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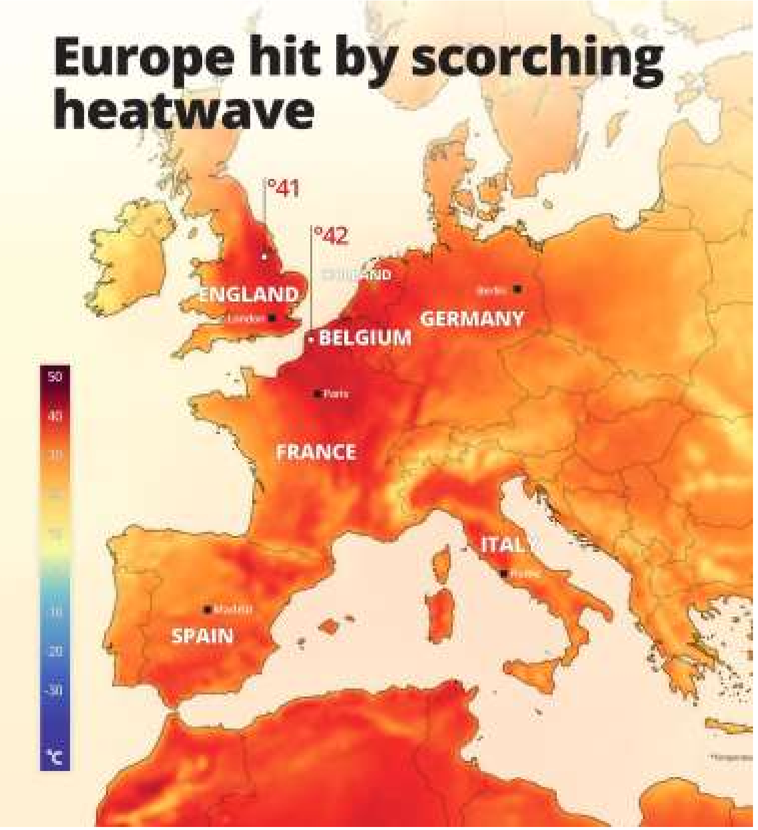
FUTURE CHALLENGES IN ENERGY & WATER CYCLE RESEARCH

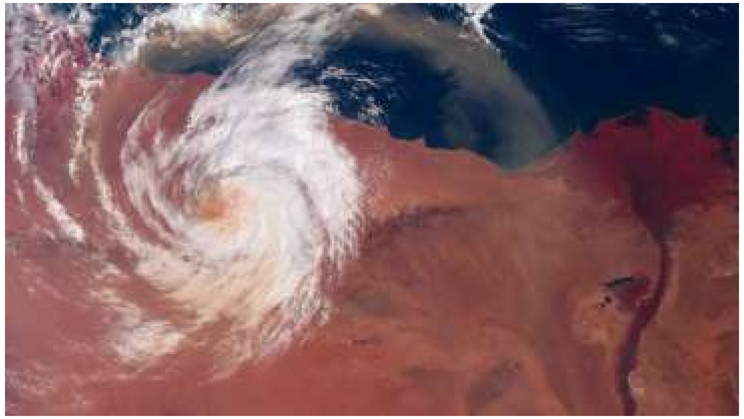
Professor Richard Allan @rpallanuk r.p.allan@reading.ac.uk

John Harries Memorial, Imperial College, 22nd September 2023

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

ONGOING CLIMATE CHANGE





www.met.reading.ac.uk/~sgs02rpa/extreme.html

The Earth in space

Processes fluctuate naturally, molecules shoot around, chaotic limits apply, but basically nothing changes, until…

The only information and the only energy, that gets in or out is via electromagnetic radiation.....

This is the climate system (physical + biological)

....Light and Heat

Energy arriving gives rise to myriad of processes between high frequency energy in and low frequency energy out (entropy!)

Precious little exchange of matter of any sort

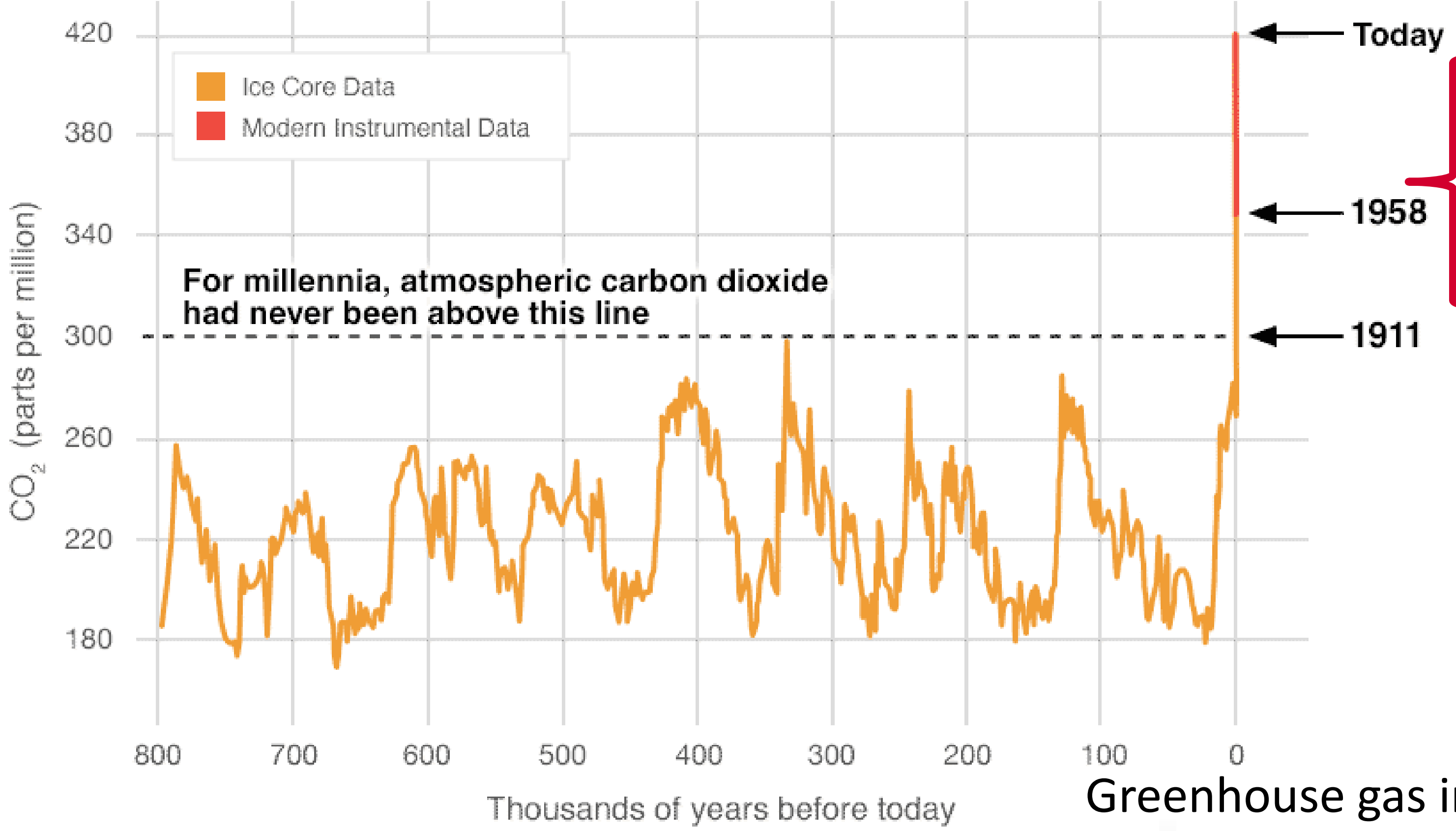
Some incoming light is reflected, by clouds, surface, ice

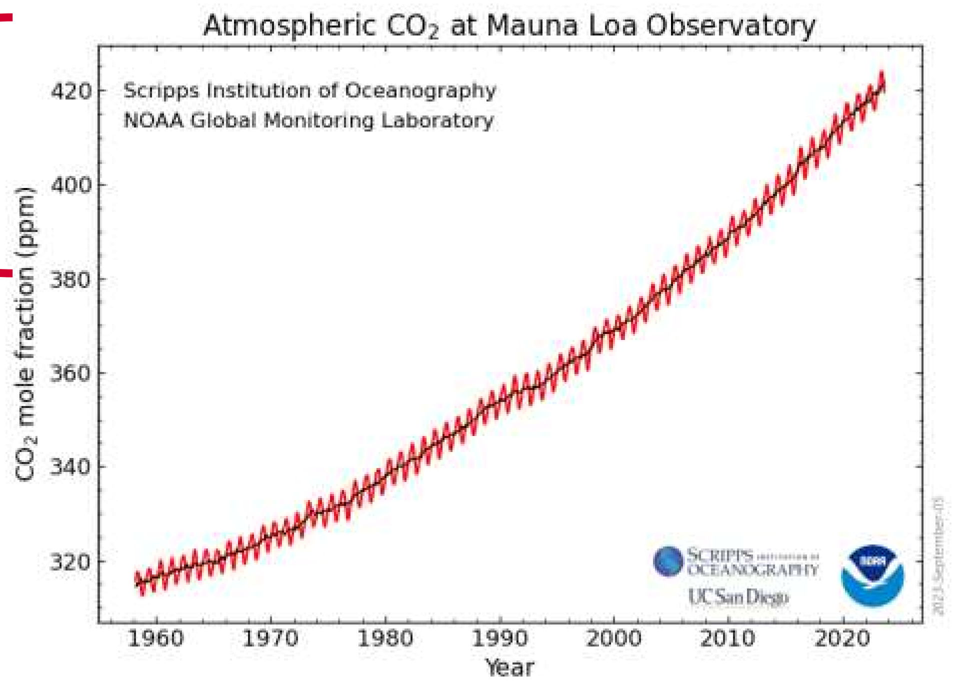
..until flux of energy/second/m^2 absorbed = emitted

