

Estimation of the radiative effect of stratospheric aerosols using **a new set of radiative kernels**

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Kernel-Based Estimation of Stratospheric Aerosol Radiative Effects From Volcanic and Wildfire Events

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Stratospheric aerosols

- Increasing perturbations in changing climate
- High spatiotemporal inhomogeneity



Volcano



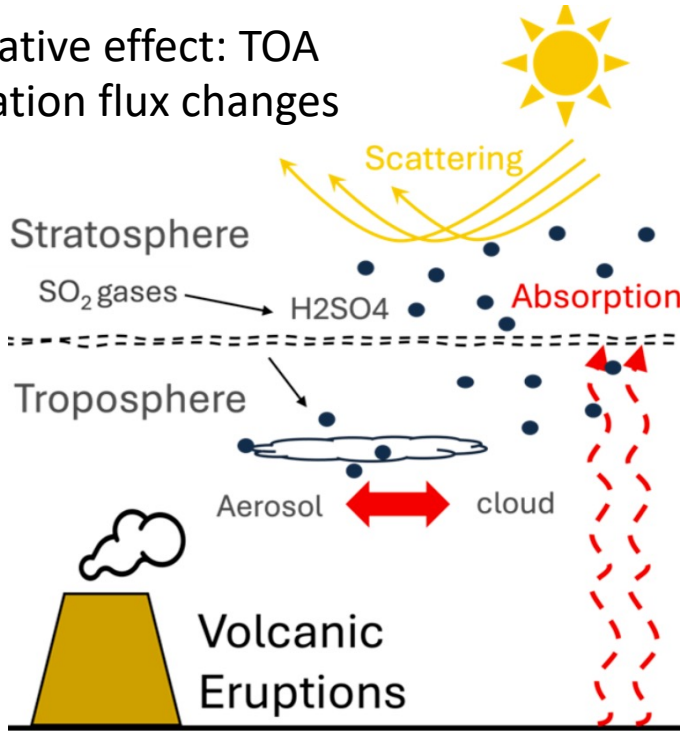
Cb and Pyro-Cb



Geo-engineering

Radiative effect

Radiative effect: TOA radiation flux changes



(Ke et al., 2025)

- Radiative effect (PRP concept)

$$\Delta R = R(\tau_0 + \Delta\tau) - R(\tau_0)$$

↑ AOD

- Method I: Model radiative transfer

$$\mu \frac{dI(\tau, \mu)}{d\tau} = -I(\tau, \mu) + (1 - \varpi(\tau))B(\tau) + \frac{\varpi(\tau)}{4\pi} \int_0^{2\pi} d\phi' \int_{-\pi/2}^{\pi/2} I(\tau, \mu') P(\tau, \mu; \mu') d\mu'$$

- Method II: Estimate it by scaling

$$\Delta R = \frac{\partial R}{\partial \tau} \cdot \Delta\tau$$

↑

Radiative kernel: K_{AOD}

Stratospheric kernels

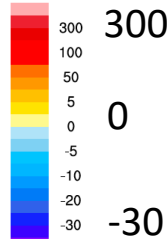
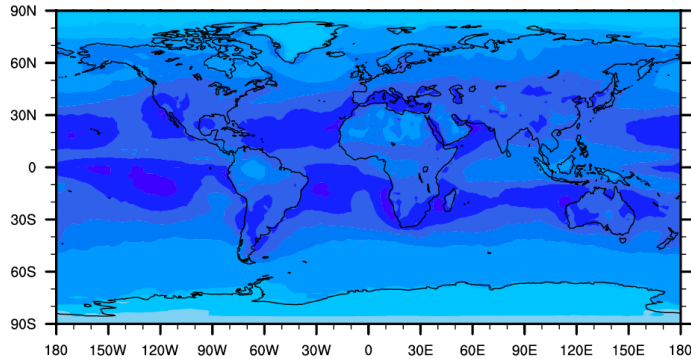
Stratospheric scat. kernels

(Yu & Huang 2026)

G.M.= -20.0

Units:

W/(m² AOD)



- Global mean radiative effect:

$$\langle \Delta R \rangle = \left[\iint K_s(\mathbf{r}, t) \cdot \Delta \tau_s(\mathbf{r}, t) d\mathbf{r} dt + \dots \right]$$

