Brasilian Academy of Science
Reunião Magna - Museu do Amanhã
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The role of science in climate change and on the implementation of the sustainable development goals

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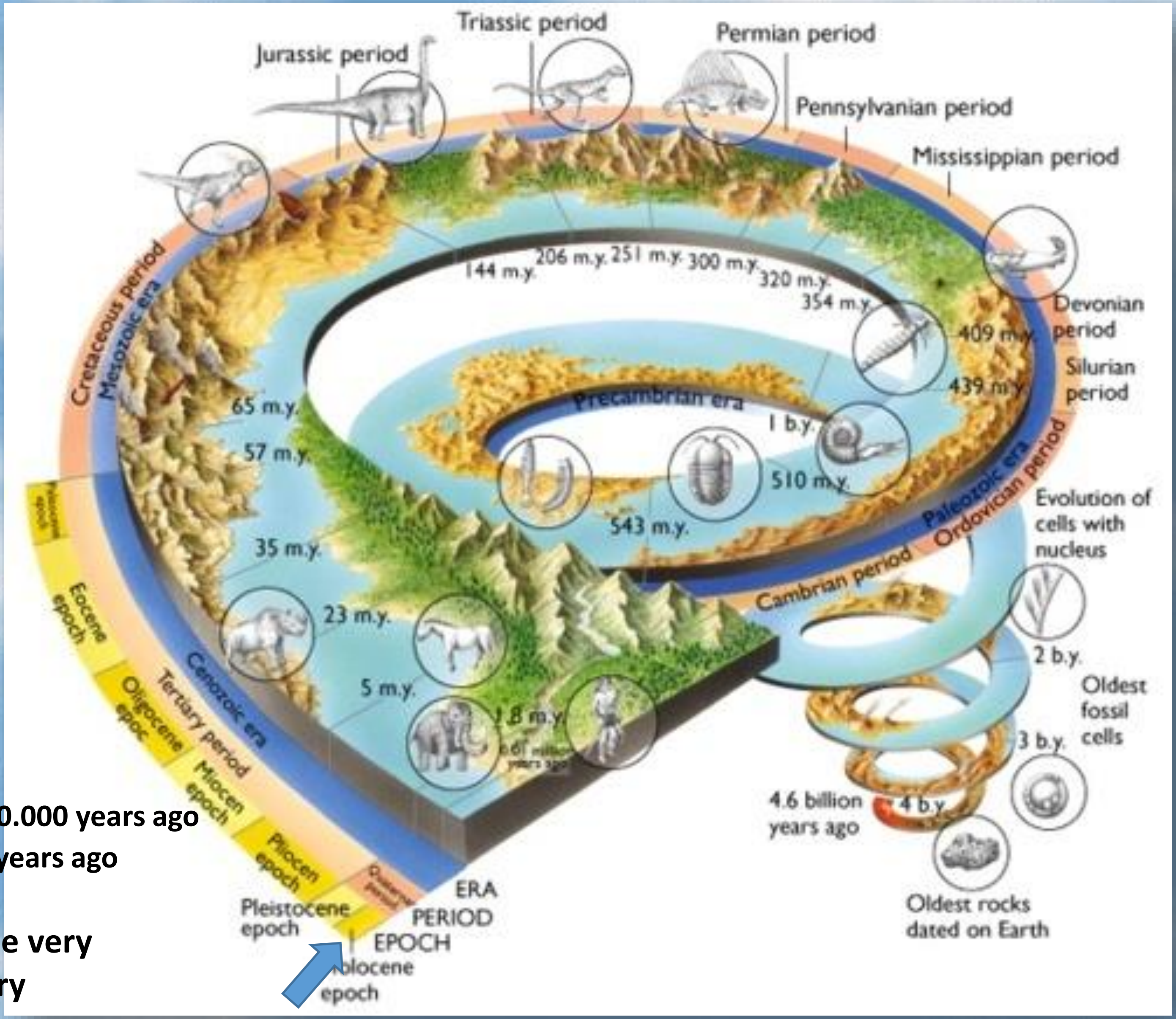
Strong linkages between climate and achievement of the Sustainable Development Goals

There are synergies and trade-offs in terms of climate costs on implementing the Sustainable Development Goals

Direct linkages are shown with bold arrows, indirect linkages with light arrows.

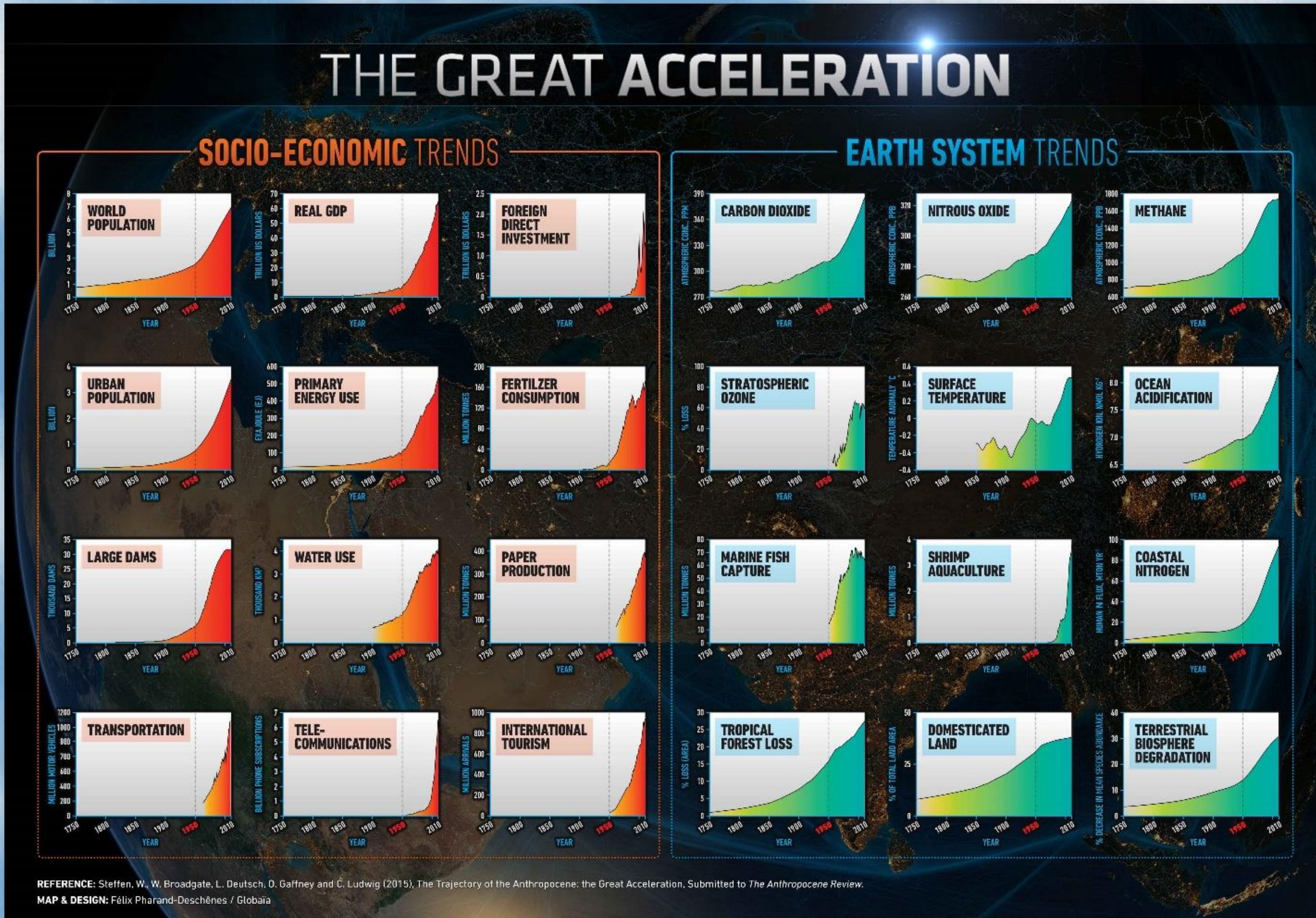
The joint evolution of life, geology and climate in our planet



Homo sapiens in Africa: ~ 200.000 years ago
Holocene: Started at 11.700 years ago

Humans are present in the very last second in Earth history

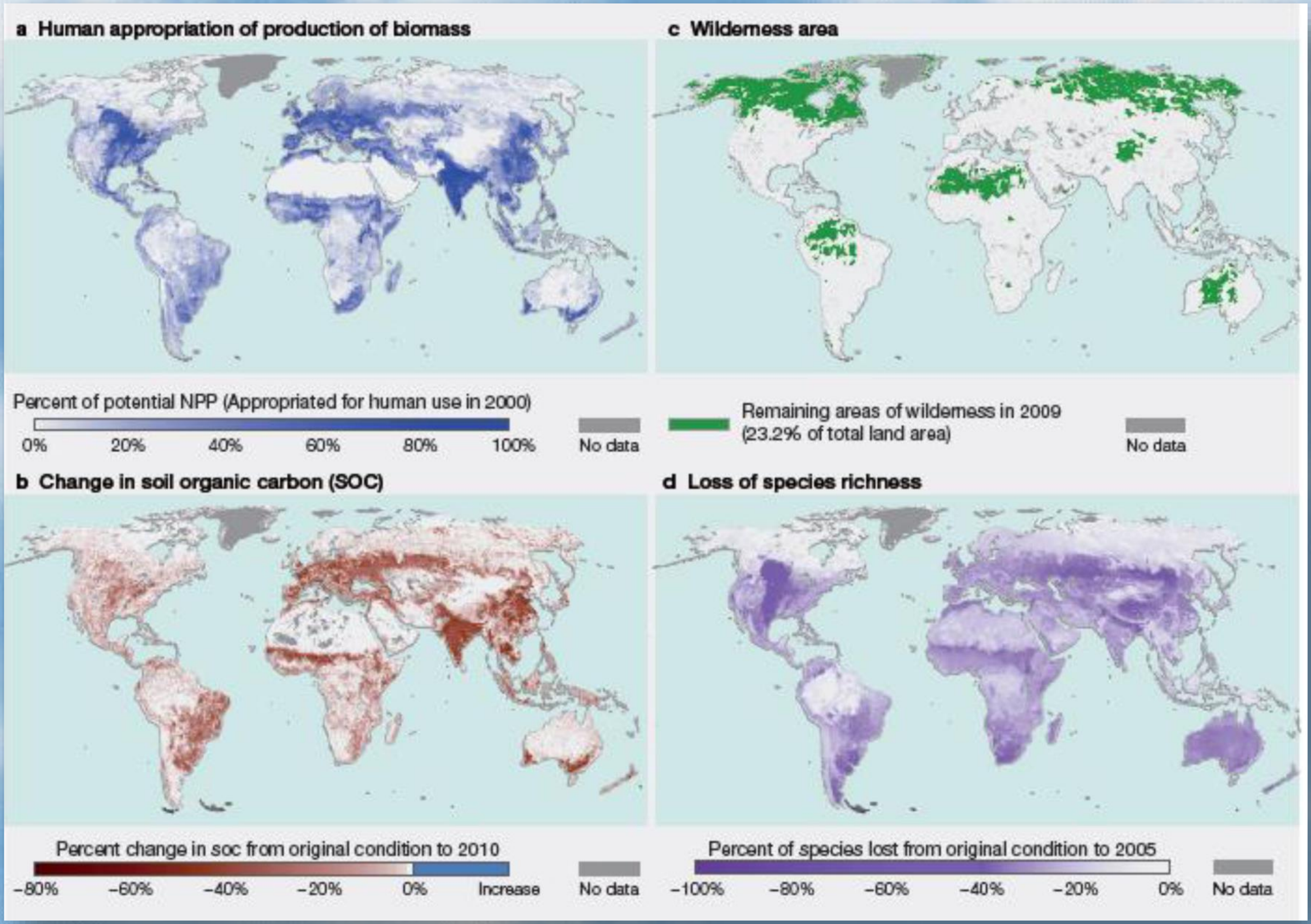
We are changing the face of our world very quickly and in many ways



Which will be the impacts in our society of these changes?

Will Stefan, 2015

Impact of human activity on our planet



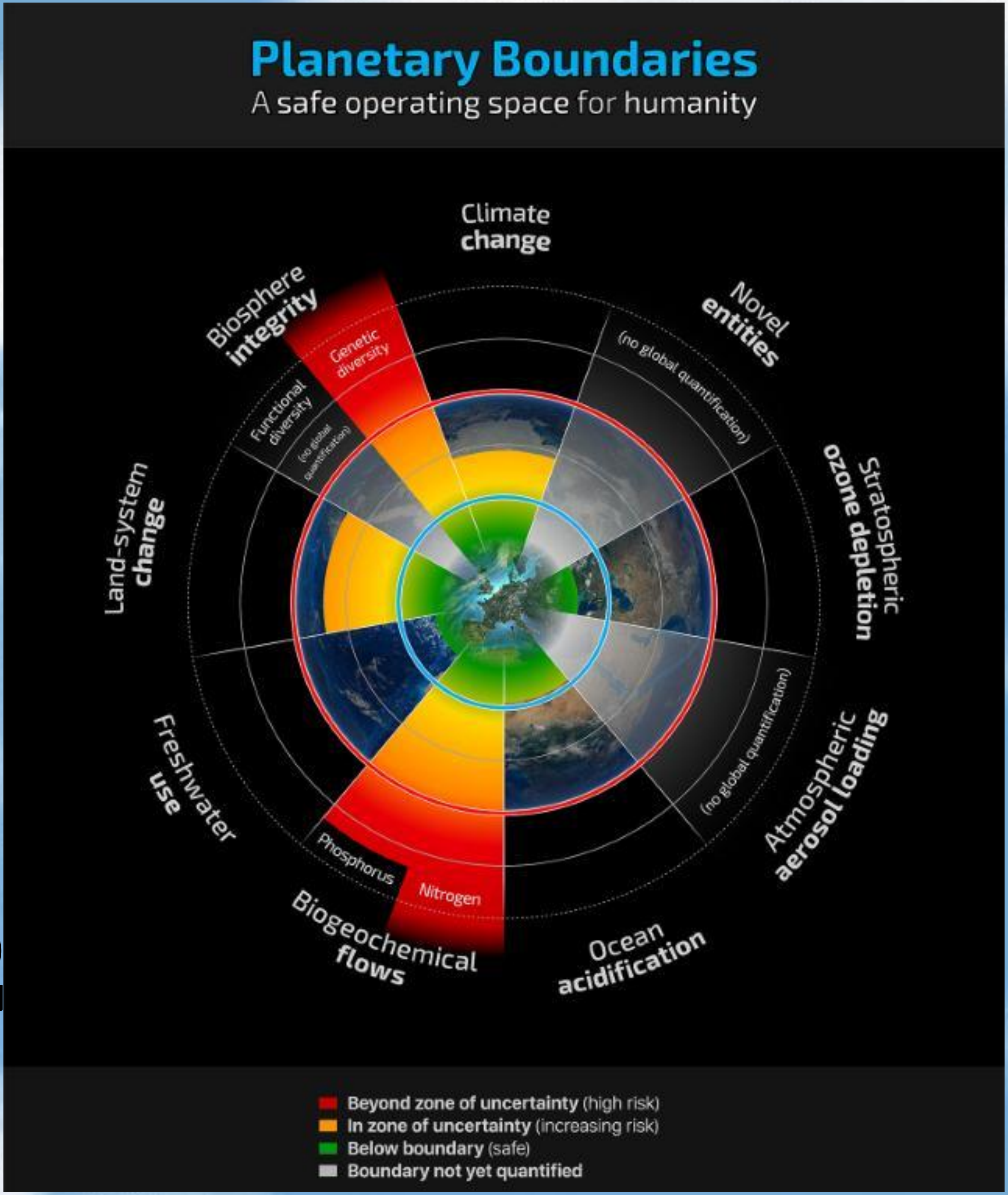
IPBES, 2018

Planetary boundaries: Where is the safe space for humanity?

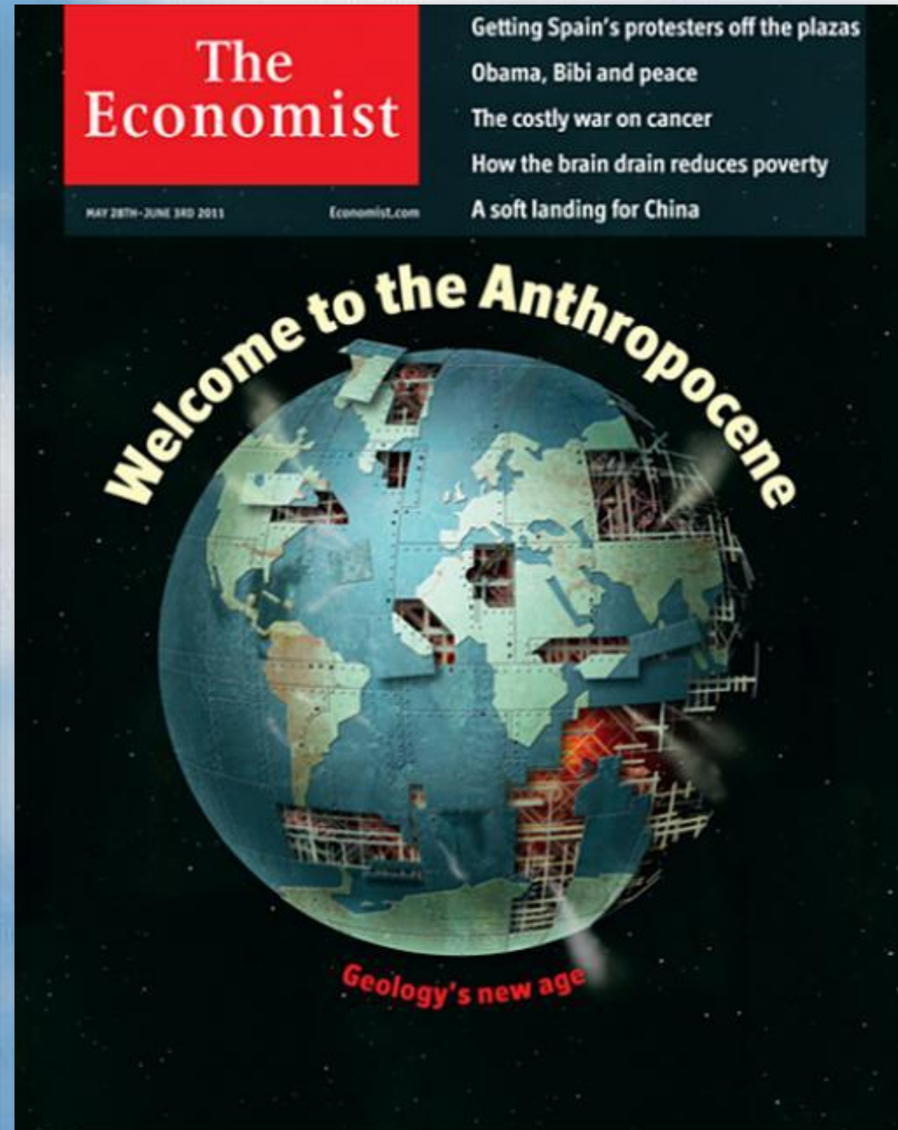
9 Boundaries identified

4 transgressed:

- Climate
- Biosphere integrity
- Land use (deforestation)
- Biogeochemical flows (N and P fertilizer use)



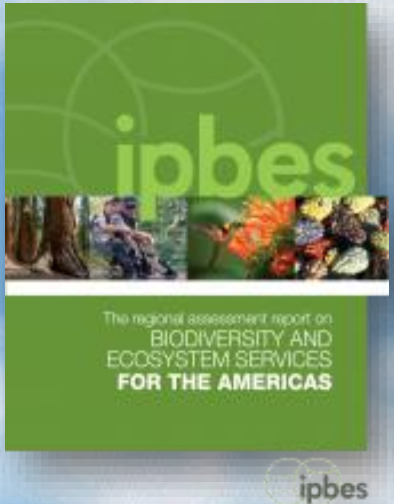
Science Feb 2015

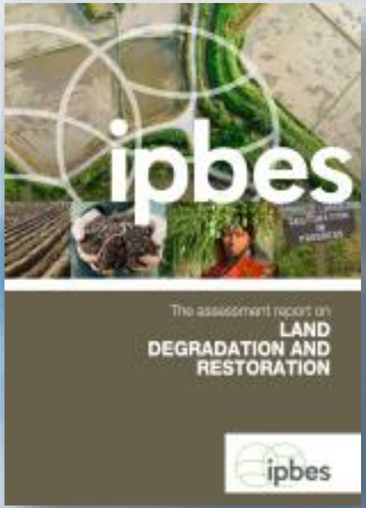


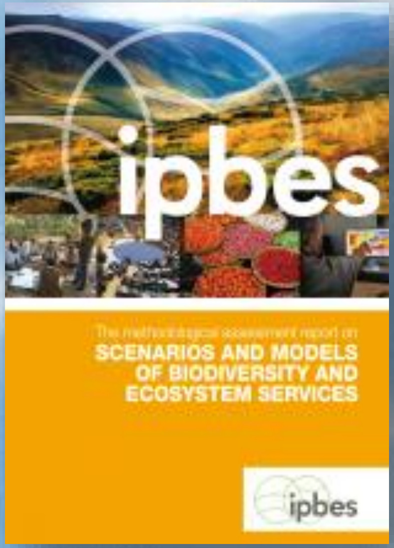
The Anthropocene is a time when humans and our civilization became a major geophysical planetary force

The Economist, 2011

VEJA magazine this week: IPBES Report







UN environment
United Nations Environment Programme

MARCAS DA DESTRUIÇÃO

O levantamento da ONU compilou 15 000 estudos para retratar a dimensão da devastação ambiental decorrente da civilização. Conheça as principais causas e consequências das ações promovidas pela humanidade ao longo das últimas cinco décadas

AS CAUSAS...