Remainder absorbed, heats the planet

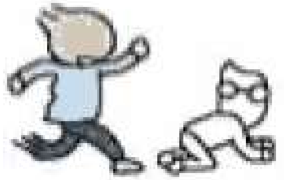
Planet goes on warming....

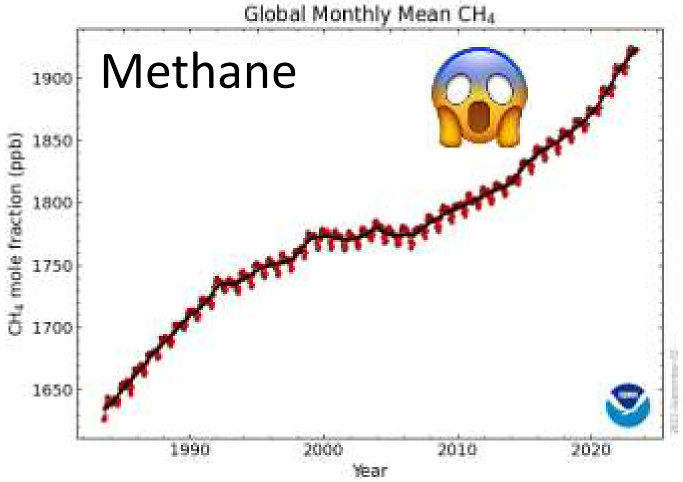
Temperature rises, IR emission back to space starts



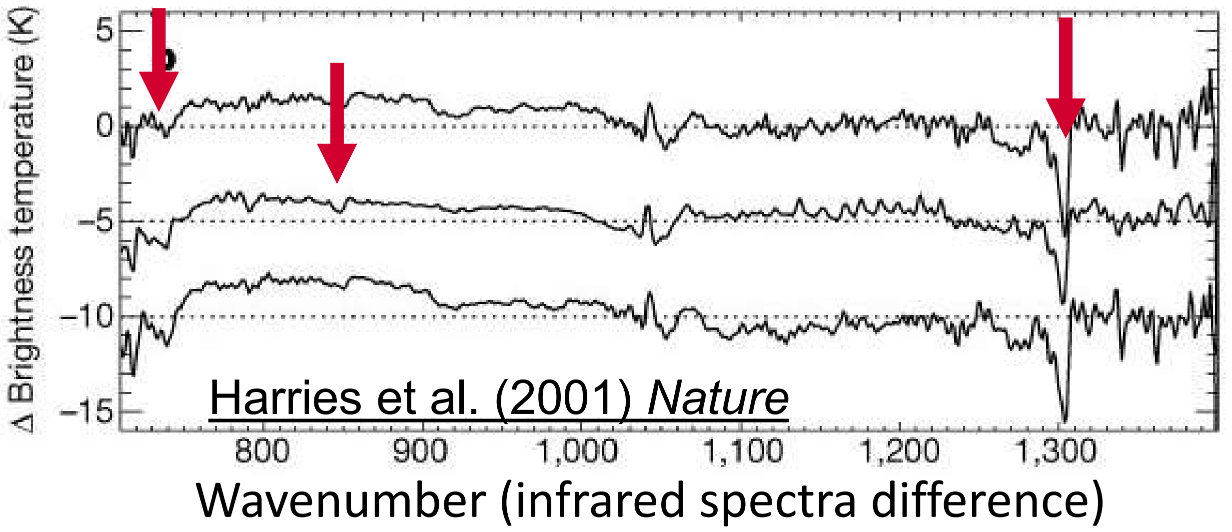


Ouch!



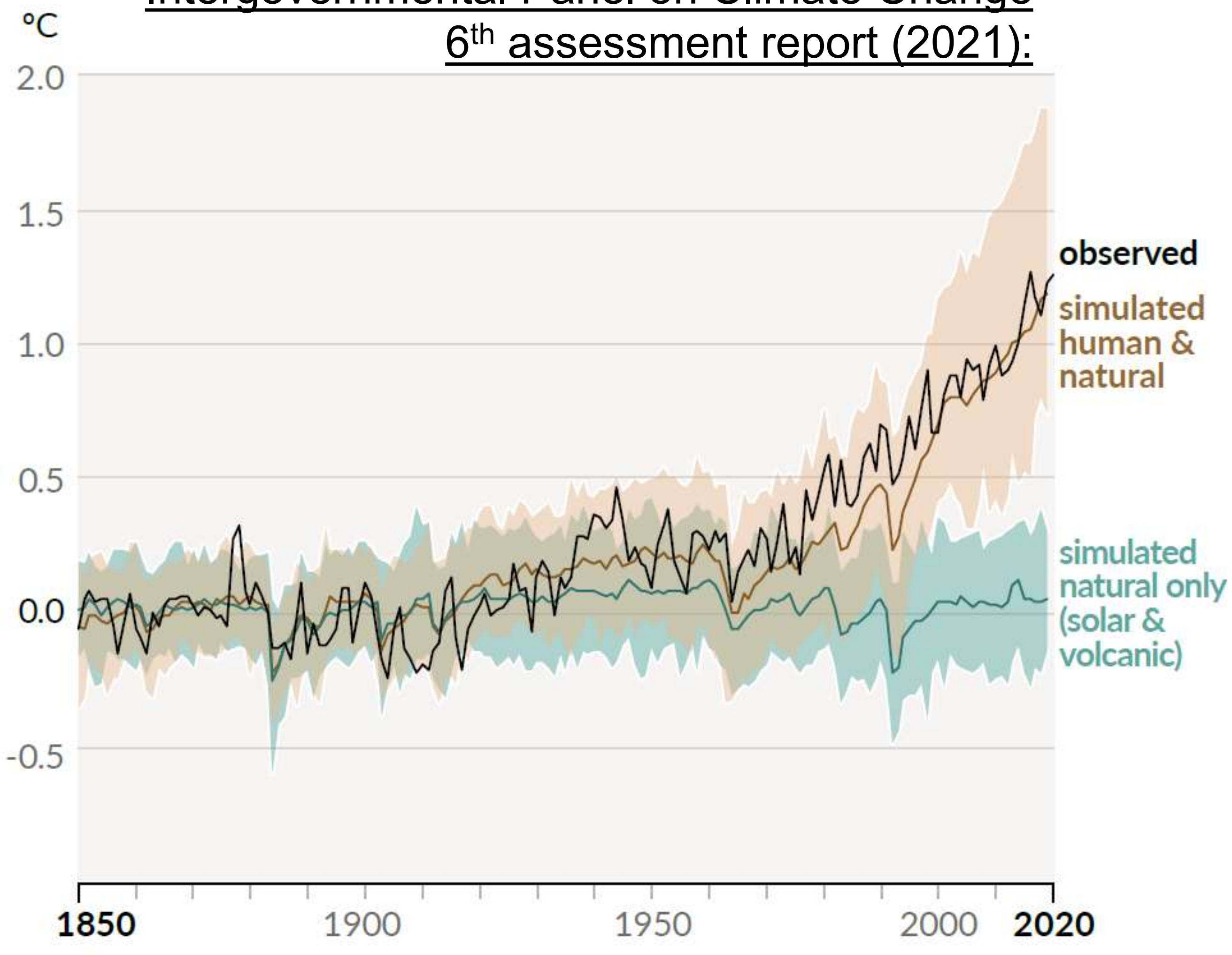


Greenhouse gas increases reduce outgoing infrared emission



It is indisputable that human activities are causing climate change

Intergovernmental Panel on Climate Change 6th assessment report (2021):



- ►Observed warming is driven by emissions from human activities
- ► Natural factors do not contribute to rapid warming over past 5 decades
- ► Greenhouse gas warming has been partly masked by aerosol cooling
- ► Warming is amplified by feedback loops involving water vapour, ice & clouds