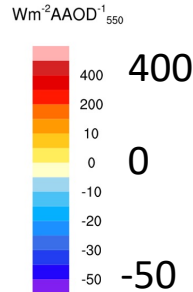
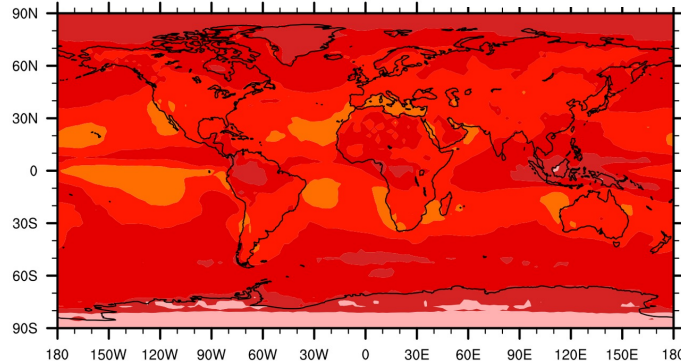
$$\iint K_a(\mathbf{r}, t) \cdot \Delta \tau_a(\mathbf{r}, t) d\mathbf{r} dt \Big/ \iint d\mathbf{r} dt$$



Spatiotemporally varying, accounting for adjustment

(b) AAOD Kernel inst

G.M.= 301.9



- Kernel production

Model: RRTMG SW + LW

Atmos data: MERRA2 + OMPS-LP

aerosols (3-hourly profiles)

Scattering AOD kernel: $\partial R / \partial (SAOD)$,

SSA = 1

Absorptive AOD kernel: $\partial R / \partial (SAOD)$,

SSA = 0

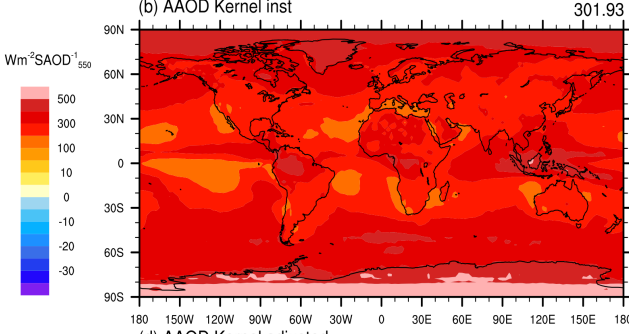
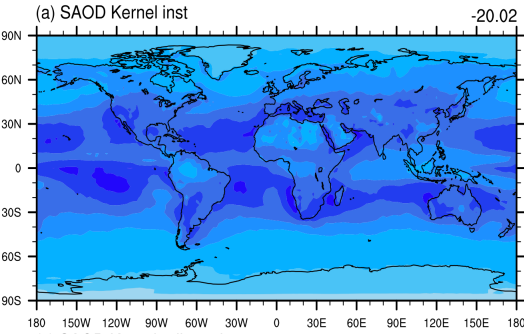
Stratospheric kernels including adjustments

Stratospheric kernels: instant vs. adjusted
(Yu & Huang 2026)

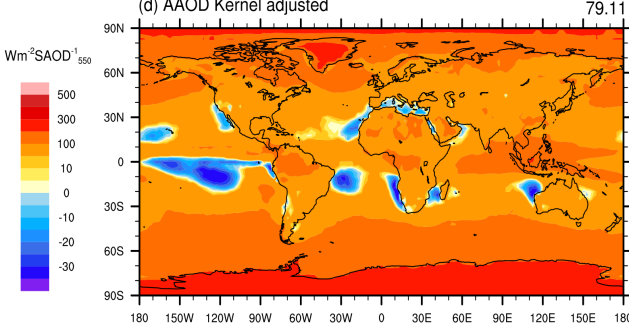
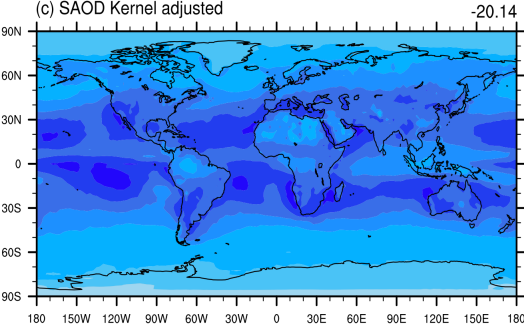
- SAOD kernel: little difference.

- AAOOD kernel: adjustment can lead to sign change!

Inst.



Adj.

