



*26 Encontro Técnico AESABESP
Centro de Convenções Expo Center Norte
5 de Agosto de 2015*

Mudanças climáticas globais e o ciclo hídrico em nosso planeta

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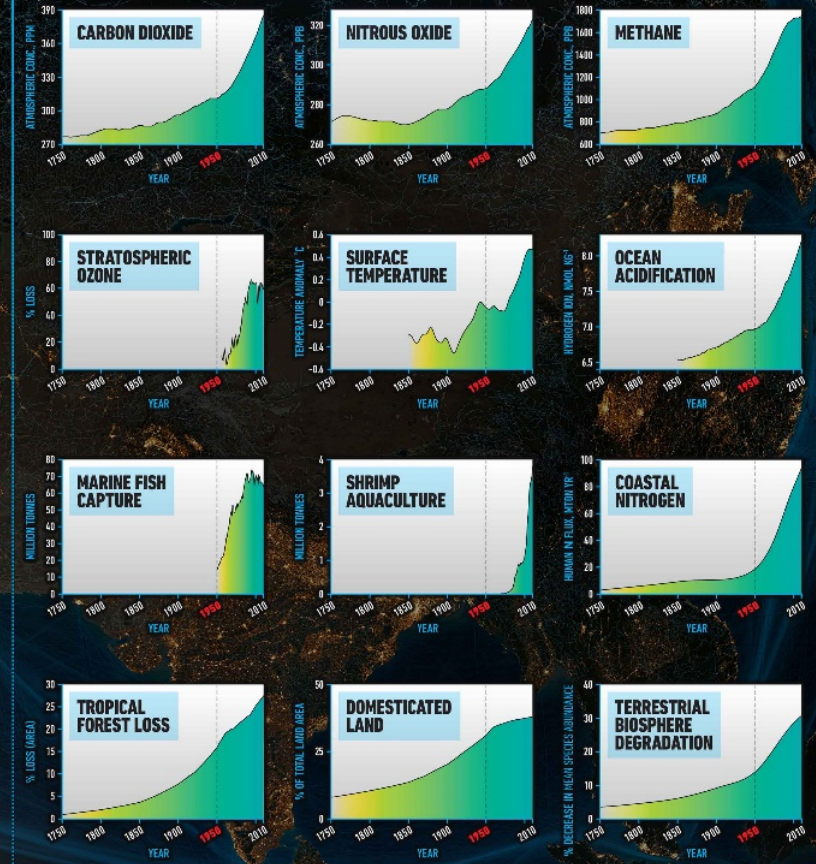
Estamos mudando nosso planeta rapidamente e de muitas formas

THE GREAT ACCELERATION

SOCIO-ECONOMIC TRENDS



EARTH SYSTEM TRENDS



REFERENCE: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig (2015), The Trajectory of the Anthropocene: the Great Acceleration, Submitted to *The Anthropocene Review*.

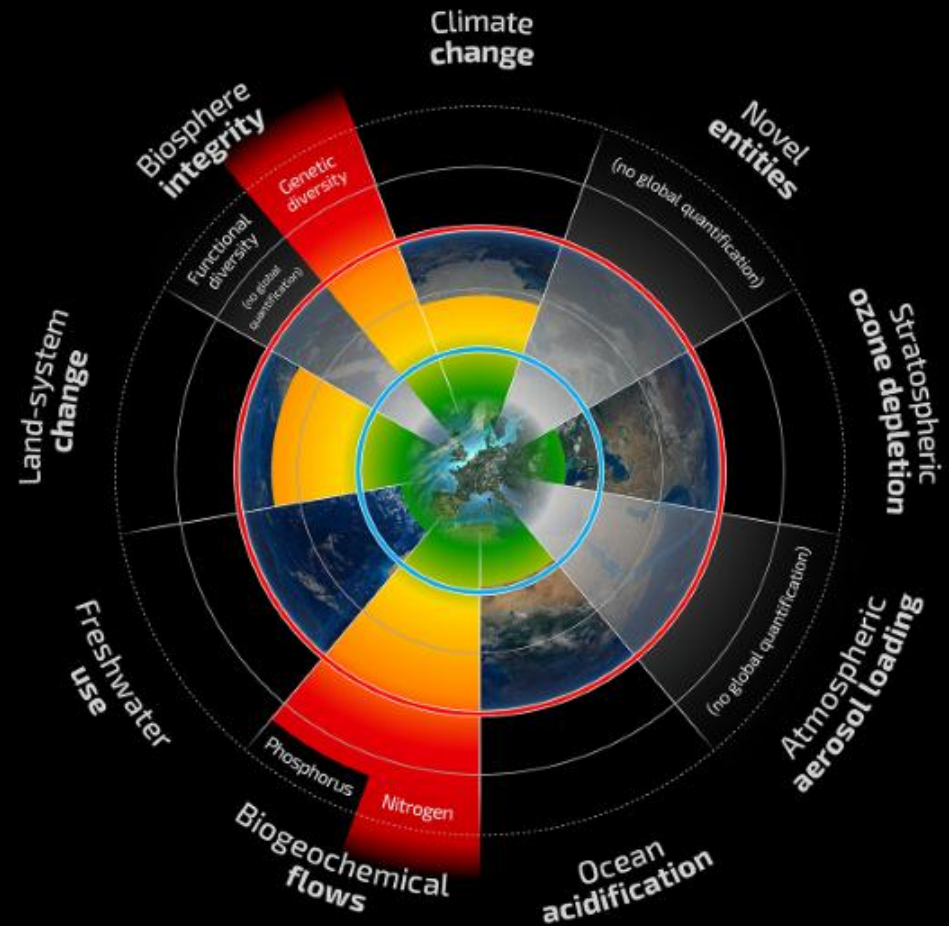
MAP & DESIGN: Félix Pharand-Deschênes / Globaia

Quais são os efeitos destas mudanças?

Estimativas da evolução quantitativa de variáveis de controle para alguns limites planetários desde níveis pré-industriais até o presente

Planetary Boundaries

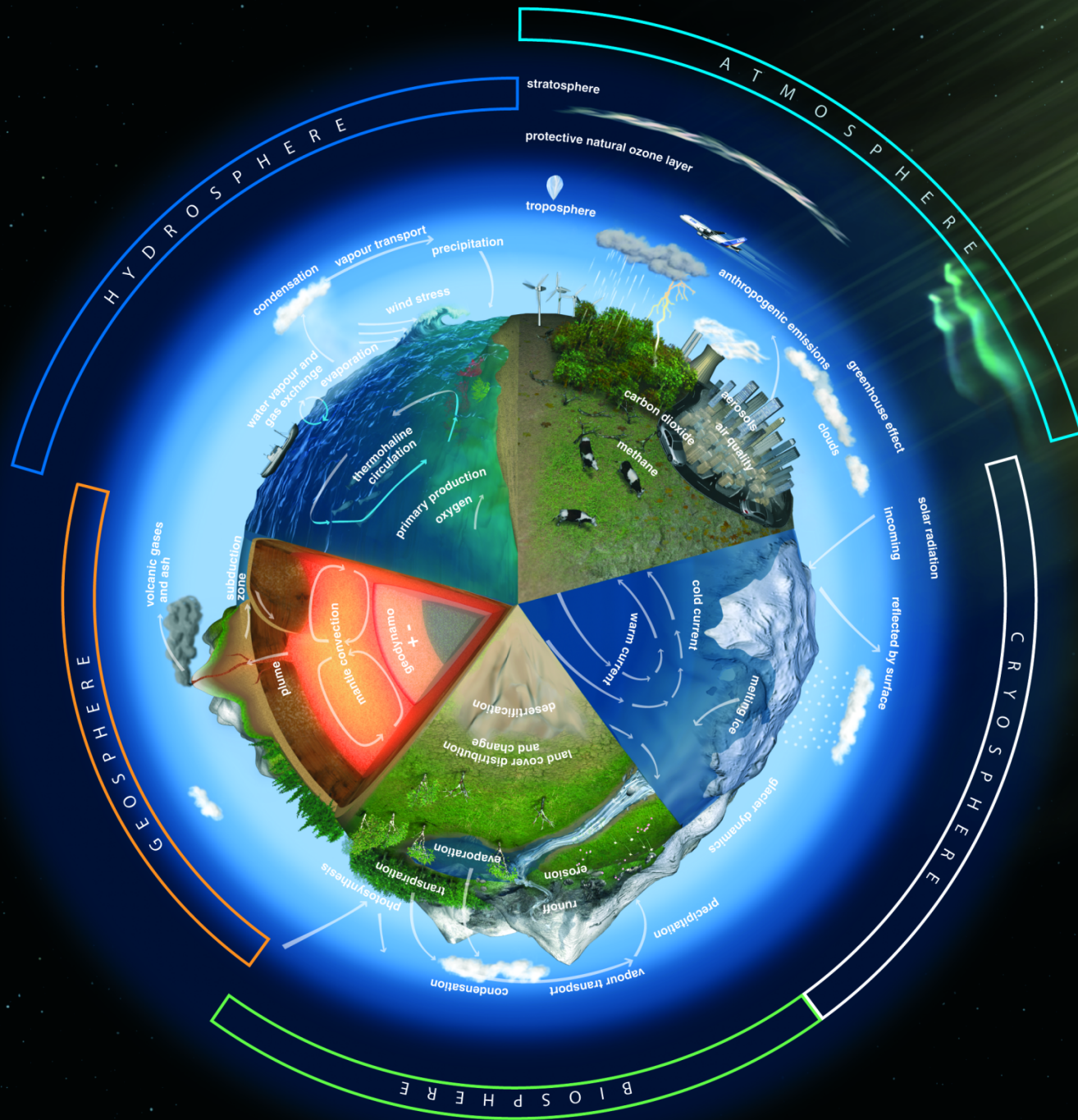
A safe operating space for humanity



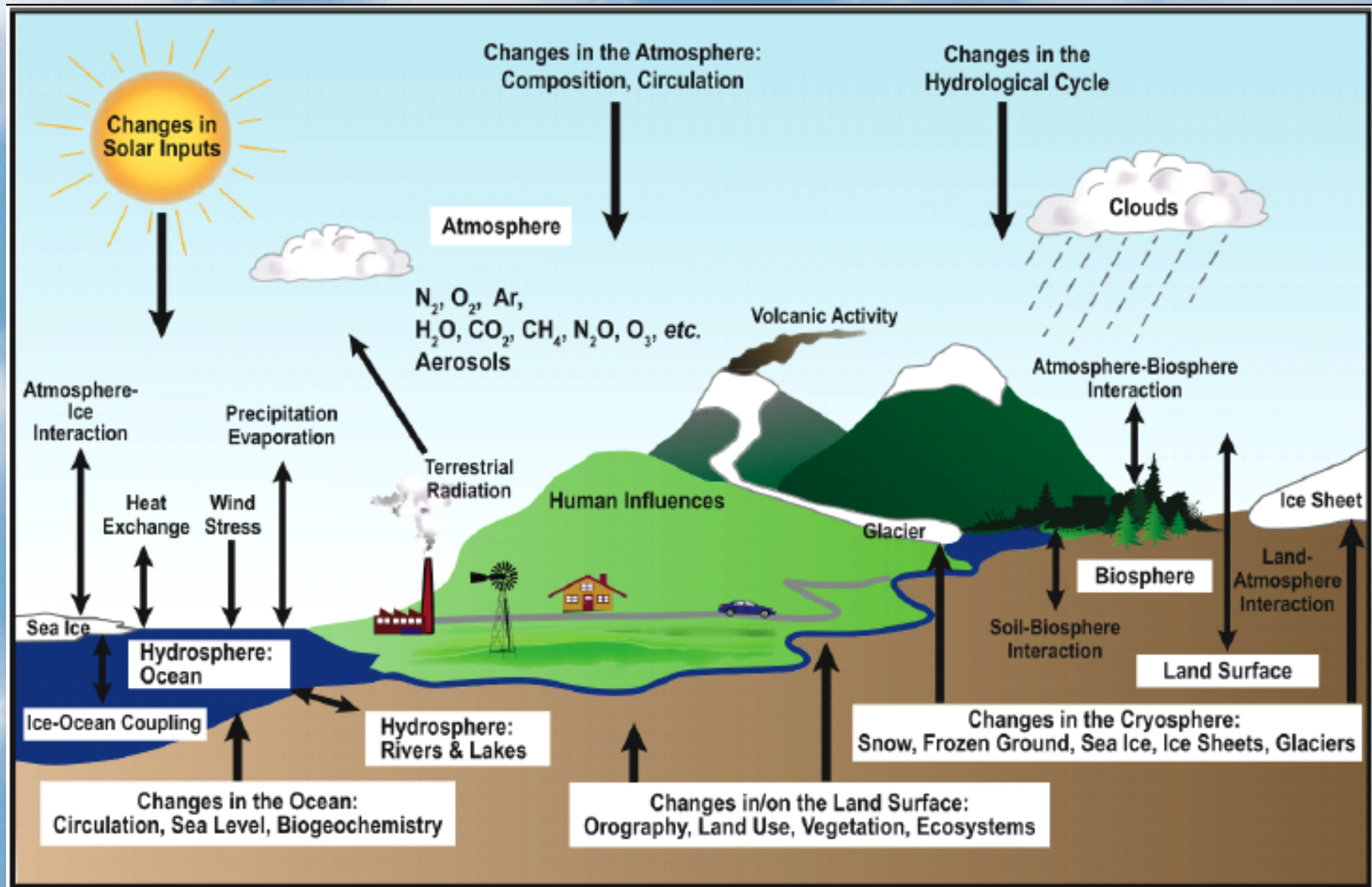
- Beyond zone of uncertainty (high risk)
- In zone of uncertainty (increasing risk)
- Below boundary (safe)
- Boundary not yet quantified

Nosso planeta em mudança, nos compartimentos:

Atmosfera
Criosfera
Biosfera
Geosfera
Hidrosfera



O sistema climático global



Nosso clima depende das interações entre a biosfera e a atmosfera



Perturbações humanas no ciclo do carbono global



Perturbações humanas no ciclo do carbono global

(Global Carbon Project 2010)

Atmosphere
(800)

120 + 3

Photosynthesis

60

Plant
respiration

Plant
biomass
(550)

60

Microbial
respiration and
decomposition

Soil carbon

9
Fossil fuels,
cement, and
land-use
change

Atmospheric
Carbon Net
Annual Increase
4

↑↑ GtC/y: Gigatons
of carbon/year

Numbers in parentheses
refer to stored carbon
pools. Red indicates
carbon from human
emissions.

90 + 2

Air-sea gas
exchange

90

Surface ocean
(1000)

Phytoplankton
photosynthesis

Respiration
and
decomposition

Net ocean
uptake
2

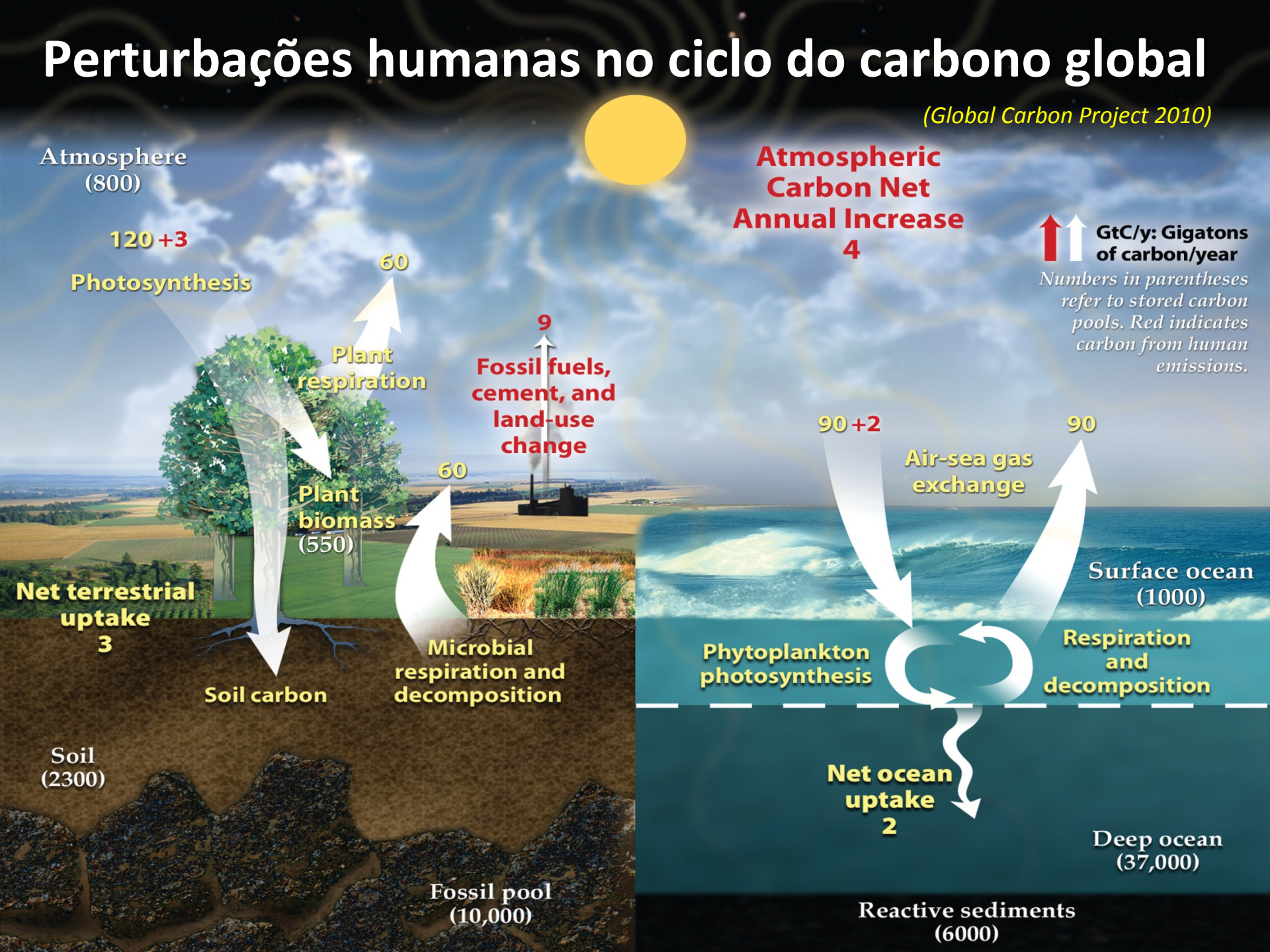
Deep ocean
(37,000)

Reactive sediments
(6000)

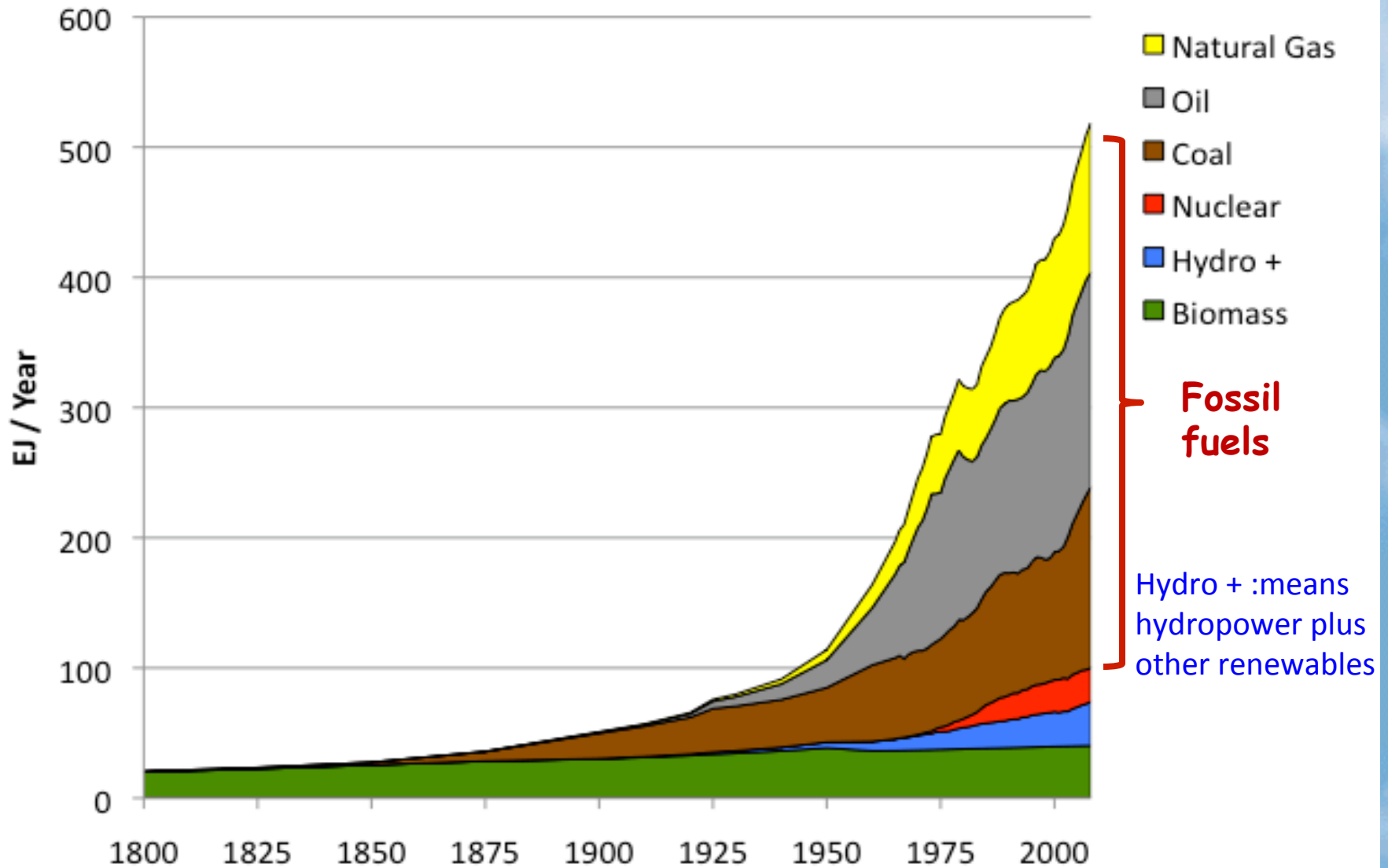
Fossil pool
(10,000)

Soil
(2300)

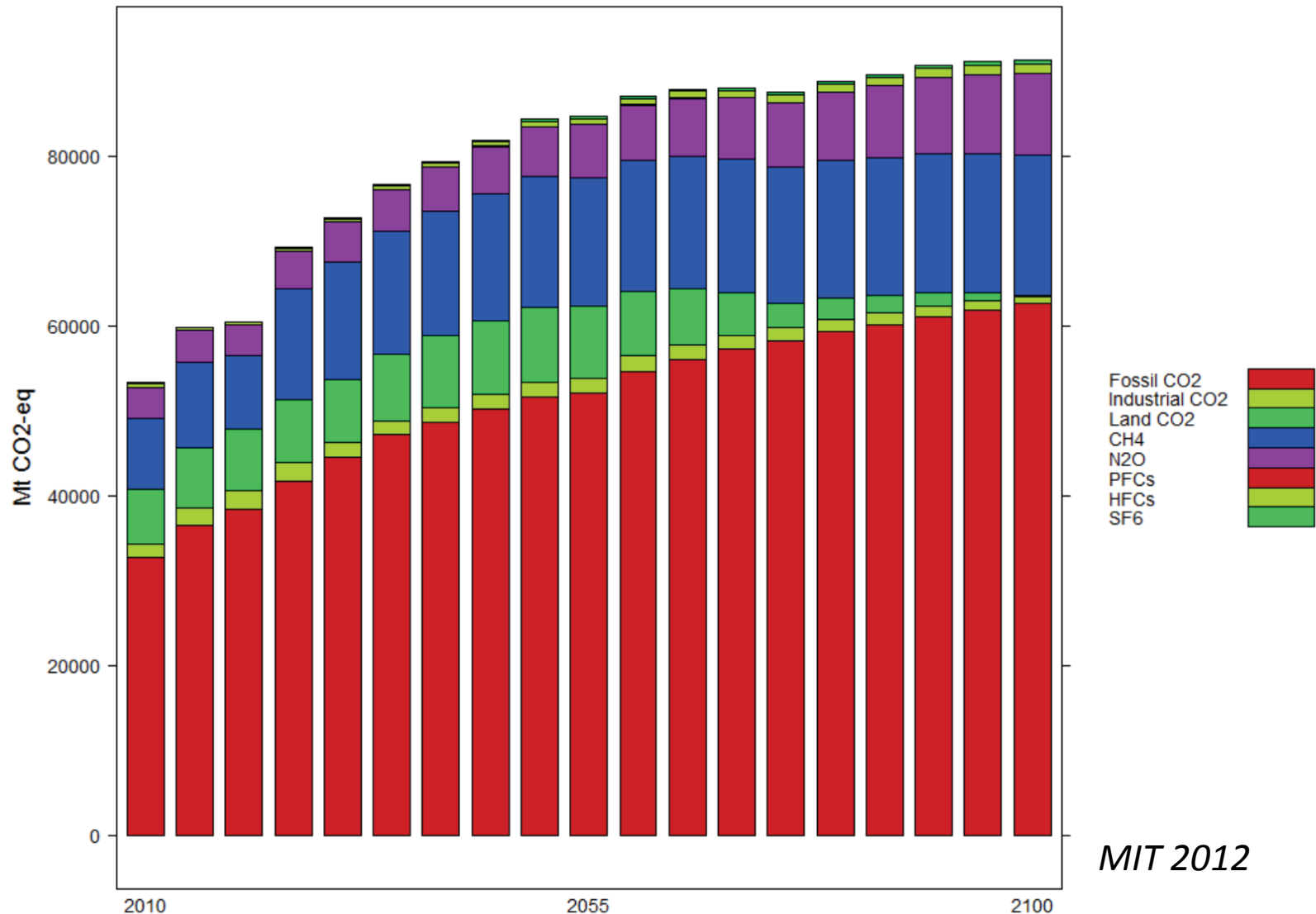
Net terrestrial
uptake
3



Suprimento de energia global: 1800 – 2008



Emissões globais de gases de efeito estufa 2010-2100



MIT 2012

Global carbon dioxide budget (gigatonnes of carbon per year)

1990-2000

2000-2008

Fossil fuel &
cement

6.4 ± 0.4

7.7 ± 0.5

Atmospheric
growth

3.1 ± 0.1

4.1 ± 0.1

Land-use
change

1.6 ± 0.7

1.4 ± 0.7

Land sink

2.6 ± 0.9

2.7 ± 1.0

Ocean sink

2.2 ± 0.4

2.3 ± 0.5

Geological
reservoirs

Global CO₂ budget for 1990-2000 (blue) and 2000-2008 (red) (GtC per year). Emissions from fossil-fuel and land-use change are based on economic and deforestation statistics. Atmospheric CO₂ growth is measured directly. The land and ocean CO₂ sinks are estimated using observations for 1990-2000 (Denman *et al.* IPCC 2007). For 2000-2008, the ocean CO₂ sink is estimated using an average of several models, while the land CO₂ sink is estimated from the balance of the other terms.

