

Earth's East-West Albedo Symmetry

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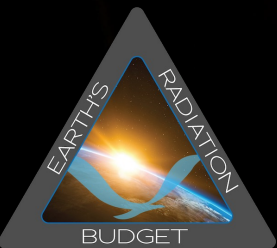
¹CIRES, University of Colorado Boulder

²NOAA Chemical Sciences Laboratory (CSL)

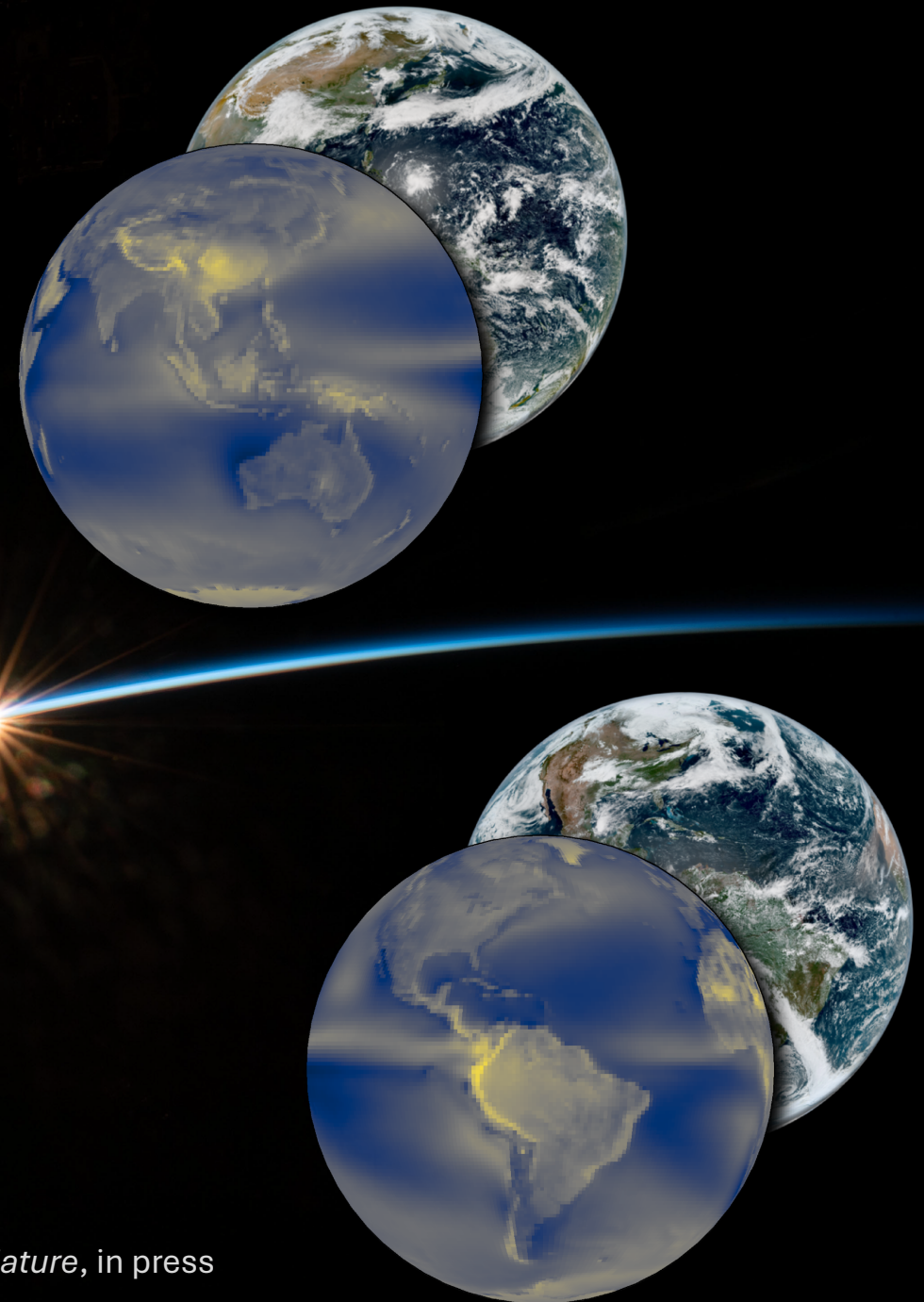
³LASP, University of Colorado Boulder

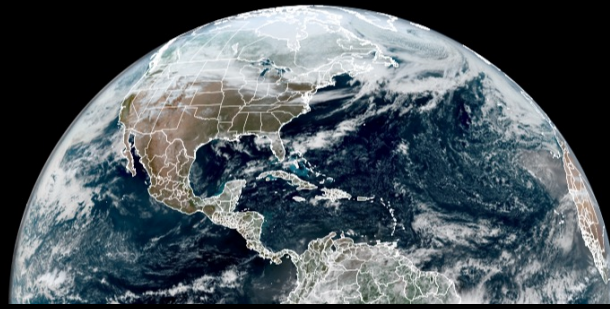


CERES STM, May 13, 2026



Zhang, Gristey, Feingold (2026), *Nature*, in press





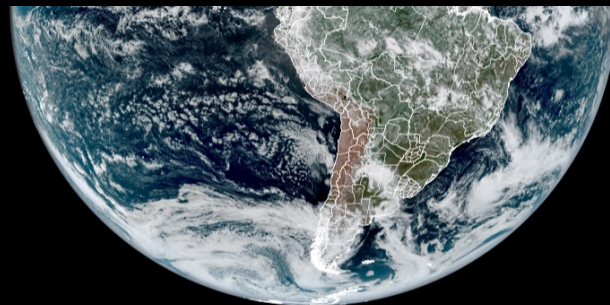
Measurements of the Earth's Radiation Budget from Satellites During a Five-Year Period. Part I: Extended Time and Space Means

THOMAS H. VONDER HAAR¹ AND VERNER E. SUOMI

Dept. of Meteorology, The University of Wisconsin, Madison

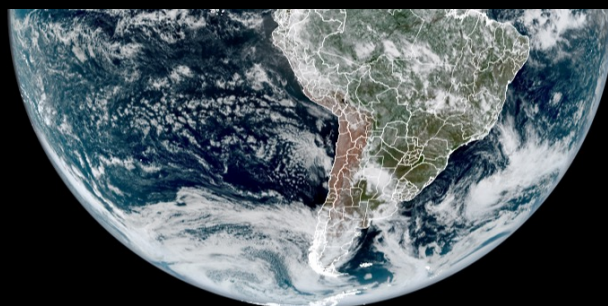
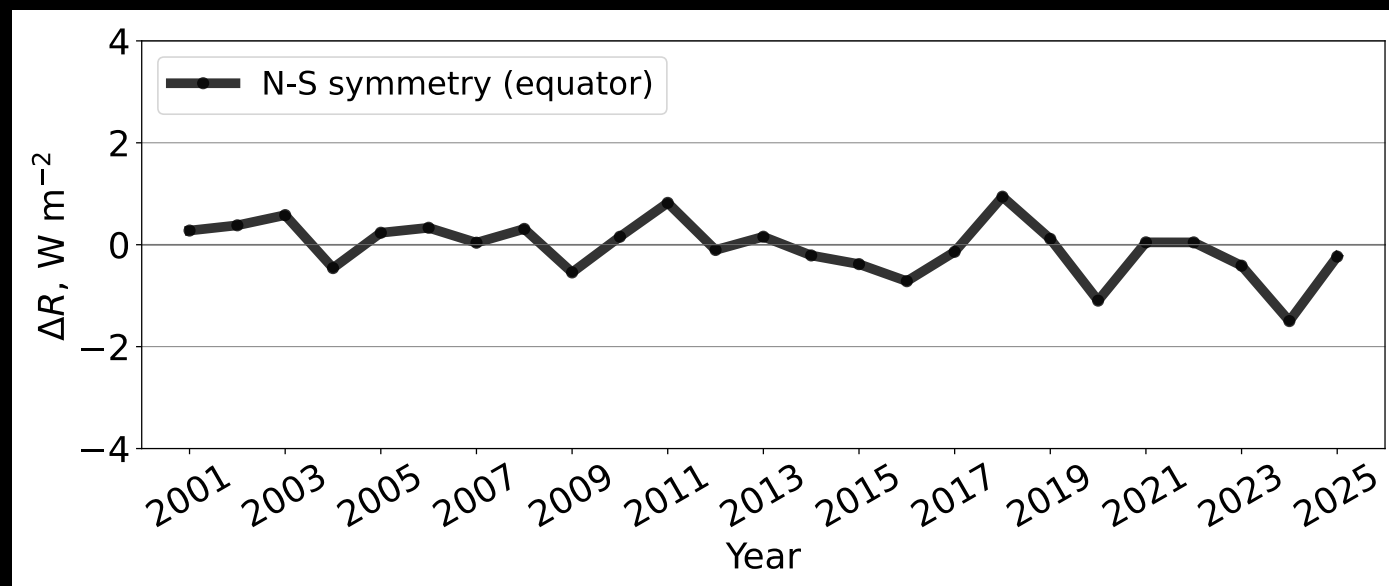
(Manuscript received 20 May 1970, in revised form 28 December 1970)

	Planetary albedo (%)		
	Northern Hemi- sphere	Southern Hemi- sphere	Global
First generation satellites*	29	29	29
Second generation satellites**	30	30	30

