Seasonal Cloud base Microphysical Dependencies on Boundary Layer Aerosol and Turbulence during ARM LASIC

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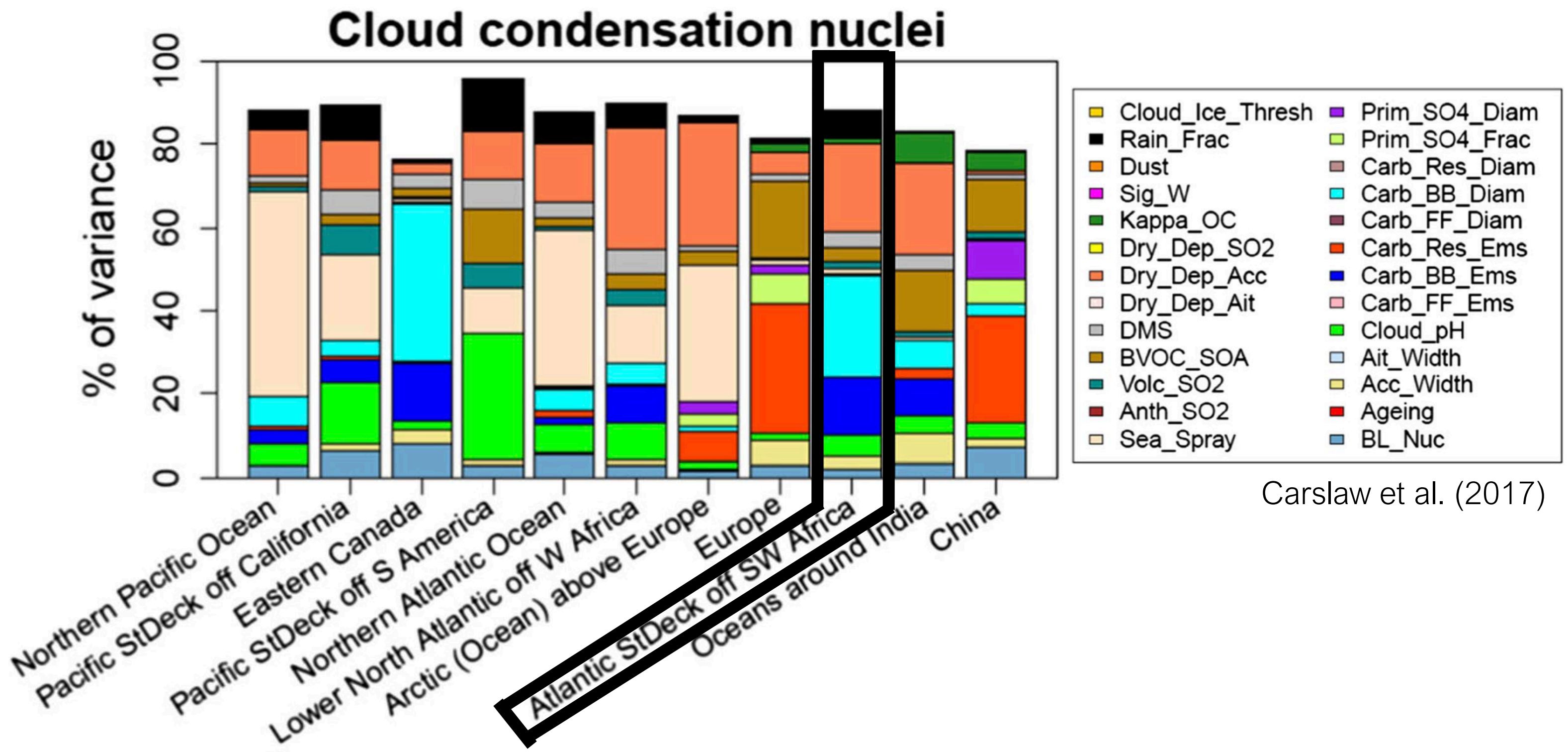
ARM/ASR PI Science Team Meeting
Plenary Session – Poster Talks



Carslaw et al. (2017)

Uncertainty in modeled variance of CCN largely controlled by size-dependent particle properties

(mean size, number, composition)

Direct measurements in clean regions can help constrain model processes that determine when and which particles act as CCN

DOE ARM Layered Atlantic Smoke Interactions with Clouds (LASIC)

