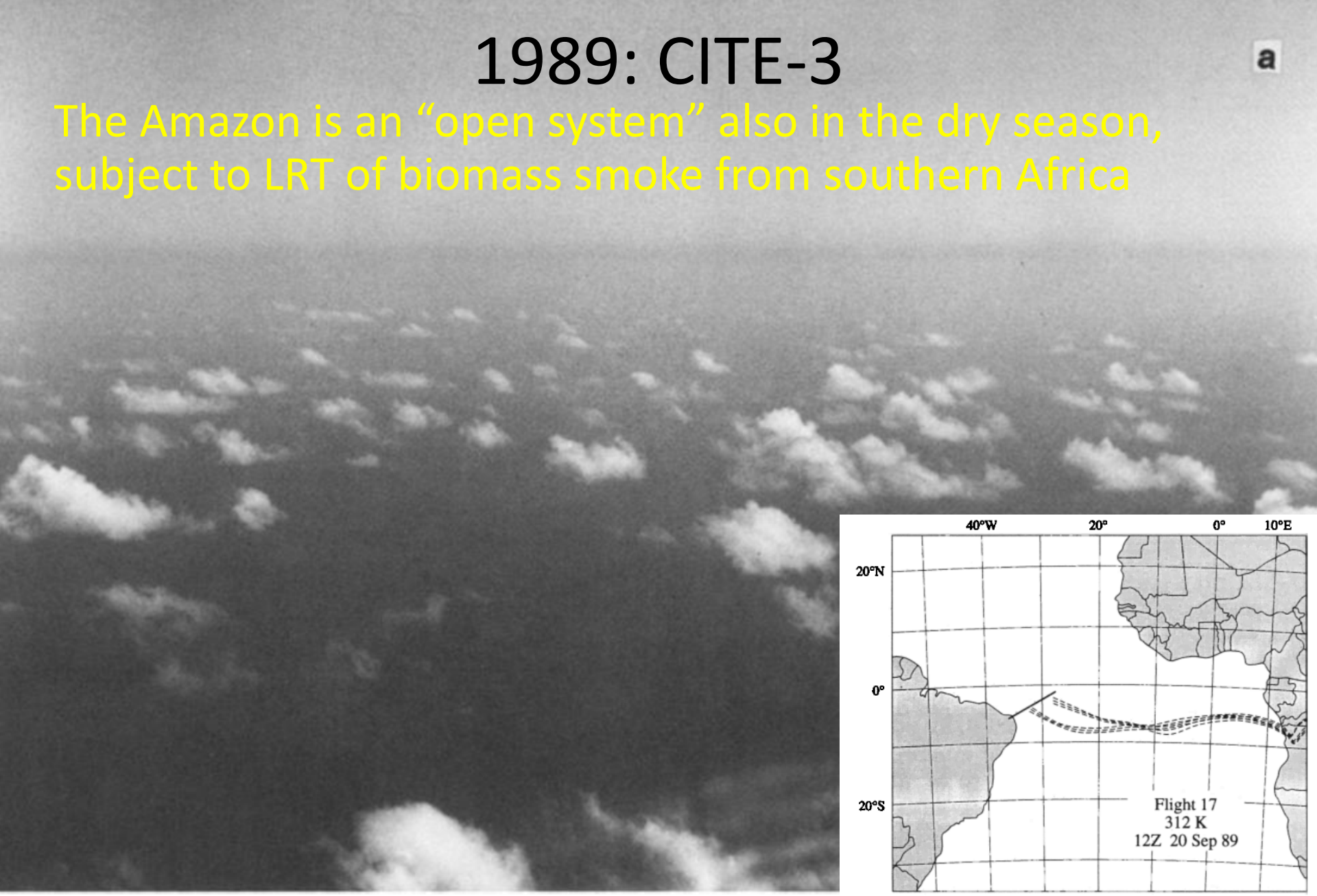


Figure 9. Haze layers, as seen from the NASA Electra aircraft during flight 14 on September 15, 1989 (a) near 5°S and 34°W at an altitude of 2 km and (b) near 1°N and 34°W at an altitude of 1.5 km.

A contemporary view:

