Observational constraints on aerosol forcing over the Southeast Atlantic

SARAH DOHERTY

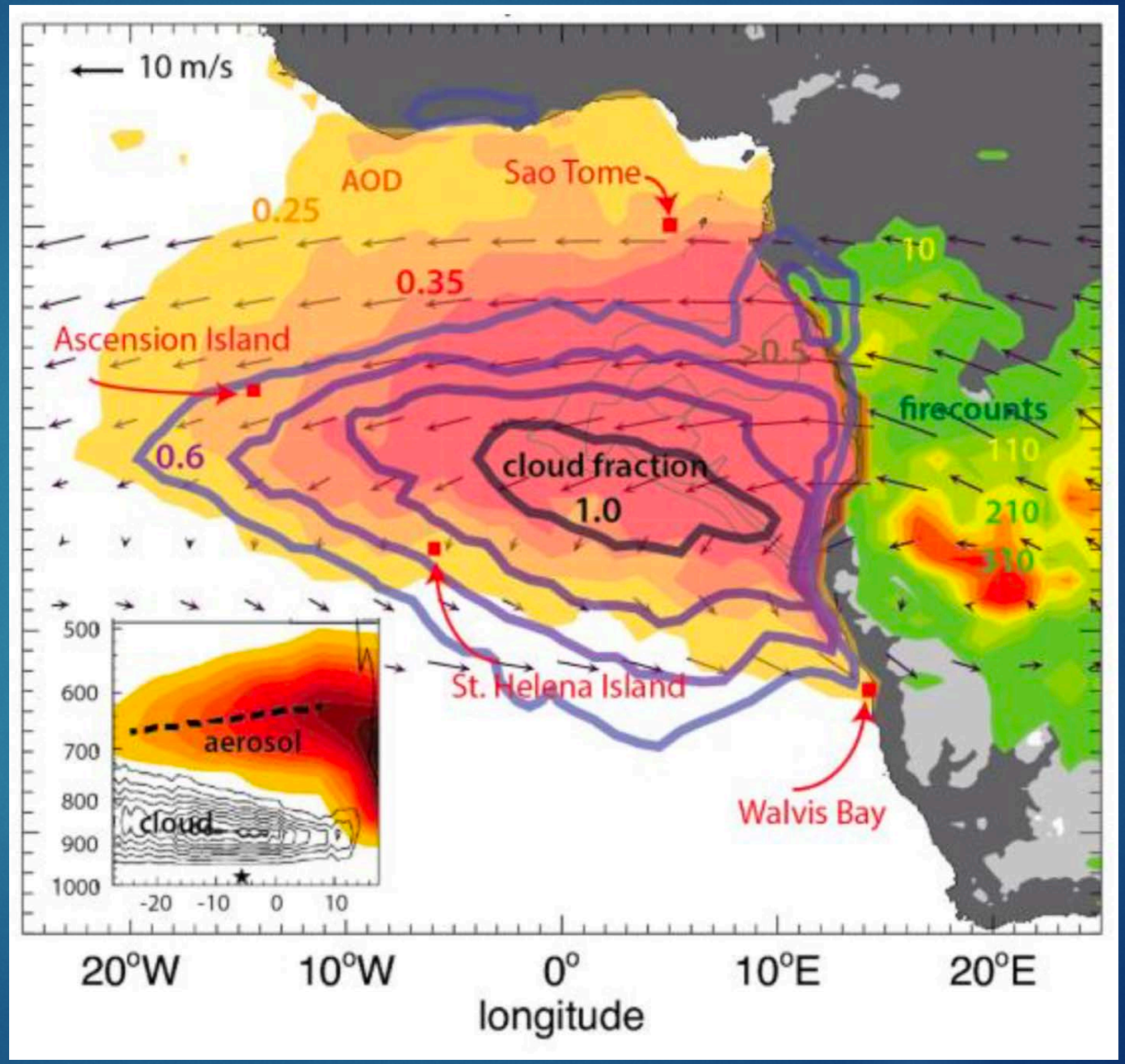
WITH INPUT FROM THE NASA-ORACLES TEAM, INCLUDING:

JENS REDEMANN, ROB WOOD, PAQUITA ZUIDEMA, PABLO SAIDE, YOHEI SHINOZUKA, STEVEN HOWELL, STEFFEN FREITAG, AMIE DOBRACKI, JIM PODOLSKE, MICHAEL DIAMOND, JIANHAO ZHANG, MARY KACARAB, KERRY MEYER, DAVID PAINEMAL, …

SE Atlantic aerosol forcing

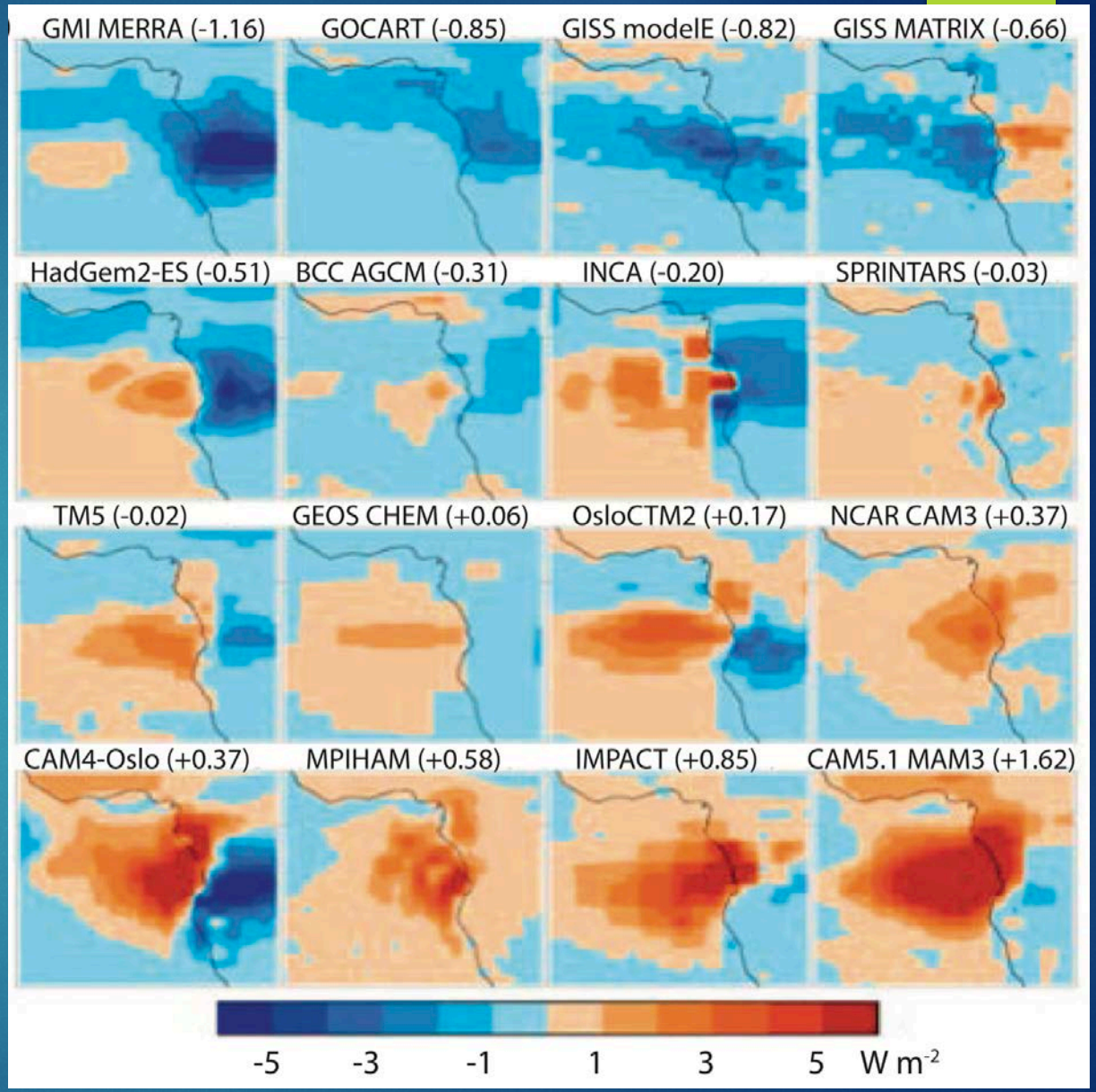
September-mean (2002-2012)
MODIS
- *low-level cloud fraction*
- *fine-mode AOD*
- *fire pixel counts*

ERA-Interim
- *600-hPa winds*



Modeled RF_{ari} forcing uncertain in both sign & magnitude!

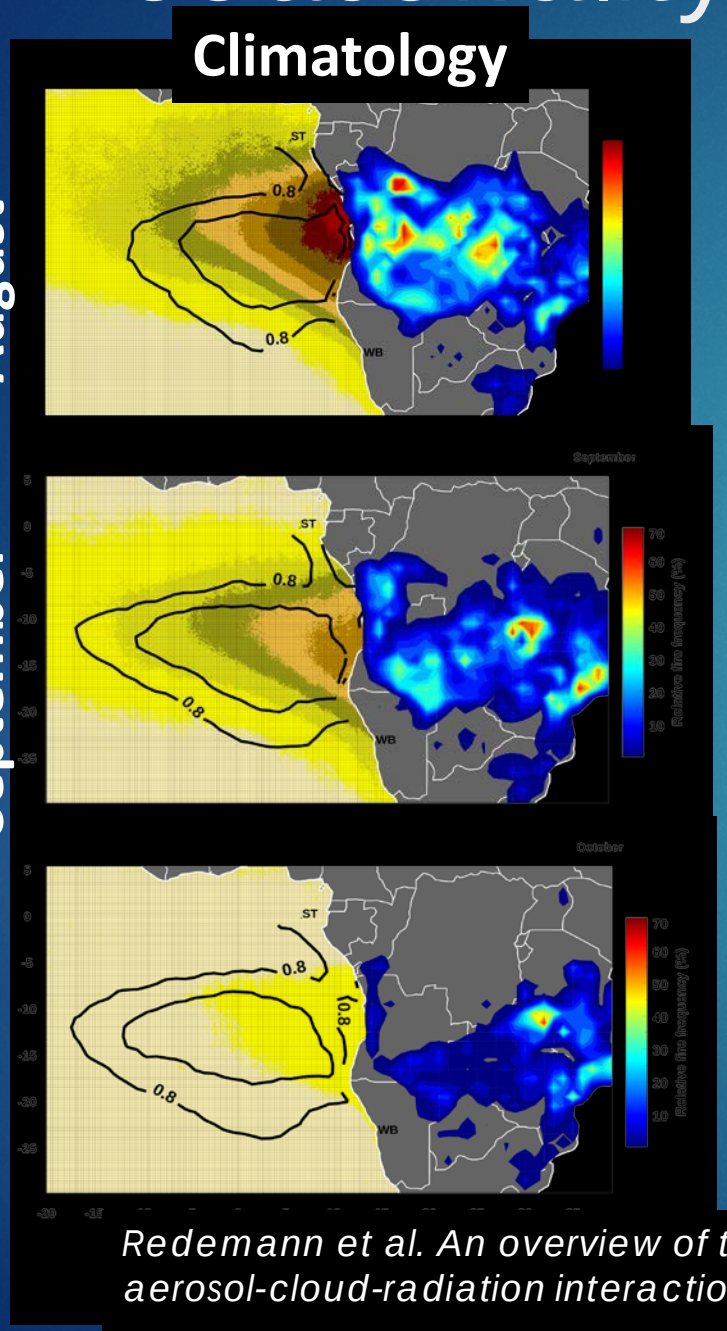
Aug-Sept avg Rf_{ari} spread across 16 AeroCom models (Steir et al., 2013)



Activities that might benefit AeroCom aerosol forcing estimates for the SE Atlantic

