Aerosol-Radiation-Cloud Interactions in the southeast Atlantic: Results from 3 years of ORACLES deployments

ObseRvations of AerosolsAbove Clouds and Their IntEractionS

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AMS 2019 Annual

Aerosol-radiation-cloud interactions over the SE Atlantic

ORACLES Implementation

- 5-year 2014-2019 NASA Earth Venture Sub-orbital project
- Radio-polarimetric and in situ observations of radiation, aerosol & cloud microphysics.
- 3 campaigns with P-3 (2016-2018), 1 with ER-2 (2016)

2016: 15 P-3 and 12 ER-2 flights (Namibia)

2017: 13 P-3 flights (Sao Tome)

2018: 15 P-3 flights (Sao Tome)

- Coordinated with CLARIFY, LASIC, AEROCLO-sA
- Involves 6 NASA centers, 10 universities
- Establishes 2 new AERONET sites (1 Namibia & Angola), many other central African sites re-established simultaneously
- Includes LES, WRF-Chem, and GEOS-5 modeling
- features 50% routine flights to facilitate model-relevant observations (for regional & global models)

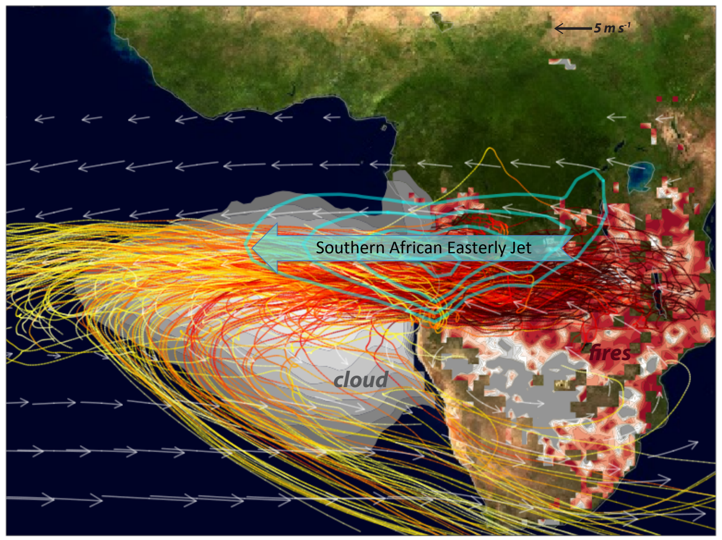
P-3: Profiling aircraft
2016, 2017 & 2018

ER-2: High-flying
2016 only

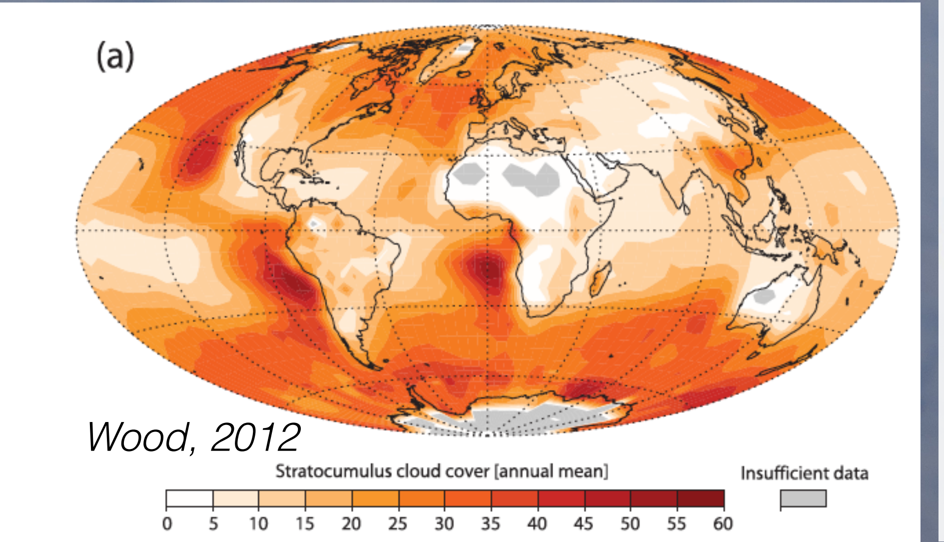
Why?

- Africa is world's largest emitter of biomass-burning aerosols (BBA): 50% of all carbon *v.d.Werf et al., 2010*
- relative proportion likely to increase *Andela et al., 2017*
- free-tropospheric winds advect the BBA far over the southern Atlantic ocean *Adebiyi & Zuidema, 2016*
- global majority of BBA above clouds occur here *Waquet et al., 2013*
- colocated with one of the world's largest subtropical stratocumulus deck
- global aerosol models missing key aerosol, aerosol-cloud interaction processes in this region *Myrhe et al., 2013*

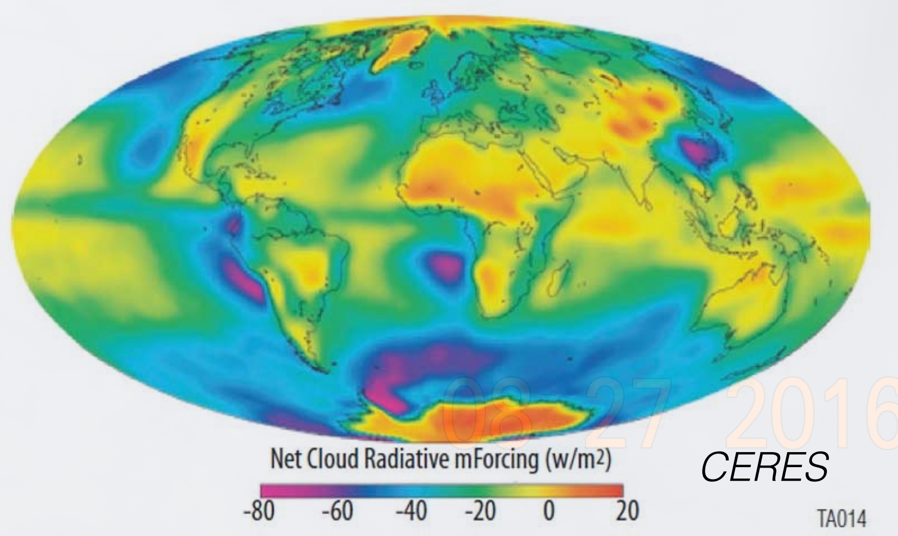
how do we explain the high albedo of the southeast Atlantic?



