Aerosols, PSCs and ozone after 2015 Calbuco eruption

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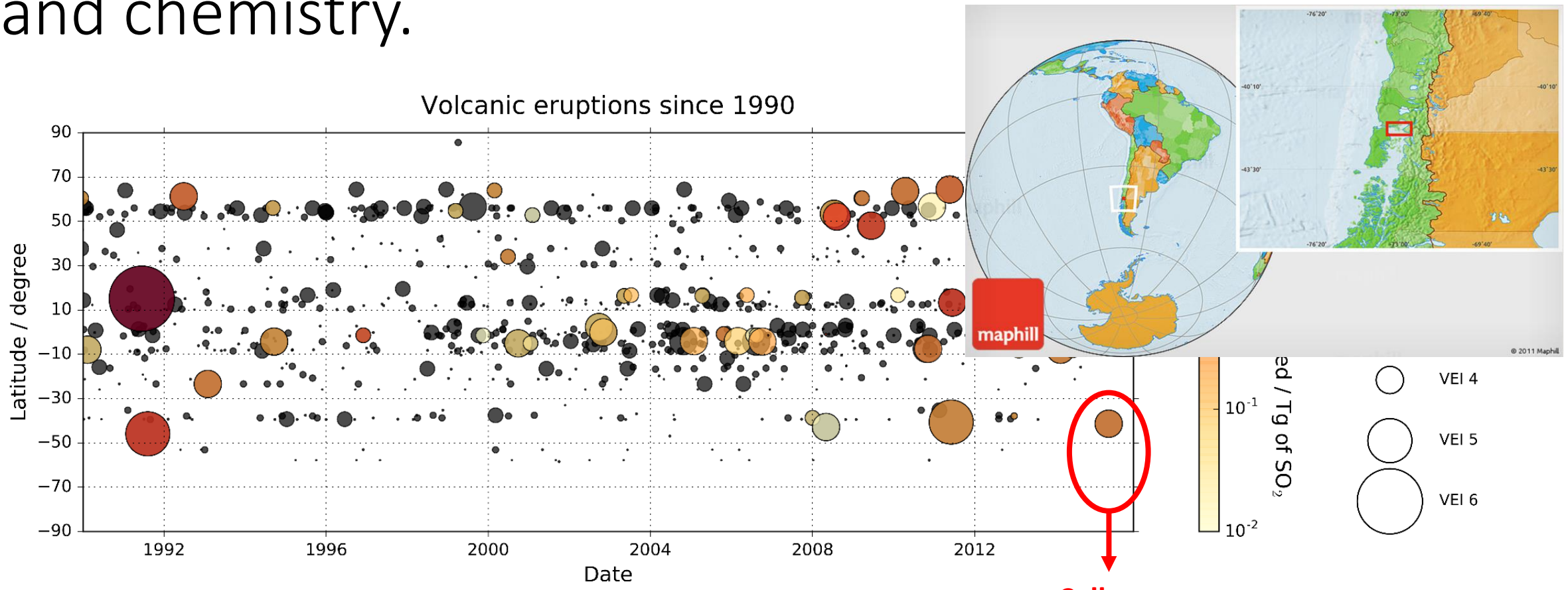
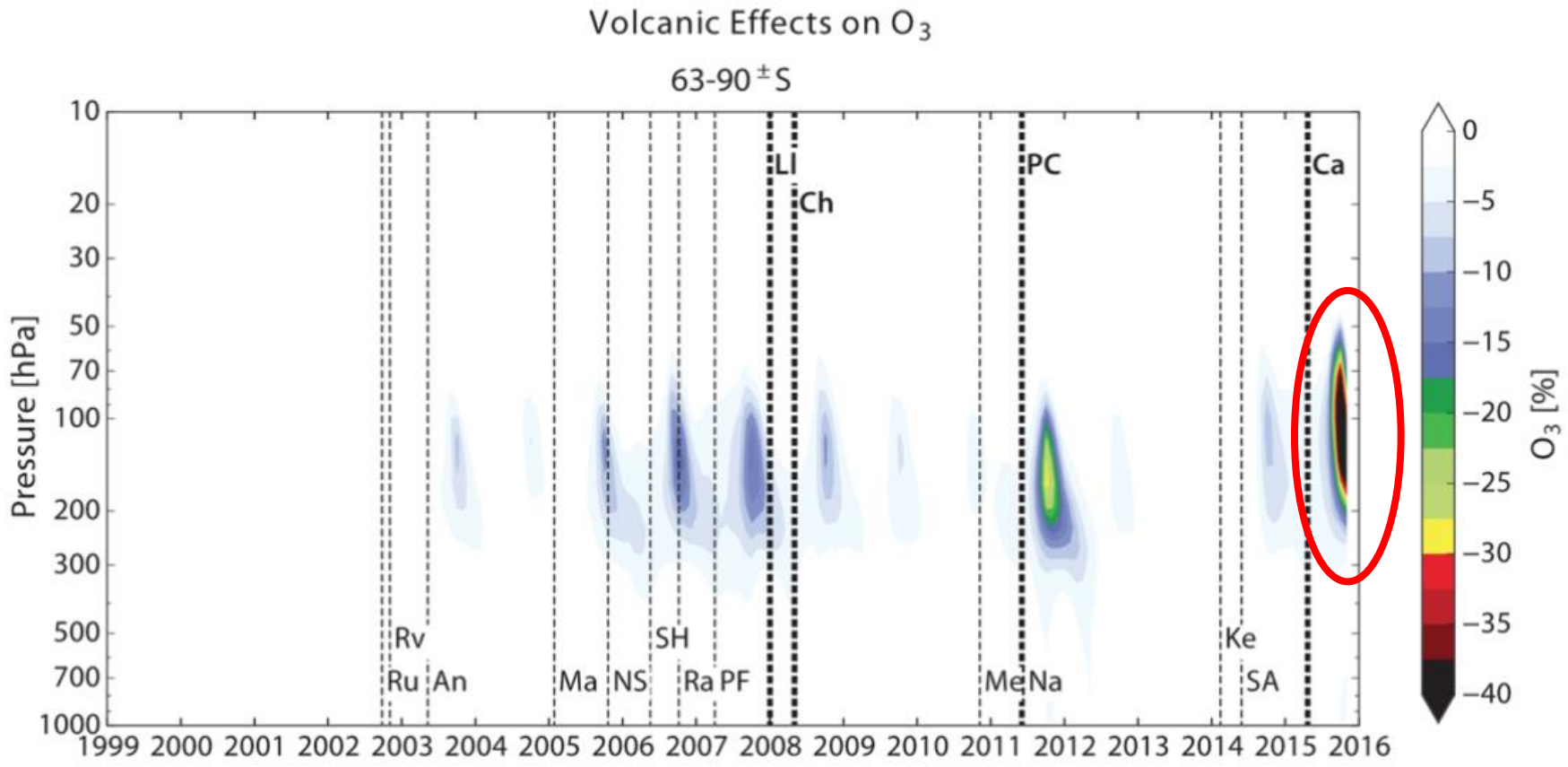
Small eruptions, that occur almost every year, are observed to change the stratospheric radiative flux and chemistry.



[Figure by Anja Schmidt]

A small eruption that reaches stratosphere ~0.4 tg SO_2

We are interested in the Calbuco eruption in 2015, because this eruption is responsible for extra 40% ozone depletion [Solomon et al., 2016].



We will use a climate model with detailed aerosol microphysics (WACCM/CARMA) to look into this event. The model will provide:

- extinction and backscatter of aerosol and PSCs, because the microphysical package CARMA tracks the numbers and sizes of particles.

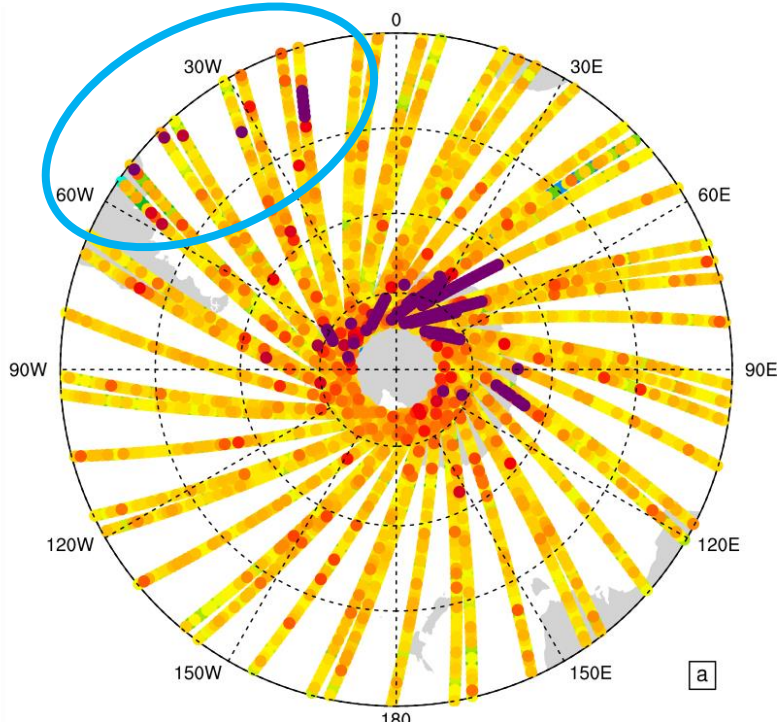
- The model also tracks ozone and its related chemicals.

