Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

# Identifying anomalous and non-sulfate aerosol layers through Angstrom exponent goodness-of-fit: proof of concept from *in situ* data

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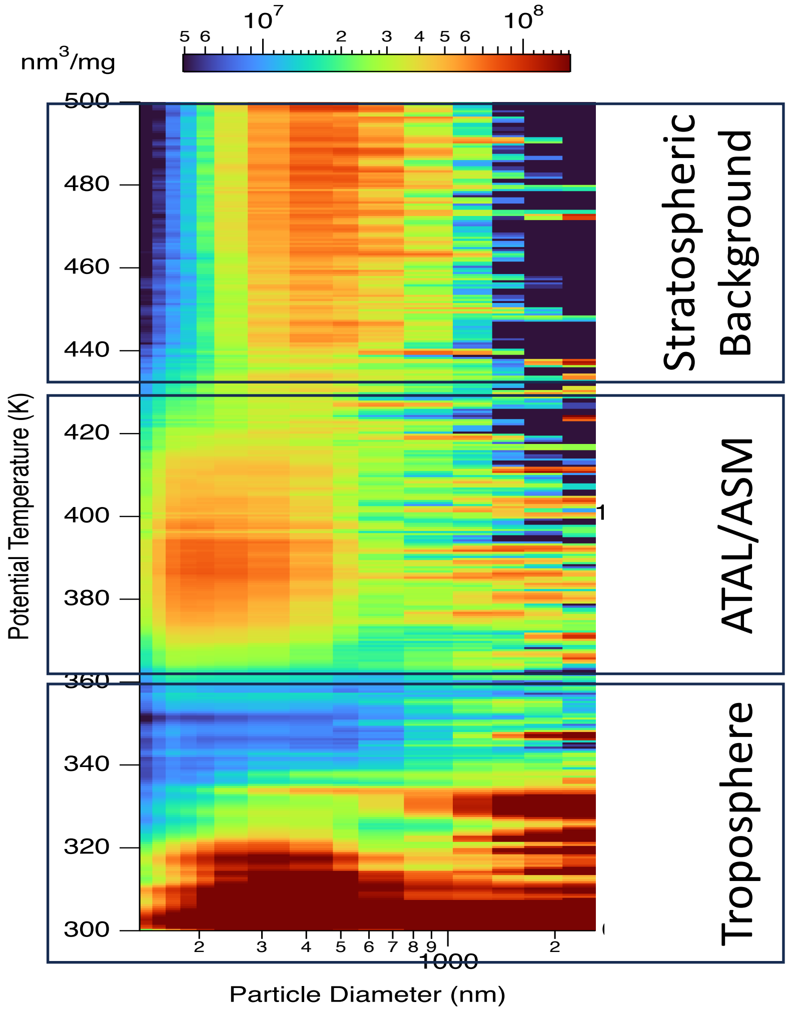
# Concept

- Efforts to estimate particle size distributions from spectral aerosol extinction data from SAGE II, III, III/ISS have a long history and continue
- Summary: **It is hard**! And it is really hard when the size distributions are not unimodal log-normal
- Idea: Identify times when the spectral information deviates from the expected response as an indicator of ‘anomalous’ non-stratospheric background aerosol layers.

Examples of ‘interesting’ stratospheric aerosol




Vertical profile of aerosol volume size distributions in the ASM/ATAL (courtesy of Doug Goetz)

# Angstrom Exponent

1929

ON THE ATMOSPHERIC TRANSMISSION OF SUN RADIATION AND ON DUST IN THE AIR.

BY *ANDERS ÅNGSTRÖM.*

In recent years the elaborate investigations of Abbot and his collaborators have in a high degree attracted the interest of meteorologists to the determinations of the solar constant and its variations. This interest is well deserved and will probably in the future result in considerable progress especially as regards long range forecasts of temperature.

vented because [*Angstrom*, 1929] noted that the spectral dependence of extinction by particles may be approximated as a power law relationship:

$$\tau(\lambda) = \tau_1 \lambda^{-\alpha}, \qquad (1)$$

where $\tau(\lambda)$ is the aerosol optical thickness (AOT) at the wavelength $\lambda$, $\tau_1$ is the approximated AOT at a wavelength of 1 μm (sometimes called the turbidity coefficient, as per [*Angstrom*, 1964]), and $\alpha$ has come to be widely known as the Angstrom exponent.