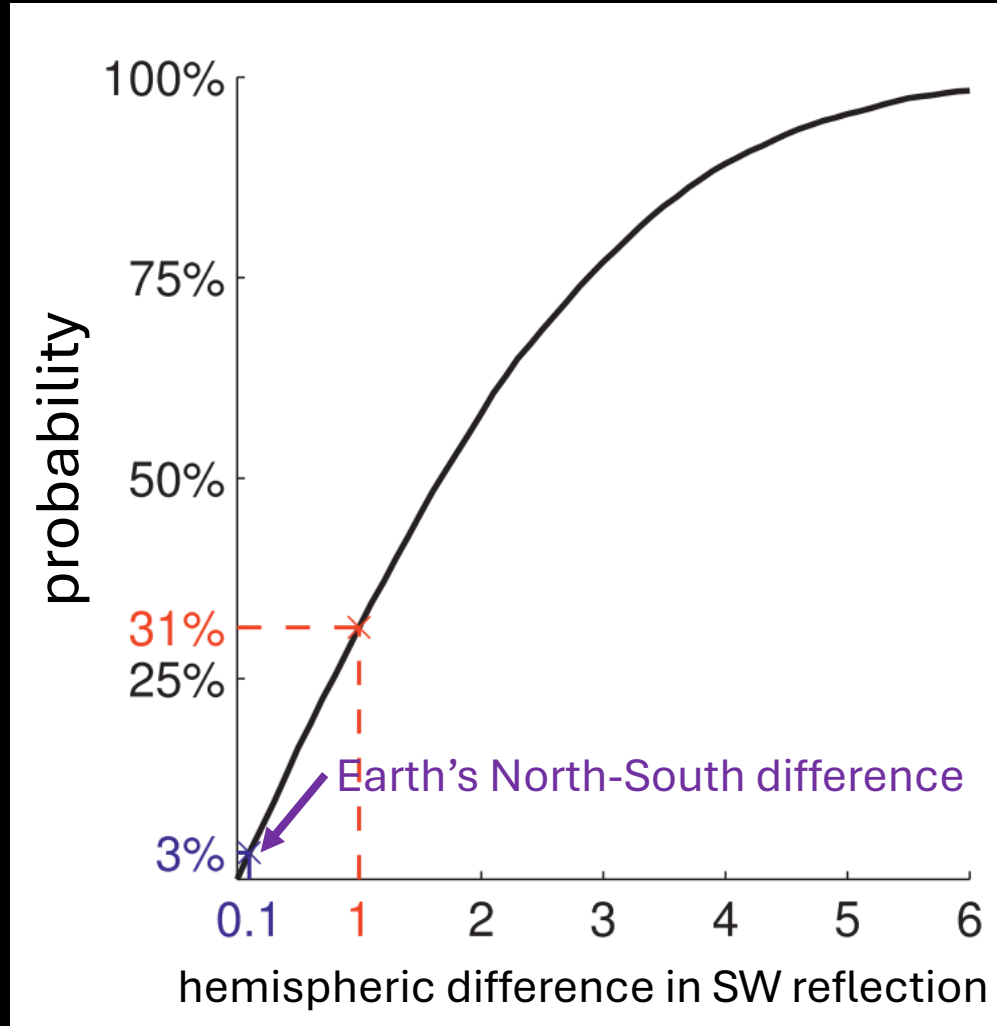




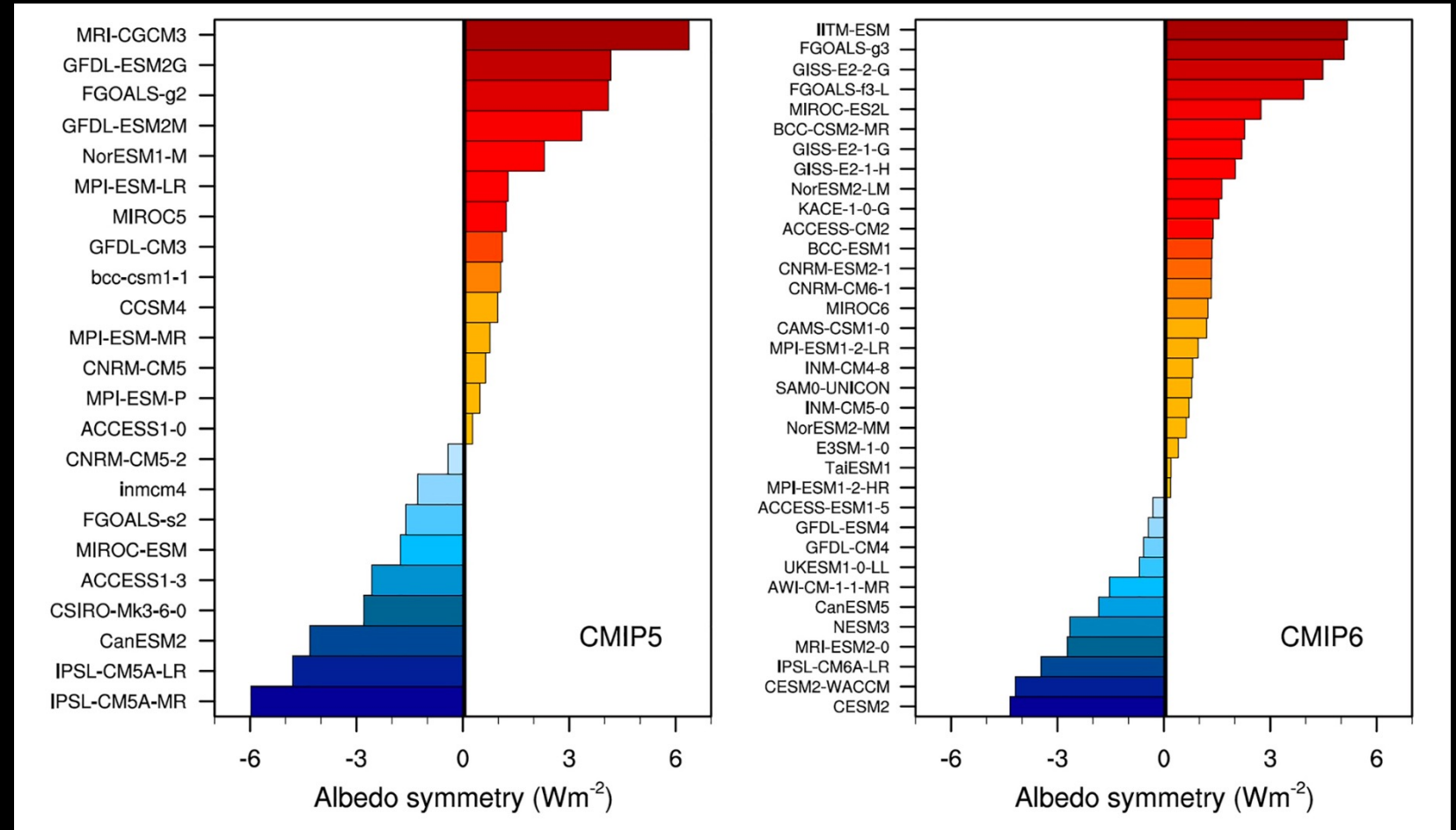
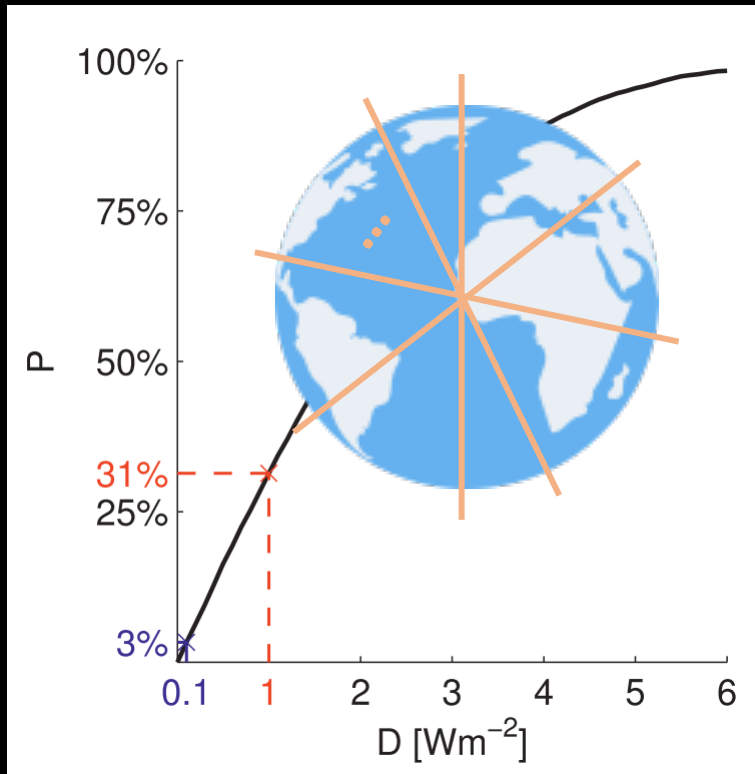
CERES record (2001-2025)



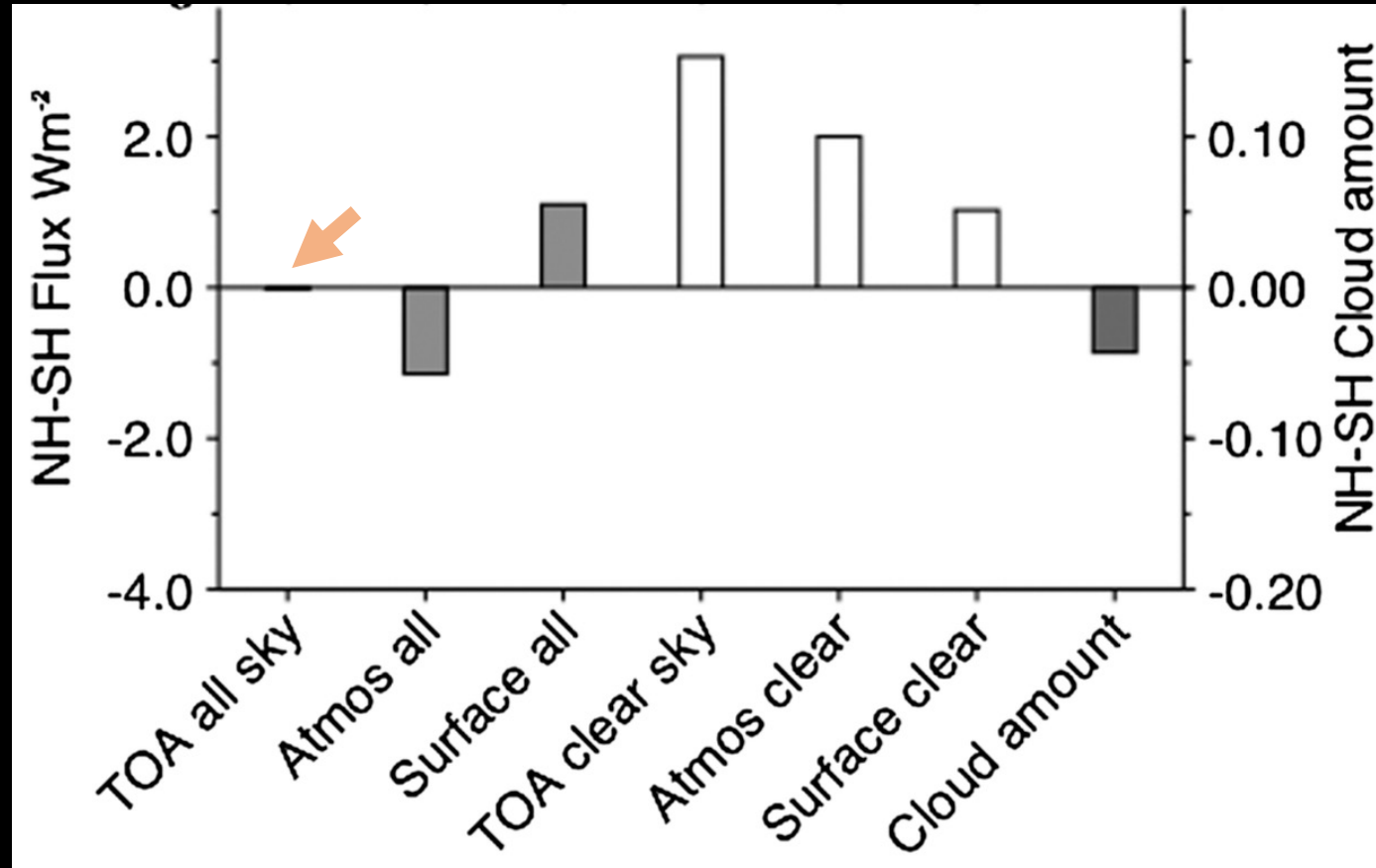
trivial or non-trivial?