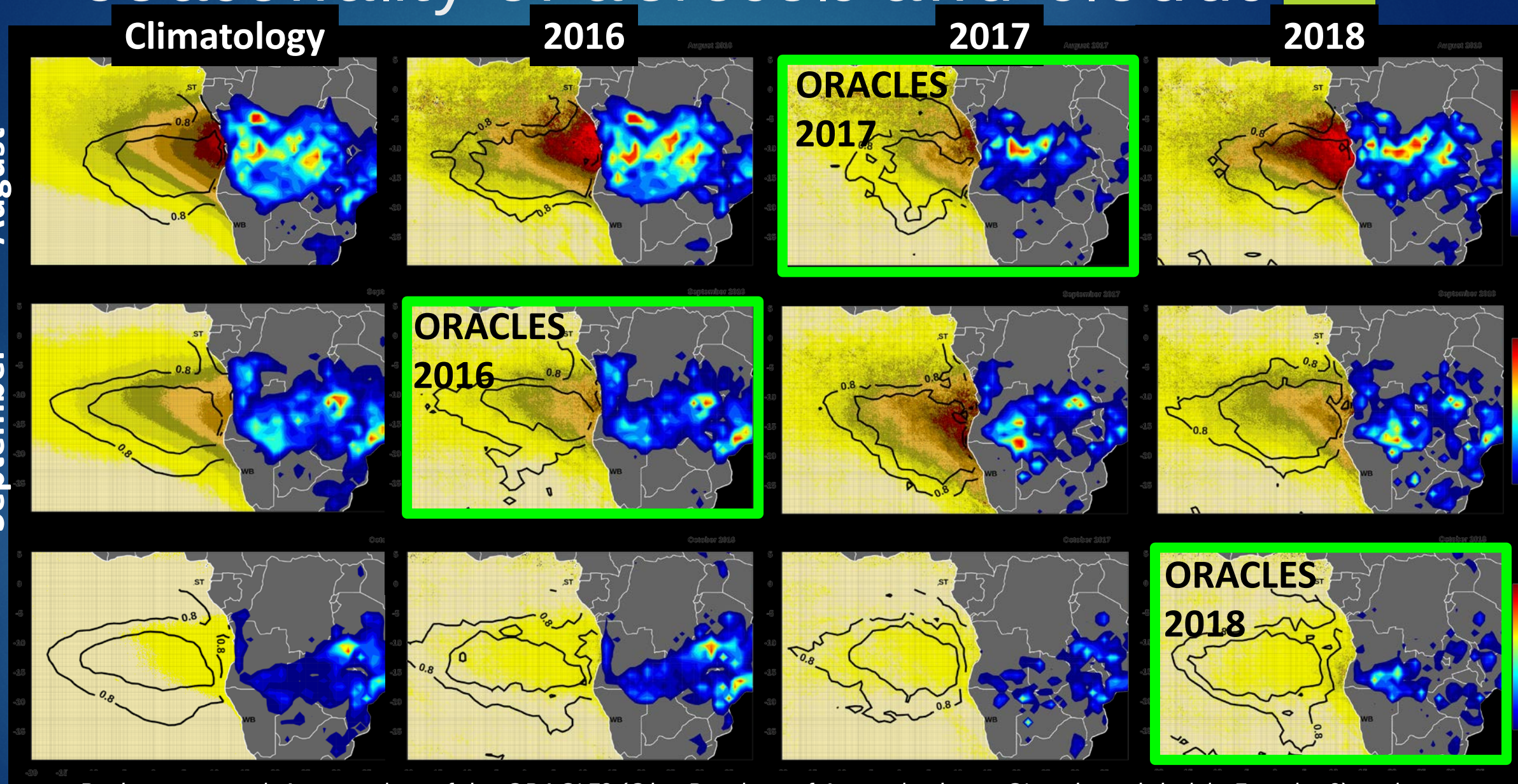
- Dataset contribution to the AeroCom “Aircraft” experiment
- Measure of seasonal differences (Aug, Sept, Oct)
- Model-obs comparisons of aerosols properties across transects
  → *primarily focused on DARE*
  - Column values & vertical variations
  - Aerosol properties (*extinction, SSA, SAE, AAE, size*), component masses (*CO, BC, OA*)
  - RH profiles
  - Warm cloud fraction & optical depth
- Assessment of DARE across different methods
- Assessment of SDE/IDE using LES studies + observations
- Process-level studies

Seasonality of aerosols and clouds



Redemann et al. An overview of the ORACLESx (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol-cloud-radiation interactions in the Southeast Atlantic basin, submitted soon!

Seasonality of aerosols and clouds



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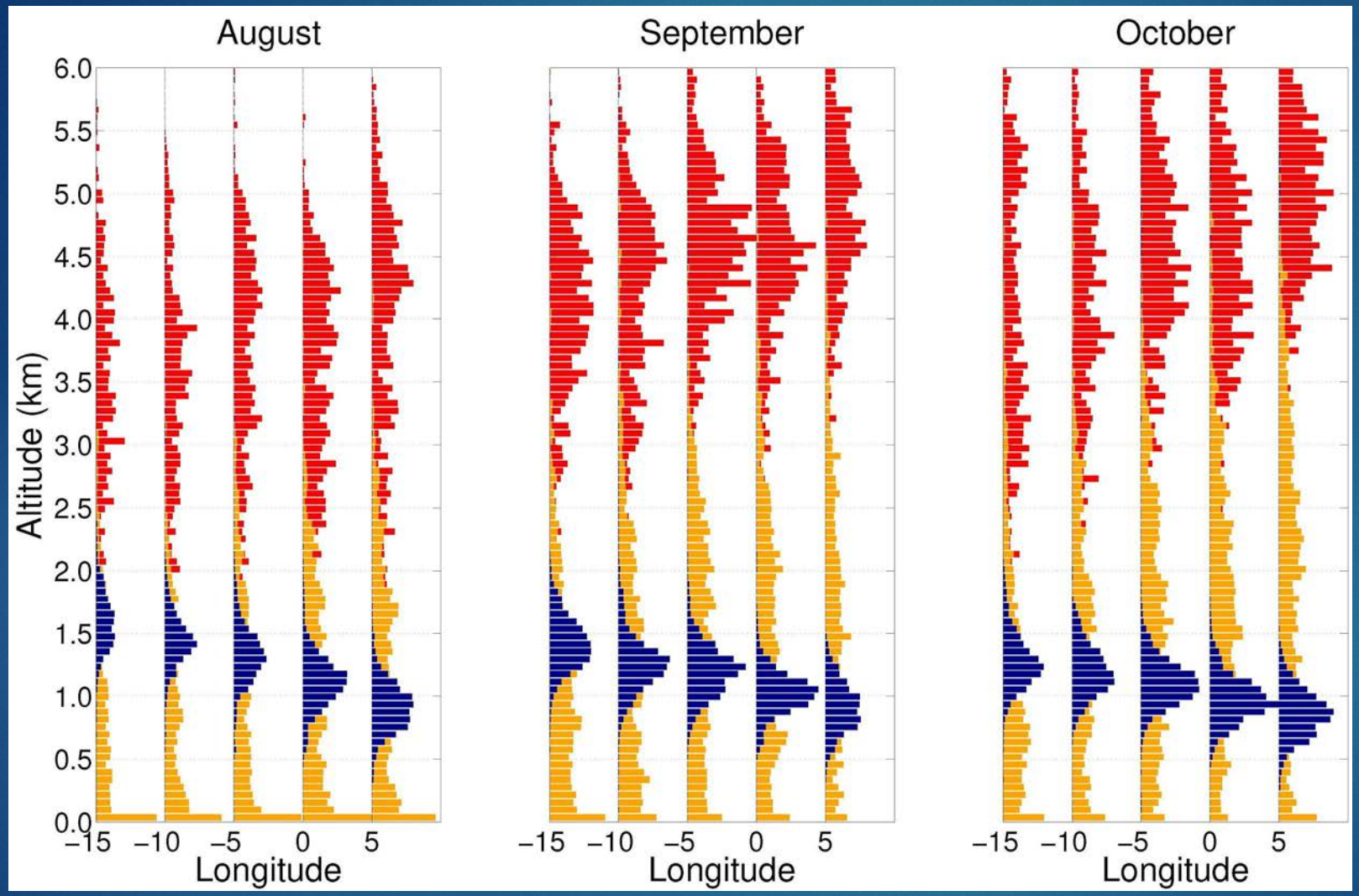
Seasonality of aerosols and clouds



aerosol top height
cloud top height
separation between clouds & aerosols

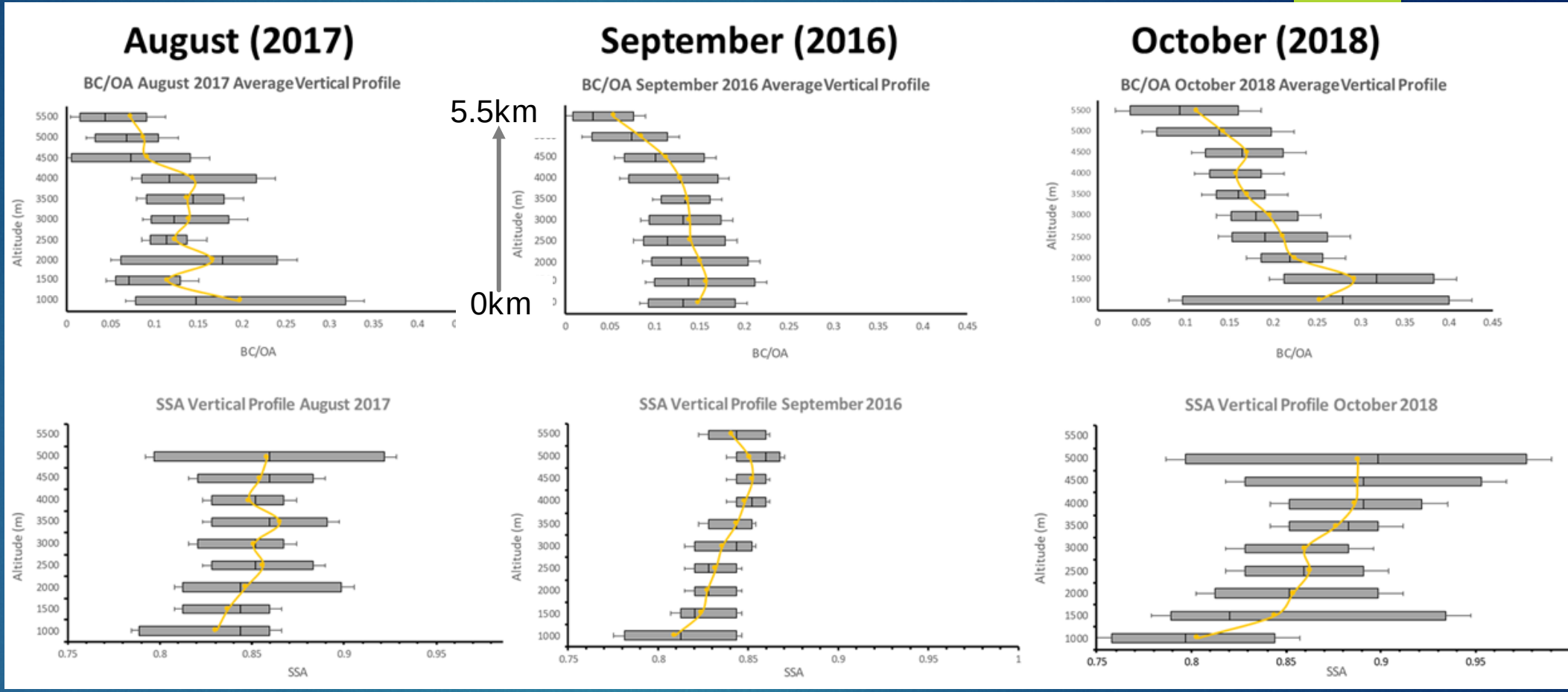
CALIOP v.3 aerosol profile product 2006-2012

Redemann et al. An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol-cloud-radiation interactions in the Southeast Atlantic basin, submitted soon!

Seasonality of aerosols and clouds

BC/OA

SSA



Redemann et al. An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol-cloud-radiation interactions in the Southeast Atlantic basin, submitted soon!

