

# MUDANÇAS CLIMÁTICAS GLOBAIS

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II Treinamento em Modelagem de  
Cenários de Mudanças Climáticas  
Cachoeira Paulista, 31 de Agosto de 2009

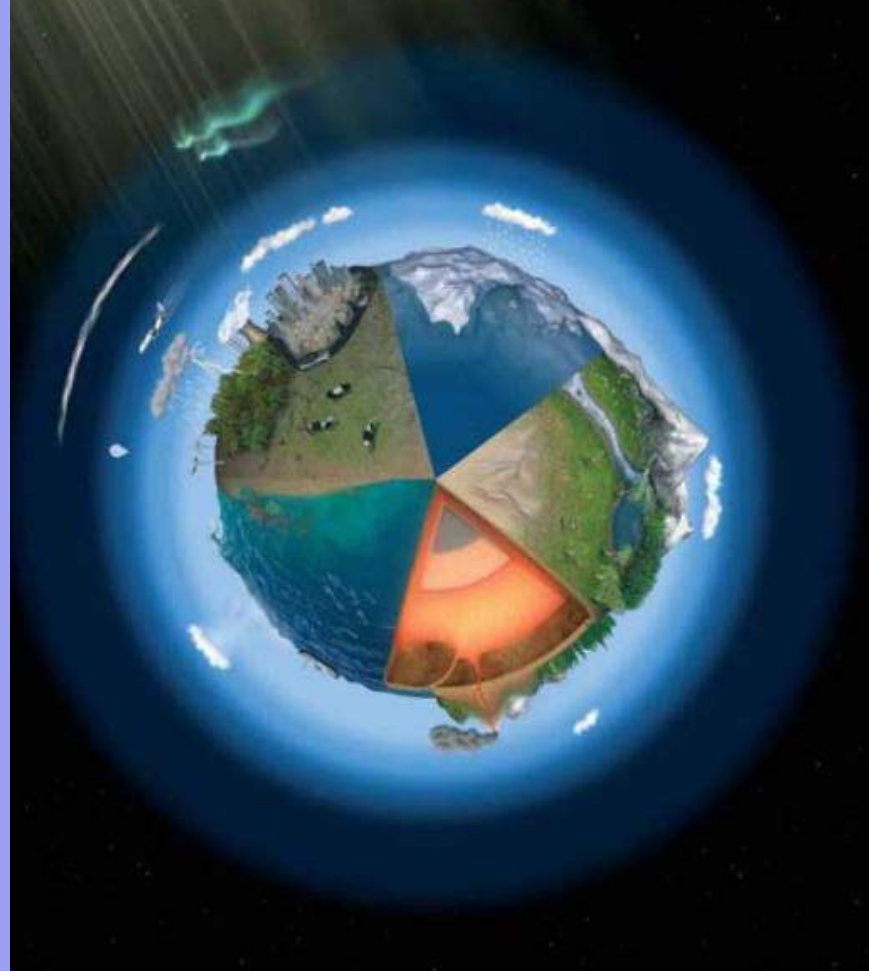
NATURE|Vol 458|30 April 2009

CLIMATE CRUNCH NEWS FEATURE



**A BURDEN BEYOND BEARING**

*Como o ambiente da Terra está mudando, e  
quais as consequências para a nossa  
civilização?*



# *Antropoceno*

*“A influência da humanidade no Planeta Terra  
nos últimos séculos tornou-se tão  
significativa a ponto de constituir-se numa  
nova era geológica”*

S30

*Prof. Paul Crutzen*

*Prêmio Nobel de Química 1995*

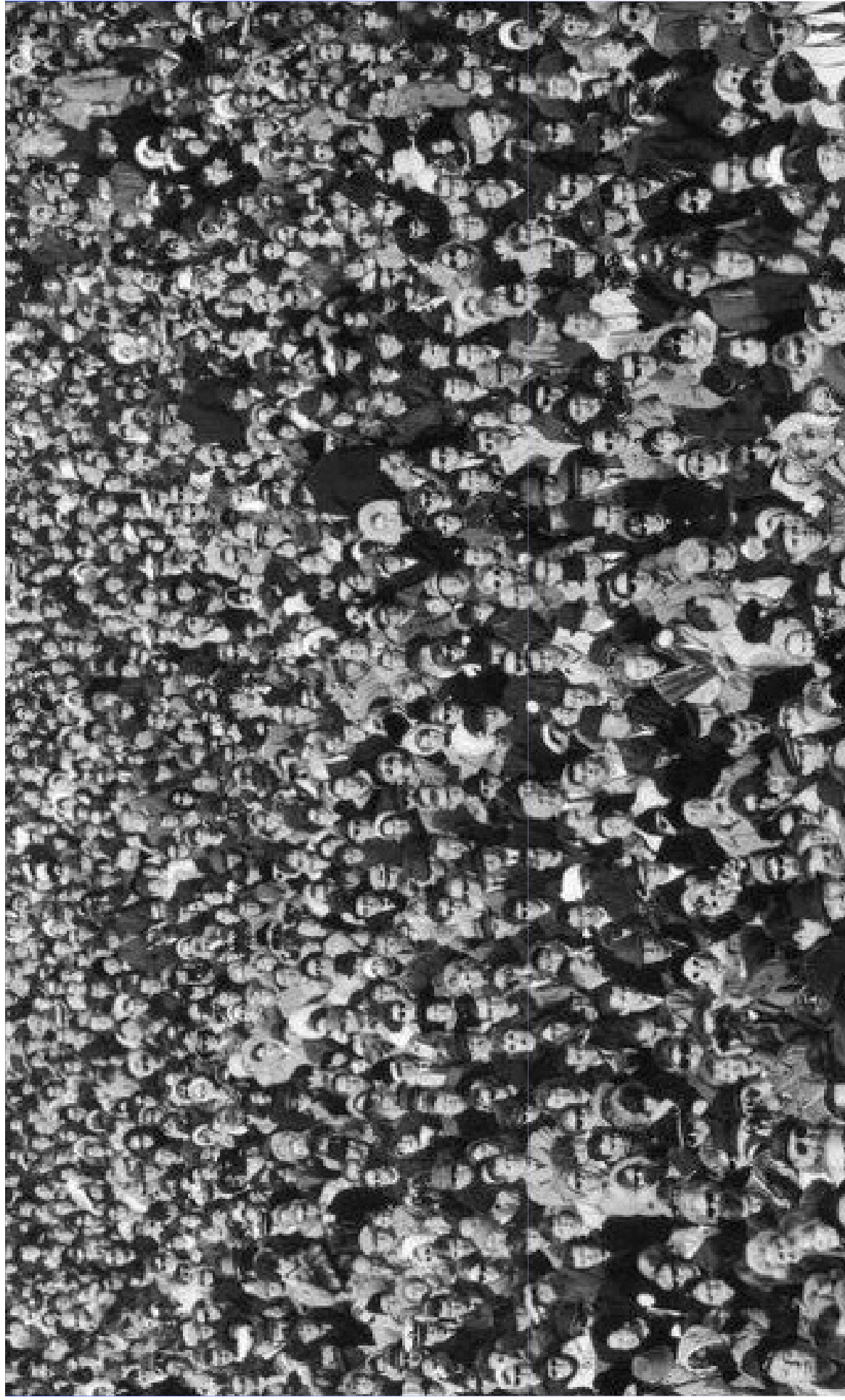
### Slide 3

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#### S30

The term Anthropocene was coined in 2000 by Nobel Prize winning scientist Paul Crutzen to describe the most recent period in the Earth's history, starting with the industrial revolution in the 18th Century when the activities of the human race first began to have a significant global impact on the Earth's climate and ecosystems.

Carlos; 01/10/2007



*A cada hora,  
10,000 pessoas se somam à população  
mundial*



*A cada hora,*

**4 Milhões de toneladas de CO<sub>2</sub> são emitidos**



*A cada hora,  
1,500 hectares de florestas são derrubadas*



**A cada hora,  
3 espécies são extintas**  
(1000 vezes mais rápido do que os processos naturais)



# The Tale of the Disappearing Frogs of Central American Mountains

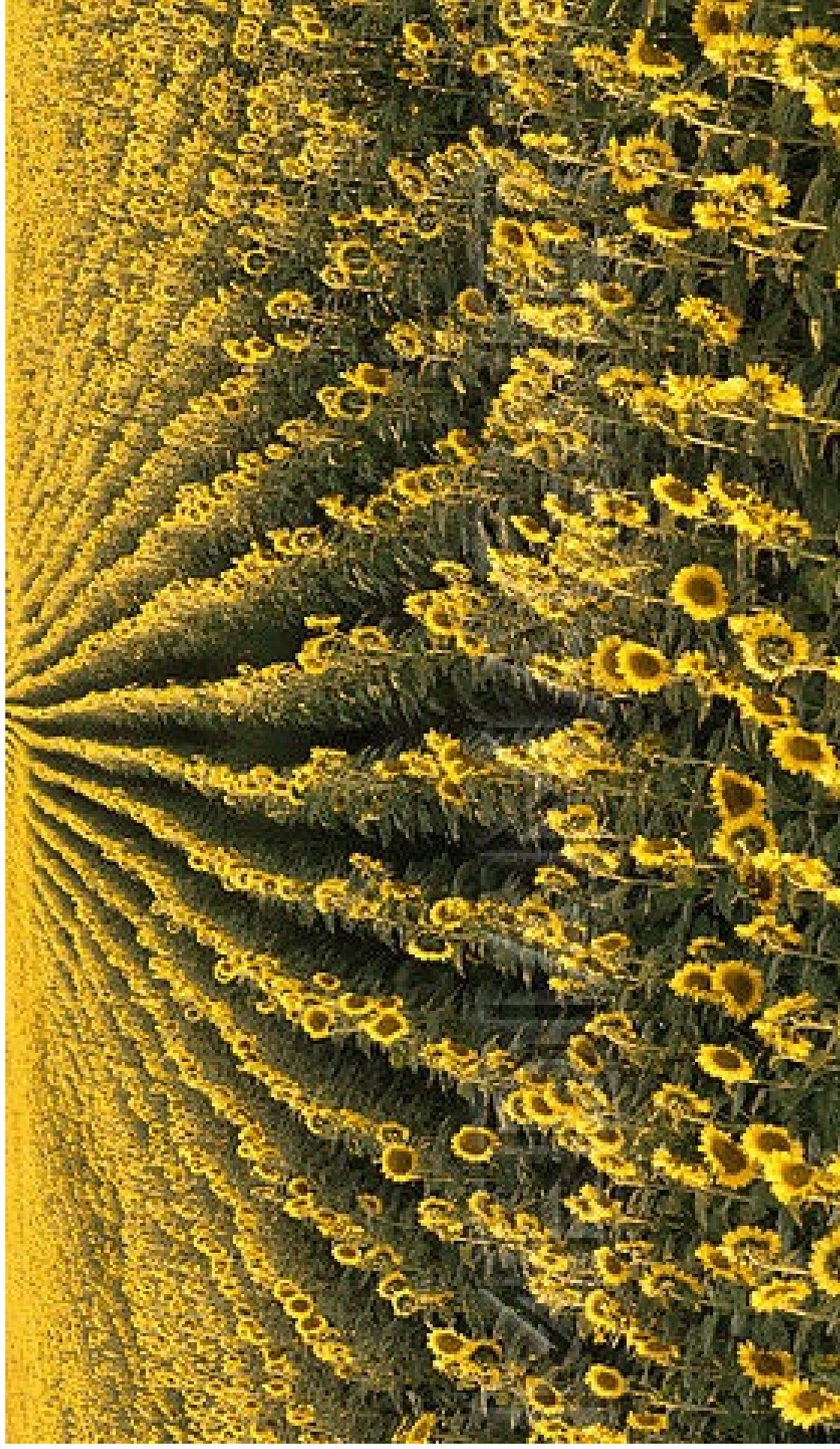


**Figure 1 | Amphibian alarm call.** The Panamanian golden frog is one of roughly 110 species of harlequin frog (*Atelopus*), many of which are dying out. Although this species still survives, its numbers have fallen significantly.

Chytridthermal-  
optimum hypothesis for  
Batrachochytrium

A.R. Blaustein and A. Dobson – Nature, vol.439, pp. 143-144, January, 2006  
*Pounds, J. A. et al. Nature. Vol. 439, pp.161-167. 2006*

What are the accessible but intolerable domains (to frogs) in  
'Earth System phase space'?



**A cada hora,**

**Atividades humanas adicionam 1.7 milhões de Kg nitrogênio  
reativo às florestas, campos agrícolas e corpos d'água**

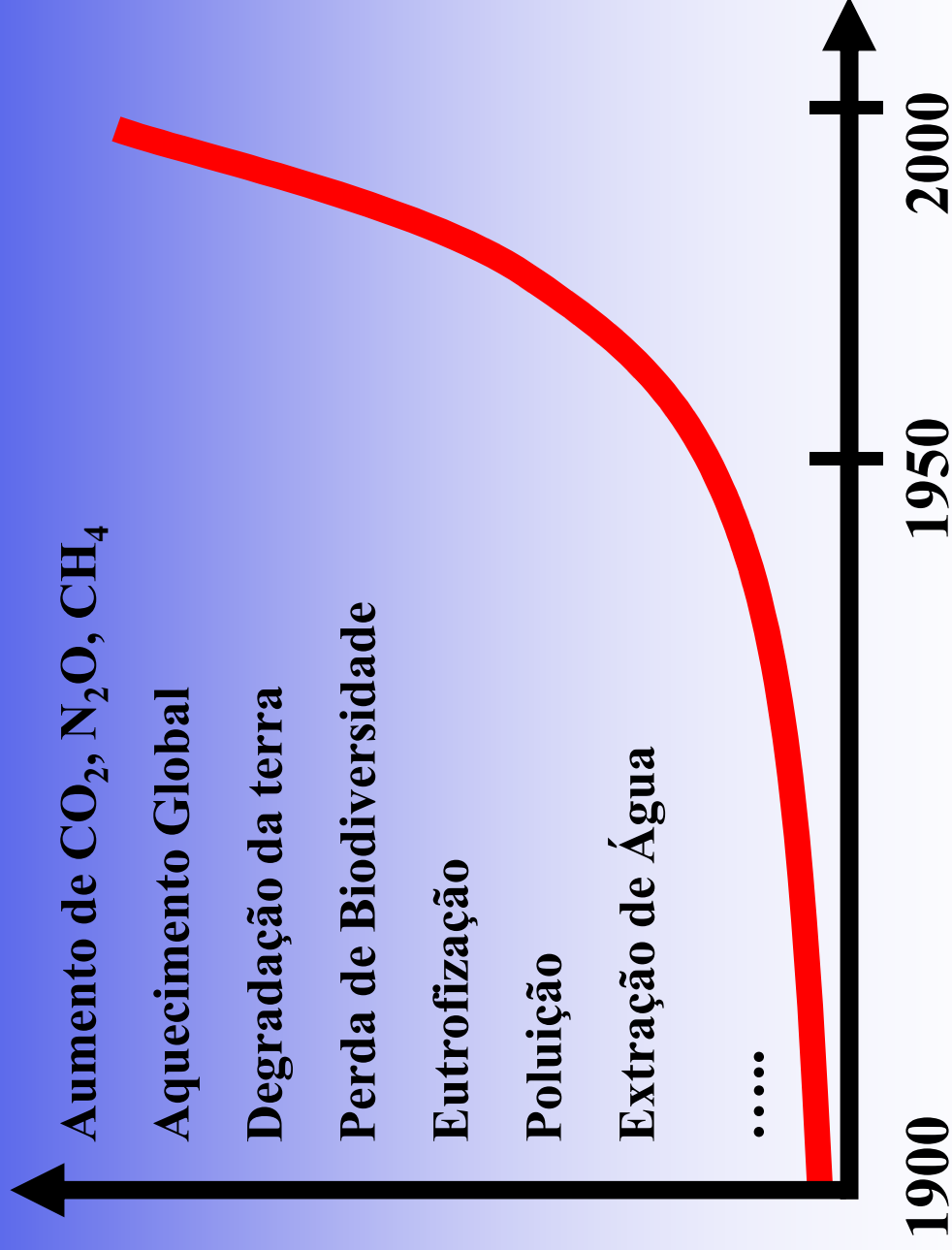
# O Desafio Populacional

- 1 bilhão de pessoas em países ricos
- 2 bilhões de pessoas progredindo
- 3 bilhões de pobres que necessitam progredir
- 3 bilhões de pessoas ainda por vir.

