The OMPS Limb Profiler Stratospheric Aerosol Observations and Comparisons to the GEOS-5 Chemistry-Climate Model

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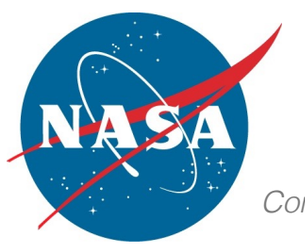


Composition and Transport in the Tropical Troposphere and Lower Stratosphere Meeting, Boulder, CO, July 20 - 24, 2015

Outline

- OMPS Limb Profiler
- Aerosol detection in the UTLS
- Comparisons to GEOS-5 model
- Future Directions

OMPS Limb Profiler

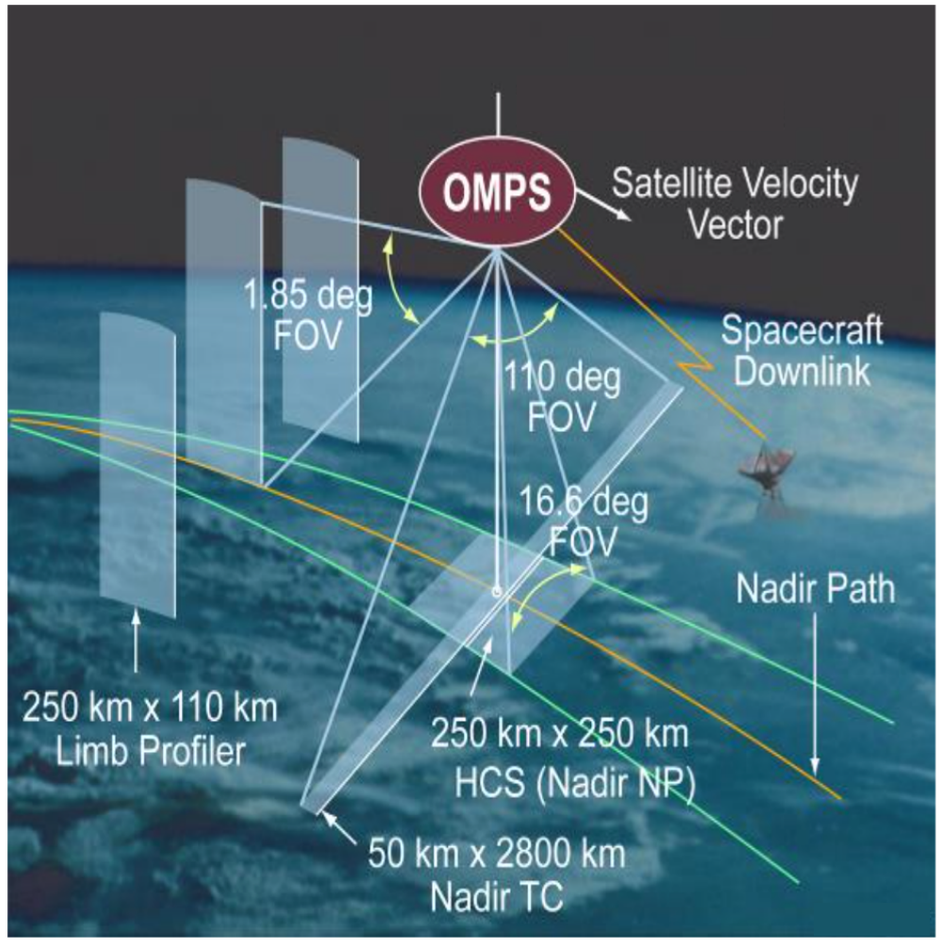
- OMPS is the Ozone Mapping Profiler Suite, launched on the Suomi NPP satellite on October 28, 2011

- OMPS consists of three instruments:
  - Nadir Mapper (NM)
  - Nadir Profiler (NP)
  - Limb Profiler (LP)

- OMPS LP looks behind the satellite line of flight and views light scattered from molecules and aerosols in the illuminated limb through three vertically aligned slits with 250 km across-track spacing

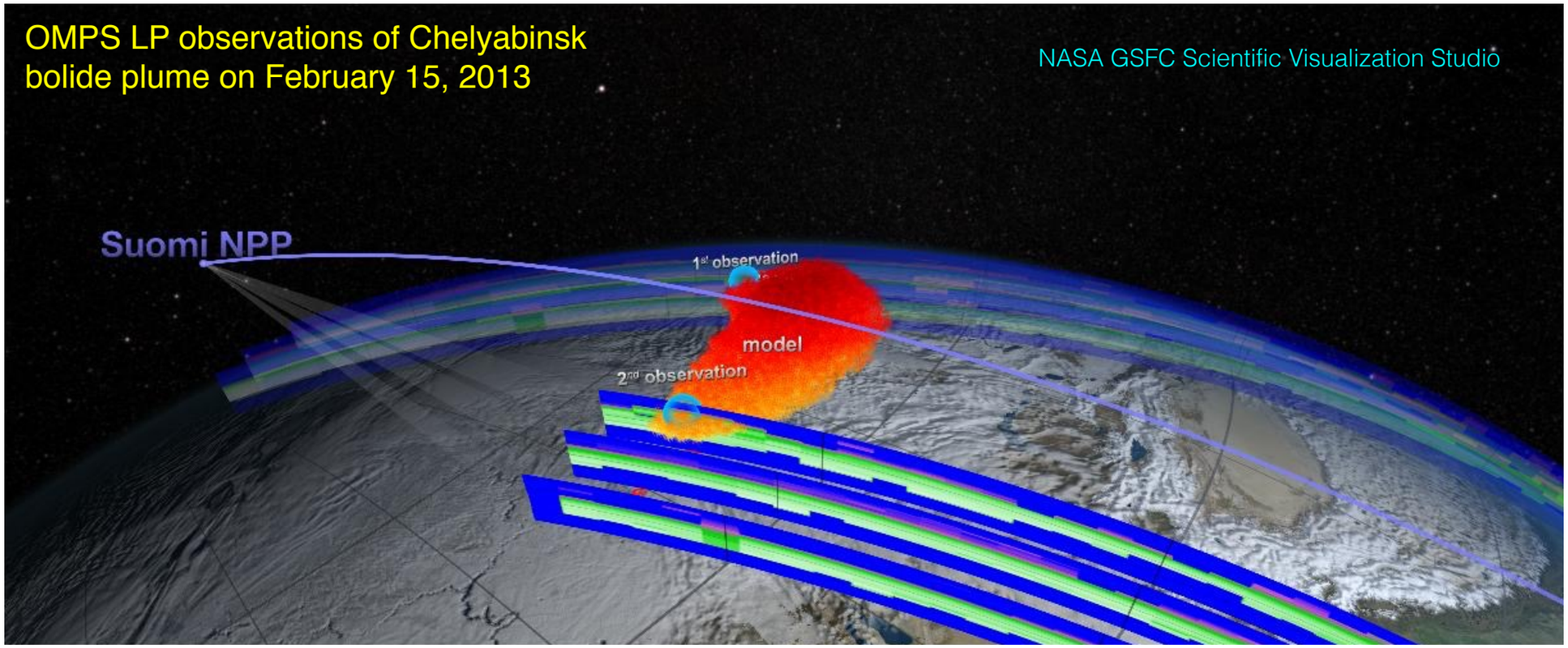
- OMPS LP is a hyperspectral instrument viewing the wavelength range 290 - 1000 nm, with 1 nm spectral resolution in the UV and 10 nm resolution in the VIS

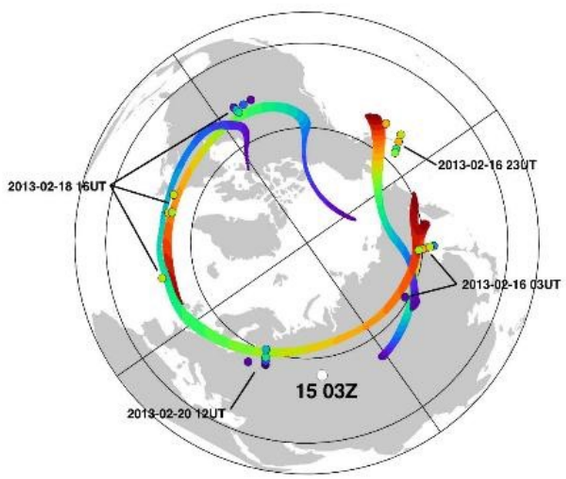
- Heritage: SOLSE/LORE, OSIRIS, SCIAMACHY, GOMOS



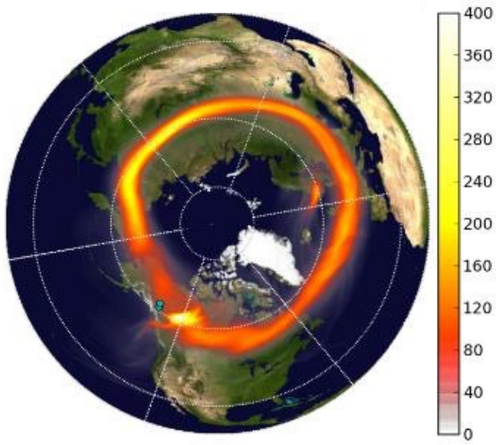
- 1330 local time ascending, sun-synchronous orbit
- OMPS LP limb view tangent follows nadir view point by about 7 minutes
- near-continuous curtains along track
- 1 km vertical sampling from near surface to about 105 km altitude effective ~2 km vertical resolution

