

Planetary Boundaries: A stable operating space for humanity

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Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems



Stockholm
University

A centre with:



Outline

- Beyond climate change: Forging into the Anthropocene
- Consequences of global environmental change
- It's all connected
- Planetary boundaries
- Implications for sustainable development



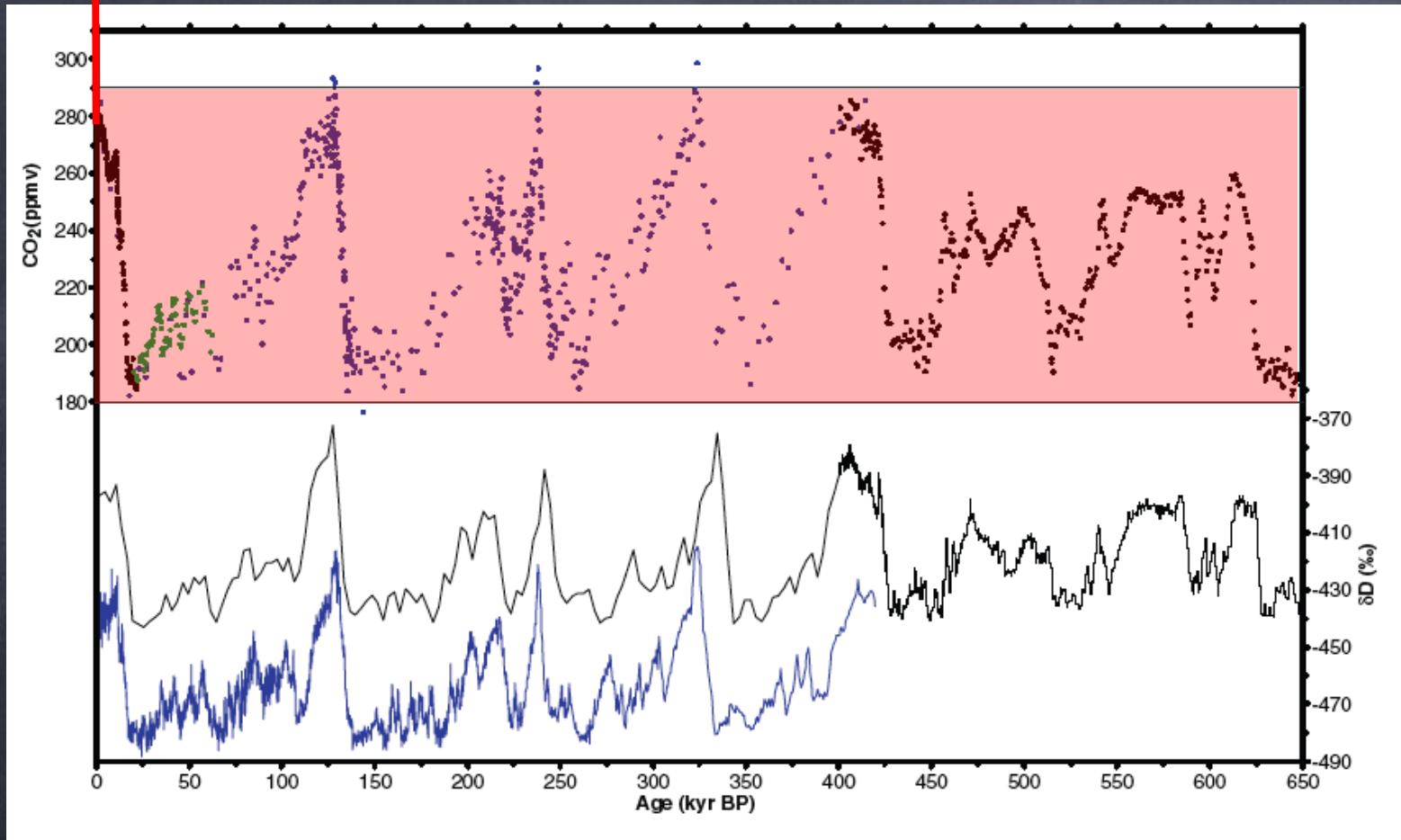
Forging into the Anthropocene

We have moved well outside the envelope of our historical experience in terms of our relationship with our planet



380

A look back in time - CO₂



A temperature and CO₂ record 650 000 years back in time



Dome C

Siegenthaler, et al., Science 310, 25 Nov. 2005

A few facts to gain some perspective...

Annual value of global agricultural production	\$1.3 trillion
Percentage of global agricultural lands showing soil degradation	65%
Population directly dependent on forests for survival	350 million
Decline in global forest cover since pre-agricultural times	50%
Population dependent primarily on fish for protein	1 billion
Percentage of global fisheries over-fished or fished at their biological limit	75%
Percentage of world population living in water-stressed river basins	41%
Percentage of normal global river flow extracted for human use	20%
Percentage of major river basins strongly or moderately fragmented by dams	60%
Percentage of Earth's total biological productivity diverted to human use	40-50%

Human influence seen from space

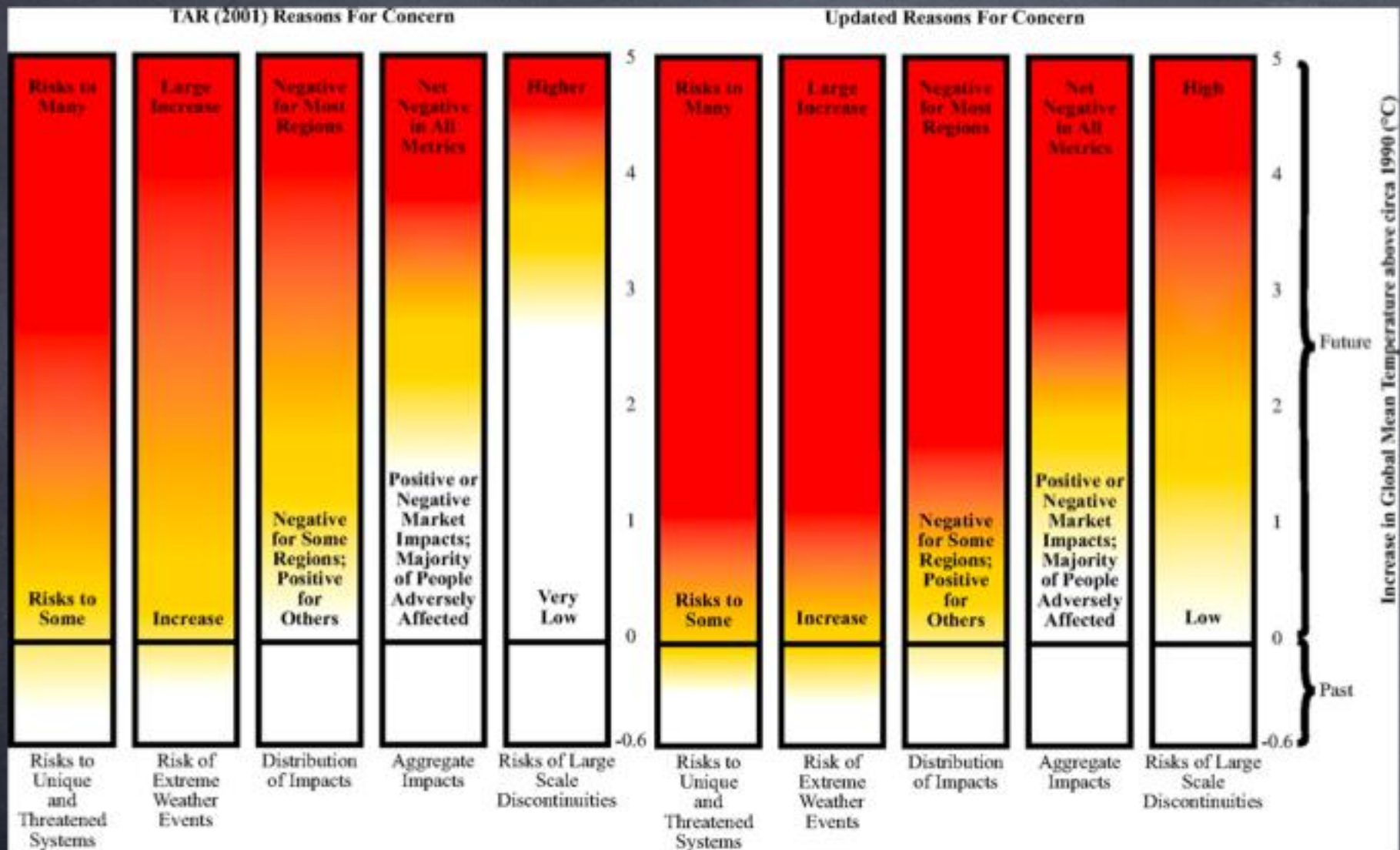


<http://visibleearth.nasa.gov>

Consequences of change



Impacts



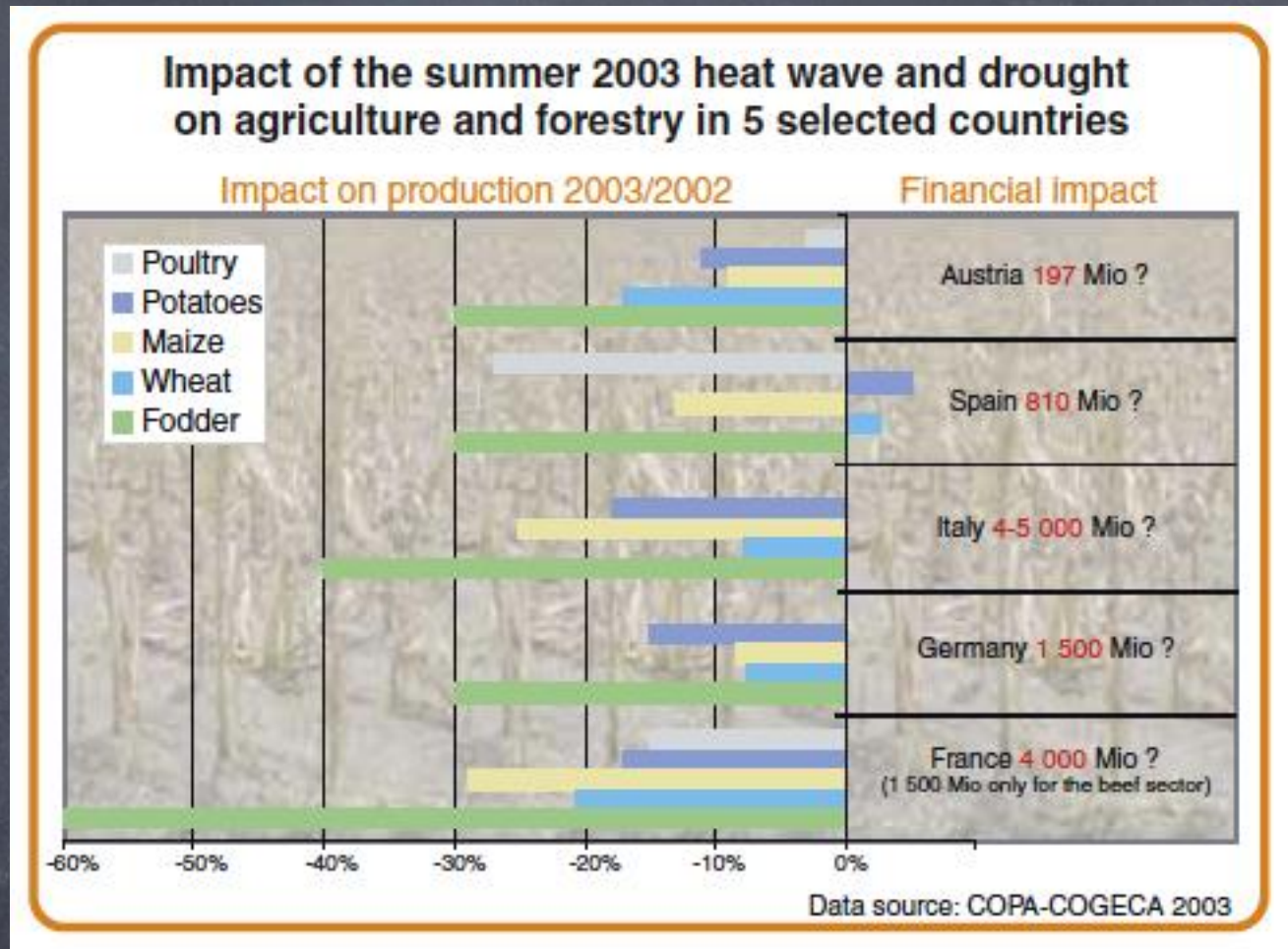
Smith, J. B., et al., 2009: Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern". Proceedings of the National Academy of Sciences, 106, 4133-4137.

