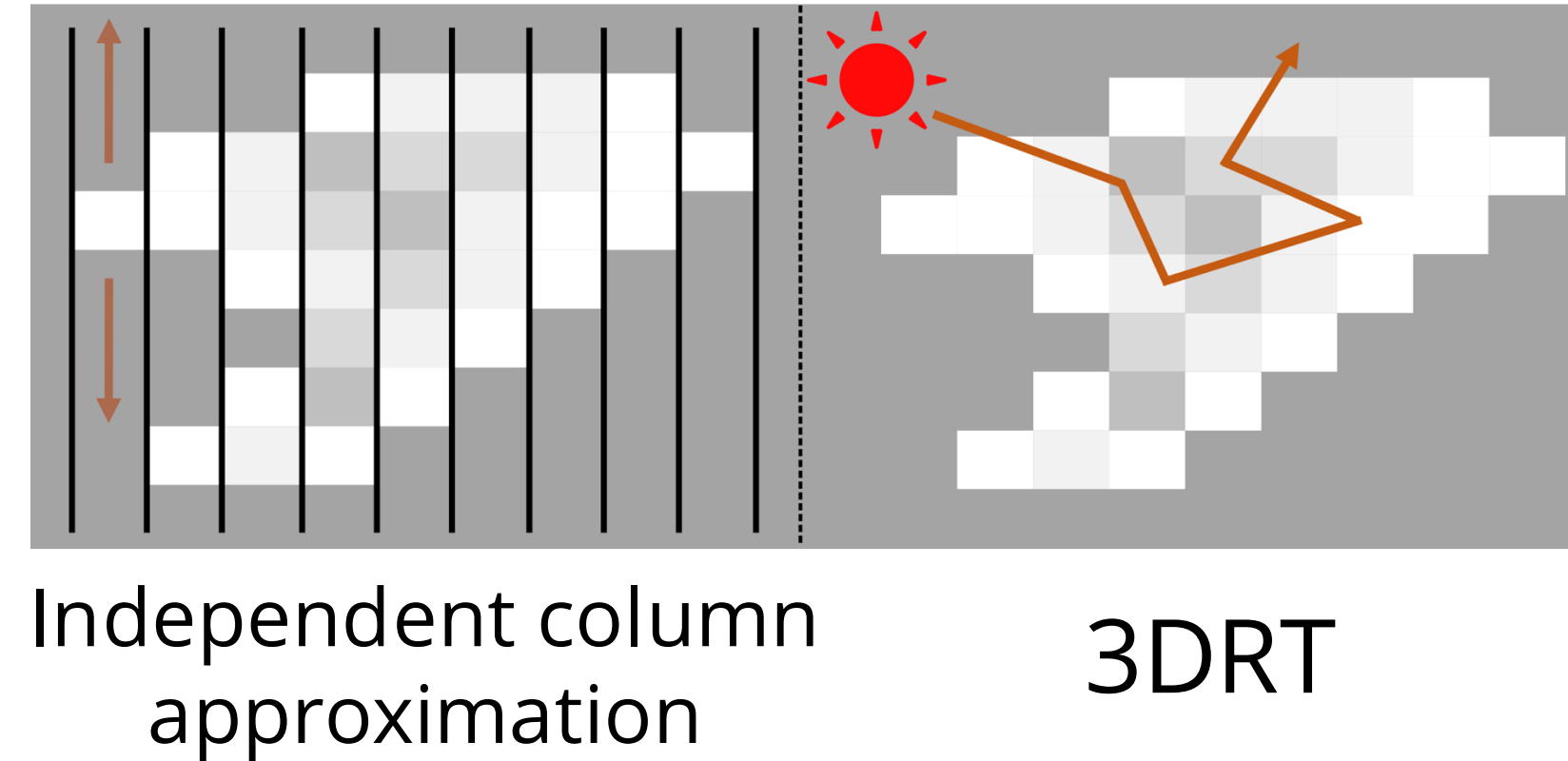


About our study

3D radiative transfer(RT) effect

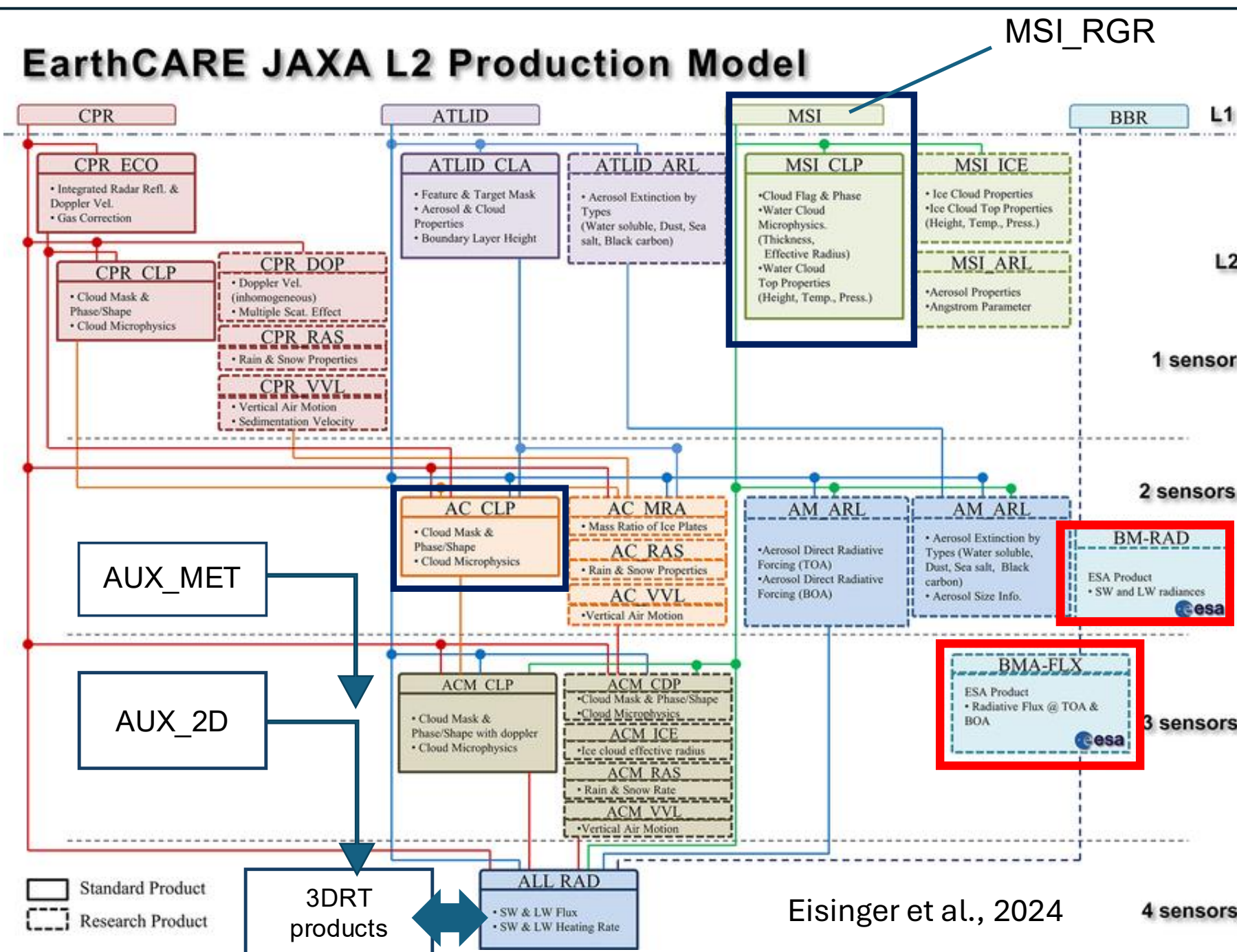
Radiation biases arising from the neglect of horizontal radiative transport, which can introduce non-negligible errors in estimates of Earth's radiative budget and cloud dynamics

- Develop 3D radiative products derived from the three-dimensional atmospheric characteristics captured by EarthCARE's multi-sensor observations
- Evaluate 3D radiative transfer effects over broad spatial domains.