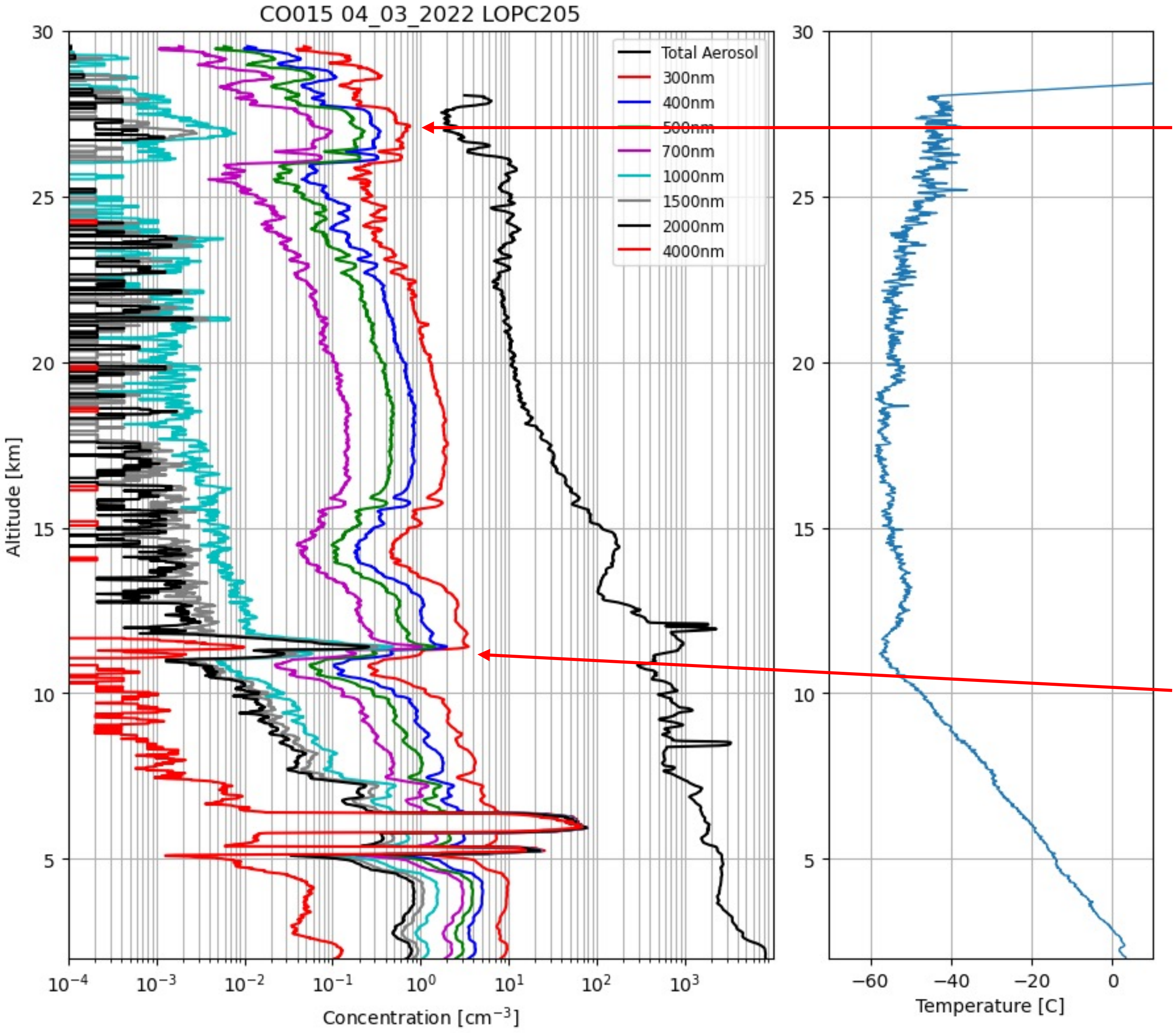
$\alpha << 1$ for very large particles (clouds)
$1 < \alpha < 2$ for super micron aerosol
$\alpha > 2$ for fine mode particles, $d < 0.5\mu m$

*Schuster et al., 2006*

# Process

- Find correlated SAGE III/ISS and in situ OPC measurements.
- Calculate extinction at SAGE III/ISS wavelengths from OPC size distributions
- Fit the Angstrom exponential curve across SAGE and OPC extinction wavelengths to find the Angstrom Exponent ($\alpha$) using 1021nm channel as the reference
- Calculate at each altitude for profiles of Angstrom Exponent
- Calculate the 'goodness of fit' to the curve at each altitude
- Hypothesis – more complex size distributions (bi-modal, mixed RI, absorbing aerosol) will deviate from the Angstrom curve – lower $r^2$ goodness of fit metric.

