Examining the feasibility of detailed decomposition of radiative flux anomalies to cloud changes

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What the work is about

- Resolving Cloud Radiative Effect (CRE) changes in terms of changes in cloud extinction and height during the last two decades.
- Partitioning CRE changes into two major terms, **cloud fraction distribution anomalies under fixed mean Cloud Radiative Kernel (CRK),** and **changes in CRK under a fixed mean cloud fraction distribution**.

Datasets and methods

- **CERES FlxByCldTyp (FBCT)** combined Terra and Aqua daytime 1°-regional gridded monthly top-of-the-atmosphere radiative fluxes and associated MODIS-derived cloud properties stratified by Cloud Top Pressure (CTP) and Cloud Optical Thickness (COT) histograms (Sun et al. 2022).

  CER_FluxByCldTyp-Month_Terra-Aqua-MODIS_Edition4A, monthly
- Cloud Radiative Effect (CRE) is defined as :

$$CRE = F^{all-sky} - F^{clear-sky} = CF\left(F^{ovc} - F^{clr}\right)$$

$*\ F^{ovc}$, CF histograms from CERES FlxByCldTyp

- Trend calculations are performed on deseasonalized anomalies (the monthly flux for a particular year is subtracted from the multiannual mean for the same month) at 1° spatial scale for 17 years (2003-2019). Noise is suppressed by averaging over larger domains: **Tropics [30S-30N], South/North Mid-latitudes[30S/N-60S/N] and high latitudes [between 60S/N and poles.**
- The CRE anomalies due to cloud fraction anomalies occurring under fixed mean Cloud Radiative Kernel (CRK) can be split into contributions that account for the change in total cloud amount (cloud fraction, CF), vertical distribution of clouds (cloud top pressure, CTP), cloud extinction (cloud optical thickness, COT) and a residual. A similar breakdown for the CRK anomaly term under a fixed mean cloud fraction distribution is also possible, but not pursued here because of its unclear physical interpretation.

$$\Delta CF\,(\overline{F_{over\,cast} - F_{clear}}) = \boxed{K_0 \Delta C_{tot}} \leftarrow \text{amount}$$

$$+ \boxed{\sum_{p=1}^{P}\left(K'_p \sum_{\tau=1}^{T} \Delta C^*_{p\tau}\right)} + \boxed{\sum_{\tau=1}^{T}\left(K'_\tau \sum_{p=1}^{P} \Delta C^*_{p\tau}\right)} + \boxed{\sum_{p=1}^{P}\sum_{\tau=1}^{T} K'_R\, \Delta C^*_{p\tau}}$$

residual

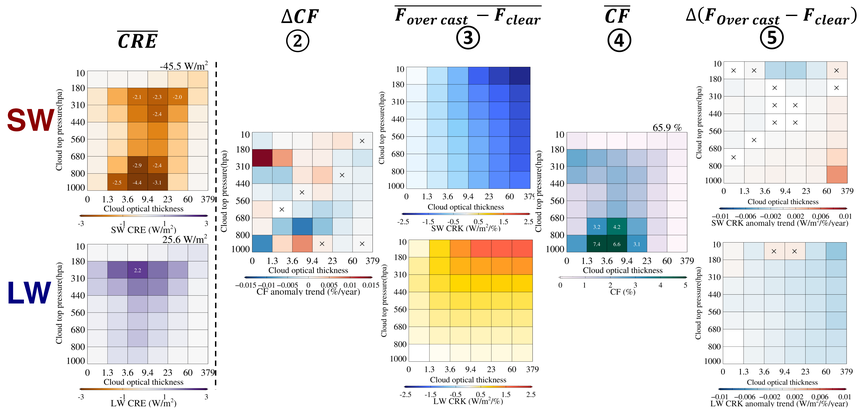
altitude

Optical depth

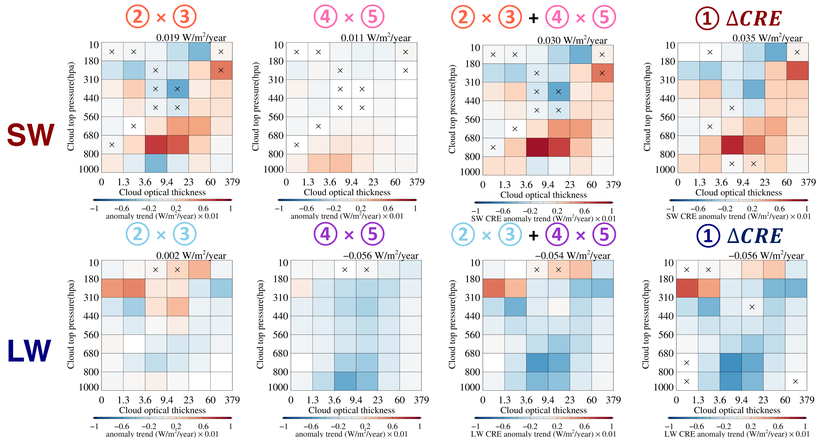
details in Zelinka et al., 2013

CRE anomaly decomposition framework (Global)

