Inferring Cloud Radiative Response from CERES FluxByCldtyp

Norman G. Loeb[1], Moguo Sun[2], Tyler J. Thorsen[1], David R. Doelling[1], Seiji Kato[1]

[1]NASA Langley Research Center, Hampton, VA
[2]Analytical Mechanics Associates, Hampton, VA

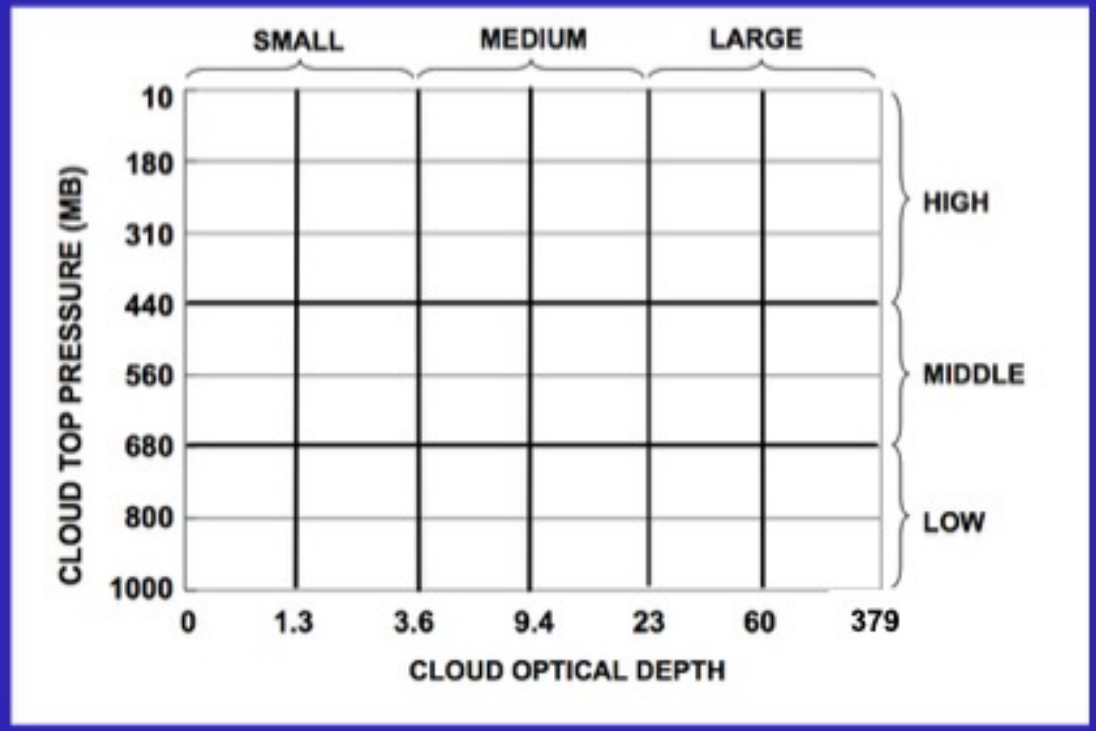
CERES Science Team Meeting, October 27-29, 2026
NASA Langley Research Center, Hampton, VA

OUTLINE

1) **SW TOA Flux Anomaly Comparison**
   - From empirical MODIS narrow-to-broadband regressions and CERES observations

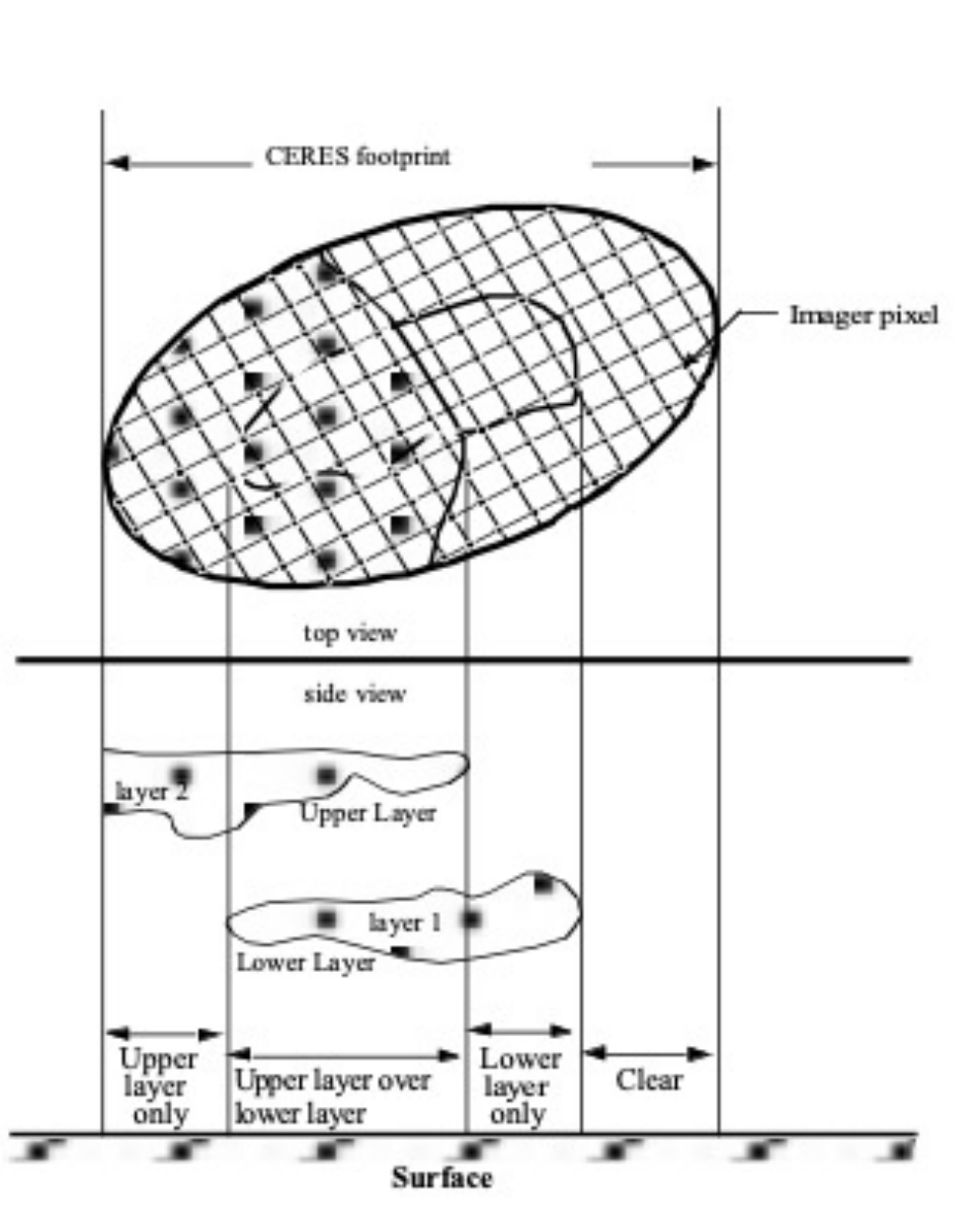
2) **Cloud Radiative Response from FluxByCldTyp**

Flux by Cloud Type (FluxByCldTyp) Data



- A daytime dataset that stratifies CERES observed fluxes and MODIS cloud properties from the SSF data into 42 cloud type bins based on cloud optical depth (tau) and cloud effective pressure.
- **Motivation**: To provide the community a data set with both radiative fluxes and cloud properties by cloud type for modeling and observational studies.

CERES SSF Footprint



- A CERES footprint is subdivided into Clear, Cloud Layer 1 and Cloud Layer 2 sub-footprint areas.
- Infer broadband flux for each sub-footprint area from MODIS pixel information.
  - Empirical narrow-to-broadband regressions
  - CERES ADMs
- Normalize the computed footprint flux with observed CERES observation.
- Stratify fluxes into P_c–τ cloud types

1. SW TOA Flux Anomaly Comparison

FBCT Offline Tests

- Static NB2BB regressions between MODIS and CERES:
  - NB2BB training period: 2007-2011
  - MODIS spectral bands (Edition 4):
    - SW: 0.47, 0.65, 0.86 μm
    - LW: 11 μm, 12 μm

1. Normalized (Official product):

- Each footprint normalized to CERES TOA flux

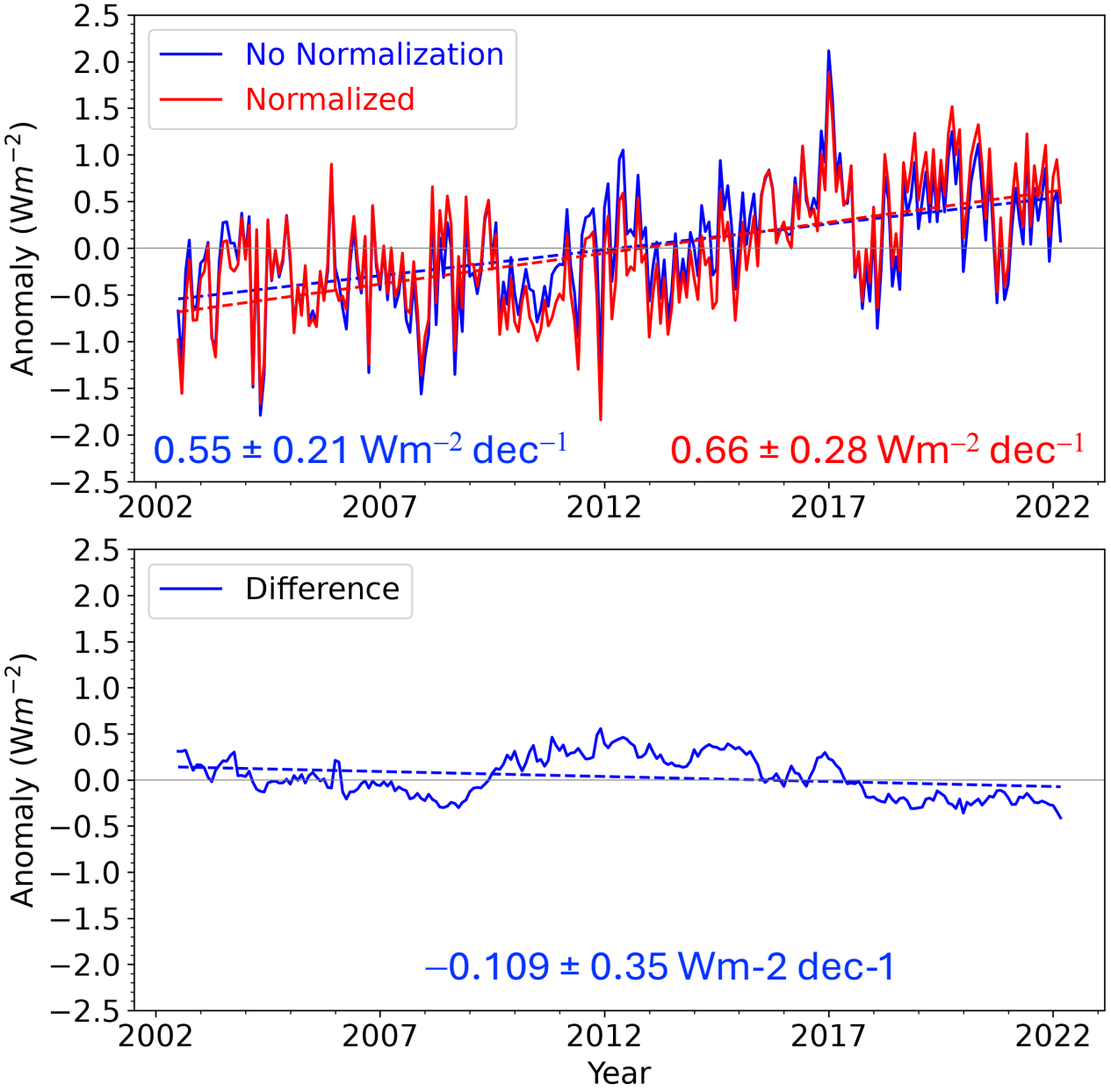
2. No Normalization (Test case):