Satellite data:

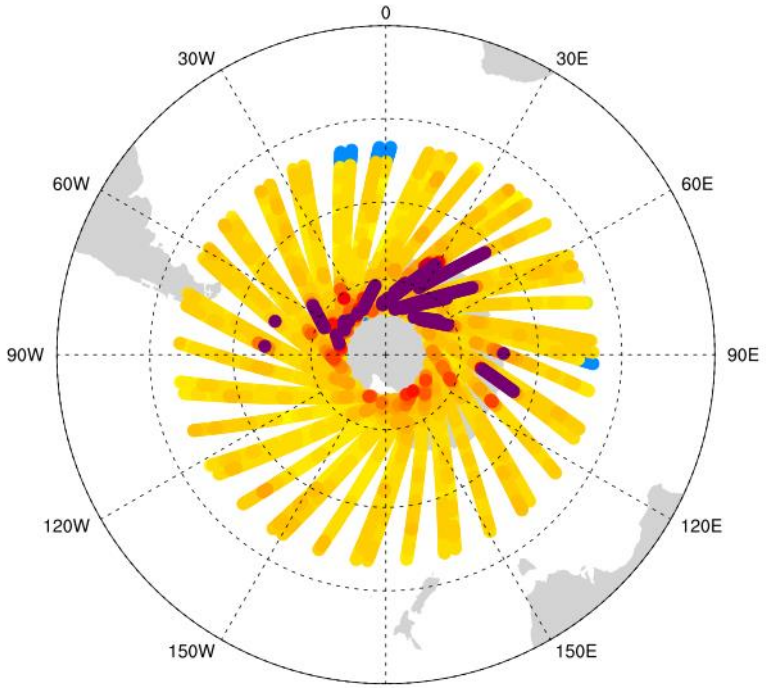
- CALIPSO : 532 nm backscatter
  - L1B
  - L2 PSC
  - L2 Aerosol profile
- OMPS: 675 nm extinction – retrieved from limb-scattered radiation
  - AER675: Version 1.0
- OSIRIS: 750 nm extinction – retrieved from limb-scattered radiation
  - version 5.07
- MLS: O3
  - Version 4-20

We use the CALIPSO Level1B data for comparisons, since it shows aerosol extinction in mid-latitudes that we are interested in.

