Department of Meteorology

University of Reading

TRUTHS potential contributions in atmospheric modelling and understanding changes in Earth's radiation budget

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TRUTHS for Climate Workshop 27-28 June 2024

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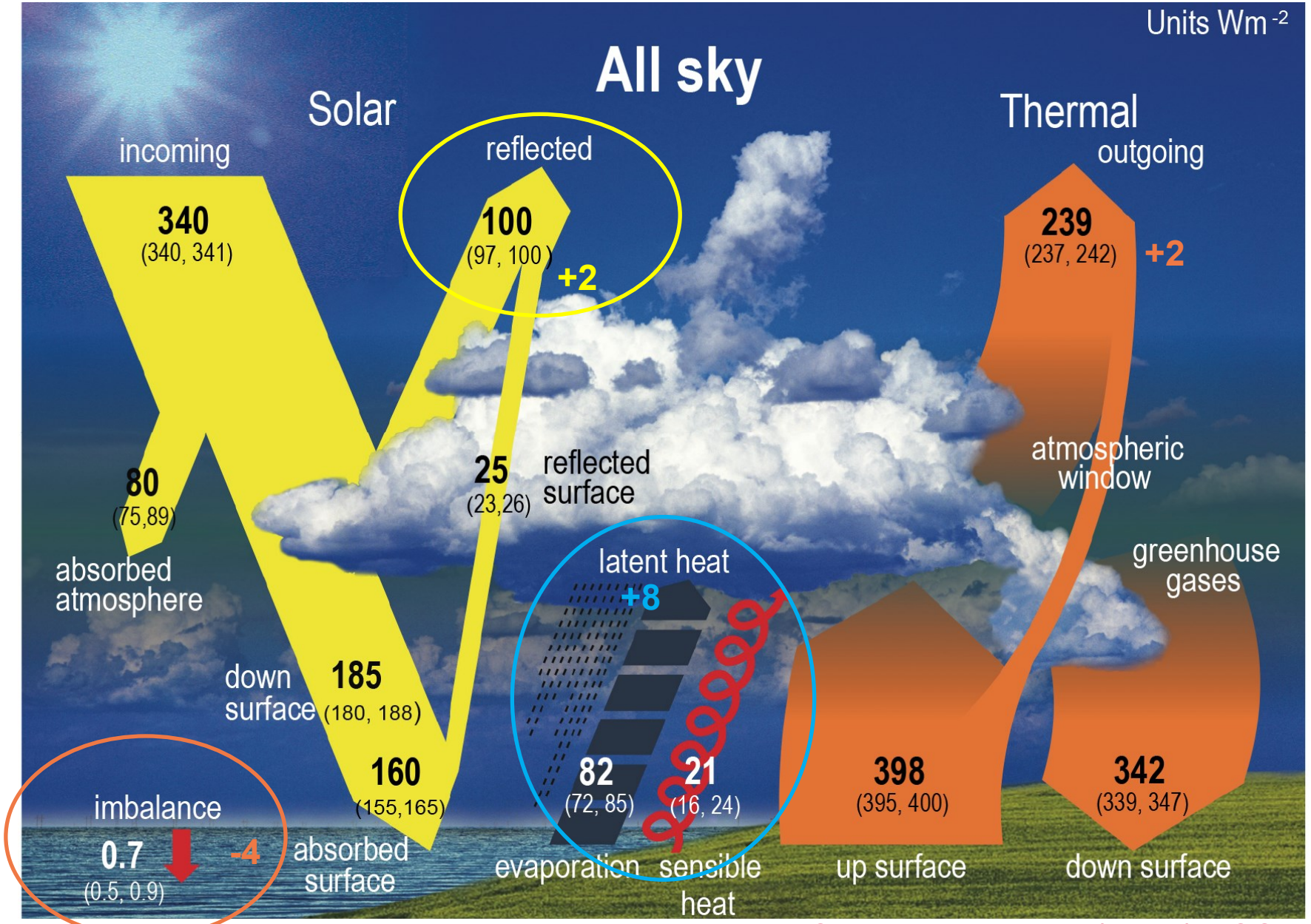


Latest bottom up estimate: von Shuckmann et al. (2023) ESSD

SPOT THE IMBALANCE…

← Earth's present day energy budget

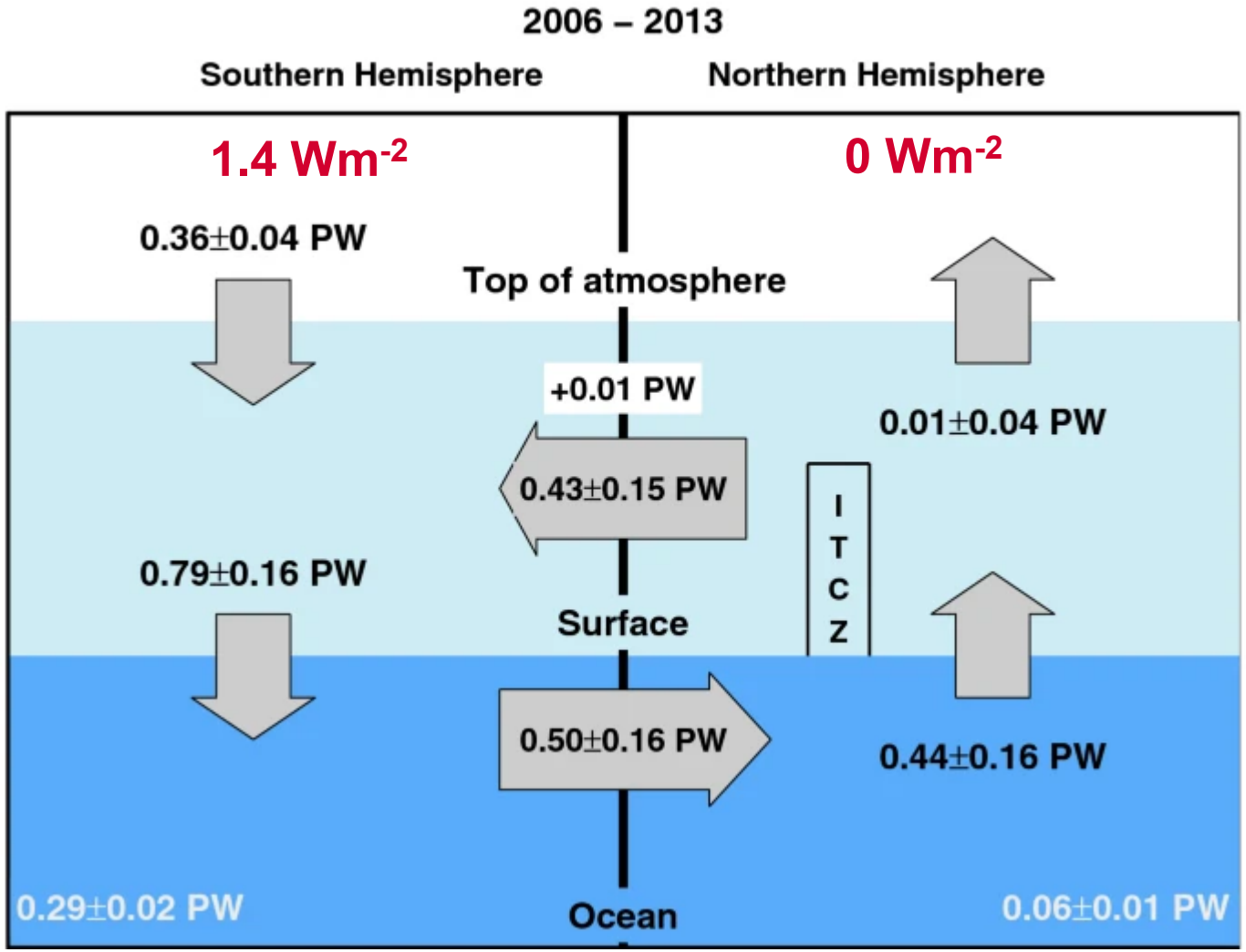
Forster et al. (2021) Chapter 7 of IPCC report, Figure 7.2

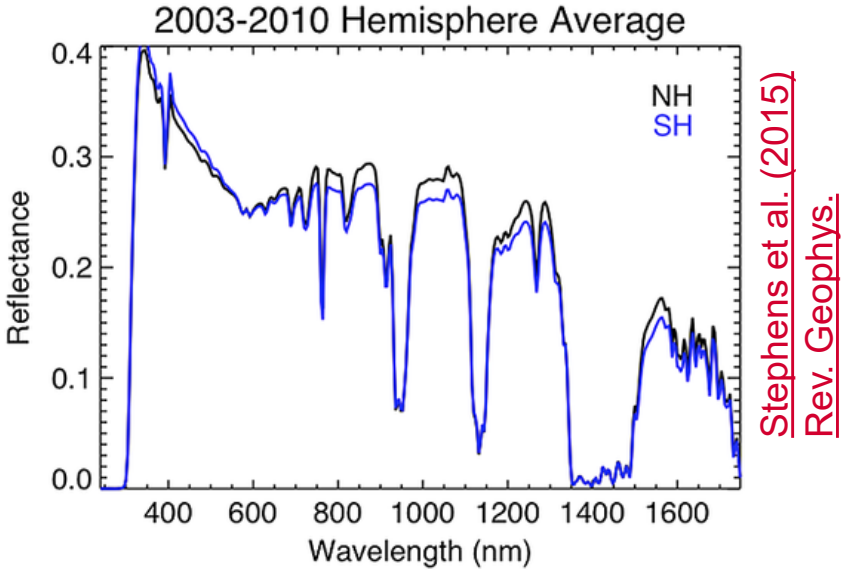
CERES adjusts reflected shortwave to force small imbalance to agree with Argo ocean heating

e.g. Loeb et al. (2018) J. Clim

→ Energy – water cycle uncertainty e.g. Stephens et al. (2012) Nature Geosci.

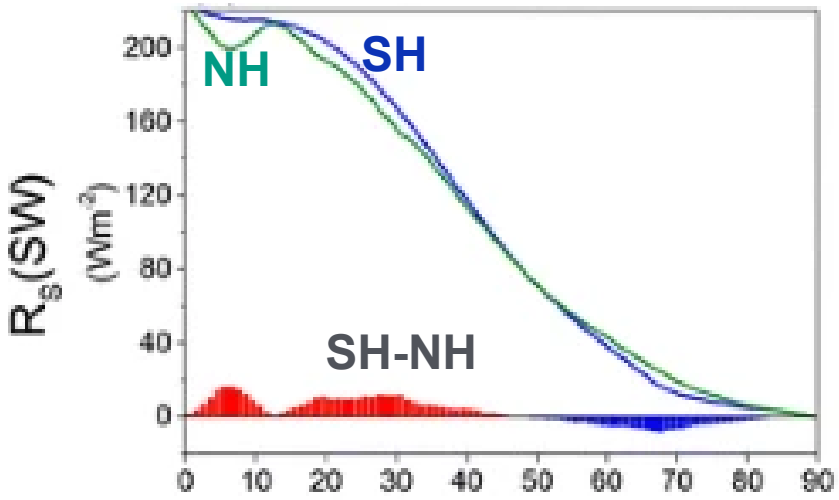
HEMISPHERIC IMBALANCE





Stephens et al. (2015) Rev. Geophys.

