# A proposed AeroCom-ATom study/analysis

Huisheng Bian, Christina Willingsom, and Mian Chin

## What's the AToM mission

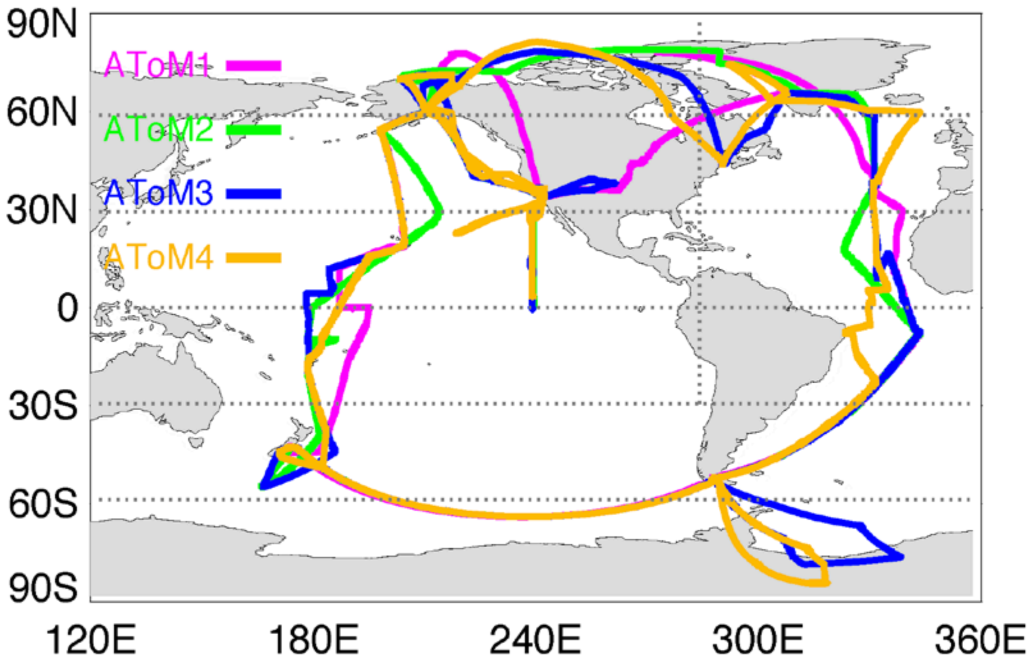
### A 5-year mission funded by NASA Earth Venture Suborbital-2 (EVS2) program

(i) four deployments in each of the 4 seasons over a 3-year period (starting 2016);

(ii) flight routes over the Pacific, Atlantic, Southern Ocean, North America, and Greenland from 85°N to 65°S to establish a comprehensive, global-scale dataset;

(iII) profiling continuously from 0.2 to 12 km altitude.

(iv) use ~20 instruments on the NASA DC-8;



**ATom fills the following aerosol observational gaps relevant to this study:**

(i) Aerosol vertical distributions over remote oceans over global scale and 4 seasons;

(ii) particle size distributions from 0.004 µm through 50 µm diameter, spanning newly formed, CCN-active, and larger particles;

(iii) organic and inorganic aerosol composition data;

(iv) gas-phase tracer data to provide source and transport information.

# Experiment design

Share the same Base simulation with aircraft-general, but with some different output fields.
*only on three years of 2016-2018* and ask for sensitive simulations

1. ATom-general ----- aerosol composition, vertical distribution, size distribution, and processes
   - Base – all emissions
   - ExpA – no anthropogenic emission
   - ExpB – no biomass burning emission
   - ExpC – ocean emission only (optional)

2. ATom-NPF ----- atmospheric new particle formation processes
   - Base - same as ATom-general
   - ExpNuc - Free tropospheric aerosol nucleation switched off
   - ExpSO2 - Anthropogenic $SO_2$ emissions switched off
   - ExpIon, ExpTer, ExpOrg - If your nucleation scheme includes multiple elements (e.g. ion-induced, ternary, organic), swithching each of these elements off

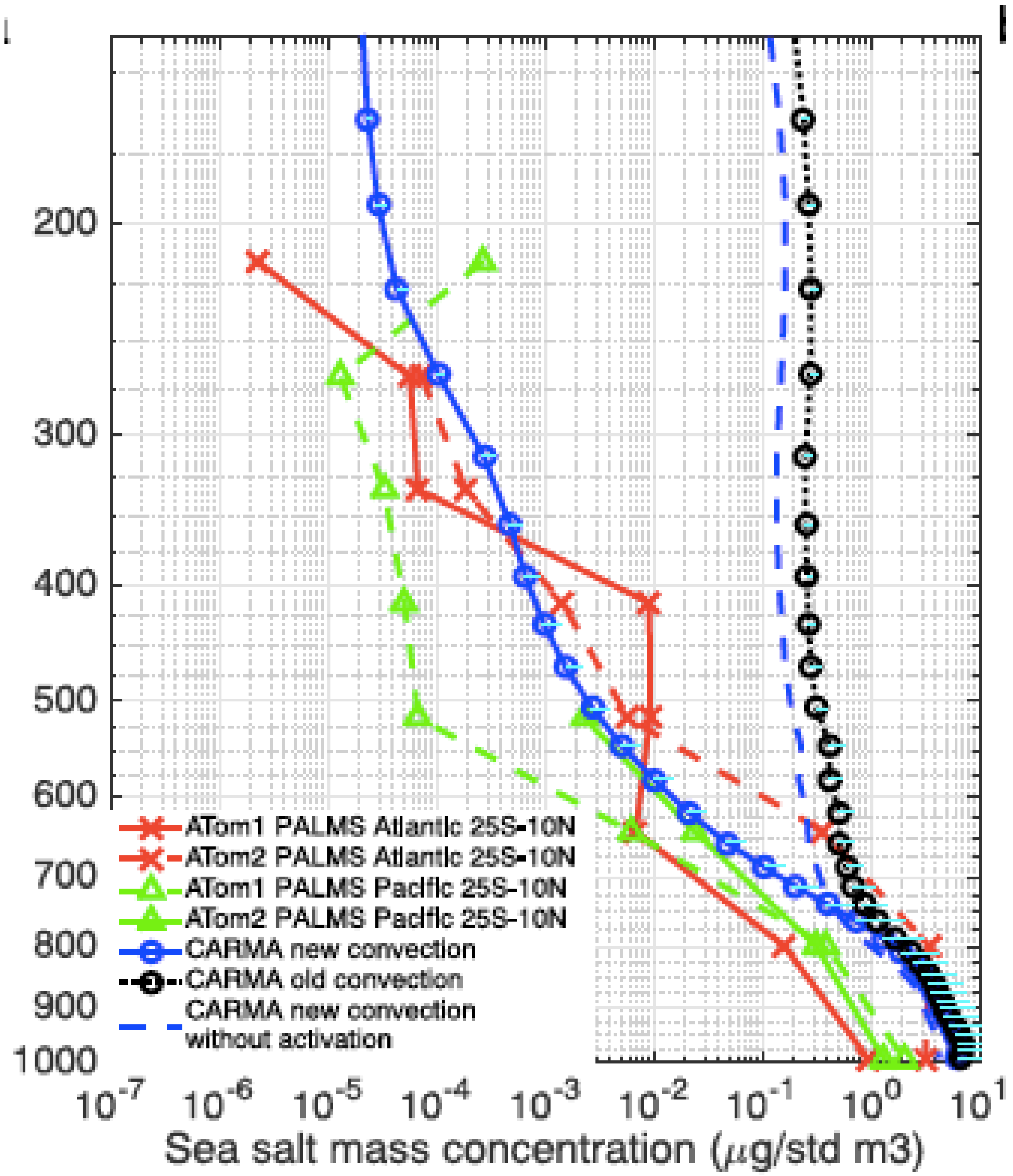
# Scientific Questions:

- *What are the distributions of aerosols and precursor gases in the remote areas measured in ATom and simulated by models?*
- *What are the sources (anthropogenic, natural, transported from land, emitted from ocean) of aerosols in the remote areas?*
- *How do chemistry, transport, and removal processes determine the composition and vertical distributions of aerosols in different seasons and locations?*

- *What are the sources of new particles in the remote marine boundary layer (MPBL) and free troposphere, how rapidly do they grow to Cloud Condensation Nuclei (CCN)-active sizes, and how well are these processes represented in models?*

- *How to improve the processes in models to best represent the ATom observations?*

