Earth's East-West Albedo Symmetry

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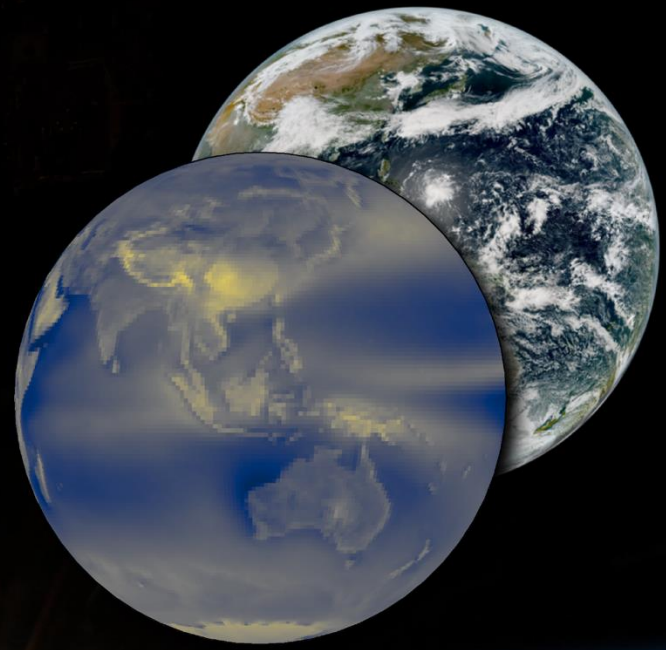
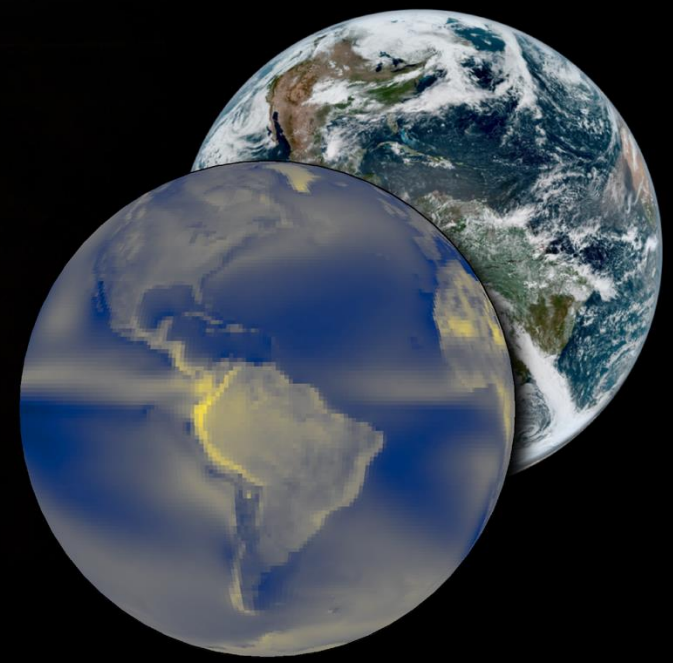
NOAA CHEMICAL SCIENCES LABORATORY



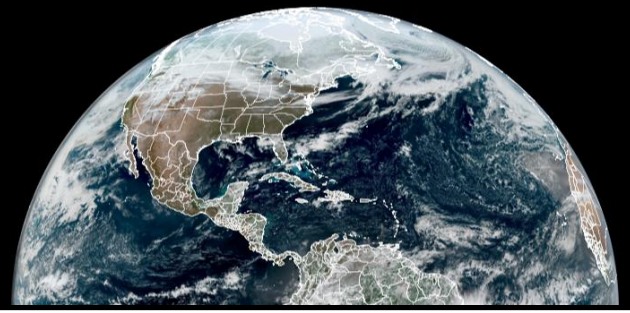


GEWEX 2nd EEI Workshop, June 1-5, 2026, Pasadena, CA

EARTH'S RADIATION BUDGET

Reflective

Zhang, Gristey, & Feingold (2026), *Nature*



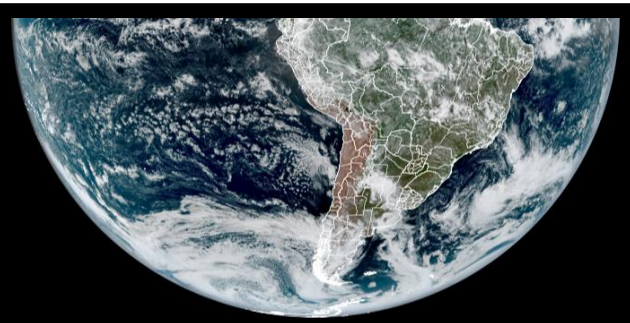
Measurements of the Earth's Radiation Budget from Satellites During a Five-Year Period. Part I: Extended Time and Space Means

THOMAS H. VONDER HAAR[1] AND VERNER E. SUOMI

Dept. of Meteorology, The University of Wisconsin, Madison

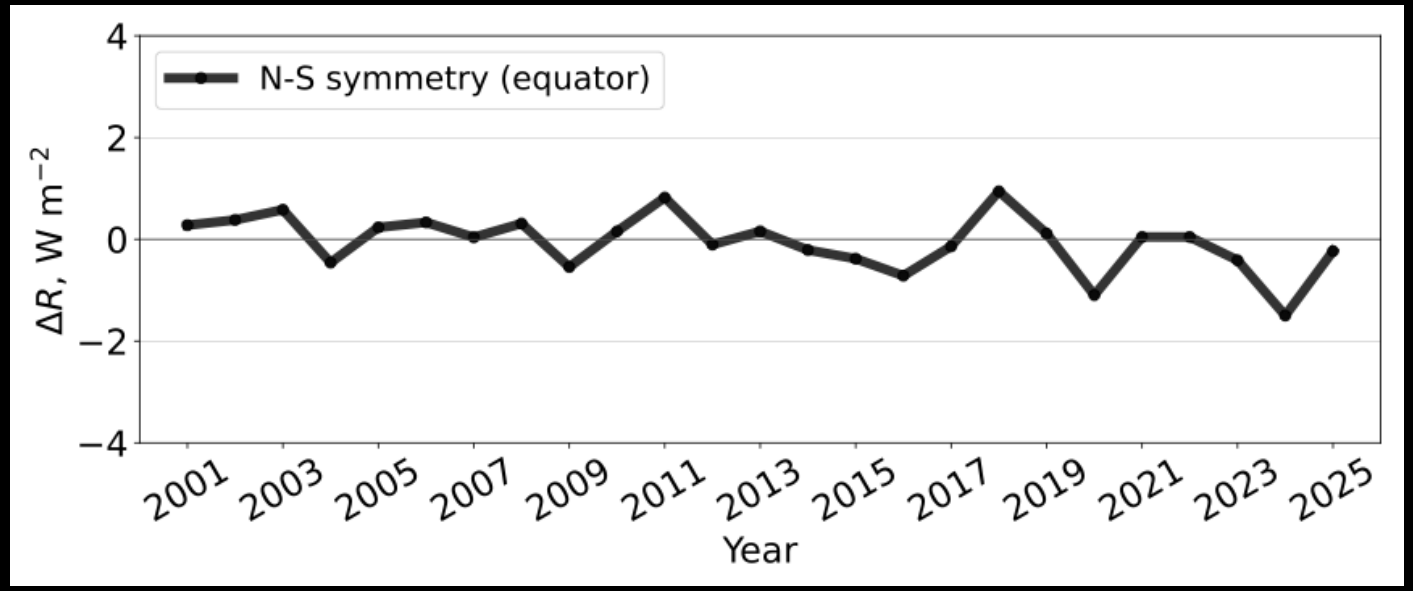
(Manuscript received 20 May 1970, in revised form 28 December 1970)