Para onde vão as emissões antropogênicas de CO₂ (média 2002-2011)

8.3±0.4 PgC/yr 90%



1.0±0.5 PgC/yr 10%



+

4.3±0.1 PgC/yr 46%



2.6±0.8 PgC/yr 28%

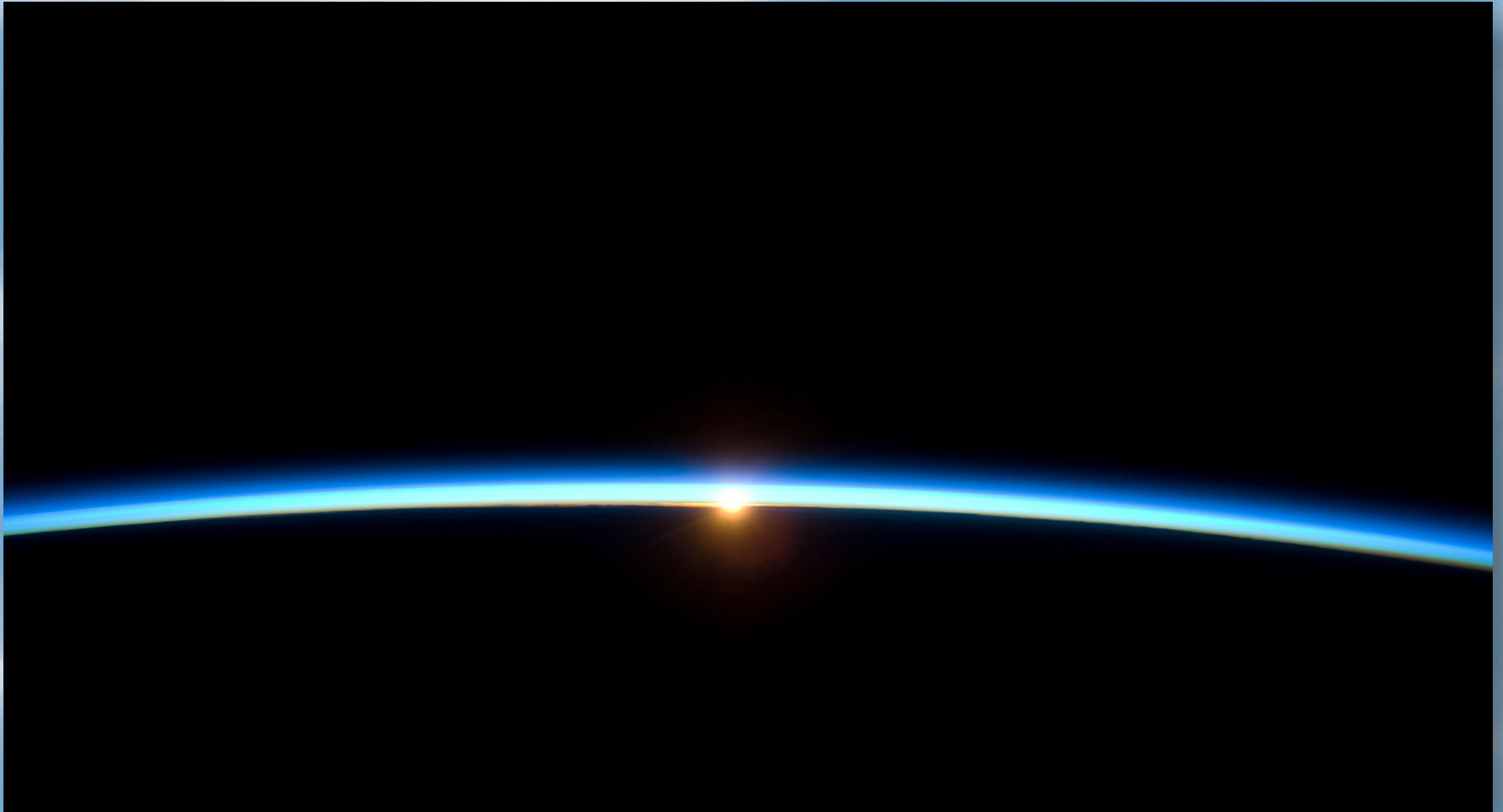


2.5±0.5 PgC/yr 26%

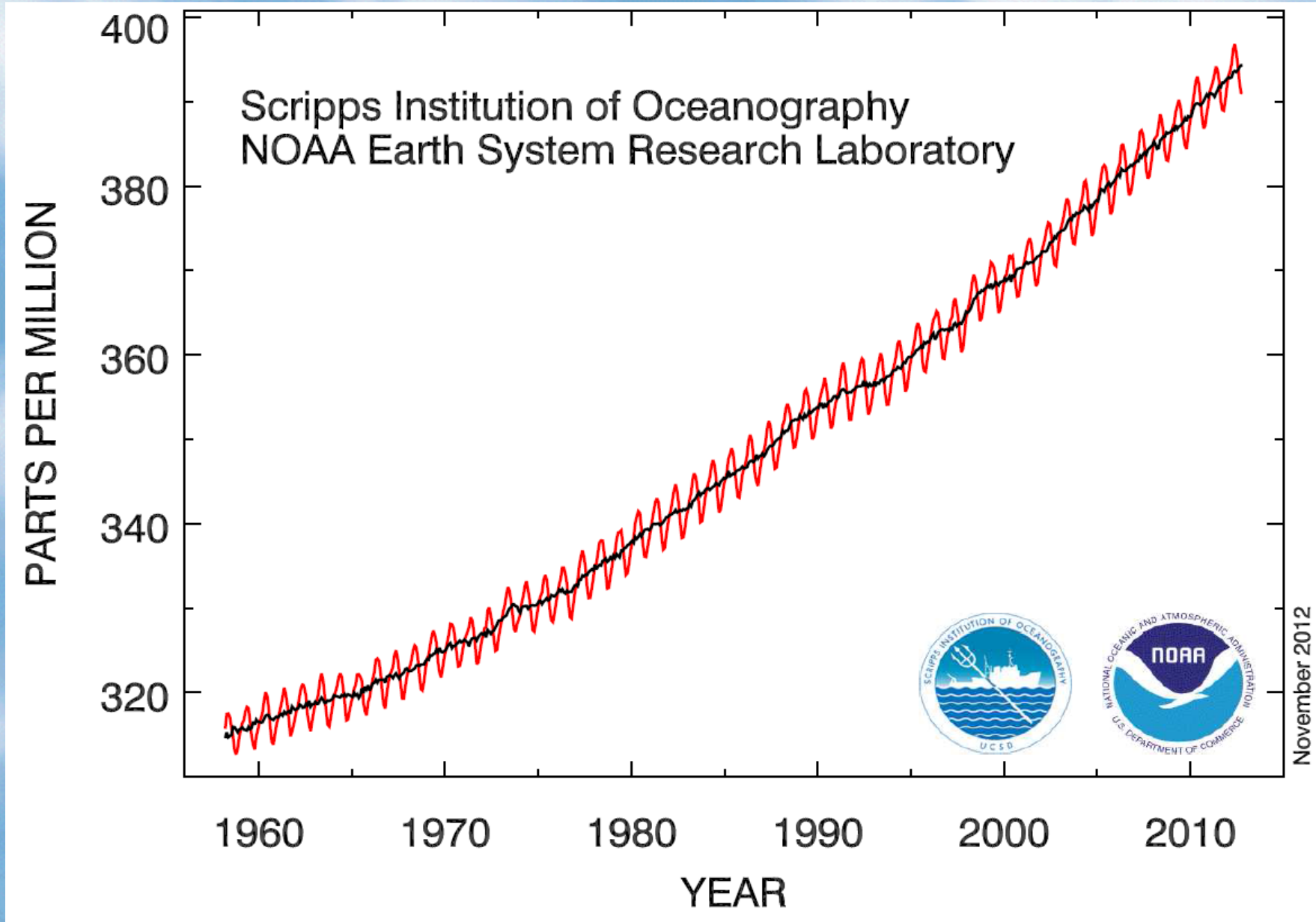


1 PgC = 10¹⁵ g C

**A atmosfera terrestre é MUITO fina:
80% da massa está em até 15 Km...**



CO₂ atmosférico em Mauna Loa desde 1958

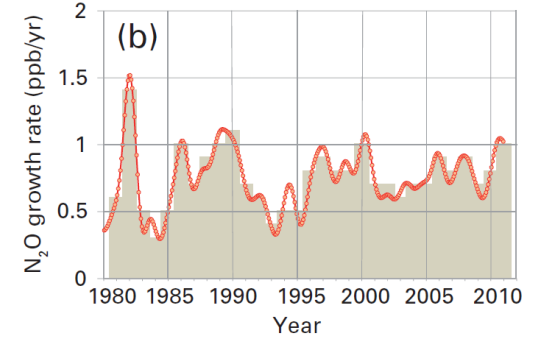
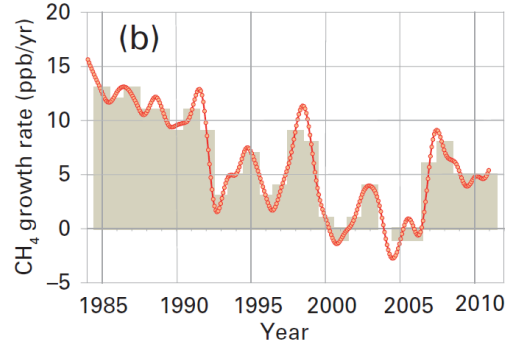
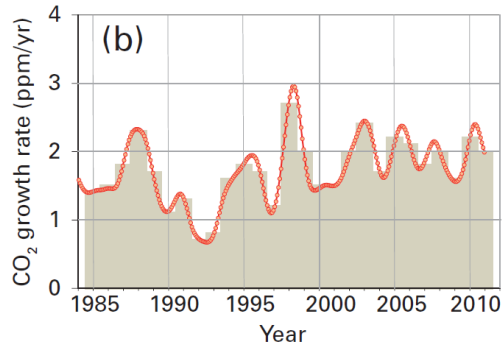
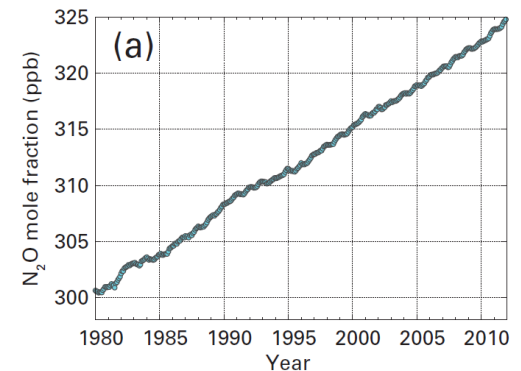
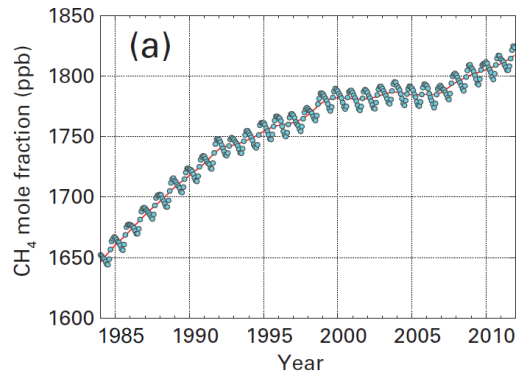
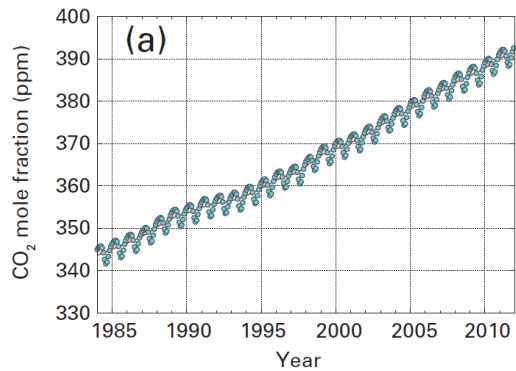


CO₂, CH₄ e N₂O de 1985 a 2011

40% aumento desde 1850

158% aumento desde 1850

20% aumento desde 1850



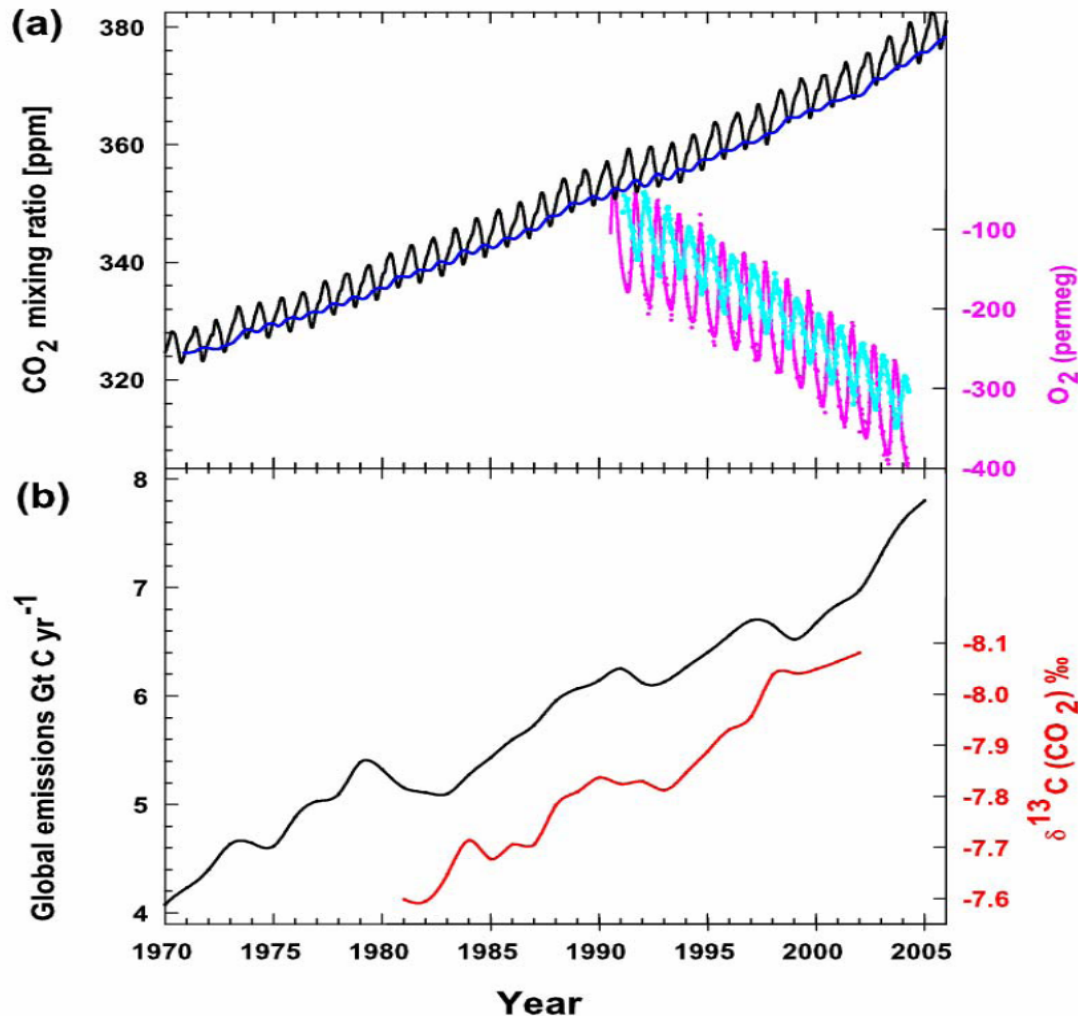
Globally averaged CO₂ mole fraction (a) and its growth rate (b) from 1984 to 2011.

Globally averaged CH₄ mole fraction (a) and its growth rate (b) from 1984 to 2011.

Globally averaged N₂O mole fraction (a) and its growth rate (b) from 1980 to 2011.

O aumento de CO₂ é devido às emissões antropogênicas

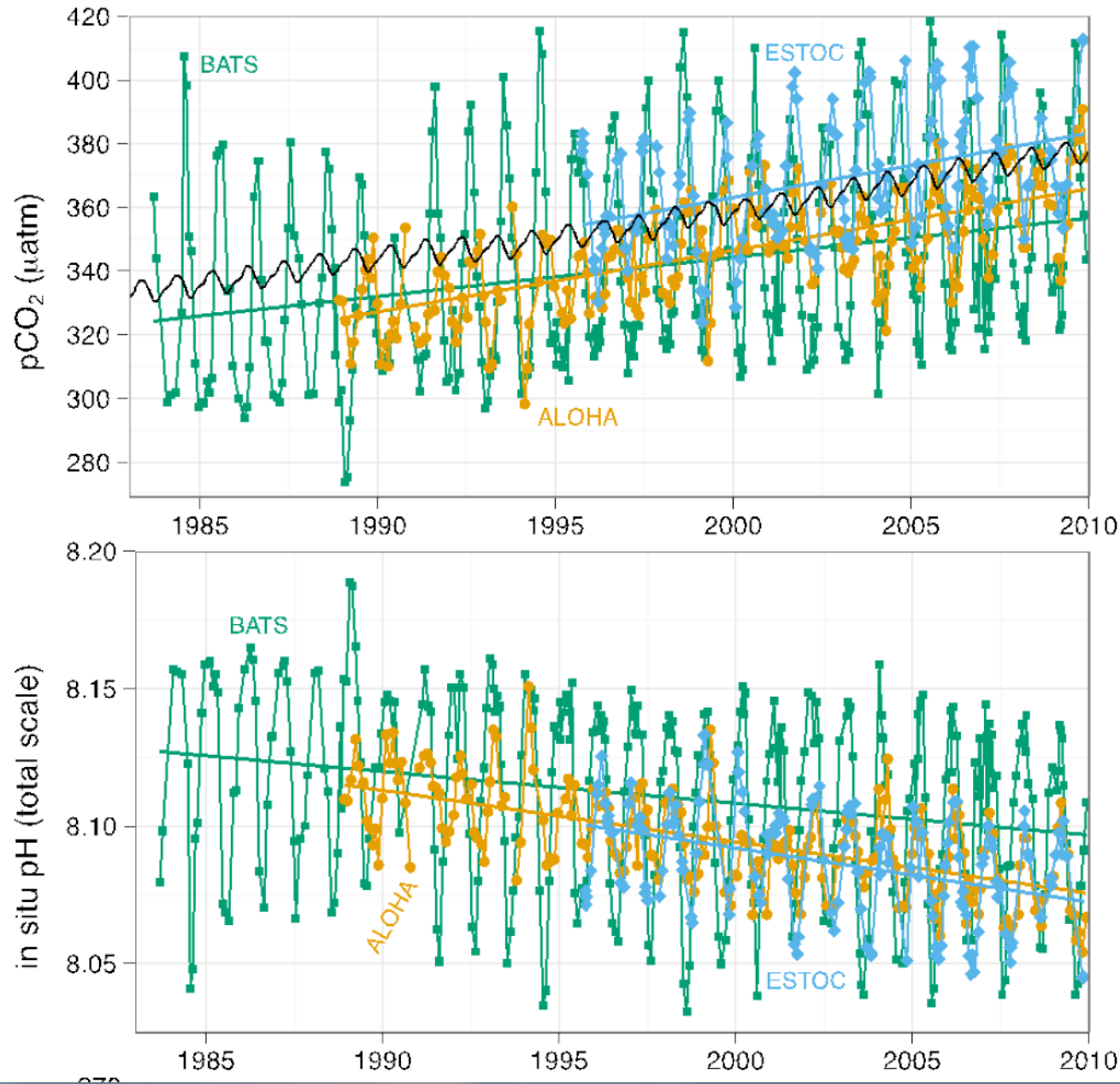
Isótopos de carbono e oxigênio mostram fontes antropogênicas



A concentração de oxigênio está diminuindo

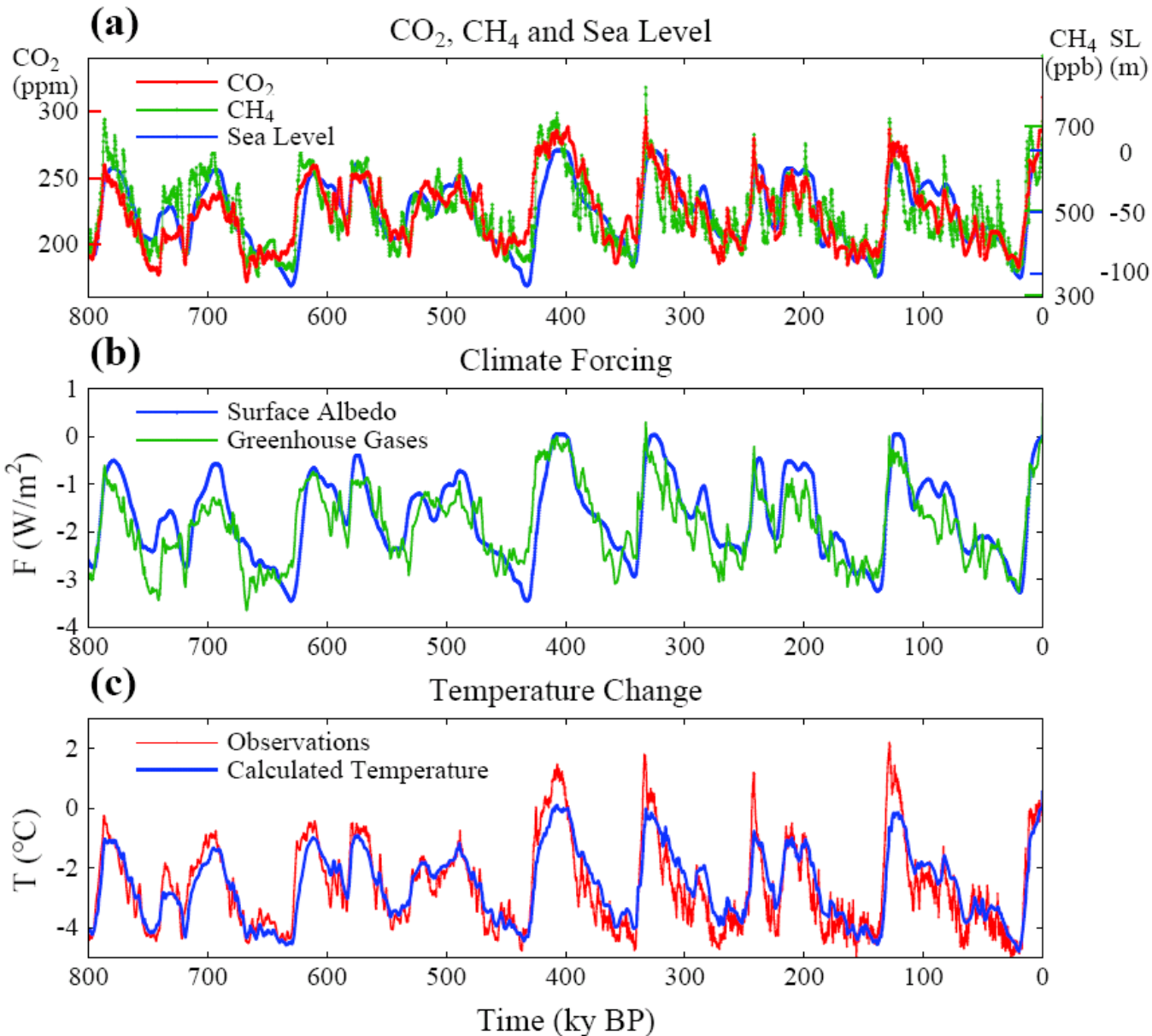
Composição isotópica mostra aumento de carbono fóssil

Concentração de CO₂ na água do mar (pCO₂) e pH



**Acidez do mar
aumentou
30%**

800.000 anos de história climática



(a) CO₂, CH₄ e nível do mar nos últimos 800.000 anos

(b) Forçantes climáticas devido a mudanças nos gases de efeito estufa e áreas congeladas.

(c) Temperatura global calculada baseada nas forçantes acima e em uma sensibilidade climática de $\frac{3}{4}$ °C por W/m².

Jim Hansen, NASA GISS

Em 1896, a primeira previsão climática de Svante Arrhenius



Arrhenius

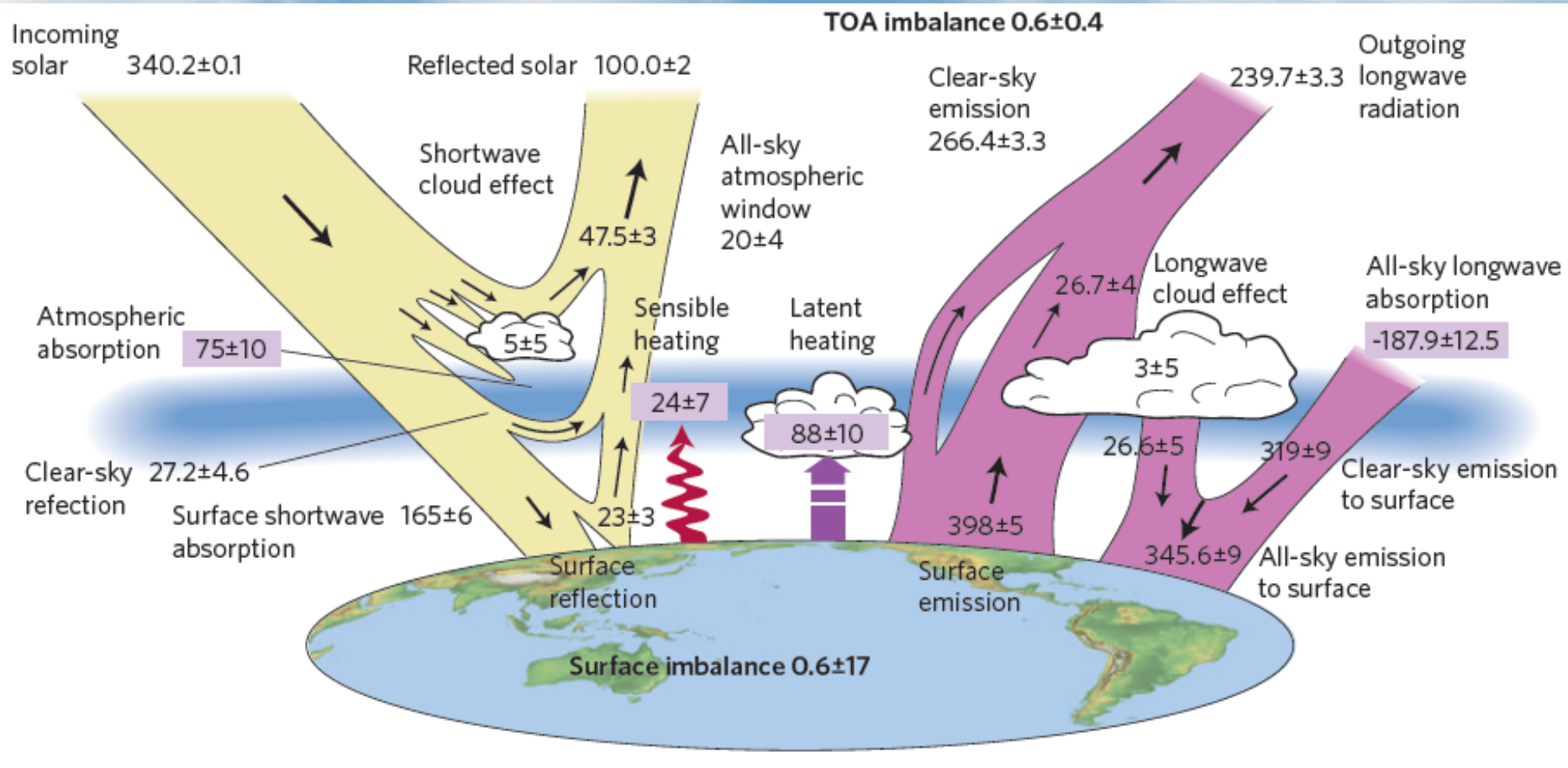
- Arrhenius quantifies in 1896 the changes in surface temperature (approx. 5 C) to be expected from a doubling in CO₂, based on the concept of "glass bowl" effect introduced in 1824 by Joseph Fourier

Os principais gases de efeito estufa

Name	Pre-industrial concentration (ppmv *)	Concentration in 1998 (ppmv)	Atmospheric lifetime (years)	Main human activity source	GWP **
Water vapour	1 to 3	1 to 3	a few days	-	-
Carbon dioxide (CO₂)	280	365	variable	fossil fuels, cement production, land use change	1
Methane (CH₄)	0,7	1,75	12	fossil fuels, rice paddies waste dumps, livestock	23
Nitrous oxide (N₂O)	0,27	0,31	114	fertilizers, combustion industrial processes	296
HFC 23 (CHF₃)	0	0,000014	260	electronics, refrigerants	12 000
HFC 134 a (CF₃CH₂F)	0	0,0000075	13,8	refrigerants	1 300
HFC 152 a (CH₃CHF₂)	0	0,0000005	1,4	industrial processes	120
Perfluoromethane (CF₄)	0,00004	0,00008	> 50 000	aluminium production	5 700
Perfluoroethane (C₂F₆)	0	0,000003	10 000	aluminium production	11 900
Sulphur hexafluoride (SF₆)	0	0,0000042	3 200	dielectric fluid	22 200

