CERES Joint Science Team Meeting –
The Pattern Effect on
Cloud feedback in CERES

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Cloud:
Changes in clouds can amplify or dampen the global warming
Cloud Feedback

\[ \Delta R_{\text{cloud}} \]

\[ \Delta T_{\text{surface}} \]
Cloud Feedback

\[ \Delta R_{\text{cloud}}: \]
- CERES EBAF Ed 4.1
- CRE = All-sky flux minus clear-sky flux
- adjusted for cloud masking on non-cloud feedbacks using radiative kernels

\[ \Delta T_{\text{surface}}: \]
- ERA5 reanalysis

Time:
2000/03–2020/12
Cloud Feedback

\[ \lambda = 0.53 \pm 0.83 \text{ W/m}^2/\text{K} \]

(90%CI)
Cloud Feedback

Period 1: 2000/03 – 2010/07
Period 2: 2010/08 – 2020/12
Cloud Feedback

\[ \Delta \lambda = 1.6 \pm 1.1 \text{ W/m}^2/\text{K} \ (90\% \text{CI}) \]

Pattern Effect

Period 1: 2000/03 – 2010/07
\[ \lambda = -0.45 \pm 0.85 \text{ W/m}^2/\text{K} \]

Period 2: 2010/08 – 2020/12
\[ \lambda = +1.2 \pm 0.78 \text{ W/m}^2/\text{K} \]
Cloud Feedback

\[ \Delta \lambda = 1.6 \pm 1.1 \text{ W/m}^2/\text{K} \text{ (90\%CI)} \]

Pattern Effect

Period 1: 2000/03 – 2010/07

Geophysical Research Letters

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Pattern effect in CMIP6 models

26 CMIP6 pre-industrial control runs
For each model (~500 years):
Pattern effect in CMIP6 models

\[ \Delta \lambda (W/m^2/K) = \lambda_a - \lambda_b (\lambda_a > \lambda_b) \]
Pattern effect in CMIP6 models

27% of $\Delta \lambda$ fall in the uncertainty range of the observations.

Observed $\Delta \lambda$ (with 90% CI)

$\Delta \lambda = 1.6 \text{ W/m}^2/\text{K}$

27% of $\Delta \lambda$ fall in the uncertainty range of the observations.
Pattern effect in CMIP6 models

$$\Delta \lambda_{\text{cloud}} = \Delta \lambda_{\text{cloud SW}} + \Delta \lambda_{\text{cloud LW}}$$
Pattern effect in CMIP6 models

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Pattern effect in CMIP6 models

\[ \Delta \lambda_{\text{cloud}} = \Delta \lambda_{\text{cloud SW}} + \Delta \lambda_{\text{cloud LW}} \]
Spatial structure of pattern effect:

CERES (Period 1: 2000/03-2010/07)
\[ \lambda = -0.45 \pm 0.85 \text{ W/m}^2/\text{K} \]

CERES (Period 2: 2010/08-2020/12)
\[ \lambda = +1.2 \pm 0.78 \text{ W/m}^2/\text{K} \]
Spatial structure of pattern effect:

\[ \Delta \left( \frac{T}{T_{\text{global}}} \right) \]

**CERES** (Period 1: 2000/03-2010/07)

\[ \lambda = -0.45 \pm 0.85 \text{ W/m}^2/\text{K} \]

**CERES** (Period 2: 2010/08-2020/12)

\[ \lambda = +1.2 \pm 0.78 \text{ W/m}^2/\text{K} \]
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$\lambda = +1.2 \pm 0.78 \text{ W/m}^2/\text{K}$

Mauritsen (2016), Zhou et al. (2017)
Spatial structure of pattern effect:

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Mauritsen (2016), Zhou et al. (2017)
Spatial structure of pattern effect: CERES observations vs. CMIP6 models
Spatial structure of pattern effect:
CERES observations vs. CMIP6 models

\[ \Delta(T/T_{\text{global}}) \]
Spatial structure of pattern effect:
CERES observations vs. CMIP6 models

\( \Delta (T/T_{\text{global}}) \)
Spatial structure of pattern effect: CERES observations vs. CMIP6 models

Δ(T/global) − λ

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Conclusions

✓ Cloud feedbacks are dependent on the surface temperature warming pattern, which is known as pattern effect.

✓ We found a large pattern effect on cloud feedback in CERES data
  o related to the temperature pattern over East Pacific

✓ The CMIP6 models can reproduce the pattern effect with similar magnitude and main features of spatial structure
Supplement
CERES EBAF Ed 4.1: 2000/03-2020/12 (color shading)
CMIP6: ensemble mean of 20-yr feedbacks (black lines)
(a) The ensemble-average feedback differences between 2000-year control run and 68 members of 1%CO₂ ensemble. For the control run, the values are averaged cloud feedbacks derived from non-overlapping 20-year segments. For the 1%CO₂ ensemble, the 20-year period that has ensemble averaged warming of 0.8 K is first identified. The values are the ensemble average of 20-year cloud feedbacks from each member. The uncertainty is 90% confidence intervals. (b-d) The spatial pattern of cloud, cloud SW, cloud LW feedback differences between control run and 1%CO₂ ensemble (color) and the feedbacks from control run (black lines).
Spatial structure of pattern effect:
CERES observations vs. CMIP6 models

\( \Delta (T/T_{\text{global}}) \)

\( \Delta \Lambda \)