trivial or non-trivial?

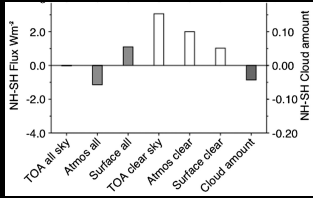


A remarkable yet *puzzling* observation



Strong asymmetries in clear-sky and CRE yield the all-sky symmetry

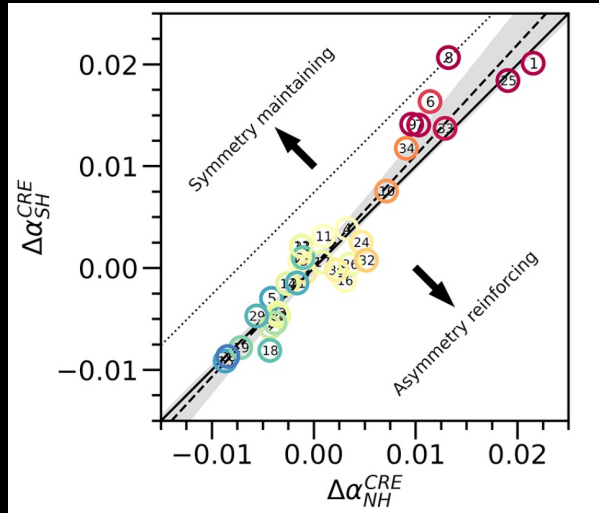
A remarkable yet *puzzling* observation



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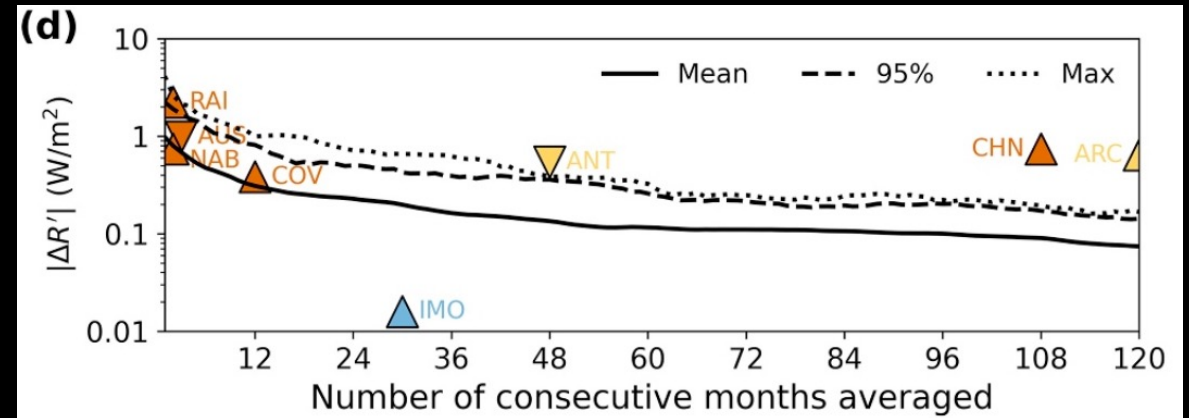
Whether and how the symmetry is maintained? ... remain unresolved

CMIP6 models disagree on local vs remote mechanisms ($\text{CO}_2 \times 4$)



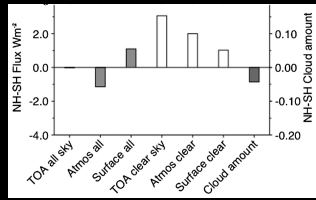
Jönsson & Bender (2023), ESD

Observed natural “experiments” produce null results

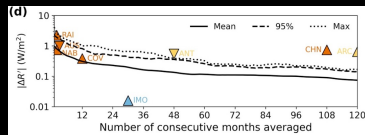
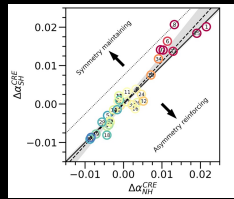