Chelyabinsk Bolide

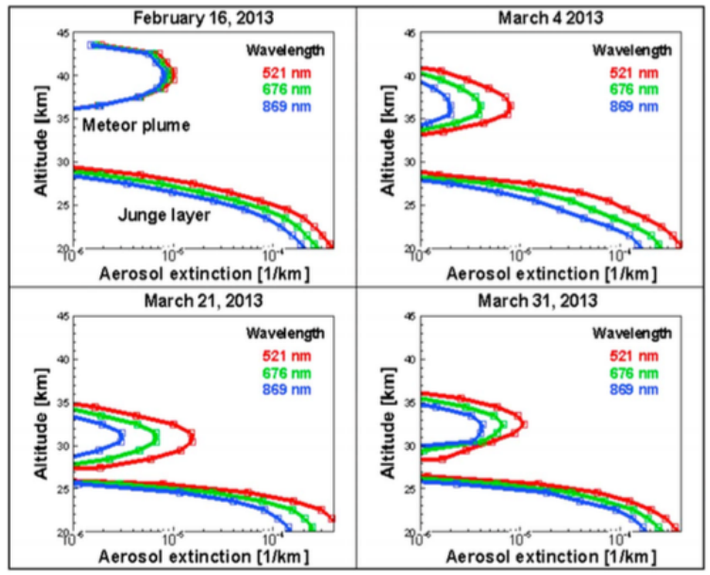




Goddard Trajectory Model
Feb. 16-20, 2013

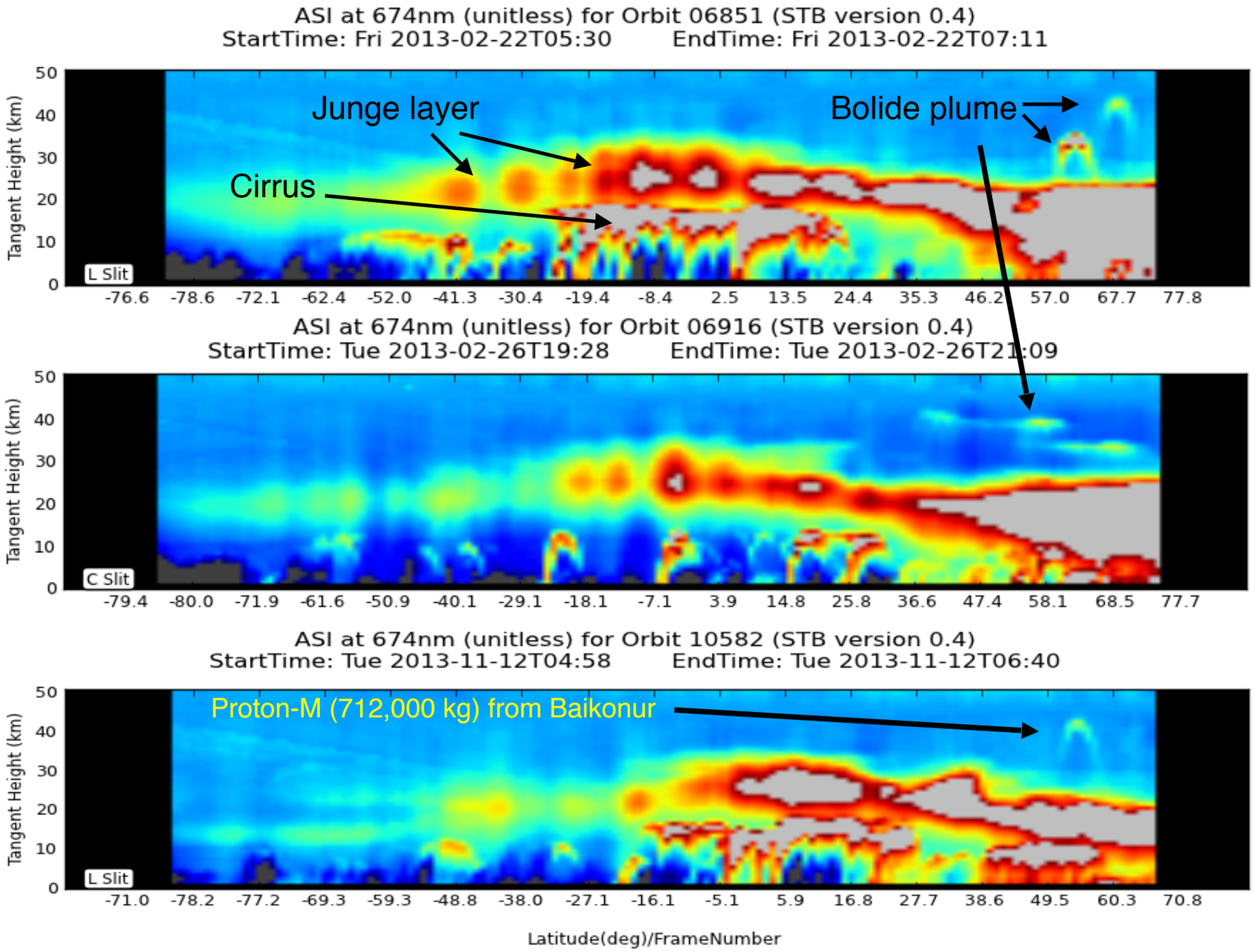


GEOS-5 simulation
Feb. 23, 2013



Gorkavyi et al., *GRL*, 2013

Cloud and Aerosol Capabilities



View spanning three orbits, February 22, 2013

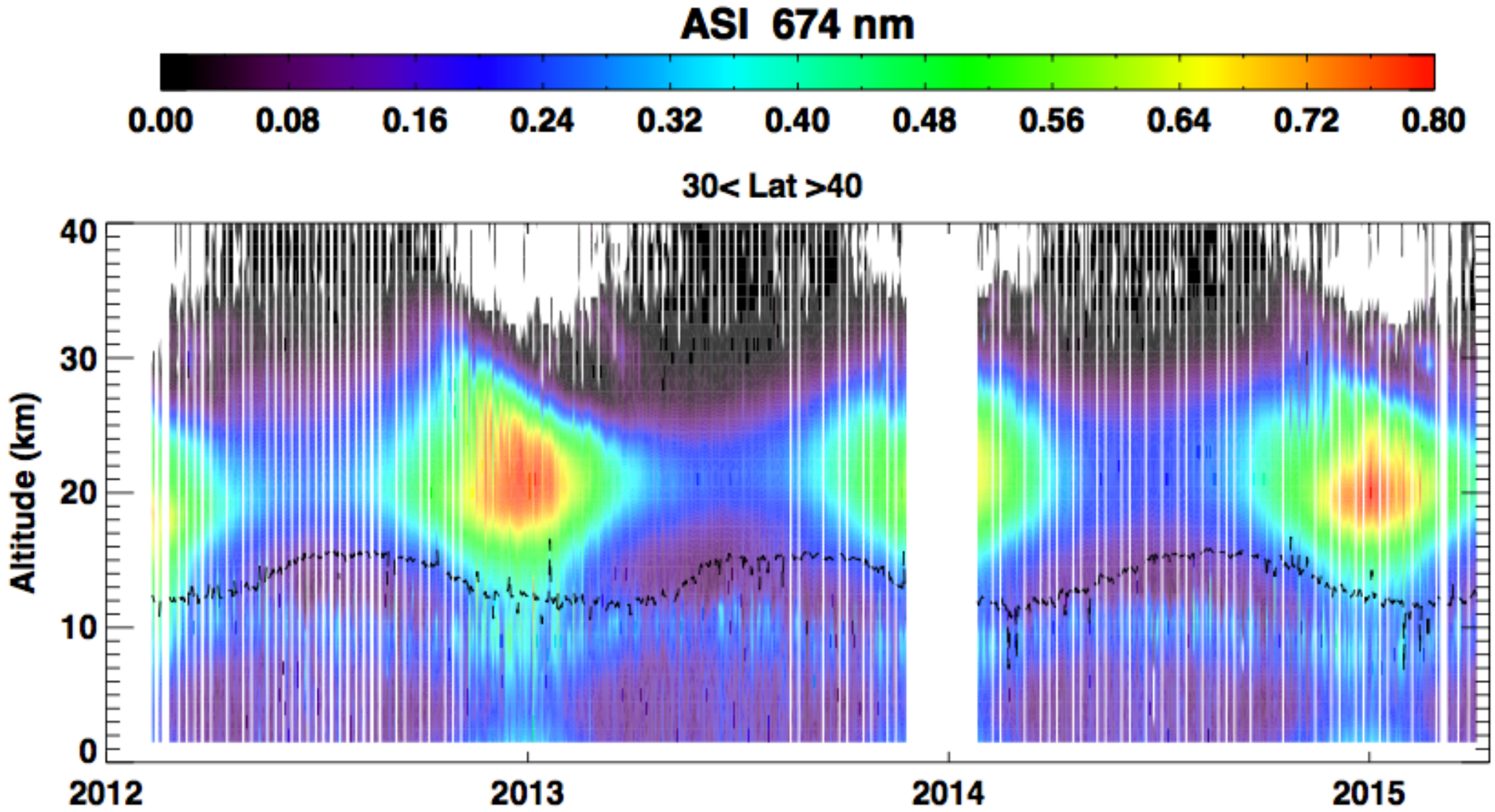
Aerosol Scattering Index (ASI)