The steamy summer of 2003

Country	Casualties
France	14 082
Germany	7 000
Spain	4 200
Italy	4 000
UK	2 045
Netherlands	1 400
Portugal	1 300
Belgium	150

INSERM: "Surmortalité liée à la canicule de l'été 2003", AP September 25, 2003

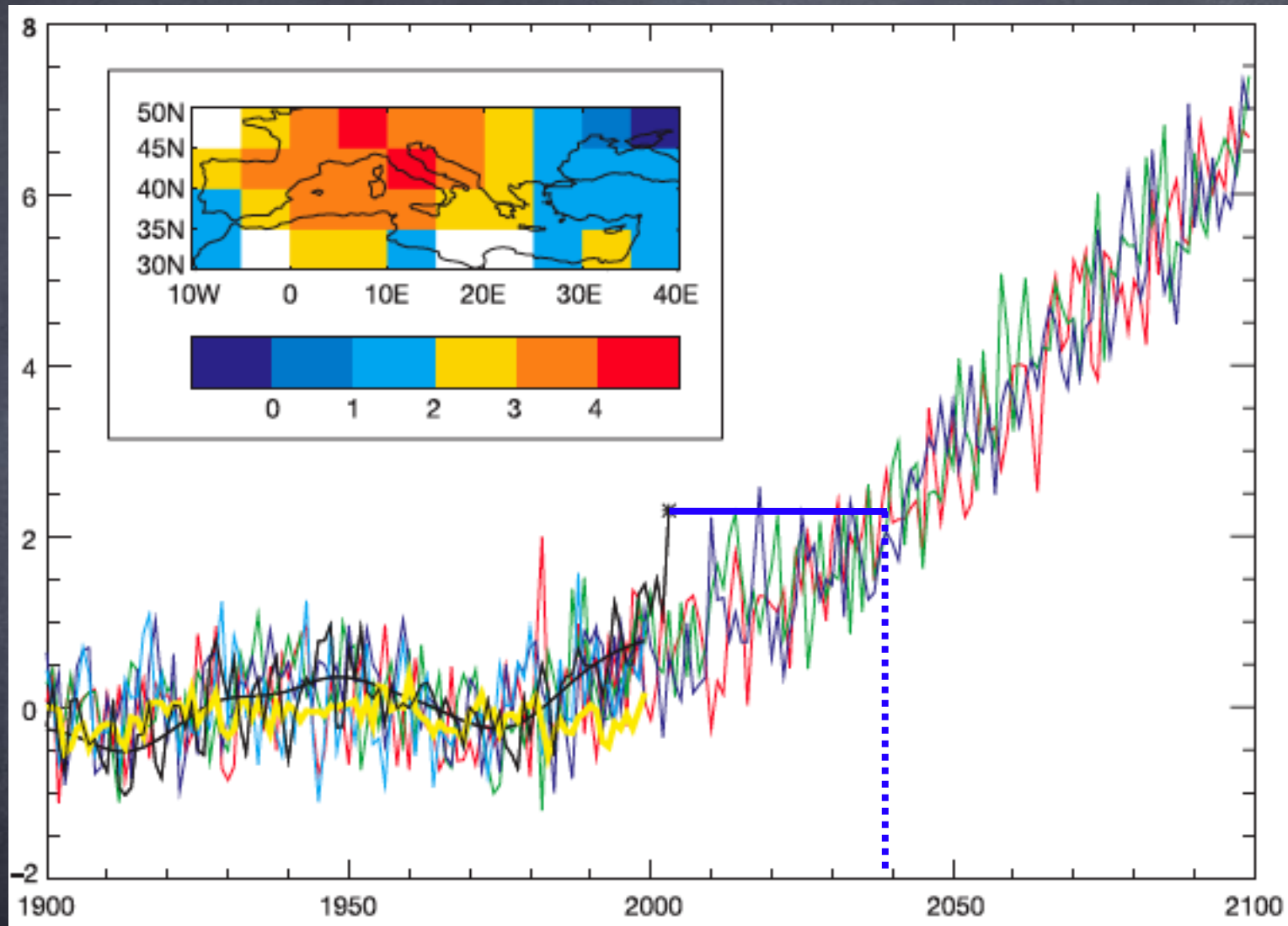
Casualties



Economic effects

Unusual or normal?

Temperature Anomaly (K)