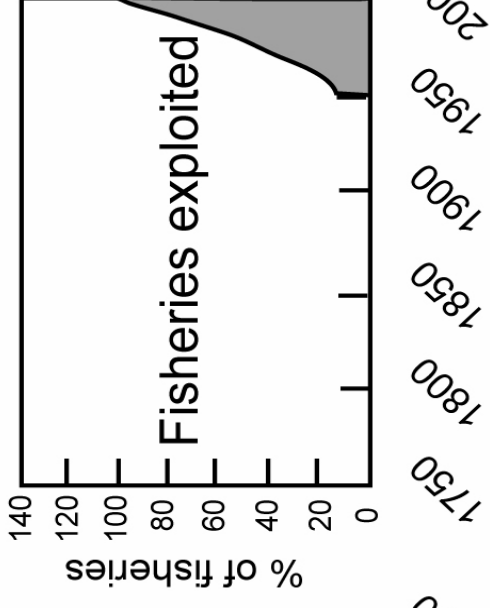
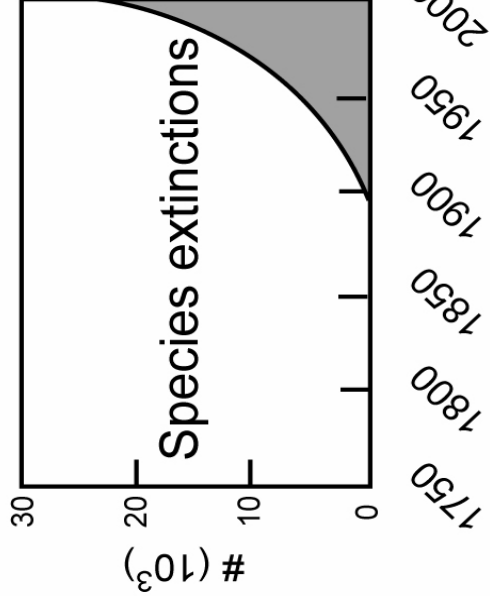
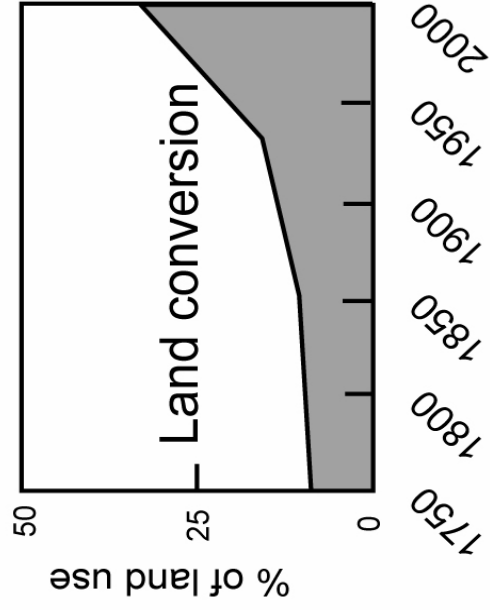
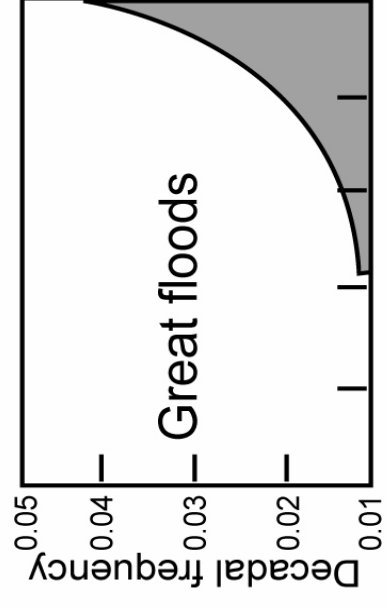
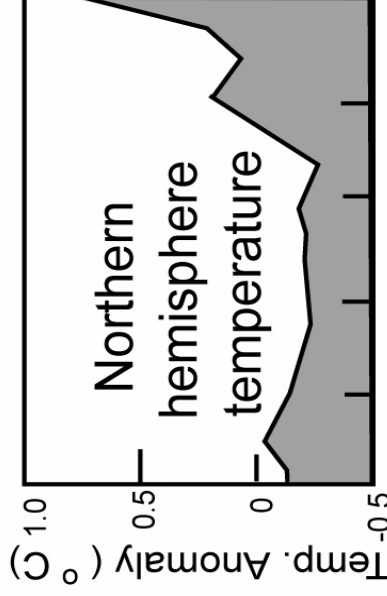
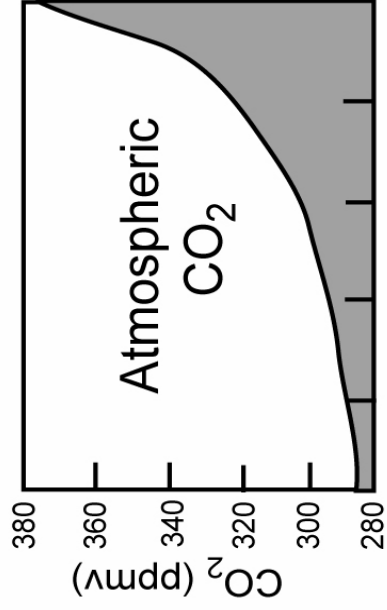
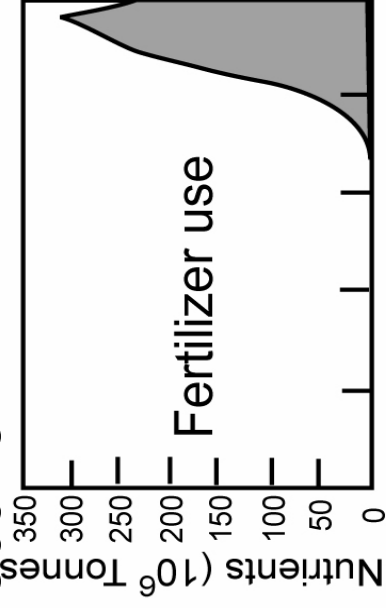
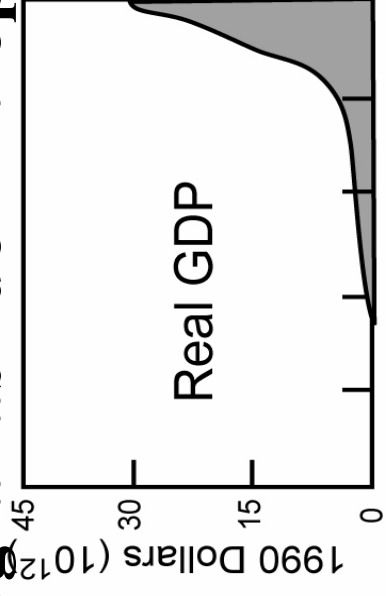
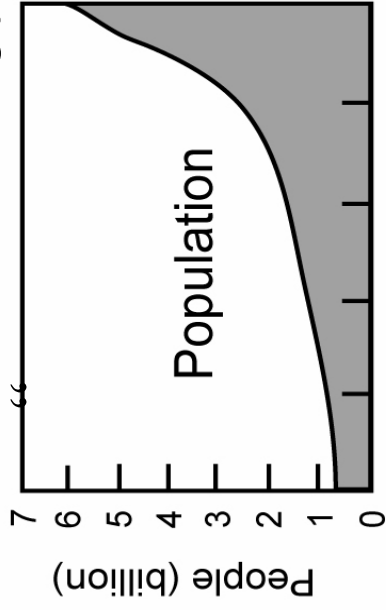
Em 2050, 86% da população mundial estarão nos países (hoje) em desenvolvimento, isto é, mais de 8,000,000,000 de consumidores tentando atingir os padrões de vida do Países Desenvolvidos.

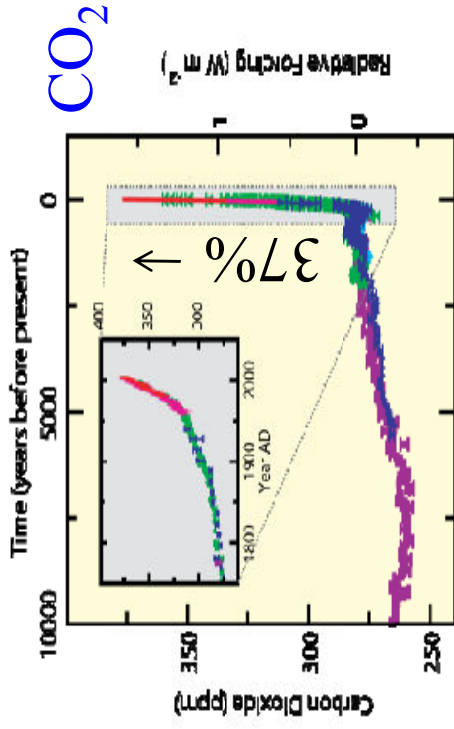


# Os últimos 50 anos testemunharam uma dramática degradação do capital natural da Terra



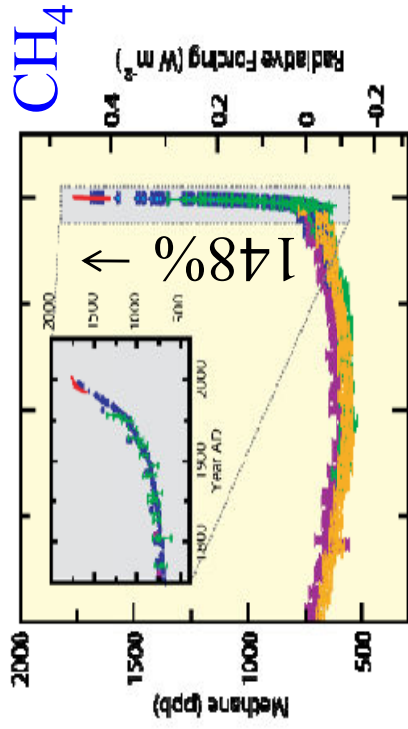
# “Fotografias” do Antropoceno





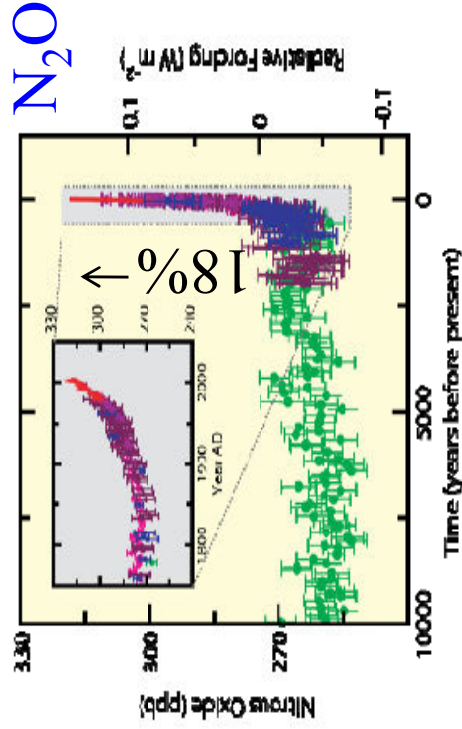
**Observações da composição da atmosfera mostram que**

**[CO<sub>2</sub>] aumentou de 280 ppm em 1750 para 383 ppm em 2007**  
**140 anos**



**[CH<sub>4</sub>] aumentou de 715 ppb em 1750 para 1754 ppb em 2005**  
**11 anos**

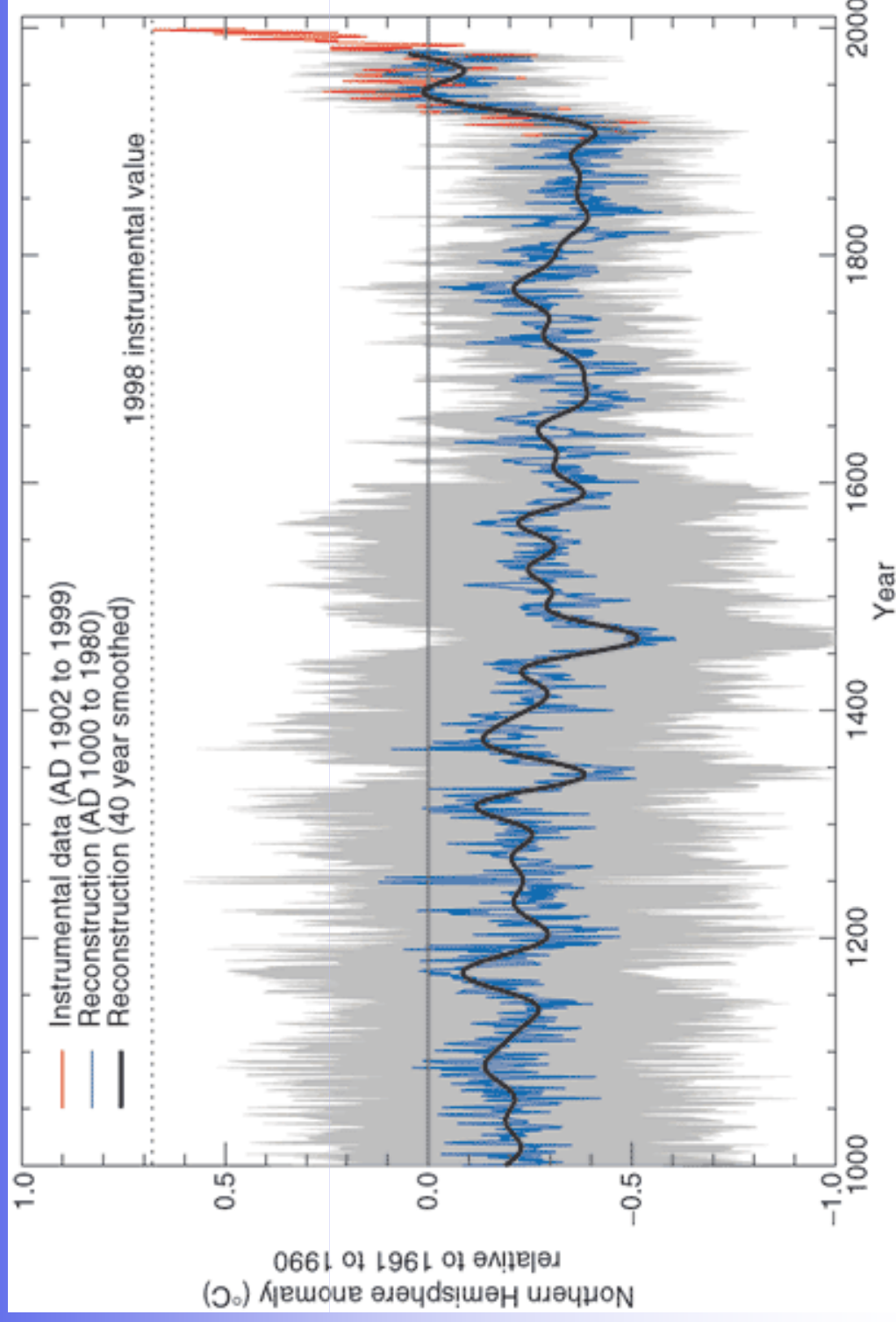
**Todas as concentrações atmosféricas dos Gses de Efeito Estufa vêm aumentando,**



**[N<sub>2</sub>O] aumentou de 270 ppb em 1750 para 319 ppb em 2005**  
**80 anos**

**tornando o aquecimento futuro inequívoco**

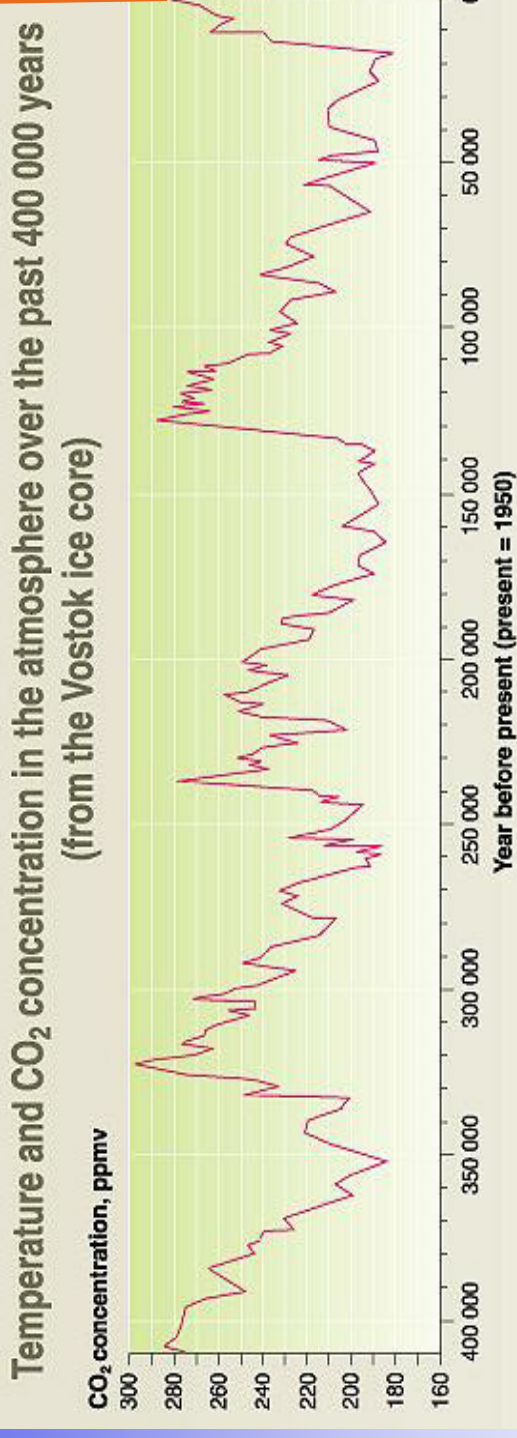
# Variações da temperatura à superfície da Terra no Hemisfério Norte no último milênio e nas últimas décadas



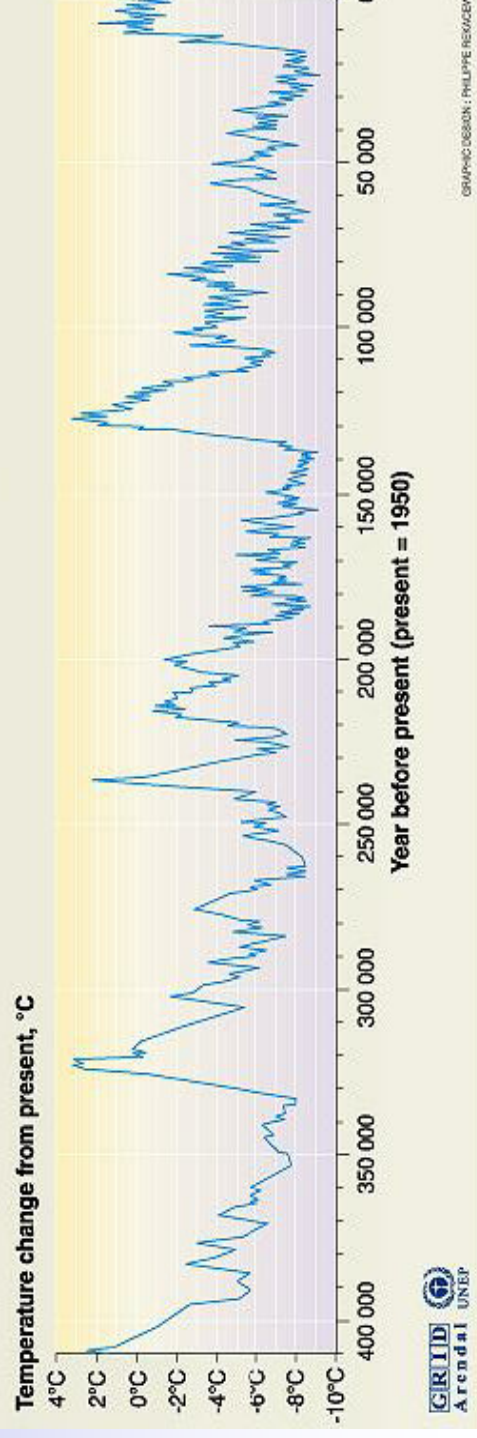
Source: IPCC 2001

# Dióxido de Carbono e Temperatura

2008



Carbon Dioxide



Temperature Change from present



Source: J.P. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica. Nature 399 (3 June), pp 429-436, 1999.