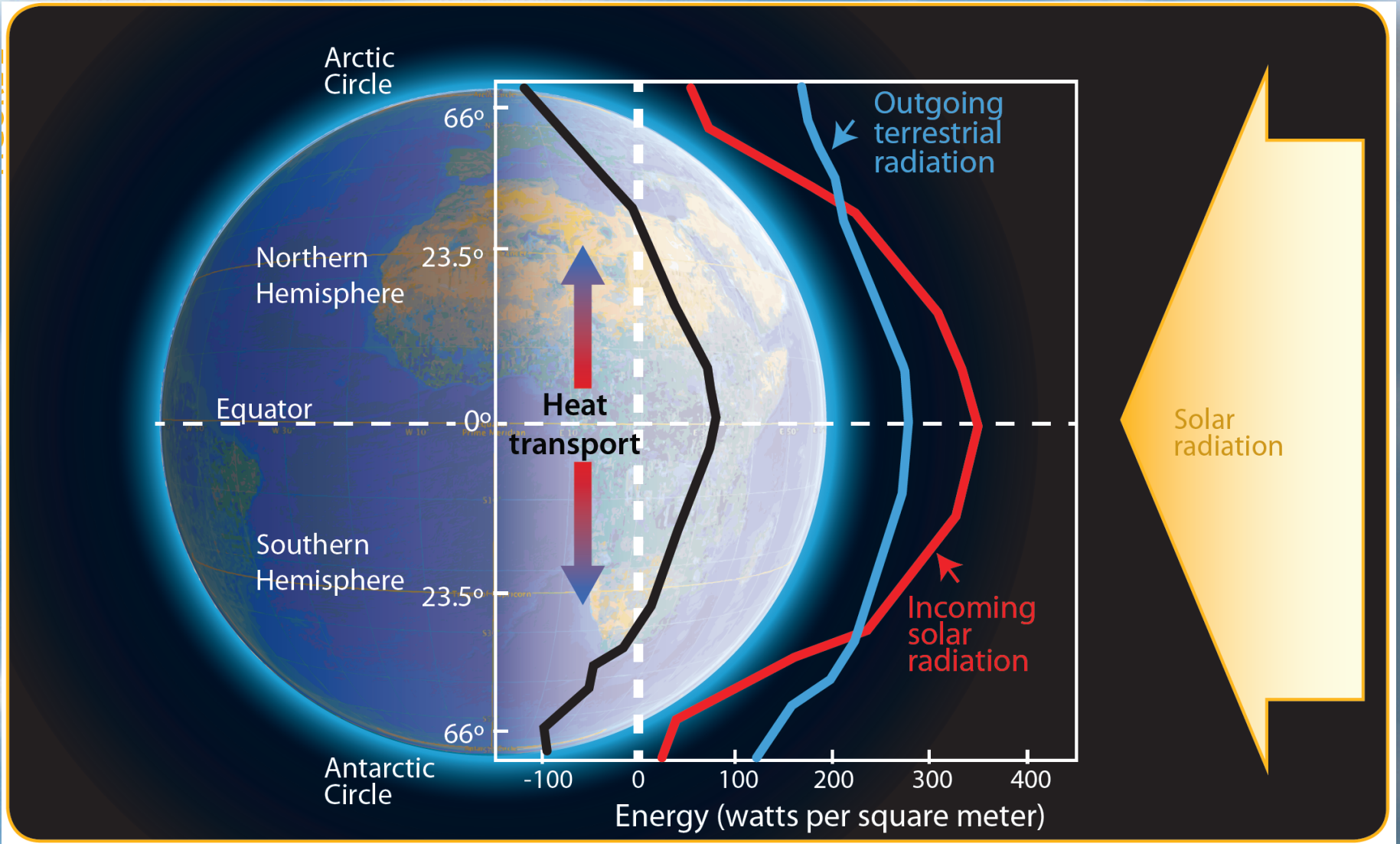
GWP Global Warming Potential – 100 anos

Balanço de Energia do sistema terrestre

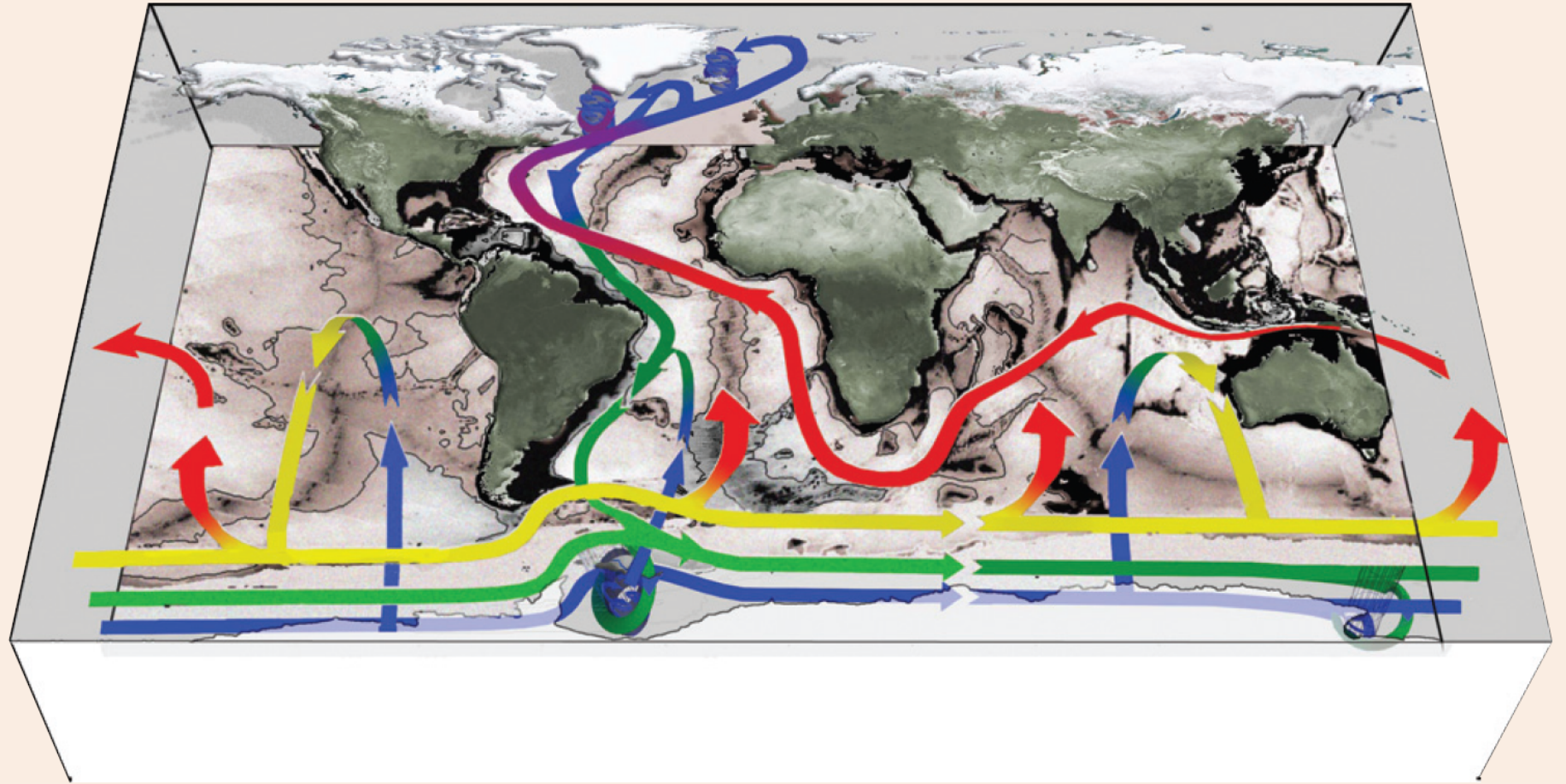


The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2} . Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance. (Stephens, Nature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

Balanço de radiação solar



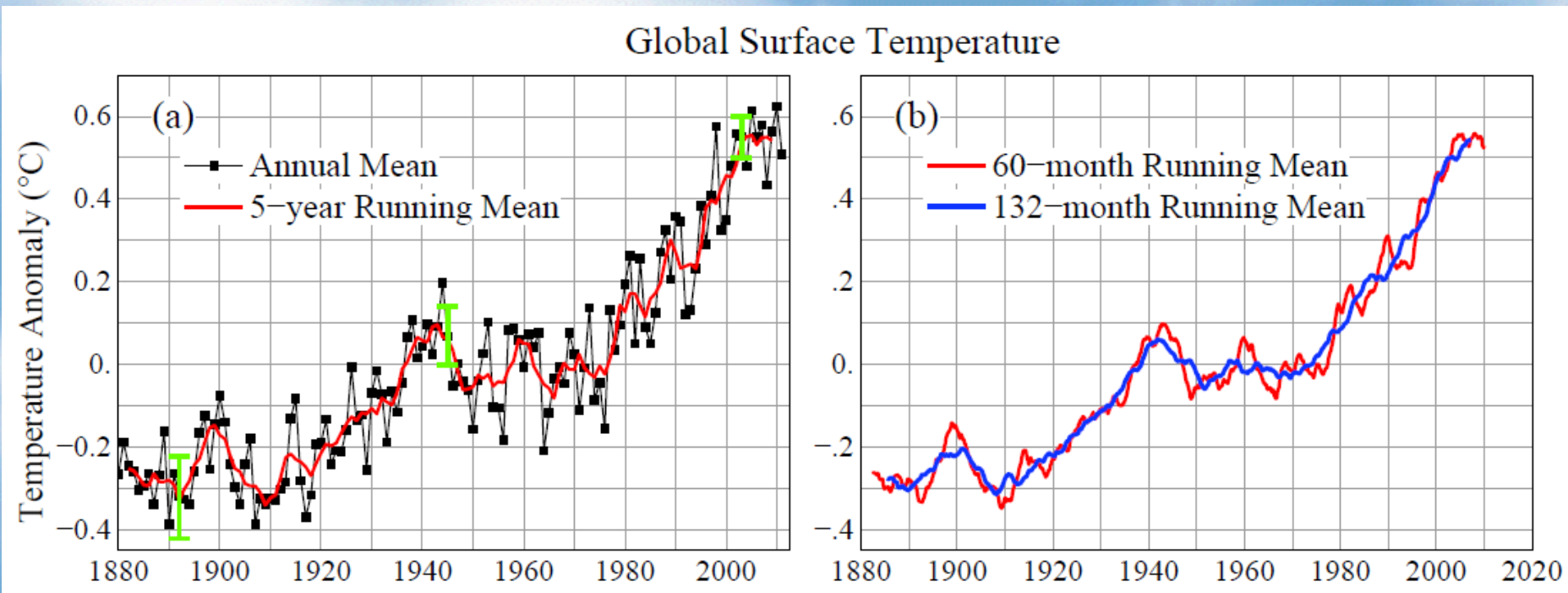
Circulação oceânica global: Redistribuição de energia



Deep-water formation in the Northern Hemisphere has long received much attention as the axis of climate change. The upwelling branch in the Southern Ocean is now being recognized as a vital component of our climate system and an equally important agent of global change.

Marshall and Speer Nature Review, 2012

As temperaturas globais variam, mas nosso planeta está se tornando mais quente

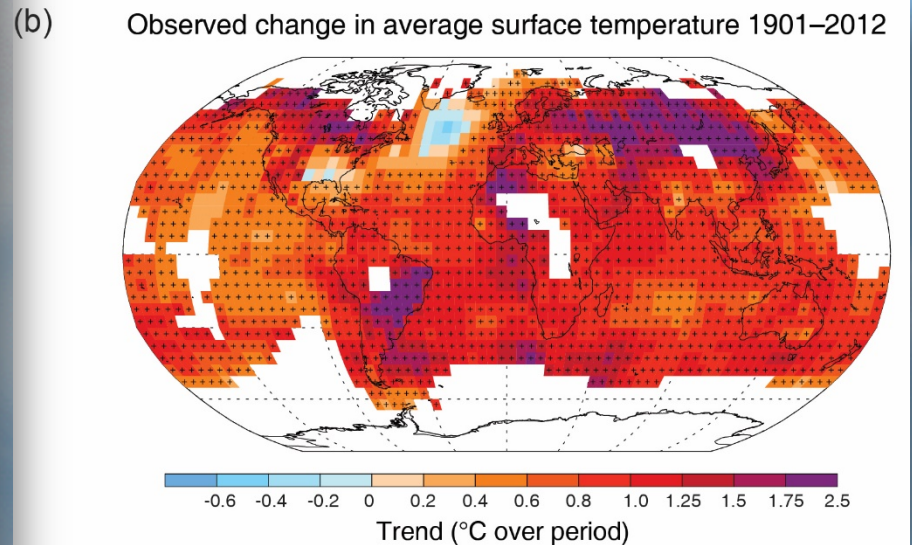
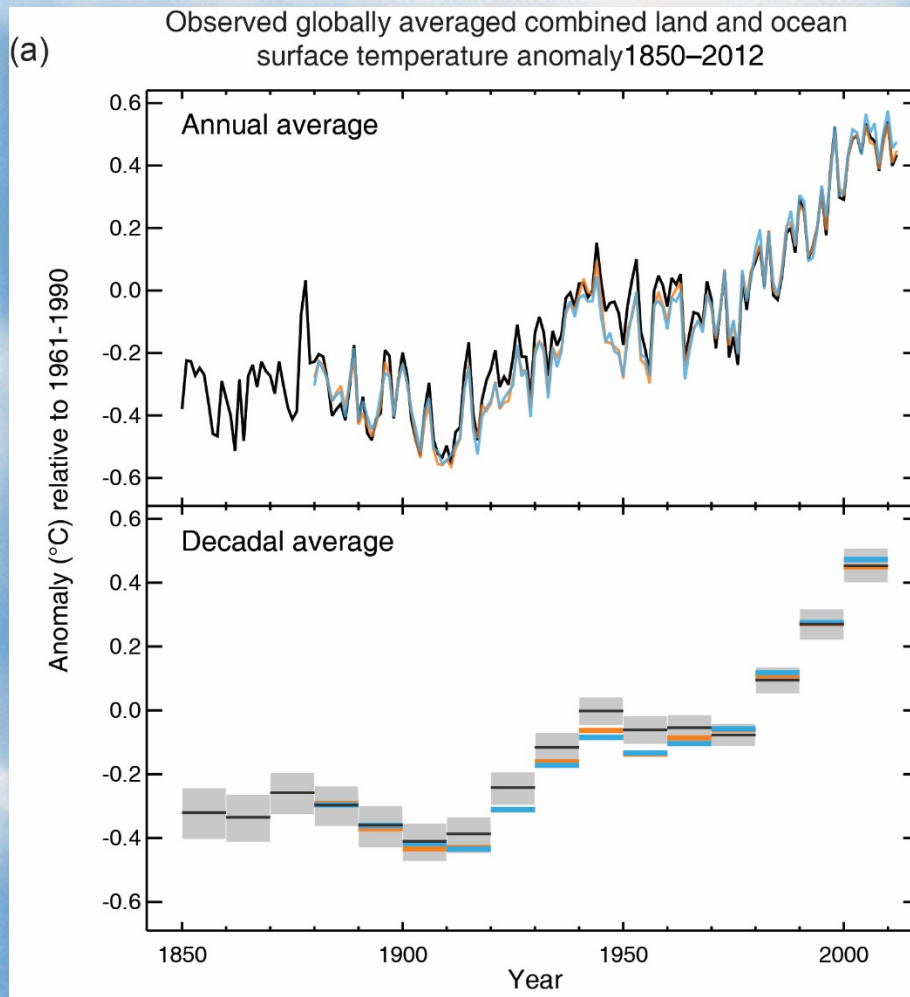


Global surface temperature anomalies relative to 1951-1980 average for (a) annual and 5-year running means through 2010, and (b) 60-month and 132-month running means through July 2012.

(Hansen, J., Ruedy, R., Sato, M., and Lo, K., 2010: Global surface temperature change, Rev. Geophys. 48, RG4004.)

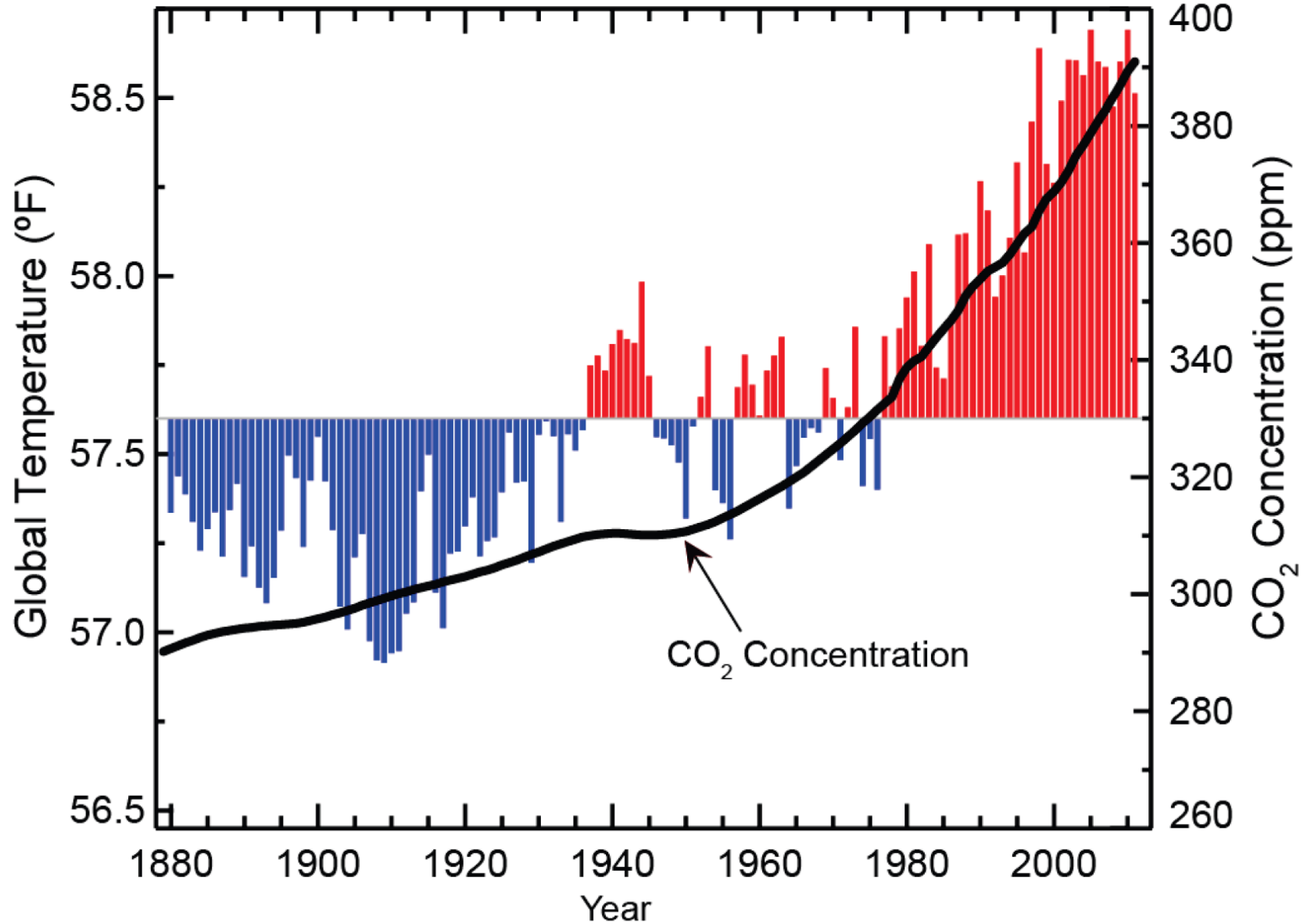
Gases de efeito estufa e aerossóis dominam a variabilidade da temperatura global

Aumento médio da temperatura observado de 1850-2012: 1.0 °C

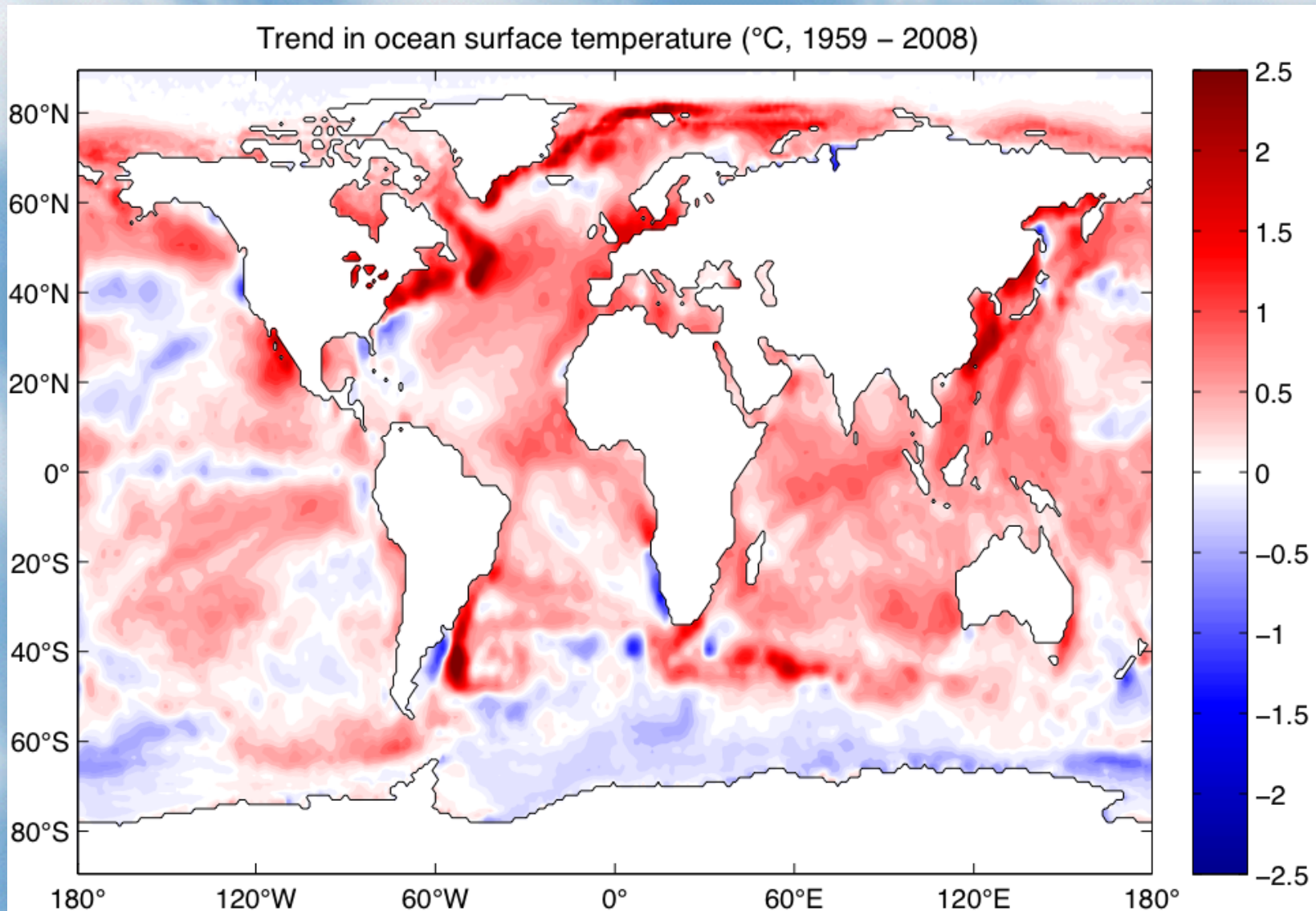


Distribuição espacial

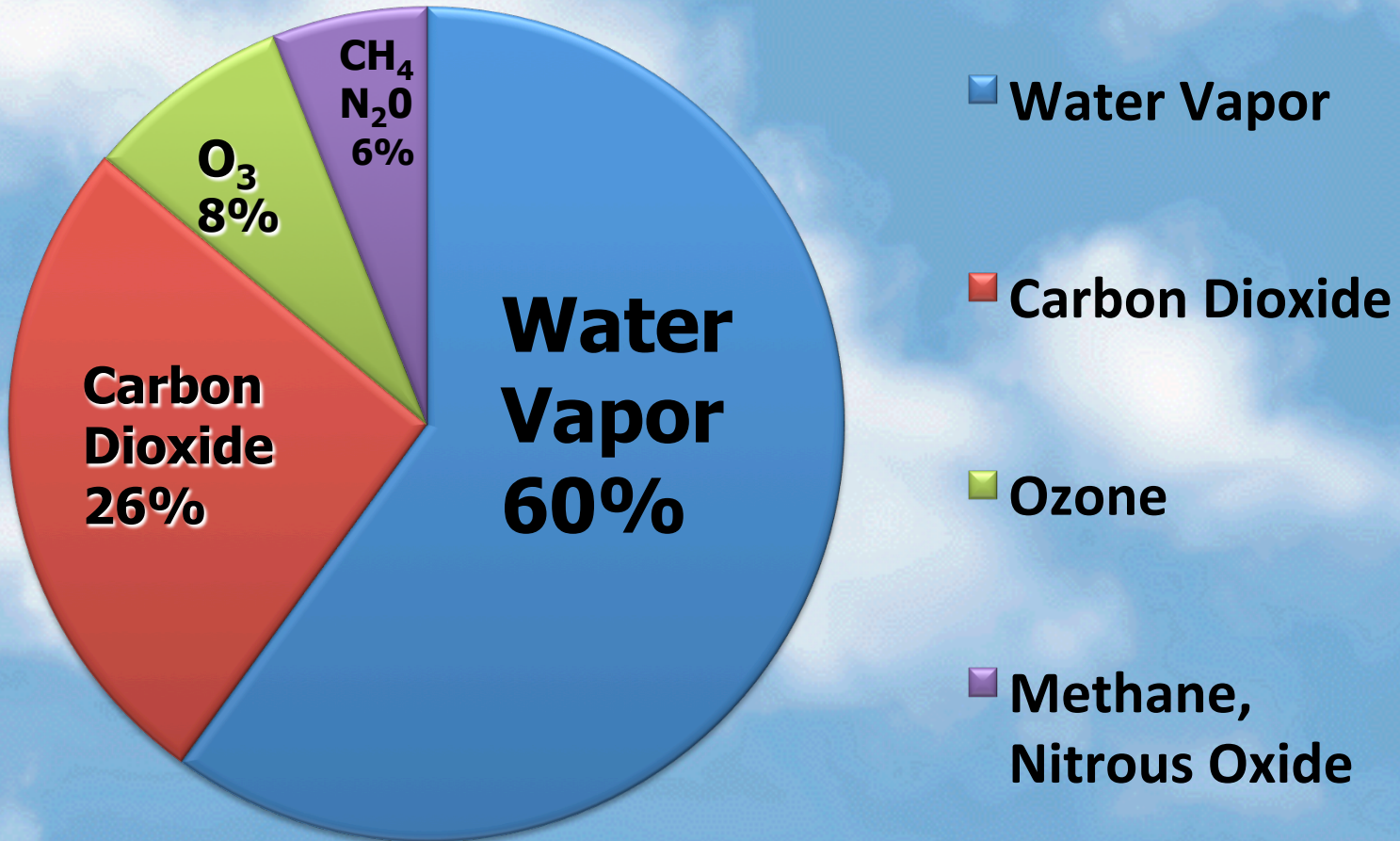
Temperatura Global e Concentração de CO₂



