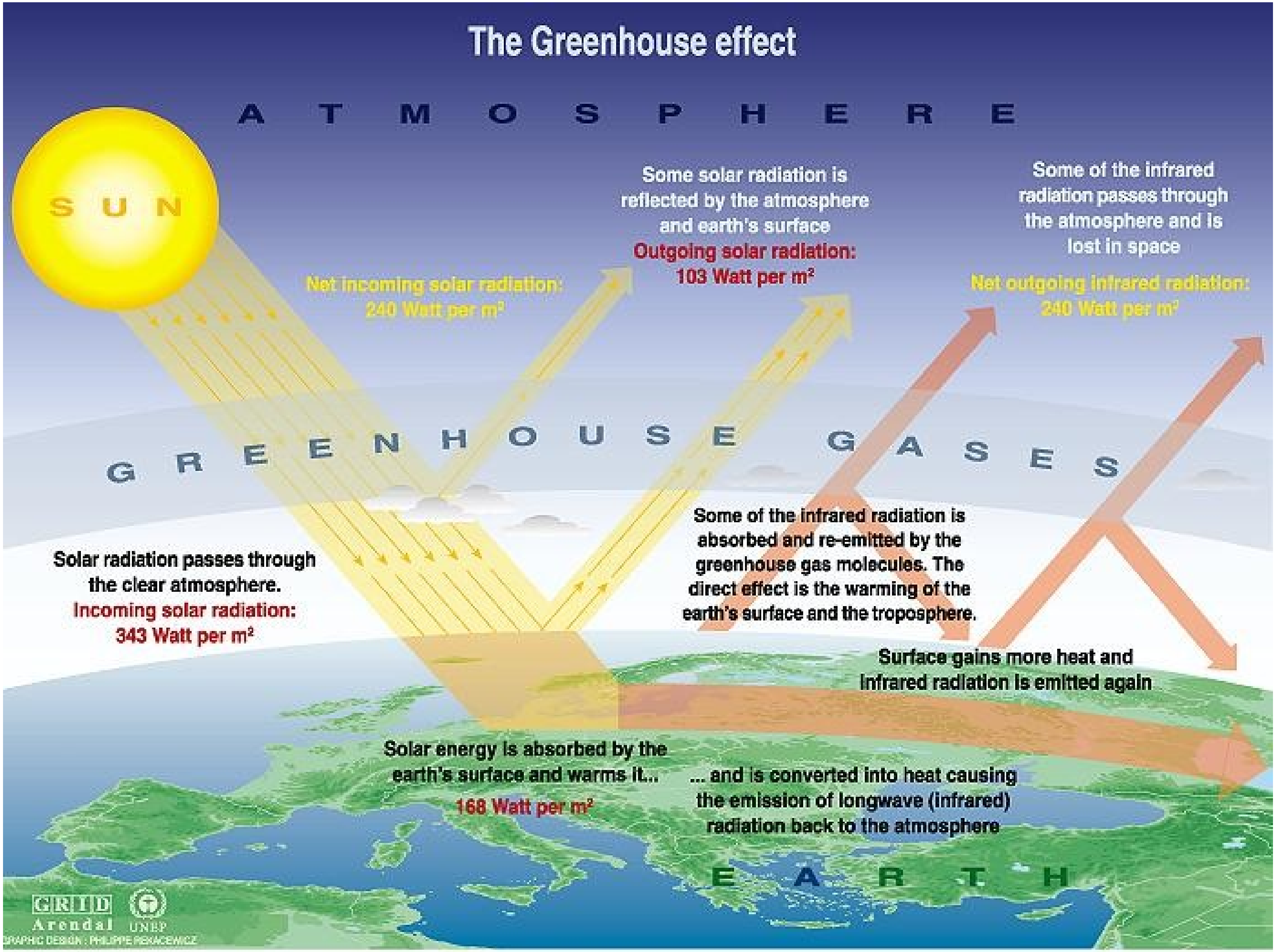
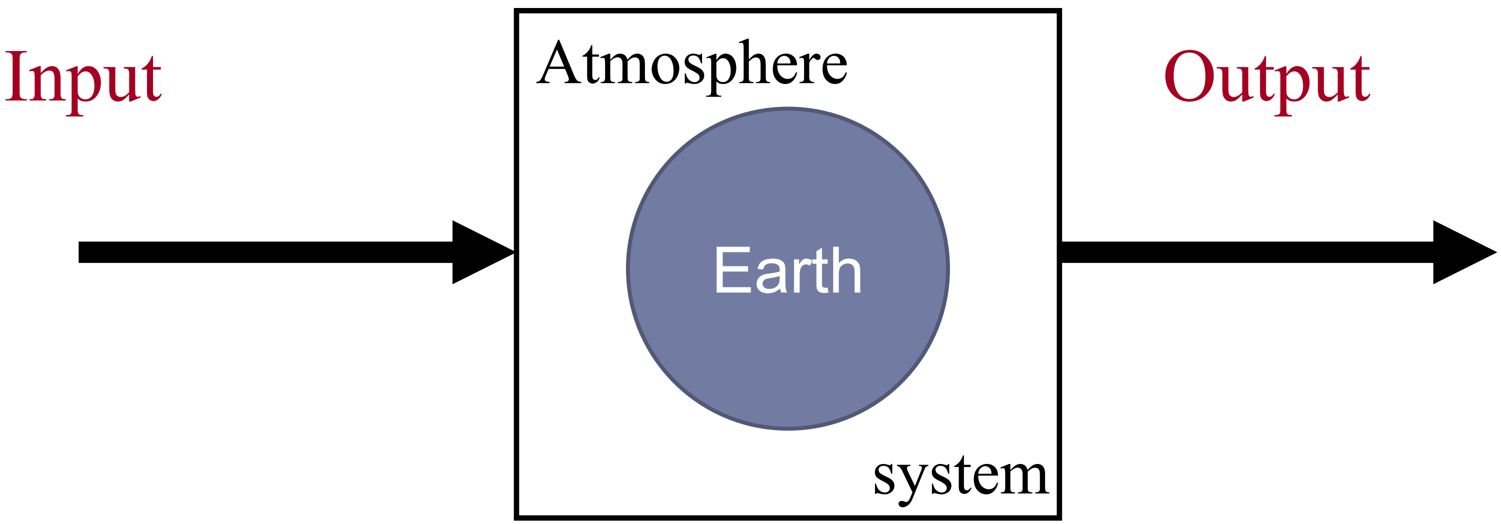
Global Climate Change

Introduction and Implications



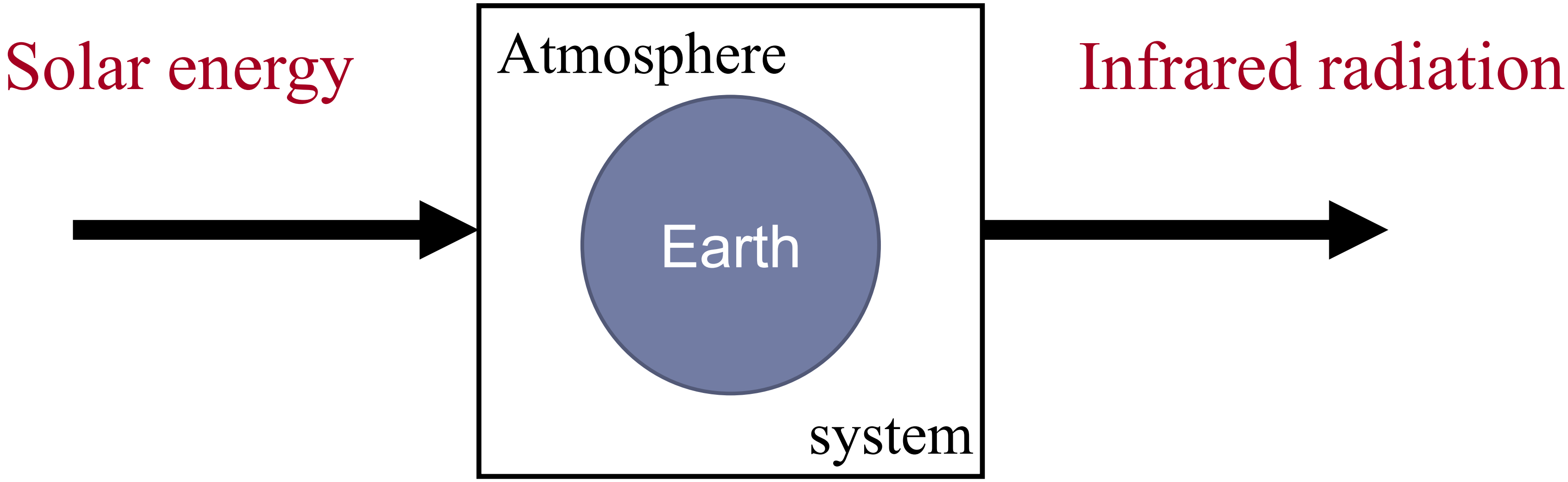
Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Energy Balance



Energy Balance

More energy in the system leads to warming



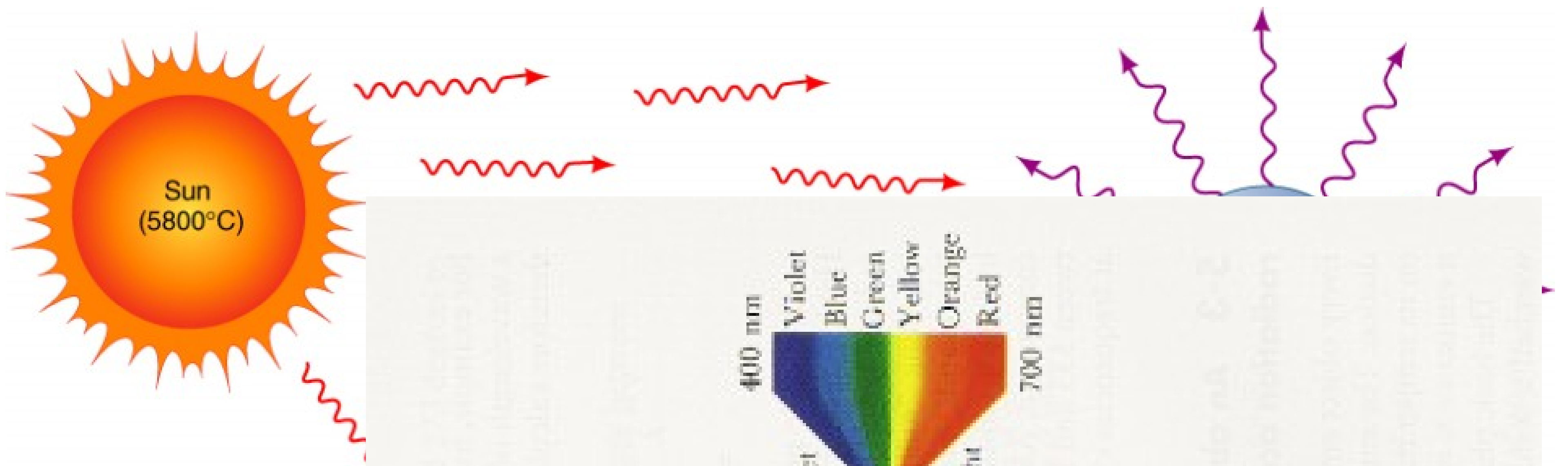
Energy In > Energy out

Not because E_{in} is $\uparrow$,
but because E_{out} is $\downarrow$

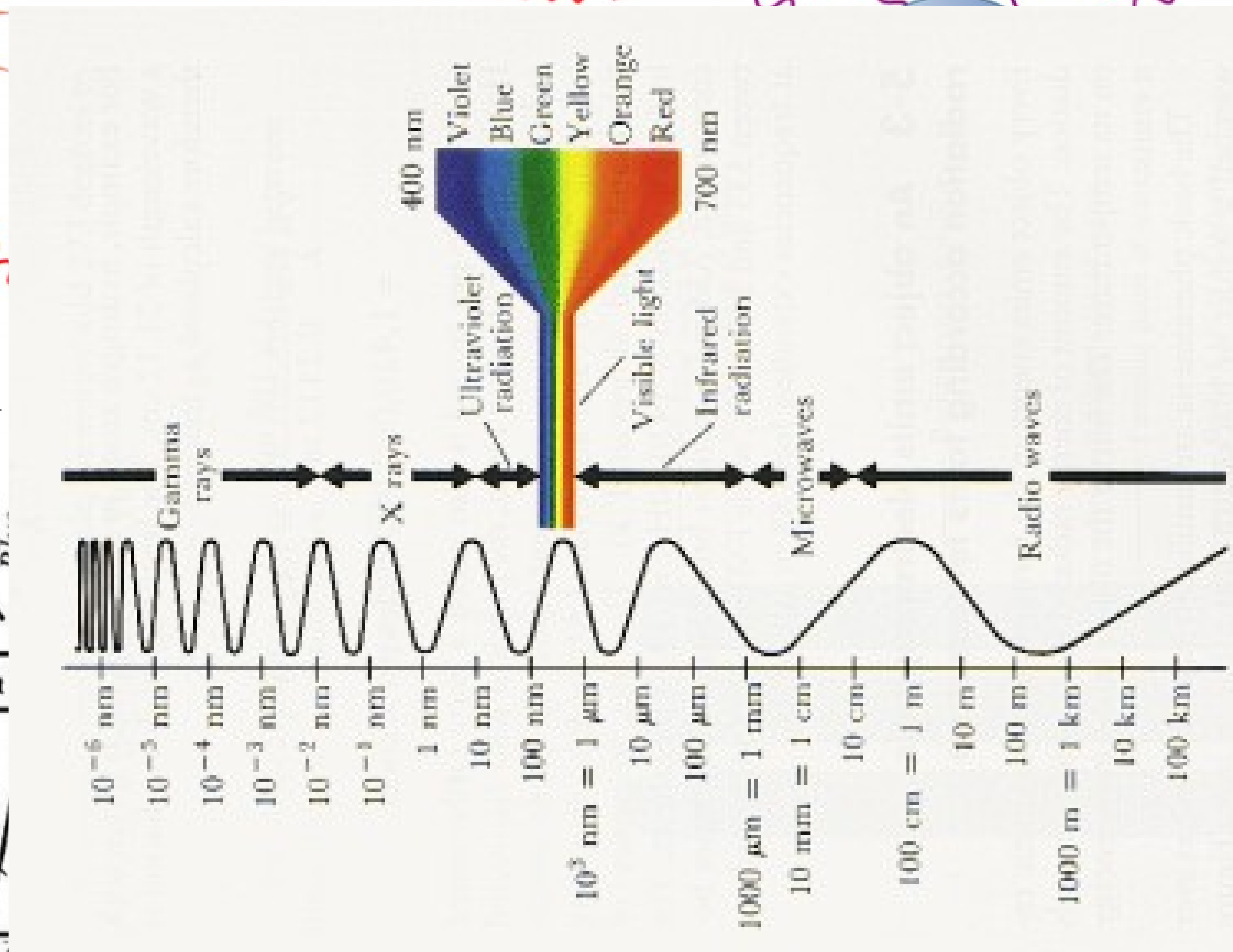
Atmosphere is thin layer encircling the earth – Troposphere ~10Km

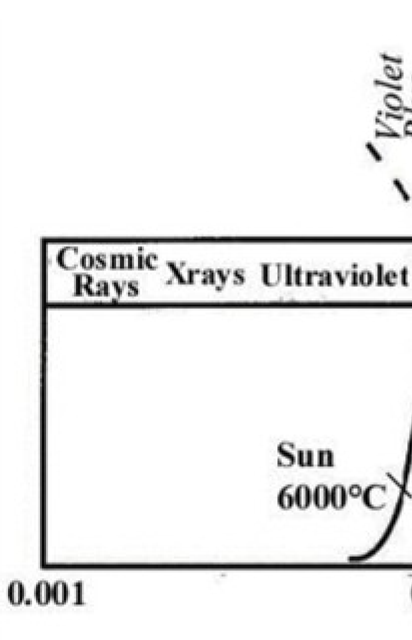
Three Climate Basics

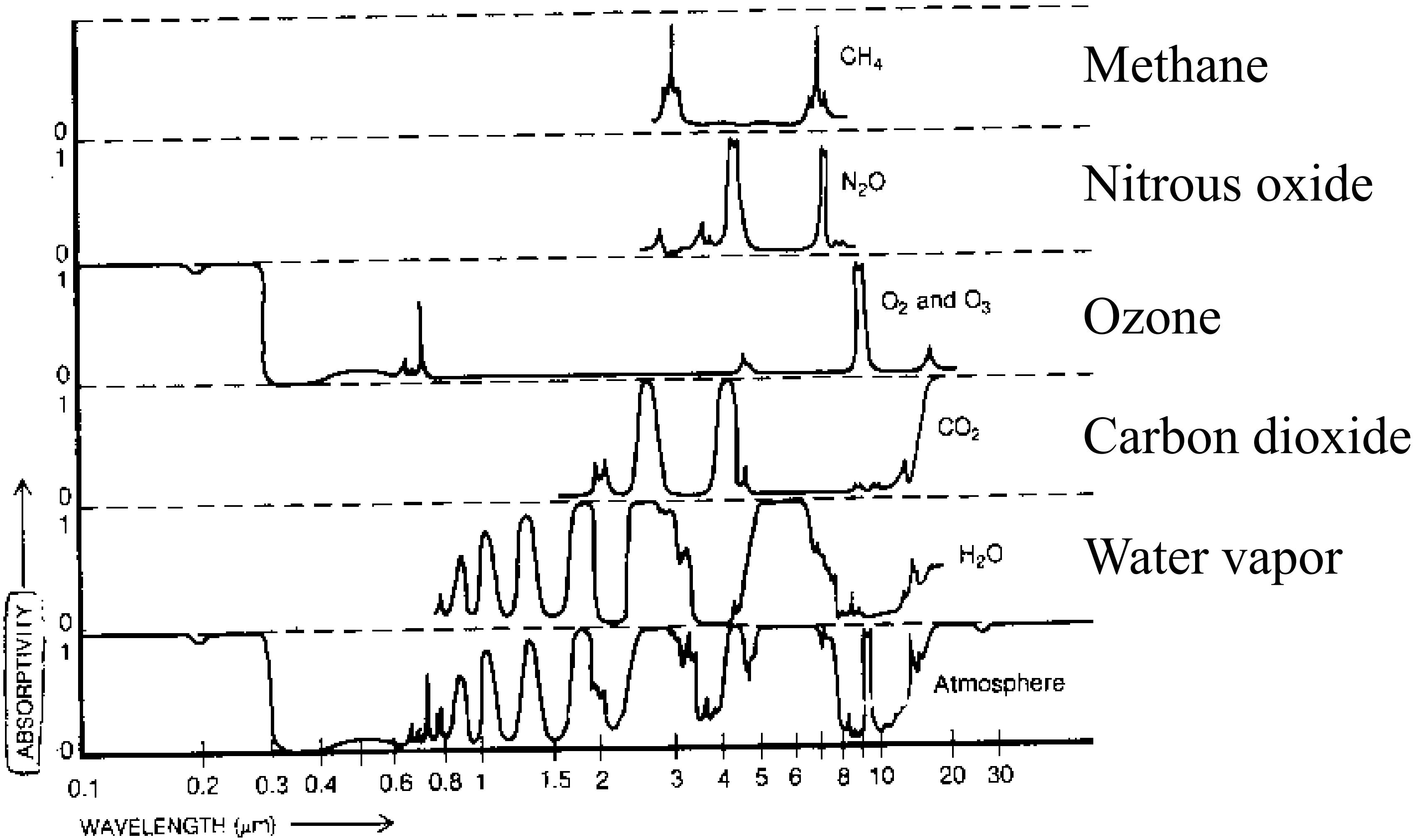
1) Earth and Sun are at different temperatures, therefore radiate energy at different wavelengths
   - Earth – long-wave – infrared radiation
   - Sun – short-wave – visible light radiation
2) Certain gases (GHG) in the atmosphere respond to energy at different wavelengths (passing short, absorbing long)
3) The concentration of greenhouse gases in the atmosphere is increasing



1) Earth and sun

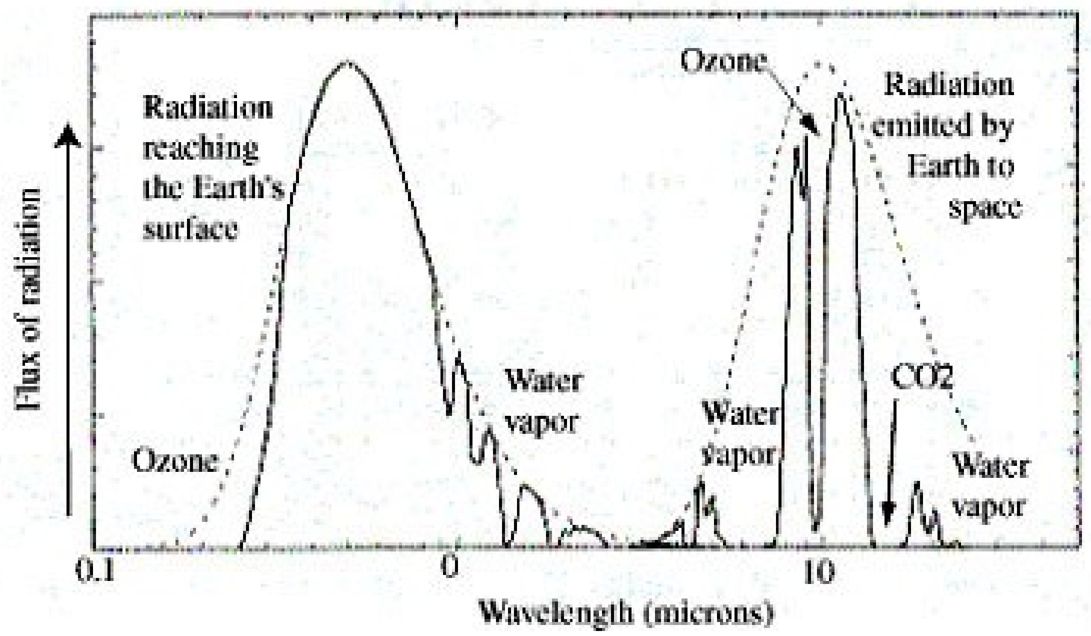




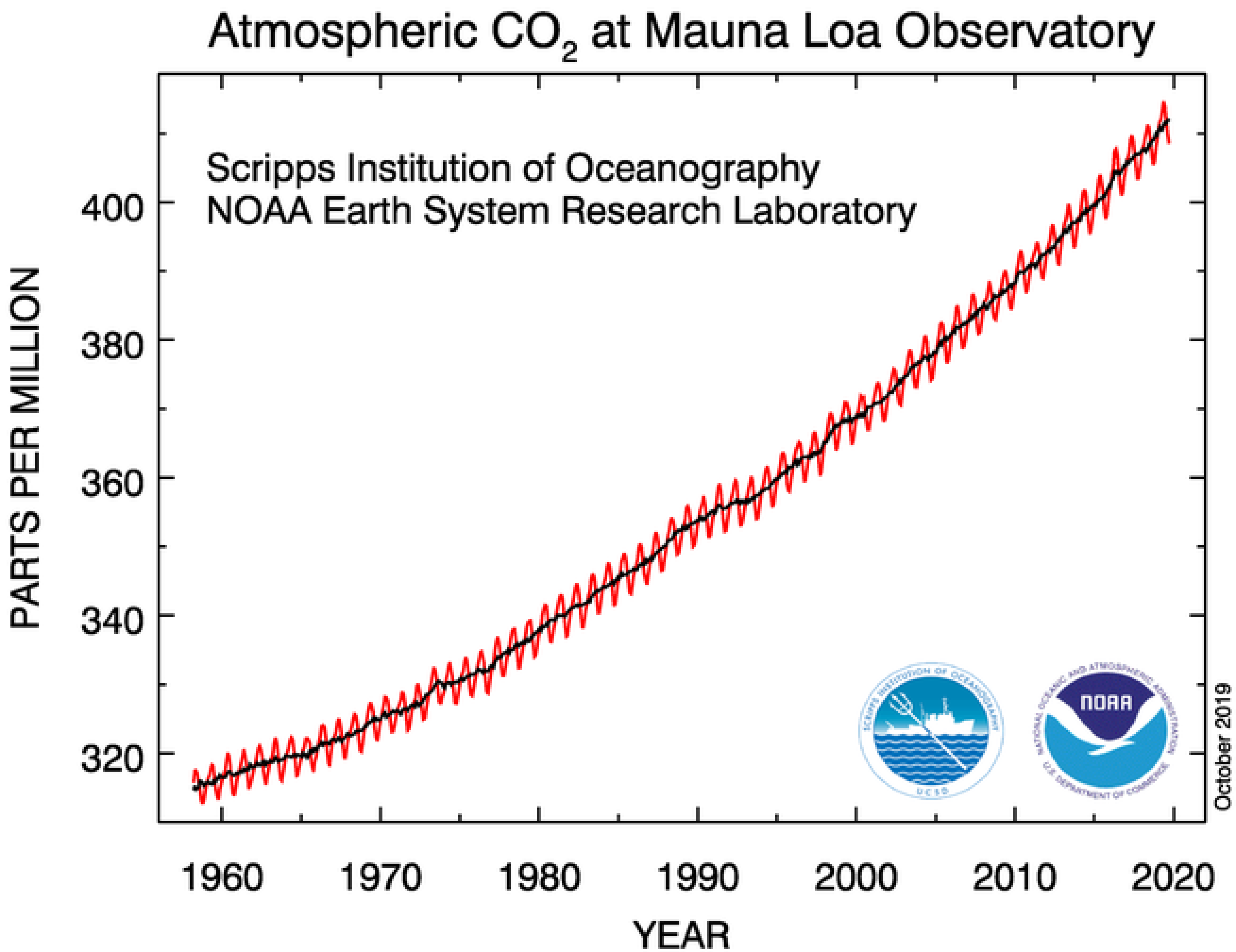


2) Certain gases in the atmosphere respond to energy at different wavelengths

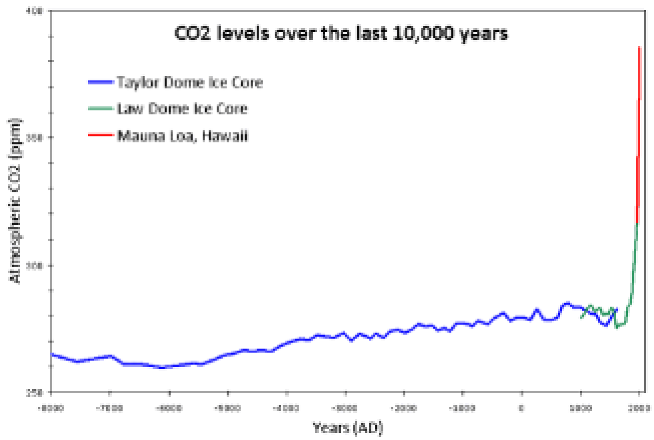
Carbon Dioxide Demonstration

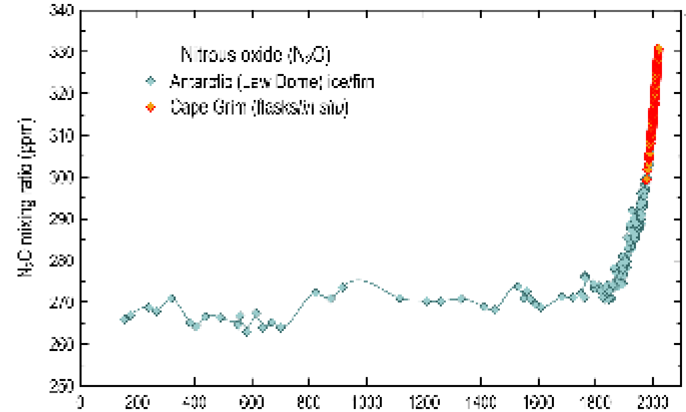


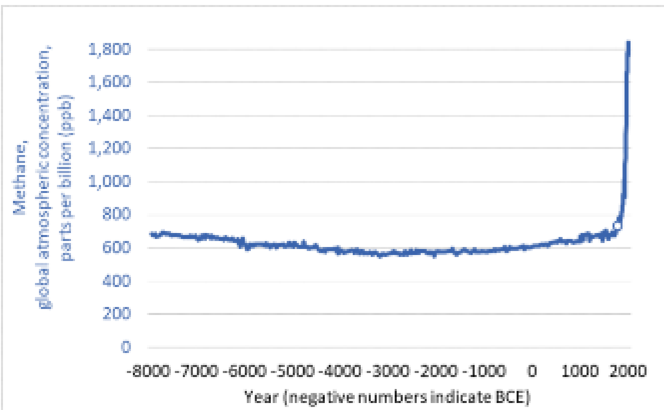
3) The concentration of greenhouse gases in the atmosphere is increasing

