

IS 2023 GLOBAL WARMING SURGE EXPLAINED BY EARTH'S ENERGY BUDGET?



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ACRC meeting 30 October 2023



IS 2023 GLOBAL WARMING SURGE EXPLAINED BY EARTH'S ENERGY BUDGET? NO DON'T BE SILLY



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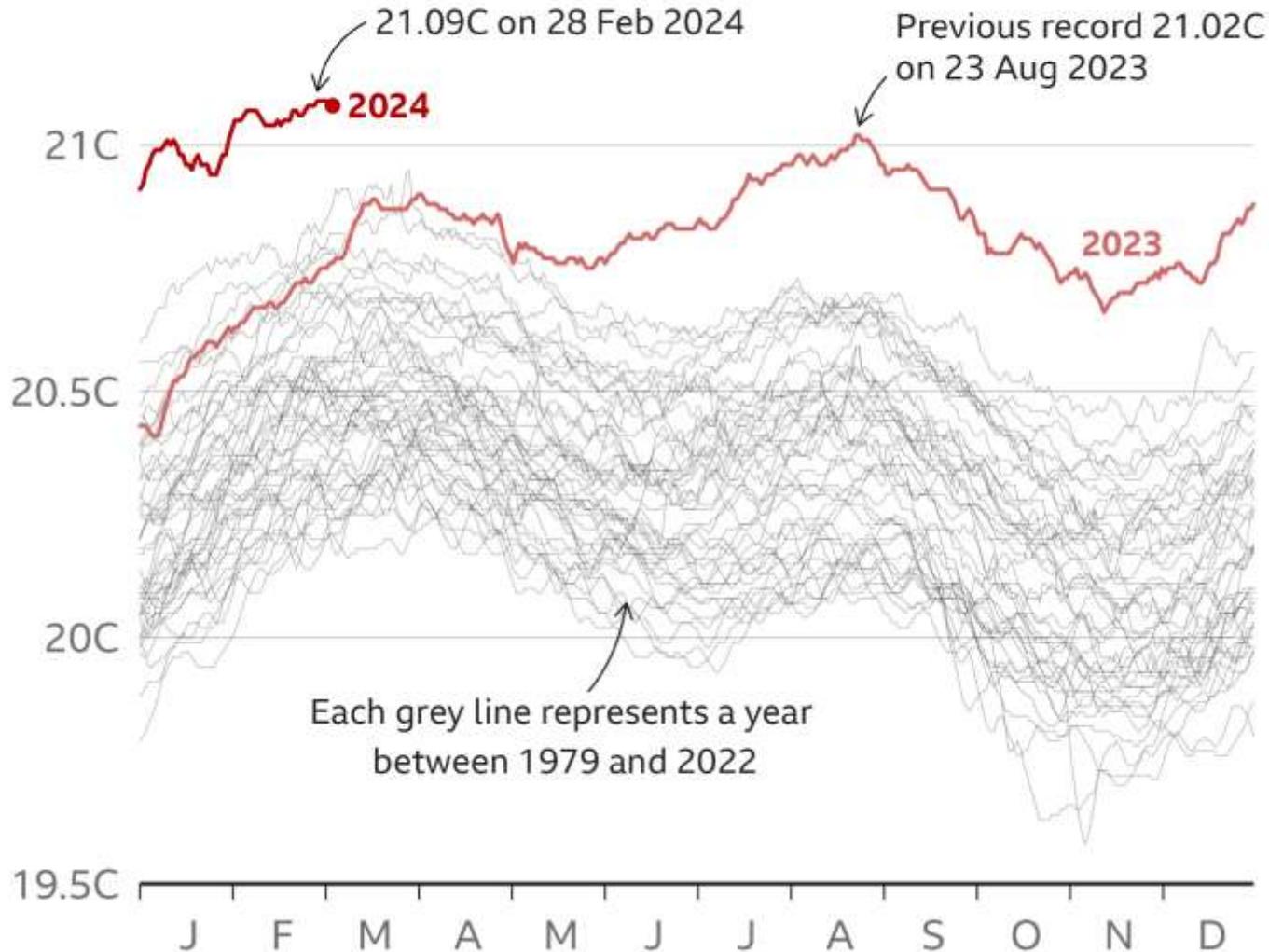
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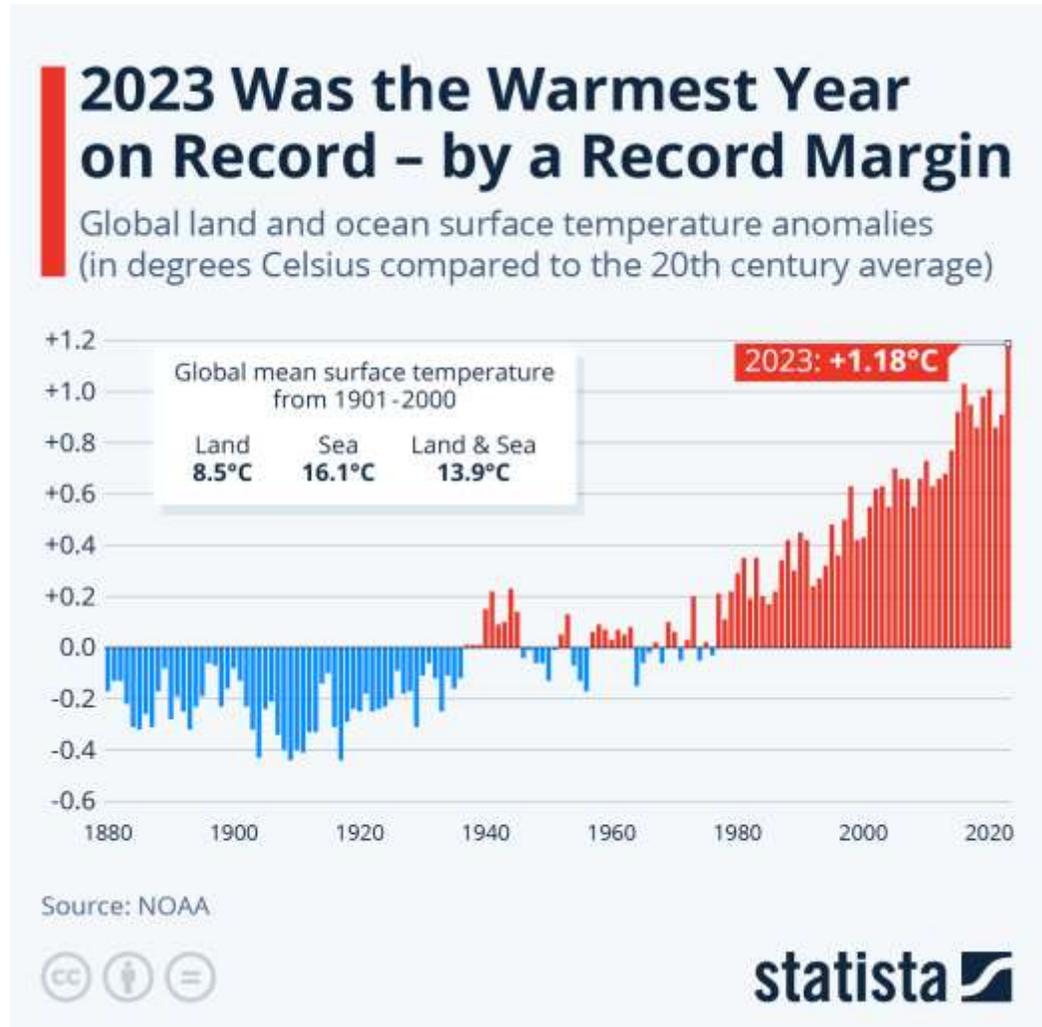


