Environmental Quality Authority

EU funded project

Promoting Science & Technology

Introduction to climate science : global climate variability and change, findings of IPCC AR5

Imad Khatib

Palestine National Training Seminar on Climate Change
26 – 28 January, 2015

Project implemented by
AGRICONSULTING CONSORTIUM
Agriconsulting Agrer CMCC CIHEAM-IAM Bari
d'Appolonia Pescares Typsa Sviluppo Globale

Outline:

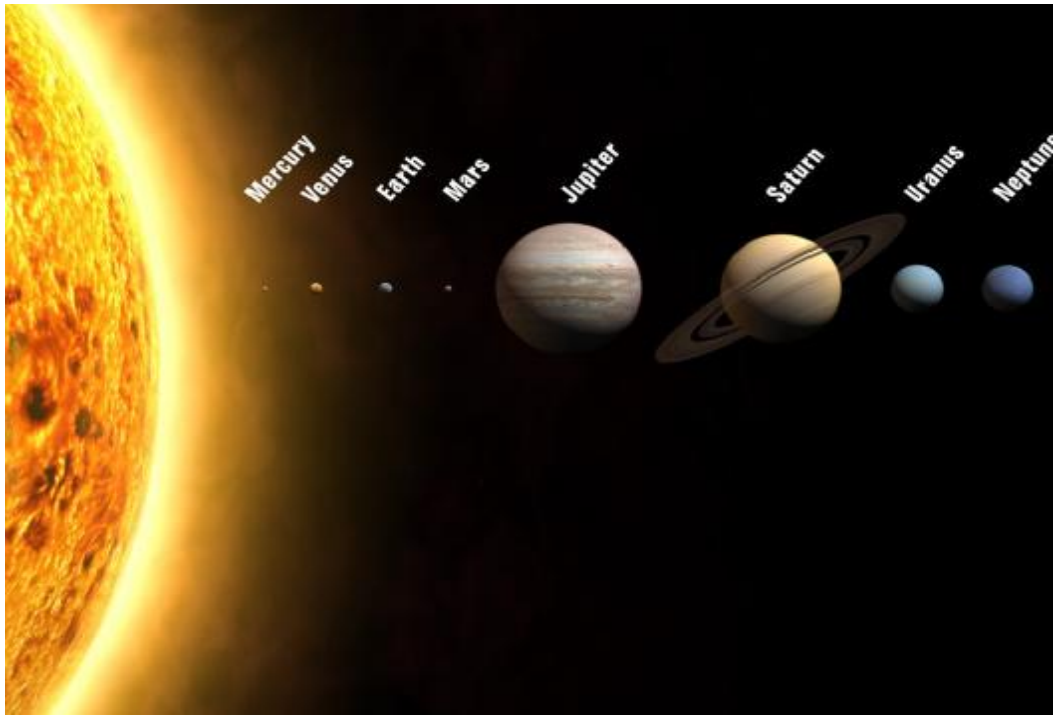
Basic Science of Climate Change

The IPCC and the AR5 findings

Climate change: East Mediterranean and Palestine, The GLOWA – Jordan River

Basic Science of Climate Change

The Earth's Place in Solar System

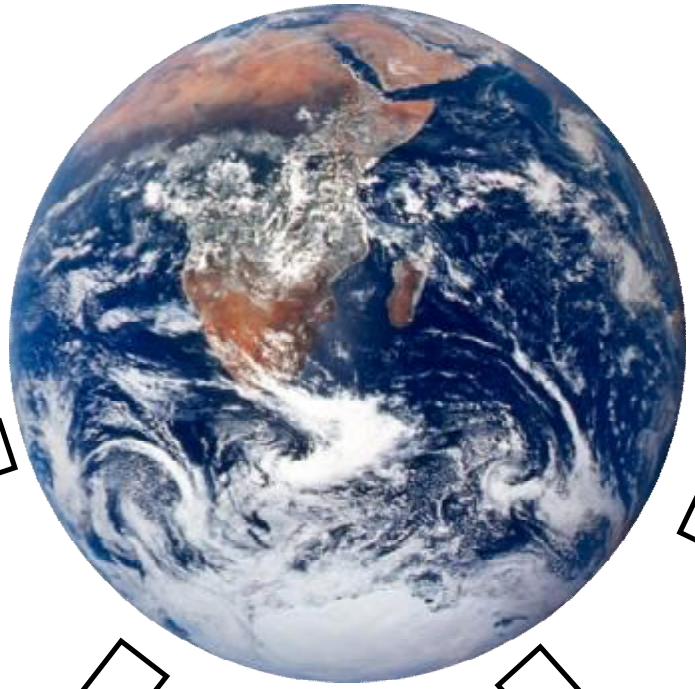


MARS:
Atmosphere: **Very thin composed of CO_2**
Mean temperature: **–65°C (-140 to +20)** **Pressure: 0.006 bar**

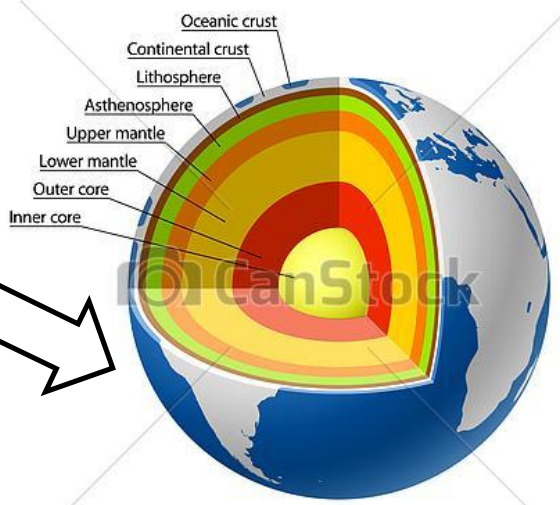
VENUS:
Atmosphere: **Thick composed mainly of CO_2**
Mean temperature: **+464°C** **Pressure: 90 bar**

EARTH:
Atmosphere: **N_2 , O_2 , H_2O and a little CO_2 (0.03%)**
Mean temperature: **+16°C** **Pressure: 1 bar**

The Earth System

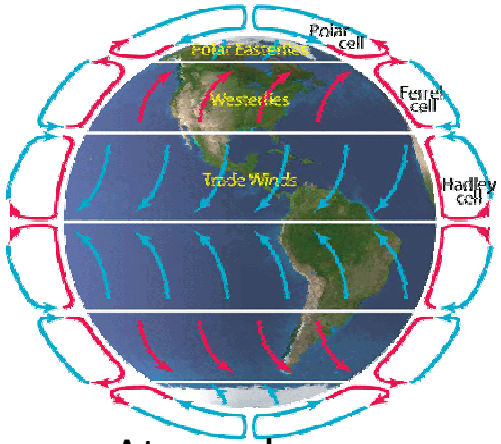


Hydrosphere



Lithosphere

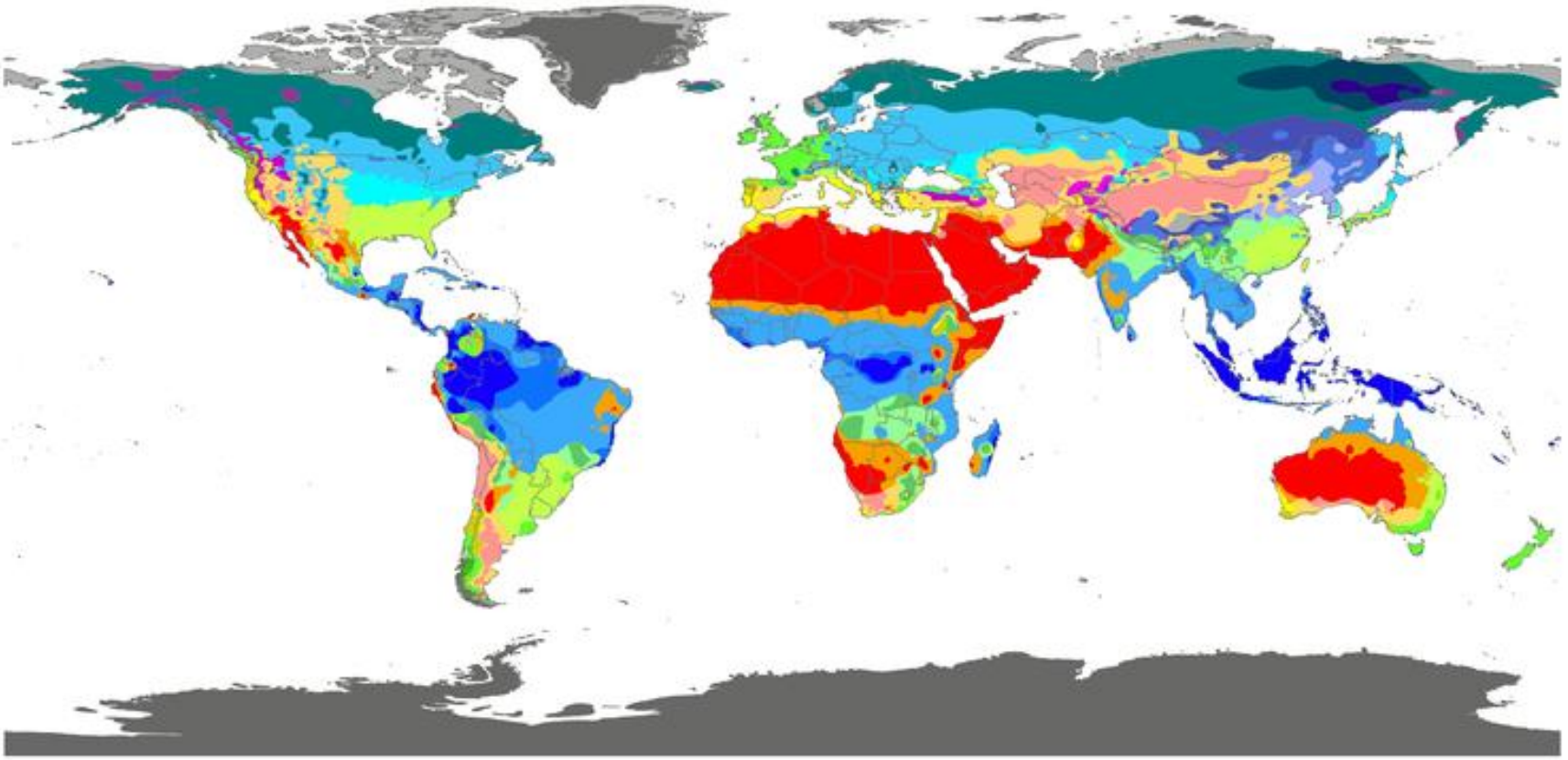
Biosphere



Atmosphere

Cryosphere

The Earth's Climate - Köppen Classifications



THE UNIVERSITY OF MELBOURNE

Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh		Cwc	Cfc	Dsc	Dwc	Dfc	
	BSk				Dsd	Dwd	Dfd	

Contact : Murray C. Peel (mpeel@unimelb.edu.au) for further information

DATA SOURCE : GHCN v2.0 station data
Temperature (N = 4,844) and
Precipitation (N = 12,396)

PERIOD OF RECORD : All available

MIN LENGTH : ≥30 for each month.

RESOLUTION : 0.1 degree lat/long

The Earth Energy Budget

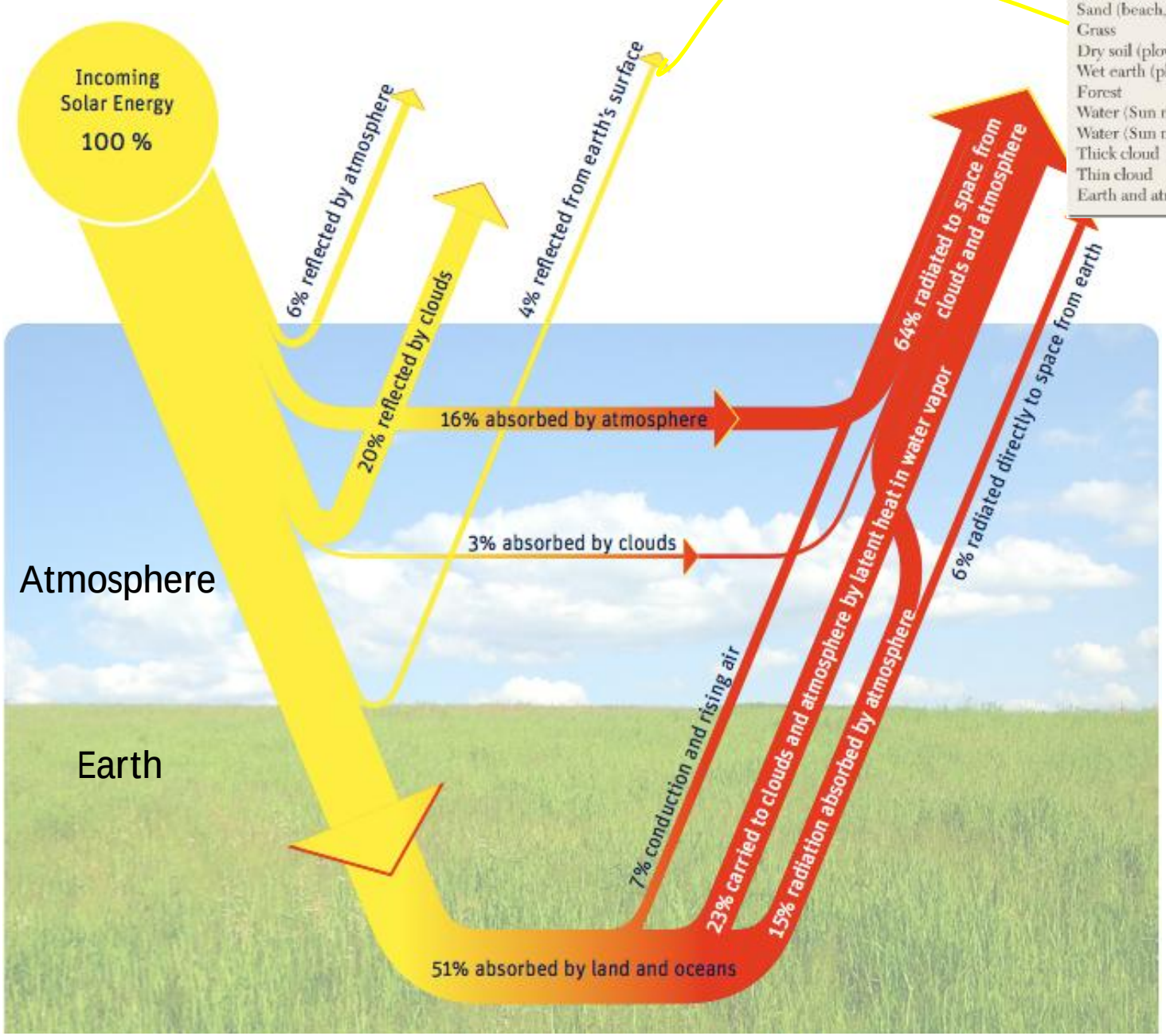


TABLE 2-3 Albedo (reflectivity) of various surfaces

Surface	Percent Reflected
Fresh snow	80–90
Old snow	50–60
Sand (beach, desert)	20–40
Grass	5–25
Dry soil (plowed field)	15–25
Wet earth (plowed field)	10
Forest	5–10
Water (Sun near horizon)	50–80
Water (Sun near zenith)	5–10
Thick cloud	70–85
Thin cloud	25–30
Earth and atmosphere (overall total)	30

The Atmosphere and the Global Mean Temperature

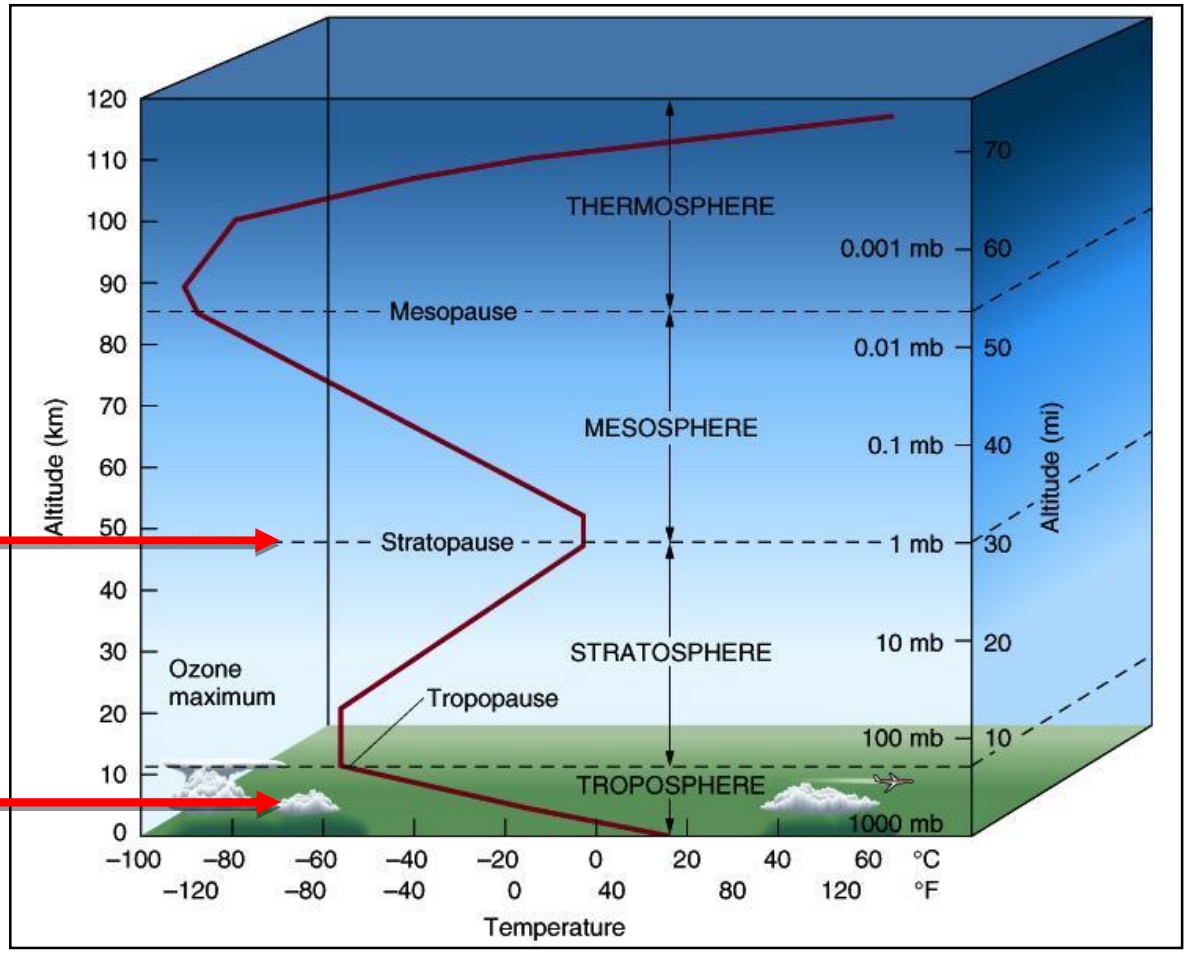
- **q** The Earth's atmosphere has 4 distinct layers that are identified by the way temperature changes with height. These layers are:
- Ø Troposphere
- Ø Stratosphere
- Ø Mesosphere
- Ø Thermosphere

