Aerosol and Cloud Experiments in Eastern North Atlantic (ACE-ENA)

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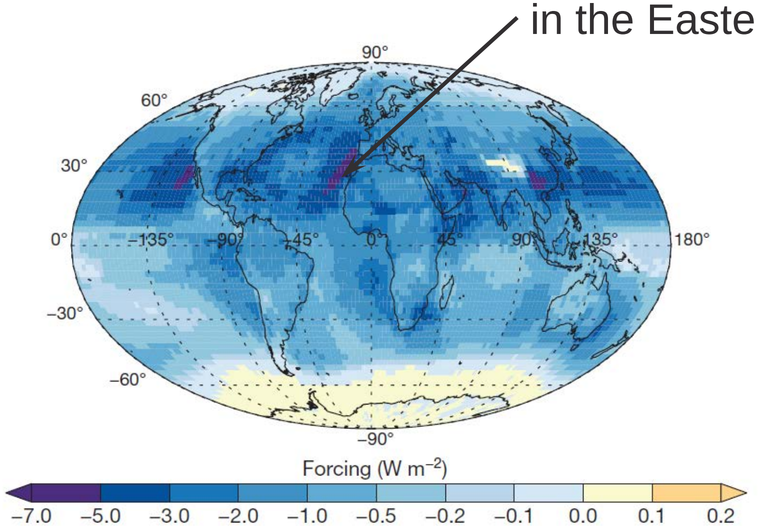
ARM
CLIMATE RESEARCH FACILITY

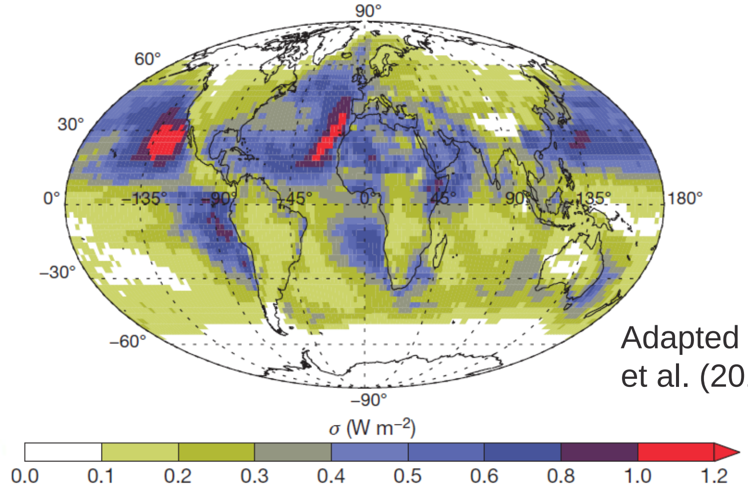
ASR
Atmospheric System Research

Motivation

Strong impact of aerosol on clouds
in the Eastern North Atlantic



Simulated Aerosol 1st indirect forcing

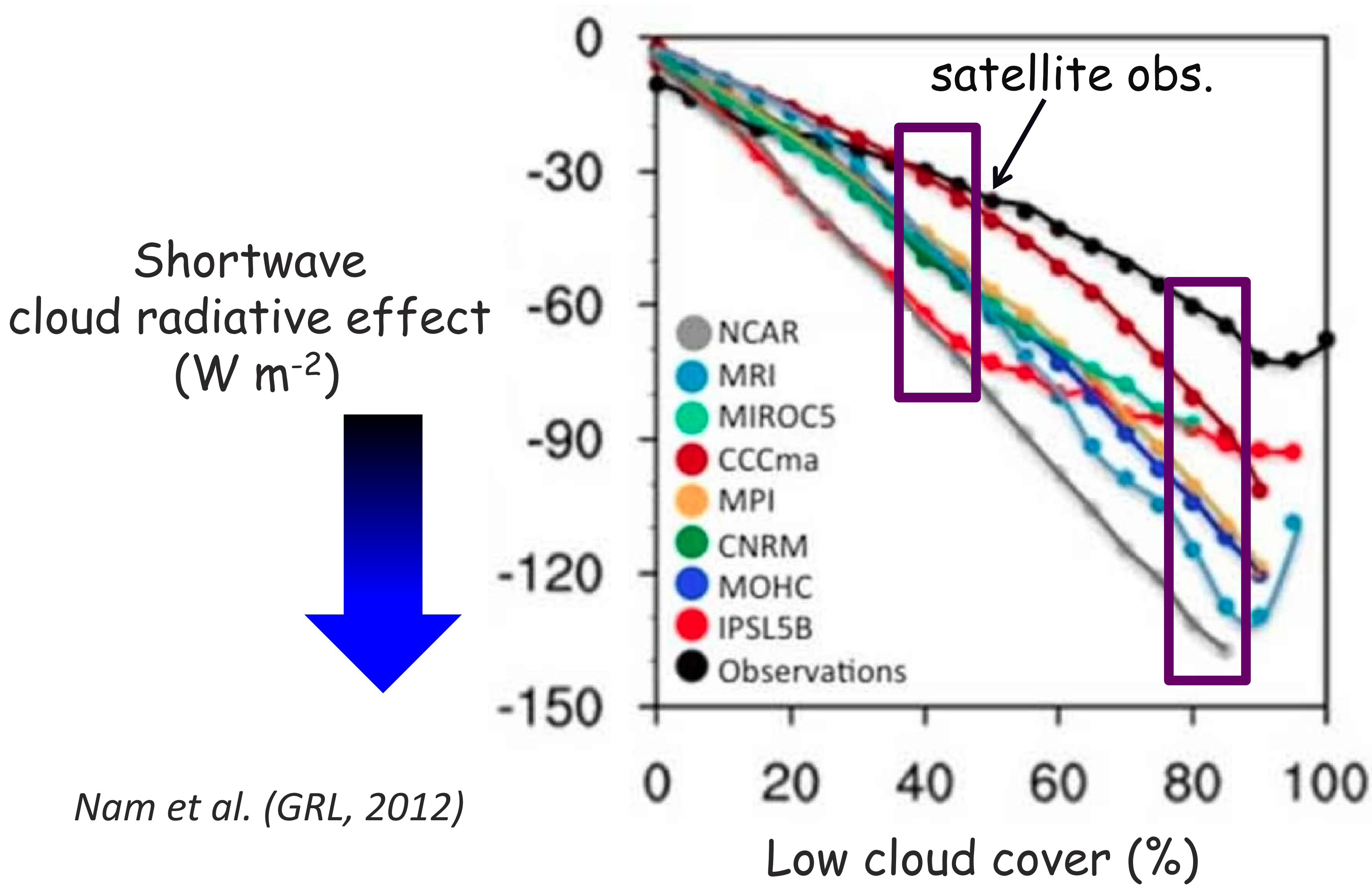


Adapted from Carslaw et al. (2013)

Uncertainty in simulated 1st indirect forcing due to uncertainty in model parameters

- Marine low clouds are particularly susceptible to perturbations in aerosols.
- MBL aerosol in the ENA is often influenced by long-range transported continental pollutions.

Clouds are too bright in CMIP5 global climate models



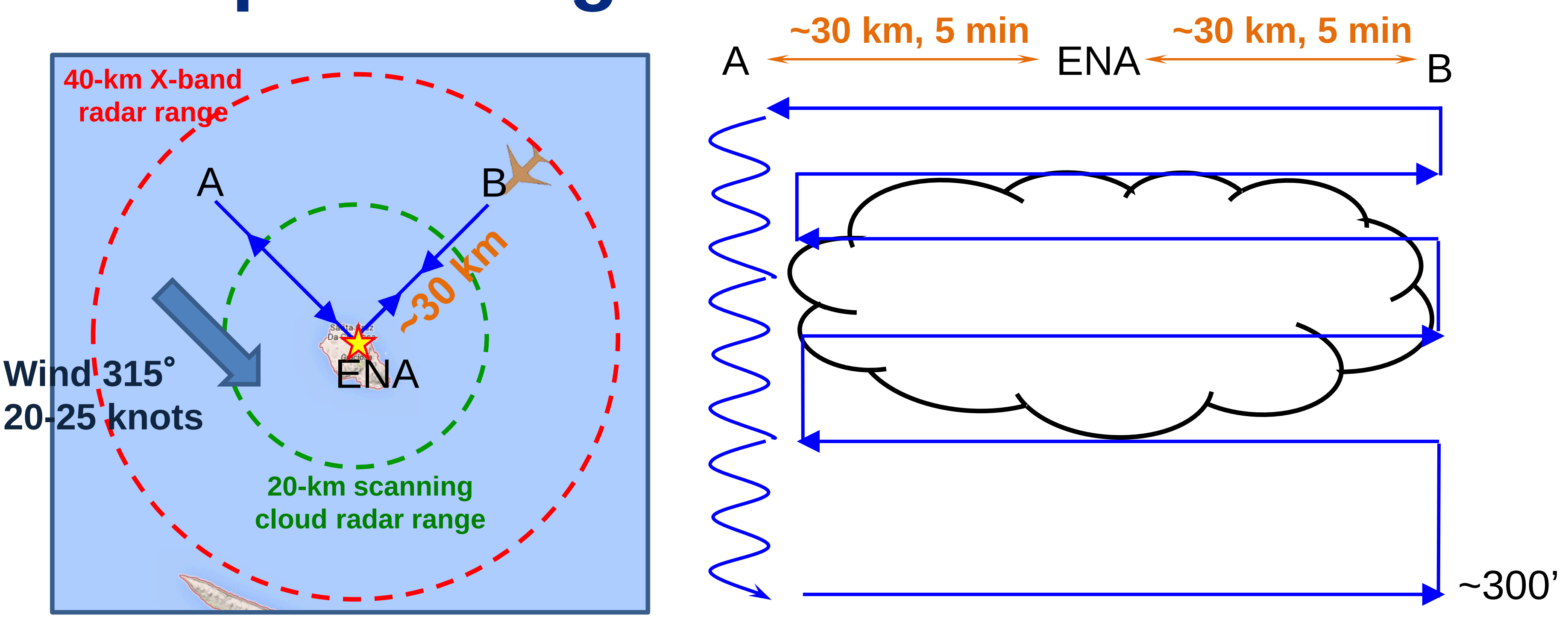
Nam et al. (GRL, 2012)

Courtesy of Christine Chiu

Aerosol and Cloud Experiments in Eastern North Atlantic (ACE-ENA)

- 1st IOP (summer): 78 flight hours, June 21-July 20, 2017
- 2nd IOP (winter): ~80 flight hours, January 11-February 20, 2018
- Synergy between the in-situ measurements onboard the G-1 and the ongoing measurements at the ENA site.

