CLARIFY 2017, **CLouds-Aerosol-Radiation Interaction and Forcing: Year 2017**

Ascension Island

Aerosol Cloud and Aerosol Radiation interactions studies

Paul Barrett (Met Office), Paquita Zuidema (U. Miami), Tim Onasch (Aerodyne), Steven Abel, Kate Szpek, Anthony Jones (Met Office), Jianhao Zhang (U. Miami), Jim Haywood (Exeter), Ian Crawford, Jonathon Taylor, Huihui Wu, Hugh Coe (University of Manchester), Hamish Gordon (University of Leeds), and many others

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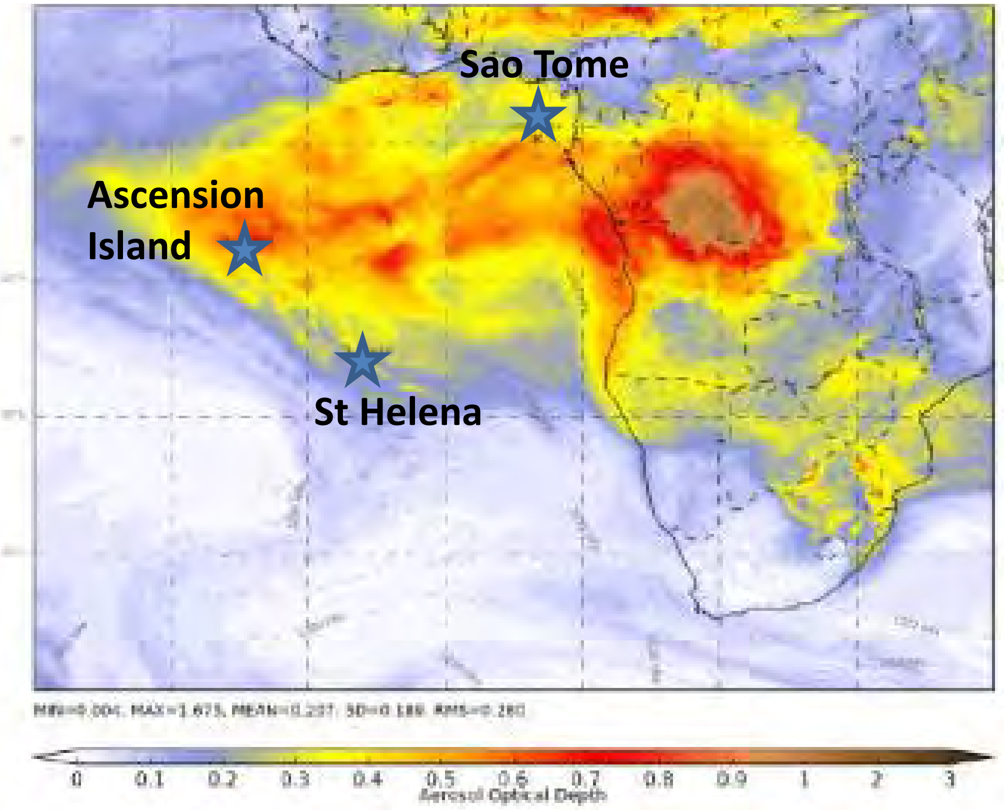
Data were obtained from the Atmospheric Radiation Measurement (ARM) User Facility, a U.S. Department of Energy (DOE) Office of Science user facility managed by the Office of Biological and Environmental Research.

The CLouds-Aerosol-Radiation Interaction and Forcing: Year 2017 (CLARIFY-2017) programme

MetUM 17 km Global Model Forecast Model Prognostic Biomass Burning Aerosol AOD



LASIC (Layered Atlantic Smoke Interactions with Clouds)

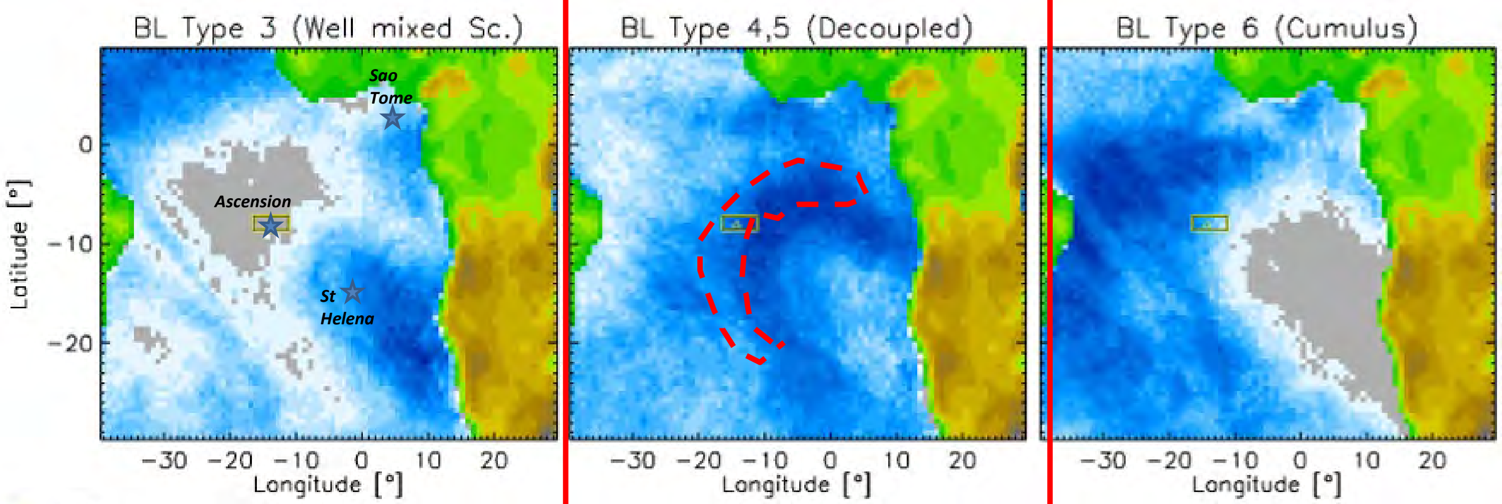
DoE ARM mobile facility on Ascension Island

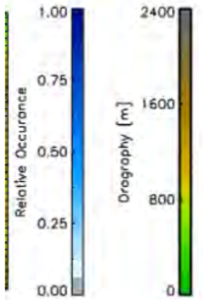
FAAM BAe146 (Taken from NASA P2 in ORACLES

Ascension Island

Met Office | University of Exeter | University of Leeds | Manchester 1824 The University of Manchester | University of Oxford | University of Reading | National Centre for Atmospheric Science, Natural Environment Research Council

South Atlantic Boundary Layer types
Climatology from Unified Model, 65km





- Boundary Layer Scheme performs stability analysis - Categorises mixing type based on parcel ascents/descents
- **Well Mixed** – Stratocumulus near Namibian Coast
- **Decoupled Stratocu-Cumulus–** St. Helena → Ascension
- **Trade Cumulus** beyond

- Often Ascension on the boundary of the Sc-Cu Transition
- 19 Flights with transition Sc-Cu characteristics – mix of aerosol radiation and aerosol cloud interactions flying
- 3 Cumulus convective flights,
- 3 POCs flights

Cui, EGU2020
(paper in prep)

Development of convection in a mesoscale cloud system and its effect on the microphysics over the tropical Atlantic Ocean

Zhiqiang Cui[1], Alan Blyth[1,2], Steven Abel[3], Paul Barrett[3], and Hamish Gordon[1]

Gordon *et al.*, ACPD2020

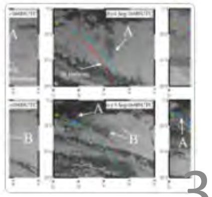
Improving aerosol activation in the double-moment Unified Model with CLARIFY measurements

Hamish Gordon[1,2], Paul R. Field[1,3], Steven J. Abel[3], Paul Barrett[3], Keith Bower[4], Ian Crawford[4], Zhiqiang Cui[1], Daniel P. Grosvenor[1], Adrian A. Hill[3], Jonathan Taylor[4], Jonathan Wilkinson[3], Huihui Wu[4], and Ken S. Carslaw[1]