Diamond et al. (2024), GRL

A remarkable yet *puzzling* observation

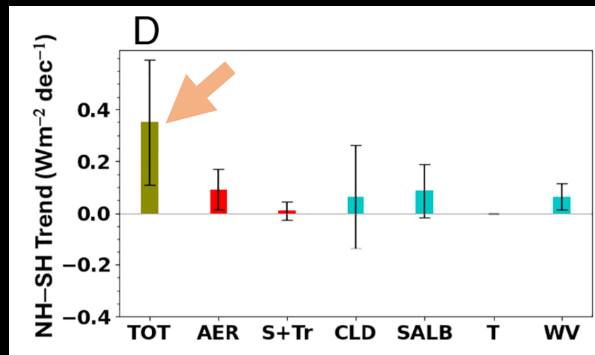


Strong asymmetries in clear-sky and CRE yield the all-sky symmetry

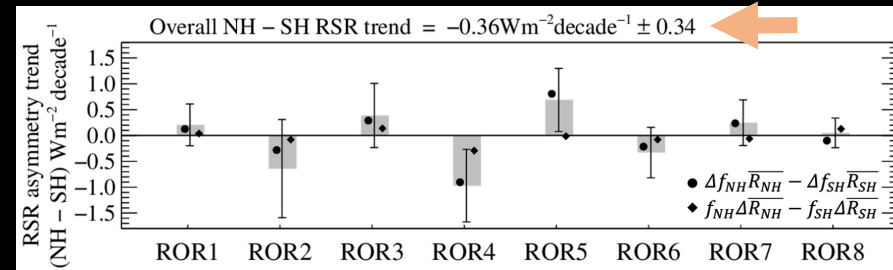


Whether and how the symmetry is maintained remain unresolved

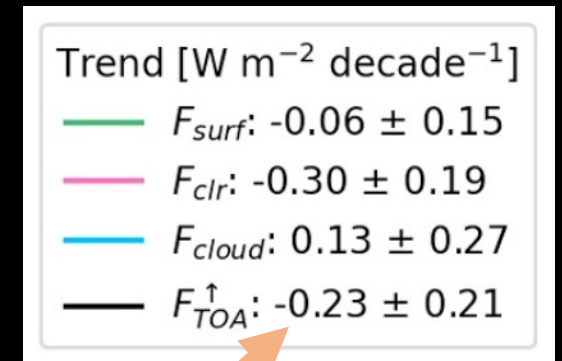
Loeb et al. (2025), PNAS



Oreopoulos et al. (2025), J Clim

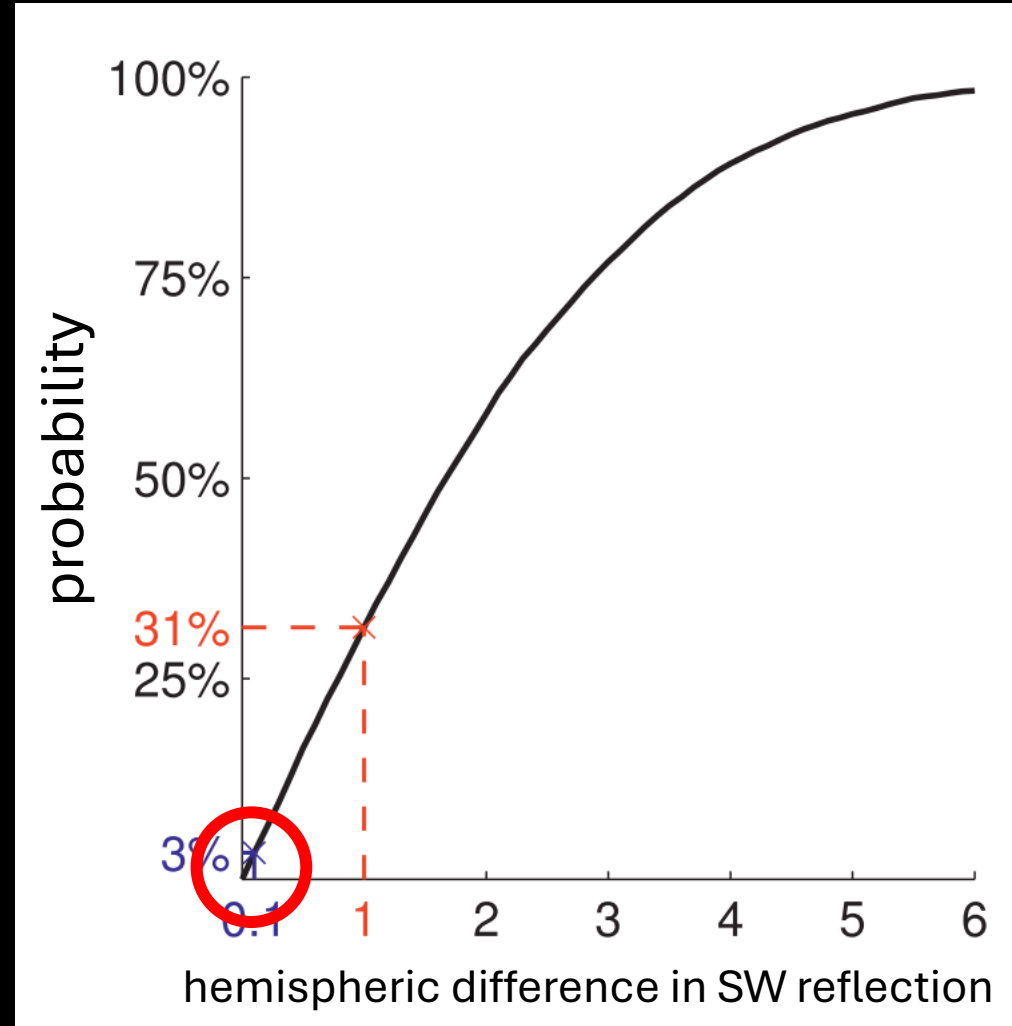


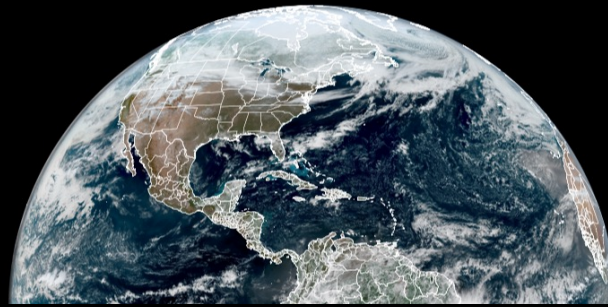
Singer & Pincus (2026), GRL



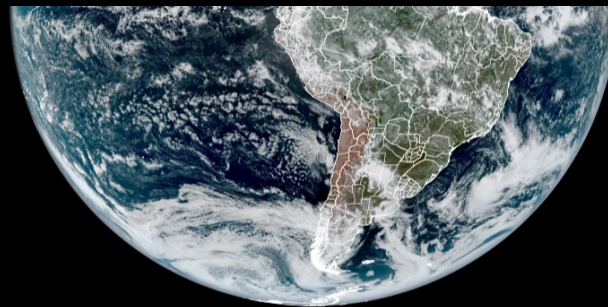
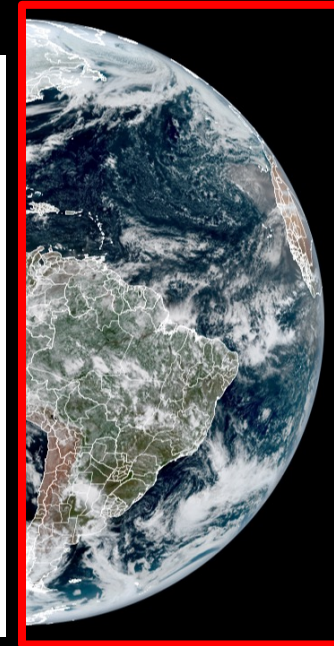
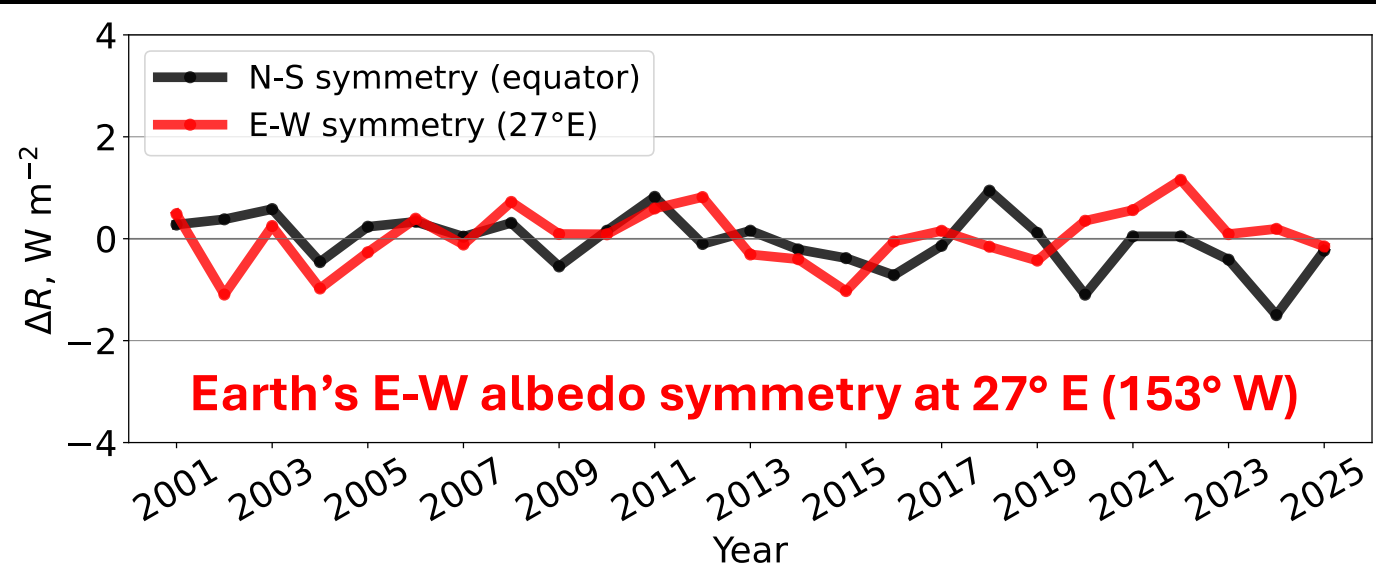
An emerging departure from symmetry, hinting at its transient (coincidental) nature (?)

What about the other pairs?





CERES record (2001-2025)



CERES EBAF & FBCT products

- ❑ **25 years (2001-2025), Ed4 (downloaded April 8, 2026)**
- ❑ **R**: all-sky SW (0.3-5 μm) reflection at TOA
- ❑ **R_{clr}**: TOA SW reflection assuming clear-sky
- ❑ **CRE**: Cloud Radiative effect, **CRE = R - R_{clr}**

$$R = R_{\text{clr}} + \text{CRE}$$

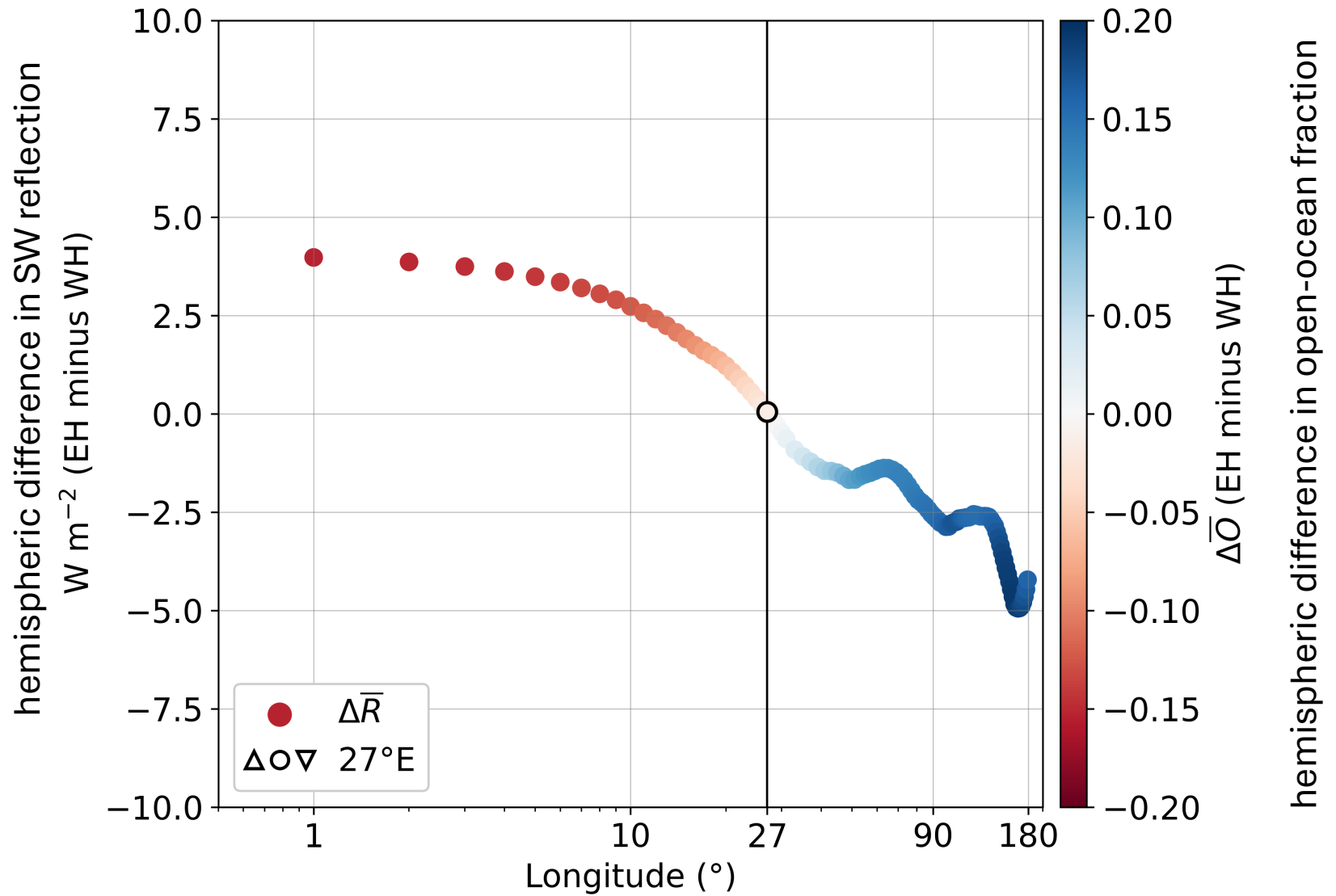
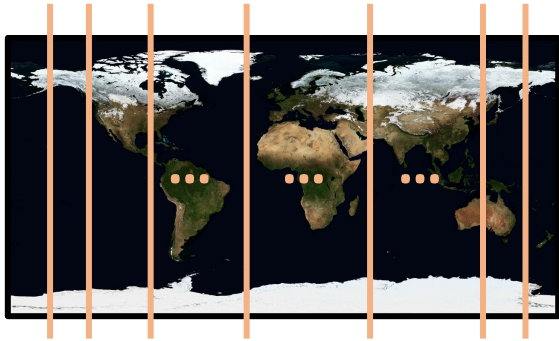
↓
 $R_{\text{atm}} + R_{\text{sfc}}$

$$\Sigma \text{CRE}_{\text{ct}} = \Sigma \text{CF}_{\text{ct}} (F_{\text{ct},\text{TOA}}^{\uparrow} - F_{\text{clr},\text{TOA}}^{\uparrow})$$