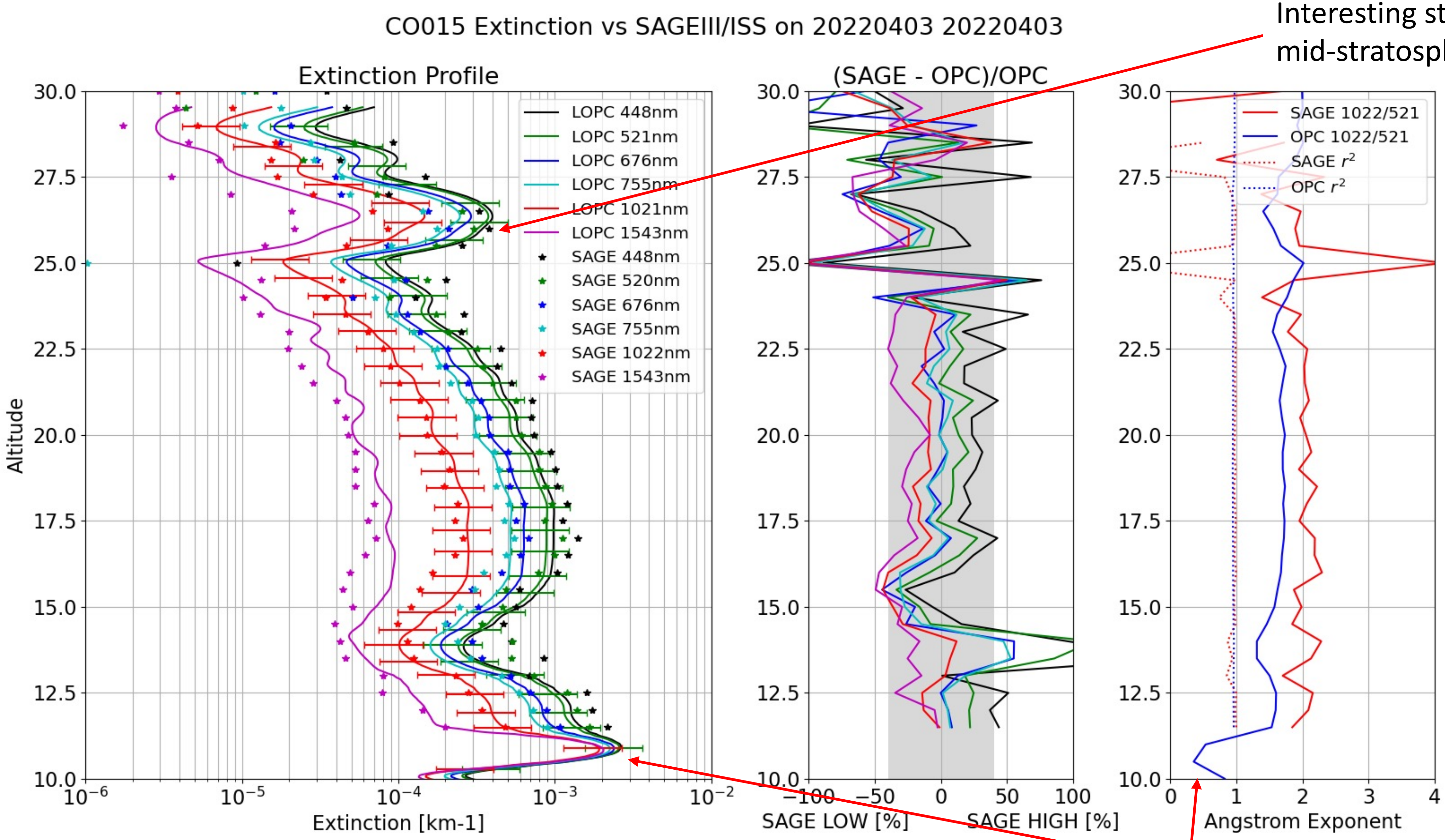
# Test Case – CO015




Interesting stuff in mid-stratosphere

Cloud @ lapse rate tropopause

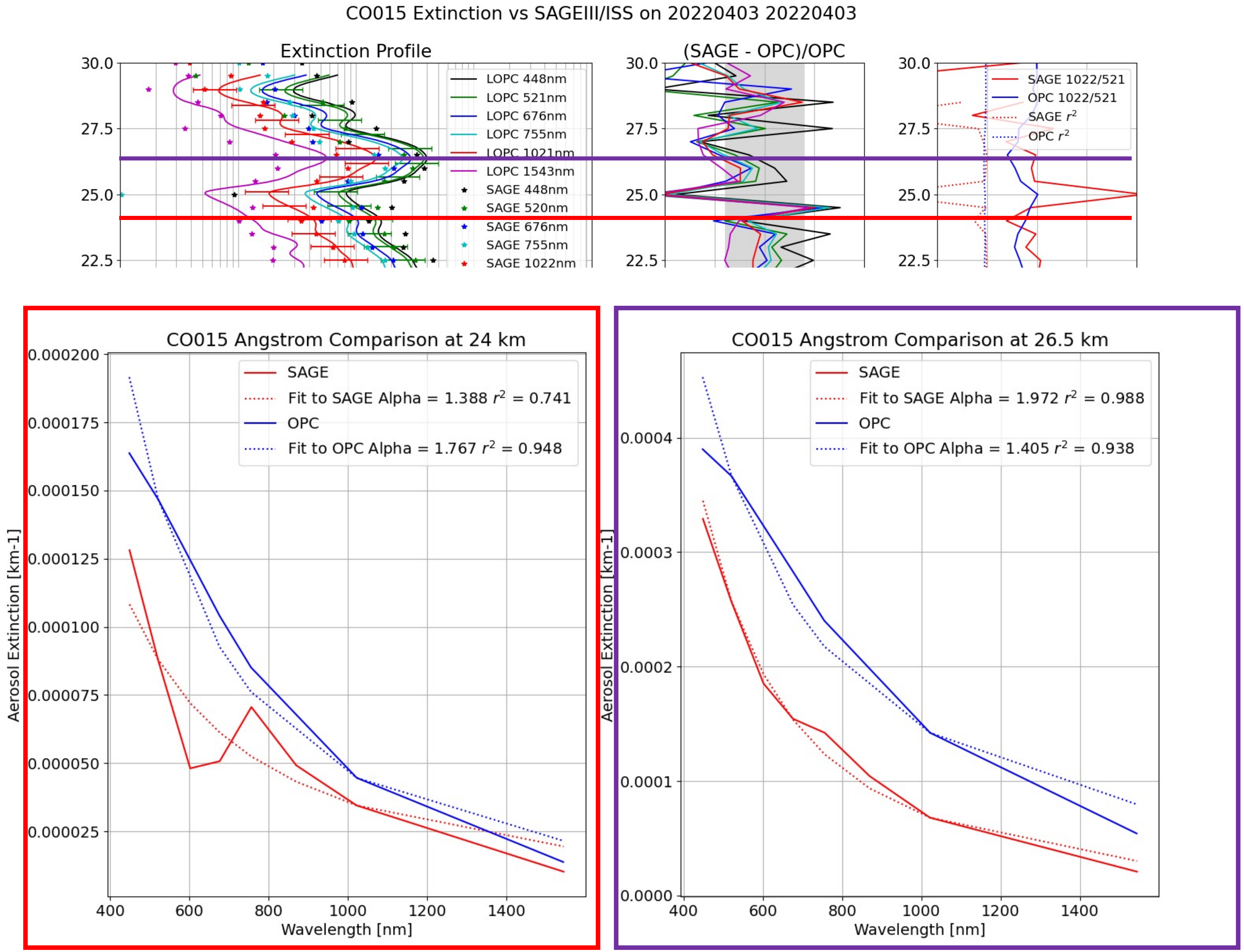
