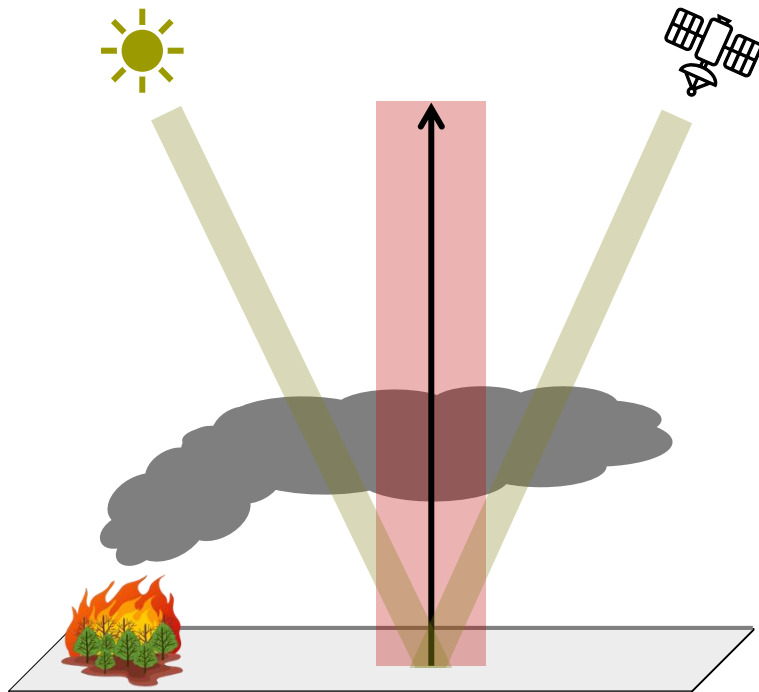


# Aerosol-Corrected TEMPO NO<sub>2</sub> Retrievals over Biomass Burning Plumes

2026/06/16

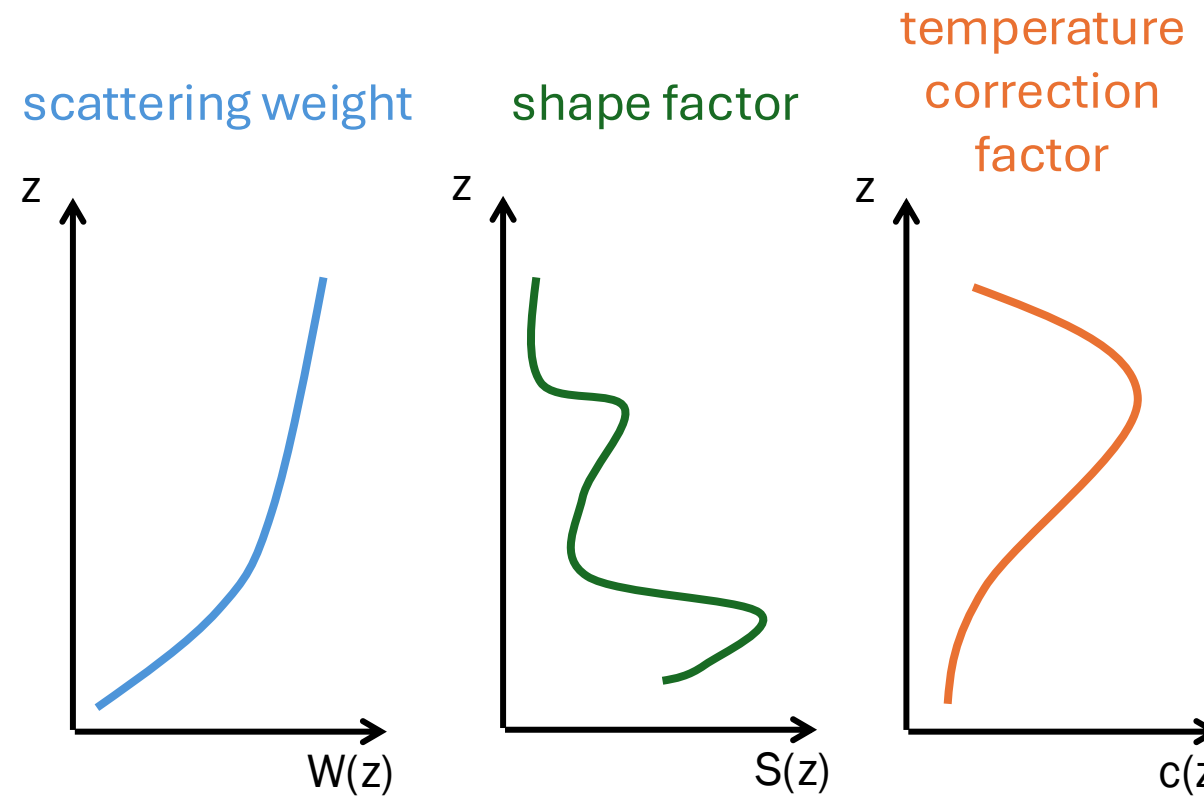
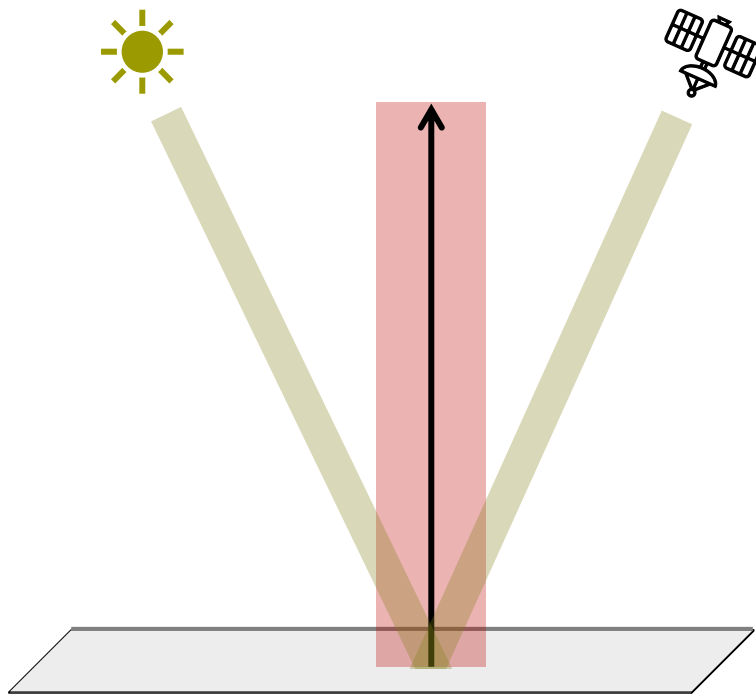


Joseph O. Palmo<sup>1</sup>, Arlene Fiore<sup>1</sup>, Caroline Nowlan<sup>2</sup>,  
Gonzalo Gonzalez-Abad<sup>2</sup>, Jan-Lukas Tirpitz<sup>3</sup>, Hai  
Zhang<sup>4</sup>, Amy Huff<sup>4</sup>, Shobha Kondragunta<sup>4</sup>

<sup>1</sup>MIT, <sup>2</sup>Harvard-Smithsonian CfA, <sup>3</sup>CU Boulder, <sup>4</sup>NOAA

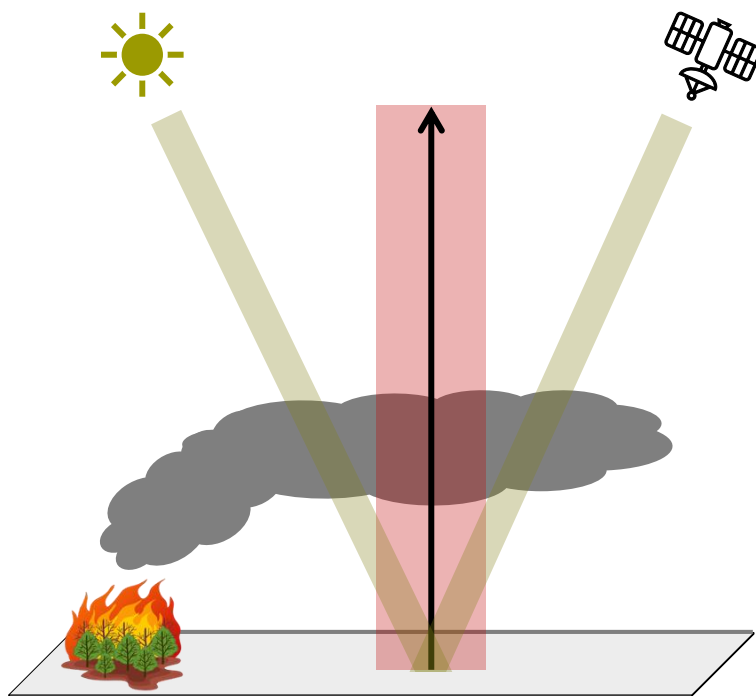
$$AMF = \frac{\Omega_s}{\Omega_v} = \frac{\text{slant column}}{\text{vertical column}}$$

$$AMF = \int_{\text{surface}}^{TOA} \underbrace{w(z)}_{\text{scattering weight}} \underbrace{S(z)}_{\text{shape factor}} \underbrace{c(z)}_{\text{temperature correction factor}} dz$$

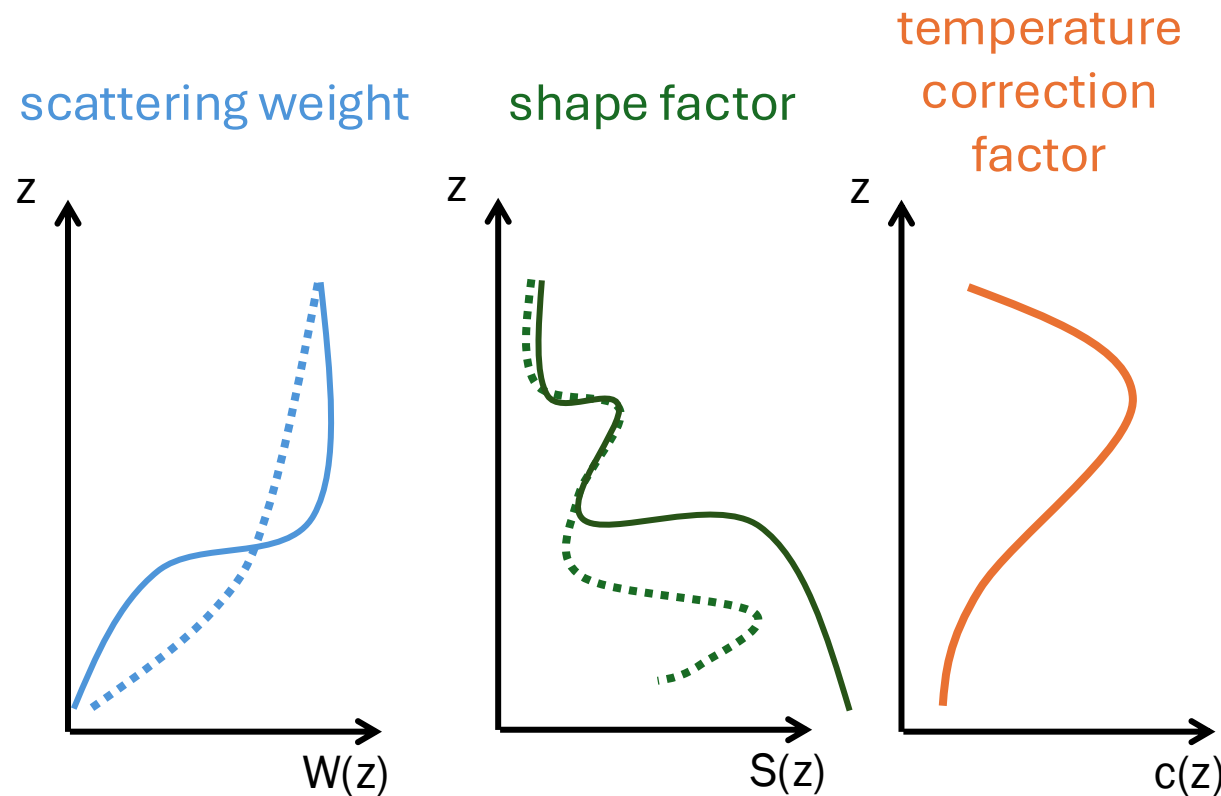


$$AMF = \frac{\Omega_s}{\Omega_v} = \frac{\text{slant column}}{\text{vertical column}}$$

$$AMF = \int_{\text{surface}}^{TOA} \underbrace{w(z)}_{\text{blue}} \underbrace{S(z)}_{\text{green}} \underbrace{c(z)}_{\text{orange}} dz$$

