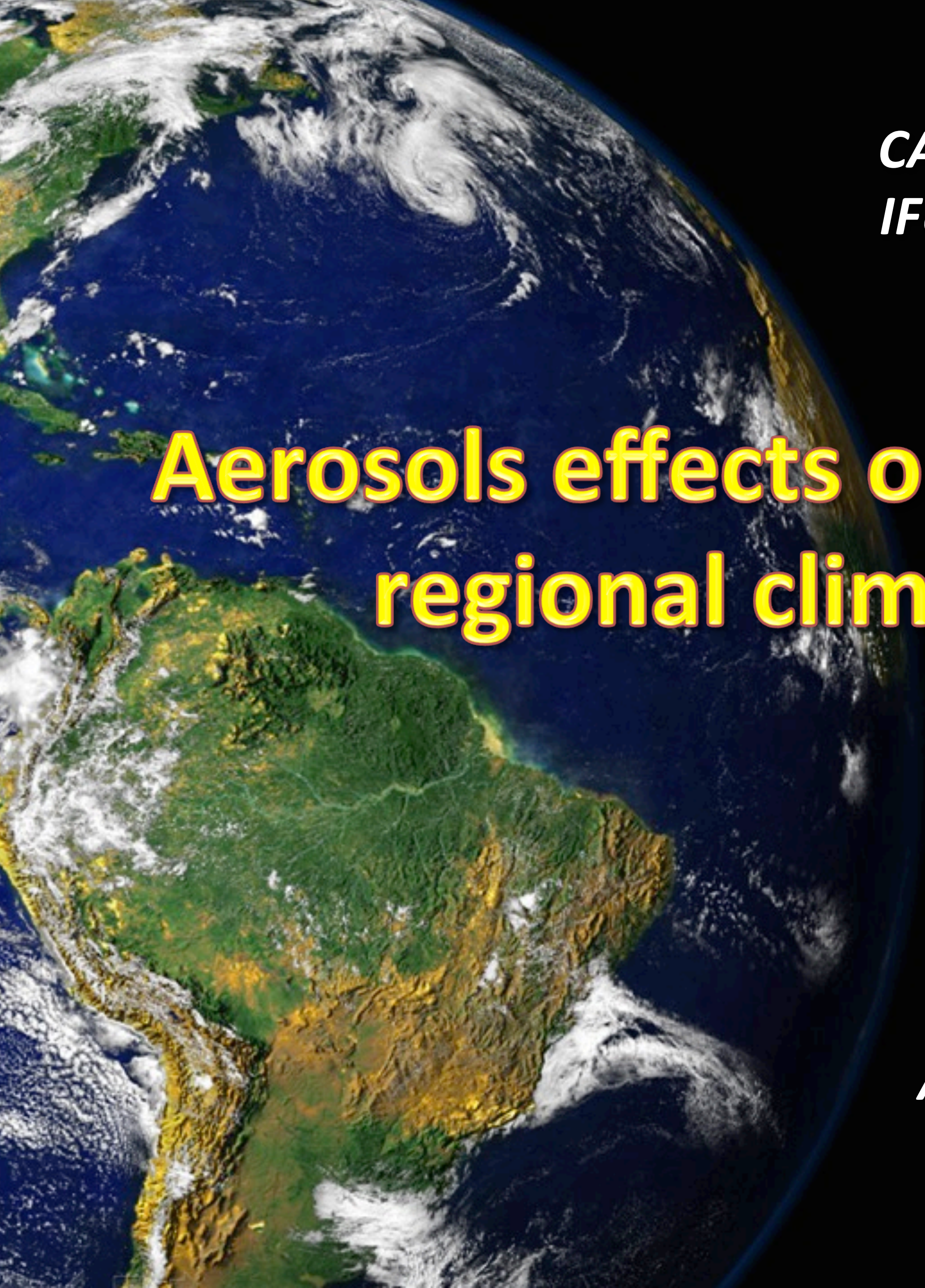
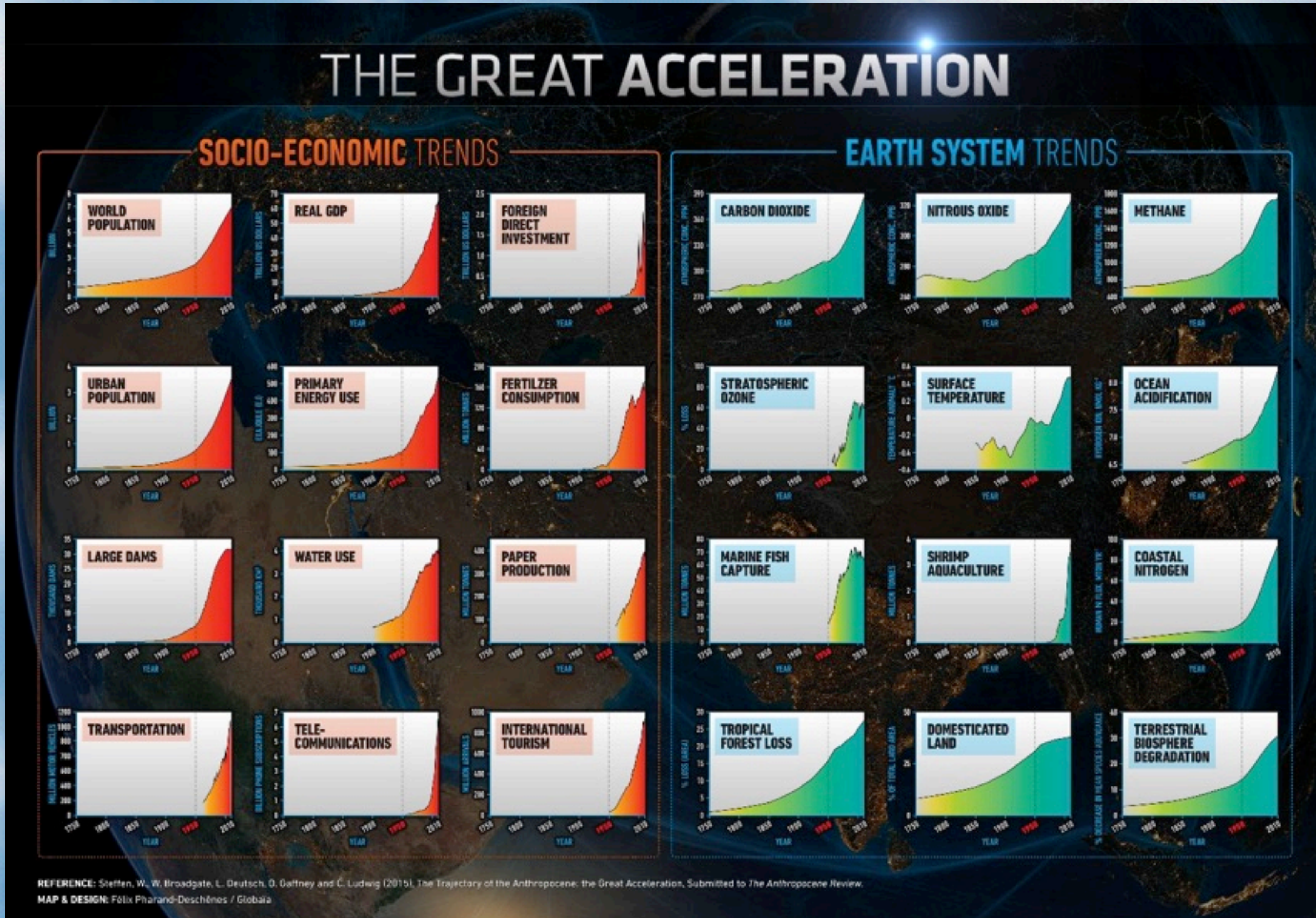


CAPES-STINT Aerosol course
IFUSP, 16 de Março de 2015

Aerosols effects on the global and regional climate system

Paulo Artaxo
Departamento de Física Aplicada Instituto de Fisica da USP
artaxo@if.usp.br

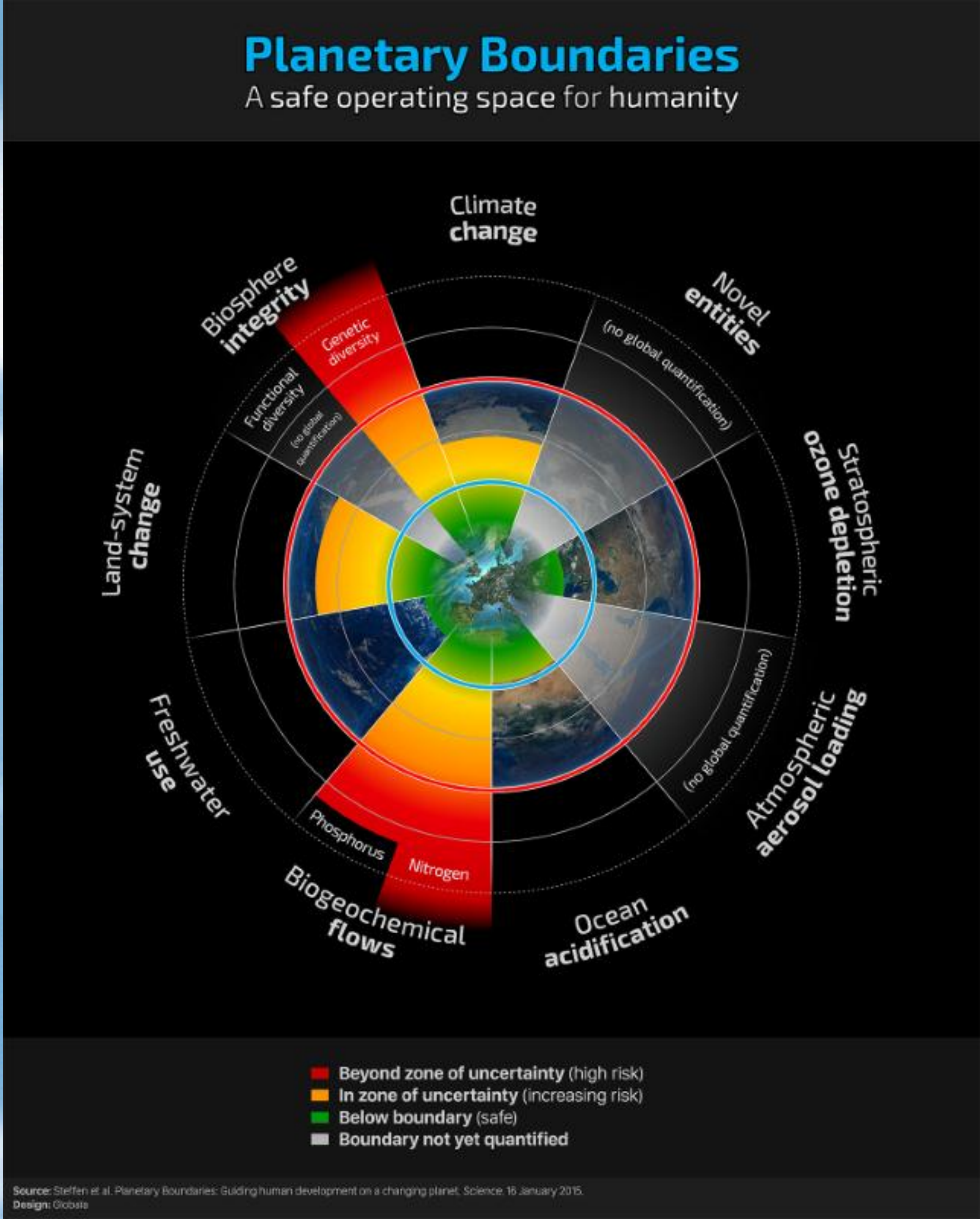
Estamos mudando nosso planeta rapidamente e de muitas formas



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

Aerosol loading: NO METRIC!!!

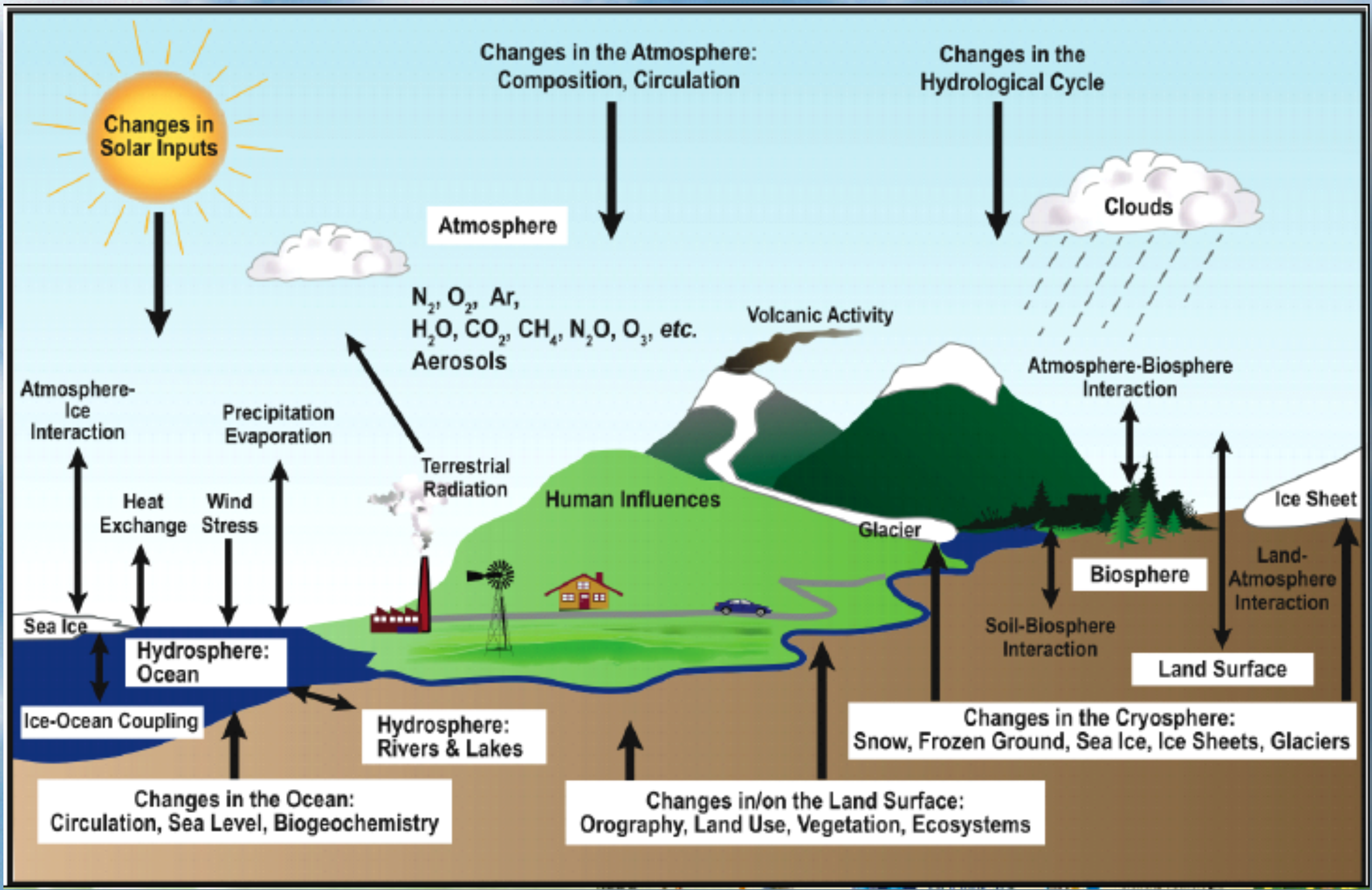


Science Fev 2015

Nosso planeta em mudança, nos compartimentos:

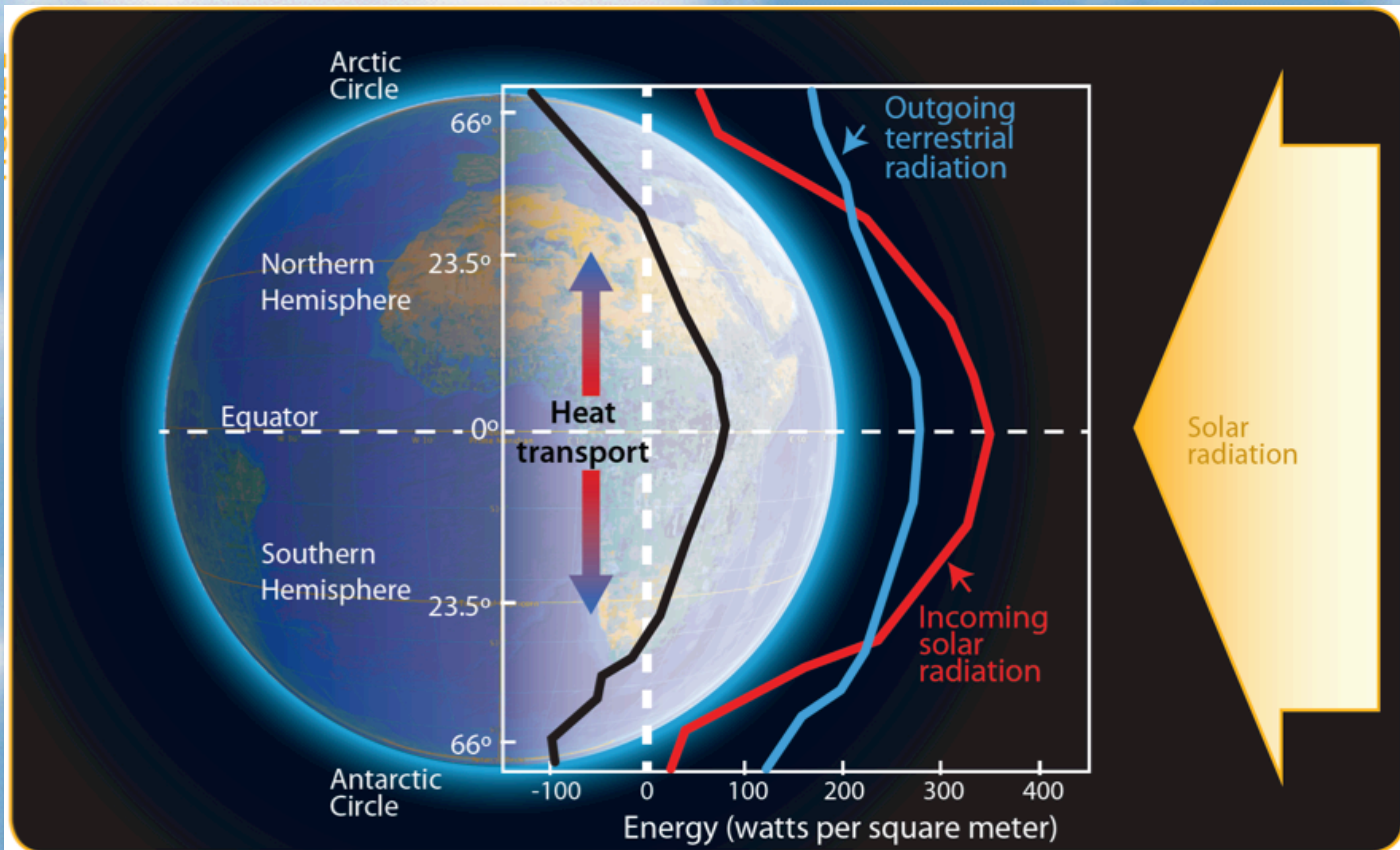
Atmosfera
Criosfera
Biosfera
Geosfera
Hidrosfera

O sistema climático global

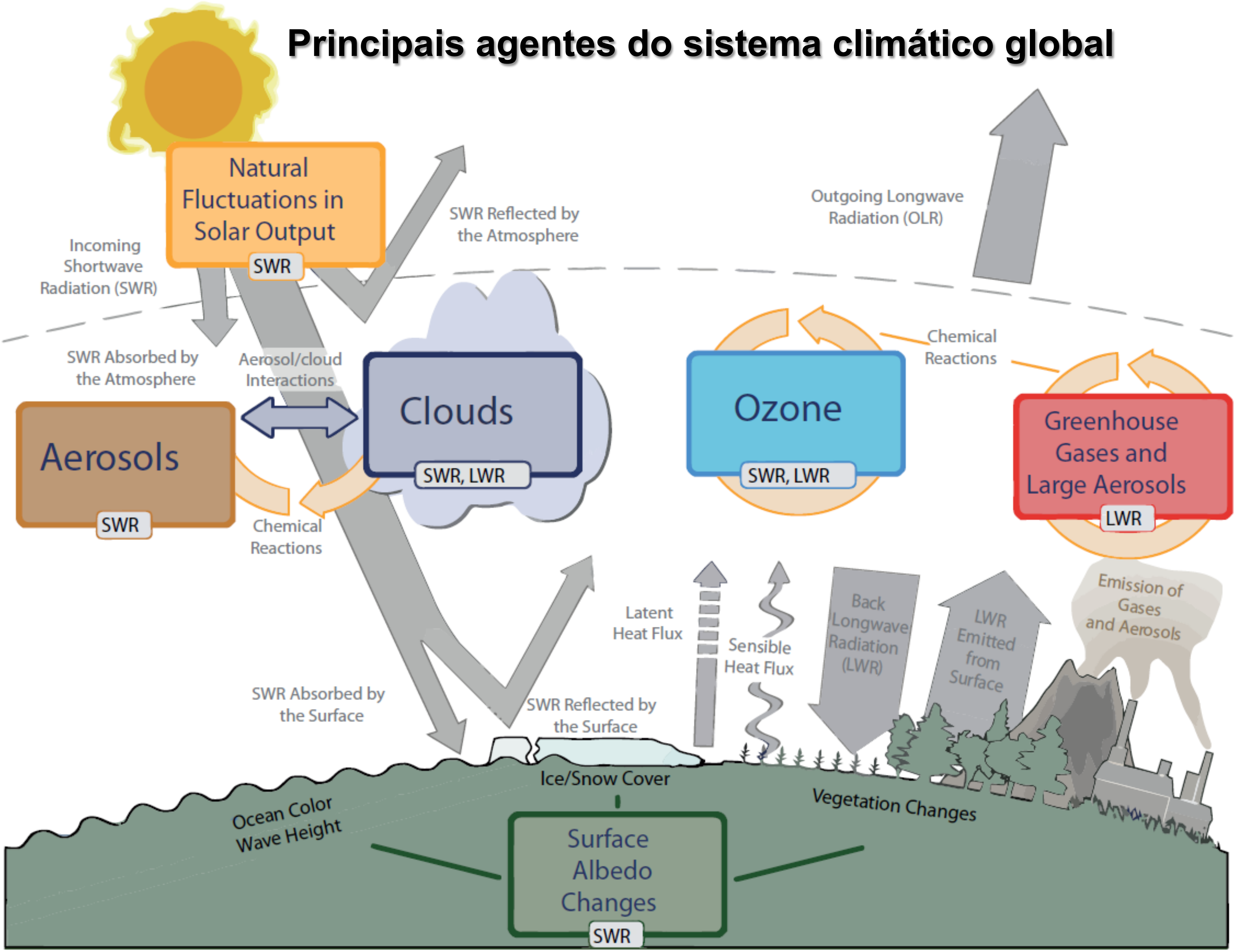


Balanço de radiação solar

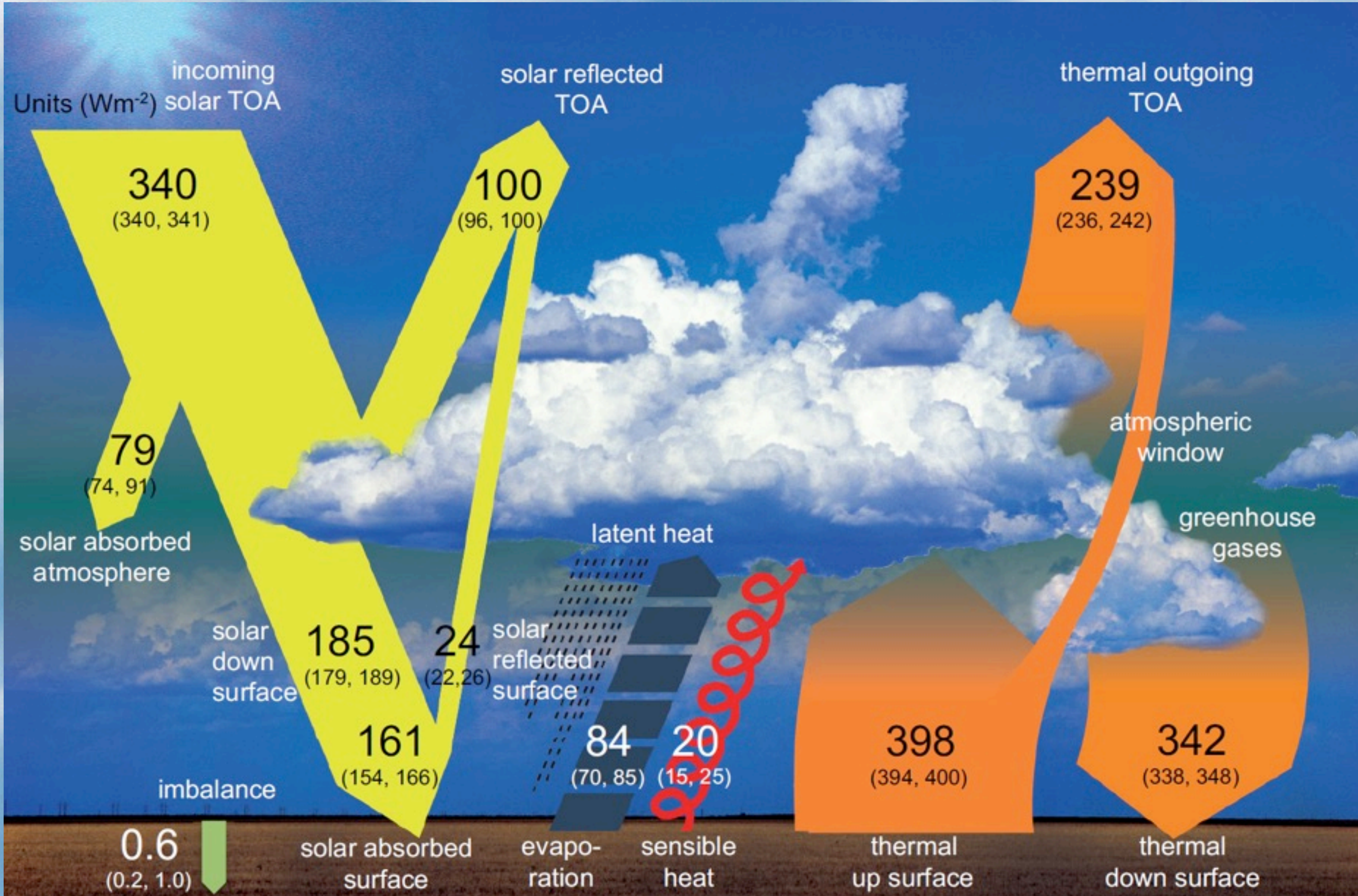
The main external influence on planet Earth is from radiation.
Incoming solar shortwave radiation is unevenly distributed owing to the geometry of the Earth-sun system, and the rotation of the Earth.
Outgoing longwave radiation is more uniform.



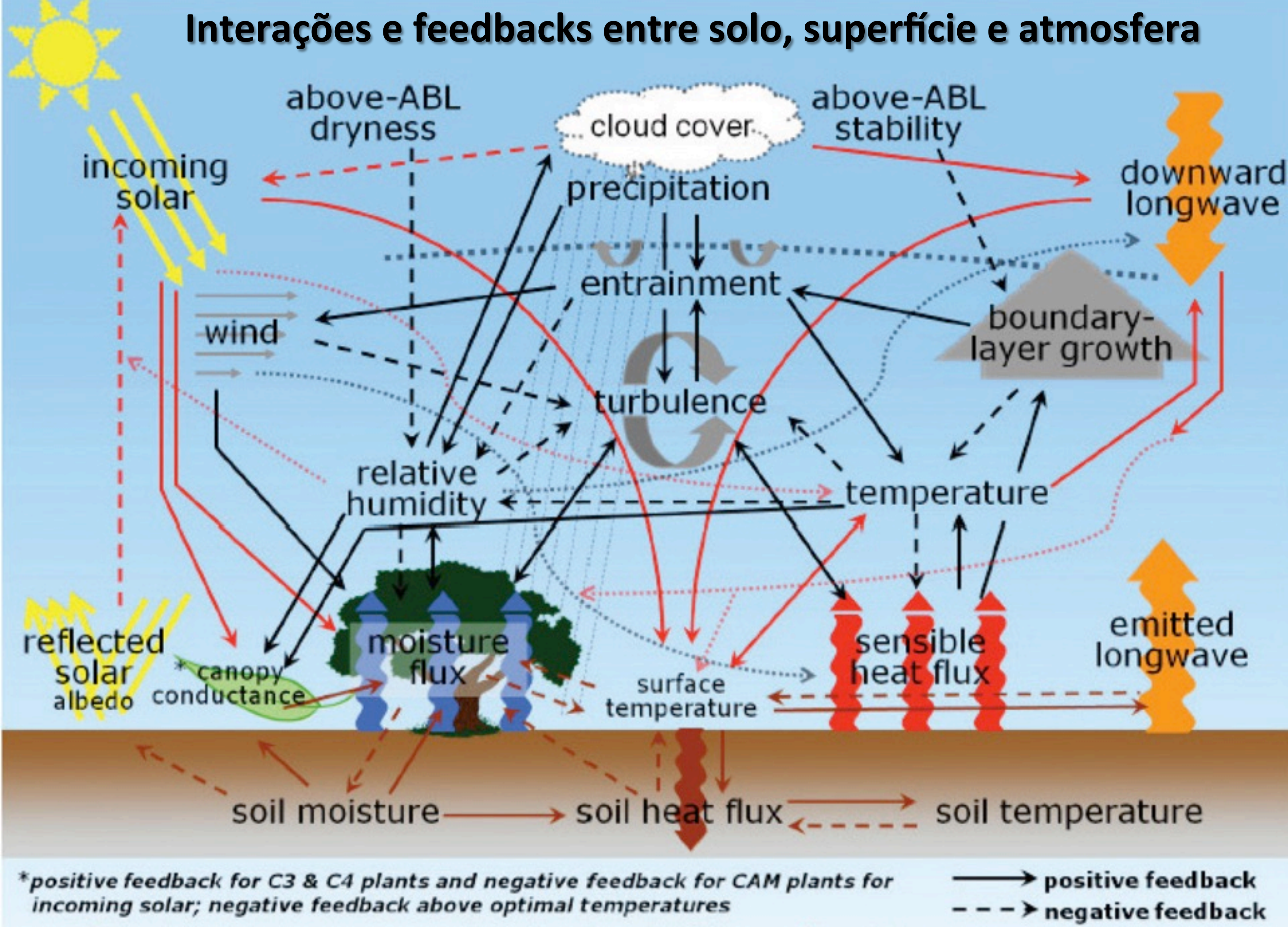
Principais agentes do sistema climático global



Balanço de energia regional e global

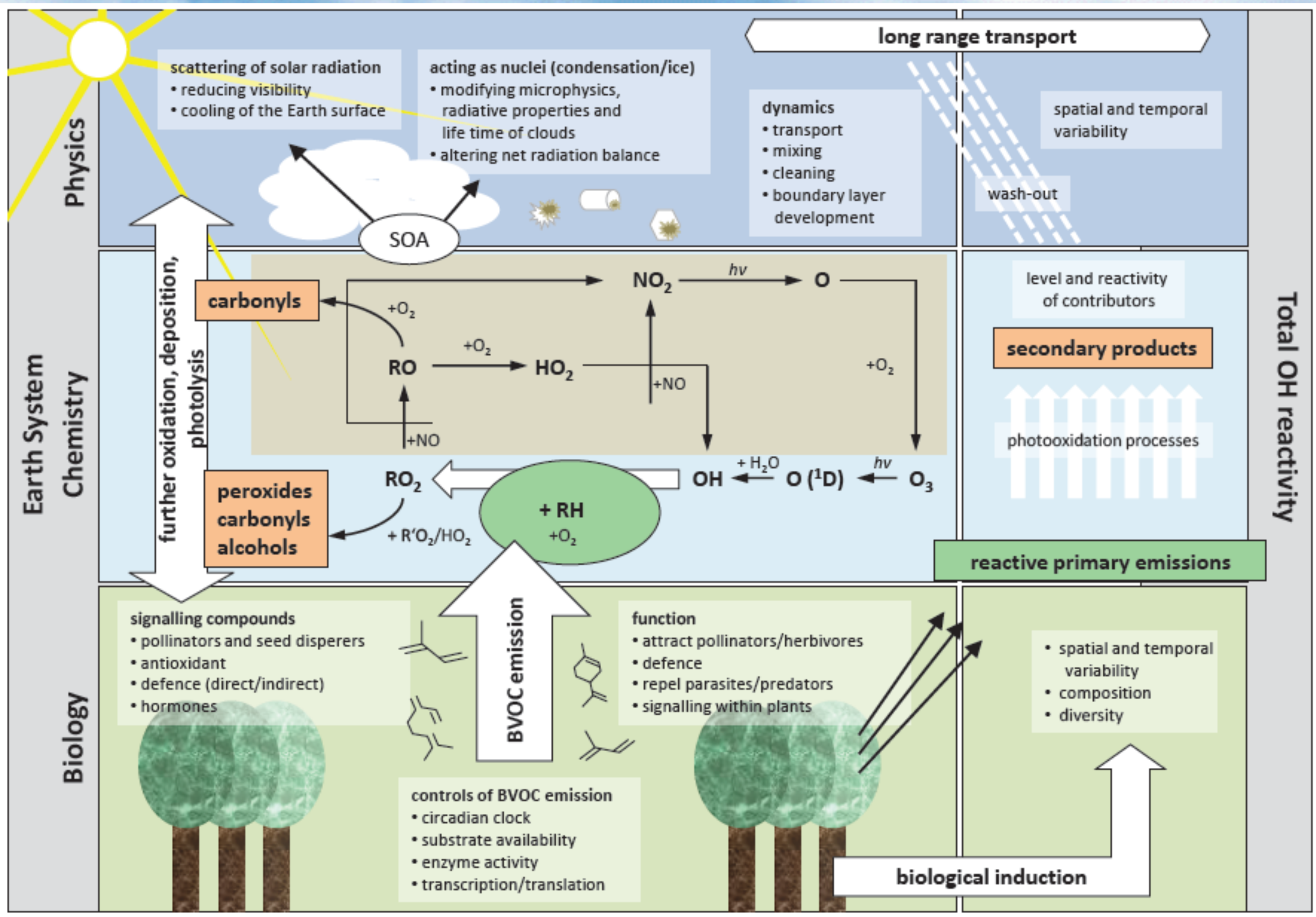


Interações e feedbacks entre solo, superfície e atmosfera



(GEWEX 2013)

Processos químicos atmosféricos são fundamentais



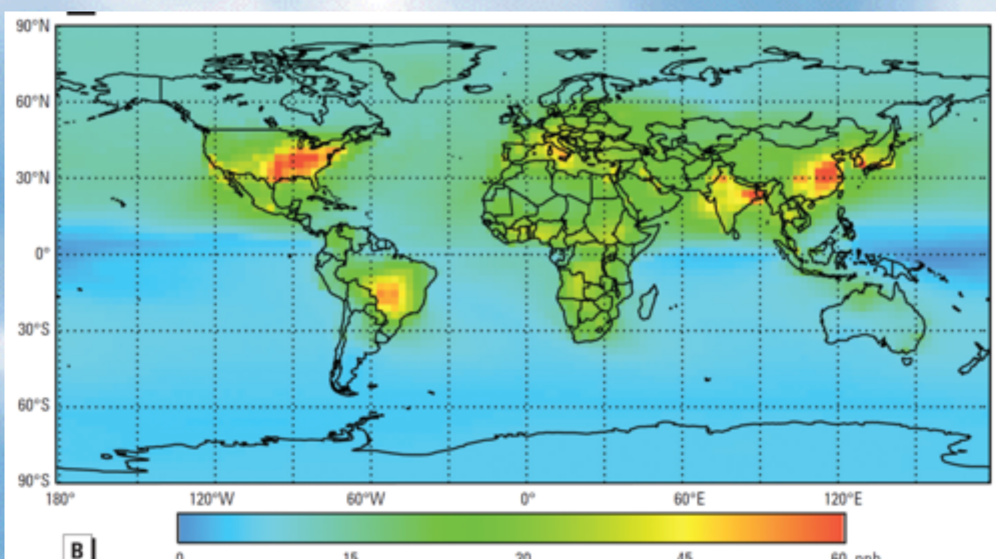
Química Atmosférica e Mudanças Climáticas

VOCs em fase gasosa: Ozônio

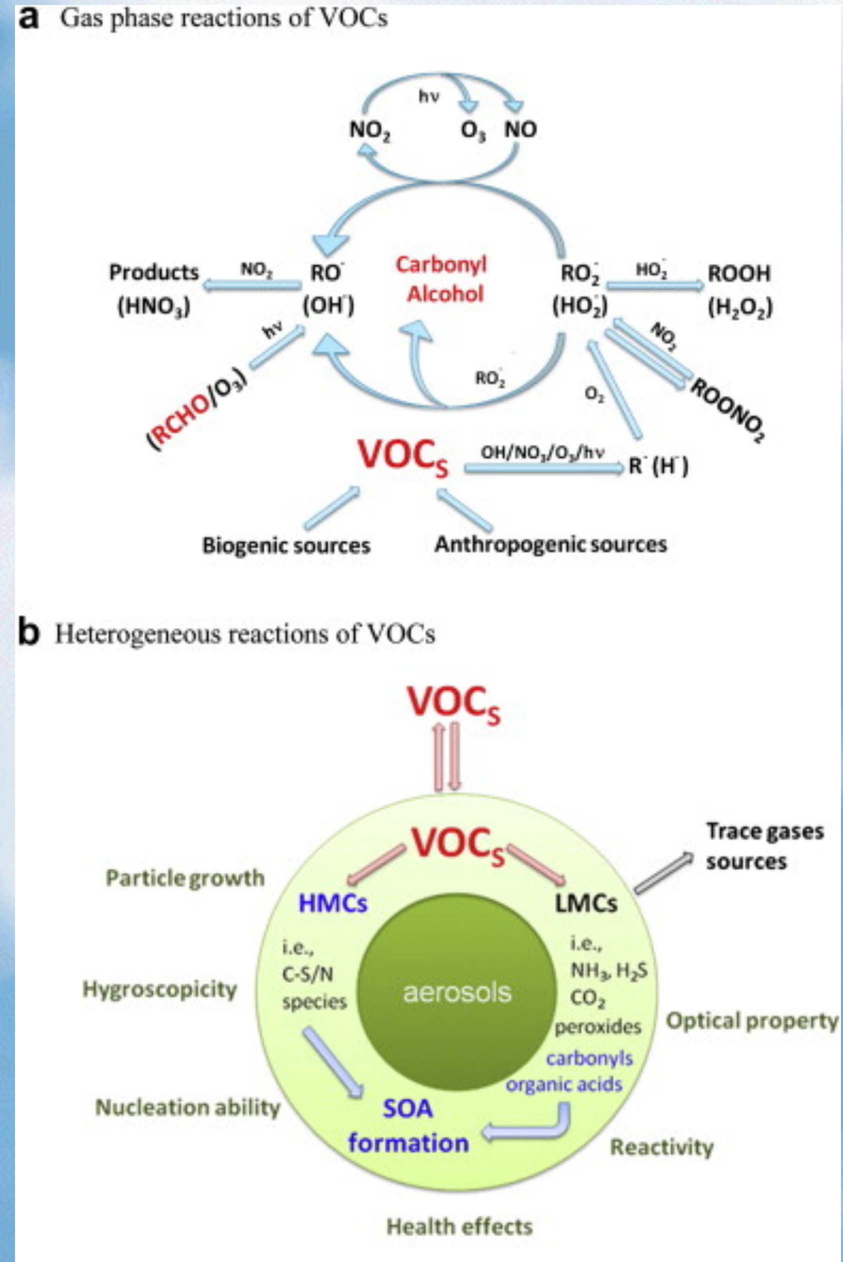
VOCs e produção de aerossóis secundários

Meia vida de metano controlada pelo radical OH^-

Monóxido de carbono (CO): importante no balanço de carbono

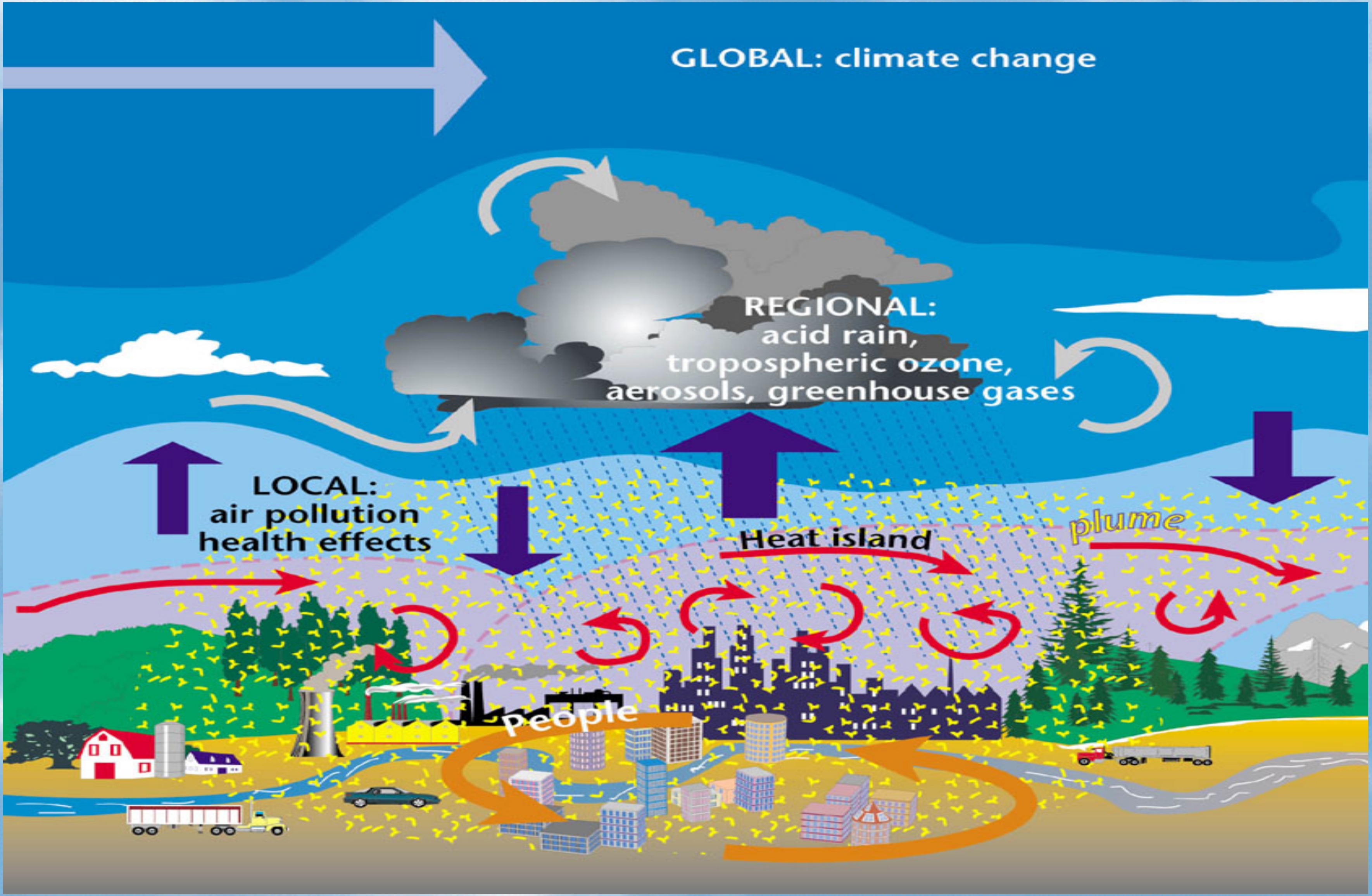


Aumento de ozônio (2010-1850) Máximo diário



HMCs: high molecular weight compounds; LMCs: low molecular weight compounds

É fundamental considerar todas as escalas

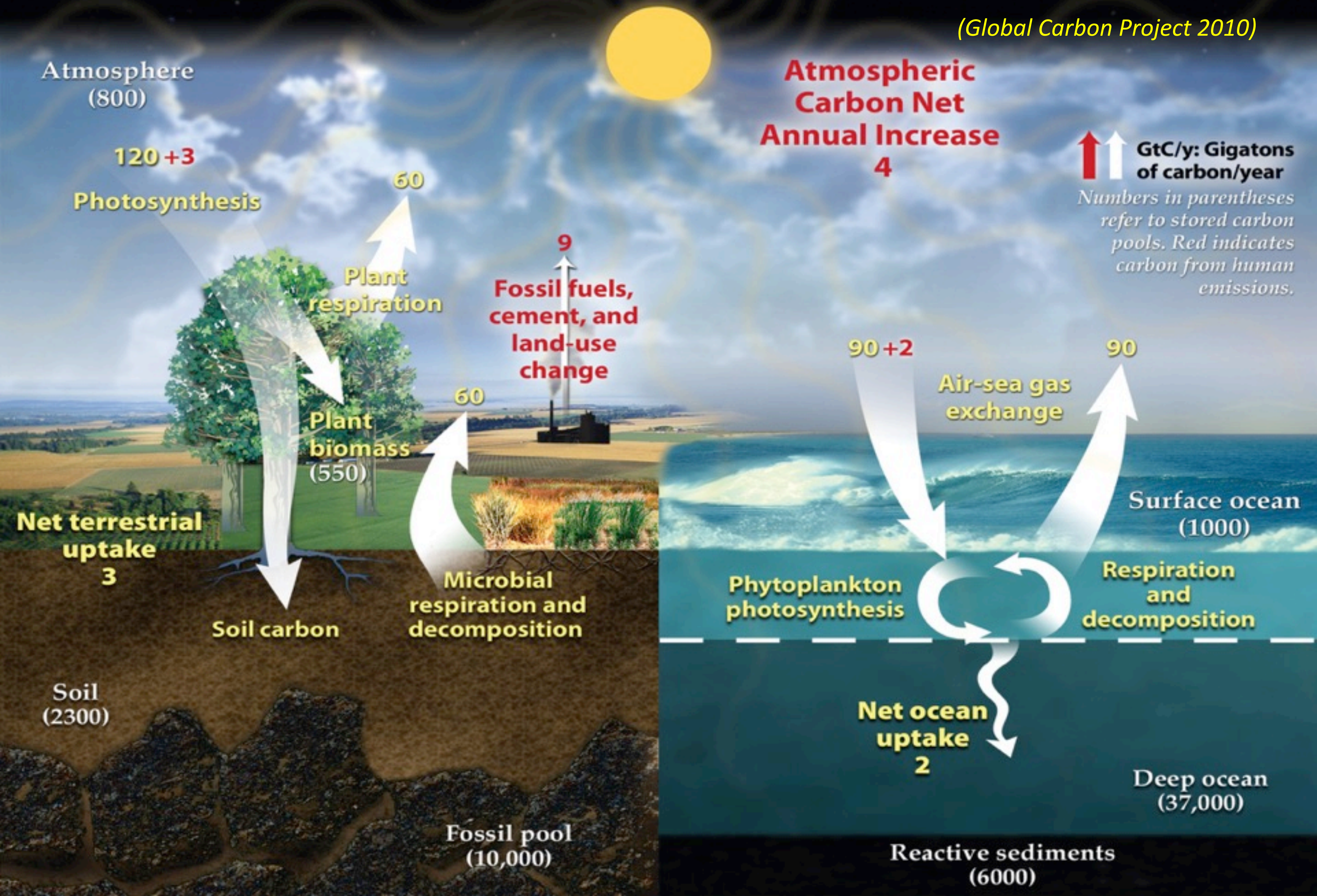


Interações entre a biosfera e a atmosfera

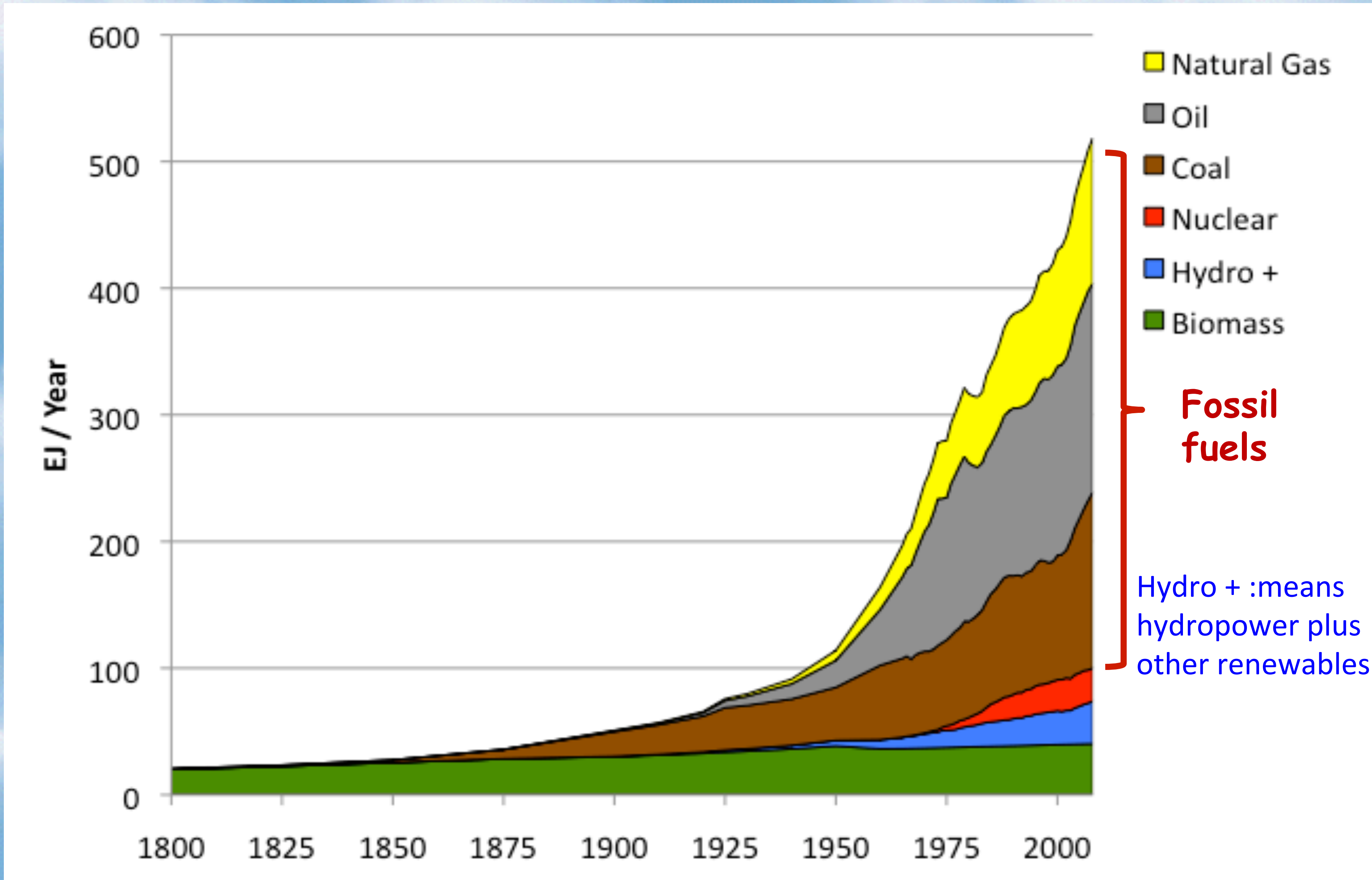
Perturbações humanas no ciclo do carbono global

Human Perturbations of the Global Carbon Cycle

(Global Carbon Project 2010)

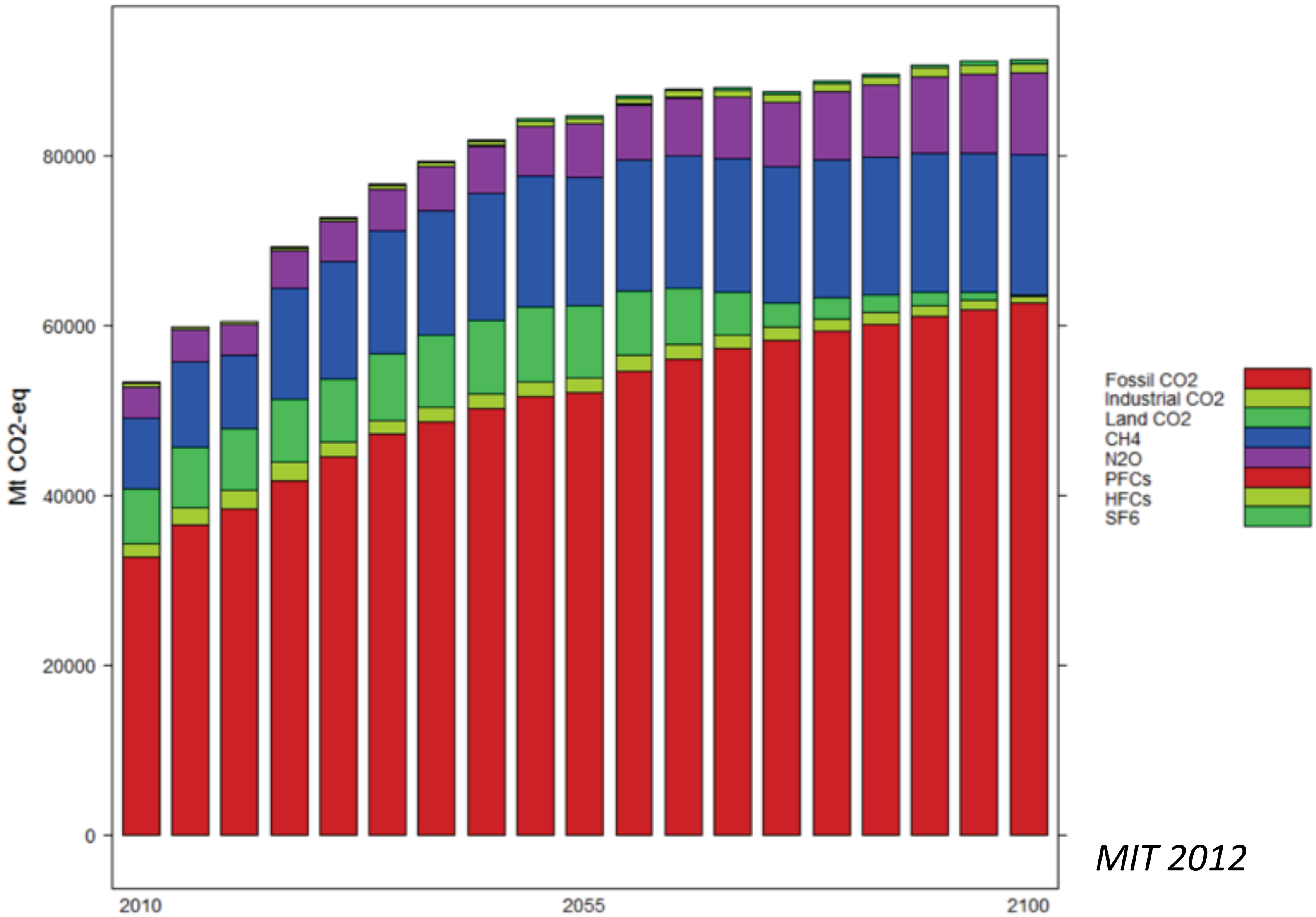


Suprimento de energia global: 1800 – 2008

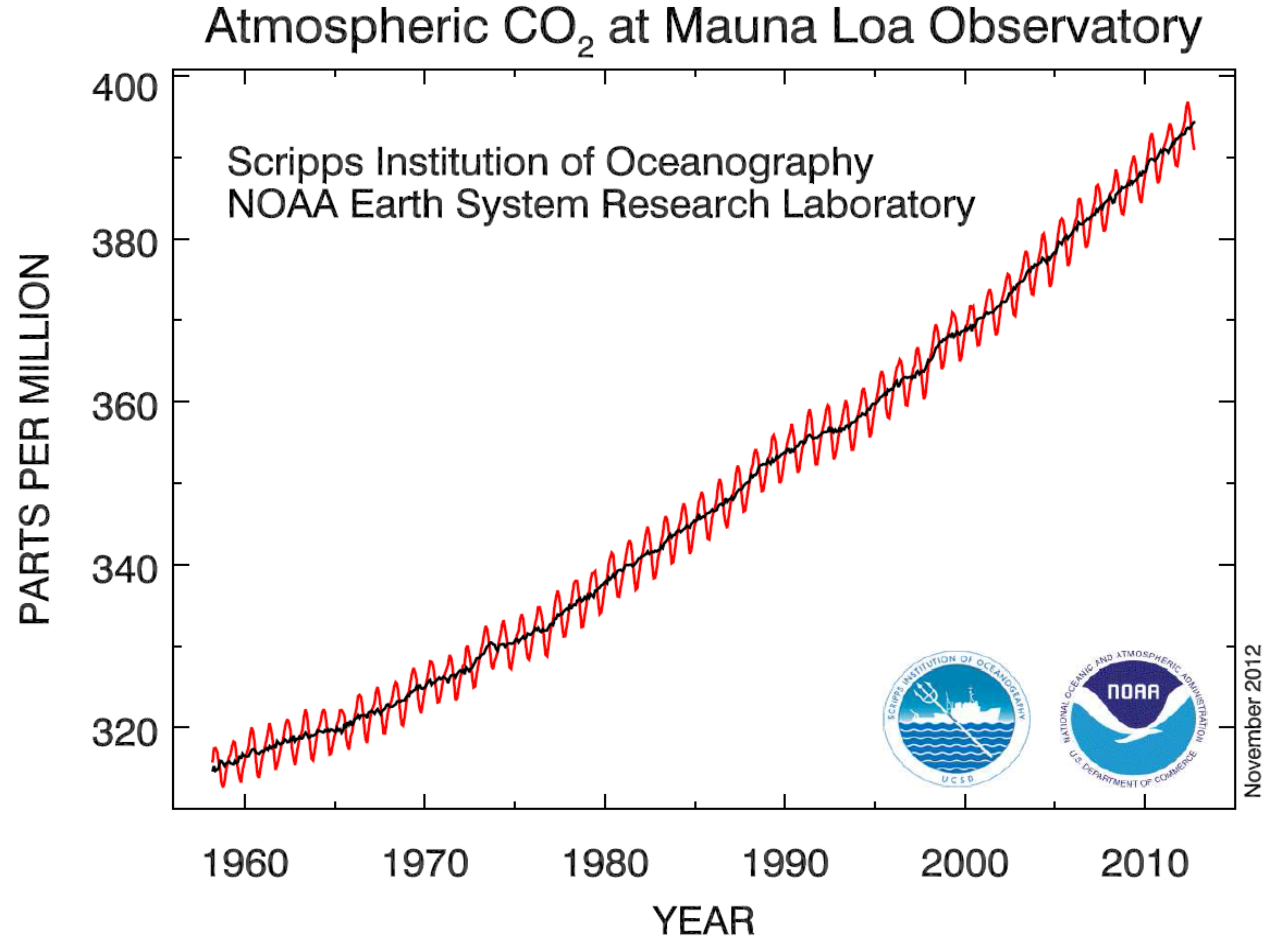


Sources: Grubler (2008) - Energy Transitions, BP (2009) – Statistical Review of World Energy, EIA (2009) – International Energy Annual

Emissões globais de gases de efeito estufa 2010-2100

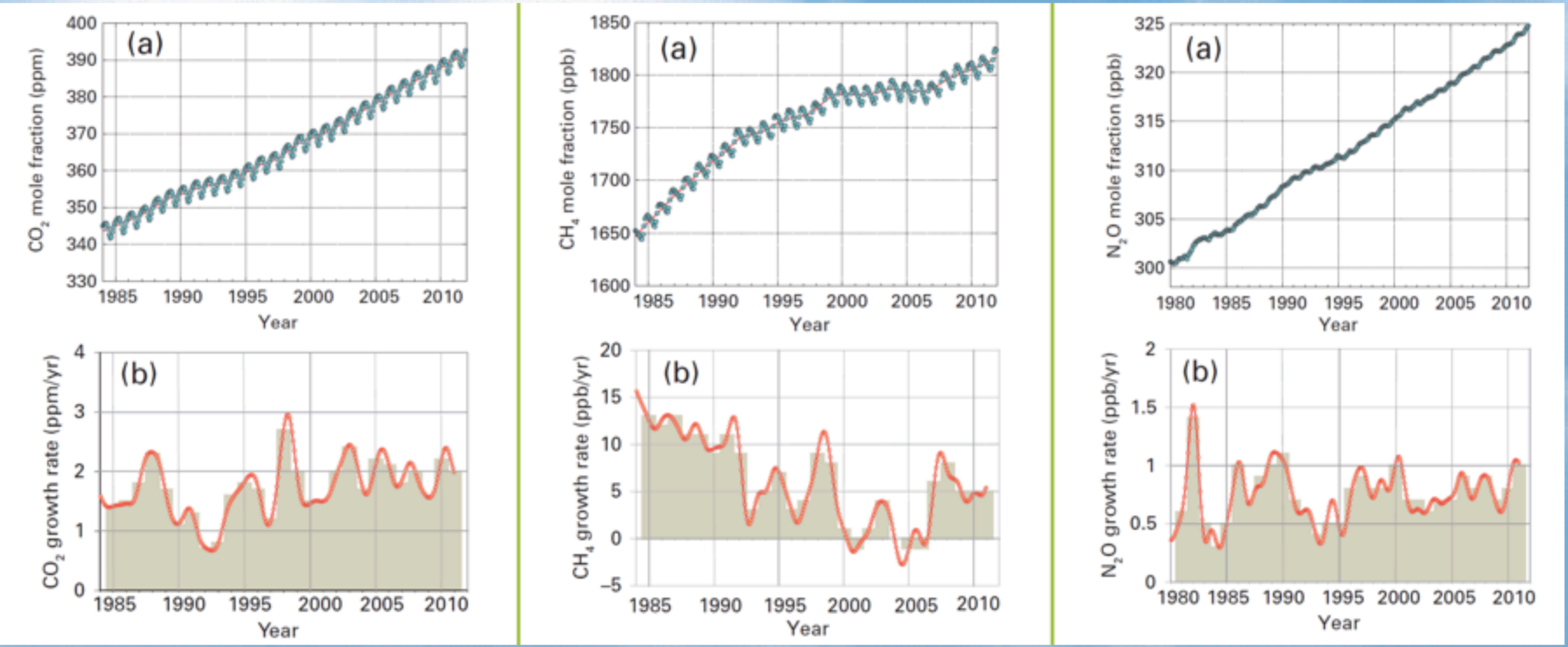


MIT 2012


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
November 2012
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UCSD
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

CO_2, CH_4 e N_2O de 1985 a 2011

39% 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.