Ocean temperatures highest on record

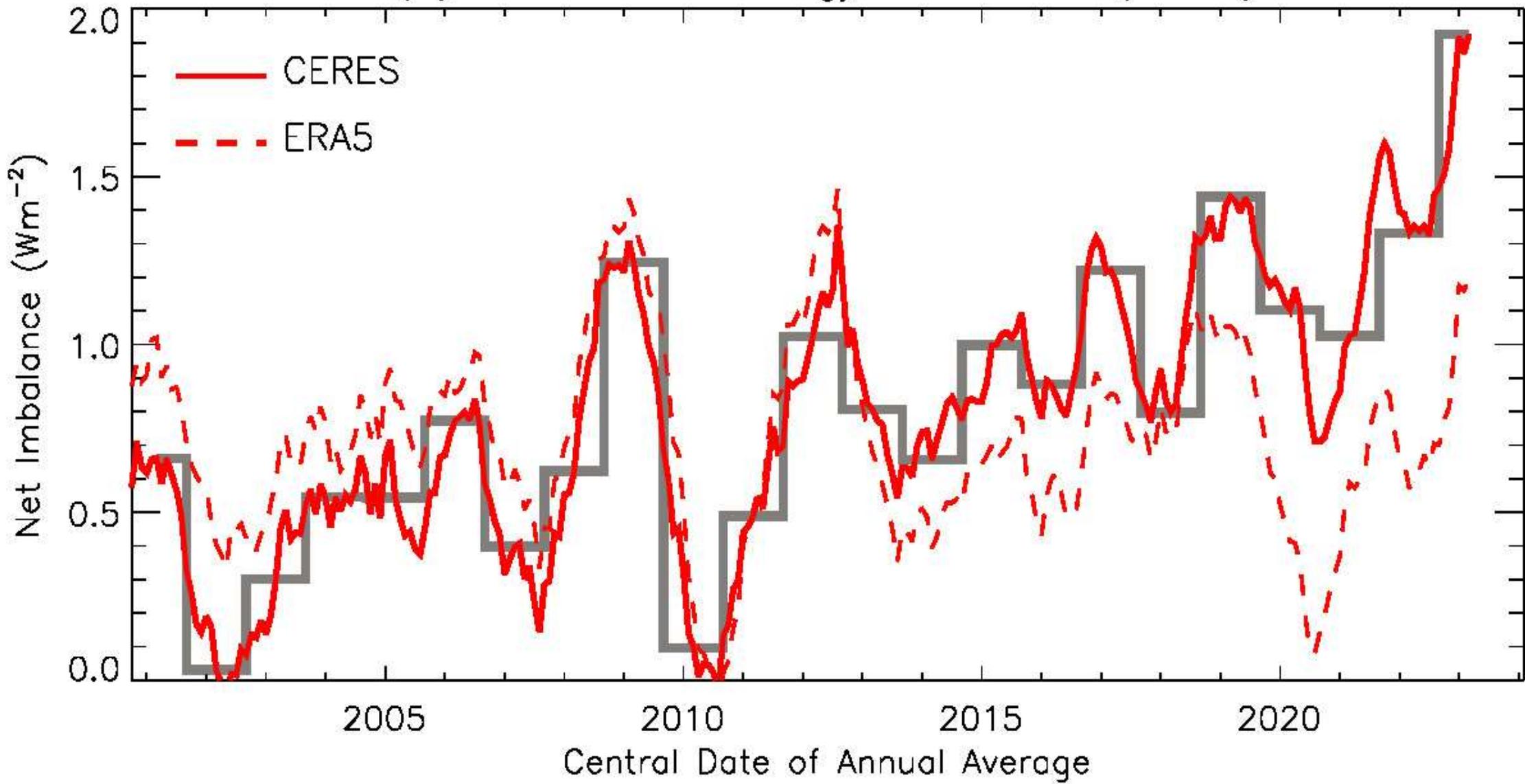
Daily average sea surface temperature between 60° North and 60° South, 1979-2024



