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Modeling the smoky troposphere of the southeast Atlantic: a comparison to ORACLES airborne observations from September of 2016

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Now published!

- September 2016 ORACLES flights capture monthly-mean values (systematic deviations < 30%)
- Models not run in the AEROCOM setup: follow their own protocols
- Comparison focuses on the free troposphere

The main take-aways:

- Models tend to place their aerosol layer bottom lower than in observations
- Most models overestimate BC+OA in the offshore boundary layer
- Models tend to overestimate the mean of most smoke quantities (black carbon, CO, extinction) closer to the coast, and underestimate them further offshore
- Most models overestimate the secondary organic aerosol mass relative to the black carbon mass, and with less skill, indicating model uncertainty in secondary organic aerosol processes.
- Model ambient single-scattering-albedos vary widely (0.83-0.93), compared to in-situ dry values centered on 0.86 (humidification impact on scattering is minimal).
- Modeled ratios of extincion/(BC+OA) is typically too low and too spatially-invariant
- The diversity in model biases suggests different model processes are responsible
- No single model is superior to all others in all metrics evaluated

2 regional models, 4 global
No attempt to control for inputs, protocols (unlike AEROCOM)

Table 2. Model specifications.

Model	Domain extent	Horizontal grid spacing	Vertical levels (> and < 700 hPa)	Initializing meteorology	Initialization frequency	Aerosol scheme	PMBL scheme	Fire emissions source	Emission temporal resolution
WRF-CAM5	41° S–14° N, 34° W–51° E	36 km	75, 50	NCEP Final Analysis	5 d	MAM3	Bretherton and Park (Bretherton and Park, 2009)	QFED2	Daily
GEOS-5	Global	25 by 31 km	72, 17	GEOS-FP	Daily	AeroChem (GOCART)	TURBDAY	QFED2	Daily
GEOS-Chem	Global	2.5° by 2 (long, lat)	17, 55	GEOS-FP	Hourly	GEOS-Chem standard	VDIFF: non-local scheme formulated by Holtslag and Boville (1993)	QFED2	Daily
EAM-E3SM	Global	100 km	72, 17	ERA-INT	Every 3 h	MAM4	CLUBB (Larson and Golaz, 2005)	GFED*	Monthly
Unified Model	Global	61 by 92 km	65, 20	ERA-INT	Every 6 h	GLOMAP-mode	Lock et al. (2000)	FEER	Daily
ALADIN-Climate	37° S–9° N, 33° W–45° E	12 km	34, 6	ERA-INT	Once	Interactive		GFED	Monthly

* Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) emissions, based on GFED emissions averaged between 1997 and 2002.

Active participant

Pablo Saide (UCLA) (also main ORACLES aerosol forecaster)

Gonzalo Ferrada (UIowa)

Yafang Chen (MPI-Mainz)

Yan Feng (DOE Argonne)

Hamish Gordon (Leeds/Drexle

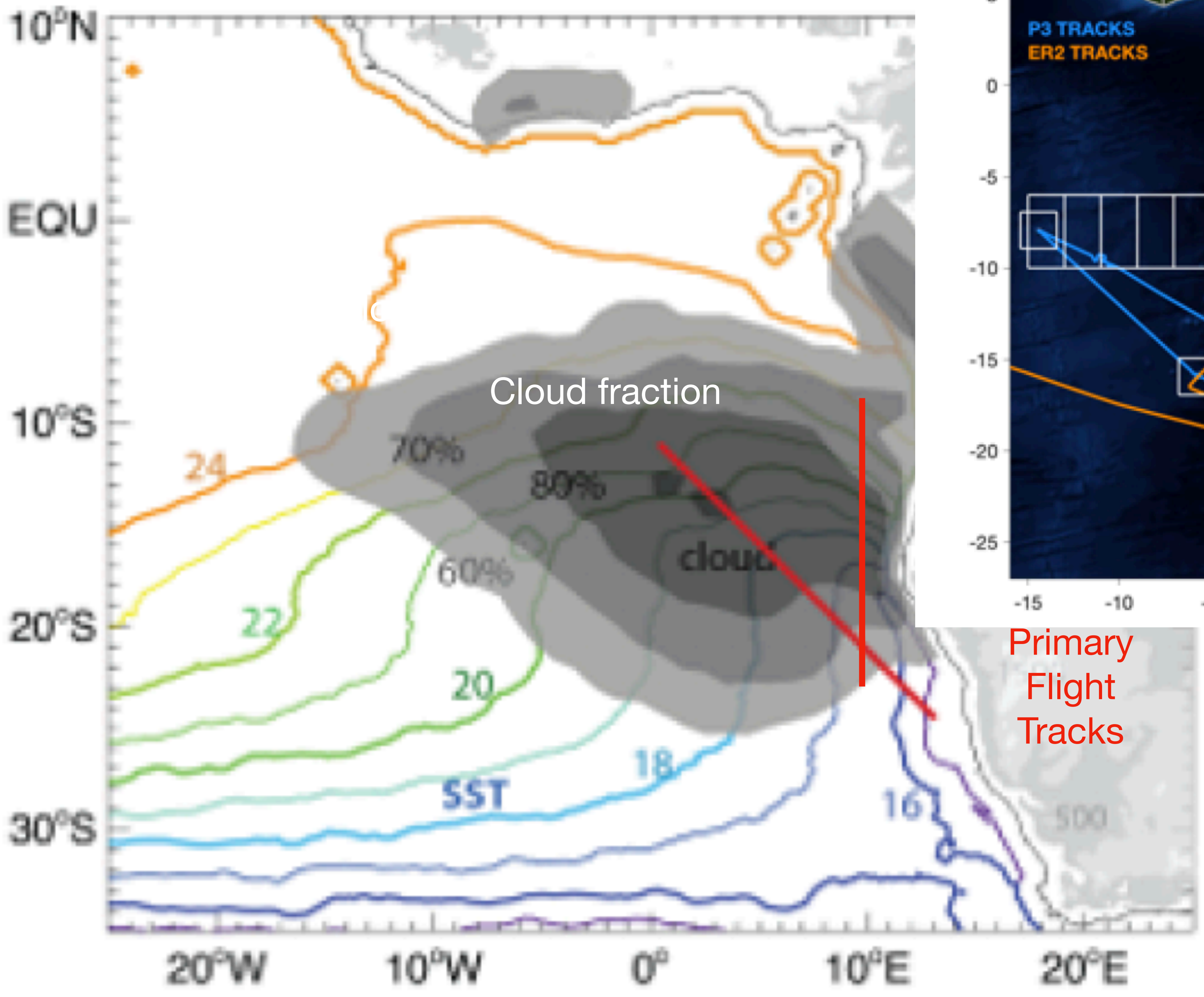
Marc Mallet (Meteo France)