WMO GREENHOUSE GAS BULLETIN Oct 2012

Para onde vão as emissões antropogênicas de CO_2 (média 2003-2012)

8.6 ± 0.4 GtC/yr 92%

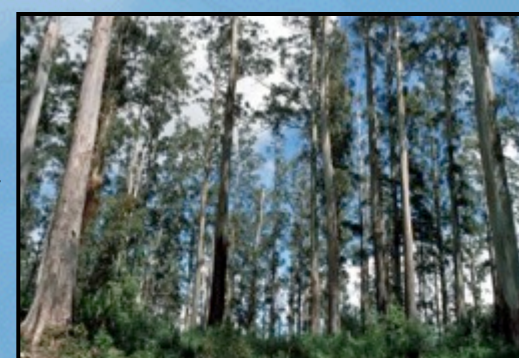
0.8 ± 0.5 GtC/yr 8%

+

4.3±0.1 GtC/yr
45%

2.6 ± 0.5 GtC/yr
27%

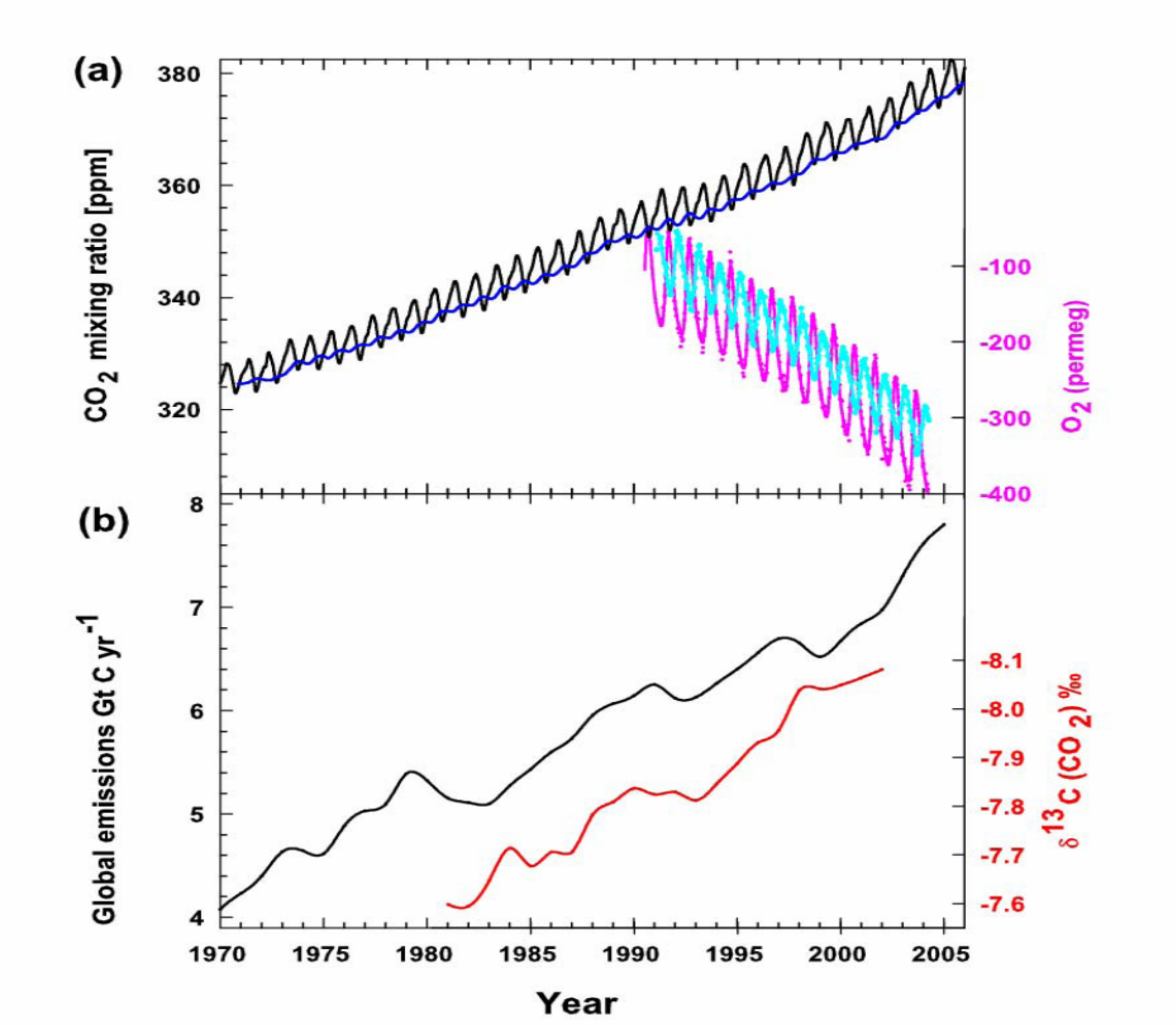
2.6 ± 0.8 GtC/yr
27%



Source: Le Quéré et al 2013; CDIAC Data; Global Carbon Project 2013

O aumento de CO_2 é devido às emissões antropogênicas

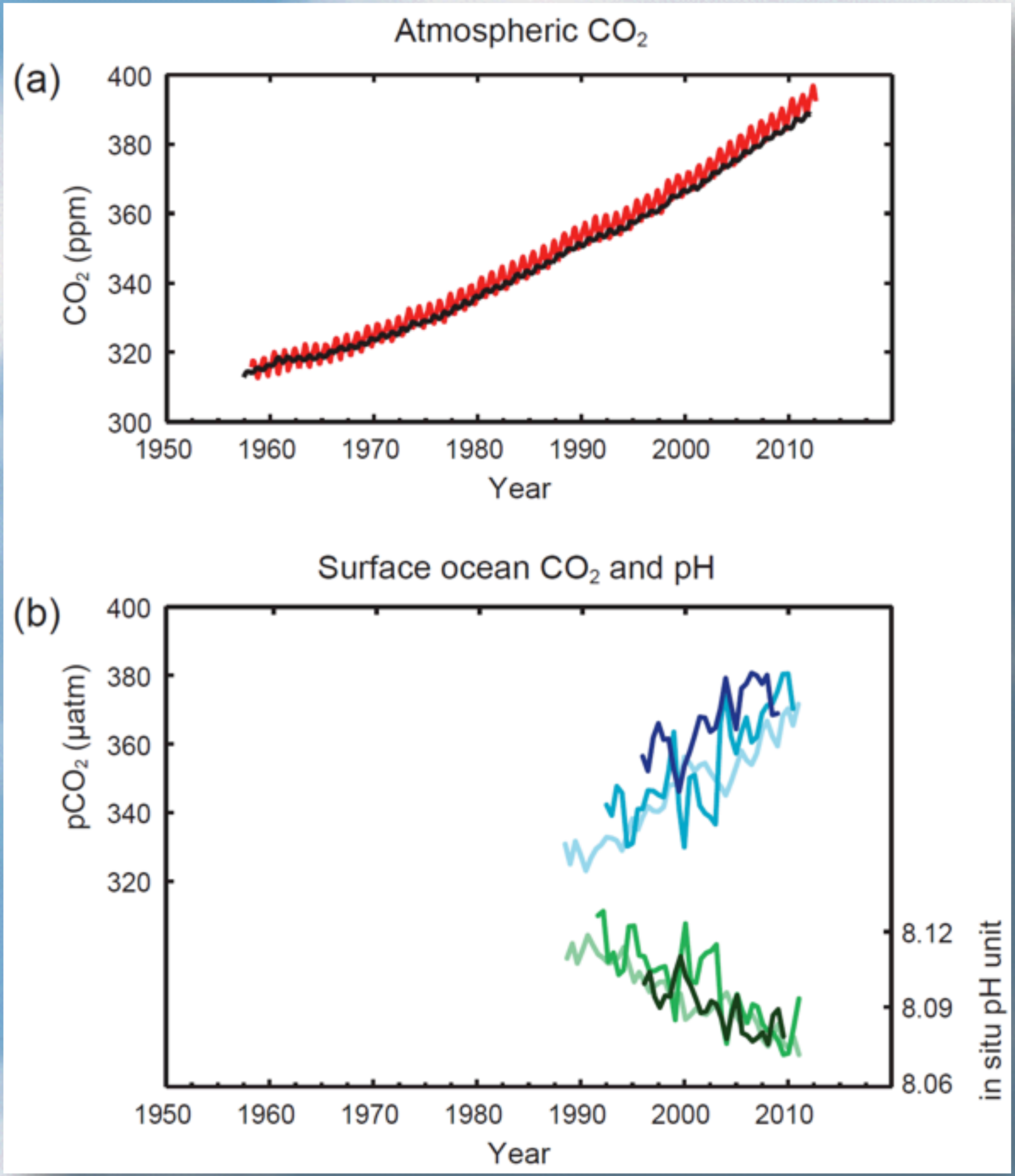
Isótopos de carbono e oxigênio mostram fontes antropogênicas



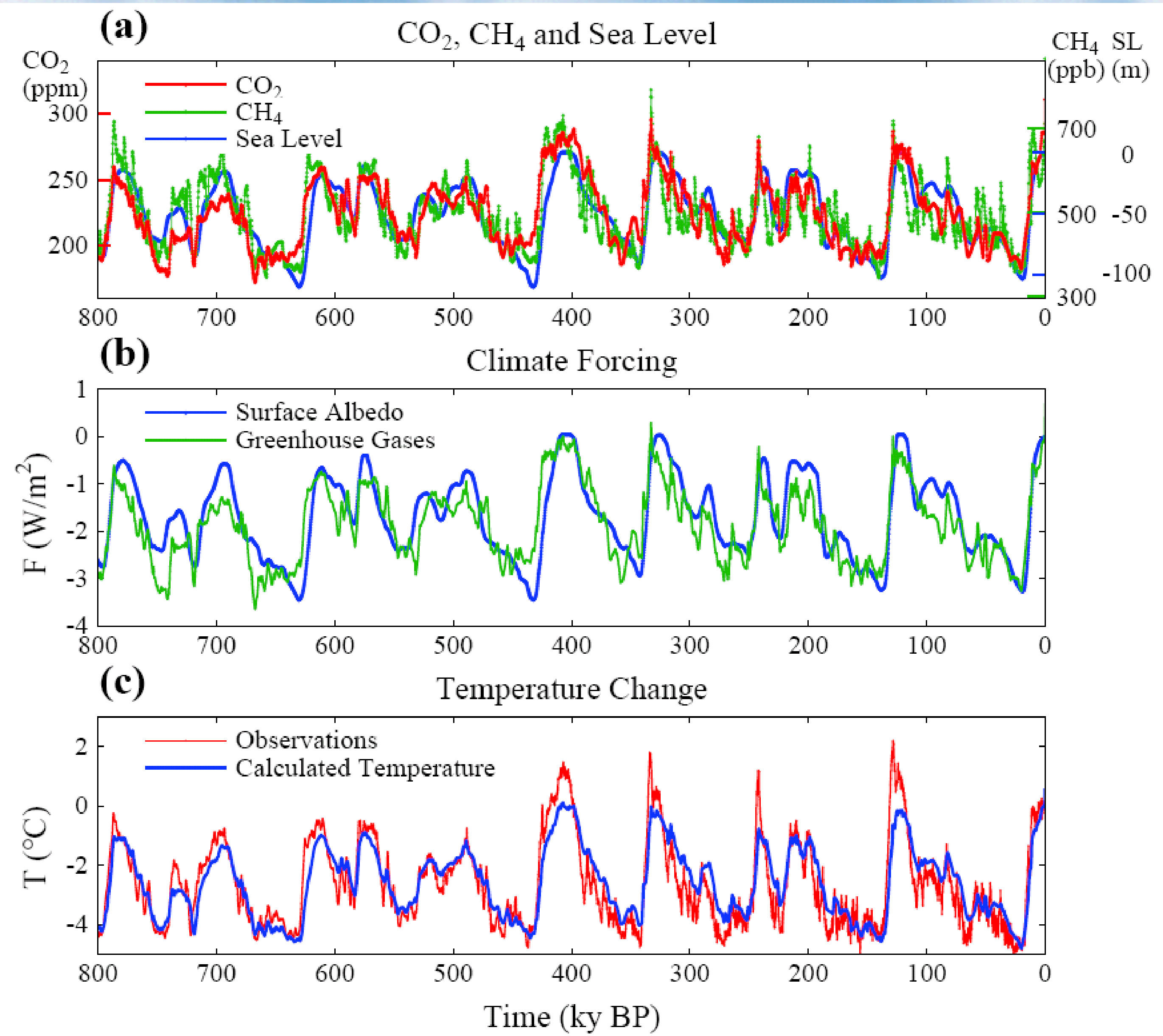
A concentração de oxigênio está diminuindo

Composição isotópica mostra aumento de carbono fóssil

CO_2 atmosférico e nos oceanos



800.000 anos de história climática



(a) CO_2, CH_4 e nivel 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 ¾°C por W/m^2.

Jim Hanssen, NASA GISS

Absorção Infravermelha de radiação por gases de efeito estufa

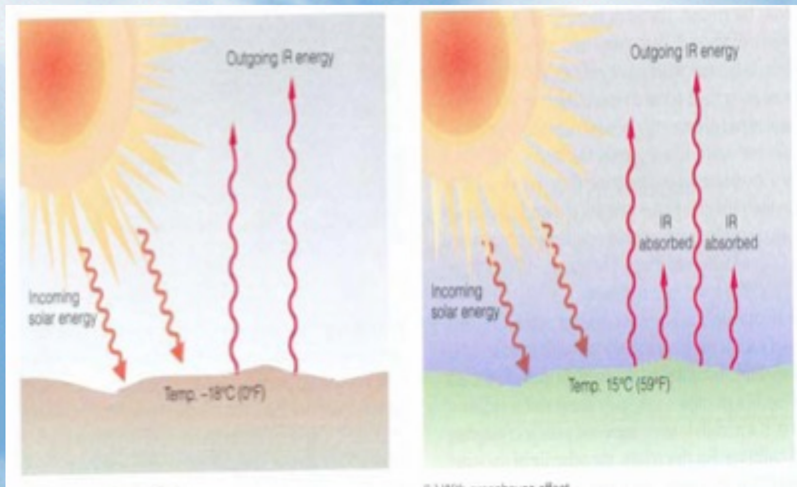


TABLE 1.1 Composition of the Atmosphere Near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
Gas	Symbol	Percent (by Volume) Dry Air	Gas (and Particles)	Symbol	Percent (by Volume)	Parts per Million (ppm)*
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.036	365*
Argon	Ar	0.93	Methane	CH_4	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium	He	0.0005	Ozone	O_3	0.000004	0.04**
Hydrogen	H_2	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO_2, 365 parts per million means that out of every million air molecules, 365 are CO_2 molecules.

**Stratospheric values are about 5 to 12 ppm.

Trace gases

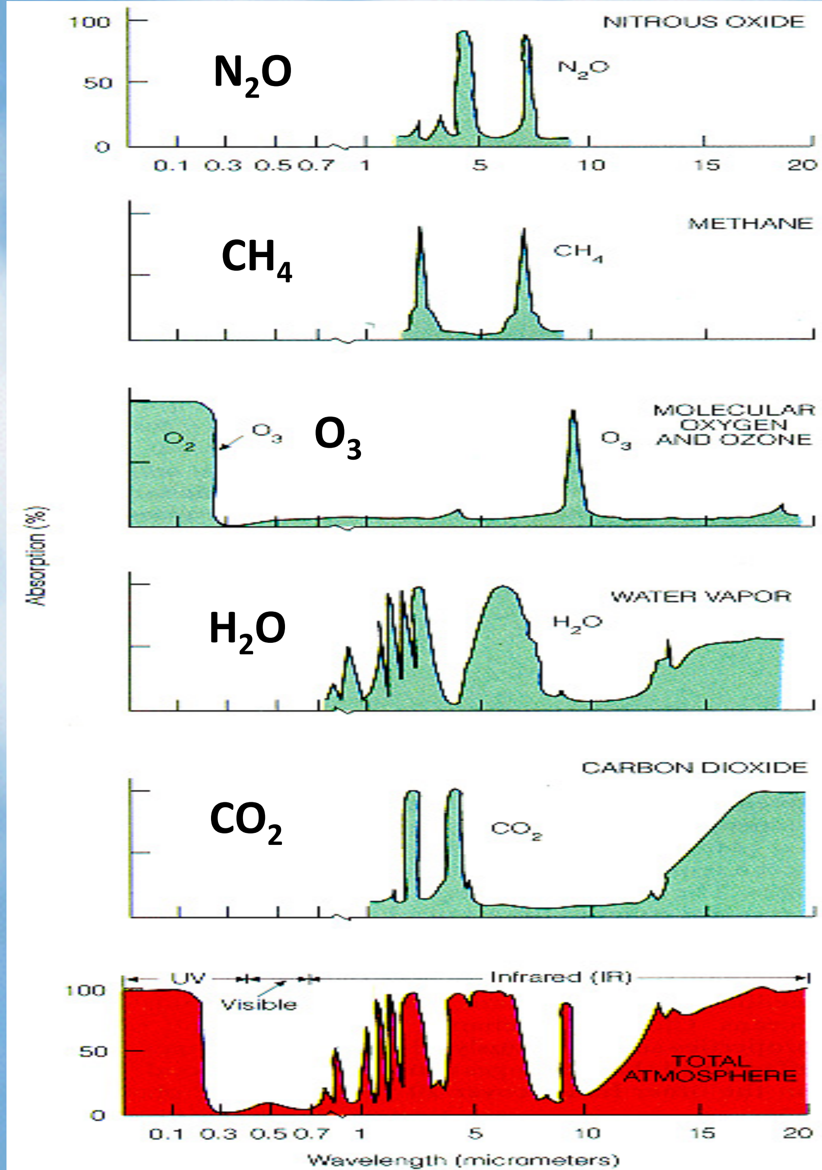


FIGURE 2.10
Absorption of radiation by gases in the atmosphere.

Em 1896, a primeira previsão climática de Svante Arrhenius


Arrhenius

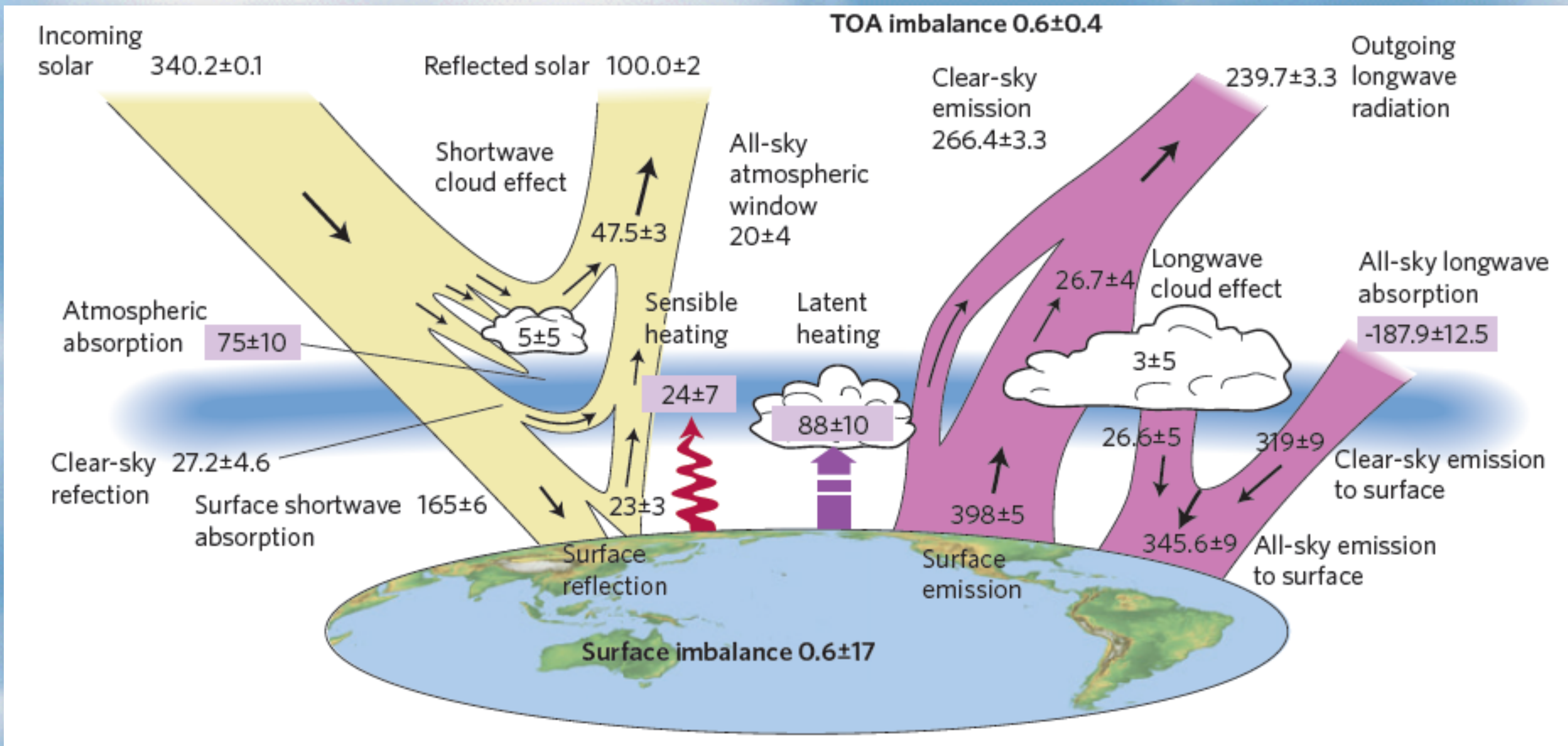
- Arrhenius quantifies in 1896 the changes in surface temperature (approx. 5 C) to be expected from a doubling in CO_2, based on the concept of "glass bowl" effect introduced in 1824 by Joseph Fourier

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 (CO_2)	280	365	variable	fossil fuels, cement production, land use change	1
Methane (CH_4)	0,7	1,75	12	fossil fuels, rice paddies waste dumps, livestock	23
Nitrous oxide (N_2O)	0,27	0,31	114	fertilizers, combustion industrial processes	296
HFC 23 (CHF_3)	0	0,000014	260	electronics, refrigerants	12 000
HFC 134 a (CF_3CH_2F)	0	0,0000075	13,8	refrigerants	1 300
HFC 152 a (CH_3CHF_2)	0	0,0000005	1,4	industrial processes	120
Perfluoromethane (CF_4)	0,00004	0,00008	> 50 000	aluminium production	5 700
Perfluoroethane (C_2F_6)	0	0,000003	10 000	aluminium production	11 900
Sulphur hexafluoride (SF_6)	0	0,0000042	3 200	dielectric fluid	22 200

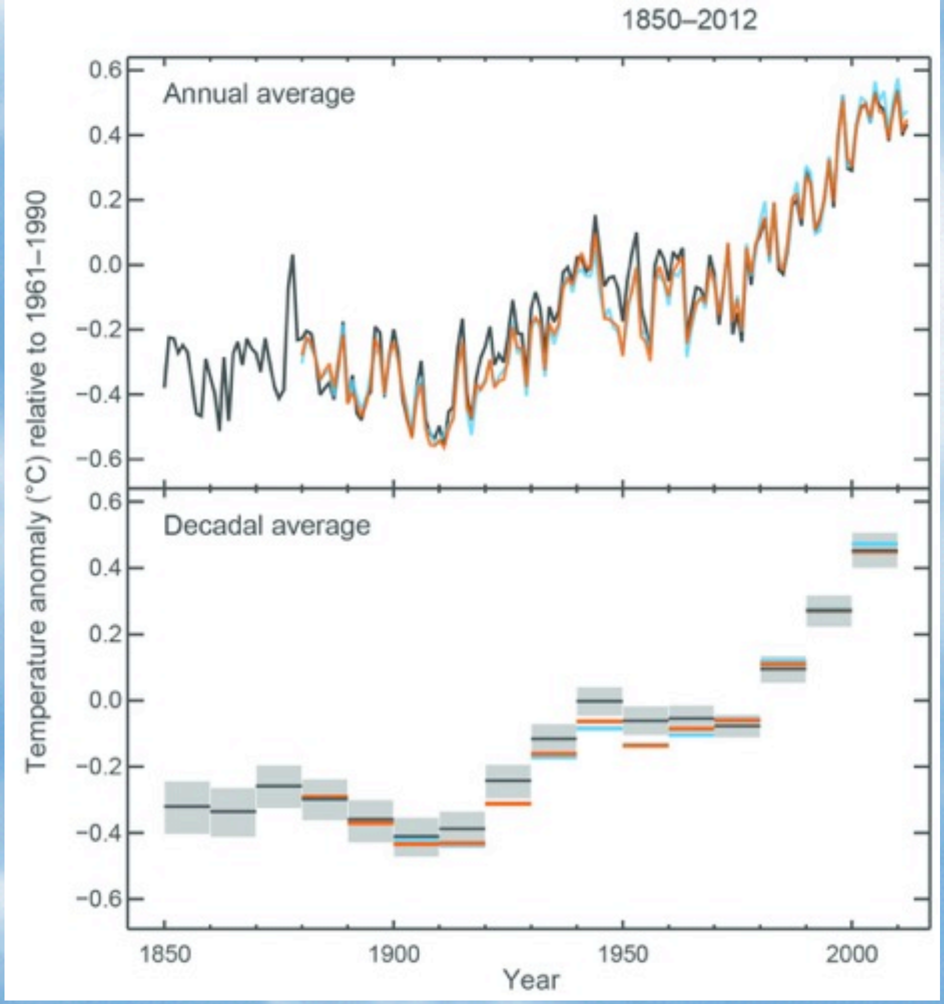
GWP Global Warming Potential – 100 anos

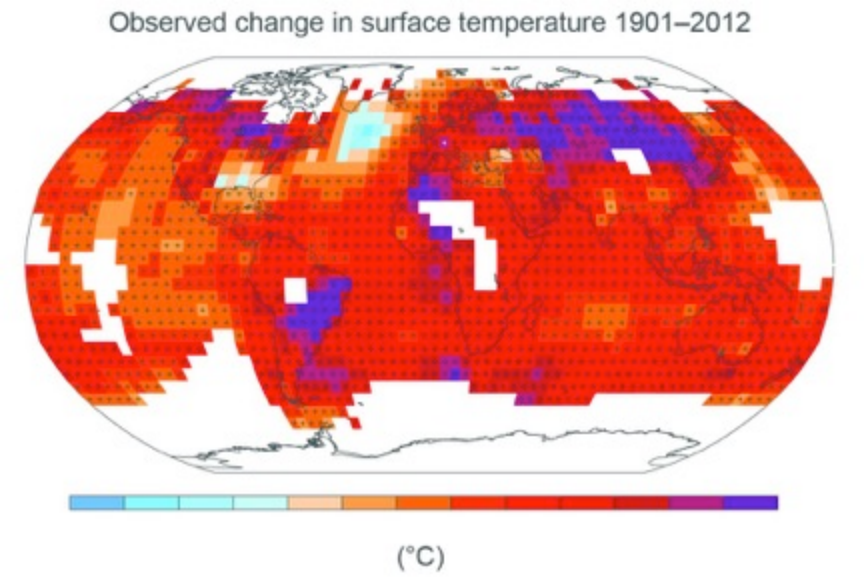
O balanço de energia global de nosso planeta



Fluxos em Wm^{-2}. Fluxo solar em amarelo e terrestre em rosa.
Desbalanço: 0.6 w/m^2 (Stephens, Nature 2012)

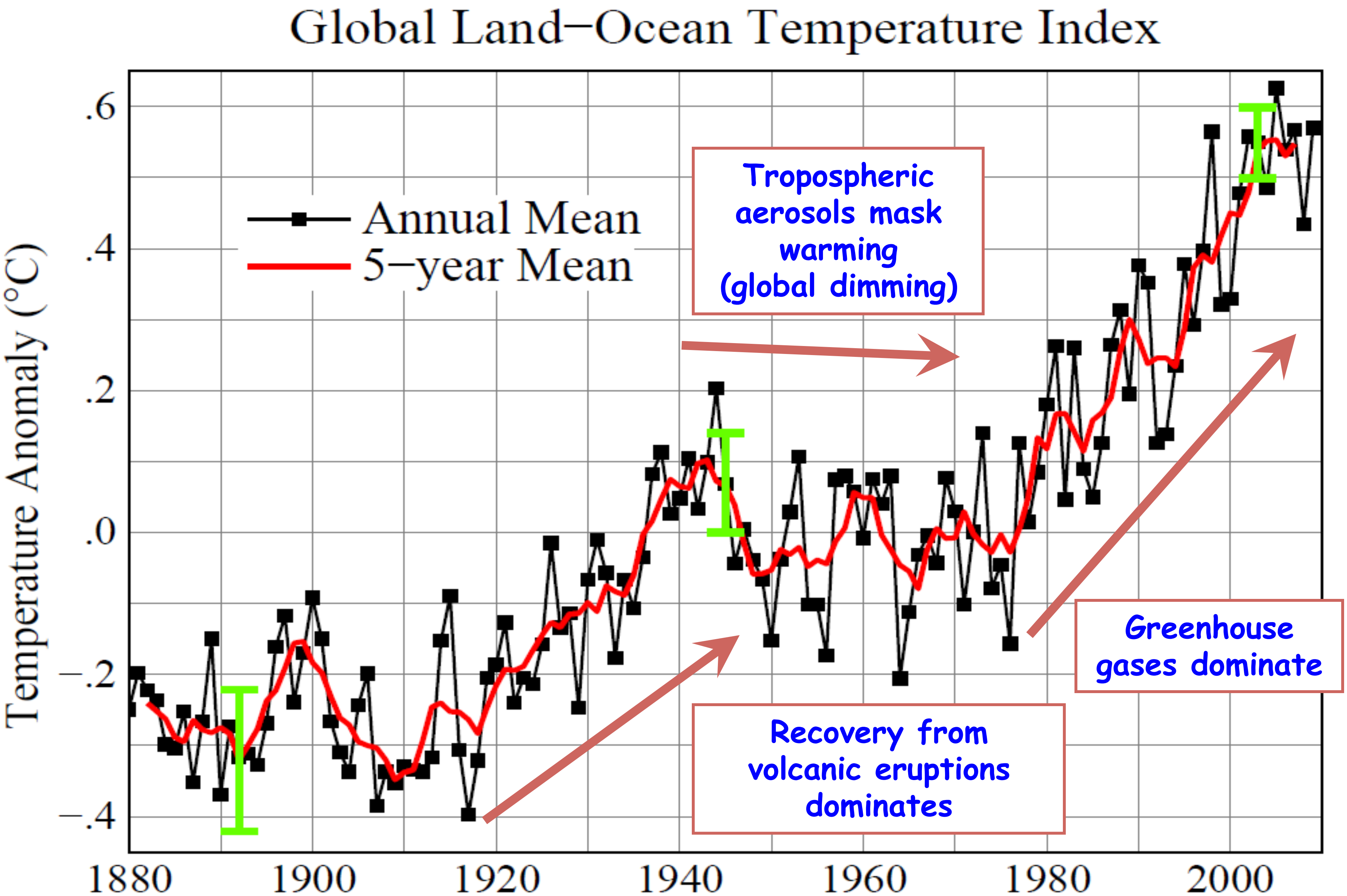
Aumento médio da temperatura observado de 1850-2012: 1.0 °C





Distribuição espacial

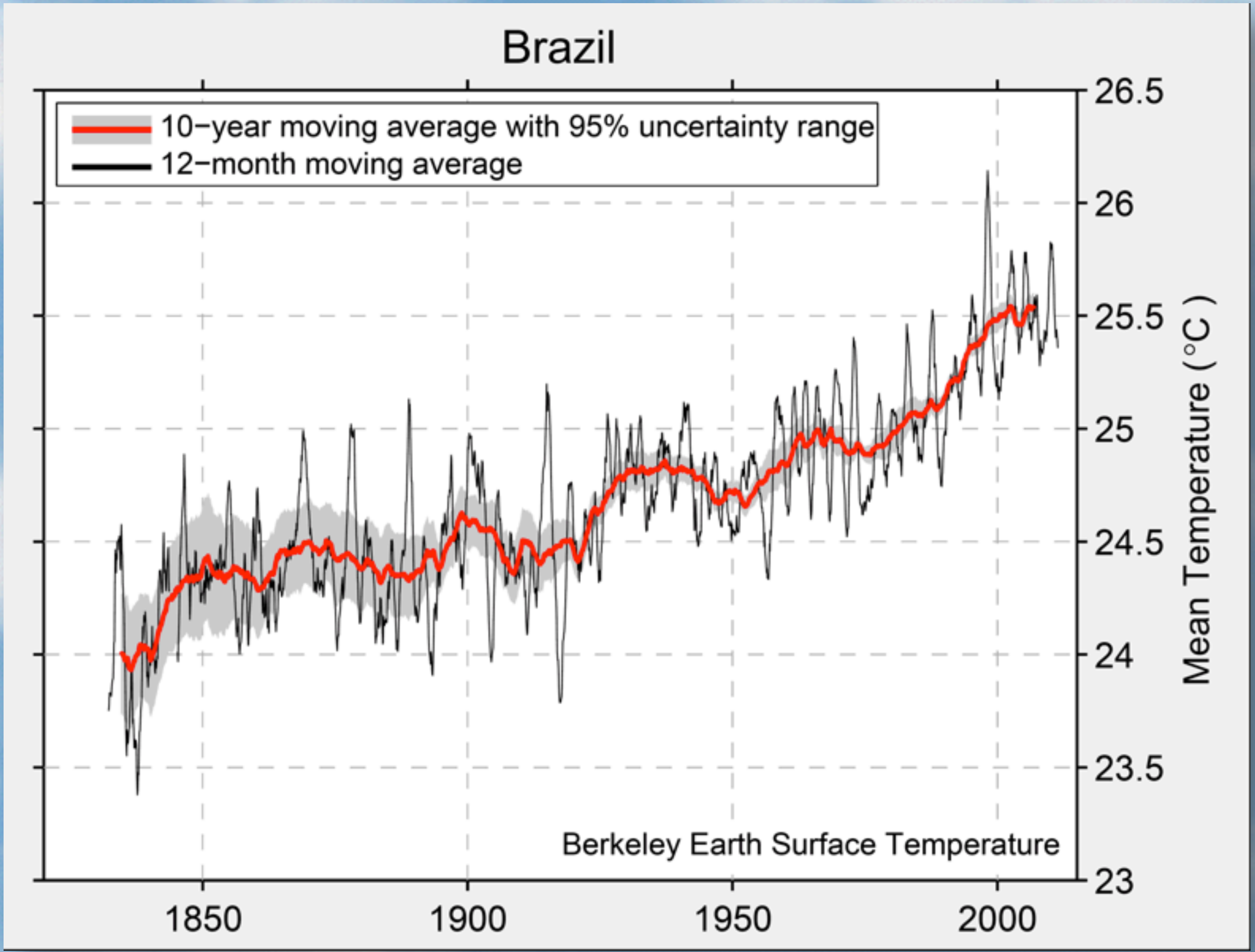
IPCC AR5 2013



Aerosols (and greenhouse gases) dominate the temperature change

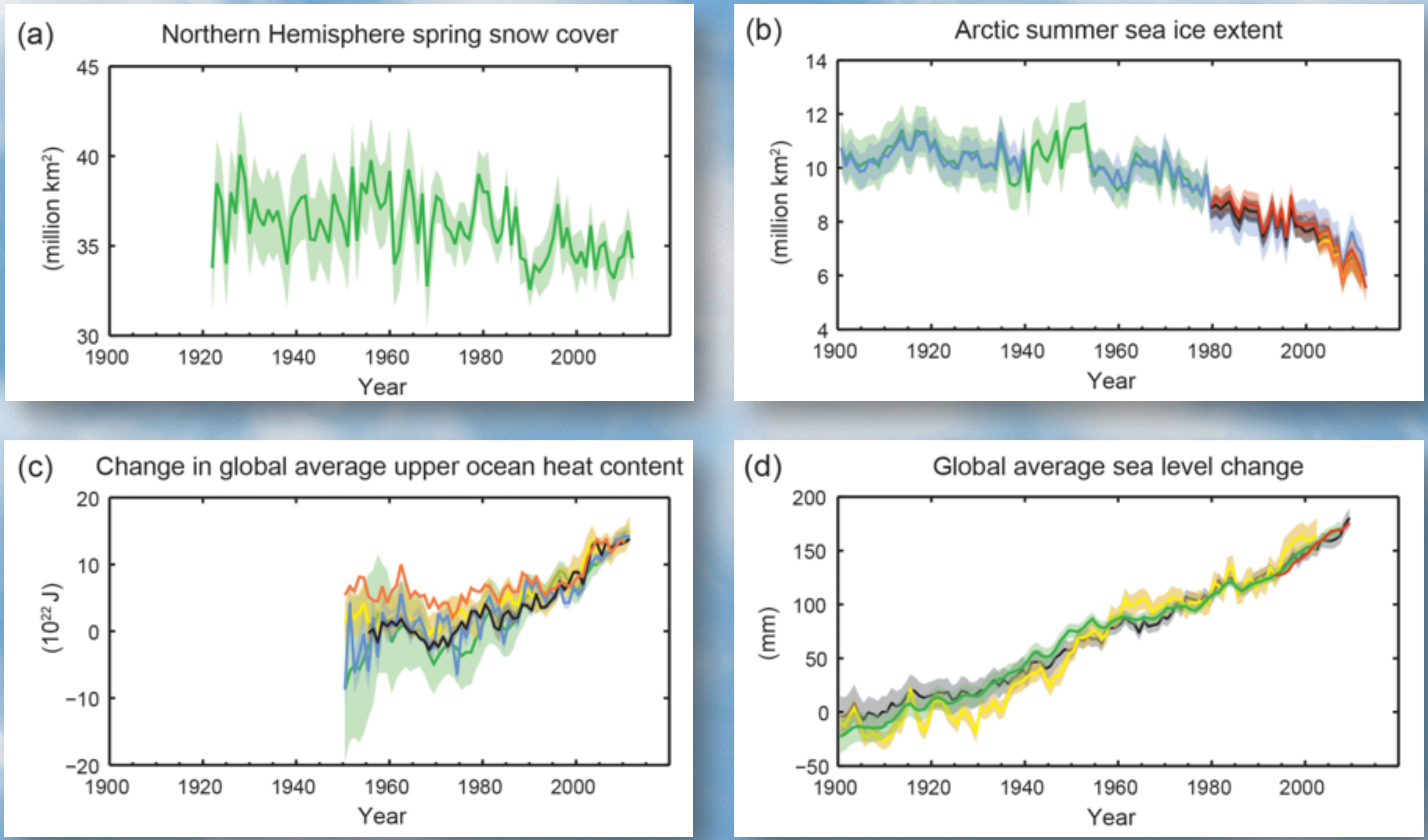
Aumento da temperatura média no Brasil

1.5 C



http://berkeleyearth.org/

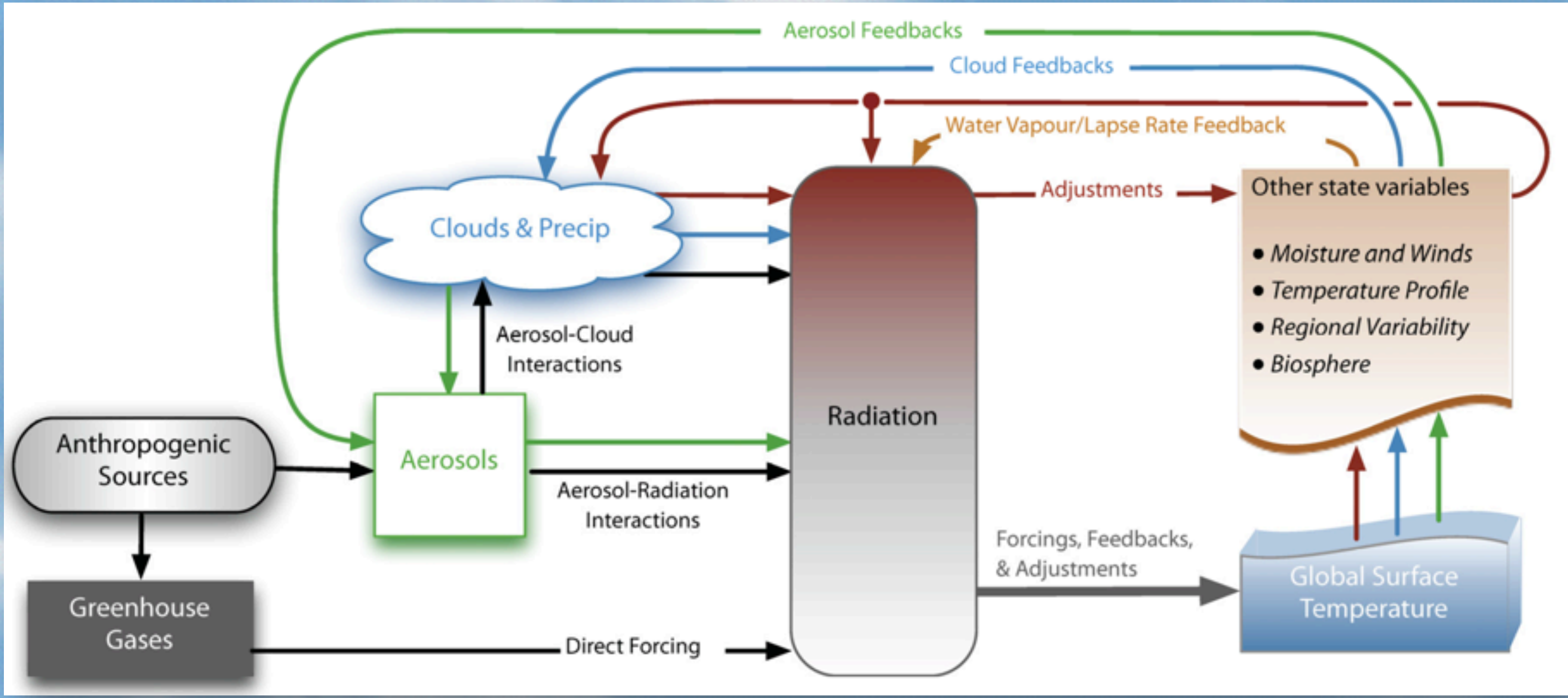
Múltiplos indicadores observados de um clima em mudança



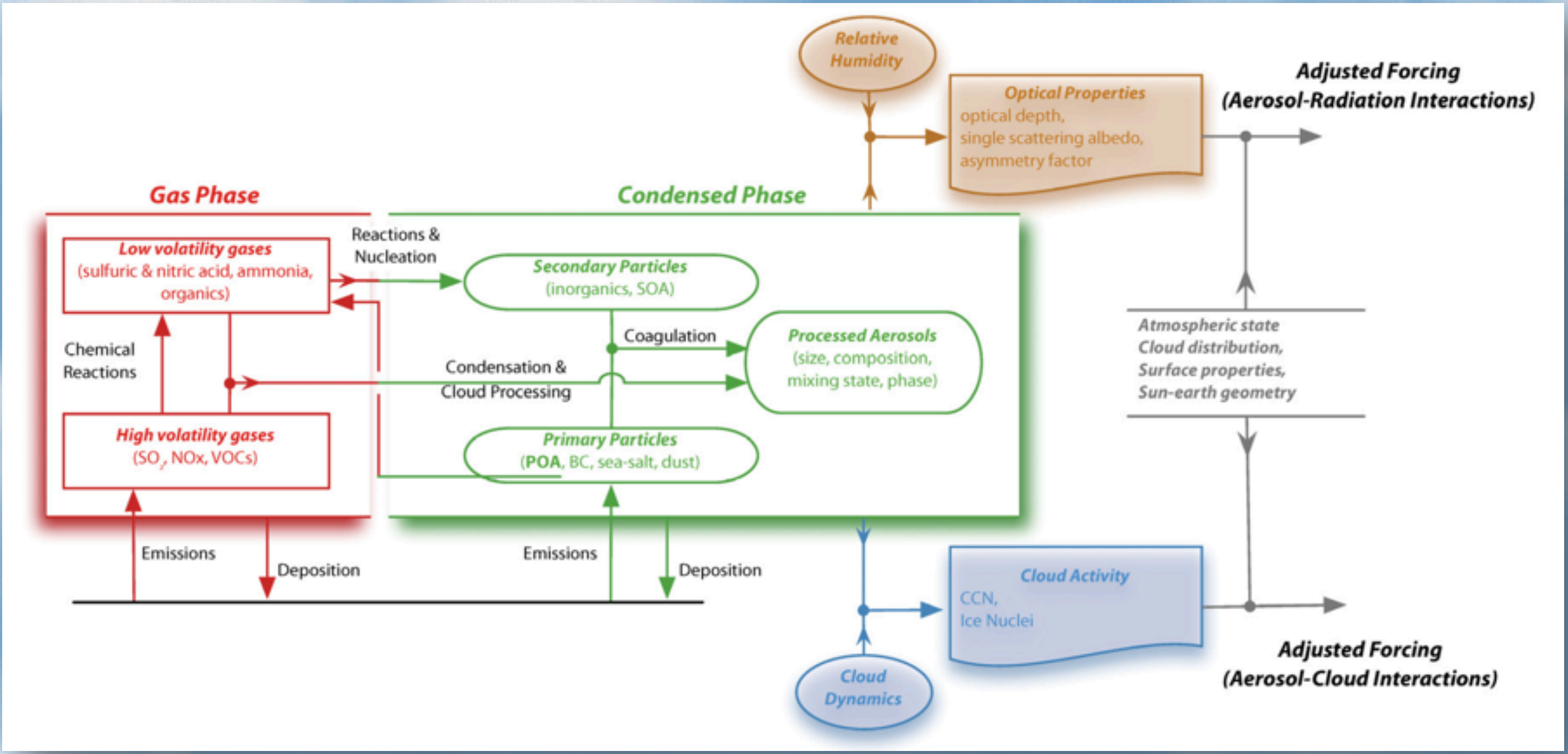
IPCC AR5 Fig. SPM3

Overview of feedback and forcing pathways involving clouds and aerosols

Forcing mechanisms are represented by black arrows; forcing agents are boxes with grey shadows, rapid forcing adjustments (also called rapid responses) are shown with brown arrows and feedbacks are other-coloured arrows.



Gases, aerossóis e nuvens: um sistema integrado impossível de separar

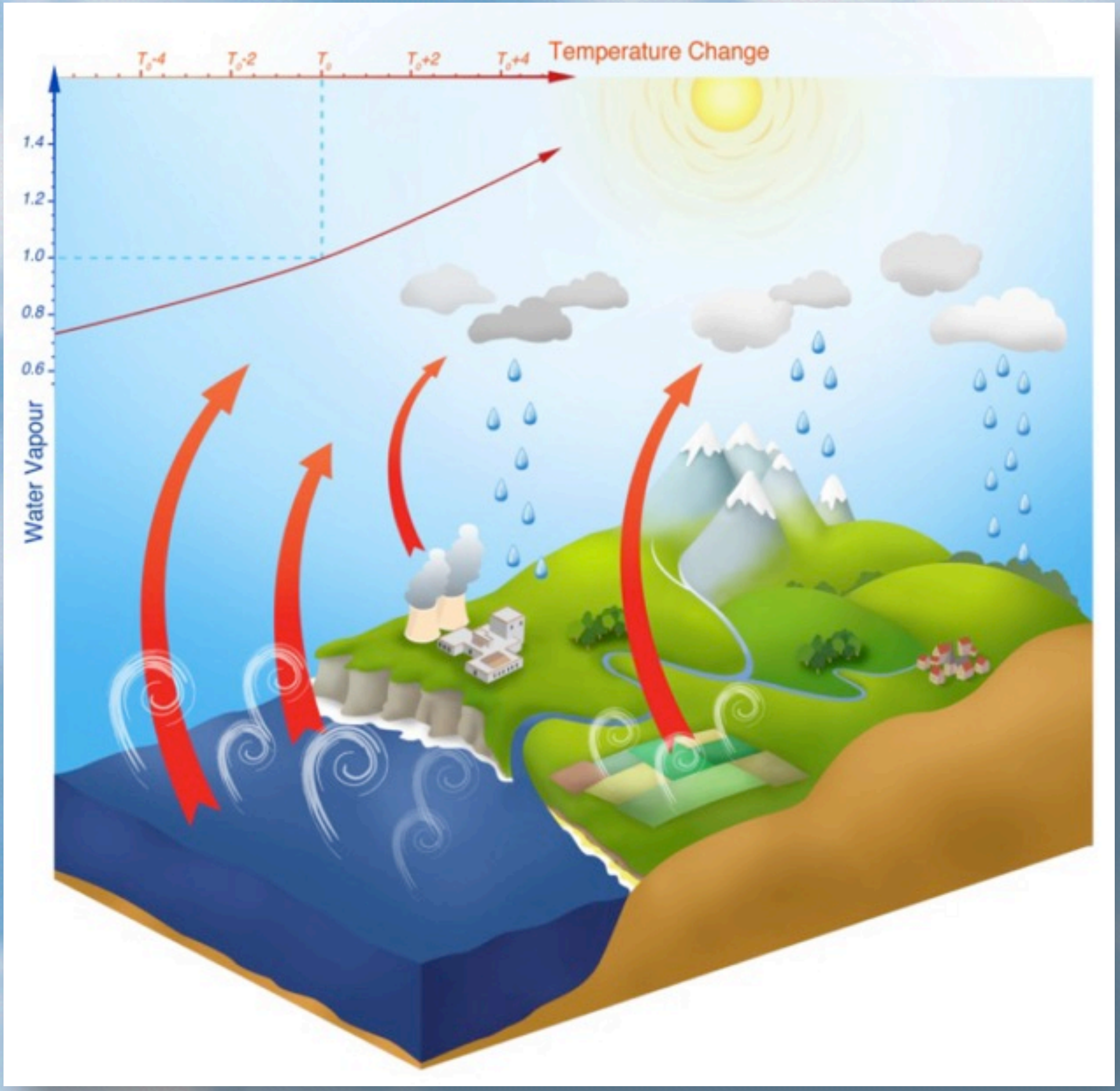


Overview of atmospheric aerosol processes and environmental variables influencing aerosol-radiation and aerosol-cloud interactions. Although this figure shows a linear chain of processes from aerosols to forcings, it is increasingly recognized that aerosols and clouds form a coupled system with two-way interactions

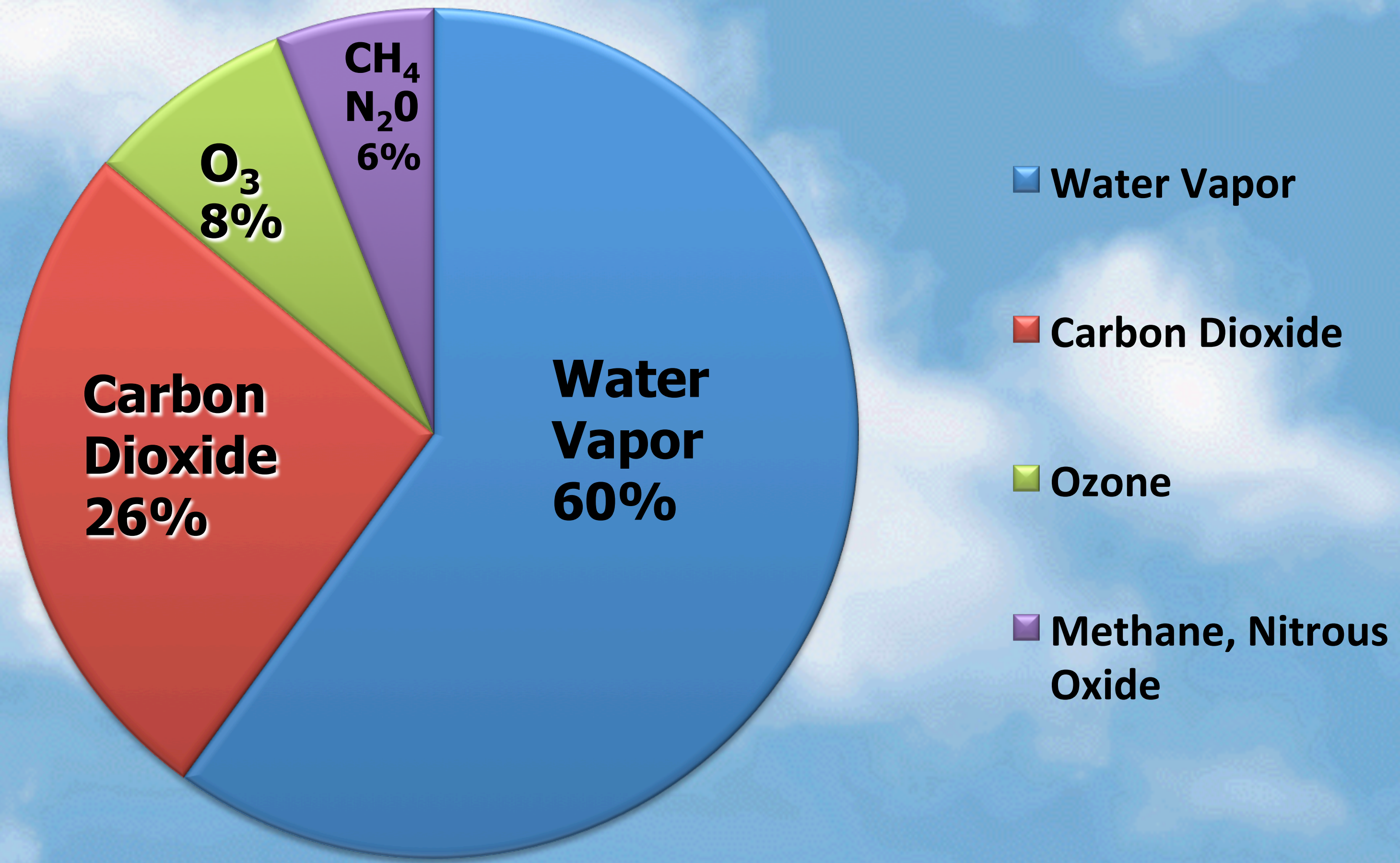
Ciclo da água e sua interação com o efeito estufa

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

7% para cada grau Celcius



The Natural Greenhouse Effect: clear sky

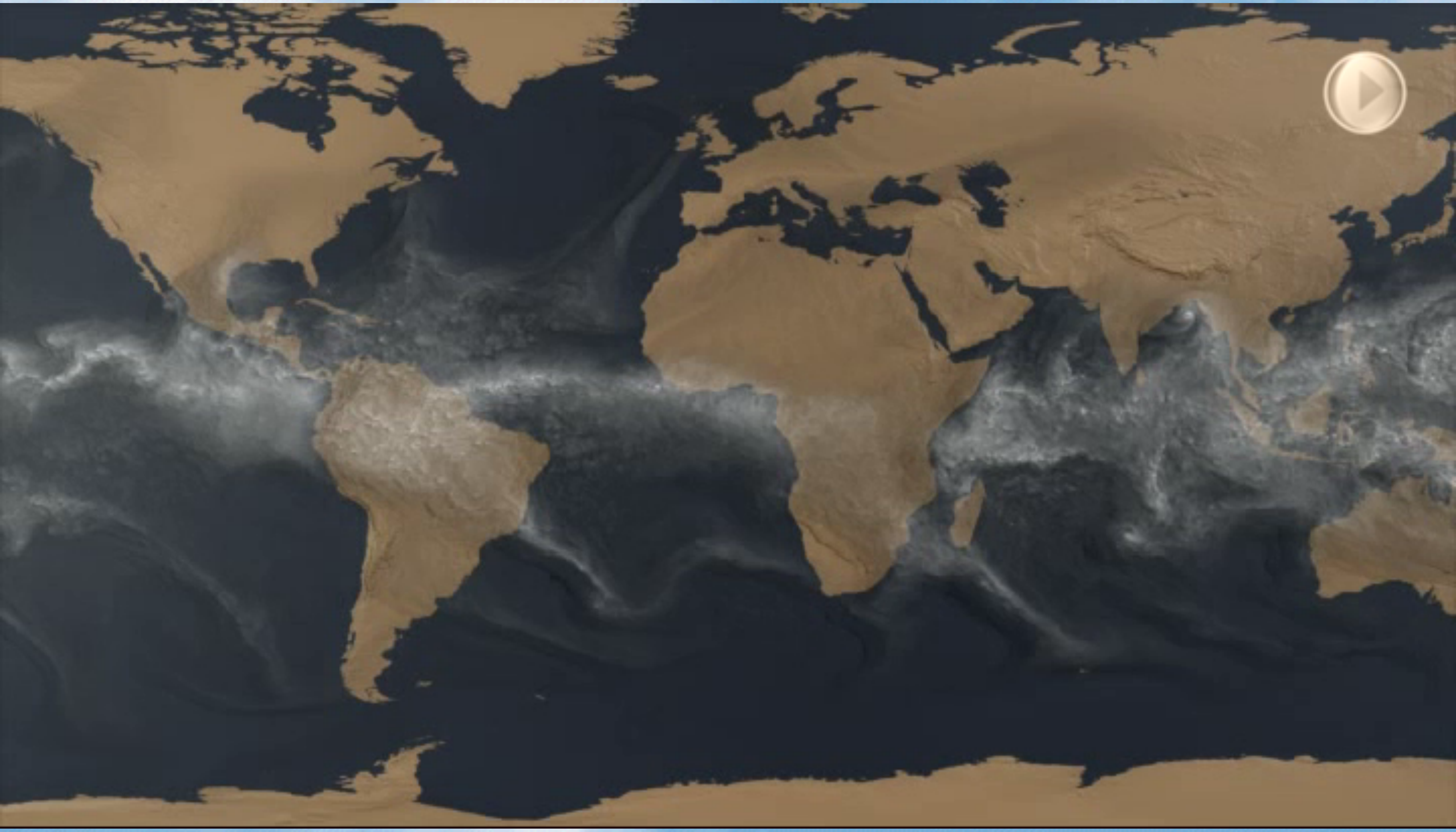


Clouds also have a greenhouse effect

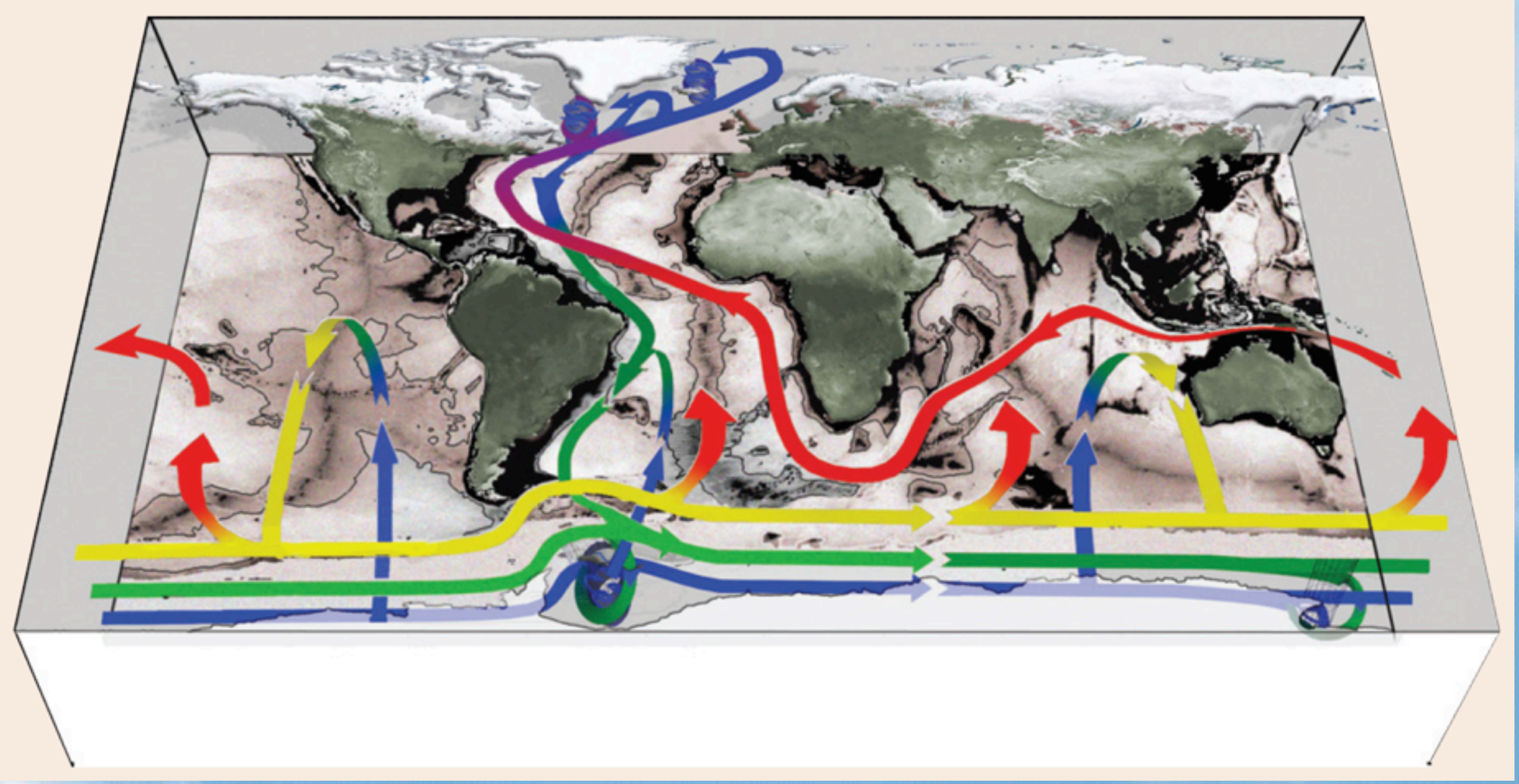
Kiehl and Trenberth 1997


Amazonia is critically important for water vapor transport in South America
30% Amazônia
30% Oceano Atlântico
40% Sul do Brasil
Araut et al., 2012
Image NASA
Google

Distribuição de umidade global



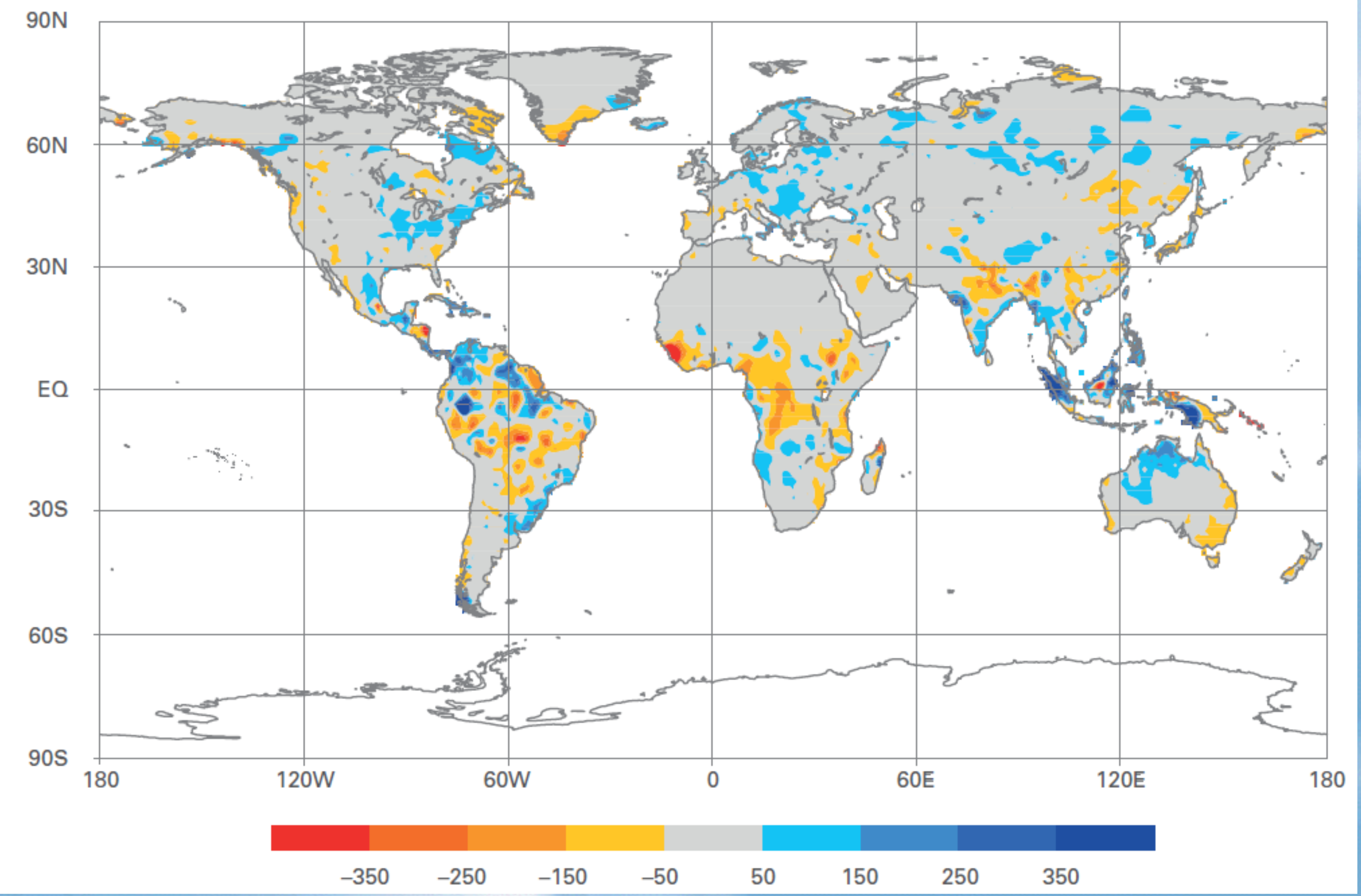
Circulação oceânica global: Redistribuição de energia



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.

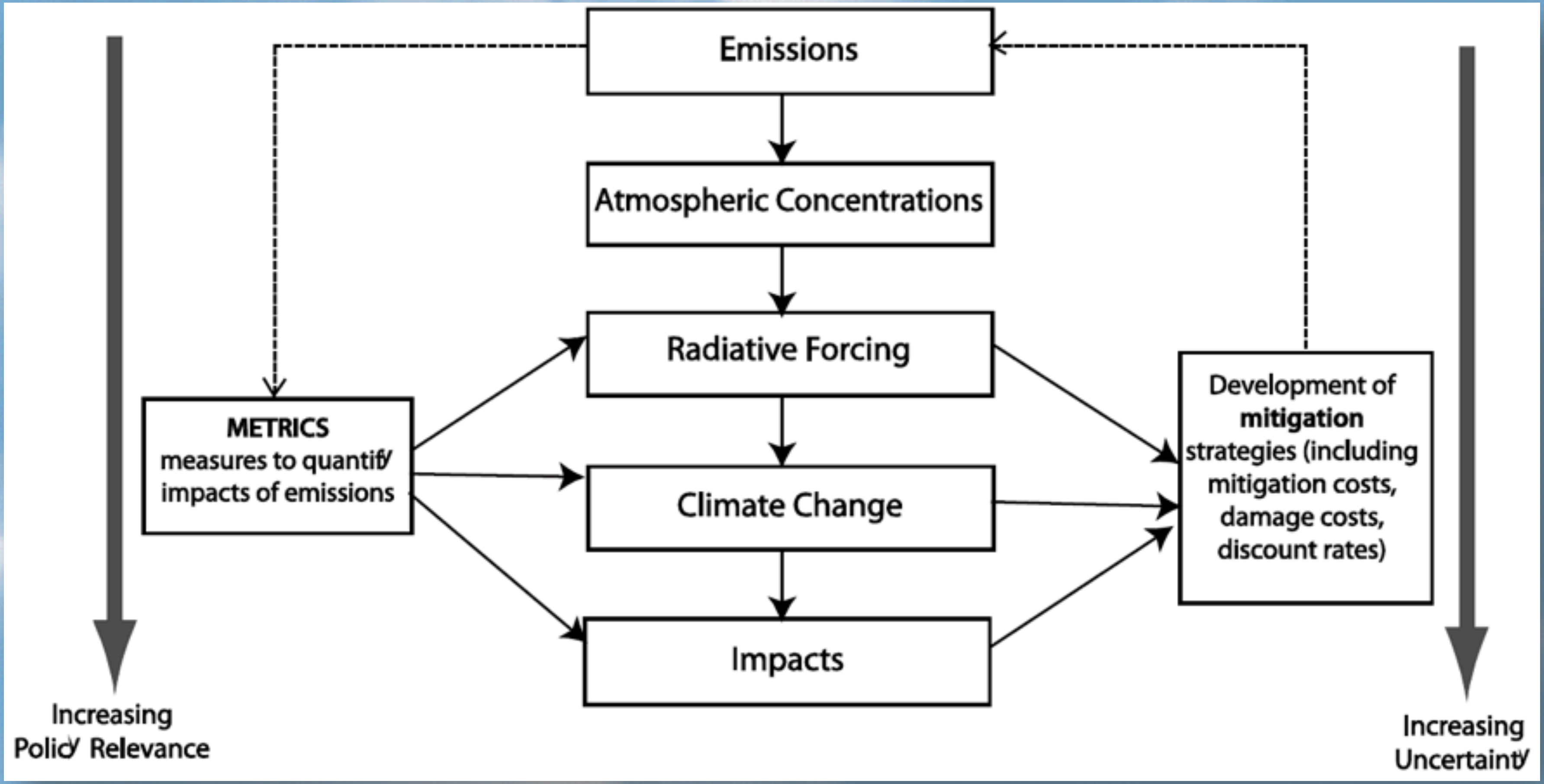
Marshall and Speer Nature Review, 2012

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

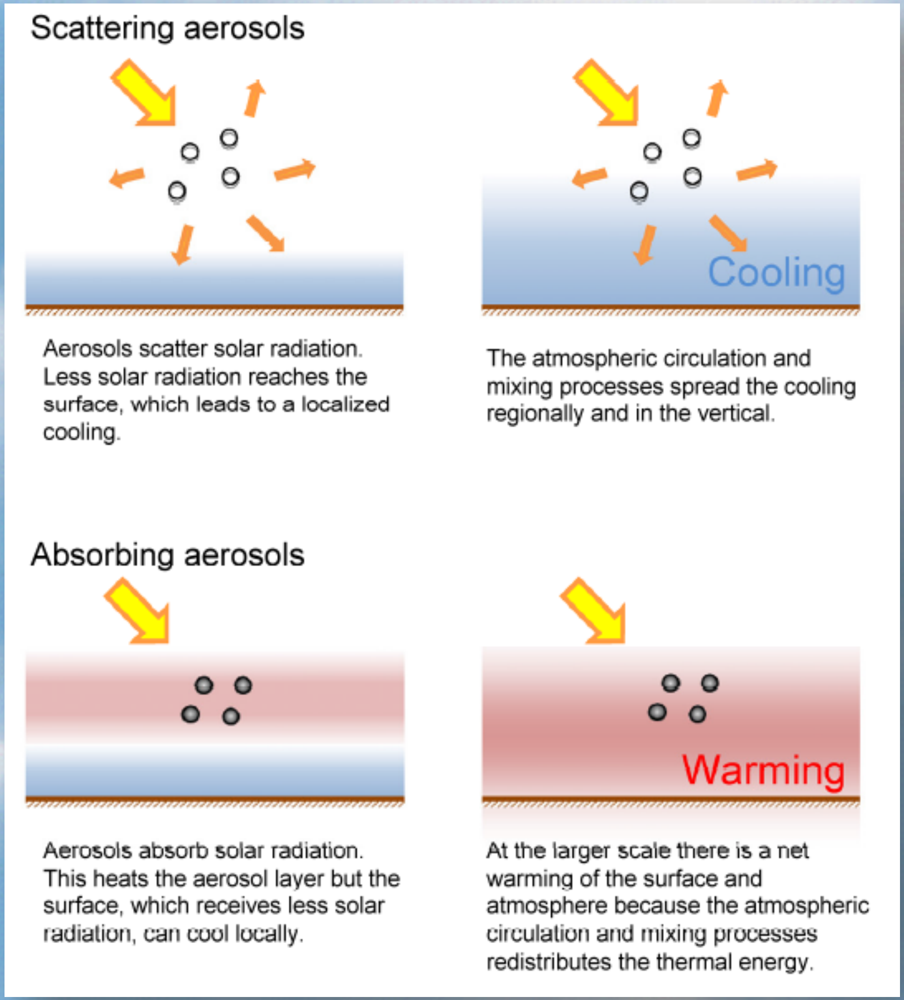


What is Radiative Forcing?