- Variability entirely from MODIS

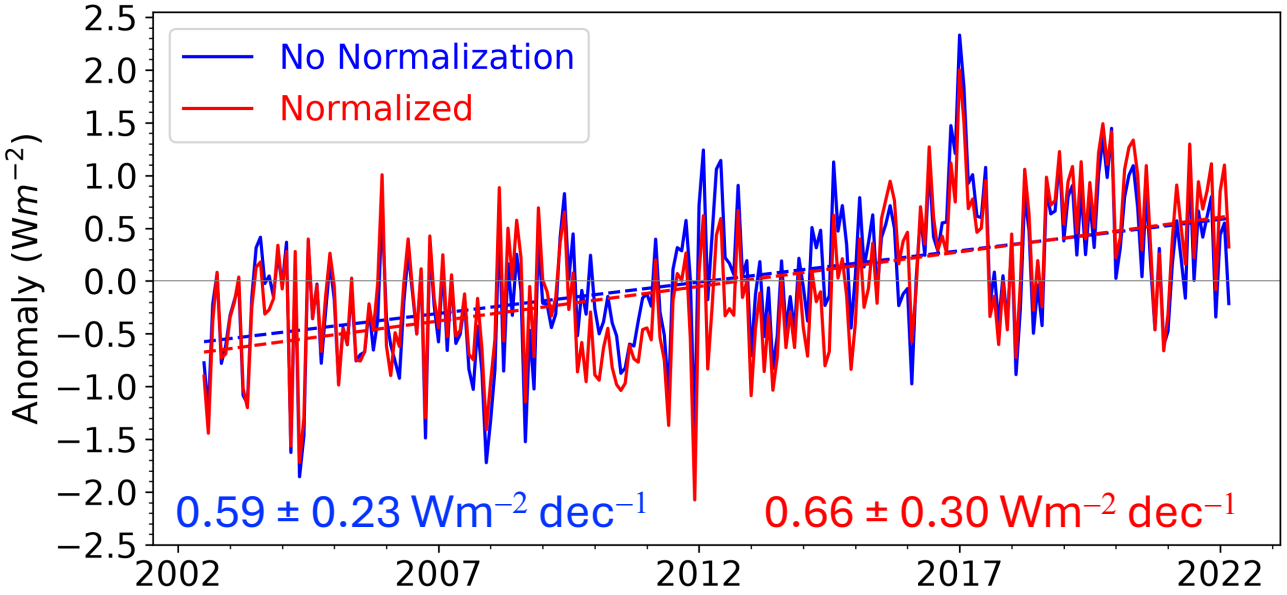
Analysis Period: July 2002–March 2022

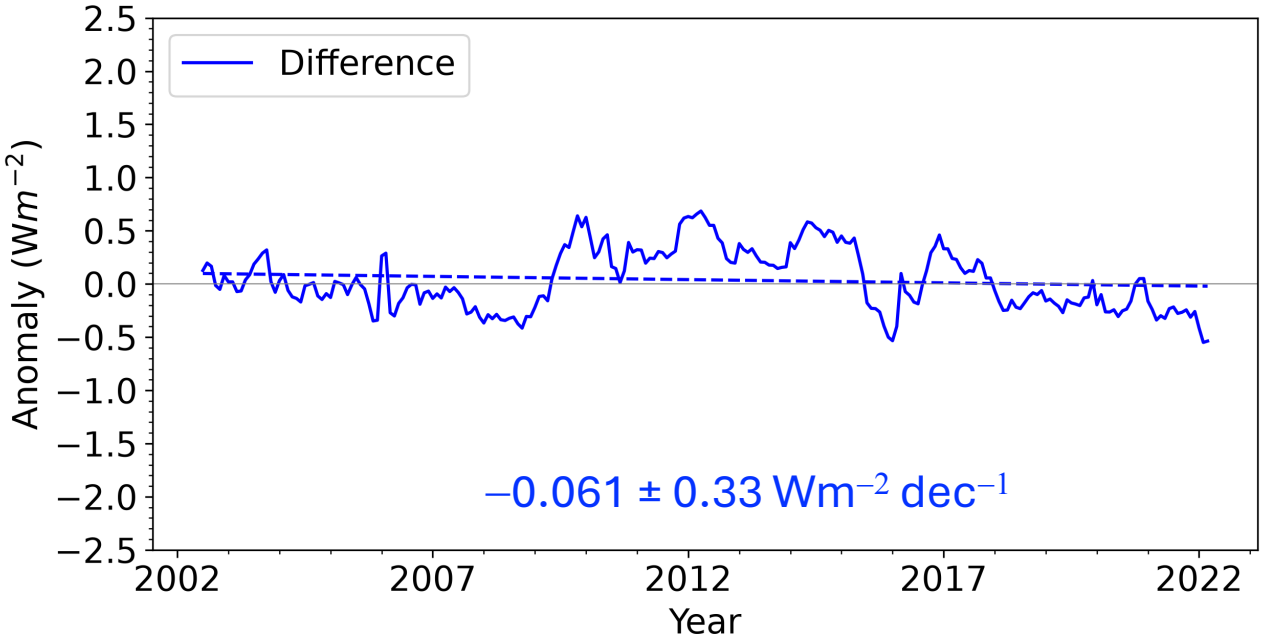
MLT Drift	Terra (min)	Aqua (min)
Mar 2022	7	1
Feb 2023	19	9

All-Sky SW TOA Flux Anomaly (07/2002-03/2022; Terra+Aqua; +ve down)

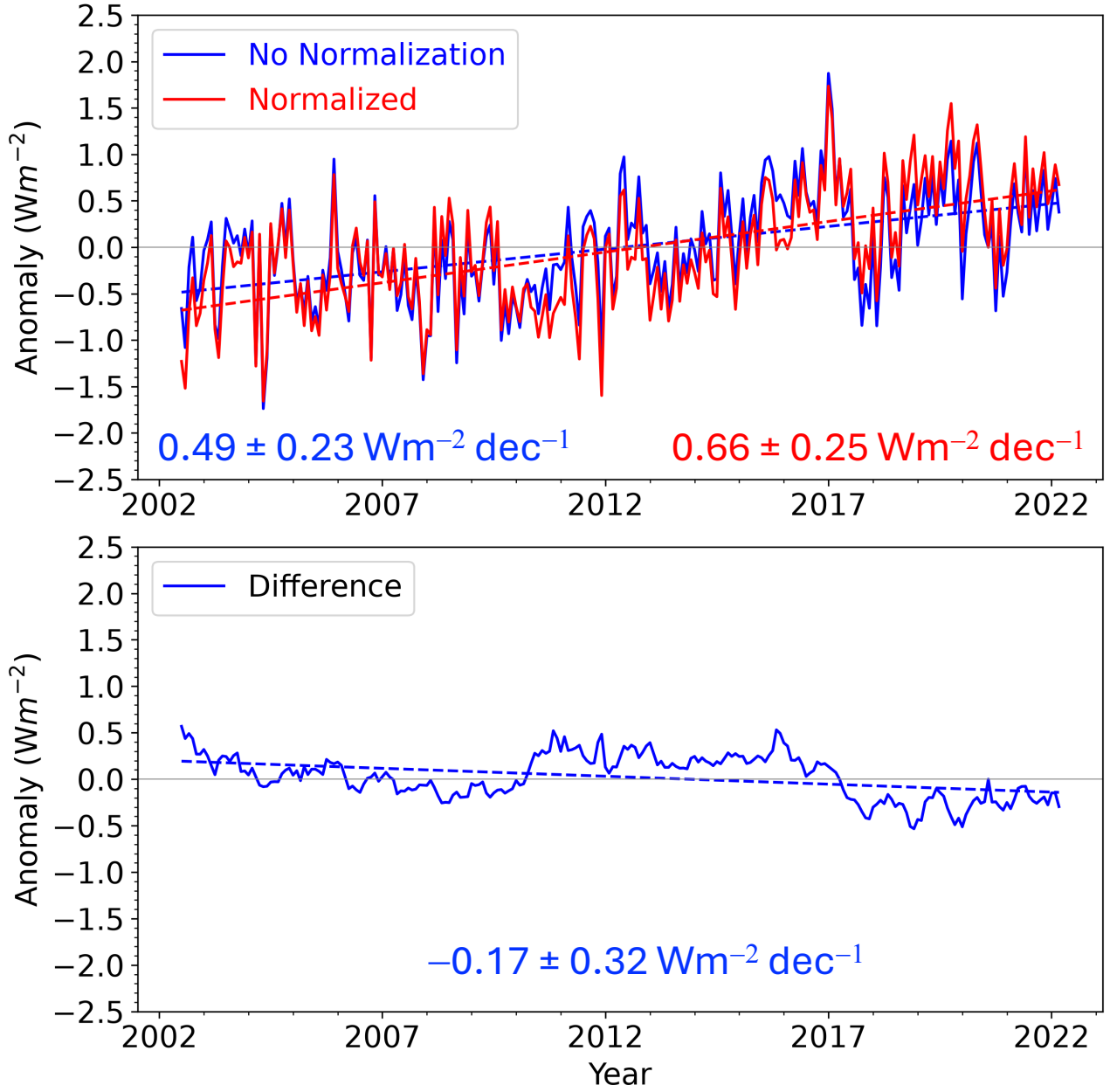


All-Sky SW TOA Flux Anomaly (07/2002-03/2022; Terra; +ve down)