$$ASI = \ln\left(\frac{I_o}{I_R}\right)$$

I_o = observed reflectance
I_R = modeled Rayleigh-only reflectance

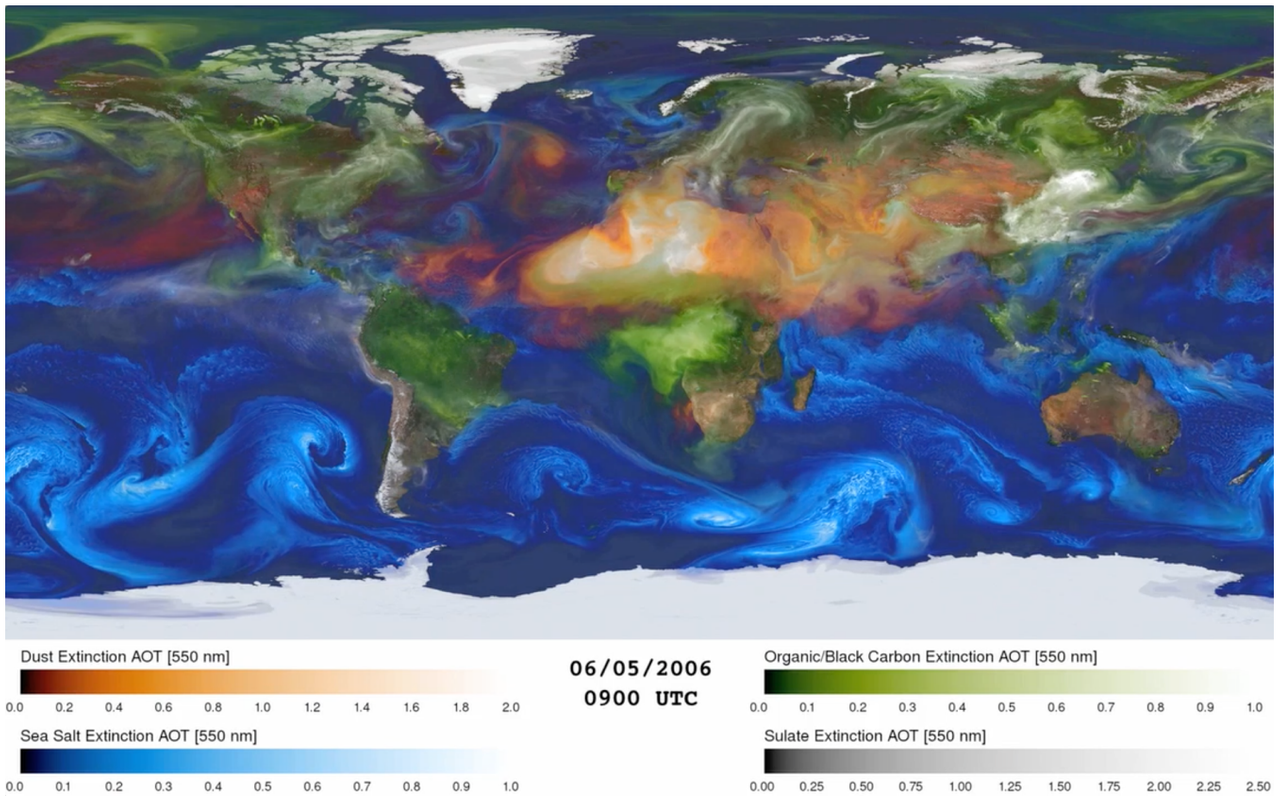
ASI is not a retrieval, but a semi-quantitative indication of presence of aerosols/clouds

Stratospheric Aerosol Layer



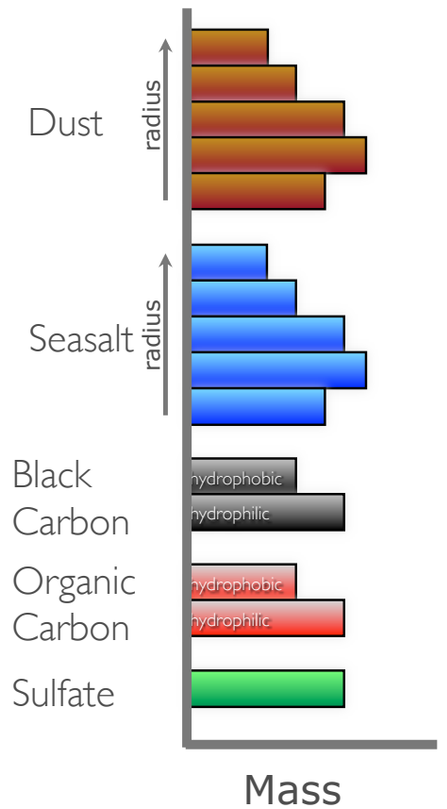
Zonal, daily mean ASI 30° - 40°N

GEOS-5 Model



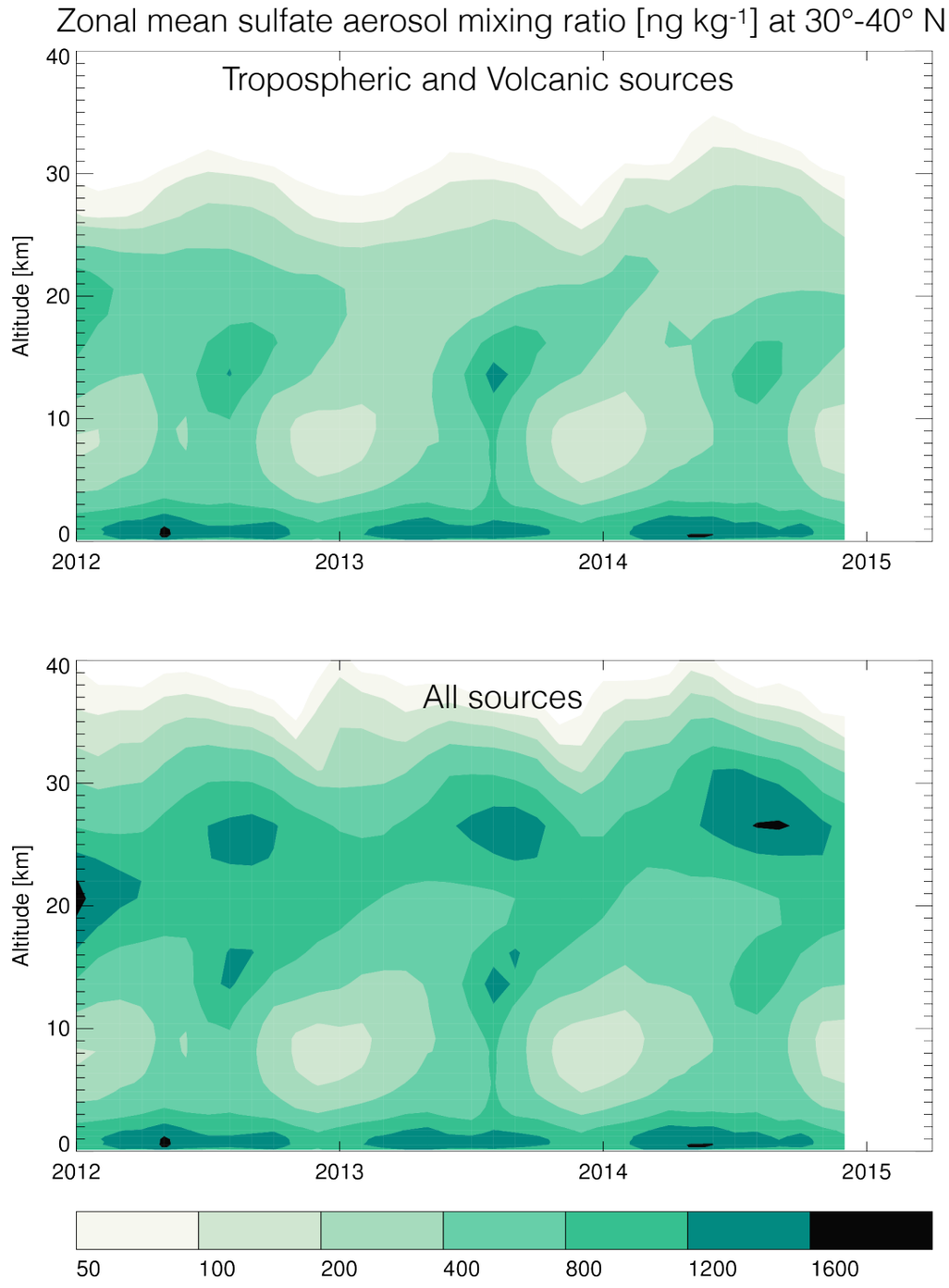
GEOS-5 7-km nature run simulated aerosol distribution

- Goddard Earth Observing System (GEOS-5) Earth system model supports NASA science and mission support activities (e.g., field campaigns, mission development)
- Applications include meteorological and constituent reanalysis, OSSEs, and chemistry-climate modeling
- Current aerosol modeling capability is based on the **GOCART** scheme: size-resolved **dust** and **sea salt**, bulk mass of **sulfate**, and bulk **black** and **organic carbon** in hydrophobic and hydrophilic modes
- GOCART is run near-real time forecasting system and is the basis for the MERRAero and MERRA-2 aerosol reanalyses