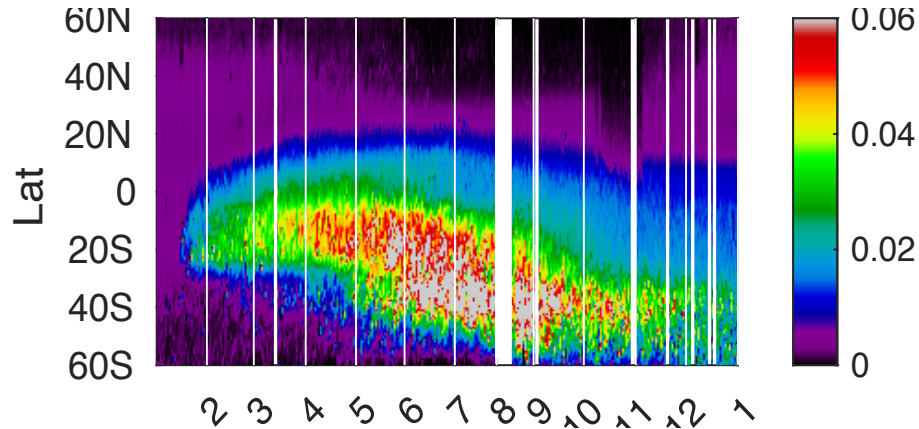


SAOD kernel

AAOOD kernel

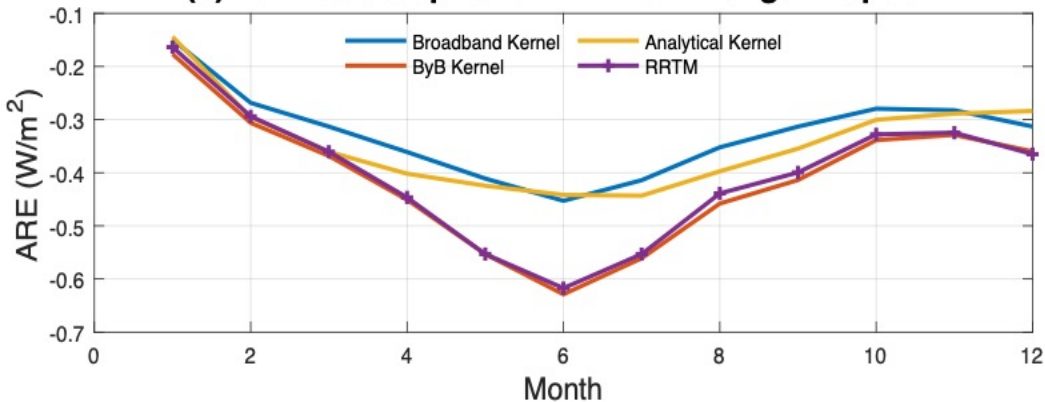
Application: Hunga volcano

Satellite (OMPS)-measured AOD anomalies



Kernel-estimated ADRE vs RTM-modelled truth

(b) 2022 Stratospheric ARE from Hunga Eruption



- Kernel estimation:

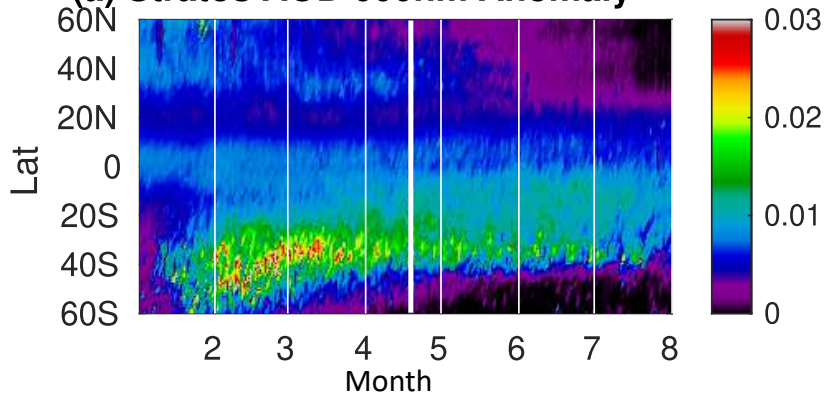
$$\langle \Delta R \rangle = \frac{\iint K_{AOD}(x, y) \cdot AOD(x, y) dx dy}{\iint dx dy}$$

- Cooling in the Southern Hemisphere: -0.4 W/m^2
- Band-by-band aerosol kernels utilize more spectral information and achieve best estimation

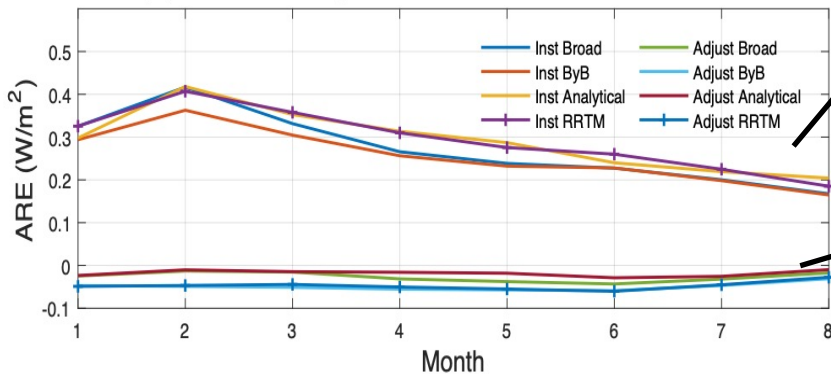
(Yu & Huang 2026 JGR)

