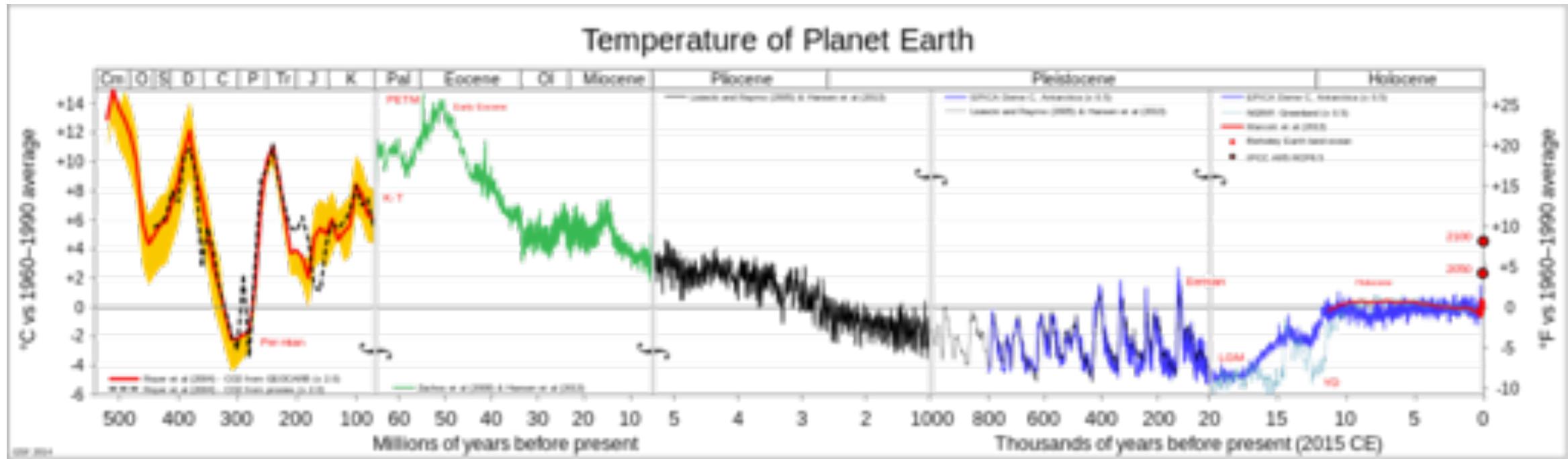


Changes in the Earth System

November 5, 2019



Have we entered a new epoch?



The Case for the Anthropocene

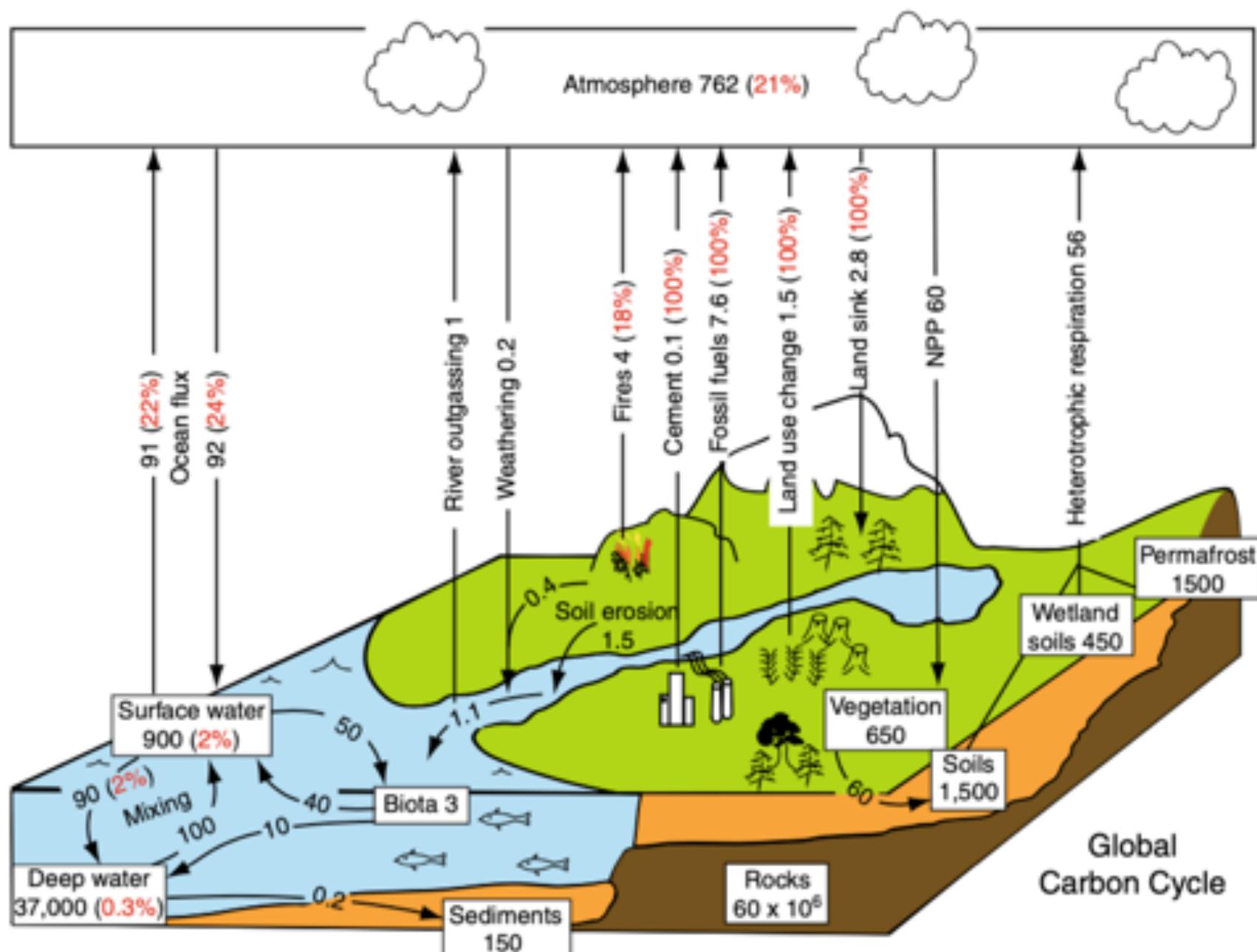
- Proposed new epoch that has resulted primarily from human changes to the planet's:
 - Elemental cycles
 - Climate
 - Biological diversity



The Case for the Anthropocene

- Proposed new epoch that has resulted primarily from human changes to the planet's:
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CO_2 is increasing in the atmosphere

Earth Syst. Sci. Data, 10, 2141–2194, 2018
<https://doi.org/10.5194/essd-10-2141-2018>
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Open Access Earth System
Science
Data

Global Carbon Budget 2018

Corinne Le Quéré¹, Robbie M. Andrew², Pierre Friedlingstein³, Stephen Sitch⁴, Judith Hauck⁵, Julia Pongratz^{6,7}, Penelope A. Pickers⁸, Jan Ivar Korsbakken², Glen P. Peters², Josep G. Canadell⁹, Almut Arneth¹⁰, Vivek K. Arora¹¹, Leticia Barbero^{12,13}, Ana Bastos⁶, Laurent Bopp¹⁴, Frédéric Chevallier¹⁵, Louise P. Chini¹⁶, Philippe Ciais¹⁵, Scott C. Doney¹⁷, Thanos Gkritzalis¹⁸, Daniel S. Goll¹⁵, Ian Harris¹⁹, Vanessa Haverd²⁰, Forrest M. Hoffman²¹, Mario Hoppema⁵, Richard A. Houghton²², George Hurtt¹⁶, Tatiana Ilyina⁷, Atul K. Jain²³, Truls Johannessen²⁴, Chris D. Jones²⁵, Etsushi Kato²⁶, Ralph F. Keeling²⁷, Kees Klein Goldewijk^{28,29}, Peter Landschützer⁷, Nathalie Lefèvre³⁰, Sebastian Lienert³¹, Zhu Liu^{1,34}, Danica Lombardozzi³², Nicolas Metzl³⁰, David R. Munro³³, Julia E. M. S. Nabel⁷, Shin-ichiro Nakaoaka³⁴, Craig Neill^{35,36}, Are Olsen²⁴, Tsueno Ono³⁸, Prabir Patra³⁹, Anna Peregon¹⁵, Wouter Peters^{40,41}, Philippe Peylin¹⁵, Benjamin Pfeil^{24,37}, Denis Pierrot^{12,13}, Benjamin Poulter⁴², Gregor Rehder⁴³, Laure Resplandy⁴⁴, Eddy Robertson²⁵, Matthias Rocher⁴⁵, Christian Rödenbeck⁴⁶, Ute Schuster⁴, Jörg Schwinger³⁷, Roland Séférian⁴⁵, Ingunn Skjelvan³⁷, Tobias Steinhoff⁴⁷, Adrienne Sutton⁴⁸, Pieter P. Tans⁴⁹, Hanqin Tian⁵⁰, Bronte Tilbrook^{35,36}, Francesco N. Tubiello⁵¹, Ingrid T. van der Laan-Luijkx⁴⁰, Guido R. van der Werf⁵², Nicolas Viovy¹⁵, Anthony P. Walker⁵³, Andrew J. Wiltshire²⁵, Rebecca Wright^{1,8}, Sönke Zaehle⁴⁶, and Bo Zheng¹⁵

Flux	Amount (Pg C/yr)
Fossil fuel burning	9.4
LULCC	1.5
Ocean uptake	2.4
Land uptake	3.2
Atmospheric growth	4.7
Uncertainty	0.5

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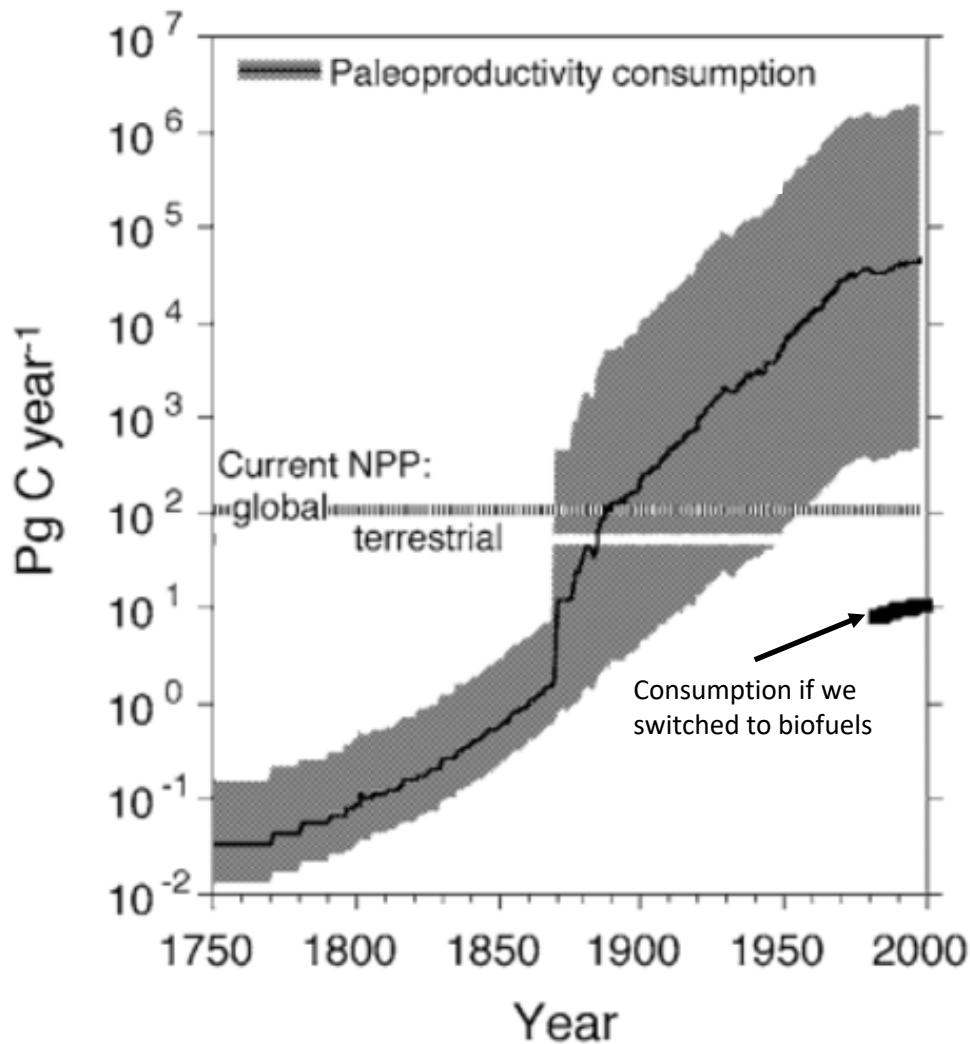
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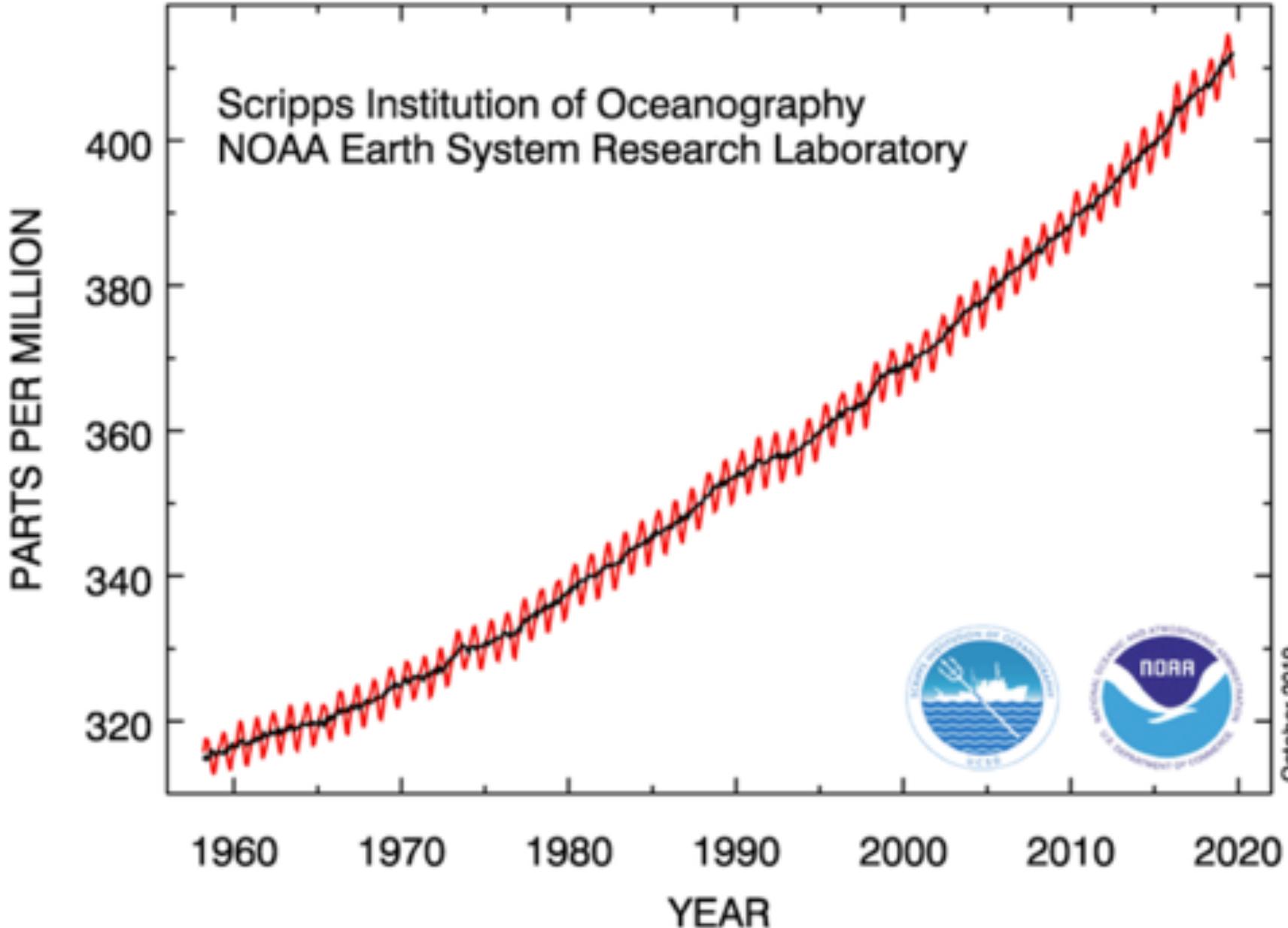
0.6 higher than book
estimate (2007)



