Tipping Points in the Earth System

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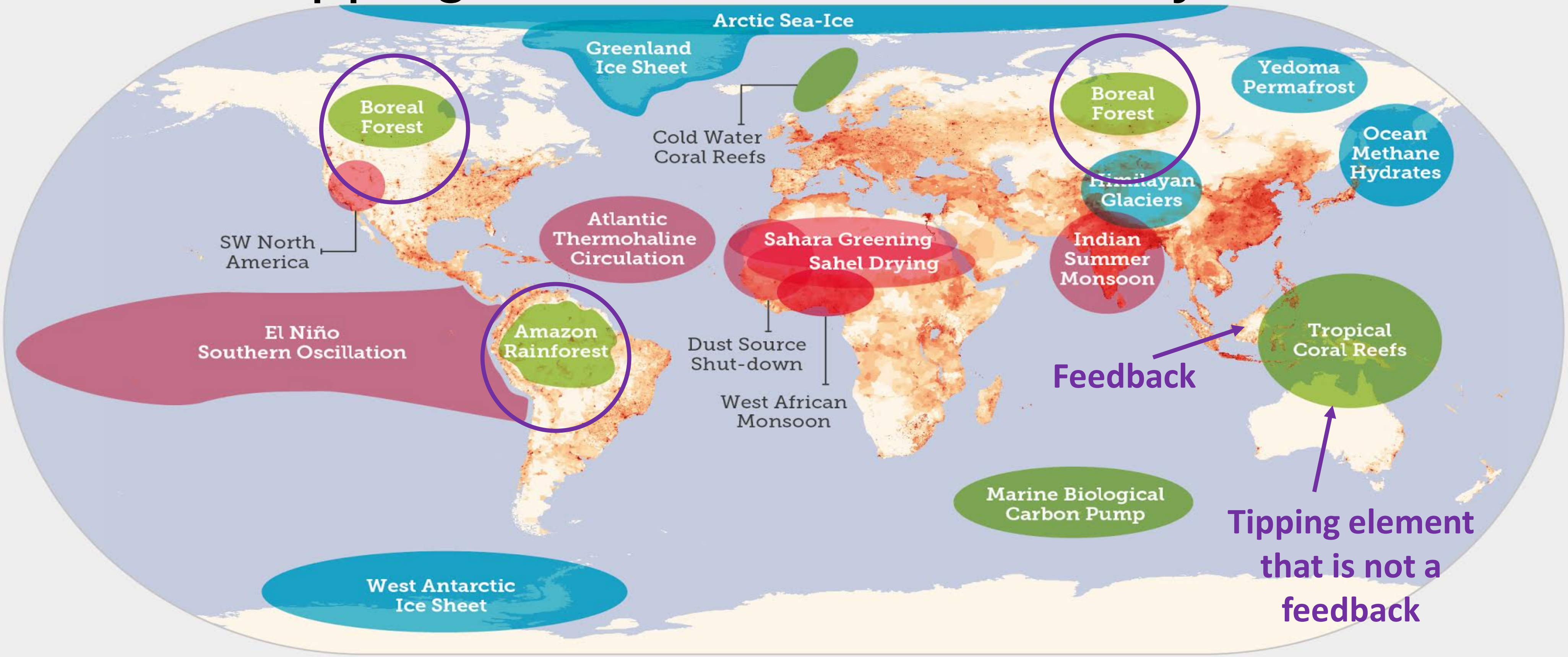
Tipping Points and Feedbacks

Tipping Point – a position in a system where a small, additional increase in an external forcing factor triggers internal processes that drive system change – often rapid and unexpected, sometimes irreversible.

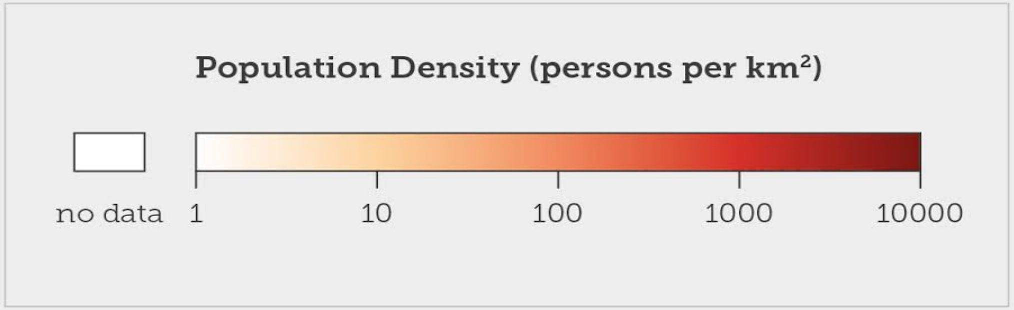
Feedback – a process within a system that can either accelerate (positive) or dampen (negative) a change in the system driven by an external forcing factor.

Not all feedback processes have tipping points (some are slow and gradual) and not all tipping points feed back to further system change.

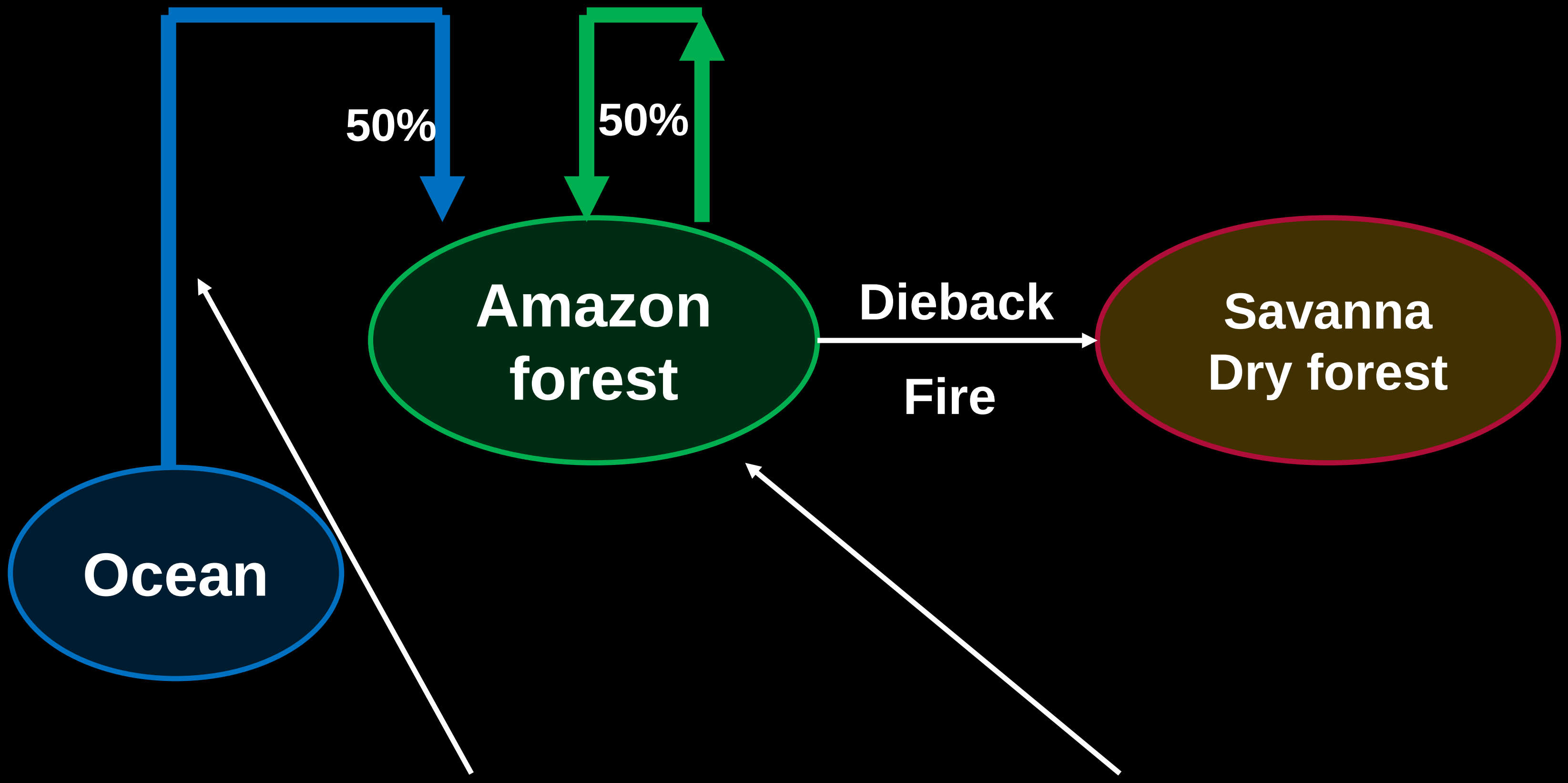
Tipping Elements in the Earth System



Huber, Lenton, and Schellnhuber, in Richardson et al. 2011



The Amazon tipping element



Climate change: change in ocean/atmos circulation → reduced rainfall; increased drought

Deforestation: conversion to cropland or pasture → reduced evaporation and water recycling

The Amazon tipping element

Deforestation alone: tipping point at ~20-25% clearing of forest and conversion to cropland and pasture.

Climate change alone: 3-4ºC temperature increase in the Amazon region.

Deforestation + climate change: Paris 2ºC target would reduce allowable deforestation to significantly less than 25%. Paris commitments - ~3ºC temperature rise – would reduce allowable deforestation to near zero.