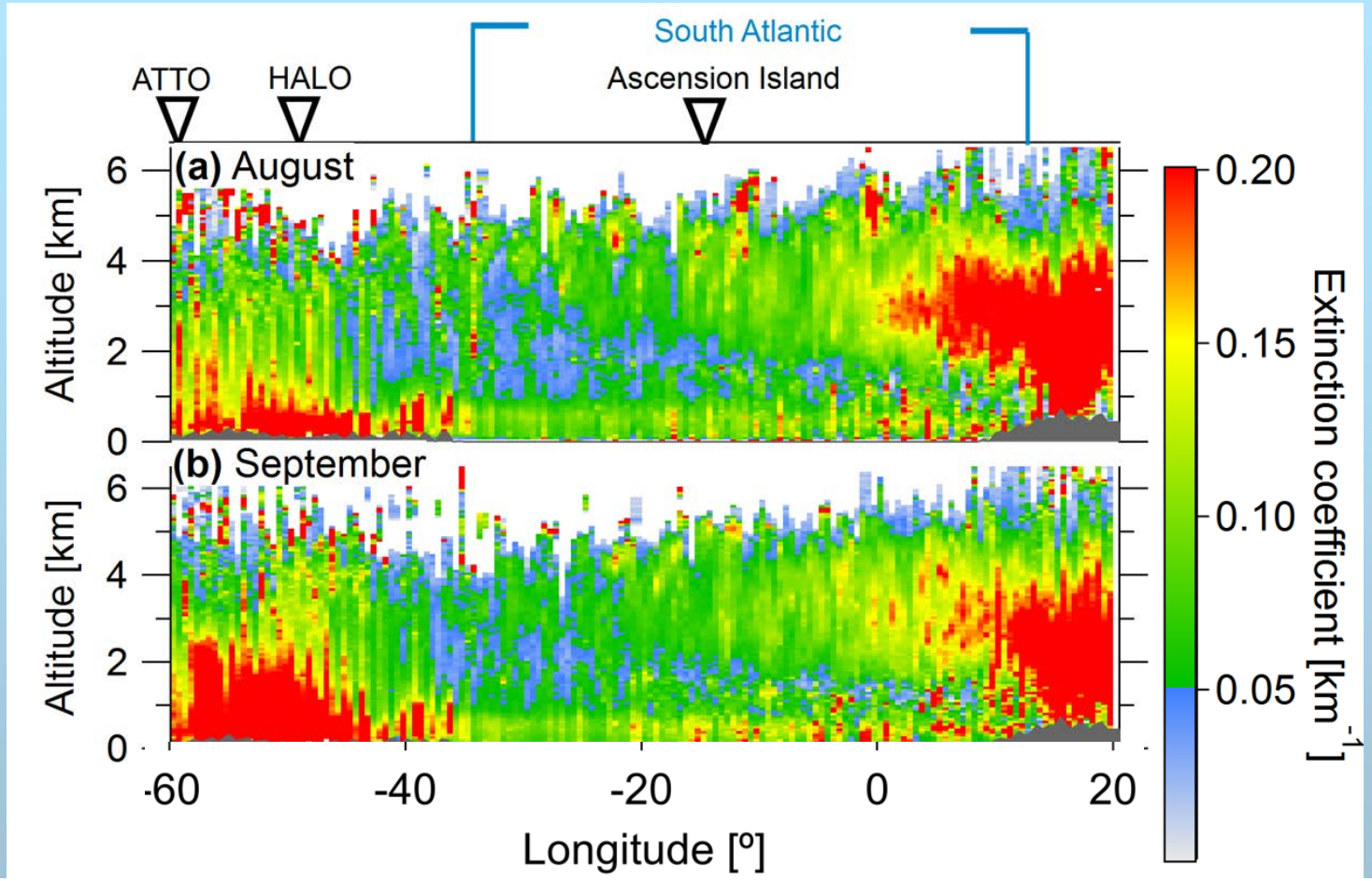
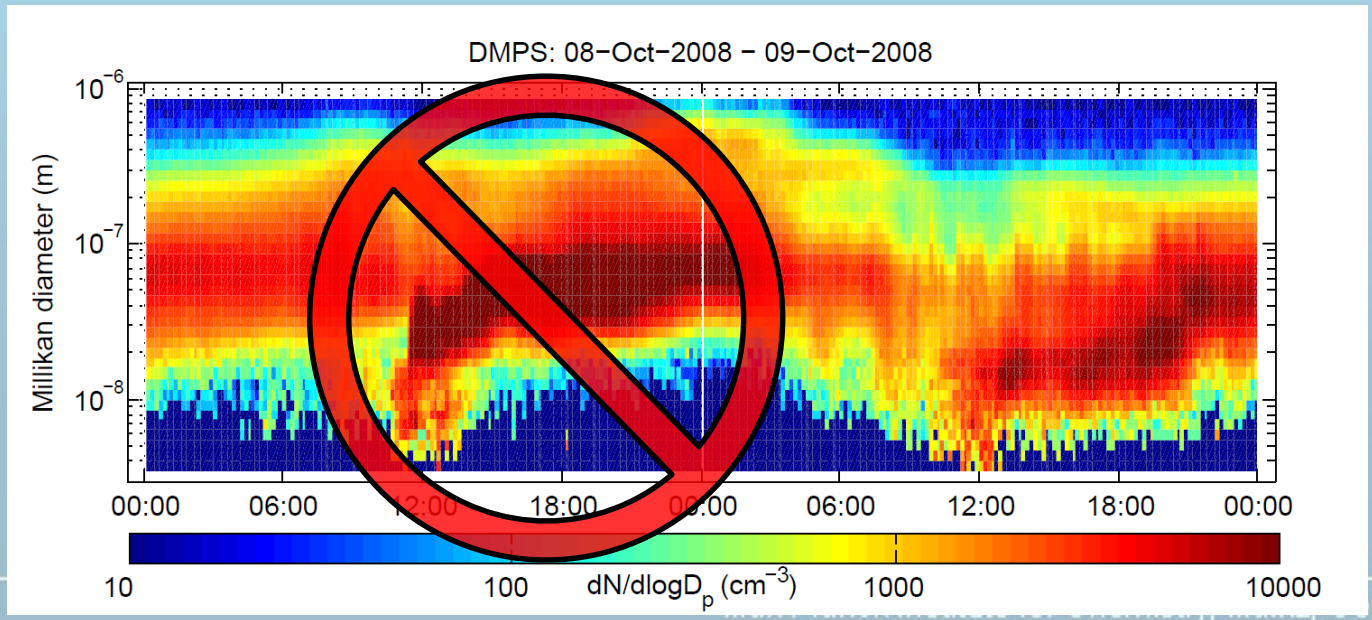


