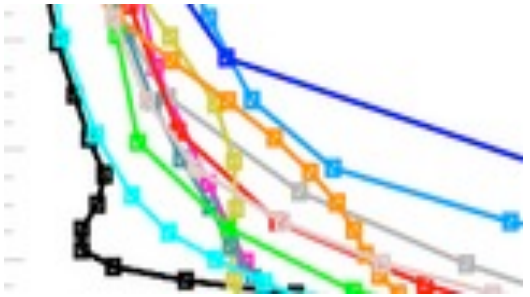


AeroCom
aerosol comparisons between observations and models

# Vertical profile, vertical profile, vertical profile:
## Are models getting better after all these years?


Mian Chin and AeroCom modelers:

Huisheng Bian, Susanne Bauer, Paul Ginoux , Alf Kirkevag, Harri Kokkola, Tom Kucsera, Hitoshi Matsui , Gunnar Myhre, David Neubauer, Toshi Takemura, Kostas Tsigaridis

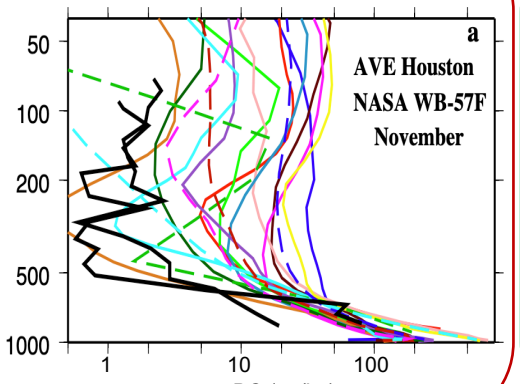


With acknowledgement of the ATom aerosol data

# BC vertical profile

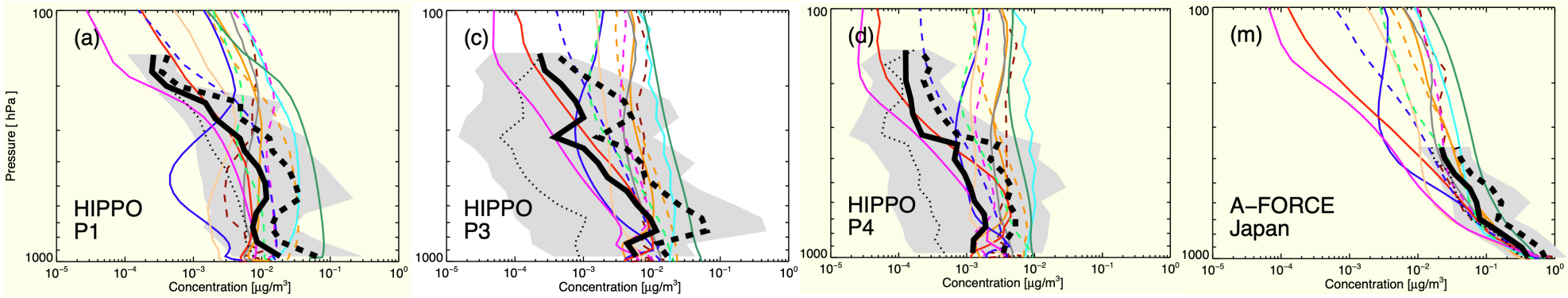
## It was then…

**AeroCom I** (17 models)




(Koch et al. 2009)

**AeroCom II** annual mean profiles (13 models)

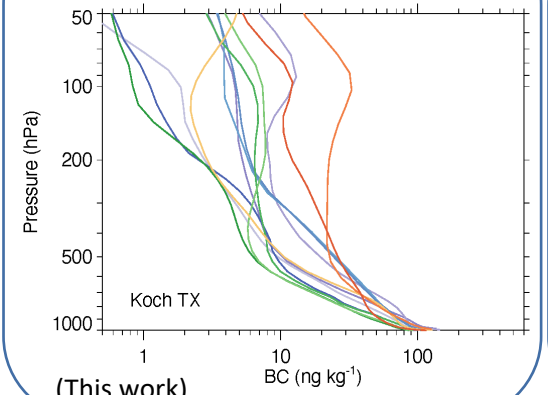



(Samset et al. 2014)

For the annual mean profiles, A3 model simulated BC shows better agreement with each other in the Pacific, especially in the upper troposphere, but the spread near the tropopause is still in 2 orders of magnitudes. The spread of A3 models over Texas does not get reduced from A1 at all.