GRAPHIC DESIGN: PHILIPPE REVAZ/EMC

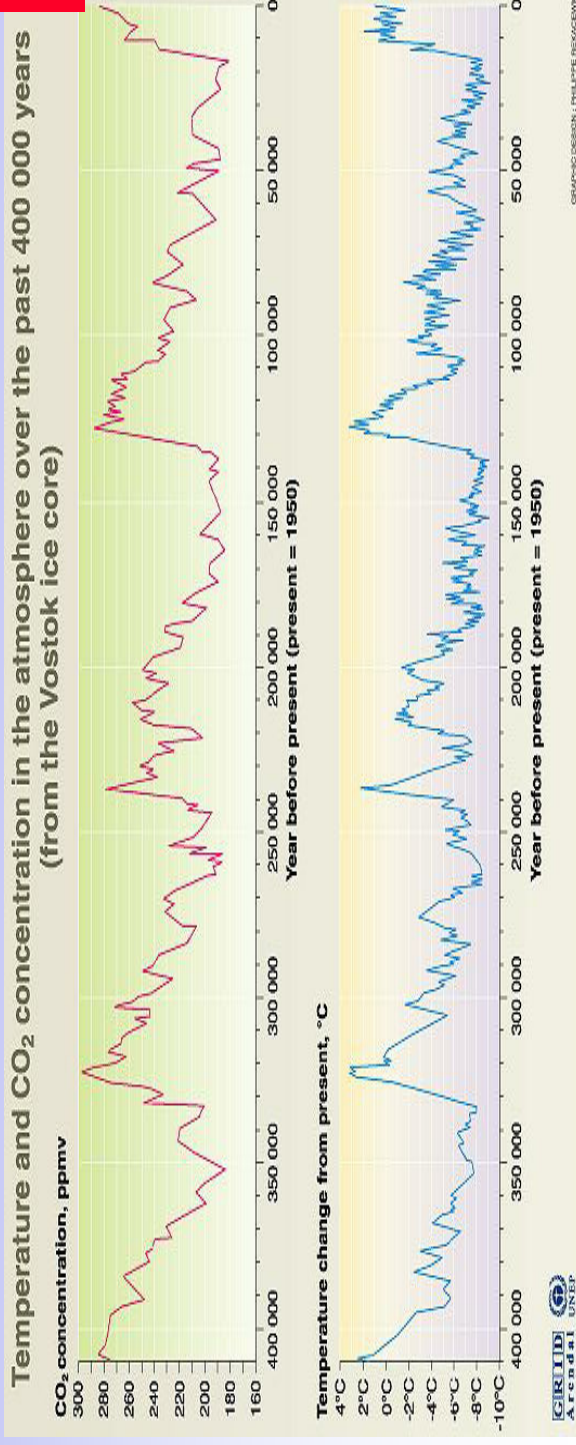


# Dióxido de Carbono e Temperatura

“Business as Usual”  
(economia intensiva em  
Combustível fóssil ) em 2100

Carbon Dioxide

Temperature  
Change  
from present



# O Aquecimento é inequívoco!

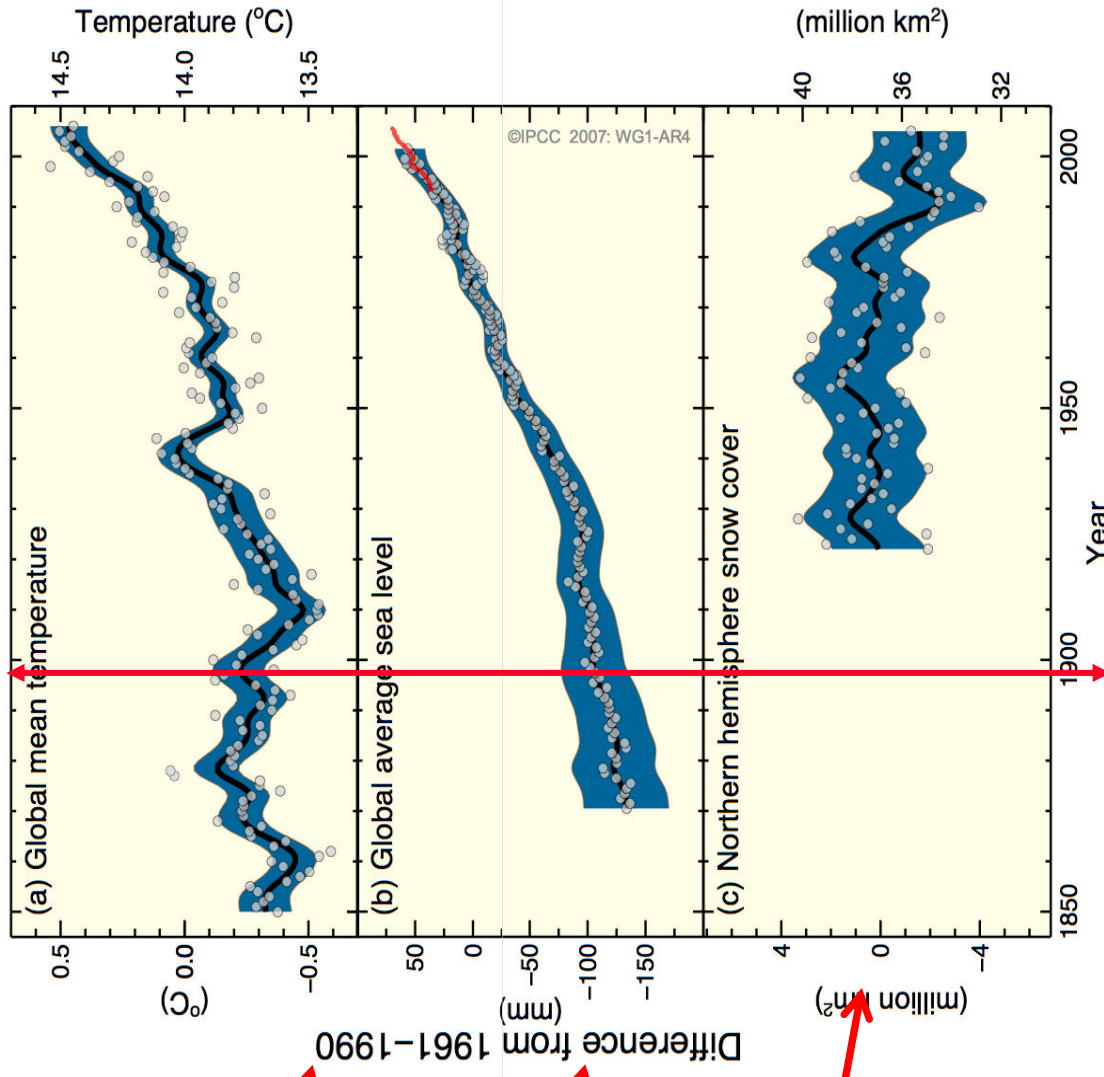
Aumento das temperaturas atmosféricas

Aumento do nível do mar

Reduções da neve no HN e os oceanos...

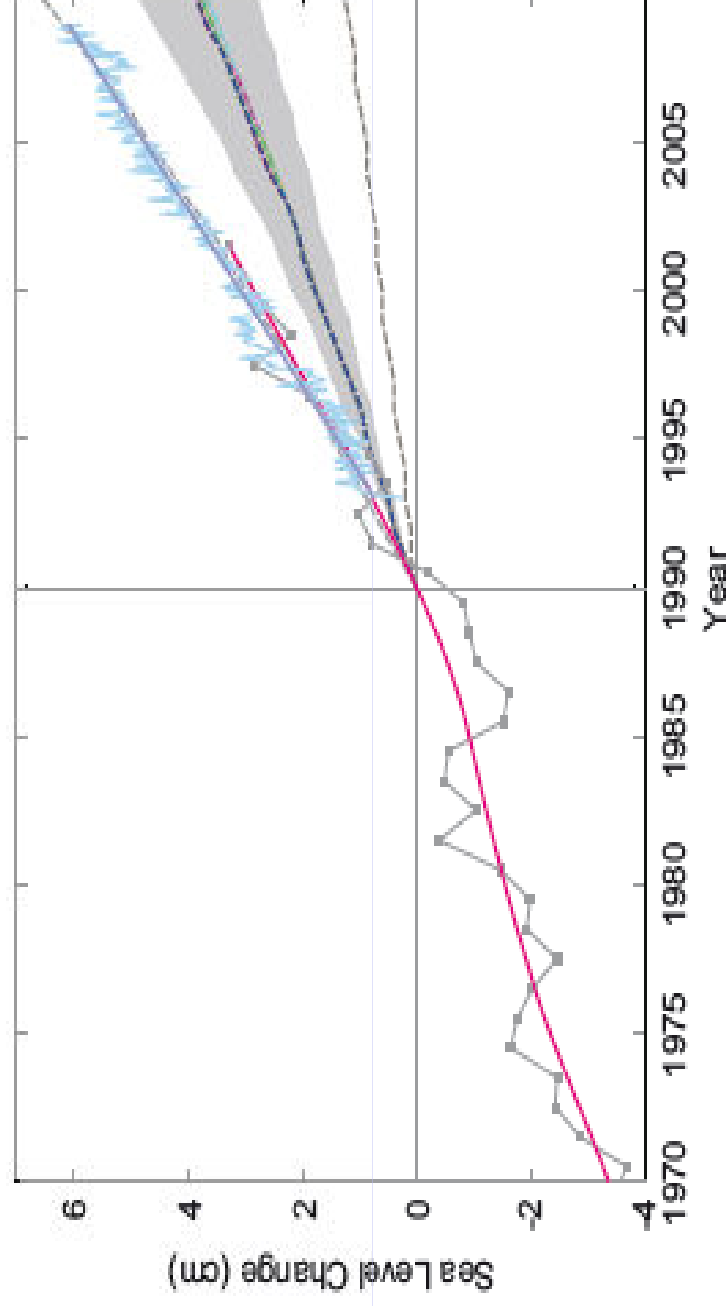
e a alta atmosfera....

Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover



1896: Arrhenius liga causa a efeito!

# Elevação do Nível do Mar está acima das Projeções do IPCC

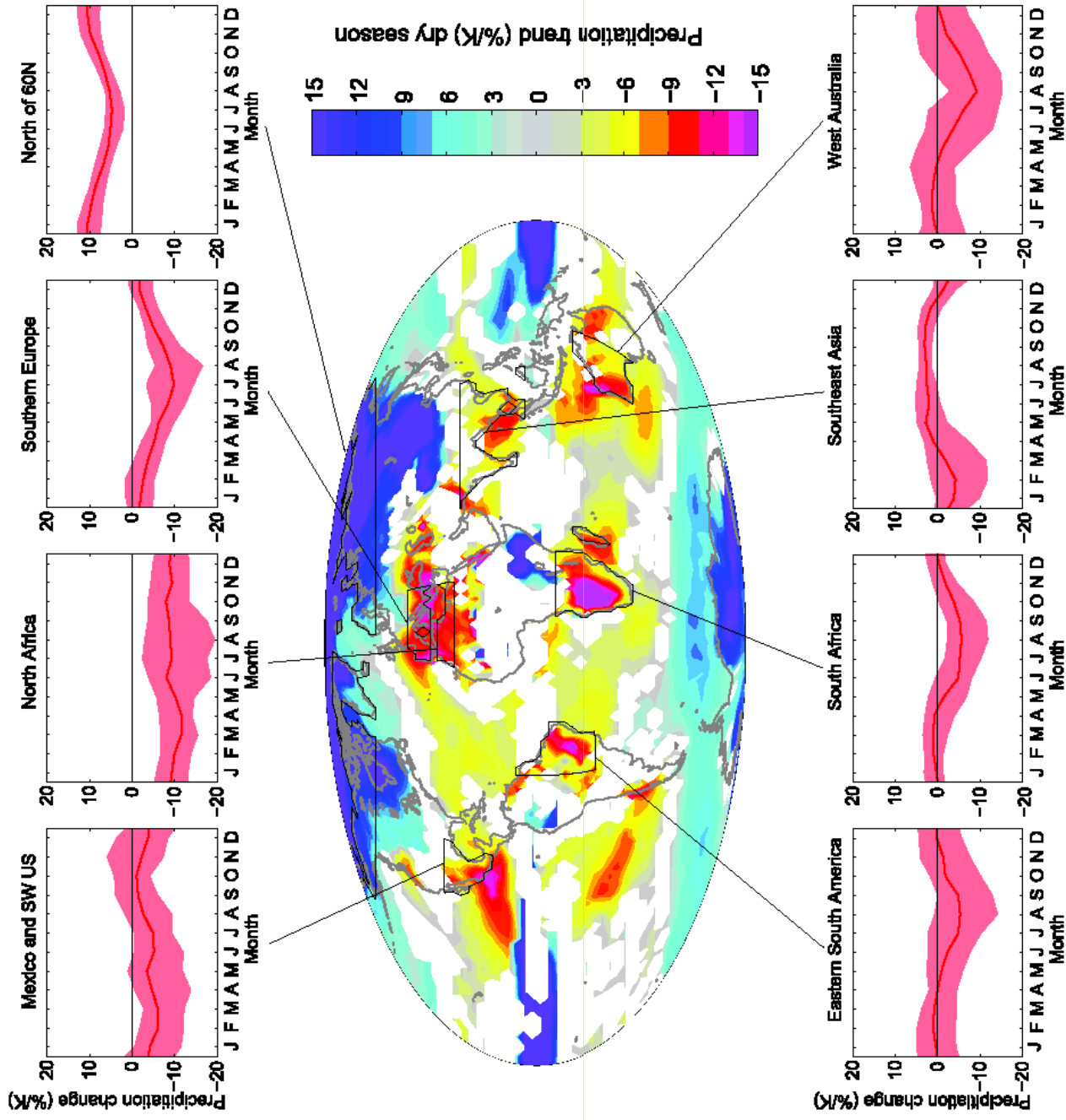


**Figure 1**  
Change in sea level from 1970 to 2008, relative to the sea level at 1990. The solid lines are based on observations smoothed to remove the effects of interannual variability (light lines connect data points). Data in most recent years are obtained via satellite based sensors. The envelope of IPCC projections is shown for comparison; this includes the broken lines as individual projections and the shading as the uncertainty around the projections<sup>2</sup>.

## “Riscos Sistêmicos”

- A crise financeira global está popularizando o conceito de ‘risco sistêmico’
- Receito de colapso de instituições financeiras fez com que Governos em todo mundo injetassem mais de US\$ 7 trilhões para evitar um “risco sistêmico” para a economia global
- **“Riscos Sistêmicos” para o Sistema Terrestre**

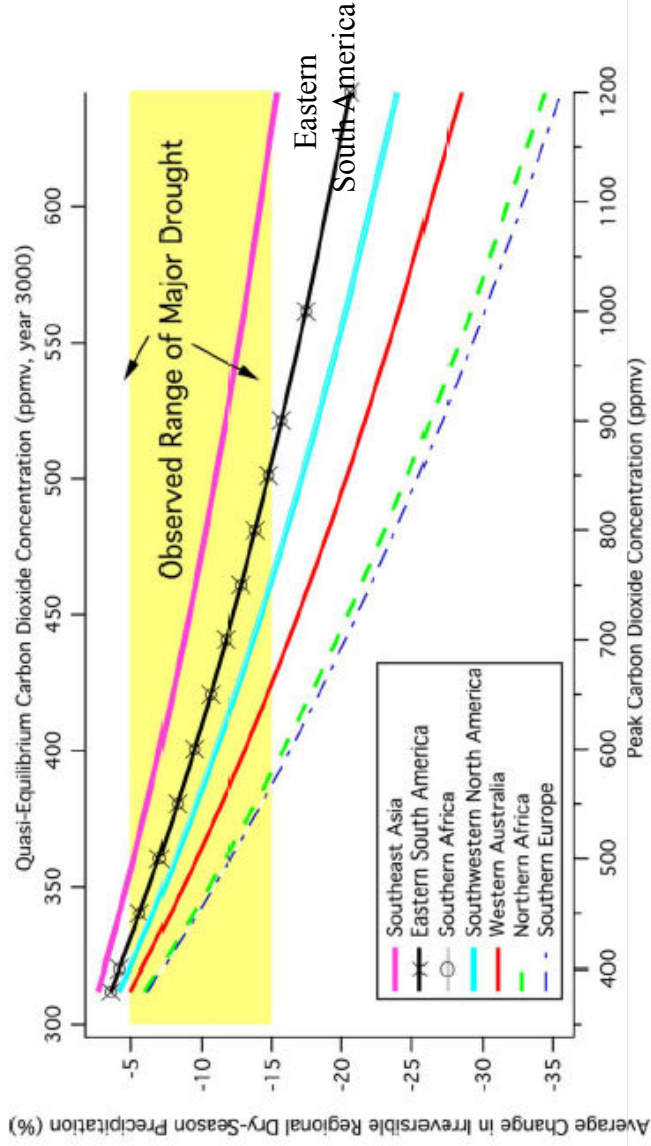
# **“Estamos hipotecando o Planeta a taxas “sub-prime”**



**Fig. 3.** Expected decadal averaged changes in the global distribution of precipitation per degree of warming (percentage of change in precipitation per degree of warming, relative to 1900–1950 as the baseline period) in the dry season at each grid point, based upon a suite of 22 AOGCMs for a midrange future scenario (A1B, see ref. 5). White is used where fewer than 16 of 22 models agree on the sign of the change. Data are monthly averaged over several broad regions in *Inset plots*. Red lines show the best estimate (median) of the changes in these regions, while the red shading indicates the  $\pm 1-\sigma$  likely range (i.e., 2 of 3 chances) across the models.

## Mudança de Precipitação (%/década) na Estação Seca

# Irreversibilidade das Mudanças Climáticas



**Fig. 4.** Illustrative irreversible climate changes as a function of peak carbon dioxide reached. (Upper) Best estimate of expected irreversible dry-season

precipitation changes for the regions shown in Fig. 3, as a function of the peak carbon dioxide concentration during the 21st century. The quasi-equilibrium CO<sub>2</sub> concentrations shown

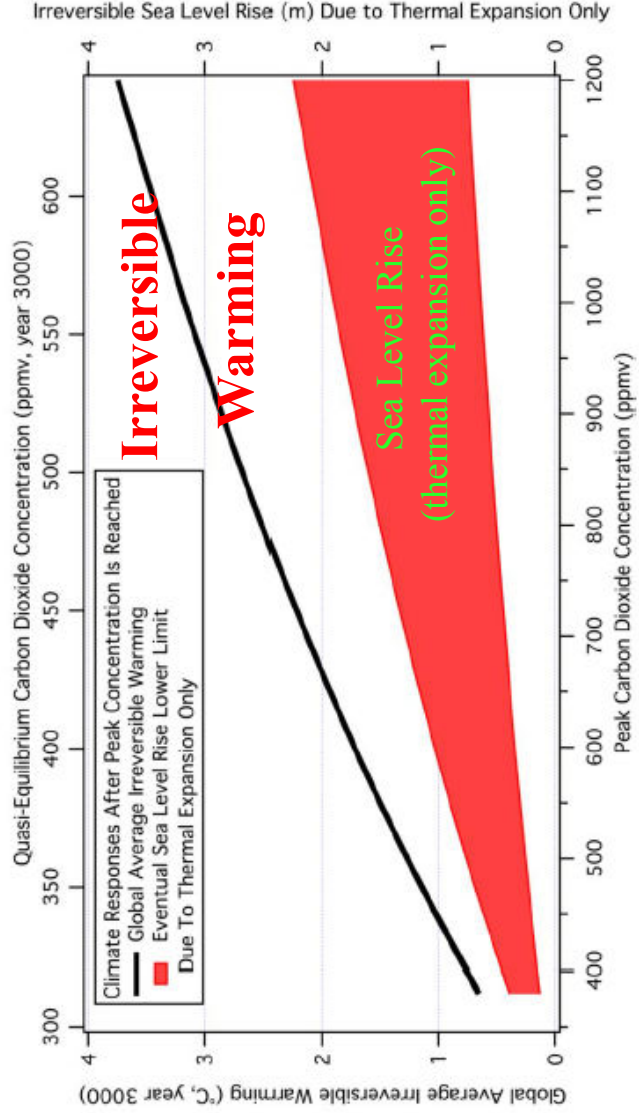
correspond to 40% remaining in the long term as discussed in the text. The precipitation change per degree is derived for each region as in Fig. 3; see also Fig. S3. The yellow box indicates the range

of precipitation change observed during typical major regional droughts such as the “dust bowl” in North America (32). (Lower) Corresponding irreversible global warming (black line). Also

shown is the associated lower limit of irreversible sea level rise (because of thermal expansion only based upon a range of 0.2–0.6 m/°C), from an assessment across available models (5). Smaller values (by ≈30%) for expected

warming, precipitation, and thermal sea level rise would be obtained if climate sensitivity is smaller than the best estimate while larger values

(by ≈50%) would be expected for the upper end of the estimated likely range of climate sensitivity (49).