50 km (-2ºC)
Main element O_3

10-16 km (-56ºC)

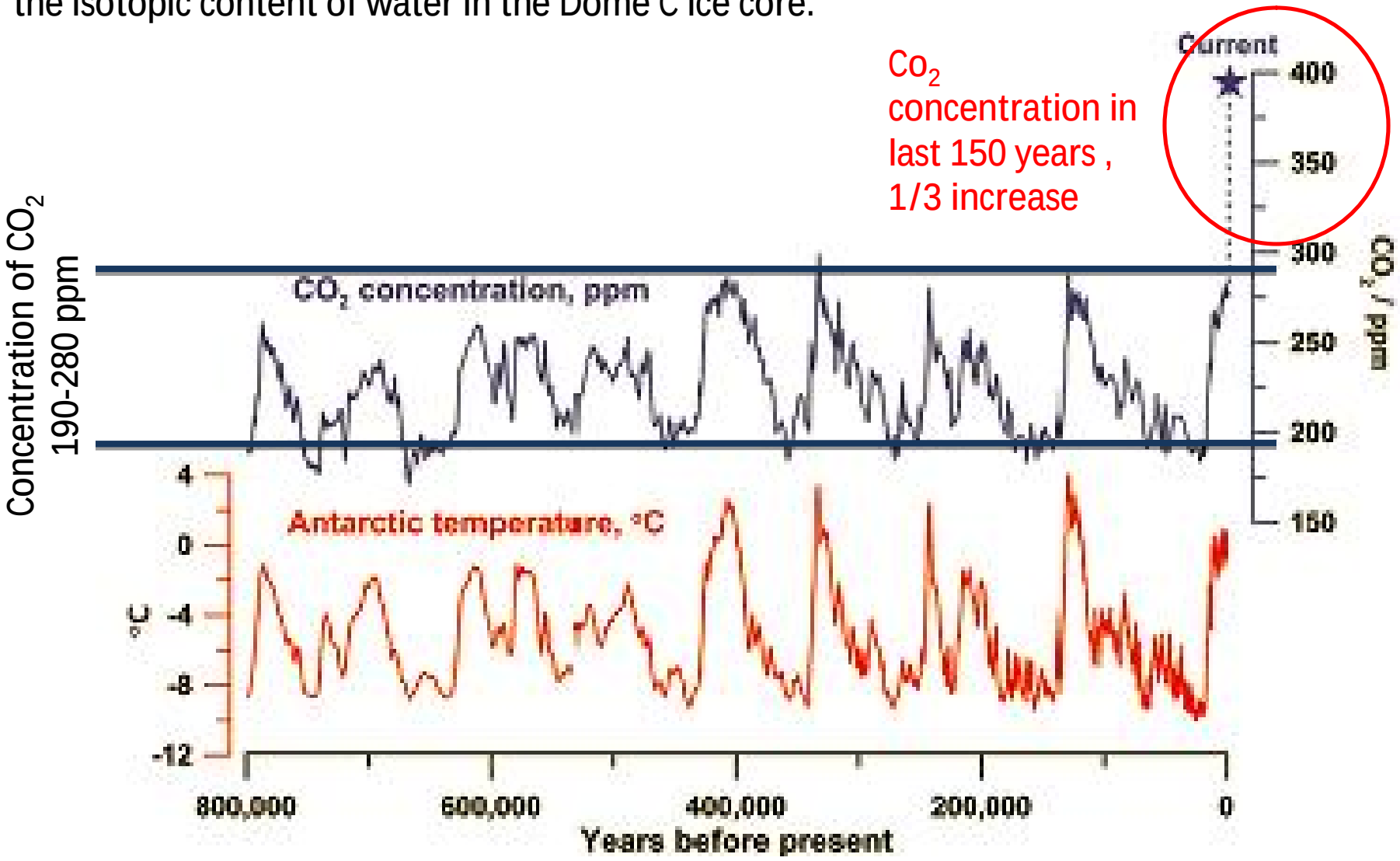
Main elements N_2,O_2,CO_2,H_2O

Global Mean Temperature 16ºC

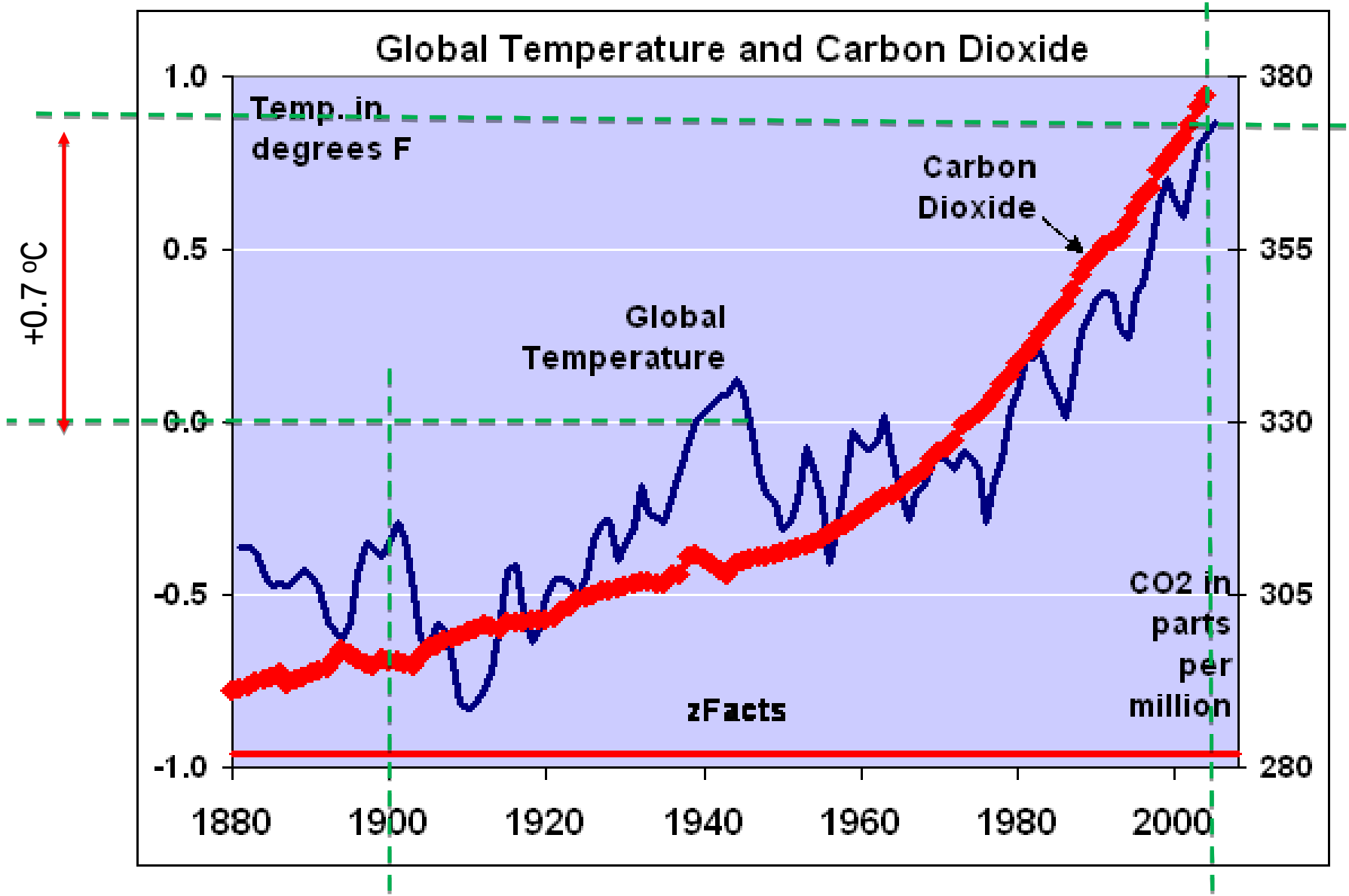


Global Earth Temperature and Carbon Dioxide

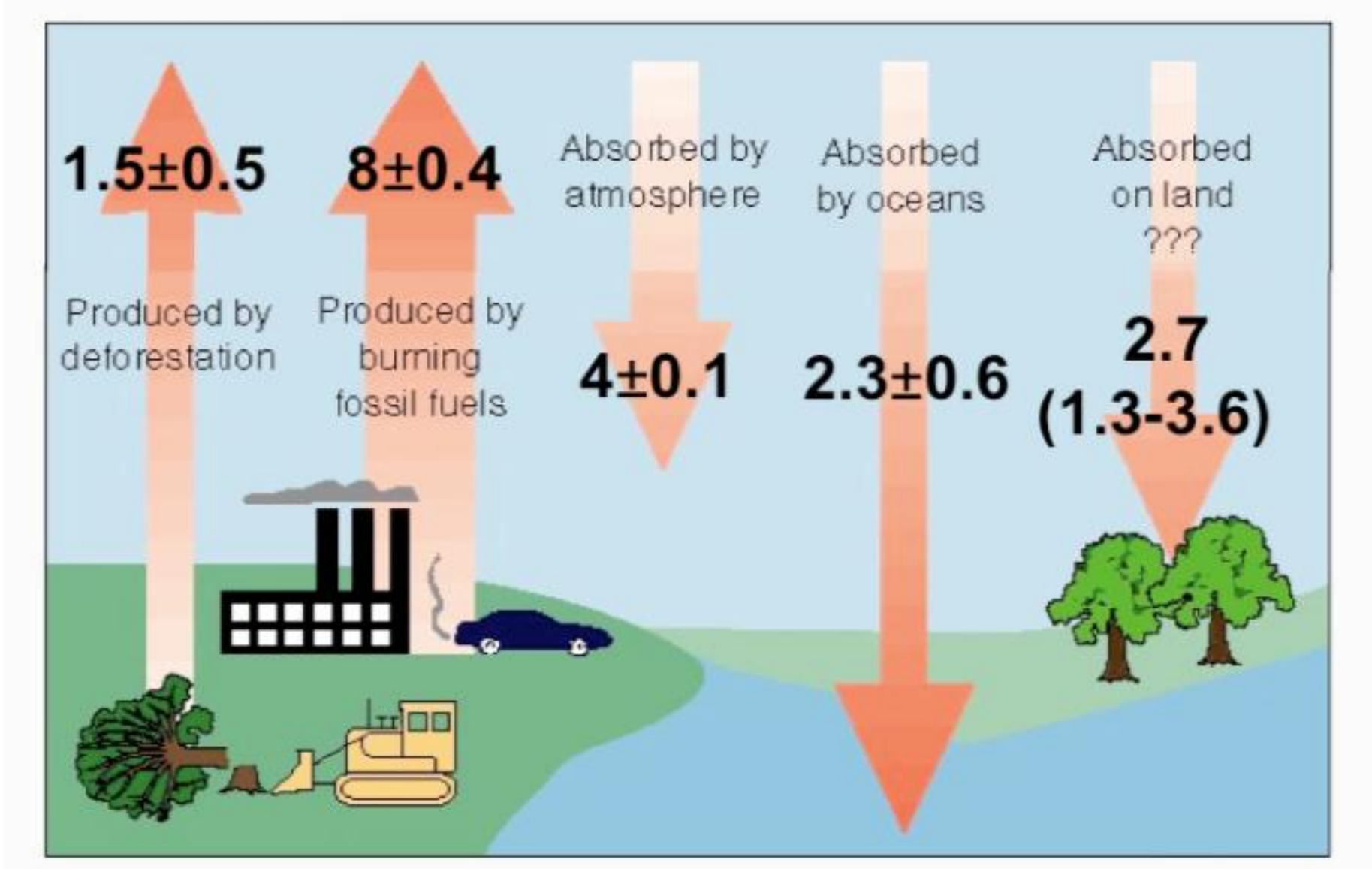
Data from ice cores have been used to reconstruct Antarctic temperatures and atmospheric CO_2 concentrations over the past 800,000 years. Temperature is based on measurements of the isotopic content of water in the Dome C ice core.



Increasing the Global Mean Temperature with CO_2 Concentration Increase



Anthropogenic CO_2 Sources and Sink (2005)



Historic study of CO2 influence on Global mean temperature:

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction: Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.

† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).

‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.

§ *Comptes rendus*, t. vii. p. 41 (1838).

Doubling concentration of CO_2 = 4 - 6 °C increase => "Climate sensitivity"

On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

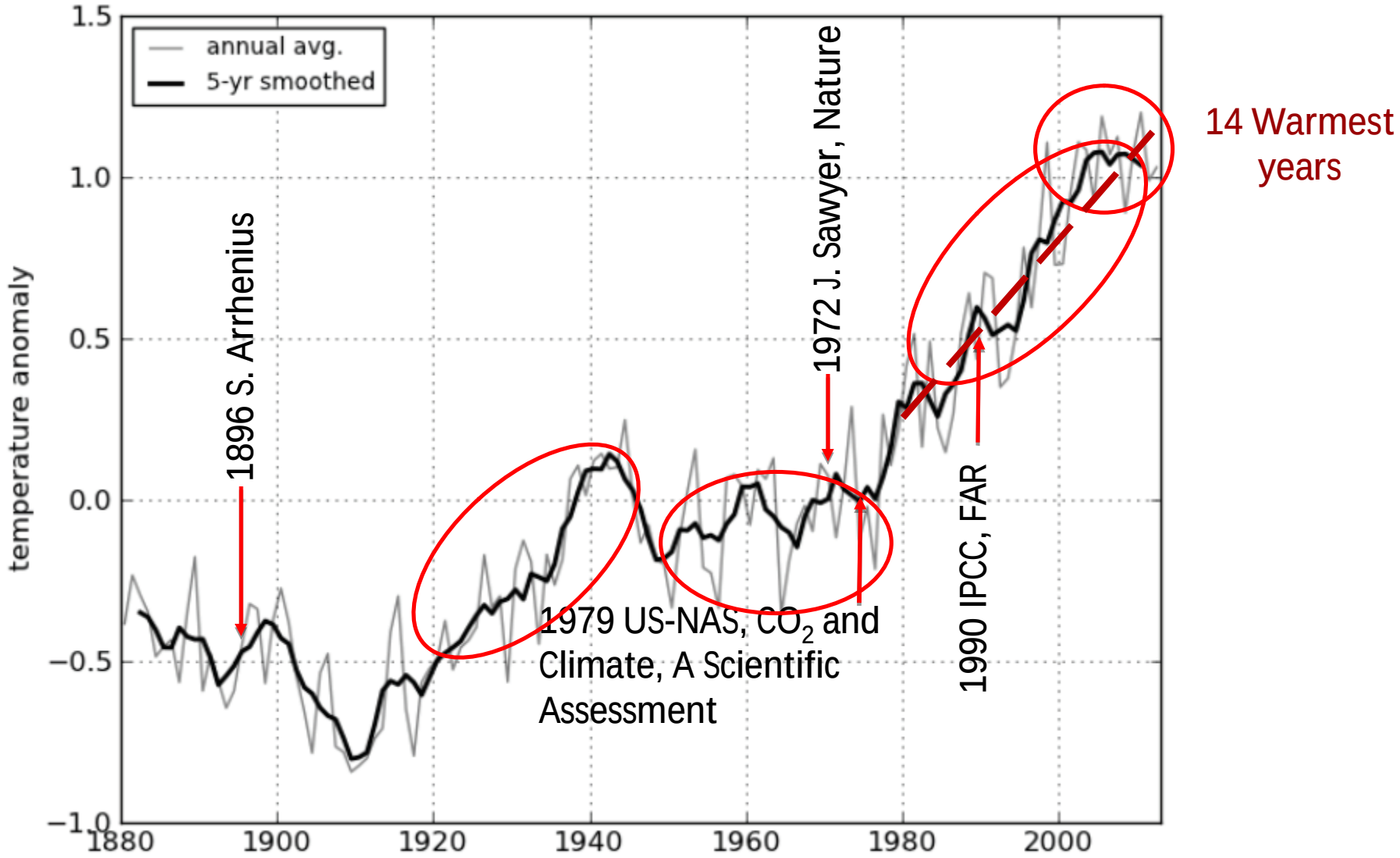
Arrhenius's paper is the first to quantif
dioxide to the greenhouse effect (Section
whether variations in the atmospheric co
have contributed to long-term variatio
Throughout this paper, Arrhenius refers t
acid" in accordance with the convention at

Contrary to some misunderstandings, A
suggest in this paper that the burning of
warming, though it is clear that he is
potentially significant source of carbon di
explicitly suggest this outcome in later wo

Portrait of Arrhenius

Svante Arrhenius 1859-1927

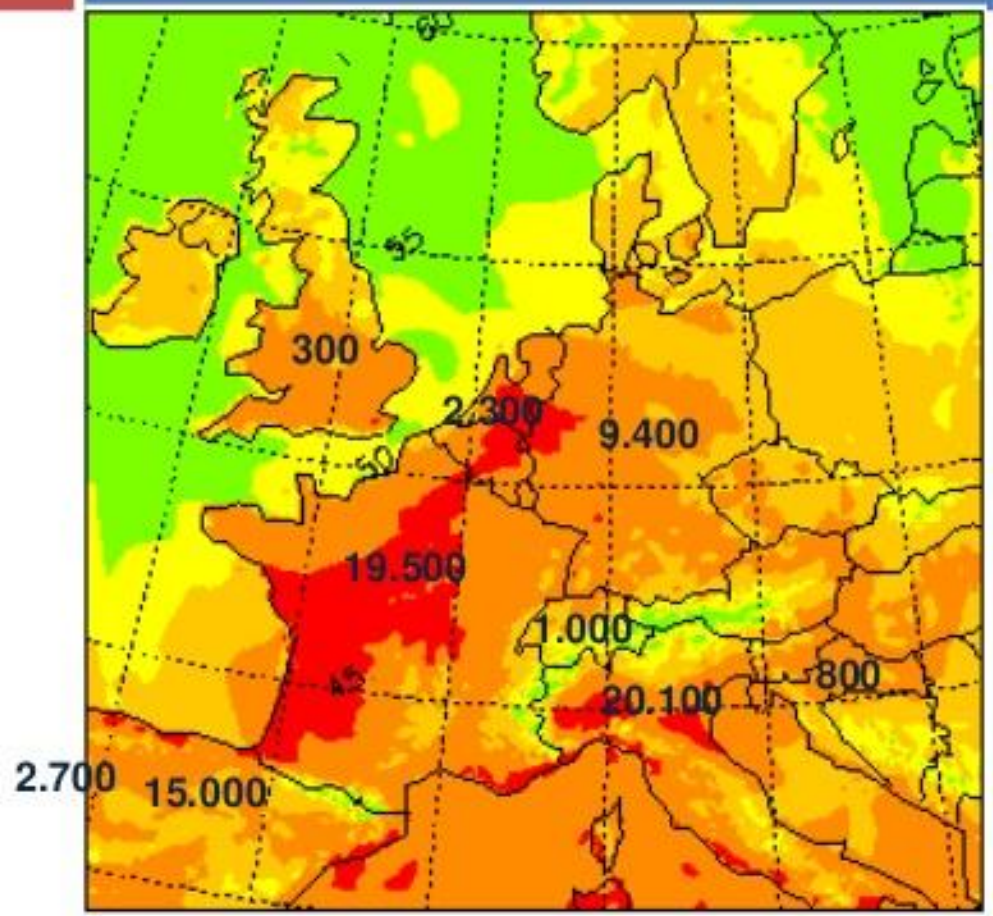
Global Earth Temperature and Carbon Dioxide



"The increase of 25% CO_2 expected by the end of the century therefore corresponds to an increase of 0.6°C in the world temperature – an amount somewhat greater than the climatic variation of recent centuries."