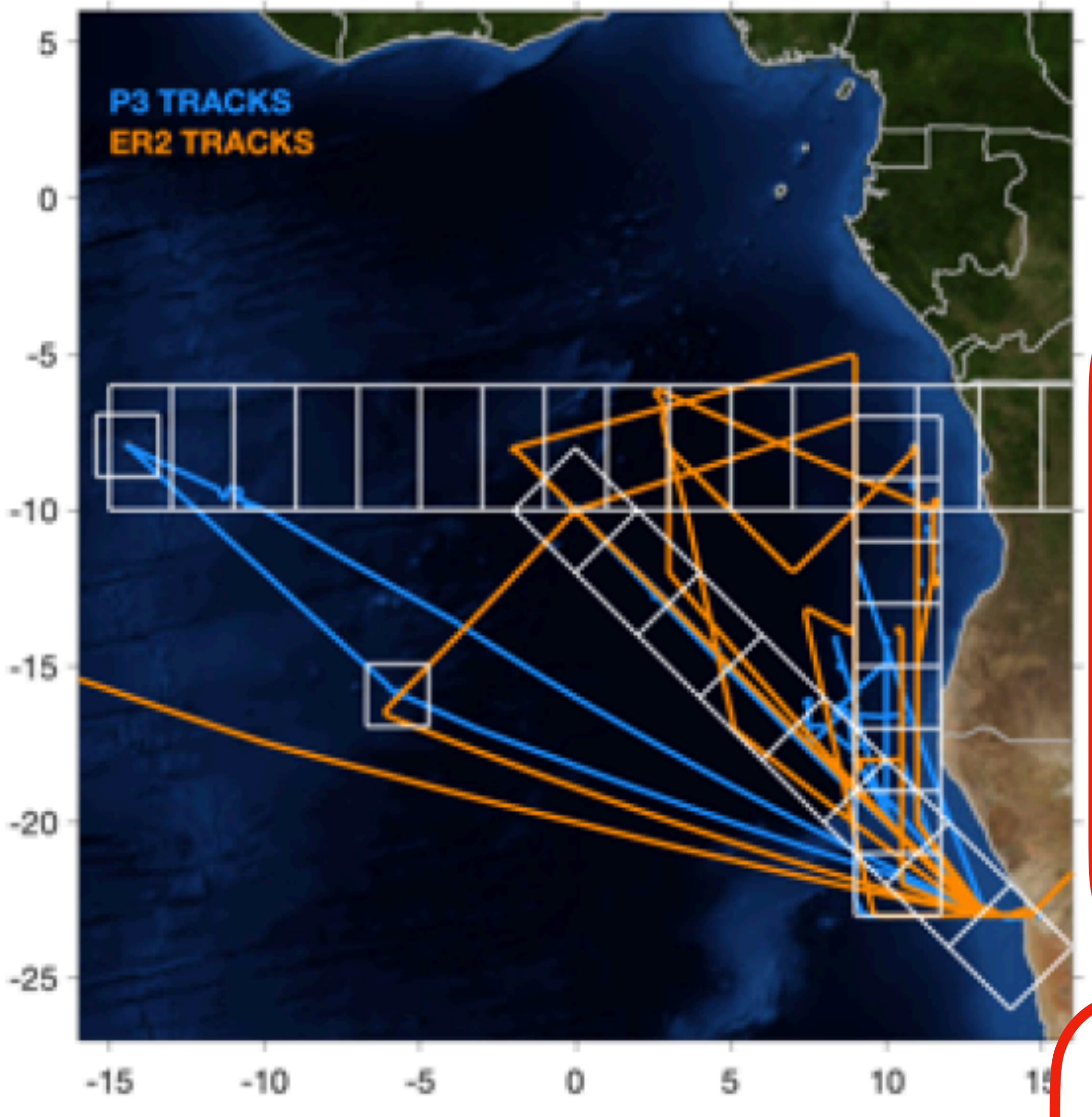
Observations

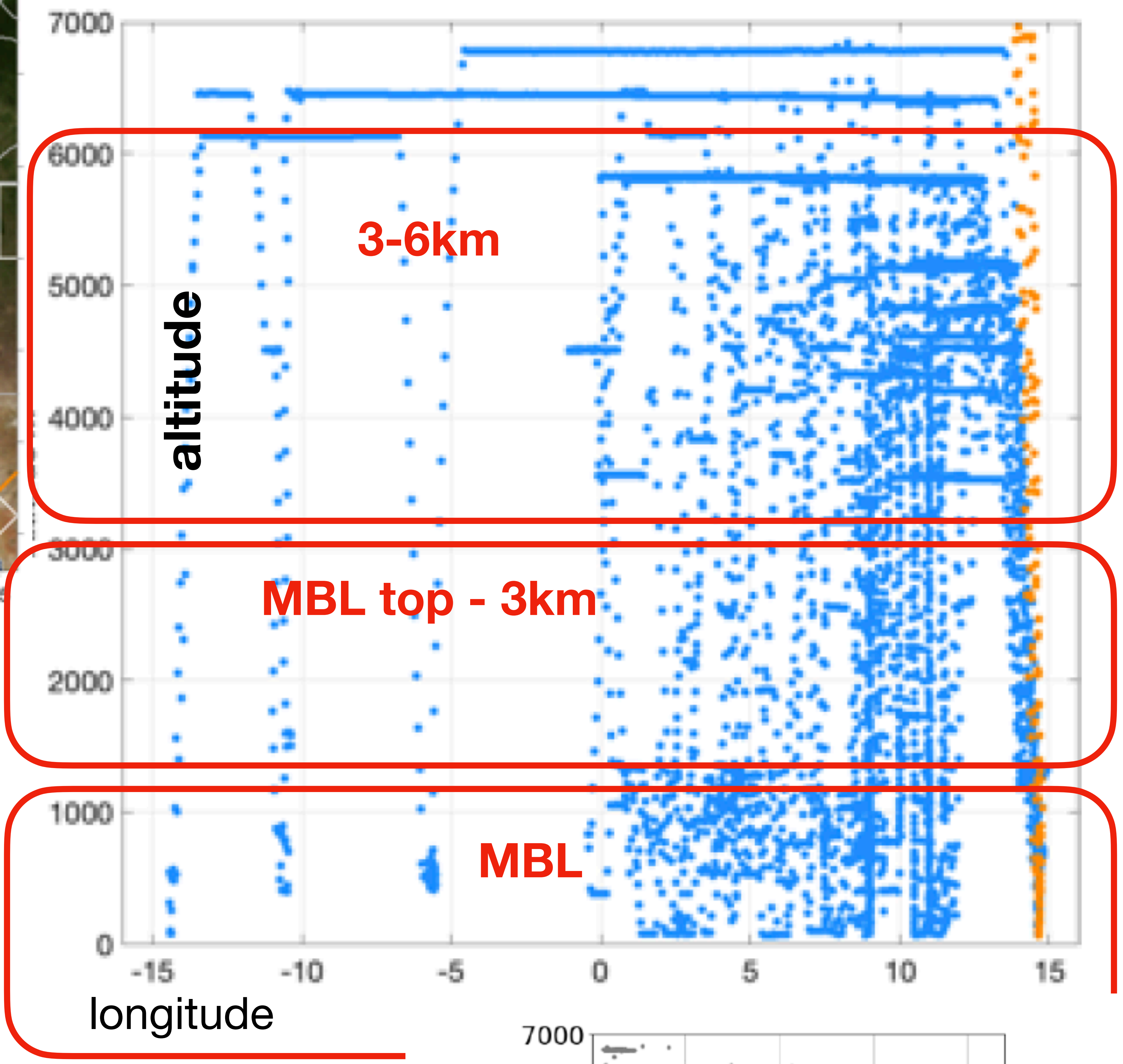
Instrument (platform)	Primary measurement	Temporal resolution
SP2 (P3)	Black carbon mass per particle, 90–500 nm	Particle by particle
Time-of-flight (ToF) Aerodyne aerosol mass spectrometer (AMS) (P3)	Non-refractory aerosol composition (∼ 50 to 500 nm vacuum aerodynamic diameter)	5 s
UHSAS, ultra-high-sensitivity aerosol spectrometer (P3)	Number size distribution for dry particle diameters between 60 and 1000 nm	1 s
Nephelometer (P3)	Submicron dry particle scattering coefficient at 450, 550, 700 nm	6 s
PSAP, particle soot absorption photometer (P3)	Submicron dry particle light absorption at 470, 530 and 660 nm	1–60 s depending on concentration
4STAR, an airborne Sun/sky photometer (P3)	Hyperspectral direct solar beam transmittance, AOD; values at 550 nm	1 s
HSRL-2, the NASA Langley second-generation airborne High Spectral Resolution Lidar (ER2)	Aerosol backscattering and extinction coefficients, values at 532 nm	10 s for aerosol backscatter coefficient and 60 s for aerosol extinction coefficient
$CO/CO_2/H_2O$ analyzer (P3)	Carbon monoxide	1 s