# Improve model vertical convection using ATom measurement



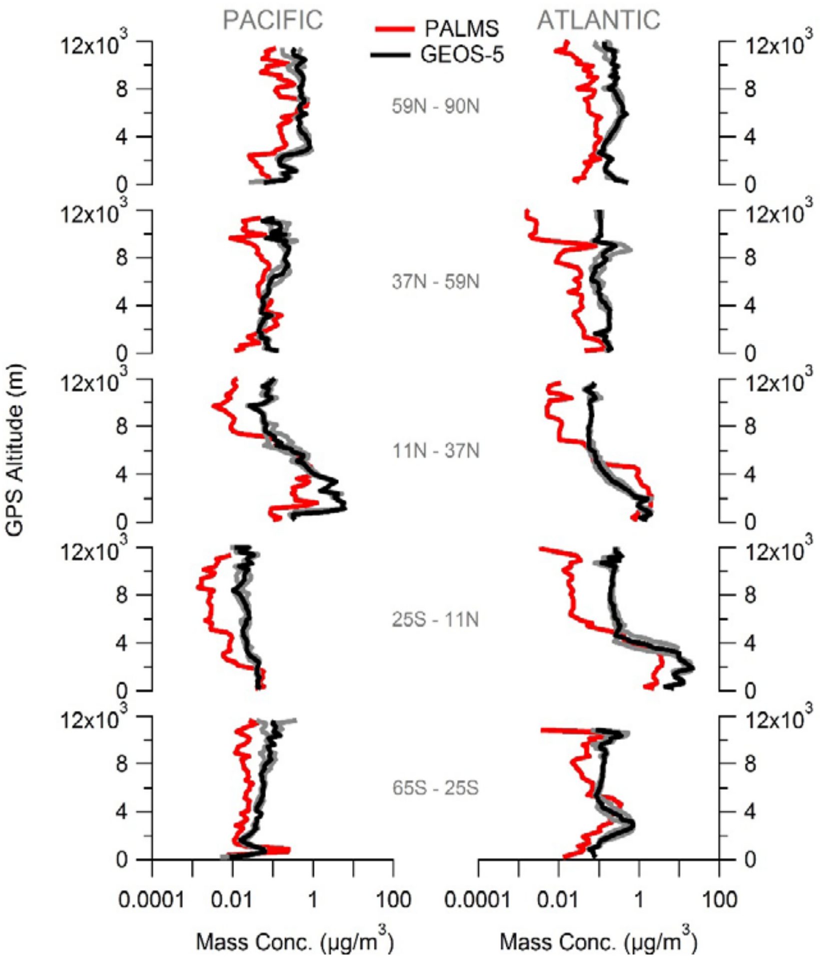

Yu et al., 2019, GRL

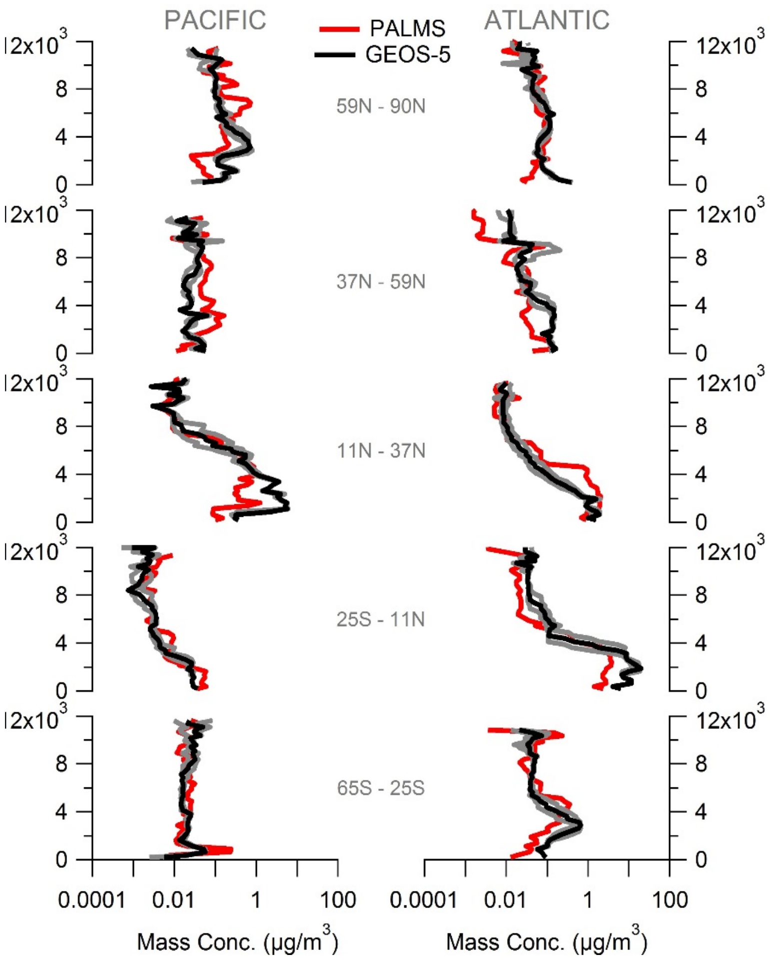
**Improve model wet scavenging**

# ATom1: Removal Processes

| OA in standard version | OA Cold Cloud Scavenging |
| --- | --- |

PALMS
GEOS-5





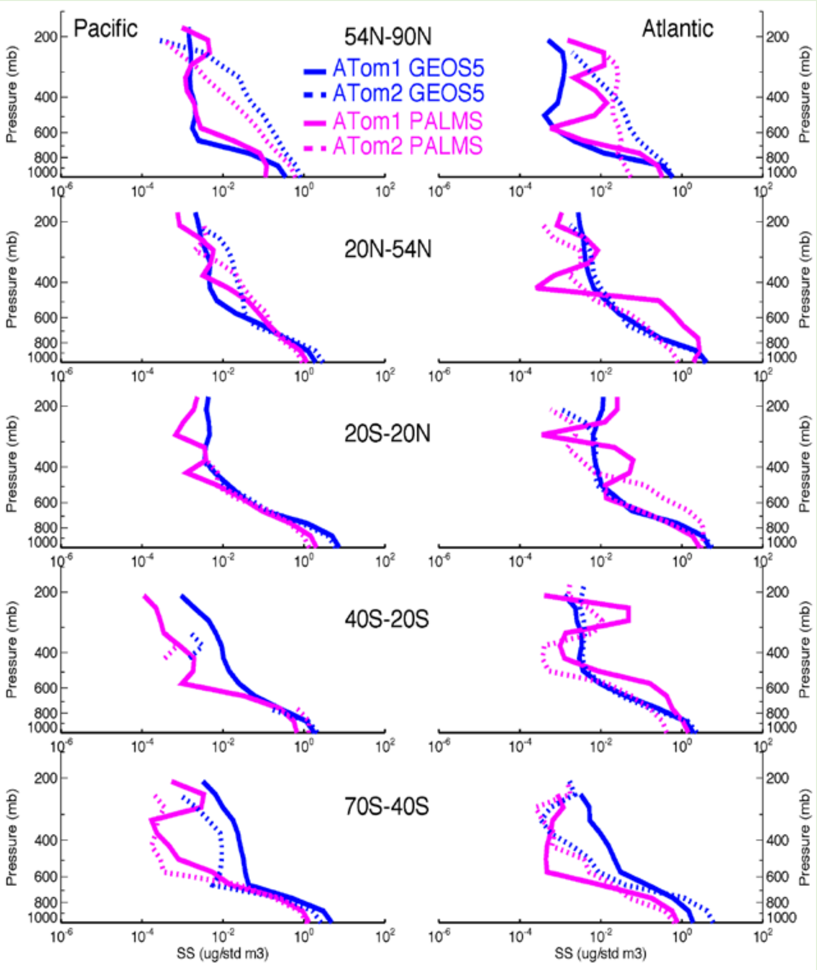
Gregory Schill
Huisheng Bian

Paper submitted

# Diagnose problem

Bian et al., (2019), ACP

## SS Vertical Profiles

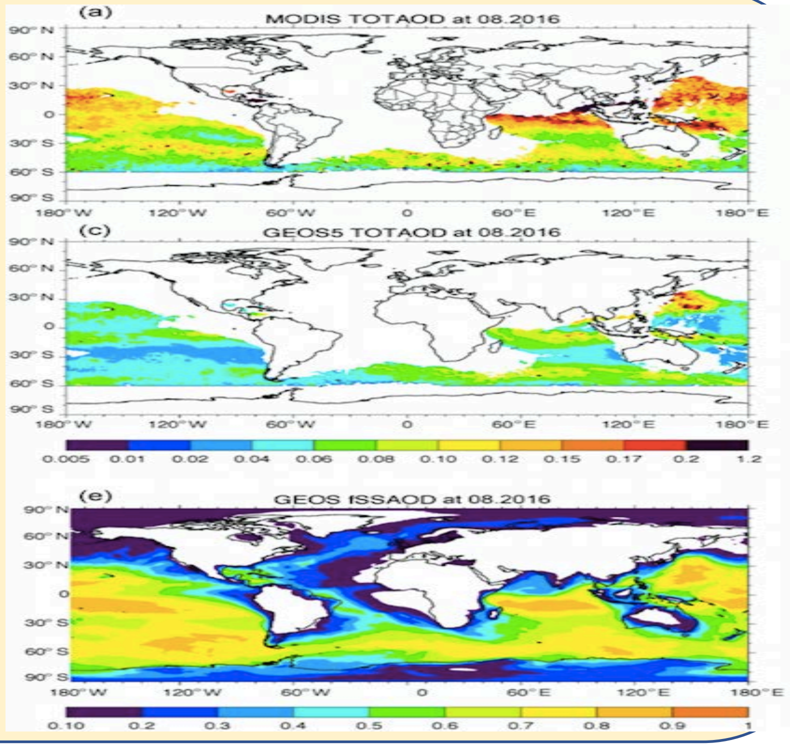