We are using more carbon than plants are putting back

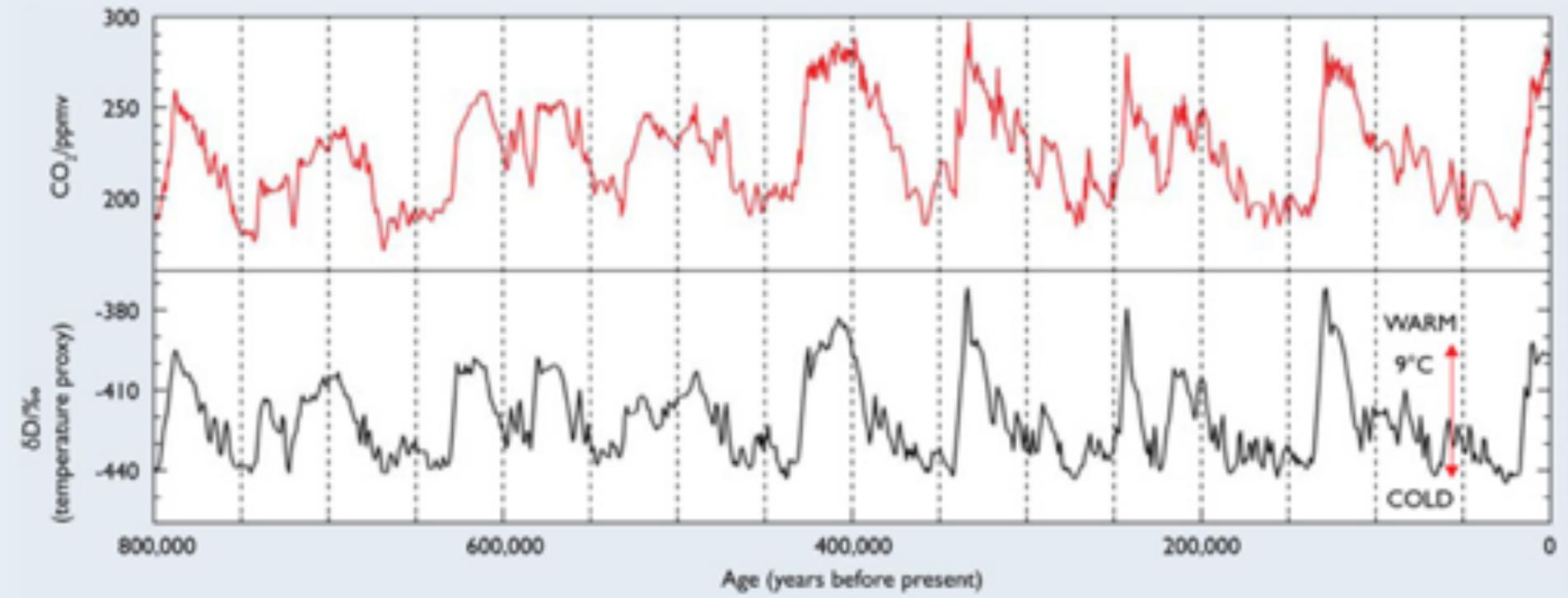
Dukes (2003) “Burning buried sunshine”

Atmospheric CO₂ at Mauna Loa Observatory



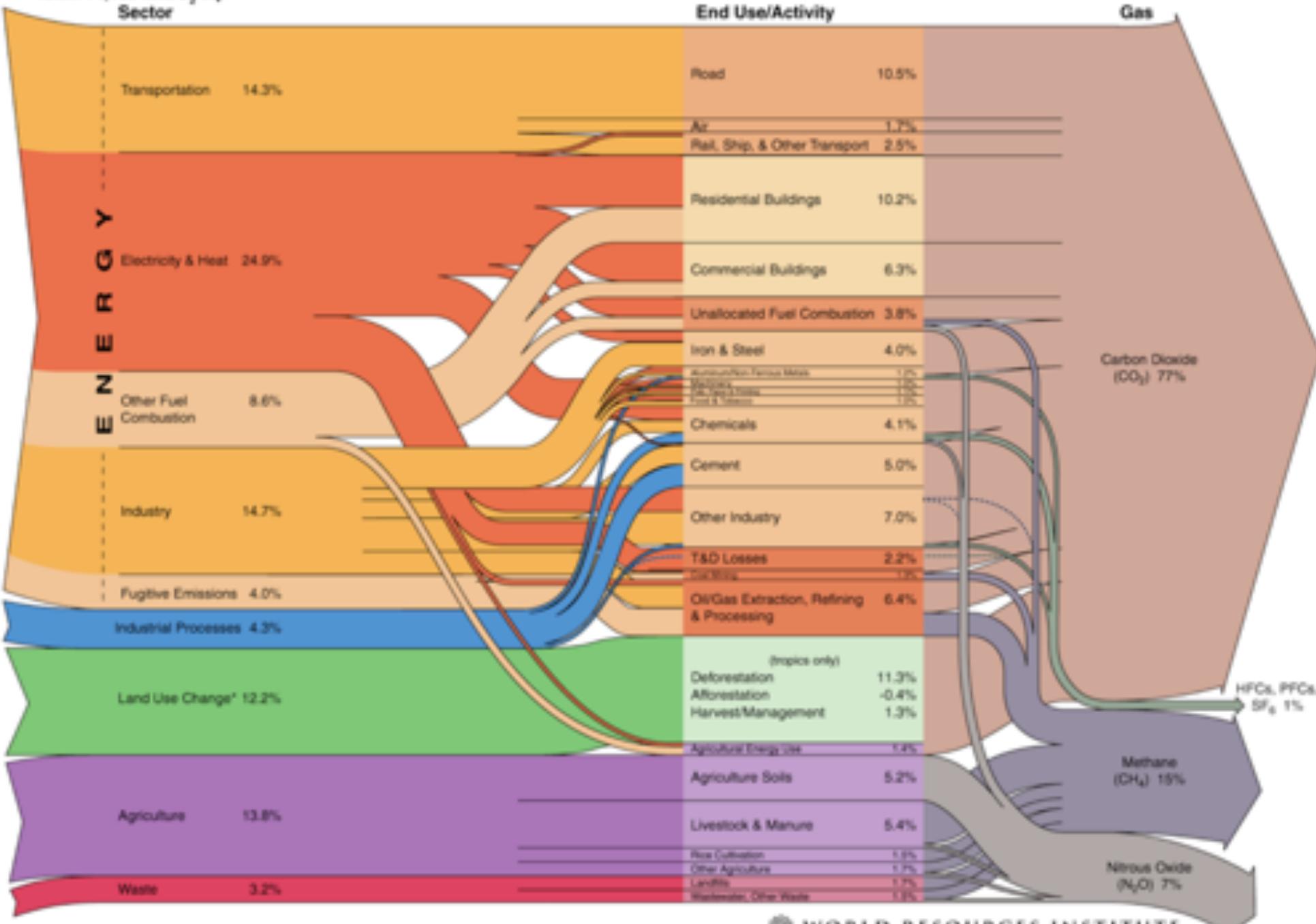
Going up 5
ppm / year

Fig. 3: ice core data from the EPICA Dome C (Antarctica) ice core: deuterium (δD) is a proxy for local temperature; CO_2 from the ice core air⁽⁵⁶⁾

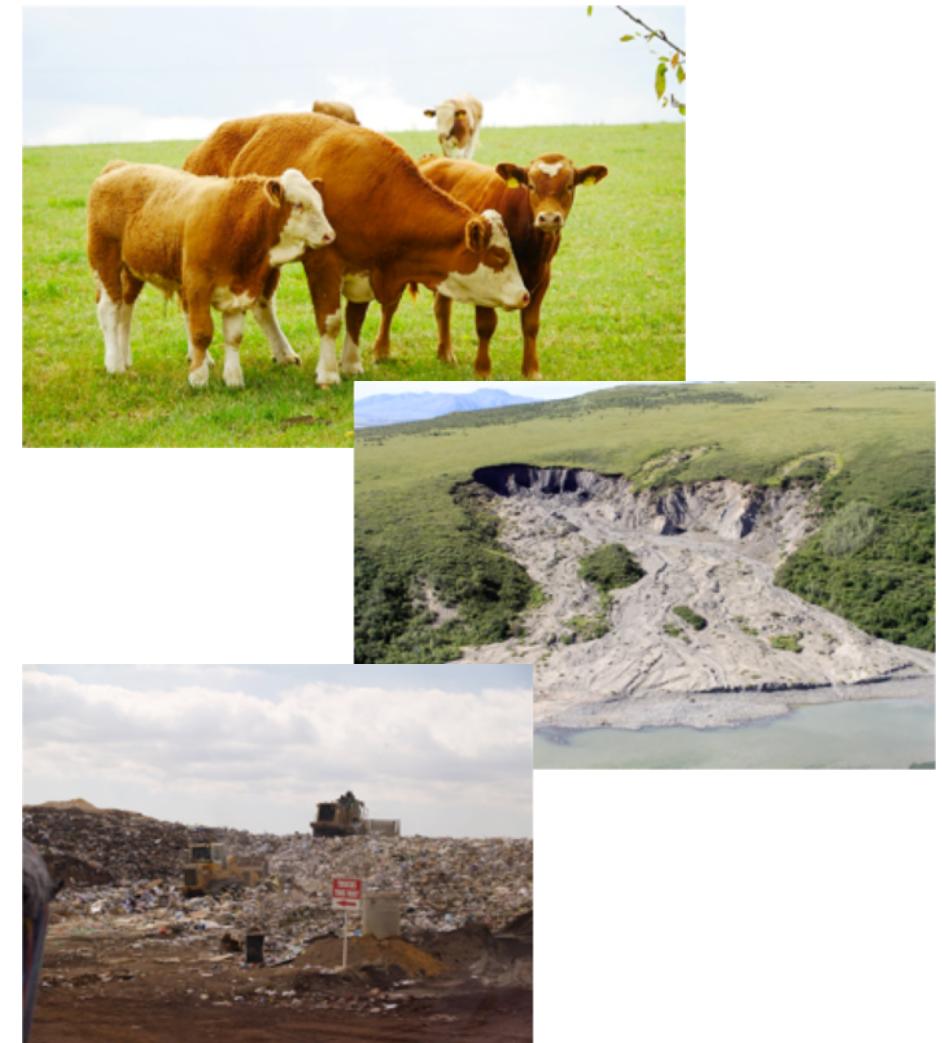
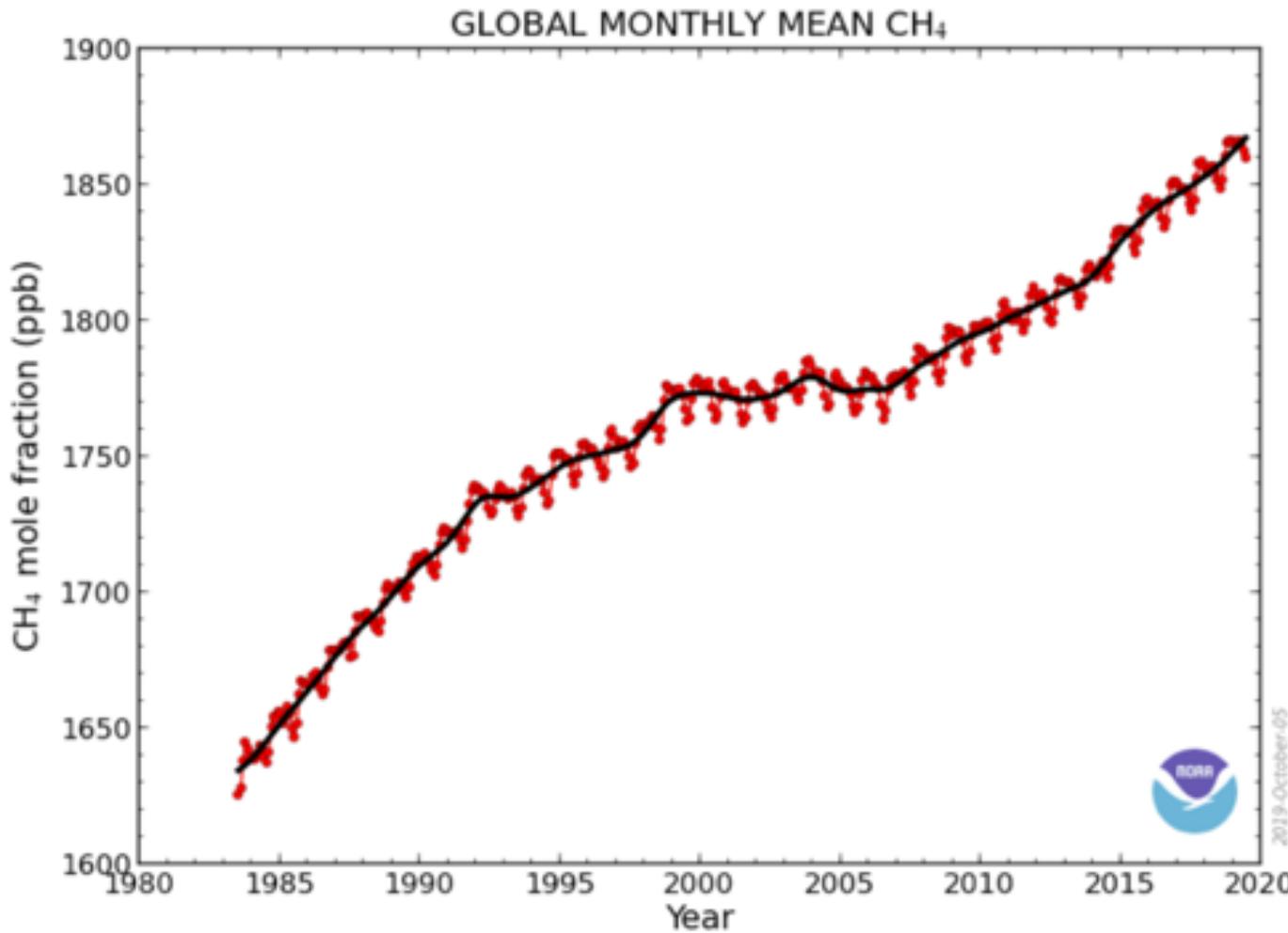


Historical rate of change: 0.002 ppm / year

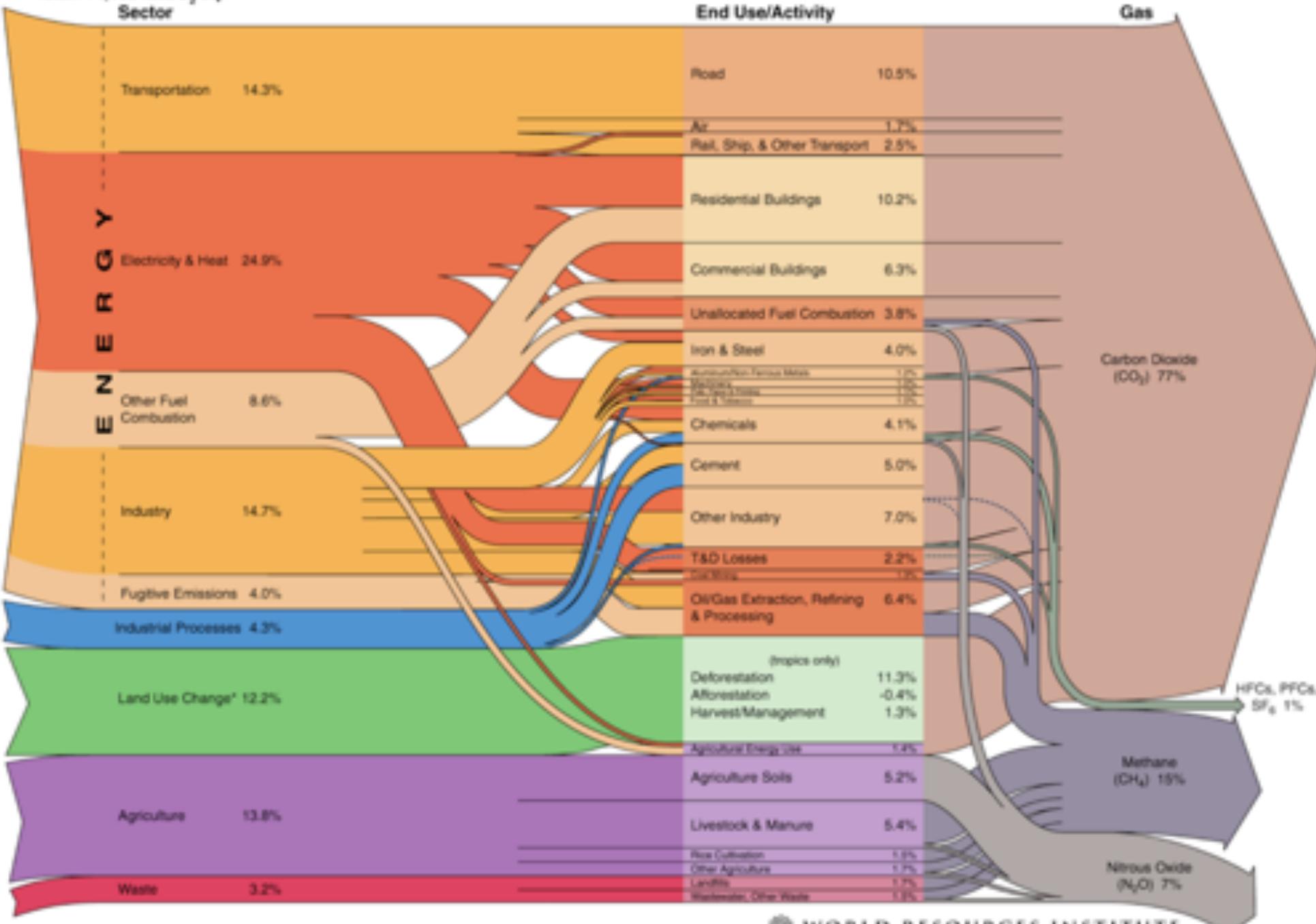
World Greenhouse Gas Emissions in 2005
Total: 44,153 MtCO₂ eq.