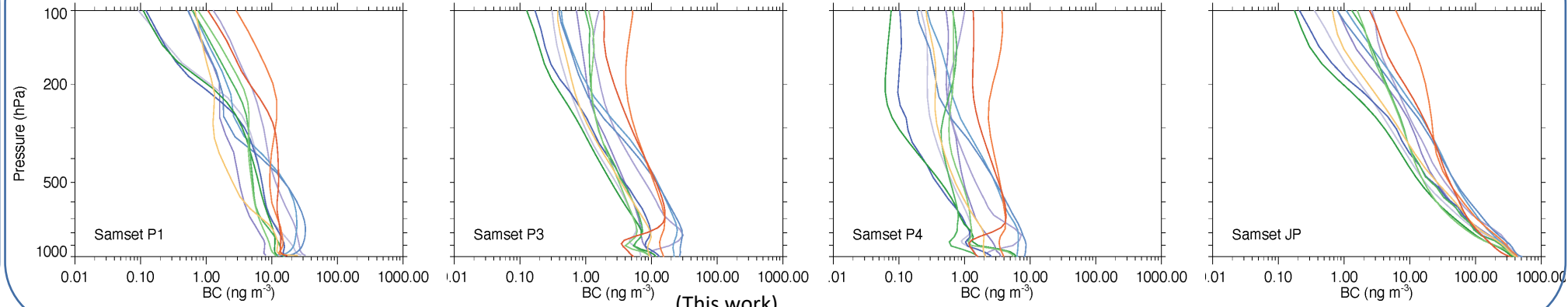
## It is now!

**AeroCom III** (13 models)




(This work)