Detailed aerosol vertical structure measurements
of black carbon, aerosol composition, aerosol size,
aerosol optical scattering and absorption, CO

goes beyond previous assessments
Based primarily on CALIOP

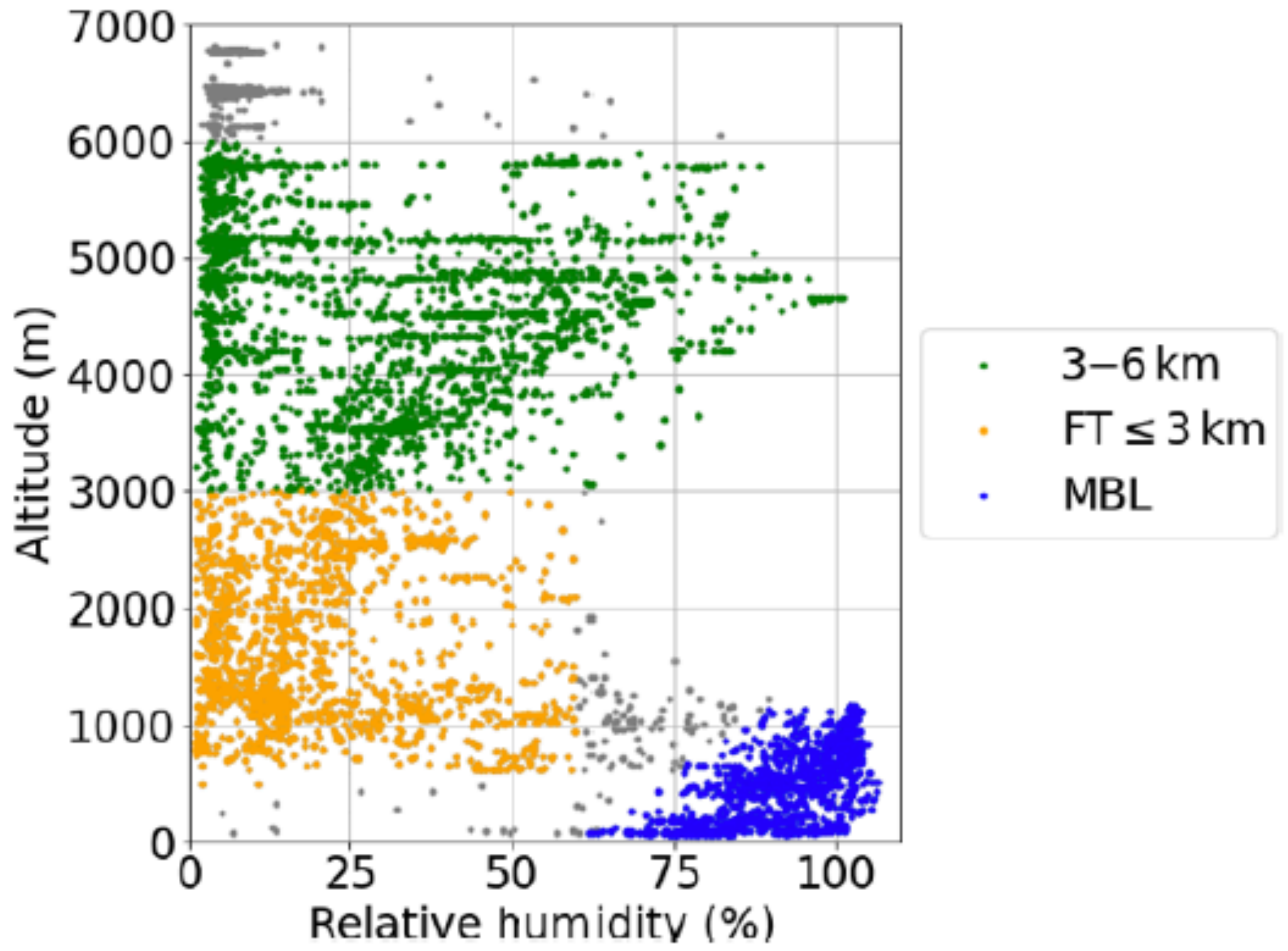




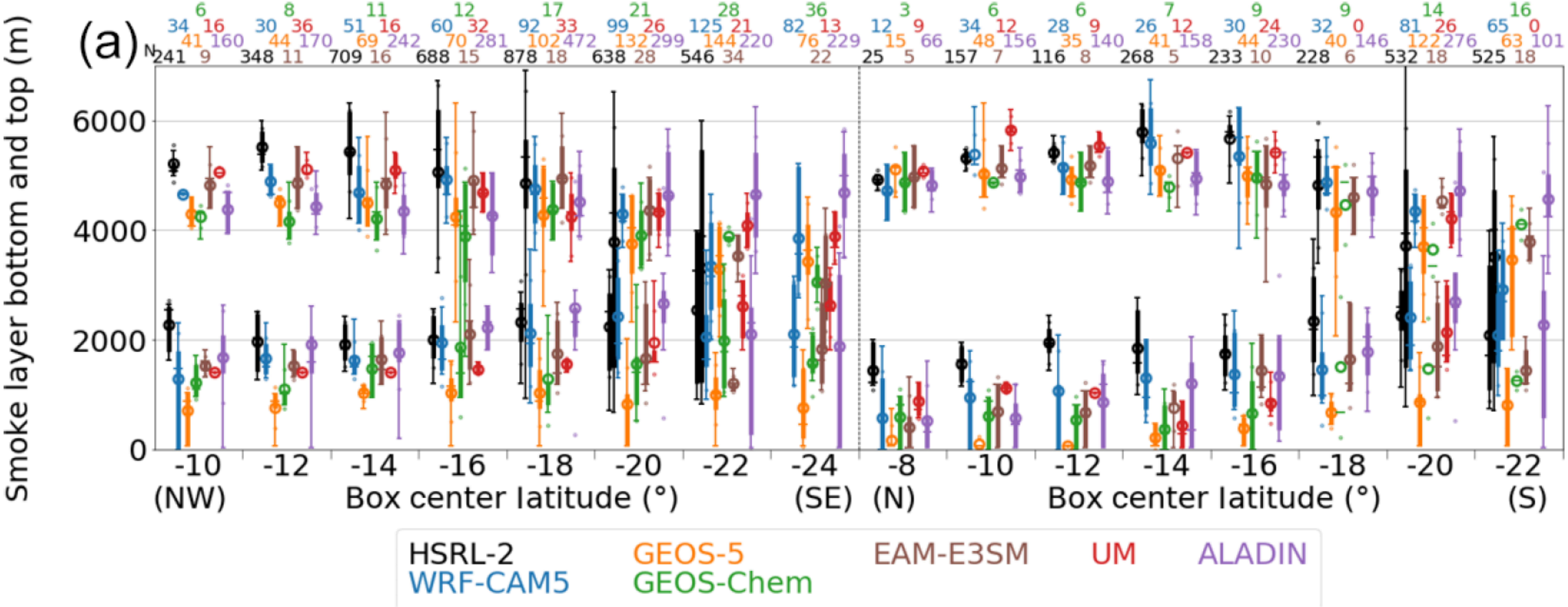


