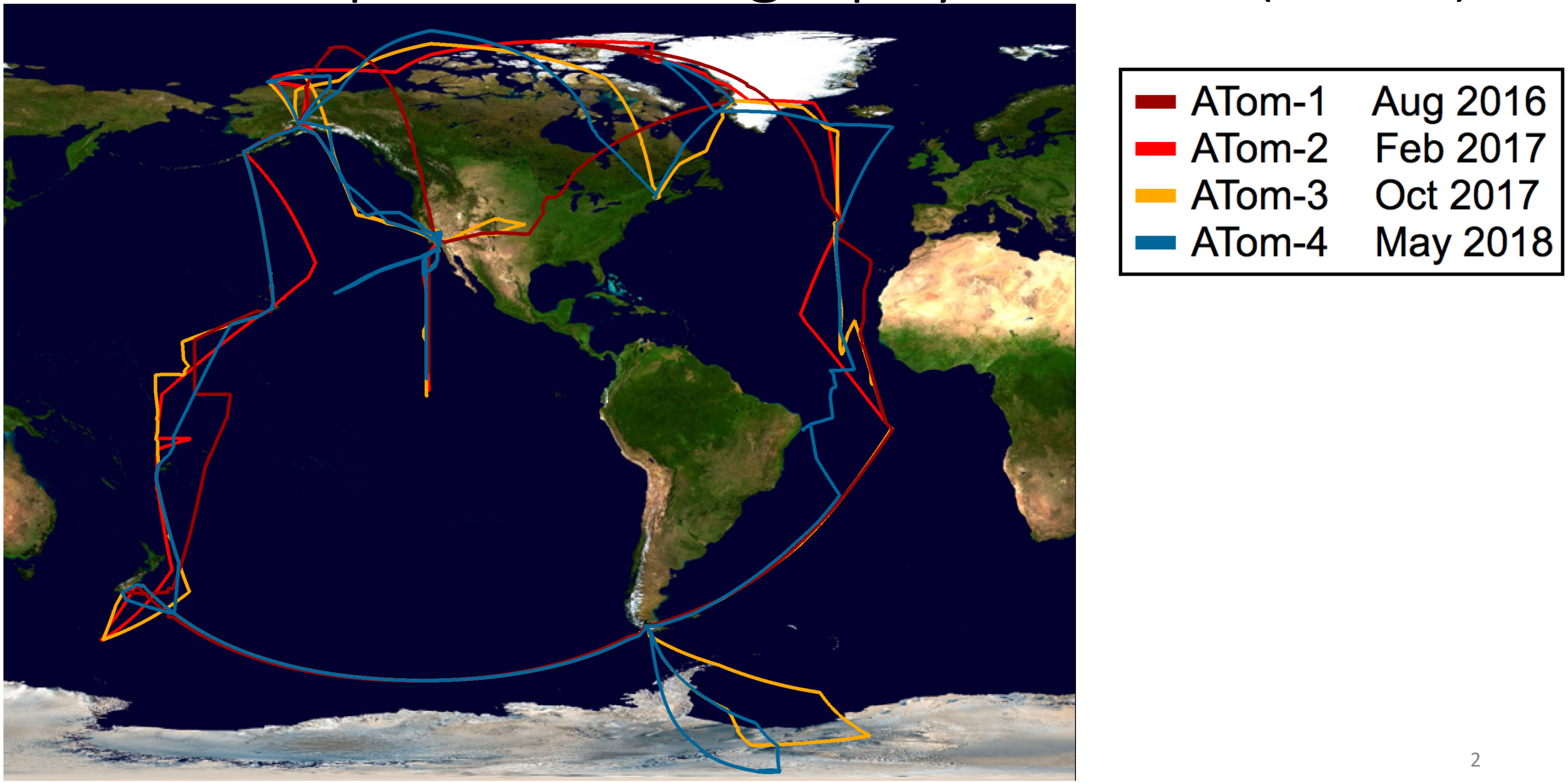
Global-Scale in-situ measurements of Atmospheric Aerosol from the NASA Atmospheric Tomography Mission

<u>Christina Williamson</u>, Hannah Allen, Huingshen Bian, Charles Brock, Taopaul Bui, Pedro Campuzano-Jost, Mian Chin, Simon Clegg, Peter Colarco, John Crounse, Doug Day, Maximillian Dollner, Karl Froyd, Jose Jimenez, Joseph Katich, Michelle Kim, Agnieszka Kupc, Eloise Marais, Daniel Murphy, Ben Nault, Jeffrey Pierce, Karen Rosenlof, Gregory Schill, Jason Schroder, Joshua Schwarz, Simone Tilmes, Kostas Tsigaridis, Pengfei Yu, Bernadett Weinzierl

Photograph: Samuel Hall, NCAR

@chasingcloudsCW

The Atmospheric Tomography Mission (ATom)



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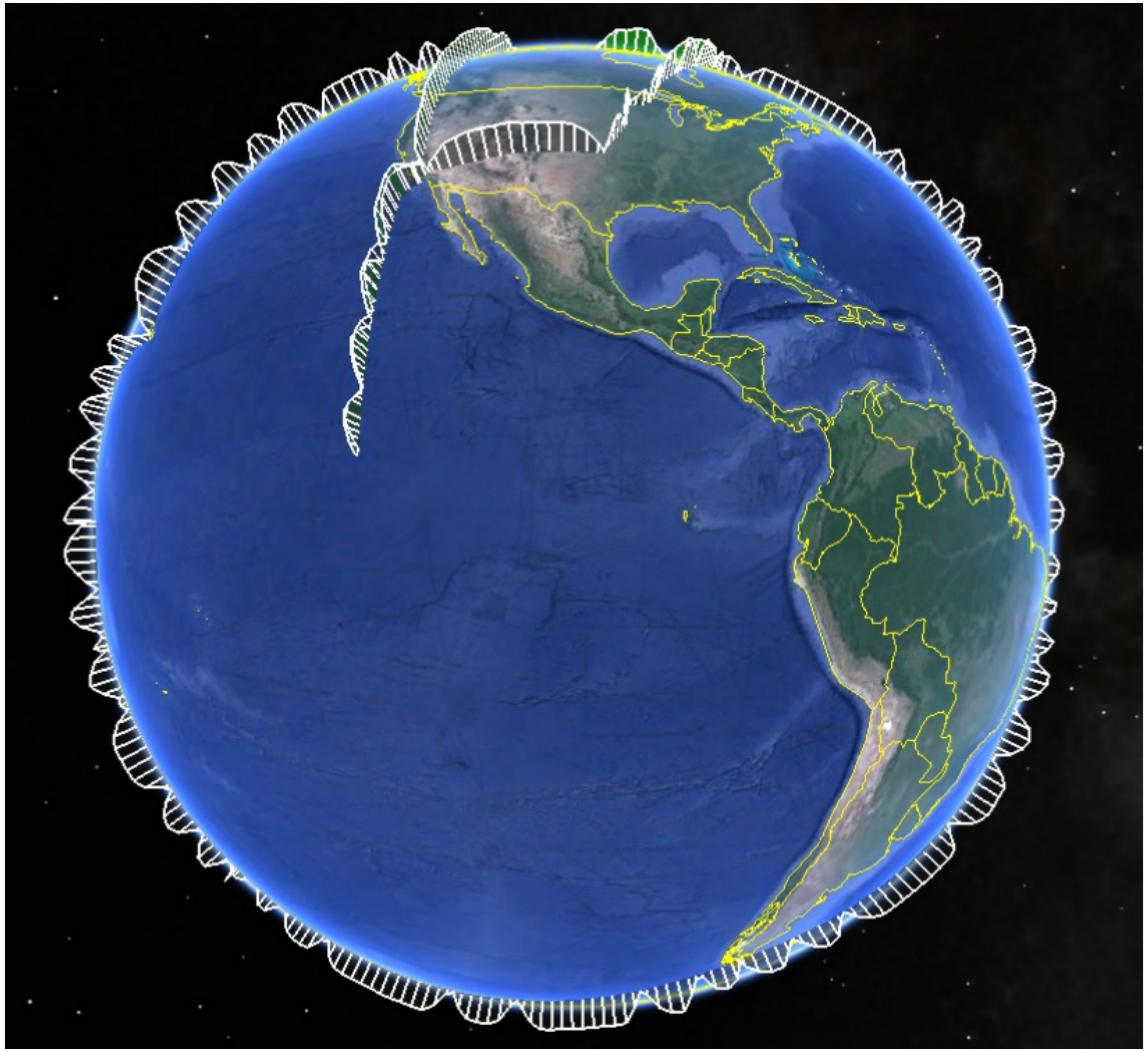


Vertical Profiling
~0.2 – 12km

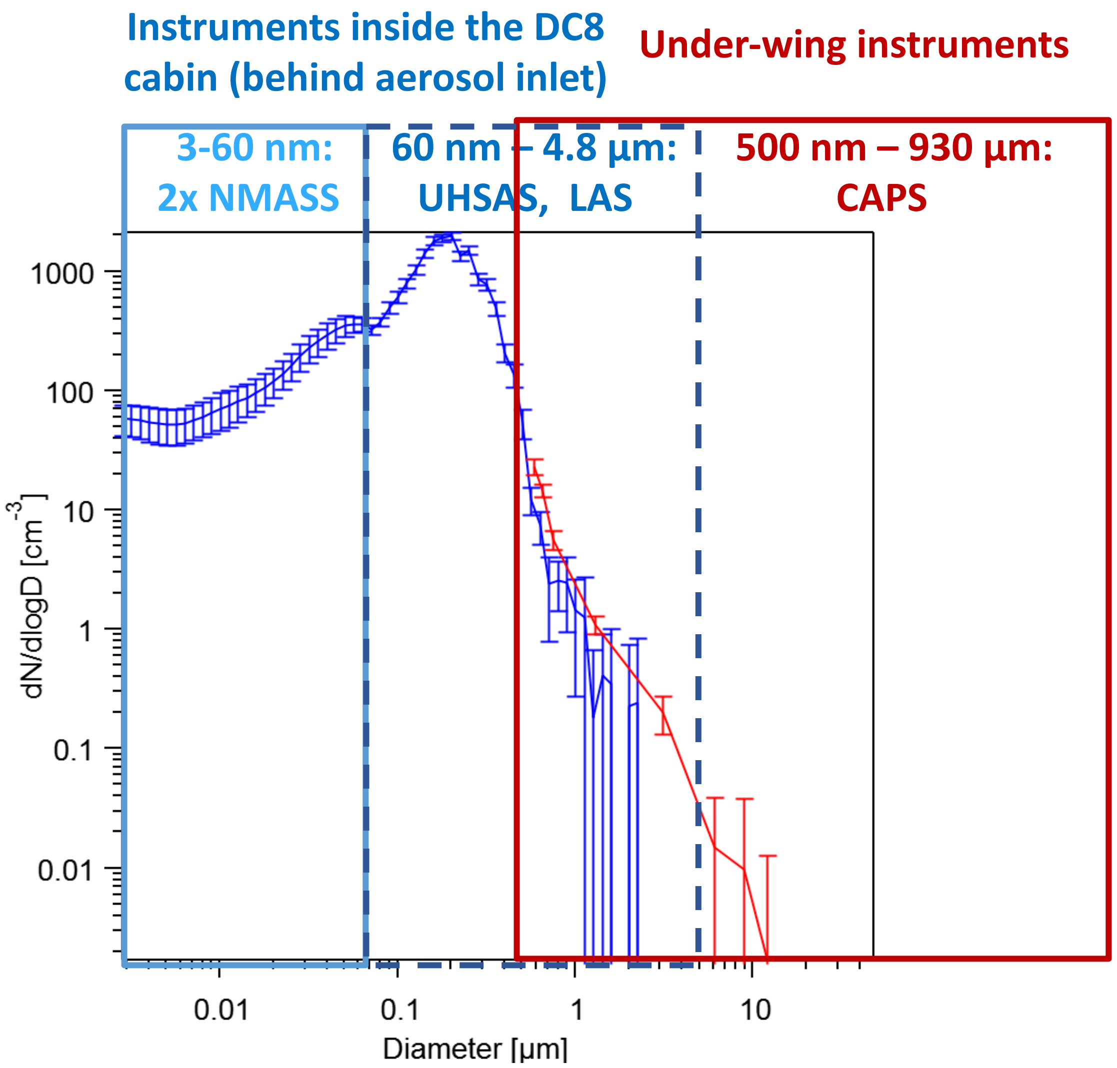
ATom Aerosol Measurements

- Size Distributions
- Composition
  - Bulk non-refractory (AMS)
  - Bulk (filters)
  - Single Particle (PALMS)
  - Volatility
- Black Carbon (SP2)
- Brown Carbon
- Optical Properties (scattering, extinction)

Gas Phase:
- Tracers
- VOCs
- GHGs
- NOx and NOy
- …

Photograph: Samuel Hall, NCAR

Aerosol Size Distributions



- Minimizing inlet effects on coarse mode data
- Full size distribution between 3 nm and 930 µm
- Quantification of size distribution uncertainties

CAPS: **Bernadett Weinzierl** and Maximilian Dollner, University of Vienna

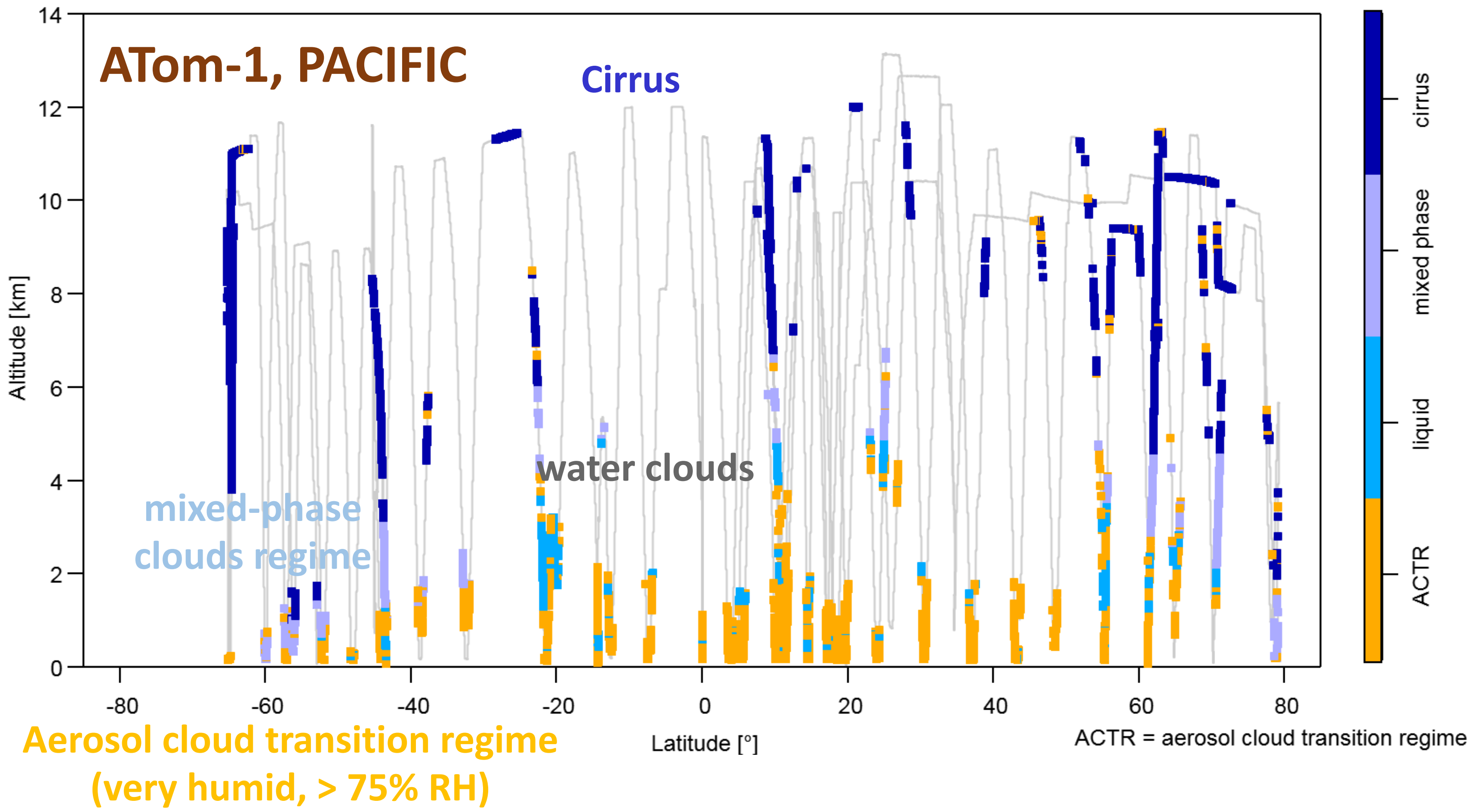
AMP: **Christina Williamson** and Charles Brock, NOAA/CIRES and Agnieszka Kupc, University of Vienna

Using ATom Data

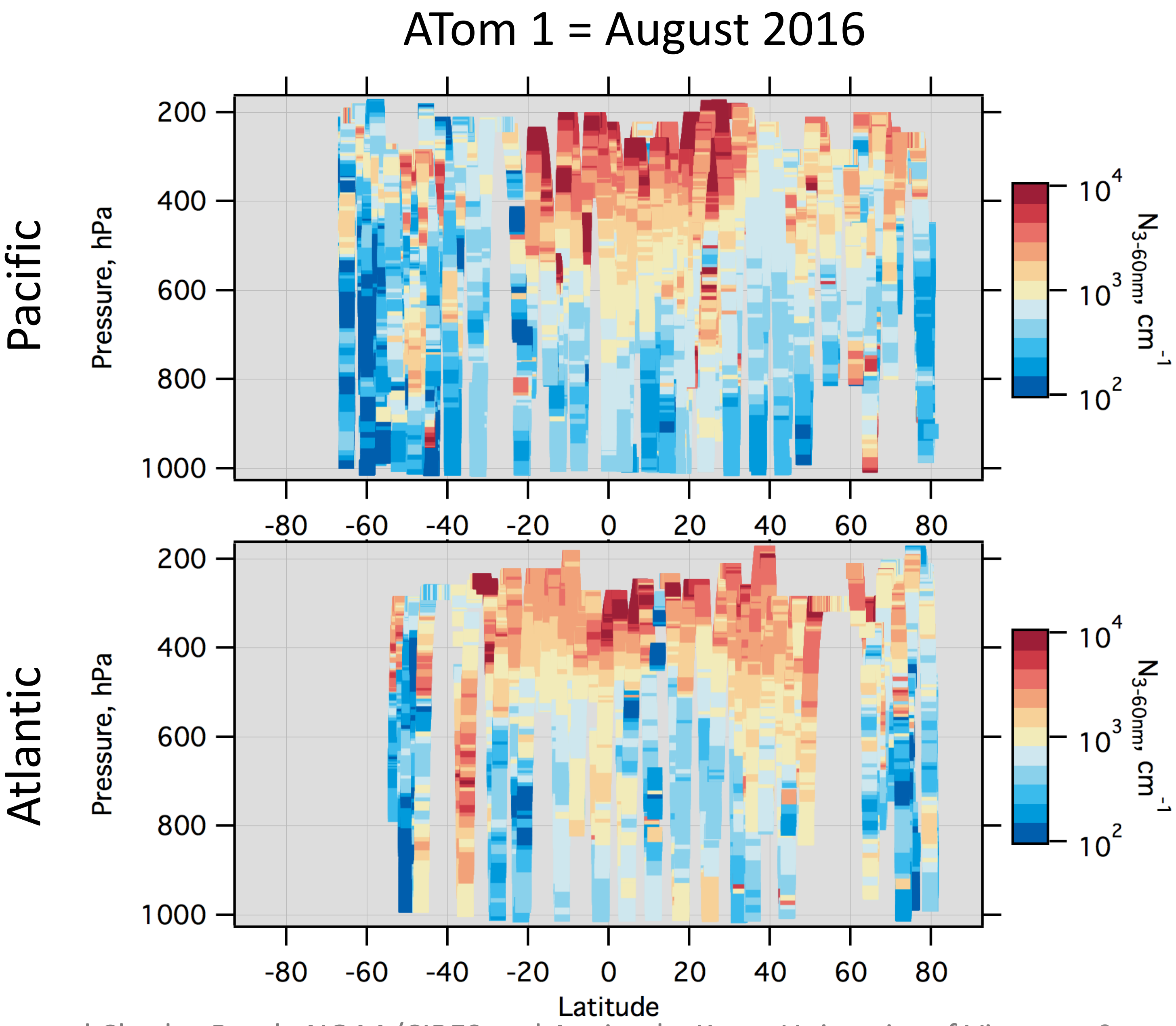
- Data publicly available on the NASA ESPO archive
- Contact and collaboration with instrumentalists (contact details on ESPO archive) strongly advised before beginning a study with any ATom data