Global Warming and Heat Waves = the 2003 catastrophe

Heat wave of 2003, with more than 70,000 fatalities the largest humanitarian natural catastrophe in Europe for centuries



Perceived Temperature on 8 August 2003 and excess mortality

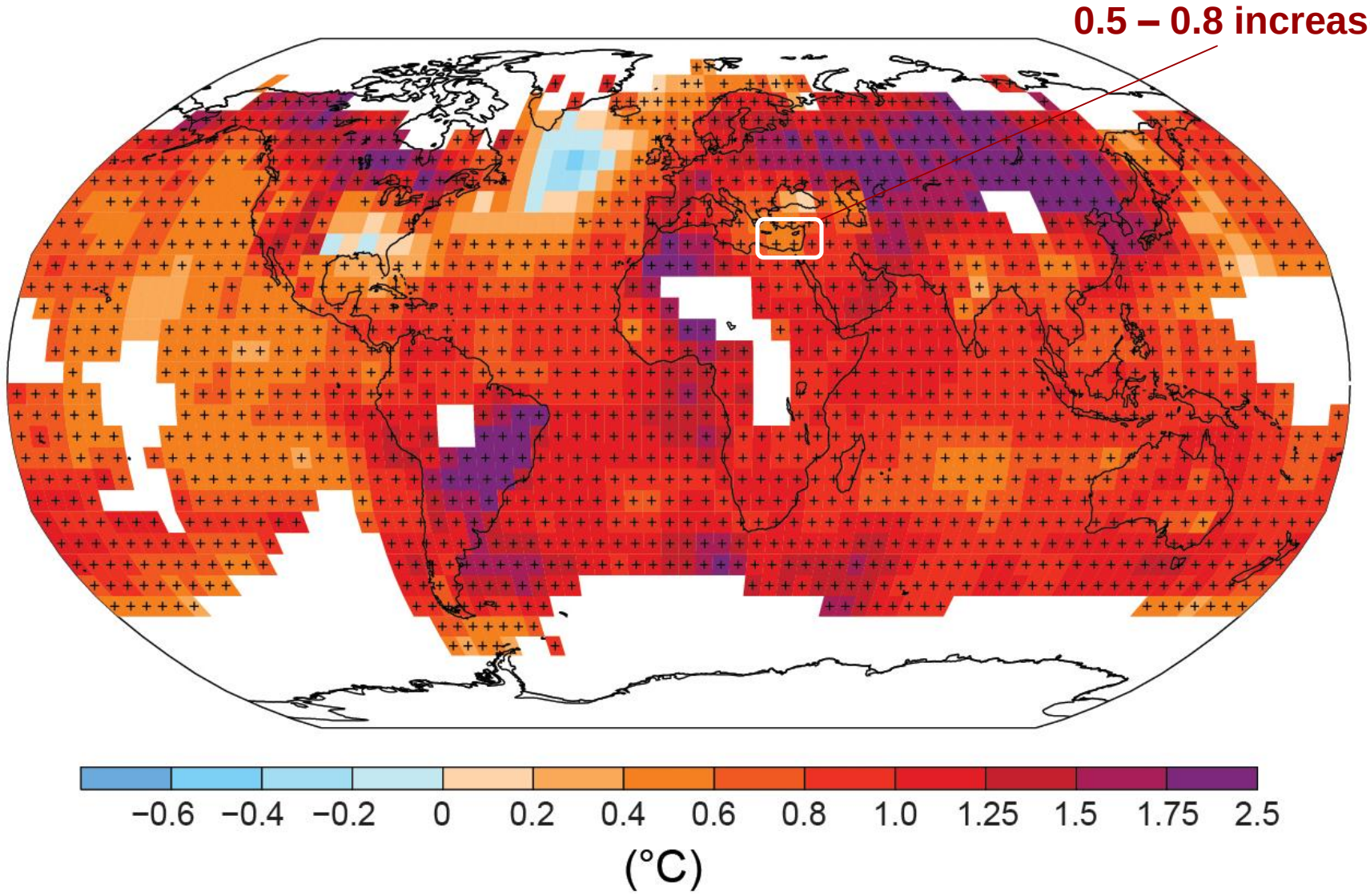
Heat stress

Cold stress

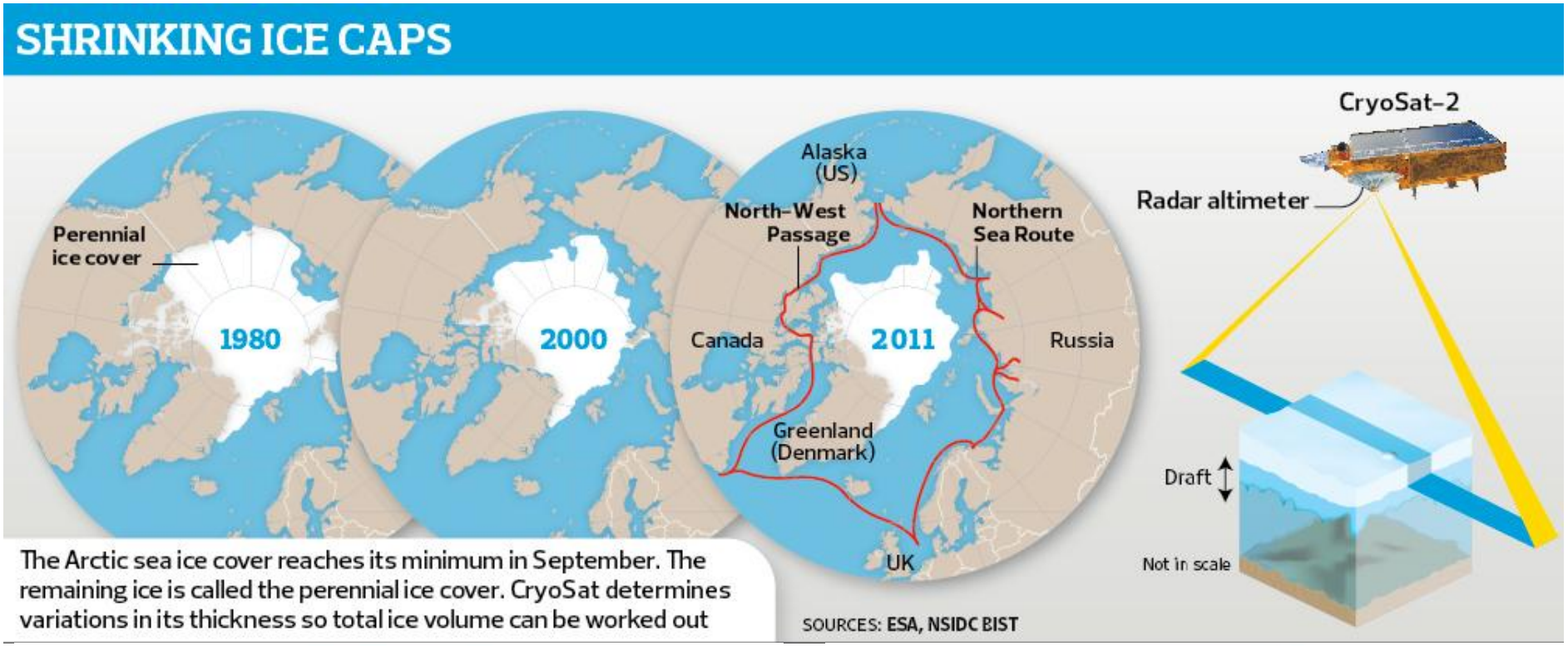
Sources: Robine et al., 2007;
German Weather Service, 2004

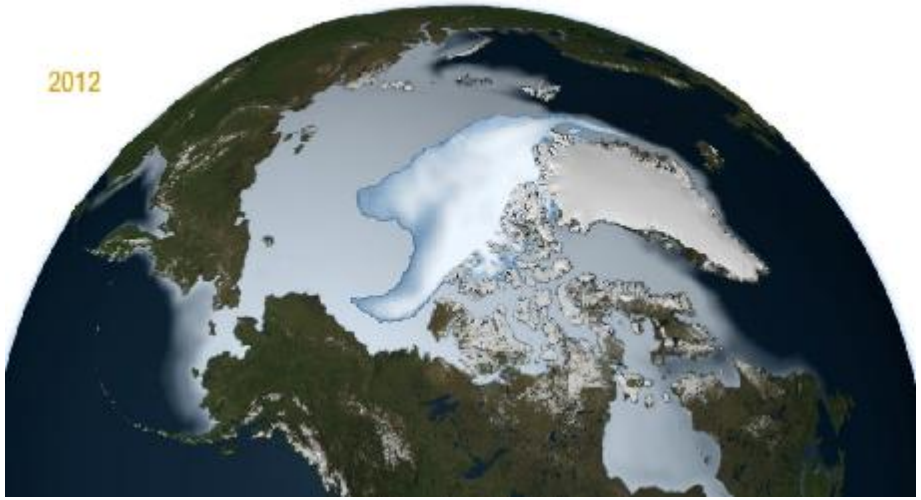
Figure SPM.1b

Observed change in surface temperature 1901-2012



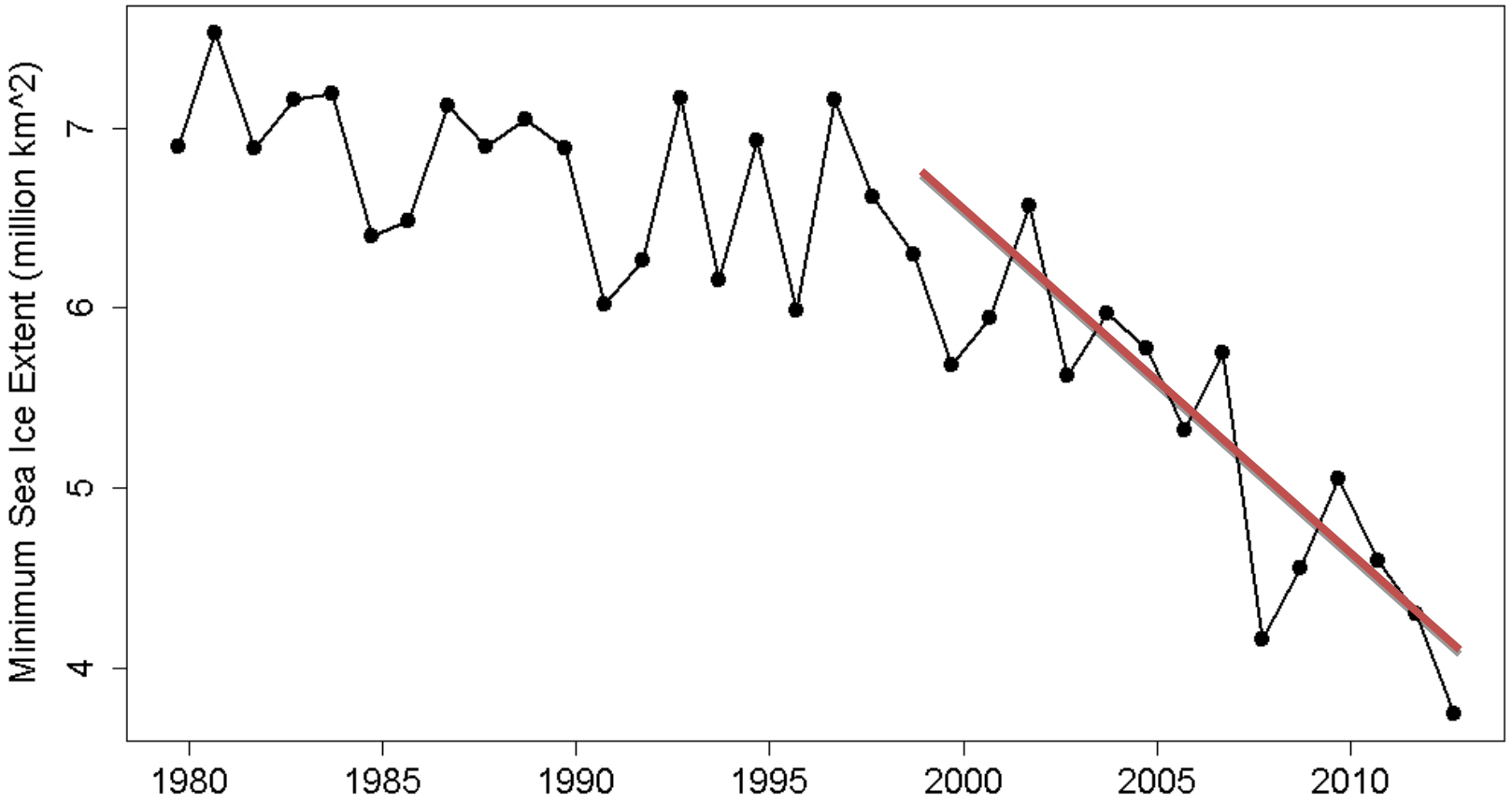
Global Warming and the Shrinking of Ice Caps = Observation



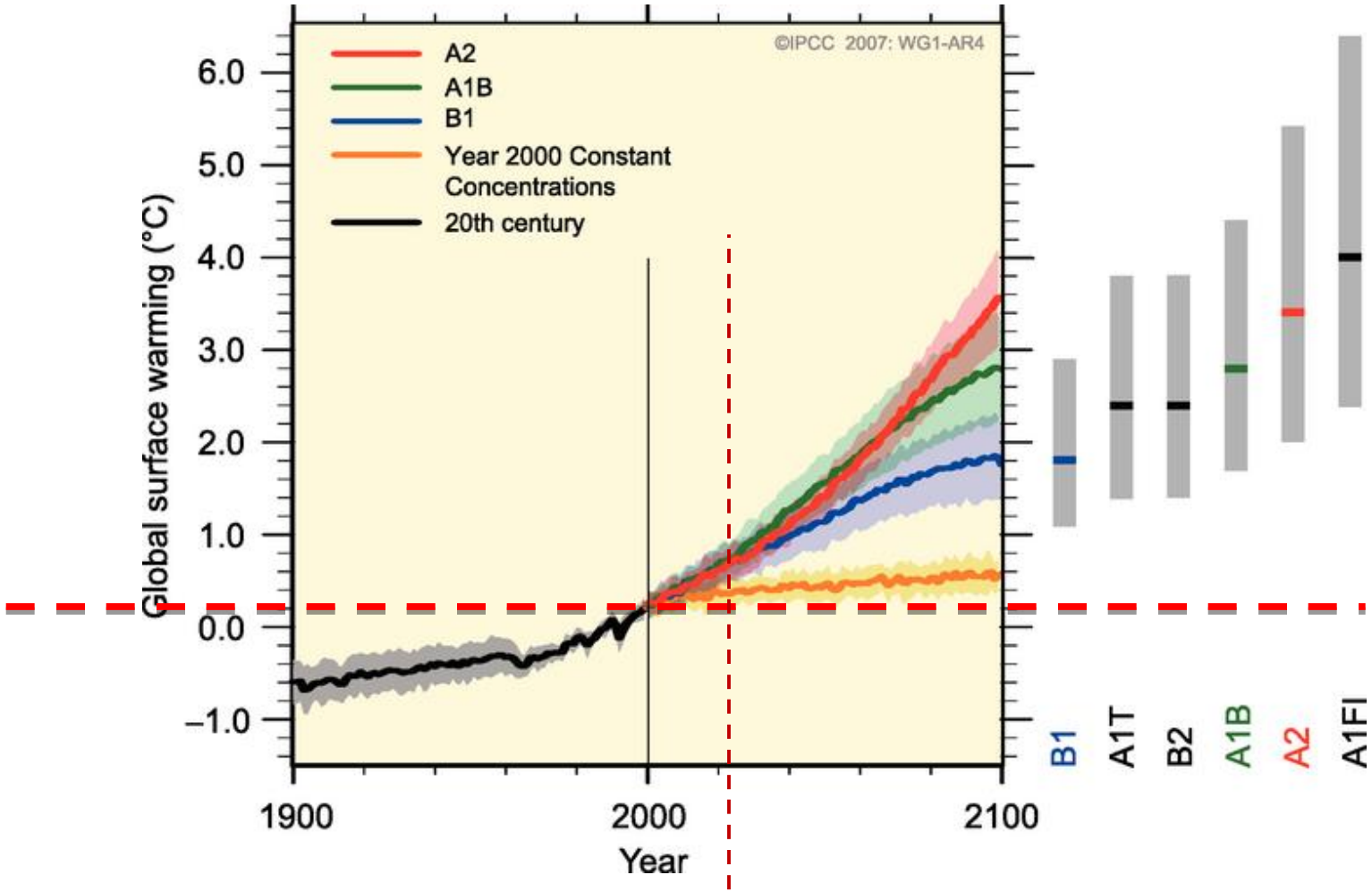


Global Warming and the Shrinking of Ice Caps = Observation

Melting of ice is accelerating in particular during the last 20 years.