1-minute mean observations (~7-10km) aggregated into 2-2.5 degree boxes, and 3 vertical ranges:

96 hours for P3, 30 hours for ER2 (HSRL2)



HSRL-2 lidar (black) indicates most models place aerosol layer top too low further offshore&at northern end, too high near coast



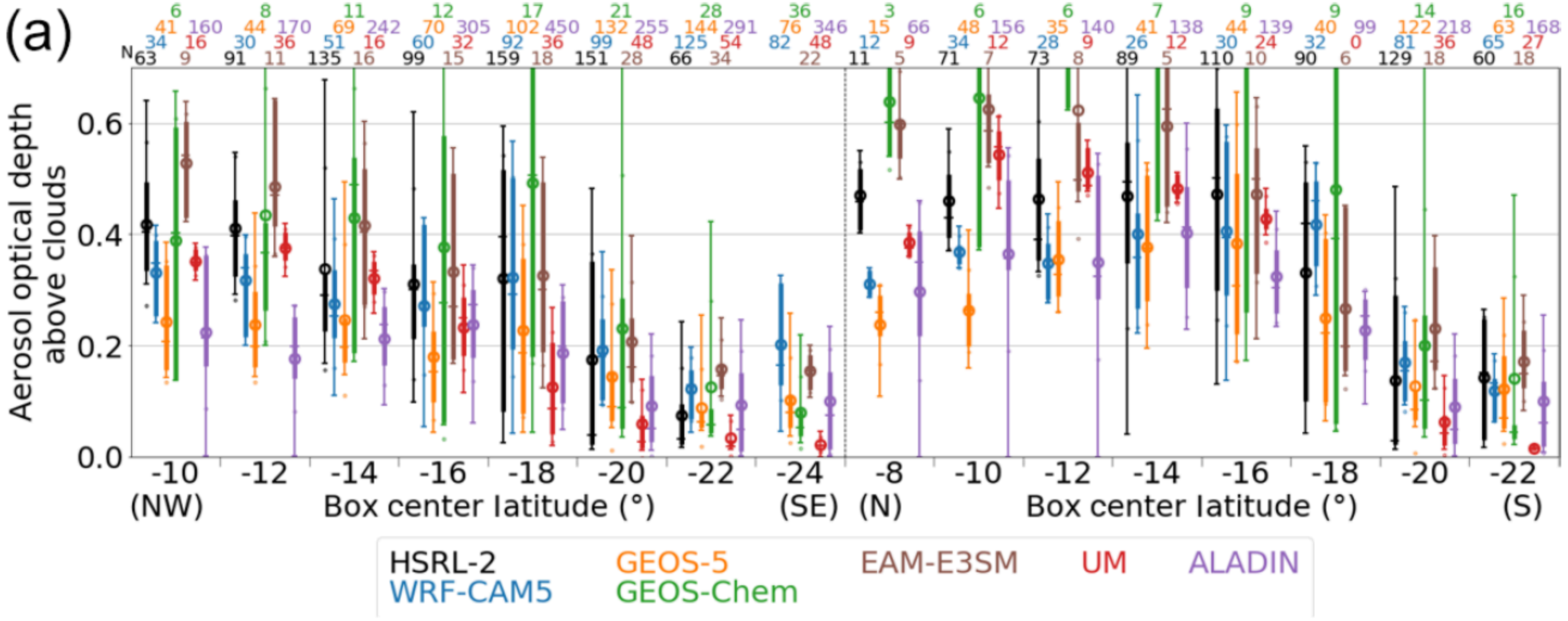
While most models place aerosol layer bottom too low almost everywhere