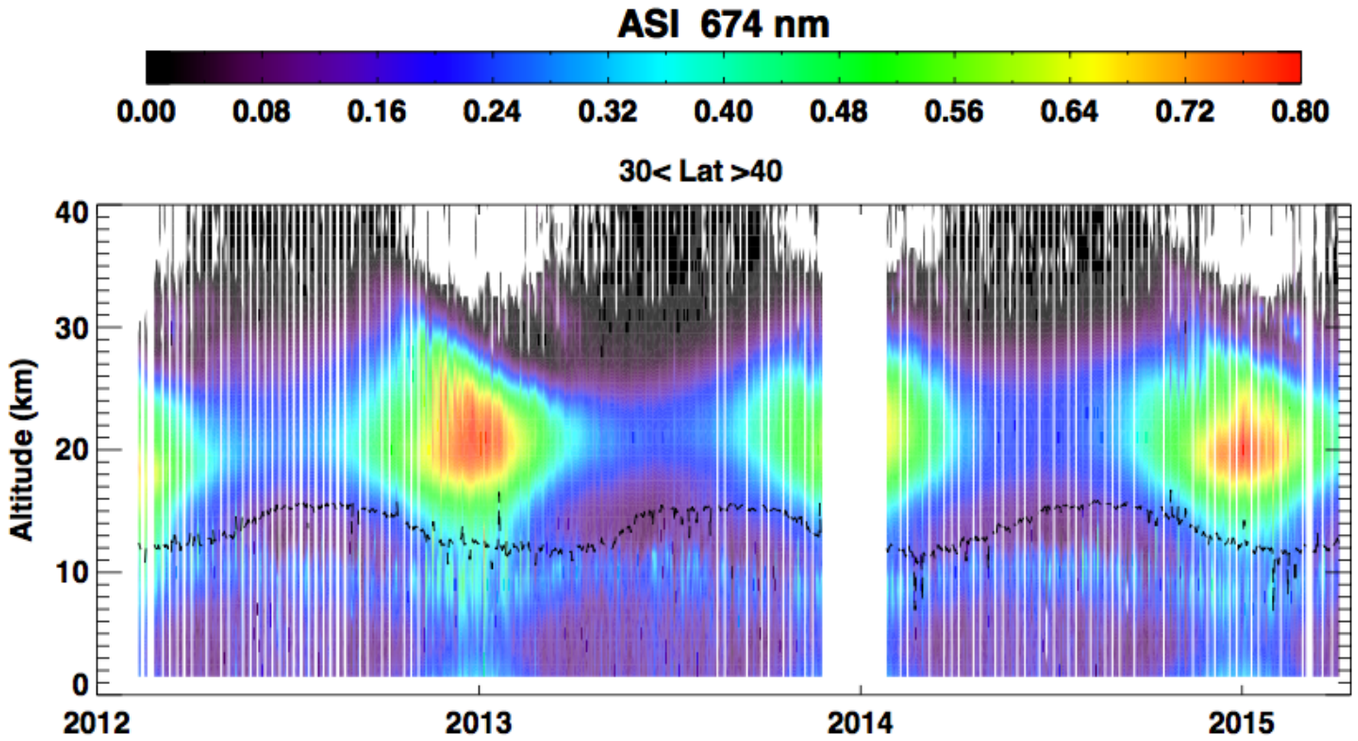


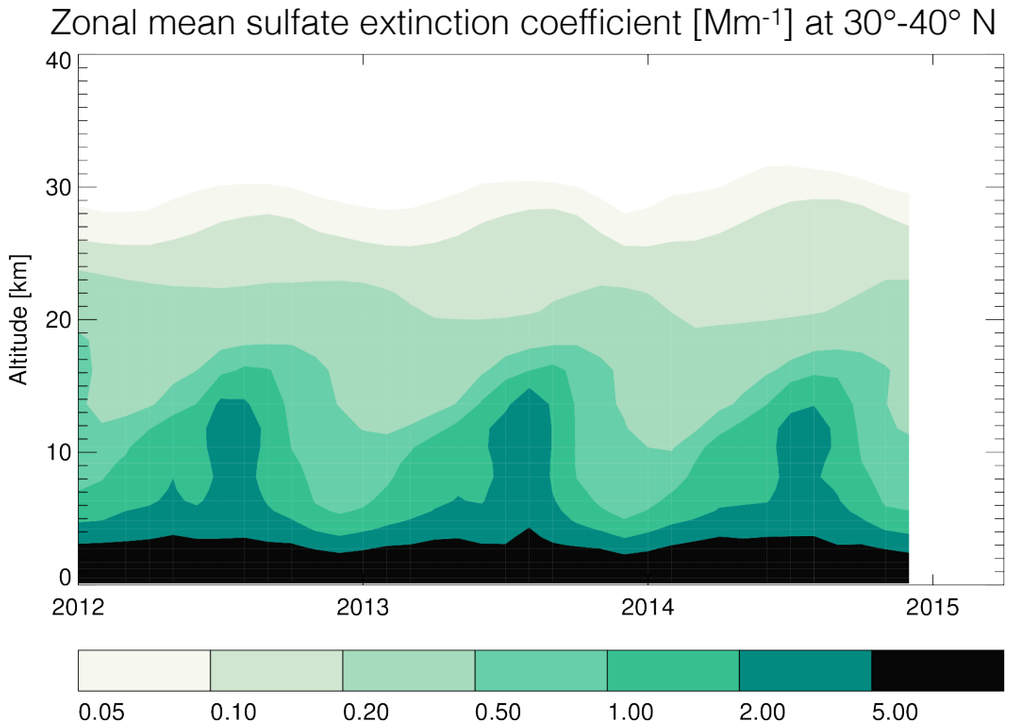
Modeling Stratospheric Aerosols

- Baseline version of GOCART focused on tropospheric aerosols
- Recently added OCS tracer and associated chemistry (coupling GOCART to stratospheric chemistry mechanism) to simulate production of stratospheric sulfate aerosol layer
- Application to stratospheric chemistry/ dynamics, impacts of volcanic eruptions, geoengineering
- OMPS LP data set will be used to evaluate simulations; model will be used to help interpret OMPS LP observations
- *In development* is a microphysical model to simulate variations and perturbations in particle size



Comparison to OMPS ASI





- We want to find an appropriate field from the model to compare to OMPS LP observations
- OMPS: At latitudes 30° - 40° N (influenced, e.g., by Asian anthropogenic aerosol and precursor sources) the ASI shows a peak signal around 20 km altitude near January 1
- GEOS-5: For the same region the model sulfate extinction profile peaks at near the surface with an elevated mid-year extinction peak reaching the tropopause

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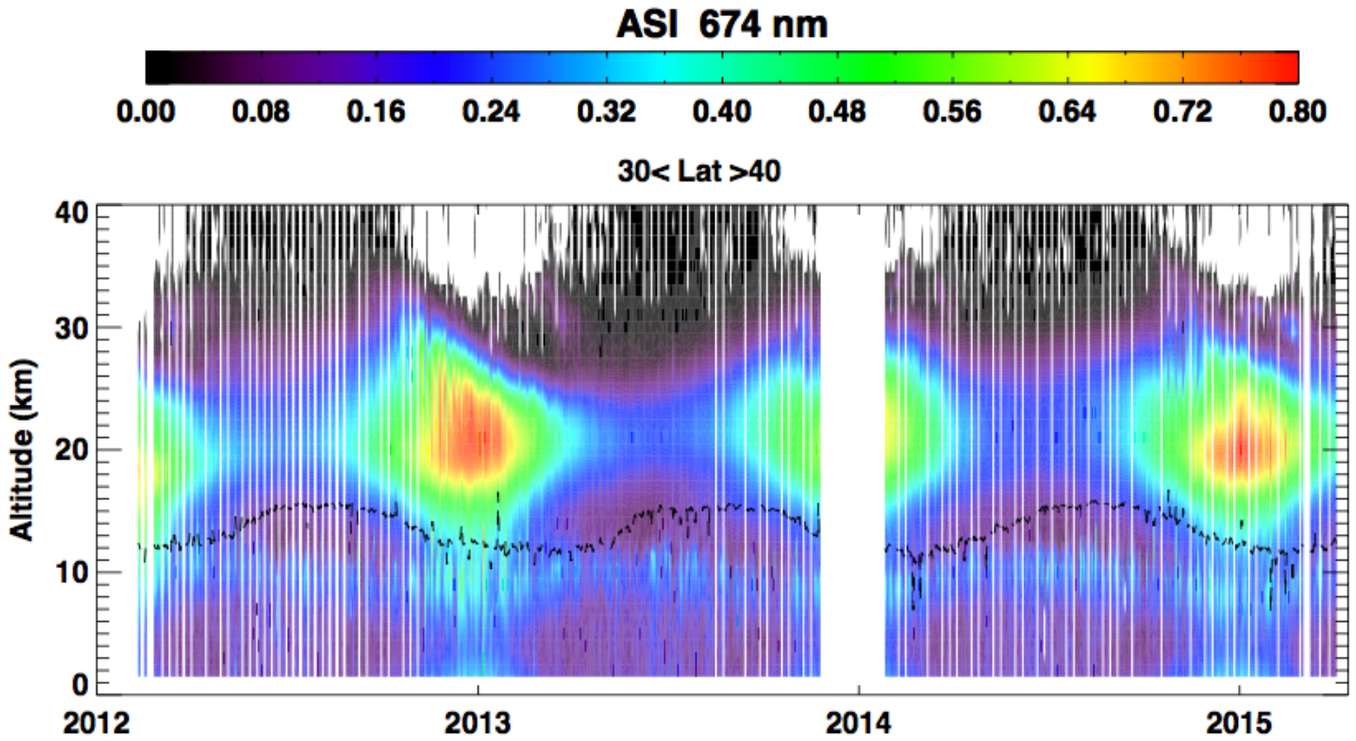

