Amplified seasonal cycle in low-clouds over the remote southeast Atlantic when biomass-burning aerosol is present

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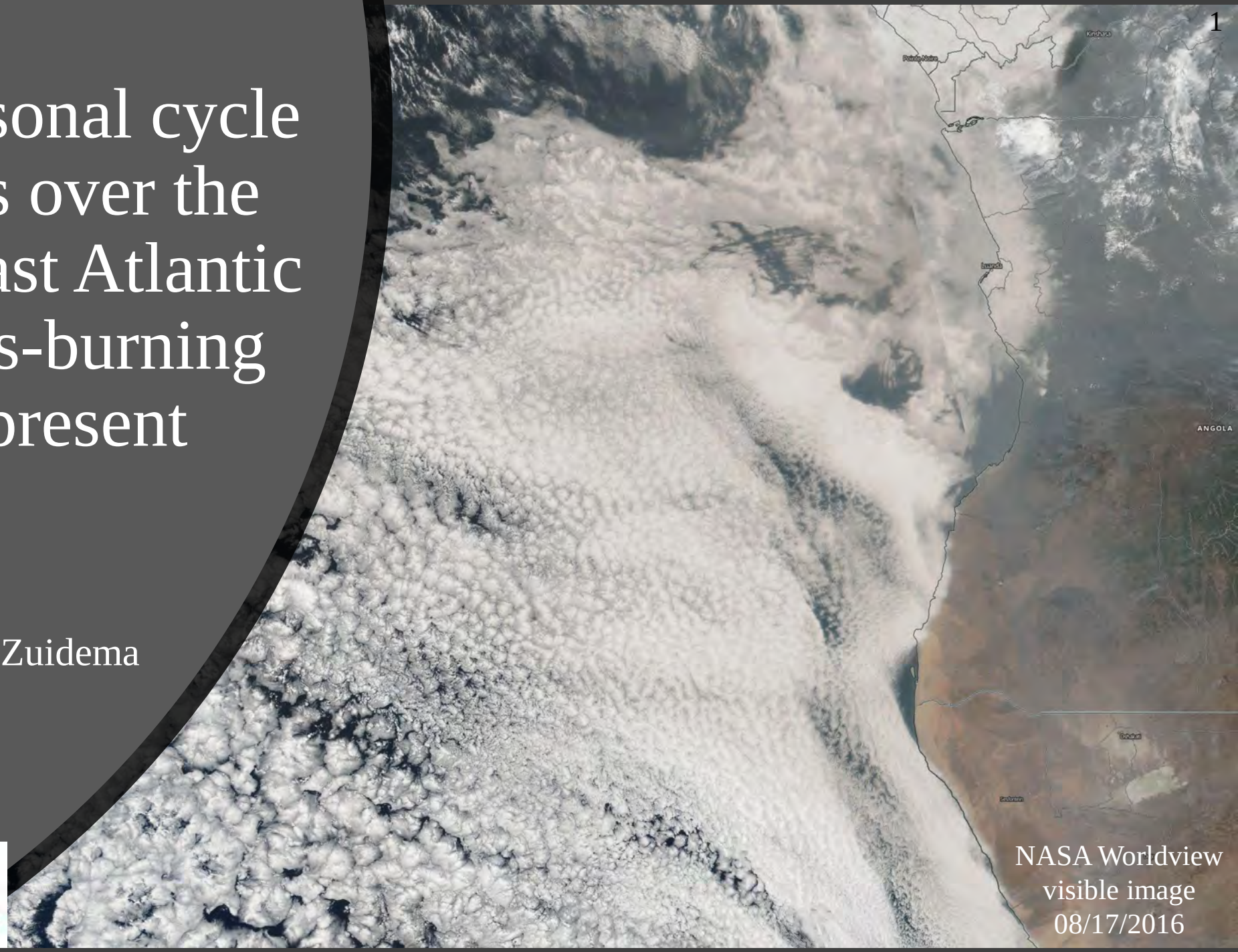
MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