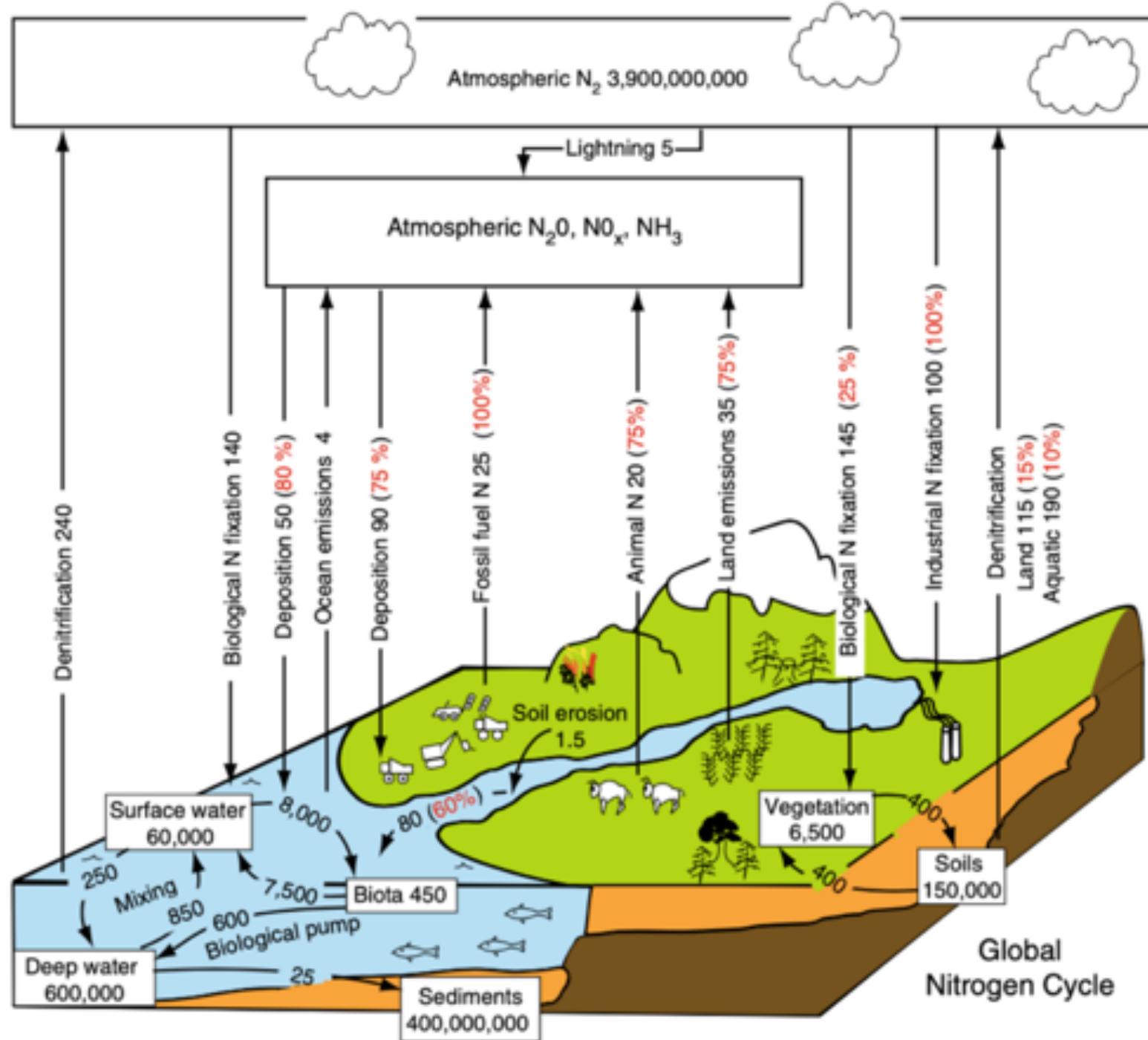


Caron from methane (CH_4) is also going up

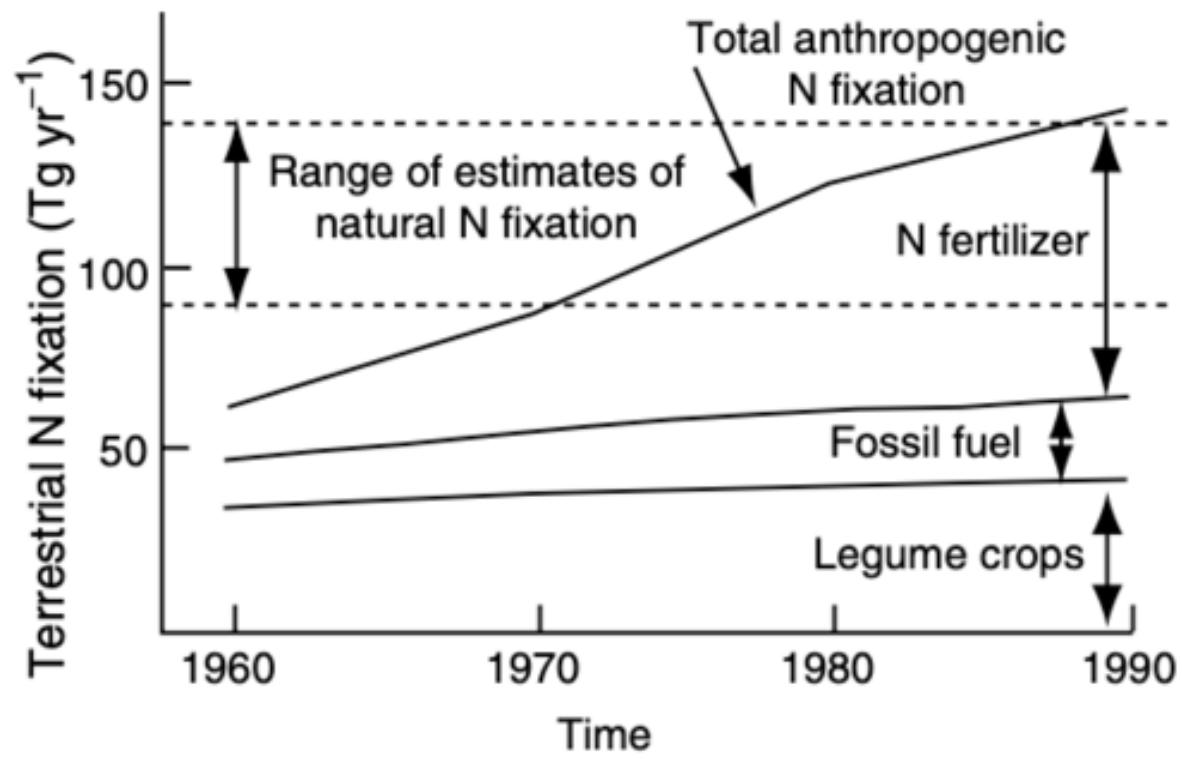


World Greenhouse Gas Emissions in 2005
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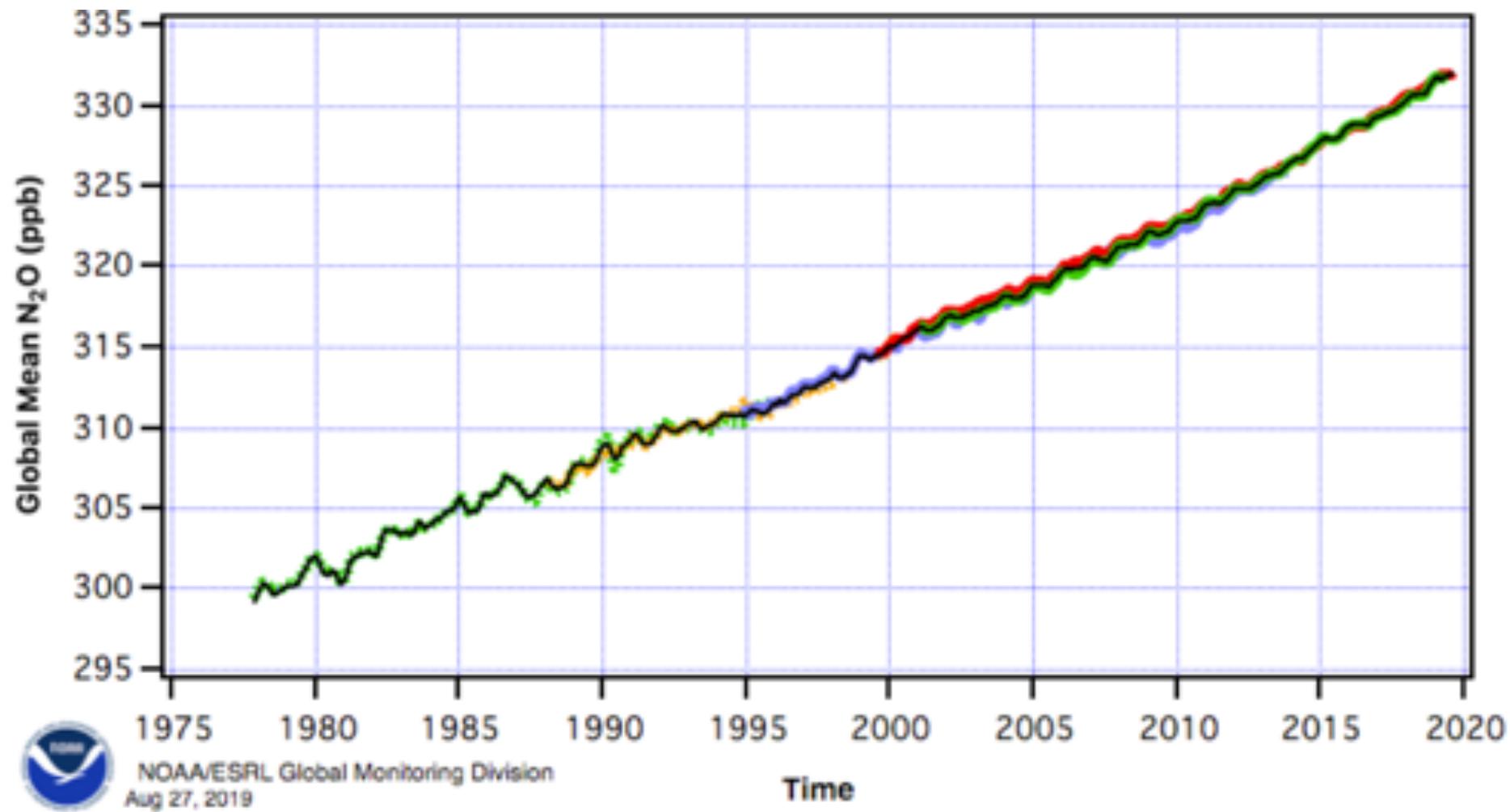




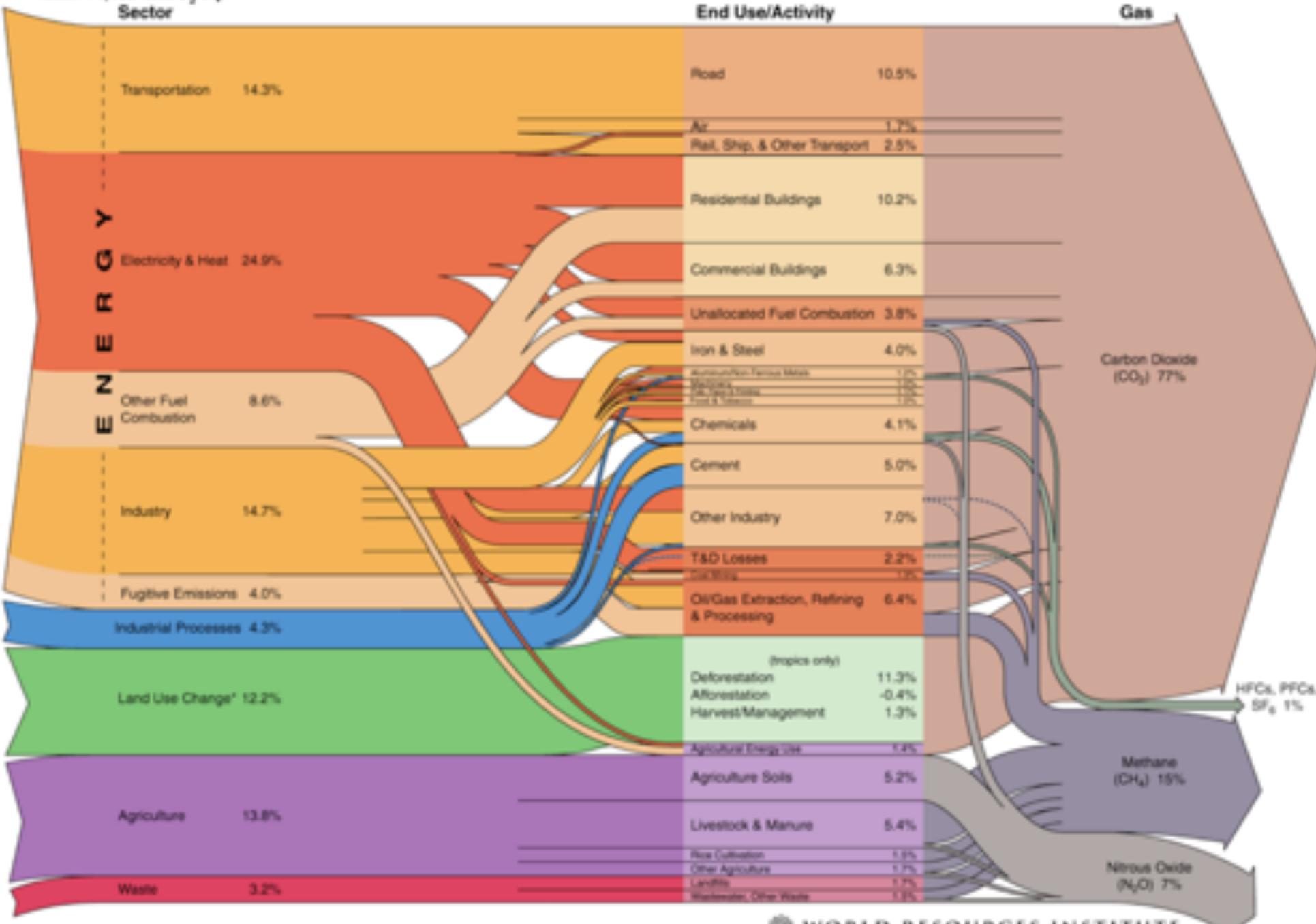
We're pulling in a lot of atmospheric N...