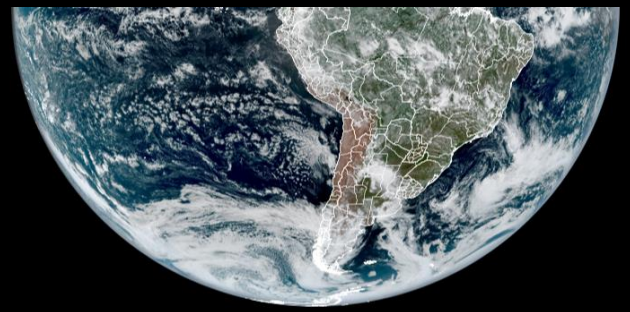
	Planetary albedo (%)		
	Northern Hemisphere	Southern Hemisphere	Global
First generation satellites*	29	29	29
Second generation satellites**	30	30	30



Vonder Haar & Suomi (1971), JAS

CERES record (2001-2025)





Zhang et al. (2026), Nature

A *remarkable* yet *puzzling* observation

Strong **a**symmetries in clear-sky and CRE yield the all-sky symmetry

Stephens et al. (2015), Rev Geophys

Whether and how the symmetry is maintained remain unresolved

Jönsson & Bender (2023), ESD; Diamond et al. (2024), GRL

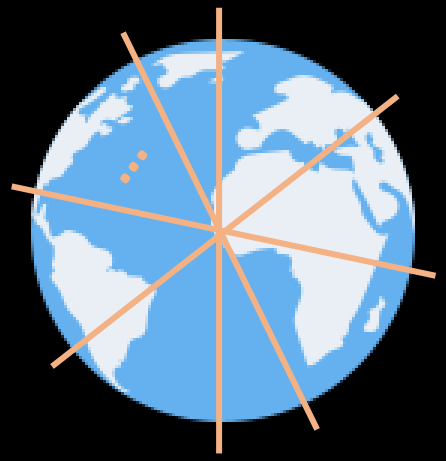
An emerging departure from symmetry, hinting at its transient (coincidental) nature (?)

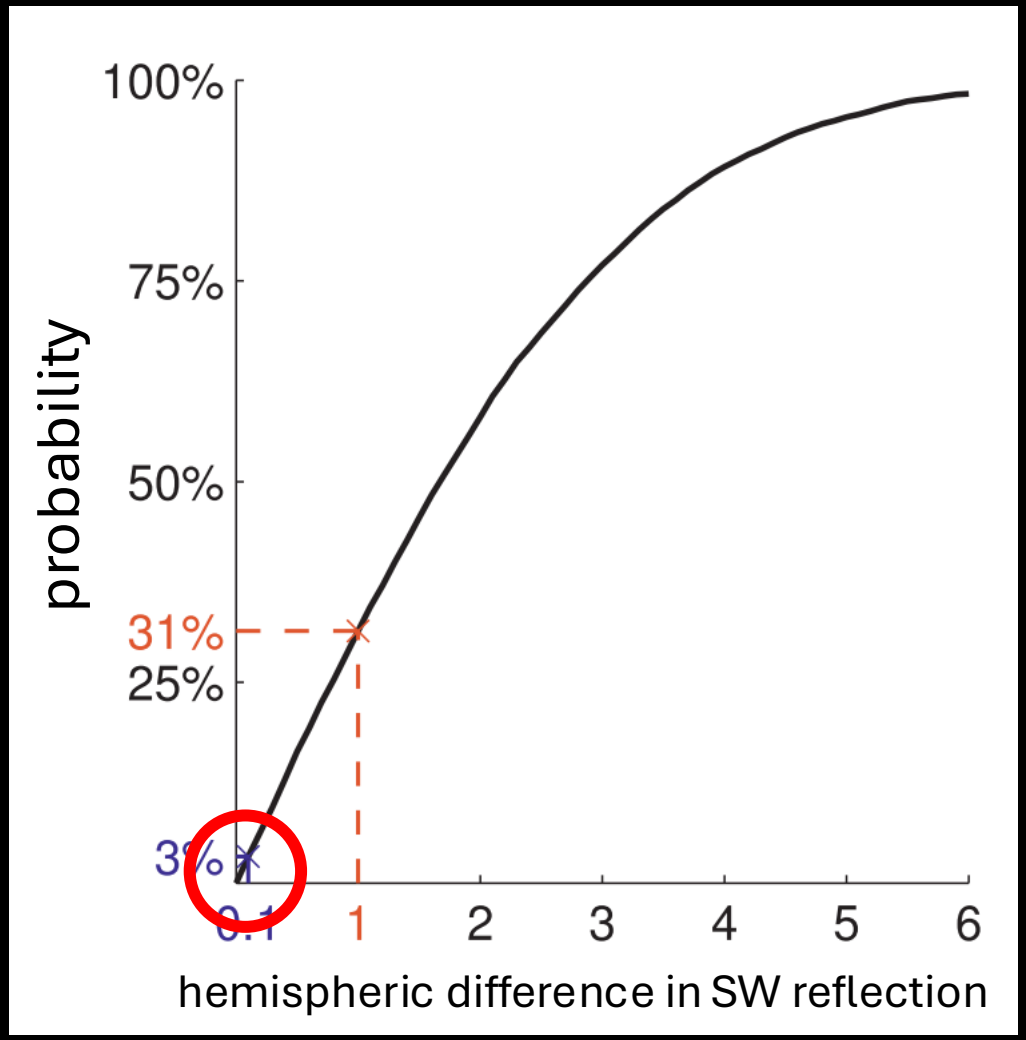
Loeb et al. (2025), PNAS; Oreopoulos et al. (2025), J Clim; Singer & Pincus (2026), GRL

What about the other pairs?

too trivial?

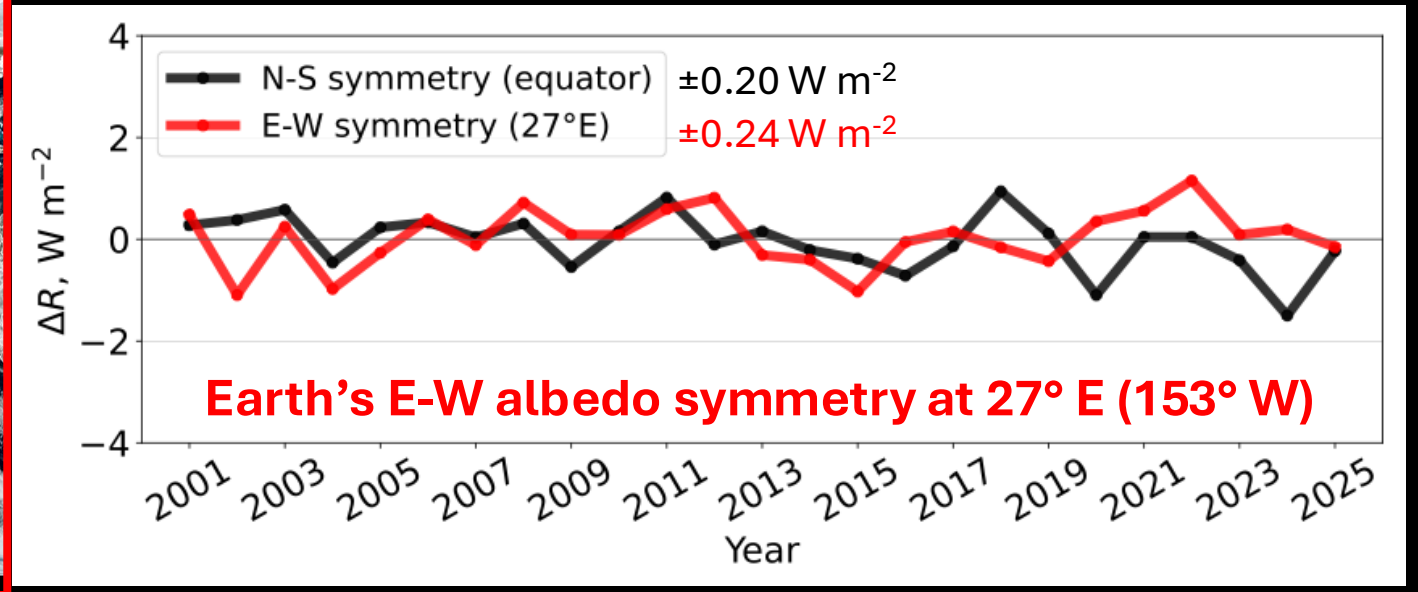
overlooked?