75%
do ambiente terrestre foi severamente alterado por atividades humanas

66%
das áreas marinhas também foram atingidas

60 bilhões
de toneladas de recursos são extraídas da natureza anualmente, em todo o mundo – o dobro do que era retirado em 1980

30%
foi a redução dos hábitats continentais devido à deterioração provocada pela sociedade

...E AS CONSEQUÊNCIAS

1 milhão
de espécies de animais e plantas estão sob ameaça de extinção

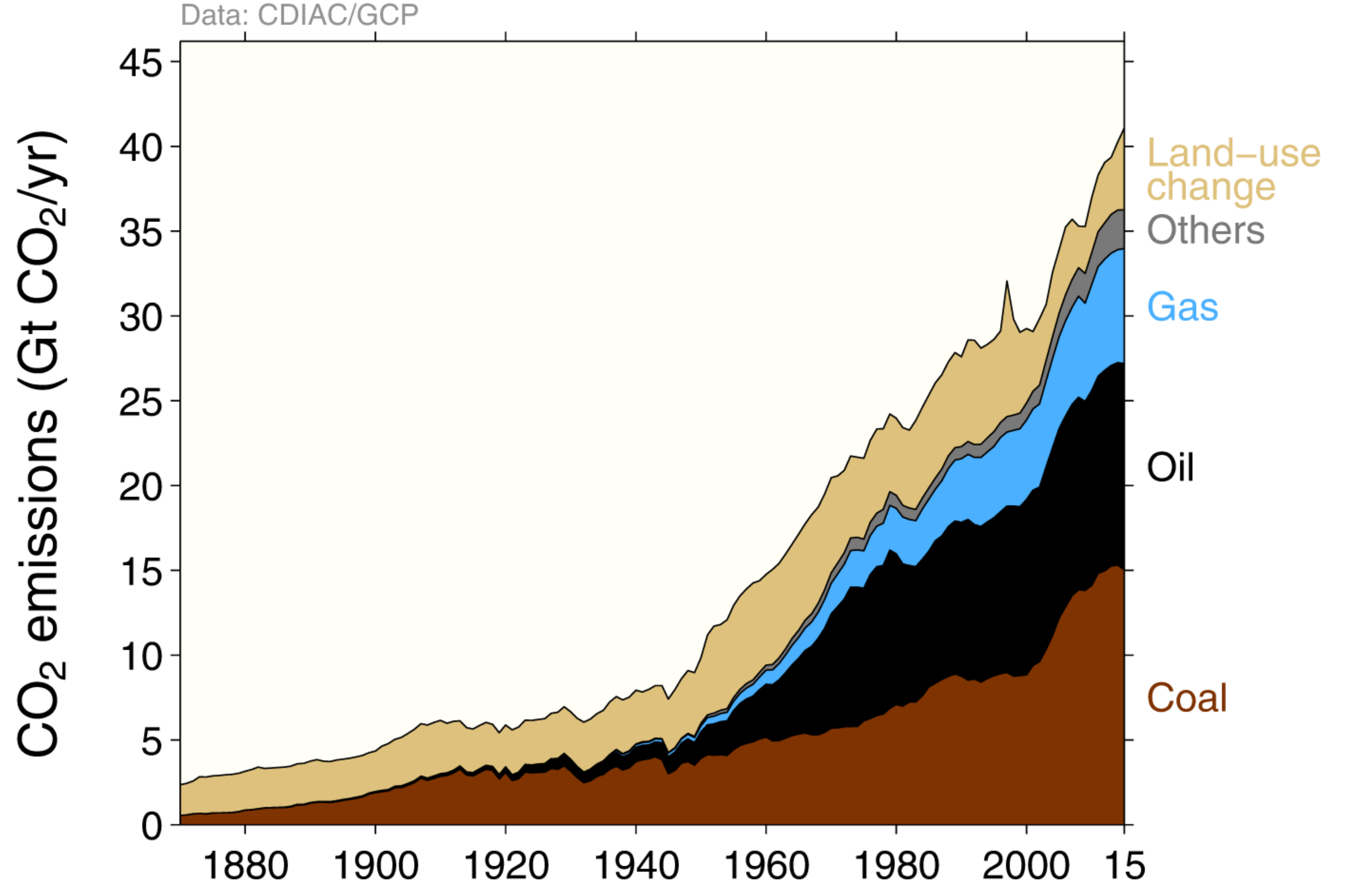
47%
dos mamíferos terrestres foram impactados direta e negativamente pela mudança climática

40%
dos anfíbios podem desaparecer

33%
dos corais, dos tubarões e dos mamíferos marinhos correm risco de extinção

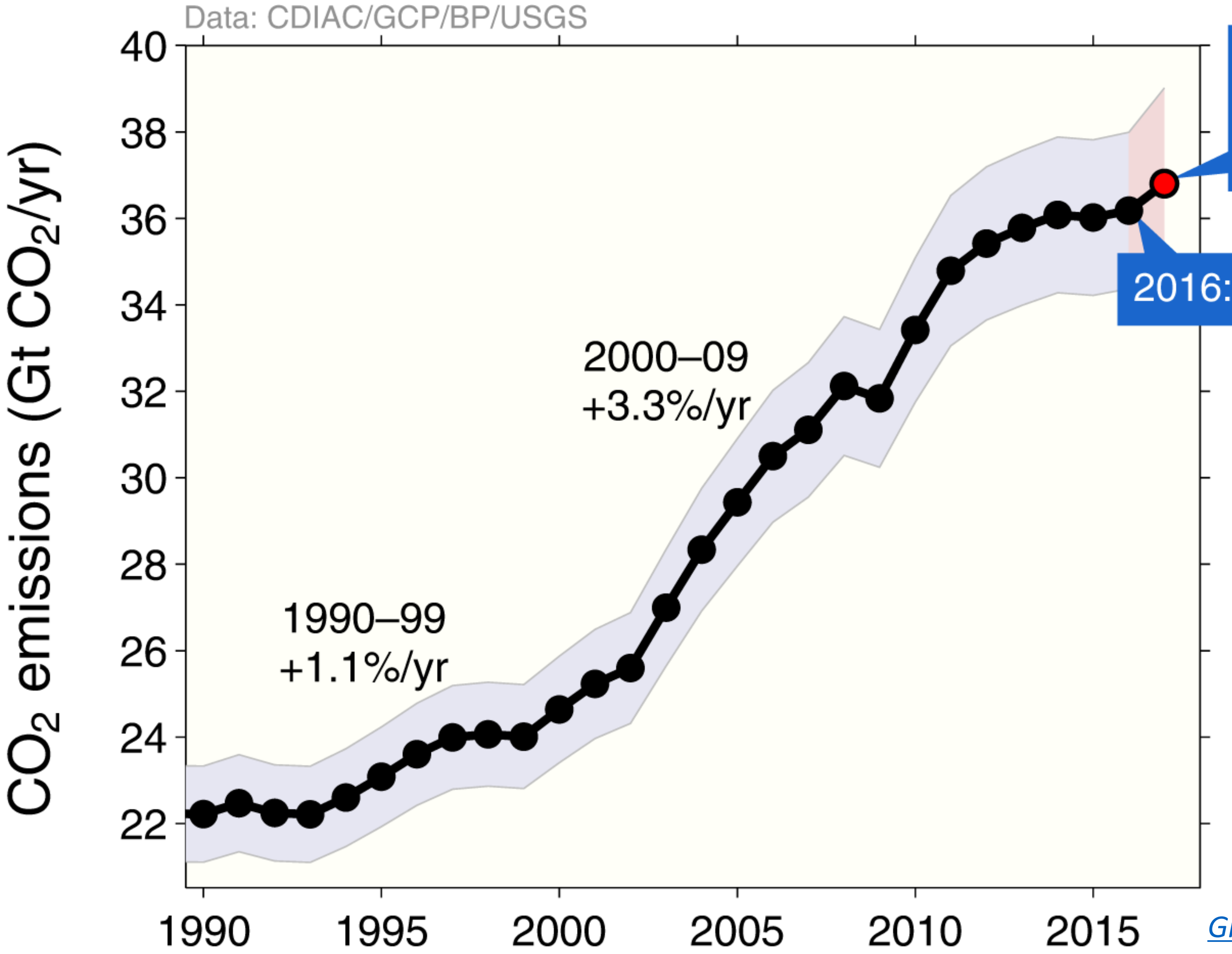
9%
das espécies terrestres certamente não sobreviverão nas próximas décadas sem a restauração de seus hábitats

Carbon emissions from 1870 to today: Energy from fossil fuel dominates



Source: Global Carbon Project 2016

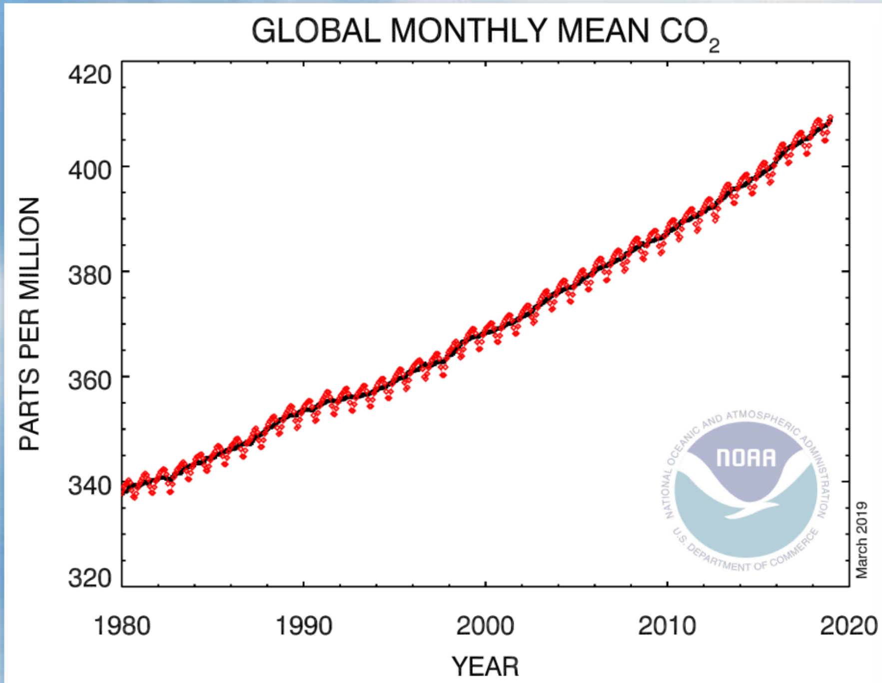
Global emissions from fossil fuel and industry: 36.8 GtCO_2 in 2017, 62% over 1990



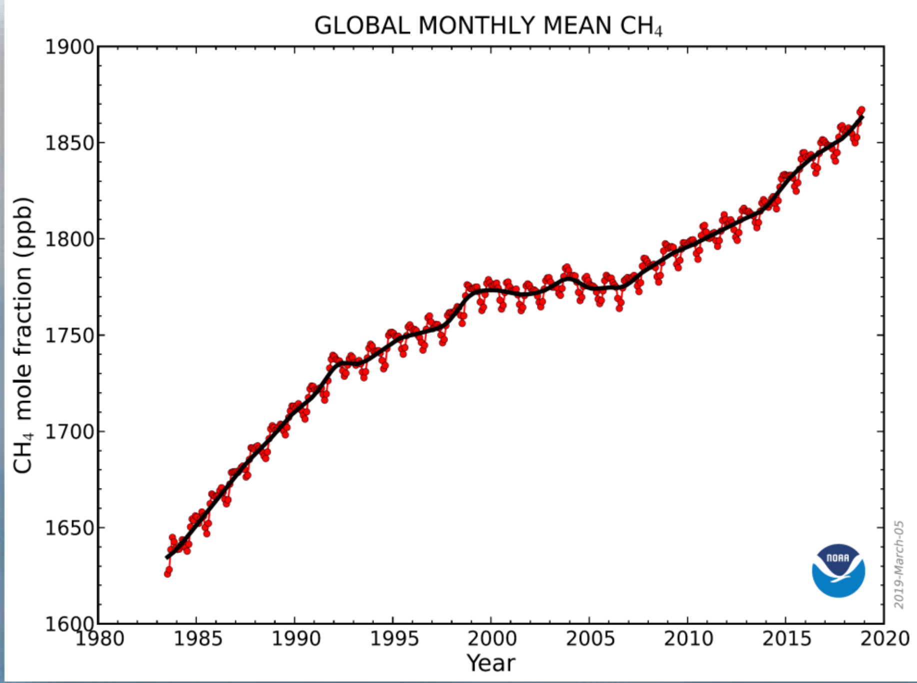
Global Carbon Budget 2017

Increase in the concentration of carbon dioxide (CO_2) and methane (CH_4)

CO_2: increase from 280 ppm to 404 ppm

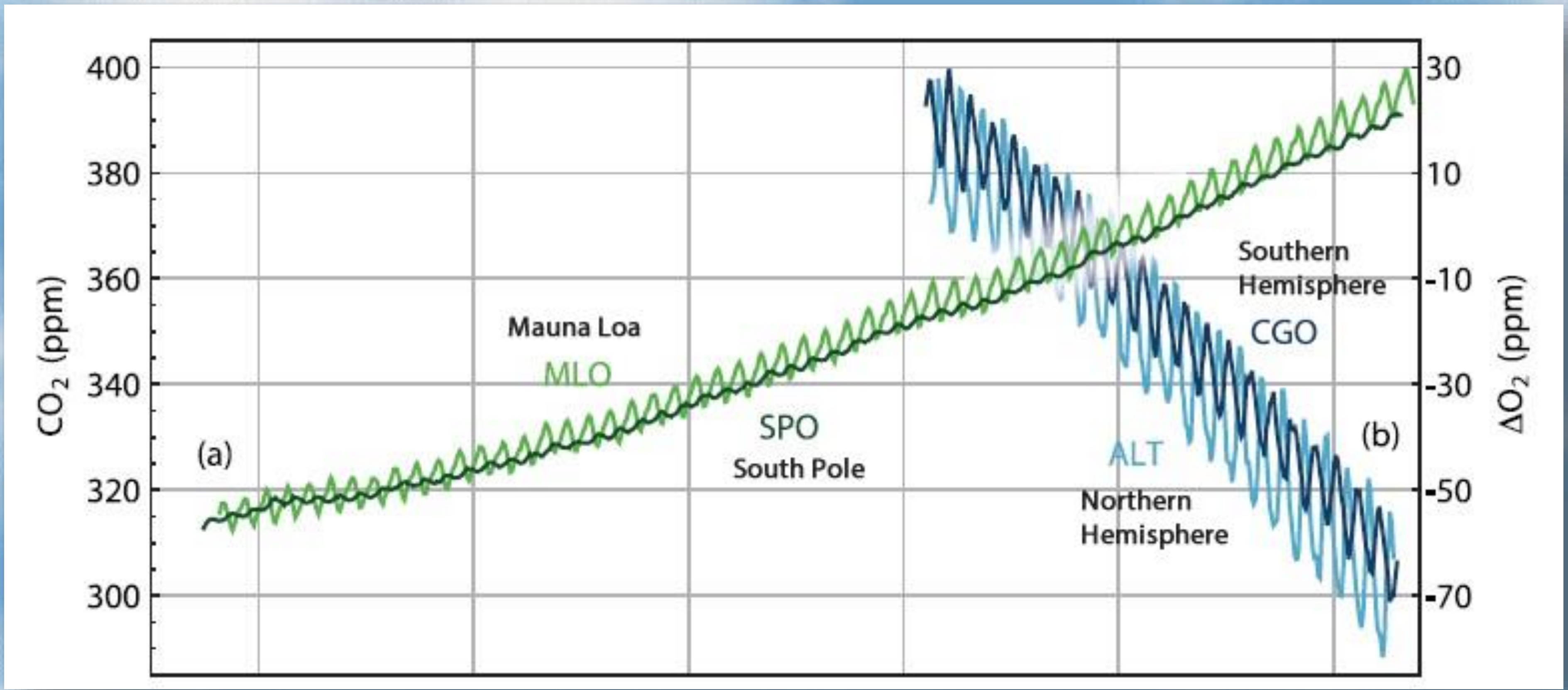


CH_4: increase from 650 ppb to 1865 ppb



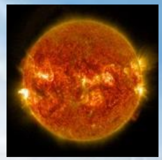
Yesterday at Mauna Loa CO_2 reached 415 ppm, the highest value in the last 3 millions years.

Increase in CO_2 and reduction in O_2

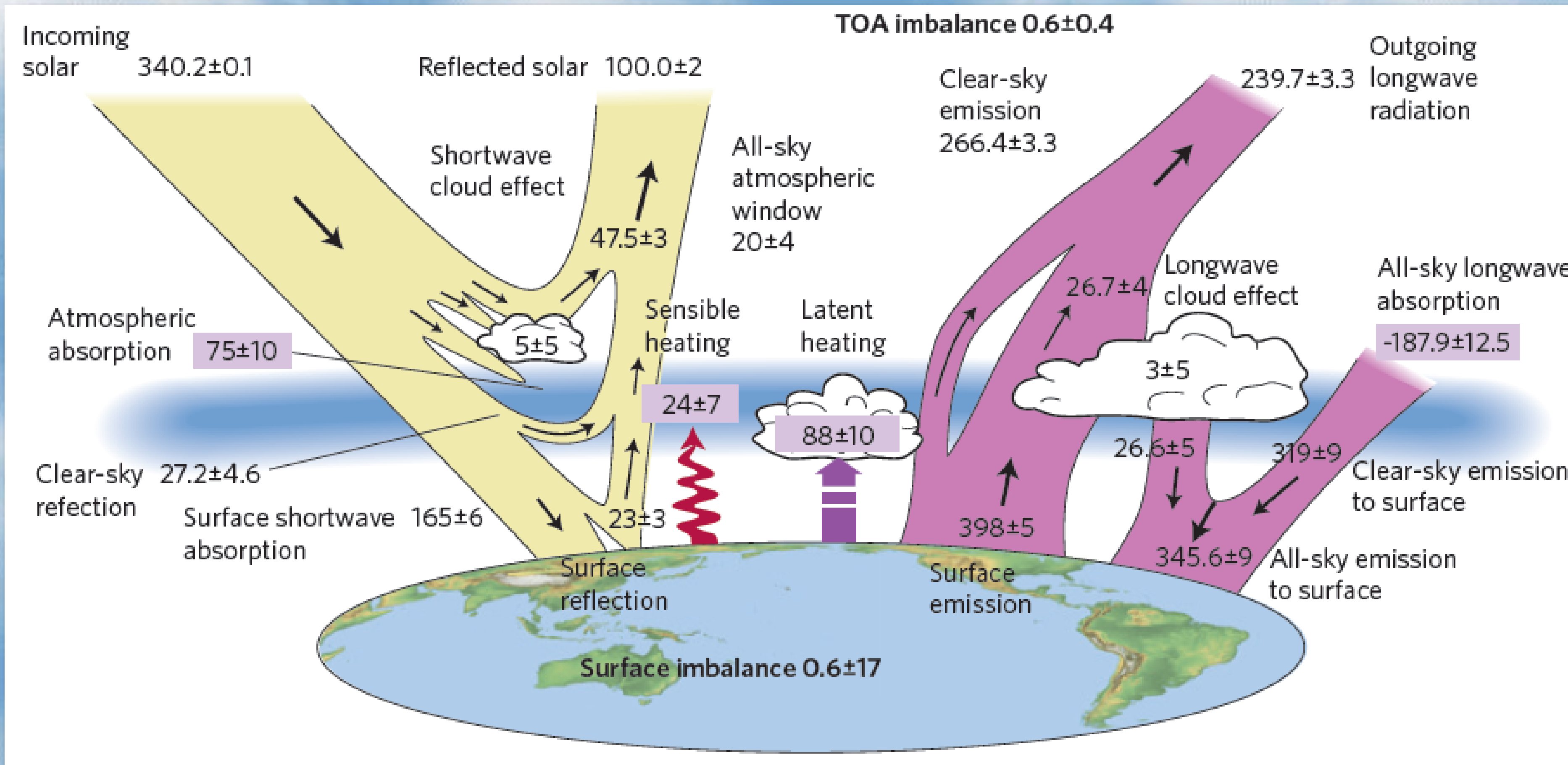


1950

2015



Earth Energy budget (W/m^2)



The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance. (Stephens, Nature 2012)

Sources and sinks of CO_2 (2006-2016)

34.1 $GtCO_2$/yr

91%

Sources

9%

3.5 $GtCO_2$/yr

Sinks

16.4 $GtCO_2$/yr

44%

31%

11.6 $GtCO_2$/yr

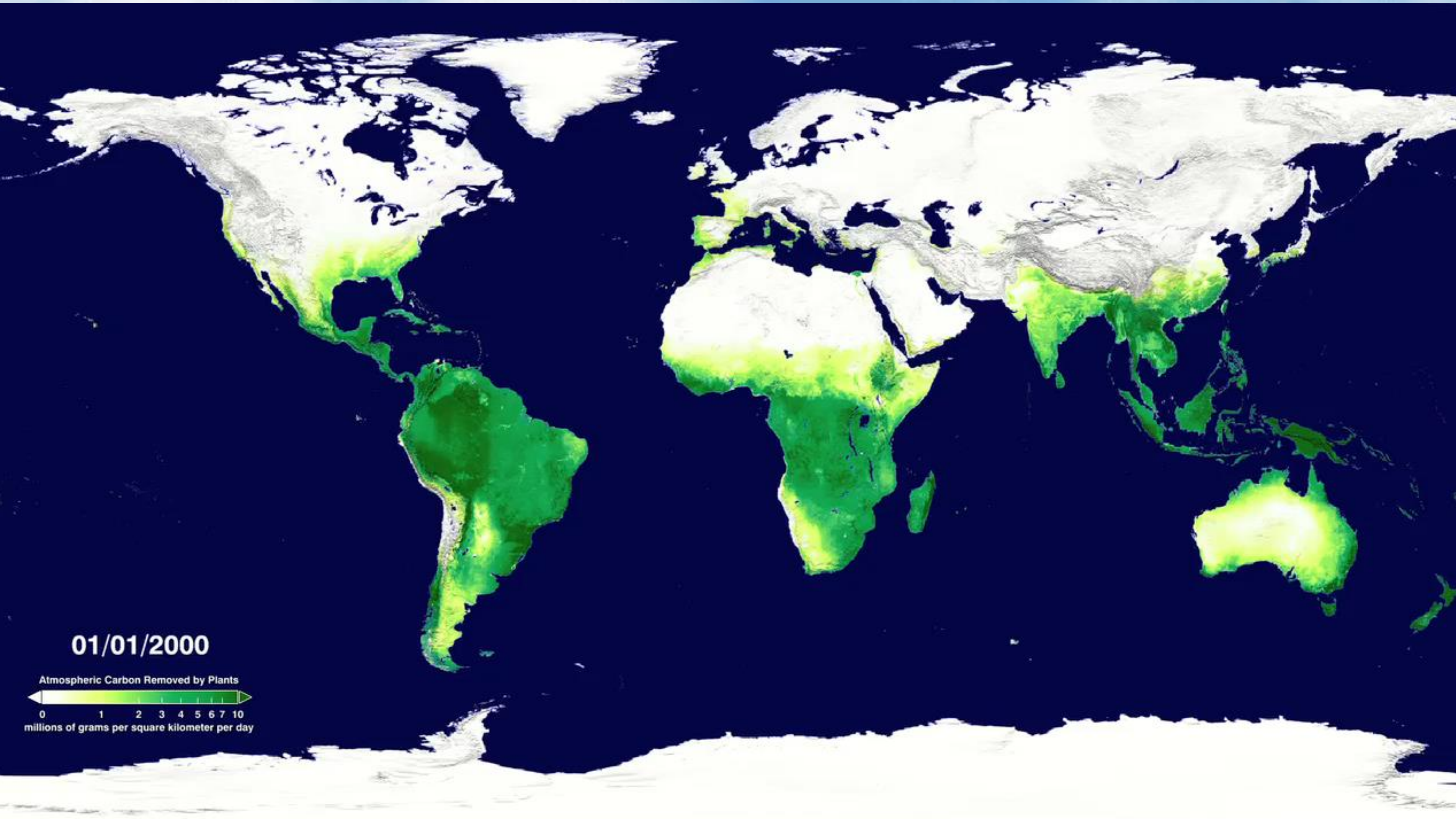
25%

9.7 $GtCO_2$/yr

Source: Le Quéré et al 2016; Global Carbon Budget 2016

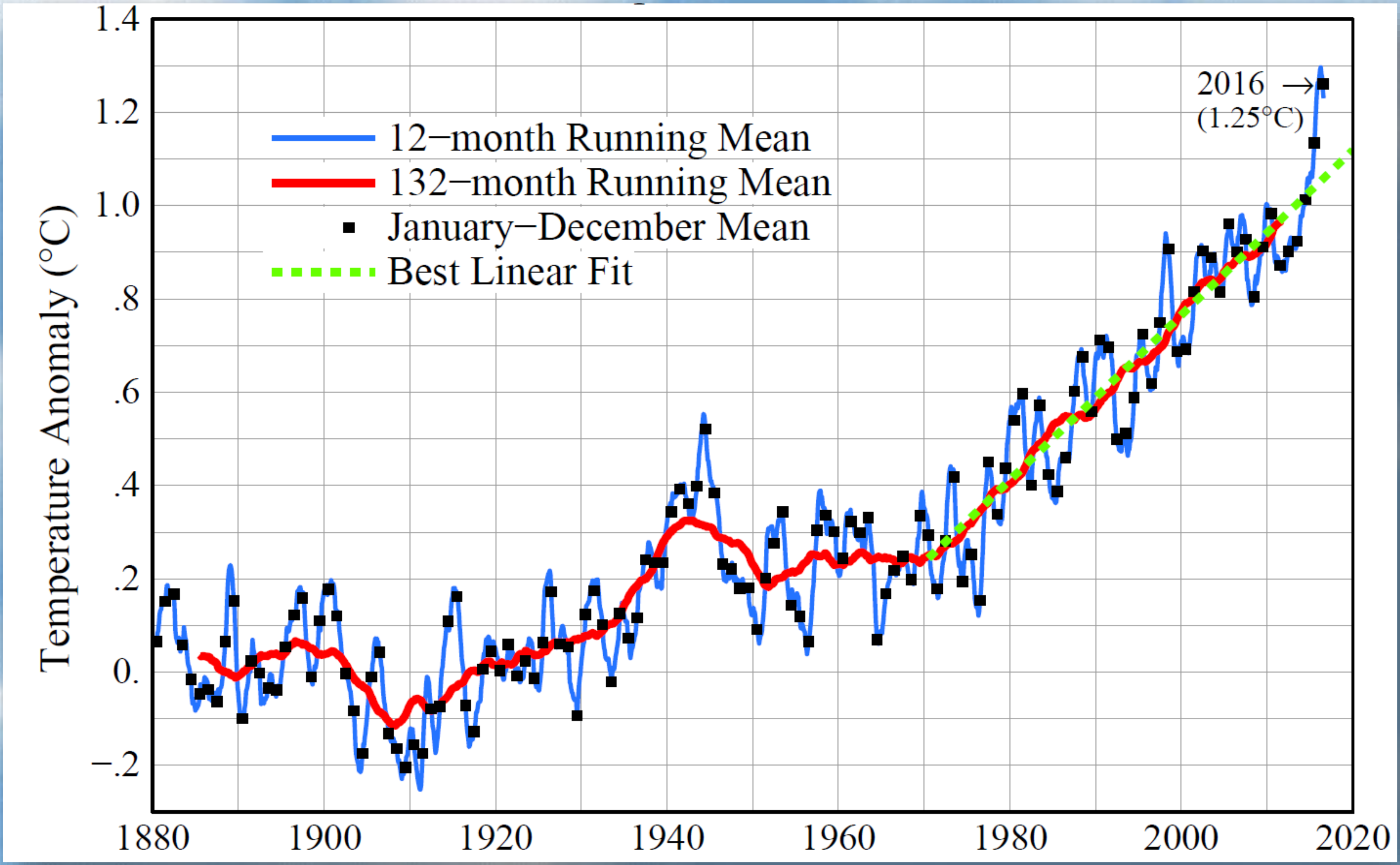
HOW MUCH CARBON DO PLANTS TAKE FROM THE ATMOSPHERE?