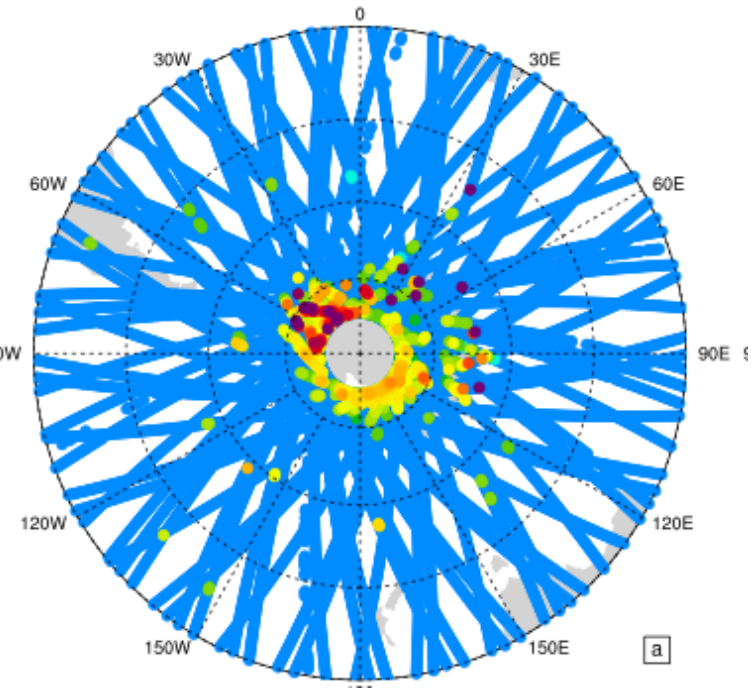
level 1B data averaged over 135km



level 2 PSC



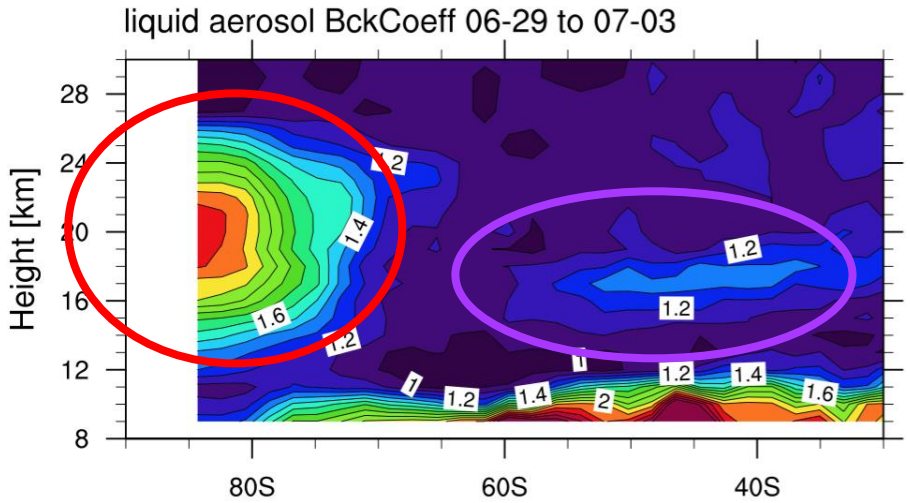
level 2 Aerosol Profile

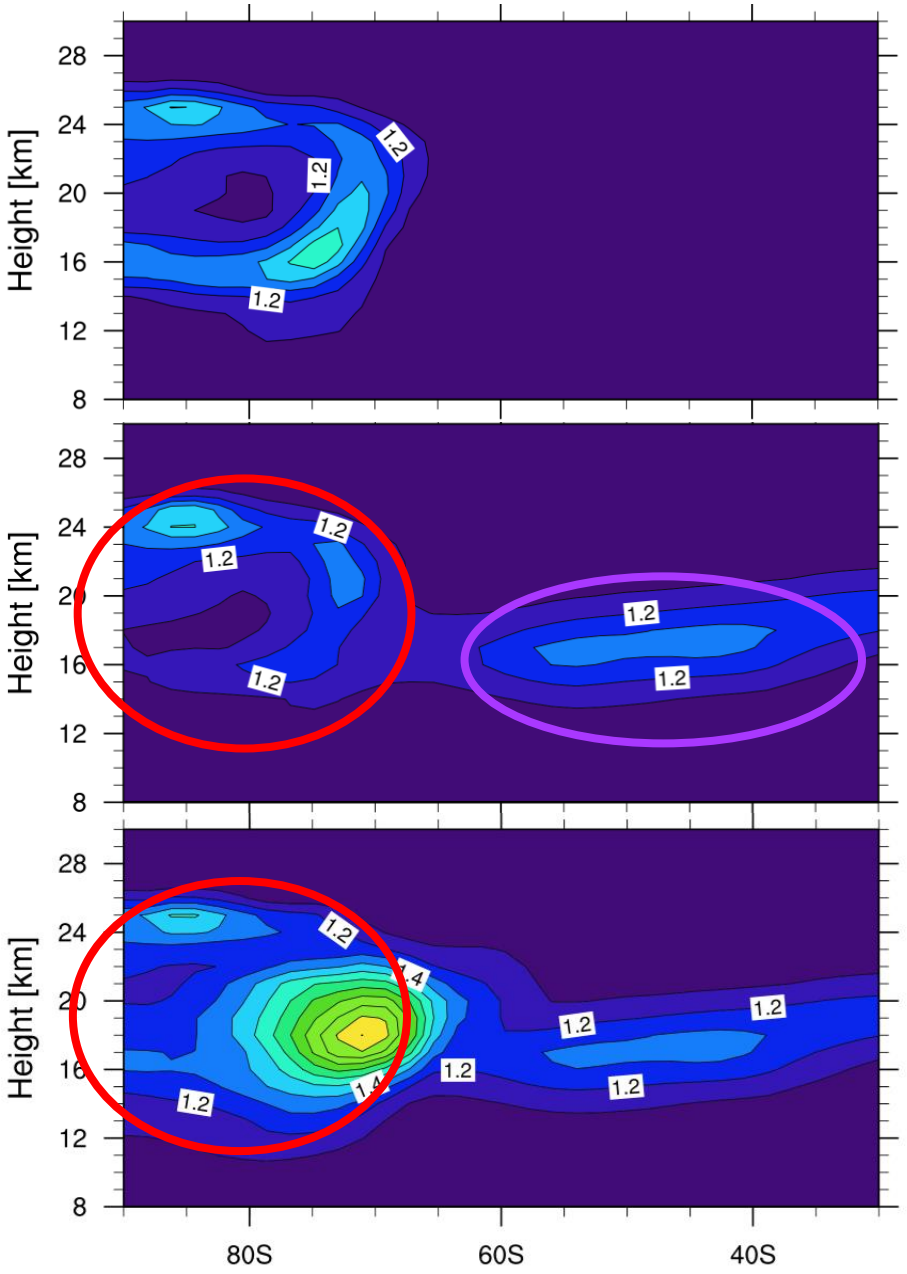


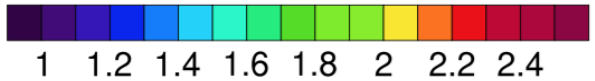
Backscatter coefficient
Sep 27-Oct 01, 12.5km

CALIPSO 532 nm scattering ratio, Jun29-Jul03

The CALIPSO scattering ratio clearly shows Calbuco backscatter in mid-latitude and a large area of backscatter for PSCs.







If no Calbuco emission, backscattering ratio only shows PSCs.

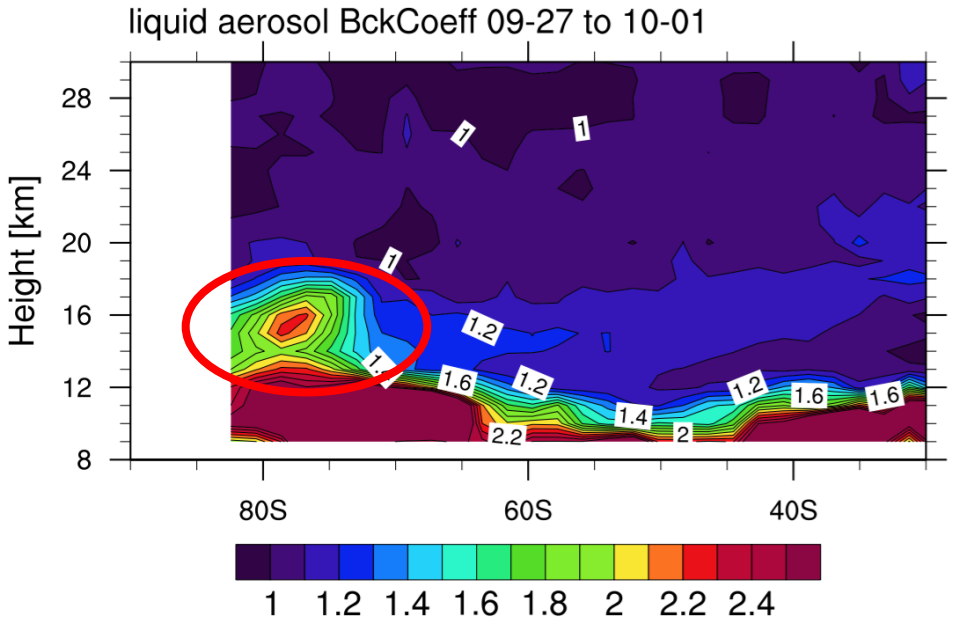
Adding the Calbuco eruption, the sulfate matches the CALIPSO mid-latitude backscatter.

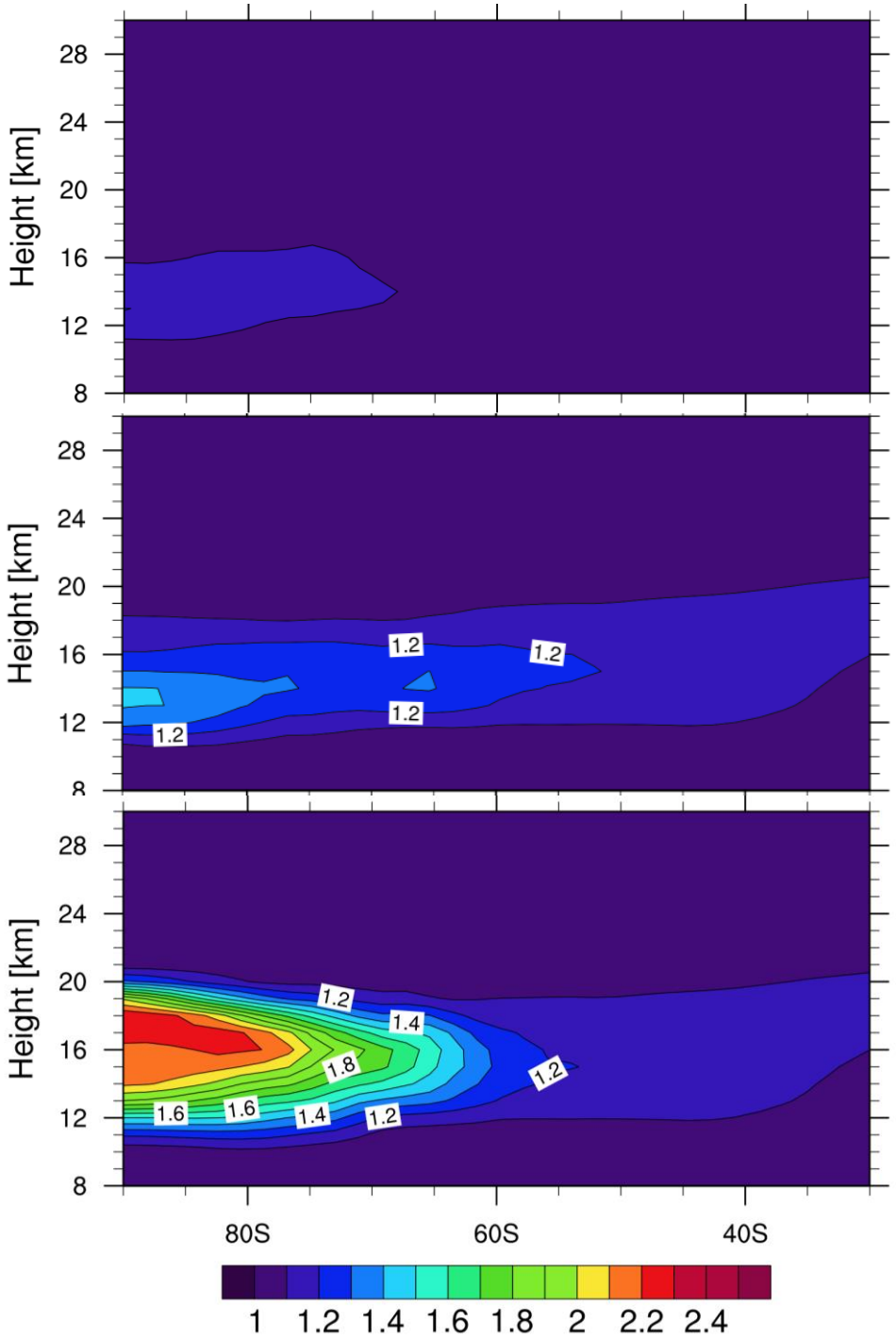
The PSC scattering ratio is smaller than no Calbuco case, because of the increased particle numbers.

Adding gravity waves over Antarctic mountains increases the scattering ratio from PSCs.

CALIPSO 532 nm scattering ratio, Sep27-Oct01

The CALIPSO scattering ratio shows large backscatter lower stratosphere near the pole.





No Calbuco case shows very small backscatter in lower altitude near the pole.

Adding Calbuco eruption increases the backscatter near the pole and extends the backscatter to mid-latitudes.