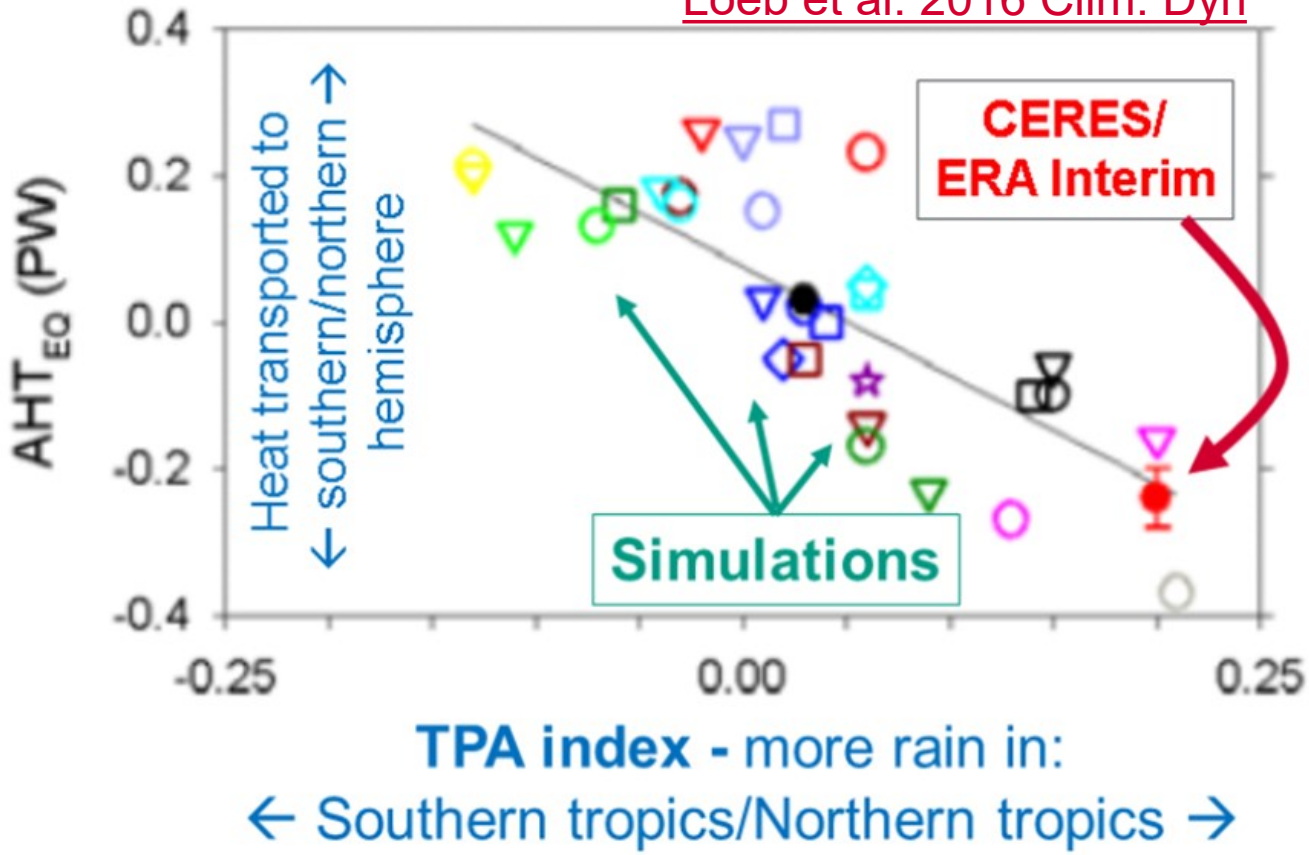
Surface shortwave with latitude



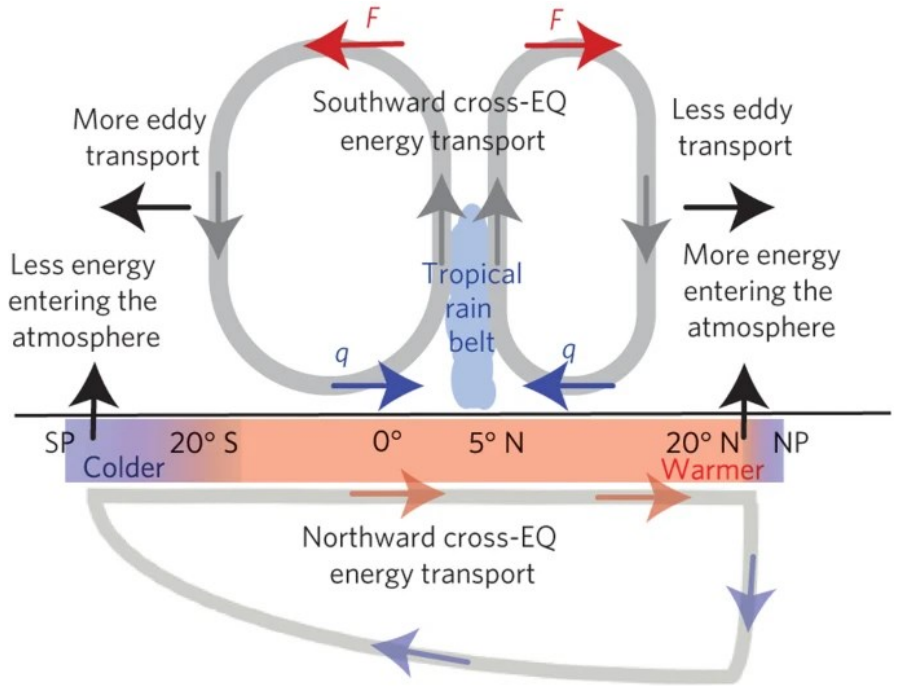
Liu et al. (2020) Clim. Dyn.; Loeb et al. 2016 Clim. Dyn

HEMISPHERIC IMBALANCE & PRECIPITATION

Loeb et al. 2016 Clim. Dyn



Estimated cross equatorial atmospheric heat transport in peta Watts (AHT_{EQ}) against an index of tropical precipitation asymmetry (TPA) between hemispheres in simulations and observations



Frierson et al. (2013) Nature Geosci.

Zhang et al. (2023) Adv.Atmos.Sci.; Pearce & Bodas-Salcedo (2023) J. Clim; Rugenstein & Hakuba (2023) GRL; Diamond et al. (2022) Comm. Earth Env.; Jonsson & Bender (2022) J. Clim. …

HEMISPHERIC SHORTWAVE DIFFERENCE & OCEAN CIRCULATION

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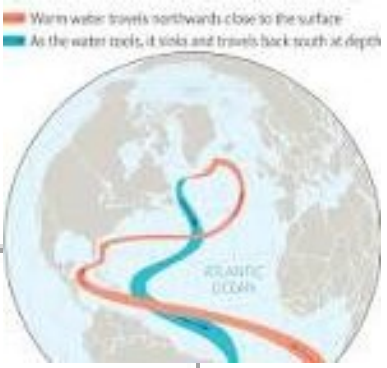
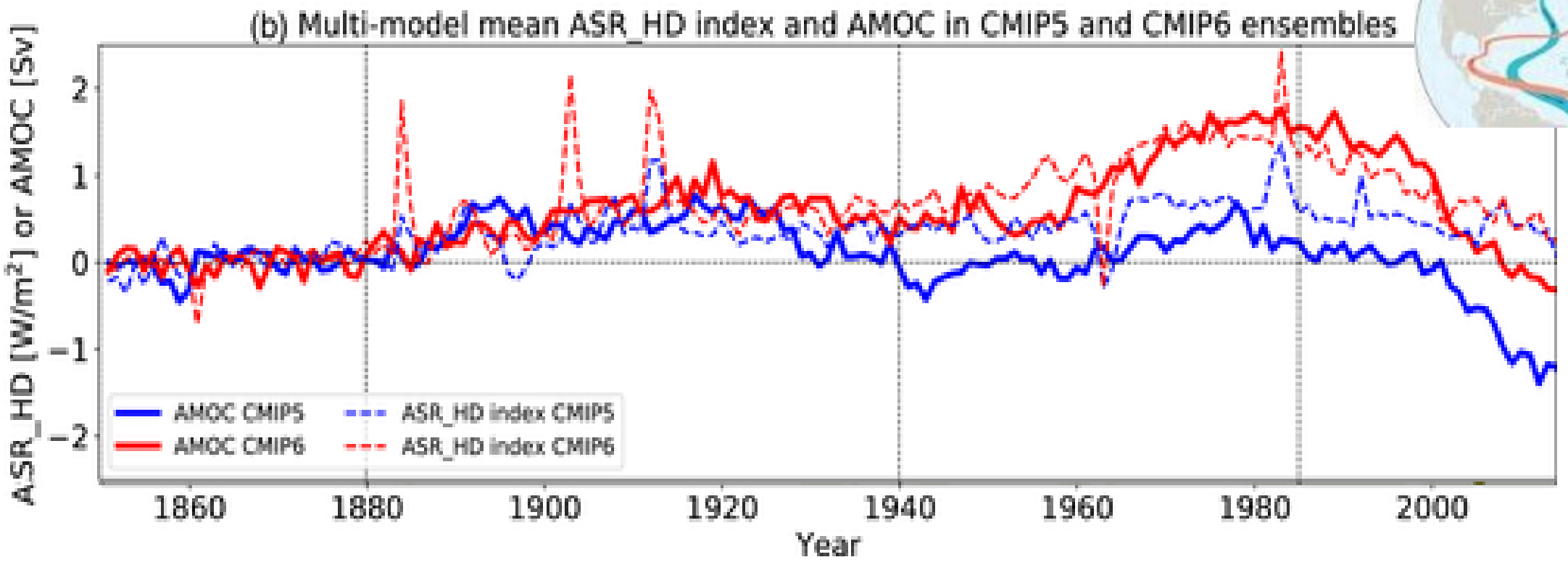
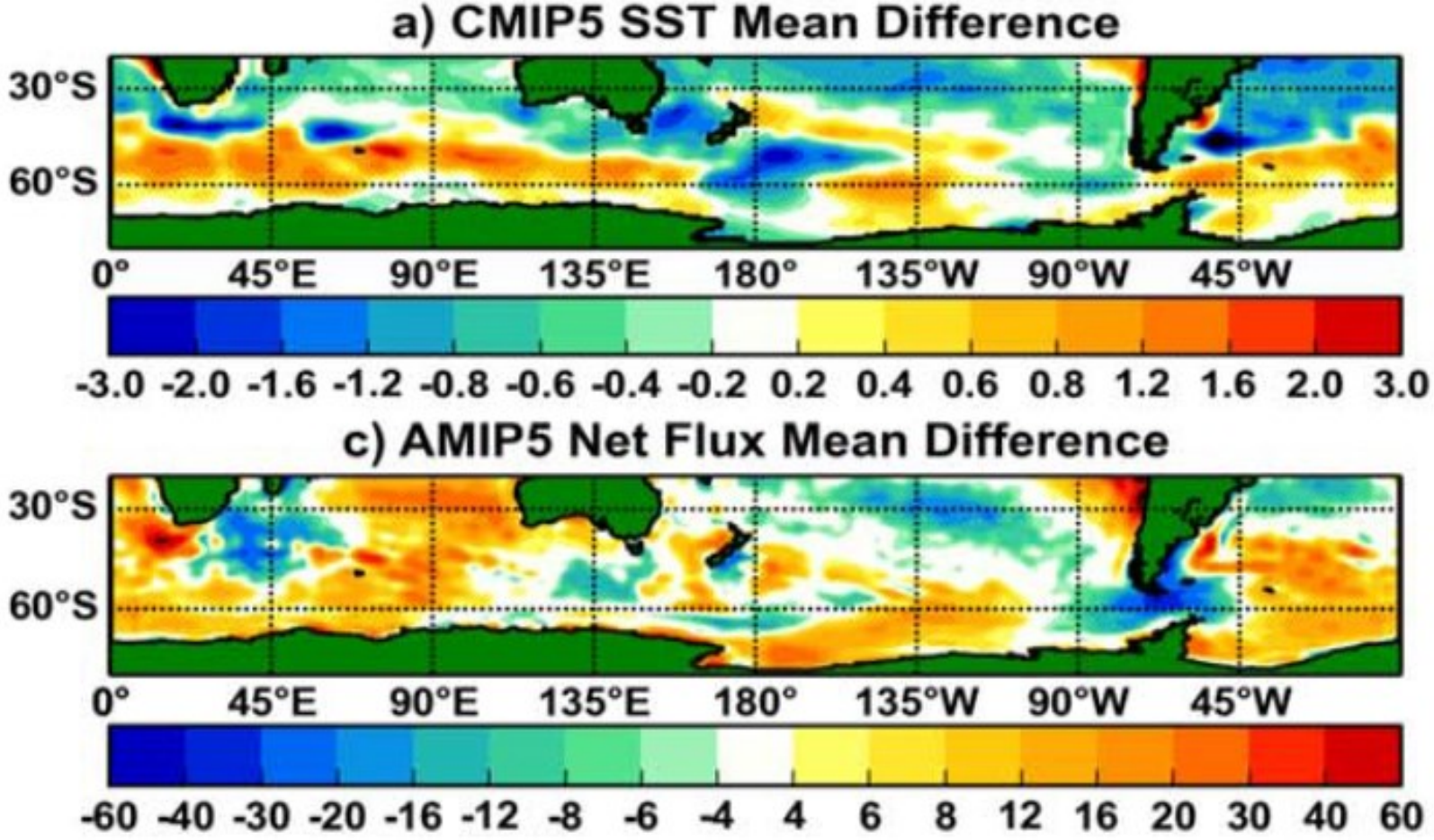