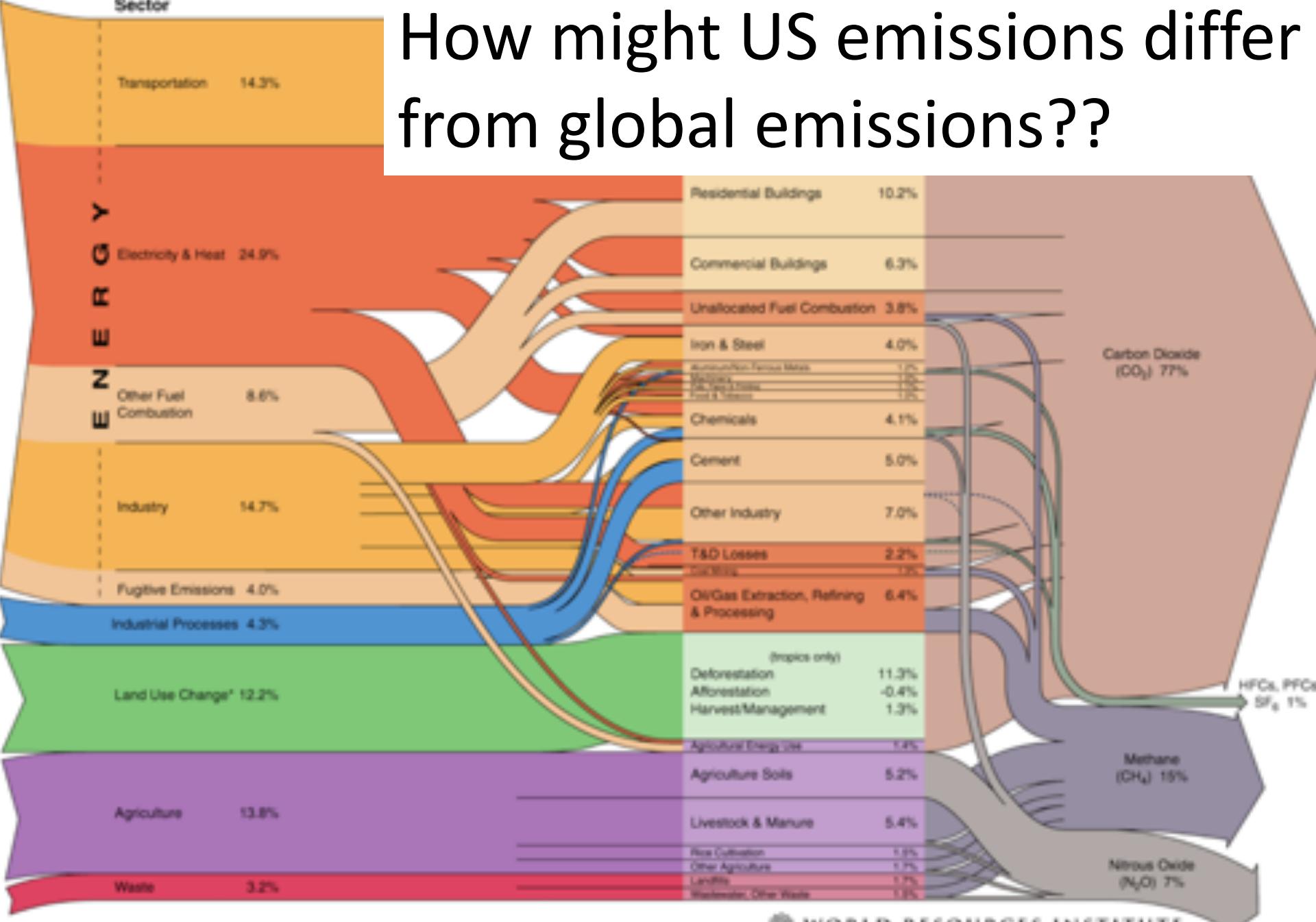


...while also pumping out a lot in new forms



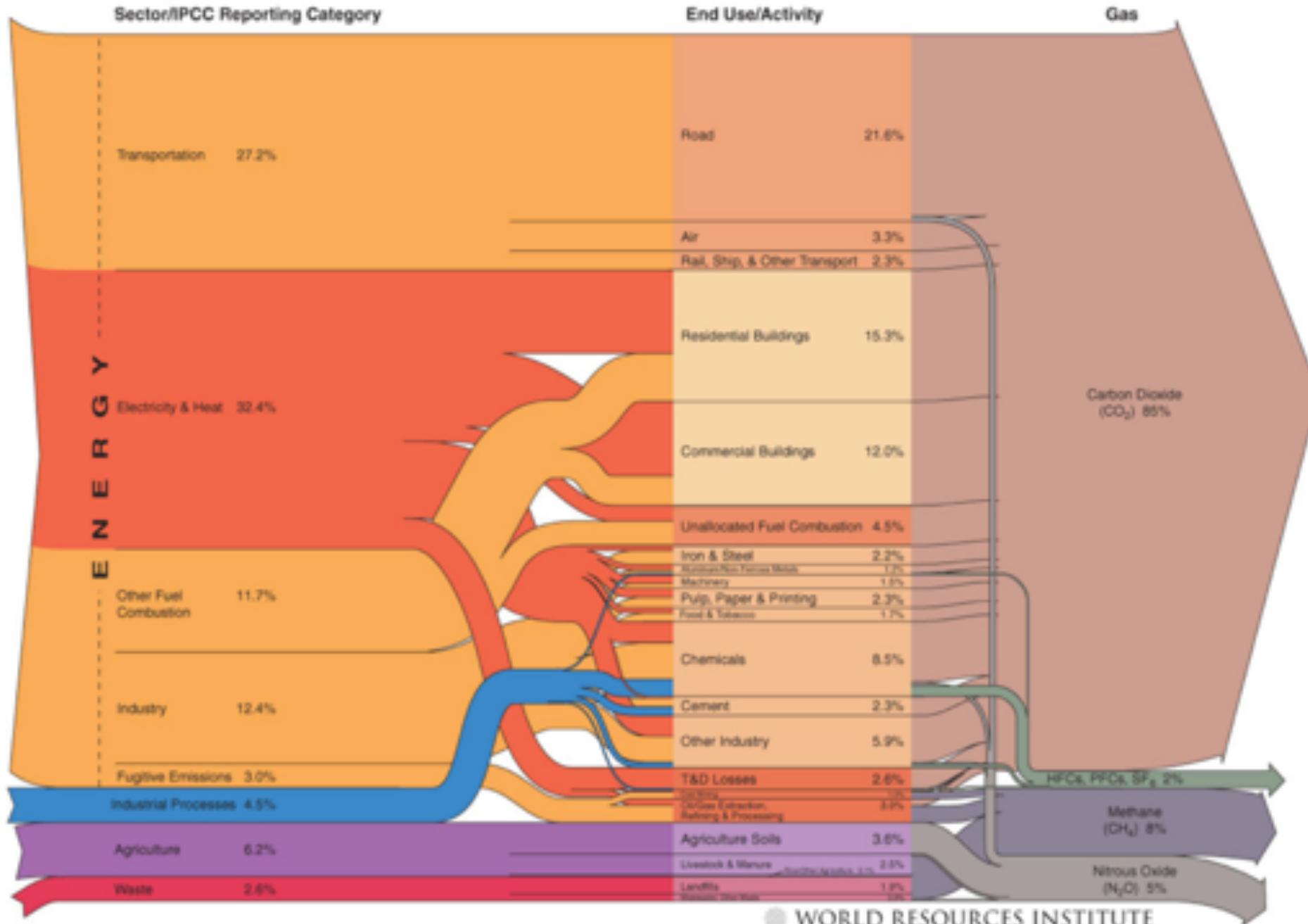
World Greenhouse Gas Emissions in 2005
Total: 44,153 MtCO₂ eq.





How might US emissions differ from global emissions??

U.S. GHG Emissions Flow Chart



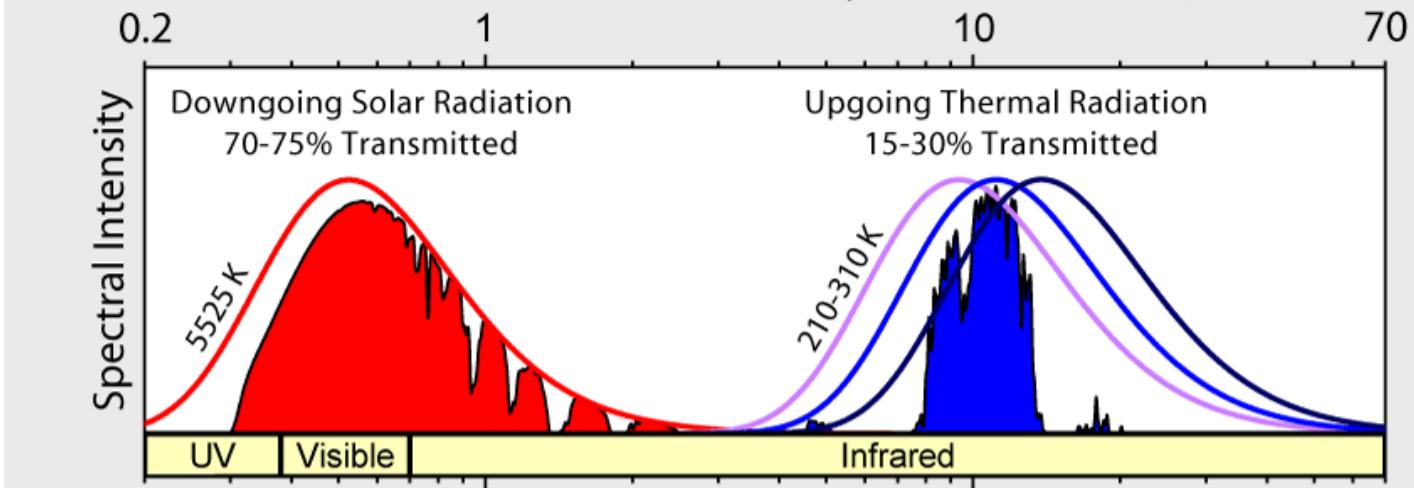
The Case for the Anthropocene

- Proposed new epoch that has resulted primarily from human changes to the planet's:
 - Elemental cycles
 - Climate
 - Biological diversity

