

How do air pollutant emissions influence solar energy generation?

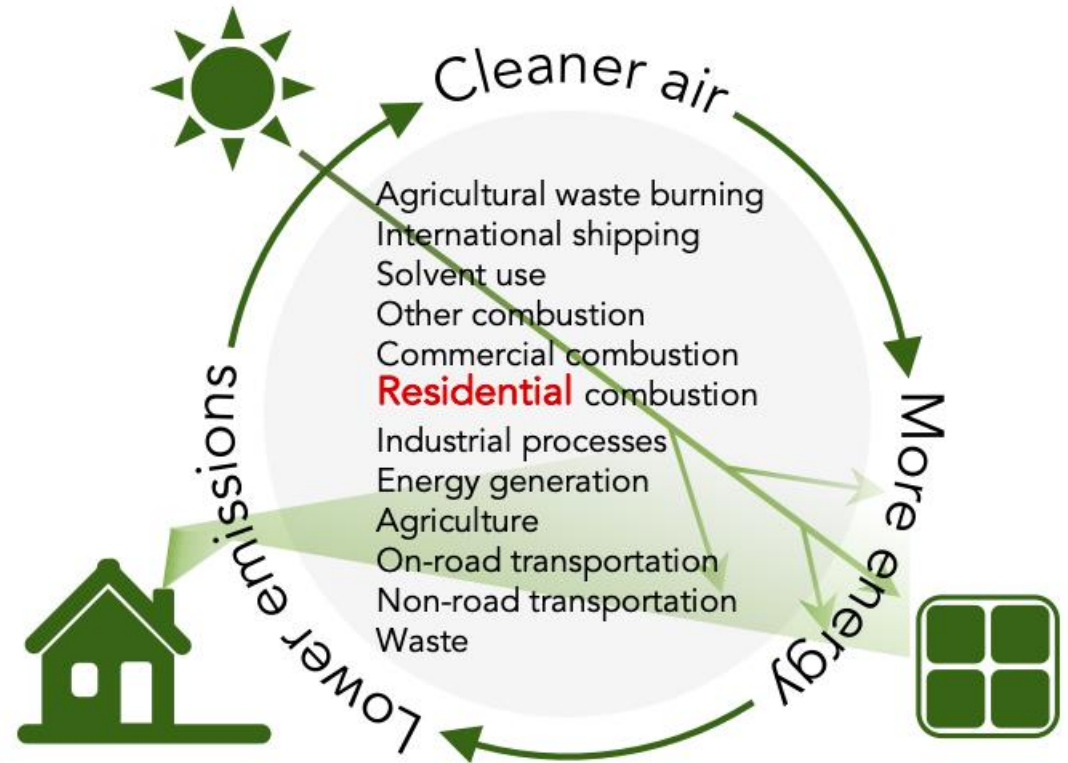
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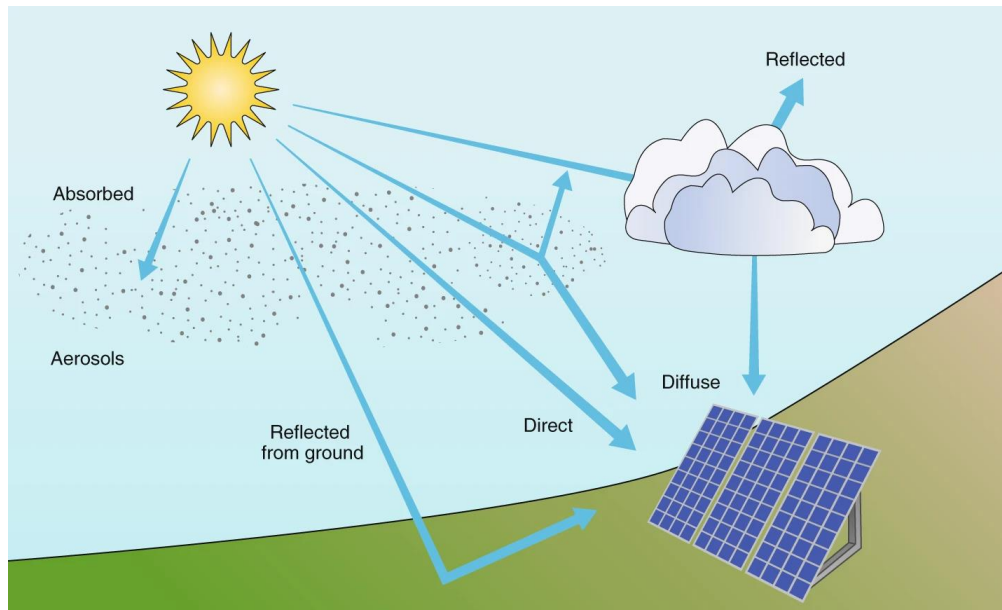