NASA ORACLES

Aircraft flight tracks:

ER-2 (*remote sensing*)

2016

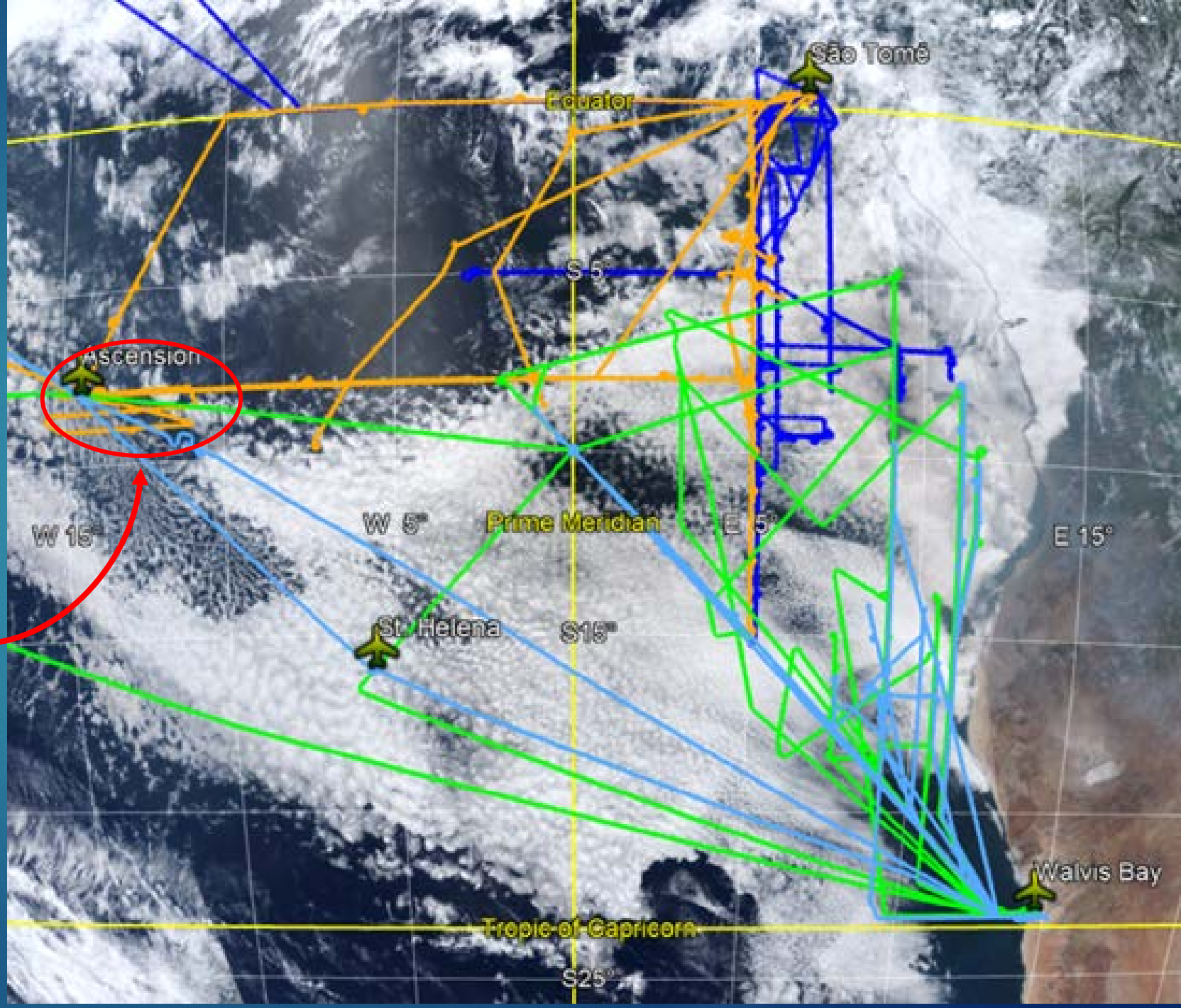
P-3 (*in-situ & r.s.*)

2016

2017

2018

LASIC (surface)
UK-CLARIFY (2017)



NASA ORACLES

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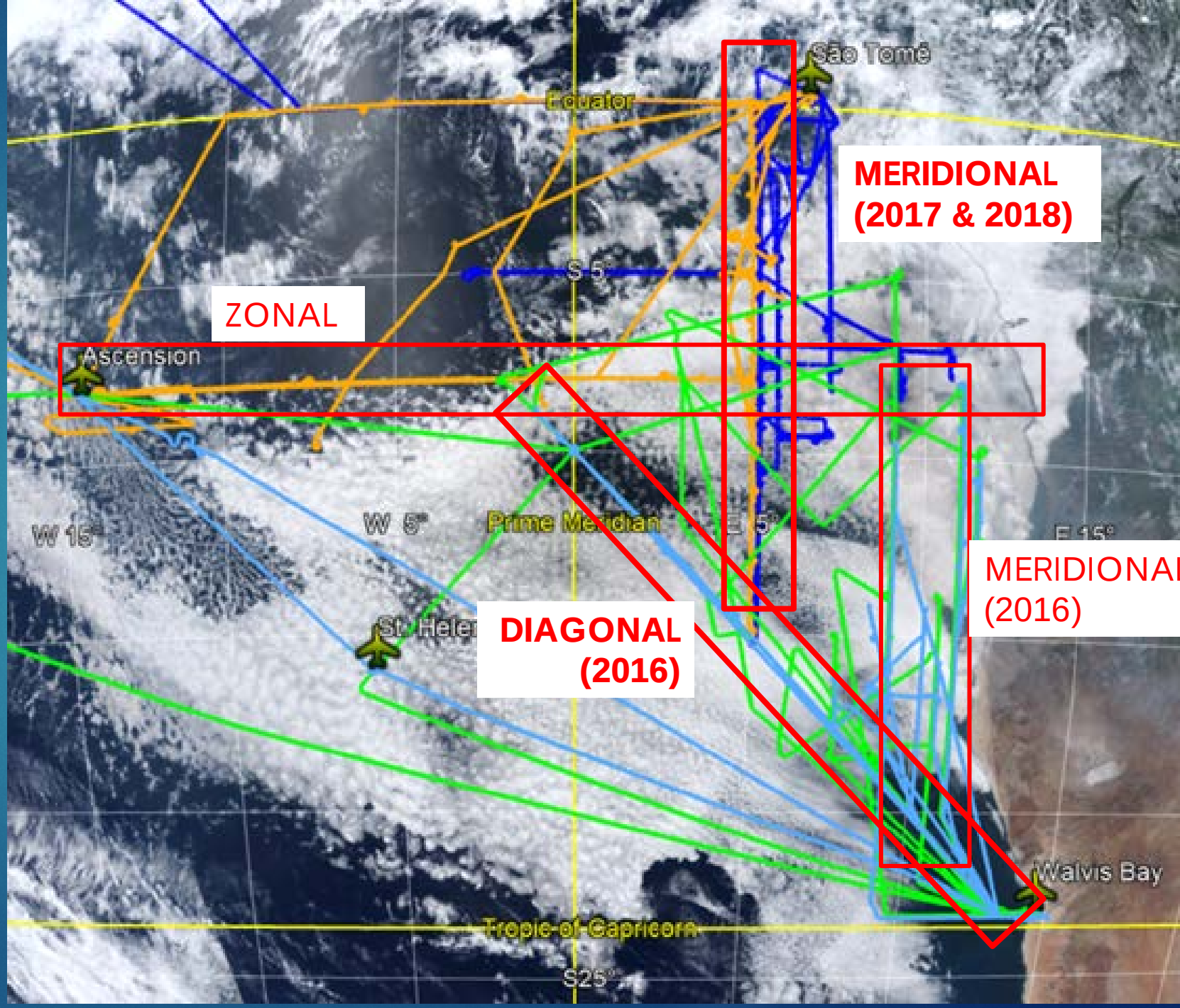
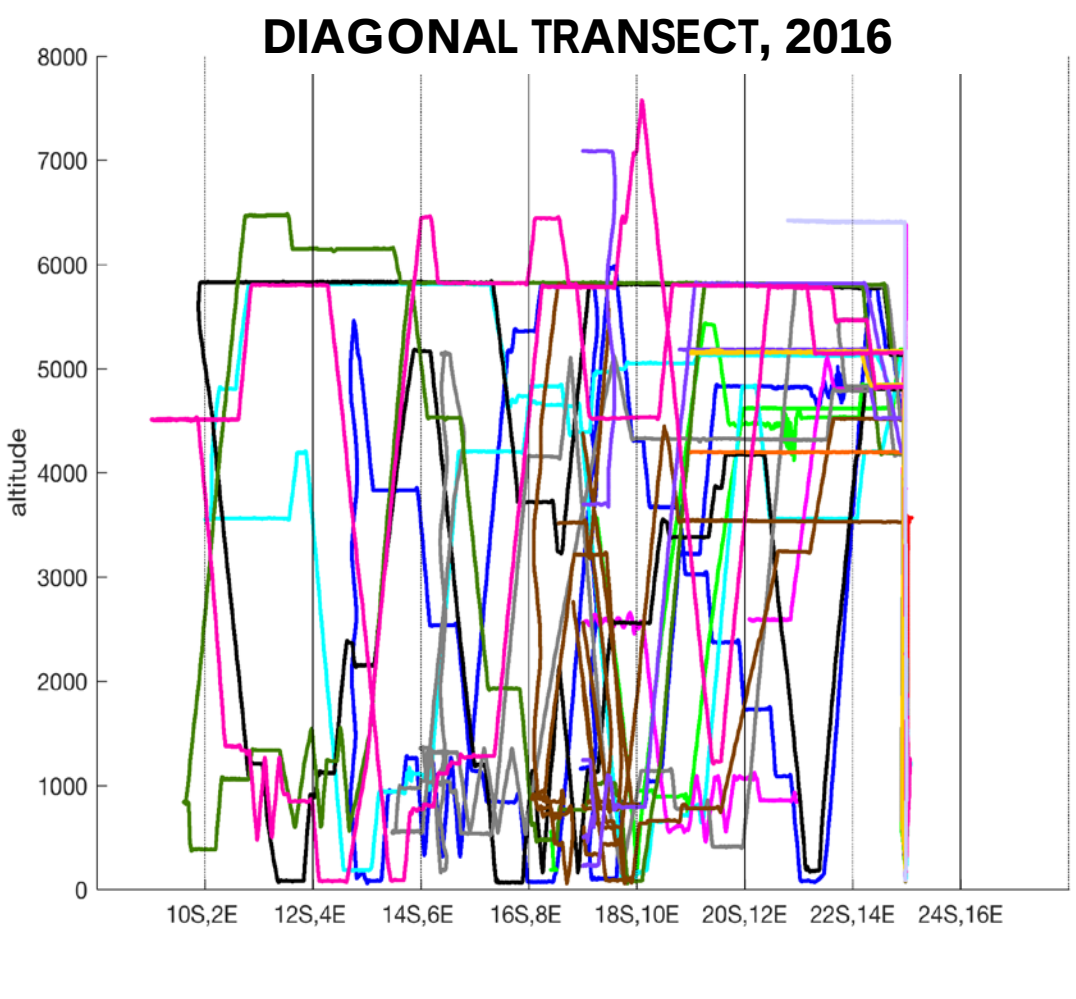
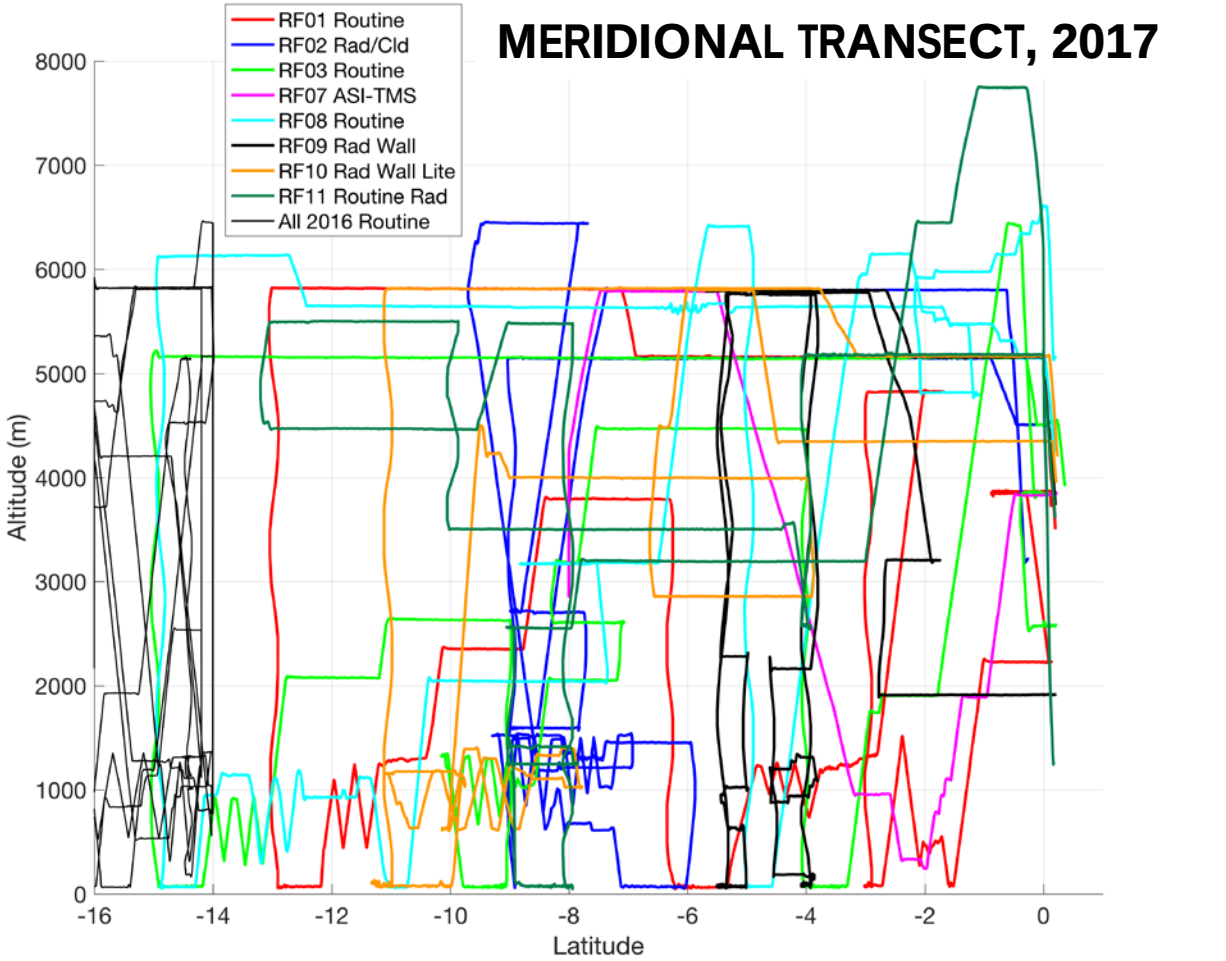


