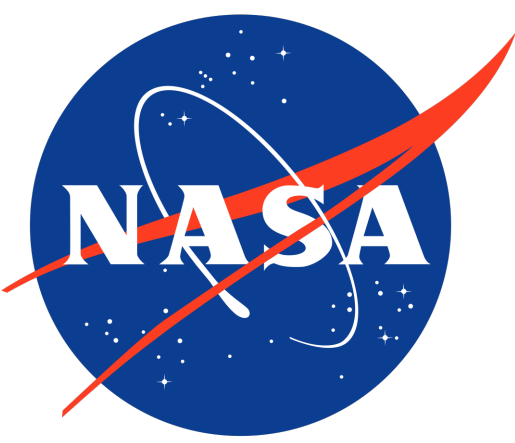
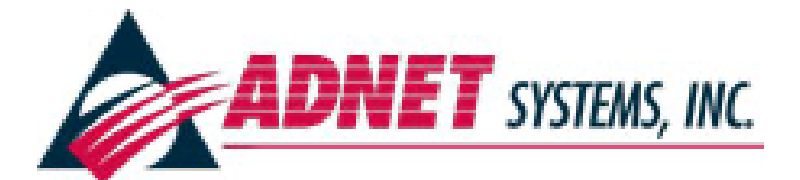


Assessing Stratospheric Aerosol Extinction Coefficients Following Perturbed Events



Using Space-Borne Observations in the Context of GloSSAC

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1. Introduction

Building on the methodology established by Thomason et al. (2021), this study utilizes multi-wavelength aerosol extinction data collected by the Stratospheric Aerosol and Gas Experiment II (SAGE II) and SAGE III on the International Space Station (SAGE III/ISS). Our goal is to establish a relationship between the 1020 nm extinction coefficient and the 525 nm to 1020 nm extinction ratio following various volcanic and wildfire perturbations. In addition to assessing the predictive capabilities of this method, we explore machine learning approaches to further test and validate the robustness of this relationship. Ultimately, this technique can be extended to improve aerosol extinction retrievals from single-channel limb scatter instruments, such as the Optical Spectrograph and Infrared Imager System (OSIRIS), and to bias-correct measurements when multi-wavelength data are absent. Once validated, we will implement this method within GloSSAC to enhance the representation of multi-wavelength extinction coefficients during periods when only single-wavelength observations are available.