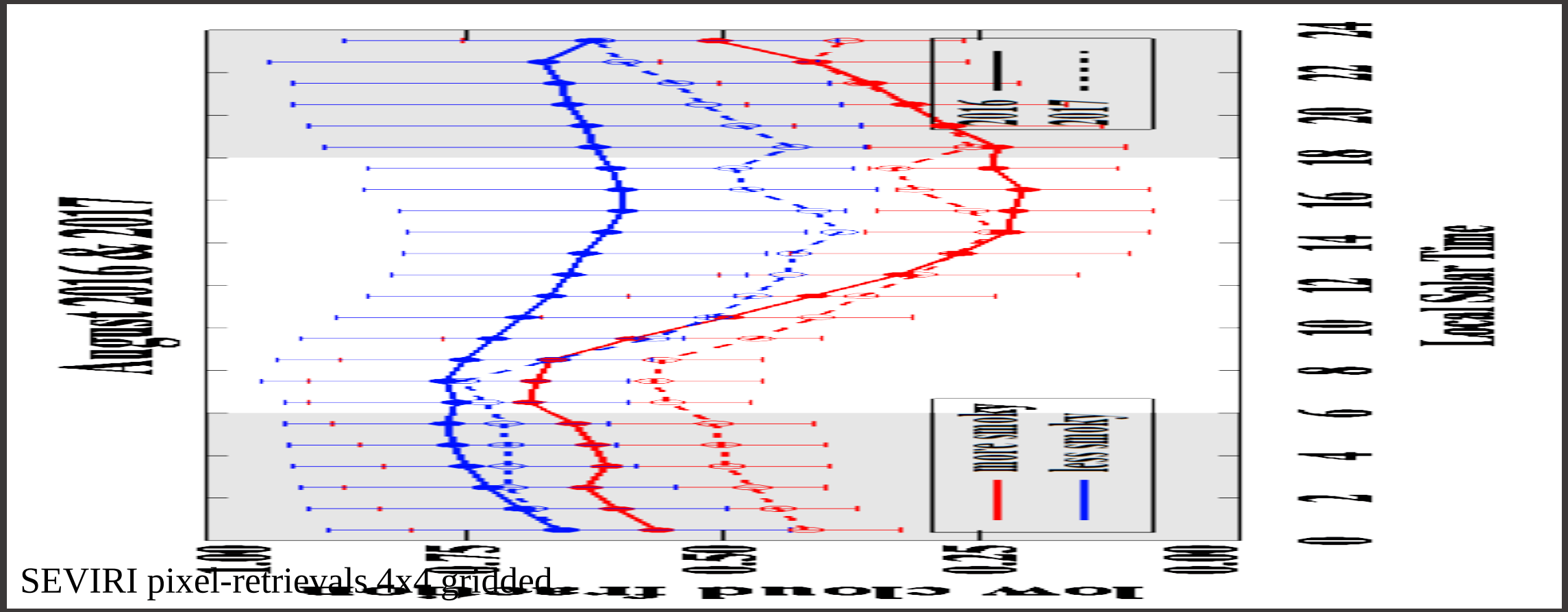


NASA Worldview visible image 08/17/2016

Previous study focused on August-only observations from LASIC

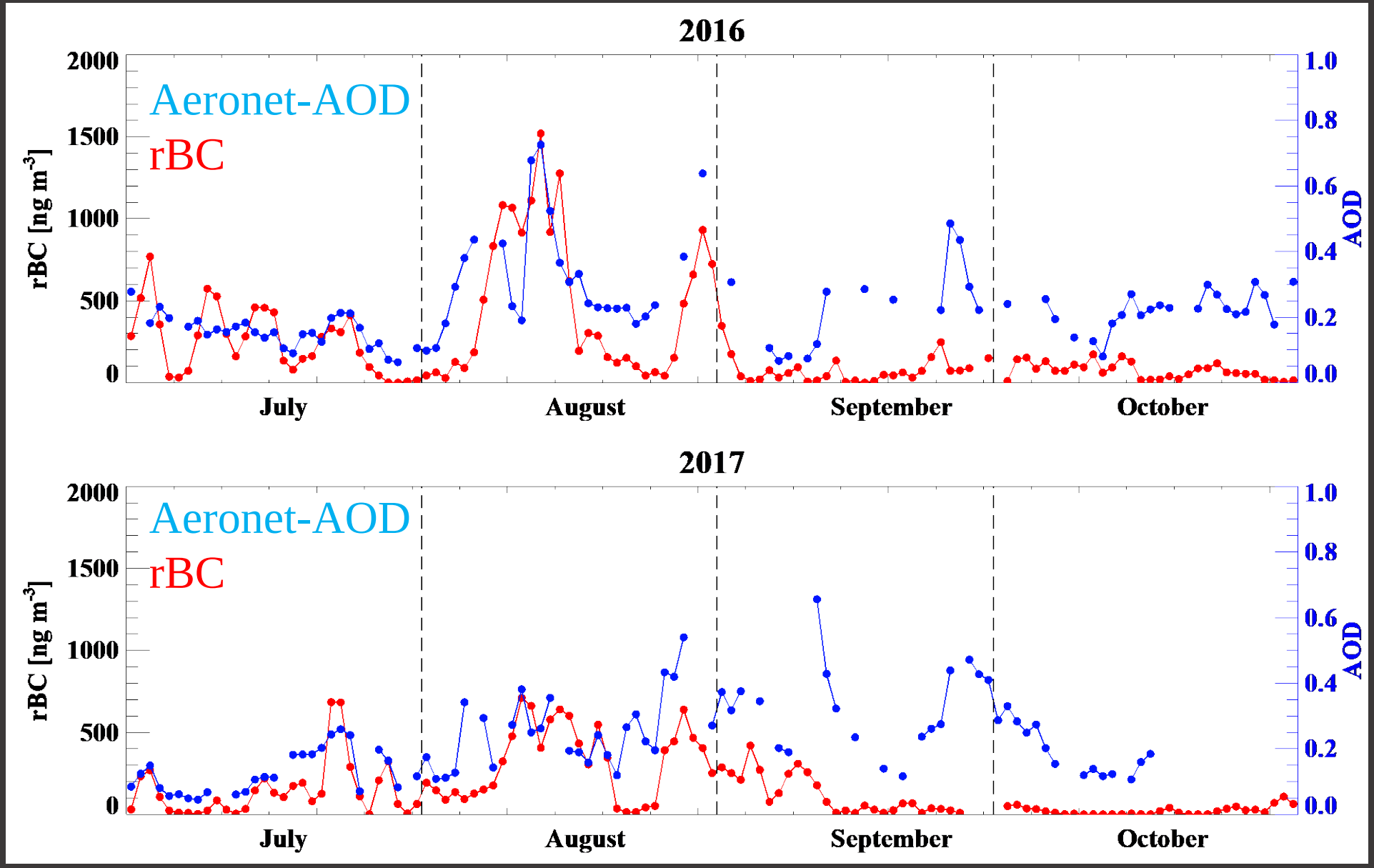
Zhang and Zuidema 2019 ACP

Highlighted a boundary layer semi-direct effect

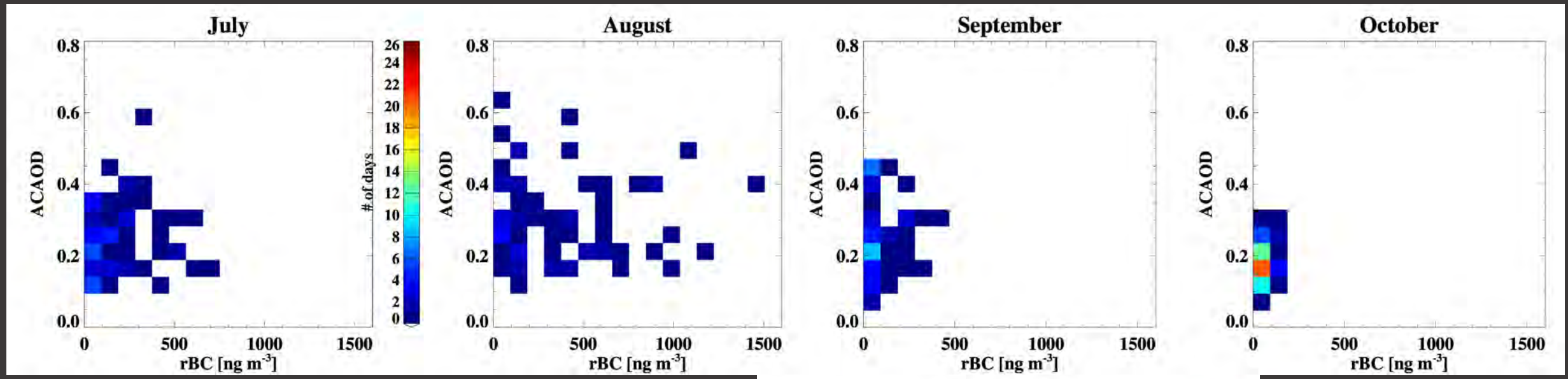


SEVIRI pixel-retrievals 4x4 gridded

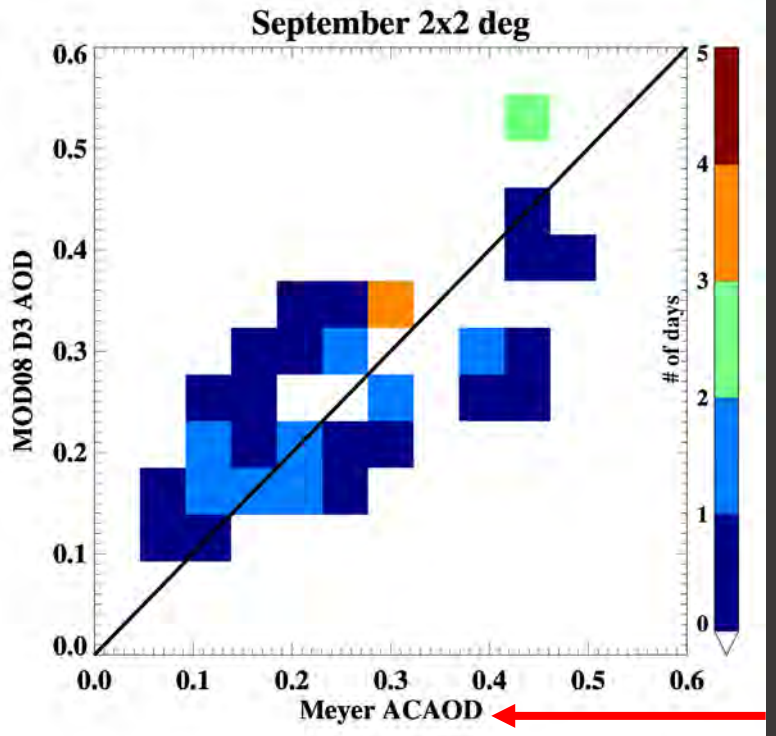
We have now expanded this analysis to cover the seasonal cycle (July-October)



AOD tracks rBC loading fairly well in July and August but dominated by smoke in the free-troposphere (ACAOD) in September and October.