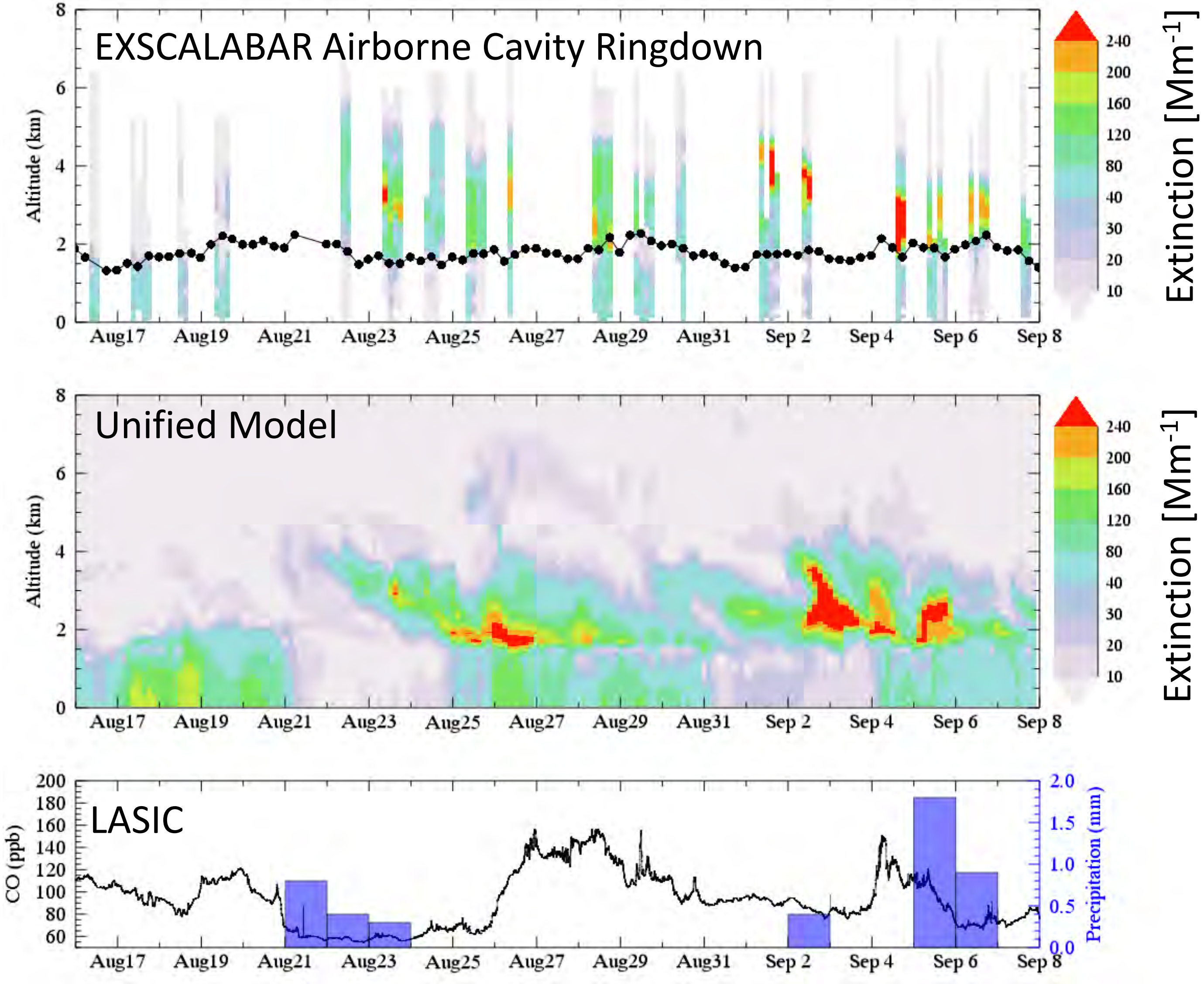
Abel *et al.*, ACP2020

Open cells exhibit weaker entrainment of free-tropospheric biomass burning aerosol into the south-east Atlantic boundary layer

Steven J. Abel[1], Paul A. Barrett[1], Paquita Zuidema[2], Jianhao Zhang[2], Matt Christensen[3], Fanny Peers[4], Jonathan W. Taylor[5], Ian Crawford[5], Keith N. Bower[5], and Michael Flynn[5]

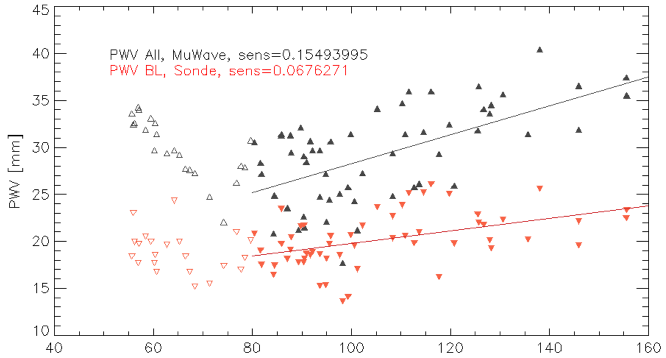


CLARIFY LASIC Ascension Island timeseries



- Precip at surface is only present when pollution (CO) is LOW.
- But, column water vapour PWV, also increases with pollution, as does LWP.

LASIC PWV from Integrated radiosondes

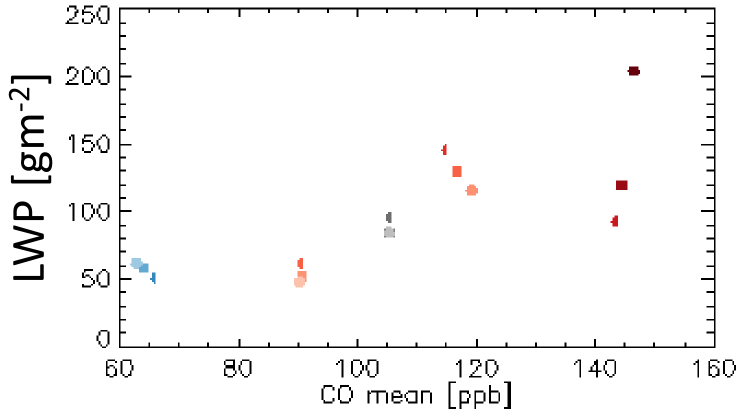


Full Column

BL

J. Zhang

LASIC LWP from MuWave Radiometer



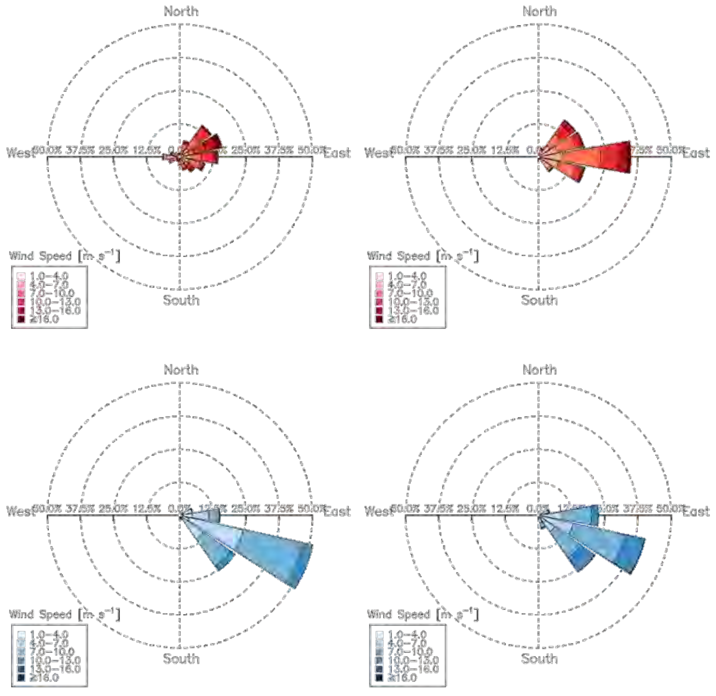
CLARIFY Overview Haywood (In prep.)

Full profiles, in “clean” and “polluted” regimes

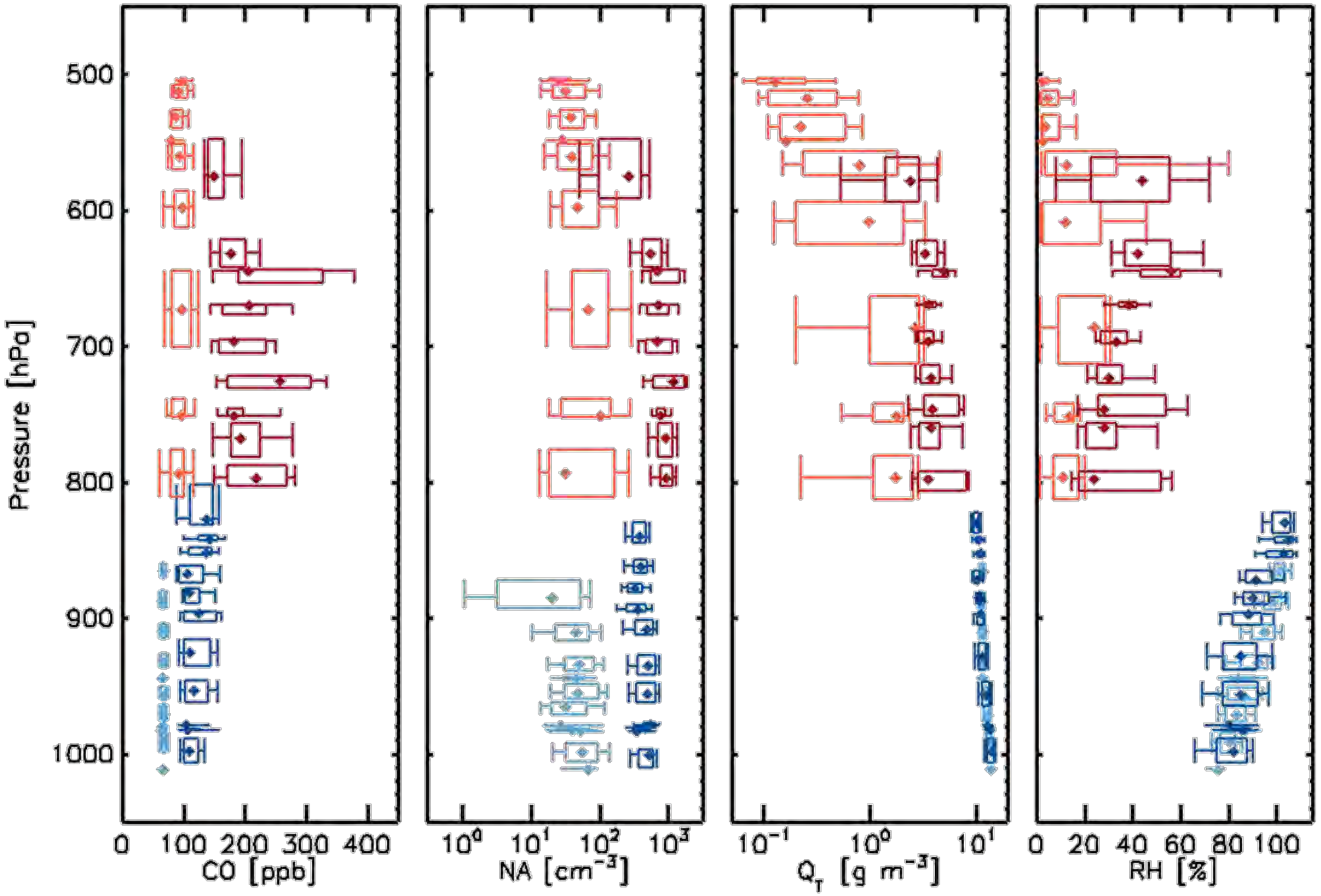
Stronger Easterly aloft brings FT pollution from African Continent