2. Methods and Results

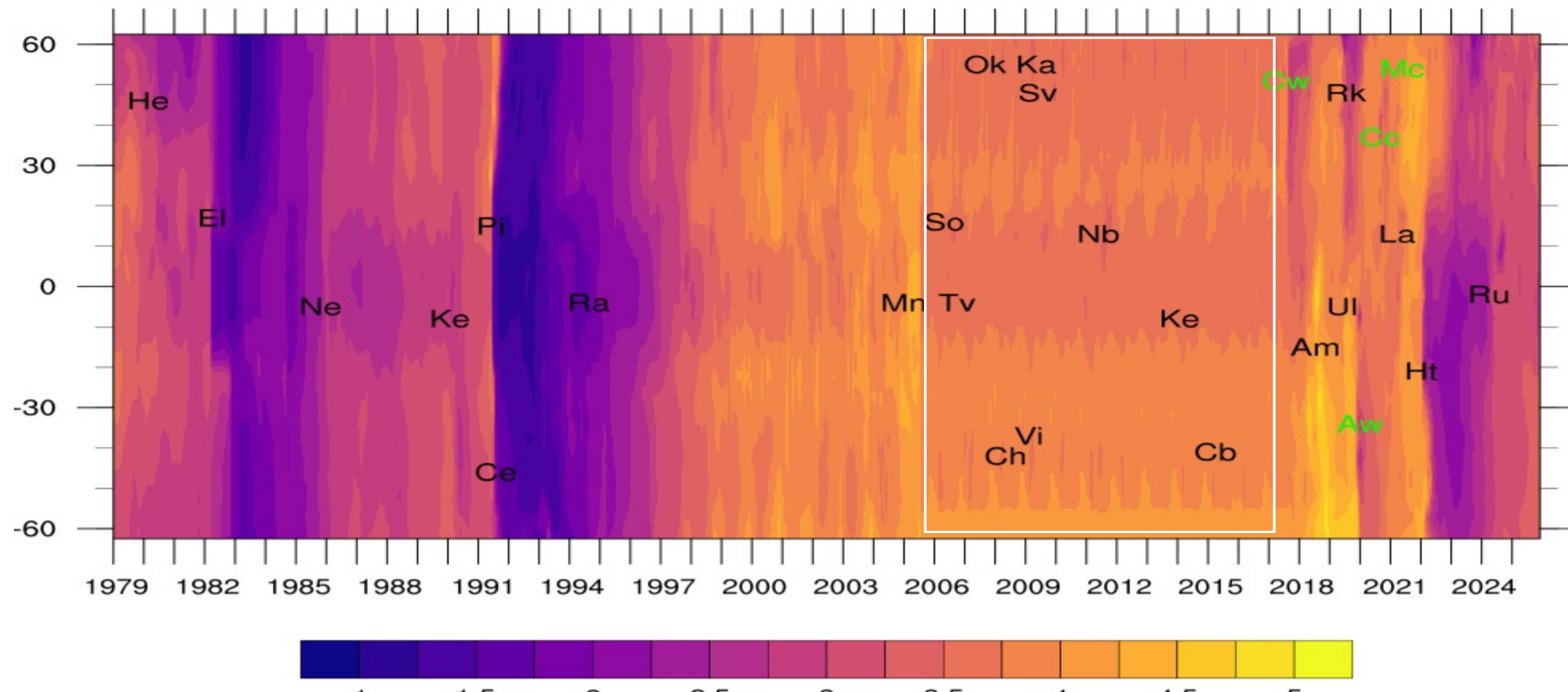


Figure 1: Time series of zonally averaged AOD ratios (525/1020 nm) from GloSSAC v2.24. Major volcanic eruptions (black) and wildfire events (green) with abbreviated codes, latitudes, and occurrence times. The event names shown are St. Helens (He), El Chichon (El), Nevado del Ruiz (Ne), Kelut (Ke), Pinatubo (Pi), Cerro Hudson (Ce), Rabaul (Ra), Manam (Mn), Soufriere Hills (So), Tavorvur (Tv), Chaiten (Ch), Victoria (Vi), Okmok (Ok), Kasatochi (Ka), Sarychev (Sv), Nabro (Nb), Kelut (Ke), Calbuco (Cb), Canadian wildfire (Cw), Ambae (Am), Raikoke (Rk), Ulawun (Ul), Australian wildfire (Aw), California Creek Fire (Cc), La Soufriere (La), McKay Creek fire (Mc), Hunga Tonga (Ht) and Ruag (Ru).

- Used GloSSAC v2.24 and SAGE II datasets; background period: SAGE II 1999-2002 zonally averaged median.
- Perturbed extinction: $\delta k_{\lambda} = k_{\lambda}(\text{after}) - k_{\lambda}(\text{background})$
- Predicted 525 nm extinction: $k_{525}(\text{predicted}) = \delta k_{1020} \times \delta_{\text{ratio}} + k_{525}(\text{background})$
- Analysis period: Jan 1992–Aug 2024, excluding 200509–201706.