Representativeness of ORACLES sampling

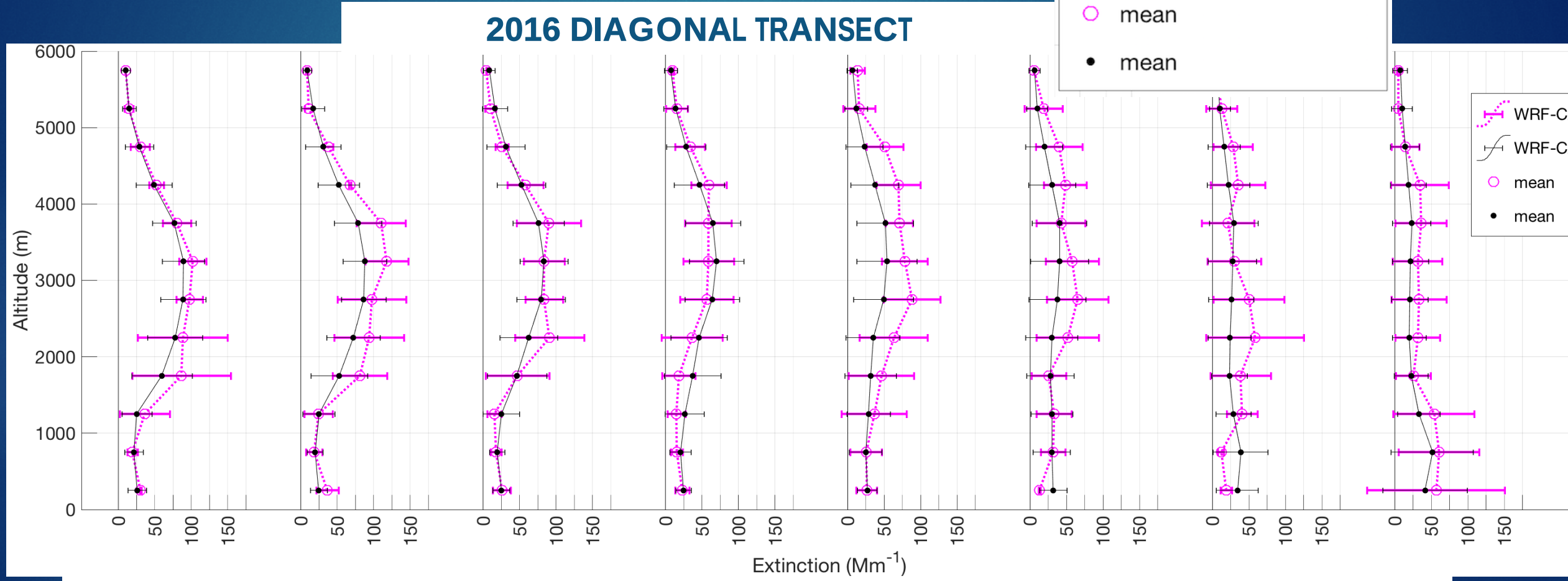
P-3 in-situ sampling along “Routine” tracks





Representativeness of ORACLES sampling

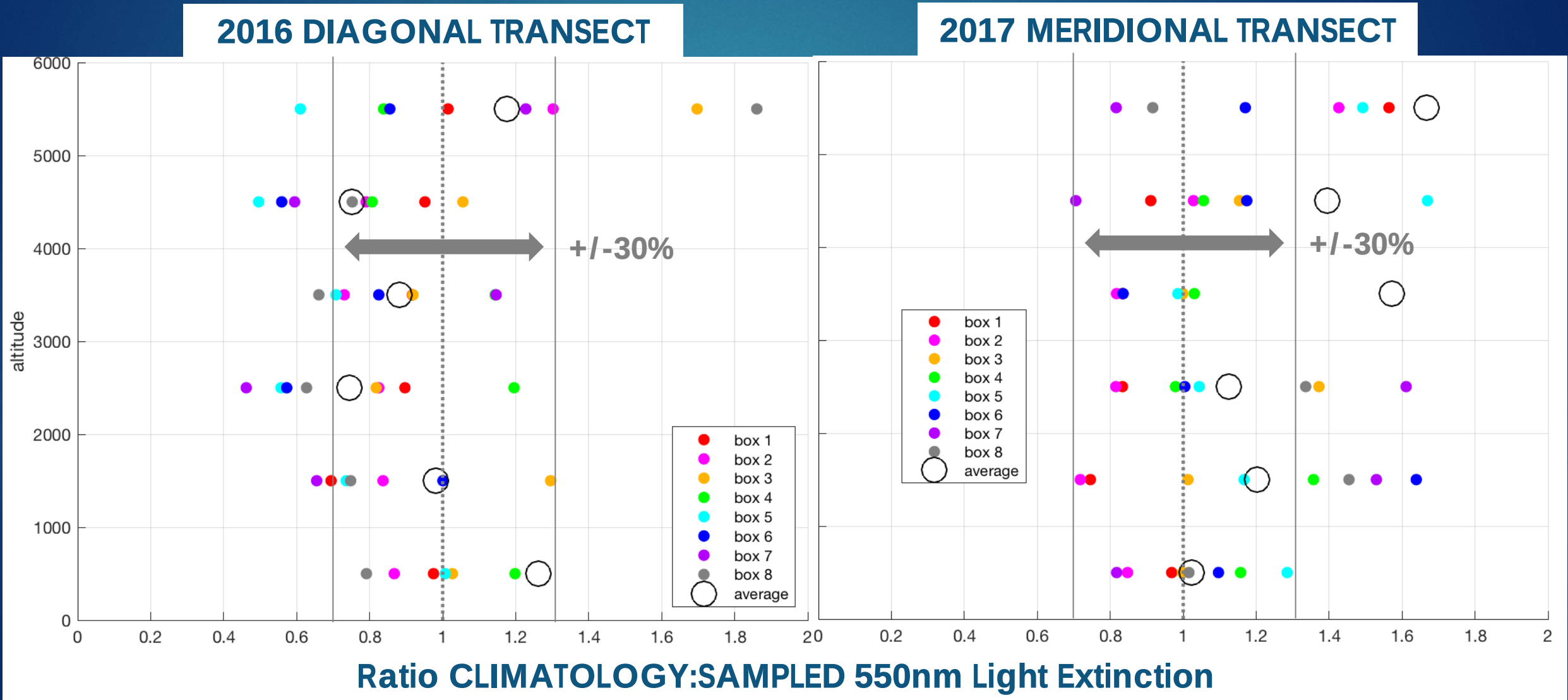
WRF-CAM5 model extractions
EXTINCTION



NW (box 1) ----------→ SE (box 8)

Representativeness of ORACLES sampling

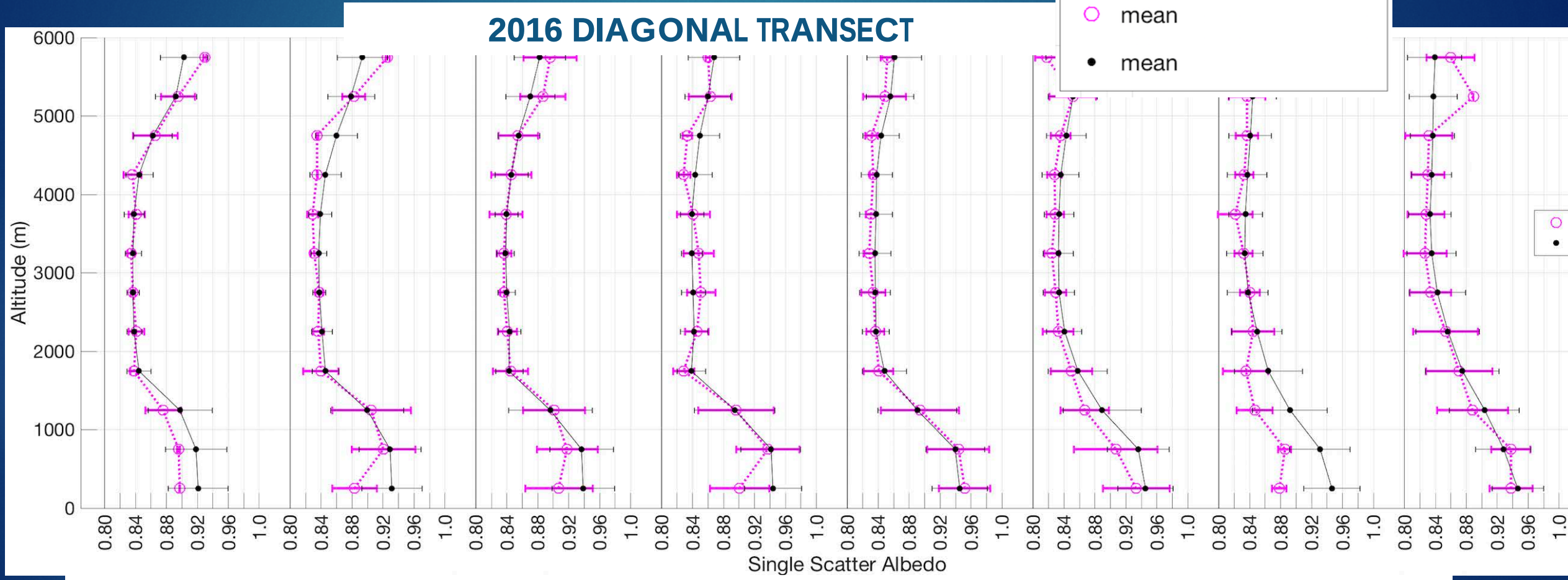
WRF-CAM5 model extractions



Representativeness of ORACLES sampling

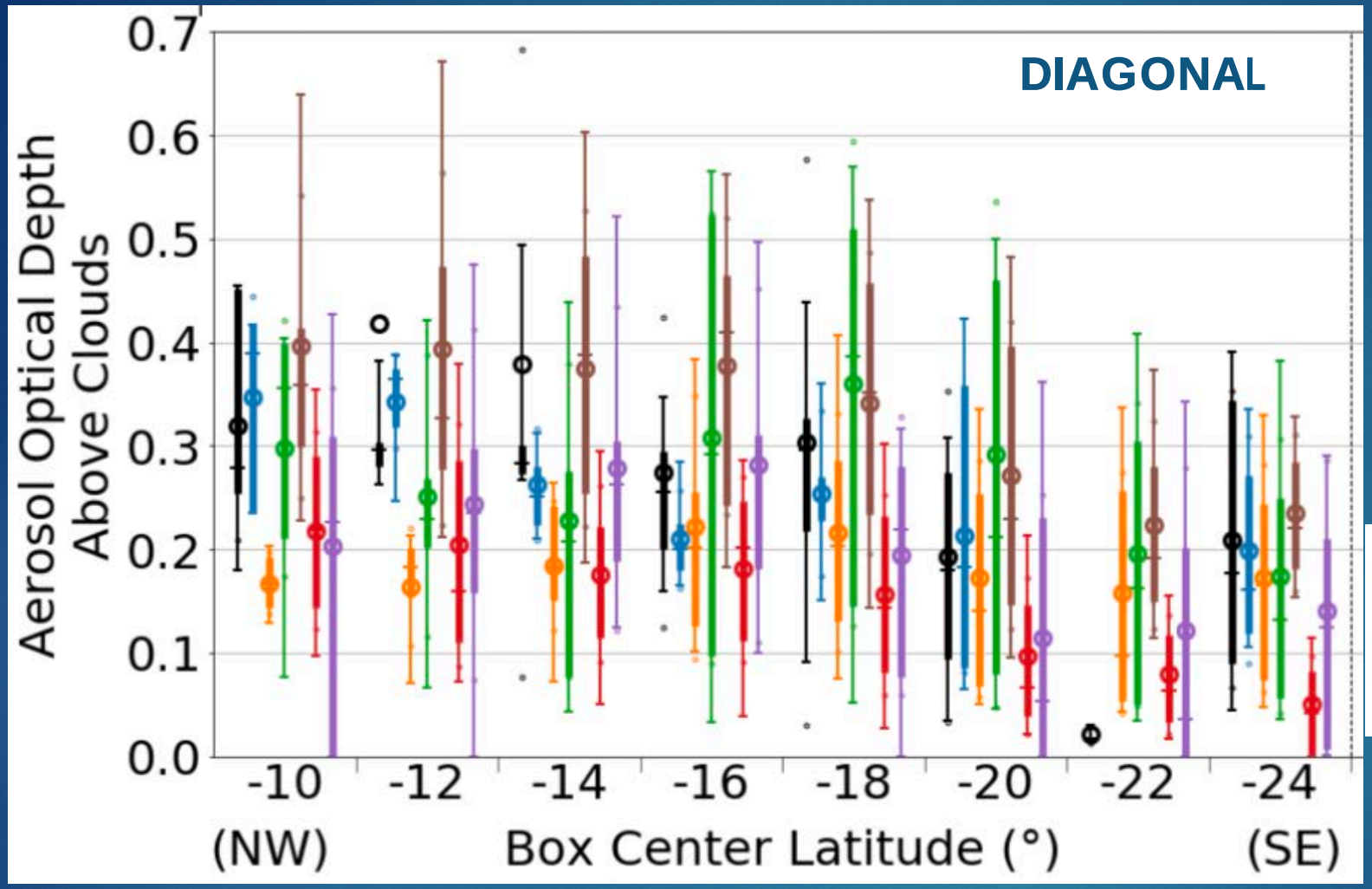
WRF-CAM5 model extractions

SSA



NW (box 1) ----------→ SE (box 8)