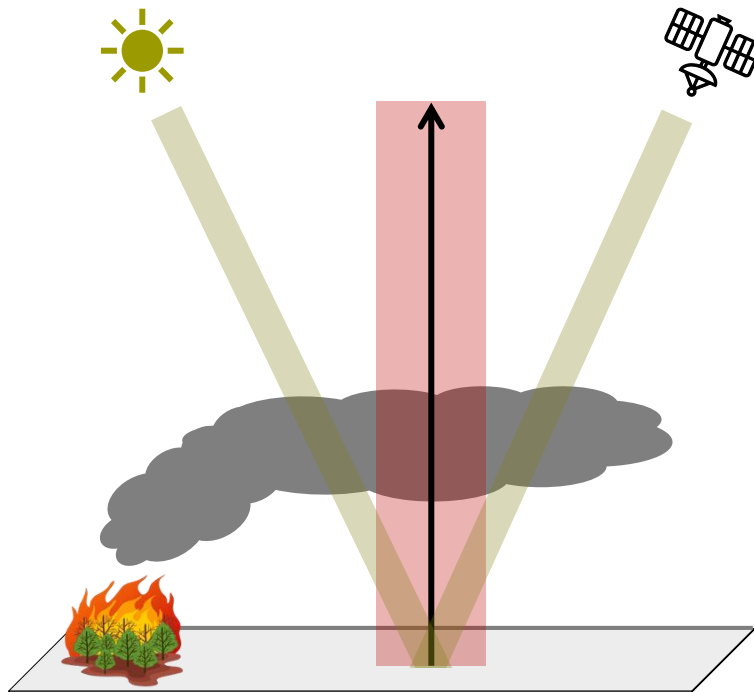


..... clear-sky  
 ————— smoky



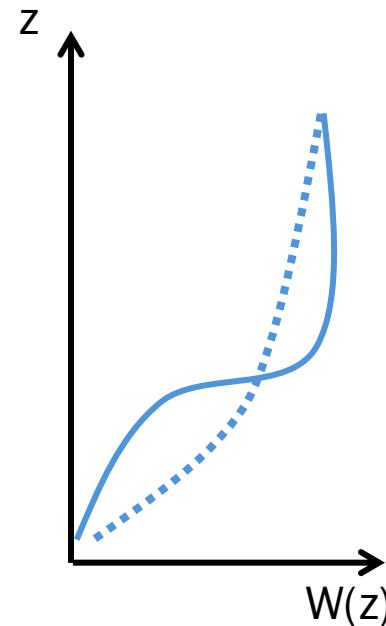
We account for smoke in satellite retrievals of  $\text{NO}_2$  in biomass burning plumes using measured aerosol information

We measure retrieval sensitivity across several shape factors / *a priori* model configurations

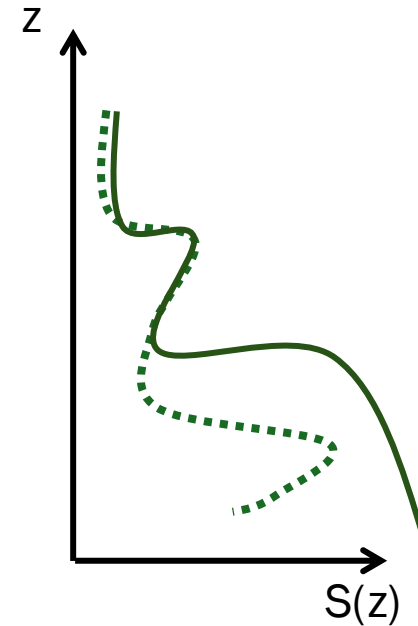


..... clear-sky  
— smoky

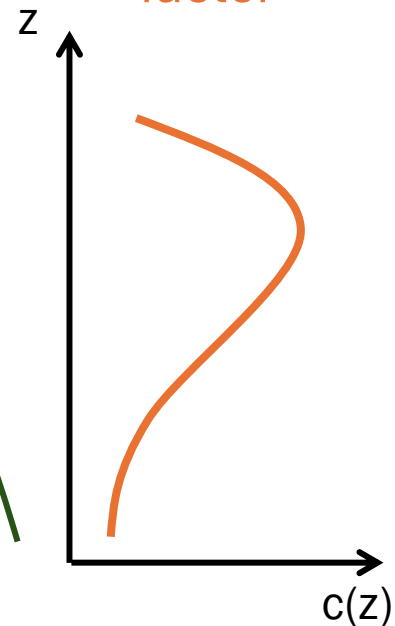
scattering weight



shape factor

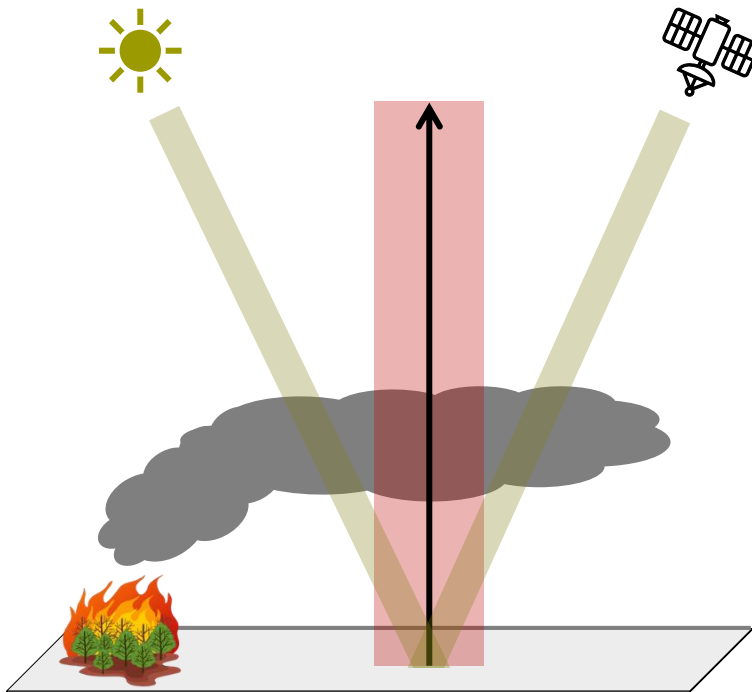


temperature  
correction  
factor



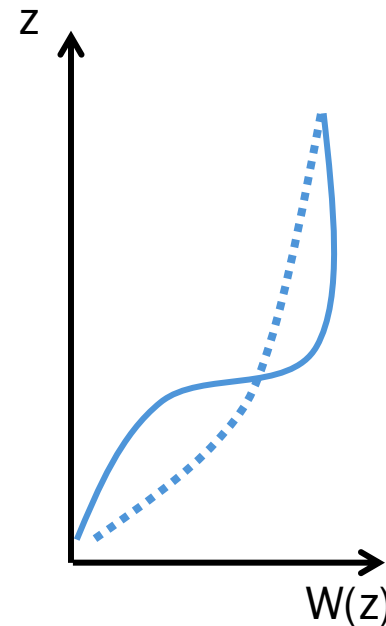
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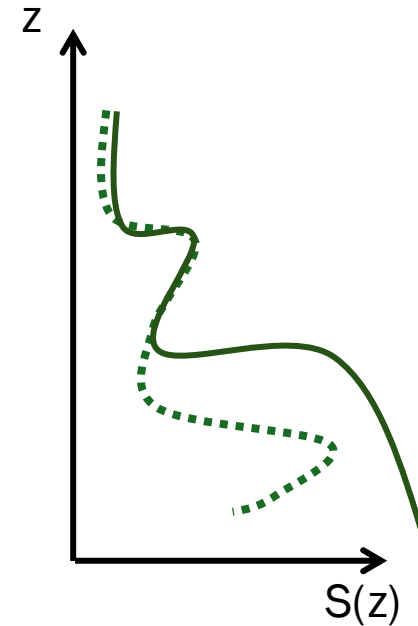


..... clear-sky  
— smoky

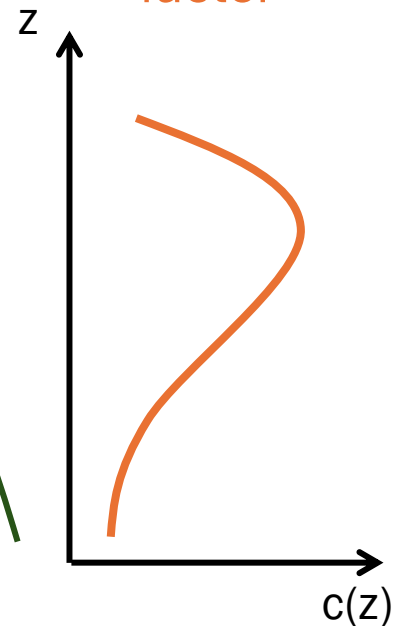
scattering weight



shape factor



temperature  
correction  
factor



# Operational scattering weight calculations use look up tables for the background atmosphere, which is problematic for high aerosol loadings

- “The AMF calculations for NO<sub>2</sub> and HCHO use precomputed look-up tables of scattering weights...parameterized as functions of viewing geometry, O<sub>3</sub> profile, surface albedo...The algorithm uses an LUT calculated with version 2.8 of the Vector Linearized Discrete Ordinate Radiative Transfer (VLIDORT) model”
- “Aerosols are not currently considered explicitly in the AMF calculation, but the effect is implicitly accounted for through the use of TEMPO-retrieved cloud radiance fractions and cloud pressures”

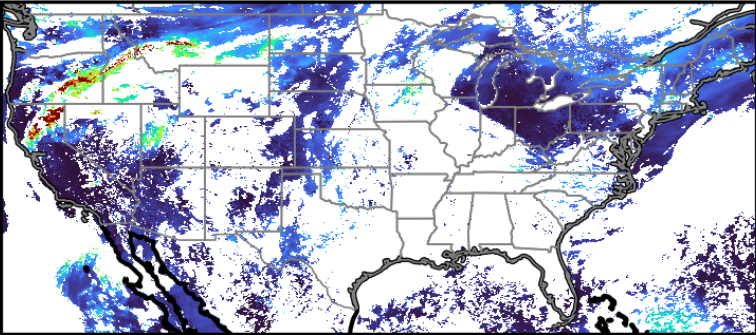
# We build an updated scattering weight LUT using VLIDORT that includes aerosol information

Parameter	Nodes	Units
Solar Zenith Angle (SZA)	0, 15, 30, 45, 55, 65, 70, 75, 80, 85, 89.9	degrees
Viewing Zenith Angle (VZA)	0, 15, 30, 45, 55, 65, 70, 75, 80, 85, 89.9	degrees
Relative Azimuth Angle (RAA)	0, 30, 60, 90, 120, 150, 180	degrees
Surface Albedo ( $\alpha$ )	0.0, 0.01, 0.05, 0.1, 0.2, 0.5, 0.8, 1.0	unitless
Surface Pressure ( $p_s$ )	500, 600, 700, 800, 900, 1013, 1050	hPa
Ozone Profile	M350	
*Aerosol Optical Depth (AOD)	0.0, 0.1, 0.3, 0.6, 1.0, 1.5, 2.0, 2.5, 3.0	unitless
*Aerosol Layer Height (ALH)	0, 1, 2, 3, 4, 5, 6	km
Wavelength	440	nm