Conclusions

- Developed an EarthCARE-based 3D radiative product using multi-sensor observations and the JAXA processor
- 3D RT effects were clearly detected in radiance, flux, and heating-rate fields
- SW 3D RT effects were prominent at spatial scales from a few kilometers to about 50 km and showed clear dependence on solar zenith angle
- The combined SW and LW 3D RT effect was about 5.9 W m^{-2} , indicating a cooling bias when 1D RT is used



3DRT from JAXA products

- Physical properties: Radiance, Flux, Heating rate
- Inputs: MSI_RGR, MSI_CLP, AC_CLP, AUX_2D, AUX_MET
- Validation(Radiative closure): BM_RAD, BMA_FLX
:Radiance and flux products from BBR sensor

3DRT products

Radiance ($\text{W/m}^2/\text{sr}$) and Flux (W/m^2):

Calculated by backward Monte Carlo RT code *Mcstar* (Okata et al., 2017; Momo et al., 2022)
TOA(20 km), Upward and downward flux (Assessment domain)
At the BMA_FLX(BM_RAD) coordinates for radiative closure

SW: 0.25 – 5.0 μm

LW: 4.0 – 500 μm

3D: 1x1 km (match to input products resolution)

1D: 100000x100000 km (virtual setting)

Ocean area only.

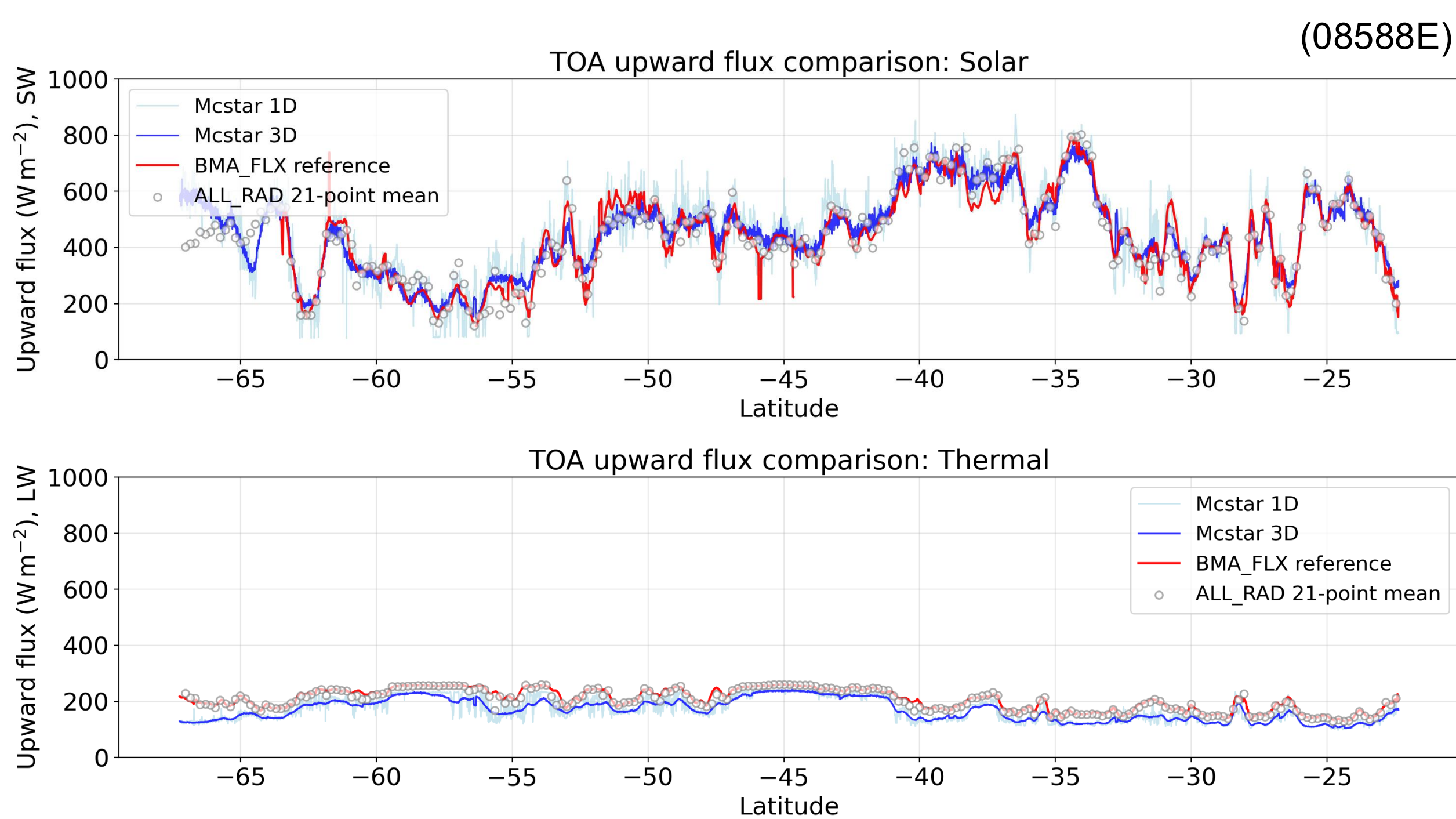
Heating rate (K/day):