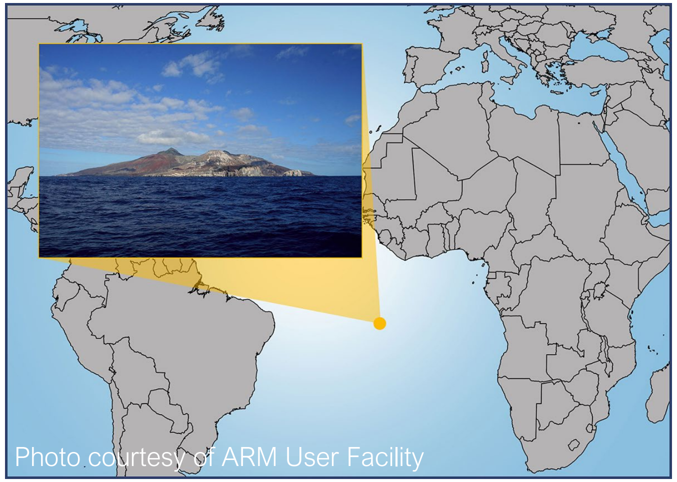
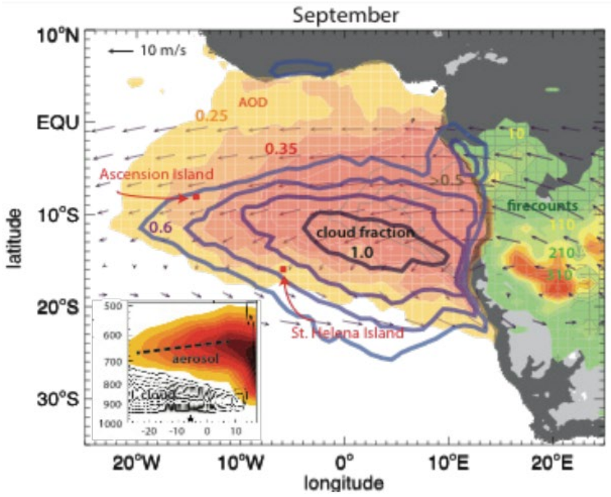


Photo courtesy of ARM User Facility

June 2016-October 2017

Ascension Island (8°S, 14.5 °W)

Aerosol size/number, composition, and microphysics



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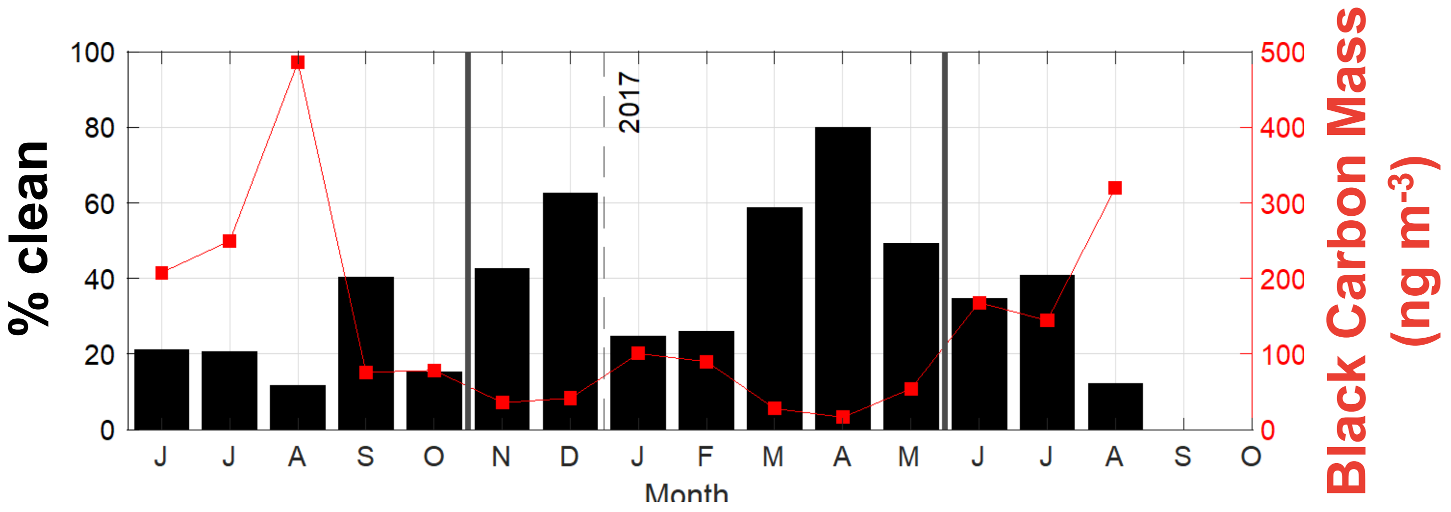
Seasons

