

**EV20001: ENVIRONMENTAL SCIENCE**



**Lecture #4**

# **Climate Change: Scientific Basis, Mitigation & Adaption**

**Dr. Shamik Chowdhury**

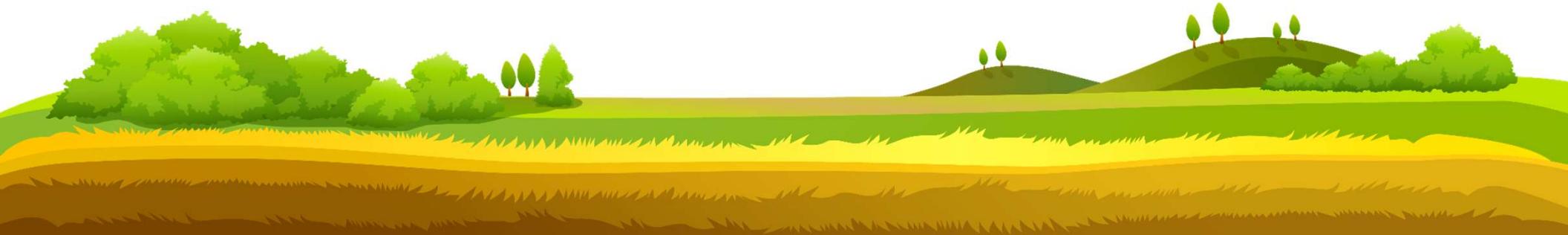
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**02 March 2022**

# Climate Change: A Primer

- Climate is the statistical description of weather conditions and their variations, including both averages and extremes.
- Climate change is the alteration in the average weather pattern over a long period of time.
- Greenhouse gases (GHGs) play an important role in determining climate and causing climate change.
- These gases act like an insulating blanket, keeping the Earth's surface warmer than it would be if they were not present in the atmosphere, a phenomenon known as greenhouse effect.
- GHGs include water vapor, carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ) and some industrial gases such as chlorofluorocarbons (CFCs).





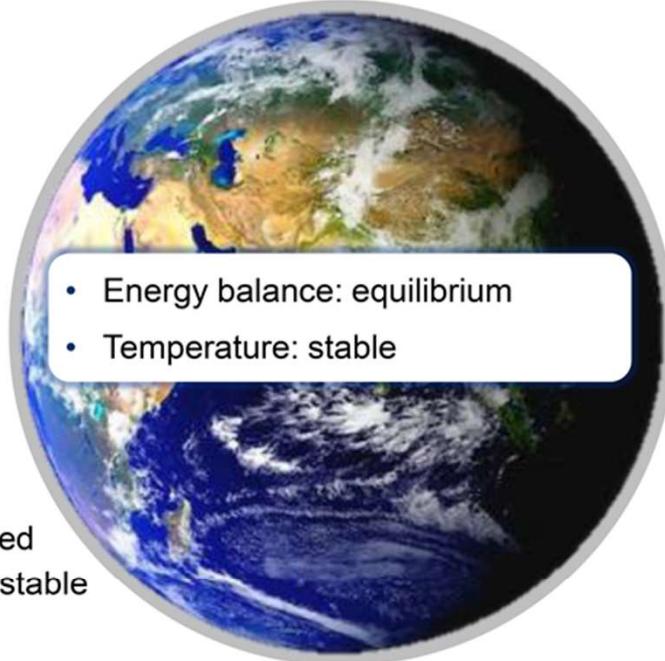
# Science of Climate Change

# The Greenhouse Effect

## EARTH'S ENERGY BUDGET VIEWED FROM THE TOP OF THE ATMOSPHERE

Greenhouse gases

Incoming solar radiation



Emitted heat radiation  
= Incoming radiation

### ① Initial equilibrium state

- ✓ Incoming and outgoing fluxes balanced
- ✓ Global average surface temperature stable

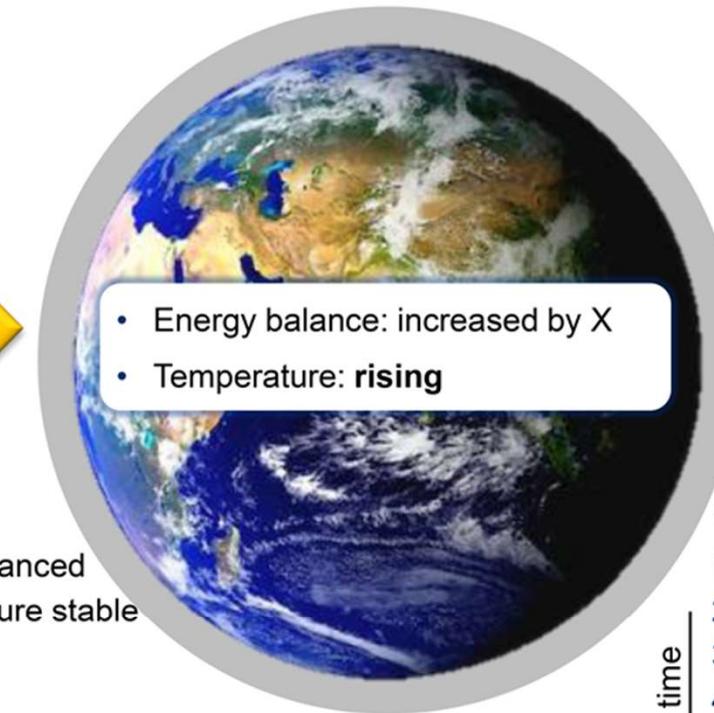


# The Greenhouse Effect

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Emitted heat radiation reduced by X

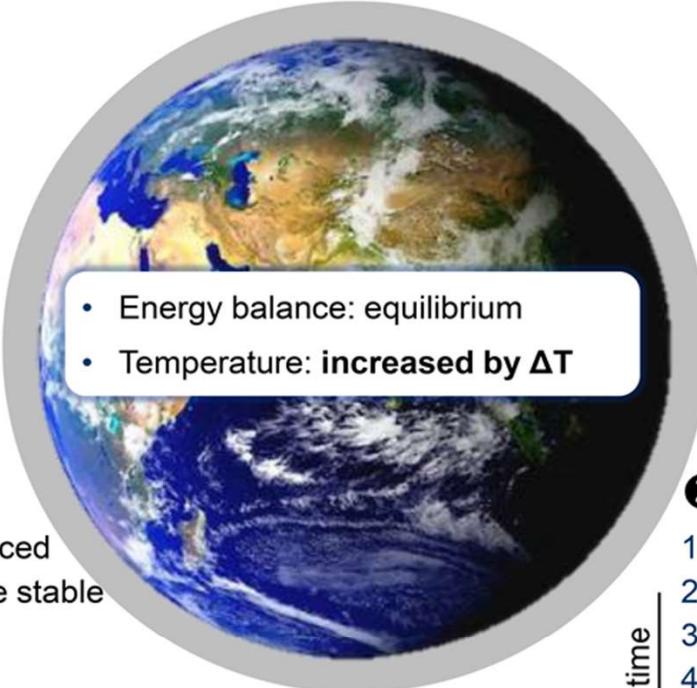
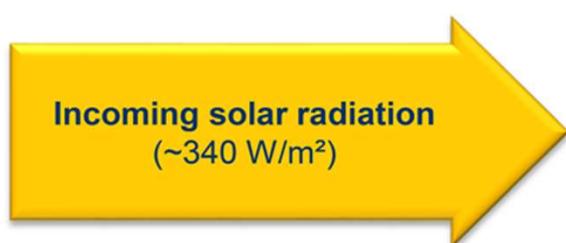
### ② Greenhouses gases are added

1. Instant decrease in emitted heat radiation
2. Positive energy imbalance
3. Extra heat retained by the Earth
4. Progressive **global warming**
5. Gradual increase in emitted heat radiation

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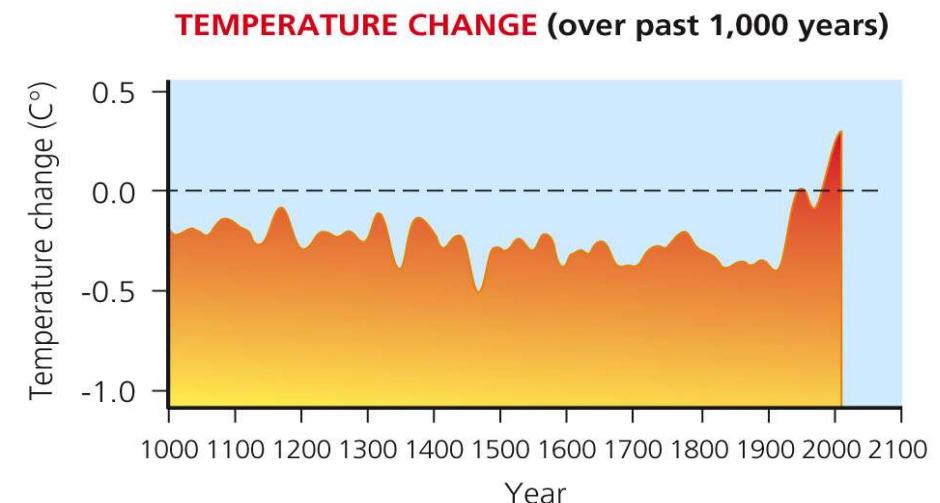
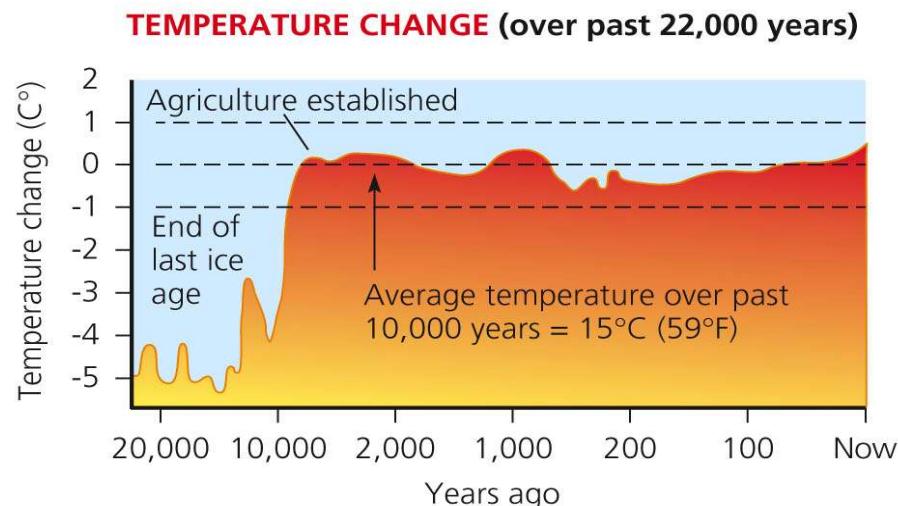
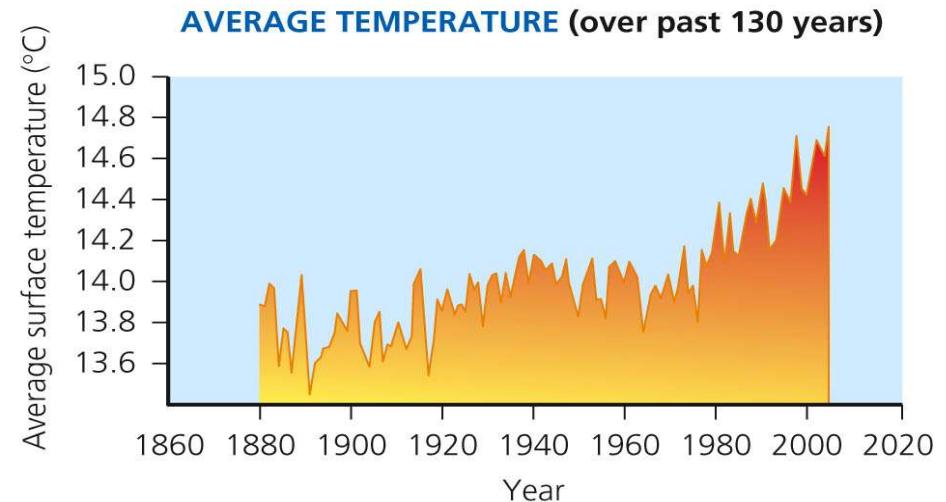
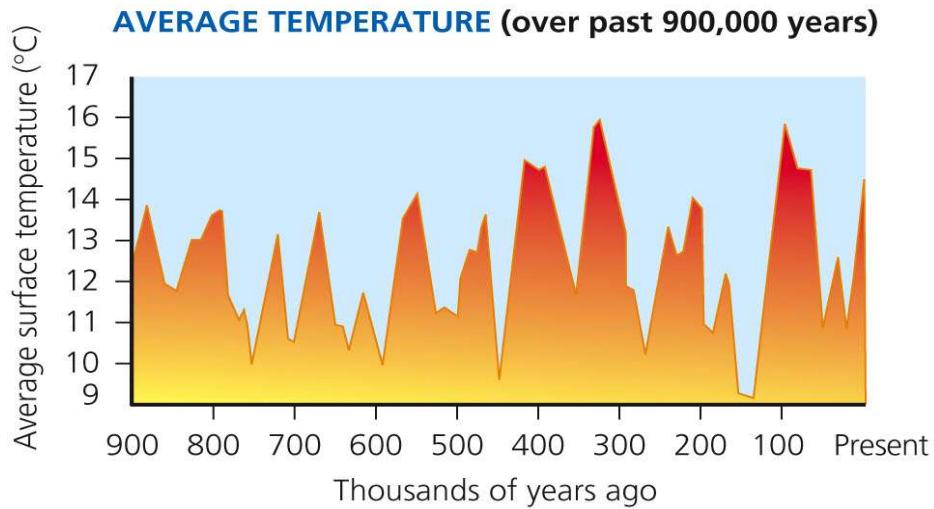
### ③ New equilibrium reached