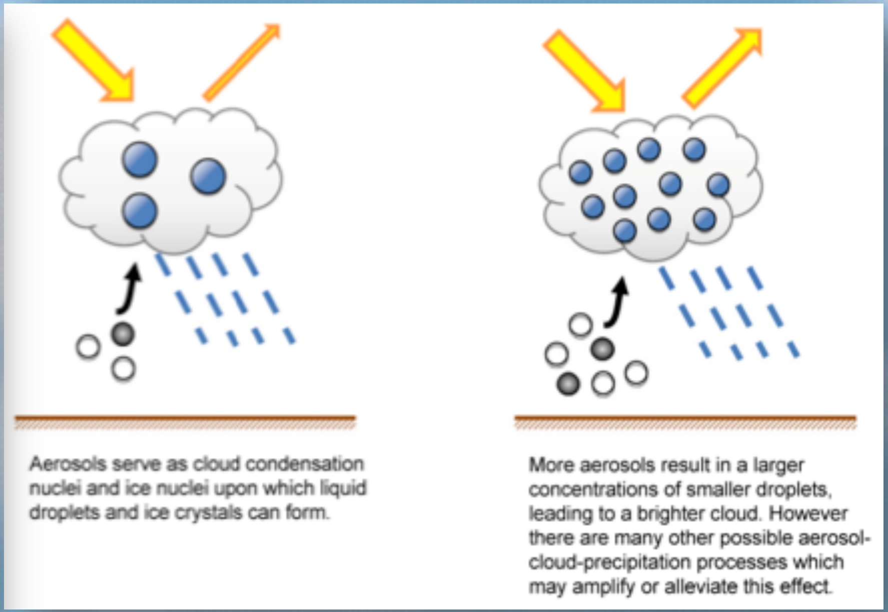
- Change in energy flux caused by natural or anthropogenic drivers of climate change (in W/m^2)
- Positive: near-surface warming
- Puts various drivers on common scale, indicates magnitude of impact
- Includes rapid adjustments (e.g. cloud formation on aerosols)
- Stratospheric temperature adjustment included in TAR & AR4 RF; additional adjustments included in Effective RF (ERF)

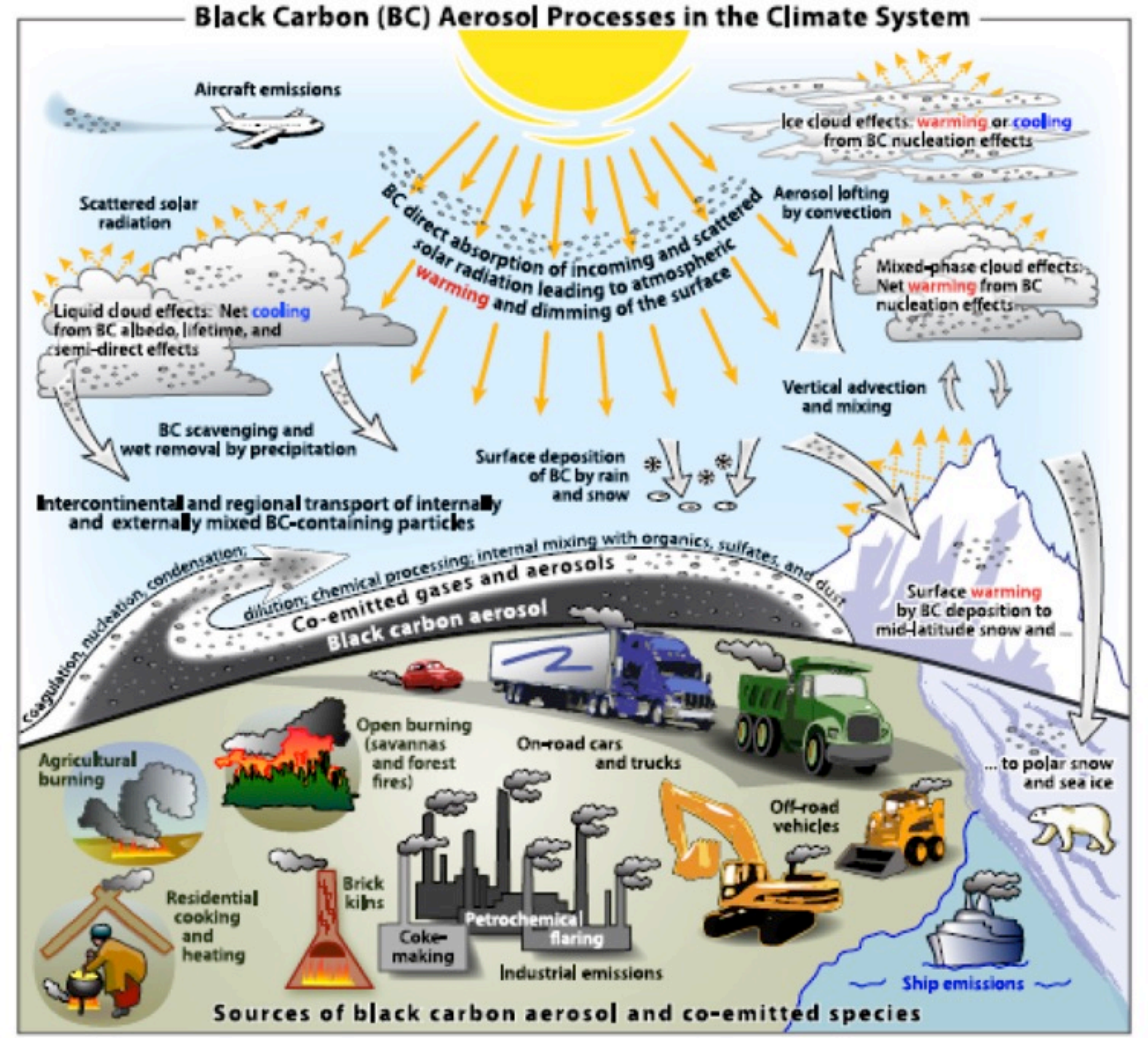


Aerosol-radiation interactions

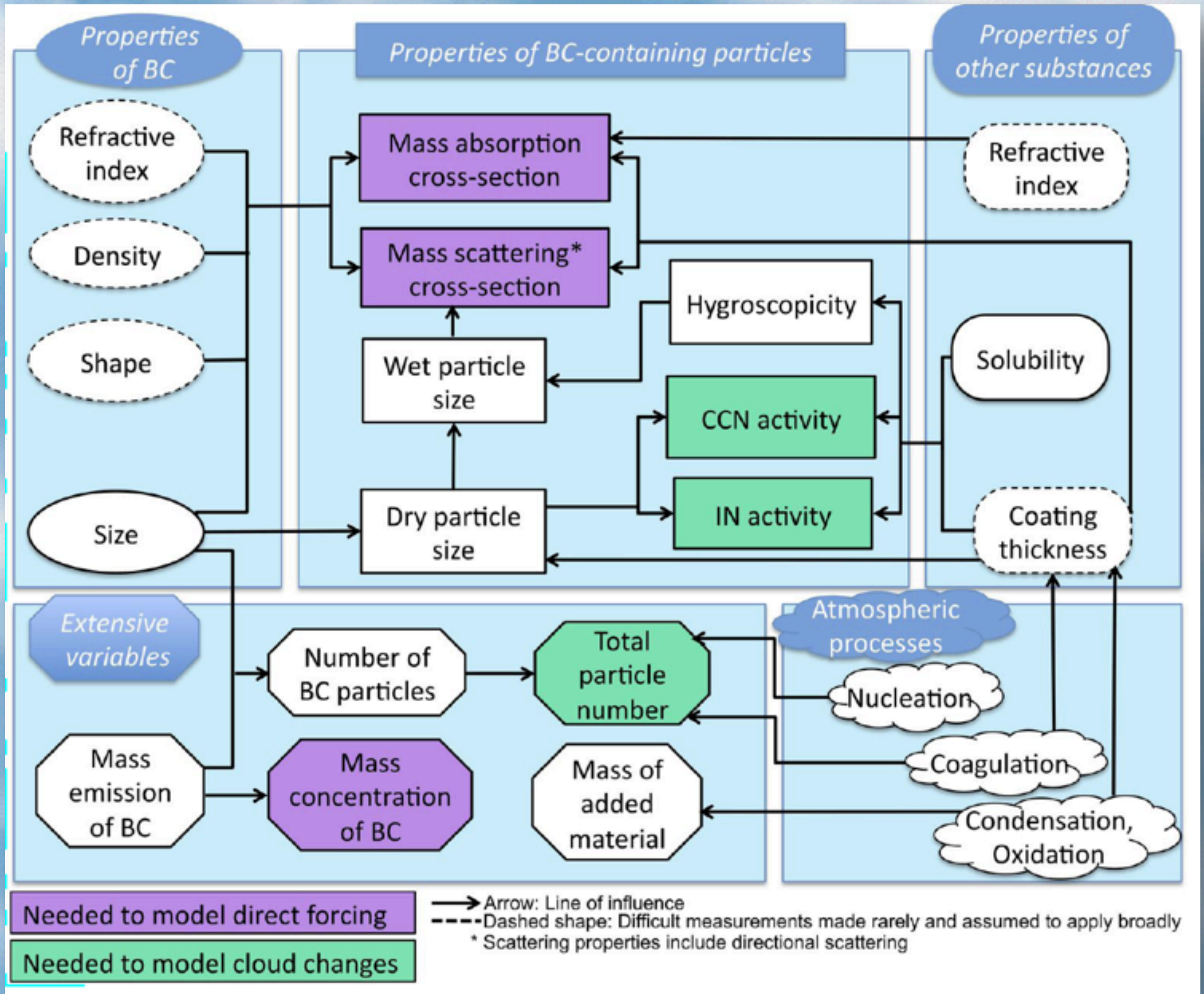


Aerosol-cloud interactions

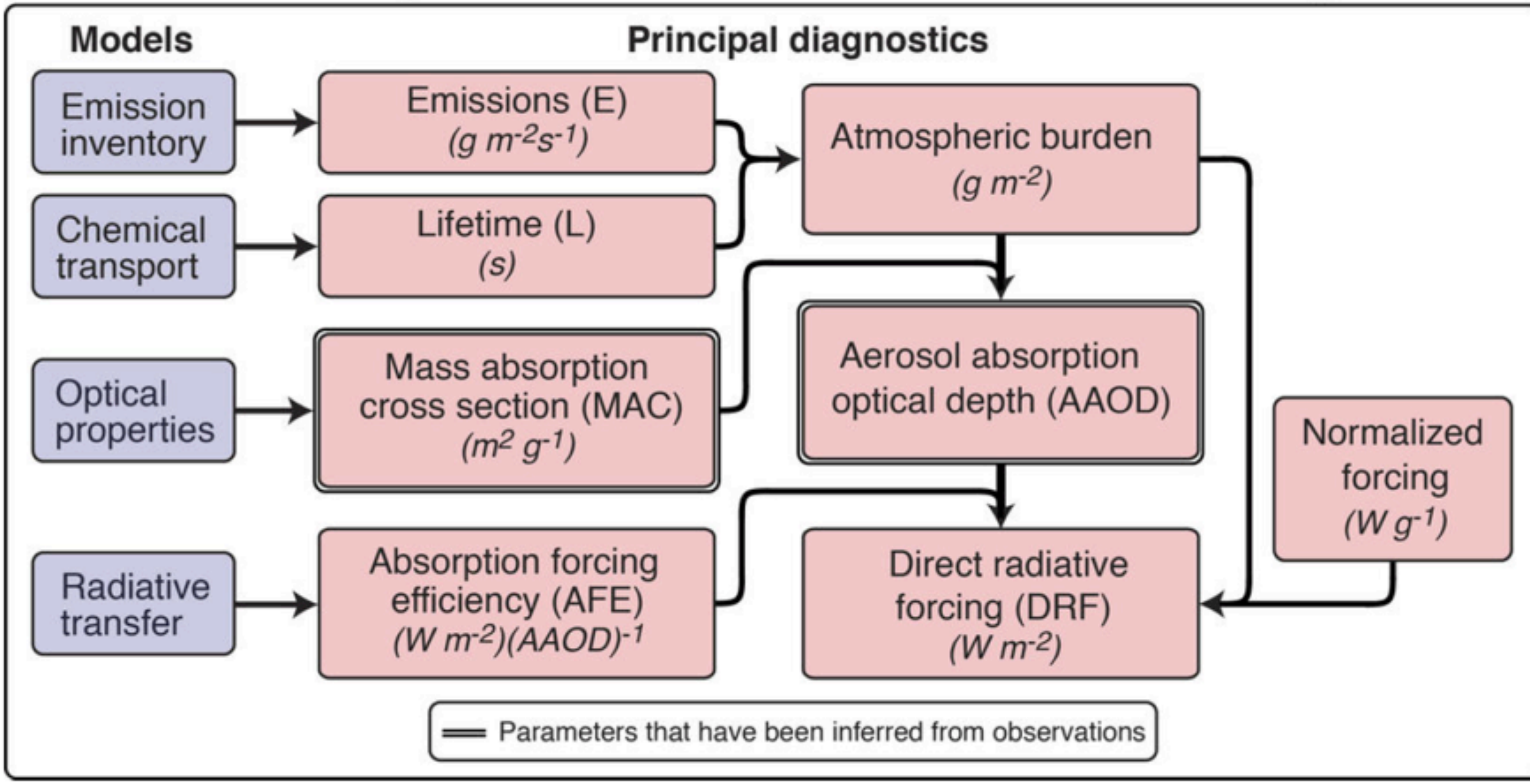



Black Carbon (BC) Aerosol Processes in the Climate System
Aircraft emissions
Ice cloud effects: warming or cooling from BC nucleation effects
Scattered solar radiation
BC direct absorption of incoming and scattered solar radiation leading to atmospheric warming and dimming of the surface
Aerosol lofting by convection
Mixed-phase cloud effects: Net warming from BC nucleation effects
Liquid cloud effects: Net cooling from BC albedo, lifetime, and semi-direct effects
Vertical advection and mixing
BC scavenging and wet removal by precipitation
Surface deposition of BC by rain and snow
Intercontinental and regional transport of internally and externally mixed BC-containing particles
coagulation, nucleation, condensation;
dilution; chemical processing; internal mixing with organics, sulfates, and dust
Co-emitted gases and aerosols
Black carbon aerosol
Surface warming by BC deposition to mid-latitude snow and ...
Open burning (savannas and forest fires)
On-road cars and trucks
Agricultural burning
... to polar snow and sea ice
Off-road vehicles
Residential cooking and heating
Brick kilns
Petrochemical flaring
Coke-making
Industrial emissions
Ship emissions
Sources of black carbon aerosol and co-emitted species

Efeitos de Black Carbon no balanço de radiação e em nuvens



Model diagnostics of black carbon direct radiative forcing

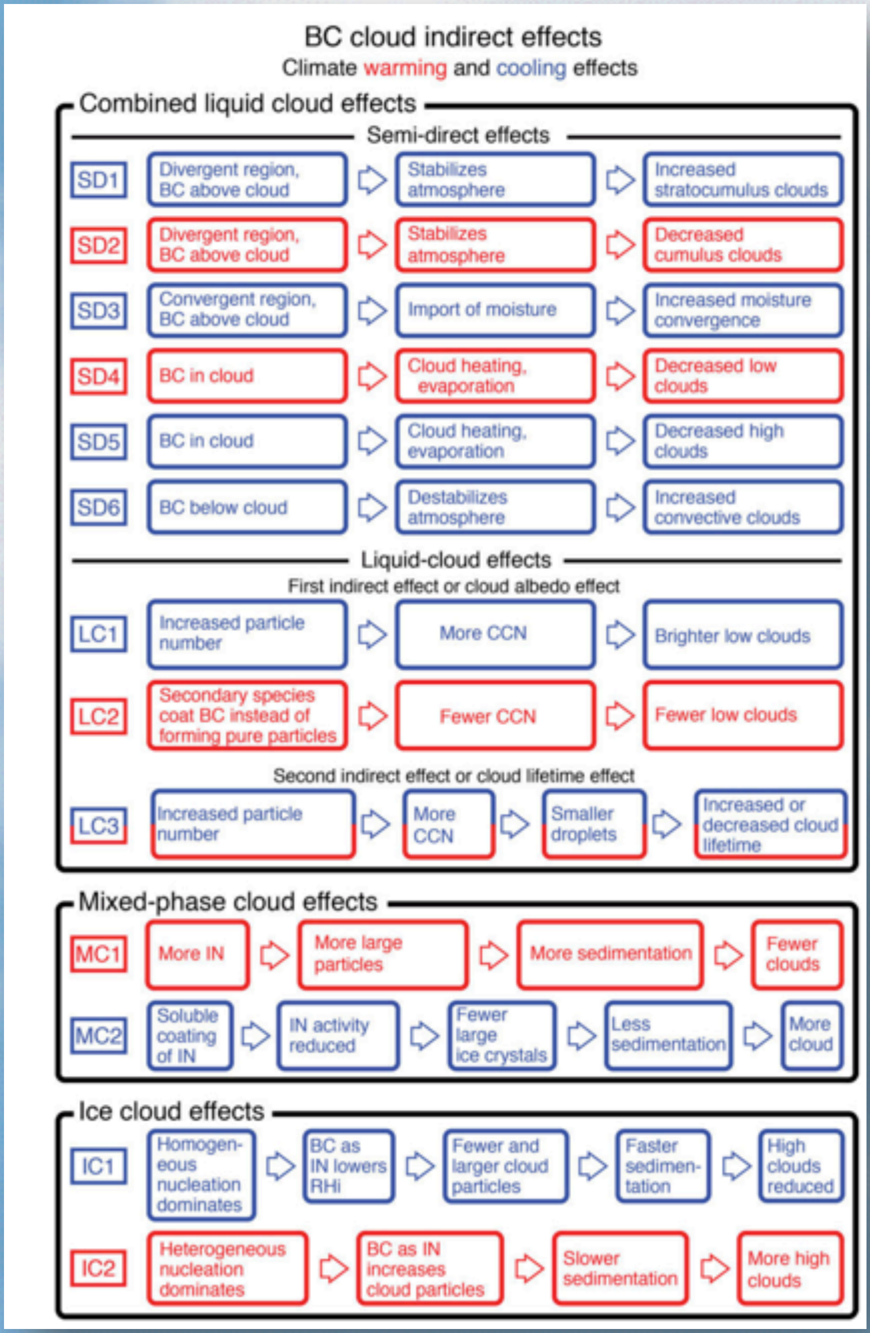


Efeitos de BC nas nuvens: Aquecimento e resfriamento

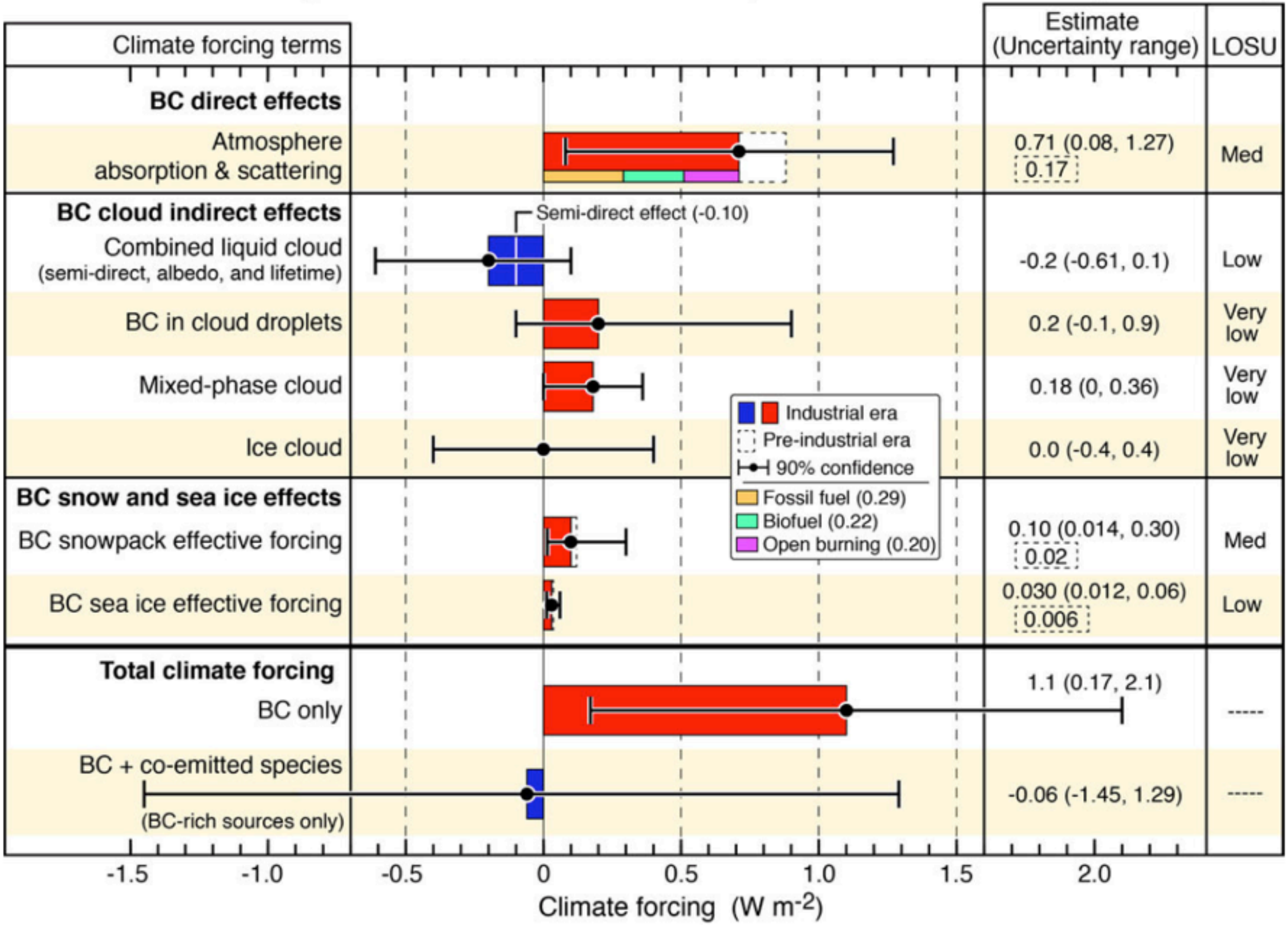
Liquid phase clouds

Mixed phase clouds

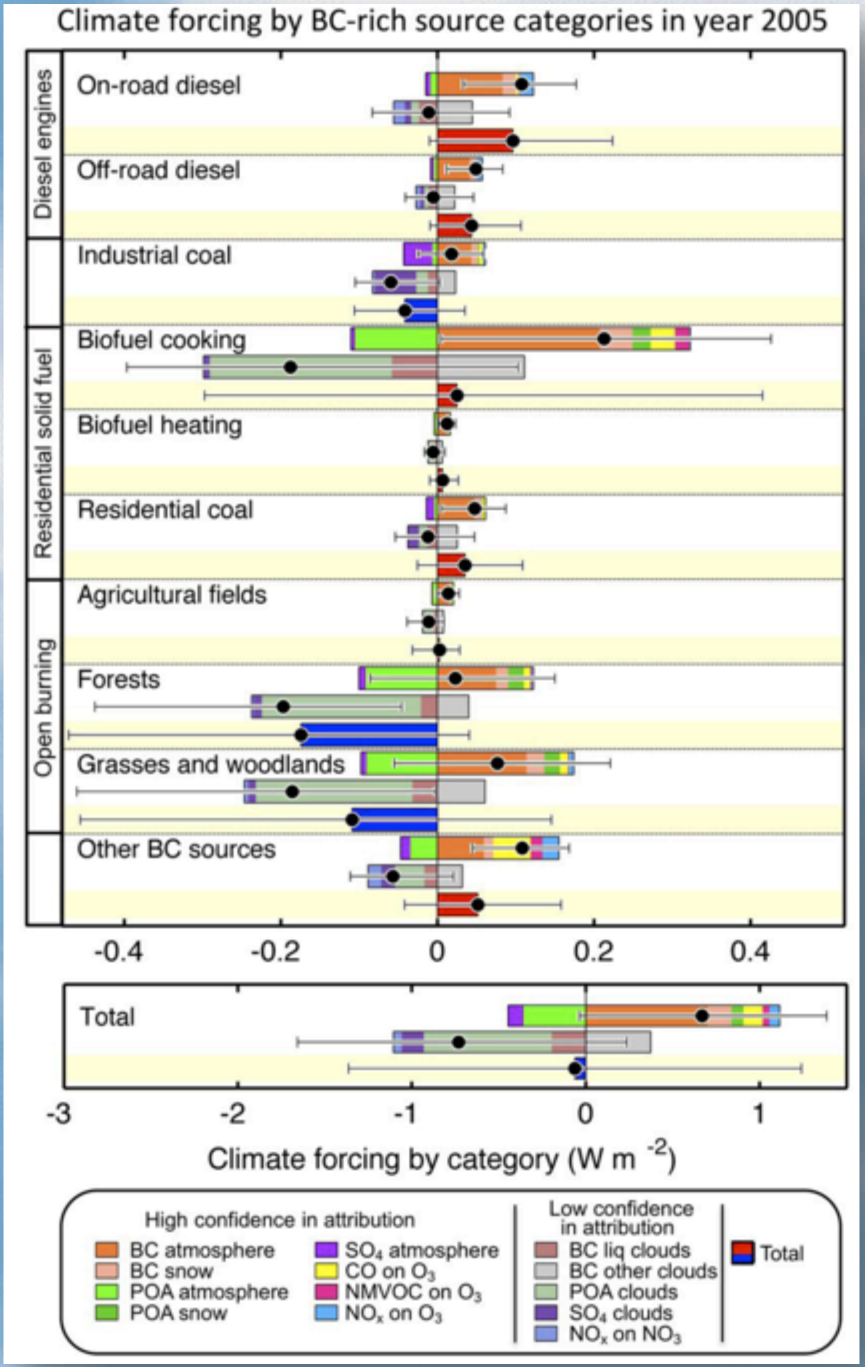
Ice clouds



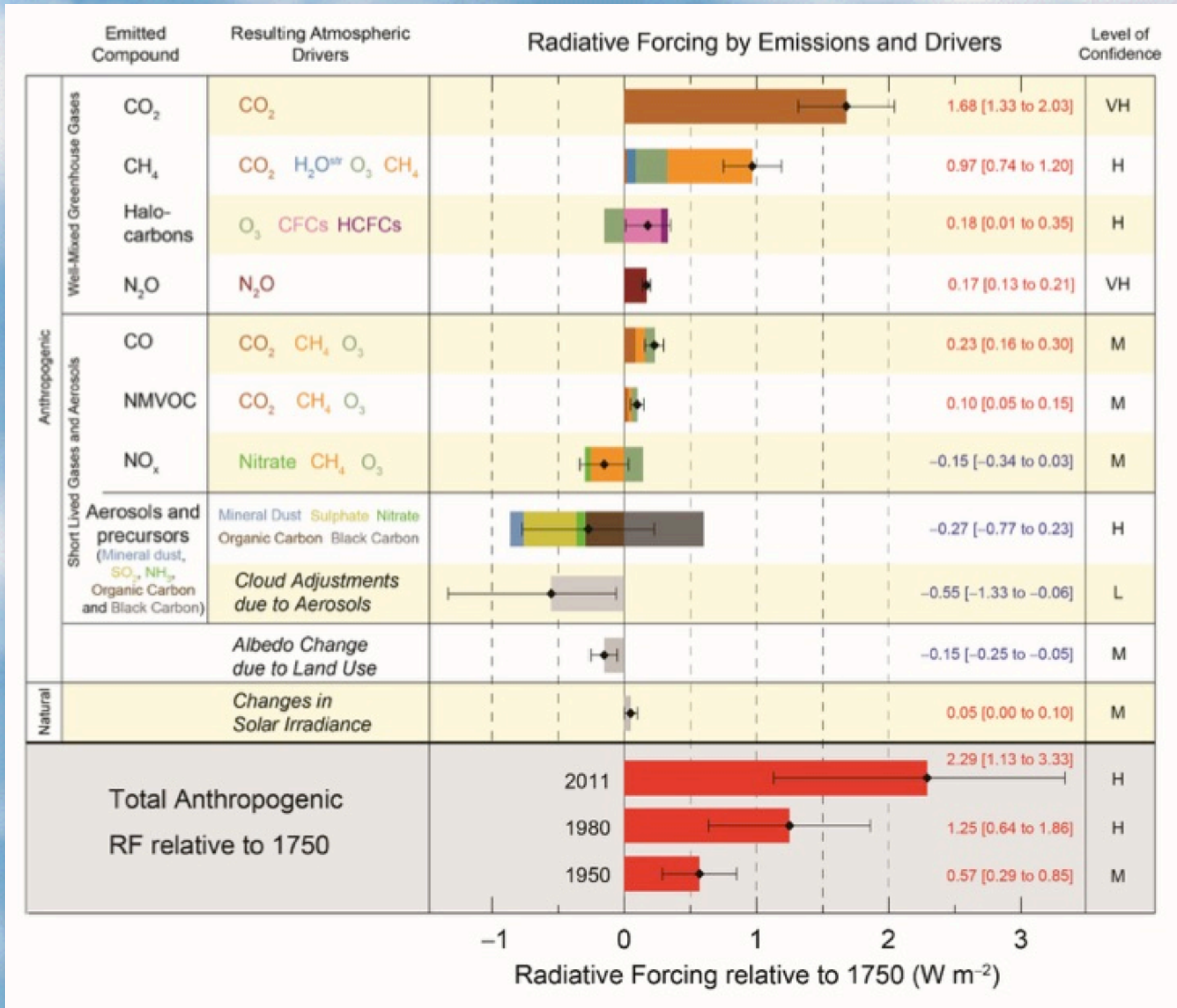
Global climate forcing of black carbon and co-emitted species in the industrial era (1750 - 2005)



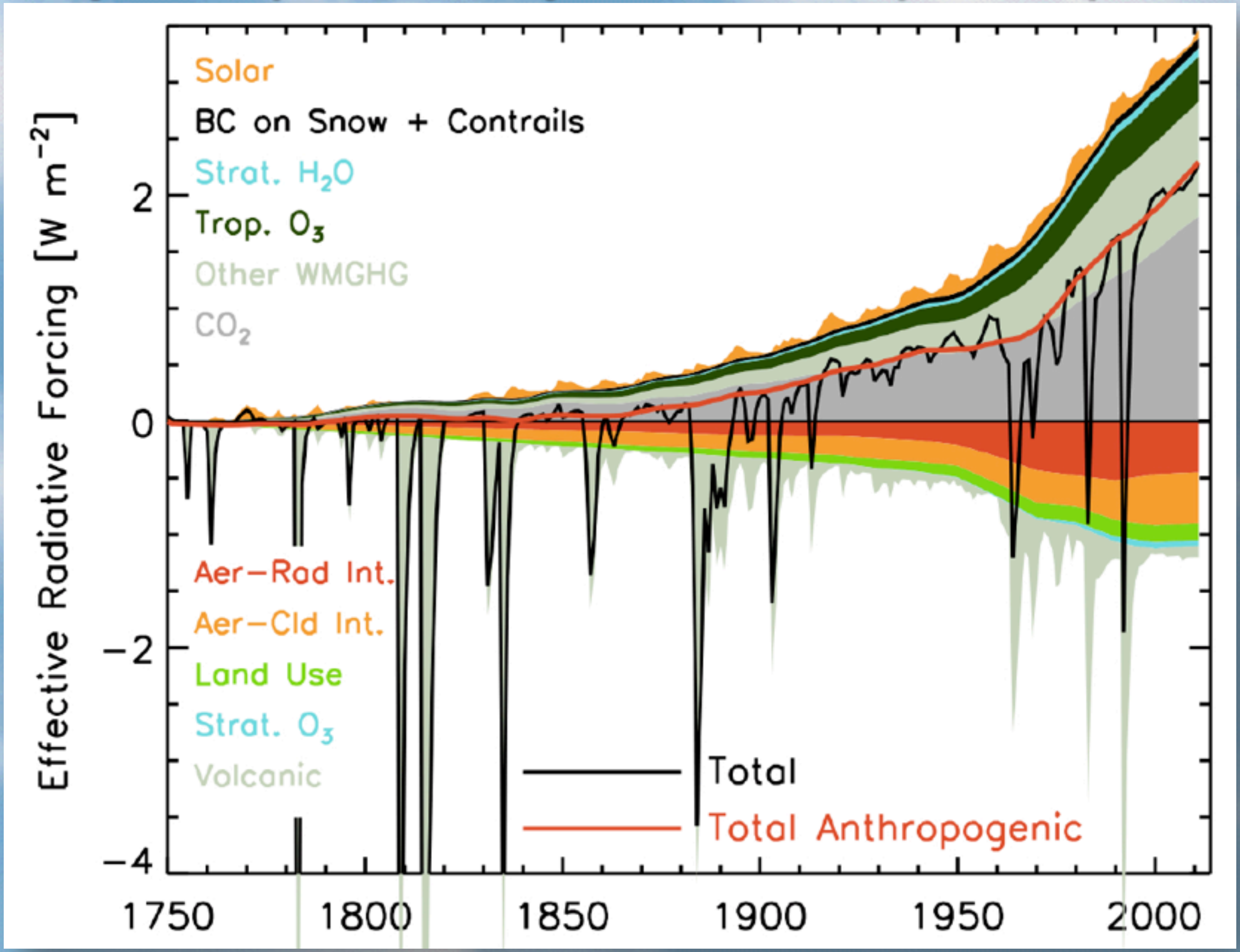
Climate forcing
By source category



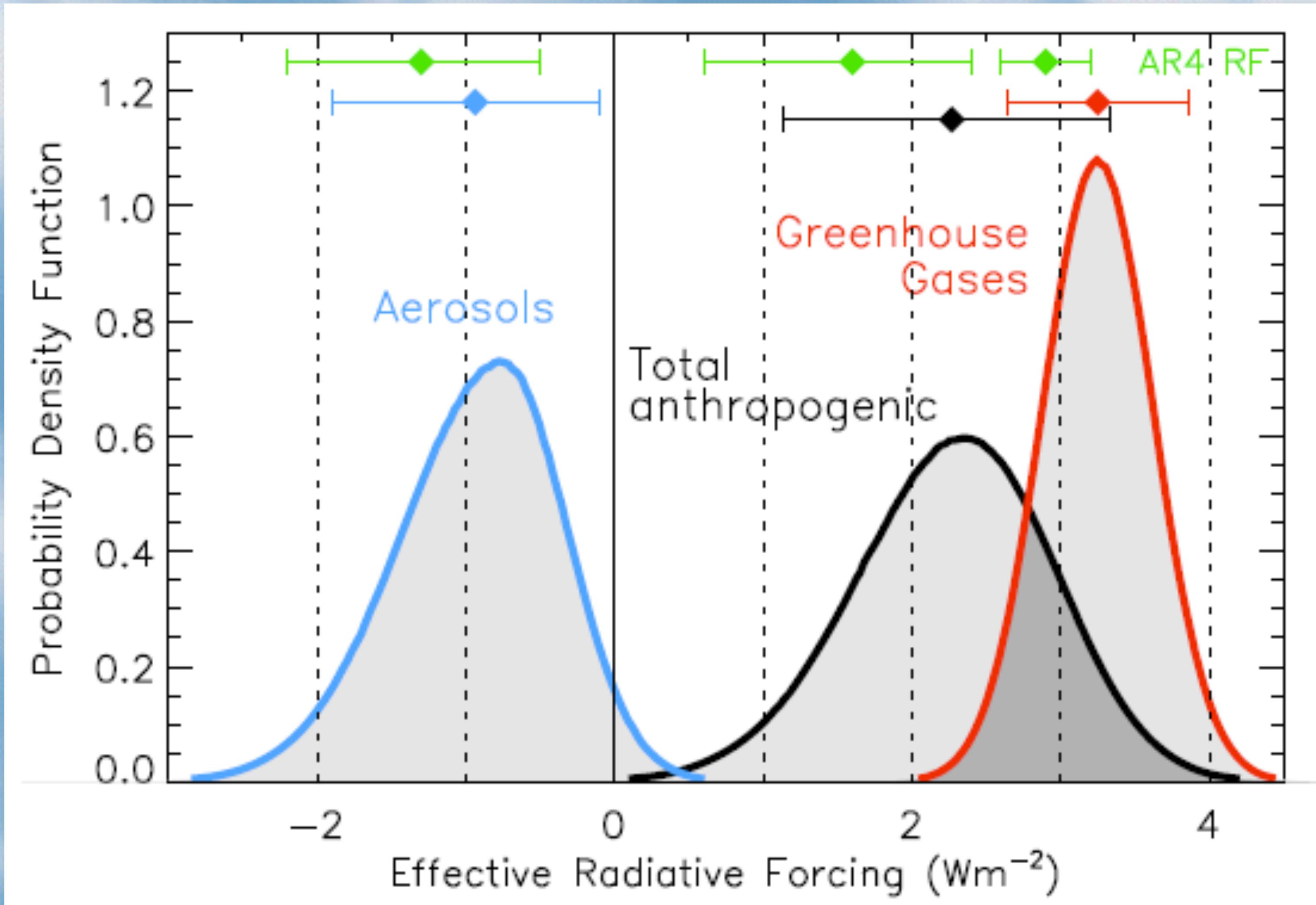
Forçante radiativa do sistema climático global (2011-1750)



Evolução temporal da forçante radiativa por componente



Climate forcing

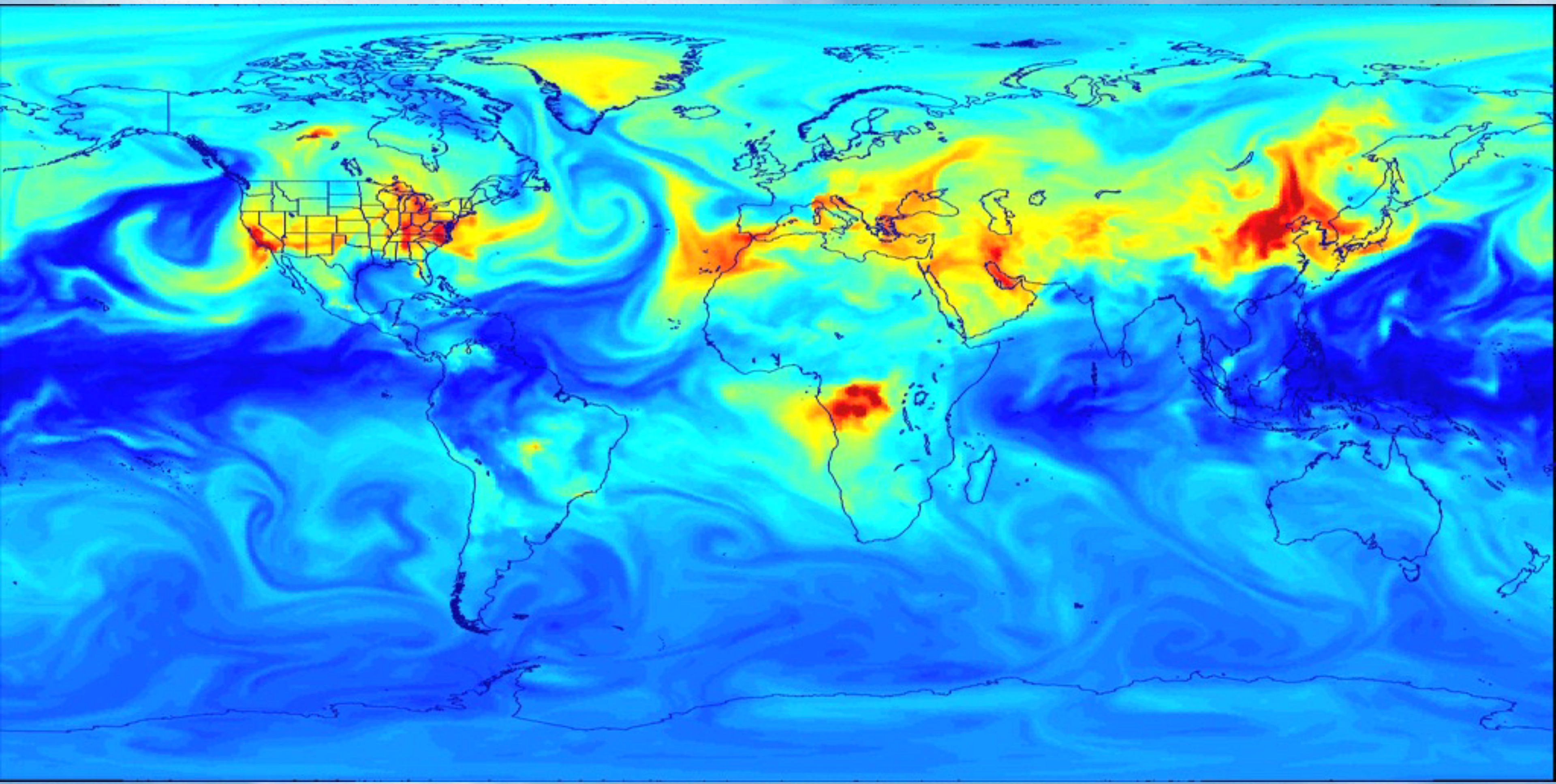


IPCC AR5, Chapter 8, 2013

"There is *high confidence* that aerosols … have offset a substantial portion of global mean forcing from well-mixed greenhouse gases. They continue to contribute the largest uncertainty to the total RF estimate."

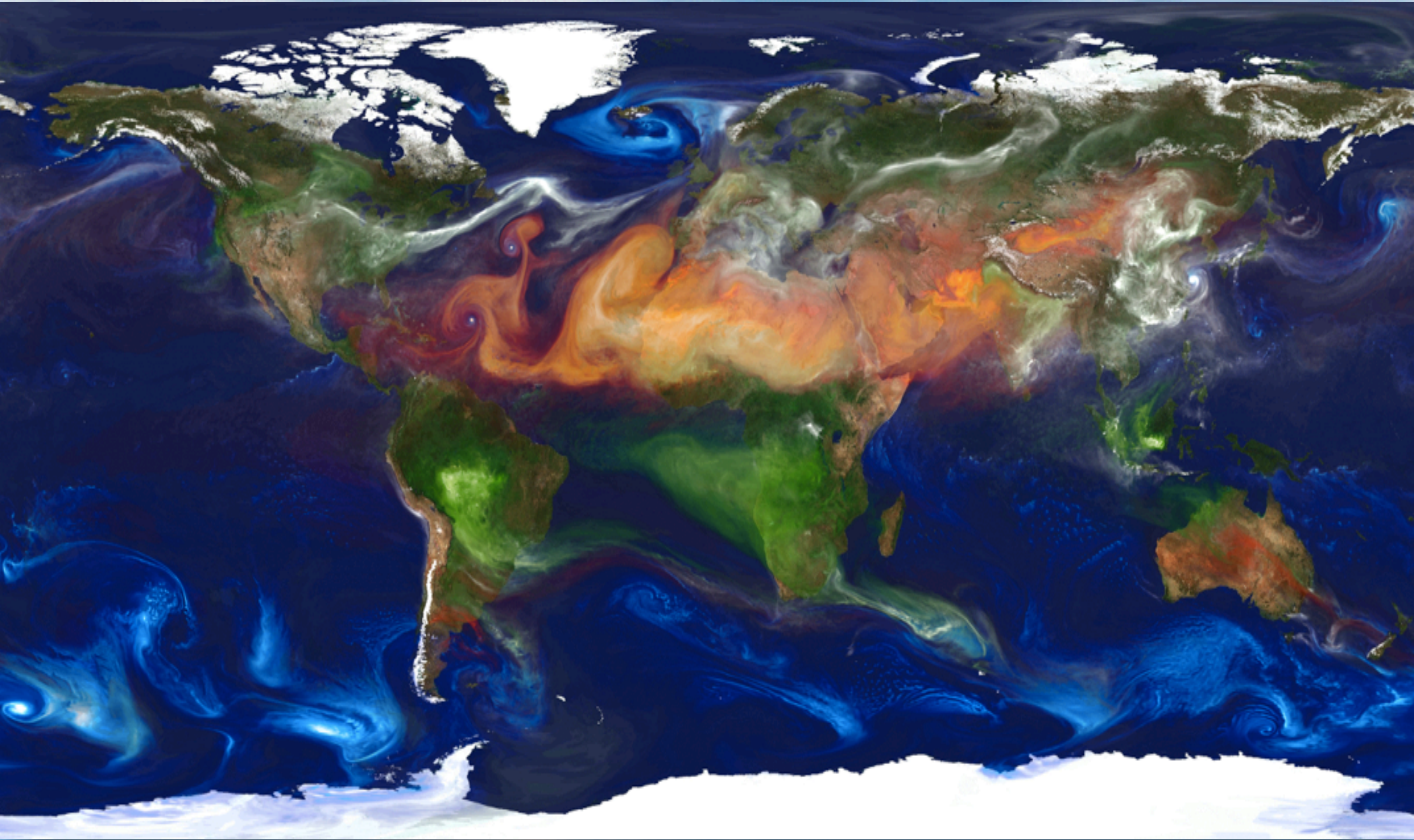
Distribuição global de ozônio CAM-chem at 0.5°

From *Louisa Emmons, NCAR*

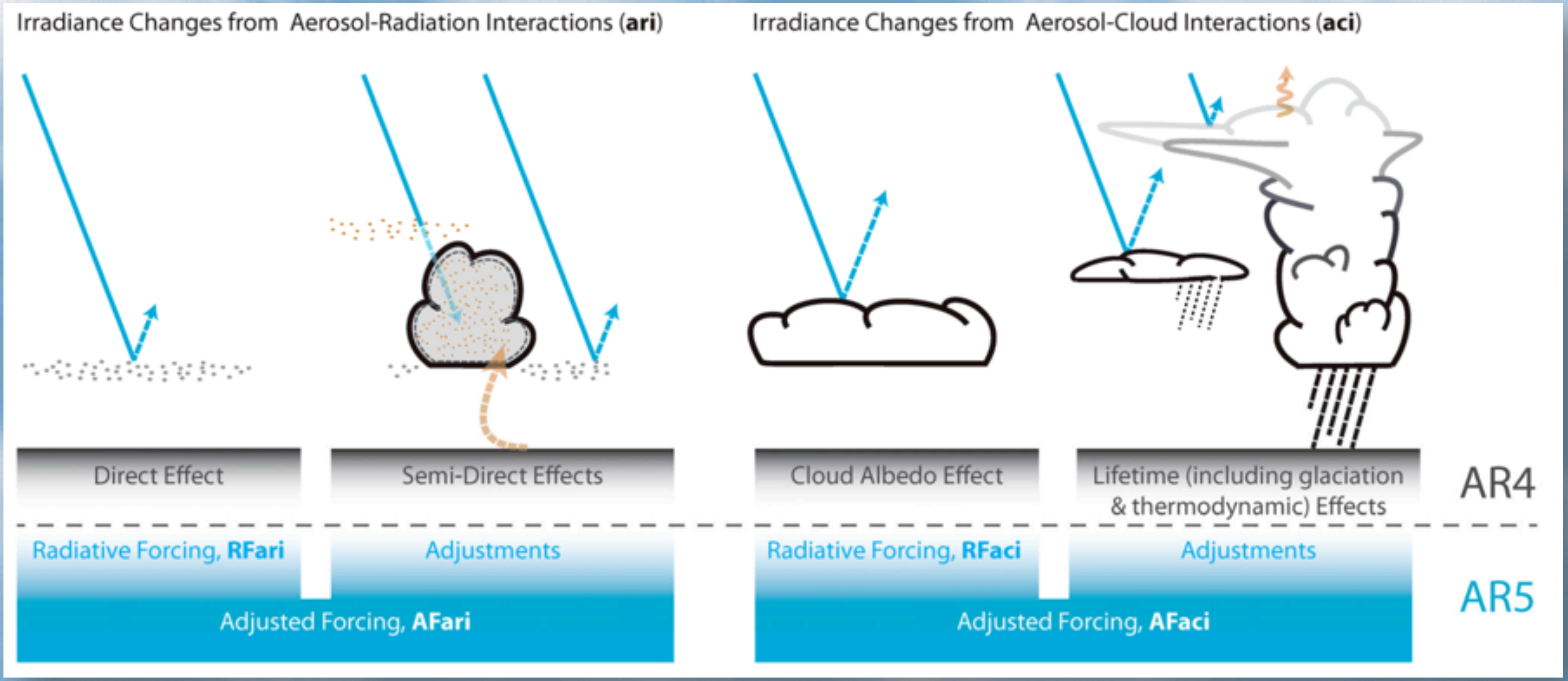


Global distribution of aerosols: dust (red), sulfate (white), smoke from fires (green), sea salt (blue).

Global modeling (10 km resolution), W. Putman, NASA Goddard



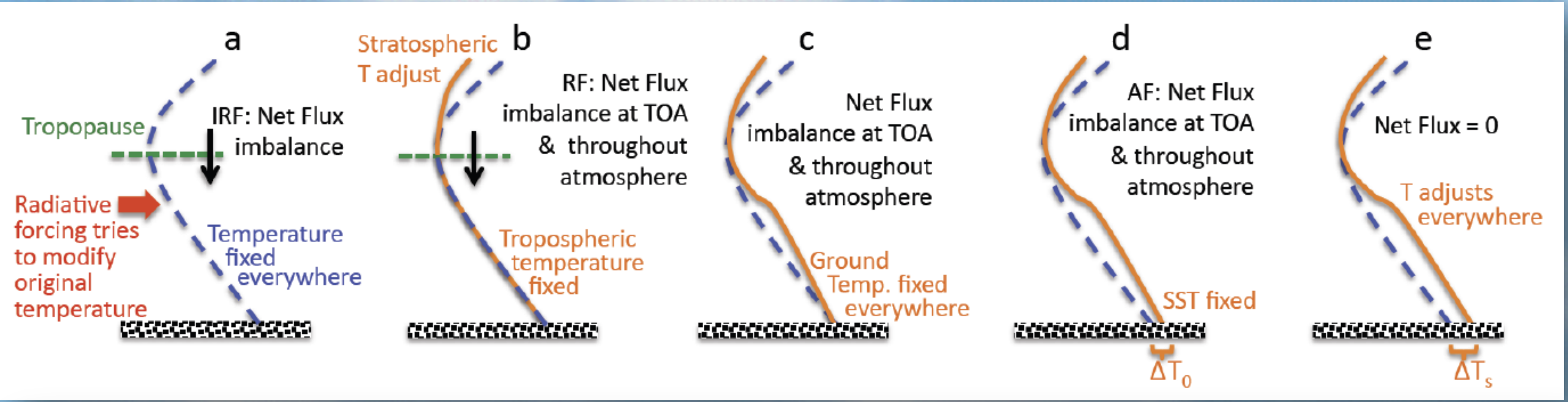
Schematic of the new terminology used in this assessment report for aerosol-radiation and aerosol-cloud interactions



The radiative forcing from aerosol-radiation interactions (abbreviated **RFari**) encompasses radiative effects from anthropogenic aerosols before any adjustment takes place, and corresponds to what is usually referred to as the aerosol direct effect. Rapid adjustments induced by aerosol radiative effects on the surface energy budget, the atmospheric profile and cloudiness contribute to the adjusted forcing from aerosol-radiation interactions (abbreviated **AFari**). They include what has earlier been referred to as the semi direct effect. The radiative forcing from aerosol-cloud interactions (abbreviated **RFaci**) refers to the instantaneous effect on cloud albedo due to changing concentrations of cloud condensation and ice nuclei. All subsequent changes to the cloud lifetime and thermodynamics are rapid adjustments, which contribute to the adjusted forcing from aerosol-cloud interactions (abbreviated **AFaci**).

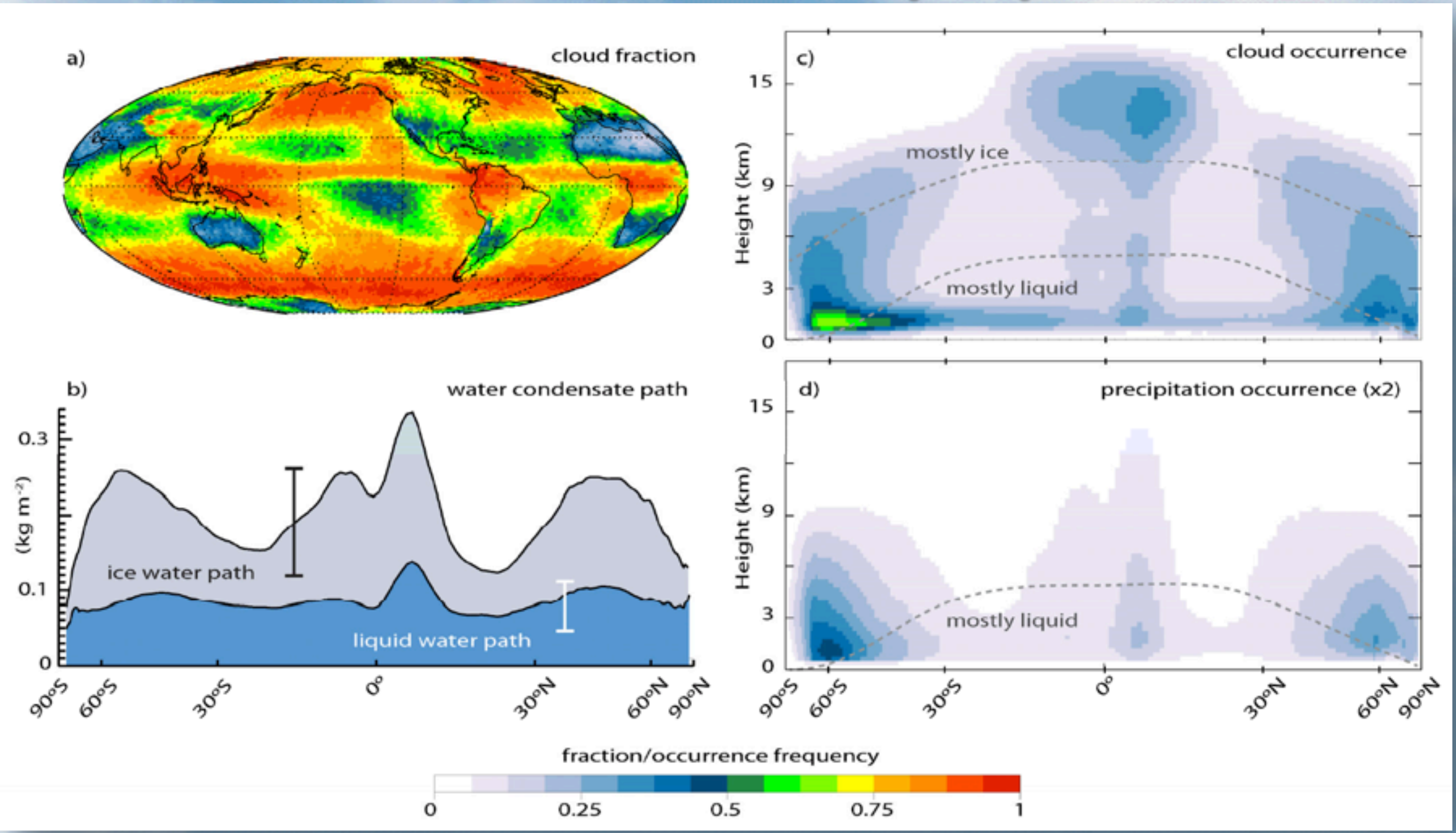
Instantaneous Radiative Forcing versus adjusted forcing

Instantaneous RF	RF, which allows stratospheric temperature to adjust	flux change when the surface temperature is fixed over the whole Earth	AF, the adjusted forcing which allows atmospheric and land temperature to adjust while ocean conditions are fixed,	the equilibrium response to the climate forcing agent.



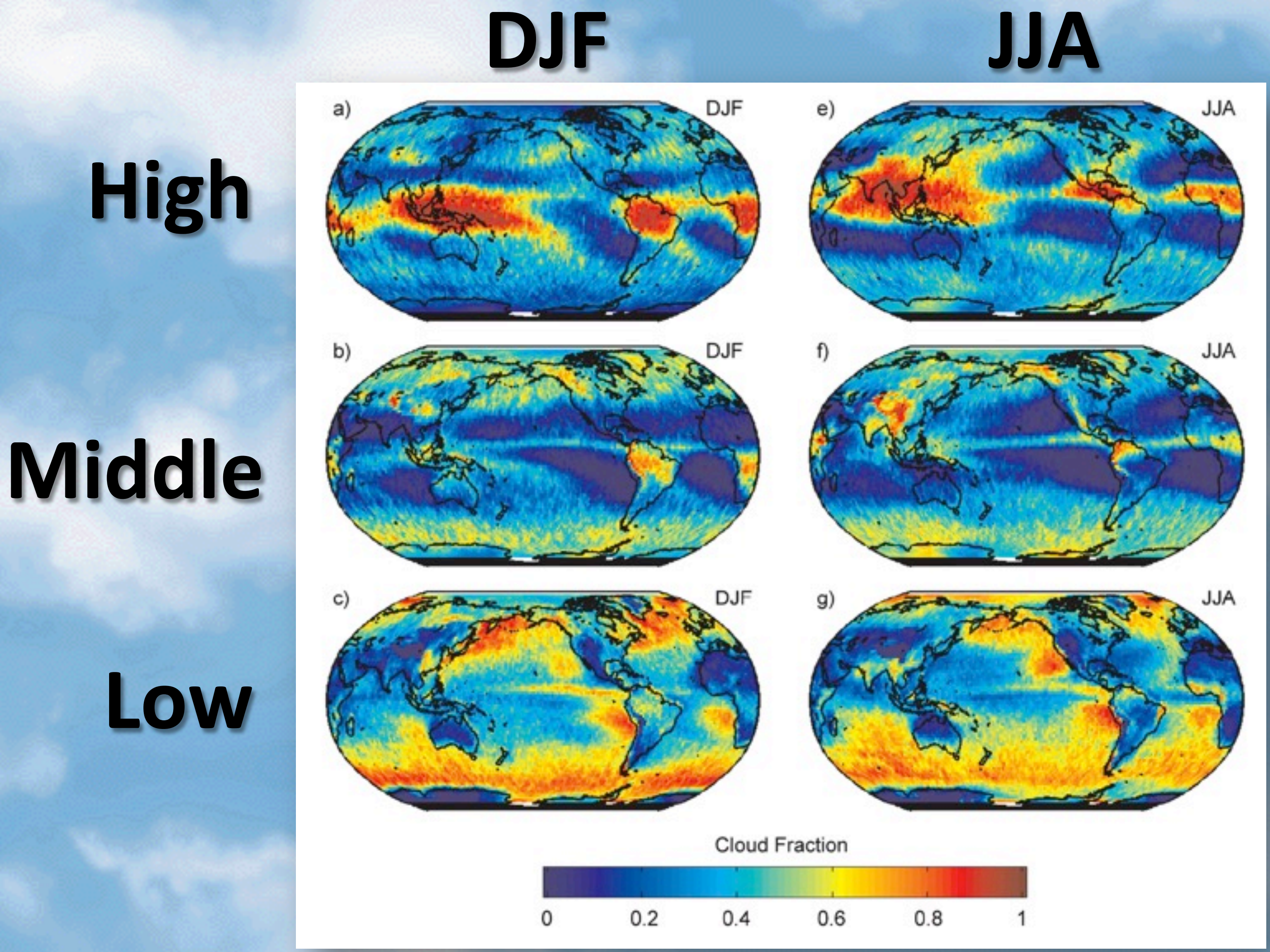
Online or offline pair of radiative transfer calculations within one simulation	Difference between two offline radiative transfer calculations with prescribed surface and tropospheric conditions allowing stratospheric temperature to adjust	Difference between two full atmospheric model simulations with prescribed surface conditions everywhere or estimate based on regression of response in full coupled atmosphere-ocean simulation	Difference between two full atmospheric model simulations with prescribed ocean conditions (SSTs and sea ice)	Difference between two full coupled atmosphere-ocean model simulations

Annual mean cloud properties

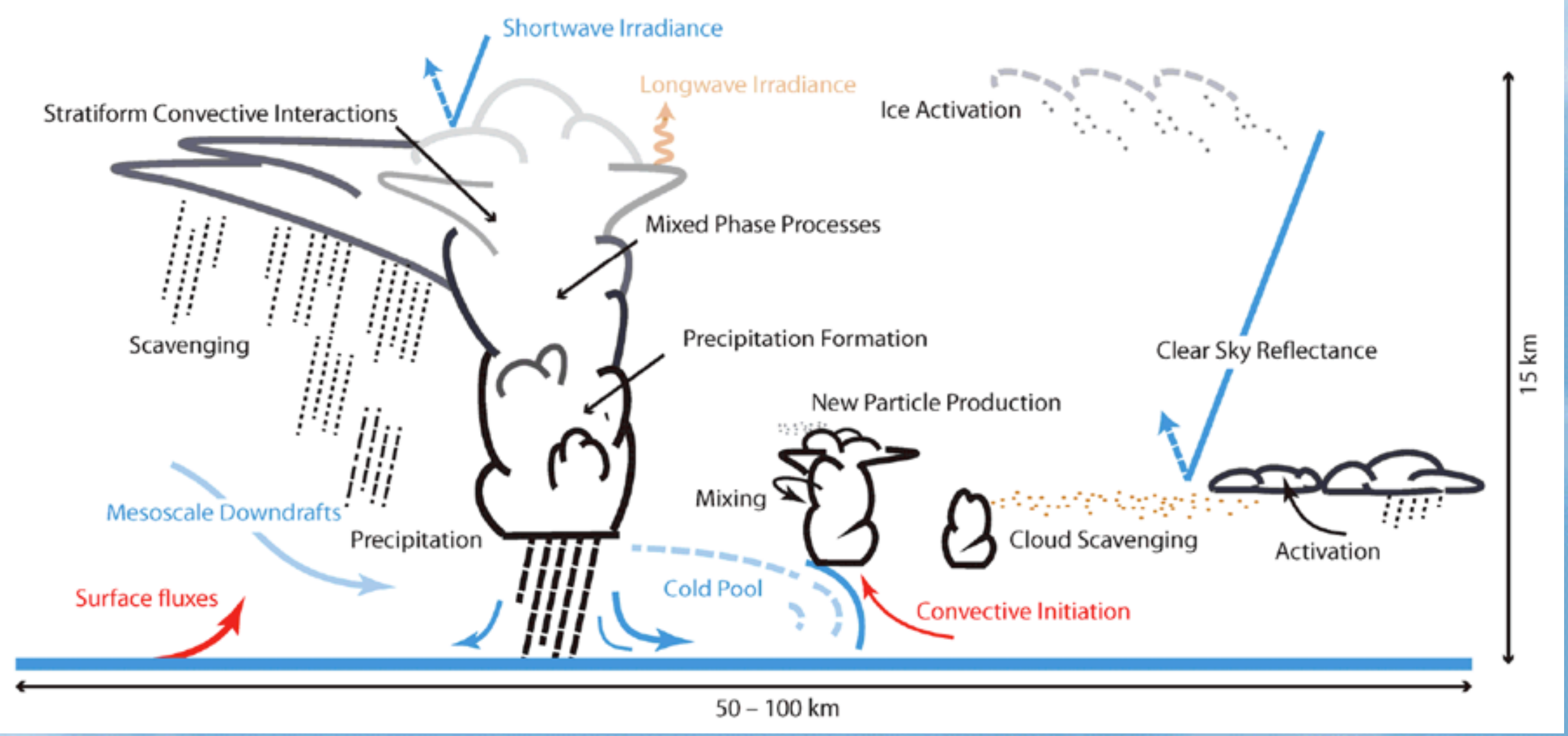


(a) Annual mean cloud fractional occurrence (CloudSat/CALIPSO 2B-GEOPROF-LIDAR dataset for 2006–2011); **(b)** annual zonal mean liquid water path (blue shading, ocean only, microwave radiometer dataset for 1988–2005; the 90% uncertainty range, assessed to be 70–150% of the plotted value, is schematically indicated by the white error bar) and ice water path (grey shading, from CloudSat 2C-ICE dataset for 2006–2011; the 90% uncertainty range, assessed to be 50–200% of the plotted value, is schematically indicated by the black error bar). **(c-d)** latitude-height sections of annual zonal mean cloud (including precipitation falling from cloud) occurrence and precipitation (attenuation-corrected radar reflectivity >0 dBZ) occurrence; the latter has been doubled to make use of a common colour scale (2B-GEOPROF-LIDAR dataset). The dashed curves show the annual-mean 0°C and −38°C isotherms.