Volume Integration for each grid boxes,
Grid size: 1x1x1 km

Radiative closure

Radiative closure for flux on the Assessment Domain (5x21 JSG(~km))

Observed: BMA_FLX (combined, Assessment domain), 1D product: ALL_RAD (1km*1km domain, average every 21 points)



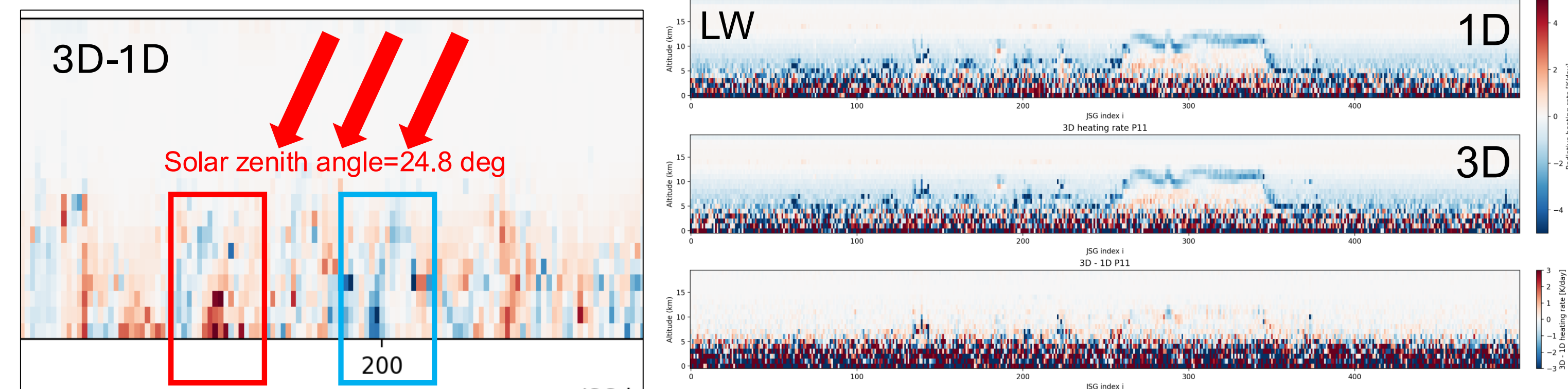
Atmospheric heating rate (K/day)