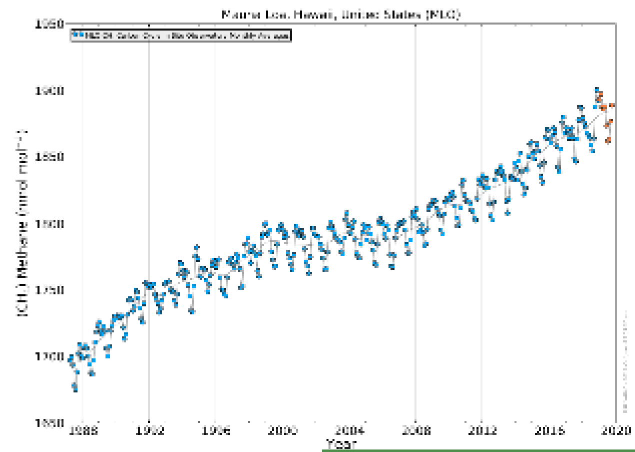


Carbon Dioxide increases measured in [Mauna Loa, Hawaii]



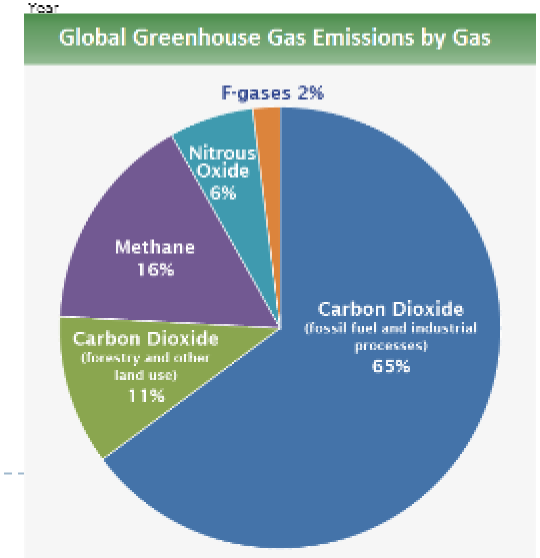






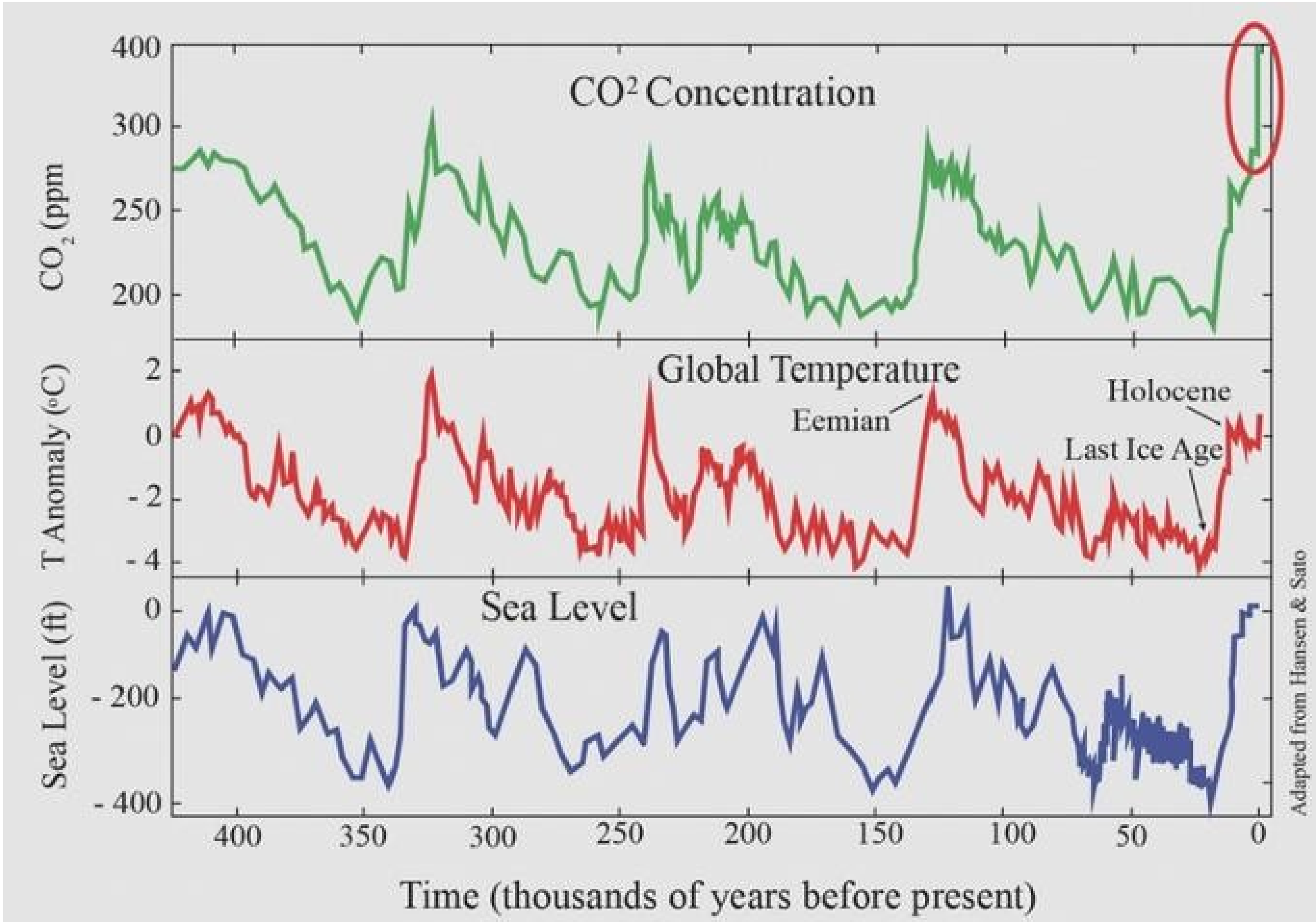
Four main anthropogenic GHGs:

1) Carbon Dioxide (CO_2) – 76%
2) Methane (CH_4) – 16%
3) Nitrous Oxide (N_2O) – 6%
4) F-gases – 2%



- Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride didn't exist pre-industrial

Correlation between CO_2 concentration, temp, and sea level over the past 400,000 years



CO_2 is now higher than at any time during that period

These facts together lead to the climate change observed

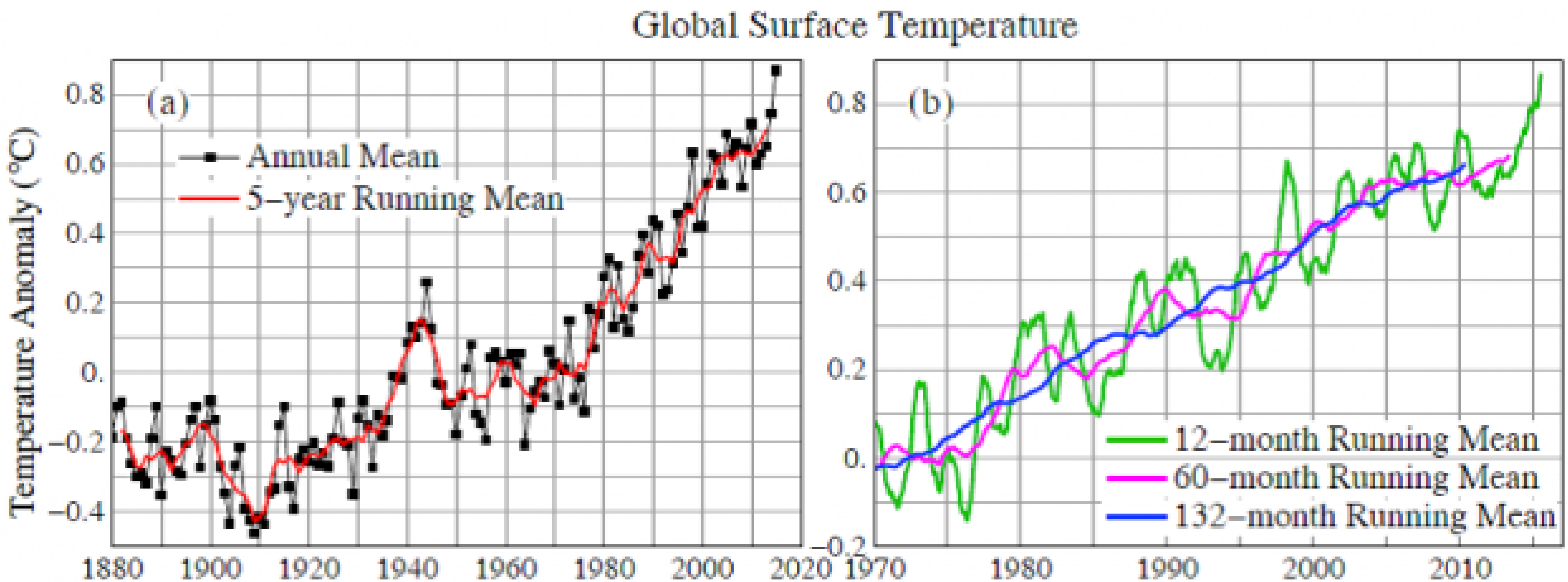
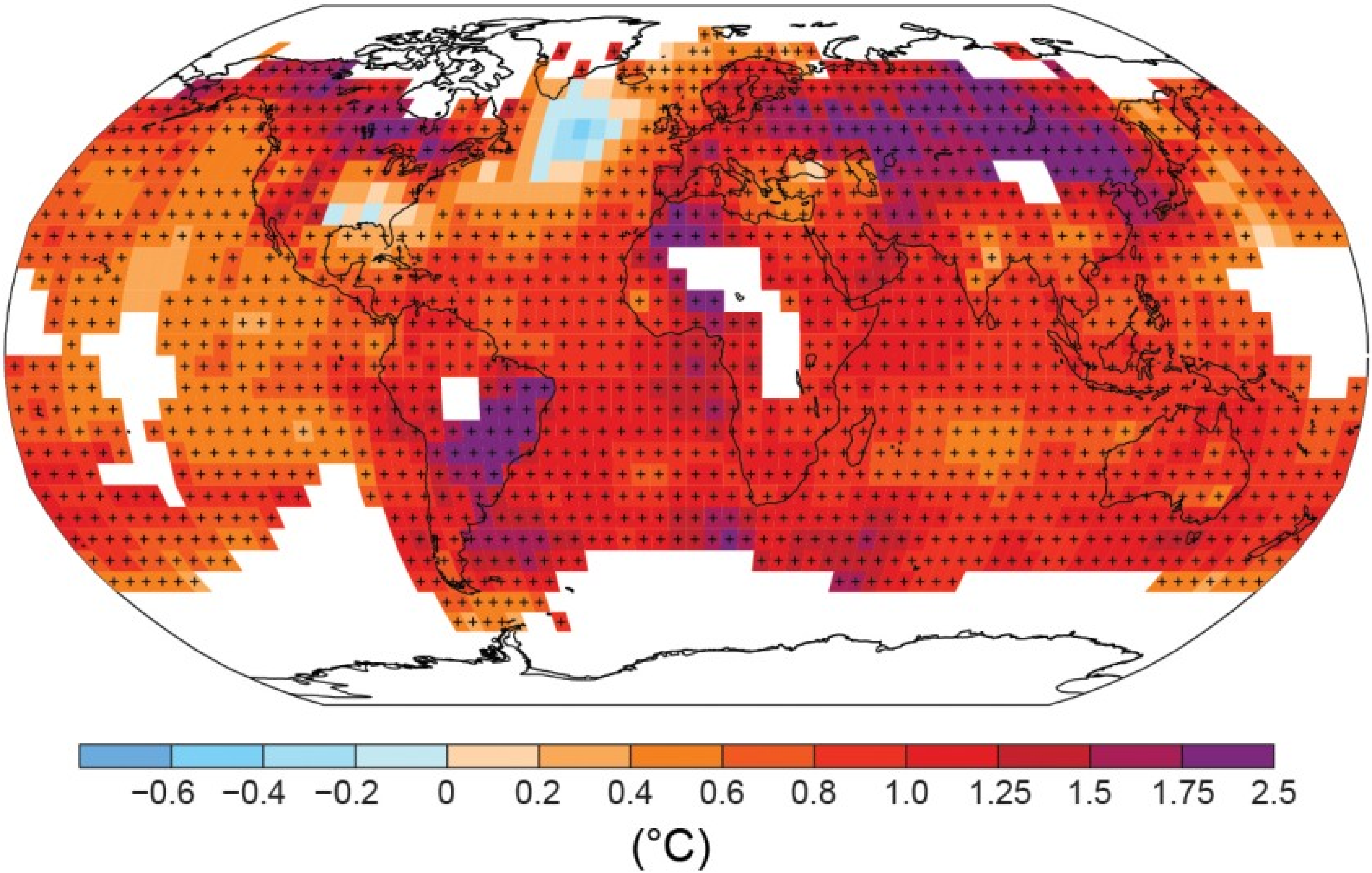
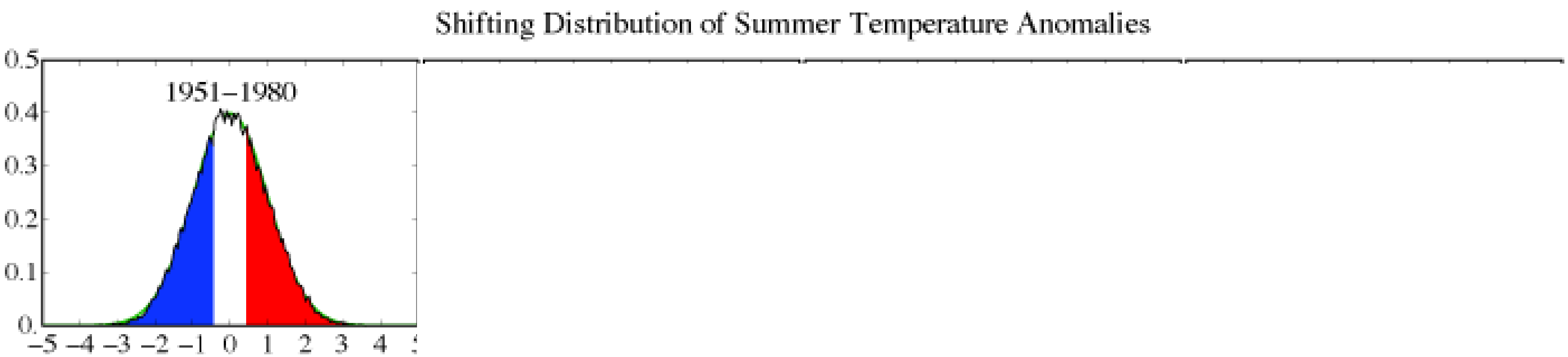
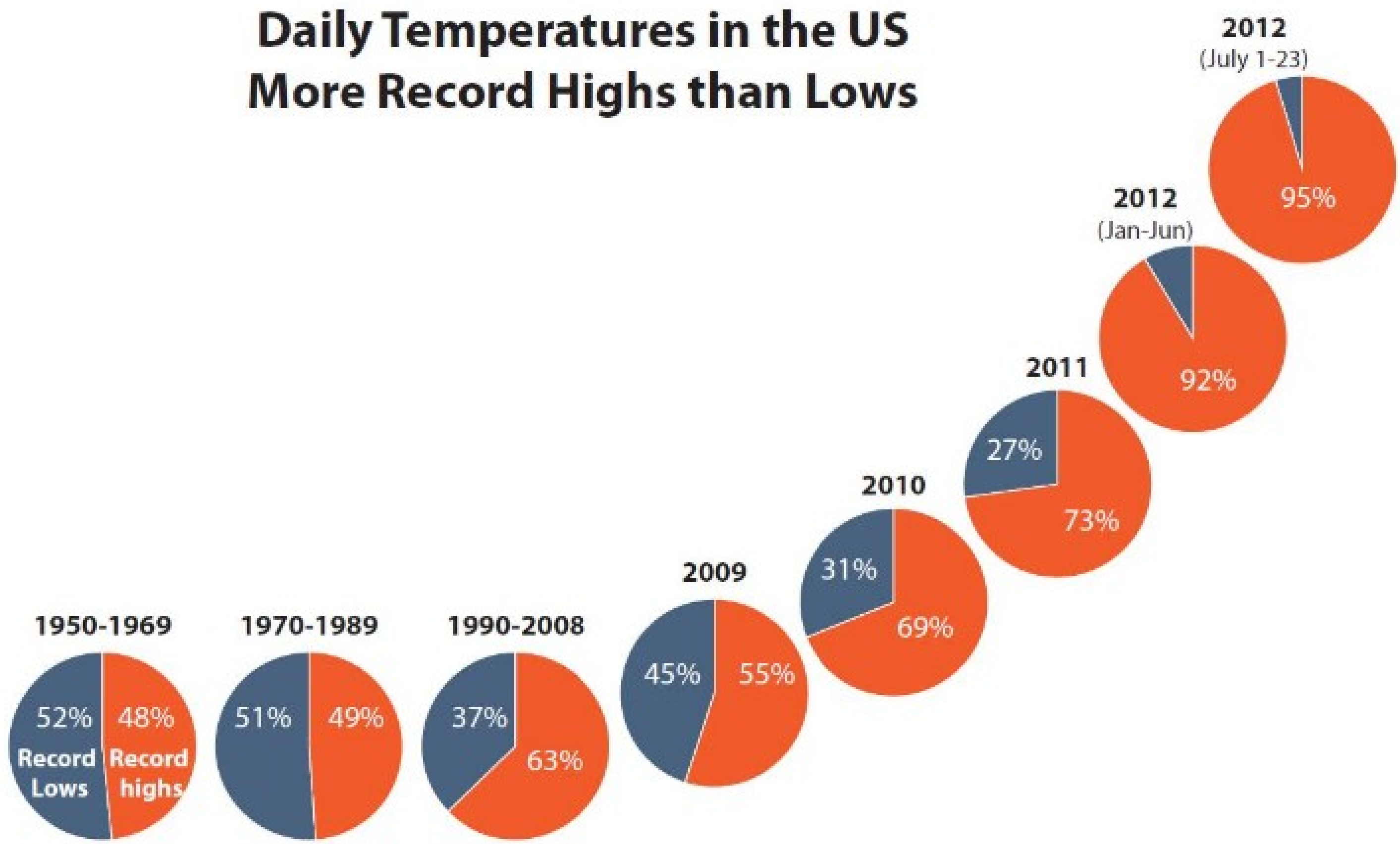


Figure SPM.1b
Observed change in surface temperature 1901-2012



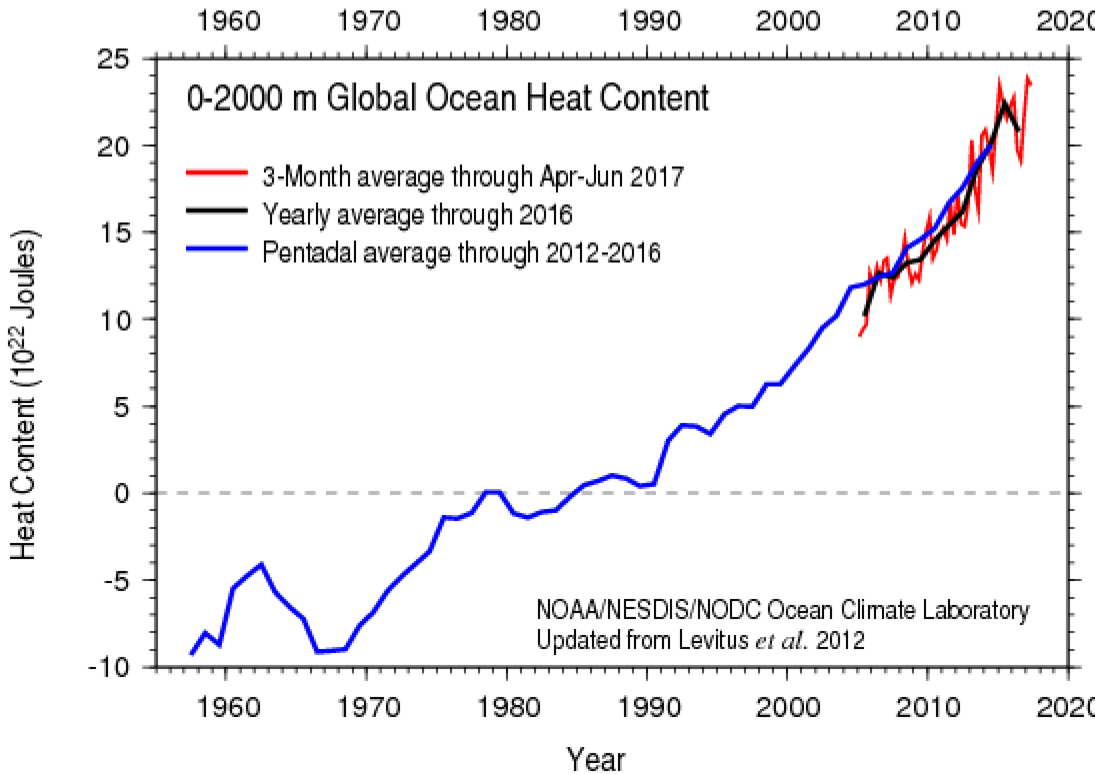
Extreme heat events are becoming more common