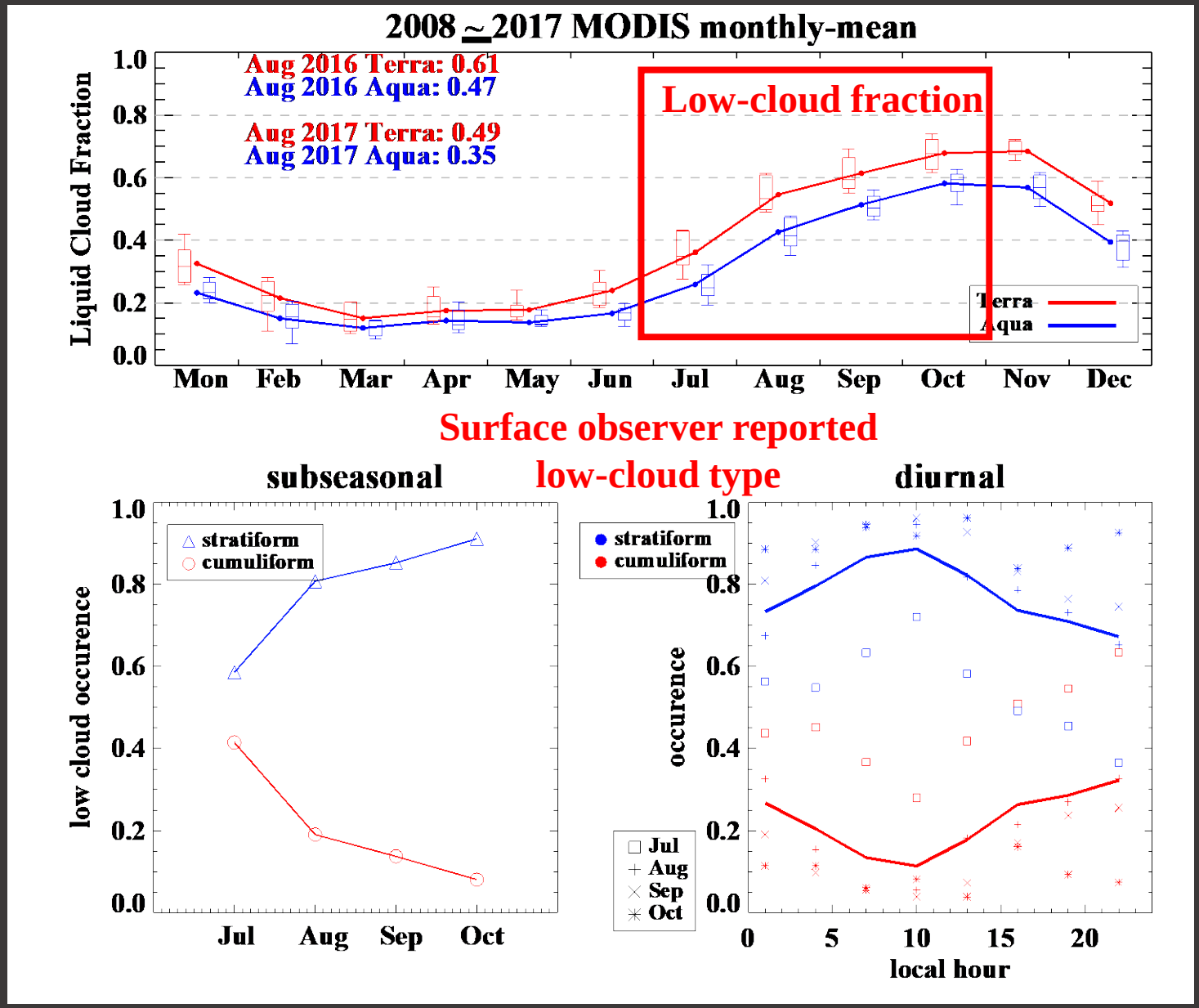


- Over Ascension, smoke presents in the BL quite often early in the season (Jul-Aug), while later stays lofted (Sept-Oct).
- September and October are composited by AOD and ACAOD (when AOD is missing).
- High-smoke days are identified as **AOD>0.3**, low-smoke days are **AOD<0.2**