Nobre and de Simone Borma 2009; Lovejoy and Nobre 2018

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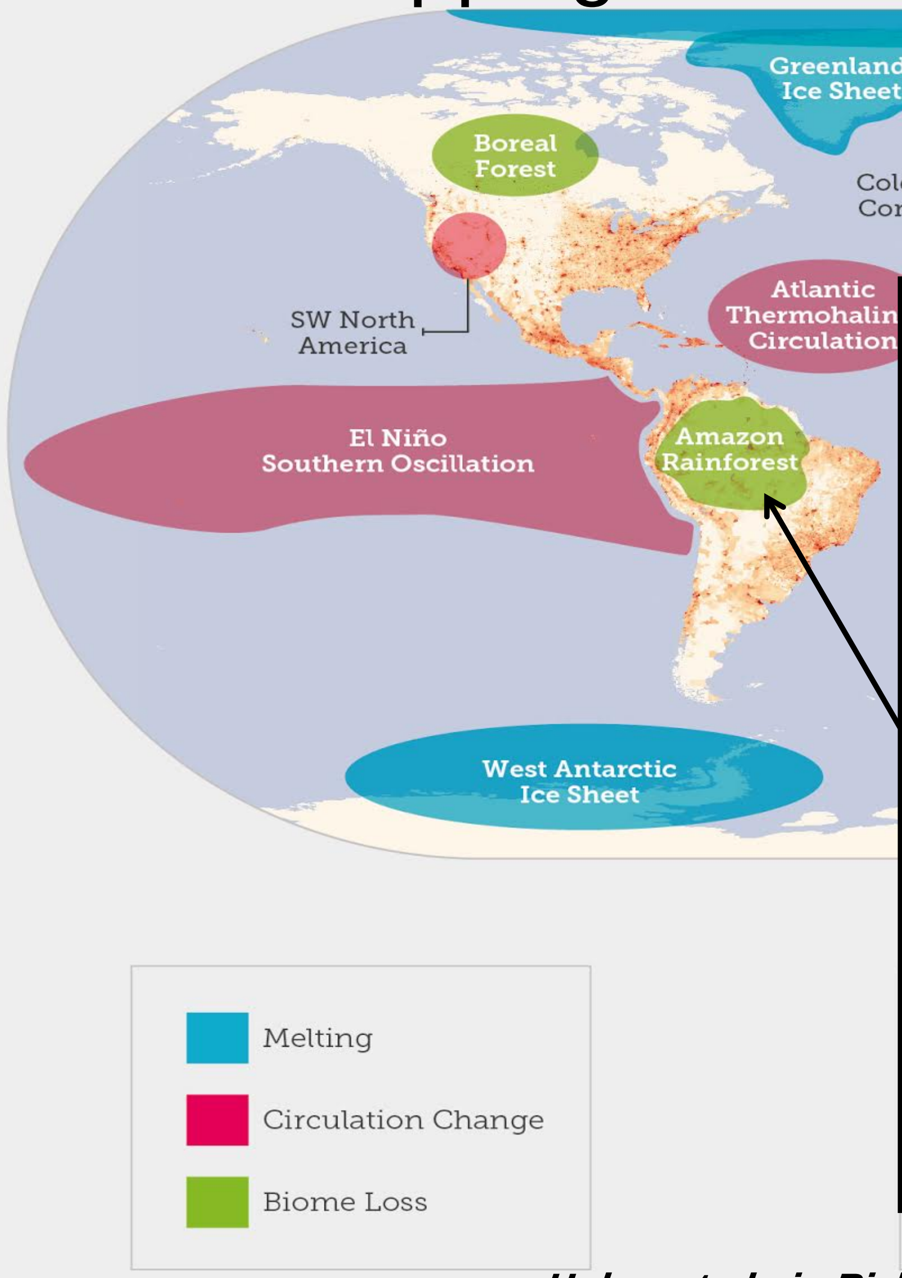
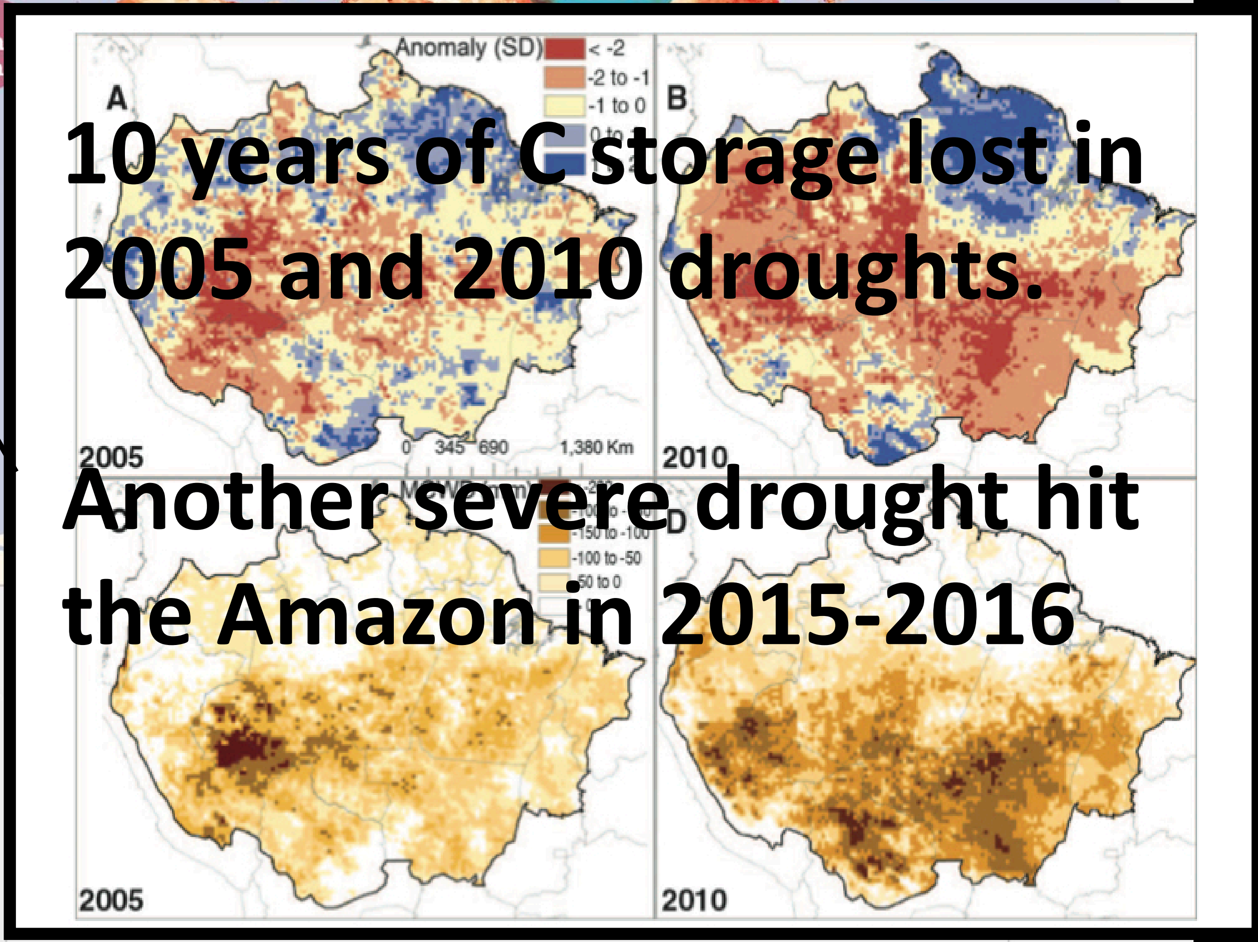




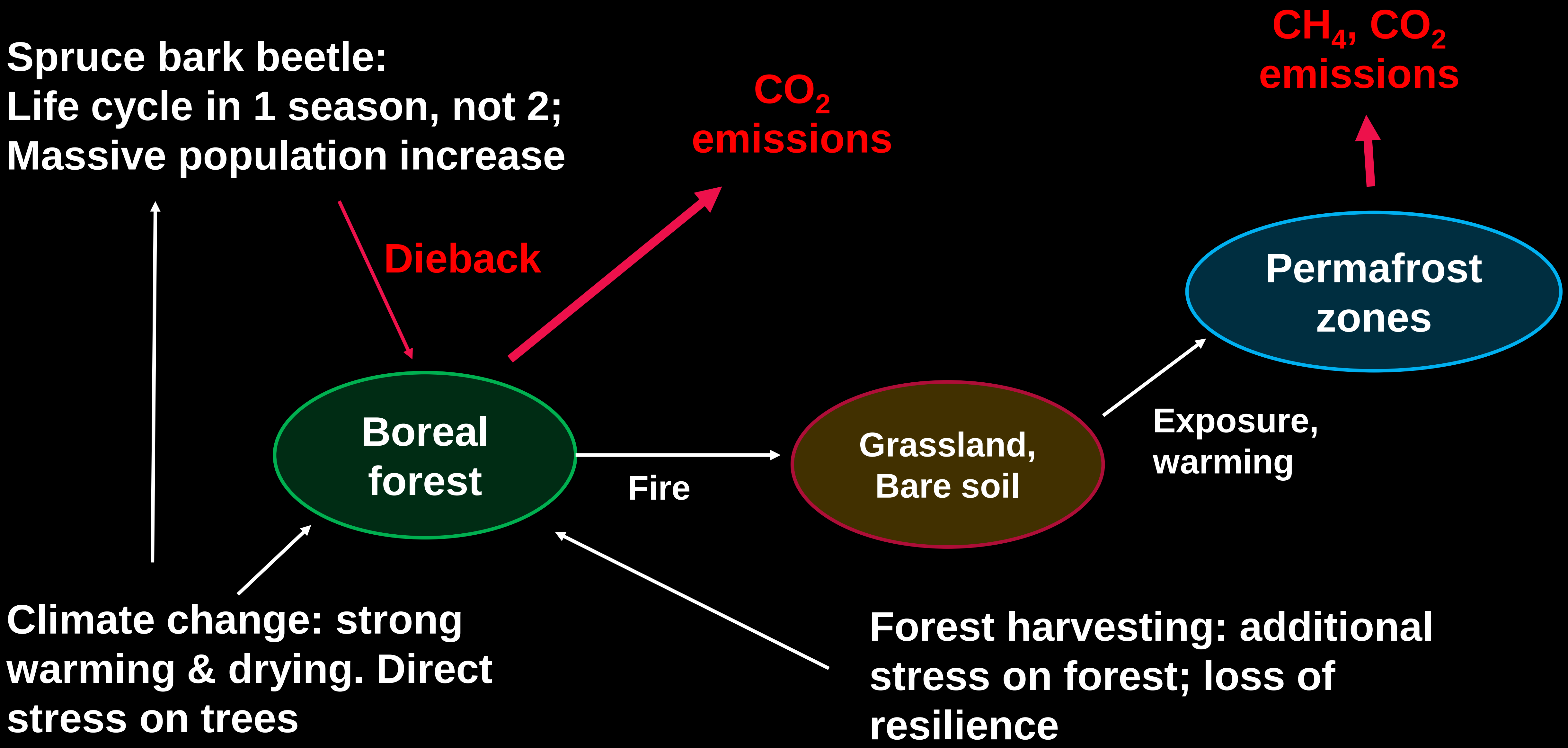
10 years of C storage lost in 2005 and 2010 droughts.