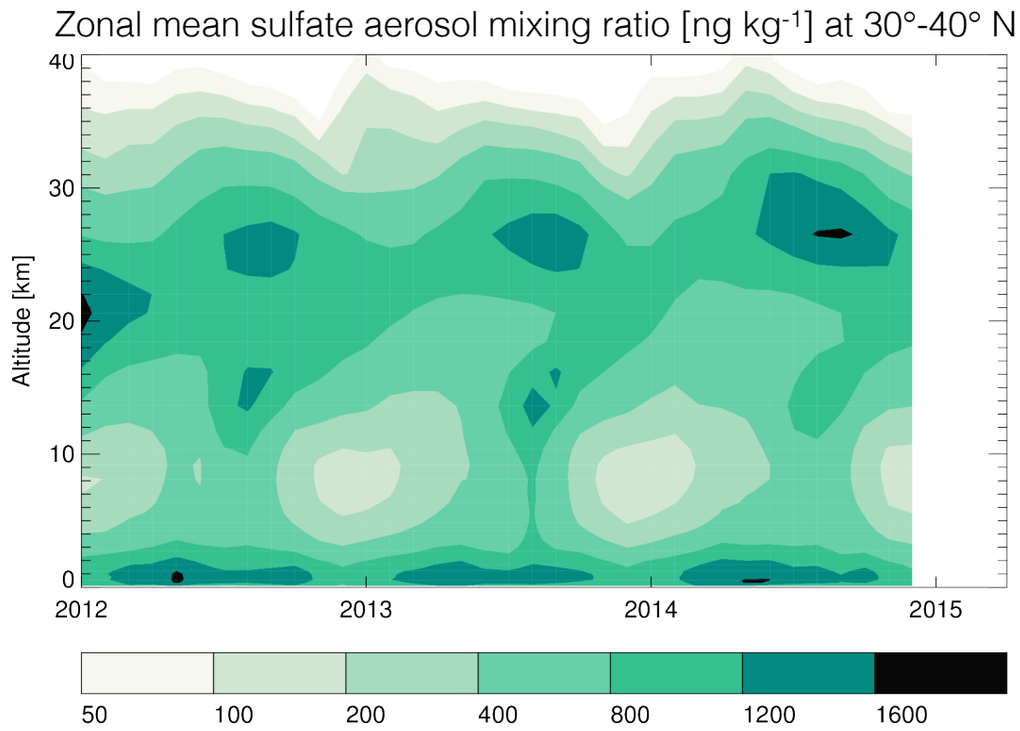

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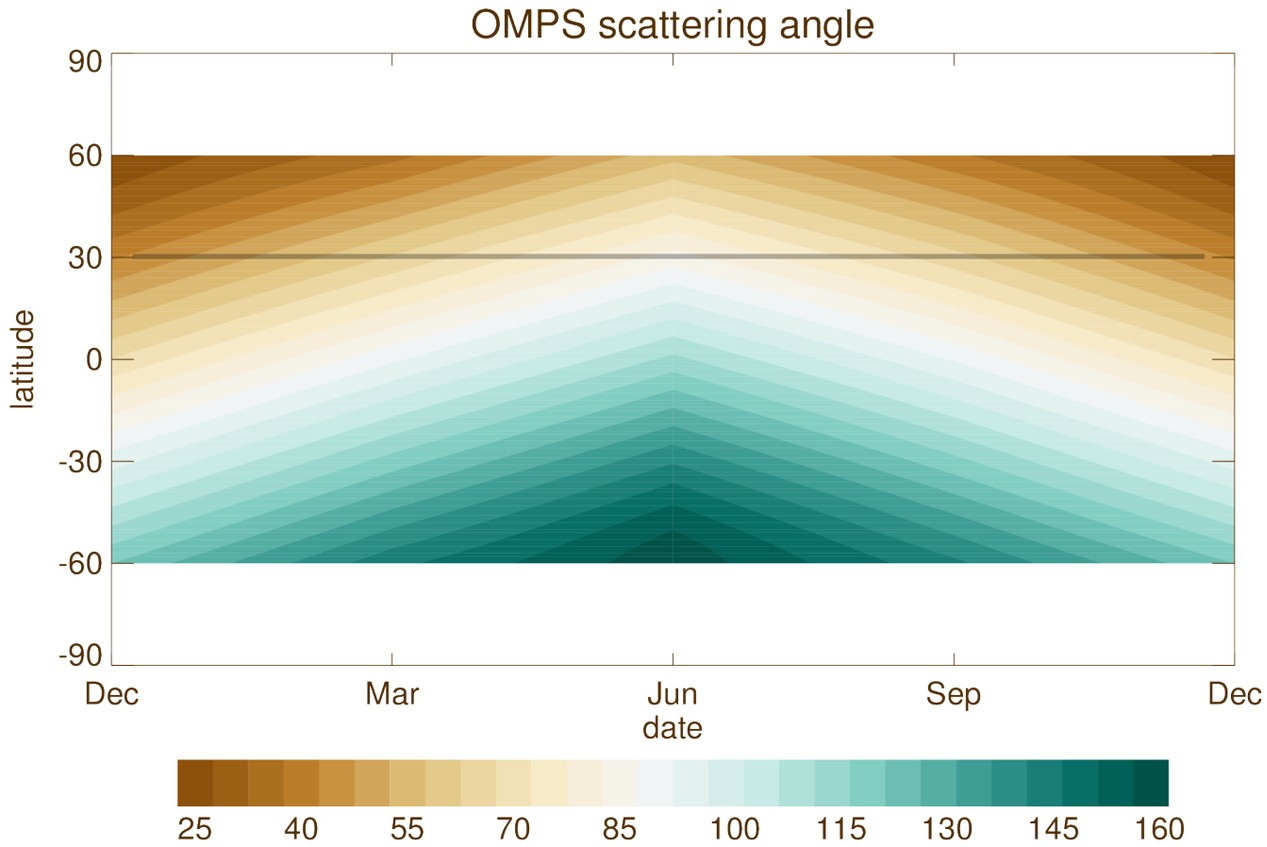
- ASI compares observed signal to expectation for pure molecular atmosphere
  - this is not unlike a mixing ratio
  - model mass mixing ratio presents a signal at similar altitudes, but seasonality is wrong

OMPS LP Scattering Angle

- Because OMPS LP is making a scattering measurement, it matters that the observation scattering angle changes with latitude and season
- At 30° N the range of scattering angle varies from 44° - 87° over the year



Aerosol Phase Functions

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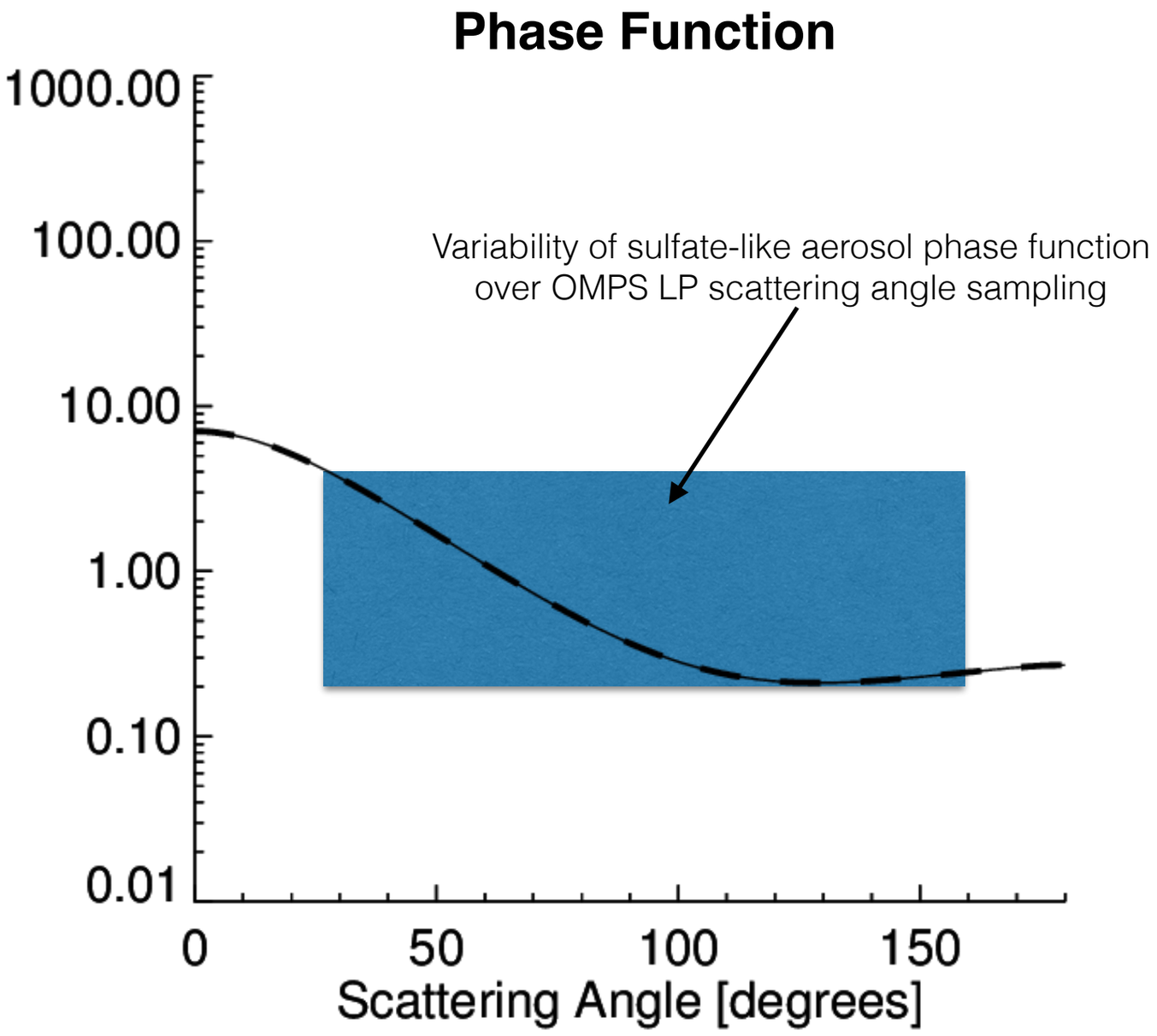
- For sulfate-like aerosol this is a range of aerosol phase function between 0.4 - 2, a factor of 5 variability in sensitivity