MODIS gross primary productivity (GPP) estimation from NDVI 2000-2010

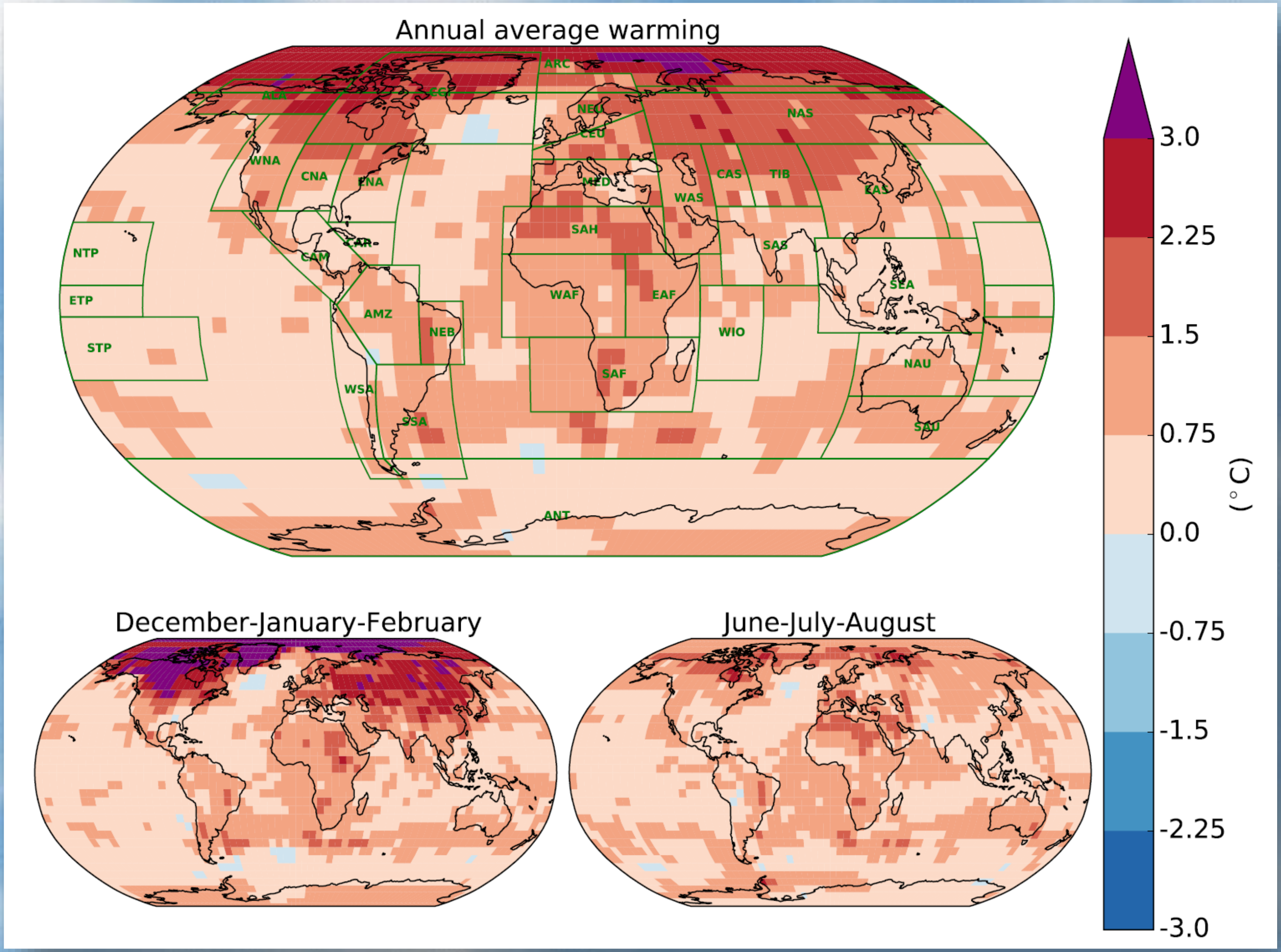


Amazonia: about 120 billion tons of carbon in the forest

Global Surface Temperature 1880-1920 base period

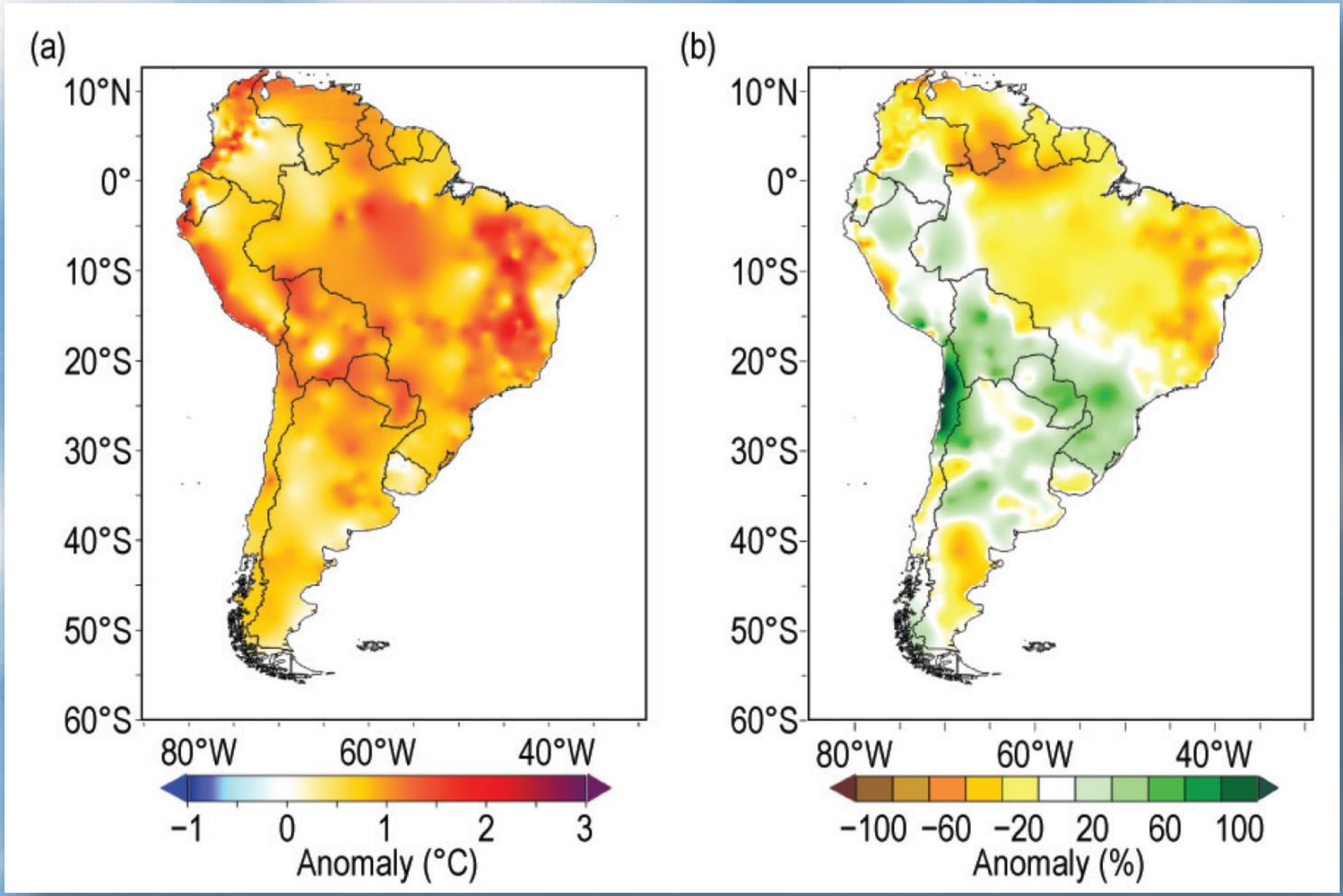


Observed increase in Temperature 1901 to 2012
Spatial distribution not homogeneous



Source: IPCC 2018 Special Report on Global Warming of 1.5°C

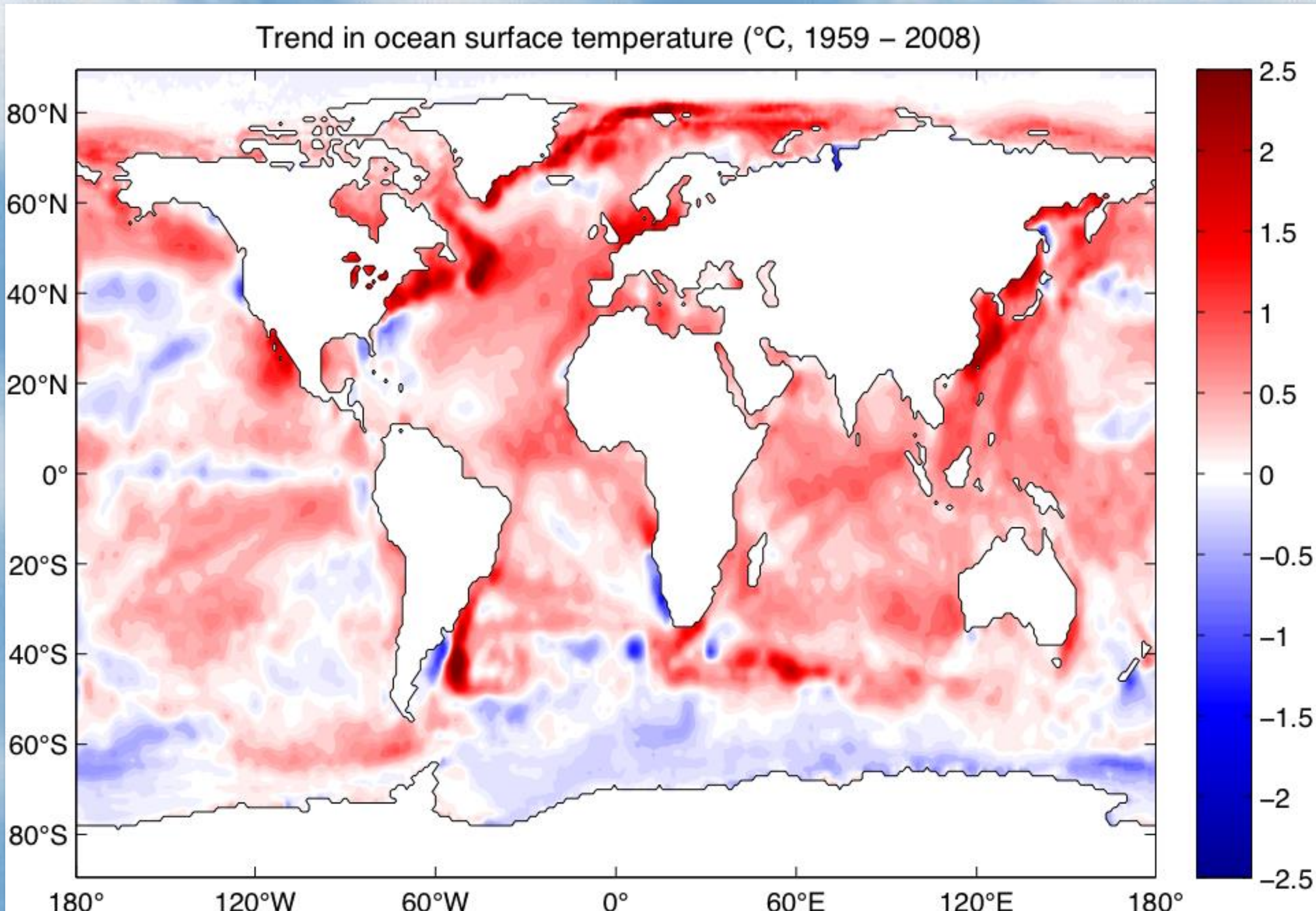
South American (a) temperature anomalies (°C) and (b) precipitation anomalies



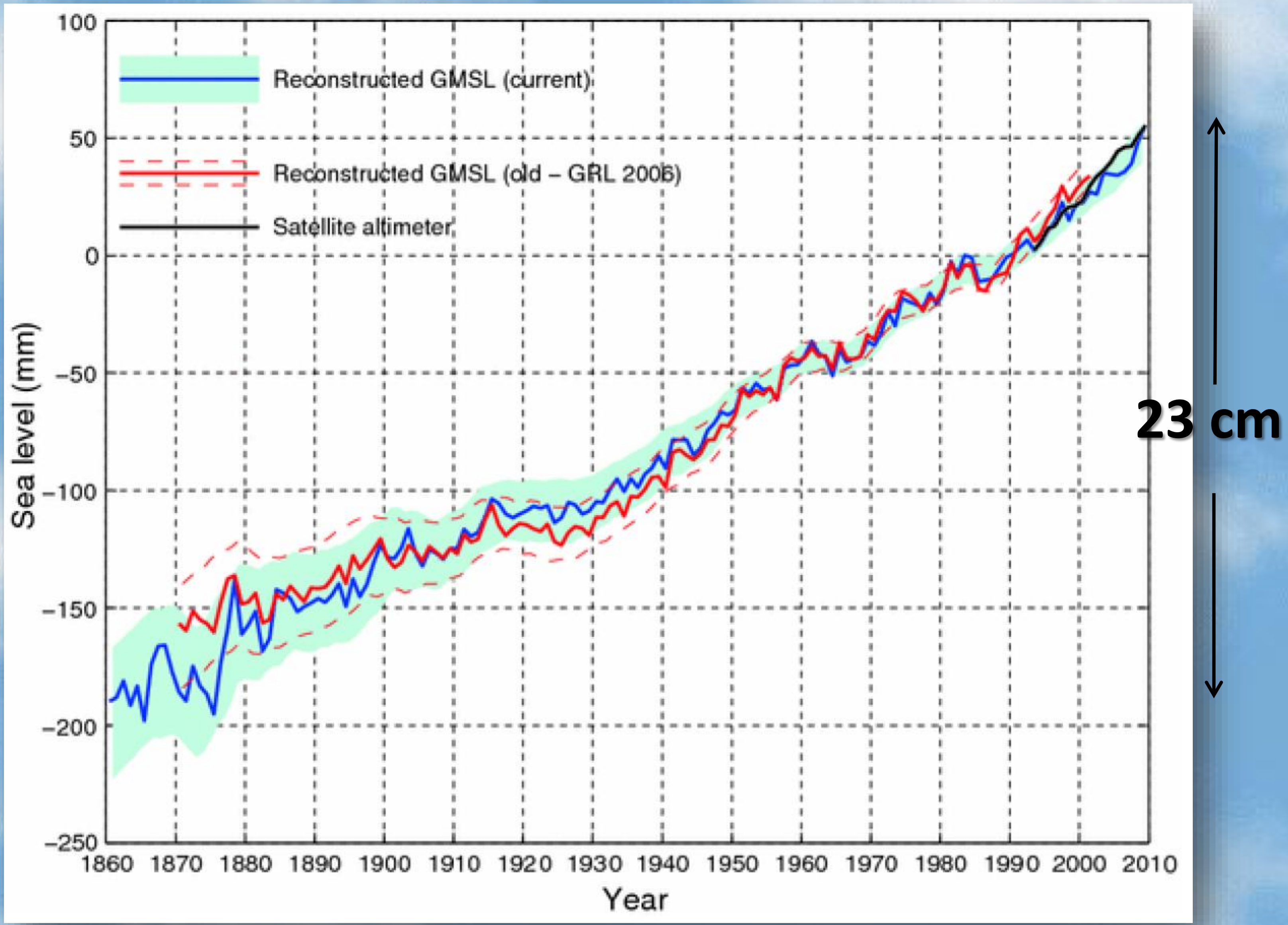
base period: 1981–2010.

Source 2016: State of the Climate in 2015, Bull. Amer. Meteor. Soc., 97 (8), 2016.

Ocean temperatures also increasing - 1959 - 2008



Seal level rise - 1860 to 2010

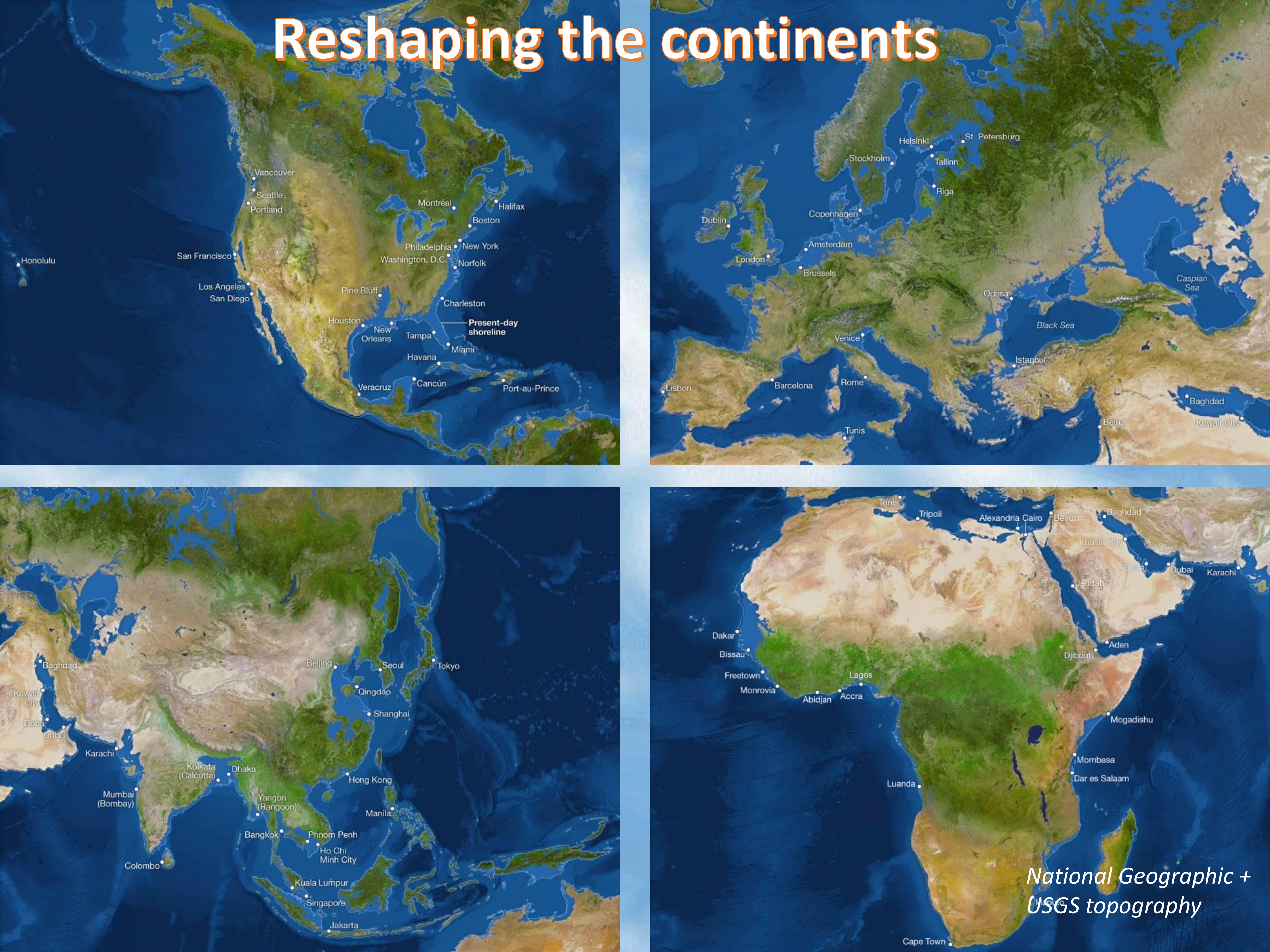


Source: Church and White (2011).

South America in the future?

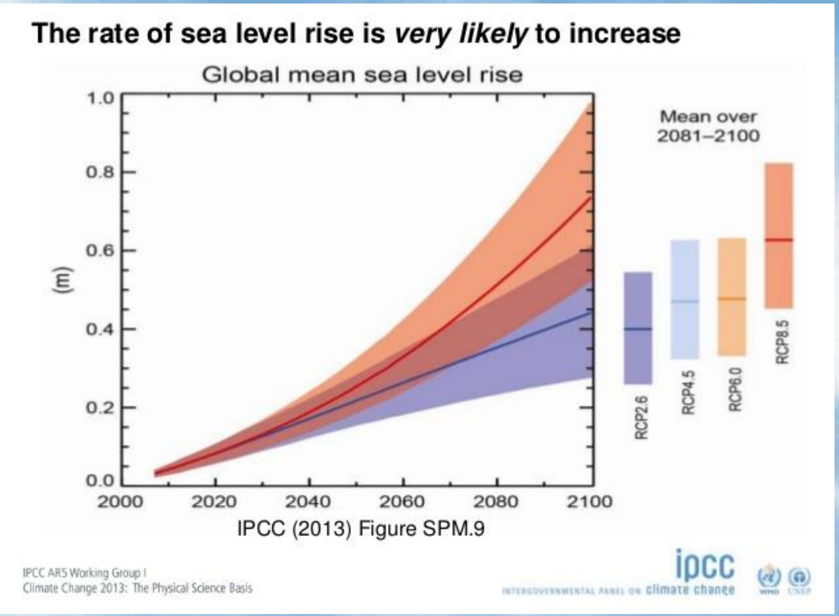
National Geographic + USGS topography

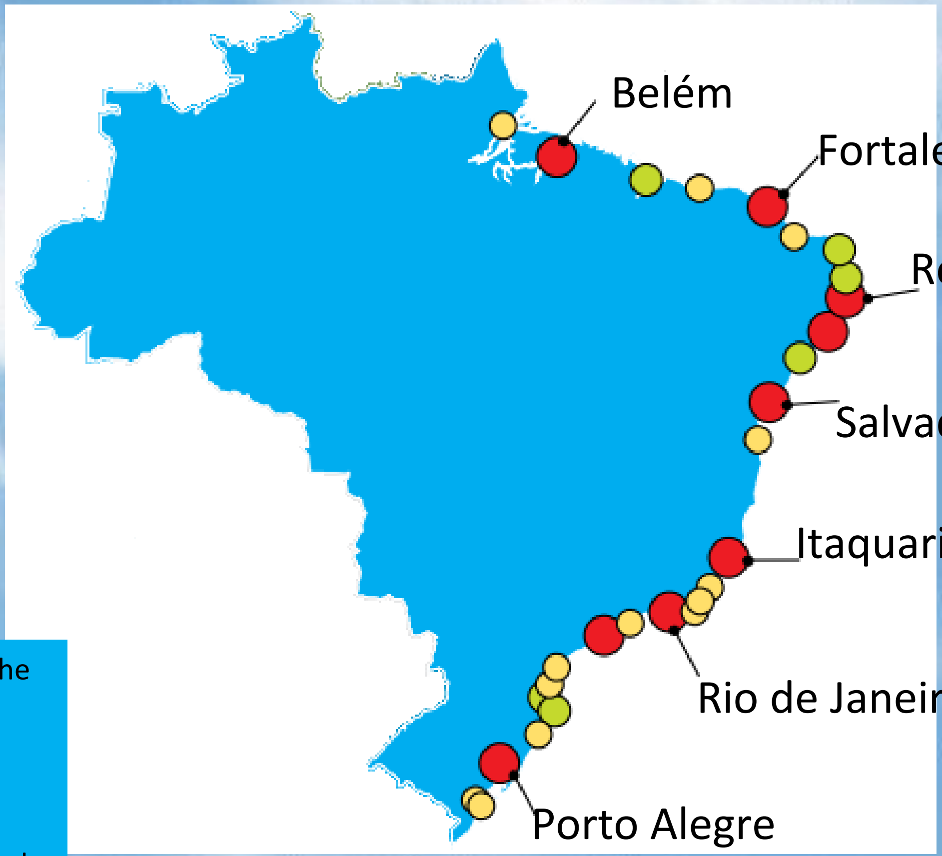
Reshaping the continents




NO ANTROPOCENO
OS OCEANOS ESTÃO SOFRENDO TRANSFORMAÇÕES
INÉDITAS EM ATÉ 300 MILHÕES DE ANOS
1°C
MAIS
QUENTES
26%
MAIS
ÁCIDOS
2%
A MENOS DE
OXIGÊNIO
DISSOLVIDO

Cidades brasileiras em risco pelo aumento do nivel do mar





City size

Small

Intermediate

Big

Population of cities
Small: 100 - 500 thousand
Intermediate: 500 thousand - 1 million
Big: More than 1 million

In the 20th century, sea levels rose by an estimated 23 cm, and the conservative global mean projections for sea-level rise between 1990 and 2080 range from 22 cm to 100 cm.

Oceans, which have been absorbing 80% of the temperature increase attributable to global warming, are expanding as ice sheets in the North and South poles melt.