Adebiyi&Zuidema, 2016

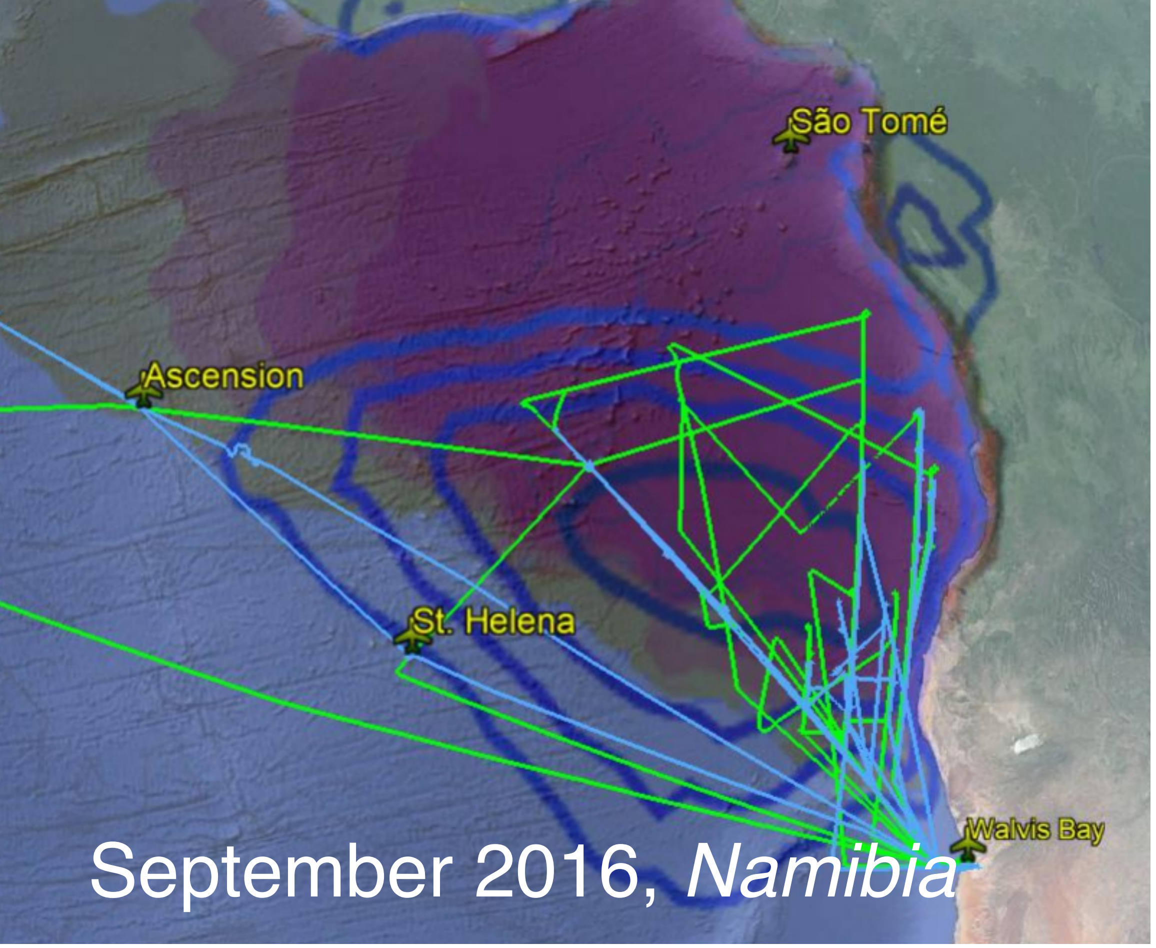


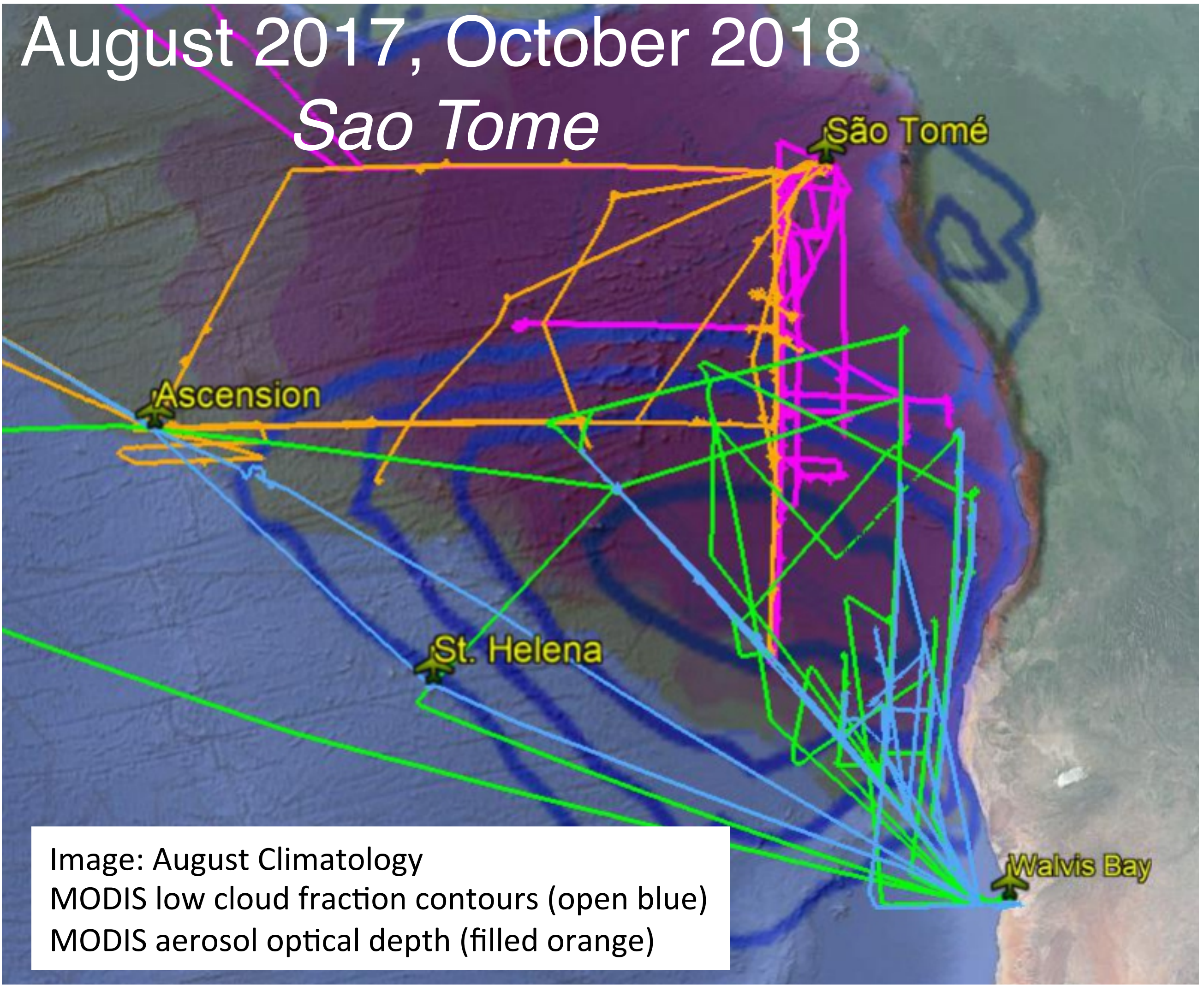
Wood, 2012



CERES

ORACLES sampling strategy:
August (2017) - September (2016) - October (2018)
to capture seasonal evolution





Flight hour summary

September 2016 – Walvis Bay
P-3: 15 flights (115.2 hrs)
ER-2: 12 flights (97.3 hrs)
8 flights coordinated

August 2017 - São Tomé
P-3: 13 flights (112.0 hrs)

October 2018 - São Tomé
P-3: 15 flights (121.4 hrs)

Totals:
P-3: 43 flights (348.6 hrs)
ER-2: 12 flights (97.3 hrs)

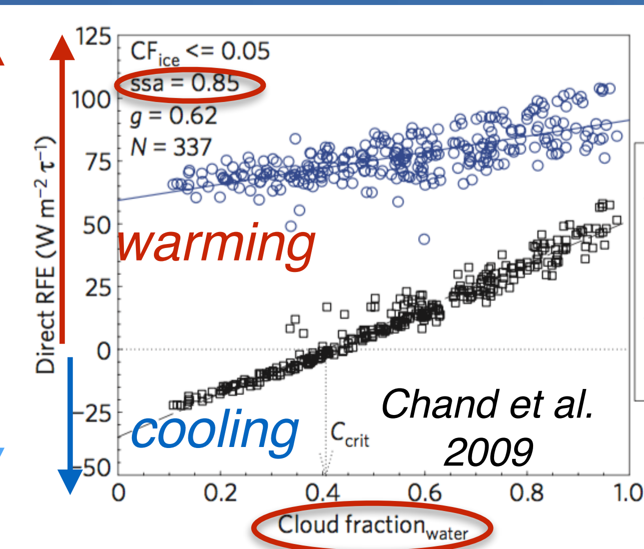

accompanied by other campaigns w/ similar goals
Ascension Island/DOE-LASIC
UK-CLARIFY
São Tome
NASA-
ORACLES
BB aerosol
downstream:
warm SST, BB
aerosol in boundary layer
boundary layer flow
St. Helena Island
UK
Fr - AEROCLO
upstream:
cool SST, BB aerosol
resting on boundary layer
Walvis Bay

ORACLES Science Questions

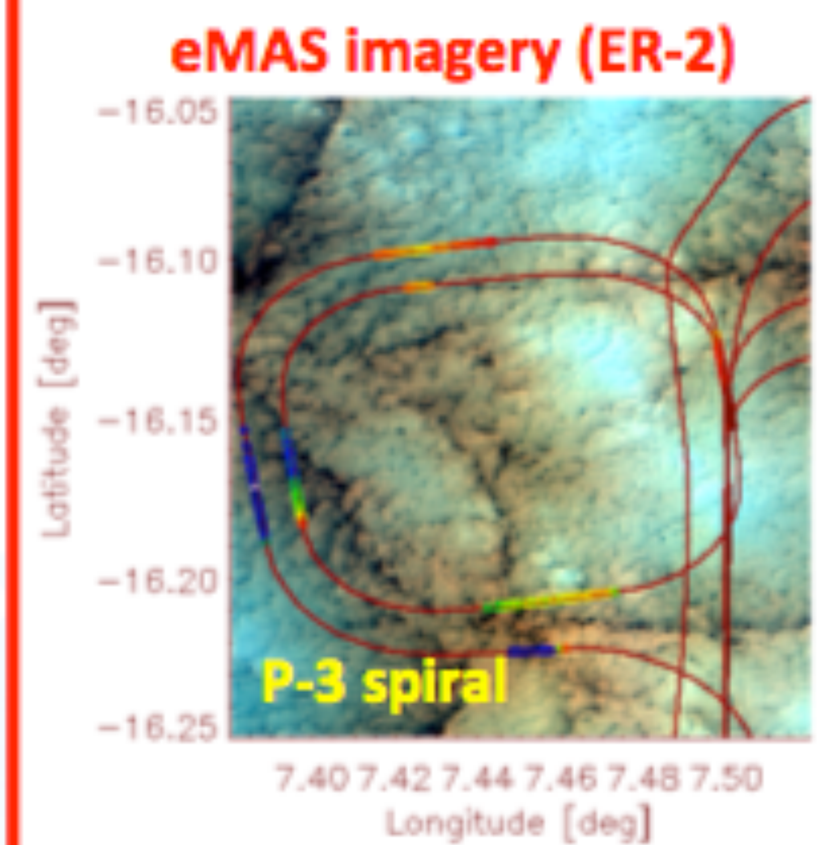
Q1: What is the direct radiative effect of the African biomass burning (BB) aerosol layer in clear and cloud sky conditions over the SE Atlantic?

Q2: How does absorption of solar radiation by african biomass burning aerosol change atmospheric stability, circulation, and ultimately cloud properties?

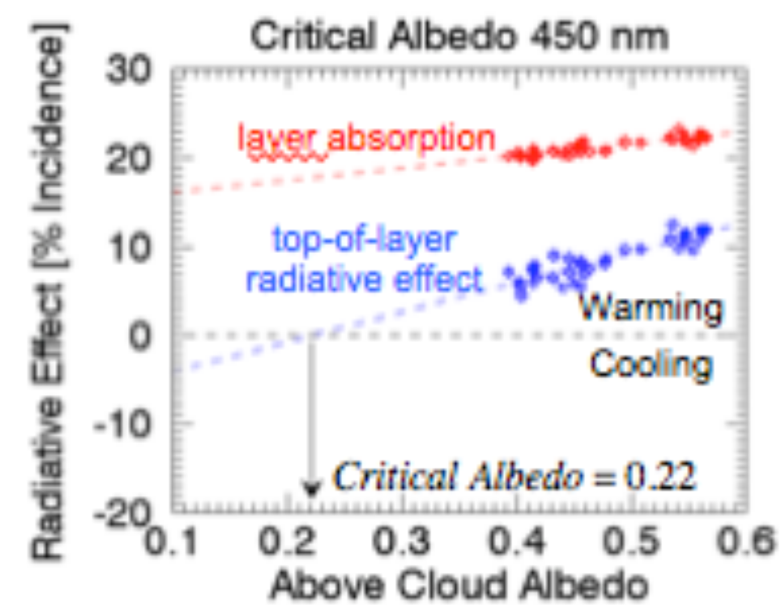
Q3: How do BB aerosols affect cloud droplet size distributions, precipitation and the persistence of clouds over the SE Atlantic?