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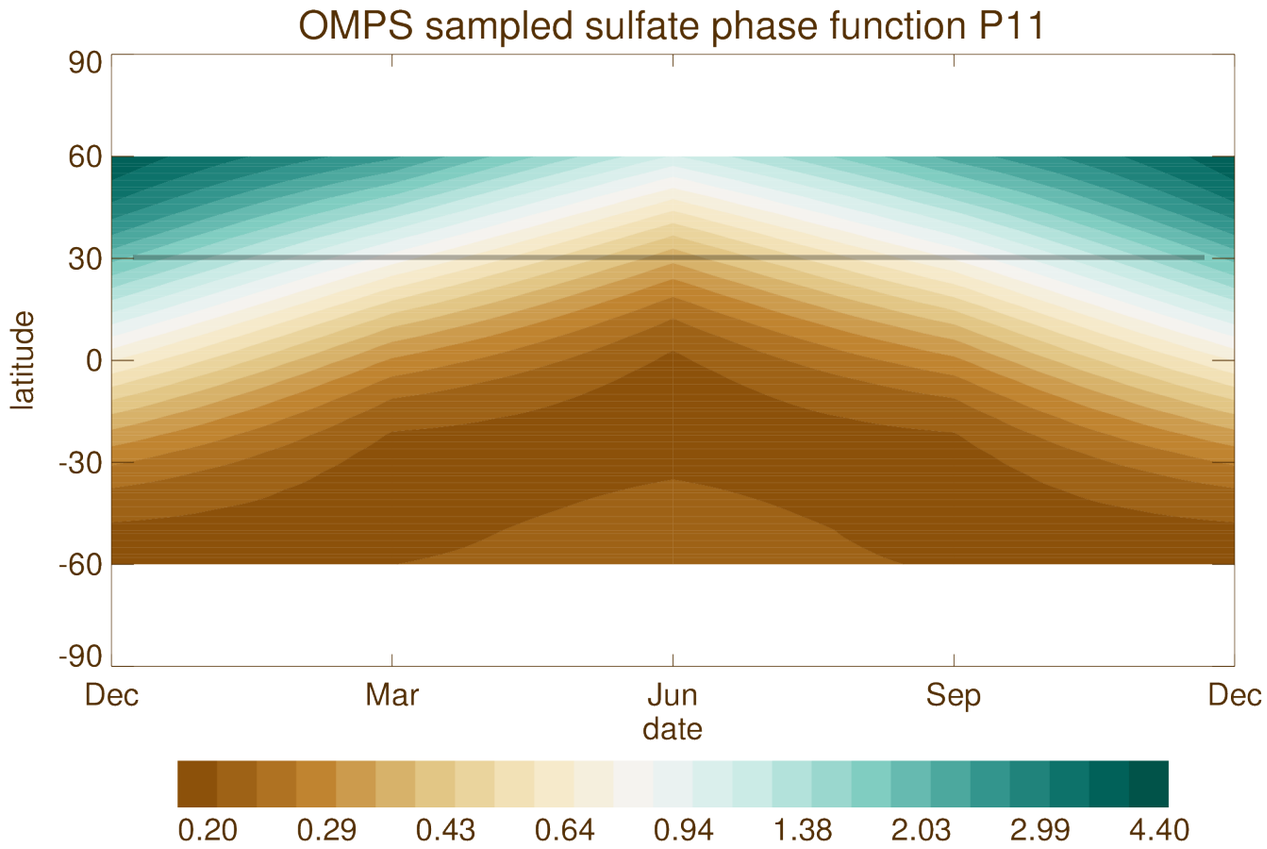

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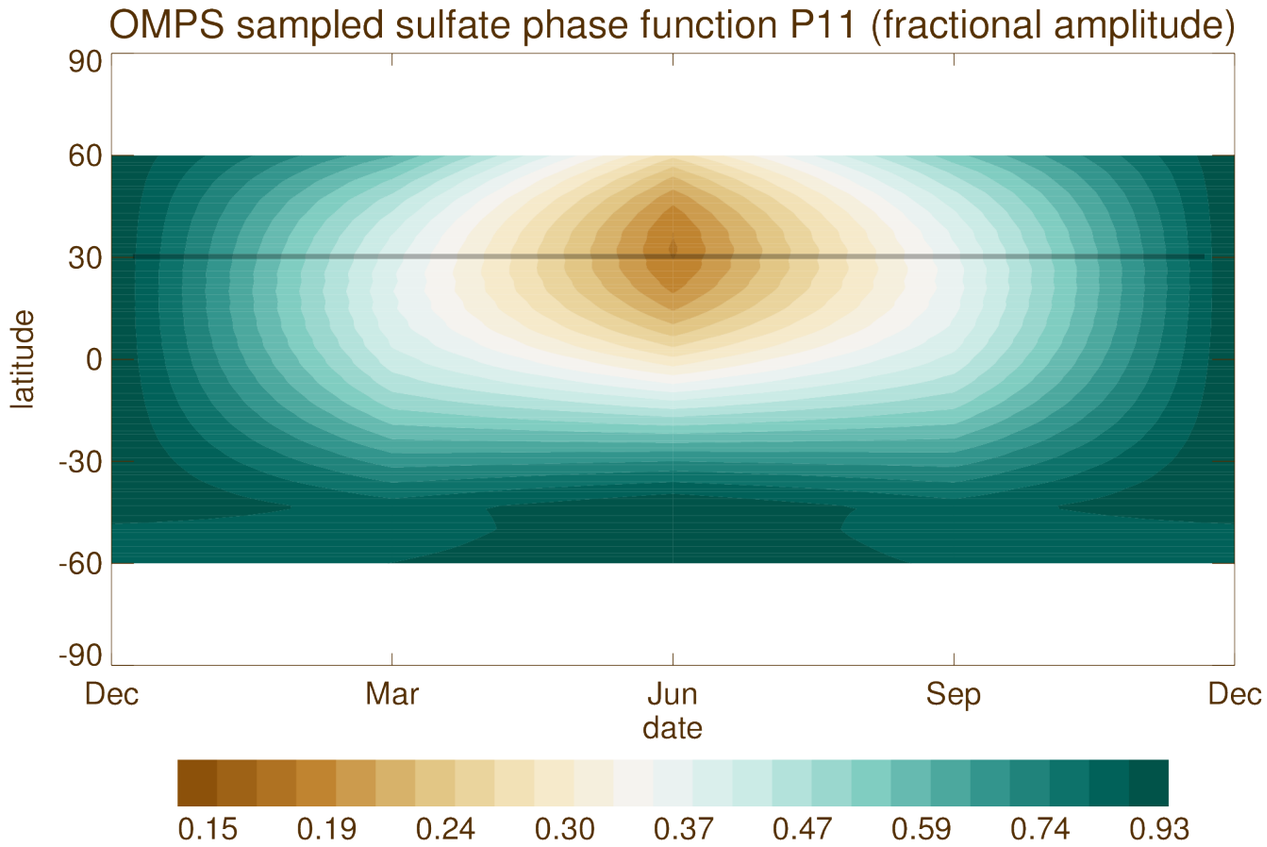
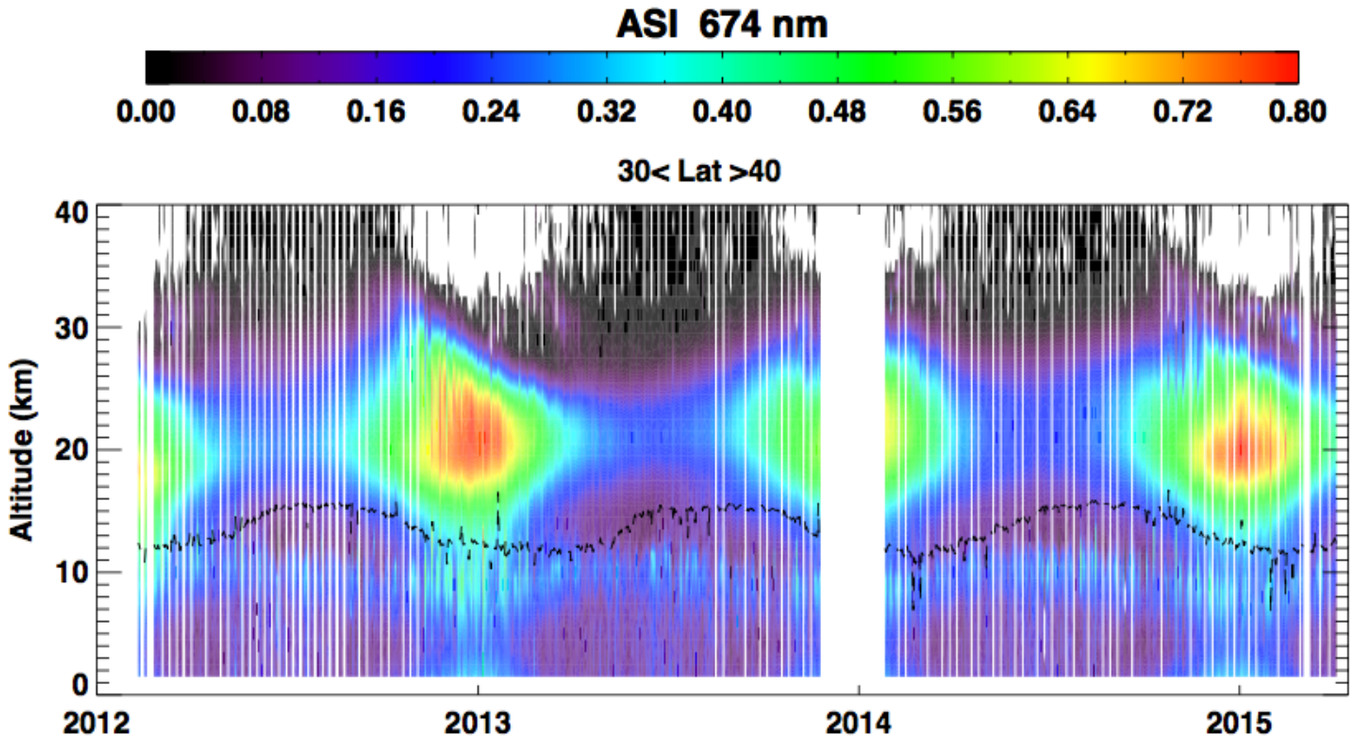
- From this reason we develop a scaling factor to account for ASI sensitivity to aerosol phase function, and apply to simulated mass mixing ratio