- ✓ Stabilization takes several centuries (**climate lag**)
- ✓ Energy balance back to equilibrium
- ✓ New average temperature (increased by  $\Delta T$ )
- ✓ Induced **climate change<sup>1</sup>**



# The Earth's Climate in the Past

- During the past million years, the average temperature of the Earth's surface has risen and fallen by about 5 °C. The millennium before the industrial revolution have been relatively stable.



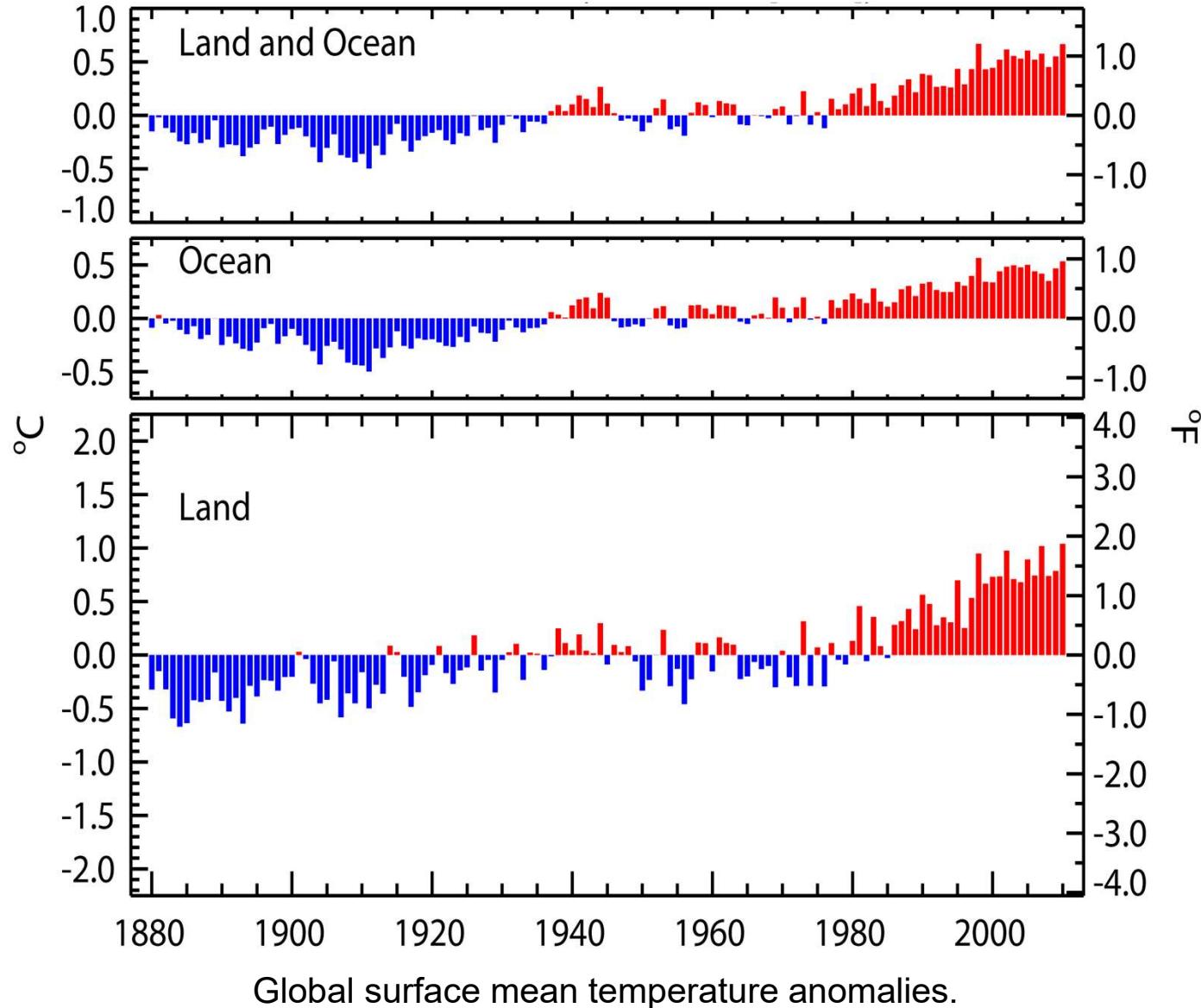
# Estimating Past Temperatures

- Past temperature changes are estimated by analysis of radioisotopes in rocks and fossils, plankton and radioisotopes in ocean sediments, tiny bubbles of ancient air found in ice cores from glaciers, pollen from bottoms of lakes, tree rings, and historical records.

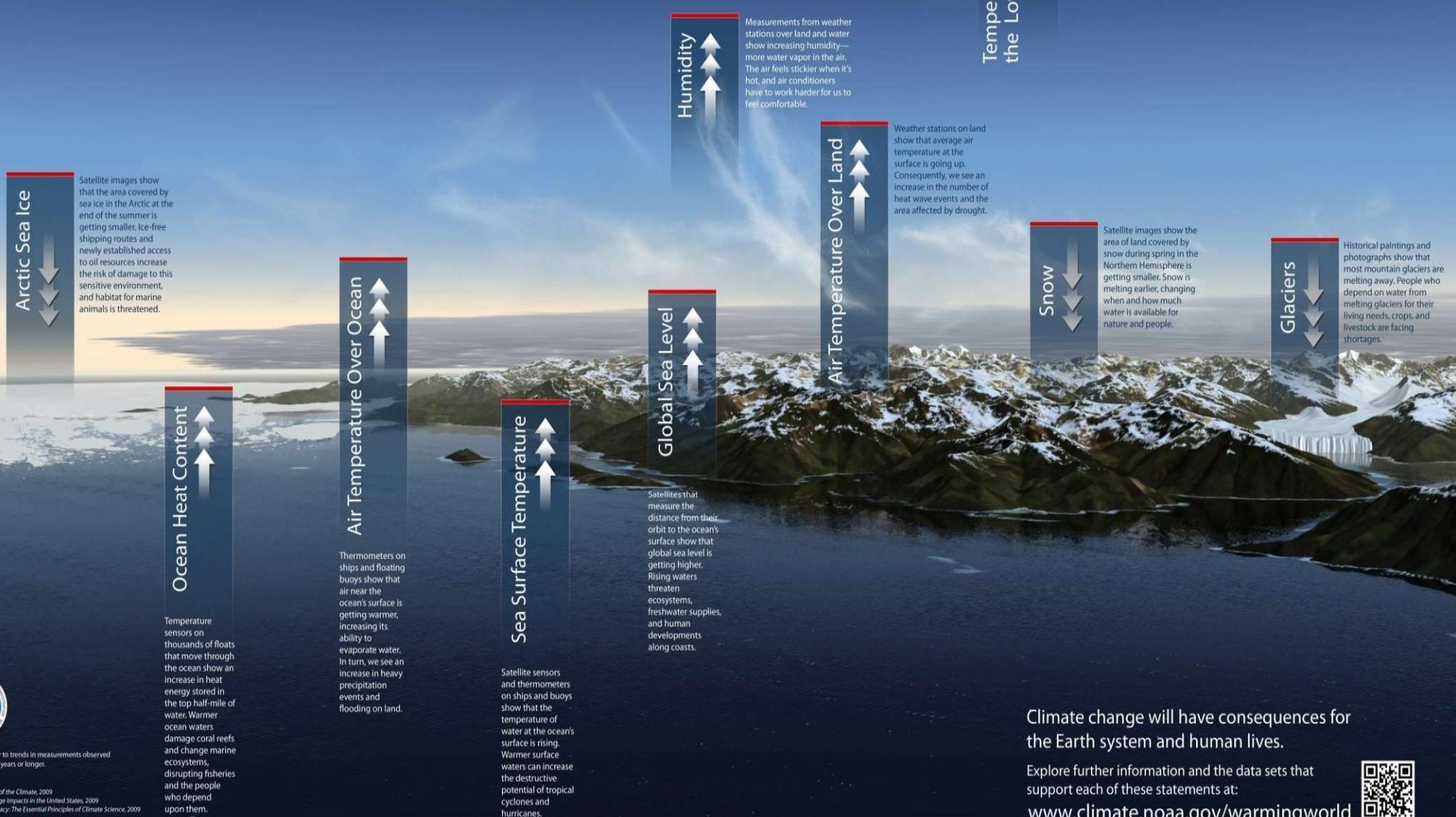


# The Earth's Climate in the Recent Past

- The upward trend since the early 1960s indicates global warming.



# Climate Change: Vital Signs of the Planet

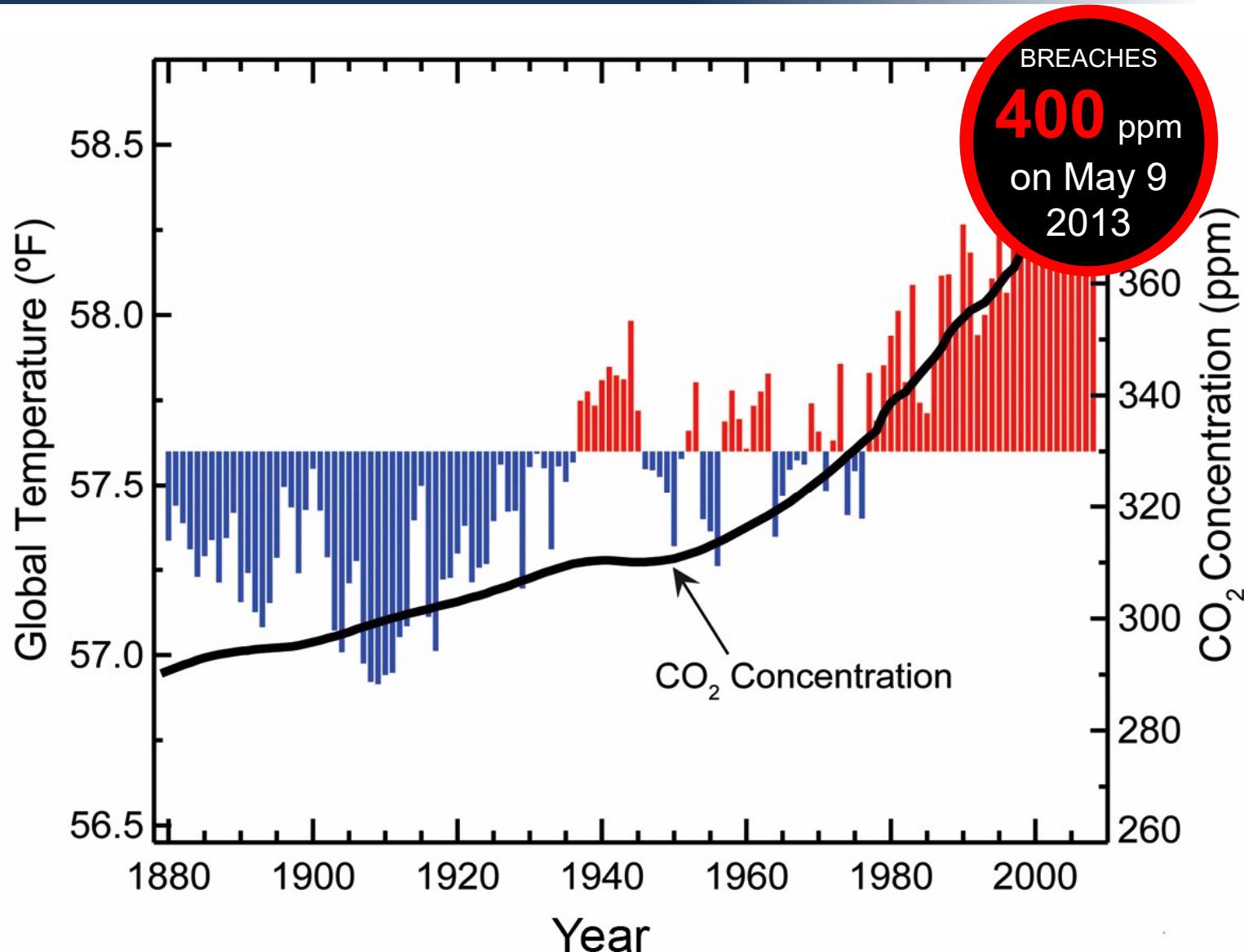


All statements refer to trends in measurements observed over a period of 30 years or longer.