# We use the NOAA TEMPO aerosol product to estimate pixel-level smoke profiles

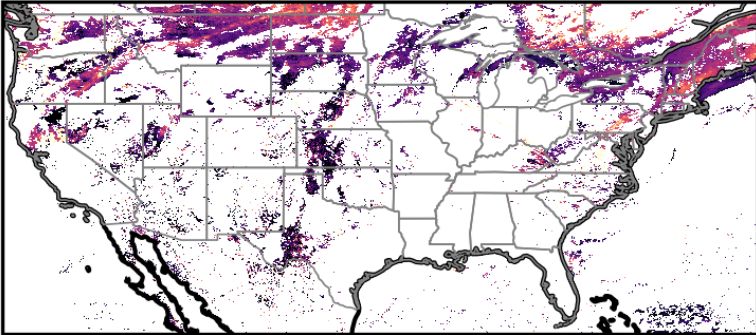
\* Data shown for 2024/7/27 Scan No. 11

### AOD at 550 nm



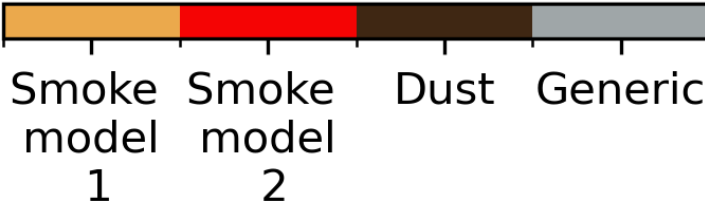
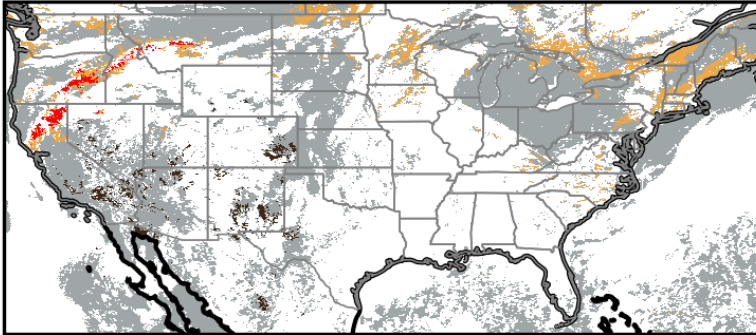
AOD

### Aerosol layer height



ALH (km)

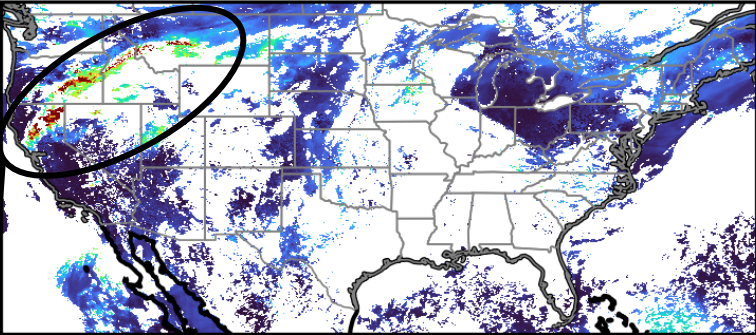
### Aerosol type



# We use the NOAA TEMPO aerosol product to estimate pixel-level smoke profiles

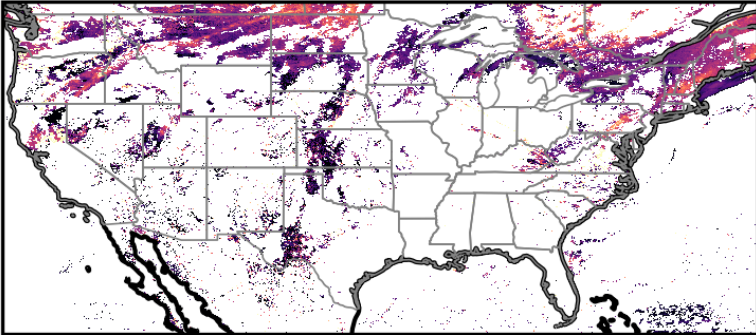
\* Data shown for 2024/7/27 Scan No. 11

### AOD at 550 nm



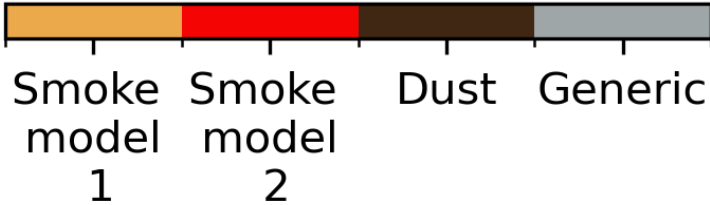
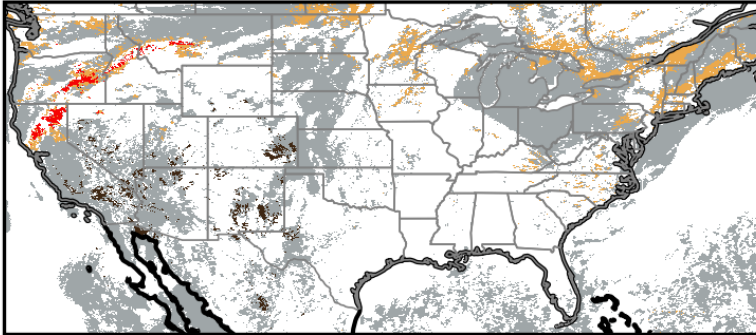
AOD

### Aerosol layer height



ALH (km)

### Aerosol type



**Park Fire Plume**



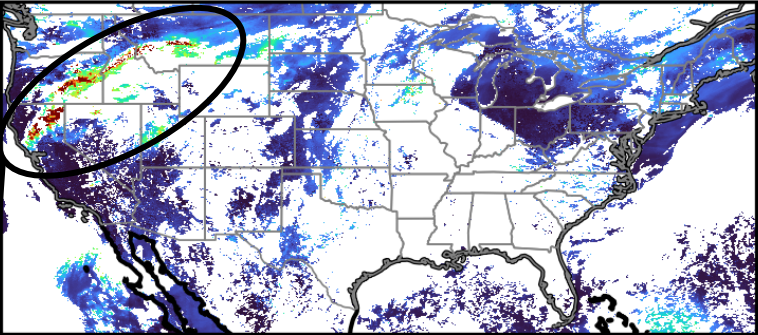
- Northern California; July 24<sup>th</sup> – Sept. 26<sup>th</sup>, 2024
- 4<sup>th</sup> largest wildfire in CA history

# We use the NOAA TEMPO aerosol product to estimate pixel-level smoke profiles

Pixel example

\* Data shown for 2024/7/27 Scan No. 11

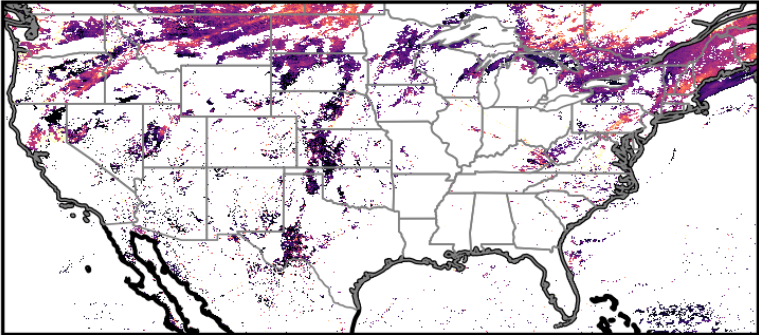
### AOD at 550 nm



0 1 2 3

AOD

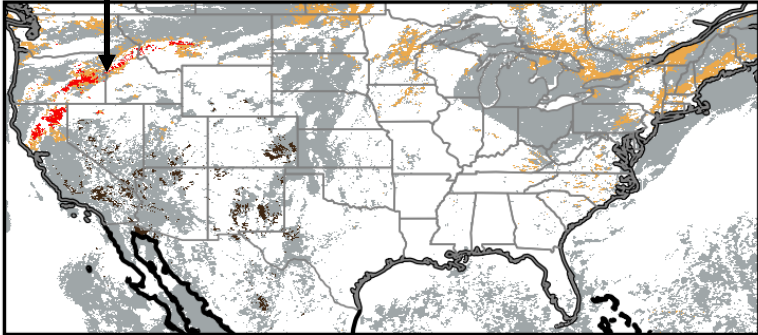
### Aerosol layer height



0 2 4 6

ALH (km)

### Aerosol type



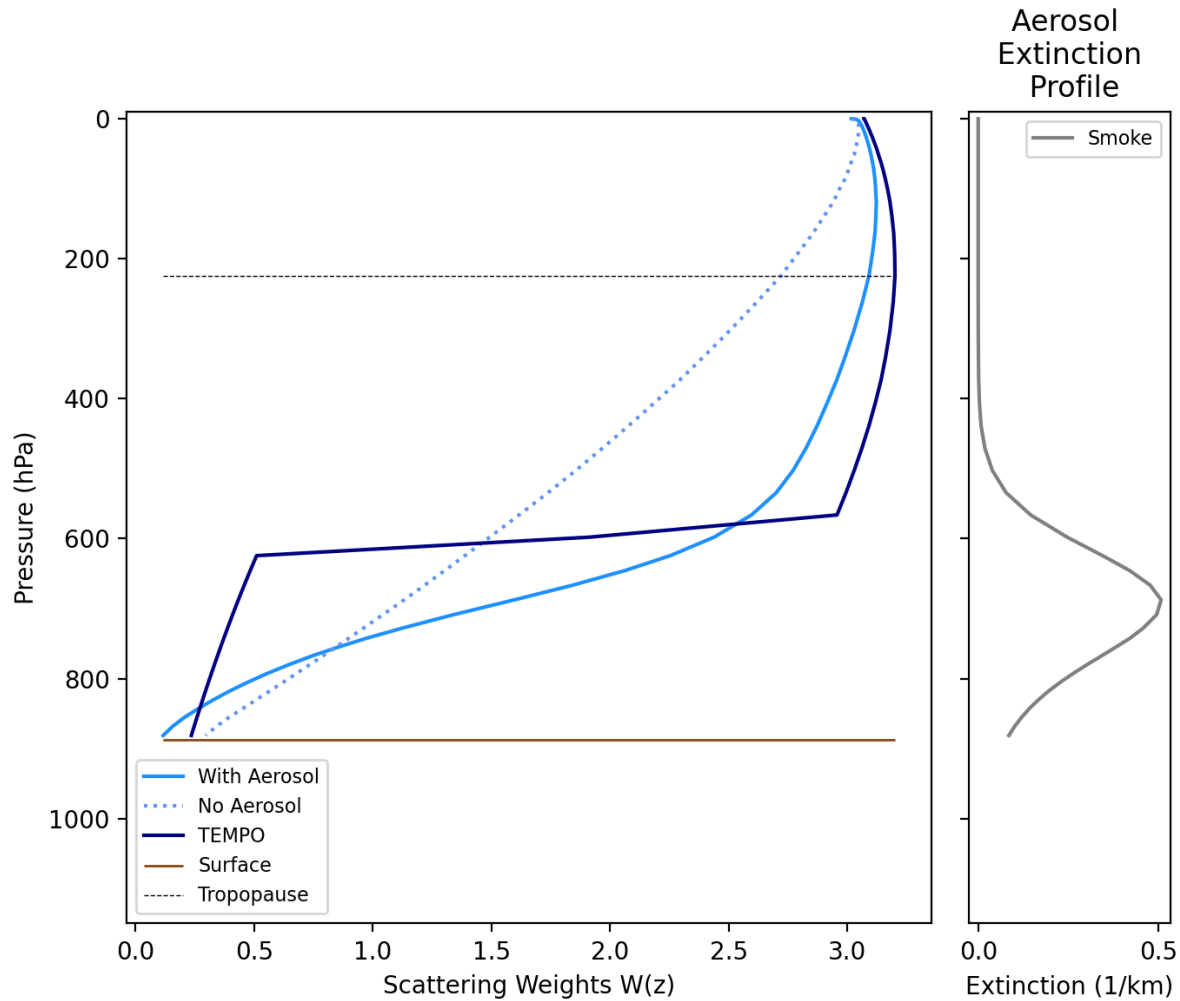
Smoke model 1    Smoke model 2    Dust    Generic