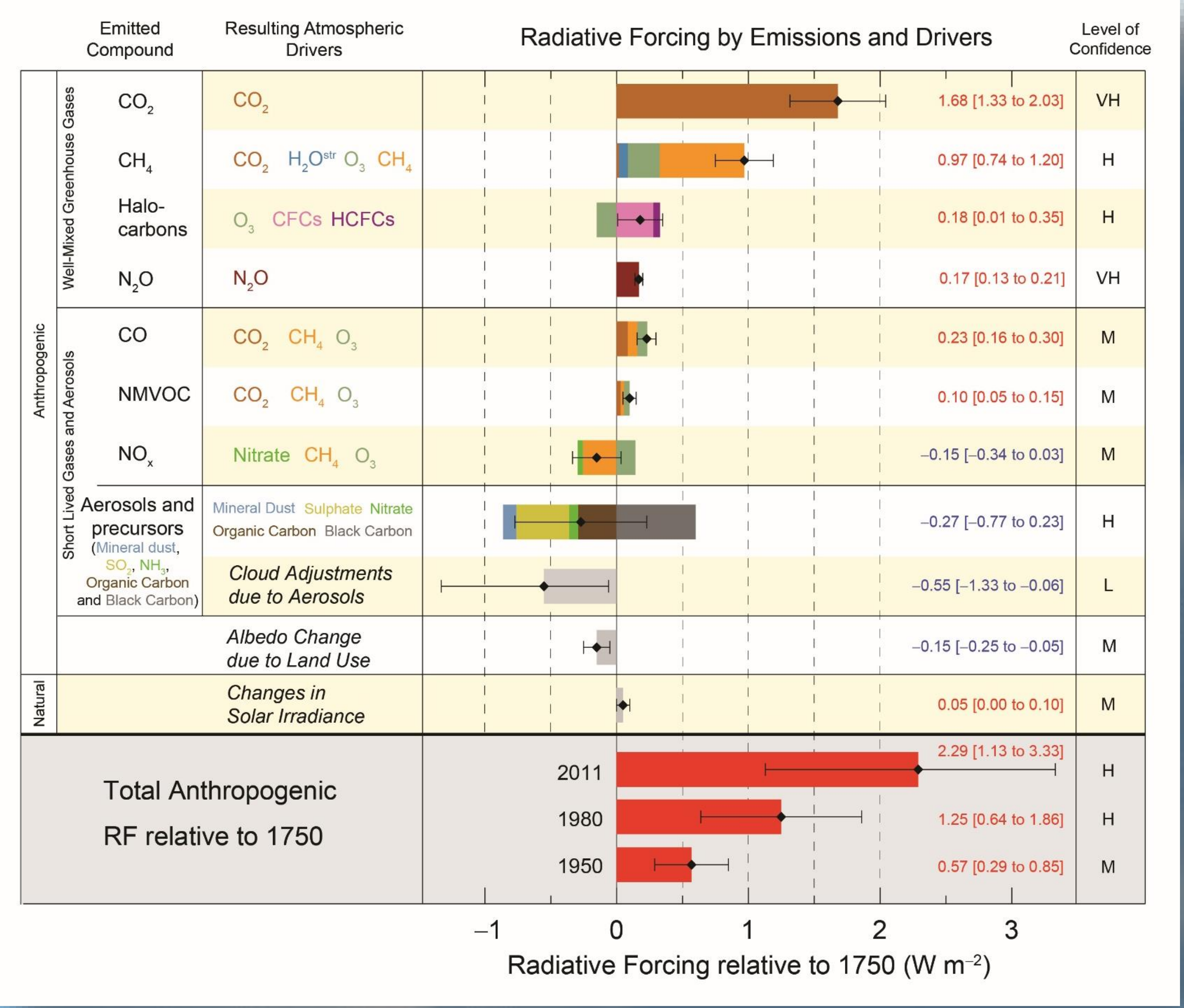
These events have led to a rise in sea levels and increased flooding in coastal cities.

The projected rise in sea levels could result in catastrophic flooding of coastal cities.

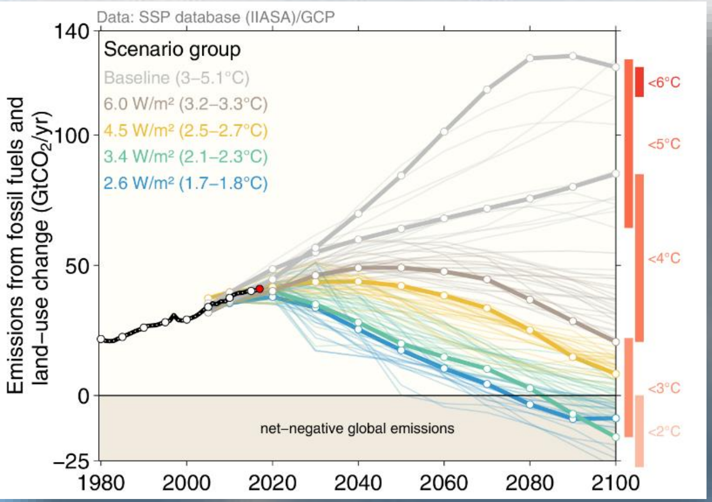
Thirteen of the world's 20 megacities are situated along coastlines.

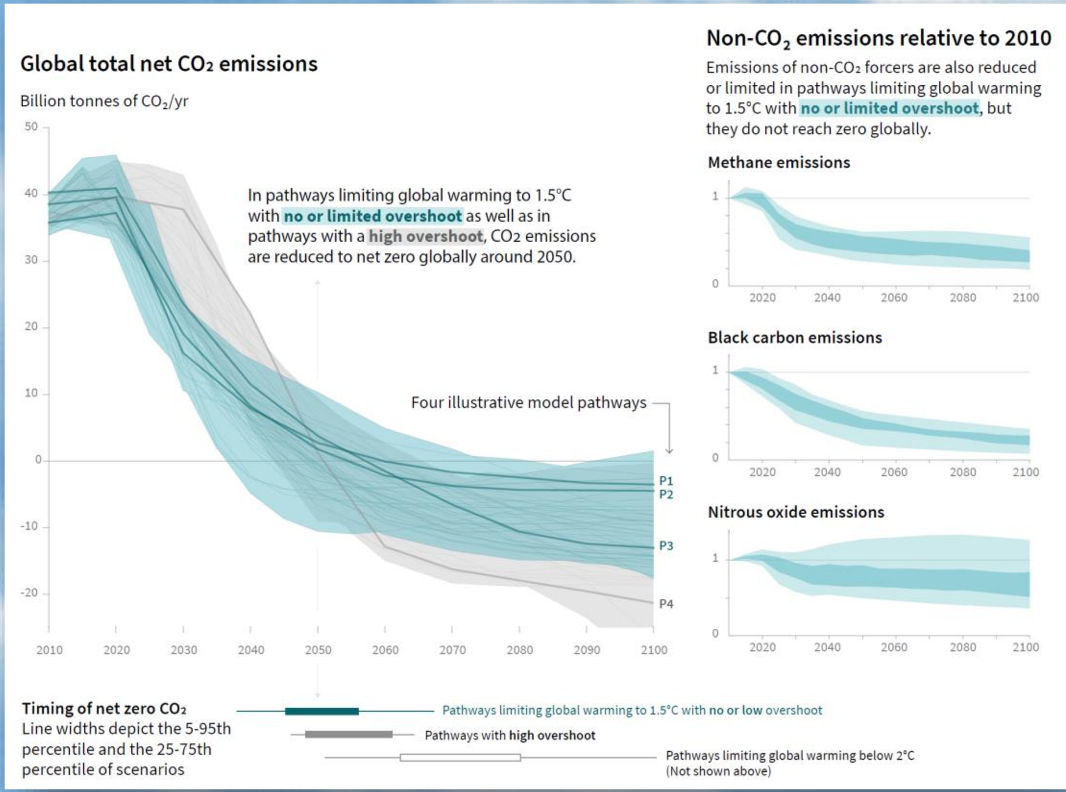
Source: *UN-HABITAT* Global Urban Observatory 2008 (adapted)

The Radiative Forcing of the global climate system (IPCC 2013)



Emissions pathways to limit temperature increase to 1.5 degrees with Short Lived Climate Forcers



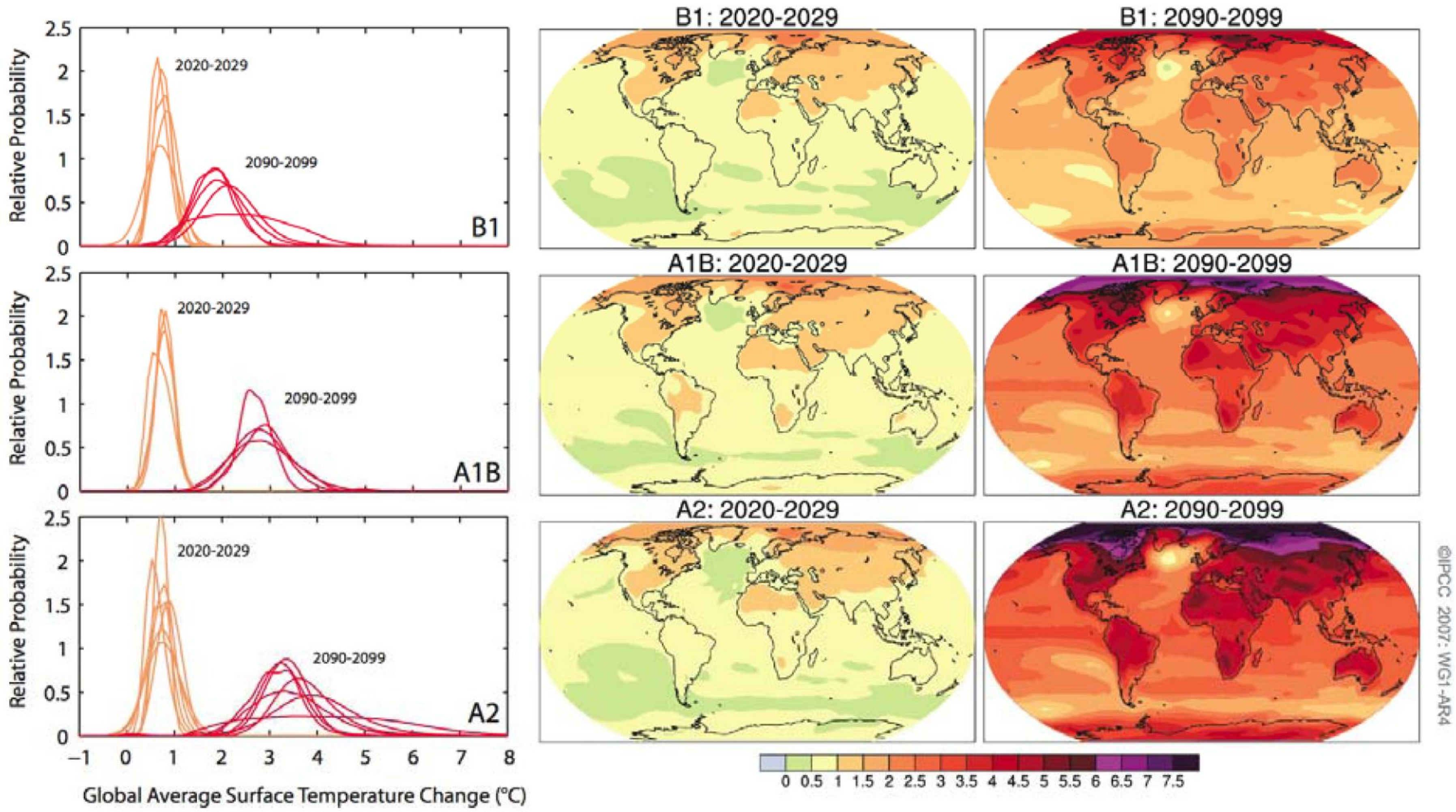


Faster immediate CO2 emission reductions (-5% per year, at 2020)

Maximum temperature rise is determined by cumulative net CO2 emissions and net non-CO2 radiative forcing due to methane, nitrous oxide, aerosols and other anthropogenic forcing agents.

Source: IPCC Special Report on Global Warming of 1.5°C

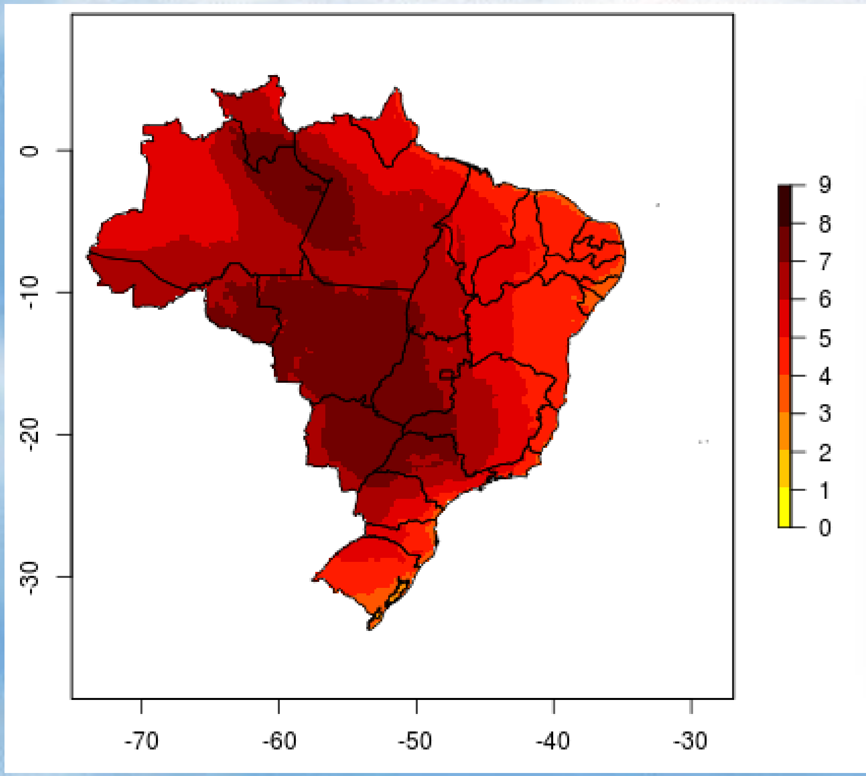
Estimates of temperature increase according to 3 emission pathways

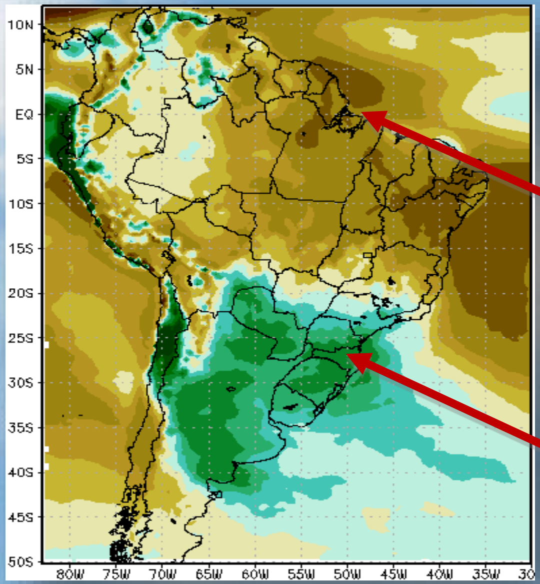


(IPCC 2013)

Aumento médio de temperatura esperado para o Brasil 2071-2099

Mudança na precipitação esperada para o Brasil 2071-2100





Mudanças na chuva (%) em 2071-2100 relativo a 1961-90.

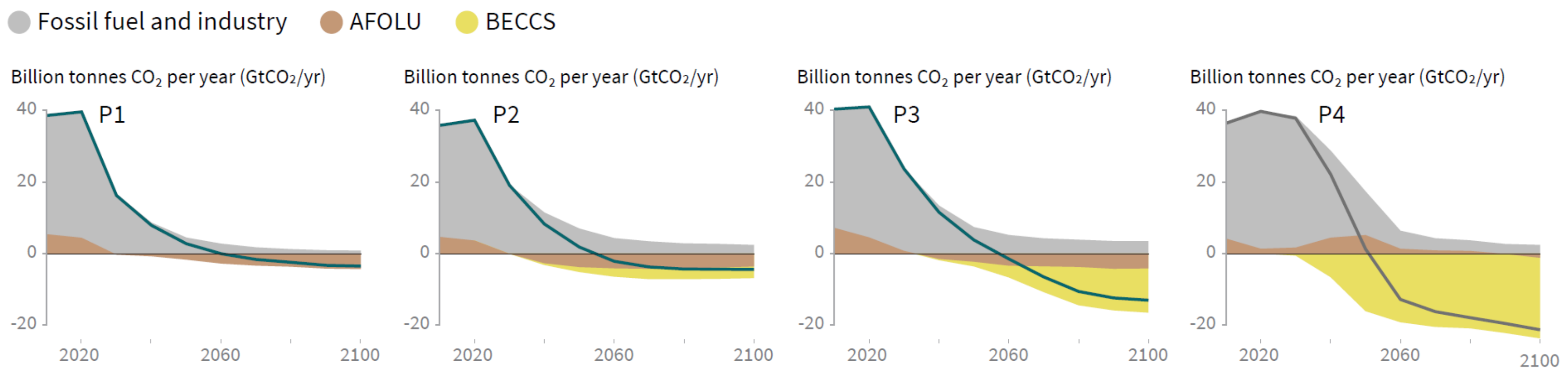
Amazonia e Nordeste do Brasil → deficiência de chuvas

Sudeste da America do Sul → aumento nas chuvas

Áreas continentais se aquecem mais que áreas oceânicas

INPE, (RCP 8.5)

Net emissions for 4 possible scenarios



P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

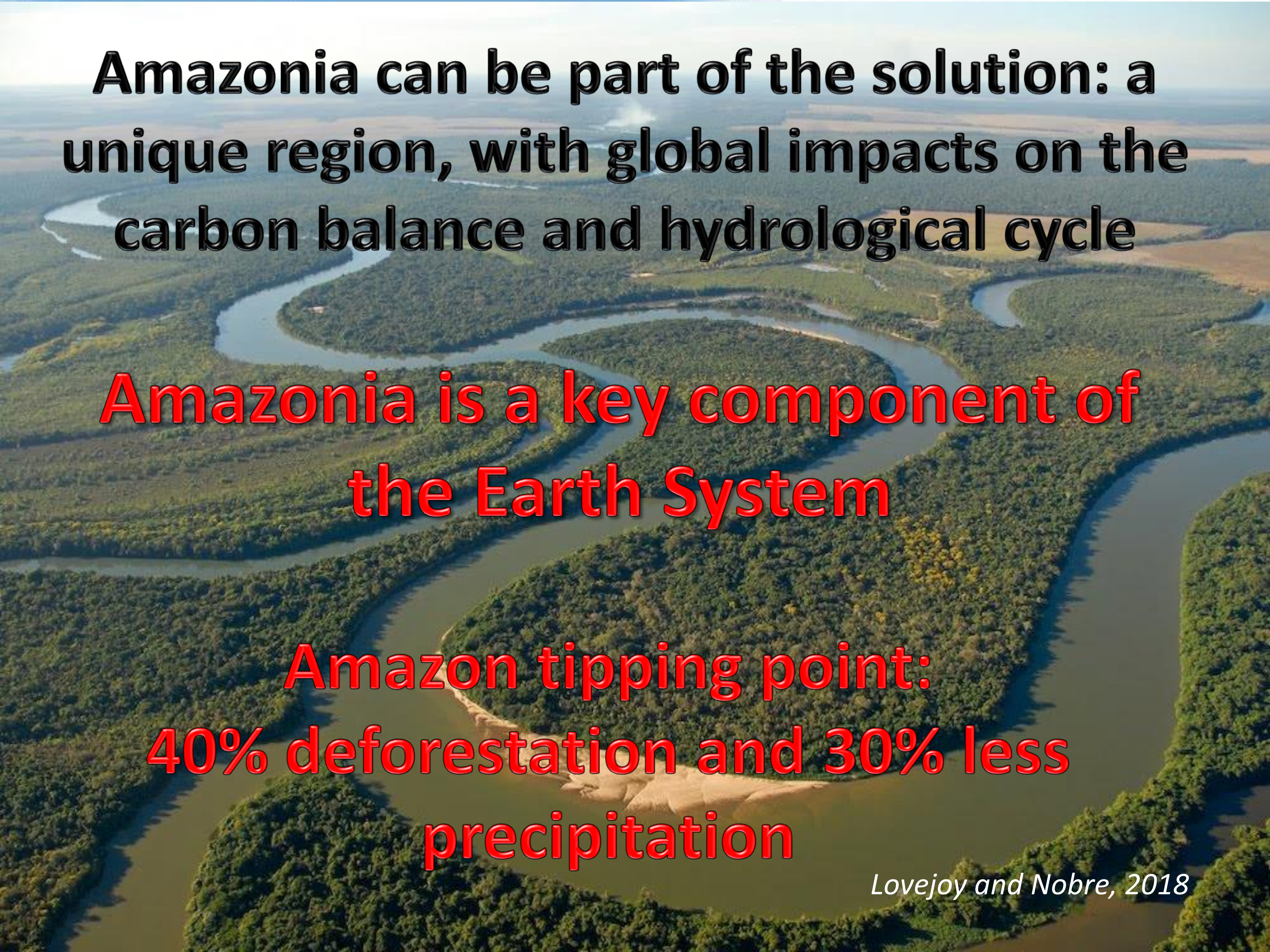
P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Source: IPCC Special Report on Global Warming of 1.5°C

AFOLU - Agriculture, Forestry and Other Land Use

CDR - Carbon Dioxide Removal

BECCS - Bioenergy with Carbon Capture and Storage


Amazonia can be part of the solution: a unique region, with global impacts on the carbon balance and hydrological cycle
Amazonia is a key component of the Earth System
Amazon tipping point:
40% deforestation and 30% less precipitation
Lovejoy and Nobre, 2018

AMAZON ECOSYSTEMS AT A GLANCE

Maintenance of global carbon cycle

- 15% of global NPP and a key carbon sink for anthropogenic CO_2
- Stores about 120 billion ton of carbon in the biomass

Climate stabilization

- Key heat source for the atmosphere
- Annual rainfall = 2400 mm

Powerful hydrology

- 18% of fresh water flow into the global oceans
- Amazon river discharge of 220,000 m^3/s

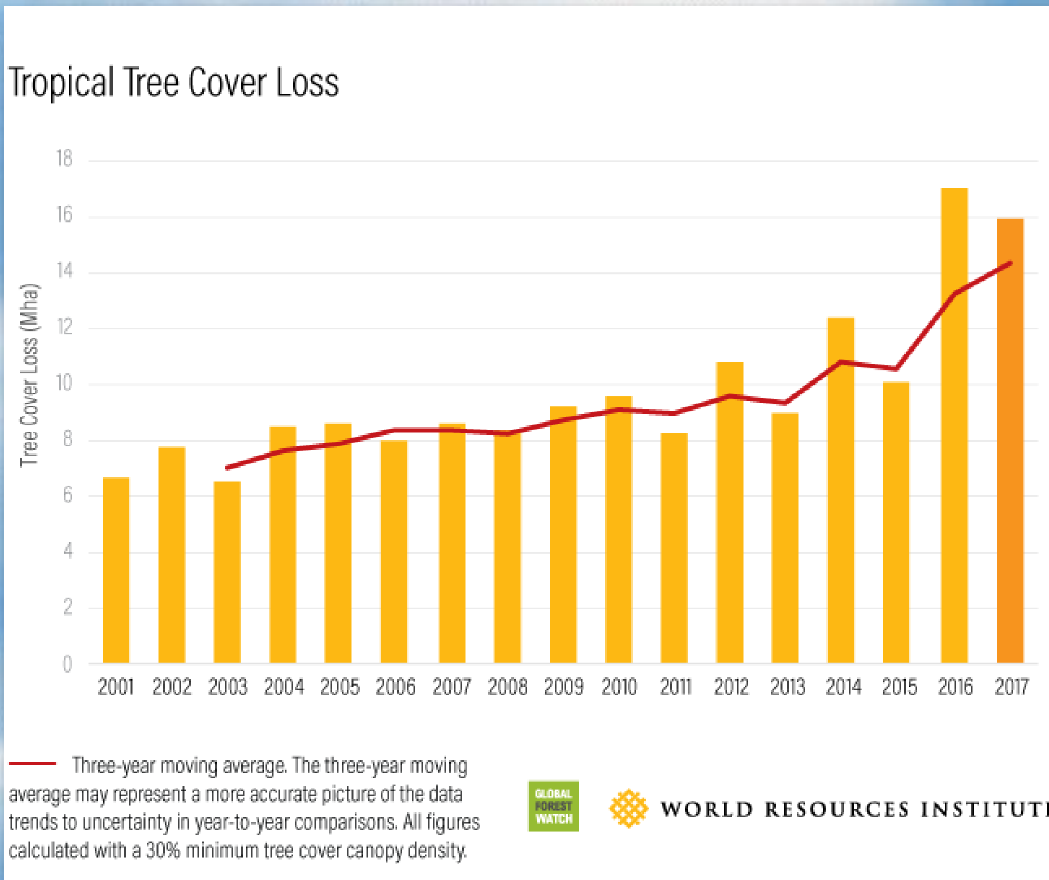
Helps to maintain cultural and ethnic diversity