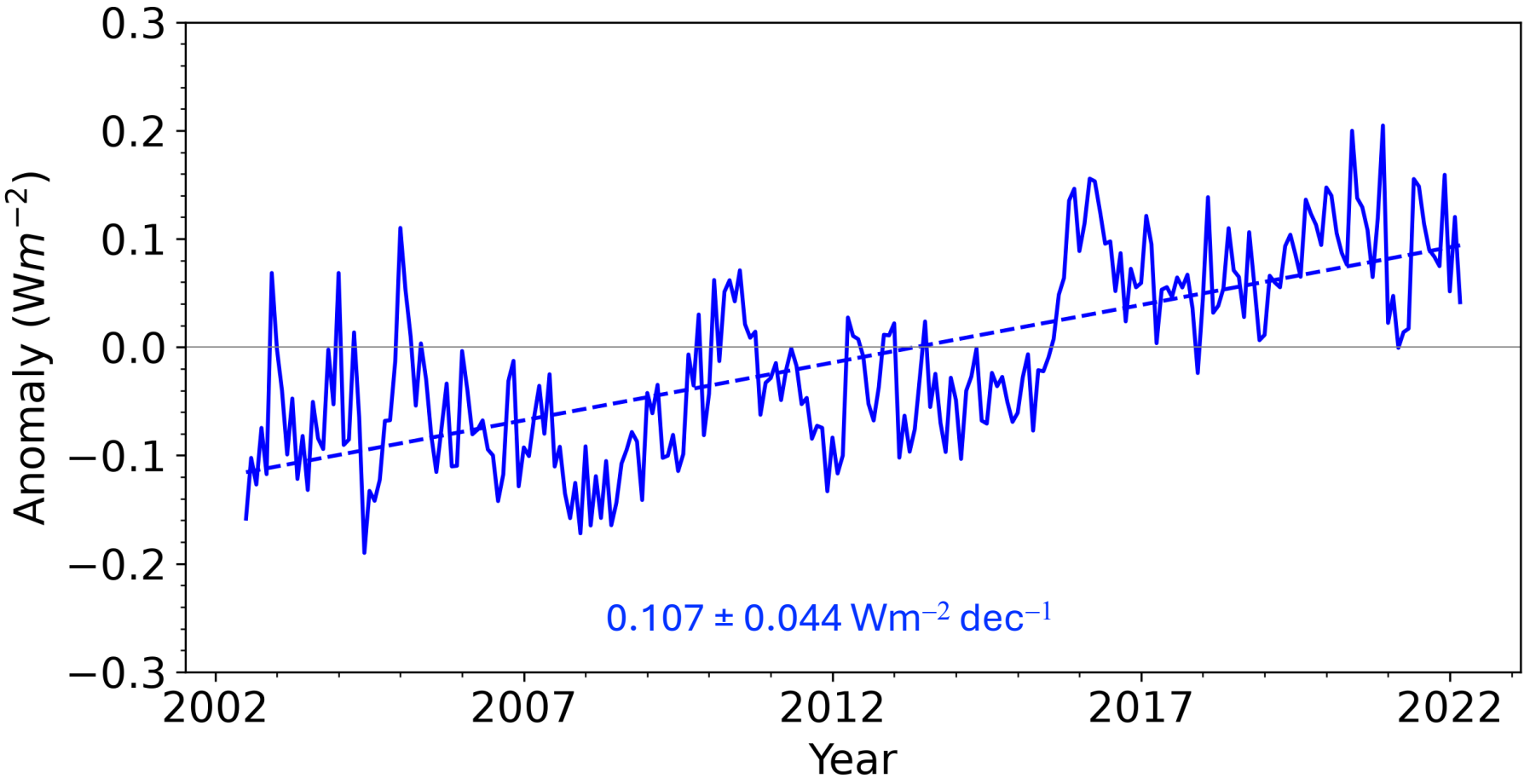




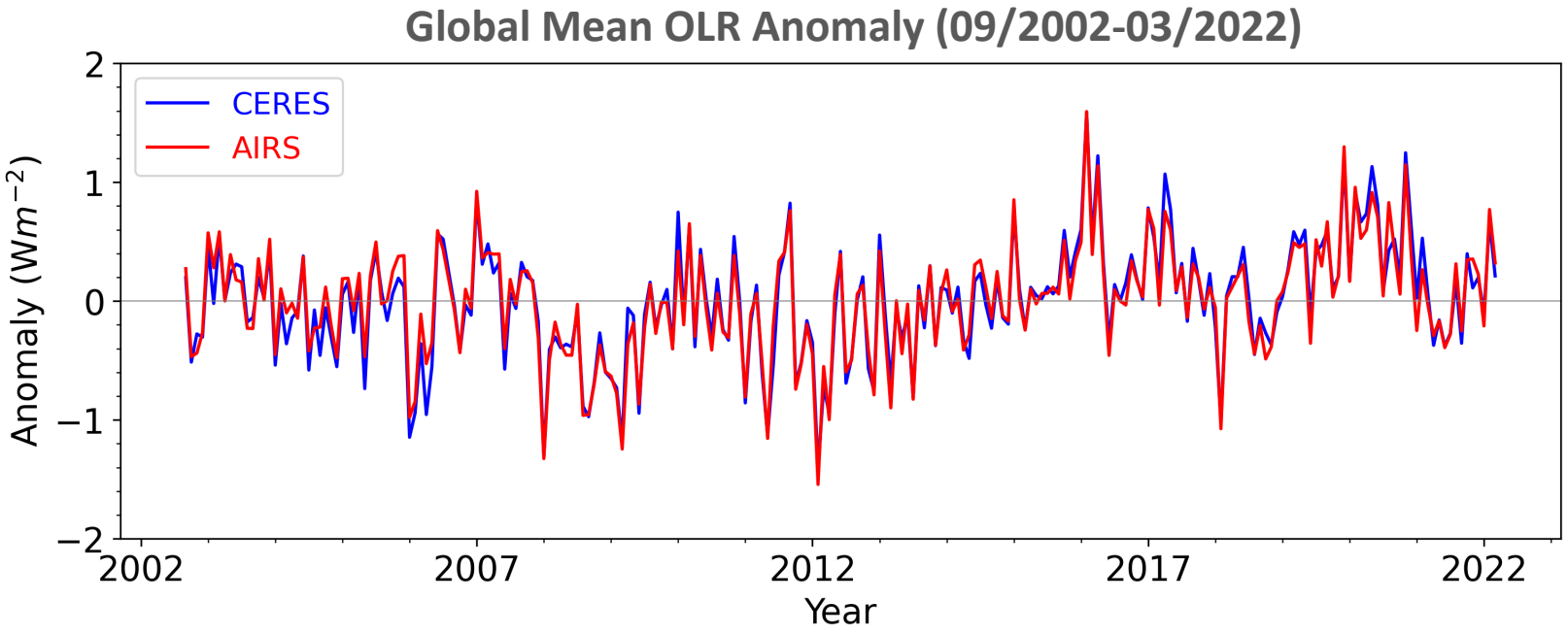
All-Sky SW TOA Flux Anomaly (07/2002-03/2022; Aqua; +ve down)

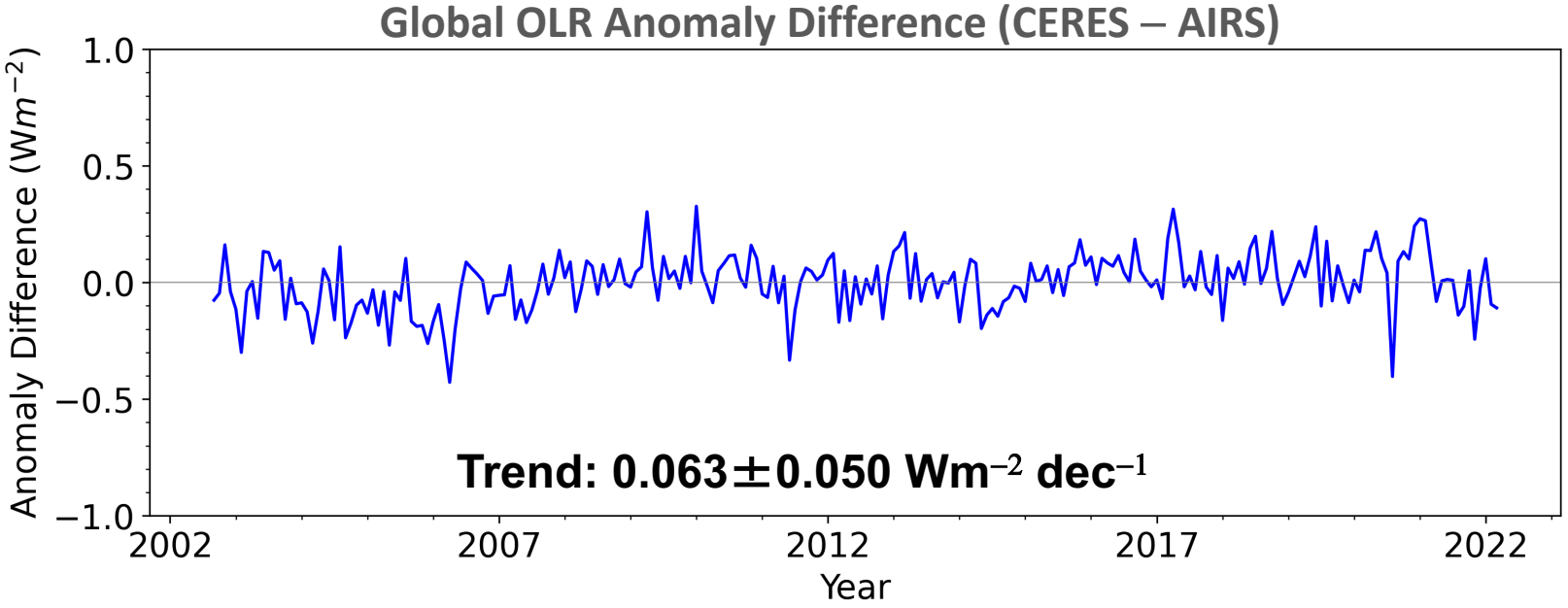


Water Vapor Contribution to All-Sky SW TOA Flux Anomaly
(Partial Radiative Perturbation Analysis)



- Accounting of water vapor contribution to all-sky ASR trend in No Normalization case would make No Normalization and Normalized trends agree to within 0.1 Wm-2 dec-1


Global Mean OLR Anomaly (09/2002-03/2022)
CERES
AIRS
Anomaly (Wm^{-2})
2
1
0
−1
−2
2002
2007
2012
2017
2022
Year


Global OLR Anomaly Difference (CERES – AIRS)
Anomaly Difference (Wm^{-2})
1.0
0.5
0.0
−0.5
−1.0
Trend: 0.063±0.050 Wm^{-2} dec^{-1}
2002
2007
2012
2017
2022
Year