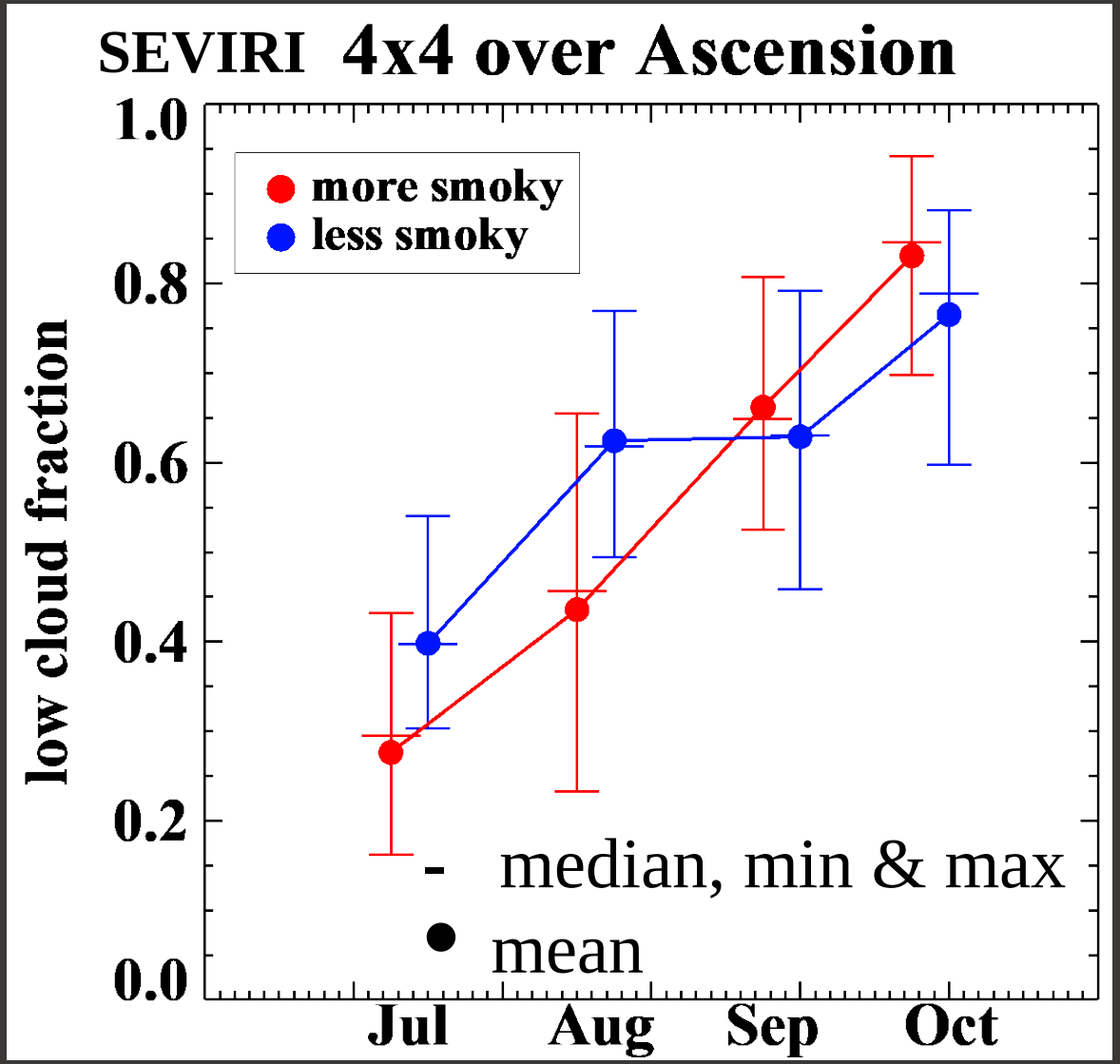


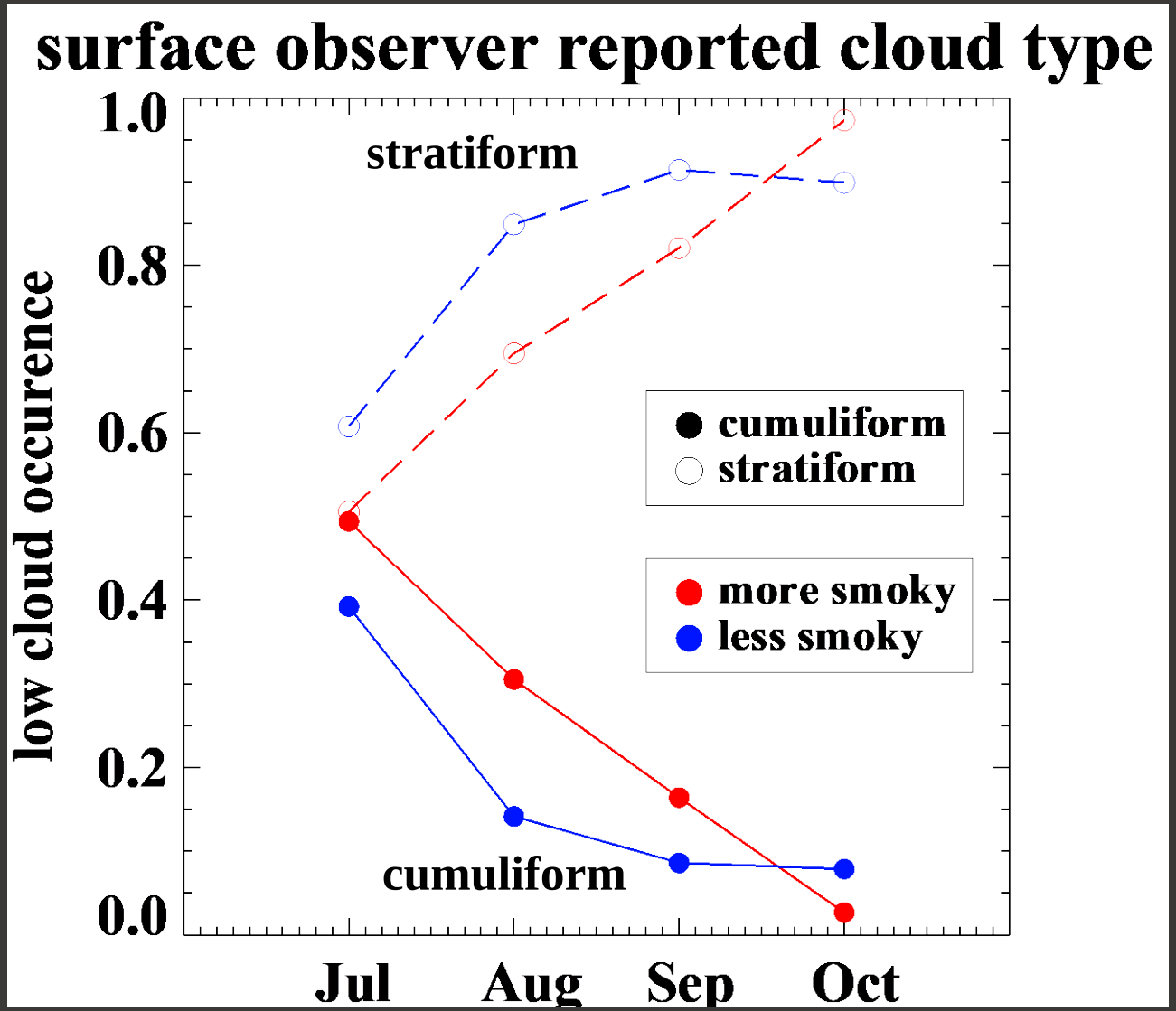
Meyer et al. 2015 JGR

low-cloud subseasonal variability over Ascension



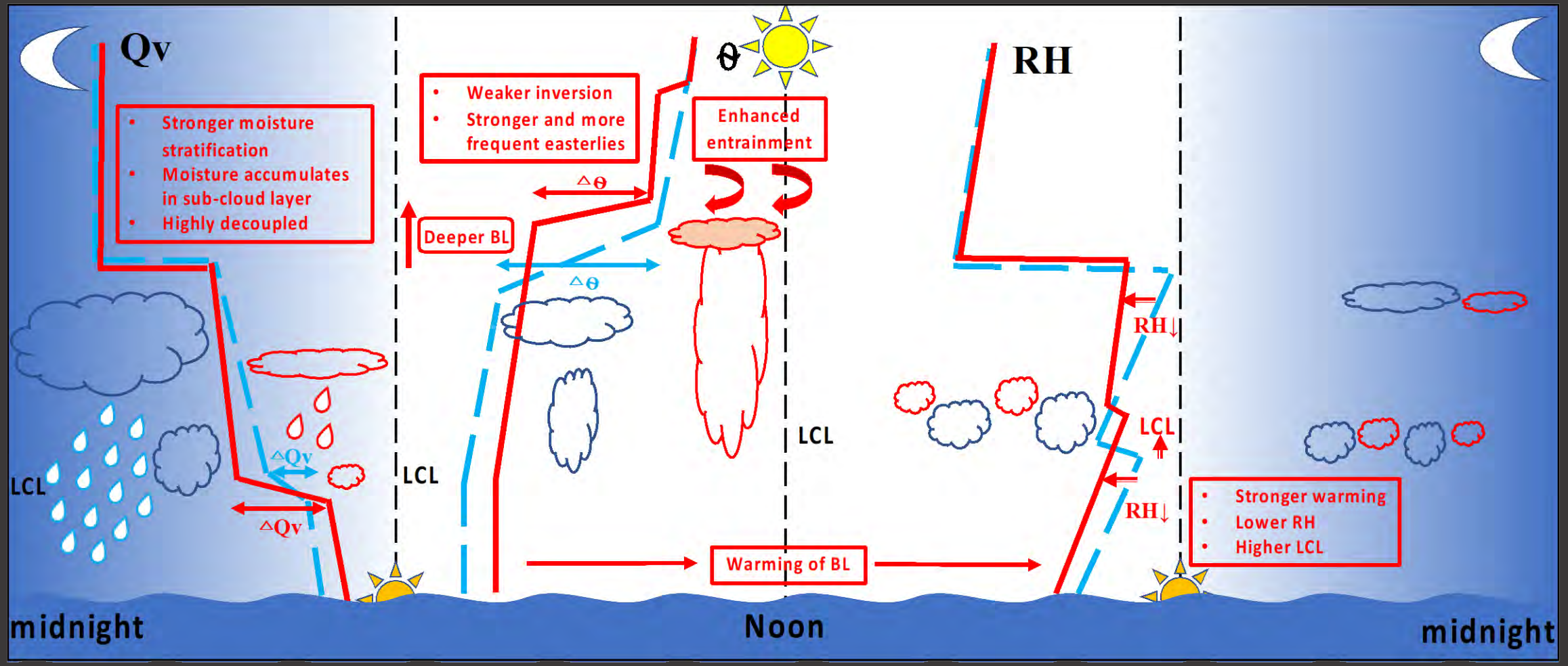
Low-cloud fraction under smokier condition decreases in July and August with more cumuliform occurrence, then increases in September and October with more stratiform occurrence