Sources:  
IPCC Annual State of the Climate, 2009  
USGCRP Global Change Impacts in the United States, 2009  
USGCRP Climate Literacy: The Essential Principles of Climate Science, 2009



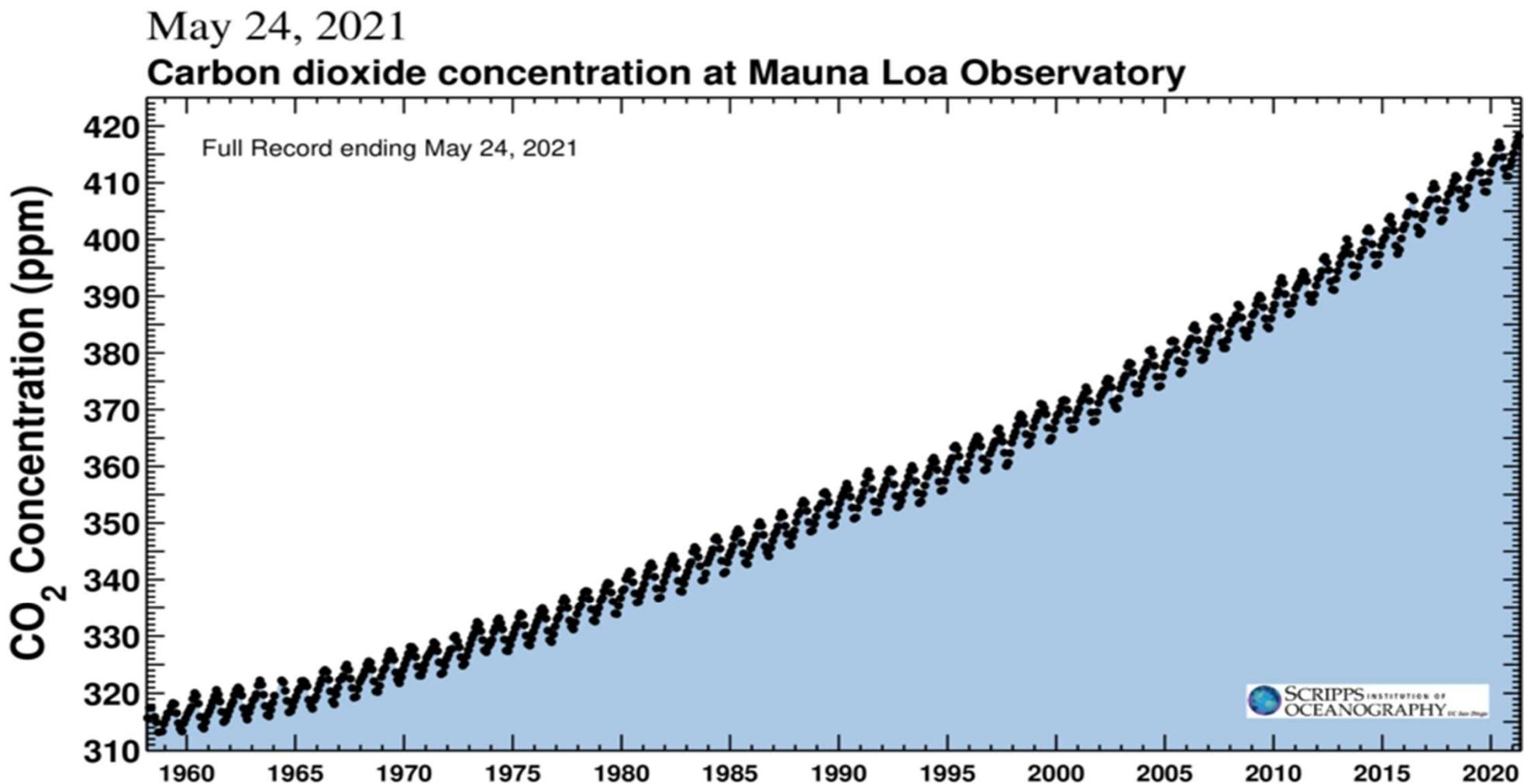
# CO<sub>2</sub> is the Major Cause of Global Warming



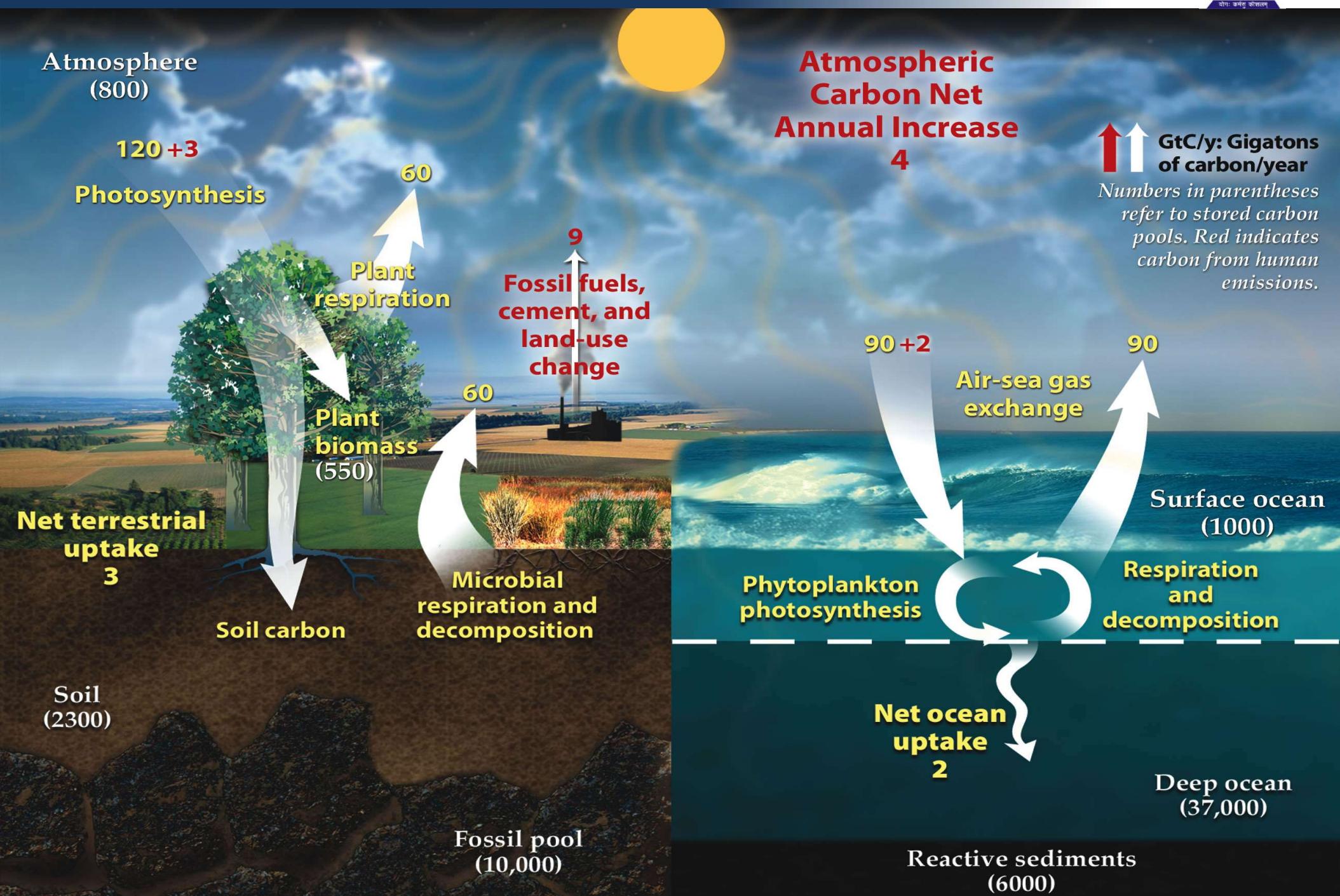
Atmospheric CO<sub>2</sub> concentrations and global annual average temperatures (as measured over both land and oceans) over the years 1880 to 2010. Red bars indicate temperatures above and blue bars indicate temperatures below the average temperature. The black line shows atmospheric CO<sub>2</sub> concentrations in parts per million (ppm).

# Keeling Curve

- The Keeling Curve, devised by Dr. Charles David Keeling of the Scripps Institution of Oceanography, represents the concentration of CO<sub>2</sub> in the Earth's atmosphere since 1958, as recorded at the Mauna Loa Observatory in Hawaii.