CO Limits [ppb]	
Boundary Layer	Free troposphere
Clean < **80 < Polluted**	Clean **< 130 < polluted**

Co-varying of Pollution (CO, aerosol number) and thermodynamics (temperature, humidity)



Clean Polluted



Barrett (in prep.)

ACI: Polluted Continental air Impacts Boundary Layer Thermodynamics and Clouds

Microphysics

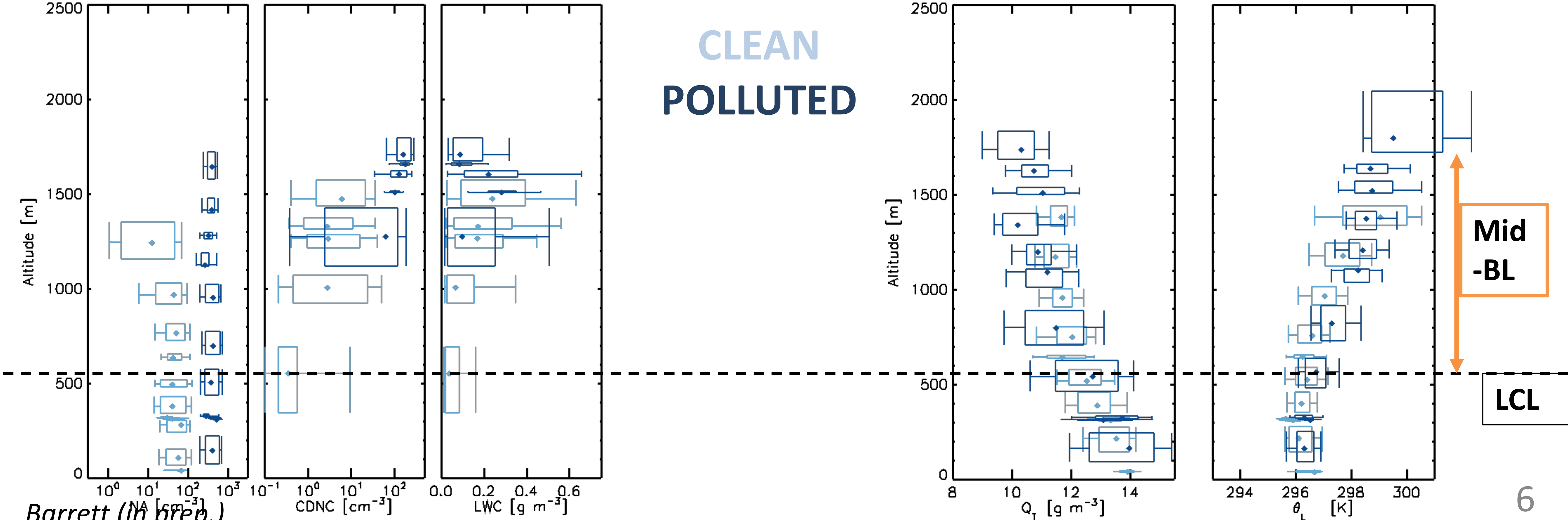
Bulk Cloud

Thermodynamics

Warmer (+1K) and drier (-1g/kg)
Cloud Layer above LCL
entrainment of FT air in pollution events

Higher CNDC,

Higher Cloud Base
Higher Cloud Top,



Barrett (in prep.)

ACI: Polluted Continental air Impacts boundary layer Thermodynamics and Clouds

Met Office

CLEAN

POLLUTED

CLARIFY 2017

Microphysics	Bulk Cloud	Thermodynamics

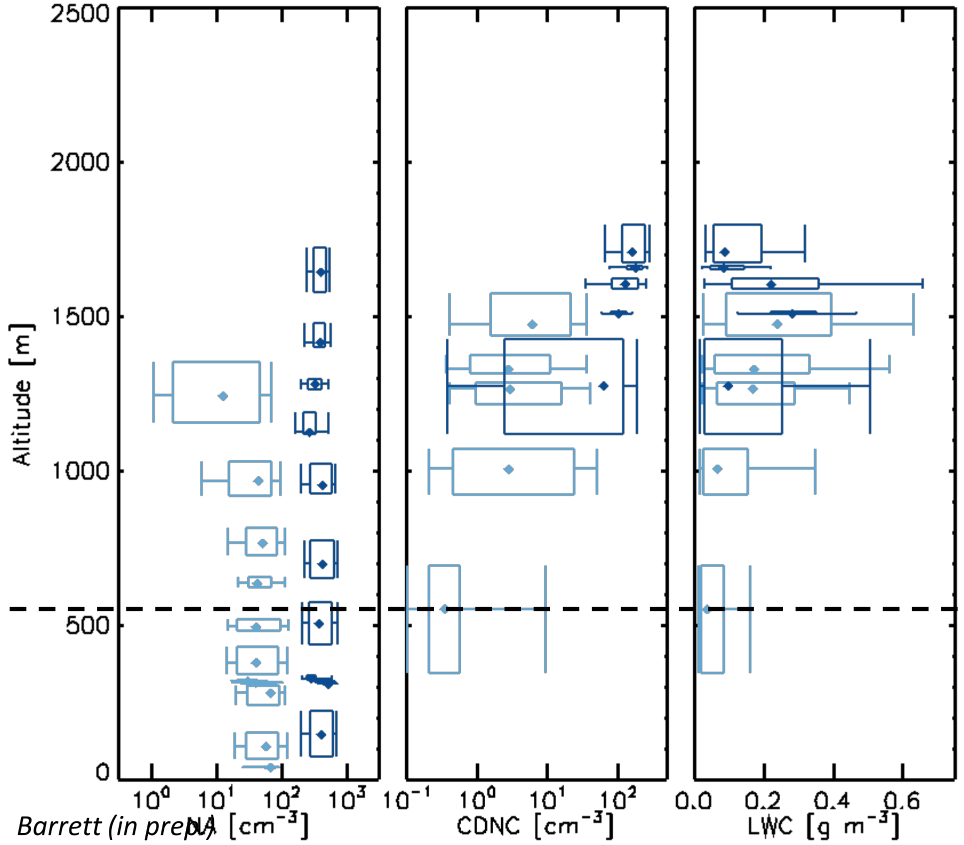
Reduction in cloud fraction in polluted skies

ΔCF= 0.5

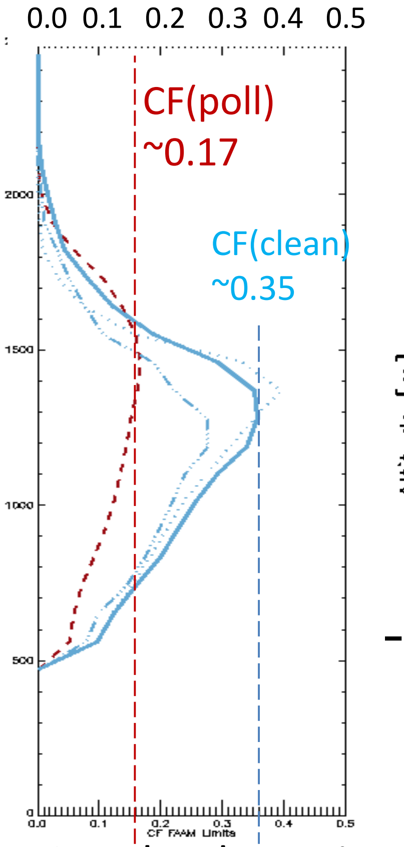
Warmer (+1K) and drier (-1g/kg) Cloud Layer above LCL *entrainment of FT air in pollution events*