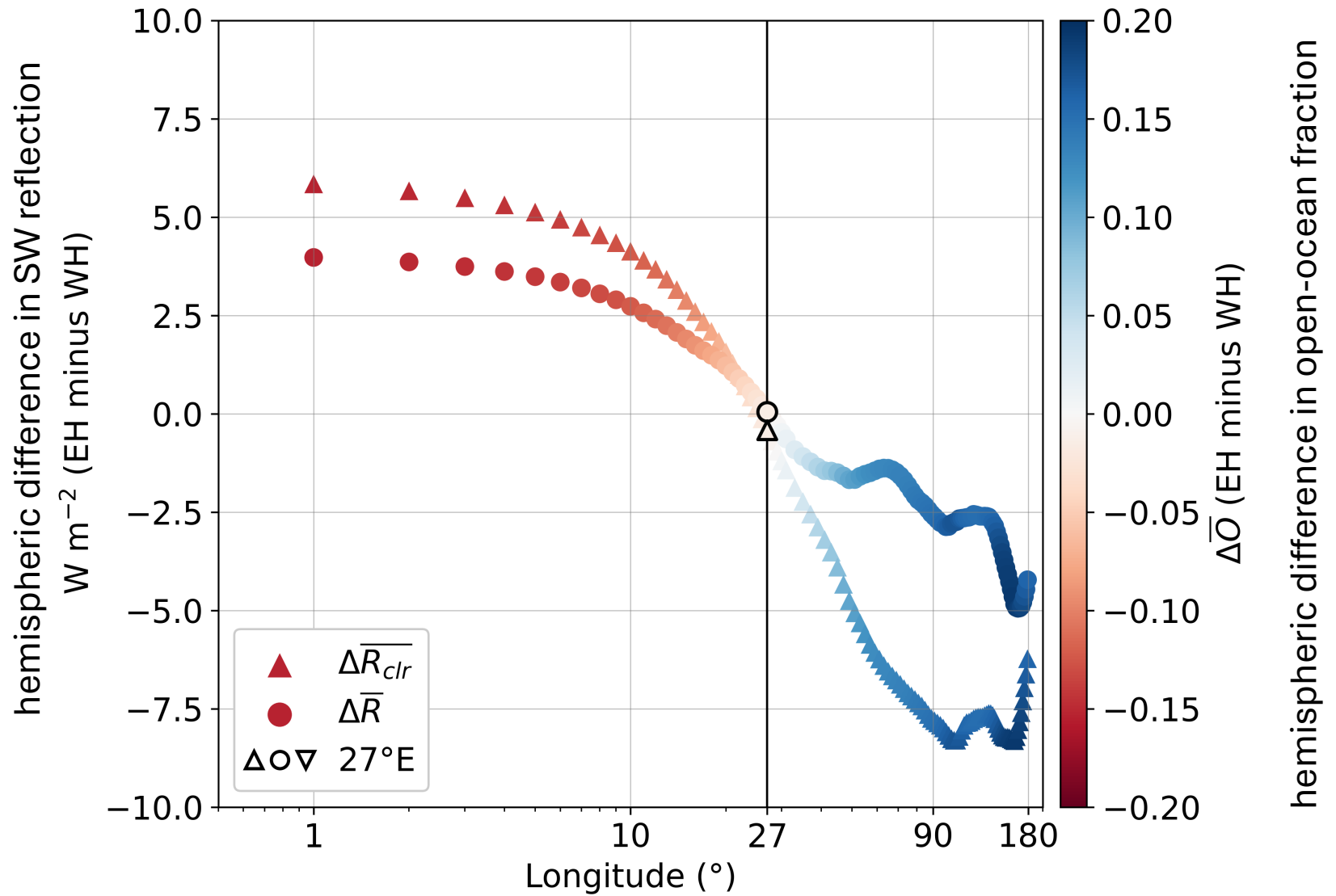
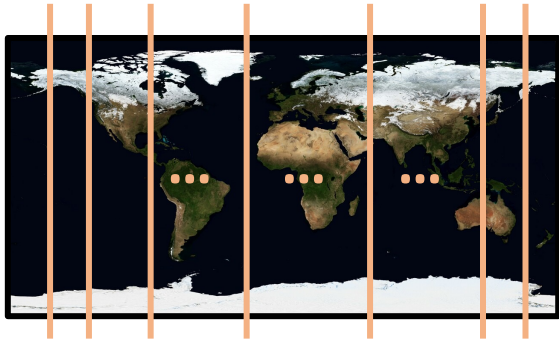
- ❑ **FBCT (2003-2022)**: $F_{\text{ct},\text{TOA}}^{\uparrow}$, CF_{ct} , and $F_{\text{clr},\text{TOA}}^{\uparrow}$
- ❑ 7 P_{eff} bins and 6 τ_{cld} bins \rightarrow **9 cloud types (ct)**
Rossow & Schiffer (1999), BAMS

- ❑ **EBAF (2001-2025)**: $F_{\text{clr},\text{TOA}}^{\uparrow}$, $F_{\text{TOA}}^{\downarrow}$, $F_{\text{clr},\text{sfc}}^{\uparrow}$, and $F_{\text{clr},\text{sfc}}^{\downarrow}$
- ❑ Single-layer atmosphere model
Donohoe & Battisti (2011), J Clim

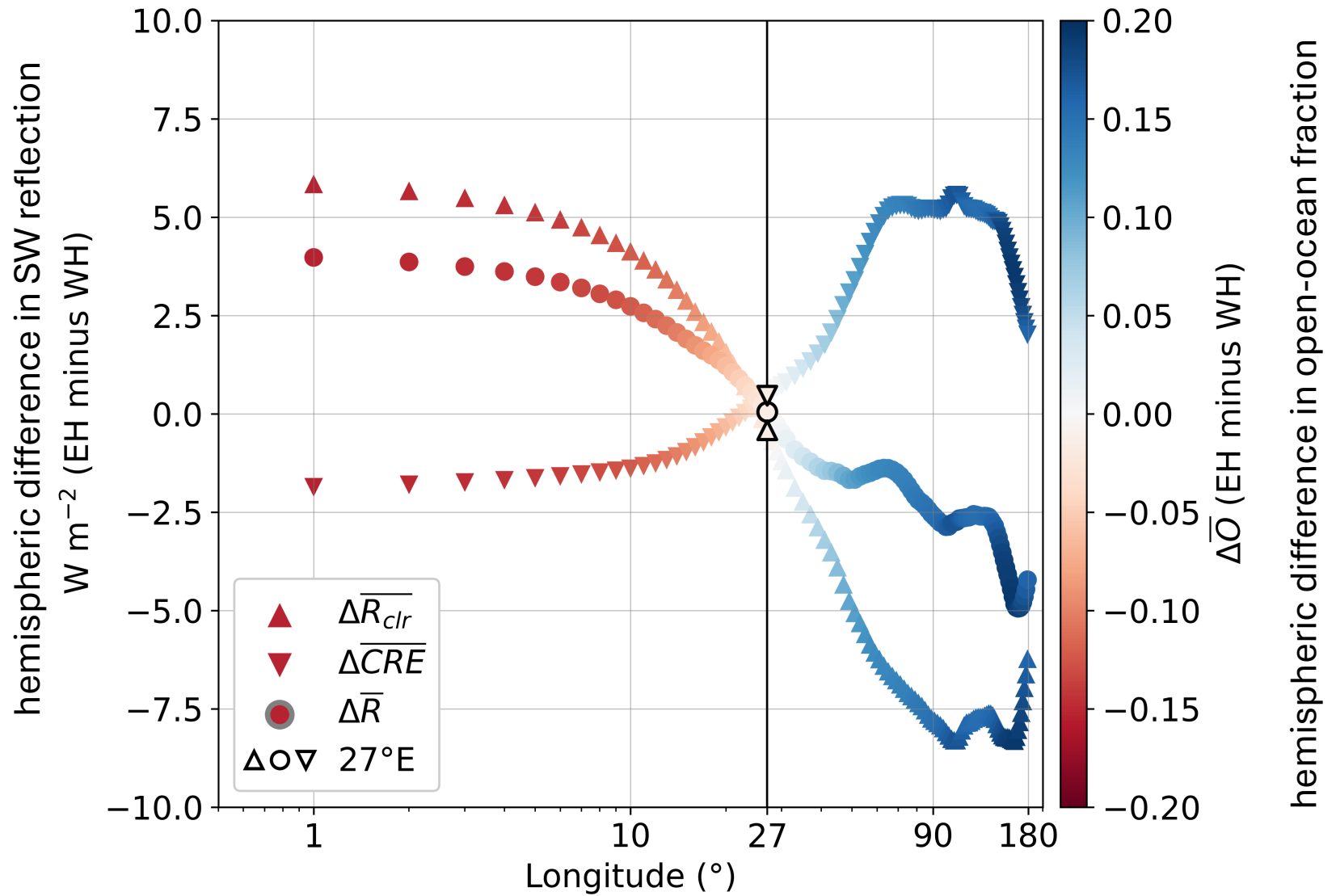
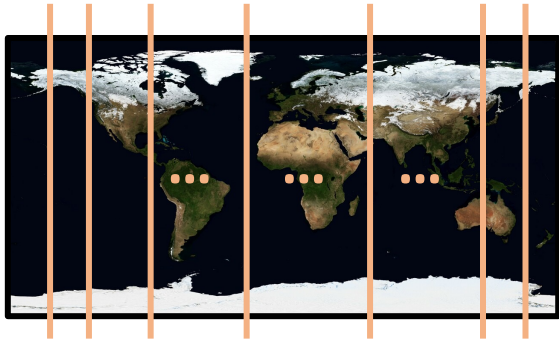
A unique “triple-symmetry” in the East-West (E-W)