Feedback Loops Amplify Climate Change

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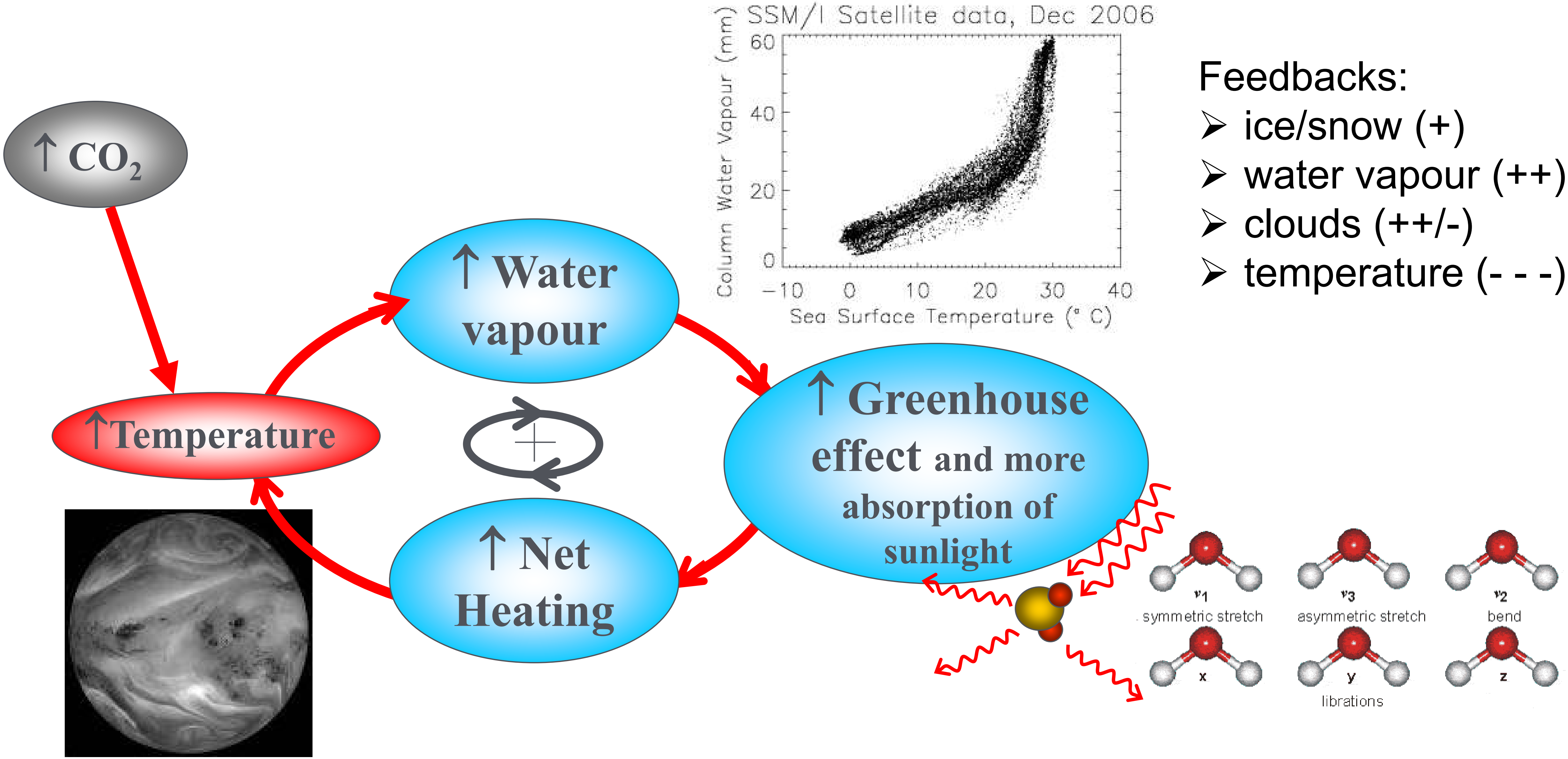

Feedbacks:

- ice/snow (+)
- water vapour (++)
- clouds (++/-)
- temperature (- - -)

“Increasing amounts of water vapour in the atmosphere are amplifying warming of climate and making extreme weather worse.

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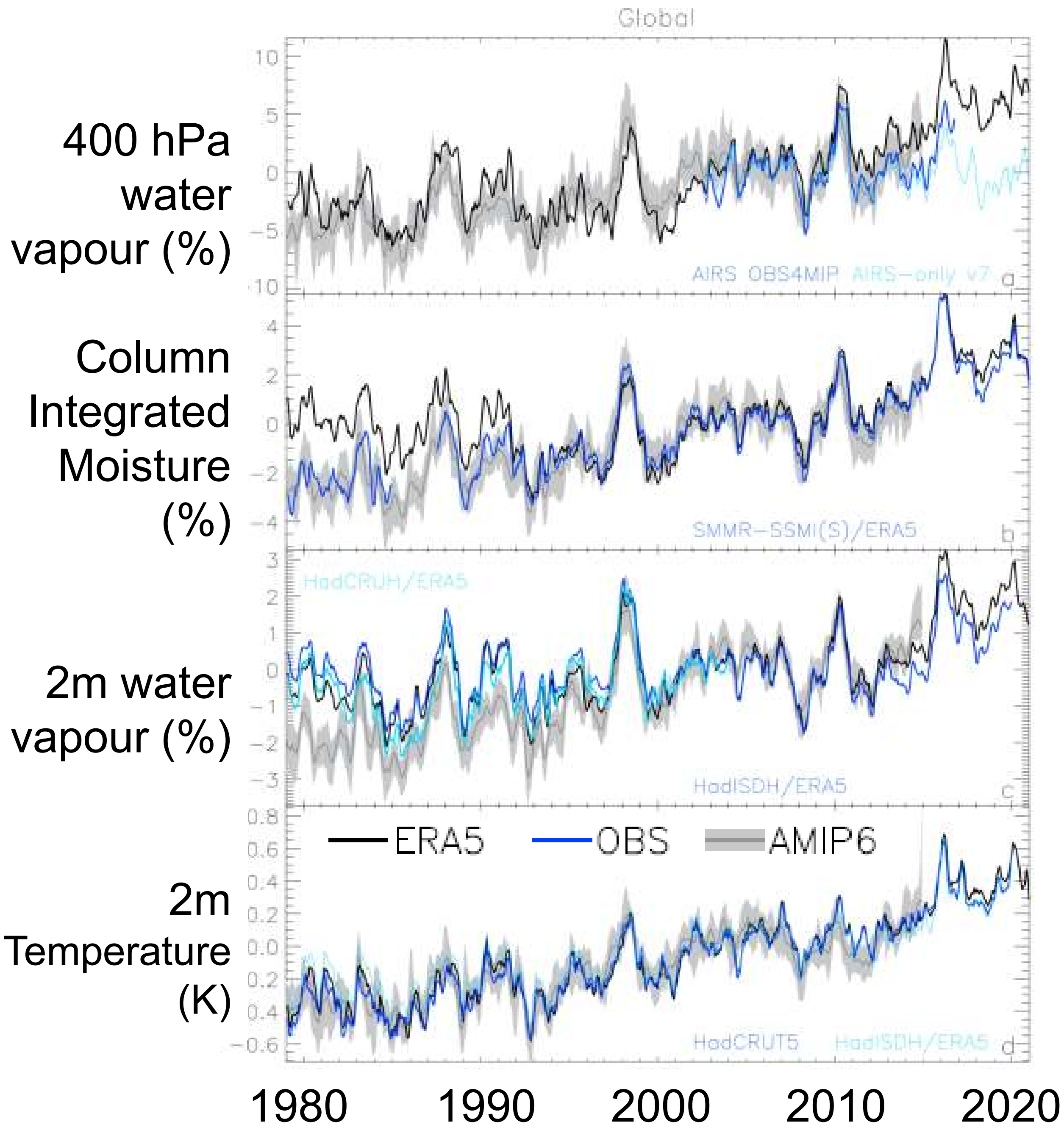
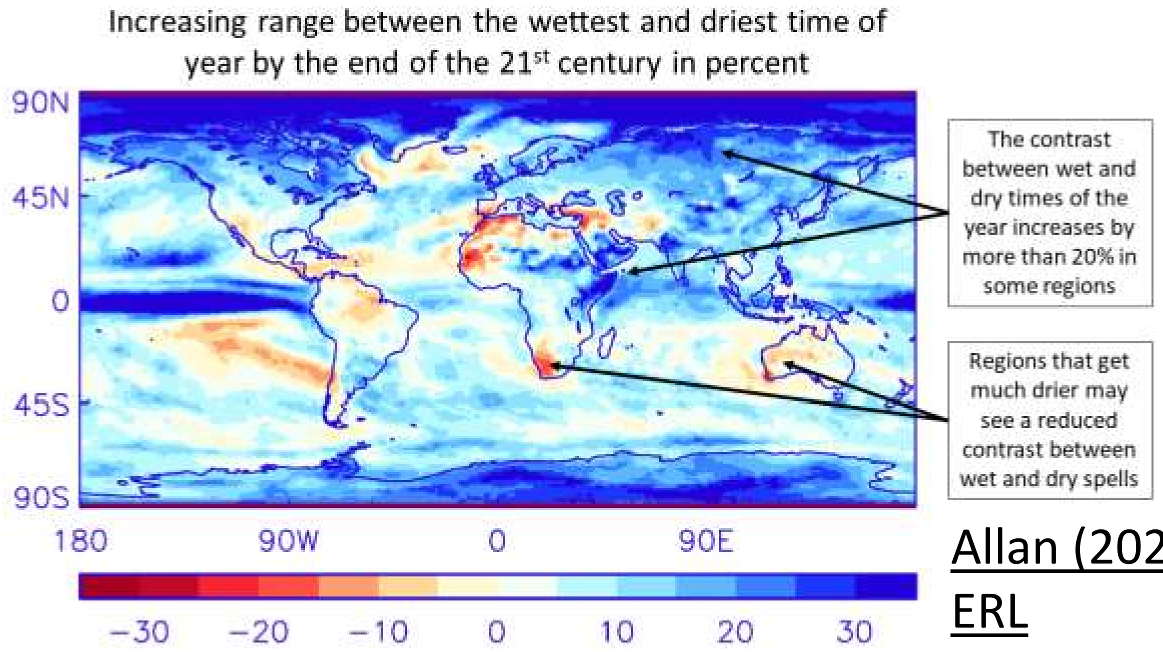
Water vapour is increasing