Temperatura do oceano, aumentando..., 1959 - 2008



O efeito estufa natural

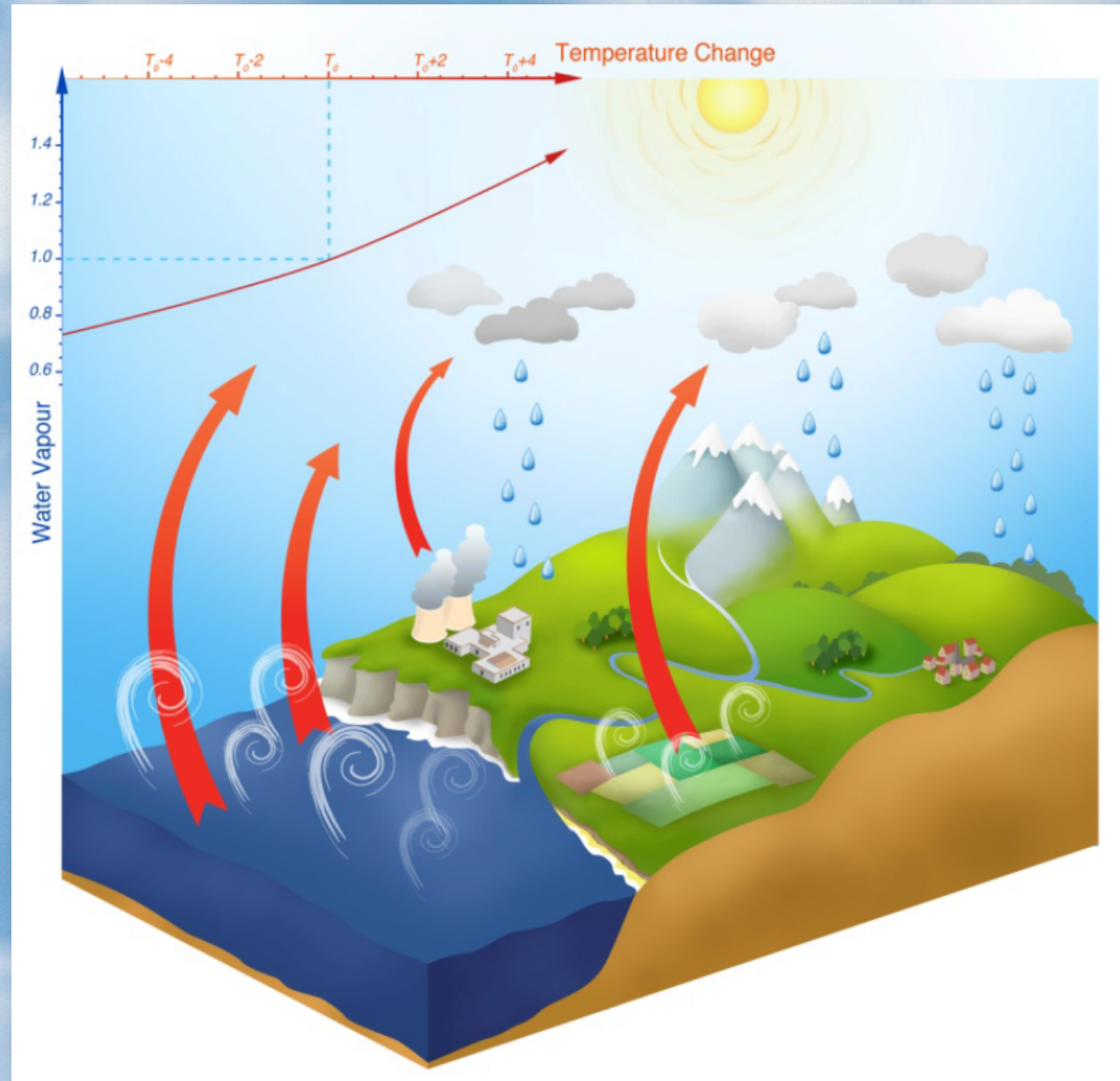


As nuvens também afetam o calor em nosso planeta

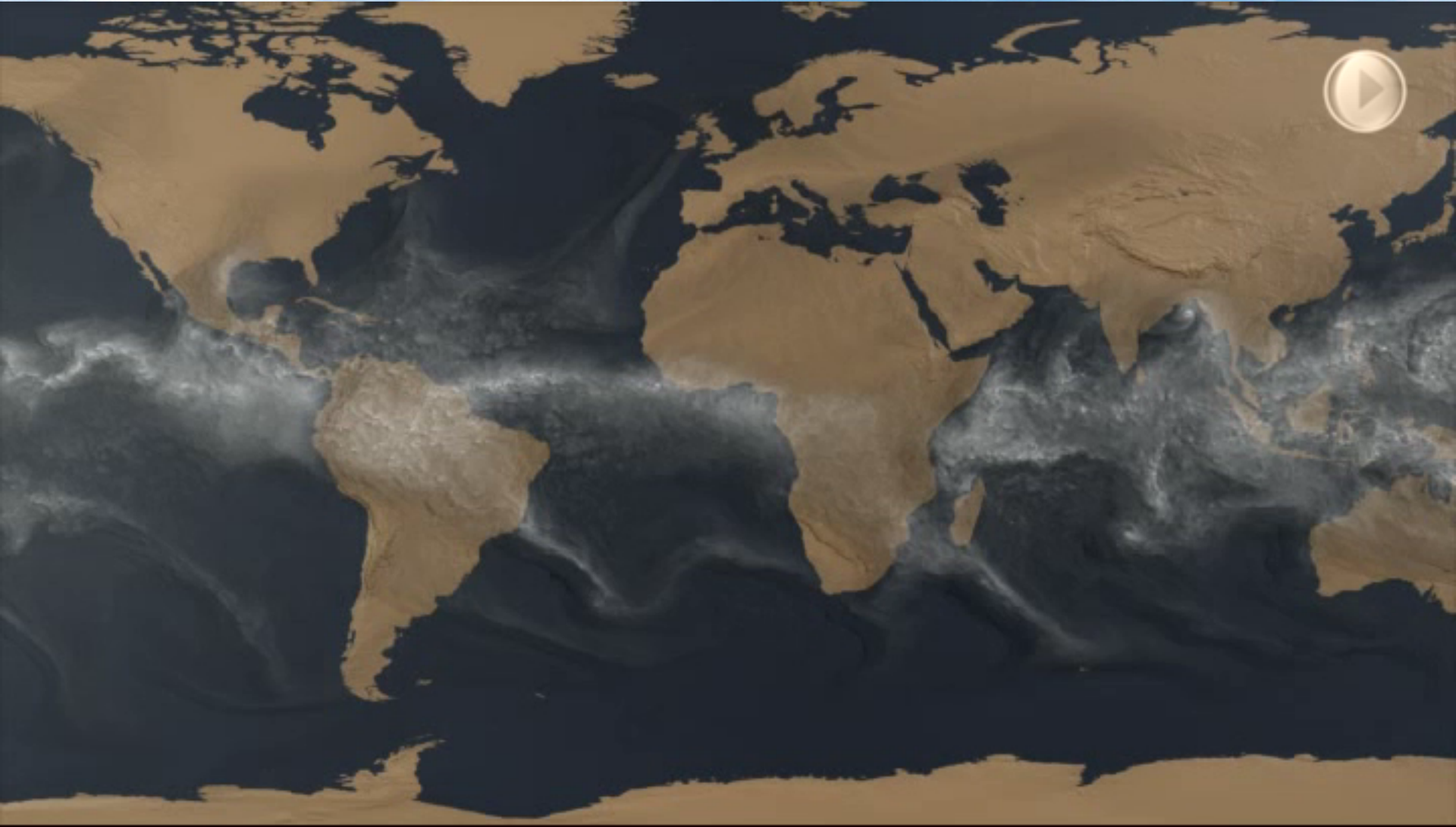
Ciclo da água e sua interação com o efeito estufa

Aumento do vapor de água na atmosfera com o aumento da temperatura

7% para cada grau Celcius



Umidade na atmosfera global

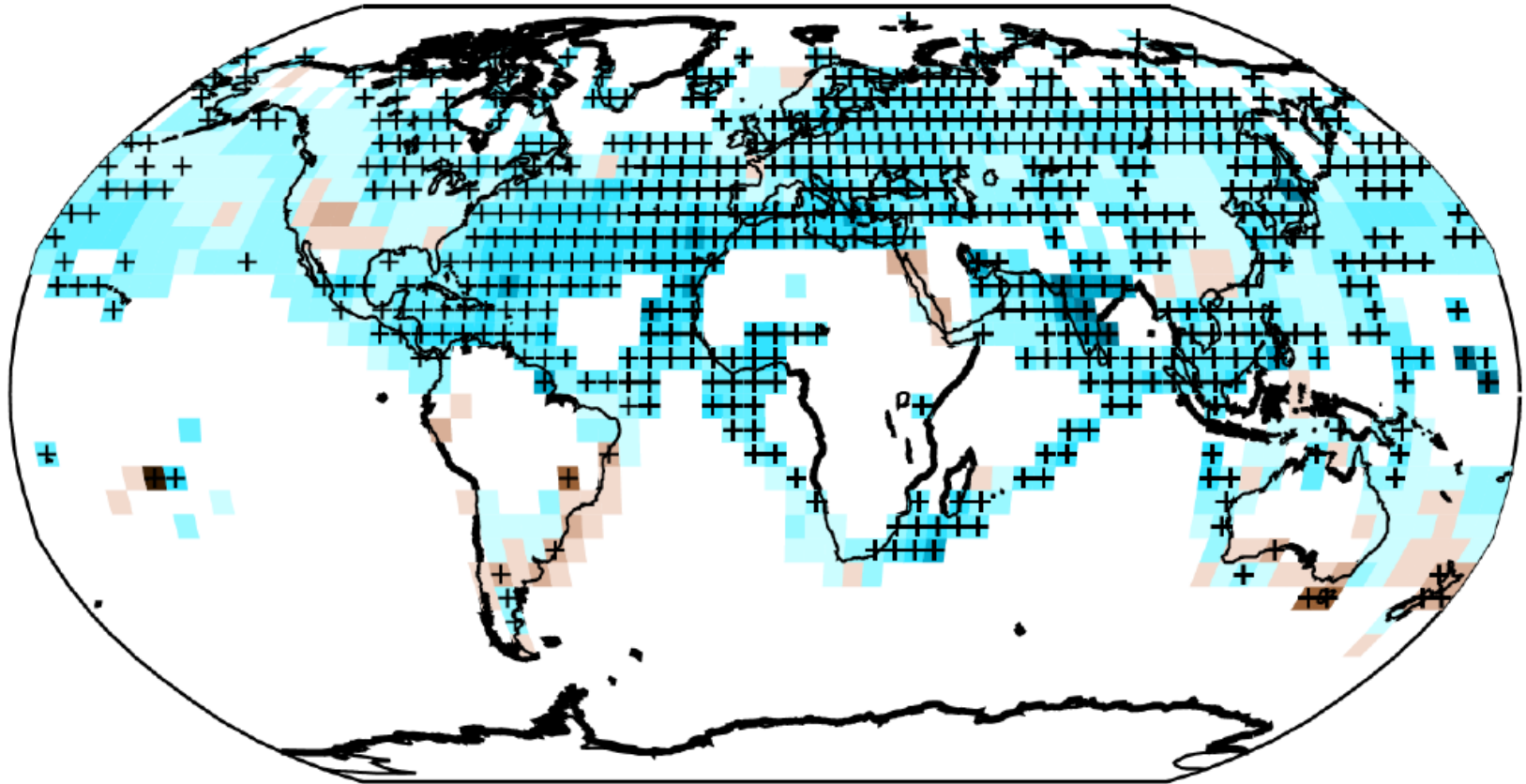


Influencias antropogênicas no ciclo da água global

Aumento da umidade atmosférica

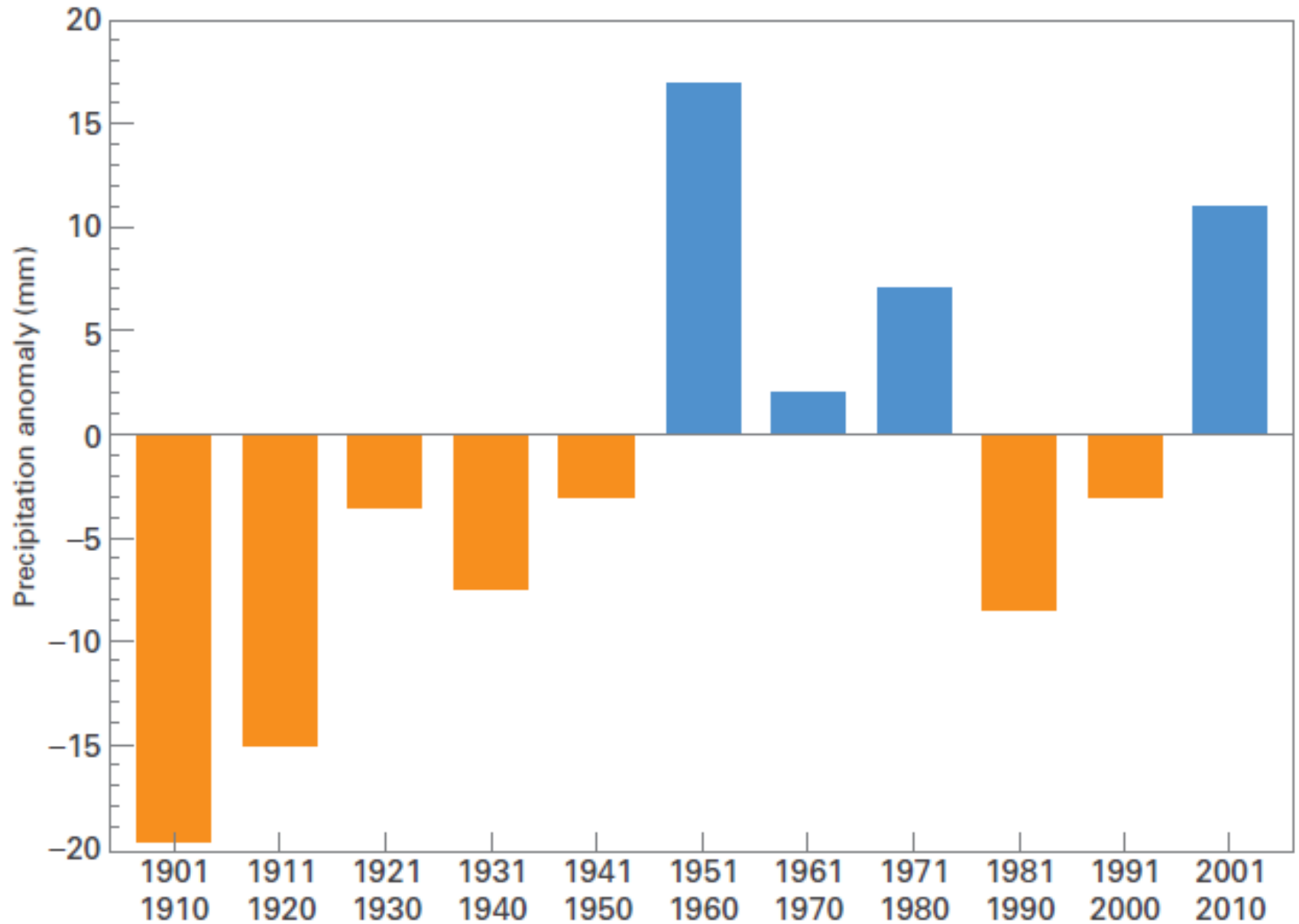
(a)

1973–2012



-0.5 -0.25 -0.2 -0.15 -0.1 -0.05 0 0.05 0.1 0.15 0.2 0.25 0.5
Trend (g/kg/decade)

Decadal global precipitation anomalies (mm) relative to the 1961–1990 WMO standard normal





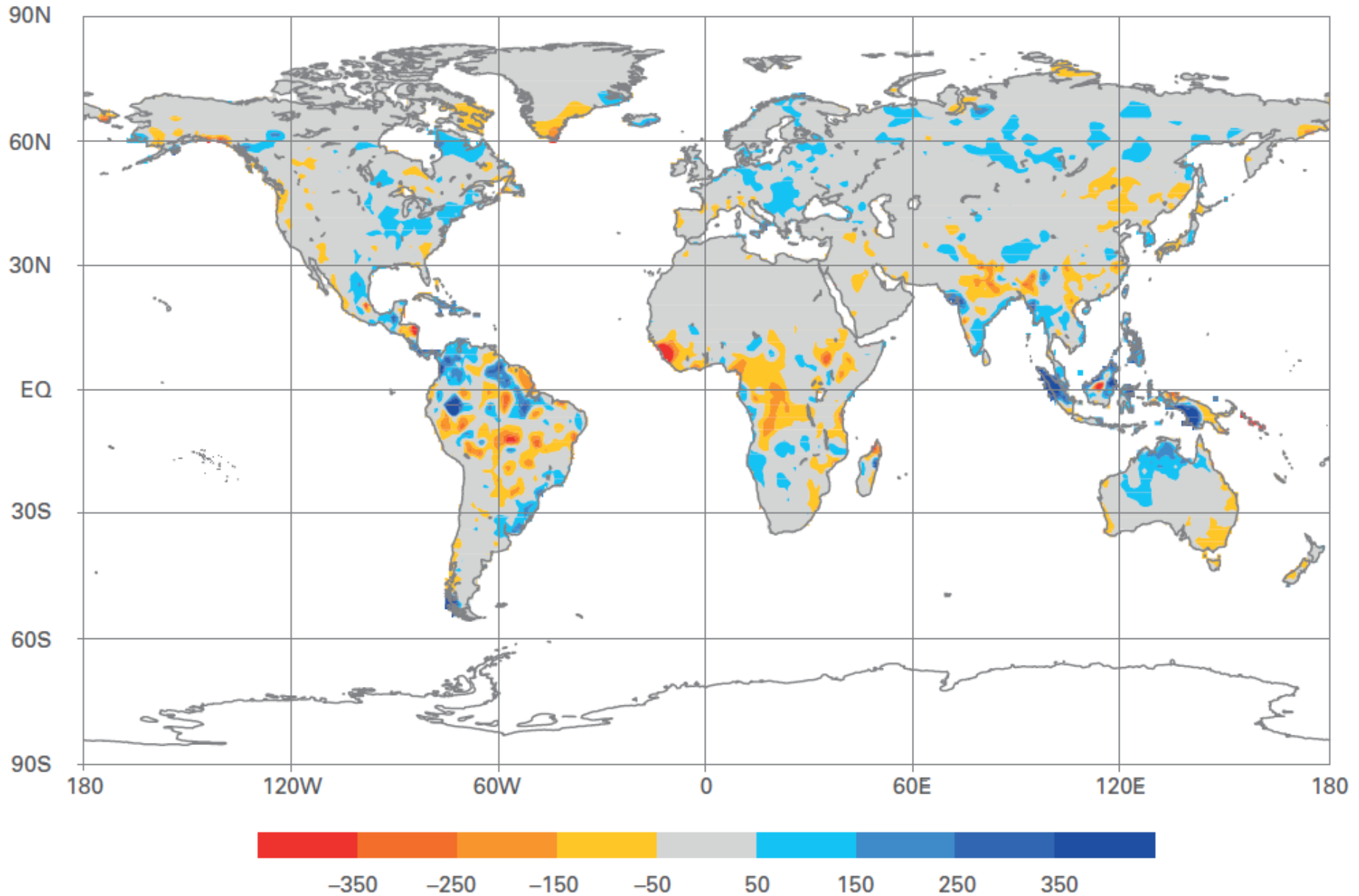
Amazonia é importante na ciclagem de vapor de água na América do Sul

1610 km

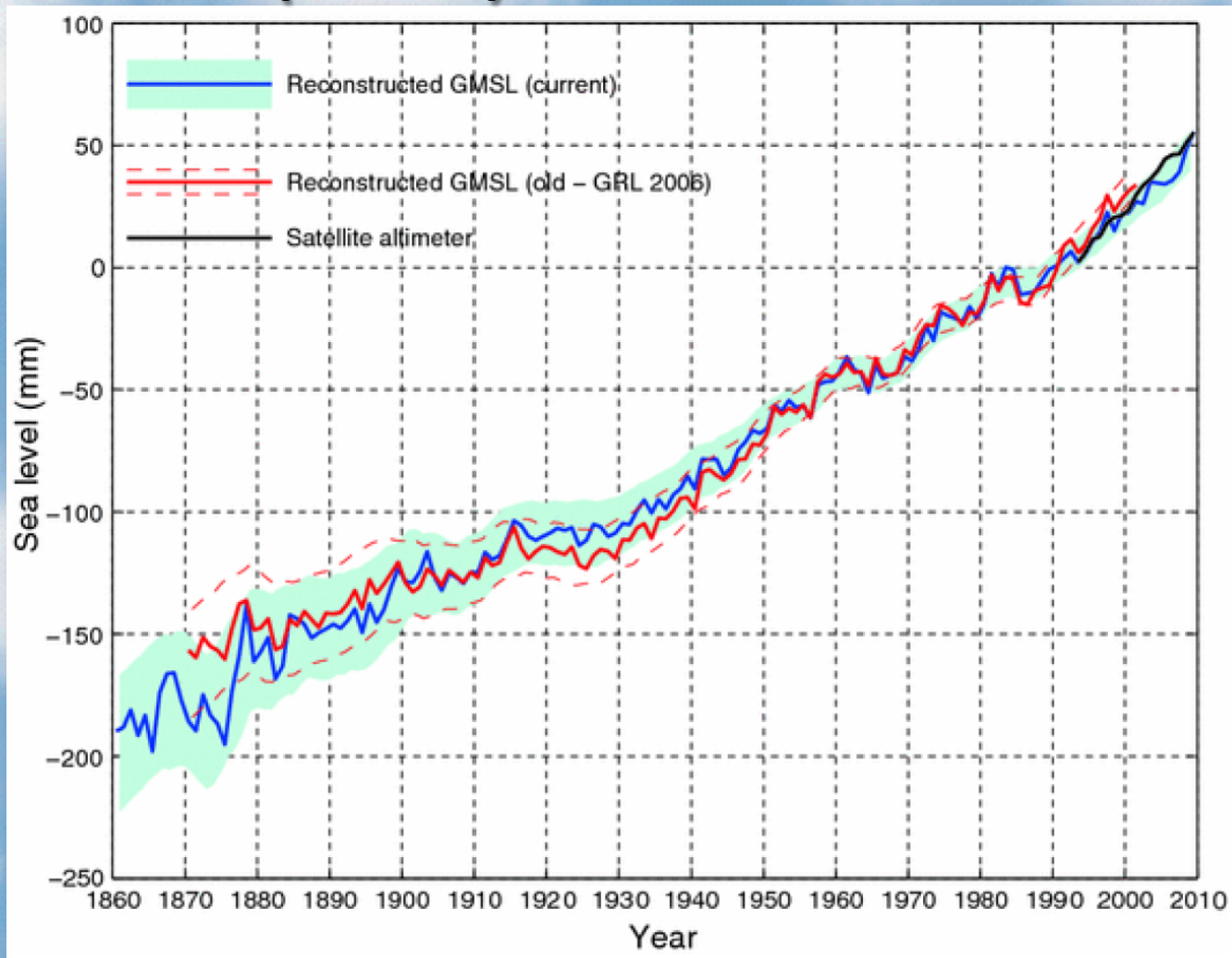
Image NASA

©2010 Google

Anomalias de precipitação em áreas continentais para 2001–2010.
Departures in mm/year from averages computed using 1951–2000 base period



Nível médio dos oceanos subindo (GMSL) de 1860 a 2010



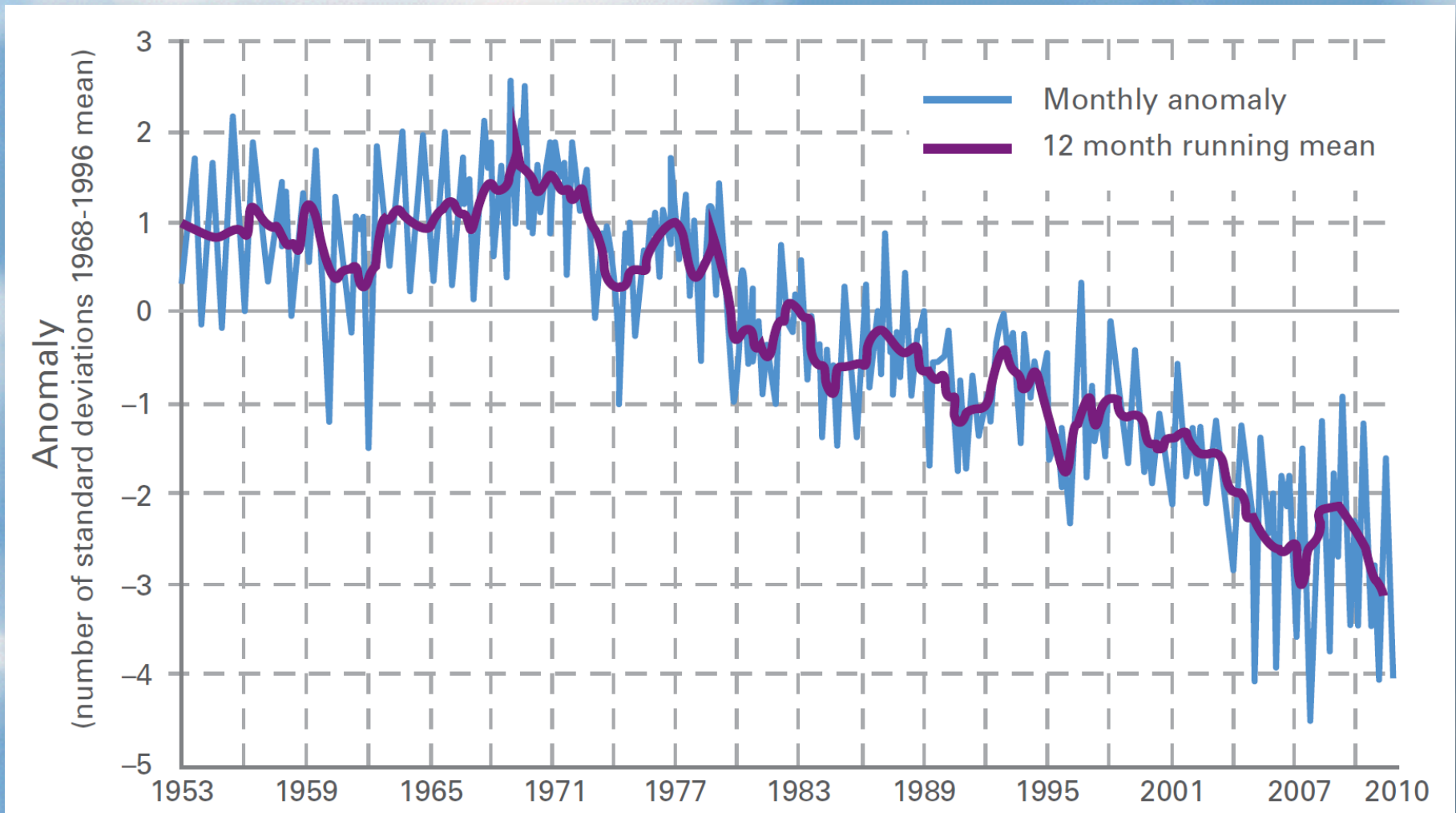
23 cm

Global mean sea level (GMSL) reconstructed from tide gauge data (blue, red) and measured from satellite altimetry (black).