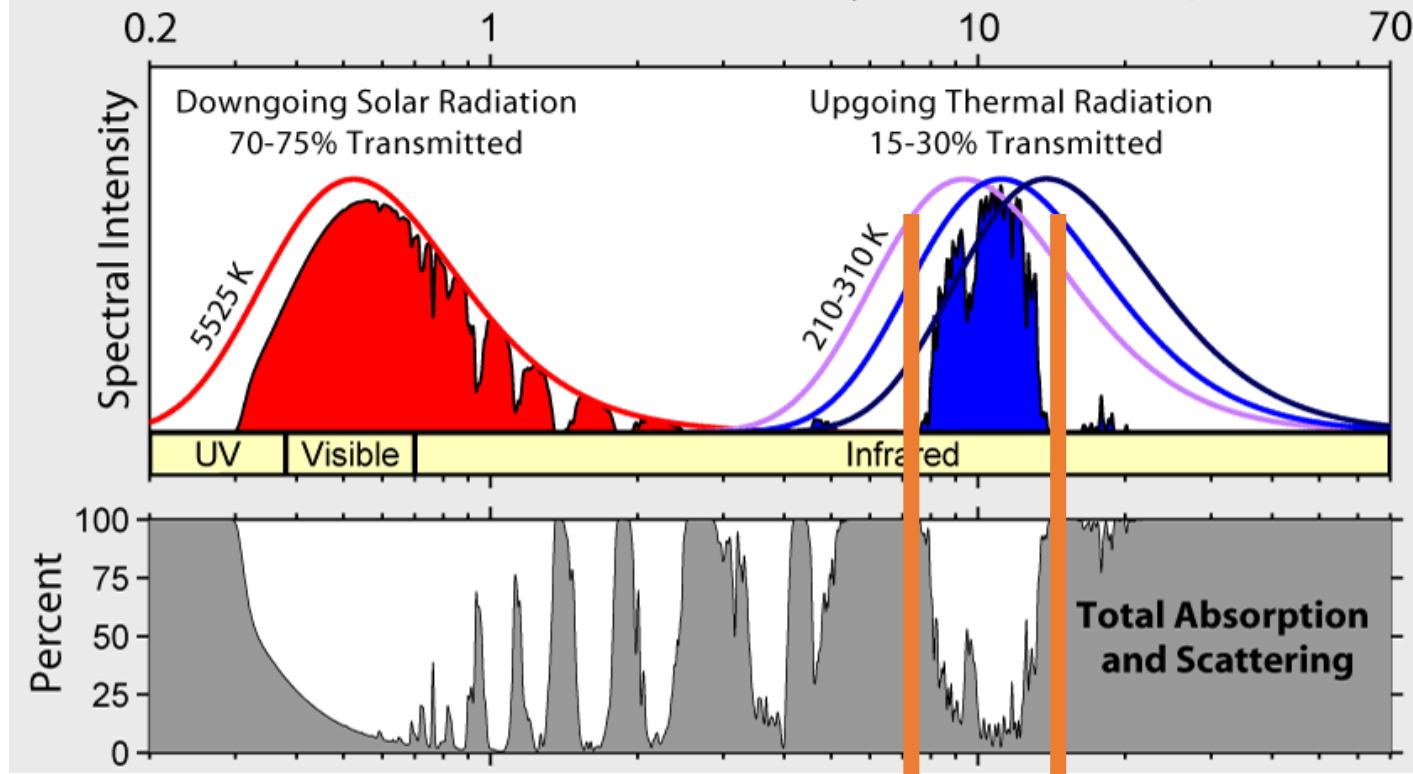


Climate change is the result of
human changes to elemental
cycles

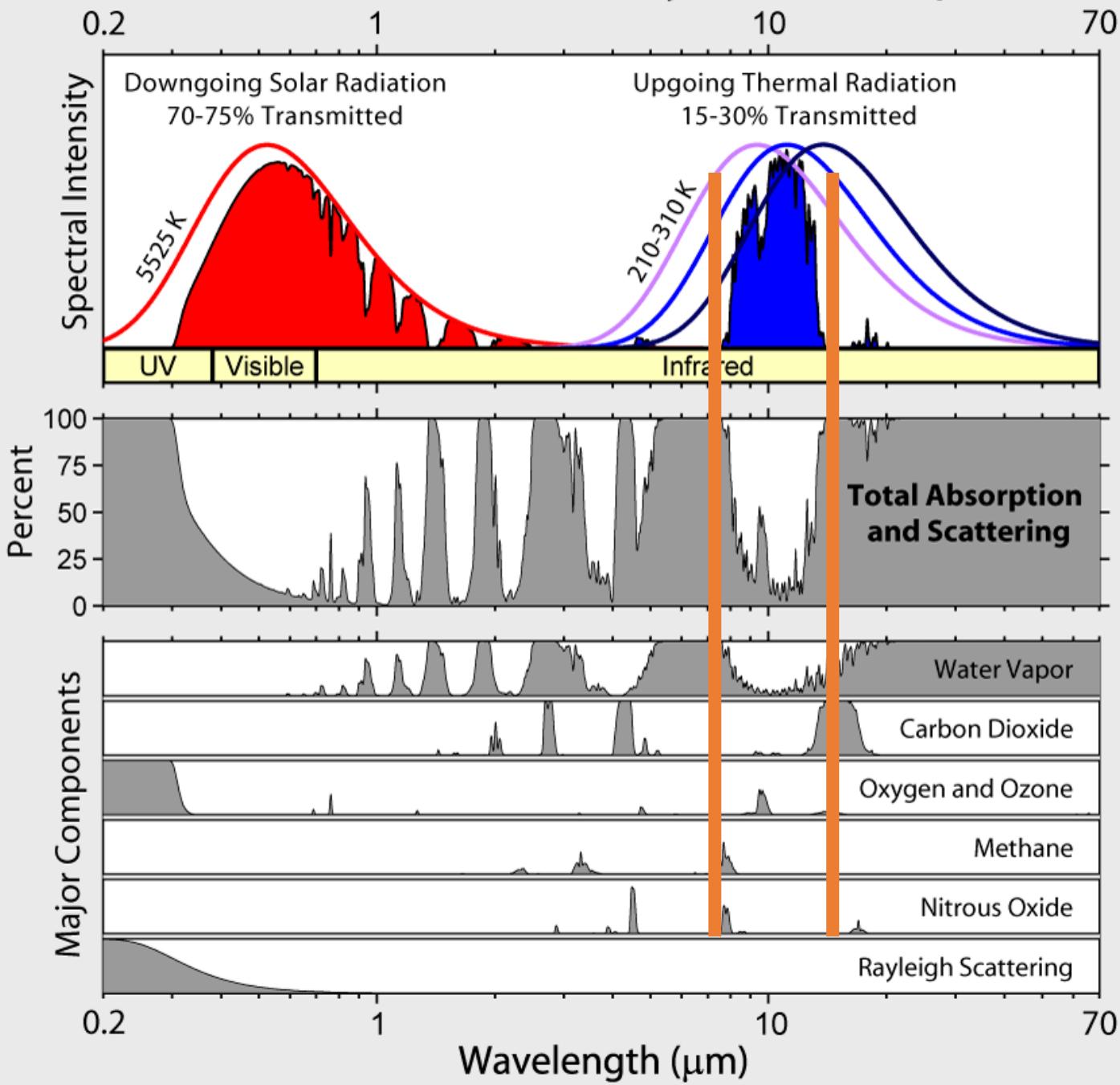
Radiation Transmitted by the Atmosphere



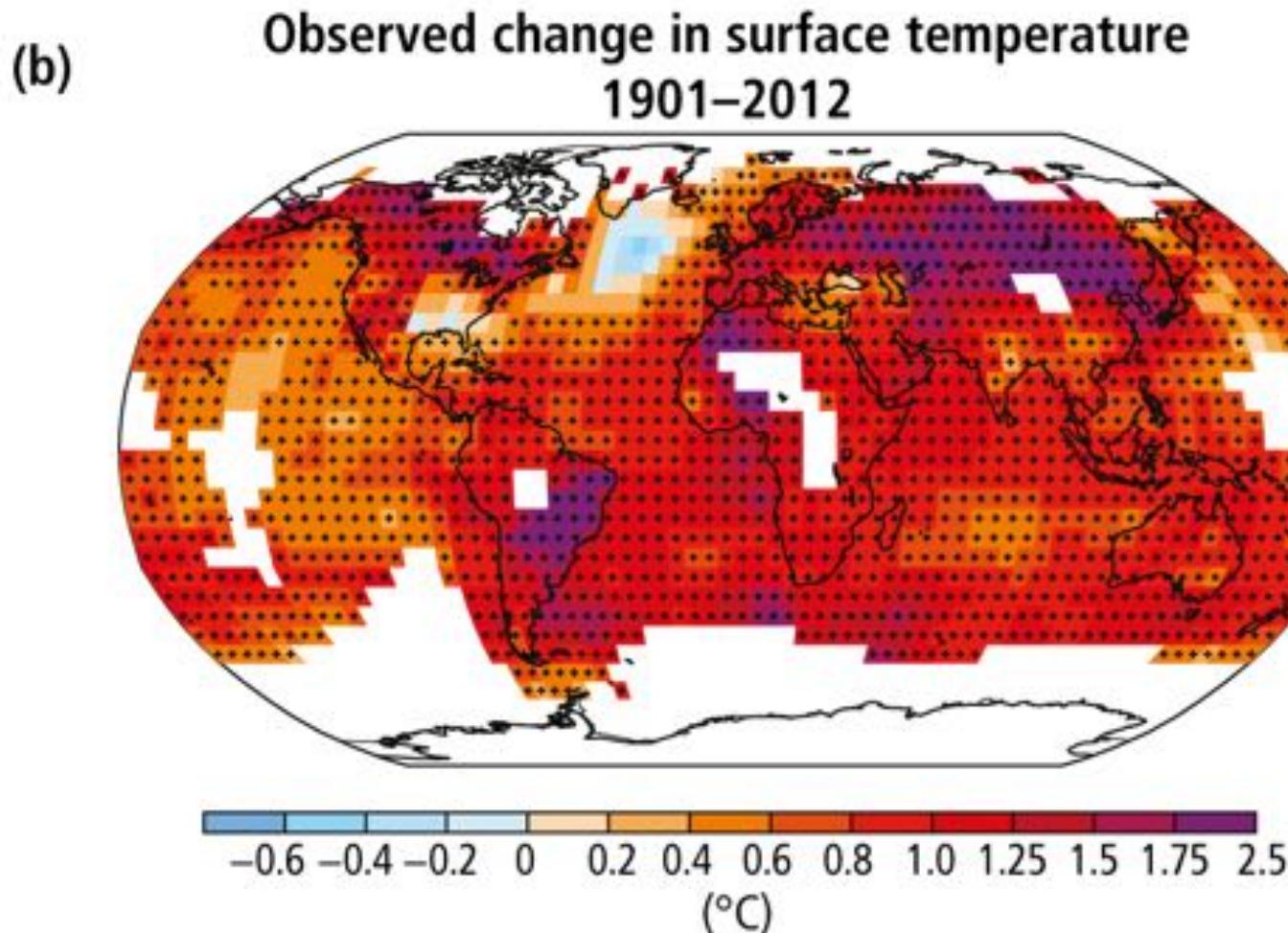
Radiation Transmitted by the Atmosphere



Radiation Transmitted by the Atmosphere

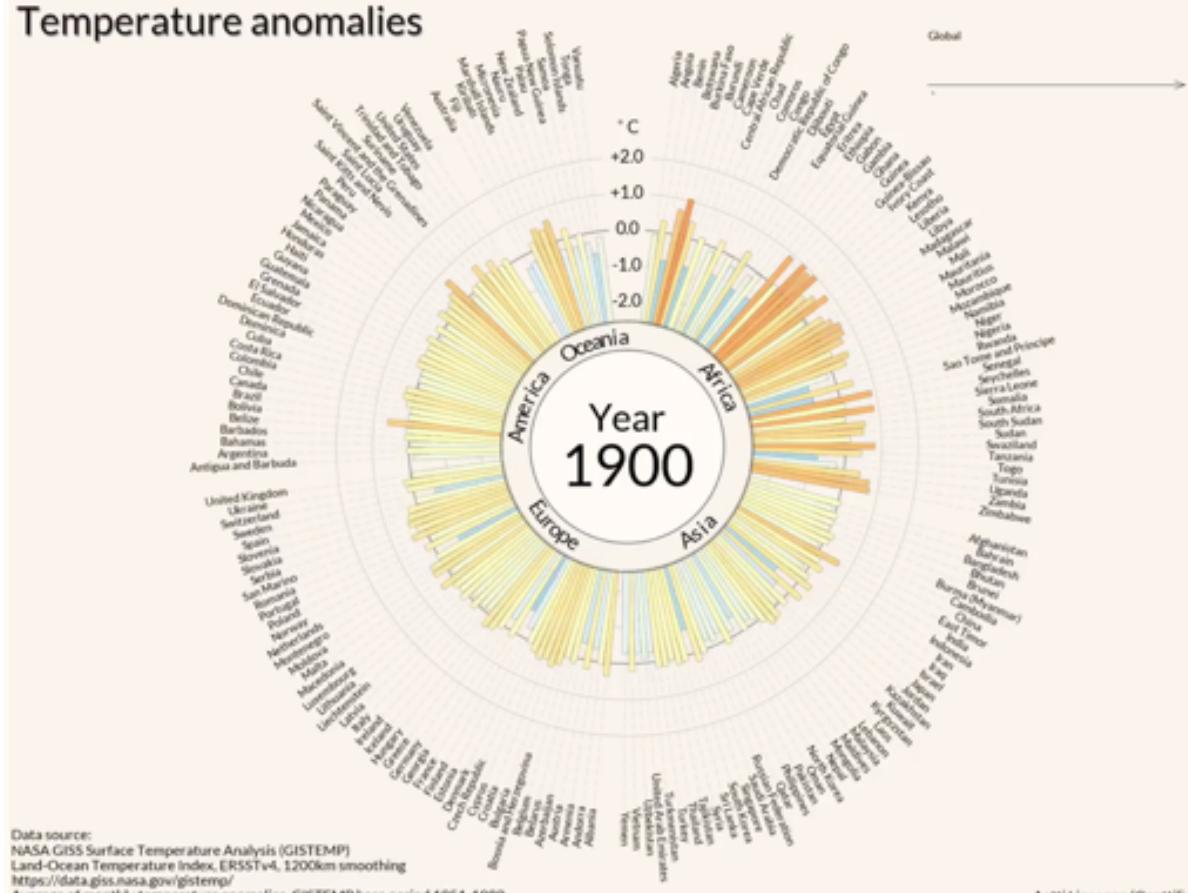


The climate is warming

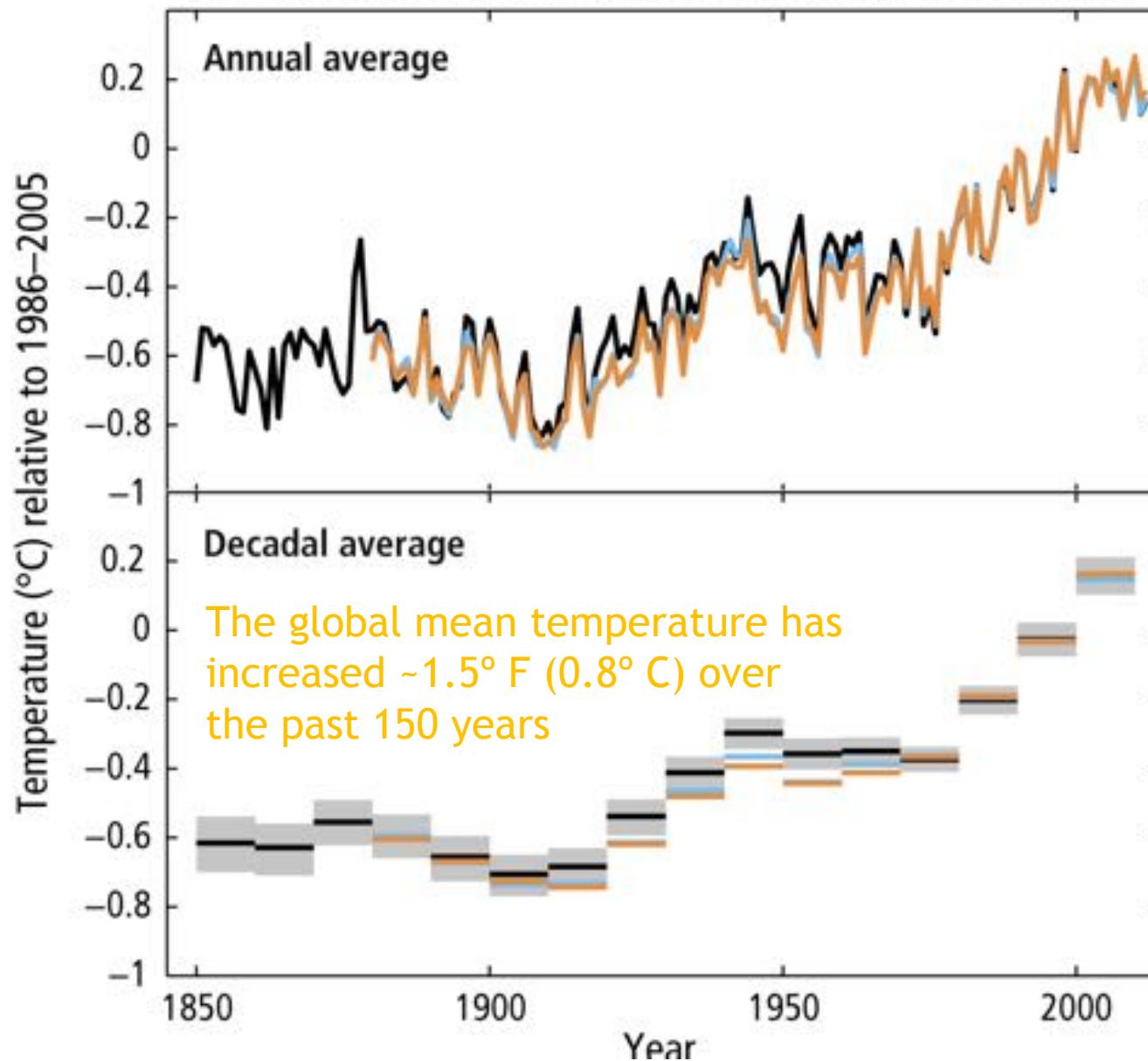


Poles and land
are warming
the fastest

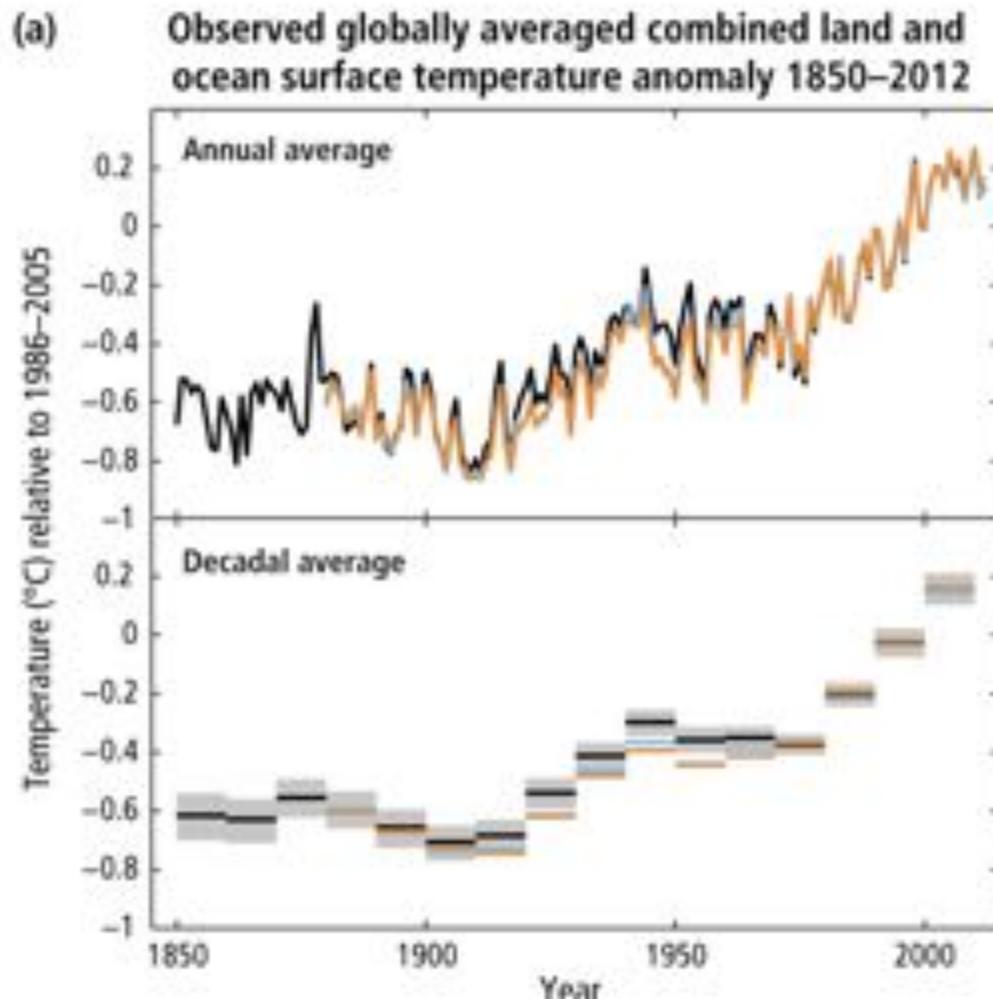
Temperature anomalies



(a) Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012

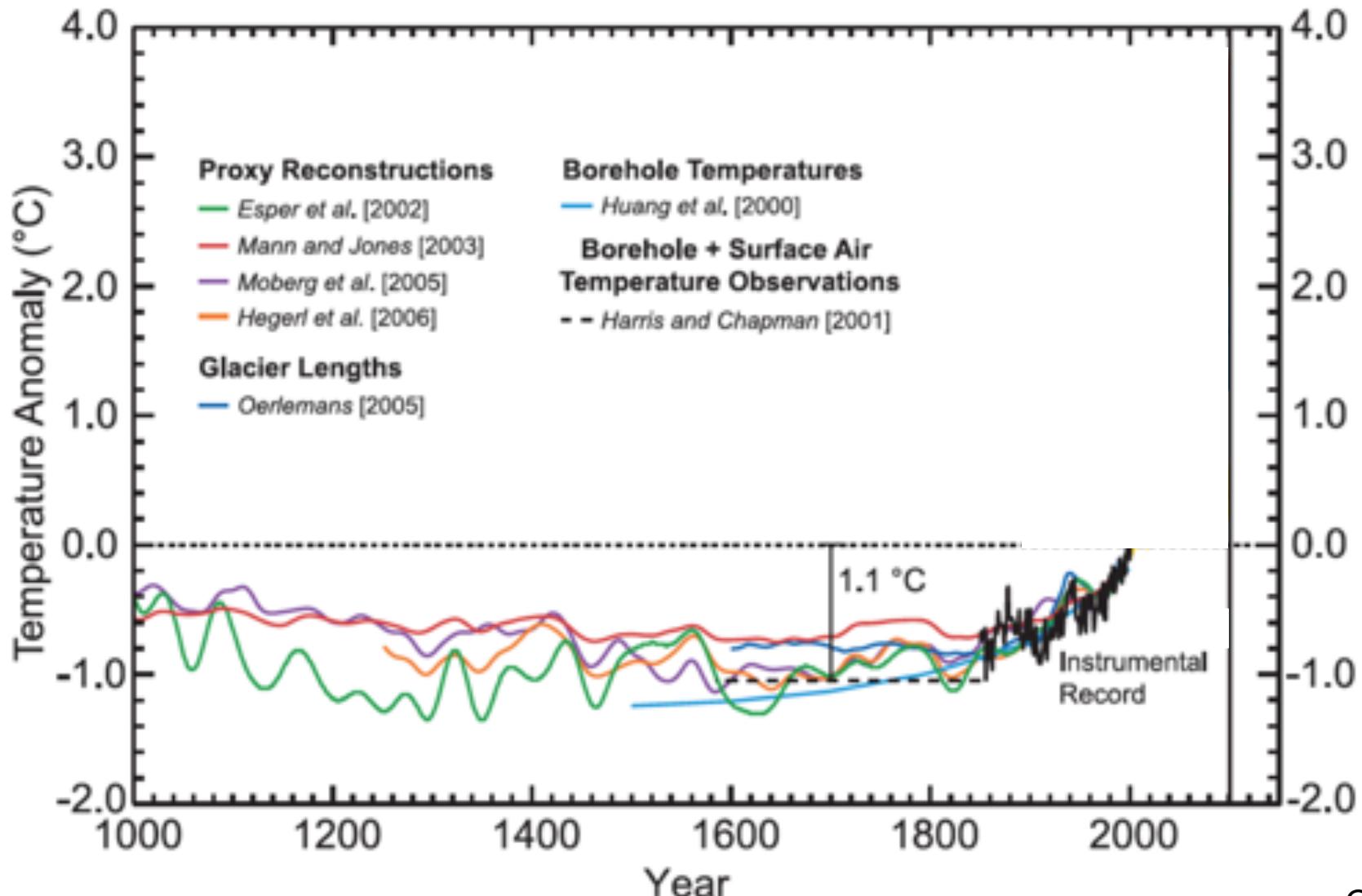


It's warmer now than 150 years ago

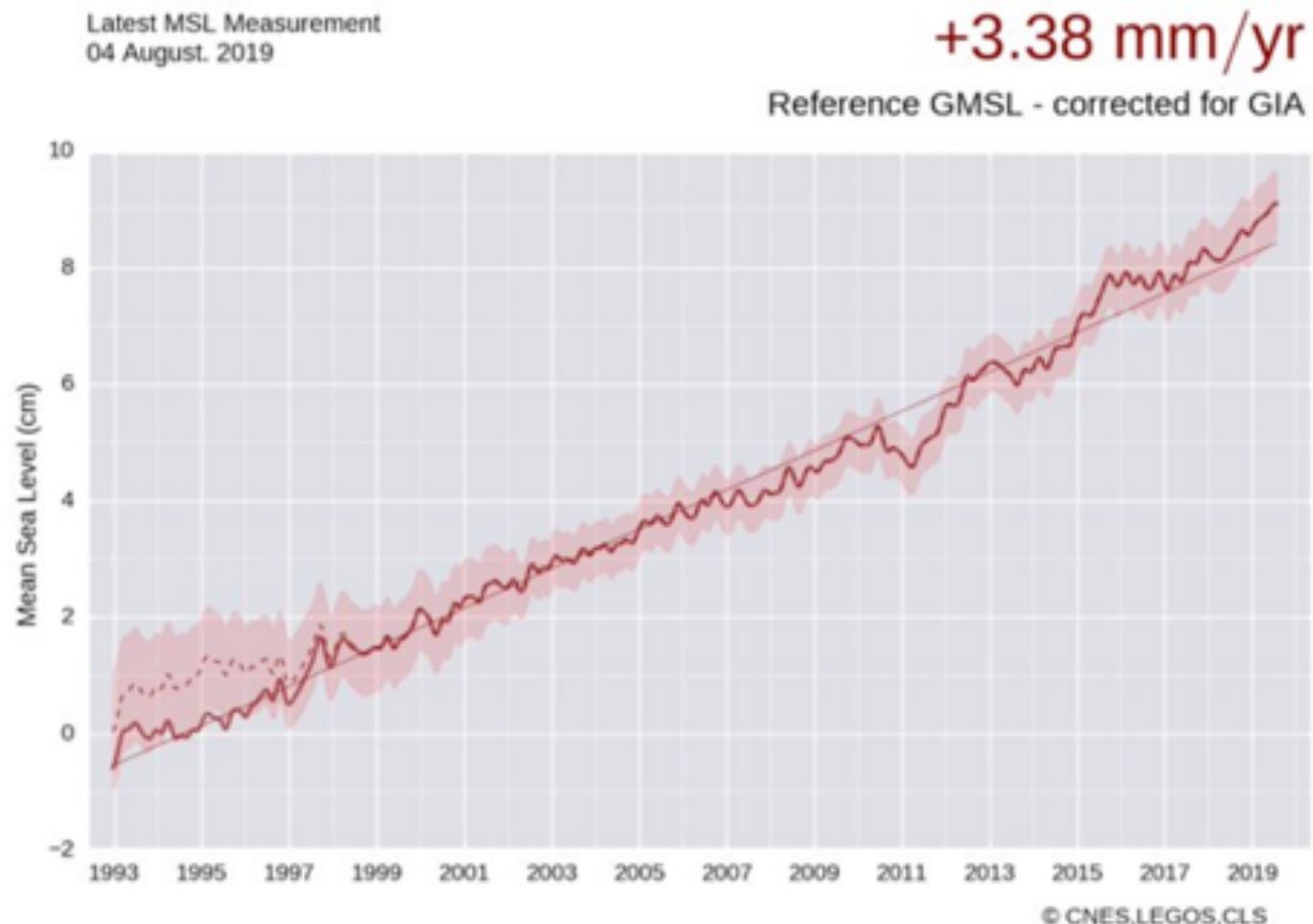


The global mean temperature has increased $\sim 1.5^{\circ}\text{ F}$ (0.8° C) over the past 150 years