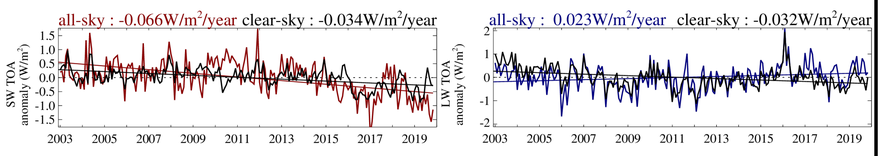
$$\overset{①}{\Delta CRE} = \Delta CF\,(\overline{F_{over\,cast} - F_{clear}}) + \overline{CF}\,\Delta(F_{over\,cast} - F_{clear})$$



- Each component of CRE anomaly decomposition stratified by Cloud Top Pressure (CTP) and Cloud Optical Thickness (COT).
- "×" in some CTP-COD bins indicates a failed F-test for the goodness of fit at the 95% confidence level.

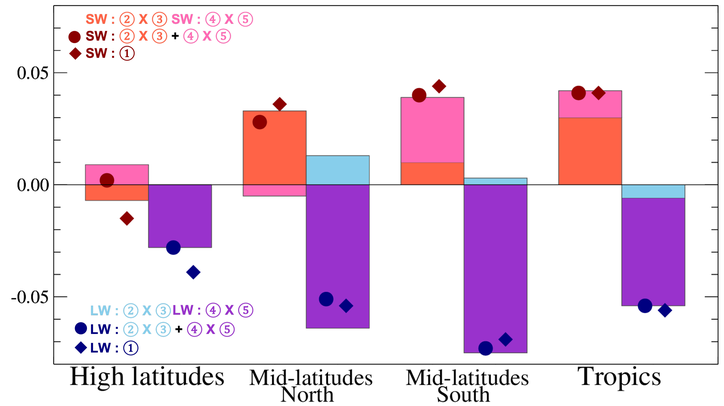


- Details of CRE decomposition with two major terms into CTP-COT bins.
- Direct calculation of ΔCRE(①) compares well with the value from decomposition = ②×③+④×⑤. Note that we neglect a co-variance term.



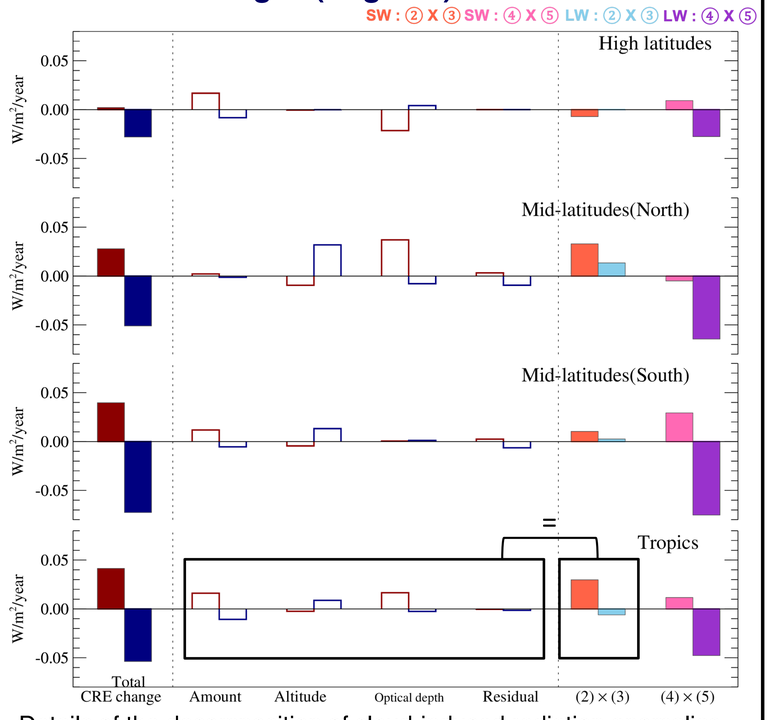
- All-sky, Clear-sky trends for both SW and LW fluxes.

Partitioning CRE changes (Regions)



- Magnitudes of the ②×③ and ④×⑤ terms as well as the direct calculation of ΔCRE(①) for four domains. LW ④×⑤ is big!

Detailed decomposition of radiative flux anomalies due to cloud changes (Regions)



- Details of the decomposition of cloud-induced radiation anomalies into contributions from cloud amount, altitude, optical depth distribution and residual components with four domains.