Photograph: Samuel Hall, NCAR

Derivation of cloud phase over global scales



The global distribution of particles from nucleation



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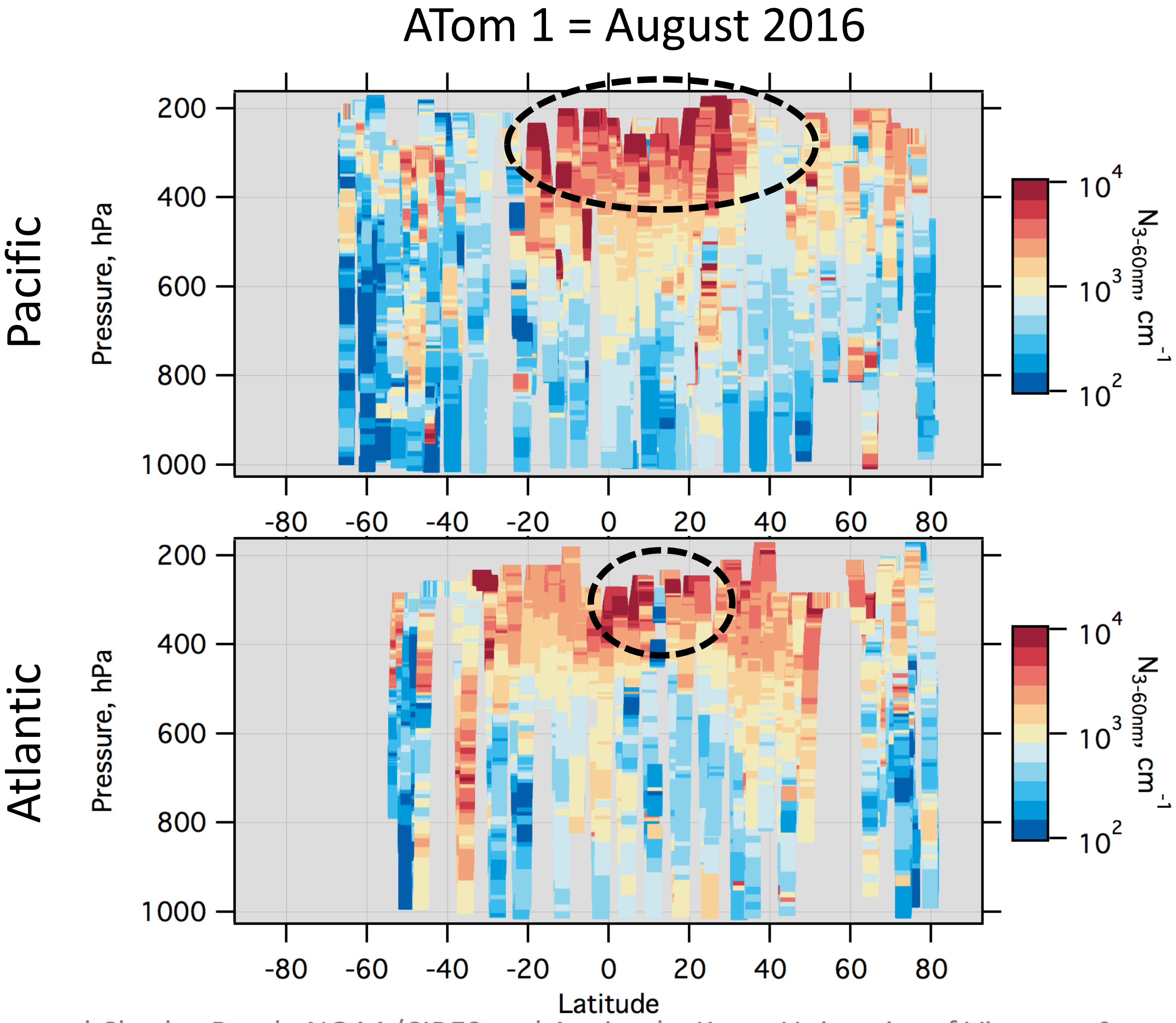
The global distribution of particles from nucleation



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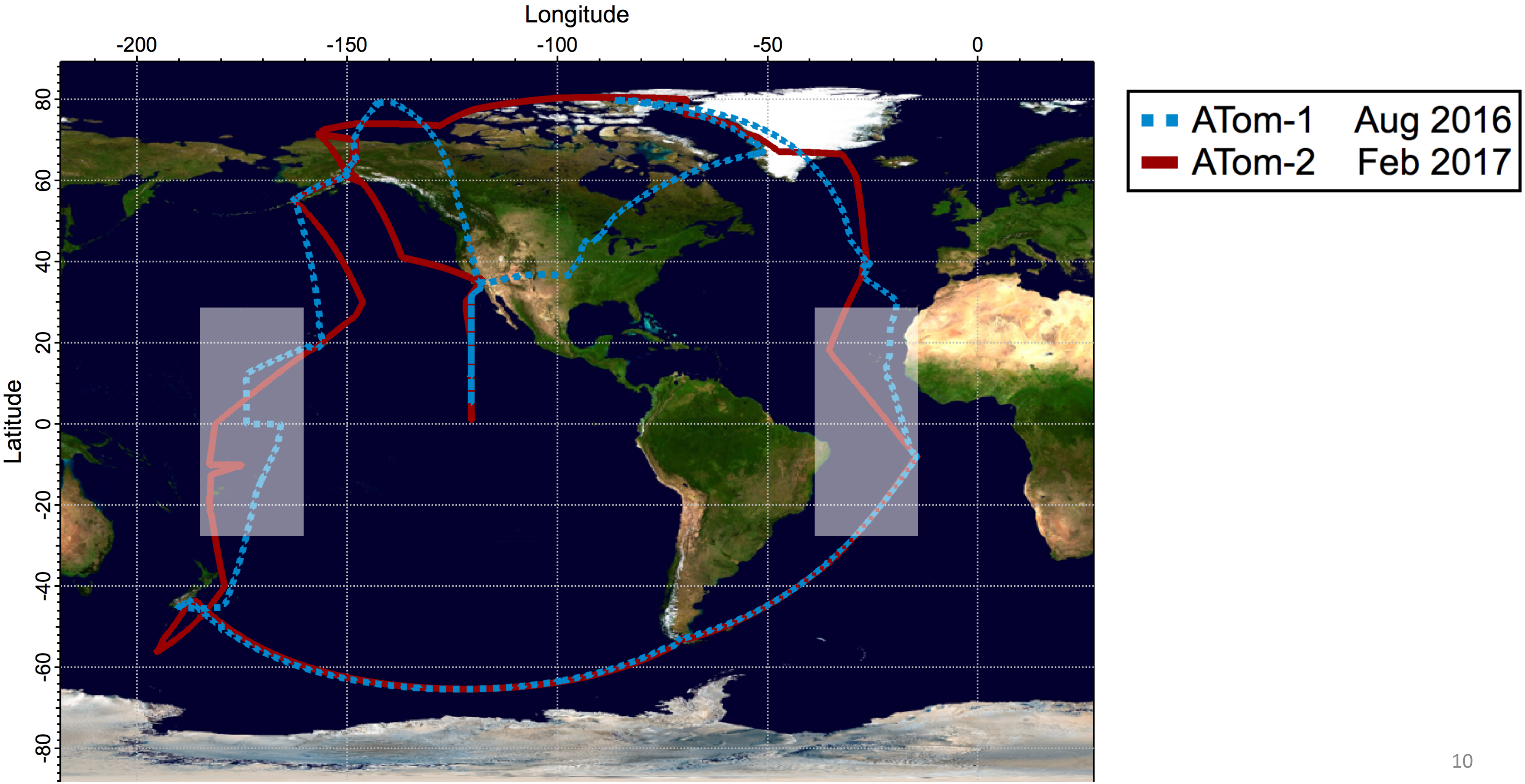
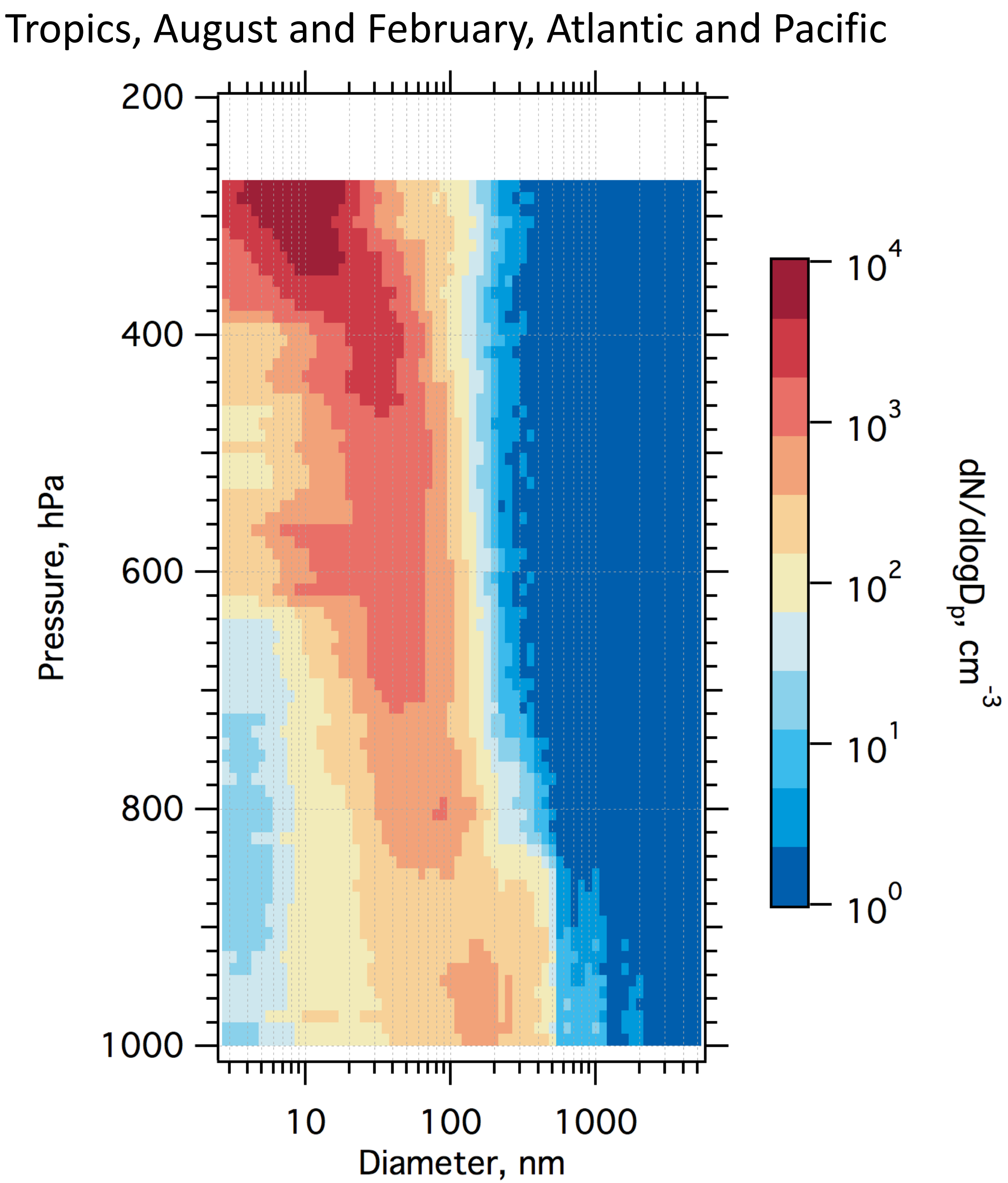
New Particle Formation and Growth in the Tropics



Particles formed in the tropical upper troposphere grow to Cloud Condensation Nuclei sizes on descent to the boundary layer



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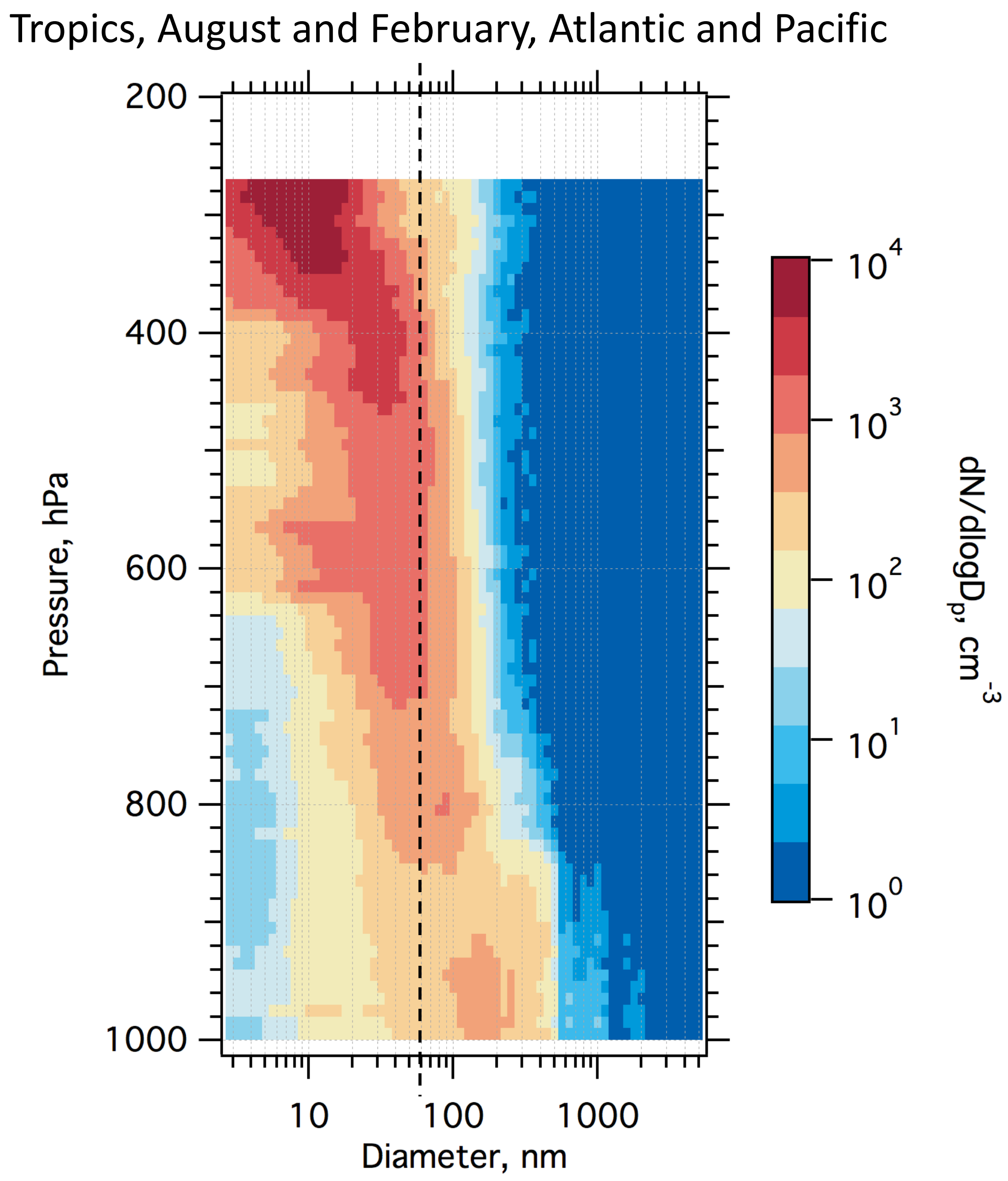
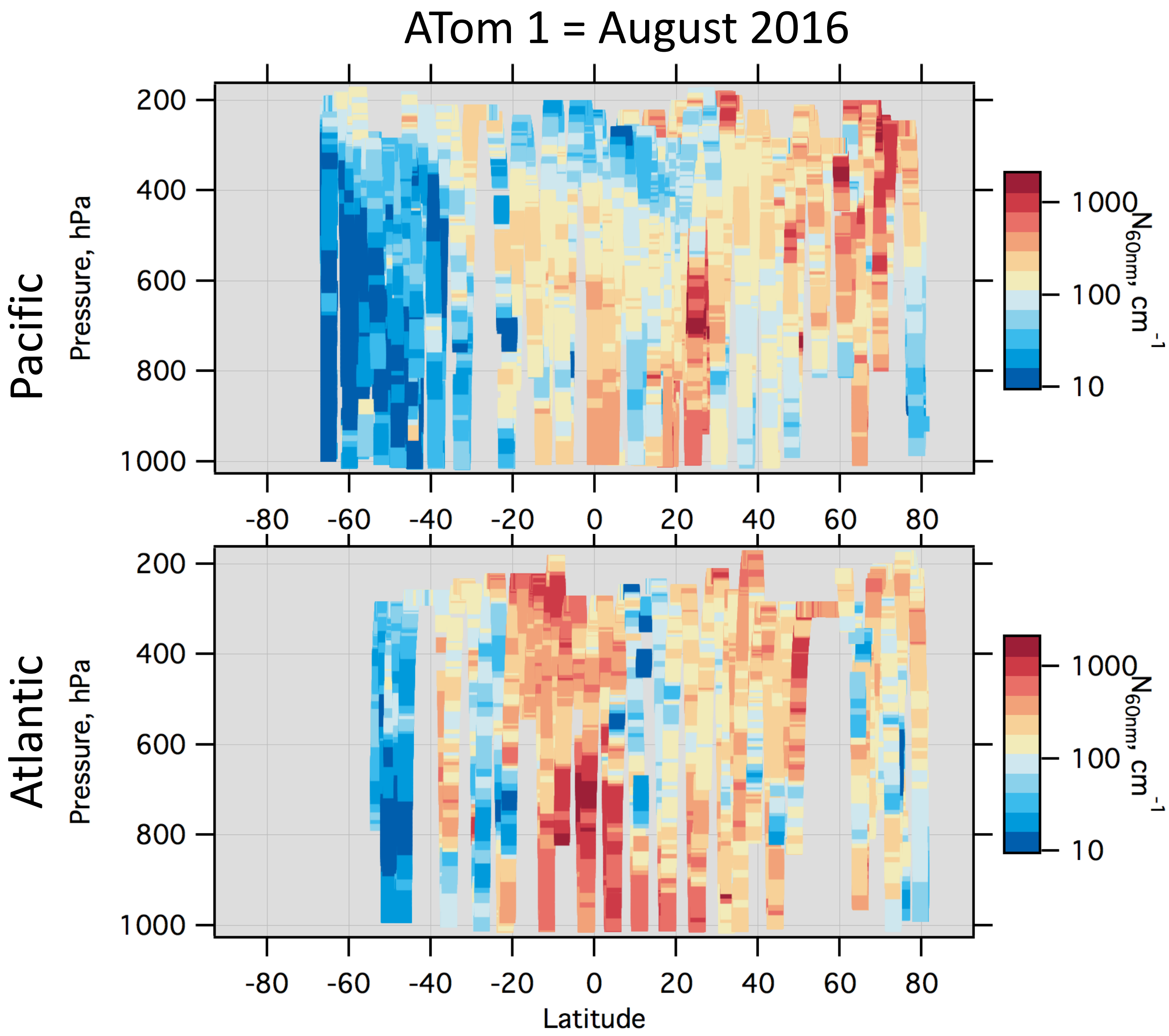


AMP: **Christina Williamson** and Charles Brock, NOAA/CIRES and Agnieszka Kupc, University of Vienna