And warmest it's been in the past 1000 years

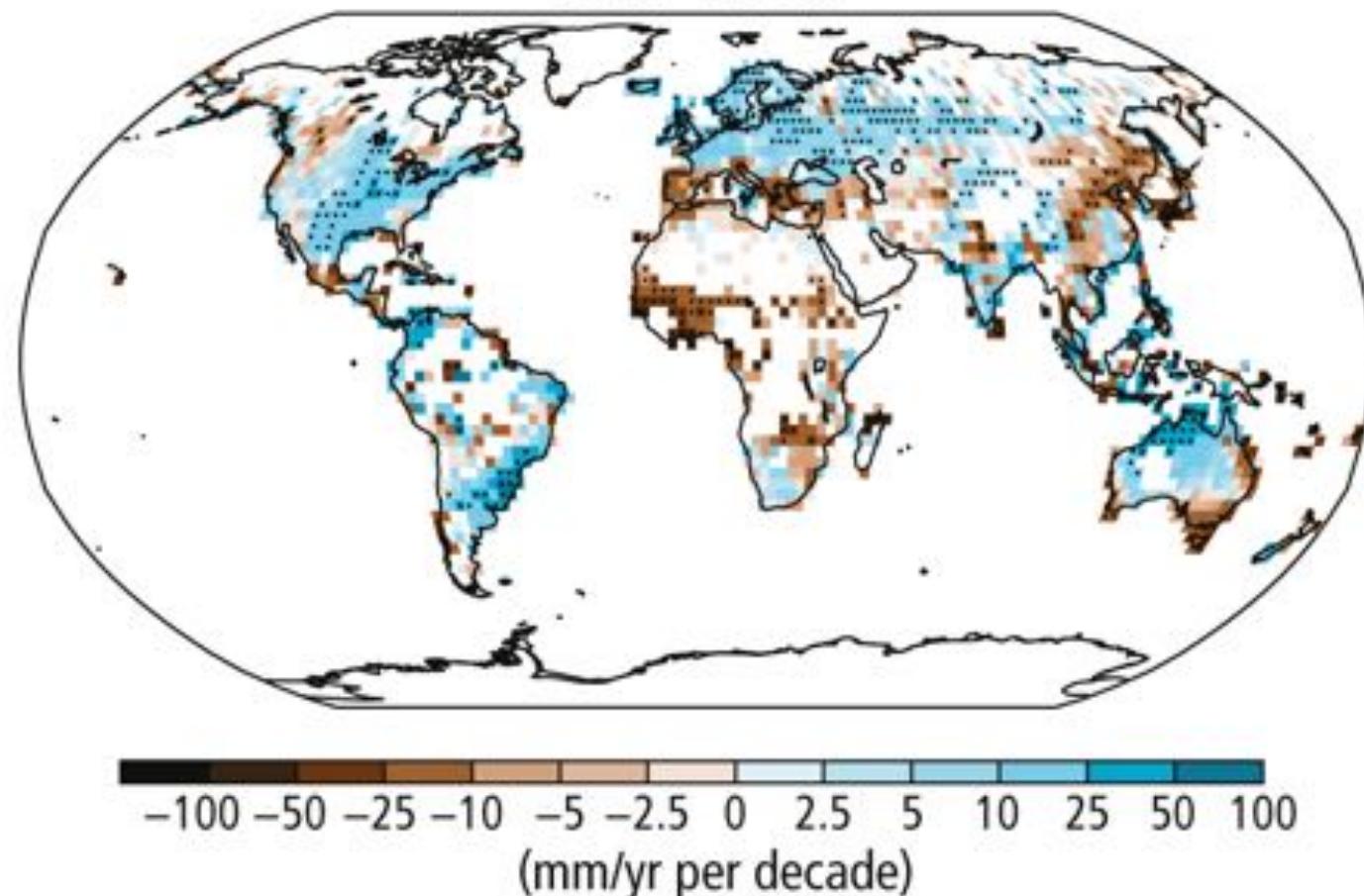


As a result sea levels are rising

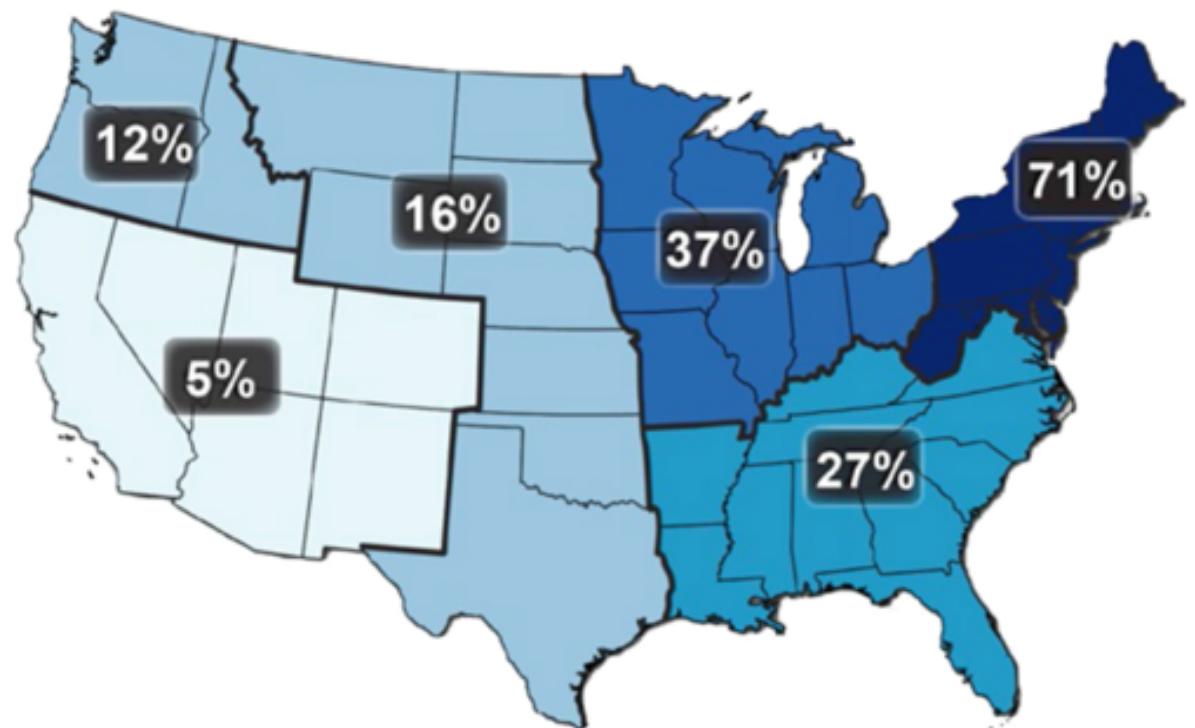
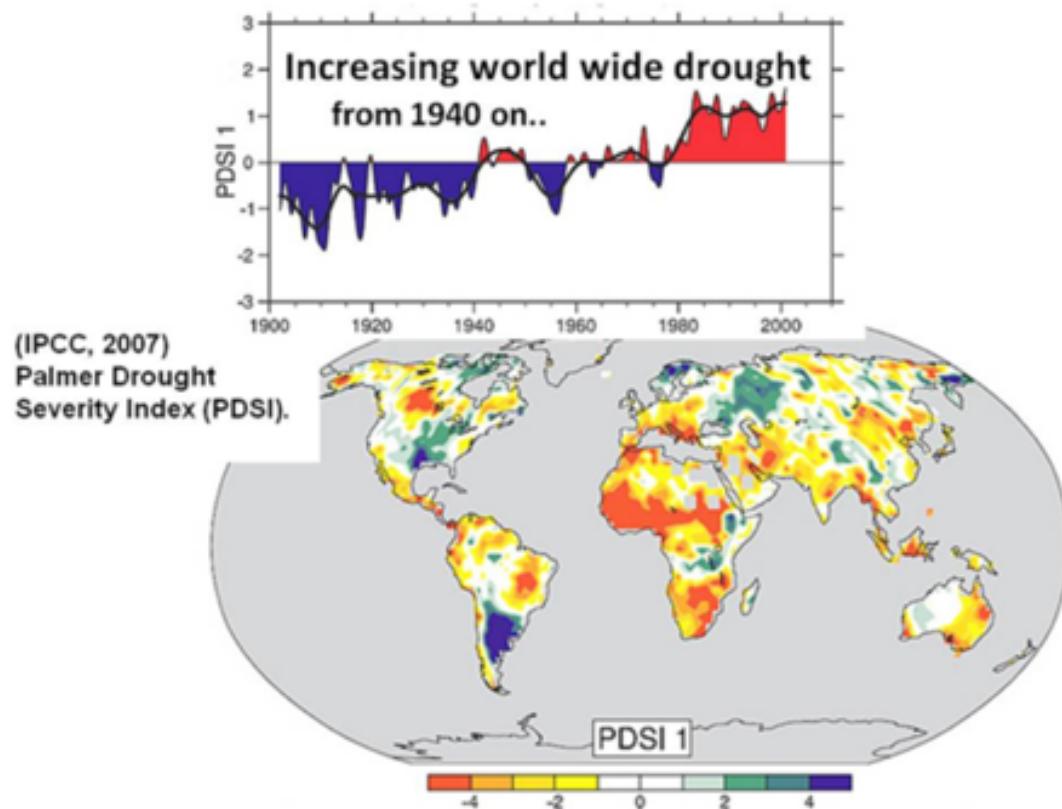


Global total precipitation is also changing

(e) Observed change in annual precipitation over land
1951–2010



As is precipitation variability

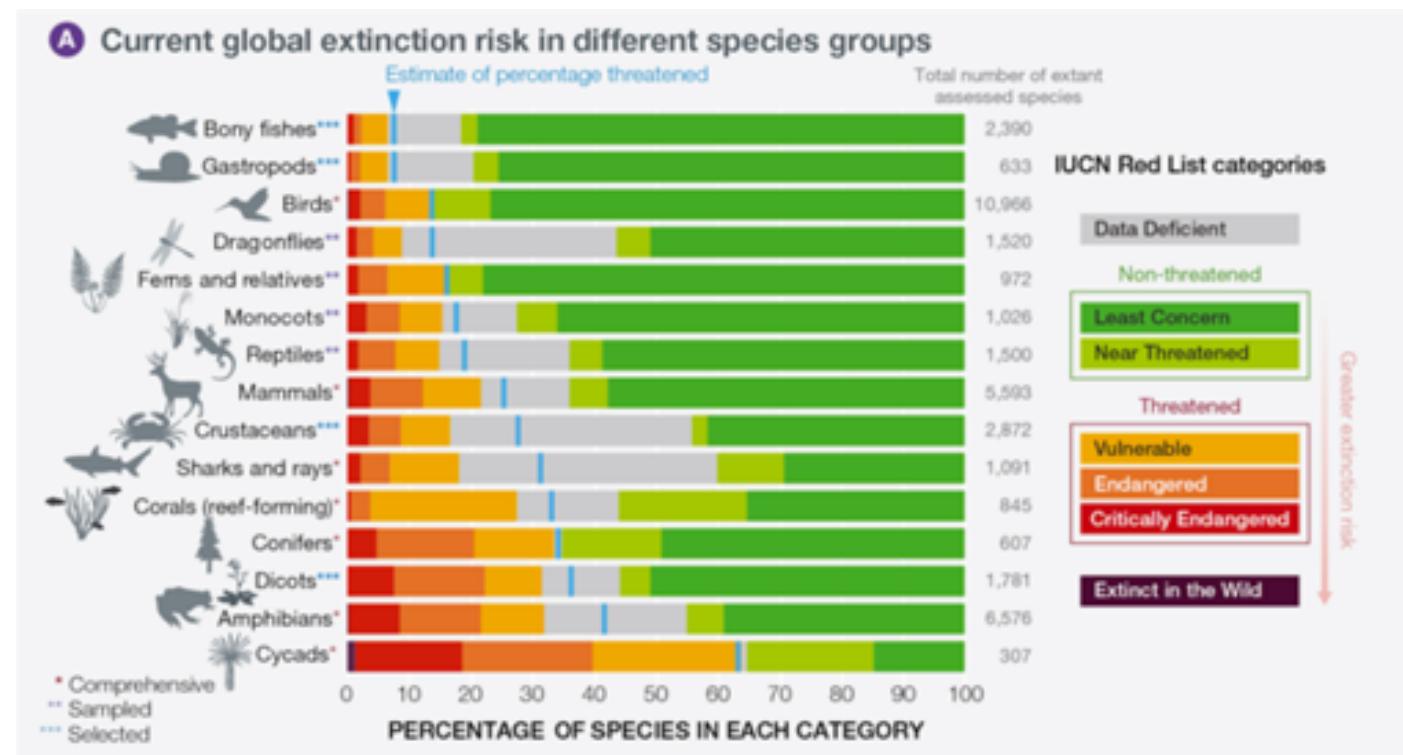


The Case for the Anthropocene

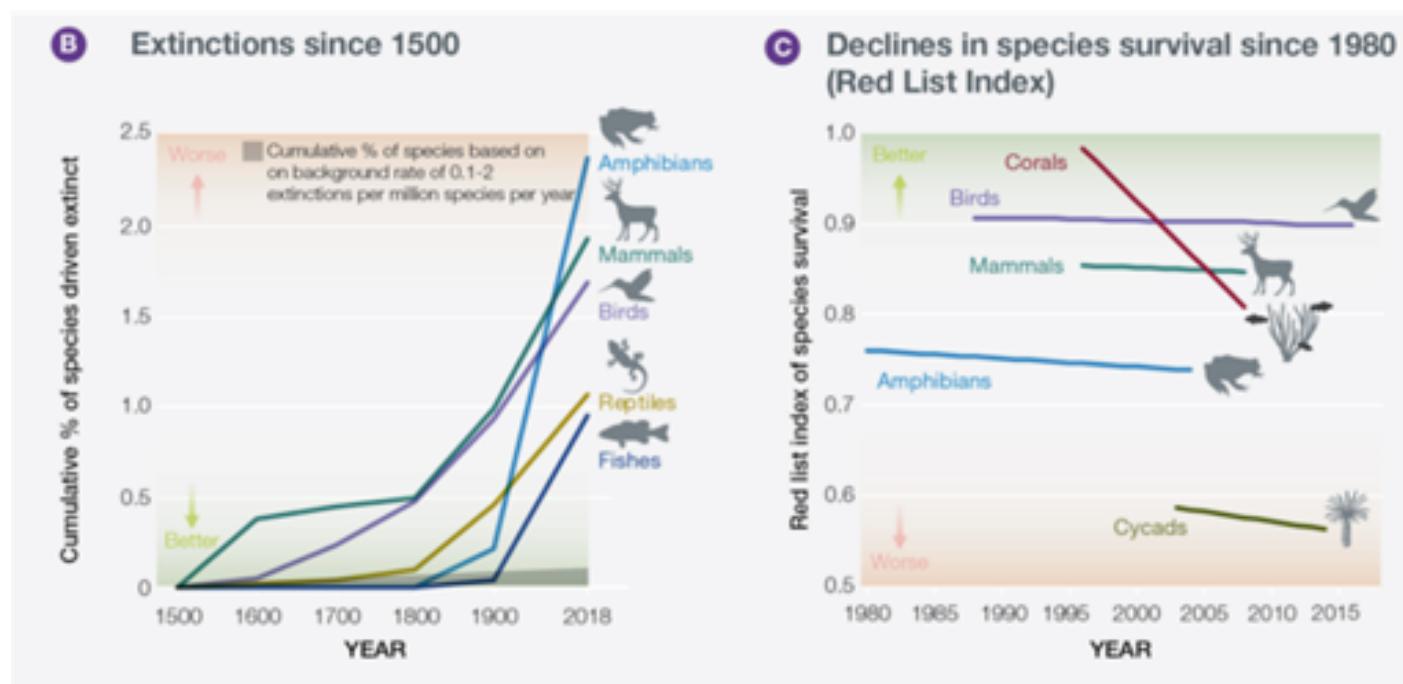
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Humans are threatening species of all types



And the threat is increasing



Species loss results from habitat loss

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2014) 23, 113–123

RESEARCH
PAPER



Extinction debt and the species-area relationship: a neutral perspective

John M. Halley^{1*}, Vasiliki Sgardeli¹ and Kostas A. Triantis^{2,3,4}

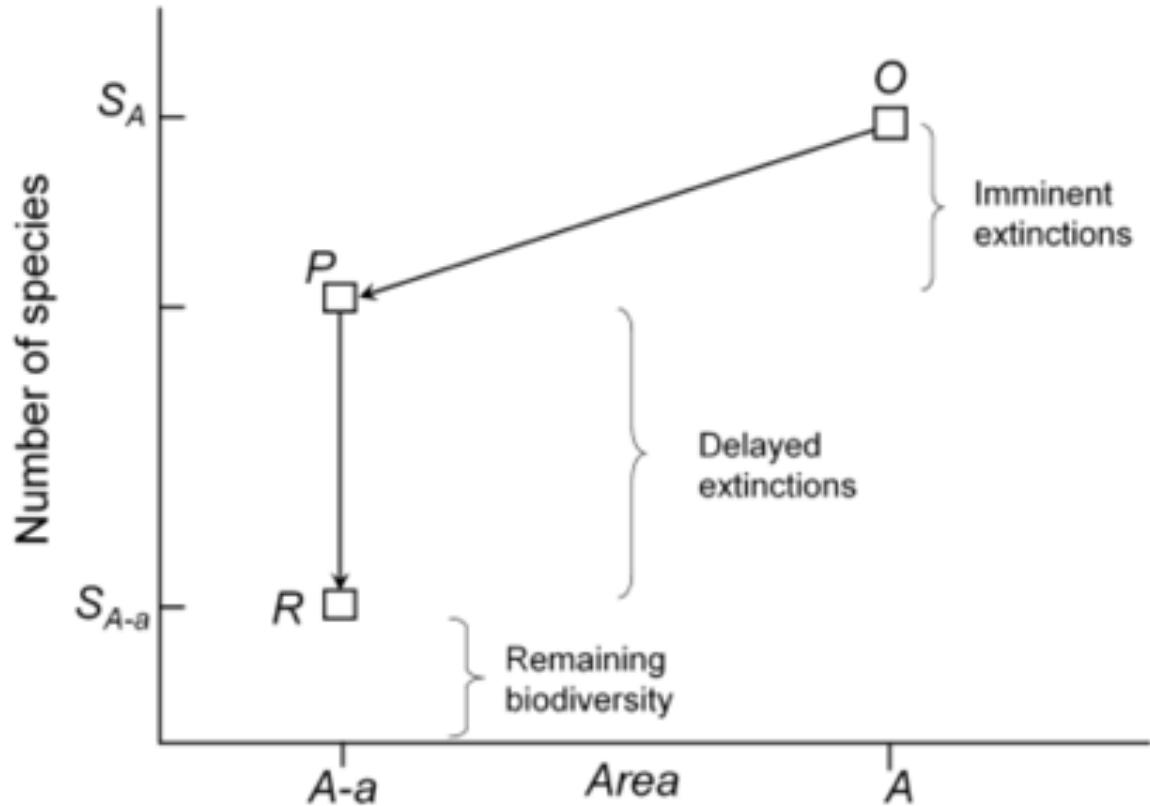


Figure 1 The phases of extinction following habitat loss. Initially the community of S_A species is in equilibrium (point O) in a habitat of area A . When habitat is lost, some extinctions happen immediately because there are species found only in the lost area (OP). More extinctions follow later due to increased isolation and smaller populations in the remaining area $A - a$. Eventually the community arrives at the new equilibrium (R) where local extinction and colonization are in balance (c.f. Rosenzweig, 2001). In this paper, although the path PR spans anything from a few years to millennia, we assume OP always to be rapid.