# Why Are CO<sub>2</sub> Emissions So Significant?

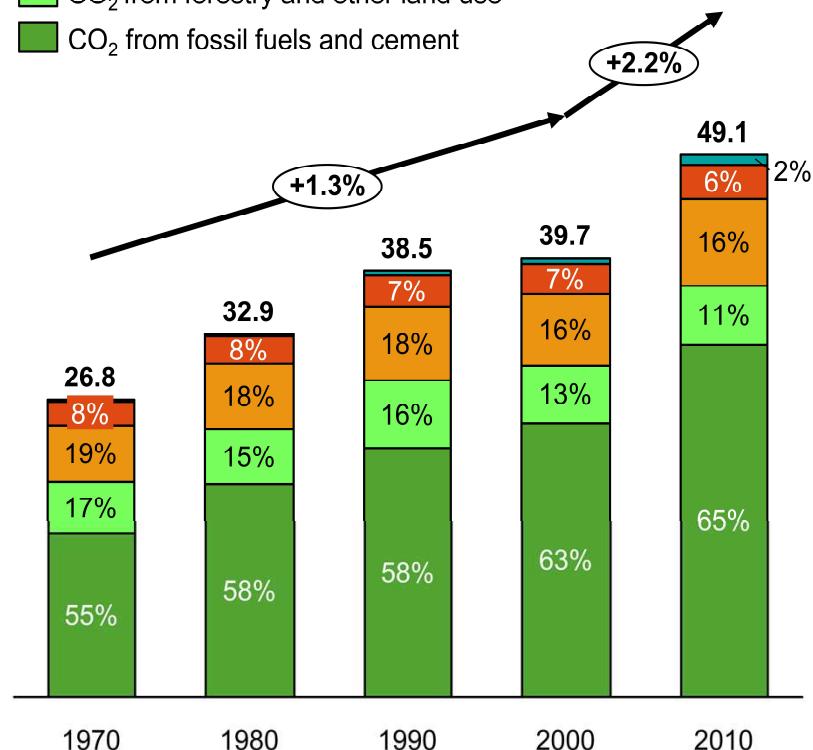


# Where Humanity's GHGs Come From?

## HUMAN GHG EMISSIONS BY ACTIVITY<sup>1</sup>

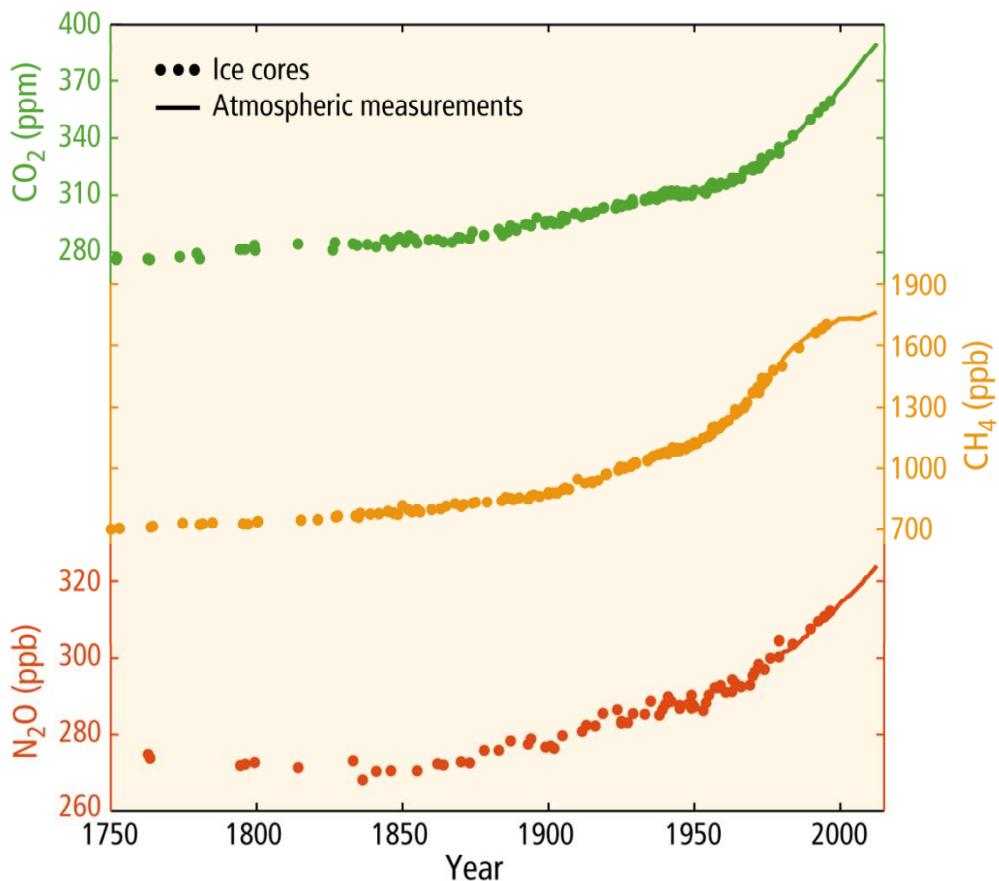
Gigatonne of CO<sub>2</sub>-e per year, and % of total emissions

- F-gases
- N<sub>2</sub>O from agriculture and others
- CH<sub>4</sub> from agriculture, waste and energy
- CO<sub>2</sub> from forestry and other land use
- CO<sub>2</sub> from fossil fuels and cement



## ATMOSPHERIC CONCENTRATION OF GHGS

Parts per billion (ppb), parts per million (ppm)



# Global Warming Potential

- Global warming potential (GWP) and CO<sub>2</sub>-equivalence are used to compare the potential warming influence of emissions of the same mass of different GHGs.
- GWP compares the warming effect of a given mass of GHG to the same mass of CO<sub>2</sub> over a specified time. As GHGs do not have the same life time in the atmosphere, the GWP depends on the time-horizon chosen.

Gas name	Chemical formula	Half-life <sup>1</sup> (years)	Global warming potential (GWP) for given time horizon	
			20-yr	100-yr
Carbon dioxide	CO <sub>2</sub>	100-1,000 years <sup>2</sup>	1 (by definition)	1 (by definition)
Methane	CH <sub>4</sub>	12.4	~80	~30
Nitrous oxide	N <sub>2</sub> O	121	~270	~300
Tetrafluoro-methane	CF <sub>4</sub>	50,000	~5,000	~7,000





# Impacts of Climate Change

# Melting of More Ice and Snow

- Over the past 30 years, more than 20% of the polar ice cap has melted away, and the melting trend is accelerating.
- September 2012 had the lowest sea ice extent ever recorded: 44% below the 1981–2010 average for that month.
- The September 2015 sea ice extent was more than 700,000 square miles less than the historical 1981–2010 average for that month.

Dwindling Arctic Sea Ice

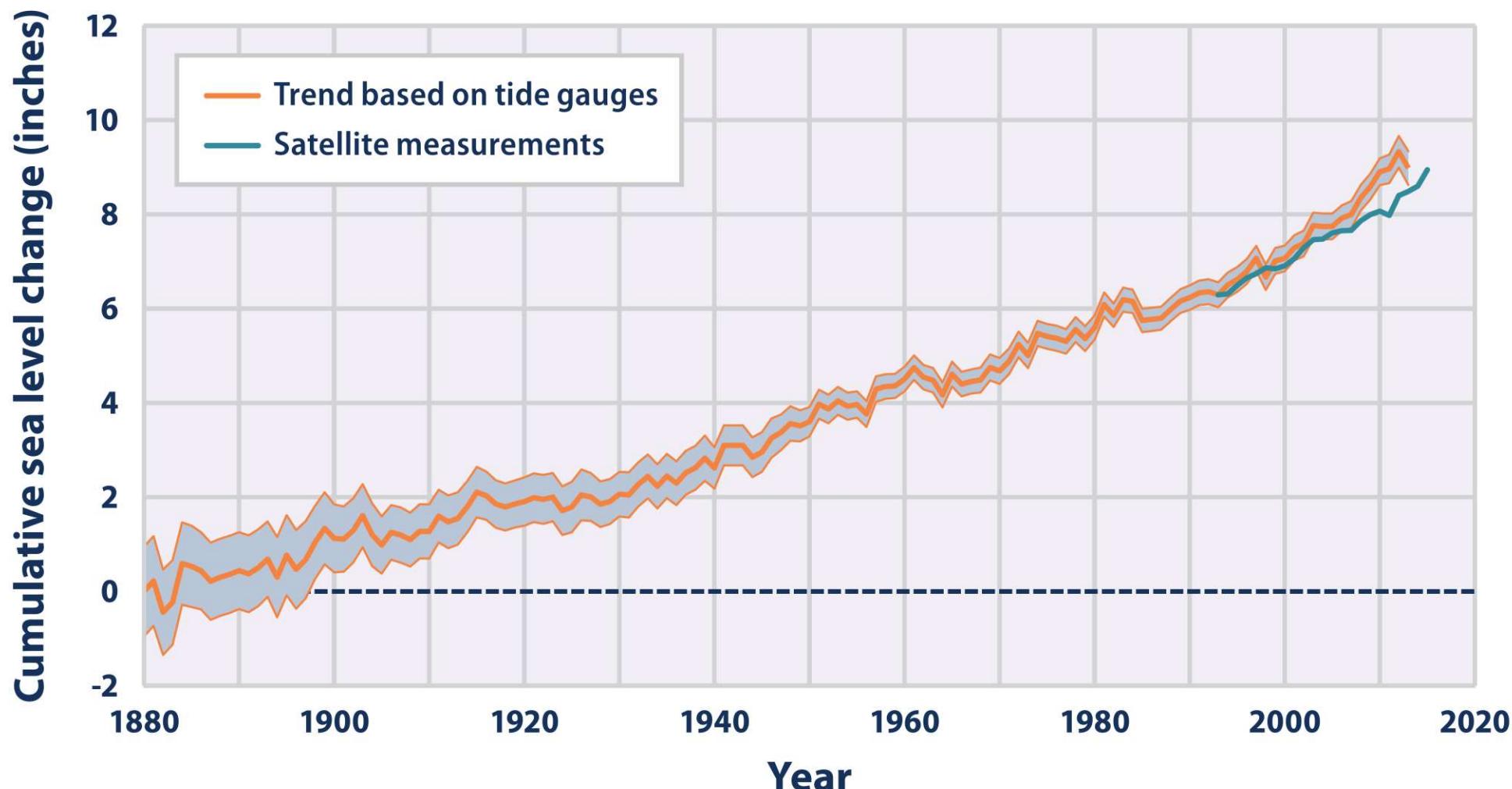


Source: NASA (National Aeronautics and Space Administration). 2016. NASA's Goddard Space Flight Center Scientific Visualization Studio. <http://svs.gsfc.nasa.gov>.

# Sea Level Rise

- Many low-lying coastal land areas are expected to be gradually submerged by rising sea levels.

## Global Average Absolute Sea Level Change, 1880–2015



- For a low-lying island nation like the Maldives in the Indian Ocean, even a small rise in sea level could spell disaster for most of its people. About 80% of the 1192 small islands making up this country lie less than 1 meter above sea level.



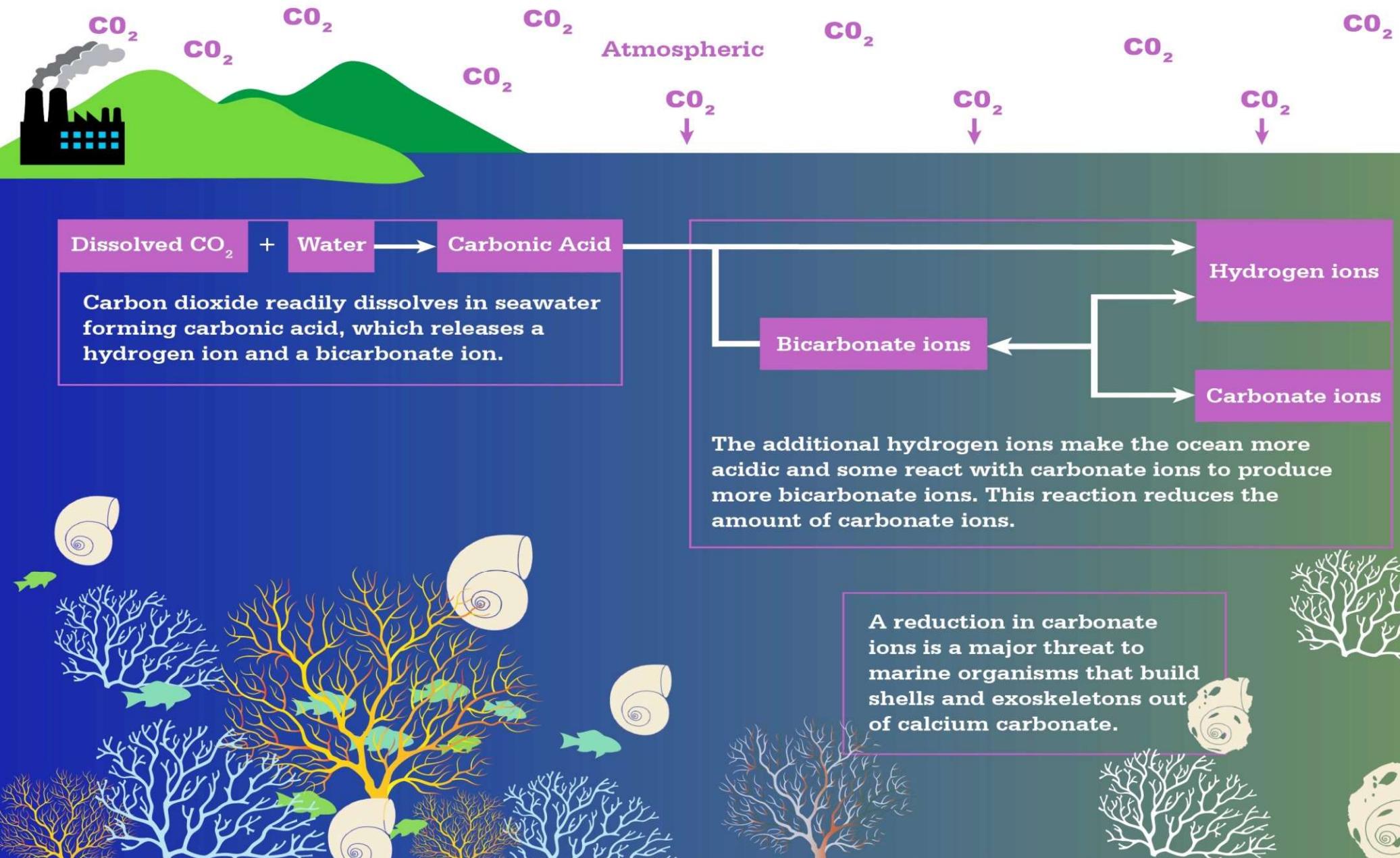
# Coastal Flooding

- Sea level rise will magnify the adverse impact of storm surges and high waves on the coast.