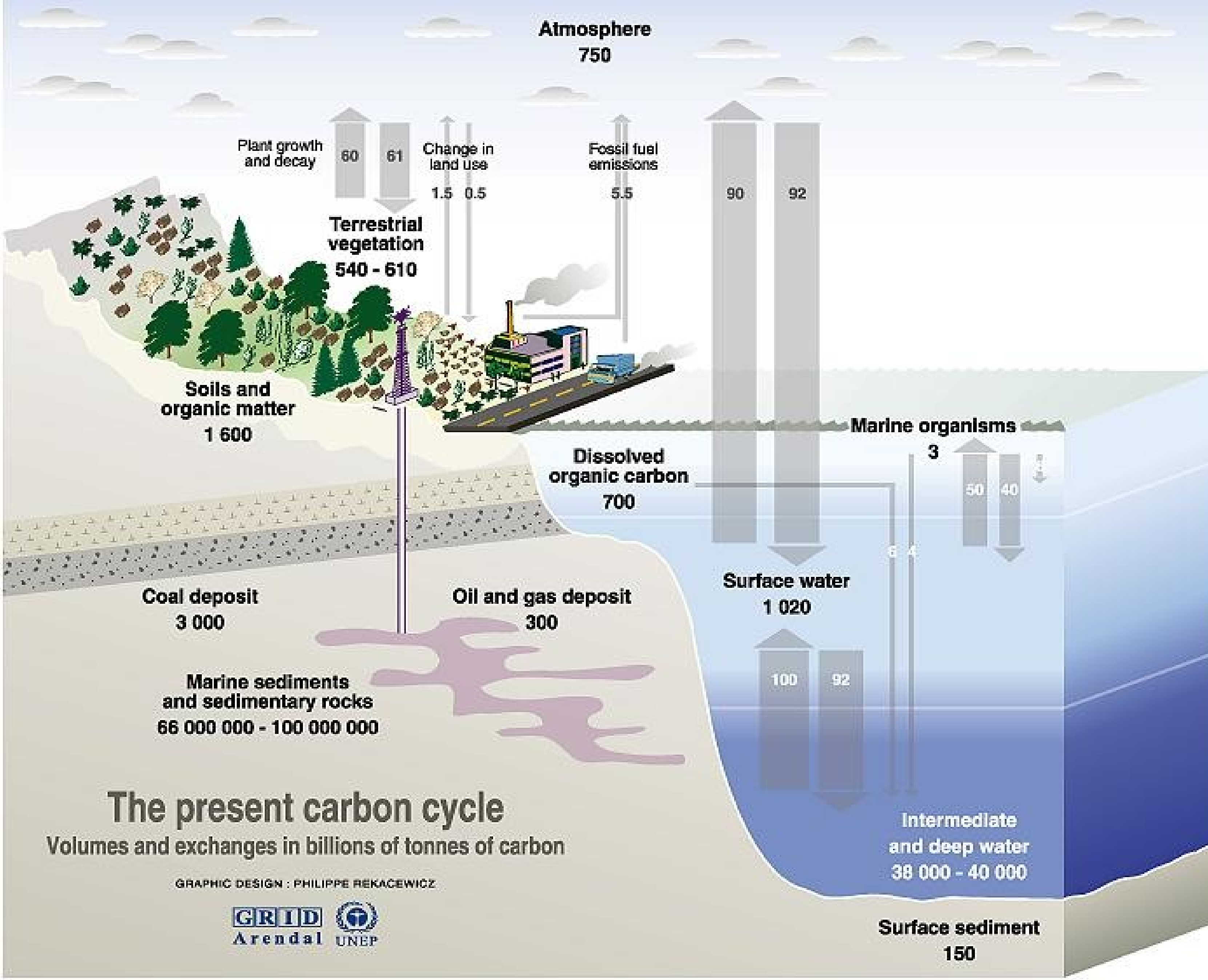
Daily Temperatures in the US
More Record Highs than Lows
1950-1969
52%
48%
Record Lows
Record highs
1970-1989
51%
49%
1990-2008
37%
63%
2009
45%
55%
2010
31%
69%
2011
27%
73%
2012
(Jan-Jun)
92%
2012
(July 1-23)
95%

Heat capacity of water is higher than that for air so most of the additional energy is going to heat the oceans (>90%)



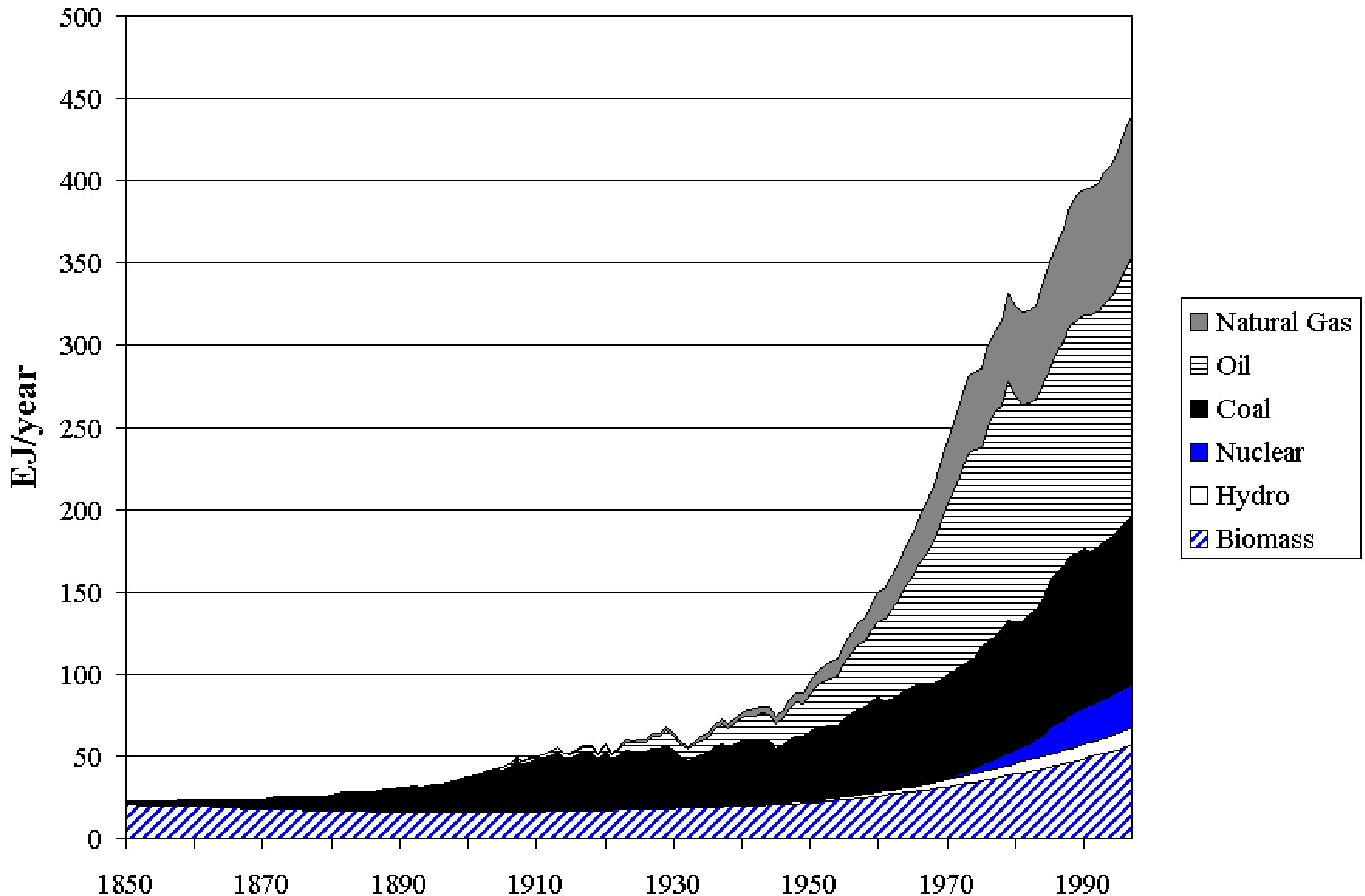
https://climate.nasa.gov/climate_resources/40/video-oceans-of-climate-change/

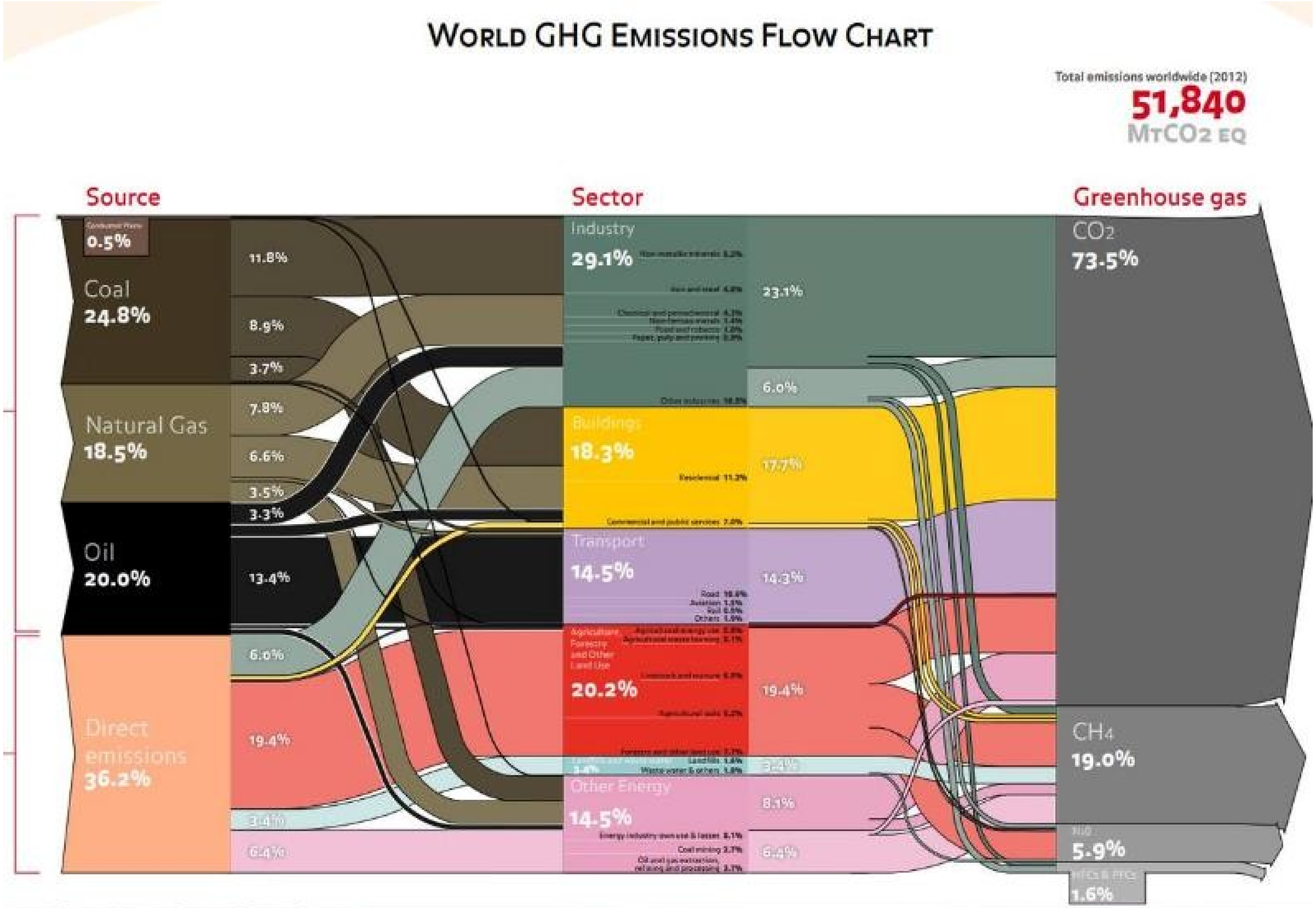
Is this human (anthropogenic) or natural?



Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

World Primary Energy Supply by Source, 1850-2000




World GHG Emissions Flow Chart
Total emissions worldwide (2012)
51,840
MtCO2 eq
Source
Sector
Greenhouse gas
0.5%
Coal
24.8%
Natural Gas
18.5%
Oil
20.0%
Direct emissions
36.2%
11.8%
8.9%
3.7%
7.8%
6.6%
3.5%
3.3%
13.4%
6.0%
19.4%
3.4%
6.4%
Industry
29.1%
Buildings
18.3%
Transport
14.5%
Agriculture, Forestry and Other Land Use
20.2%
3.4%
Other Energy
14.5%
23.1%
6.0%
17.7%
14.3%
19.4%
3.4%
8.1%
6.4%
CO2
73.5%
CH4
19.0%
N2O
5.9%
HFCs & PFCs
1.6%

Which country emits the most CO_2 in 2017?

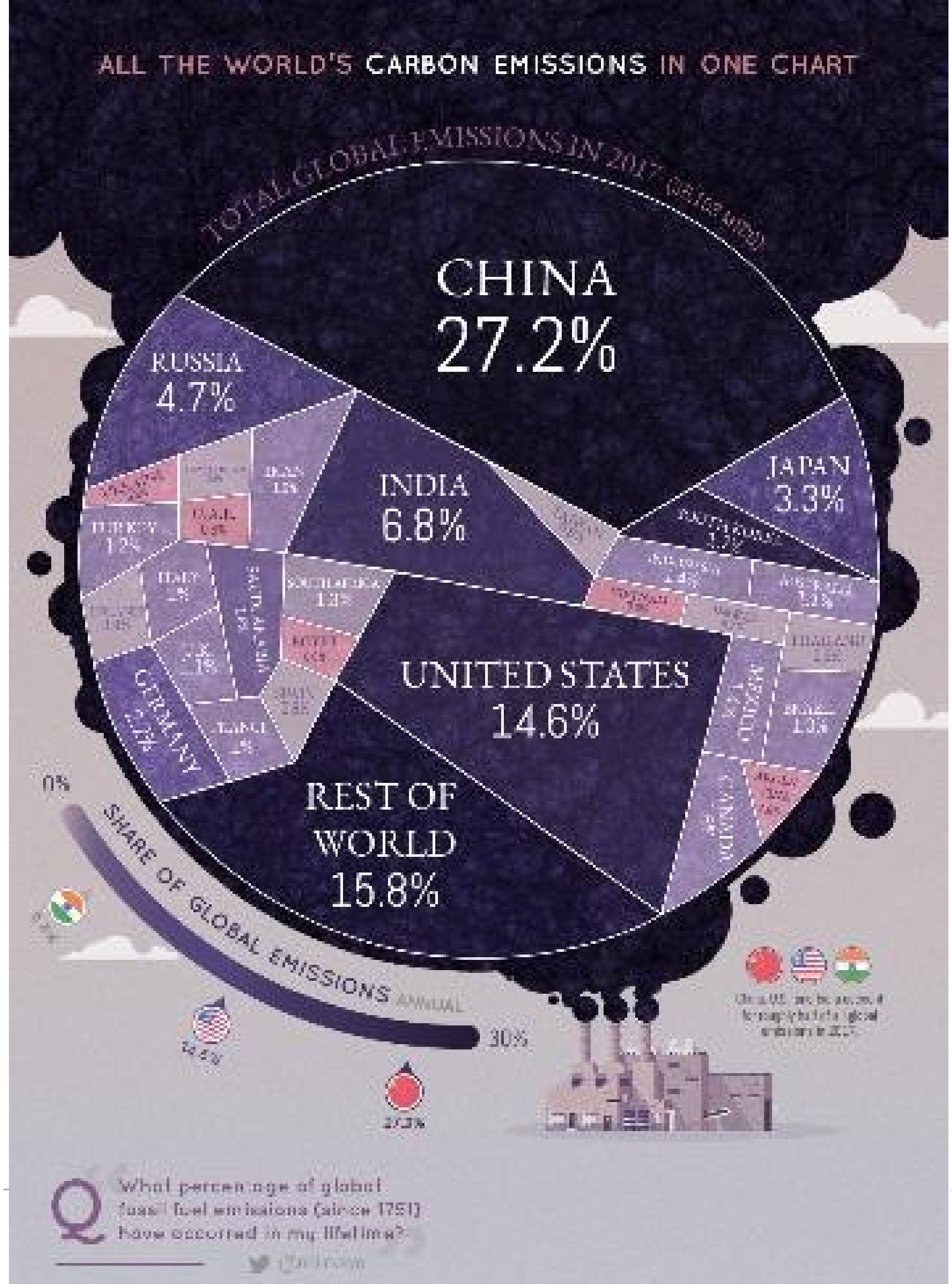
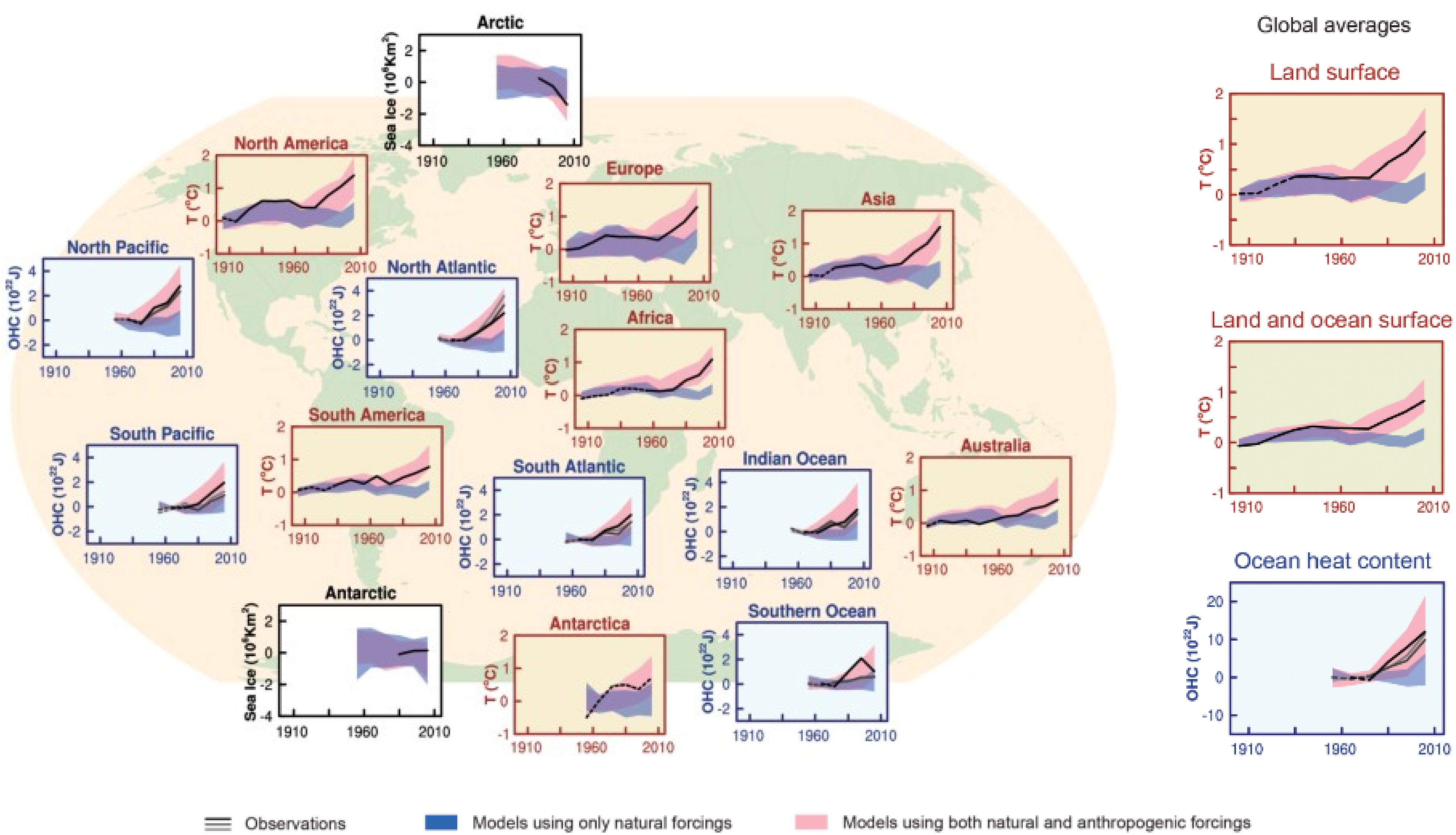


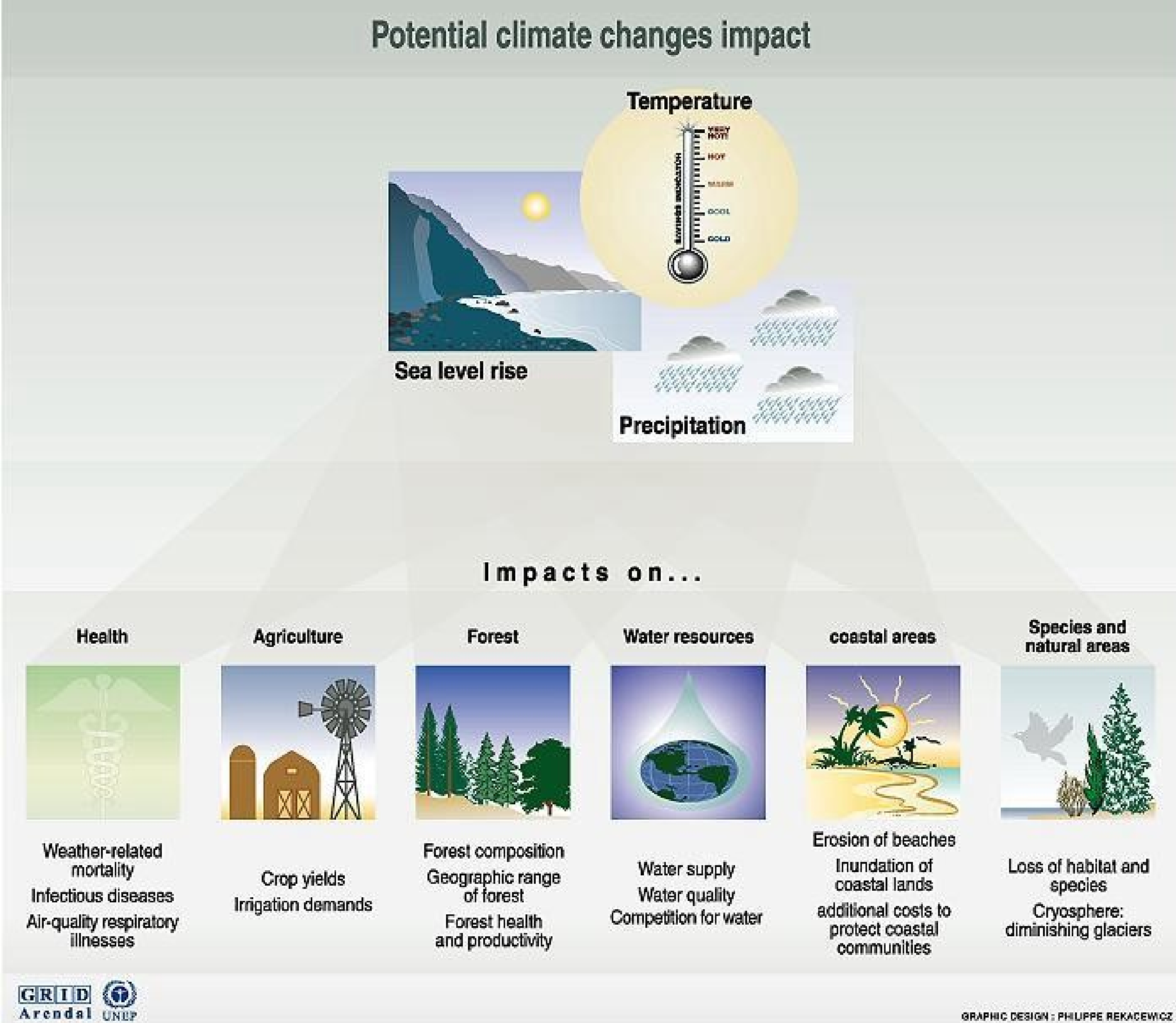
Figure SPM.6

Comparison of observed and simulated climate change



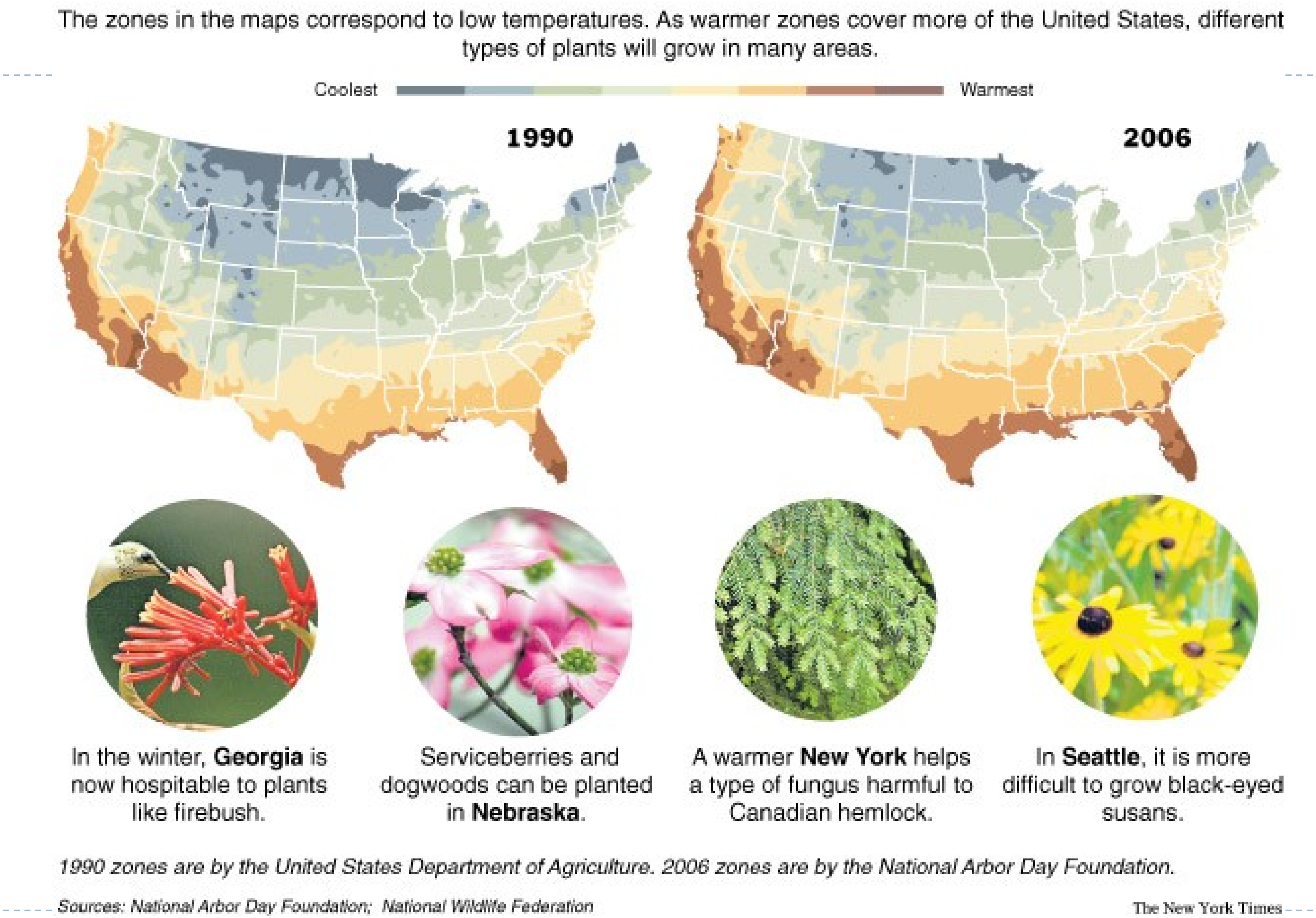
Computer models match observed ΔT on all continents

WHAT DOES ALL THIS MEAN?