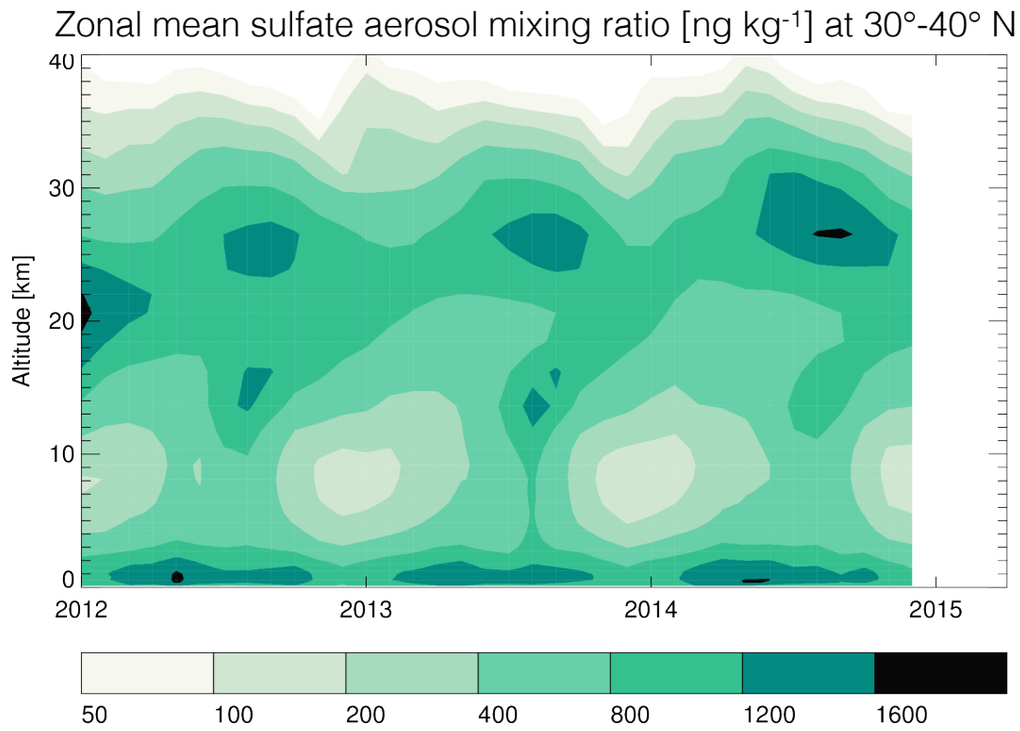


Scaling factor is time-dependent, per latitude:

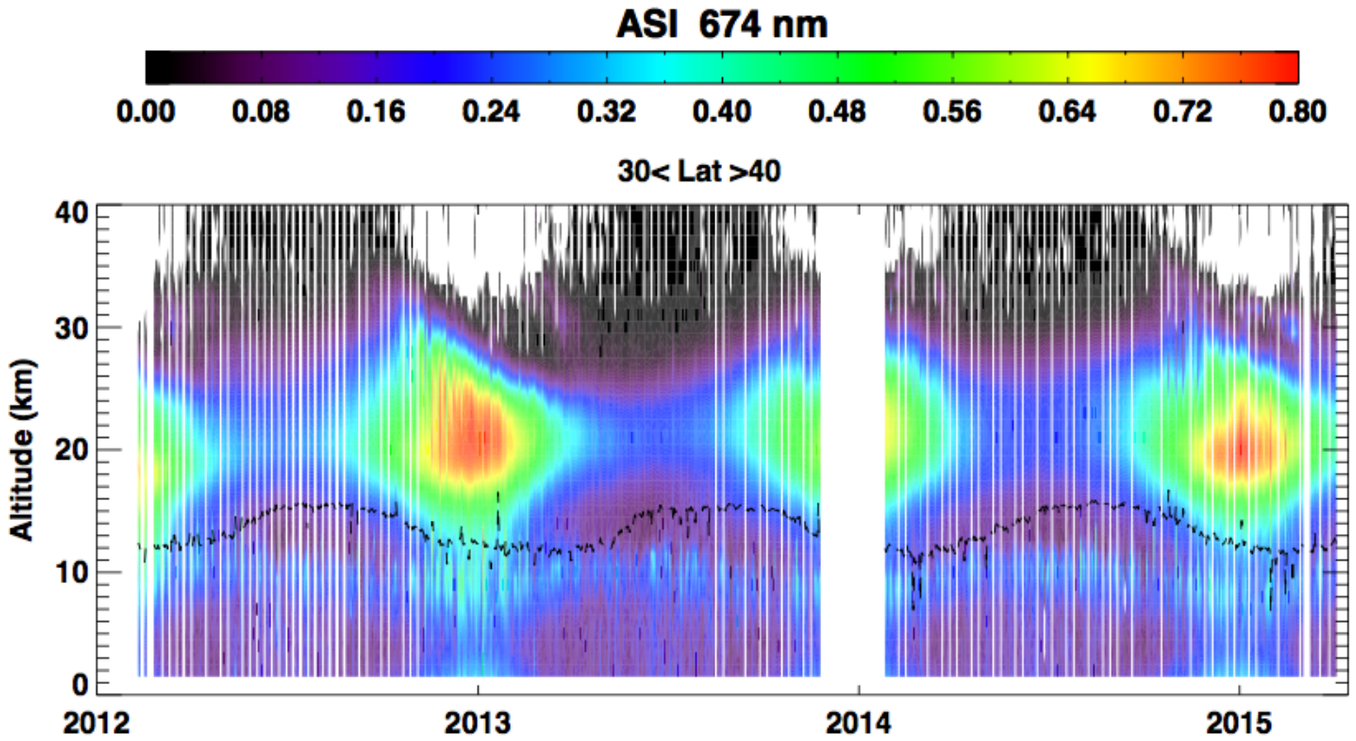
$f_{t,lat} = phase_{t,lat} / max(phase_t)_{lat}$