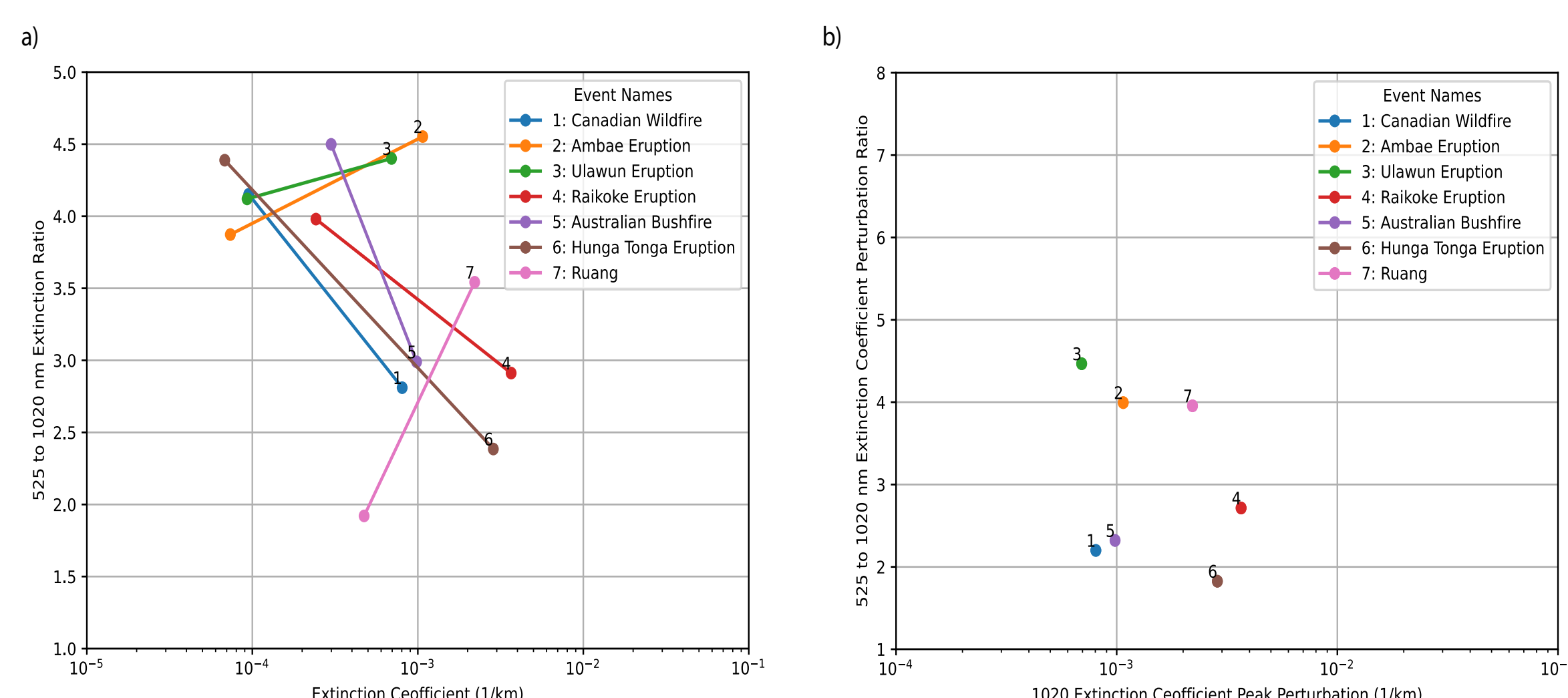


Figure 2: (a) "Before" and "after" extinction ratio vs. 1020 nm extinction for 7 events (Jun 2017–Dec 2024). (b) Perturbed ratios vs. 1020 nm extinction.

- Data Regimes:** Negative/Positive regimes separated; Enhanced regime identified using MAD threshold ($k_0 = k_a + 3.0 \times \text{MAD}$).
- Event Groups:** large eruptions pi91 (1992–2002), small eruptions Ru02 Ru24 (2002–2004, 2024), small eruptions Ma05 Am18 (2005, 2018–2019), mixed eruptions Ul Ra19 (2019), large eruptions t22 (2022–2024). Fire events excluded.
- Approaches:** Linear Regressor, HistGradientBoosting (HGB), Empirical (Thomason et al., 2018)