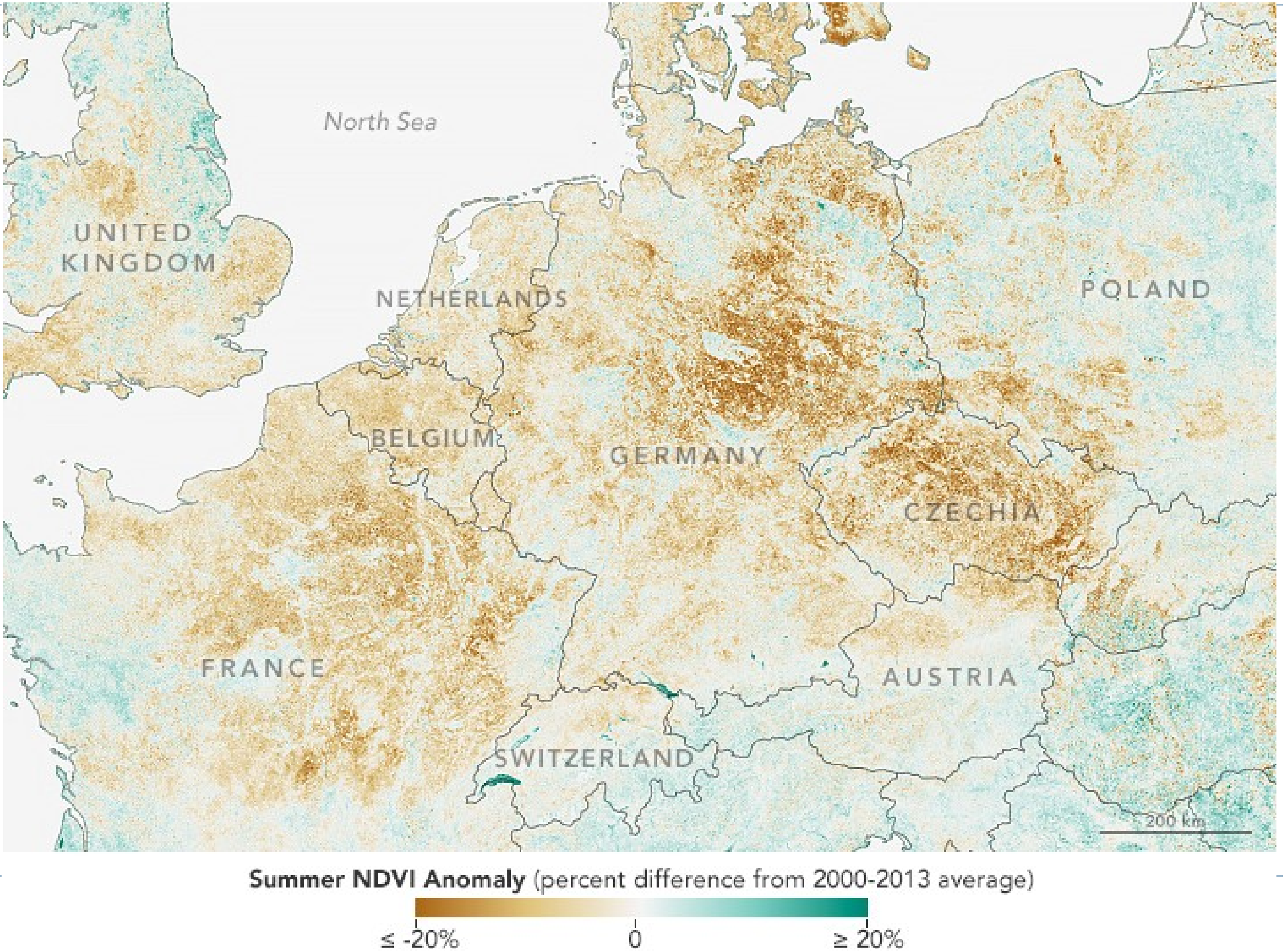
Source: United States environmental protection agency (EPA).

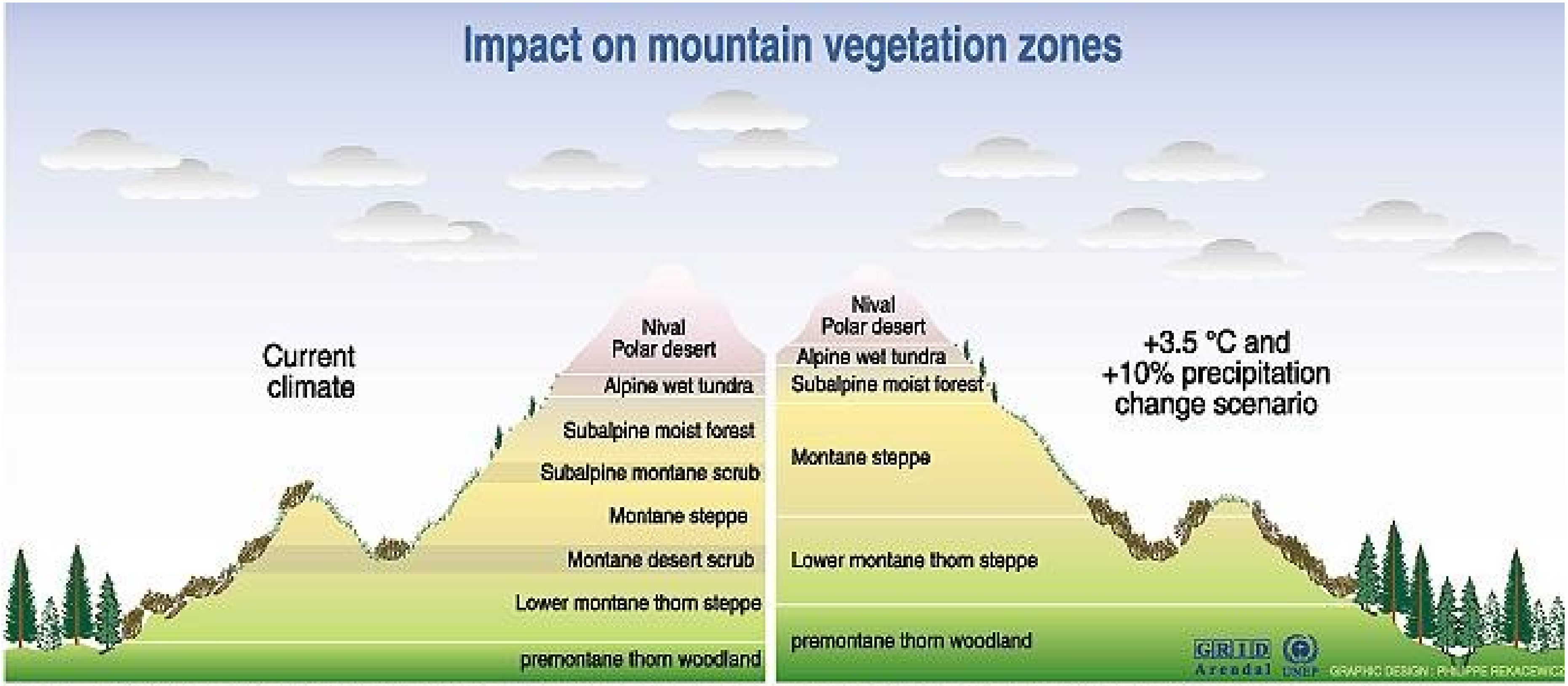
From: Feeling Warmth, Subtropical Plants Move North



Source: New York Times, May 3, 2007

Impact of 2018 heat wave on vegetation





Sources: Martin Beniston, Mountain environments in changing climates, Routledge, London, 1994; Climate change 1995, Impacts, adaptations and migration of climate change, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change (IPCC), UNEP and WMO, Cambridge press university, 1996.

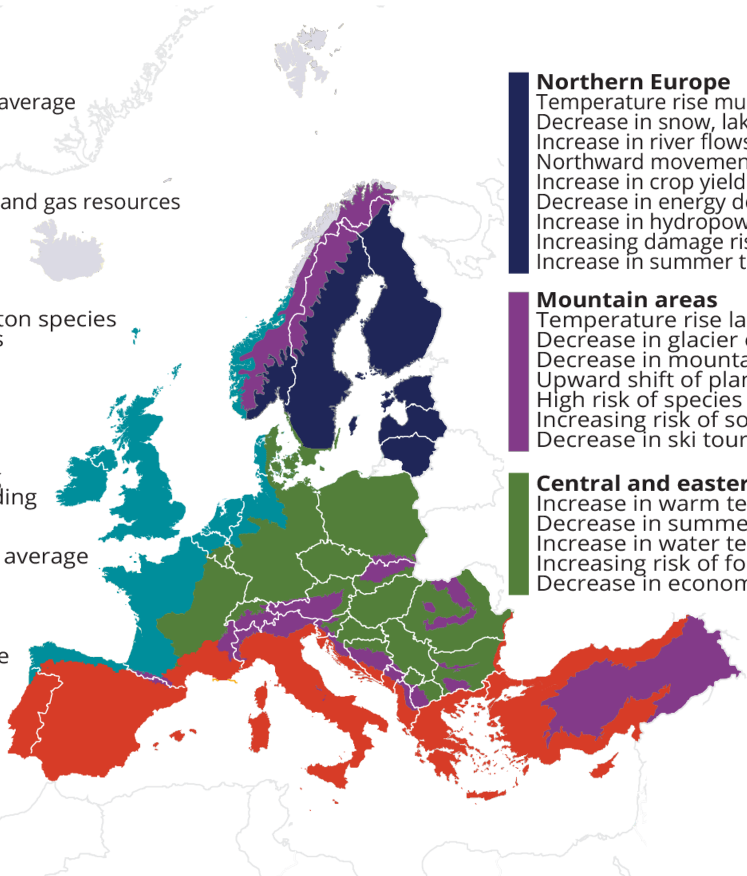
Climate change impacts on Europe

Arctic
Temperature rise much larger than global average
Decrease in Arctic sea ice coverage
Decrease in Greenland ice sheet
Decrease in permafrost areas
Increasing risk of biodiversity loss
Intensified shipping and exploitation of oil and gas resources

Coastal zones and regional seas
Sea-level rise
Increase in sea surface temperatures
Increase in ocean acidity
Northward expansion of fish and plankton species
Changes in phytoplankton communities
Increasing risk for fish stocks

North-western Europe
Increase in winter precipitation
Increase in river flow
Northward movement of species
Decrease in energy demand for heating
Increasing risk of river and coastal flooding

Mediterranean region
Temperature rise larger than European average
Decrease in annual precipitation
Decrease in annual river flow
Increasing risk of biodiversity loss
Increasing risk of desertification
Increasing water demand for agriculture
Decrease in crop yields
Increasing risk of forest fire
Increase in mortality from heat waves
Expansion of habitats for southern disease vectors
Decrease in hydropower potential
Decrease in summer tourism and potential increase in other seasons



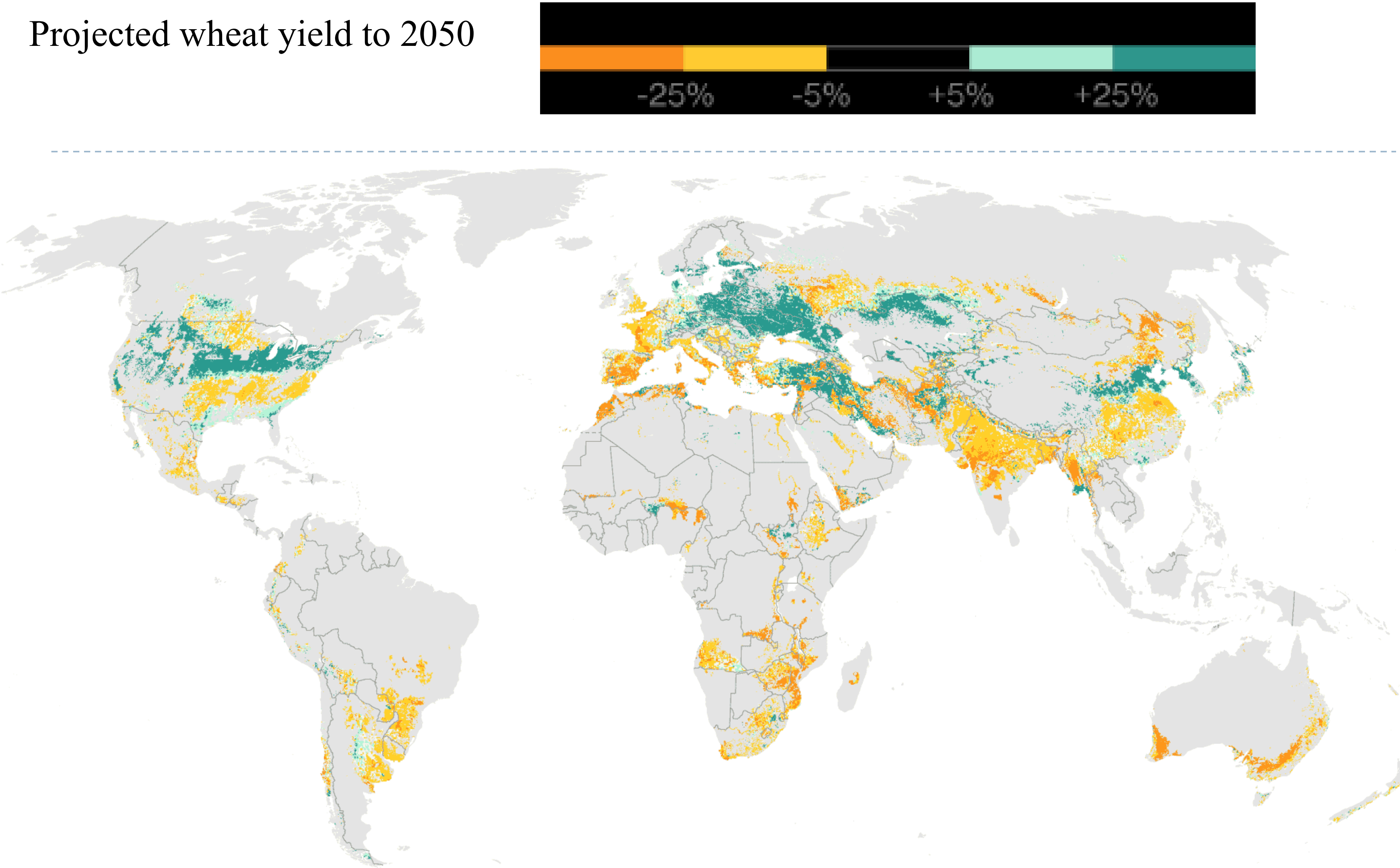
Northern Europe
Temperature rise much larger than global average
Decrease in snow, lake and river ice cover
Increase in river flows
Northward movement of species
Increase in crop yields
Decrease in energy demand for heating
Increase in hydropower potential
Increasing damage risk from winter storms
Increase in summer tourism

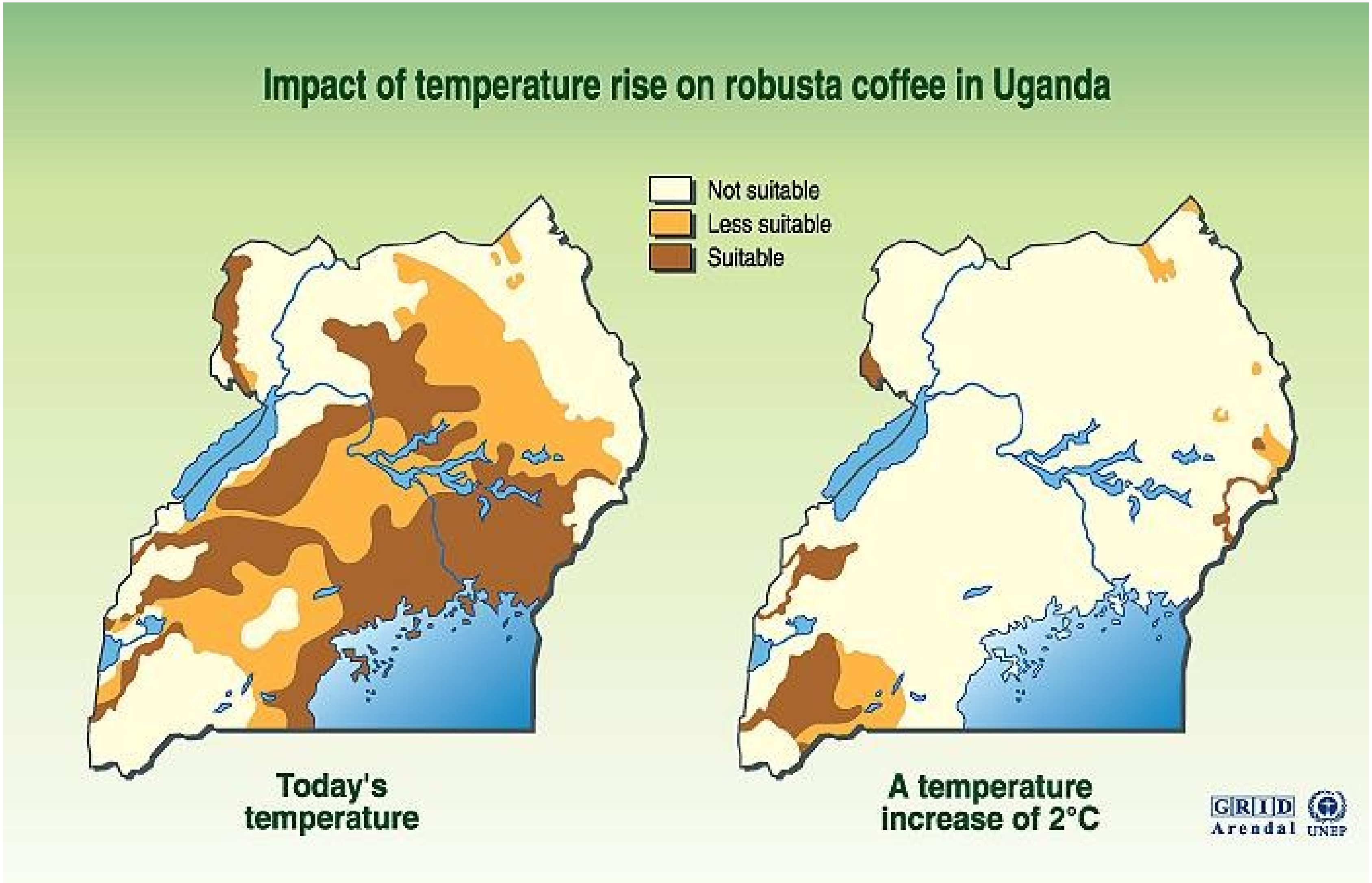
Mountain areas
Temperature rise larger than European average
Decrease in glacier extent and volume
Decrease in mountain permafrost areas
Upward shift of plant and animal species
High risk of species extinction in Alpine regions
Increasing risk of soil erosion
Decrease in ski tourism

Central and eastern Europe
Increase in warm temperature extremes
Decrease in summer precipitation
Increase in water temperature
Increasing risk of forest fire
Decrease in economic value of forests

European Environment Agency

Projected wheat yield to 2050





Source: Otto Simonett, Potential impacts of global warming, GRID-Geneva, case studies on climatic change. Geneva, 1989.

Vliv klimatických změn na možnosti pěstování cukrové řepy v České republice

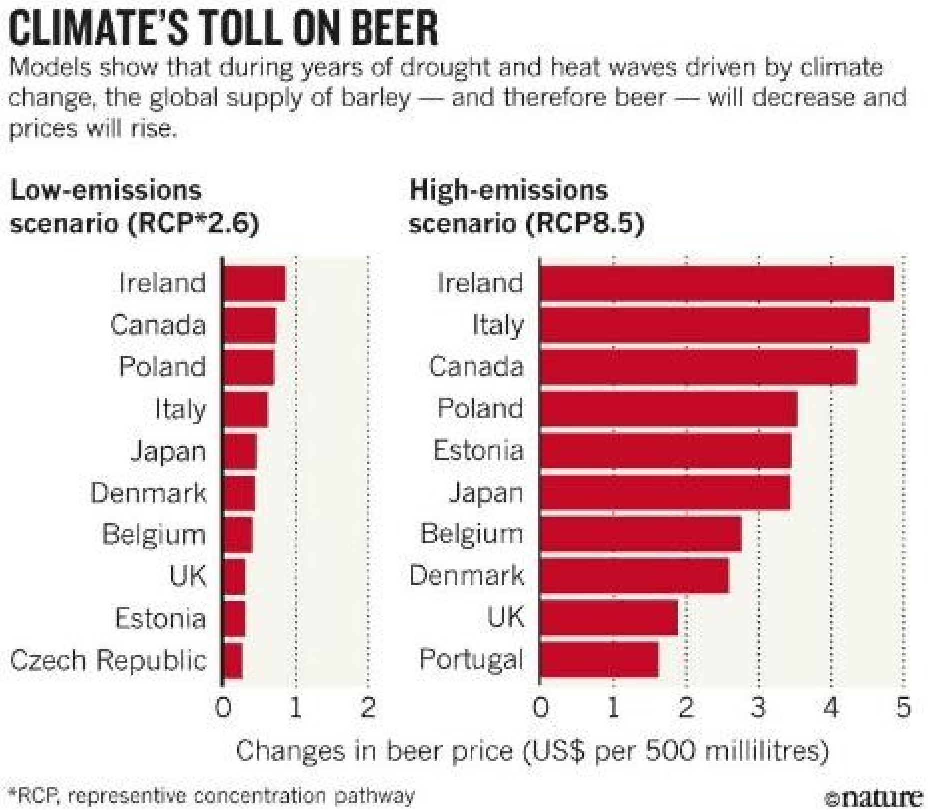
THE IMPACT OF CLIMATE CHANGES ON SUGAR BEET GROWING CONDITIONS IN THE CZECH REPUBLIC

Veronika Kopecká[1], Ivo Machar[2], Antonín Buček[3], Alois Kopecký[4]
[1]ČVUT Praha, [2]Univerzita Palackého Olomouc, [3]Mendelova univerzita Brno, [4]Ministerstvo místního rozvoje ČR