<u>Background</u> (Nov.-May): persistent clean conditions

<u>Biomass Burning</u> (Jun.-Oct.): Episodic smoke particle intrusion from South-central Africa

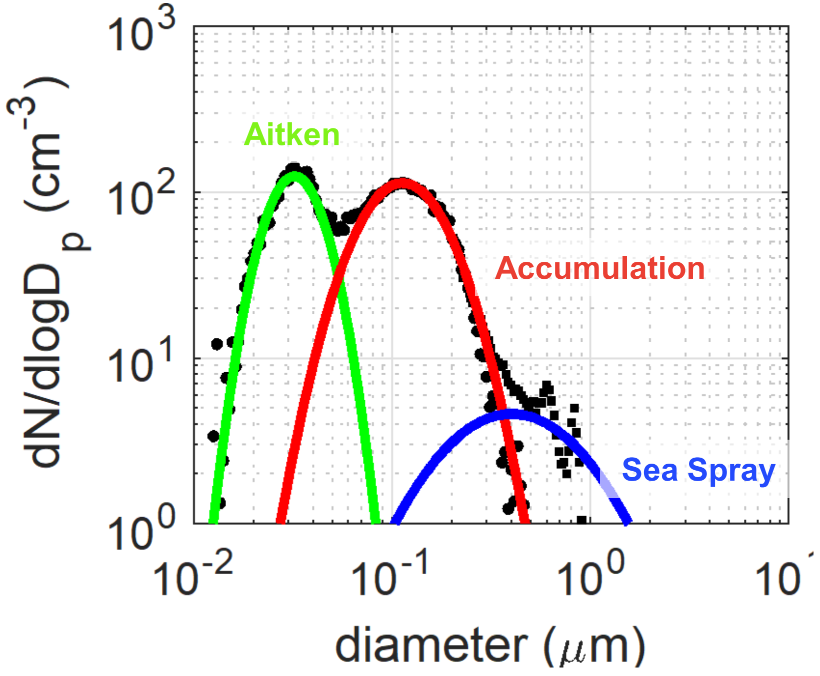
Clean versus Smoky Periods



$CN_{10} < 600\ cm^{-3}$
$rBC < 50\ ng\ m^{-3}$
CO < 70 ppbv
$SAE_{10} < 1$
(Dedrick et al. 2022)

40% of measurements "clean"

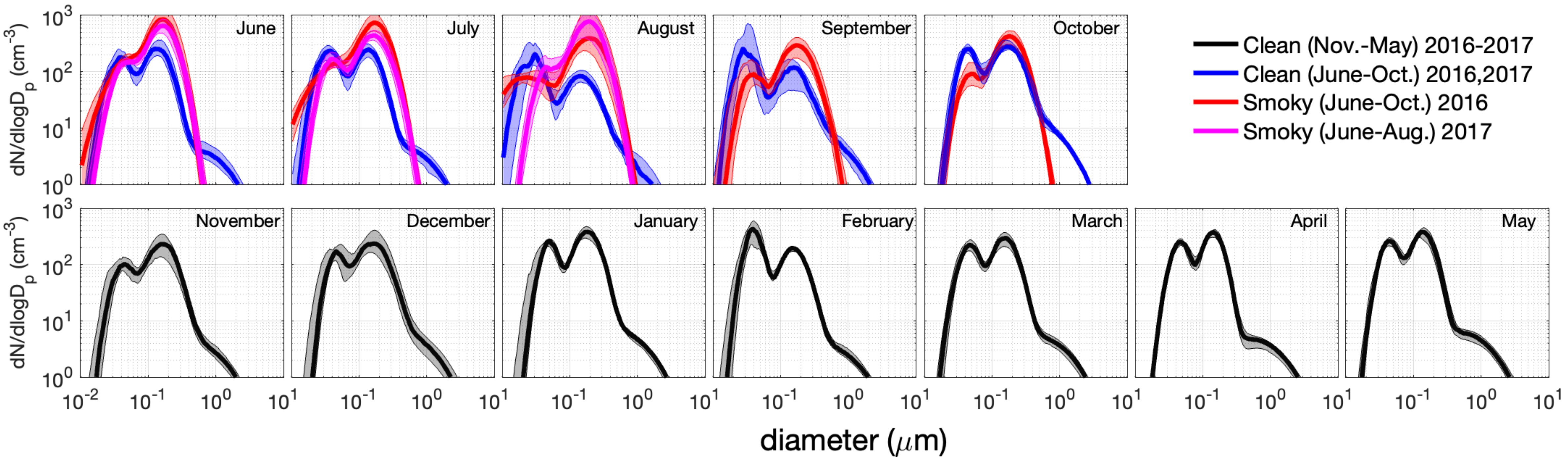
Size Mode Fitting



Mode fitting procedure for submicron size
(Modini et al., 2015; Saliba et al.,2019)