Globally GEOS SS mass is > 2x larger than PALMS SS mass

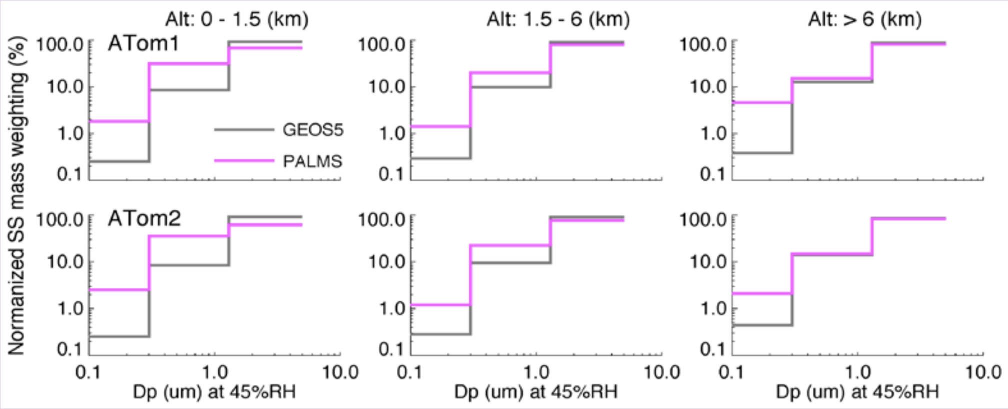
MODIS AOD

GEOS AOD

fSSAOD



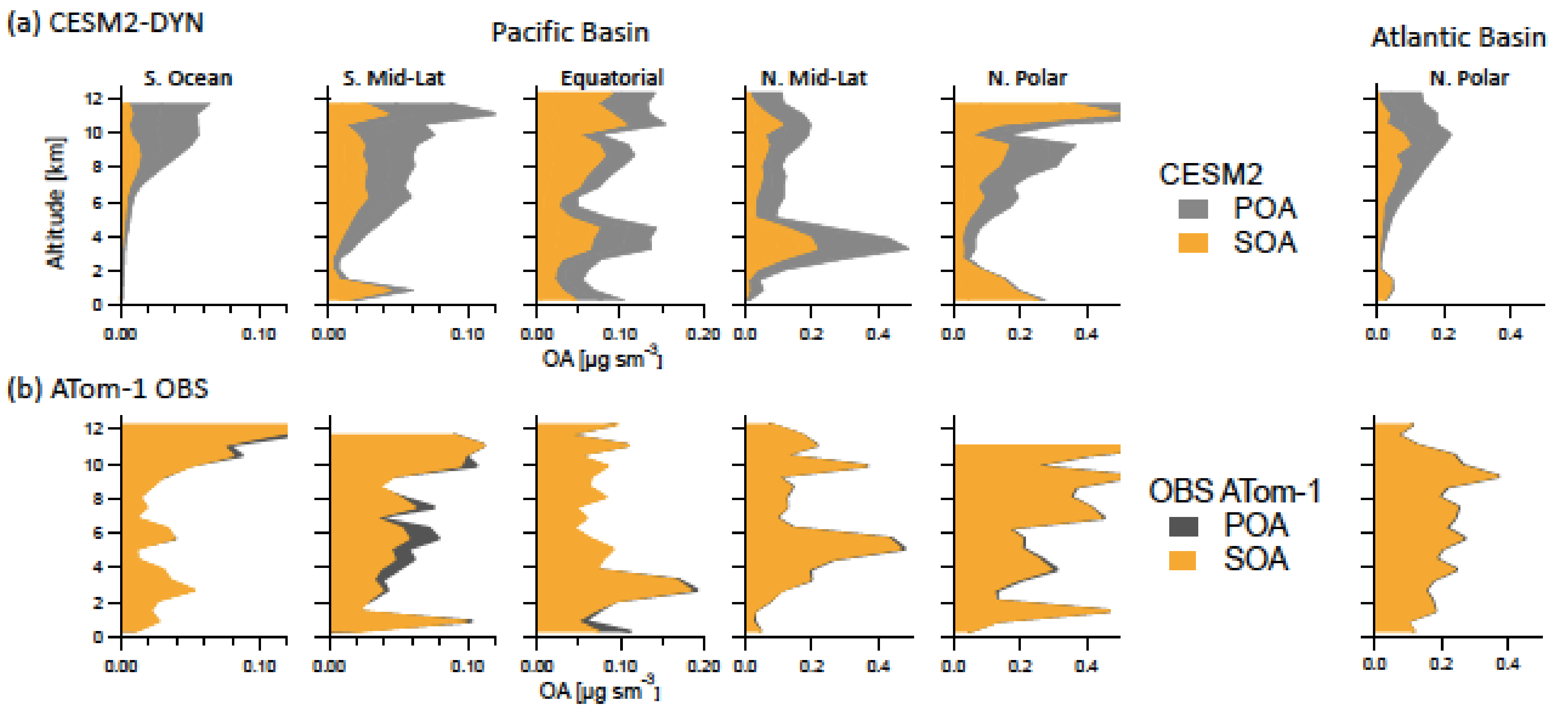

## SS size distribution




**GEOS SS size distribution favors coarse particles!!!**

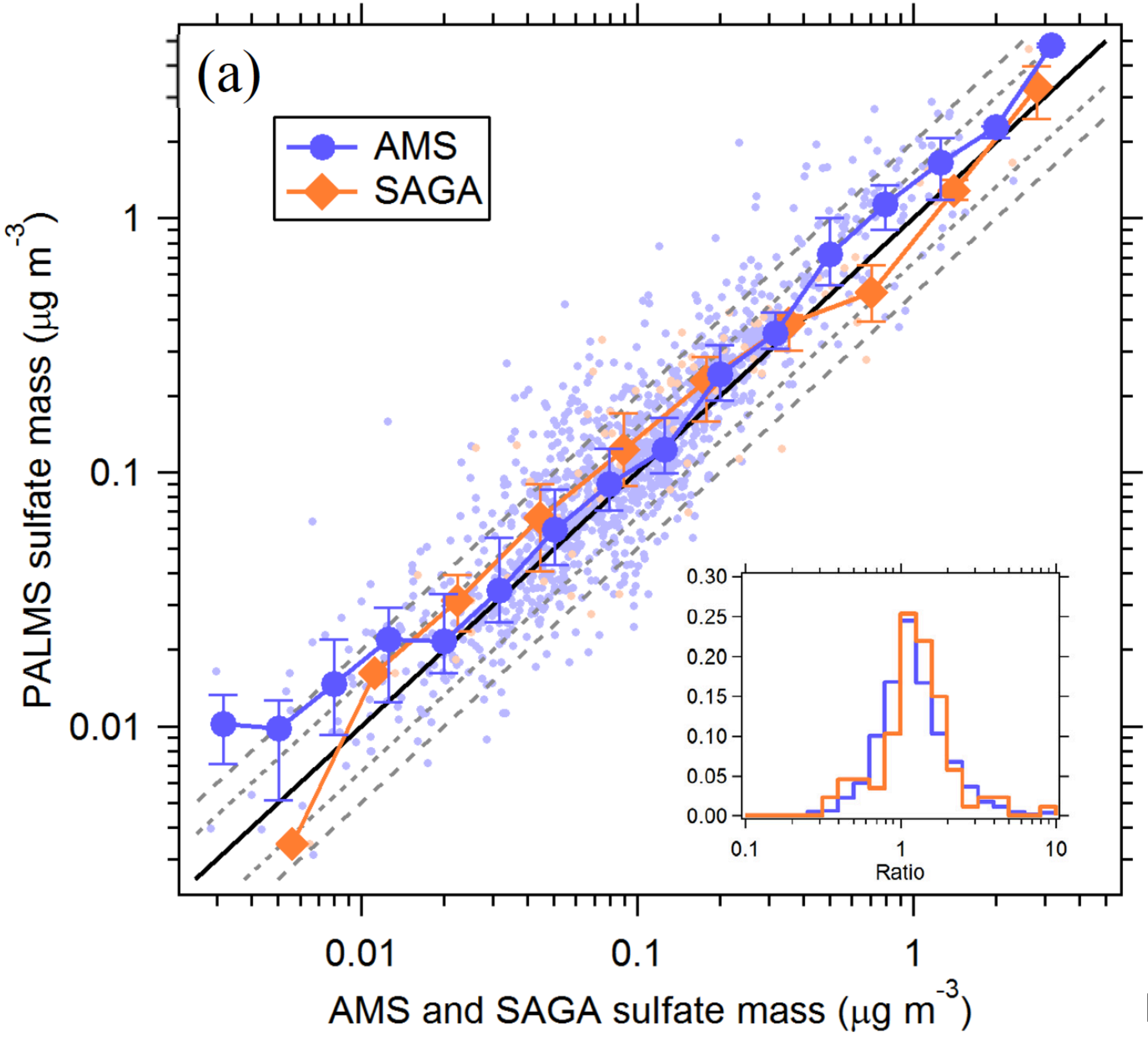
**Diagnose problem**

# Importance of POA vs SOA




Hodzic et al., 2019, ACPD

# ATom measurement for sulfate family




In additional to high quality SO4 measurements, ATom campaign also provide measurements for MSA, SO2, and DMS