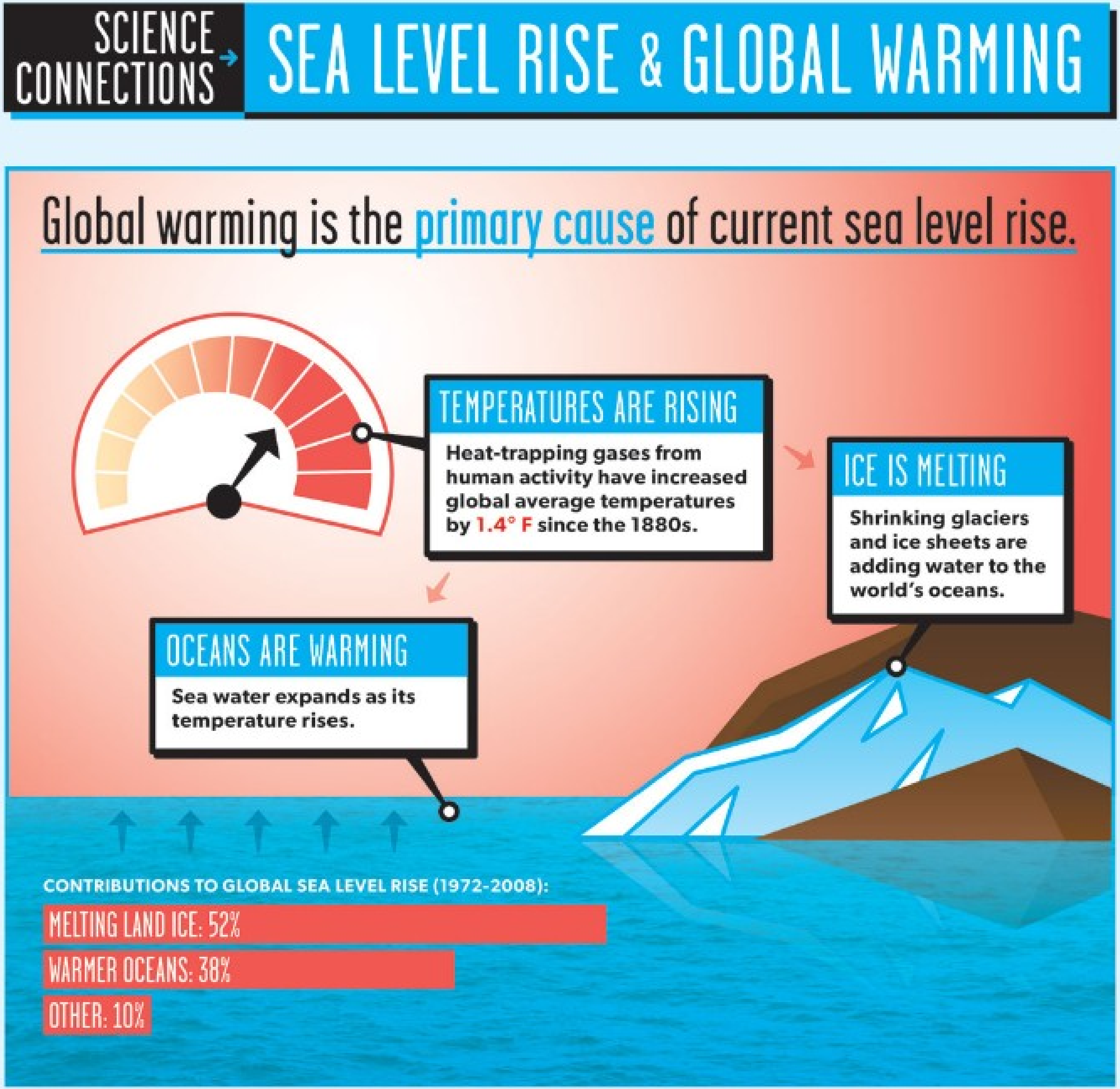
Rostoucí trendy globální teploty jsou nezpochybnitelné (1), i když se mezi odborníky obsáhle diskutuje o významu lidských aktivit při objektivně monitorovaném nárůstu skleníkových plynů v atmosféře (2). V Evropě existuje velmi hustá síť dlouhodobě měřících stanic s řadou systémů doplňujících distančních měření, proto jsou v Evropě analýzy trendů teplot mnohem přesnější než kdekoliv jinde ve světě. Teplota evropského kontinentu se během minulého století zvýšila v průměru o 1,2 °C, přičemž trend nárůstu se za posledních 20 let zvýšil dvojnásobně. Průměrné počty letních dnů v Evropě se během 20. století zdvojnásobily, počty tropických dnů se ztrojnásobily. To má samozřejmě významné důsledky pro evropské zemědělství a lesnictví (3). Trendy dlouhodobých meteorologických měření na území České republiky ukazují kromě růstu průměrných teplot i výrazný vzrůst výskytu externalit počasí – počty tropických a letních dnů i nocí narůstají a počty mrazových a ledových dnů klesají. Lineární trendy územních teplotních a srážkových úhrnů v ČR (tedy modifikované hodnoty

Pro hodnocení vlivů možných klimatických změn na růstové podmínky zemědělských plodin jsou vhodným prostorovým rámcem vegetační stupně (6). Vegetační stupně byly v ČR vymezeny metodou bioindikace a jsou detailně definovány v charakteristikách nadstavbových jednotek geobiocenologické typologie krajiny (7). Rozložení vegetačních stupňů v krajině odráží charakter orograficky podmíněných rozdílů klimatických podmínek a jejich gradientů. Klimatické změny se projevují pozvolným posunem vegetačních stupňů do vyšších nadmořských výšek, tedy změnou celkové vegetační stupňovitosti krajiny.

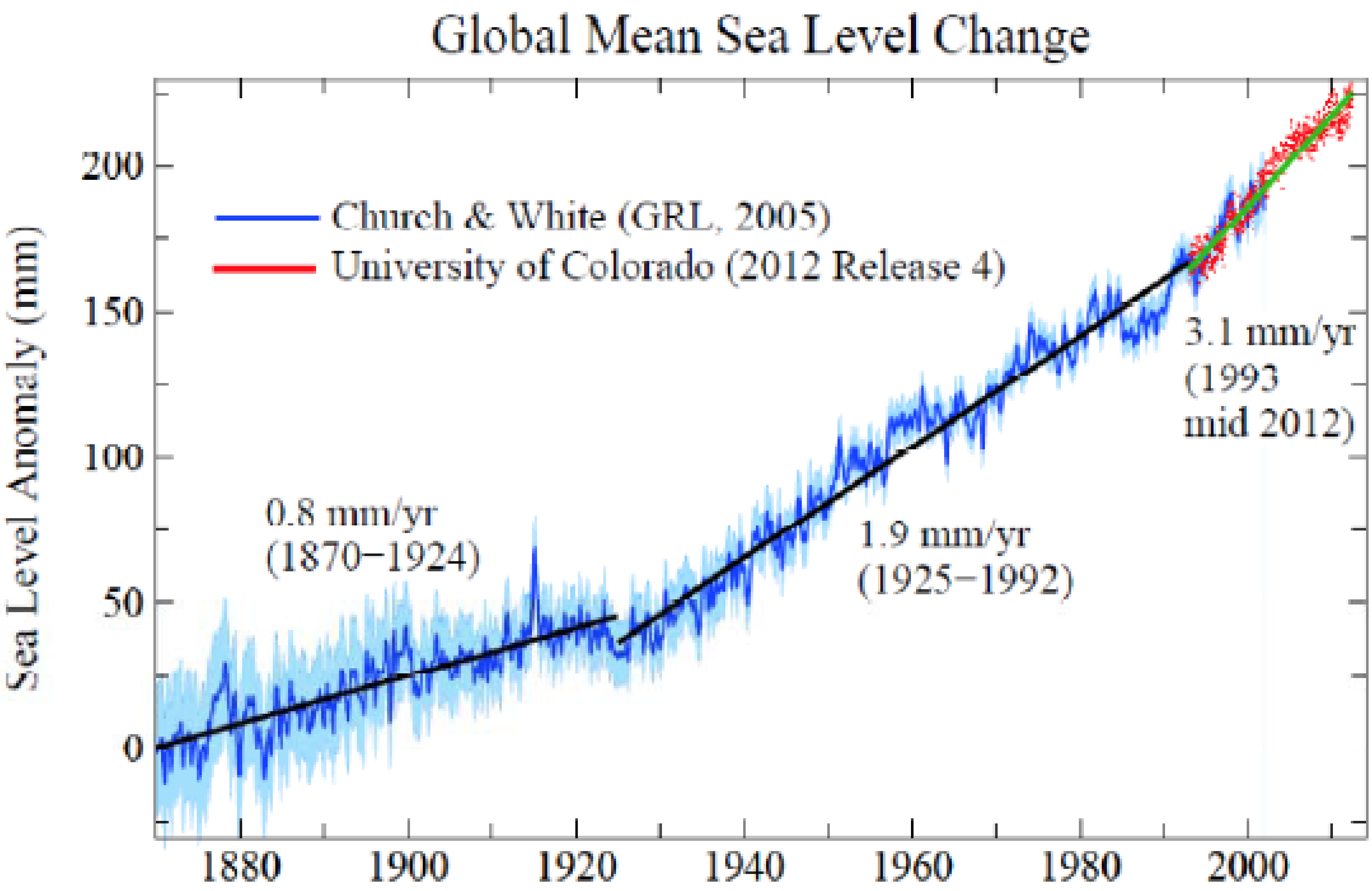
Na základě geobiocenologické typizace krajiny byl na třech českých univerzitách a ve spolupráci s Českým hydrometeorologickým ústavem vyvinut matematický model predikce změn vegetačních stupňů v závislosti na klimatických změnách (8). Článek prezentuje aplikaci tohoto modelu při predikci vlivů klimatických změn na budoucí podmínky pro pěstování cukrové řepy v ČR. Cílem článku je přispět k diskusím o budoucnosti


CLIMATE'S TOLL ON BEER
Models show that during years of drought and heat waves driven by climate change, the global supply of barley — and therefore beer — will decrease and prices will rise.
Low-emissions scenario (RCP*2.6)
High-emissions scenario (RCP8.5)
Ireland
Canada
Poland
Italy
Japan
Denmark
Belgium
UK
Estonia
Czech Republic
Ireland
Italy
Canada
Poland
Estonia
Japan
Belgium
Denmark
UK
Portugal
0
1
2
0
1
2
3
4
5
Changes in beer price (US$ per 500 millilitres)
*RCP, representive concentration pathway
©nature


TROUBLE BREWING
Climate Change Impacts on Beer
BARLEY
Susceptible to heat and drought
More profitable crops may displace barley
Drought affects starch suitability for brewing
CLIMATE CENTRAL



SCIENCE CONNECTIONS
SEA LEVEL RISE & GLOBAL WARMING
Global warming is the primary cause of current sea level rise.
TEMPERATURES ARE RISING
Heat-trapping gases from human activity have increased global average temperatures by 1.4° F since the 1880s.
ICE IS MELTING
Shrinking glaciers and ice sheets are adding water to the world's oceans.
OCEANS ARE WARMING
Sea water expands as its temperature rises.
CONTRIBUTIONS TO GLOBAL SEA LEVEL RISE (1972-2008):
MELTING LAND ICE: 52%
WARMER OCEANS: 38%
OTHER: 10%


Global Mean Sea Level Change
Church & White (GRL, 2005)
University of Colorado (2012 Release 4)
Sea Level Anomaly (mm)
0
50
100
150
200
1880
1900
1920
1940
1960
1980
2000
0.8 mm/yr
(1870–1924)
1.9 mm/yr
(1925–1992)
3.1 mm/yr
(1993
mid 2012)

Potential impact of sea level rise: Nile Delta

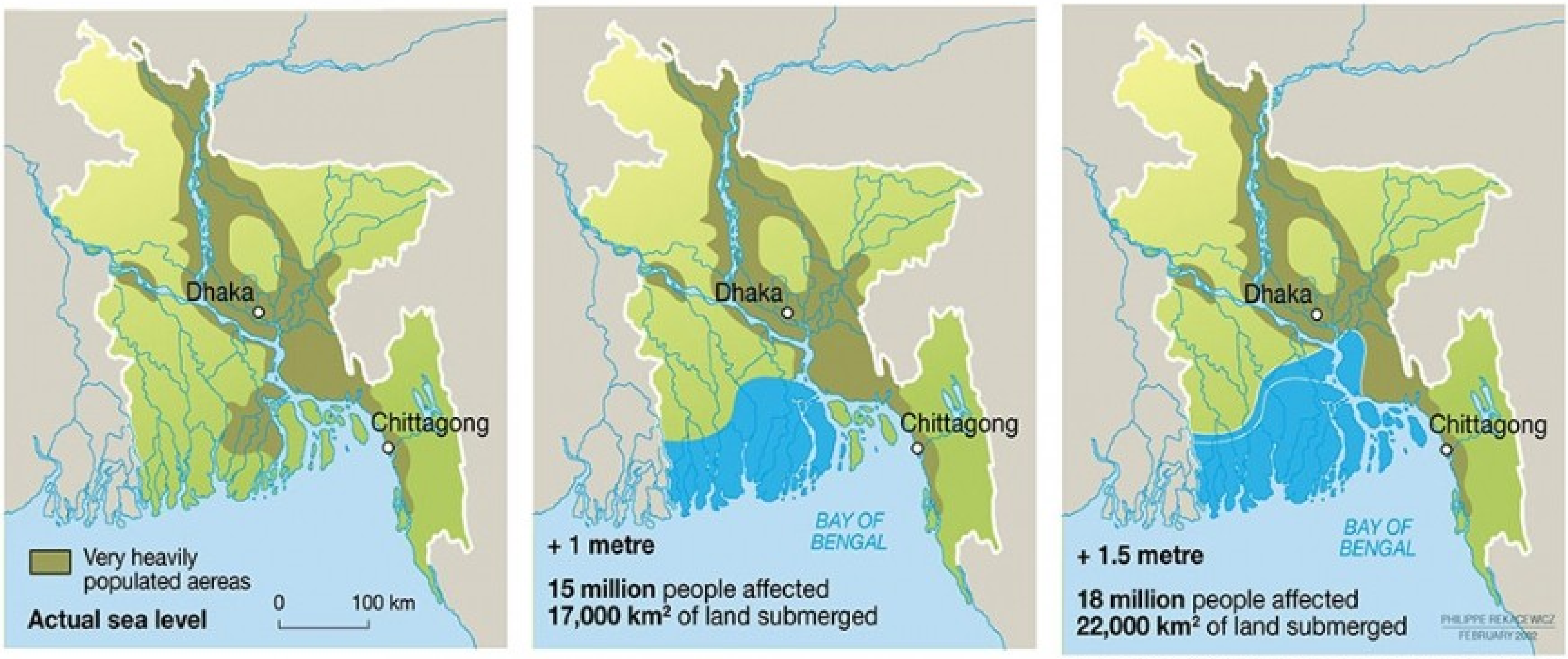
Population: 3 800 000
Cropland (Km2): 1 800

Population: 6 100 000
Cropland (Km2): 4 500

GRID Arendal UNEP IUCC

0 50 km

Sources: Otto Simonett, UNEP/GRID Geneva; Prof. G. Sestini, Florence; Remote Sensing Center, Cairo; DIERCKE Weltwirtschaftsatlas.

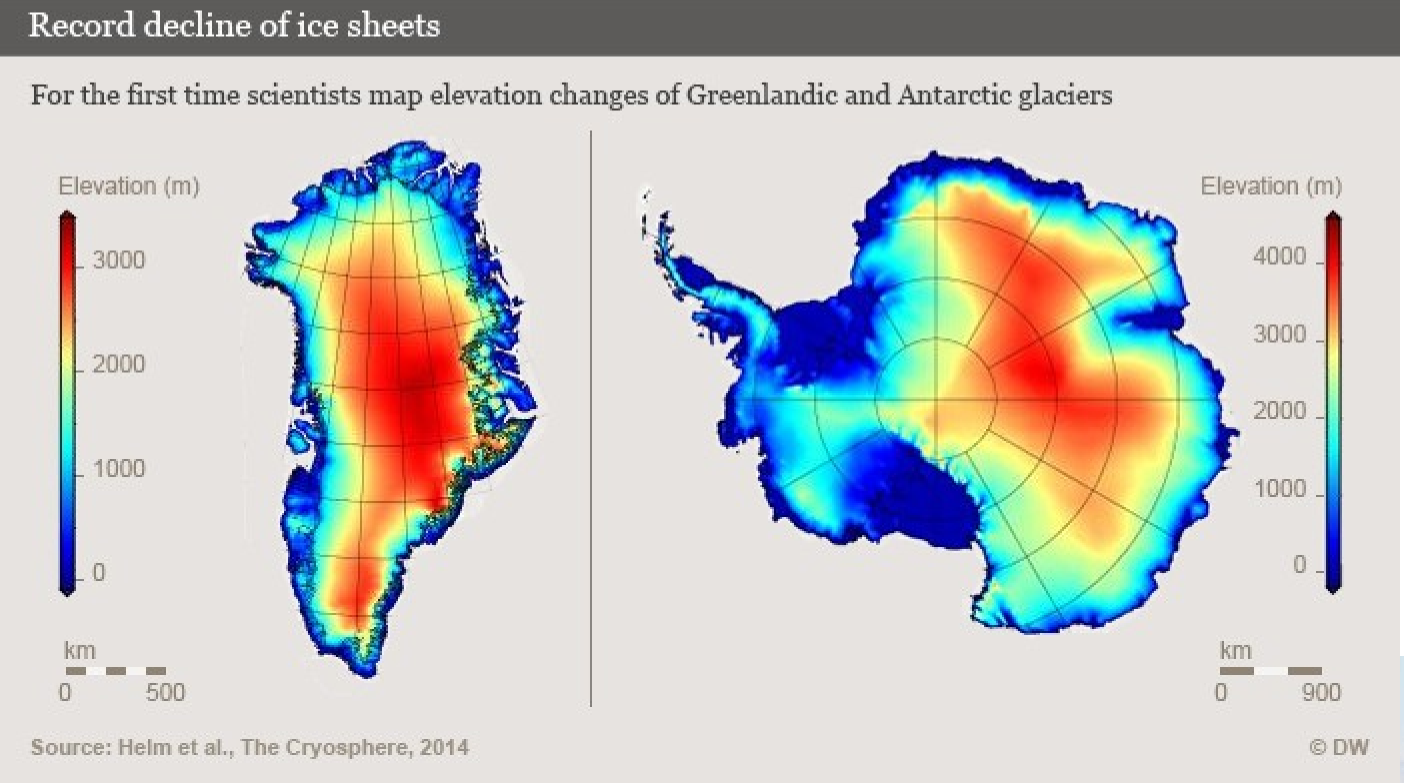


Sources: Dacca University; Intergovernemntal Pannel on Climate Change (IPCC).

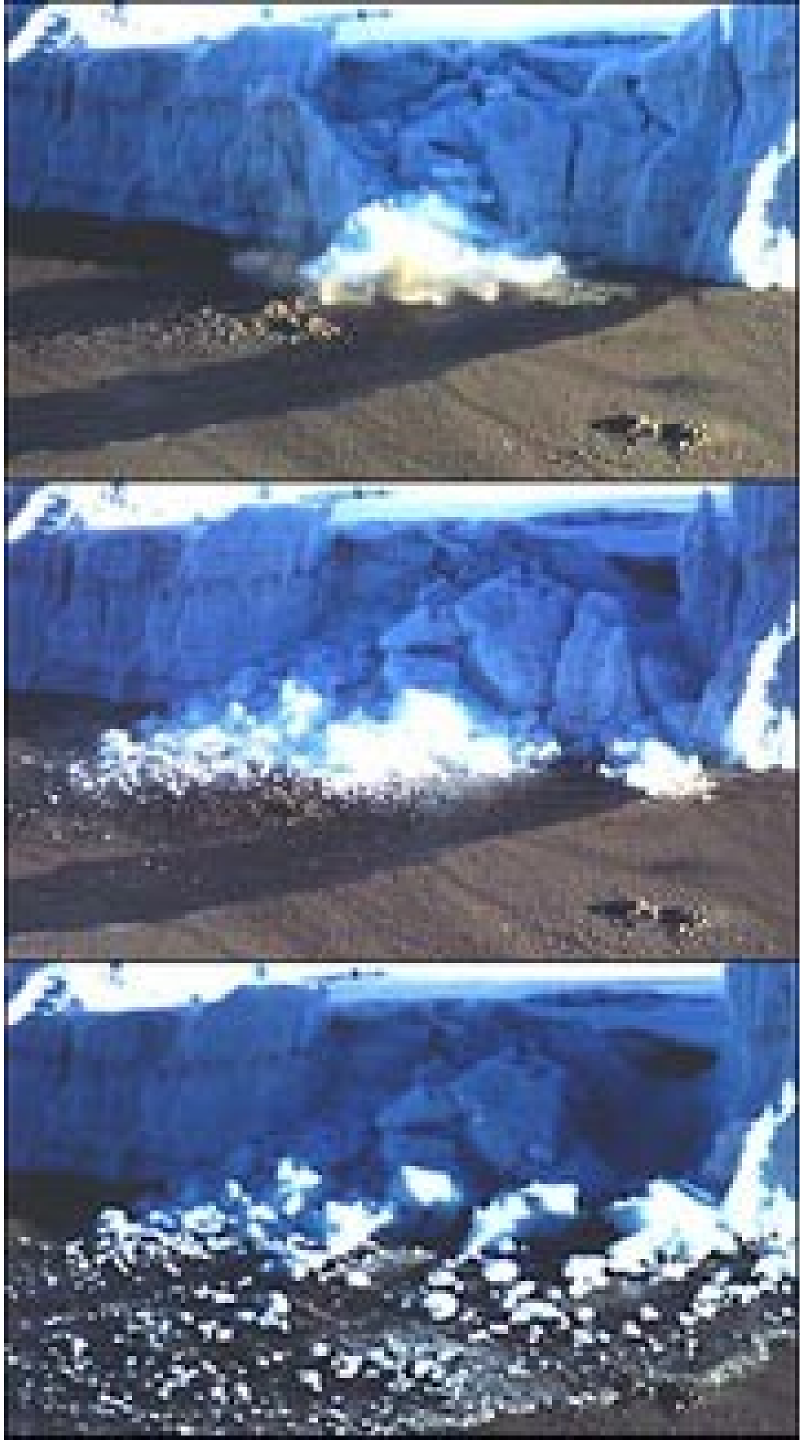
Male, Maldives

Photograph by Peter Essick, Aurora Photos

The island of Male, capital of the Maldives Islands in the Indian Ocean, is at ground zero in Earth's sea level rise dilemma. With a maximum elevation of only 8 feet (2.4 meters), even a modest increase in ocean heights would submerge a majority of its territory. To combat the threat, the government erected a seawall around the entire island.

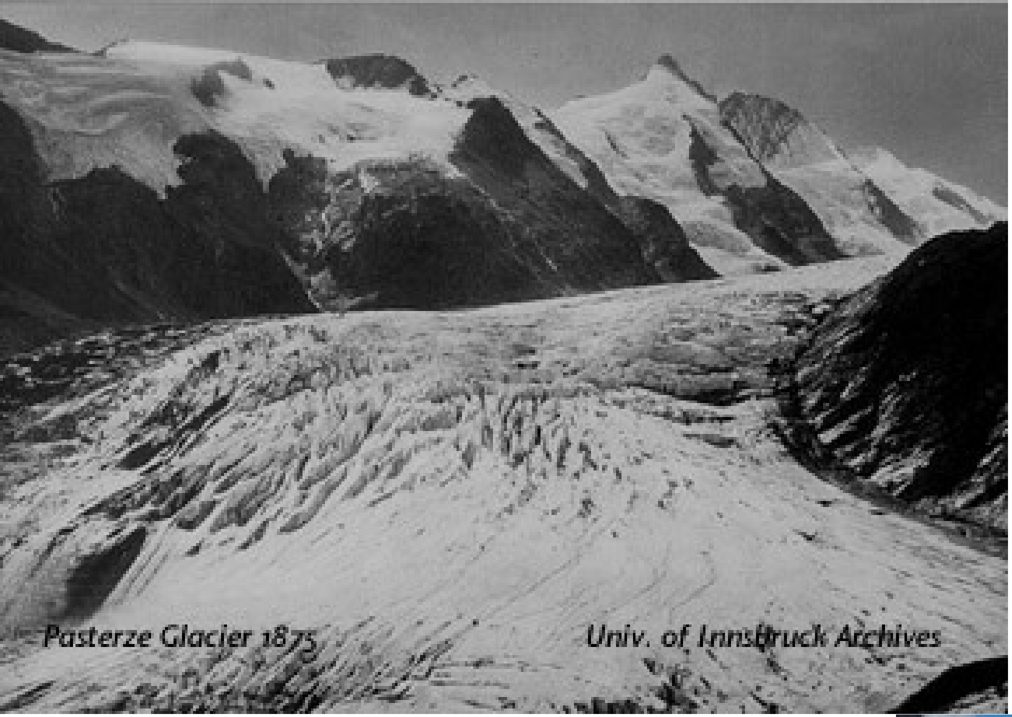


Two major glaciers in the world:
Greenland
Antarctica

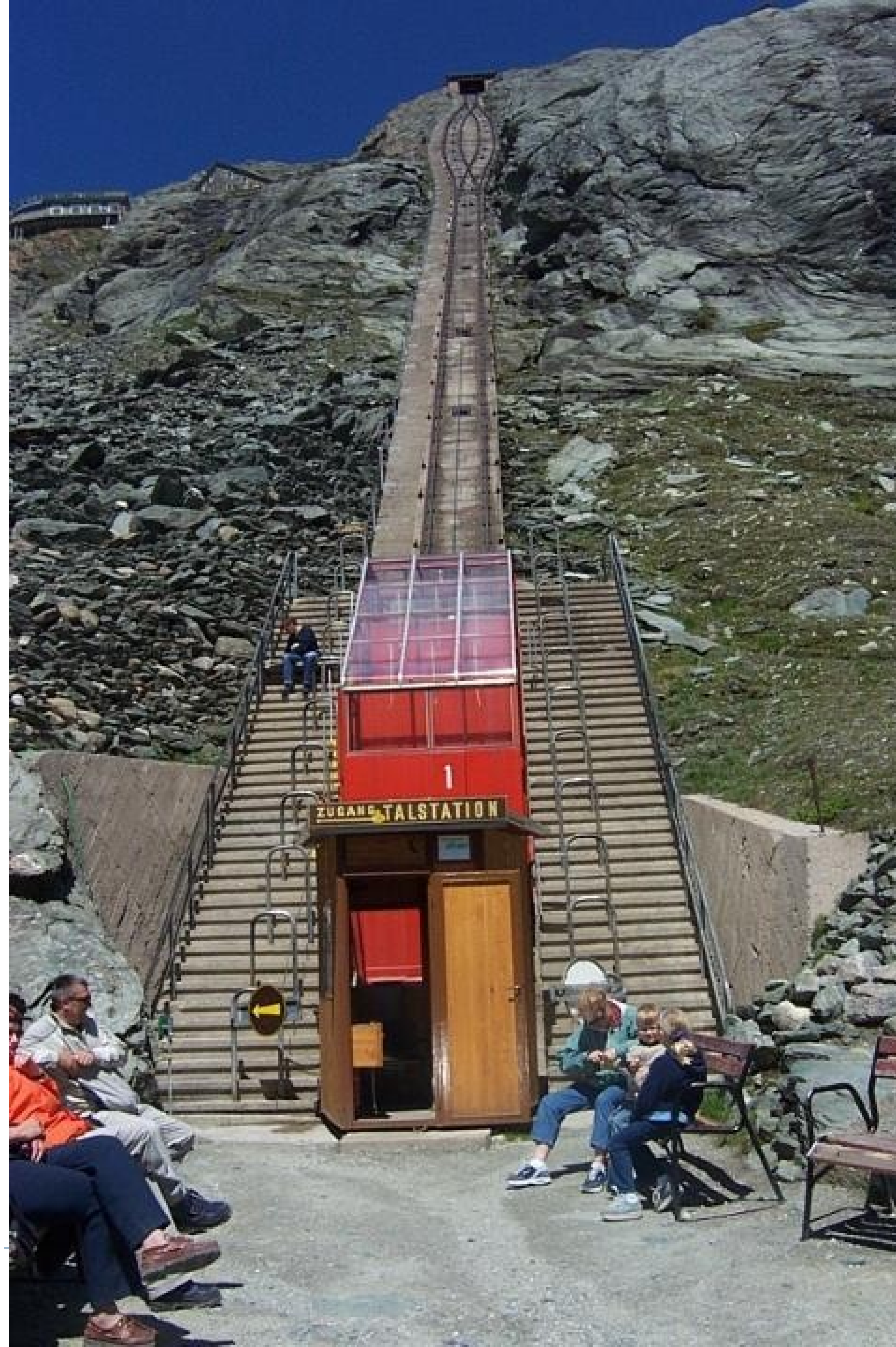


The snows of Kilimanjaro, Tanzania

http://news.nationalgeographic.com/news/2003/09/0923_030923_kilimanjaroglaciers.html



The Pasterze, Austria'a longest glacier, was much longer in the 19th C. but is now completetely out of sight from this overlook on the Grossglockner High Road.