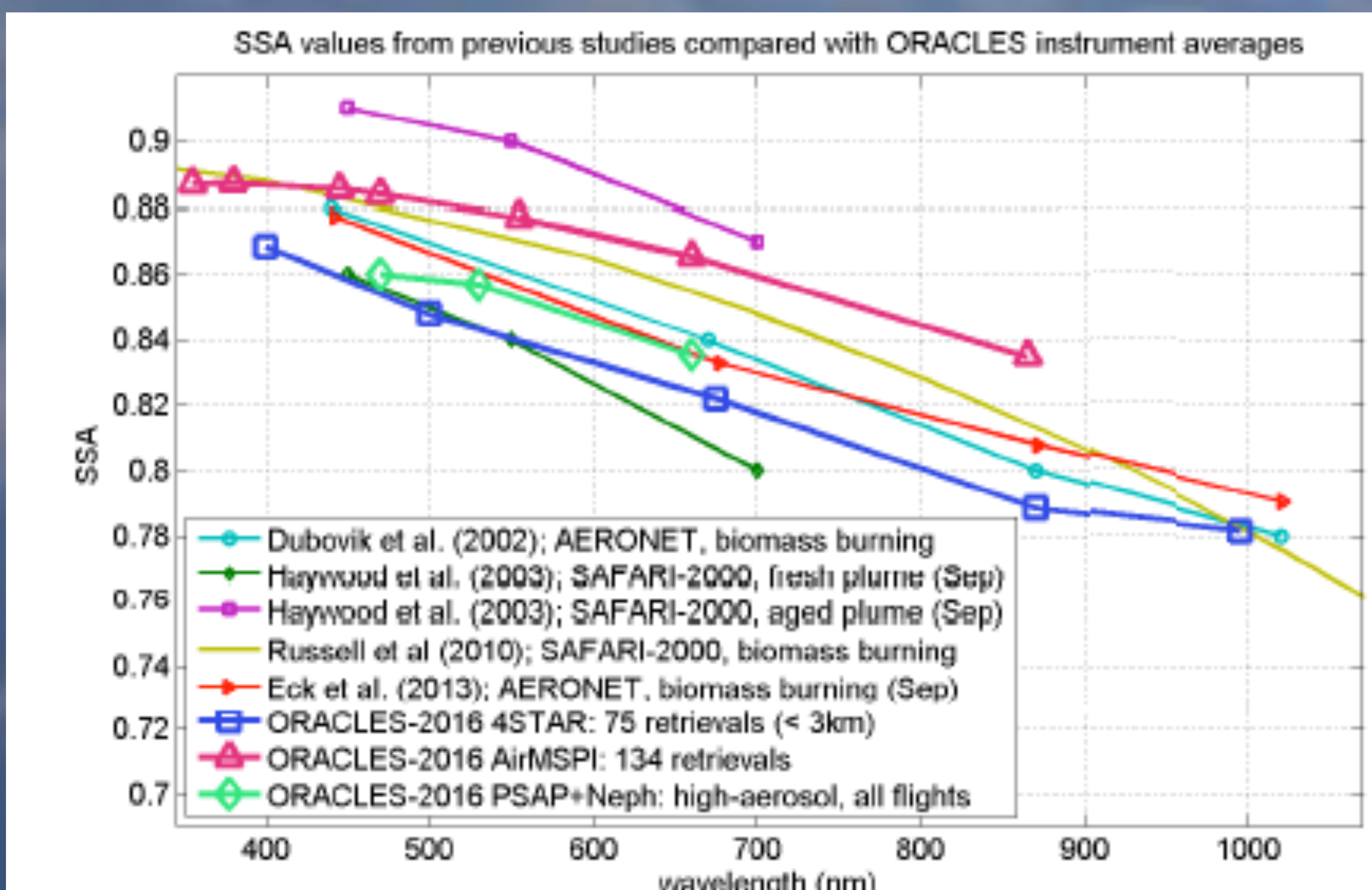
Q1: What is the direct radiative effect of the African BBA layer in clear and cloud sky conditions over the SE Atlantic?



approach: redundant measurements of the single-scattering-albedo;
full-column measurements of the spectral flux



Schmidt, Cochrane, Gore
(U of Colorado, ARC)



Q2: How does absorption of solar radiation by african BBA change atmospheric stability, circulation, and ultimately cloud properties? *(semi-direct effect)*

a-priori: unclear how often smoke came into contact with the clouds

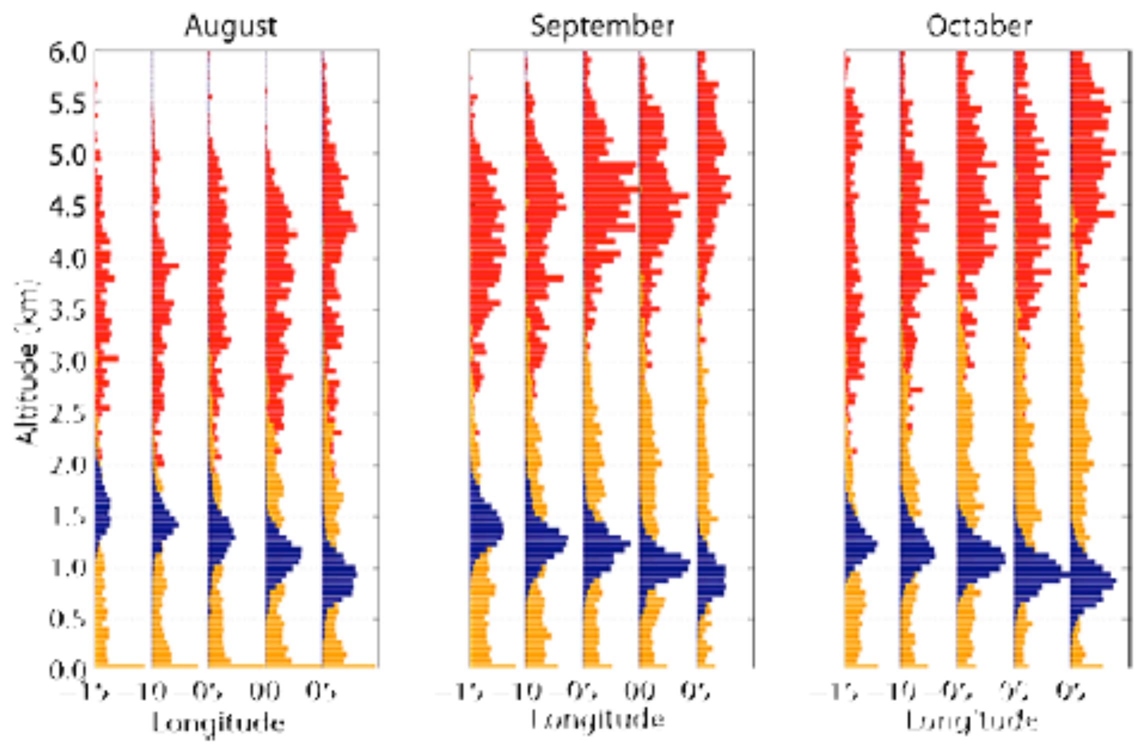
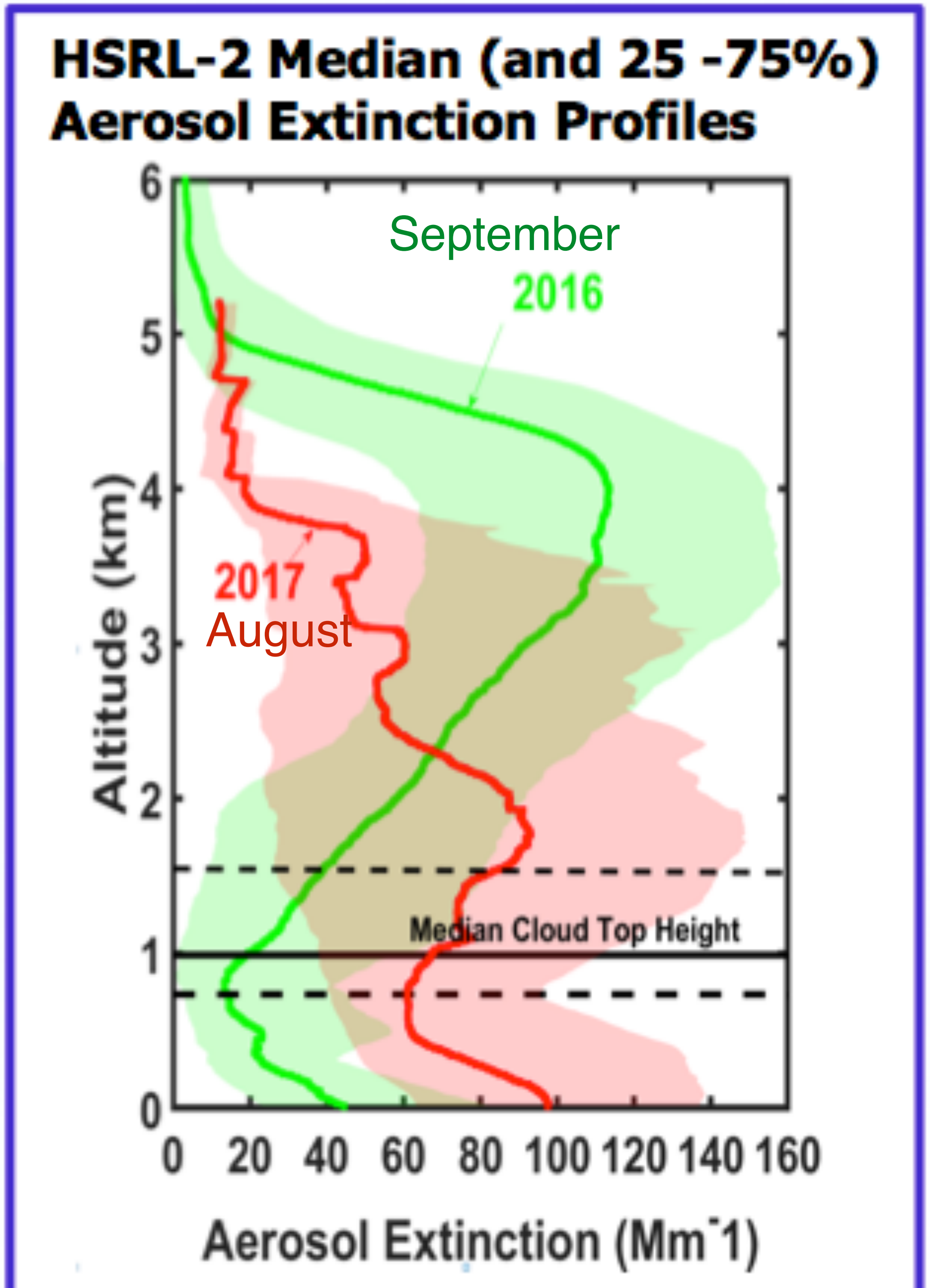