Calculated from net divergence flux by volume integration for each grid boxes

$$\nabla \cdot \bar{F} = \frac{4\pi}{V} \int \beta_a (B - \bar{I}) dV$$

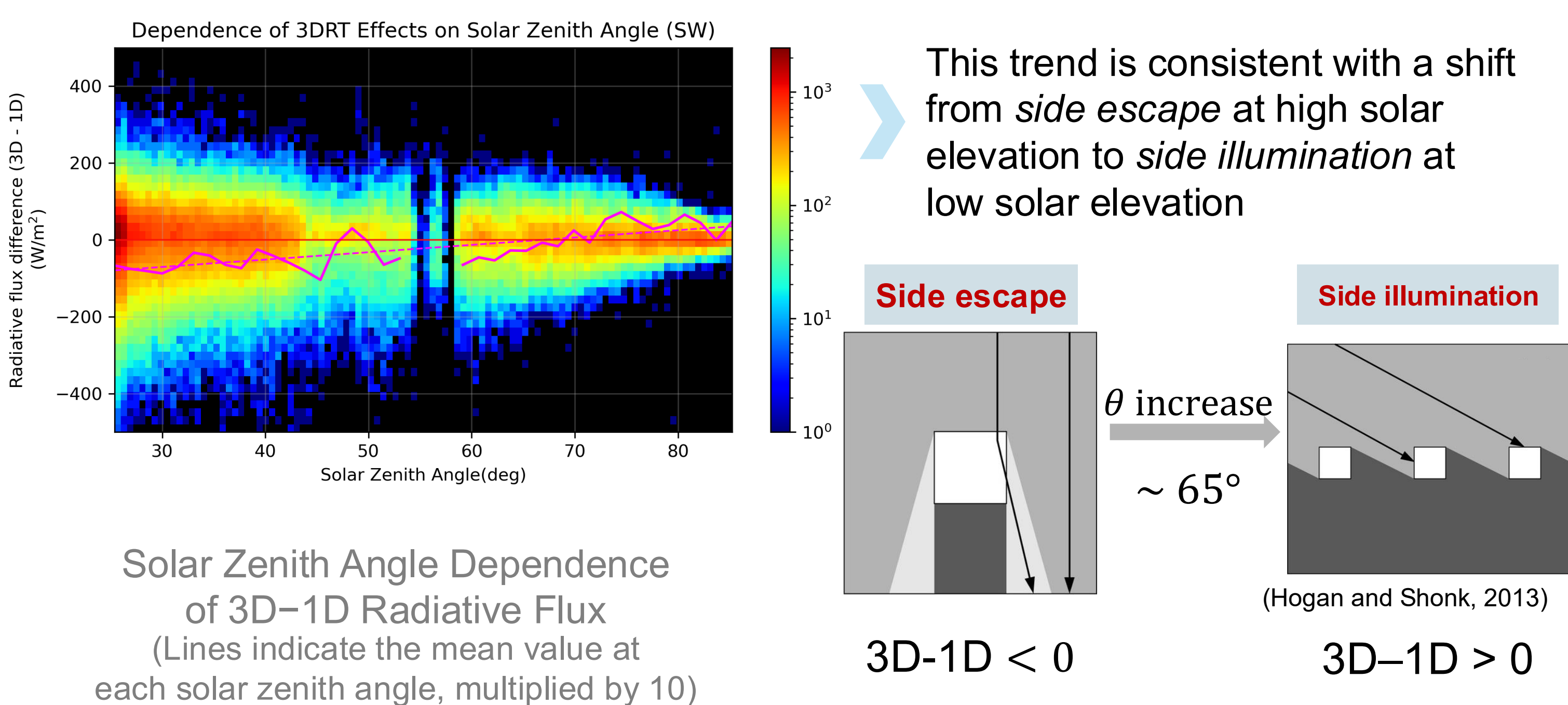
$$\text{Heating rate} = \left(\frac{\partial T}{\partial t} \right)_{\text{K/day}} = - \frac{1}{\rho c_p} \nabla \cdot \bar{F} \times 86400$$

β_a : absorption coefficient,
B: planck function,
 \bar{I} : mean radiance



Solar zenith angle dependence of 3DRT

For shortwave radiation, the 3DRT effect (3D - 1D) is overall negative. As solar zenith angle increases, the effect approaches zero and tends to become positive around 65°



Effects on Earth's radiation budget

Upward Radiative Flux at the top of atmosphere (10kmx10km scale)

	Correlation Coefficient	Mean error (3D-1D) (W/m^2)	RMSE (W/m^2)
Shortwave	0.873	- 5.77	80.9
Longwave	0.943	- 0.089	10.8

The mean 3D-1D error for total radiative flux is $- 5.77 - 0.089 = - 5.9 \text{ W m}^{-2}$
This indicates a negative contribution from 3D radiative transfer effects

1D radiative transfer calculations underestimate Earth's radiation budget by 5.9 W m^{-2} , leading to an artificial cooling bias