Source: Stott et al. Nature 432, 610-614, 2004

“Extreme” weather

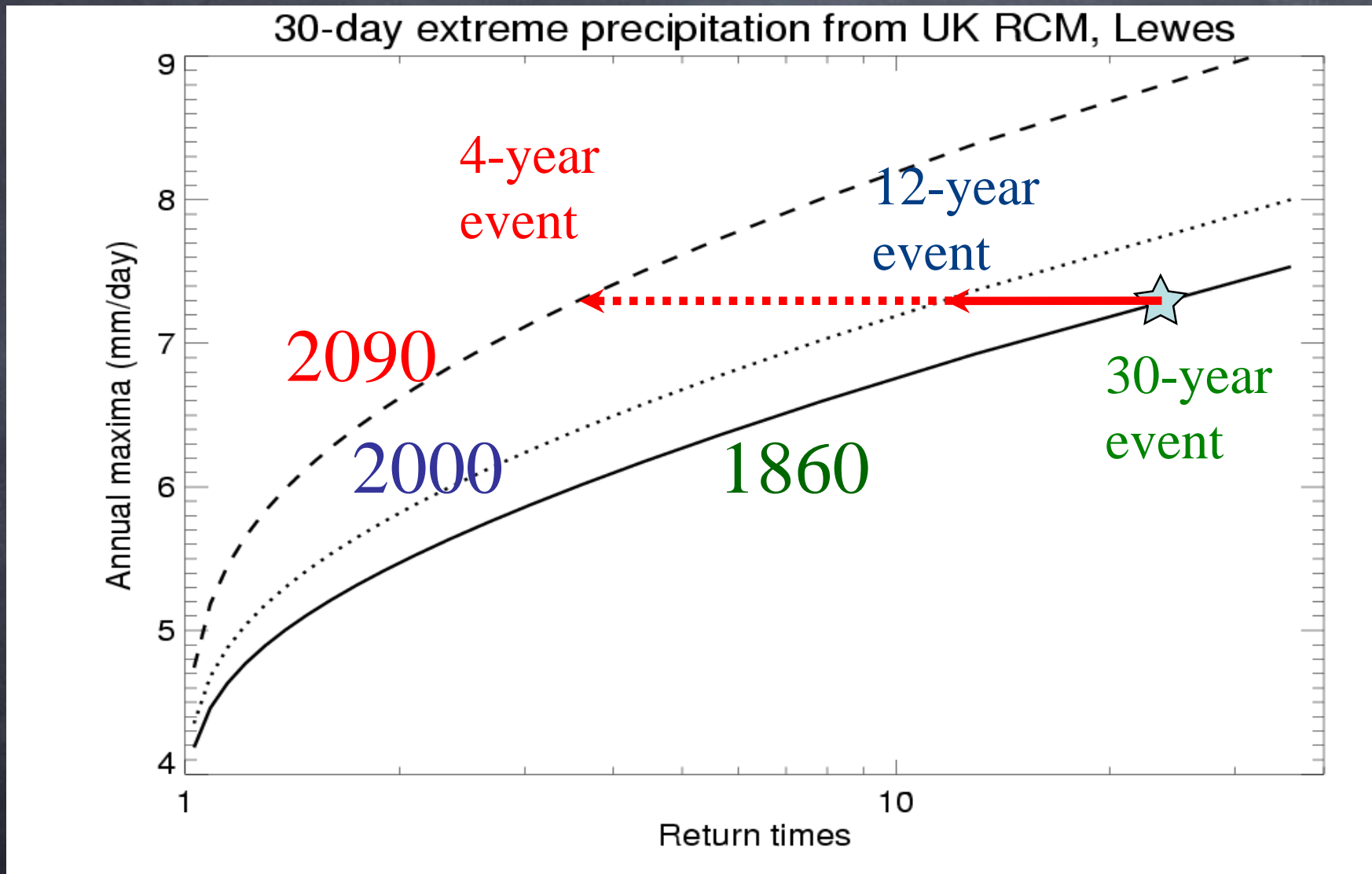


Wroclaw, Poland, 1997



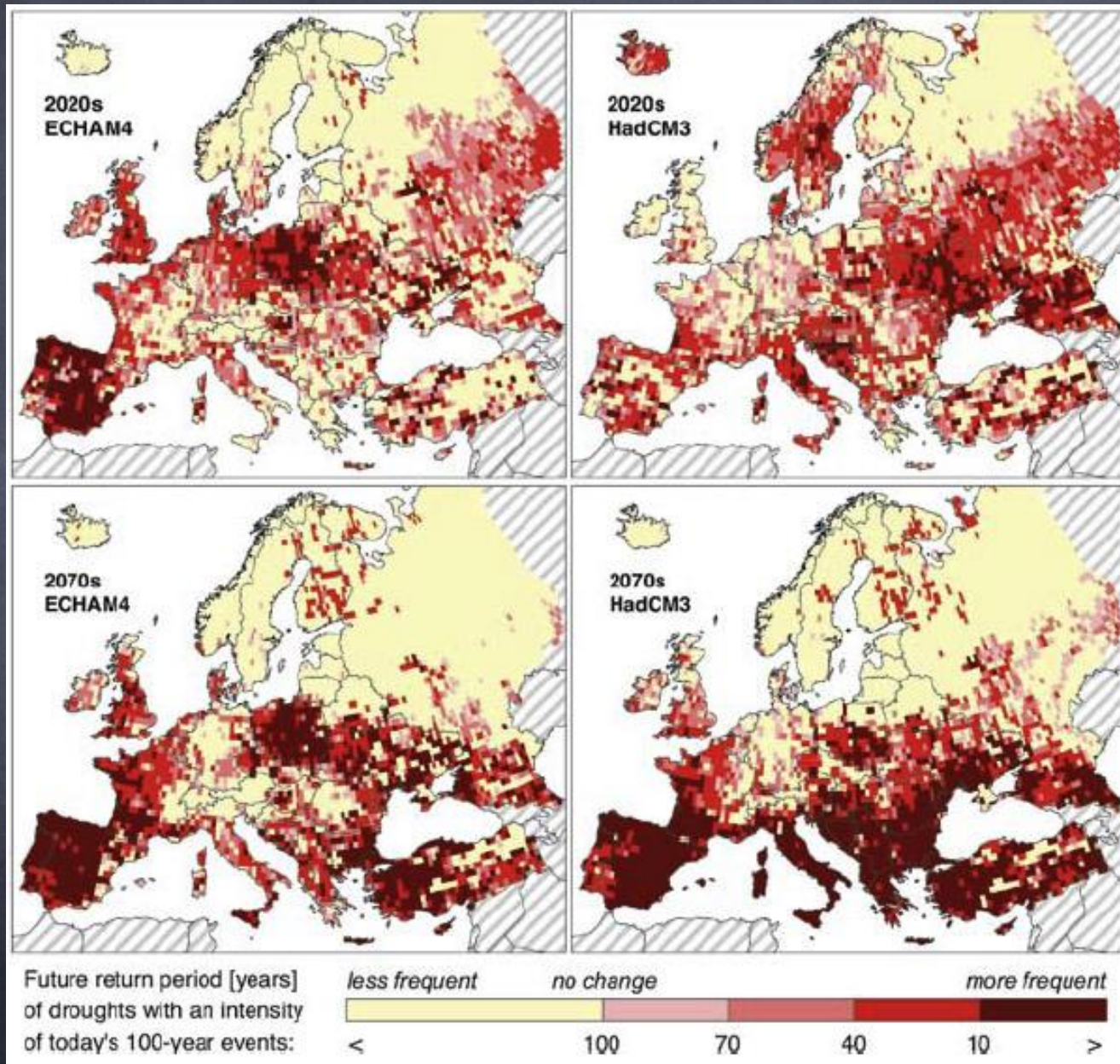
UK

Flooding in the UK

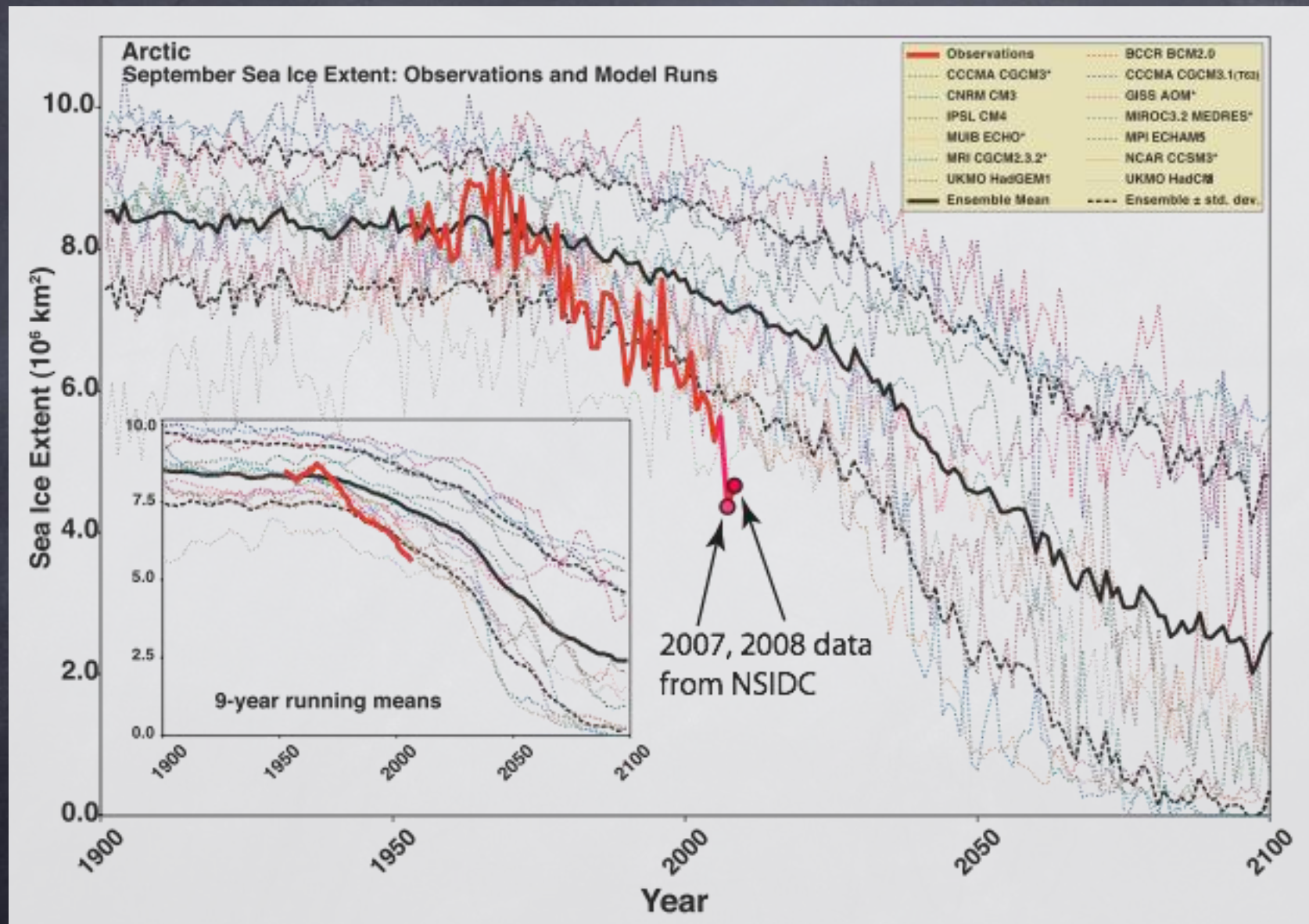


Source: Allen & Kabat, EuroScience Open Forum, 2004

More frequent droughts

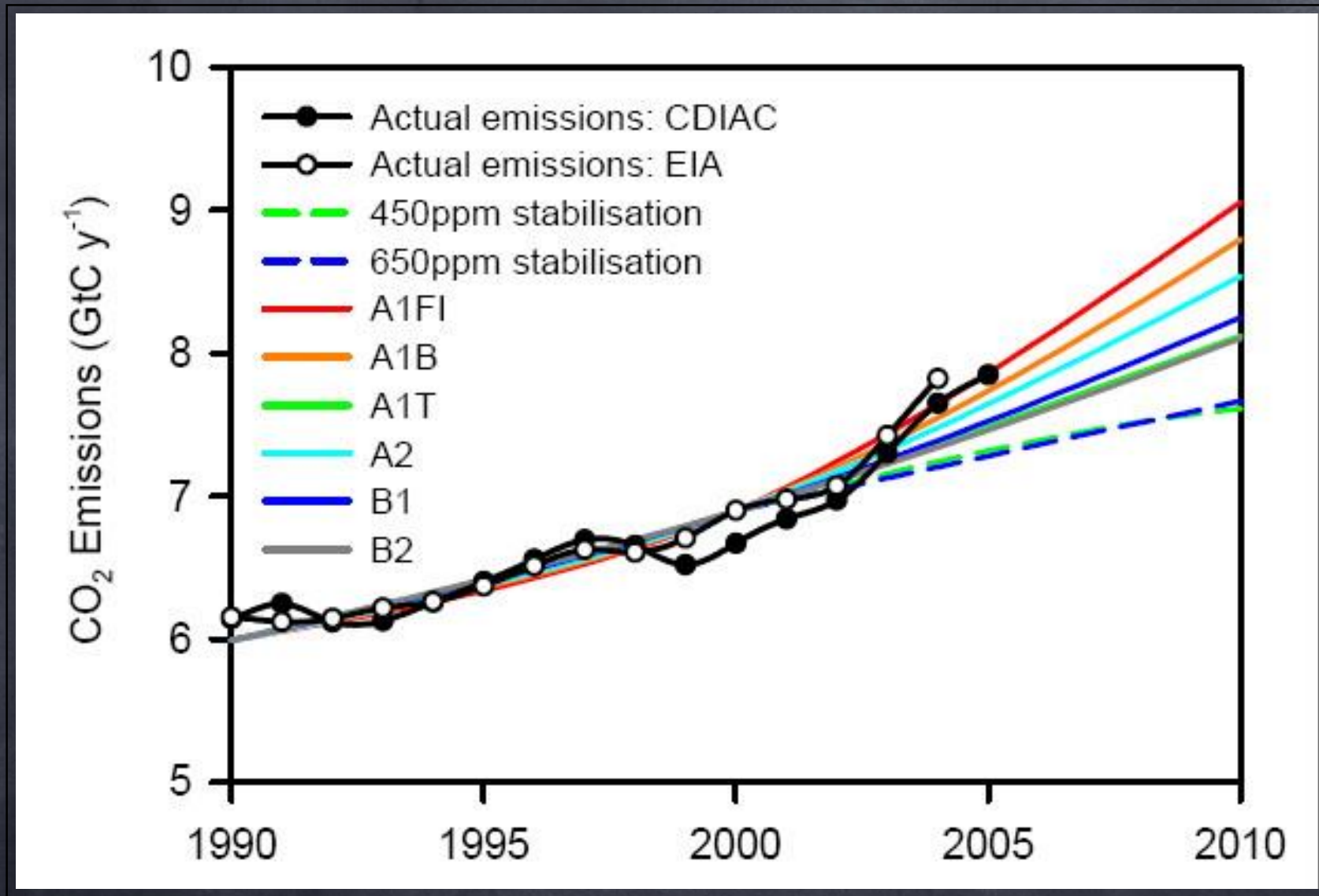


Surprise: Arctic sea ice



Stroeve, J., Holland, M.M., Meier, W., Scambos, T. and Serreze, M., 2007. Arctic sea ice decline: Faster than forecast. *Geophys. Res. Lett.*, 34: L09501.

Where are we heading?

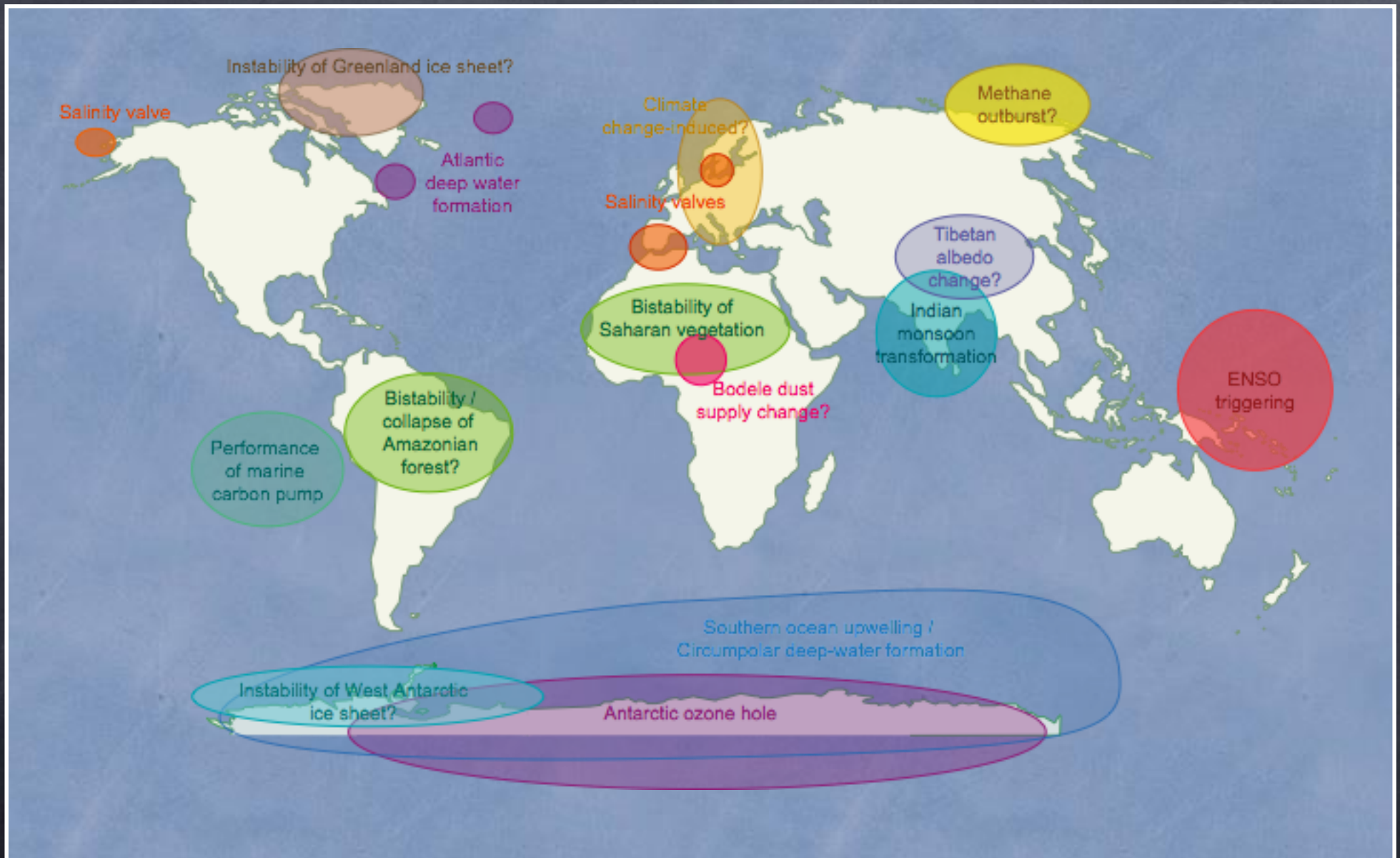


Raupach, M. R., G. Marland, P. Ciais, C. Le Quéré, J. G. Canadell, G. Klepper, and C. B. Field, 2007: Global and regional drivers of accelerating CO₂ emissions. Proceedings of the National Academy of Sciences, 104, 10288-10293.