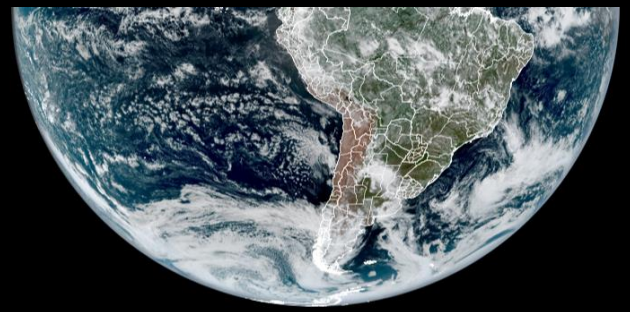




Voigt et al. (2013), J Clim

CERES record (2001-2025)





Zhang et al. (2026), Nature

CERES EBAF & FBCT products

- **25 years (2001-2025), Monthly, 1°**
- **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}**

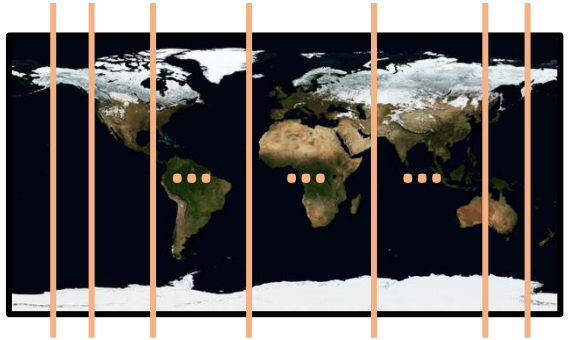
$$R = R_{clr} + CRE$$

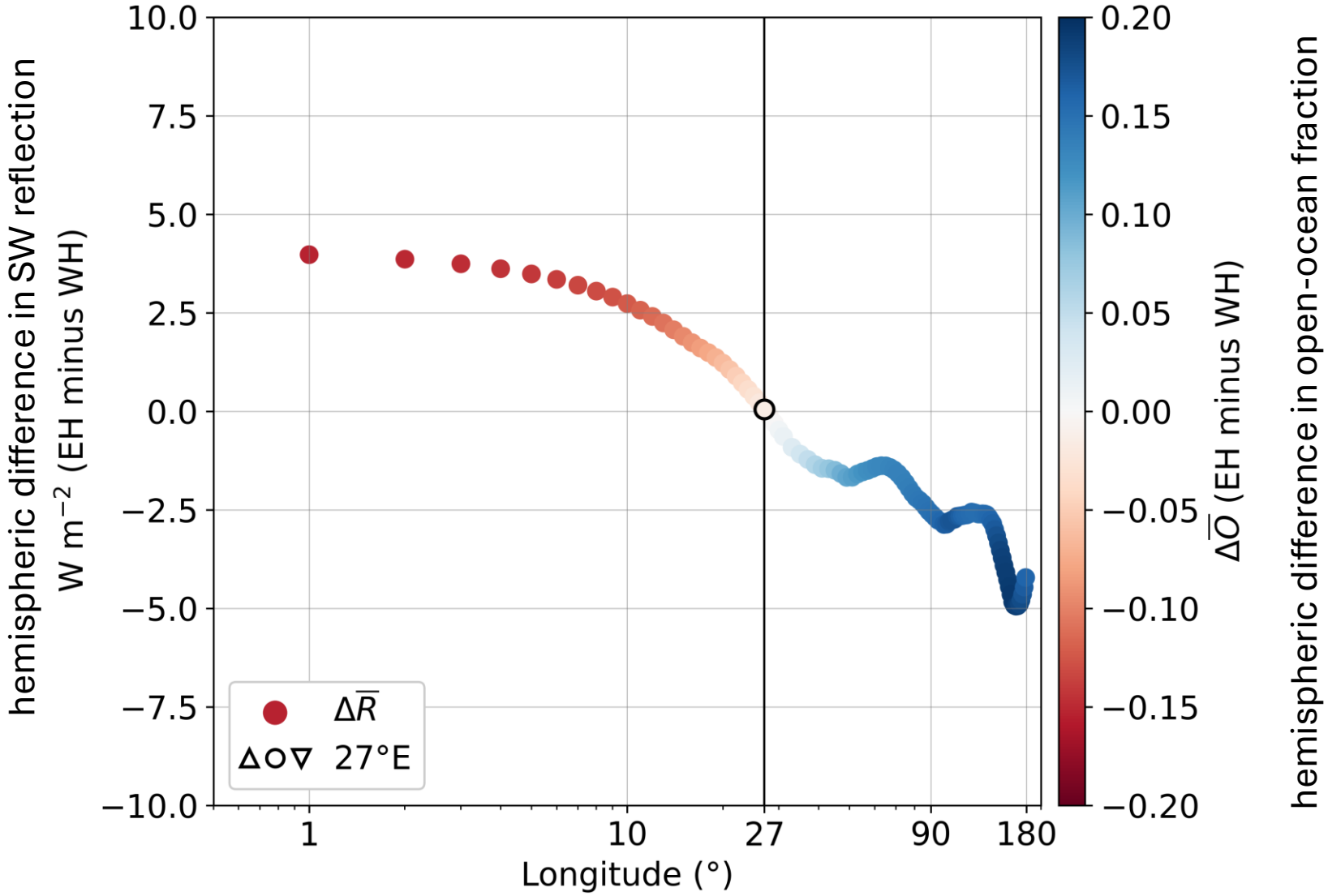
$R_{clr} = R_{atm} + R_{sfc}$

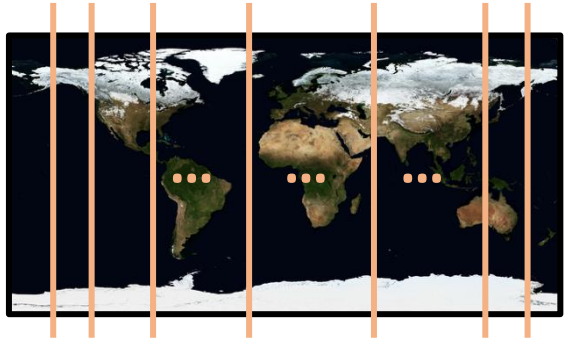
$CRE = \sum CRE_{ct} = \sum CF_{ct} (F^{\uparrow}_{ct,TOA} - F^{\uparrow}_{clr,TOA})$