Figure 3.1-4. Distributions of aerosol top height (red), cloud top height (blue) and the separation between clouds and overlying aerosols (yellow) as a function of longitude, between 10-22.5°S.

we now know from HSRL2 data: smoke is often in contact with the clouds

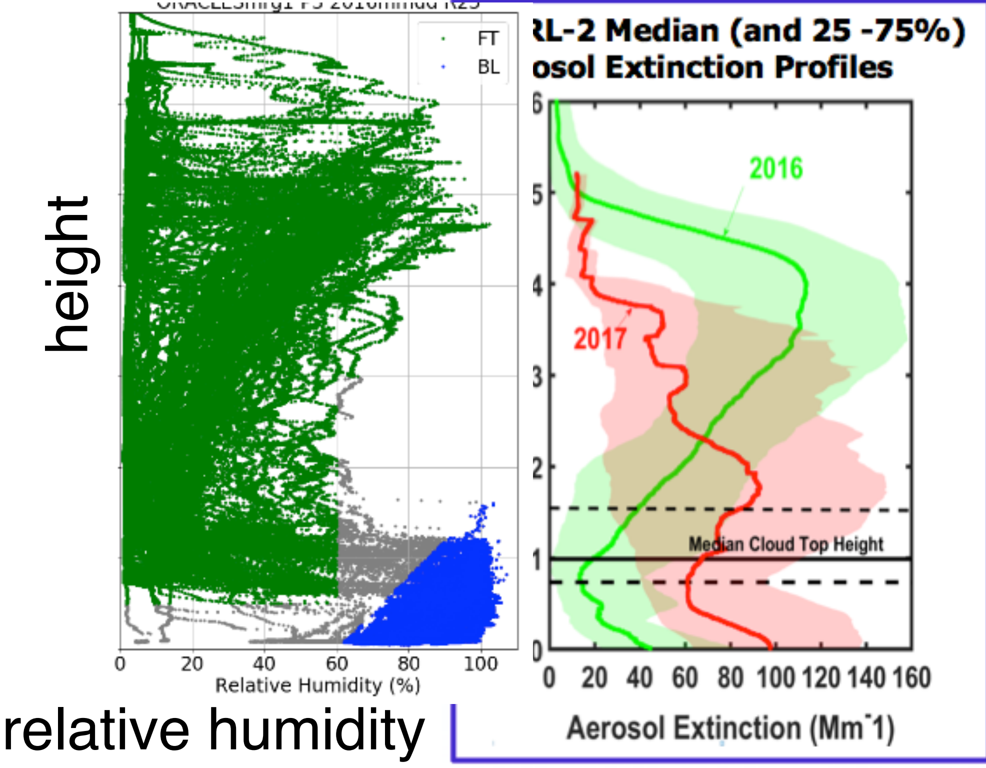
2016 smoke layer in contact with low-level clouds over 40% of the time

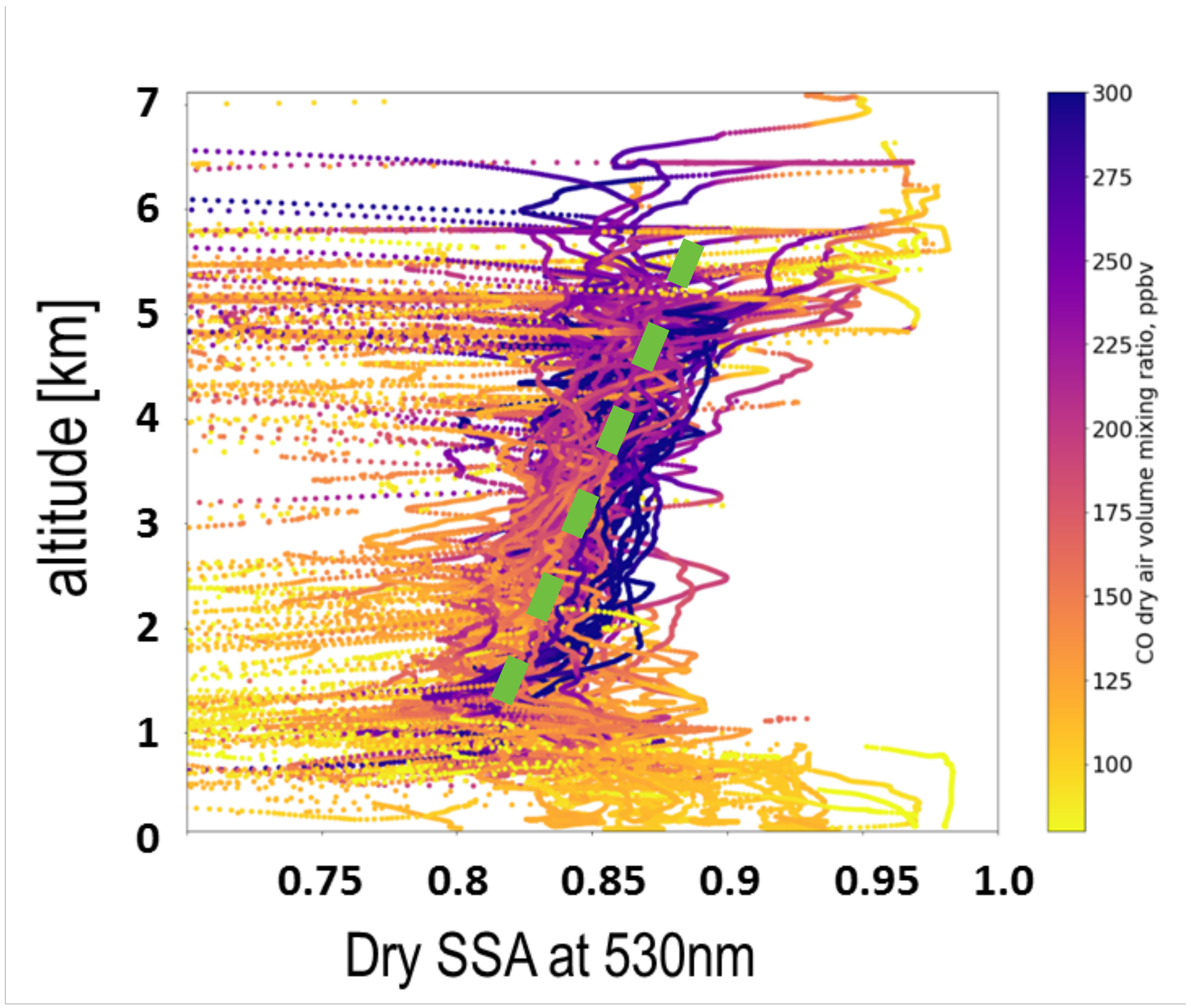
Ferrare, Burton, Hostetler, HSRL-2 team (NASA LaRC)

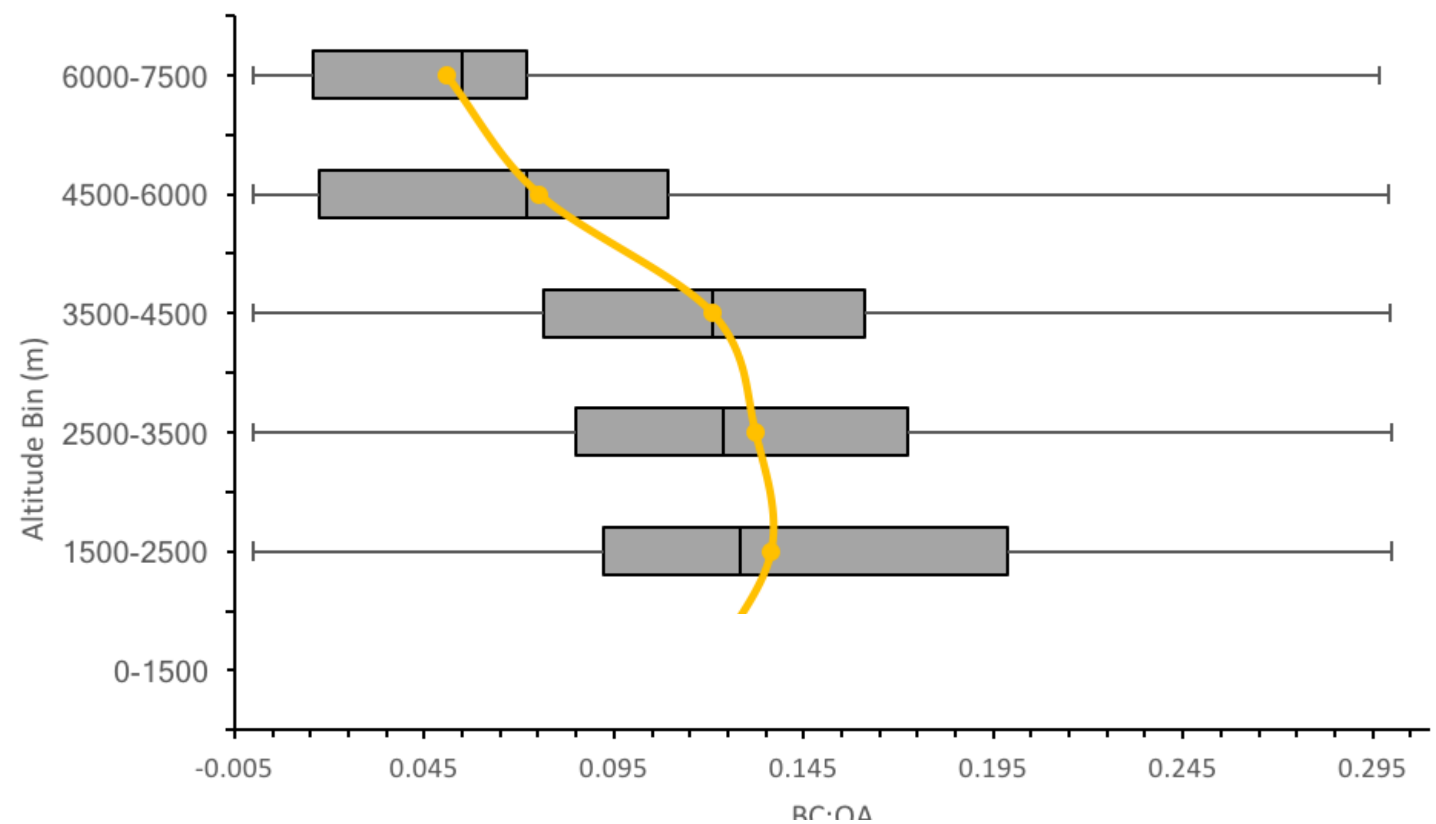


a pronounced vertical structure evident in 2016

more absorbing aerosol located lower down, with higher black carbon:organic aerosol ratios







ref. black carbon:organic aerosol ratio

Steve Howell, Amie Dobracki, Steffen Freitag,Art Sedlacek on the relationship of BBA to the large-scale circulation:

what we thought in 2013….