The global distribution of Cloud Condensation Nuclei-sized particles



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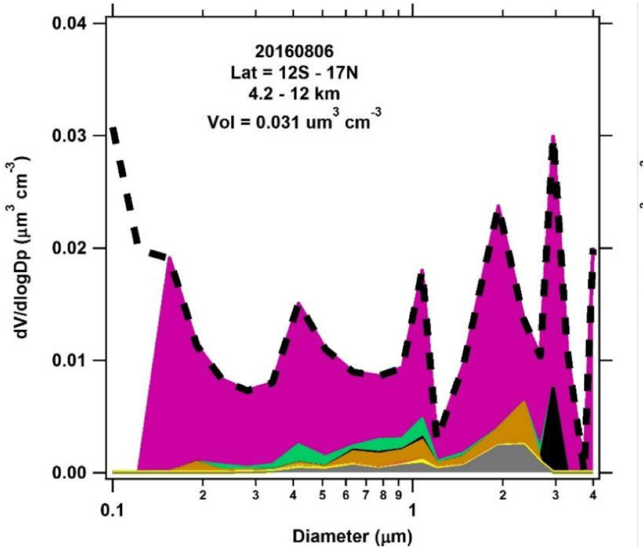
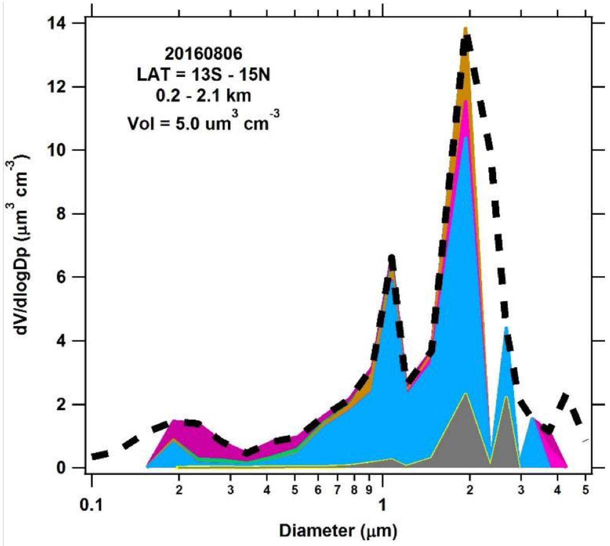
Origins of Cloud Condensation Nuclei -sized particles

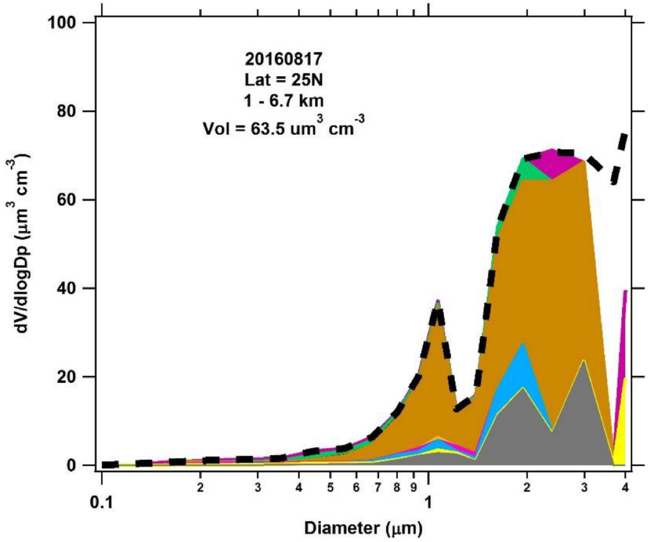
Sulfate/Organic/Nitrate



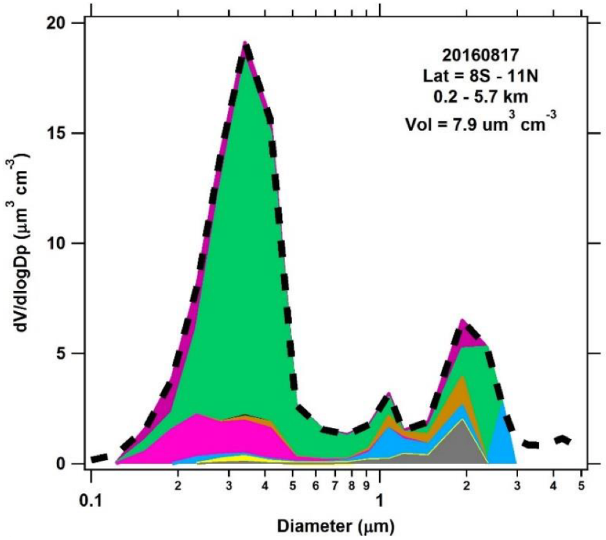
Sea-Salt



Mineral Dust



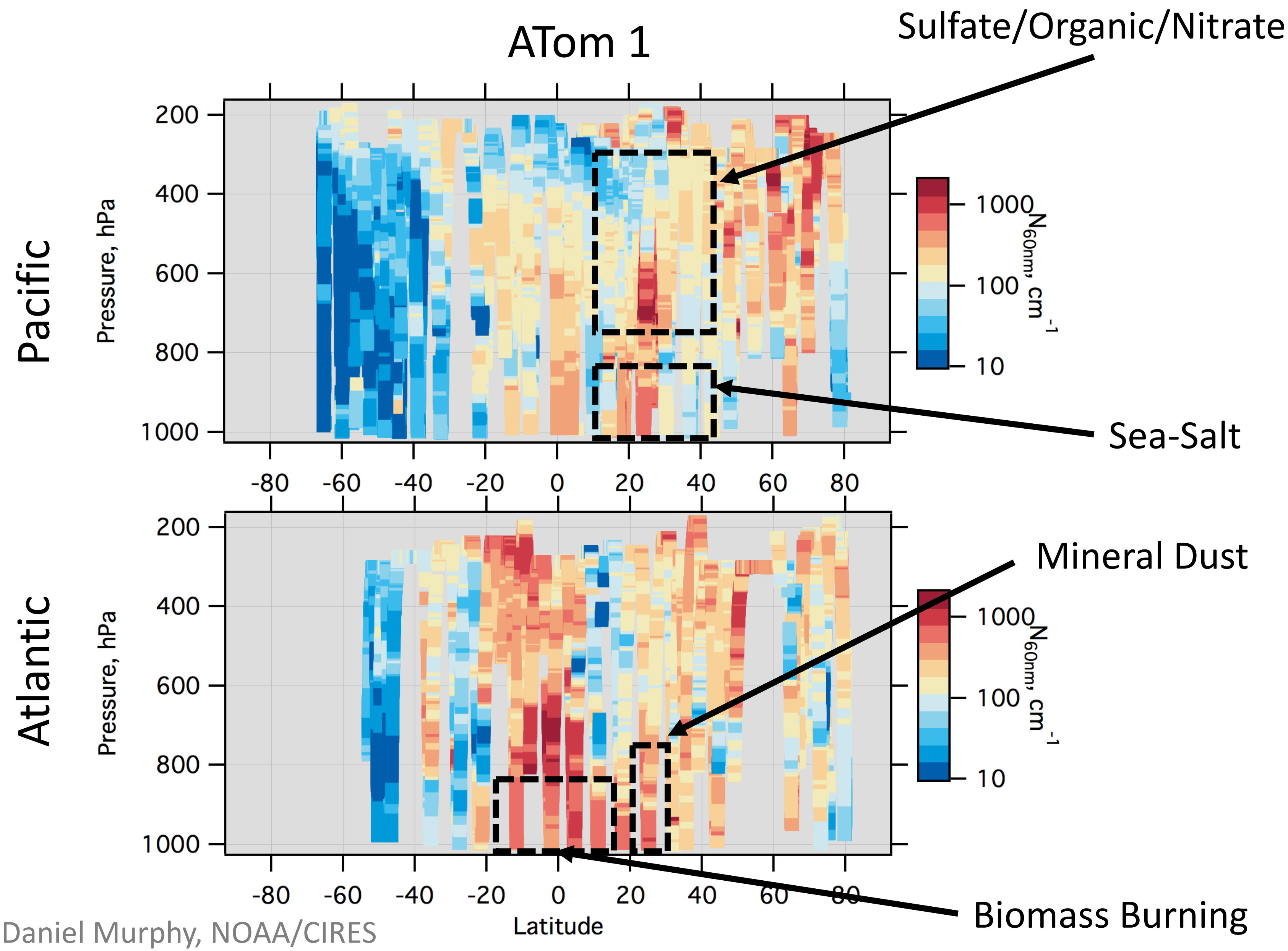
Biomass Burning



PALMS: **Karl Froyd**, Gregory Schill, Daniel Murphy, NOAA/CIRES

AMP: Christina Williamson and Charles Brock, NOAA/CIRES and **Agnieszka Kupc**, University of Vienna

Origins of Cloud Condensation Nuclei-sized particles



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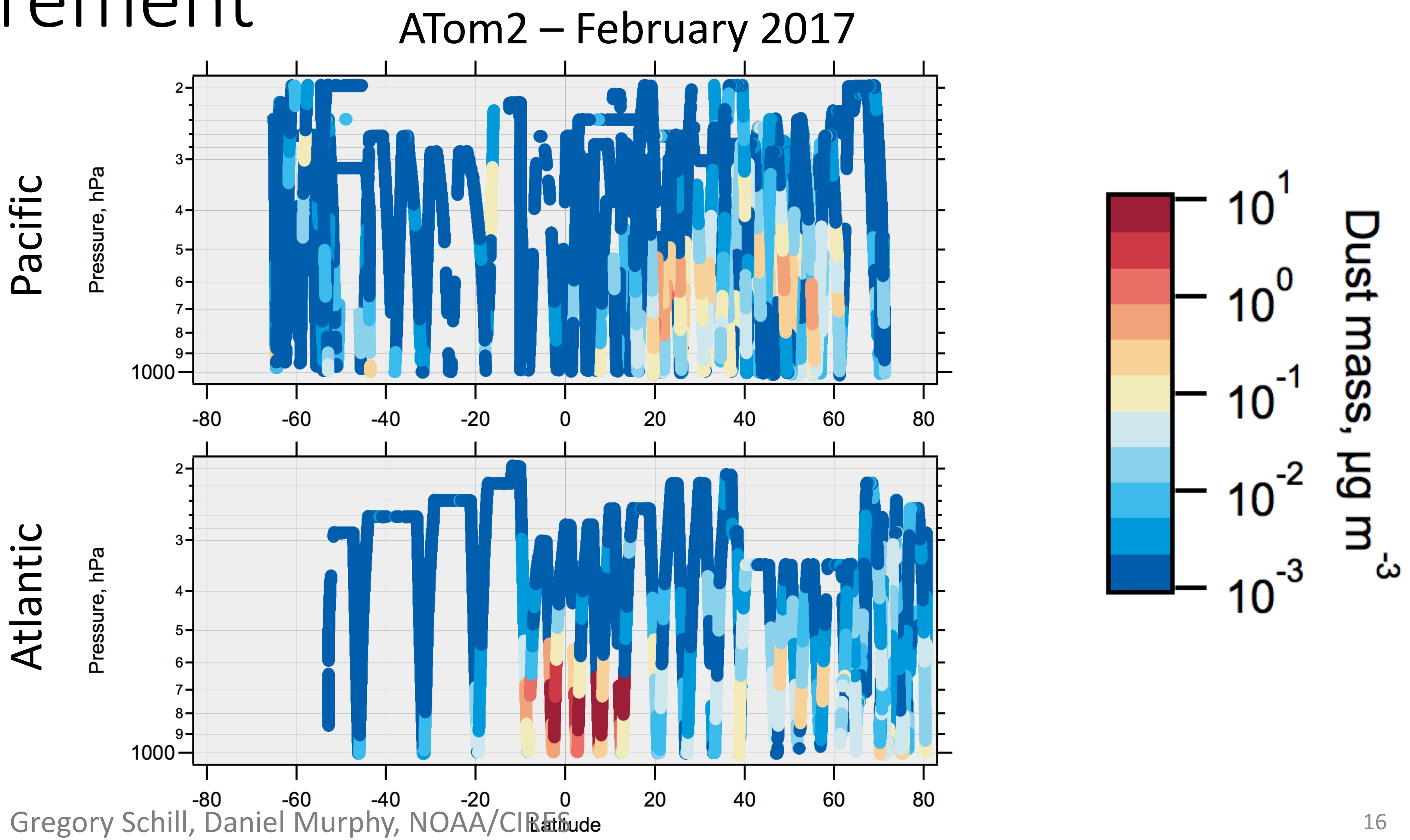
First global maps of mineral dust by direct measurement