Figure 10. Curtain plot showing the columnar aerosol extinction coefficient at 532 nm, based on multi-year CALIOP data from 2012 to 2018 (only night time data). Panels represent monthly averages for the months of **(a)** August, **(b)** September, and **(c)** October within the latitude band from 10° S to 5° N, (Holanda et al., 2020)

LRT of biomass smoke from southern Africa is a dominant aerosol source in the northern Amazon during the dry season!

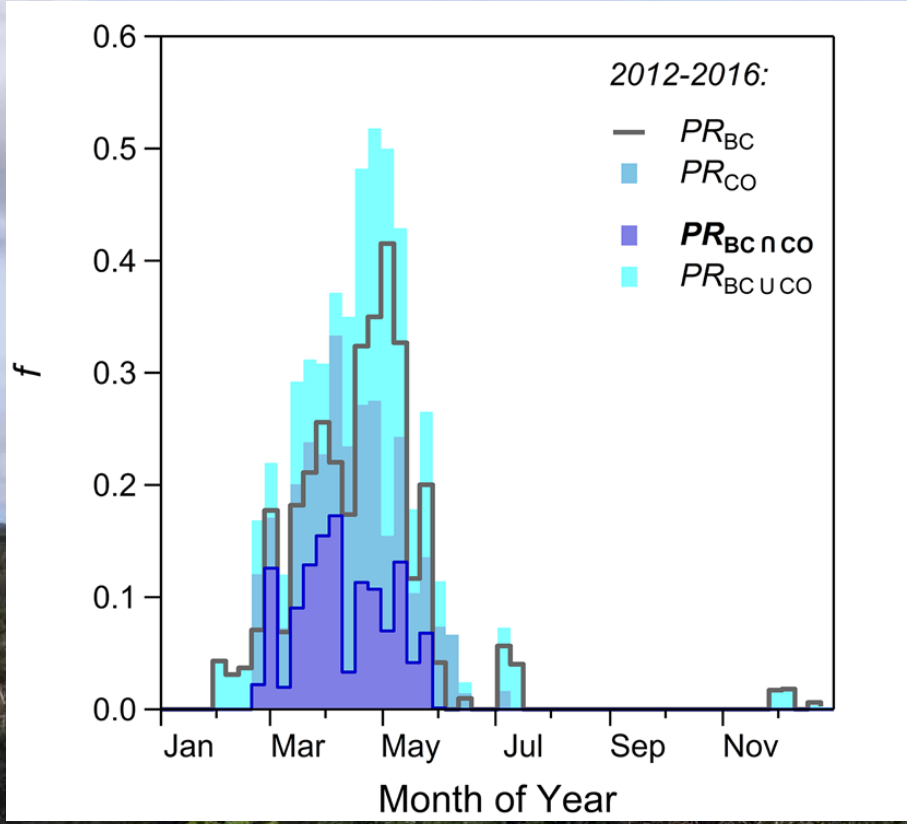
So much for external sources, but…

- What controls the lifecycle – especially the sources – of aerosols in the pristine Amazon?
- How do secondary aerosol particles originate?
- Why are there no nucleation “banana” events?



(Kerminen et al., 2012)