Example of Flight Plan

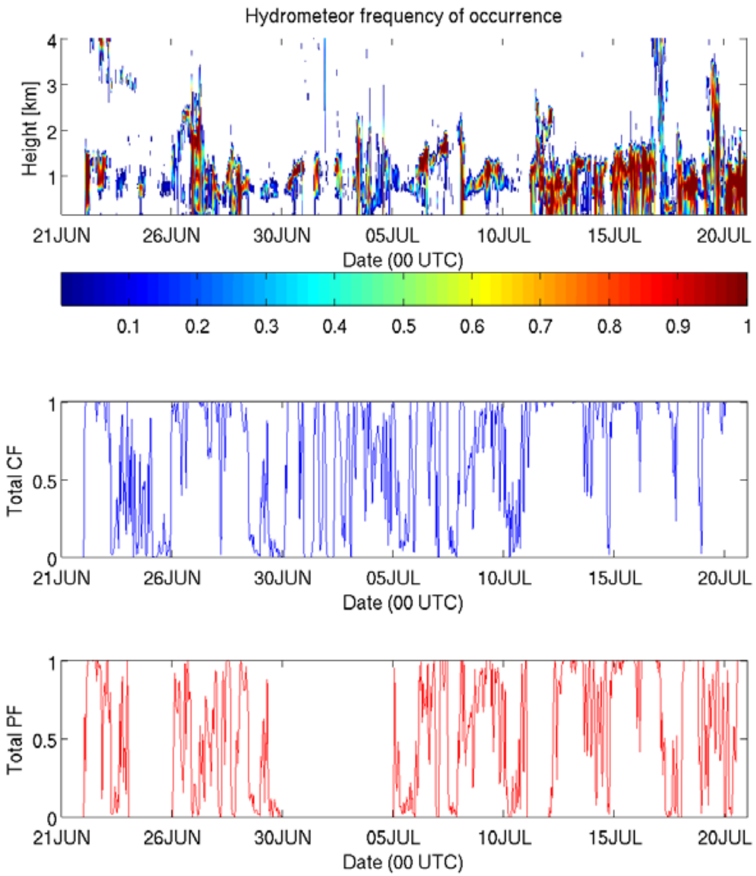


July 18th, 2017

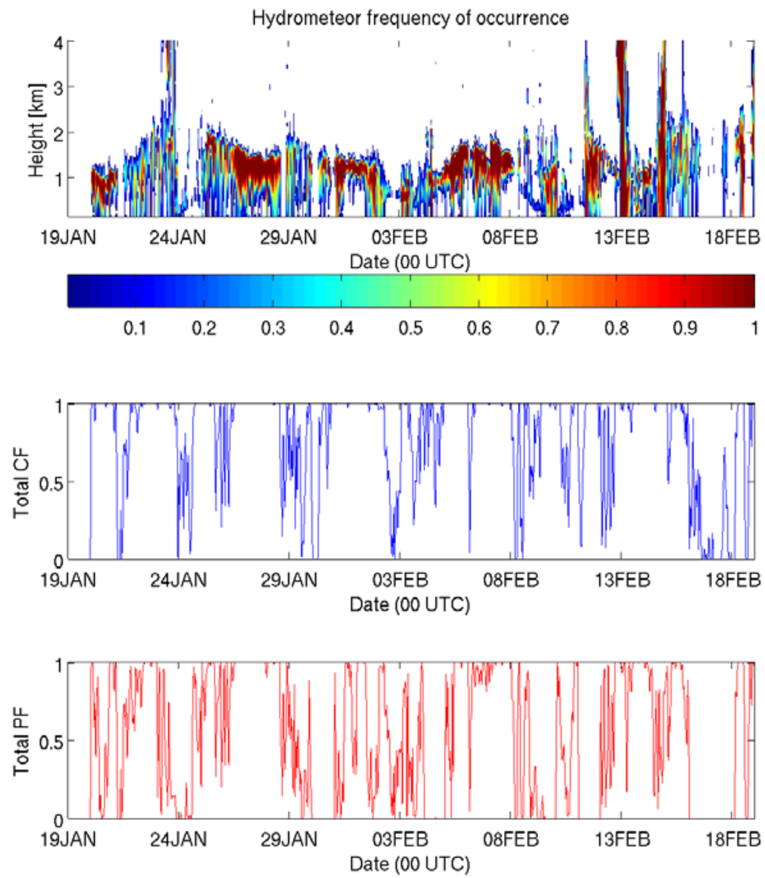
- L shaped legs (cross and along wind) at different altitudes below, inside, and above clouds, overpassing the ENA site.
- Along and cross wind RHI scans during the flight

Overview of Cloud Characteristics

IOP1 (summer)



IOP2 (winter)

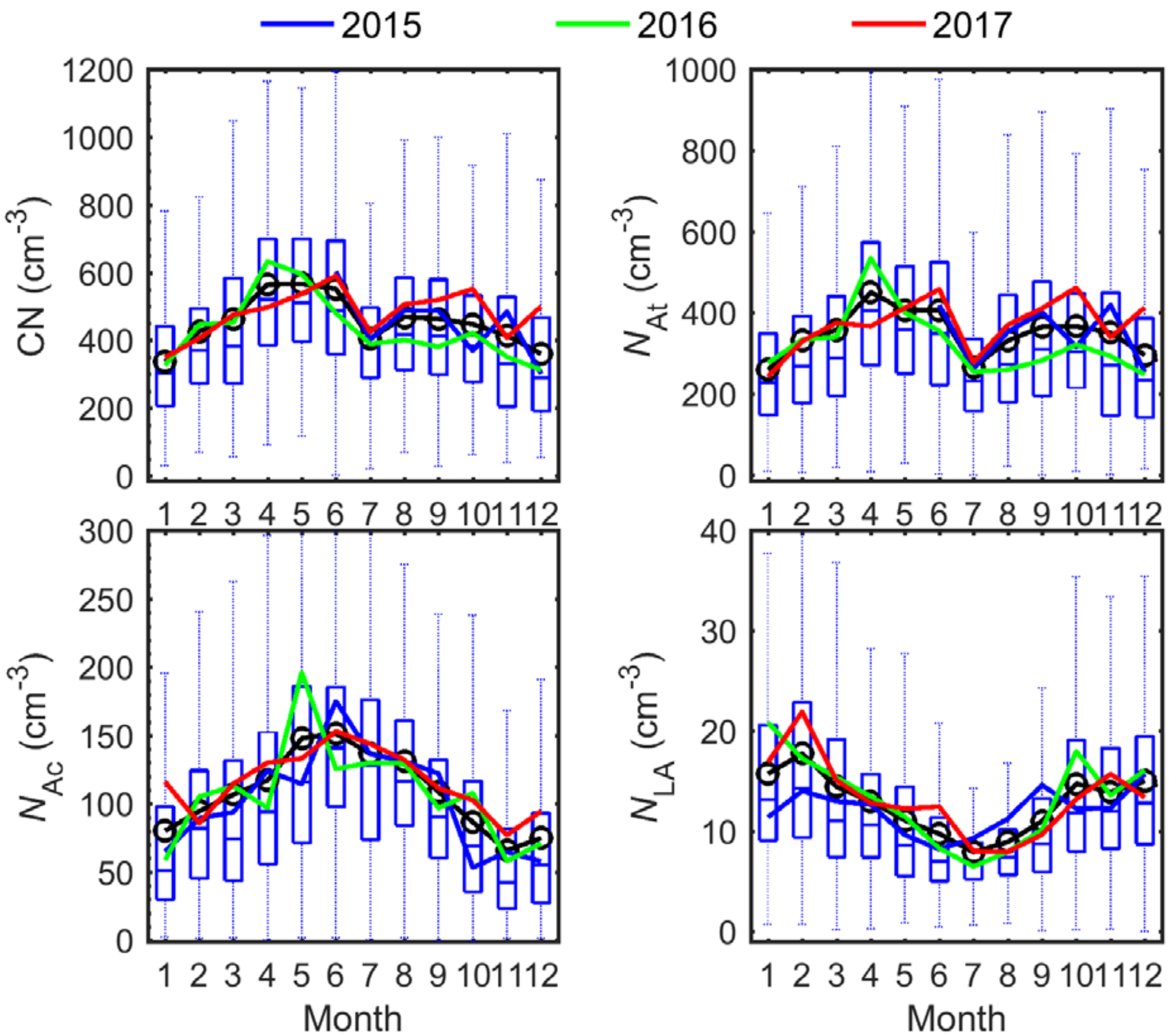


- Overall, higher cloud and precipitation fractions during IOP2
- Higher cloud and precipitation fractions during the latter part of the IOP 1