- Over 300 indigenous populations, language diversity

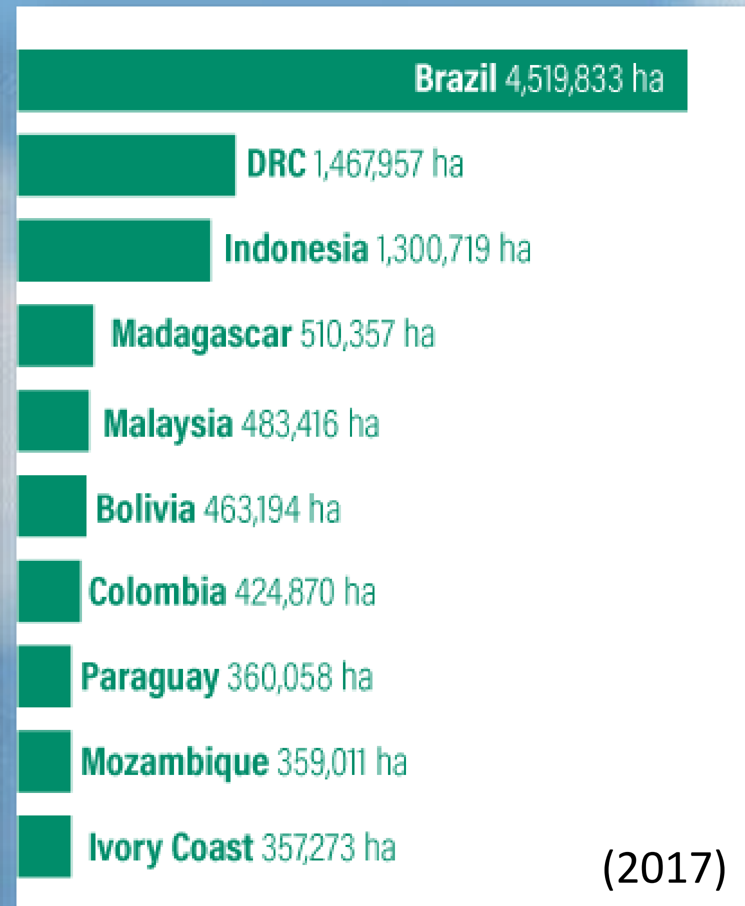
Biodiversity richness

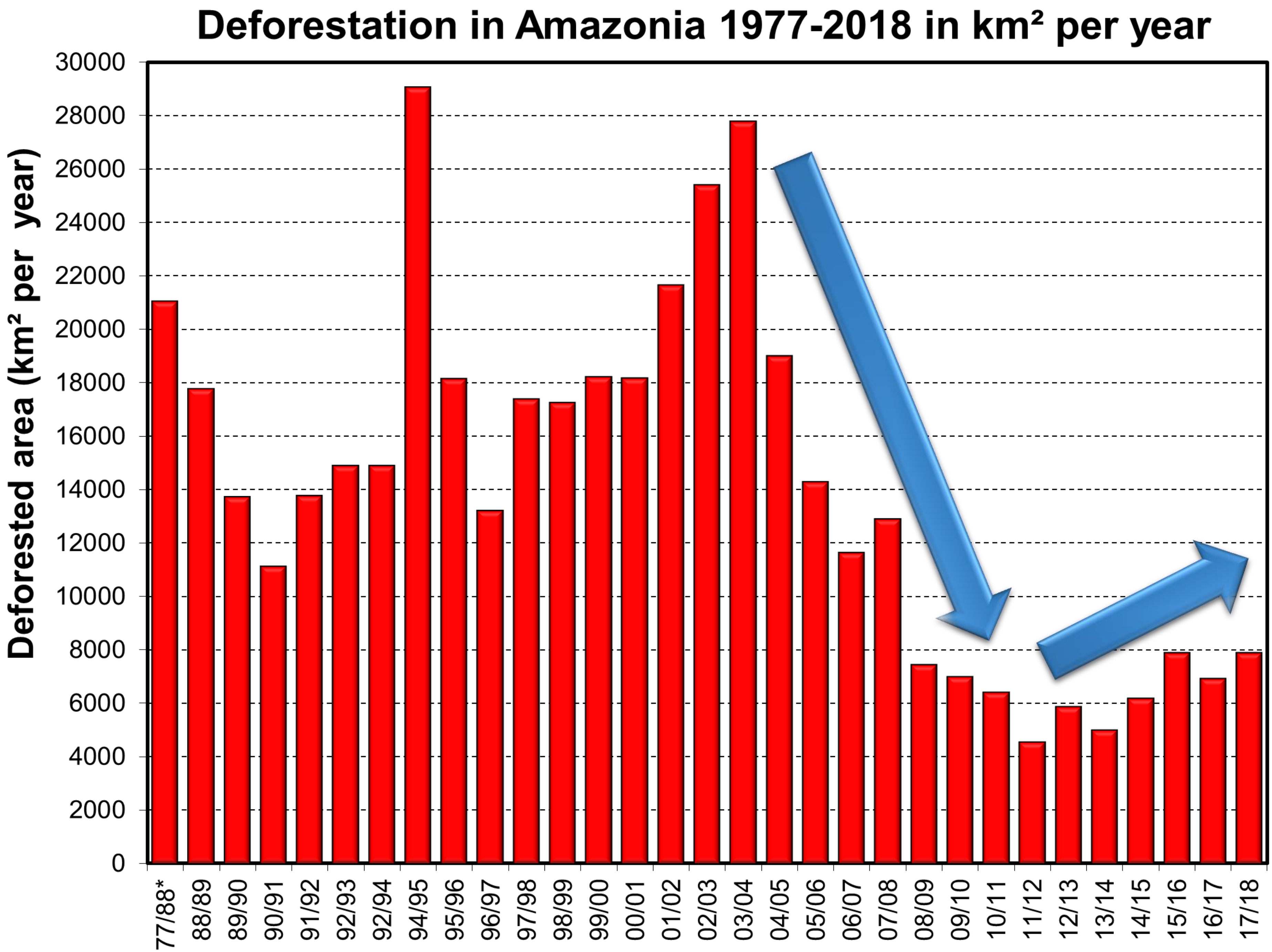
- > 10% of species

Tropical Tree Cover Loss



Tropical forest loss: which country?




Deforestation in Amazonia 1977-2018 in km² per year
Deforested area (km² per year)
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
77/88*
88/89
89/90
90/91
91/92
92/93
92/94
94/95
95/96
96/97
97/98
98/99
99/00
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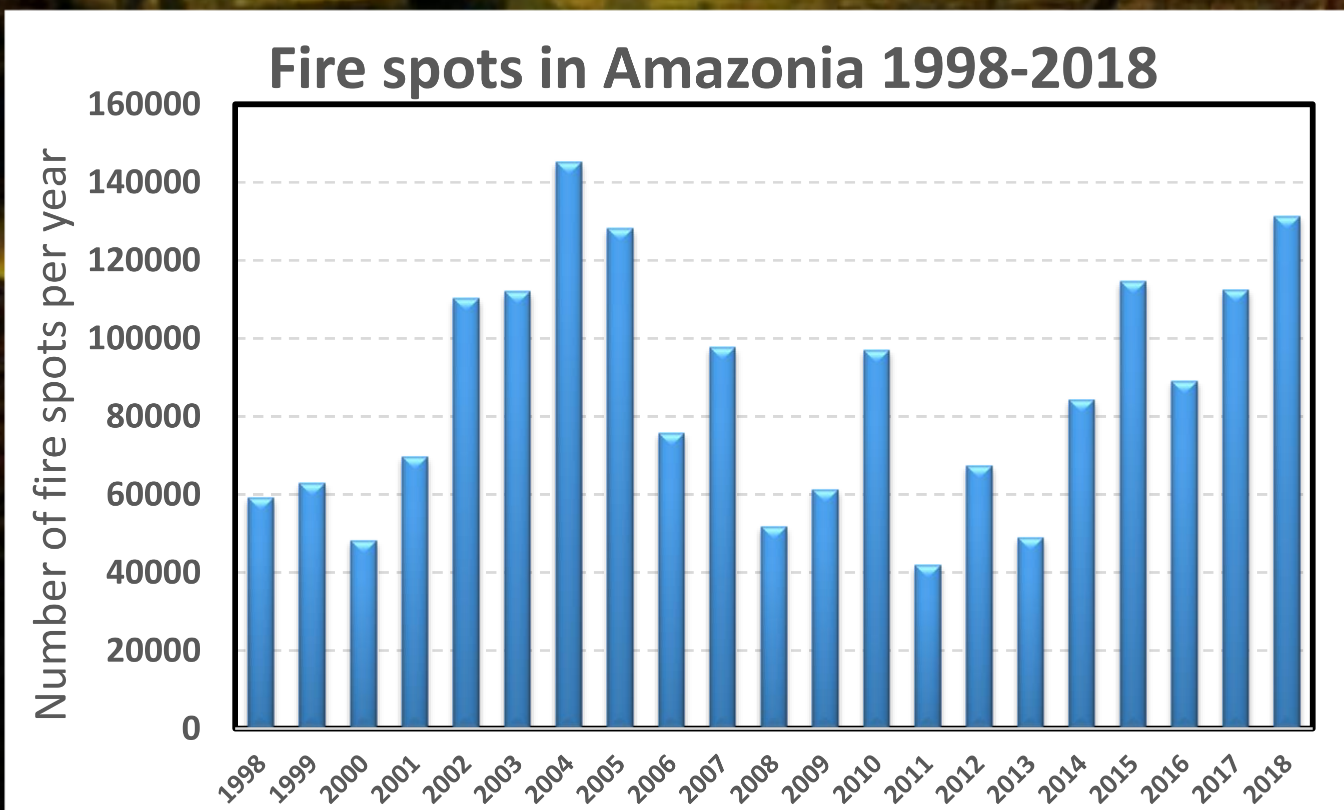
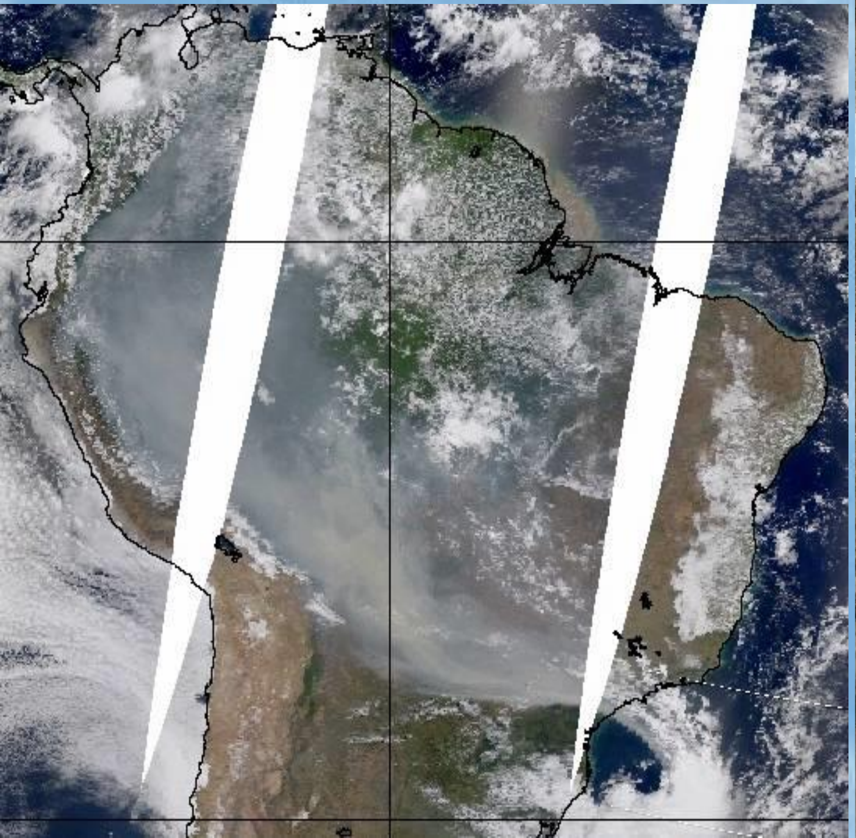
17/18

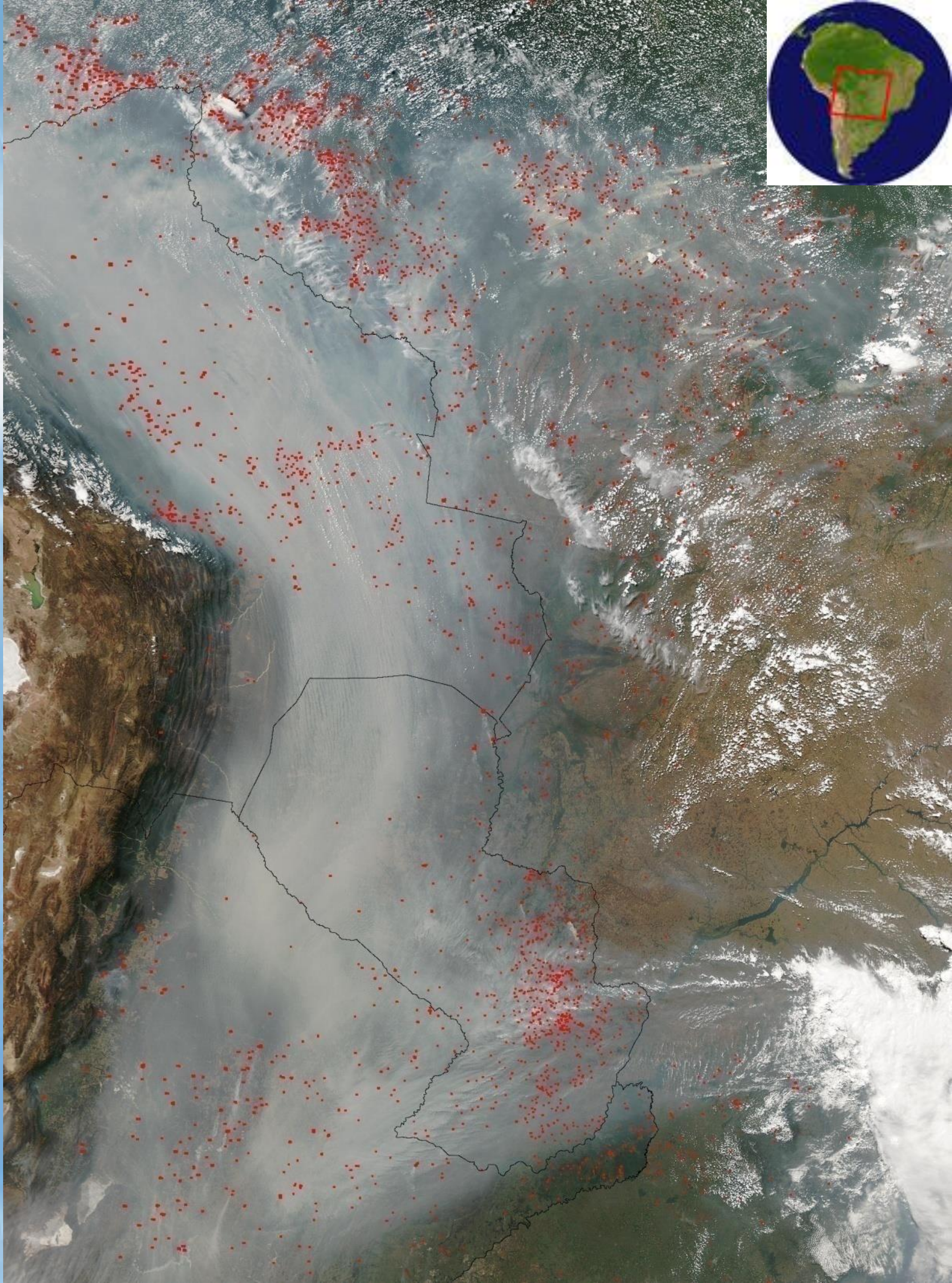
Biomass Burning…



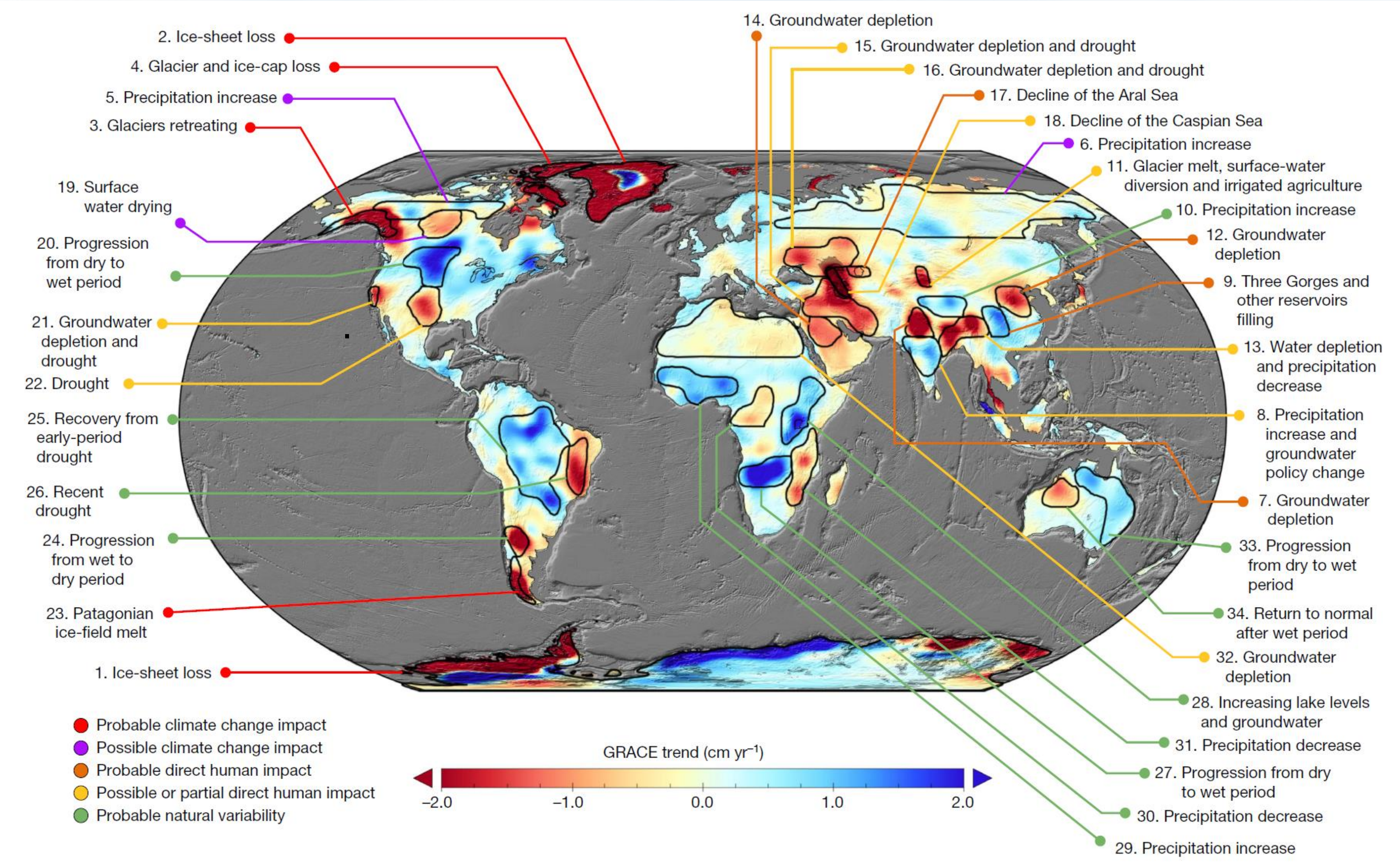
Large scale aerosol distribution in Amazonia

- Severe health effects on the Amazonian population (about 20 million people)
- Climatic effects, with strong effects on cloud physics and radiation balance.
- Changes in carbon uptake and ecosystem functioning





The changing terrestrial water cycle (in cm per year) GRACE satellite from 2002 to 2016

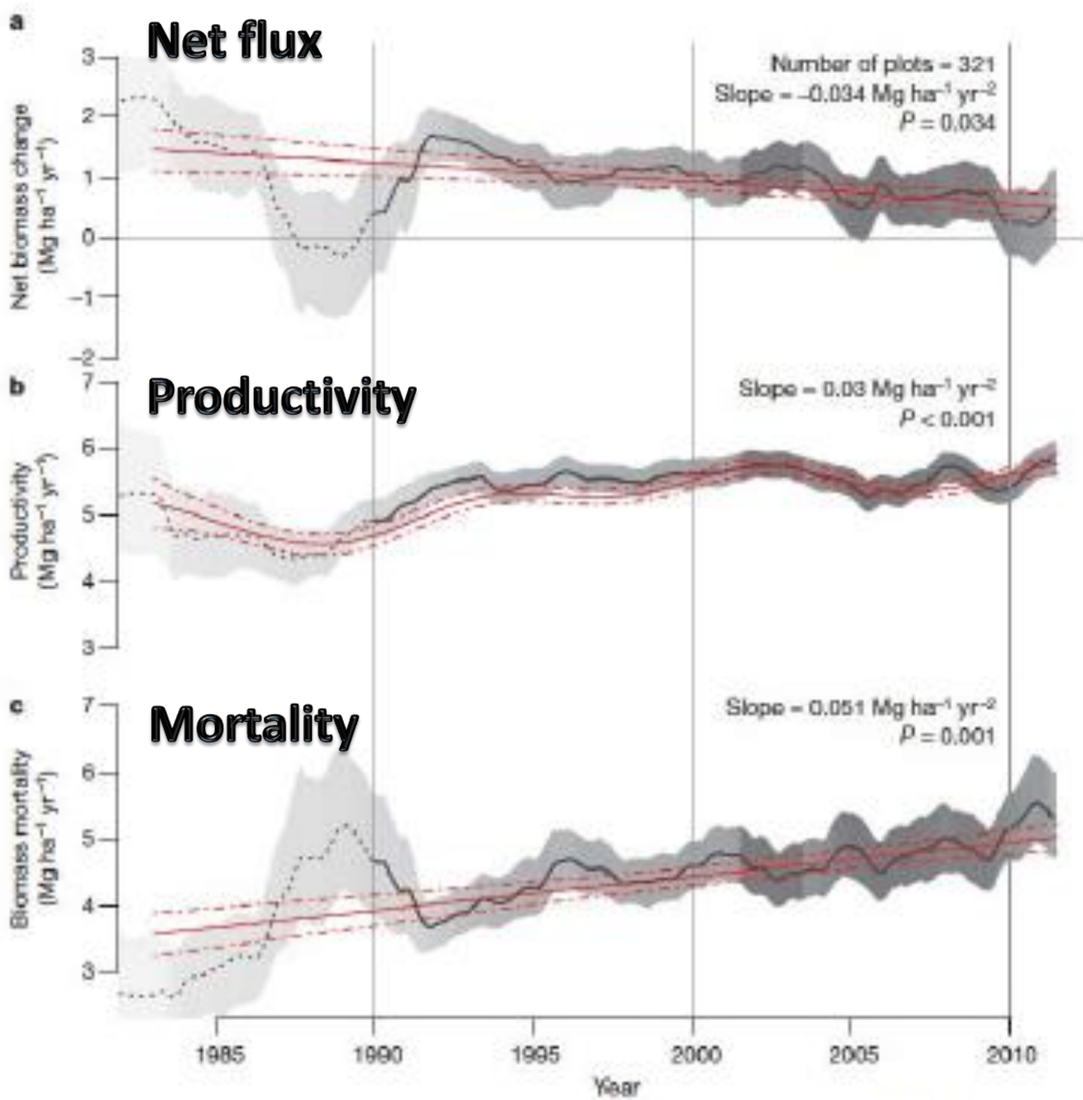


Terrestrial water cycle: sum of groundwater, soil moisture, surface waters, snow and ice

Amazon is critical for water vapor transport over South America

What processes controls these fluxes?