# Ocean Acidification

- ‘Acidification’ of ocean water can harm marine life.



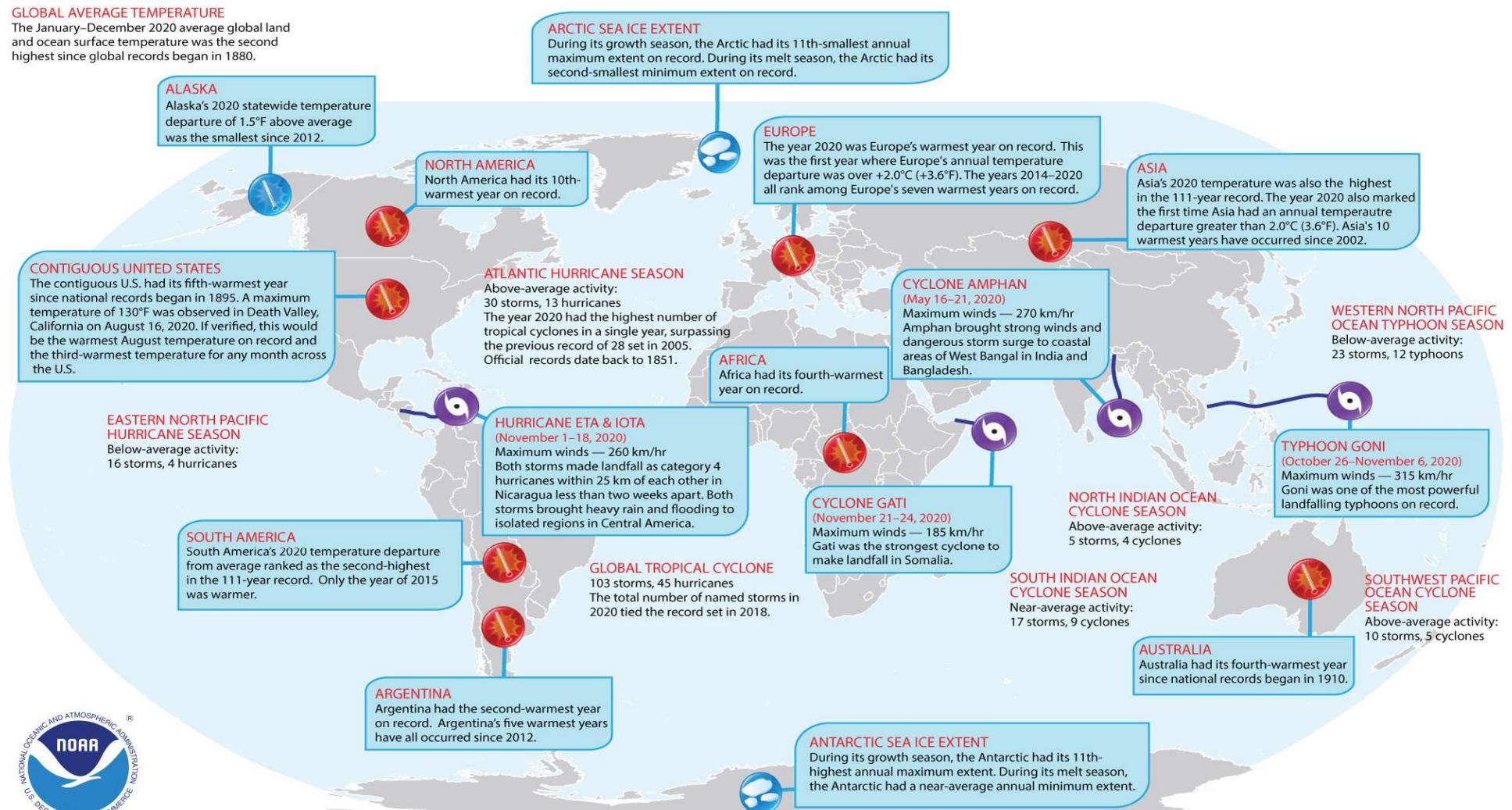
- Declining pH levels in the world's oceans interferes with many species ability to form shells.



# Extreme Weather Events

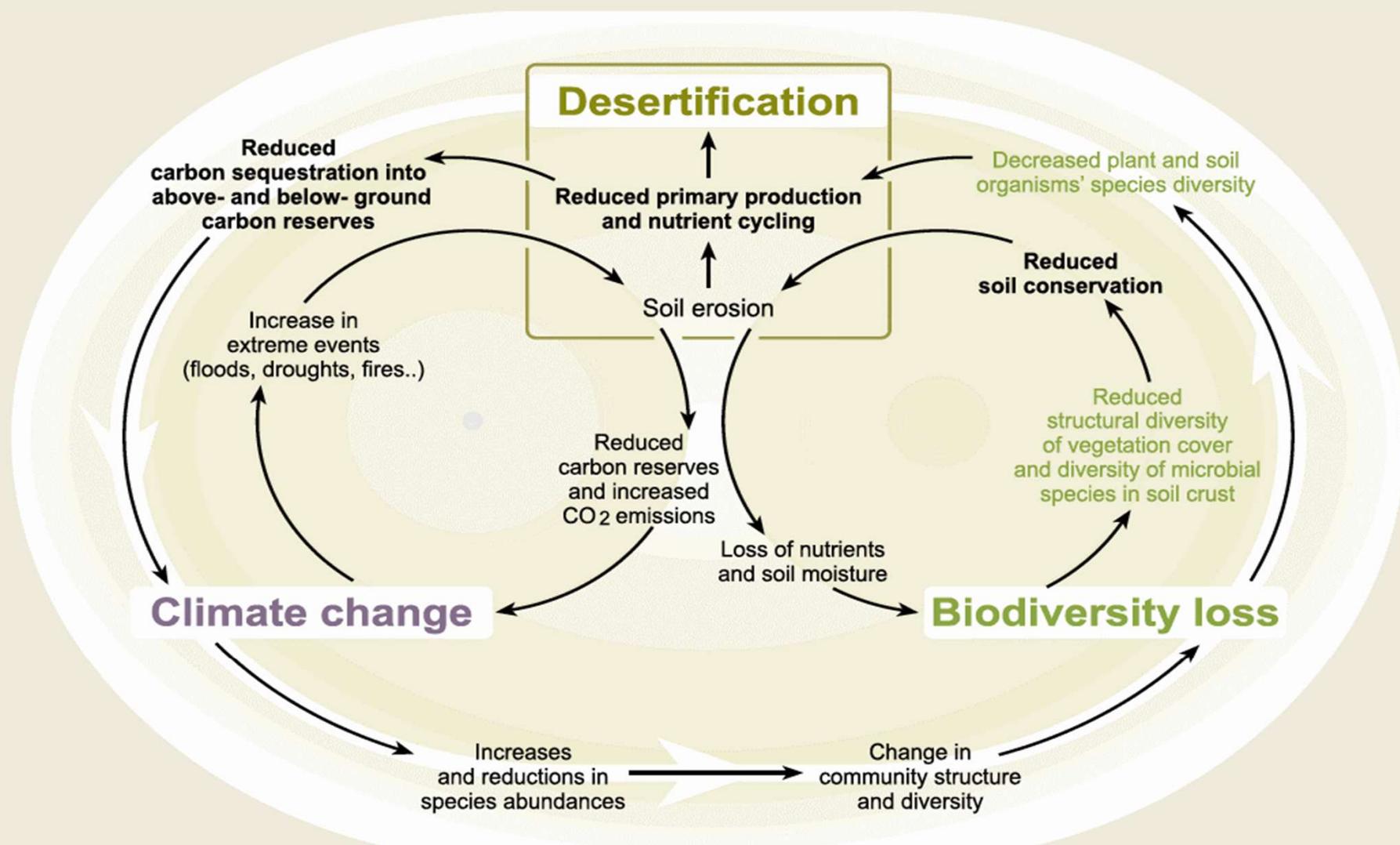
- As the climate has warmed, some types of extreme weather have become more frequent and severe in recent decades.

## Selected Significant Climate Anomalies and Events in 2020



# Biodiversity Loss

- Climate change alone is expected to threaten with extinction approximately one quarter or more of all species on land by the year 2050, surpassing even habitat loss as the biggest threat to life on land.



# Impact on Food Production

## POSITIVE IMPACTS

Increased productivity from warmer temperatures

Possibility of growing new crops

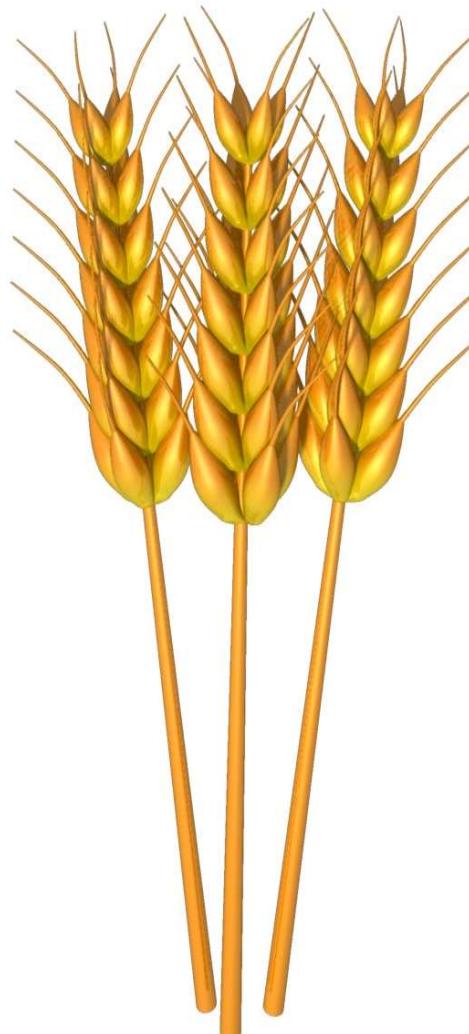
Longer growing seasons

Increased productivity from enhanced CO<sub>2</sub>\*

Accelerated maturation rates

Decreased moisture stress (for some crops)

\*CO<sub>2</sub> fertilization only applies to some crops and will at best be a small temporary benefit for higher altitudes.