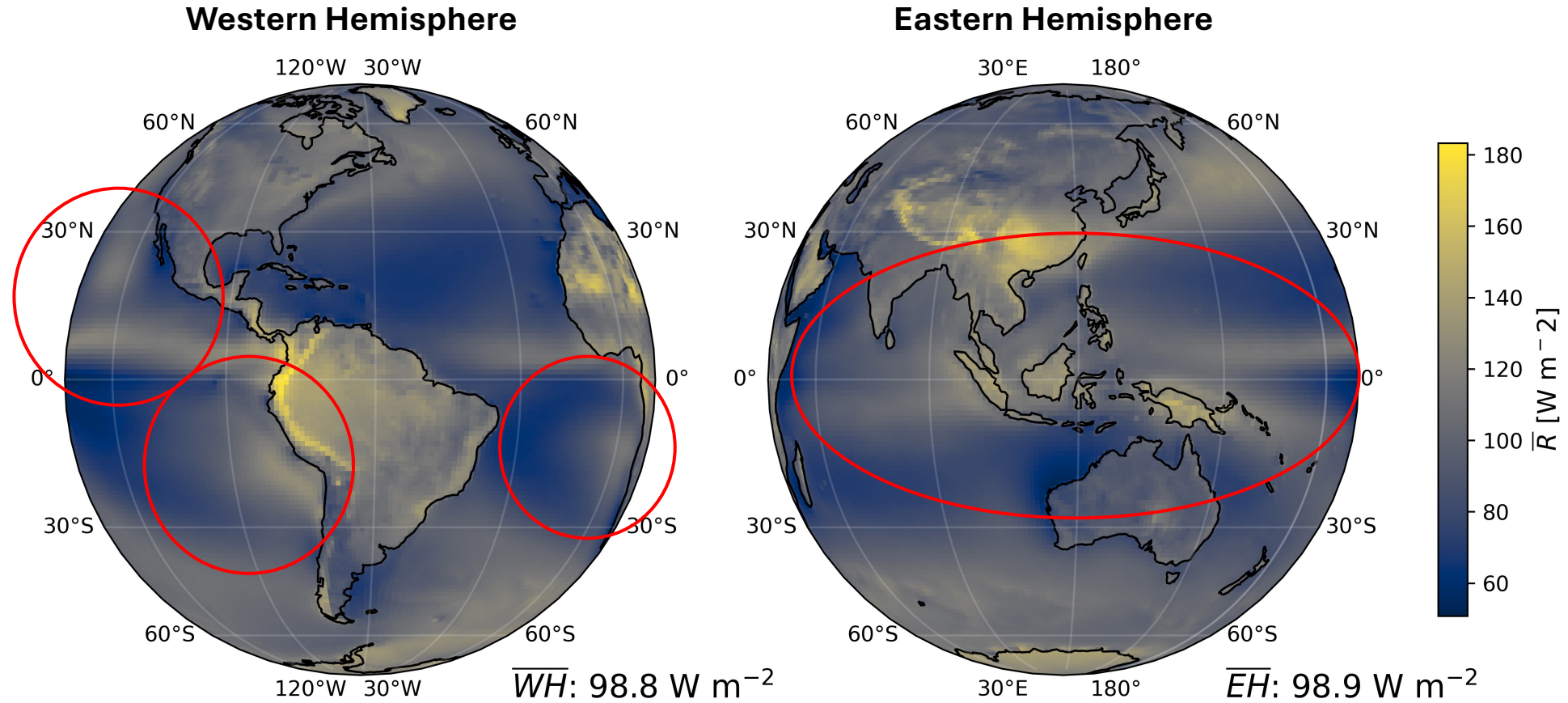
A unique “triple-symmetry” in the East-West (E-W)



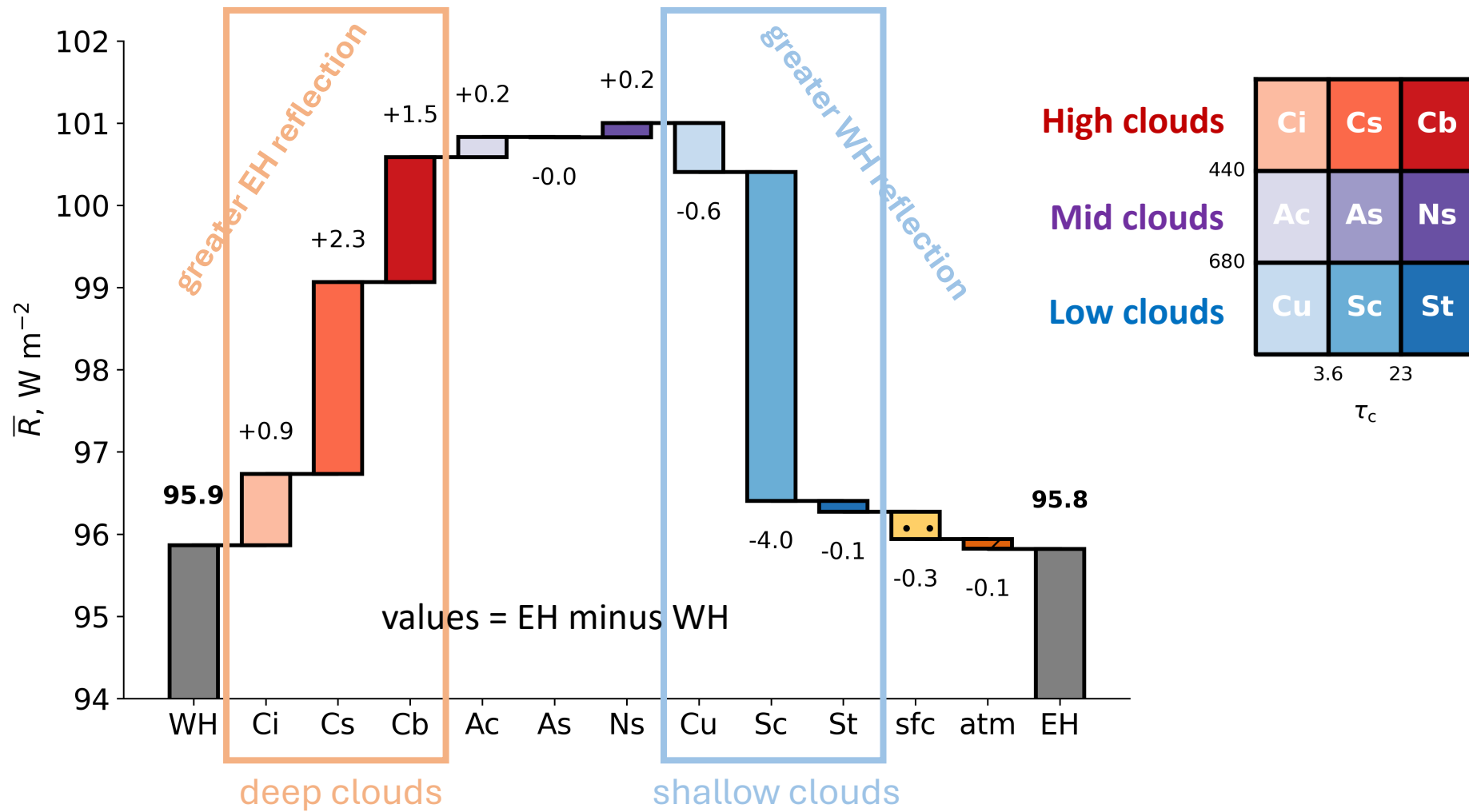
A unique “triple-symmetry” in the East-West (E-W)