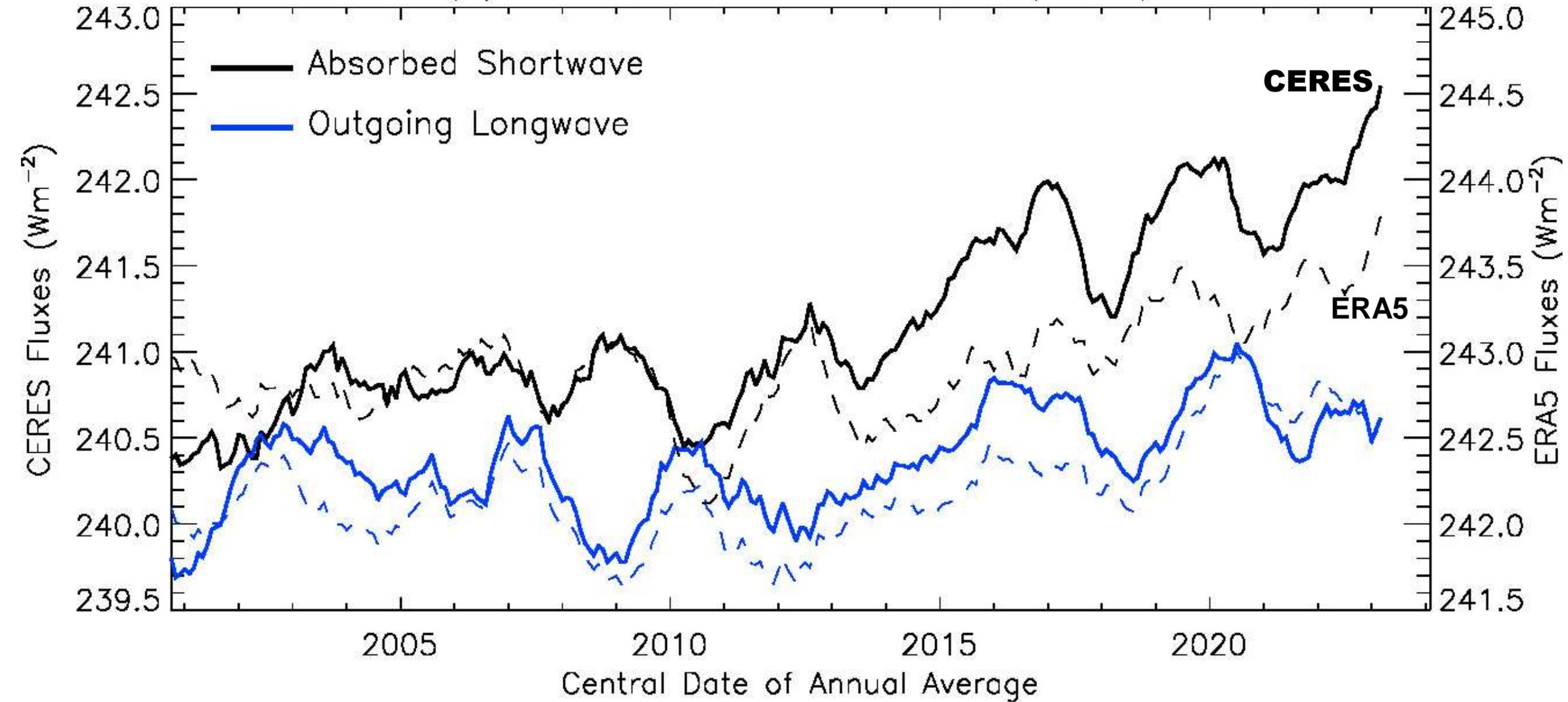
Source: ERA5, C3S/ECMWF

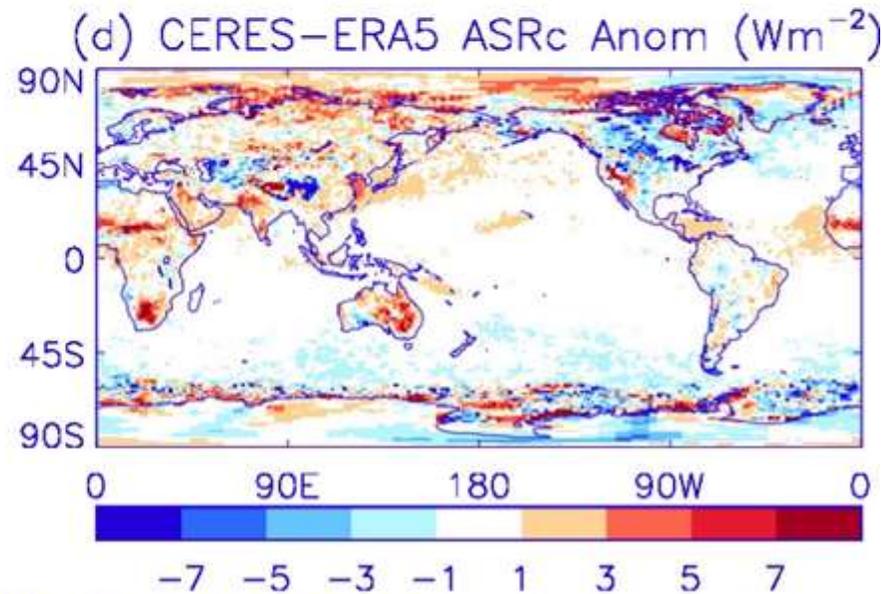