“Pristine” aerosol conditions are rare in the present-day Amazon

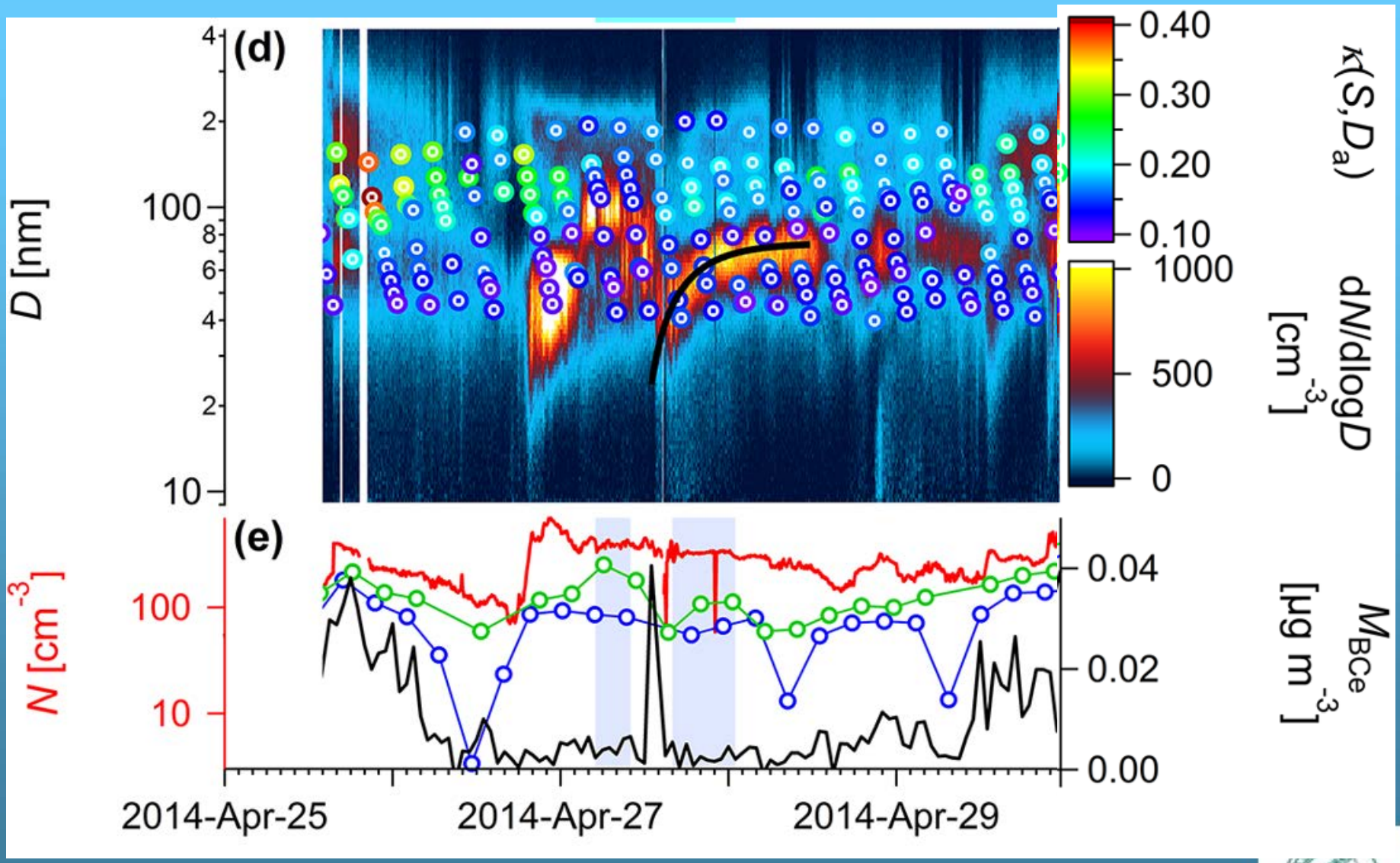


ATTO Tower

$D_{Ait} \approx 70$ nm; $N_{Ait} \approx 160$ cm^{-3}
$D_{acc} \approx 160$ nm; $N_{acc} \approx 90$ cm^{-3}
OA: 0.64, NO_3^- : 0.03, SO_4^{2-} : 0.04, BC: < 0.01 µg m^{-3}