**Park Fire Plume**

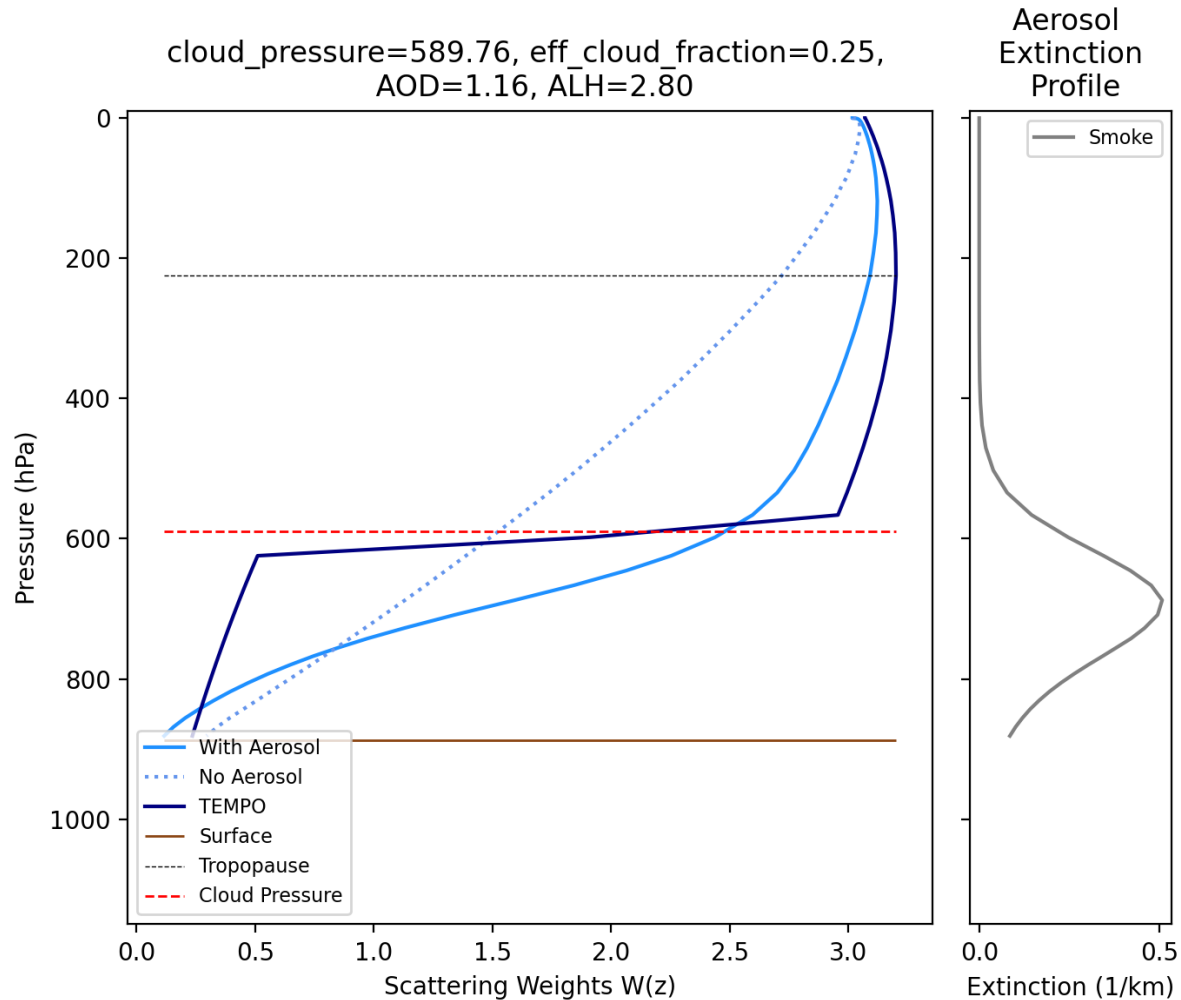


- Northern California; July 24<sup>th</sup> – Sept. 26<sup>th</sup>, 2024
- 4<sup>th</sup> largest wildfire in CA history

# We recompute scattering weights using VLIDORT

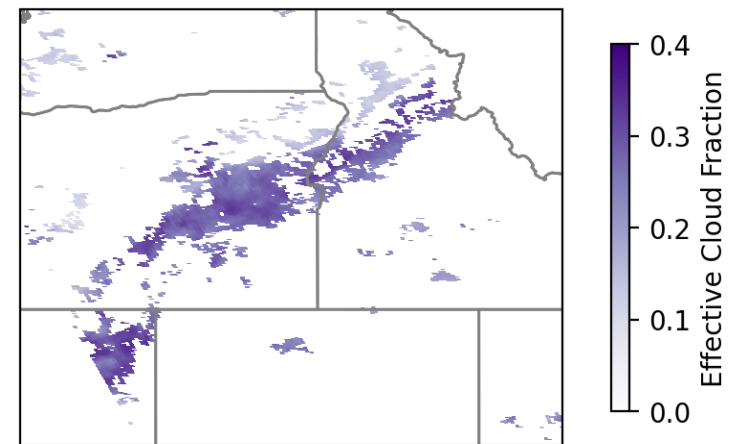


# The TEMPO cloud treatment may have some fortuitous effects



- cloud fraction ( $f_c$ )
- cloud pressure ( $p_c$ )
- To compute cloudy scattering weights, place a surface with an albedo of 0.8 at  $p_c$

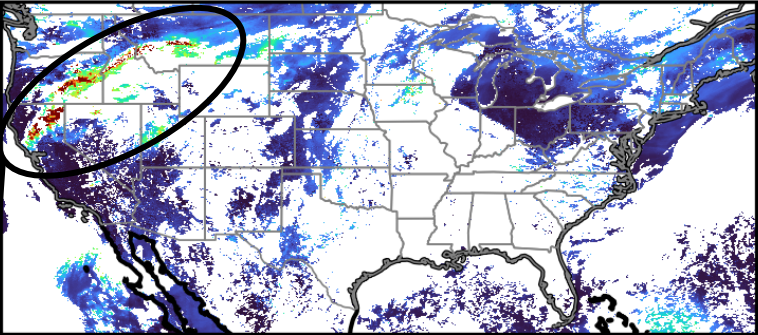
$$w(z) = (1-f_c) \cdot w(z)_{\text{clear}} + f_c \cdot w(z)_{\text{cloudy}}$$



# We use the NOAA TEMPO aerosol product to estimate pixel-level smoke profiles

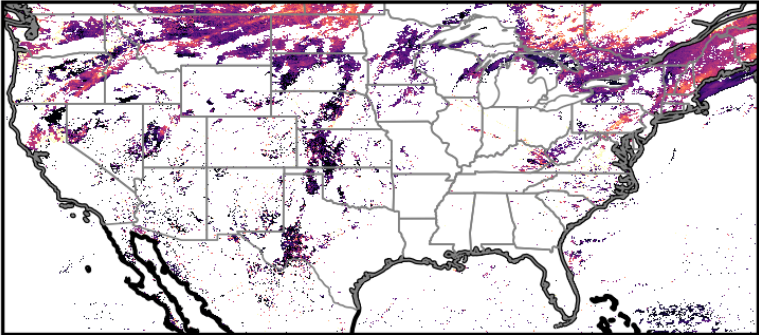
\* Data shown for 2024/7/27 Scan No. 11

### AOD at 550 nm



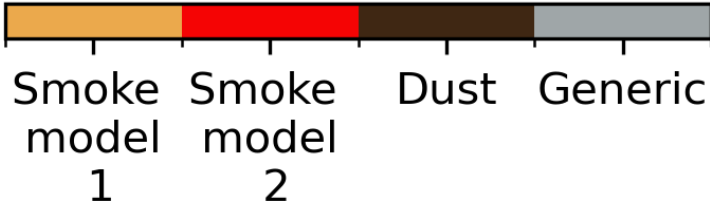
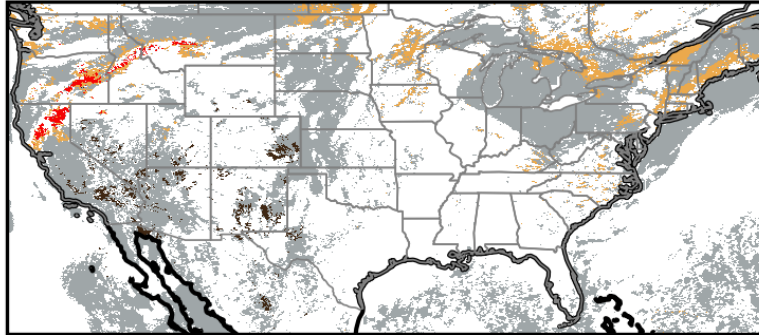
AOD

### Aerosol layer height



ALH (km)

### Aerosol type

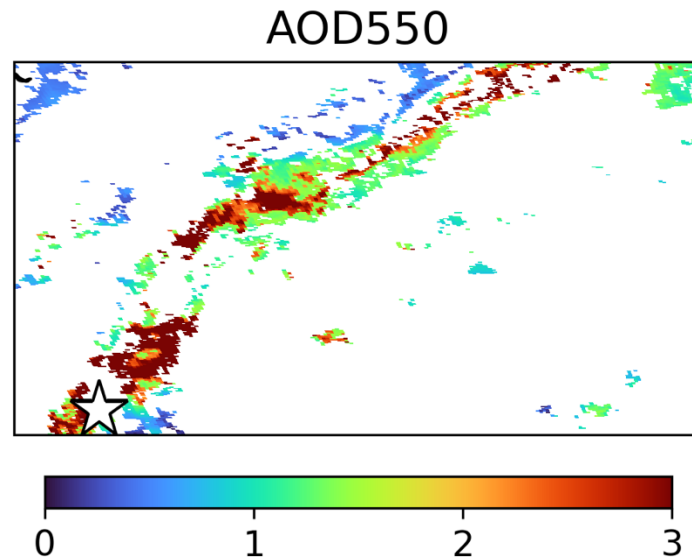
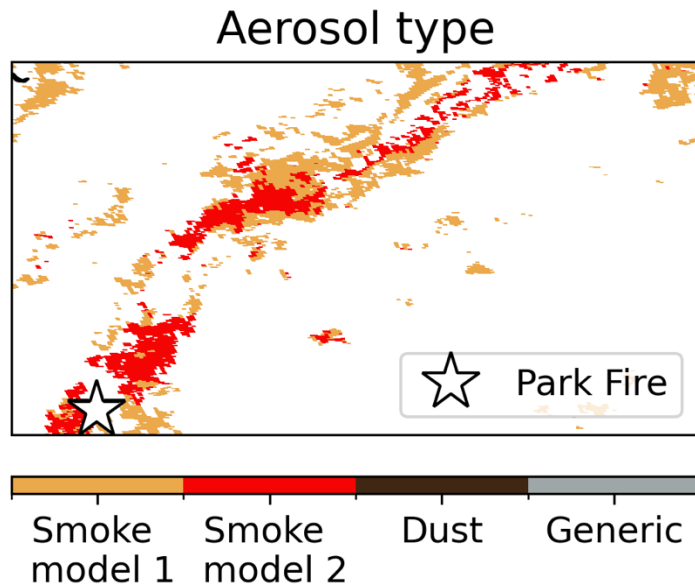


**Park Fire Plume**

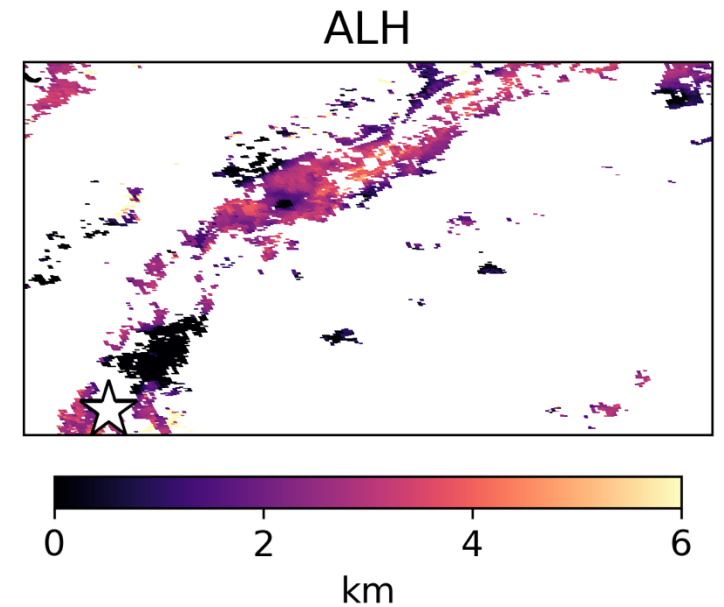


- Northern California; July 24<sup>th</sup> – Sept. 26<sup>th</sup>, 2024
- 4<sup>th</sup> largest wildfire in CA history