**AeroCom III** (CTRL) 2010 annual mean profiles (13 models)

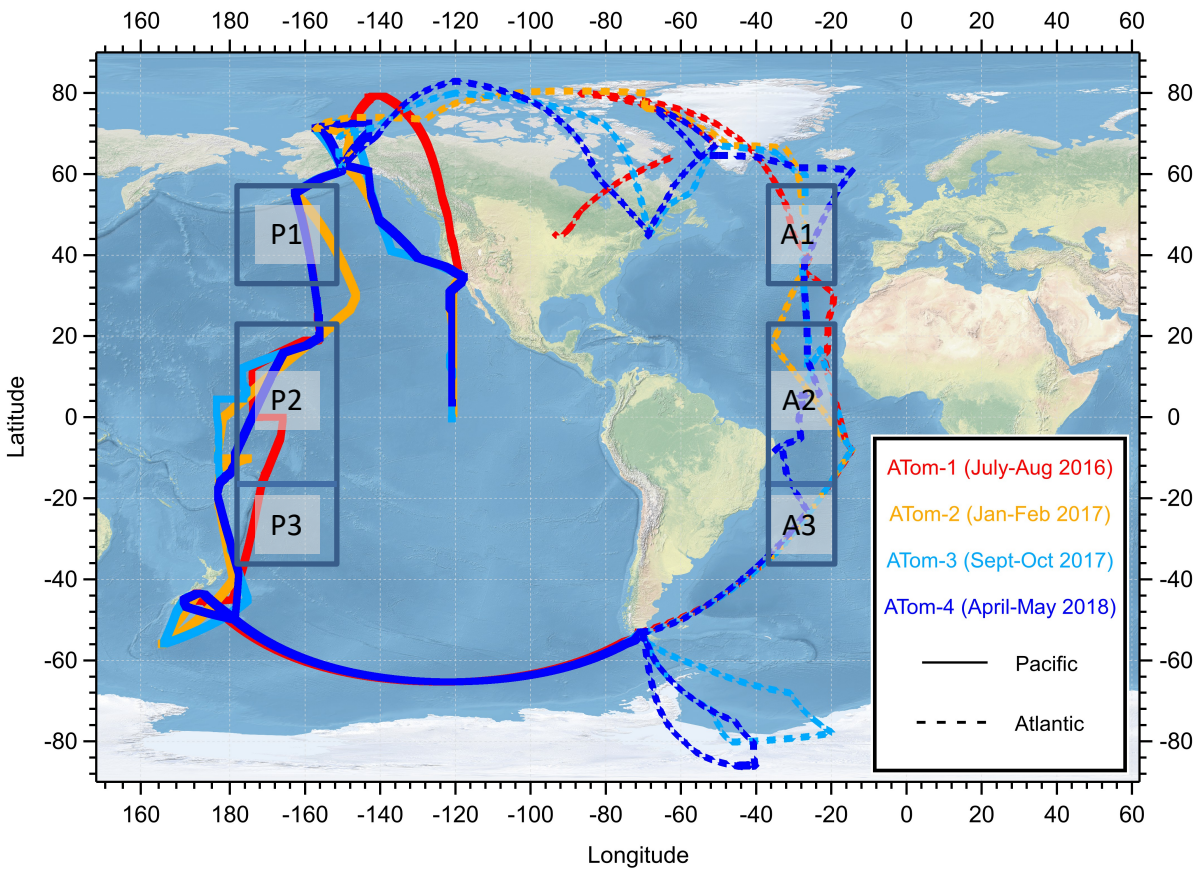



(This work)

Model simulation years: AeroCom I, 2000; AeroCom II, 2006: AeroCom III, 2010. Colored lines: AeroCom models. Black lines: Aircraft measurements

# Diversity of model simulated vertical profiles of aerosol species: Comparisons among A3 model simulations and with ATom data

ATom flight track and areas of model-data or model-model comparisons




**Atmospheric Tomography Mission (ATom)**

- ATom-1: July-Aug 2016
- ATom-2: Jan-Feb 2017
- ATom-3: Sept-Oct 2017
- ATom-4: April-May 2018

We examine the features of A3 model simulated aerosol species vertical profiles in the Atlantic and Pacific Oceans (areas indicated in the left figure) and compare them to the available ATom data (dust and SS data are not included because the particle size mismatch).

**13 AeroCom III models**:

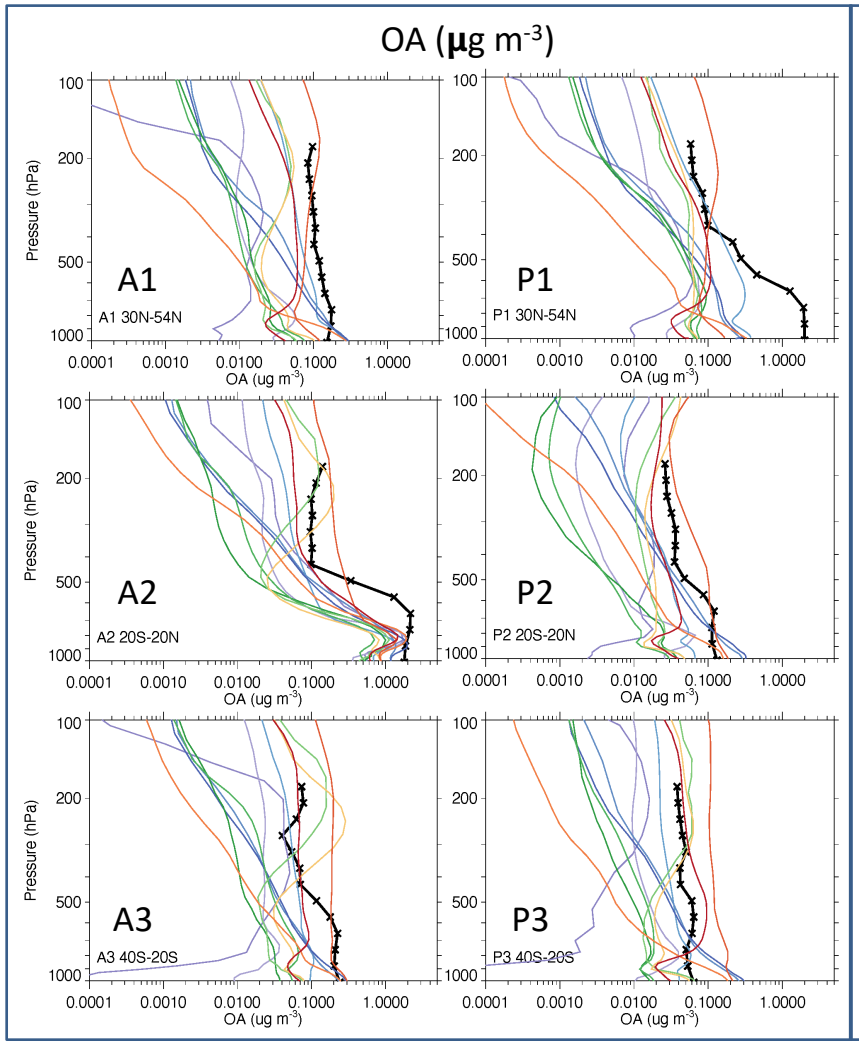
- CAM5-ATRAS
- ECHAM-HAM
- ECHAM-SALSA
- GEOS-i33p2
- GFDL-AM4-fSST
- GFDL-AM4-met2010
- GISS-E-MATRIX
- GISS-E-MATRIX-fSST
- GISS-E-OMA
- GISS-E-OMA-fSST
- MIROC-SPRINTARS
- NorESM2
- OsloCTM3