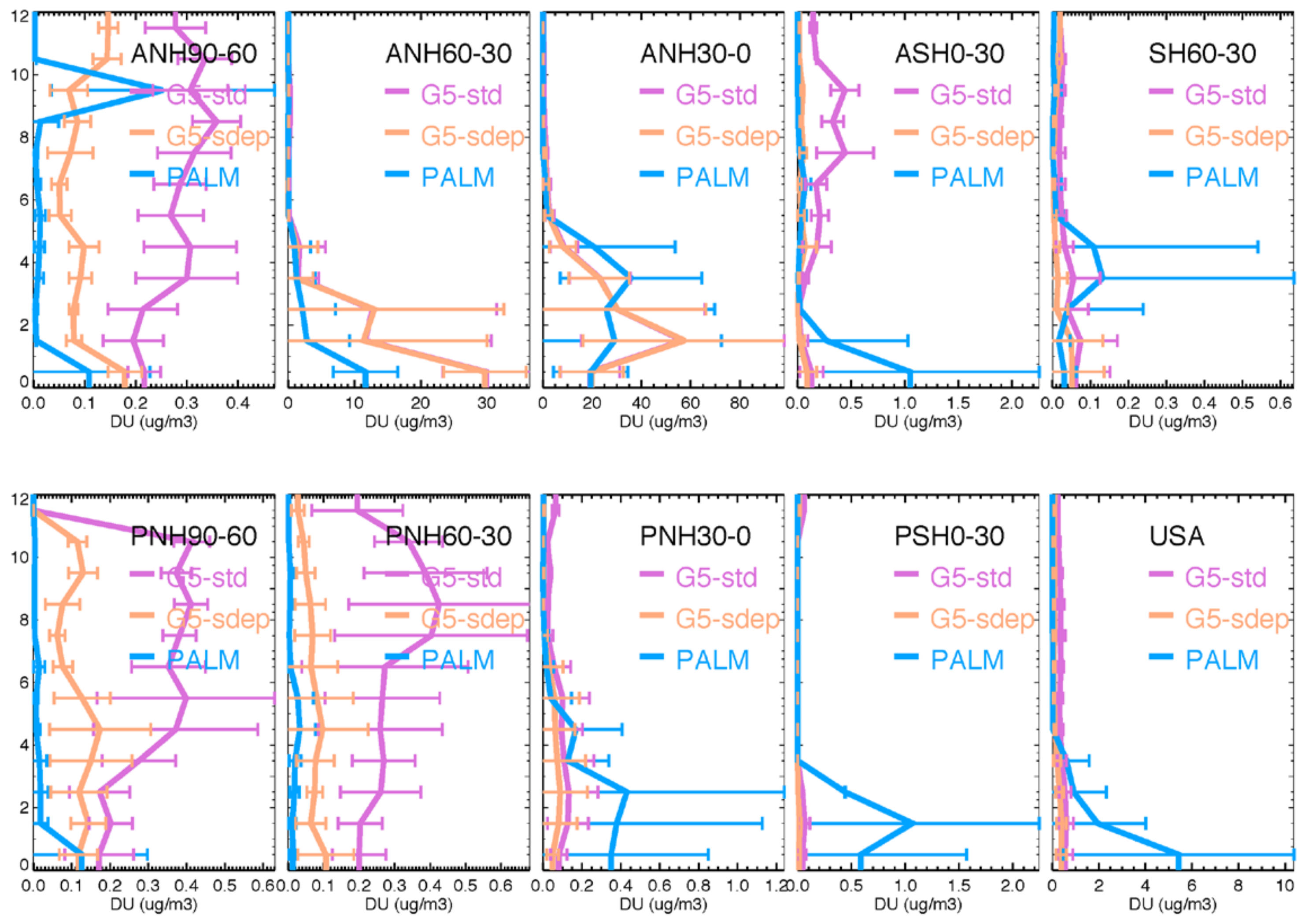
Froyd et al., 2019, AMTD

Six groups express interest in participating the experiment

We call more modelers to join in

Go to https://wiki.met.no/aerocom/phase3-experiments to get more information for ATom experiment

# Improve model wet scavenging




Dust wet deposition experiment set up:

1. G5-Std: Current default
2. G5-Sdep: allow large scale rainout when T < 258K

By Huisheng Bian

# Potential participants

| model | modeler | Which institution |
|---|---|---|
| CEMS | Pengfei Yu | NOAA, USA |
| ECHAM | David Neubauer | ETHZ, Australia |
| GEOS | Huisheng Bian | NASA, USA |
| IMPROVE | Jialei Zhu | U. Of Michigan, USA |
| OsloCTM3 | Gunnar Myhre | cicero.oslo, Norway |
| SPRINTARS | Toshihiko Takemura | riam.kyushu-u.ac, Japan |

We call more modelers participate the experiment

Go to https://wiki.met.no/aerocom/phase3-experiments to get more information for ATom experiment

# A proposed AeroCom-ATom study/analysis

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(ii) flight routes over the Pacific, Atlantic, Southern Ocean, North America, and Greenland from 85°N to 65°S to establish a comprehensive, global-scale dataset;

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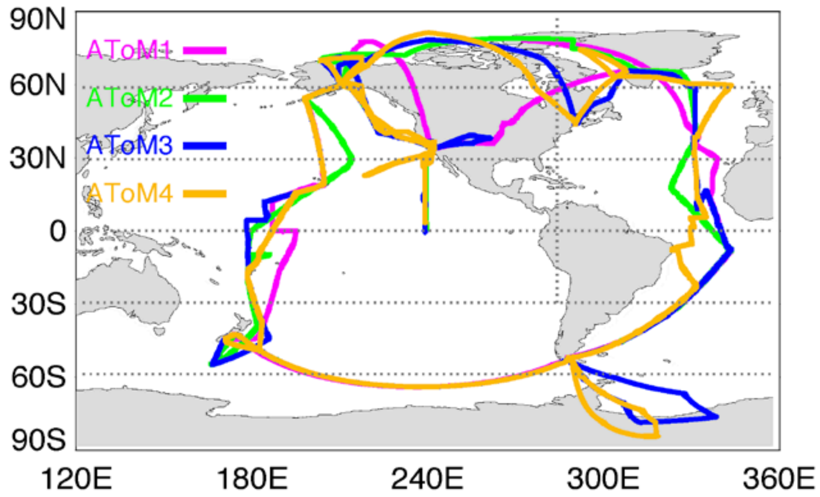
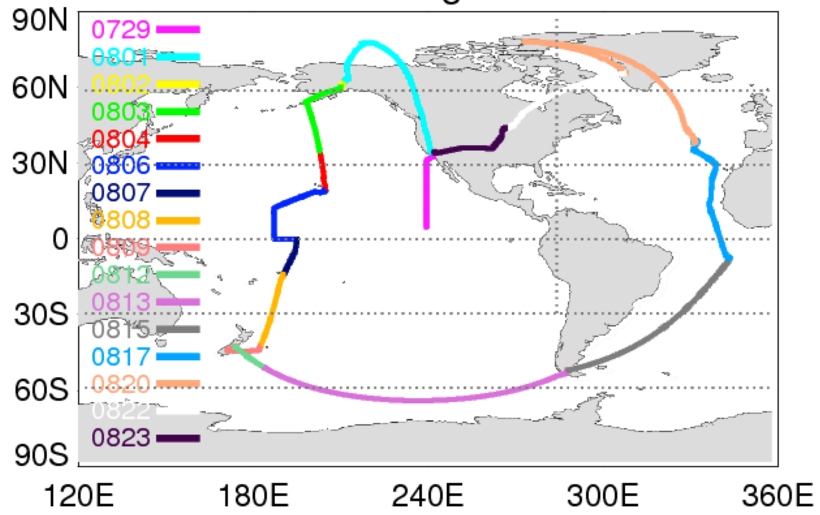



AToM1 flighttrack



Aerosol and related species from ATom measurements

| Species | Instrument* |
|---|---|
| ***Aerosol composition and microphysics:*** | |
| Particle distribution (4-1000 nm) | AMP |
| Cloud droplet size distribution (2-50 μm) | AMP |
| BC mass concentration and coating state | SP2 |
| $SO_4^{2-}$, $NO_3^-$, $NH_4^+$, $Cl^-$ | HR-AMS |
| OA, particle O/C, H/C, and OM/OC ratio | HR-AMS |
| Single particle composition (200-4000 nm), particle type fractions for $SO_4^{2-}$/OA/ $NO_3^-$, EC, sea salt, dust, biomass burning | PALMS |
| Particle type volume concentration | PALMS |
| MSA/ $SO_4^{2-}$ ratio | PALMS |
| $SO_4^{2-}$, $NO_3^-$, $NH_4^+$, $Cl^-$, $Na^+$, $Ca^{2+}$, $K^+$, $Mg^{2-}$ | SAGA filters |
| $^{7}Be$, $^{210}Pb$ | SAGA filters |
| ***Precursor gases and related species:*** | |
| $SO_2$ | CIT-CIMS |
| DMS | WAS, TOGA |
| OCS | WAS, PANTHER, PFP |
| CO | HTS, PANTHER/UCATS |
| $CO_2$ | HTS |
| ***Other:*** | |
| Pressure, temperature, winds, turbulence | MMS |
| Spectrally-resolved actinic flux (280-650 nm) | CAFS |