## NEGATIVE IMPACTS

Increased insect infestations

Crop damage from extreme heat

Planning problems due to less reliable forecasts

Increased soil erosion

Increased weed growth

More plant disease

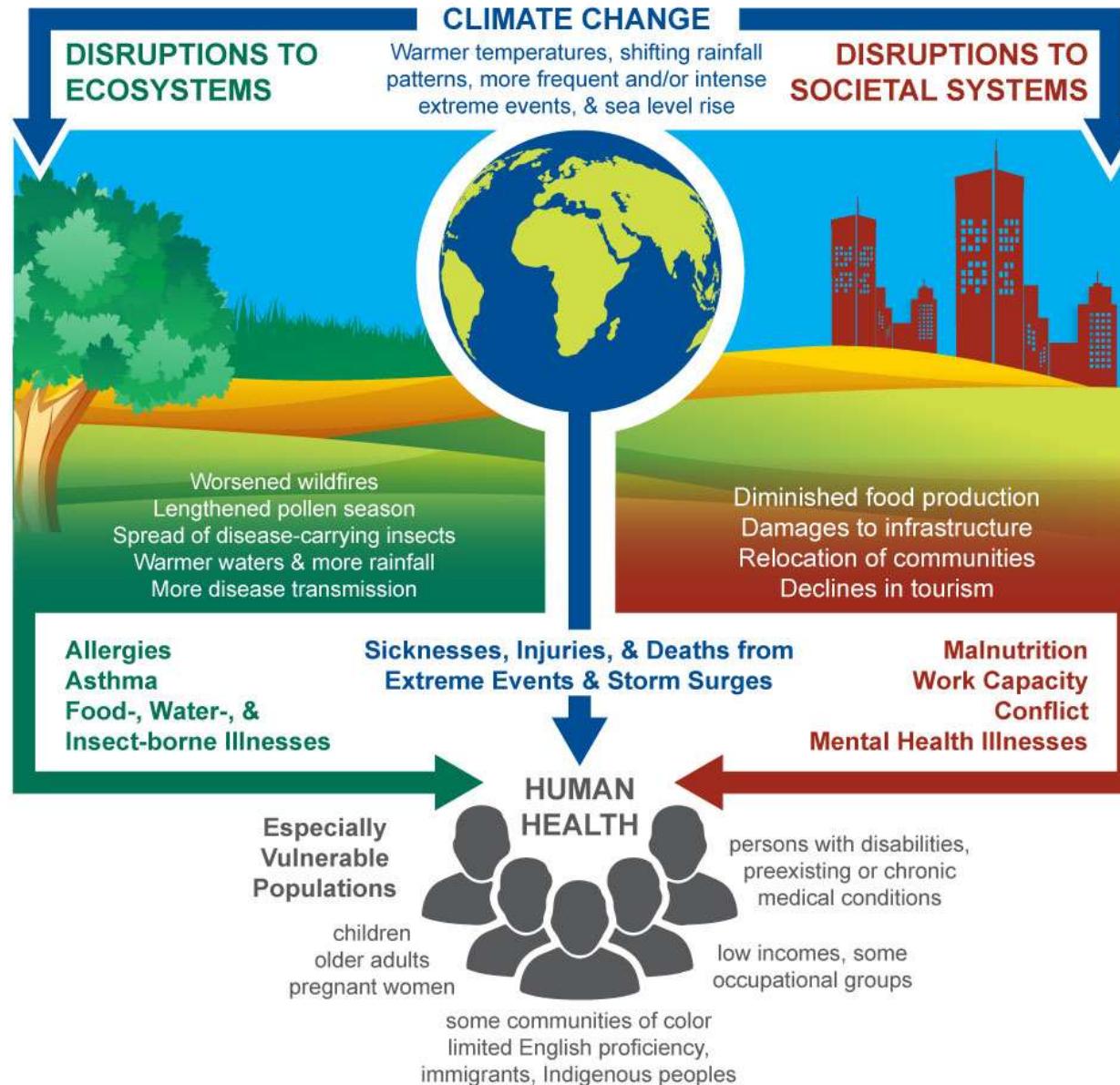
Decreased herbicide and pesticide efficiency

Increased moisture stress (for most crops)

# Threat to Human Health

- Climate crisis can have serious consequences for human health and well-being.

## The Impacts of Climate Change on Human Health





# Mitigating Climate Change

# Climate solutions are within reach

## Solutions

### Slowing Climate Change

#### Prevention

Cut fossil fuel use (especially coal)

Shift from coal to natural gas

Improve energy efficiency

Shift to renewable energy resources

Transfer energy efficiency and renewable energy technologies to developing countries

Reduce deforestation

Use more sustainable agriculture and forestry

Limit urban sprawl

Reduce poverty

Slow population growth



#### Cleanup

Remove CO<sub>2</sub> from smokestack and vehicle emissions

Store (sequester) CO<sub>2</sub> by planting trees

Sequester CO<sub>2</sub> in soil by using no-till cultivation and taking cropland out of production

Sequester CO<sub>2</sub> deep underground (with no leaks allowed)

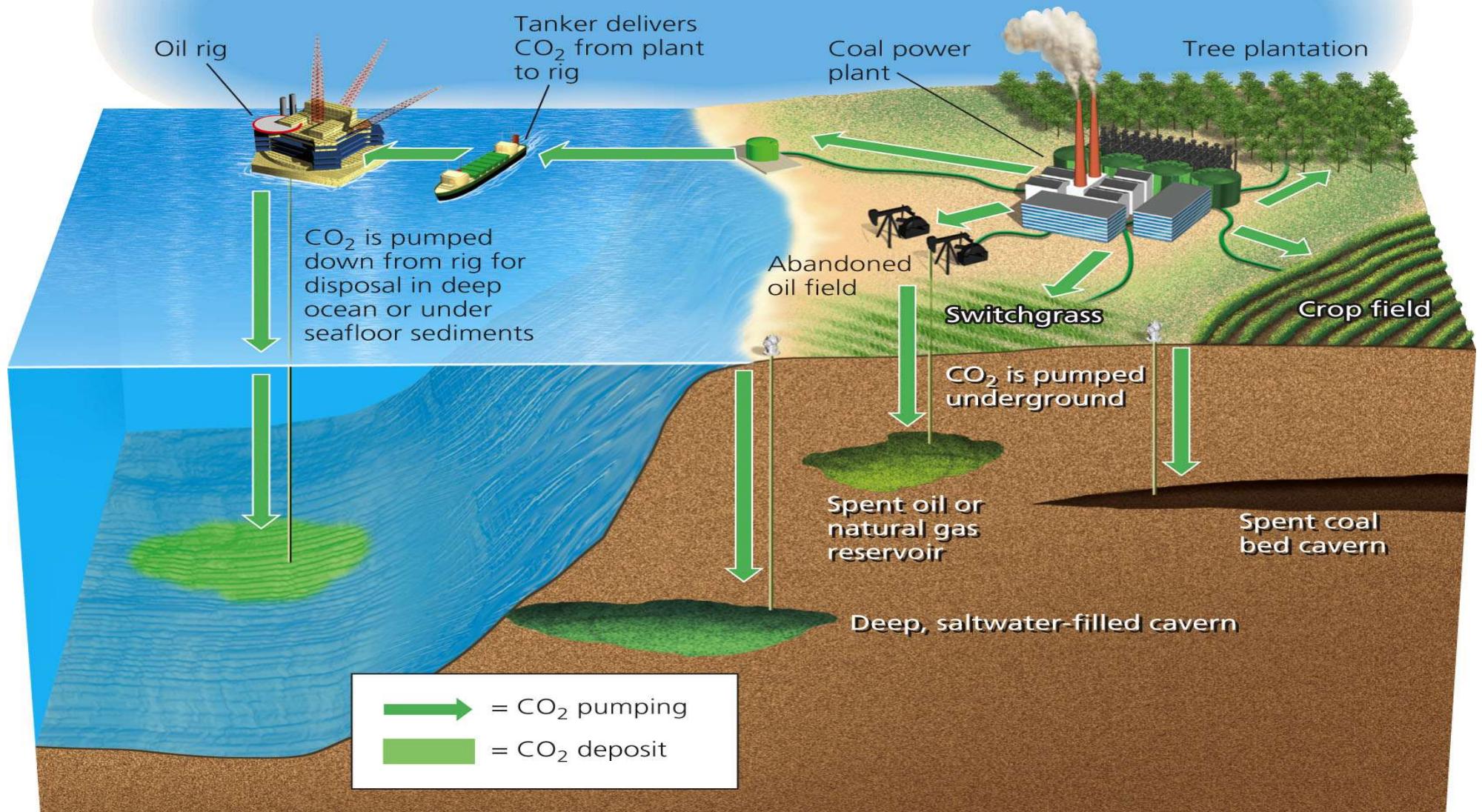
Sequester CO<sub>2</sub> in the deep ocean (with no leaks allowed)

Repair leaky natural gas pipelines and facilities

Use animal feeds that reduce CH<sub>4</sub> emissions from cows (belching)

# Climate solutions are within reach

- Output strategies for dealing with CO<sub>2</sub> would allow us to keep burning fossil fuels. However, they would require us to capture and store as much CO<sub>2</sub> as possible in soil, in vegetation, underground, and in the deep ocean, and to hope that it would never leak out.



# Geoengineering

## CLIMATE-READY CROPS

Creating paler crops to reflect light, and crops that are drought resistant

## ARTIFICIAL TREES

Extracting CO<sub>2</sub> from the air and burying it in the ground

## BIOCHAR

Burning then burying agricultural carbon waste underground

## ENHANCED WEATHERING

Curbing atmospheric CO<sub>2</sub> by spreading olivine (magnesium iron silicate) over land

## OCEAN FERTILISATION

Adding iron or nitrogen to the oceans to promote carbon sequestration by phytoplankton

## WHITE PAINTING

Covering roofs and roads to reflect sunlight

## SPACE MIRRORS

Firing trillions of tiny aluminium mirrors into space to deflect sunlight

## CLOUD SEEDING

Spraying seawater into clouds to precipitate rain

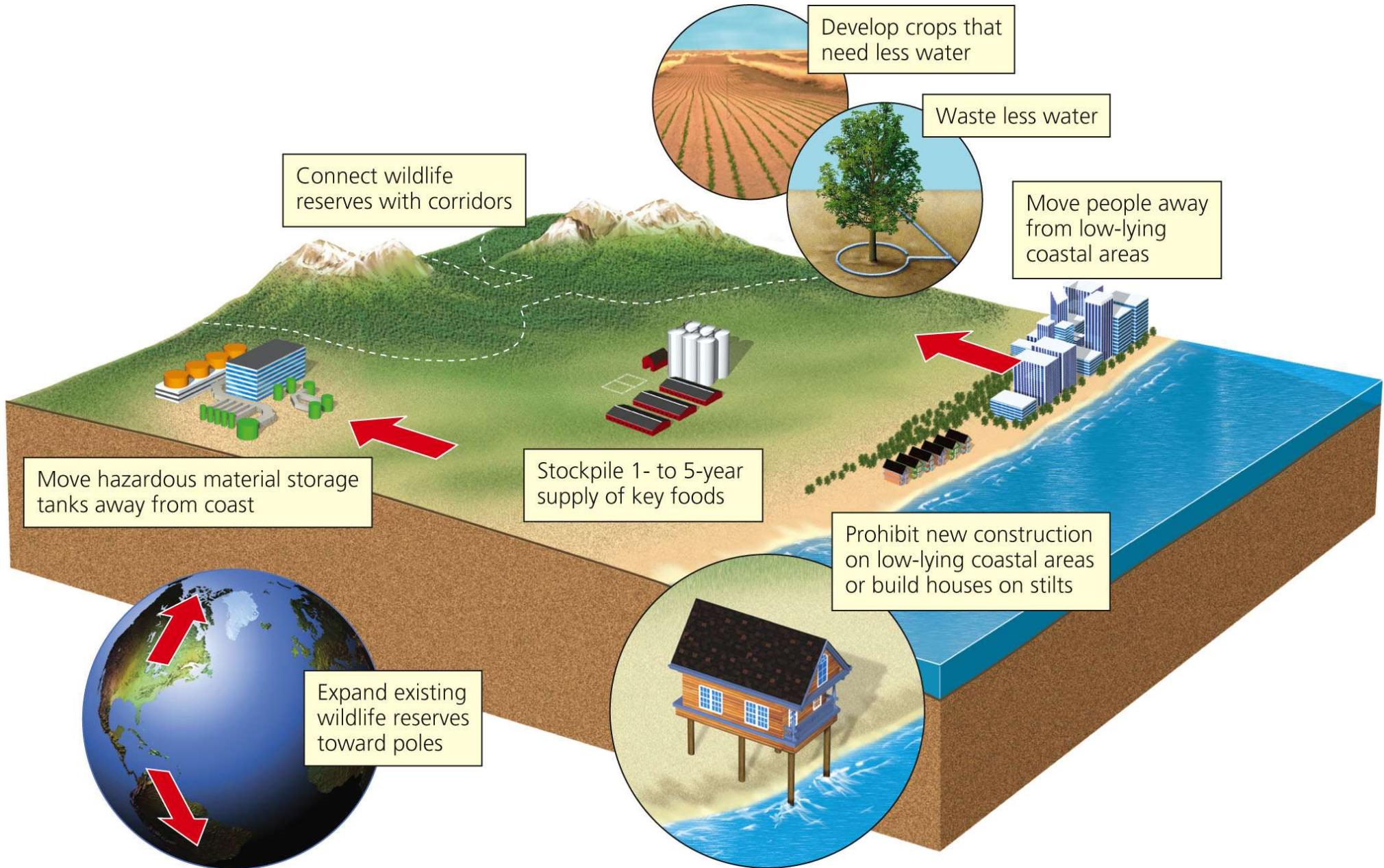
## ENGINEERED MICROBES

Creating synthetic microbes and engineered algae to sequester CO<sub>2</sub>



# Adapting to Climate Change

# We can prepare for climate disruption





# Governments can play a critical role

- Governments can adopt the following strategies to reduce the threat of climate disruption:
  - strictly regulate CO<sub>2</sub> and CH<sub>4</sub> as climate changing pollutants.
  - phase out the most inefficient polluting coal-burning power plants and replace them with more efficient and cleaner natural gas and renewable energy alternatives.
  - put a price on carbon emissions by phasing in taxes on each unit of CO<sub>2</sub> or CH<sub>4</sub> emitted, or phasing in energy taxes on each unit of any fossil fuel burned.
  - use a cap-and-trade system which uses the marketplace to help reduce emissions of CO<sub>2</sub> and CH<sub>4</sub>.