Above-cloud AOD: 2016

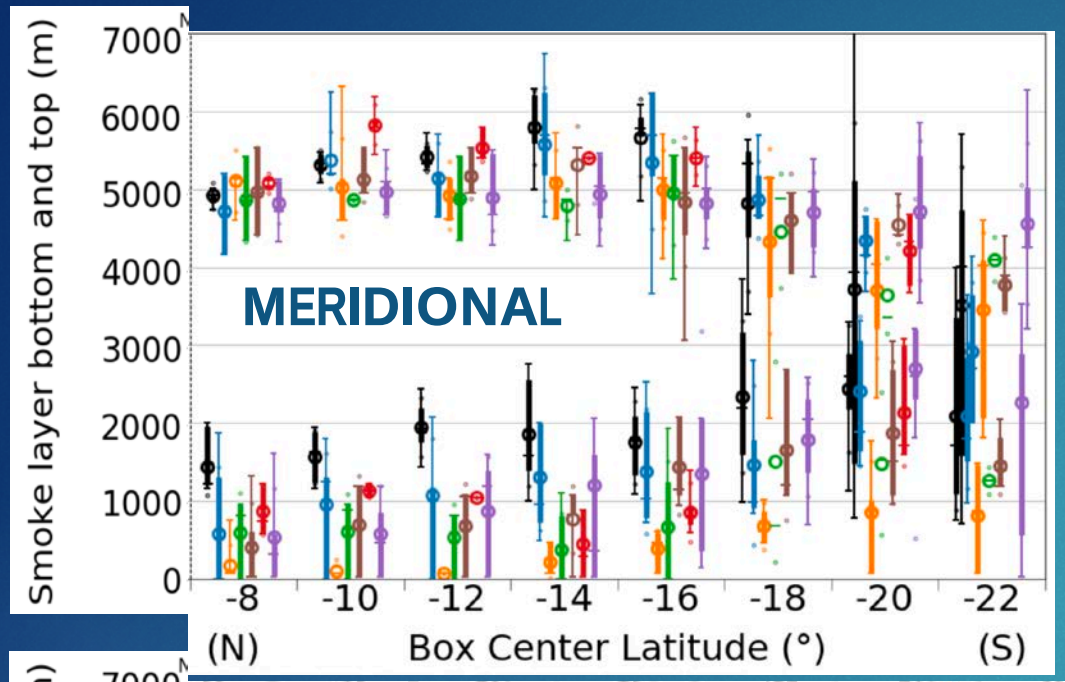


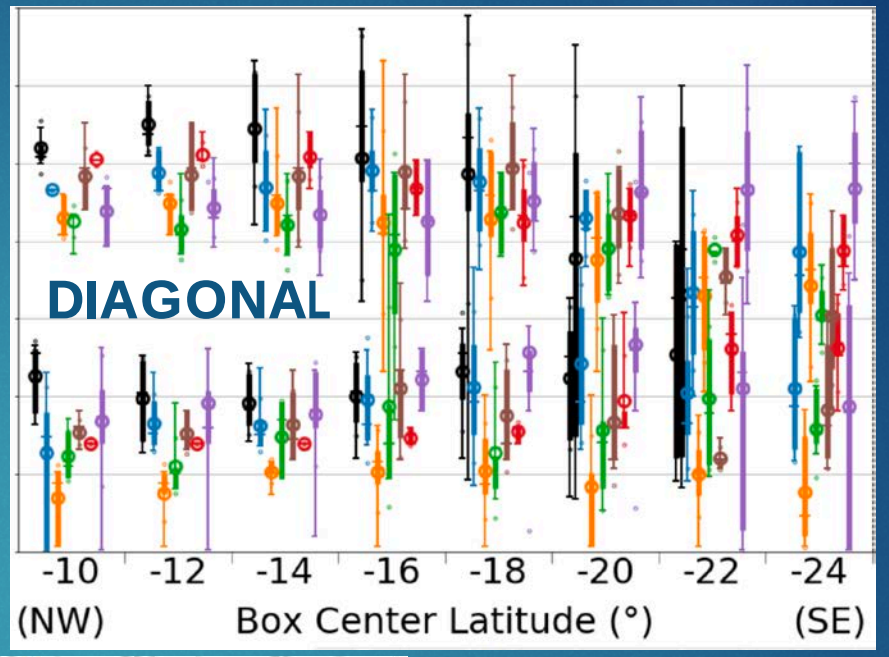
AC-AOD biases vary across models

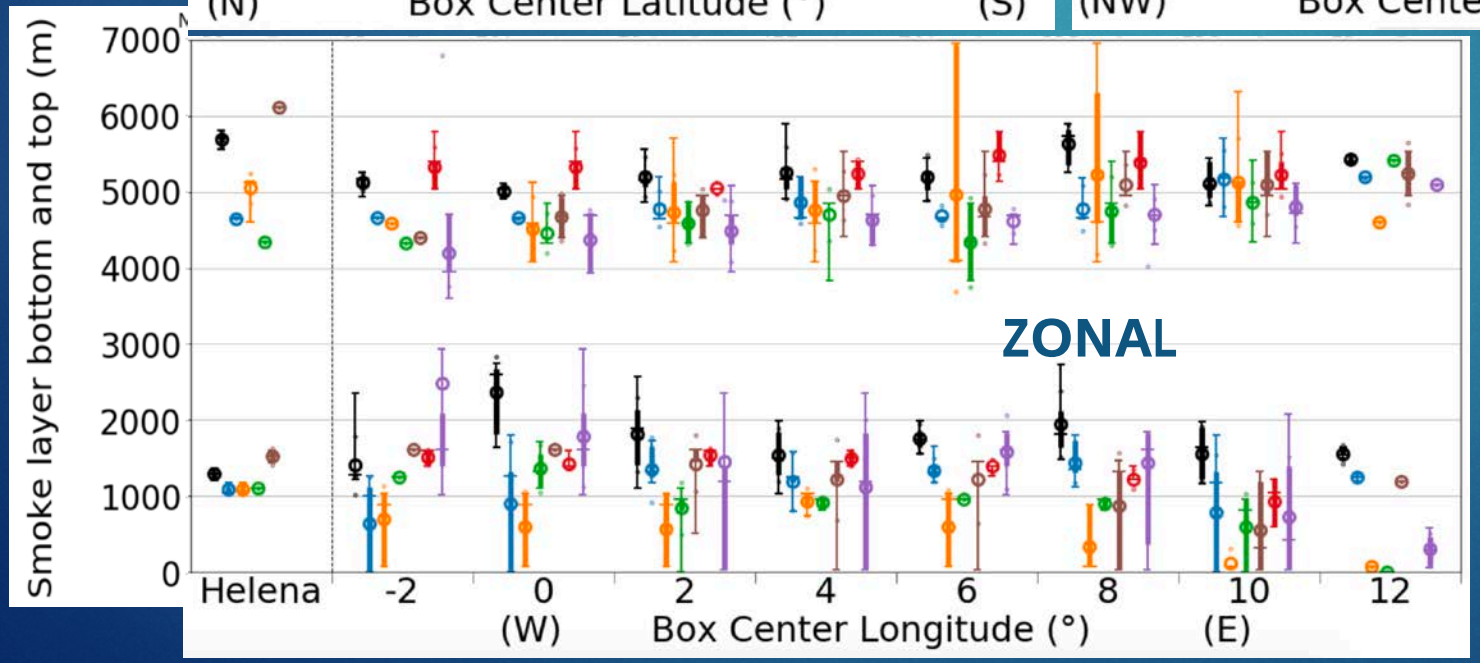
4STAR
GEOS-5
WRF-CAM5
GEOS-Chem
EAM-E3SM
UM
ALADIN

Shinozuka et al., Modeling the smoky troposphere of the southeast Atlantic: a comparison to ORACLES airborne observations from September of 2016, submitted, ACP.

Plume height: 2016







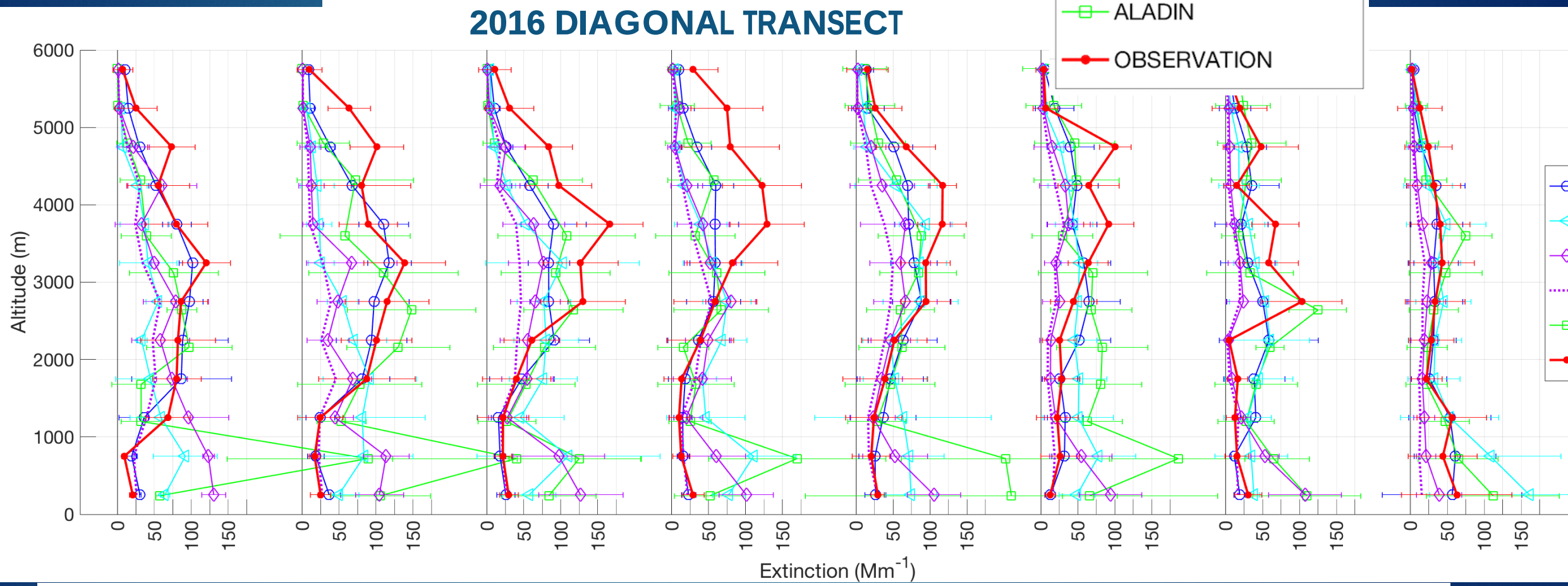
Modeled plume too low in altitude in all models

HSRL-2
GEOS-5
WRF-CAM5
GEOS-Chem
EAM-E3SM
UM
ALADIN

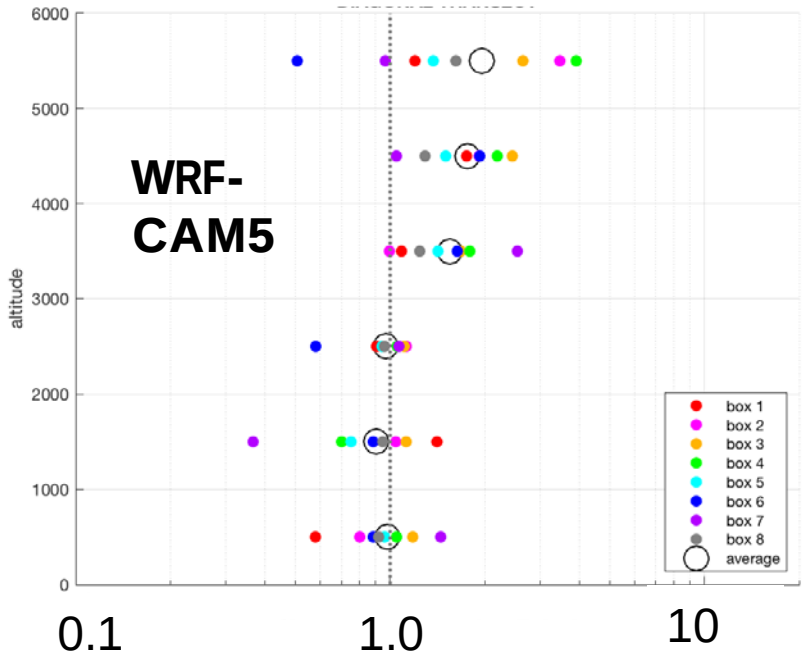
Shinozuka et al., Modeling the smoky troposphere of the southeast Atlantic: a comparison to ORACLES airborne observations from September of 2016, submitted, ACP.