Mean high, middle and low cloud cover from CloudSat/ CALIPSO GEOPROF dataset (2006– 2011),

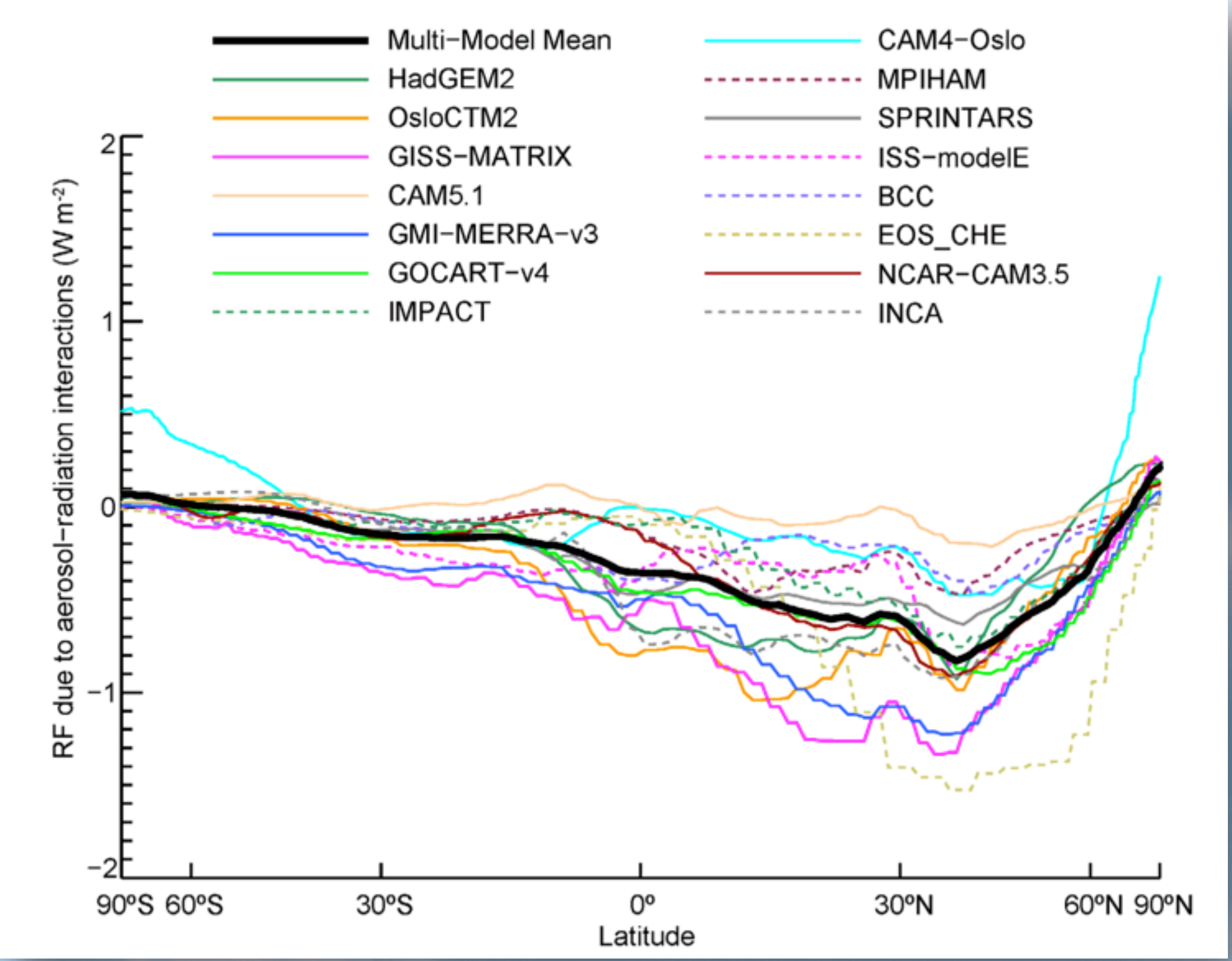


Schematic depicting the myriad aerosol-cloud-precipitation related processes



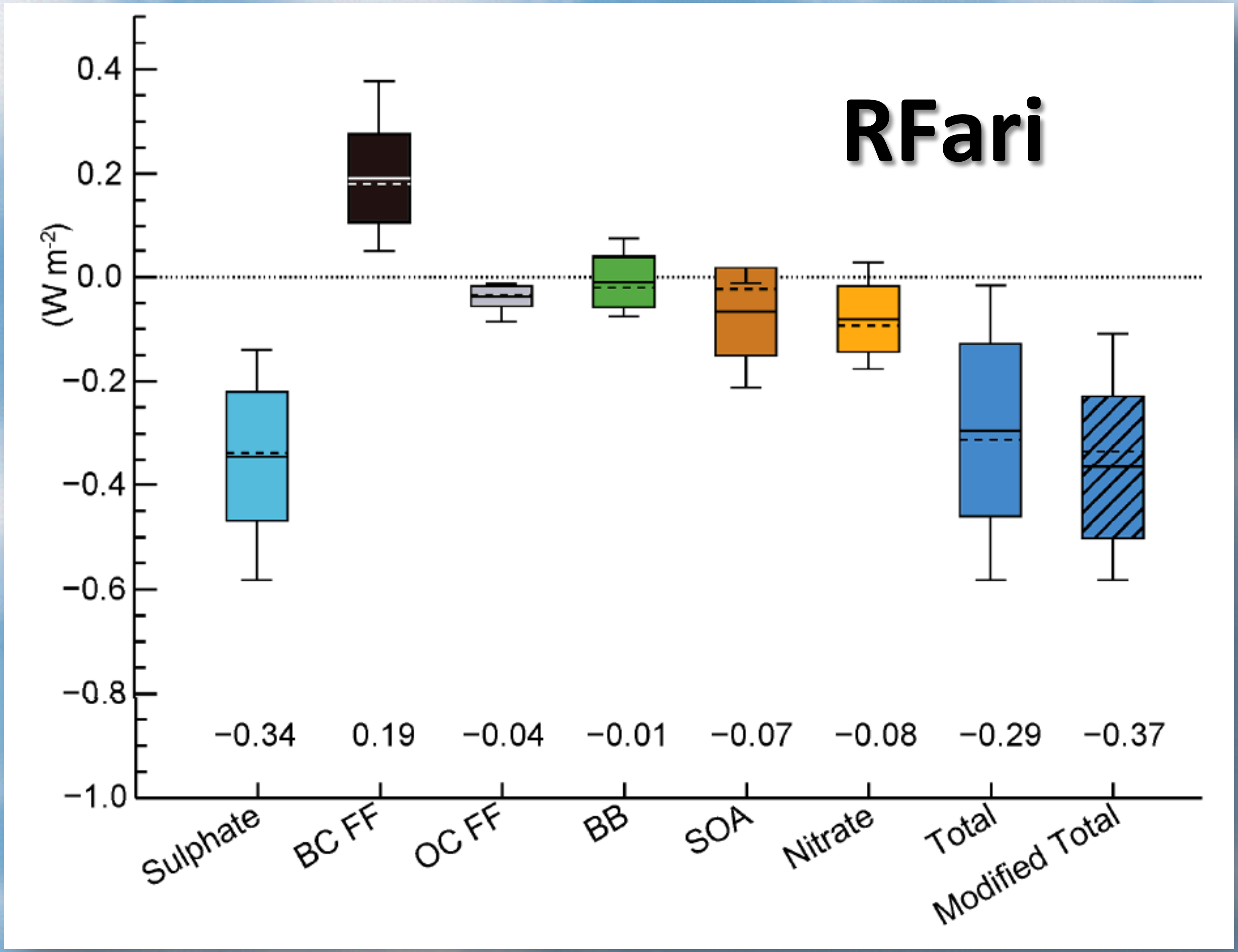
The schematic conveys the importance of considering aerosol-cloud-precipitation processes as part of an interactive system encompassing a large range of spatiotemporal scales. These processes influence the short- and longwave forcing of the system and hence climate

Annual zonal mean RFari (in W/m^2) due to all anthropogenic aerosols

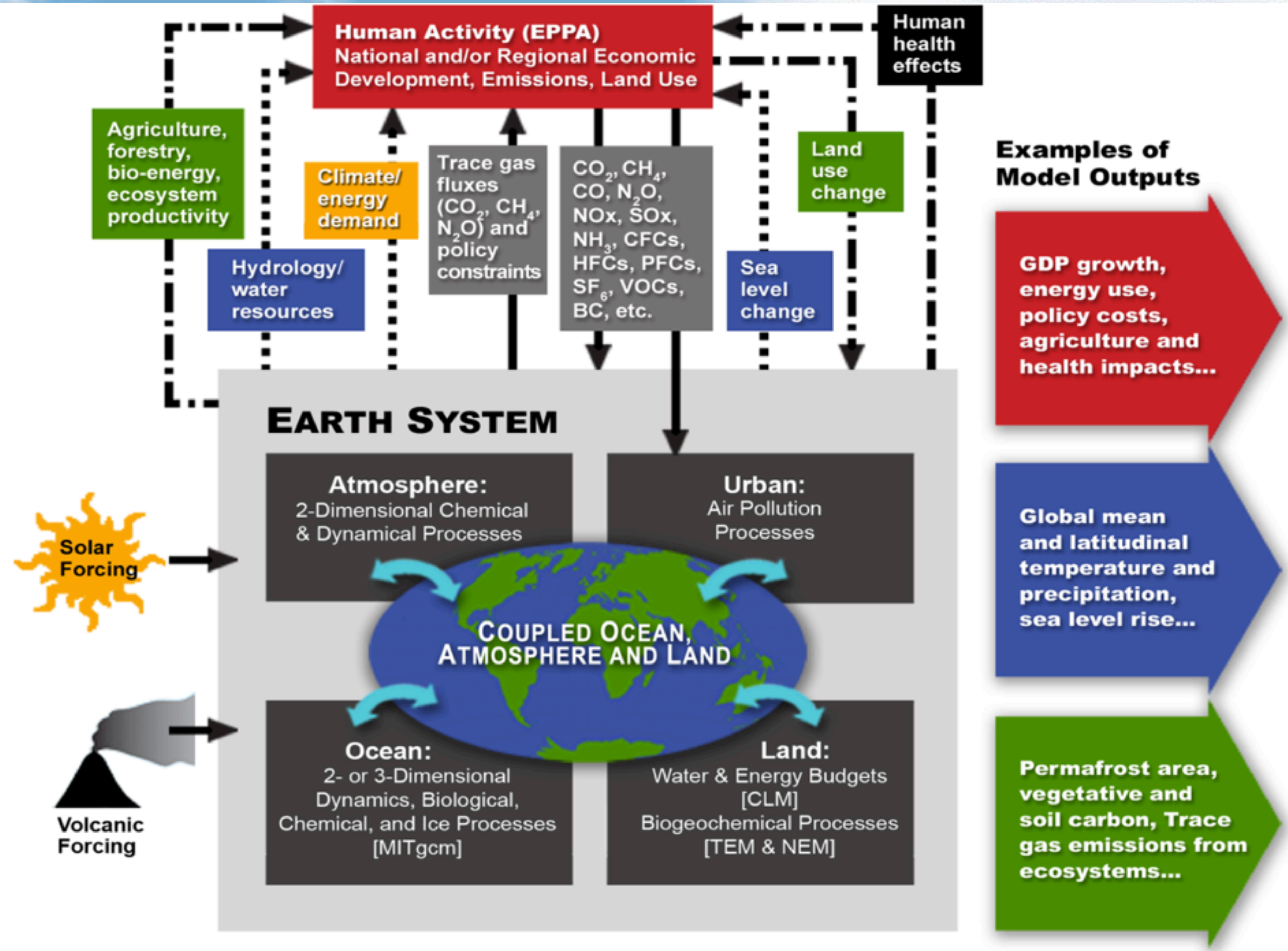


The forcings are for the 1850 to 2000 period. Myhre et al. (2012).

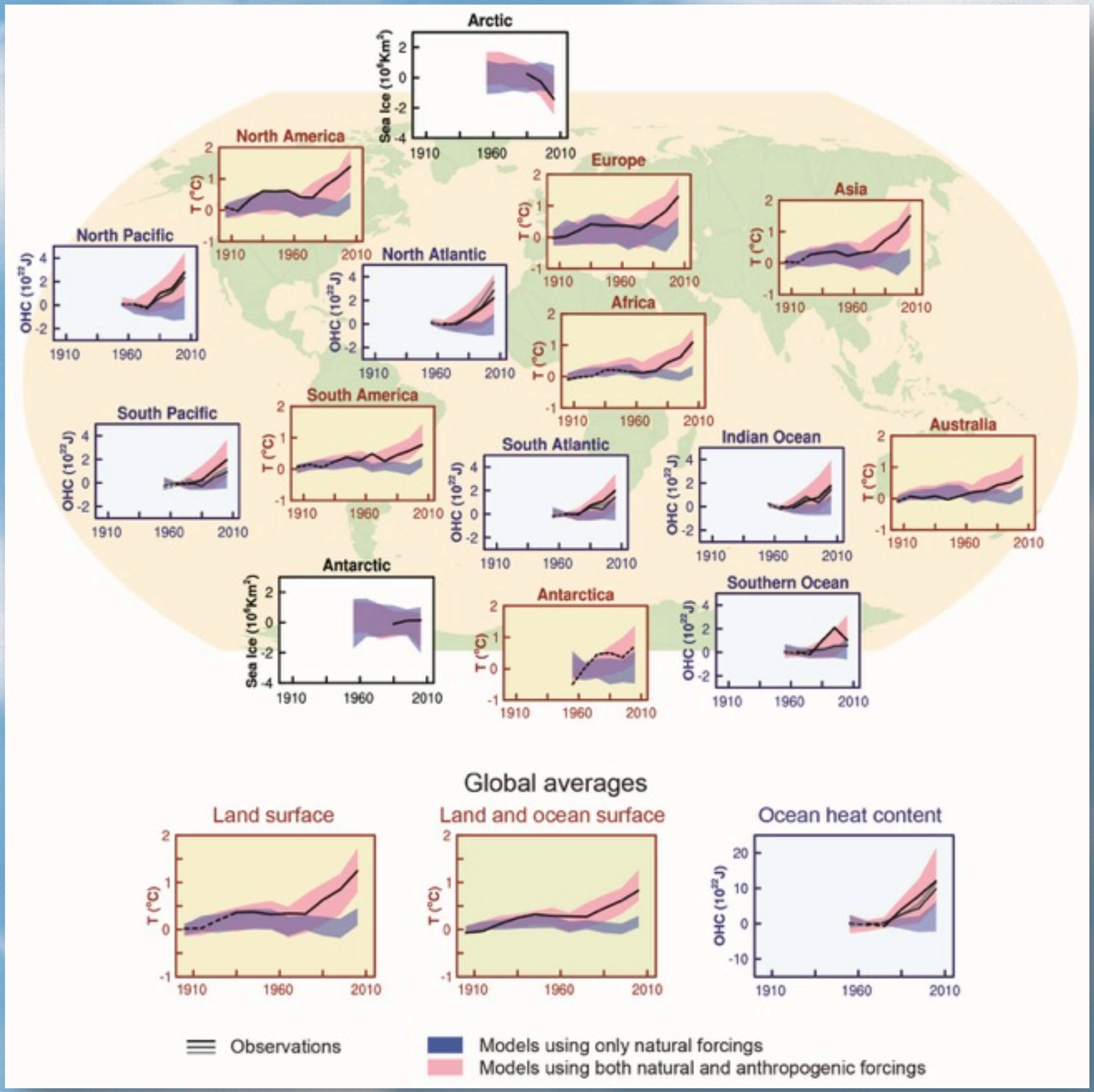
Mean (solid line), median (dashed line), one standard deviation (box) and full (min-max) range (whiskers) for RFari (in W/m²) from different aerosol types



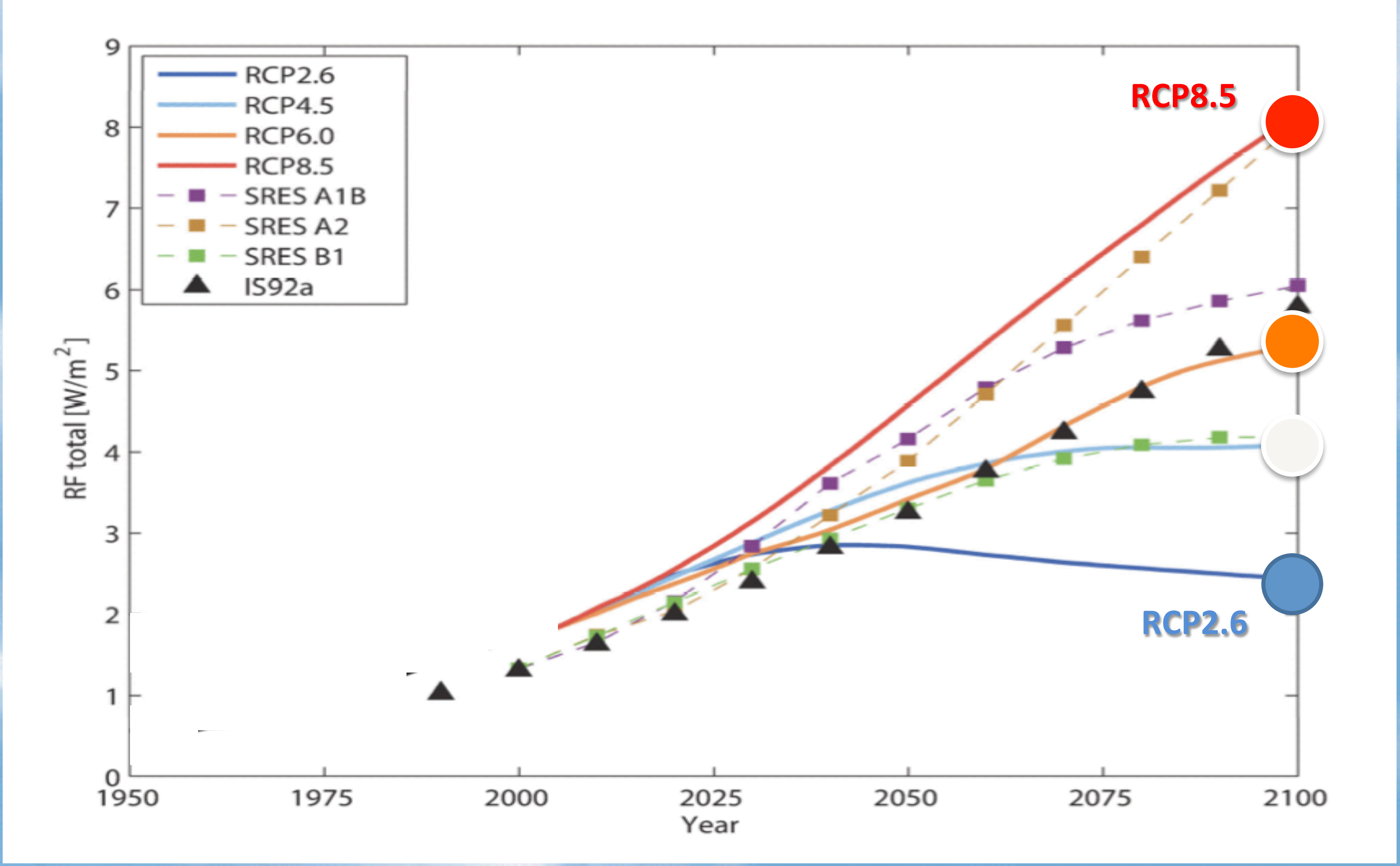
The forcings are for the 1850 to 2000 period. Myhre et al. (2012).


Human Activity (EPPA)
National and/or Regional Economic Development, Emissions, Land Use
Human health effects
Agriculture, forestry, bio-energy, ecosystem productivity
Climate/ energy demand
Trace gas fluxes (CO_2, CH_4, N_2O) and policy constraints
CO_2, CH_4, CO, N_2O, NOx, SOx, NH_3, CFCs, HFCs, PFCs, SF_6, VOCs, BC, etc.
Land use change
Hydrology/ water resources
Sea level change
Examples of Model Outputs
GDP growth, energy use, policy costs, agriculture and health impacts...
EARTH SYSTEM
Atmosphere:
2-Dimensional Chemical & Dynamical Processes
Urban:
Air Pollution Processes
Solar Forcing
COUPLED OCEAN, ATMOSPHERE AND LAND
Global mean and latitudinal temperature and precipitation, sea level rise...
Ocean:
2- or 3-Dimensional Dynamics, Biological, Chemical, and Ice Processes [MITgcm]
Land:
Water & Energy Budgets [CLM]
Biogeochemical Processes [TEM & NEM]
Volcanic Forcing
Permafrost area, vegetative and soil carbon, Trace gas emissions from ecosystems...

Atribuição: Só com emissões antropogênicas as observações são explicadas

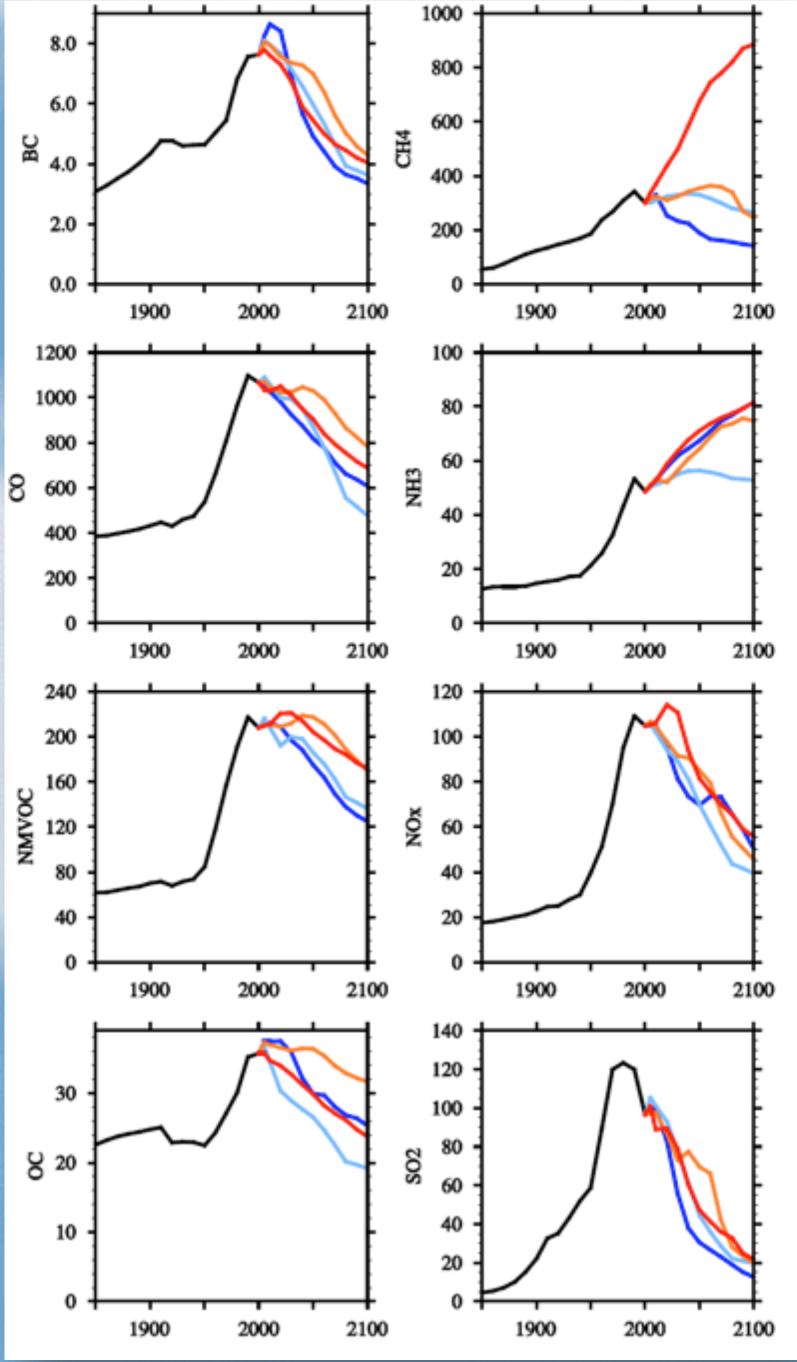


Cenários de Emissões e “RCP - Representative Concentrations Pathways”

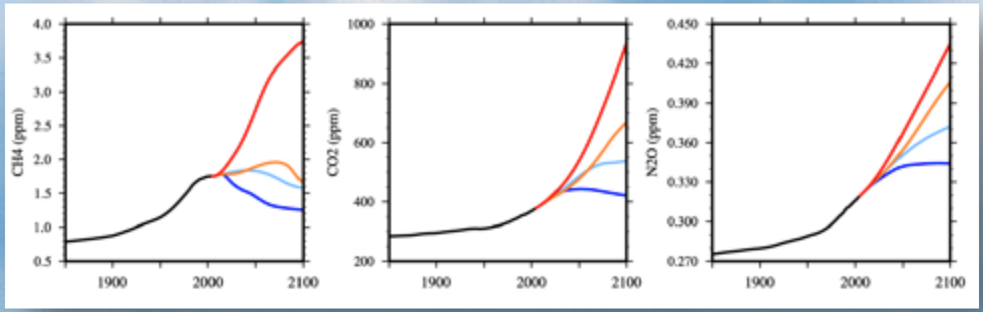


Time evolution of global anthropogenic and biomass burning emissions 1850–2100 used in CMIP5/ACCMIP following each RCP.

Blue (RCP2.6), light blue (RCP4.5), orange (RCP6.0) and red (RCP8.5). BC stands for black carbon (in Tg(C) yr–1), OC for organic carbon (in Tg(C) yr–1), NMVOC for non-methane volatile organic compounds (in Tg(C) yr–1) and NOX for nitrogen oxides (in Tg(NO2) yr–1). Other panels are in Tg(species) yr–1.



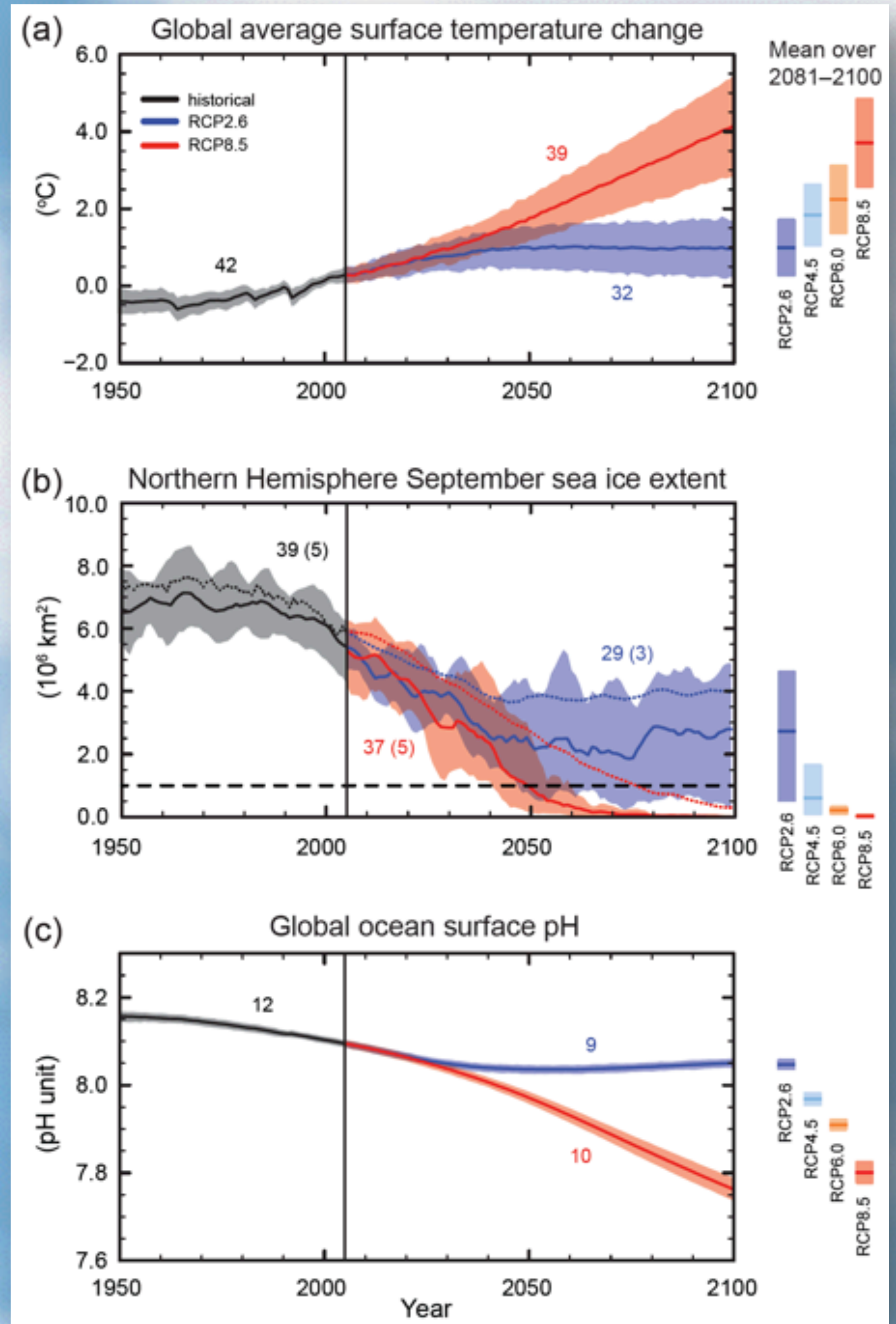
Gases de feito estufa de longa vida



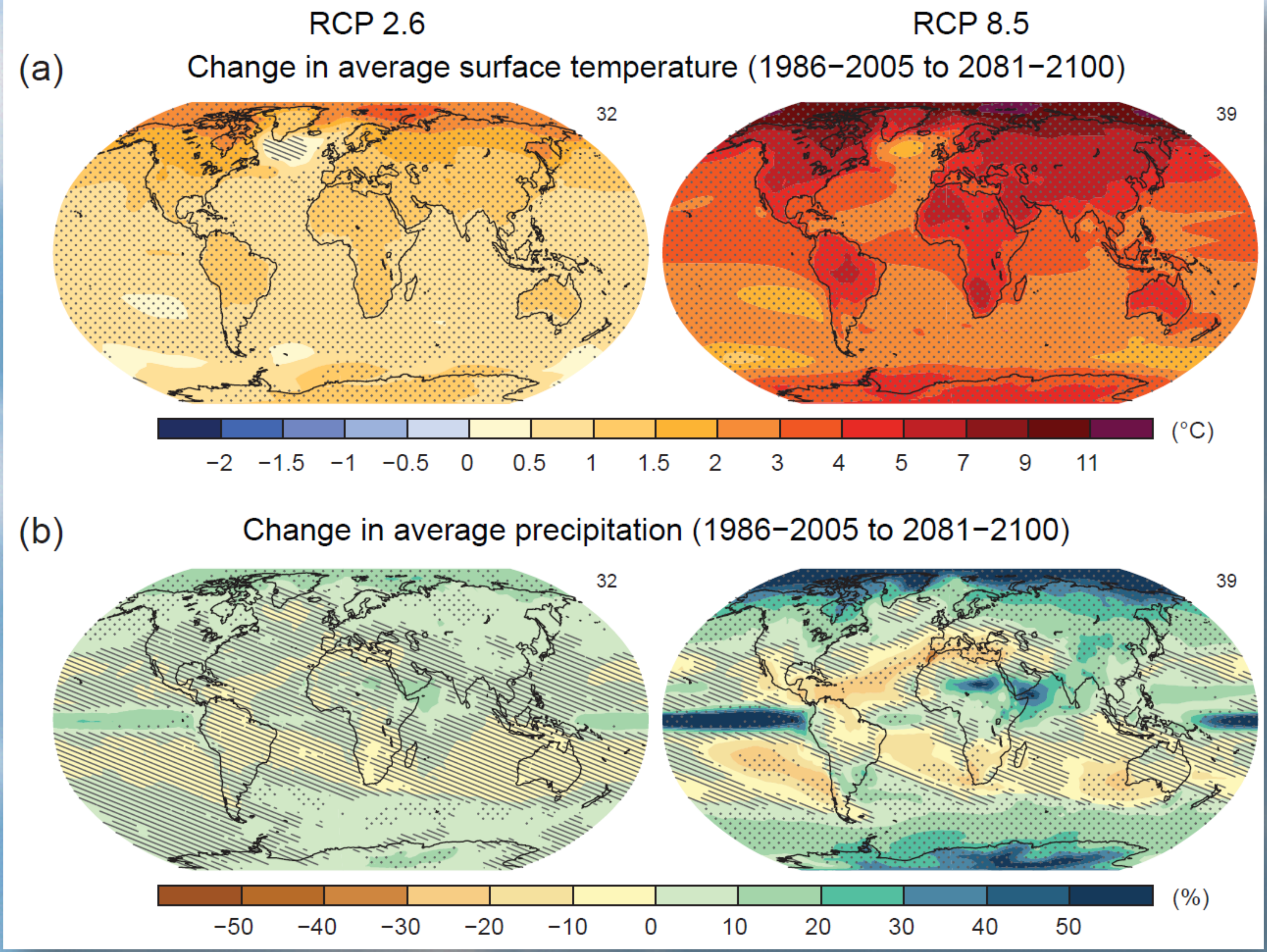
Previsões de aumento de temperatura

extensão de gelo marinho

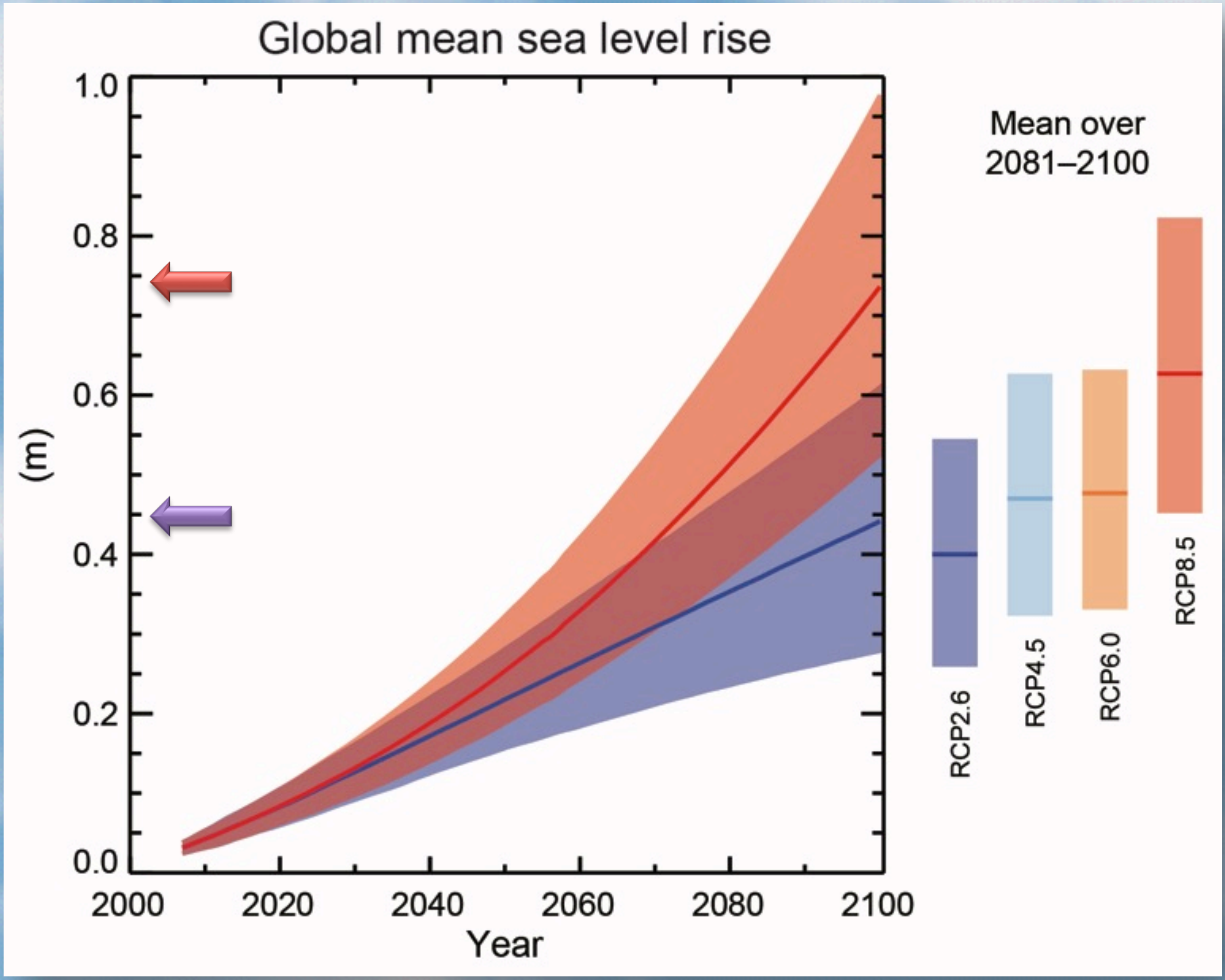
pH acidez oceânica



Projeção de aumento de temperatura e chuva em dois cenários



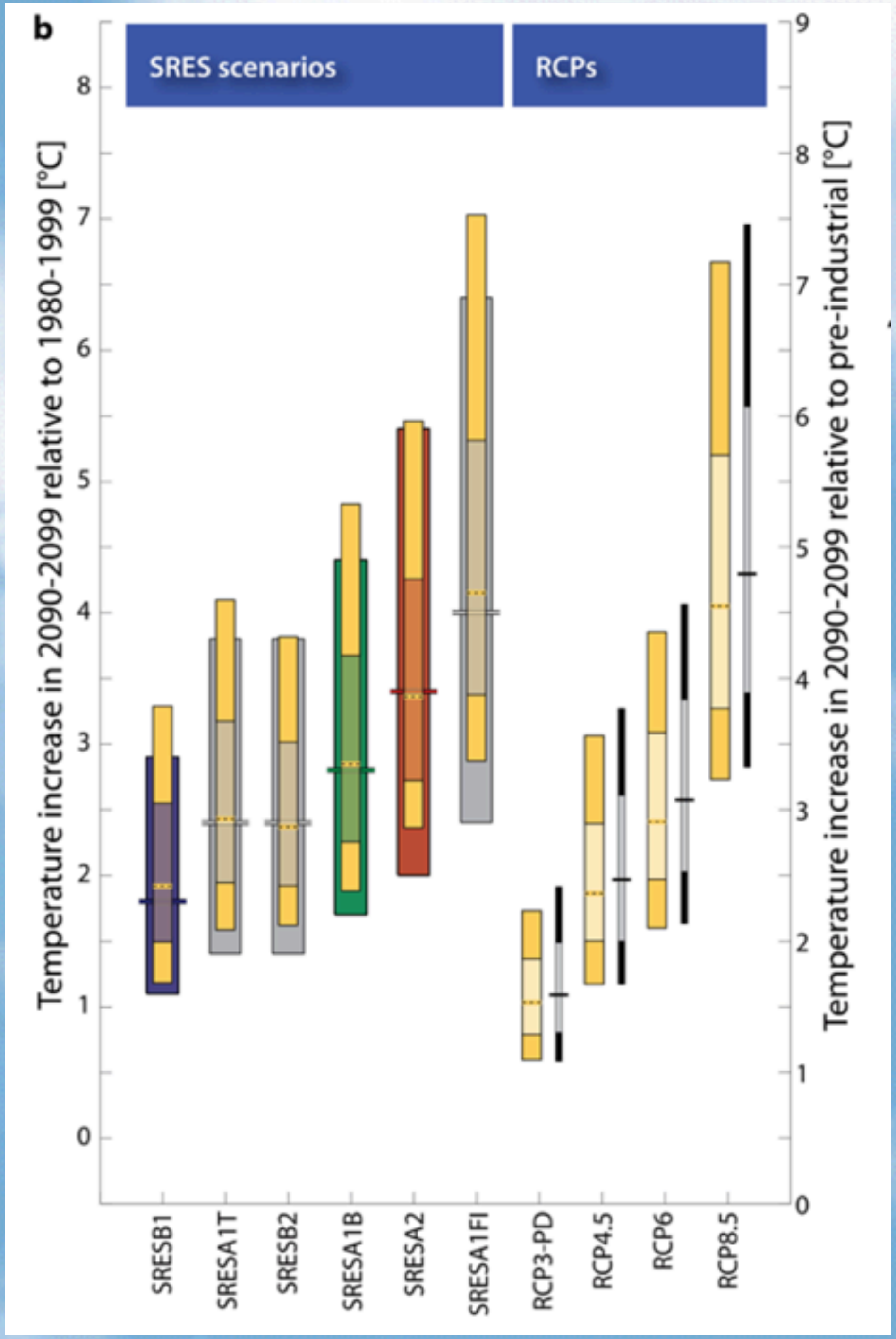
Aumento médio do nível do mar



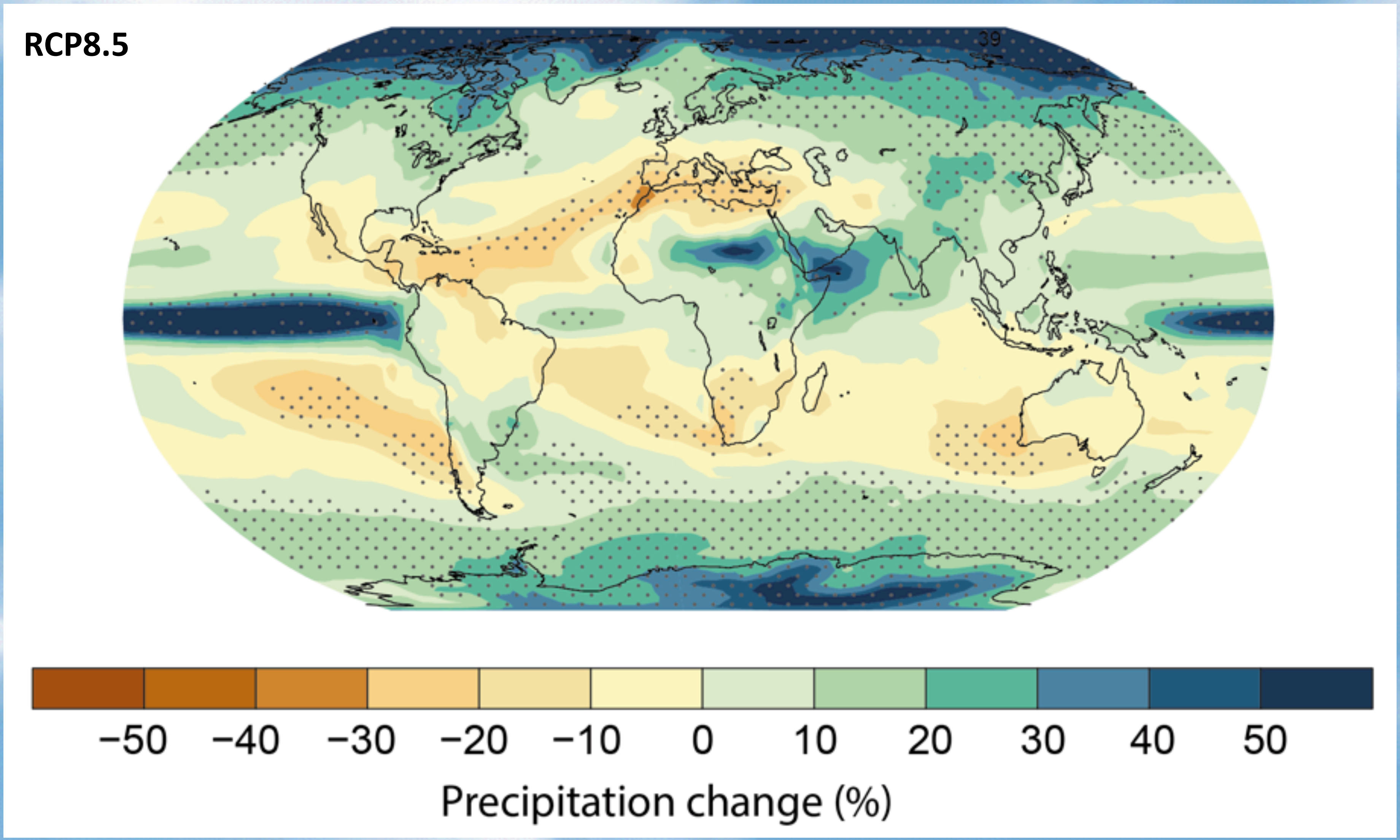
Estimativas de aumento de temperatura em função dos cenários de emissões

Probabilistic 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.

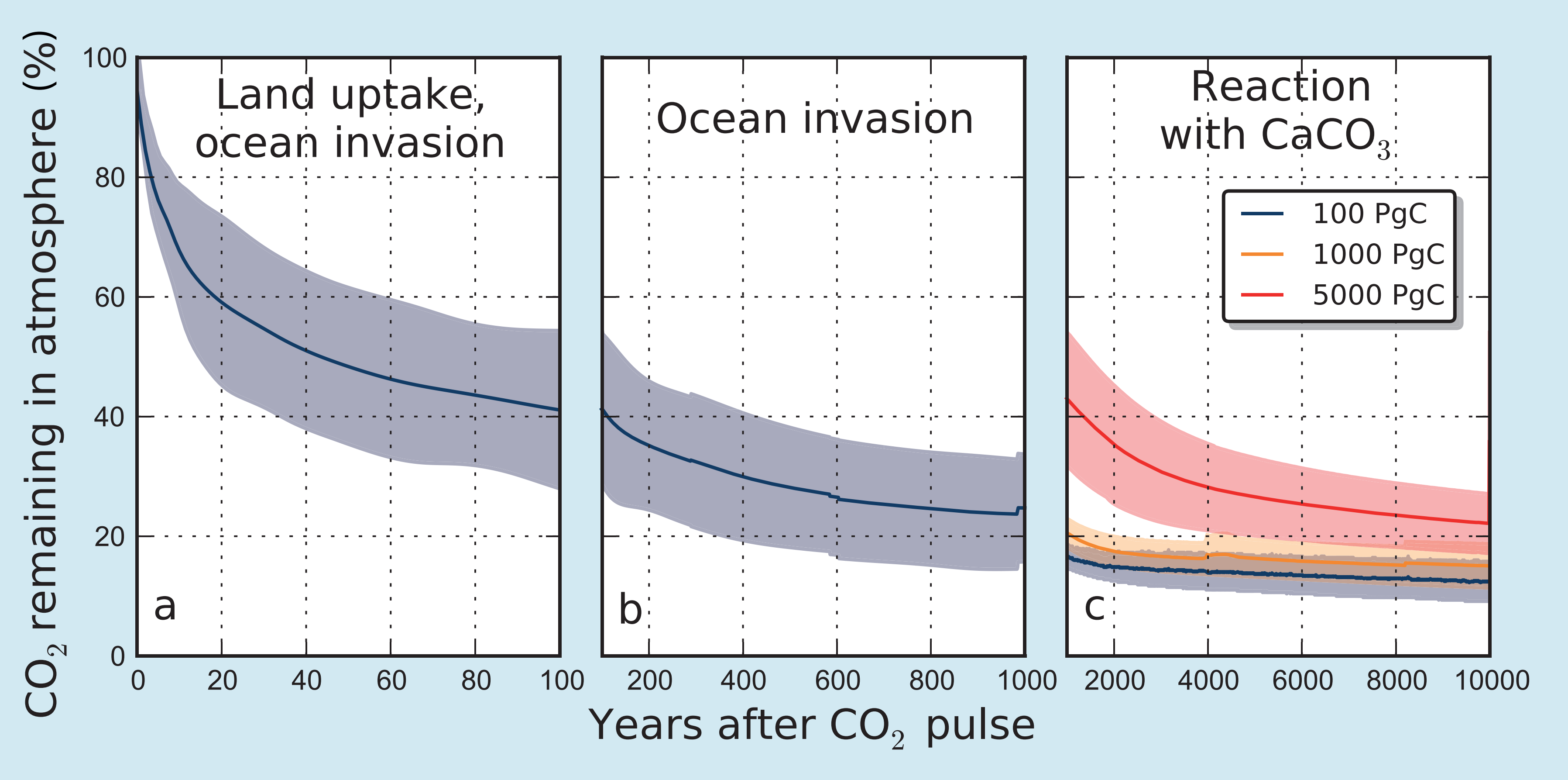
Source: Rogelj, Meinshausen, et al. 2012.



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

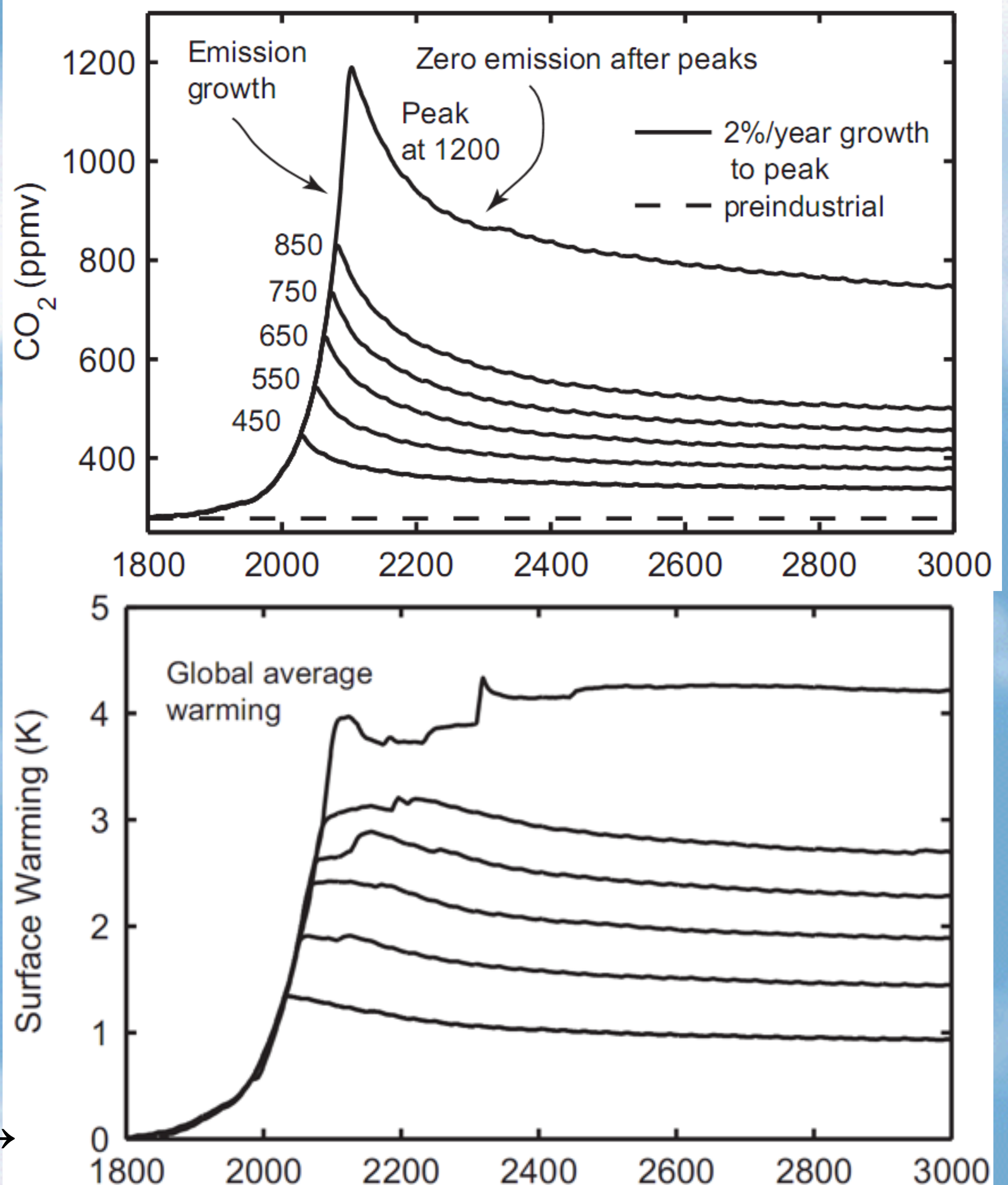


CO_2 remains in the atmosphere long after emissions



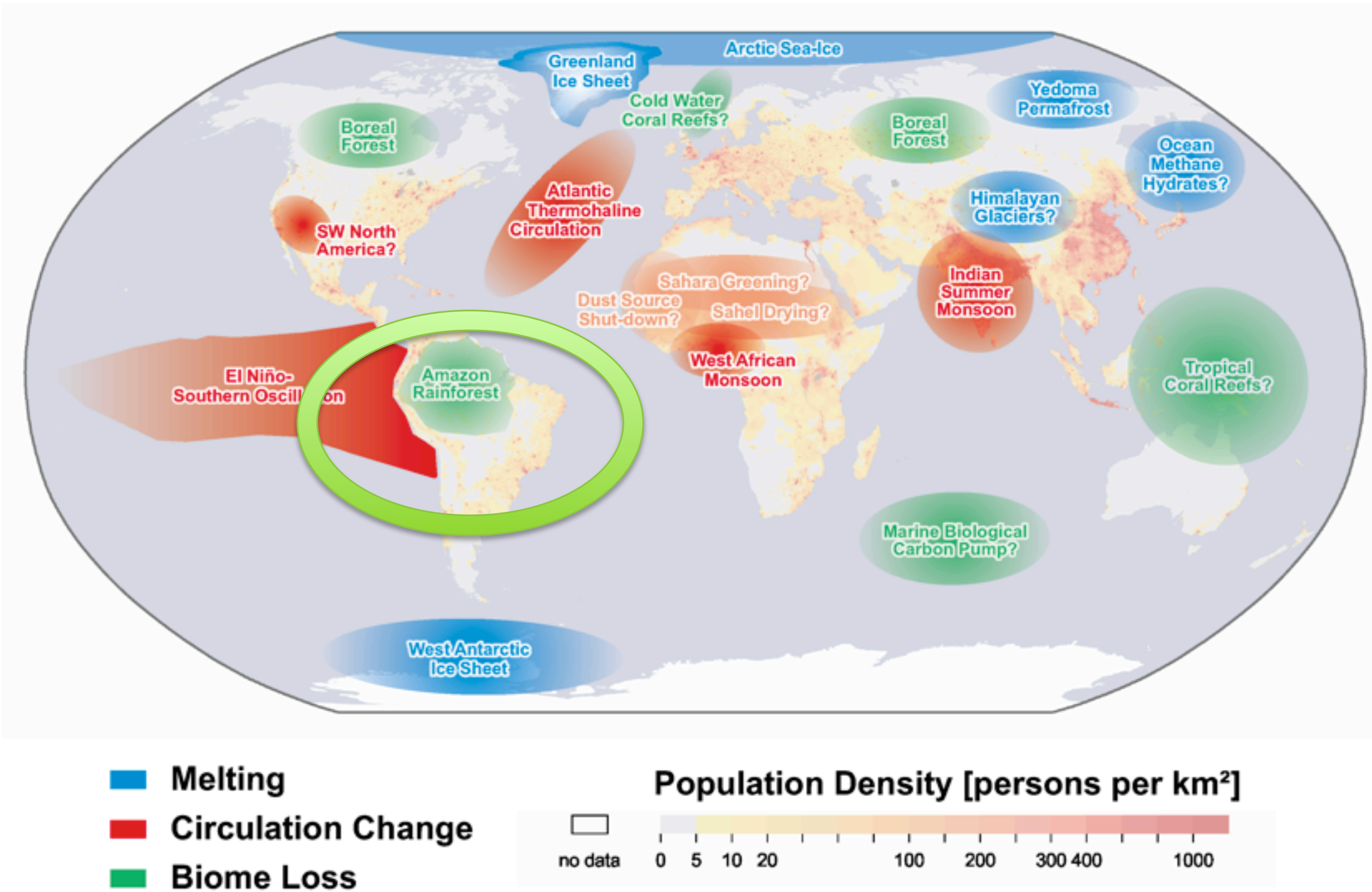
Quanto tempo o efeito do CO_2 irá afetar o clima do planeta?

Susan Salomon PNAS Fev 2009



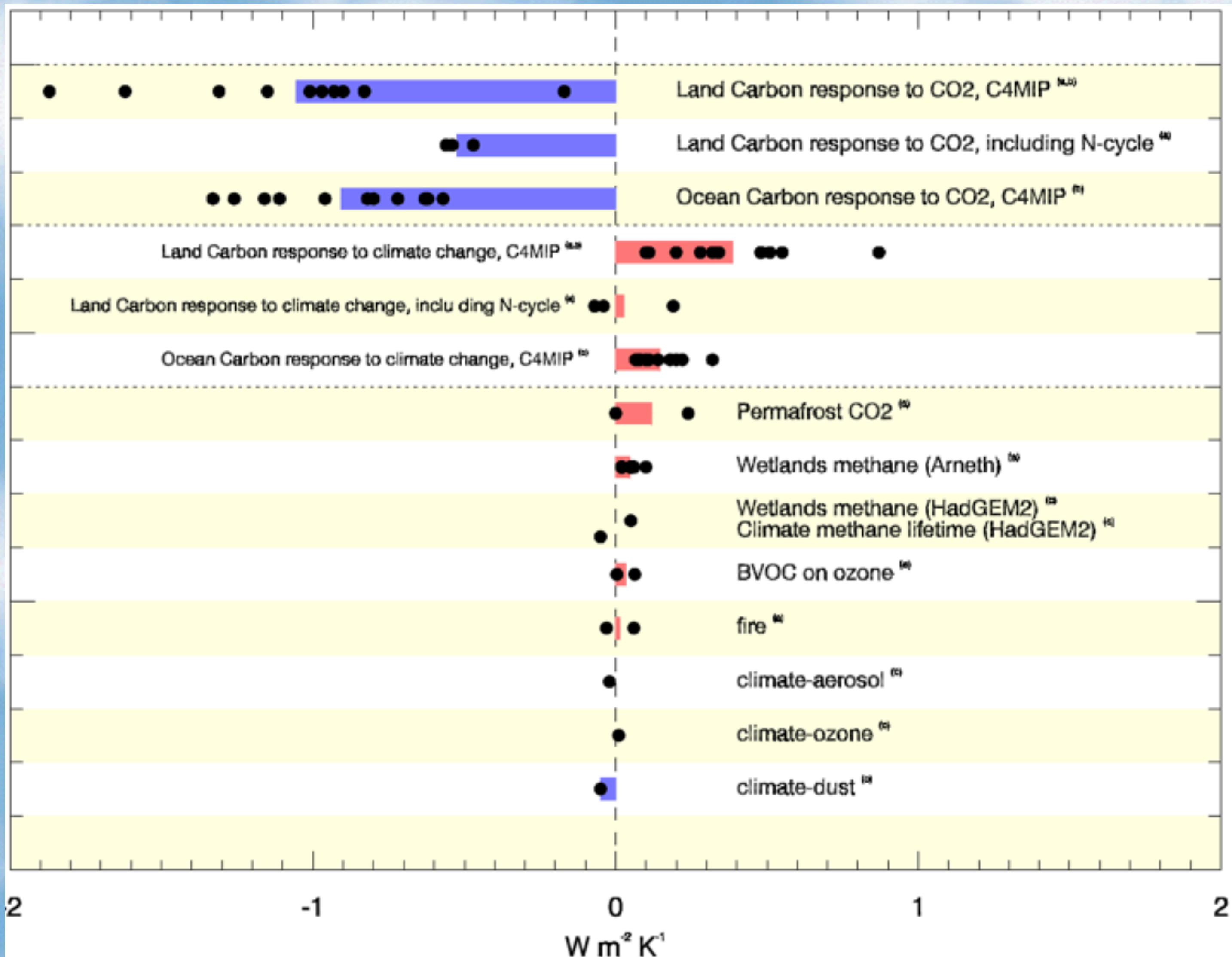
Note a escala: Até o ano 3000 →

Tipping Elements in the Earth System



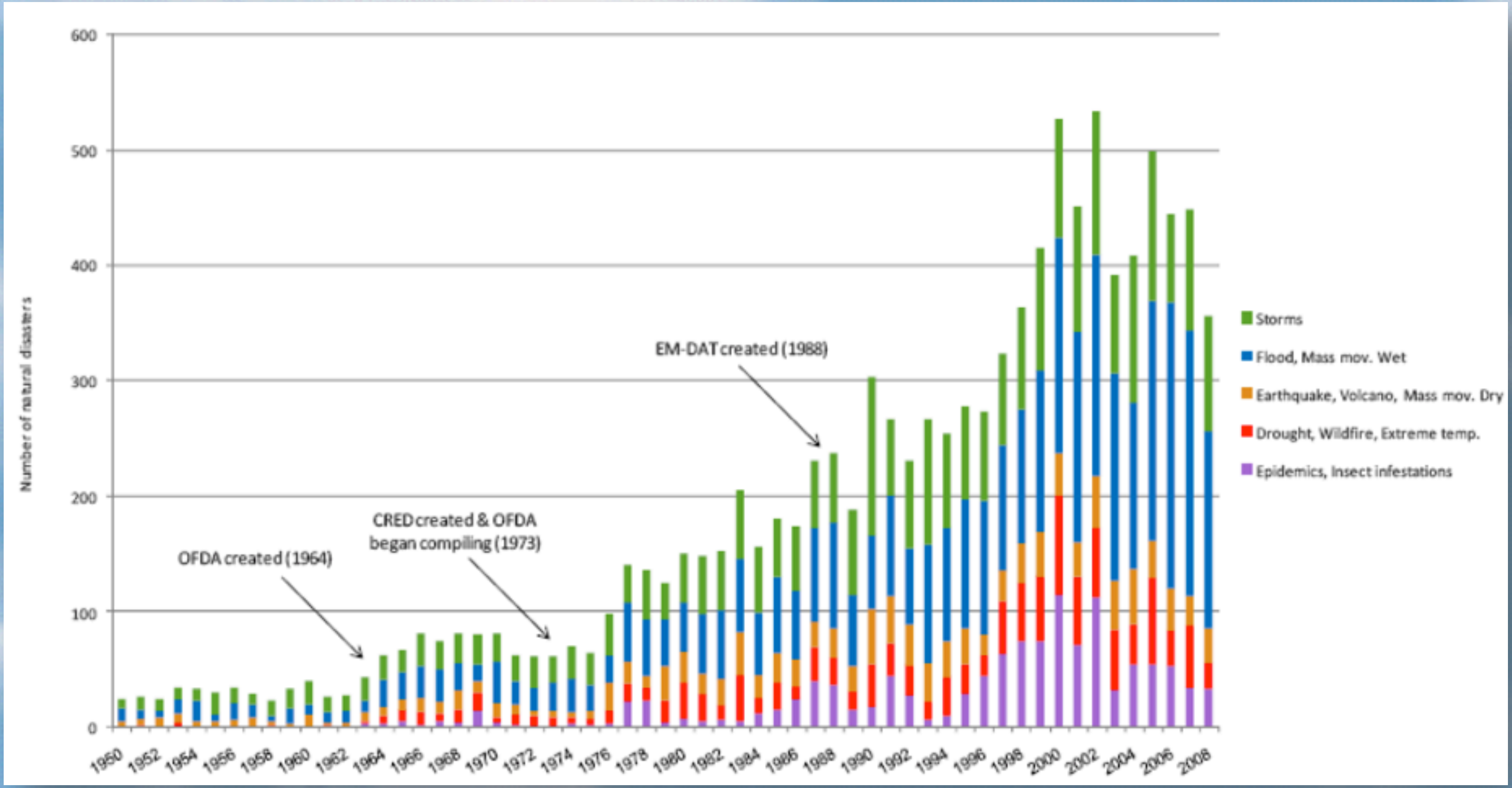
(Source: after Lenton et al. 2008)

Vivemos em um mundo biológico: Feedbacks biogeoquímicos



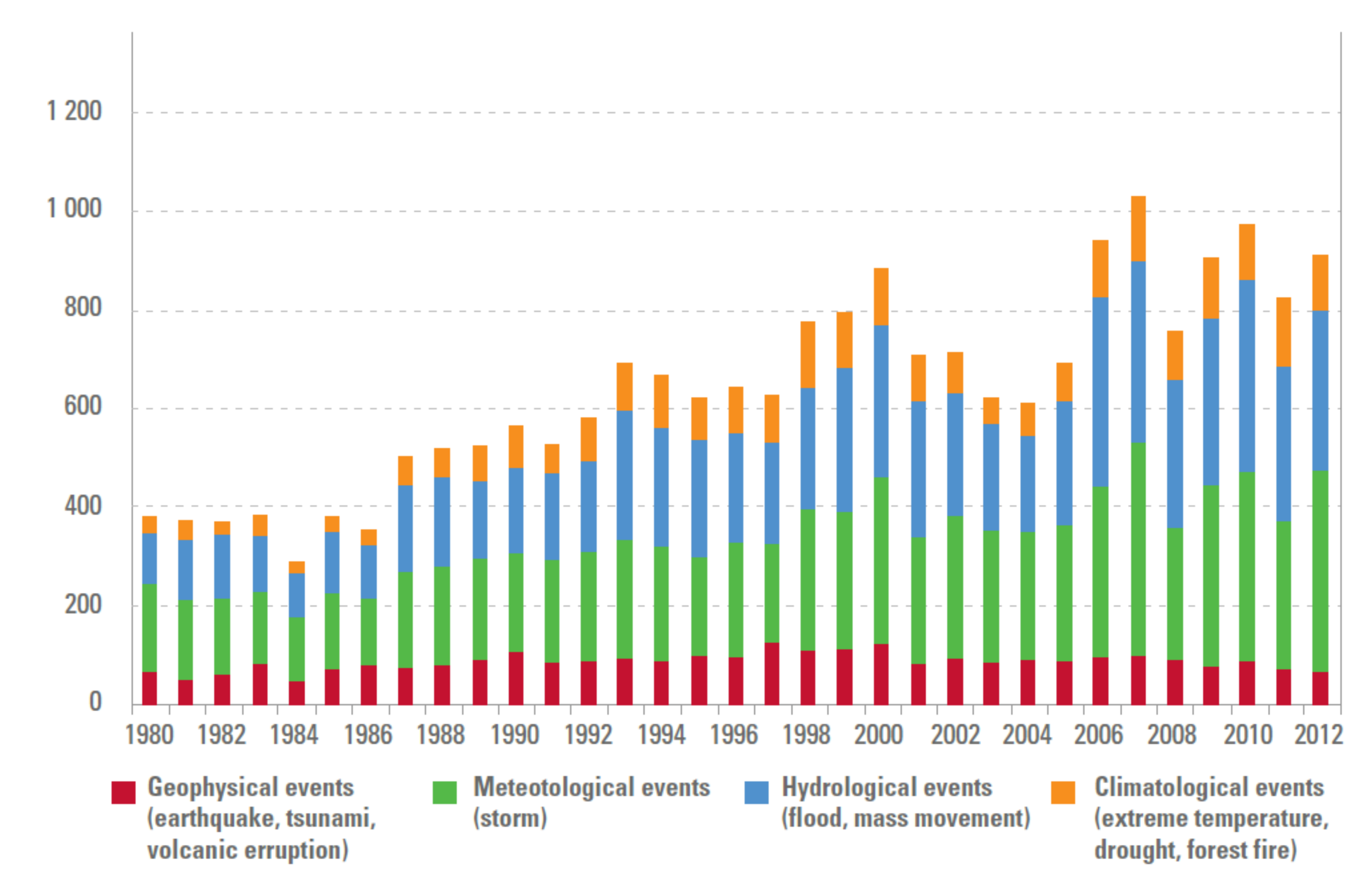
Como bactérias no solo (responsáveis por emissões de metano) vão reagir?