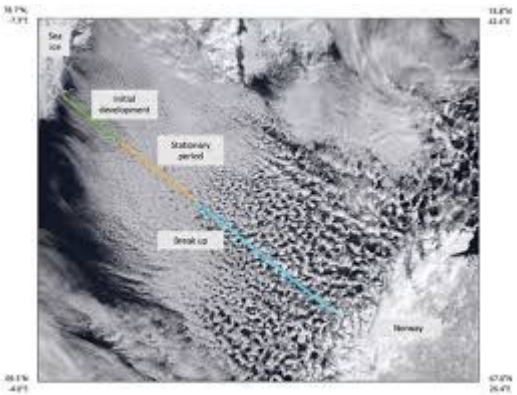
Menary et al. (2021) GRL

INTRANSIGENT SYSTEMATIC BIASES



- Subtle contrasts in reflection of sunlight crucial in understanding & addressing systematic biases in climate models

Hyder et al. (2018) *Nature Comms*



ANCIENT HISTORY

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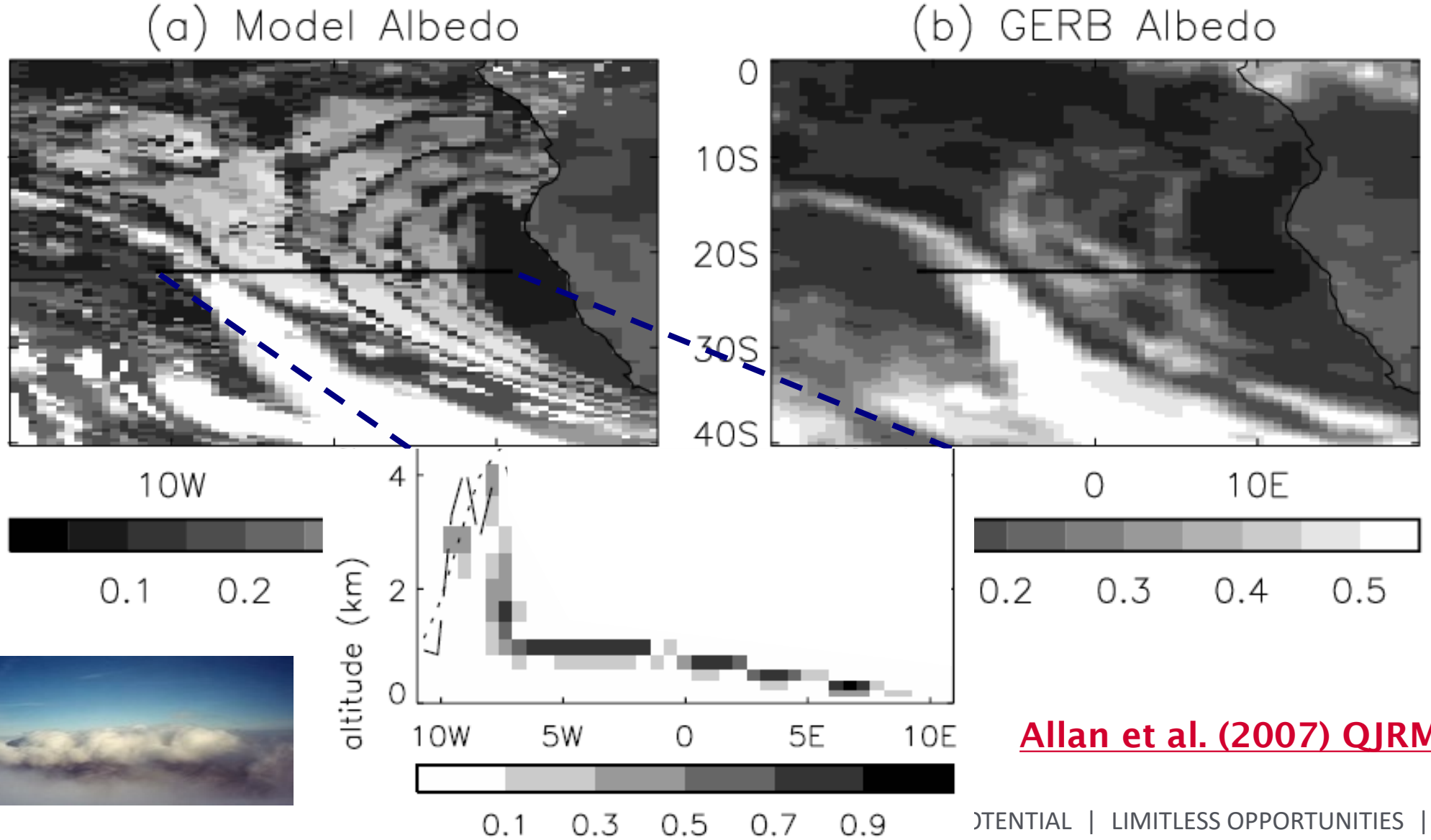
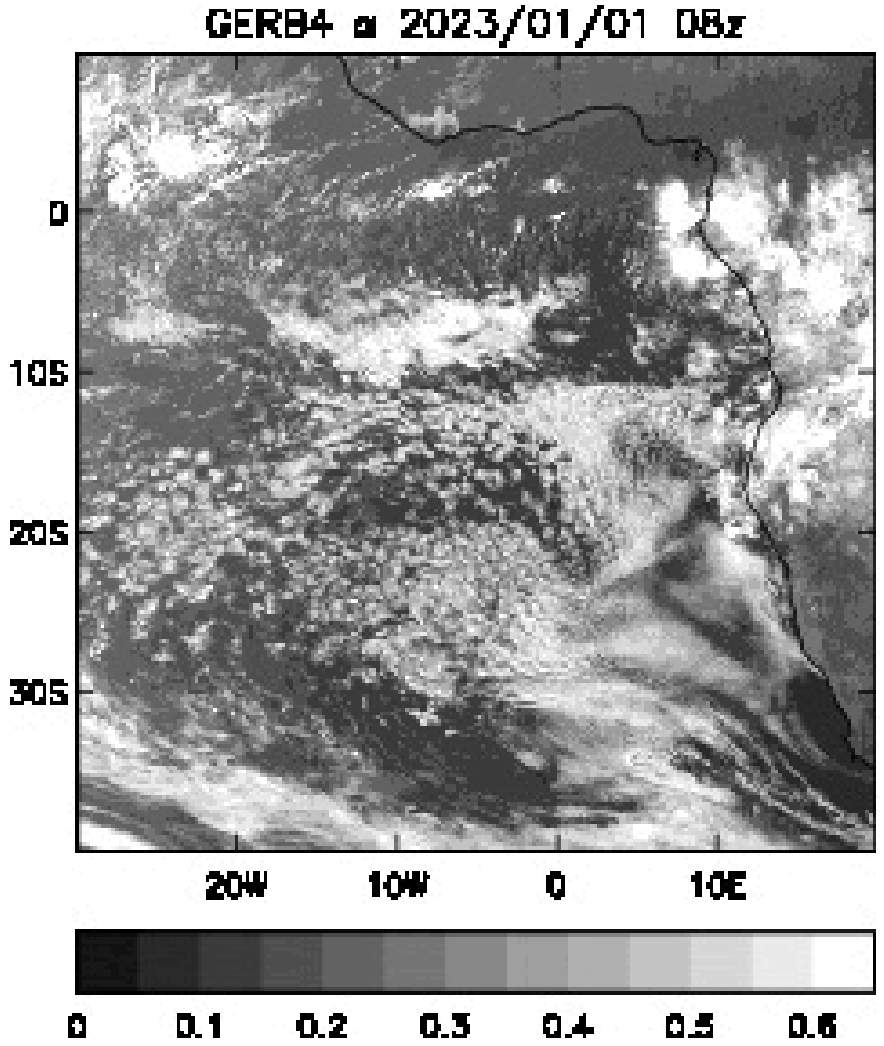
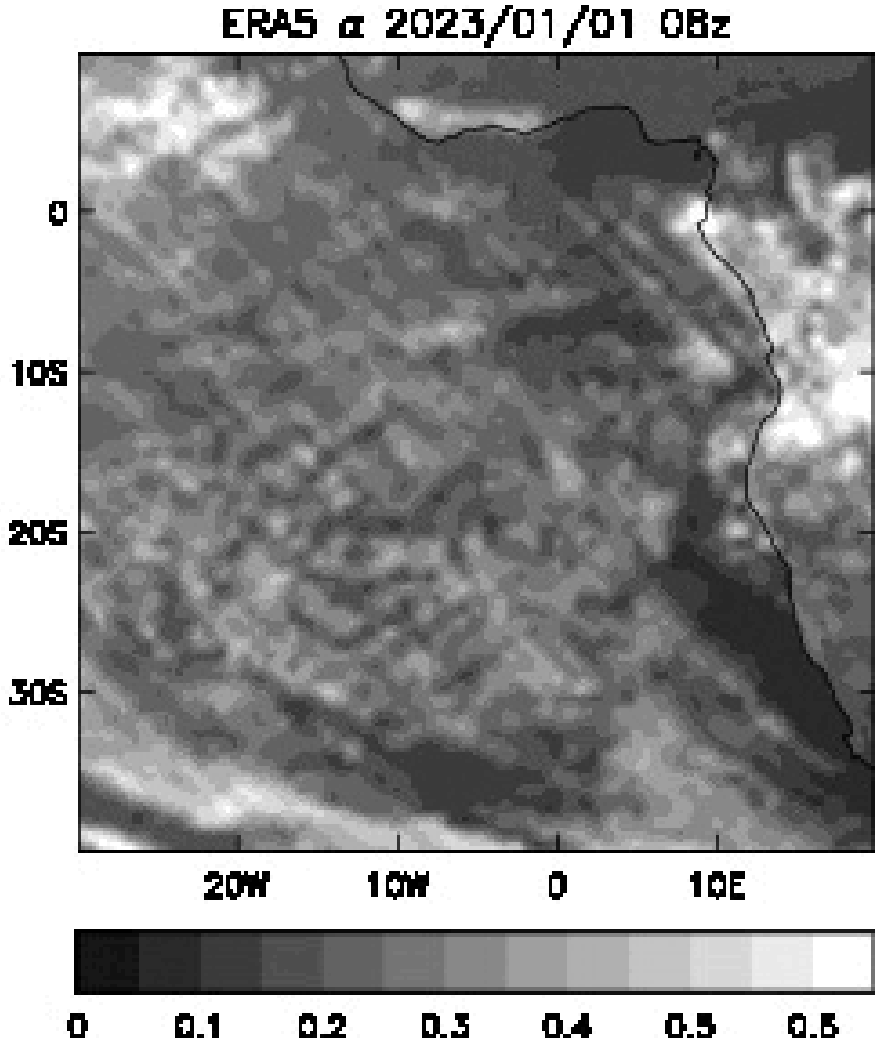
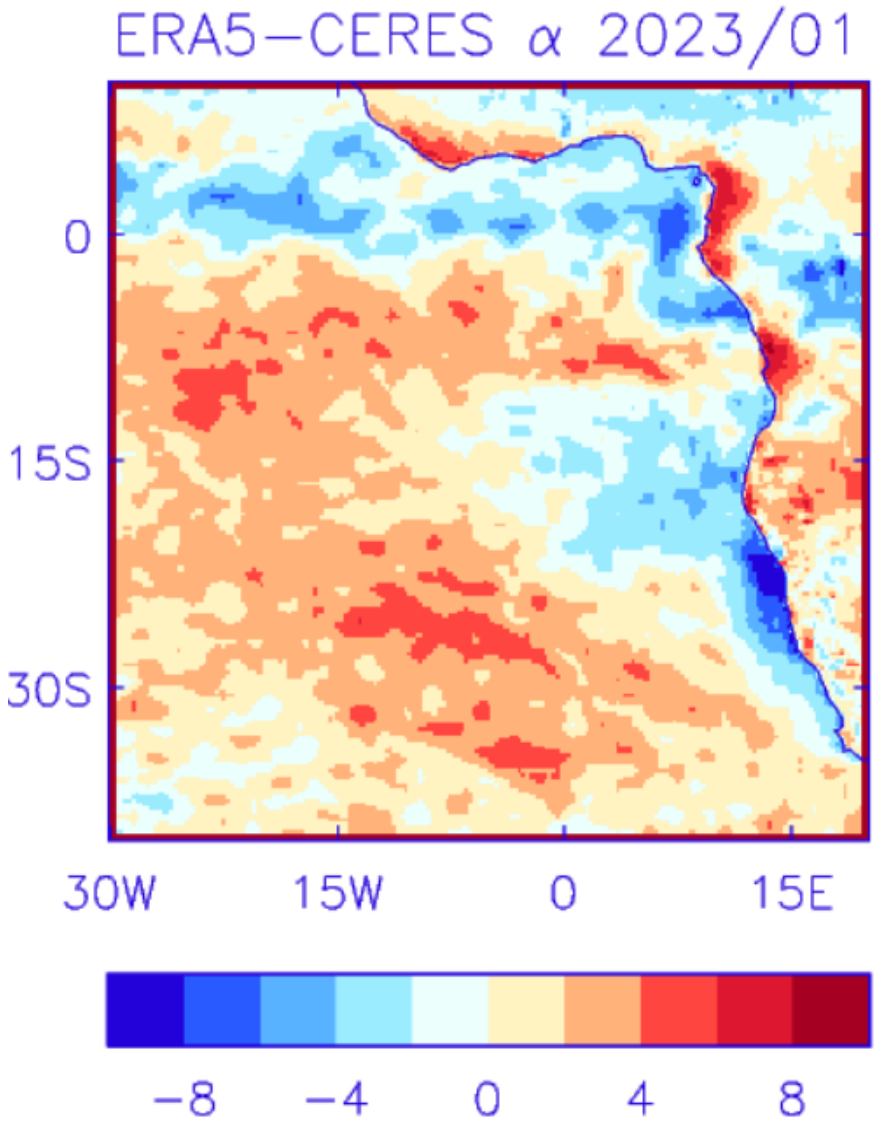