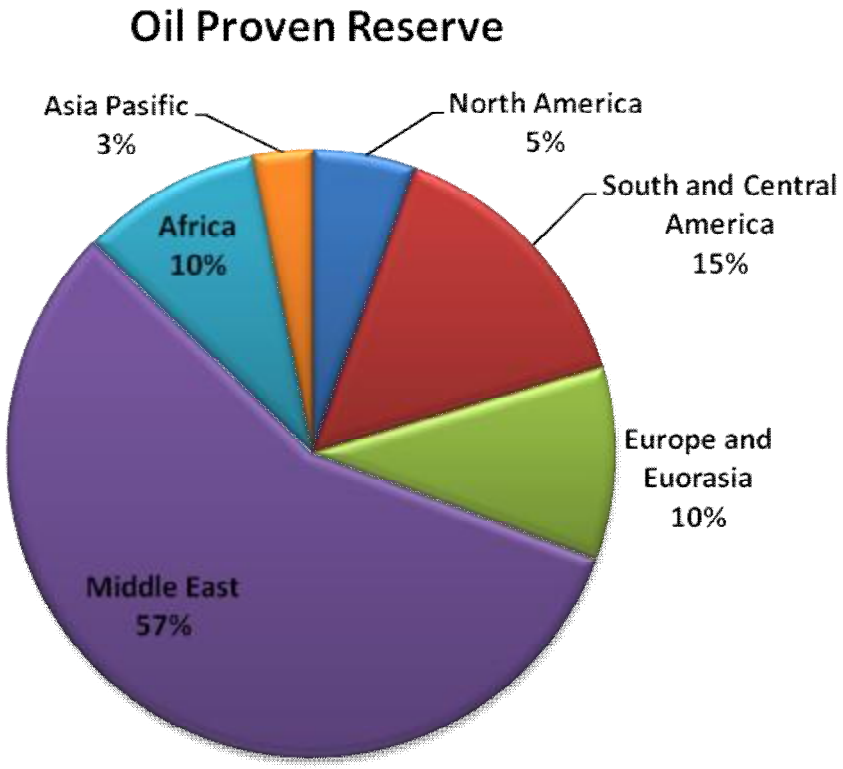
Global Warming and Future Development Scenarios

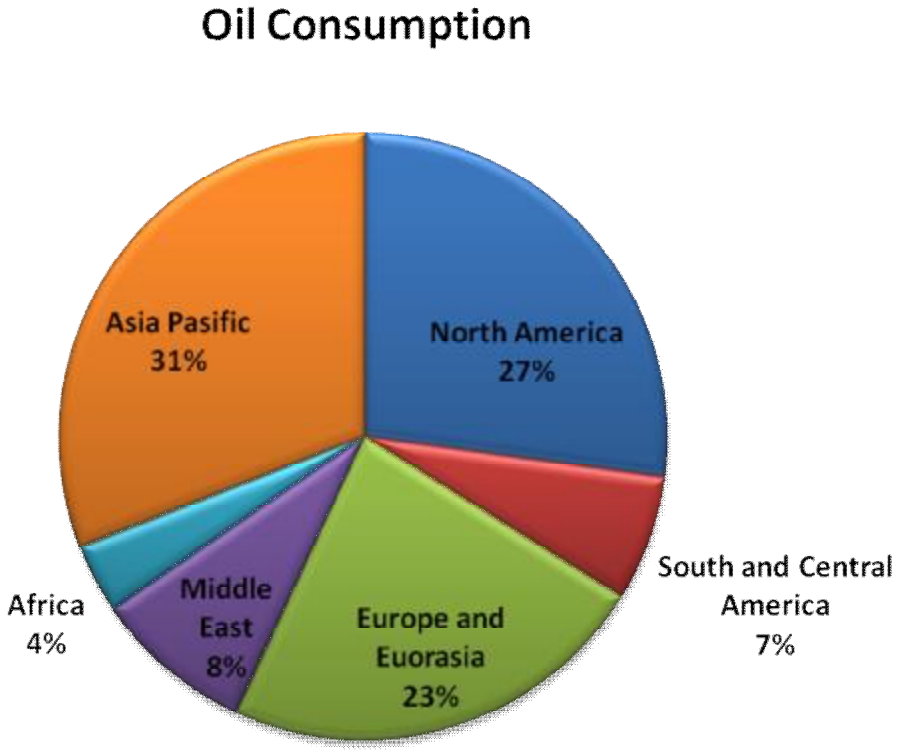


0.5 °C for all Scenarios until 2030

Where does man-made CO_2 comes from?

The Hydrocarbon fuel: Oil





World total proven reserve until end 2009: ***1,333 TMB***

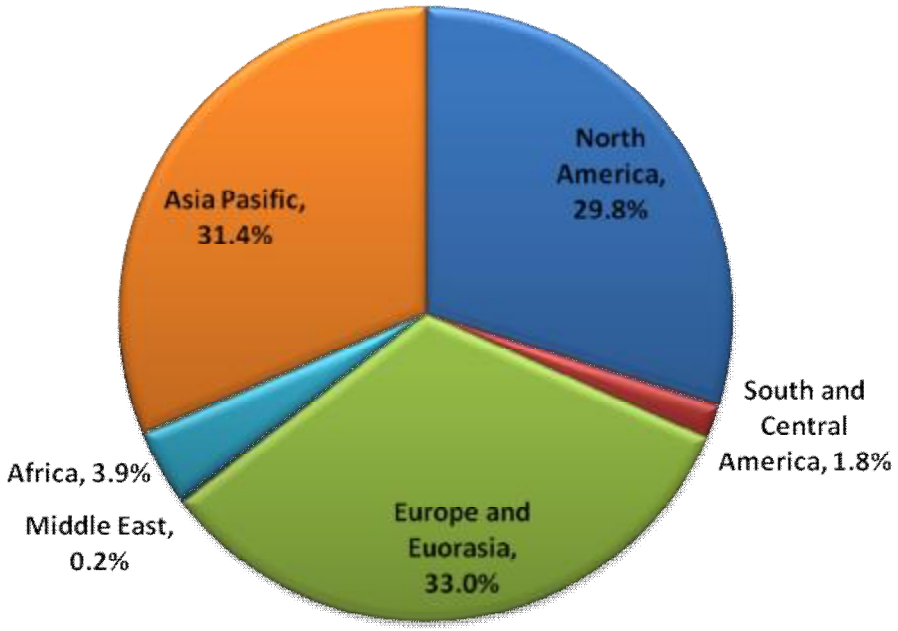
Largest Reserves: Saudi Arabia (***21%***), Iran (***11%***), Iraq (***9%***), Kuwait (***8%***) and UAE (***7.8%***)

Source: BP Statistical Review, (2010)

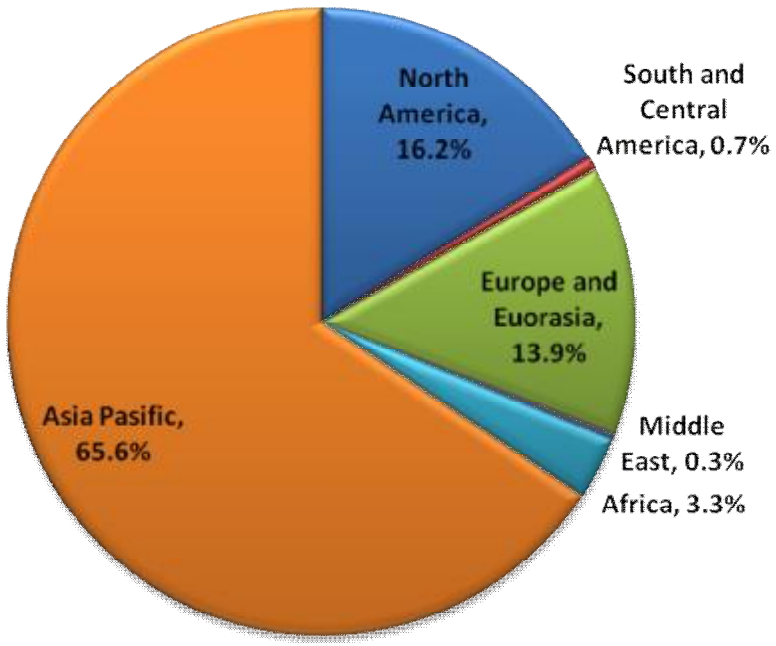
Where does man-made CO_2 comes from?

The Hydrocarbon fuel: Coal

Coal reserve



Coal consumption



World total proven reserve until end 2009: ***8,260,001 MT***

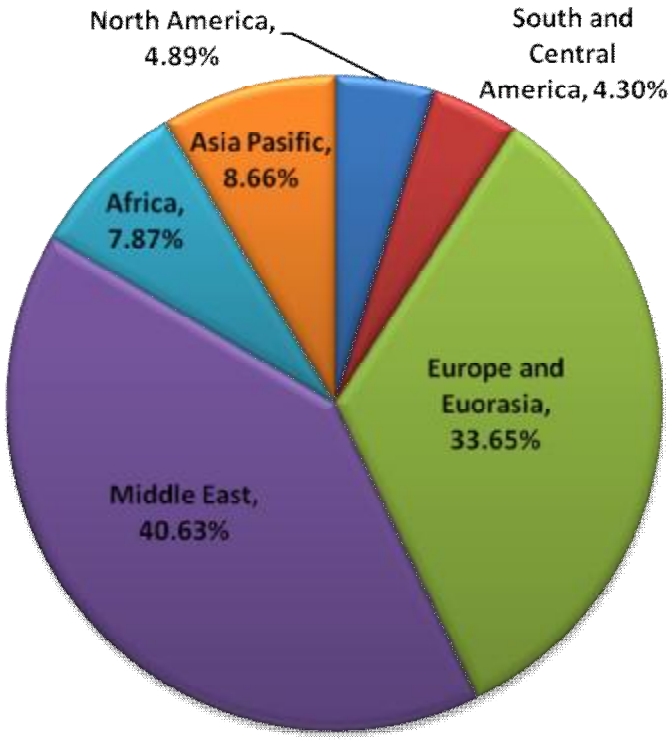
Largest Reserves: USA (***28.9%***), Russia (***19%***), China (***13.9%***) and Australia (***9.2%***)

Source: BP Statistical Review, (2010)

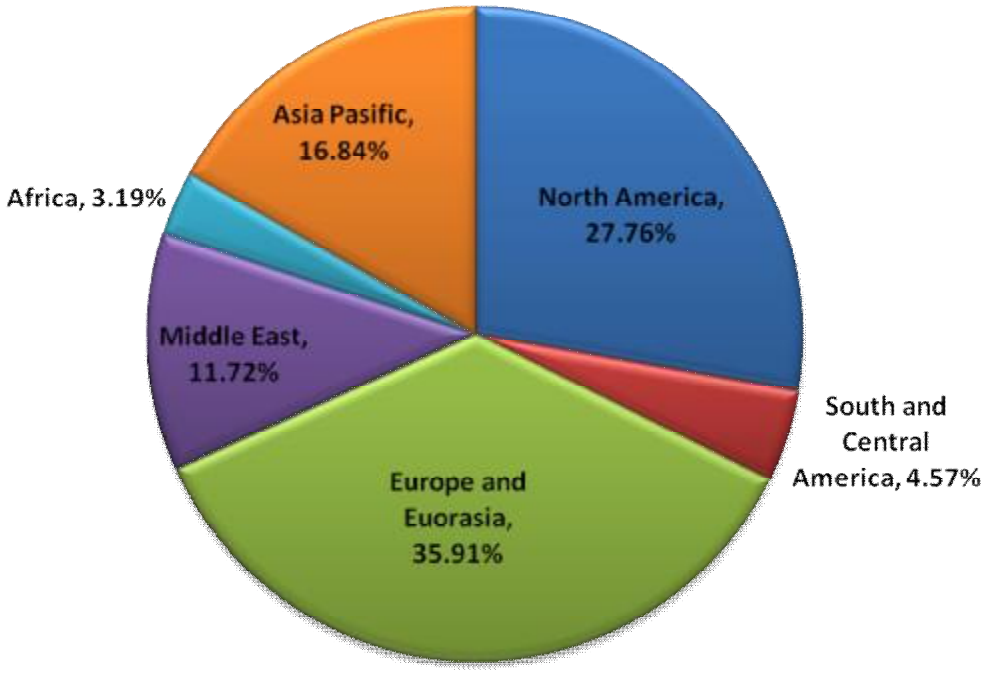
Where does man-made CO_2 comes from?

The Hydrocarbon fuel: Natural Gas

Natural Gas reserve



Natural Gas Consumption



World total proven reserve until end 2009: ***8,260,001 MT***

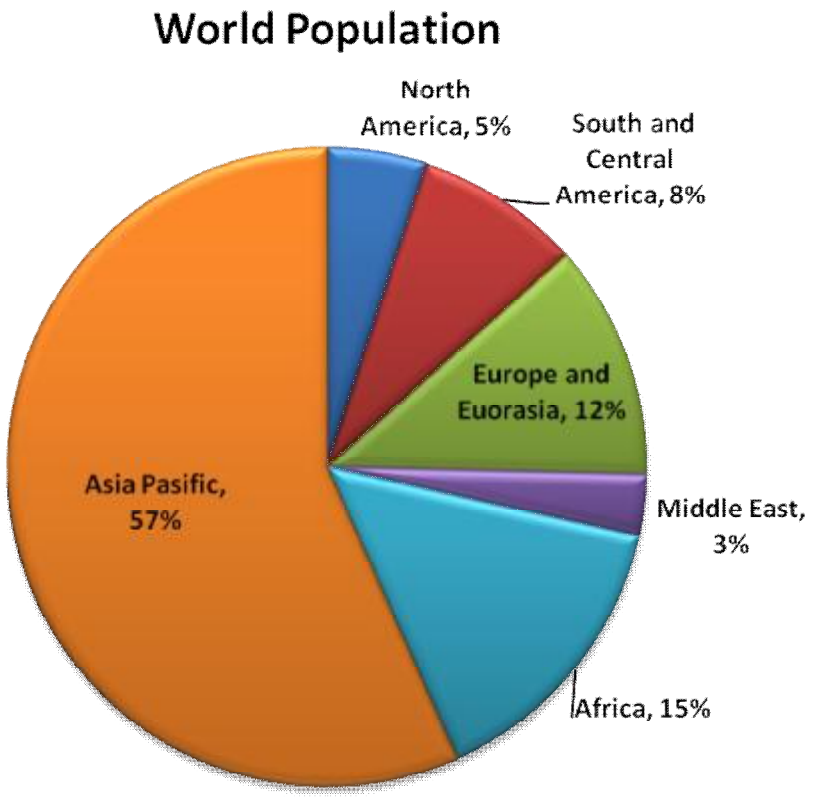
Largest Reserves: Russian Federation (***23.7%***), Iran (***15.8%***) and Qatar (***13.5%***)

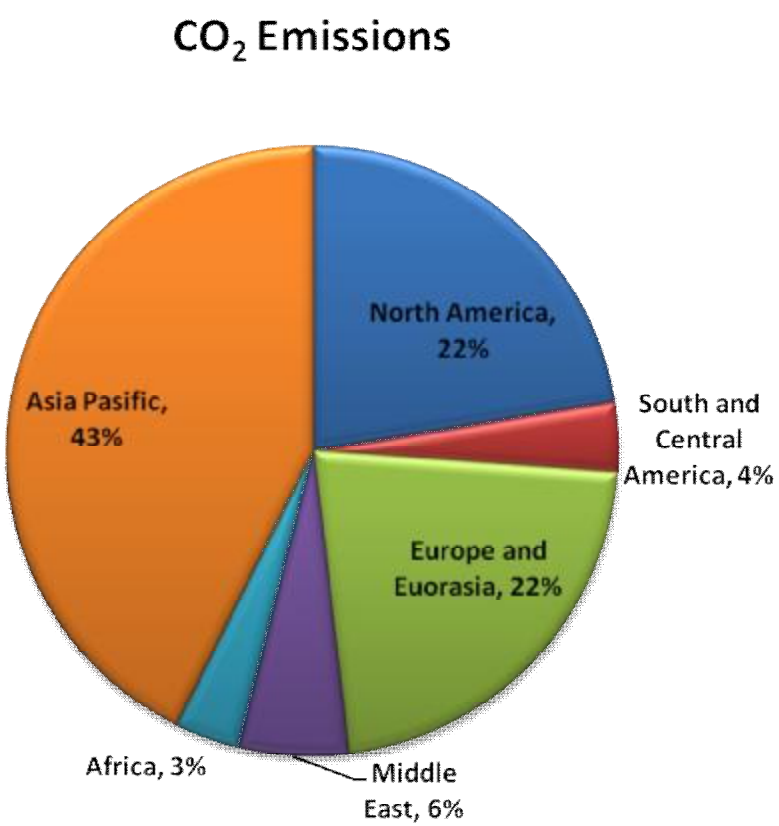
December 2011: Israel discovery of the World Largest Natural Gas Reserve

Source: BP Statistical Review, (2010)

Where does man-made CO_2 comes from?

CO_2 Emitters





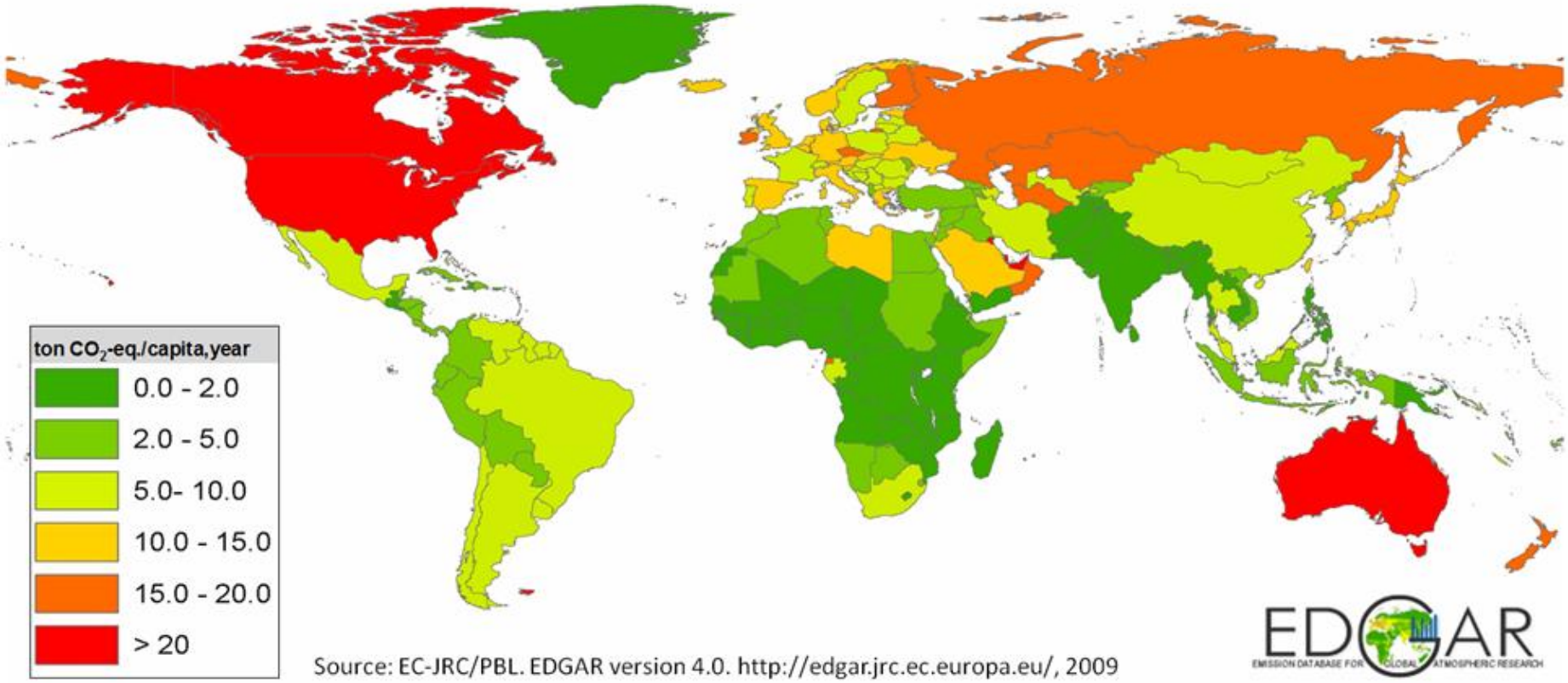
World population until End 2009: ***6,827,469,356***

(Source: Population Reference Bureau, 2010)

World total CO_2 Emission until End 2009:***31130 MT***

(Source: BP Statistical Review, 2010)

Where does man-made CO_2 comes from?