Another severe drought hit the Amazon in 2015-2016

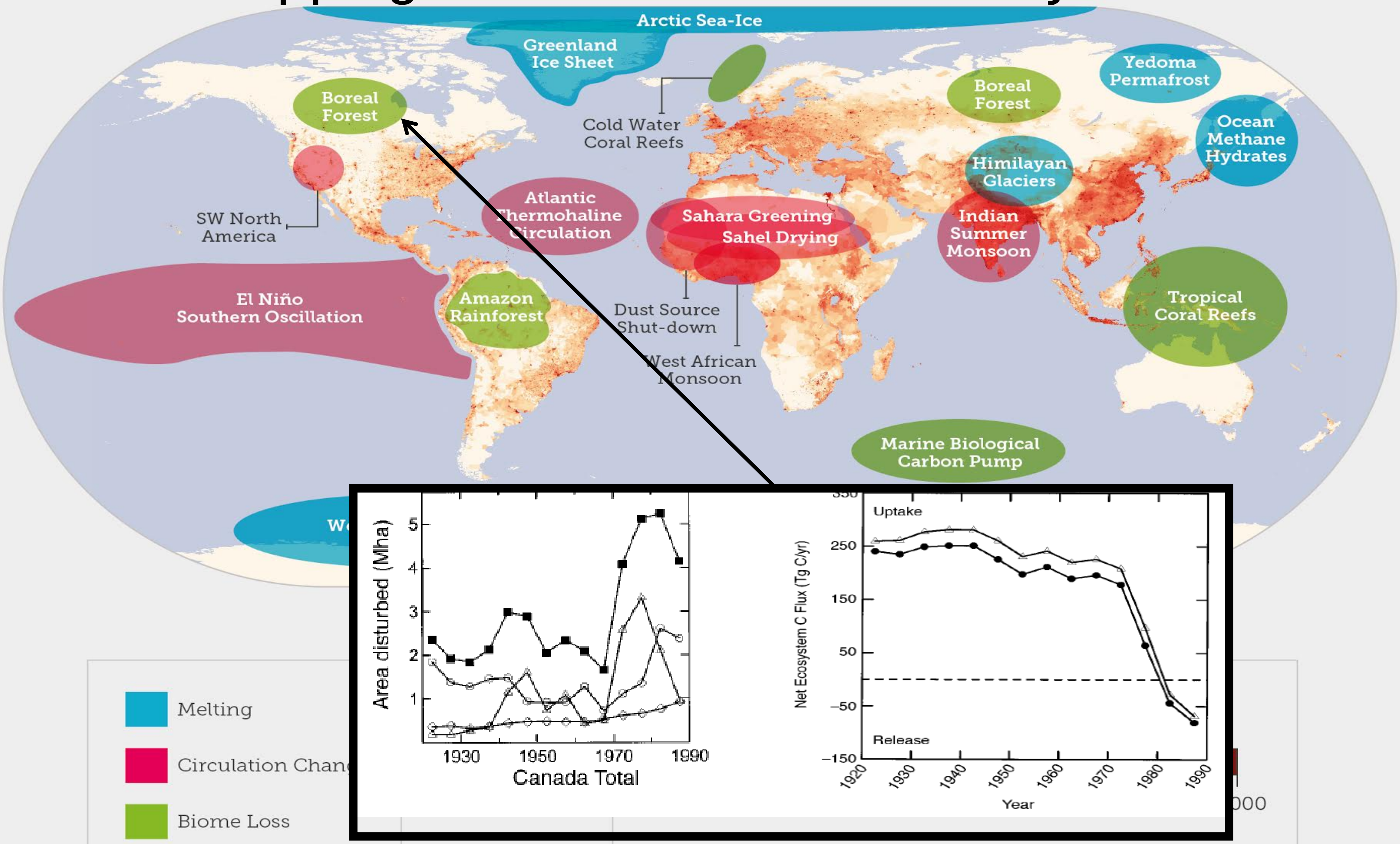
Huber et al., in Richardson et al. 2011; Phillips et al. 2009; Lewis et al. 2011; Brien