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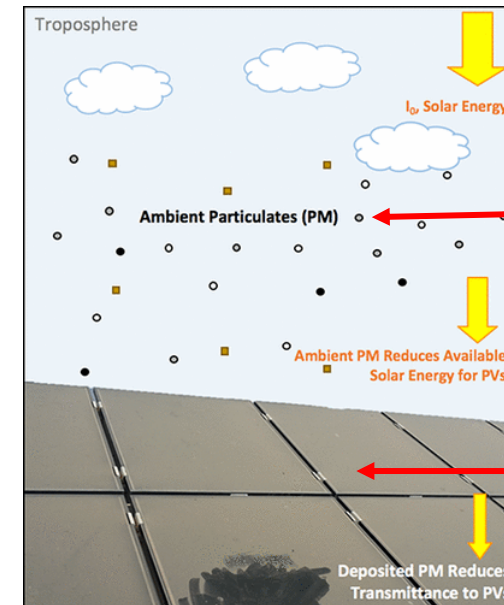
16 & 17 May 2023 – University of Aberdeen, King's College Conference Centre

Air pollution reduces solar energy generation

Particulate matter (PM) pollution reduces photovoltaic (PV) efficiency by impeding light as it passes through 1) the atmosphere (dimming), and 2) solar panel surfaces where PM can deposit (soiling).



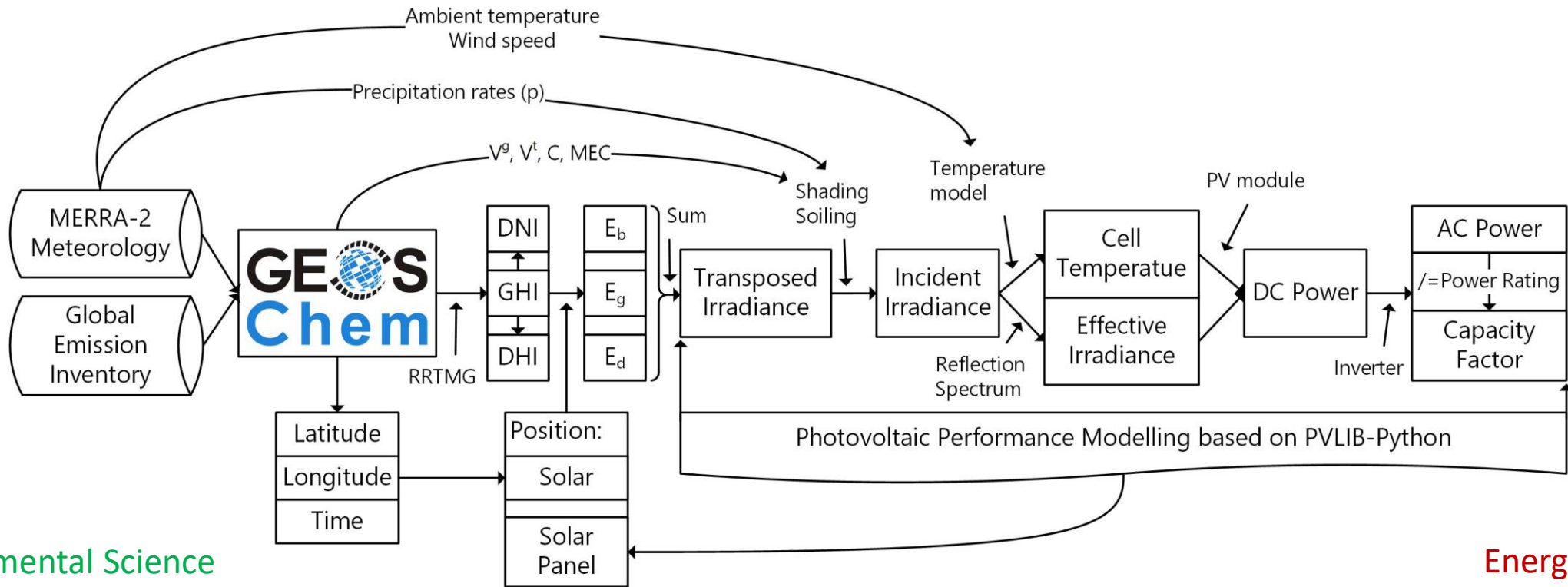
Ekins-Daukes, N. and Kay, M., Nat. Energy., 2019