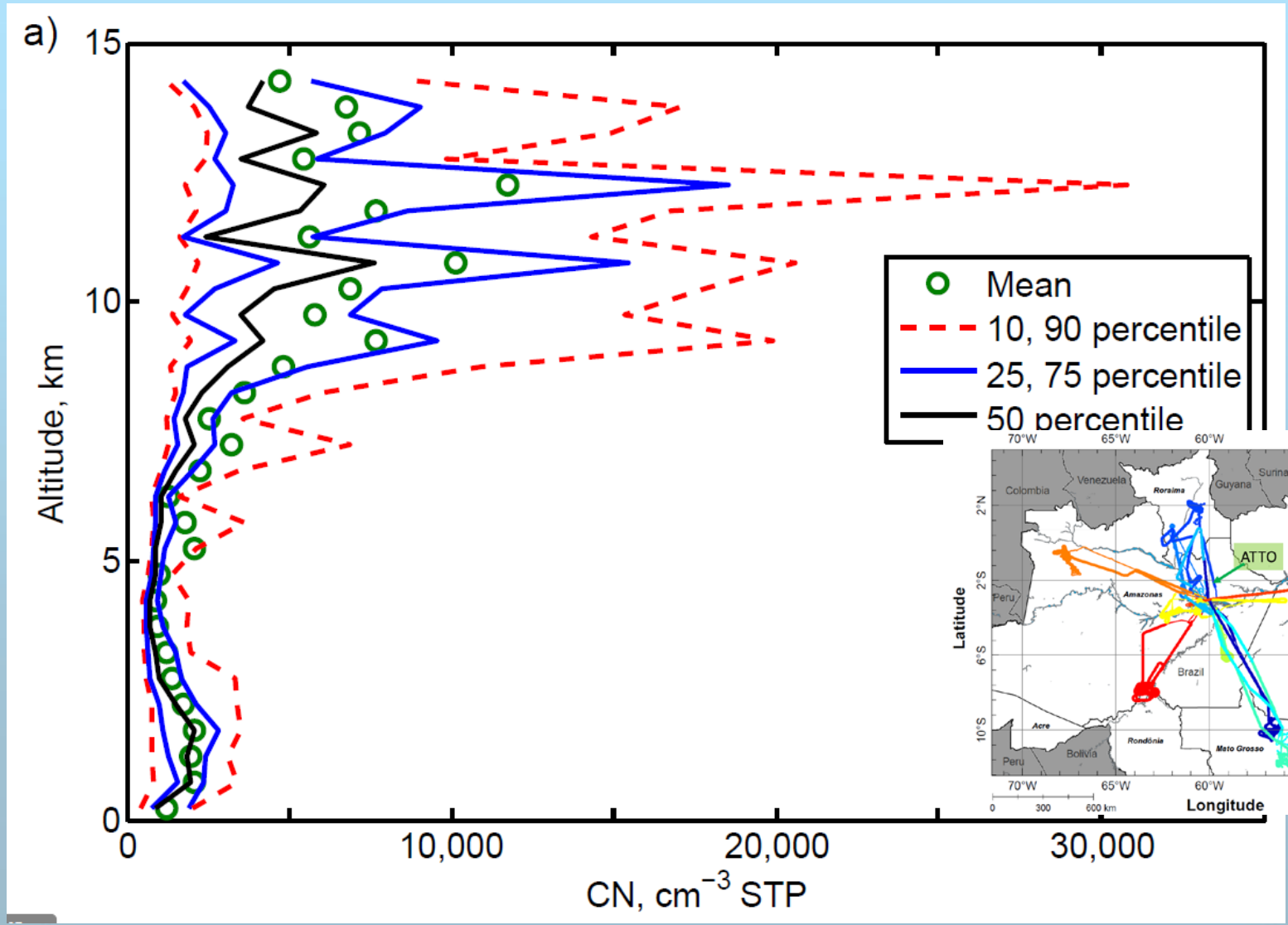
(M. Pöhlker et al., 2018)