This is intensifying the water cycle: a thirstier atmosphere more effectively saps water from the surface and transports this extra moisture into storm systems, monsoons and polar regions

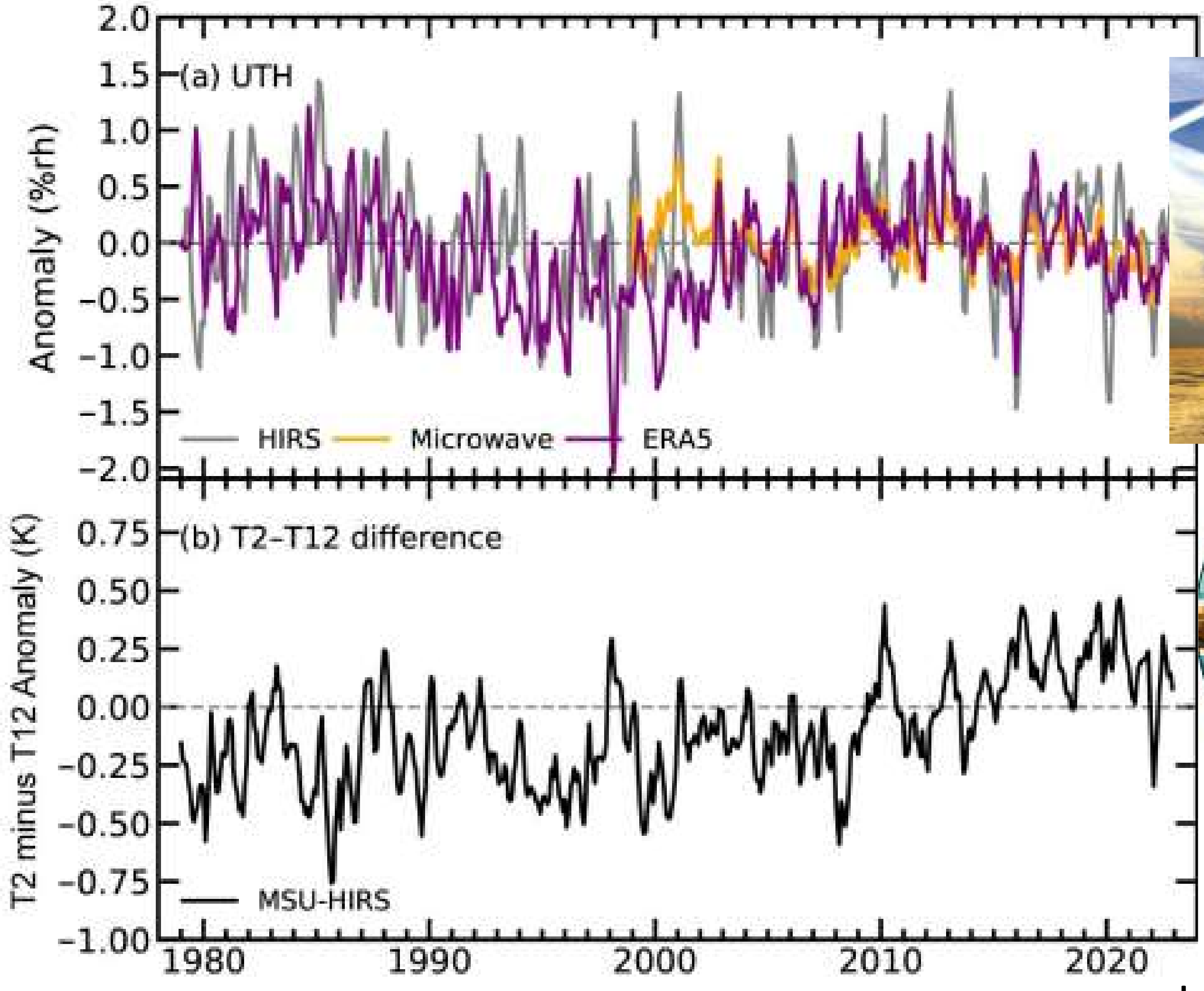


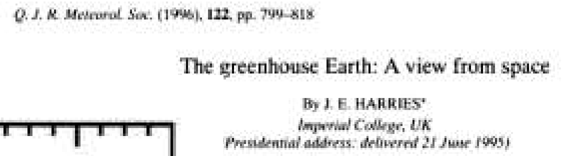
Allan et al. 2022 JGR



Allan (2023) ERL

How are moisture changes in the upper troposphere influencing climate change?



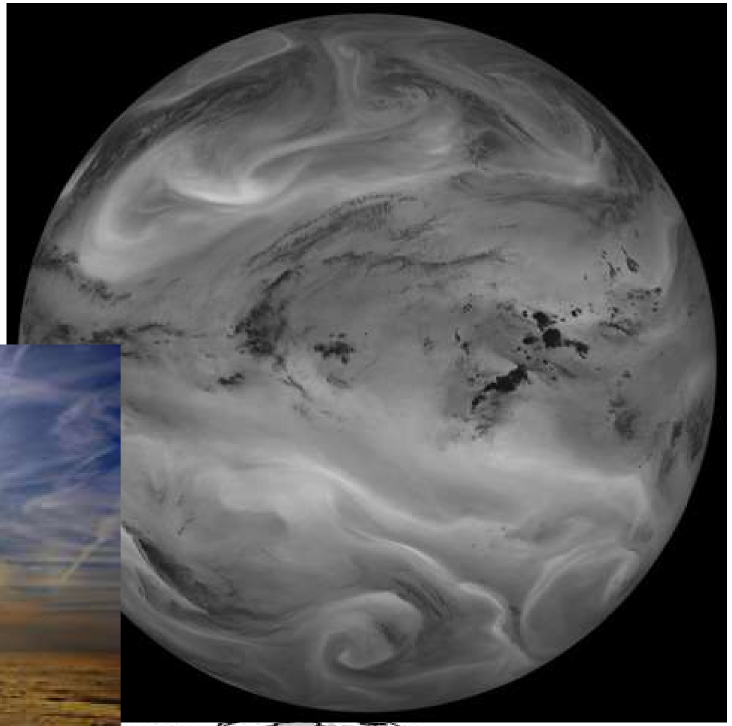

Q. J. R. Meteorol. Soc. (1996), **122**, pp. 799–818

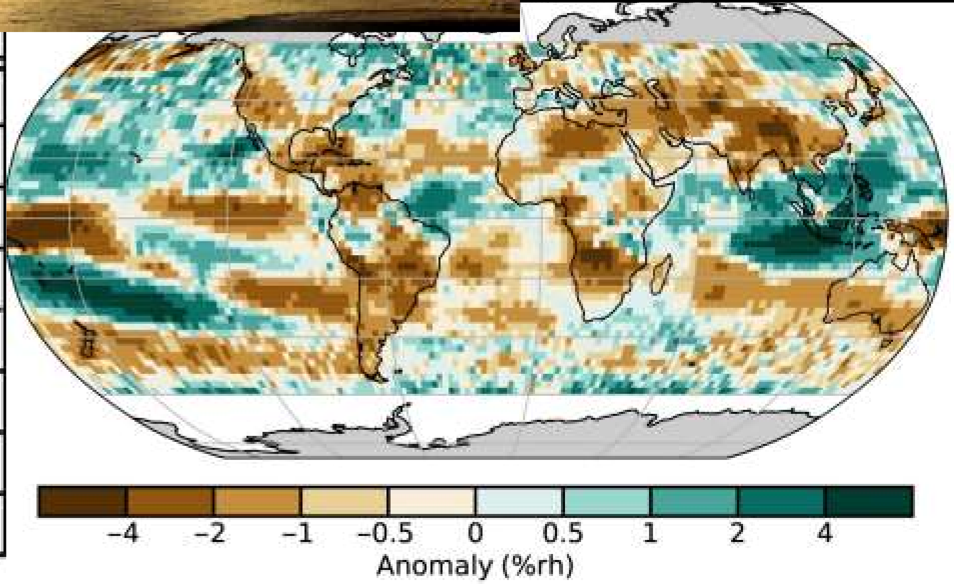
The greenhouse Earth: A view from space

By J. E. HARRIES*

Imperial College, UK

(Presidential address: delivered 21 June 1995)