# “Hotspots” do Sistema Terrestre

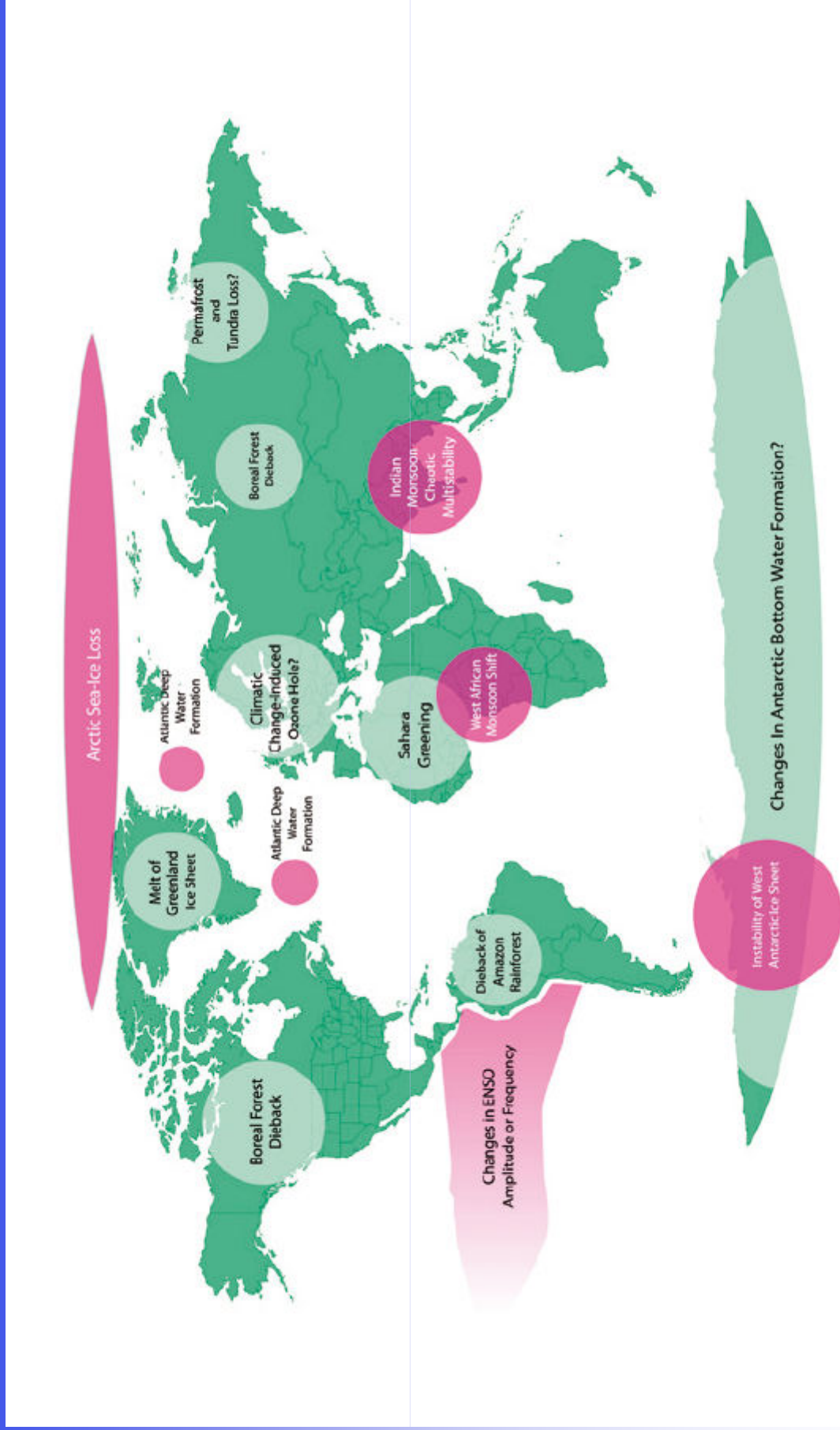


Figure 7

Map of potential climatic “tipping elements”. Tipping elements are regional-scale features of the climate that could exhibit threshold-type behaviour in response to human-driven climate change – that is, a small amount of climate change at a critical point could trigger an abrupt and/or irreversible shift in the tipping

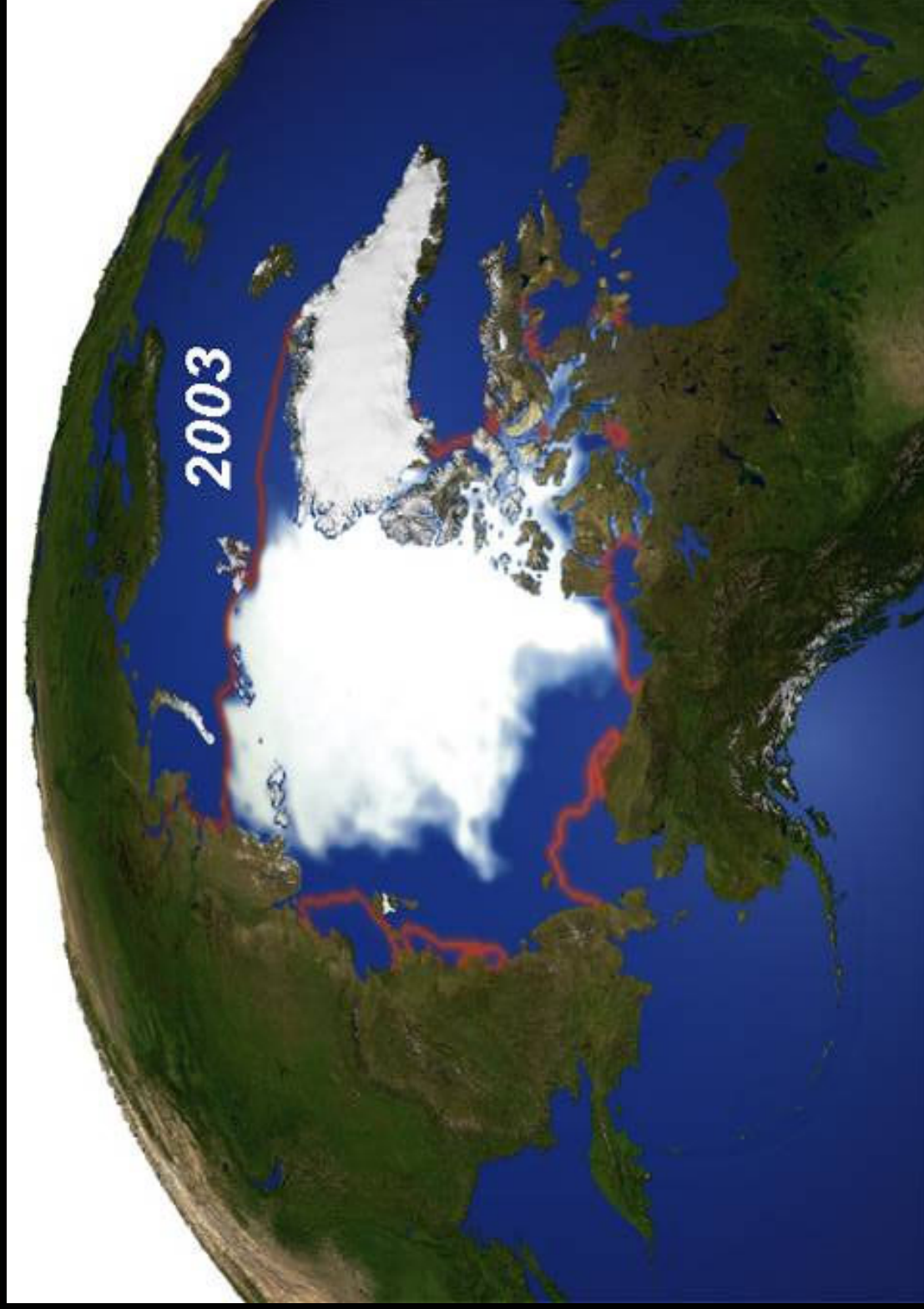
element. The consequences of such shifts in the tipping element for societies and ecosystems are likely to be severe. Question marks indicate systems whose status as tipping elements is particularly uncertain<sup>27,30</sup>.



# Limites Climáticos “Perigosos”

- 0,6 C Branqueamento de corais
- 0,6 C Perda de gelo da Antártica Ocidental
- 0,7 C Desaparecimento da geleira do Kilimanjaro
- 1,0 C Desaparecimento das geleiras dos Andes tropicais
- 1,0 C Desaparecimento do gelo sobre o Oceano Ártico no final do verão
- > 1,0 C Extinção de espécies da fauna e da flora
- 1,6 C Início do derretimento da geleira da Groelândia
- 3-4 C Colapso da floresta Amazônica
- 3-4 C Acidificação dos oceanos
- 4 C Colapso da corrente termohalina

# Dramatic Changes of the Arctic Ocean Ice

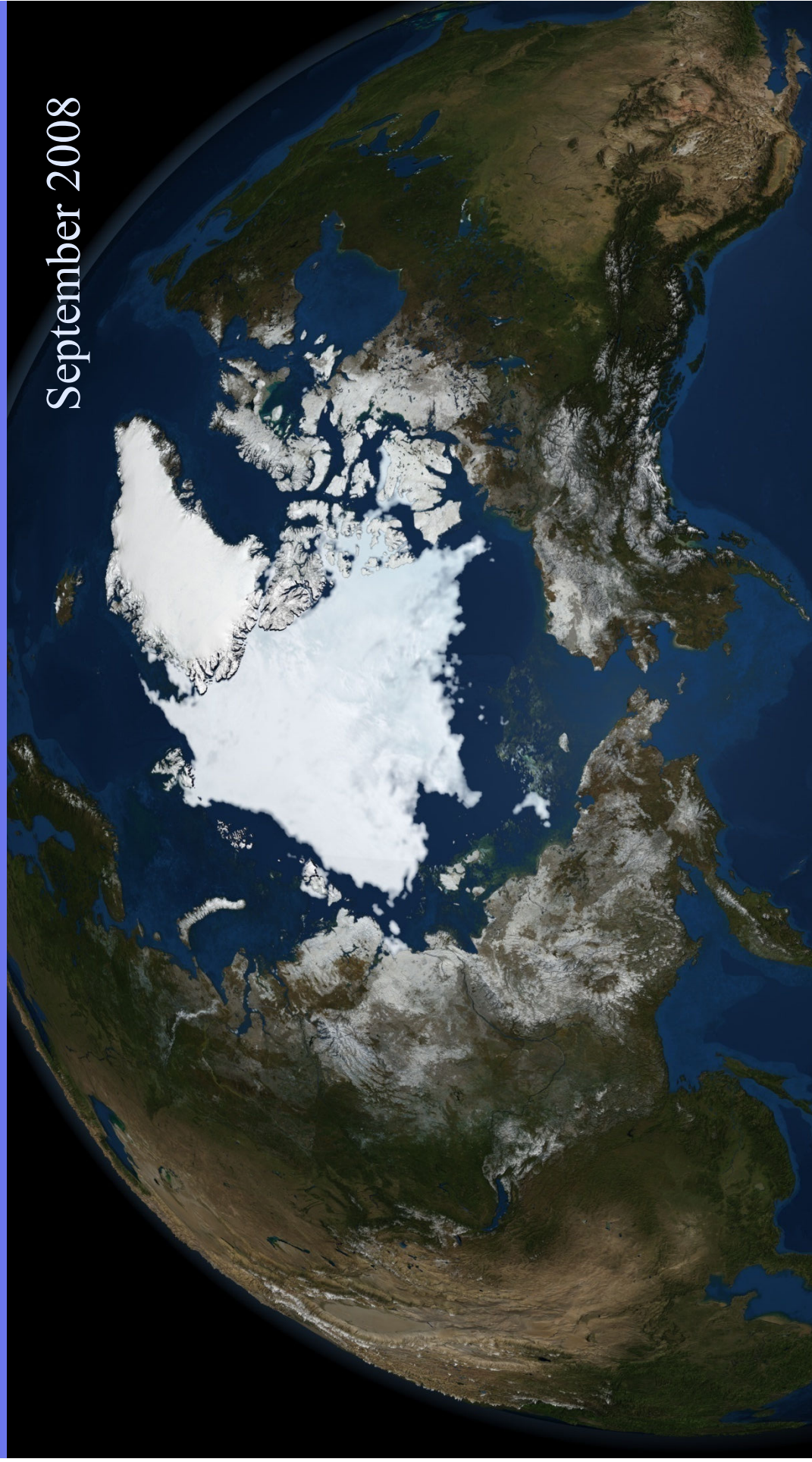


Imagine  
the Arctic  
Ocean  
without  
ice



*A tipping point we very likely have already crossed!*

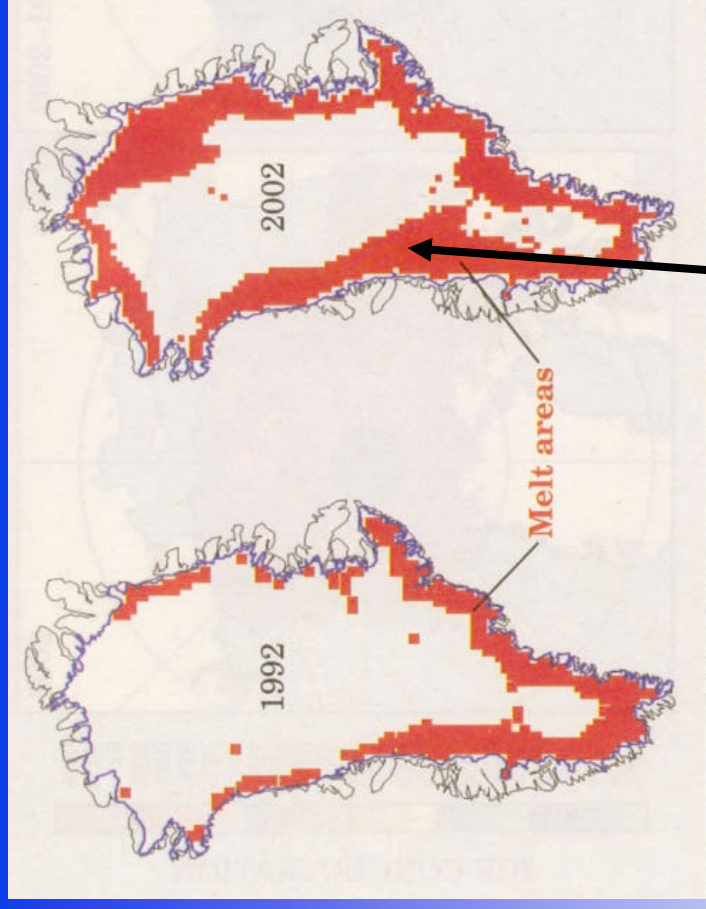
September 2008



# Degelo superficial na Groelândia acontecendo muito mais rápido do que o esperado



Fonte: Roger Braithwaite,  
University of Manchester (UK)



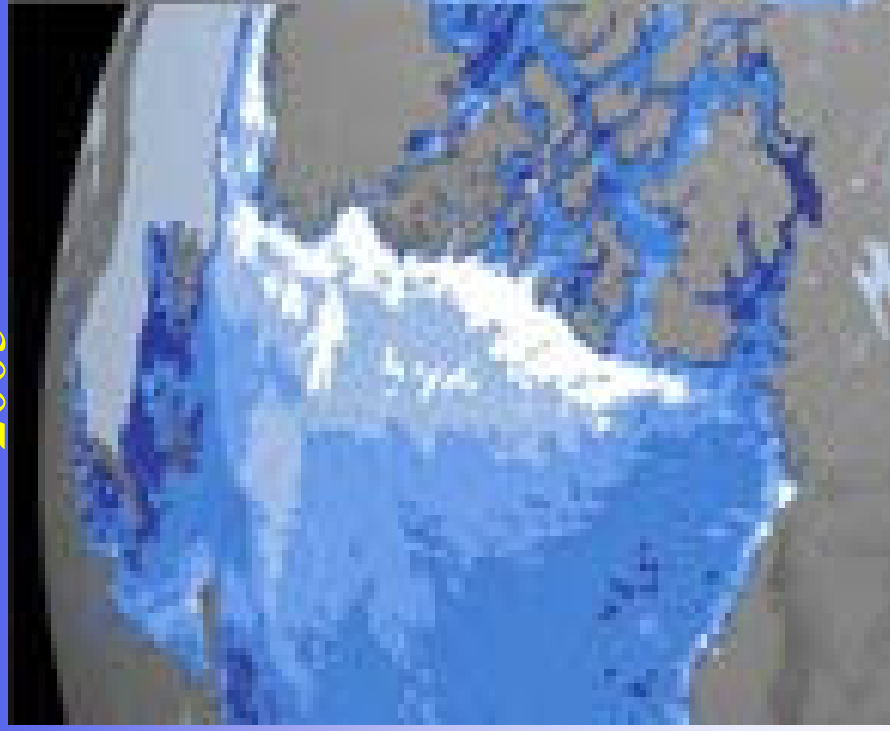
**Redução da espessura em 70 m em 5 anos**

**O recorde de degelo de verão da era de cobertura por satélites de 2002 foi excedido em 2005**

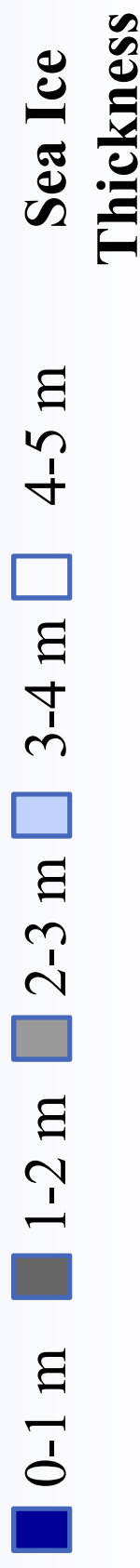
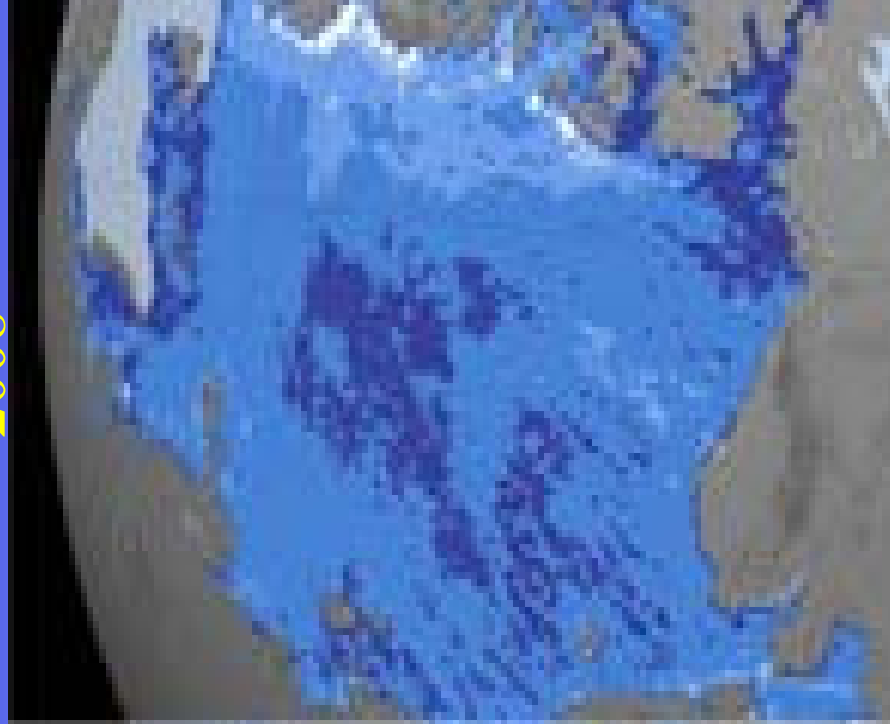
Fonte: Waleed Abdalati, Goddard Space Flight Center