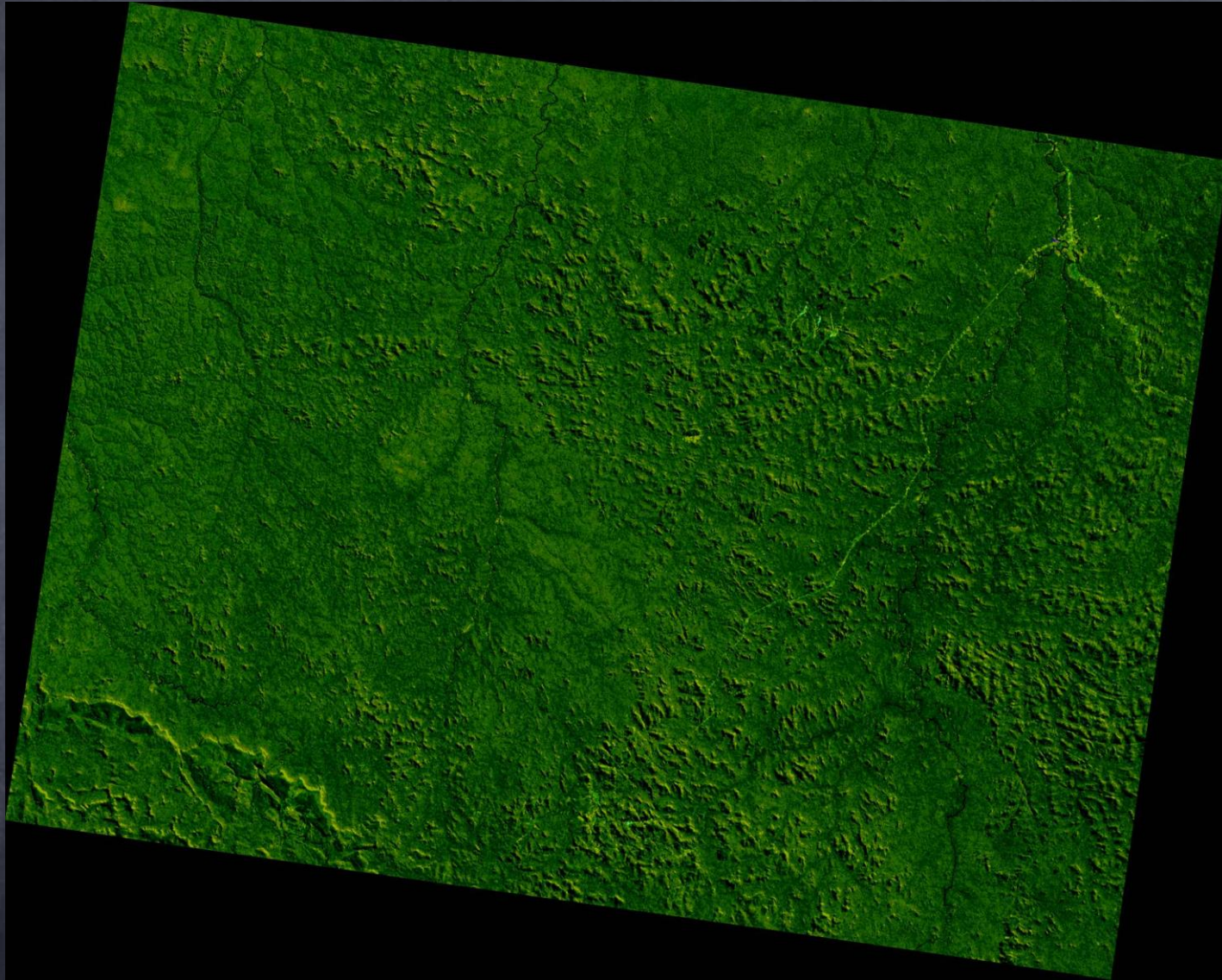
It's all connected



Tipping points

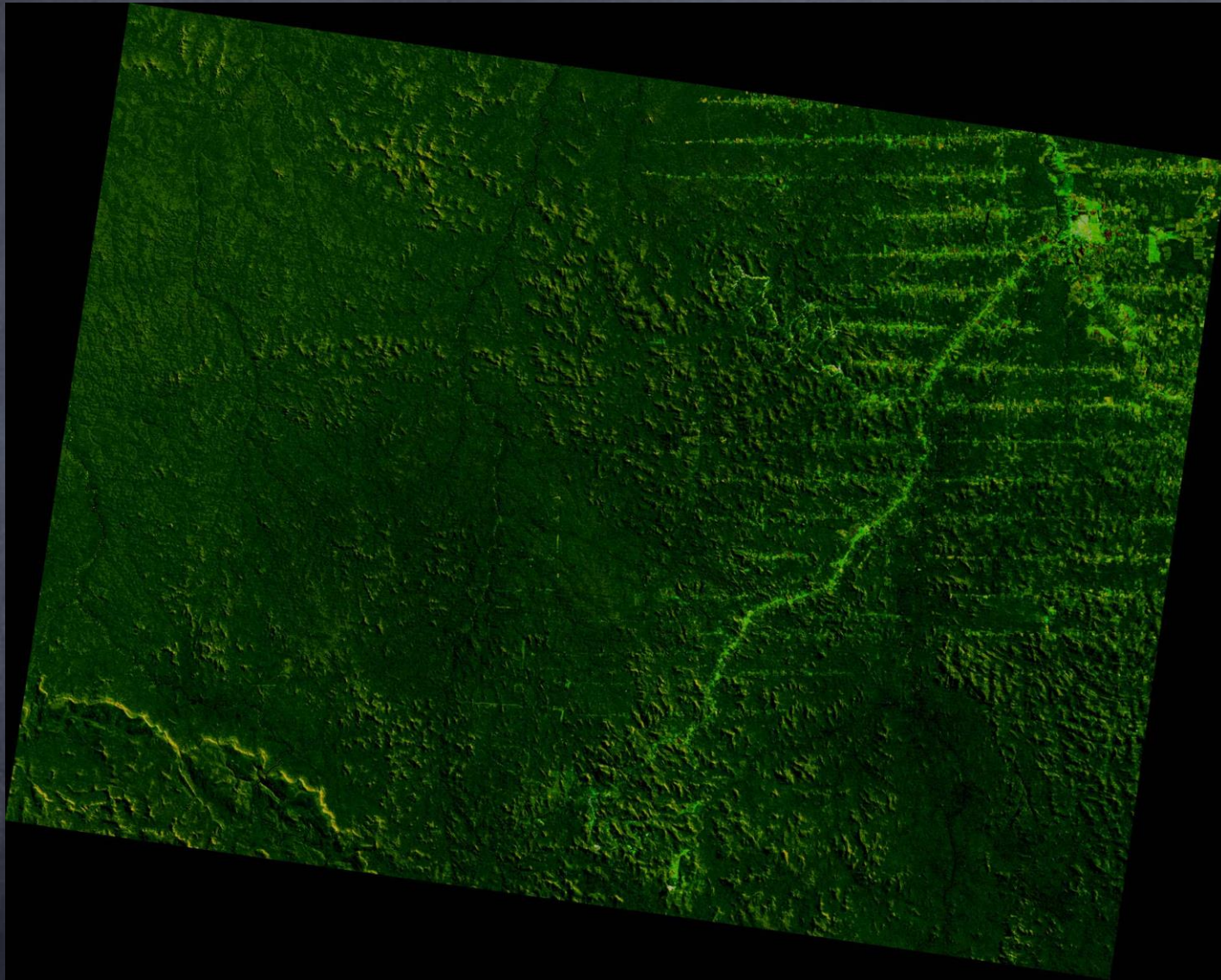


Amazonian land use changes



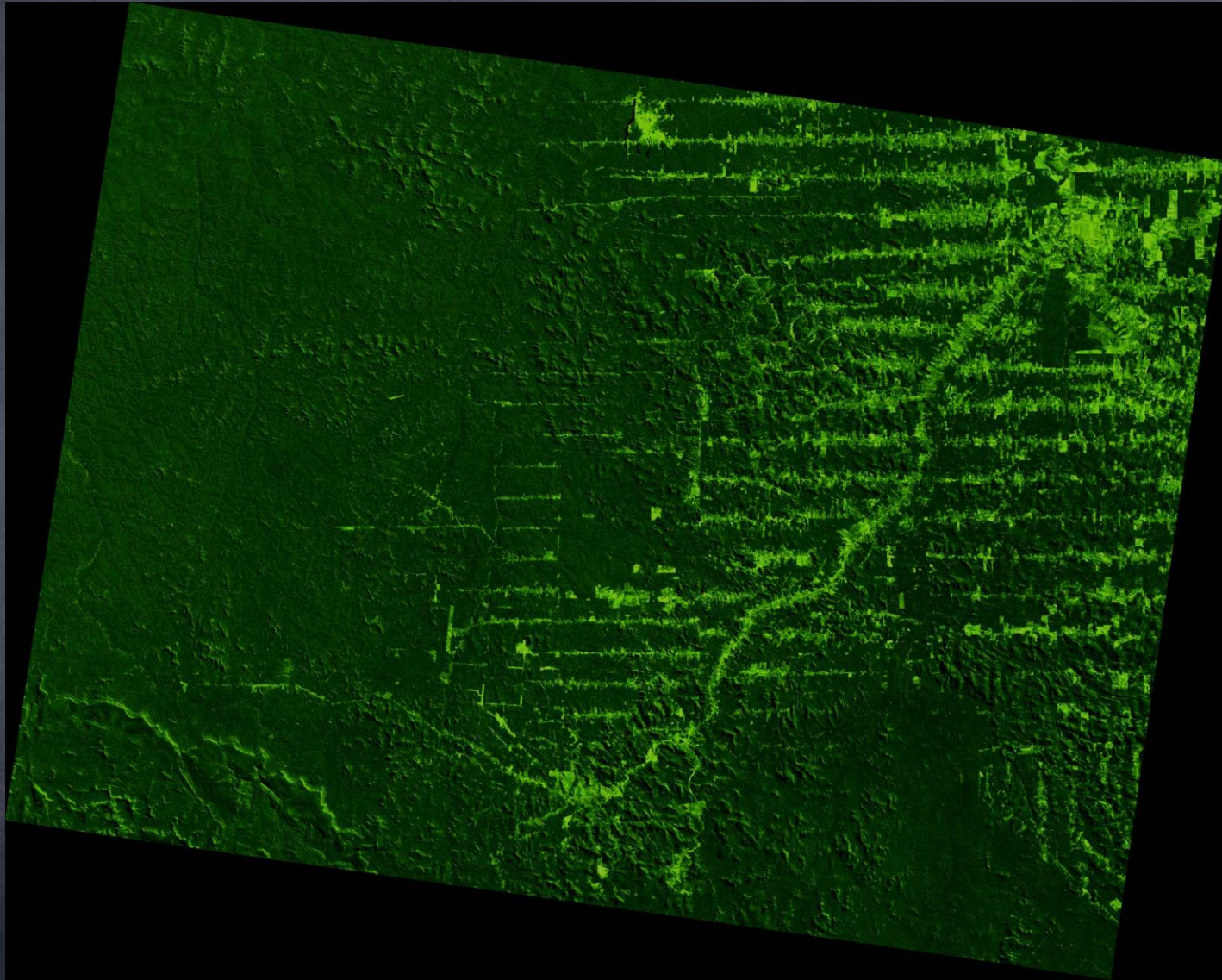
1975

Amazonian land use changes



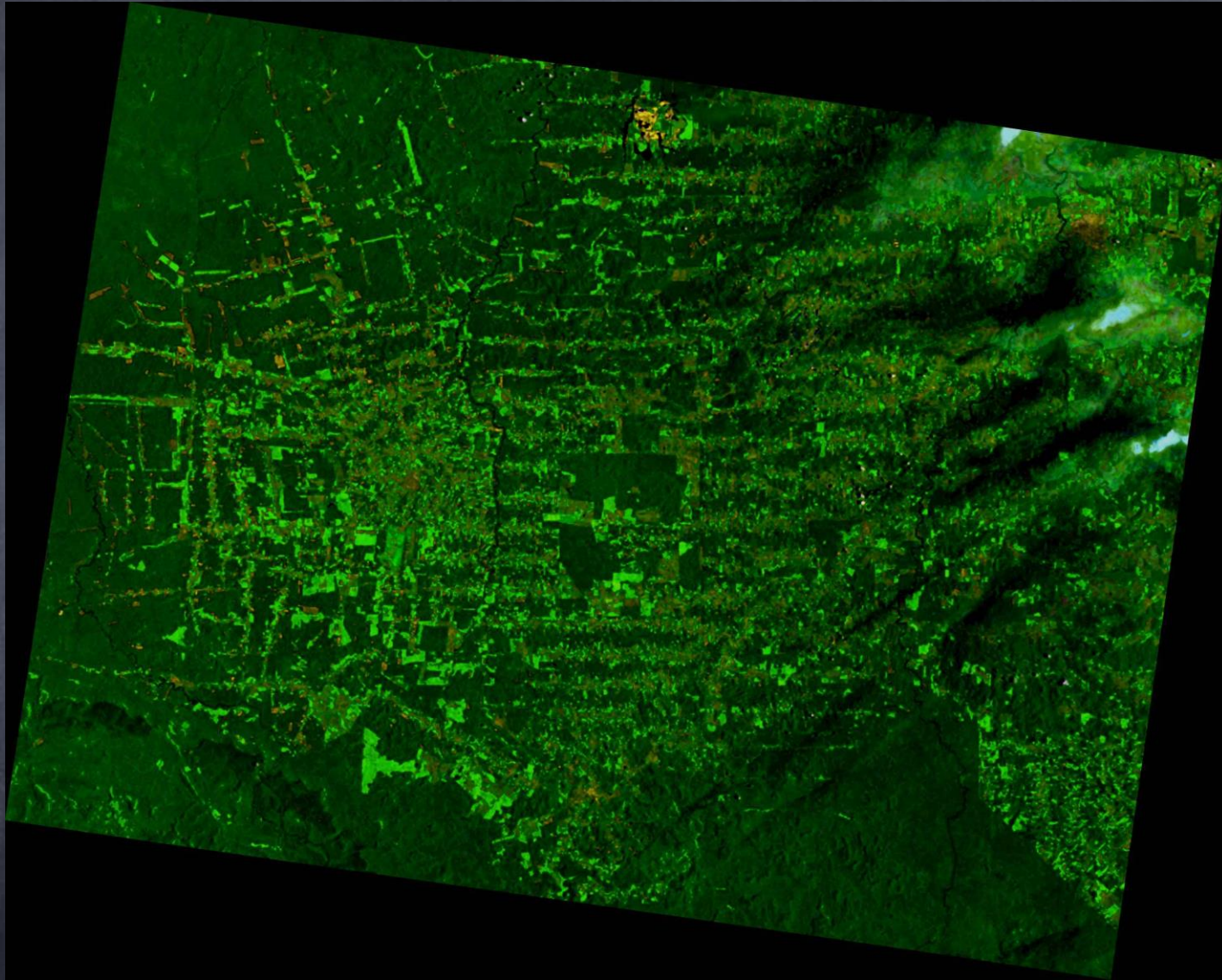
1986

Amazonian land use changes