# Park fire case study



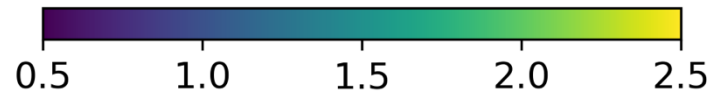
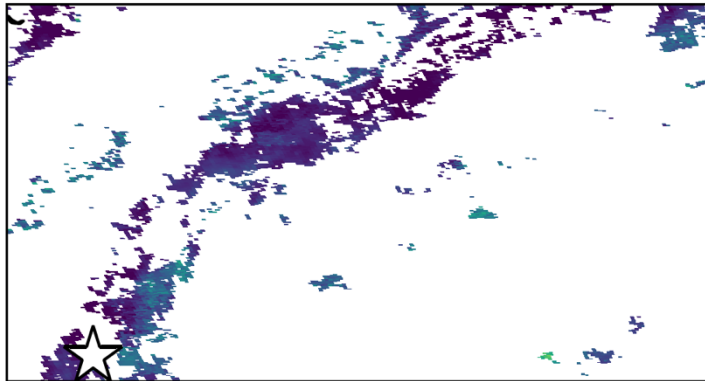
Thick smoke observed  
(AOD ~ 3)



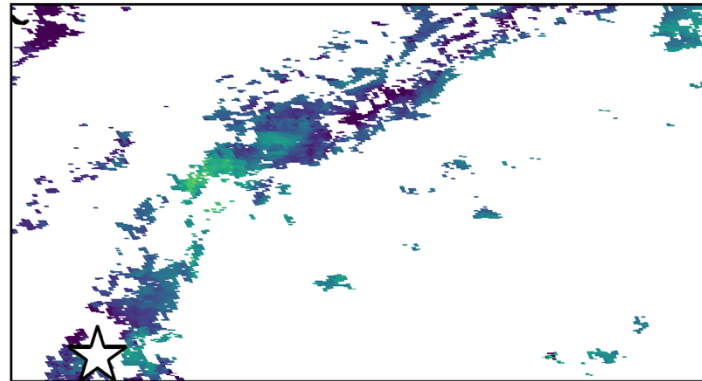
Near-surface smoke at  
source (ALH ≤ 1 km),  
lofted smoke downwind  
(ALH > 4 km)

# Park fire case study

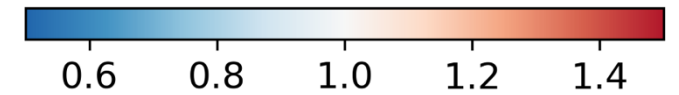
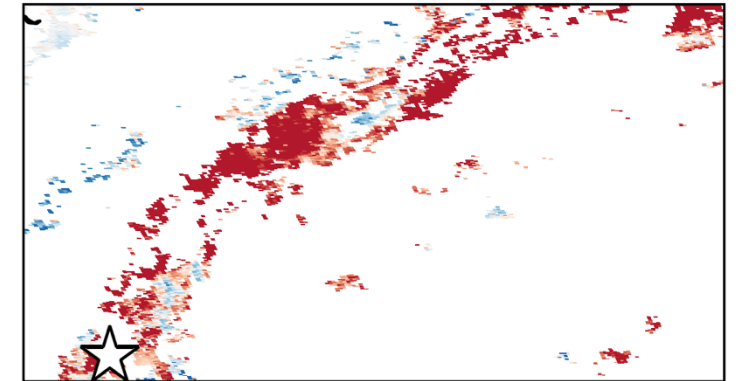
$AMF_{trop}$  original



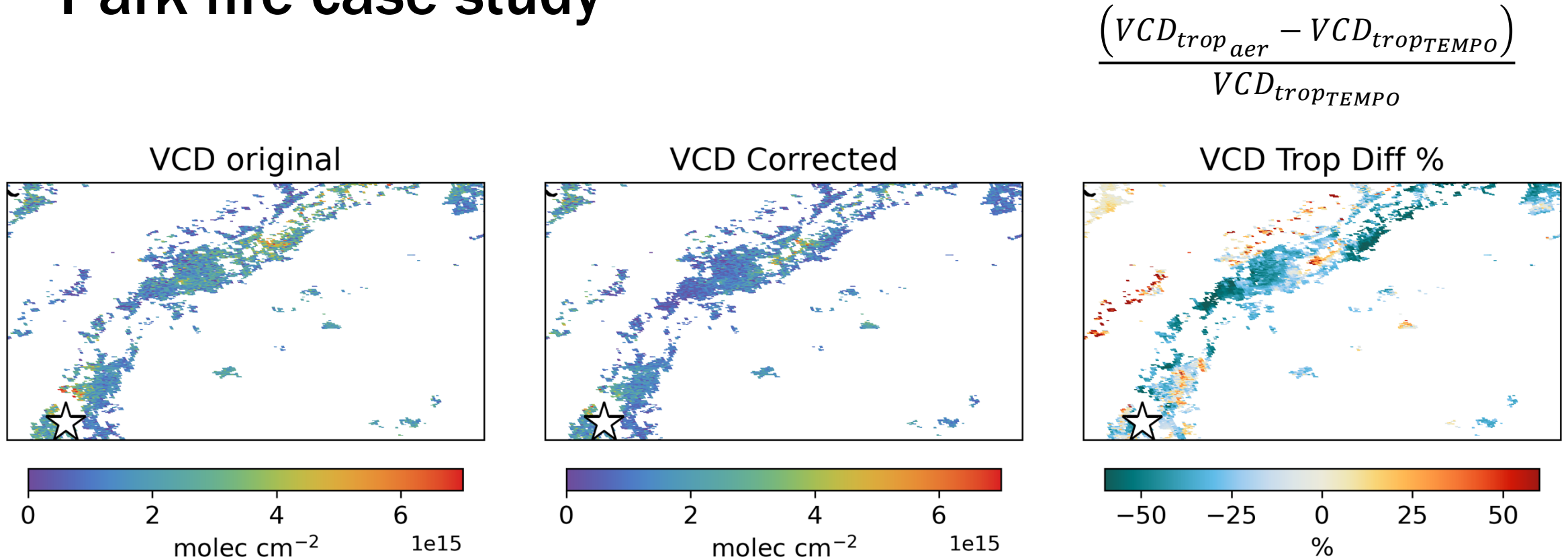
$AMF_{trop}$  corrected



$ACF_{trop}$



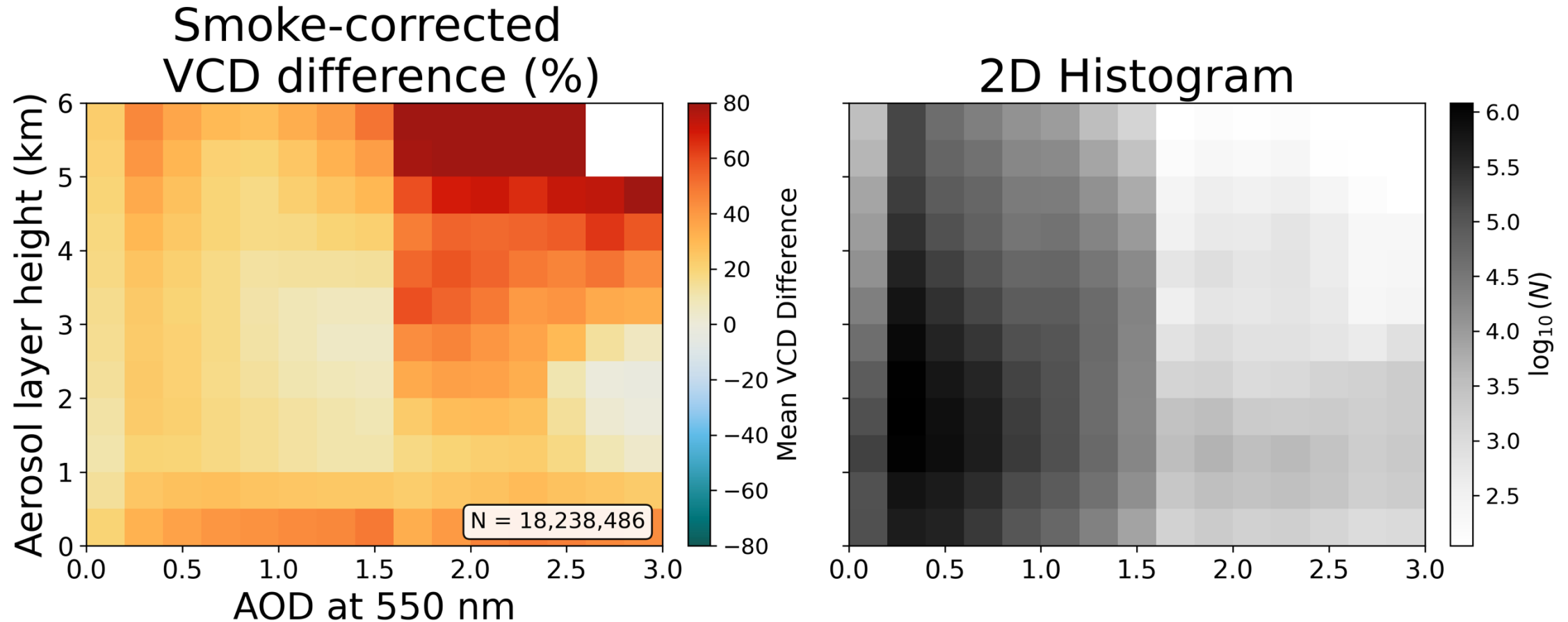
# Park fire case study



In this single plume example, we see VCD decreases in lofted smoke downwind, mixed impact (both increases and decreases) closer to source

# Average impact of smoke aerosol correction for all smoke-influenced pixels in 2024

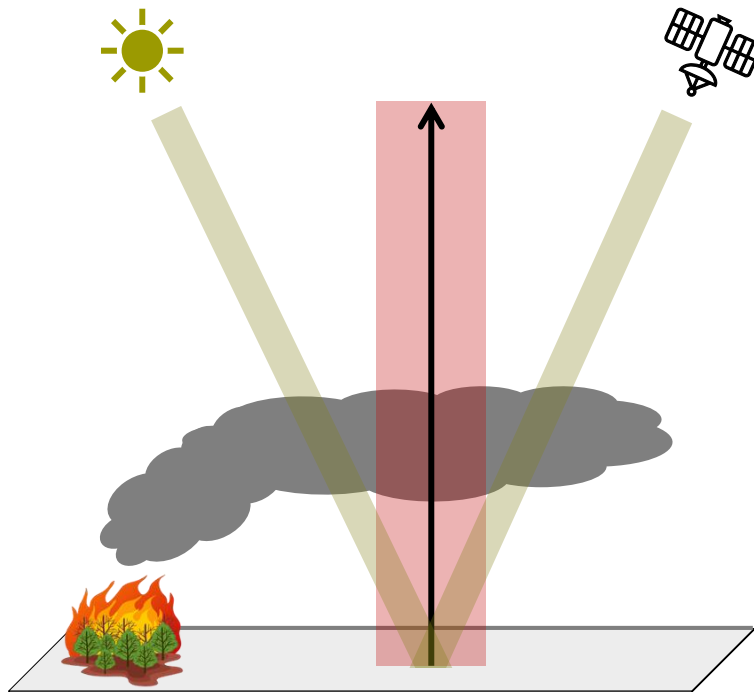
- Mean increase of smoke  $\text{NO}_2$  VCDs of 24% (std dev 34%)



\*Discontinuity due to different aerosol models used in smoke model 1 vs smoke model 2