The Boreal Forest Tipping Element

The boreal forest tipping element

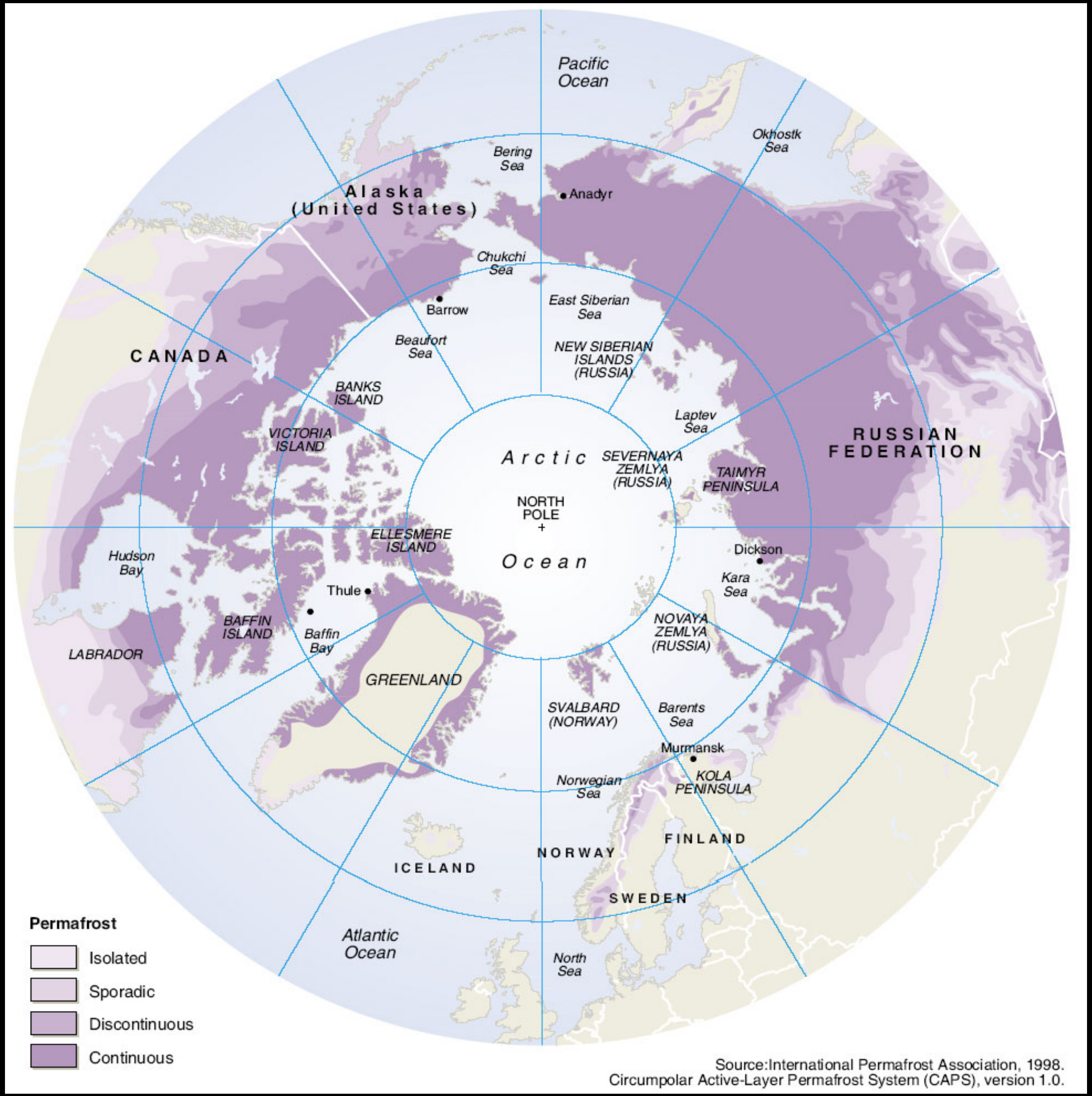


Tipping Elements in the Earth System

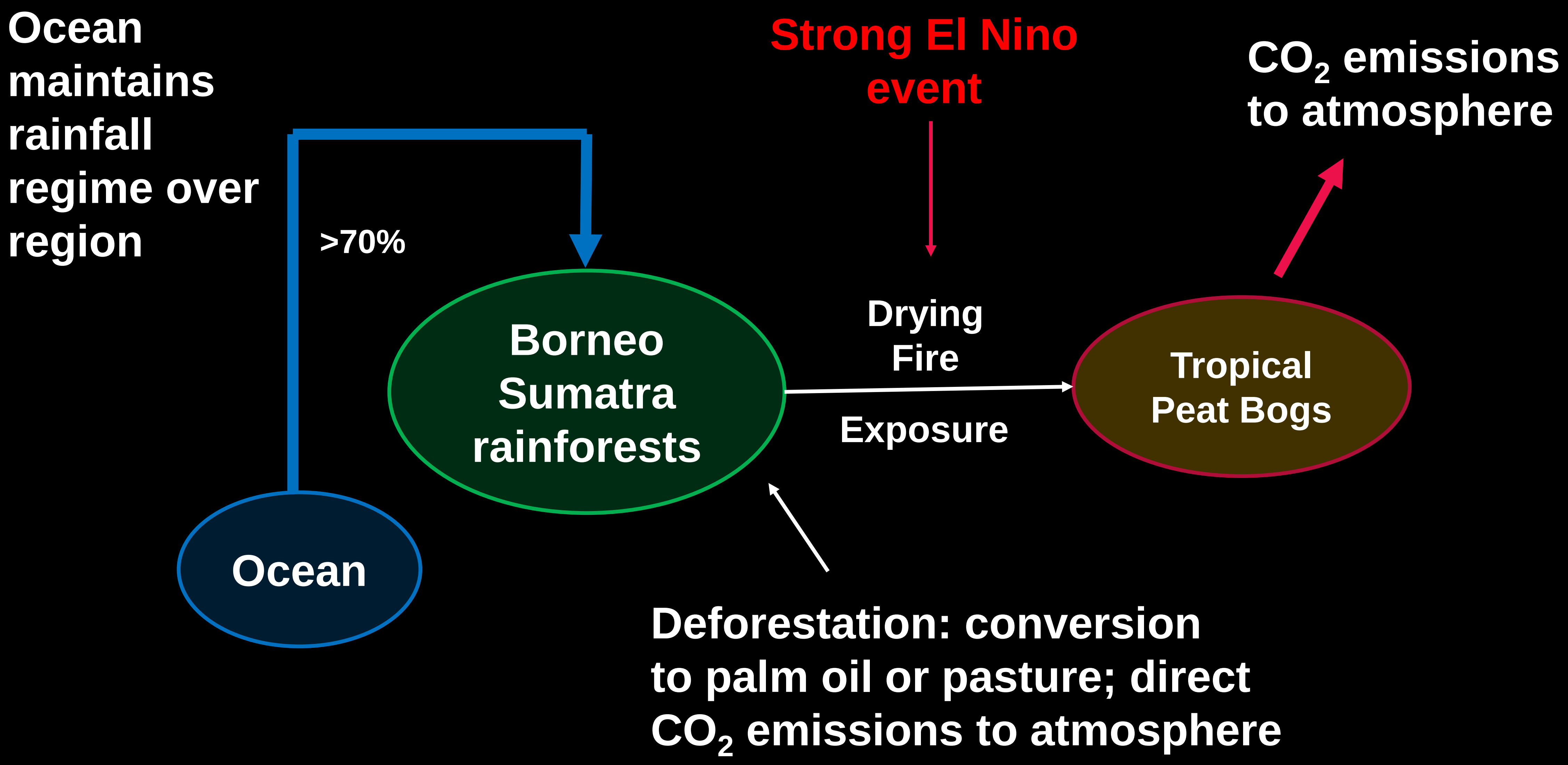


Huber et al., in Richardson et al. 2011; Kurz and Apps 1

Global Permafrost Zones

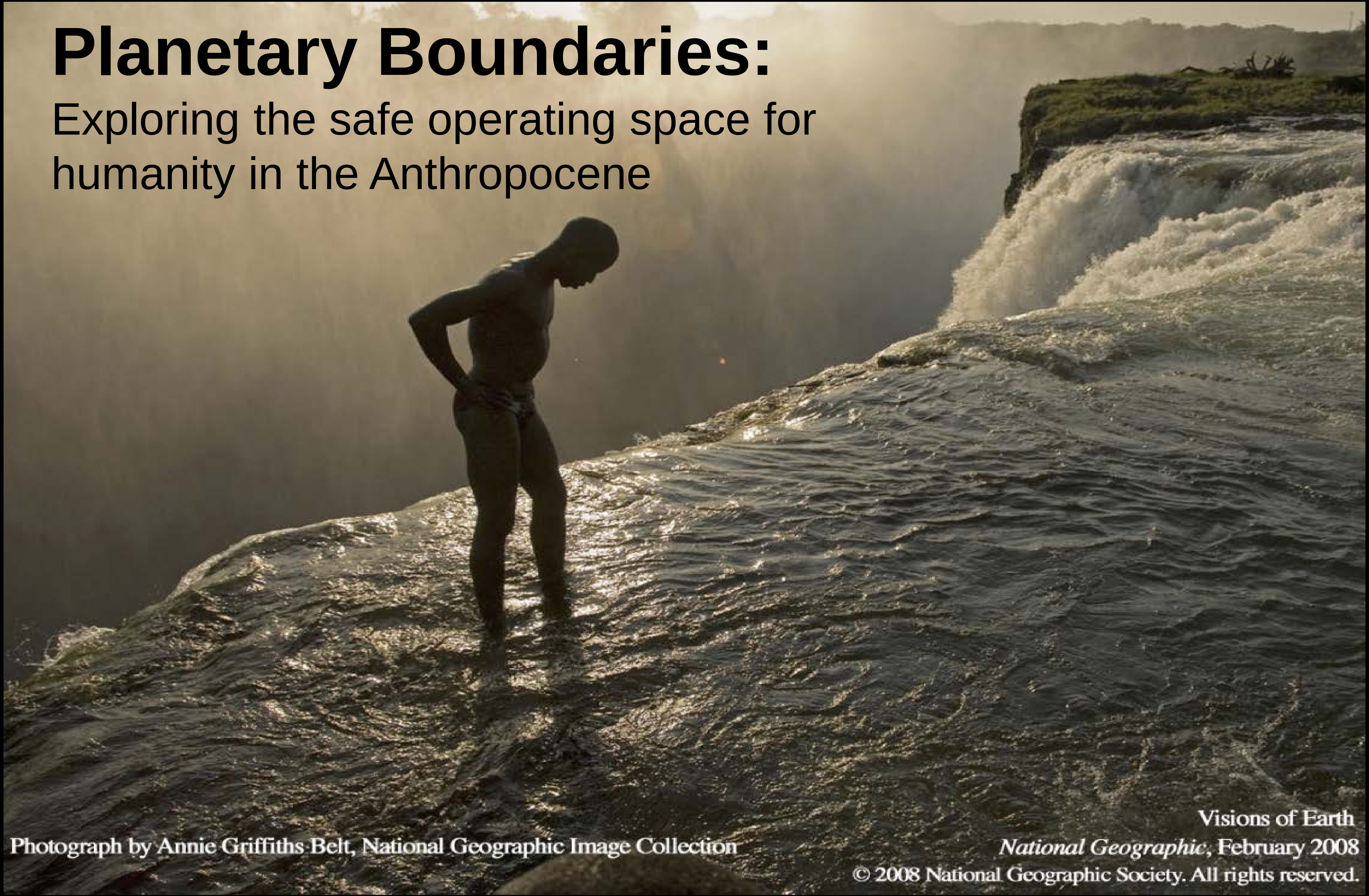


The SE Asian forest feedback



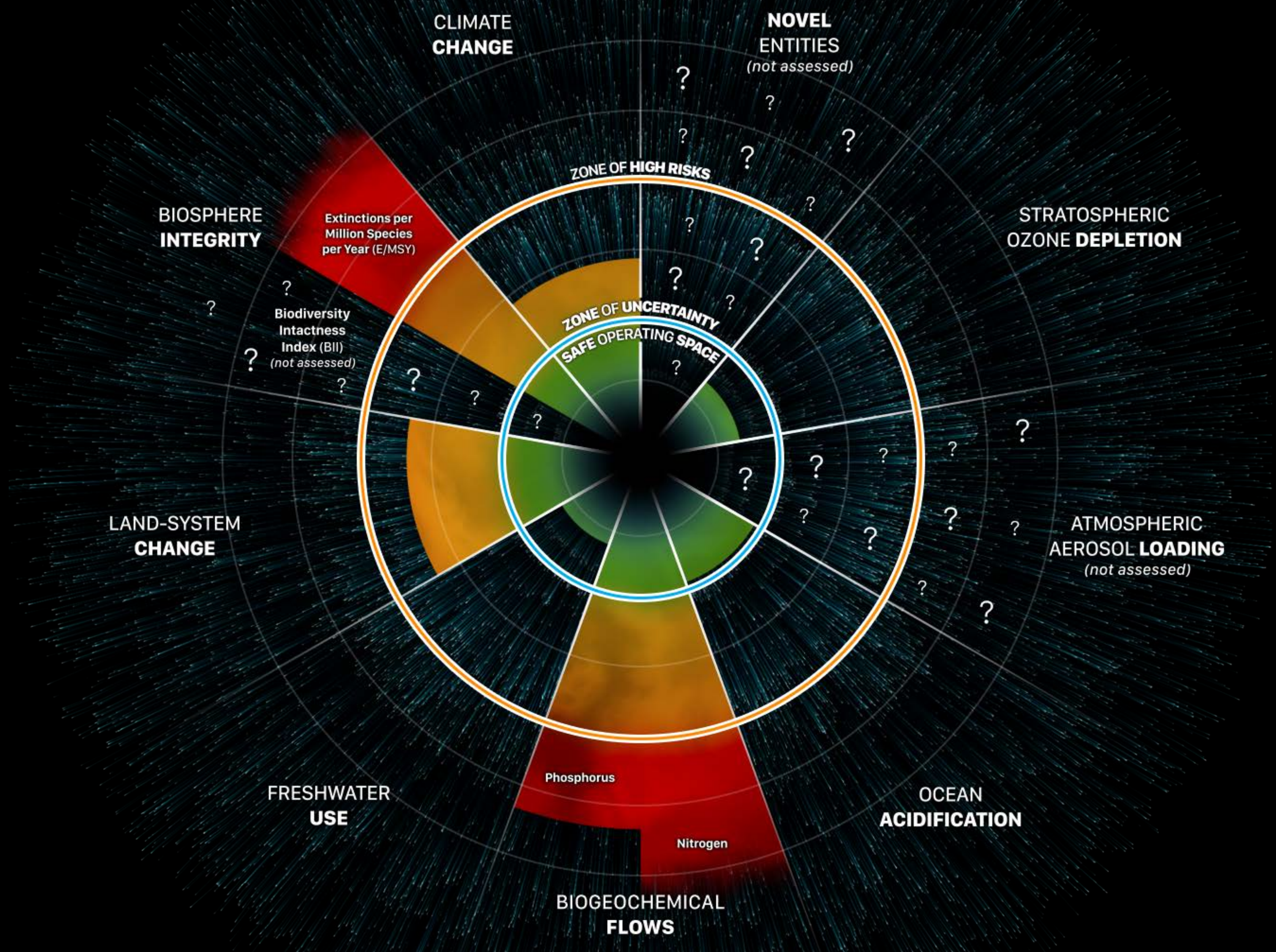
Planetary Boundaries:

Exploring the safe operating space for humanity in the Anthropocene



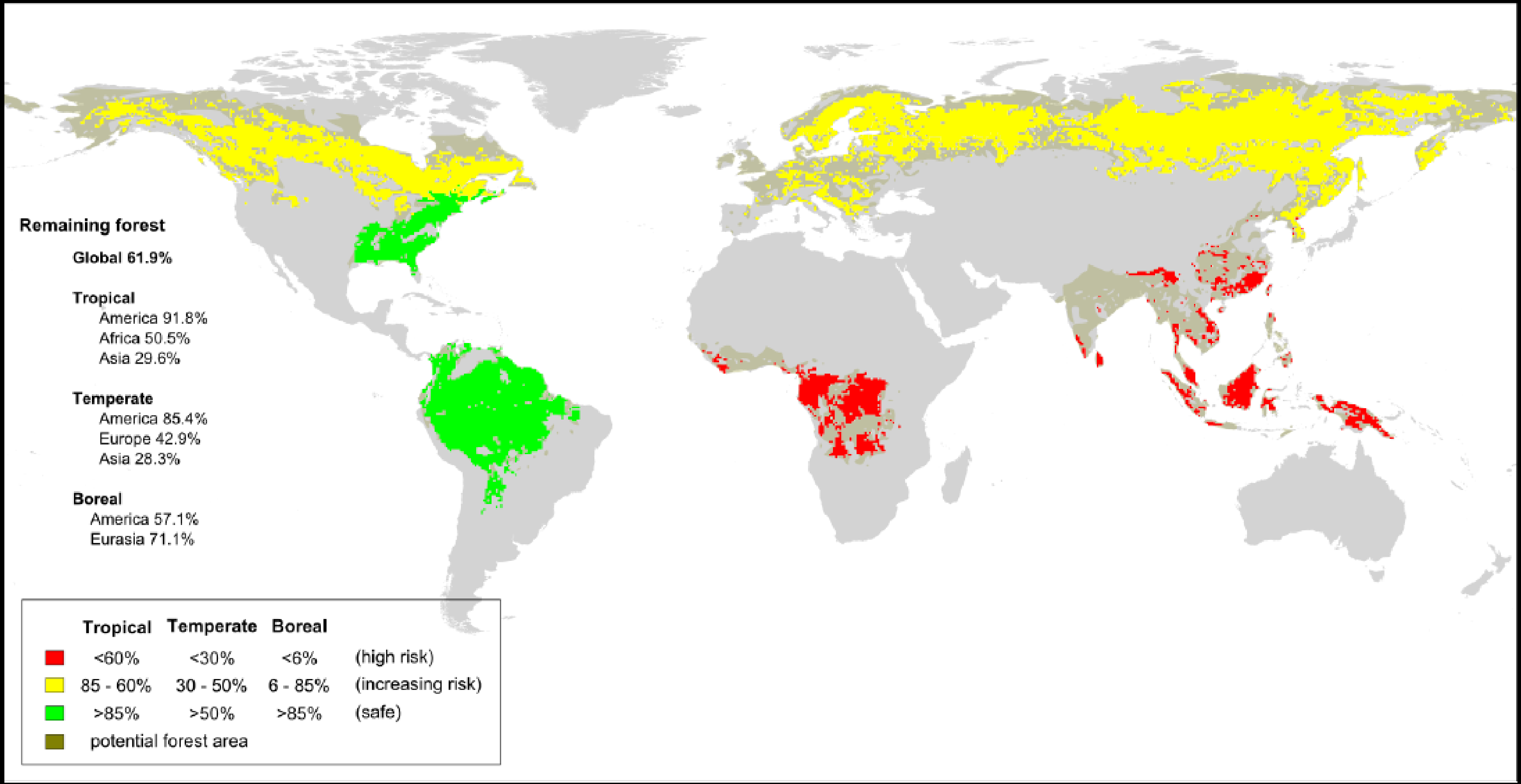
Photograph by Annie Griffiths Belt, National Geographic Image Collection