Higher CNDC,

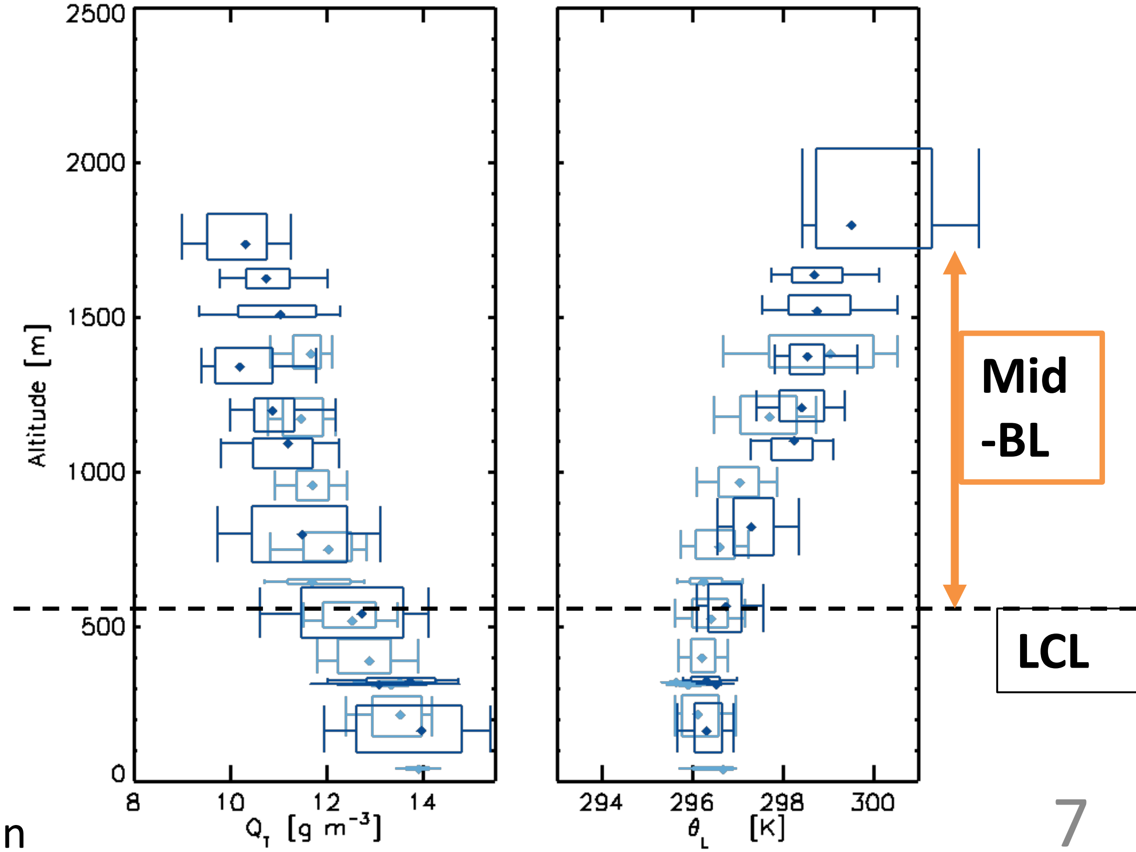
Higher Cloud Base *Higher Cloud Top,*



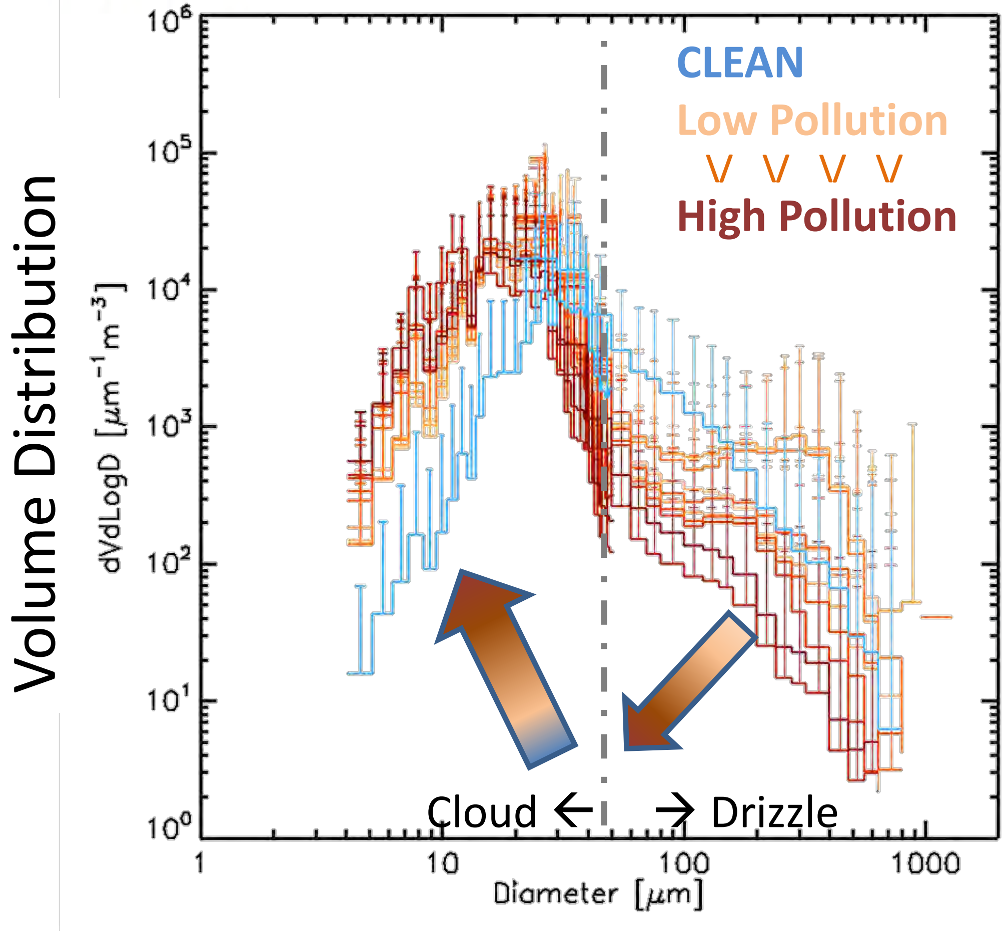
Barrett (in prep)

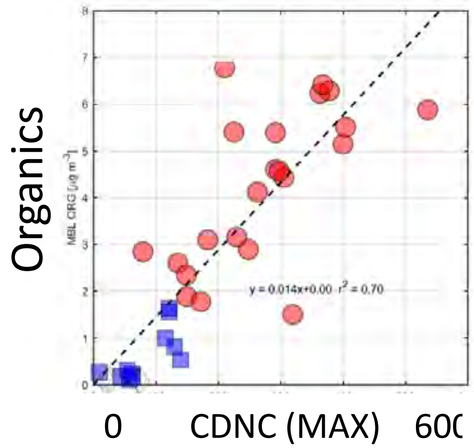


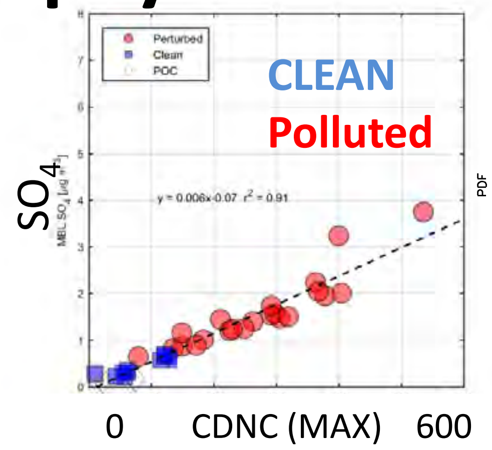
LASIC Cloud Fraction

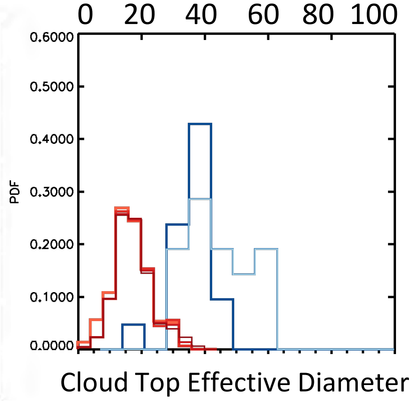


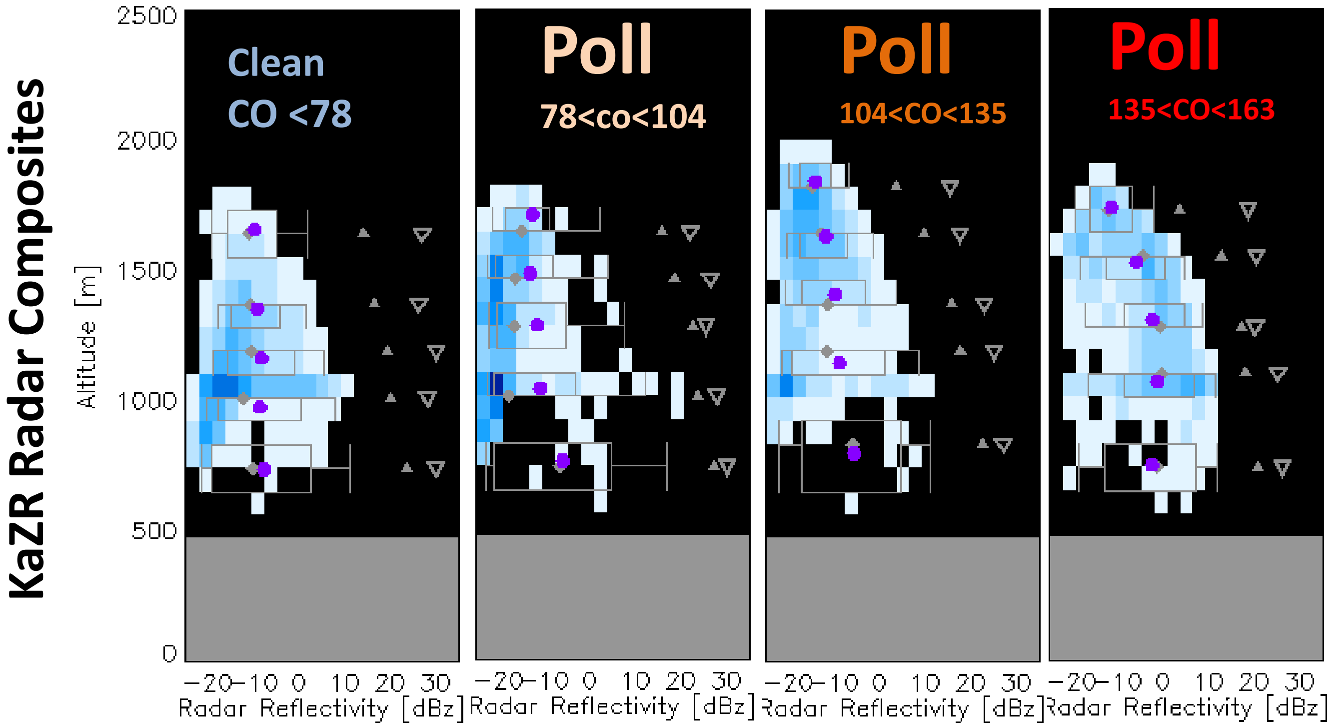
Airborne in situ observations of Impact of Pollution on Particle Size Distributions and Microphysics