Conditions Sampled During ACE-ENA IOP

Conditions Sampled	IOP1, Flight number	IOP2, Flight number
Aerosol (Mostly clear)	2, 6, 11	17
Thin Stratus Clouds	1, 3, 4, 5, 7, 9, 11, 15	6, 9, 13, 15
Solid Stratocumulus	10, 12, 16	8
Multi-Layer Stratocumulus	13, 14	3, 7, 11
Drizzling Stratocumulus/Cumulus	8, 17, 18, 19, 20	1, 2, 4, 5, 12, 14, 16, 18, 19

Particle number concentrations of different modes



- CN: Total particle number concentration (D_p>10 nm)
- N_{At}: Aitken mode number concentration
- N_{Ac}: Accumulation mode number concentration
- N_{LA}: Larger accumulation mode number concentration (dominated by sea spray aerosol)

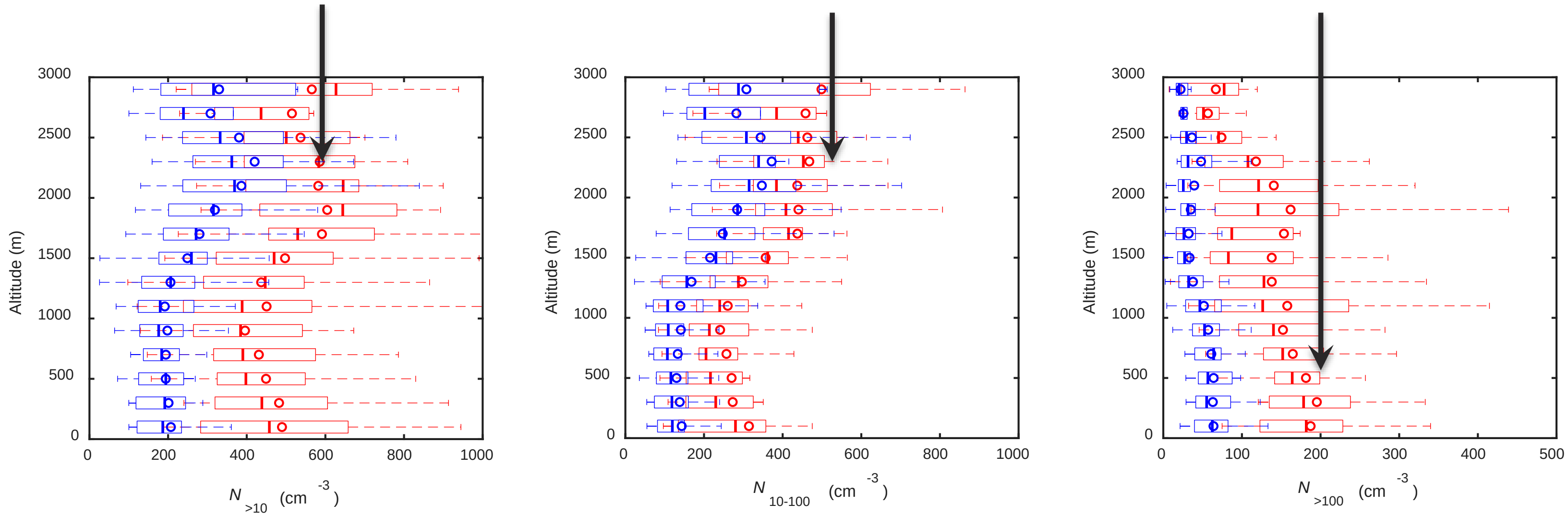
Seasonal variations based on measurements at the ENA site (Zheng et al., 2018, ACP)

Vertical profiles of particle number concentrations and size

Higher total particle number concentration in FT

Higher Aitken mode concentration in FT

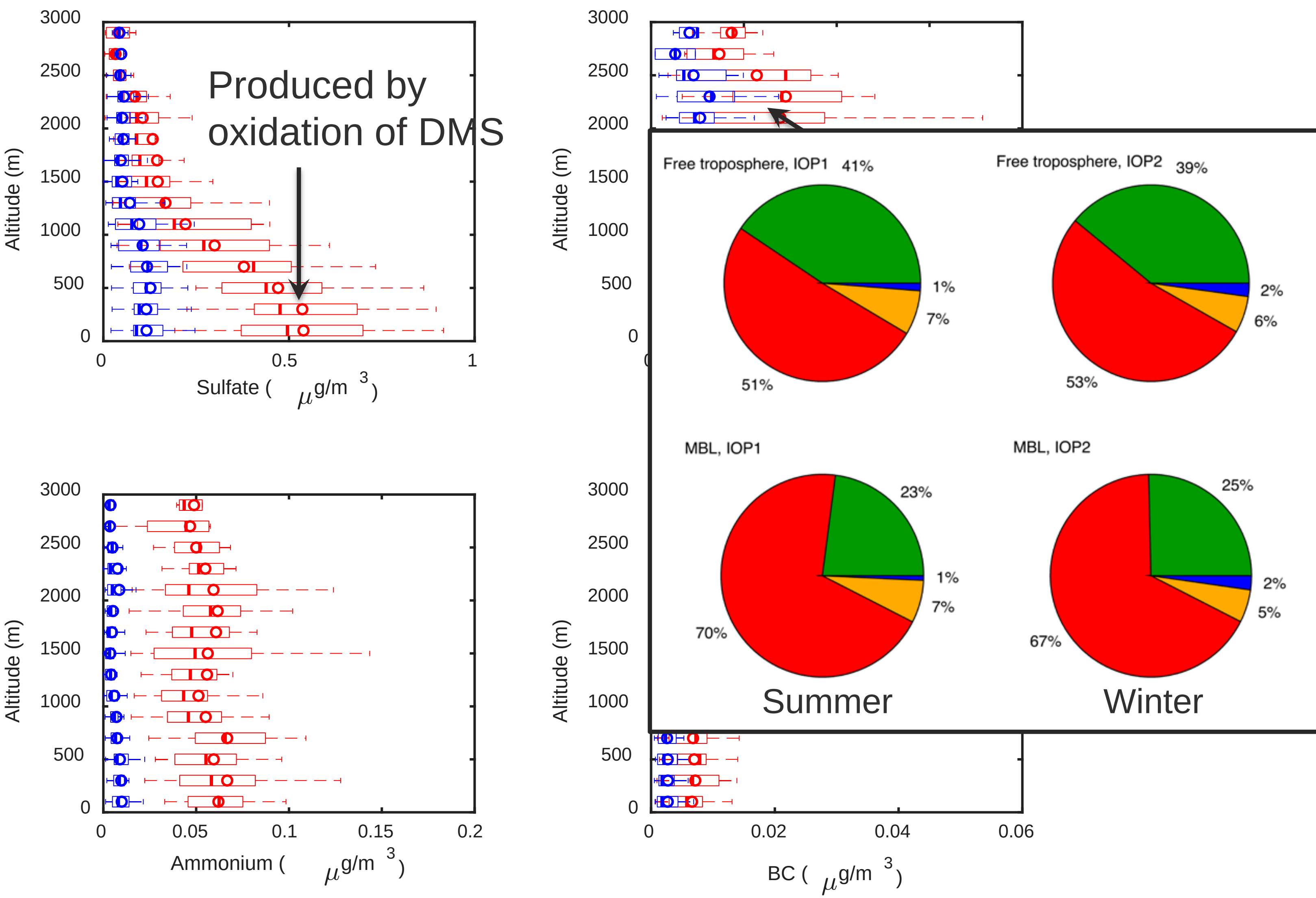
Higher accumulation mode concentration in MBL



Red: Summer IOP Blue: Winter IOP

- Entrainment of FT aerosol does not directly contribute to CCN population in marine boundary layer
- High particle number concentrations during summer season