# Test Case – CO015



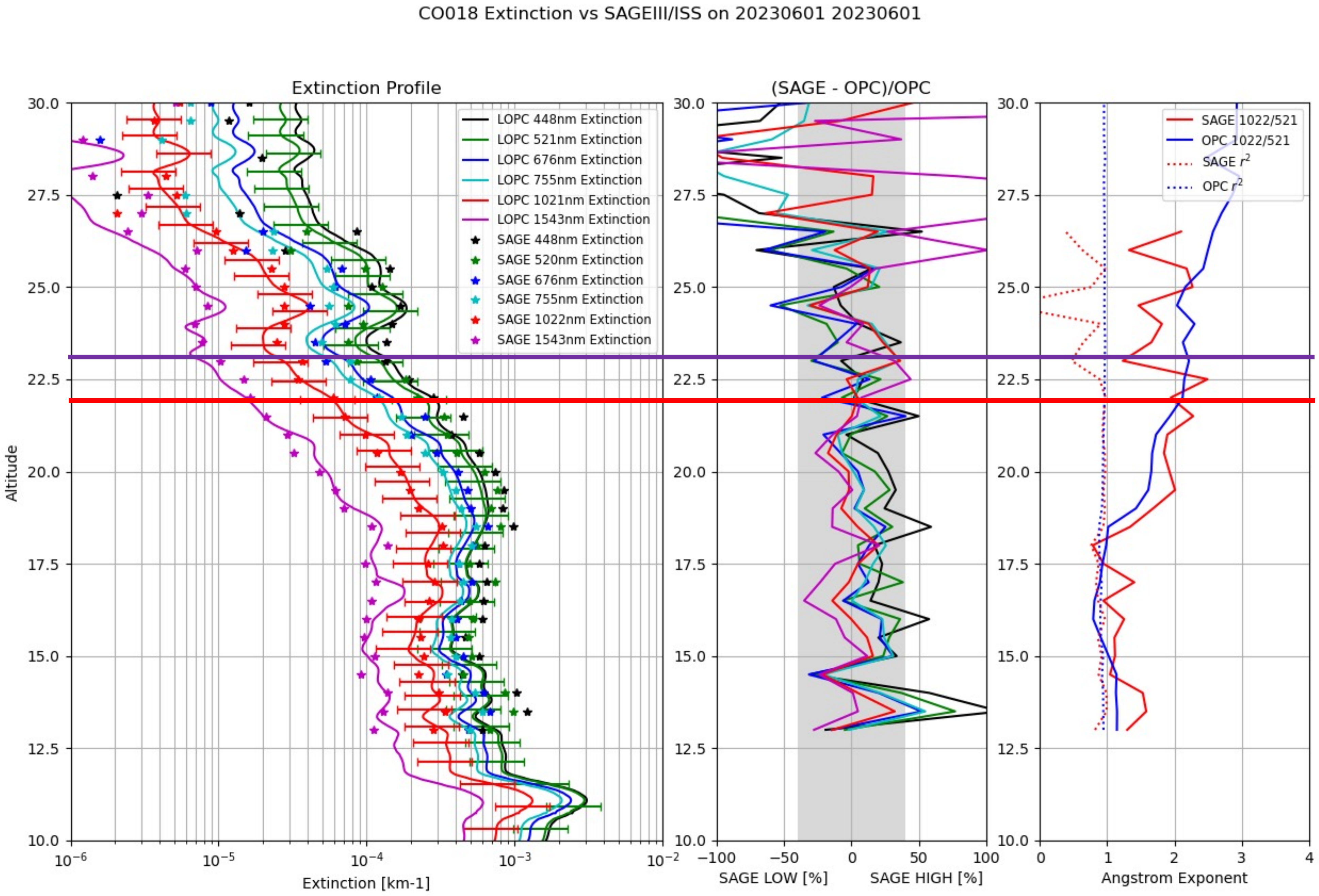

Interesting stuff in mid-stratosphere

Cloud @ lapse rate tropopause – alpha < 1.0