Carbon cycling in Amazonia from 1985 to 2010

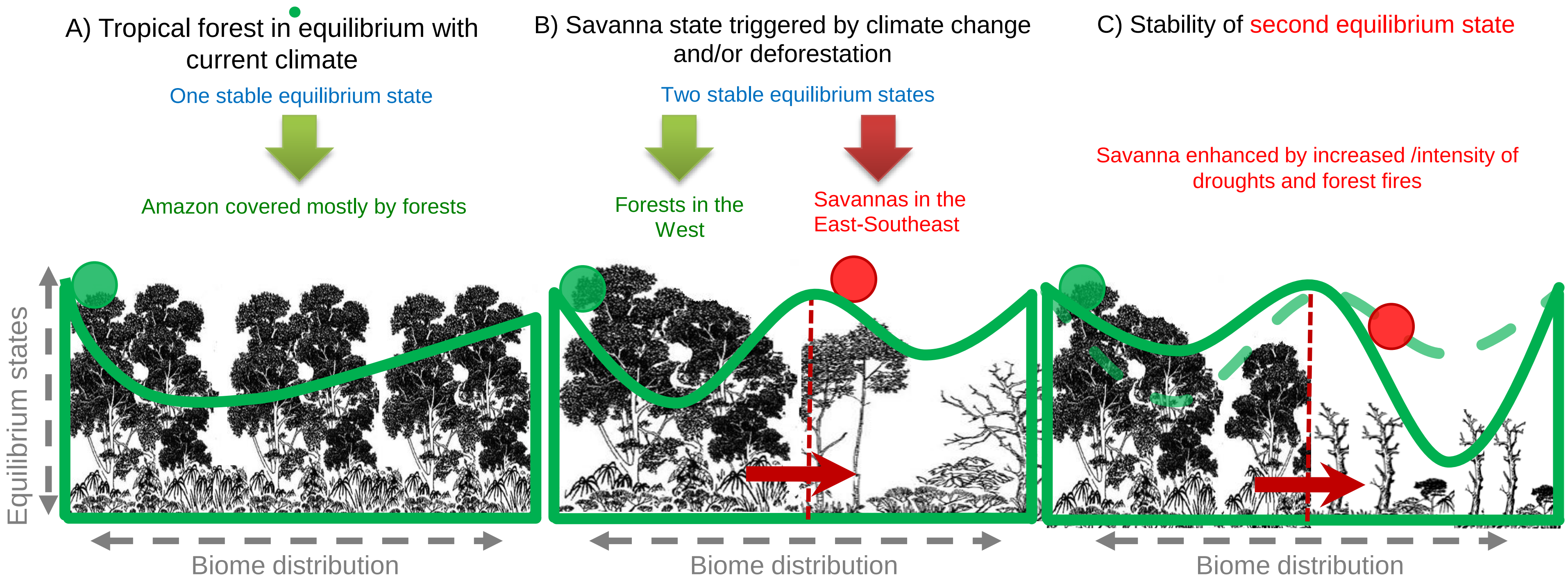


(Brienen et al., 2015)

Net carbon flux:
Today: ZERO

Tree mortality:
significant INCREASE

‘TIPPING POINTS’ OF FOREST-CLIMATE EQUILIBRIUM IN THE AMAZON



Thresholds for tipping
from state A to state B ≈ 4ºC Amazon warming or
≈ 40% of total deforested area

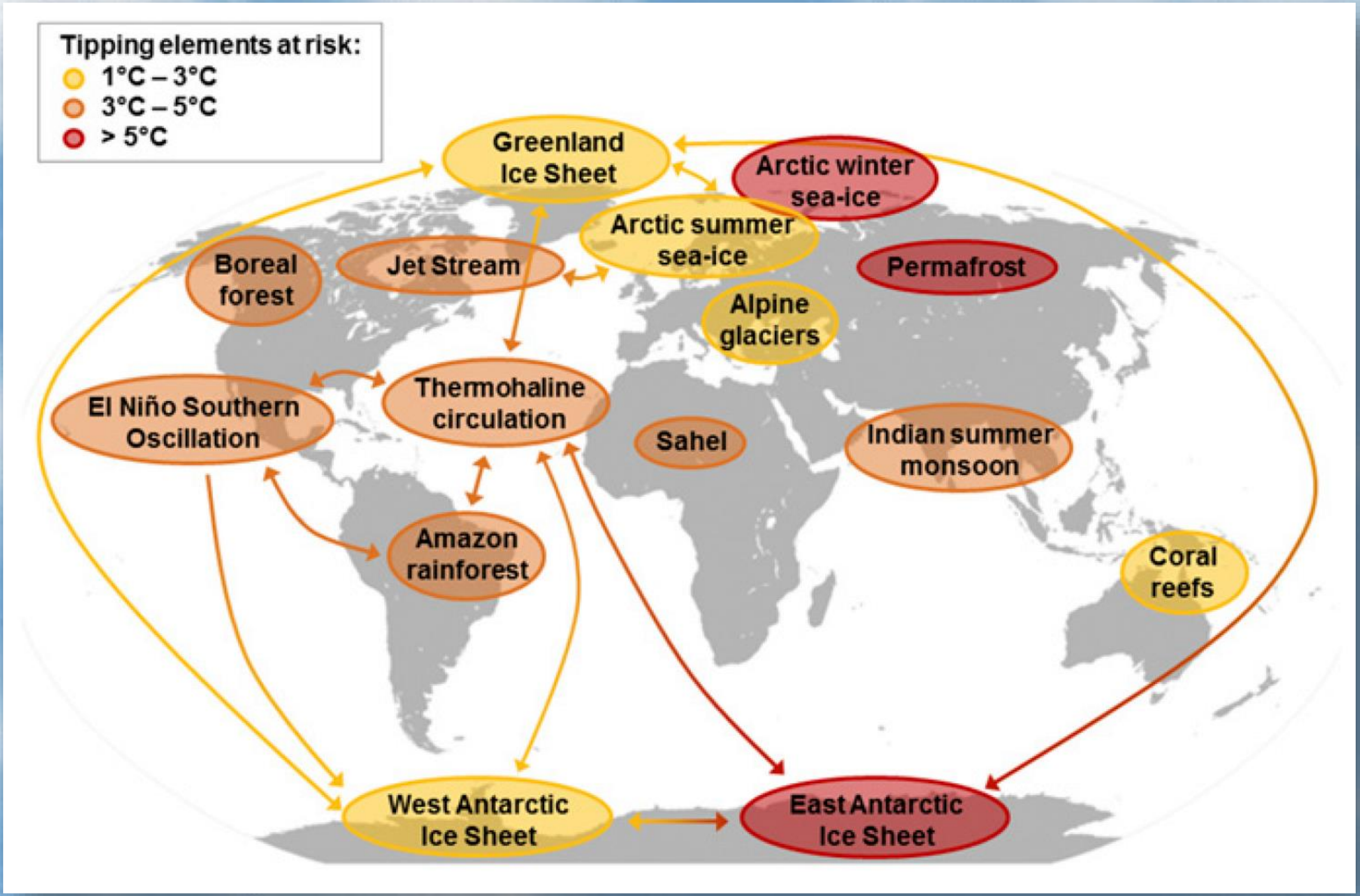
- **Observations: ΔT ≈ 1.1 to 1.5ºC**
- **Deforestation: ≈ 18%**
- **Forest fire frequency (increasing)**
- **Lengthening of dry season (increasing)**
- **Increasing climate extremes**

Adapted from Nobre et al., 2015, 2016

How close to the edge do we dare to get?

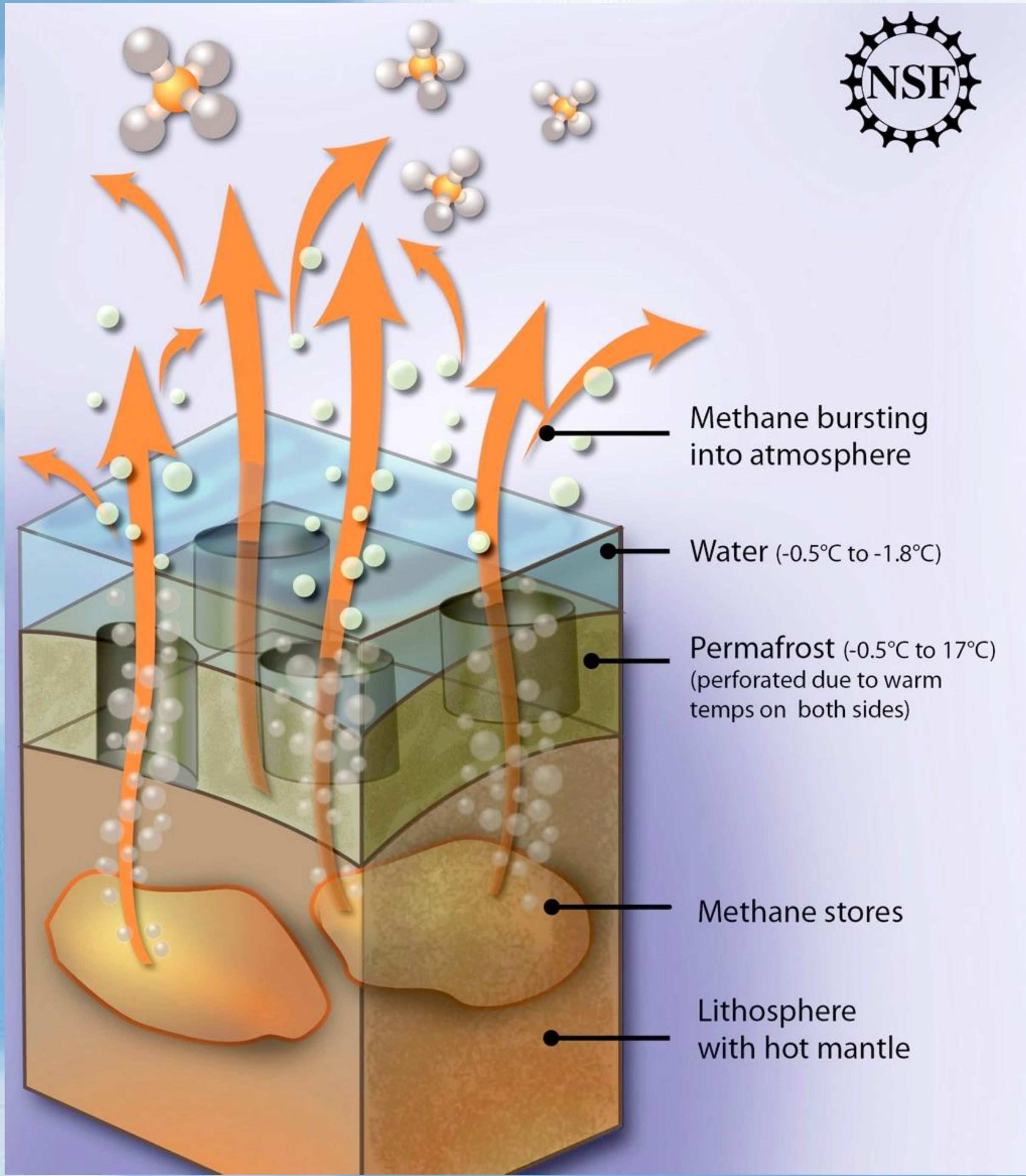
The tipping point issue…

Tipping points of the Earth climate system

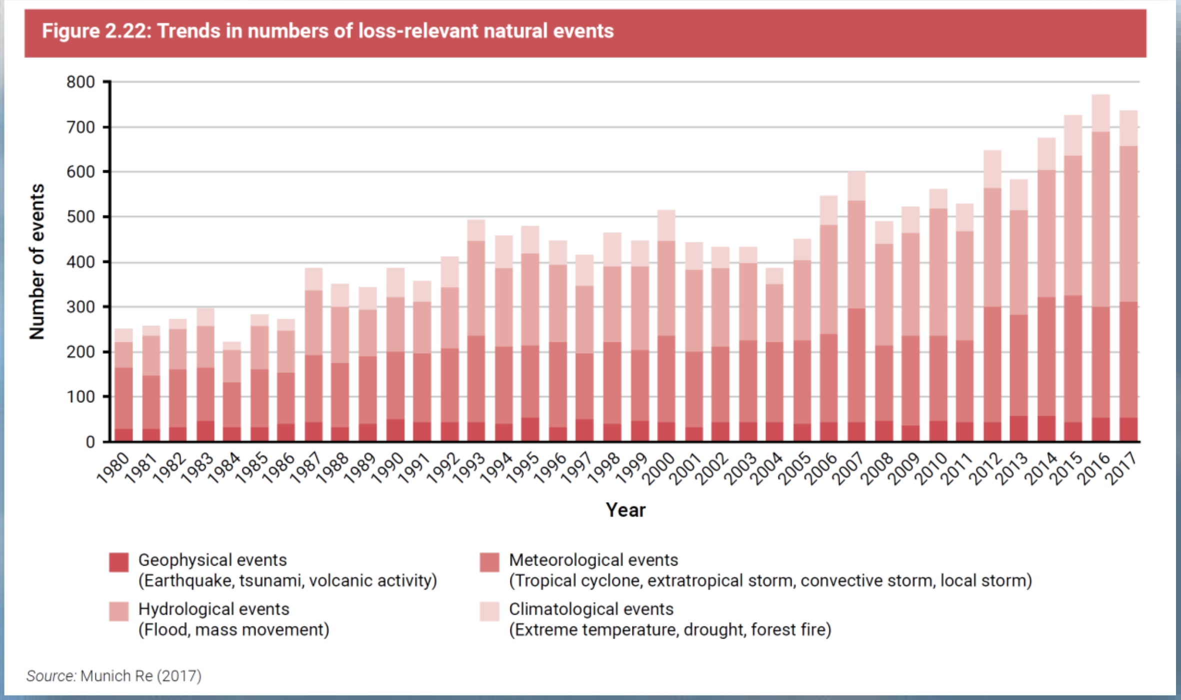


UNEP GEO-6 2019

Feedbacks: Arctic permafrost methane leakage to the atmosphere

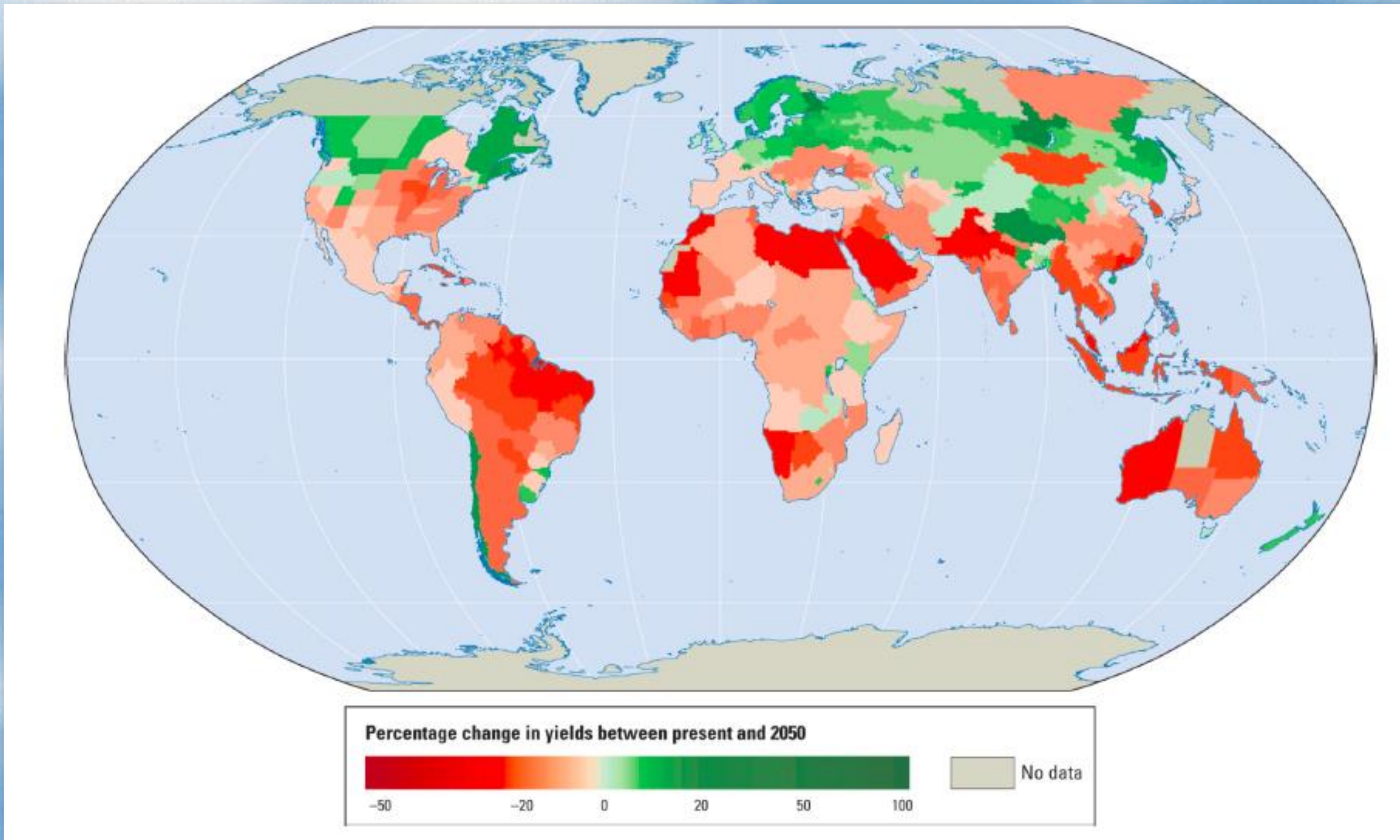


Risks: Increase in the intensity and frequency of climate extremes



It is already happening since the 80's

Food Security: Potential impacts on food production in a 3°C hotter world



FAO and World Economic Forum: Global Risks 2016

IMPACTOS ECONÓMICOS DEL CAMBIO CLIMÁTICO SOBRE EL SECTOR AGRÍCOLA

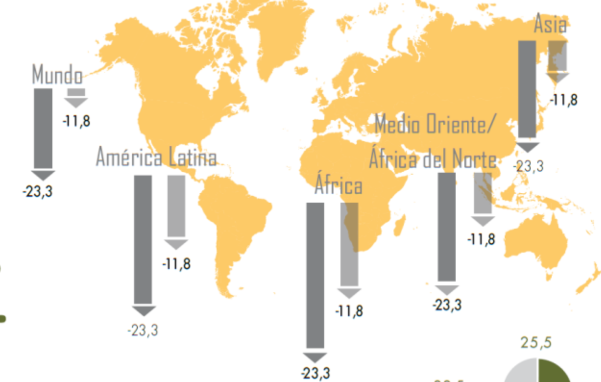
El sector agrícola tiene una importancia estratégica en América Latina y el Caribe

América Latina: indicadores seleccionados del sector agrícola, alrededor de 2012[a]
(En porcentajes)

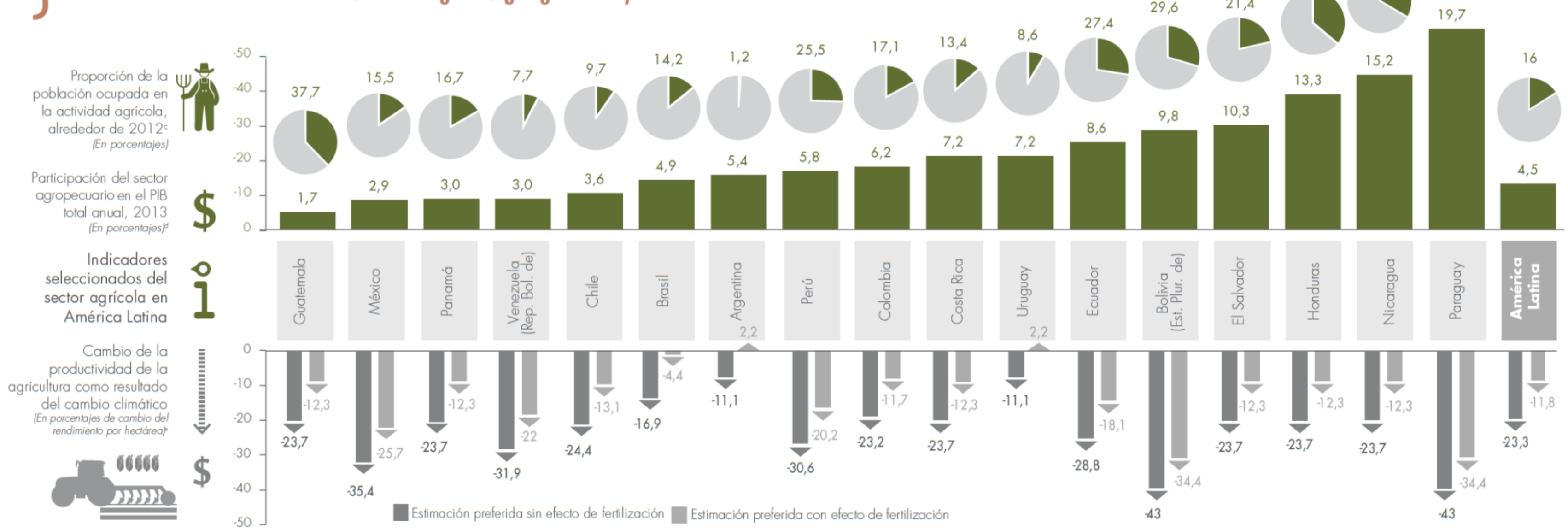
- 5% del PIB
- 16% de la población ocupada
- 23% de las exportaciones regionales
- 22% de la población vive en zonas rurales

El aumento de temperatura, el cambio de los patrones de precipitación y los eventos climáticos extremos ponen en riesgo al sector agrícola

Cambio de la productividad de la agricultura como resultado del cambio climático[b]
(En porcentajes de cambio del rendimiento por hectárea)



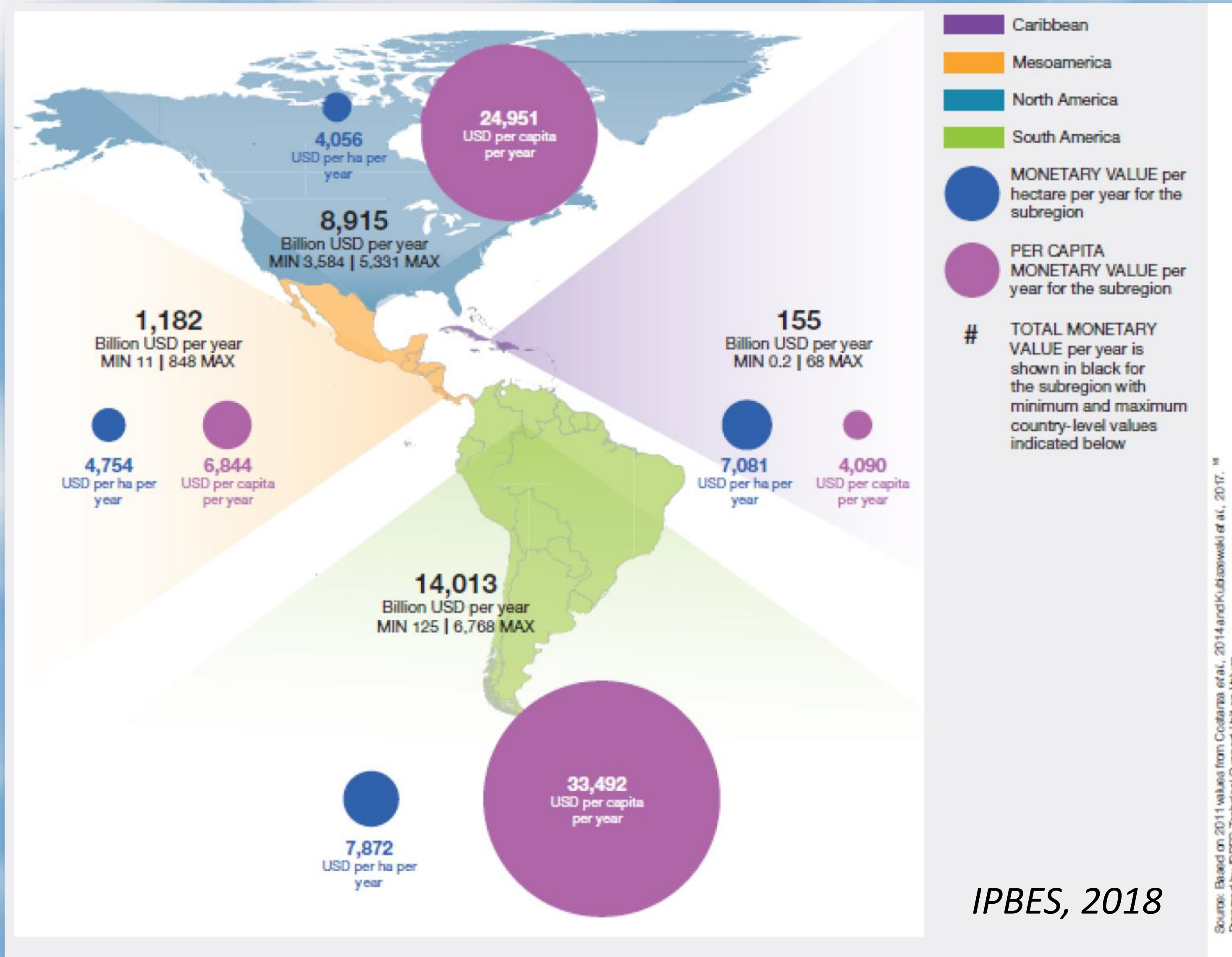
El impacto del cambio climático sobre el sector agrícola depende de las condiciones socioeconómicas, tecnológicas, geográficas y del clima



▸ [a] CEPAL, CEPALSTAT. ▸ [b] Cline, W. (2008), Global warming and agriculture, en Finance & Development. ▸ [c] CEPAL, cEPALSTAT sobre la base de encuestas de hogares de los países. ▸ [d] CEPAL, CEPALSTAT sobre la base de datos oficiales de los países. ✦Incluye agricultura, ganadería, caza, silvicultura y pesca. El dato de Argentina proviene del Banco Mundial. ▸ [e] Cline, W. (2007), Global warming and agriculture: impact estimates by country, Peterson Institute. ✦El Impacto sobre la agricultura del cambio climático se obtuvo a partir de una función lineal de la estimación preferida del impacto en 2080 incluido en el Cline (2007). El impacto para América Latina y el Caribe es el promedio simple. Se supuso que el impacto para Paraguay es el reportado bajo de rubro de "Otros Sudamérica", el impacto de Uruguay es el mismo que el de Argentina. ▸ [f] Valores obtenidos del Banco Mundial. ▸ Algunos elementos gráficos incluidos en la lámina han sido diseñados por Freepik.com.