“Growth” event at ATTO



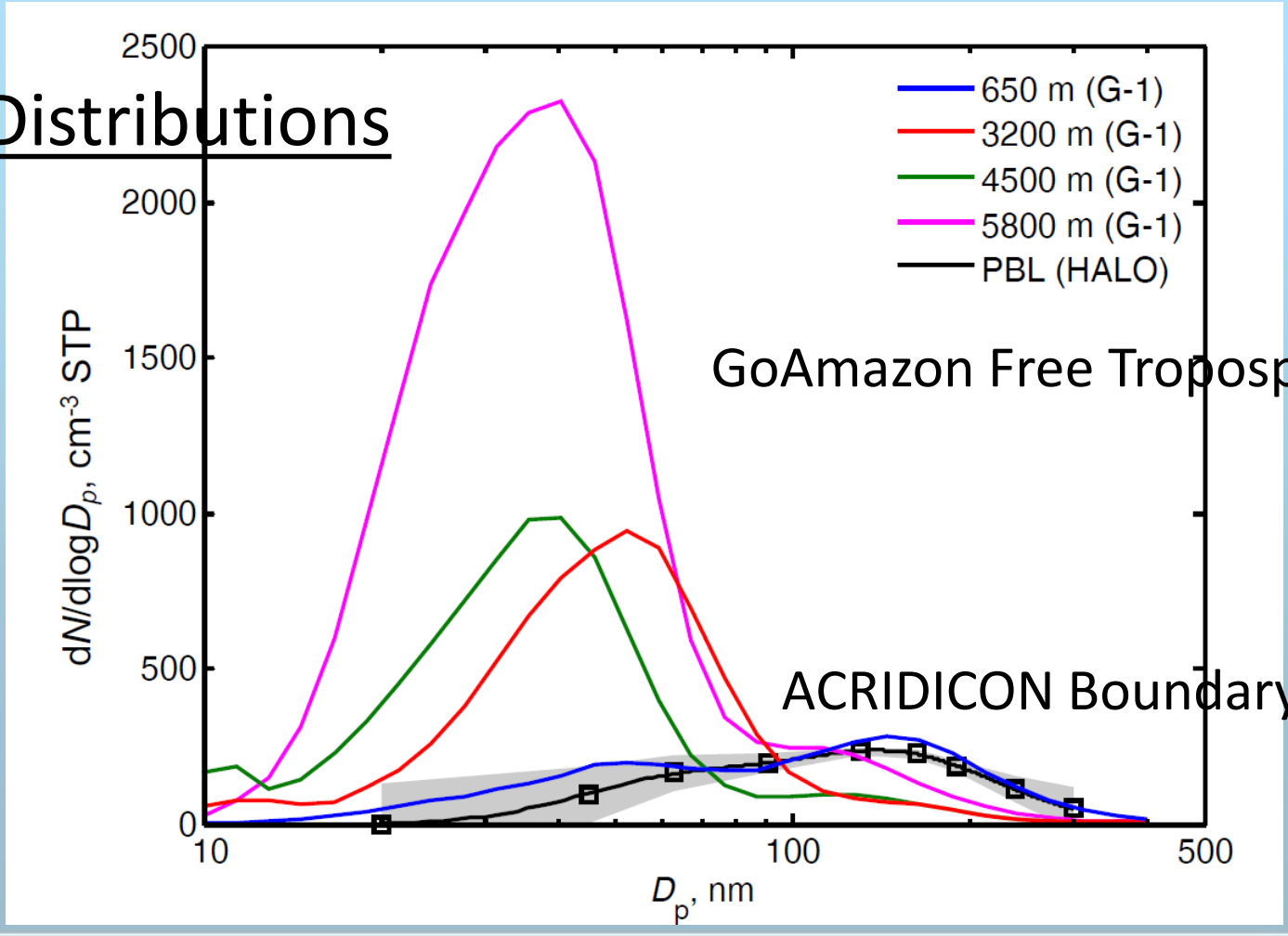
M. Pöhlker et al., 2018

Aerosol Particle Vertical Distribution over Amazonia (ACRIDICON-CHUVA 2014)

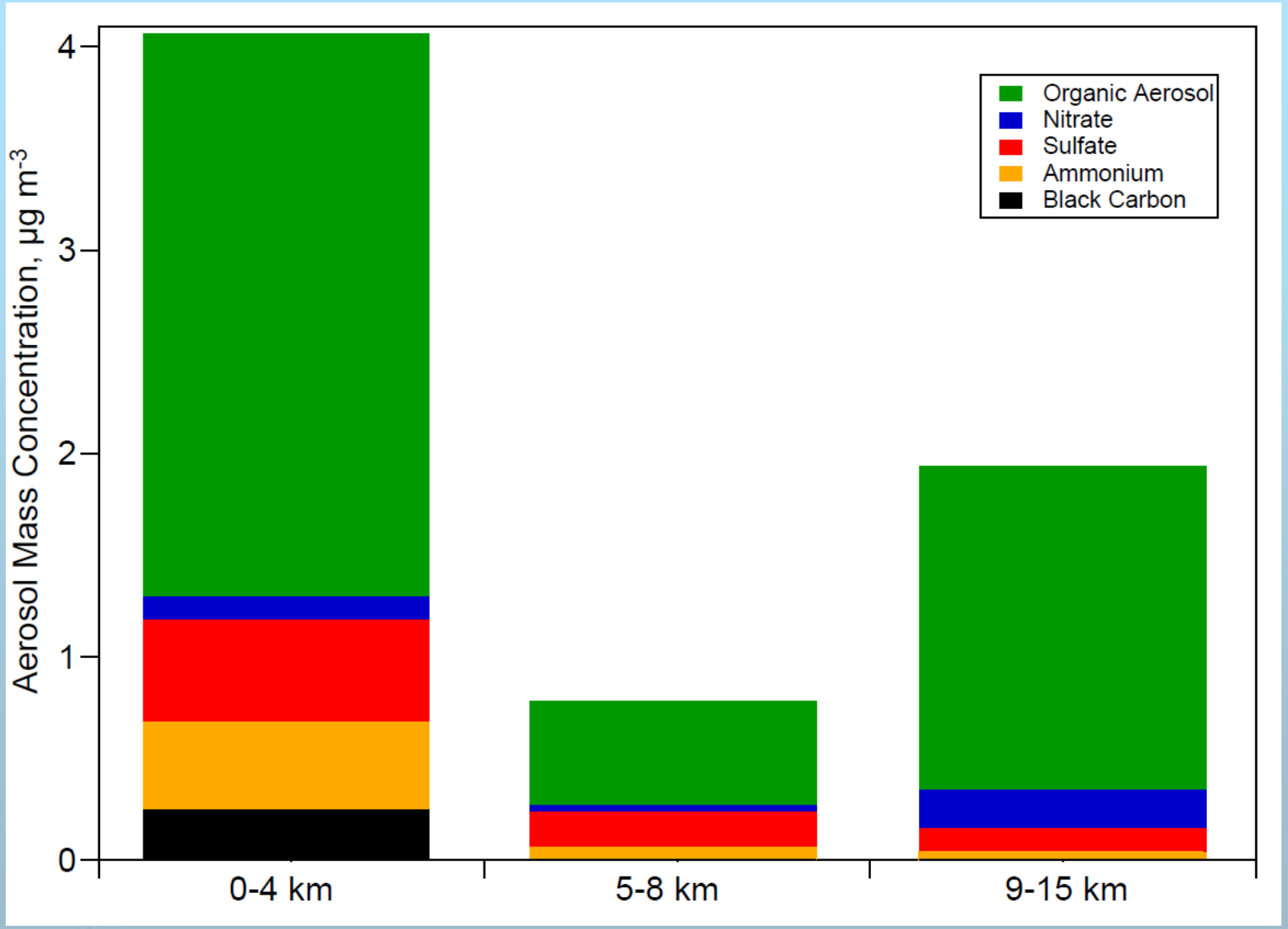


The aerosols in the upper troposphere are completely different from the boundary layer in size and composition