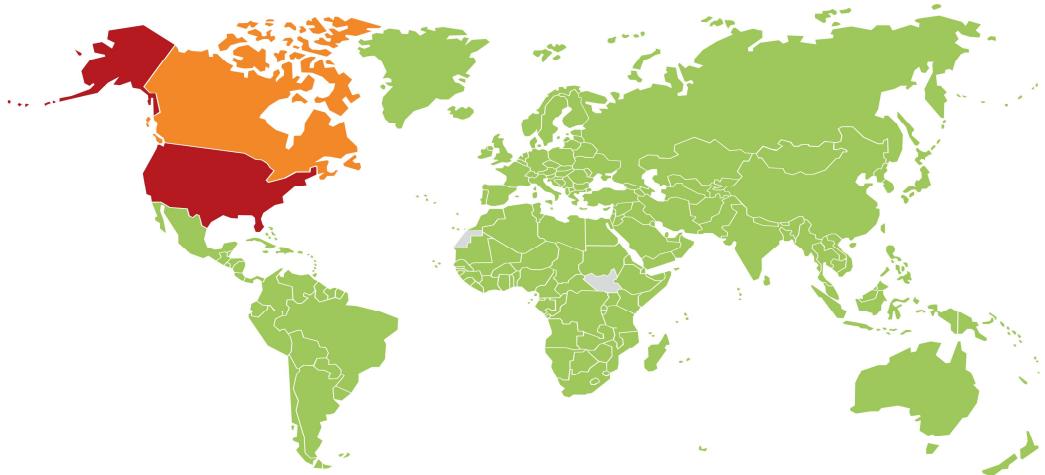
# Governments can play a critical role

- phase out government subsidies and tax breaks for fossil fuels and industrialized food production.
- phase in government subsidies and tax breaks for energy efficiency technologies, low-carbon renewable energy sources, and more sustainable agriculture.
- focus research and development efforts on innovations that lower the cost of clean energy alternatives.
- work out agreements to finance and monitor efforts to reduce deforestation.
- encourage more-developed countries to help fund the transfer of the latest energy-efficiency and cleaner energy technologies to less-developed countries.



# The Kyoto Protocol

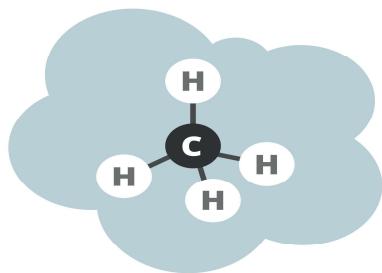
**16<sup>TH</sup> FEBRUARY – THE KYOTO PROTOCOL (2005)**



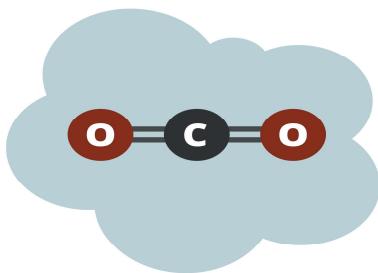
**192 COUNTRIES**

- signed and ratified
- ratified but withdrawn
- signed but not ratified

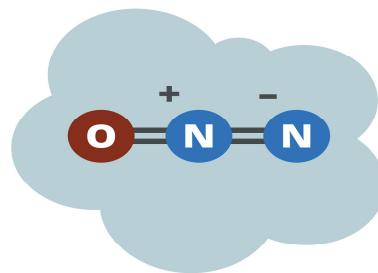
**TARGET  
↓ 5.2%**  
by 2012 relative to 1990



METHANE



CARBON DIOXIDE



NITROUS OXIDE

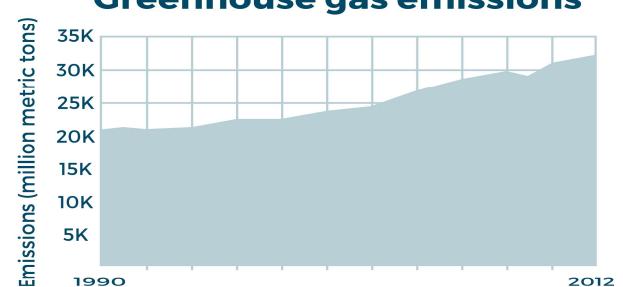
**GREENHOUSE GASES**

**HYDROFLUOROCARBONS**

**PERFLUOROCARBONS**

**SULFUR HEXAFLUORIDE**

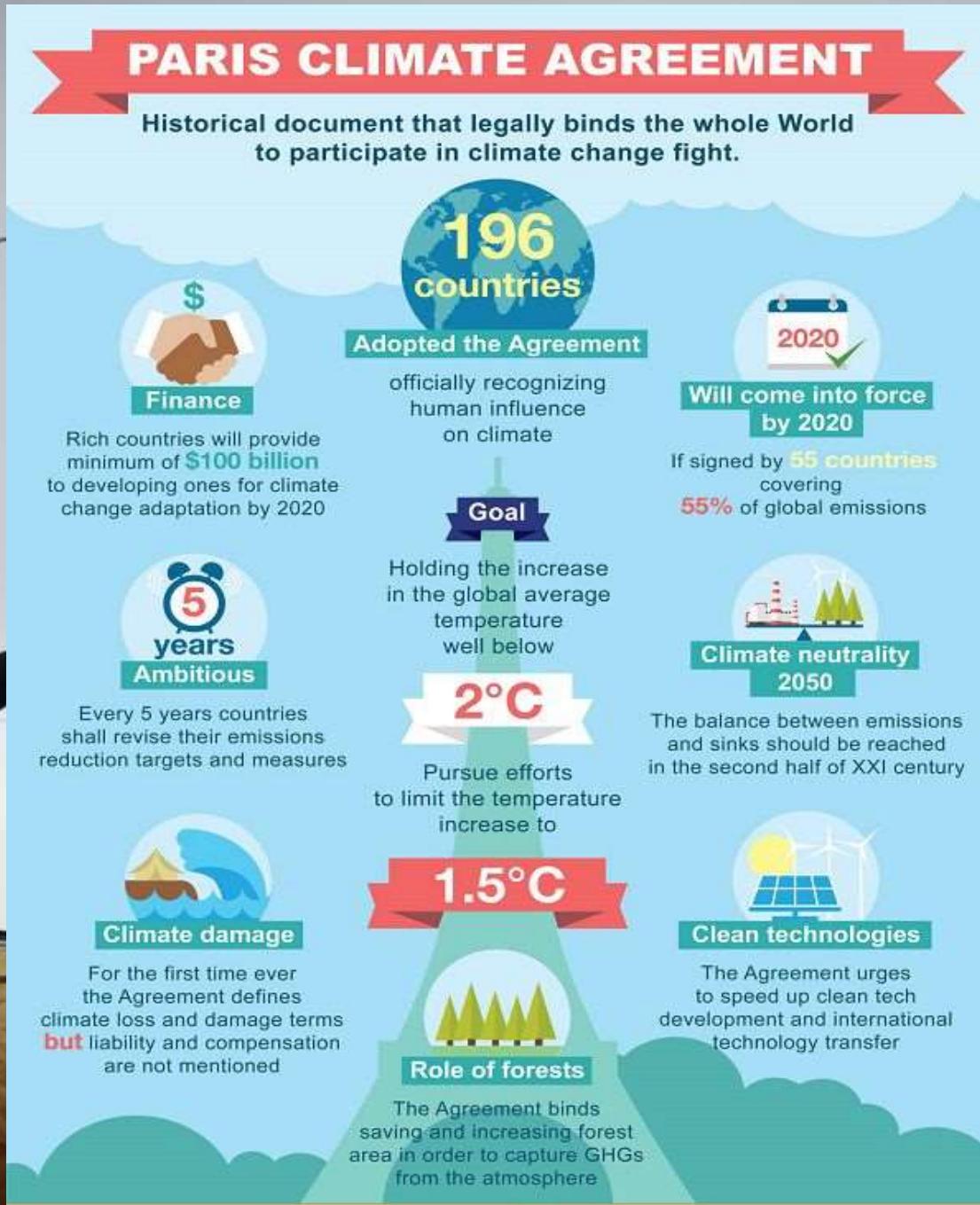
The Kyoto Protocol is an international treaty to reduce the emission of six greenhouse gases. 192 countries are party to the protocol, but only 38 had binding targets for the first period (2008–2012). These 38 countries met their target collectively – but an absence of binding targets for developing nations such as China and India meant that worldwide greenhouse gas emissions continued to rise.



# The Paris Agreement

Conférer

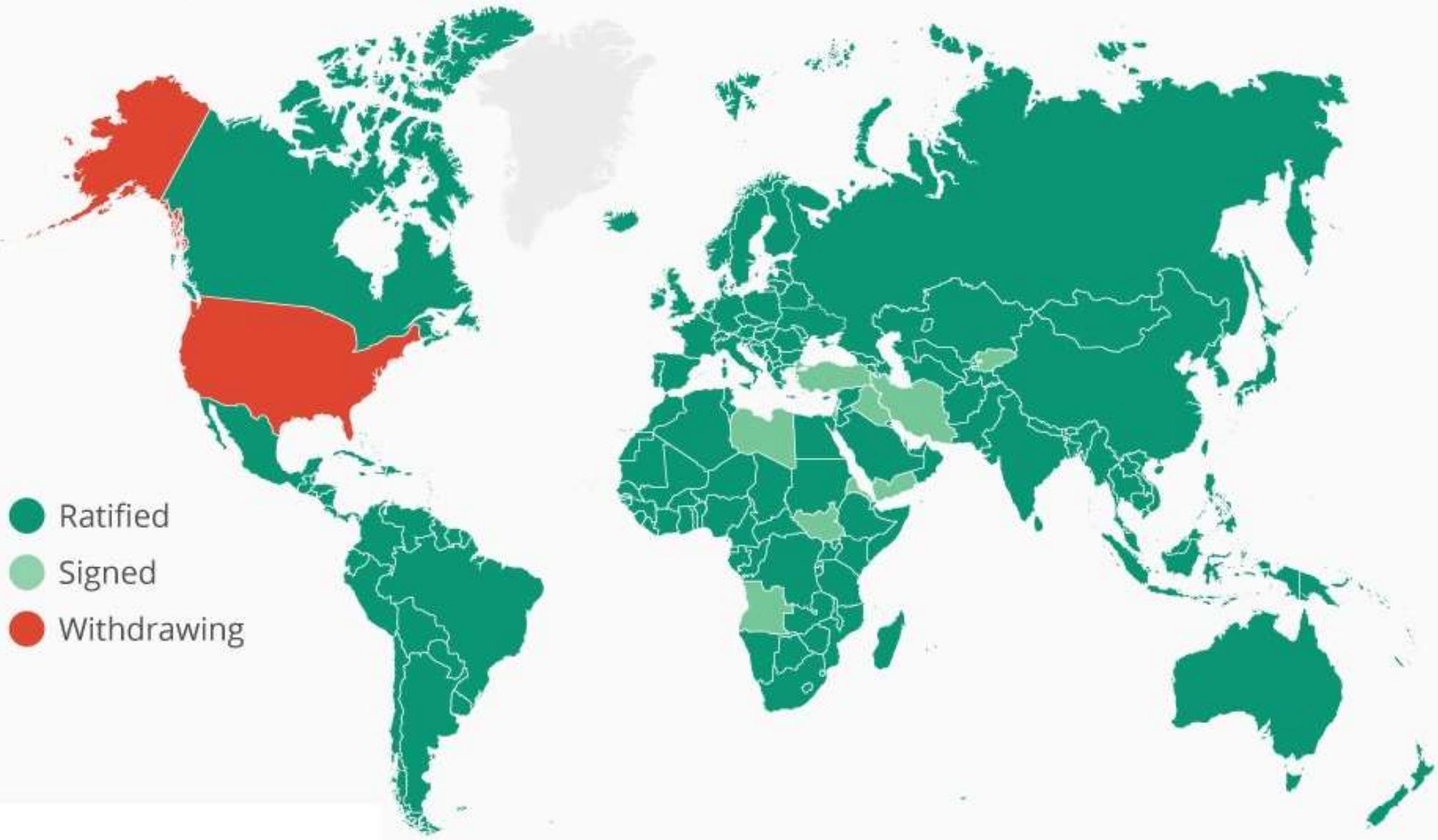
atiques 2015



# The Paris Agreement

## The State of the Paris Agreement

Countries by their participation in the Paris Agreement (as of Nov 5, 2019)



# Intergovernmental Panel on Climate Change



- The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change.
- It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.
- In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC.
- As an intergovernmental body, membership of the IPCC is open to all member countries of the UN and WMO.