# Winter Arctic Sea Ice

2005



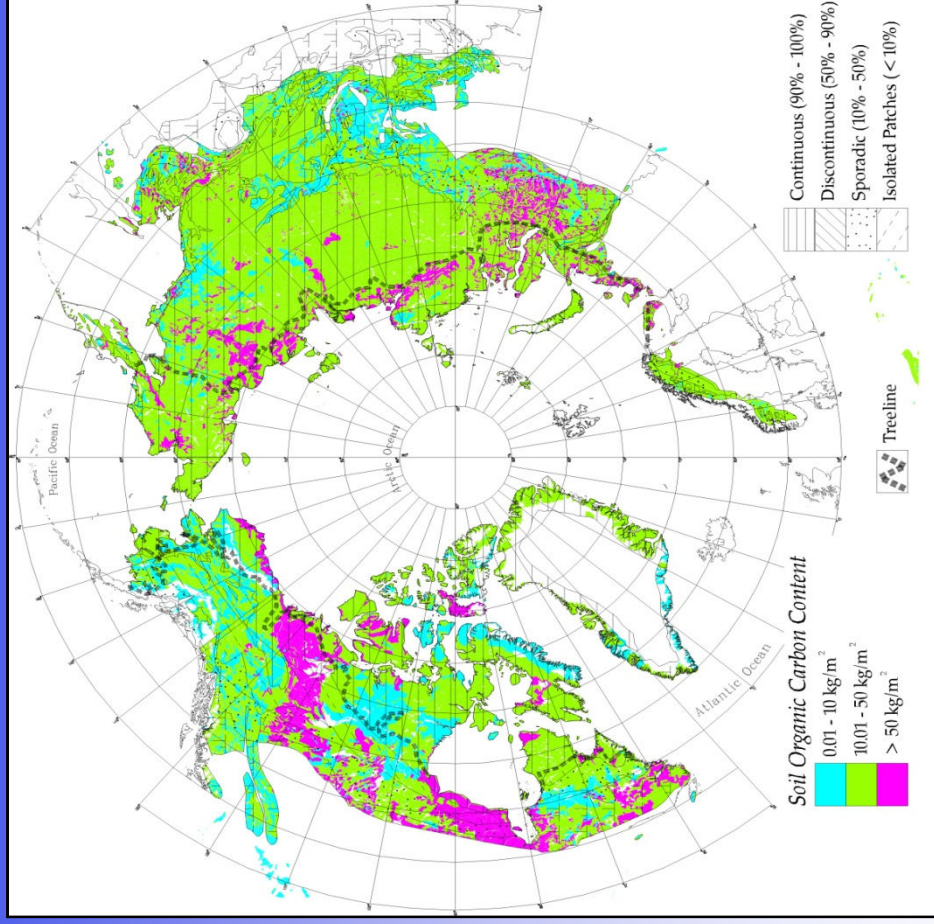
2008



Source: NASA

# New Assessment: Carbon pools in the northern circumpolar permafrost region

1 Pg = 1 billion tons or  $10^{15}$  g



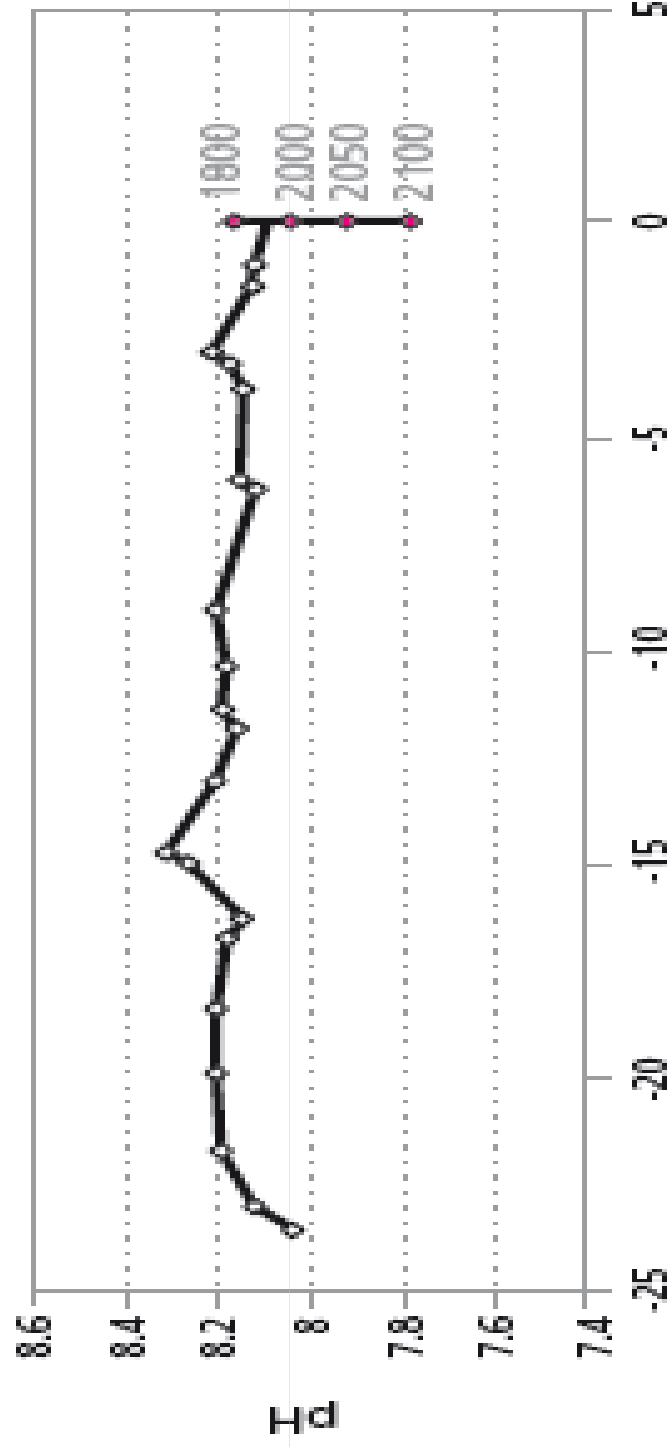
Permafrost zones	0-30 cm	0-100 cm
Continuous	110.38	298.75
Discontinuous	25.5	67.44
Sporadic	26.36	63.13
Isolated Patches	29.05	67.10
<b>Total</b>	<b>191.29</b>	<b>496.42</b>

Soil or deposit type	C stocks
Soils 0-300 cm	<b>1024</b>
Yedoma sediments	407
Deltaic deposits	241
<b>Total</b>	<b>1672</b>



Tamocai C, JG Canadell, EAG Schuur, P Kuhry, Mazhitova G (2009) Soil organic carbon pools in the northern circumpolar permafrost region. Global Biogeochemical Cycles 23, GB2023, doi:10.1029/2008GB003327.

# Acidificação dos Oceanos



Time (million years before present)

*Ocean acidity (pH) over the past 25 millions years and projected to 2100<sup>25</sup>. The lower the pH, the more acidic the ocean becomes.*

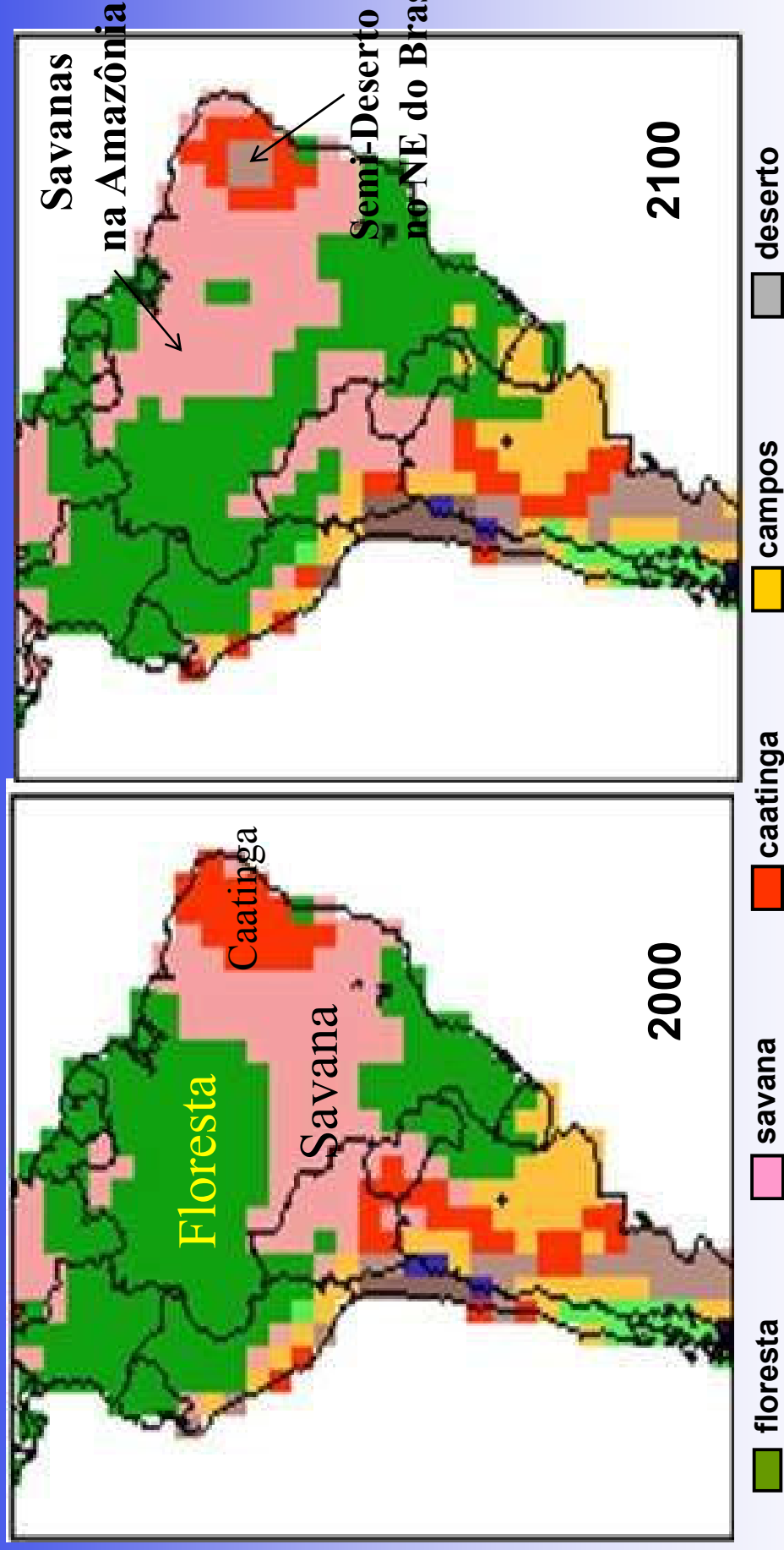
# Alguns eventos extremos inusuais durante 2004-2006:

Cortesia: G. Magrin, INTA, Argentina



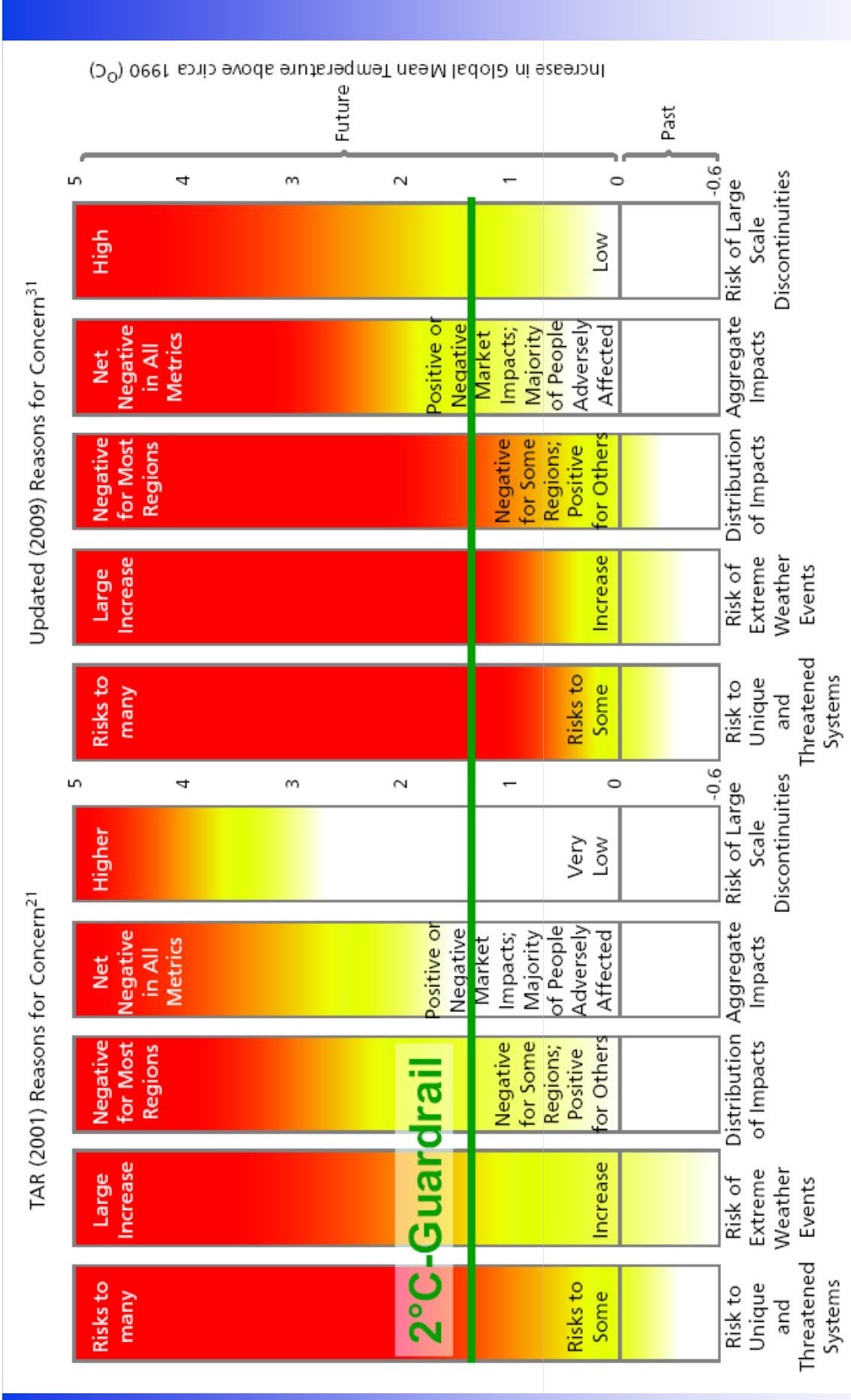


# Riscos aos Biomas Brasileiros



**‘Savanização’ na Amazônia e and ‘Aridização’ no NE do Brasil**

fontes: Oyama and Nobre, 2003 e Salazar, Nobre and Oyama, 2007



**Figure 8**

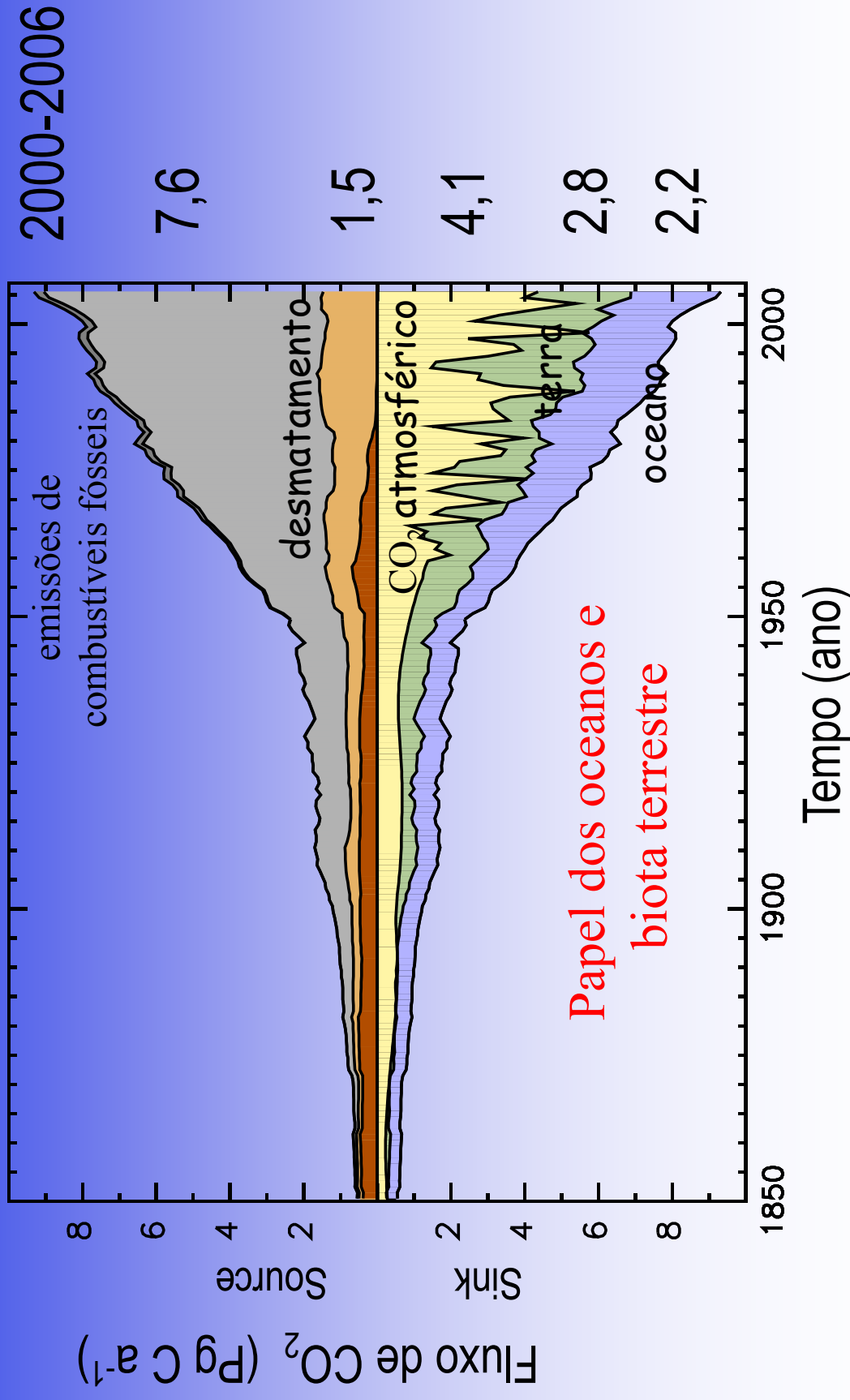
Diagram relating the potential impacts of climate change to the rise in global average temperature. Zero on the temperature scale corresponds approximately to 1990 average temperature, and the bottom of the temperature scale to pre-industrial average temperature. The level of risk or severity of potential impacts increases with the intensity of red colour. The 2°C guardrail is shown for reference.