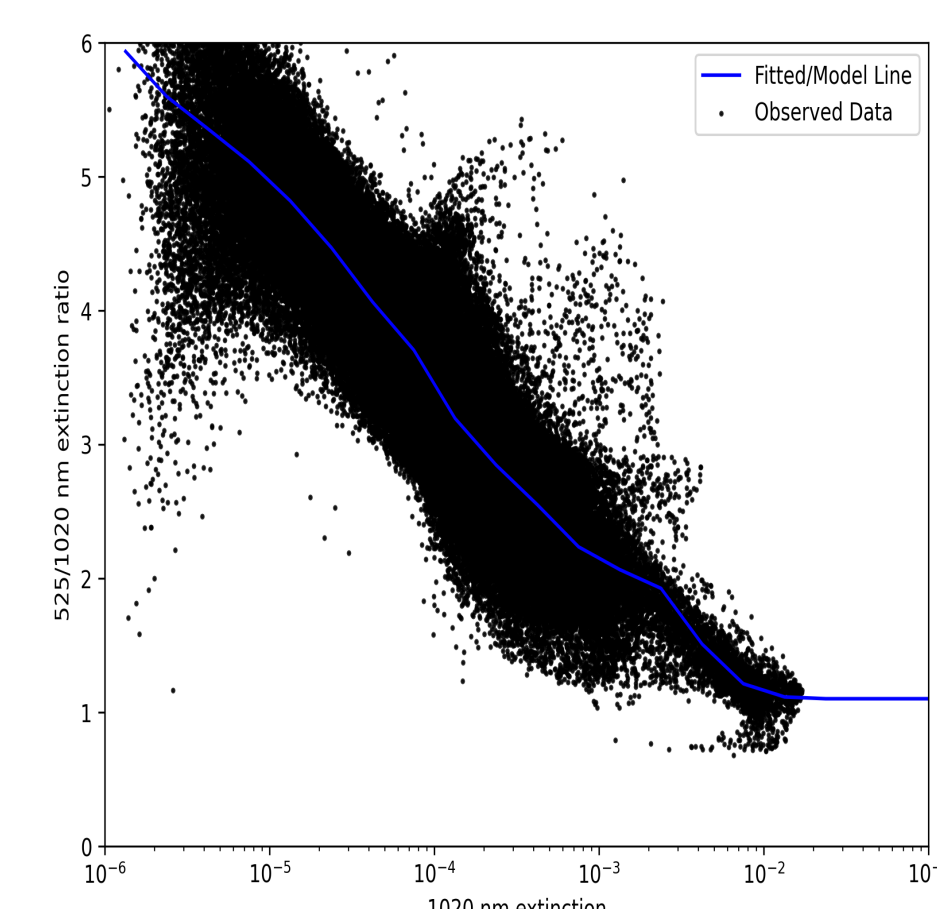


Figure 3: SAGE II extinction ratio vs. 1020 nm extinction (cloud-cleared, between tropopause+1 and 30 km). Blue line: empirical conversion relationship.

Training: Jan 1992–Aug 2024, tropopause to 25 km, incorporating regime/event features.