# Role of IPCC

- "... to 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."
- IPCC does not undertake new research, nor does it monitor climate-related data, instead, it conducts assessments of knowledge on the basis of published and peer reviewed scientific and technical literature.
- "IPCC reports should be neutral with respect to policy, although they may need to deal objectively with scientific, technical and socio-economic factors relevant to the application of particular policies."





# Structure of IPCC

UN Parent  
Organizations



Intergovernmental Panel  
(195 member states)

IPCC Plenary

IPCC Bureau

Executive Committee

IPCC Secretariat

Working  
Group I  
  
The Physical  
Science Basis

TSU

Working  
Group II  
  
Impacts,  
Adaptation,  
and  
Vulnerability

TSU

Working  
Group III  
  
Mitigation  
of  
Climate Change

TSU

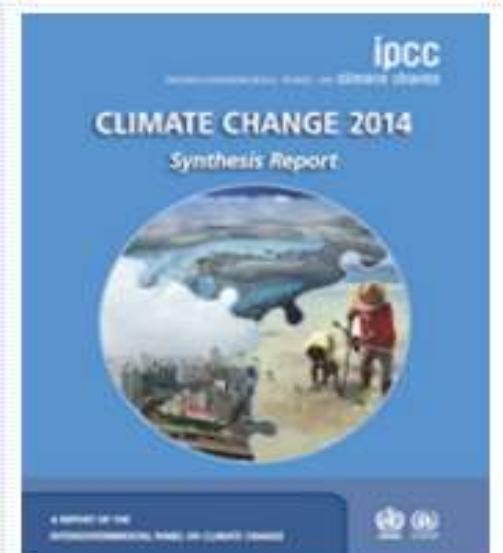
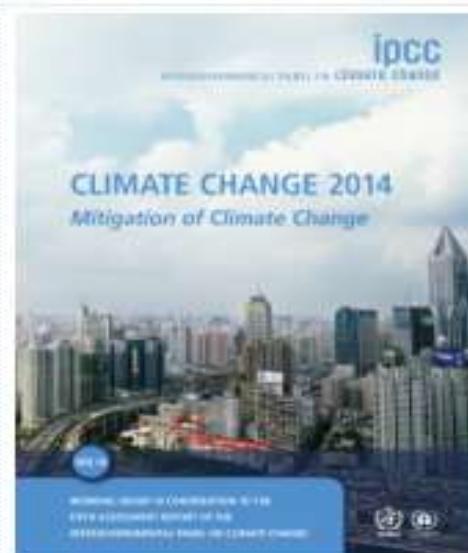
Task Force  
on  
  
National  
Greenhouse  
Gas  
Inventories

TSU

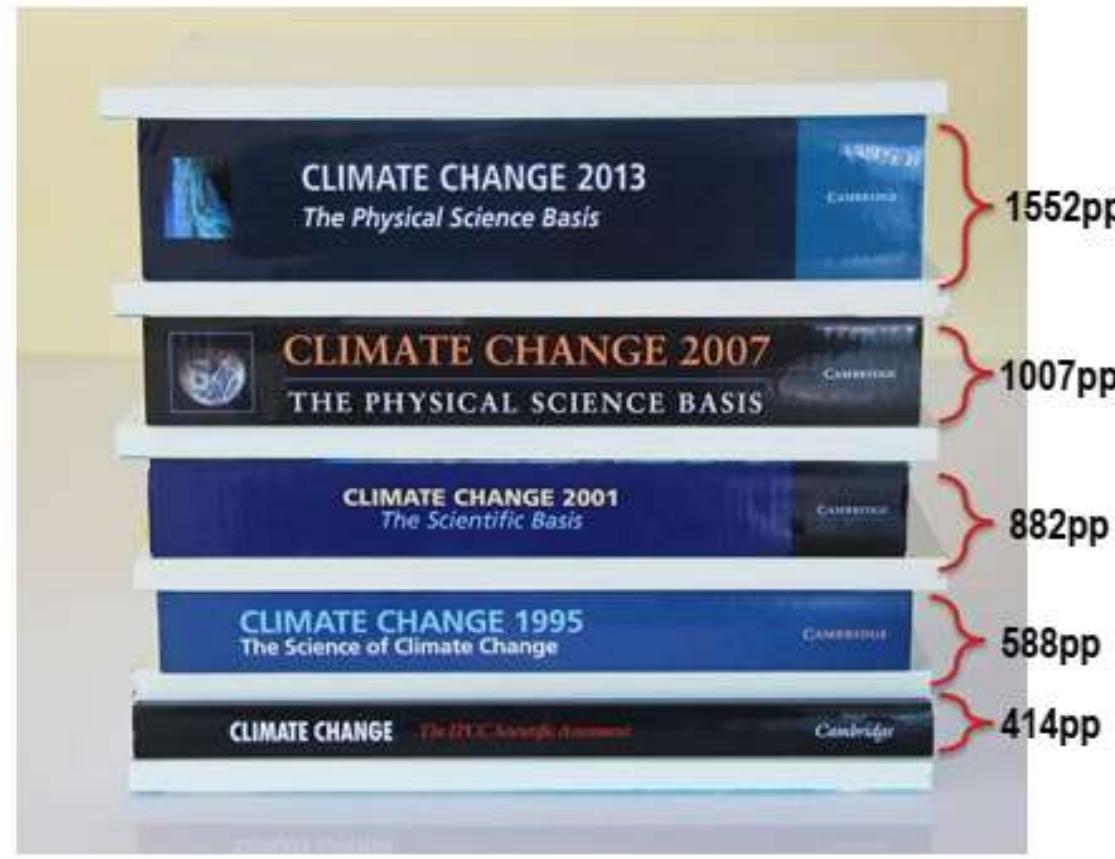
Authors, Contributors, Reviewers

# IPCC Reports

- Five **assessment reports** (1990, 1995, 2001, 2007, 2013-14)
- Nine **special reports** (1997, 1999, 2000, 2005, 2011, 2012): provide an authoritative scientific/technical assessment or guidance on any topic, which is not adequately covered in assessment reports.
- **Guidelines** for national GHG inventories, good practice guidance (1995, 2006, 2013)
- **Technical papers and supporting material:** TPs are produced from IPCC reports to provide tailored scientific/technical perspective on a particular topic; SM consists of published reports and proceedings from workshops and expert meetings within the scope of the IPCC work programme.



# Significant Progress made in Understanding Climate Change since 1990 – WG I Reports



The reports are getting more comprehensive





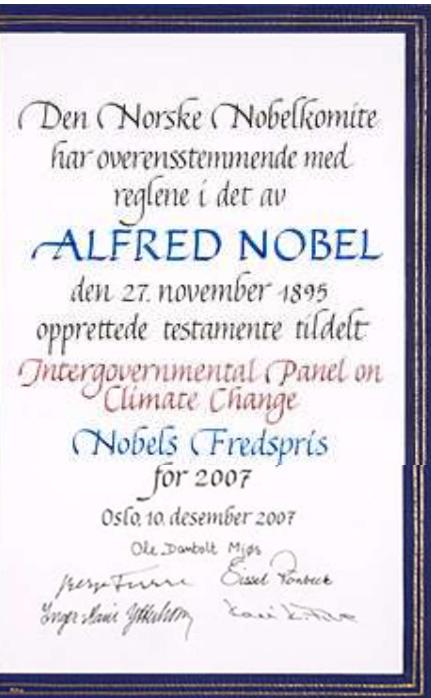
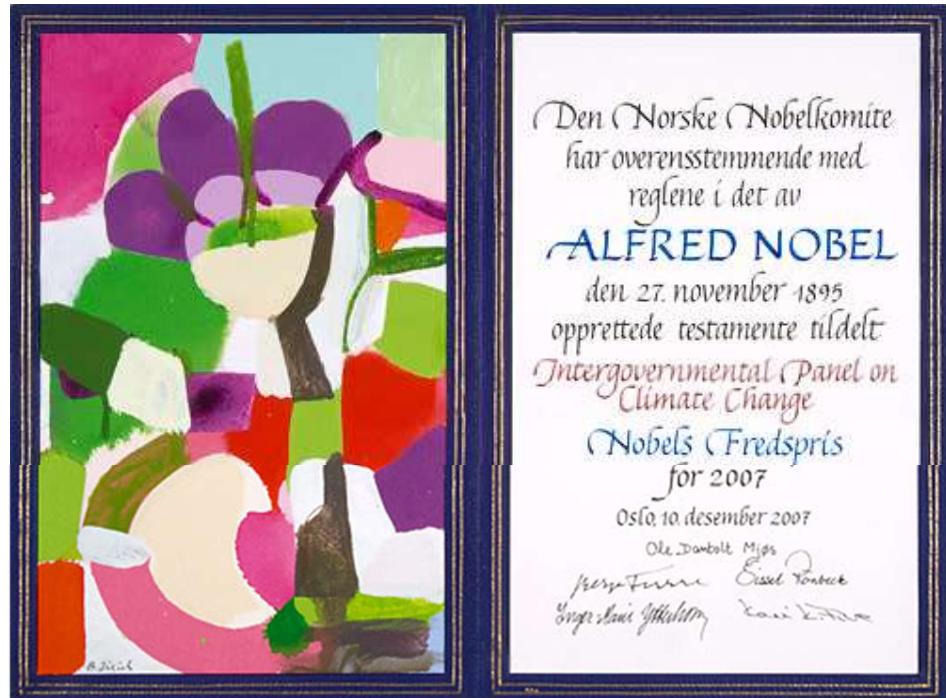
# Outcome of IPCC reports

- FAR (1990) – led to the United Nations Framework Convention on Climate Change (UNFCCC), an international environmental treaty adopted on 9 May 1992 to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"
- SAR (1995) – input for Kyoto Protocol which set targets for 37 industrialized countries to stabilize greenhouse gas emissions based on the principles of the UNFCCC.
- TAR (2001) – focused attention on impacts of climate change and need for adaptation
- AR4 (2007), AR5 (2013) – input for decision on 2 °C limit; basis for post Kyoto Protocol agreement.





# Nobel Peace Prize to IPCC



The Nobel Peace Prize 2007 was awarded jointly to Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."



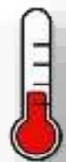


# What is next for the IPCC?

## IPCC Decision XLIII-5

“To take the outcomes of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) into consideration when determining the IPCC programme of work and products for the sixth IPCC assessment cycle”

## AR6 cycle Special Reports on



impacts of global warming of **1.5 °C** above pre-industrial levels and related global greenhouse gas emission pathways (“Global Warming of **1.5°C** -- by 2018



Climate change and **oceans** and the **cryosphere**



Climate change, **desertification**, **land degradation**, **sustainable land management**, **food security**, and **greenhouse gas fluxes in terrestrial ecosystems**



# What is next for the IPCC?

## AR6 Main Report



Expected to be released in **three working group contributions** in 2021 and a **Synthesis Report** in 2022

## Methodology Report update



Methodology Report on National Greenhouse Gas Inventories by **2019** (2019 Refinement to the 2006 Guidelines)

## Cities



Attention on **cities** in AR6 including a conference and special report on cities in AR7



## What Can You Do?

### Reducing CO<sub>2</sub> Emissions

- Drive a fuel-efficient car, walk, bike, carpool, and use mass transit
- Use energy-efficient windows
- Use energy-efficient appliances and lights
- Heavily insulate your house and seal all air leaks
- Reduce garbage by recycling and reusing more items
- Insulate your hot water heater
- Use compact fluorescent lightbulbs
- Plant trees to shade your house during summer
- Set your water heater no higher than 49 °C (120 °F)
- Wash laundry in warm or cold water
- Use a low-flow showerhead
- Buy products from, or invest in, companies that are trying to reduce their impact on climate