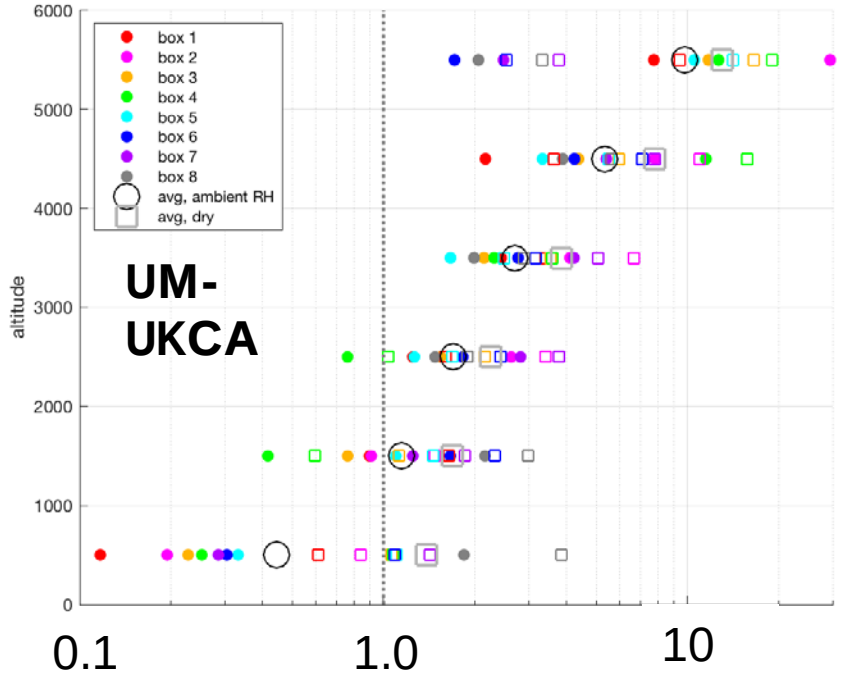
Doherty et al., A summary and model-observation comparison of vertically-resolved aerosol and cloud properties over the Southeast Atlantic, in prep, ACP.

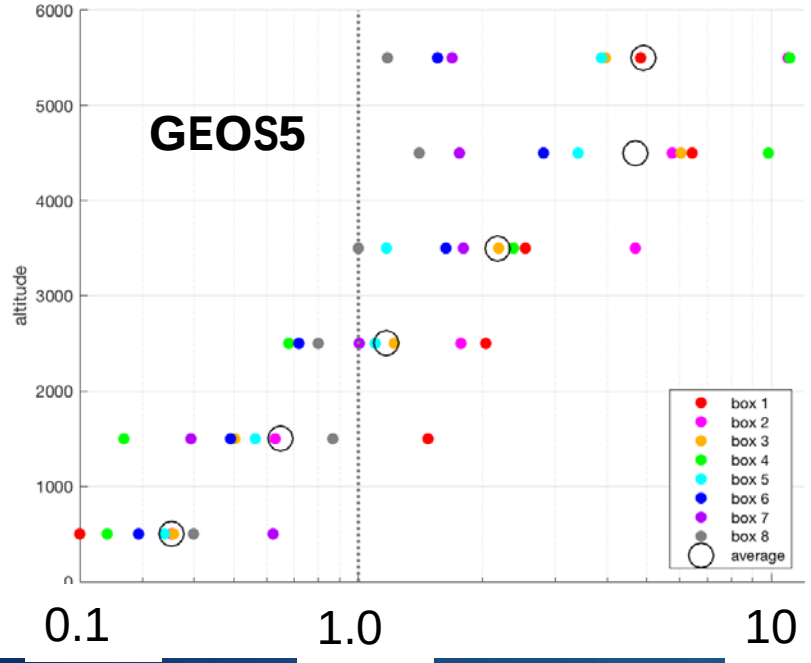
Light extinction: 2016

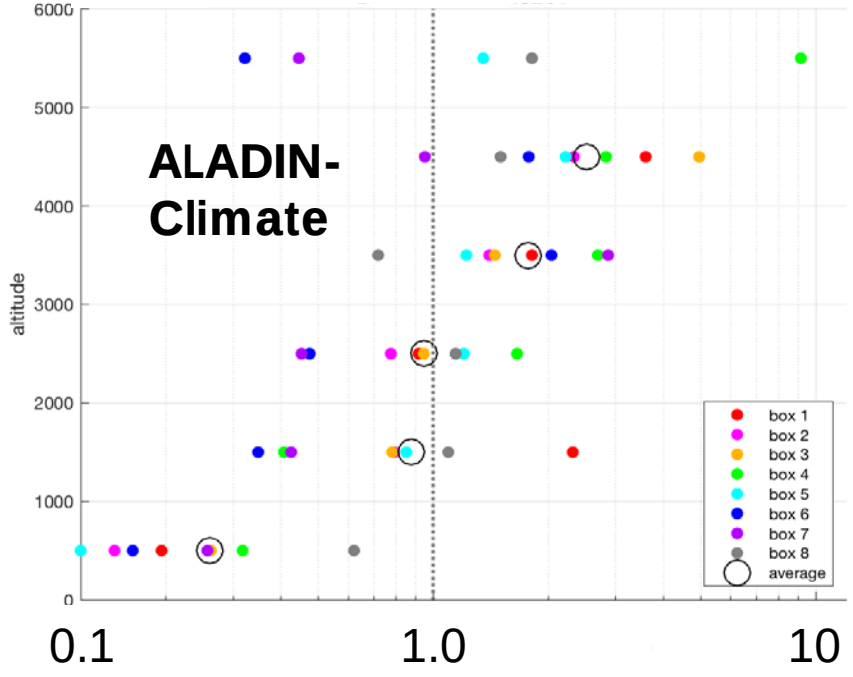


NW (box 1) ----------→ SE (box 8)







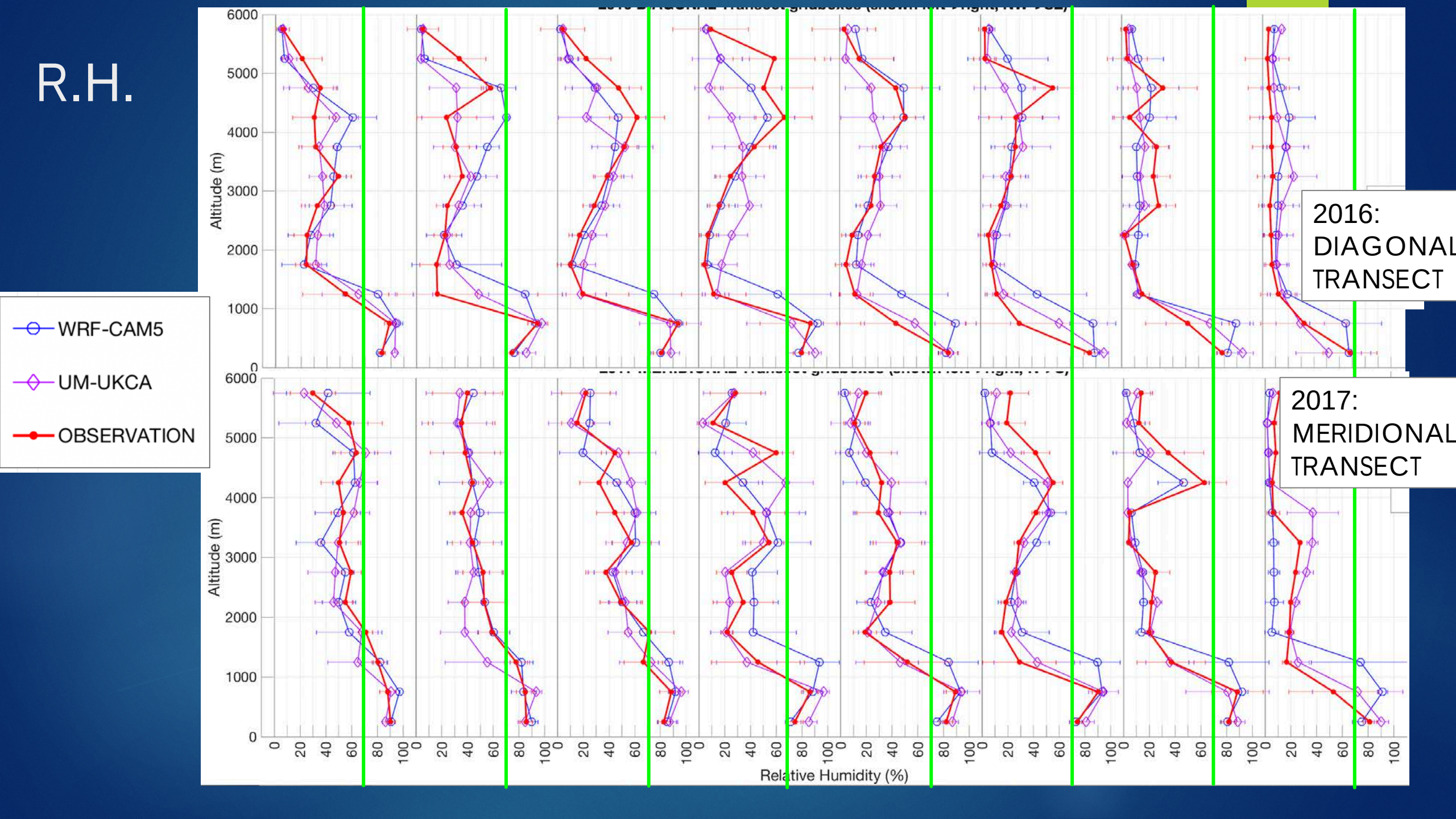


Observed: Modeled Extinction

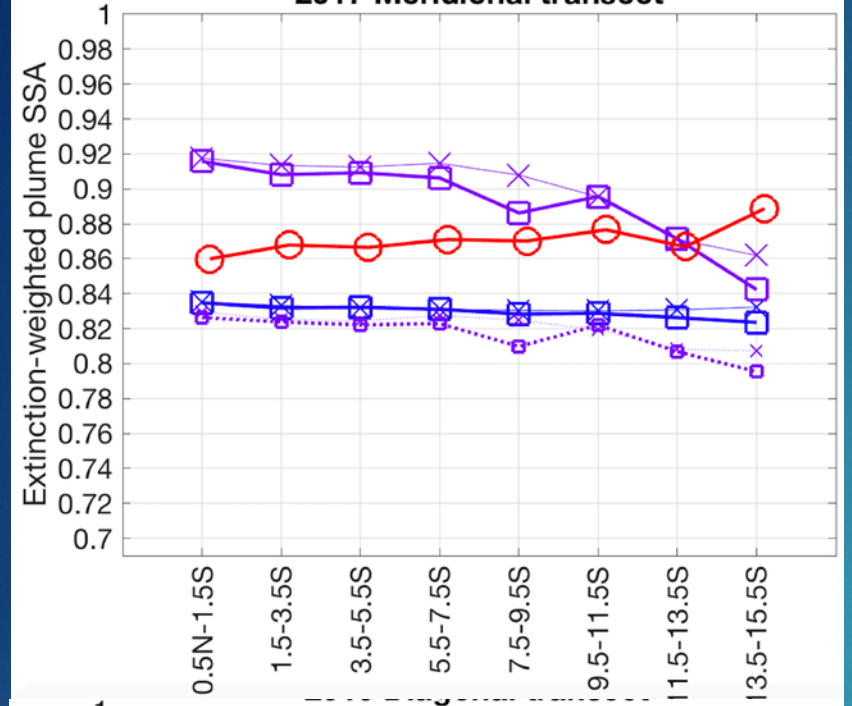
2016 Diagonal transect

Doherty et al., A summary and model-observation comparison of vertically-resolved aerosol and cloud properties over the Southeast Atlantic, in prep, ACP.