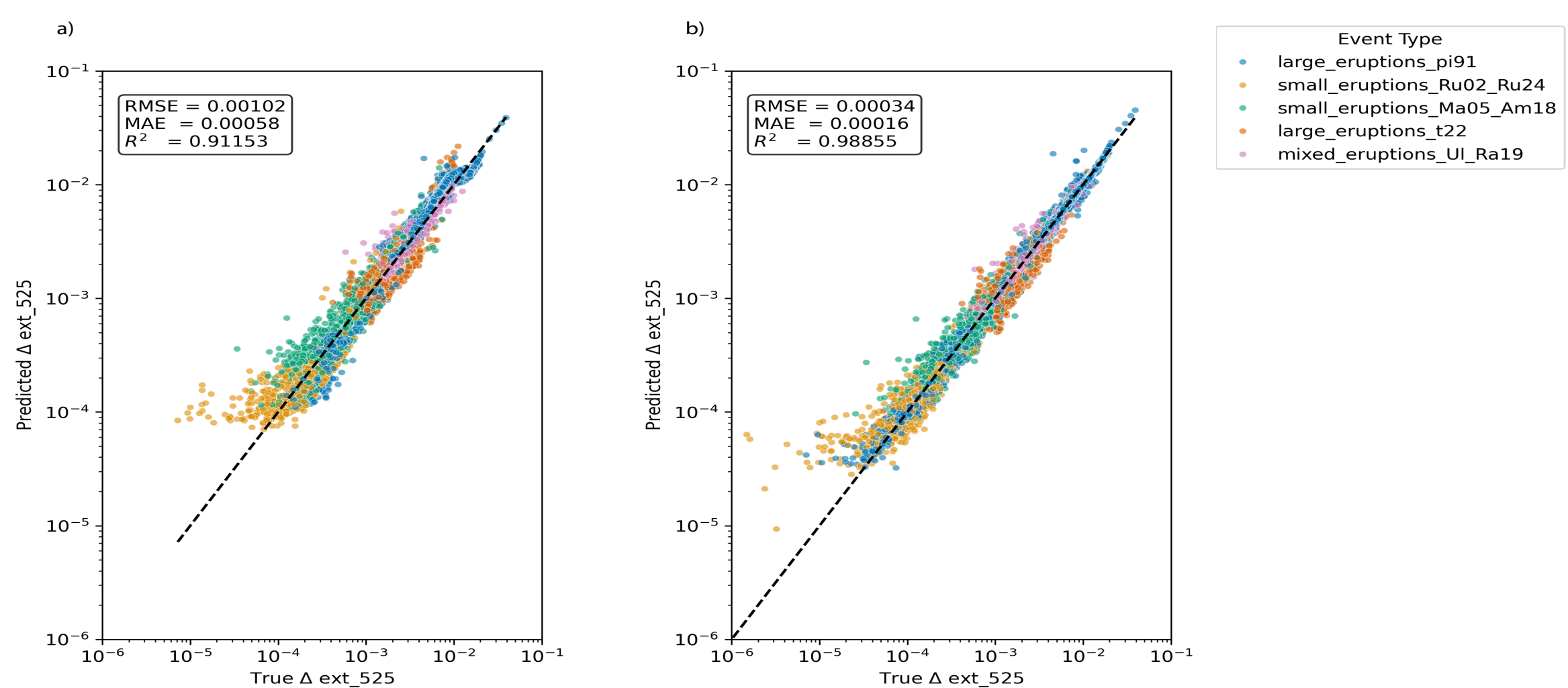


Figure 4: Predicted vs. measured perturbed 525 nm extinction: (a) Linear Regressor (201709), (b) HGB Regressor (all enhanced data).