Adding gravity waves increases the backscatter.

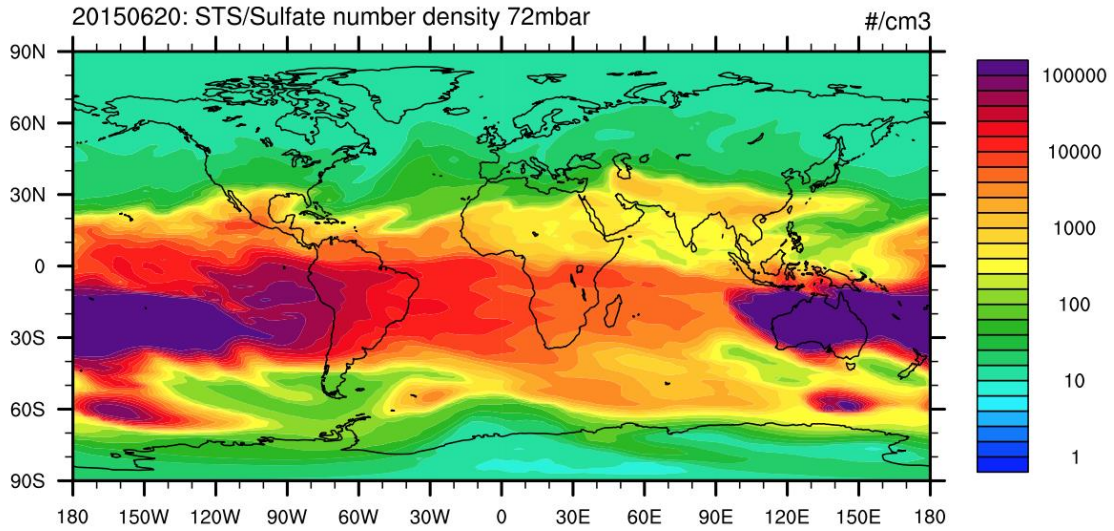
Table of parameters for extinction calculation

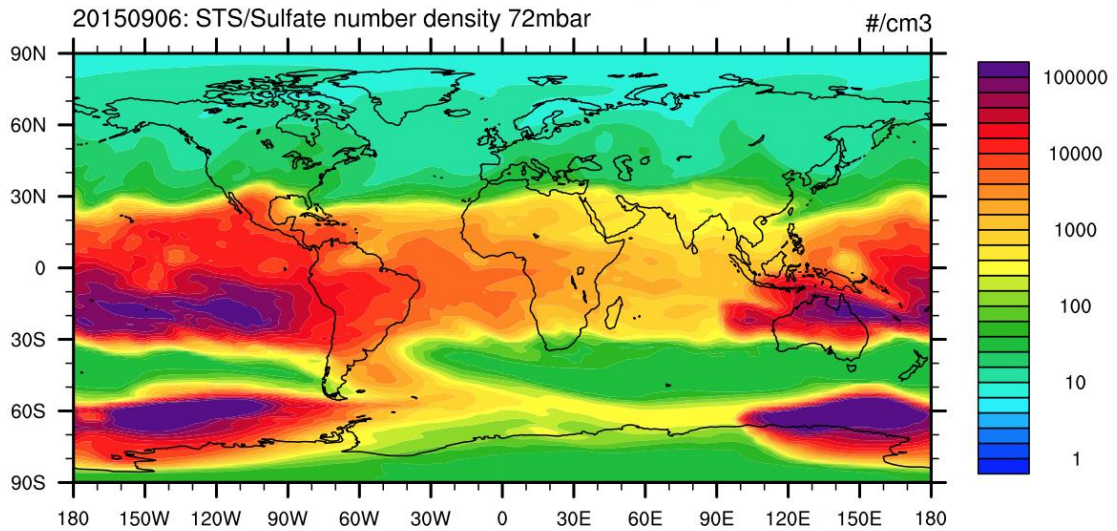
	Model	OMPS	OSIRIS
Refractive index	1.41	1.448	75%H2SO4+25%H2O (around 1.44)
Particle Size	next slide	Bi-modal distribution (0.09 µm and 0.32 µm)	0.08 µm
Angstrom Exponent	next slide	2.0	2.3

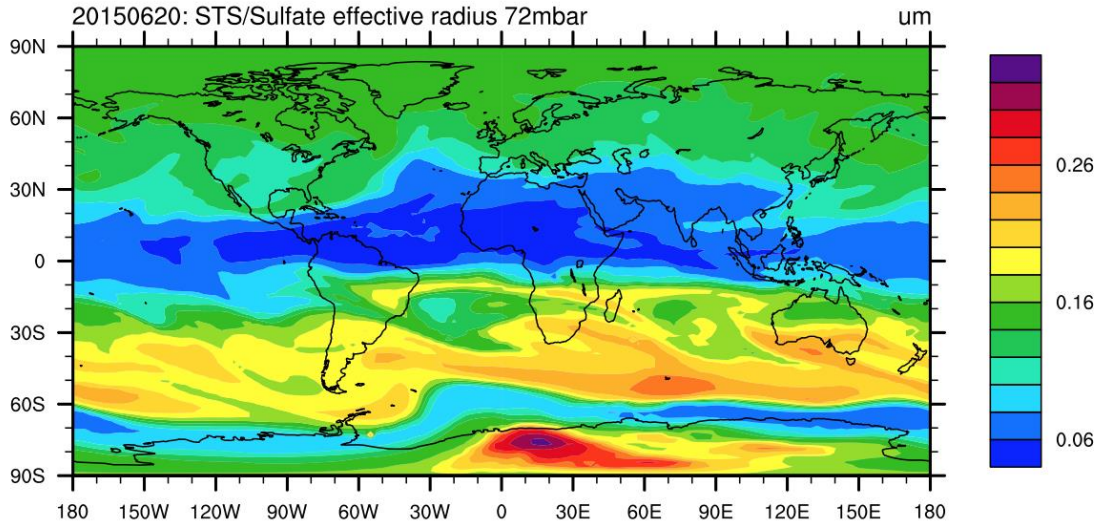
Modeled effective Radius and number density

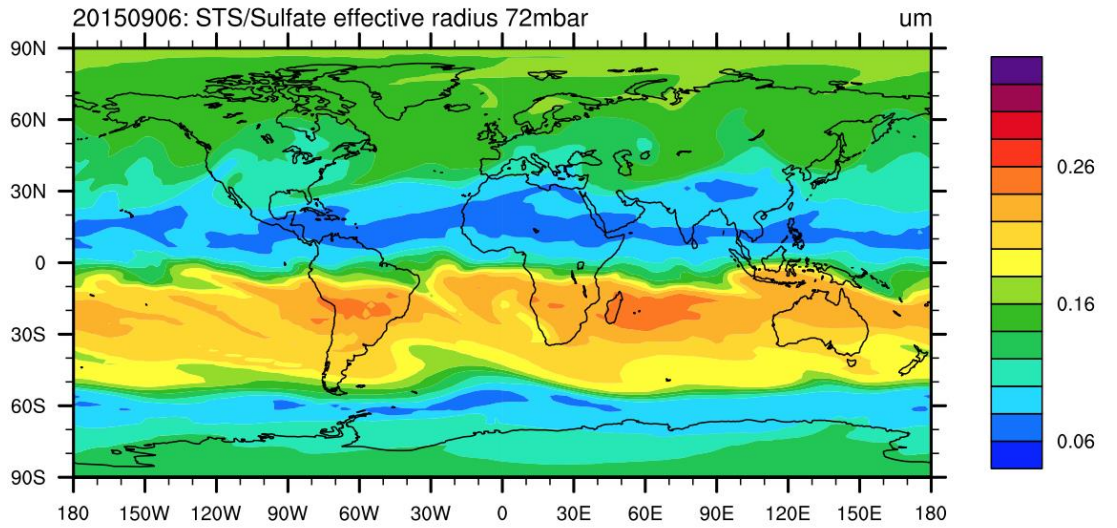
Number density is large in mid-latitude.

Effective radius is large for volcanic sulfuric aerosols and PSCs.