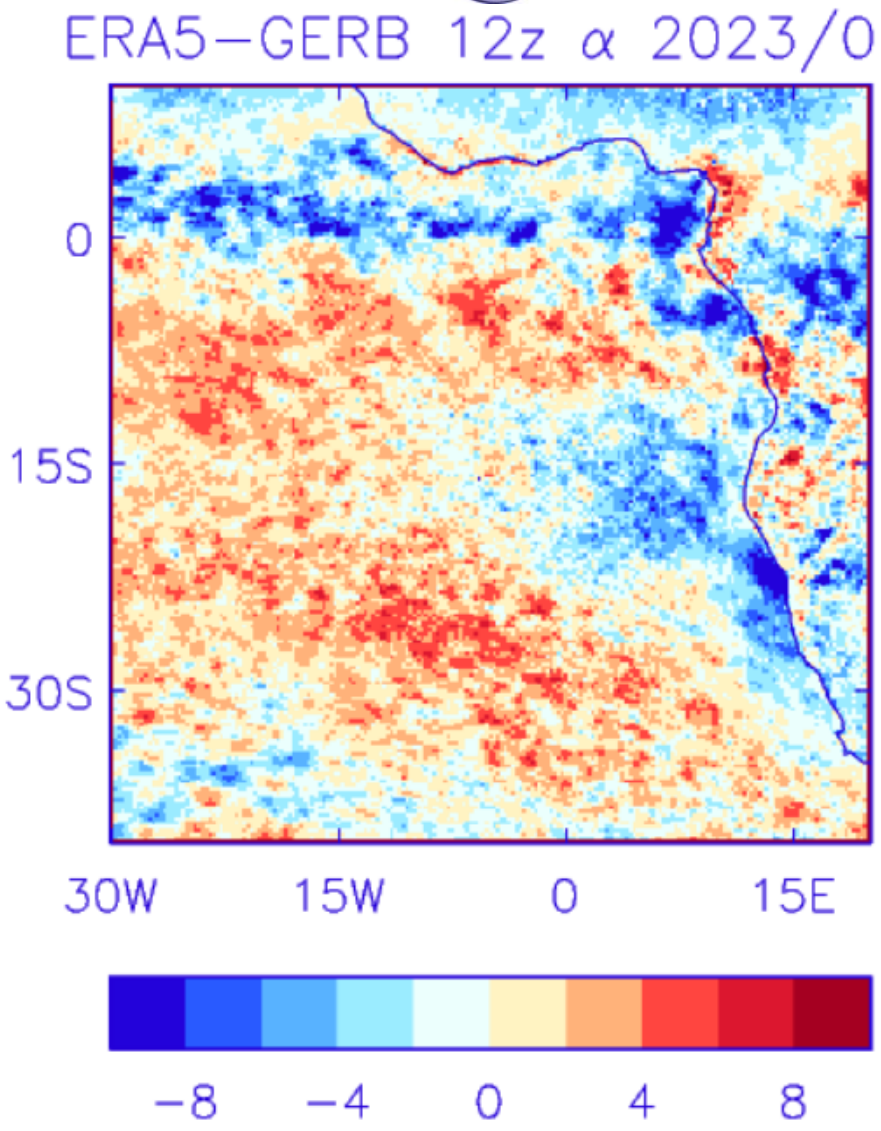
Allan et al. (2007) QJRMetS

GERB4 VS ERA5 HOURLY









- ERA5 minus observations (% albedo)
- Monthly daily mean (CERES)
- Monthly 12-13z mean (GERB4)

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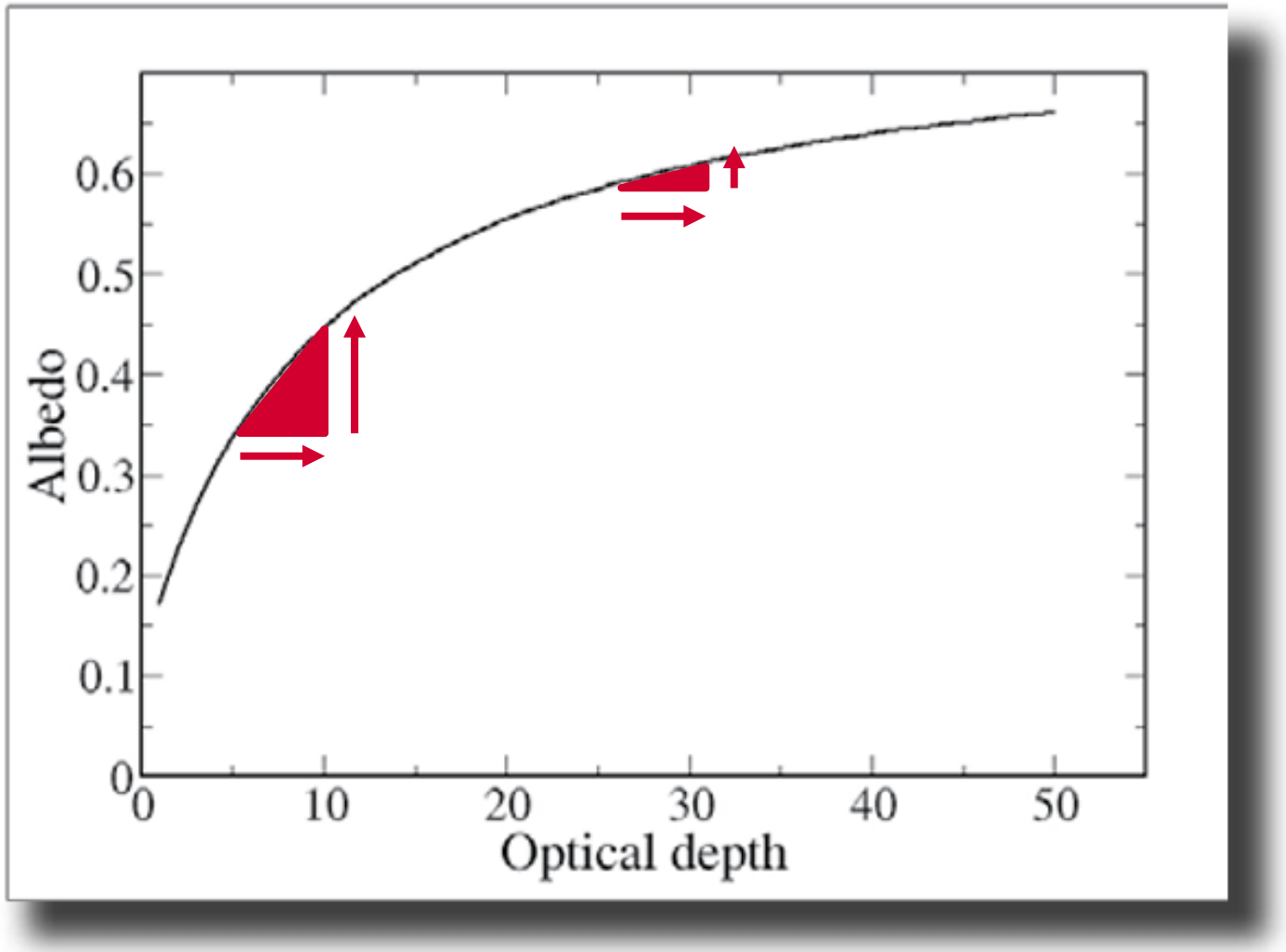
OPTICAL DEPTH FEEDBACKS

- Sensitivity of cloud albedo to cloud optical depth changes increases rapidly for dimmer clouds



Calculated relationship between cloud albedo and optical depth based on a simple radiation model where vertically incident sunlight is assumed.

HAVE CLOUDS BEEN DISSOLVING?