Bergin et al., ES&T, 2017

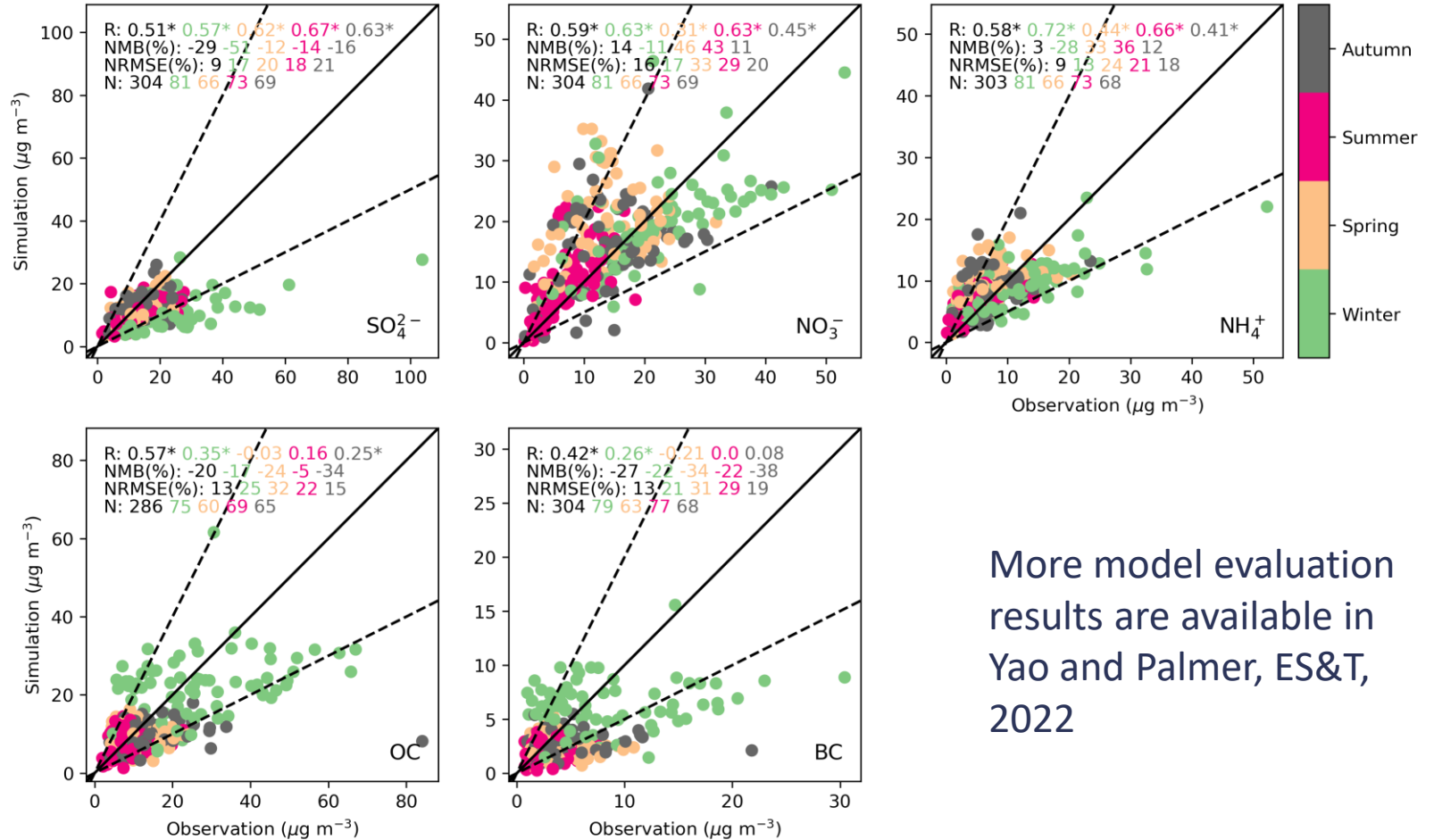
Reducing PM sources will improve PV efficiency

- We lack a global understanding of the source sectors that would be the most effective at achieving the necessary reductions in anthropogenic PM sources.
- Natural PM sources can be significant but are not easily controlled.



Model evaluation

The integrated model can generally reproduce the observed variations in GHI and levels of atmospheric and deposited PM and its major components during both periods of high and low solar insolation.



More model evaluation results are available in Yao and Palmer, ES&T, 2022

Experimental design

Calculate three CFs to determine:

- PM soiling impact: CF2-CF1
- PM dimming impact: CF3-CF2
- PM total impact: CF3-CF1

CF	PM dimming	PM soiling
CF1	Yes	Yes
CF2	Yes	No
CF3	No	No

Compare PM impacts across CTRL and 0.5SECTOR scenarios to determine:

- Cleaning benefit:
 - $(CF2-CF1)_{CTRL} - (CF2-CF1)_{0.5SECTOR}$
- Brightening benefit:
 - $(CF3-CF2)_{CTRL} - (CF3-CF2)_{0.5SECTOR}$
- Total benefit:
 - $(CF3-CF1)_{CTRL} - (CF3-CF1)_{0.5SECTOR}$