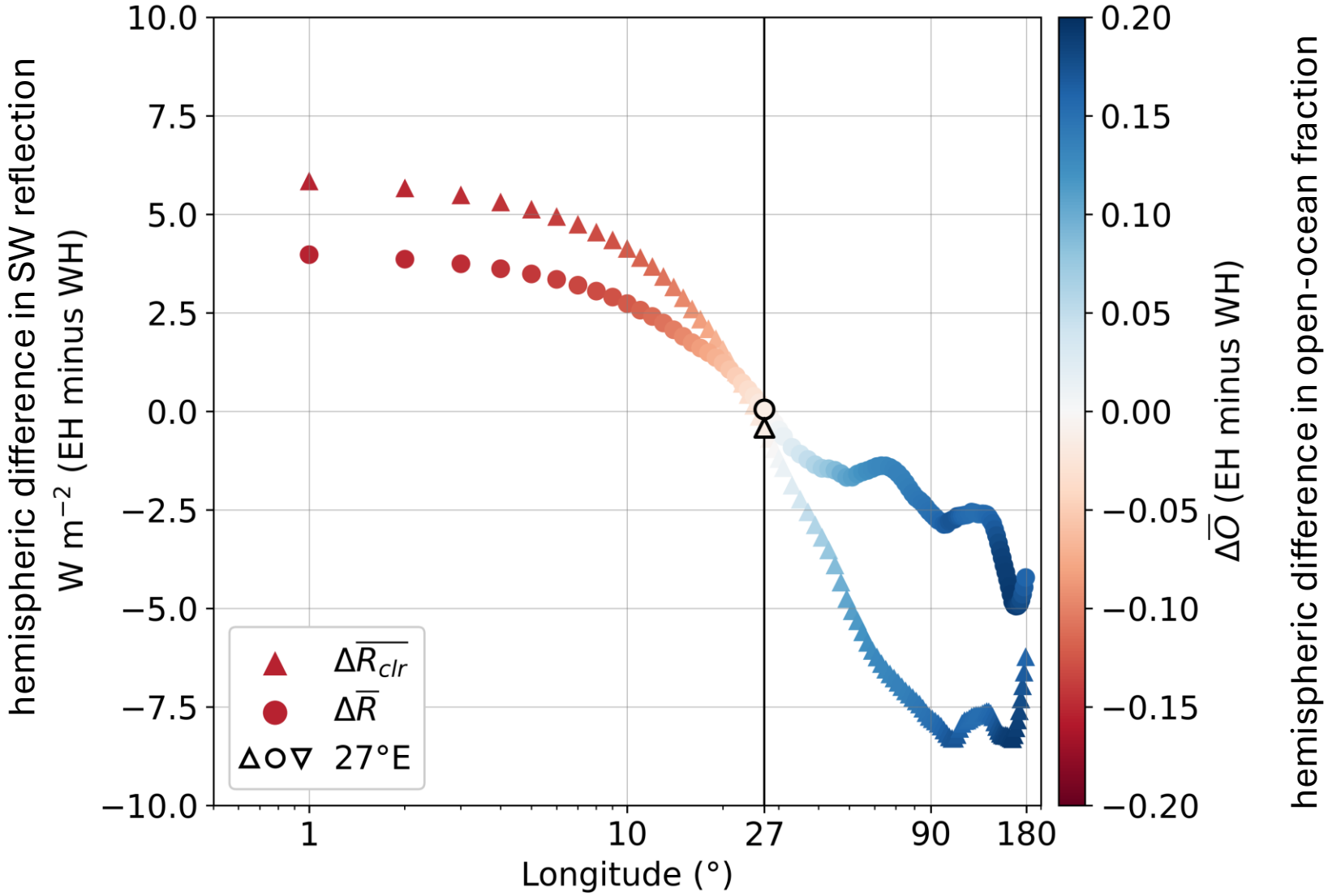
- **EBAF (2001-2025):** $F^{\uparrow}_{clr,TOA}$, $F^{\downarrow}_{TOA}$, $F^{\uparrow}_{clr,sfc}$, and $F^{\downarrow}_{clr,sfc}$
- Single-layer atmosphere model
  Donohoe & Battisti (2011), J Clim

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




hemispheric difference in SW reflection
W m^{-2} (EH minus WH)
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
1
10
27
90
180
Longitude (°)
$\Delta\overline{R}$
27°E
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
$\Delta\overline{O}$ (EH minus WH)
hemispheric difference in open-ocean fraction

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−10.0
1
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27
90
180
Longitude (°)
$\Delta\overline{R_{clr}}$
$\Delta\overline{R}$
27°E
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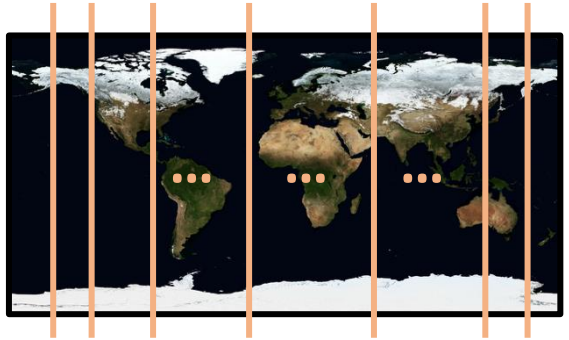
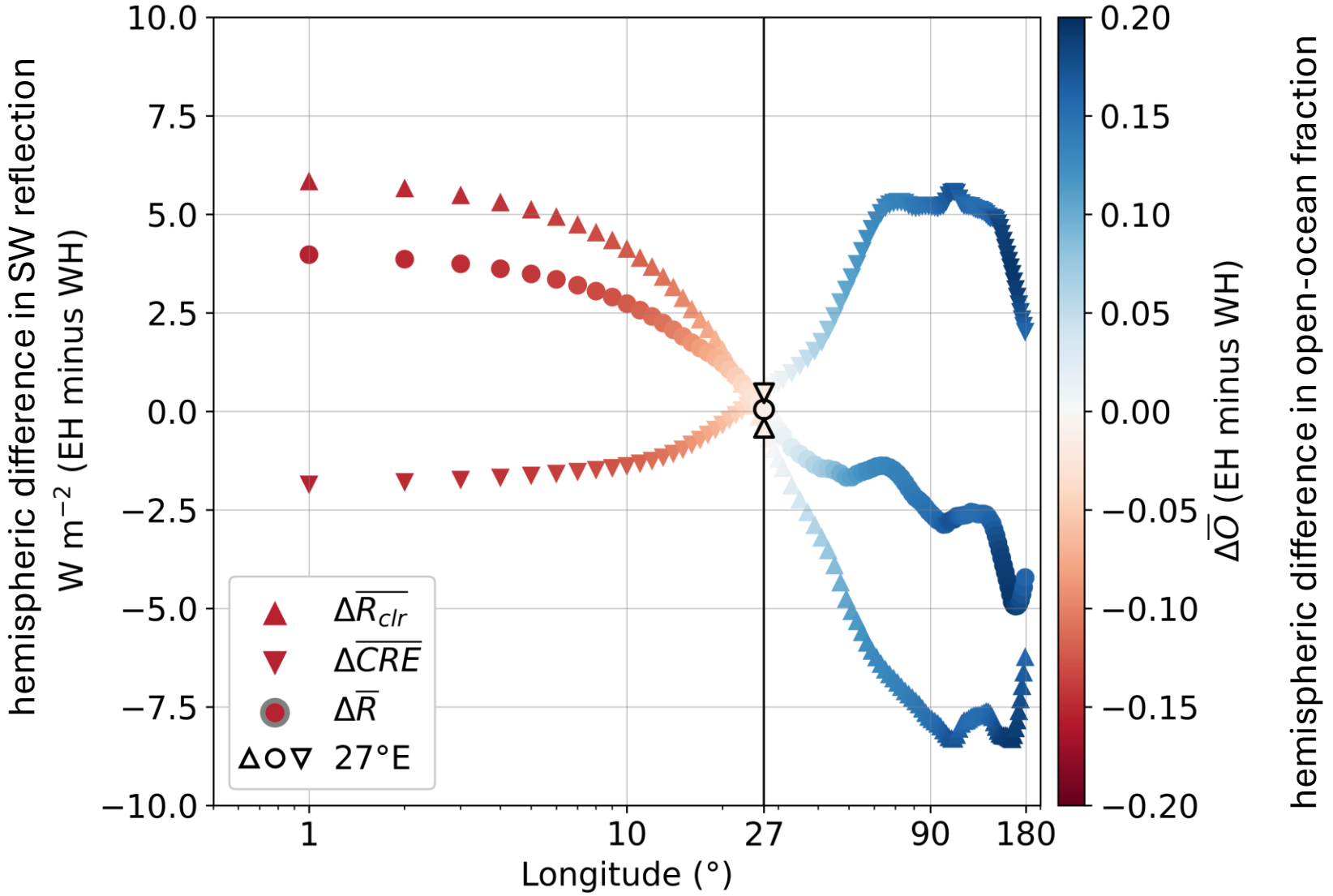
0.00
−0.05
−0.10
−0.15
−0.20
$\Delta\overline{O}$ (EH minus WH)
hemispheric difference in open-ocean fraction