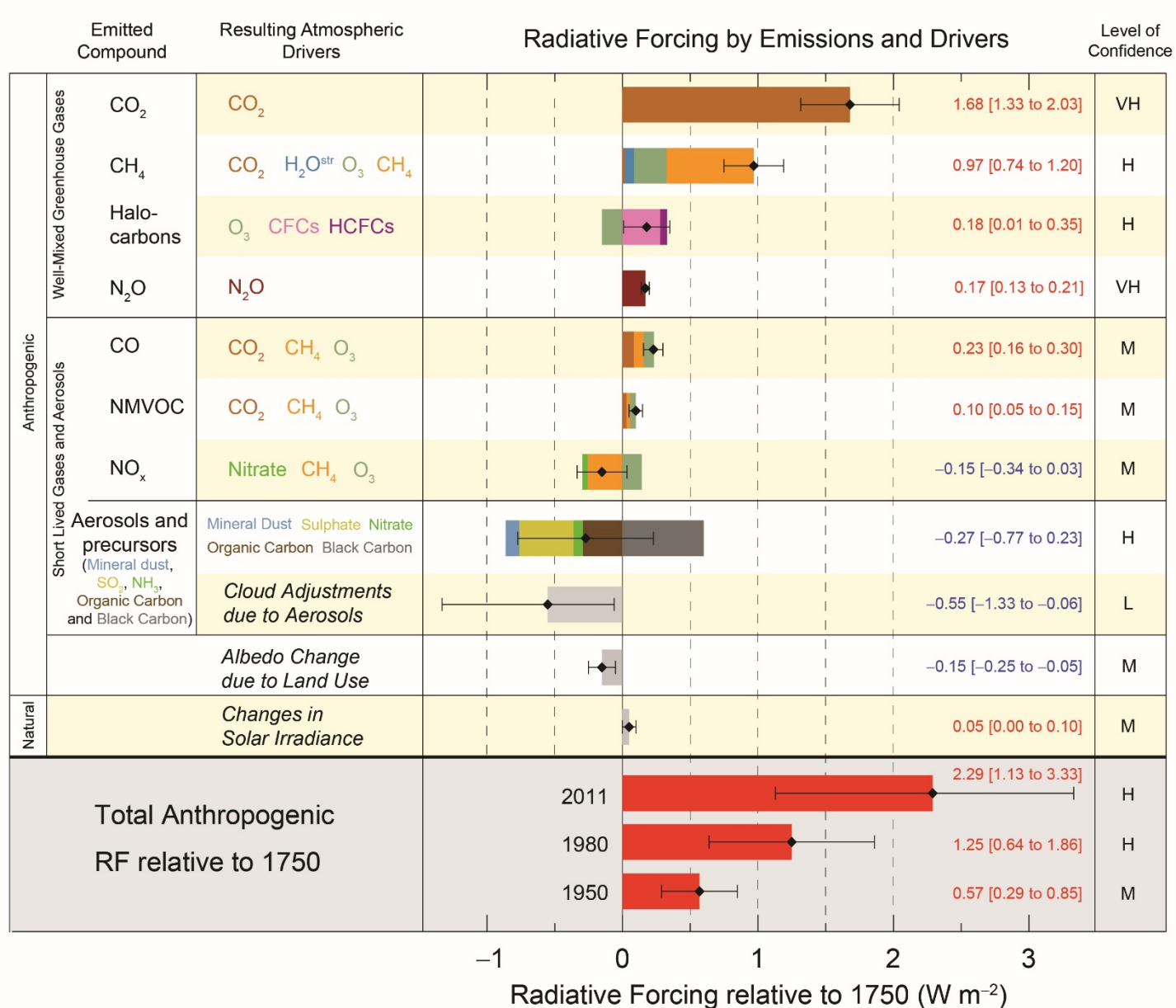
Source: Church and White (2011).

Arctic sea-ice extent standardized anomaly 1953-2012

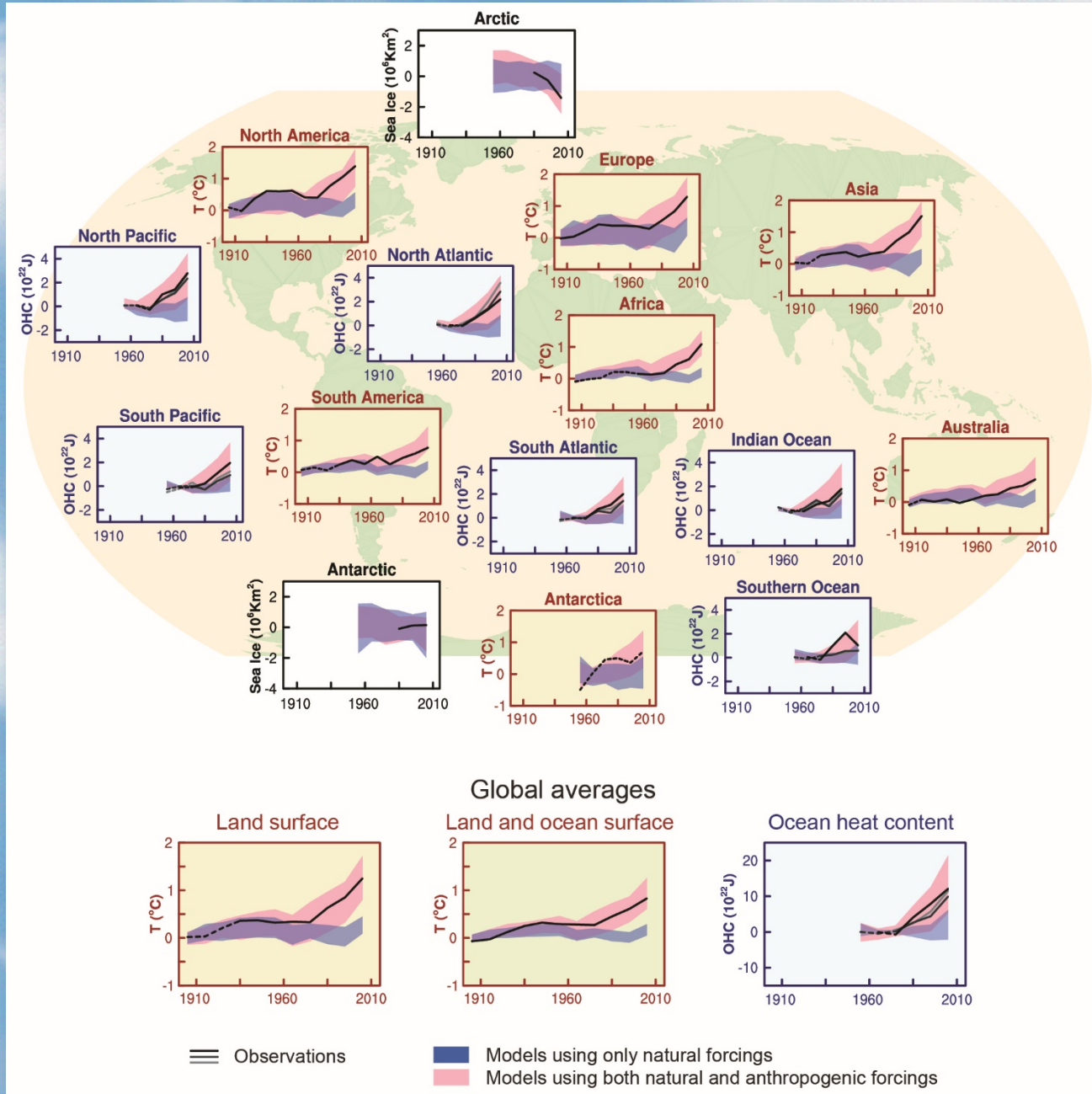
source: National Snow and Ice Data Center, USA

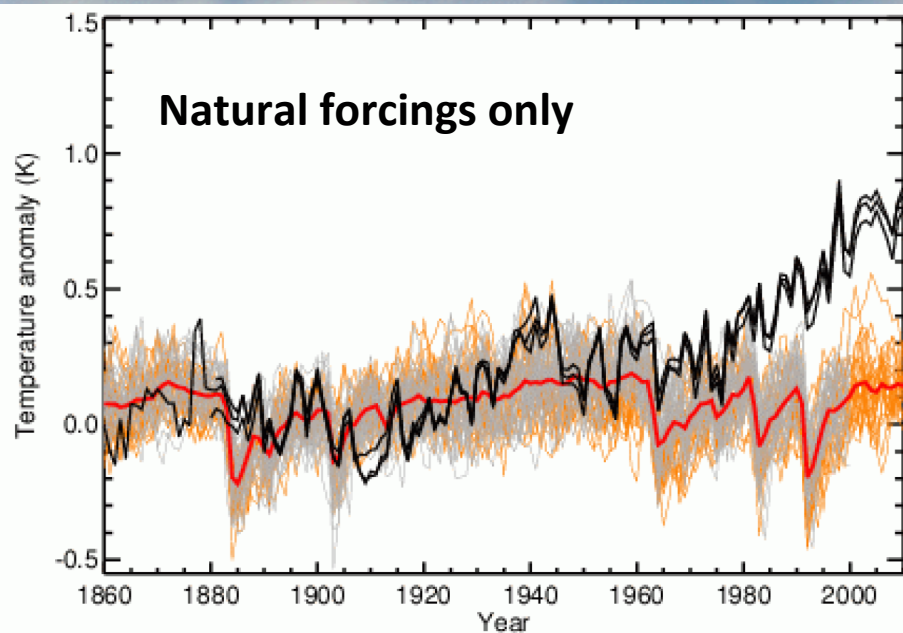
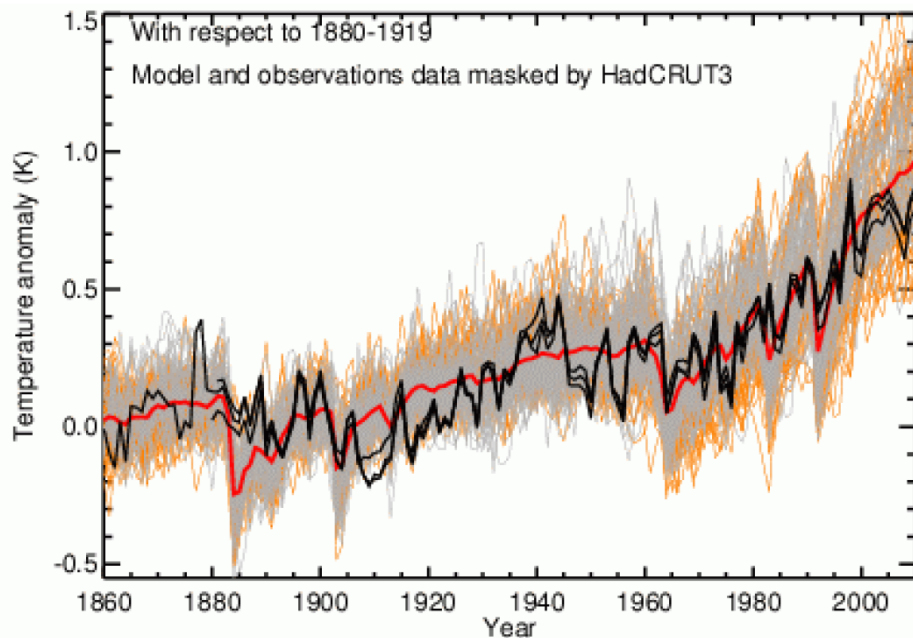


Forçante radiativa do sistema climático global (IPCC 2013)



Atribuição: Só com emissões antropogênicas as observações são explicadas





Os modelos acertam na previsão climática dos últimos 150 anos?

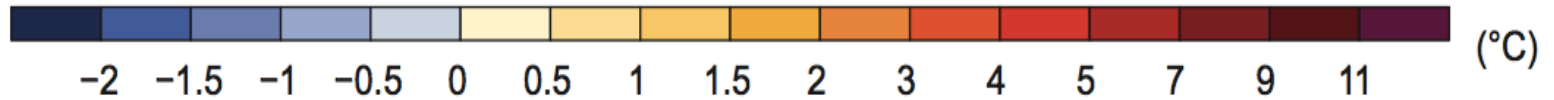
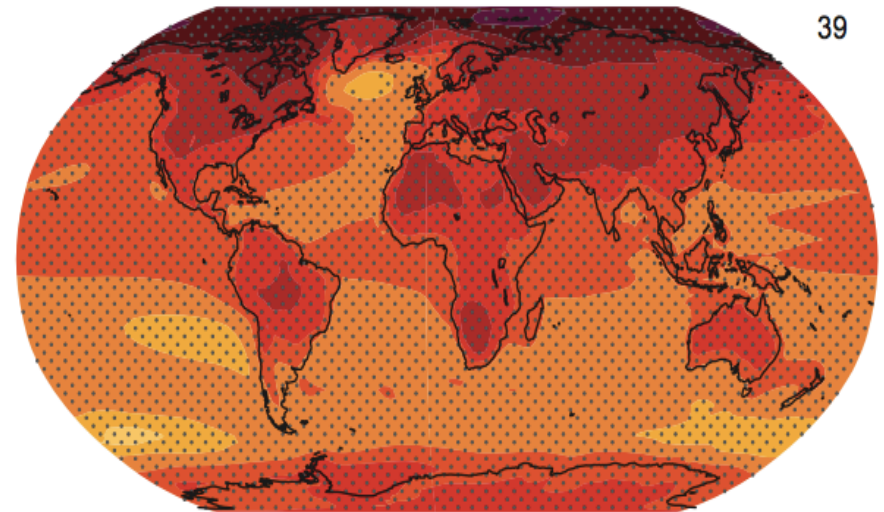
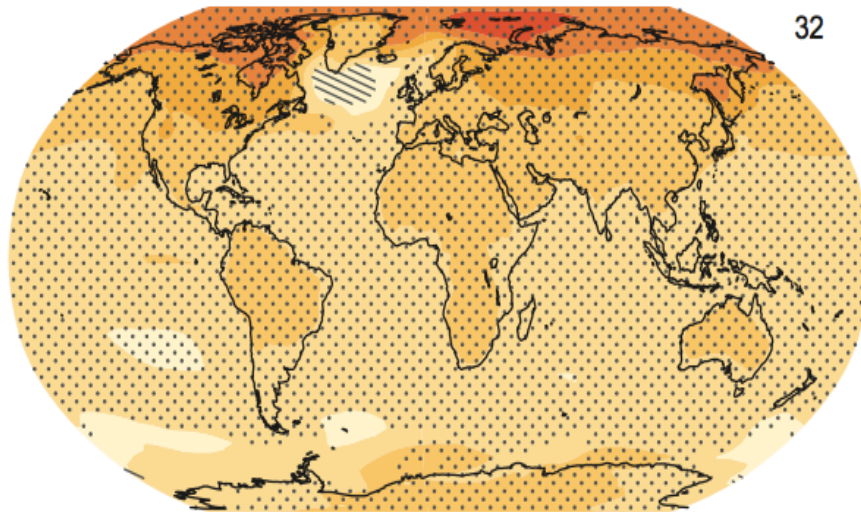
Observational estimates of global mean temperature (black lines), compared to model simulations with natural forcings only (bottom panel) and anthropogenic and natural forcings (upper panel). (IPCC2012)

Projeção de aumento de temperatura em dois cenários

RCP 2.6

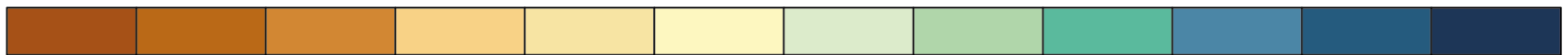
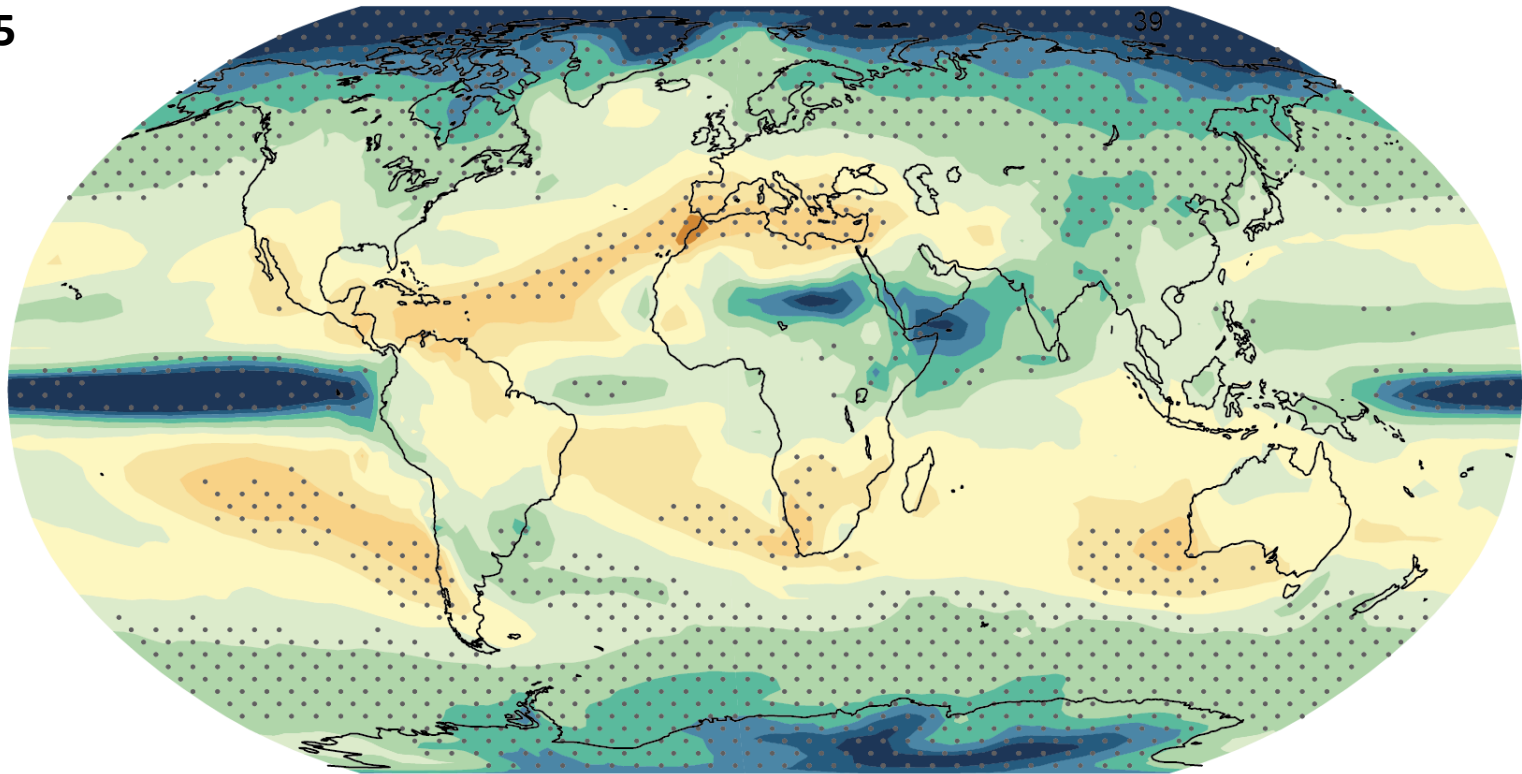
RCP 8.5

(a) Change in average surface temperature (1986–2005 to 2081–2100)



Projeções de mudanças na precipitação 1986-2005 to 2081-2100

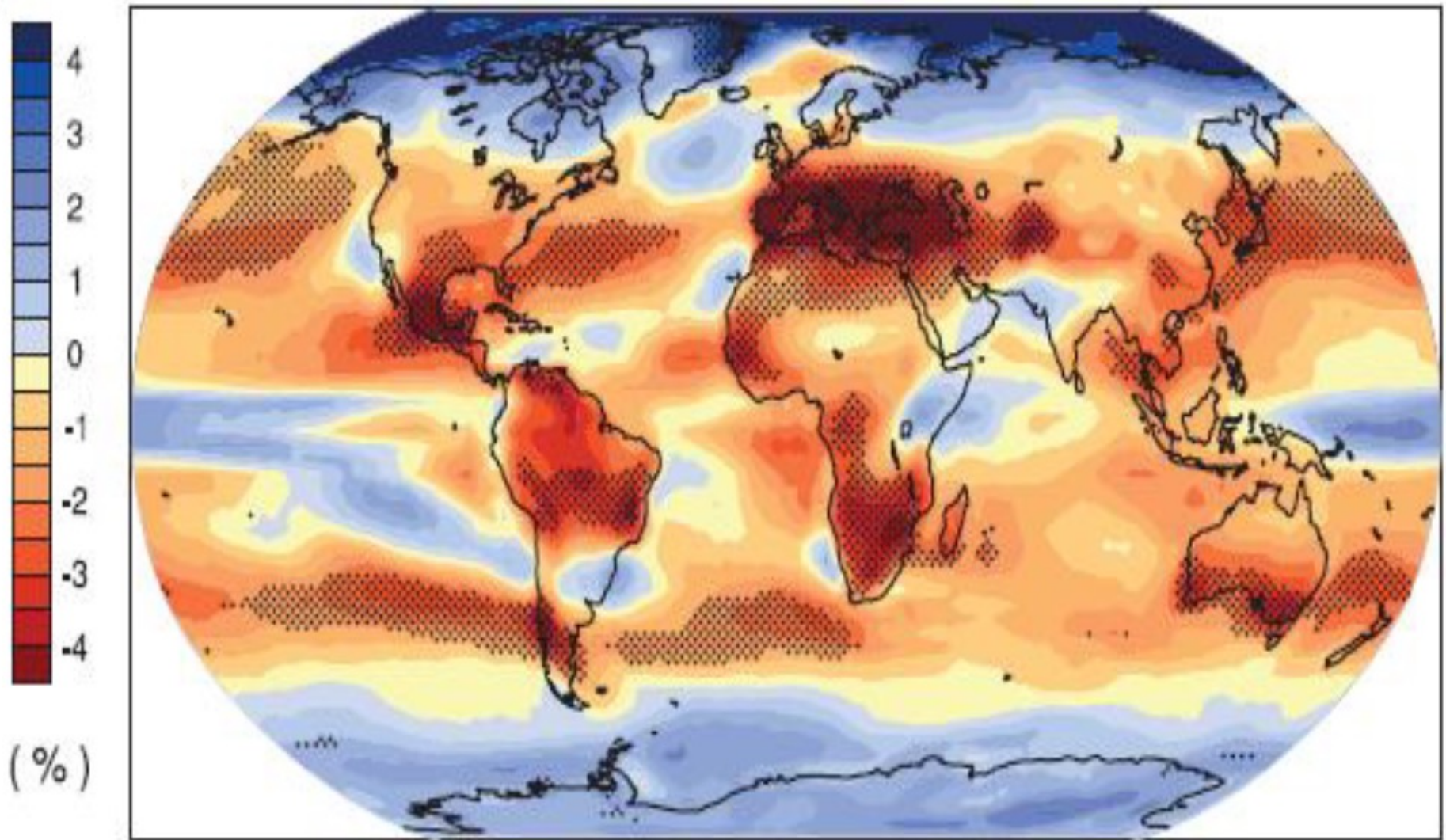
RCP8.5



-50 -40 -30 -20 -10 0 10 20 30 40 50

Precipitation change (%)

Mean changes in total cloud area fraction

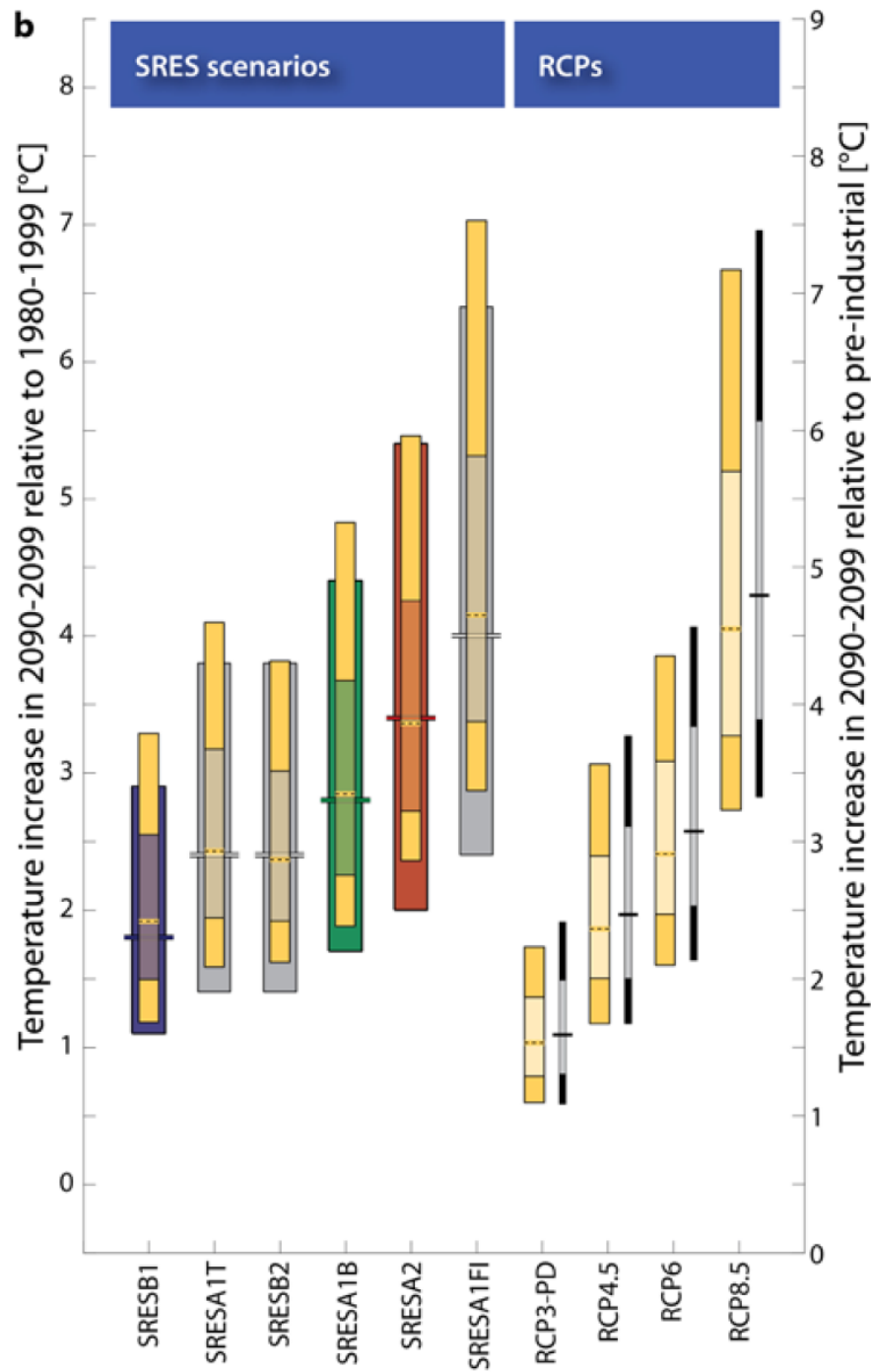


Multi model mean changes in total cloud area fraction . Changes are given as annual means for the SRES A1B scenario for the period 2080 to 2099 relative to 1980 to 1999.