2. Cloud Radiative Response from FBCT Product

All-Sky Decomposition

$$F_{all} = (1 - f)F_{clr} + \sum_j f_j F_{ovc_j} \quad (1)$$

$$f = \sum_j f_j \quad (2)$$

$$dF_{all} = (1 - \bar{f})dF_{clr} + \sum_j (\bar{F}_{ovc_j} - \bar{F}_{clr})df_j + \sum_j \bar{f}_j dF_{ovc_j} + \sum_j (dF_{ovc_j} - dF_{clr})df_j \quad (3)$$

$$dF_{cld-con} = \sum_j (\bar{F}_{ovc_j} - \bar{F}_{clr})df_j + \sum_j \bar{f}_j dF_{ovc_j} \quad (4)$$

$$CRR = dF_{cld-con} - \sum_j \bar{f}_j dF_{ovc_j}^{non-cld} \quad (5)$$

$$CRR = dF_{cld-con} - (dF_{all}^{non-cld} - (1 - \bar{f})dF_{clr}) \quad (6)$$

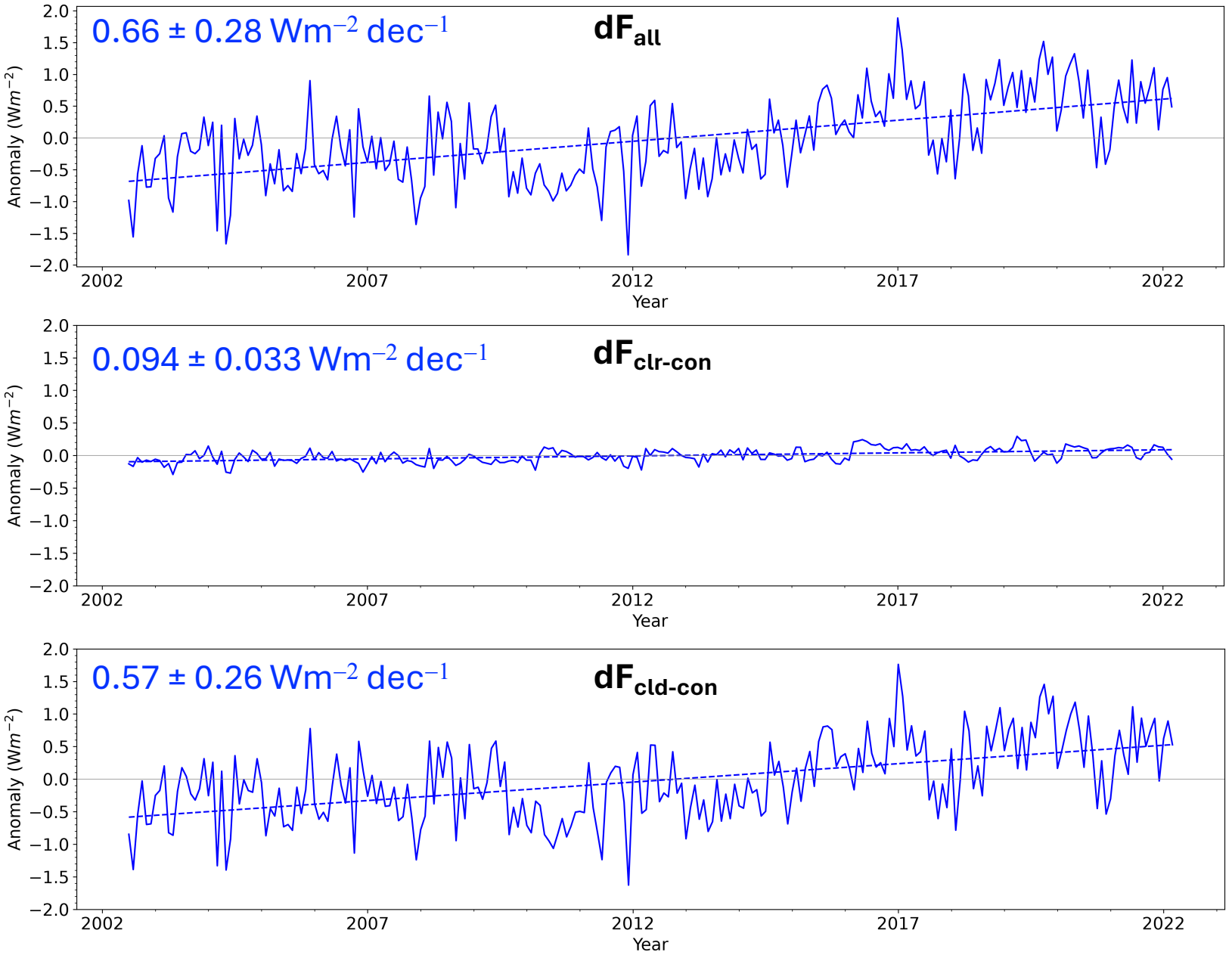
$dF_{cld-con}$ => Flux by Cloud Type

$dF_{all}^{non-cld}$ => Partial Radiative Perturbation (PRP) Method

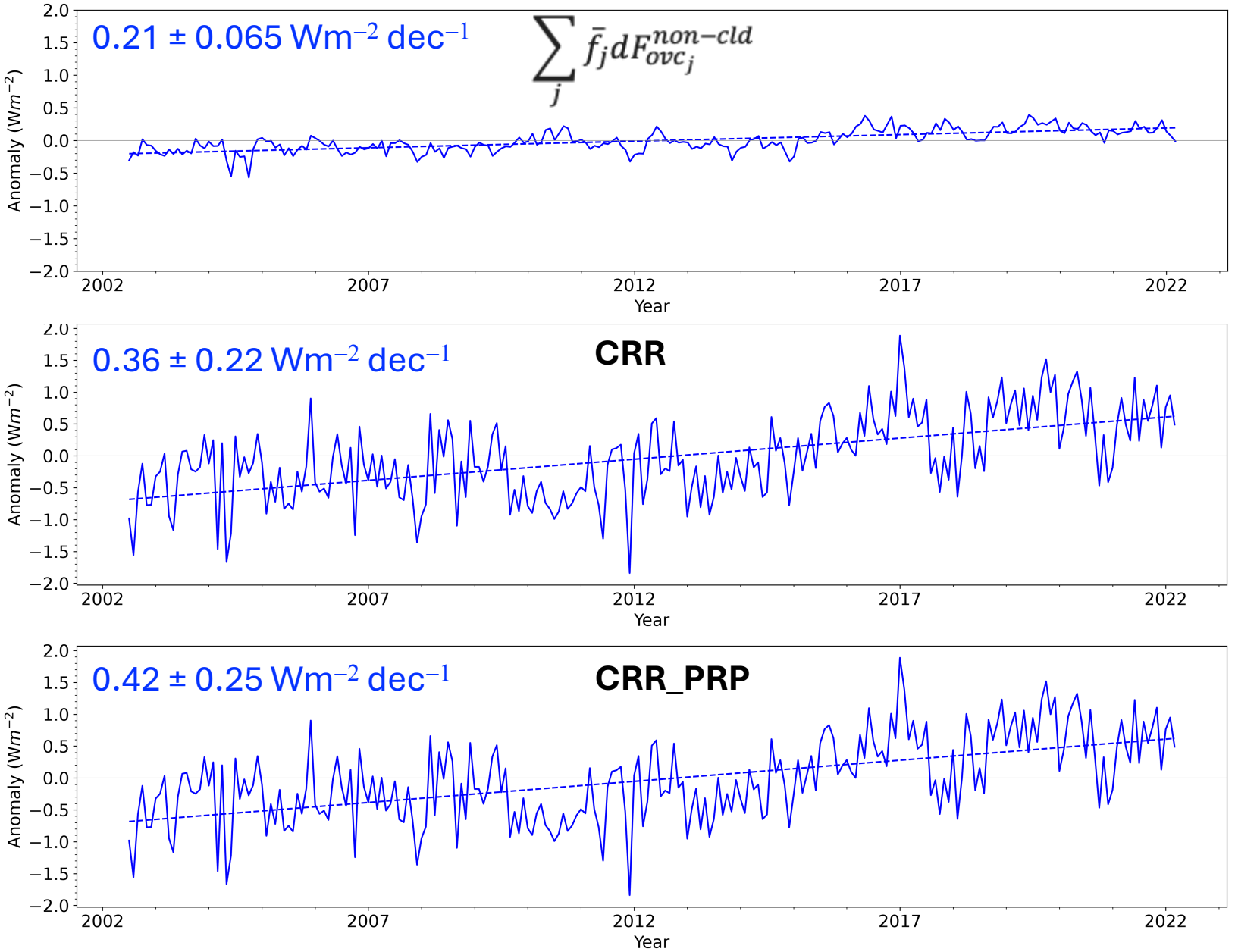
dF_{clr} => Partial Radiative Perturbation (PRP) Method

SW All-Sky Decomposition (07/2002-03/2022)