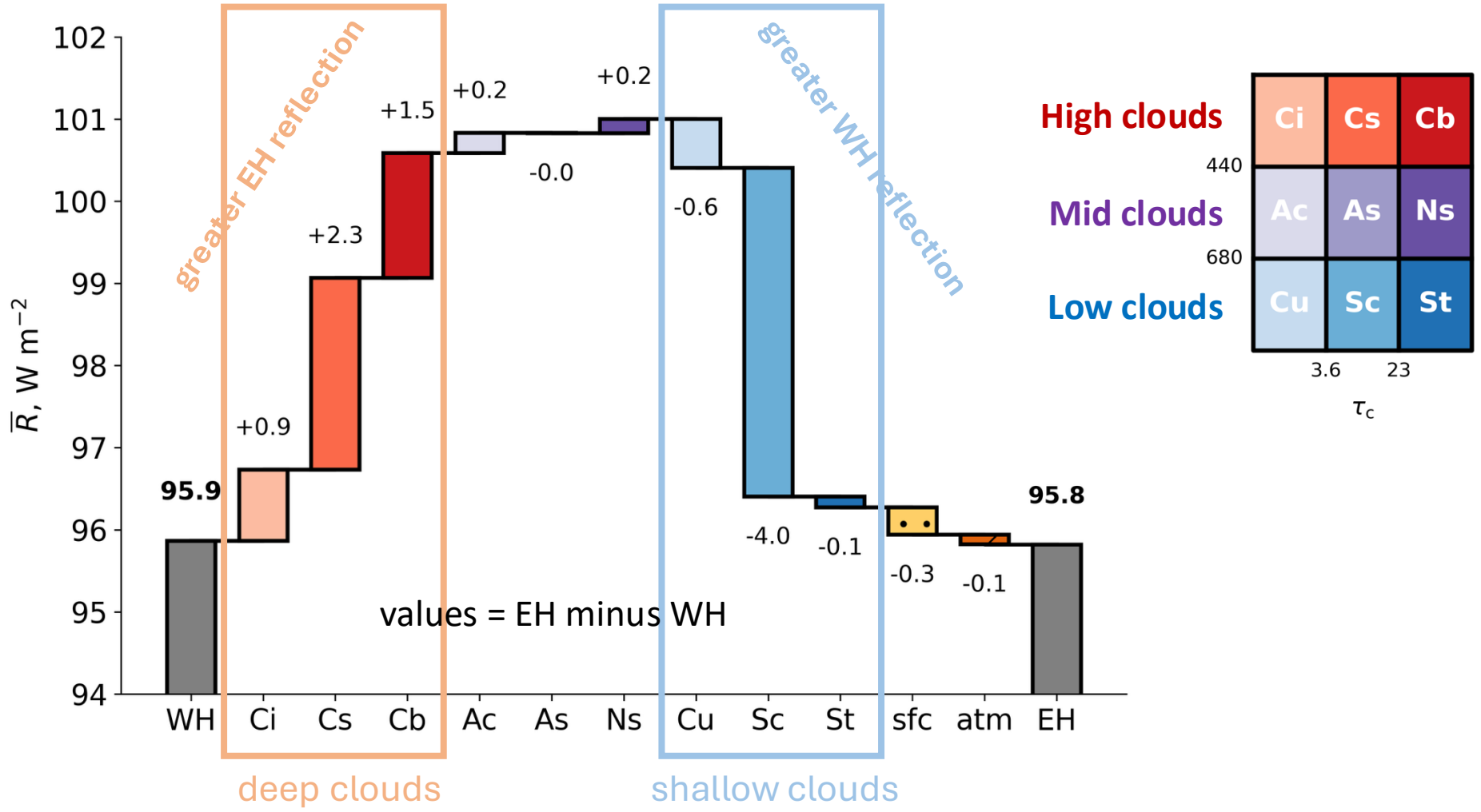
A “triple-symmetry” in the East-West (E-W)





CERES EBAF Ed4.2.1 (2001-2025)