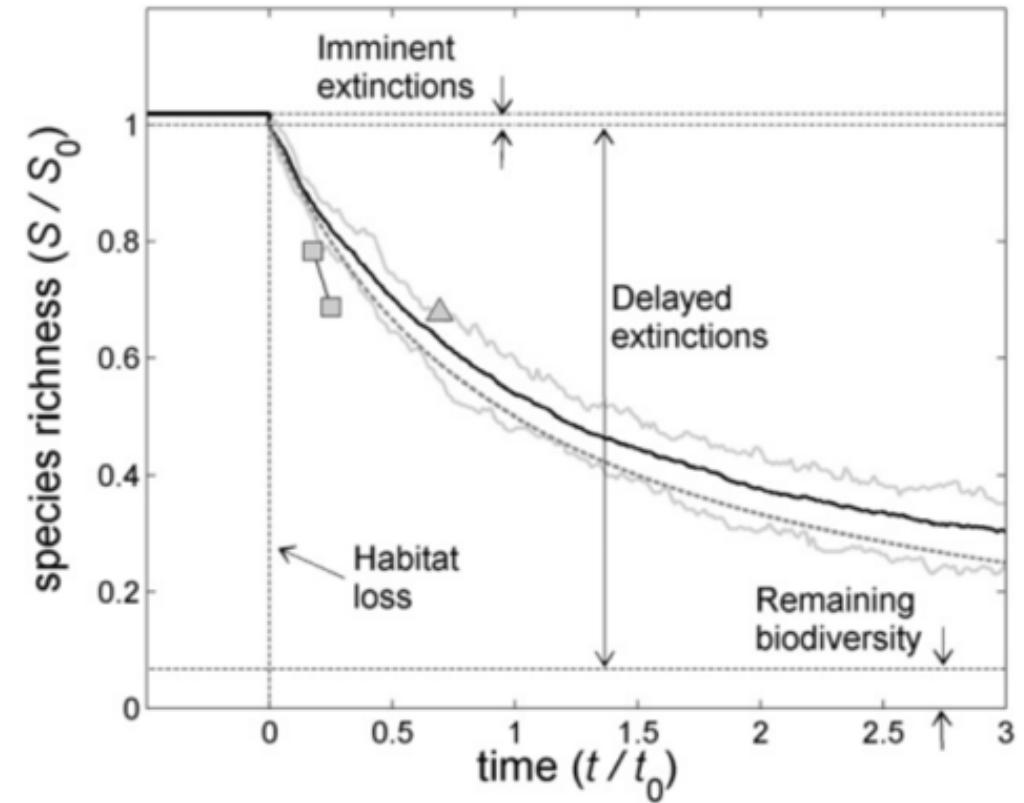
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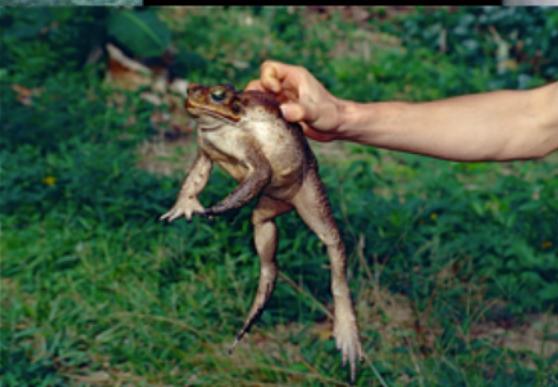


Extinction debt and the species-area relationship: a neutral perspective

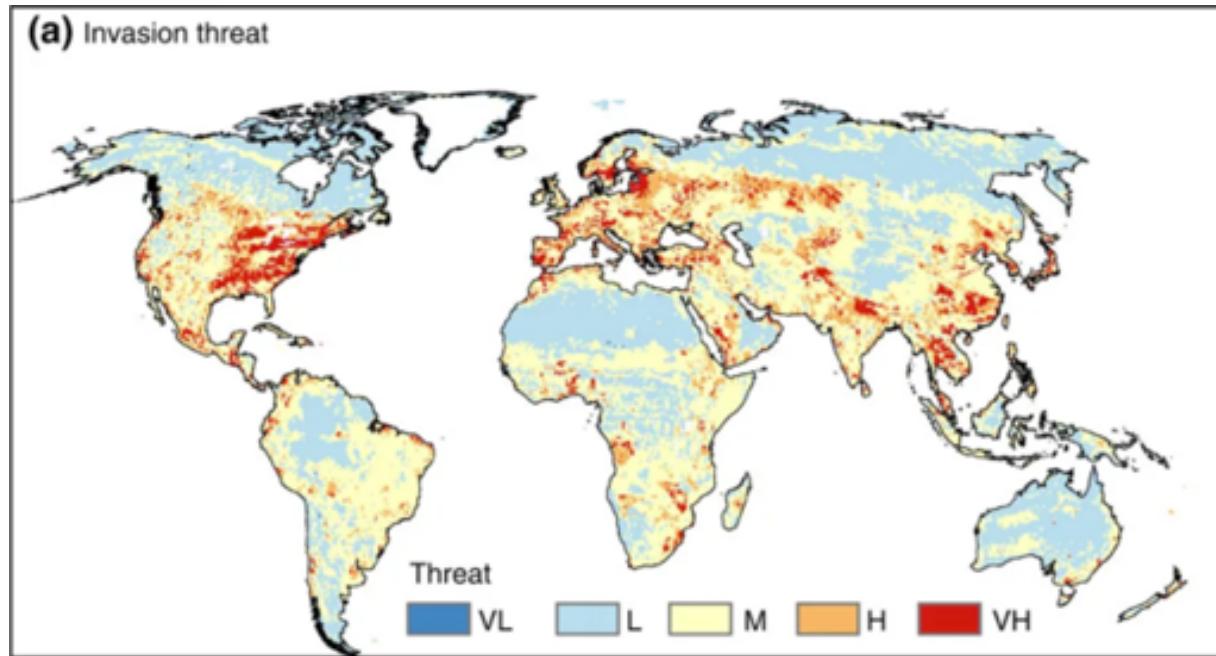
John M. Halley^{1*}, Vasiliki Sgardeli¹ and Kostas A. Triantis^{2,3,4}



Invasive species are spreading...

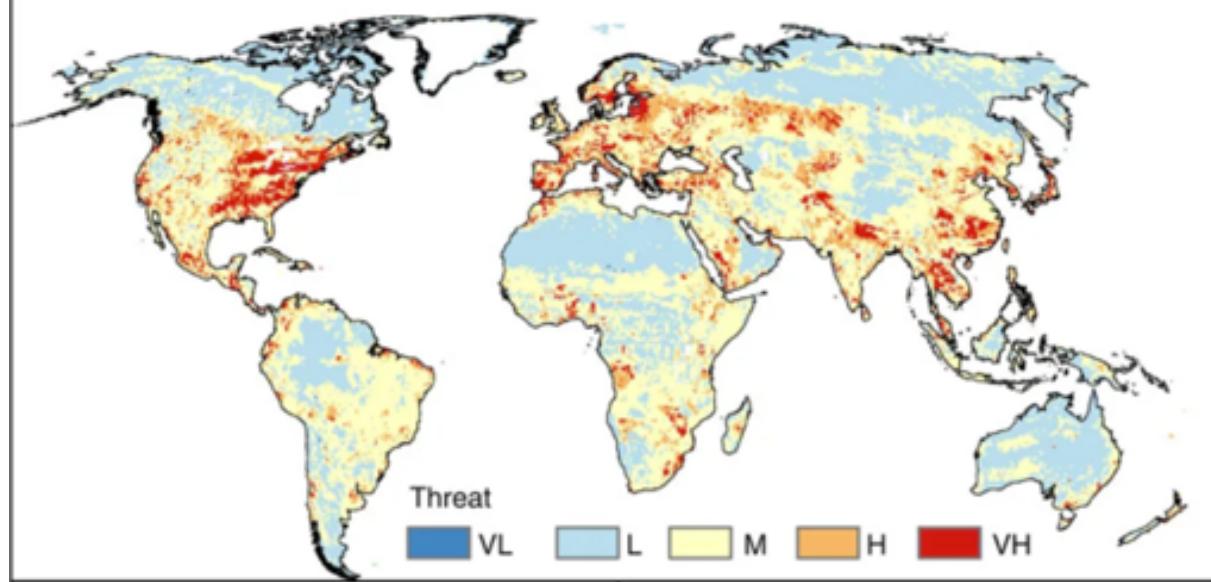


Invasives are a threat everywhere

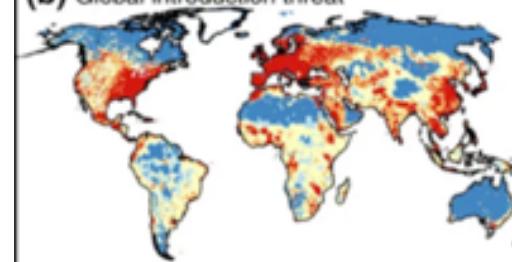


Why more of a threat some places than others?