Vertical profiles of aerosol composition



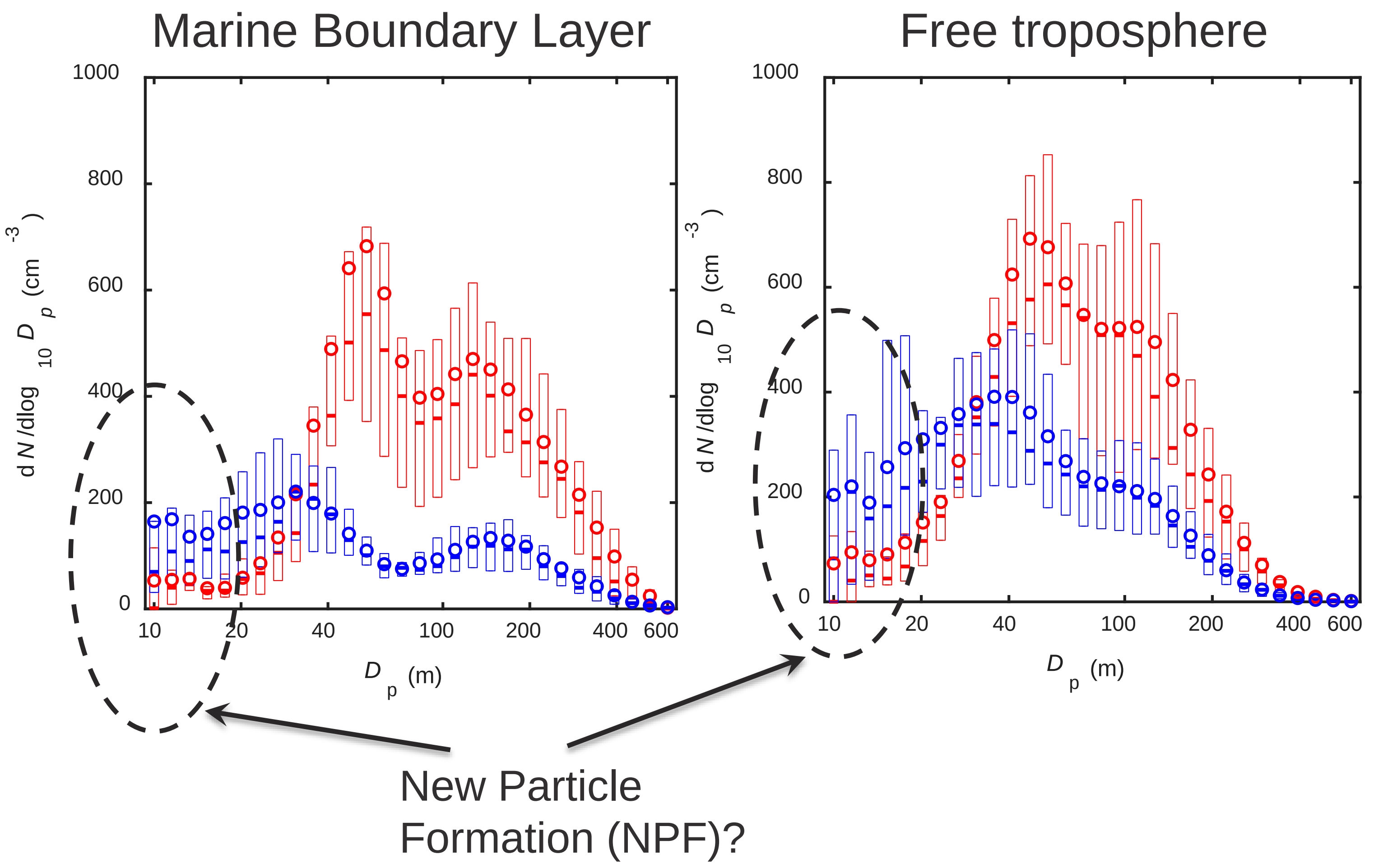
mass
osol

Zawadowicz et al.

Red: Summer IOP Blue: Winter IOP

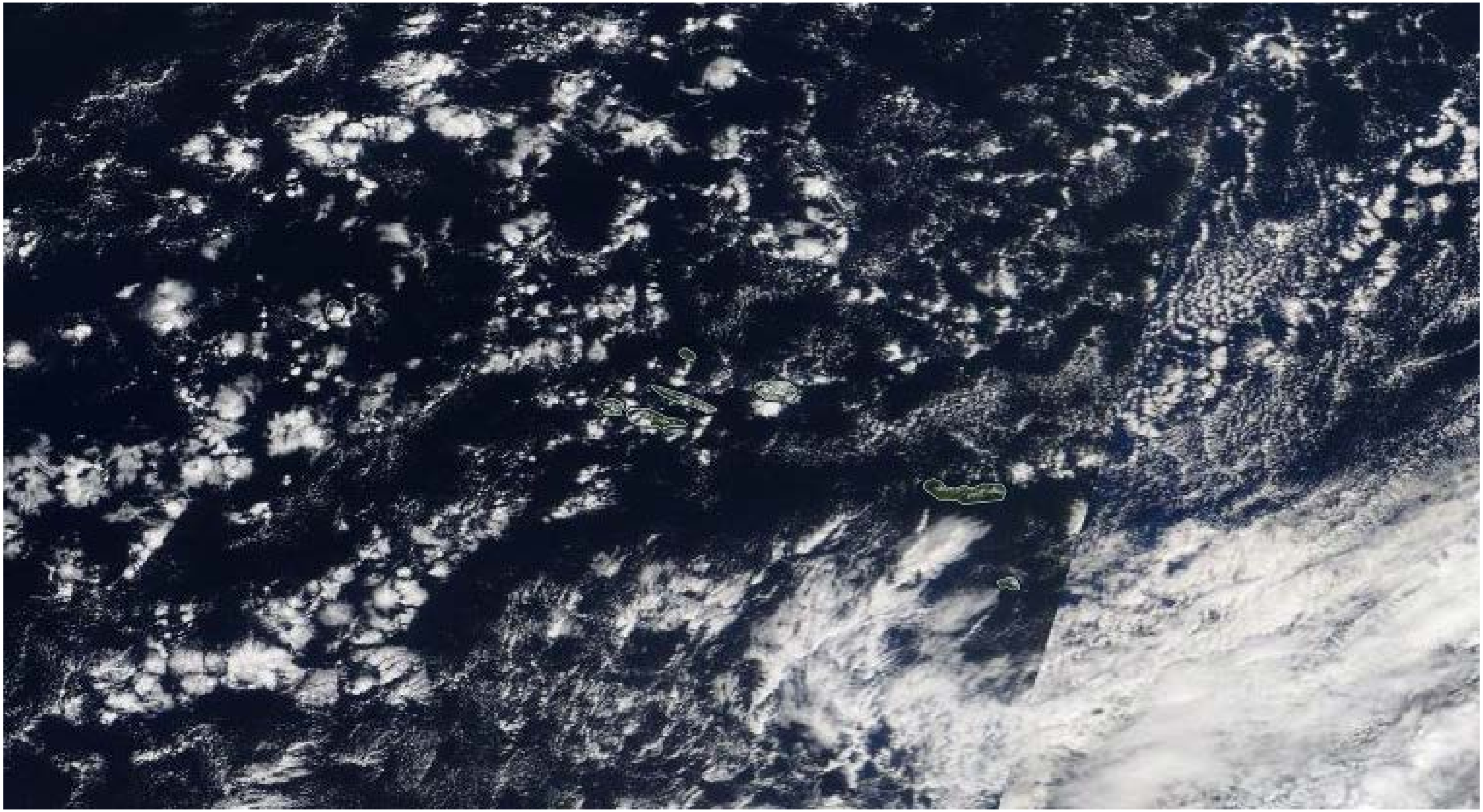
Seasonal variation of aerosol size distributions

Red: Summer IOP Blue: Winter IOP

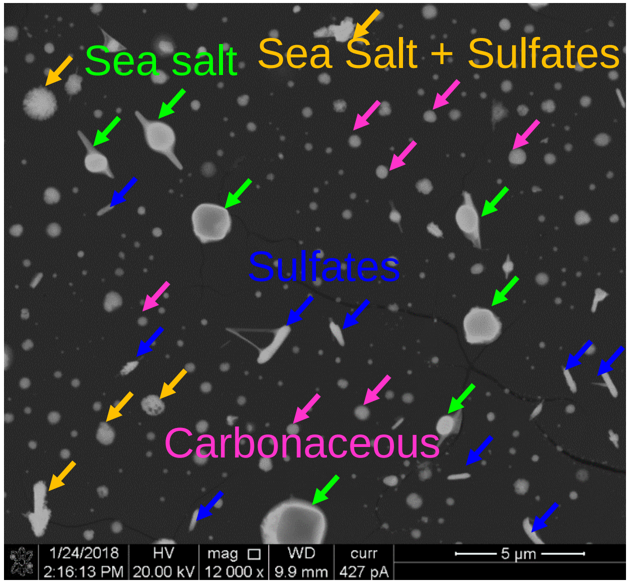


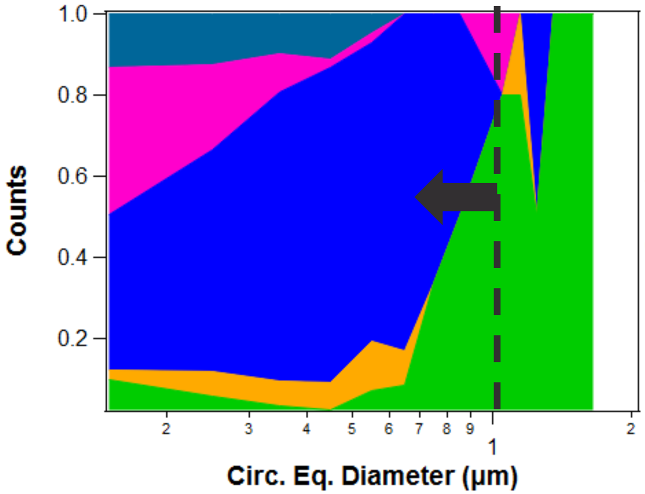
New particle formation following the passage of cold front

February 16, 2018

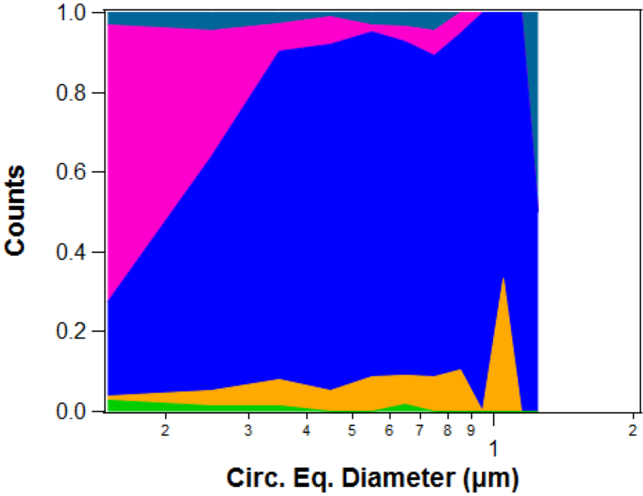


Submicron particles dominated by sulfate and carbonaceous aerosol





Boundary Layer (July 18th 2017)