Geophysical Research Letters

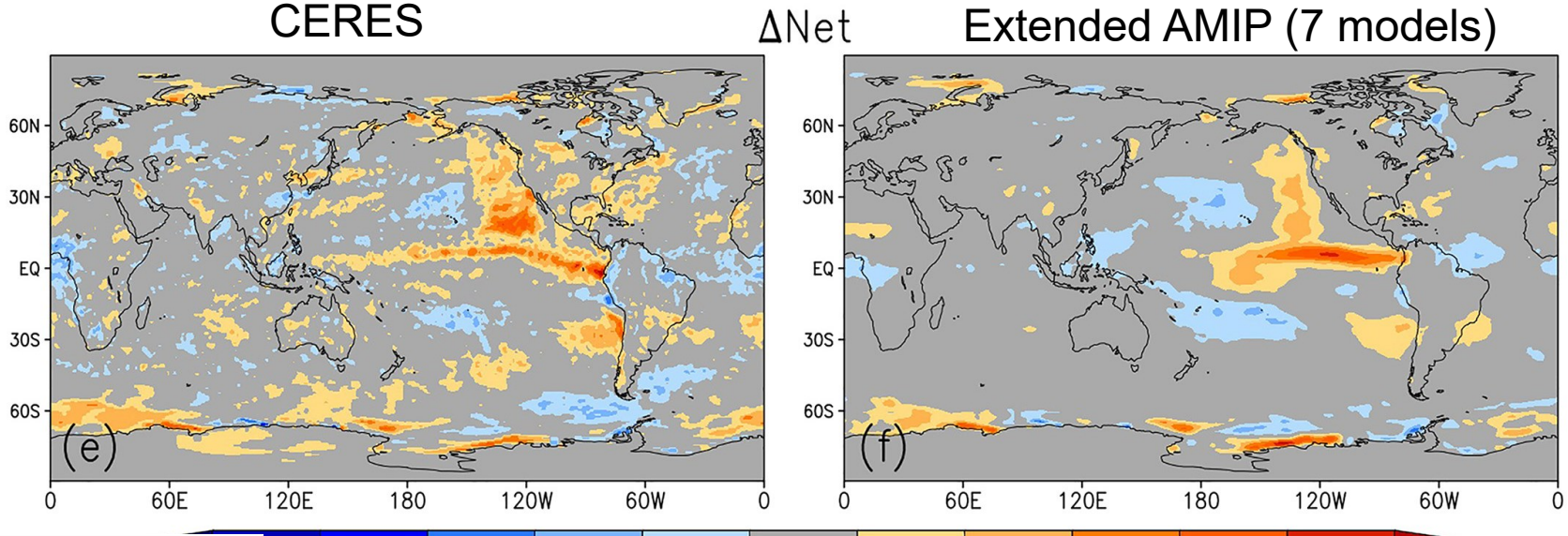
RESEARCH LETTER
10.1029/2019GL086705

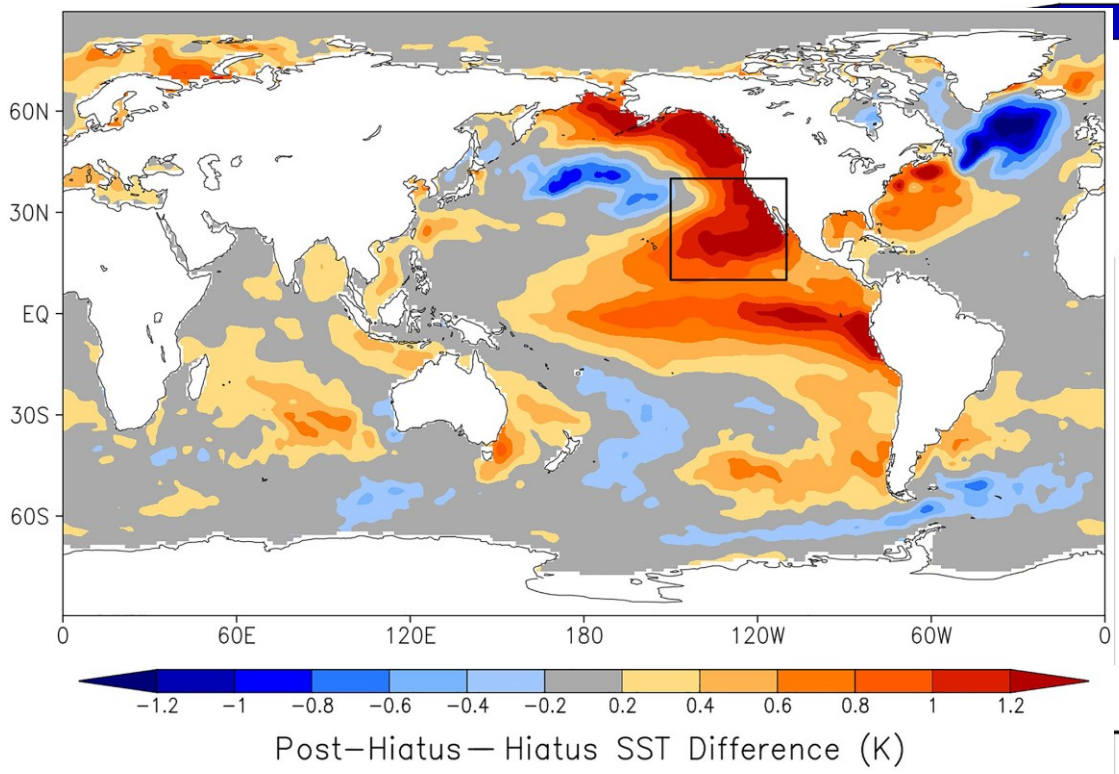
Key Points:
- There is good agreement between radiation budget variations observed by CERES and simulated by seven state-of-the-art climate models
- The relationship between global mean net TOA radiation and surface temperature is sensitive to changes in regions dominated by low clouds
- Most models underestimate shortwave flux changes in response to SST changes over the east Pacific, suggesting too weak a "pattern effect"

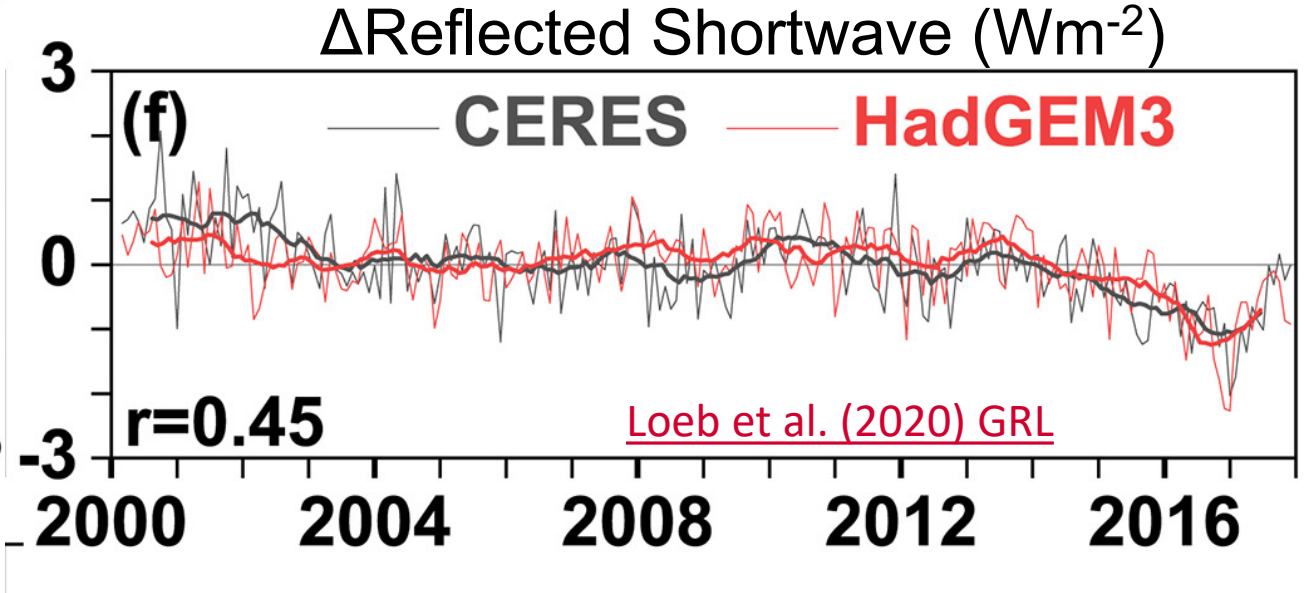
New Generation of Climate Models Track Recent Unprecedented Changes in Earth's Radiation Budget Observed by CERES

Norman G. Loeb[1], Hailan Wang[2], Richard P. Allan[3], Timothy Andrews[4], Kyle Armour[5], Jason N. S. Cole[6], Jean-Louis Dufresne[7], Piers Forster[8], Andrew Gettelman[9], Huan Guo[10], Thorsten Mauritsen[11], Yi Ming[10], David Paynter[10], Cristian Proistosescu[12,13], Malte F. Stuecker[14], Ulrika Willén[15], and Klaus Wyser[15]

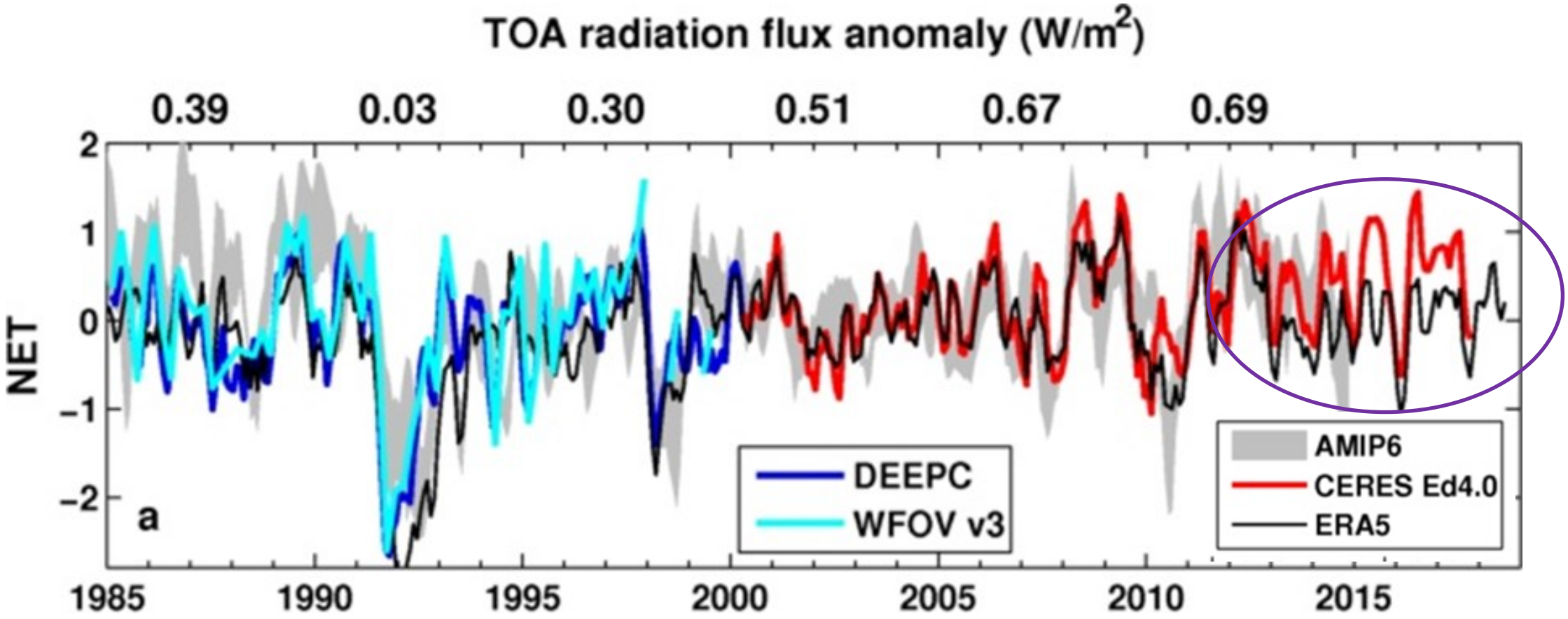
[1]NASA Langley Research Center, Hampton, VA, USA, [2]Science Systems and Applications, Inc., Hampton, Virginia, USA, [3]Department of Meteorology and National Centre for Earth Observation, University of Reading, Reading, UK, [4]Met Office Hadley Centre, Exeter, UK, [5]Department of Atmospheric Sciences, University of Washington, Seattle, WA, USA, [6]Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Victoria, British







INCREASING NET HEATING OF PLANET



Liu et al. (2020) Clim. Dyn. based on method in Allan et al. (2014) GRL

IS THE PLANET IS SOAKING UP MORE SUNSHINE?