Richardson, K. et al., 2009. Climate Change. Global Risks, Challenges and Decisions Synthesis Report. Copenhagen 2009, 10-12 March. [www.climatecongress.ku.dk](http://www.climatecongress.ku.dk)

# Mitigação das Mudanças Climáticas é Possível

A necessária “descarbonização”  
quase completa dos sistema de  
produção

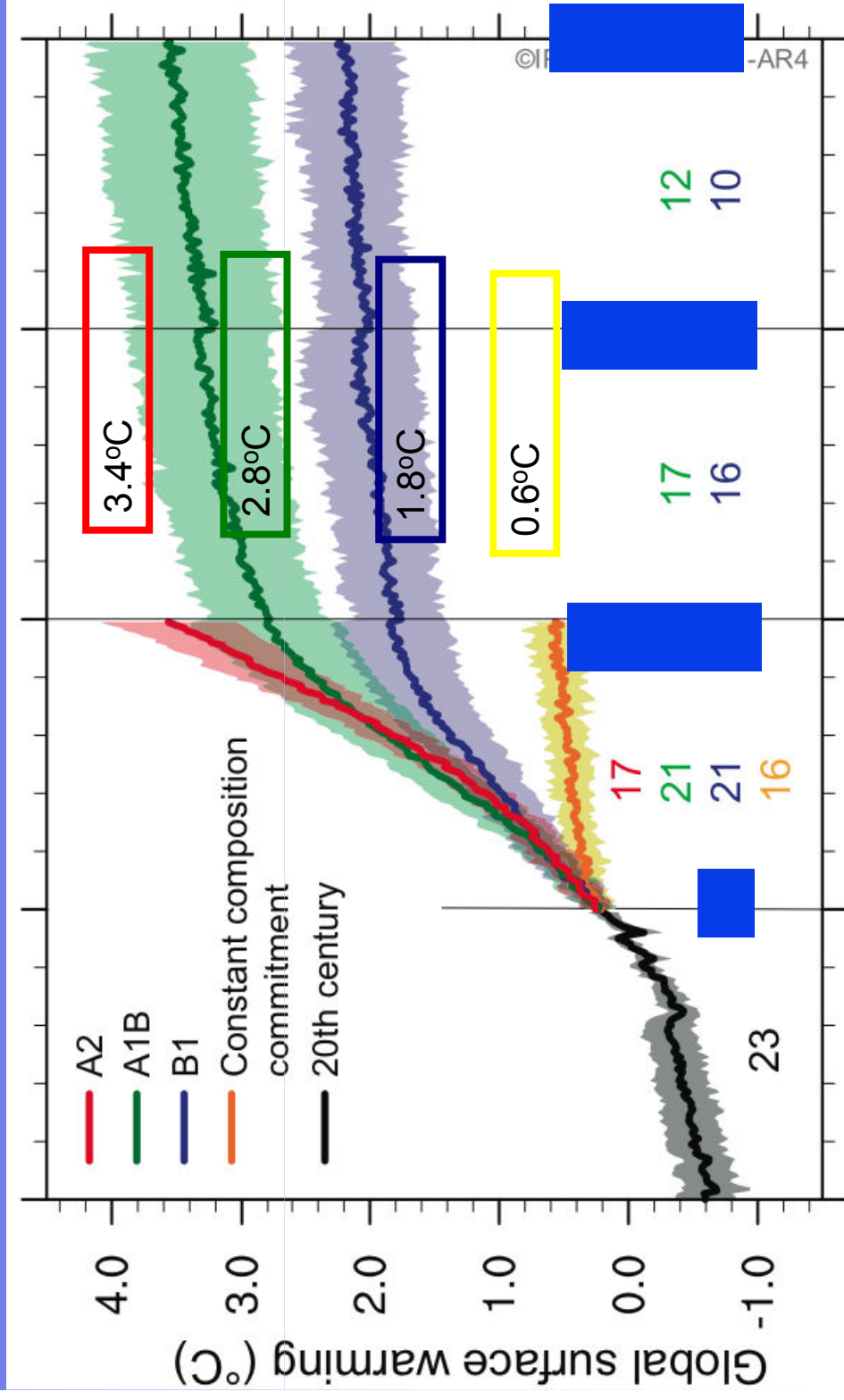
## Balanco Global de Carbono Antropogênico (1850-2006)



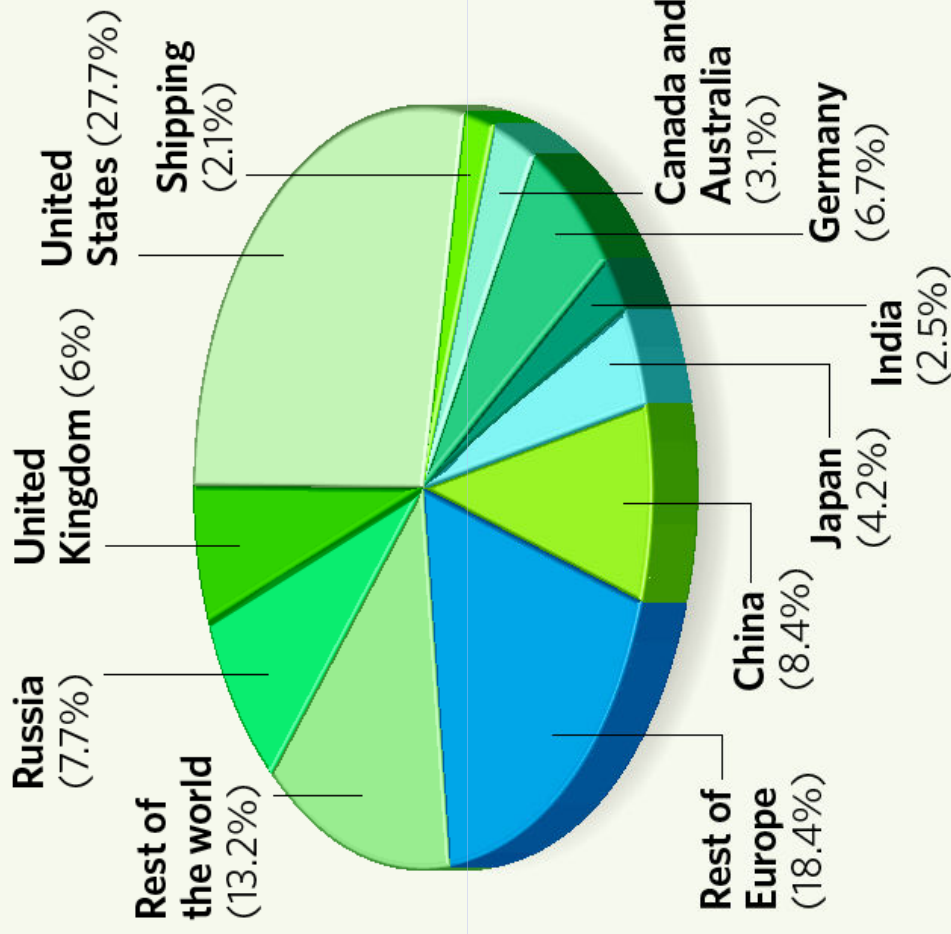
# O que nos aguarda no futuro e o que já foi comprometido

O Aquecimento vai aumentar se os GEEs aumentarem. Se os GEEs fossem mantidos constantes nos níveis atuais, um comprometimento de 0,6°C de aquecimento adicional aconteceria até 2100.

CO<sub>2</sub> Eq

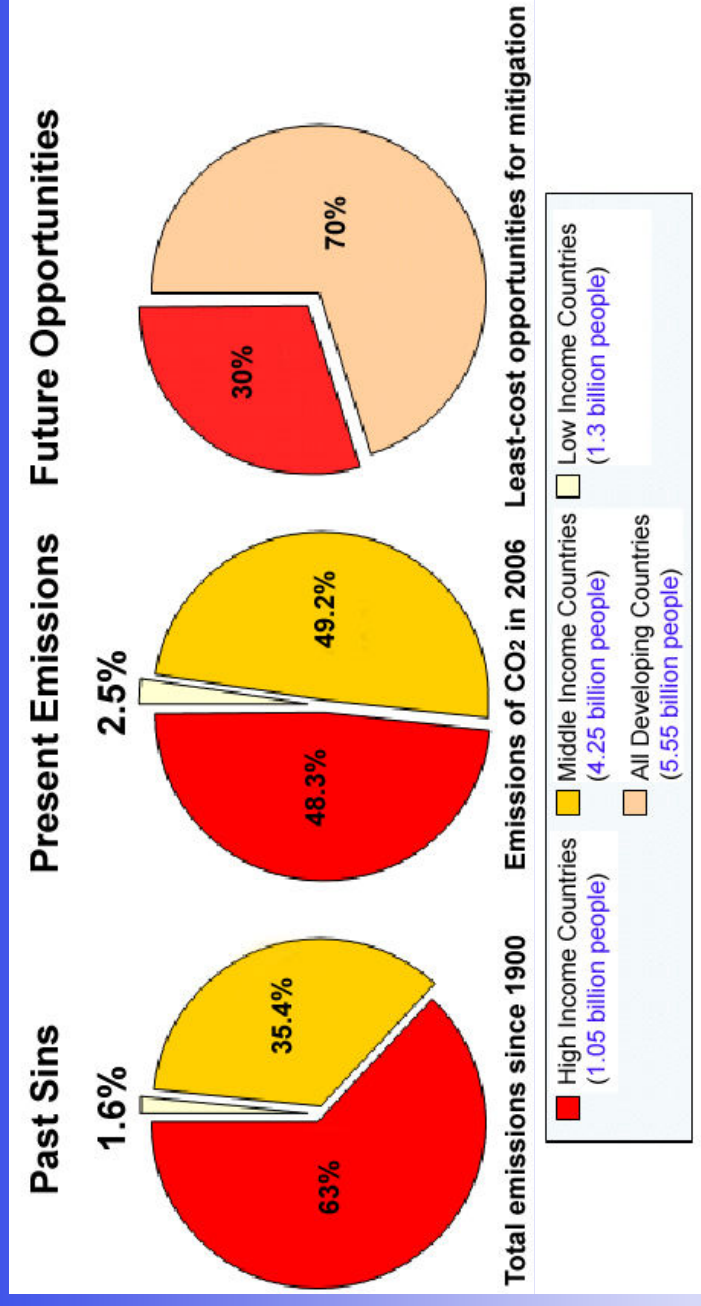


# CUMULATIVE CO<sub>2</sub> EMISSIONS 1750-2006



SOURCE: CARBON DIOXIDE INFORMATION ANALYSIS CENTER, OAK RIDGE NATIONAL LAB  
NATURE|Vol 458|30 April 2009 NEWS FEATURE CLIMATE CRUNCH

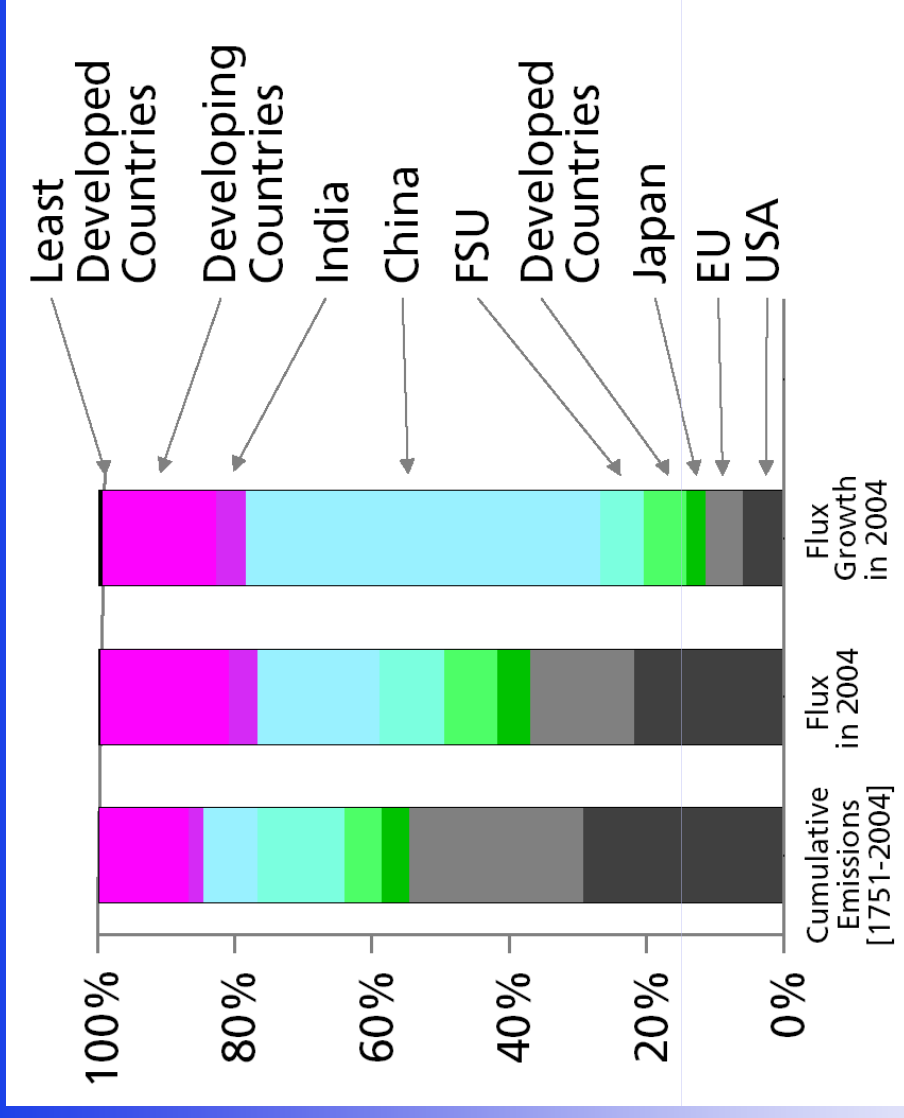
# Emissões Passadas Presentes e Oportunidade Futuras



Países ricos são responsáveis pela maior parte do CO<sub>2</sub> atualmente na atmosfera, mas muitas

oportunidades para mitigação que é custo-efetiva estão em países em desenvolvimento

Fontes: dados de emissões de CDIAC 2007, e EIA 2006; dados de população de WDI 2008; oportunidades de mitigação: McKinsey 2009; e cálculos baseados em dados reportados em IPCC 2009).

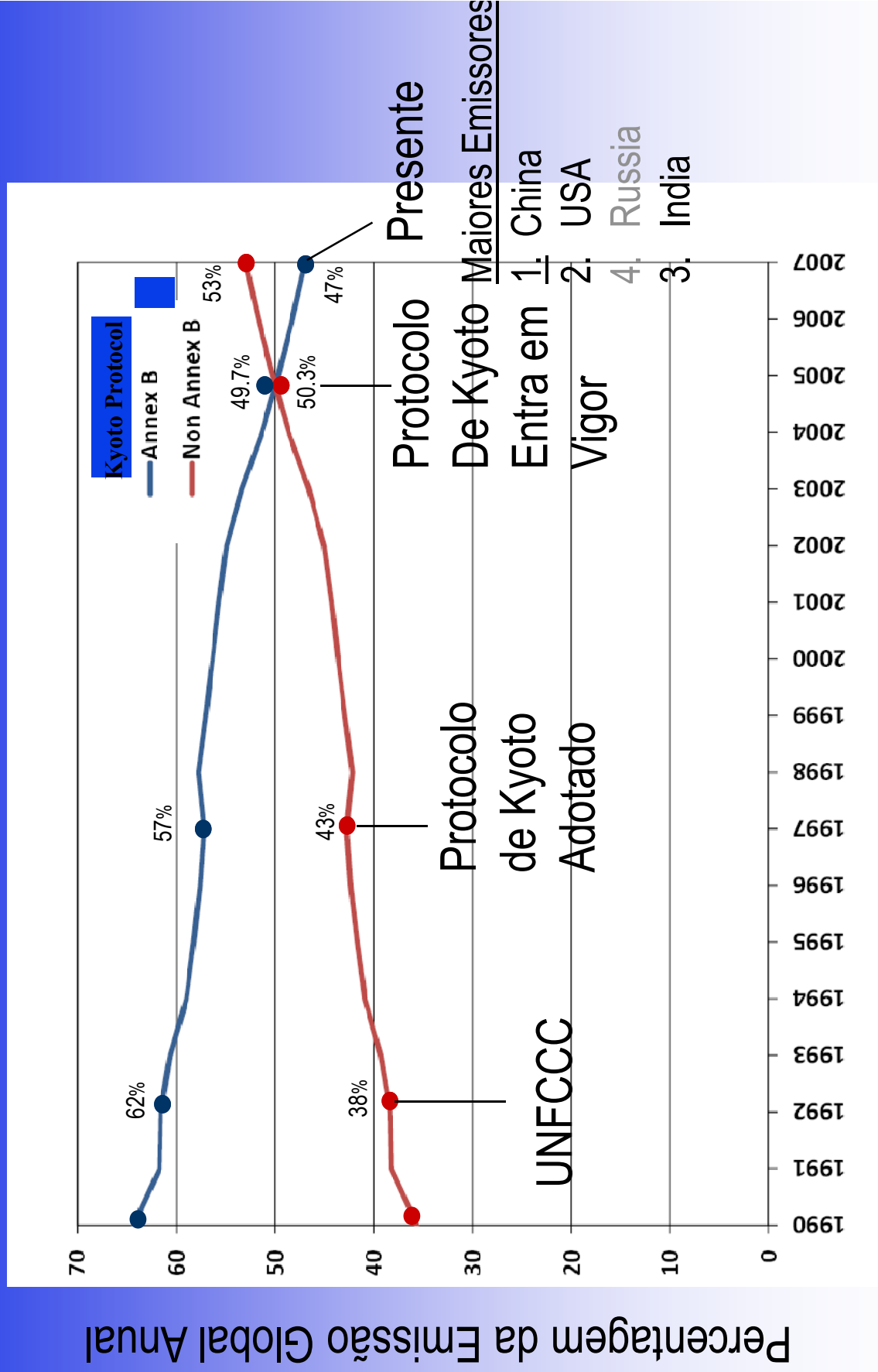


**Figure 11**

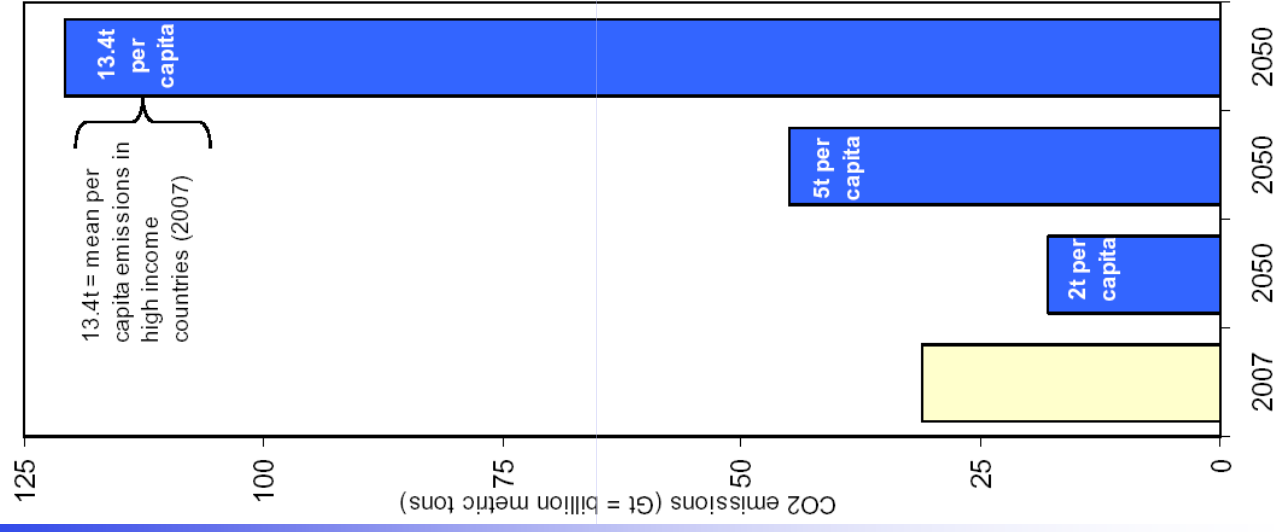
*Various aspects of human carbon emissions by country/region, highlighting the so-called stocks and flow problem. The first column shows the cumulative emissions from the beginning of the industrial revolution to 2004. It is these stocks of carbon in the atmosphere that are largely driving observed climate change. The second column shows the flow rate of human carbon emissions into the atmosphere in 2004. The third column shows the annual rate in 2004 by which the flows of carbon into the atmosphere are growing. FSU is the Former Soviet Union.*