Not entirely news - e.g. consistent w/ Das et al. 2017 comparison to CALIOP

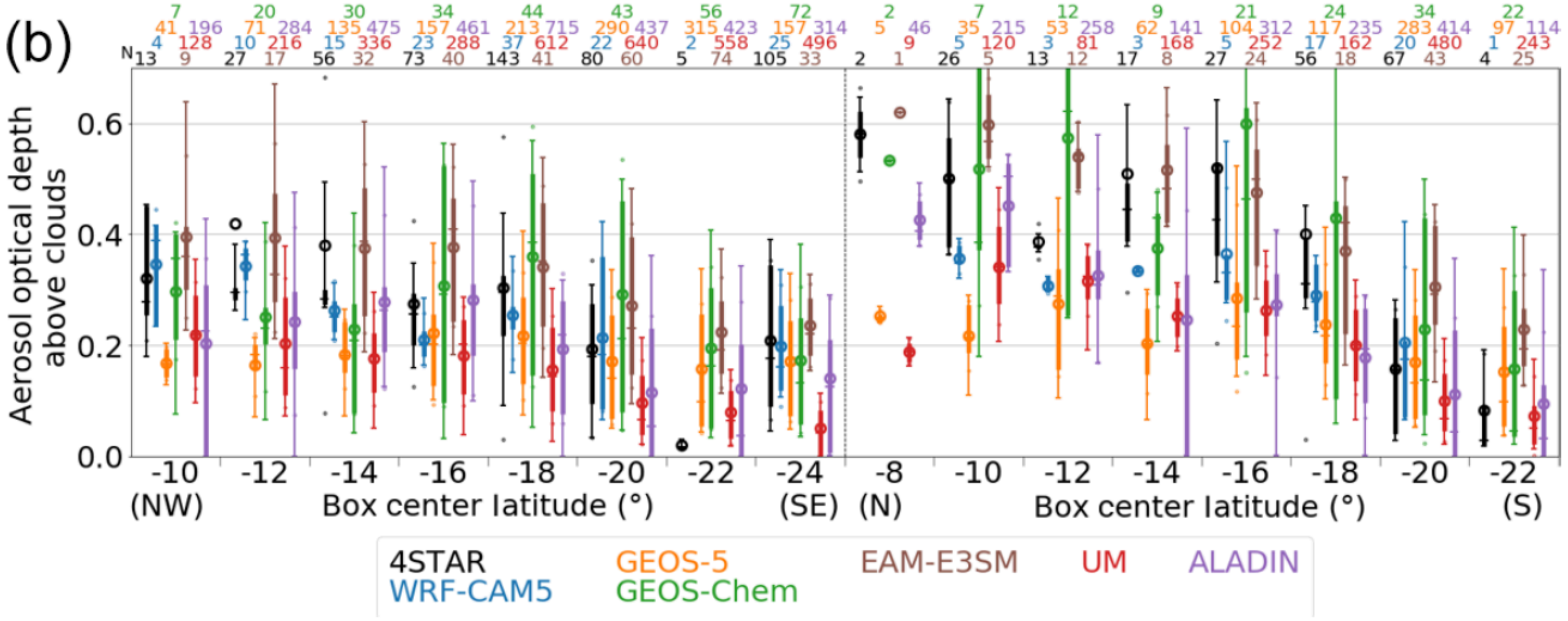
As a result, in general, model aerosol mass, extinctions too small in 3-6km layer

Aerosol optical depth comparisons more variable (than layer thickness); wider range in model values

ER2 HSRL2 (black)



P3 4STAR (black)