(Domain-time averaged ATom data shown in this work have been processed by Huisheng Bian)

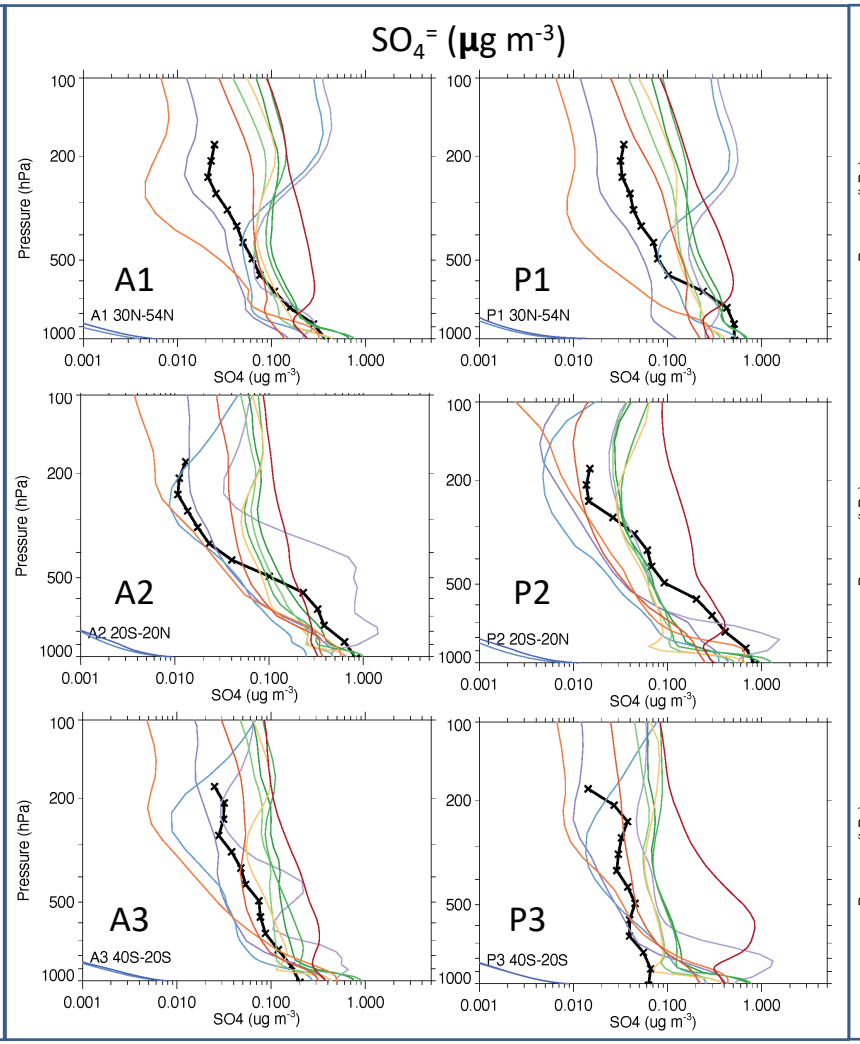
# OA, $SO_4^=$, $NO_3^-$ compared to ATom-1 data

For OA and sulfate, models different by 1-3 orders of magnitudes. For nitrate, models are ridiculous!