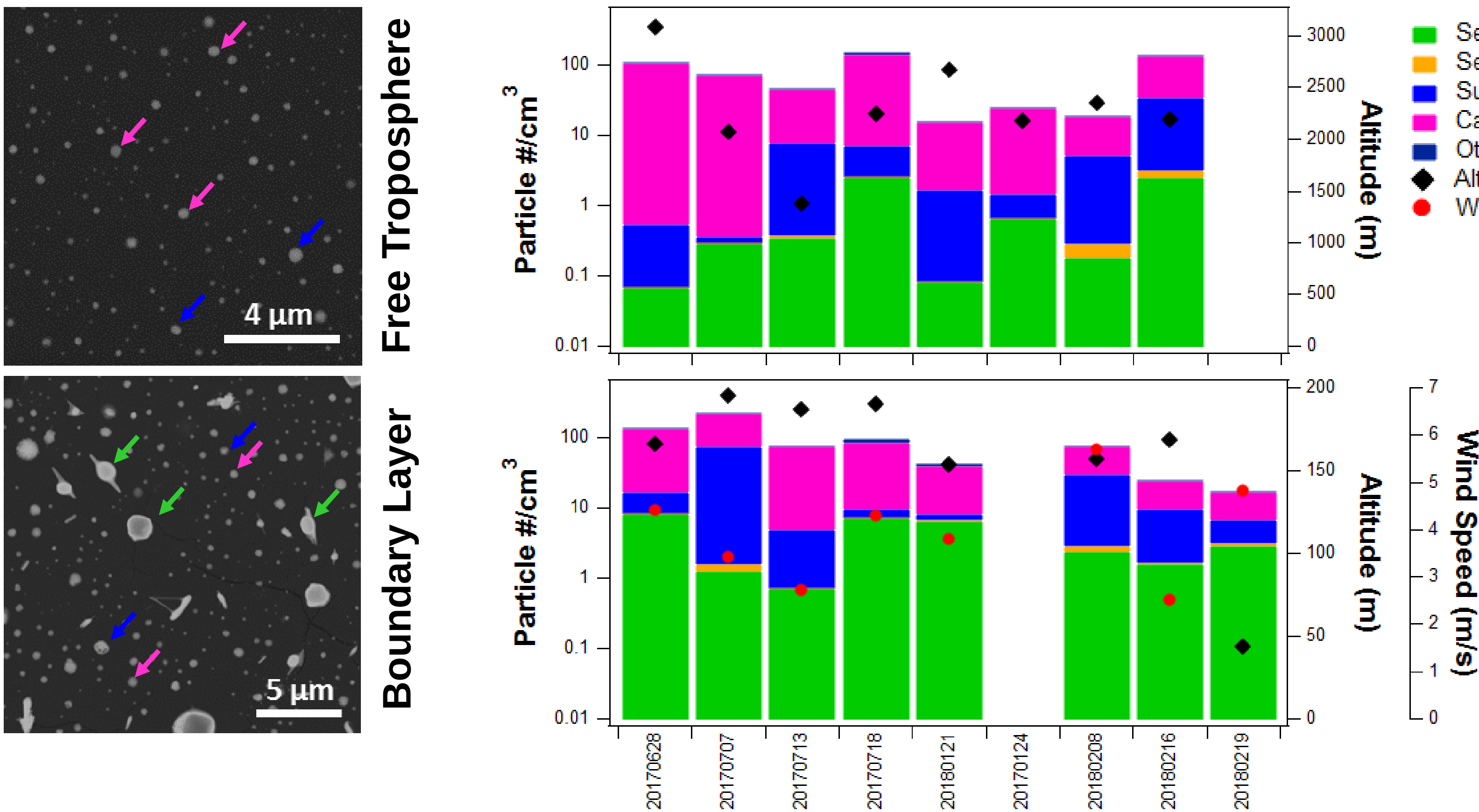


Free troposphere (July 18th, 2017)

- Number fraction of submicron aerosol dominated by sulfate and carbonaceous aerosol
- The contribution of sea spray aerosol to marine boundary layer CCN appears to be minor during summer season

Veghte et al.

Minor contribution of sea-salt to boundary layer aerosol number conc.



- Number fraction of submicron aerosol dominated by sulfate and carbonaceous aerosol
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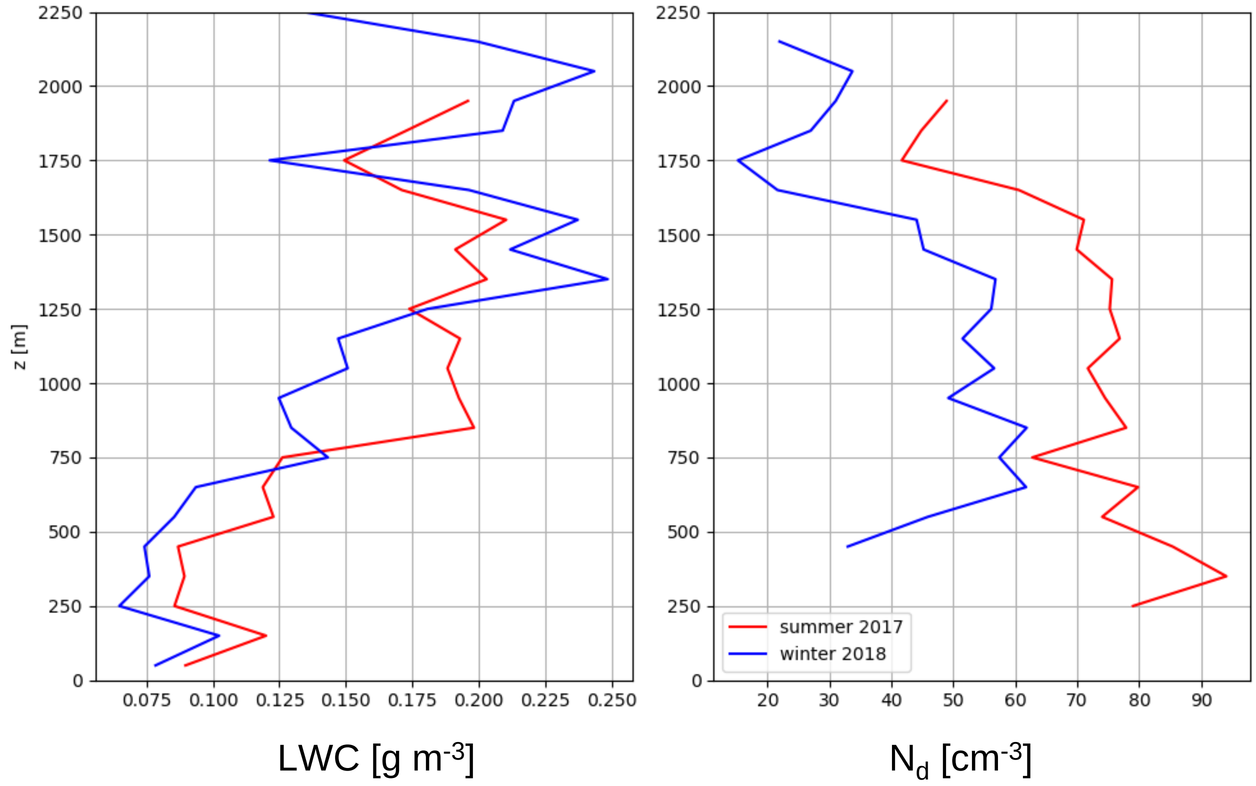
Veghte et al.

Vertical profiles of mean cloud liquid water and droplet concentration

Red: Summer IOP Blue: Winter IOP

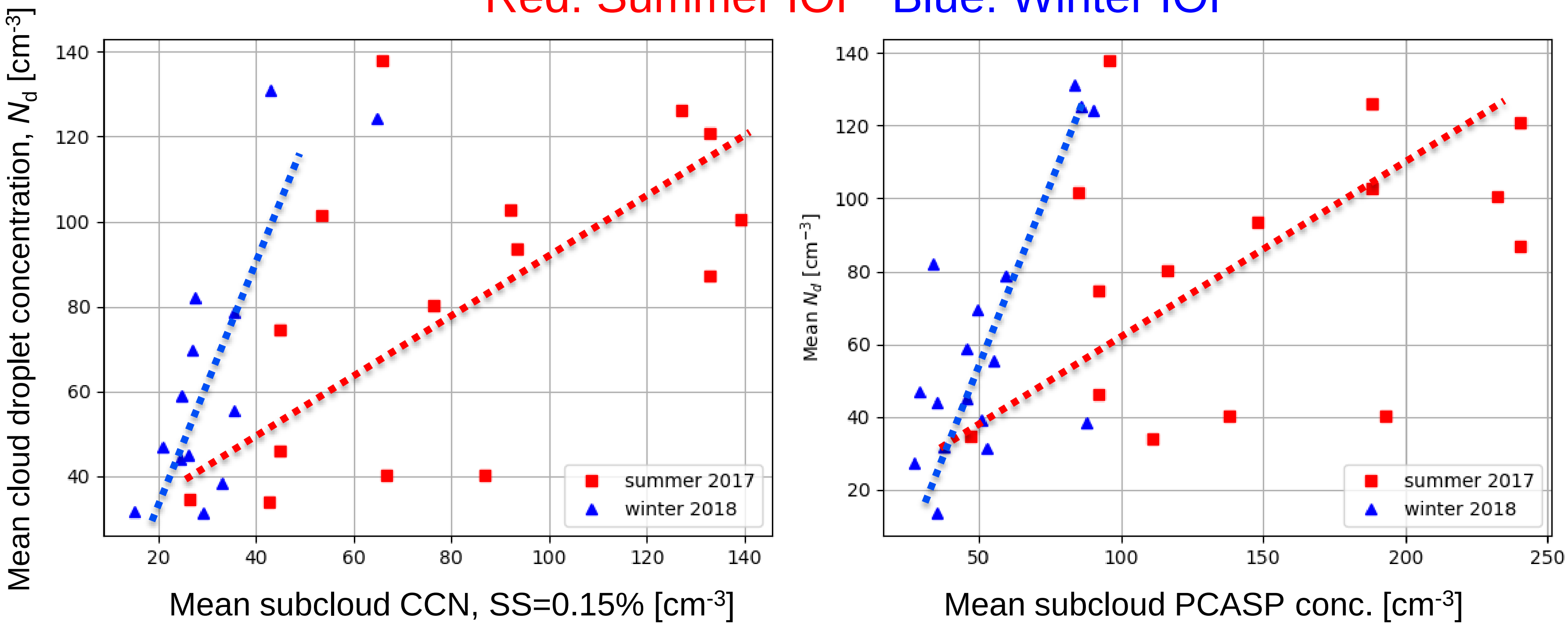
- Cloud-conditional mean profiles of liquid water content (left) and cloud droplet concentration (right)
- Weak seasonal cycle of mean LWC
- N_d ~ 40% higher during summer than winter, qualitatively consistent with CCN/accumulation mode aerosol concentrations, but quantitatively weaker seasonal cycle



Wood et al.