Application: Australian bushfires

(a) Stratos AOD 600nm Anomaly



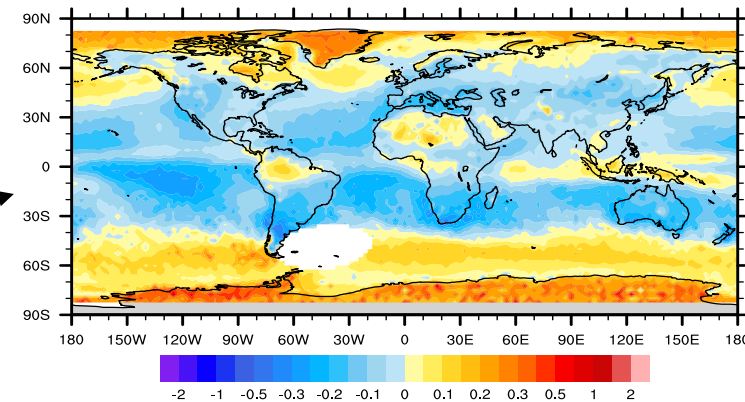
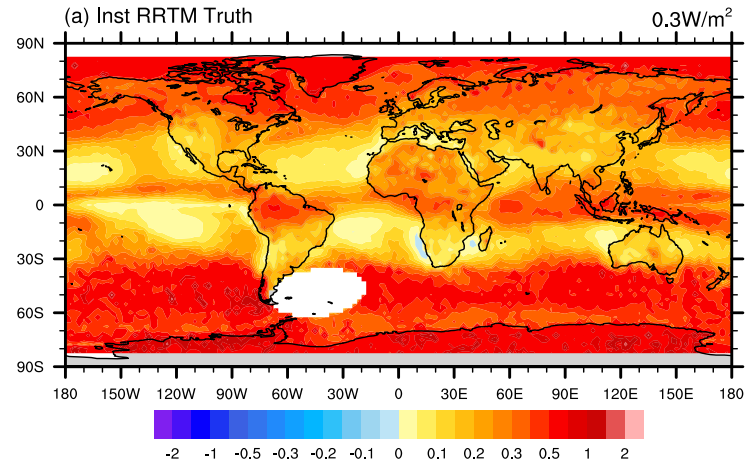
(b) 2020 Stratospheric ARE from Australia Wildfire



Instantaneous

Adjusted

(a) Inst RRTM Truth



(Yu & Huang 2026 JGR)

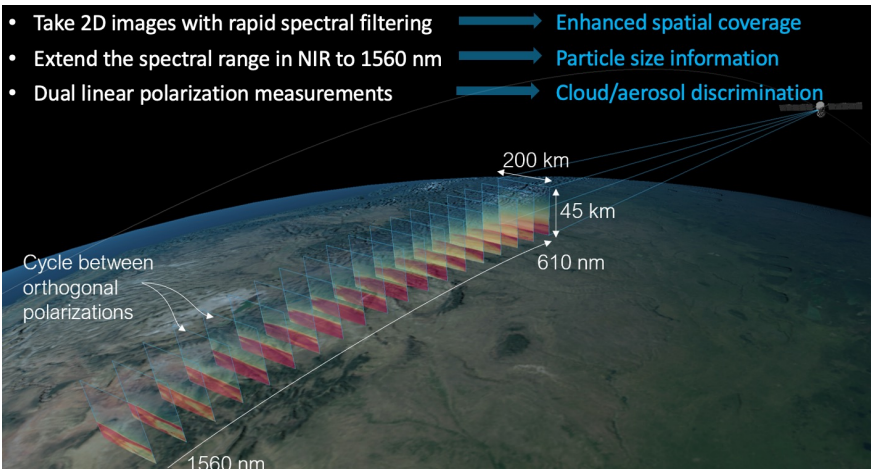
- Instantaneous ADRE: $+0.3 W/m^2$
- Adjusted ADRE: $-0.04 W/m^2$

Take-home messages

- Theoretic basis – non-constant radiative sensitivity

$$\langle \Delta R \rangle = [\iint K_s(\mathbf{r}, t) \cdot \Delta \tau_s(\mathbf{r}, t) d\mathbf{r} dt + \iint K_a(\mathbf{r}, t) \cdot \Delta \tau_a(\mathbf{r}, t) d\mathbf{r} dt] / \iint d\mathbf{r} dt$$

- Practical use – <New satellite measurements of stratospheric aerosol distribution> + <Kernels> = <Better climate assessments>



HAWC satellite ALI: Aerosol Limb Imager



Reference

Yu, Q. and Y. Huang, (2026), Kernel-based estimation of stratospheric aerosol radiative effects from volcanic and wildfire events, J. Geophys. Res.-Atmos., <https://doi.org/10.1029/2025JD044278>