The IPCC and the AR5 Findings

Climate Change in a Context – Timeline

1979 First World Climate Conference (WCC) organized by WMO in Geneva

1988 The set up of the Intergovernmental Panel on Climate Change (IPCC) by WMO and UNEP in recognition of the Global Warming

1990 The IPCC's First Assessment Report is released coinciding with the Second WCC held in Geneva. The development at the WCC has lead to the establishment of the United Nations Framework Convention of Climate Change (UNFCCC) and the establishment of the Global Climate Observatory System (GCOS) for climate and climate-related observations.

1991 First meeting of the Intergovernmental Negotiating Committee (INC) takes place.

1992 The Earth Summit is Rio and the adoption of the UNFCCC text by the INC. The UNFCCC is opened for signature. The development of the Kyoto Protocol (KP).

1994 UNFCCC enters into force.

1995 The IPCC's Second Assessment Report is released. The first Conference of the Parties (COP 1) takes place in Berlin

Climate Change in a Context – Timeline

1996 The UNFCCC Secretariat is set up to support action under the convention.

1997 KP formally adopted in December at COP 3 in Kyoto, JAPAN.

2001 The IPCC's Third Assessment Report (TAR) is released. Marrakesh Accords adopted at COP 7, detailing rules for implementation of KP. Setting up new funding and planning instruments for adaptation.

2005 KP enters into force. The first Meeting of Parties to Kyoto Protocol (MOP 1) in Montreal. Parties launching negotiations on the next phase of KP.

2007 The IPCC's Fourth Assessment Report (AR4) released. Climate Science enters into popular consciousness. COP 13 and the agreement of parties on the Bali Road Map.

2009 Copenhagen Accord drafted at COP 15 in Copenhagen. Countries later submitted emissions reduction pledges or mitigation action pledges.

2010 Cancun Agreements drafted and largely accepted at COP 17

Climate Change in a Context – Timeline

2011 The Durban Amendment to the KP is adopted at COP 17.

2012 The Doha Amendment (2012 – 2020) to KP is adopted. COP 18.

2013 Key decisions adopted at COP 19 including the Green Climate Fund and Long-Term Finance.

2014 The IPCC's Fifth Assessment Report (AR5) relapsed.

The IPCC

Established in 1988 by

- World Meteorological Organization (WMO)
- United Nations Environment Program (UNEP)

Supports the UN Framework Convention on Climate Change (UNFCCC)

- Adopted in 1992 and entered into force in 1994.
- Overall policy framework for climate change issue

Its role:
"assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation“

"The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature."

The IPCC

Working Groups and Task Forces

Working Group I (WGI) - "The Physical Science Basis"

Working Group II (WGII) - "Impacts, Adaptation and Vulnerability"

Working Group III (WGIII) - "Mitigation of Climate Change"

Task Force on National Greenhouse Gas Inventories

The IPCC

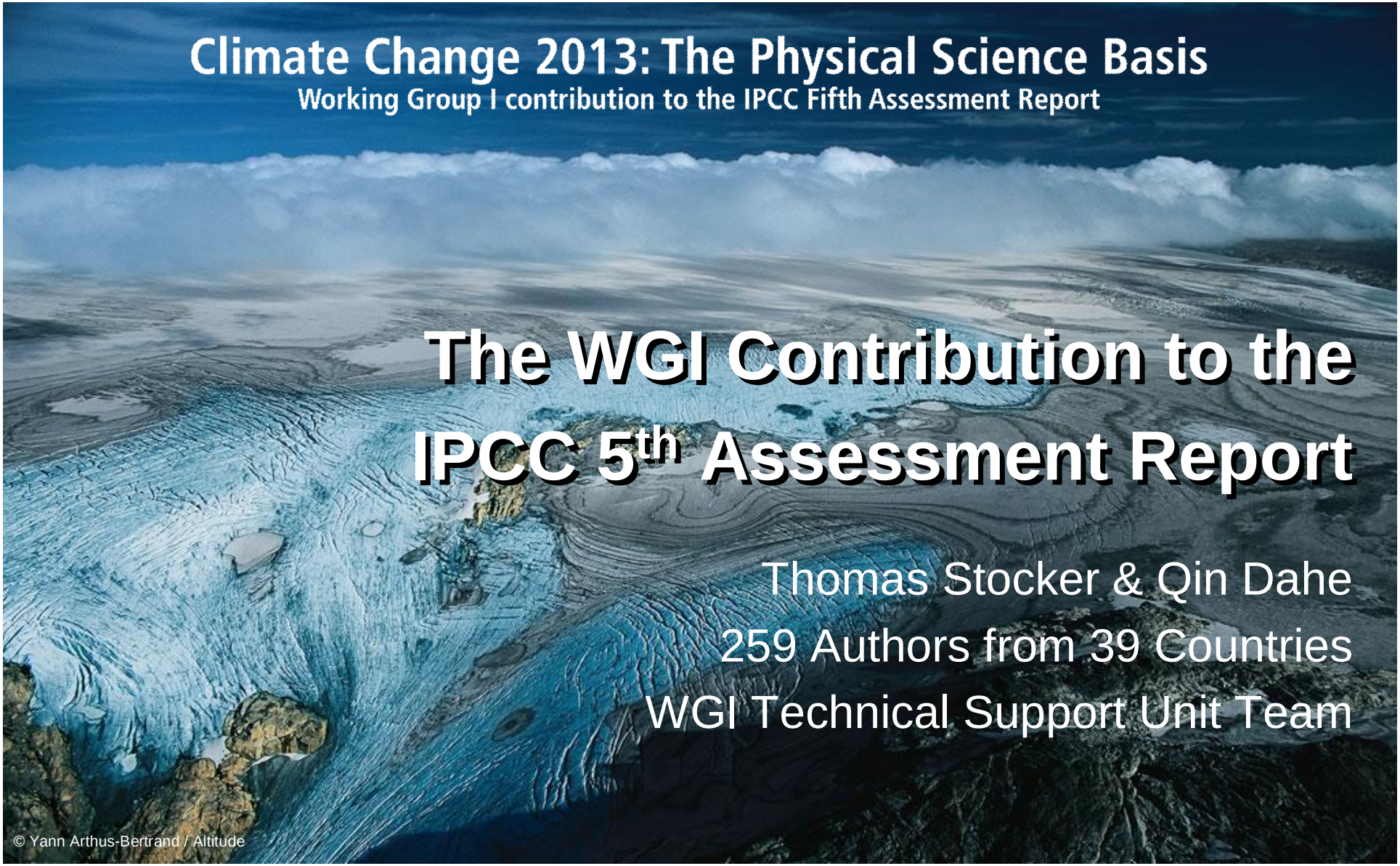
The Fifth Assessment Report – AR 5

WG I: The Physical Science Basis – 30 September 2013, Summary for Policymakers published 27 September 2013.

WG II: Impacts, Adaptation and Vulnerability – 31 March 2014

WG III: Mitigation of Climate Change – 11 April 2014

AR5 Synthesis Report (SYR) – 2 November 2014



The WGI Contribution to the IPCC 5th Assessment Report

Thomas Stocker & Qin Dahe
259 Authors from 39 Countries
WGI Technical Support Unit Team

www.climatechange2013.org

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Key SPM Messages

19 Headlines

on less than 2 Pages

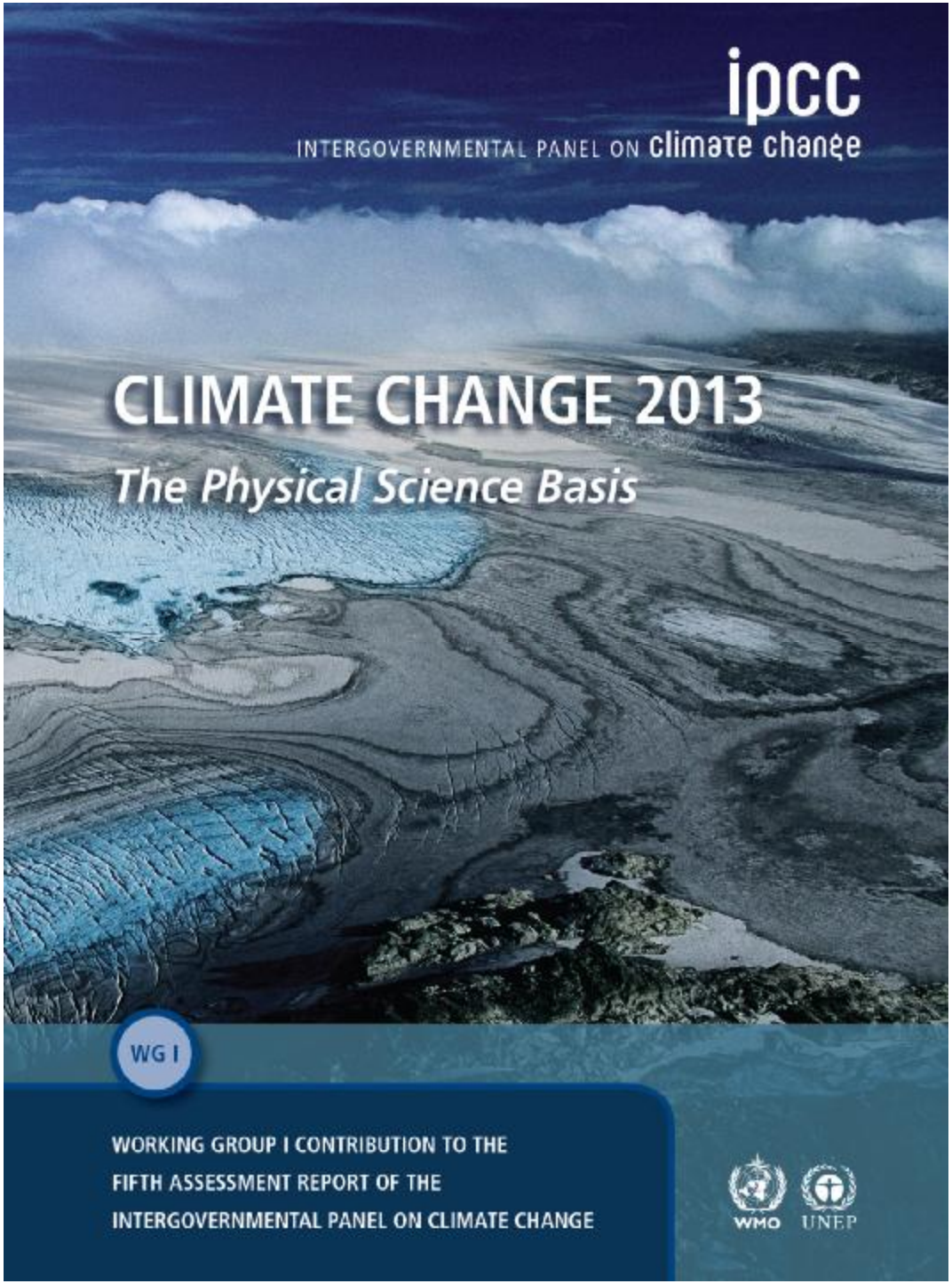
Summary for Policymakers
ca. 14,000 Words

14 Chapters
Atlas of Regional Projections

54,677 Review Comments
by 1089 Experts

2010: 259 Authors Selected

2009: WGI Outline Approved



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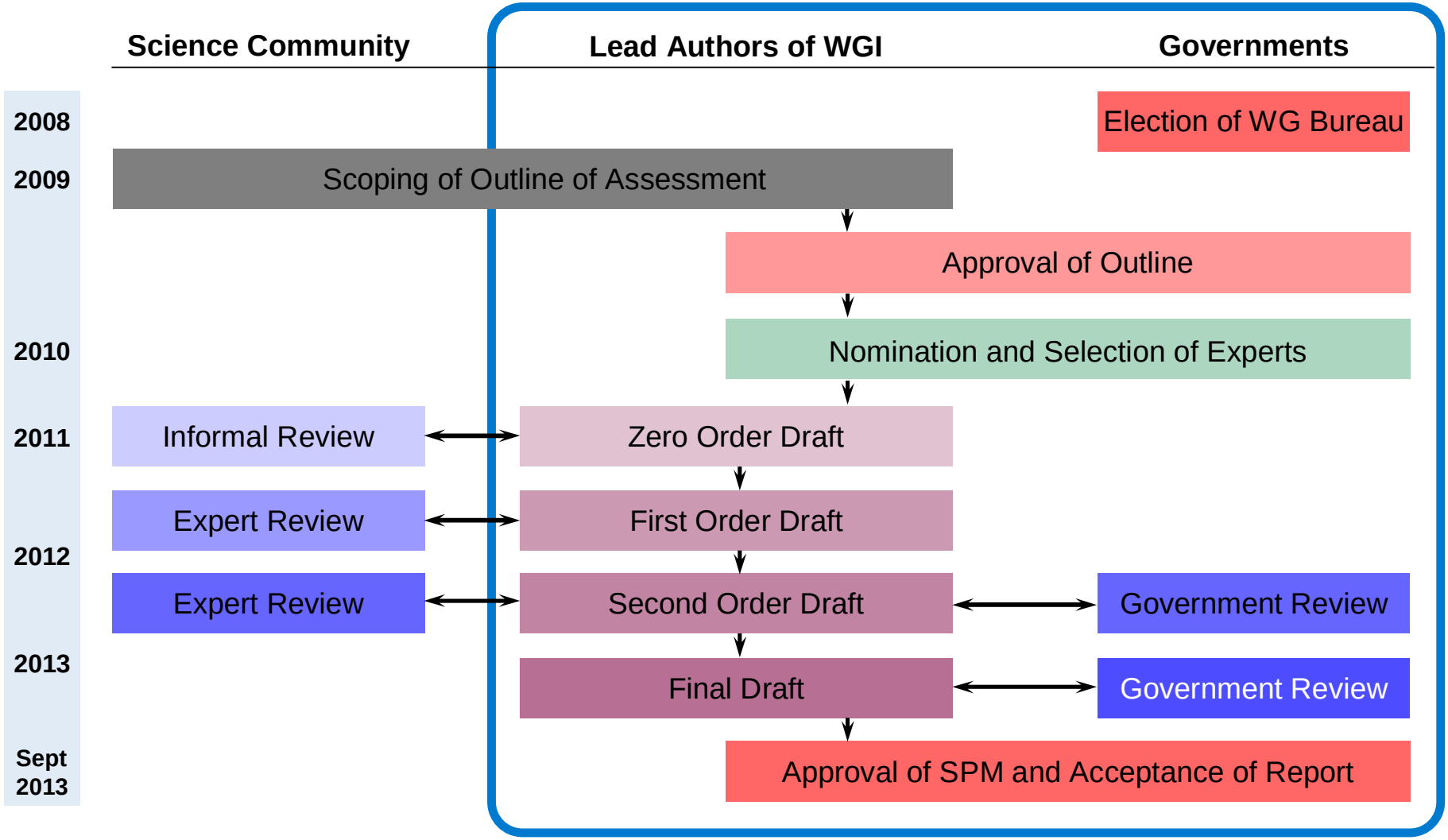
3rd Lead Author Meeting, Marrakech, Morocco, April 2012

Development Process of the WGI Contribution to the IPCC 5th Assessment Report



New findings since the Fourth Assessment Report

Increased certainty of a human influence on climate

Improved observations & models and increased understanding of many components of the climate system

New emission scenarios and projections of climate change beyond 2100 to 2300

Sea level rise projections include ice-sheet dynamical changes

Estimates of the total allowable global emissions in order to limit temperature rise to e.g. 2°C above pre-industrial