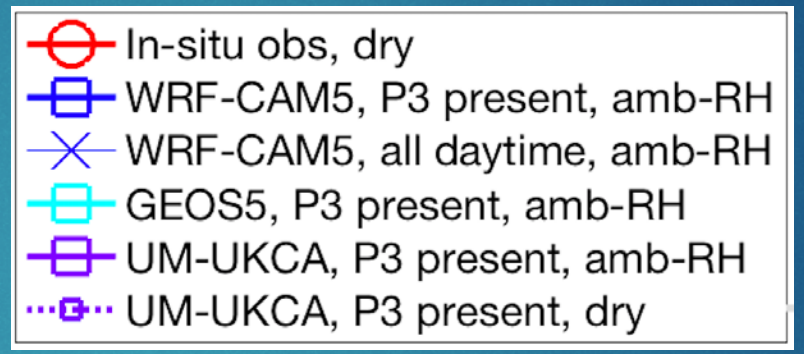
R.H.

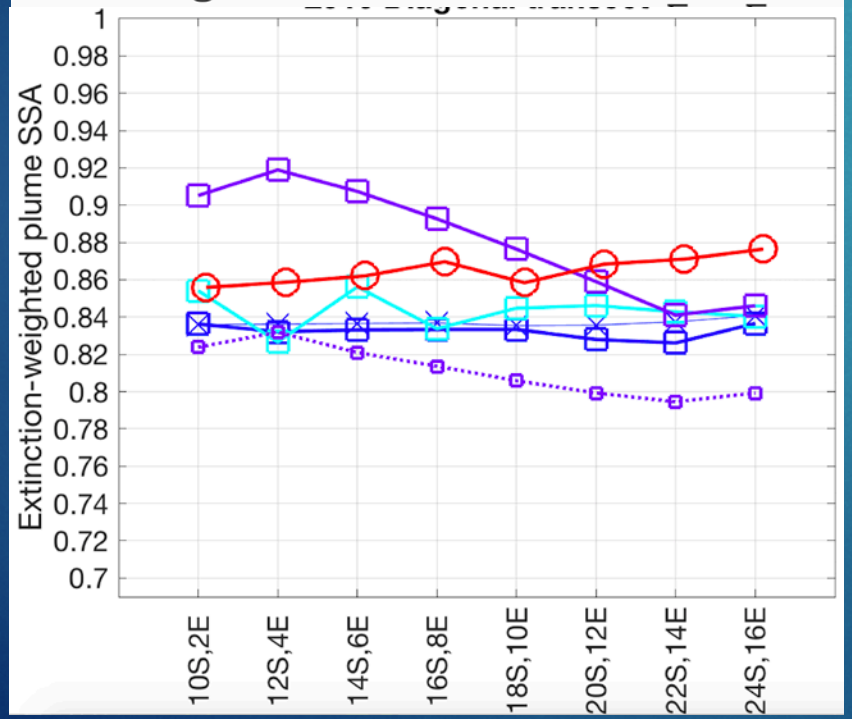

WRF-CAM5
UM-UKCA
OBSERVATION
Altitude (m)
Relative Humidity (%)
2016: DIAGONAL TRANSECT
2017: MERIDIONAL TRANSECT

Extinction-weighted SSA_{530} ("column" SSA)



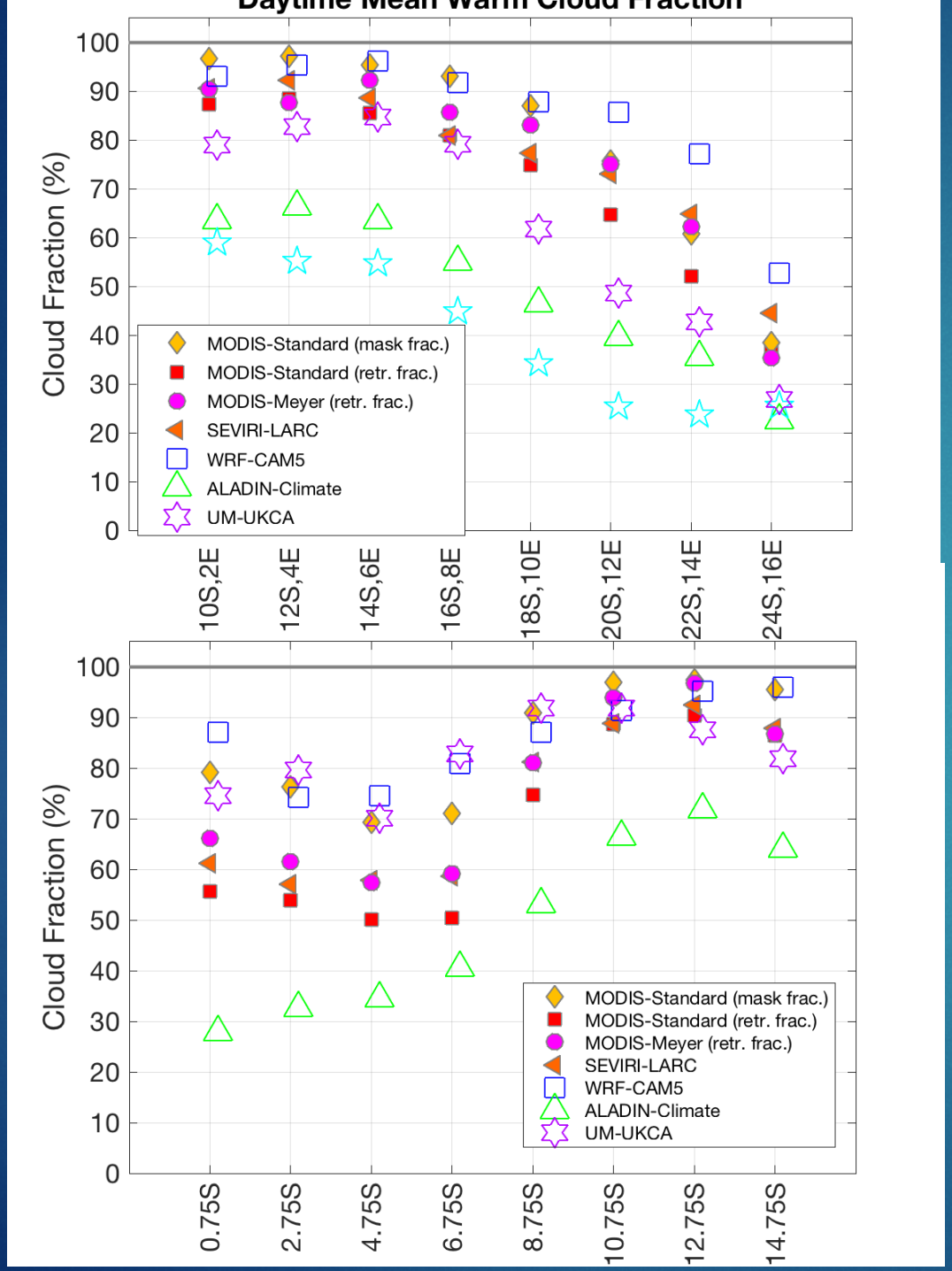
2016 Diagonal transect





2017 Meridional transect

Doherty et al., A summary and model-observation comparison of vertically-resolved aerosol and cloud properties over the Southeast Atlantic, in prep, ACP.



2016 Diagonal transect

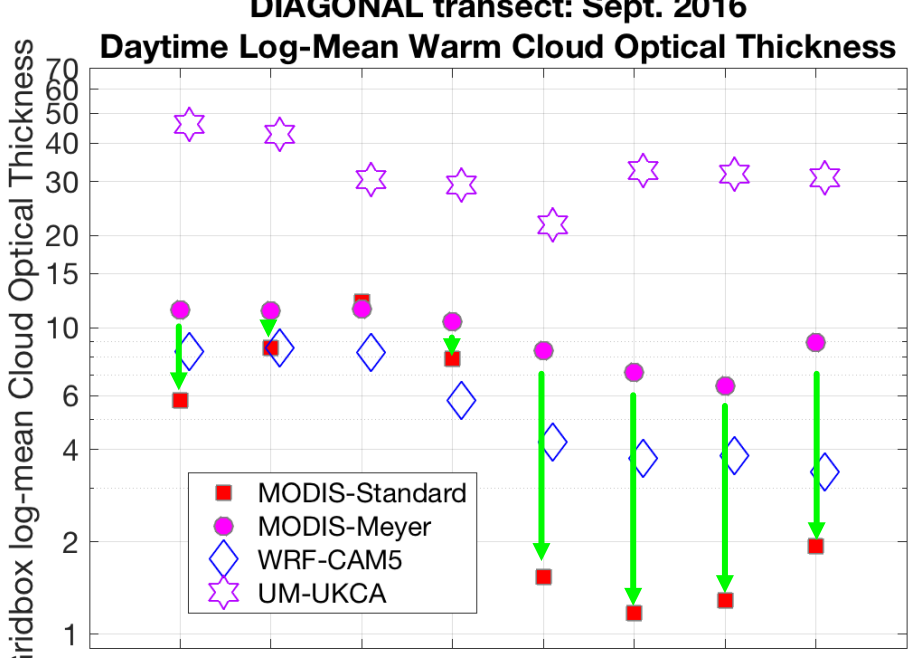
MODIS-Standard (mask frac.)
MODIS-Standard (retr. frac.)
MODIS-Meyer (retr. frac.)
SEVIRI-LARC
WRF-CAM5
ALADIN-Climate
GEOS5
UM-UKCA

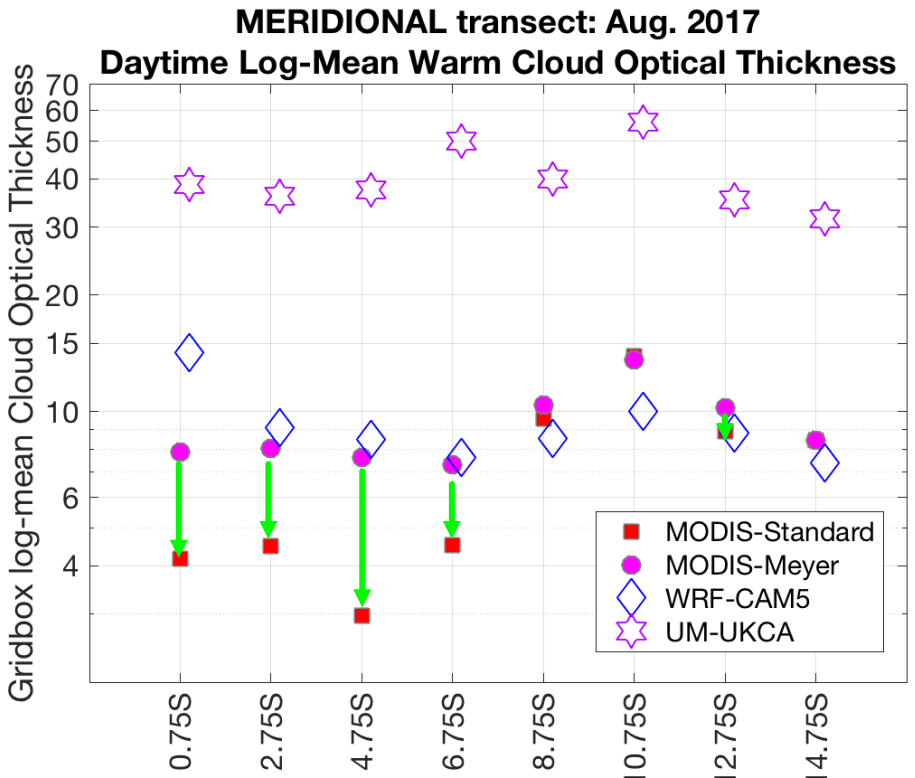
2017 Meridional transect

Cloud fraction (*monthly mean*)

ZONAL

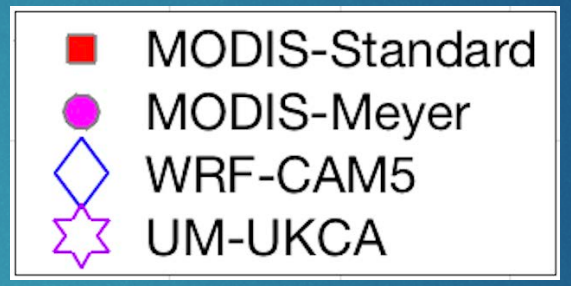
Doherty et al., A summary and model-observation comparison of vertically-resolved aerosol and cloud properties over the Southeast Atlantic, in prep, ACP.