**Objectives**

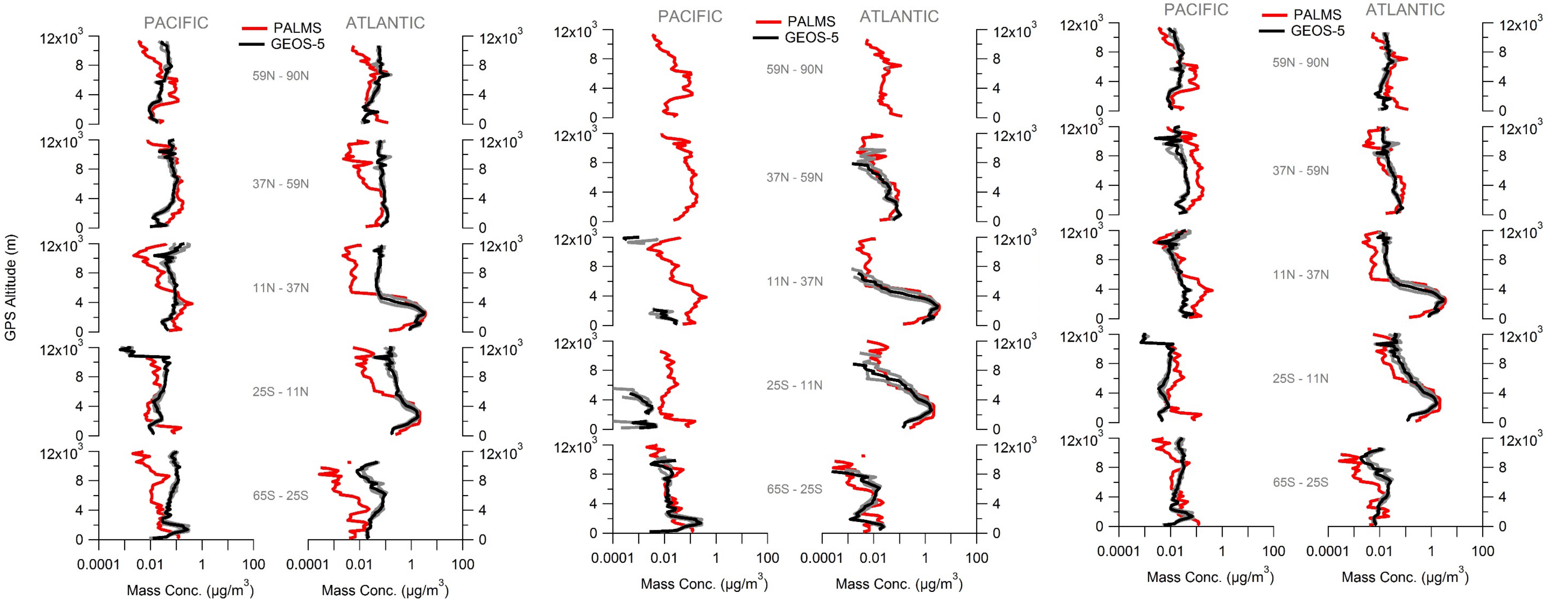
1. Evaluate model --- ATom mission provides unprecedented comprehensive measurements over remote oceans from near surface up to low stratosphere.
2. Improve the processes in models to best represent the ATom observations.
3. Investigate the sources (anthropogenic, natural, transported from land, emitted from ocean) of aerosols in the remote oceans and the processes of chemistry, transport, and removal that determine the composition and vertical distributions of aerosols in different seasons and locations.
4. Study new particle formation and CCN activation mechanisms.

Go to https://wiki.met.no/aerocom/phase3-experiments to get more information for ATom experiment

**Improve model wet scavenging**

# ATom2: Emission Inventories

| QFED | OC Cold Cloud Scavenging | OC1 Cold Cloud Scavenging |
| --- | --- | --- |

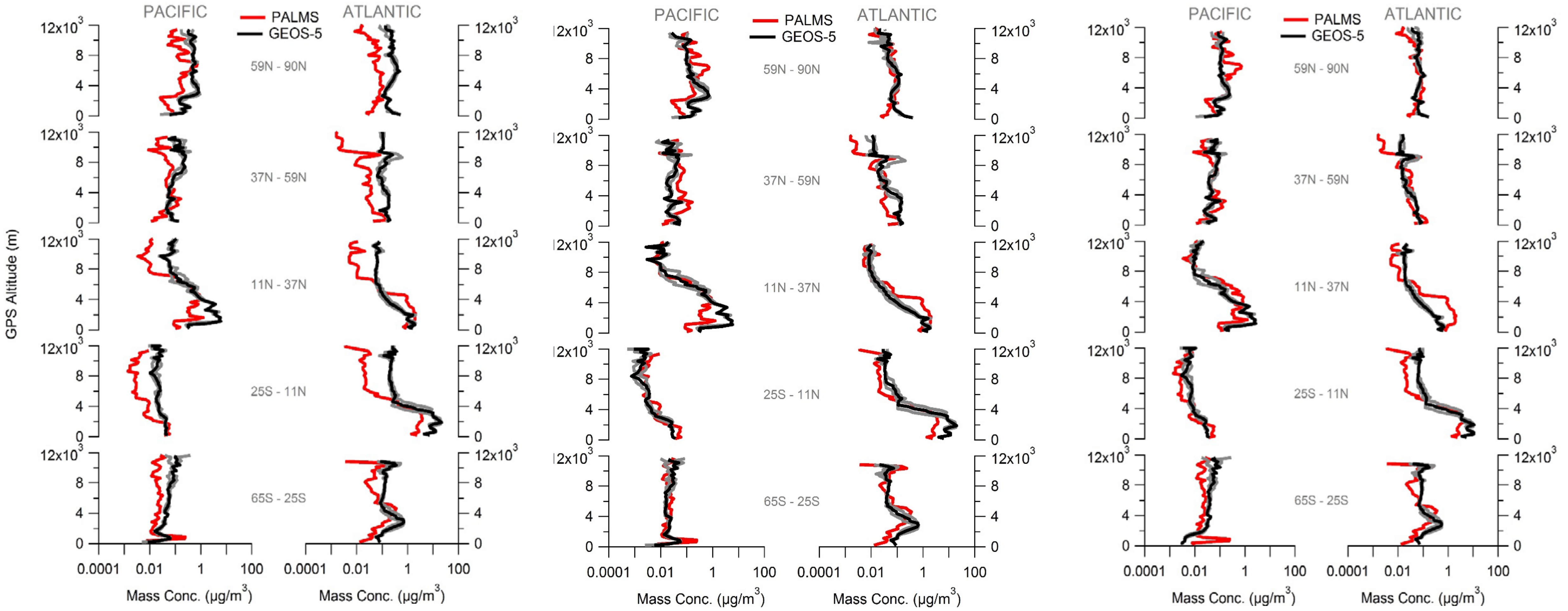


OC wet removal

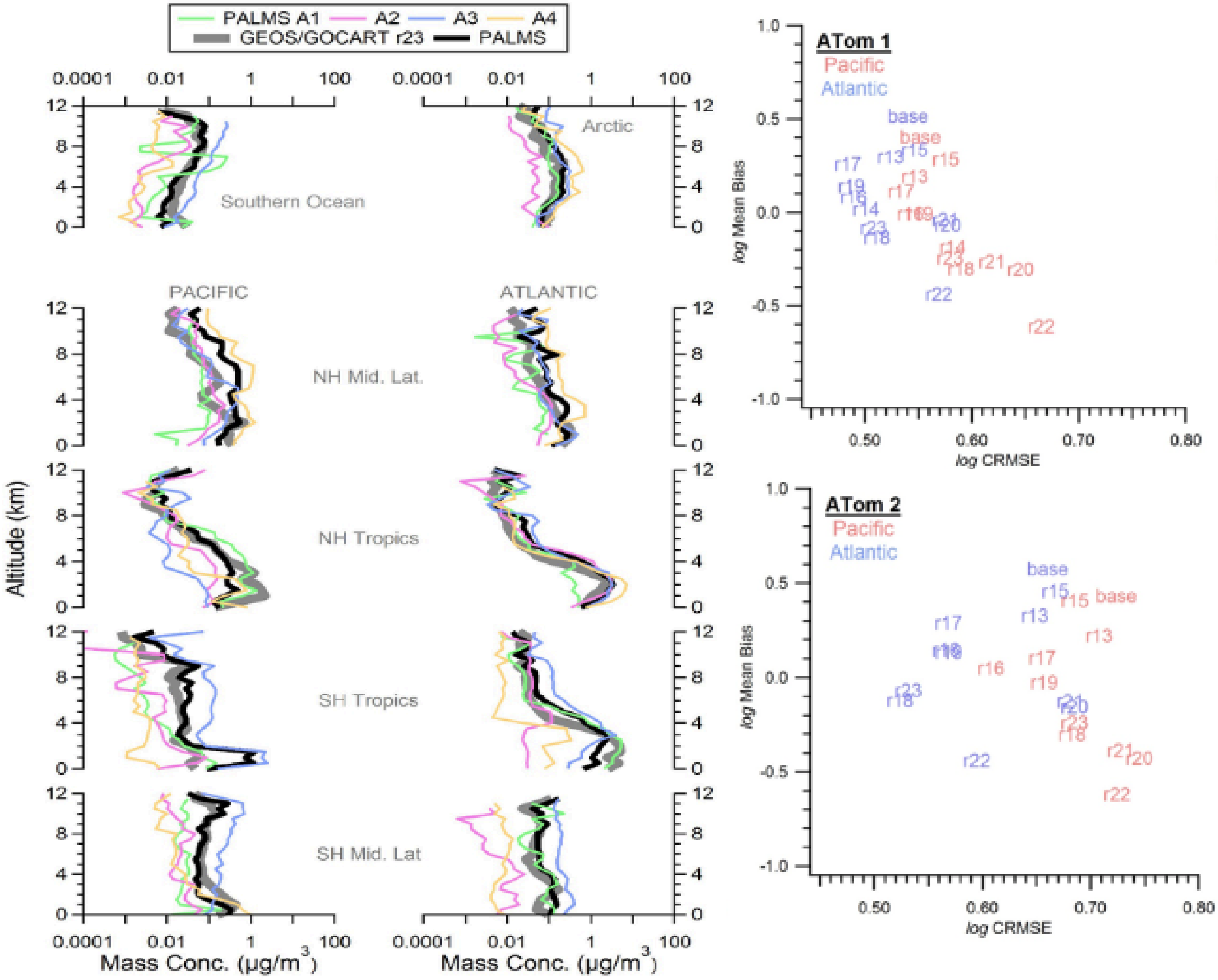
**wet scavenging**

# ATom1: Removal Processes

| QFED | OC Cold Cloud Scavenging | OC1 Cold Cloud Scavenging |
|---|---|---|



# Improve model wet scavenging




Schill et al., (2019)