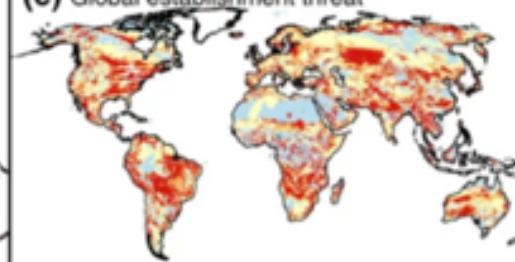
(a) Invasion threat



(b) Global introduction threat



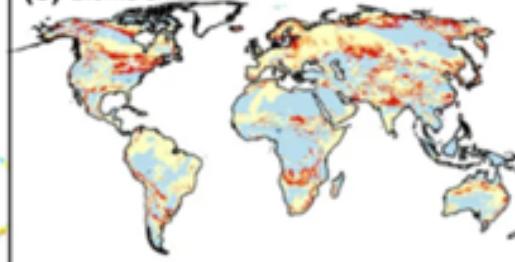
(c) Global establishment threat



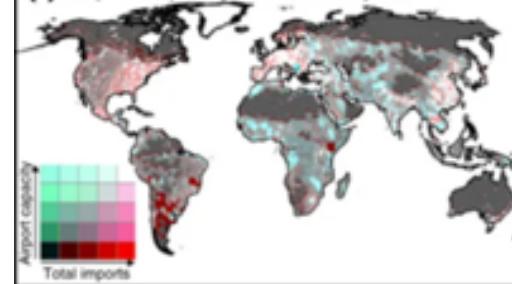
(d) Seaport capacity



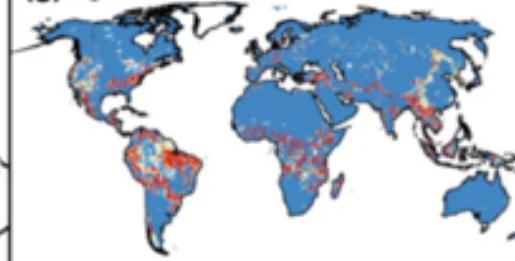
(e) Biome shift



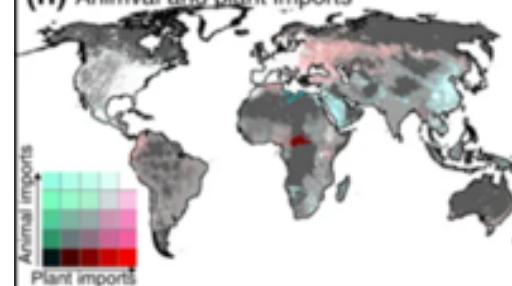
(f) Airport capacity and total imports



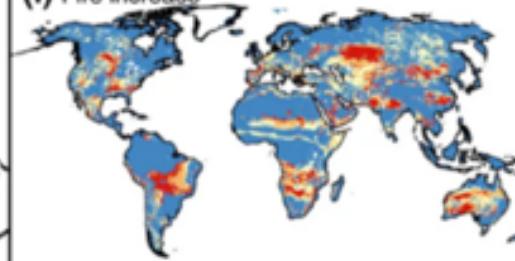
(g) Agricultural increase



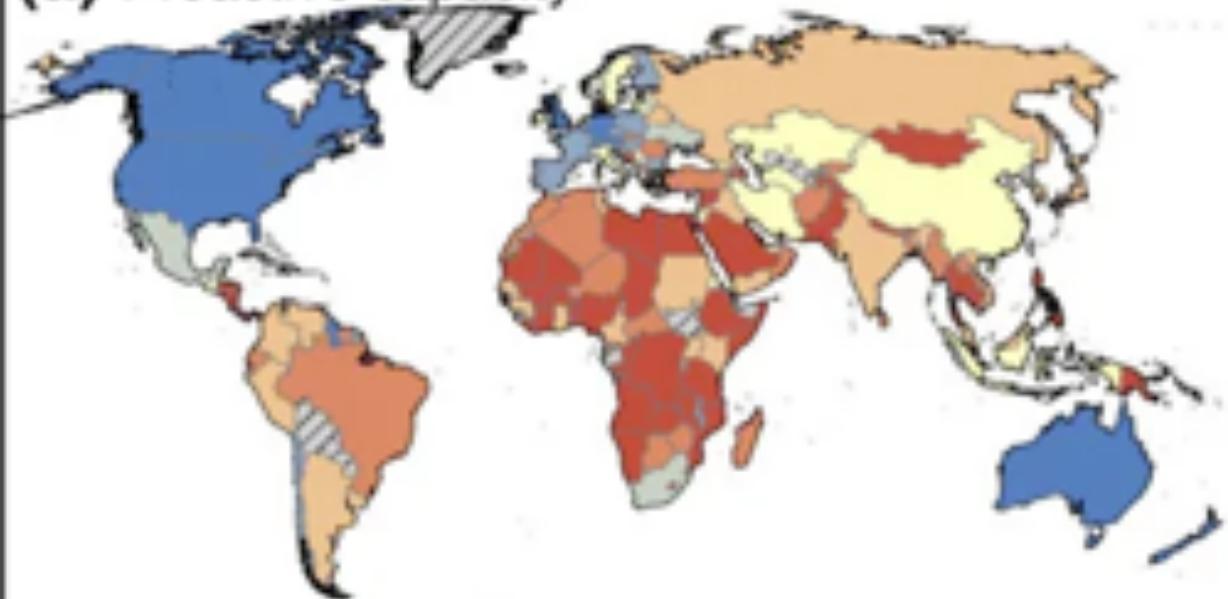
(h) Animal and plant imports



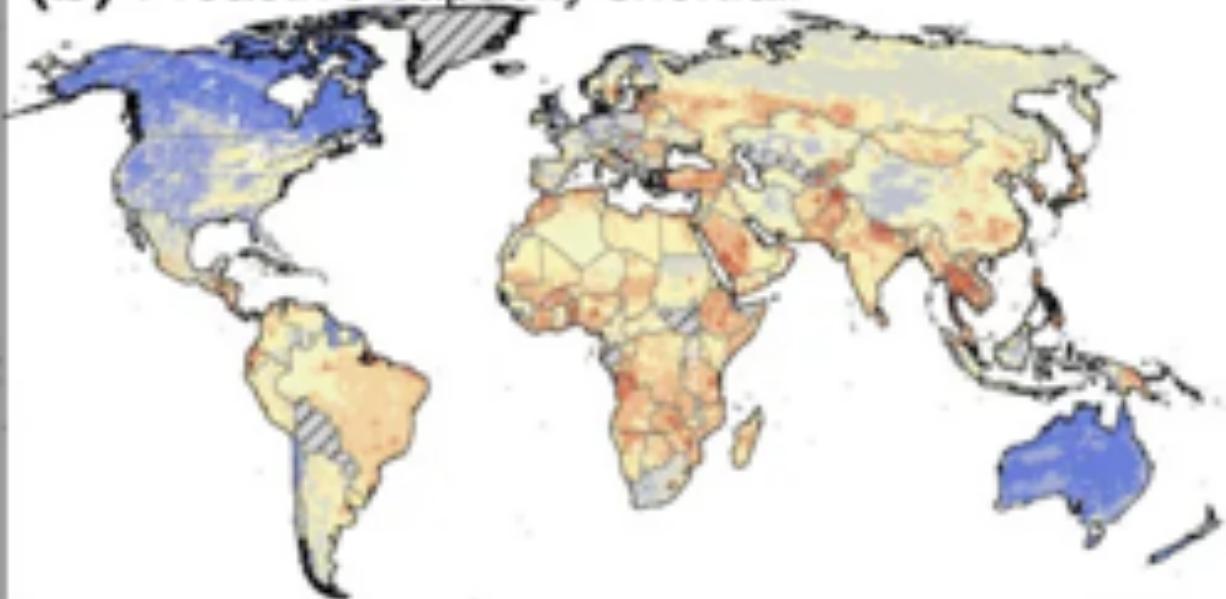
(i) Fire increase



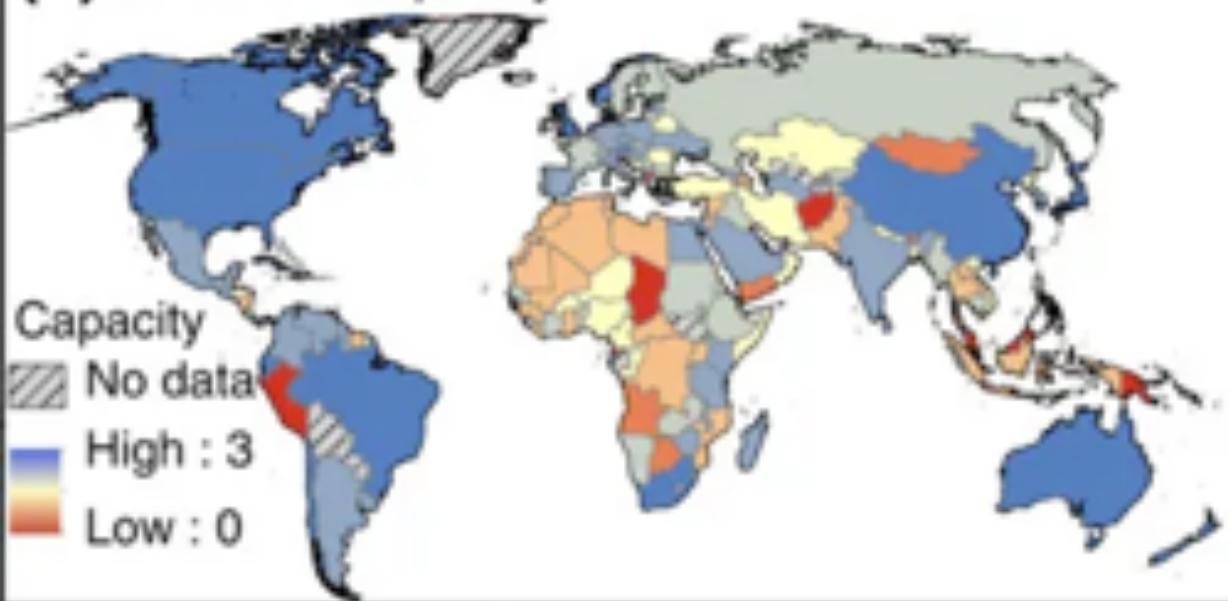
(a) Proactive capacity



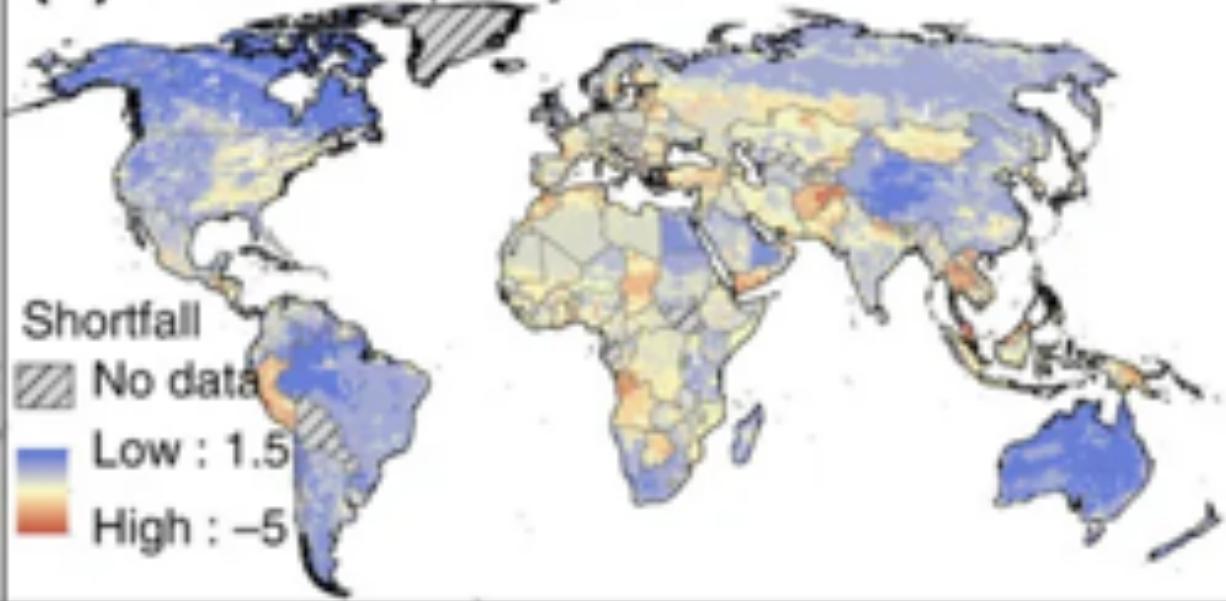
(b) Proactive capacity shortfall



(c) Reactive capacity



(d) Reactive capacity shortfall



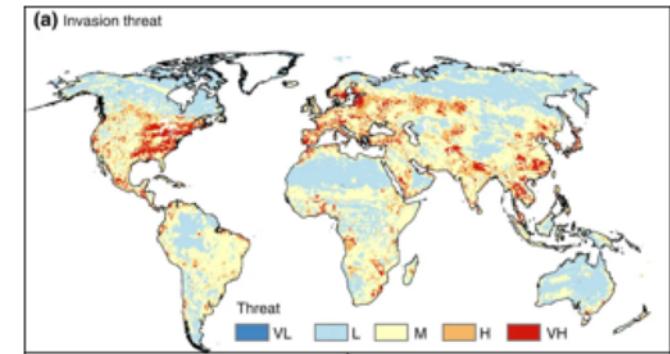
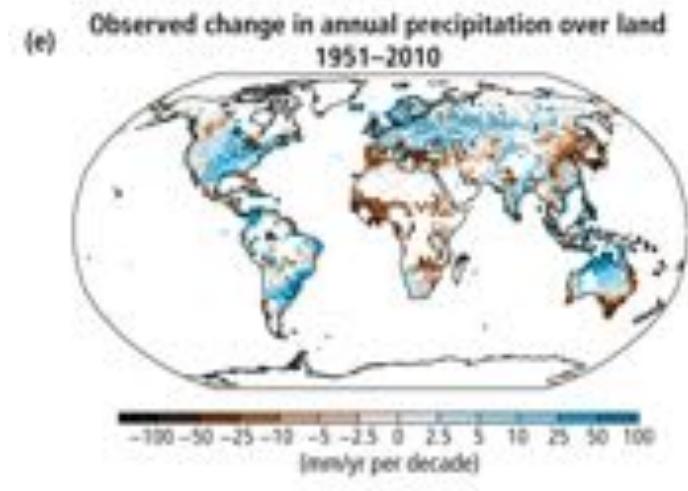
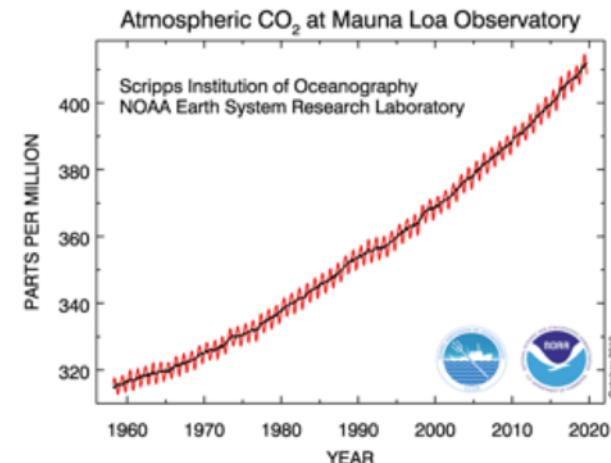
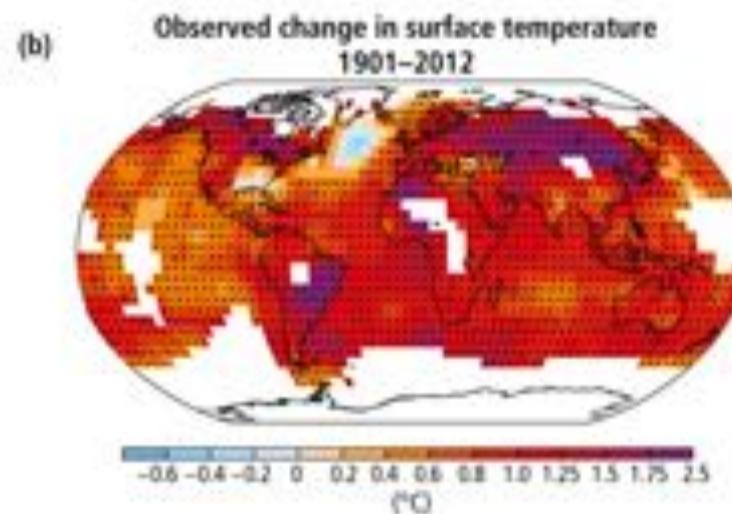
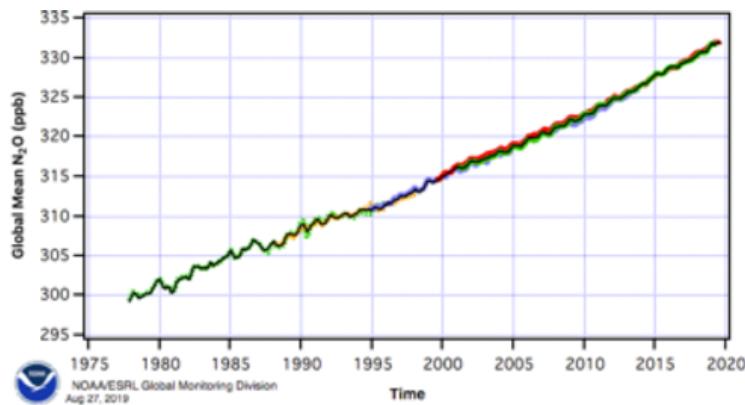
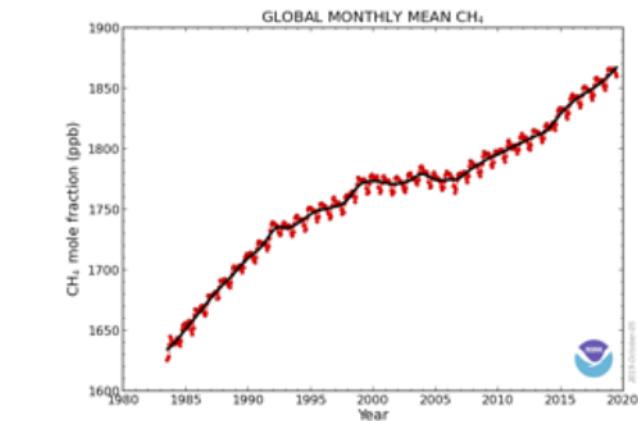
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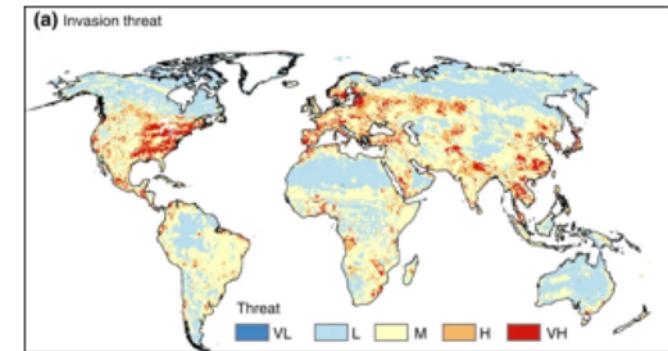
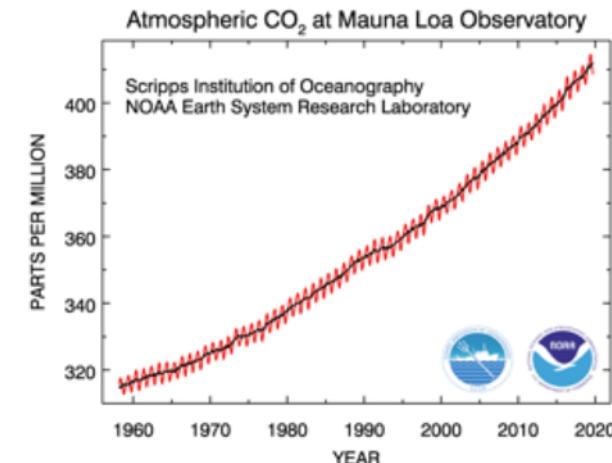
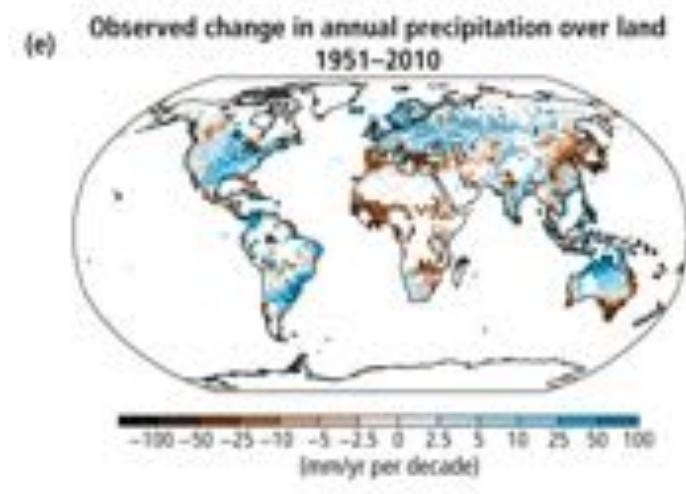
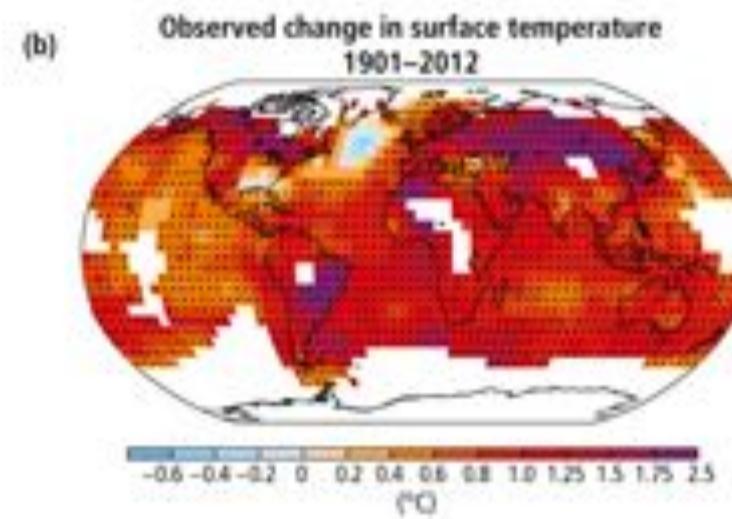
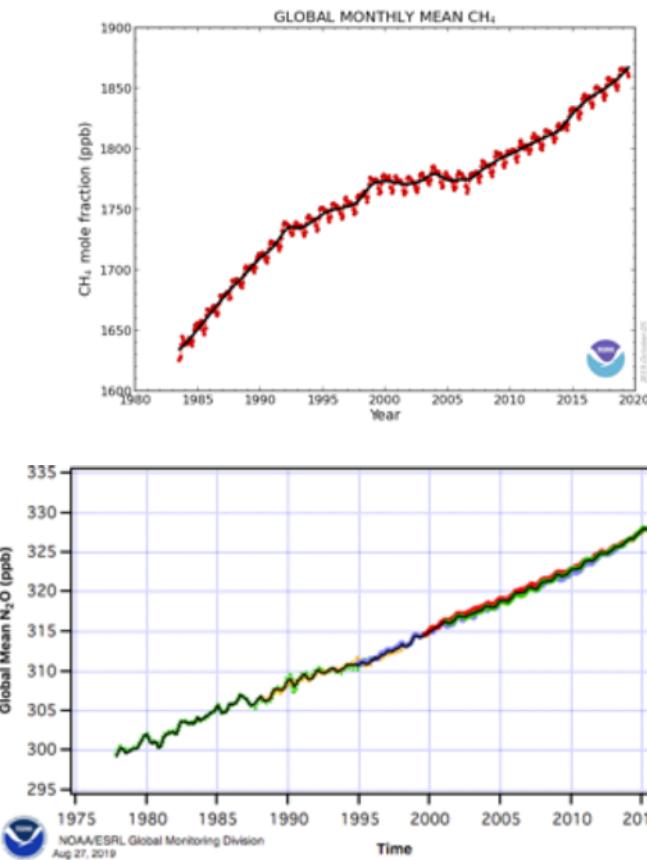
The Case for the Anthropocene

Do you buy it?



The Case for the Anthropocene

Does it matter?



Class activity (in pairs)

1. Pick an ecosystem service provided by West Texas ecosystems

1. Food
2. Fiber
3. Pollination
4. Water purity
5. Air purity
6. Energy
7. Climate regulation
8. Pest & disease control
9. Culture
10. History
11. Spiritual services
12. Recreation
13. Science Education
14. Therapy

2. Use a systems diagram to indicate how it will be impacted by global change