UHSAS-NEPH sea spray retrieval
(Dedrick et al., 2022)

Clean and Smoky Aerosol Size Modes



Clean accumulation-mode particles ~50-60% of total number concentration

Accumulation-mode number concentration doubles when smoky; 30 nm larger

Clean Aitken-mode particles ~30% of number sea-spray-mode particles ~10% of number

Smoky Aitken-mode particles smaller, less relative number contribution

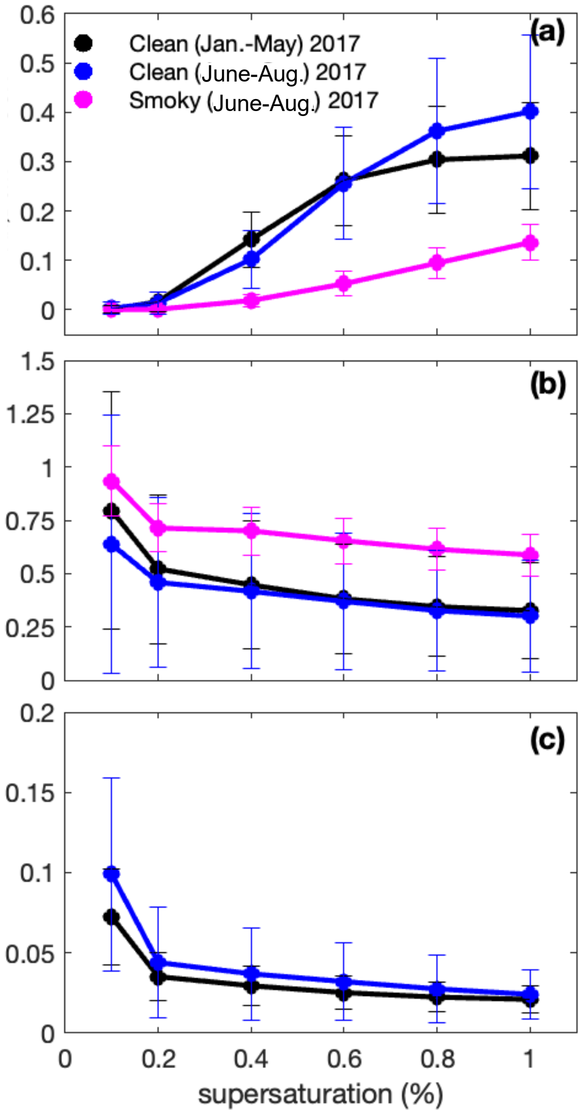
Modal Contributions to Clean and Smoky CCN