Visions of Earth
National Geographic, February 2008

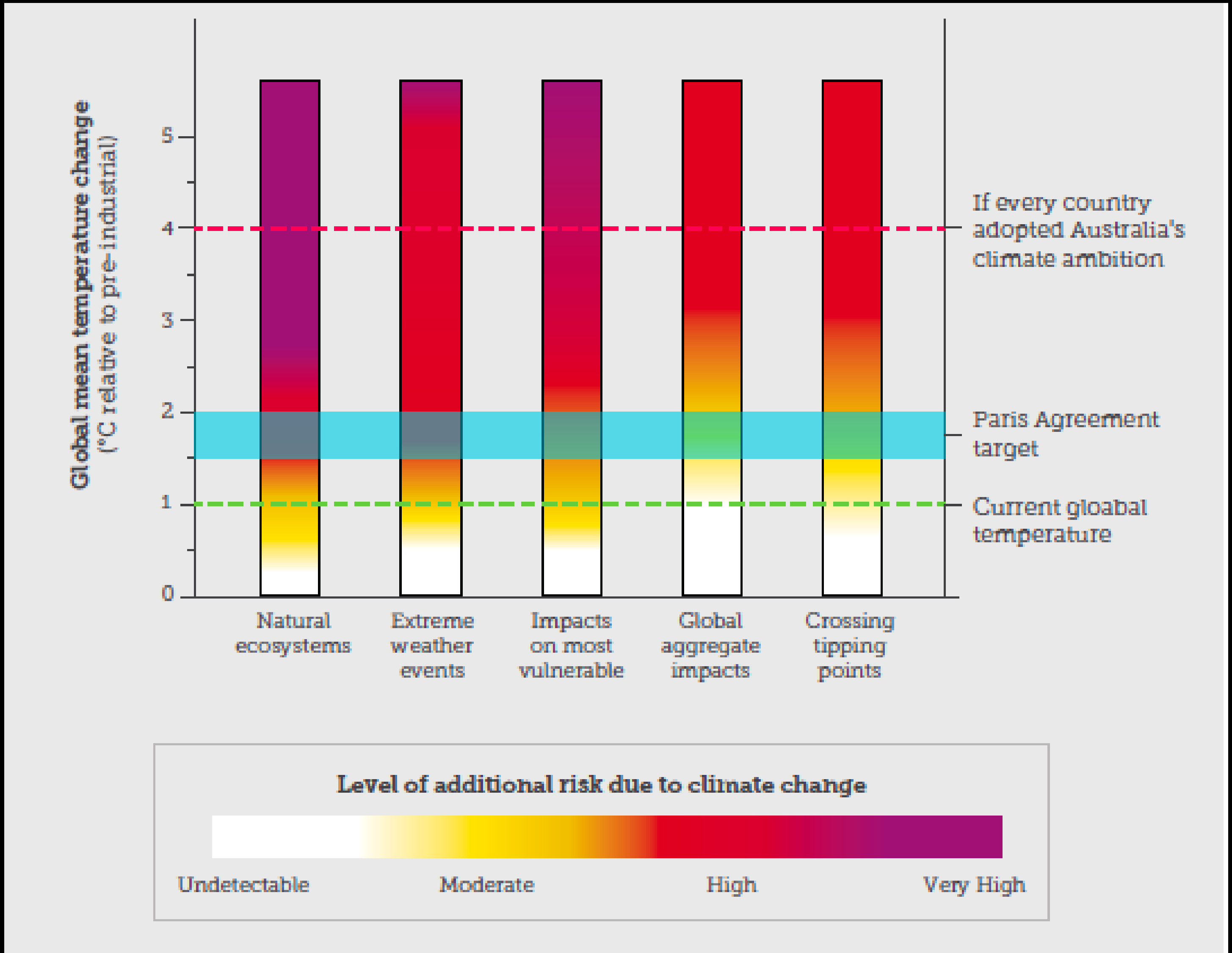


Adapted from Steffen et al. 2015

Land-system change PB:
Amount of forest cover remaining



IPCC "Reasons for Concern"



Adapted from IPCC 2014

IPCC TAR (2001), AR4 (2007), AR5 (2014), Smith et al. (2009)

The Paris 2^{o}C Target: Can We Meet It?

The total carbon budget from 1870 is about 1,000 Gt C (emitted as CO_2) for a 66% probability of meeting the 2^{o}C target.

Cumulative human emissions (fossil fuels, cement, land use) from 1870 through 2018 were about 585 Gt C, leaving 415 Gt C in the budget.

Accounting for non-CO_2 gases (e.g. CH_4, N_2O) reduces the C budget by 210 Gt C.

The remaining budget is 205 Gt C in total.

At current rates 10 Gt C per year at current rates, the budget would last only two decades.

Sources; IPCC AR5 WGI SPM; GCP 2018

Carbon Cycle Feedbacks

Assumption: 2^{o}C temperature rise; no deforestation; estimates of C loss by 2100

- **Amazon dieback could release 25 (15-55) Gt C**
- **Boreal forest dieback could release 30 (10-40) Gt C**
- **Permafrost thawing could release 40 Gt C**
- **Peat fires in Borneo and Sumatra could release more C**

Notes:

1. **Higher temperature rises (e.g. ~3^{o}C) would lead to much higher losses of carbon**
2. **Including the effects of human-driven deforestation would also lead to much higher losses of carbon**
3. **By comparison, current human emissions are ~10 Gt C yr^{-1}**

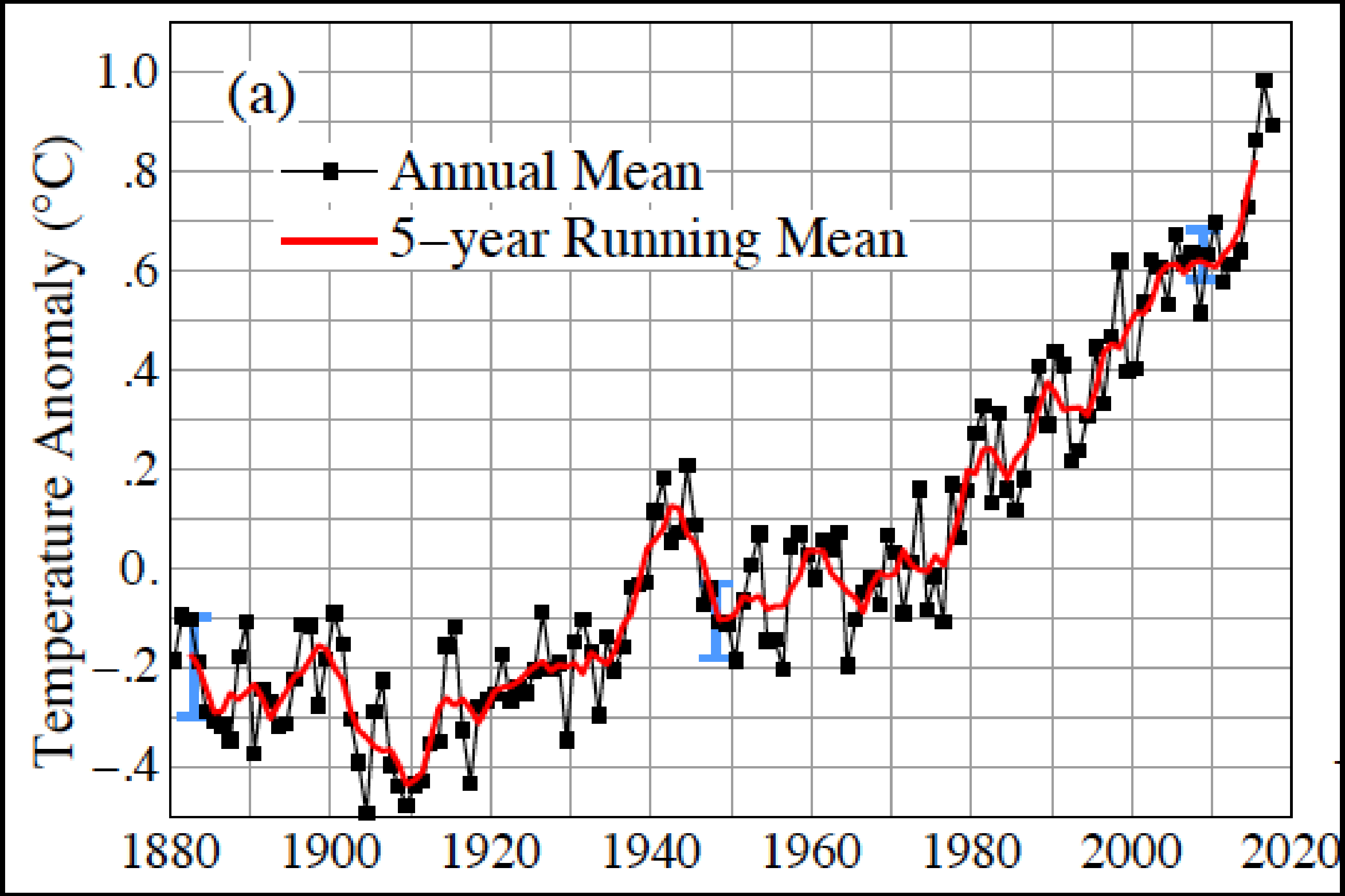
Steffen et al. 2018

Feedbacks from the Amazon, boreal forest-tundra and Borneo/Sumatra regions could release enough carbon to cut the 2ºC carbon budget in half – down to ~100 Gt C, or about 10 years of emissions.