Seasonal differences in aerosol-cloud interactions

Red: Summer IOP Blue: Winter IOP



- Cloud N_d well correlated with CCN and PCASP concentrations in both summer and winter, but slope significantly higher in winter
- Invites more detailed exploration of N_d closure, exploring roles of updraft speed, layering/decoupling, etc.

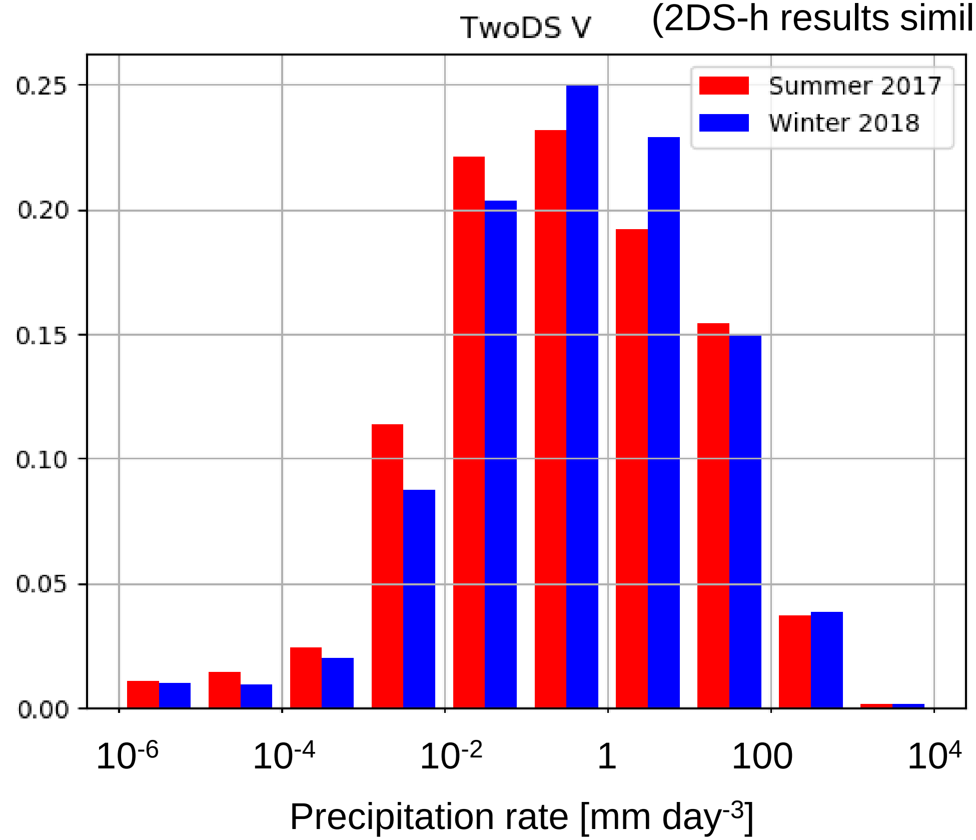
Wood et al.

Precipitation rate from 2D-S on the G-1

- Precipitation rates estimated using 2D-S size spectra for all clouds sampled in summer and winter campaigns
- Rates shifted to higher values in winter on average (consistent with similar LWC but lower N_d in winter ⇒ larger drops ⇒ more coalescence)
- Little seasonal difference in highest rates, biggest differences in intermediate rates (~mm day^{-1}), consistent with KAZR results.

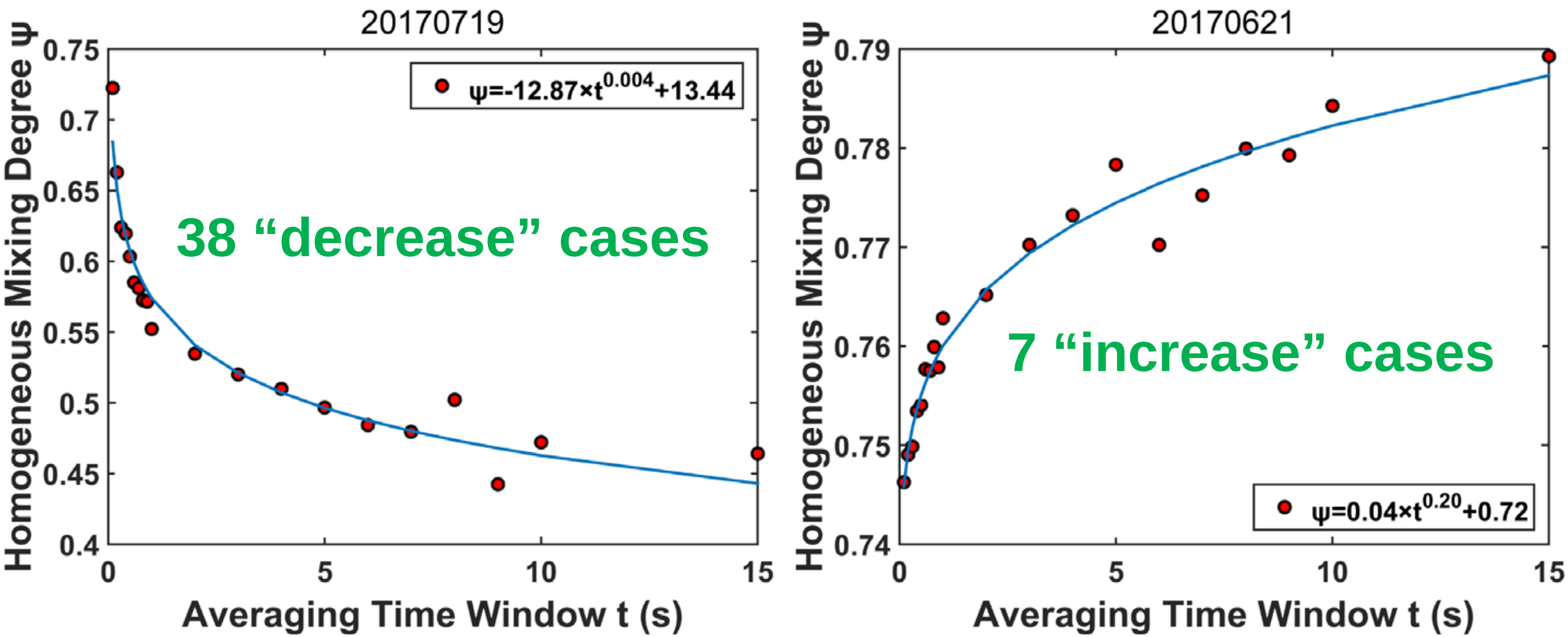
Red: Summer IOP Blue: Winter IOP

(2DS-h results similar)



Wood et al.

Scale Dependence of Entrainment-Mixing Mechanisms

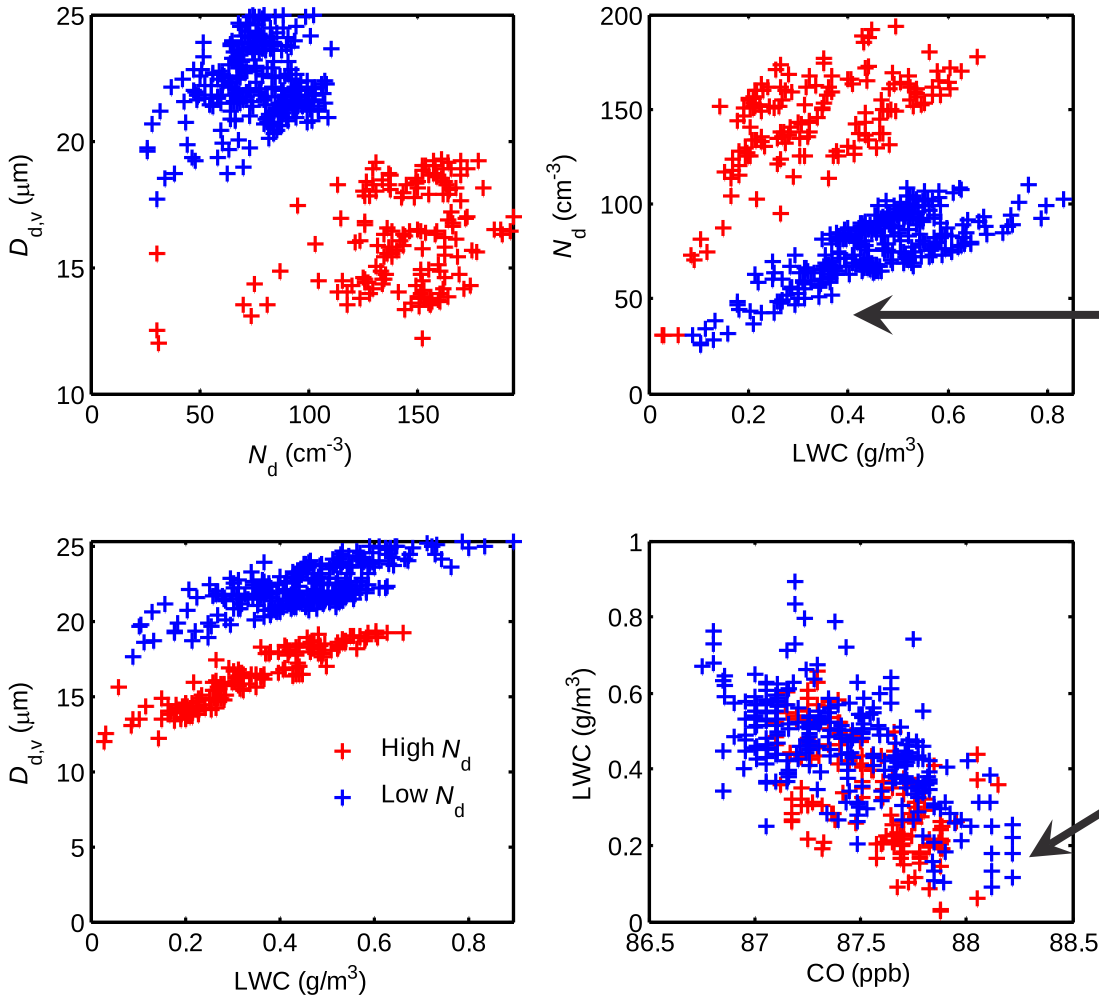


Lu et al.