# Improve model wet scavenging

Dust wet deposition experiment set up:

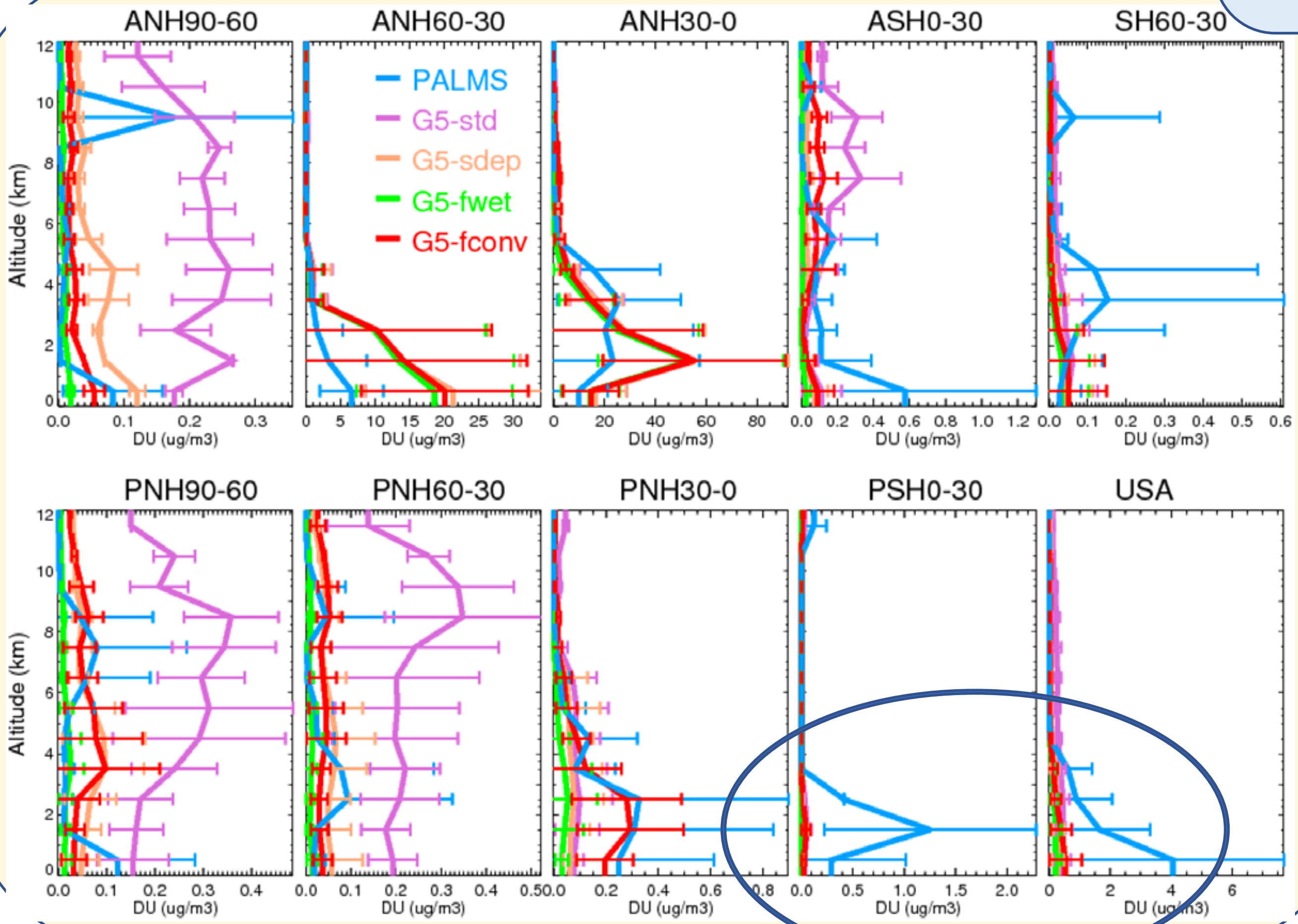
1. G5-Std: Current default
2. G5-Sdep: allow large scale rainout when T < 258K
3. G5-Fwet: increase fwet from 0.3 to 0.8 base on G5-Sdep
4. G5-Fconv: decrease fconv from 1.0 to 0.2 base on G5-fwet

By Huisheng Bian

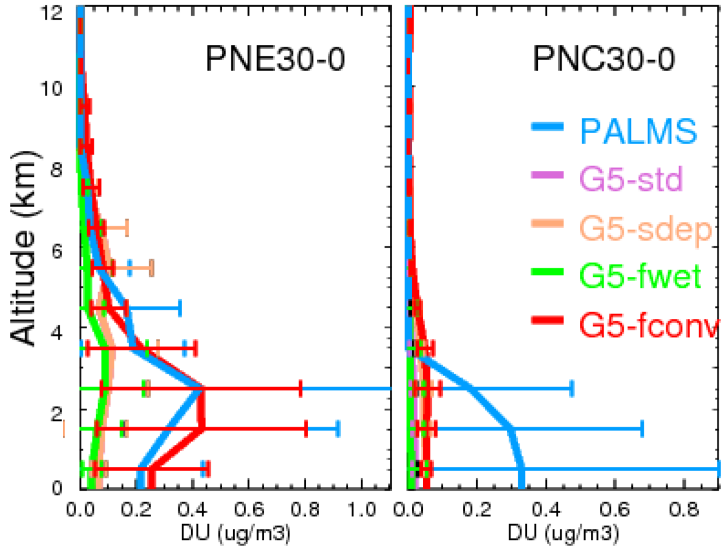
# DUST wet removal

Dust wet deposition experiment set up:

1. G5-Std: Current default explained in left box
2. G5-Sdep: allow large scale rainout when T < 258K
3. G5-Fwet: increase fwet from 0.3 to 0.8 base on Sdep
4. G5-Fconv: decrease fconv from 1.0 to 0.2 base on fwet




| | G5-std | G5-sdep | G5-fwet | G5-conv |
|---|---|---|---|---|
| Rwet (T<258K) | no | yes | yes | yes |
| fwet | 0.3 | 0.3 | 0.8 | 0.8 |
| fconv | 1.0 | 1.0 | 1.0 | 0.2 |



## wet removal

Three kinds of dust wet removal are accounted in GEOS GOCART:

1. Large scale rainout (only when T > 258K):

$$dC = C_0 * F * fwet * \exp(-B*dt)$$

dC: dust loss, $C_0$: dust initial concentration, F: fraction of grid box covered by precipitation cloud,
fwet: large-scale clould scavenging coefficient,
B: precipitation frequency, and dt is timestep.

2. Large scale washout:

$$dC = C_0 * F * \exp(-B*dt).$$

B: 0.1*precipitation

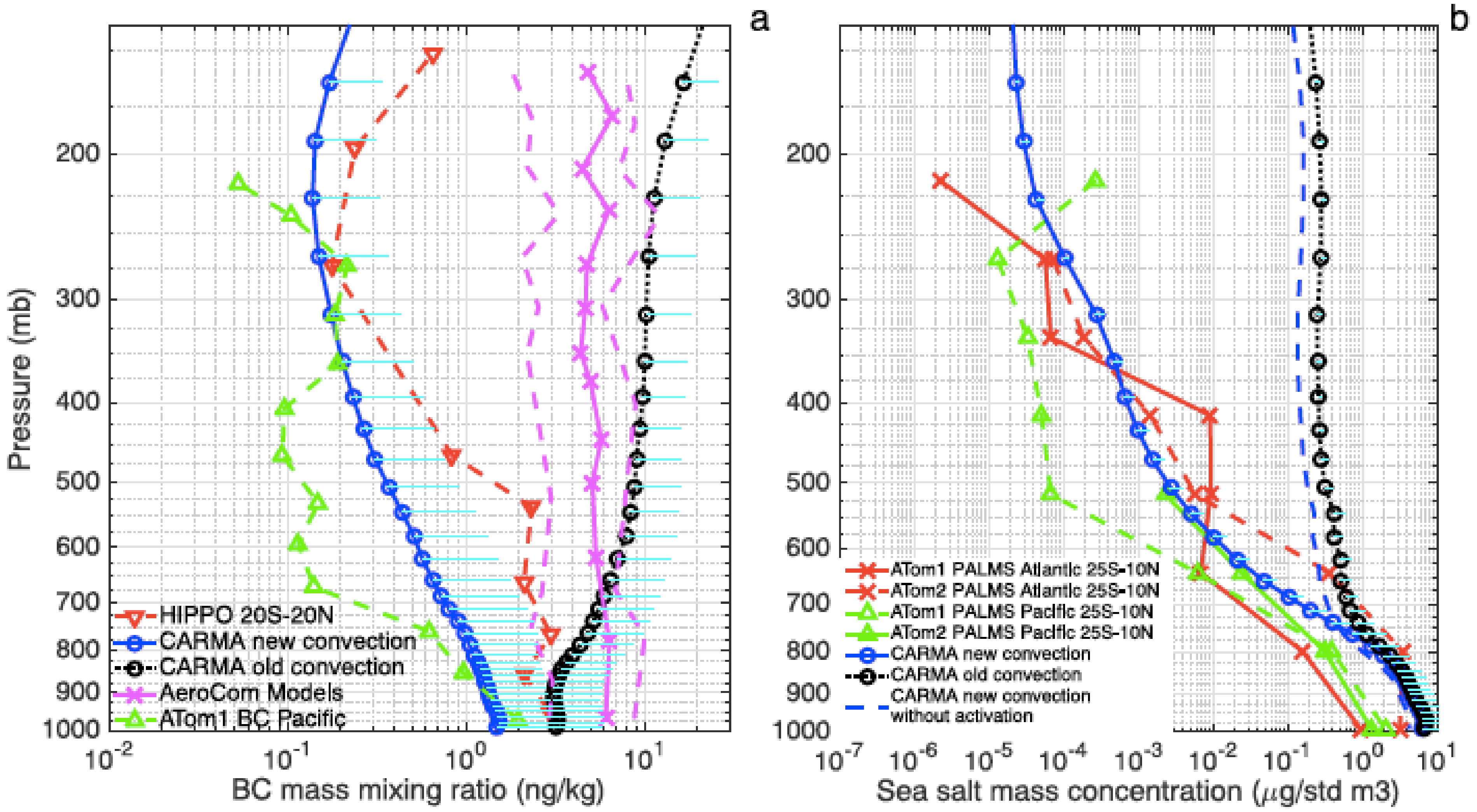
3. Convective updraft:

call a cumulus transport module to calculate dC with f (removal rate) as in input

$$f = fconv * \exp(-kc * bxheight/vud)$$

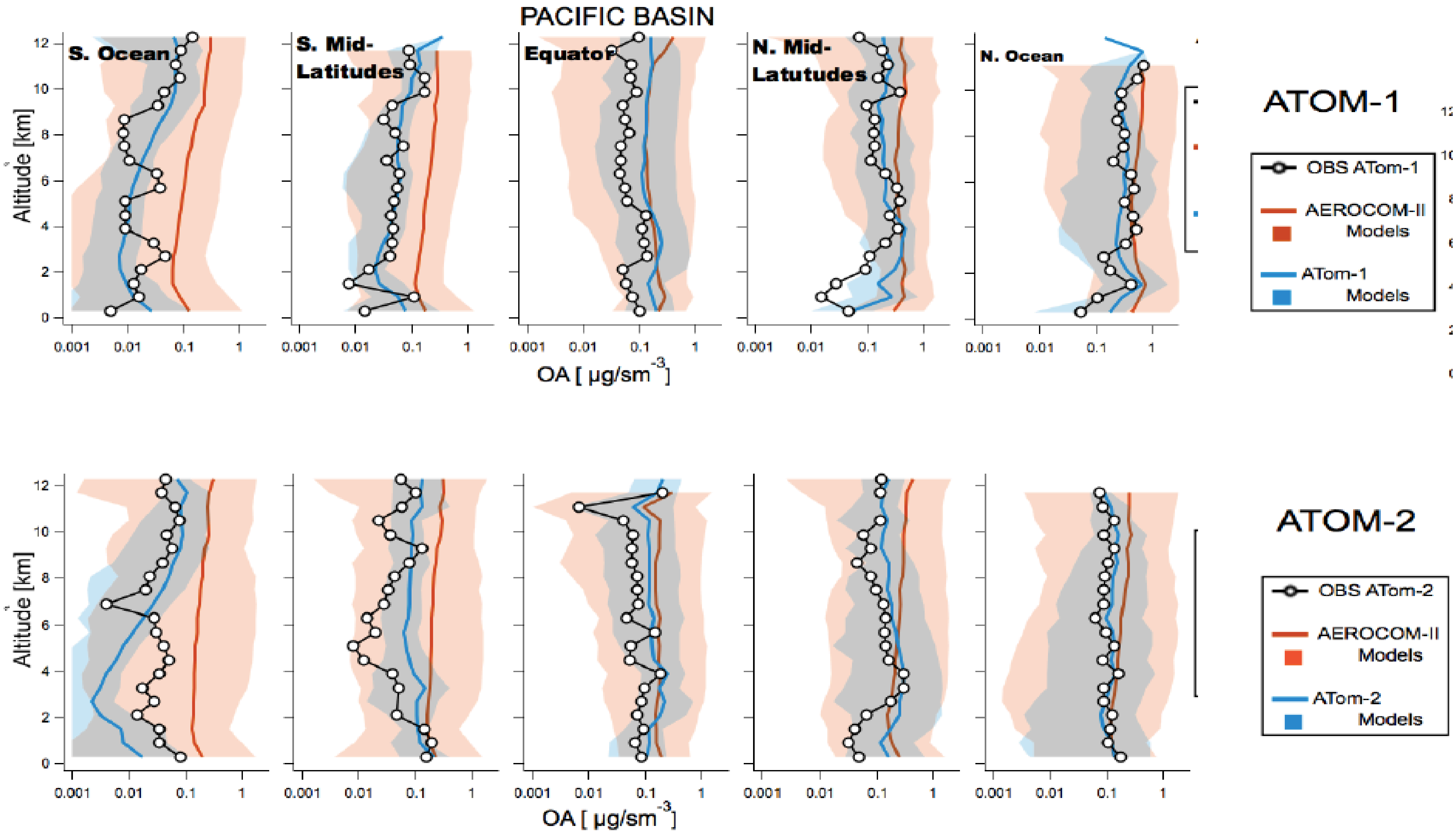
fconv: convective cloud scavenging coefficient (1.0), kc: conversion rate from cloud condensate to precipitation, bxheight is grid box height, and vud is cloud updraft velocity.