Key finance/investment decisions could make the difference between meeting the Paris climate targets or not.

Climate Change 2017

Global Average Temperature Anomaly, 1880-2017

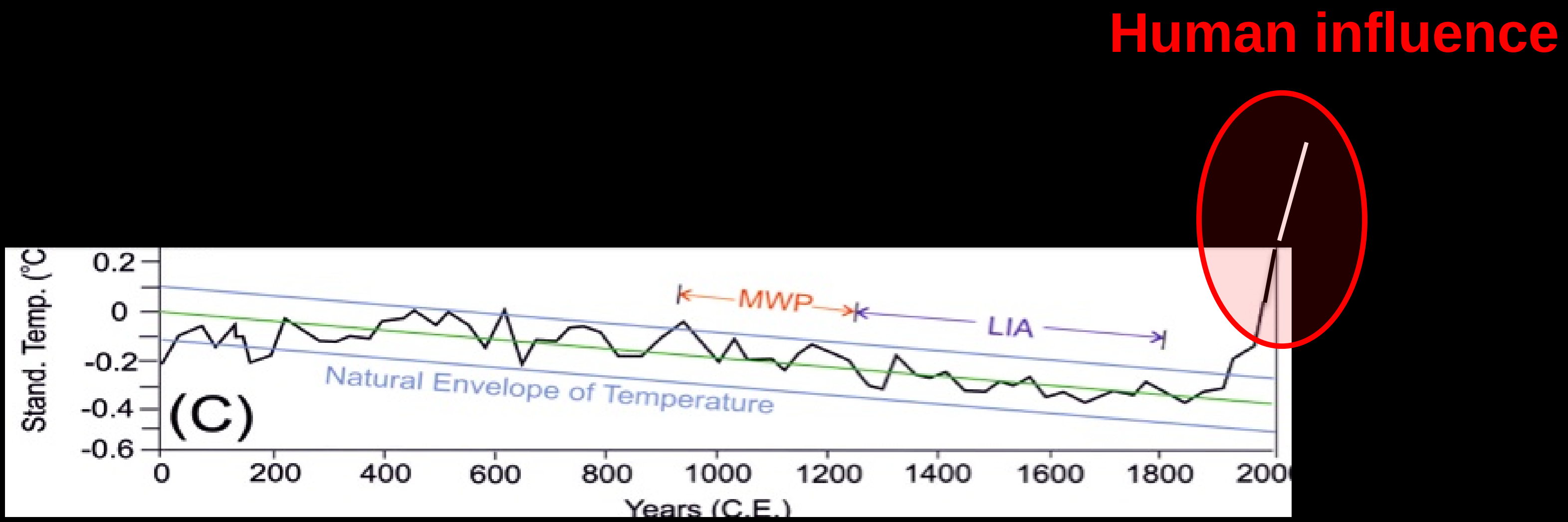


Baseline is 1951-1980

NASA 2018

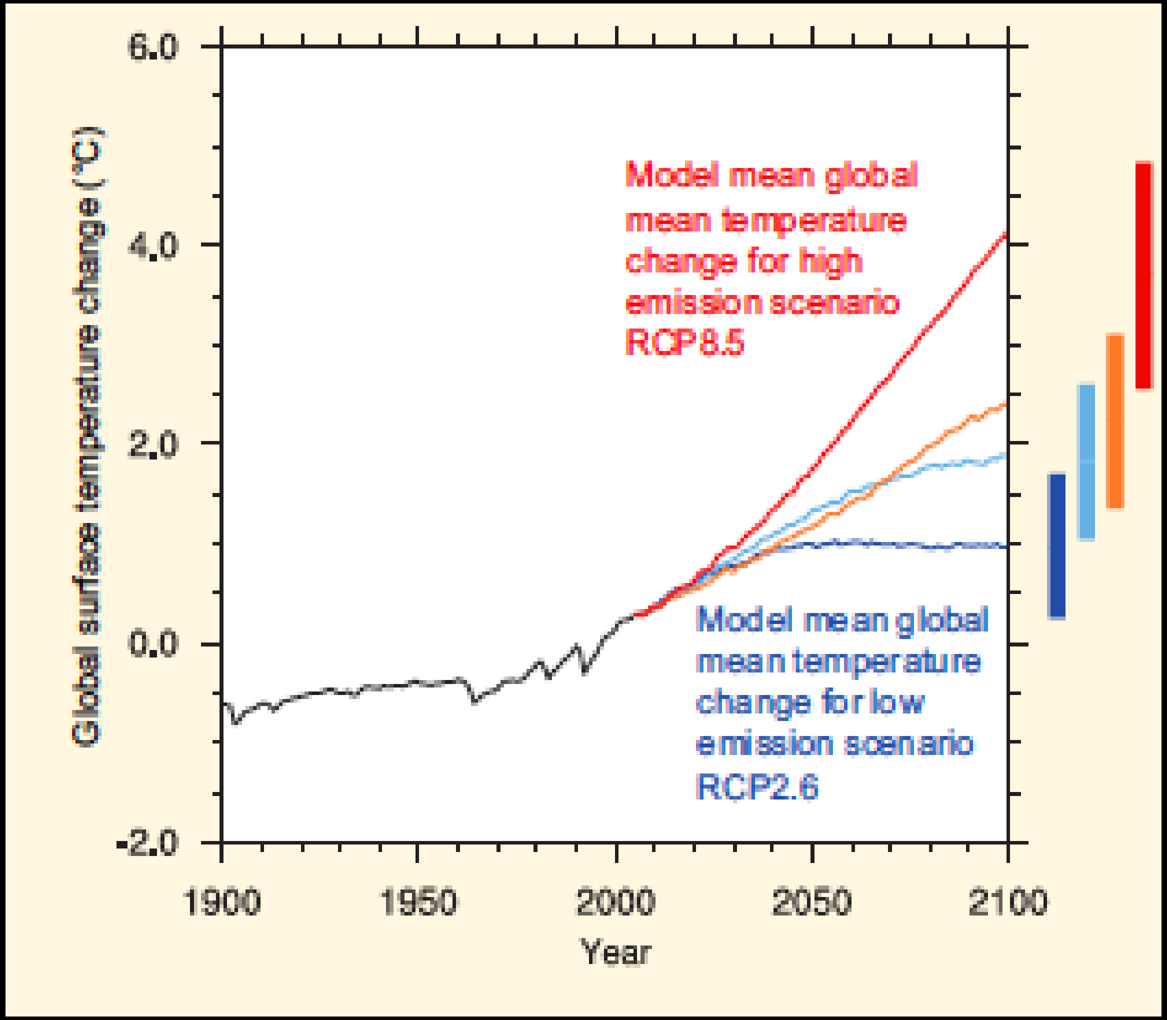
An Earth System Perspective

Temperature rise:
Beyond the envelope of natural variability!