Mode Contribution to CCN

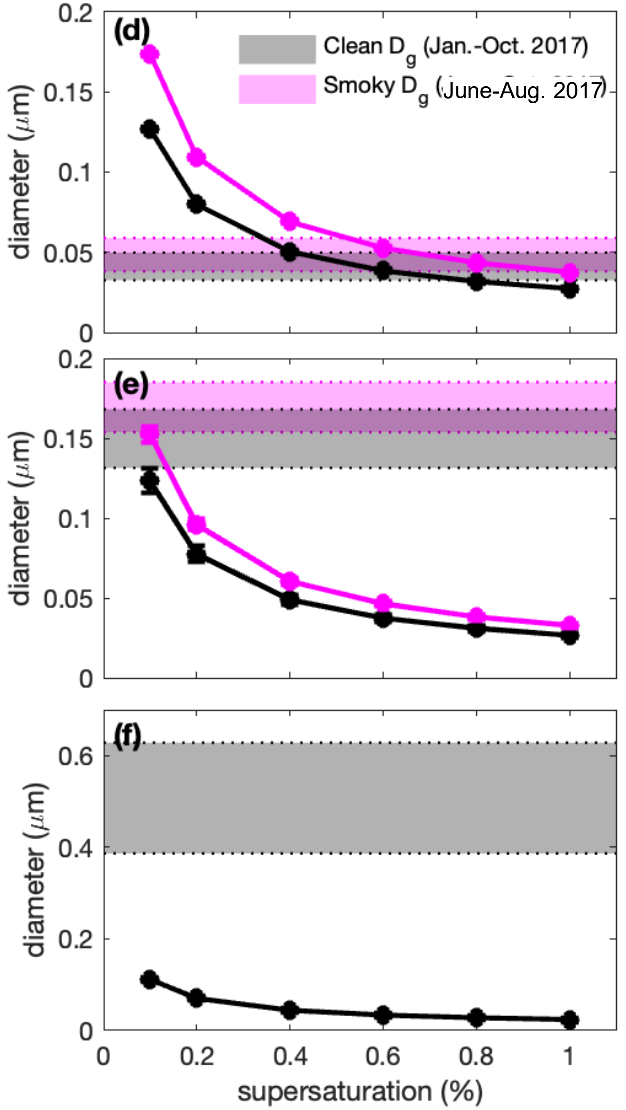
$$\frac{N_{Ait,Dcrit}}{N_{CCN,\%}}$$

$$\frac{N_{acc,Dcrit}}{N_{CCN,\%}}$$

$$\frac{N_{ss,Dcrit}}{N_{CCN,\%}}$$



Mode Mean and Critical Diameters



$$\frac{\int_{D_{crit}} N_{mode}}{N_{CCN,\%}}$$

$D_{crit}\,(\kappa, s)$

seasonal differences have small effect on modal D_{crit} between seasons

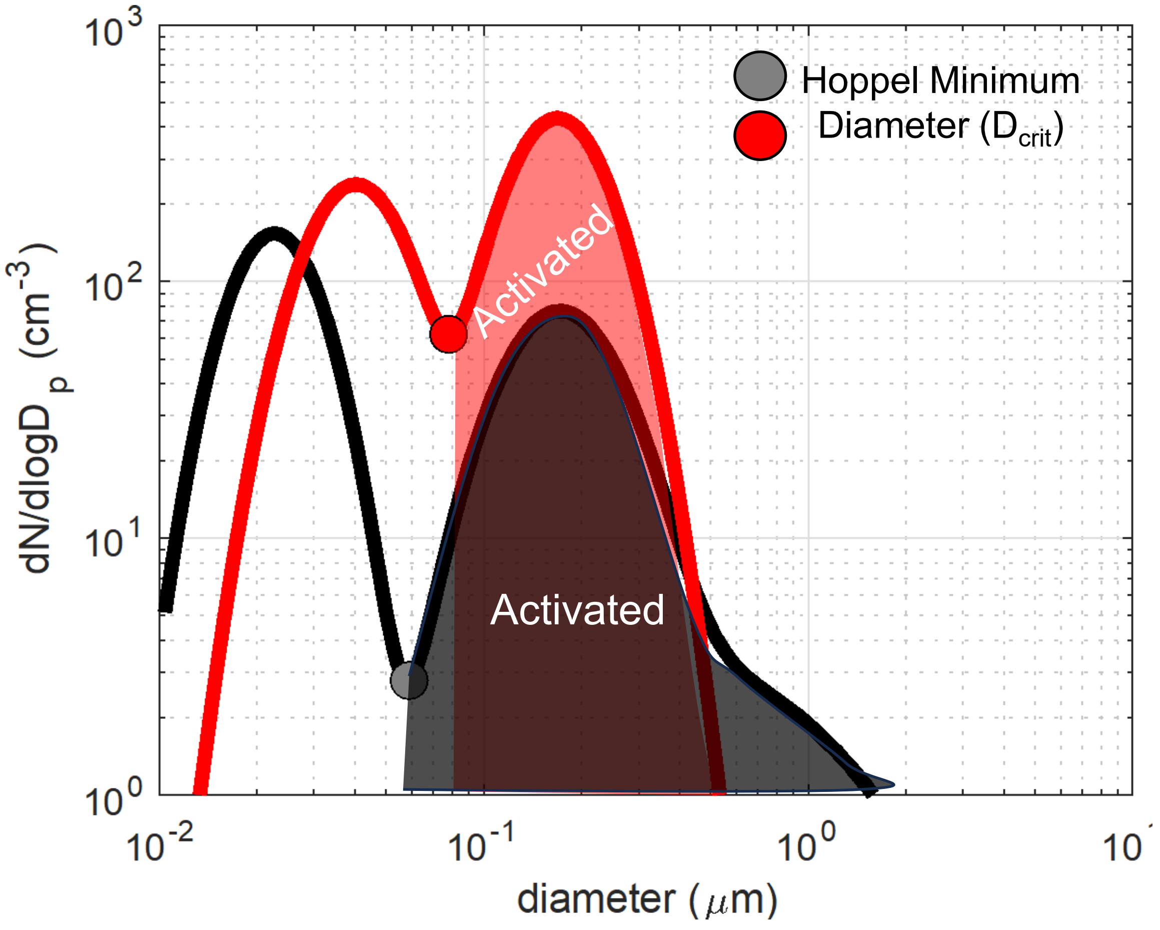
Clean CCN at <0.3% *s* were 70% accumulation-mode, <20% Aitken, and <10% sea spray