All-Sky SW TOA Flux Anomaly Decomposition

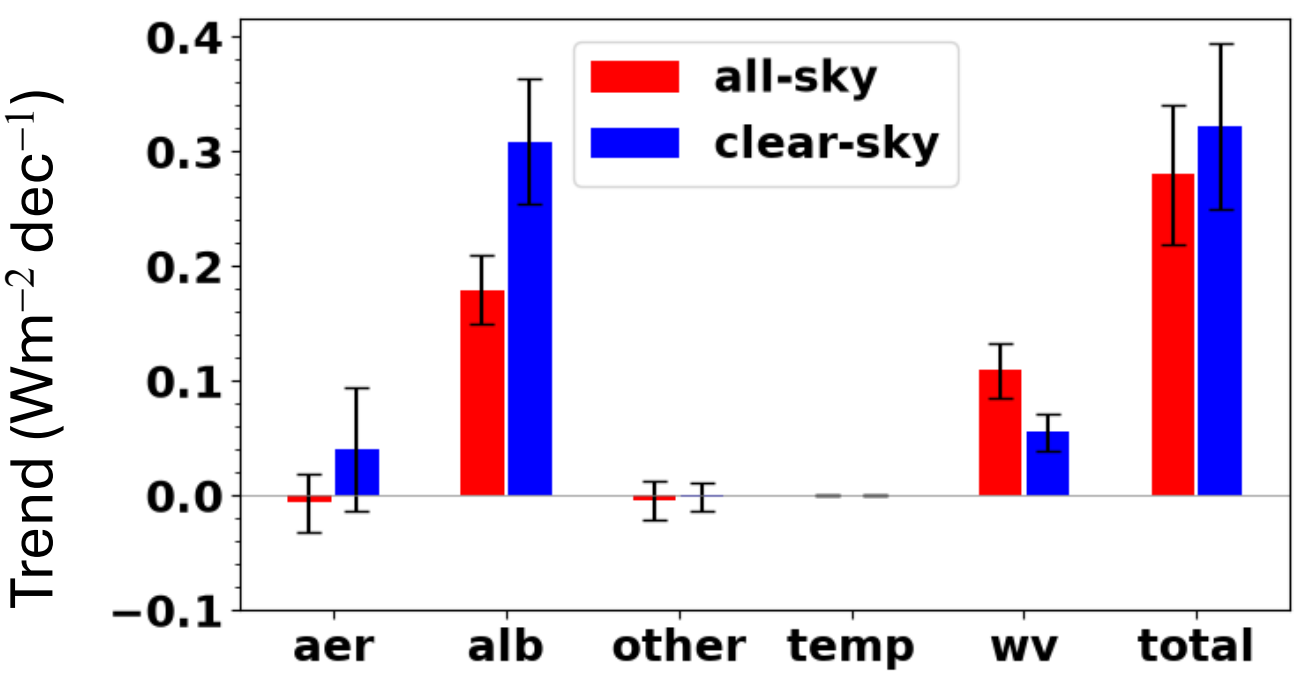


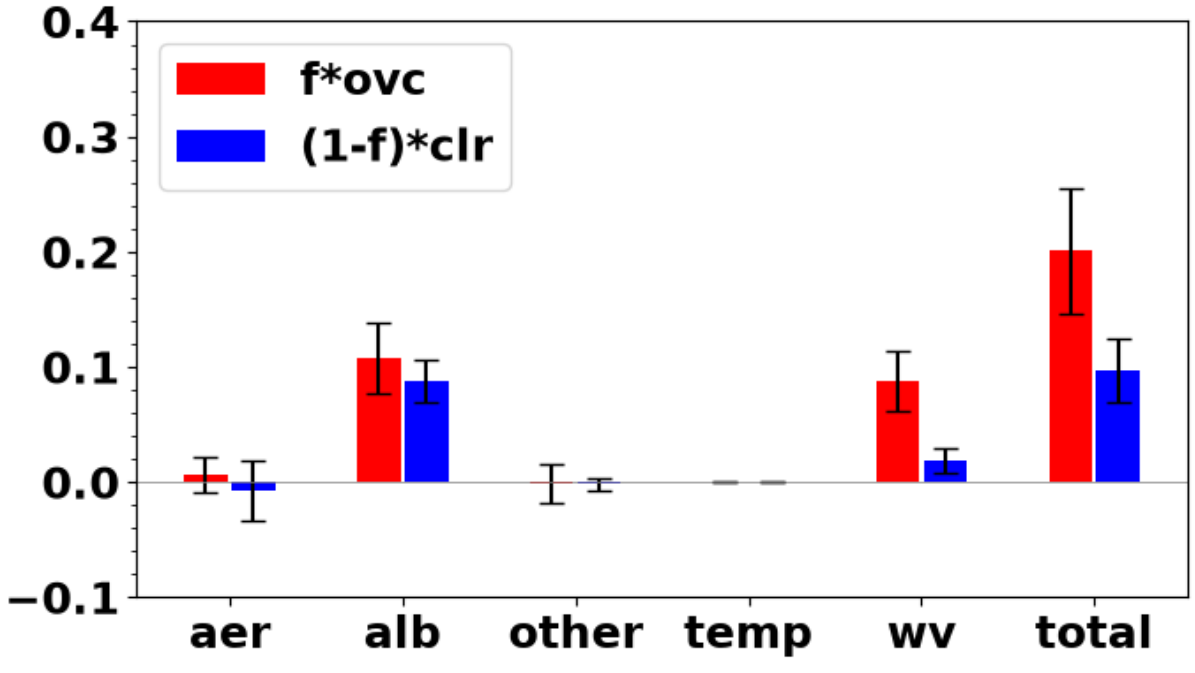
All-Sky SW TOA Flux Anomaly Decomposition



Non-Cloud Trend Contribution (SW)

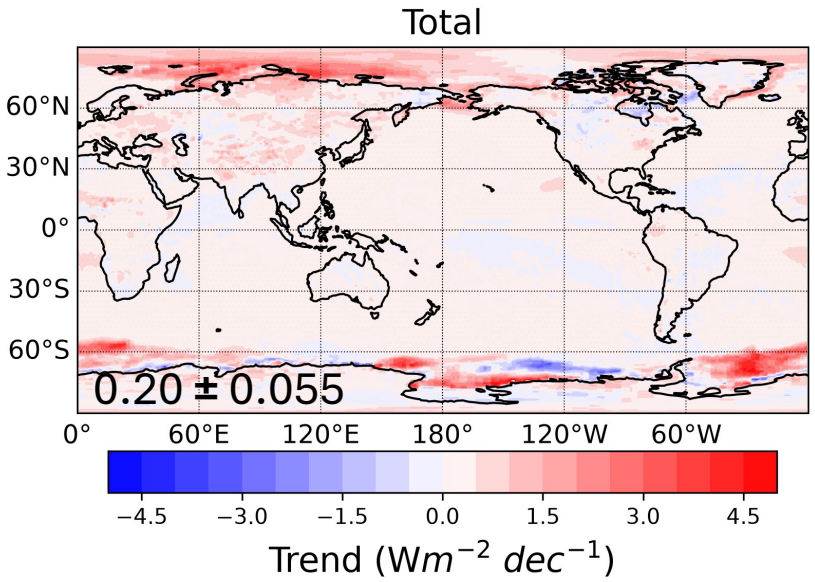
(Partial Radiative Perturbation Analysis)

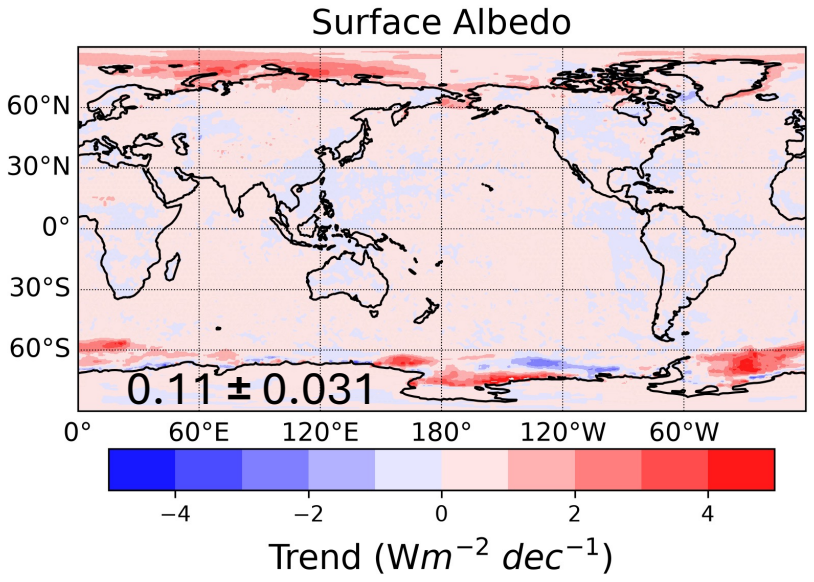


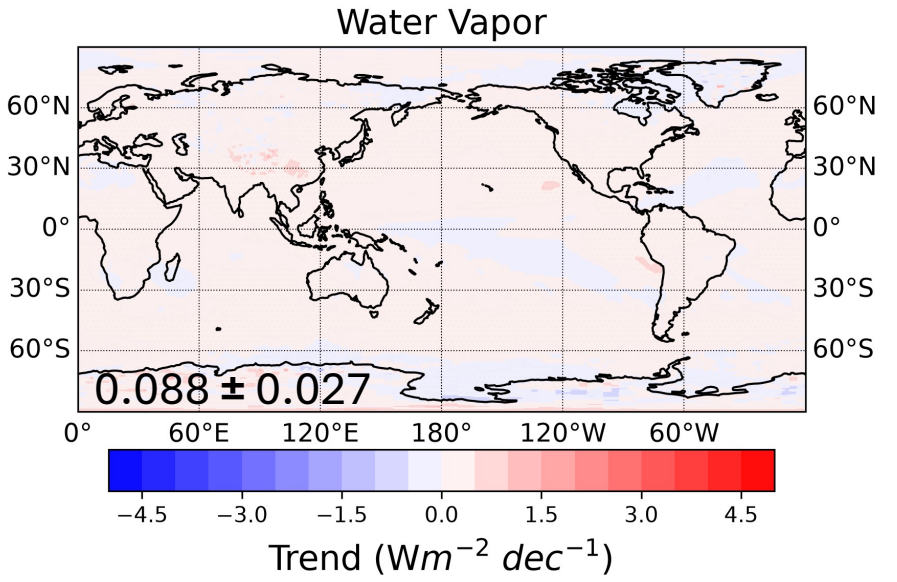


Overcast Non-Cloud Trend Contribution (SW)

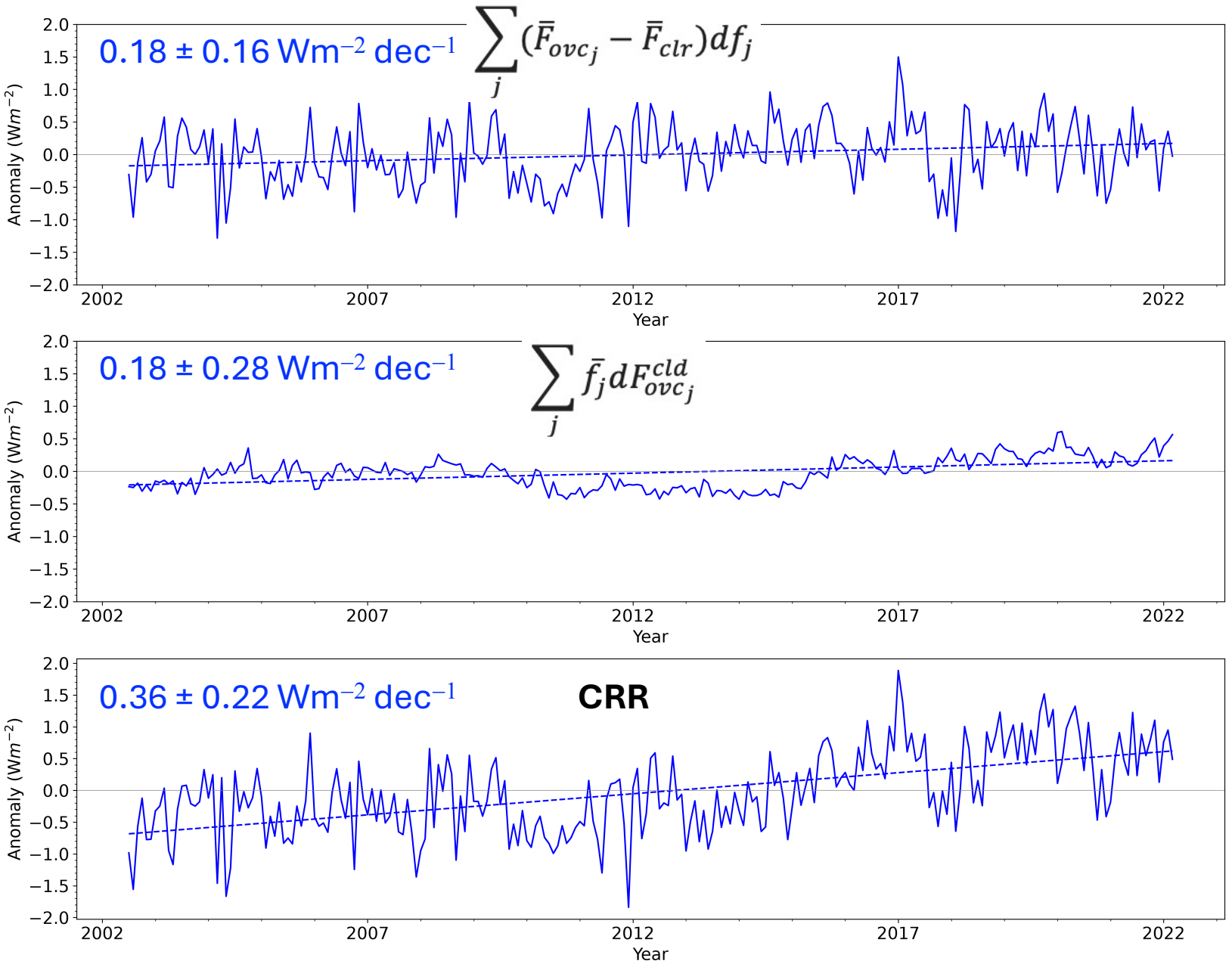
$$\sum_j \bar{f}_j dF_{ovc_j}^{non-cld}$$