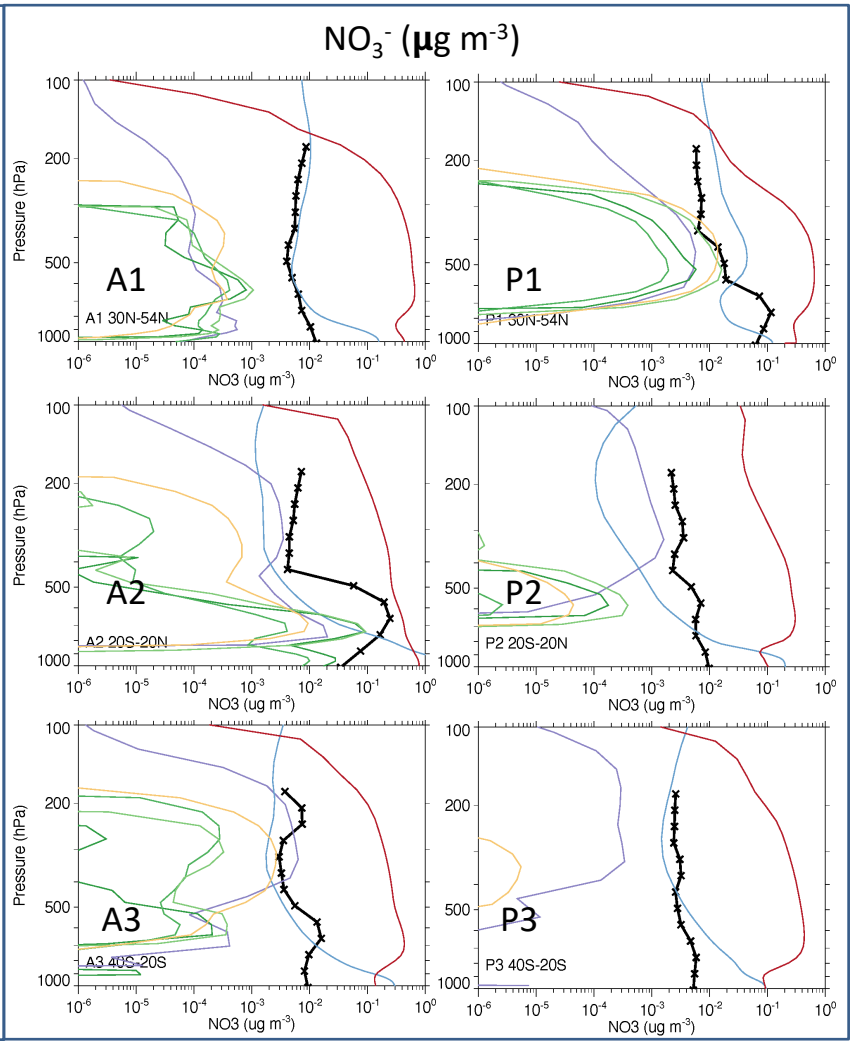
CAM5-ATRAS
ECHAM-HAM
ECHAM-SALSA
GEOS-i33p2
GFDL-AM4-fSST
GFDL-AM4-met2010
GISS-E-MATRIX
GISS-E-MATRIX-fSST
GISS-E-OMA
GISS-E-OMA-fSST
MIROC-SPRINTARS
NorESM2
OsloCTM3