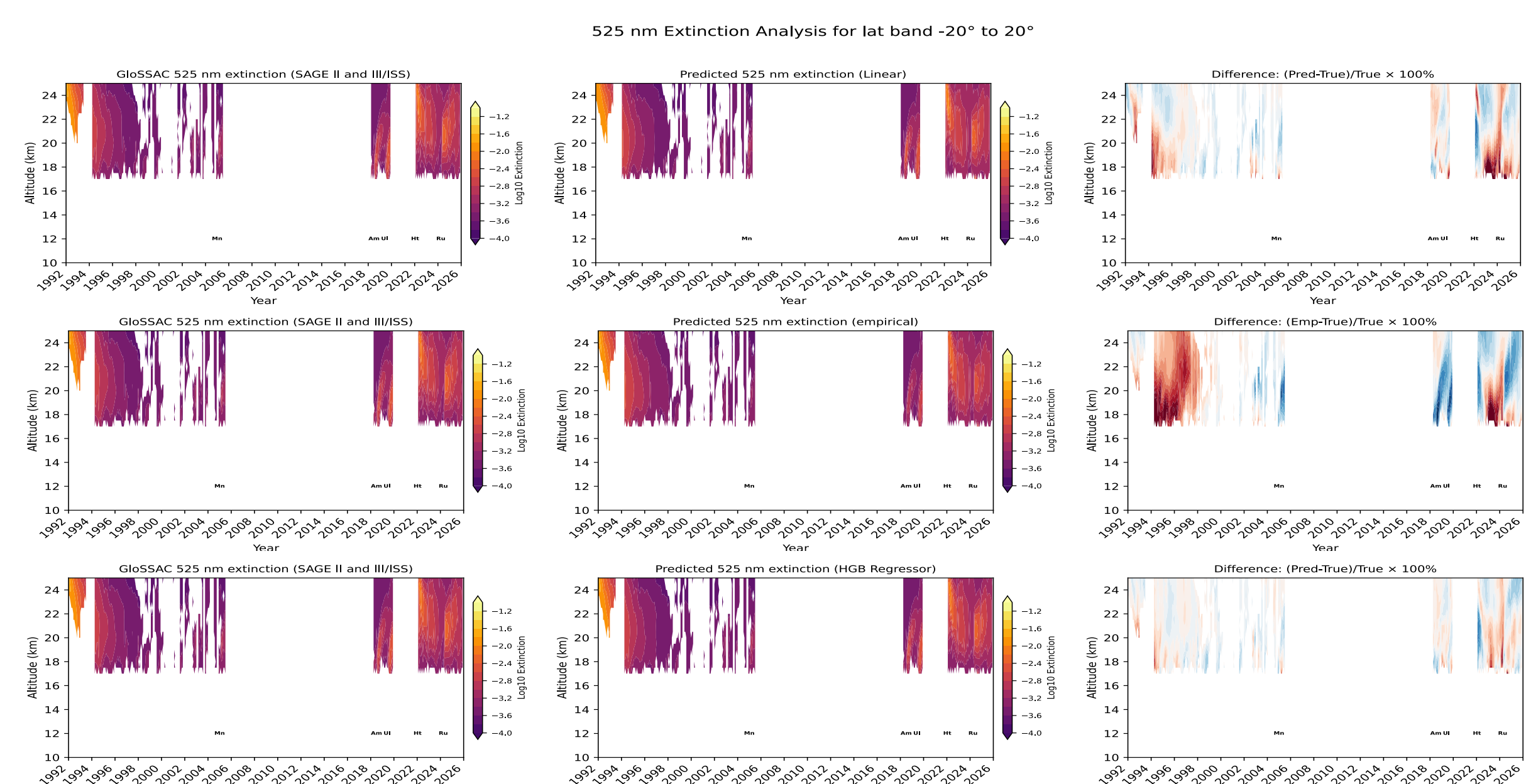


Figure 5: Time series of zonally averaged (between 20°S and 20°N) monthly extinction coefficient at 525 nm (Altitude vs Time). Top panel: measured vs. linear regressor predictions with percent difference. Middle panel: measured vs. empirical method predictions with percent difference. Bottom panel: measured vs. ML approach predictions with percent difference. Major volcanic eruptions in the tropics are also shown as abbreviated codes.