Aumento da incidência de eventos climáticos extremos – 1950-2008



EMDAT - The International Emergency Disasters Database (www.emdat.be)

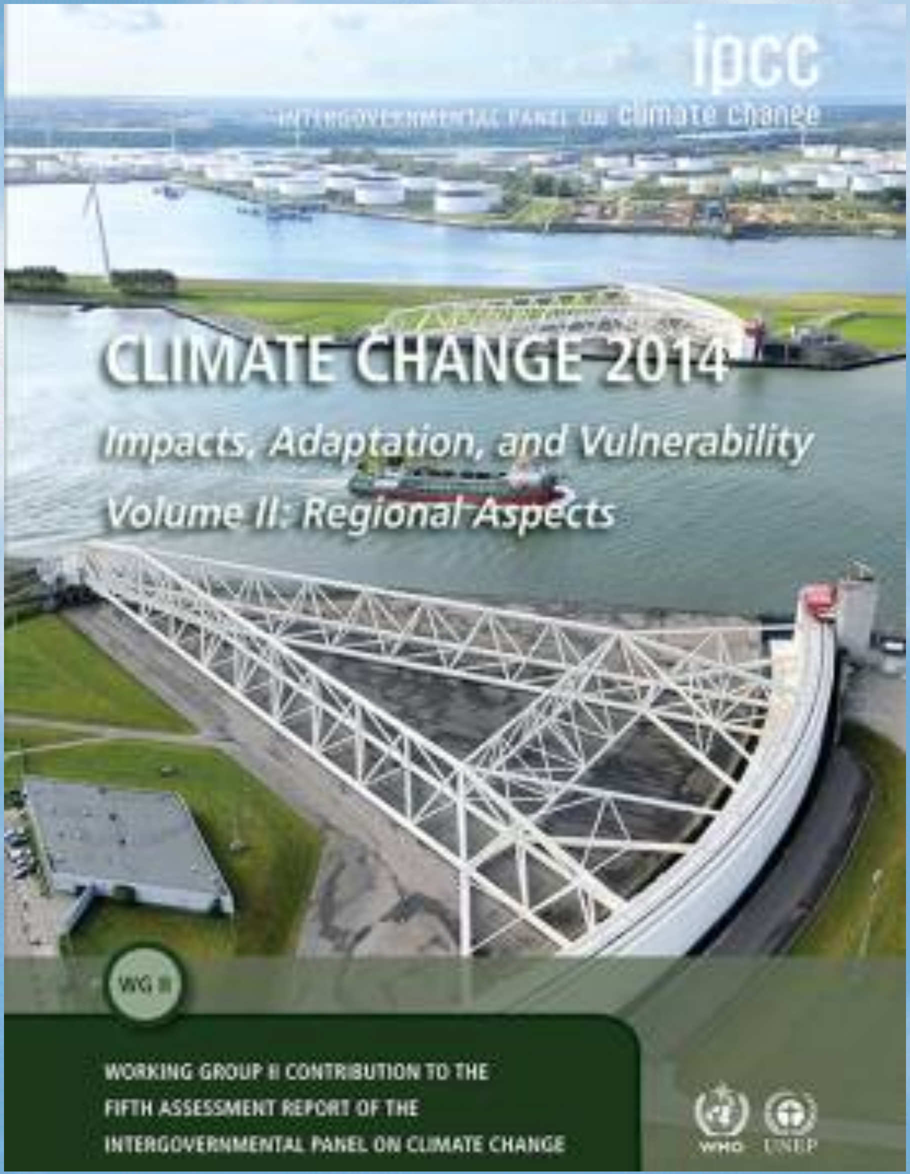
Number of natural disasters 1980–2010



source: MunichRe NatCatSERVICE

The Global Climate Report WMO 2013

IPC Working Group 2 – Impactos Adaptação e Vulnerabilidades



C40 - Megacidades e emissões de gases de efeito estufa

América Latina: 80% população urbana em 2012

Em 2100 80% da população mundial (10 billões) vai estar vivendo em cidadaes

Sustentabilidade em um planeta urbanizado

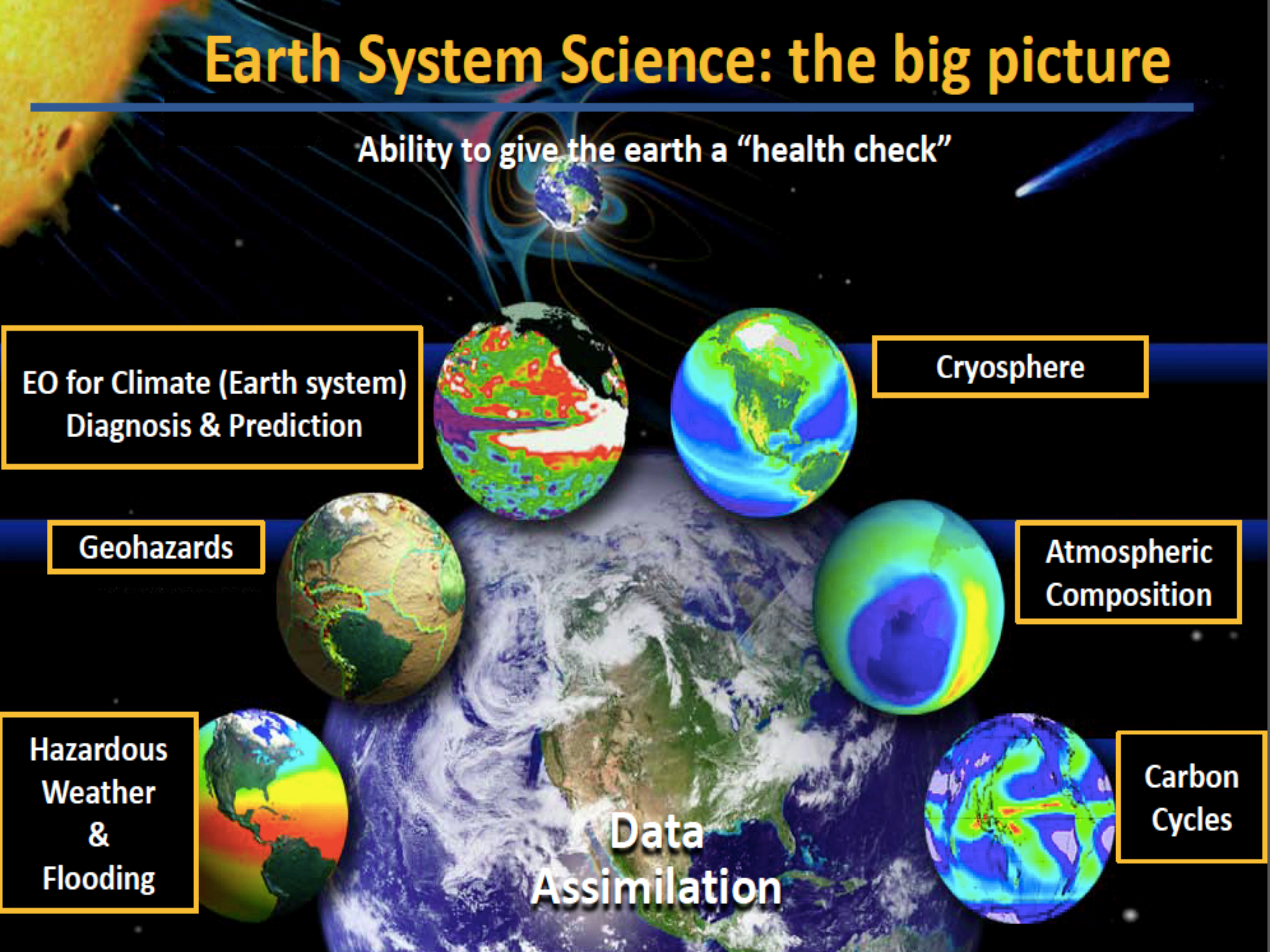
- Se o adicional de 3.2 bilhões de pessoas em 2100 vão viver em cidades de cerca de 1 milhão de habitantes, vamos ter que contruir 3.200 cidades de 1 milhão de pessoas cada em 89 anos, ou seja:
- **~ 1 nova cidade de 1 milhão a cada 10 dias!!!**

Agricultura e produção de alimentos com menor emissão de gases de efeito estufa


Água será uma questão
fundamental neste nosso século 21

Consumo em UMA SEMANA...

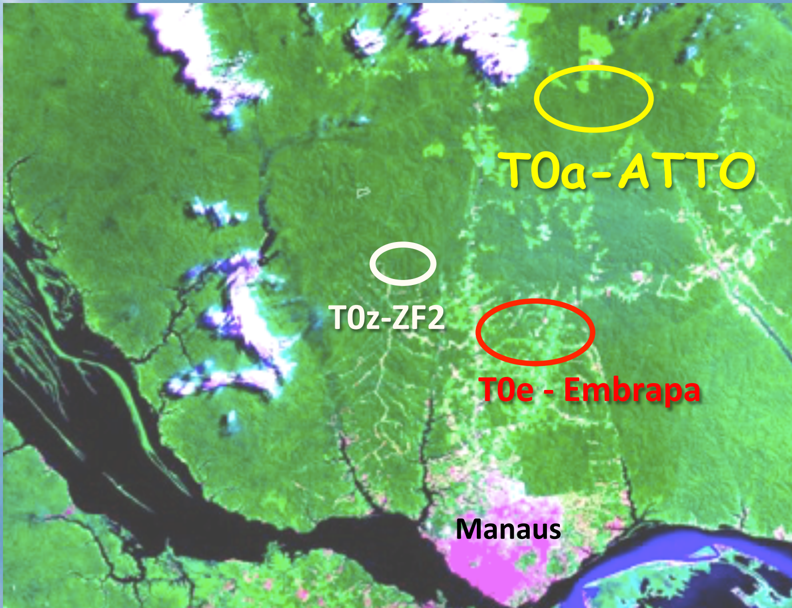
Edifício das Alterações Climáticas
Em construção
Adaptação
Mitigação
Durban 2011
Protocolo de Montereal
Copiar
colar
Segurança energética
Common but Differentiated Responsibilities
Actividade solar
Media
Cepticismo
Medo
Indiferença
Responsabilidade
Direitos humanos
Princípio da precaução
Sem acordo global
Governança e direito
Poluidores pagadores
Saúde
Emissões de luxo
Transformação social
Segurança alimentar
Custo social
Sociedade
Gerações futuras
Responsabilidade
Justiça climática
Religião e Clima
Valores
Bens comuns globais
Sistema de captura e comércio
Mercantilização
H_2O
Dinheiro
Investimento
Lucro
Limites do crescimento
Bio-combustíveis
Desenvolvimento
Desenvolvimento limpo
Redução da pobreza
Objectivos do Milénio
Ar quente
Carros
Economia
REDD
Desflorestação
Em construção por
CQNUAC
IPCC
UE
EUA
China
Índia
AOSIS
Greenpeace
OPEP
G2/G20/G77/G??
Probabilidade
Energias alternativas
Armazenamento de carbono
Evidência de dados
Agricultura
Incerteza
Modelação
Camada de gelo
Degelo dos glaciares
Em construção
Acidificação do oceano
Subida do nível do mar
Seca
Desflorestação
Ciência
Cancun 2010
Quioto 1997
Rio 1992
Petróleo
Biodiversidade
DiPLO
Concept: Kurbalija Illustration: Marcetic
Creative Commons by DiploFoundation


Earth System Science: the big picture
Ability to give the earth a "health check"
EO for Climate (Earth system) Diagnosis & Prediction
Cryosphere
Geohazards
Atmospheric Composition
Hazardous Weather & Flooding
Carbon Cycles
Data Assimilation


Obrigado pela atenção !!!

GoAmazon 2014/5 sampling sites

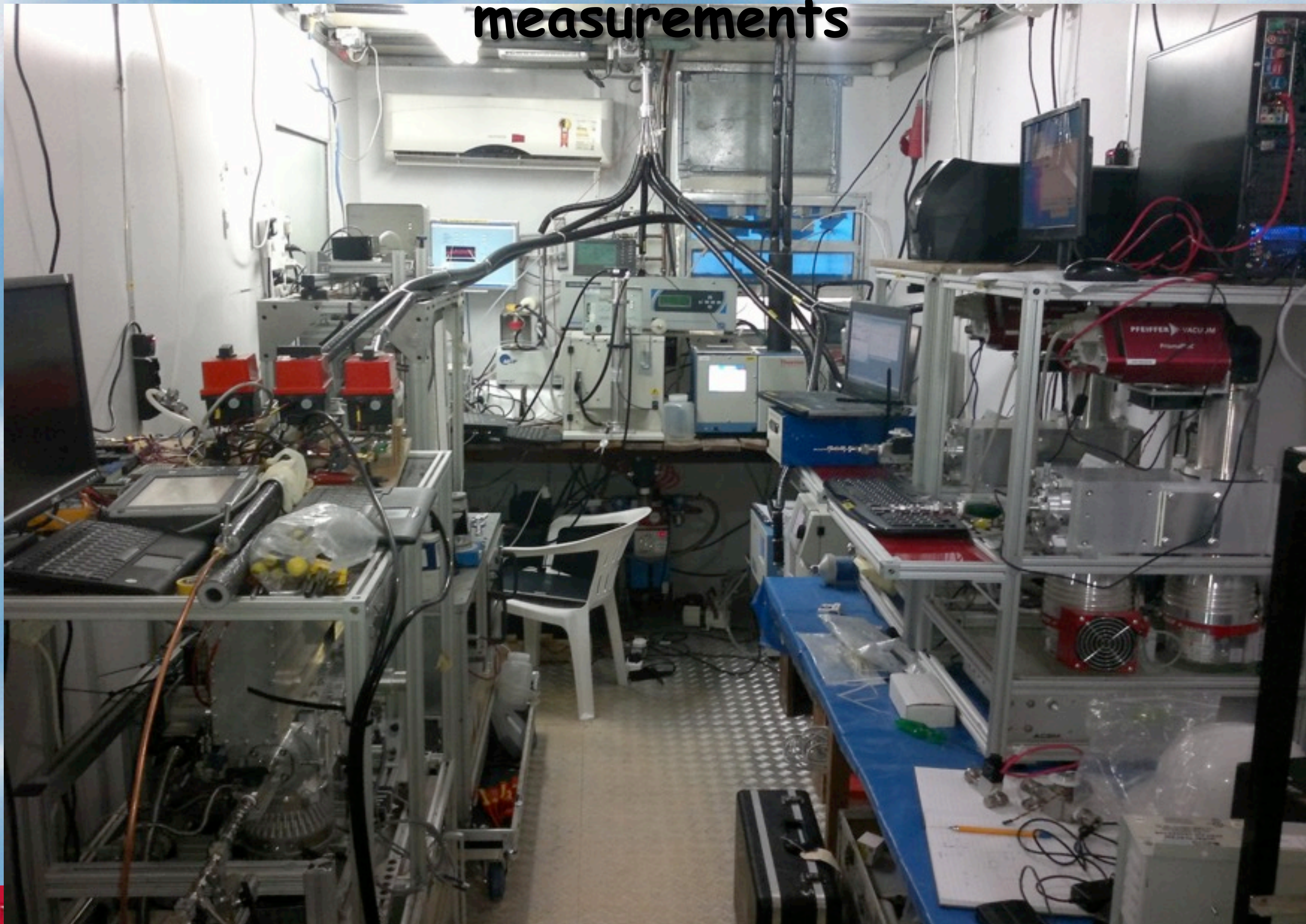
Background atmosphere before Manaus plume



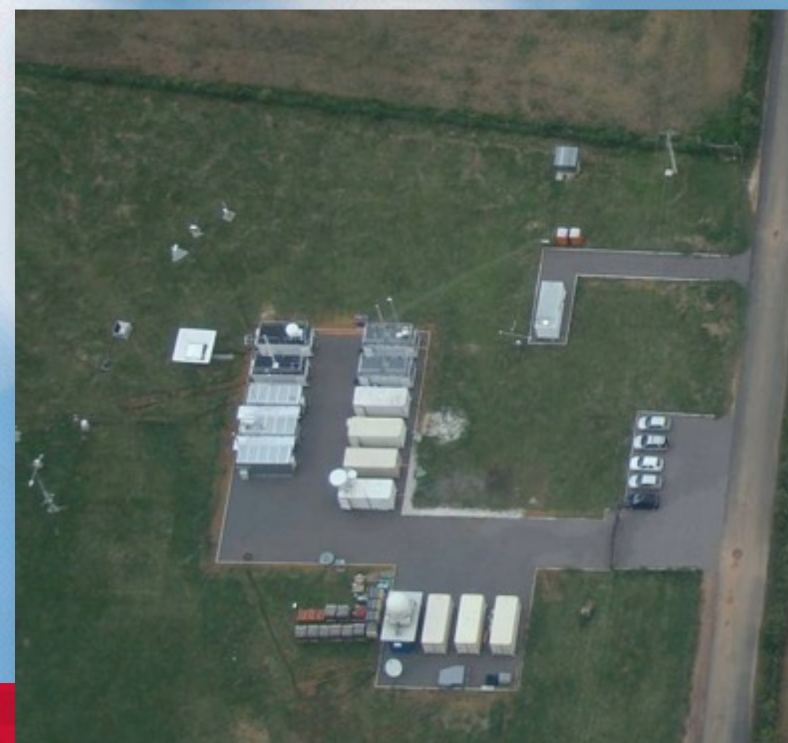
T0a - ATTO site

T0z - ZF2 Rebio Cuieras site

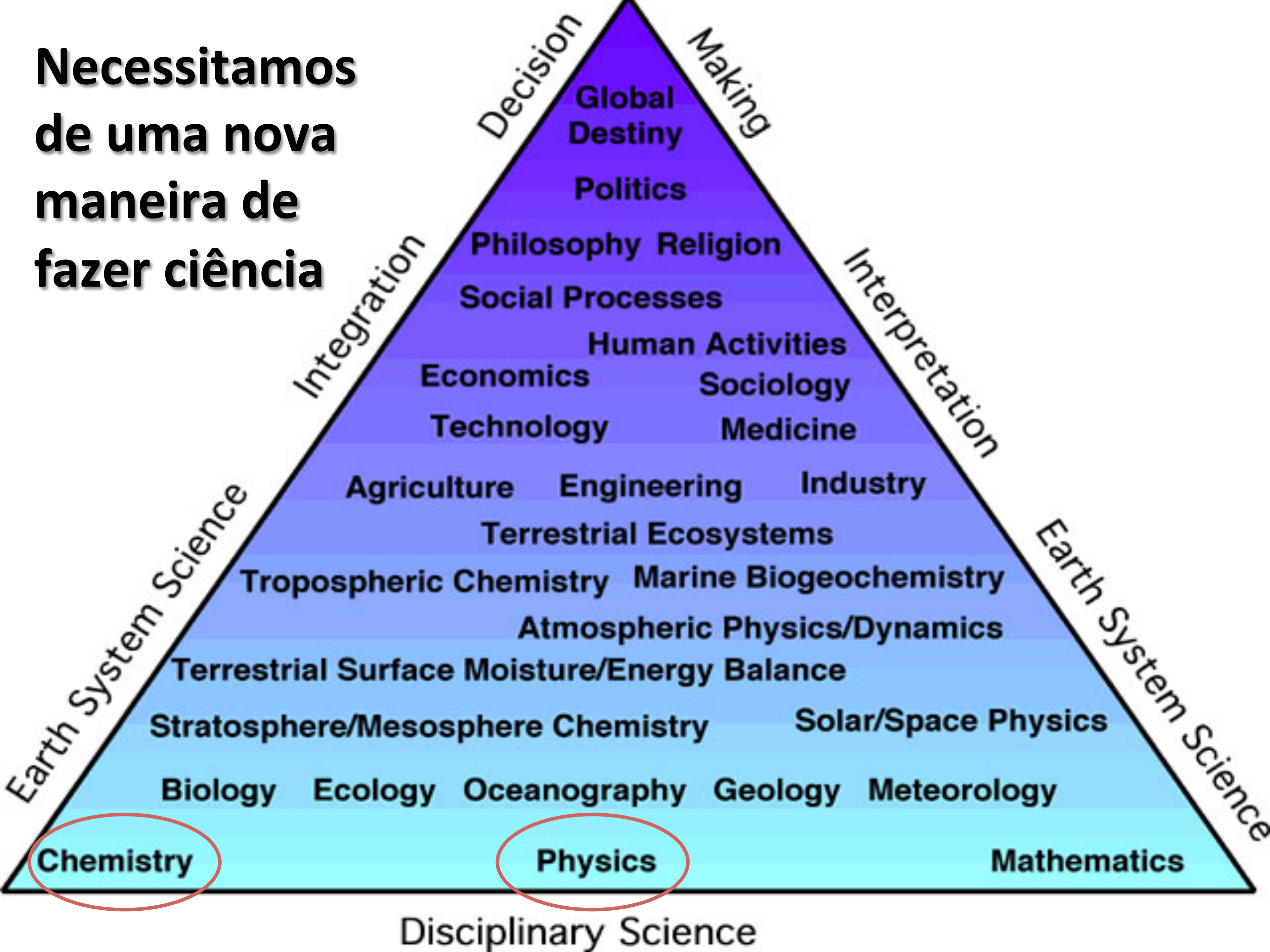
T0z - Manaus ZF2 aerosol and trace gas measurements



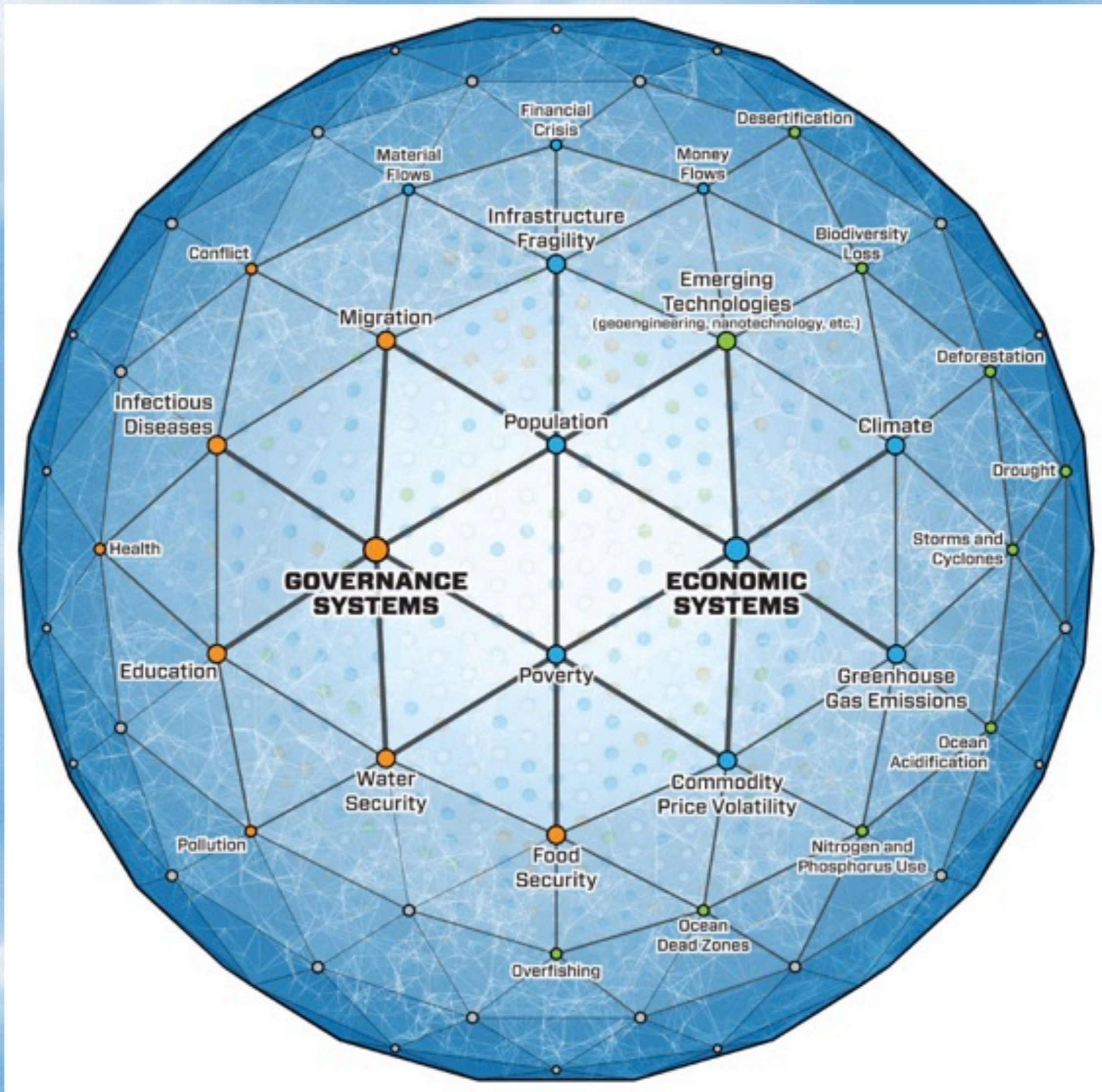
From T2-Tiwa to T3-Manacapuru



Necessitamos de uma nova maneira de fazer ciência



A Governança das mudanças globais e as interconexões



Interconnected global challenges.Global Risks Report (2011)

Dificuldades de acordos internacionais:

E os países com baixa emissão per capita?

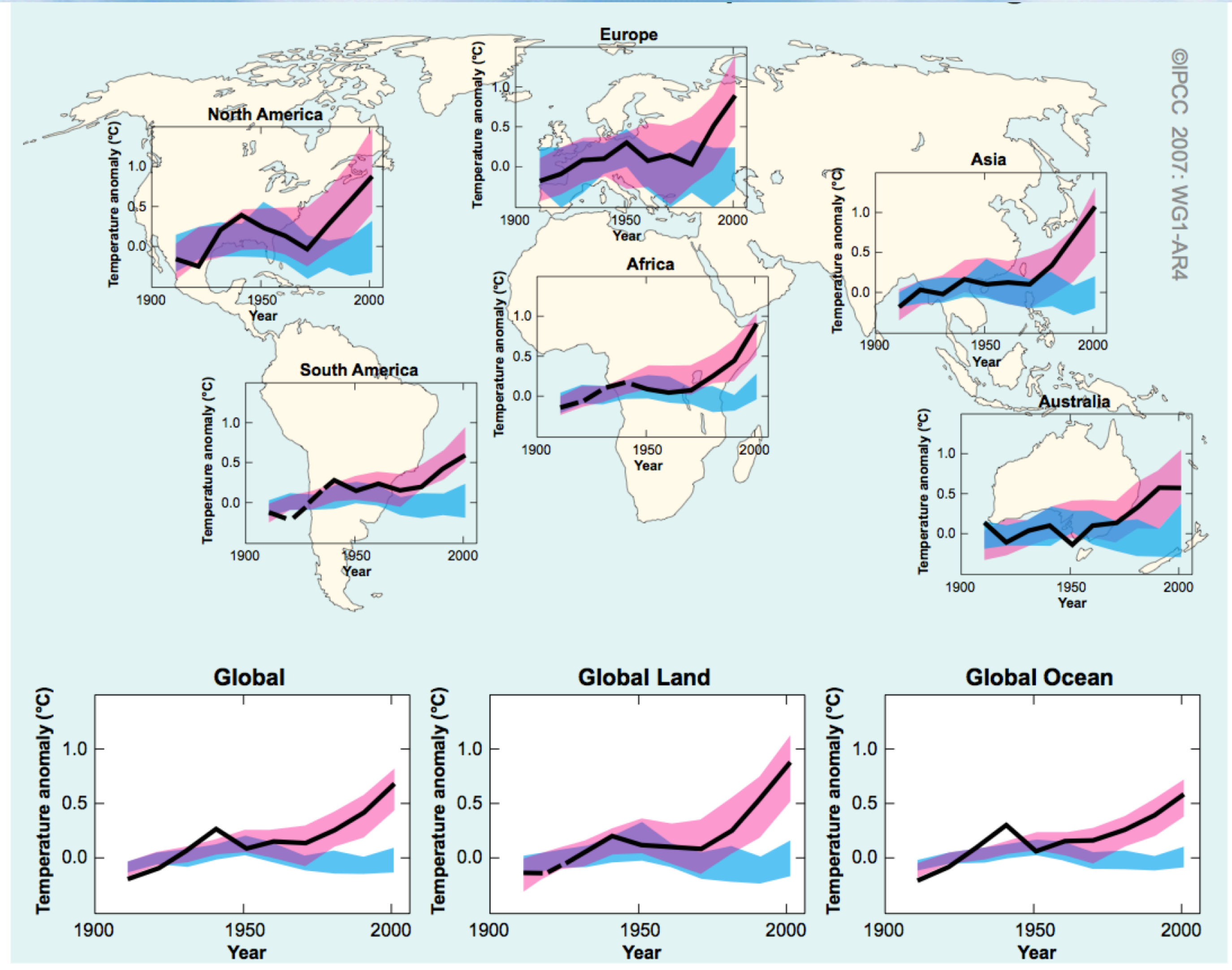
Países desenvolvidos aceitam redução em seu nível de consumo?

Quem paga a conta?

Quem perde e quem ganha economicamente?

Prazos para redução de emissões?
Muitos etc...

Atribuição do aumento observado de temperatura

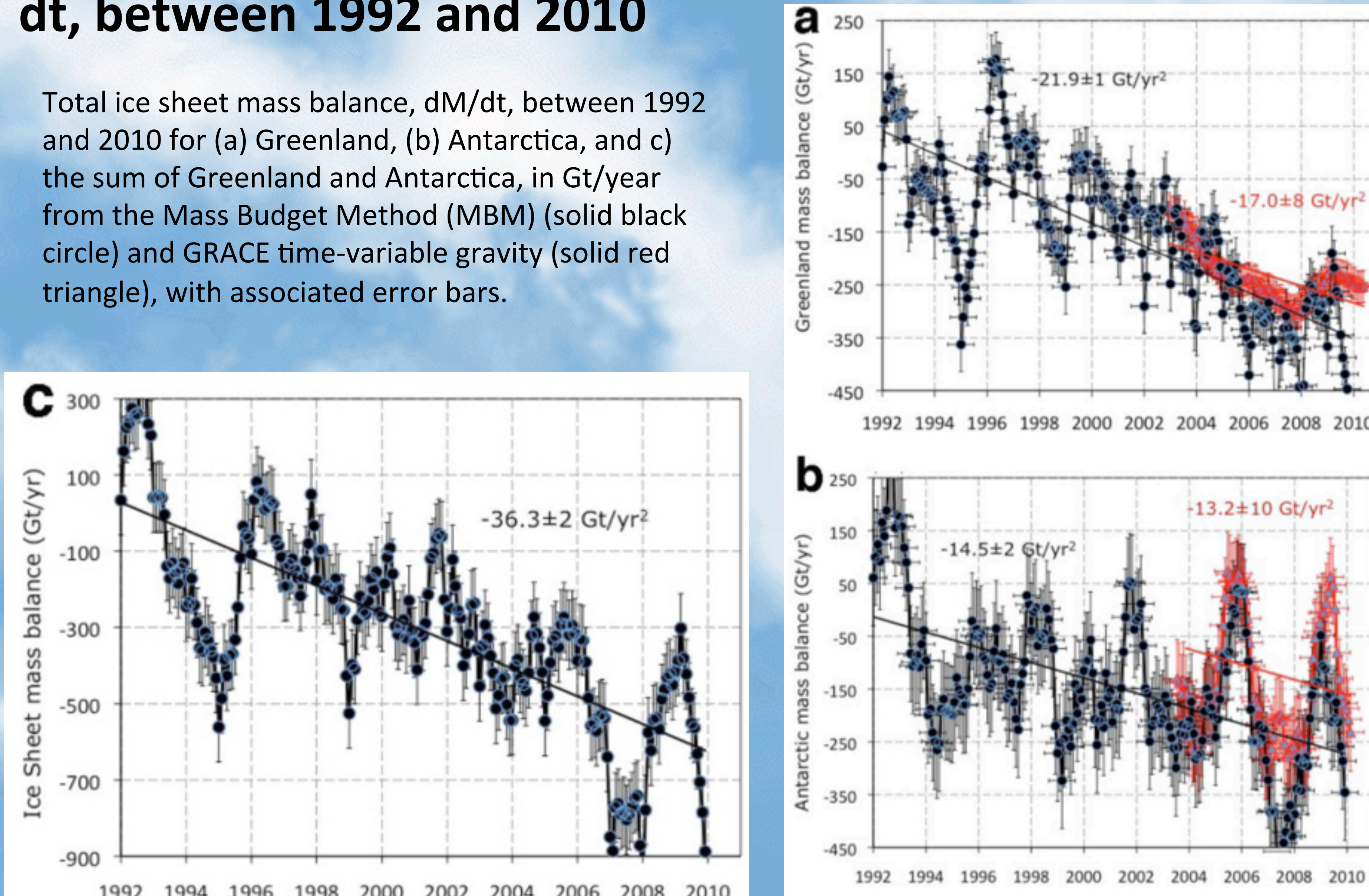


Comparação de temperaturas modeladas e observadas usando forçantes climáticas naturais e antropogênicas para cada região do planeta.

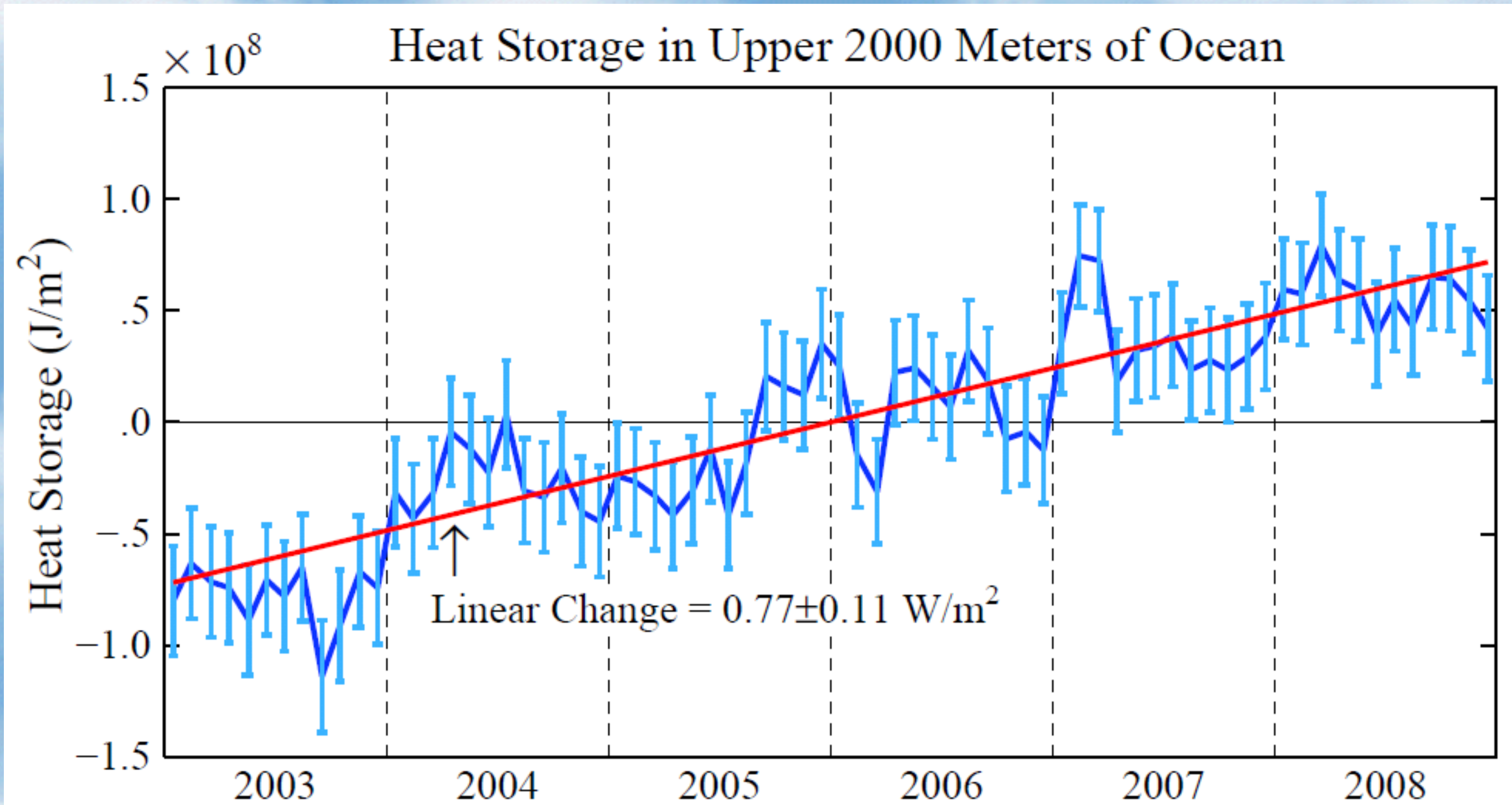
Total ice sheet mass balance, dM/dt, between 1992 and 2010

Source: E. Rignot, Velicogna, Broeke, Monaghan, and Lenaerts 2011.

Total ice sheet mass balance, dM/dt, between 1992 and 2010 for (a) Greenland, (b) Antarctica, and c) the sum of Greenland and Antarctica, in Gt/year from the Mass Budget Method (MBM) (solid black circle) and GRACE time-variable gravity (solid red triangle), with associated error bars.

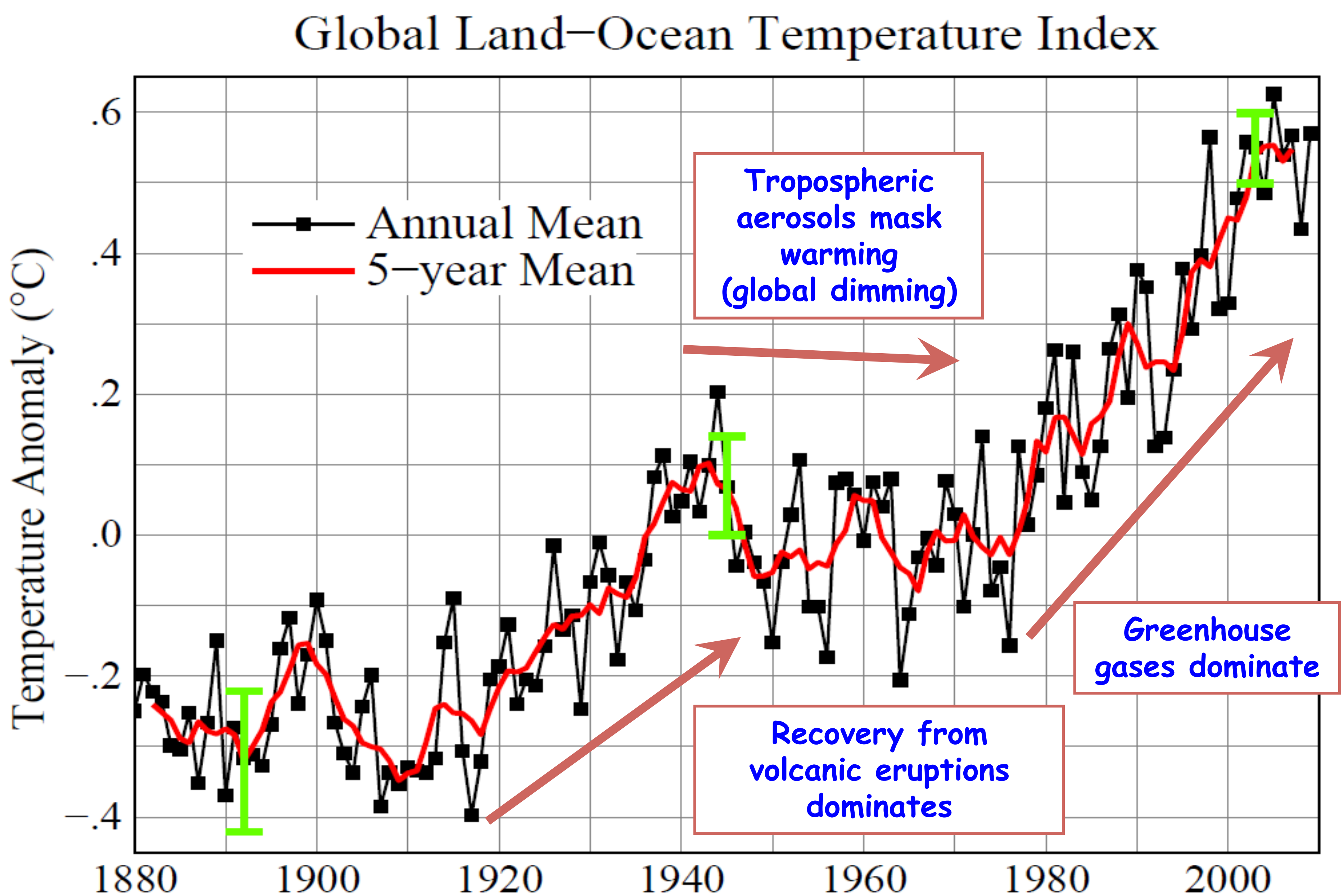


Armazenamento de calor nos oceanos até 2000 metros de profundidade



Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data. Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

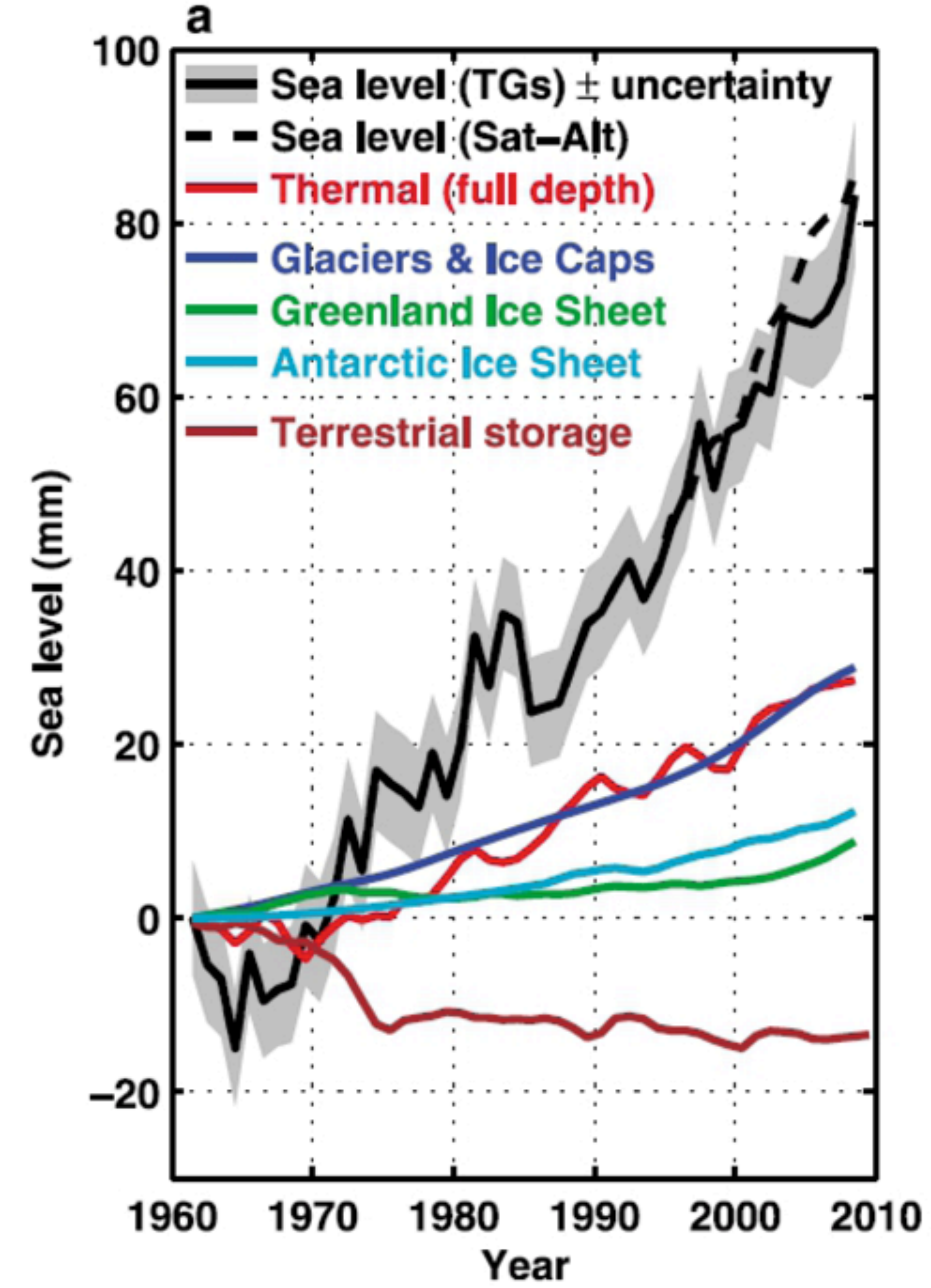
Data source: von Schuckmann et al. J. Geophys. Res. ***114****, C09007, 2009.*



Aerosols (and greenhouse gases) dominate the temperature change

Aumento do nível do mar pelas diferentes contribuições

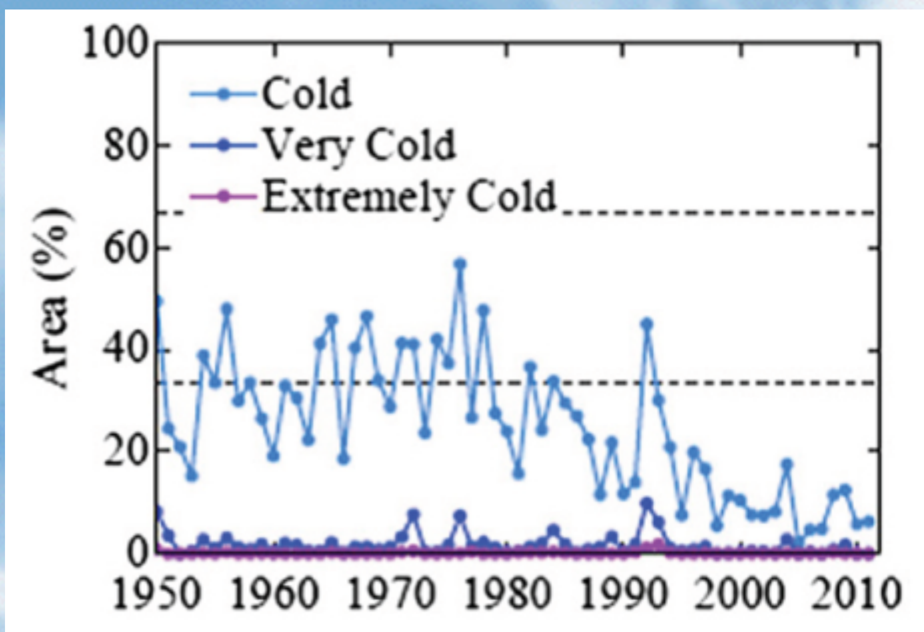
The contributions of land ice (mountain glaciers and ice caps and Greenland and Antarctic ice sheets), thermosteric sea level rise, and terrestrial storage (the net effects of groundwater extraction and dam building), as well as observations from tide gauges (since 1961) and satellite observations (since 1993).

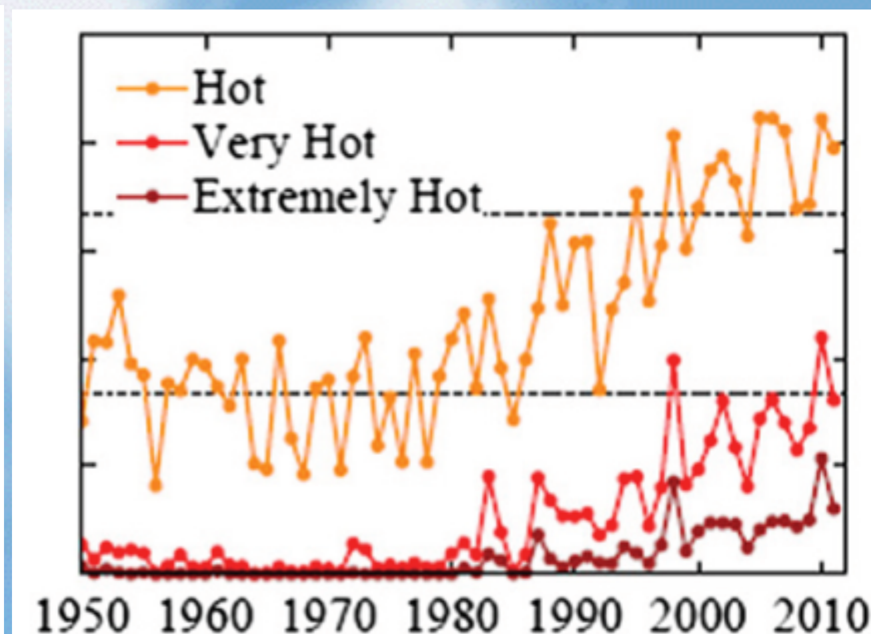


Source: Church et al., 2011.

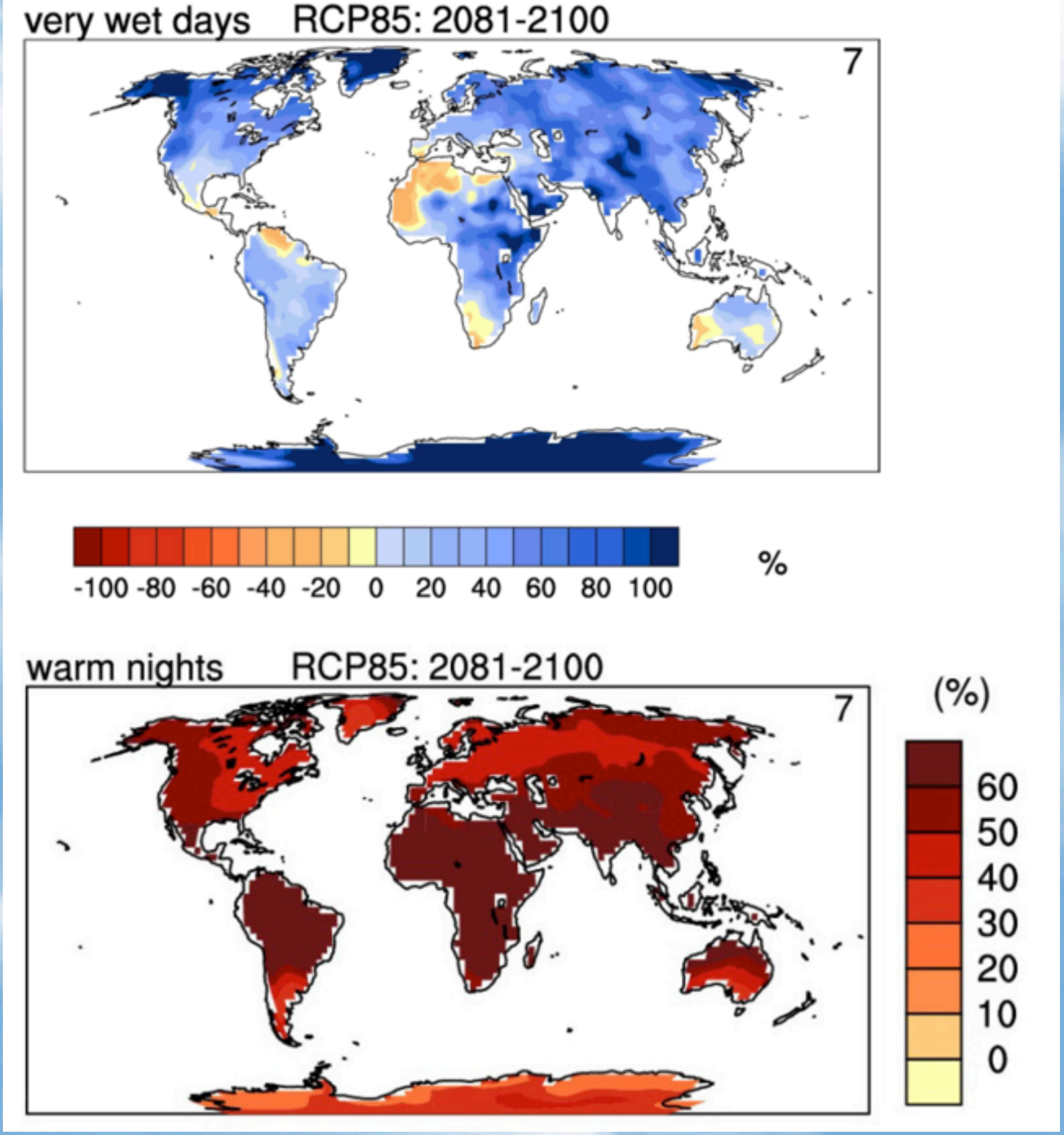
Série temporal de extremos de temperatura

Northern Hemisphere land area covered (left panel) by cold (< –0.43σ), very cold (< –2σ), extremely cold (< –3σ) and (right panel) by hot (> 0.43σ), very hot (> 2σ) and extremely hot (> 3σ) summer temperatures.





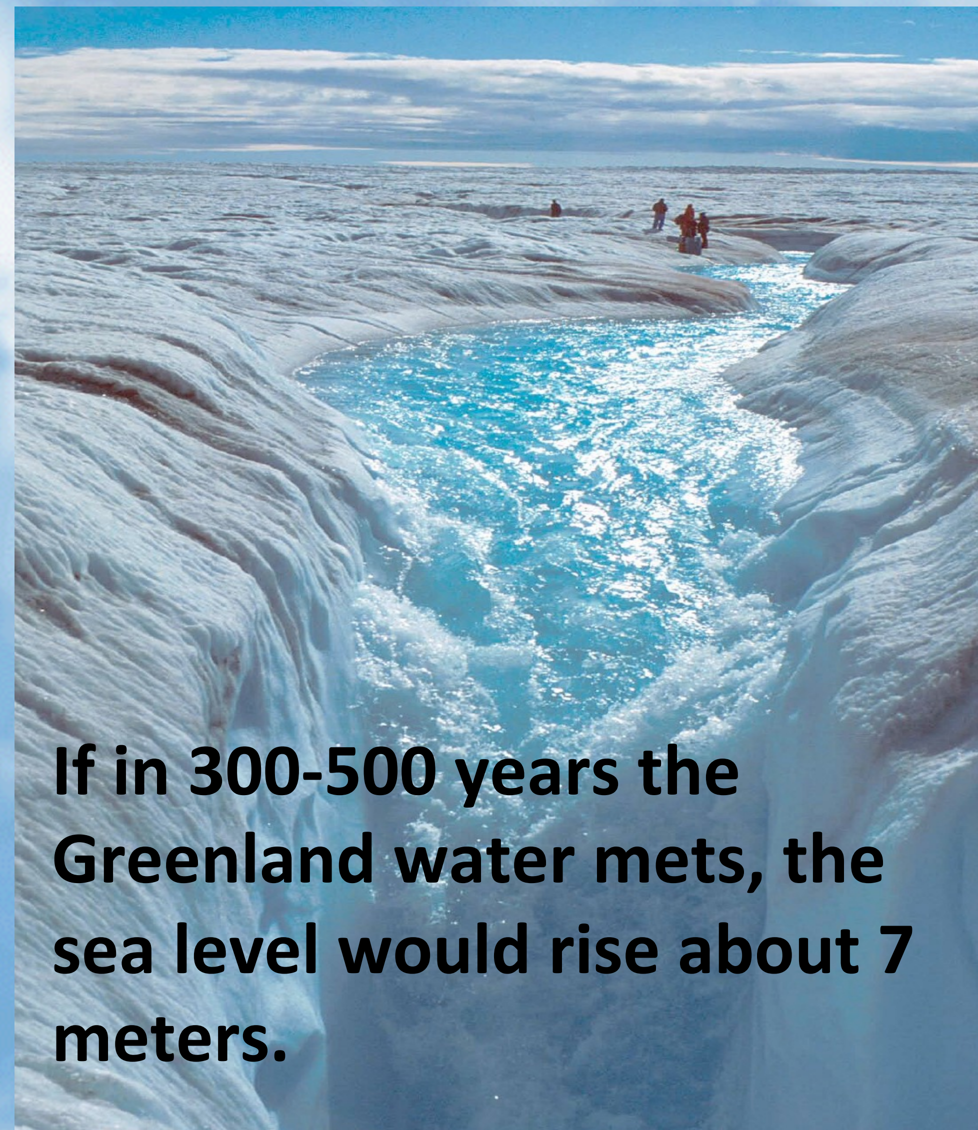
Source: Hansen et al. 2012



Frequência de eventos extremos 2081-2100

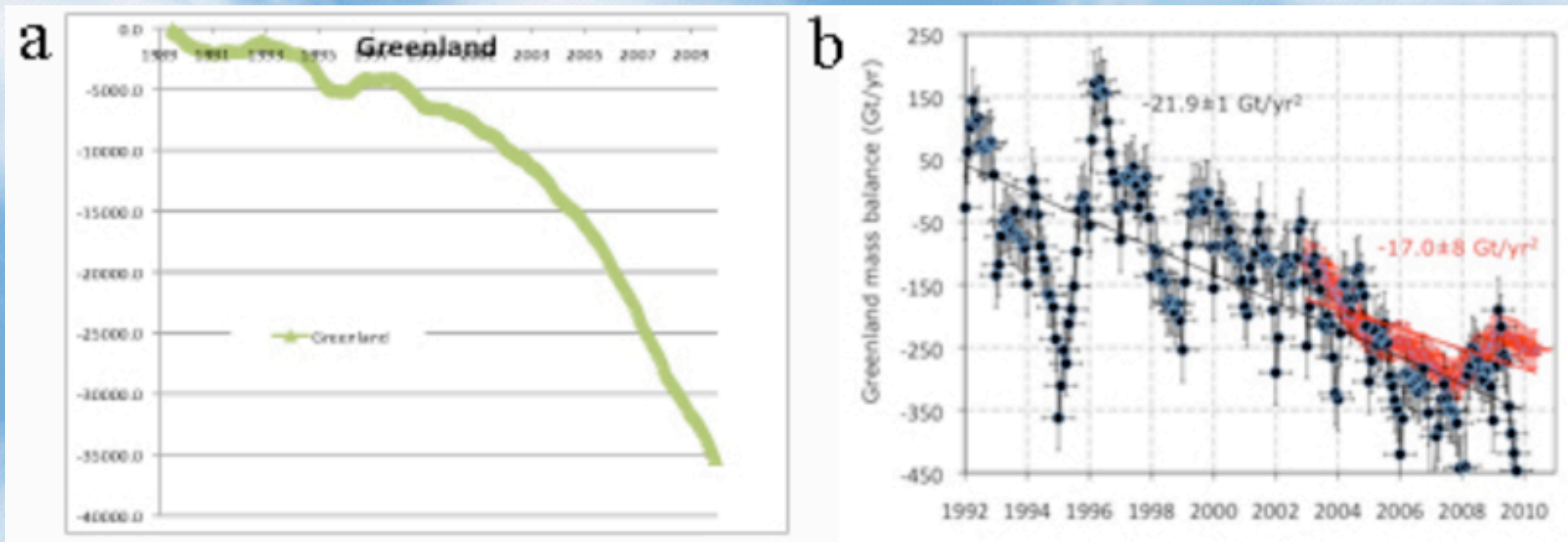
Changes in selected extreme indices in 2100

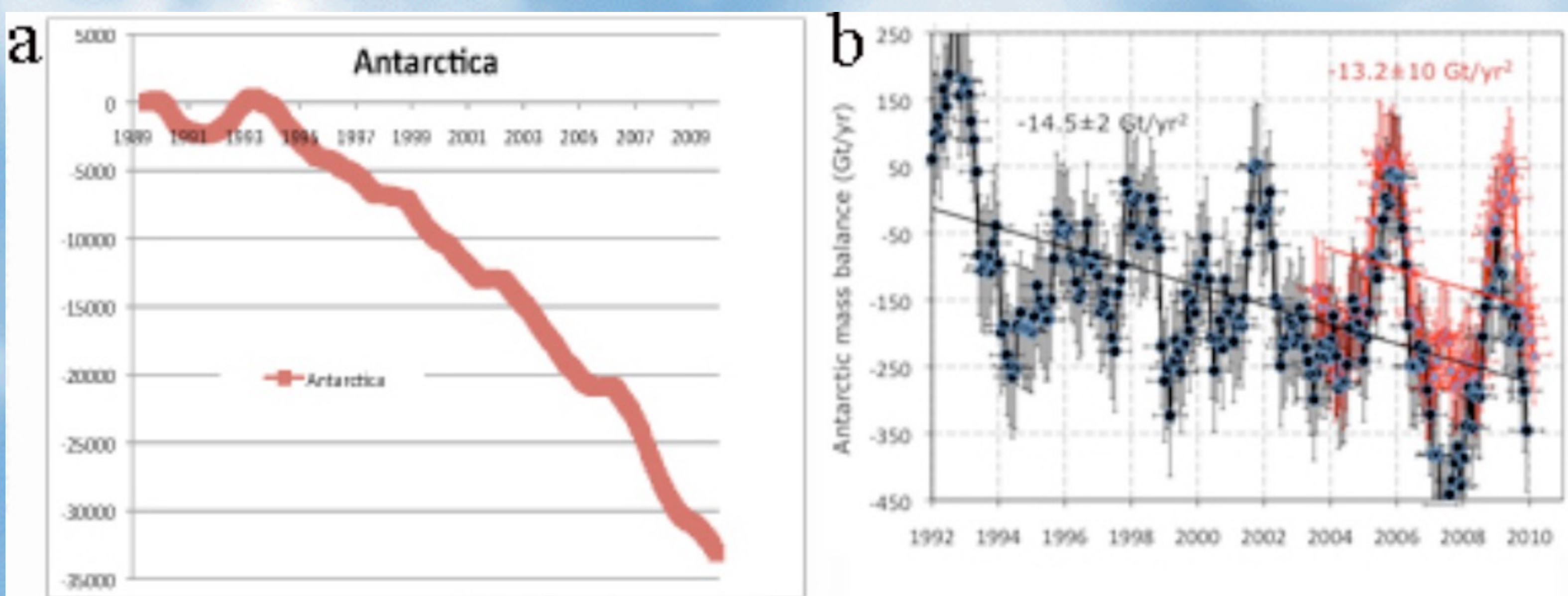
Arctic climate is changing very fast



If in 300-500 years the Greenland water mets, the sea level would rise about 7 meters.