13 models




13 models

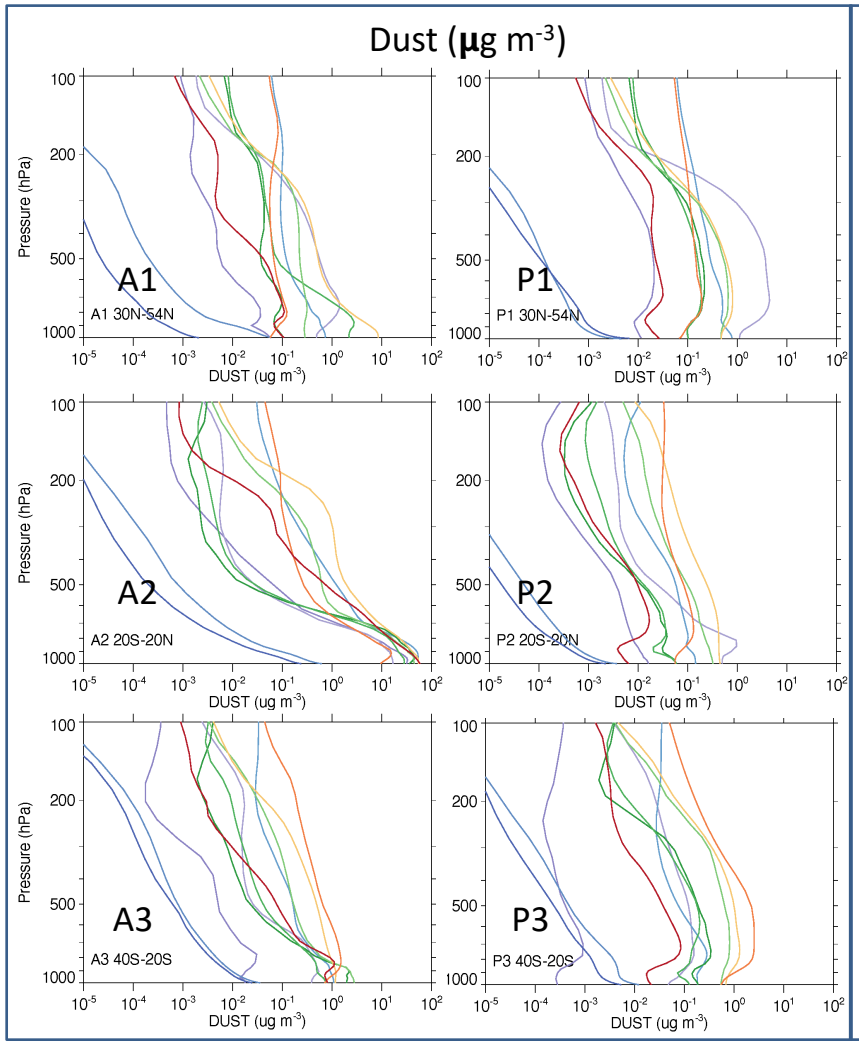



7 models

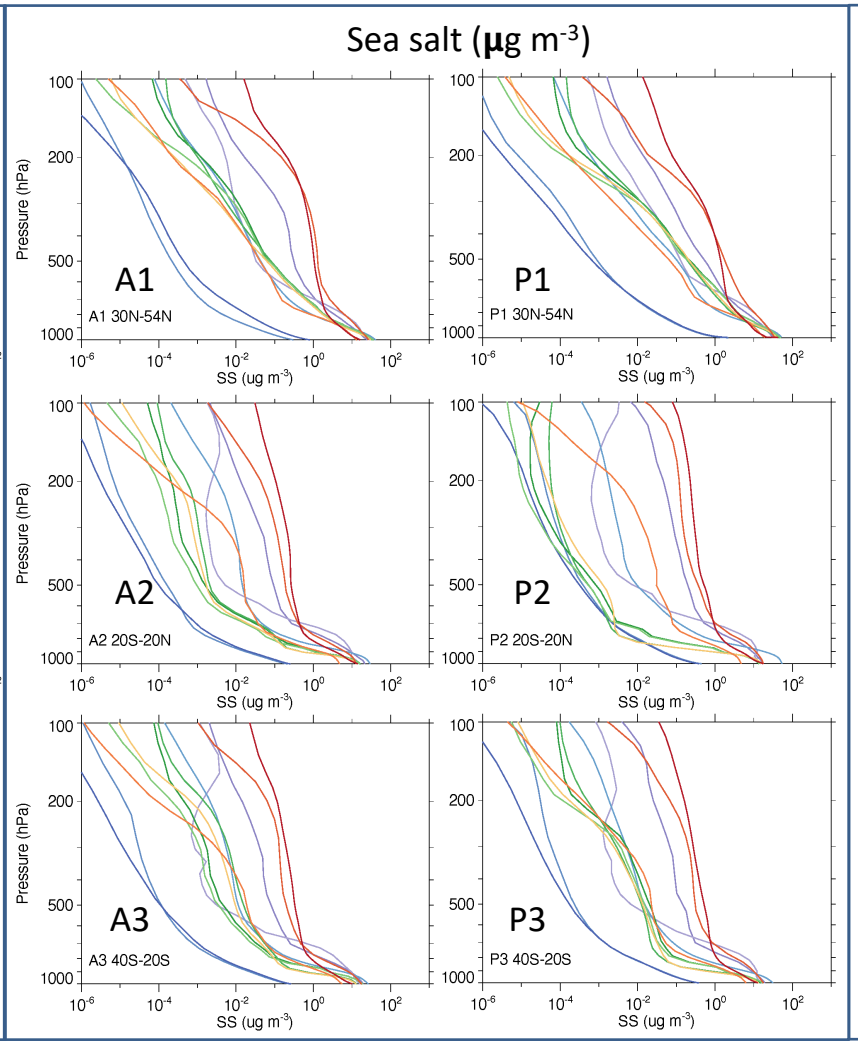
# Dust, sea salt, ec550 - model diversity