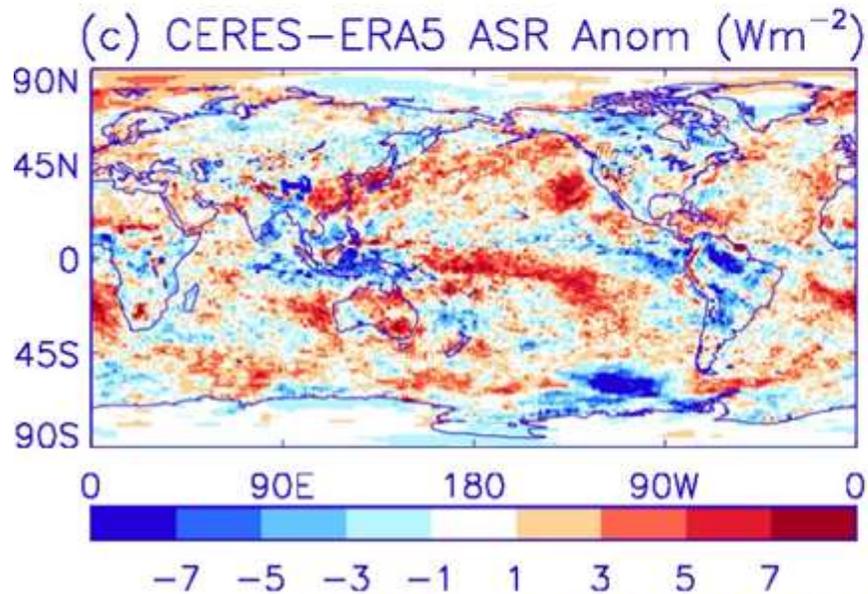
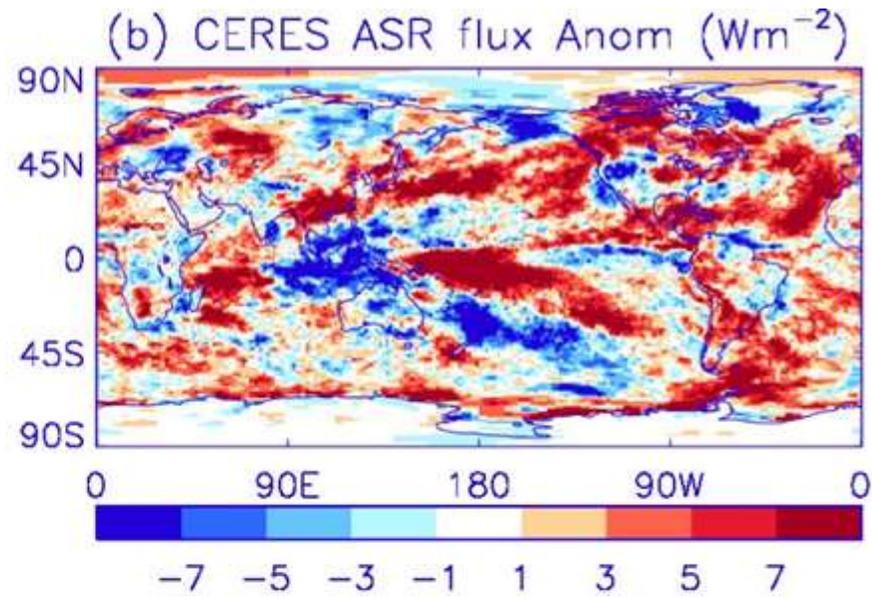
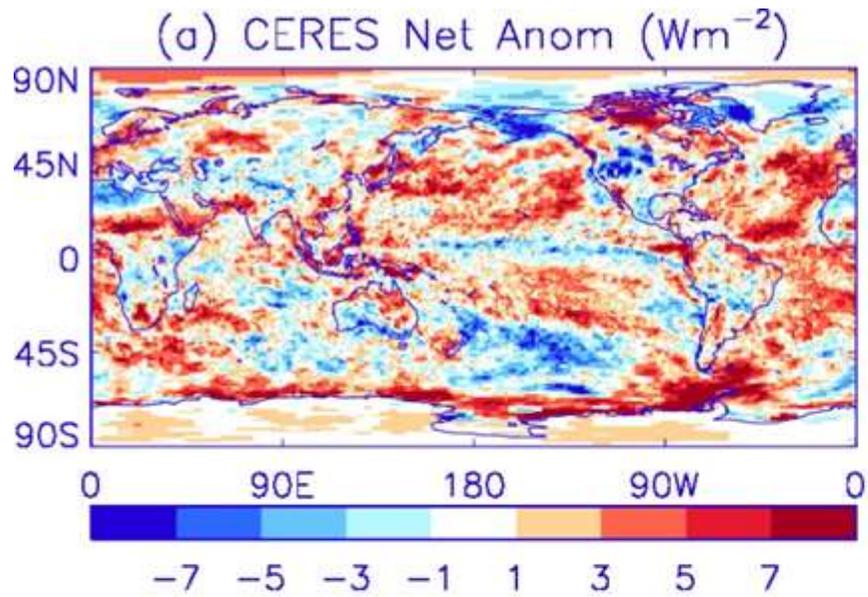