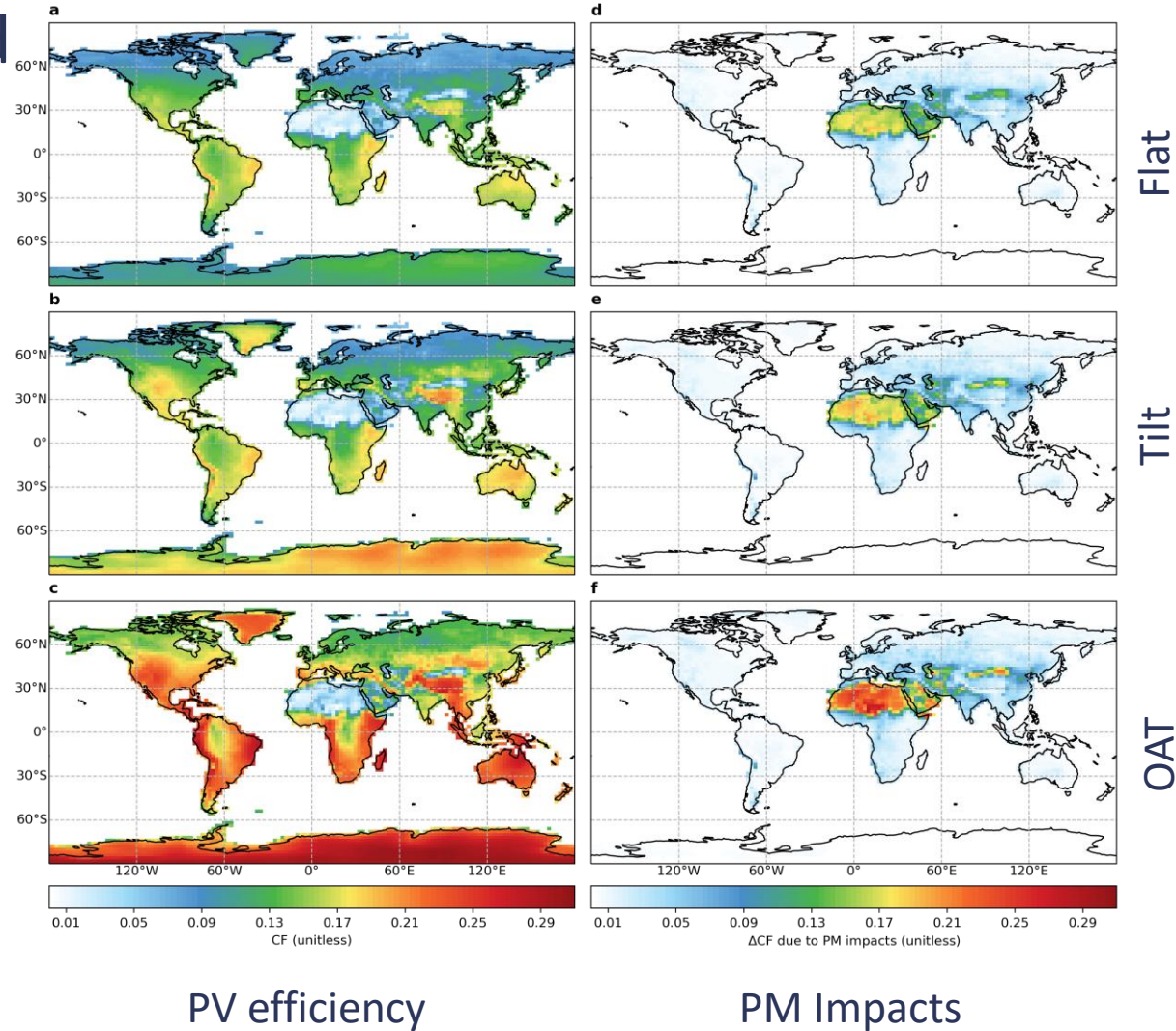
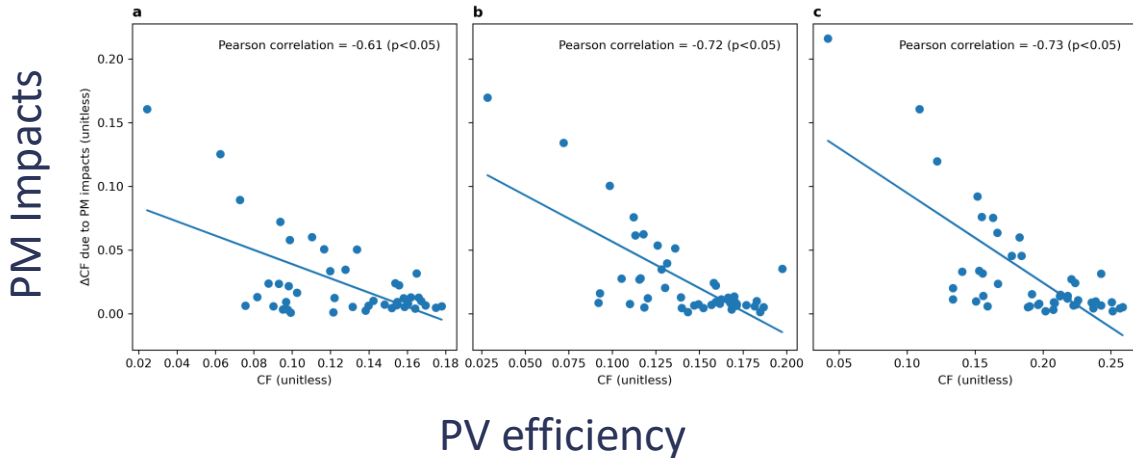
Role of precipitation: $CF1_{CTRL} - CF1_{CTRL+NOPrecip}$

Role of cleaning panels: $CF1_{CTRL+SWEEPING} - CF1_{CTRL}$

	AGR	ENE	IND	ROAD	NRTR	RCOR	RCOC	RCOO	SLV	WST	SHP	AWB
CTRL	Leave them as they are											
0.5SECTOR	Halve them one by one											
CTRL+NOPrecip	Same as CTRL but without precipitation											
CTRL+SWEEPING	Same as CTRL with solar panels cleaned periodically											