Cloud optical depth (*month log-mean*)

2016 Diagonal transect



2017 Meridional transect

ZONAL

Doherty et al., A summary and model-observation comparison of vertically-resolved aerosol and cloud properties over the Southeast Atlantic, in prep, ACP.

Observational statistics available for transects across SE Atlantic:

- Plume height (specified thresholds)
- AC-AOD
- Extinction
- SSA
- SAE
- AAE
- Mean particle size (vol mean dia.)*
- Component masses (BC, OA, CO)
- RH**
- Cloud fraction**
- Cloud optical depth**

<u>*Shinozuka et al.*</u>:
Box-whisker plots for:
- MBL
- MBL top → 3km
- 3→6km

<u>*Doherty et al.*</u>:
- Vertical profiles (250m alt. bins)
- Ext-weighted SSA
- 2-D CF, COD

* Only in Shinozuka et al.
** Only in Doherty et al.

Synthesis of multiple estimates of **Direct Aerosol Radiative Effects (DARE)**

Idea still in development – please join!

Each estimate of DARE is accompanied by associated values of:

- SSA
- Asymmetry parameter
- AOD
- Cloud fraction (mean)
- Cloud optical depth (log-mean)

→ Compare PDFs of variables

How do they compare to observed PDFs?

→ Accompany by sensitivity study of DARE to each variable

Process-level studies around the Aerosol indirect effects

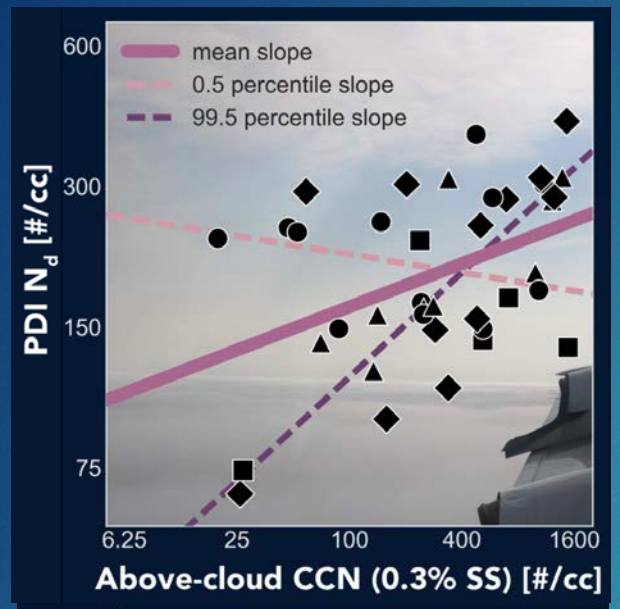
Kacarab et al., Biomass Burning Aerosol as a Modulator of Droplet Number in the Southeast Atlantic Region, *ACPD*, 2019.

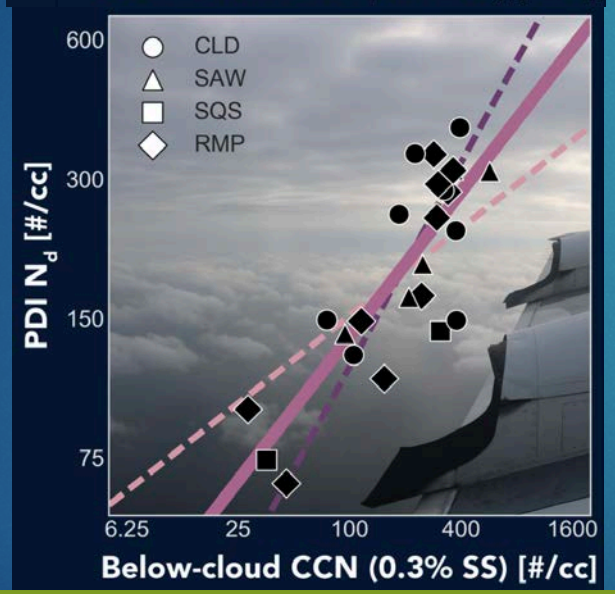
Droplet formation parameterization: f(N_a, ω_o, κ)

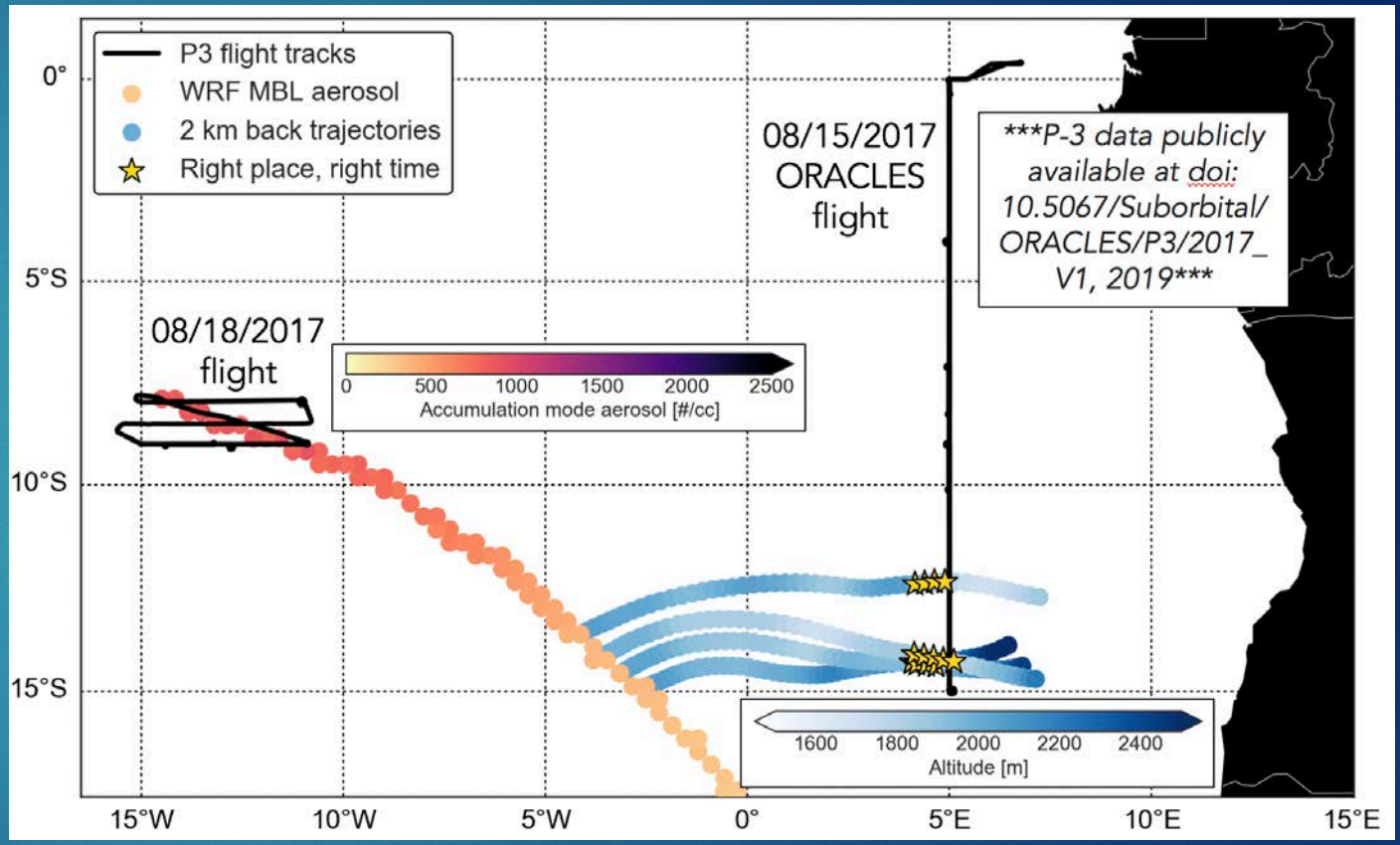
Found 3 regimes:

- **N_a< ~500 cm^{-3} ("clean" MBL)**
  - CDNC more sensitive to N_a than to ω_o
- **500 cm^{-3} < N_a < 900 cm^{-3}**
  - "competitive" regime
  - CCN more sensitive to κ
- **N_a > ~900 cm^{-3} & S_{max} approaches 0.1%**
  - "Velocity-limited" regime: ω_o controlling factor
  - CDNC responds weakly to CCN concentration increases

Process-level studies around the Aerosol indirect effects







Diamond et al., in progress

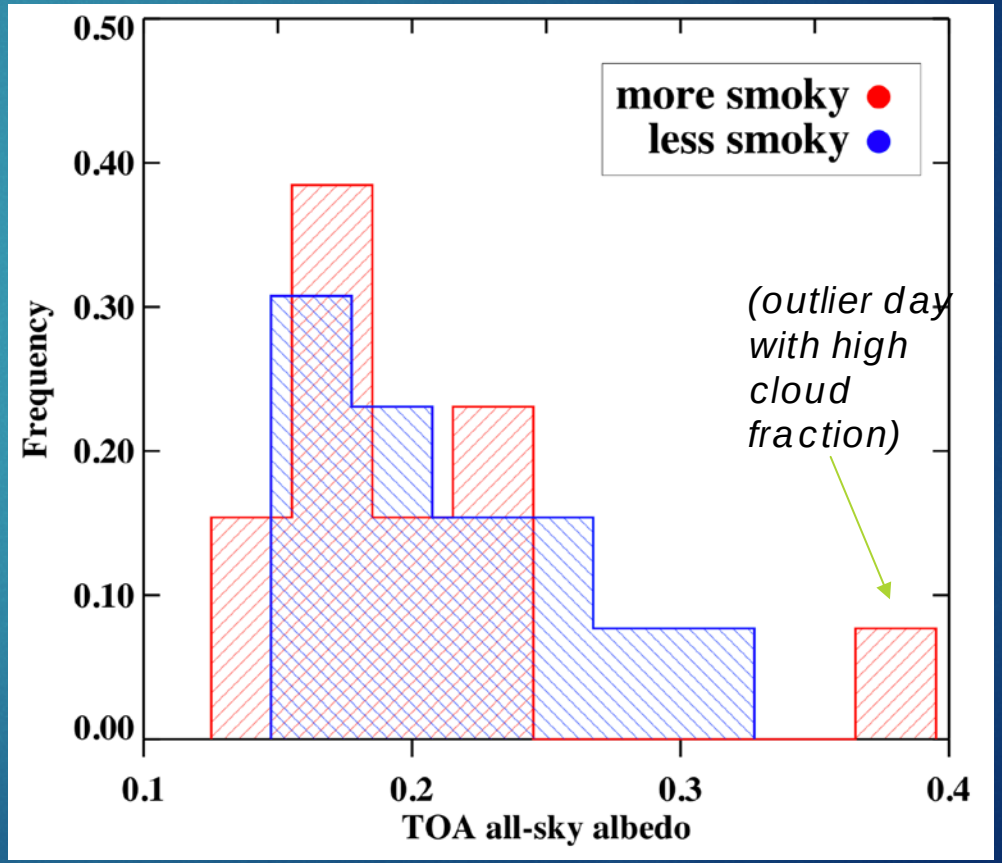
Diamond, M. S., et al. Time-dependent entrainment of smoke presents an observational challenge for assessing aerosol–cloud interactions over the southeast Atlantic Ocean, *ACP*, 2018.

Process-level studies around the Aerosol indirect effects

Zhang, Jianhao and P. Zuidema, The diurnal cycle of the smoky marine boundary layer observed during August in the remote southeast Atlantic, *ACP*, in revision, 2019.

Ascension Island (DOE-LASIC)

- Observed reduction in all-sky albedo when there's more smoke present in BL (August)
- BL SDE that reduces low cloud cover is a cooling response added to aerosol direct effects (DARE<0 because of low CF)
- In September, low cloud cover increases & aerosol is more clearly aloft; expect the DARE sign to flip (DARE>0 w/ high CF)
- Recommendation: Look at the evolution in aerosol forcing in monthly increments, rather than seasonal.



- More to come in ACP Special Issue on Aerosol Forcing in the SE Atlantic