August

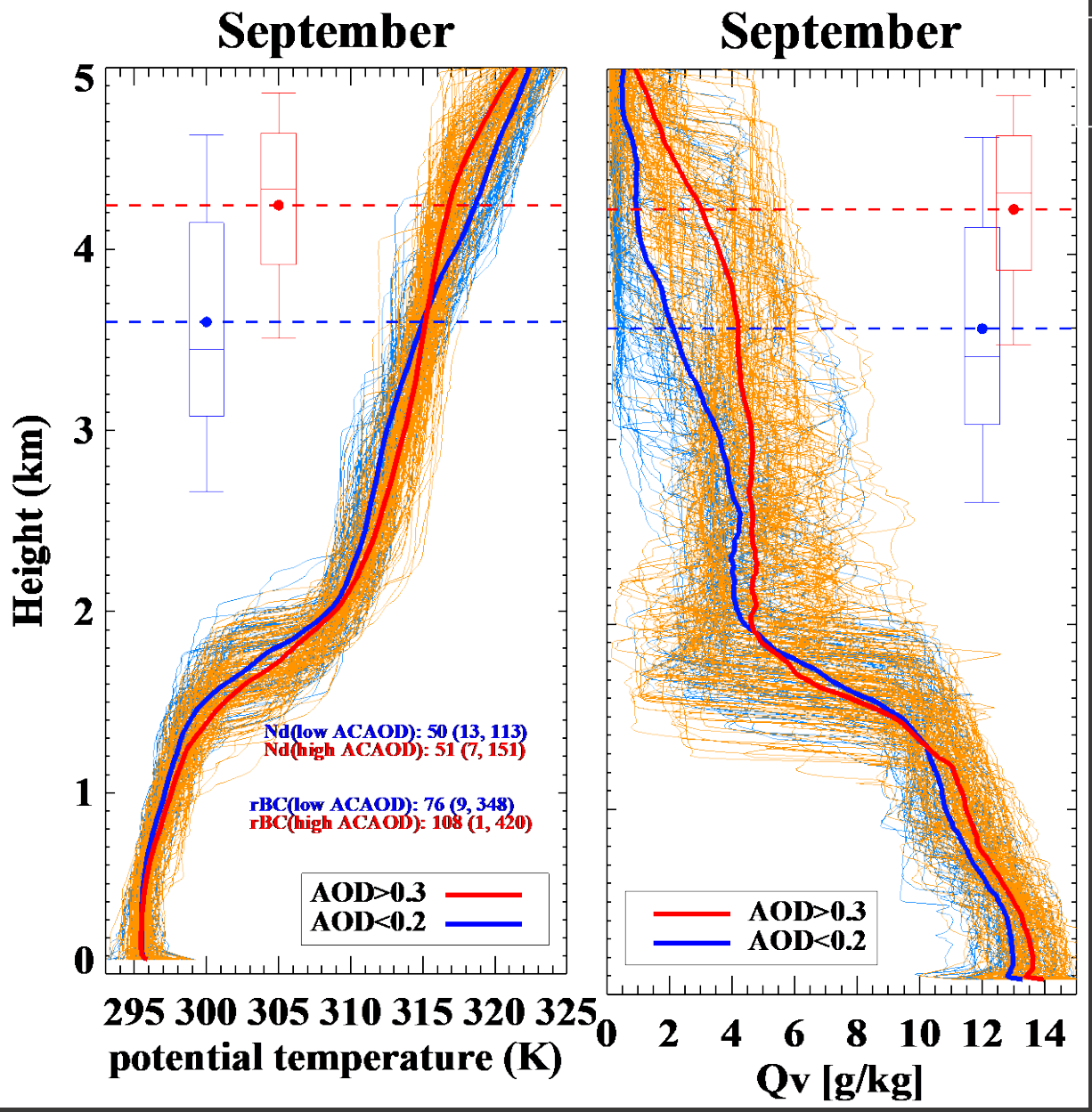
Complicated diurnal cycle – we argue that enhanced decoupling, persisting through the night, aids a radiatively-assisted coupling after sunrise