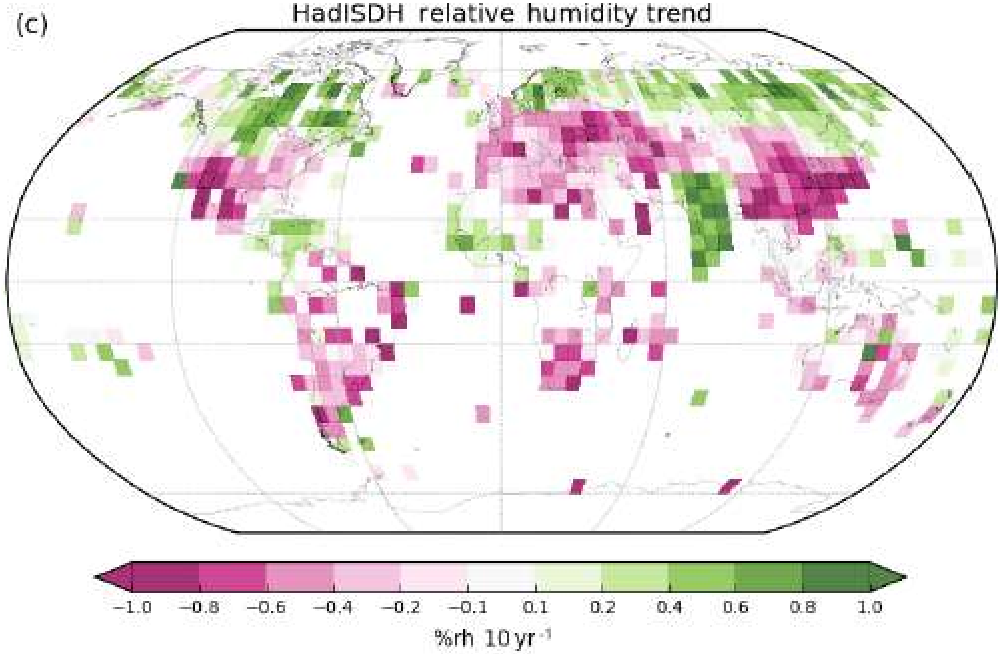


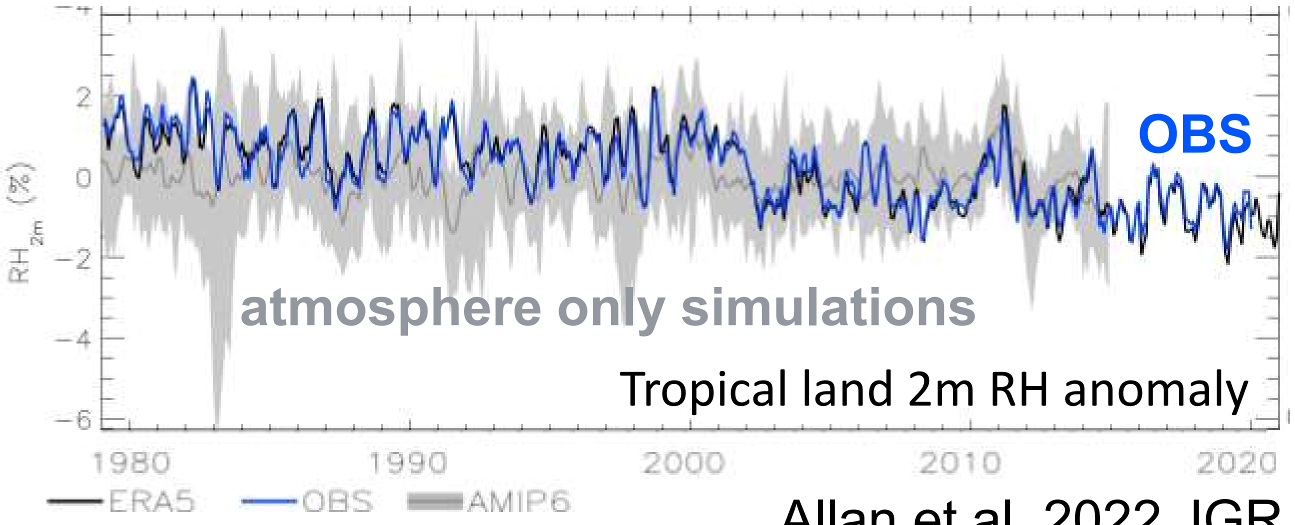


John et al. (2023) in BAMS state of climate 2022

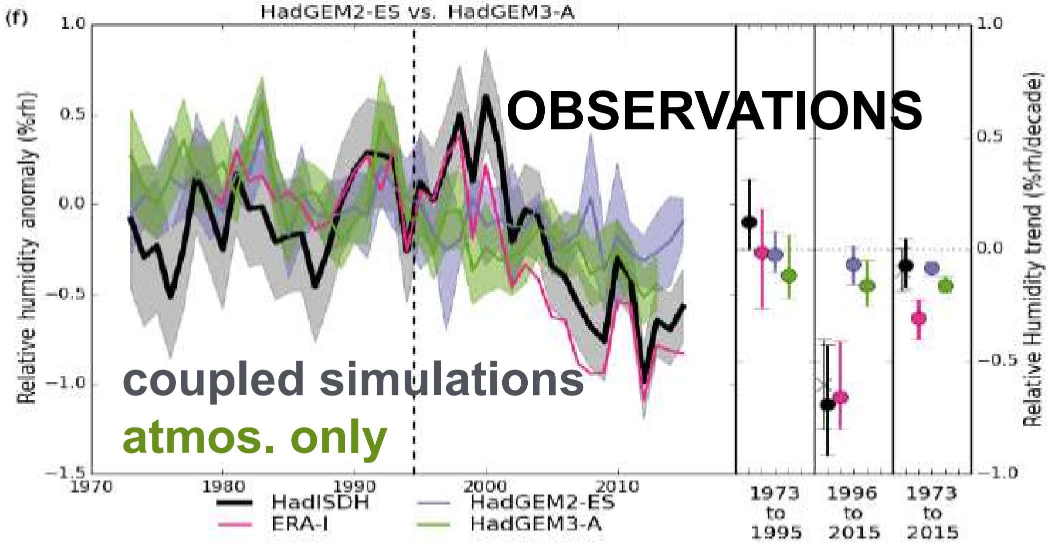
IS CONTINENTAL DRYING UNDERESTIMATED BY MODELS?

- Declining Relative Humidity over land
- Consistent with larger warming over land than sea e.g. O'Gorman & Byrne (2018) PNAS
- Not fully captured by CMIP5/6 simulations even when forced with observed SST e.g. Allan et al. 2022 JGR, Dunn et al. 2017 ESD