Greenland and Antarctic ice loss



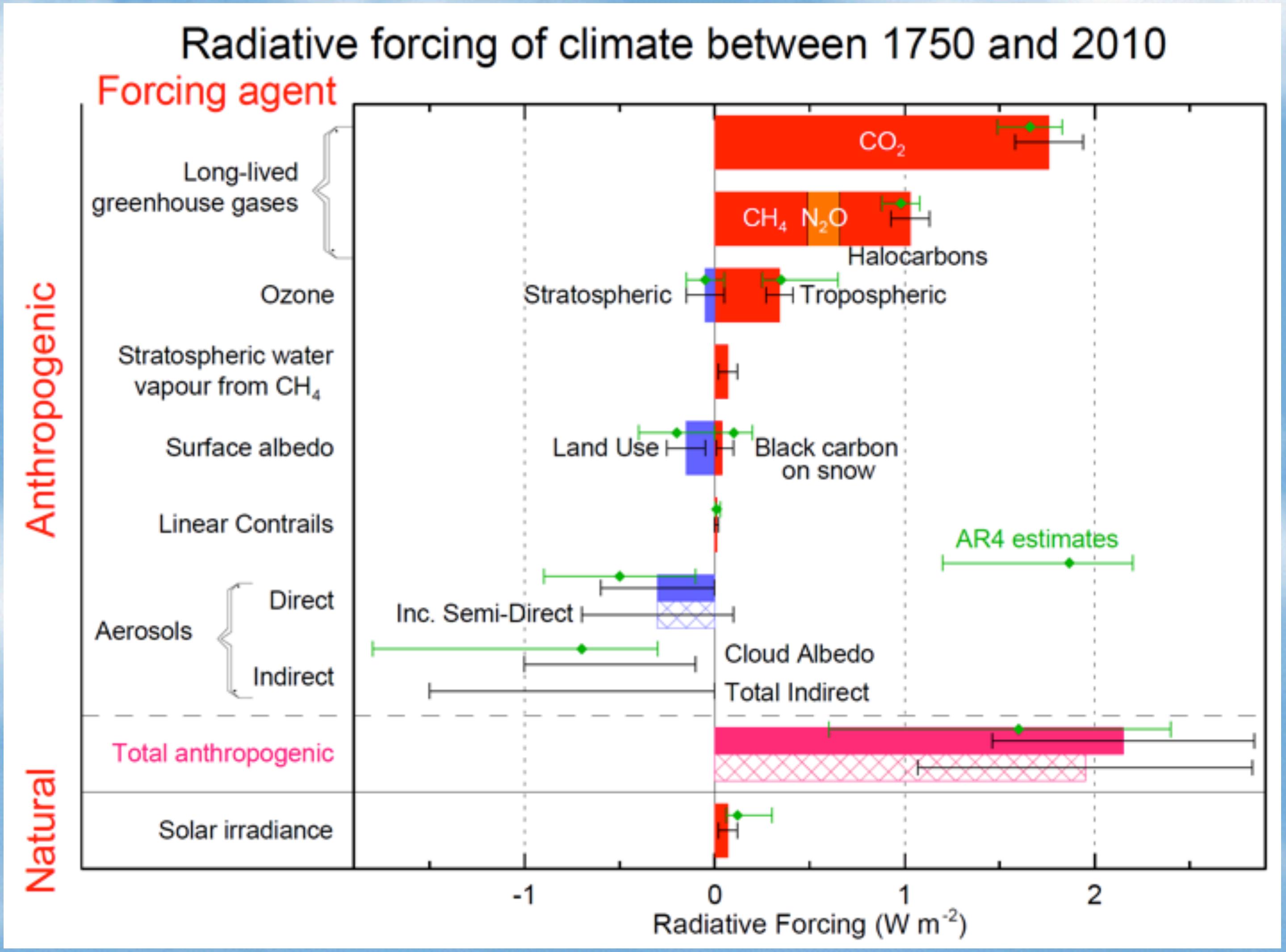


Selection of record-breaking meteorological events since 2000, their societal impacts and qualitative confidence level that the meteorological event can be attributed to climate change

Region (Year)	Meteorological Record-breaking Event	Confidence in attribution to climate change	Impact, costs
England and Wales (2000)	Wettest autumn on record since 1766. Several short-term rainfall records[2]	Medium based on[3–5]	~£1.3 billion[3]
Europe (2003)	hottest summer in at least 500 years[6]	High based on[7,8]	Death toll exceeding 70,000[9]
England and Wales (2007)	May to July wettest since records began in 1766[10]	Medium based on[3,4]	Major flooding causing ~£3 billion damage
Southern Europe (2007)	Hottest summer on record in Greece since 1891[11]	Medium based on[8,12–14]	Devastating wildfires
Eastern Mediter-ranean, Middle-East (2008)	Driest winter since 1902 (see Fig. 20)	High based on[15]	Substantial damage to cereal production[16]
Victoria (Aus) (2009)	Heat wave, many station temperature records (32–154 years of data)[17]	Medium based on[8,14]	Worst bushfires on record, 173 deaths, 3,500 houses destroyed[17]
Western Russia (2010)	Hottest summer since 1500[18]	Medium based on[8,13,14,19]	500 wildfires around Moscow, crop failure of ~25%, death toll ~55,000, ~US$15B economic losses[18]
Pakistan (2010)	Rainfall records[20]	Low to Medium based on[21,22]	Worst flooding in its history, nearly 3000 deaths, affected 20M people[23].
Colombia (2010)	Heaviest rains since records started in 1969[26]	Low to Medium based on[21]	47 deaths, 80 missing[26]
Western Amazon (2010)	Drought, record low water level in Rio Negro[27]	Low[27]	Area with significantly increased tree mortality spanning3.2 million km[27]
Western Europe (2011)	Hottest and driest spring on record in France since 1880[28]	Medium based on[8,14,29]	French grain harvest down by 12%
4 US states (TX, OK, NM, LA) (2011)	Record-breaking summer heat and drought since 1880[30,31]	High based on[13,14,31,32]	Wildfires burning 3 million acres (preliminary impact of $6 to $8 billion)[33]
Continental U.S. (2012)	July warmest month on record since 1895[34] and severe drought conditions	Medium based on[13,14,32]	Abrupt global food price increase due to crop losses[35]

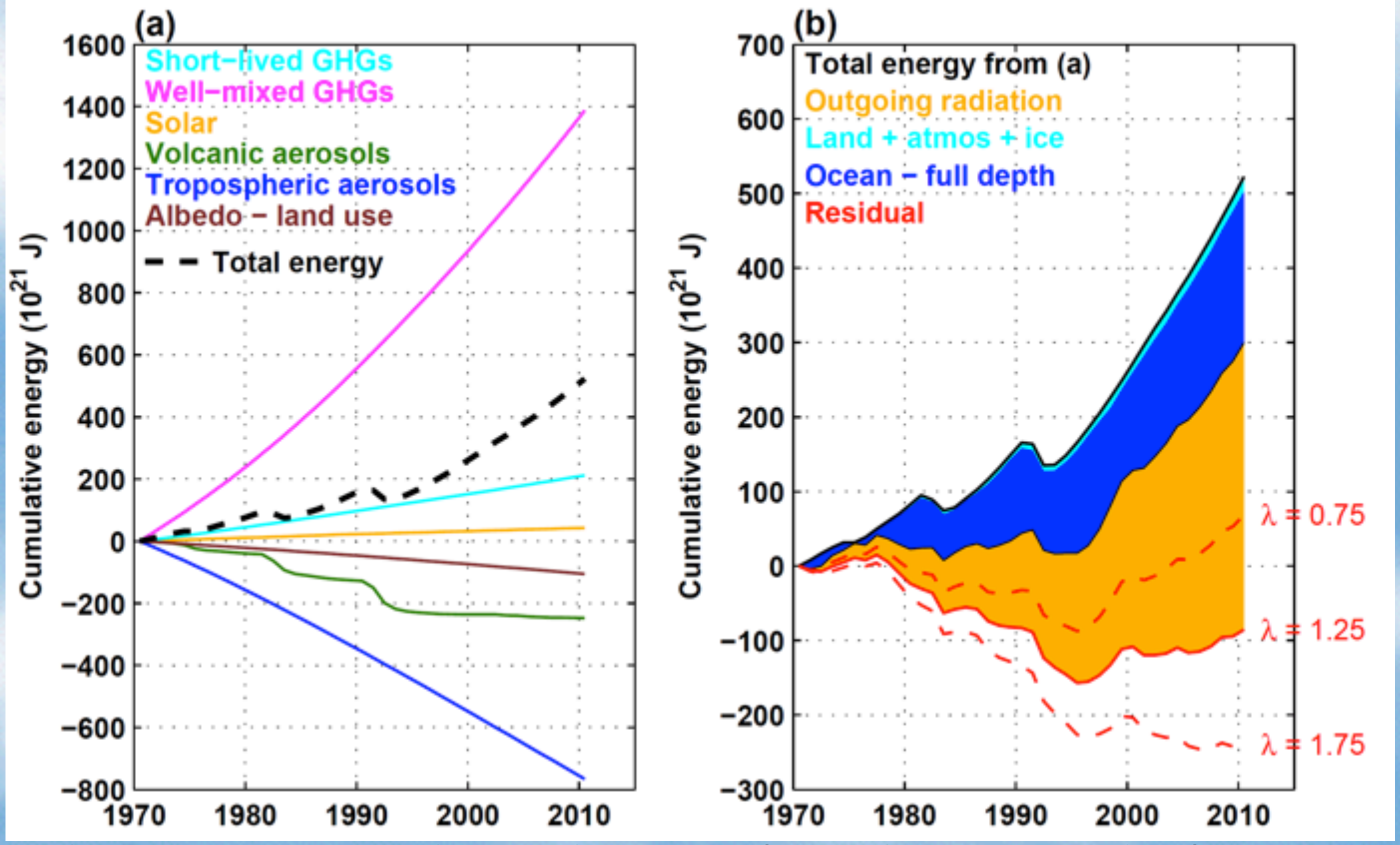
D Coumou and S Rahmstorf, Nature Climate Change 2, 491 (2012).

Radiative forcing of climate change during the industrial era.



Forcing by component between 1750 and 2010 with associated uncertainty range (solid bars are RF, hatched bars are AF, green diamonds and associated uncertainties are those assessed in AR4).

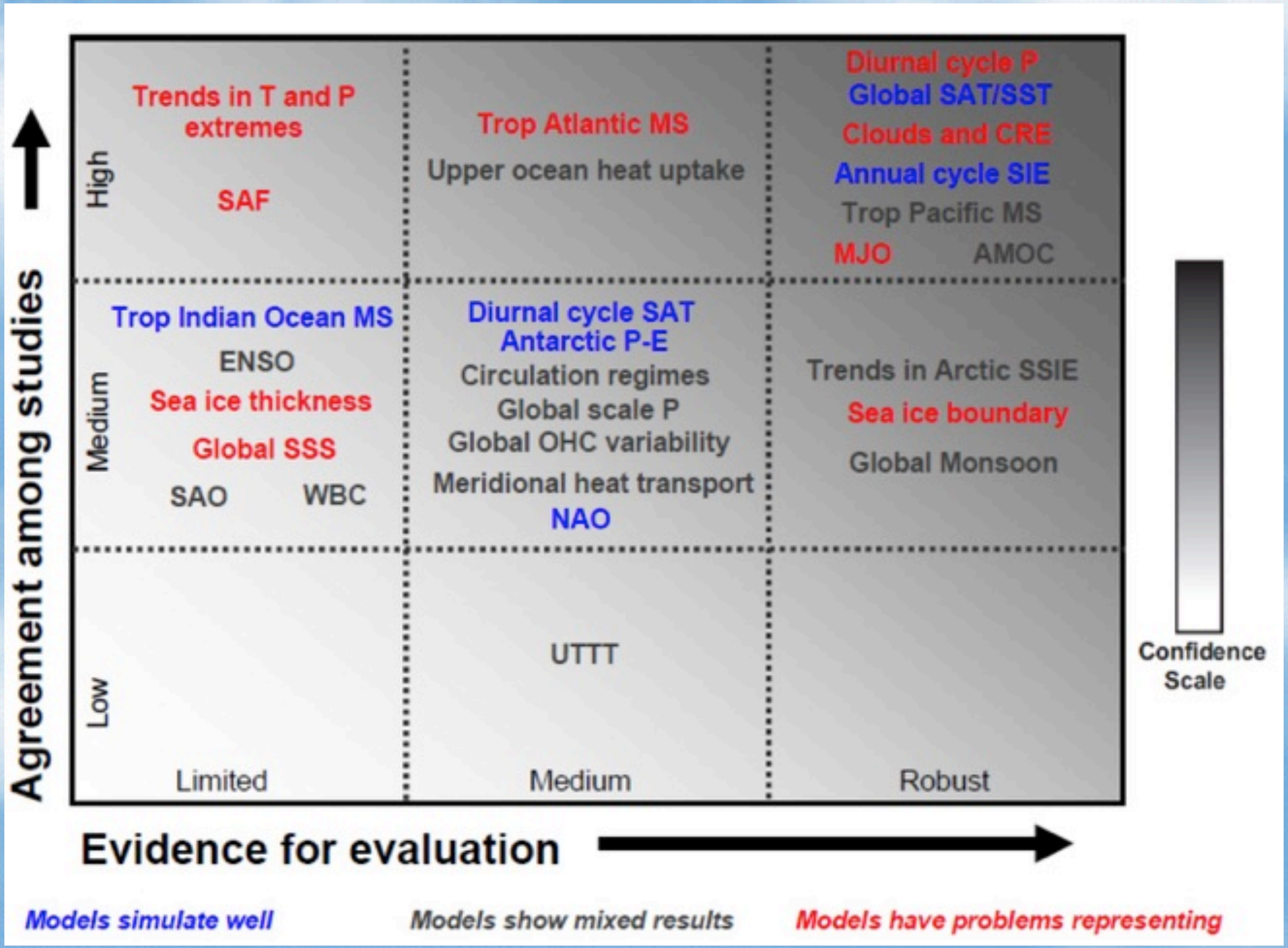
The Earth's energy budget from 1970 through 2010



(a) The cumulative energy into the Earth system from changes in solar forcing, well-mixed and short-lived greenhouse gases, changes in surface albedo, volcanic forcing and tropospheric aerosol.

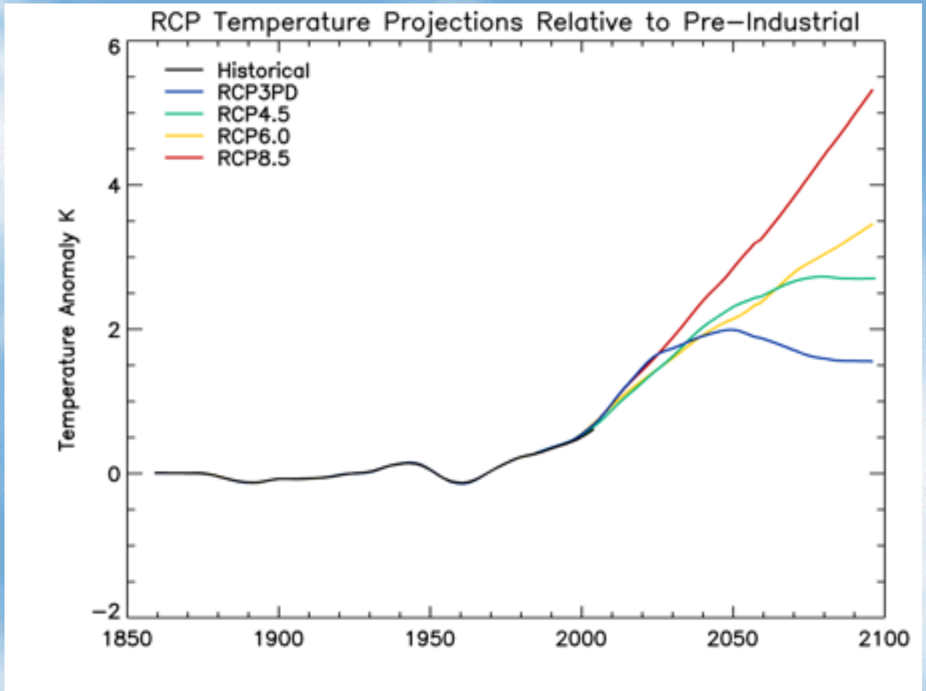
(b) The cumulative energy from (a), with an expanded scale, is balanced by the warming of the Earth system (energy absorbed in the melting of ice and warming the atmosphere, the land and the ocean) and an increase in outgoing radiation inferred from temperature change of a warming Earth.

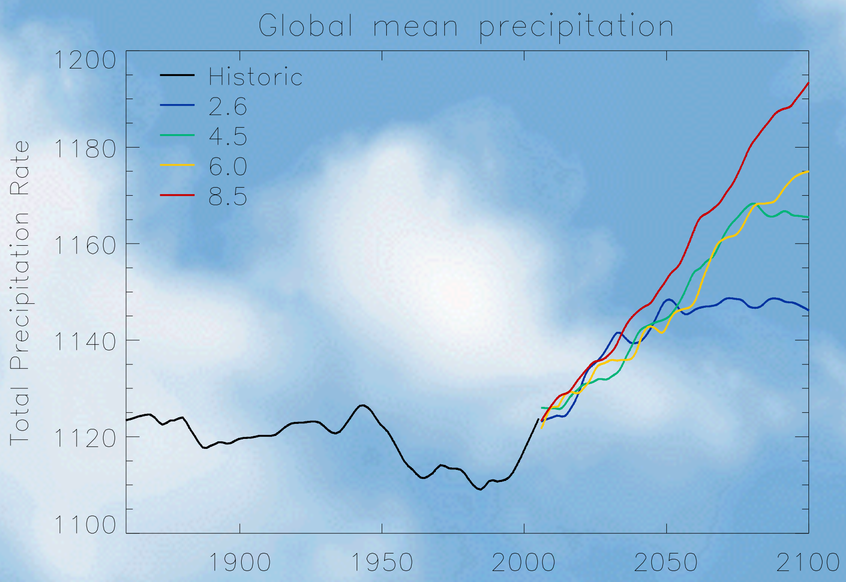
How well the models simulate important features of the climate of the 20th century

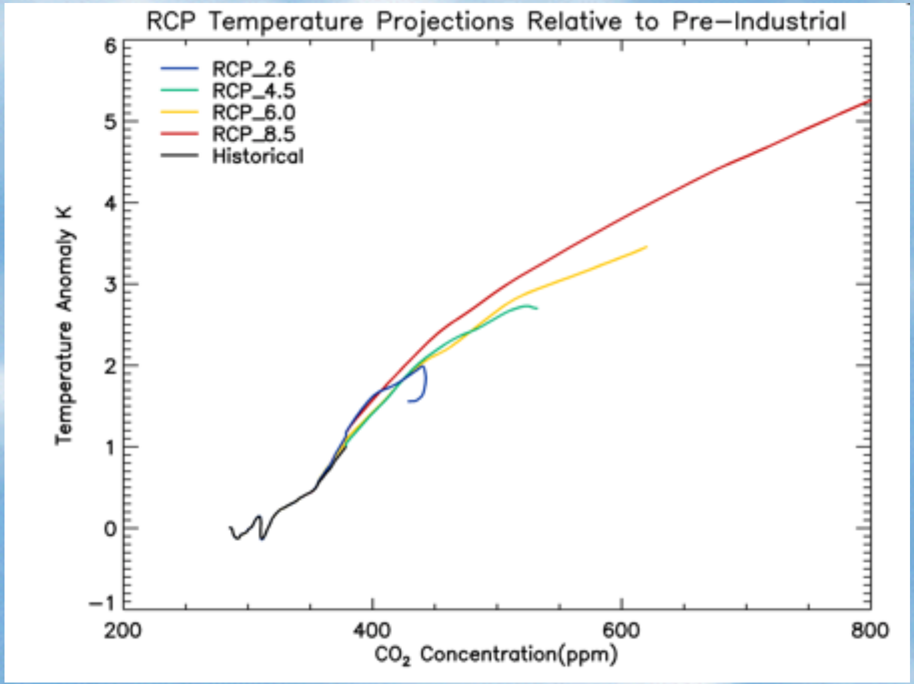


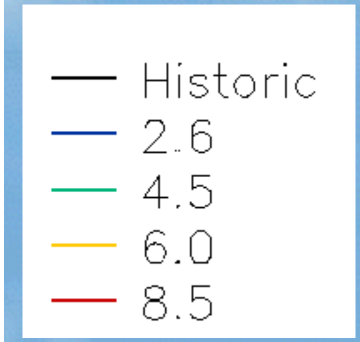
Confidence in the assessment increases towards the top-right corner as suggested by the increasing strength of shading. Features that current state-of-the-art AOGCMS and ESMs simulate well, show mixed results, or have problems representing are shown in blue, grey, and red, respectively.

Hadley Center Predictions

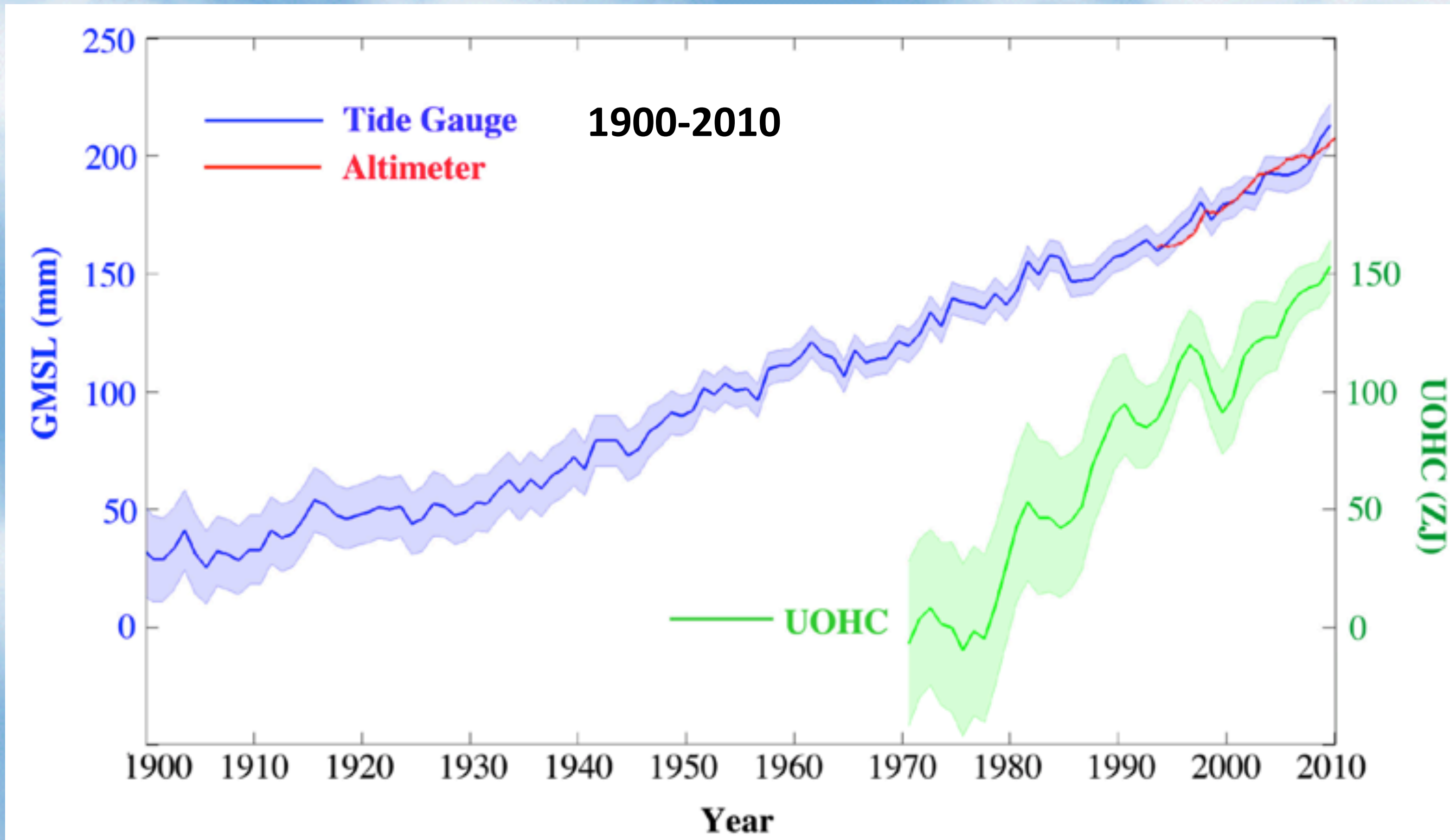






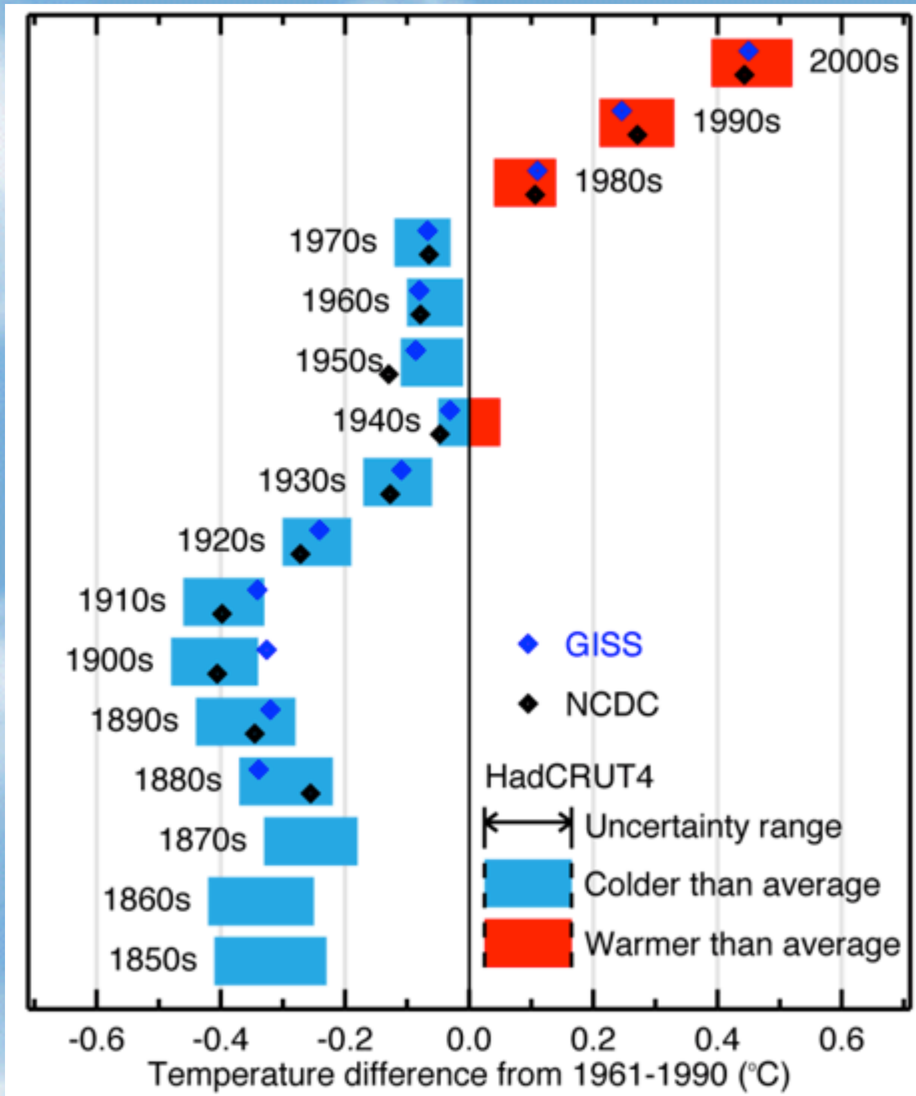


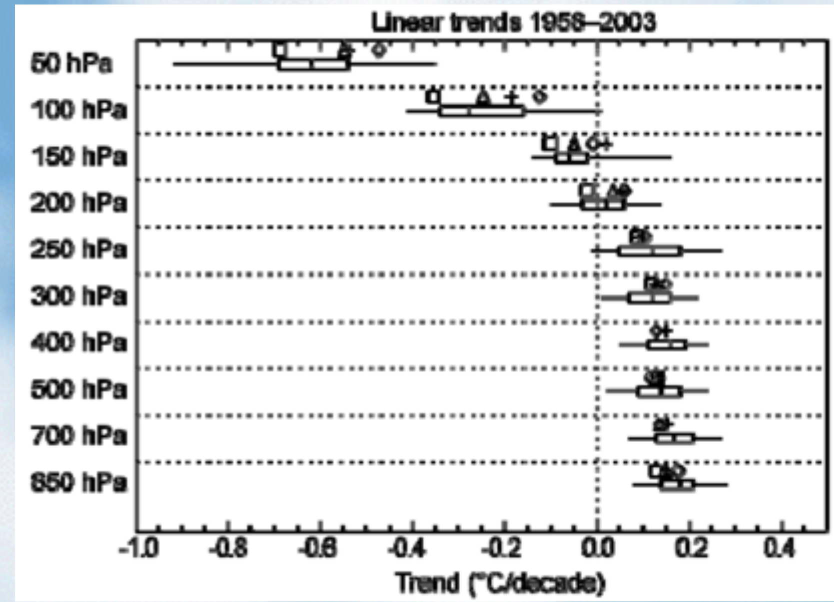
Global mean sea level (GMSL) and upper ocean heat content anomaly (UOHCA) from 1900-2010



Global mean sea level (GMSL) from the different measuring systems . **Blue:** Yearly average GMSL reconstructed from tide gauges (1880–2010) **Red:** from altimetry. **Green:** Observation-based estimates of annual global mean upper ocean heat content anomaly (UOHCA) in ZJ (1021 J) from 0–700 m.

Nerem et al., 2010, Domingues et al. (2008)

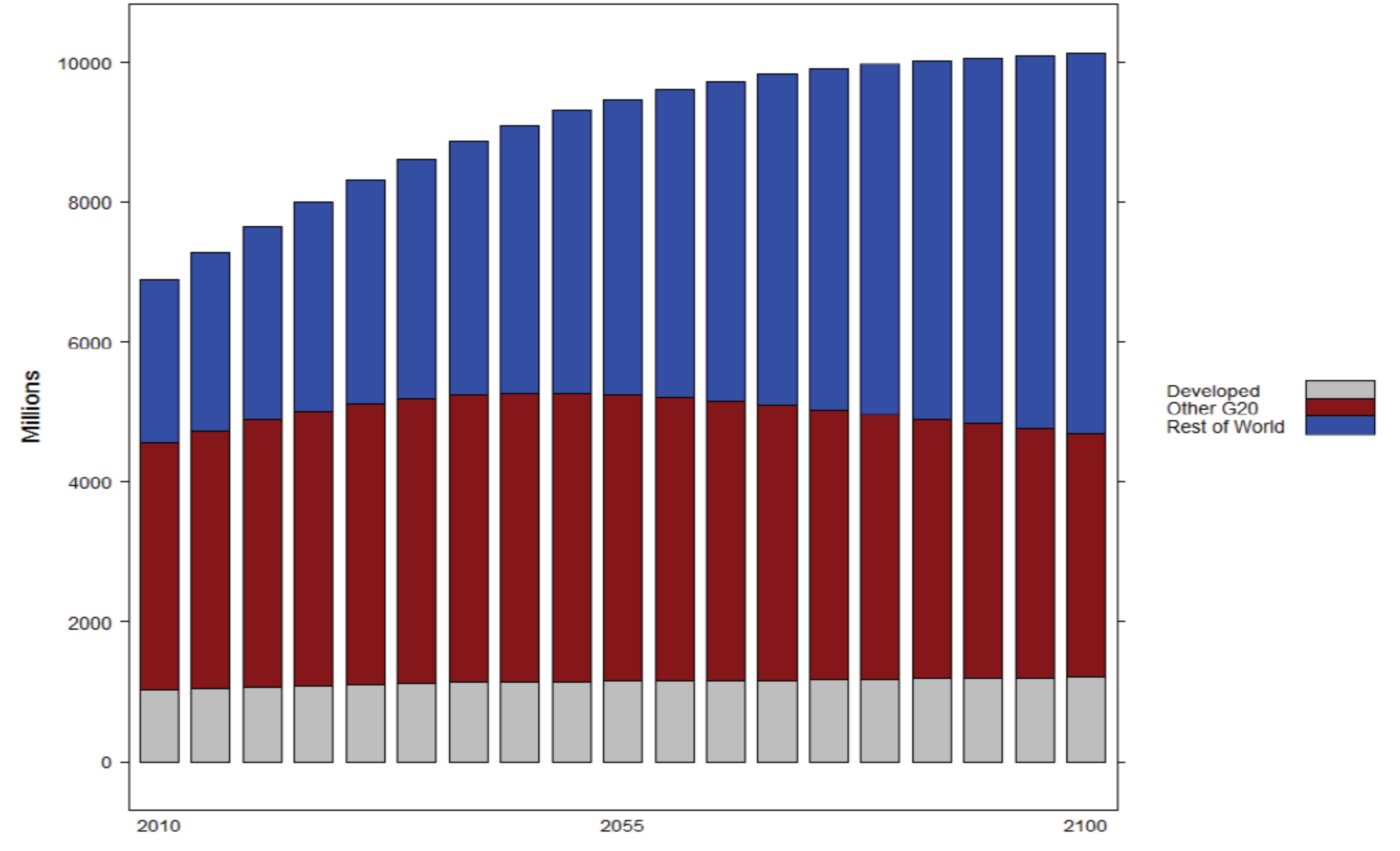


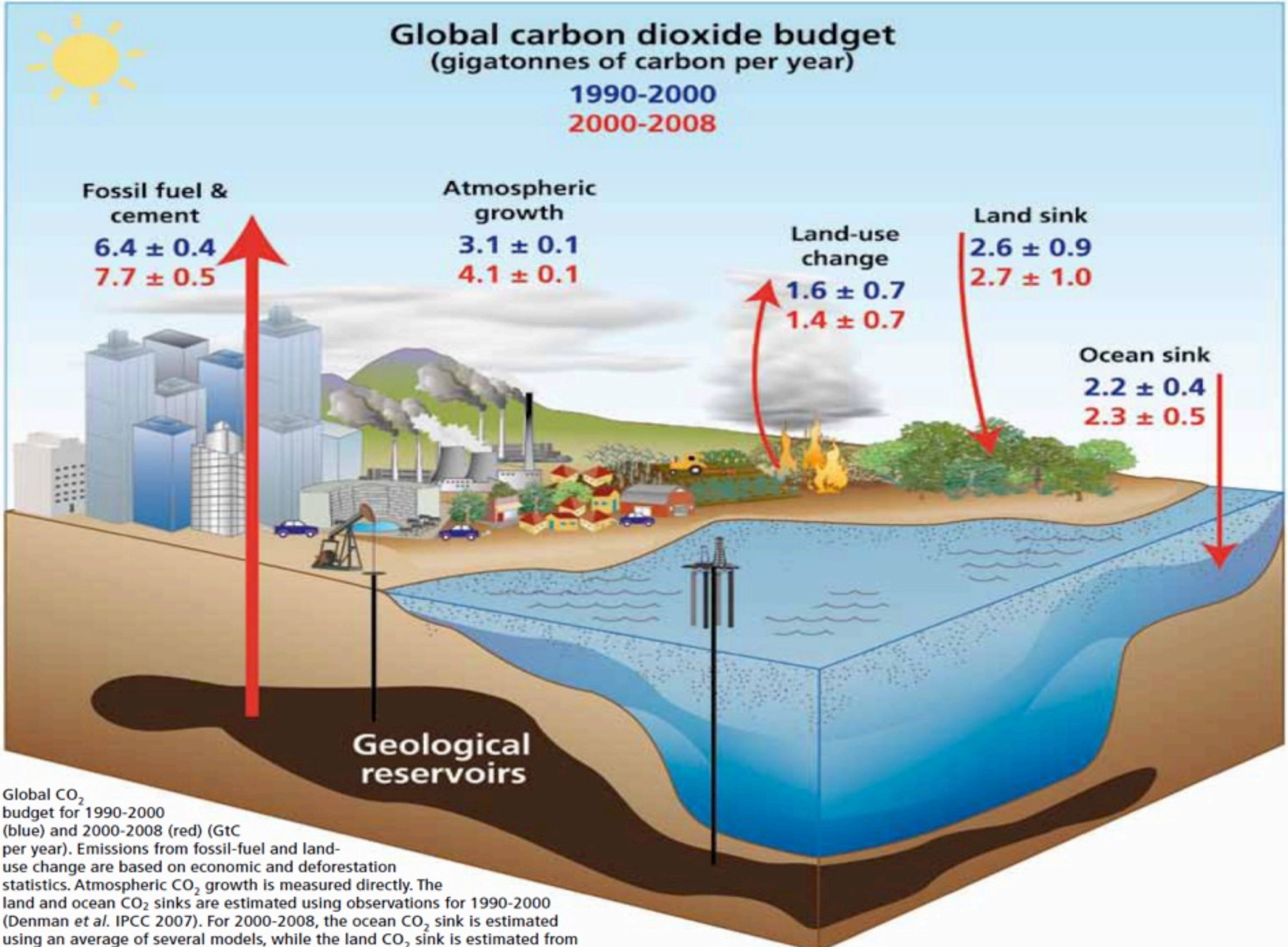


Global temperature trend. **Atmosphere**: 1958– 2003. Radiosonde product global temperature trend estimates. (IPCC AR5, 2012

Decadal mean anomalies and associated uncertainties based upon the HadCRUT4 ensemble (Morice et al., Submitted). Anomalies are relative to a 1961–1990 climatology period. NCDC MLOST and GISS dataset estimates are also shown. (IPCC AR5, 2012)

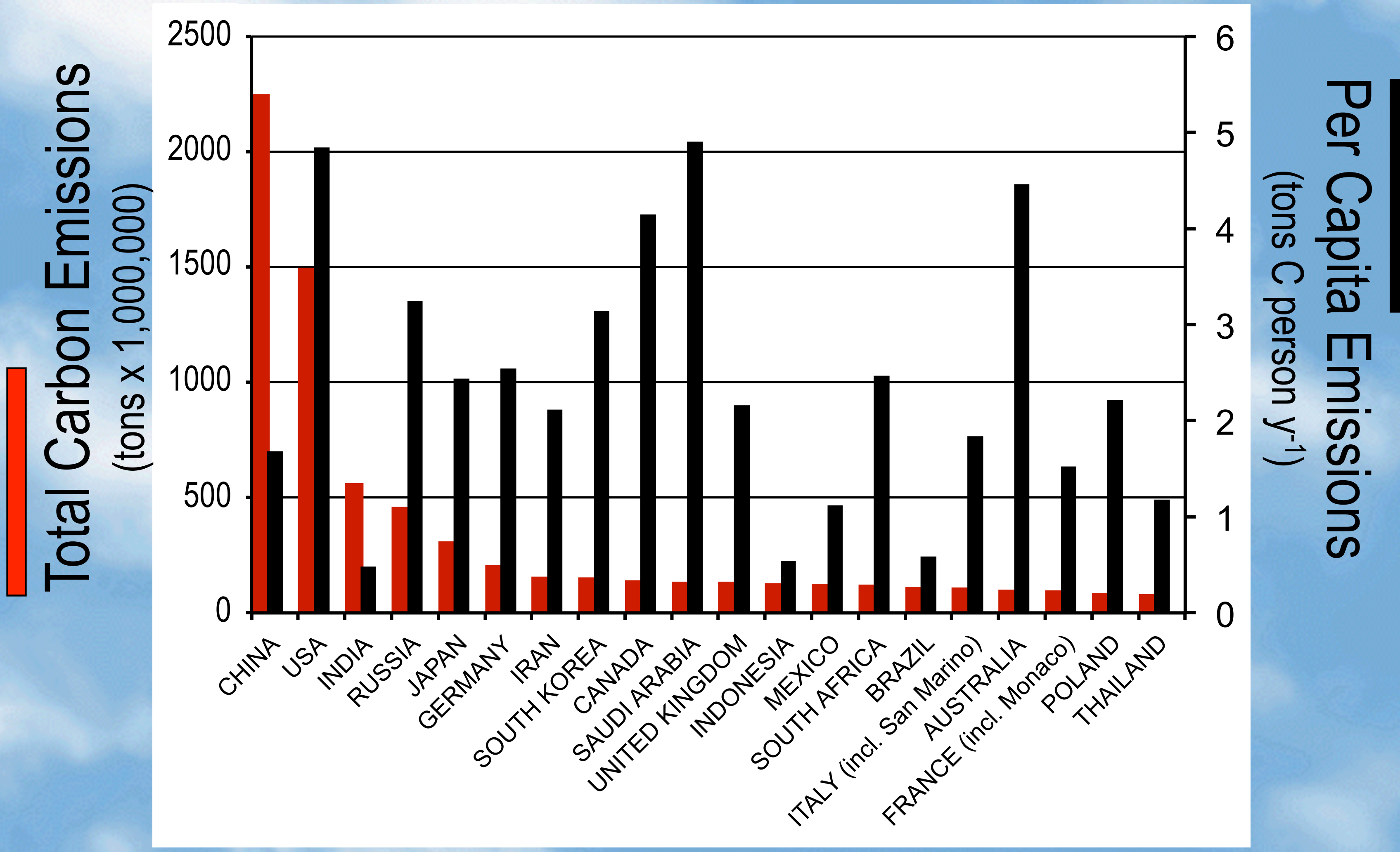
Crescimento da população 2010-2050





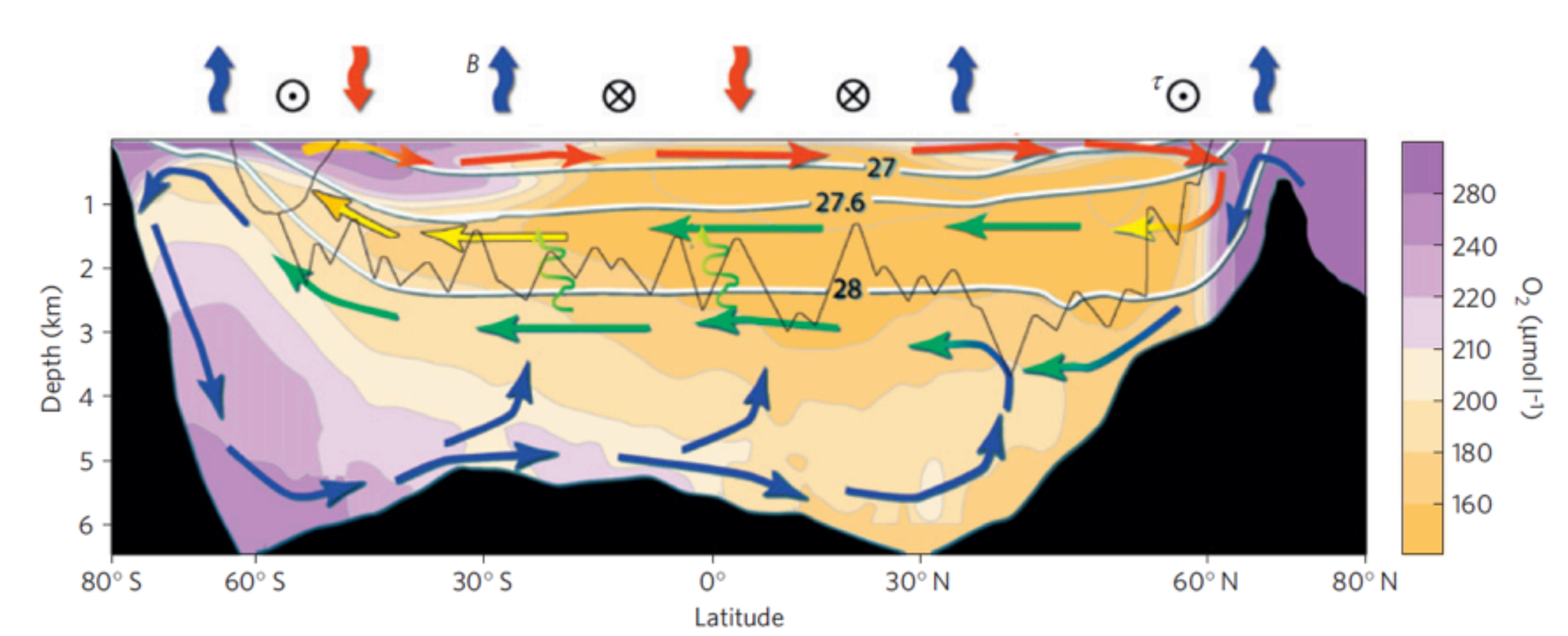
Global CO_2 budget for 1990-2000 (blue) and 2000-2008 (red) (GtC per year). Emissions from fossil-fuel and land-use change are based on economic and deforestation statistics. Atmospheric CO_2 growth is measured directly. The land and ocean CO_2 sinks are estimated using observations for 1990-2000 (Denman *et al.* IPCC 2007). For 2000-2008, the ocean CO_2 sink is estimated using an average of several models, while the land CO_2 sink is estimated from the balance of the other terms.

Top 20 CO_2 Fossil Fuel Emitters & Per Capita Emissions 2010



Global Carbon Project 2011; Data: Boden, Marland, Andres-CDIAC 2011; Population World Bank 2011

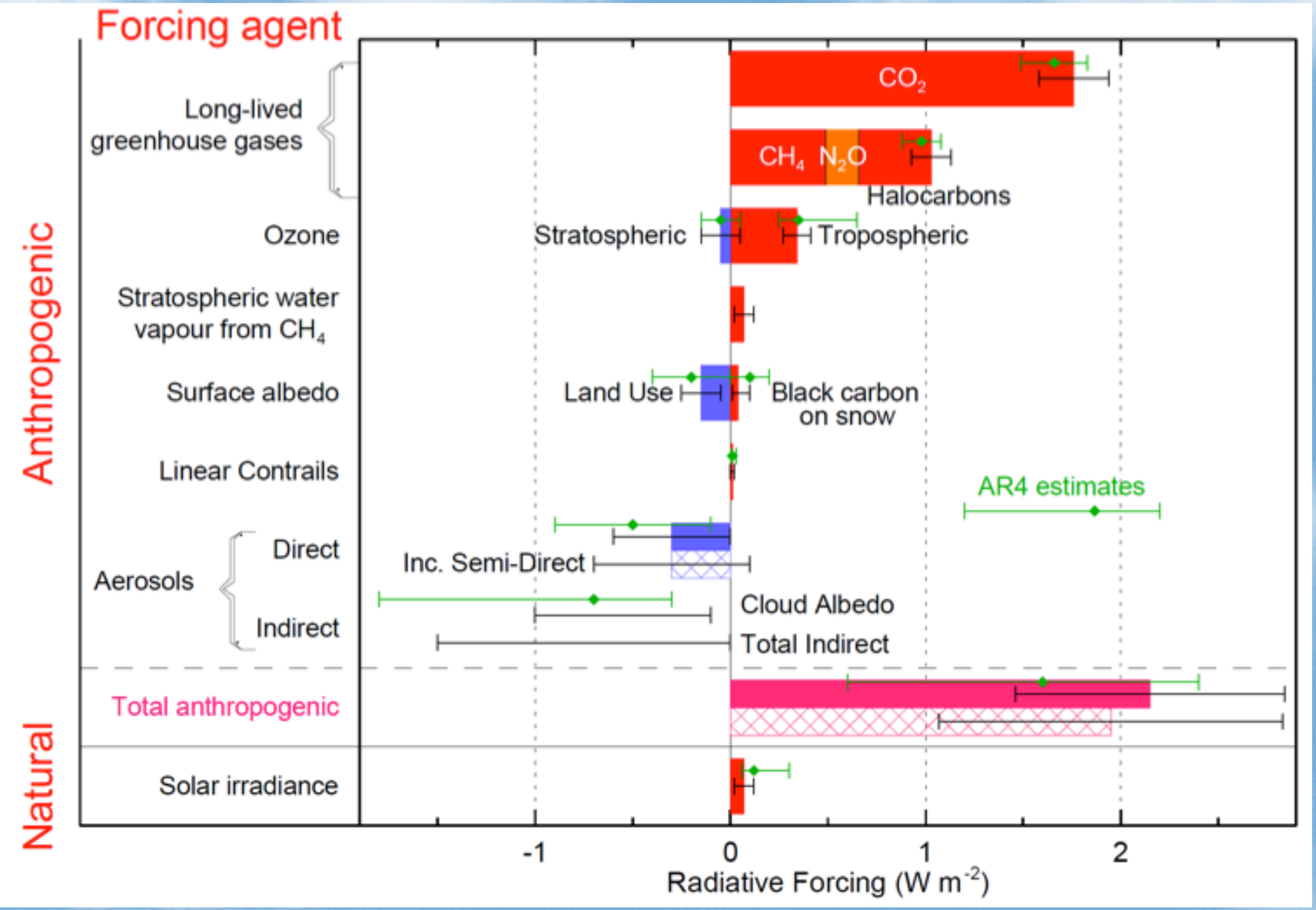
Closure of the meridional overturning circulation through Southern Ocean upwelling



A schematic diagram of the Upper Cell and Lower Cell of the global MOC emanating from, respectively, northern and southern polar seas.

John Marshall and Kevin Speer, Nature 2012

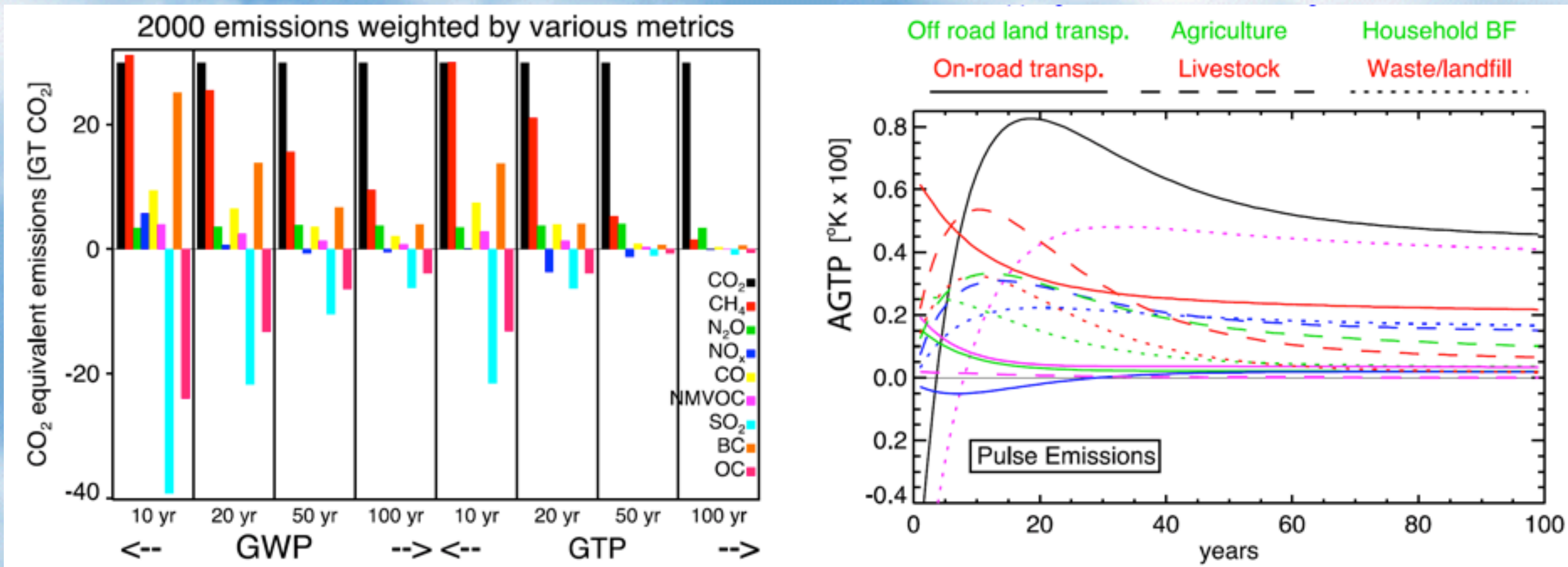
Radiative forcing of climate change 1750-2010



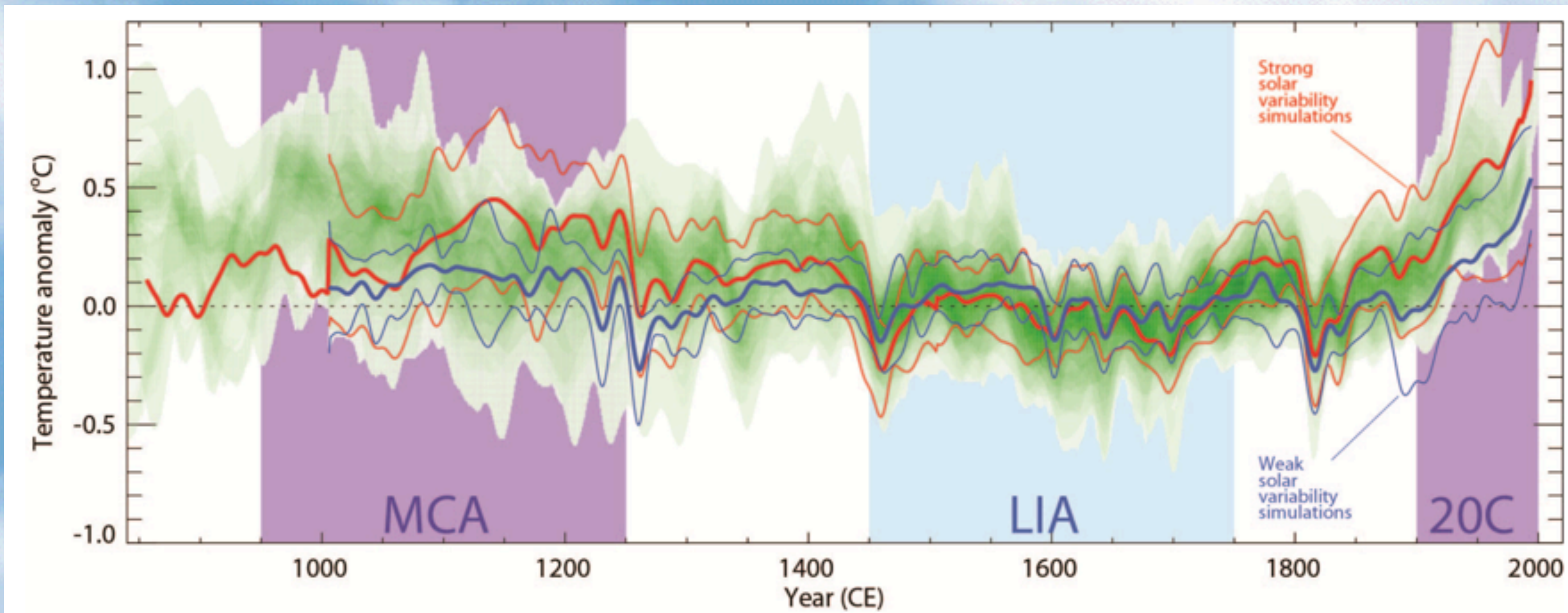
Forcing by component between 1750 and 2010 with associated uncertainty range (solid bars are RF, hatched bars are AF, green diamonds and associated uncertainties are those assessed in AR4).

IPCC 2012

Global anthropogenic present-day emissions weighted by GWP and GTP for the chosen time horizons

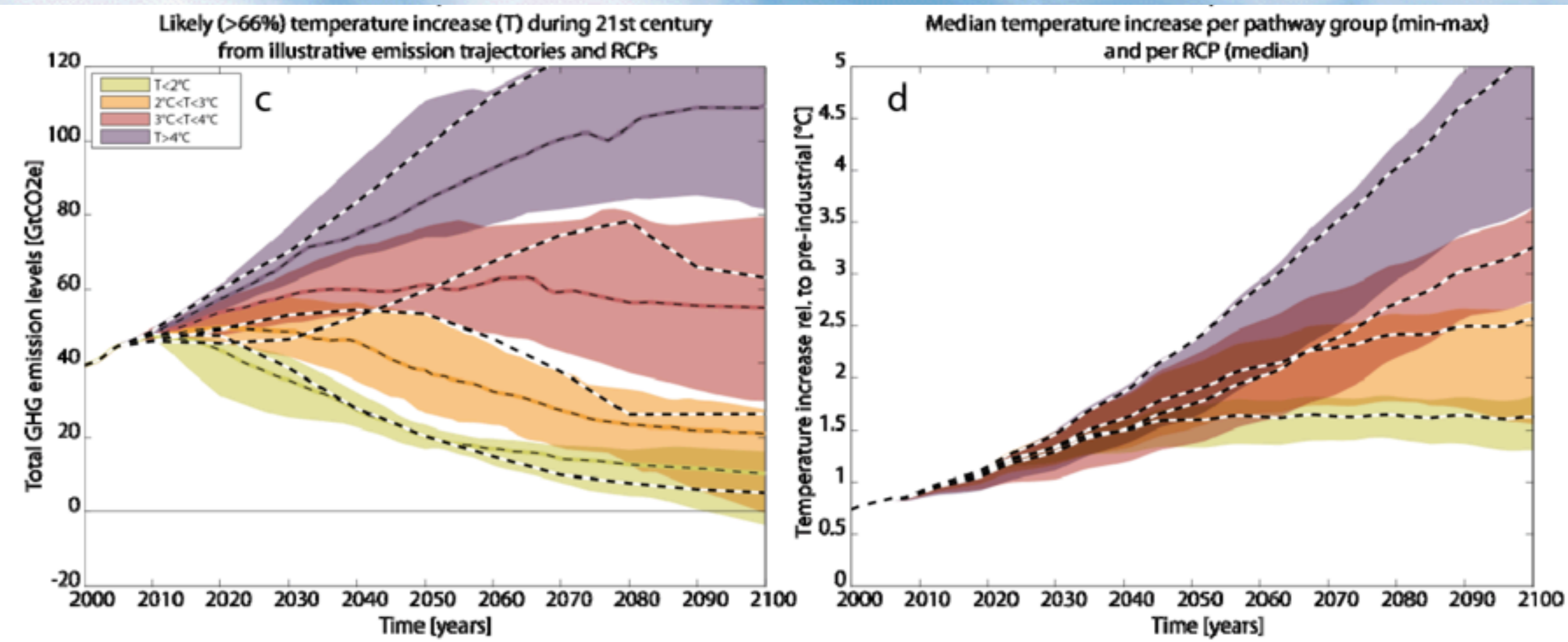


Effective amount of year 2000 (single-year pulse) using the Global Warming Potential (GWP), which is the global mean radiative forcing integrated over the indicated number of years relative to the forcing from CO2 emissions, and the Global Temperature Potential (GTP) which estimates the impact on global mean temperature based on the temporal evolution of both radiative forcing and climate response relative to the impact of CO2 emissions. The Absolute GTP as a function of time for year 2000 emissions of all compounds from the indicated sector is shown on the right, which is the same as GTP, except is not normalized by the impact of CO2 emissions. The effects of aerosols on clouds (and in the case of black carbon, on surface albedo) are not included.



Reconstructed Northern Hemisphere temperature change but without model simulations. Data are expressed as anomalies from their 1500–1850 CE mean and smoothed.

Emissões de CO2 e aumento provável da temperatura ao longo deste século

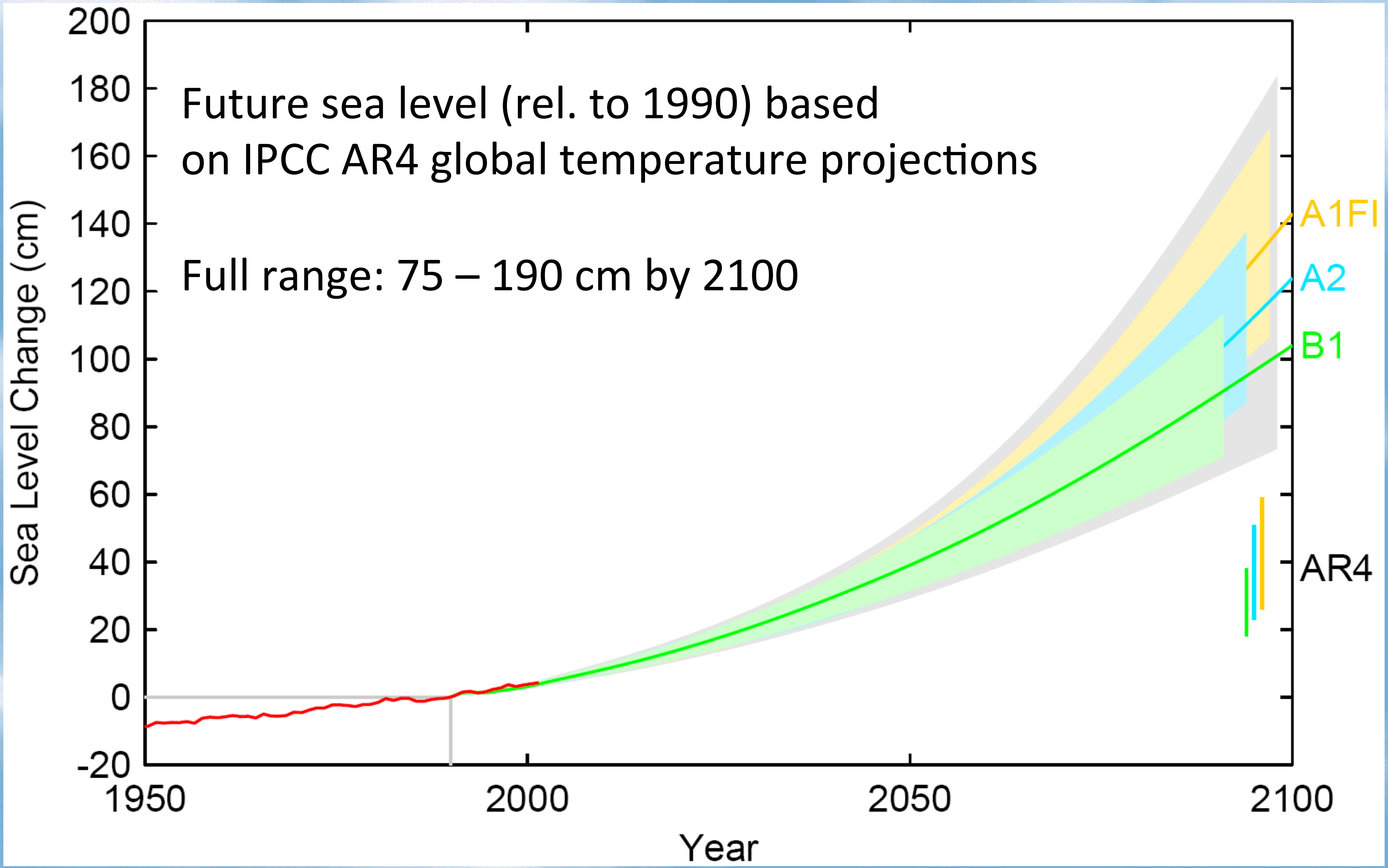


Emissões de CO2 ao longo deste século e o provável aumento da temperatura (>66%) para 4 cenários de emissões.

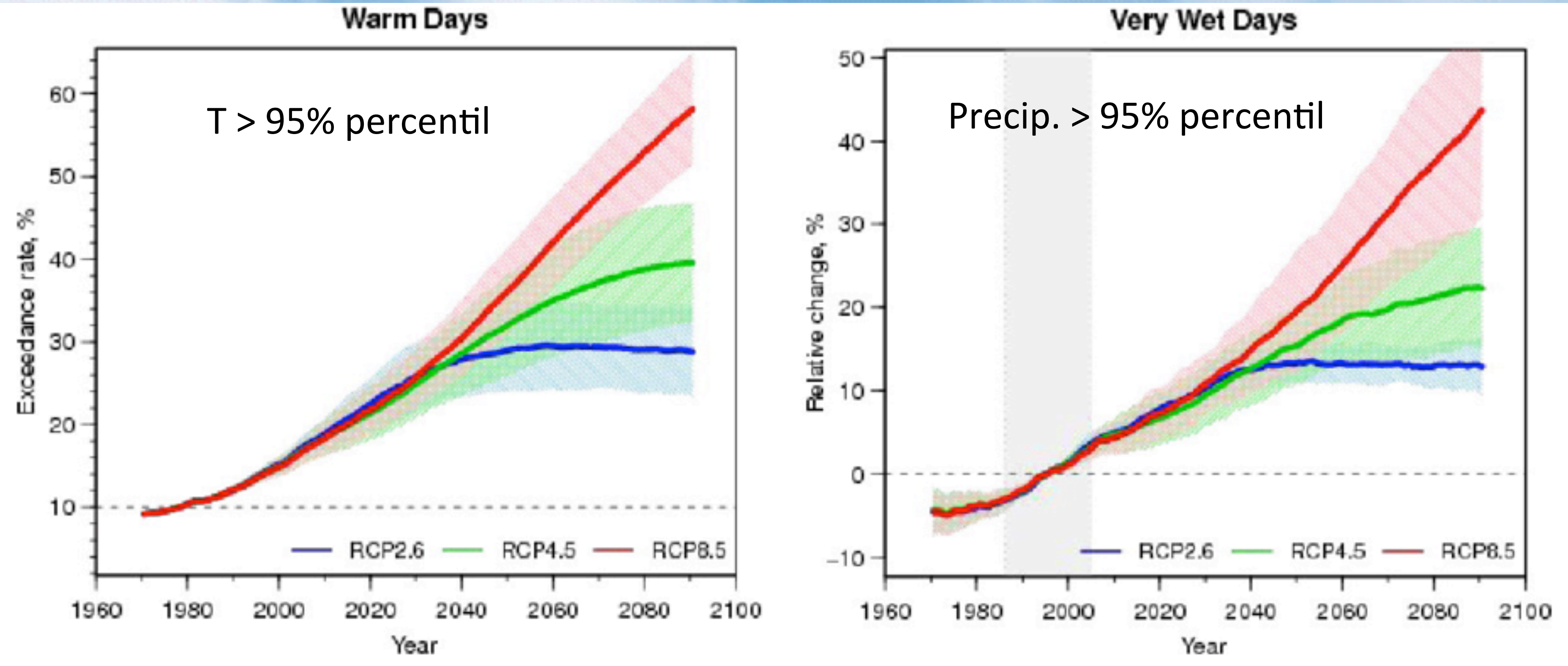
Aumento provável da temperatura (>66%) ao longo deste século para 4 cenários de emissões.