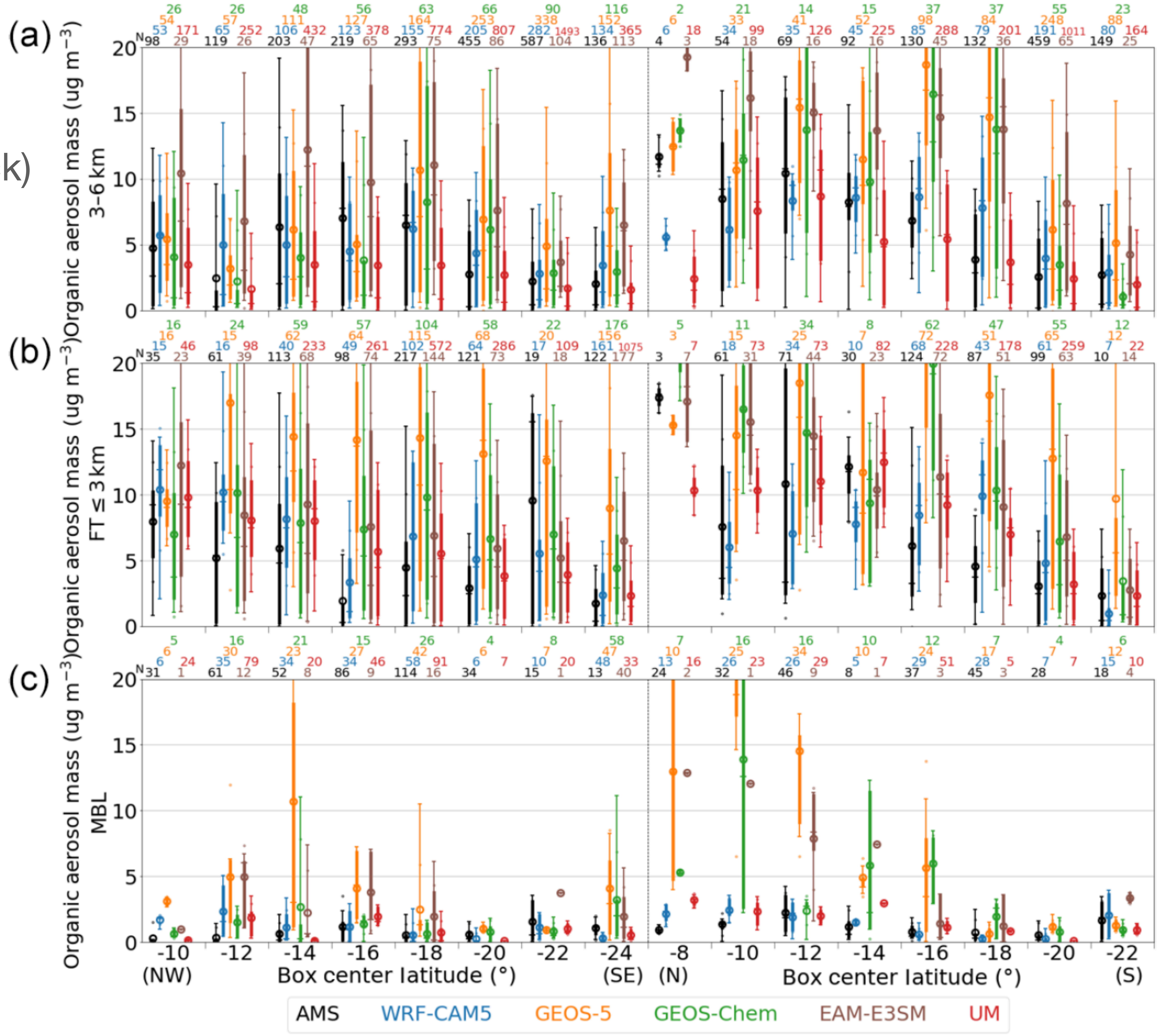


Organic aerosol mass often overestimated in lower free troposphere; better agreement in upper troposphere compensated by too-low vertical placement

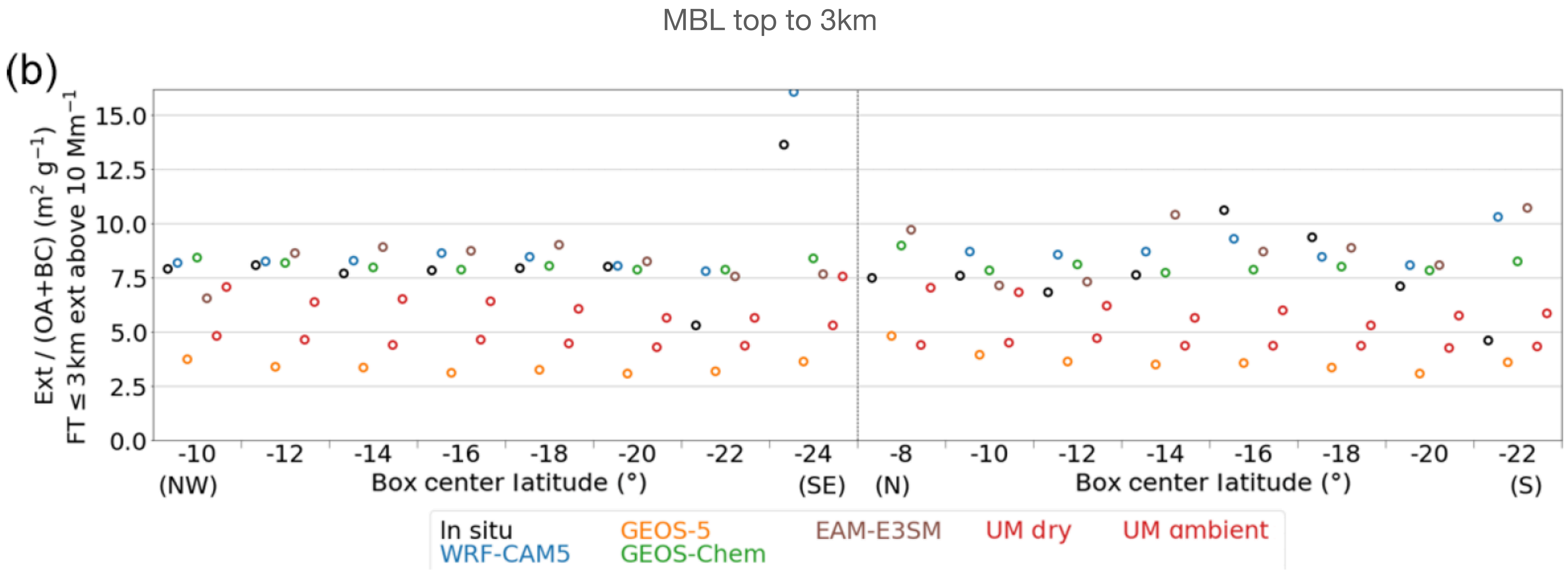
3-6 km
(measurement in black)