Modeled dust and sea salt differs by 2-6 orders of magnitudes! The ec550 agrees near the surface closely but differs at higher altitudes by 2 orders of magnitudes

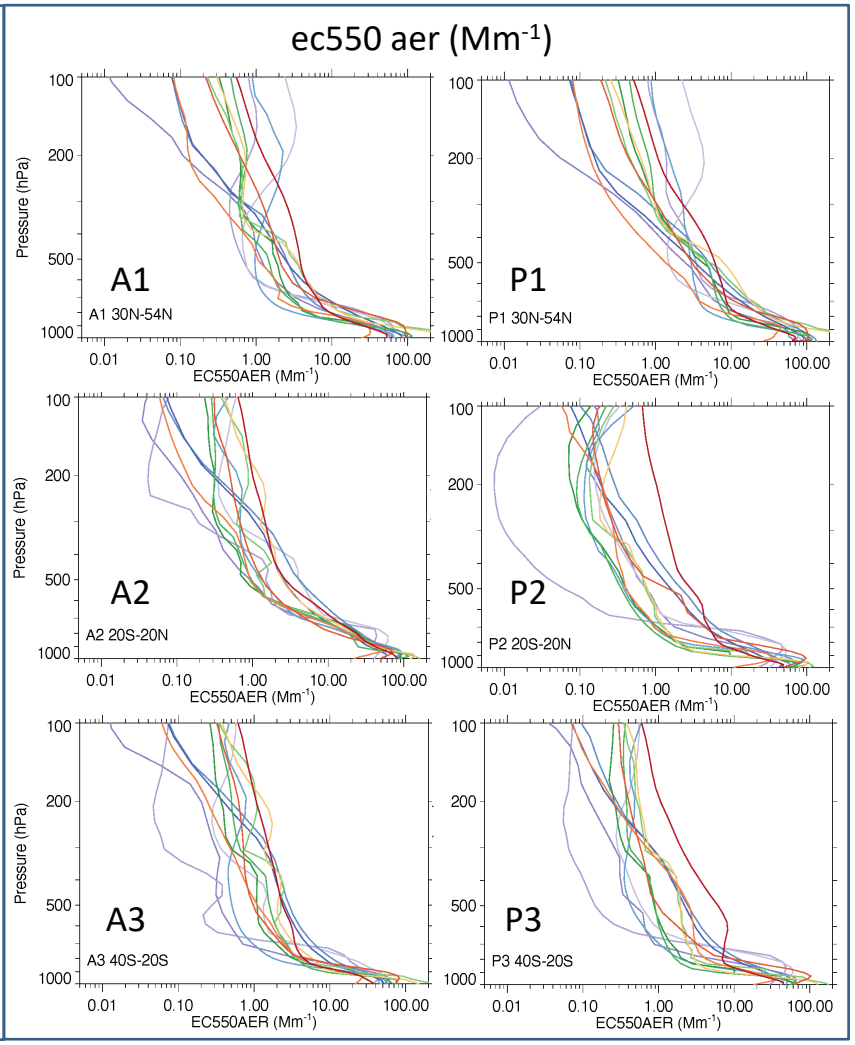
CAM5-ATRAS
ECHAM-HAM
ECHAM-SALSA
GEOS-i33p2
GFDL-AM4-fSST
GFDL-AM4-met2010
GISS-E-MATRIX
GISS-E-MATRIX-fSST
GISS-E-OMA
GISS-E-OMA-fSST
MIROC-SPRINTARS
NorESM2
OsloCTM3