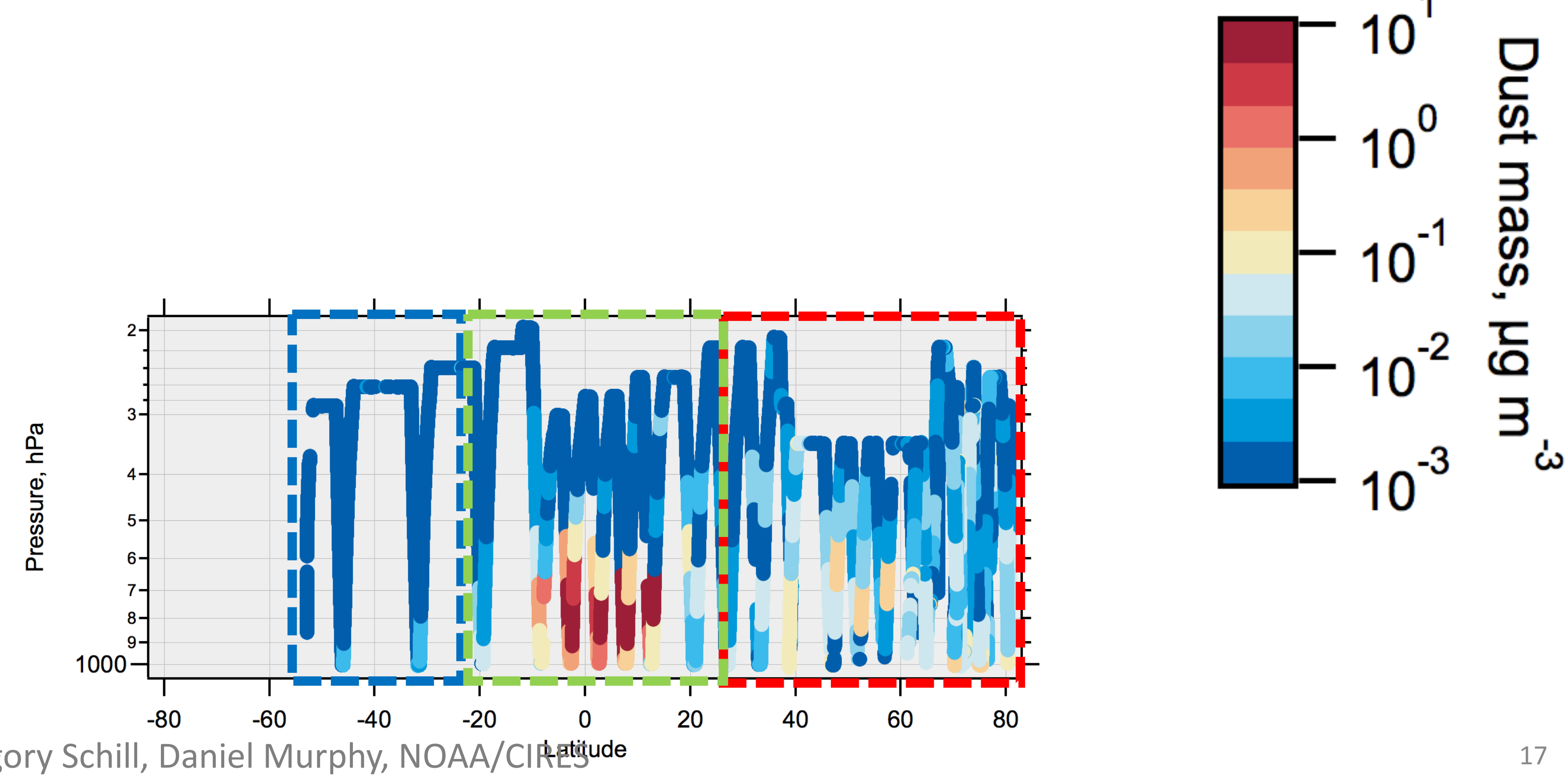


PALMS: **Karl Froyd**, Gregory Schill, Daniel Murphy, NOAA/CIRES

First global maps of mineral dust by direct measurement

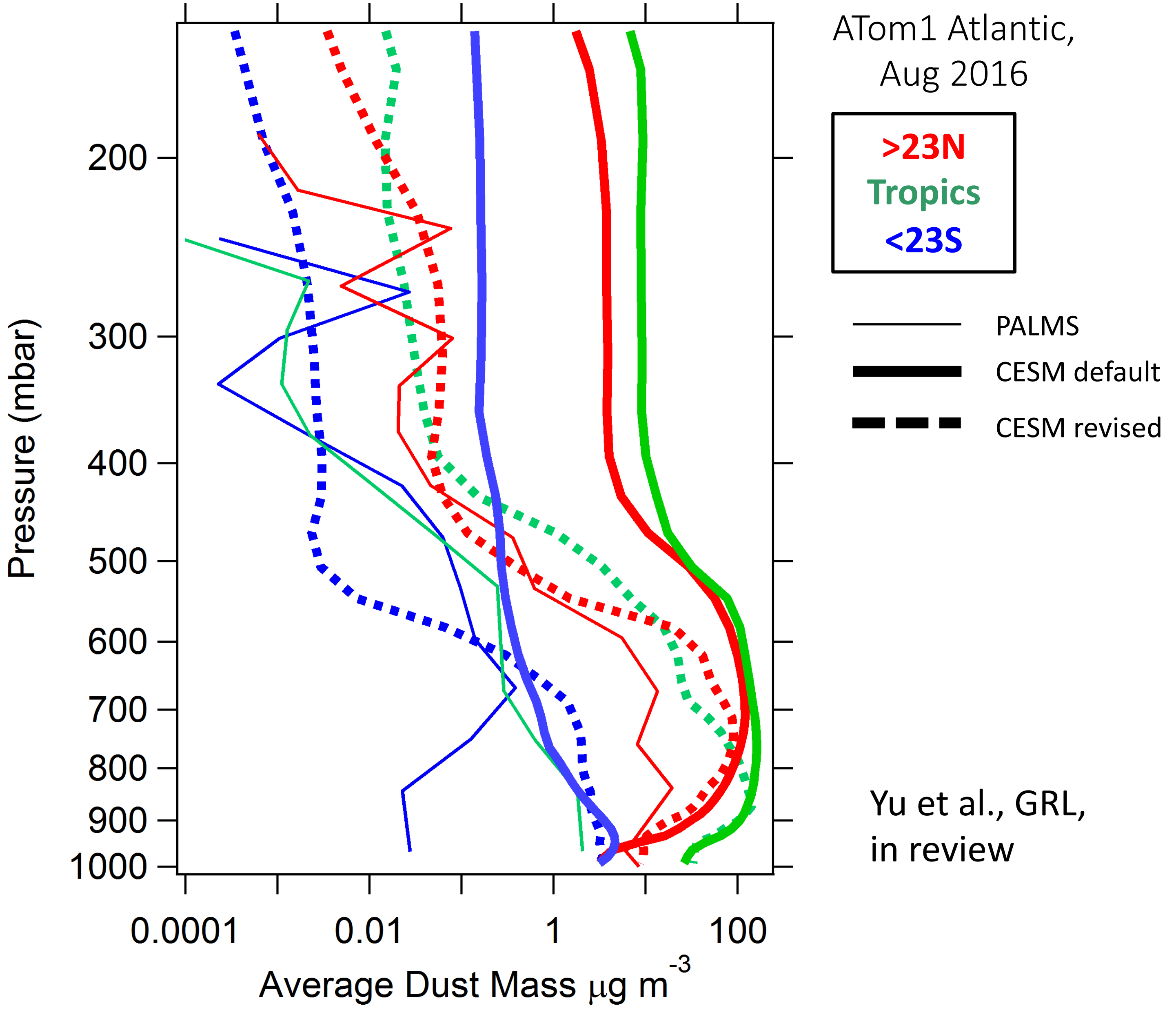
ATom2 – February 2017

Atlantic



PALMS: **Karl Froyd**, Gregory Schill, Daniel Murphy, NOAA/CIRES

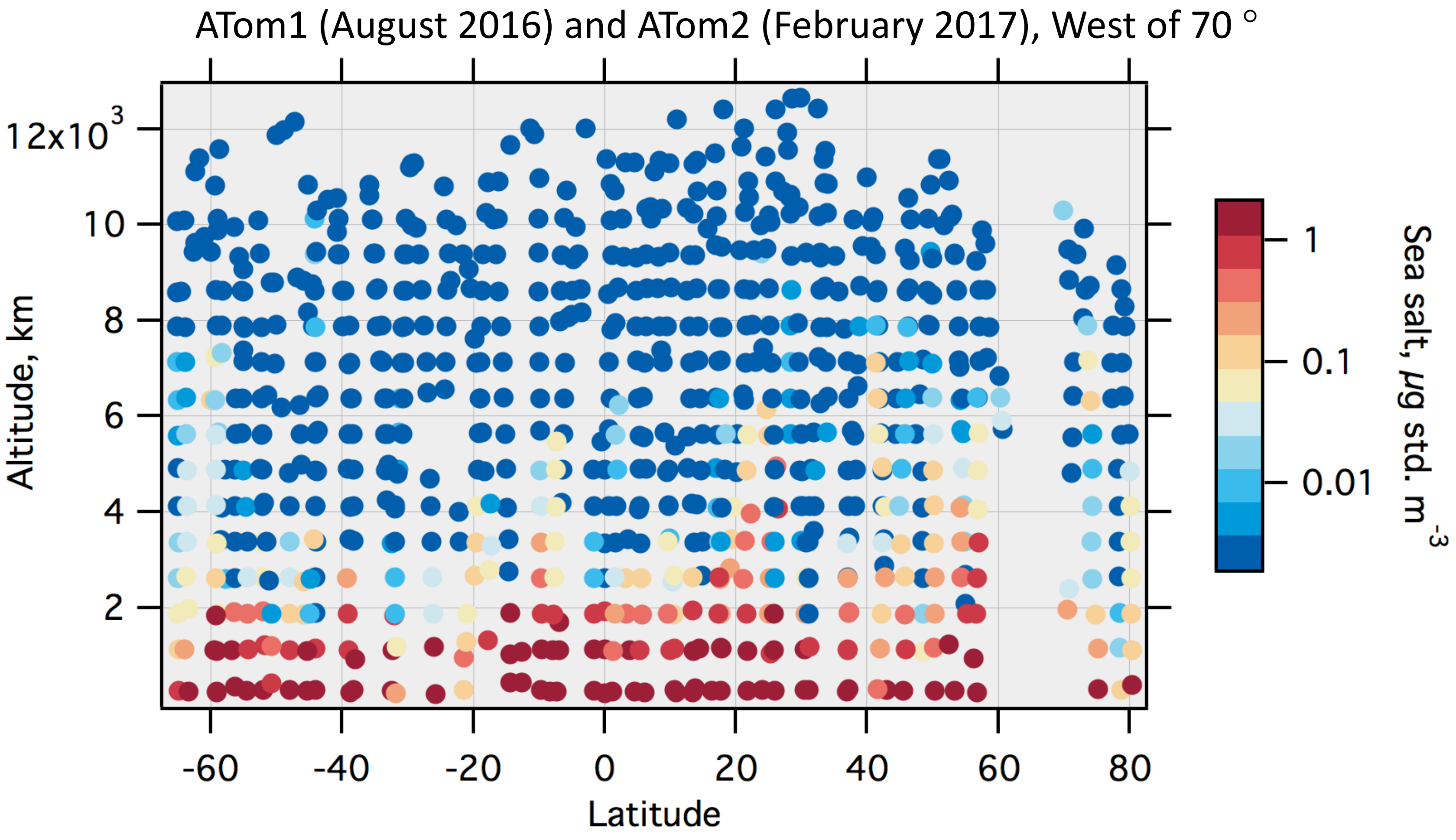
Revised convective removal in CESM-CARMA better aligns modeled dust with ATom observations



Yu et al., GRL, in review

PALMS: **Karl Froyd**, Gregory Schill, Daniel Murphy, NOAA/CIRES; CESM: **Pengfei Yu**, NOAA/CIRES

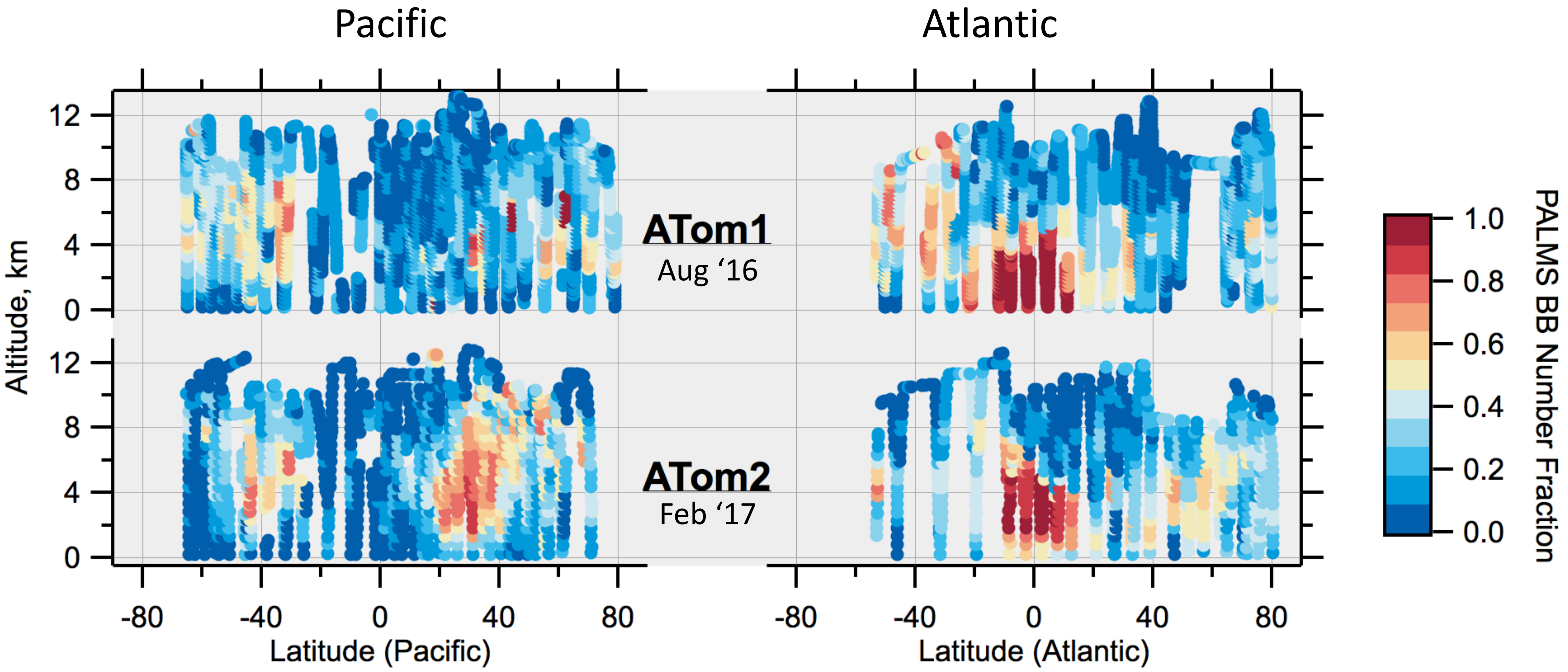
First data on sea salt above 2 km and over a wide range of latitudes



- Extremely low sea-salt (~ 1ppt) in upper troposphere
- New constraints on halogen chemistry

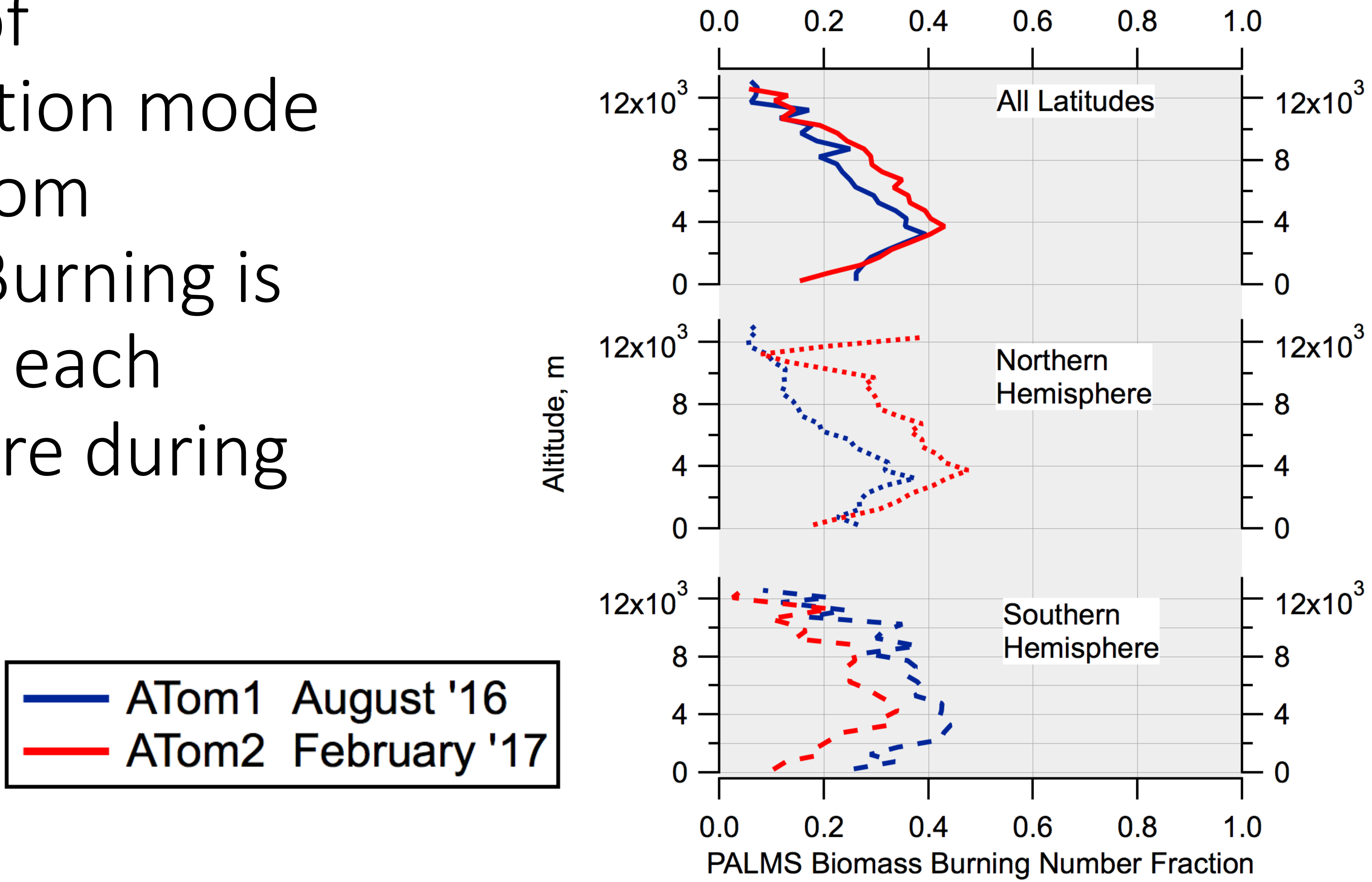
PALMS: Karl Froyd, Gregory Schill, **Daniel Murphy**, NOAA/CIRES

Biomass Burning can dominate accumulation mode aerosol number, even far from sources



PALMS: Karl Froyd, **Gregory Schill**, Daniel Murphy, NOAA/CIRES; CESM: Pengfei Yu, NOAA/CIRES

Fraction of accumulation mode aerosol from Biomass Burning is greater in each hemisphere during winter



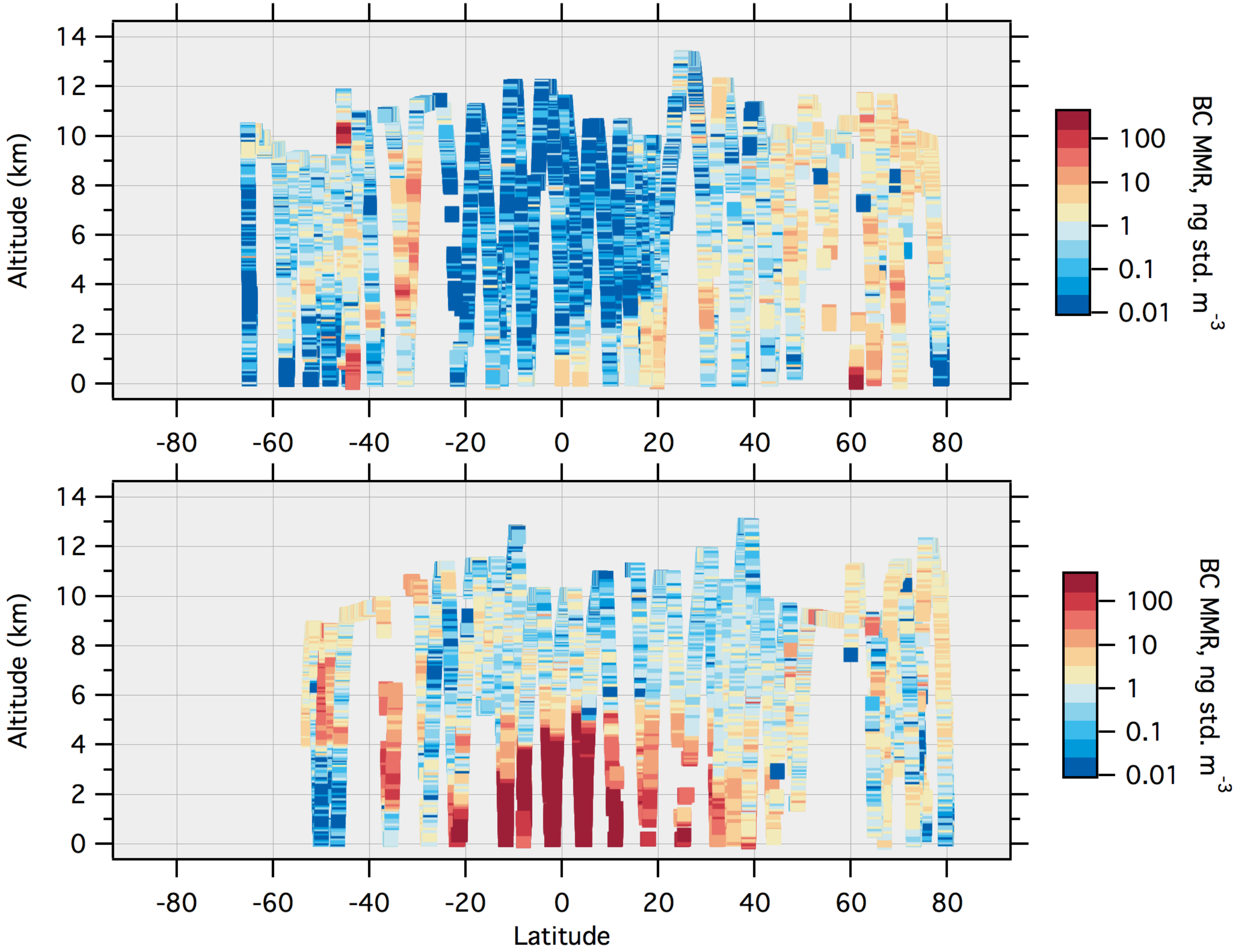
PALMS: Karl Froyd, **Gregory Schill**, Daniel Murphy, NOAA/CIRES; CESM: Pengfei Yu, NOAA/CIRES

Global Distribution of Black Carbon

ATom 1
Aug '16

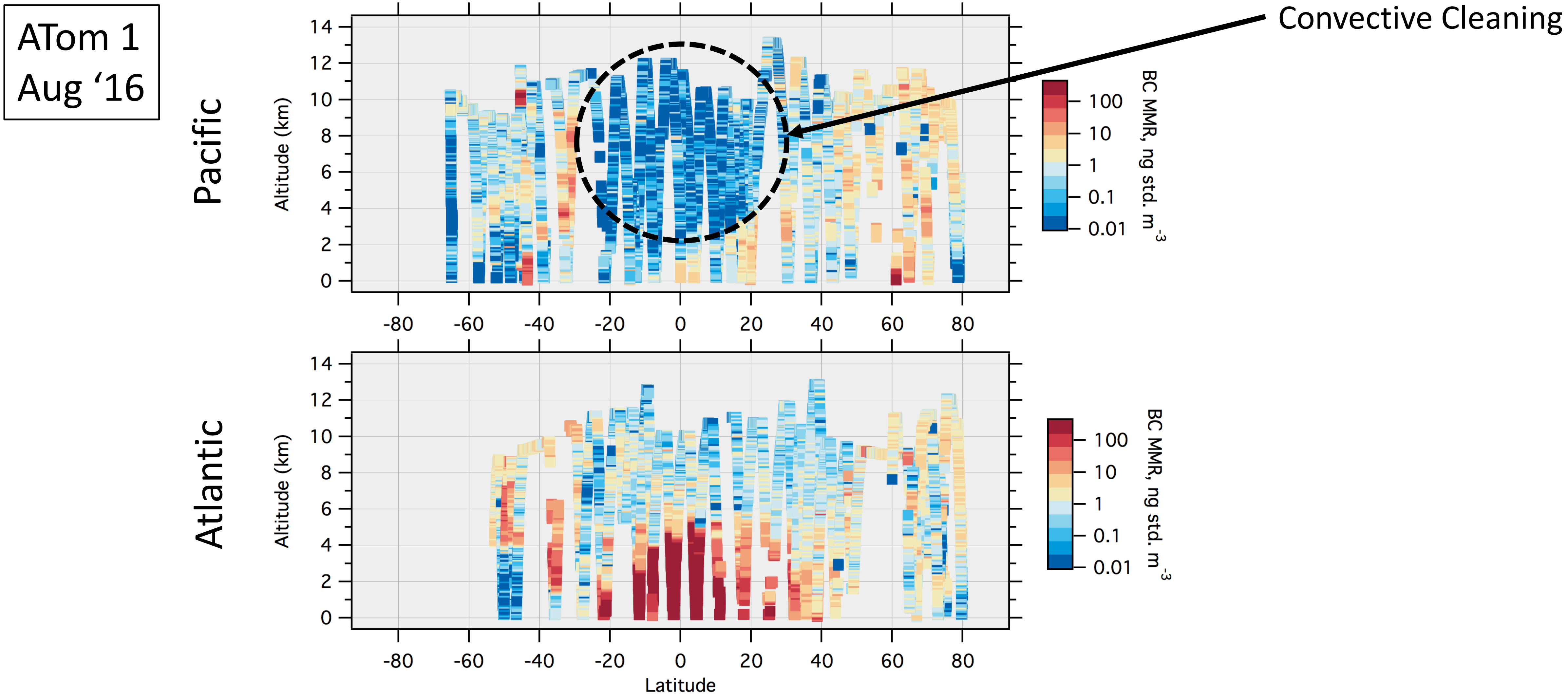
Pacific

Atlantic



SP2: **Joseph Katich**, Joshua Schwarz, NOAA/CIRES

Global Distribution of Black Carbon



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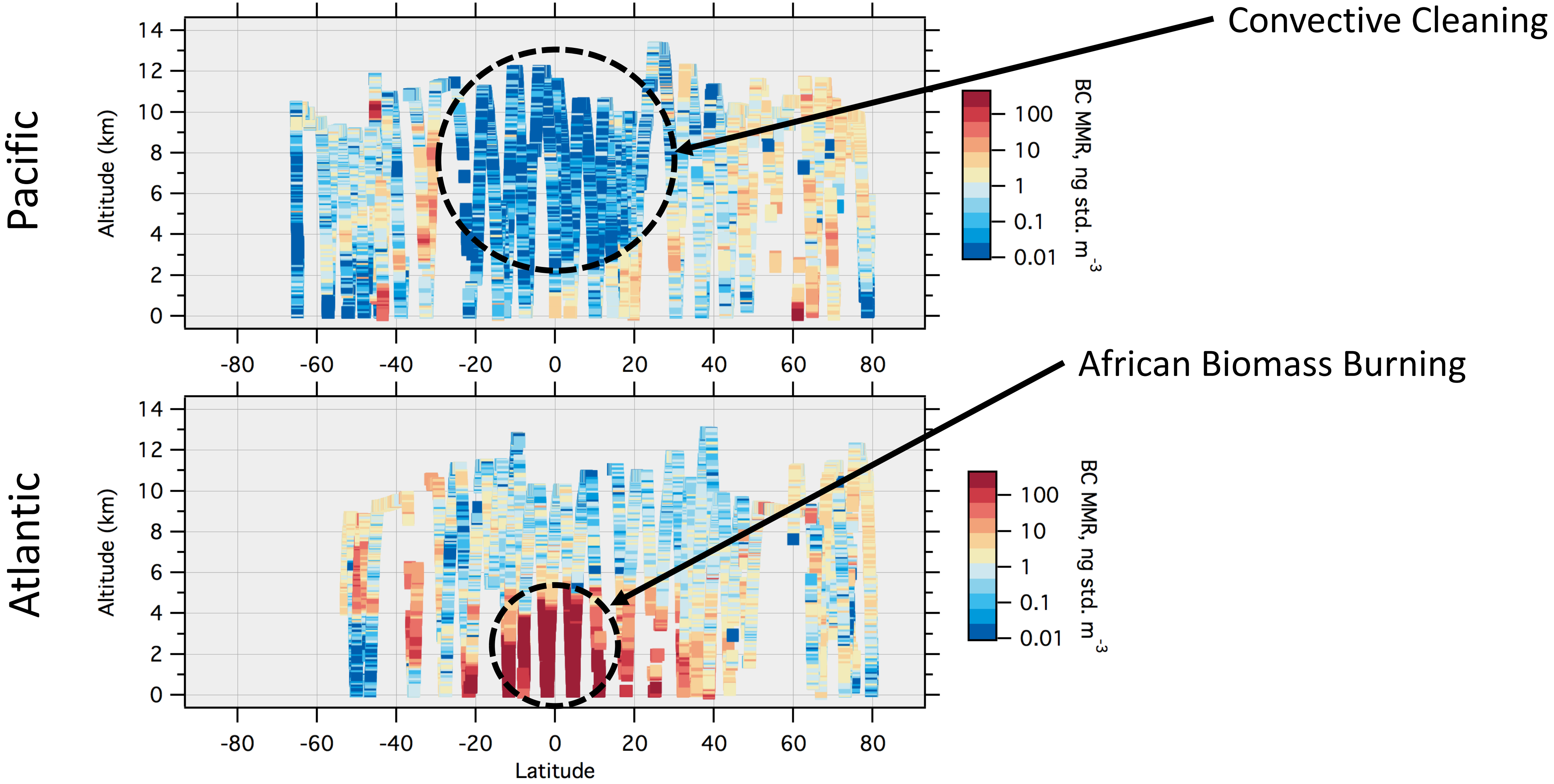
Global Distribution of Black Carbon