1992

Amazonian land use changes



2001

A biological feedback loop

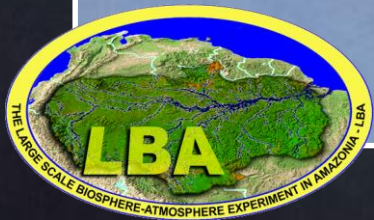
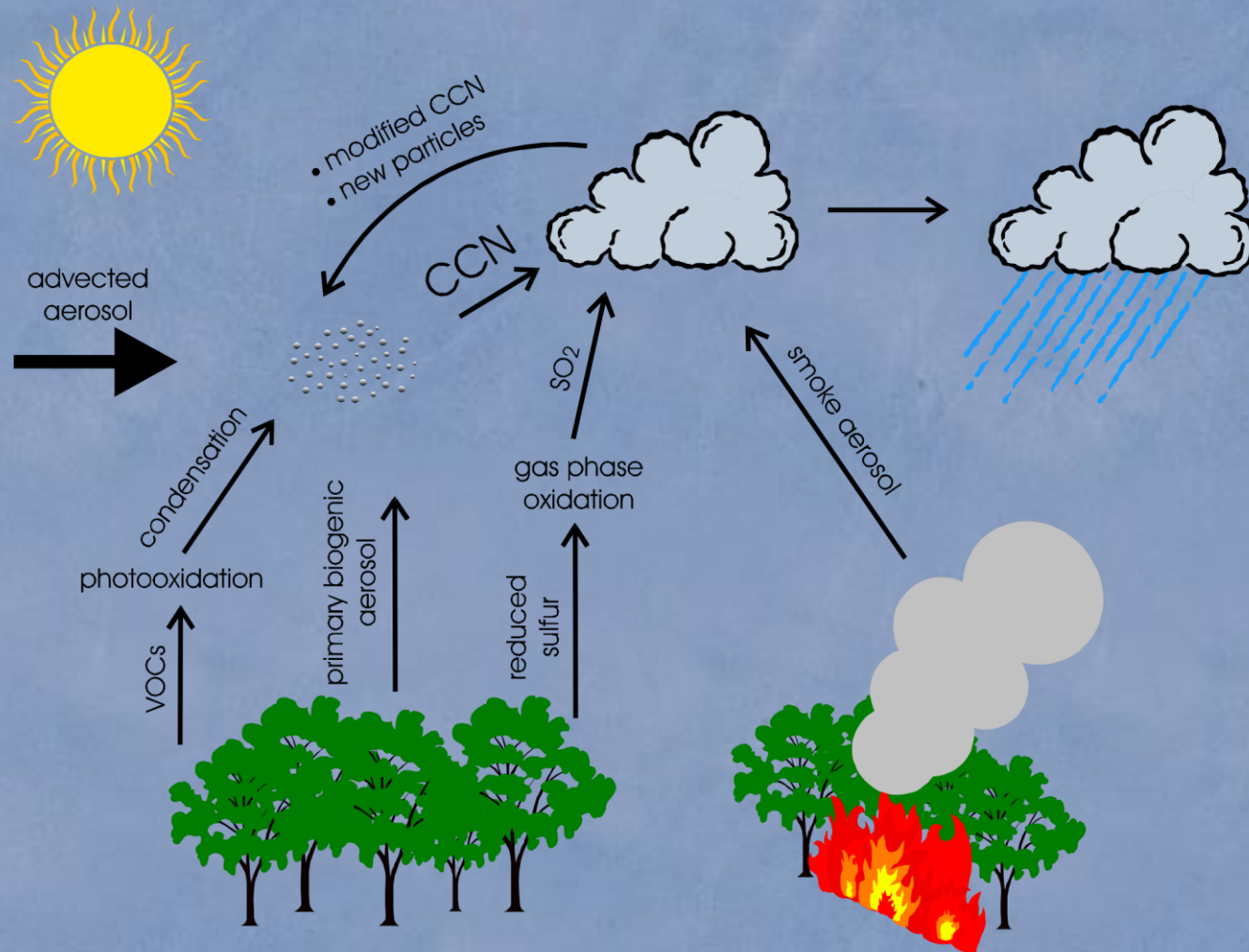
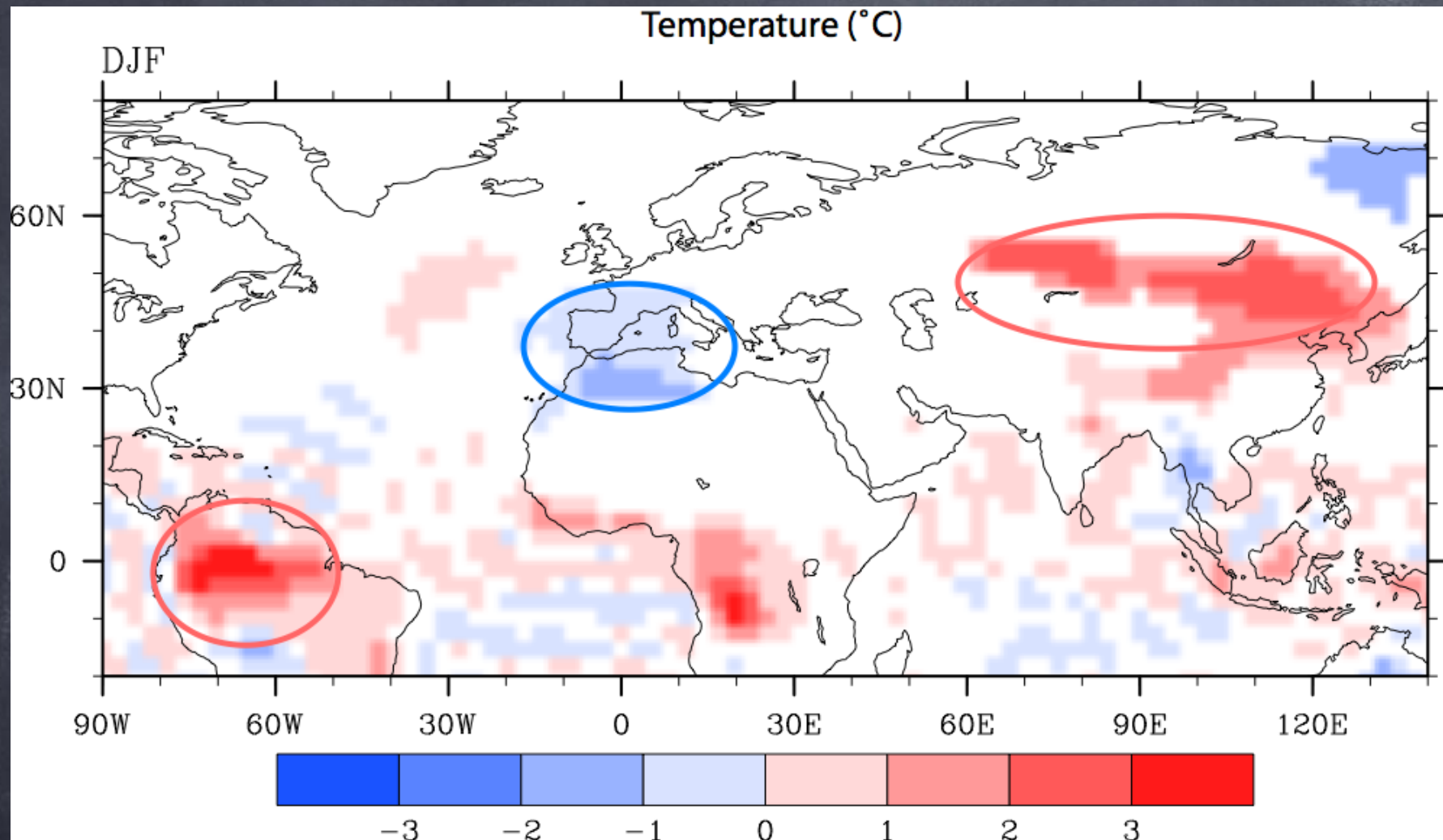


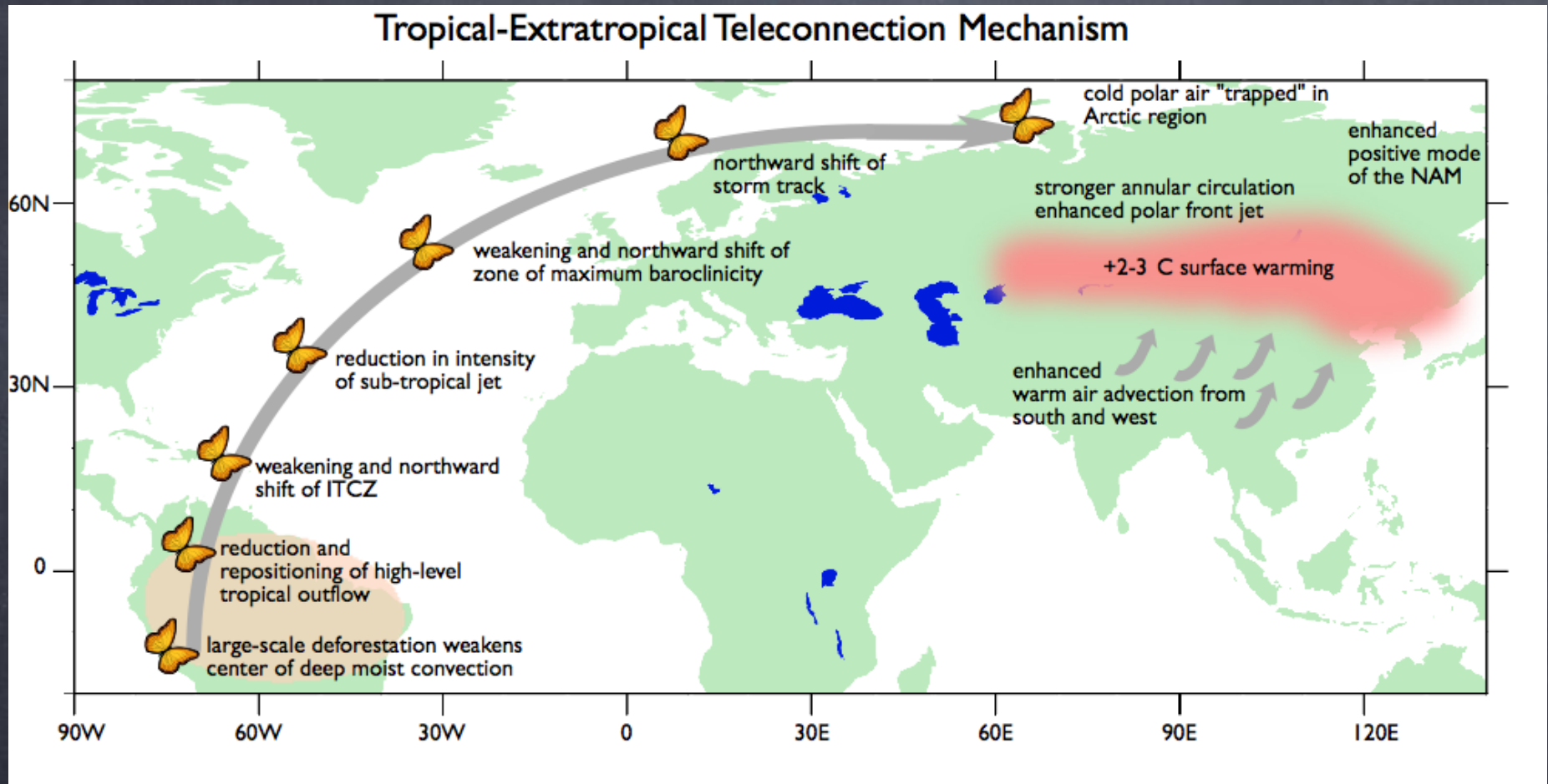
Illustration: Paulo Artaxo, Univ. São Paulo