# Improve model vertical convection using ATom measurement

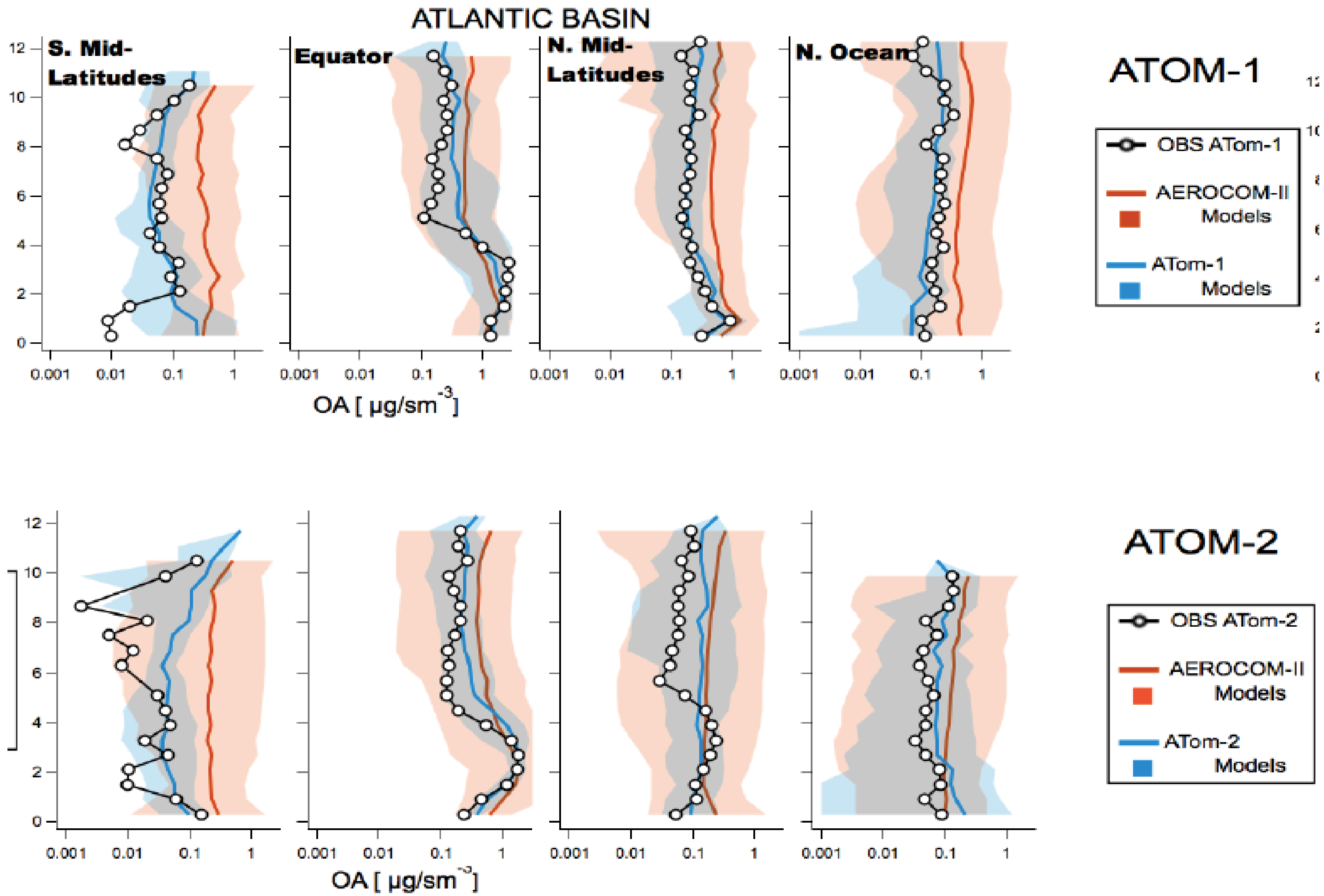



Yu et al., 2019, GRL

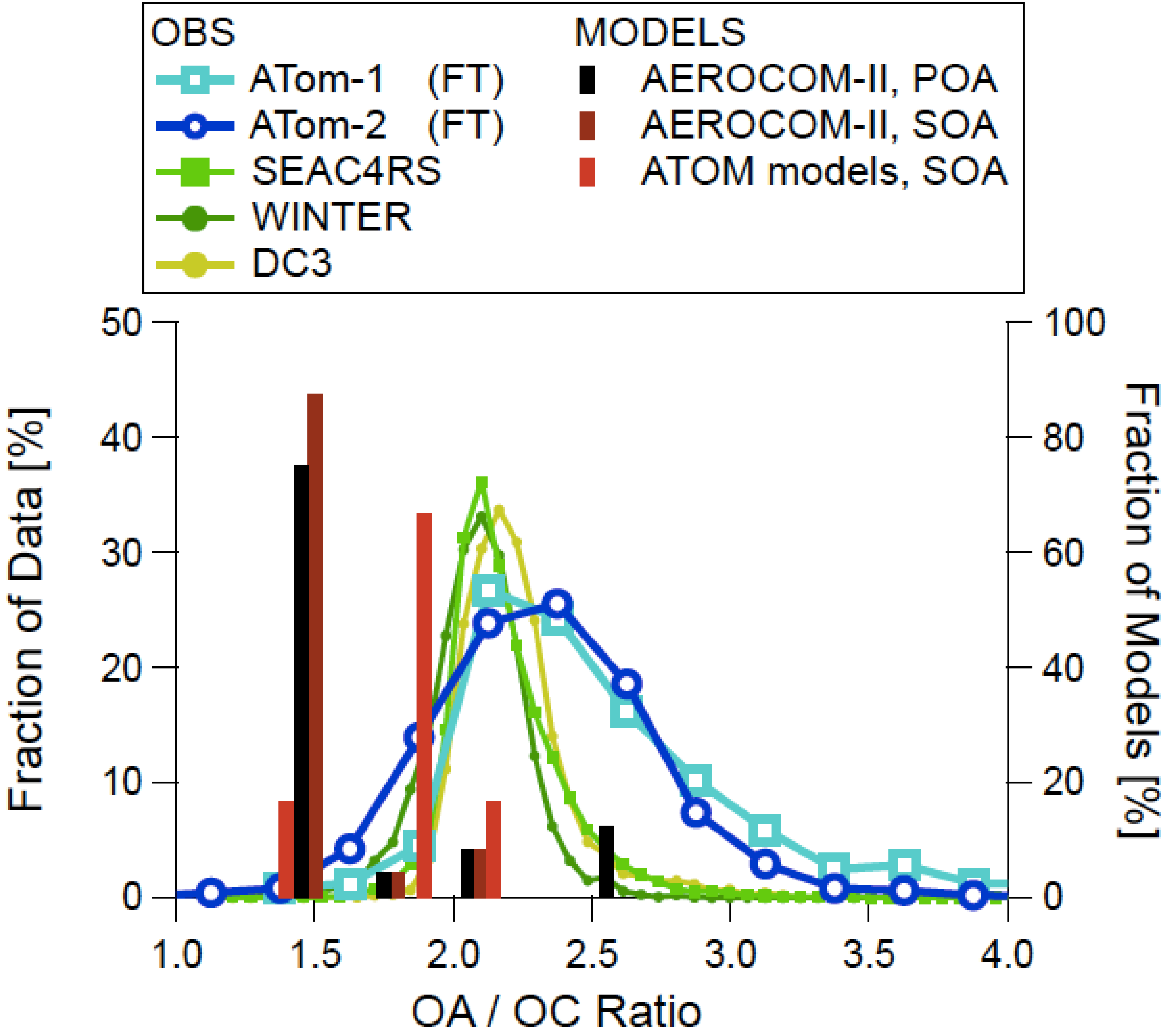
# OC (Ama or Yu)


PACIFIC BASIN
S. Ocean
S. Mid-Latitudes
Equator
N. Mid-Latutudes
N. Ocean
Altitude [km]
OA [ µg/sm-3]
ATOM-1
OBS ATom-1
AEROCOM-II Models
ATom-1 Models
ATOM-2
OBS ATom-2
AEROCOM-II Models
ATom-2 Models

OC (Ama or Yu)

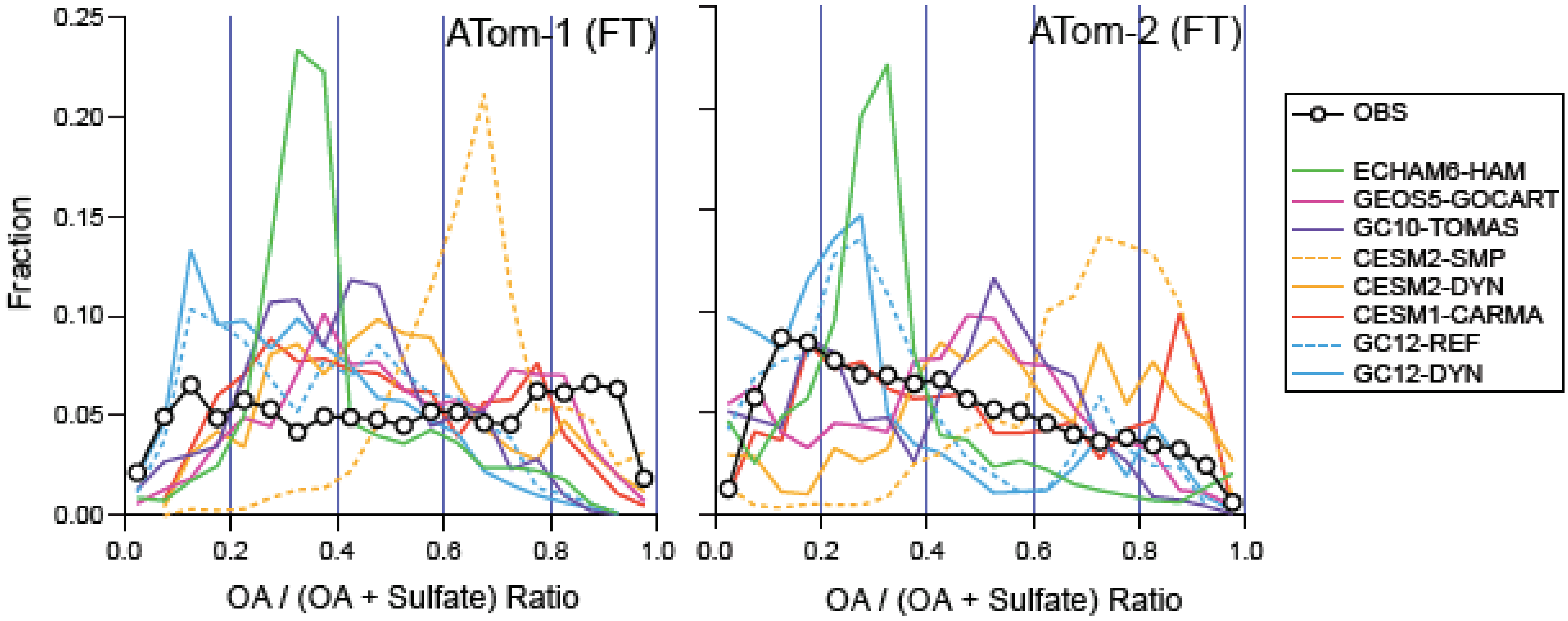

ATLANTIC BASIN
S. Mid-Latitudes
Equator
N. Mid-Latitudes
N. Ocean
ATOM-1
OBS ATom-1
AEROCOM-II Models
ATom-1 Models
OA [ µg/sm-3]
ATOM-2
OBS ATom-2
AEROCOM-II Models
ATom-2 Models
OA [ µg/sm-3]

Alma



OBS
ATom-1 (FT)
ATom-2 (FT)
SEAC4RS
WINTER
DC3
MODELS
AEROCOM-II, POA
AEROCOM-II, SOA
ATOM models, SOA
Fraction of Data [%]
Fraction of Models [%]
OA / OC Ratio
0
10
20
30
40
50
0
20
40
60
80
100
1.0
1.5
2.0
2.5
3.0
3.5
4.0

Alma



ATom-1 (FT)
ATom-2 (FT)
Fraction
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.2
0.4
0.6
0.8
1.0
OA / (OA + Sulfate) Ratio
OA / (OA + Sulfate) Ratio
OBS
ECHAM6-HAM
GEOS5-GOCART
GC10-TOMAS
CESM2-SMP
CESM2-DYN
CESM1-CARMA
GC12-REF
GC12-DYN

# Potential participants

| model | modeler | Which institution |
|---|---|---|
| CEMS | Pengfei Yu | Pengfei Yu - NOAA Affiliate <pengfei.yu@noaa.gov> |
| ECHAM | David Neubauer | **david.neubauer@env.ethz.ch** |
| GEOS | Huisheng Bian | |
| | Jialei Zhu | Jialei Zhu <jialeiz@umich.edu> |
| OsloCTM2 | Gunnar Myhre | Gunnar Myhre <gunnar.myhre@cicero.oslo.no> |
| Sprintar | Toshihiko Takemura | Toshihiko Takemura <toshi@riam.kyushu-u.ac.jp> |

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