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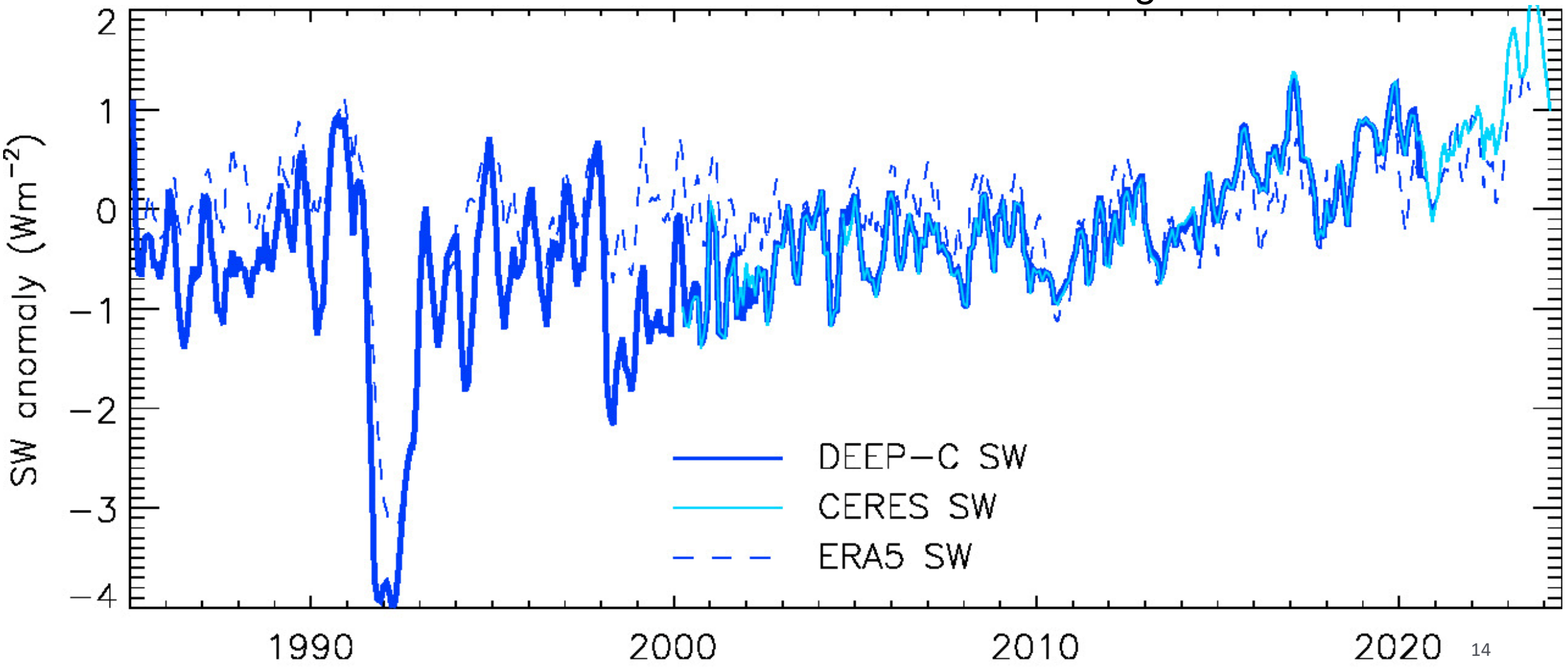
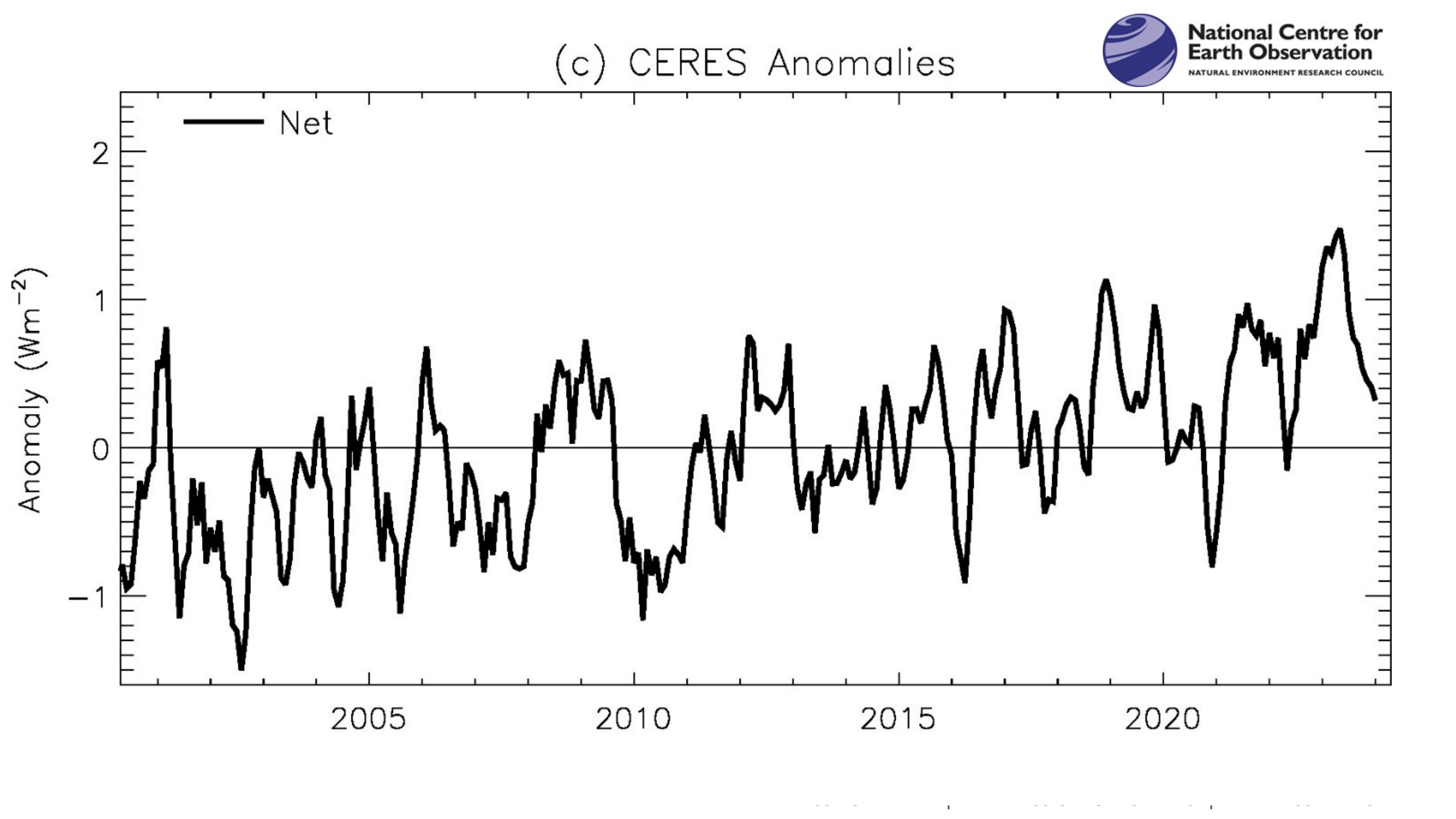
Global mean anomalies in absorbed sunlight




(c) CERES Anomalies
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Net
Anomaly (Wm^{-2})
2
1
0
−1
2005
2010
2015
2020

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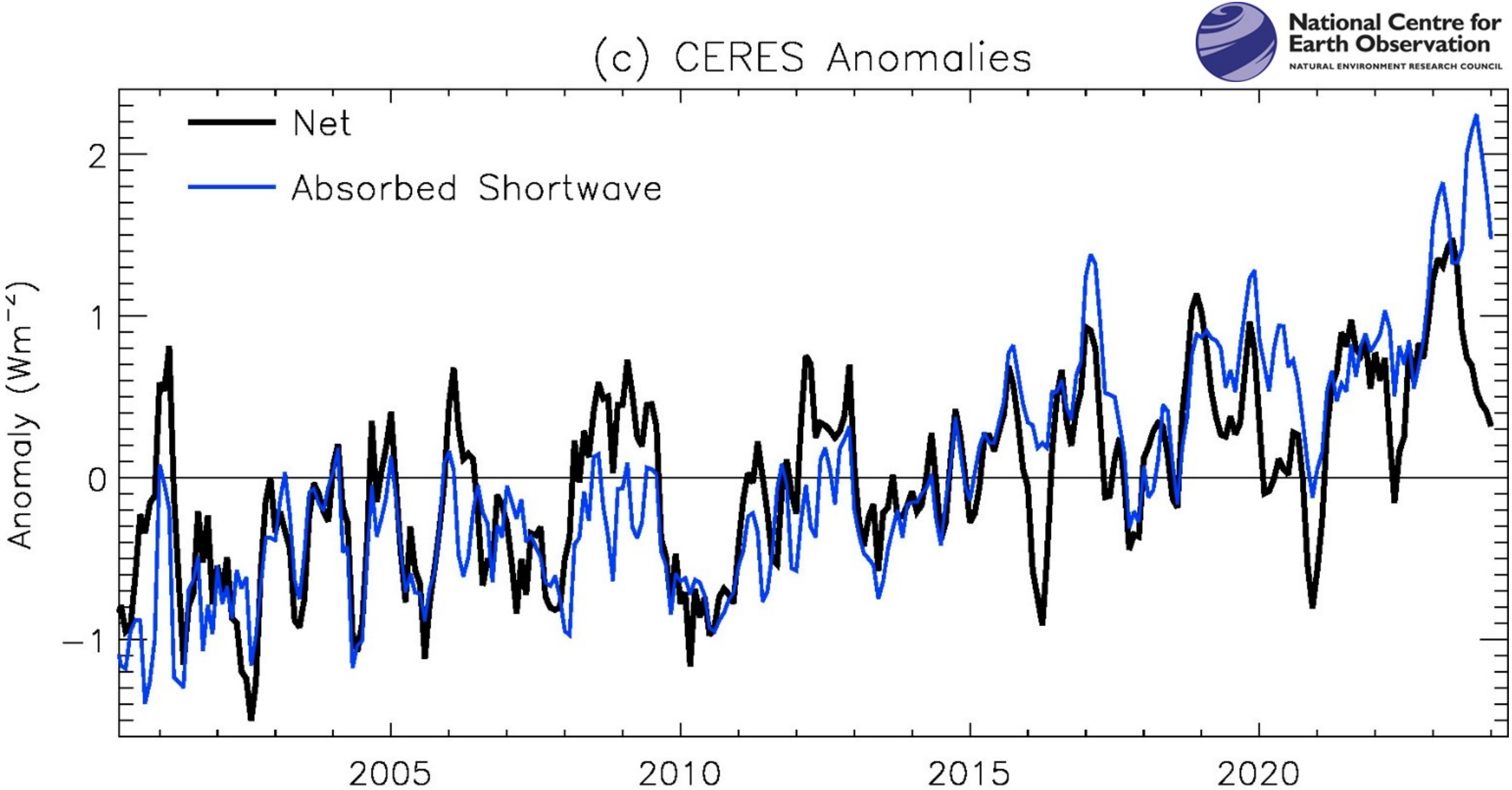

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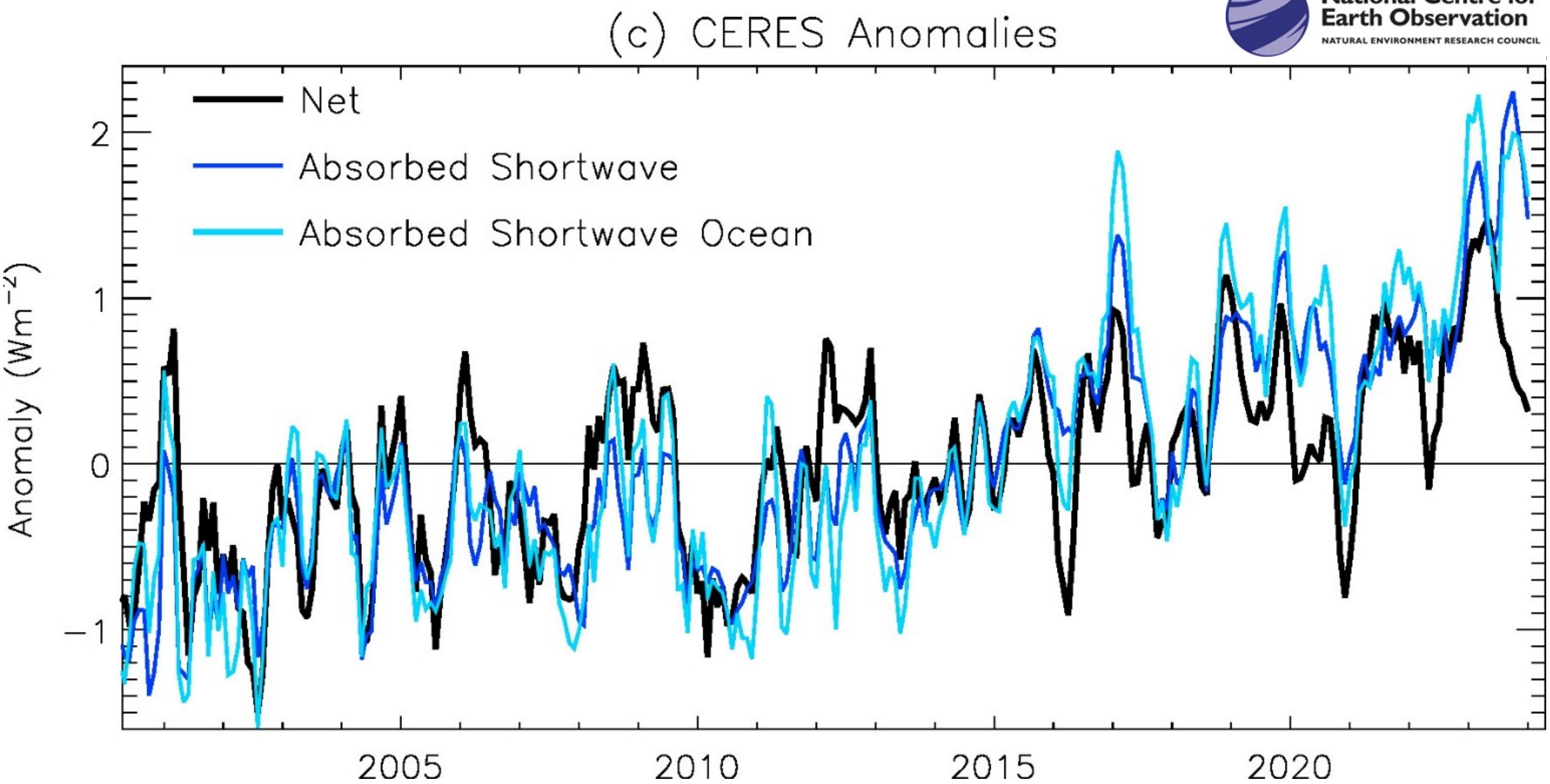