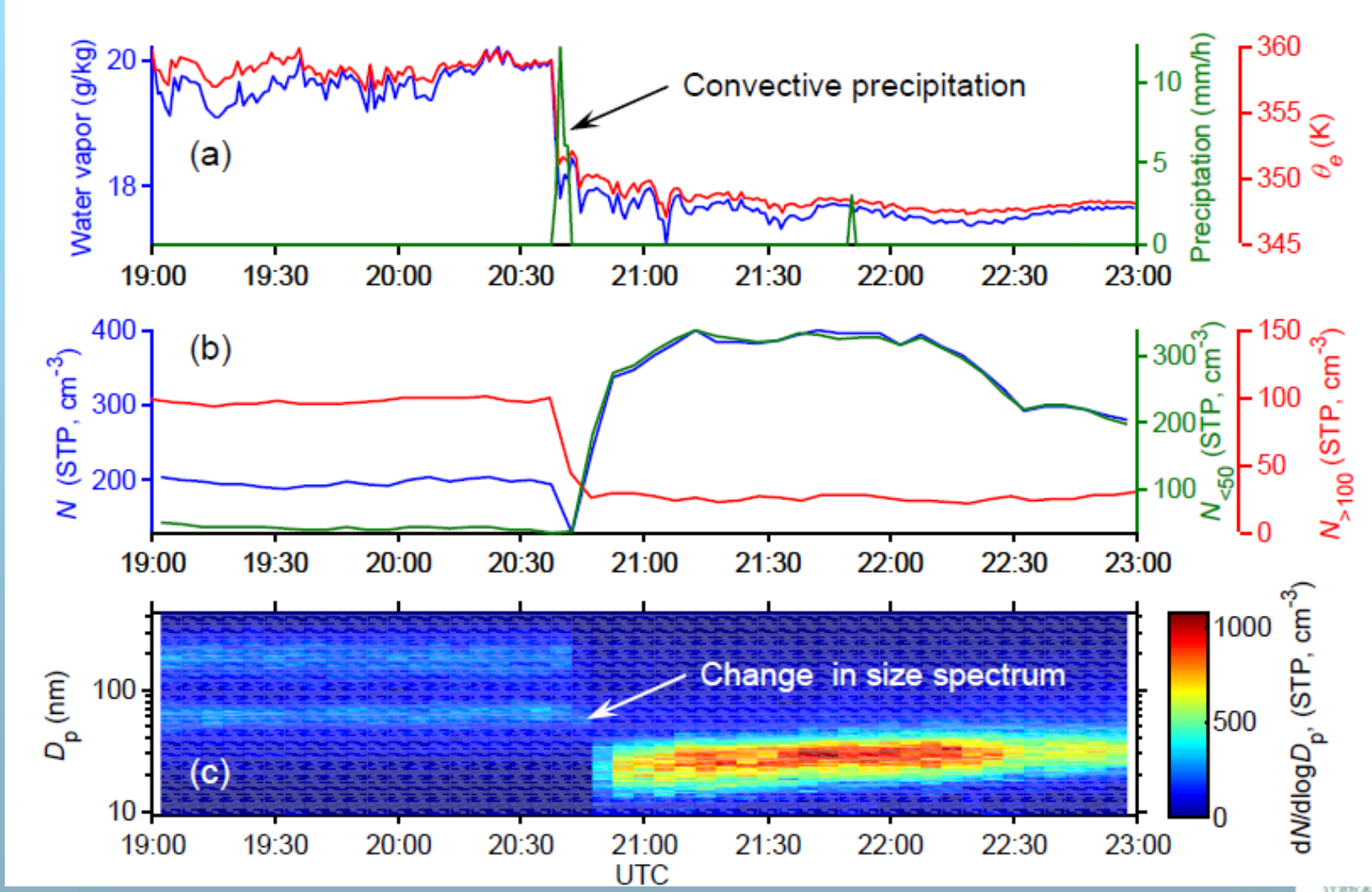
Size Distributions



Chemical composition: AMS

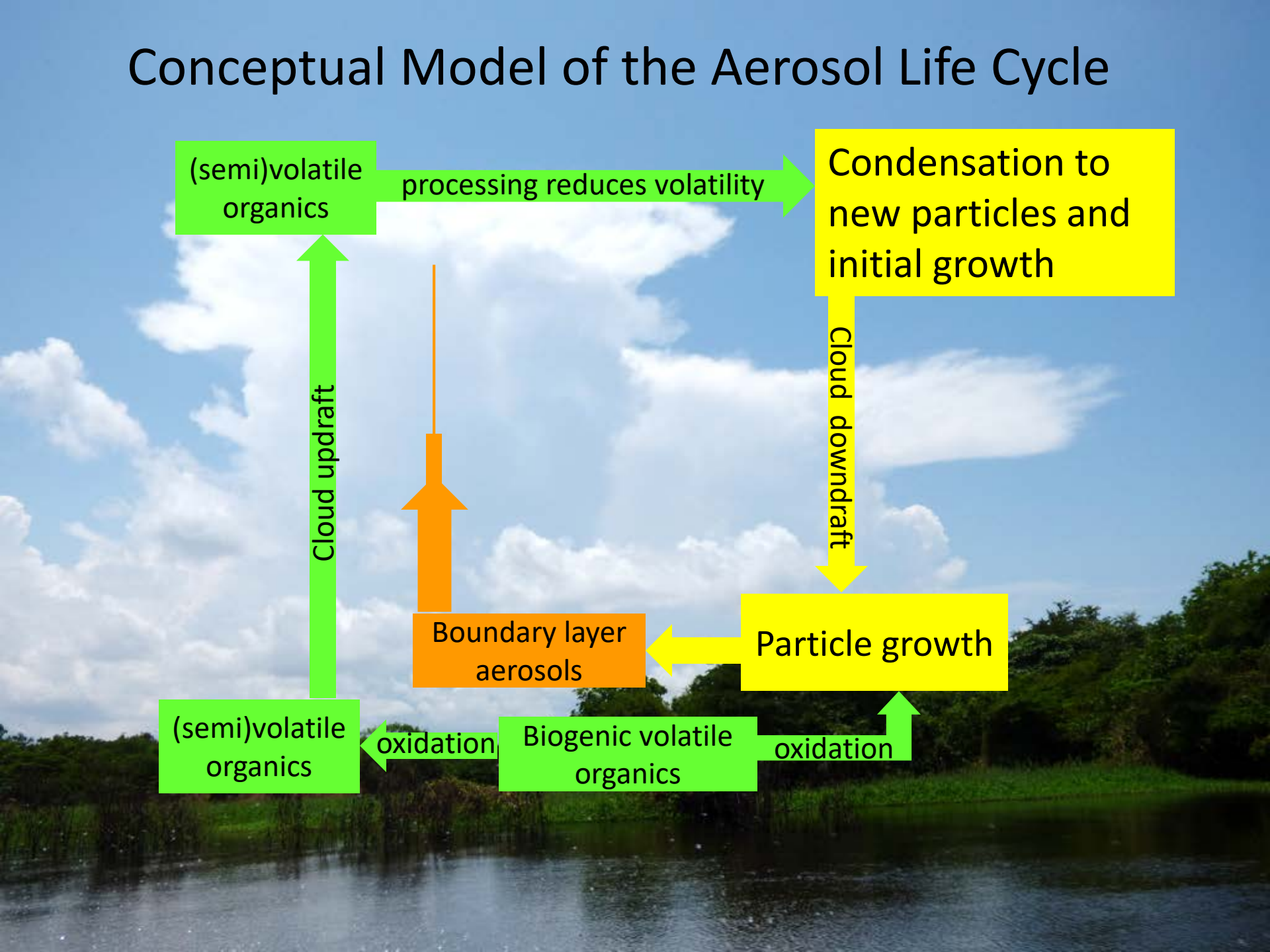


Injection of UT air into the boundary layer



Wang et al. (Nature, 2016)

Conceptual Model of the Aerosol Life Cycle



Conclusions

- The Amazon is an “open system”, where LRT, especially from Africa, plays an important role both in the wet and dry seasons.
- “Empirically pristine” periods are rare, even in the wet season. They have low particle concentrations (~300 cm^{-3}, with a dominant Aitken mode).
- “Pristine” aerosols consist mostly of organic matter, with some sulfate and nitrate.
- Nucleation “bananas” do not occur in the Amazon boundary layer.
- New particle formation is abundant in the upper troposphere, as convective transport removes preexisting aerosols and brings (S)VOCs into regions with low temperature, conducive to nucleation and new particle formation.
- Downward mixing supplies small particles to PBL, where they grow into the CCN range.
- This may have been the dominant mode of aerosol production in the pre-industrial atmosphere.
- Deep convection is essential both as sink and source of aerosols!

Some Open Questions

- How representative are these measurement in UT for other seasons and regions?
- What VOC species are transported by deep convection to the UT?
- What are the mechanisms and kinetics of VOC oxidation at low pressures and temperatures of -60 to -80 C?
- How general and efficient are the mechanisms of downward transportation of CN from the UT?
- Is there a significant competition for nucleation in the PBL?
- What role may entrainment of UT aerosols play in secondary nucleation in convective clouds in the middle troposphere?
- …