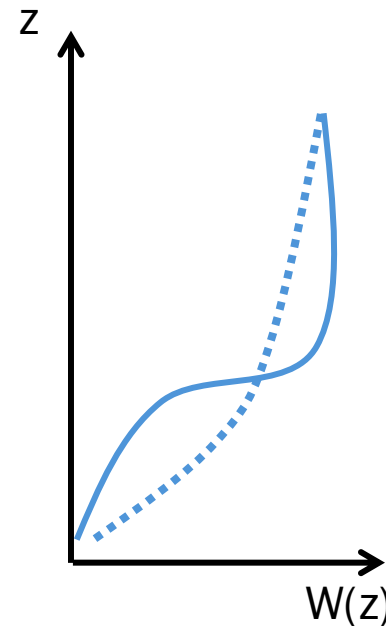
We account for smoke in satellite retrievals of  $\text{NO}_2$  in biomass burning plumes using measured aerosol information

We measure retrieval sensitivity across several shape factors / *a priori* model configurations

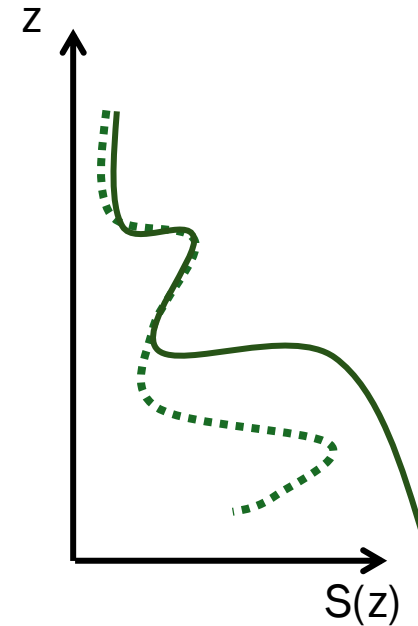


..... clear-sky  
— smoky

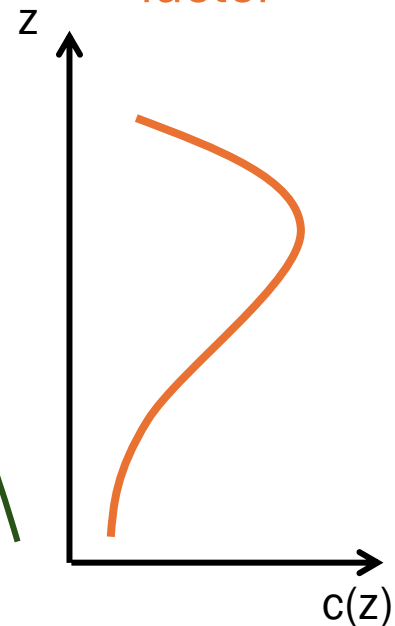
scattering weight



shape factor



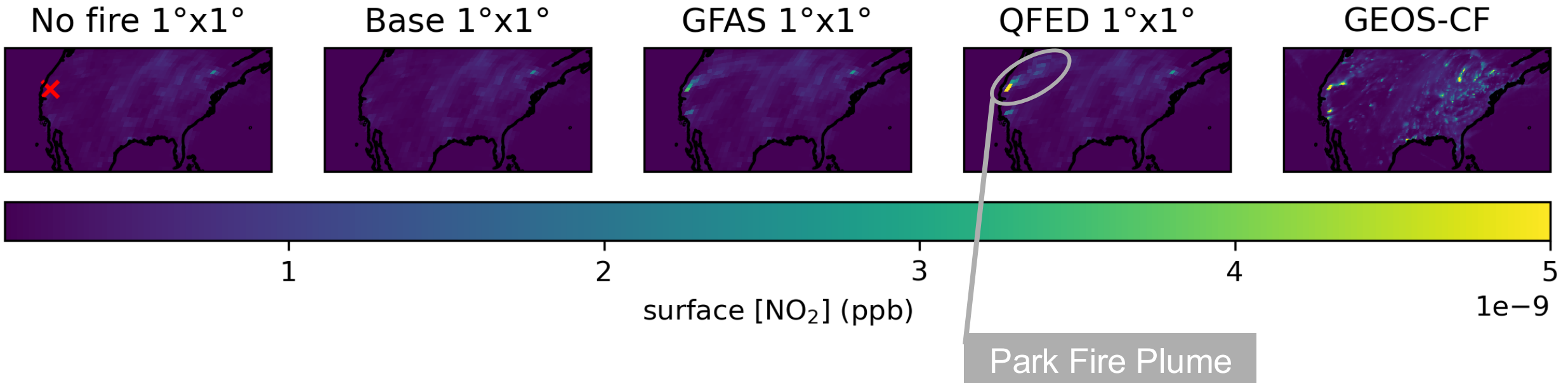
temperature correction factor



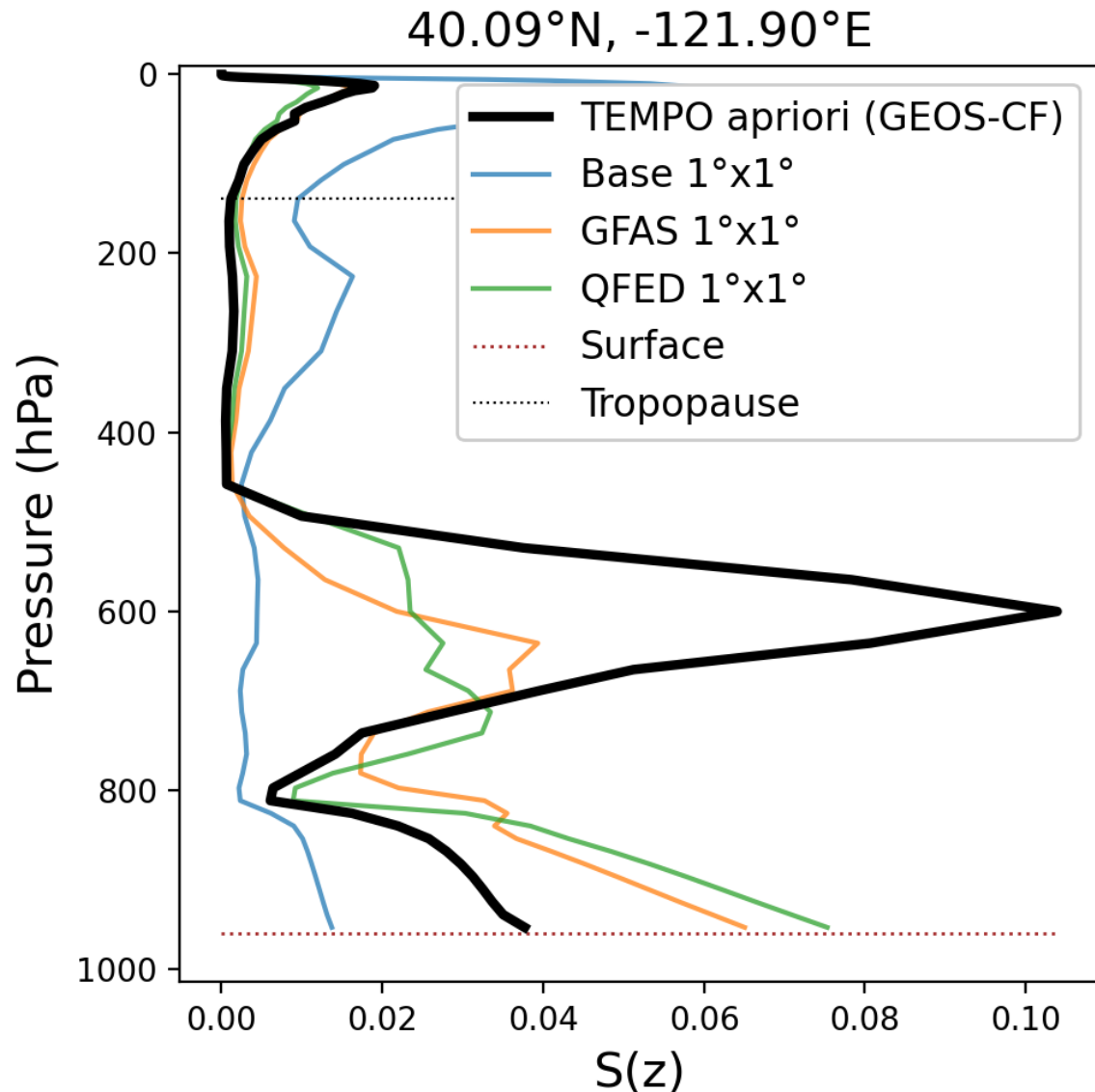
# We build an ensemble of NO<sub>2</sub> shape factor profiles using GEOS-Chem High Performance (GCHP)

<i>Simulation Name</i>	<i>Description</i>
Base	GCHP w/ GFED4s at 1°x1°
BB <sub>zero</sub>	GCHP w/ no fire emissions at 1°x1°
BB <sub>GFAS</sub>	GCHP w/ GFAS emissions and injection height parameterization at 1°x1°
BB <sub>QFED</sub>	GCHP w/ QFED emissions and simple injection height scheme (65% PBL, 35% FT)

\* Data shown for 2024/7/27 20:00 UTC

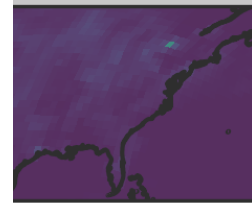


# We build an ensemble of NO<sub>2</sub> shape factor profiles using GCHP

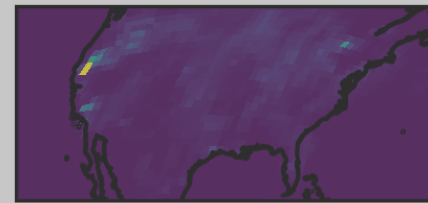


at 1°x1°  
 and injection height parameterization at 1°x1°  
 and simple injection height scheme (65% PBL, 35% FT)

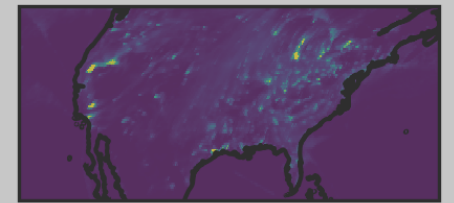
Base 1°x1°



QFED 1°x1°



GEOS-CF



[NO<sub>2</sub>] (ppb)