12 models



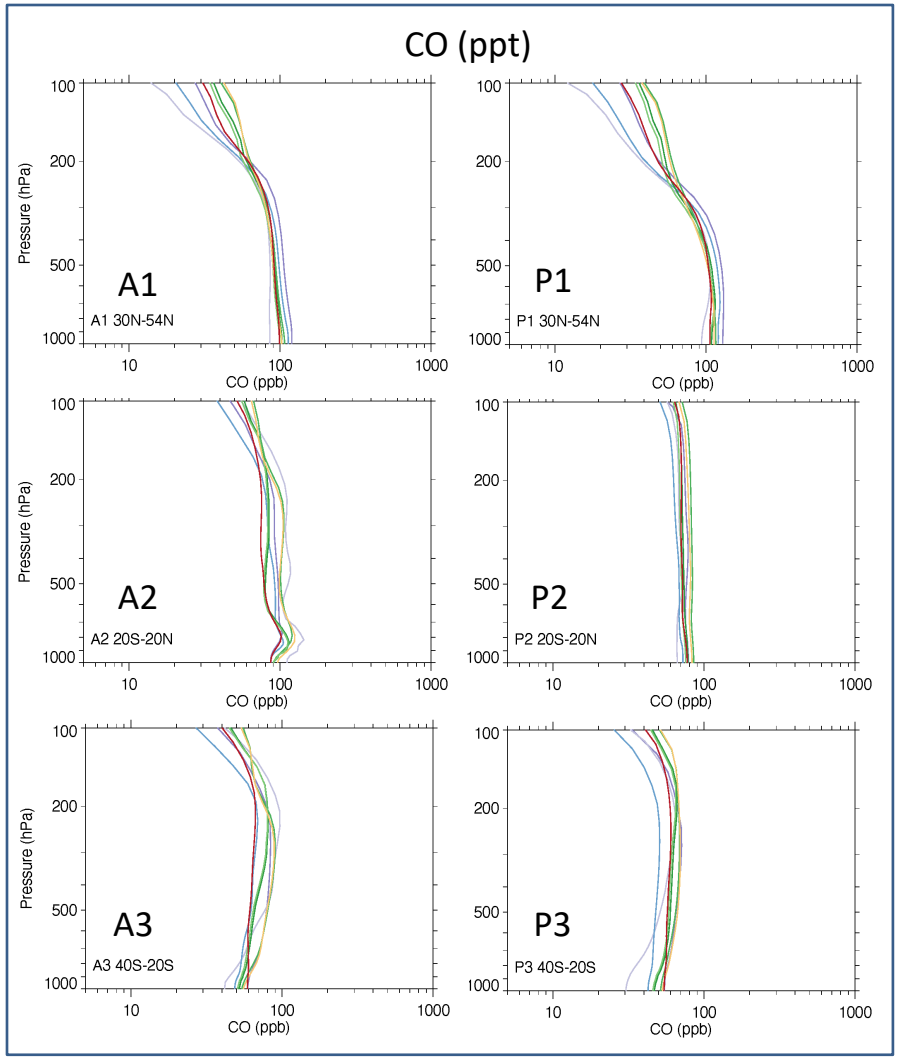

13 models

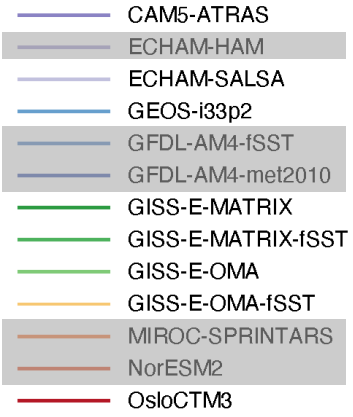



13 models

# Is the diversity due to transport or aerosol-related processes?

- CO has a much longer lifetime (30-50 days) than aerosol and the predominant loss is the reaction with OH. It can be used effectively as a transport tracer
- Models show a close agreement of CO amount and vertical profile shape, although the range of model difference in the tropopause region is up to a factor 3
- The sharp contrast of the diversities between model-simulated CO and aerosol species is a strong evidence that the aerosol-related physical and chemical processes are the reasons of the irreconcilable differences among models




8 models submitted CO simulations

# How to move forward to improve the model simulated aerosol vertical profiles?

- Without making significant progress on model representations of aerosol vertical distributions, the credibility of model estimates of aerosol radiative effects on climate, aerosol-cloud interactions, and air quality will be hindered
- What should we do in the near term?
  - Perform focused AeroCom model experiments and analysis to diagnose (not to guess) the reasons for diversity in order to resolve the issues.
    - Primary aerosols: 1) BC: loss processes in the upper troposphere, lifetime. 2) Dust and sea salt: use prescribed emission and size bins to diagnose the removal processes (e.g., settling, wet removal)
    - Secondary aerosols involve chemical processes. Among them, nitrate exhibits the largest problem with most complex chemical processes. It requires special attention to carefully design step-by-step model experiments
  - Incorporate transport and removal tracers in all model experiments for diagnostics
  - Data, data, data! We should be very serious about using the vertical profile measurement data to diagnose model performance, even though many processes are not directly observable but they can be indirectly inferred from multiple datasets