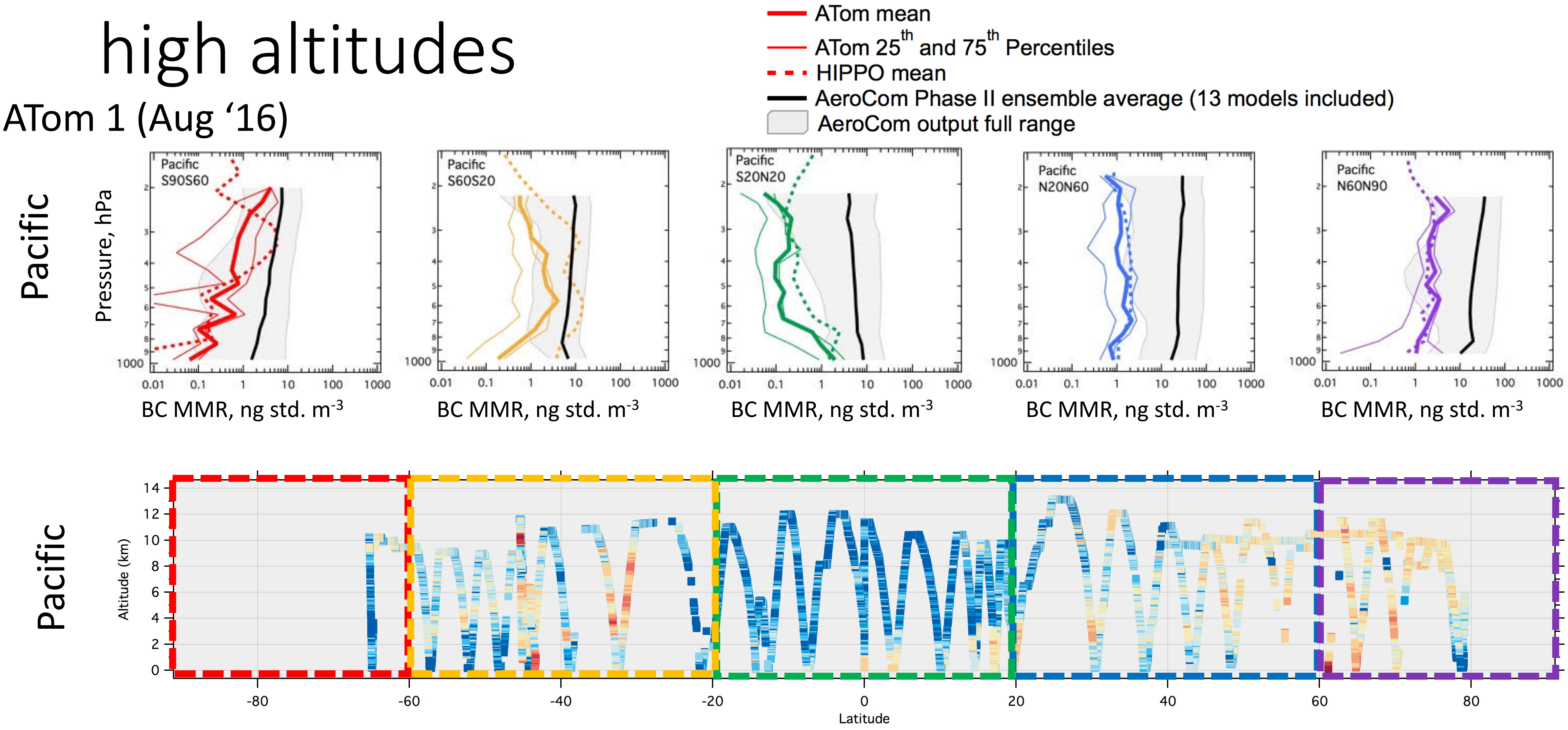
ATom 1
Aug '16



SP2: **Joseph Katich**, Joshua Schwarz, NOAA/CIRES

Models tend to over-estimate black carbon at high altitudes

ATom 1 (Aug '16)



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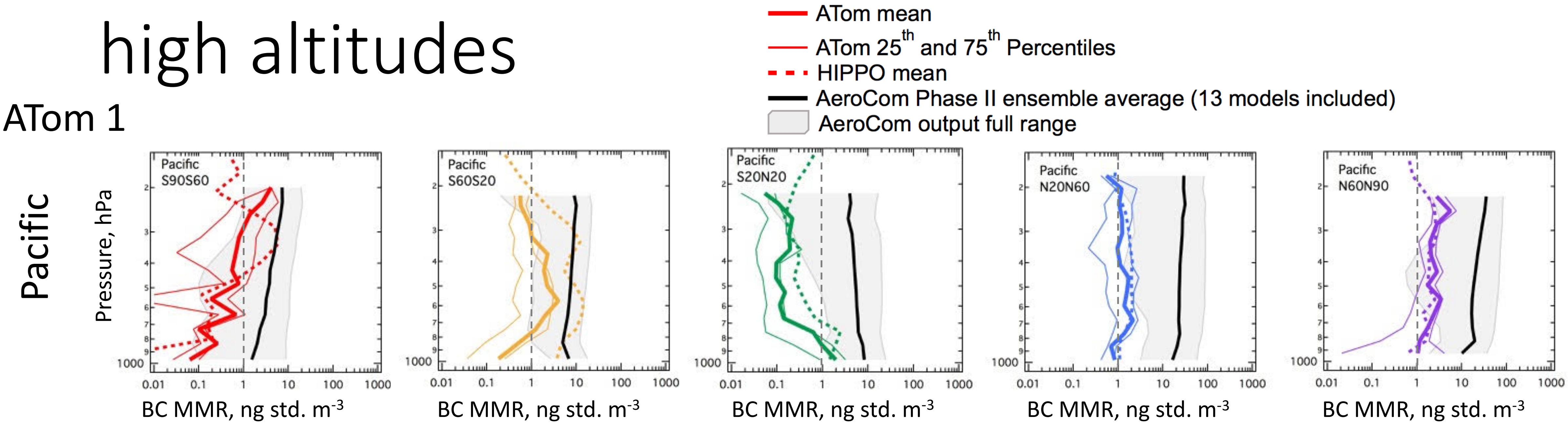

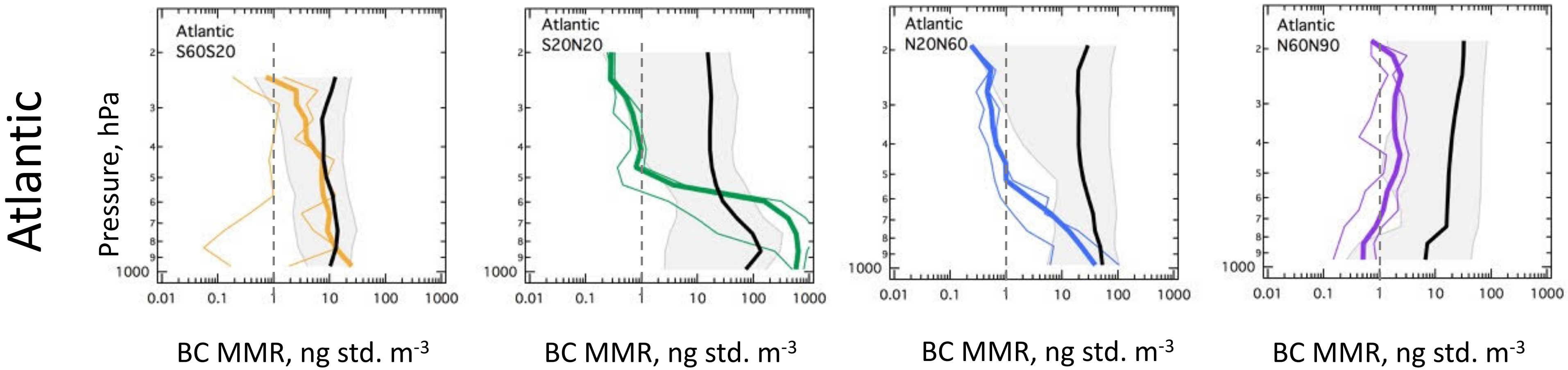

Katich et al. (2018), Strong contrast in remote black carbon aerosol loadings between the Atlantic and Pacific basins, *JGR,* in review

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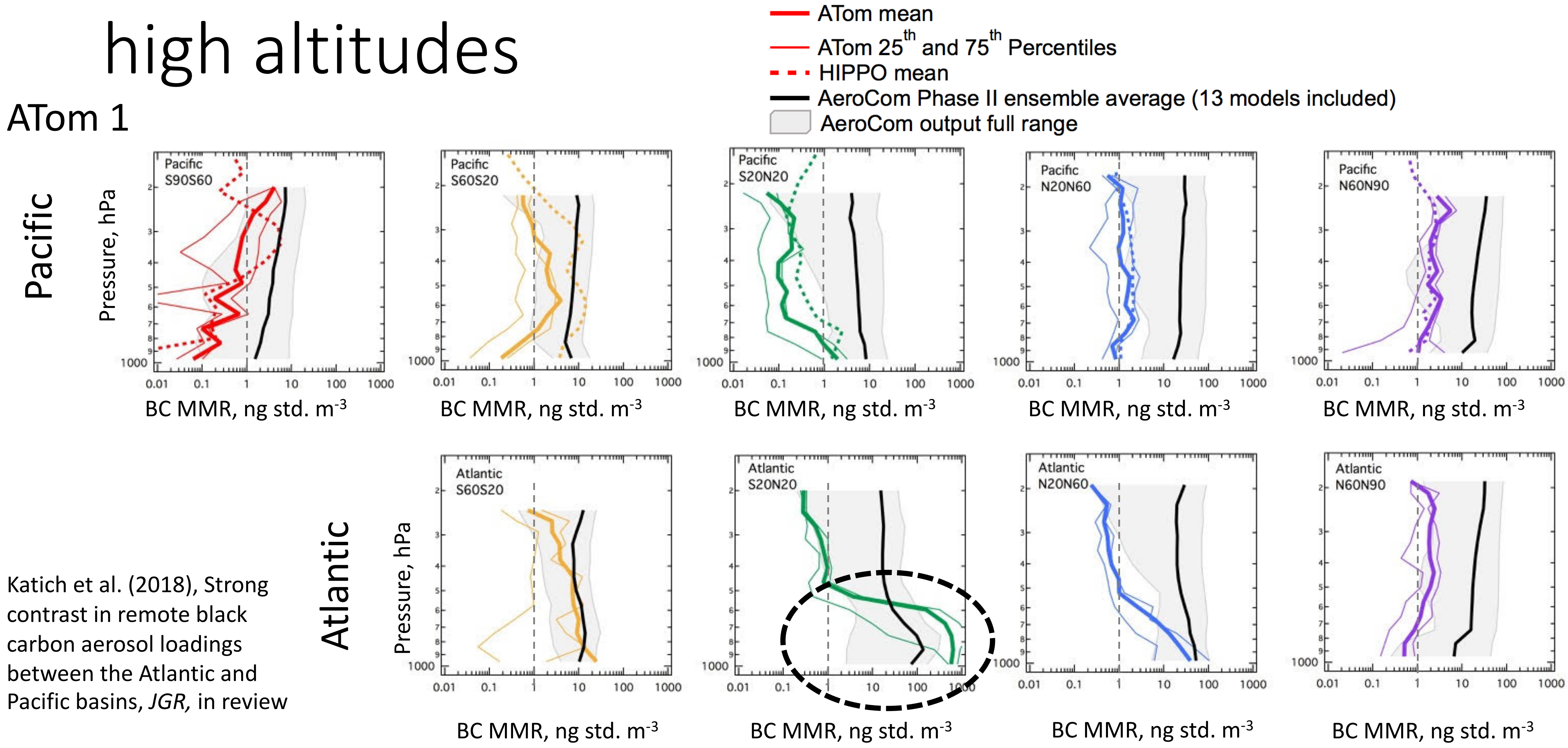

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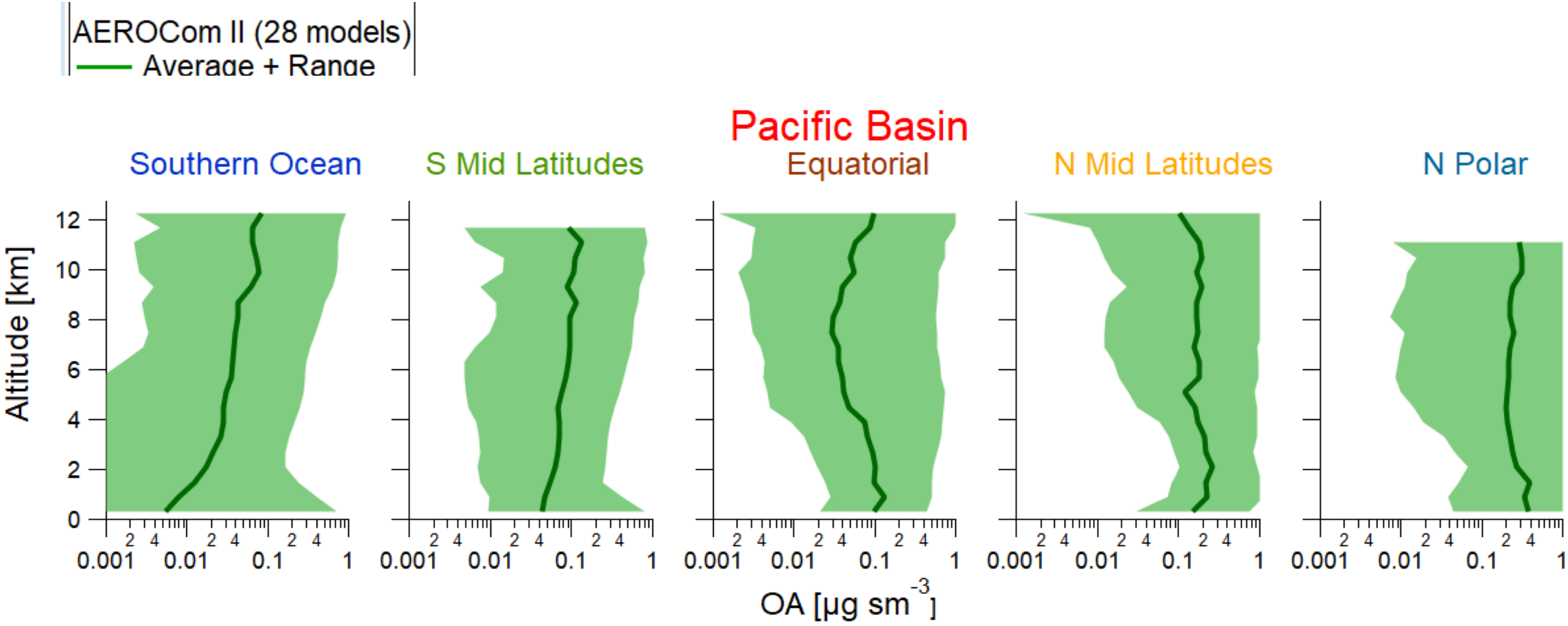
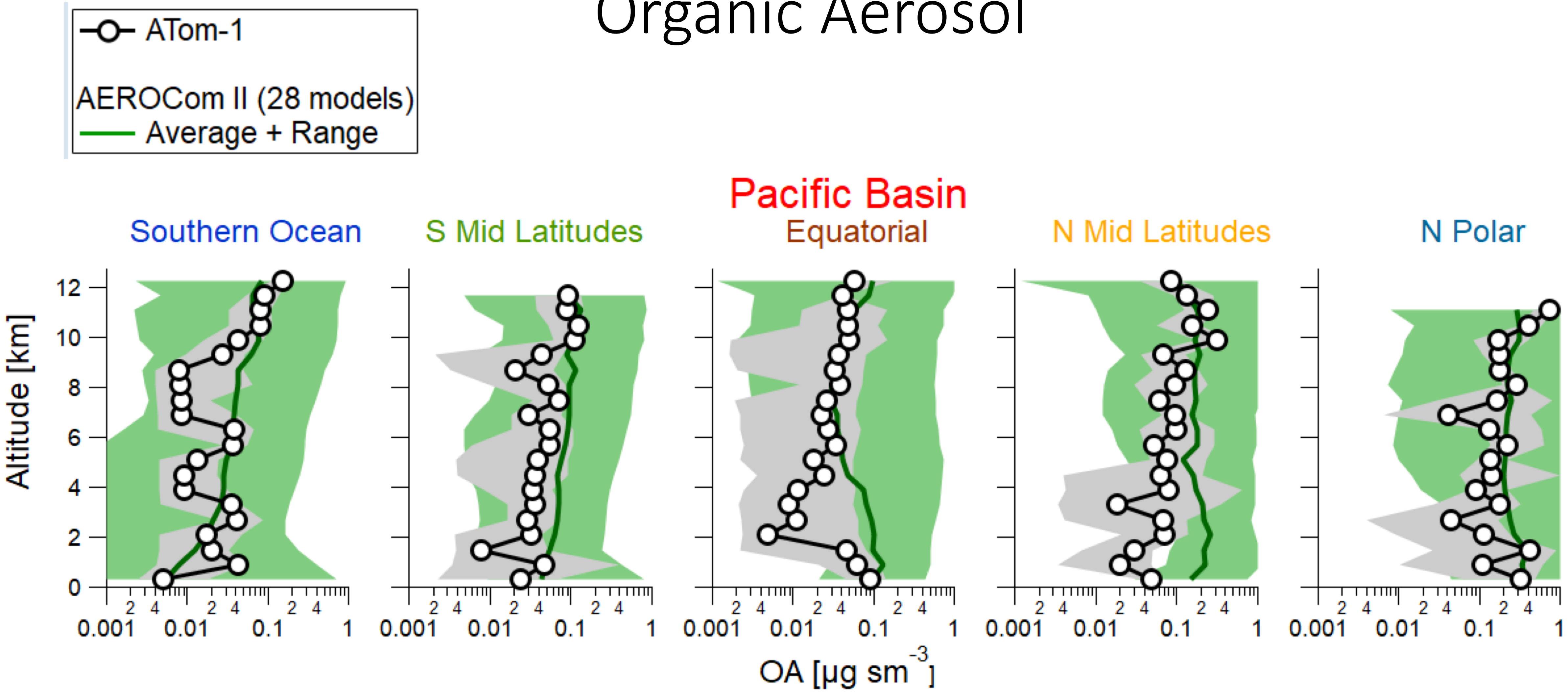
AEROCom II Models tend to overestimate remote Organic Aerosol