Cloud microphysics

Strong inversion, well mixed, persistent Sc deck with drizzle (July 18, 2017)

Regions with high and low CCN concentrations



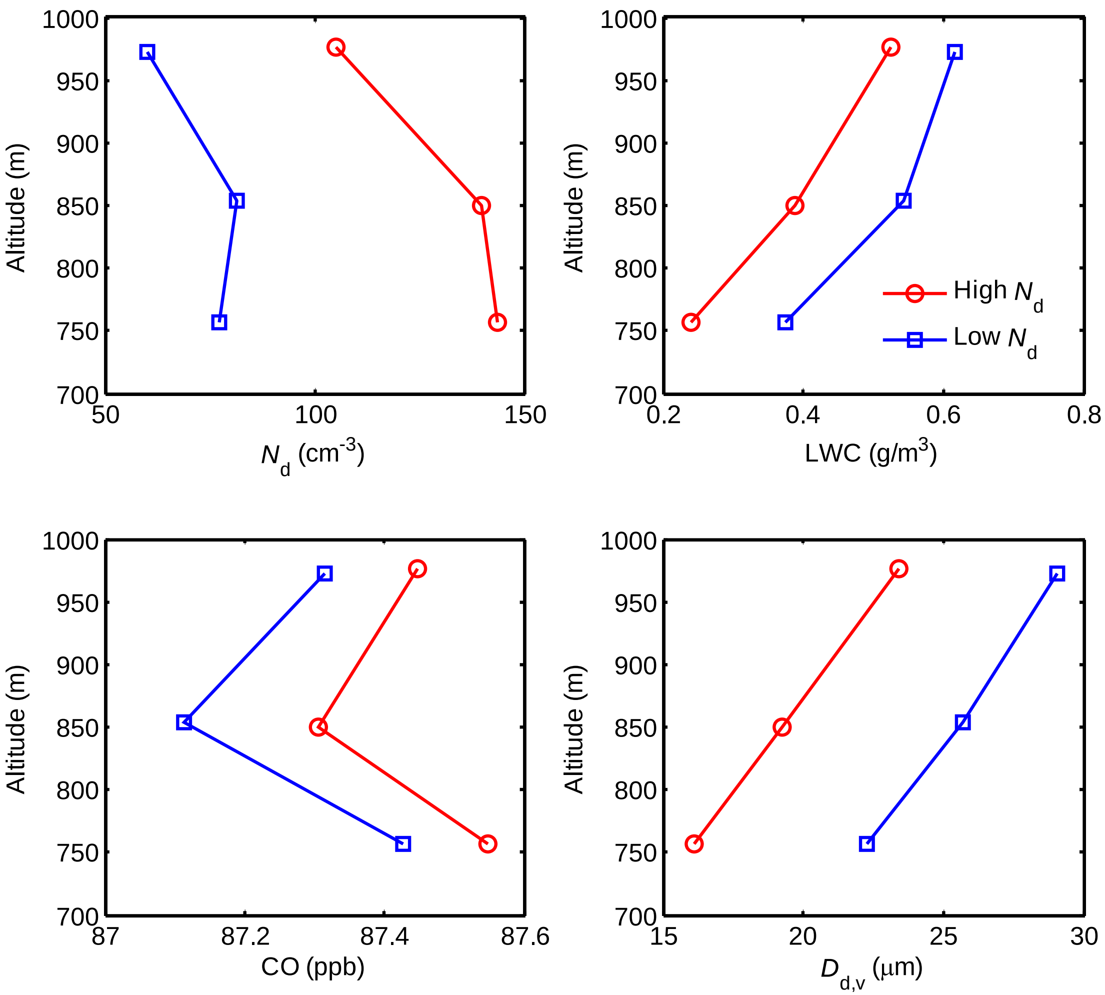
Data from 760 m leg inside clouds (Cloud base: ~600 m, Cloud top: ~1000 m.)

Lower N_d due to entrainment mixing (i.e., evaporation and dilution)

Lower LWC likely due to entrainment mixing

Influence of aerosol on LWC and entrainment

Regions with high and low CCN concentrations (July 18, 2017)

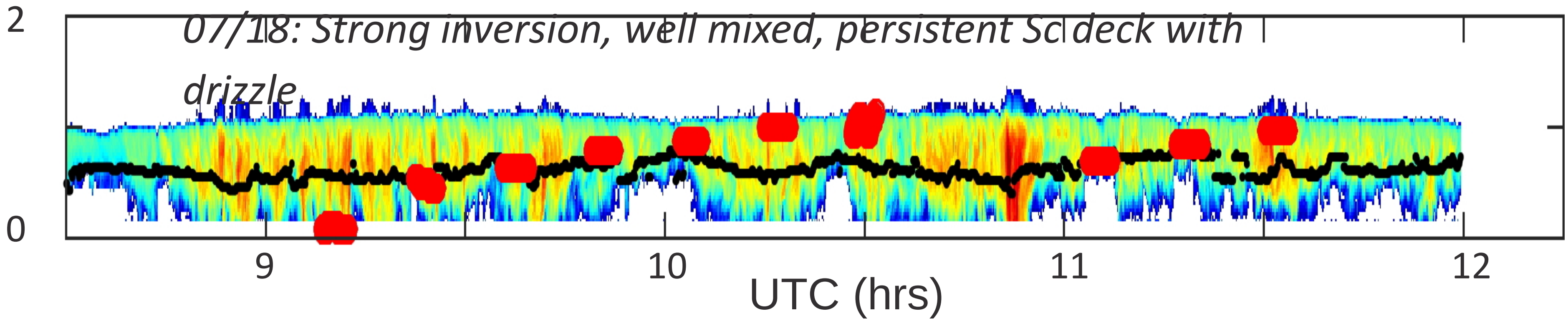


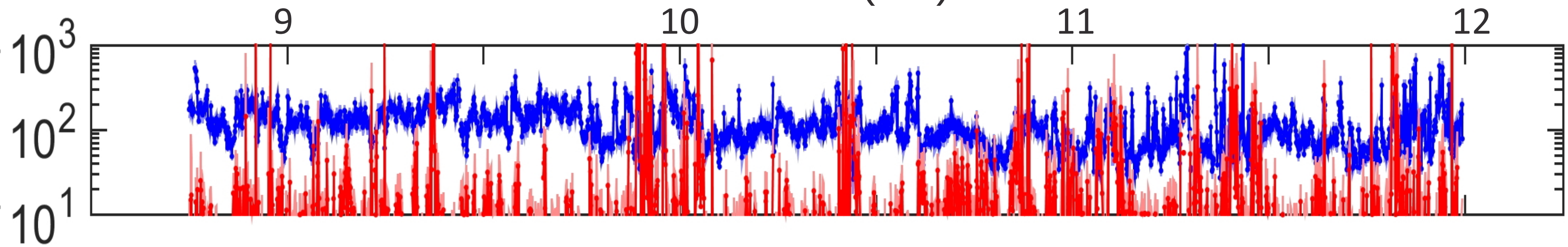
- Increased entrainment rate (i.e., higher CO mixing ratio) and lower LWC for clouds with higher droplet number concentration
- Drizzle/sedimentation stabilizes boundary layer, reduces turbulence and/or entrainment (Ackerman et al. 2004, Bretherton et al., 2007, Wood 2007)

Joint cloud/drizzle retrieval

Christine Chiu and Yann Blanchard, Colorado State University

- Separation between drizzle and cloud is challenging
- Drizzle retrieval in clouds is cutting-edge research