IPCC 2012

Future Sea Level Relative to 1990

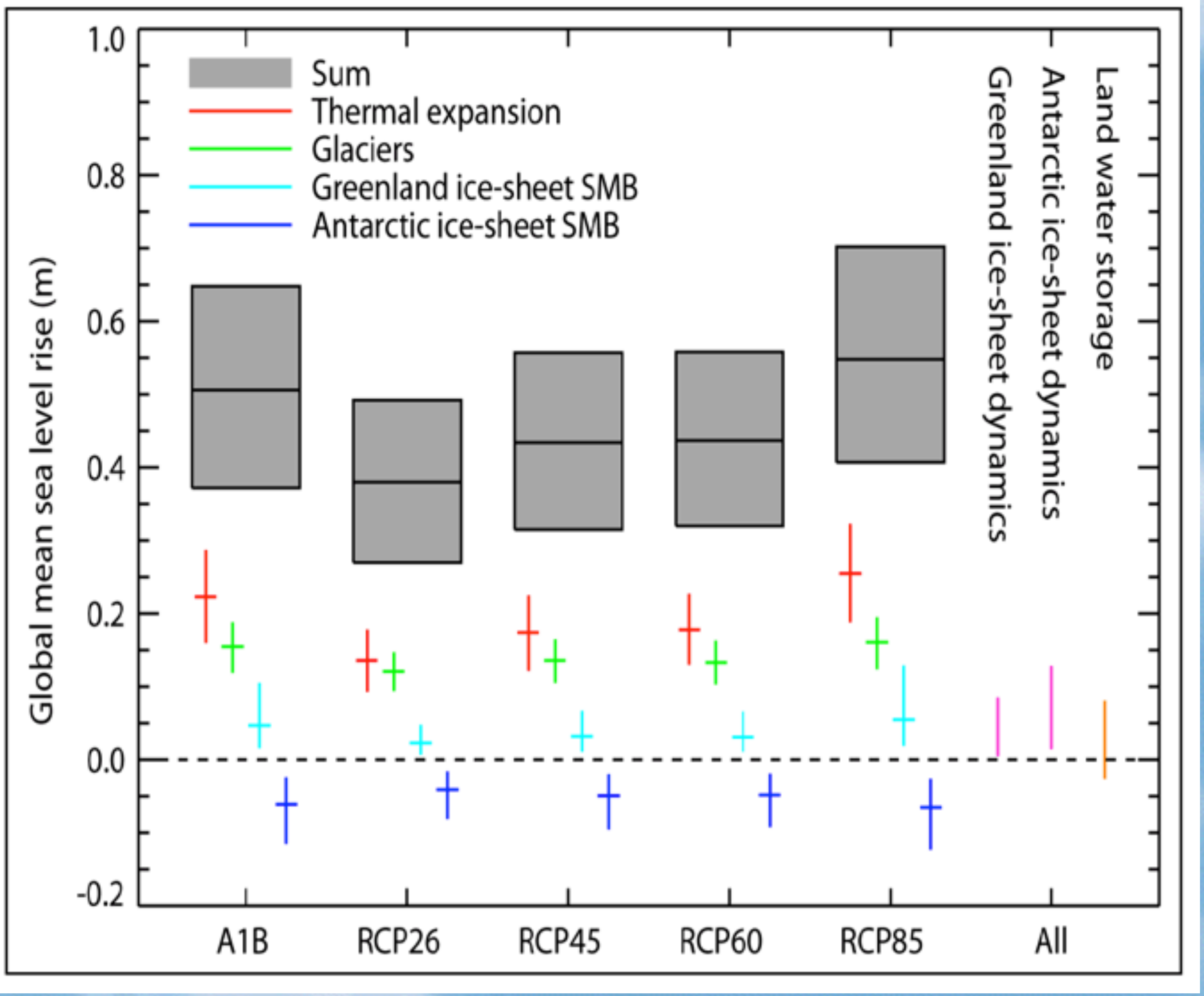


Frequência de ocorrência de eventos extremos em temperatura e precipitação



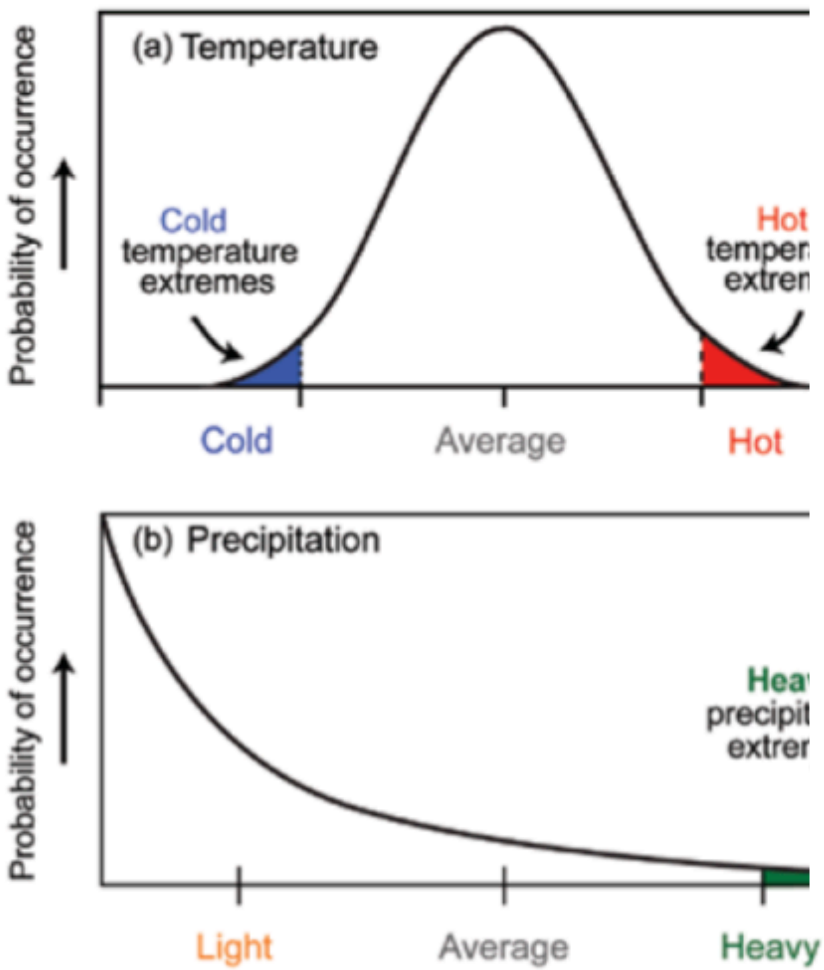
Global mean projections for the occurrence of warm and wet days from CMIP5 for the RCP2.6, RCP4.5 and RCP8.5 scenarios relative to 1986–2005. Panel (a) shows percentage of warm days (tx90p: Tmax exceeds the 90th percentile), panel (b) shows relative change of very wet days (pr95p: annual total precipitation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

Global mean sea level rise - Projections with ranges for contributions (2081–2100 relative to 1986–2005)

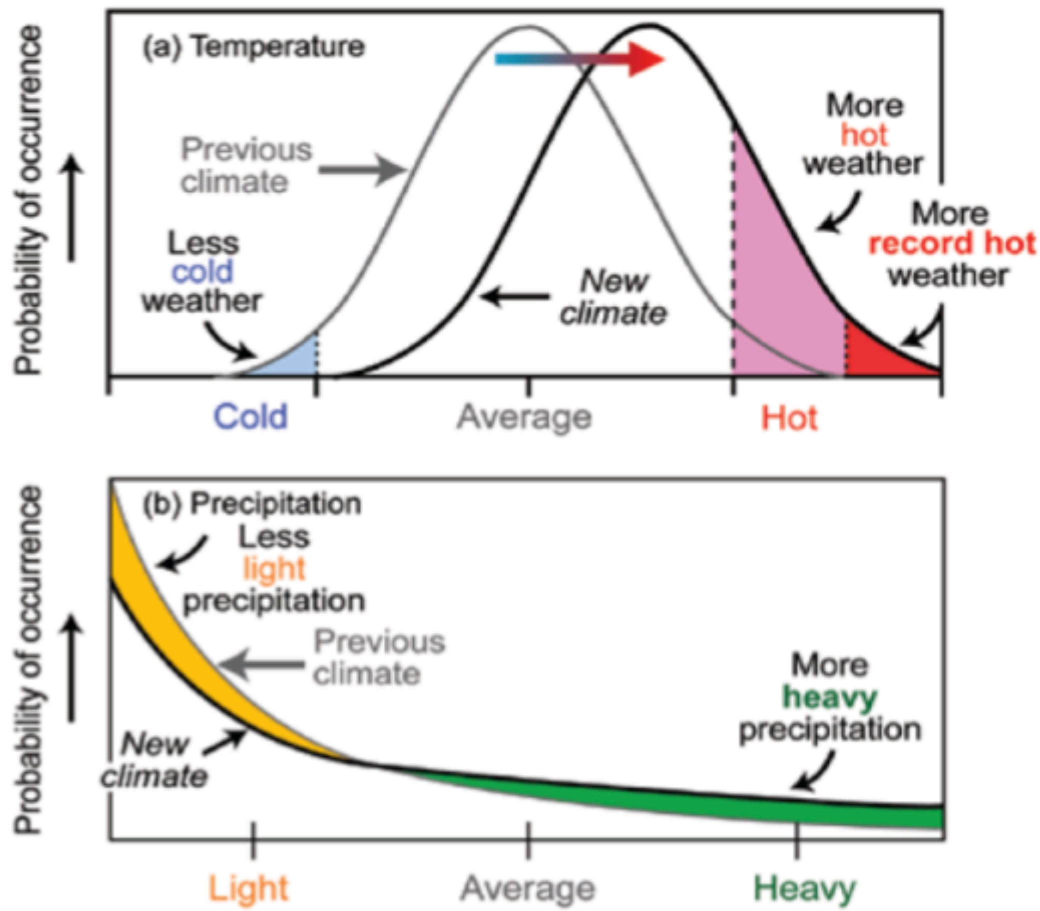


It was used four RCP scenarios and scenario SRES A1B used in the AR4.

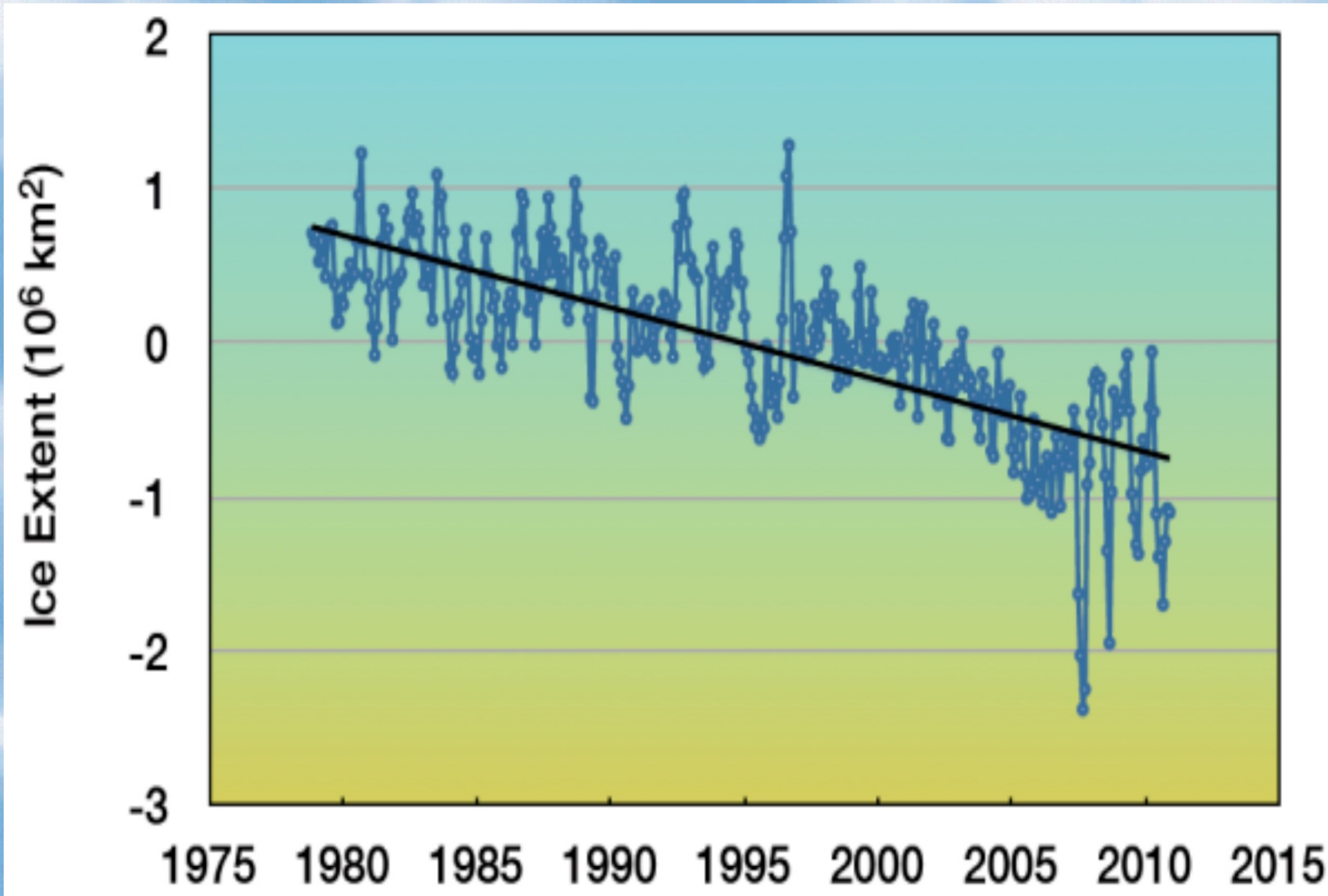
What Is an Extreme?



Increase in Probability of Extremes in a Warmer Climate

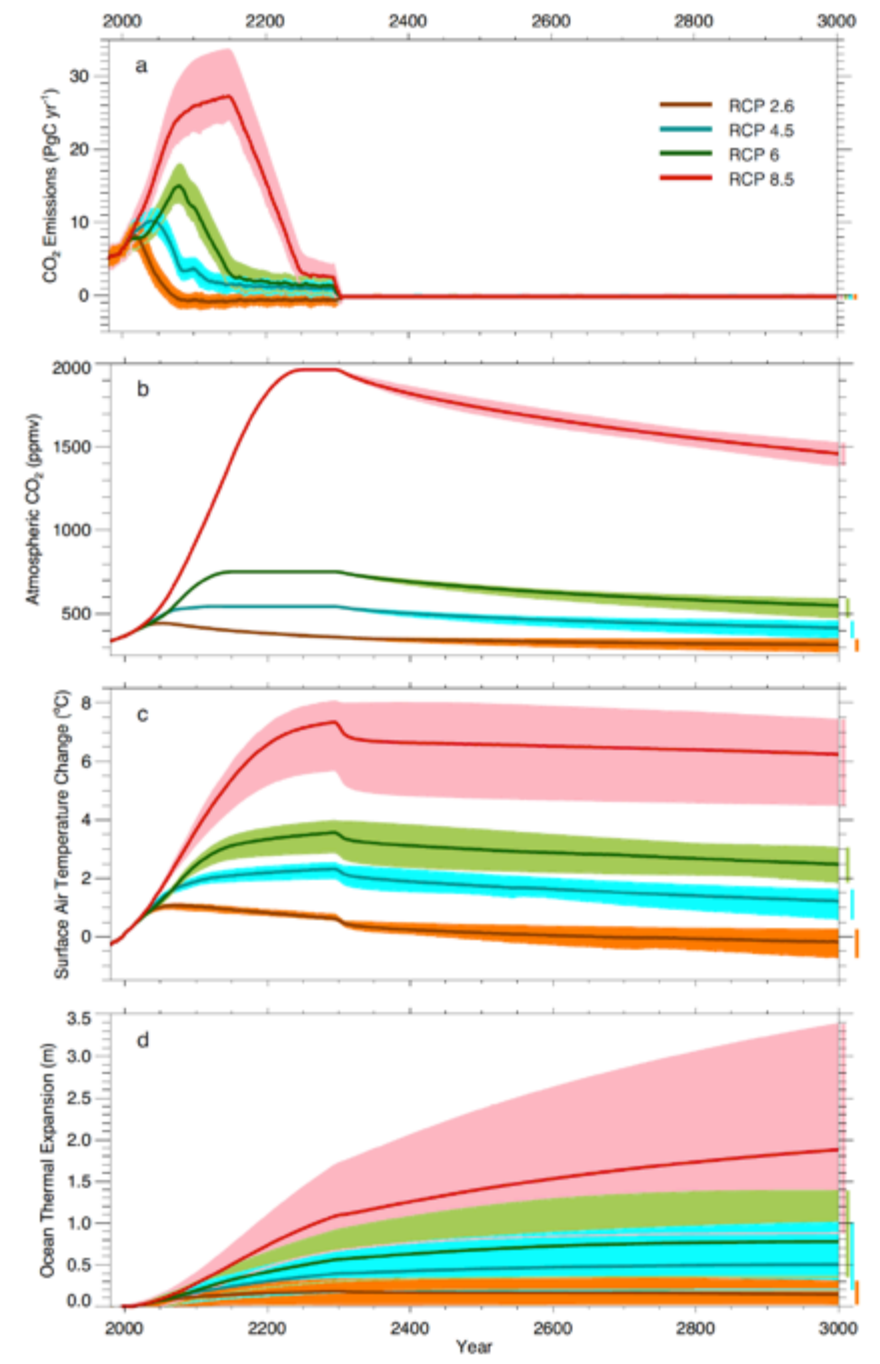


Northern Hemisphere Sea Ice Extent Anomalies



C40 - Megacidades e emissões de gases de efeito estufa

América Latina: 80% população urbana em 2012



Efeitos até o ano 3.000

As simulated by 6 EMICs (Bern3D, CLIMBER 2,CLIMBER 3-alpha, DCESS, MESMO and UVic) for the 4 RCPs, **assuming zero anthropogenic emissions after 2300**

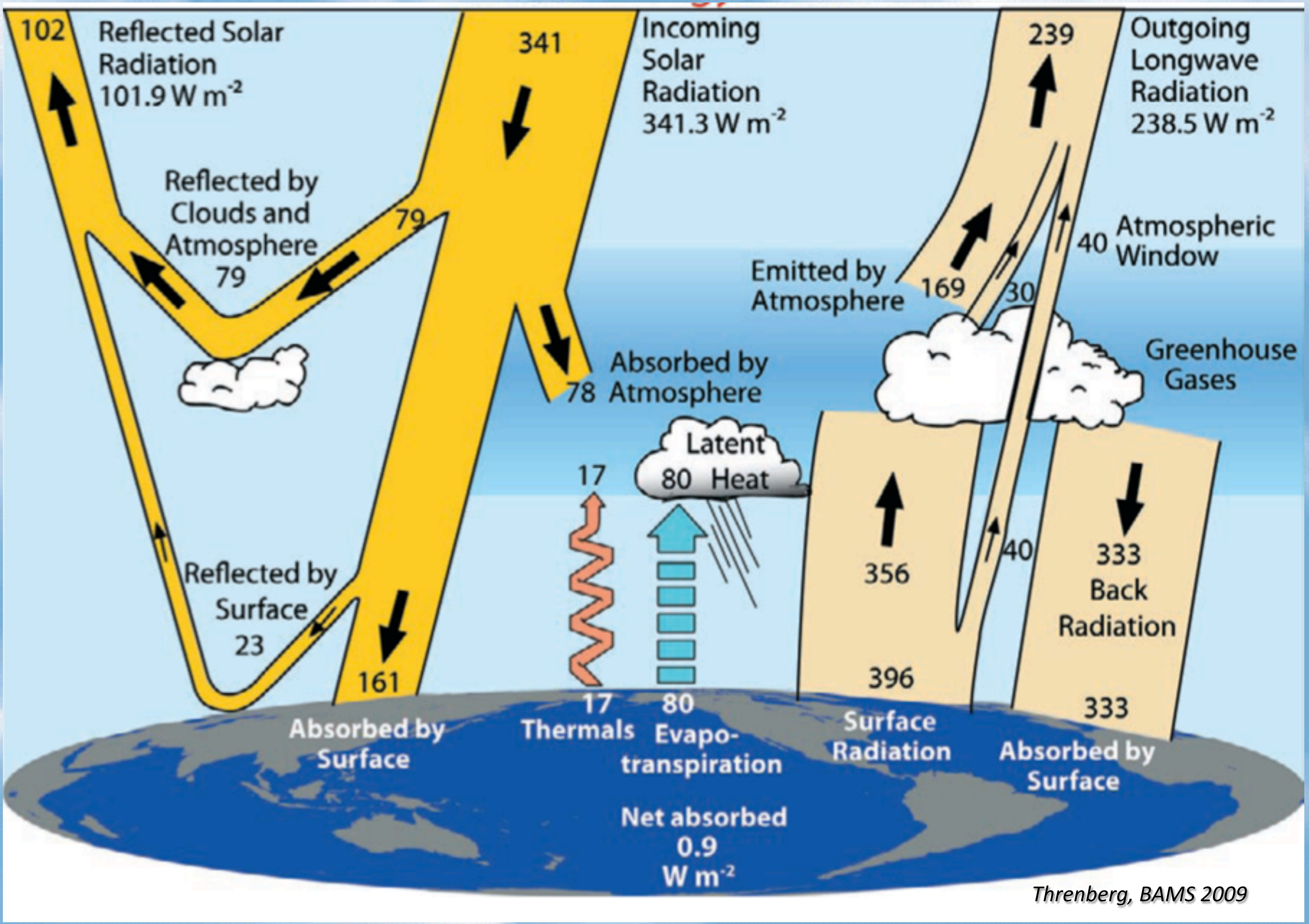
a) Compatible anthropogenic CO2 emissions,

b) Projected atmospheric CO2 concentration,

c) Global mean surface temperature change .

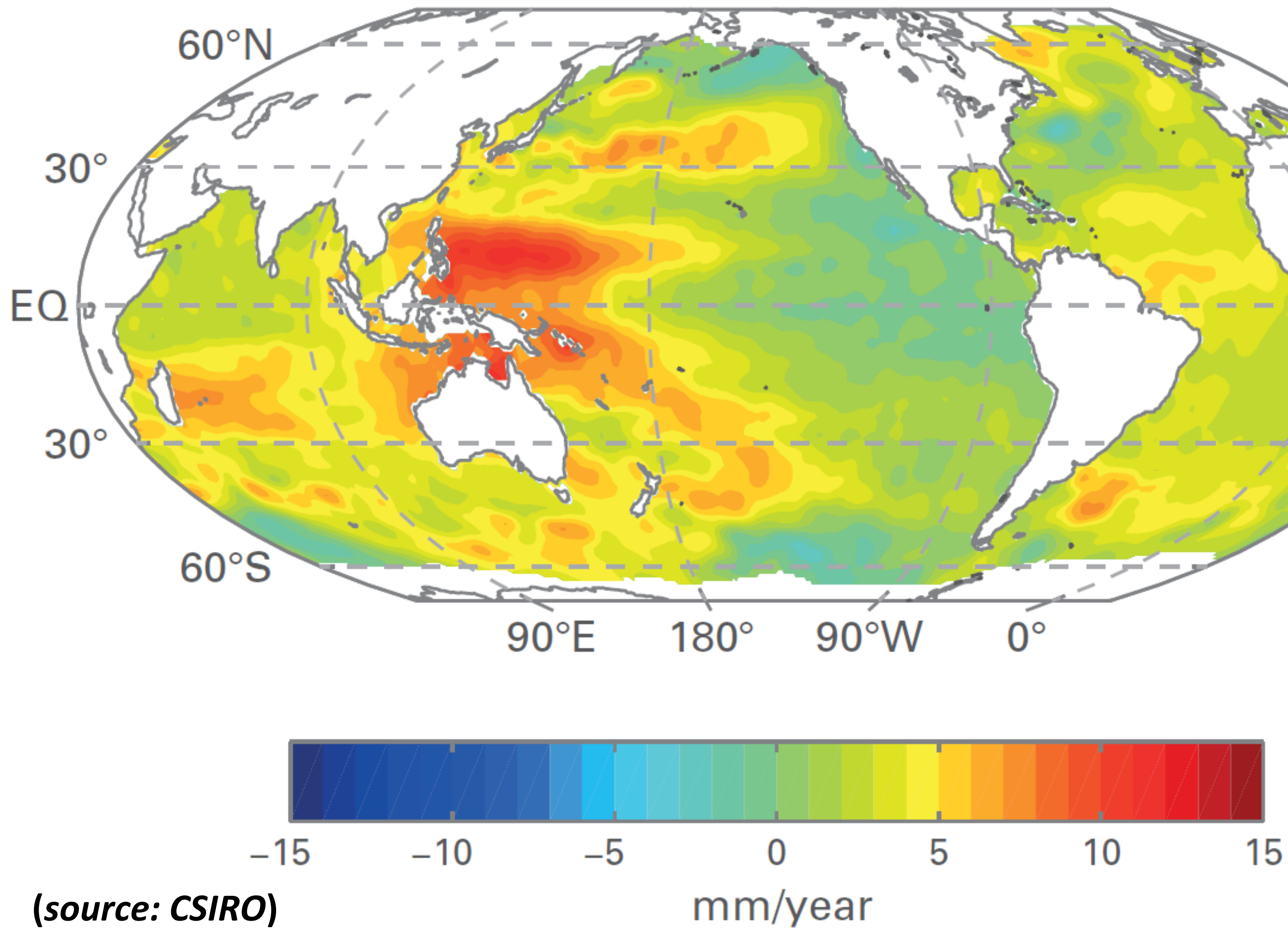
d) Ocean thermal expansion.

Balanço de radiação terrestre (Wm^{-2})

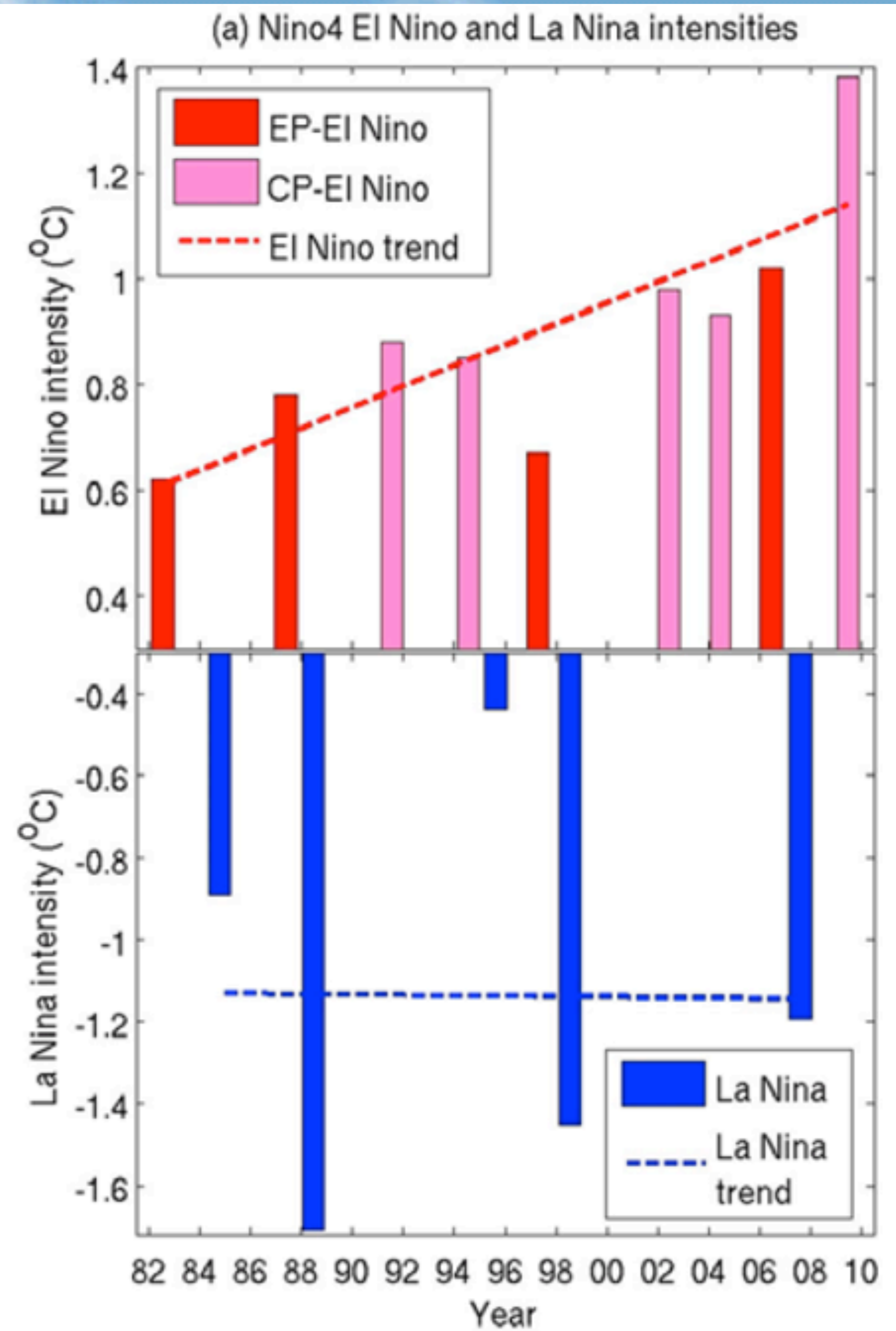


Threnberg, BAMS 2009

Mean sea-level trend over the period 1993–2010 (mm/year), derived from satellite altimeter data.



(*source: CSIRO*)

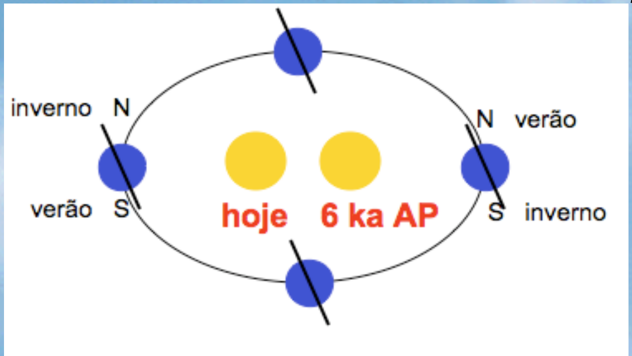


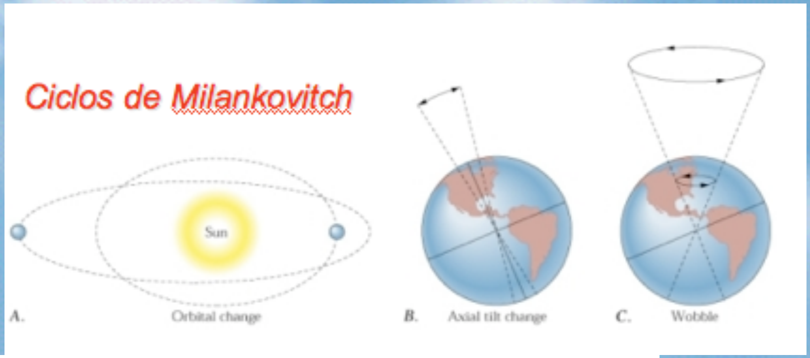
Intensities of El Niño and La Niña events in the central equatorial Pacific (Niño4 region) and the estimated linear trends, which is 0.20(±0.18)°C/decade for El Niño and −0.01(±0.75)°C/decade for La Niña events.

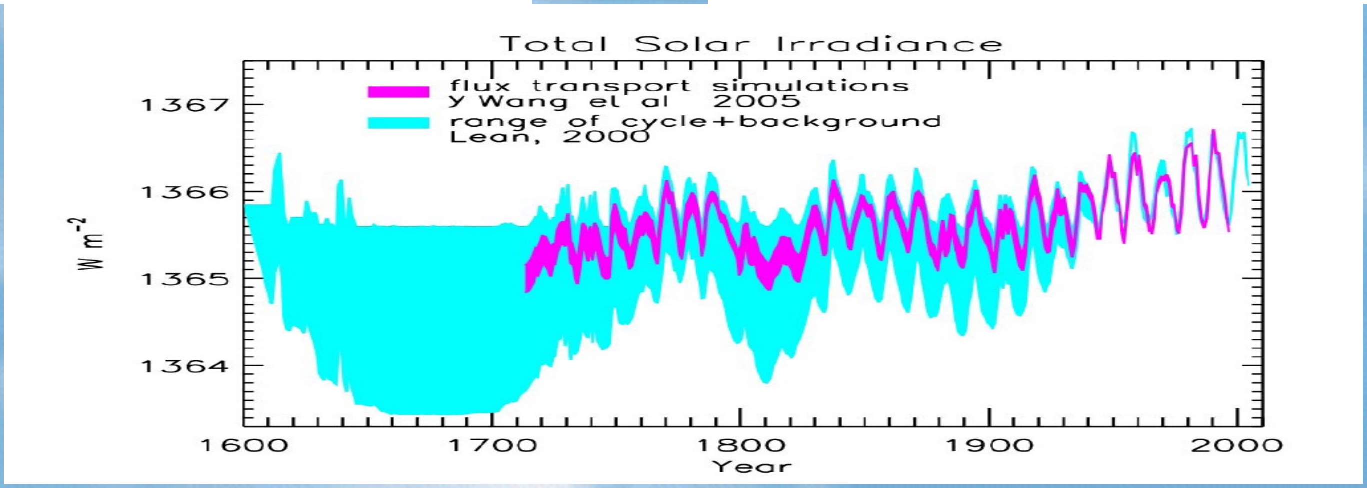
(Lee and McPhaden, 2010).

•**Mudanças climáticas devido a causas naturais:**

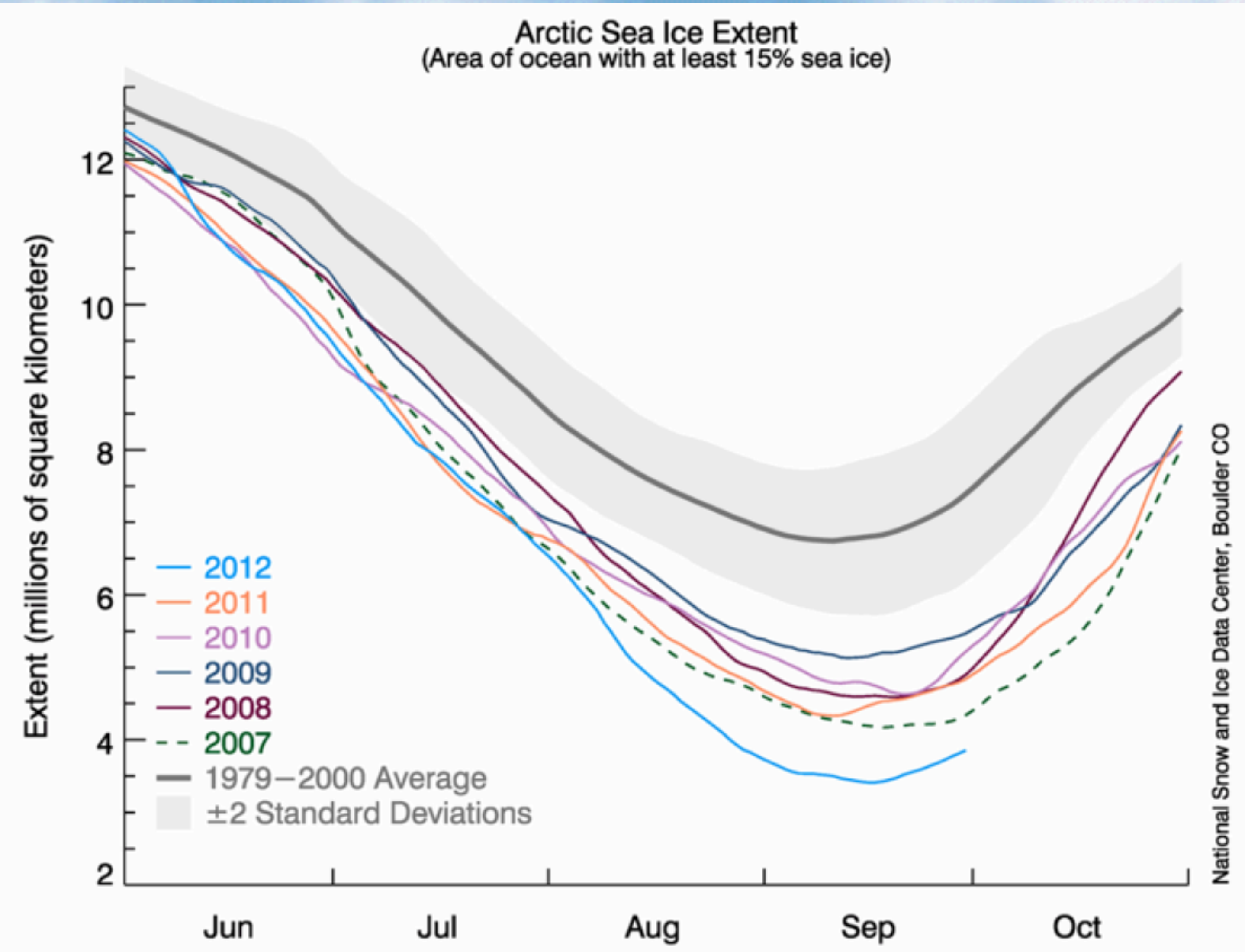
- *Forçante solar :*
  - *Mudanças orbitais da Terra: Ciclos de Milancovitch*
  - *Variações na emissão de energia solar*
- *Vulcanismo, choques de cometas….*







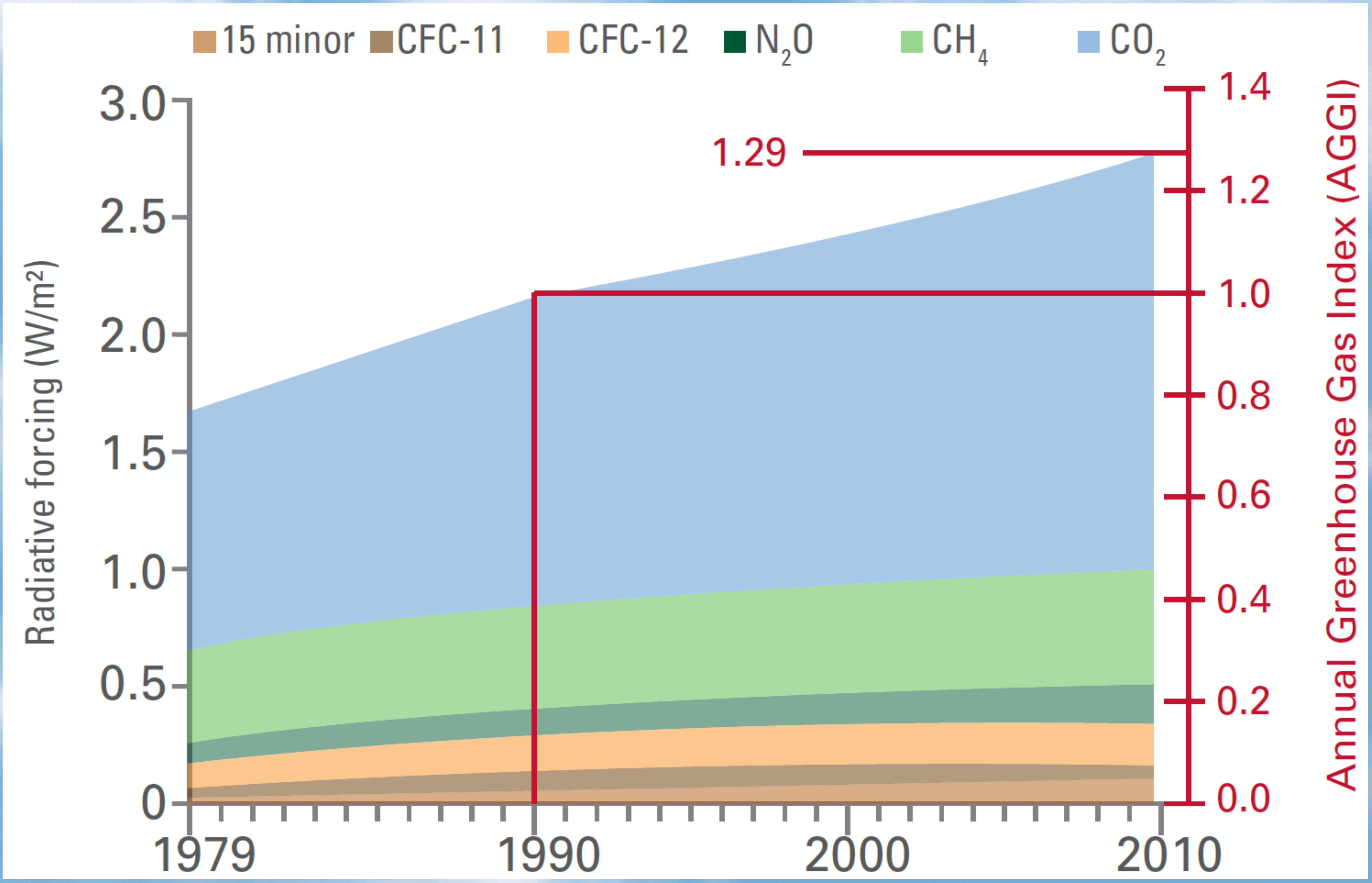
Arctic sea ice extent for 2007–12, with the 1979–2000 average in dark grey



Source: NASA 2012. Credits (right panel): NSIDC (2012) and M. Tschudi and J. Maslanik, University of Colorado Boulder

Mudança de uso do solo: Os maus exemplos da Europa e Norte América...

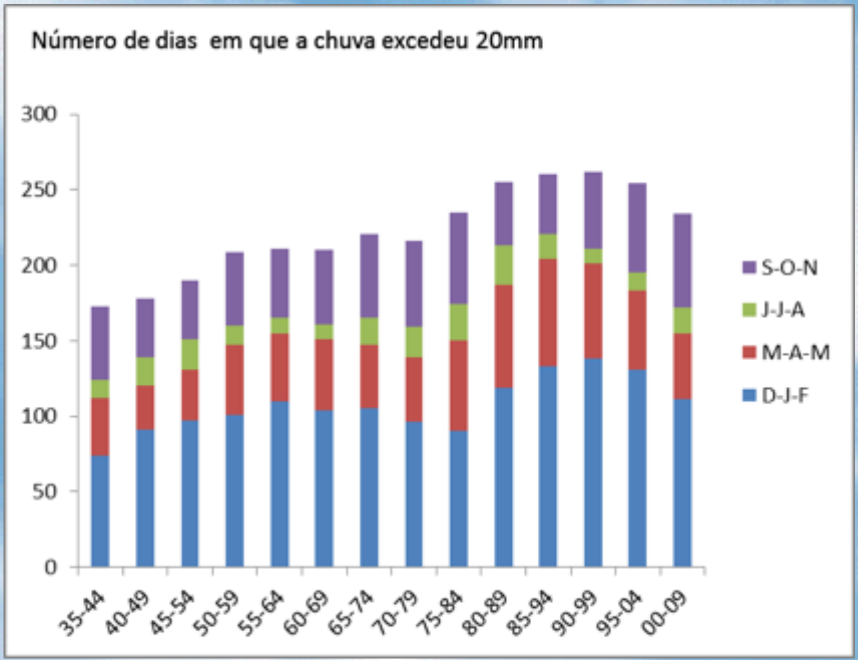
Atmospheric radiative forcing, relative to 1750, of all LLGHGs and the 2010 update of the NOAA AGGI. The reference year for the index is 1990 (AGGI = 1)

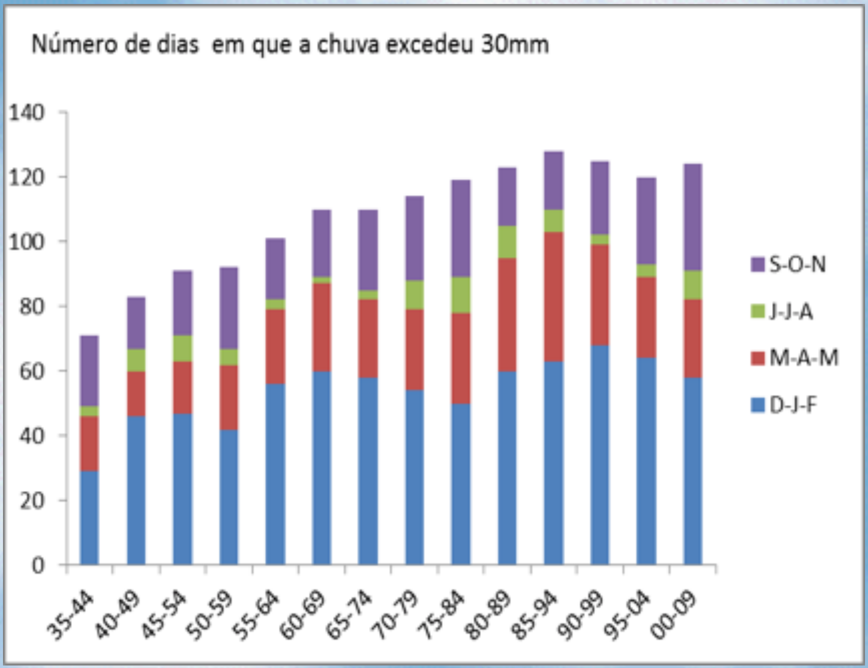


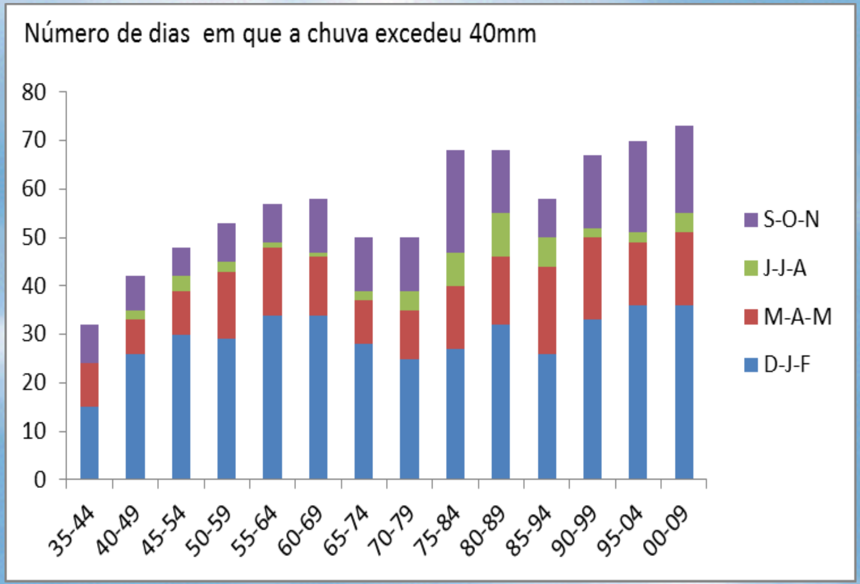
IPCC Special report on managing the risks of extreme events

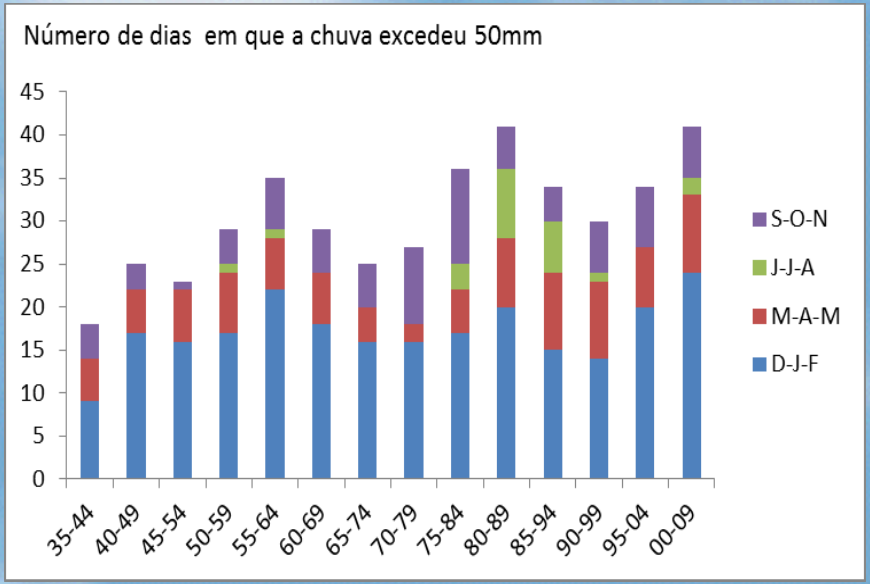
The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

Intensidade de chuva em São Paulo





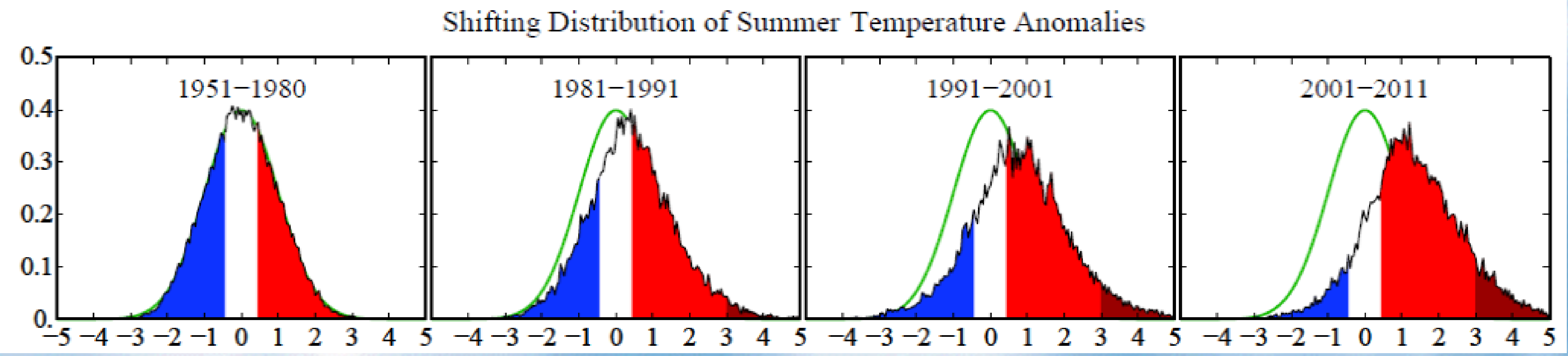




Aumento da temperatura pode estar aumentando a frequenciade eventos climáticos extremos

Extreme summer heat anomalies now cover about 10% of land area, up from 0.2%.

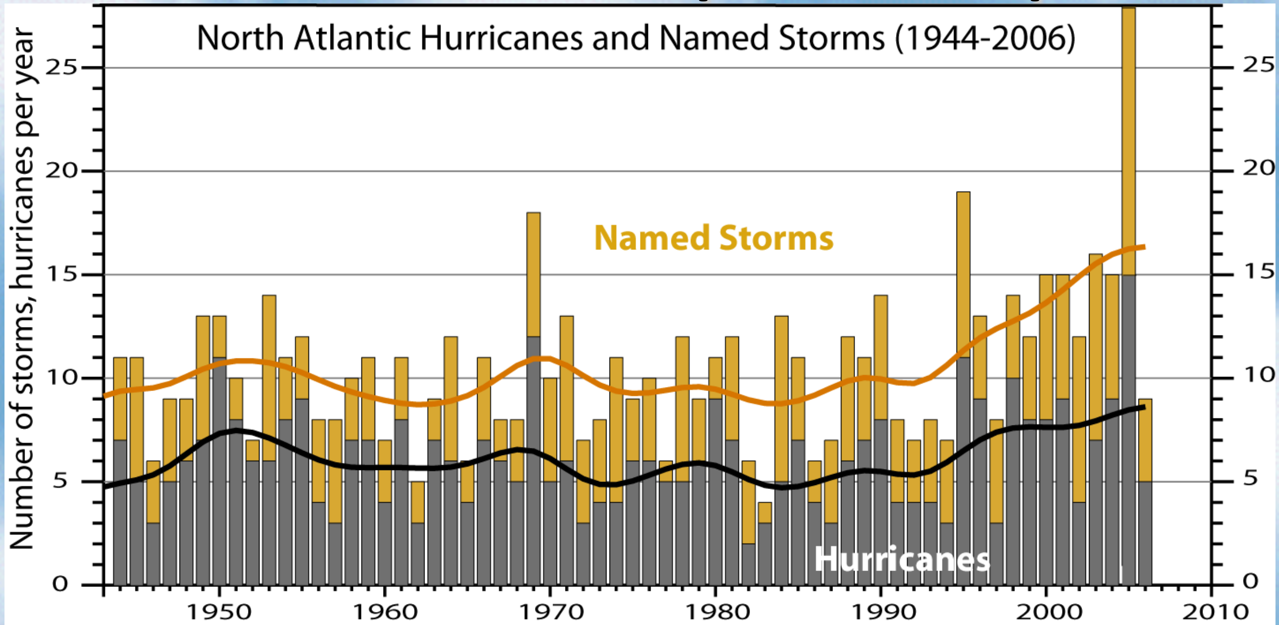
This is based on observations, not models.

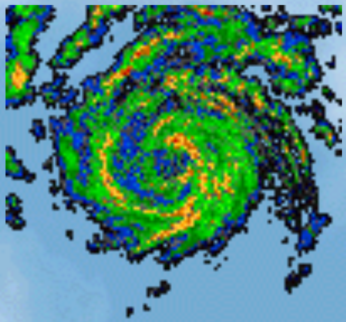


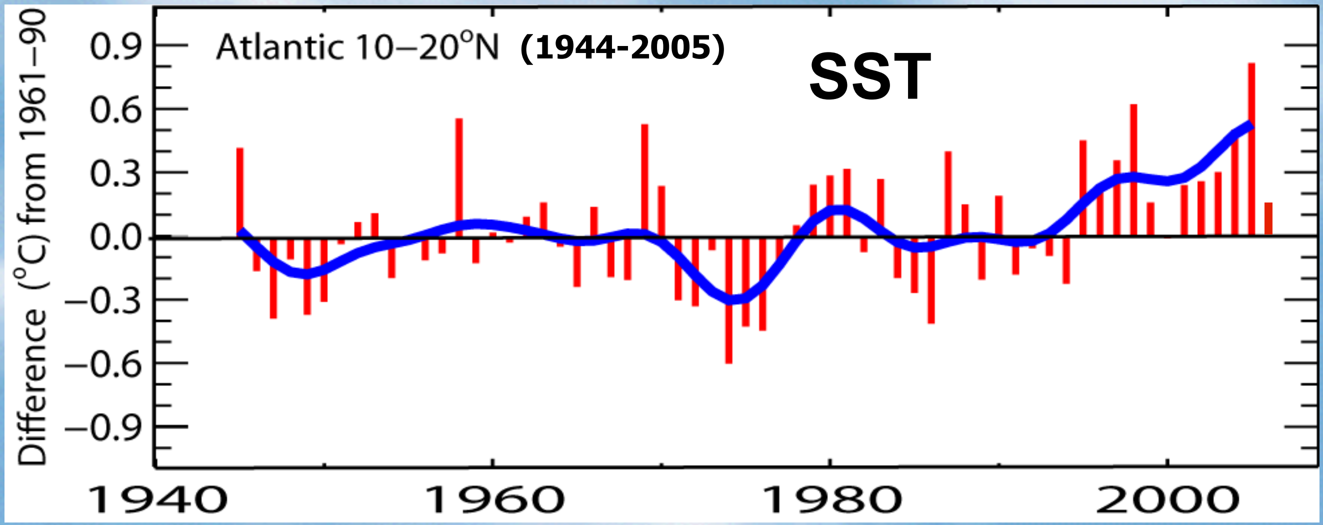
Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies (relative to 1951-1980 mean) for Northern Hemisphere land in units of local standard deviation (horizontal axis). Temperature anomalies in the period 1951-1980 match closely the normal distribution ("bell curve", shown in green), which is used to define cold (blue), typical (white) and hot (red) seasons, each with probability 33.3%. The distribution of anomalies has shifted to the right as a consequence of the global warming of the past three decades such that cool summers now cover only half of one side of a six-sided die, white covers one side, red covers four sides, and an extremely hot (red-brown) anomaly covers half of one side.

Source: Hansen, J., Sato, M., and Ruedy, R., Proc. Natl. Acad. Sci., 2012.

O aumento da incidência de furacões está ligada ao aumento da temperatura superficial do mar

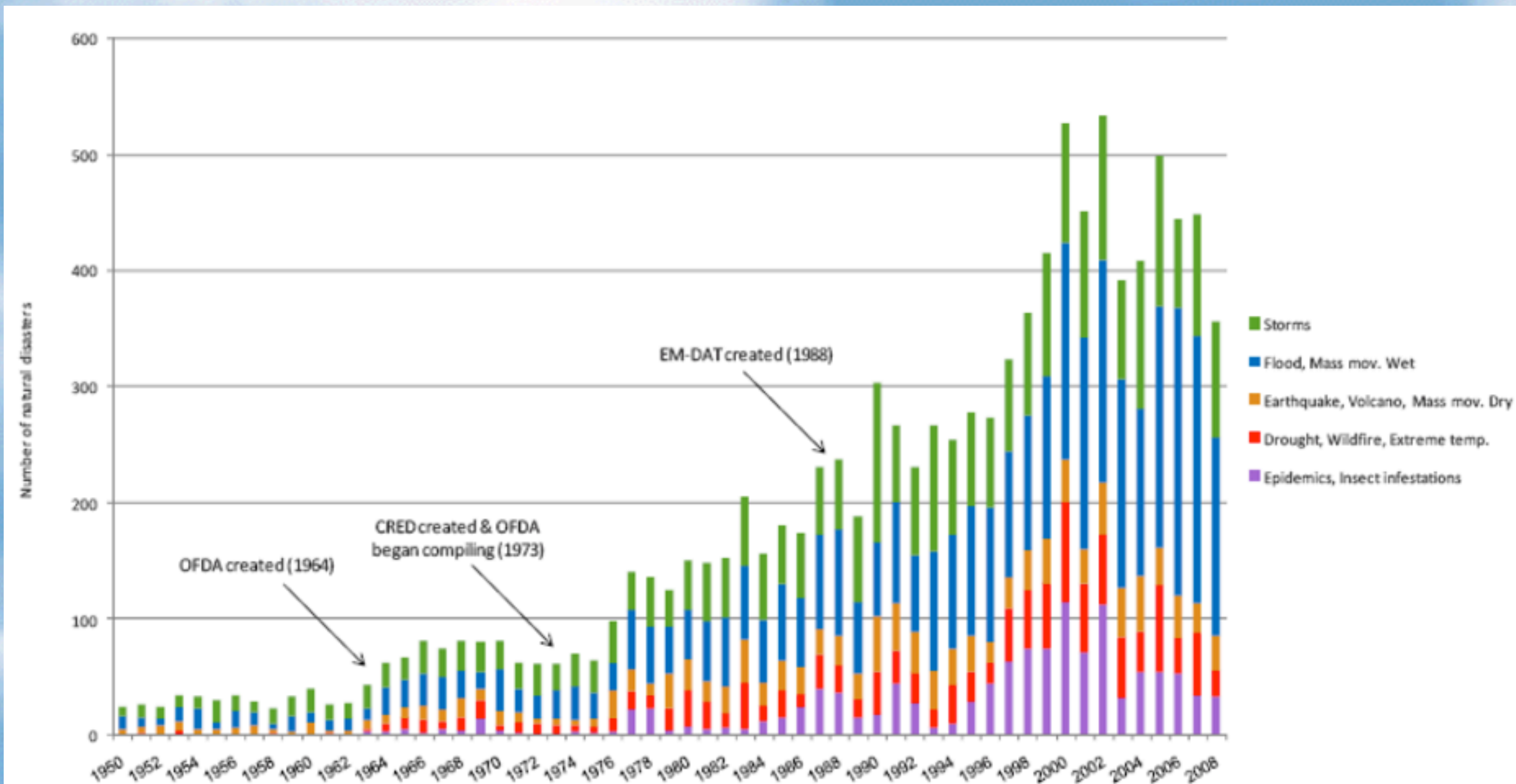






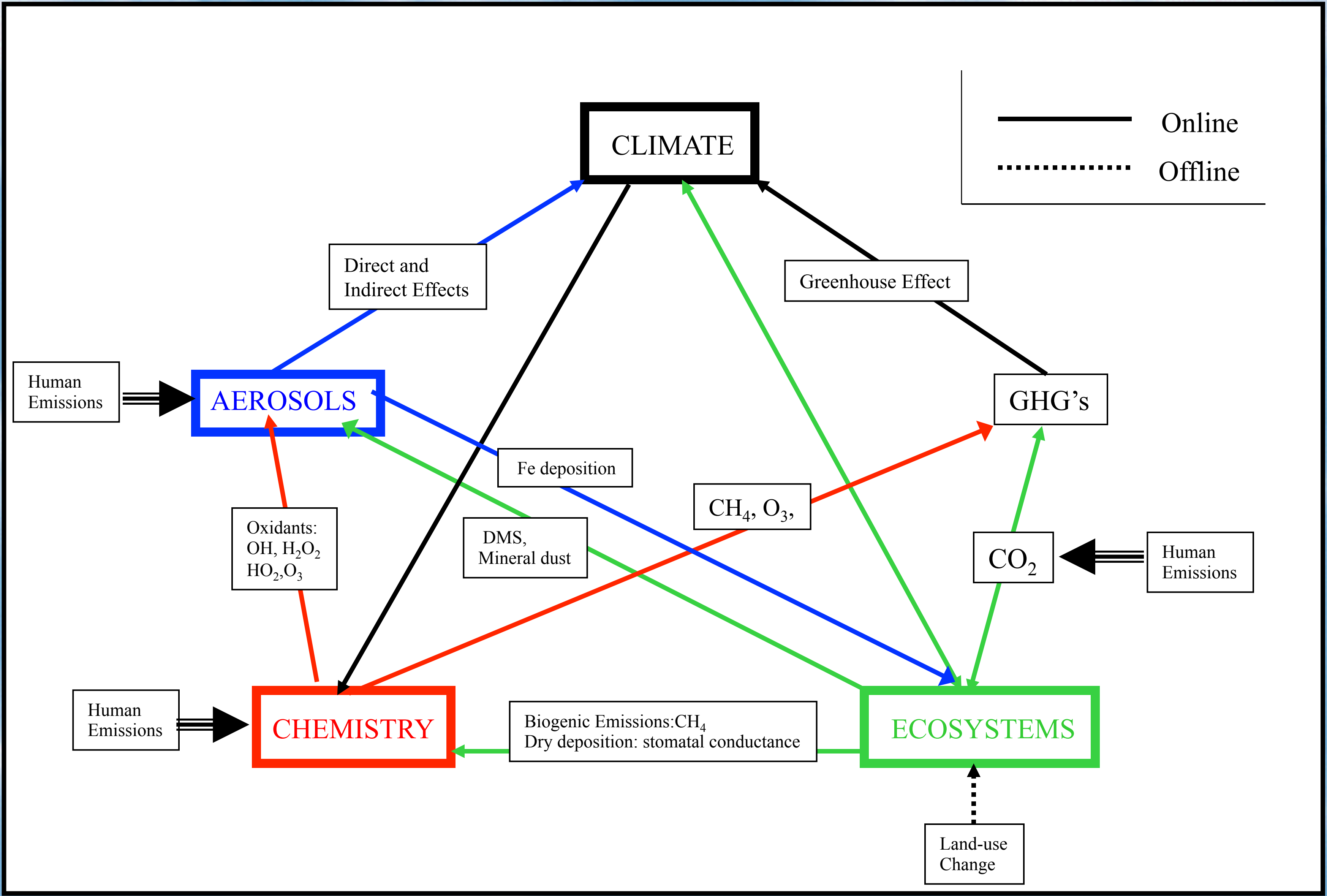
A percentagem de furacões categoria 4 e 5 está aumentando desde 1944

Aumento da incidência de eventos climáticos extremos – 1950-2008



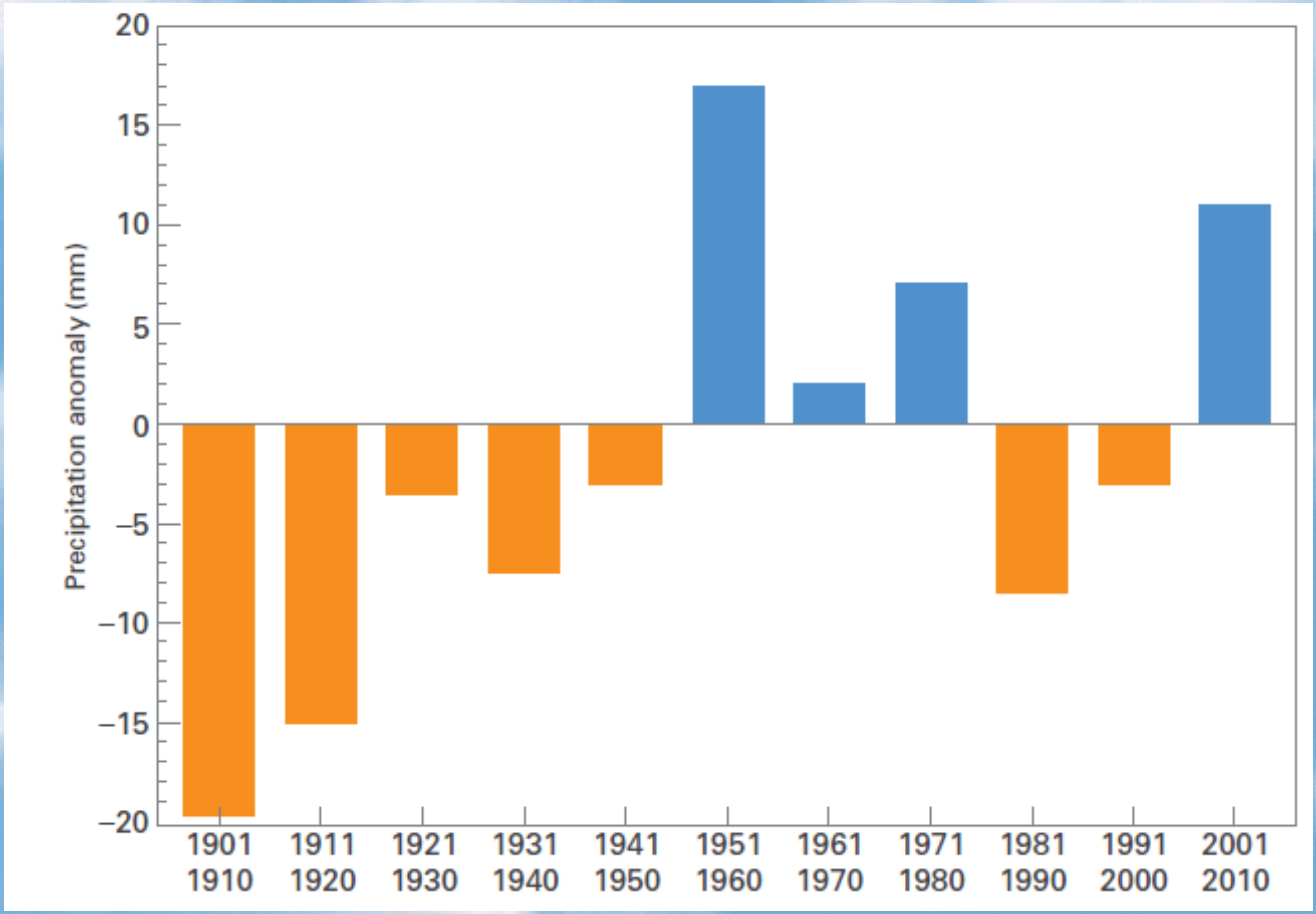
EMDAT - The International Emergency Disasters Database (www.emdat.be)

The climate system – HadGEM2



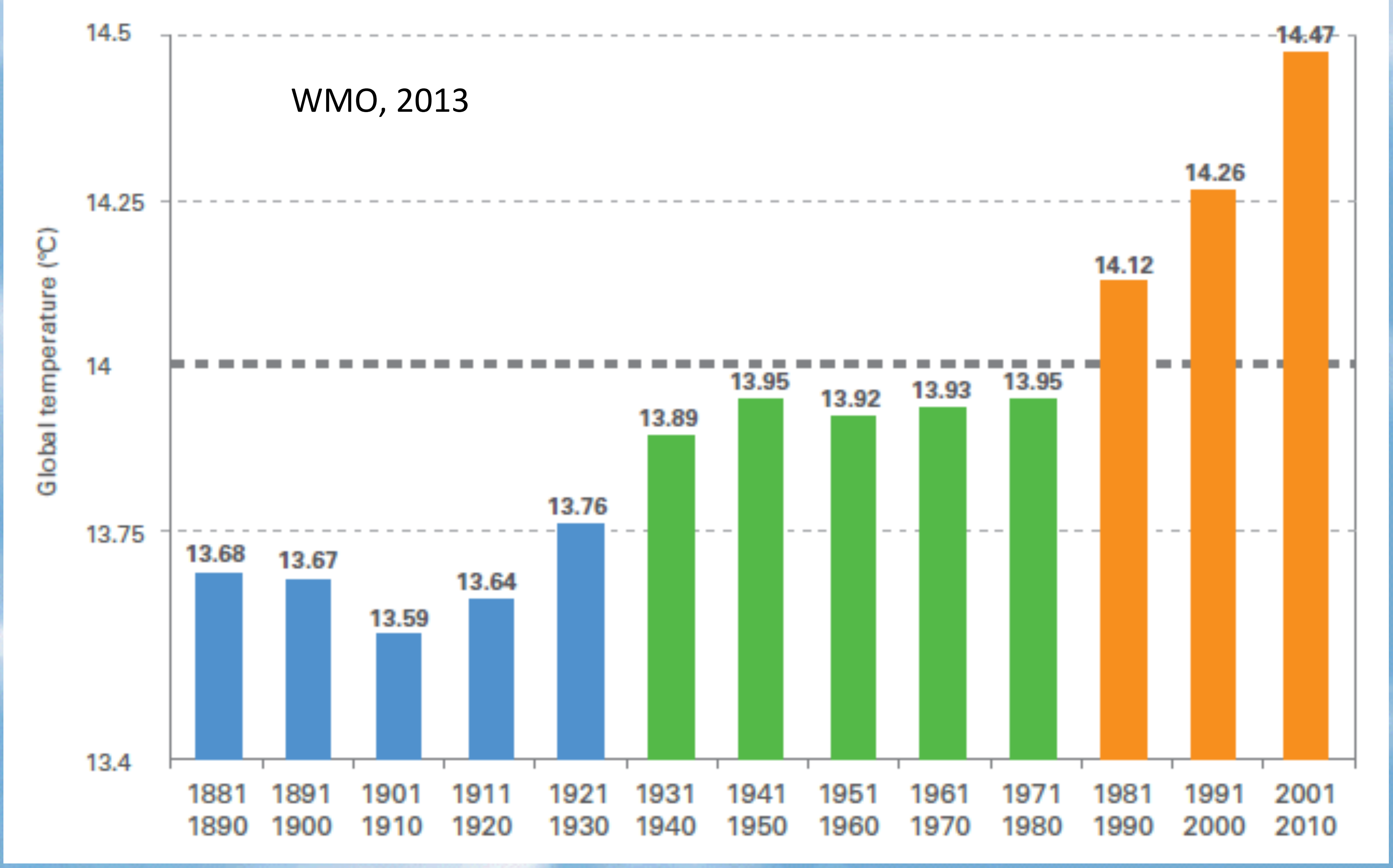
Falta MUITA coisa...