Allan et al. 2022 JGR

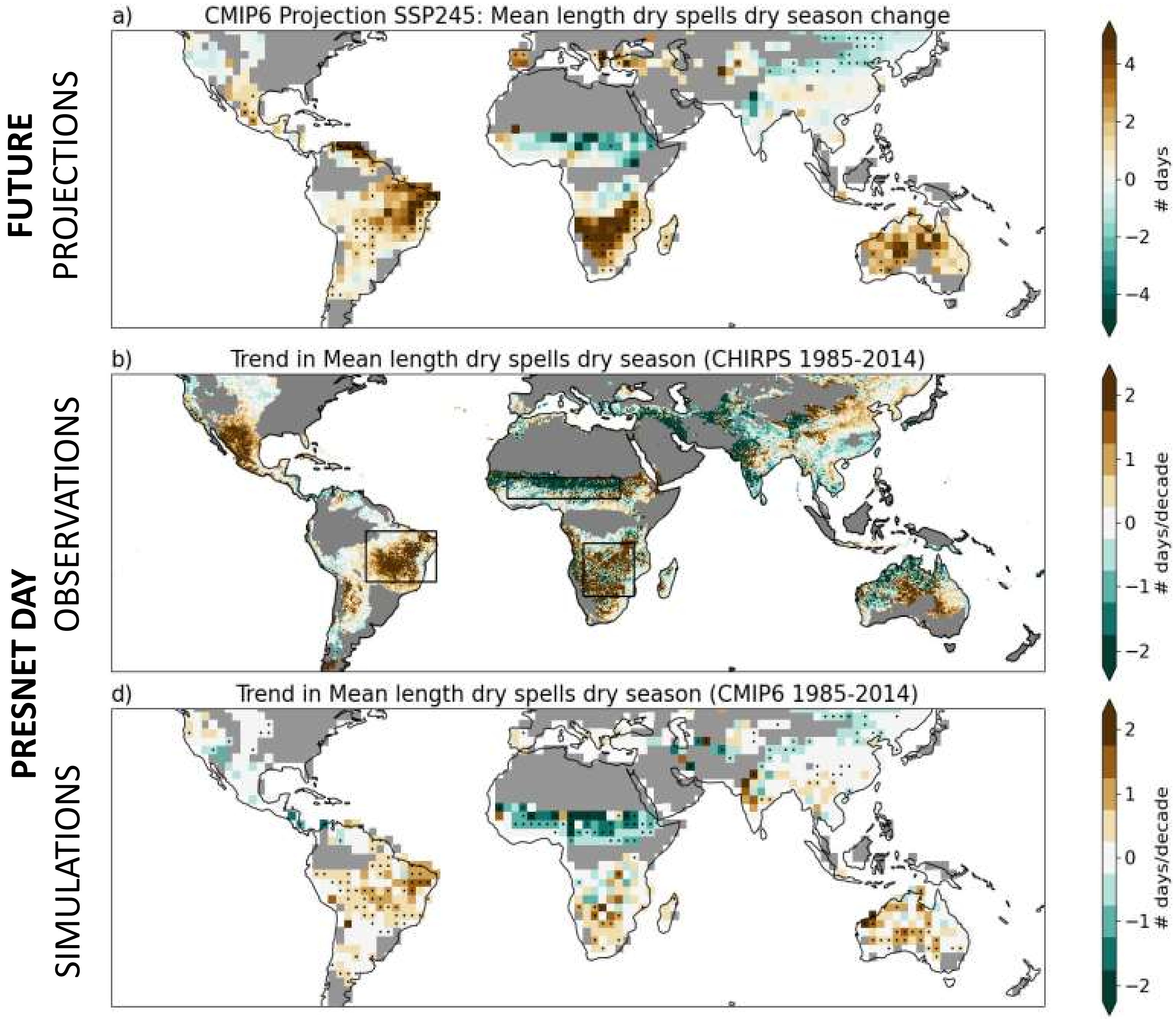


Dunn et al. 2017 ESD

Can we detect emerging signals of water cycle change?

➢ Emerging signals of more intense dry seasons over eastern Brazil, southern Africa and Australia (opposite in Sahel)

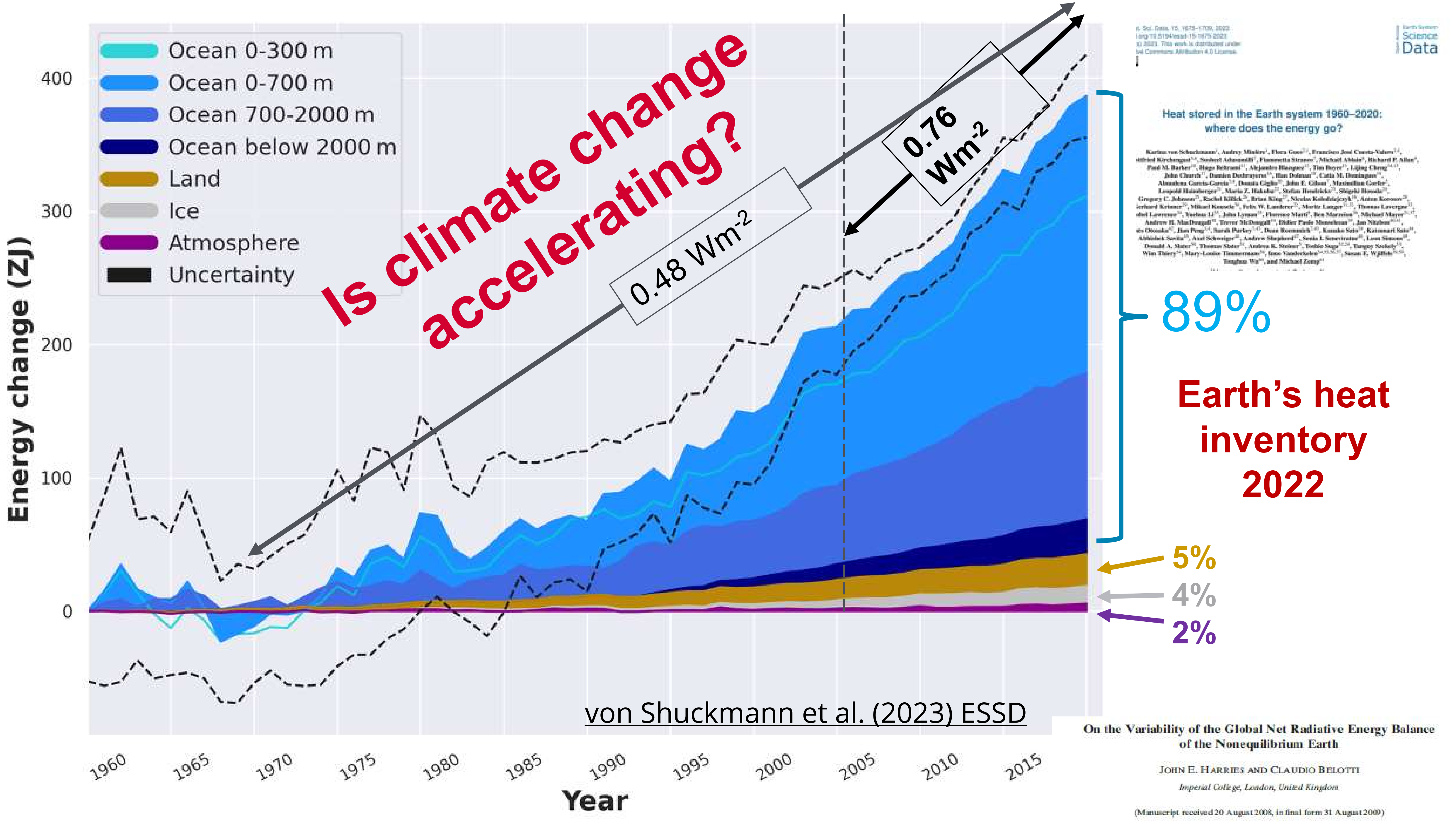
Wainwright et al. (2022) GRL →



Spectral Signatures of Earth's Climate Variability over 5 Years from IASI

HELEN BRINDLEY, RICHARD BANTGES, JACQUELINE RUSSELL, JONATHAN MURRAY, CHRISTOPHER DANCEL, CLAUDIO BELOTTI, AND JOHN HARRIES

Space and Atmospheric Physics Group, Imperial College London, London, United Kingdom


Ocean 0-300 m
Ocean 0-700 m
Ocean 700-2000 m
Ocean below 2000 m
Land
Ice
Atmosphere
Uncertainty
Energy change (ZJ)
Year
Is climate change accelerating?
0.48 Wm-2
0.76 Wm-2
89%
Earth's heat inventory 2022
5%
4%
2%
von Shuckmann et al. (2023) ESSD
Earth System Science Data
Heat stored in the Earth system 1960–2020: where does the energy go?
On the Variability of the Global Net Radiative Energy Balance of the Nonequilibrium Earth
JOHN E. HARRIES AND CLAUDIO BELOTTI
Imperial College, London, United Kingdom
(Manuscript received 20 August 2008, in final form 31 August 2009)

Unexpected pattern of global warming?