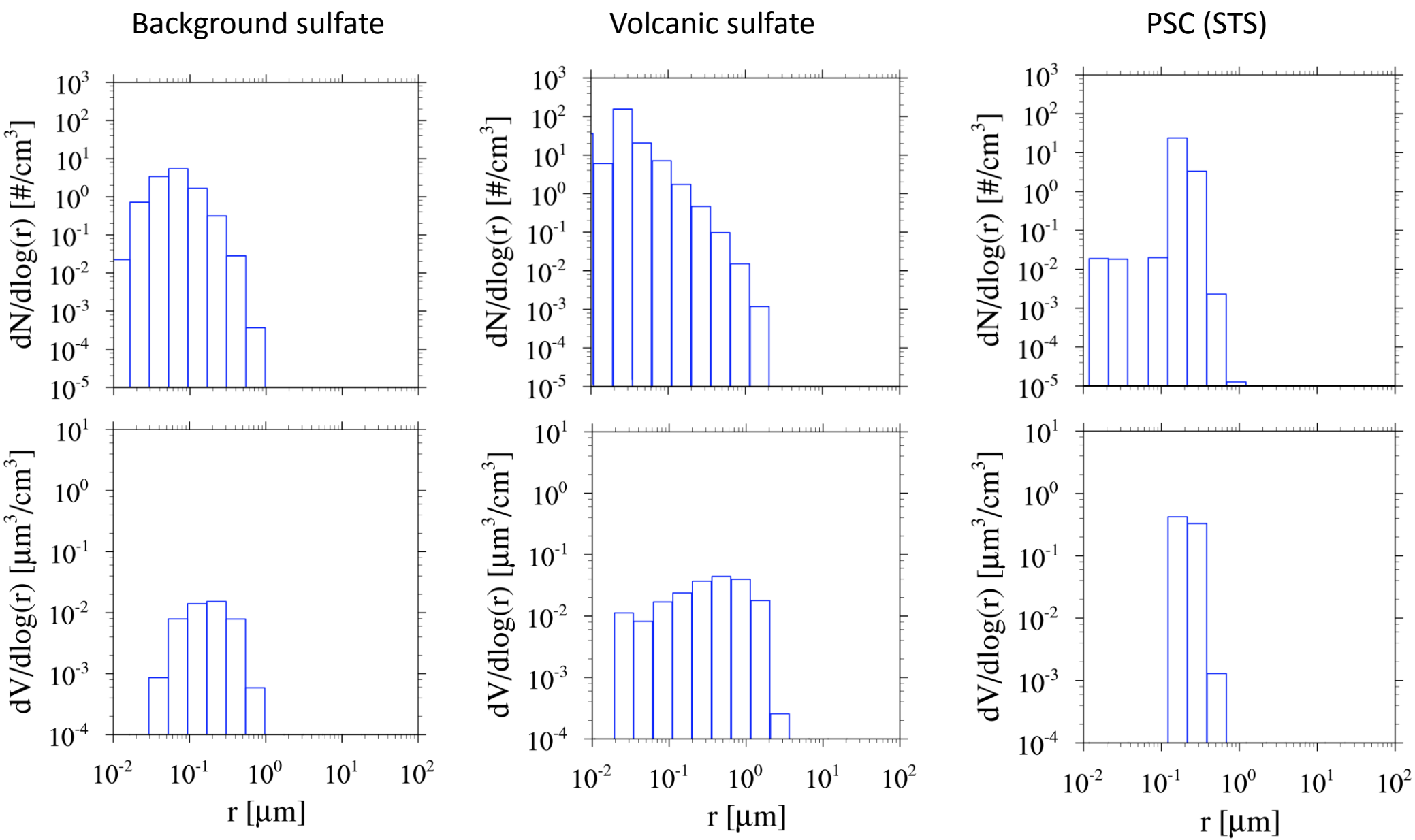








Modeled particle size distributions



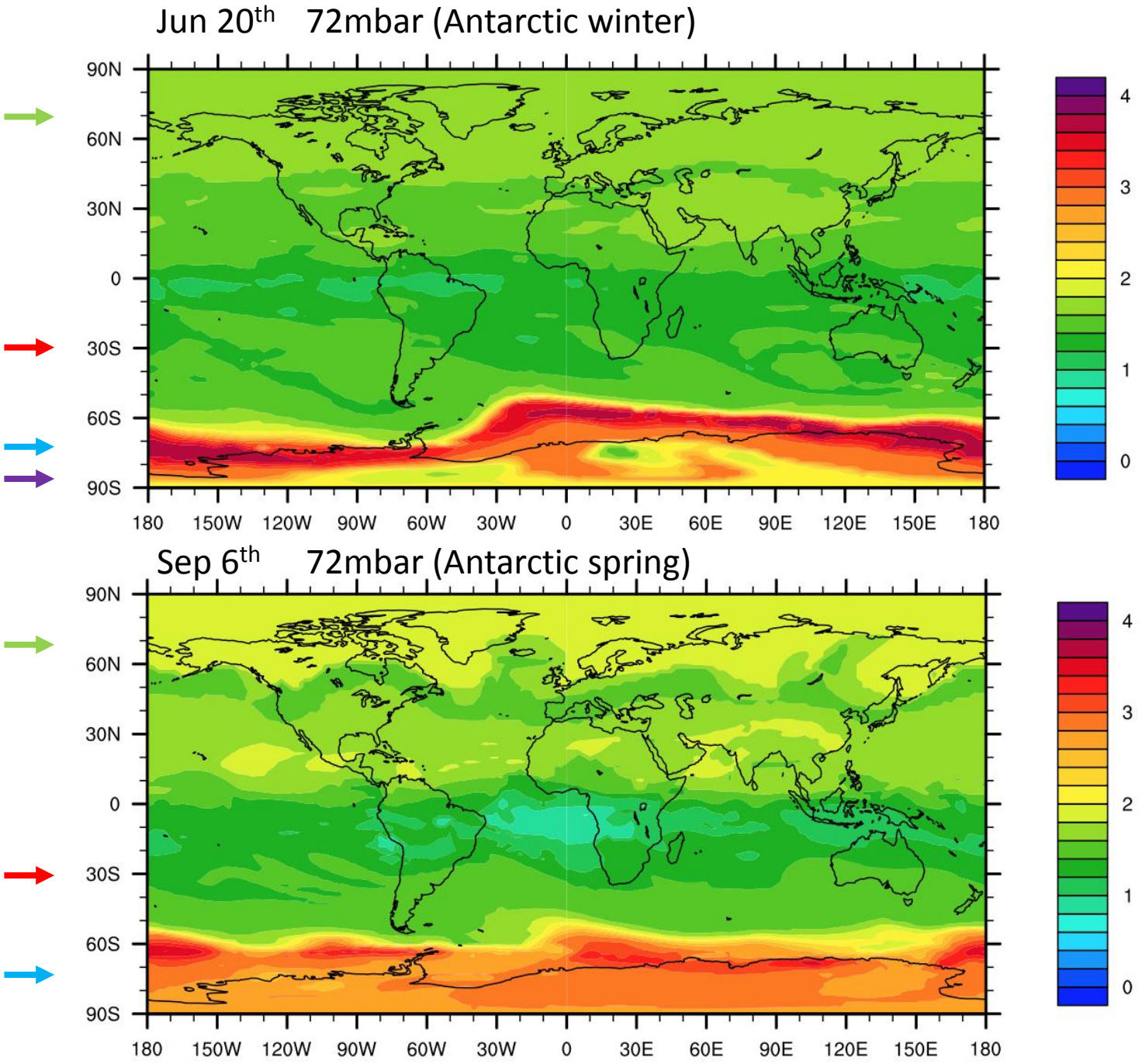
Angstrom Exponent

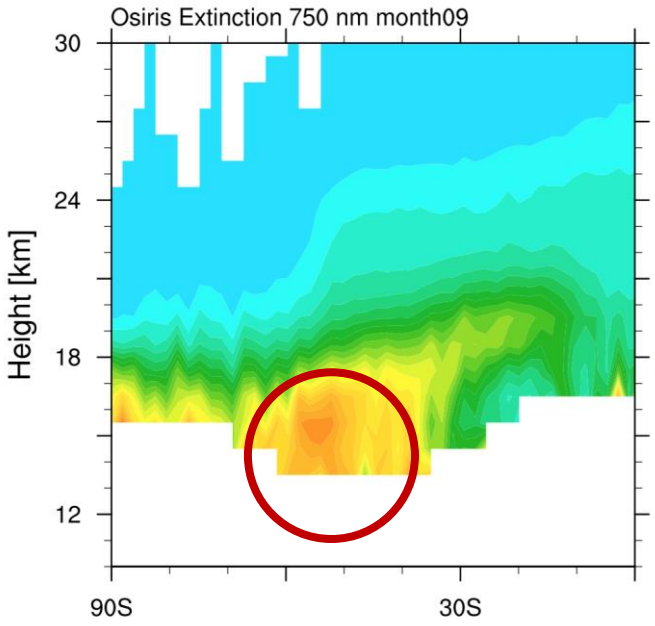
~ 1.8 for Northern hemisphere;