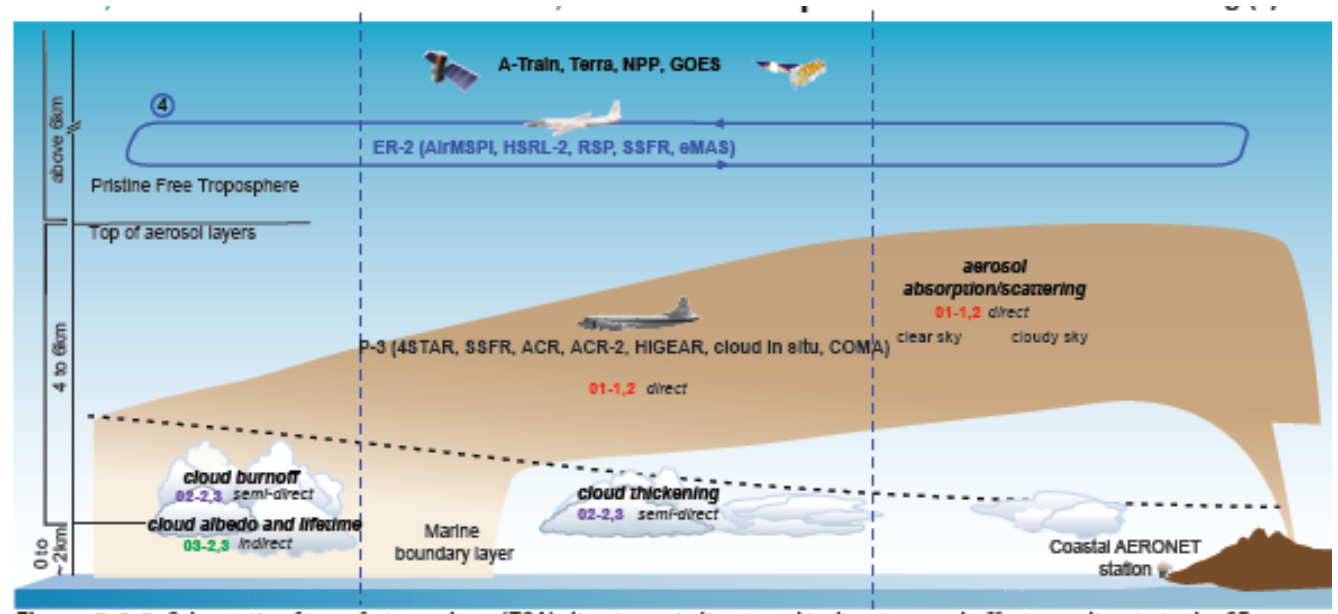
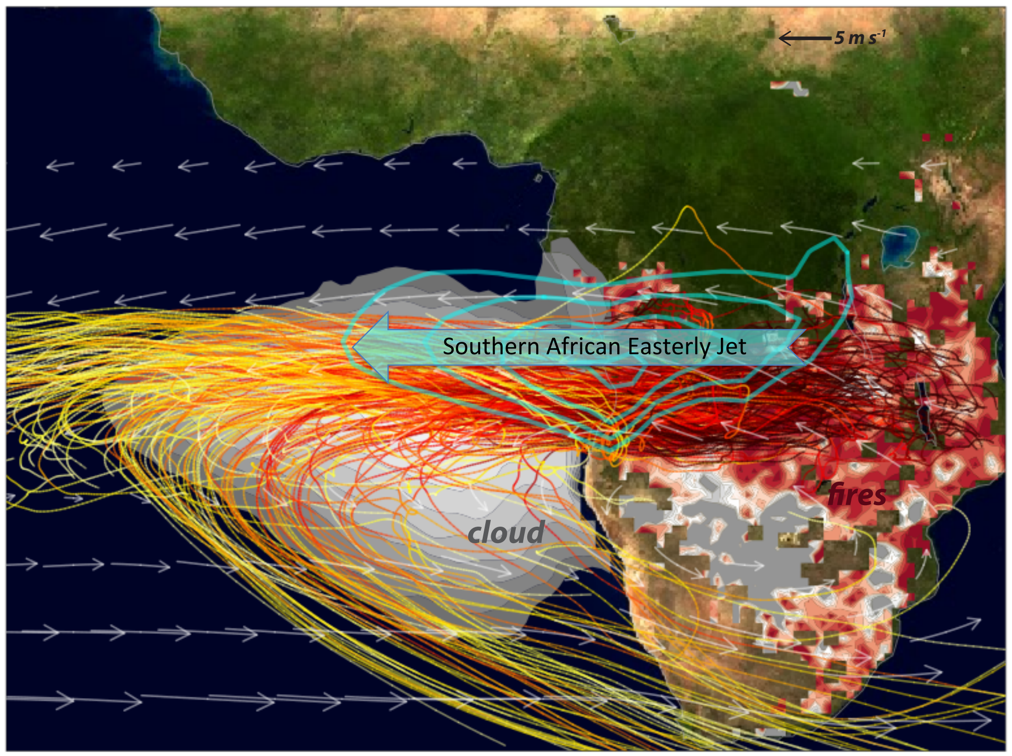
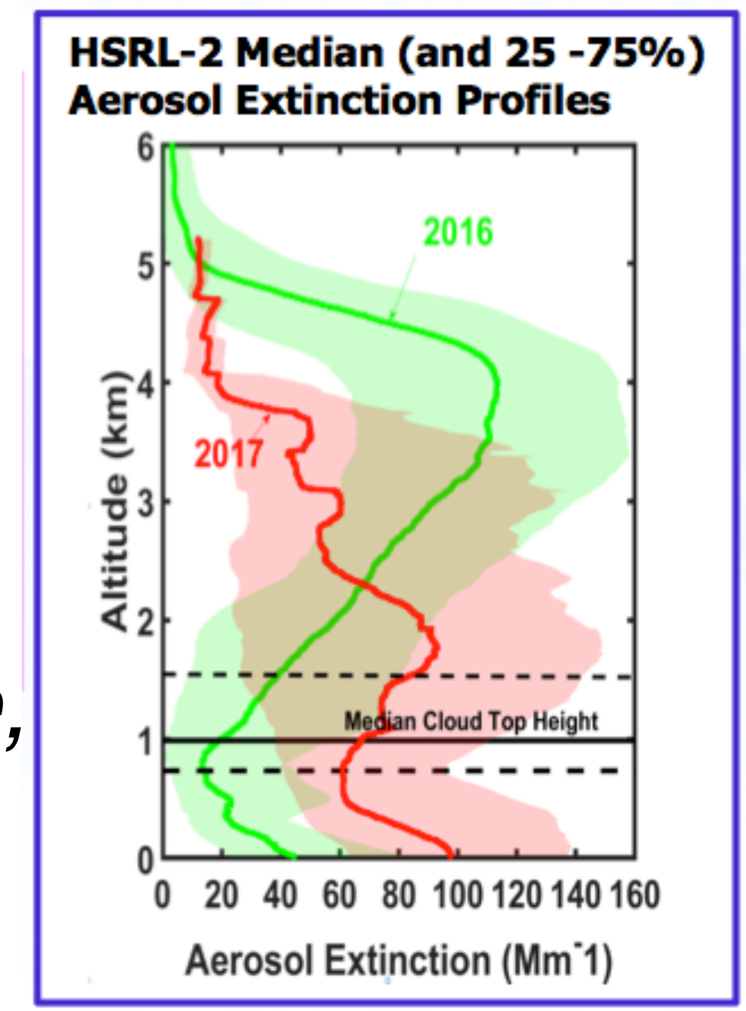


Figure 3.1-2. Schematic of top of atmosphere (TOA) direct, semi-direct, and indirect aerosol effects on climate in the SE Atlantic and their relationship to science objectives stated below.