AMS: **Pedro Campuzano-Jost**, Ben Nault, Jose Jimenez, CU Boulder; AEROCom II: Kostas Tsigaridis, NASA GISS/Columbia

AEROCom II Models tend to overestimate remote Organic Aerosol



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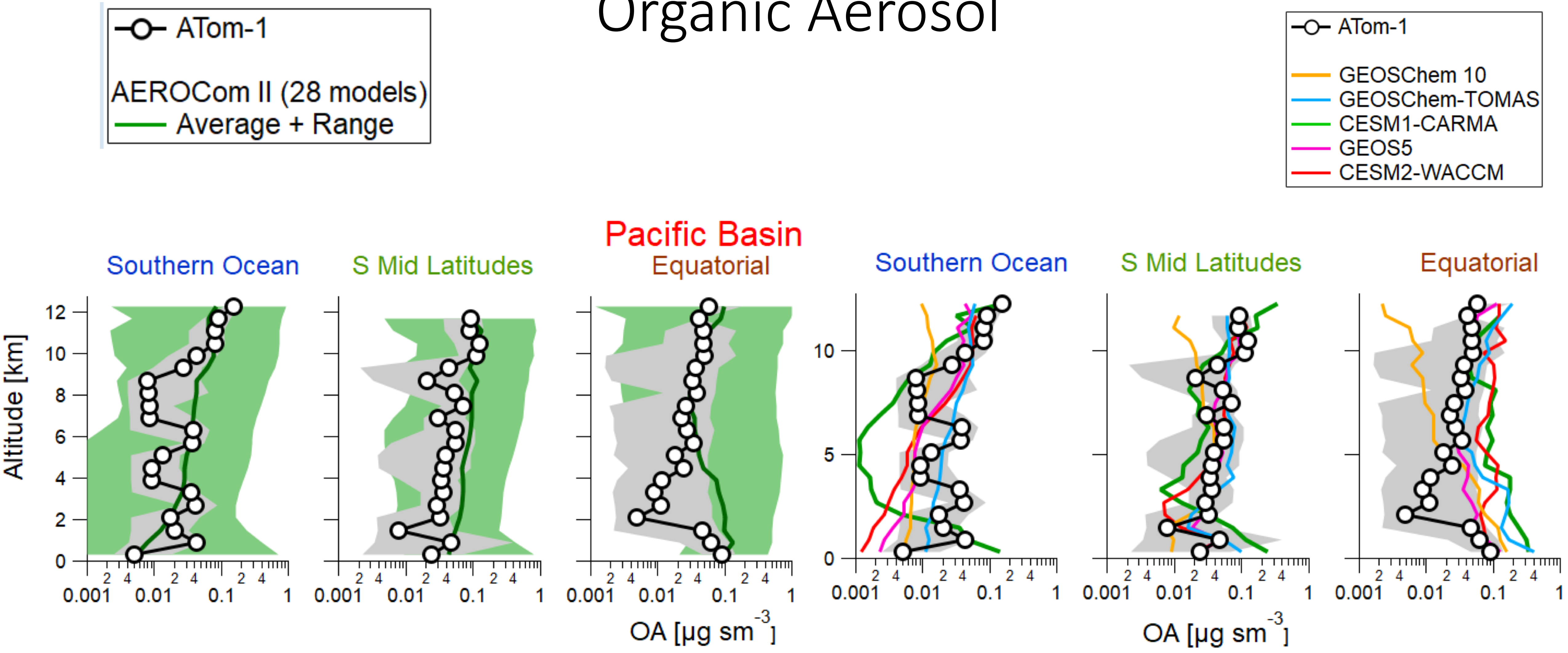
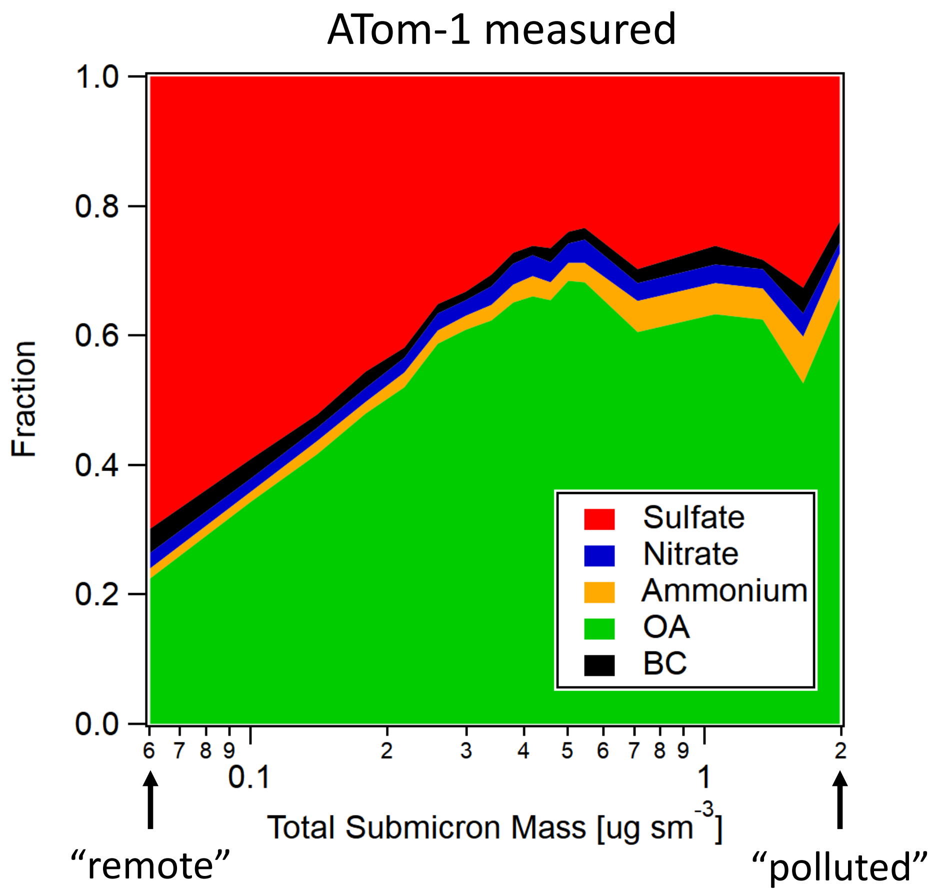


AMS: **Pedro Campuzano-Jost**, Ben Nault, Jose Jimenez, CU Boulder; AEROCom II: Kostas Tsigaridis, NASA GISS/Columbia

A missing chemical loss process for organic aerosol?

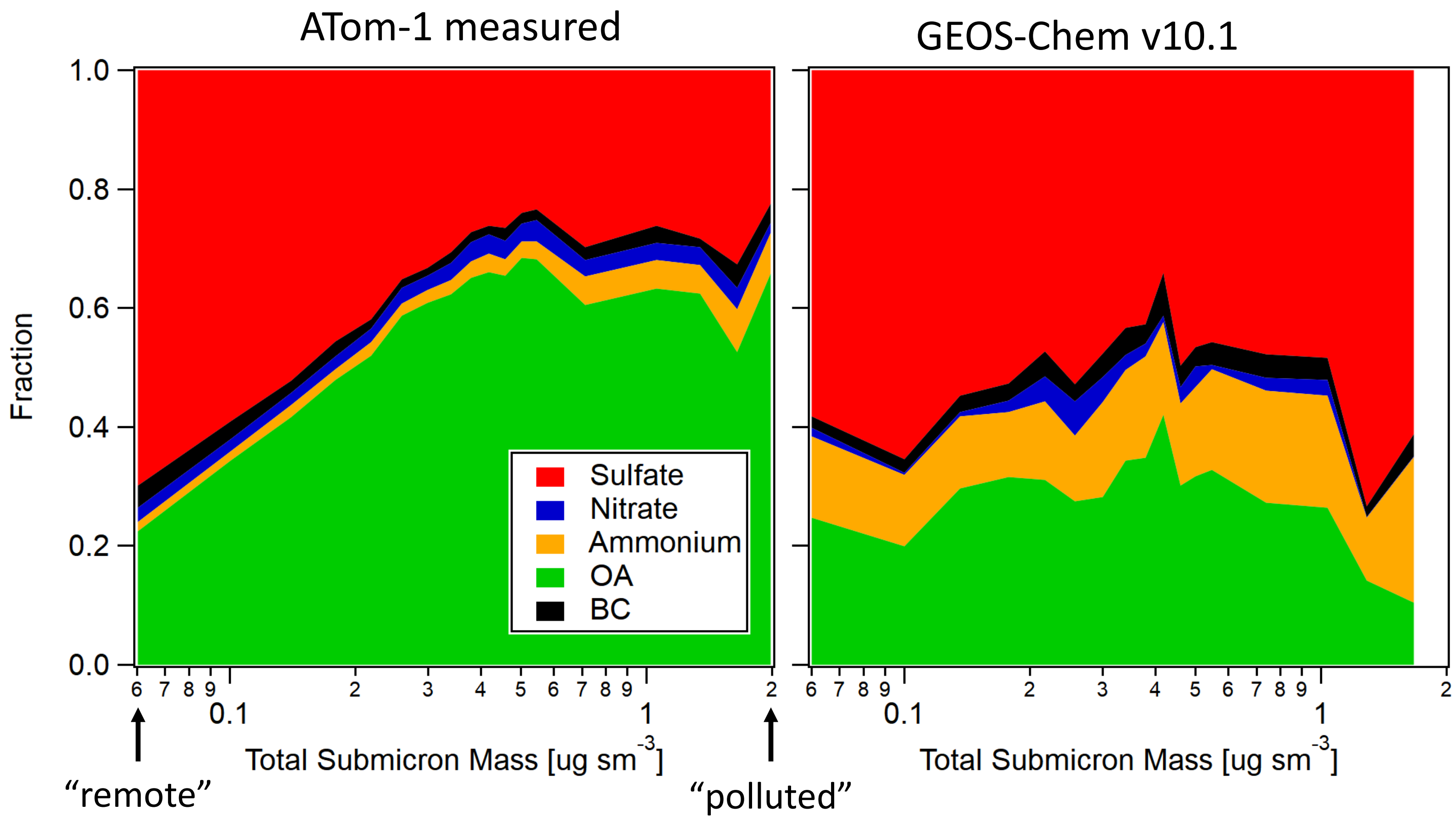


Cleanest areas have lower f(OA), suggesting:

- Strong local sulfate production or
- Removal of OA at faster rates than other species

AMS: **Pedro Campuzano-Jost**, Ben Nault, Jose Jimenez

A missing chemical loss process for organic aerosol?



Cleanest areas have lower f(OA), suggesting:

- Strong local sulfate production or
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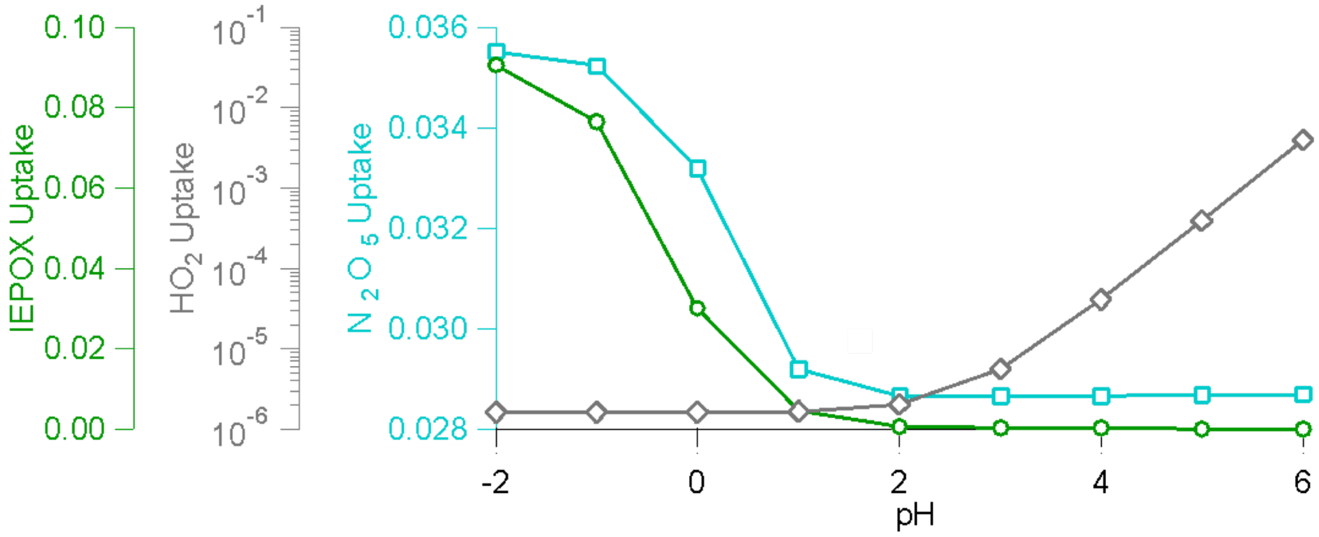
Models without OA-specific removal fail to reproduce this trend

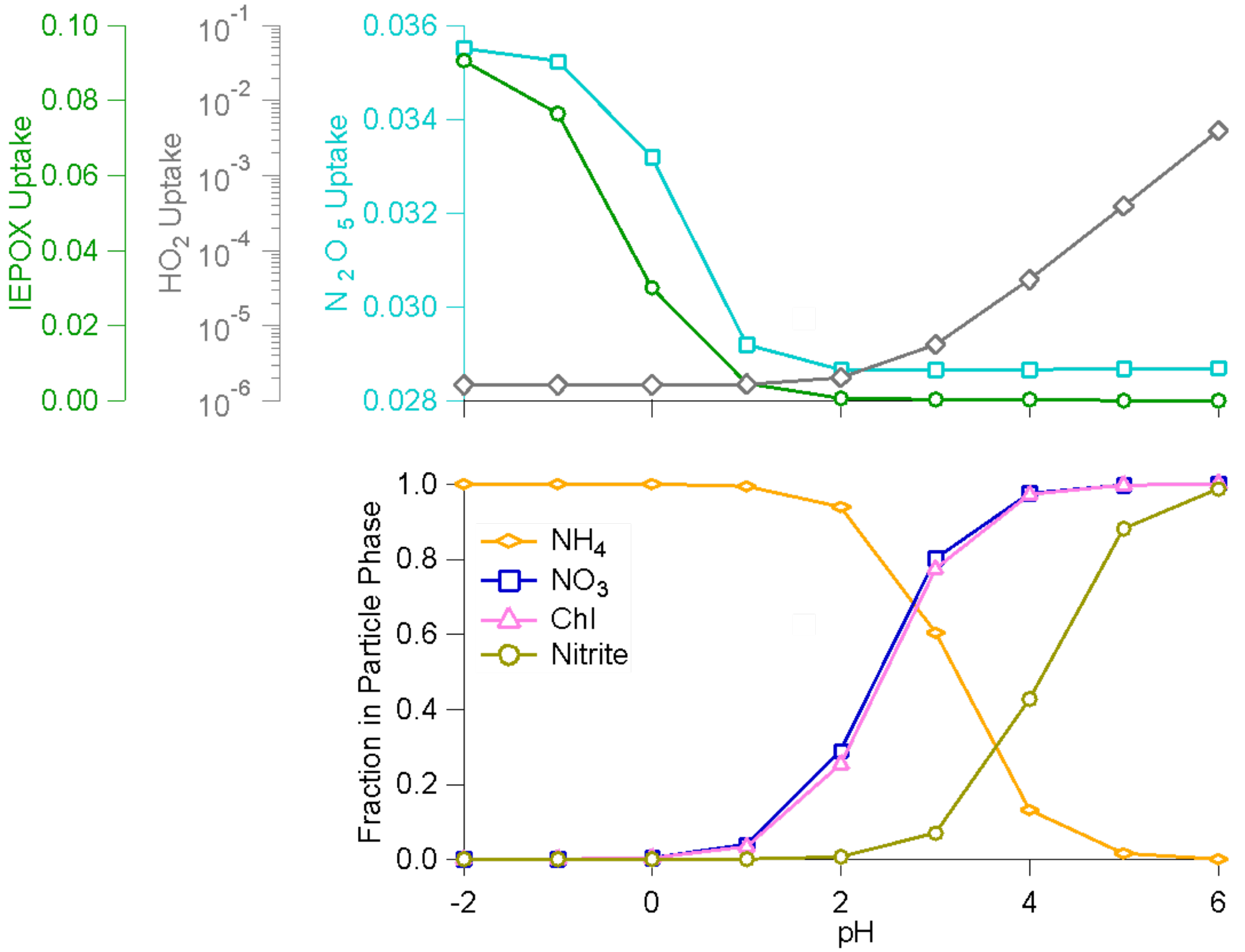
AMS: **Pedro Campuzano-Jost**, Ben Nault, Jose Jimenez

Aerosol pH is important



Various aerosol processes depend on pH, including uptake and partitioning

Aerosol pH is important

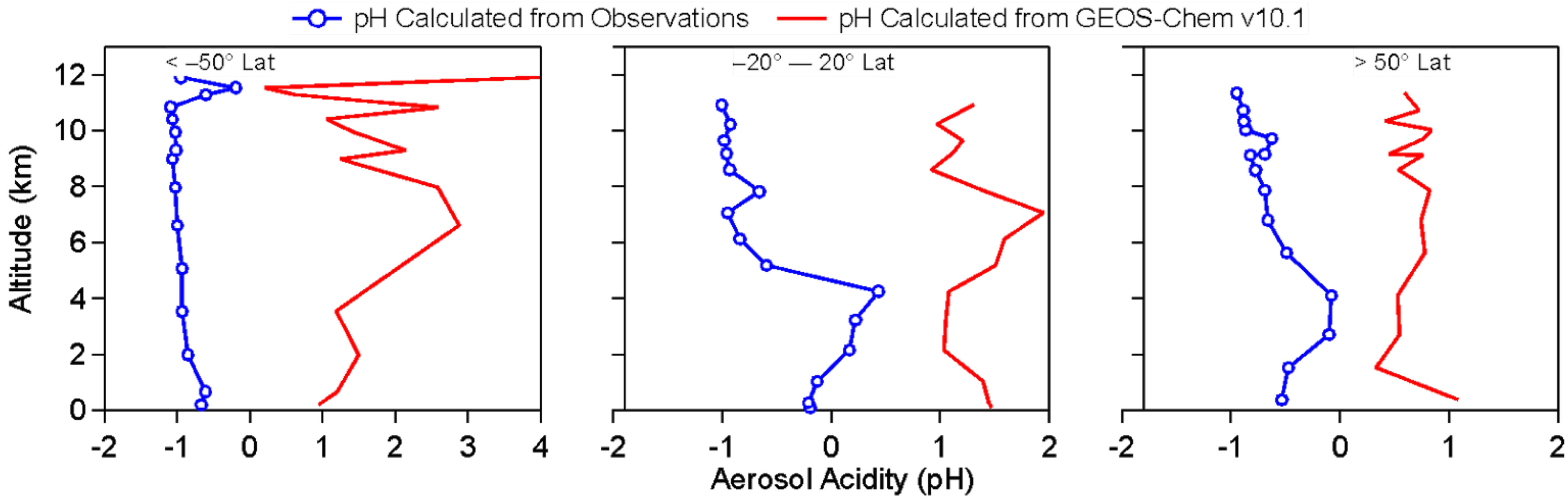


Various aerosol processes depend on pH, including uptake and partitioning

AMS: Pedro Campuzano-Jost, **Ben Nault**, Jose Jimenez, CU Boulder

pH from observations is lower than predicted by models

ATom1 – August '16



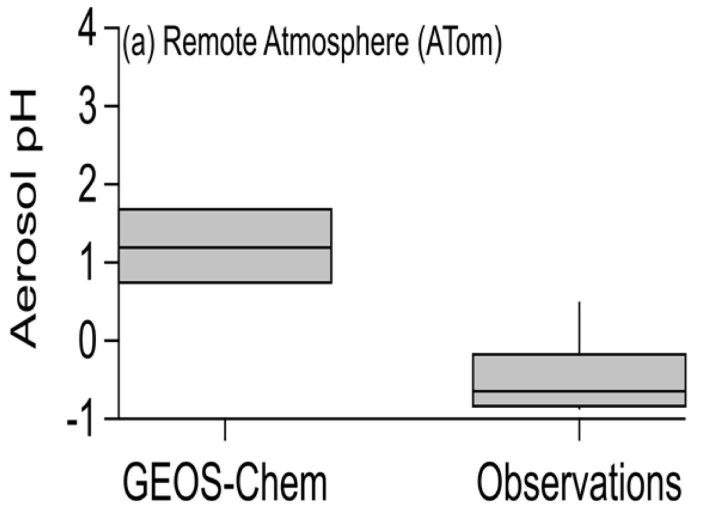
Uncertainty on pH calculated from observation ± 0.5