WGI Summary for Policymakers

Figures

Figure SPM.1b

Observed change in surface temperature 1901-2012

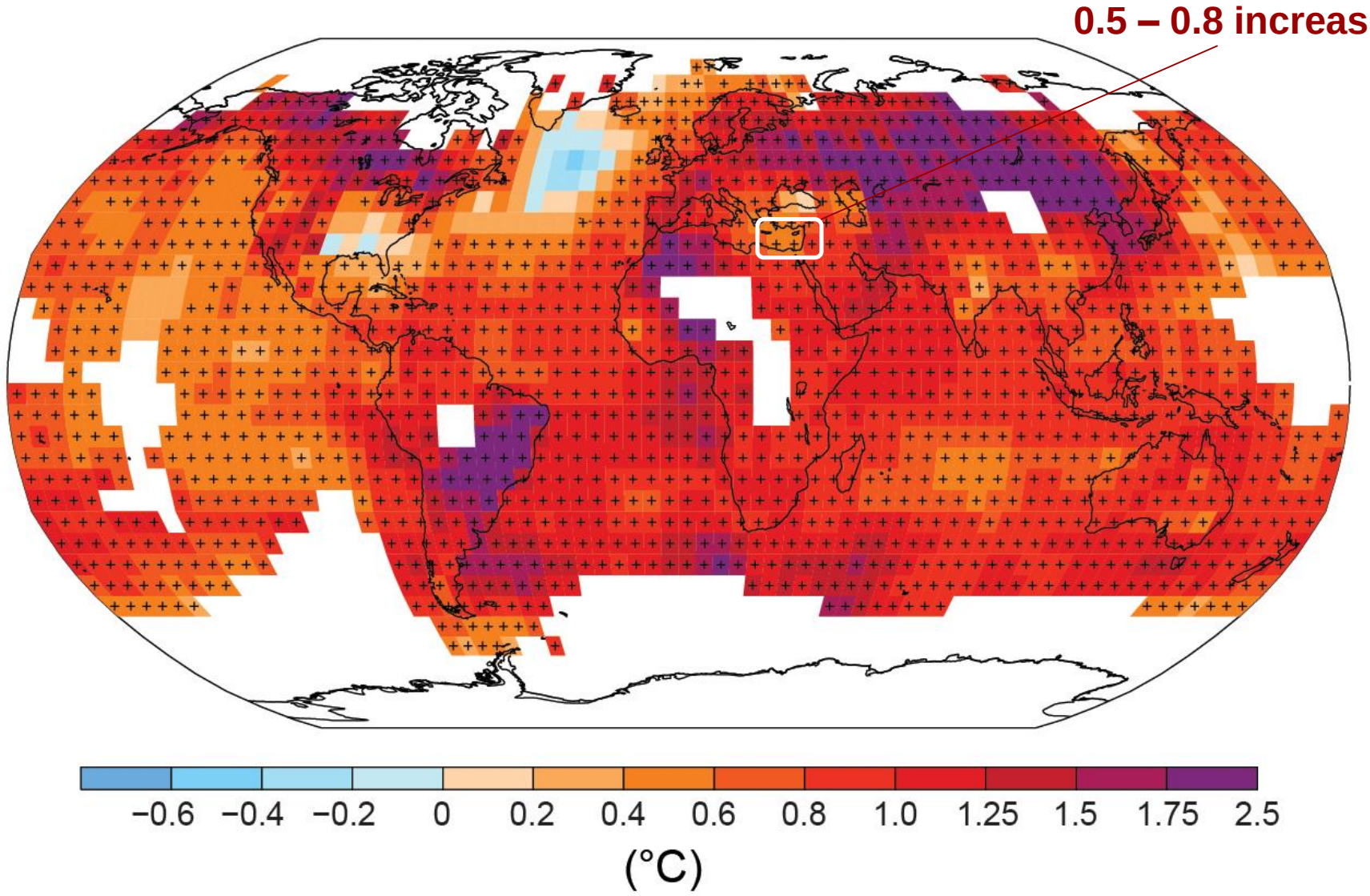
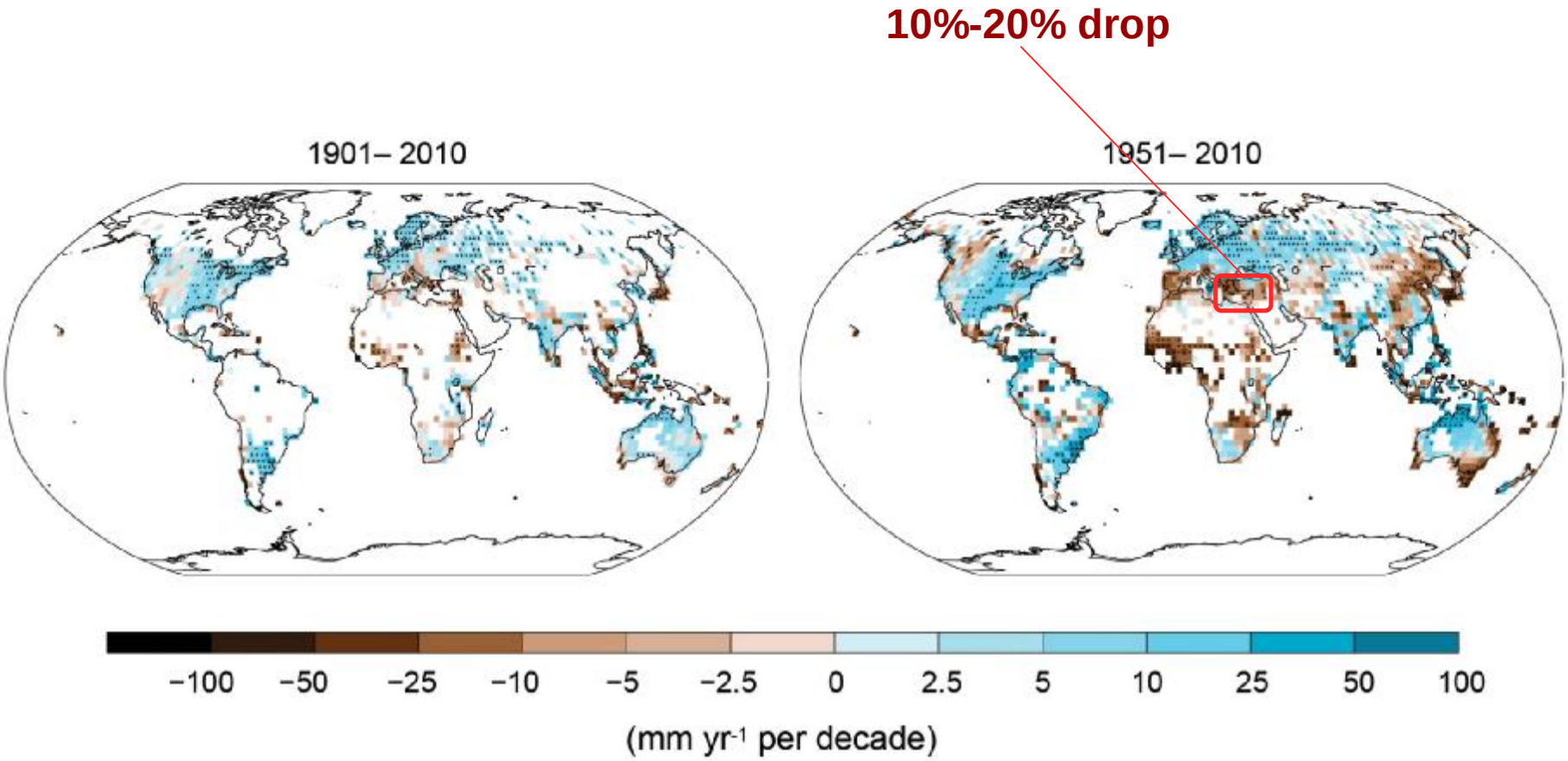
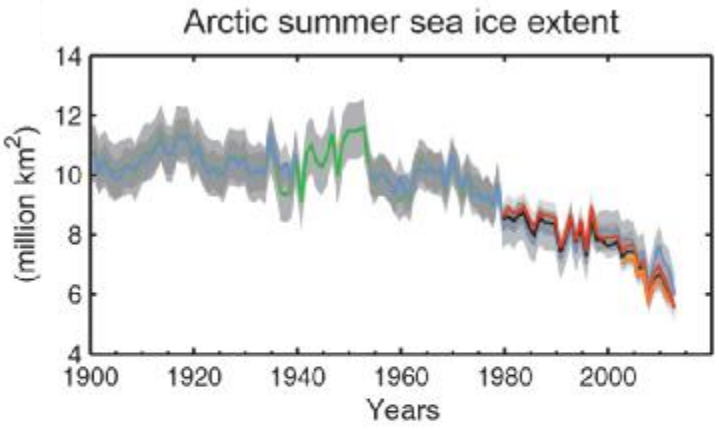
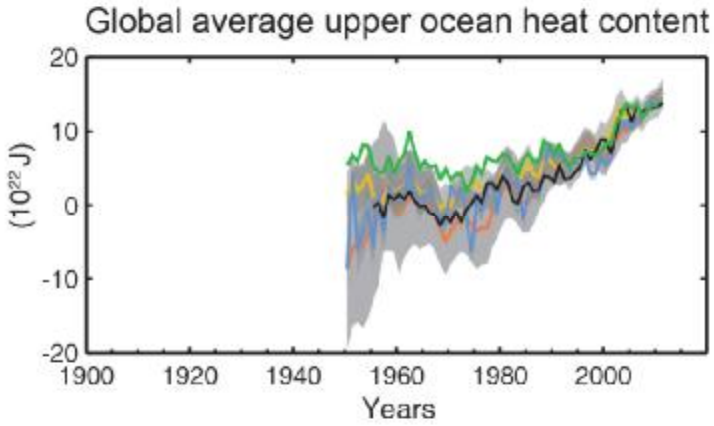


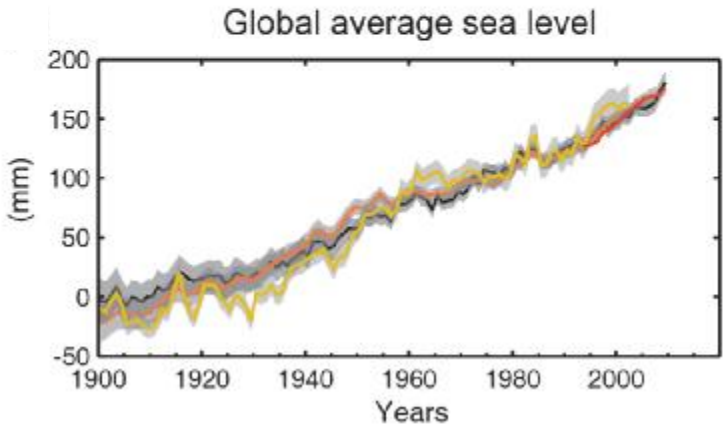
Figure SPM.2

Observed change in annual precipitation over land

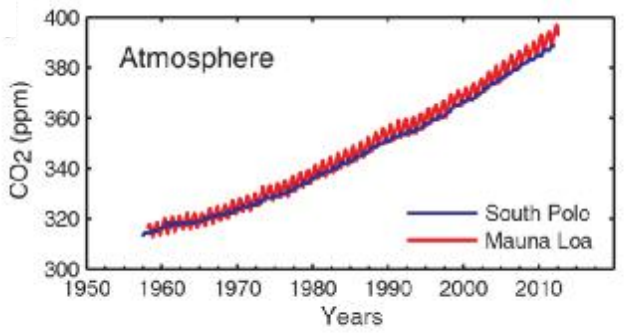


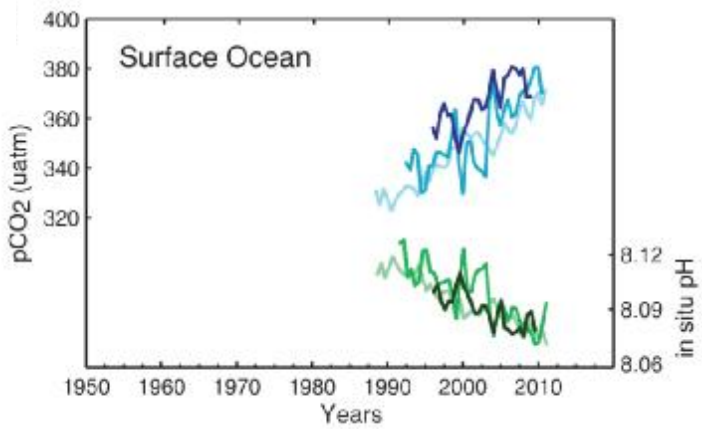






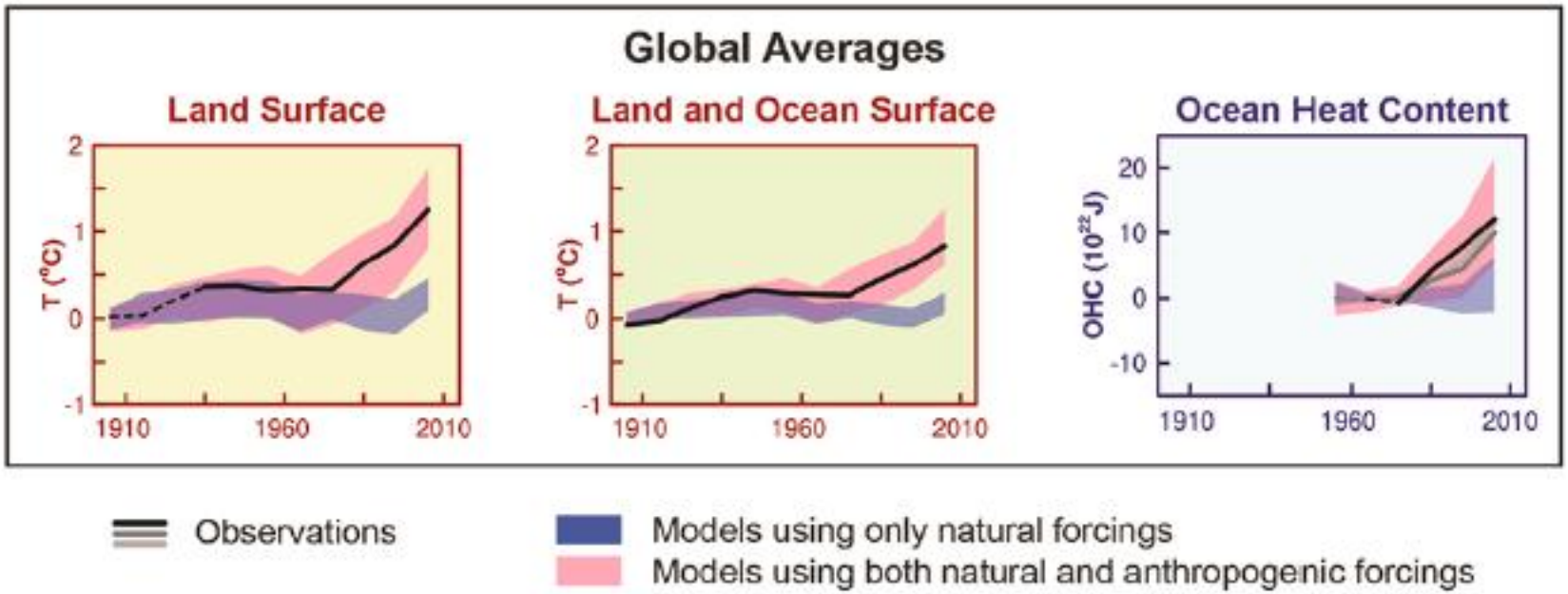
Multiple lines of robust and compelling evidence support the conclusion that many aspects of the climate system have changed





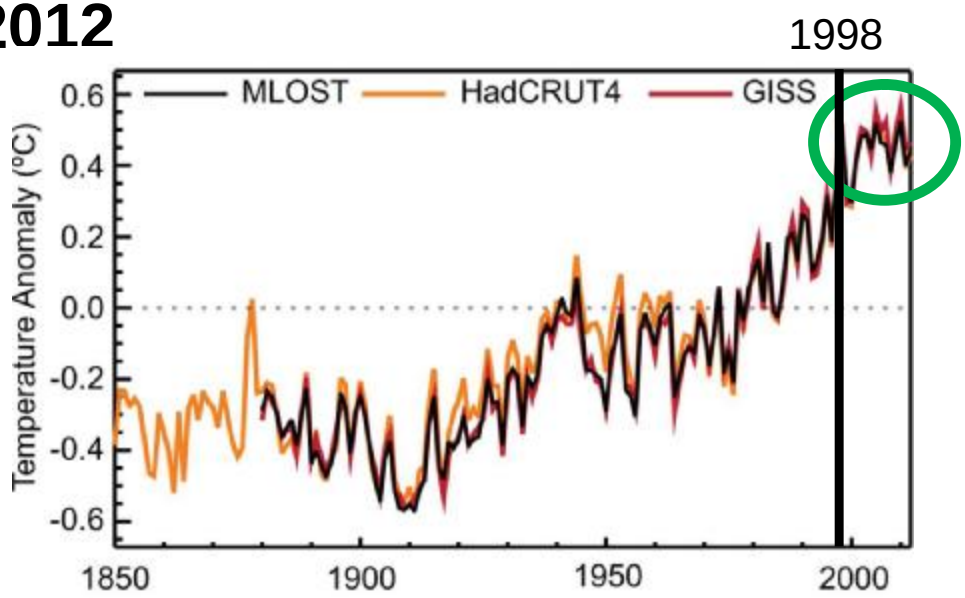
Human influence on climate is clear

It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century



IPCC (2013) Figure SPM.6

Global warming continues despite slow-down in surface temperature rise over 1998-2012



⇒ trends over short records are very sensitive to start and end dates and natural climate variability

IPCC attributes the slow-down in roughly equal measure to:

⇒reduction in energy reaching the surface due to a downward phase of the 11-year solar cycle and "shading" by aerosols produced by volcanic eruptions (*low confidence*)

⇒internal variability including a possible redistribution of heat within the ocean (*medium confidence*)