(a) Annual Net Energy Imbalance (Wm^{-2})



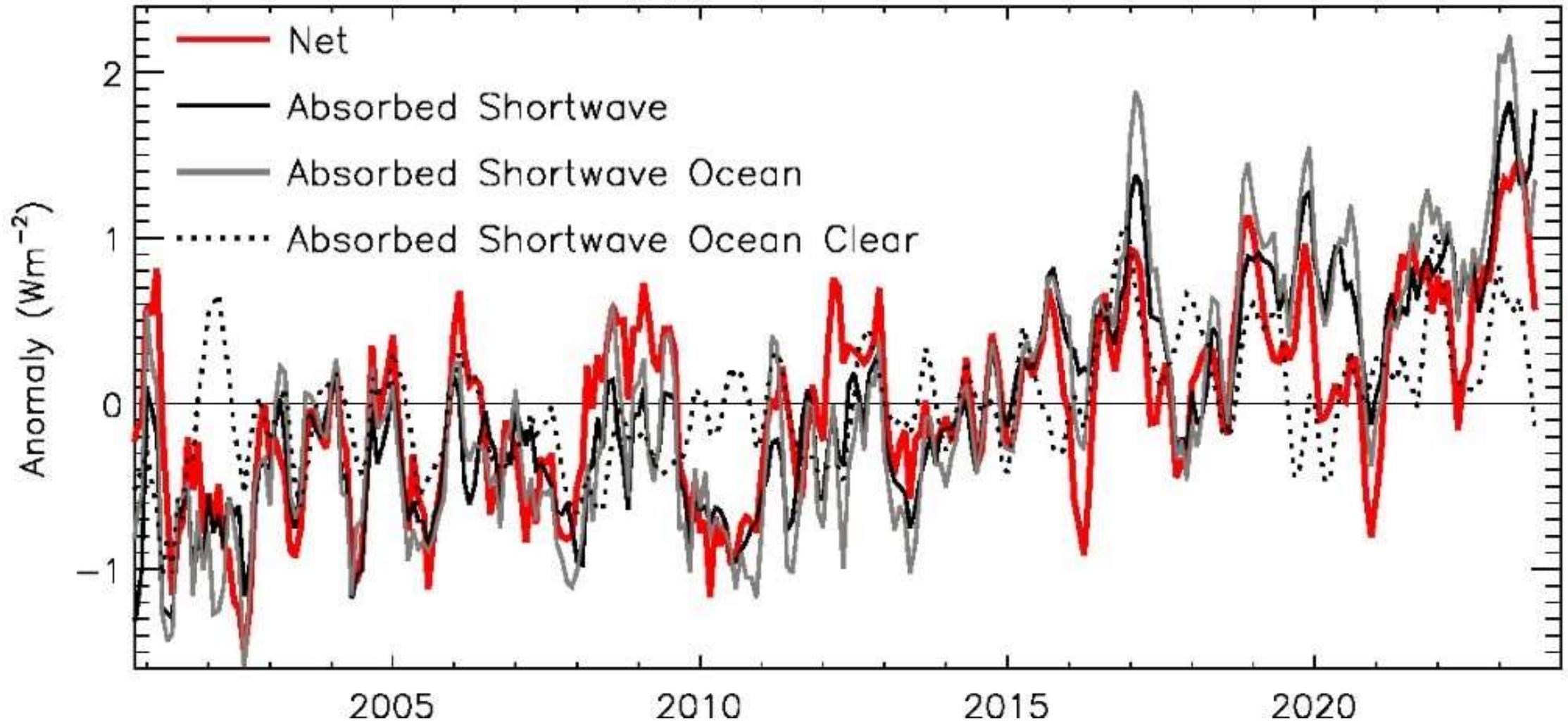
(b) Annual SW and LW Fluxes (Wm^{-2})





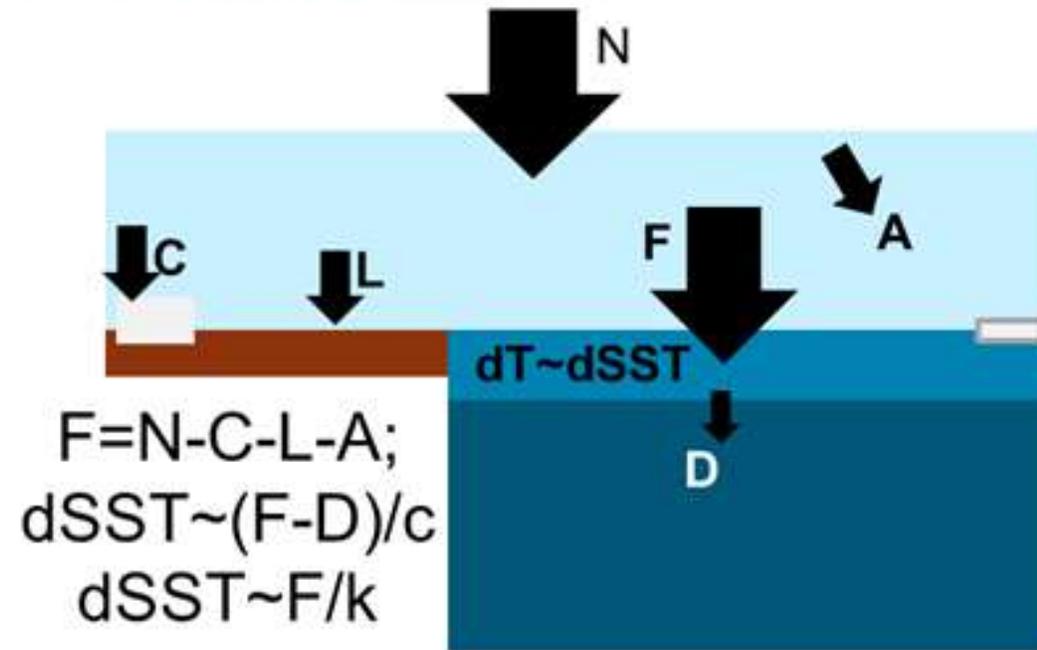
Aug 2022-Jul 2023 relative to 2006-2020 climatology