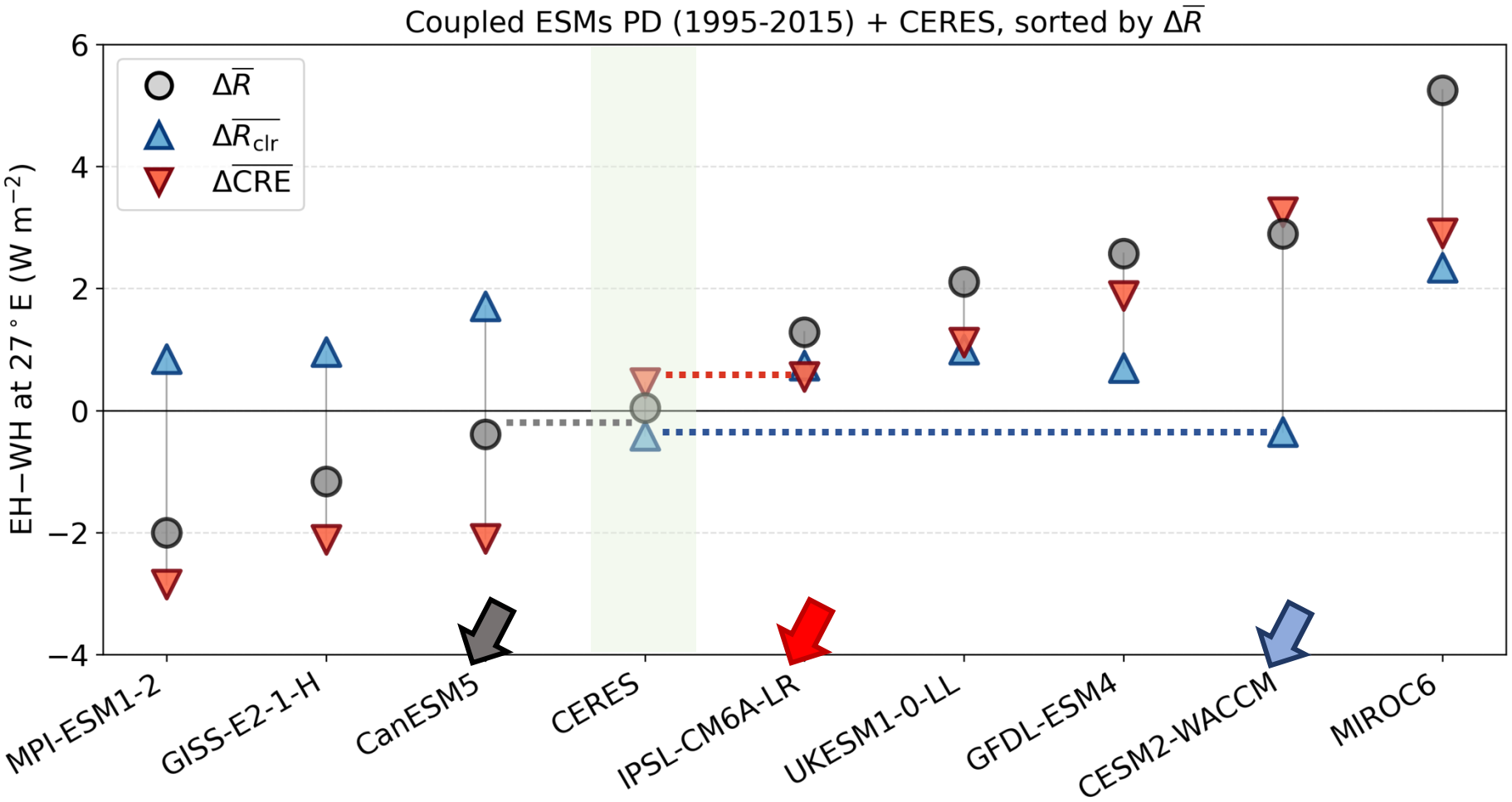
A compensation between low and high clouds



CERES FBCT Ed4.1 (2003-2022)

Waterfall plot following Diamond et al. (2024), GRL

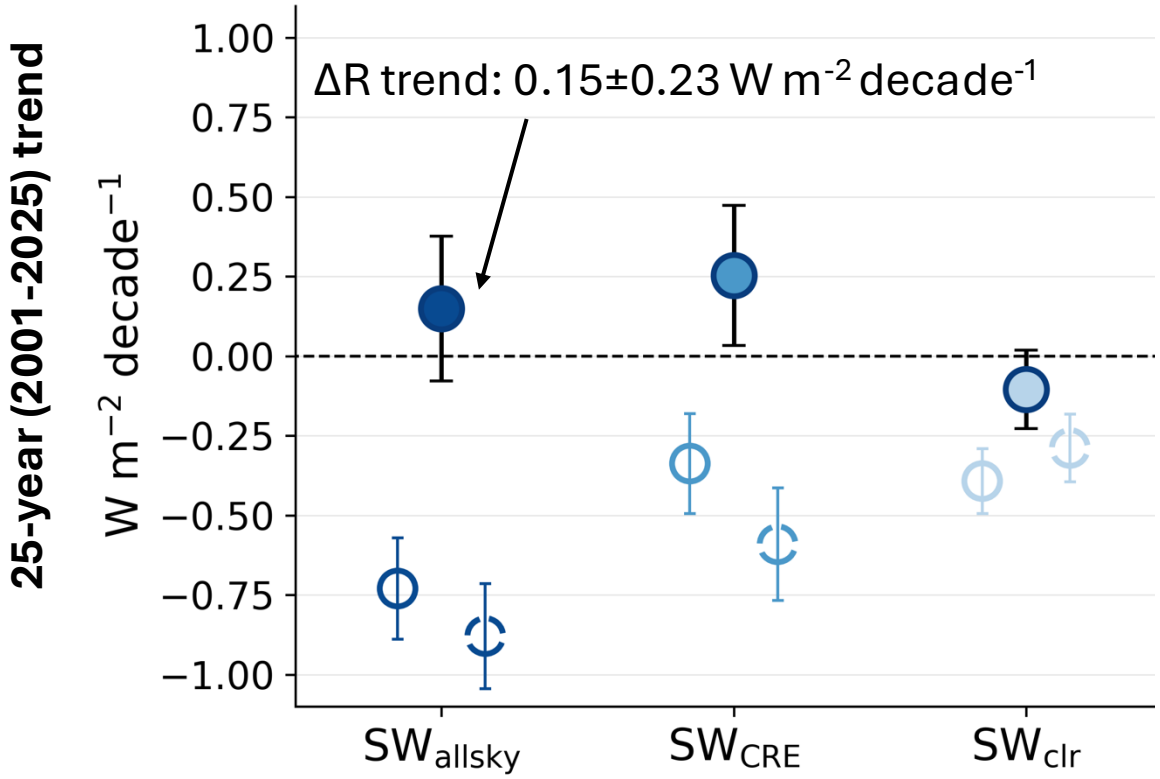
CMIP6 models do not capture the observed E-W symmetry at 27 E and its ‘triple symmetry’ feature

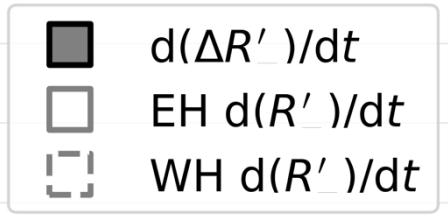


CMIP6 & CERES EBAF Ed4.2.1 (2001-2025)

Earth is darkening,

‘triple symmetry’ is breaking down due to asymmetry trends in CRE and R_{clr} , which compensate to maintain the all-sky (R) symmetry