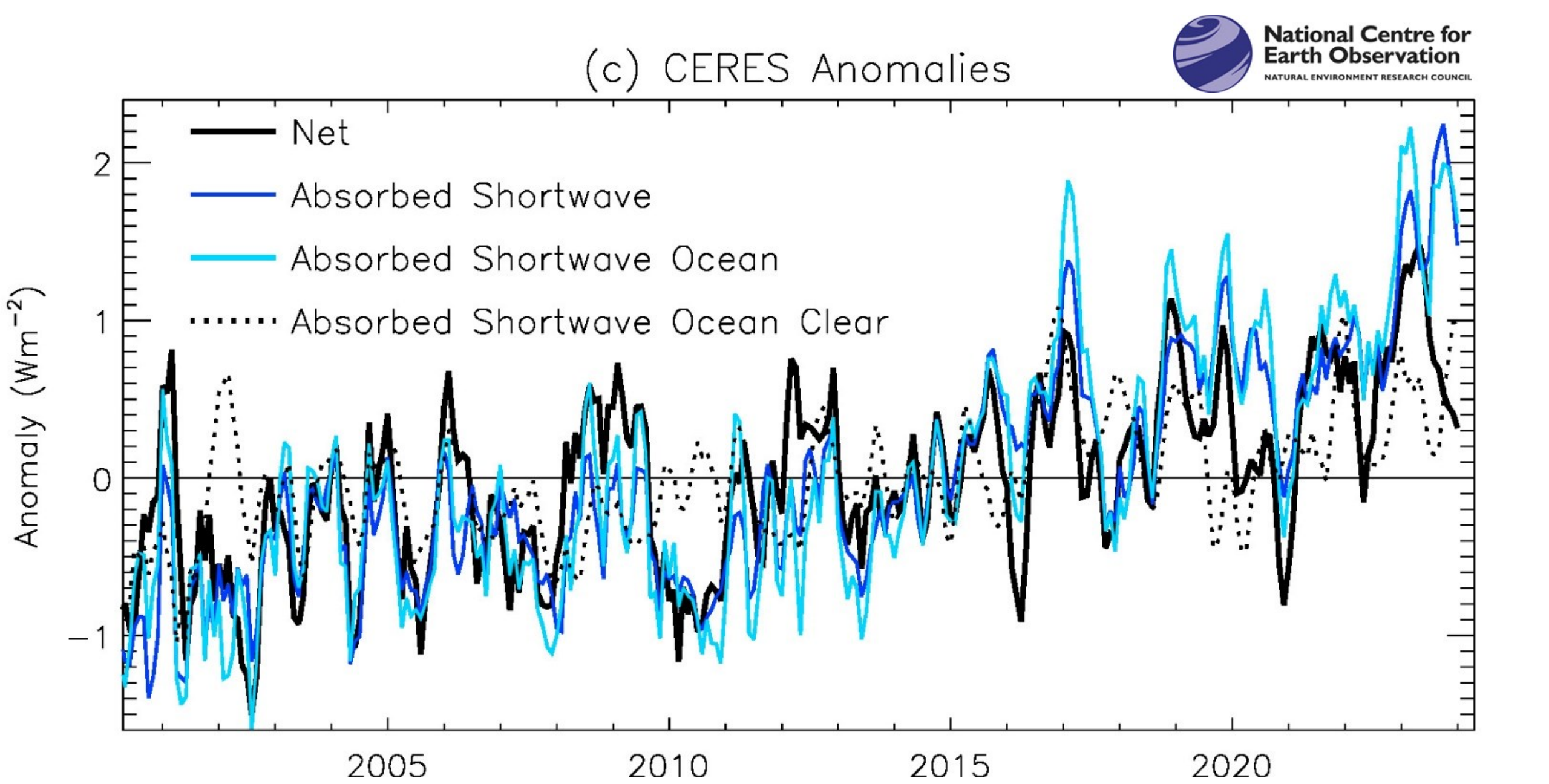
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(c) CERES Anomalies
Net
Absorbed Shortwave
Absorbed Shortwave Ocean
Absorbed Shortwave Ocean Clear
Anomaly (Wm^{-2})
2
1
0
−1
2005
2010
2015
2020

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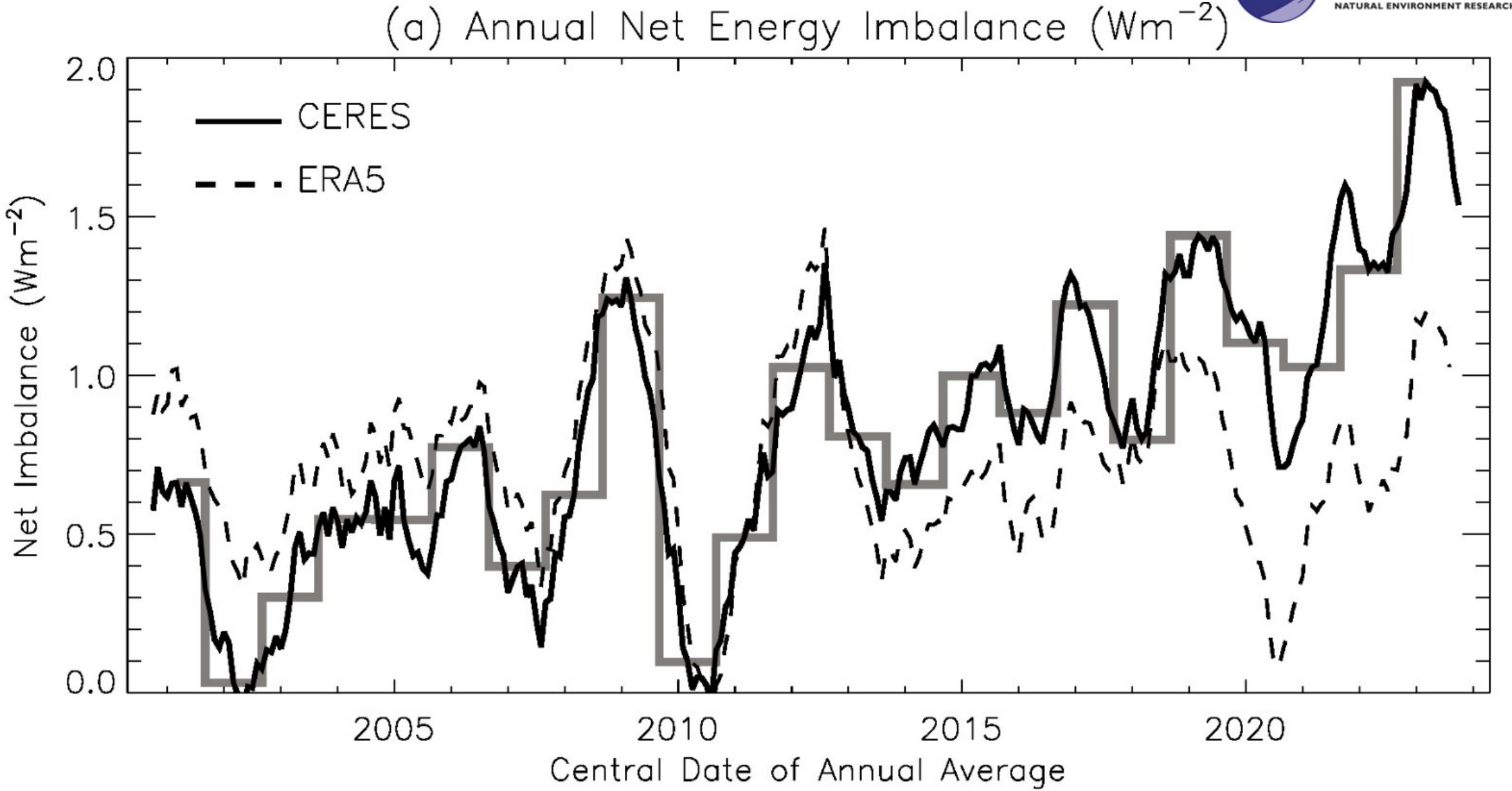

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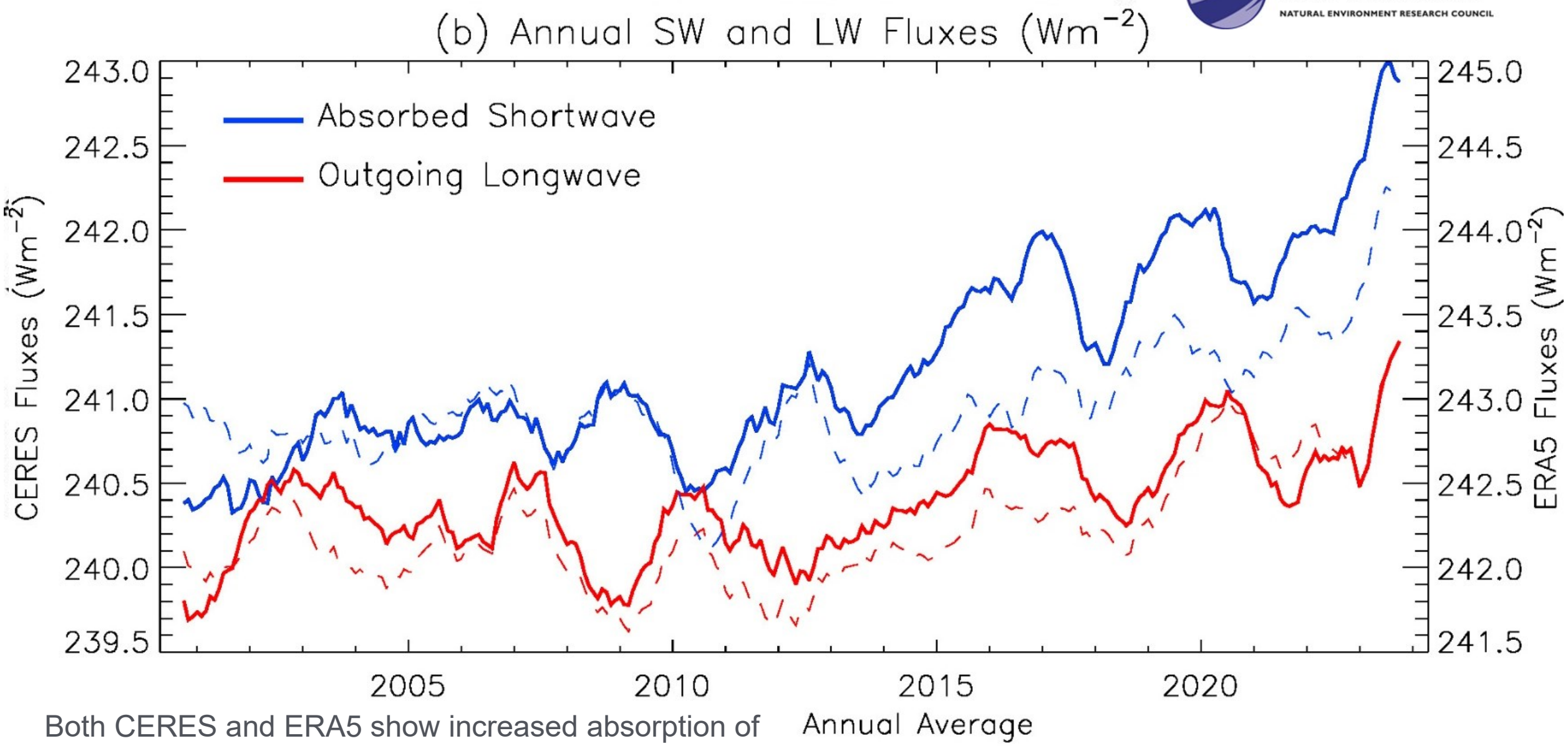

Both CERES and ERA5 show increased absorption of sunlight, but this effect is larger in CERES and in ERA5 LW emission compensates for SW absorption