Clean Aitken-mode accounts for 30-40% CCN at >0.3%

Smoky CCN controlled by accumulation-mode (>75%) at <0.3%

Aitken and accumulation-mode CCN contributions largely dependent on number and mean size

Evidence of Cloud Processing Effects on CCN



canonical “gap”/separation feature between Aitken and accumulation modes in marine size distributions

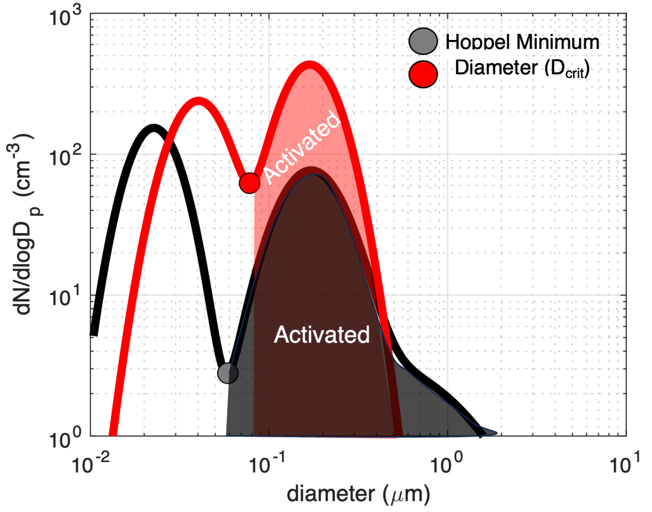
successive cycle of cloud processing (particle activation to droplets in-cloud and evaporation)
(Hoppel et al., 1986)