The two hemispheres contain very different clouds

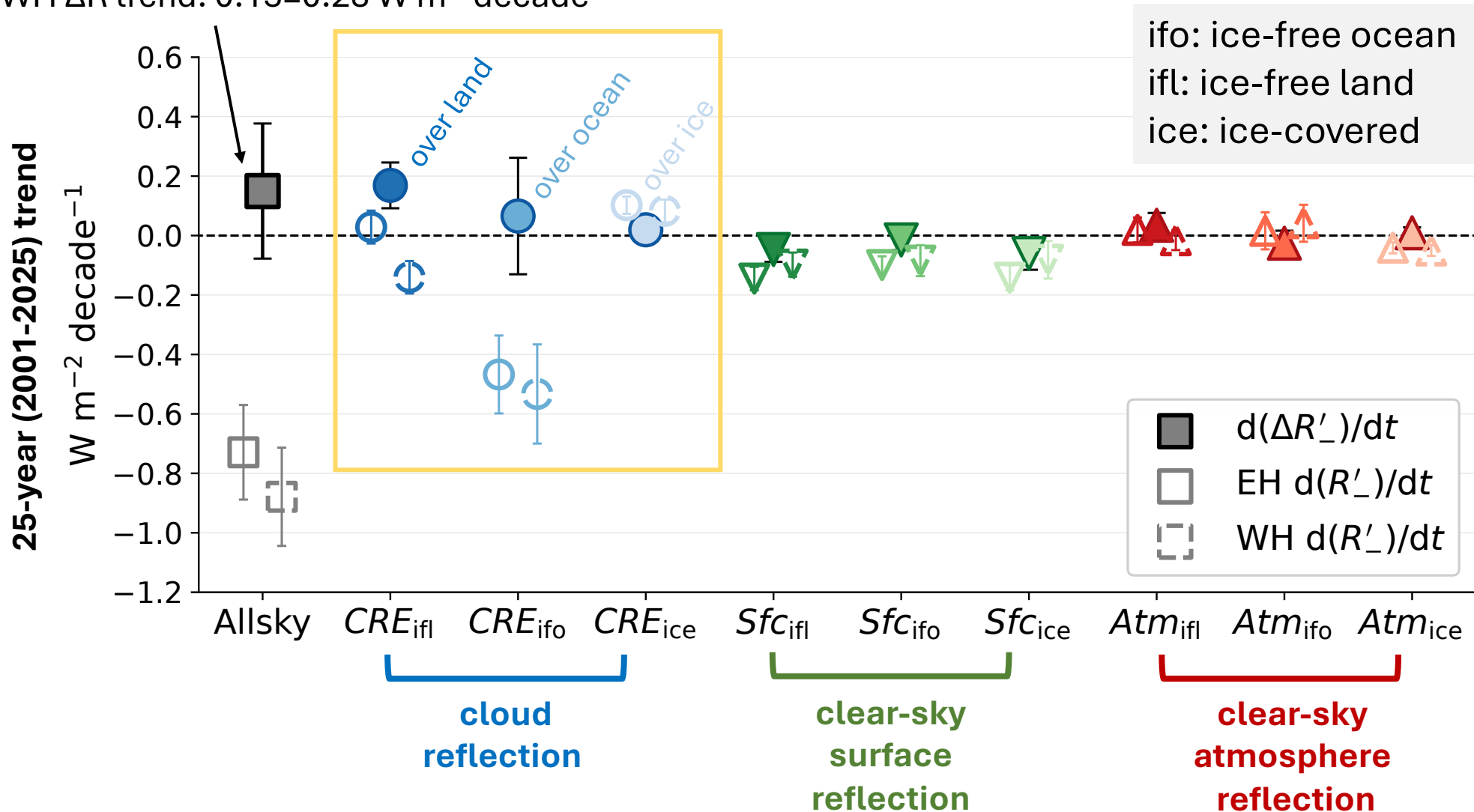


A remarkable compensation between low and high clouds

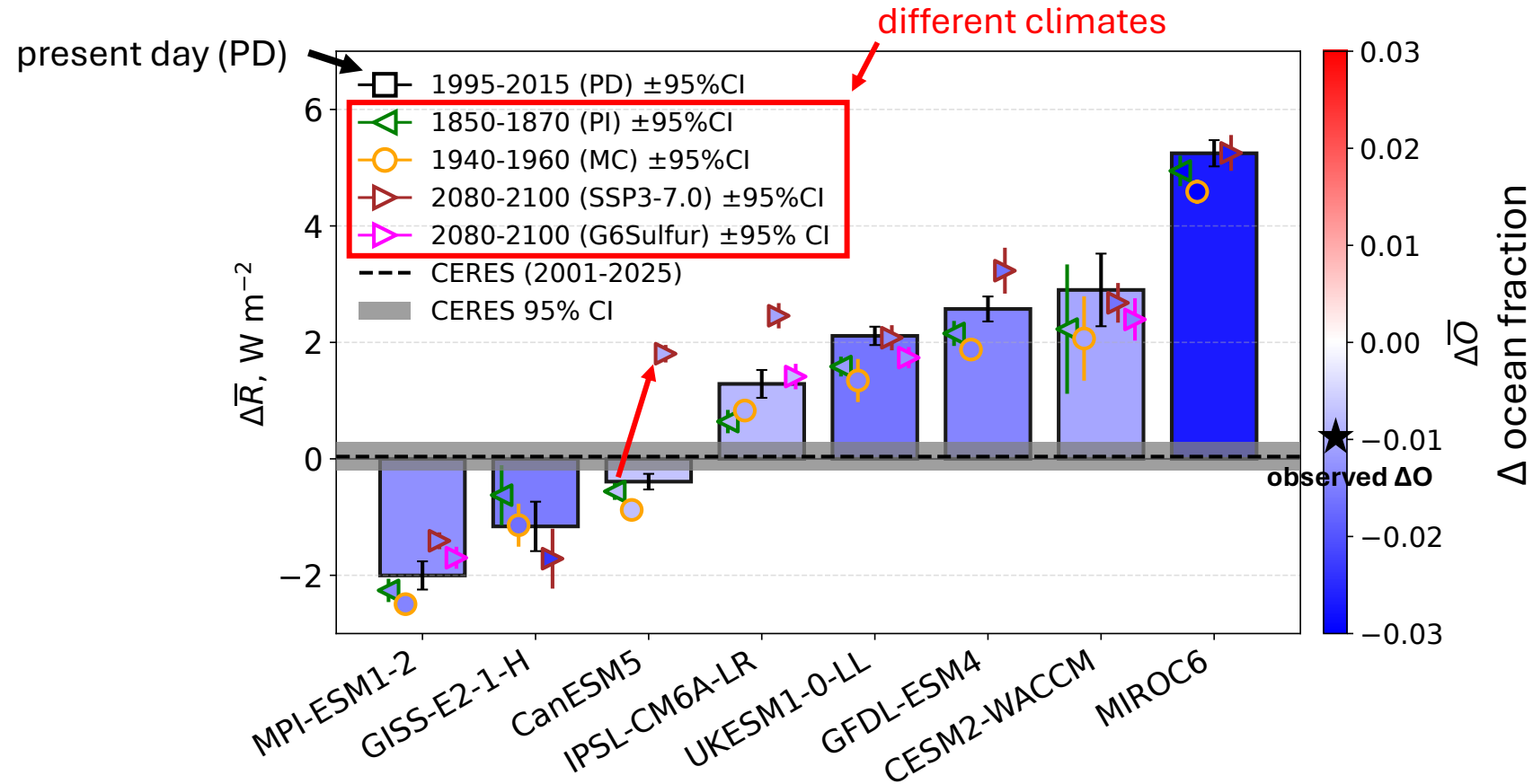


Earth is darkening, but at different rate between the EH and WH

EH-WH ΔR trend: $0.15 \pm 0.23 \text{ W m}^{-2} \text{ decade}^{-1}$



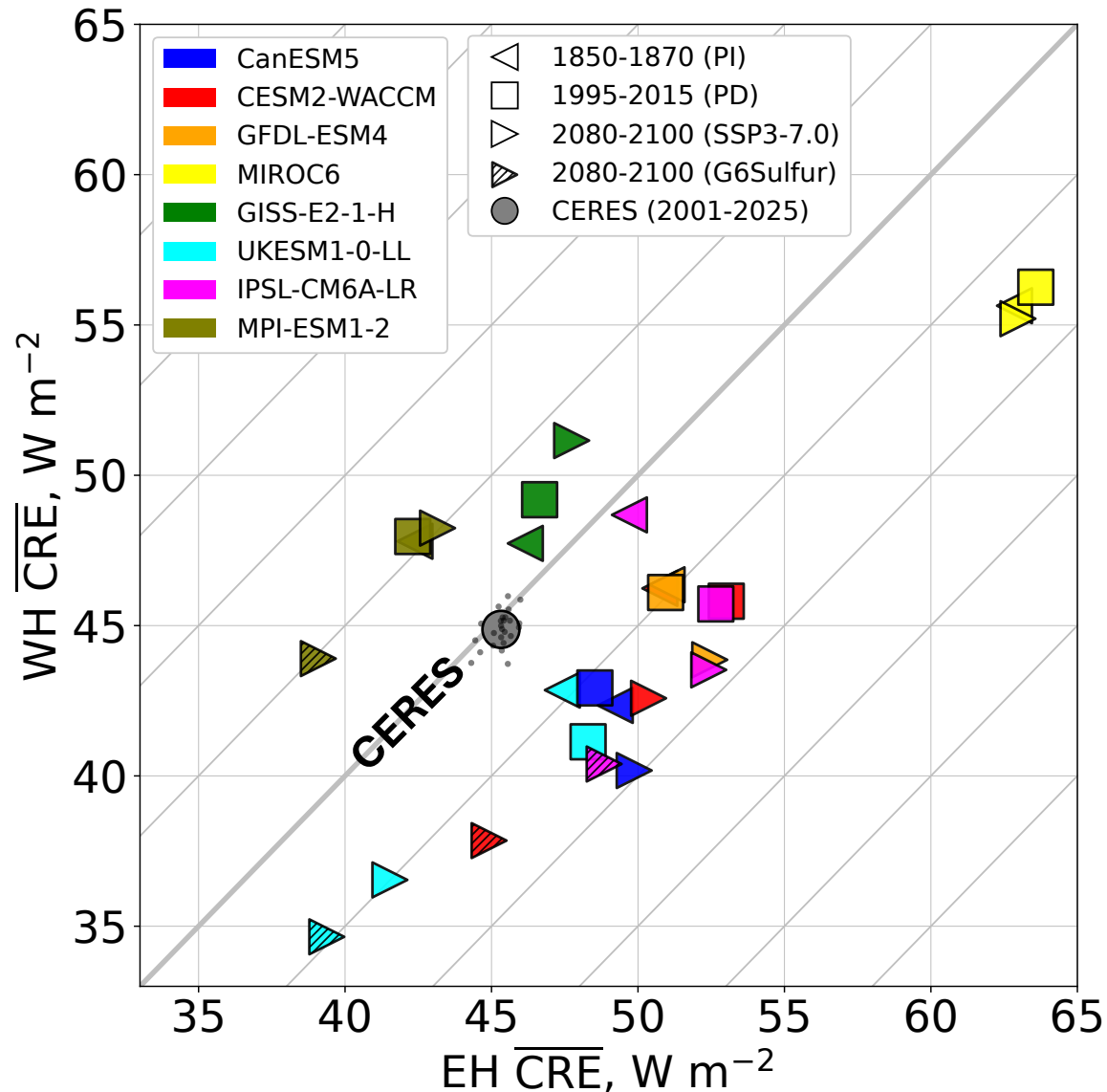
CMIP6 models do not capture the observed E-W symmetry



□ ΔO (ocean fraction; determined by sea-ice variability) at 27E is overall captured, suggesting couplings among Earth system components is not well represented.