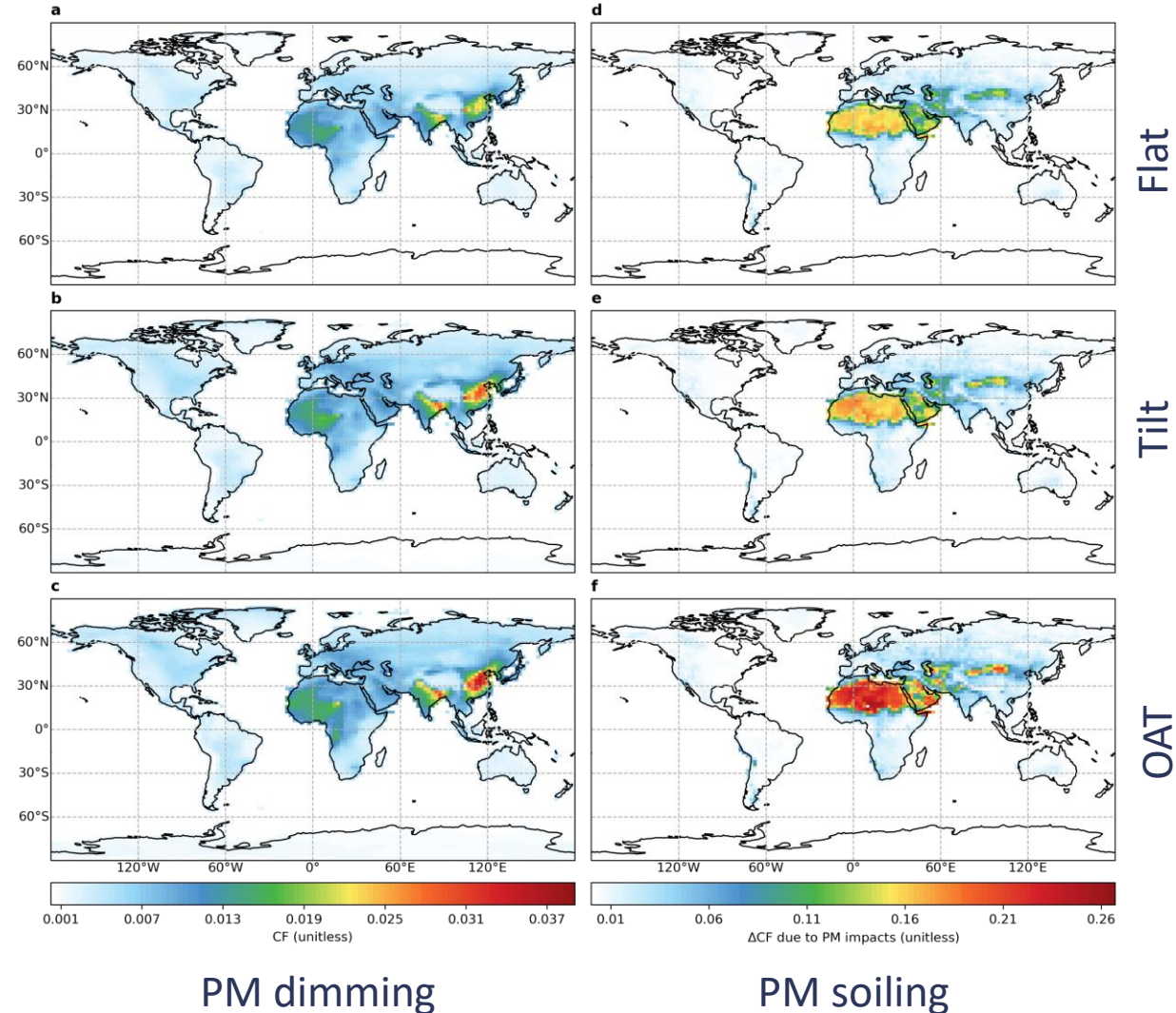
PV efficiency and PM impacts

- High PV efficiency is found in North and South America, Eastern and Southern Africa, the Tibetan-Plateau, Southeast Asia, Australia, Madagascar, and high-latitude regions (with Tilt and OAT).
- Regions with low PV efficiency are associated with high PM impacts.