1
ZUGANG TALSTATION


2003


2014


GLETSCHERSTAND
GLACIERPOSITION
2000

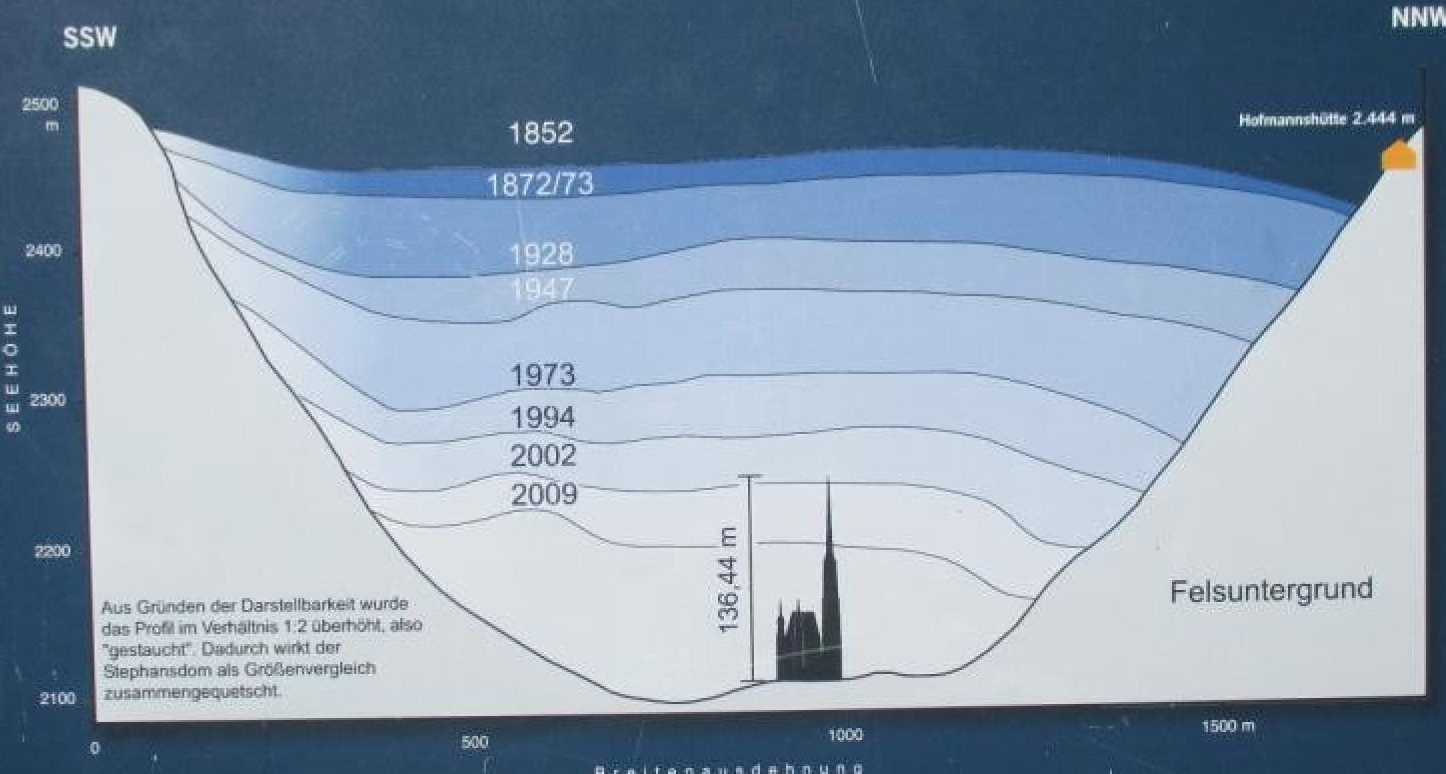
l-Ausdehnung
Pasterze konti-
) bis heute ist
st eine Fläche
nennt und die
reinwanderung
edelung kann
n.

n Klimawandel
wundes in der
senschaftlicher
erze gewonnen
eiszeit, das ist
Zeiträume hin-
sphasen wech-
mperatur- und
hasen ab. Die
wa so groß wie

Moränen oder
hinterließen, ist
Pasterze hatten
melzwasser des
stmals im Jahr
chsen sein müs-
Auszählung der
drochronologie")
me bestimmen.
nnt, in denen an
e Wald stockte.

bale Erwärmung
eser ist derzeit
während der mei-
tsächlich drama-
hen können – die
oberfläche in ver-
stellung davon zu

Querprofil der Pasterze 1852 – 2009



Im Querprofil der Pasterze nahe der ehemaligen Hofmannshütte ist die exakte Höhe der Gletscheroberfläche aus alten Landkarten und für die letzten Jahrzehnte aus den alljährlichen Messungen bekannt. Deutlich erkennt man, wie stark die Eisoberfläche bereits abgesunken ist und dass dieses Einsinken spätestens seit den 1990er Jahren wesentlich rascher als zuvor stattfindet (Entwurf und Zeichnung: M. Krobath).

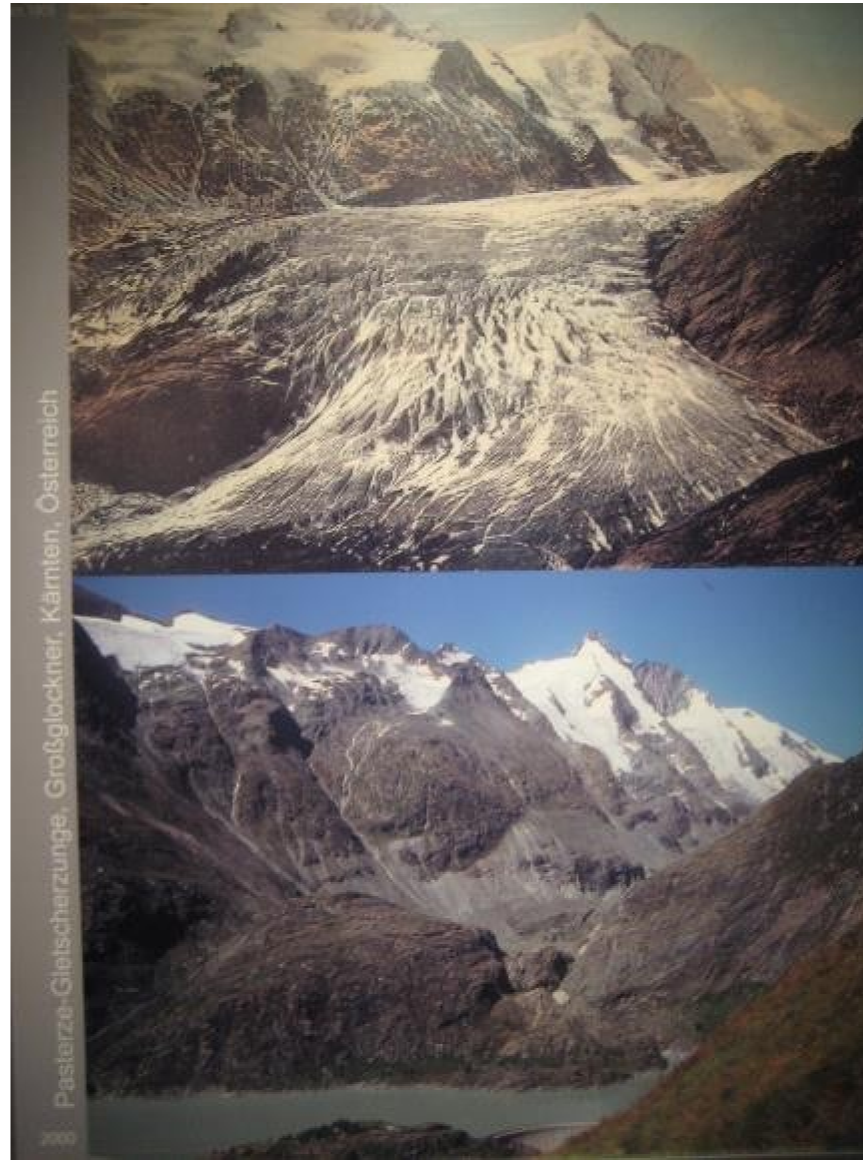
Längen, Flächen und Volumsänderung:

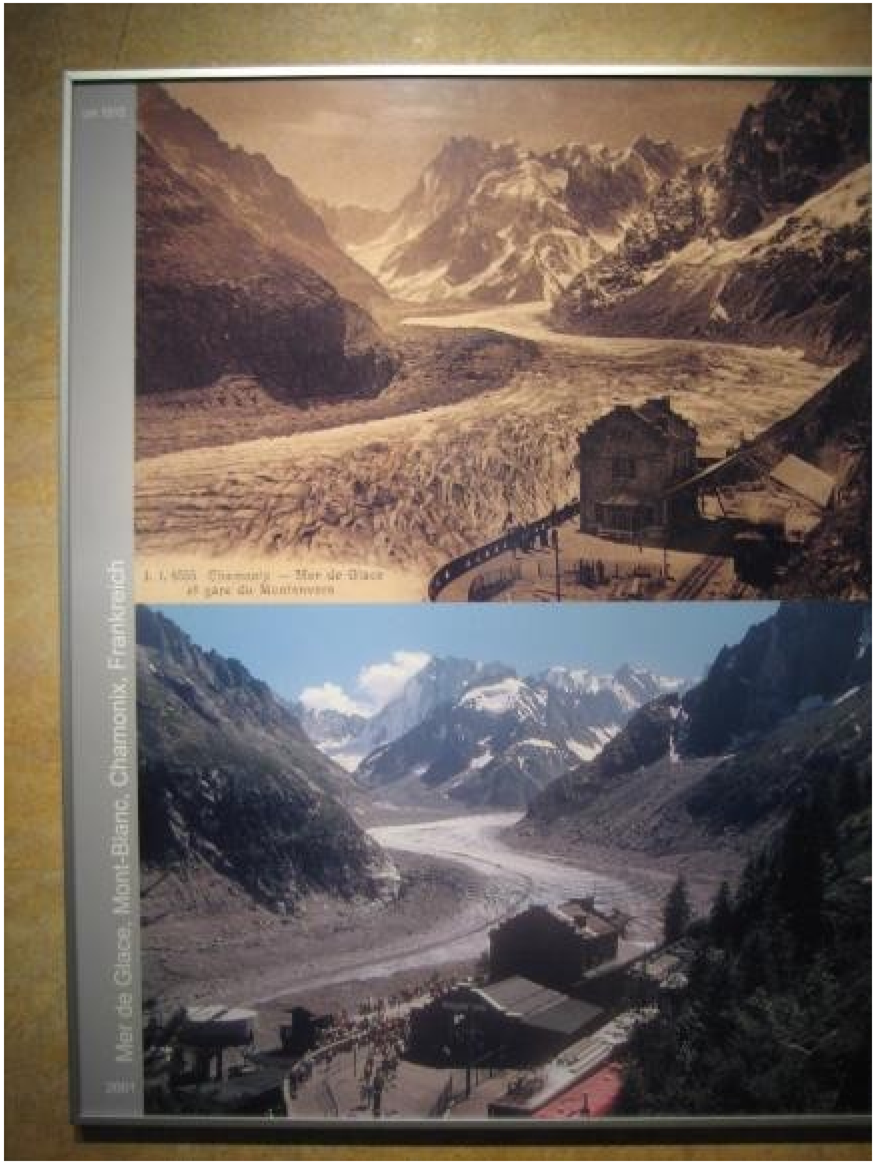
Jahr	1851	1924	1969	1985	2006
Länge	11 km	10,3 km	9,5 km	9,0 km	8,3 km
Fläche	26,5 km²	22,6 km²	19,8 km²	18,9 km²	17,3 km²
Volumen	3,5 km³	2,9 km³	2,2 km³	2,0 km³	1,7 km³

Der P

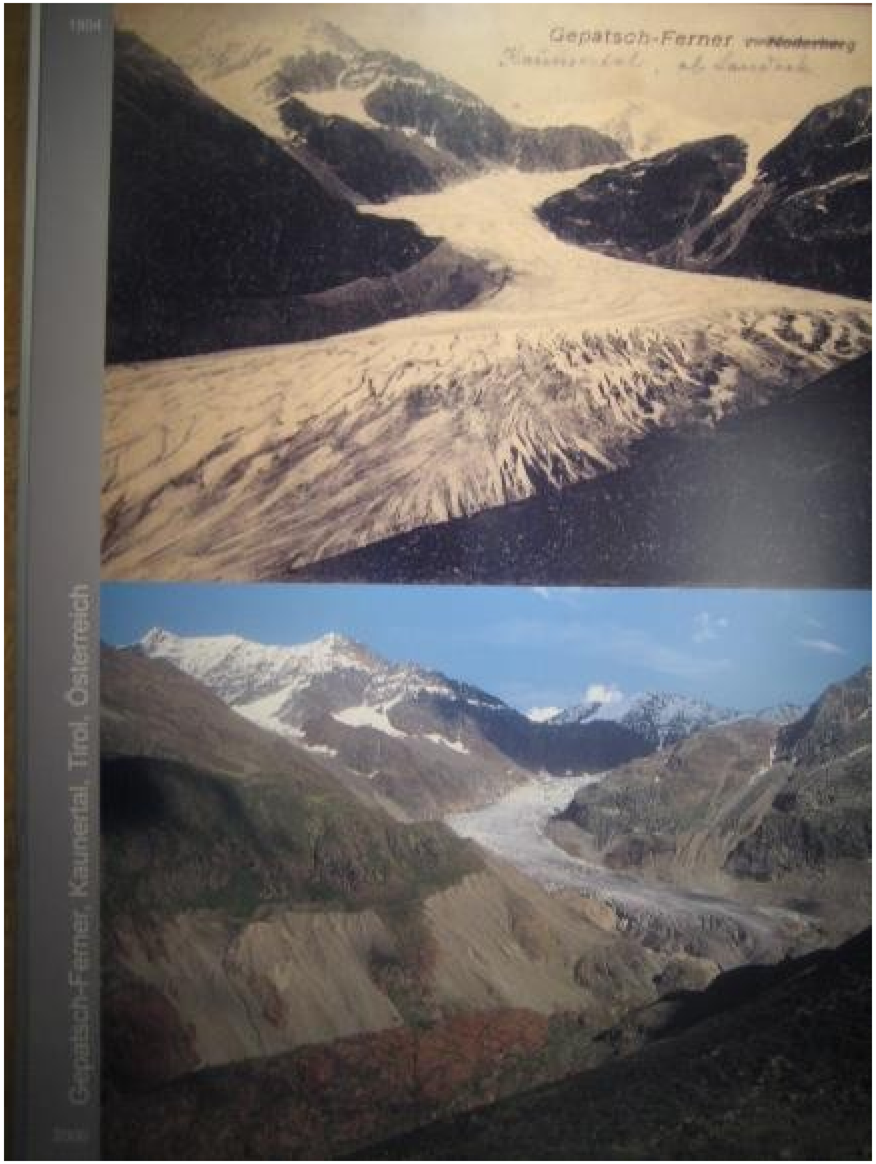
Was im e
nach der
der Jahre
10.000 J


Waxegg-Kees, Berliner Hütte, Zillertal, Österreich


Pasterze-Gletscherzunge, Großglockner, Kärnten, Österreich


Mer de Glace, Mont-Blanc, Chamonix, Frankreich


Aletsch-Gletscher, Belalp, Wallis, Schweiz


Gepatsch-Ferner
Gepatsch-Ferner, Kaunertal, Tirol, Österreich

Portage Glacier, near Anchorage, Alaska, in about 1914 and in 2004.

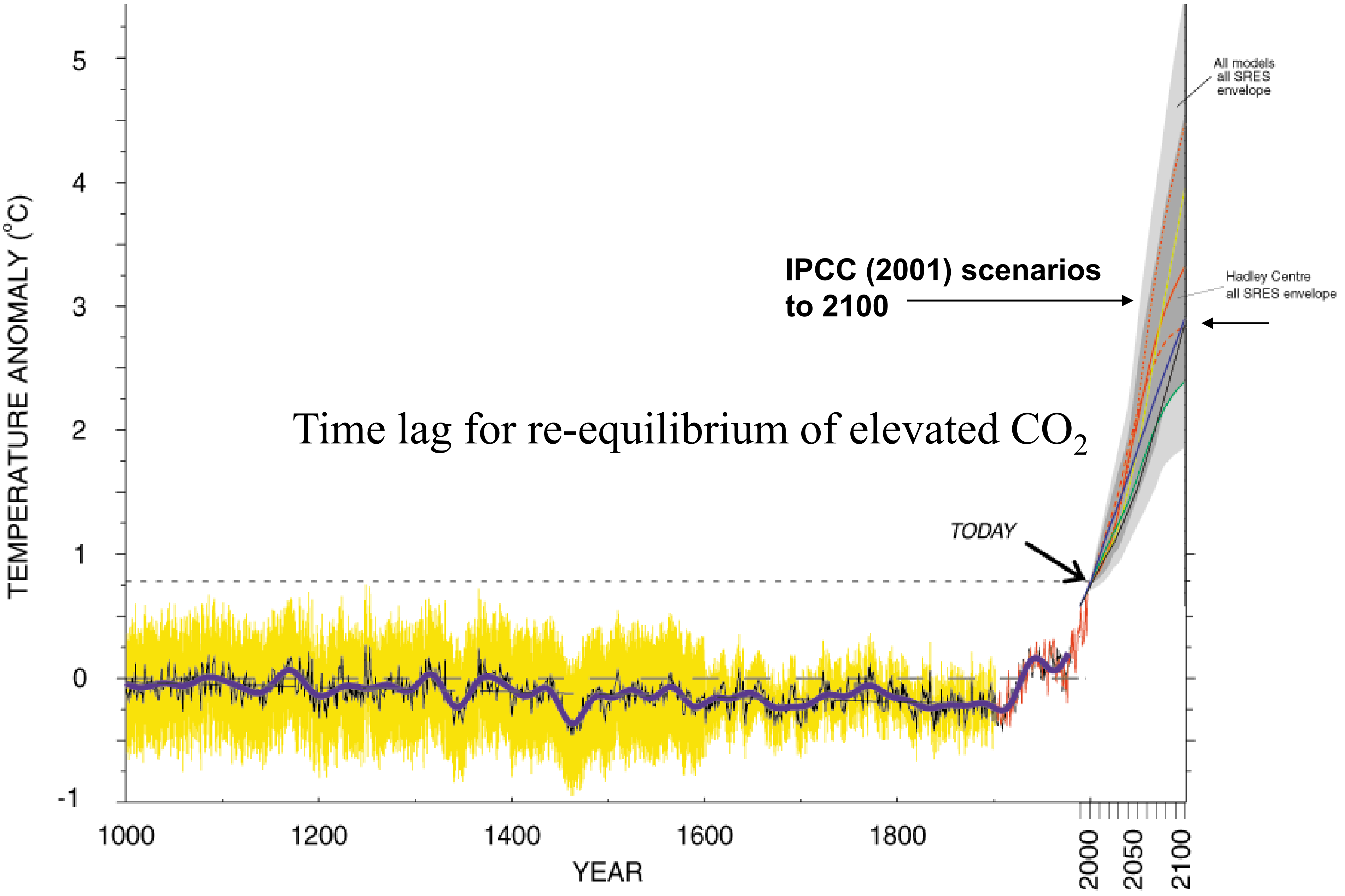
https://www.youtube.com/watch?v=JMwneiXMzo0

http://www.worldviewofglobalwarming.org/pages/glaciers.html

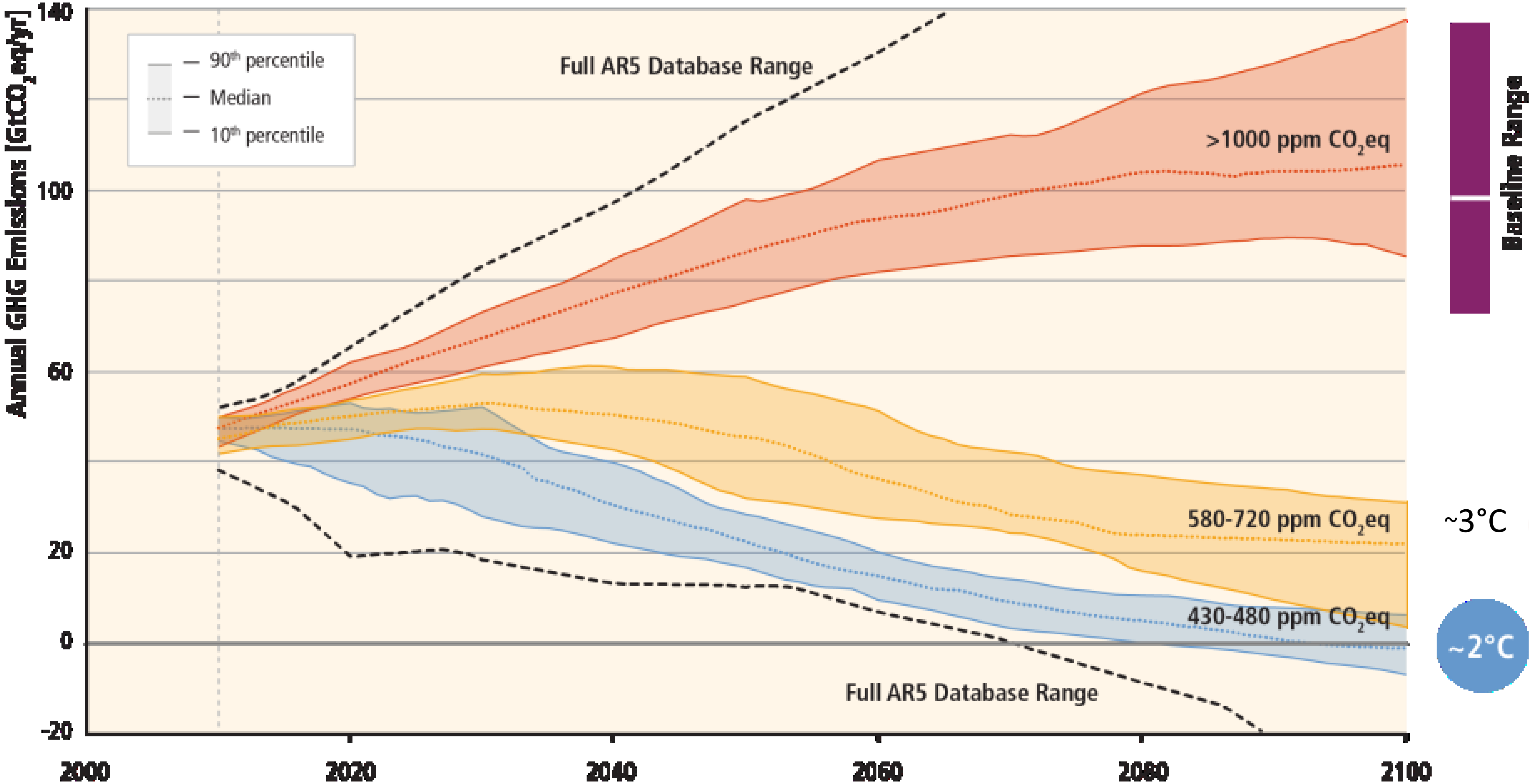
Videos!

https://climate.nasa.gov/climate_resource_center/earthminute

1000 years of Earth temperature history…and 100 years of projection



Stabilization of atmospheric concentrations requires moving away from the baseline – regardless of the mitigation goal.