# Mudança nos Padrões Regionais de Emissões



9 billion people at 2, 5, or 13.4 tons CO<sub>2</sub> per capita

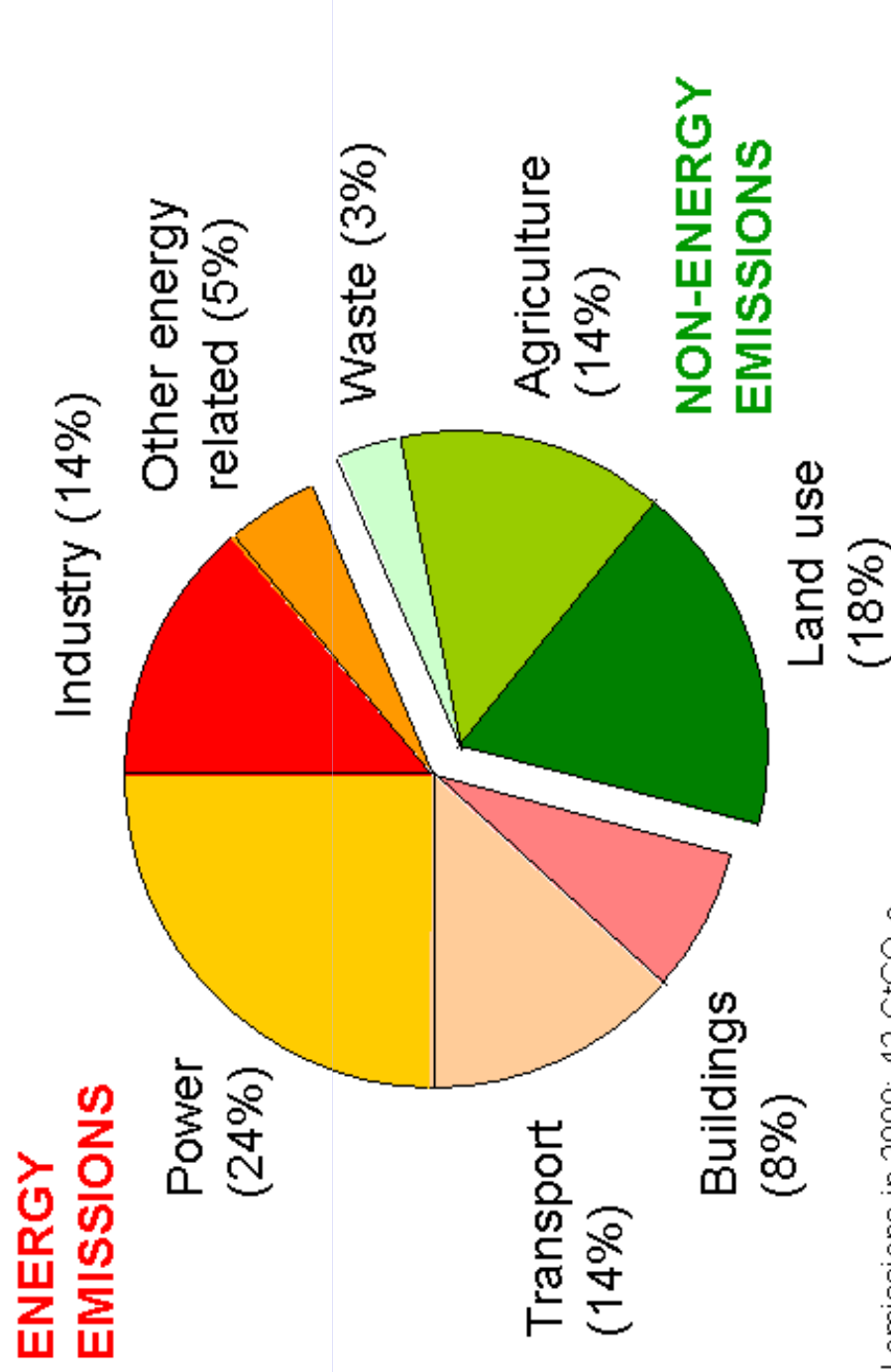


## A crescente ‘pegada ecológica: diferentes possibilidades para 2050

**Notas:** A coluna para 2007 representa observações preliminares de emissões de CO<sub>2</sub> em 2007 provenientes somente de fontes fósseis (sem emissões de usos da terra). Os cenários para 2050 se baseiam em população mundial de 9 bilhões e valor *per capita* médio global de emissões de 2 t, 5 t ou 13,4 t de CO<sub>2</sub>—que é a média de emissões dos países de alta renda em 2007.

**Fonte:** CDIAC 2009.

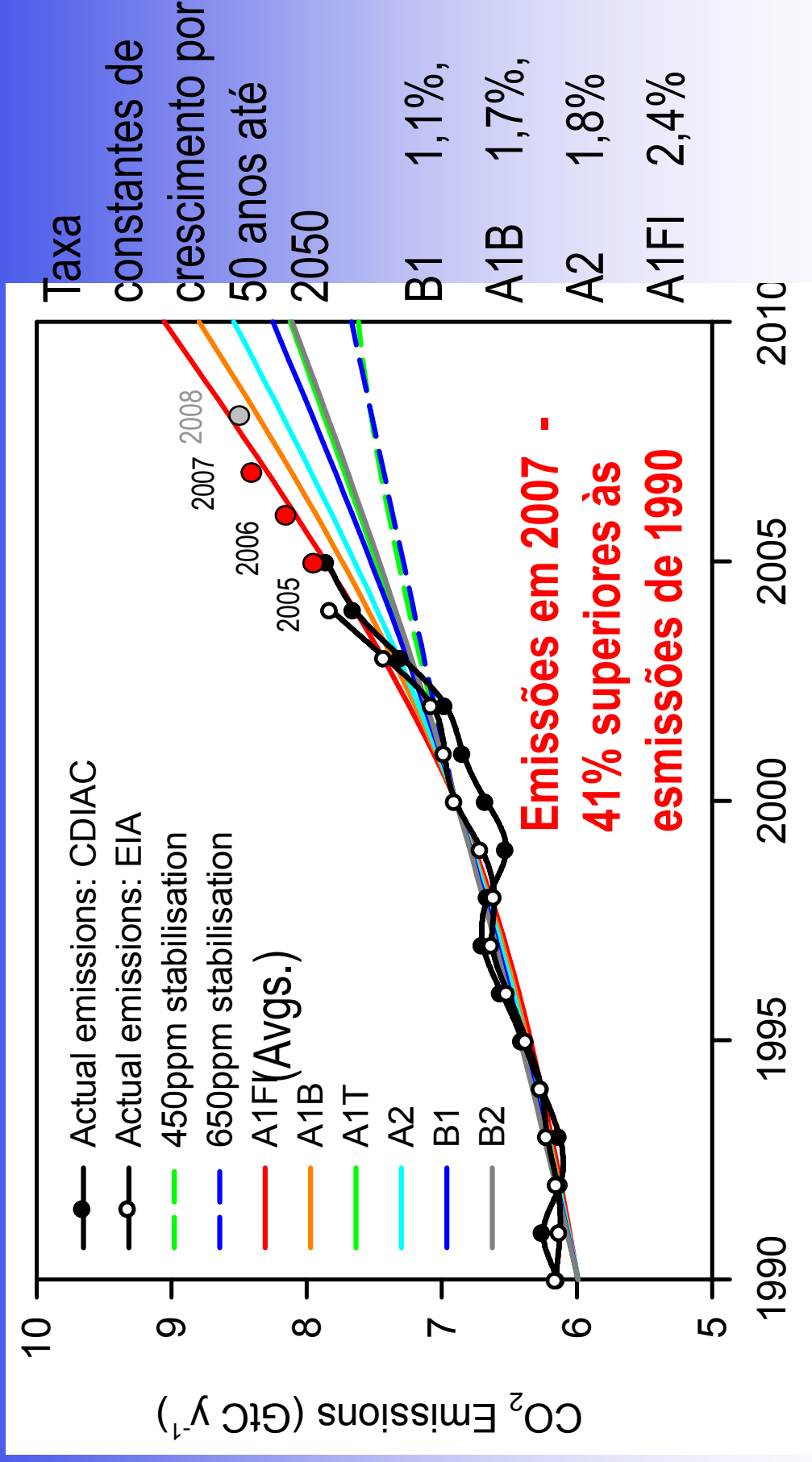
# Redução de emissões requerem ações em todos os setores



Total emissions in 2000: 42 GtCO<sub>2</sub>e.

# PROBLEMA... DE DIFÍCIL SOLUÇÃO..

Emissões estão além do cenário de mais altas emissões!



## Trajetória das Emissões Globais de Combustíveis Fósseis

## Slide 43

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### CN1

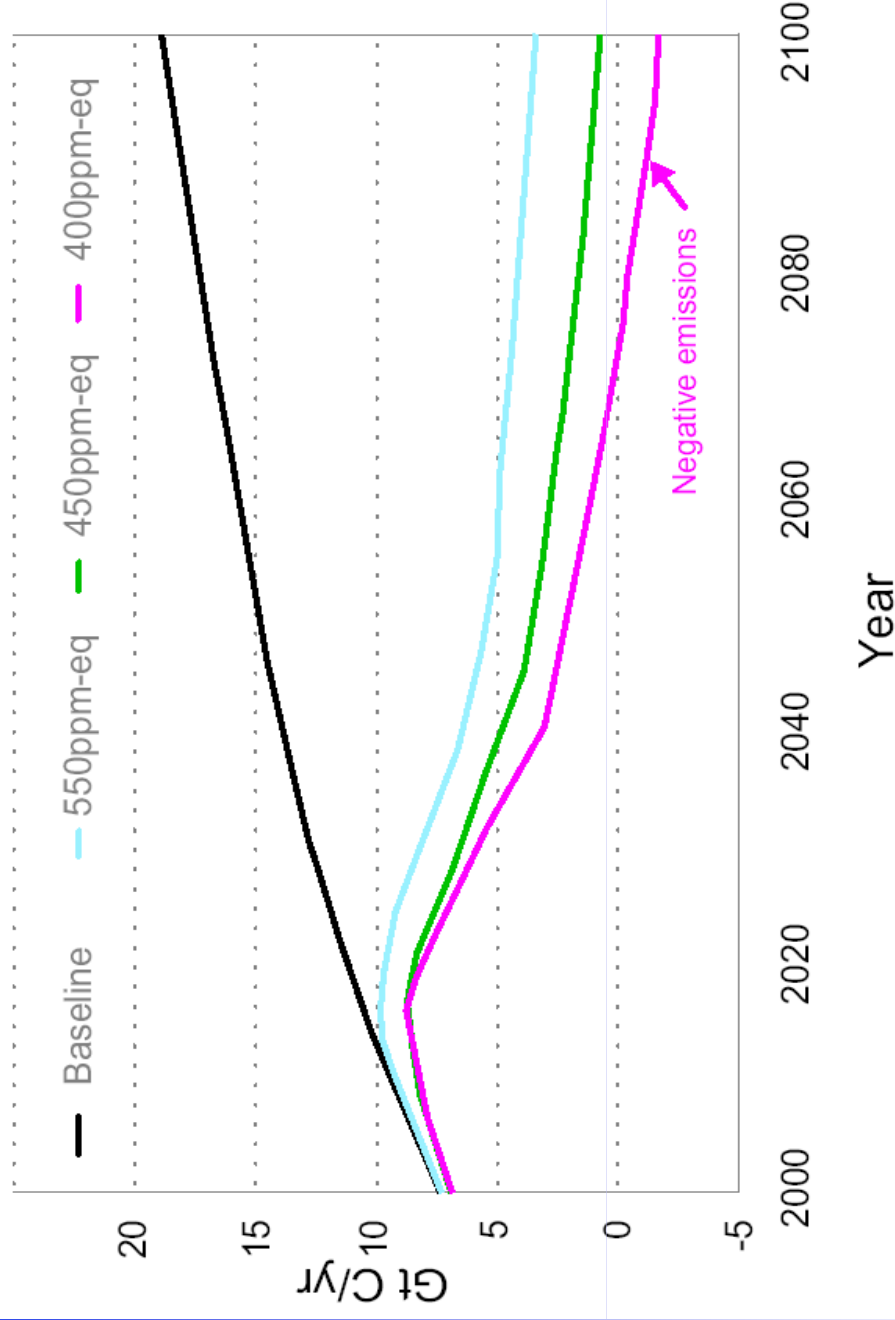
As emissões globais de CO2 de origem fóssil vinham subindo a uma taxa de 1,5% ao ano durante a década de 90. Porém, esta taxa de crescimento saltou para 3,5% nos últimos 8 anos (2000-2007). Em 2008, a taxa de crescimento foi menor, provavelmente em decorrência da crise financeira e do menor crescimento da economia mundial.

Carlos Nobre; 23/08/2009

# **Necessidade de limitar o aumento de temperatura global a menos de 2 C (em relação ao período pré-industrial)**

- Taxa de crescimento das emissões globais na última década indica padrão incompatível com aumento da temperatura em menos de 2 C.
- Necessidade de esforço global para reduzir emissões.
- Ações de adaptação para mudanças climáticas que já se tornaram inevitáveis.

## Energy-related CO<sub>2</sub> emissions



Limitar  
Aquecimen  
to global a

2C

~15% prob.

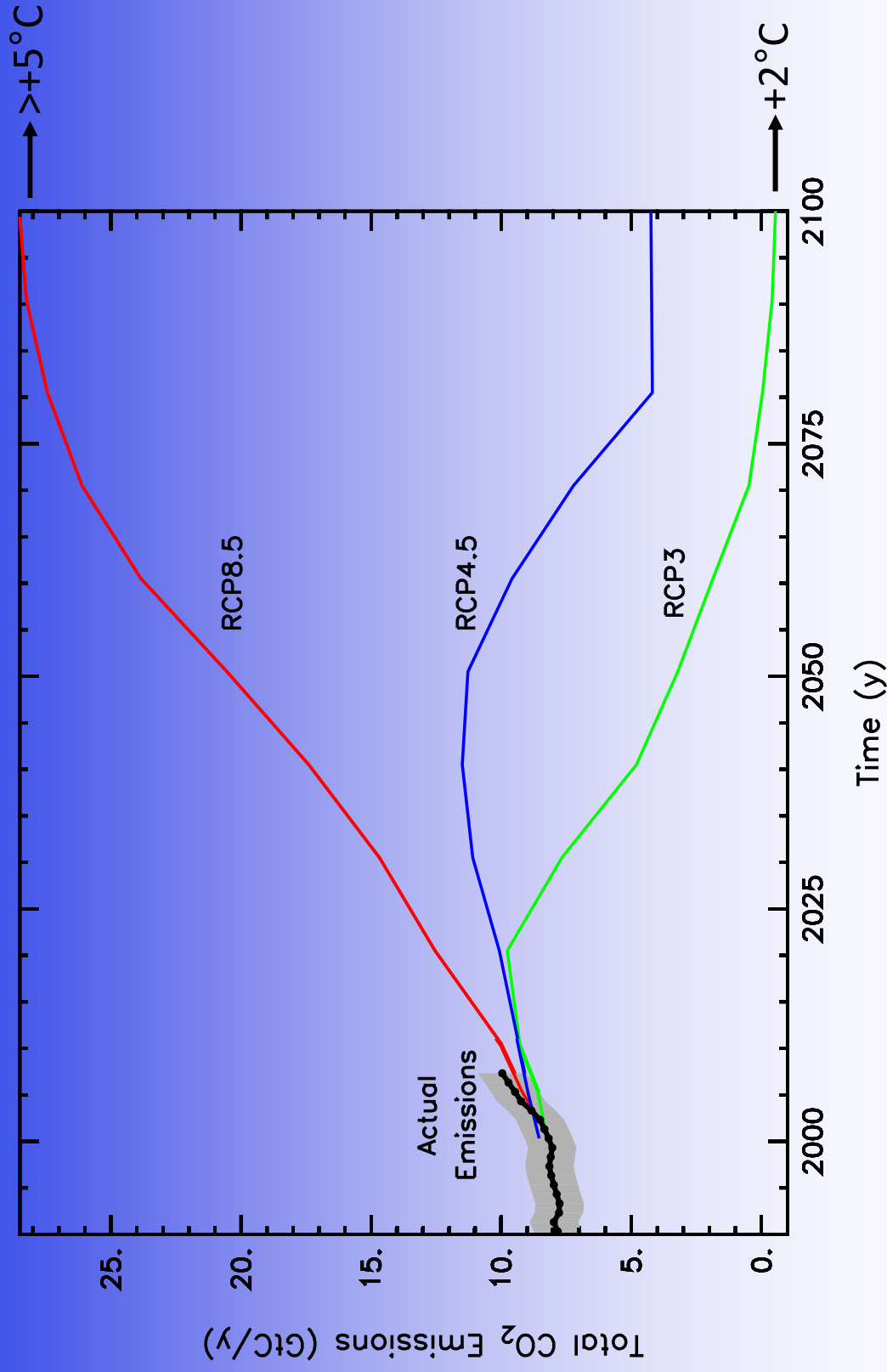
~50% prob.

~75% prob.

Trajetórias das emissões relacionadas ao uso de energia para atingir a estabilização das concentrações de GEE na atmosfera e o percentual de probabilidade que esta determinada concentração limite o aquecimento global a 2°C

Richardson, K. et al., 2009. Climate Change: Global Risks, Challenges and Decisions Synthesis Report. Copenhagen 2009, 10-12 March. [www.climatecongress.ku.dk](http://www.climatecongress.ku.dk)

# Novos cenários de Emissões de CO<sub>2</sub> (IPCC)



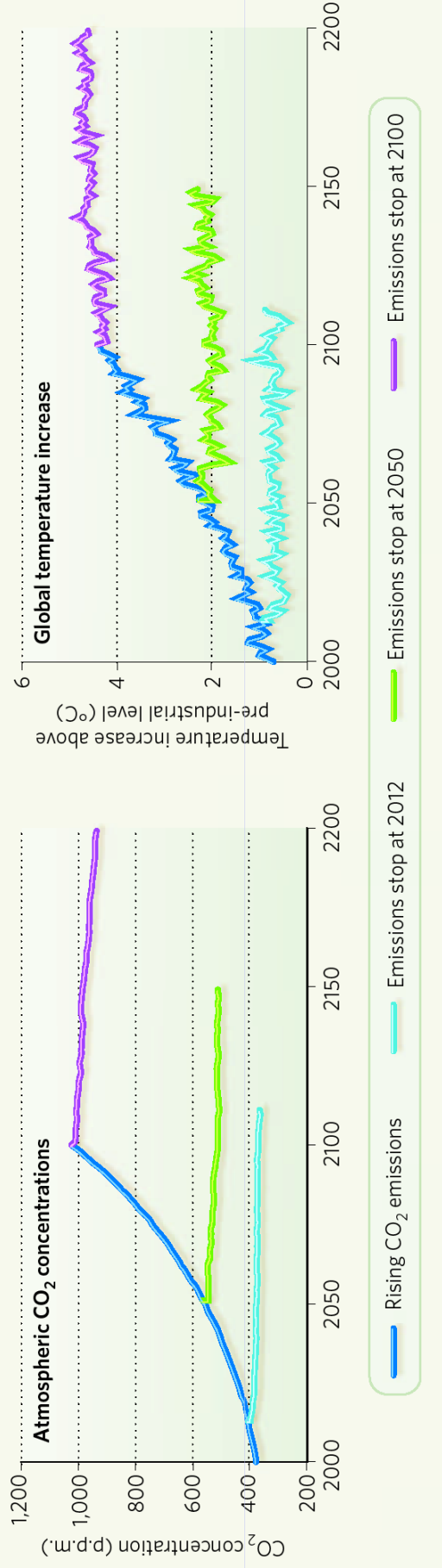
*Atualizado a partir de Canadell et al. 2007*



# O Risco de Adiar a Redução das Emissões

## THE LONG ROAD HOME

A complex computer model shows how Earth might respond if carbon dioxide emissions from humans stopped instantly at various points in the future.