Zhang and Zuidema 2019 ACP

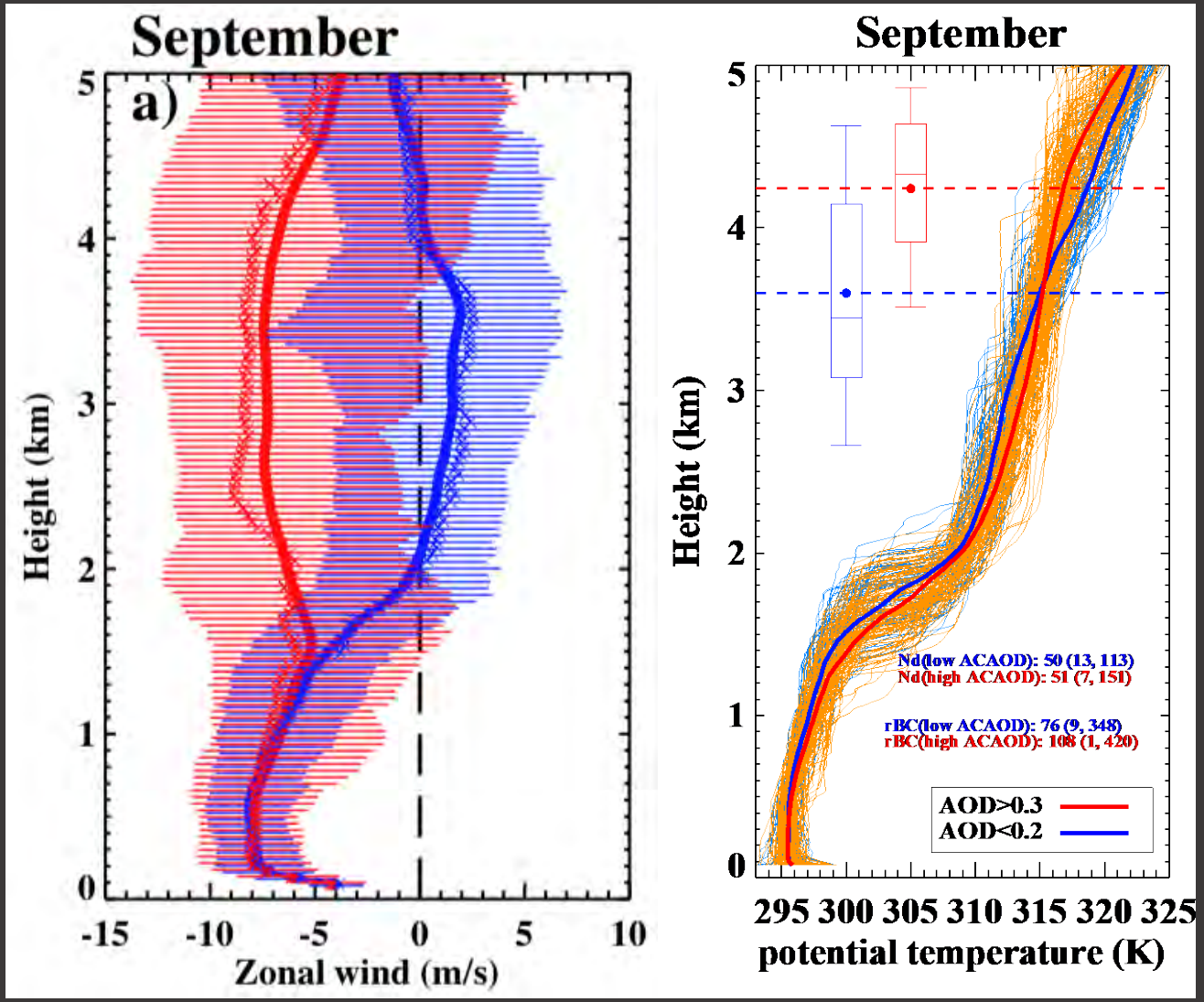
September

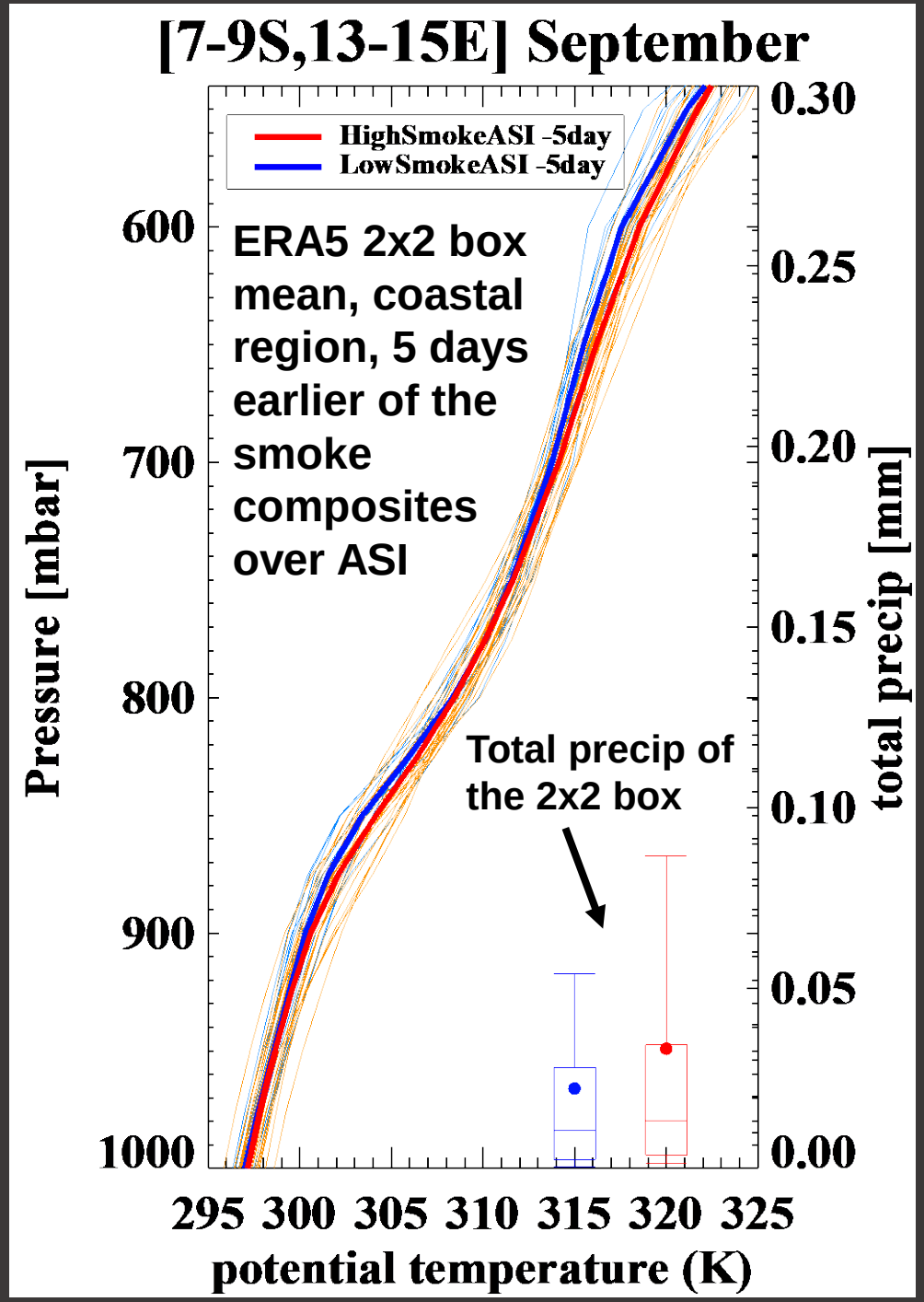
Smoke plume is more elevated when AOD is high, potential temperature is cooler at layer-top, and FT is better mixed.



Box-whisker: Top of the well-mixed layer

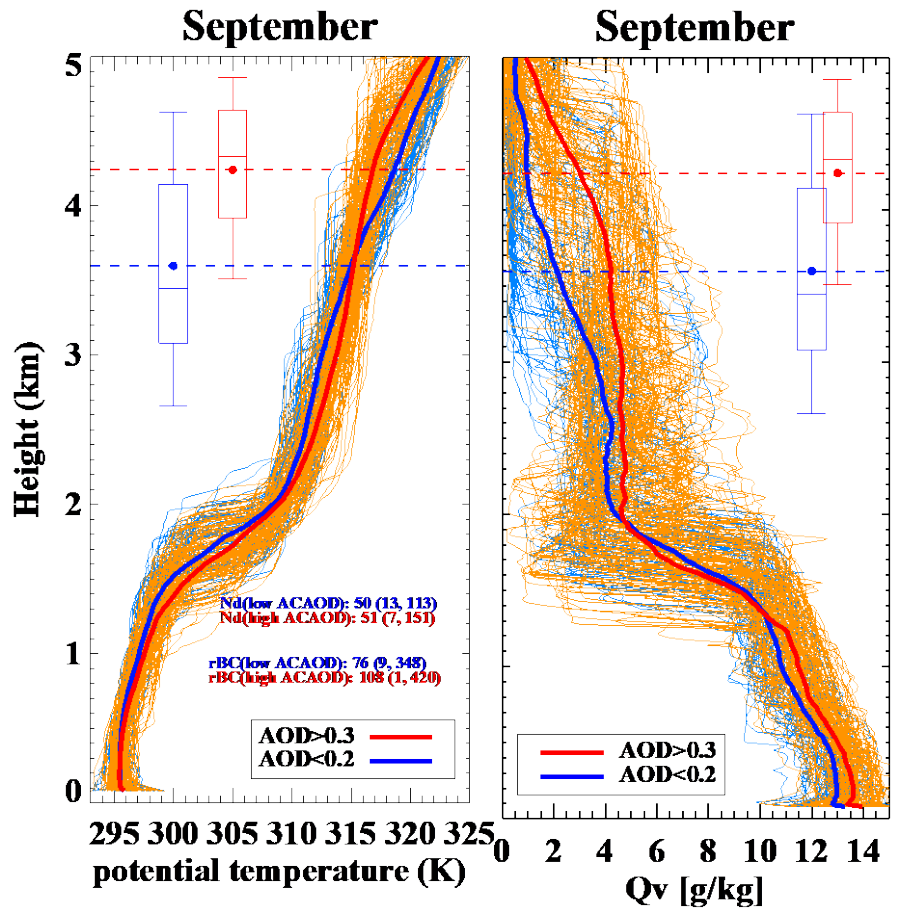
- Cooler potential temperatures at the top of the well-mixed layers highlights the role of additional water vapor (often colocating with the smoke layer) enhancing the LW cooling.
  - A delta_Qv of +0.85 g/kg could produce a net cooling of -0.4 K/day from an RT-calculation based on 10-year radiosonde data of Sept and Oct from St. Helena Island (*Adebiyi et al. 2015 JClimate*).
- Anomalous cooling maximizing at layer-top and gradually decreasing towards layer-bottom help destabilize the layer (*Mapes and Zuidema 1996 JAS, Gutleben et al. 2019 GRL*).





Could this temperature anomalies be advected from continental region?

September BL is shallower, more humid and less turbulent



10 S 10 W buoy data (2017)	High AOD (>0.3)	Low AOD (<0.2)
Latent heat flux	159.12	163.16
Sensible heat flux	16.99	18.18

- For high AOD condition,
  - rBC is slightly elevated (108 vs 76 ng/m3)
  - BL is more humid, consistent with more low-clouds
  - Less turbulent BL with reduced surface fluxes
  - Shallower MBL
- The midtroposphere elevated loading of moisture could reduce net LW cloud-top cooling and LW-induced turbulence production. But is it enough?