Based on Figure 6.7

AR5 WGIII SPM

Figure SPM.10

Temperature increase and cumulative carbon emissions

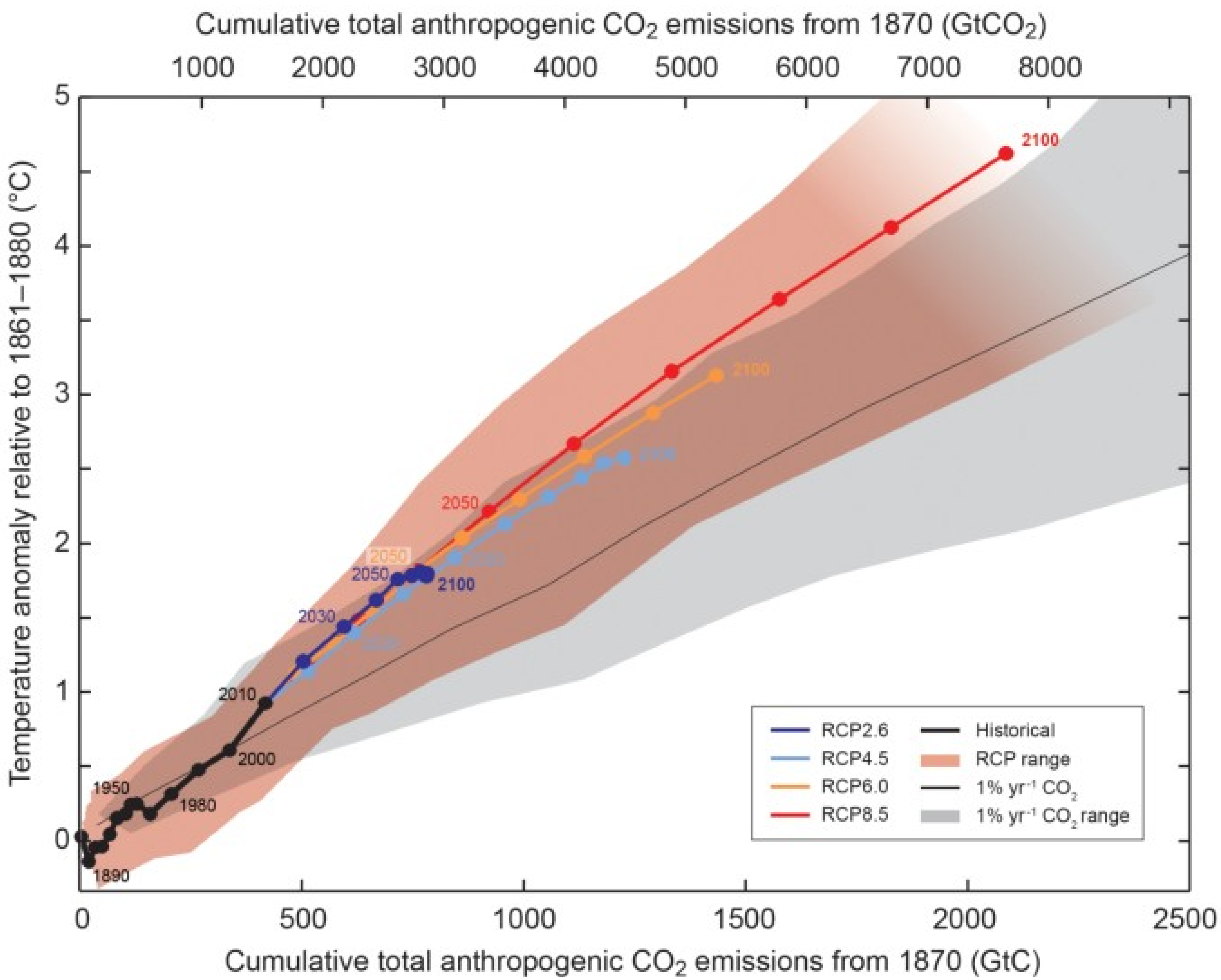
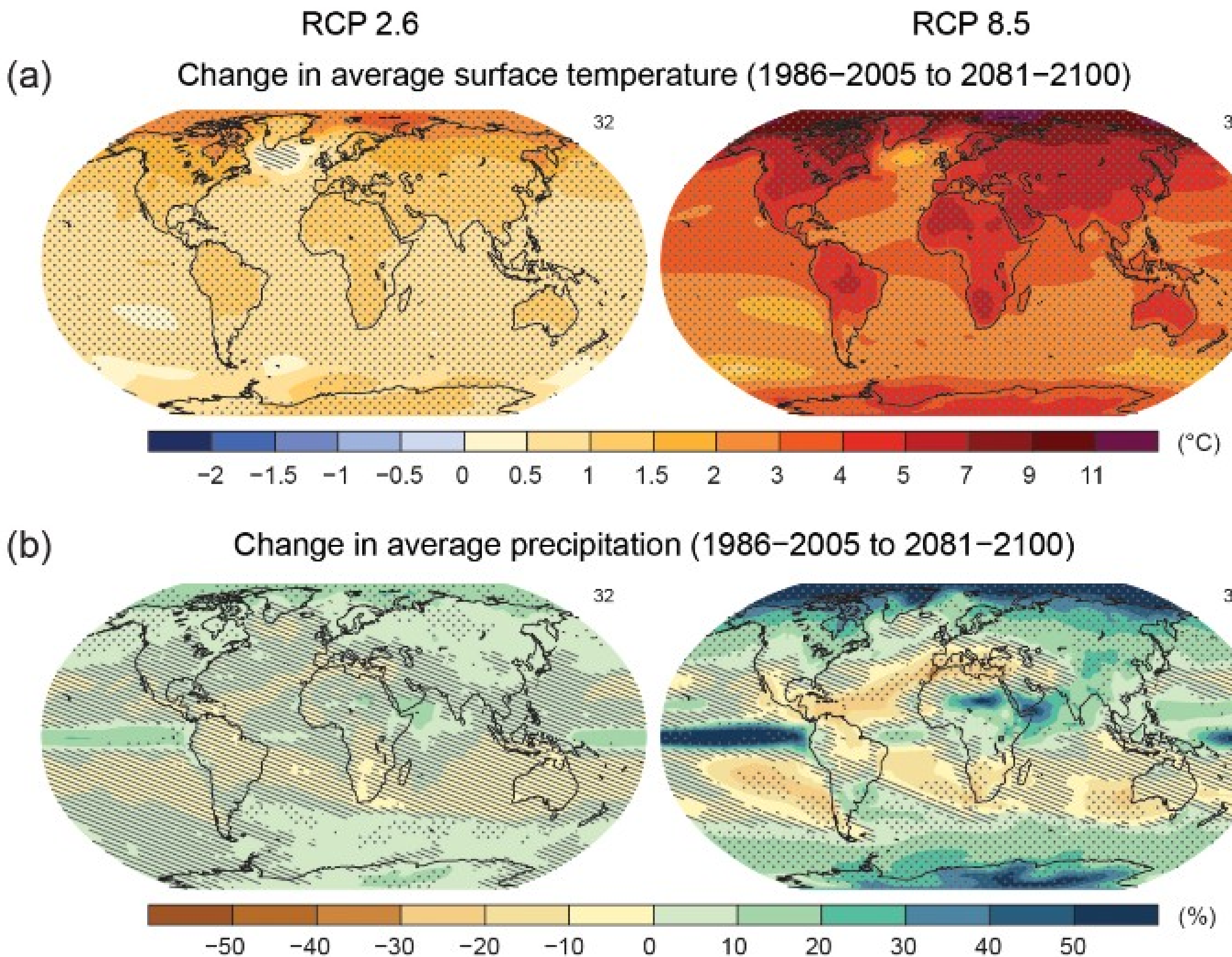
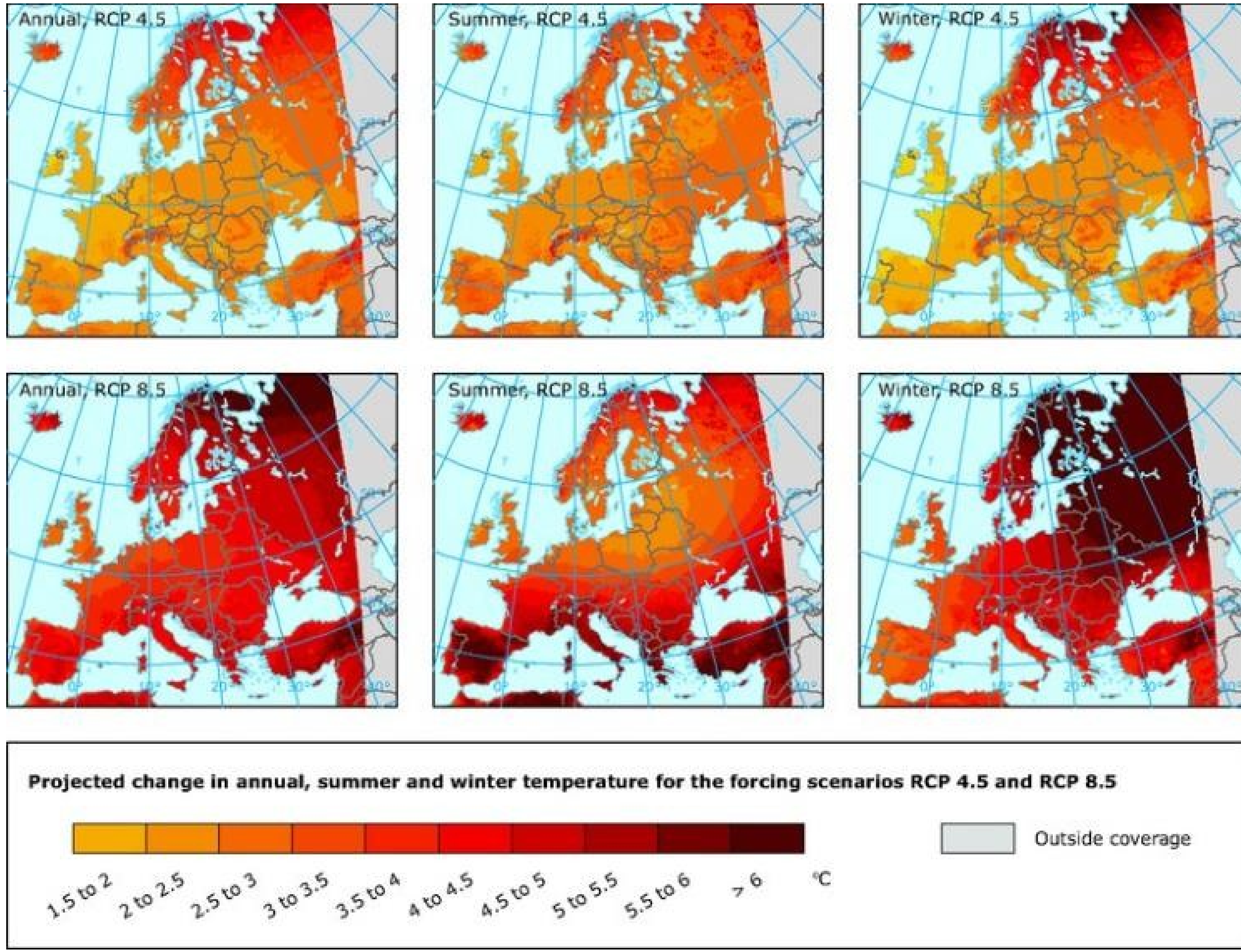


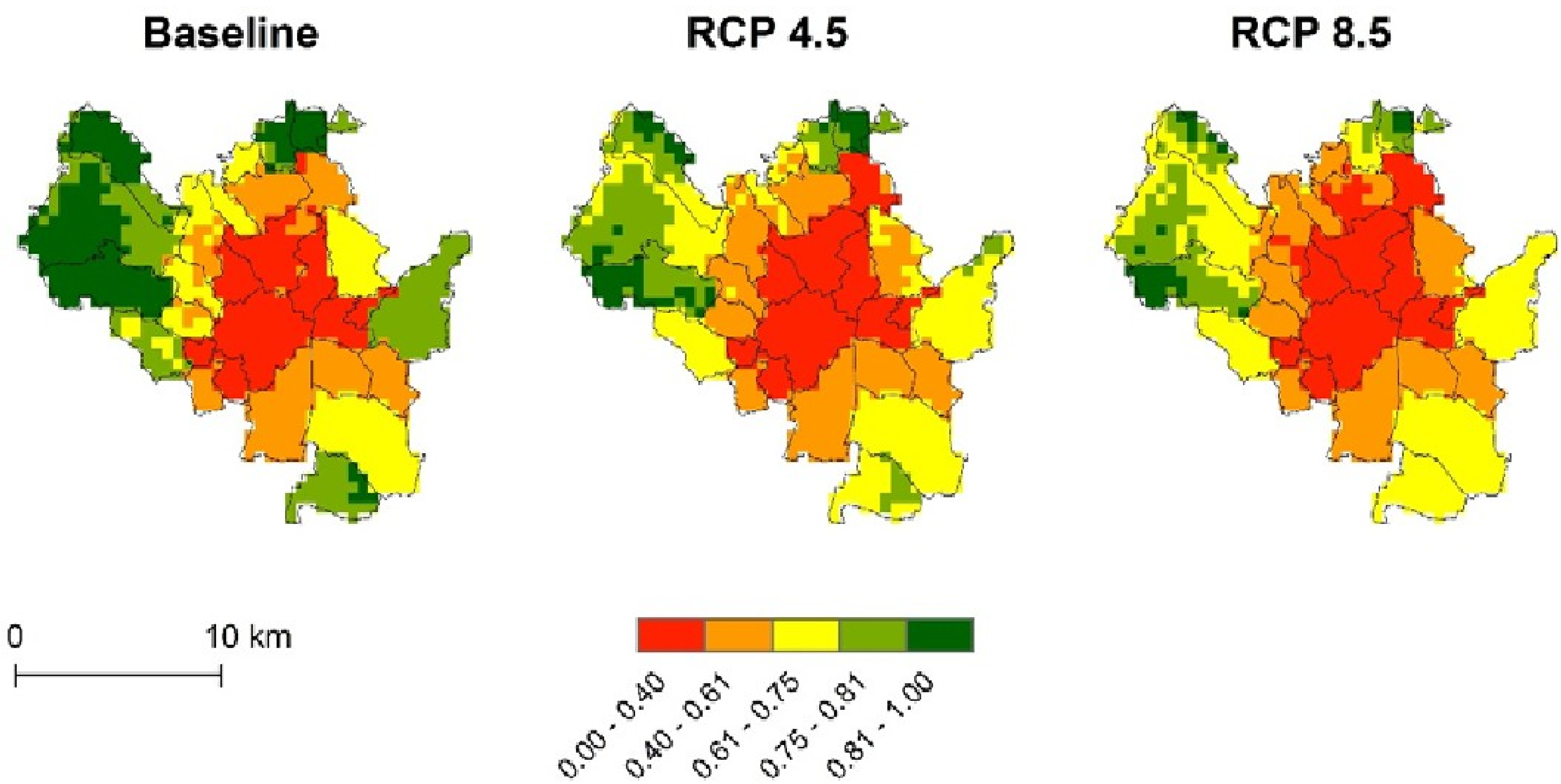
Figure SPM.8a,b

Maps of CMIP5 multi-model mean results




Annual, RCP 4.5
Summer, RCP 4.5
Winter, RCP 4.5
Annual, RCP 8.5
Summer, RCP 8.5
Winter, RCP 8.5
Projected change in annual, summer and winter temperature for the forcing scenarios RCP 4.5 and RCP 8.5
1.5 to 2
2 to 2.5
2.5 to 3
3 to 3.5
3.5 to 4
4 to 4.5
4.5 to 5
5 to 5.5
5.5 to 6
> 6
°C
Outside coverage

Participatory Climate Change Impact Assessment in Three Czech Cities: The Case of Heatwaves 2018. Lorencová, et al.



Brno in-city comparison of potential climate change impacts of heatwaves for the baseline (2015) and RCP 4.5 and RCP 8.5 (2030).

WHAT TO DO ABOUT IT?

Scientific, policy and people response

The Intergovernmental Panel on Climate Change (IPCC)

Scientists sound the alarm

•It fell to scientists to draw international attention to the threats posed by global warming. Evidence in the 1960s and '70s that concentrations of carbon dioxide in the atmosphere were increasing first led climatologists and others to press for action. It took years before the international community responded.

•1988, IPCC was formed (World Meteorological Organization and the UN Environment Programme).

- first report in 1990 reflecting views of 400 scientists stating that global warming was real and urged that something be done about it.

IPCC Assessment Reports since 1990: WGI Contribution

1990

1995

2001

2007

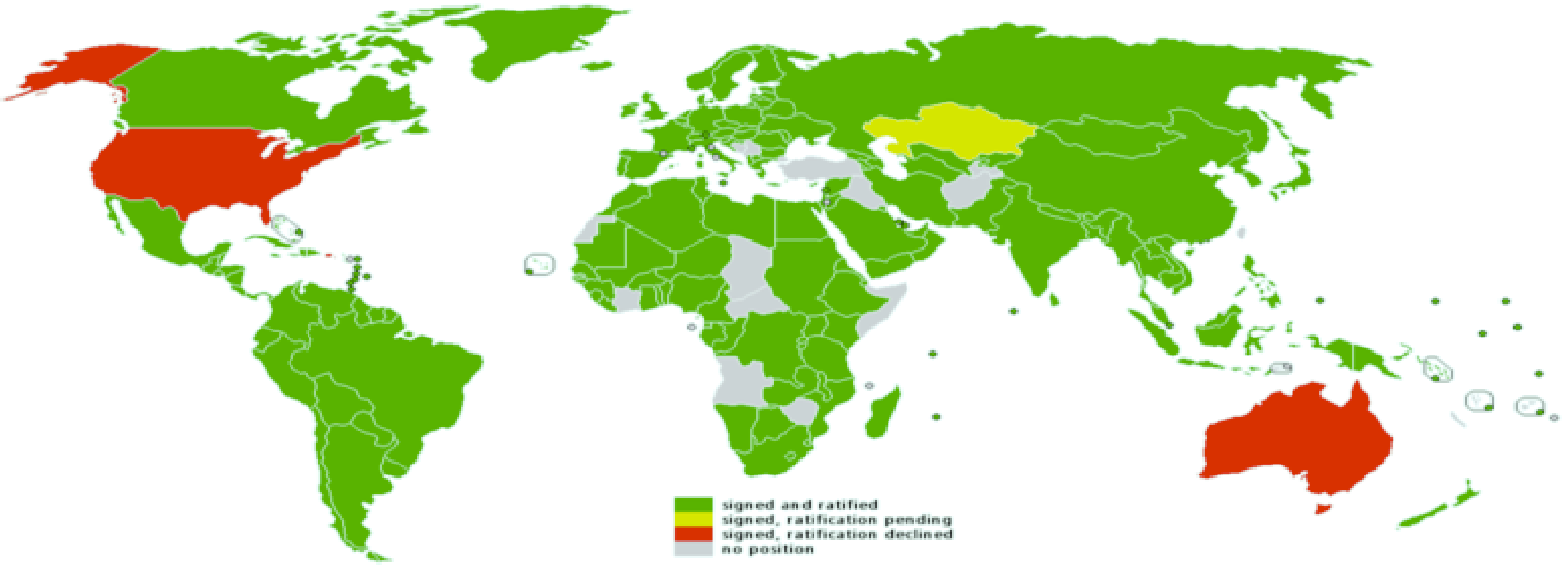
2013

IPCC

•The Panel's findings spurred governments to create the **United Nations Framework Convention on Climate Change**. It was ready for signature at the 1992 UN Conference on Environment and Development -- the "Earth Summit" -- in Rio de Janeiro.

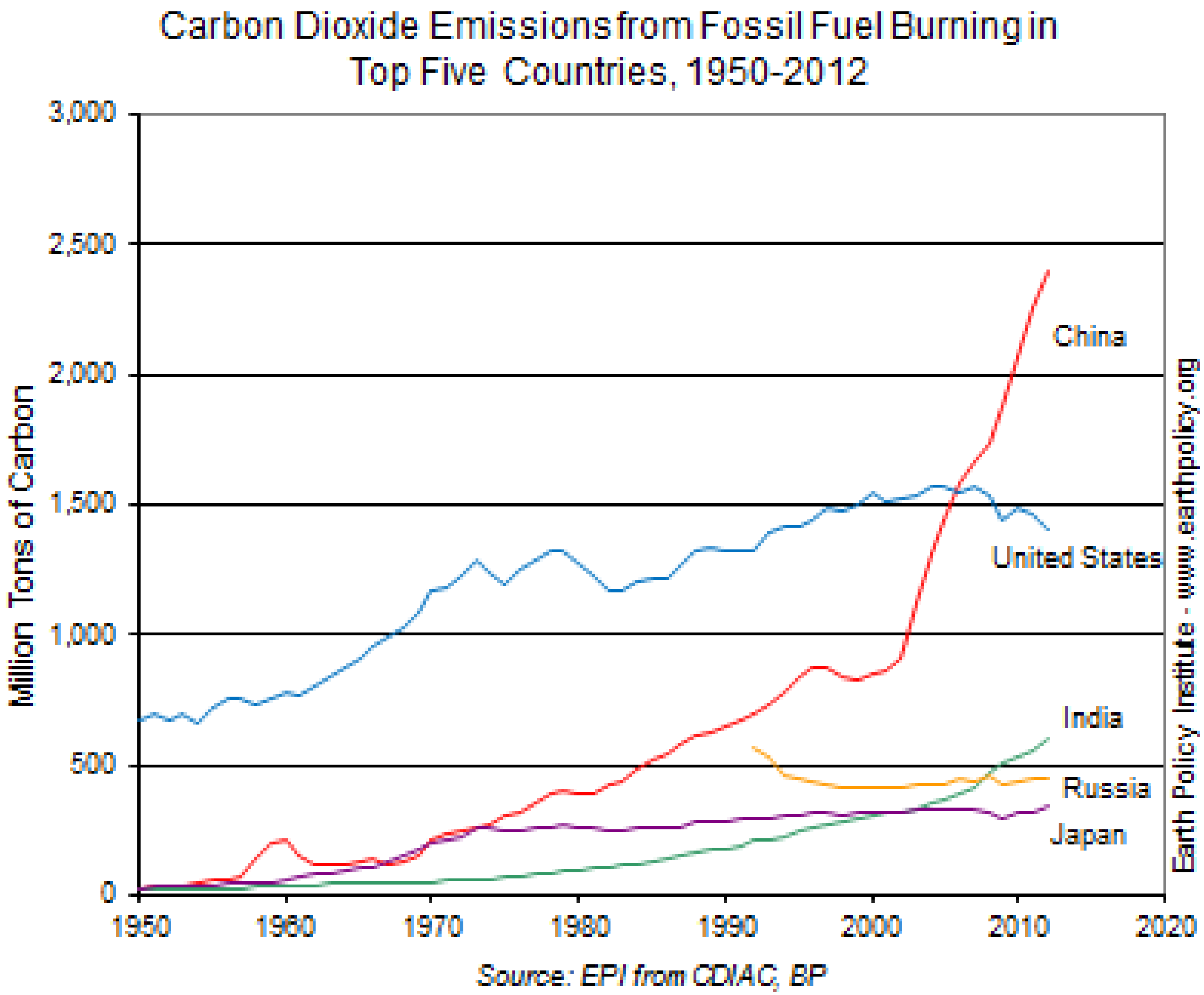
•The IPCC's findings, because they reflect global scientific consensus and are apolitical, form a counterbalance to the highly charged political debate over what to do about climate change. IPCC reports played a major role in the negotiations leading to the **Kyoto Protocol**, in 1997 a second, more far-reaching international treaty on climate change.