(c) CERES Anomalies



Domain	2006-2020 trend (Wm ⁻²) (von Shuckmann 2023 ESSD)
Atmosphere	0.014 ± 0.003 (ERA5: 0.017)
Land	0.039 ± 0.004
Cryosphere	0.028 ± 0.008
0-2000m Ocean	0.61 ± 0.2
>2000m Ocean	0.06 ± 0.03
Total Ocean	0.67 ± 0.3
Total N	0.76 ± 0.2
CERES N	0.83 ± 0.18

ENERGY BUDGET



$$dSST/dt = 0.24^{\circ}\text{C/decade} \quad (60^{\circ}\text{S}-60^{\circ}\text{N}, \text{ESA CCI})$$

$$\text{Heating efficiency, } k = (dSST/dt) / N = 0.033 \text{ } (^{\circ}\text{C/yr}) / (\text{Wm}^{-2})$$

2006-2020

- $N = 0.76 \text{ Wm}^{-2}$
- $d\text{SST}/dt = 0.24^\circ\text{C}/\text{decade}$ (60°S-60°N, ESA CCI)
- Heating efficiency, $k = (d\text{SST}/dt)/N = 0.033$ ($^\circ\text{C}/\text{yr})/(\text{Wm}^{-2})$
- 89% of net energy imbalance heats the ocean ($F = 0.67 \text{ Wm}^{-2}$)

What 'effective' layer of ocean is being heated?

- Ocean heat capacity, $c = 4003 \text{ J/kg/K}$; Ocean water density, $\rho = 1027 \text{ kg/m}^3$.
 $d = F/\rho c(d\text{SST}/dt)(A_o/A_g)$ (times s/decade, divide ocean/global area) $\sim 300 \text{ m}$



Domain	2006-2020 trend (Wm ⁻²) (Von Shuckmann 2023)	2022-2023 proportional heating (Wm ⁻²) Aug-Jul
Atmosphere	0.014 ± 0.003 (ERA5: 0.017)	0.034
Land	0.039 ± 0.004	0.095
Cryosphere	0.028 ± 0.008	0.068
0-2000m Ocean	0.61 ± 0.2	1.49
>2000m Ocean	0.06 ± 0.03	0.15
Total Ocean	0.67 ± 0.3	1.64
Total N	0.76 ± 0.2	1.85
CERES N	0.83 ± 0.18	1.92 (+1.1)

2022-2023

$$N = 1.85 \text{ Wm}^{-2}$$

$$2023-2022 \text{ dSST (60°S-60°N)} = \mathbf{0.27^\circ\text{C}}$$

Applying 2006-2020 heating efficiency, $k = 0.033 \text{ (}^\circ\text{C/yr)/(Wm}^{-2}\text{)}$

$$\rightarrow \text{dSST} = kN = 0.033 \times 1.85 = \mathbf{0.06^\circ\text{C/yr}}$$

(effective heating of ~300m)

Or if only upper **70m ocean** (70% globe) is heated ($d=70$): $\text{dSST} = 0.89N/0.7dpc = \mathbf{0.26^\circ\text{C}}$

(similar to observed warming)

Domain	2006-2020 trend (Wm⁻²) (Von Shuckmann 2023)	2022-2023 proportional heating (Wm⁻²)	2022-2023 estimated heating (Wm⁻²)
Atmosphere	0.014 ± 0.003 (ERA5: 0.017)	0.034	0.120 (ERA5: 0.146)
Land	0.039 ± 0.004	0.095	0.200
Cryosphere	0.028 ± 0.008	0.068	0.040
0-2000m Ocean	0.61 ± 0.2	1.49	1.34
>2000m Ocean	0.06 ± 0.03	0.15	(0.15)
Total Ocean	0.67 ± 0.3	1.64	1.49
Total N	0.76 ± 0.2	1.85	1.85
CERES N	0.83 ± 0.18	1.92 (+1.1)	1.92

Based on further calculations, estimates of minor heating terms are larger proportion of total heating than 2006-2020 so ocean heating was slightly smaller proportion (1.5 Wm⁻²)