Planetary teleconnections



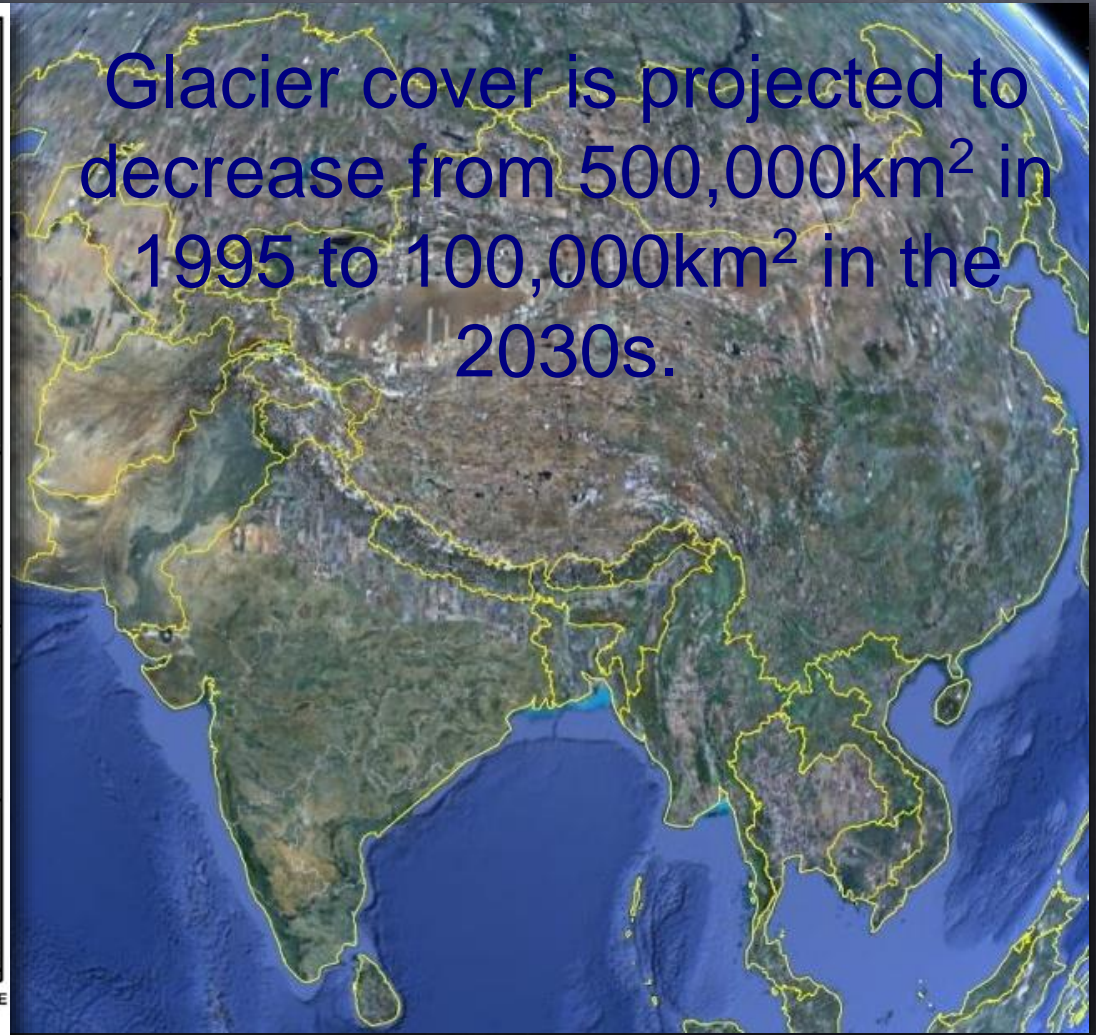
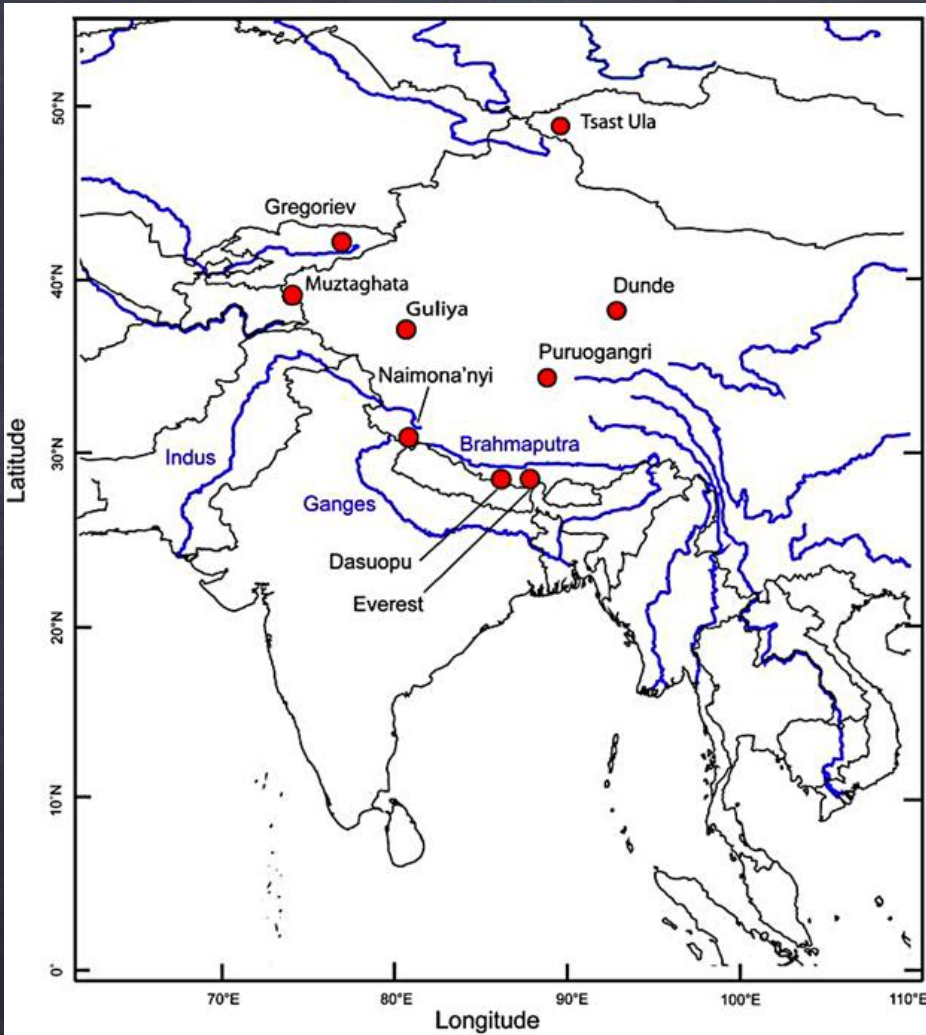
Rockström et al., Nature (in press);
see also Snyder, et al., Climate Dynamics 23, 279-302, 2004;
Werth & Avissar, JGR 107 (D20), 8087, 2002

... and how they work



Snyder, et al., *Climate Dynamics* 23, 279-302, 2004;

Impacts in Asia

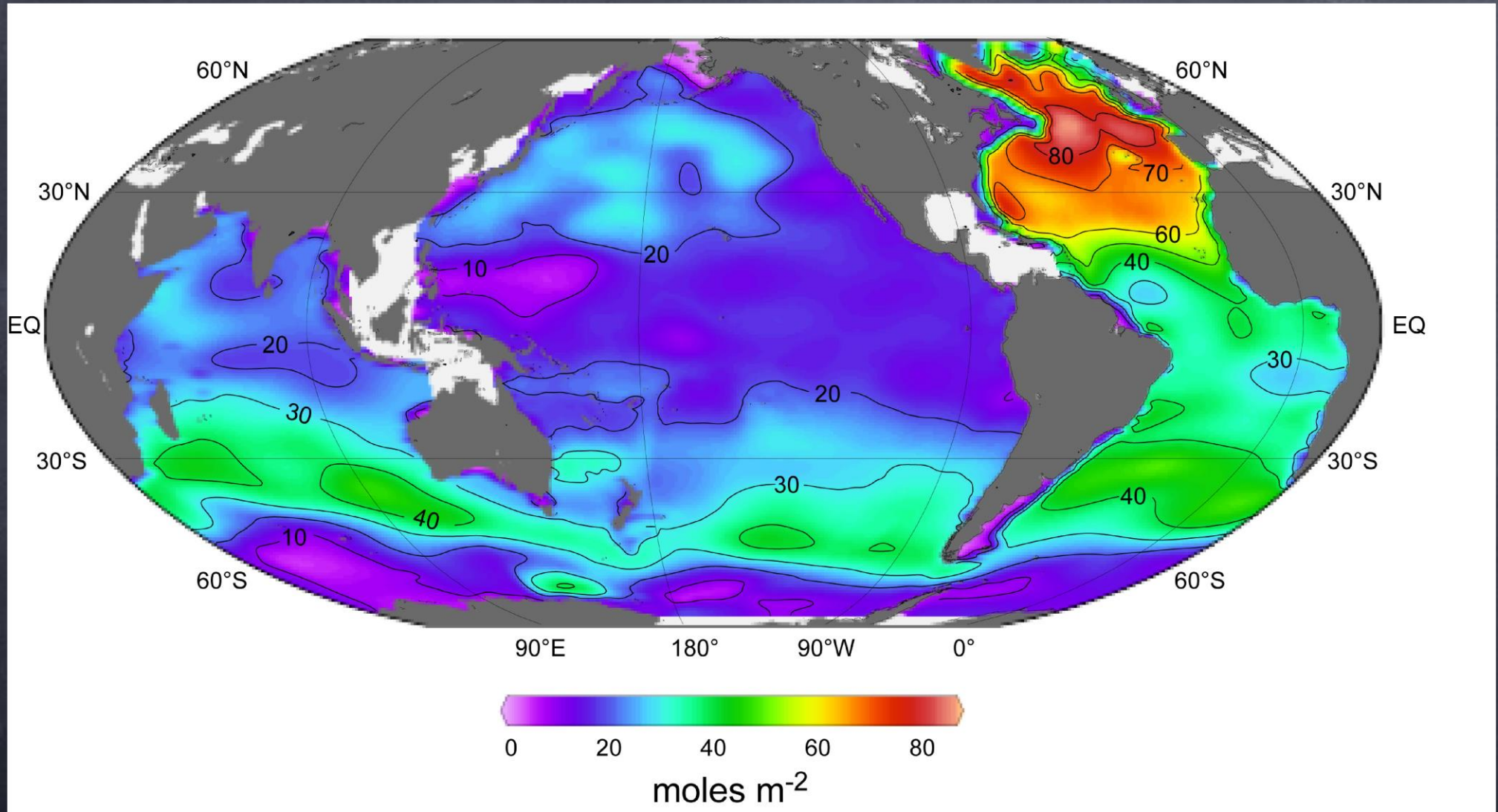


3/4 billion people in S and SE Asia depend on glacial melt for their water supplies