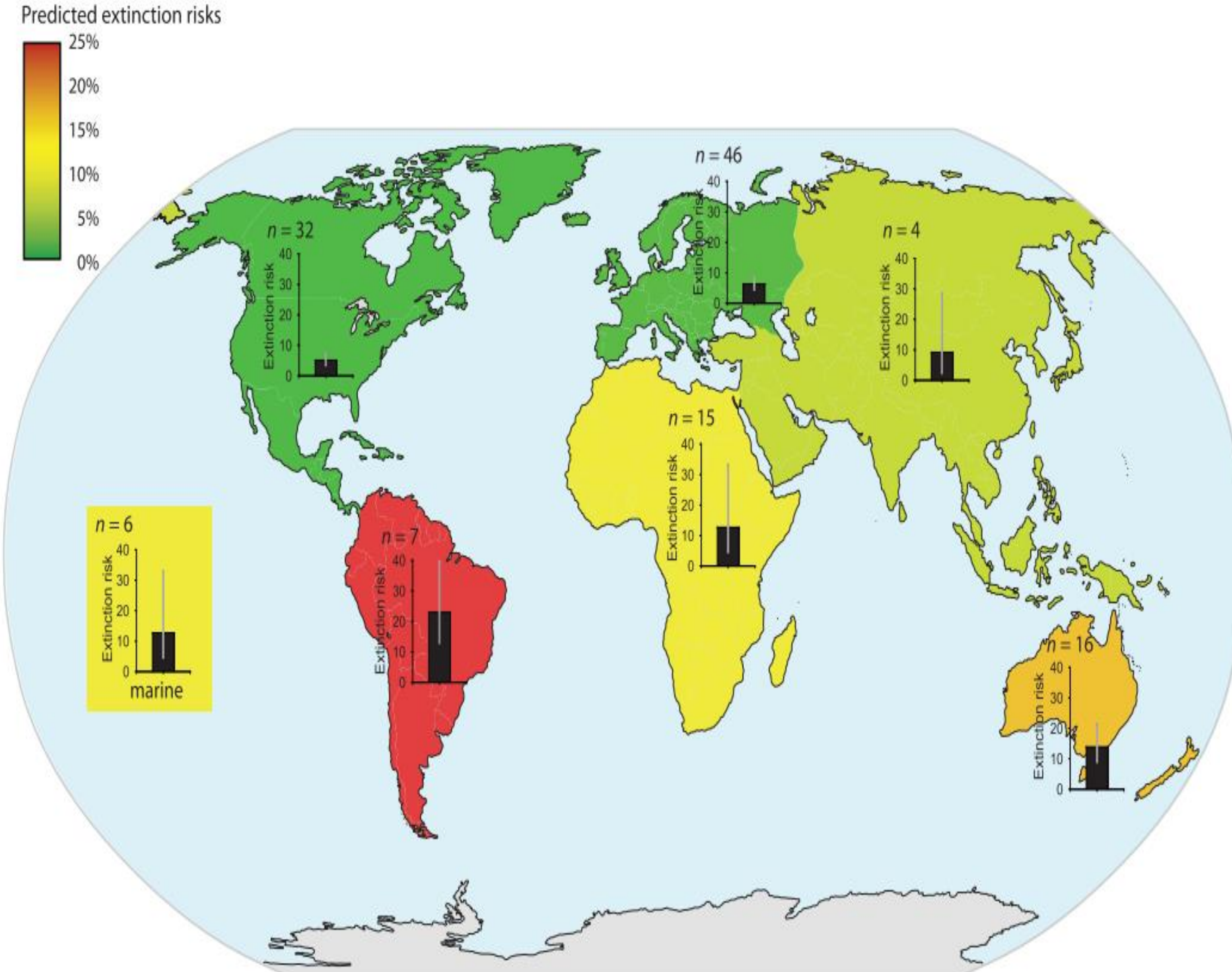
Fuente: Comisión Económica para América Latina y el Caribe (CEPAL).

Valor econômico estimado dos serviços ecossistêmicos nas Américas



IPBES, 2018

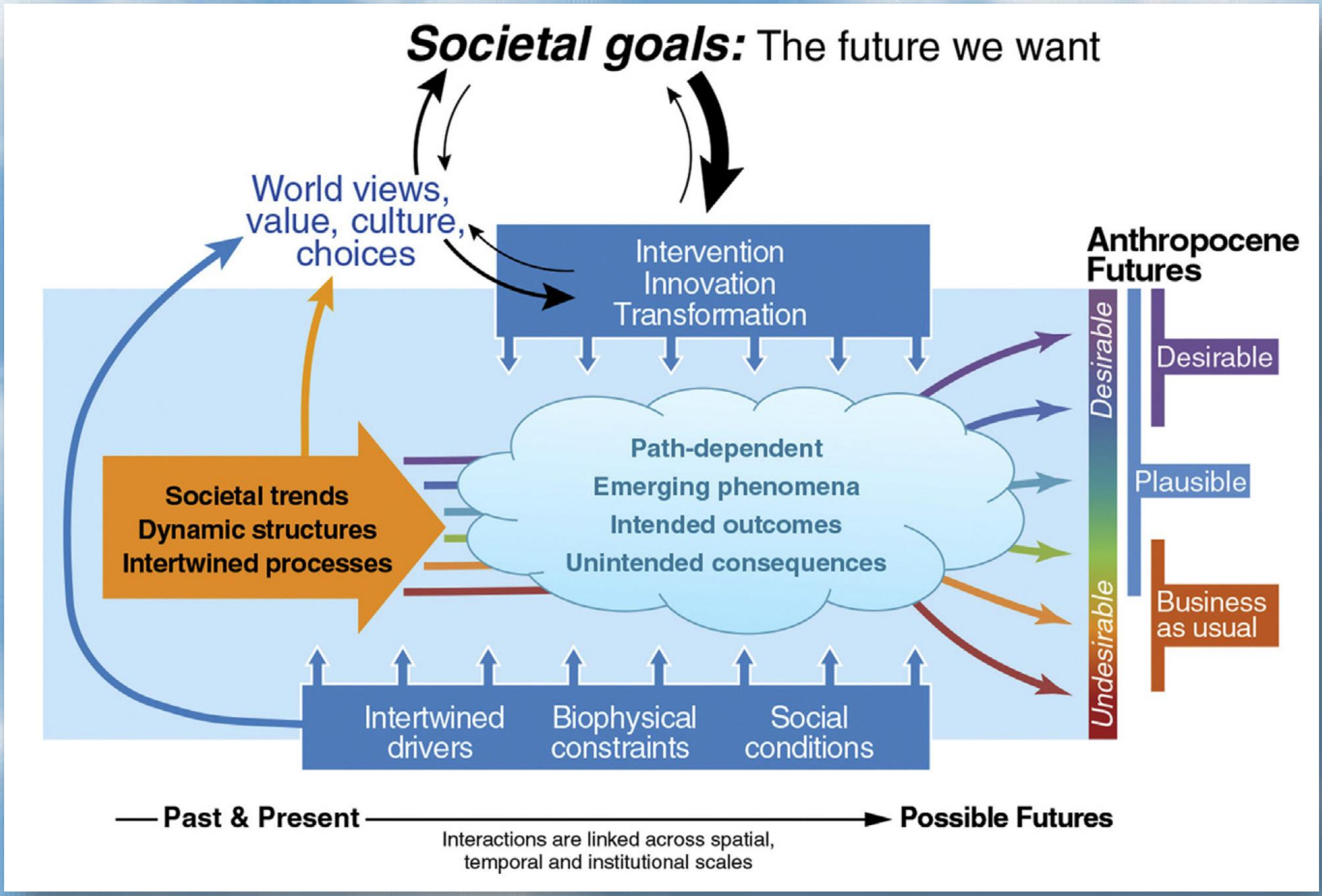
Predicted Extinction Risks of Biological Species



The highest risks: South America, Australia, and New Zealand (14 to 23%)

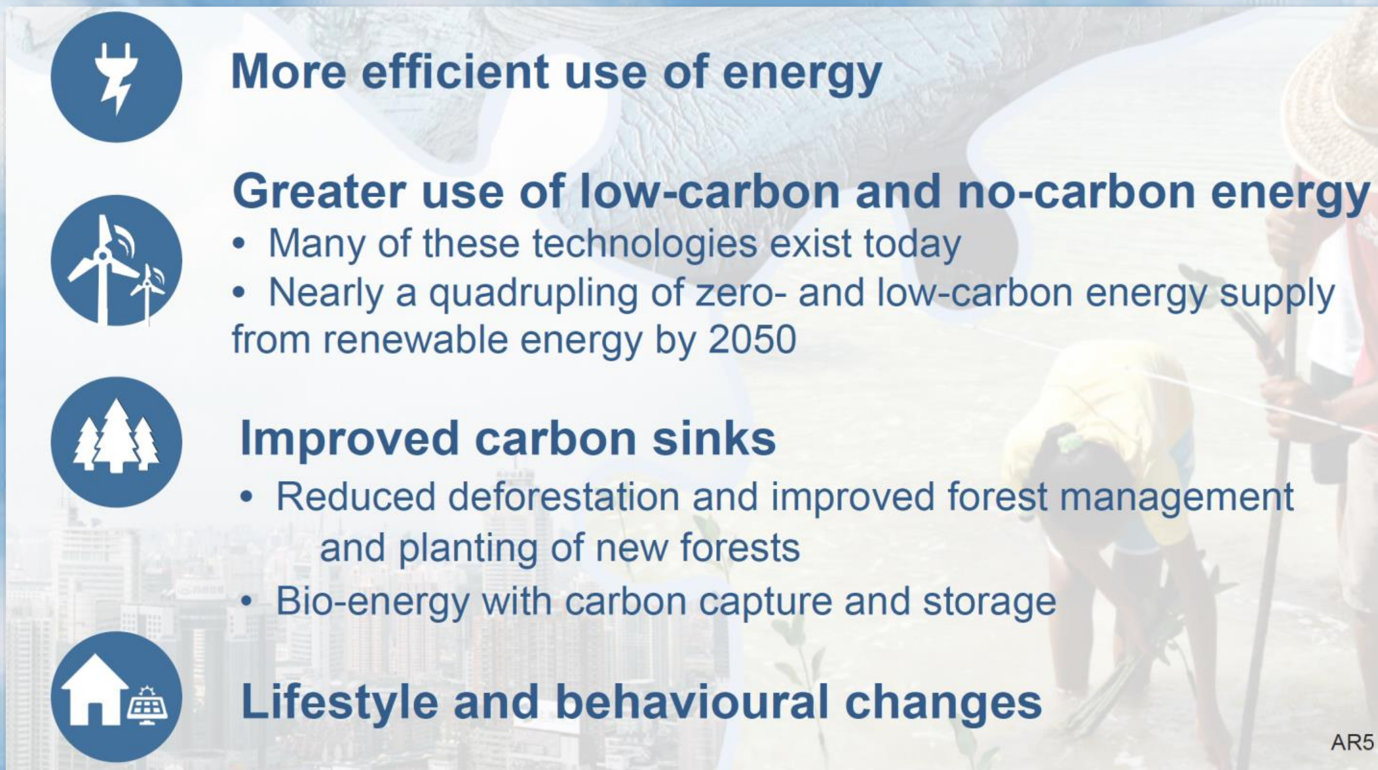
Source: Urban M.C-Nature, 2015

Which future do we want? The future of the Anthropocene



Global Environmental Change 39 (2016) 351–362

Solutions



Energy production

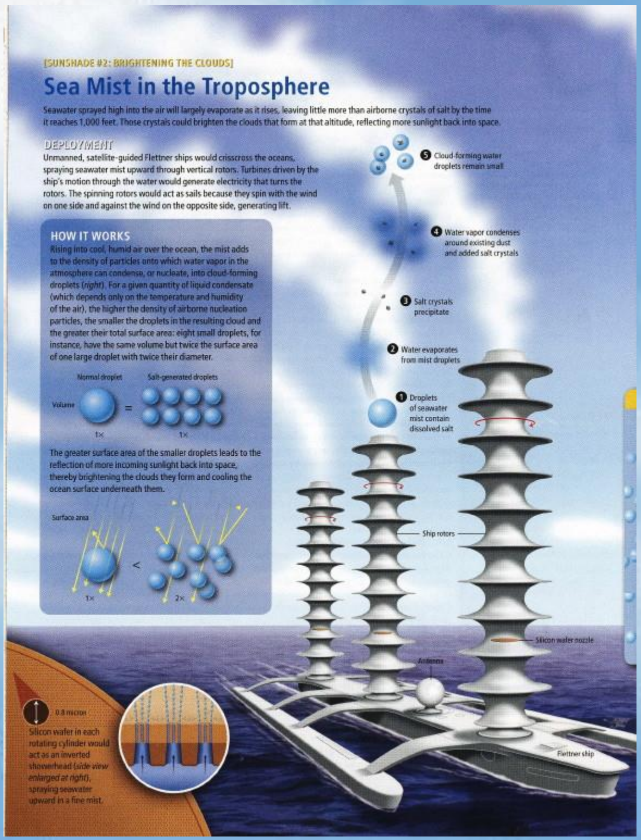
Transportation

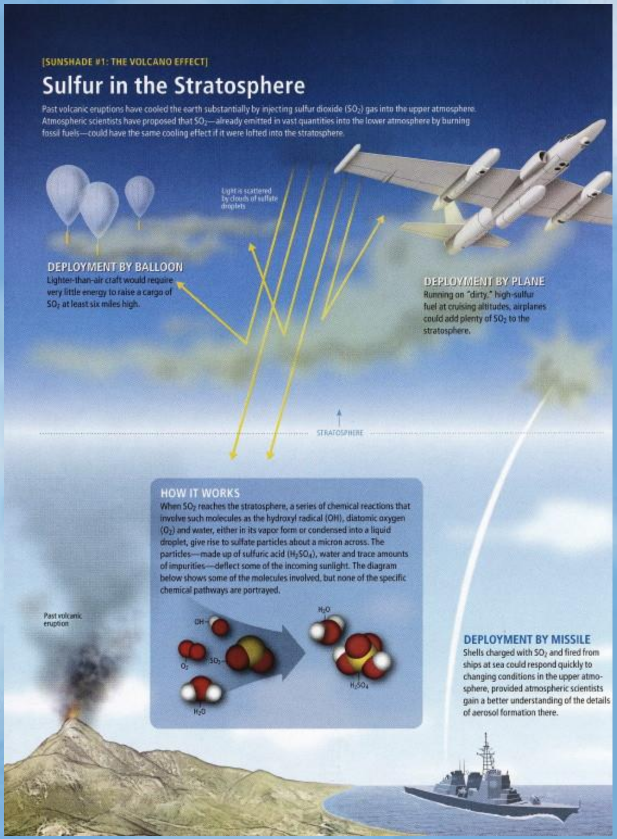
Agriculture

Biofuels?

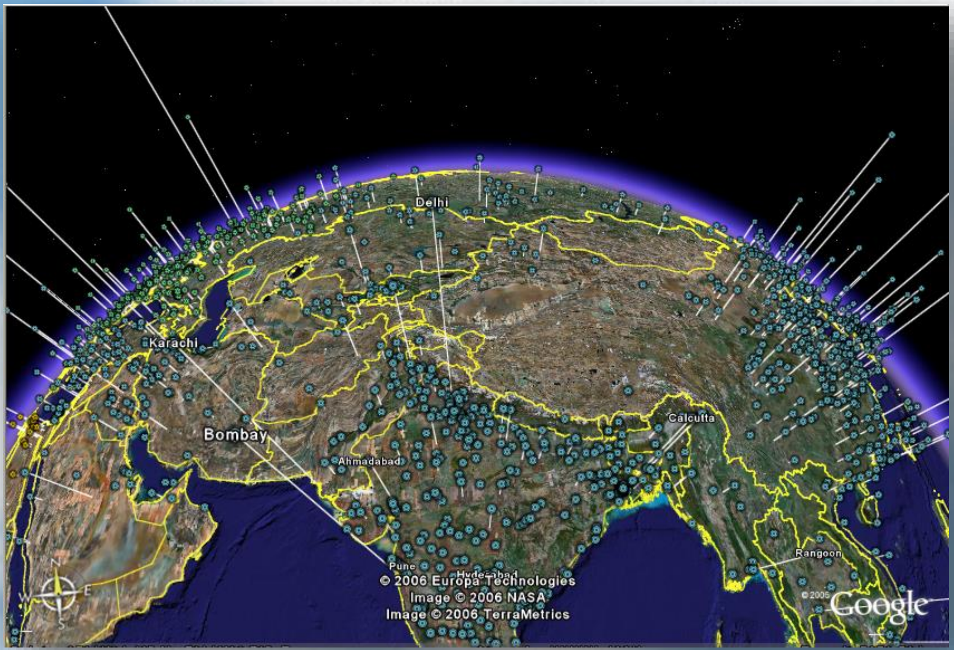
Geoengenharia climática? Possível? Desejável?

Espelhos no espaço? | **Aumentar cobertura de nuvens?** | **Enxofre na estratosfera?**





<u>Meeting at ABC June 10-11</u> to discuss Climate Geoengineering: Aerosols in the stratosphere? Carbon Capture and Storage?



In 2050 about 85% of the world population will be living in cities…

World Economic Forum: The Global Risks Report 2019

Top 5 Global Risks in **Terms of Likelihood**

2017	2018	2019
Extreme weather events	Extreme weather events	Extreme weather events
Large-scale involuntary migration	Natural disasters	Failure of climate-change mitigation and adaptation
Major natural disasters	Cyber-attacks	Natural disasters
Large-scale terrorist attacks	Data fraud or theft	Data fraud or theft
Massive incident of data fraud/theft	Failure of climate-change mitigation and adaptation	Cyber-attacks

Top 5 Global Risks in **Terms of Impacts**

2017	2018	2019
Weapons of mass destruction	Weapons of mass destruction	Weapons of mass destruction
Extreme weather events	Extreme weather events	Failure of climate-change mitigation and adaptation
Water crises	Natural disasters	Extreme weather events
Major natural disasters	Failure of climate-change mitigation and adaptation	Water crises
Failure of climate-change mitigation and adaptation	Water crises	Natural disasters

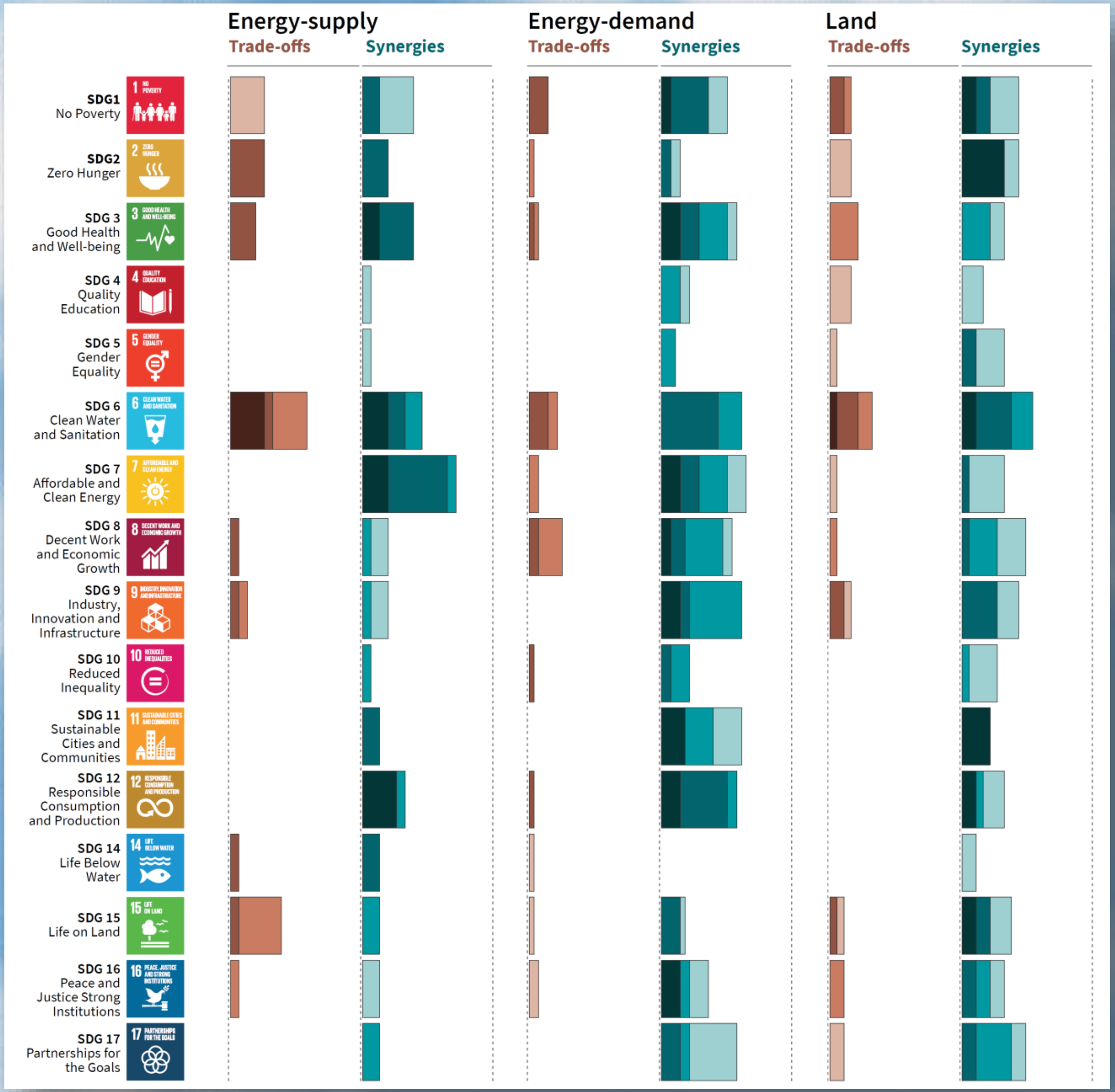
Economic Environmental Geopolitical Societal Technological

P.S.: These are issues raised by economists, not scientists or NGOs…

UN 17 goals to transform our world

SUSTAINABLE DEVELOPMENT GOALS

Mitigation options and sustainable development using SDGs



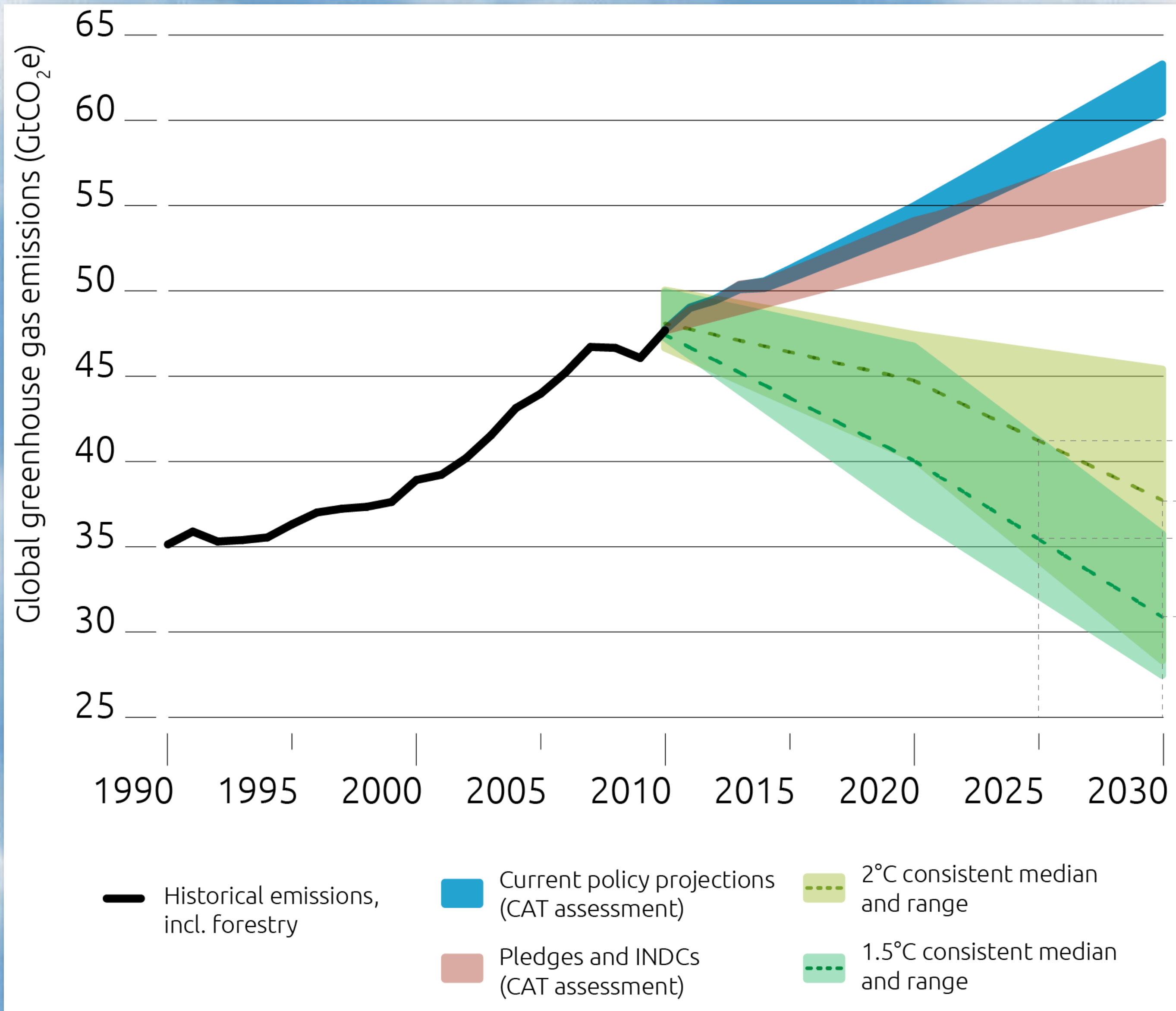
Potential positive effects (synergies)

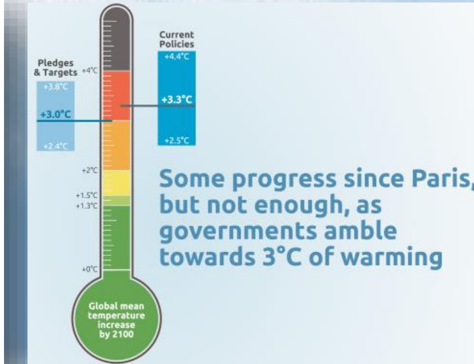
Negative effects (trade-offs)

IPCC SR1.5, 2018

Science basically have done his job…

Paris Agreement: IF all iNDC fulfilled: warming of about 2.7-3.0 degrees in 2050





http://climateactiontracker.org

Brazilian iNDC

Emissions reductions in 2025	Reduction in 2030
37%	**43%**

A few of the Brazilian iNDC commitments (*Reference point:* 2005):

- **ZERO illegal deforestation at 2030 and compensation of emissions from legal deforestation at 2030;**
- **Restore and reforest 12 millions hectares of forests till 2030, for multiple uses;**
- **Restoration of 15 millions of hectares in degraded pastures till 2030**
- **Participation of 45% renewable energy in the energy system at 2030**

Governance is a critical issue

Stephen Hawking "Our planet and the human race face multiple challenges. These challenges are global and serious – climate change, food production, overpopulation, the decimation of other species, epidemic disease, acidification of the oceans. Such pressing issues will require us to collaborate, all of us, with a shared vision and cooperative endeavor to ensure that humanity can survive."