MBL top - 3km

MBL



Ratio of extinction to (OA+BC) often too low in the models - attributed to too much organic aerosol

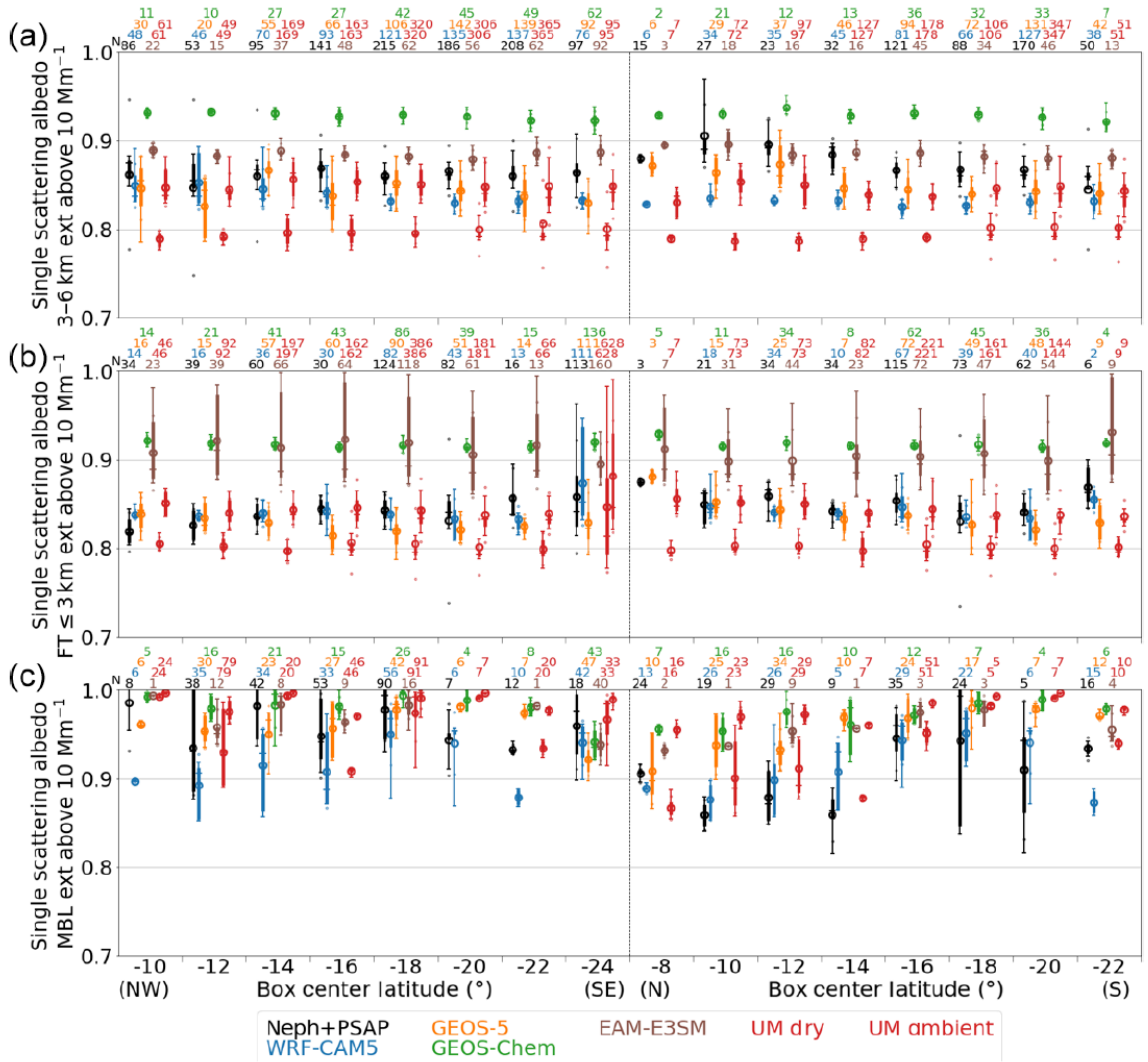


neph+PSAP (black) single scattering albedo of ~0.84-0.86, models vary between 0.8-0.92

3-6 km

MBL top - 3km

MBL



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