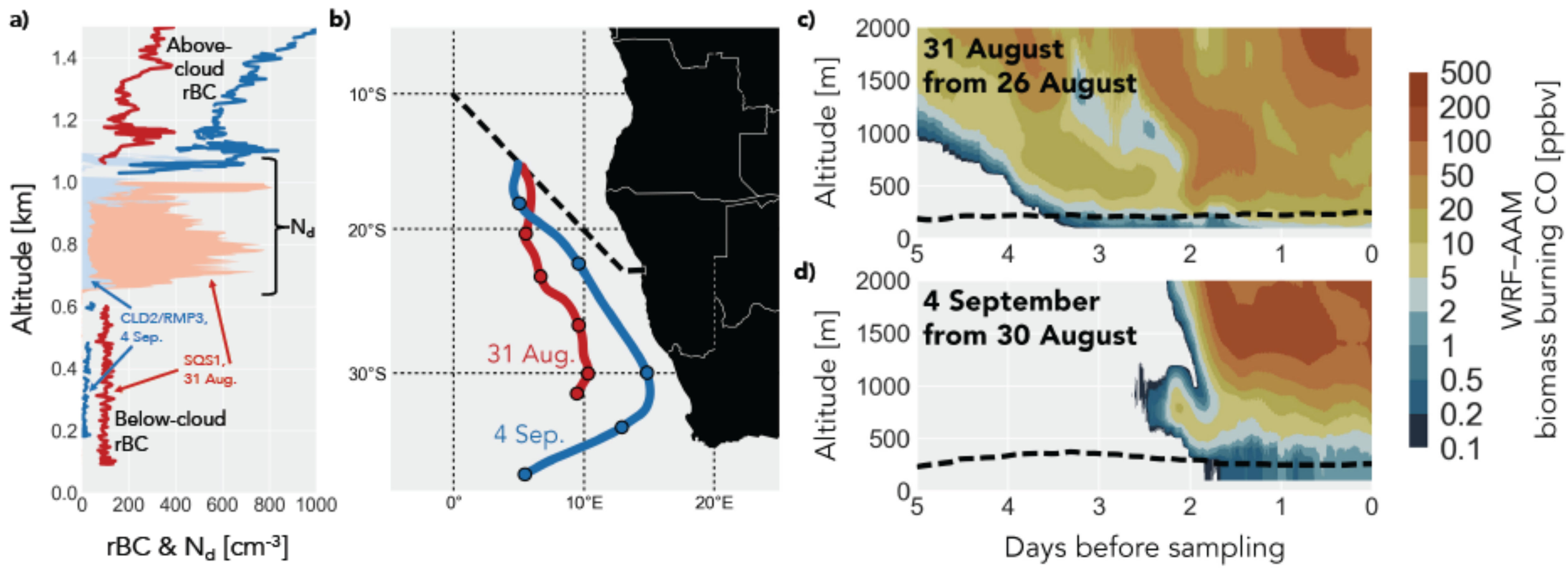
in 2016….





after fieldwork: in September, smoke advected off of the continent at high altitude, subsiding as it recirculates, ages, changing its chemical/optical properties near southern end of the stratocumulus deck, cloud microphysical properties are strongly affected by the large-scale recirculation bringing smoke to rest on top of the cloud layer, allowing entrainment of smoke into the boundary layer over multiple days

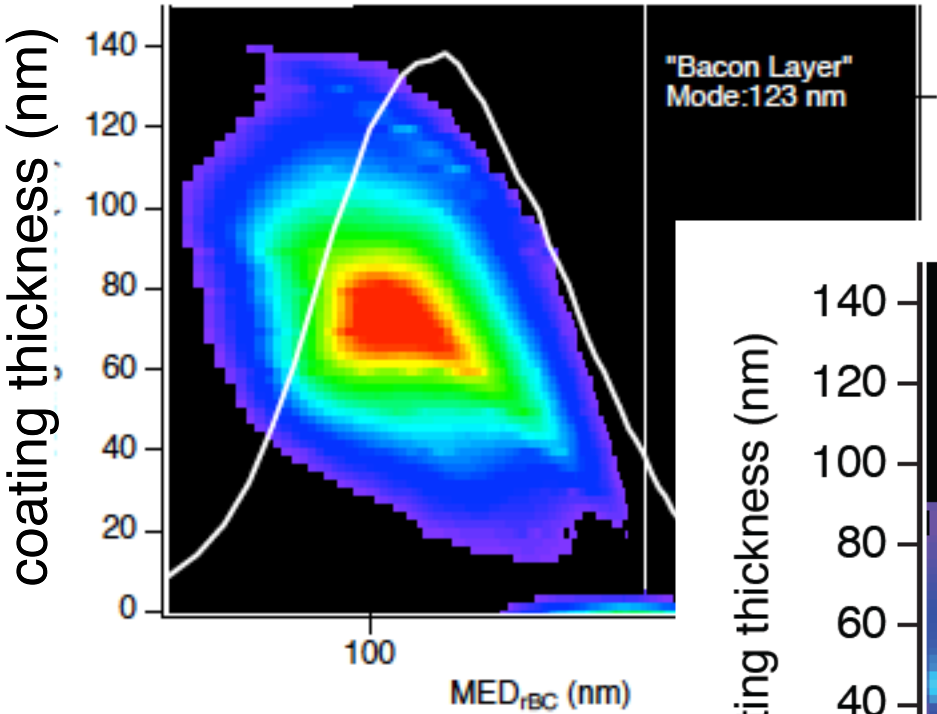
An illustrative case: Contrasting the August 31st and September 4th ORACLES-2016 flights



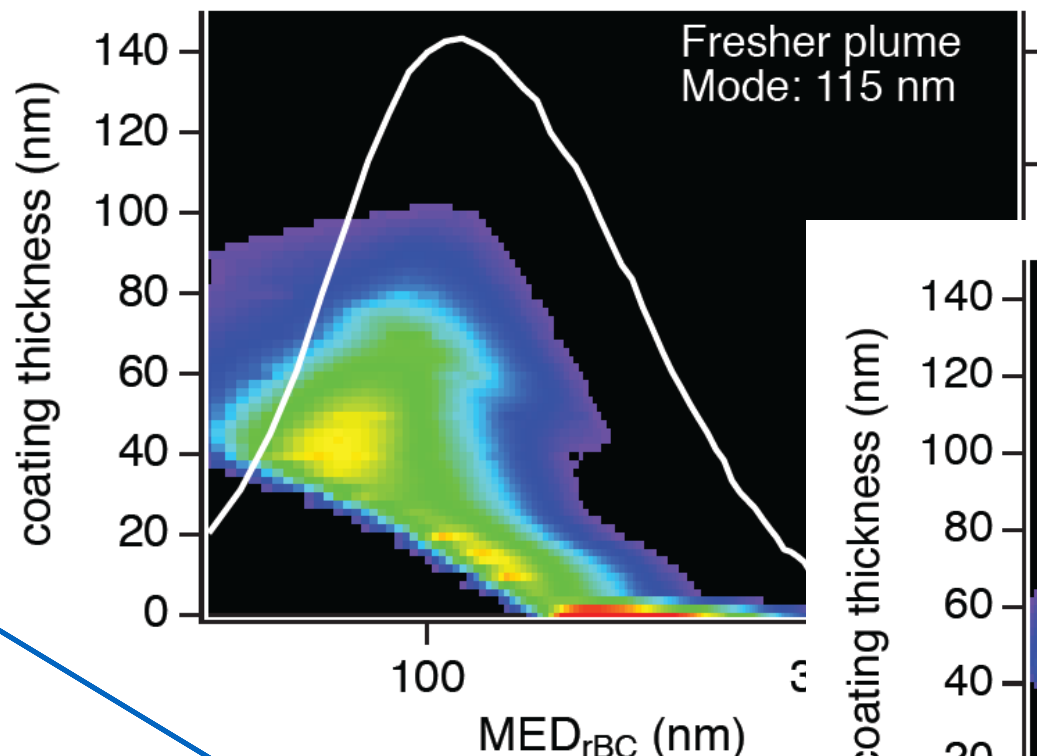
Michael Diamond, Rob Wood et al., 2018, Atmos. Chem. Phys.

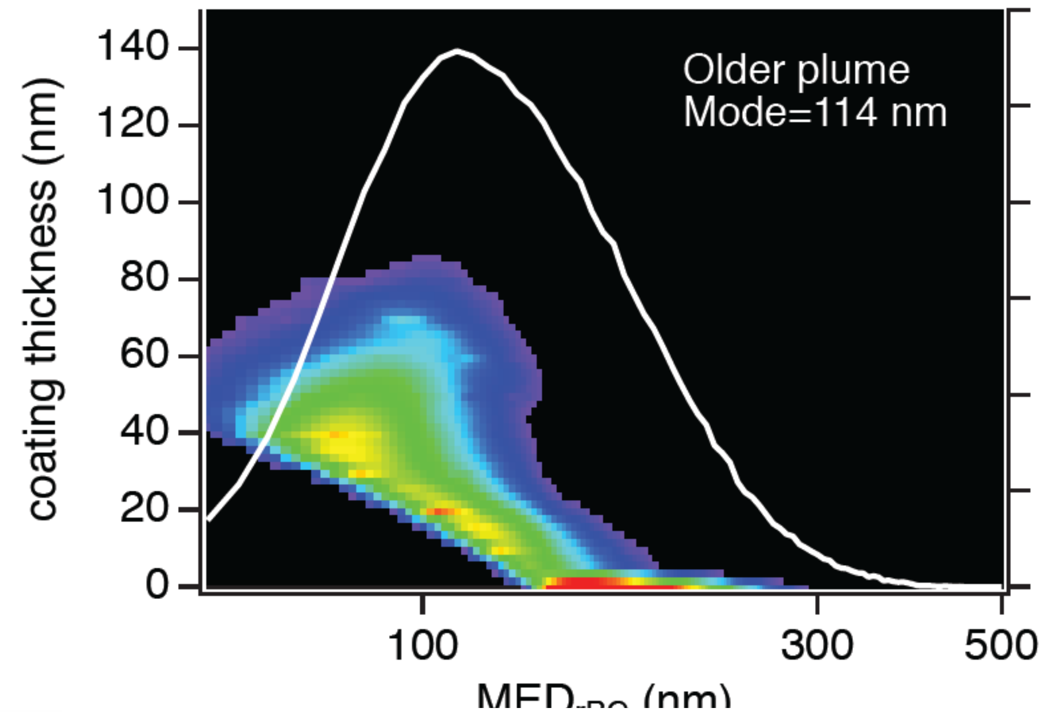
Special Issue "New observations and related modelling studies of the aerosol–cloud–climate system in the Southeast Atlantic and southern Africa regions "