# Test Case – CO015



# Test Case – CO018



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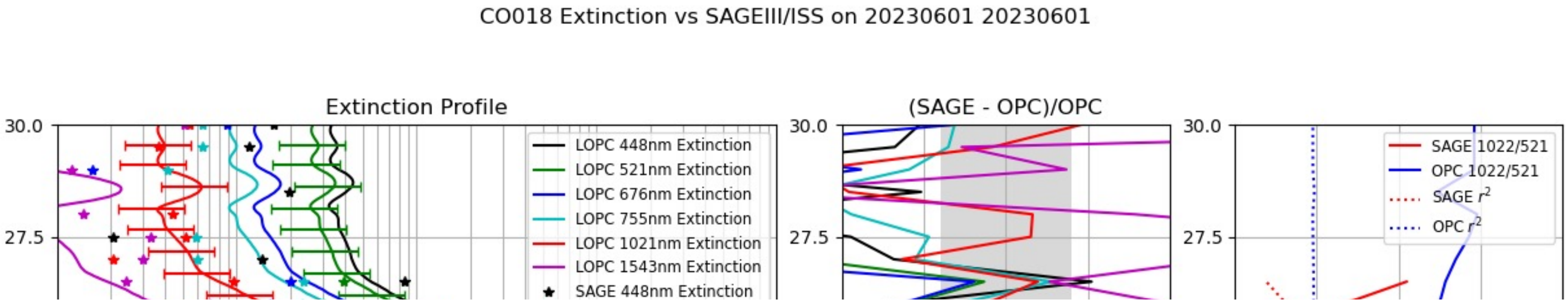