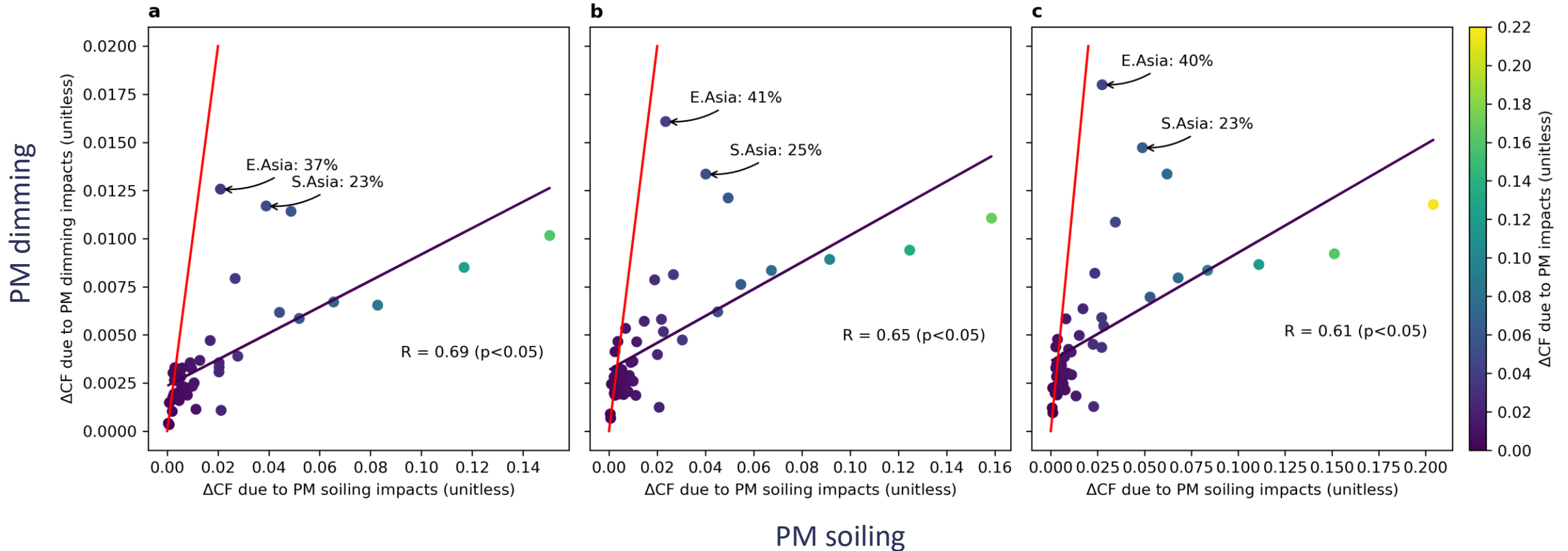
PV dimming versus soiling

- The magnitude and distribution of PM impacts is almost exclusively determined by soiling.
- East and South Asia feature high PM dimming impacts of up to 0.04.
- Desert regions including the Sahara, Arabian-Peninsula, and Central Asia feature high PM soiling impacts.