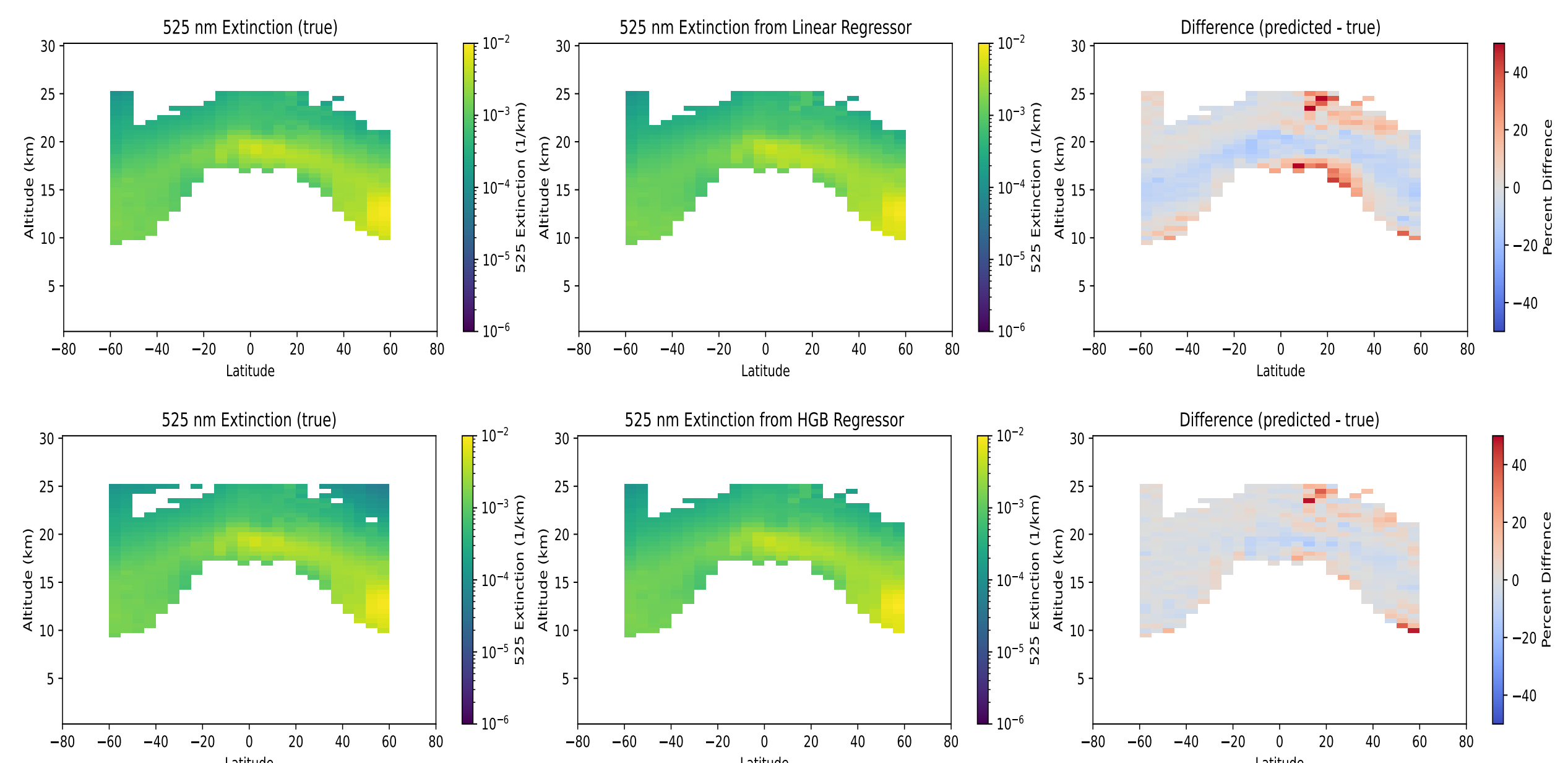


Figure 6: Zonally averaged monthly extinction coefficient at 525 nm for October 2019 following Raikoke. Top panel: measured vs. linear regressor predictions with percent difference. Bottom panel: measured vs. ML approach predictions with percent difference.

3. Summary and Conclusions

- We followed Thomason et al., 2021 method to study the predictability of k_{525} from k_{1020} using different approaches with SAGE III/ISS measurements.
- The Linear Regression for predicting the 525 nm extinction coefficient (k_{525}) works but appears to overestimate ($\sim 30\%$) for Pinatubo in particular and for Ambae eruption it underestimates at the peak and overestimates except the peak.
- The HGB regression for predicting the 525 nm extinction coefficient (k_{525}) works well for Pinatubo and other events but for Ambae eruption it underestimates at the peak and overestimates except the peak similar to Linear Regression
- Regardless of any method we choose for prediction, limitations persist due to the variability of each event.
- While ML methods may help reconstruct missing wavelength, results may not be robust due to the absence of direct measurements during key periods.
- Given the increasing frequency of fires and volcanic events, accurate measurements of stratospheric aerosol are critical. Solar occultation measurements are particularly valuable as they provide reliable multi-wavelength extinction coefficients.
- Future:** Implement methods for the single-wavelength period although validation during 2005-2017 creates challenges. We will also incorporate OMPS-LP into the record after evaluation/bias-correction.

4. References

- NASA/LARC/SD/ASDC, GloSSAC v2.24, 2026. <https://doi.org/10.5067/GLOSSAC-L3-V2.24>
- Thomason et al., Earth Syst. Sci. Data, 10, 4697492, <https://doi.org/10.5194/essd-10-469-2018>, 2018.
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