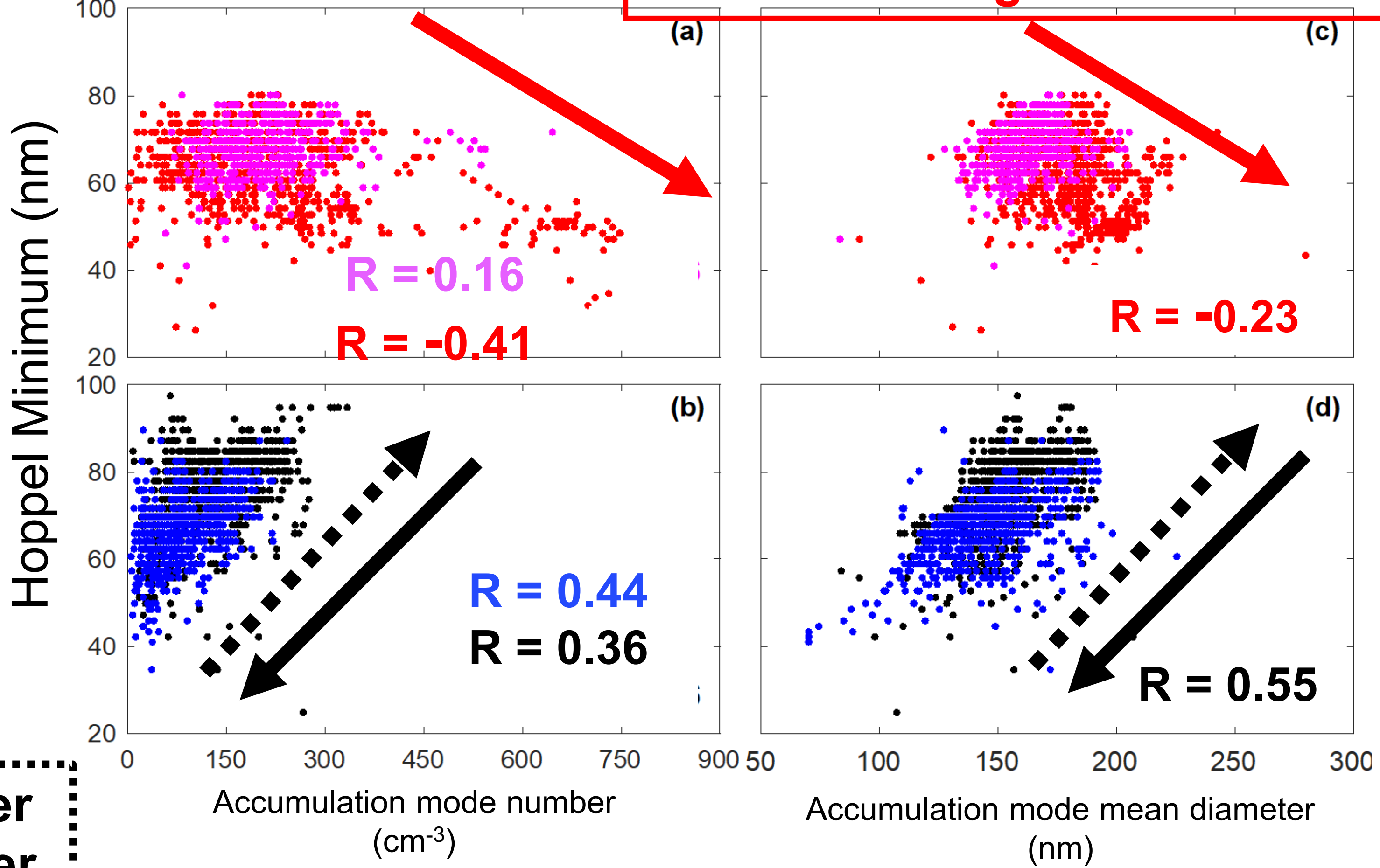
lower size cutoff of particles that activated to form droplets in clouds (i.e. D_{crit})

indicates effective average cloud supersaturation recently experienced by measured aerosol