We have not yet managed to adopt a model of production capable of preserving resources for present and future generations, while limiting as much as possible the use of non-renewable resources, moderating their consumption, maximizing their efficient use, reusing and recycling them.

Governance is key:
How the necessary measure will be implemented?
Who drives and controls the implementation?

Papel das empresas e setor privado

Governos respondem muito mais aos interesses empresariais do que interesses públicos. Em geral empresas e governos tem visão limitada a no máximo 4-6 anos. Quem pensa no planeta daqui a 50 ou 100 anos?

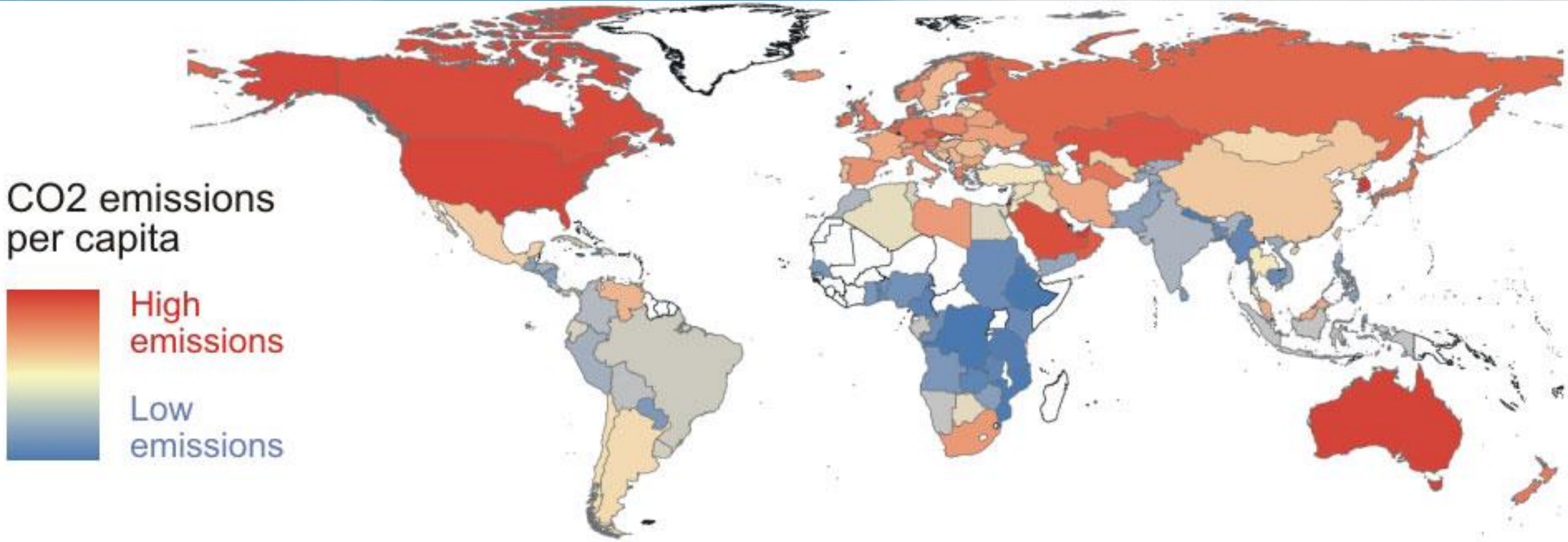
Papel das empresas até o momento:

Setor petrolífero: Shell, BP, Exxon sabiam nos últimos 70 anos dos impactos. Industria teve lucros de mais de centenas de trilhões de dólares. Quem paga a adaptação e os efeitos nos 7 bilhões de habitantes do planeta?

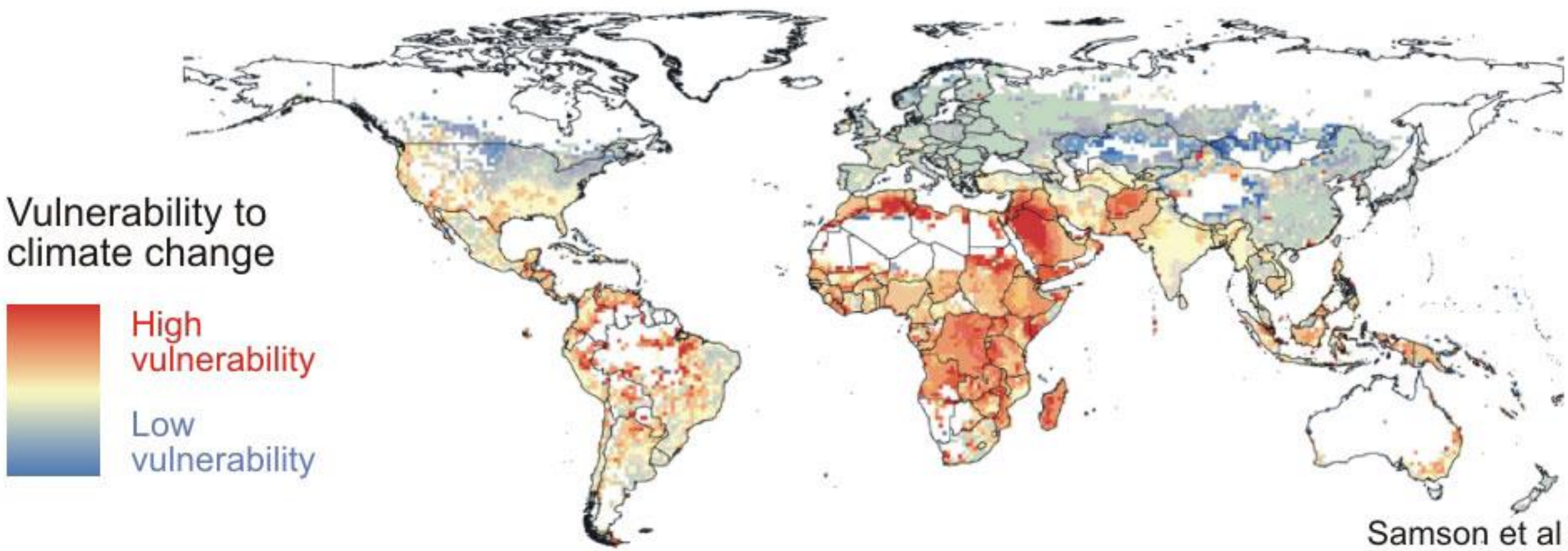
Setor automobilístico: Volks, AUDI, e outros fabricantes na questão das emissões de veículos a diesel: Se pudermos enganar a legislação, o faremos.

Setor agropecuário brasileiro: Pressão para desmatar o mais possível a Amazônia, para plantar soja e criar gado de modo ineficiente, ignorando o potencial futuro.

Setor privado fica com os lucros, setor publico paga os prejuízos. É justo e eticamente correto?



Those who contribute the least greenhouse gases will be most impacted by climate change



Samson et al 2011

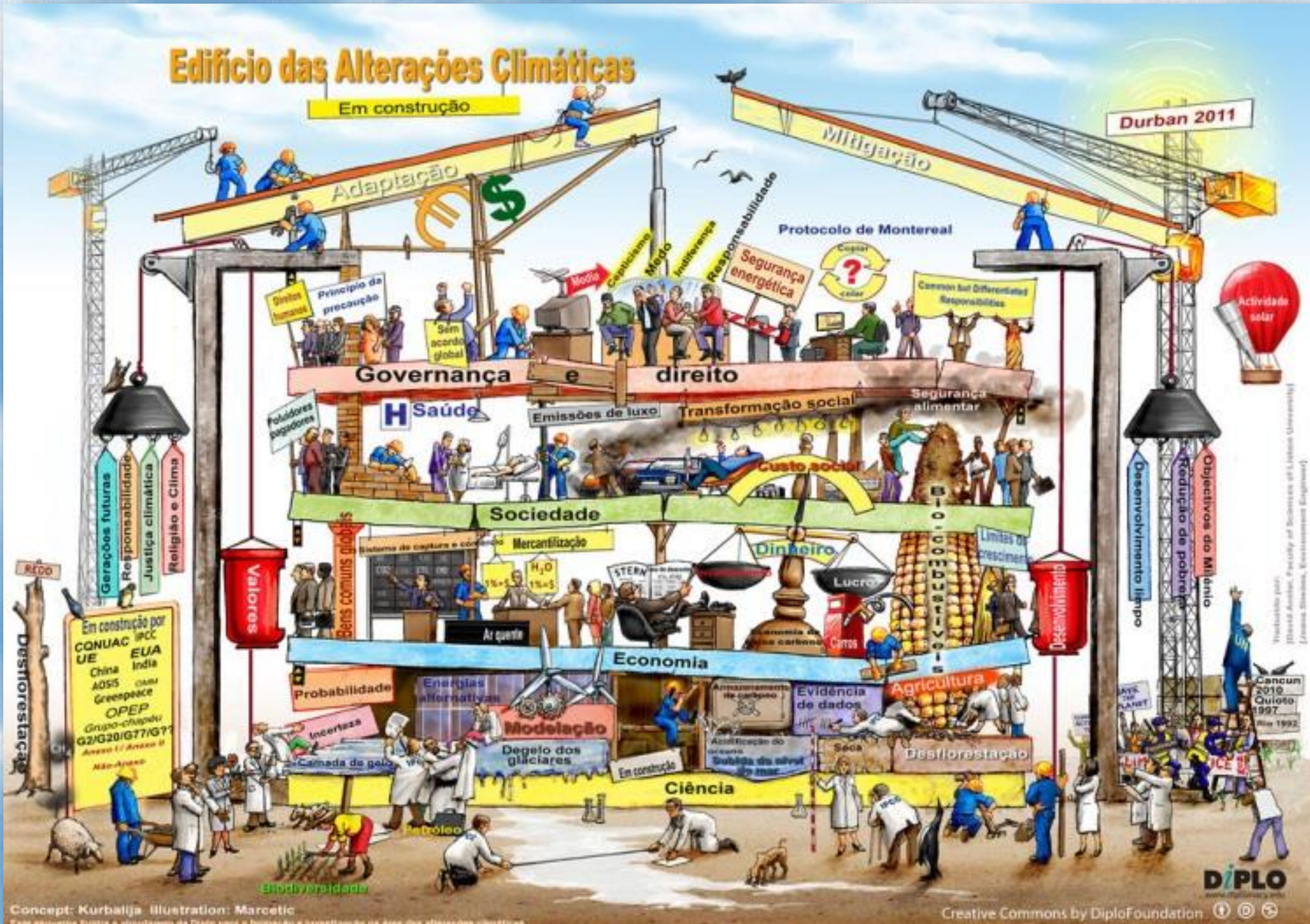
Table 21.1: Percentage of countries by region projected to achieve selected SDG targets in 2030

	Europe and Russian Federation	Latin America and Caribbean	Middle East and North Africa	Non-OECD Asia Pacific	North America	OECD Asia Pacific	South Asia	Sub-Saharan Africa	World
Extreme poverty	100	68	85	70	100	100	79	21	67
Hunger	95	32	70	26	100	100	43	10	48
Underweight children	82	48	30	26	100	100	14	0	37
Child mortality	98	90	90	74	100	50	71	6	67
Primary school completion	100	94	85	78	100	100	86	33	77
Lower secondary school	89	35	40	48	100	100	50	4	45
Access to safe water	98	94	95	70	100	100	93	17	72
Improved sanitation	80	29	65	43	100	100	43	4	44
Access to electricity	100	68	90	48	100	100	71	2	60

Source: Moyer and Hedden (2018).

Global inequality is a big issue: consumption in one week...

The role of Science versus economy, society, governance, etc...



How to build a safe space to our humanity?

Combining the Earth System with societal needs

Steffen et al. 2015, Science

We need solid science and public policies to build this space

SDGs and the six transformations required for The World in 2050

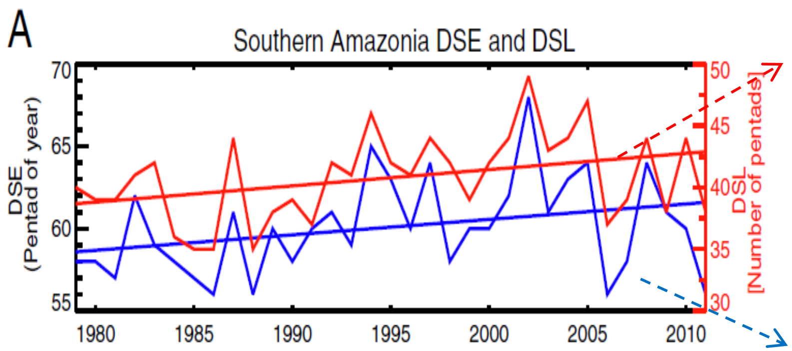
Source: TWI2050

Our home work: If we want to avoid a warming of 4-5 degrees in our planet, there is no other way than to use the natural resources of our planet more efficiently and intelligently.

Reaching the SDG must be done together with adapting and mitigating climate change

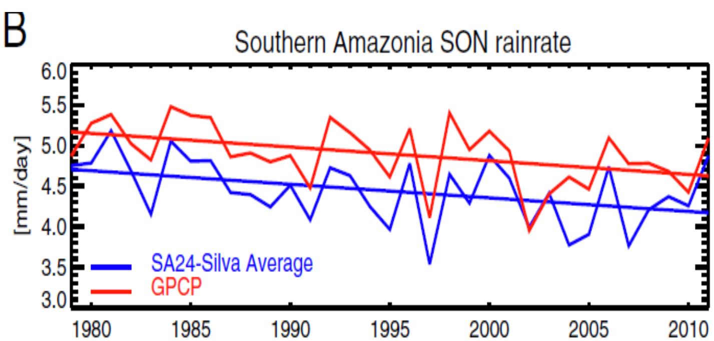
Thanks for the attention!!!

Dry season length is increasing in Amazonia



Annual time series of dry season length (DSL)

Annual time series of dry season END (DSE)

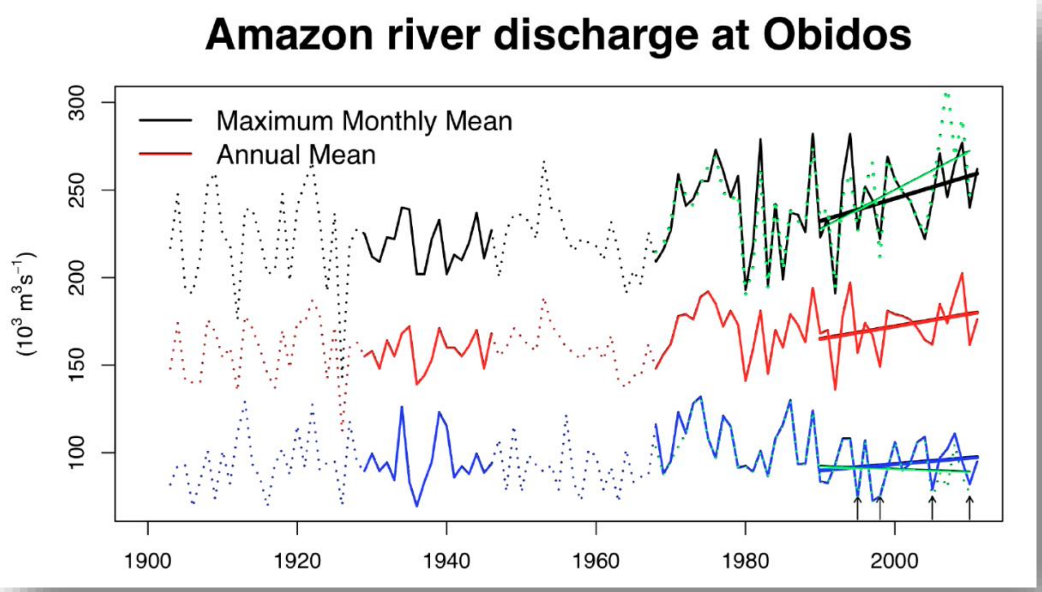


Dry season length has increased by **6.5±2.5** days/decade;

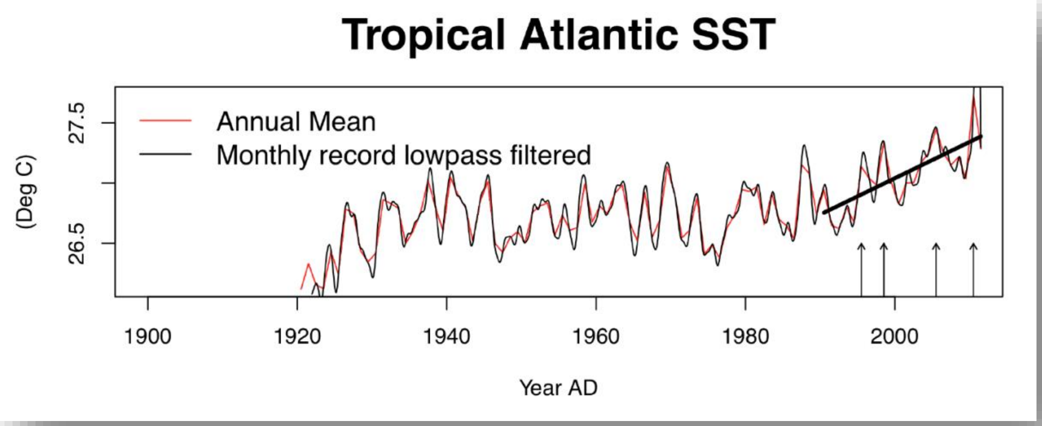
Fu et al. 2013 (PNAS)

Is the Amazonian hydrological cycle intensifying?

Maximum monthly, annual mean and minimum monthly mean Amazon river discharge at Óbidos and in green maximum and minimum daily mean river discharge.

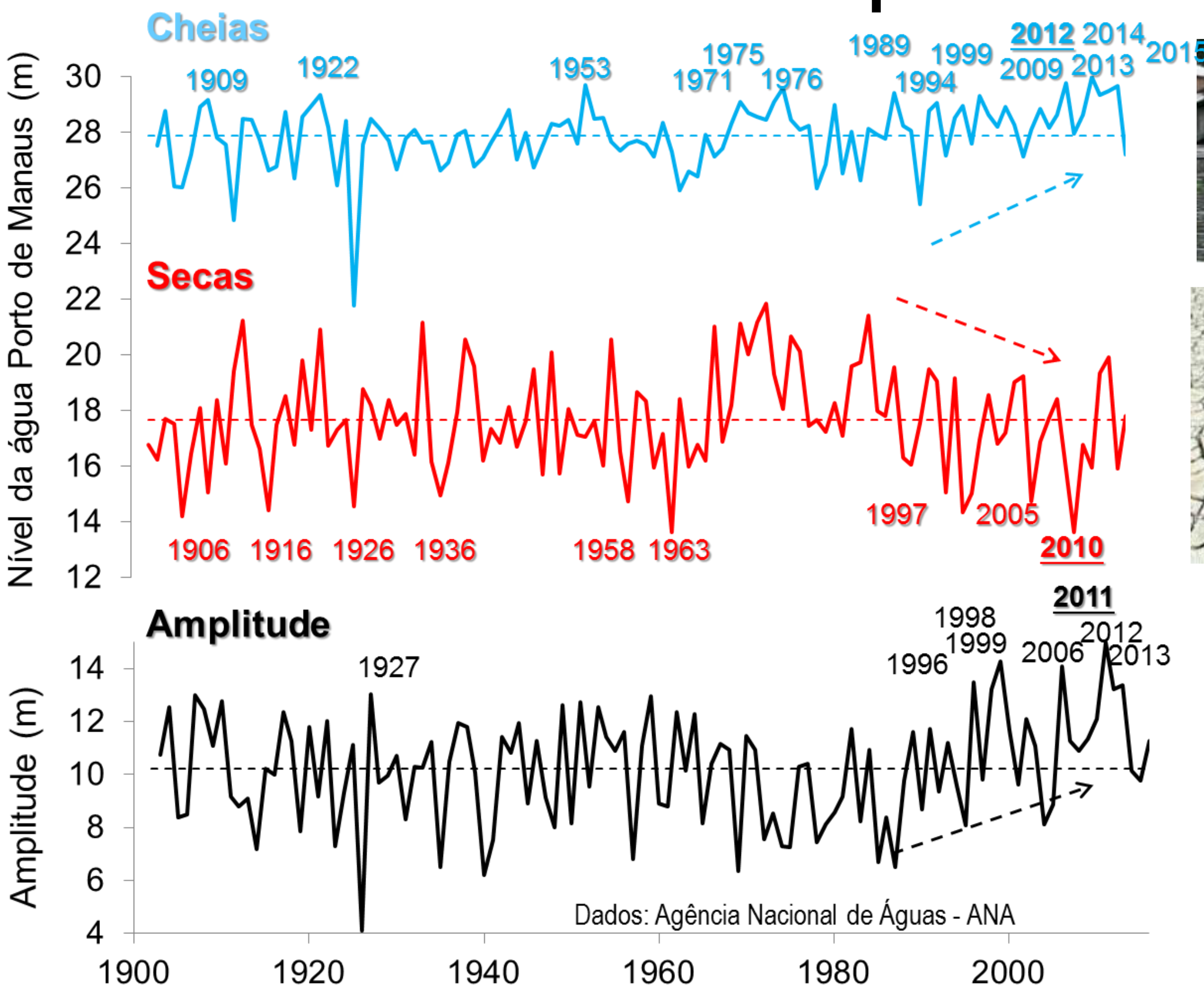


Tropical Atlantic sea surface temperature from Extended reconstructed sea surface temperature.



Gloor et al. 2013

Port of Manaus maximum and minimum levels of water and amplitude



Jochen Schöngart, 2017