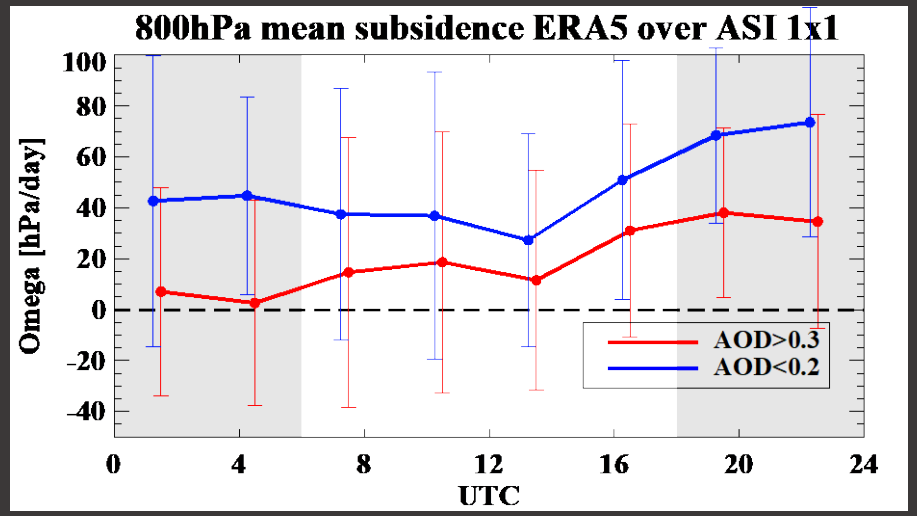
September

Ascension data also suggests another line of thinking, although requiring a longer adjusting time,

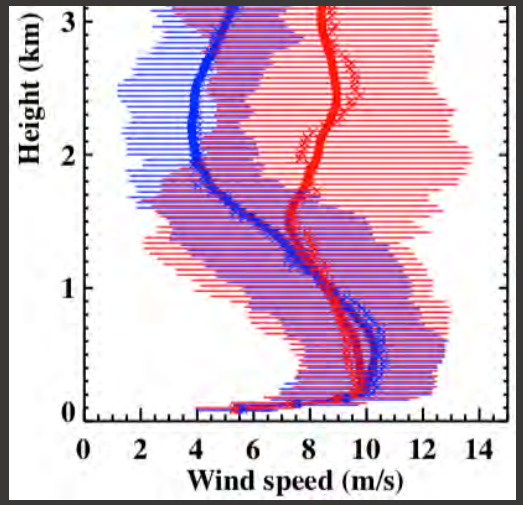
Elevated smoke loading and moisture in the FT reduces SW radiation reaching MBL by ~0.1K/day (*Adebeyi et al. 2015 JClimate*), and this could lead to reduction surface fluxes if the large-scale circulation had enough time to adjust.

Evidence of such line of thinking is suggested by recent regional climate modeling study (*Mallet et al. 2020 ACPD*),

- FT smoke heating reduces subsidence (increase buoyancy in FT)



- → creating surface low pressure anomaly
- → creating cyclonic anomaly of surface wind, acting against the prevailing southeasterlies
- → surface winds weakened and fluxes reduced.



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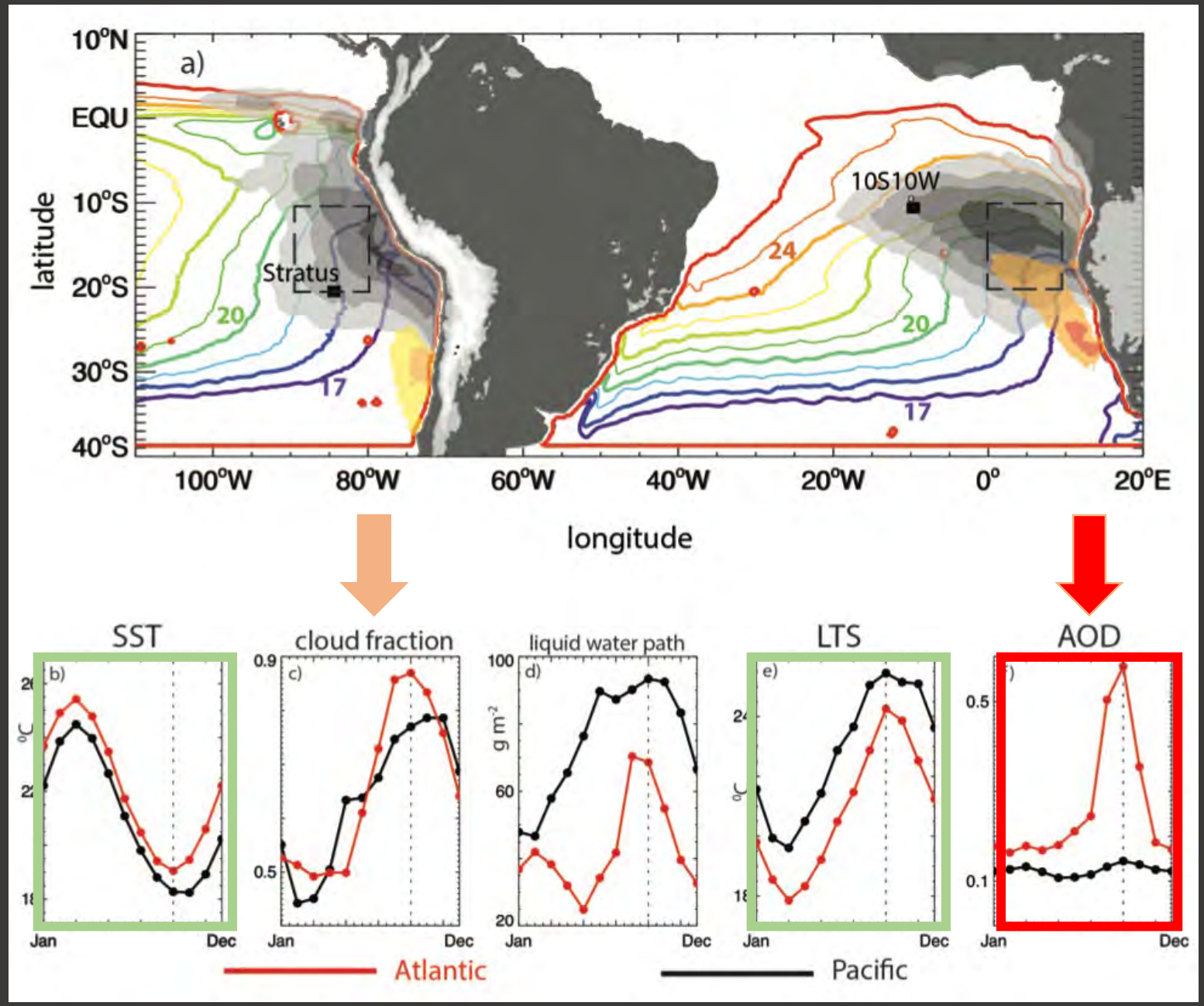
The presence of smoke seems to amplify the cloudiness evolution during austral winter (July-October)