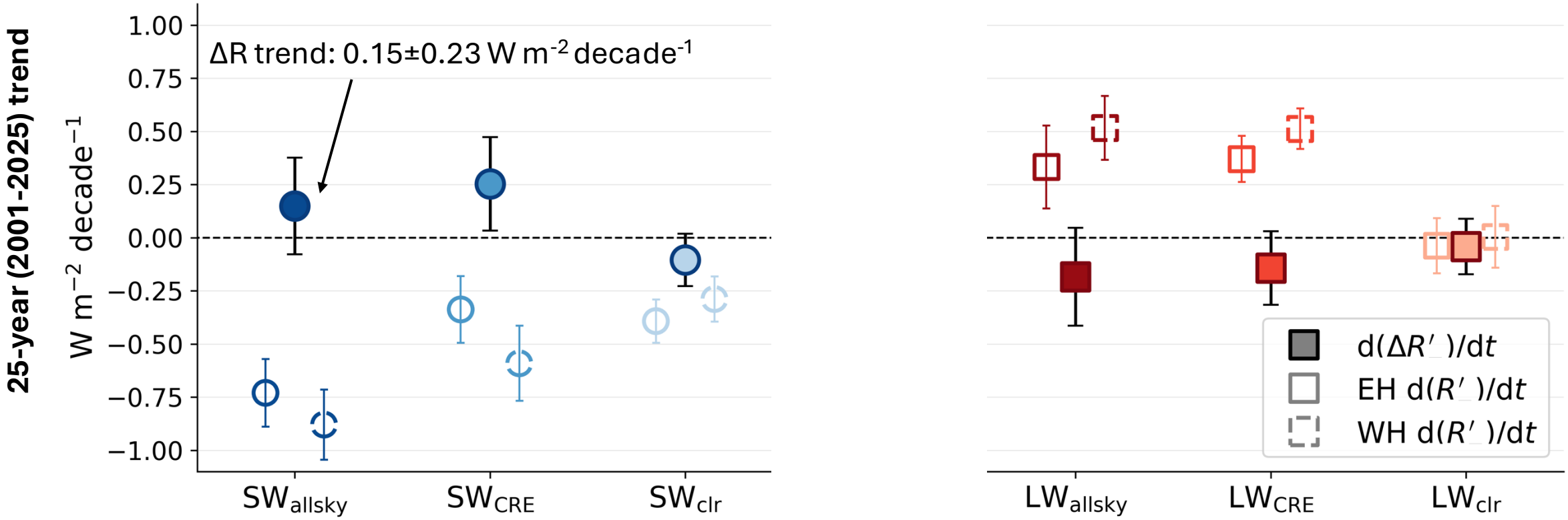




Δ = EH – WH at 27 E

CERES EBAF Ed4.2.1 (2001-2025)

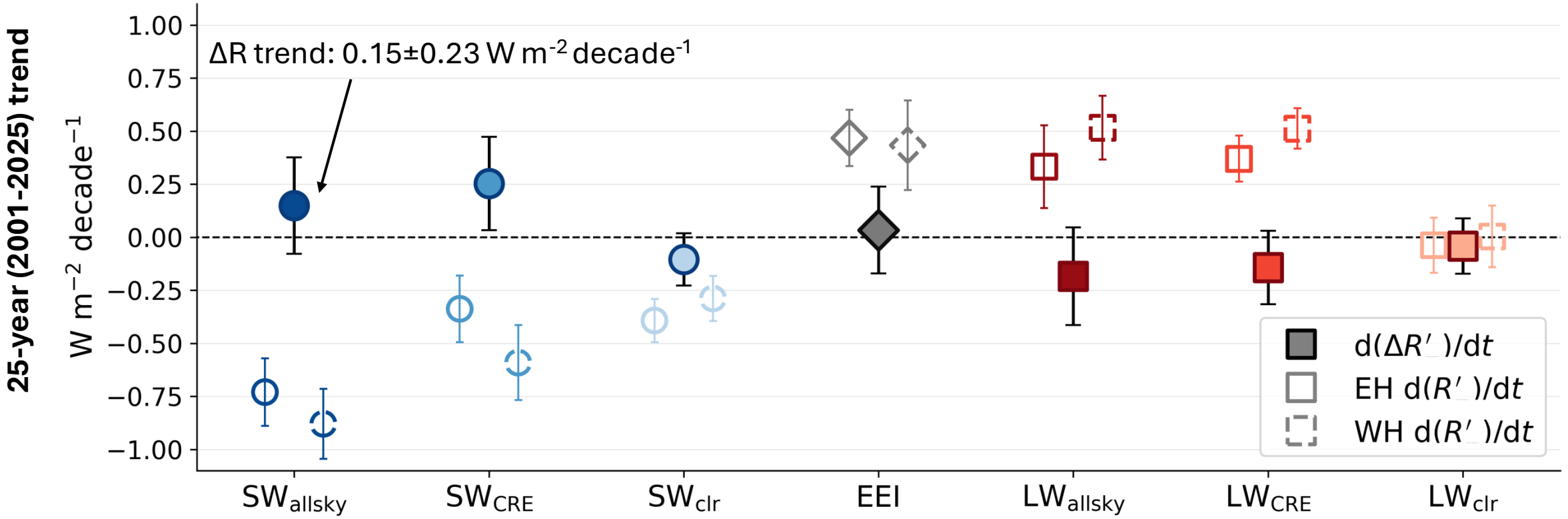
Trends in outgoing LW radiation (OLR) compensate



Δ = EH – WH at 27 E

CERES EBAF Ed4.2.1 (2001-2025)

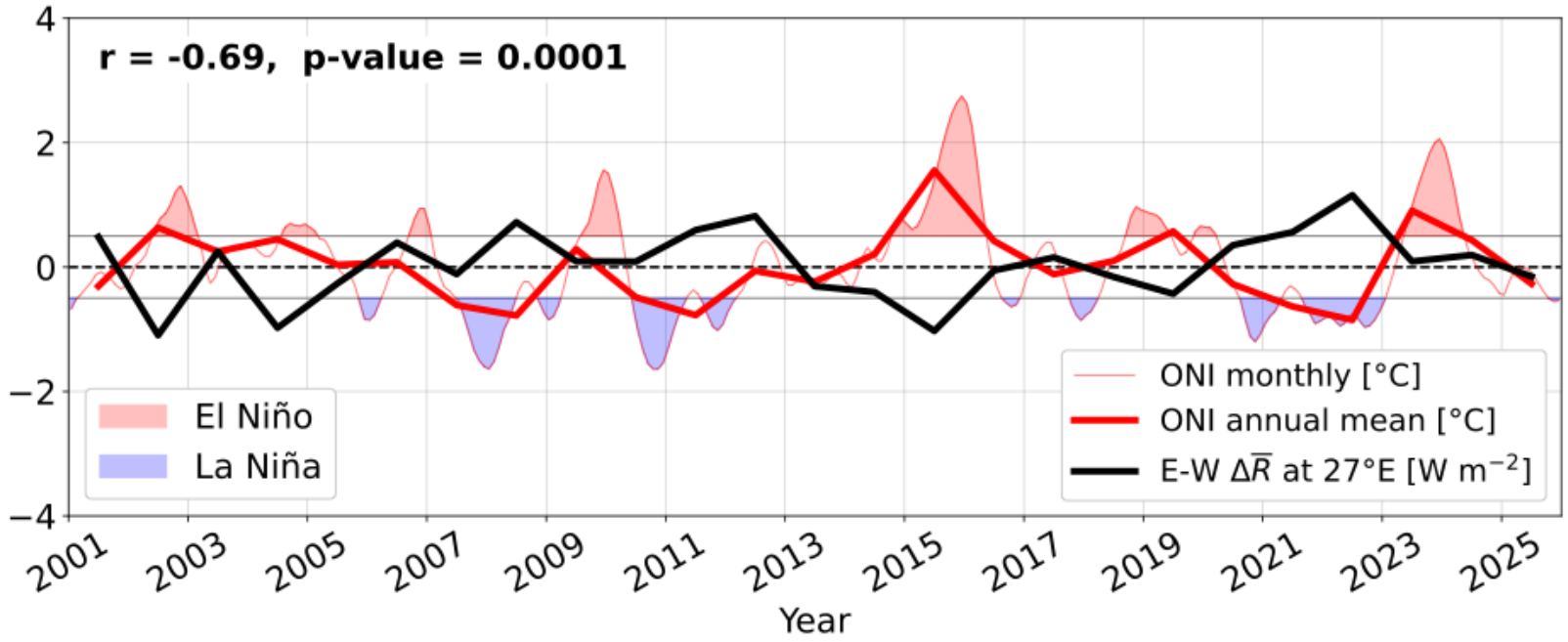
Resulting in similar EEI trends between the two hemispheres



Δ = EH minus WH at 27 E

CERES EBAF Ed4.2.1 (2001-2025)

Whether and how the symmetry is maintained?