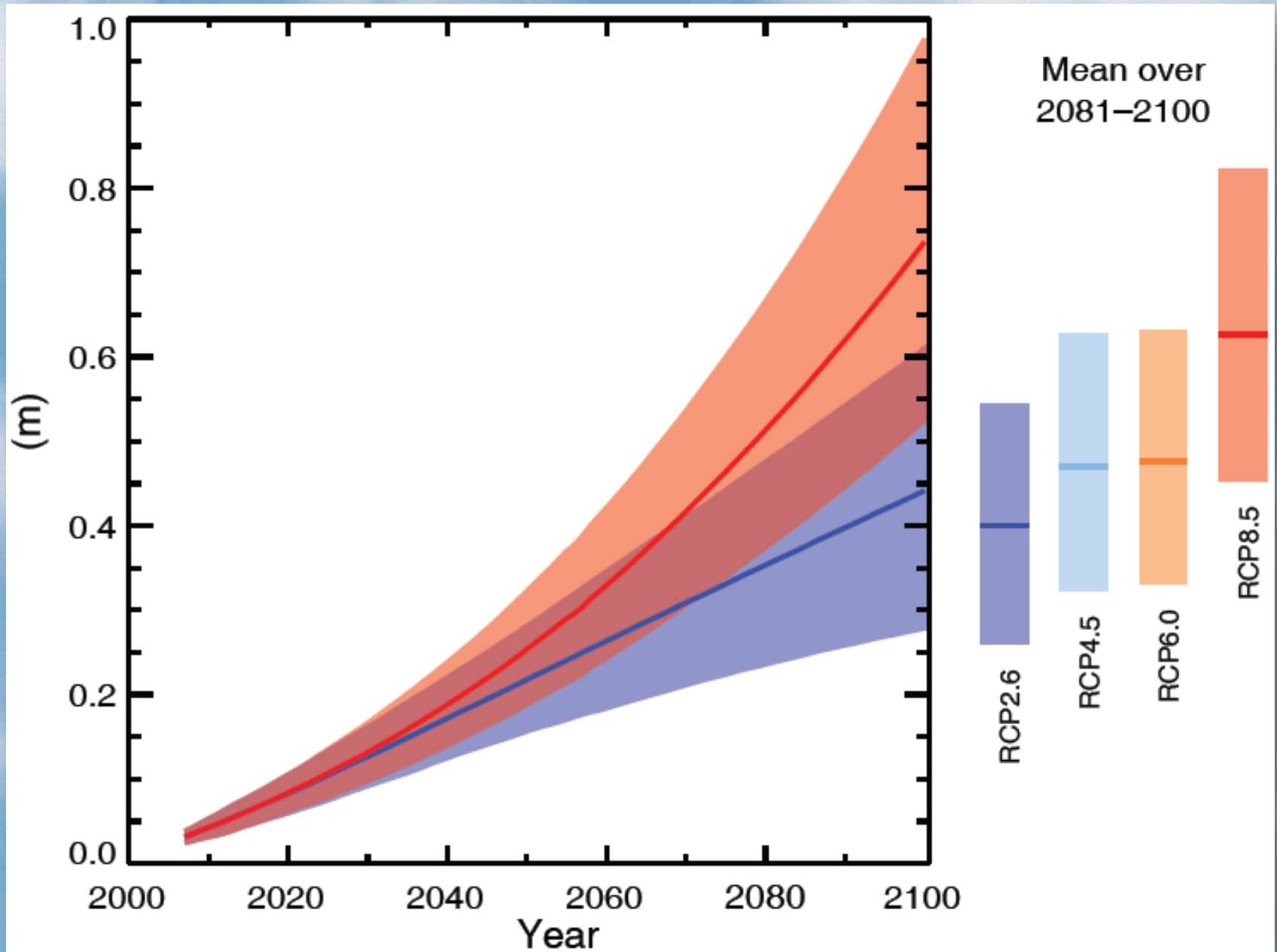
Estimativas de aumento de temperatura em função dos cenários de emissões

Temperature estimates for old (SRES) and new (RCP) IPCC scenarios. Depending on which global emissions path is followed, the 4°C temperature threshold could be exceeded before the end of the century.

Source: Rogelj, Meinshausen, et al. 2012.



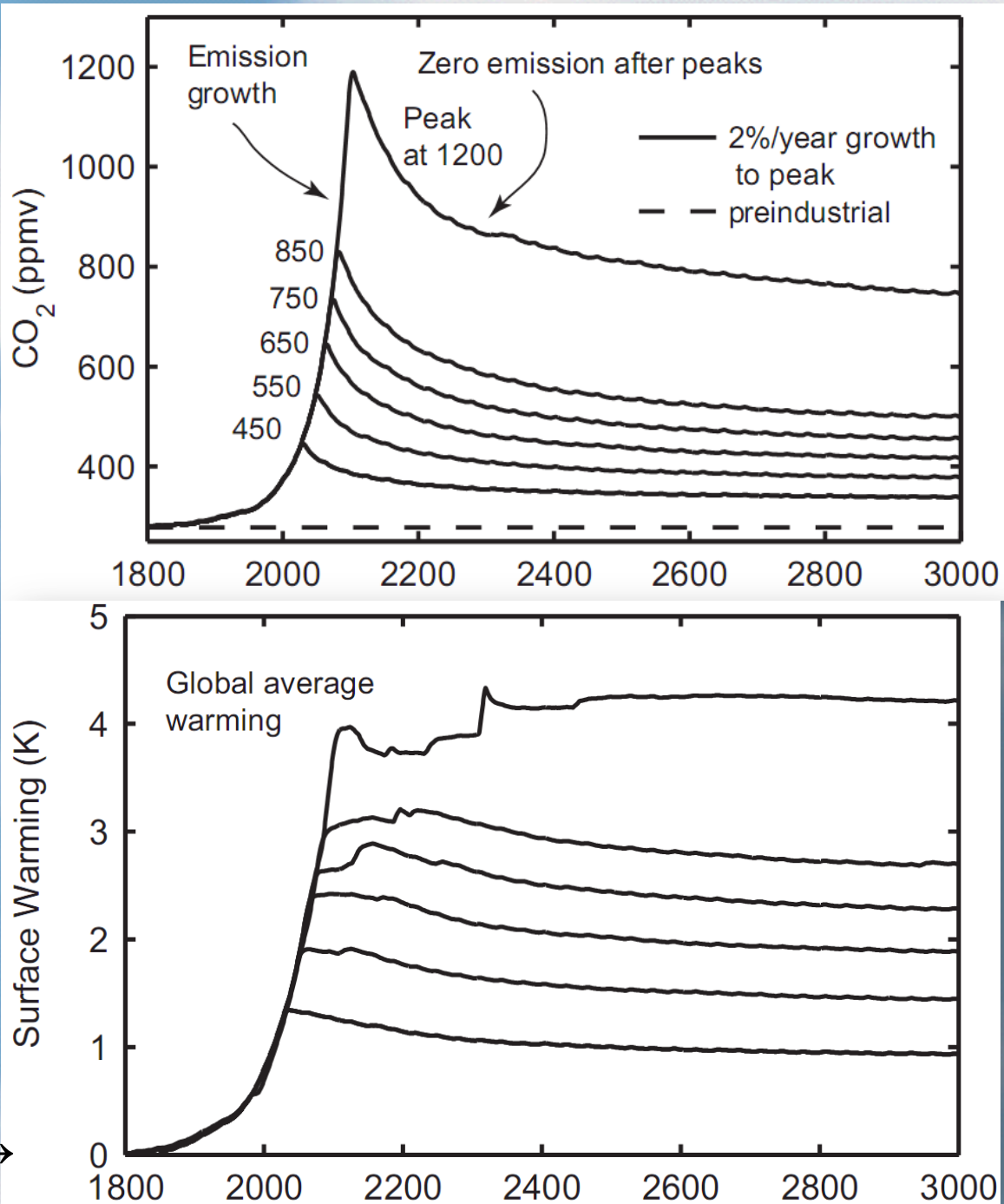
Projeções do aumento médio do nível do mar para os vários RCP



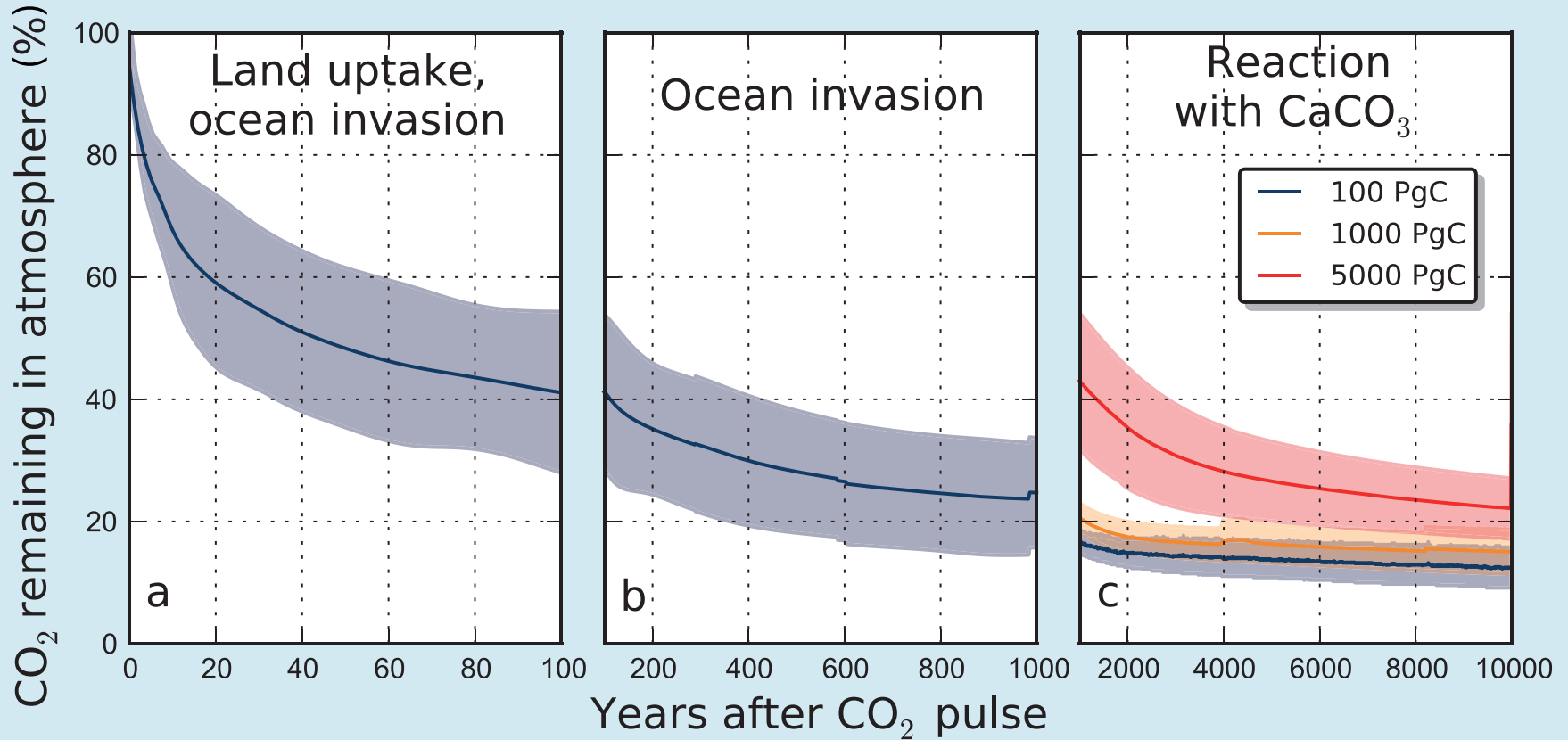
Quanto tempo o efeito do CO₂ irá afetar o clima do planeta?

Susan Salomon PNAS Fev 2009

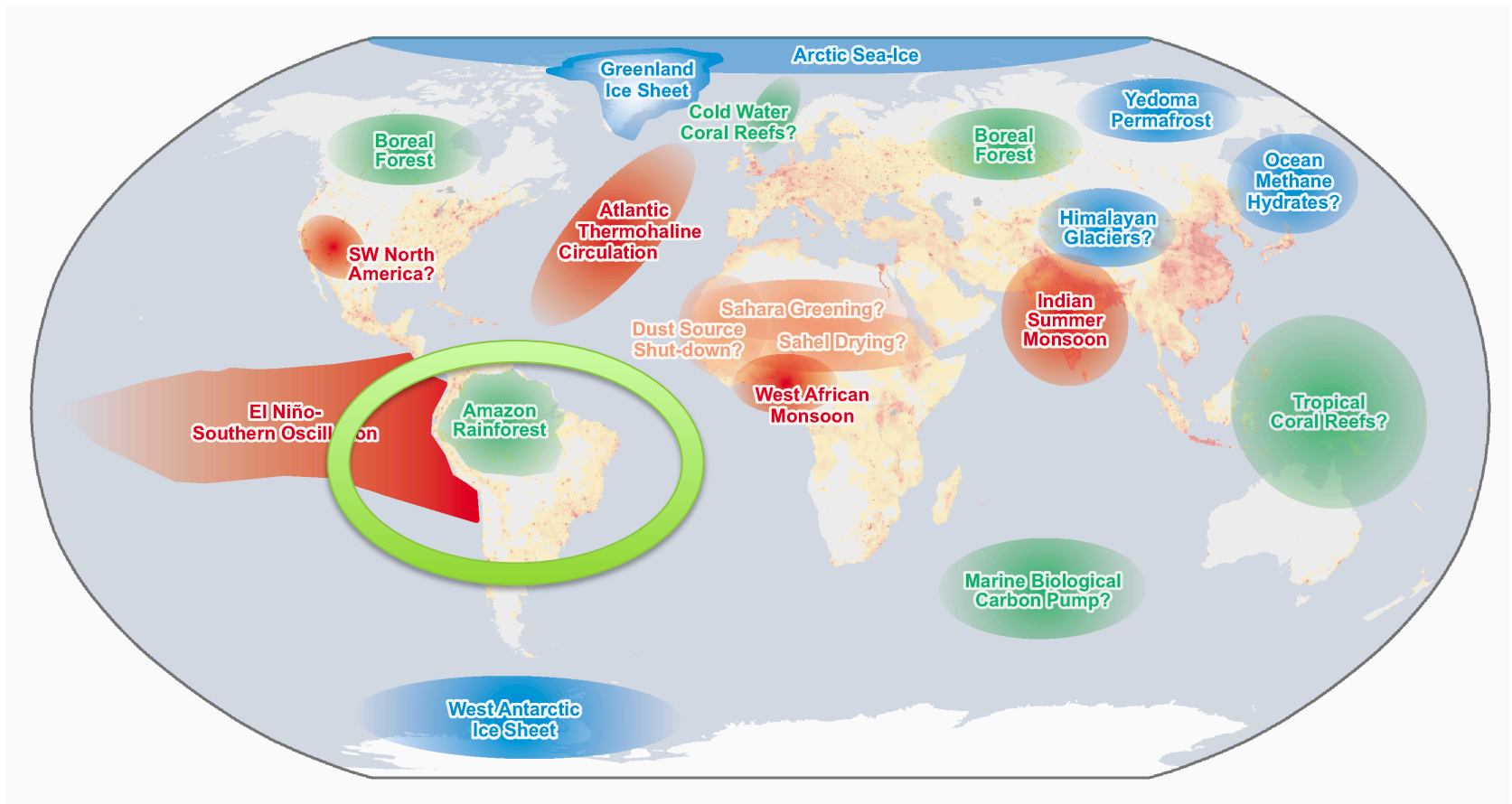
Note a escala: Até o ano 3000 →



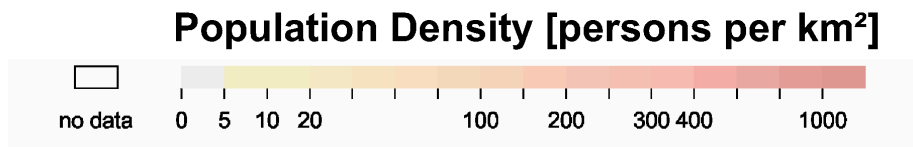
CO₂ remains in the atmosphere long after emissions



Tipping Elements in the Earth System



- Melting
- Circulation Change
- Biome Loss

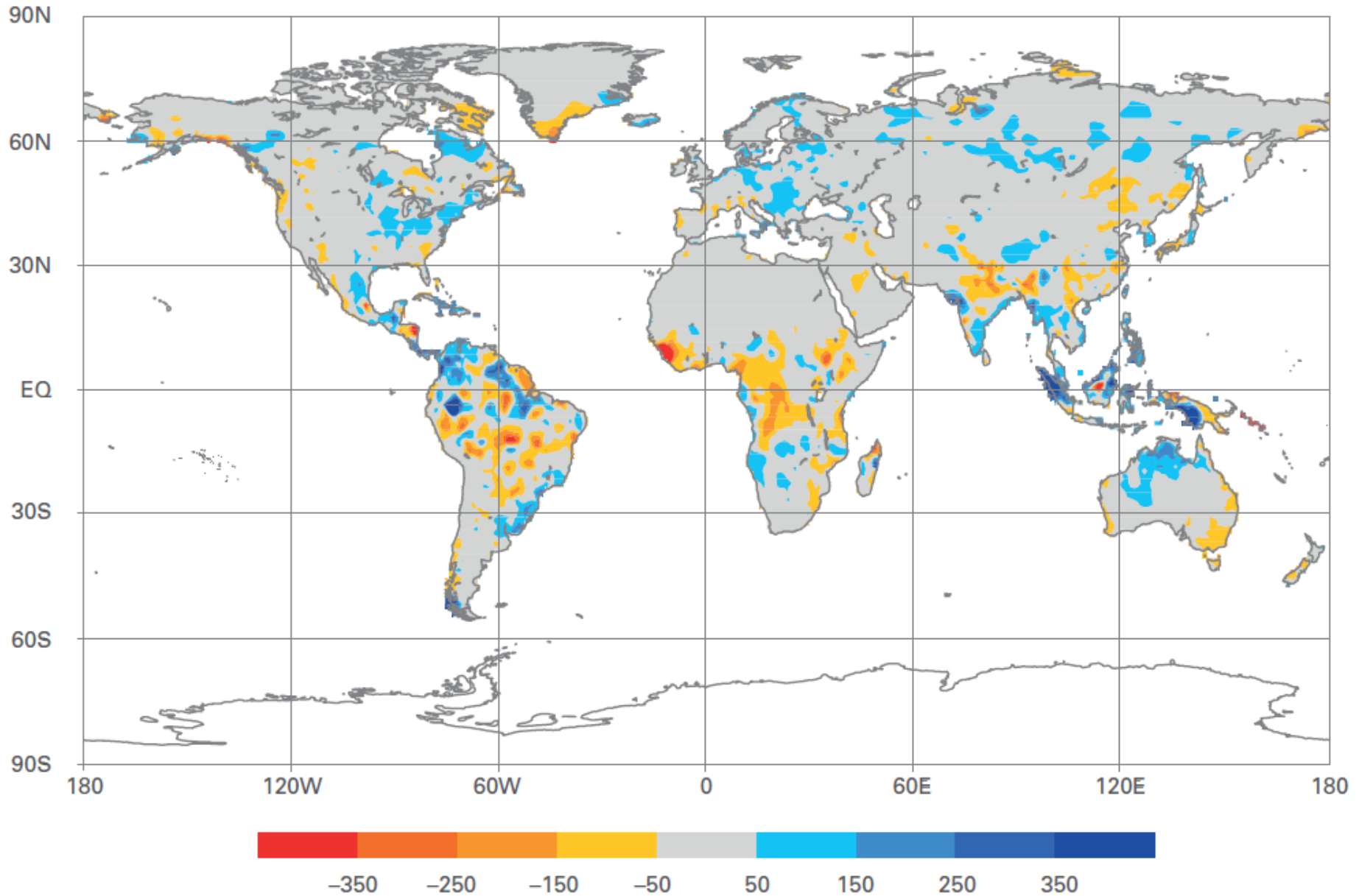


(Source: after Lenton et al. 2008)

Aonde estão os limiares de desestabilização do clima terrestre?

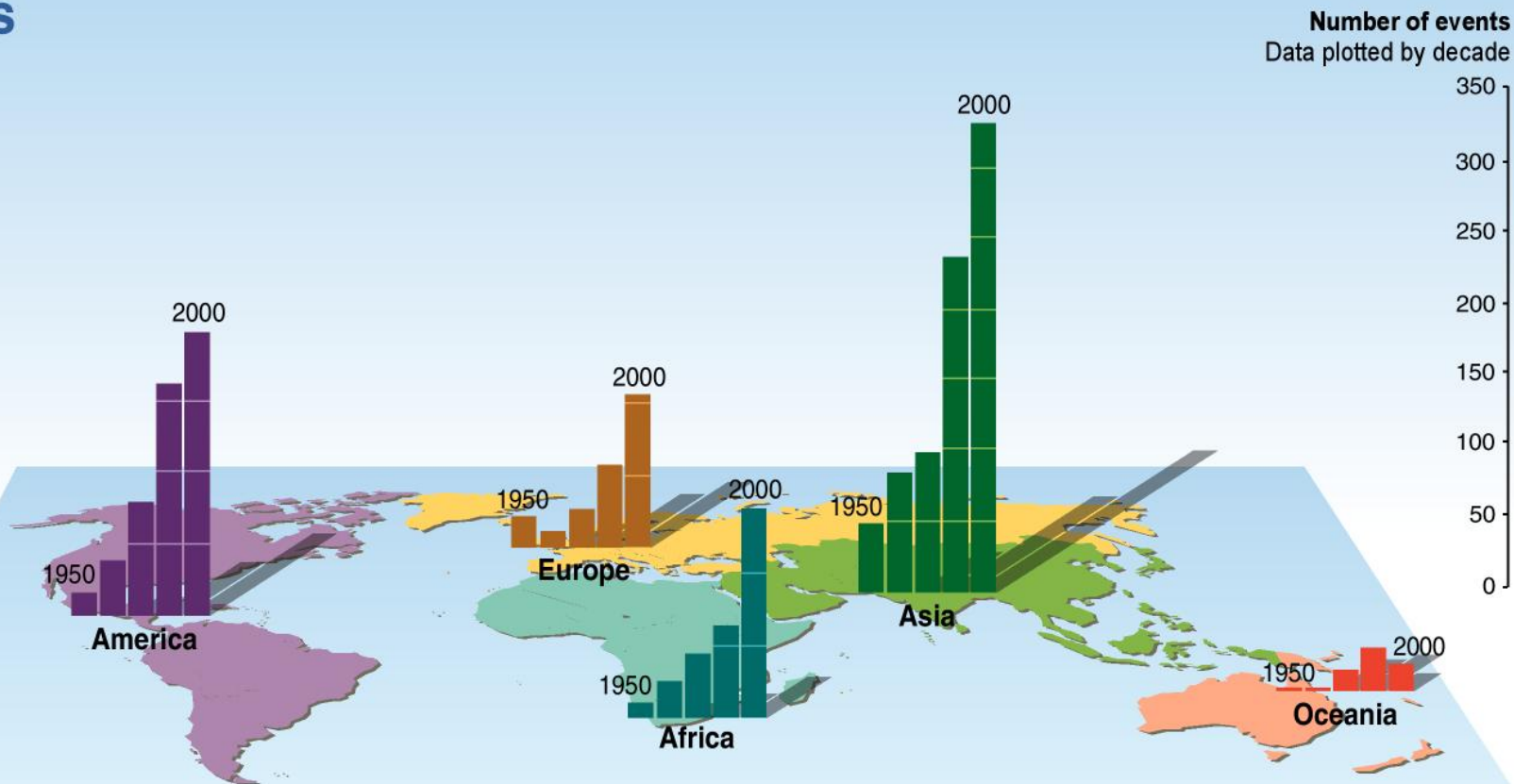


Decadal precipitation anomalies for global land areas for 2001–2010. departures in mm/ year from averages computed using 1951–2000 base period



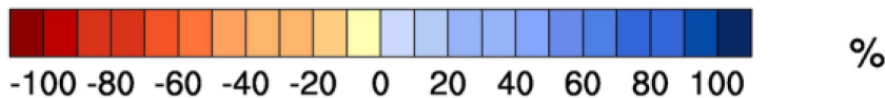
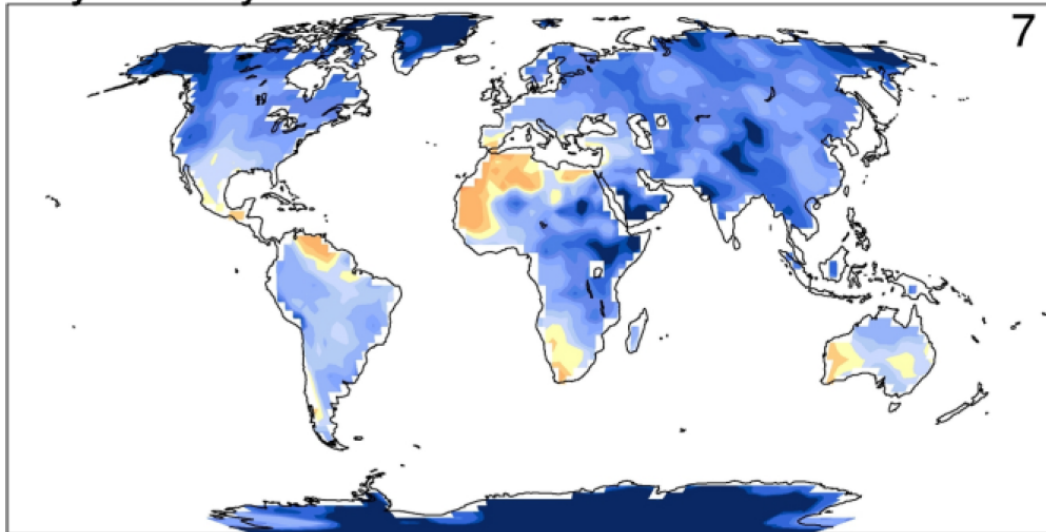
Aumento na incidência de eventos climáticos extremos 1950-2000

Floods

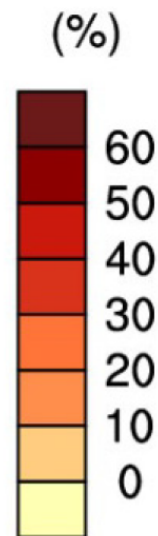
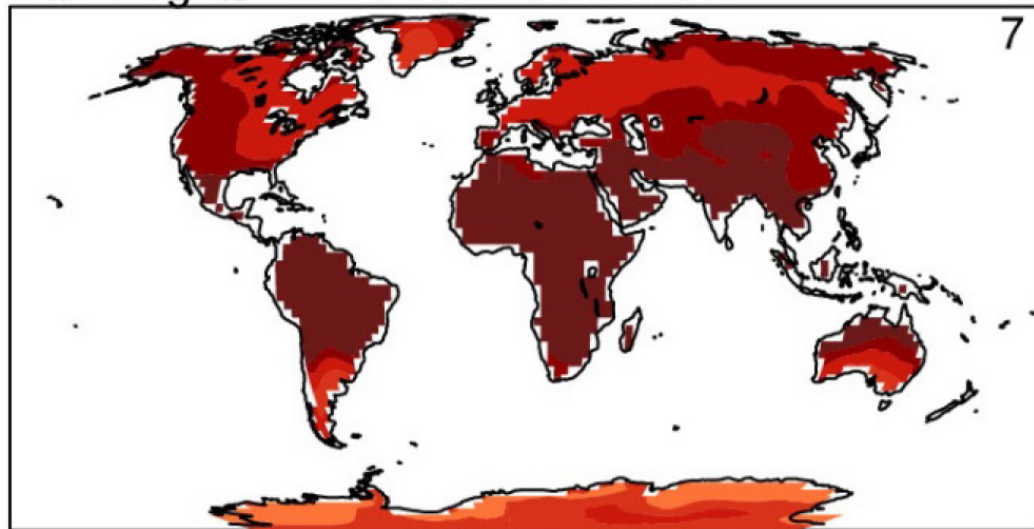