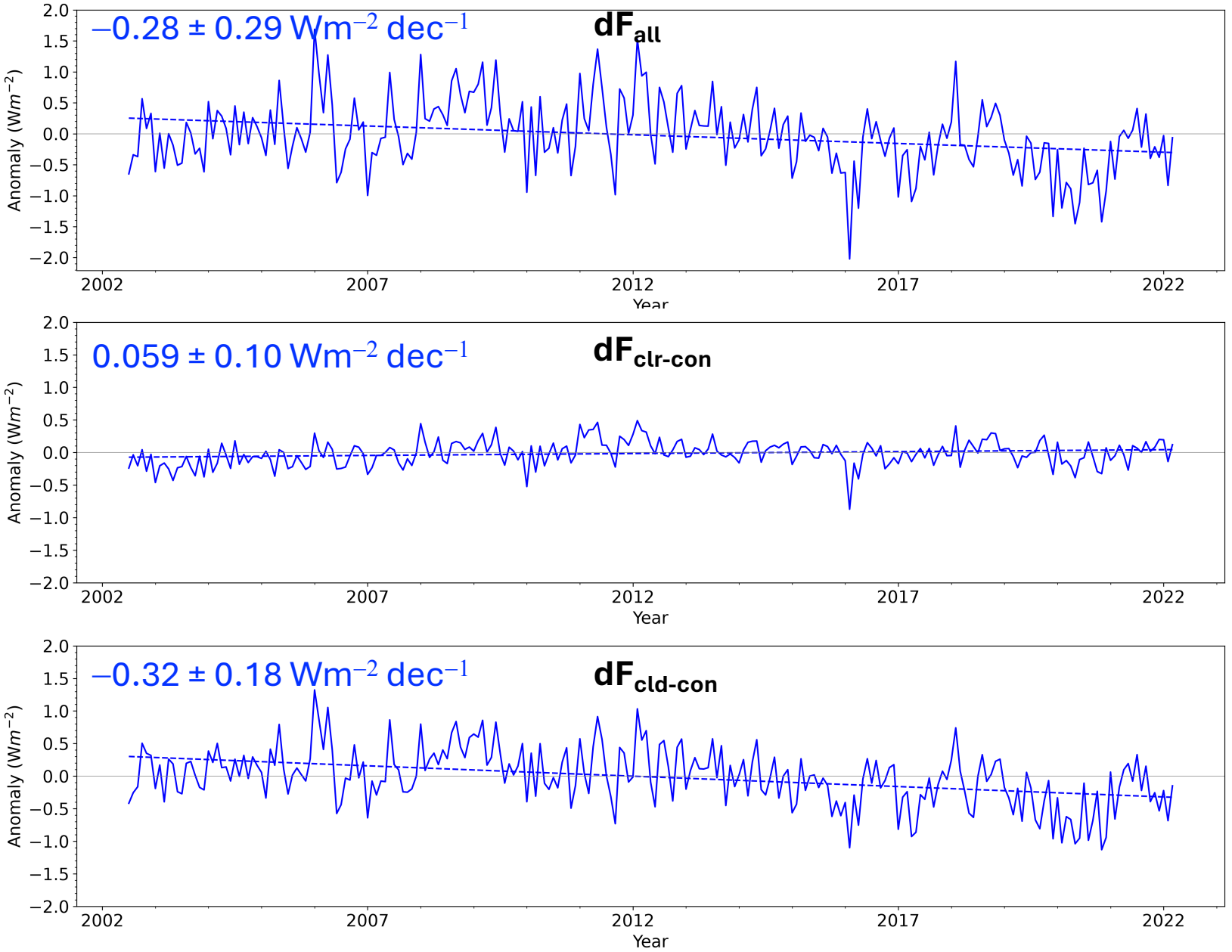


SW CRR Decomposition

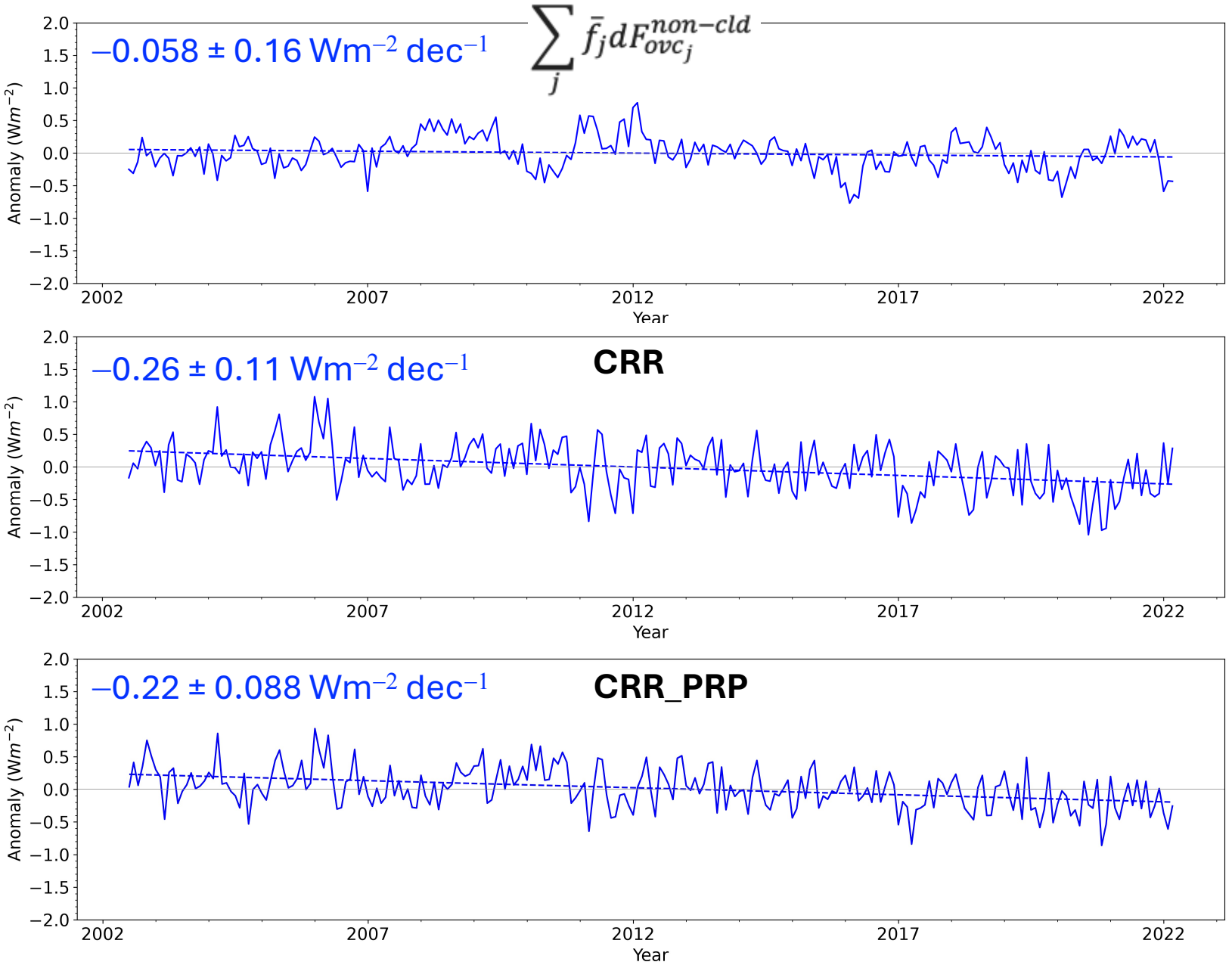


LW All-Sky Decomposition (07/2002-03/2022)

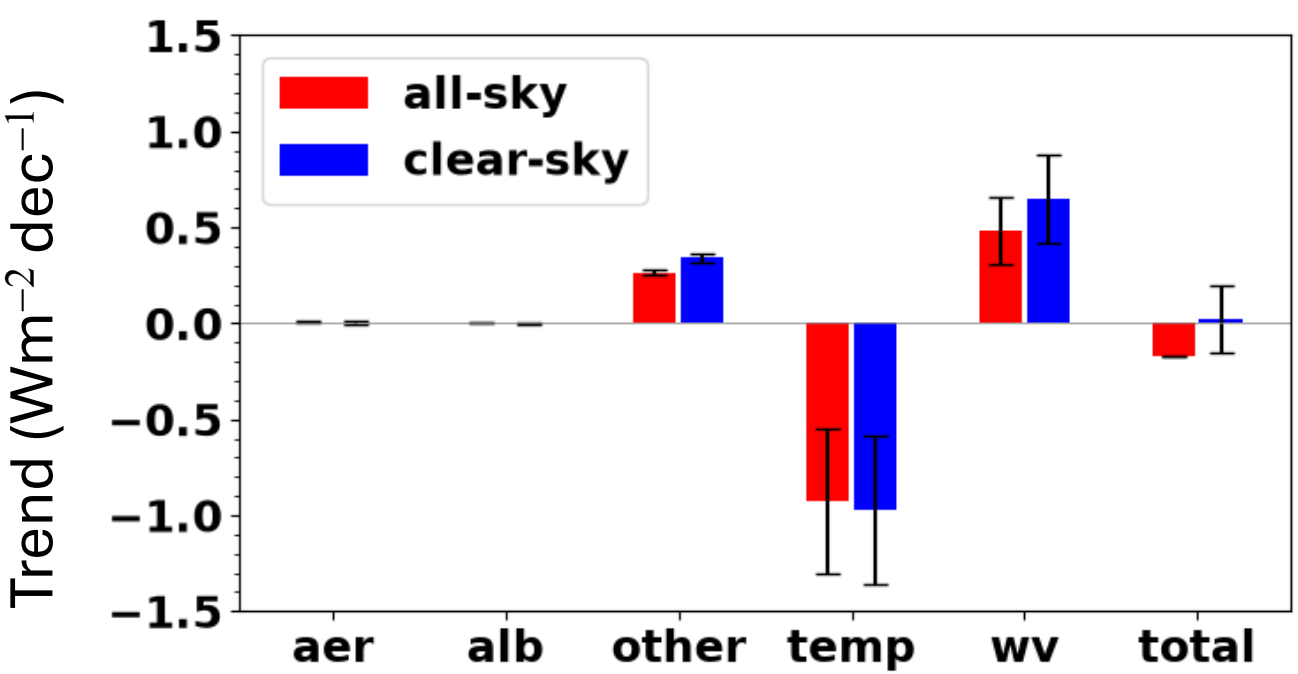
All-Sky LW TOA Flux Anomaly Decomposition