Figure SPM.3

Multiple observed indicators of a changing global climate

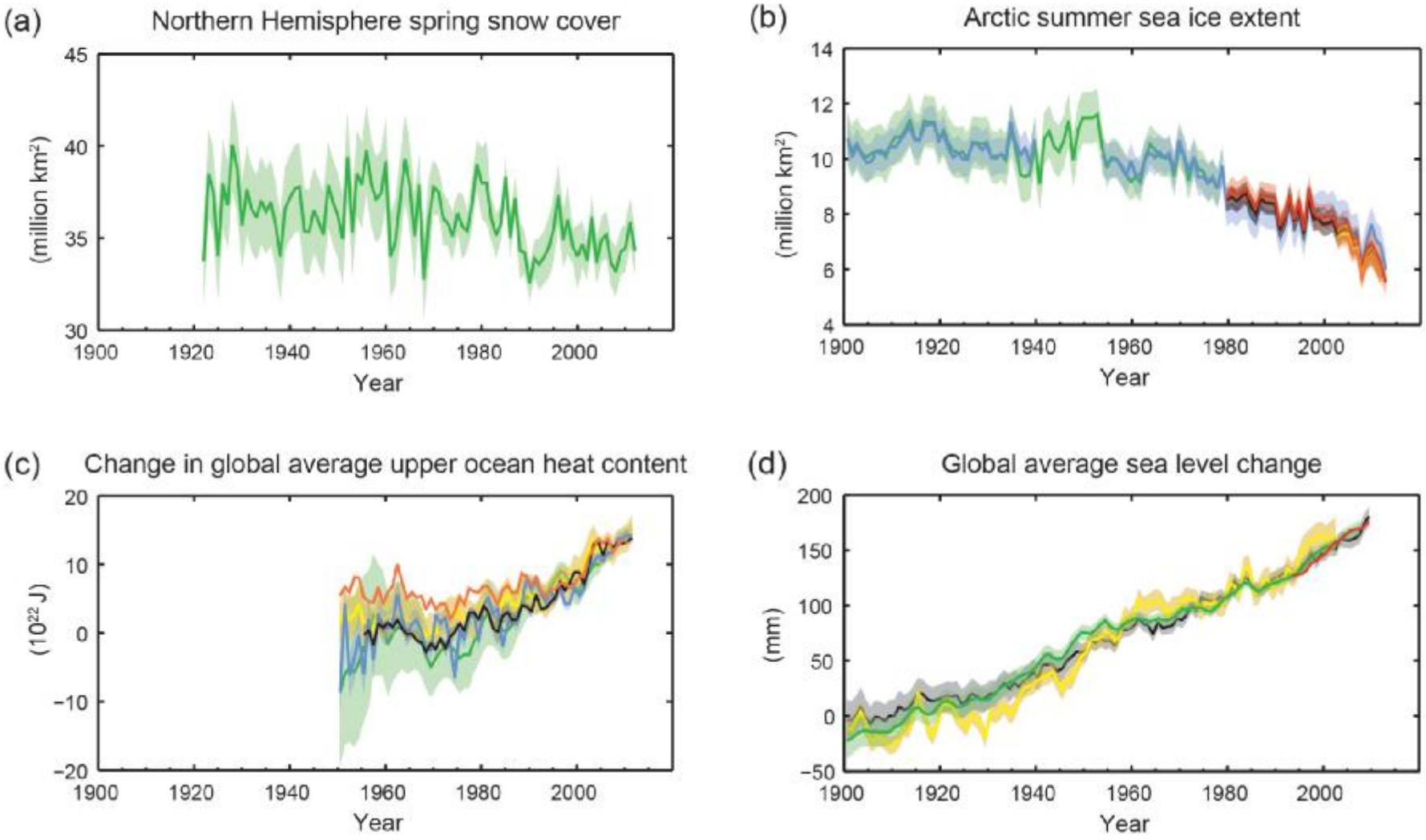
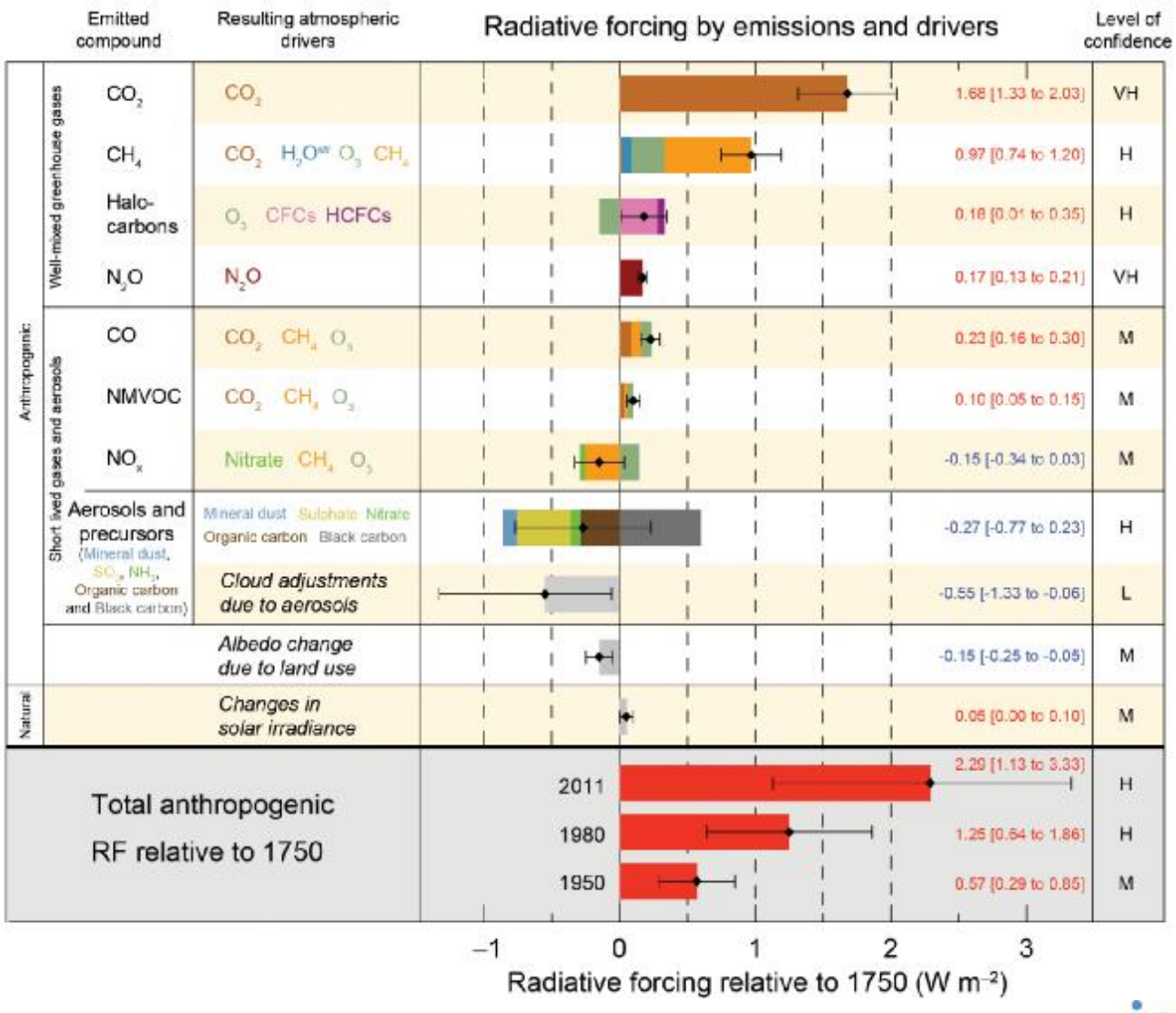
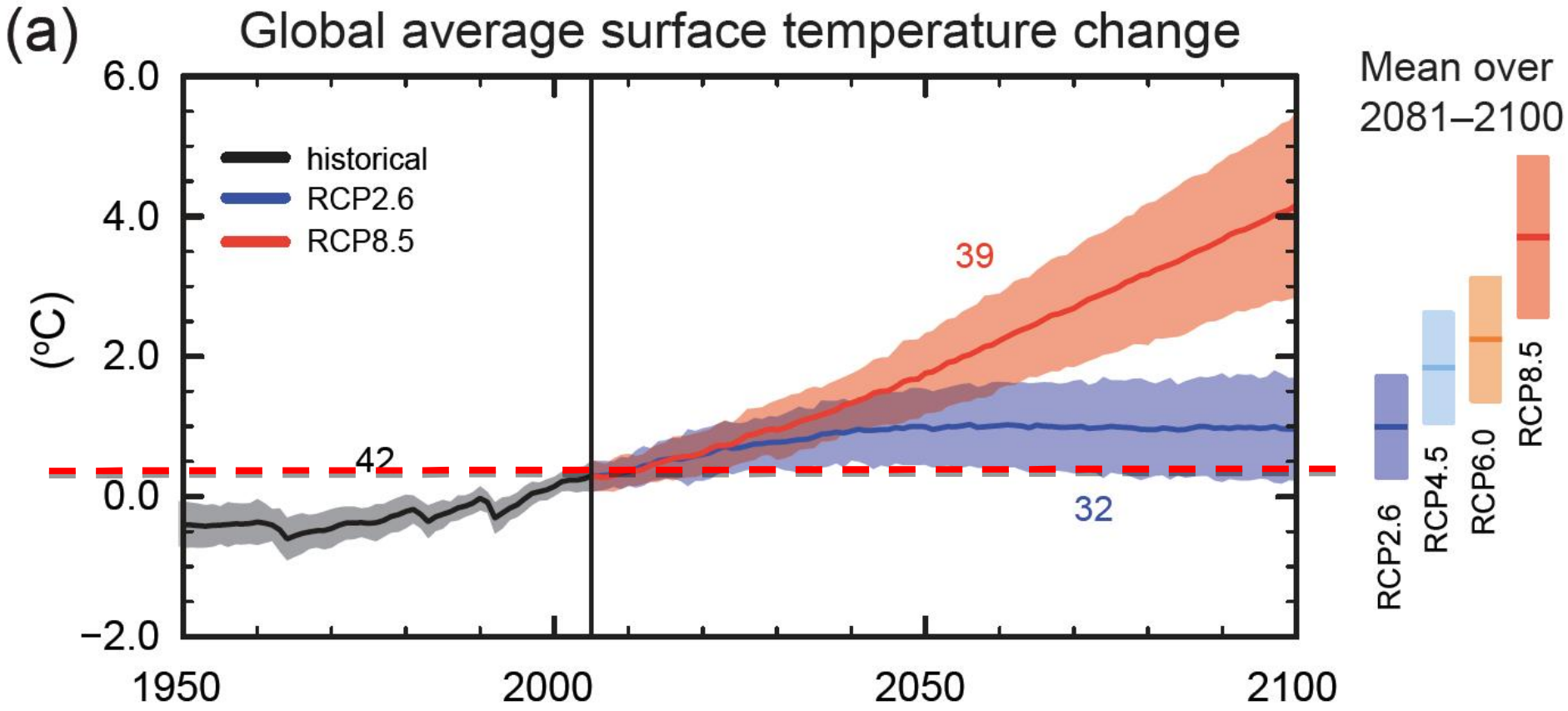


Figure SPM.5

Radiative forcing estimates in 2011 relative to 1750



Distinction in warming between scenario changes with time



Global temperatures are *likely* to exceed 1.5°C for all RCPs except RCP2.6 by the end of the 21stC and *likely* to exceed 2°C for RCP6.0 and RCP8.5

Headlines of the IPCC WGI 5th Assessment Report

=> Warming is unequivocal. Many observed changes are unprecedented on timescales of decades or millennia

=> Human influence on climate is clear

=> Climate will continue to change in future

=> Limiting future climate change will require substantial and sustained reductions in emissions

WGI Summary for Policymakers

Headline Statements

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Observed Changes in the Climate System (1/2)

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was *likely* the warmest 30-year period of the last 1400 years *(medium confidence)*.

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 *(high confidence)*. It is *virtually certain* that the upper ocean (0–700 m) warmed from 1971 to 2010, and it *likely* warmed between the 1870s and 1971.

Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent *(high confidence)*.

Observed Changes in the Climate System (2/2)

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia *(high confidence)*. Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m.

The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification.

Drivers of Climate Change (1/1)

Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.

Understanding the Climate System and its Recent Changes (1/1)

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

Climate models have improved since the AR4. Models reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions *(very high confidence)*.

Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing.

Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

Future Global and Regional Climate Change (1/2)

Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

Global surface temperature change for the end of the 21st century is *likely* to exceed 1.5°C relative to 1850 to 1900 for all RCP scenarios except RCP2.6. It is *likely* to exceed 2°C for RCP6.0 and RCP8.5, and *more likely than not* to exceed 2°C for RCP4.5. Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Warming will continue to exhibit interannual-to-decadal variability and will not be regionally uniform.

Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions.

The global ocean will continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation.

Future Global and Regional Climate Change (2/2)

It is *very likely* that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. Global glacier volume will further decrease.

Global mean sea level will continue to rise during the 21st century. Under all RCP scenarios, the rate of sea level rise will *very likely* exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets.

Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere *(high confidence)*. Further uptake of carbon by the ocean will increase ocean acidification.

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2.

Prediction

Climate Change:

East Mediterranean and Palestine

GLOWA – Jordan River

GLOWA Project – Global Change of Hydrology Cycle

A research project initiated by several research institutions and funded by the German Federal Ministry of Education and Research (BMBF).

It focuses on the problem of water availability at river basins in order to develop simulation-tools and instruments that could provide vital information needed to develop future sustainable development strategies for water management at regional level, while taking into account global environmental changes.

Within GLOWA project there are five large cluster projects:

GLOWA – Danube (Europe)
GLOWA – Elbe (Europe)
GLOWA – Volta (Africa)
GLOWA – Drâa and Ouémé (Africa)
GLOWA – Jordan River (Middle East)

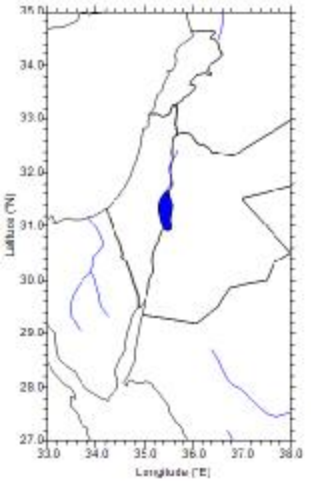
Core scientific themes tackled by research groups are:
1.Climate change future scenario (variability of precipitation, temperature),
2.Regional hydrological cycle and future climate change impact,
3.Interactions between biosphere/land use and the hydrology cycle,
4.Socioeconomic development and future climate change impact.

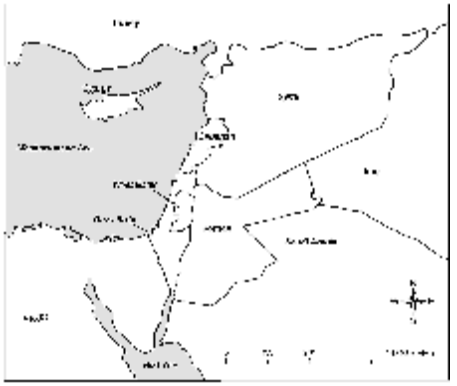
GLOWA – Jordan River – Regional Climate Change

Phase III (2008 – 2011)
Application – Stakeholder dialogue

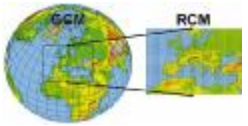
Phase II (2005 – 2008)
Climate Scenario (2000-2045) – Jordan River and the region

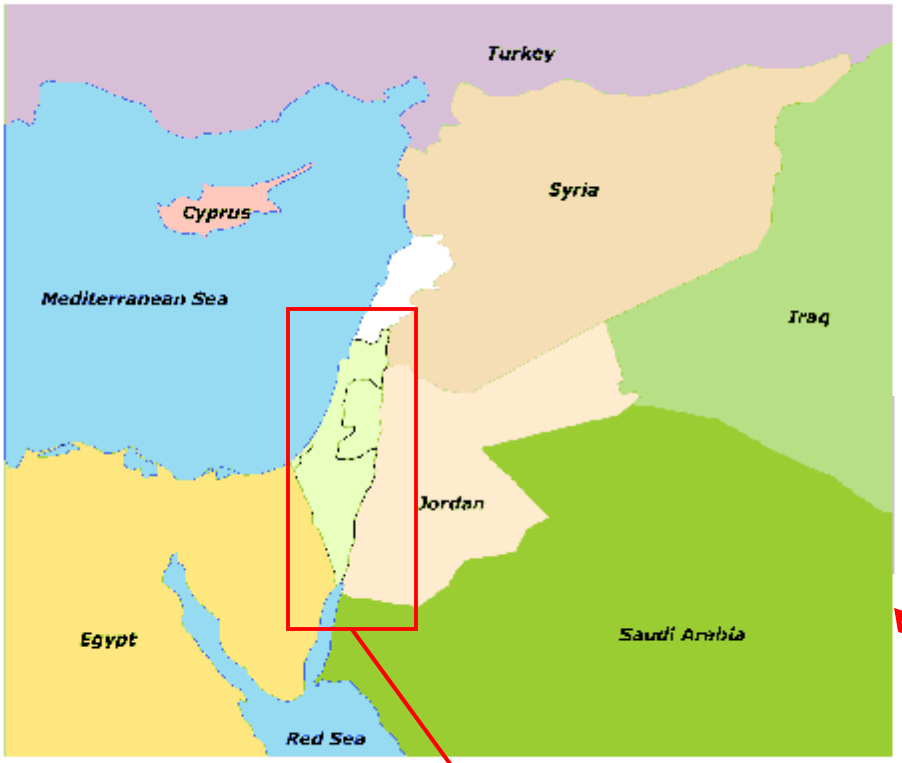
Phase I (2002 – 2005)
Data Collection and Consolidation – Climate Trend of East Mediterranean Region

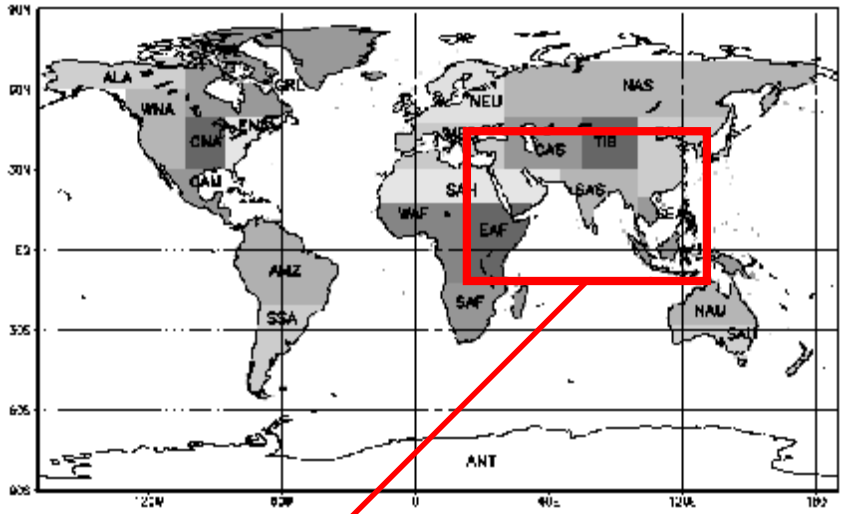


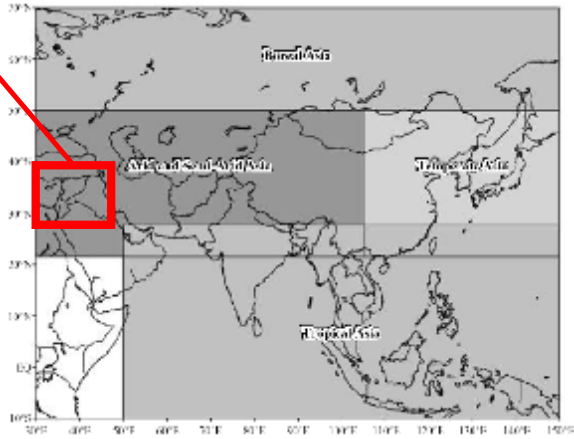


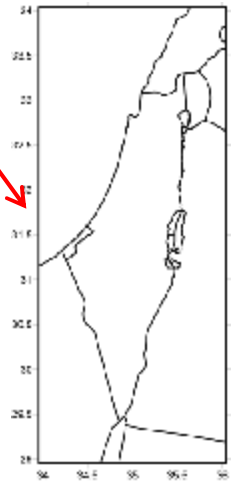
GLOWA – Jordan River – Regional Climate Change



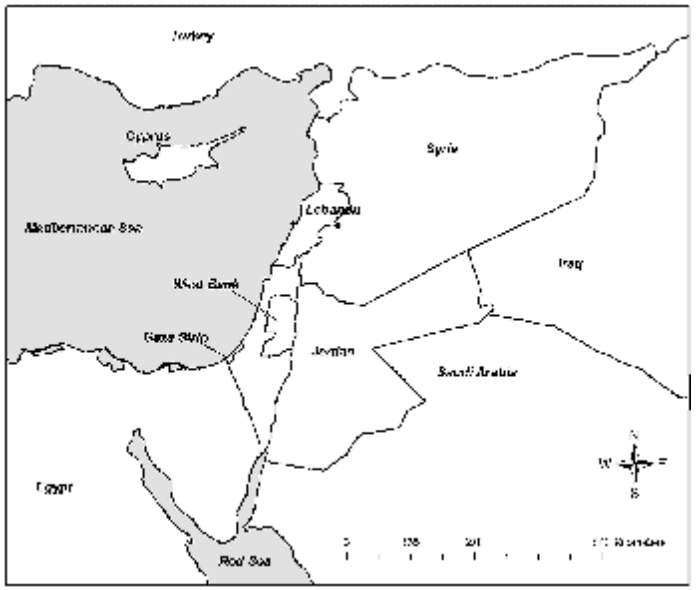








GLOWA – Jordan River – Regional Climate Change



Spatial resolution of 0.5º x 0.5º

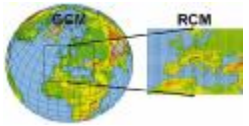
q Use a statistical non-hierarchical multivariate modeling approach,