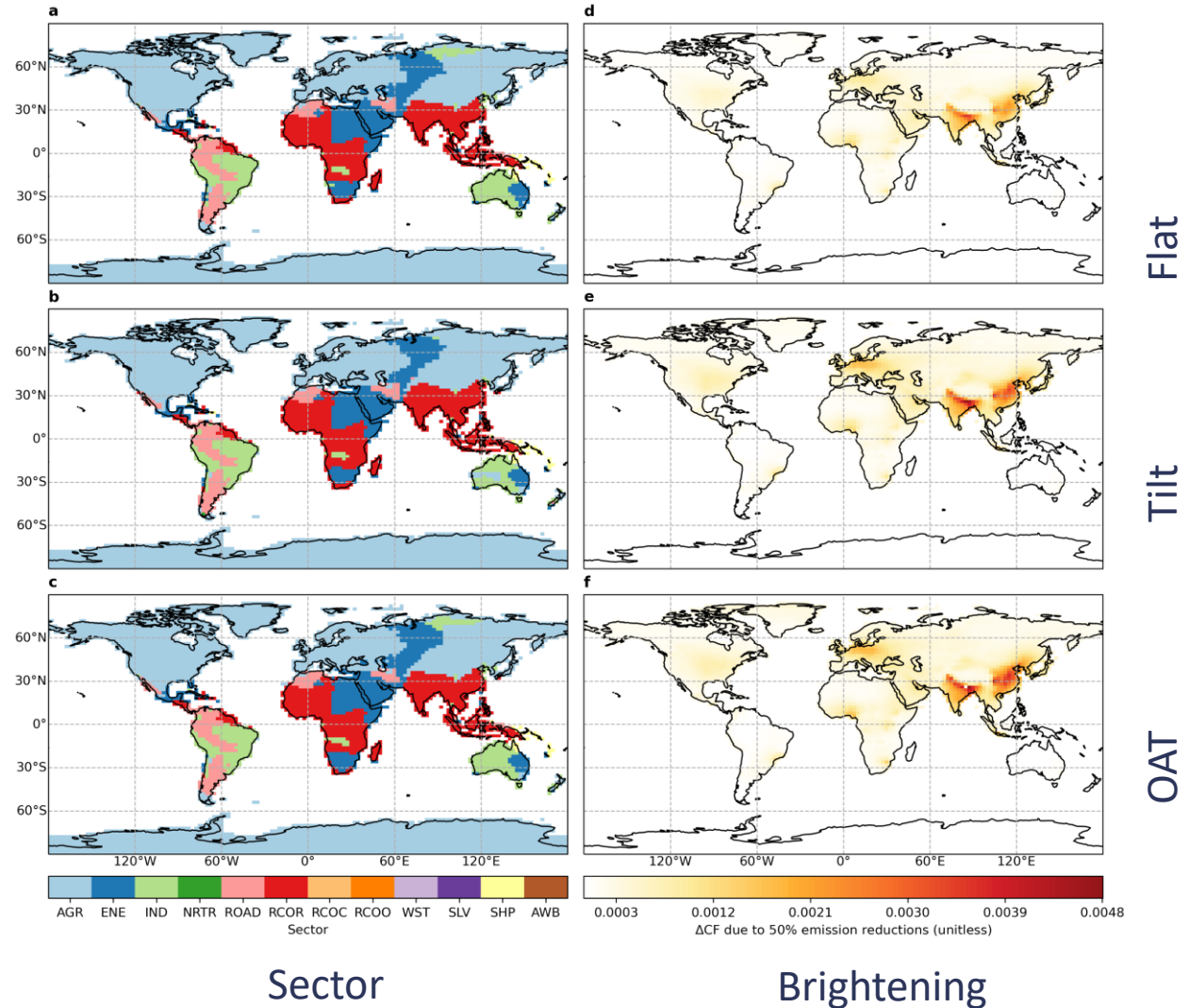
PV dimming versus soiling

PM dimming and soiling impacts usually occur together, so reducing emissions can address both simultaneously.



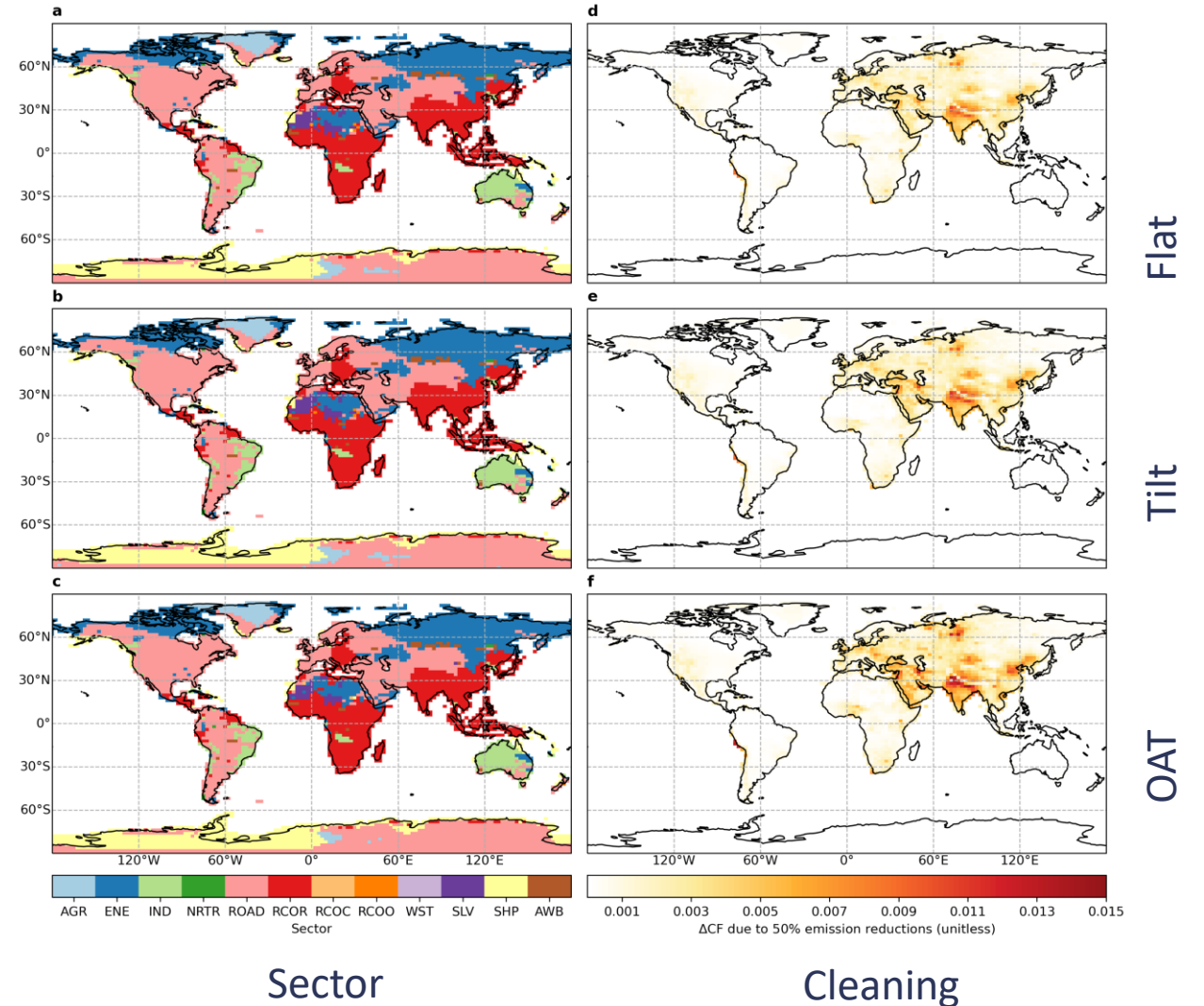
Brightening benefits of reducing emissions

- Halving residential emissions results in widespread decreases in PM dimming over East and South Asia.
- Halving agricultural emissions results in widespread decreases in PM dimming over East Asia and Western and Central Europe.