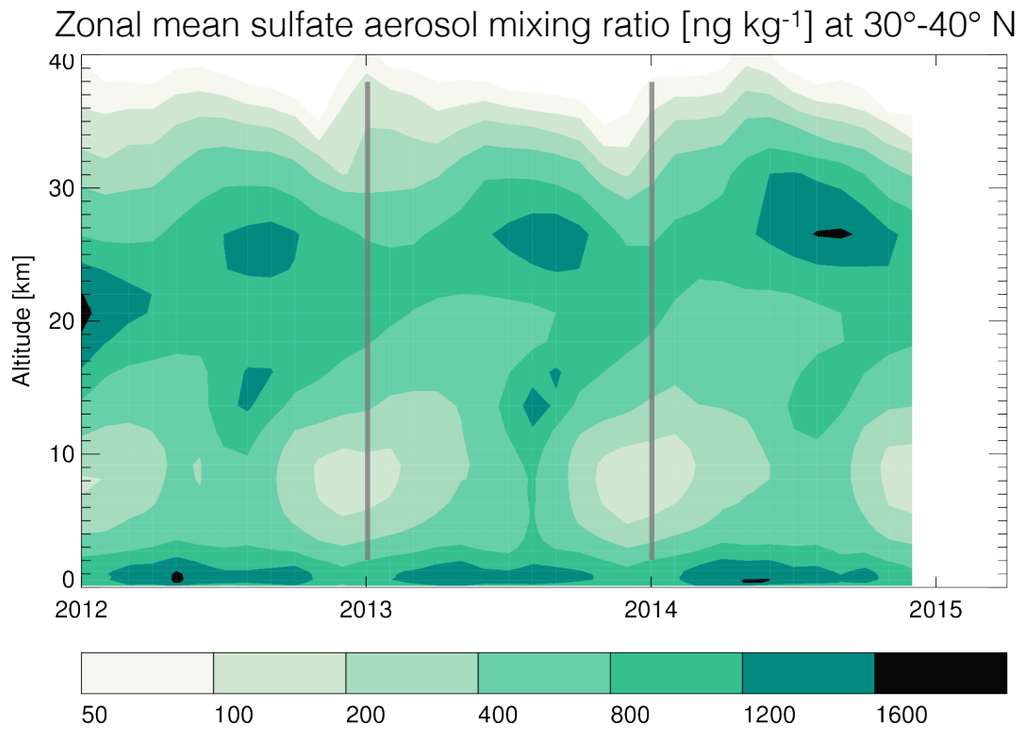
Original mixing ratio comparison



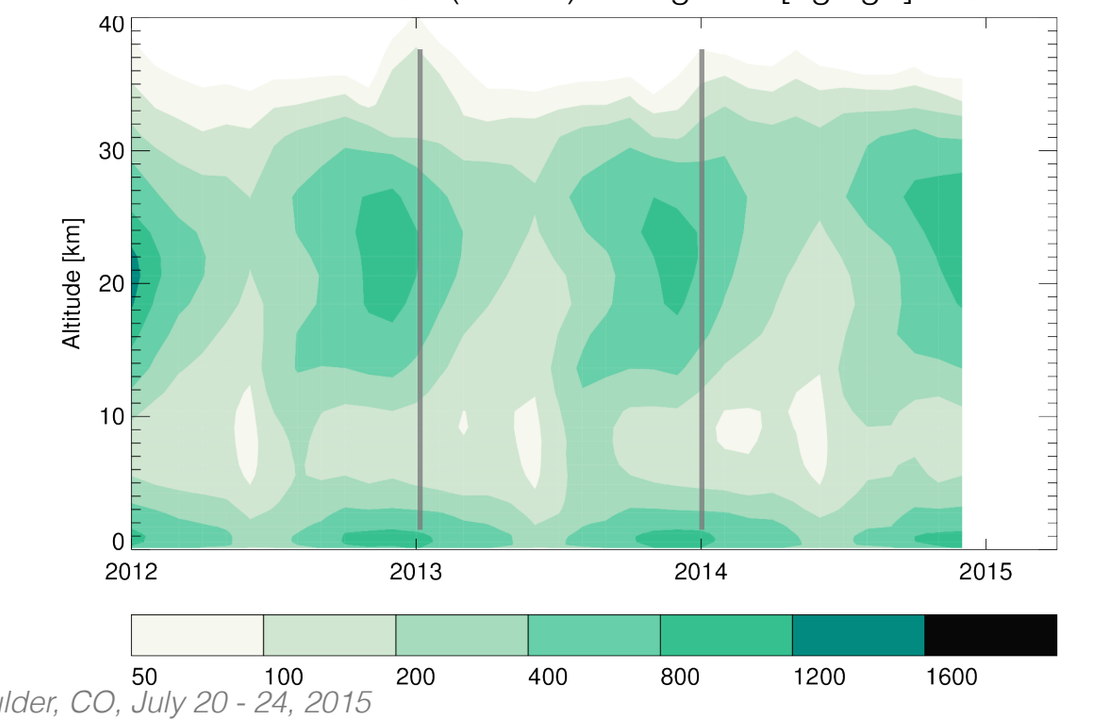


Scaled mixing ratio comparison

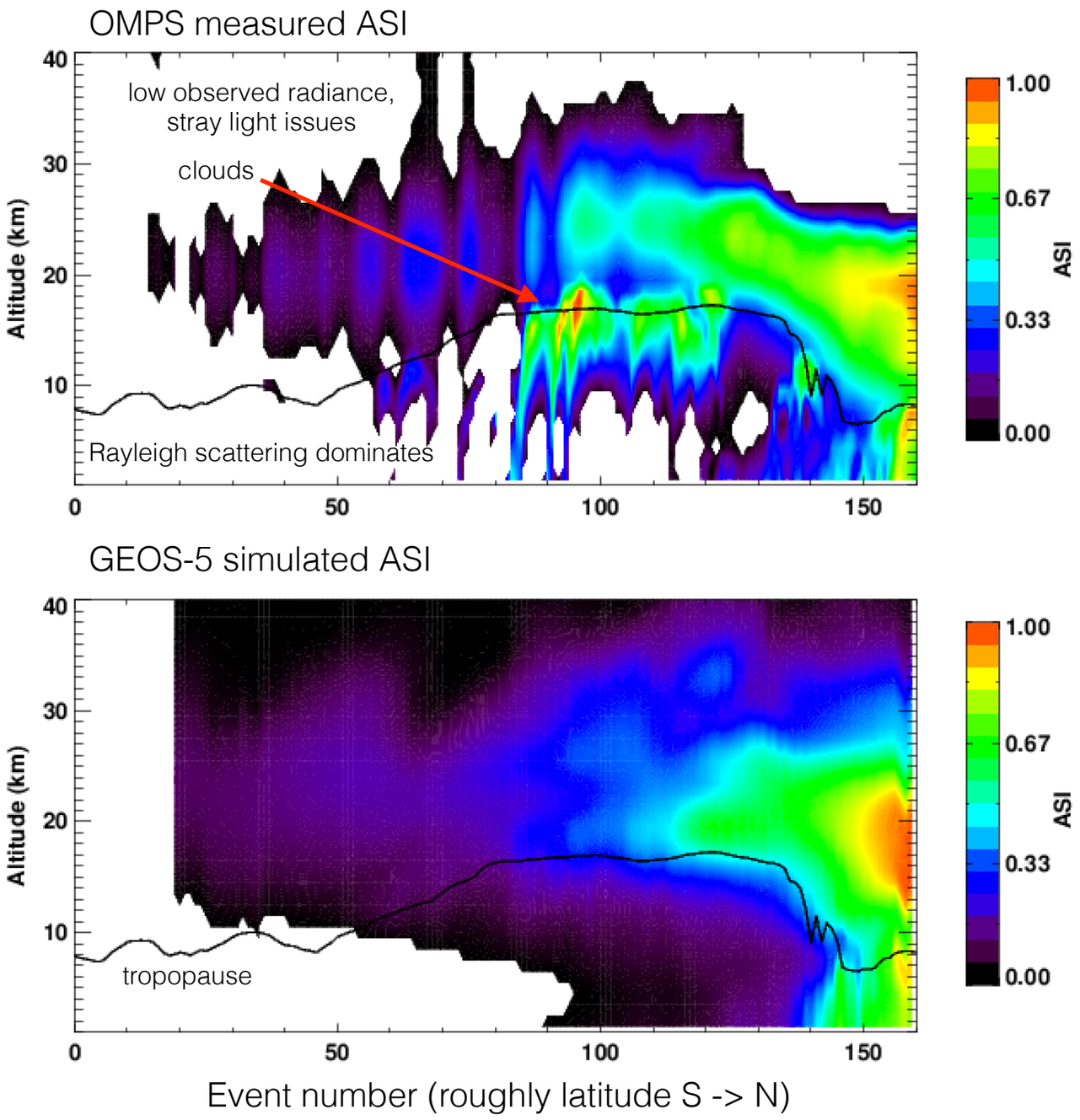




- Scaling brings the modeled seasonal cycle of stratospheric aerosol mixing ratio much more in line with the OMPS LP observations
- Similar results at other latitudes



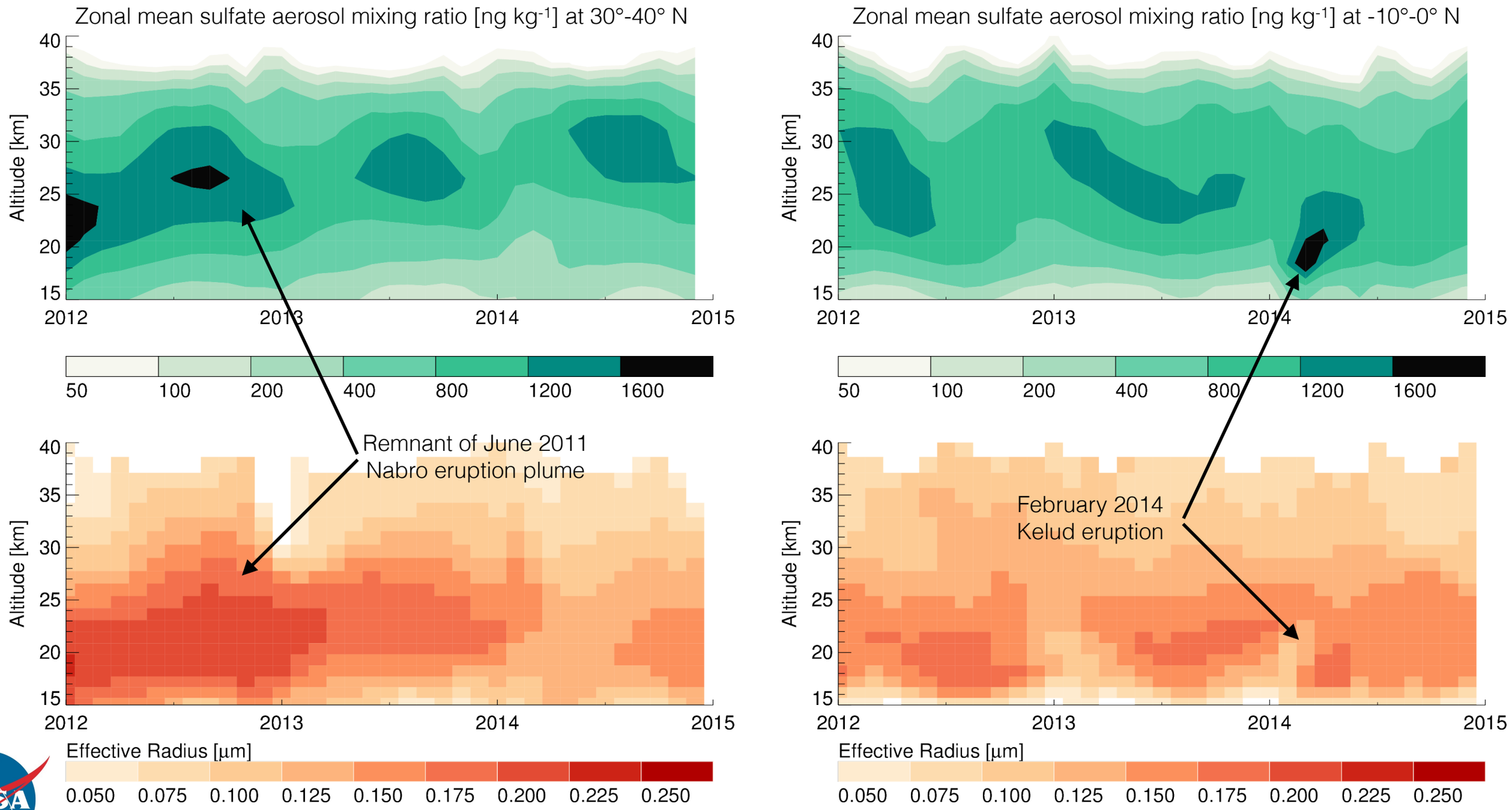
Future Directions
Forward Modeling ASI



- Another approach is to simulate ASI directly from the model results
- This requires a radiative transfer code, which takes as input the simulated aerosol extinction profile and some assumptions on the aerosol properties (i.e., phase function, which implies particle size and other properties)
- This has been done for a single day (1/14/2013, one orbit example shown)
- Hemispheric asymmetry again reflects OMPS LP viewing scattering angle
- Clouds were not included in model simulation
- Simulated aerosol appears slightly too low in altitude

Future Directions
Simulating Stratospheric Particle Sizes

Sectional aerosol module (CARMA) sees same sources of OCS-produced and volcanic SO_2
This permits simulation of aerosol particle size distribution, not possible with GOCART



Conclusions

- OMPS LP provides near-continuous, daytime observations of clouds and aerosols from near the tropopause to altitudes > 40 km

- Simulations with the GEOS-5 model are being performed to evaluate our modeling capabilities but also to help interpret the OMPS LP observations

- Comparisons of ASI to GEOS-5 model show model stratospheric aerosol seasonal cycling consistent with observations if you account for aerosol scattering properties

- Forward modeling the ASI and aerosol microphysical model simulations will help develop an extinction retrieval

Kelud Volcanic Eruption