Cruz, et al., IPCC AR4, WGII, Ch. 10

Kehrwald et al., GRL 35, L22503, 2008

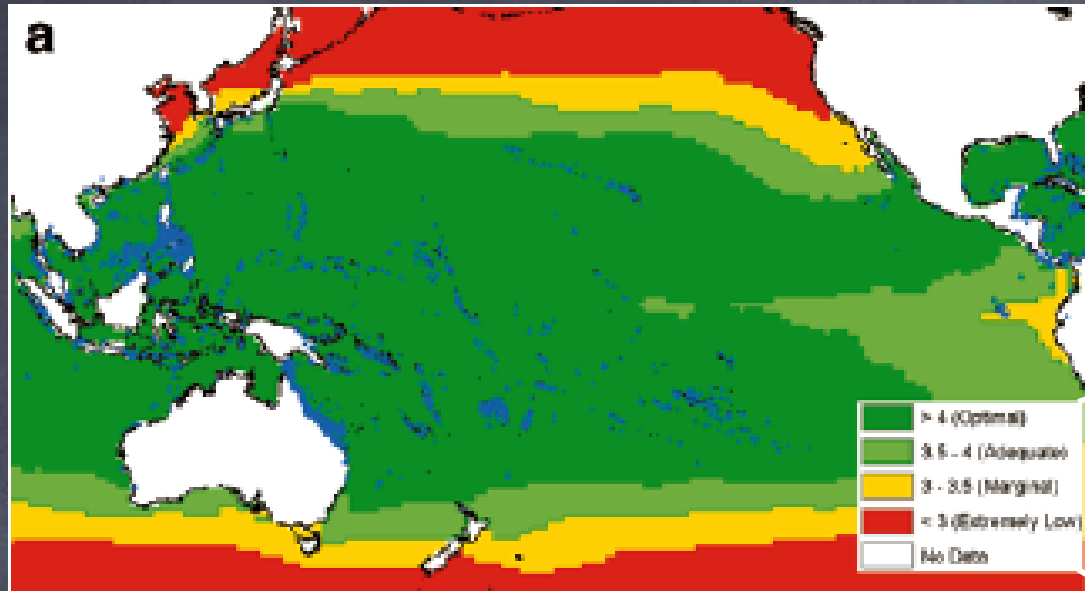
Anthropogenic CO₂ in the oceans



Source: Sabine, et al., Science 305, 367-371, 2004

Changing ocean pH

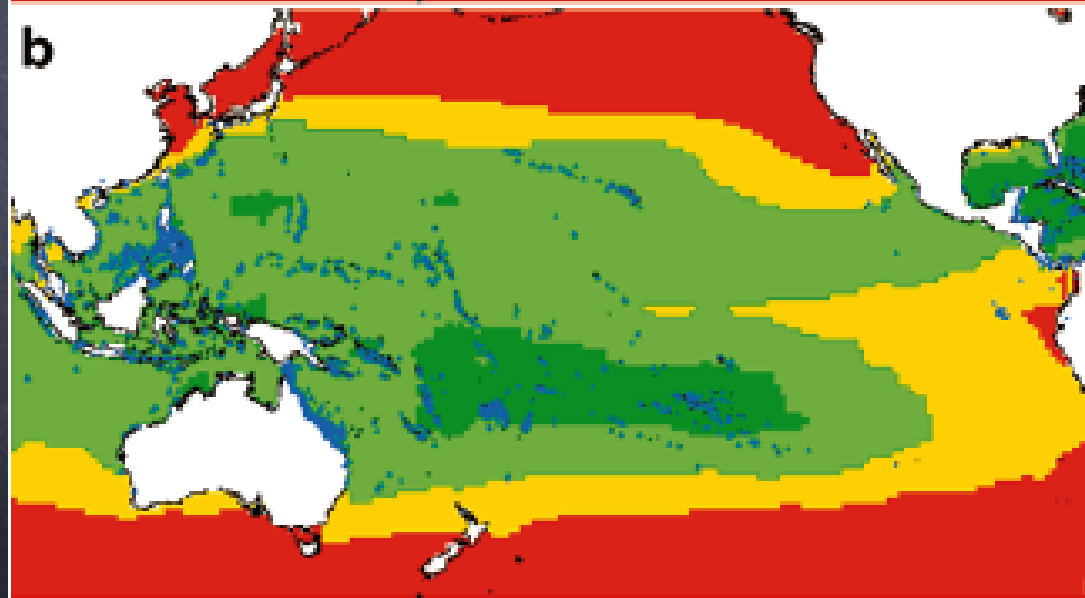
1870



$p\text{CO}_2 = 280 \text{ ppmv}$



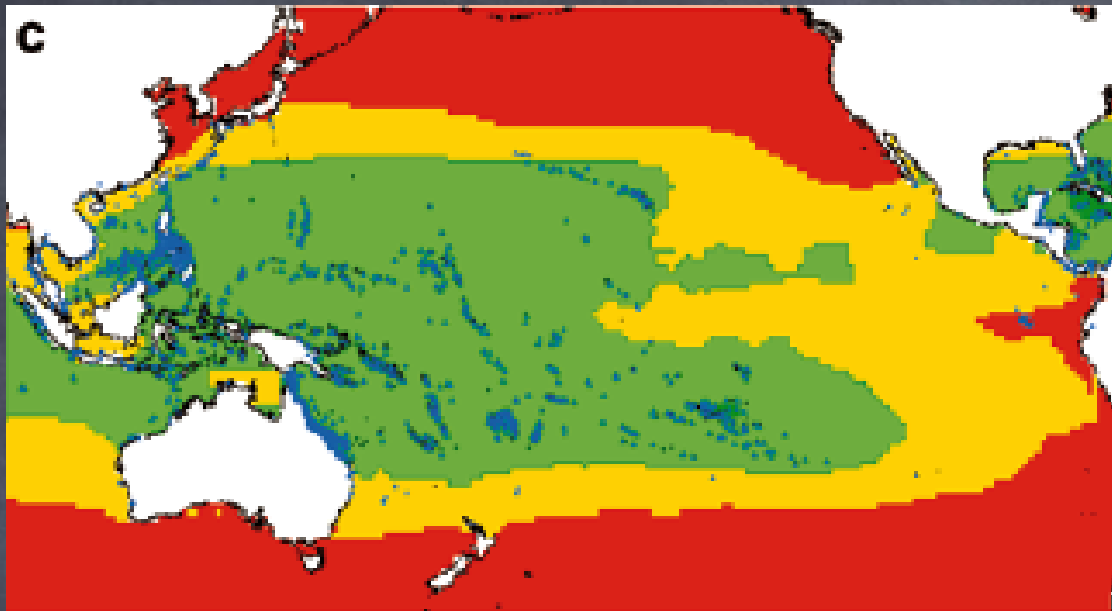
2000-
2009



$p\text{CO}_2 = 375 \text{ ppmv}$

Changing ocean pH

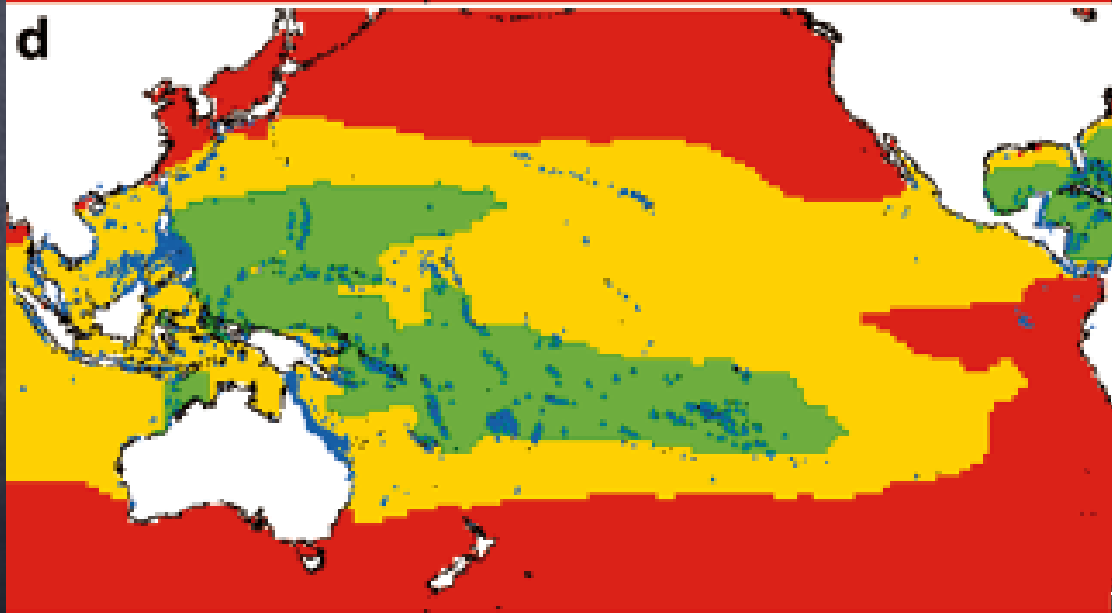
2020-
2029



$p\text{CO}_2 =$
415 ppmv

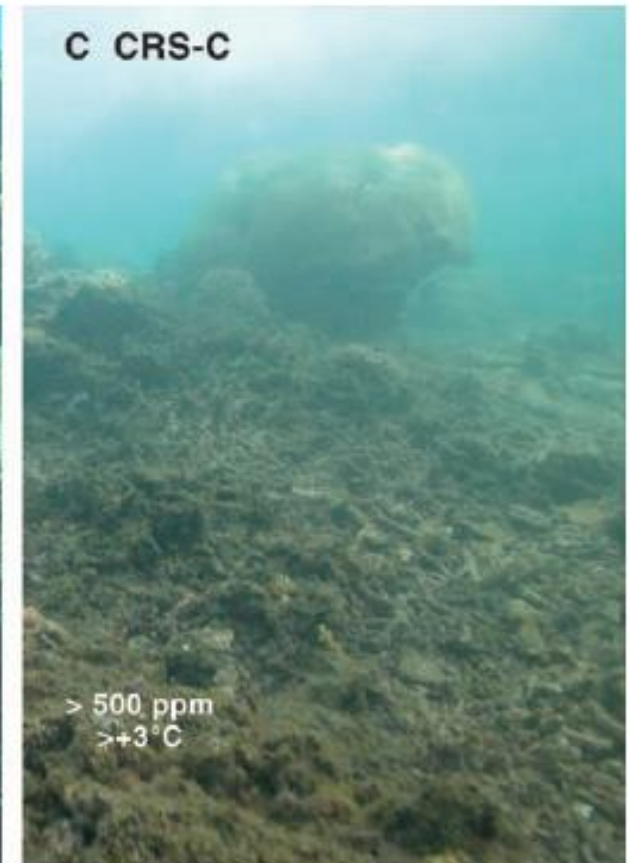


2040-
2049



$p\text{CO}_2 =$
465 ppmv

Tropical coral reefs of the future

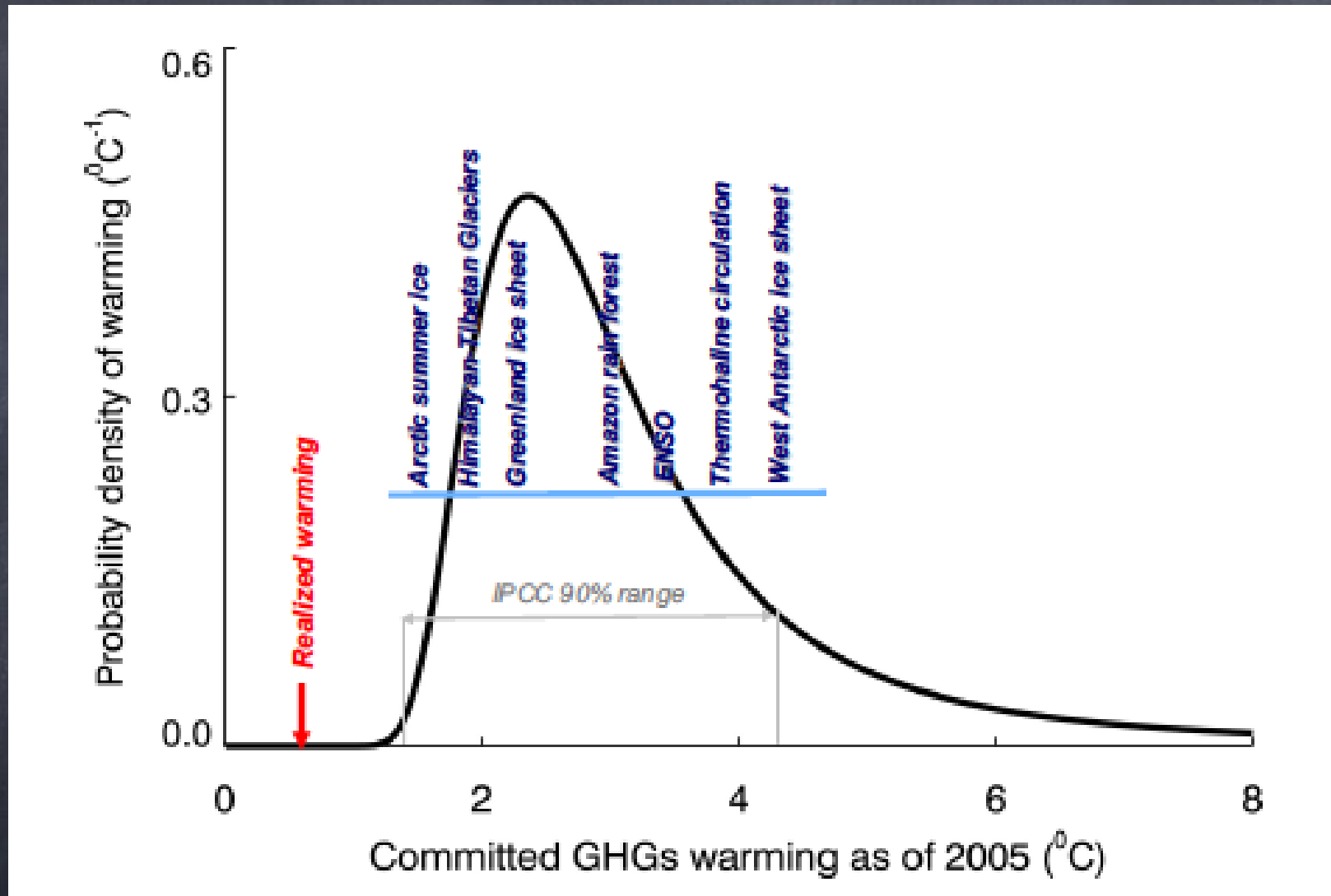


Examples of reefs from the Great Barrier reef that are analagous to the state of coral reefs in the future under different climate scenarios CRS-A, CRS-B and CRS-C. CRS-A = conditions stabilised at todays CO₂ levels. IPCC scenario B1 is predicting 550ppm CO₂ by 2100 and A2 800ppm.

Planetary Boundaries



Tipping elements



Ramanathan & Feng, 2008: PNAS, 105 (38), 14,245-14,250.

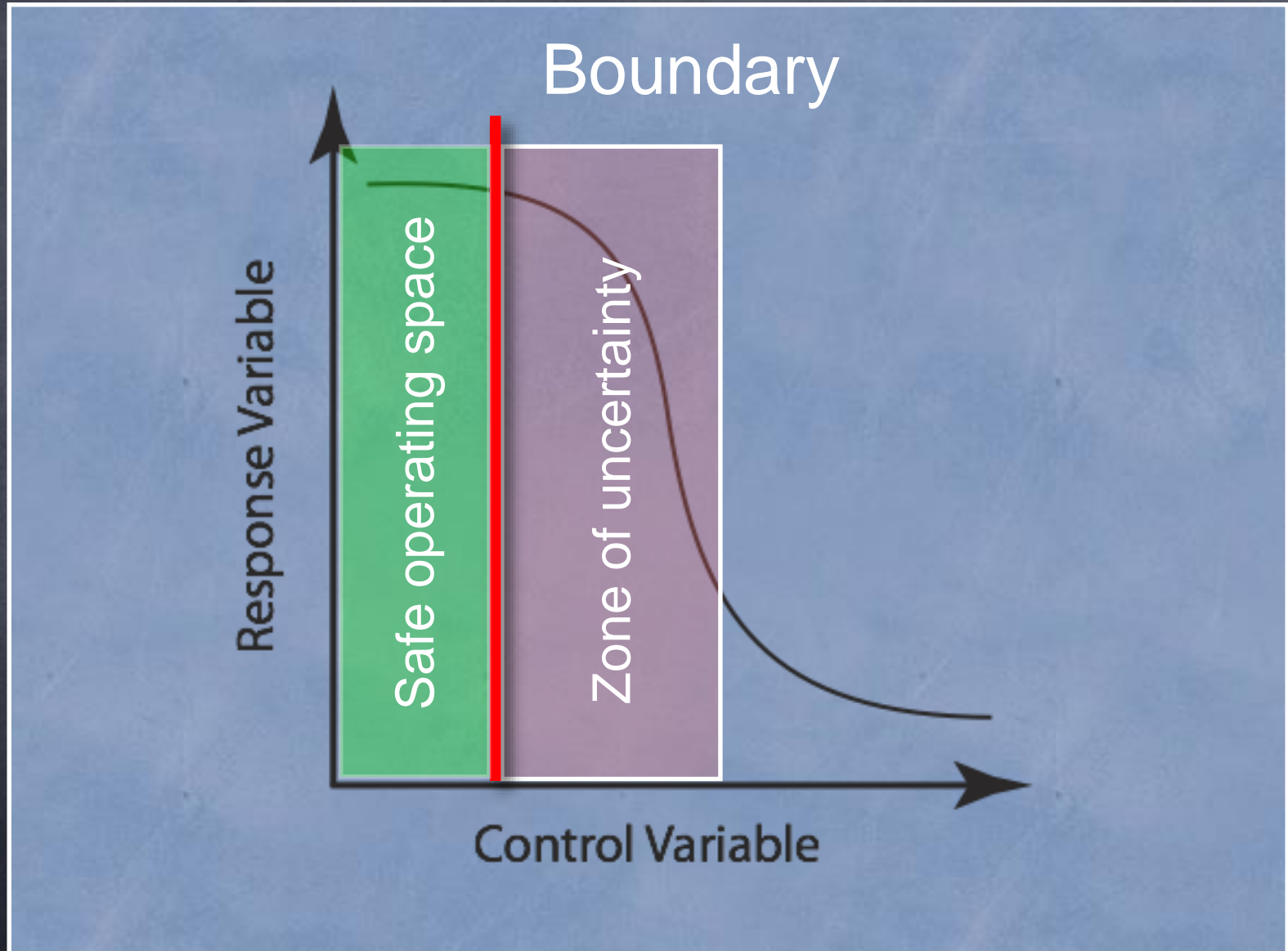
Planetary boundaries: authors

Johan Rockström, Will Steffen, Kevin Noone, Åsa Persson, F. Stuart Chapin, III, Eric F. Lambin, Timothy M. Lenton, Marten Scheffer, Carl Folke, John Schellnhuber, Björn Nykvist, Cynthia A. de Wit, Terry Hughes, Sander van der Leeuw, Henning Rodhe, Sverker Sörlin, Peter K. Snyder, Robert Costanza, Uno Svedin, Malin Falkenmark, Louise Karlberg, Robert W. Corell, Victoria J. Fabry, James Hansen, Diana Liverman, Katherine Richardson, Paul Crutzen, Jonathan A. Foley

Some properties of PBs

- Associated with a large-scale change in how planetary systems function (often a threshold or “tipping point”); these are non-negotiable