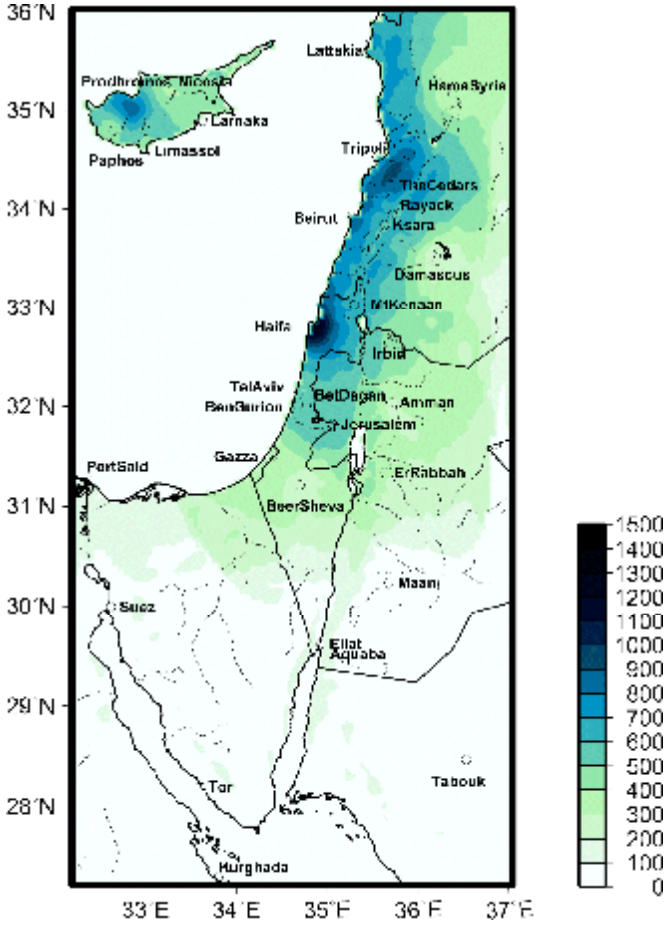
q Climate data are extracted from the climate data record of the Climate Research Unit (CRU) of the University of East Anglia for the period 1901 – 2003 that include monthly values for:

- **Ø** air temperature, and
- **Ø** precipitation

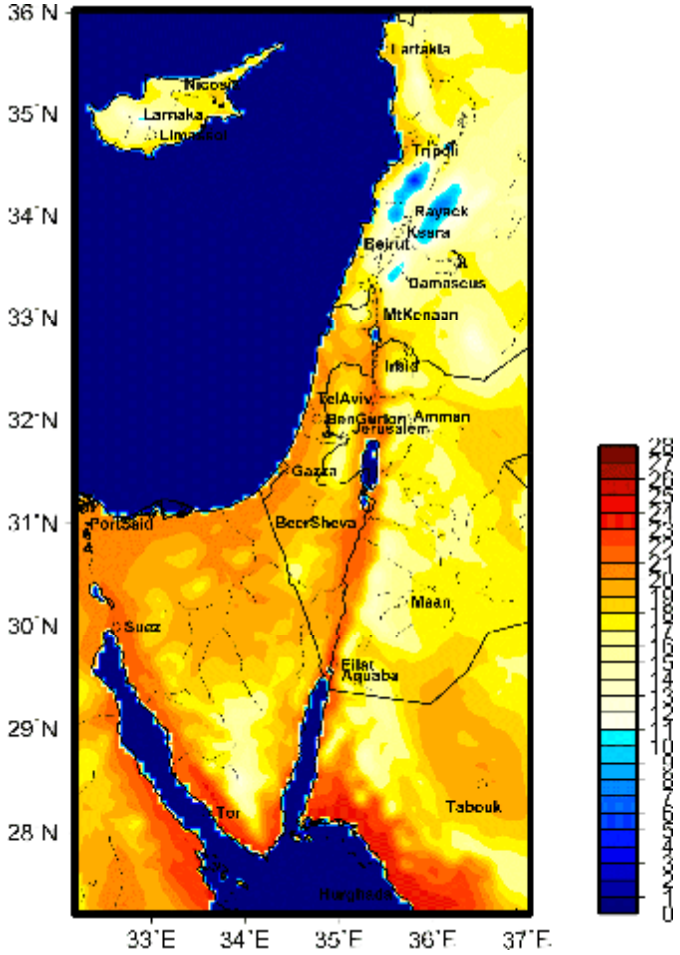
q Data are distributed over the domain on same grid size of 0.5º x 0.5º

Climate Change and Palestine – Regional Climate





Yearly average precipitation
(35 station values interpolated)



Yearly average temperature
(30 station values interpolated)

Climate Characteristics – Palestine and the Region

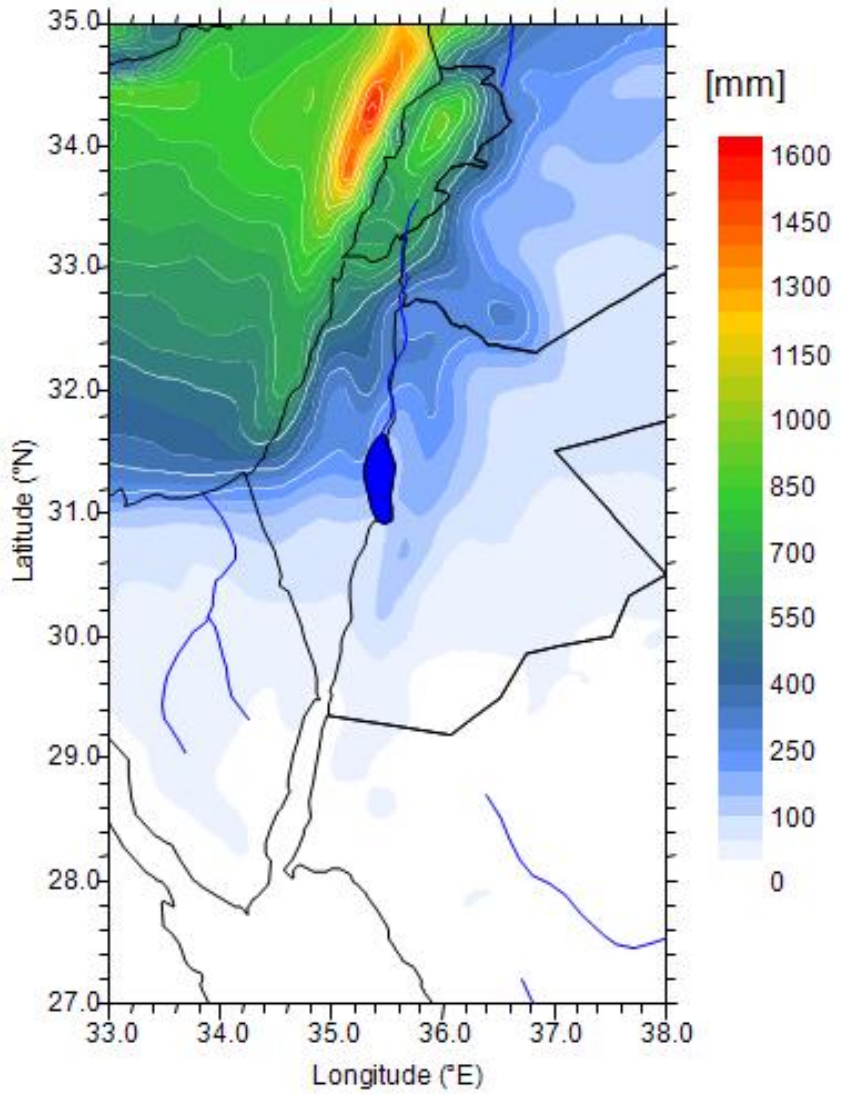
Sub-Mediterranean

Humid Mediterranean

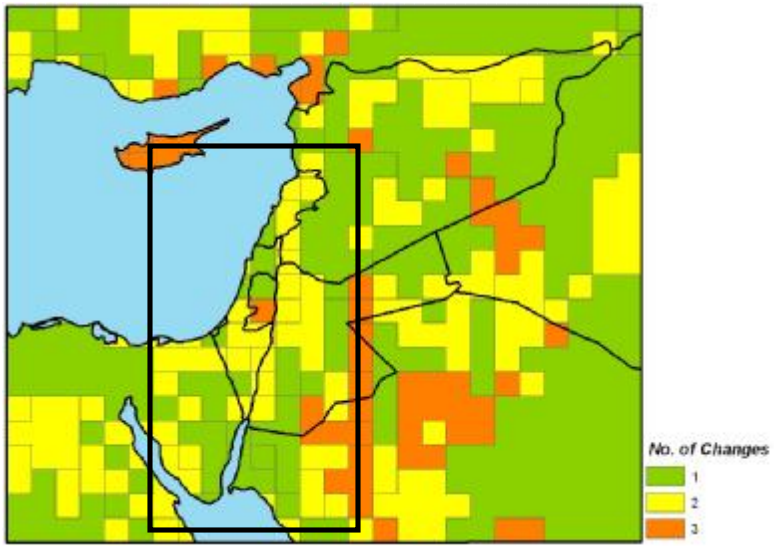
Semi-arid

Arid

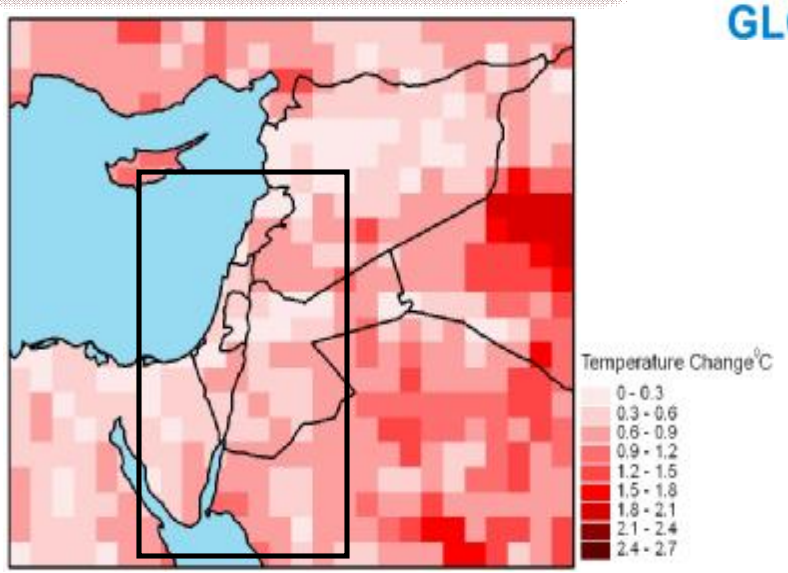
hyper-arid



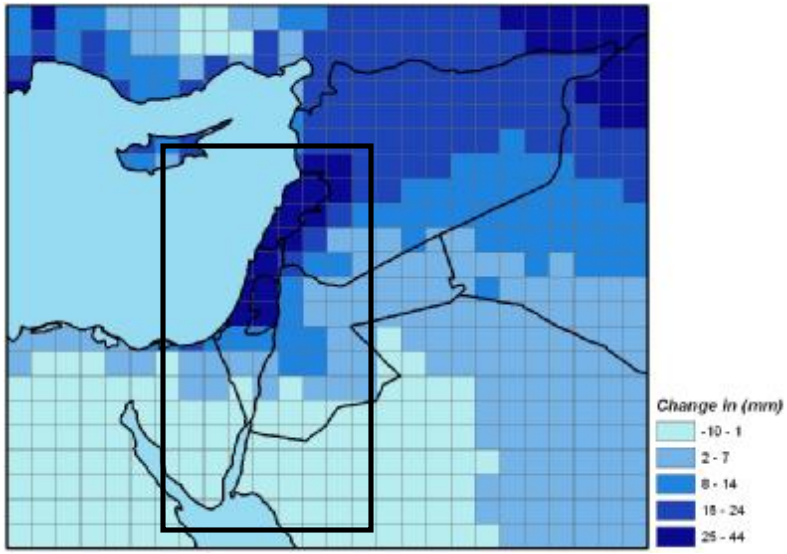
GLOWA – Jordan River – Regional Climate Change



Climate Type Change over 1901 - 2003



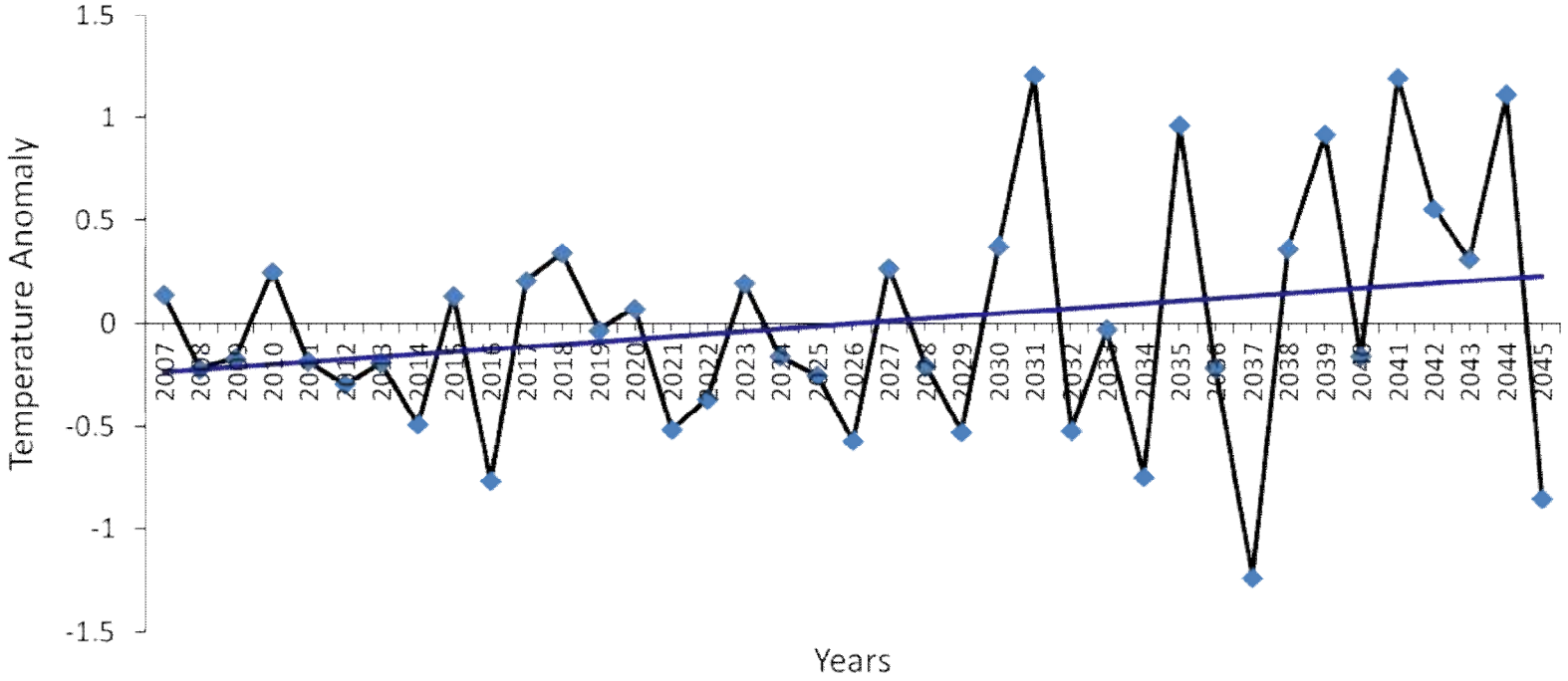
Temperature Change over 1901 - 2003



March Rainfall Change over 1901 - 2003

- Increase of aridity and semi-aridity over sub-humid climate,
- Increase of average seasonal summer temperature,
- Decrease of annual precipitation,
- Winter rainfall shift towards February and March,
- Increase in frequent occurrence of extreme climate events (e.g. drought, intense rain, etc.).

Possible Climate Change Scenario (2000 – 2045) - Temperature



- Ø Increase of summer temperature,
- Ø Decrease of winter temperature,
- Ø Increase in frequent occurrence of extreme event
- Ø Overall average temperature increase by more than 0.8 K

Demand on Energy increases

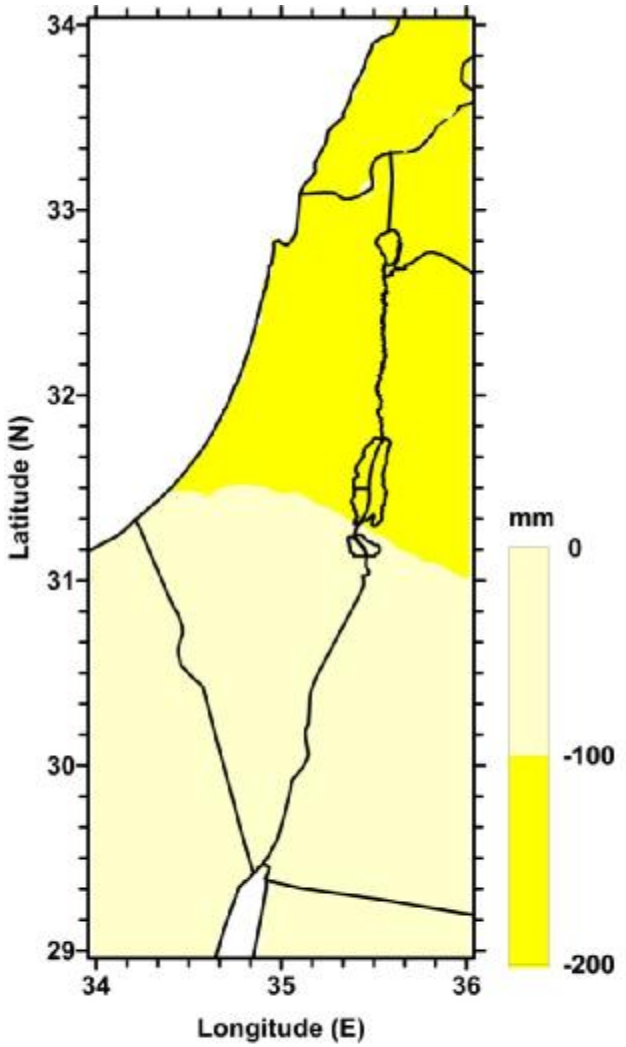
Possible Climate Change Scenario (2000 – 2045) - Precipitation

Ø A 10%-20% reduction in annual precipitation,

Ø An increase frequent occurrence of extreme weather events (intensive rainfall, drought, etc.),

Ø Seasonal shift of rainfall towards February and March,

Water scarcity -> intensified conflict over water,
Dry land extension (desertification),
Health problems, and other related ..



Thanks for your patience