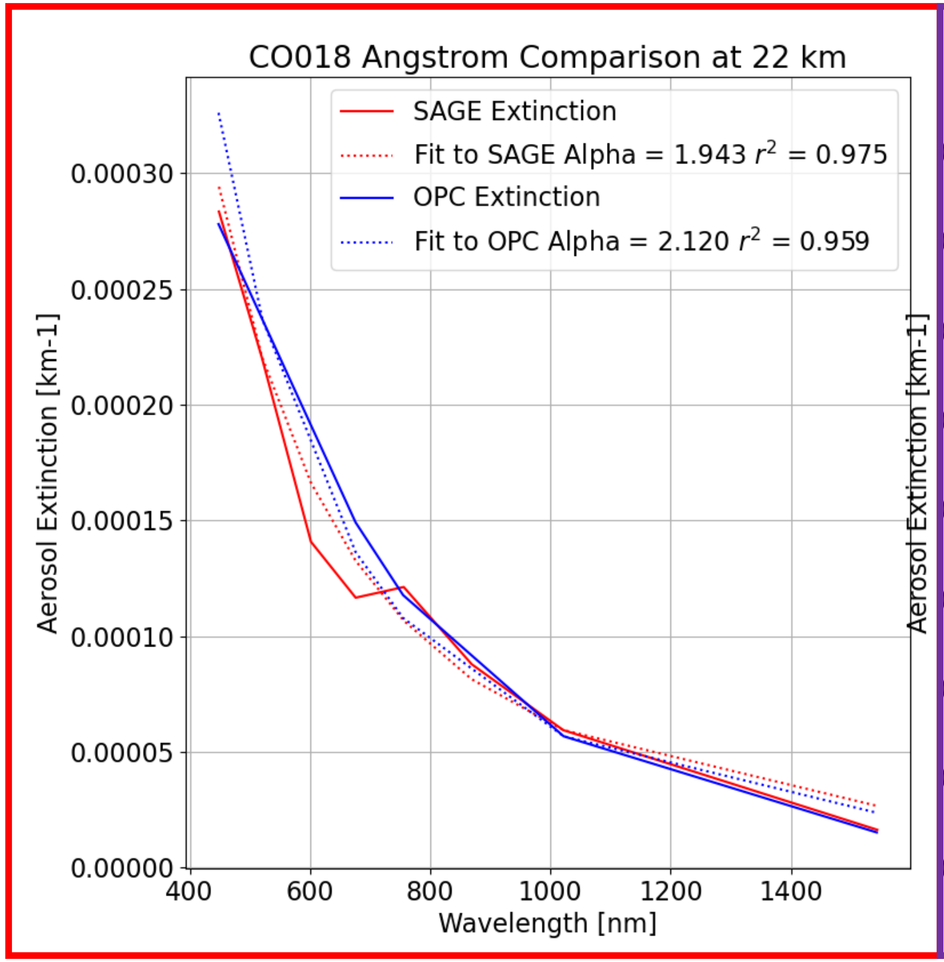


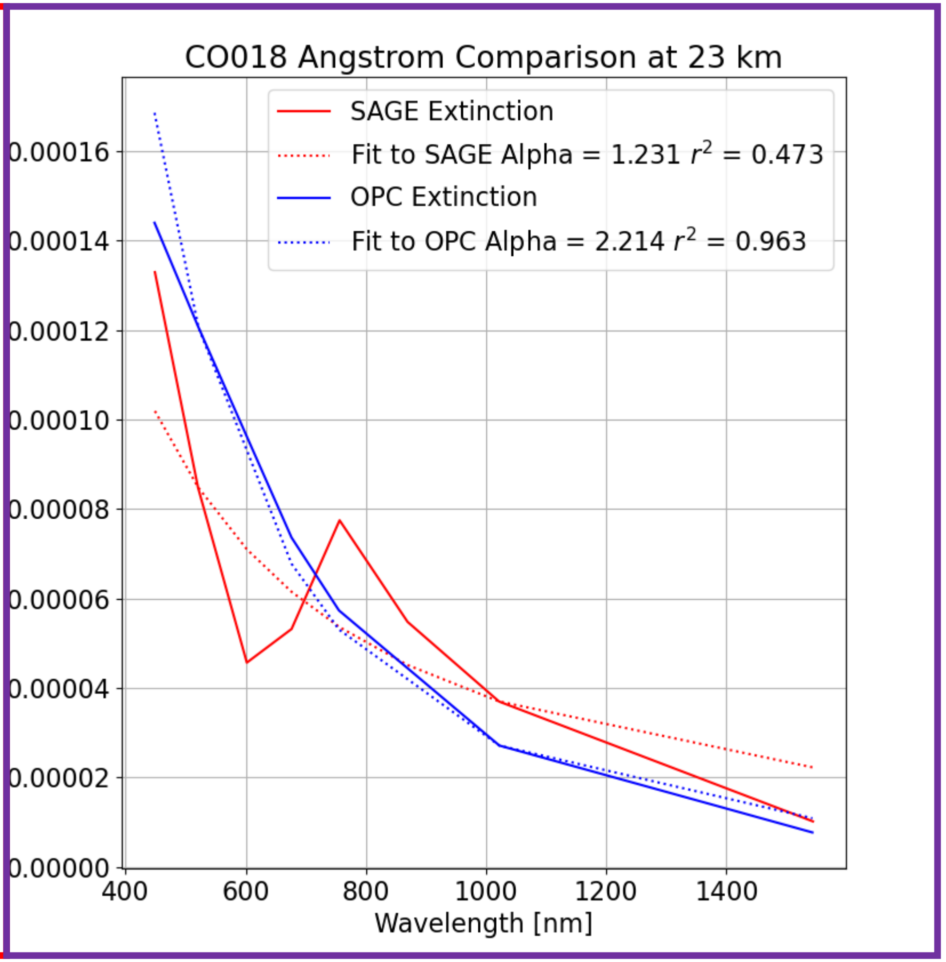

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2020JD032430

# Validation of SAGE III/ISS Solar Occultation Ozone Products With Correlative Satellite and Ground-Based Measurements

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**Key Points:**

- Among the three SAGE III/ISS solar occultation retrievals, AO3 (v5.1) ozone product shows the smallest bias and the best precision
- The mean biases of AO3 ozone are less than 5% for ~15–55 km in the midlatitudes and ~20–55 km in the tropics. It increases to ~10% near the tropopause
- The precision of AO3 ozone is ~3% for altitudes 20–40 km. It degrades to ~10–15% in the lower mesosphere (~55 km) and ~20–30% near the tropopause

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Aerosol Extinction 'gull wing' issue?