- Have some “control” variable
- Include normative aspects of defining preferred states - holocene stability
- Operate on time scales over which ethics and political action are relevant
- A “safe operating space” can be created within the boundaries

Planetary Boundaries



Planetary boundaries

Climate

350 ppm CO₂
+1 W/m²

Ozone depletion

276 DU

Biogeochemical loading

35 MT N/yr
11 MT P/yr

Biodiversity loss

10 E/MSY

Agricultural land use

15%

Atmospheric aerosol loading

TBD

Ocean acidification

Aragonite saturation
ratio > 2.75

Freshwater use

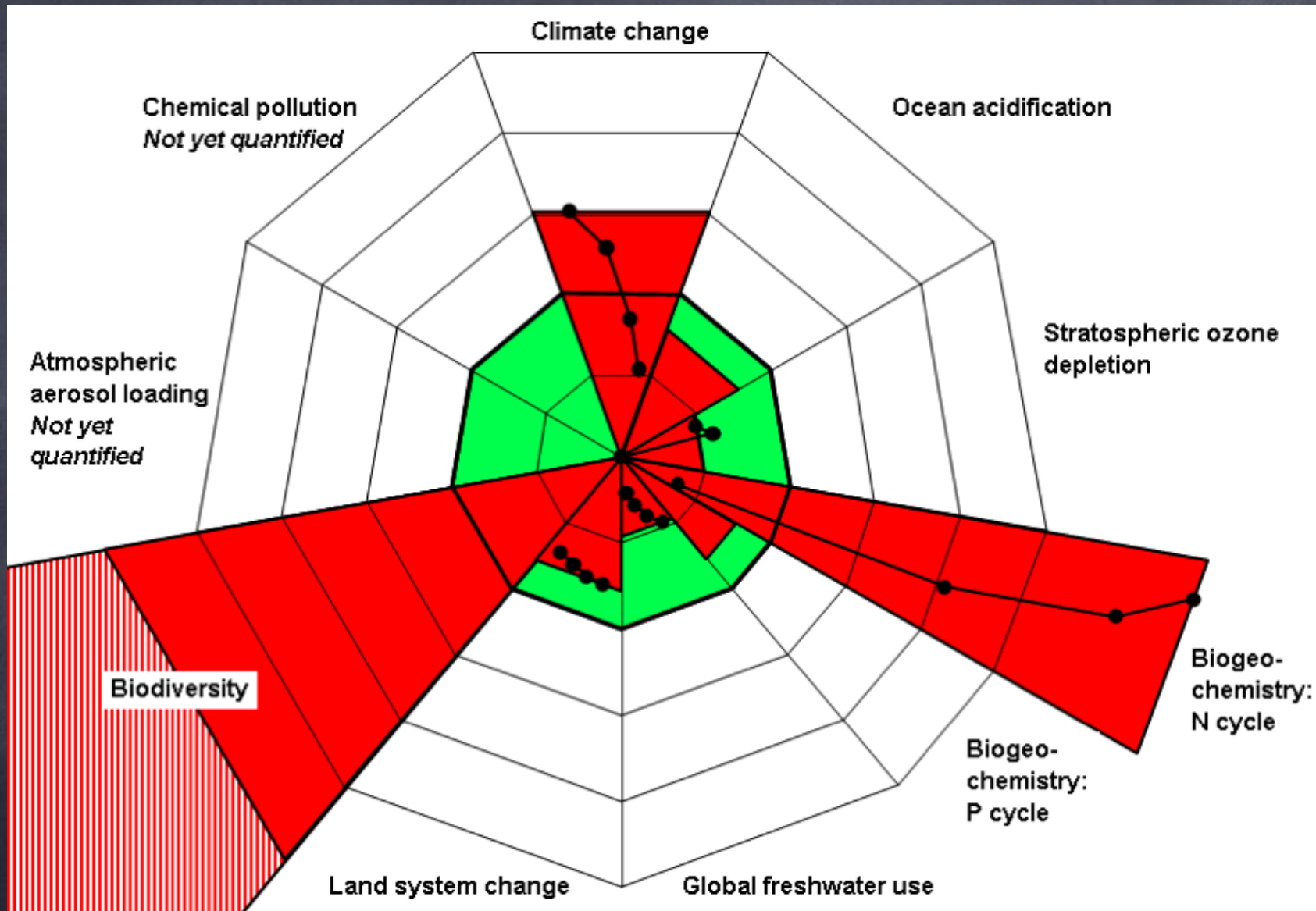
4000 km³/yr

Chemical pollution

TBD




Planetary boundaries



Rockström, J. et al., 2009. Nature, in press.

Transformations for sustainability



The image features four circular satellite photographs of Earth, each showing a different view of the planet at night. The continents are outlined in a dark blue color, and the city lights are depicted as bright yellow and white specks. The background is a deep black space filled with numerous small white stars. The text is centered over the four images.

"We are experiencing a very chaotic time, where humanity determines the outcome for the Planet – sustainability or collapse...?"

Professor Will Steffen

A sustainable future

What can we do to minimize our “footprint”?
Which activities most influence our environment?

- Energy production
- Agriculture
- Transportation



Where have we been today?

- ✓ We have moved far into the Anthropocene
- ✓ It's all connected
- ✓ There are planetary boundaries we need to respect
- ✓ Transformations for sustainability require a concerted, coordinated approach





Thanks for your attention!