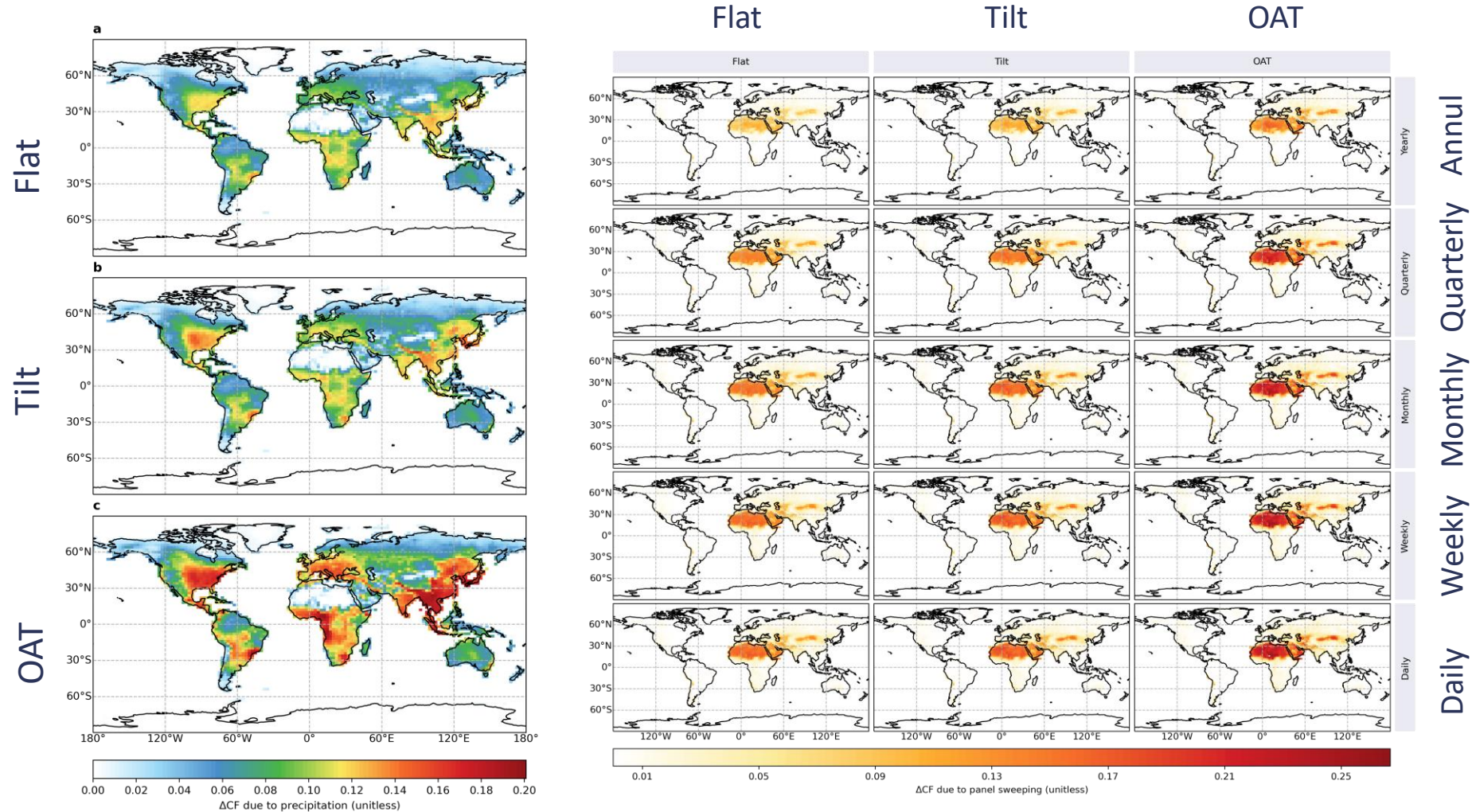
Cleaning benefits of reducing emissions

- Halving residential emissions results in widespread decreases in PM soiling over East and South Asia and the Tibetan-Plateau.
- Halving on-road emissions results in widespread decreases in PM soiling over Central Asia and the Arabian-Peninsula.
- Halving energy emissions results in widespread decreases in PM soiling over western Siberia.



Role of precipitation and panel cleaning

- Precipitation plays an important role in shaping the spatial pattern of current-level PV efficiency.
- Routine sweeping of panels could overcome most PM soiling impacts.



Concluding remarks

- PM pollution can significantly damage PV efficiency, with deposited PM causing more damage than atmospheric PM.
- Reducing residential emissions, especially from solid fuel combustion, can greatly benefit PV efficiency in East and South Asia.
- Sweeping deposited PM and precipitation can decrease PM soiling and improve PV efficiency.

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Article

Source Sector Mitigation of Solar Energy Generation Losses Attributable to Particulate Matter Pollution

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