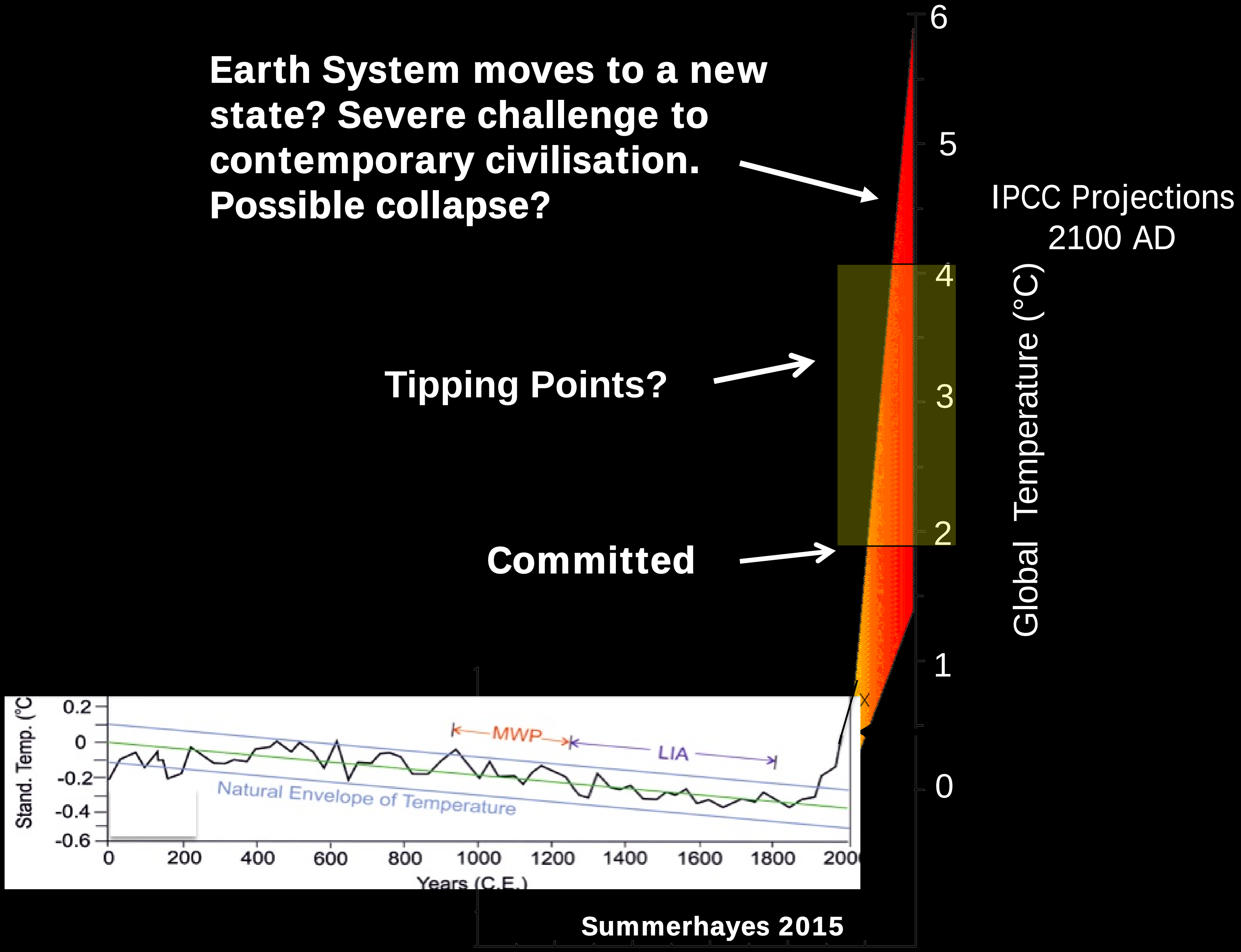


Summerhayes 2015

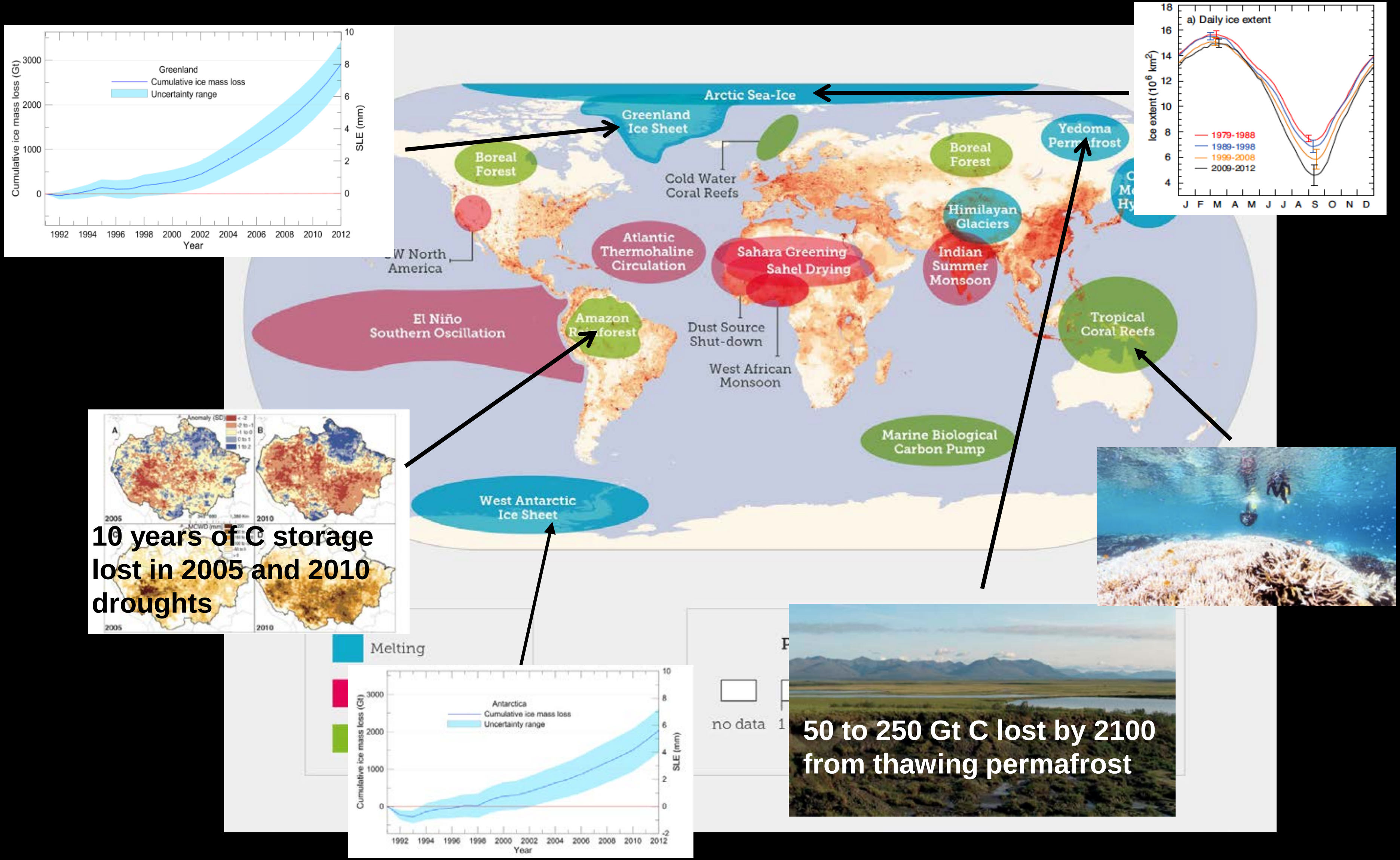
IPCC temperature projections



IPCC 2013

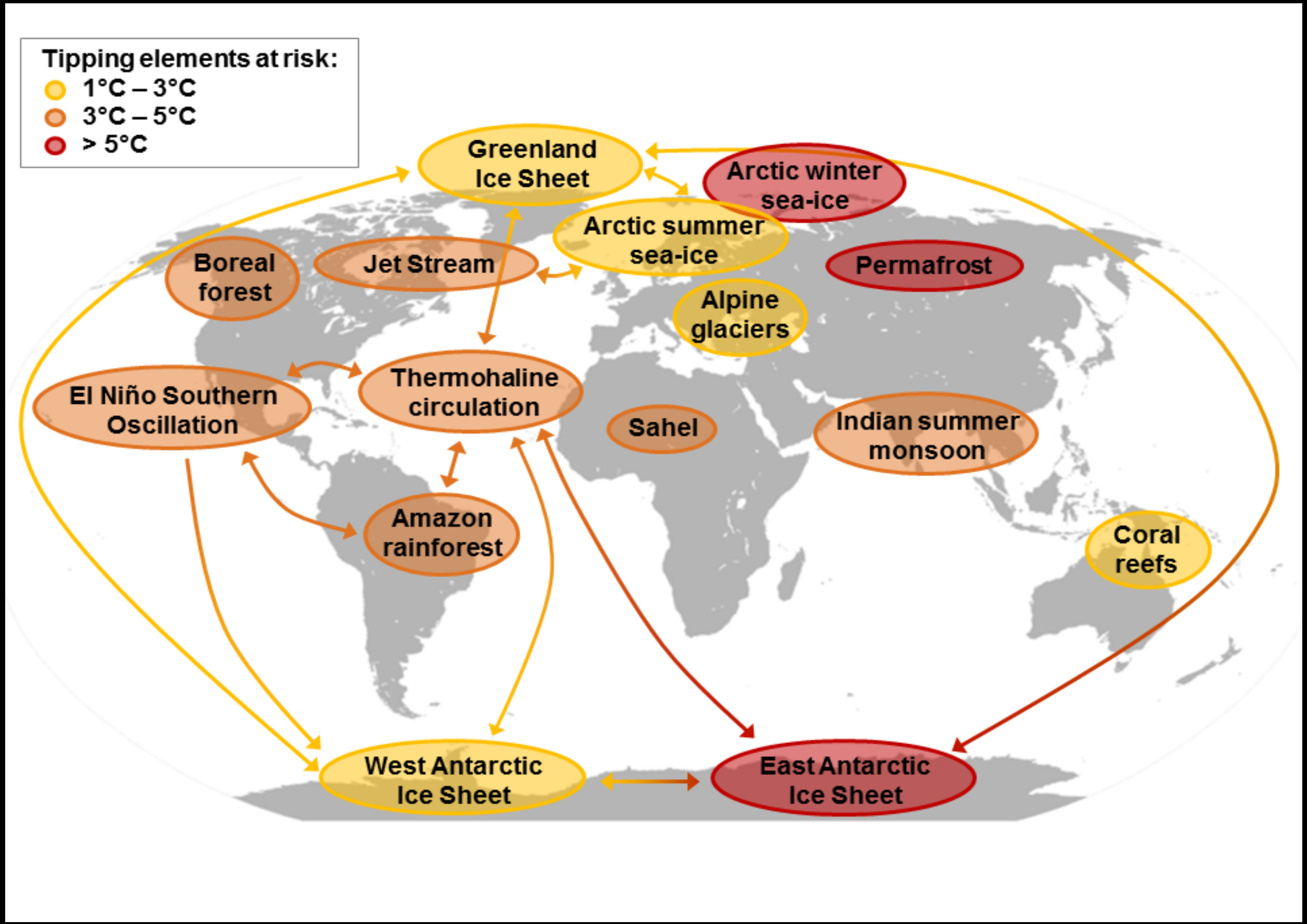

Earth System moves to a new state? Severe challenge to contemporary civilisation. Possible collapse?
Tipping Points?
Committed
IPCC Projections
2100 AD
Global Temperature (°C)
6
5
4
3
2
1
0
Stand. Temp. (°C
0.2
0
-0.2
-0.4
-0.6
MWP
LIA
Natural Envelope of Temperature
0
200
400
600
800
1000
1200
1400
1600
1800
Years (C.E.)
Summerhayes 2015

Tipping Elements in the Earth System



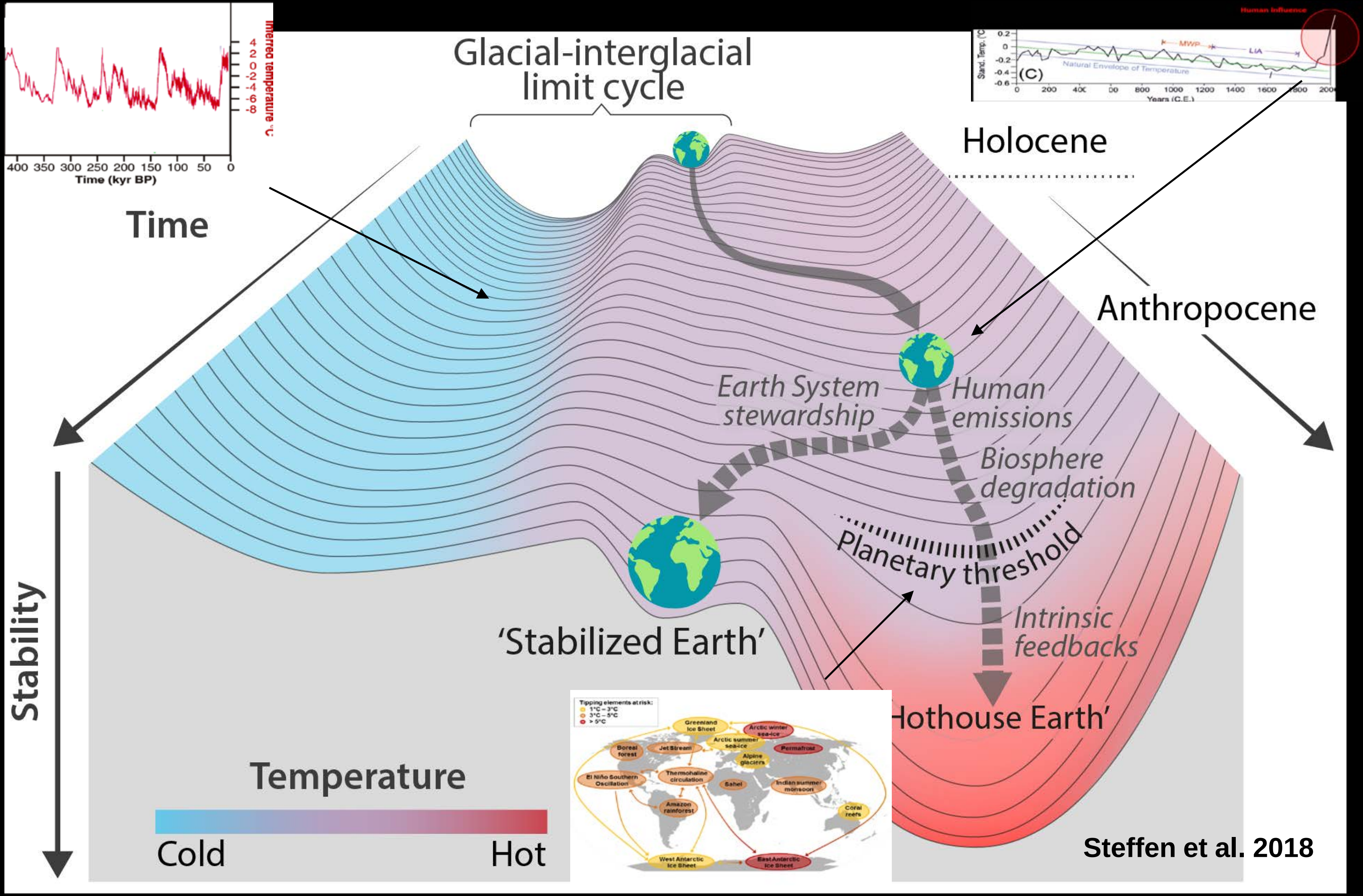
Huber, Lenton, and Schellnhuber, in Richardson et al. 2011