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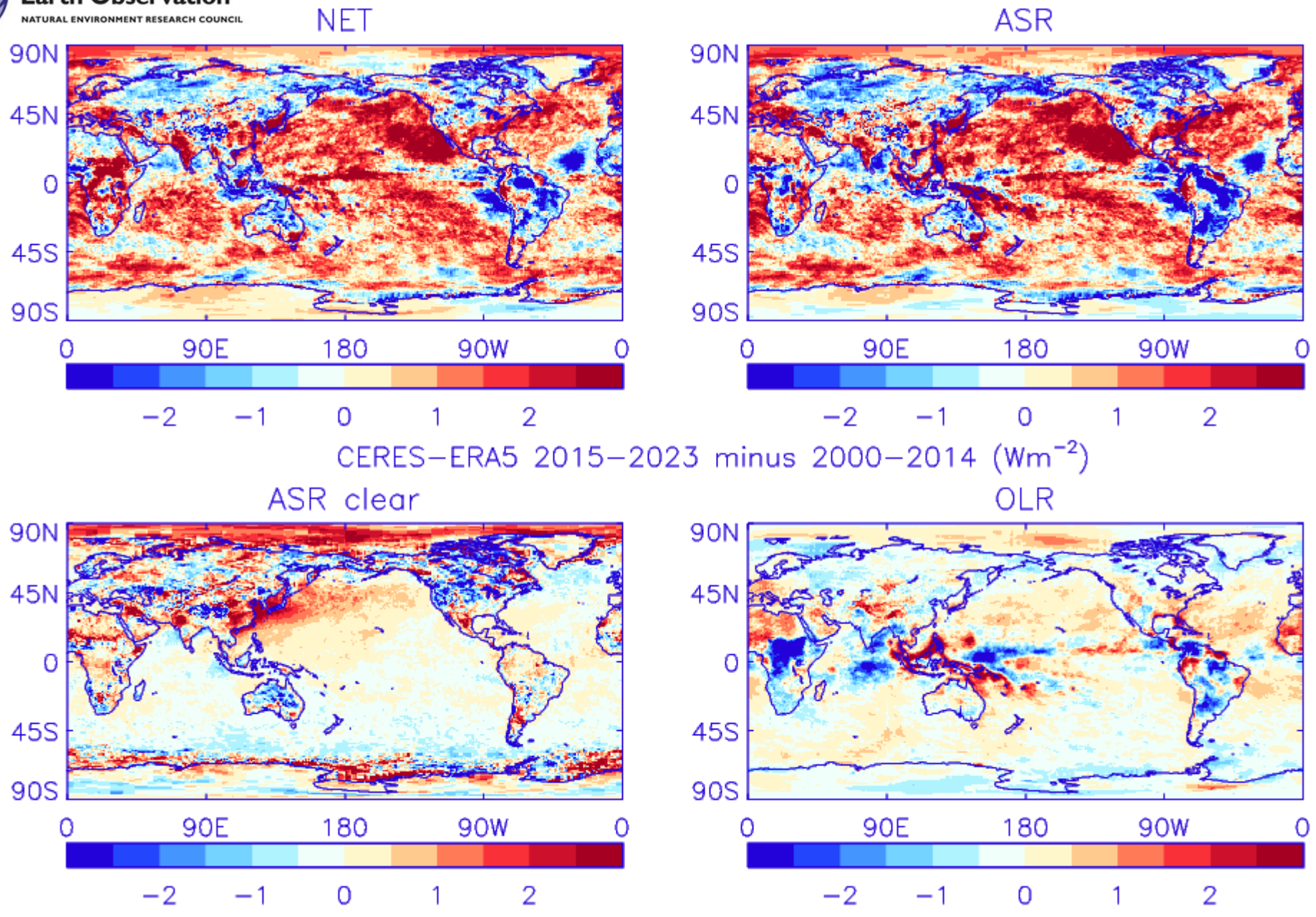
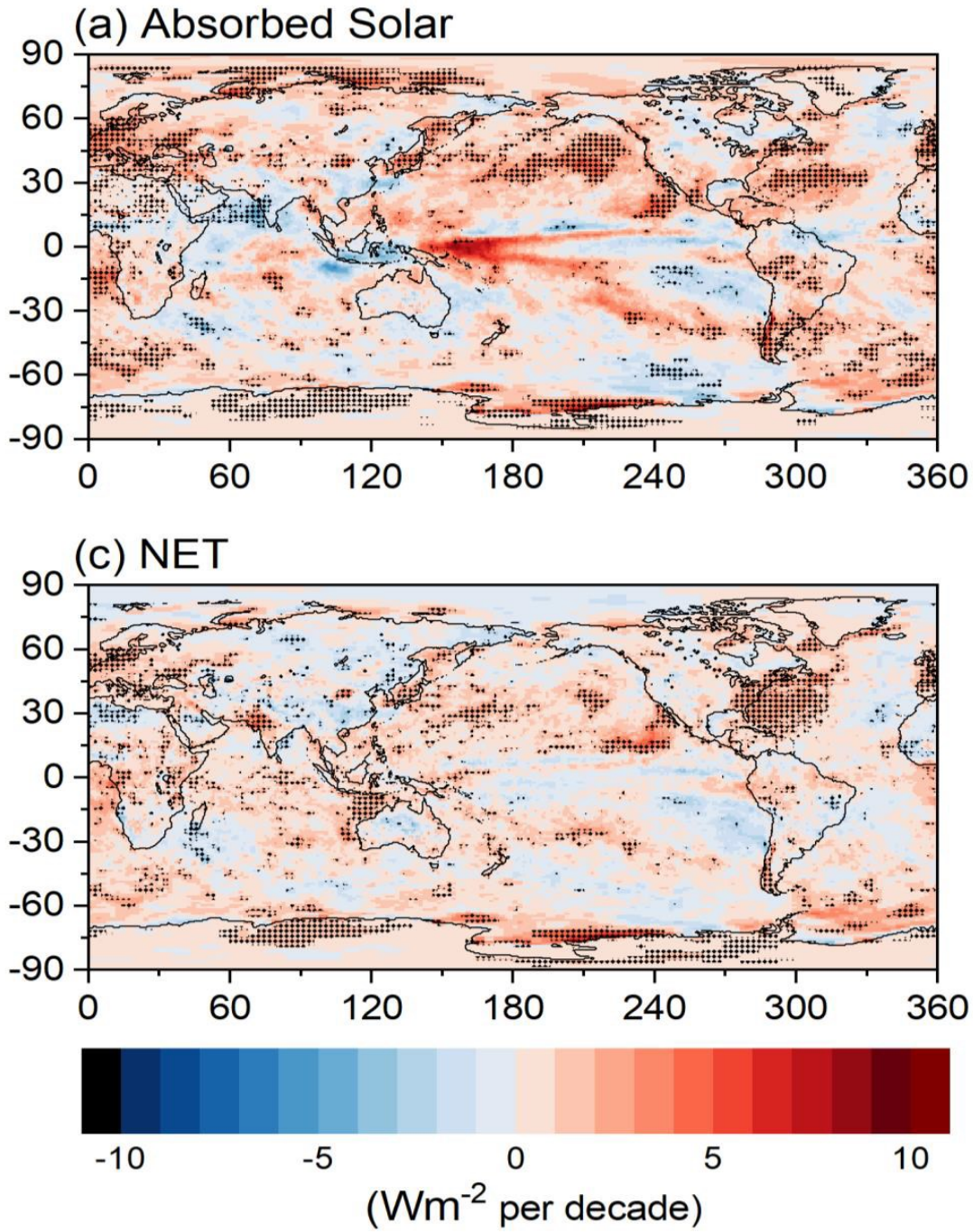


- Change in CERES-ERA5 differences
- Large signals over subtropical stratocumulus cloud
- …which ERA5 poorly represents
- East Asia aerosol has reduced more than ERA5 (which uses CMIP historical & projection scenarios)
- Arctic ice melted more than in ERA5



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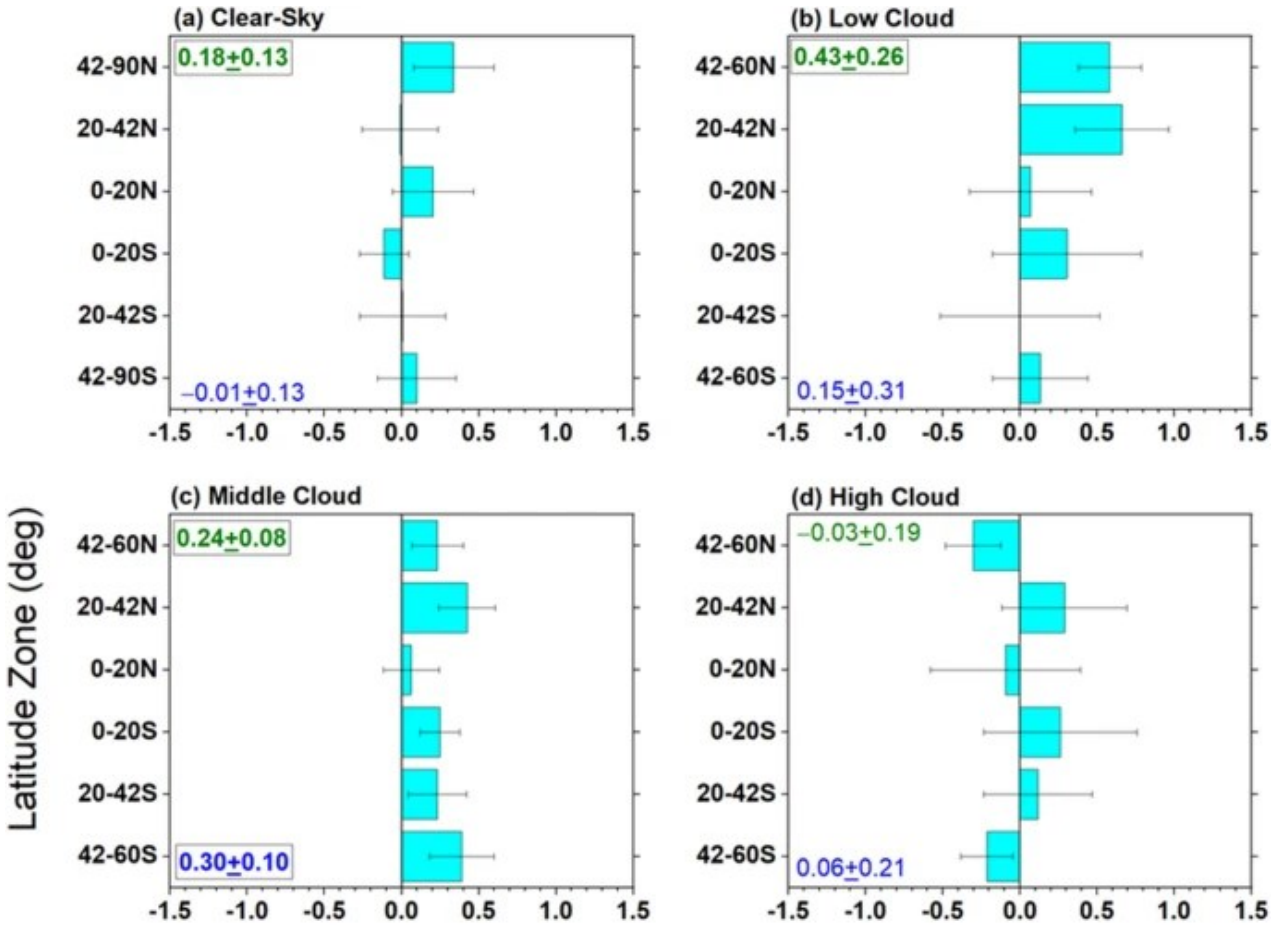

Loeb et al. (2024) Surv. Geophys

OPEN QUESTIONS

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- TRUTHS + Argo = SW + LW? Constraint on global energy & water cycles.
- How bright are clouds? Where do clouds end?
- How are aerosols affecting clouds and Earth's albedo?
- How does hemispheric asymmetry control climate?
- Is systematic bias in absorbed sunlight affecting simulated warming patterns?
- Why is the Earth becoming dimmer?
  - Earth's energy imbalance has increased rapidly over past 10 years

  … from 0.67 Wm^{-2} in 2006-2020 to 1.85 Wm^{-2} in 2022/23
  - due to more absorbed sunlight over the ocean
  - Dominated by cloud effects
  - Not captured by ERA5
- Are current changes subject to sensor degradation?
- Space and time sampling can dominate estimation of biases…