Aerosol-limited Effects on CCN

Weak, negative relationship during smoky suggest meteorological influence

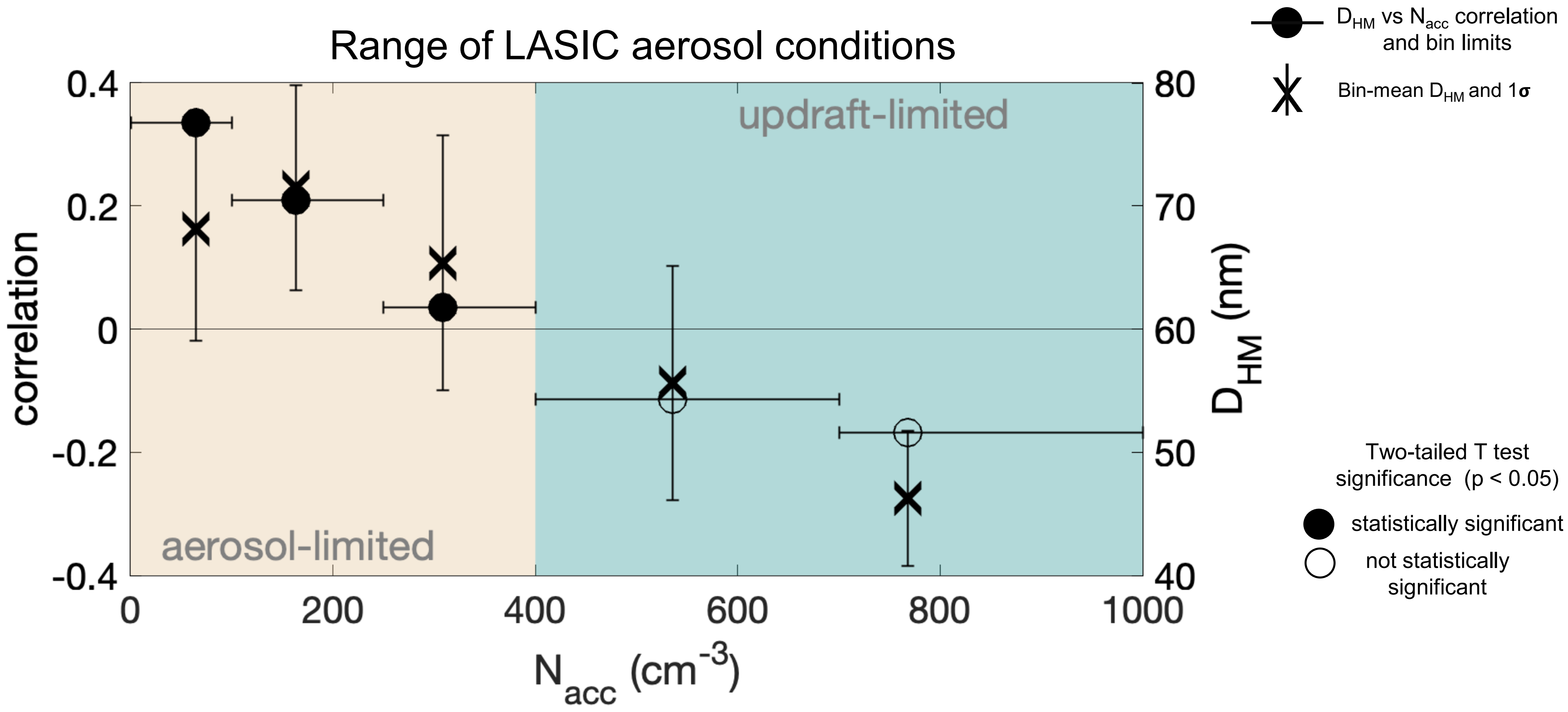




Increased N_{acc} grow to bigger sizes and deplete water faster (limiting CCN activation)

Lower N_{acc} and smaller $D_{g,acc}$ grow slowly, more water available

Aerosol-limited Effects on CCN



Decreasing relationship between D_{HM} and N_{acc} separate CCN activation regimes of aerosol-limitation (<400 cm^{-3}) and updraft-limitation (>400 cm^{-3})

Summary

Supported by ASR award
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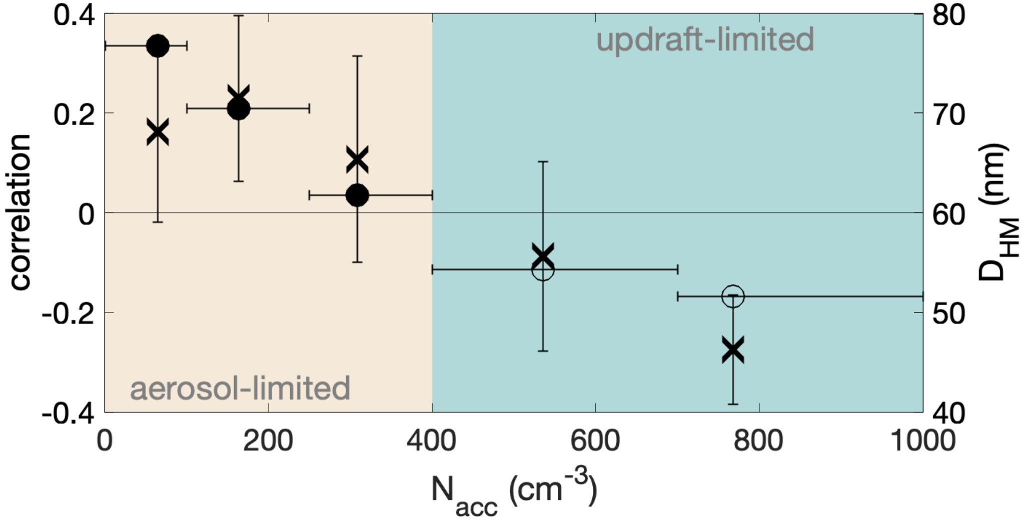
Clean CCN at <0.3% supersaturation were 70% accumulation-mode particles, <10% sea-spray, and 20% Aitken.

Smoky accumulation-mode particles were 30 nm larger, double the concentration and had 15-30% more particles acting as CCN than clean.

Hoppel minimum diameters correlated to accumulation-mode particles showing aerosol-limited mechanisms for clean conditions (<400 cm^{-3}).

Results can provide specific constraints for representing increased aerosol perturbations on marine boundary layer clouds and size distribution controls on aerosol-cloud interactions.



Thank You!

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Dedrick et al. (2023): Aerosol-Limited Effects on Cloud Condensation Nuclei in Clean Conditions in the Tropical South Atlantic Boundary Layer during LASIC. Submitted to *Geophys. Res. Lett.*