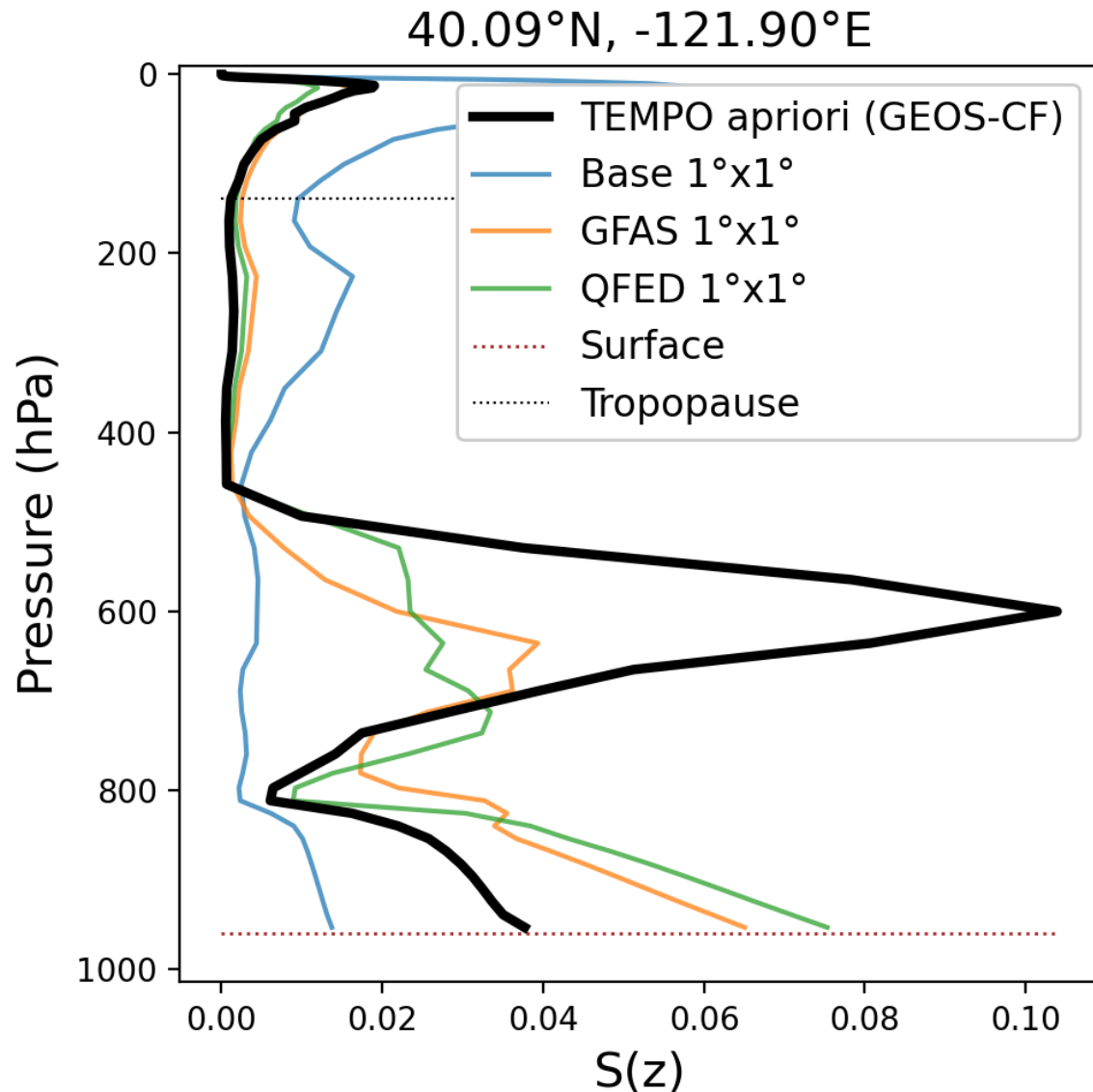
1e-9

3

4

5

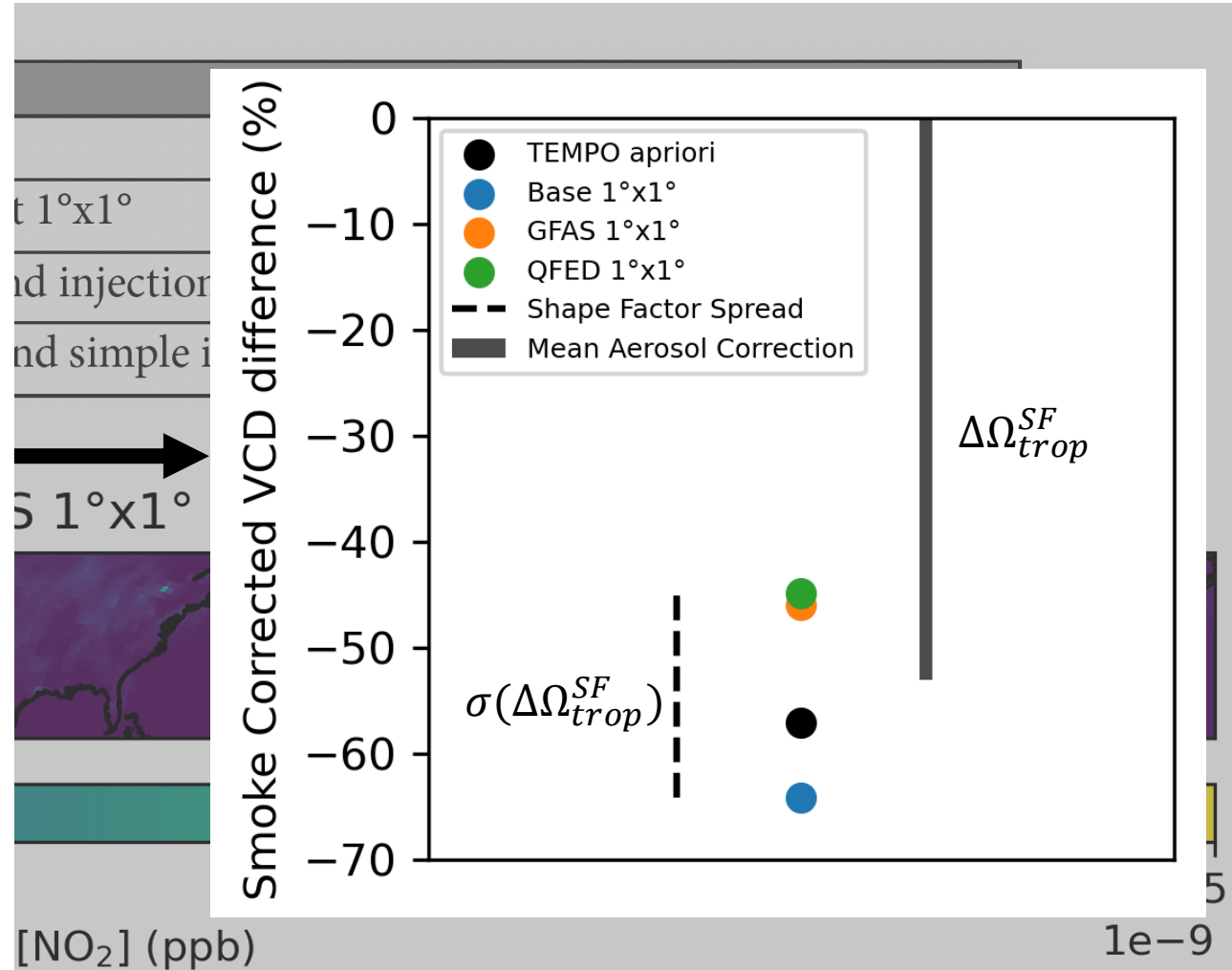
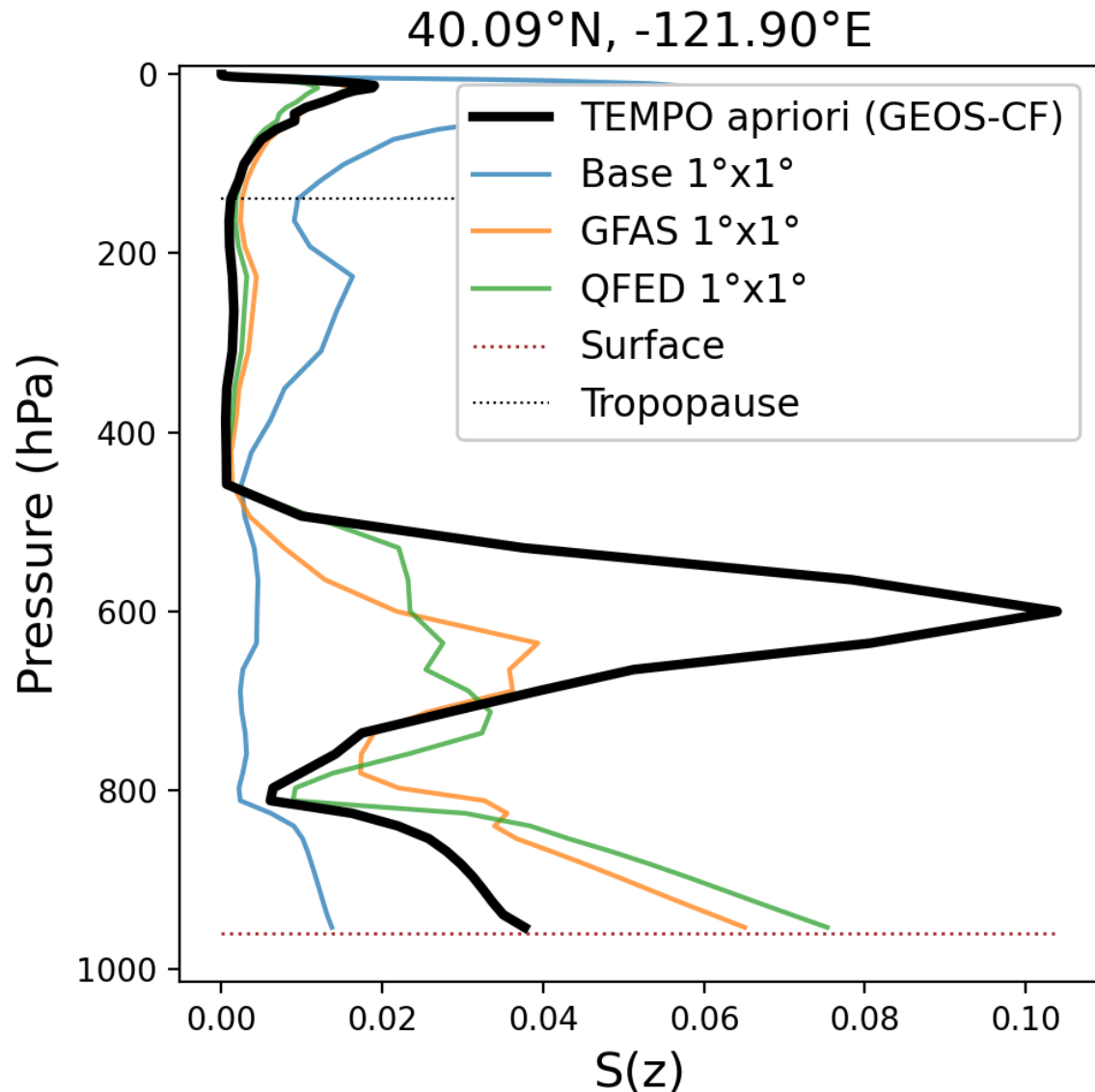
# We build an ensemble of NO<sub>2</sub> shape factor profiles using GCHP



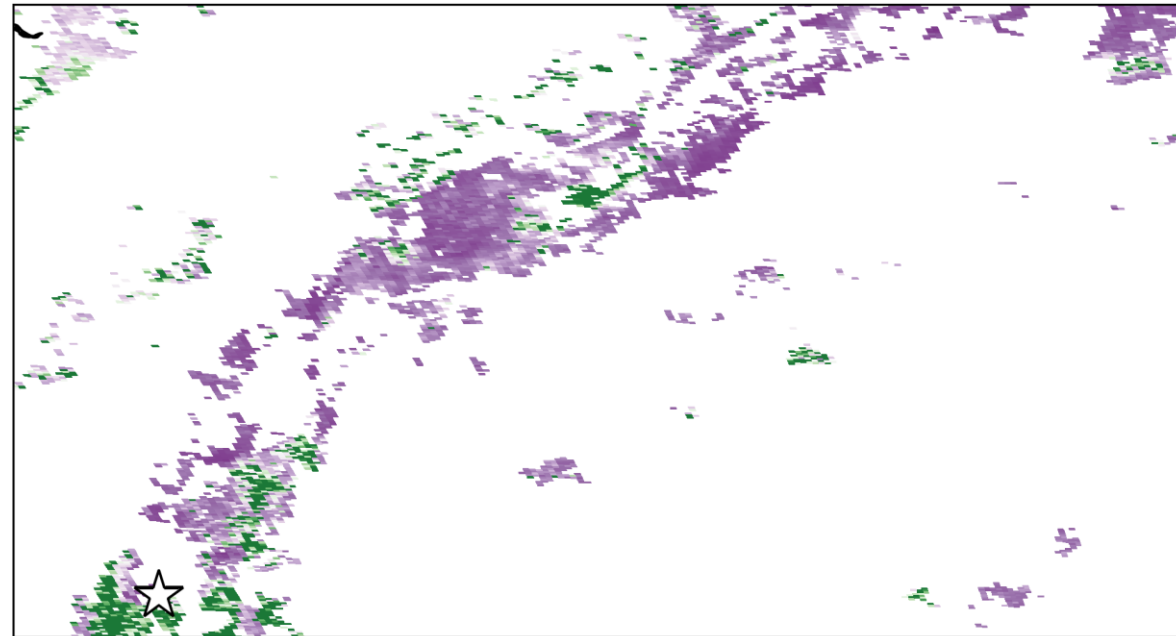
*How robust is the aerosol correction to shape factor profile choice?*

[NO<sub>2</sub>] (ppb)