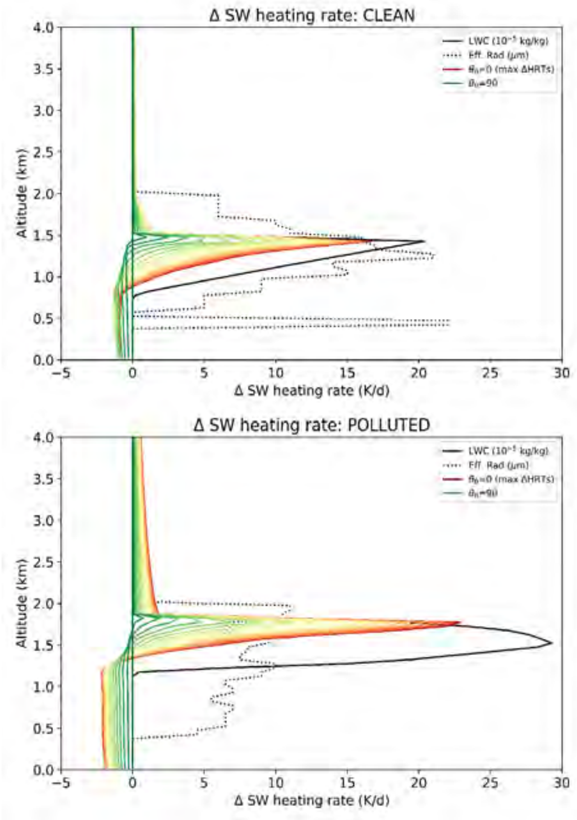




CLARIFY 2017

Barrett *(in prep.)*

Single Column Radiation Calculations (Anthony Jones)



___ LWC profile [10^{-1} kg/kg]
----- Re profile [μm]
0 deg Colours – Computed SW
90 deg Heating profiles as Fn (SZA)

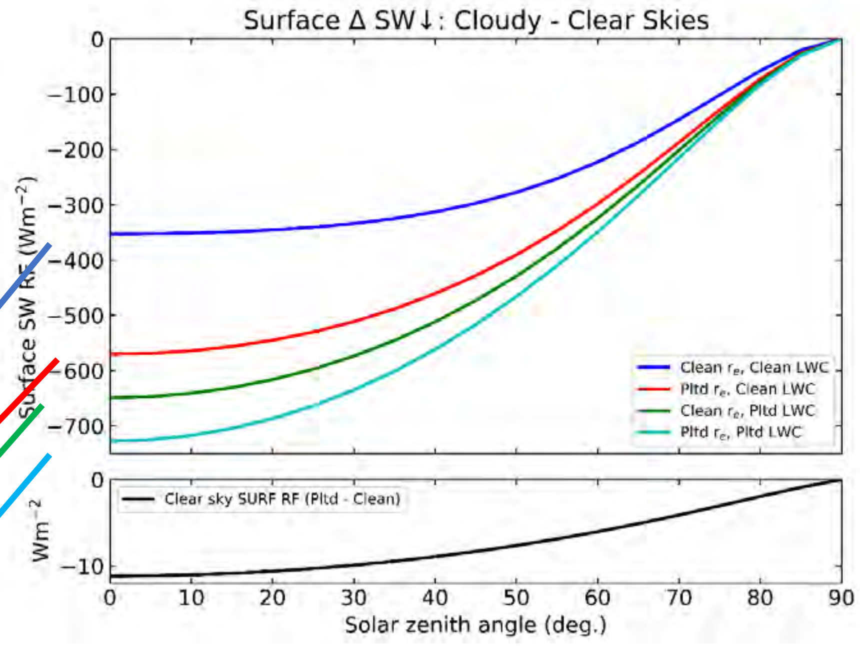
Barrett (in prep.)

- Run SOCRATES using clean and polluted thermodynamic profiles (see above)
- Look at difference between cloudy and clear skies in SW (solar) at Surface)
- And to check – put clean clouds Re in polluted cloud LWC profile (order of magnitude test)

Reff	LWC	Δ from Clear skies
Clean	Clean	-350 W/m²
Polluted	Clean	-575 W/m² (65%)
Clean	Polluted	-650 W/m² (85%)
Polluted	Polluted	-700 W/m² (100%)

Factor of 2 reduction in surface SW radiation under polluted clouds –***driven largely by enhanced LWC***

ACI: Cancellation of albedo effect in polluted clouds through reduction in cloud fraction (lifetime effect).

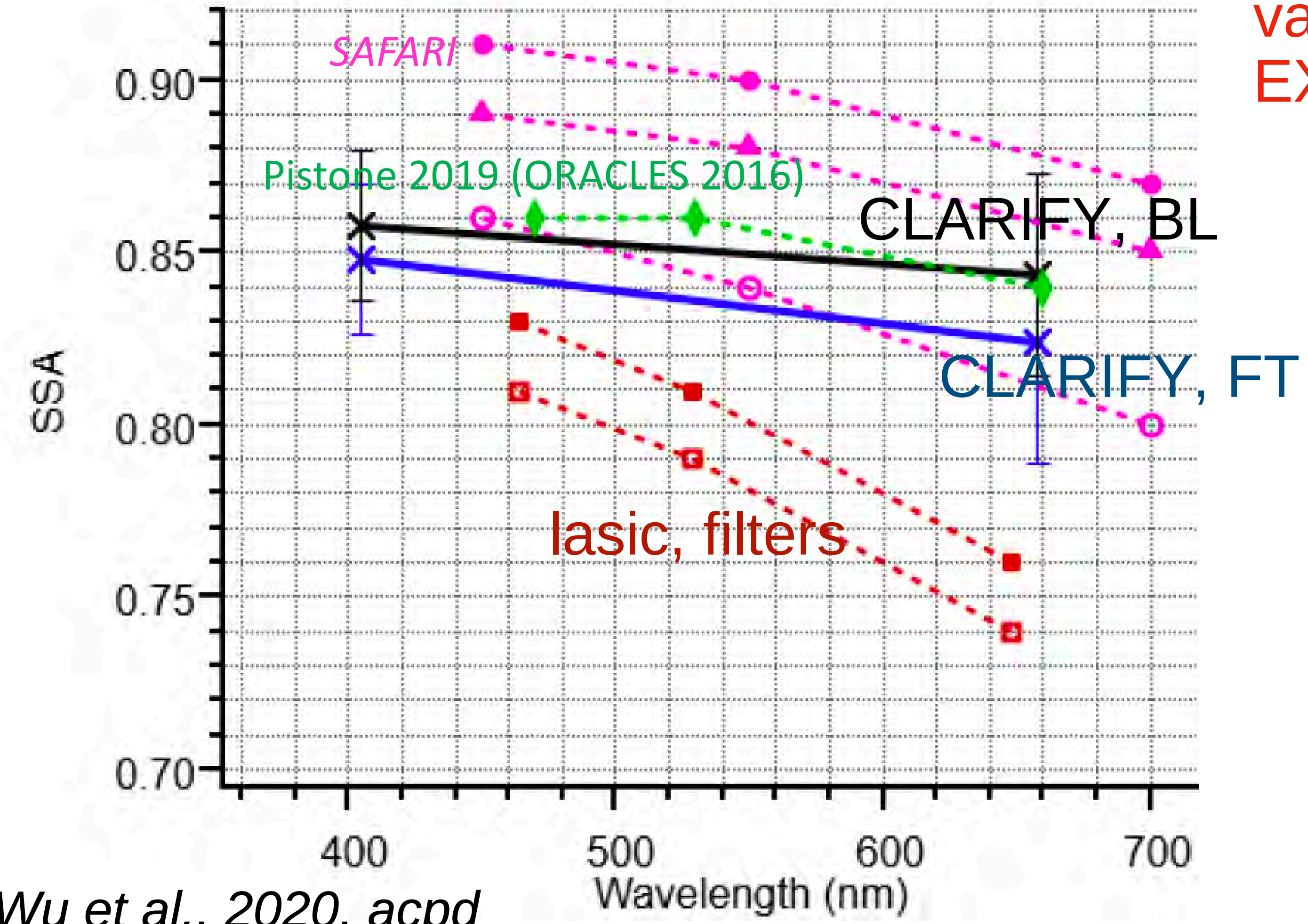


Reduction in cloud fraction in polluted skies

ΔCF= 0.5

Next: Will now be using LASIC pyranometer data to look for this impact in observations

Single Scattering Albedo comparisons



Wu et al., 2020, acpd

(note CLARIFY SSA in BL > SSA, FT)

Why are the LASIC filter-based SSA values so much lower than CLARIFY EXSCALABAR in the boundary layer?