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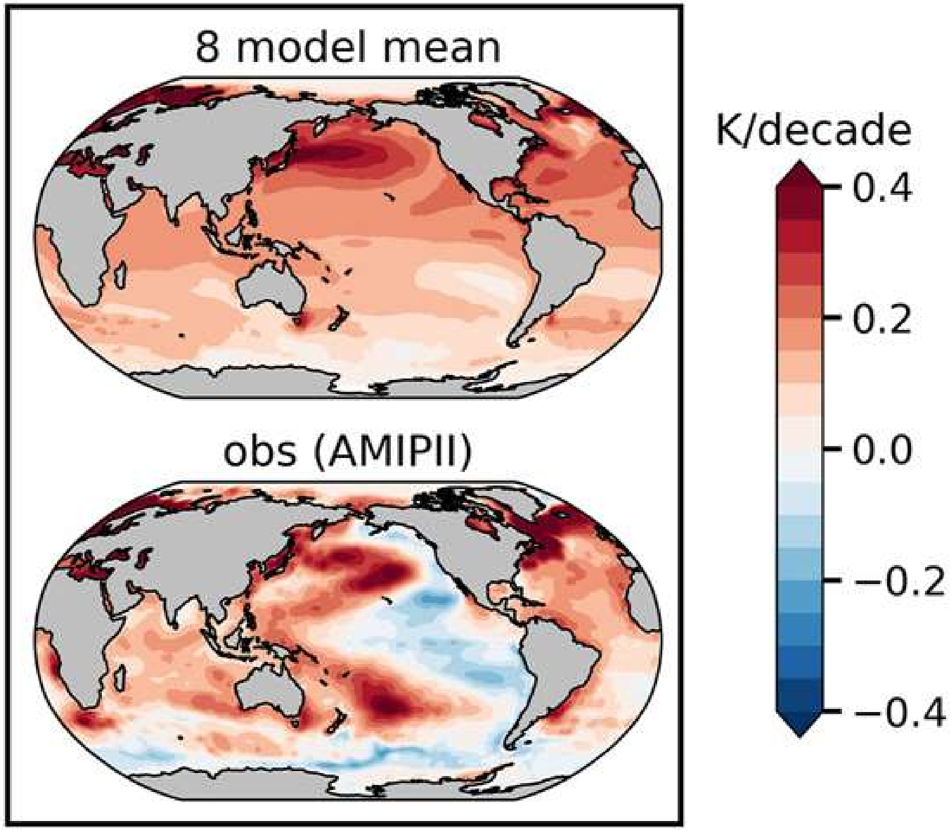
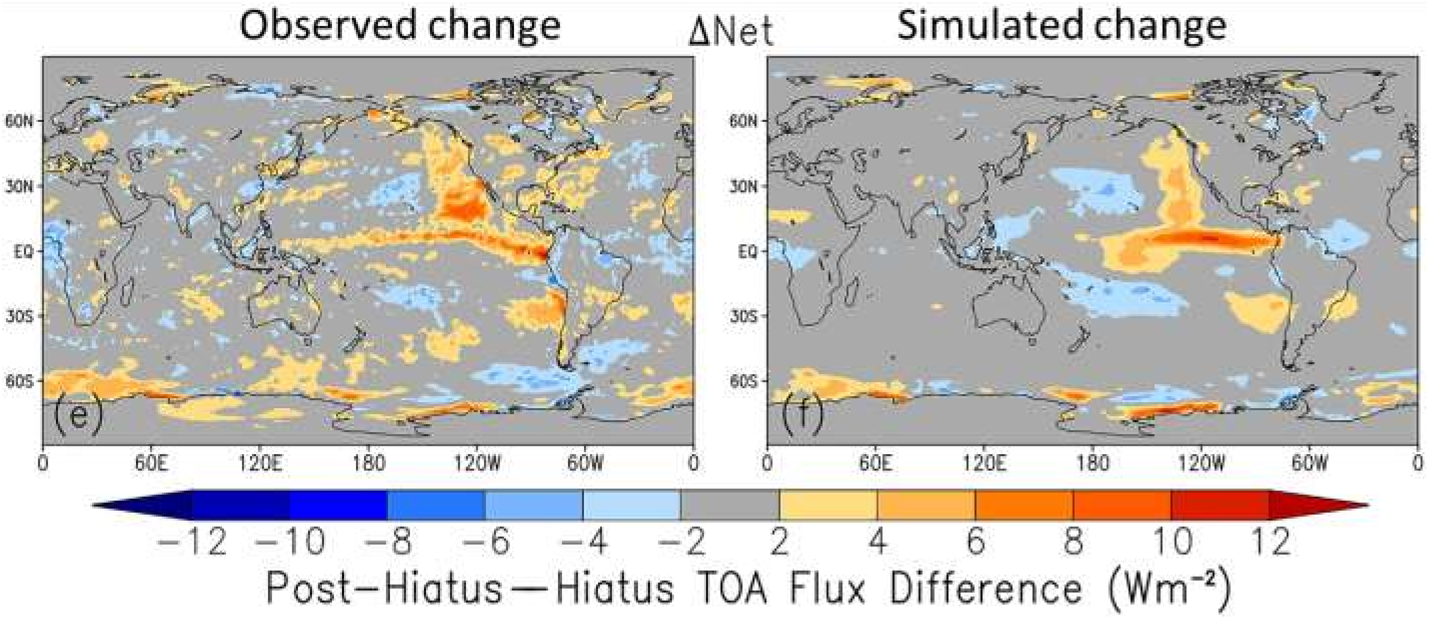


This has weakened amplifying climate feedbacks relative to coupled models (Andrews et al. 2022 JGR)

…but new Earth radiation budget measurements and simulations suggest clouds are now awakening and causing more sunlight to be absorbed (Loeb et al. 2020 GRL)



Pattern of observed warming (1979-2014) is unexpected!
Dong et al. (2021) GRL

Can we geoengineer our climate back to safety?