coating thickness on ref. black carbon decreases with age



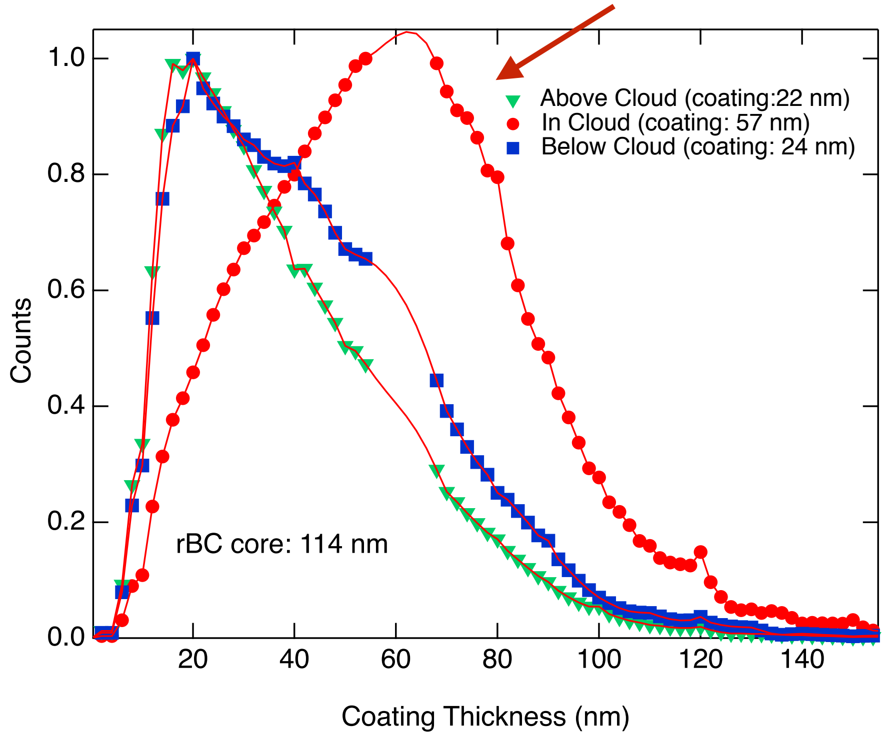
fresh

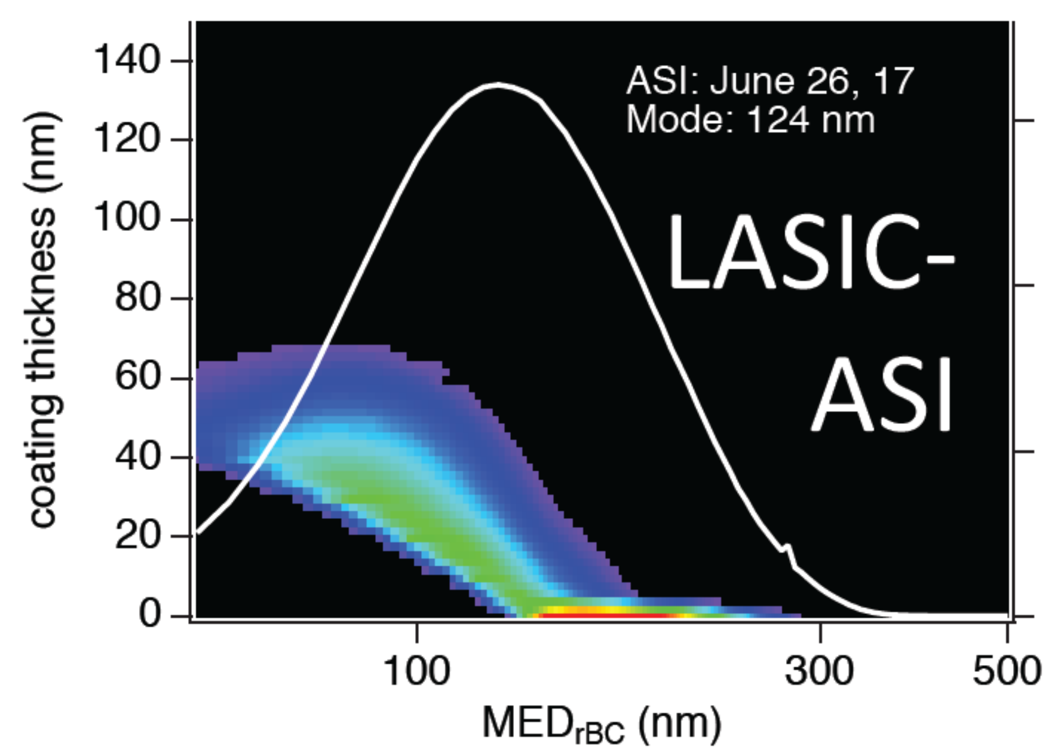




aged

with larger rBC particles preferentially activated within clouds

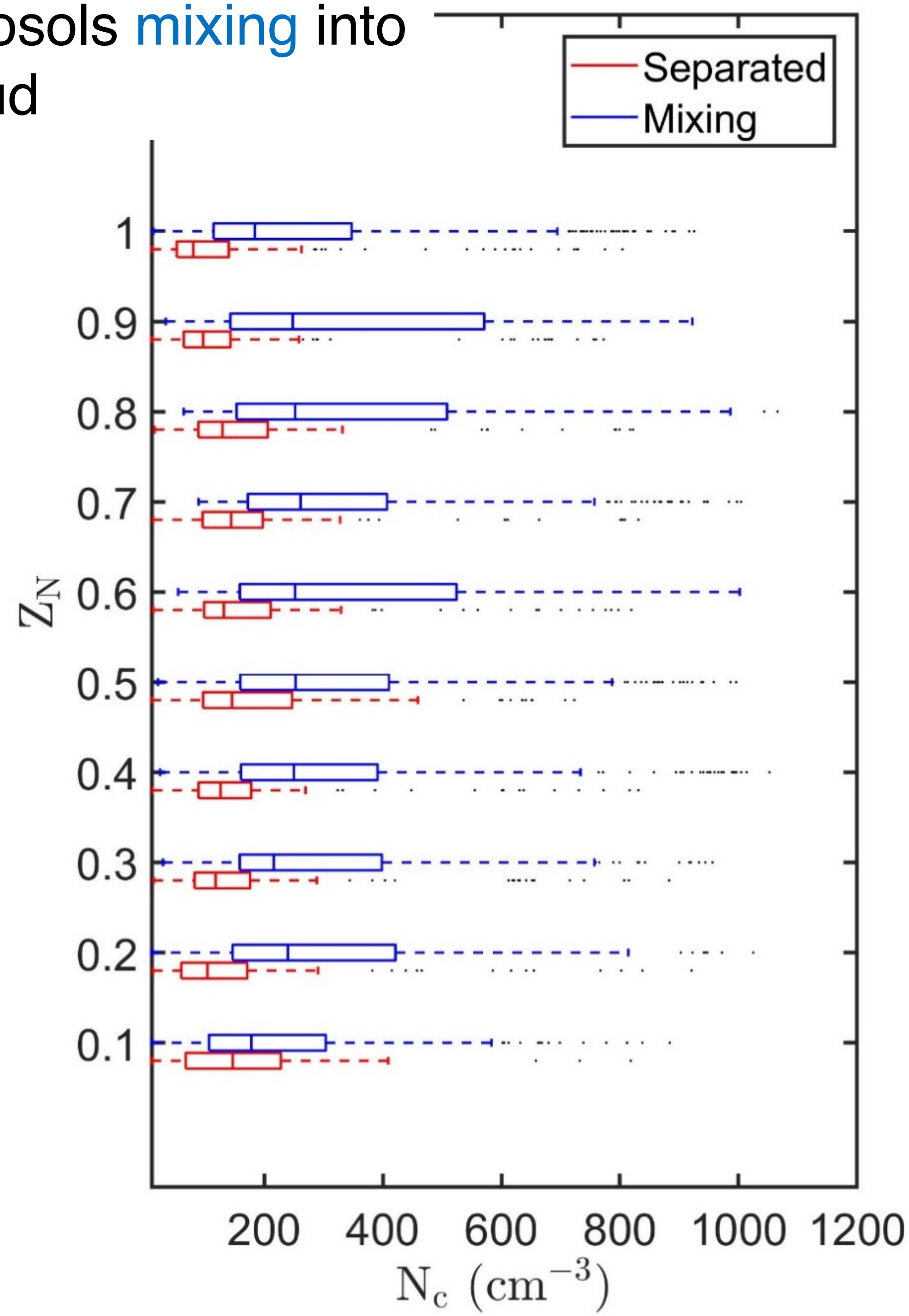




Art Sedlacek - SP2
David Noone - CVI

Q3: How do BB aerosols affect cloud droplet size distributions, precipitation and the persistence of clouds over the SE Atlantic? *(indirect effect)*

Greater N_c when aerosols mixing into cloud



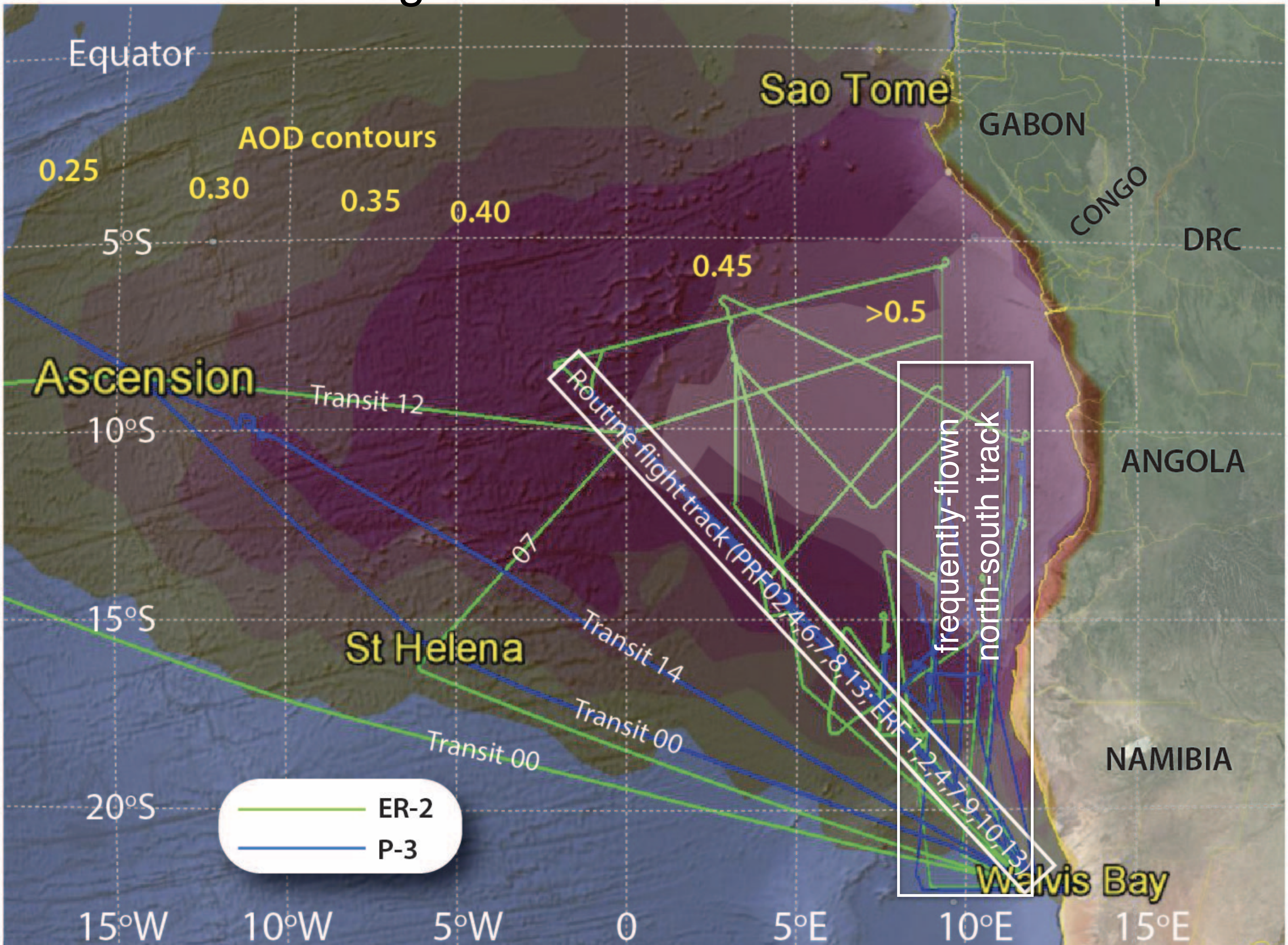
McFarquhar, Gupta (OU);