# We build an ensemble of NO<sub>2</sub> shape factor profiles using GCHP



# The aerosol correction is robust against shape factor choice



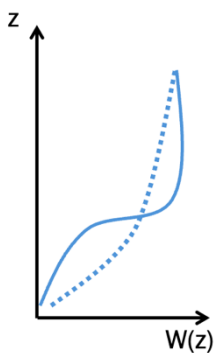
$$\sigma(\Delta\Omega_{\text{trop}}^{\text{SF}}) (\%) \div \Delta\Omega_{\text{trop}}^{\text{SF}} (\%)$$

Aerosol-correction

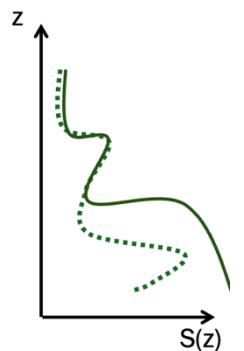
Shape factor spread

relative importance  
(sensitivity of VCD impact)

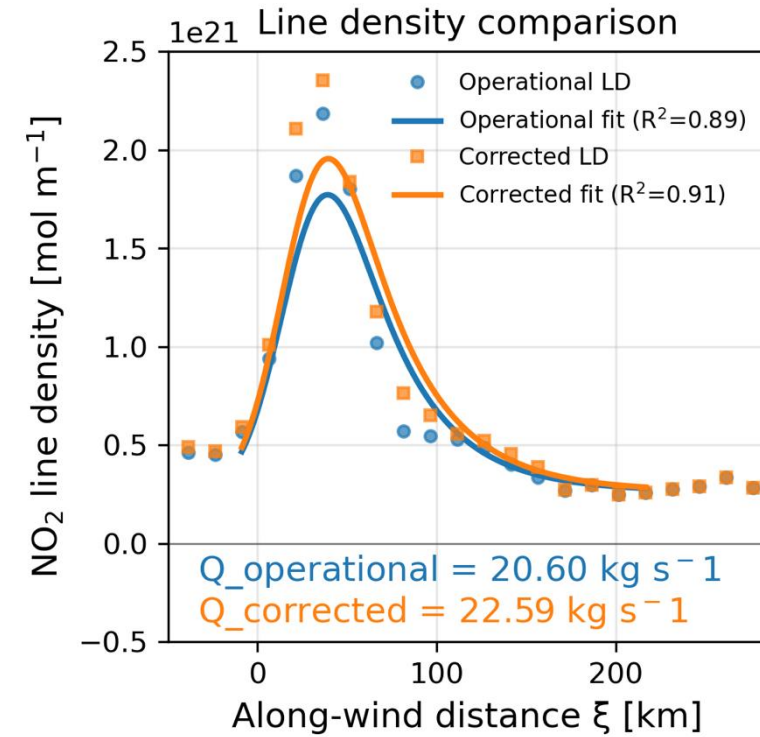
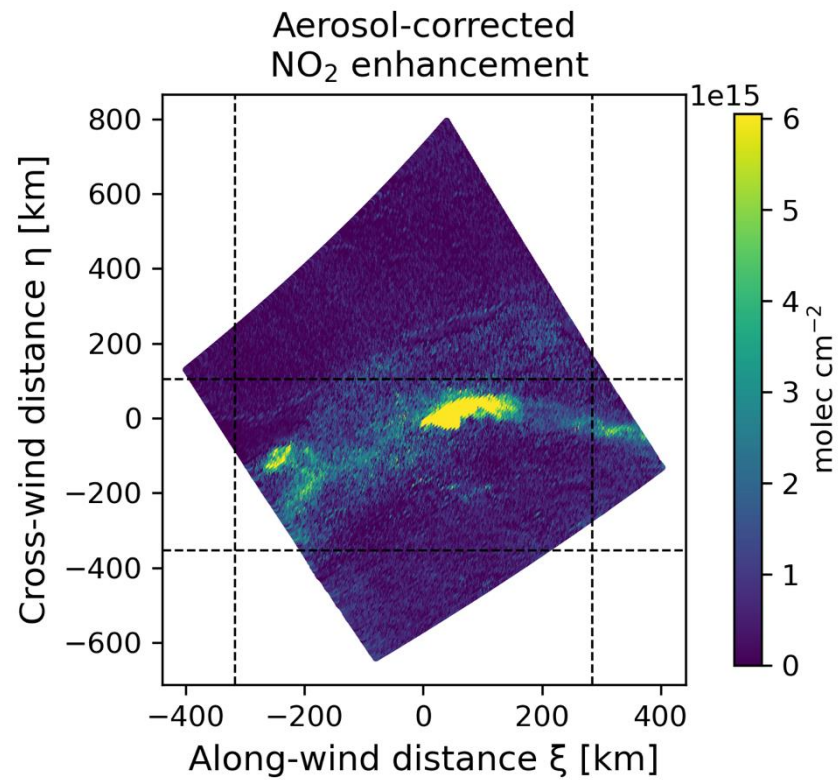
scattering weight



shape factor

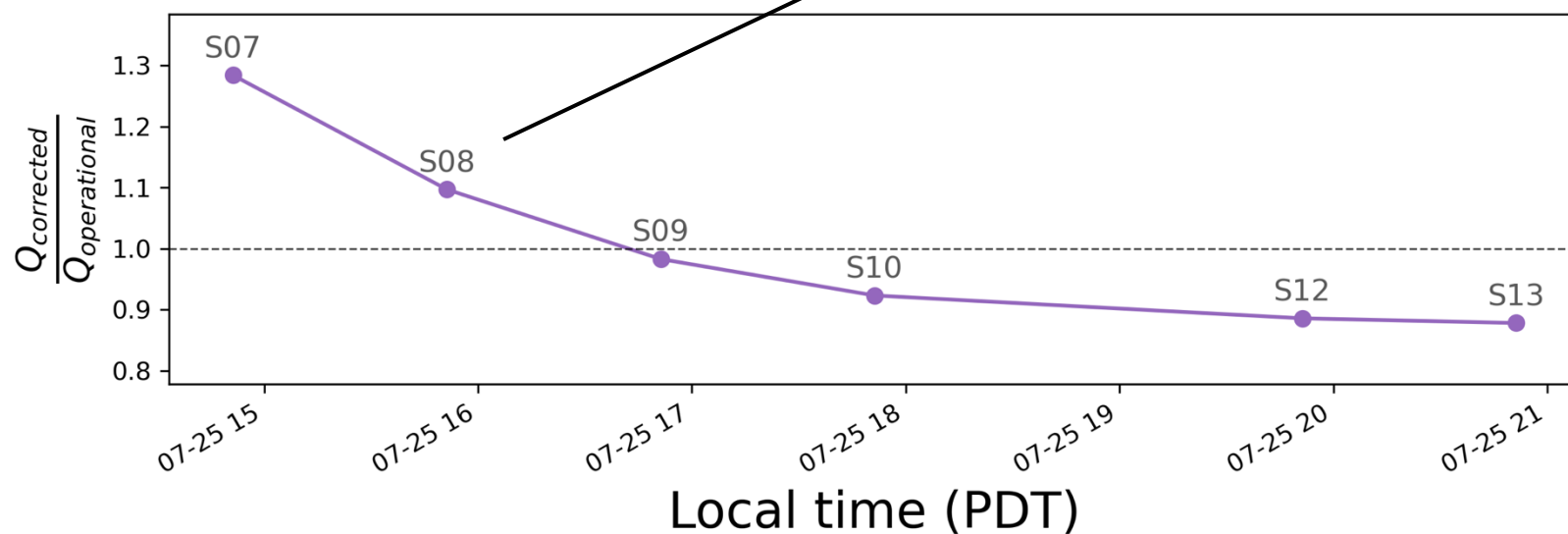
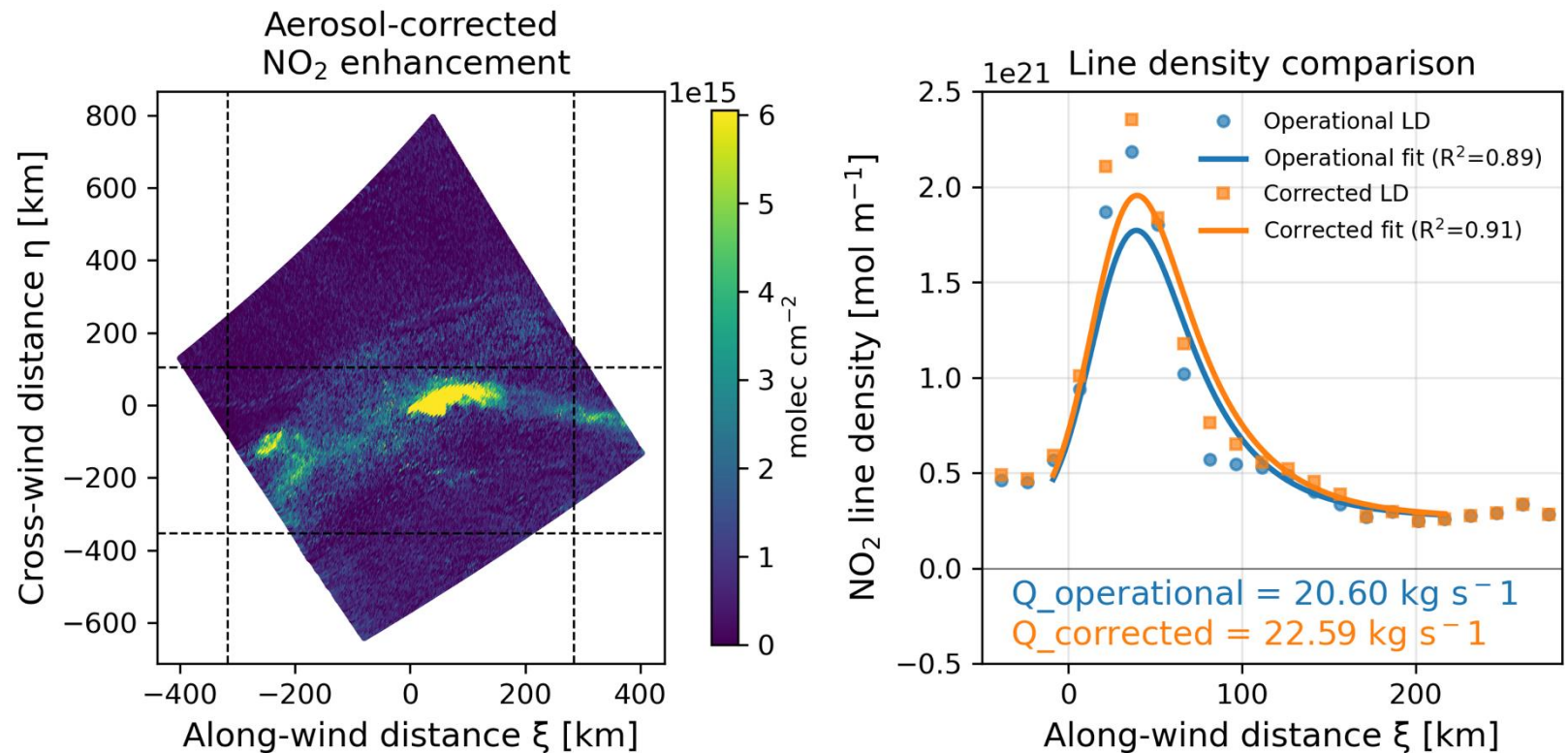


Future work: top-down  $\text{NO}_x$  emissions estimates change after accounting for aerosol impacts



# Future work: top-down $\text{NO}_x$ emissions estimates change after accounting for aerosol impacts

- Top-down emissions differences reach nearly 30% (preliminary!)



# Conclusions and future work

- We develop a method to correct the TEMPO  $\text{NO}_2$  retrieval in biomass burning plumes using satellite-derived aerosol information from the NOAA product
- We demonstrate the effects of the current cloud treatment in TEMPO smoke measurements
- We quantify AMF sensitivity to smoke AOD, ALH, viewing geometry, and TEMPO cloud information
- We explore the relative sensitivity of the  $\text{NO}_2$  retrieval to the aerosol correction compared to shape factor uncertainty
- Next:  $\text{NO}_x$  emissions estimates!