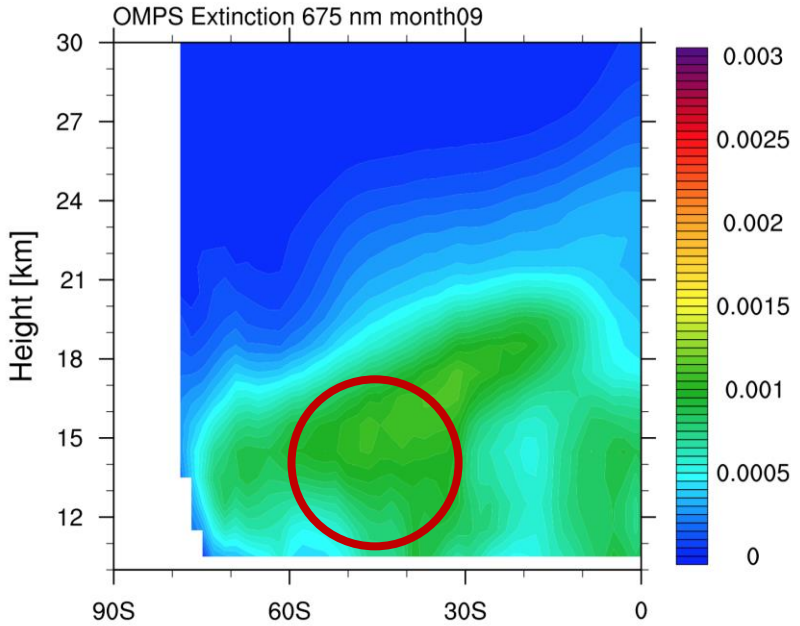
~1.4 for volcanic sulfate region in tropical and mid-latitude in Southern hemisphere;

~3.5 near the pole but outside the vortex;