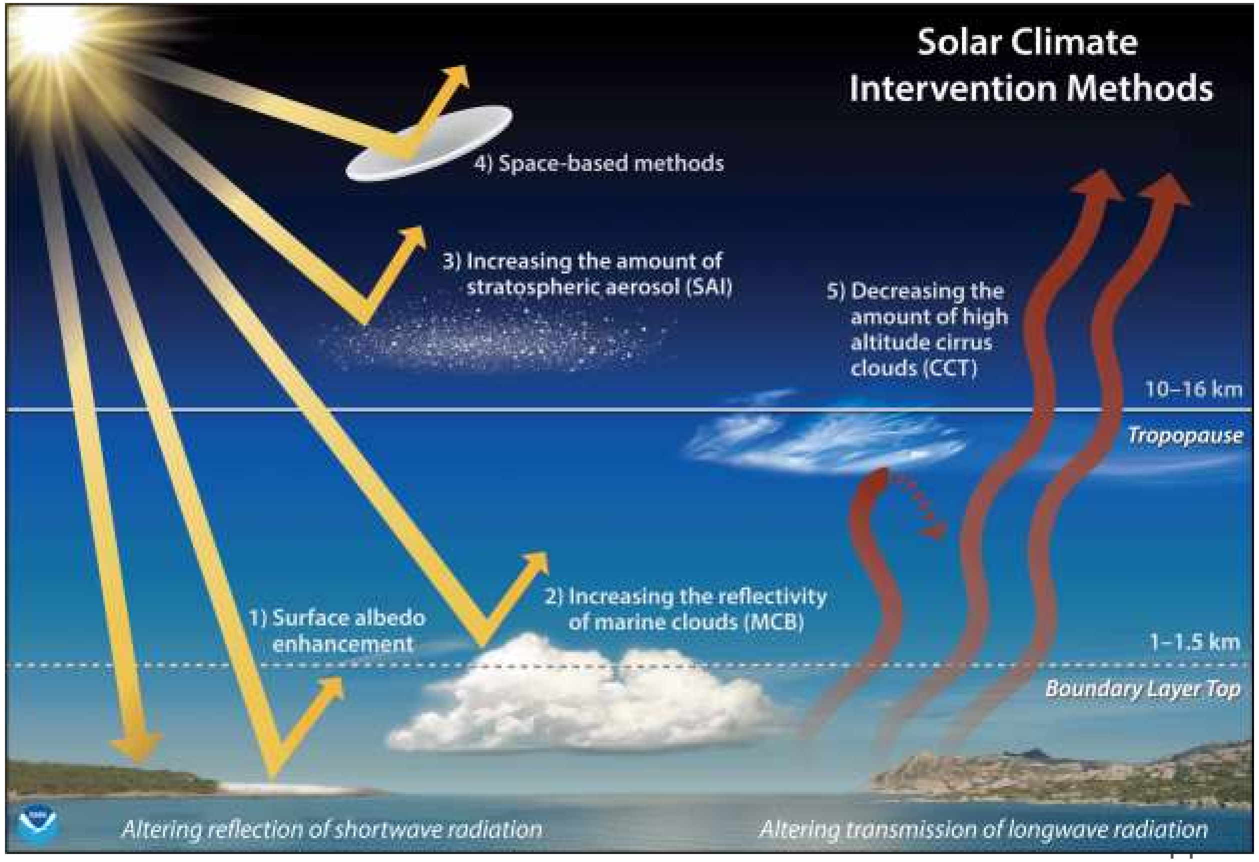
GEOPHYSICAL RESEARCH LETTERS, VOL. 24, NO. 19, PAGES 2355-2358, OCTOBER 1, 1997

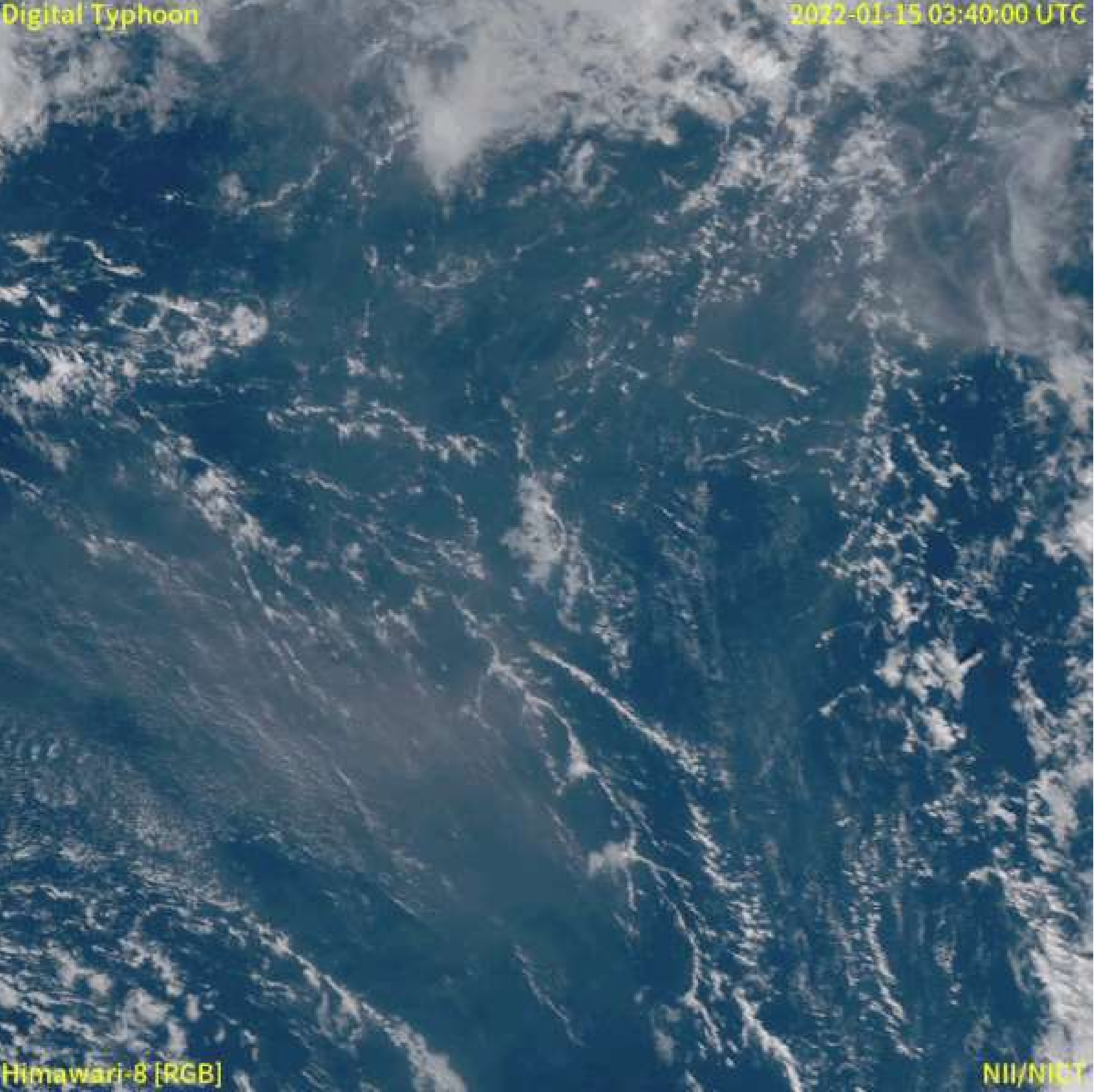
Possible change in climate parameters with zero net radiative forcing

Ashok Sinha and John E. Harries

Space and Atmospheric Physics Group, Blackett Laboratory, Imperial College of Science, Technology and Medicine, Prince Consort Road, London SW7 2BZ

No





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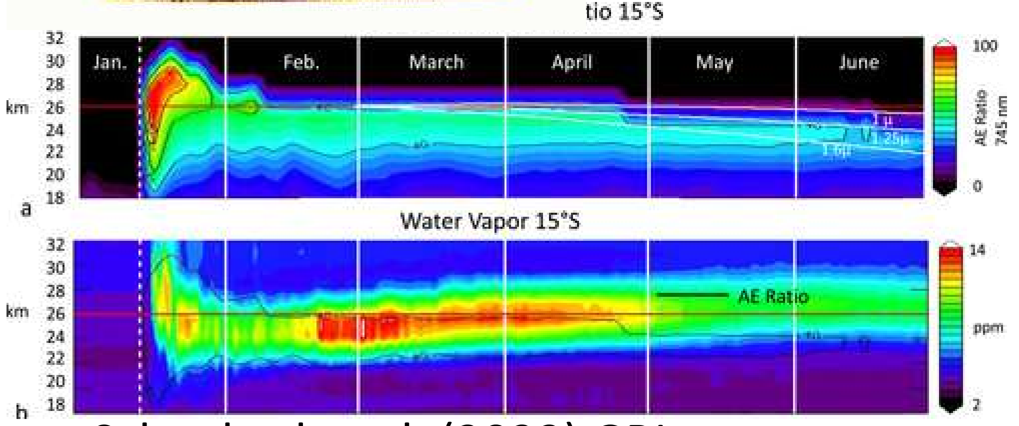

Schoeberl et al. (2022) GRL

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L23814, doi:10.1029/2006GL027457, 2006

On the stability of the Earth's radiative energy balance: Response to the Mt. Pinatubo eruption

J. E. Harries[1] and J. M. Futyan[2]

Received 4 July 2006; revised 27 September 2006; accepted 7 November 2006; published 15 December 2006.

REVIEWS OF GEOPHYSICS AND SPACE PHYSICS NOVEMBER 1976

The Distribution of Water Vapor in the Stratosphere

J. E. Harries

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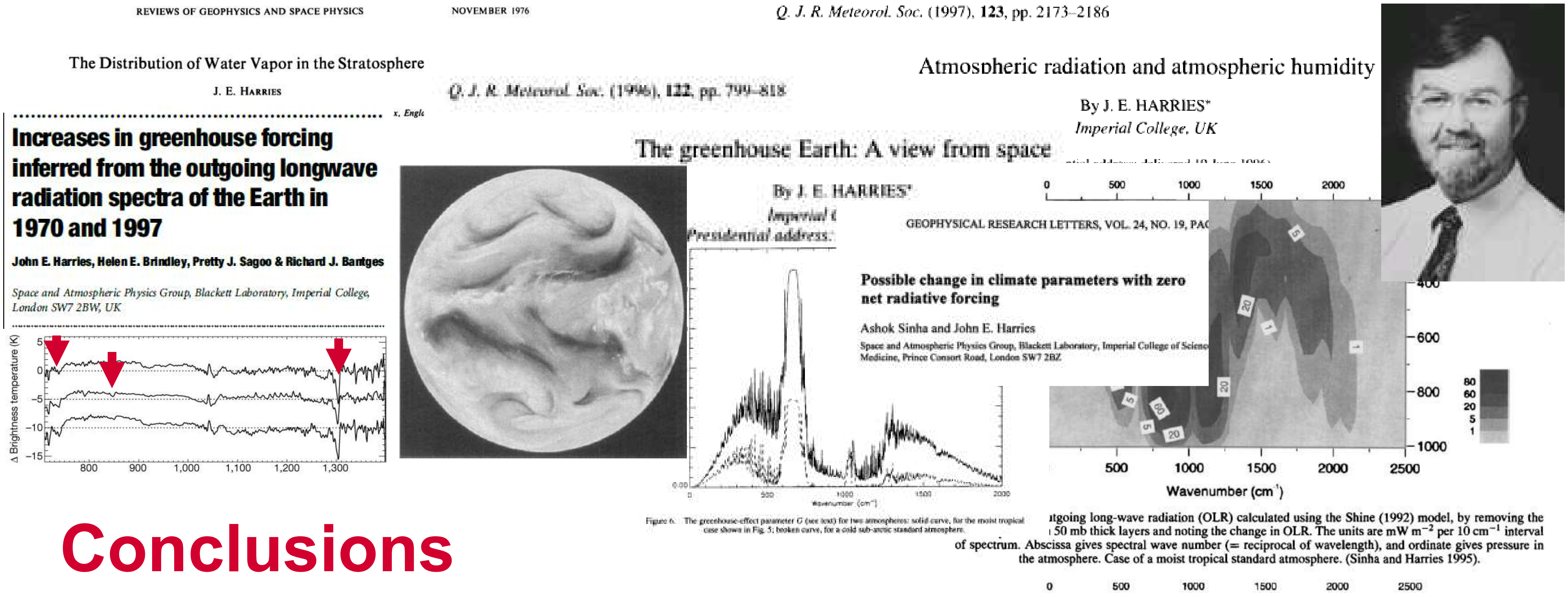

Conclusions

- John's work remains fundamental to current research challenges
- He has left his own "spectral signature" on many people who continue to pass on this wisdom for the benefit of society