AMS: Pedro Campuzano-Jost, **Ben Nault**, Jose Jimenez, CU Boulder

Models fails to capture decrease in pH between urban and remote environments

GEOS-Chem = 1.19

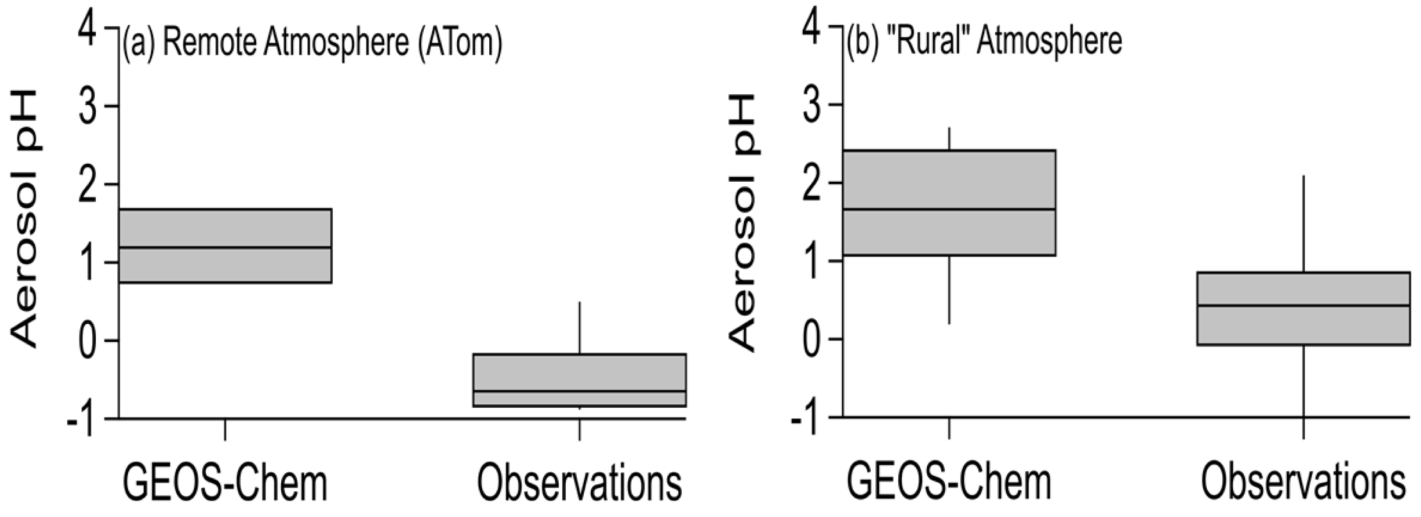
Observations = –0.65



Models fails to capture decrease in pH between urban and remote environments

GEOS-Chem = 1.19
Observations = –0.65

GEOS-Chem = 1.66
Observations = 0.43



Models fails to capture decrease in pH between urban and remote environments

GEOS-Chem = 1.19

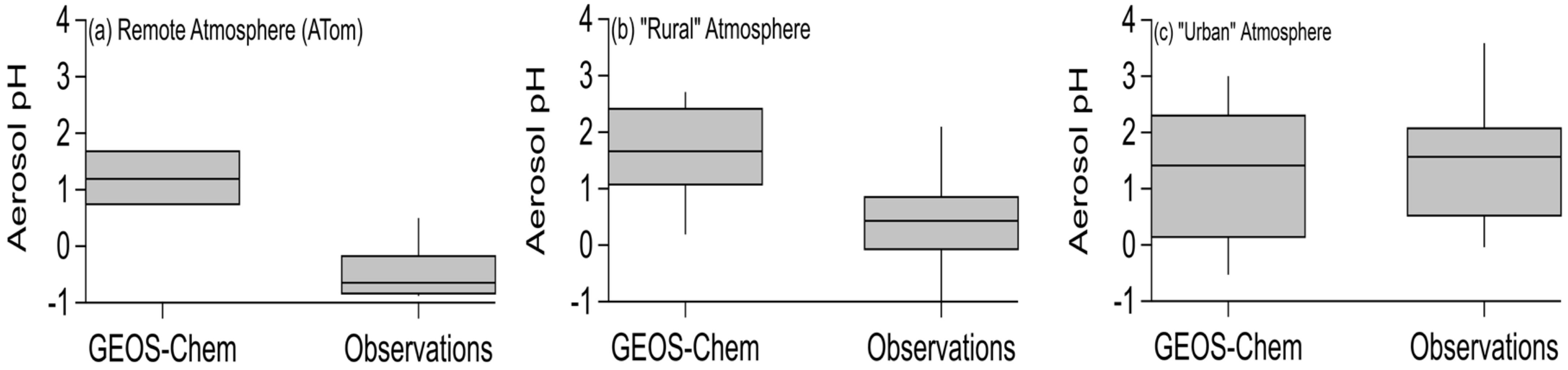
Observations = –0.65

GEOS-Chem = 1.66

Observations = 0.43

GEOS-Chem = 1.41

Observations = 1.57



AMS: Pedro Campuzano-Jost, **Ben Nault,** Jose Jimenez, CU Boulder

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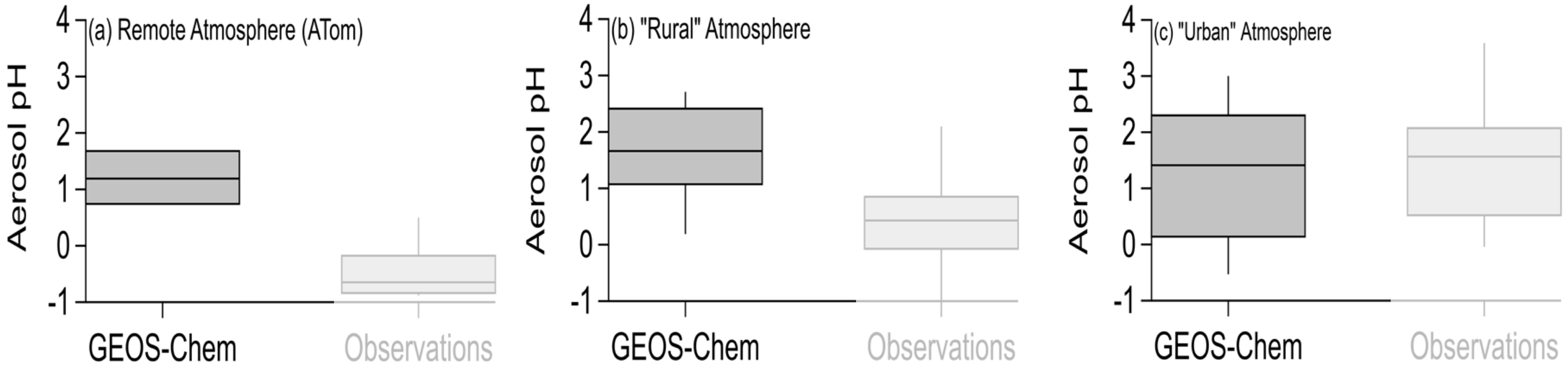

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GEOS-Chem = 1.19	**GEOS-Chem = 1.66**	**GEOS-Chem = 1.41**
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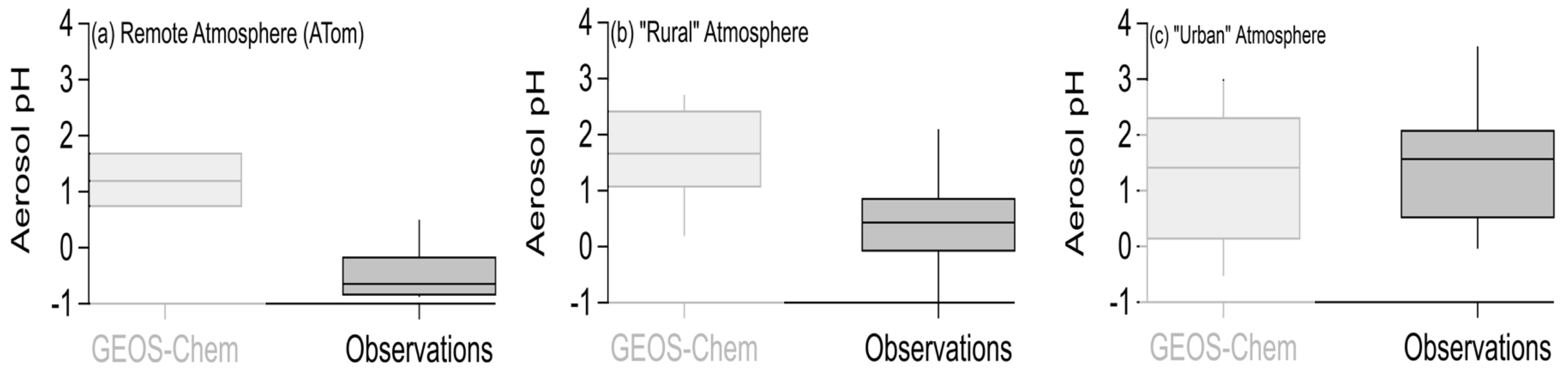

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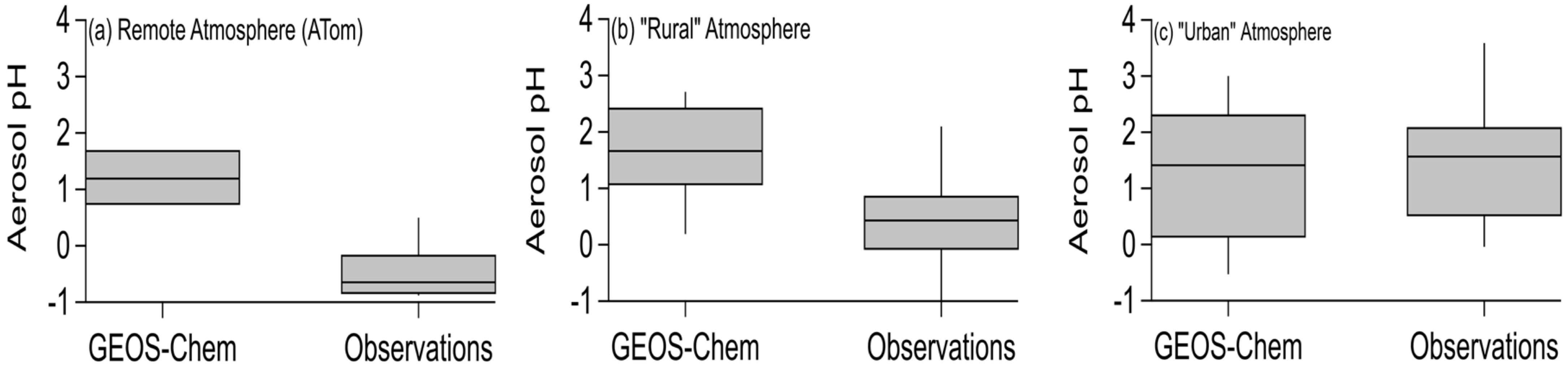
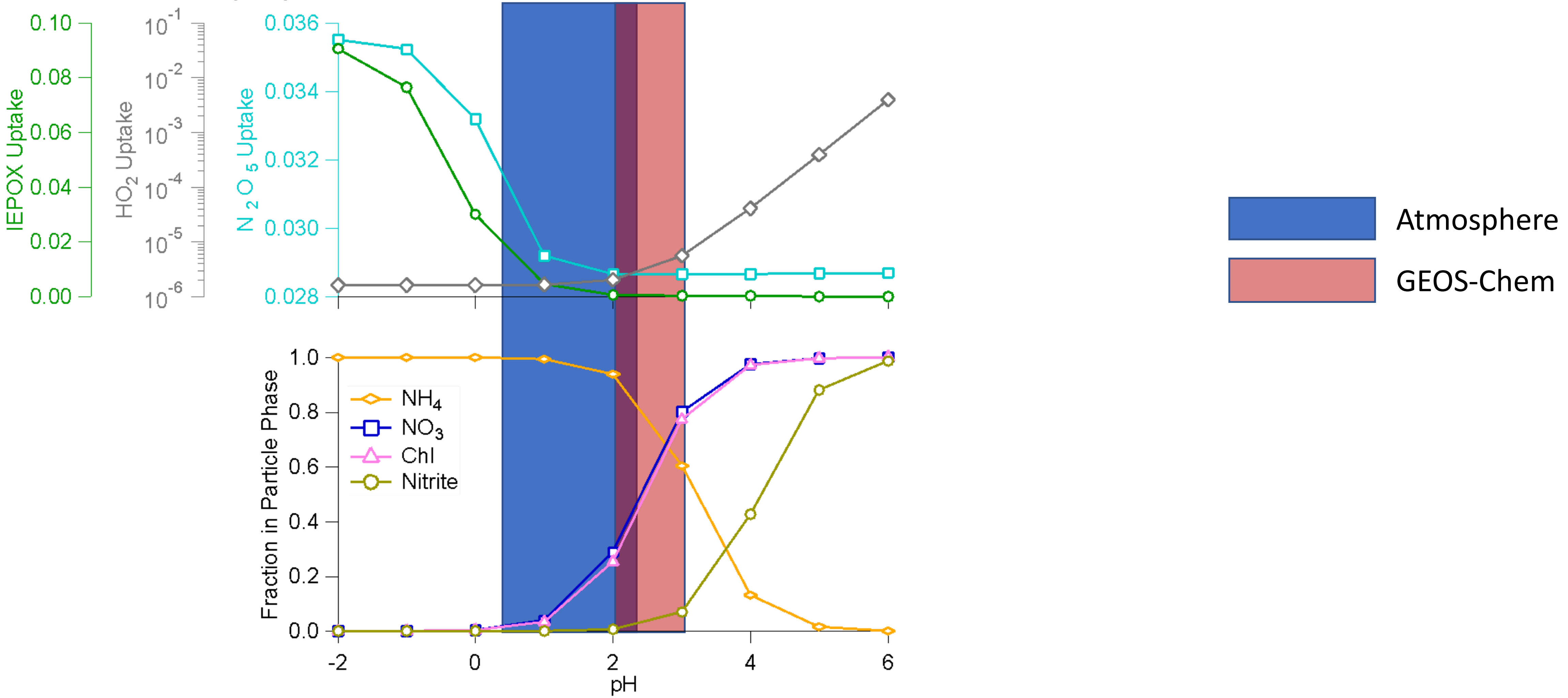


Incorrect aerosol pH in models will affect many processes



AMS: Pedro Campuzano-Jost, **Ben Nault,** Jose Jimenez, CU Boulder

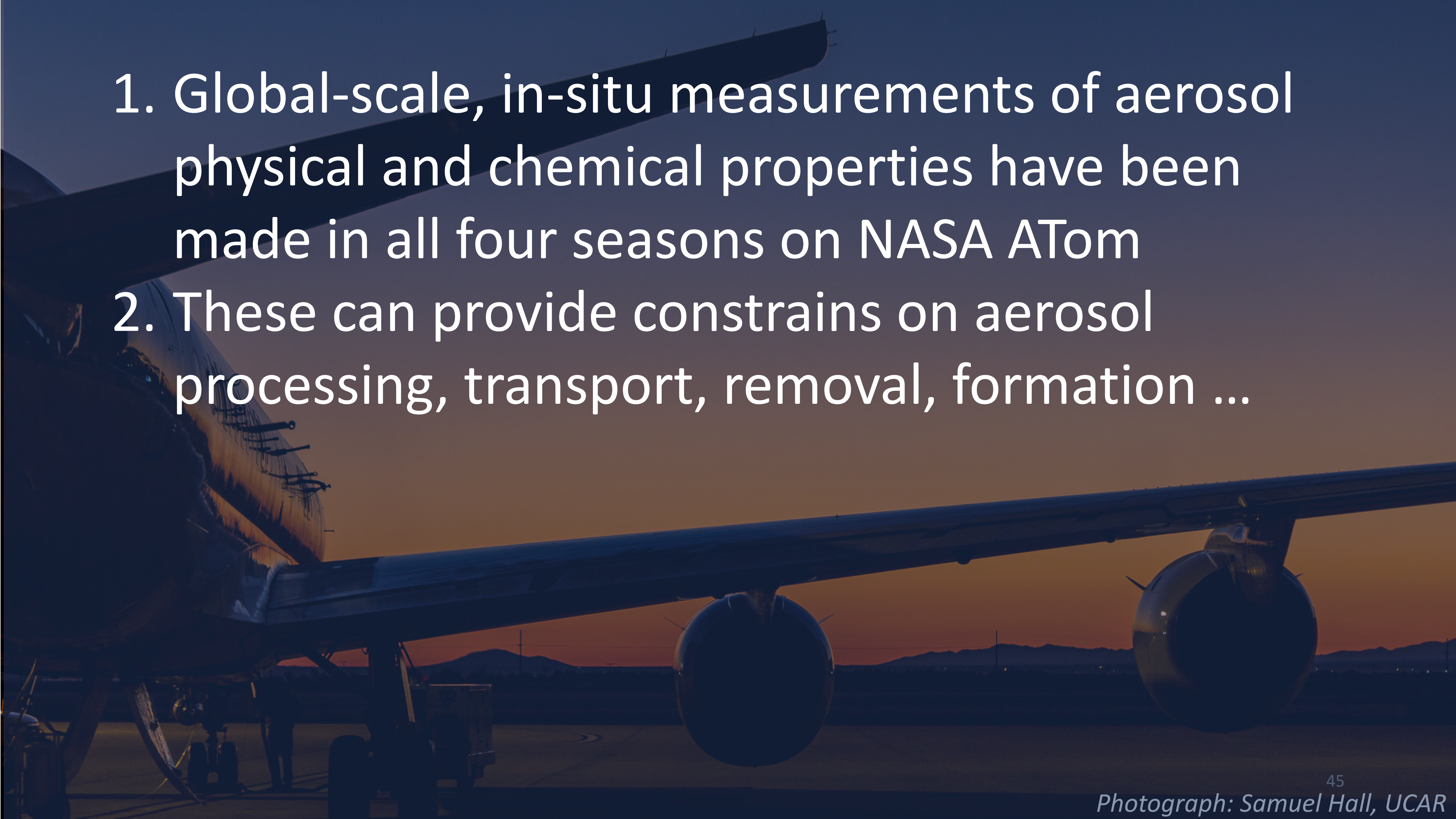
Summary

Photograph: Samuel Hall, NCAR

1. Global-scale, in-situ measurements of aerosol physical and chemical properties have been made in all four seasons on NASA ATom

Photograph: Samuel Hall, UCAR

1. Global-scale, in-situ measurements of aerosol physical and chemical properties have been made in all four seasons on NASA ATom
2. These can provide constrains on aerosol processing, transport, removal, formation …



Photograph: Samuel Hall, UCAR

1. Global-scale, in-situ measurements of aerosol physical and chemical properties have been made in all four seasons on NASA ATom
2. These can provide constrains on aerosol processing, transport, removal, formation …
3. Data are available from the NASA ESPO archive – early contact with instrumentalists strongly encouraged

Photograph: Samuel Hall, UCAR

Example Aerosol Products

- Concentration by number, surface area and volume
  - Nucleation , Aitken, Accumulation and Coarse Modes
- Aerosol Scattering, Absorption and Extinction
- Aerosol Mass
  - Organic - Ammonium - Sulfate
  - Dust- Biomass Burning - Sea Salt
  - Black Carbon - Brown Carbon …
- Number fraction from
  - Dust - Biomass Burning - Sea Salt …
- Calculated pH
- Cloud phase
- Cloud droplet number
- …

Photograph: Samuel Hall, NCAR

Contact us:

Size Distributions (AMP):
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Single Particle Composition (PALMS):
karl.froyd@noaa.gov , gregory.schill@noaa.gov , daniel.m.murphy@noaa.gov