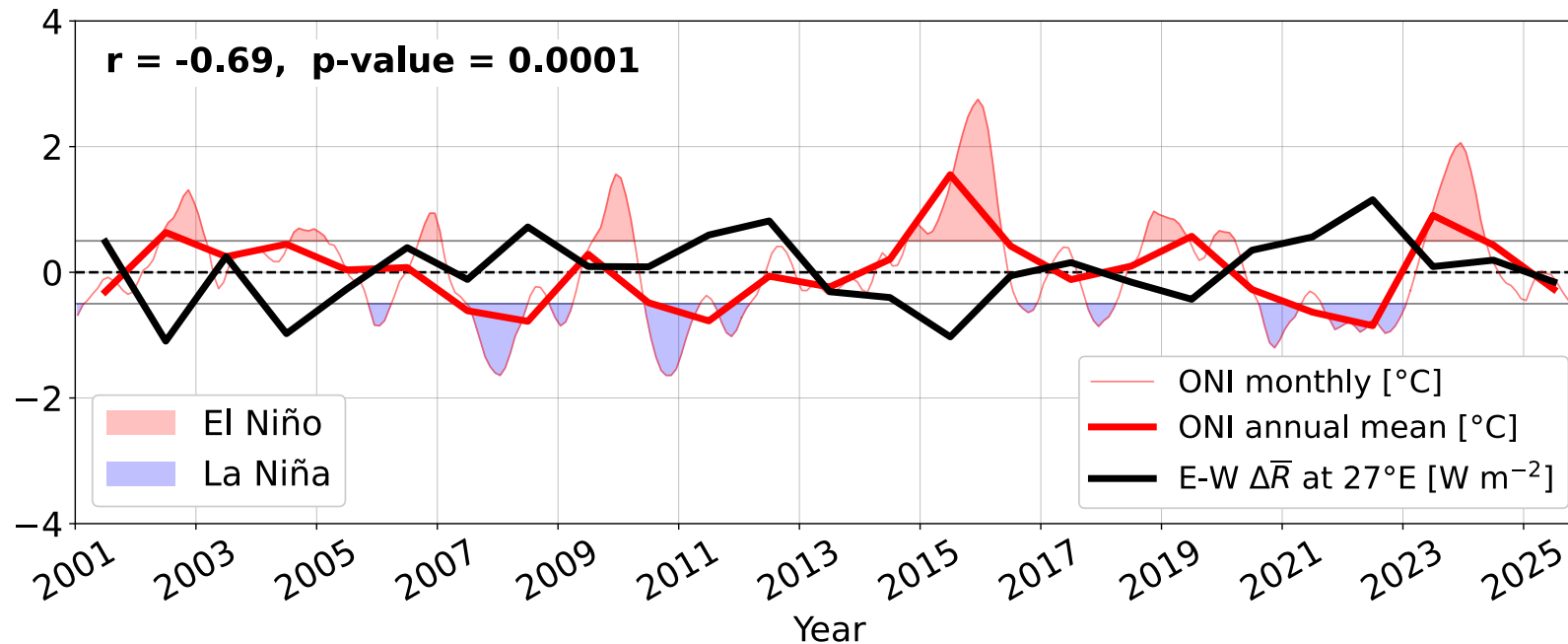
□ Models suggests Earth's albedo symmetry are non-stationary

Moreover, models do not capture the “triple-symmetry”



- Unlike the N-S symmetry, we can identify E-W all-sky R symmetry in each model's realization (ranging from 8 to 131 E!)
- CRE differs between EH and WH, again, points to potential deficiencies in Earth system couplings

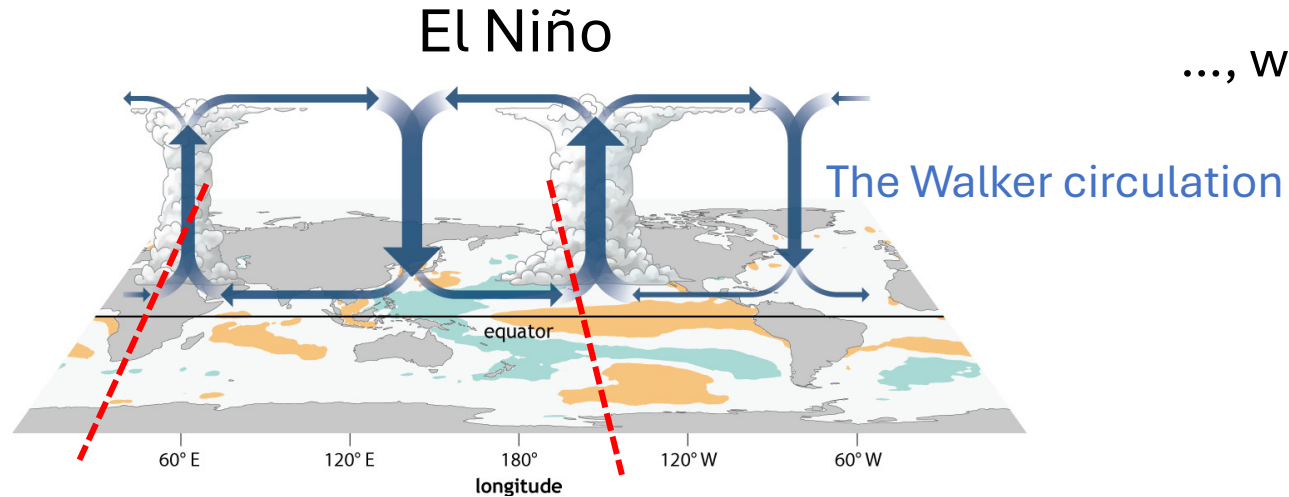
Whether and how the symmetry is maintained?



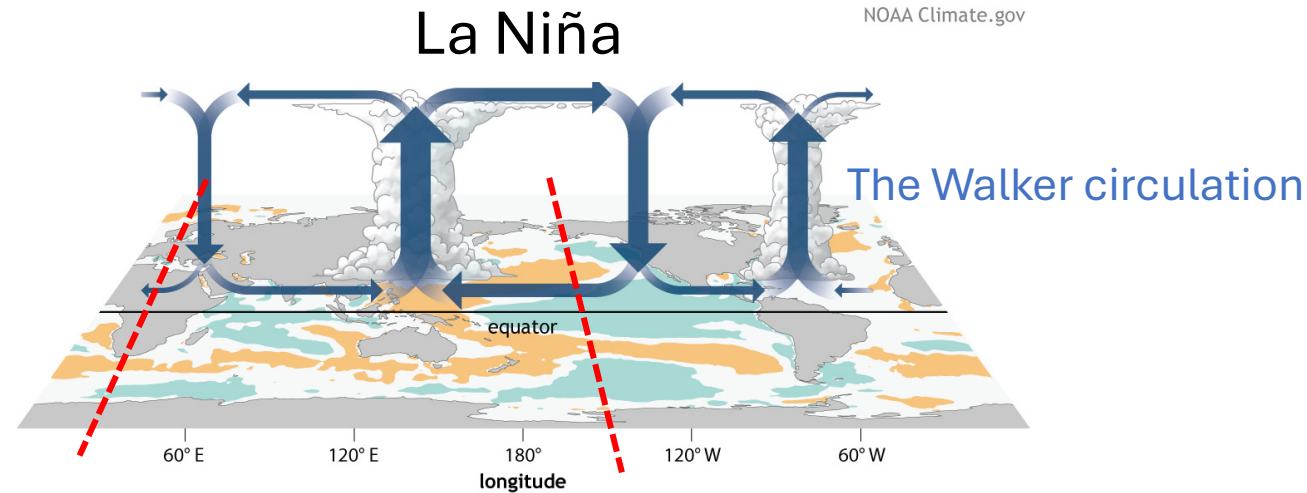
Interannual variability in E-W symmetry is connected to ENSO variability

Hypothesis: Oscillating overturning circulation is responsible for maintaining the E-W symmetry at 27E

..., which is subject to change under warming

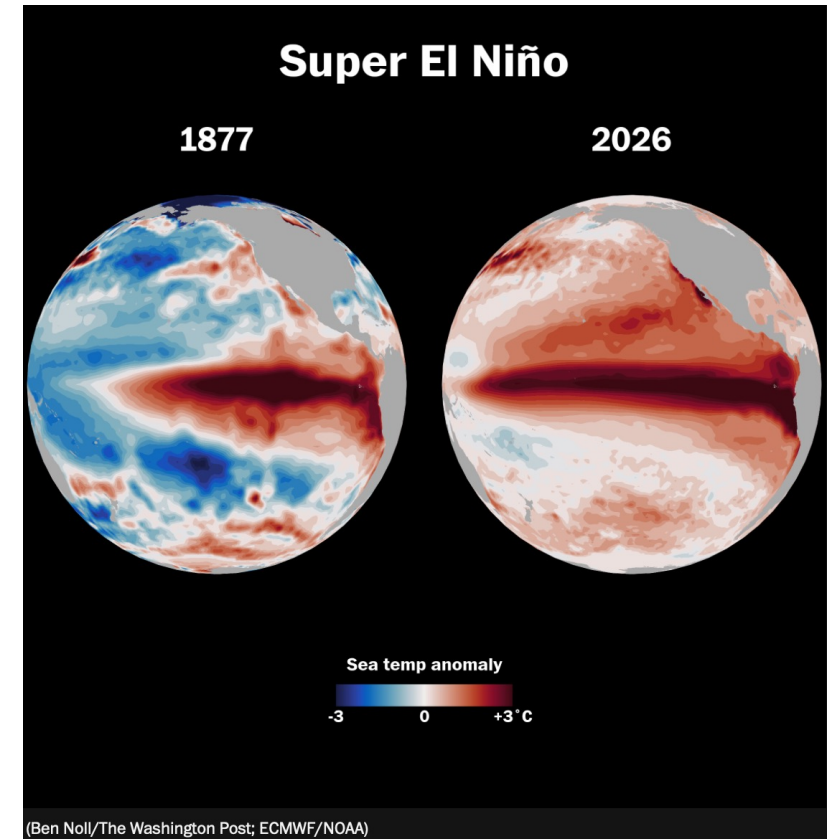


NOAA Climate.gov



NOAA Climate.gov

27 E E-W symmetry 153 W



The discovery.

- ❑ We discovered a unique and persistent East-West albedo symmetry at 27 E, with a “triple symmetry” feature.

Why should we care?

- ❑ **Model improvements.** It’s a powerful way to evaluate Earth system models (ESMs), with the “triple symmetry” serving as a reduced degree-of-freedom constraint on system couplings.
- ❑ **Fundamental understanding of the Earth system.** ENSO and EEI
- ❑ **Implication for SRM (Solar Radiation Management).** The impacts of SRM cascade through Earth system couplings.

New Avenue, More Questions.

- ❑ Are albedo symmetry pairs fundamentally connected, or do they emerge independently? (*E-W and N-S do not appear connected*)
- ❑ Is ocean fraction essential for a symmetry?

We need continued ERB measurements!