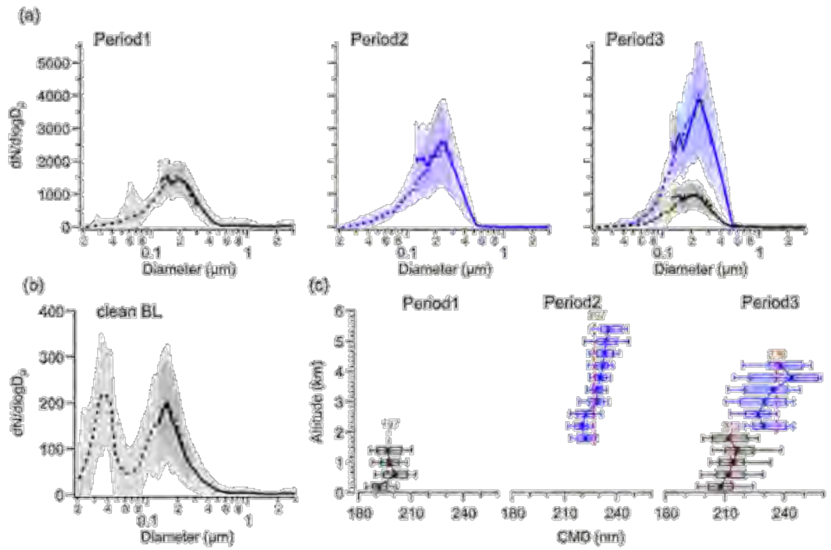
- Filter correction scheme? No – absorption looks ok – LASIC c.f. BAe146, and LASIC internal comparison - CAPS
- Relative humidity differences? No
  - RH LASIC ~25%
  - EXSCALABAR ~10%
- Genuine differences in sampling?
- Differences in inlet size cutoff!?

Onasch,Flynn,Taylor,Zuidema

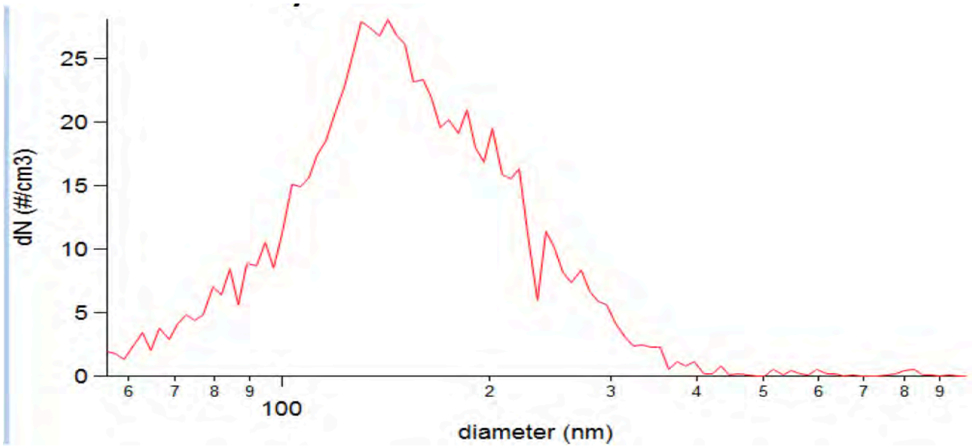
Aerosol Observations and Extinction / Scattering

Wu et al. ACPD2020

Vertical variability of the properties of highly aged biomass burning aerosol transported over the southeast Atlantic during CLARIFY-2017



LASIC UHSAS size distribution behind the PM1 cutoff to establish a size truncation correction - found that was barely needed (2% correction) (Onasch)

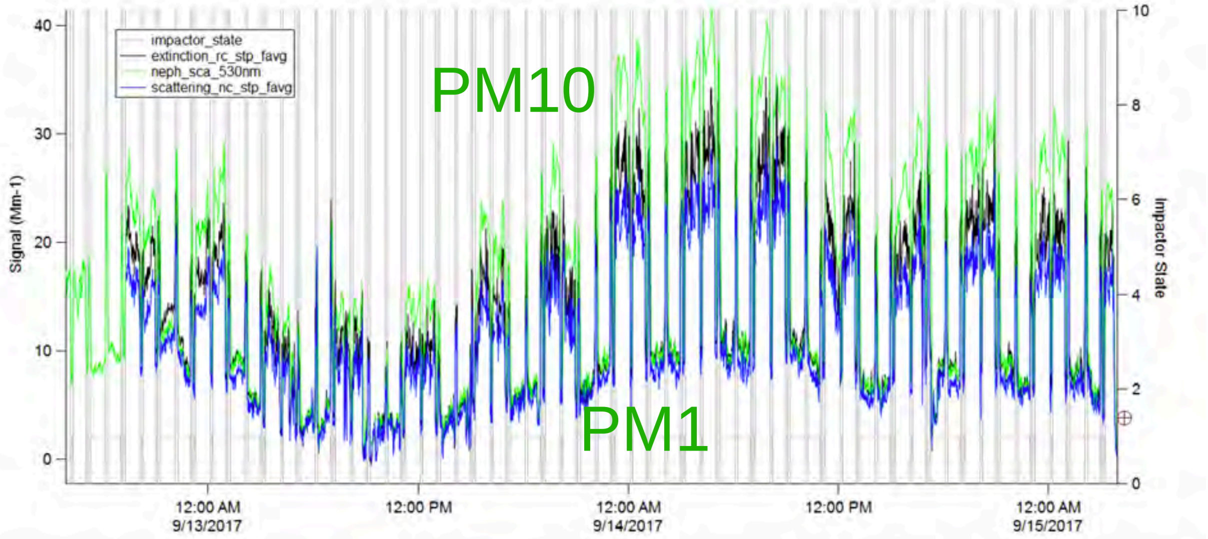


- Biomass aerosol particles tend to be smaller than 600 nm in all periods
- Taylor 2020 (ACP) – EXSCALABAR impactor 1.3 micron aerodynamic – density and pressure scaling (1000 to 600 hPa)
- LASIC cut at 1.0 micron aerodynamic
- Is this size difference allowing optically active particles in to EXSCALABAR?

Aerosol Observations and Extinction / Scattering

Large particles ARE present though - LASIC nephelometer scattering depends strongly on impactor state (a 1 versus 10 micron cut)

Is there additional Scattering from Sea spray particles >1 micron in EXSCALABAR BL observations that the ARM inlet is excluding? ***On my TO DO list!***

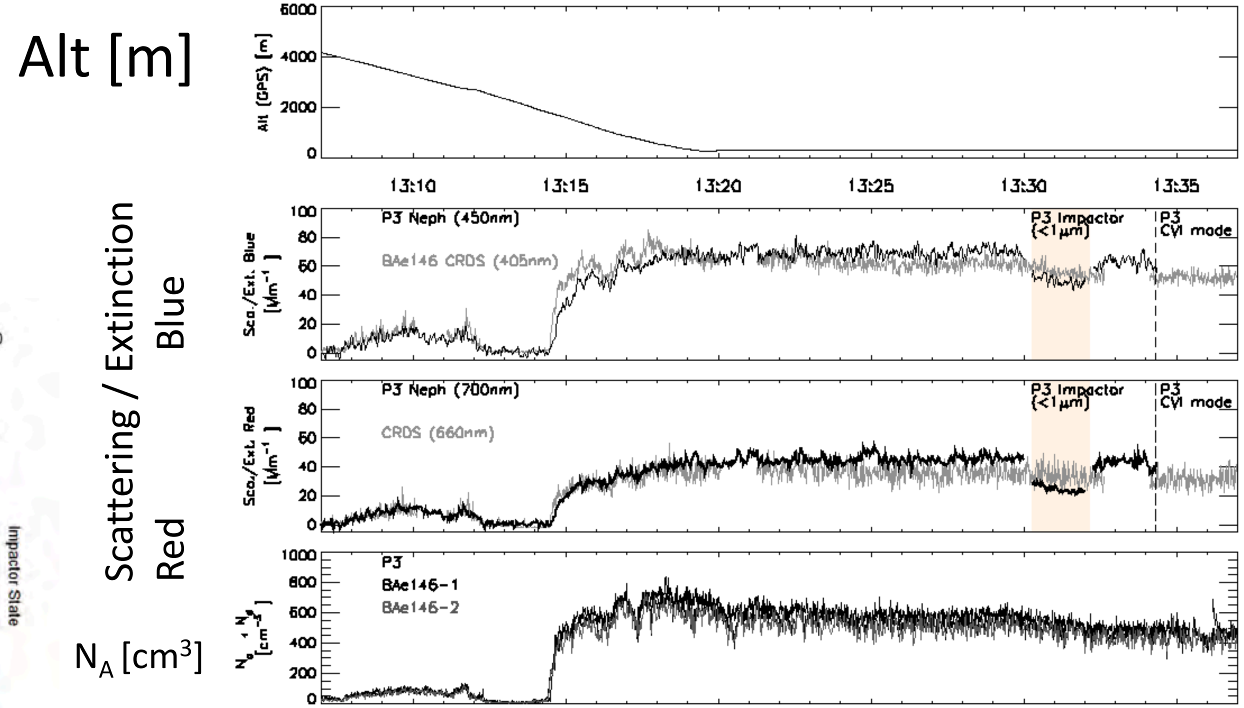


LASIC Time Series

FAAM BAe146 and NASA P3 Inter-comparison Flight

Profile descent and low level leg

Scattering (P3 Neph) and **Extinction (BA CRDS)** When P3 is behind 1 micron impactor – SCA P3 is ~10% below EXT BA, so this looks good.