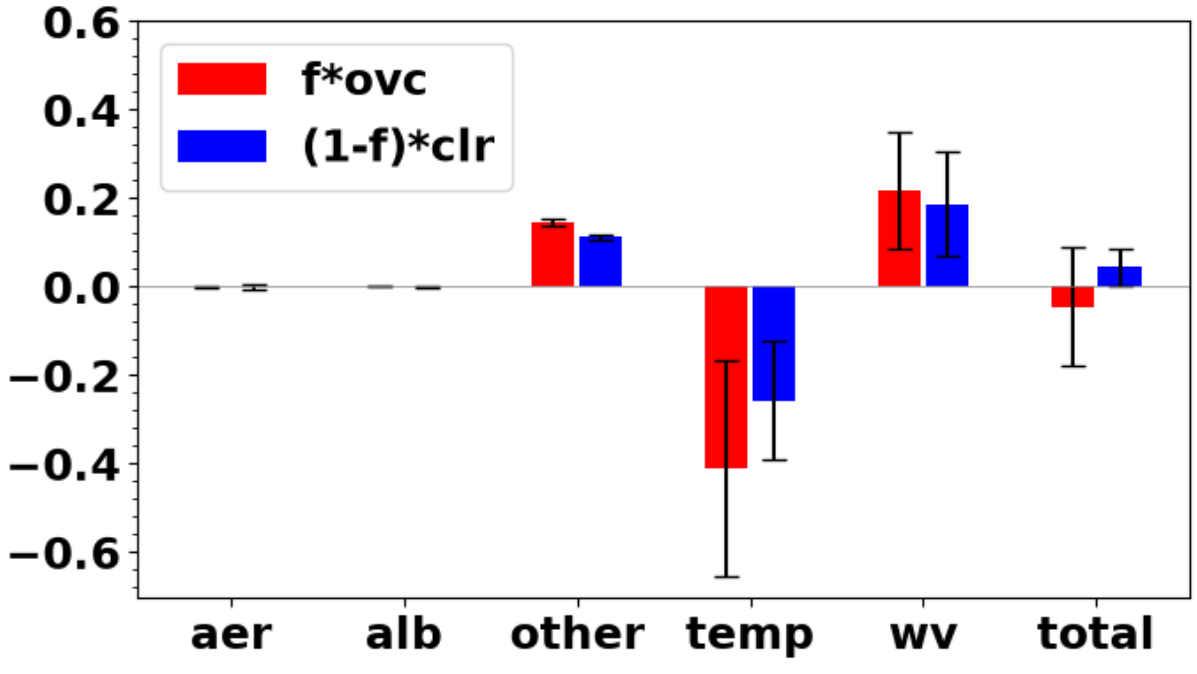


All-Sky LW TOA Flux Anomaly Decomposition



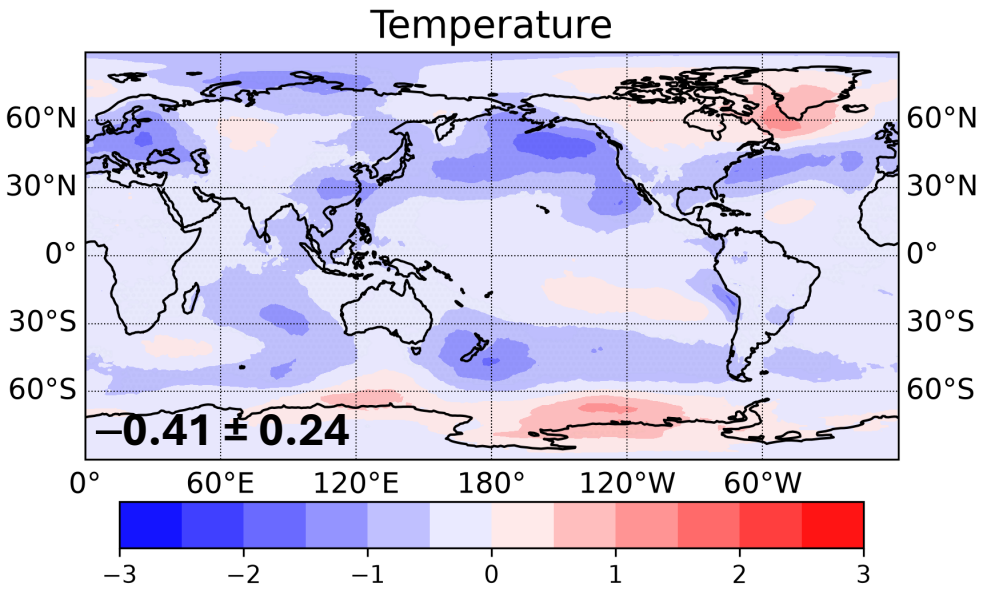
Non-Cloud Trend Contribution (LW)

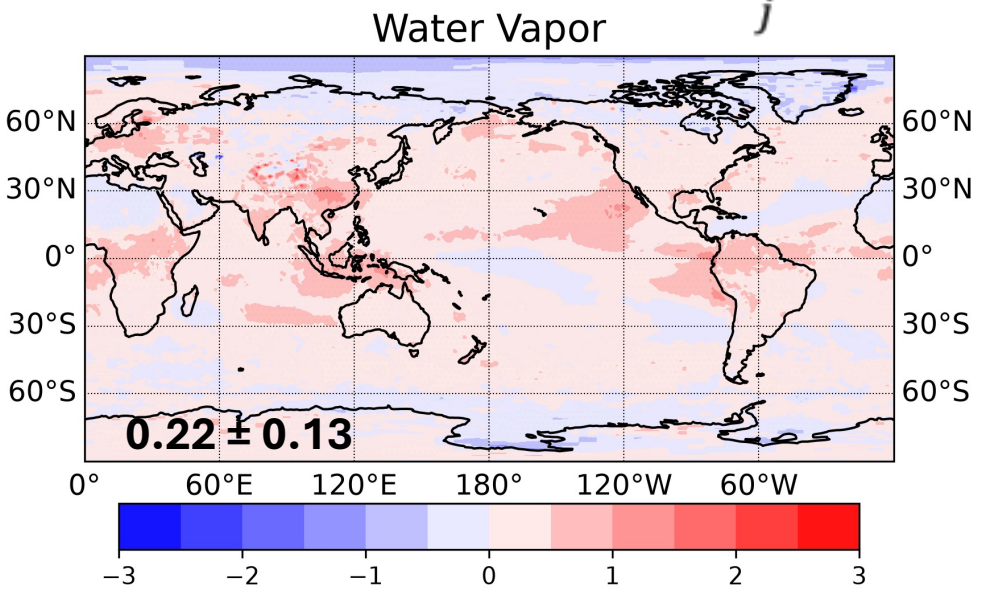


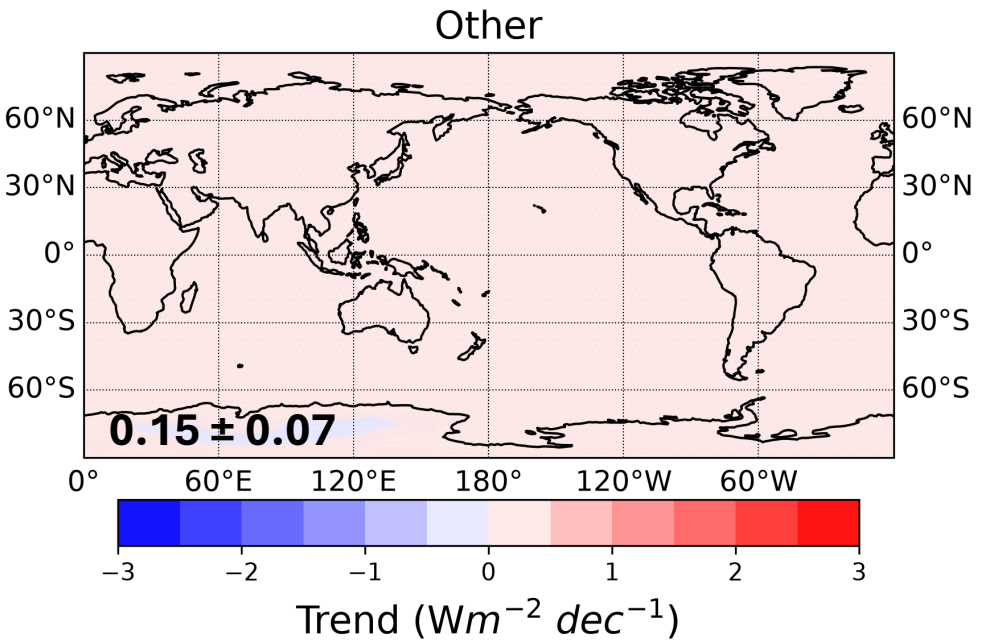


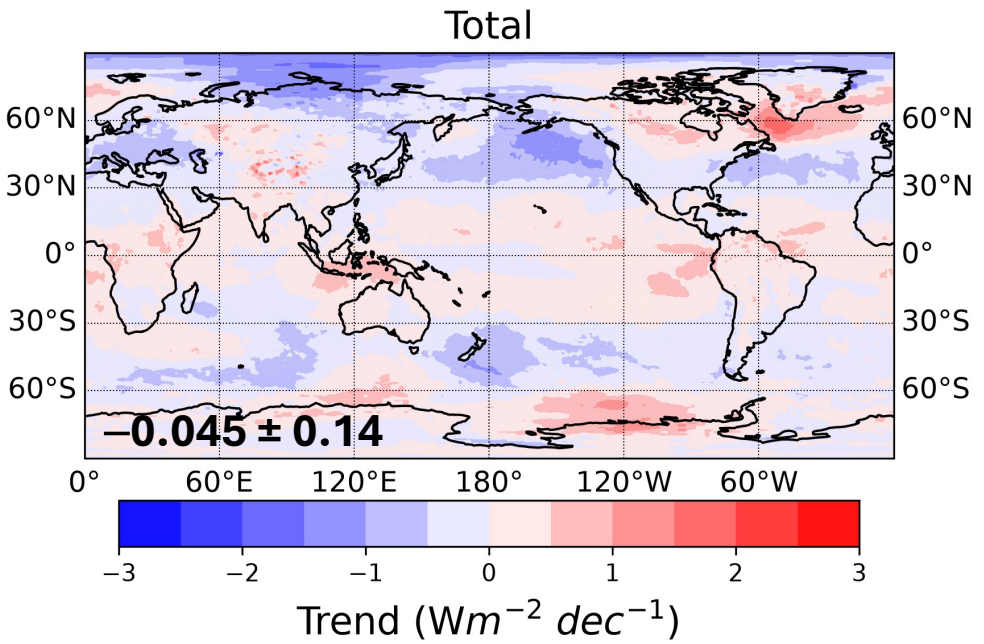
Overcast Non-Cloud Trend Contribution (LW)