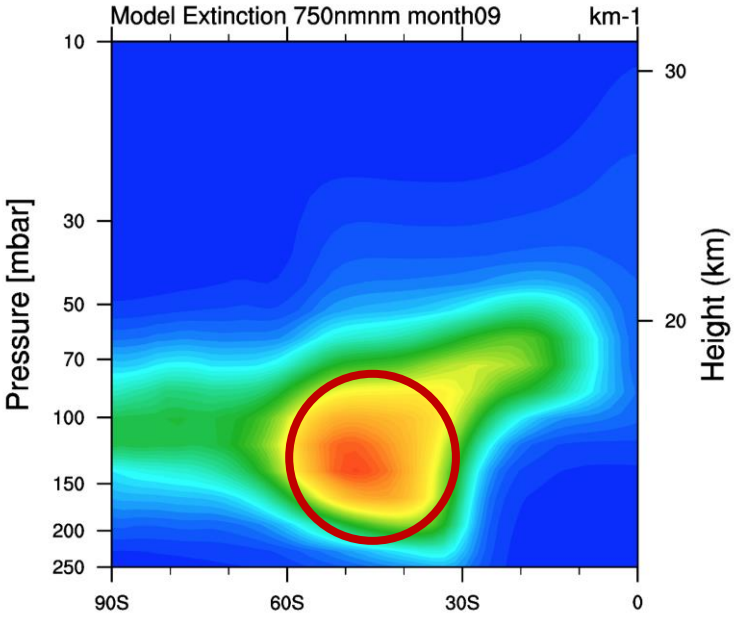
~2 for the PSCs

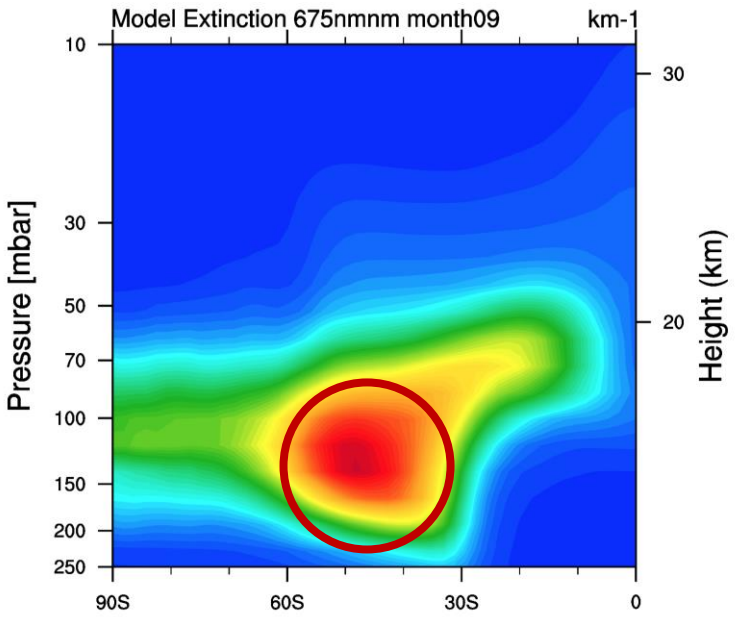






Modeled STS/sulfate extinction

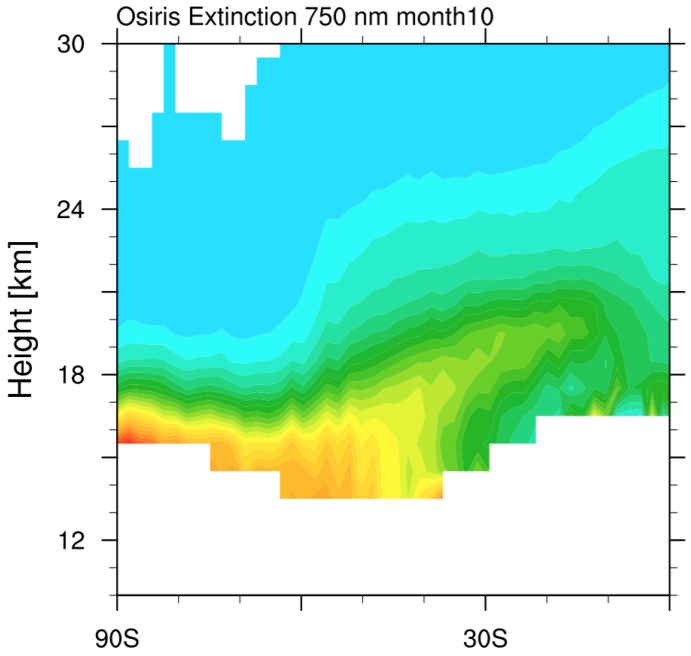


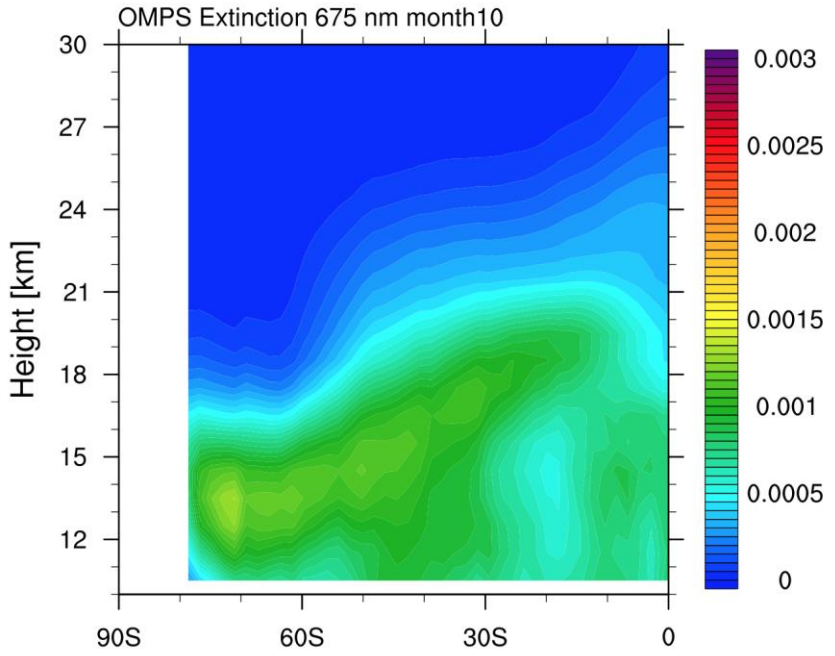


Extinctions in September

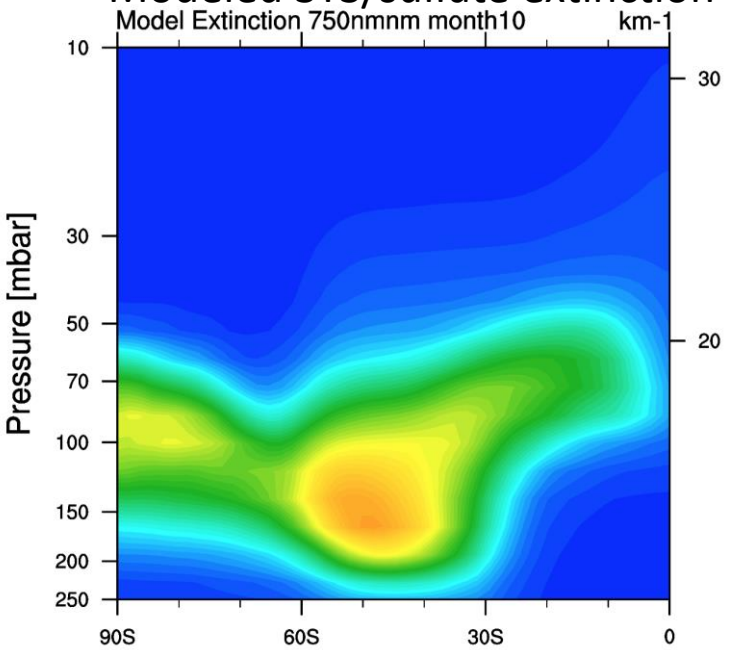
The OSIRIS 750 nm extinction is consistent with the modeled extinction in mid-latitude.

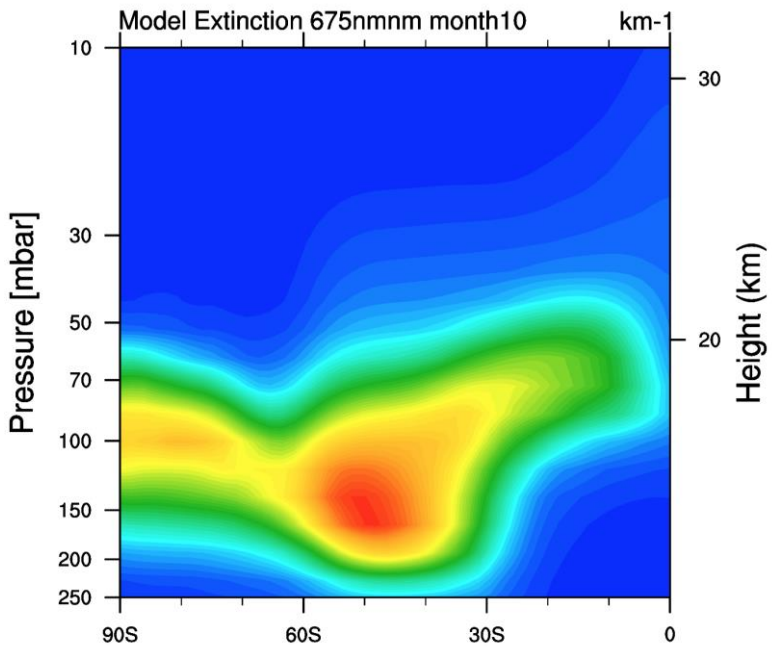
NPP-OMPS 675 nm extinction is ~ half of the modeled and Osiris extinctions.