$$dSST = 1.5/0.7 \times 70 \times \rho c$$

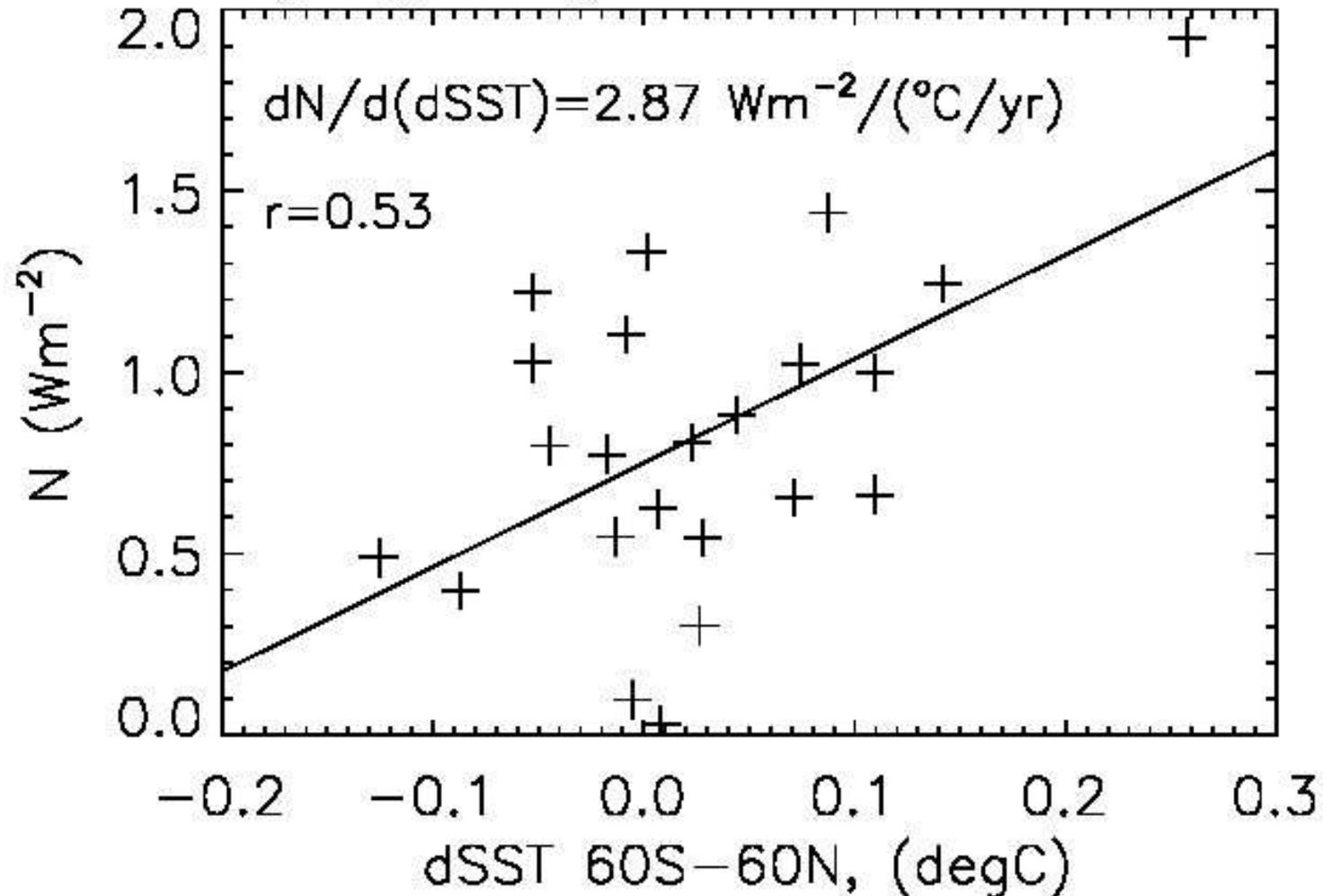
$$= 0.23^\circ C$$

$$\text{or } d = 1.5/0.7 \rho c \cdot dSST$$

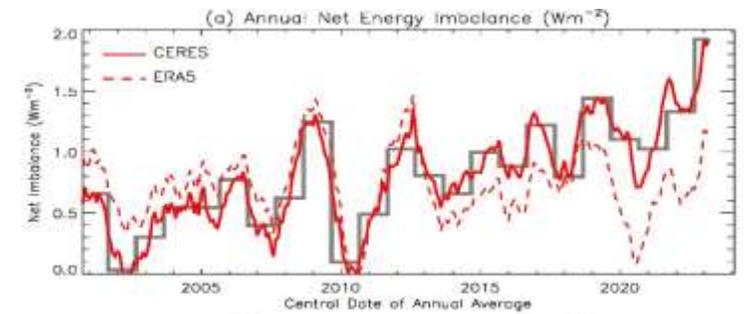
$$\sim \mathbf{60 \text{ m}}$$

...but increased N is associated with faster warming rate

CERES N (Aug–Jul) vs ERA5 dSST 2000–2023



CONCLUSIONS



- Earth's energy budget increased rapidly over past 10 years:
 - From 0.76 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
- Only explain 2022/23 SST rise (0.27°C) if all heat absorbed by upper 60m ocean
- During 2006-2020, the 'effective' layer of ocean heated was $\sim 300\text{m}$
- So ocean rearrangement of heat is primary explanatory factor in rapid warming
- ...though increased energy imbalance is related to increased rate of warming (e.g. increase in N heats surface layers first before uptaken deeper?)