Poellot, O'Brien (UND);

Griswold (UH) - PDI

Dzambo, L'Ecuyer (UWisc) - radar

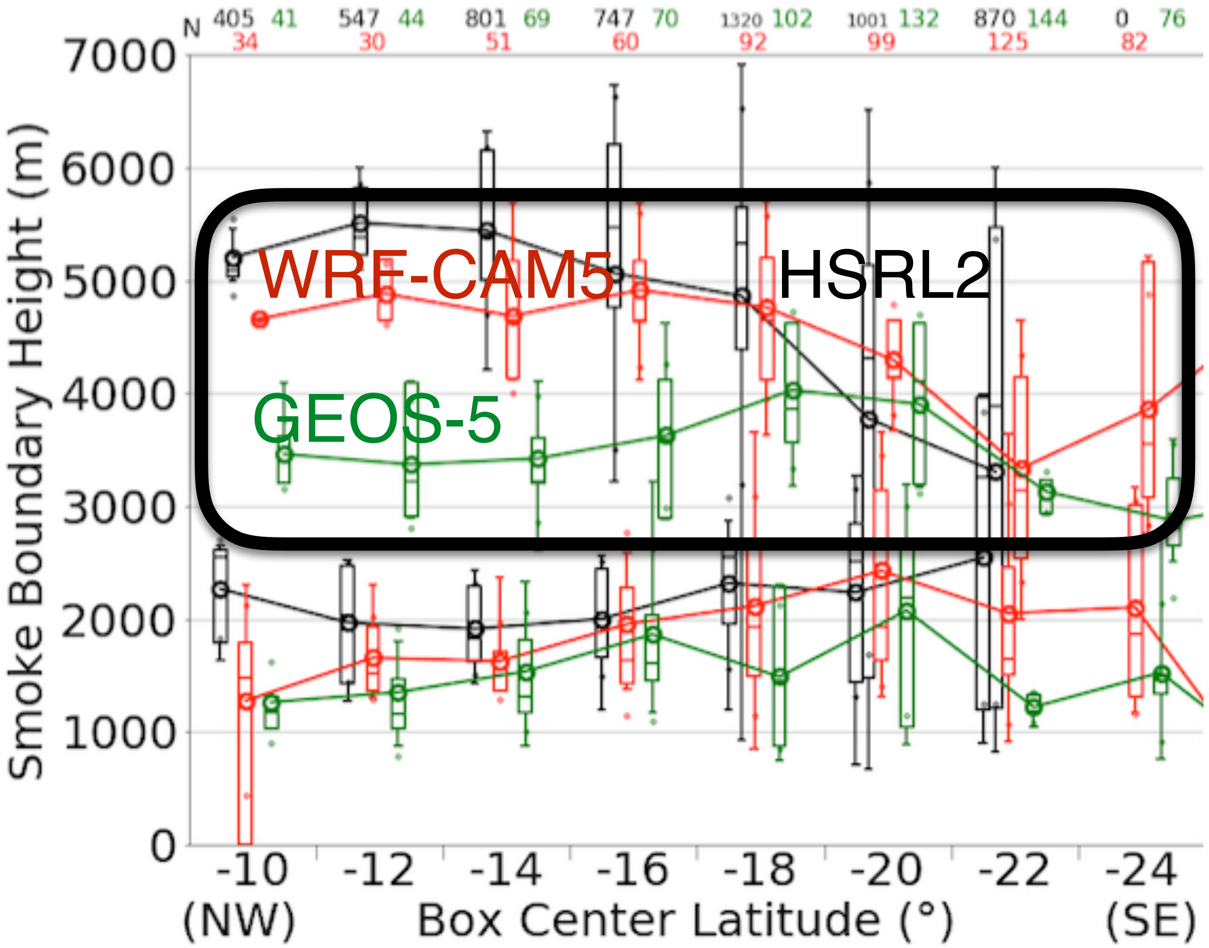
are also undertaking a model-observational inter comparison



above-cloud to 3km, box-whisker distributions

the regional model does better than the global model at capturing the smoke layer top

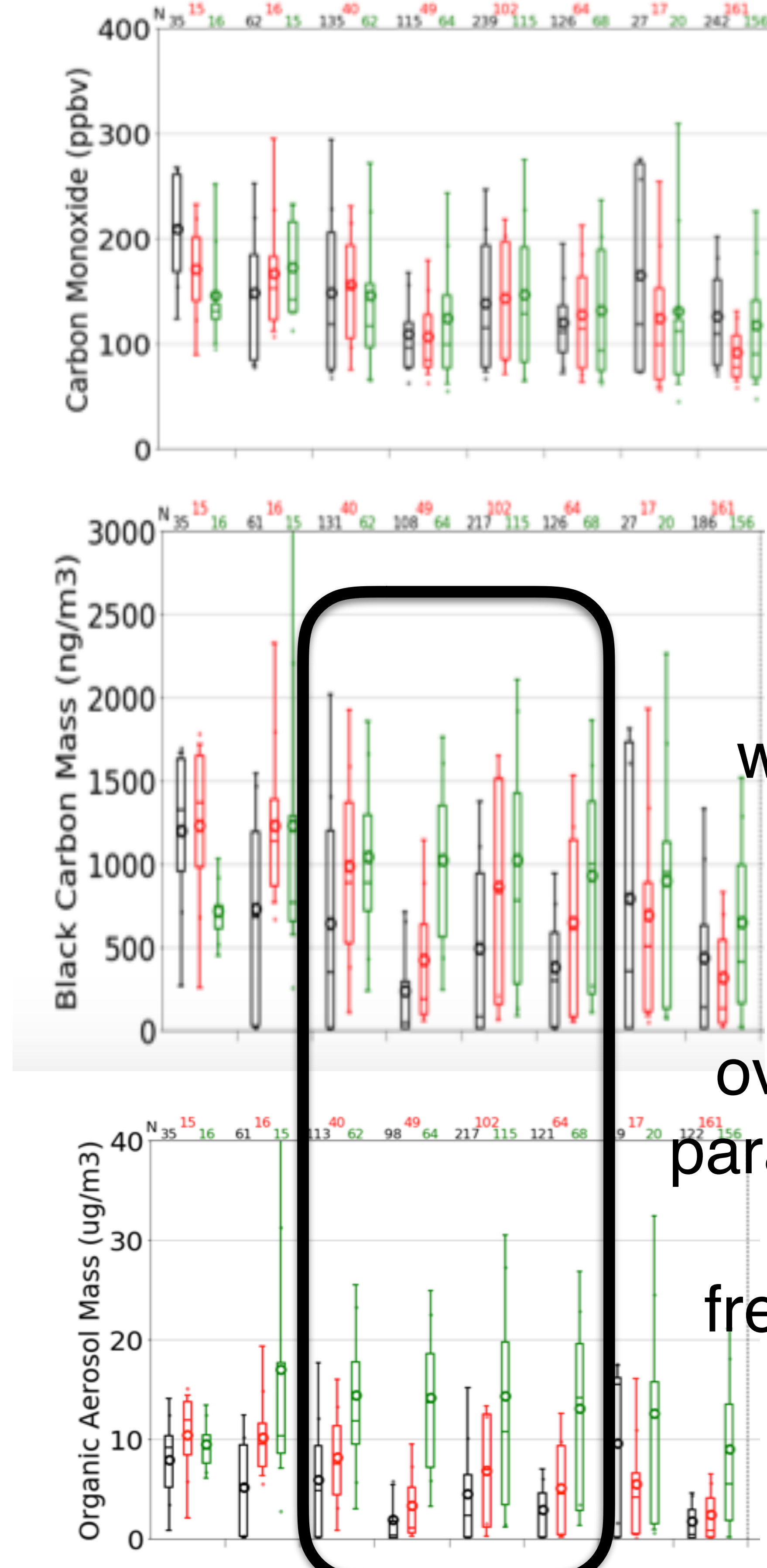
(see also Das et al., 2017)



WRF-CAM5 (regional) GEOS-5 (global)

HSRL2

Shinozuka et al., ACP SI, manuscript in preparation



NW SE

CO is reasonably represented in both models

while BC and organic aerosol are often overestimated; parameterizations based on fresher smoke?

see poster by Ian Chang Tuesday 4-6 pm

Summary

- SE Atlantic more dynamic than originally thought
- profound aerosol aging
- will likely need to revisit smoke parameterizations
- non-controversial indications of smoke-cloud interactions

2016 & 2017 data is publicly available at https://espoarchive.nasa.gov/archive/browse/oracles
2018 data will be publicly available by Sep 2019.

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