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

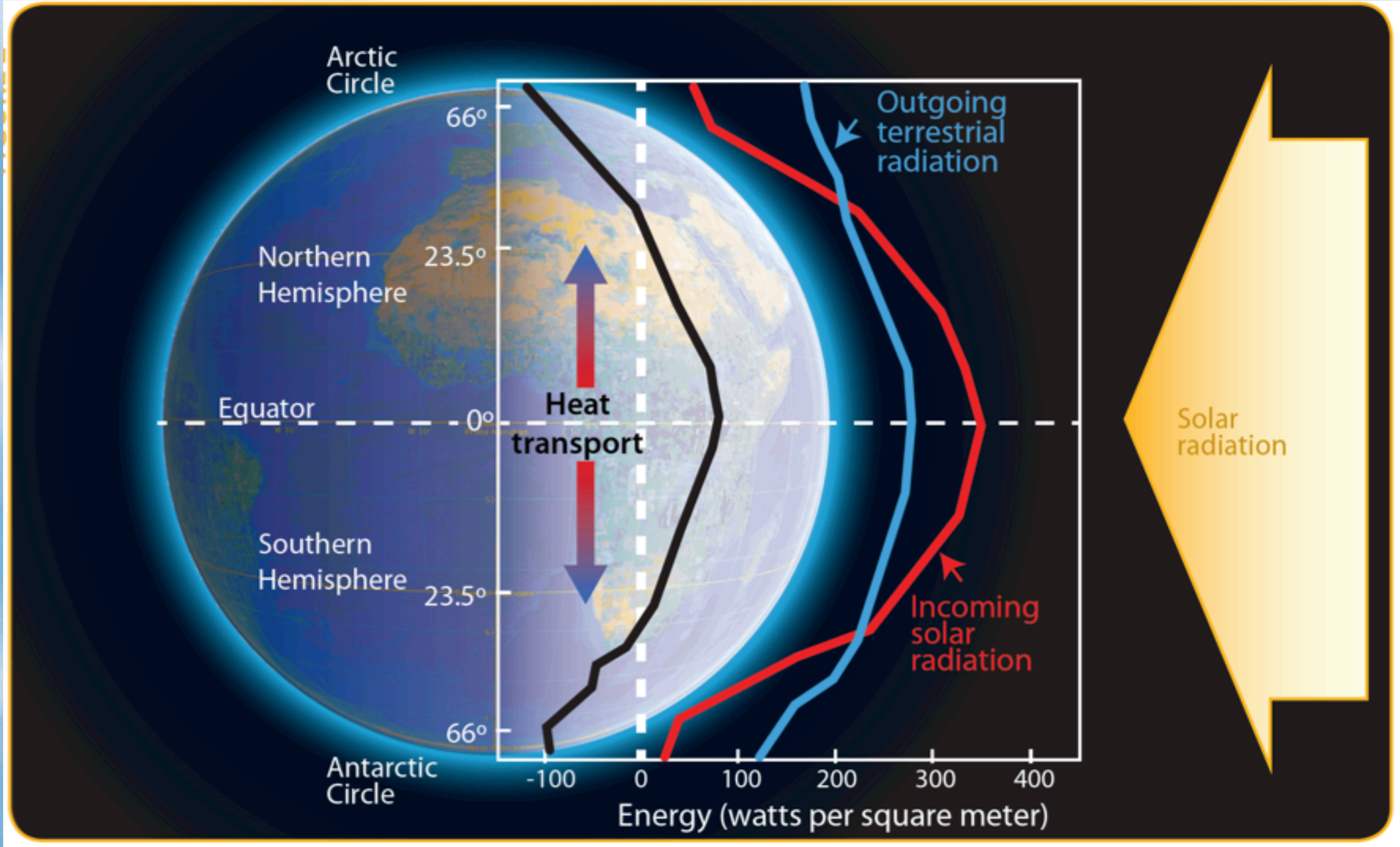


Decadal global combined surface-air temperature over land and sea-surface temperature (°C)

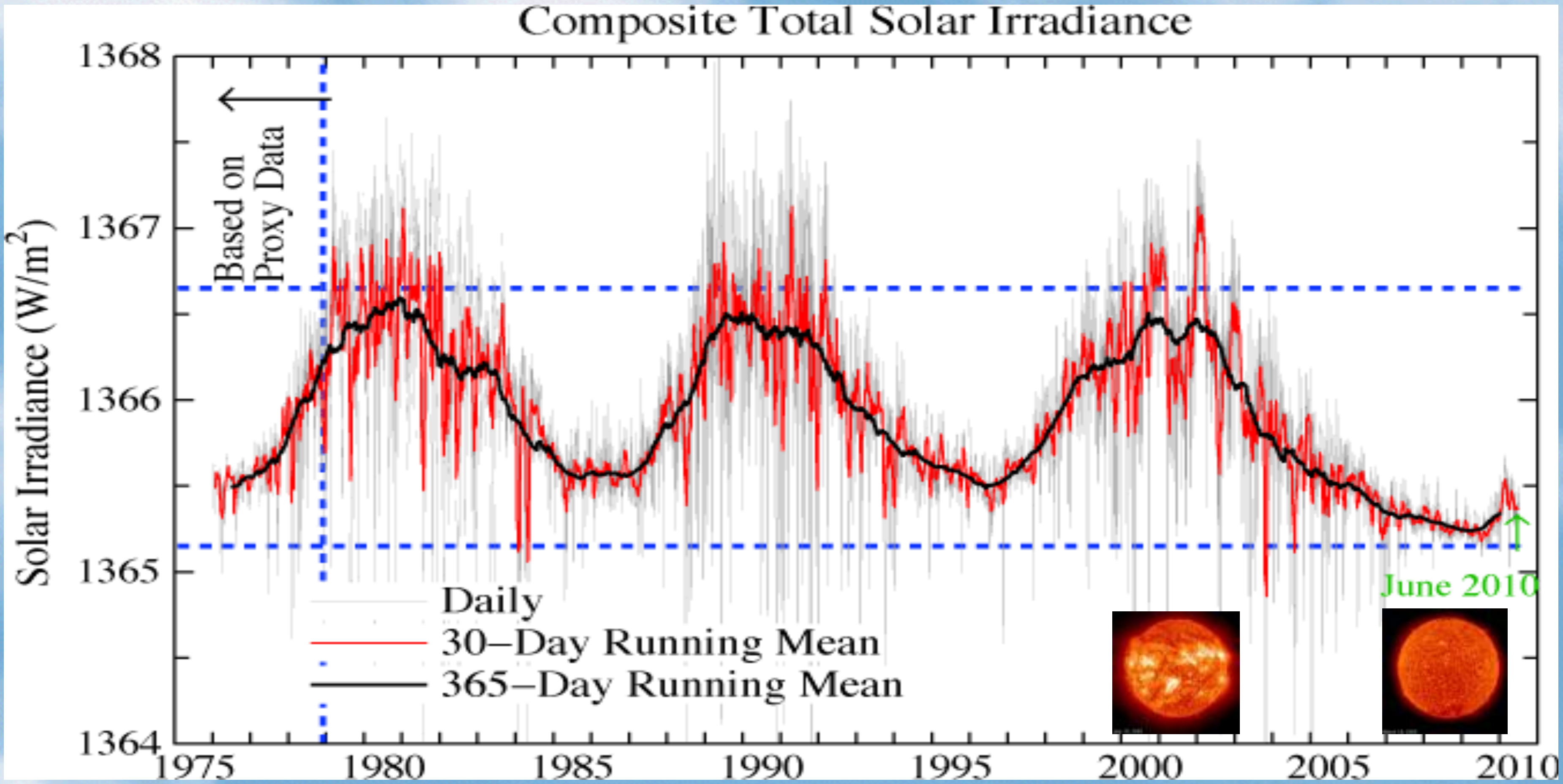
The horizontal grey line is the long-term average value (14.0°C) (1961–1990 base period).



Solar radiation balance

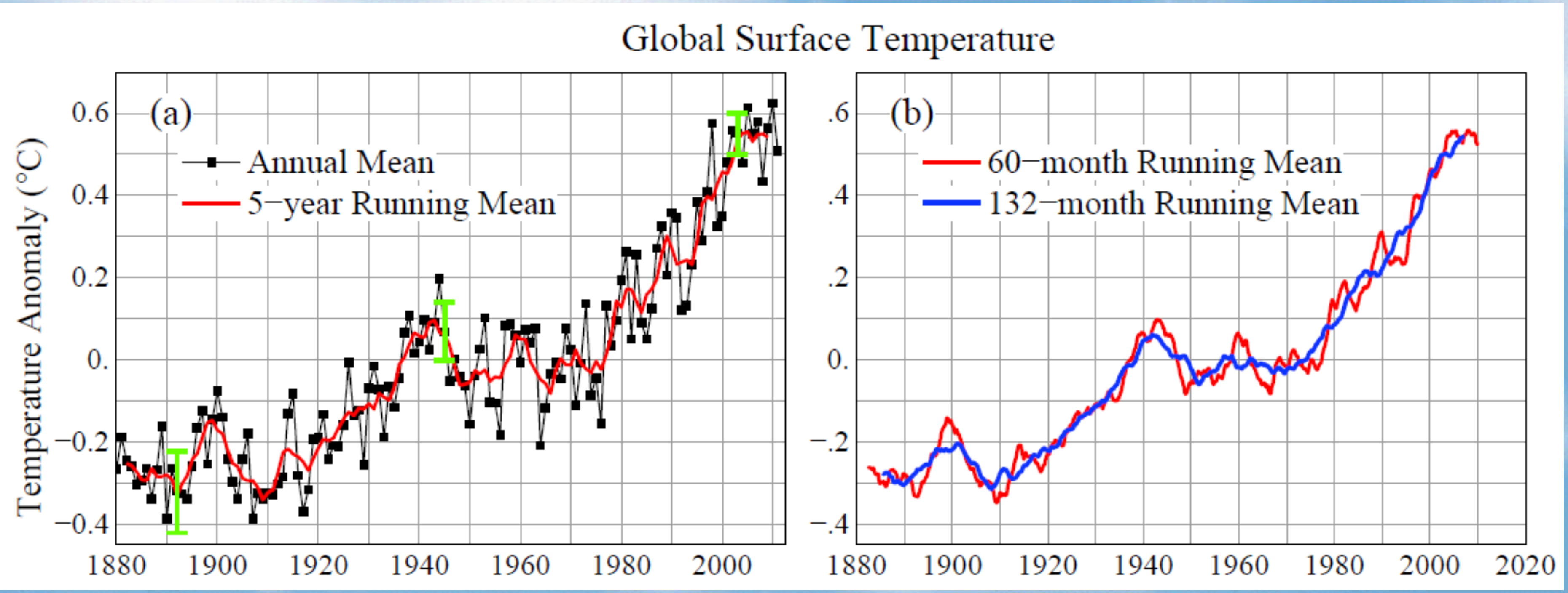


Irradiância solar 1975-2012



The drop of 1.2 W m^{-2} since 2001 is equivalent to -0.2 Wm^{-2} in radiative forcing

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



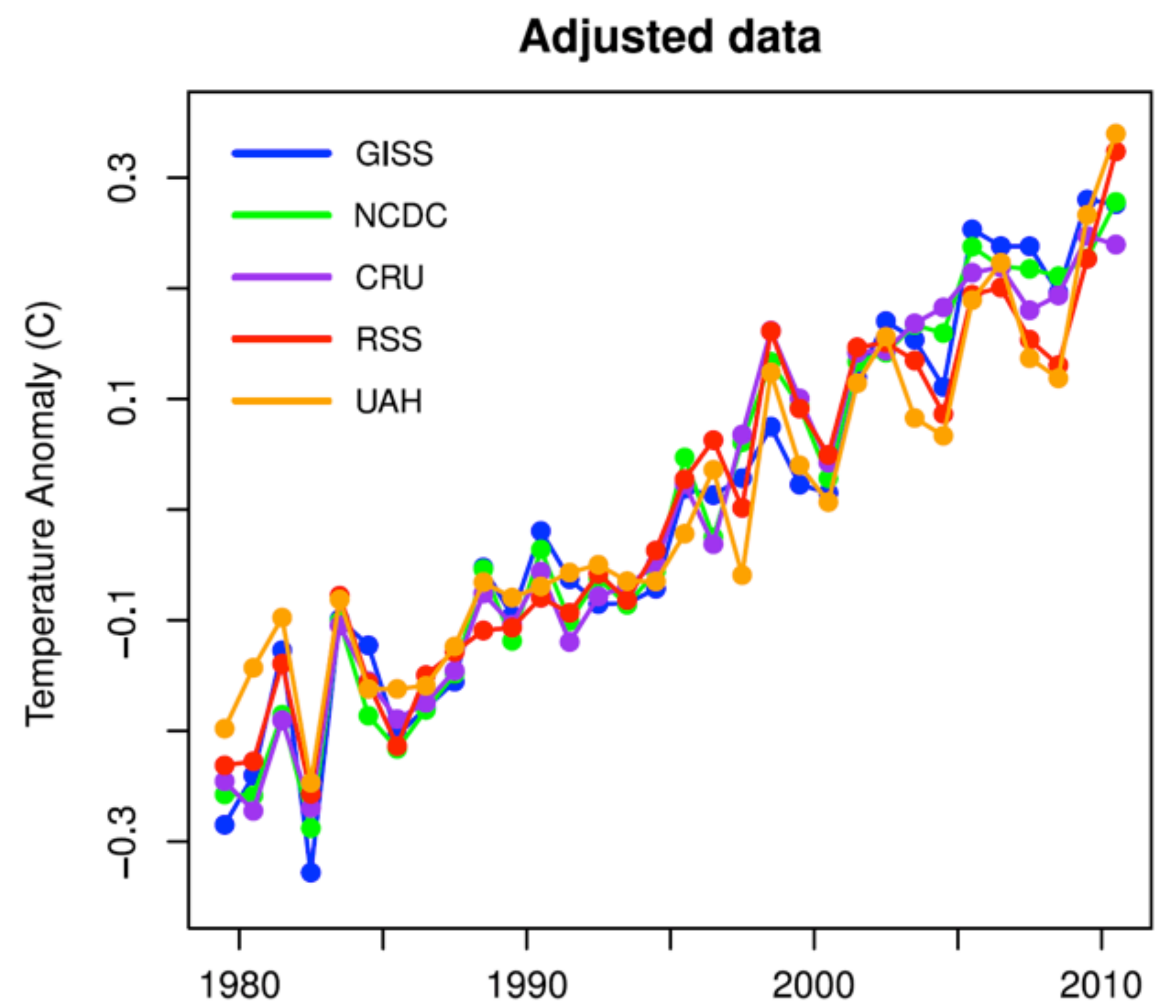
Global surface temperature anomalies relative to 1951-1980 average for (a) annual and 5-year running means through 2010, and (b) 60-month and 132- month running means through July 2012.

(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

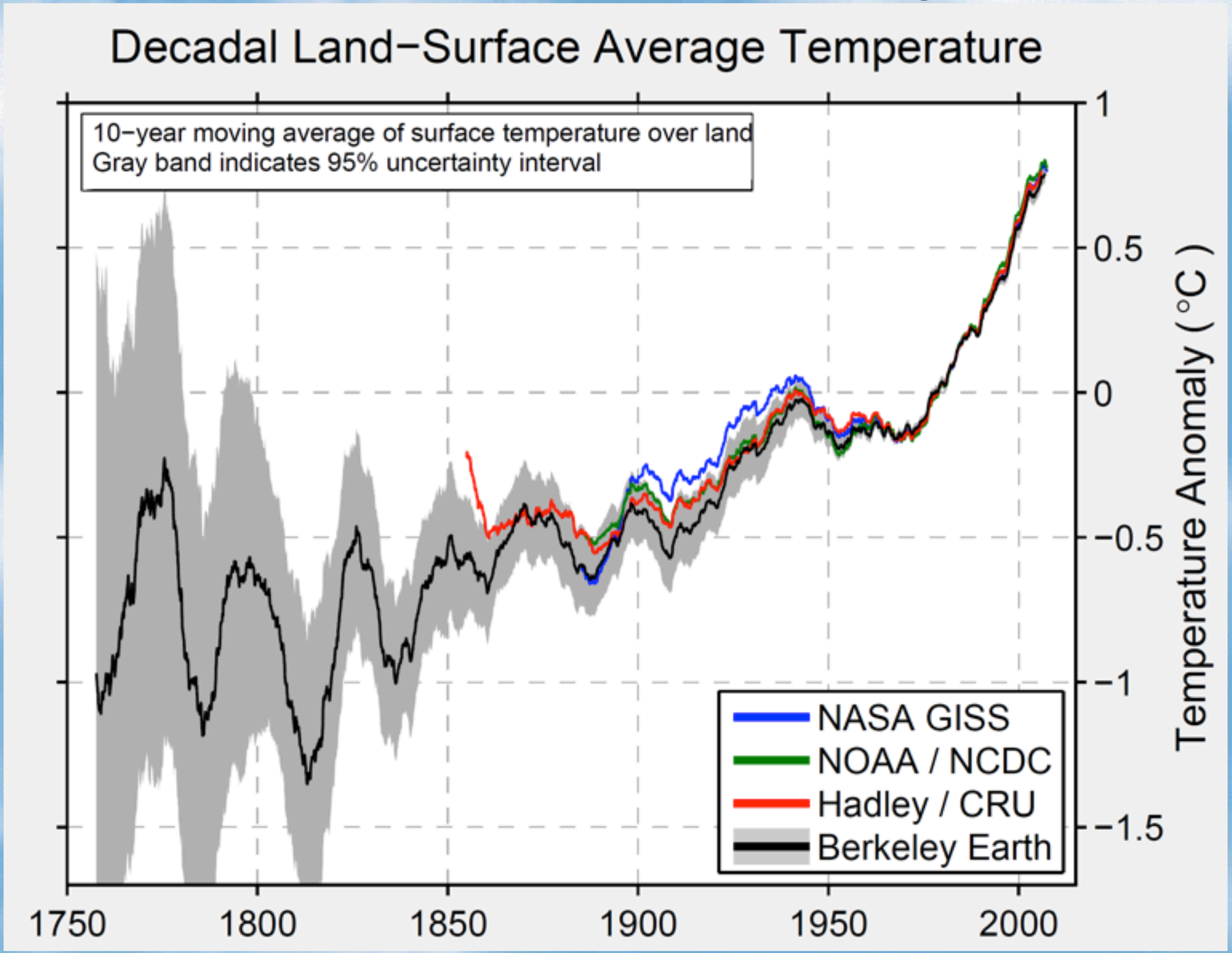
Temperature data from different sources

GISS: NASA Goddard Institute for Space Studies GISS;
NCDC: NOAA National Climate Data Center;
CRU: Hadley Center/ Climate Research Unit UK;
RSS: data from Remote Sensing Systems;
UAH: University of Alabama at Huntsville.



Source: Foster and Rahmstorf 2012.

Ex-céticos: resultados do "Berkeley Earth Group"

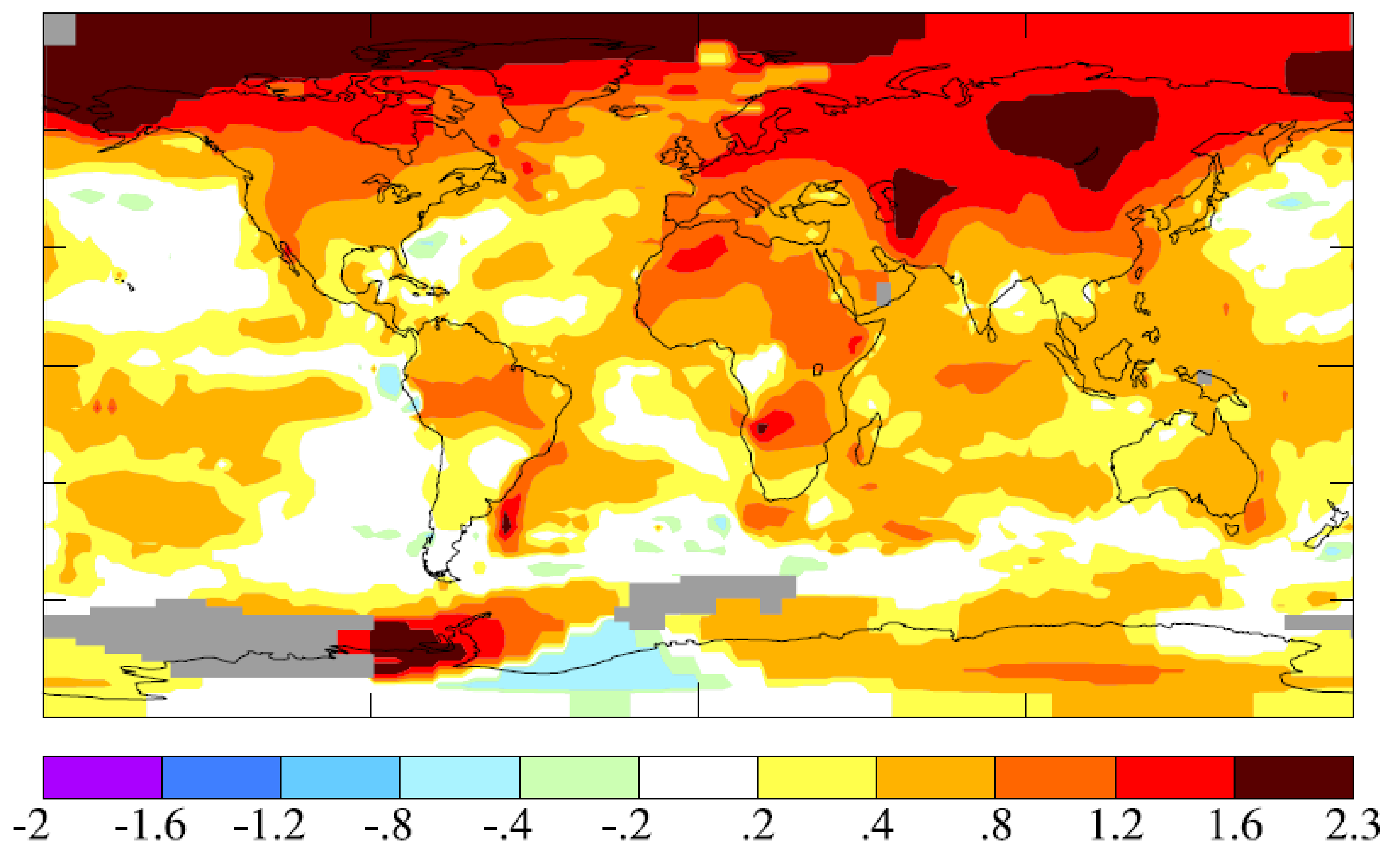


The Berkeley Earth Surface Temperature study is using over 36,000 unique stations

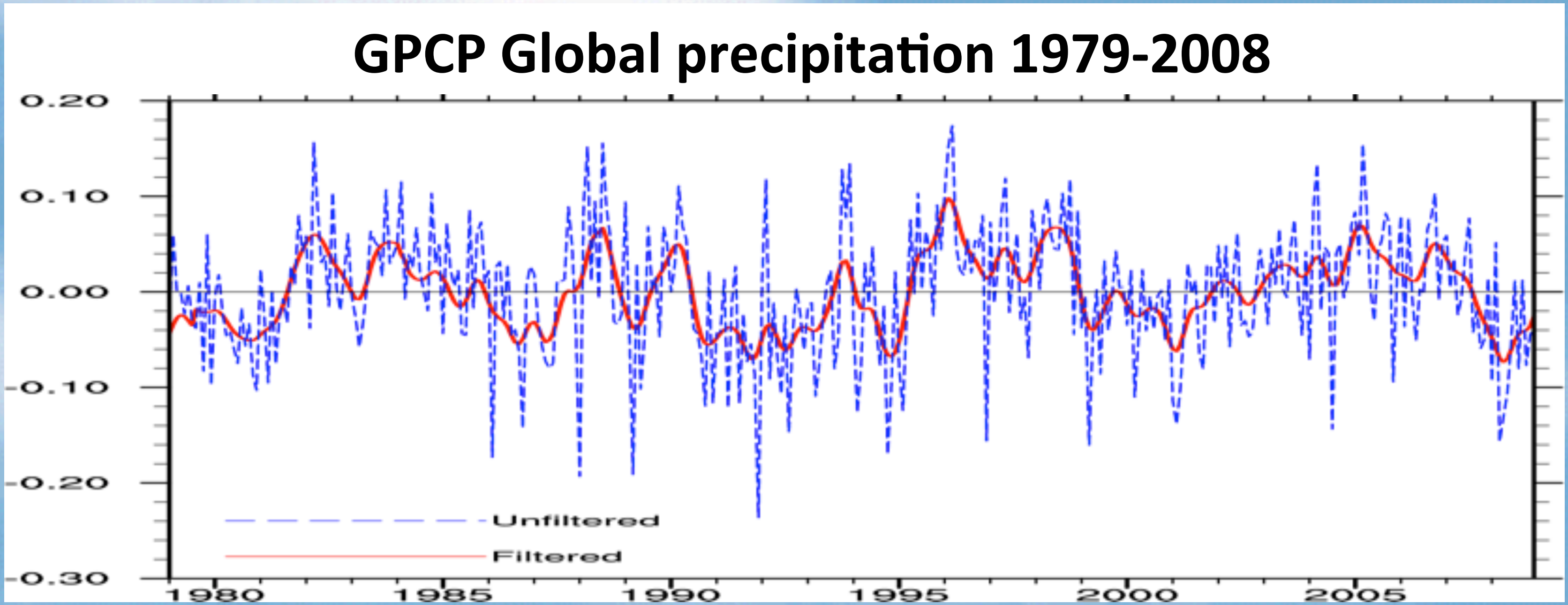
http://berkeleyearth.org/

2001-2007 Mean Surface Temperature Anomaly (◦C)

Base Period = 1951-80, Global Mean = 0.54



There is no trend in global precipitation amounts

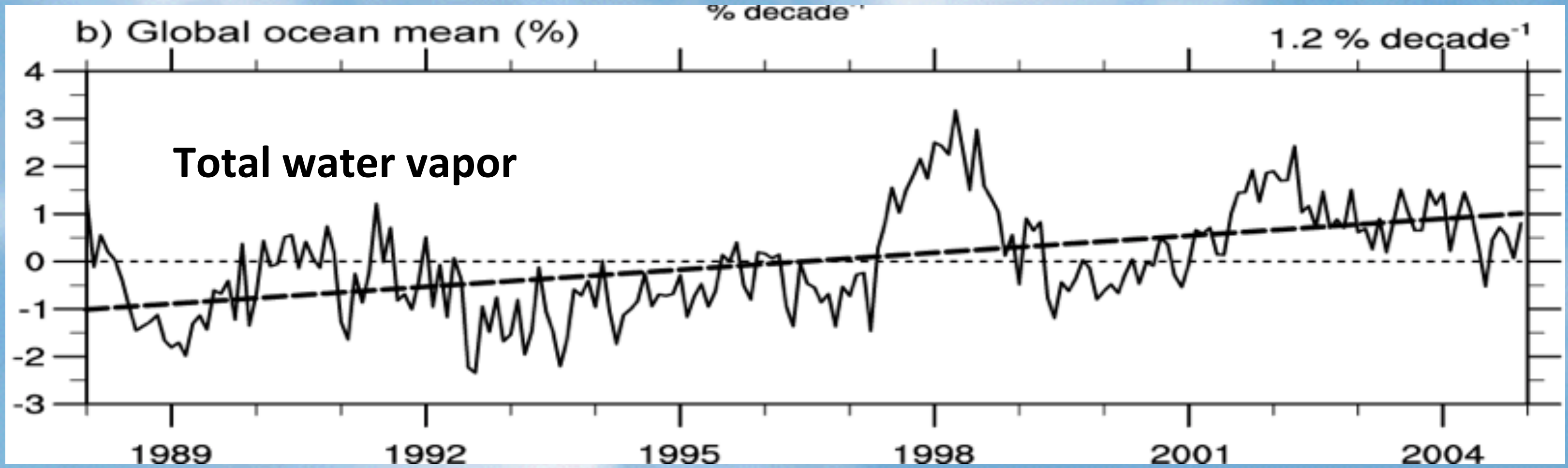


Biggest changes in absolute terms are in the tropics, and there is a strong El Niño signal

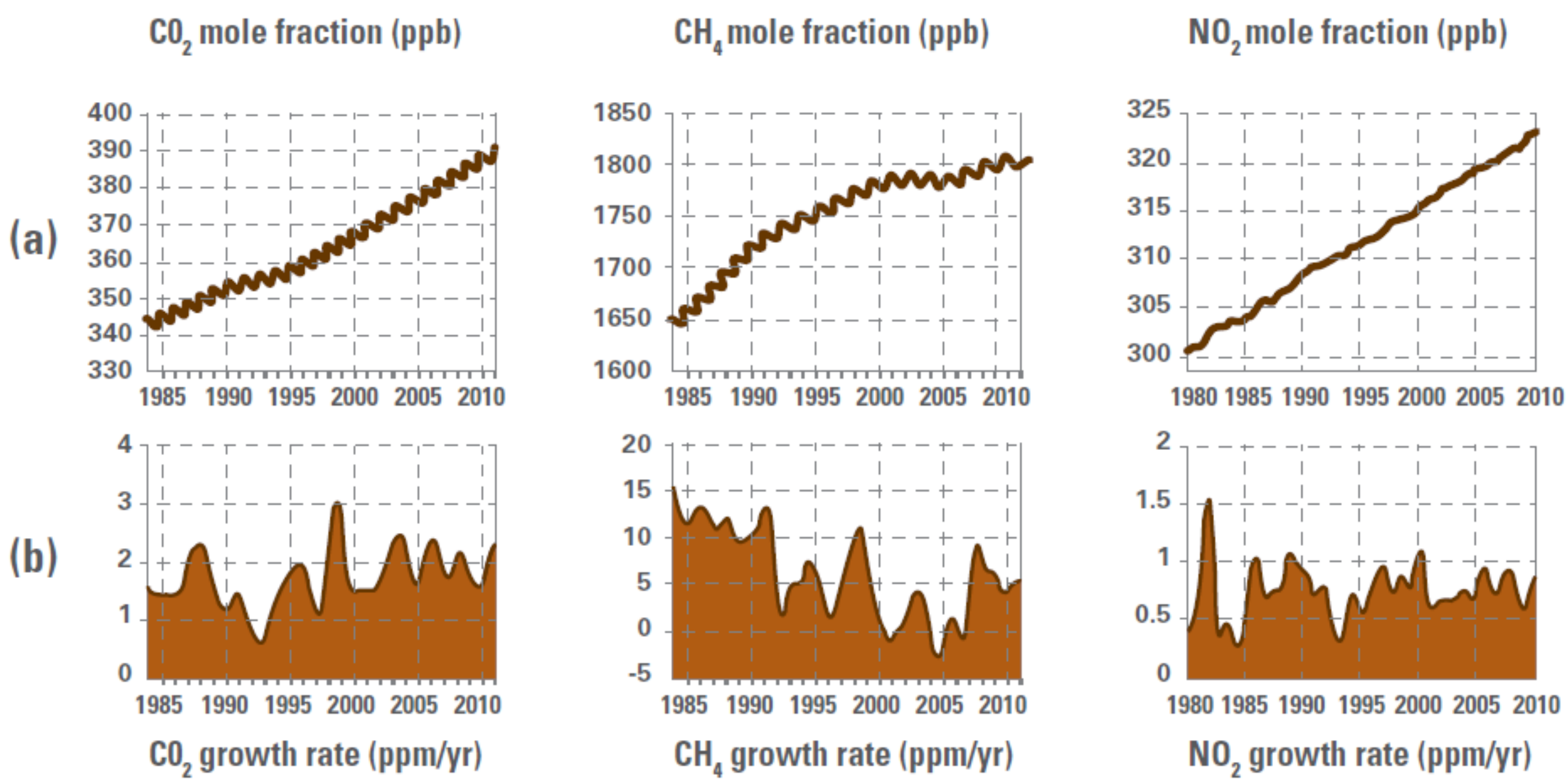
Air holds more water vapor at higher temperatures

A basic physical law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature.

Observations show that this is happening: 0.55°C since 1970 over global oceans and 4% more water vapor. This means more moisture available for storms and an enhanced greenhouse effect.

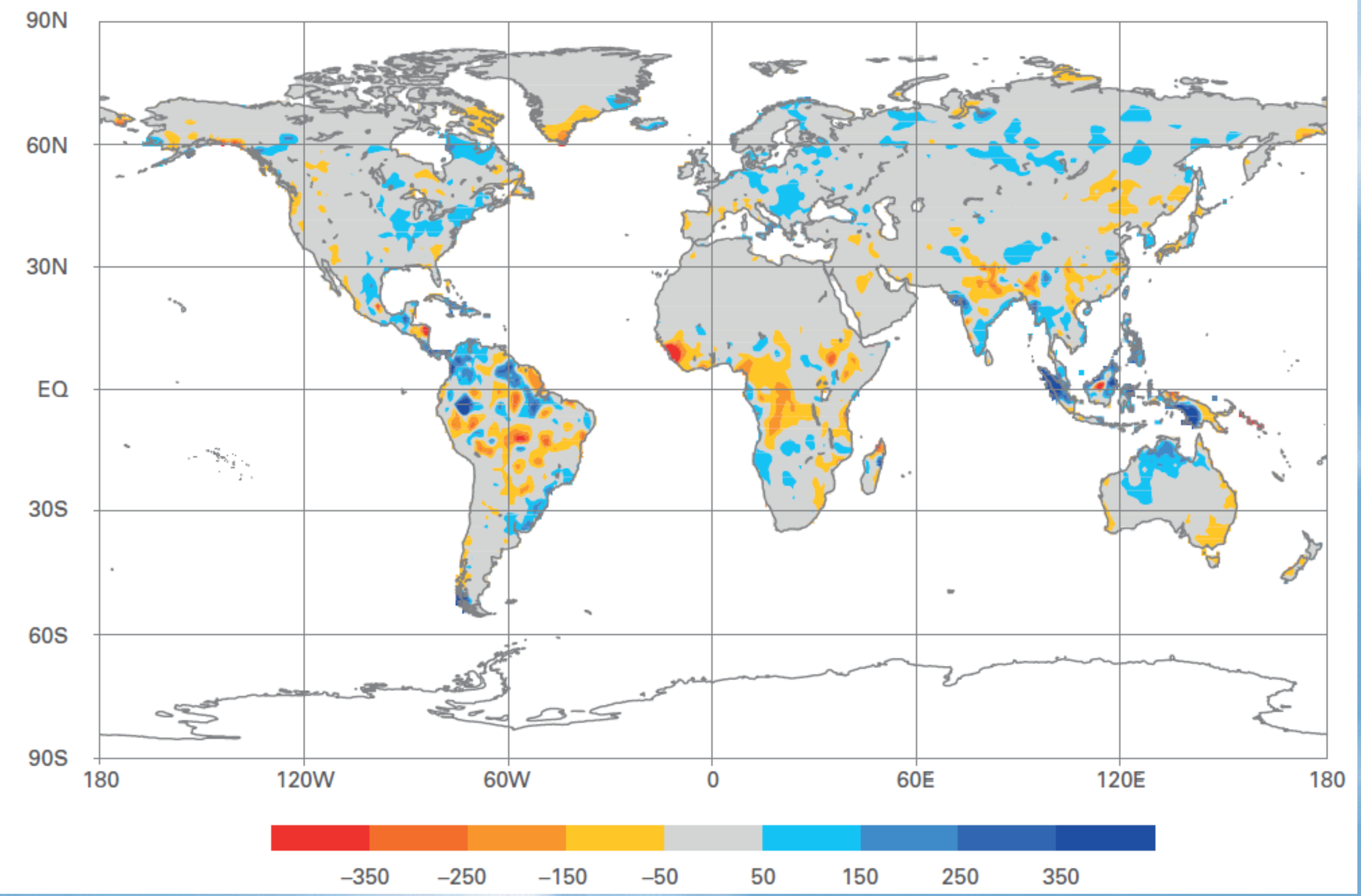


	2010	Increase since pre-industrial times	1991–2000	2001–2010
Carbon dioxide	389.0 ppm	39%	361.5 ppm	380 ppm
Methane	1808 ppb	158%	1 758 ppb	1 790 ppb
Nitrous oxide	323.2 ppb	20%	312.2 ppb	319.7 ppb

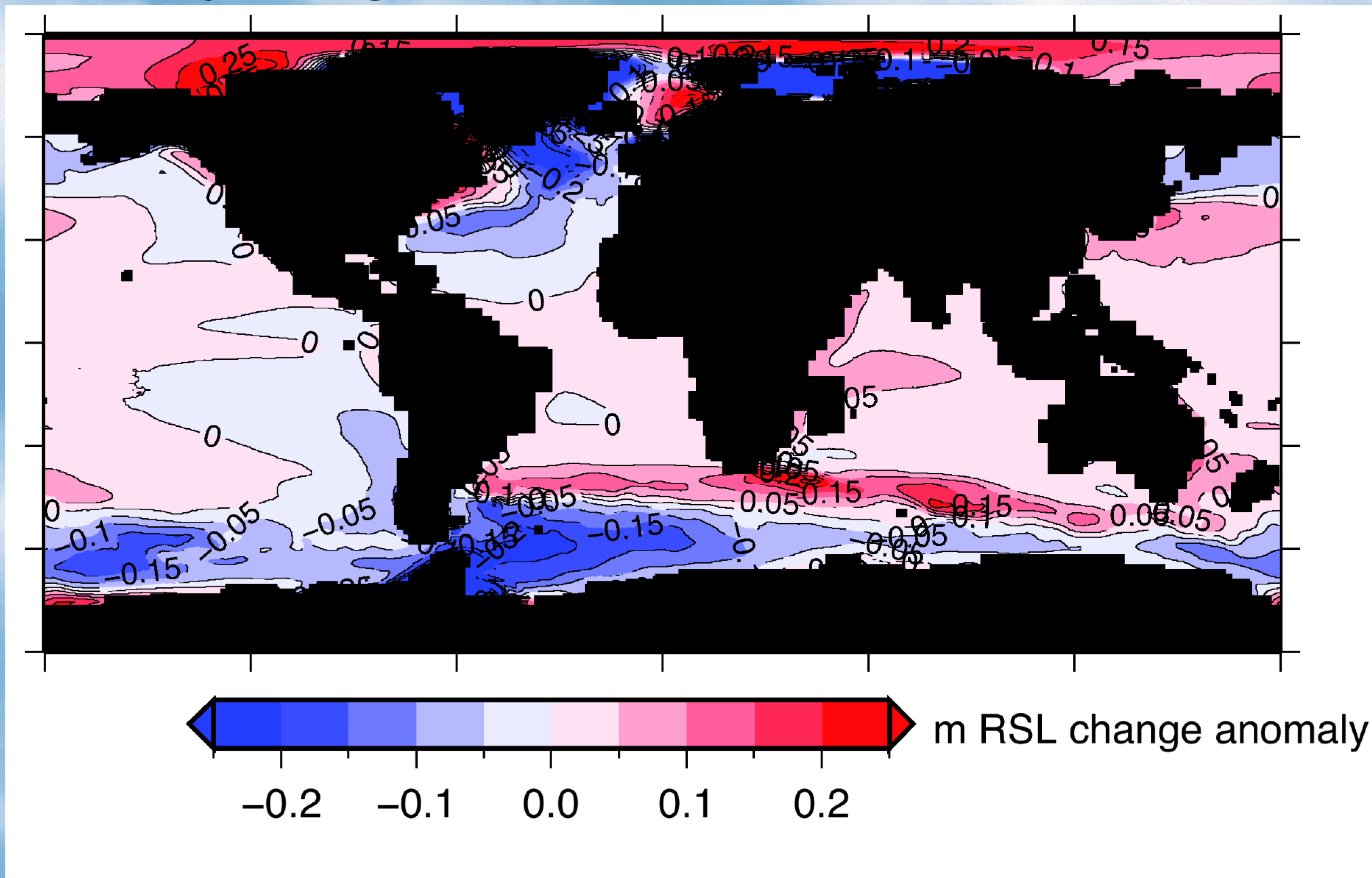


WMO Greenhouse Gas Bulletin, No.7, 2011

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



Diferenças regionais no aumento do nível do mar

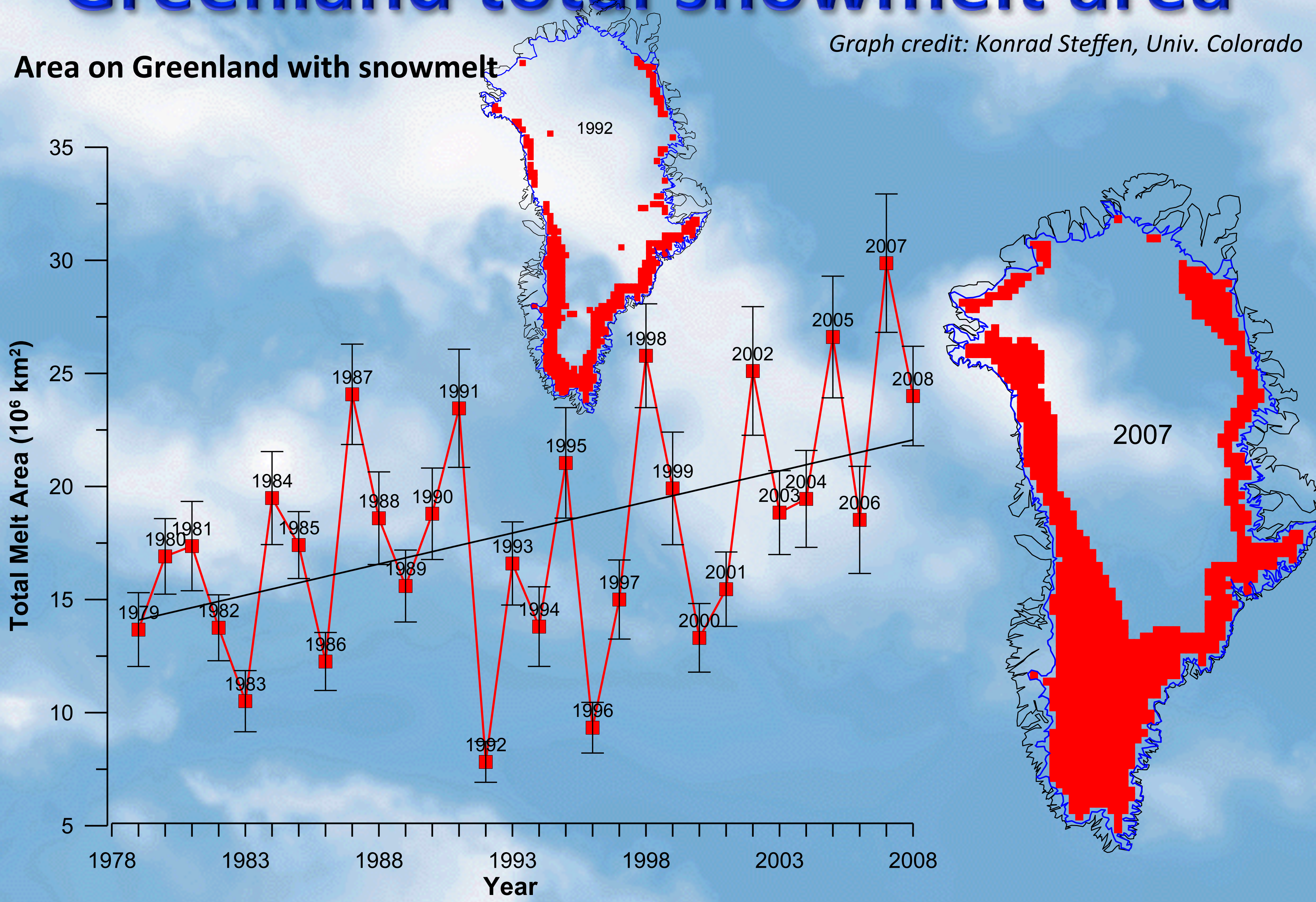


Ensemble mean sea level anomaly (m) with respect to global mean RS change (0.47 m) for scenario A1B between 1980–1999 and 2090–2099 (from Slangen et al., 2011). Global mean = 0.47 m; range = –3.65 to +1.01 m.

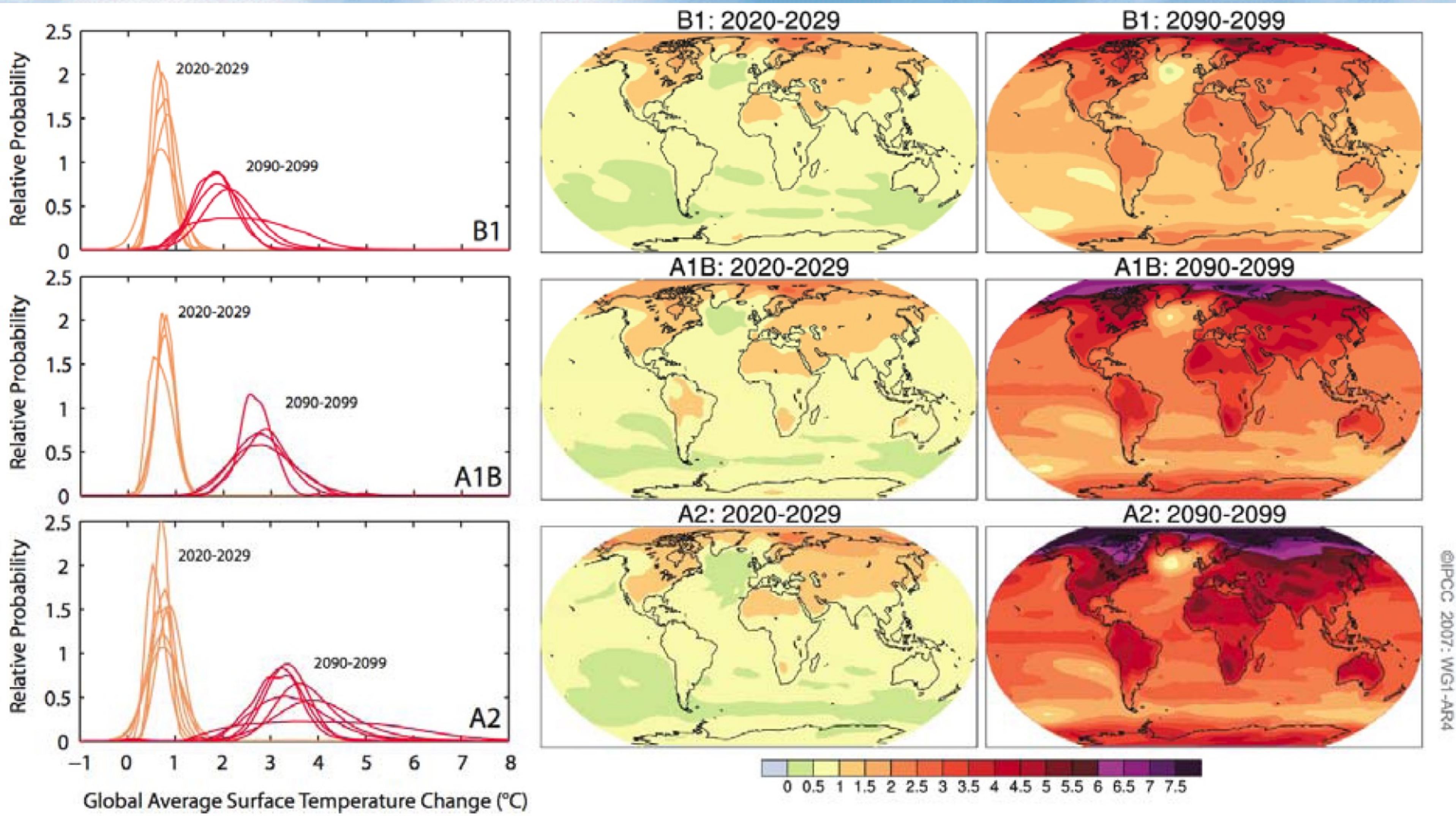
Greenland total snowmelt area

Graph credit: Konrad Steffen, Univ. Colorado

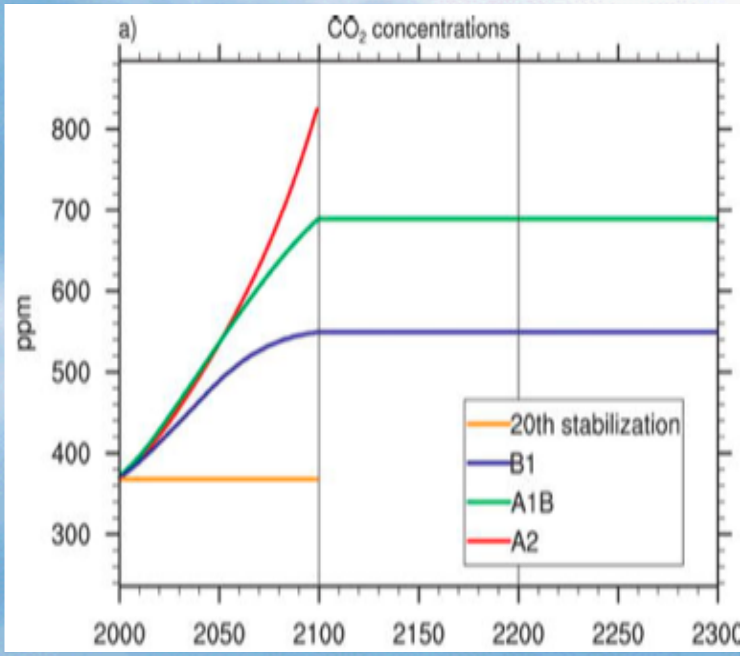
Area on Greenland with snowmelt

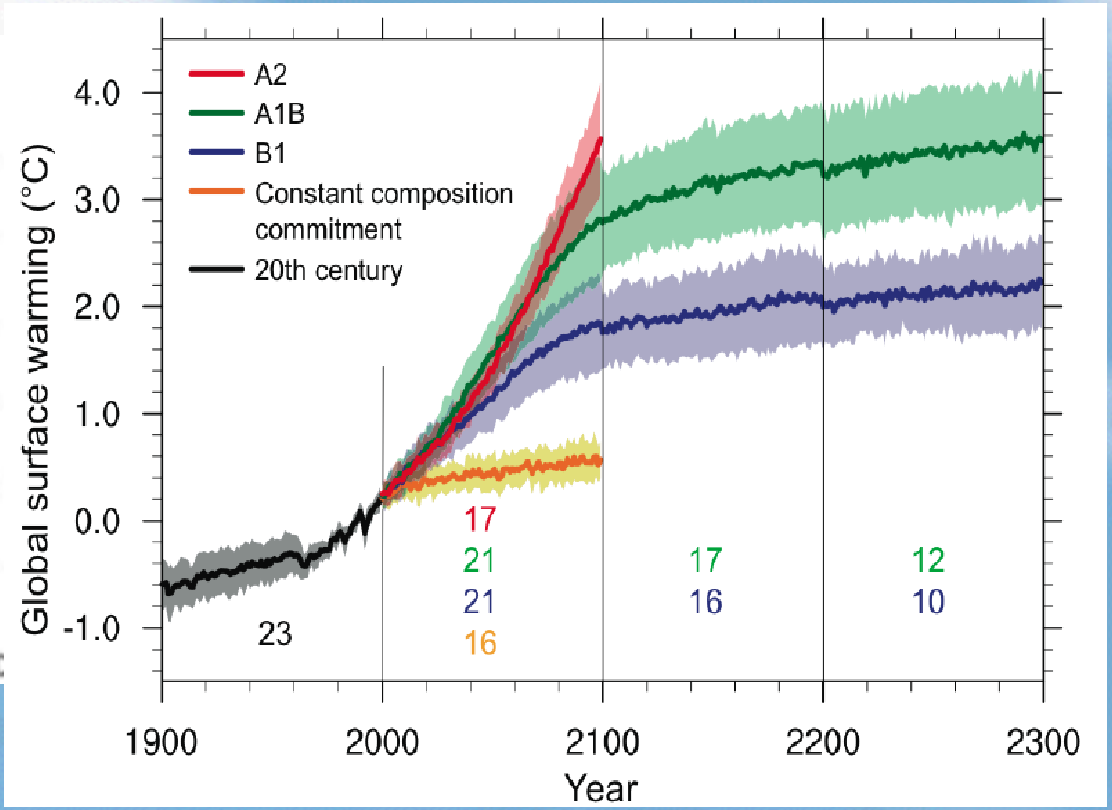


Estimates of temperature increase for 2029 and 2099 according to 3 emission scenarios



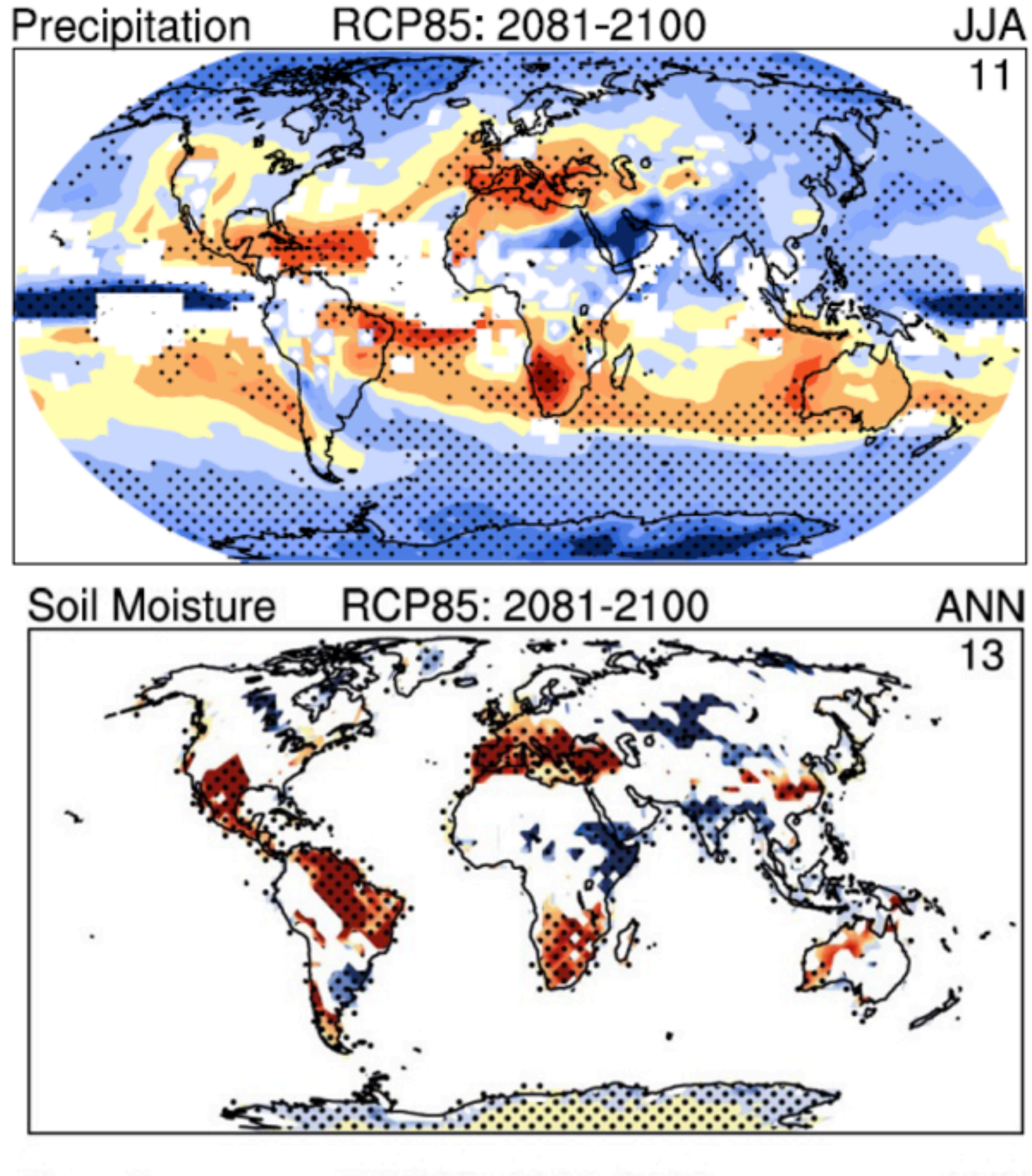
Previsão de aquecimento global ao longo dos próximos 100 anos





Cenários possíveis de aumento nas concentrações de CO_2

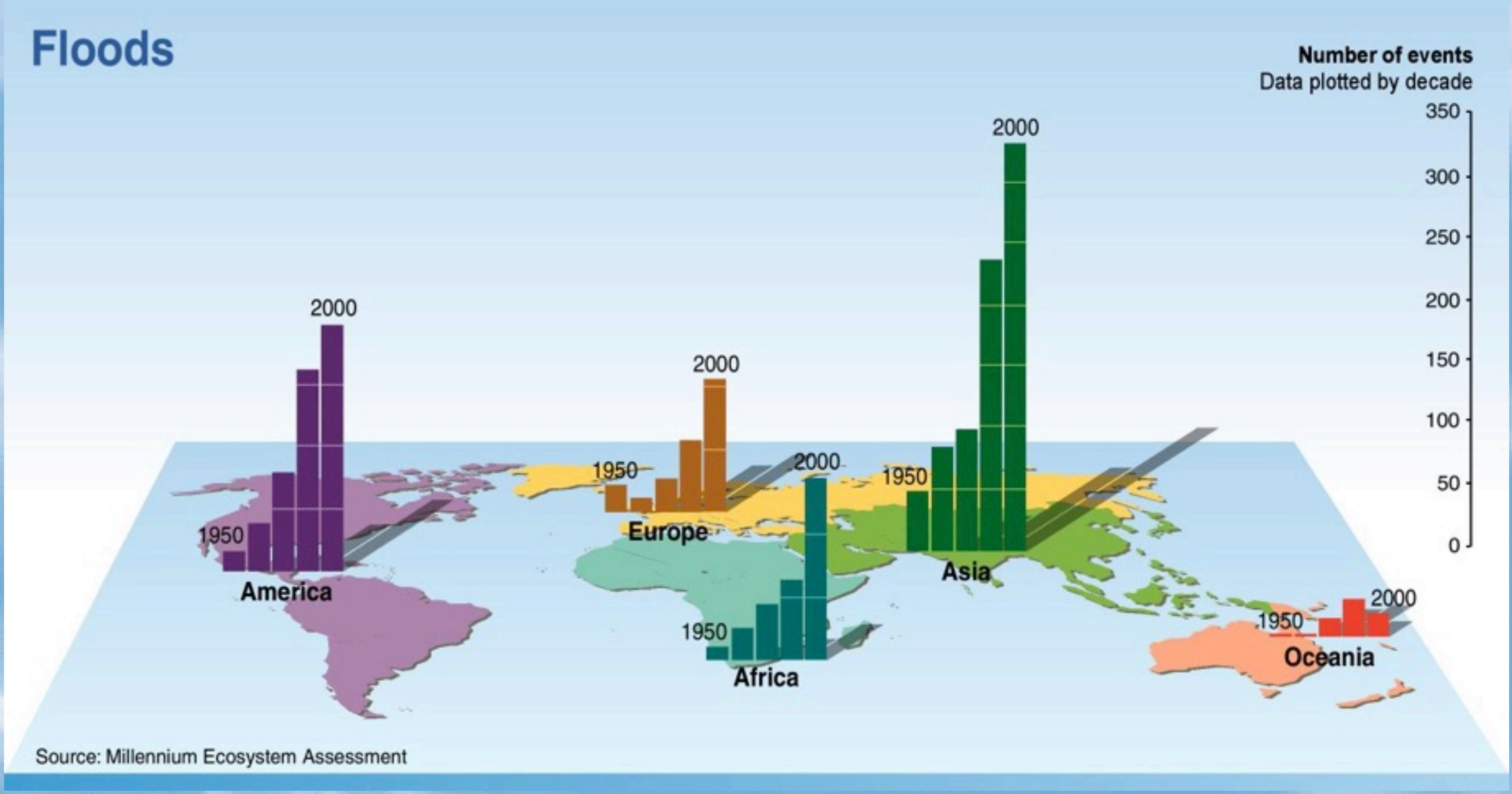
Aumento na temperatura média global: de 2 a 4 graus centígrados ao longo deste século



Changes in the water cycle in 2100

(IPCC 2012)

Increase of incidence of extreme climatic events 1950-2000



Millennium Ecosystem Assessment, 2007

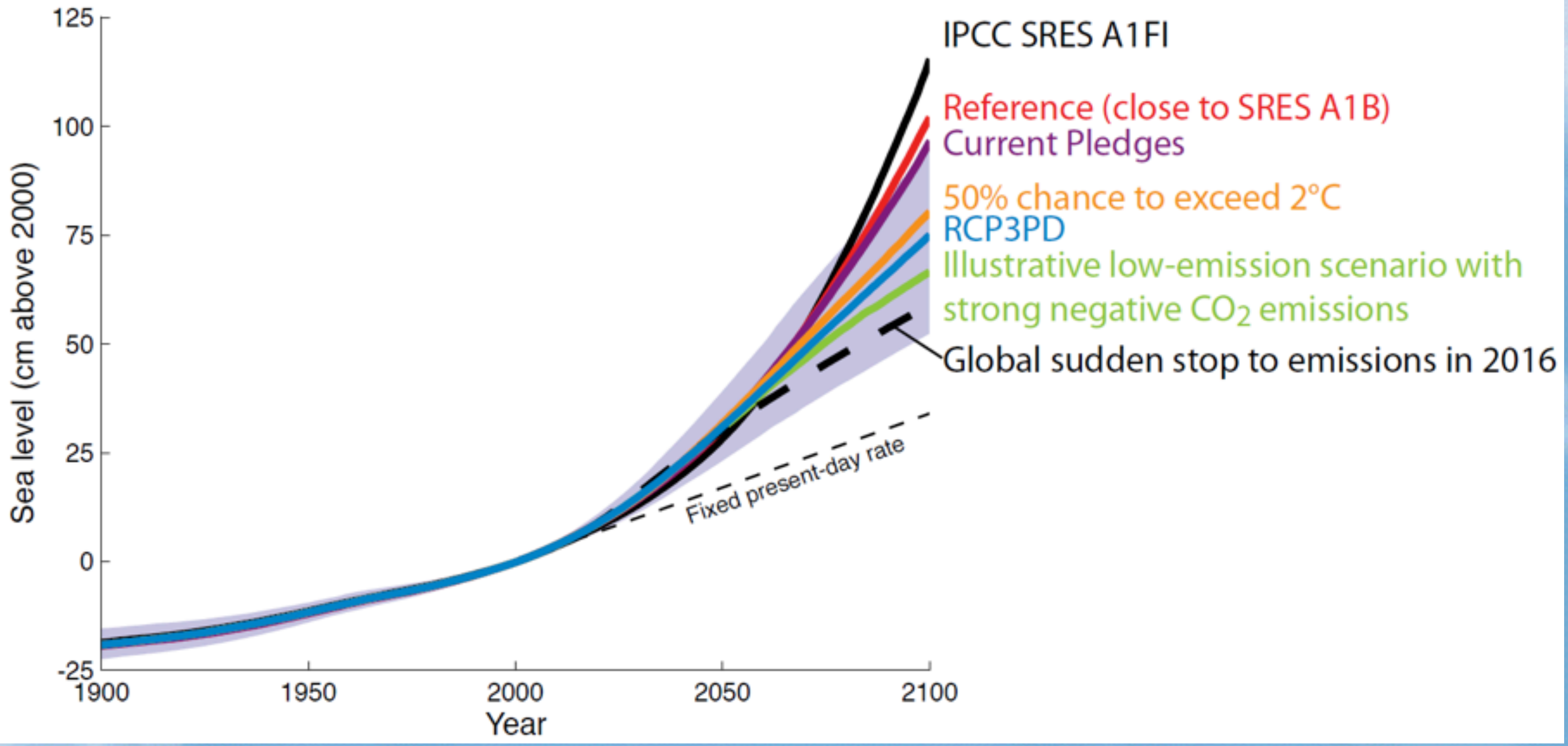
Global abundances (as mole fractions) of key greenhouse gases averaged over the 12 months of 2011 as well as changes relative to 2010 and 1750 from the WMO/GAW global greenhouse gas monitoring network

	CO_2	CH_4	N_2O
Global abundance in 2011	390.9± 0.1[5] ppm	1813± 2[5] ppb	324.2± 0.1[5] ppb
2011 abundance relative to year 1750*	140%	259%	120%
2010–2011 absolute increase	2.0 ppm	5 ppb	1.0 ppb
2010–2011 relative increase	0.51%	0.28%	0.31%
Mean annual absolute increase during last 10 years	2.0 ppm/yr	3.2 ppb/yr	0.78 ppb/yr

(*) Assuming a pre-industrial mole fraction of 280 ppm for CO_2, 700 ppb for CH_4 and 270 ppb for N_2O

Since the industrial revolution, about 375 billion tonnes of carbon have been emitted by humans into the atmosphere as carbon dioxide (CO_2).

Global mean sea-level rise 1900-2100



Global mean sea-level rise using a semi-empirical approach. The indicative/fixed present-day rate of 3.3 mm.yr-1 is the satellite-based mean rate 1993–2007 (Cazenave and Llovel 2010). Median estimates from probabilistic projections. See Schaeffer et al. (2012).

Black carbon and co-emitted species by region and source in 2000