BAe146 and NASA P3 Scattering / Extinction compare well

Small percentage difference, both red and blue

- No factor of 2 difference, so can trust BAe146 Extinction data?

Summary

- CLARIFY took place August / Sept 2017
- Regular coordination with LASIC ARM site at 1000ft for aerosol, thermodynamic and radiation properties.
- LASIC provides great context for CLARIFY both within the 2017 season and the longer term deployment
- Coordination between CLARIFY and ORACLES NASA P3 deployment (Sao Tome)
- Ongoing work with ACI and ARI including precipitation studies, cloud microphysical studies and absorbing aerosols

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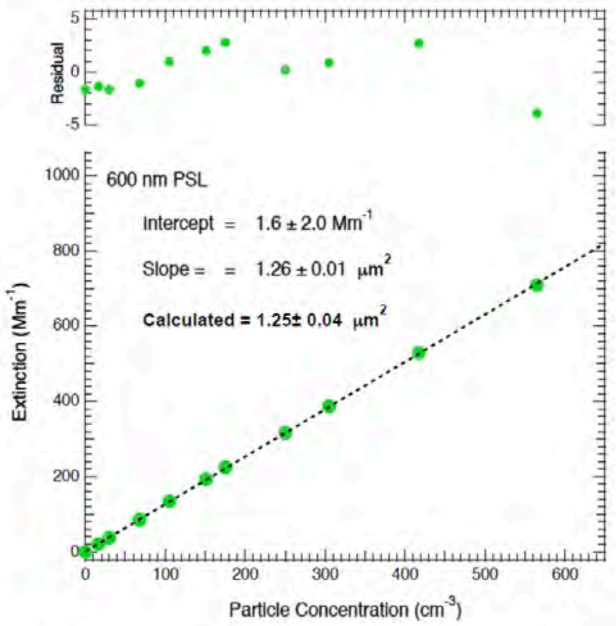
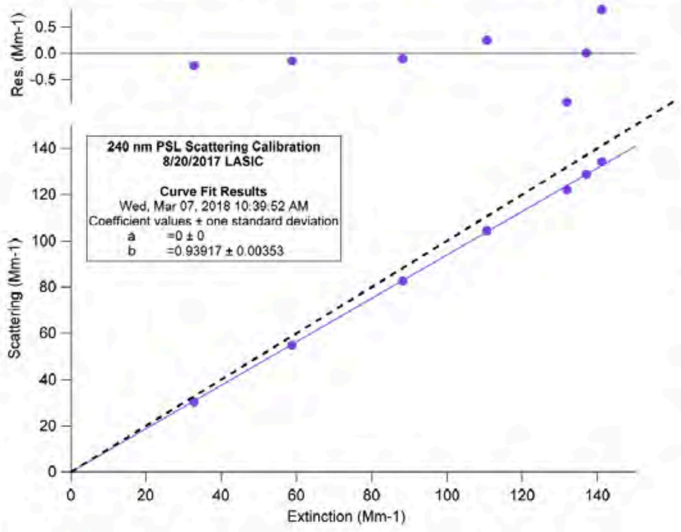
Absorption measurements agree between CLARIFY & LASIC (mass absorption cross sections of ~ 15/Mm @green)

our differences lie in the extinction comparison ([EXSCALABAR/LASIC filter] extinction of ~1.6-2.0)



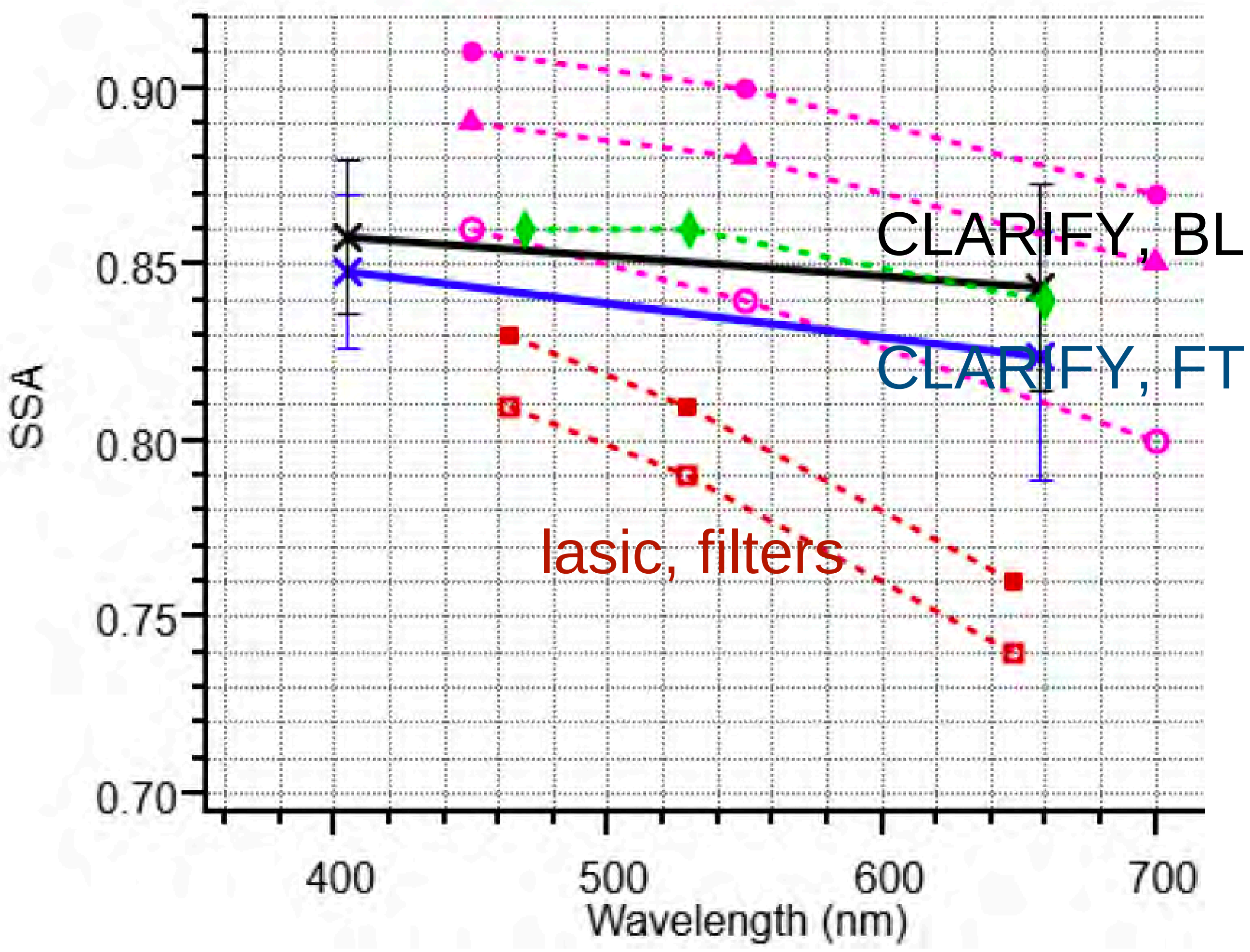
- PSL calibration done in at Aerodyne prior to LASIC
- Using 600 nm PSL
- Extinction measurements vs Mie theory for 600 nm PSL (slope matches calculated)
- Extinction measurements are good
- Scattering calibrated to extinction for white (non-absorbing) particles

Scattering calibration with 240 nm PSL



- PSL calibration done in field during LASIC by Art Sedlacek on 8/20/2017
- Using 240 nm PSL over relevant range to study
- Scattering slope requires a relatively minor 6% correction from when calibrated at Aerodyne prior to shipping
- This correction has been applied

From Onasch presentation, ASR annual meeting 2018



Wu et al., 2020, acpd

LASIC also had another independent measurement of SSA

Aerodyne provided and supported a Cavity-Attenuated Phase Shift (CAPS)-SSA instrument @ Ascension, 4 August -22 September, 2017