Also noticed relative to the southeast Pacific



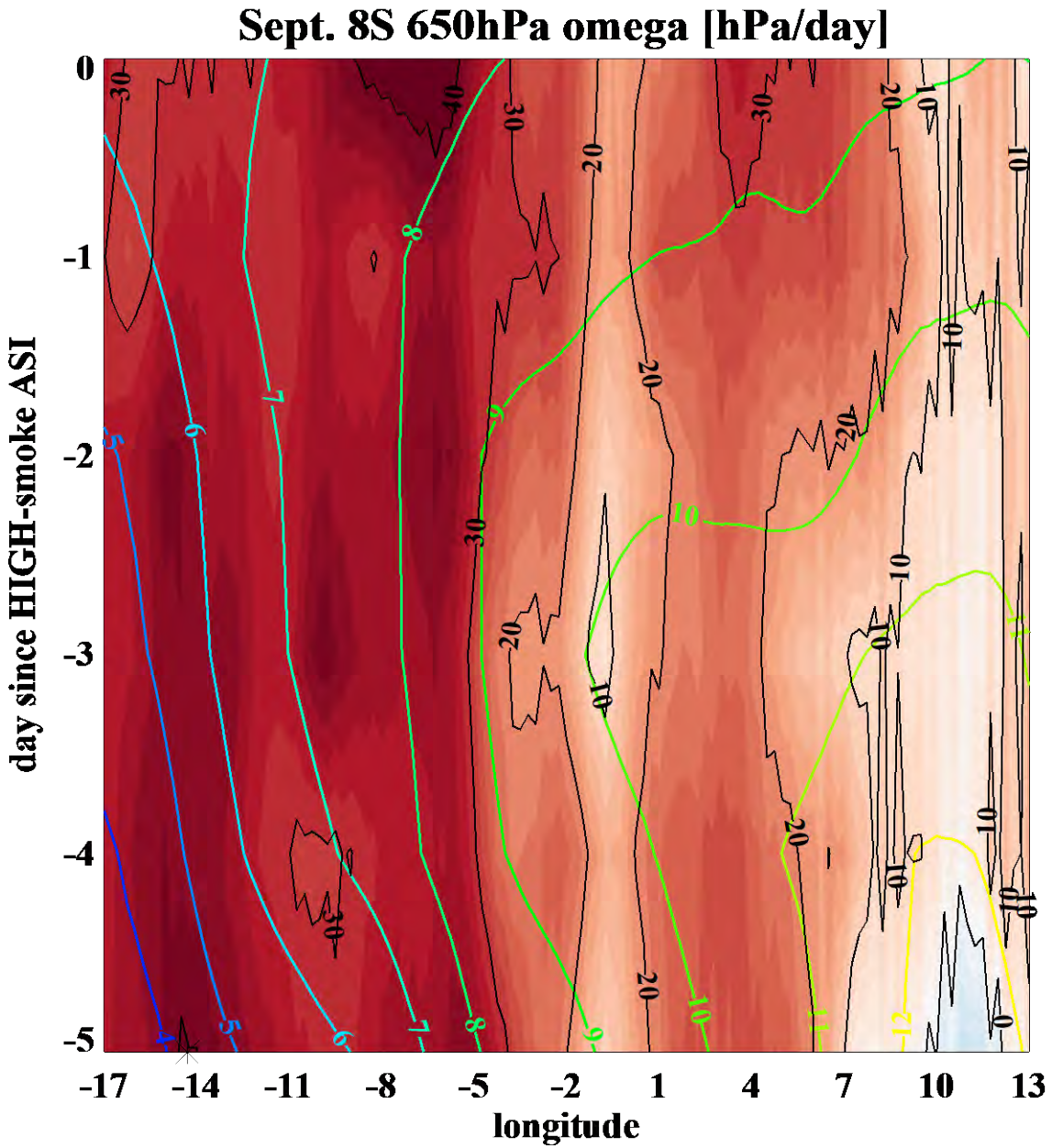
Zuidema et al. 2016b BAMS

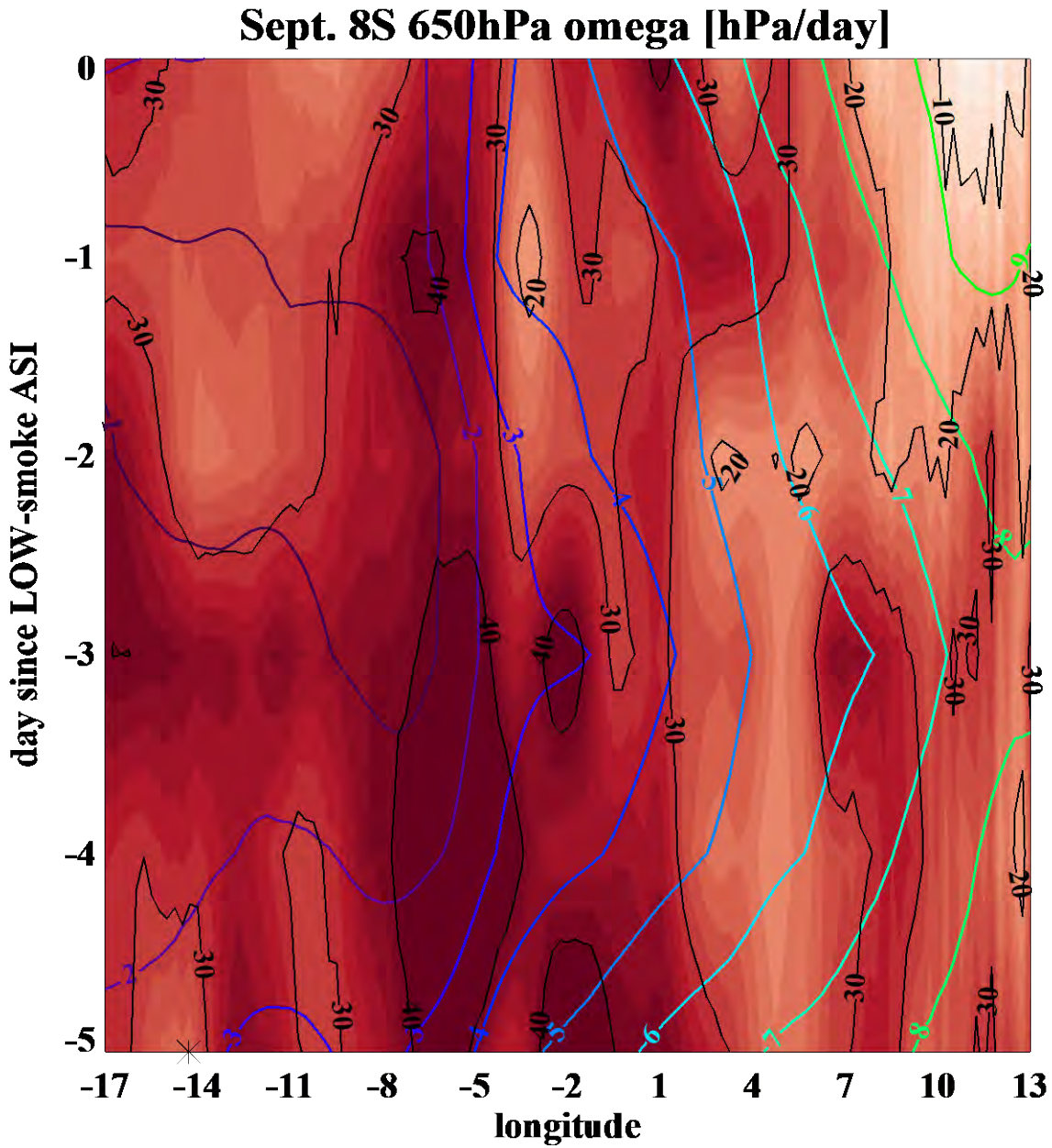
Summary

- The predominant vertical location of absorbing smoke over Ascension shifts from BL to FT during the BB season.
- The cloudiness seasonal cycle shifts from predominantly cumuliform to stratiform from July to October. This seasonal evolution is enhanced when more smoke is present.
- In September, enhanced long wave cooling at the top of elevated water vapor layers thought to be colocated with smoke, may contribute to better-mixed aerosol layers.
- Despite reduced September midtropospheric subsidence when more aerosol is present overhead, boundary layers are also more shallow, consistent with weaker surface fluxes.

Extra slides

Why smoke higher in September?





Sept. KAZR & SEVIRI