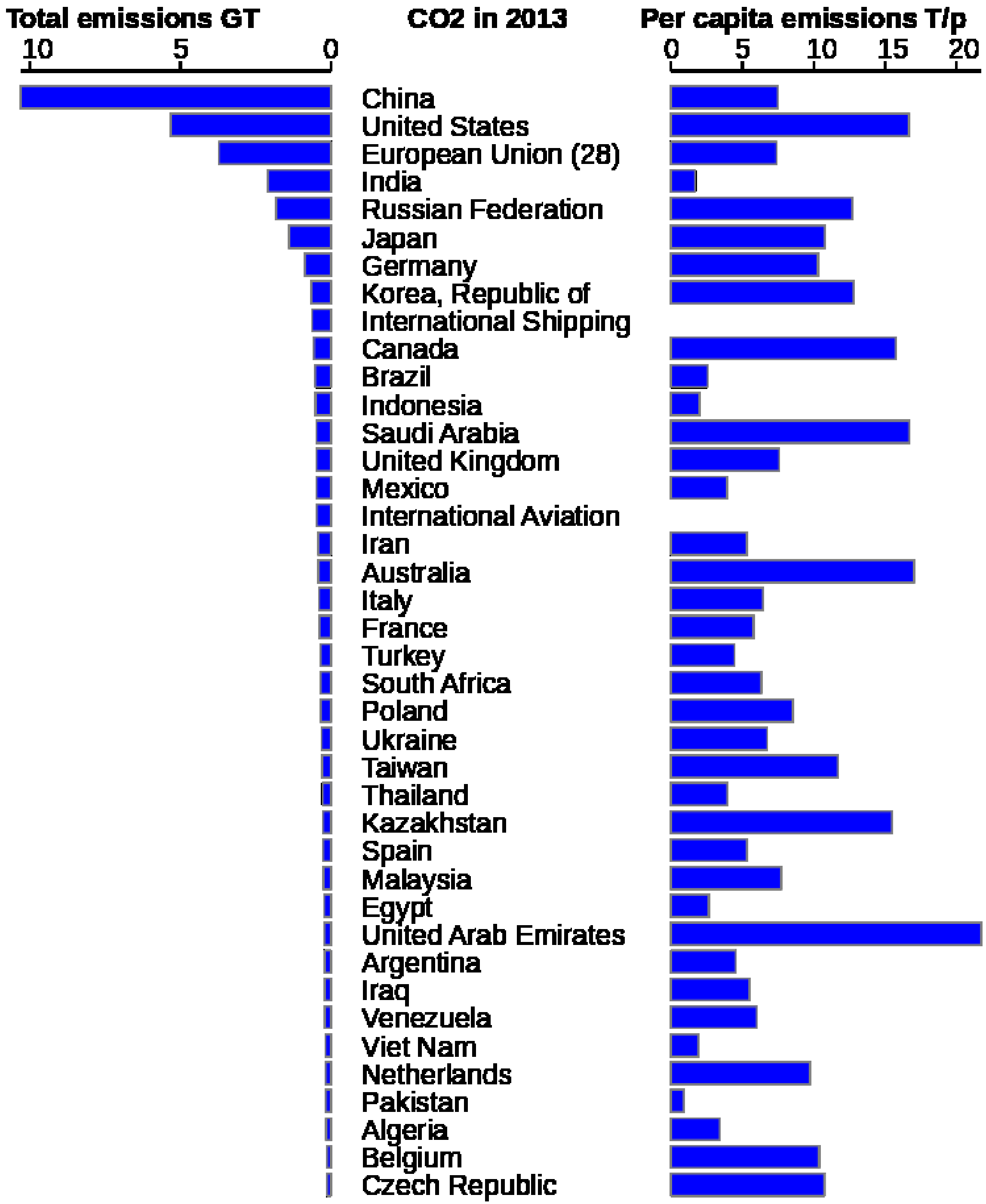
Kyoto Protocol had 192 countries – entered into force 16 February 2005 and ended in 2012



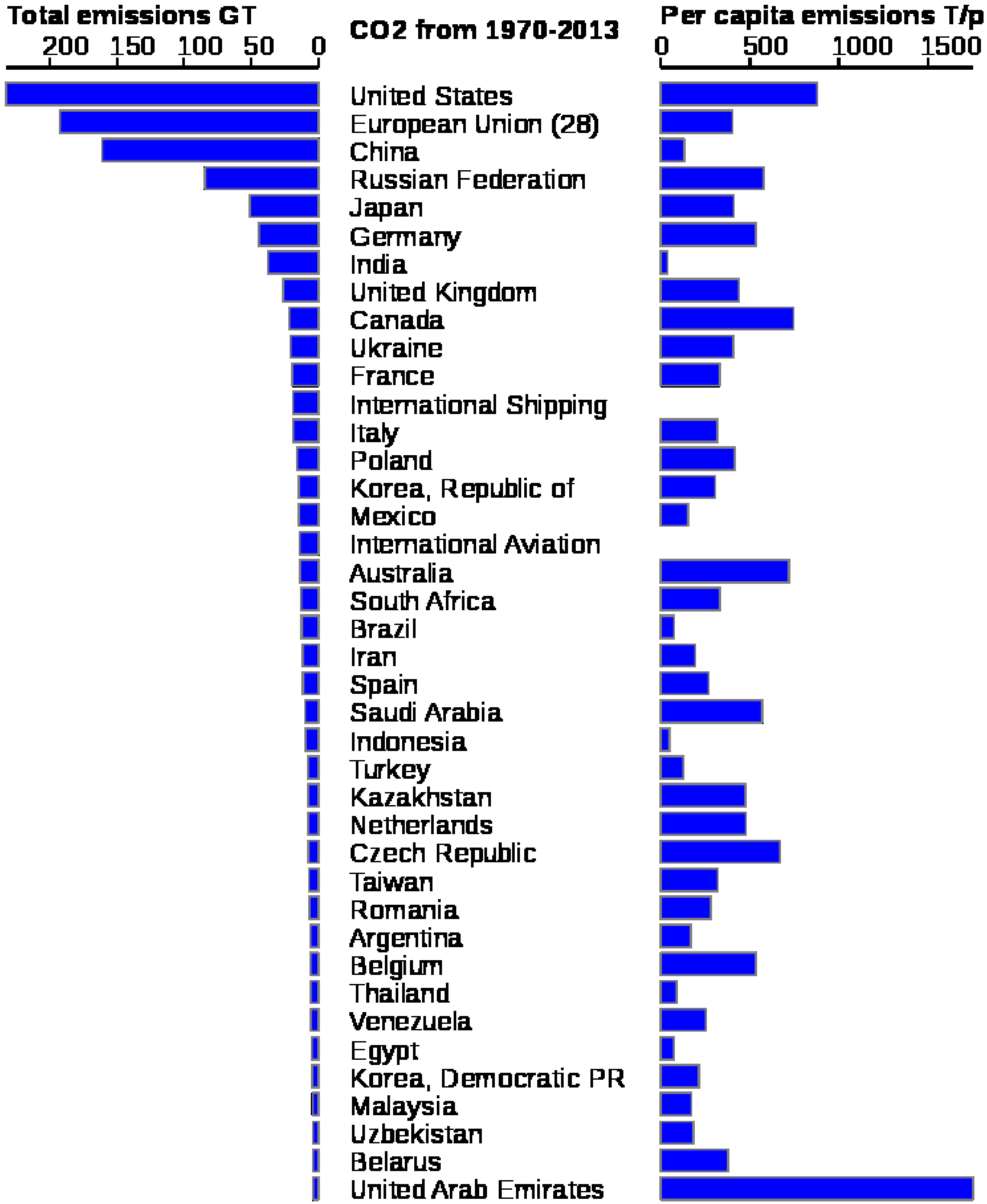
set legally binding targets and timetables for cutting GHG emissions – industrialized countries agreed to reduce GHG emissions by 5.2% compared to 1990 by 2012

got the world's attention but largely failed to make change

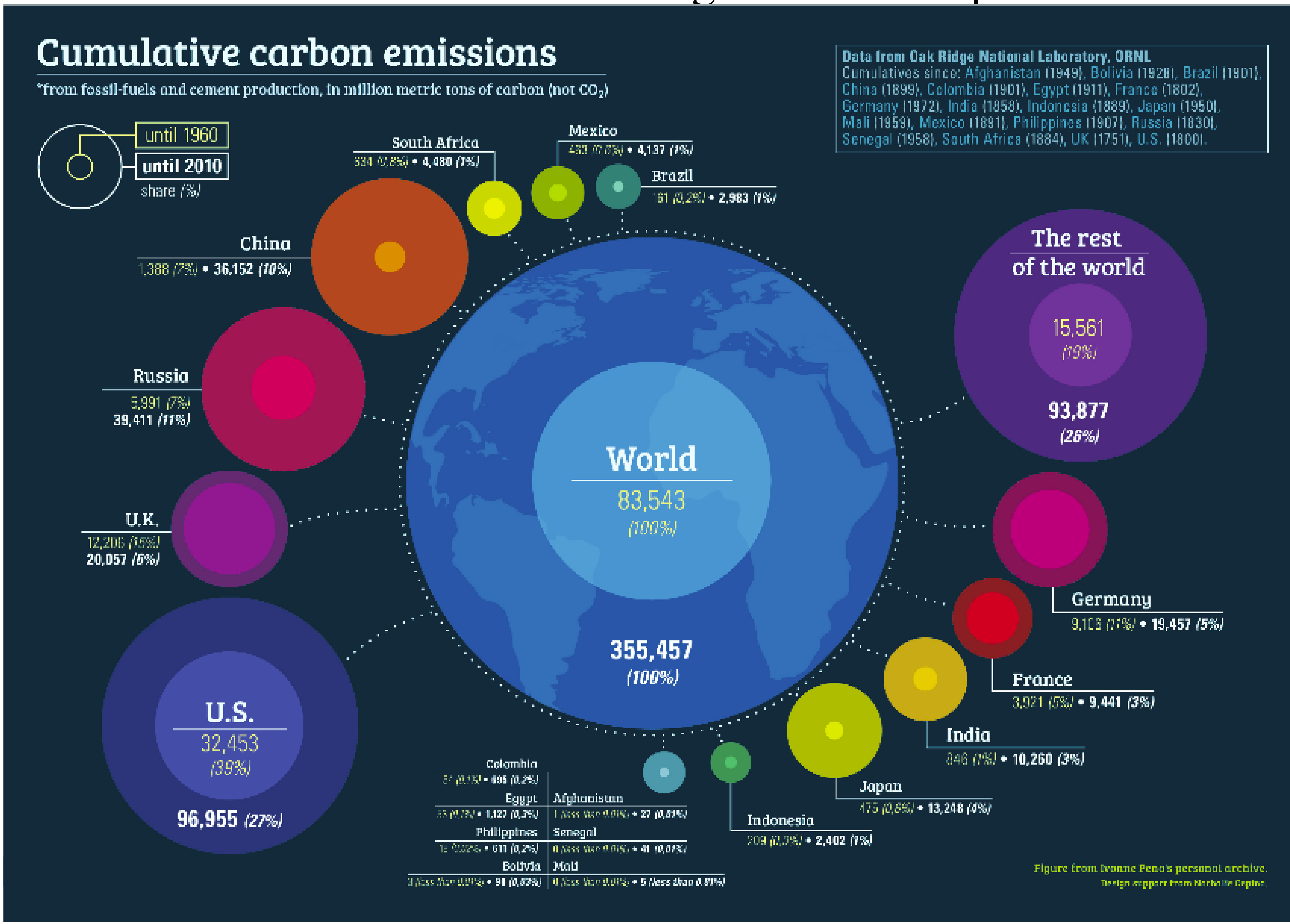

Carbon Dioxide Emissions from Fossil Fuel Burning in Top Five Countries, 1950-2012
Million Tons of Carbon
3,000
2,500
2,000
1,500
1,000
500
0
1950
1960
1970
1980
1990
2000
2010
2020
China
United States
India
Russia
Japan
Earth Policy Institute - www.earthpolicy.org
Source: EPI from CDIAC, BP



Total emissions GT
10
5
0
CO2 in 2013
Per capita emissions T/p
0
5
10
15
20
China
United States
European Union (28)
India
Russian Federation
Japan
Germany
Korea, Republic of
International Shipping
Canada
Brazil
Indonesia
Saudi Arabia
United Kingdom
Mexico
International Aviation
Iran
Australia
Italy
France
Turkey
South Africa
Poland
Ukraine
Taiwan
Thailand
Kazakhstan
Spain
Malaysia
Egypt
United Arab Emirates
Argentina
Iraq
Venezuela
Viet Nam
Netherlands
Pakistan
Algeria
Belgium
Czech Republic

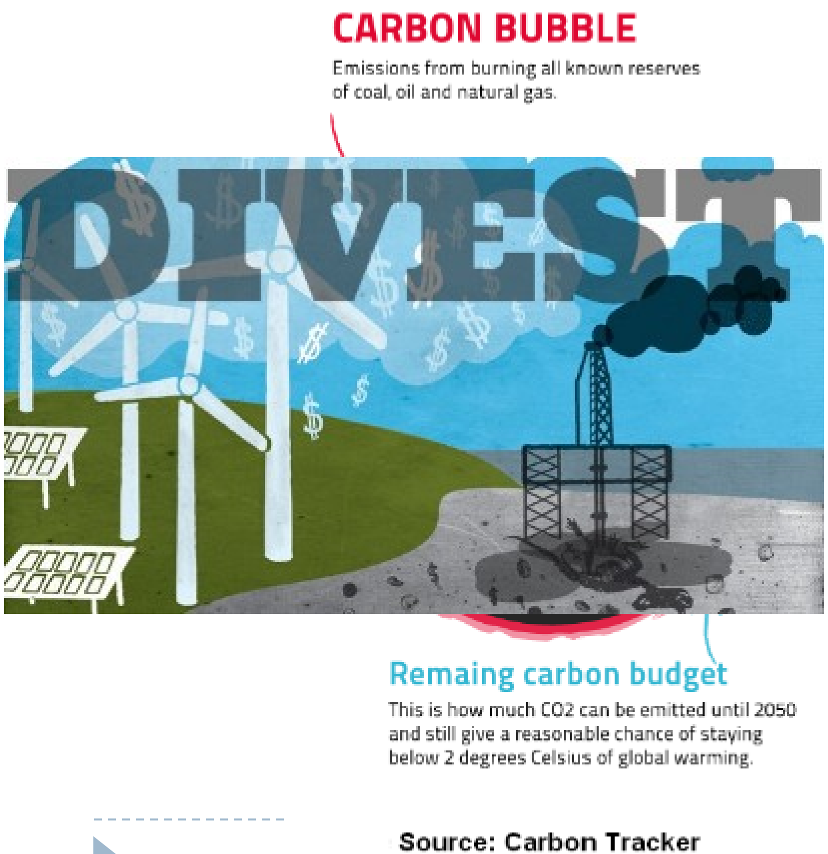

Total emissions GT
200 150 100 50 0
CO2 from 1970-2013
Per capita emissions T/p
0 500 1000 1500
United States
European Union (28)
China
Russian Federation
Japan
Germany
India
United Kingdom
Canada
Ukraine
France
International Shipping
Italy
Poland
Korea, Republic of
Mexico
International Aviation
Australia
South Africa
Brazil
Iran
Spain
Saudi Arabia
Indonesia
Turkey
Kazakhstan
Netherlands
Czech Republic
Taiwan
Romania
Argentina
Belgium
Thailand
Venezuela
Egypt
Korea, Democratic PR
Malaysia
Uzbekistan
Belarus
United Arab Emirates

Politics of climate change – who's responsible?

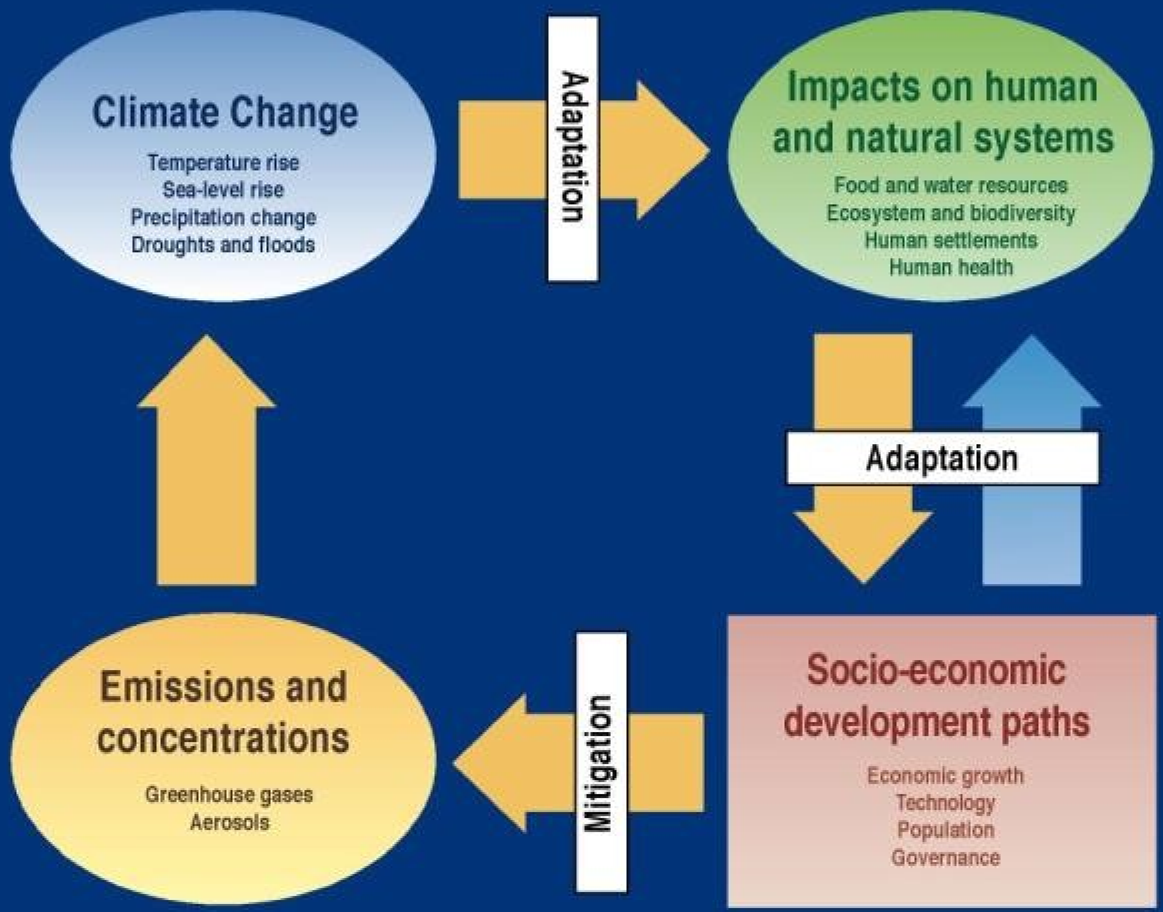


Politics of climate change – who's responsible?

Estimates there are $27 Trillion of proved fossil fuel reserves, yet to keep climate change below 2C, 80% of that must stay in the ground: stranded assets



Climate Change - an integrated framework



SYR FIGURE 1-1

Mitigation Measures

More efficient use of energy

Greater use of low-carbon and no-carbon energy

- Many of these technologies exist today

Improved carbon sinks

- Reduced deforestation and improved forest management and planting of new forests
- Bio-energy with carbon capture and storage

Lifestyle and behavioural changes

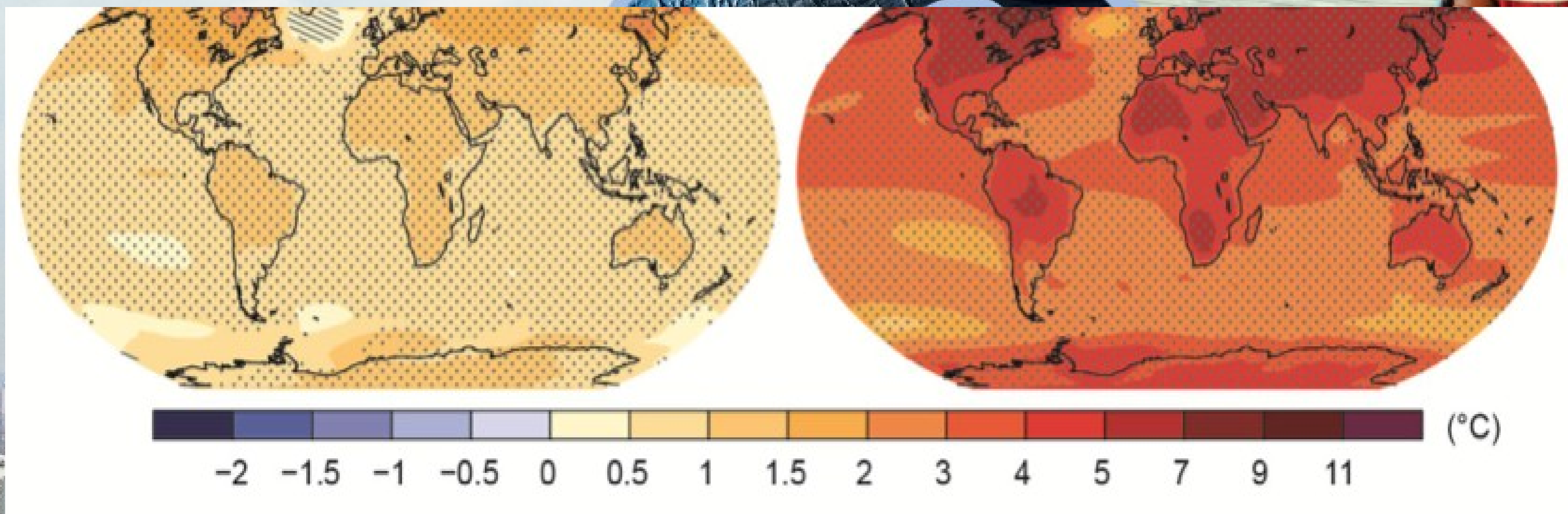
AR5 WGIII SPM

But delaying mitigation will substantially increase the challenges associated with limiting warming to 2°C

The Choices We Make Will Create Different Outcomes

With substantial mitigation

Without additional mitigation



AR5 WGI SPM

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

United Nations Climate Change Conference was in Paris, Nov 30 to Dec 11, 2015.

Bottom-up approach based on “intended nationally determined contributions" (INDCs)

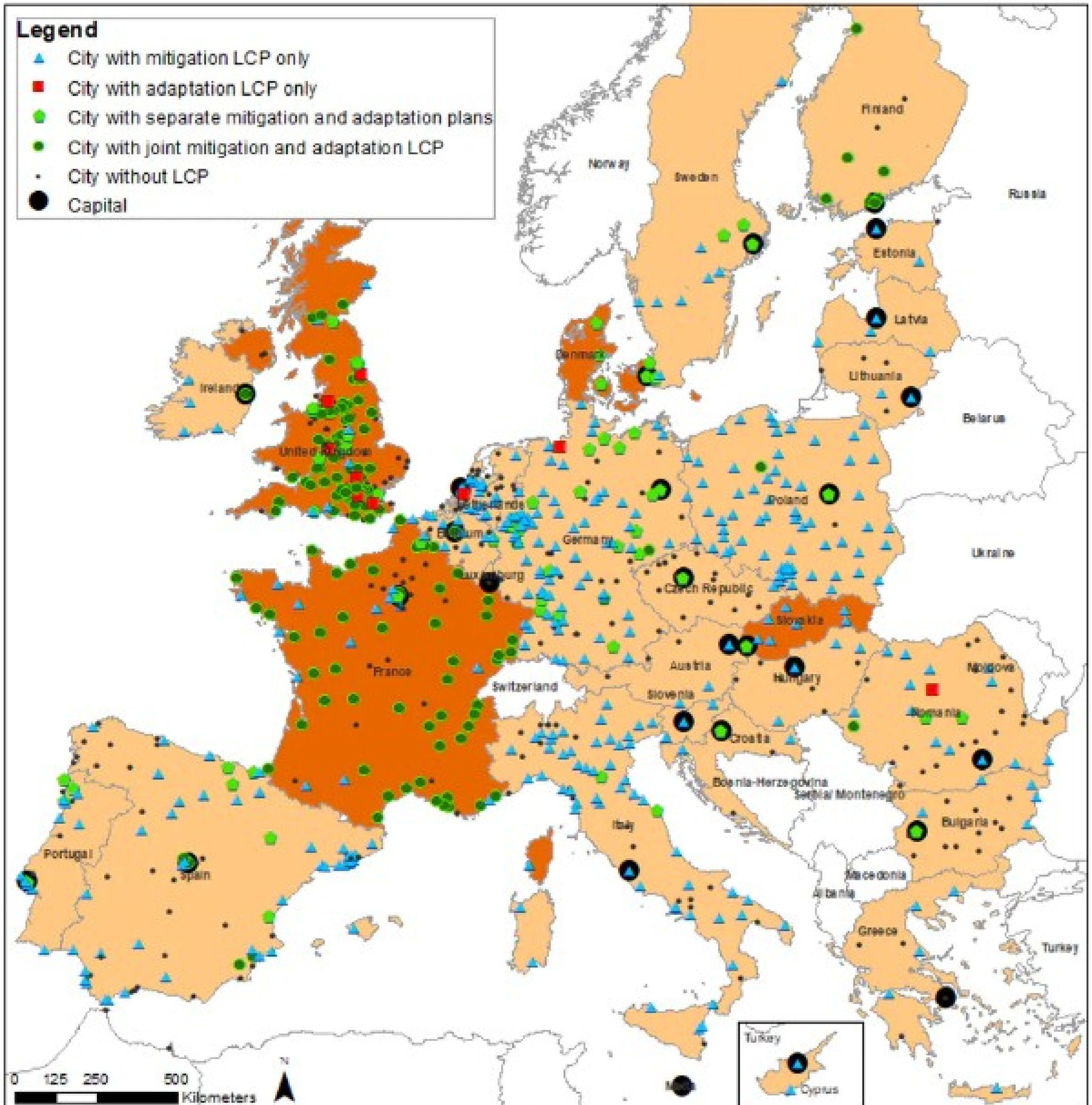
United Nations
Framework Convention on
Climate Change

195 have signed and 169 Parties have ratified of 196 Parties to the Convention

On 5 October 2016, the threshold for entry into force of the Paris Agreement was achieved. The Paris Agreement entered into force on 4 November 2016.

In June 2017, U.S. President Donald Trump announced his intention to withdraw the US. Under the agreement, the earliest effective date of withdrawal for the U.S. is November 2020.

Local efforts at Global Climate Change



March 15, 2019 – student protest

May 12, 2019 – family protest

Discussion questions

- How to convince the world that action is needed?
  - How to align international support for developing countries?
- What are the synergies between climate change mitigation and energy and agricultural crises?
  - What are bottlenecks to implementation?
- How have local people responded to climate change?
  - Adaptation
  - Mitigation

Homework #3

- What are some things that Brno has done to address Climate Change?
  - What else do you recommend?
- What can you personally do to affect climate change?

THANK YOU FOR YOUR ATTENTION