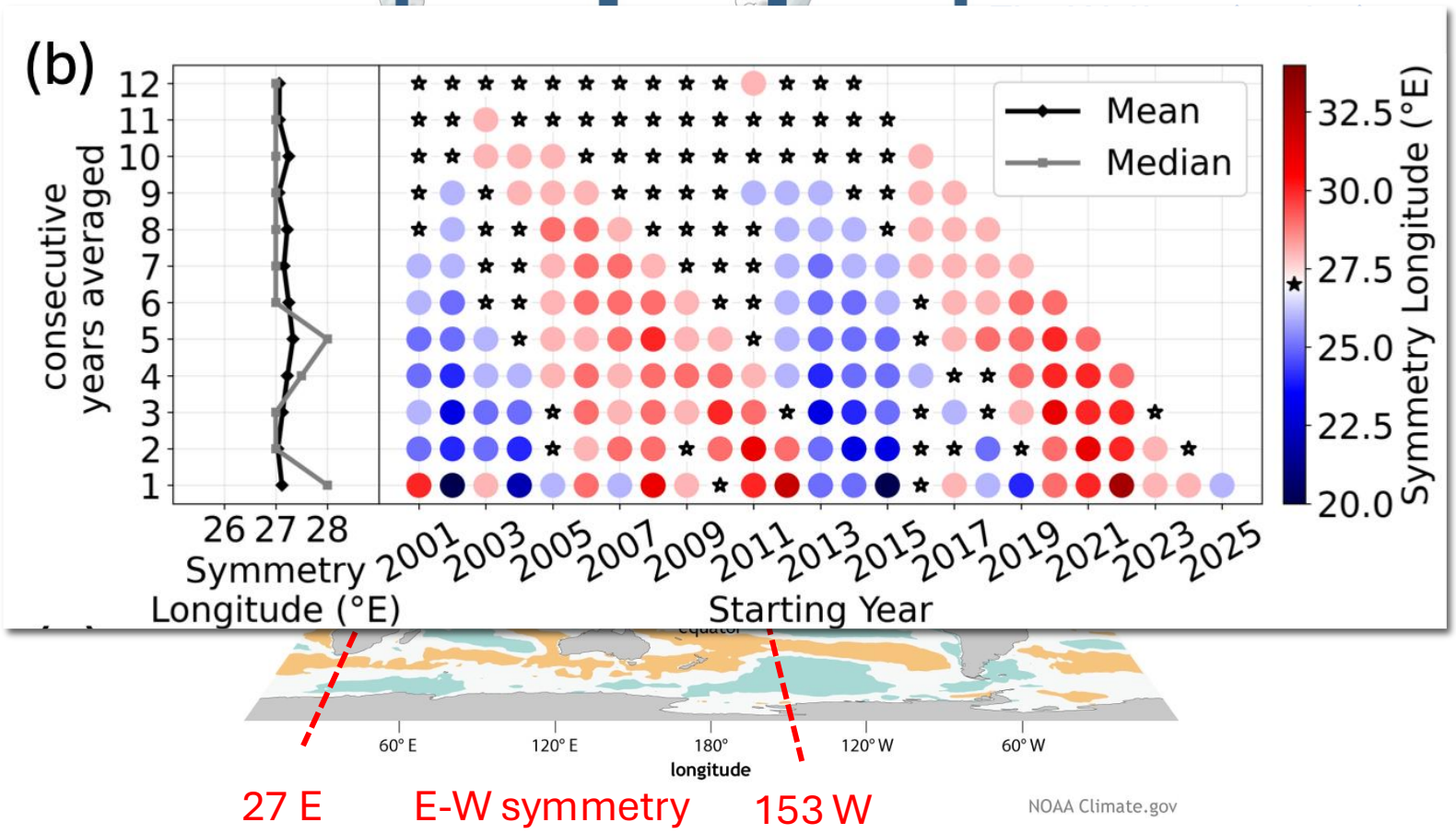


Interannual variability in E-W symmetry is connected to ENSO variability

CERES EBAF Ed4.2.1 (2001-2025); NOAA ONI index

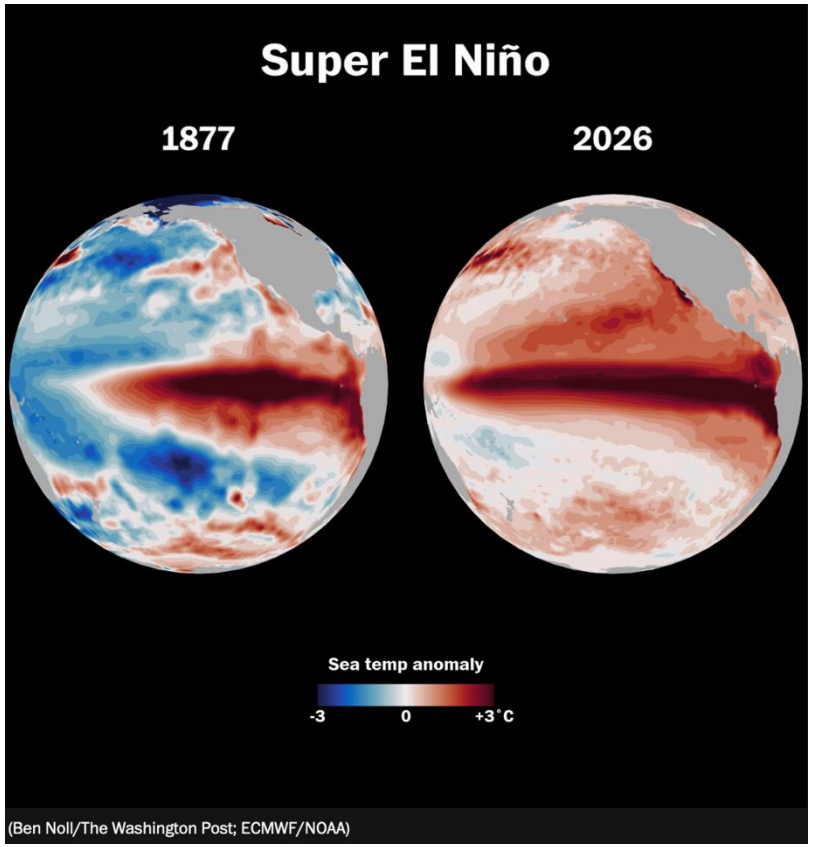
Hypothesis: Oscillating overturning circulation is responsible for maintaining the E-W symmetry at 27E

El Niño



…, which is subject to change under warming

e.g., Held & Soden (2006), J Clim and Vecchi & Soden (2007), J Clim



Bjerknes (1969), MWR

Why should we care?

- ***Model Evaluation.*** The 'triple symmetry' could help assess if models "get it right for the right reasons".
- ***Understanding of Earth system couplings.*** If the symmetry breakdown in the future, it could indicate significant shifts in circulation patterns.
- ***Implication for SRM.*** The impacts of Solar Radiation Modification (SRM) cascade through Earth system couplings.

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More Questions.

- **Are** albedo symmetry pairs fundamentally connected, or do they emerge independently? (*E-W and N-S do not appear connected*)
- **Is** the open ocean symmetry essential for the E-W all-sky symmetry? (*we don't see this in the models*)

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