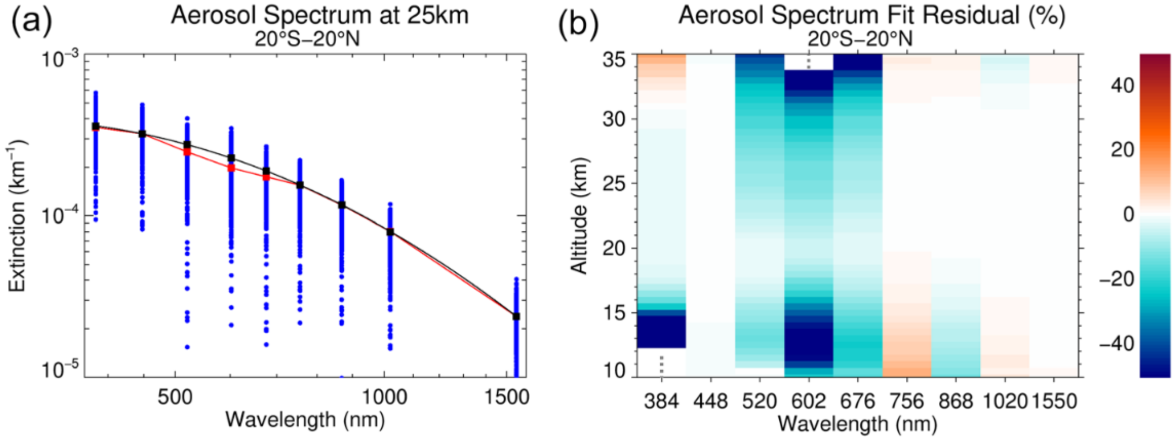
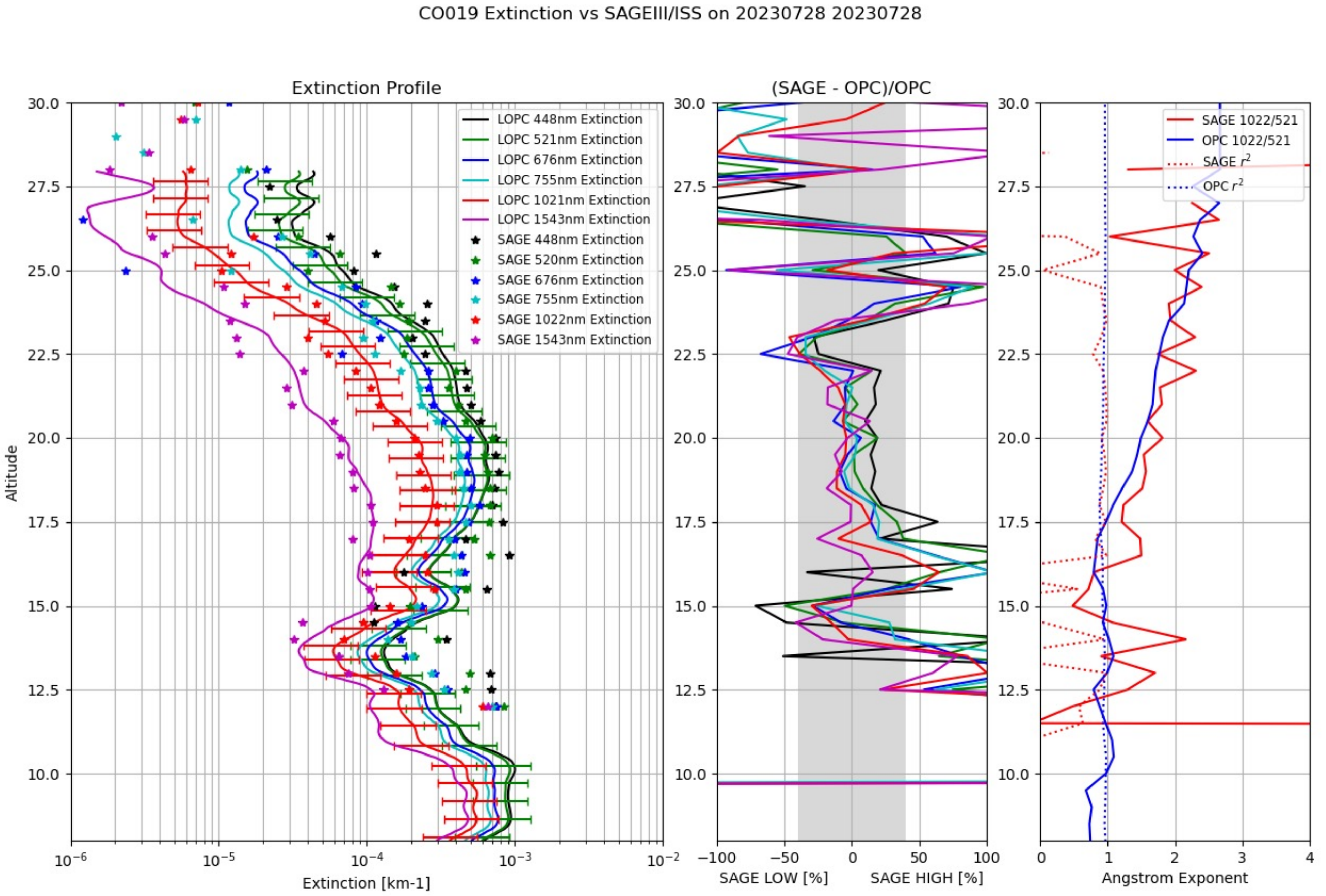



**Figure 3.** (a) SAGE III/ISS aerosol extinction data from June 2017 to May 2019 at 25 km between 20°S and 20°N at each of the nine aerosol wavelengths (blue dots). The median extinction values at each wavelength are shown by red squares, with the red line being a simple linear interpolation between points to aid the eye in seeing the spectrum. The log of extinction is fit with the log of wavelength using a simple quadratic function for each event at this altitude, and the median of fit values is shown in black. A dip between the data and the fit is clearly visible in the channels surrounding the Chappuis. (b) The median value of the relative residuals between the data and the fit to the aerosol spectrum (i.e., (data-fit)/fit) at each wavelength and altitude for the same latitude range and time period as (a). Results at midlatitudes are similar, simply shifted down in altitude. Gray stippling denotes areas where aerosol extinction data does not exist. The median residuals in the channels used for the quadratic fit are <1% between ~20 and 30 km.

# Test Case – CO019



# Conclusions

- Work in progress
- Angstrom Exponents fit the OPC size distributions is surprisingly good (maybe too good?)
- This applies even in anomalous layers – original hypothesis is a bust.
- Angstrom Exponents also fit the SAGE data well when SAGE and OPC extinctions are consistent.
- When OPC and SAGE don’t agree, the SAGE data often deviates from Angstrom’s law. Can this be a flag for checking SAGE aerosol retrievals?