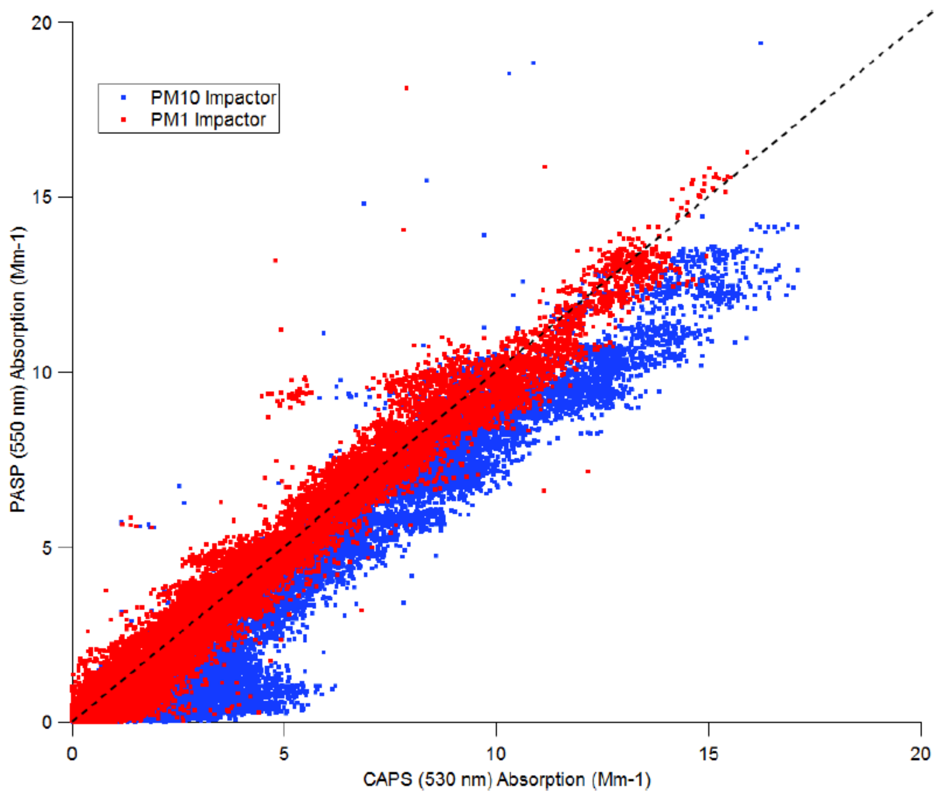
Tim Onasch, Andrew Freedman

Optically measures extinction, scattering in the same volume => SSA

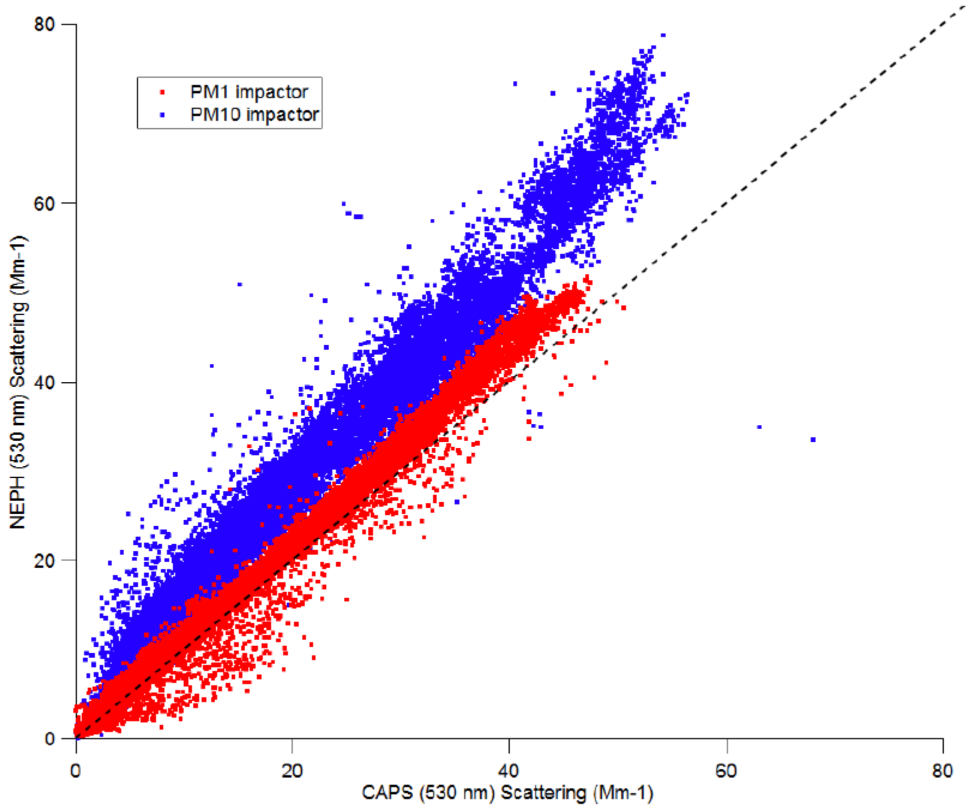
Green only (530 nm)

Onasch,Flynn,Taylor,Zuidema

PSAP absorption ~ CAPS absorption



Neph scattering > CAPS scattering, slightly



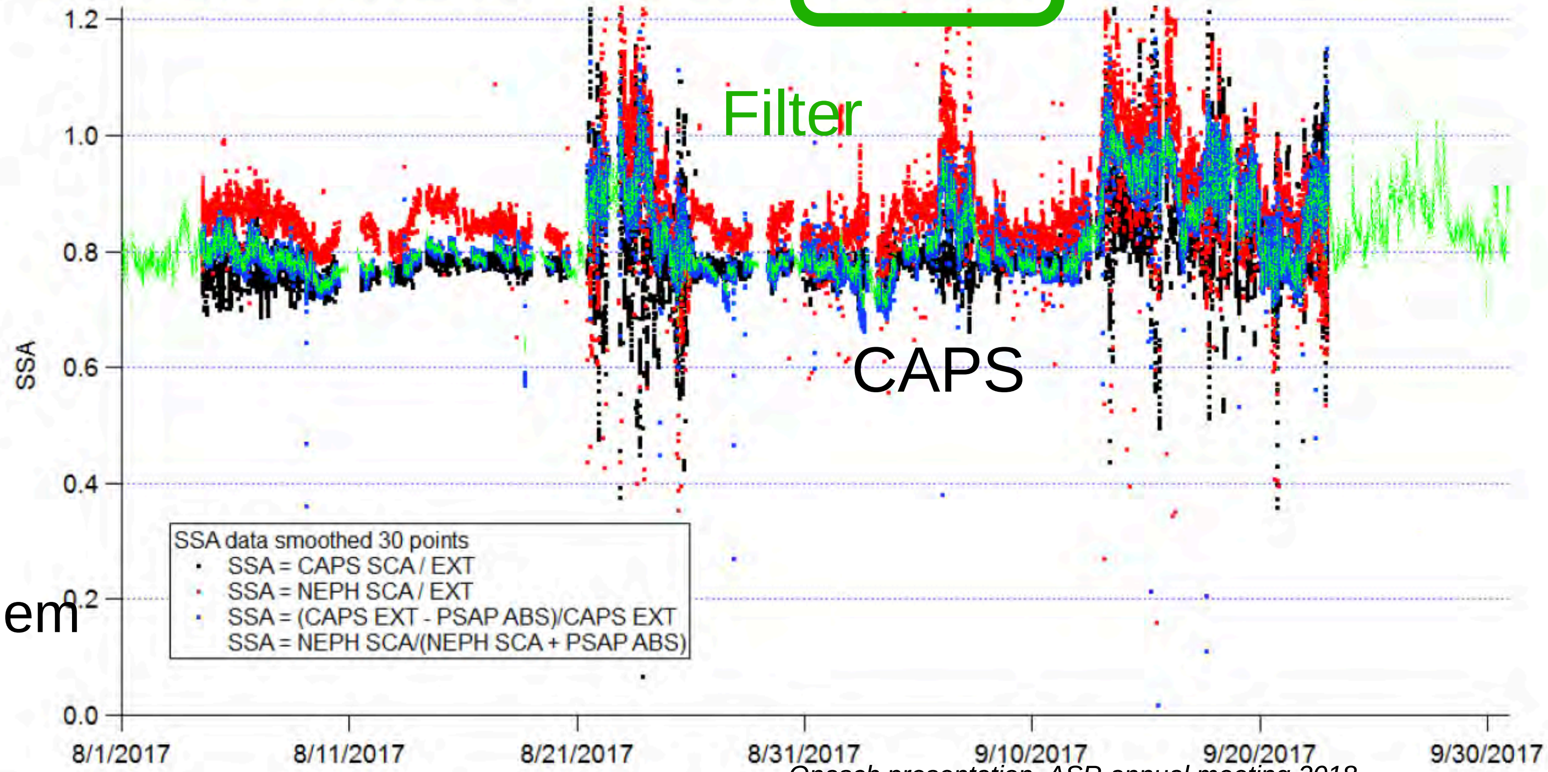
Onasch presentation, ASR annual meeting 2018

SSA measurements (PM1)

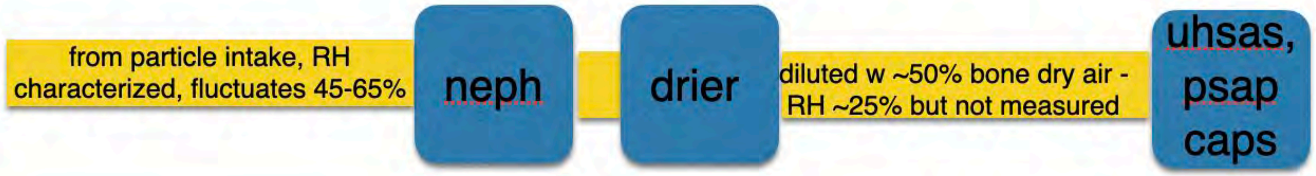
neph+psap SSA (green)

~ CAPS SSA (black)

This argues against the filter correction scheme being the problem



Onasch presentation, ASR annual meeting 2018



EXSCALABAR air ~10% RH, LASIC nephelometer air more humid, also can't explain SSA differences between the 2 campaigns