Source: Millennium Ecosystem Assessment

very wet days RCP85: 2081-2100



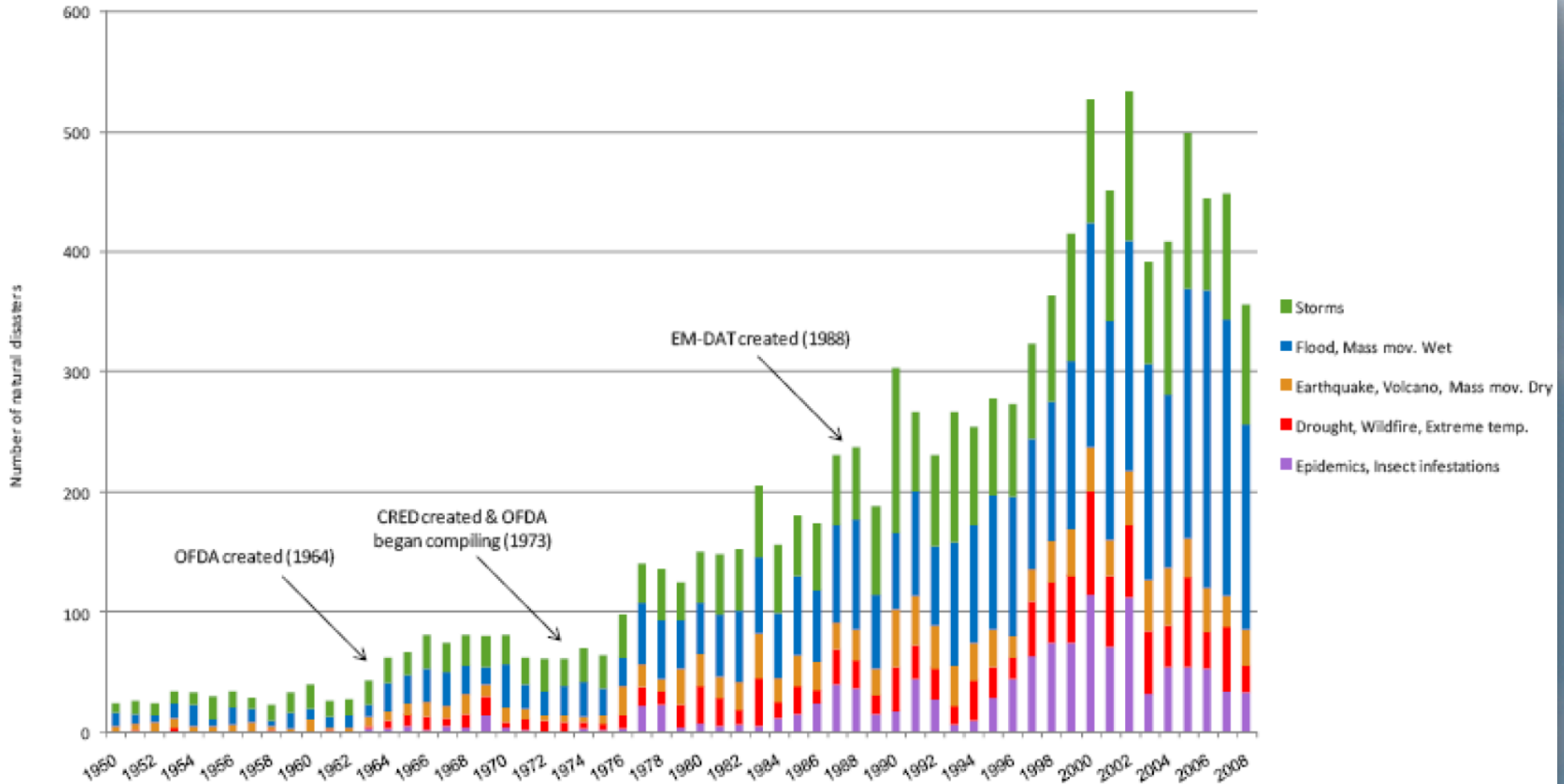
warm nights RCP85: 2081-2100



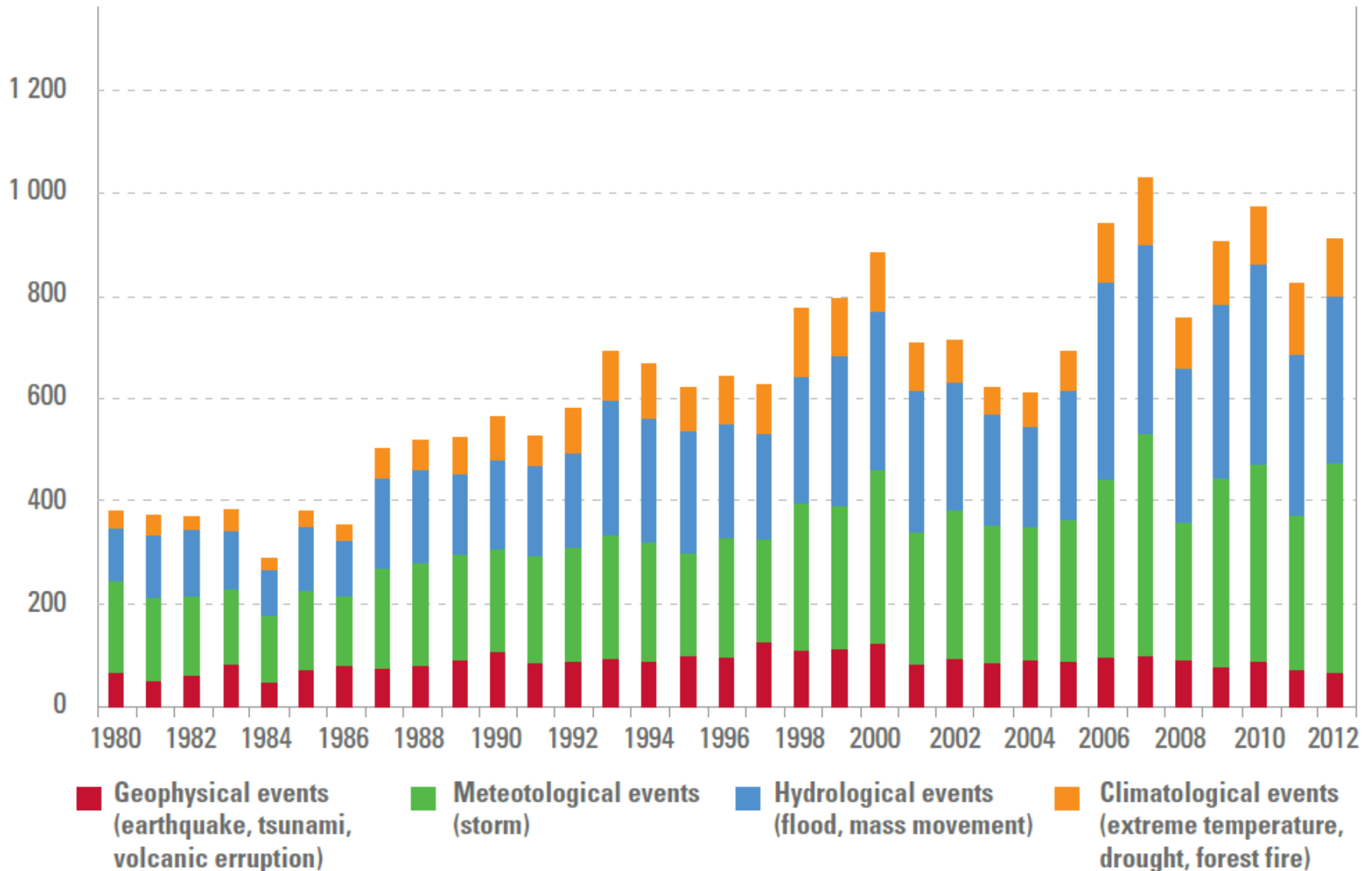
Frequência de eventos extremos 2081-2100

Changes in selected extreme indices in 2100

Aumento da incidência de eventos climáticos extremos – 1950-2008

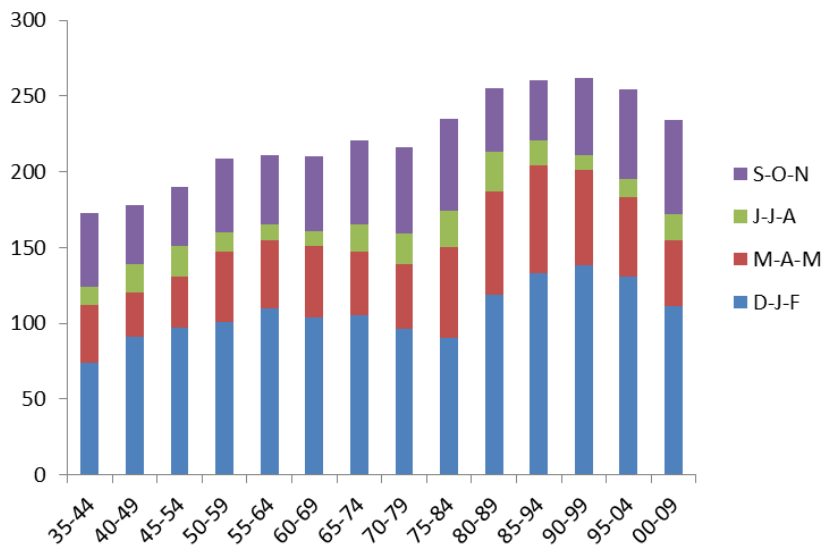


Number of natural disasters 1980–2010

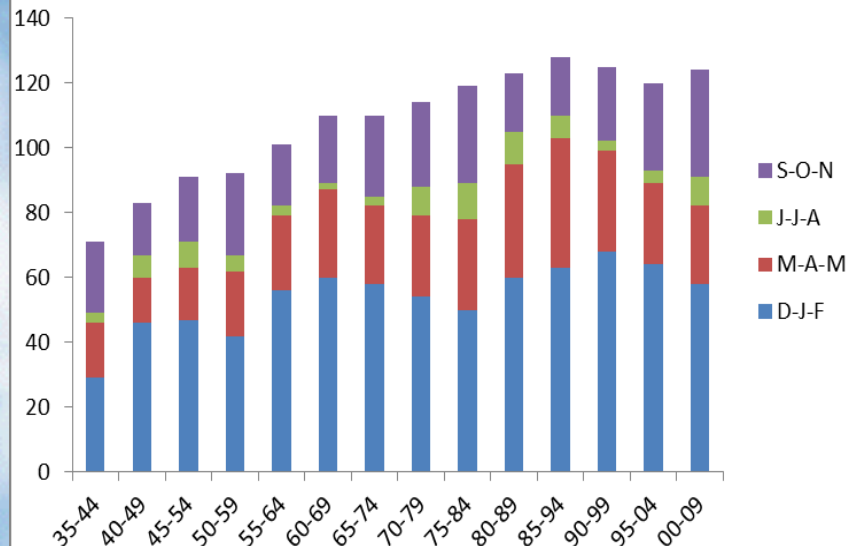


Intensidade de chuva em São Paulo

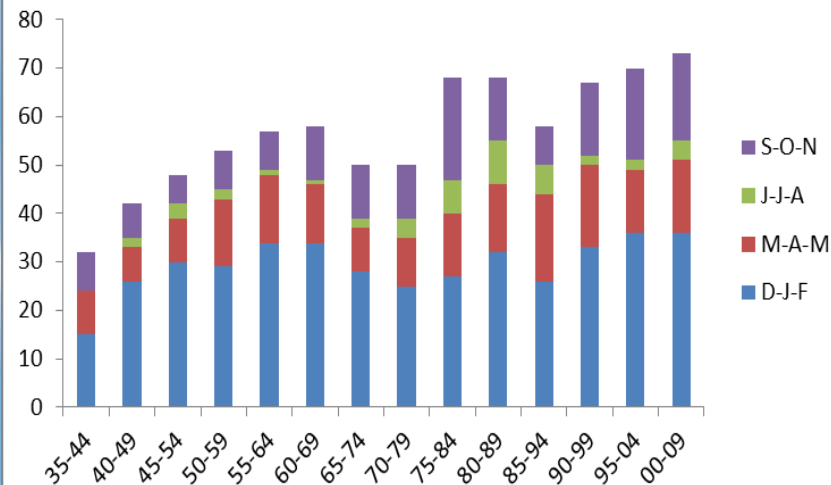
Número de dias em que a chuva excedeu 20mm



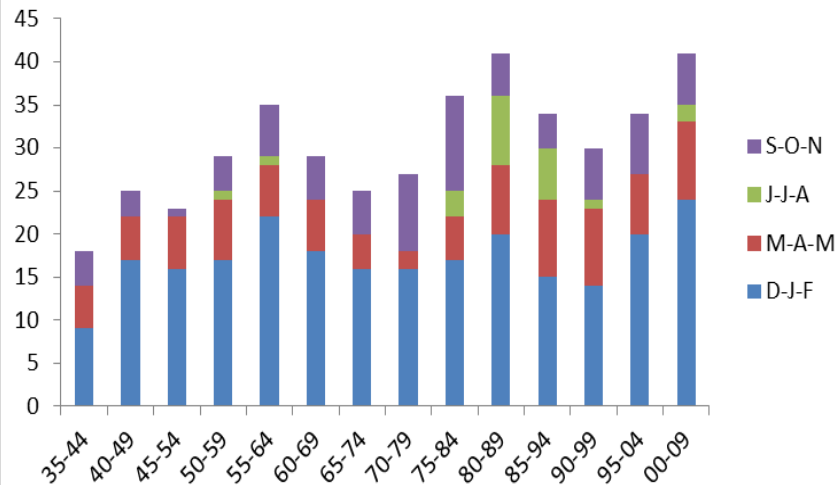
Número de dias em que a chuva excedeu 30mm



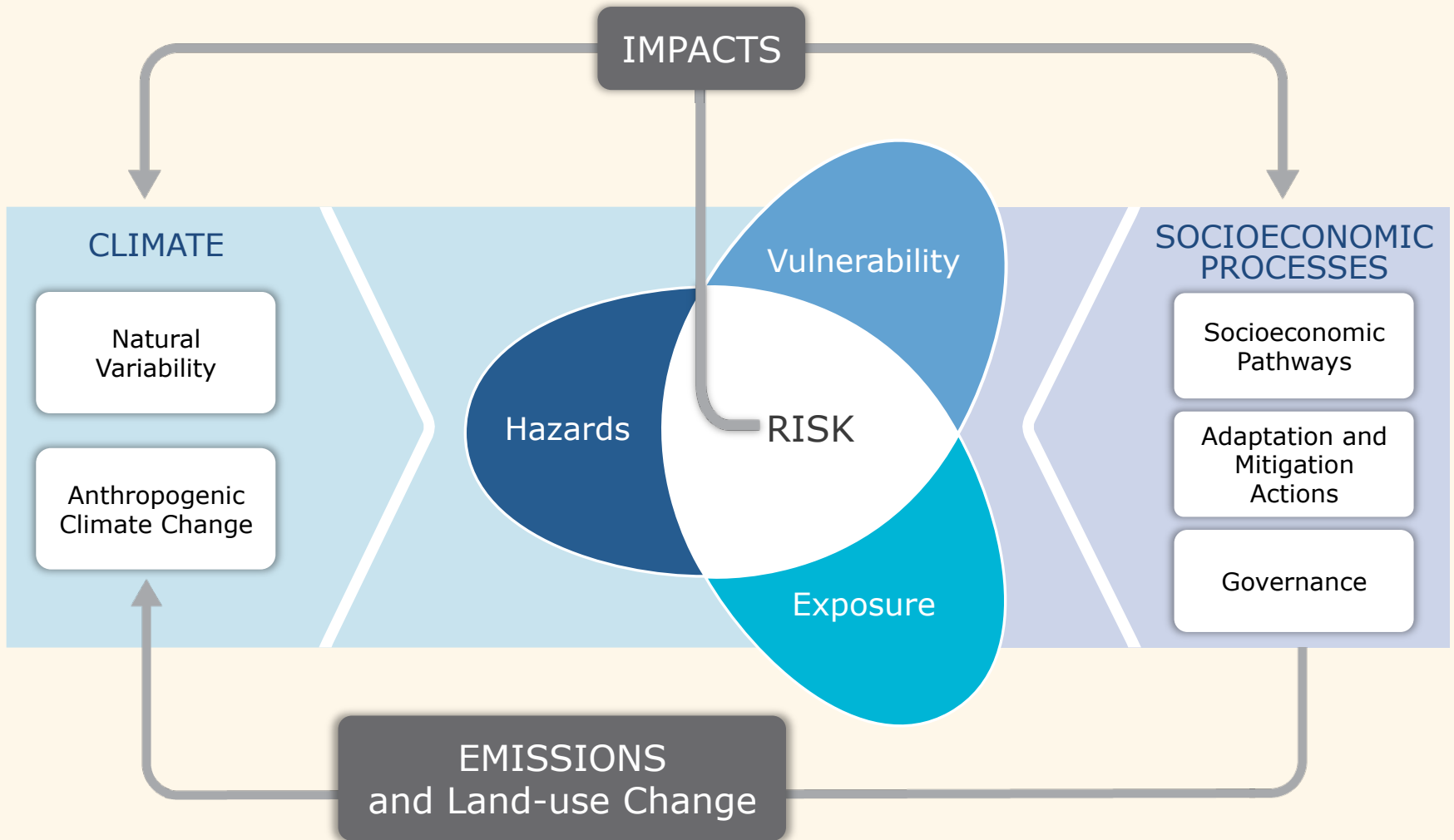
Número de dias em que a chuva excedeu 40mm



Número de dias em que a chuva excedeu 50mm

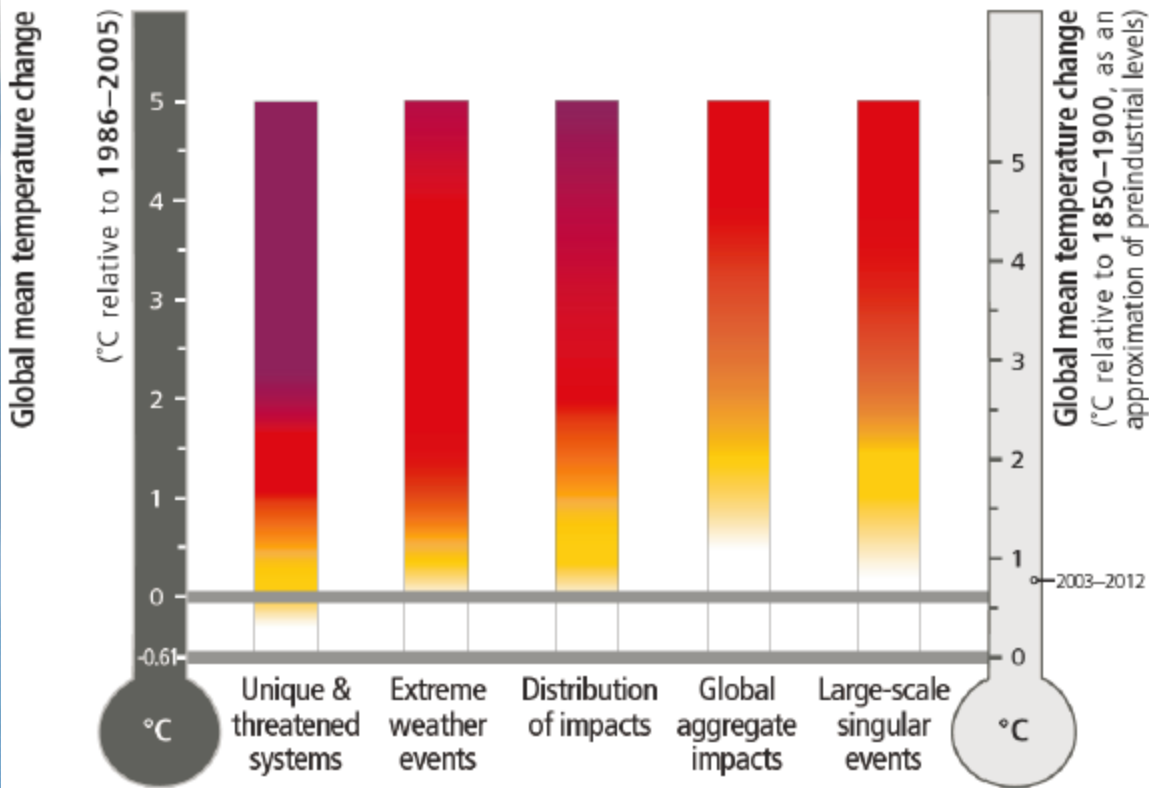
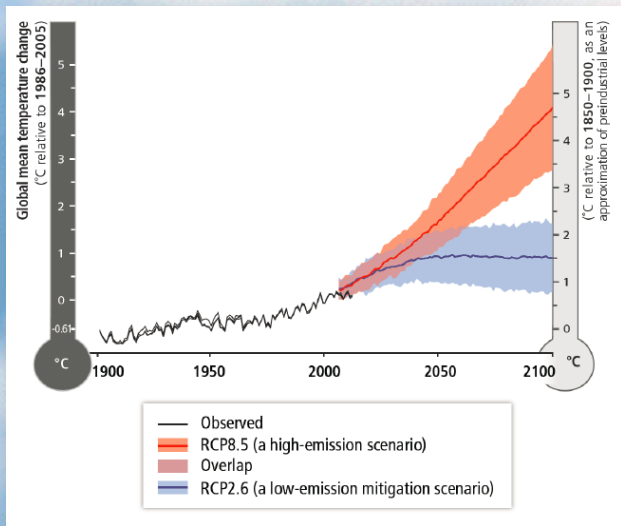


Riscos e vulnerabilidade das mudanças globais



Aumento esperado de temperatura para dois cenários de emissões

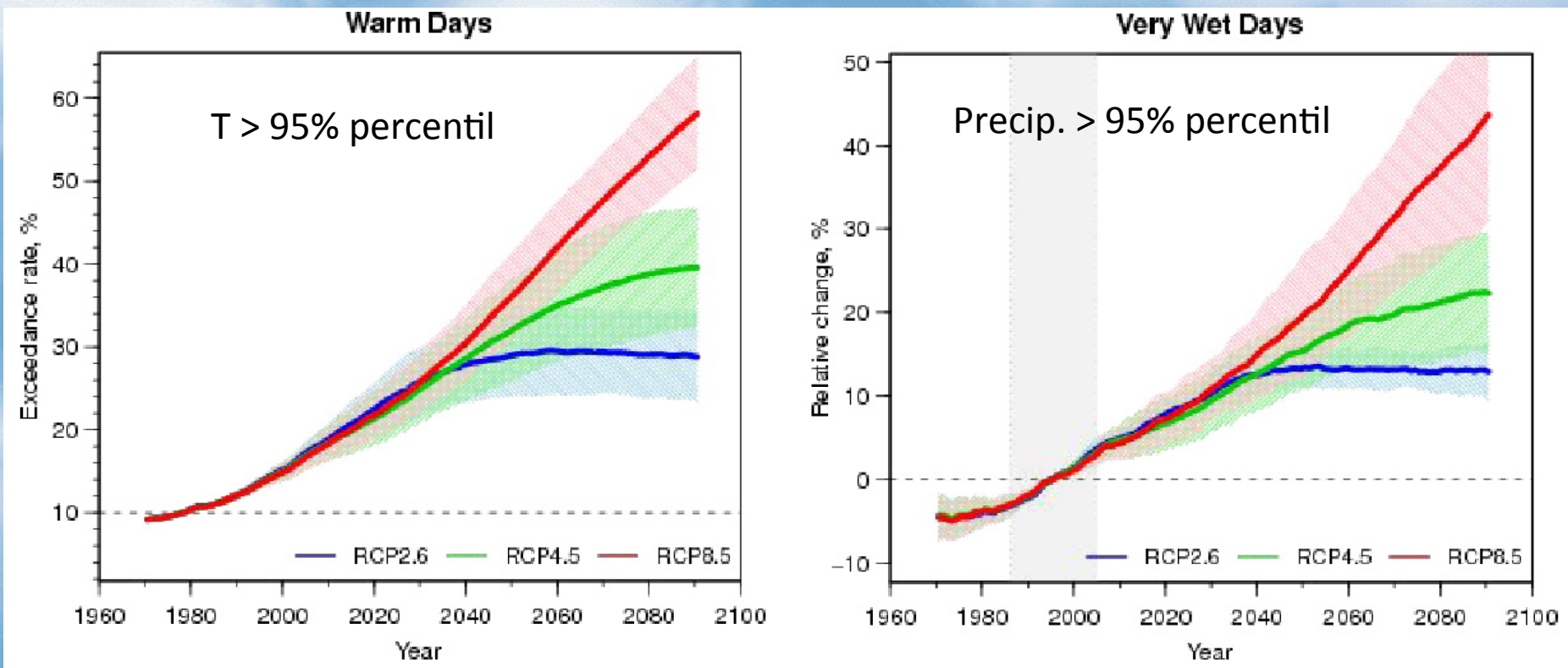
Nível de risco adicional devido às mudanças climáticas



Level of additional risk due to climate change

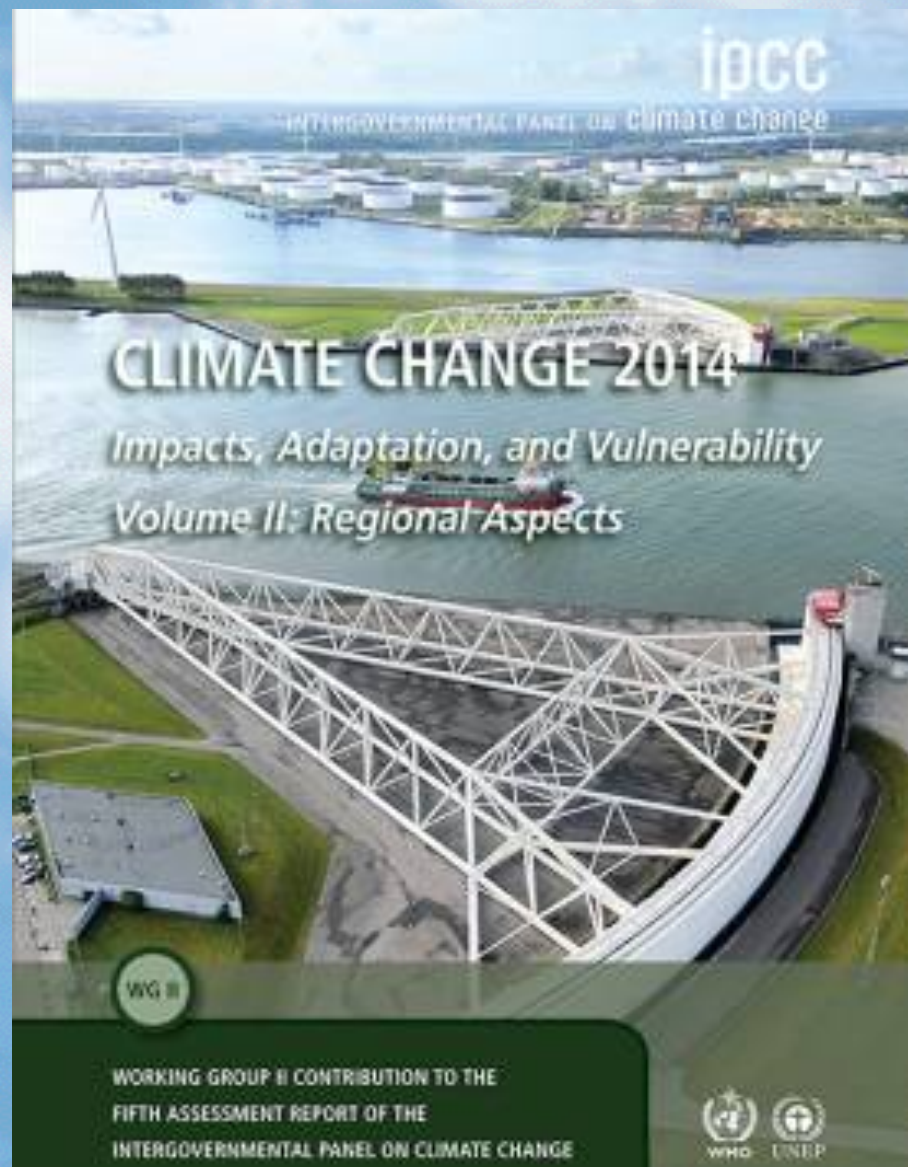
Undetectable Moderate High Very high

Frequência de ocorrência de eventos extremos em temperatura e precipitação



Global mean projections for the occurrence of warm and wet days from CMIP5 for the RCP2.6, RCP4.5 and RCP8.5 scenarios relative to 1986–2005. Panel (a) shows percentage of warm days (tx90p: Tmax exceeds the 90th percentile), panel (b) shows relative change of very wet days (pr95p: annual total precipitation when daily precipitation exceeds 95th percentile).

IPC Working Group 2 – Impactos Adaptação e Vulnerabilidades





VULNERABILITY AND EXPOSURE

AROUND THE WORLD

A photograph of a city street completely flooded with water. The water is dark and reflects the surrounding buildings and sky. On the left, a tall brick building with many windows lines the street. On the right, another brick building with a modern glass and metal facade is visible. In the distance, a person in a red shirt is wading through the water, and a dark car is partially submerged. The sky is overcast and grey.