$$\sum_j \bar{f}_j dF_{ovc_j}^{non-cld}$$

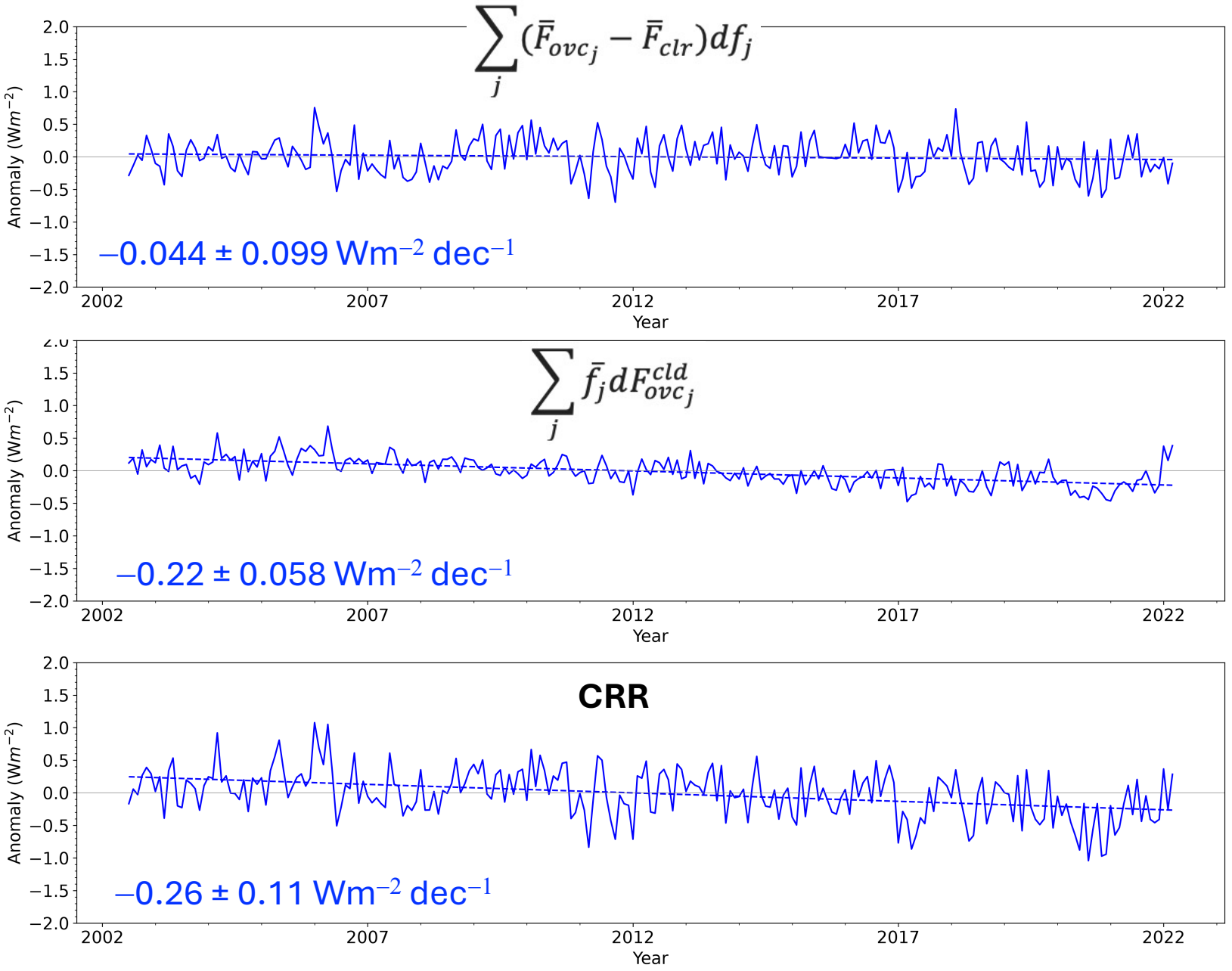








LW CRR Decomposition



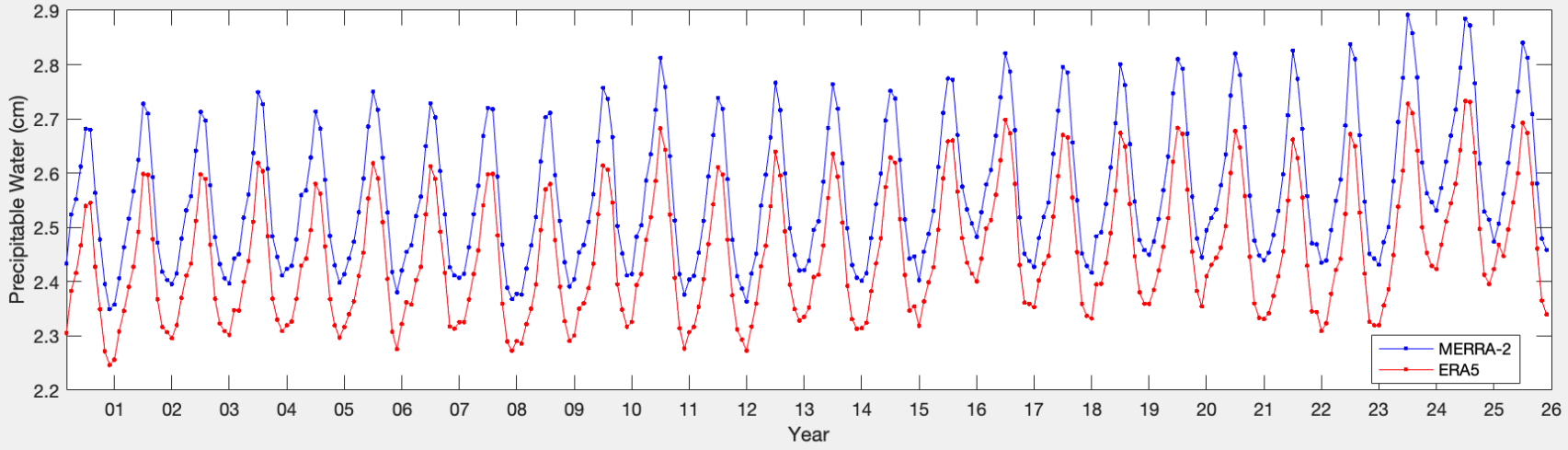
Conclusions

1) **SW TOA Flux Anomaly Comparison**
   - When accounting for water vapor changes, MODIS-inferred SW trend for 07/2002-03/2022 appears to be consistent with CERES (Edition 4).
   - Will repeat comparison with Edition 5 FluxByCldTyp (C7 MODIS calibration, more spectral bands).
2) **Cloud Radiative Response from FluxByCldTyp**
   - Short-term (monthly) variability in cloud radiative response is mostly explained by variations in cloud fraction.
   - Trends:

Trend (Wm^{-2} dec^{-1})	$\sum_j (\bar{F}_{ovc_j} - \bar{F}_{clr}) df_j$ (FBCT)	$\sum_j \bar{f}_j dF_{ovc_j}$ (FBCT)	$\sum_j \bar{f}_j dF_{ovc_j}^{non-cld}$ (PRP)	CRR
SW	0.18	0.39	0.21	0.36
LW	–0.04	–0.28	–0.06	–0.26

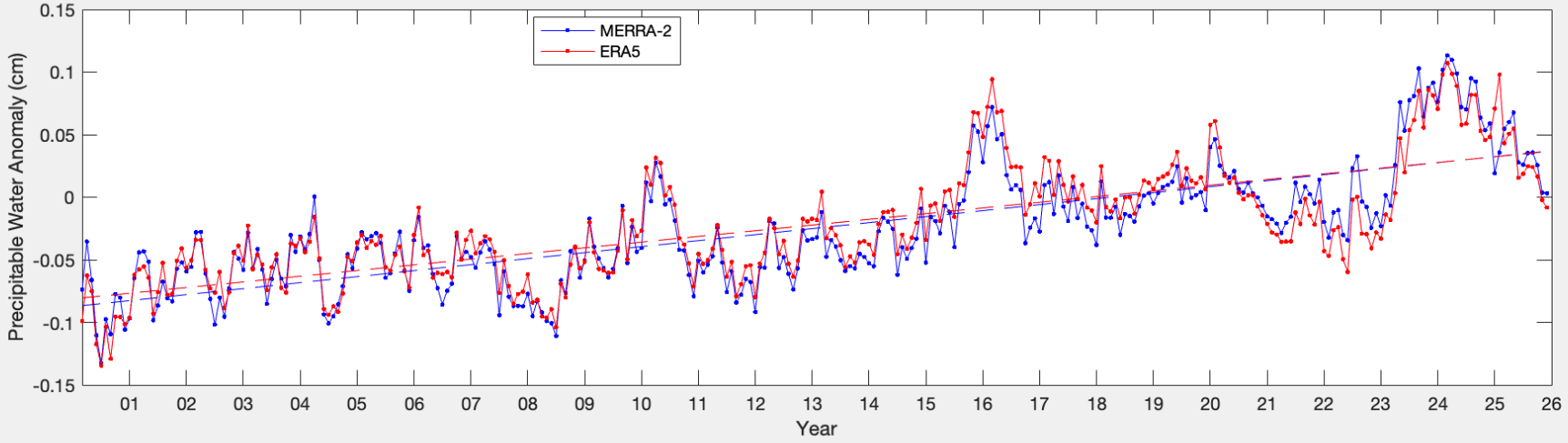
Backup Slides

March 2000 to December 2025



MERRA-2 annual mean
2.590 cm

ERA5 annual mean
2.474 cm

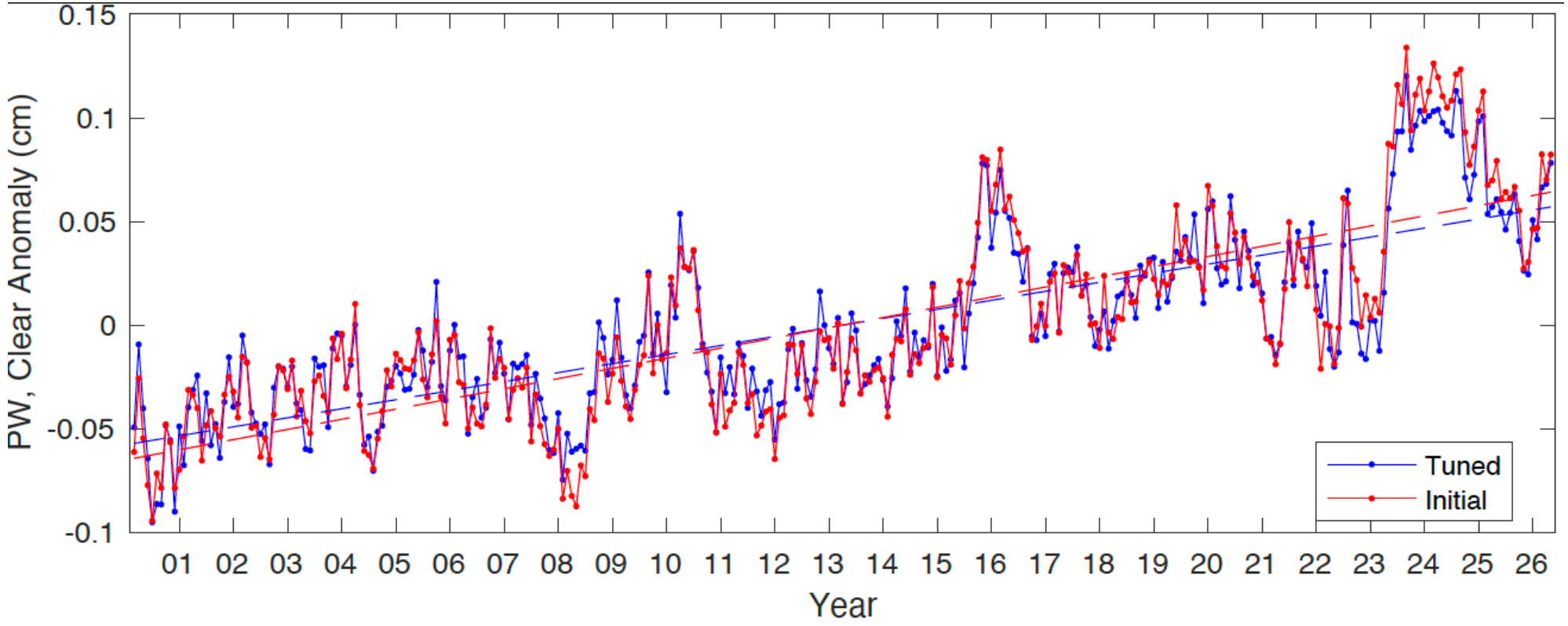


MERRA-2
0.0479 cm dec-1

ERA5
0.0454 cm dec-1

0.1% dec-1 difference

Tuned (PRP) and Initial (Merra-2) Precipitable Water (cm)



Initial
0.0491 cm dec-1

Tuned
0.0436 cm dec-1

Regional trend adjustment (cm dec^{-1})