Tipping Cascades



Source: J. Donges and R. Winkelmann in Steffen et al. 2018

Earth System Trajectories

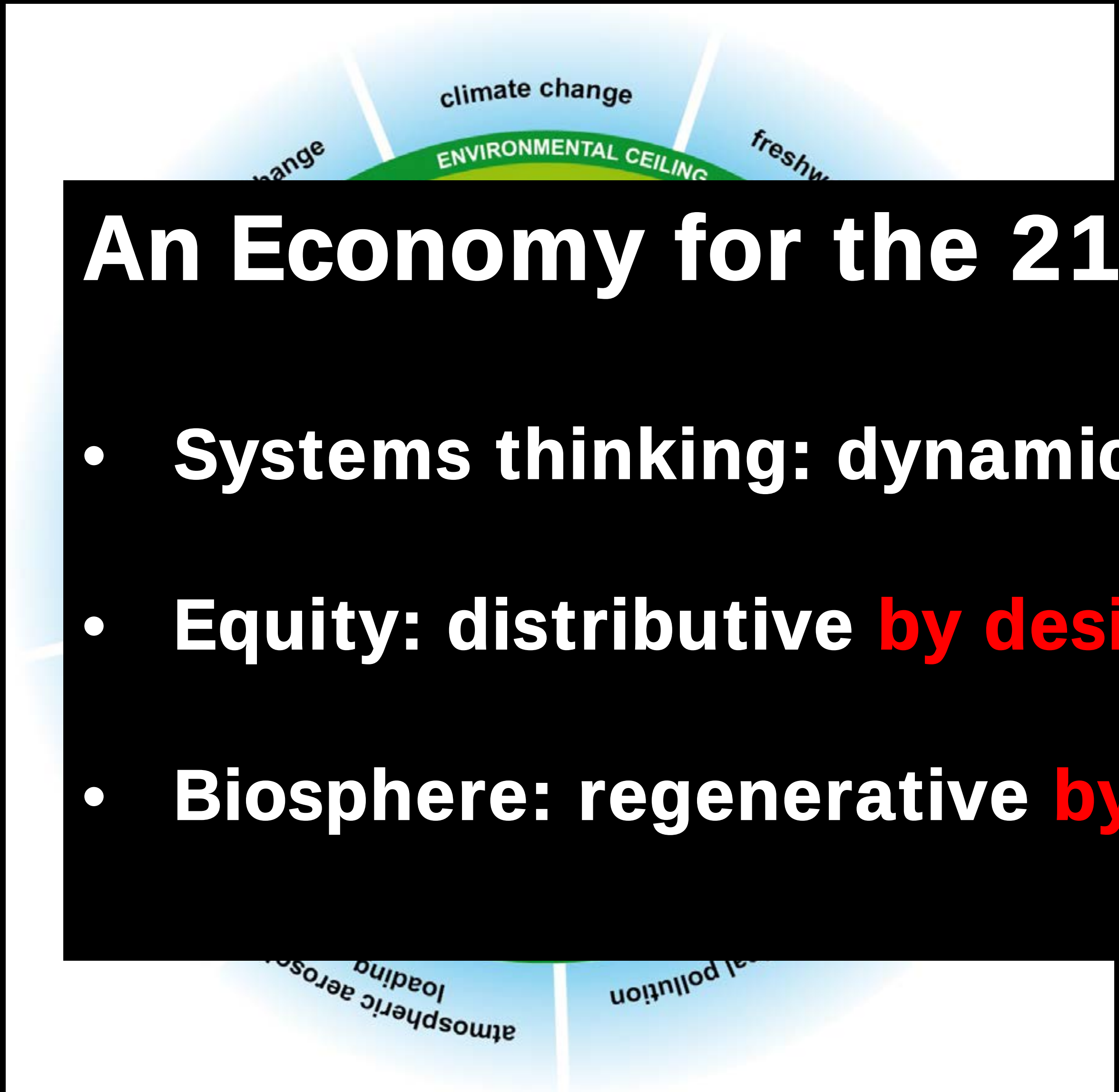


Steffen et al. 2018

Is ‘Hothouse Earth’ inhabitable?

- Most of the tropics and subtropics will be too hot for human habitation.
- Changing temperature & rainfall patterns will likely make current large agricultural zones unproductive.
- Sea-level rise of 20-40 m ultimately likely, drowning coastal cities, agricultural areas and infrastructure.
- Maximum carrying capacity of ~1 billion humans (today’s population is 7.5 billion)

The ‘Doughnut’: a safe and just space for humanity



An Economy for the 21st Century

- **Systems thinking: dynamic complexity**
- **Equity: distributive by design**
- **Biosphere: regenerative by design**

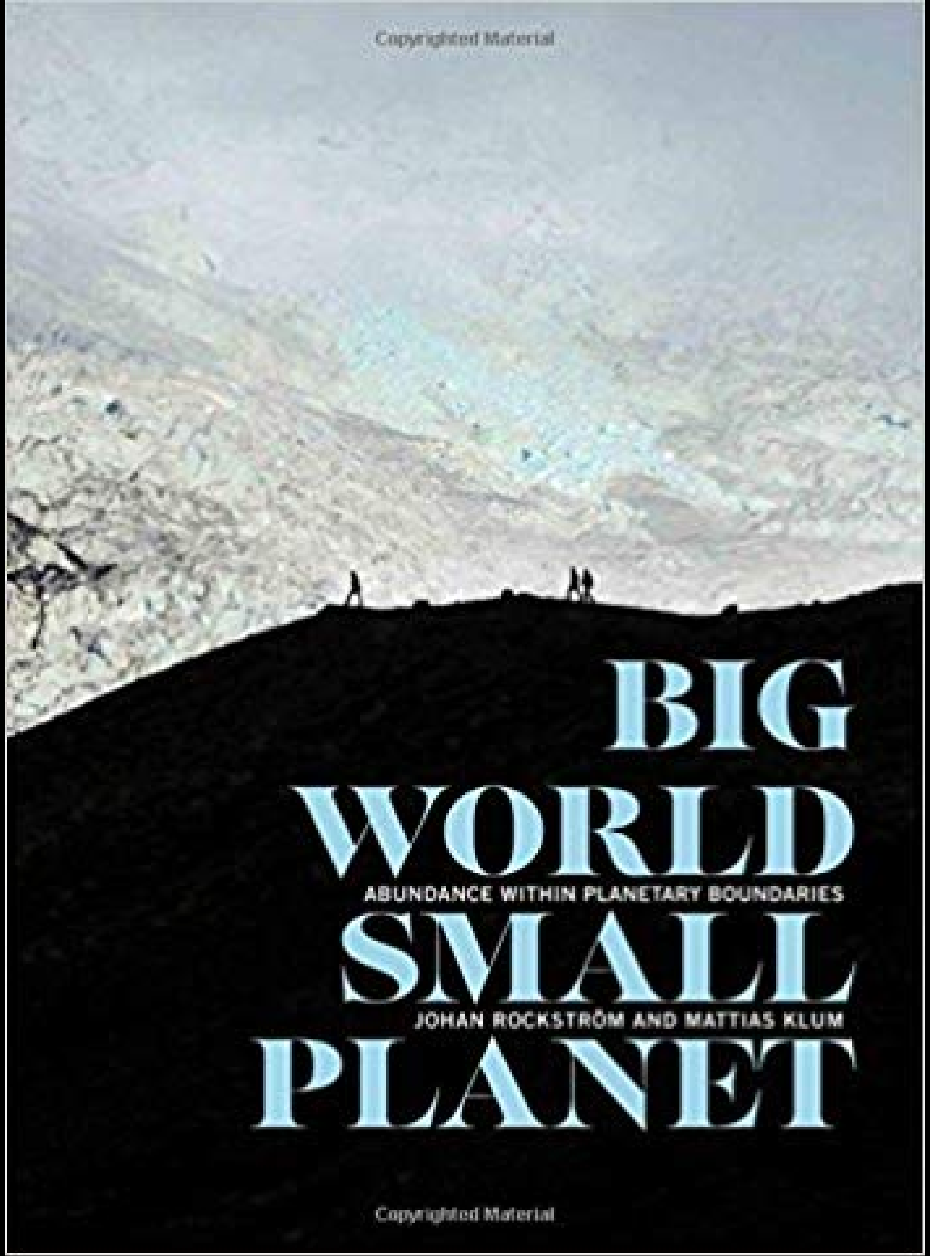
Conclusions

Boreal forests, SE Asia tropical forests and the Amazon basin are all important tipping elements/feedbacks in the Earth System. Together they could 'make or break' the Paris climate agreement .

Halting deforestation of these regions is also critical for avoiding the Earth's sixth great extinction event.

The finance sector has an absolutely crucial role to play in keeping these 'Sleeping Giants in the Earth System' asleep (or putting them back to sleep).

Halting deforestation is the necessary first step in moving from an exploitative to a regenerative global economy.



Johan Rockström and Matthias Klum