VULNERABILITY AND EXPOSURE

AROUND THE WORLD



**ADAPTATION IS
ALREADY OCCURING**

C40 - Megacidades e emissões de gases de efeito estufa

América Latina: 80% população urbana em 2012



Em 2100 80% da população mundial
(10 bilhões) vai estar vivendo em cidades

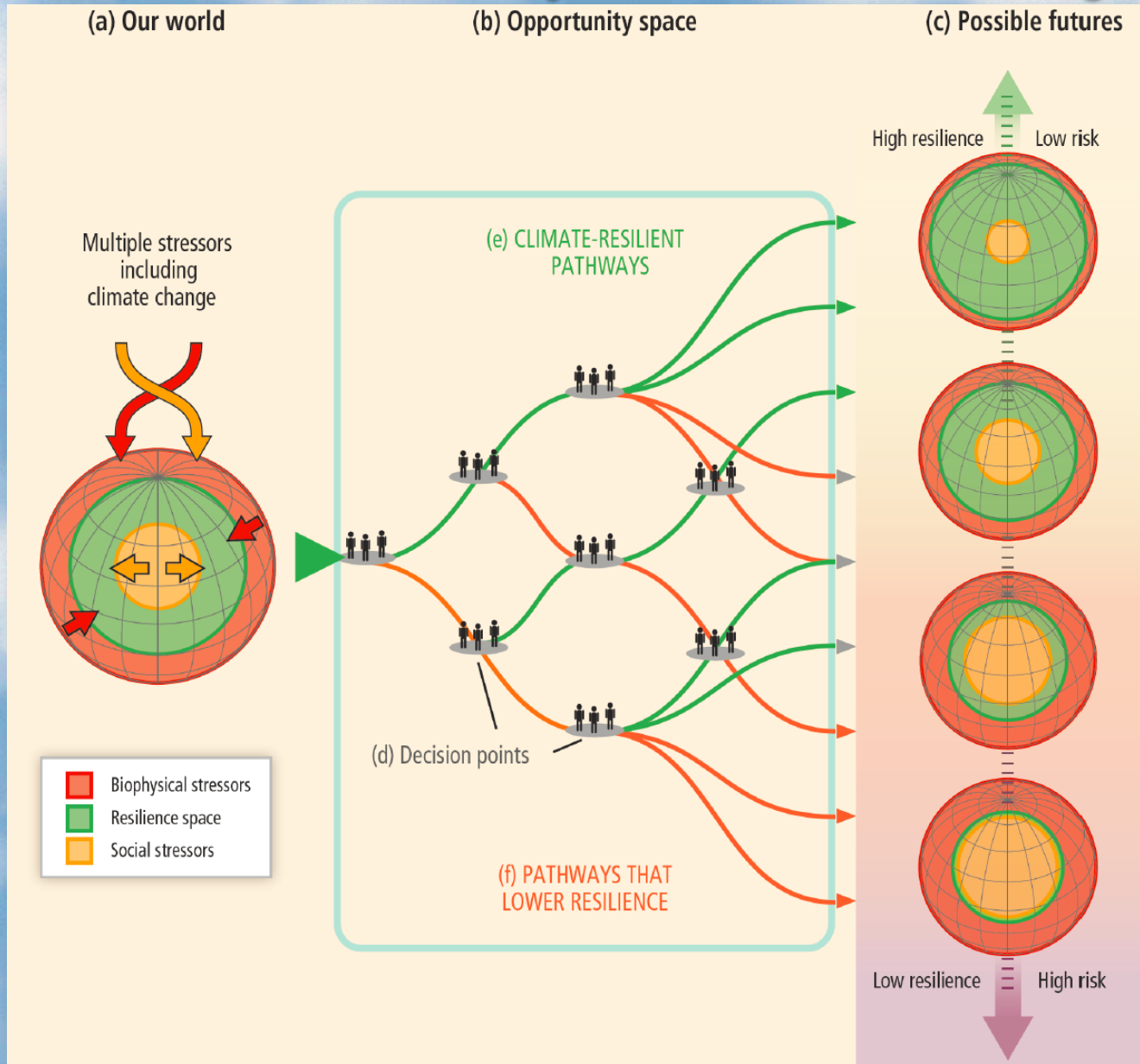


Sustentabilidade em um planeta urbanizado

- Se o adicional de 3.2 bilhões de pessoas em 2100 vão viver em cidades de cerca de 1 milhão de habitantes, vamos ter que contruir 3.200 cidades de 1 milhão de pessoas cada em 89 anos, ou seja:
- **~ 1 nova cidade de 1 milhão a cada 10 dias!!!**



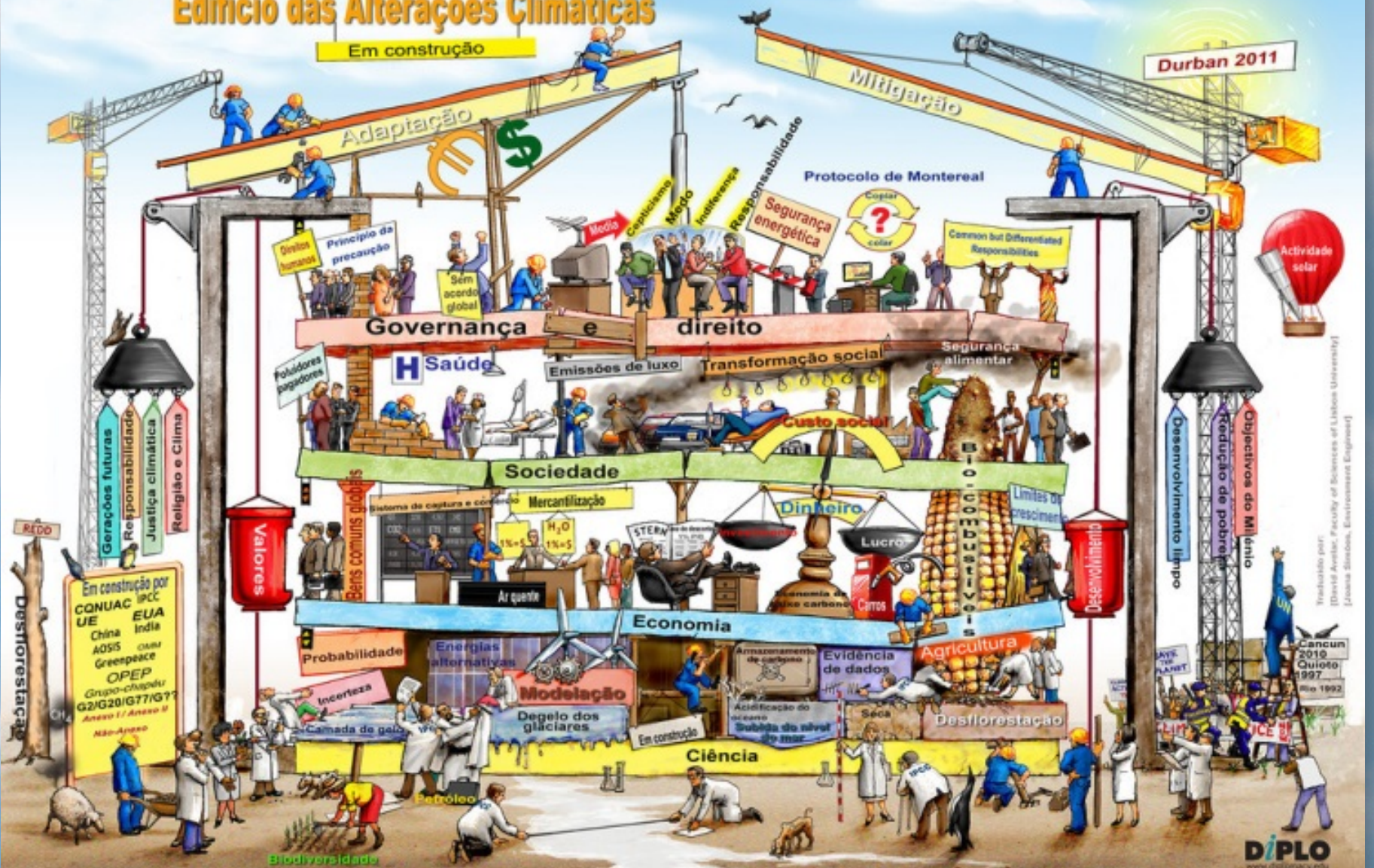
Qual caminho que iremos traçar?



Edifício das Alterações Climáticas

Em construção

Durban 2011



Concept: Kurbalija Illustration: Marcetic
Este esquema ilustra a abordagem da Diplo para a formação e investigação na área das alterações climáticas











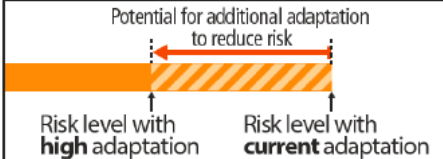
Creative Commons by DiploFoundation

DIPLO
www.diplofoundation.edu




Traduzido por:
(David Ambrós, Faculty of Sciences of Lisbon University)
(Luana Simões, Environment Engineer)

Riscos e potencial para adaptação - América do Sul

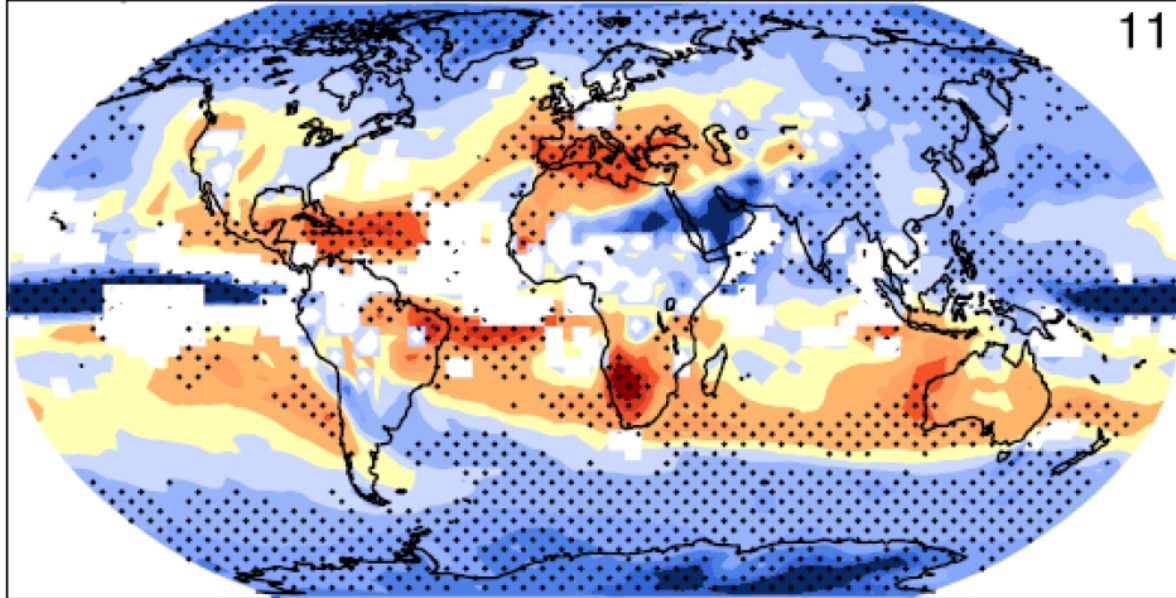
IPCC WG2 2014

Climate-related drivers of impacts										Level of risk & potential for adaptation
 Warming trend	 Extreme temperature	 Drying trend	 Extreme precipitation	 Precipitation	 Snow cover	 Damaging cyclone	 Sea level	 Ocean acidification	 Carbon dioxide fertilization	 <p>Potential for additional adaptation to reduce risk</p> <p>Risk level with high adaptation</p> <p>Risk level with current adaptation</p>

Central and South America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation																		
<p>Water availability in semi-arid and glacier-melt-dependent regions and Central America; flooding and landslides in urban and rural areas due to extreme precipitation (<i>high confidence</i>)</p> <p>[27.3]</p>	<ul style="list-style-type: none"> • Integrated water resource management • Urban and rural flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control 		<table border="1"> <tr> <td></td> <td>Very low</td> <td>Medium</td> <td>Very high</td> </tr> <tr> <td>Present</td> <td colspan="3"></td> </tr> <tr> <td>Near-term (2030-2040)</td> <td colspan="3"></td> </tr> <tr> <td rowspan="2">Long-term (2080-2100)</td> <td>2°C</td> <td colspan="2"></td> </tr> <tr> <td>4°C</td> <td colspan="2"></td> </tr> </table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)	2°C			4°C		
	Very low	Medium	Very high																			
Present																						
Near-term (2030-2040)																						
Long-term (2080-2100)	2°C																					
	4°C																					
<p>Decreased food production and food quality (<i>medium confidence</i>)</p> <p>[27.3]</p>	<ul style="list-style-type: none"> • Development of new crop varieties more adapted to climate change (temperature and drought) • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land-use change • Strengthening traditional indigenous knowledge systems and practices 		<table border="1"> <tr> <td></td> <td>Very low</td> <td>Medium</td> <td>Very high</td> </tr> <tr> <td>Present</td> <td colspan="3"></td> </tr> <tr> <td>Near-term (2030-2040)</td> <td colspan="3"></td> </tr> <tr> <td rowspan="2">Long-term (2080-2100)</td> <td>2°C</td> <td colspan="2"></td> </tr> <tr> <td>4°C</td> <td colspan="2"></td> </tr> </table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)	2°C			4°C		
	Very low	Medium	Very high																			
Present																						
Near-term (2030-2040)																						
Long-term (2080-2100)	2°C																					
	4°C																					
<p>Spread of vector-borne diseases in altitude and latitude (<i>high confidence</i>)</p> <p>[27.3]</p>	<ul style="list-style-type: none"> • Development of early warning systems for disease control and mitigation based on climatic and other relevant inputs. Many factors augment vulnerability. • Establishing programs to extend basic public health services 		<table border="1"> <tr> <td></td> <td>Very low</td> <td>Medium</td> <td>Very high</td> </tr> <tr> <td>Present</td> <td colspan="3"></td> </tr> <tr> <td>Near-term (2030-2040)</td> <td colspan="3"></td> </tr> <tr> <td rowspan="2">Long-term (2080-2100)</td> <td>2°C</td> <td colspan="2">not available</td> </tr> <tr> <td>4°C</td> <td colspan="2">not available</td> </tr> </table>		Very low	Medium	Very high	Present				Near-term (2030-2040)				Long-term (2080-2100)	2°C	not available		4°C	not available	
	Very low	Medium	Very high																			
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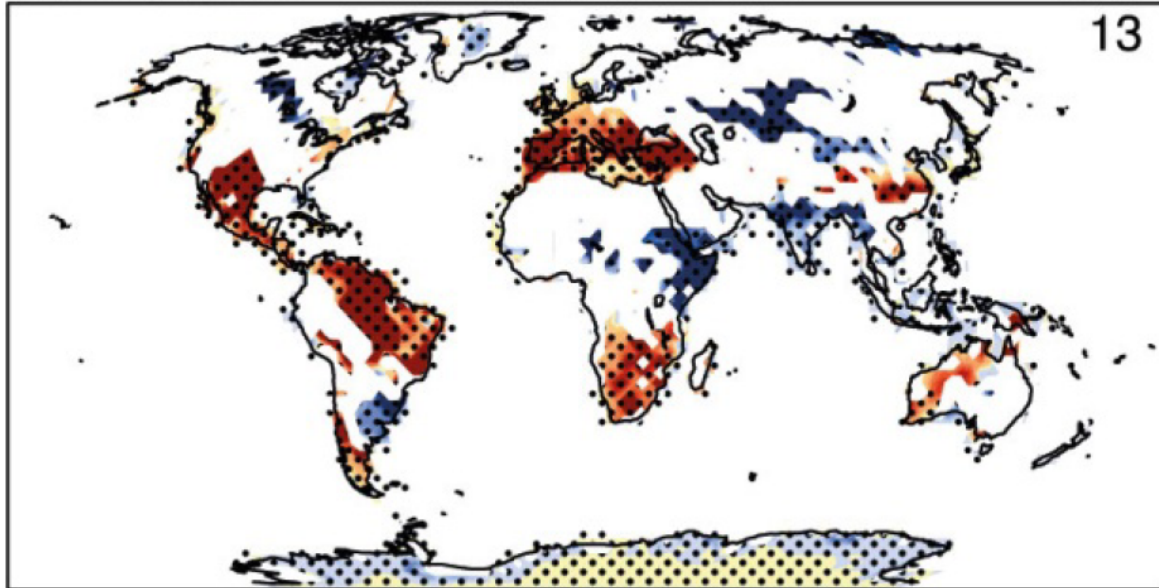
Precipitation RCP85: 2081-2100 JJA



Changes in the water cycle in 2100

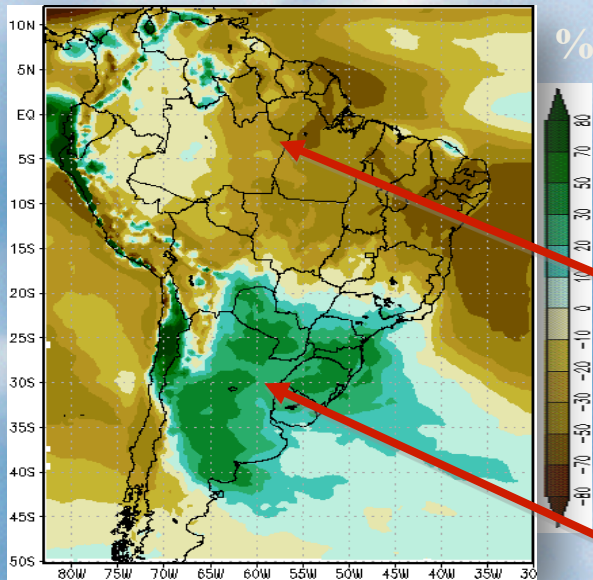
(IPCC 2012)

Soil Moisture RCP85: 2081-2100 ANN



Cenários futuros de clima- América do Sul-Extremos

Cenários futuros de clima para América do Sul derivados do Eta CPTec 40 km (modelo regional) forçados com o modelo global HadCM3 A1B sugerem que as mudanças de clima apresentam



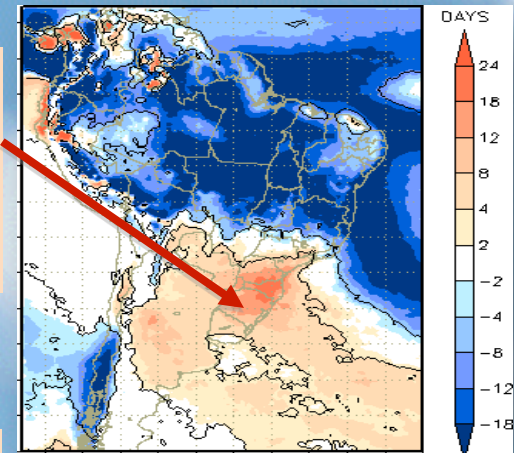
Mudanças na chuva (%) em 2071-2100 relativo a 1961-90.

Amazonia e Nordeste do Brasil ❏ deficiência de chuvas

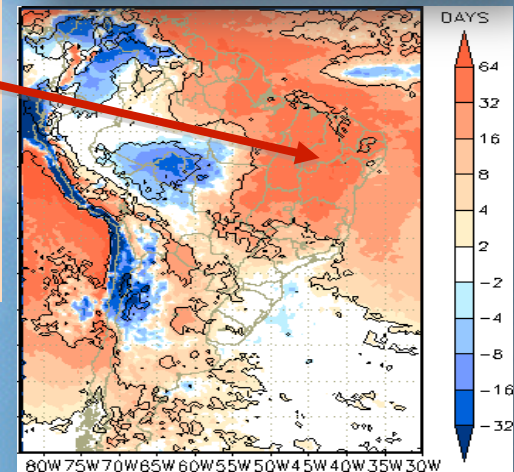
Sudeste da America do Sul ❏ aumento nas chuvas

Projeções ate finais do Século XXI mostram mudanças nos extremos de chuva, com chuvas mais intensas ou com mais areas com seca extrema

Aumento na freqüência de chuvas intensas em 2071-2100 relativo a 1961-90



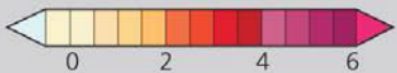
Aumento no número de dias secos consecutivos em 2071-2100 relativo a 1961-90



Marengo et al 2012,
Chou et al 2012

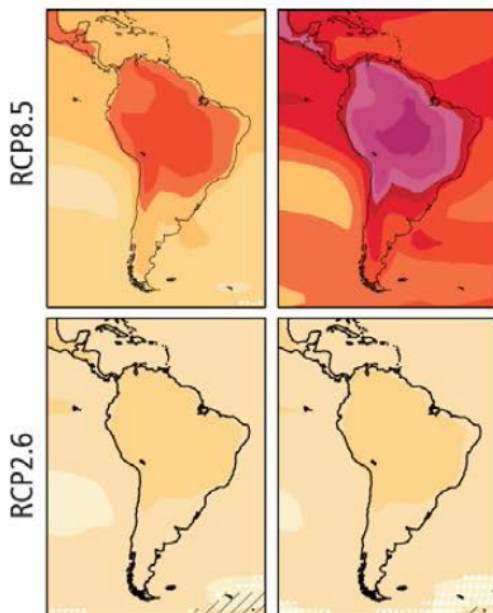
Mudanças na temperatura e precipitação na América do Sul

Annual Temperature

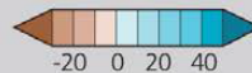


Difference from 1986-2005 mean (°C)

mid-21st century late-21st century

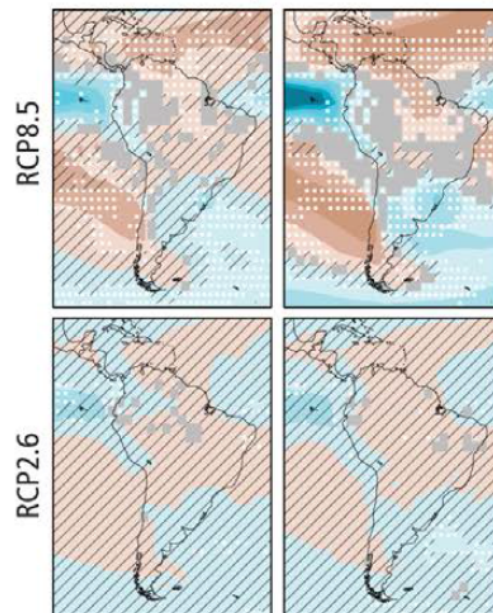


Annual Precipitation



Difference from 1986-2005 mean (%)

mid-21st century late-21st century



Solid Color	Very strong agreement	White Dots	Strong agreement	Gray	Divergent changes	Diagonal Lines	Little or no change
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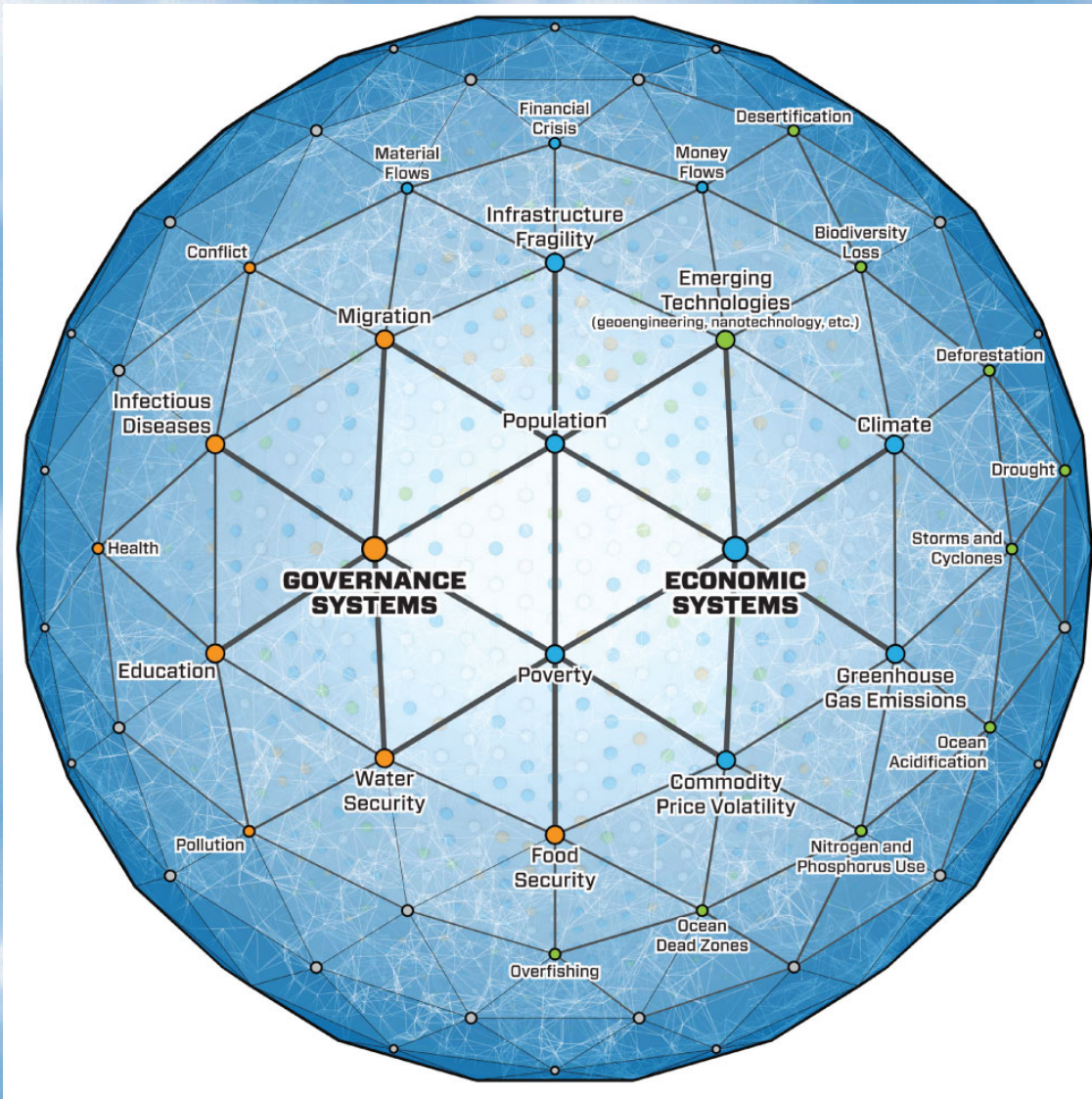
Agricultura e produção de alimentos com menor emissão de gases de efeito estufa



Água será uma questão fundamental neste nosso século 21



A Governança das mudanças globais e as interconexões



Dificuldades de acordos internacionais:

E os países com baixa emissão per capita?

Países desenvolvidos aceitam redução em seu nível de consumo?

Quem paga a conta?

Quem perde e quem ganha economicamente?

**Prazos para redução de emissões?
Muitos etc.**

Consumo em UMA SEMANA...

Deutschland
\$ 500



Italien
\$ 260



Ecuador
\$ 31,55



Chad
\$ 1,23



THE NEXT GOLDEN STATE: A 16-PAGE SPECIAL REPORT ON AUSTRALIA

The Economist

MAY 28TH-JUNE 3RD 2011

Economist.com

Obama, Bibi and peace

Britain's privacy mess

The costly war on cancer

How the brain drain reduces poverty


A soft landing for China

Welcome to the Anthropocene



Geology's new age


The Economist, 2011

A large cargo ship is seen from a high angle, sailing on the ocean. The ship's deck is visible, with several large, reddish-brown containers stacked on it. The sky is filled with heavy, grey clouds, with a bright light source breaking through near the horizon, creating a dramatic atmosphere. The water is dark and choppy.

**Um futuro muito
incerto em um
planeta mais
quente?**

**Um retorno
à condições
estáveis**

**O antropoceno em 2014:
Para onde estamos levando o planeta?**



Se quisermos evitar um aquecimento de 3 a 4 graus em nosso planeta ao longo deste século, não há outra maneira a não ser utilizar os recursos naturais de nosso planeta de modo mais inteligente.

Obrigado pela atenção !!!