Black Carbon (SP2):
joseph.m.katich@noaa.gov, joshua.p.schwarz@noaa.gov

Bulk Composition (AMS):
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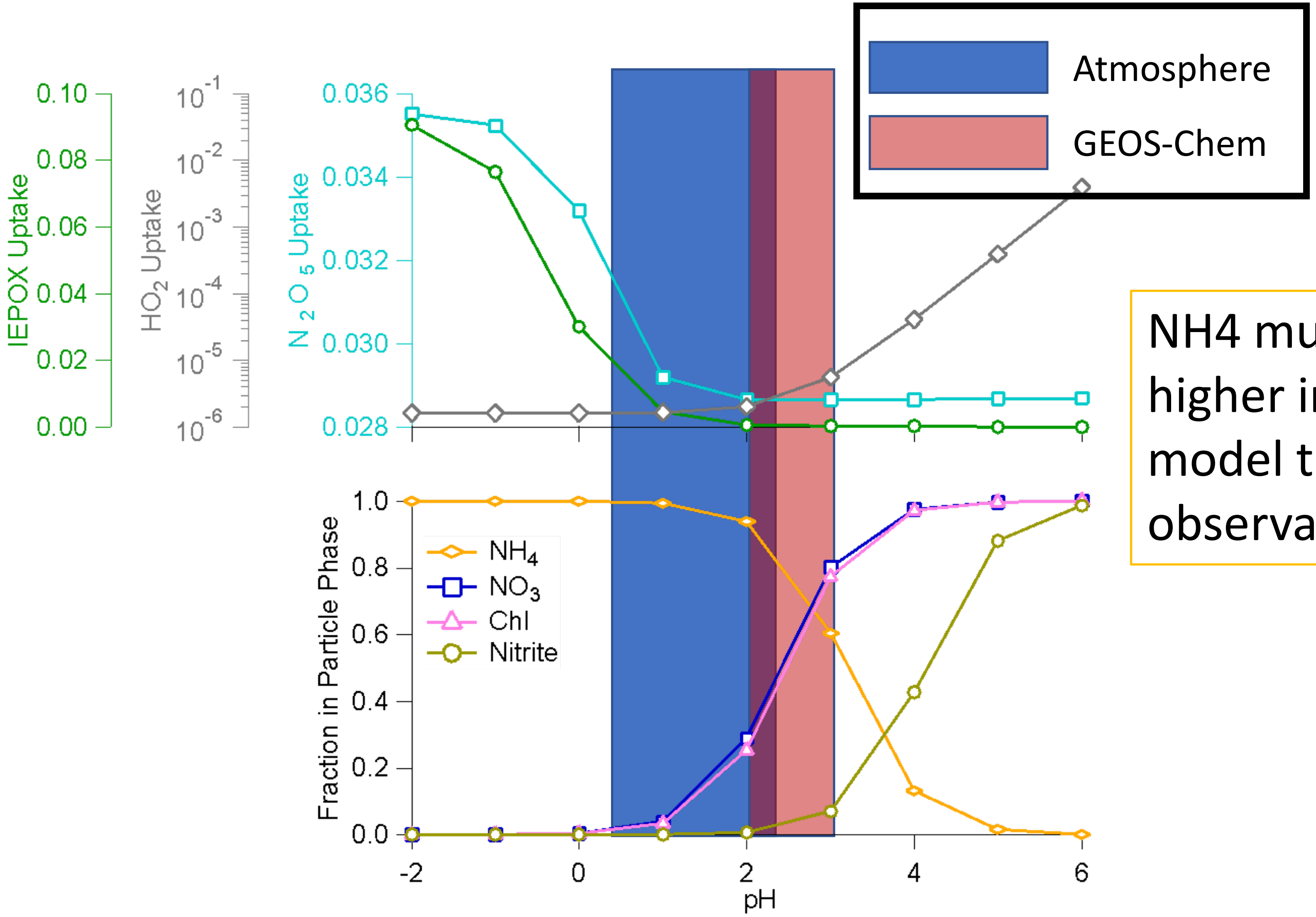
Cloud Properties (CAPS):
bernadett.weinzierl@univie.ac.at , maximilian.dollner@univie.ac.at

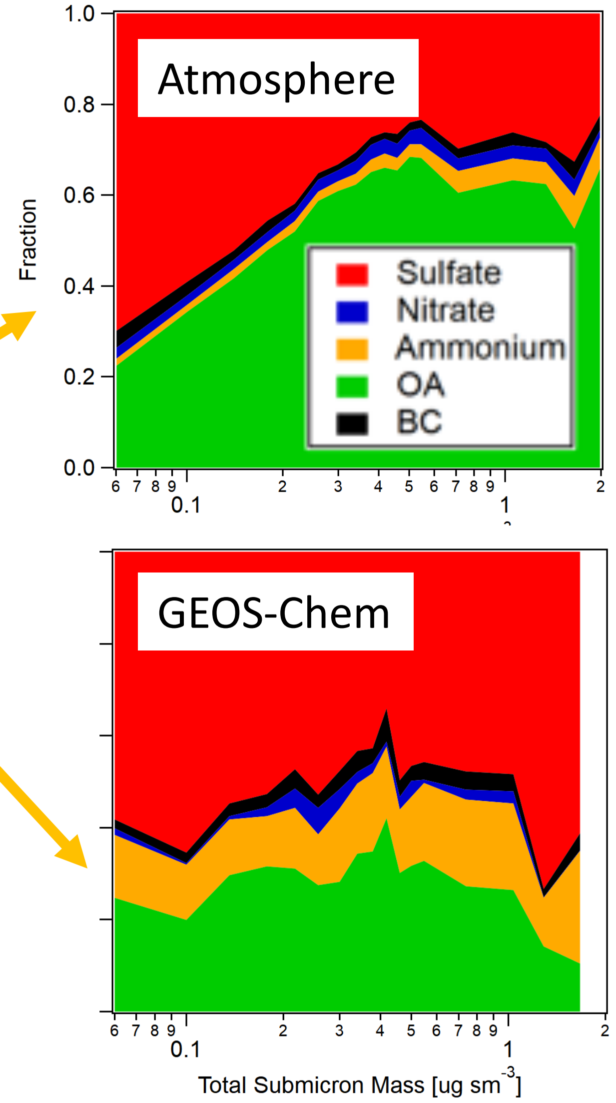
Photograph: Samuel Hall, NCAR

backup

Excess ammonia in models increases aerosol pH



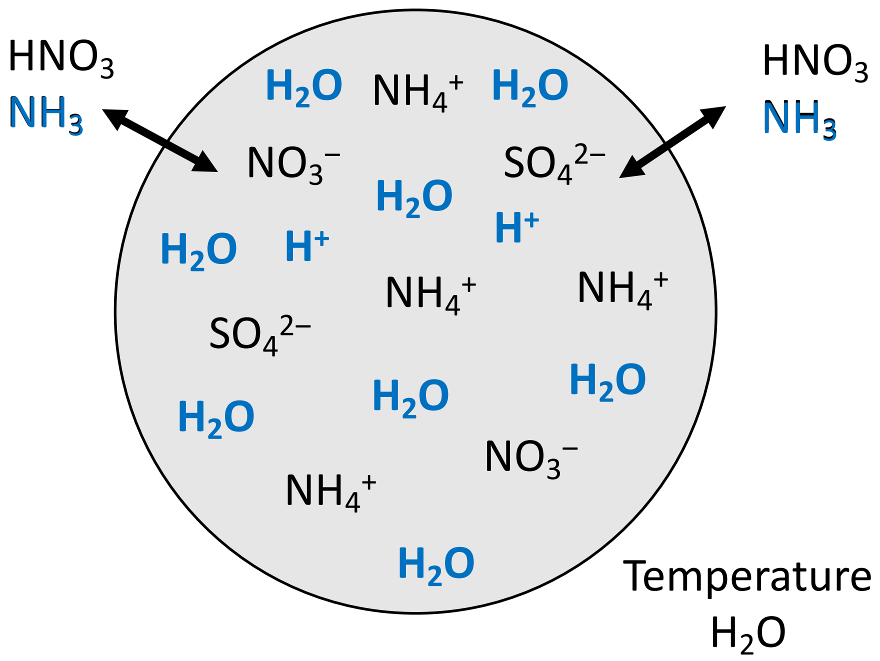
NH4 much higher in model than observations

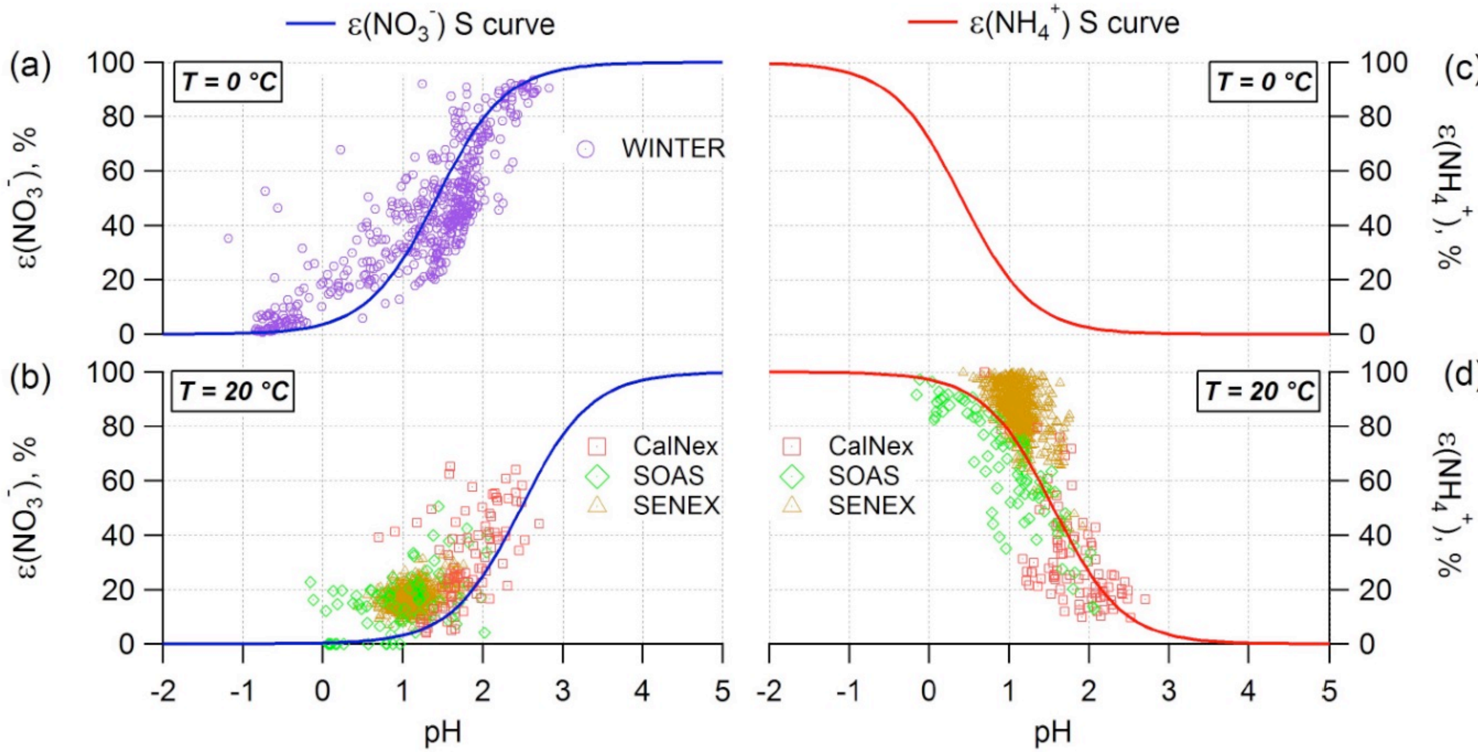


AMS: Pedro Campuzano-Jost, **Ben Nault,** Jose Jimenez, CU Boulder

How submicron aerosol pH is estimated with a thermodynamic model

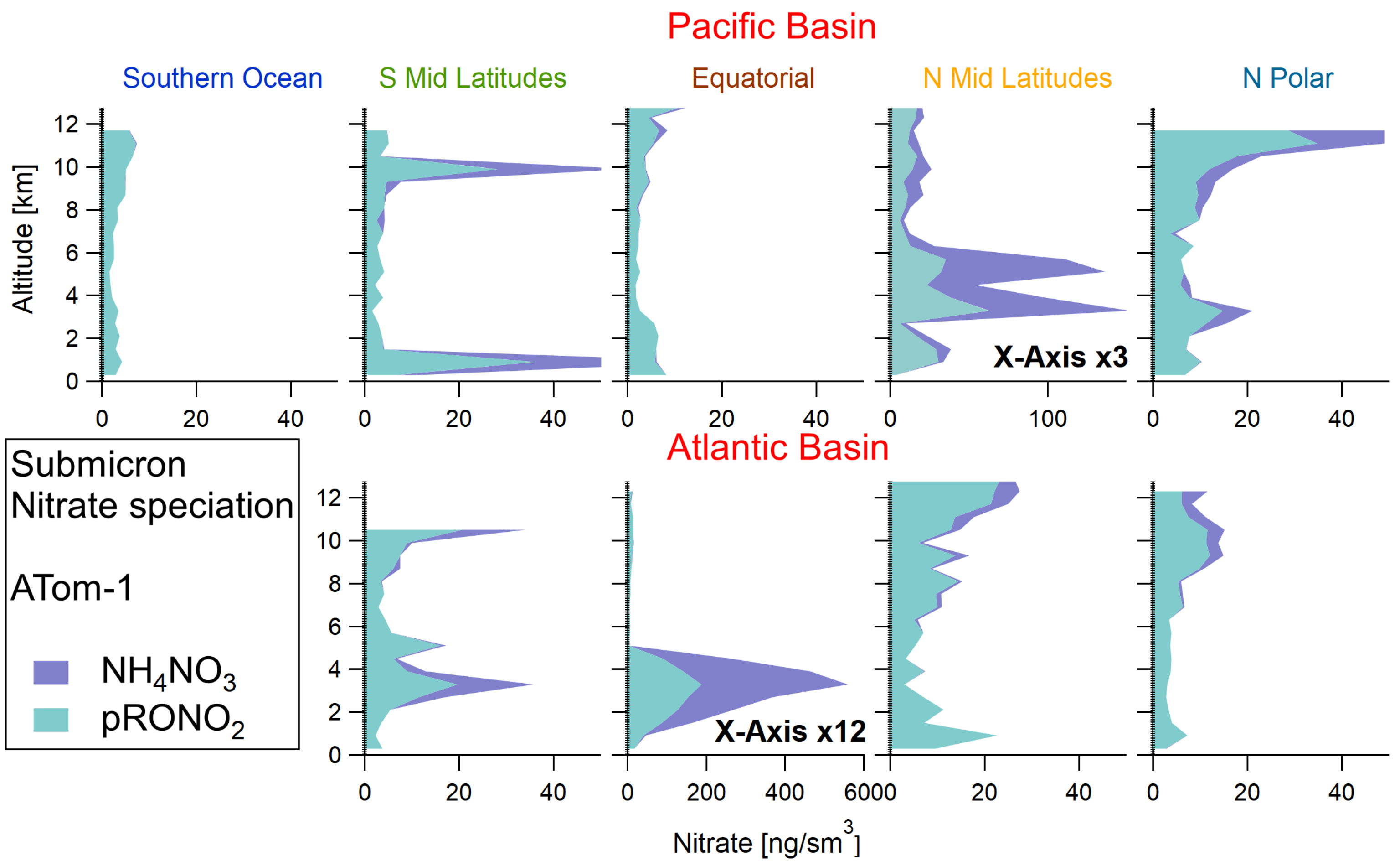
Model Input:
Total NO_3 or aerosol NO_3^-
Total NH_x or aerosol NH_4^+
SO_4
Temperature & relative humidity





Hennigan et al., *ACP*, 2015
Guo et al., *JGR*, 2016, *ACP*, 2017
Song et al., *ACP*, 2018

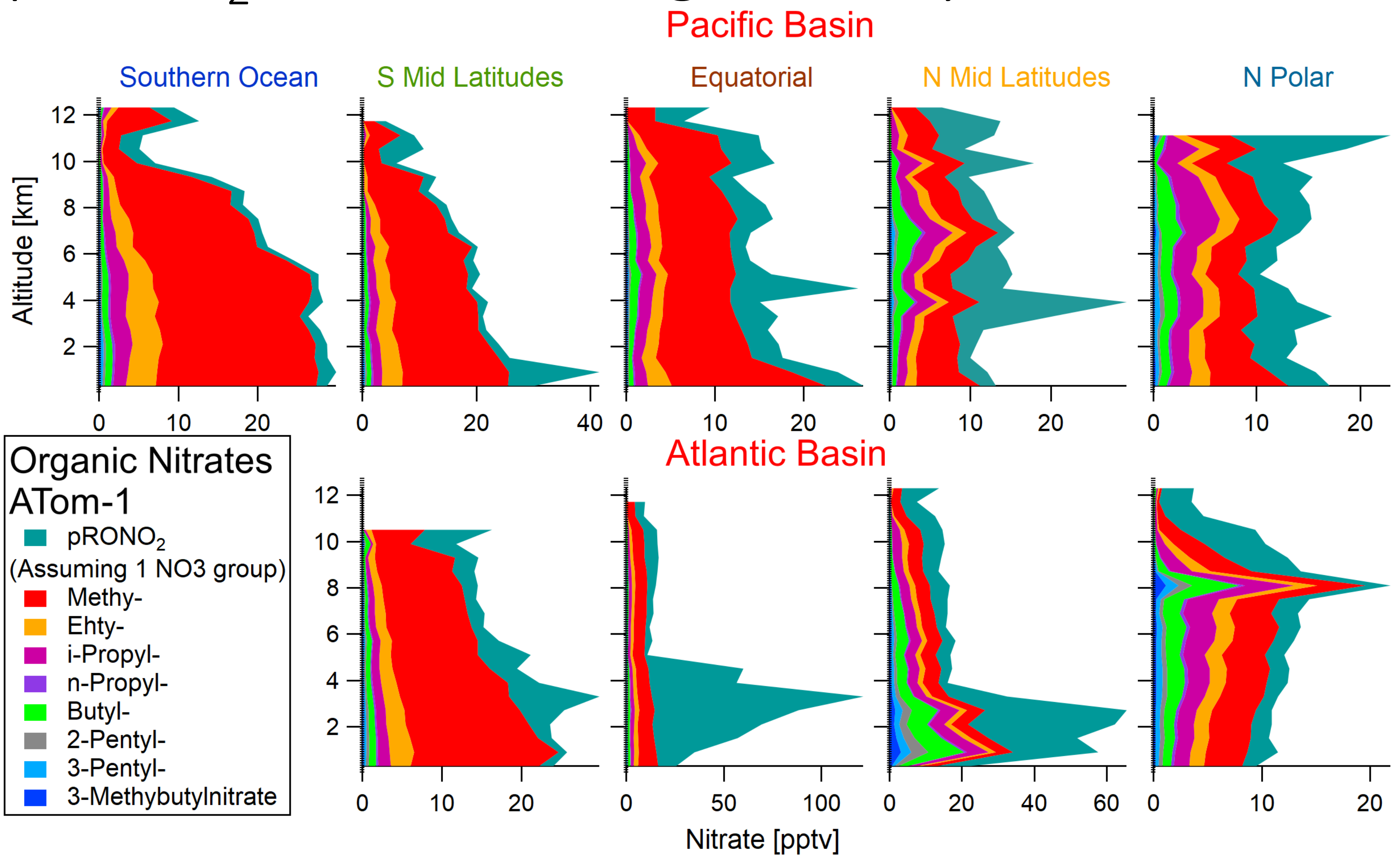
Most submicron nitrate found in ATom is organic



- Highly acidic aerosol keeps inorganic nitrate in the gas-phase (except in neutralized BB plumes)
- There is a persistent, yet very low background of (likely long-lived) particulate organic nitrate

AMS: Pedro Campuzano-Jost, Ben Nault, **Doug Day,** Jose Jimenez, CU Boulder

$pRONO_2$ contributes significantly to total $RONO_2$



AMS: Pedro Campuzano-Jost, Ben Nault, **Doug Day,** Jose Jimenez, CU Boulder; WAS (gasphase): Barbara Barletta, Don Blake, UC Irvine