Modeled STS/sulfate extinction

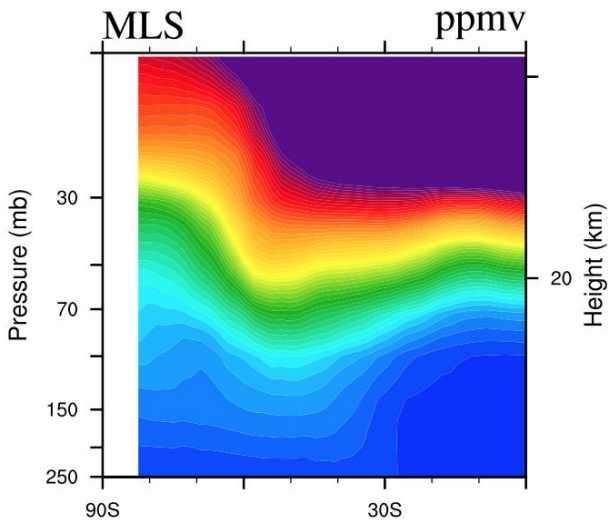


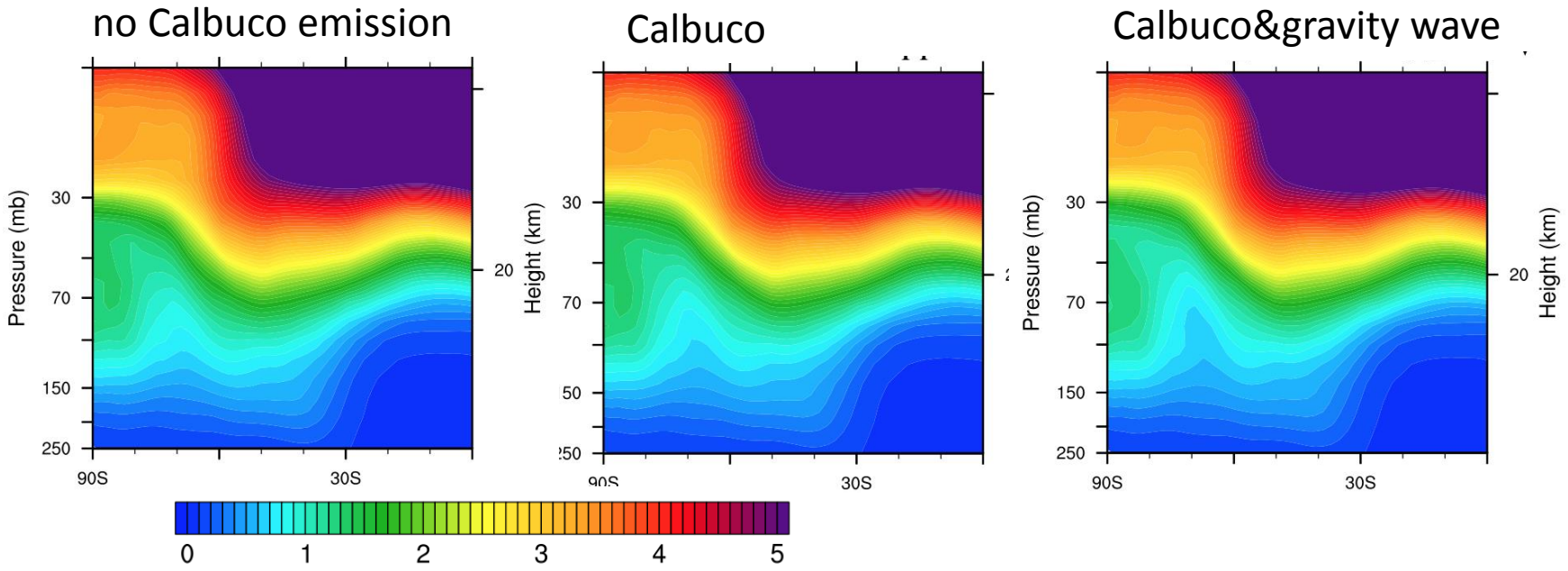


Extinctions in October

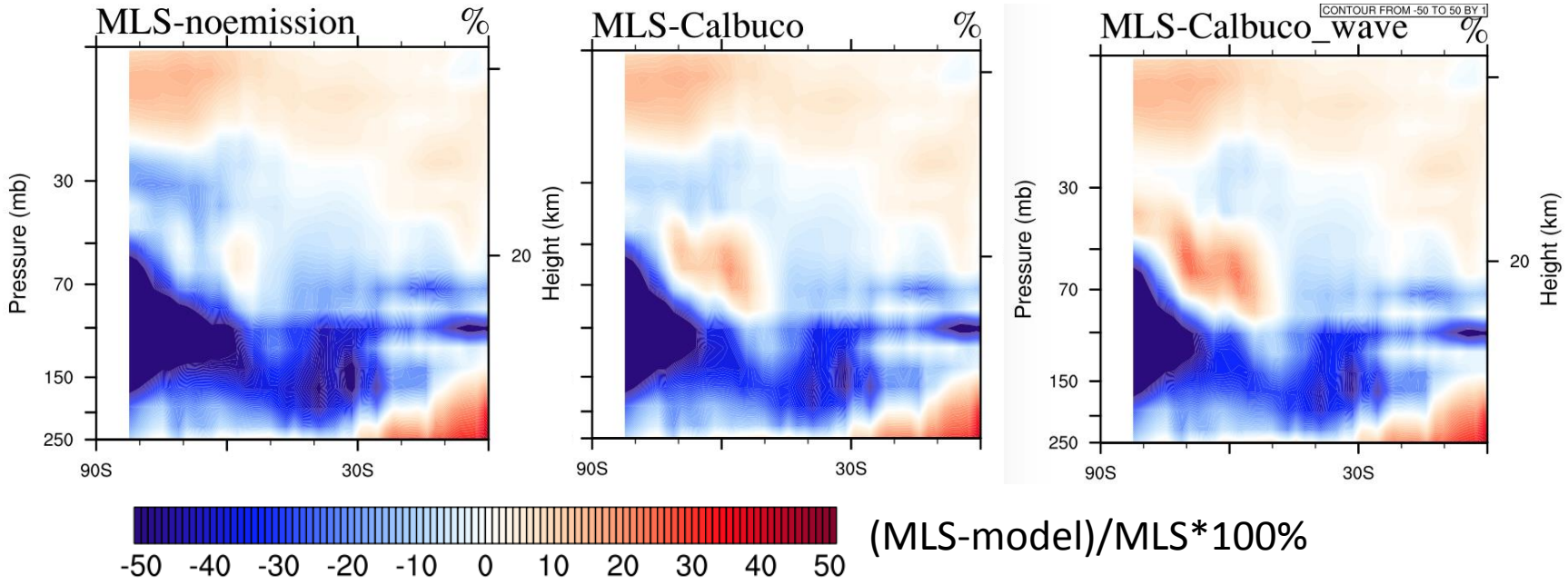
The high extinction areas shift towards to pole at lower altitudes compared to the previous month.

The OMPS and Osiris both use SAGE II 2000-2005 to validate their retrieval. The particle size and angstrom exponent assumptions are similar. Why is 675 nm extinction smaller than 750 nm extinction?



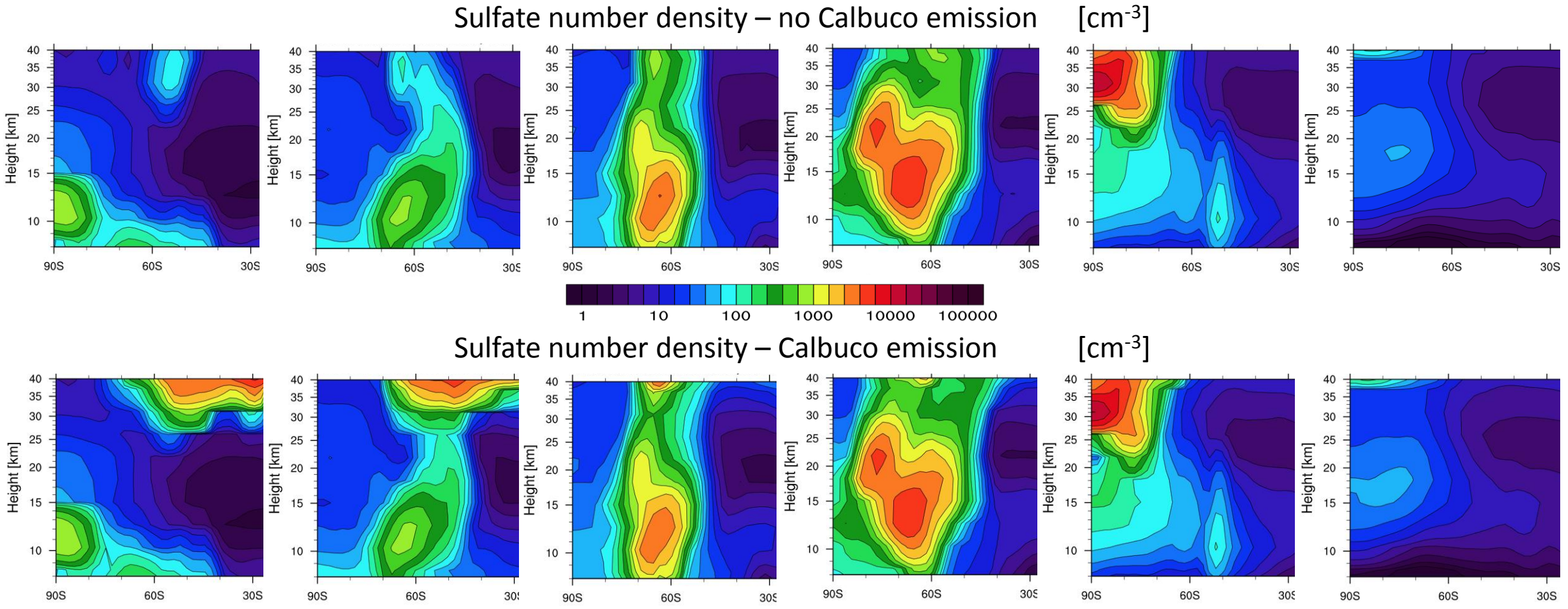


O3 mid-Sep
Our model underestimates the O3 near the pole especially below 70 hpa.
Don't know why yet.



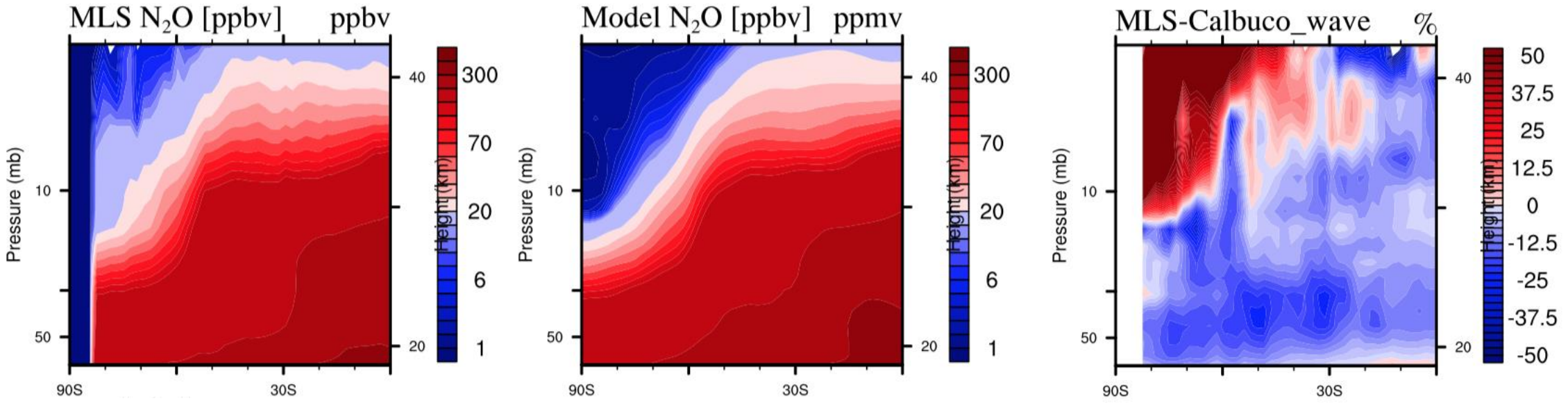
(MLS-model)/MLS*100%

Sulfate nucleates outside the vortex in Antarctic winter and ~ 30 km in the pole in September.



The modeled N2O is higher than MLS in lower stratosphere and topical area ~ 40 km, but larger than MLS near the Pole. That means the modeled descending air inside the vortex is stronger but weaker outside the vortex.

May 31



The MLS N2O is valid from 68 mbar to 0.46 mbar

Conclusions and Discussions

- The model is able to reproduce the mid-latitude extinction by OSIRIS and backscattering ratio by CALIPSO after 2015 Calbuco eruption.
- The model reproduce the high backscatter near the pole when we introduce the gravity wave for PSC formation.
- Our model indicates an Angstrom exponent of 1.8 for background sulfate; ~1.4 for volcanic sulfate; ~3.5 near the pole but outside the vortex; ~2 for the PSCs.
- OMPS and OSIRIS have similar extinction retrieval processes but OMPS aerosol extinction is half of the model's.
- The underestimation of O3 in lower altitude especially near the pole is still unexplained.
- It is unexplained how Calbuco influences sulfate nucleation at 40 km.


Thank you!