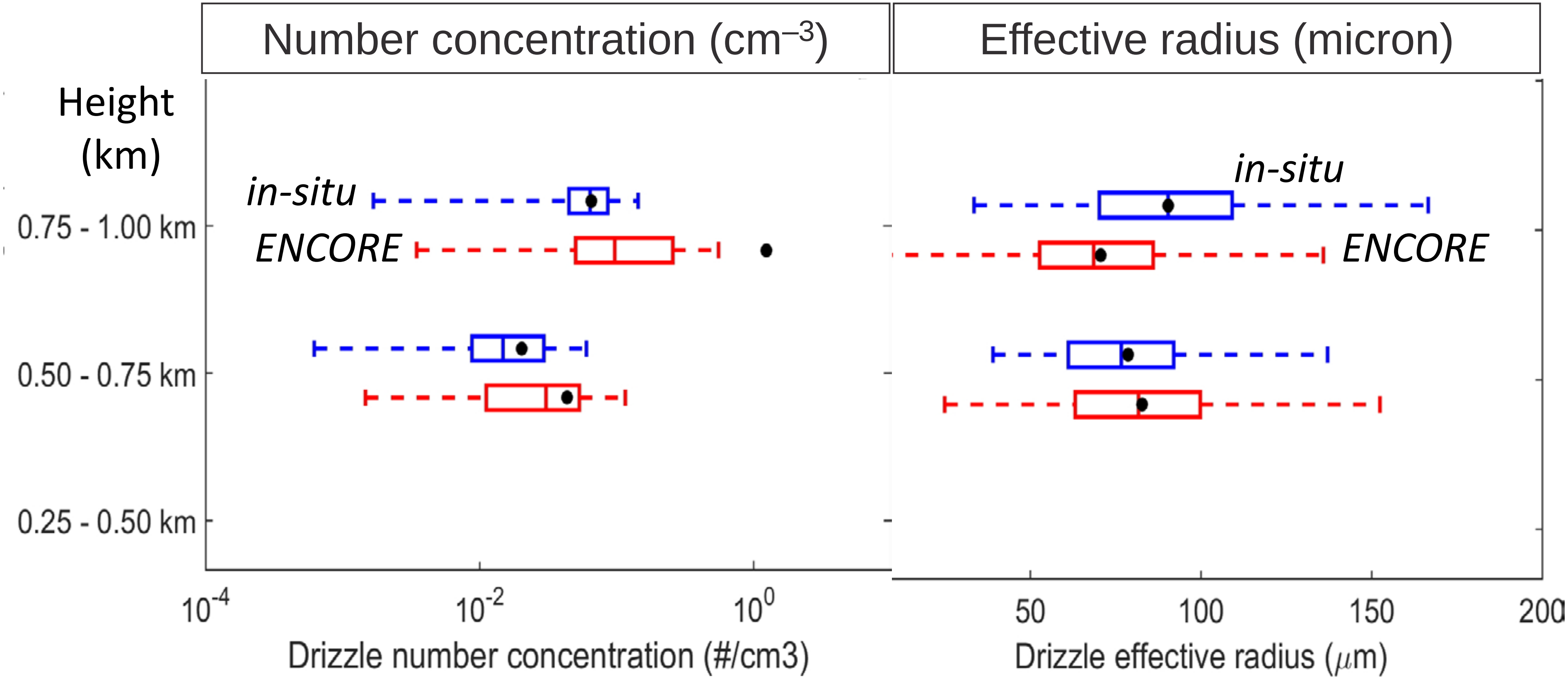


(blue) Cloud droplet number concentration (cm^{-3})

(red) Drizzle number concentration*100 (cm^{-3})

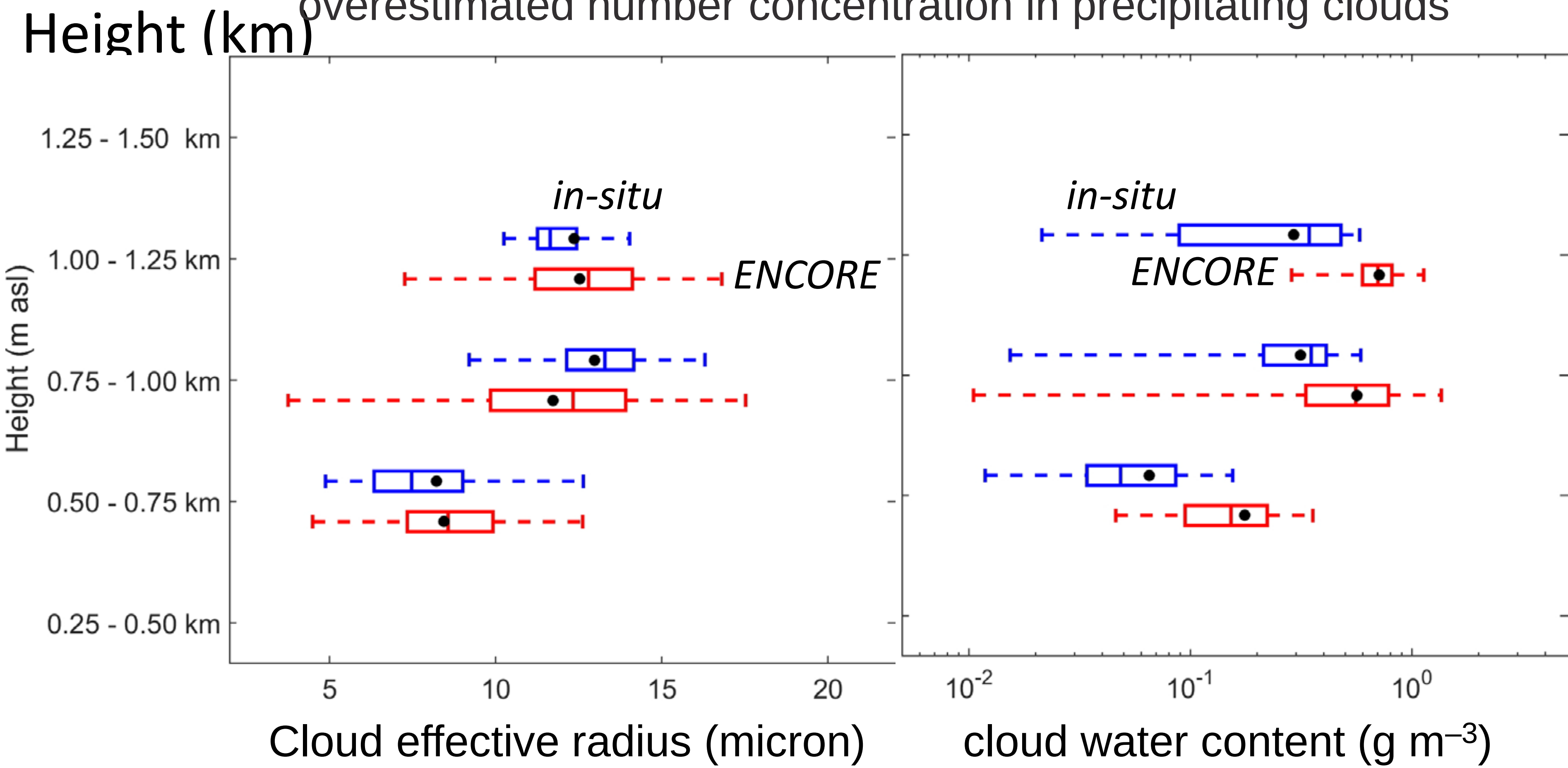
Comparison in ***drizzle*** properties

- Retrieval and in-situ data agree well, indicating that drizzle retrieval from current methods (not just ours) should be rather robust



Comparison in ***cloud*** properties

- Our retrieval method provides reasonable cloud effective radius, but cloud water content appears high due to overestimated number concentration in precipitating clouds



Summary of Preliminary results

- Rich new dataset to examine aerosol and cloud properties and their interactions under different meteorological, cloud, and aerosol conditions – most flights took place over the ARM ENA site
- Marked seasonal contrasts in MBL and FT aerosol properties
- CCN, accumulation mode aerosol concentration, sulfate, and organics higher in summer
- New particle formation following the passage of cold front
- The contribution of sea spray aerosol to marine boundary layer CCN appears to be minor during summer season
- Cloud droplet number concentration well correlated with CCN concentration in both summer and winter, but slope significantly higher during winter
- Evidence of increased entrainment and lower LWC for clouds with higher droplet number concentration

- Ongoing studies using ACE-ENA data
- Evaluation of global and LES models using observations.

Breakout Session: Aerosol and Cloud Experiments in Eastern North Atlantic (ACE-ENA)

Tuesday, June 11th, 2019, 1:30-3:30 pm (room: Salon C)		
1:30-1:40	Seasonal differences in clouds, MBL, and aerosol-cloud interactions in ENA	Robert Wood
1:40-1:50	Vertical Profiles of Trace Gas and Aerosol Properties over the Eastern North Atlantic	Yang Wang
1:50-2:00	Joint retrievals of cloud and drizzle - examples and evaluations from the ACE-ENA campaign	Christine Chiu
2:00-2:10	MBL microphysical properties retrieved from ground-based observations and aircraft in-situ measurements during ACE-ENA	Baike Xi
2:10-2:20	Chemical composition of individual particles collected onboard G-1 aircraft during the ACE-ENA study	Alex Laskin
2:20-2:30	Individual Particle Characterization of the Carbon Content of Aerosols Collected in the Eastern North Atlantic	Ryan Moffett
2:30-2:40	A new approach to estimate supersaturation fluctuations in stratocumulus cloud using ground-based remote sensing measurements	Fan Yang
2:40-2:50	Scale Dependence of Entrainment-Mixing Mechanisms in the Stratocumulus Clouds during ACE-ENA	Chunsong Lu
2:50-3:00	Simulations of Summertime Post-Frontal Transition Cloudiness during the July 17-19 Cold Frontal Passage.	Mark Miller
3:00-3:05	Aerosol filter for local sources at ENA	Allison Aiken
3:05-3:10	New Microphysical Insights from Analysis of Centimeter-Resolution Holographic Data during ACE-ENA	Neel Uday Desai
3:10-3:30	Group discussion	

Acknowledgements

- Funding agency:
  - ✓ Atmospheric Radiation Measurement (ARM) program, Dept. of Energy
  - ✓ Atmospheric System Research (ASR) program, Dept. of Energy

- ARM aerial facility Gulfstream-1 aircraft pilots and crew
- ARM climate research facility staff

Thank you!