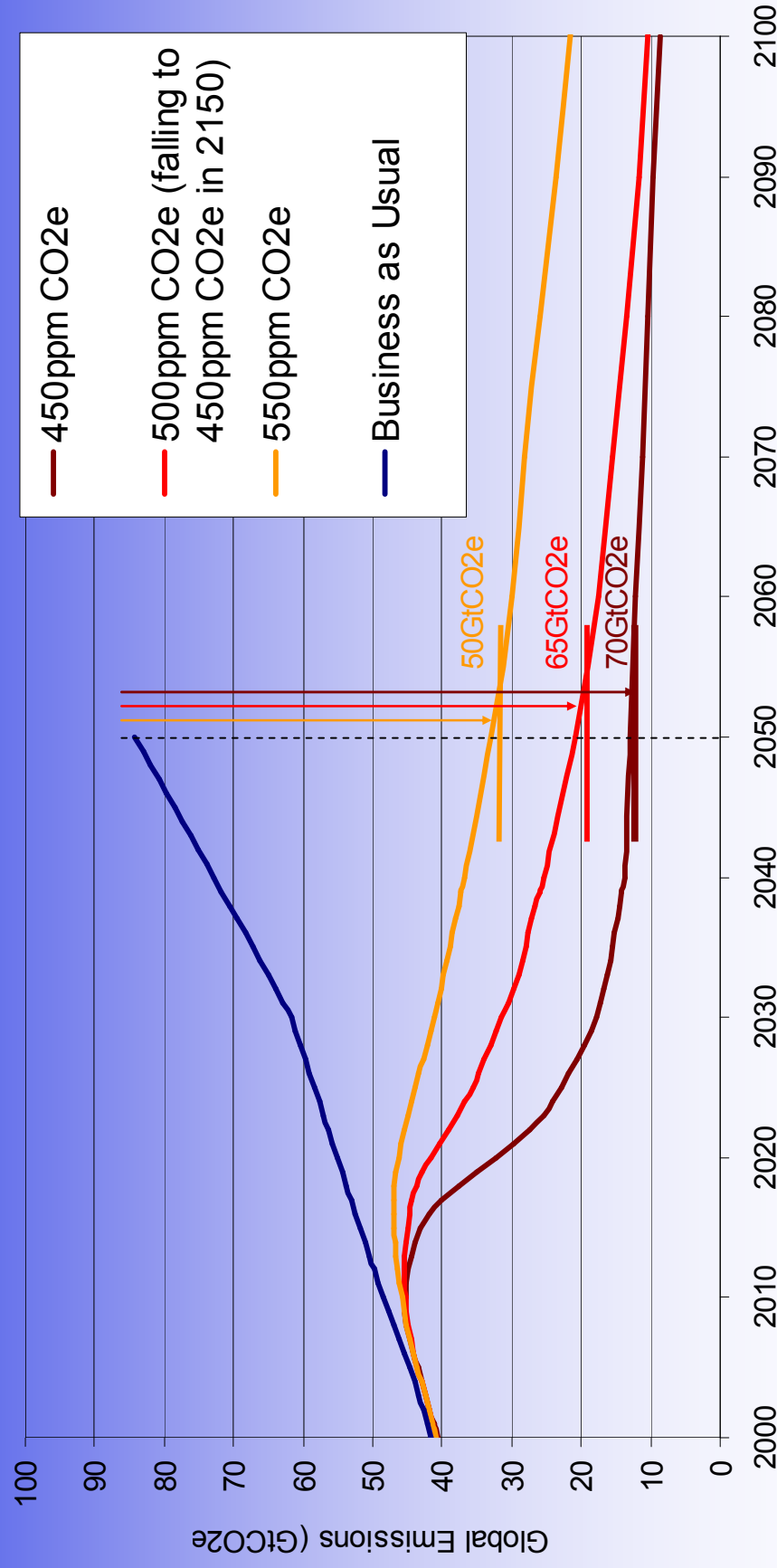
SOURCE: LOWE, J. ET AL. *ENVIRON. RES. LETT.* 4, 014012 (2009).

# Como concentrações de gases de efeito estufa se relacionam com aumentos de temperatura

Temperature rise	CO <sub>2</sub>	CO <sub>2</sub> -eq.	Year of peak emissions	% change in global emissions
Global average temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity	CO <sub>2</sub> concentration at stabilisation (2005 = 379 ppm)	CO <sub>2</sub> -eq. concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)	Peaking year for CO <sub>2</sub> emissions	Change in CO <sub>2</sub> emissions in 2050 (percent of 2000 emissions)
°C	ppm	ppm	year	percent
2.0 - 2.4	350 - 400	445 - 490	2000 - 2015	-85 to -50
2.4 - 2.8	400 - 440	490 - 535	2000 - 2020	-60 to -30
2.8 - 3.2	440 - 485	535 - 590	2010 - 2030	-30 to +5
3.2 - 4.0	485 - 570	590 - 710	2020 - 2060	+10 to +60
4.0 - 4.9	570 - 660	710 - 855	2050 - 2080	+25 to +85
4.9 - 6.1	660 - 790	855 - 1130	2060 - 2090	+90 to +140

**Table 1**  
 Characteristics of various emission trajectories to achieve stabilisation of atmospheric greenhouse gas concentrations, in CO<sub>2</sub> and CO<sub>2</sub>-eq. The equilibrium global average temperature increase above pre-industrial is given for each stabilisation target. Only the first scenario, shown in the first row, has a possibility to meet the 2°C guardrail. Note that current atmospheric greenhouse gas concentrations are about 385 ppm CO<sub>2</sub> and 396 ppm CO<sub>2</sub>-eq (including the cooling effect of aerosols). Modified from<sup>1</sup> (table 5.1, p. 67).

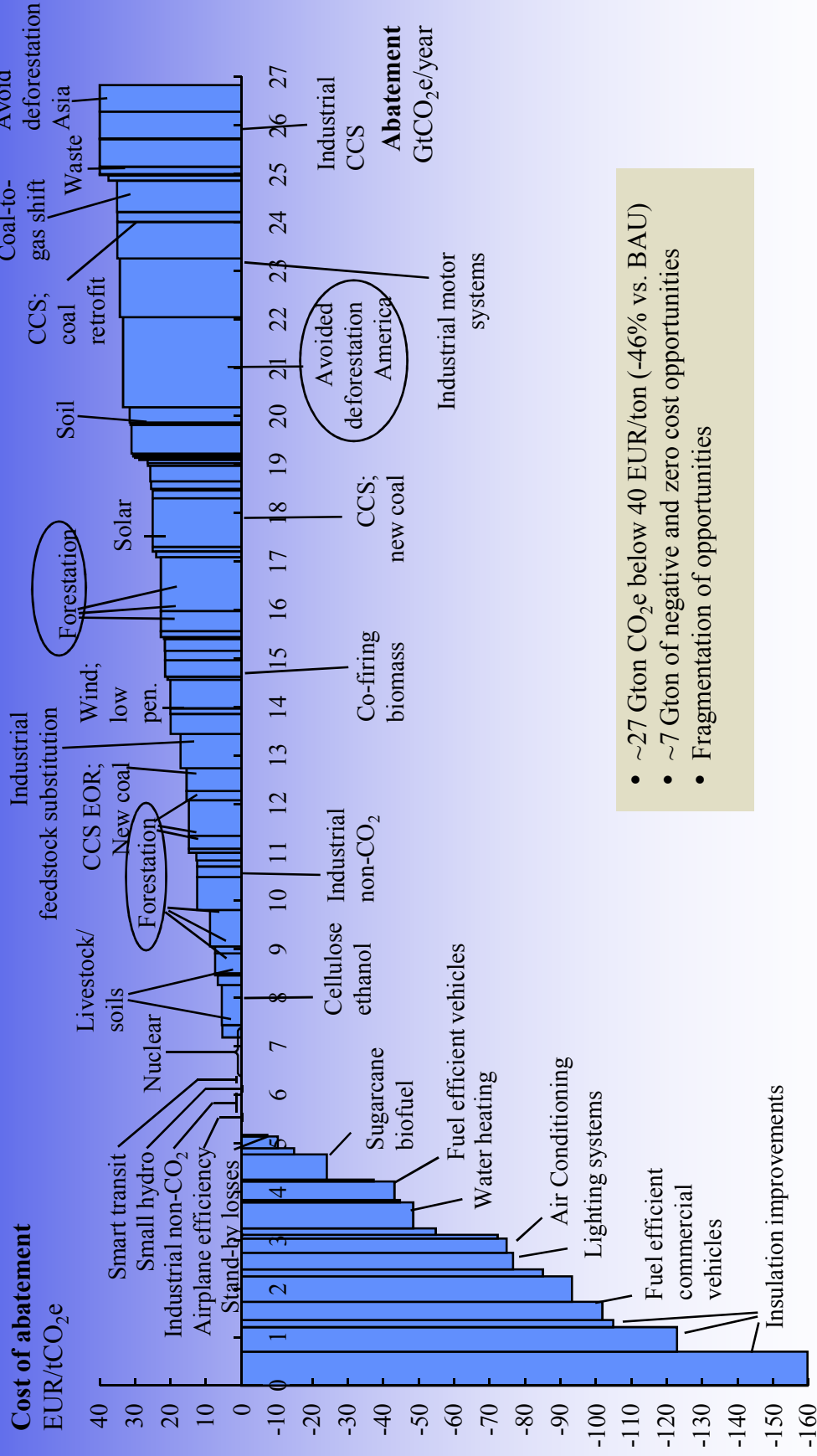
# Atrasar a mitigação é perigoso e muito caro



Source: Stern Review

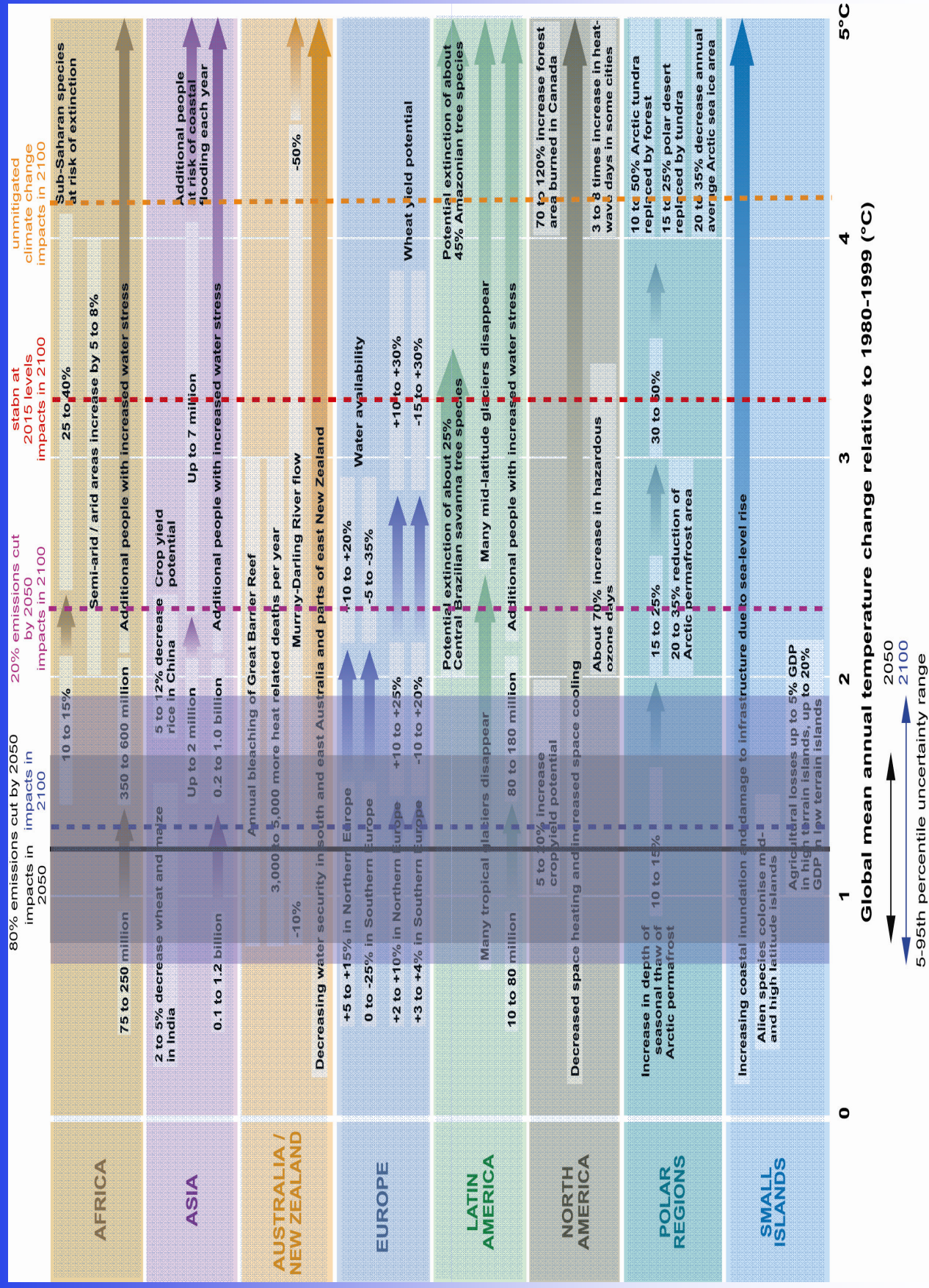
# Há inúmeras opções de mitigação: algumas são lucrativas!

2030

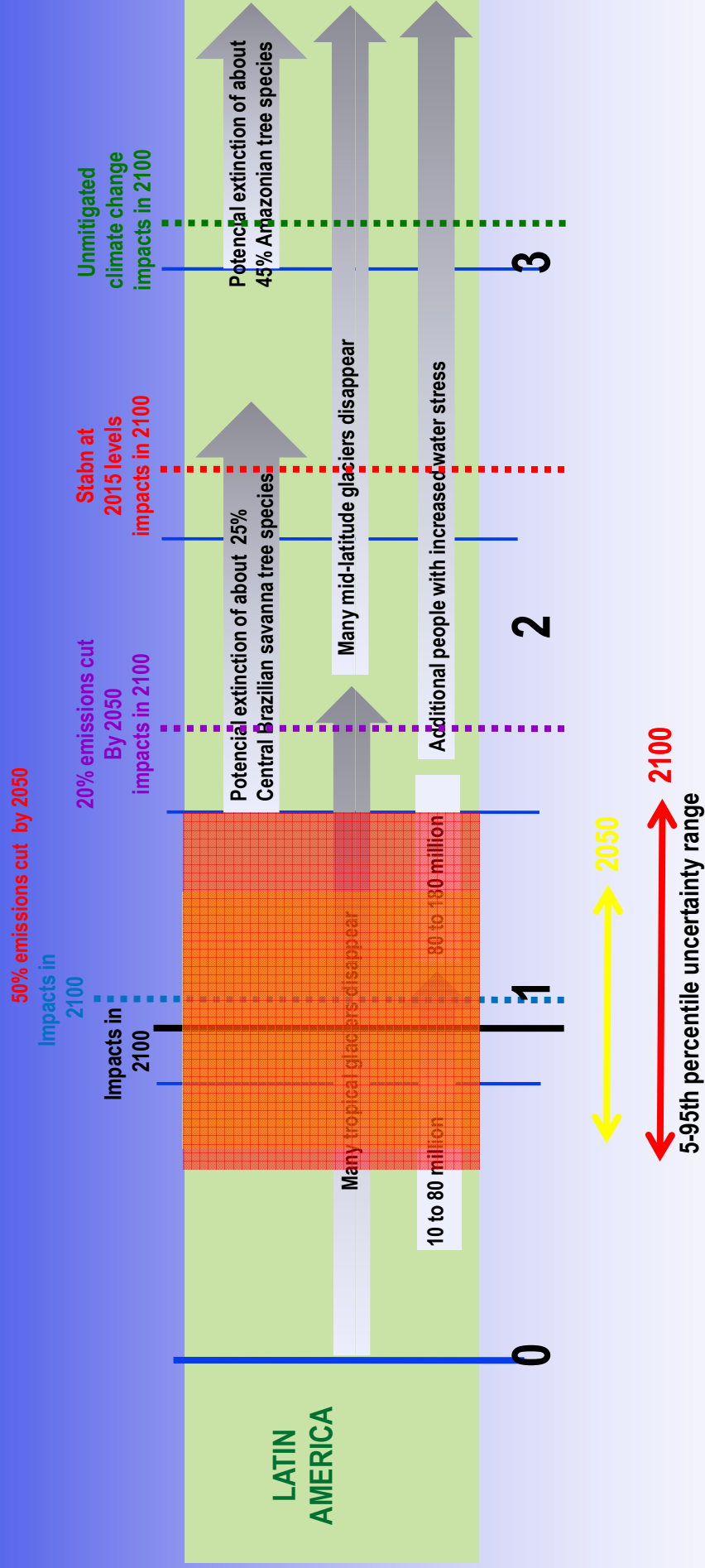


- ~27 Gton CO<sub>2</sub>e below 40 EUR/ton (-46% vs. BAU)
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

# 80 per cent cuts in emissions by 2050



# 80 per cent cuts in emissions by 2050



Global mean annual temperature change relative to 1980-1999 (°C)



*Poderão os países da América  
Latina, no Século XXI,  
tornarem-se “potências  
ambientais” ou países tropicais  
desenvolvidos?*

# Poderão os países em desenvolvimento atingir padrões aceitáveis de desenvolvimento humano sem sobrecarregar o meio ambiente?

replicable at the global level. nations such as the United States of America sustainable development.  
 Ecological Footprint and Human Wellbeing WWF– Gland, Switzerland and  
 Global Footprint Network (GFN), Oakland, California USA. ISBN 978-2-88085-290-0

Country population (coloured by region):



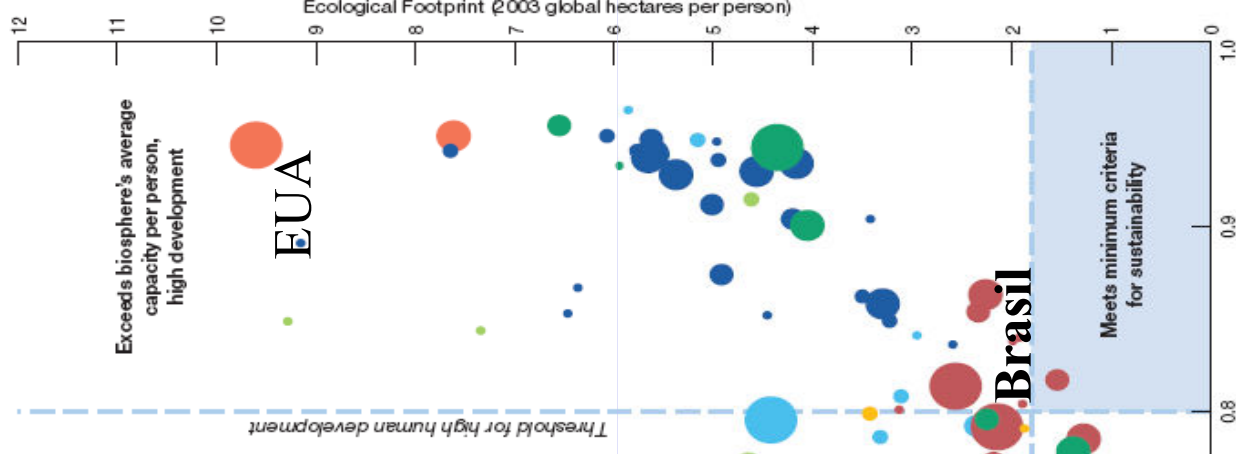
World average biocapacity available per person

Within biosphere's average capacity per person, low development



IDH

Fig. 8: HUMAN DEVELOPMENT INDEX AND ECOLOGICAL FOOTPRINTS, 2003







**OBRIGADO!**