Climate Change
&
The Atmospheric Energy Balance

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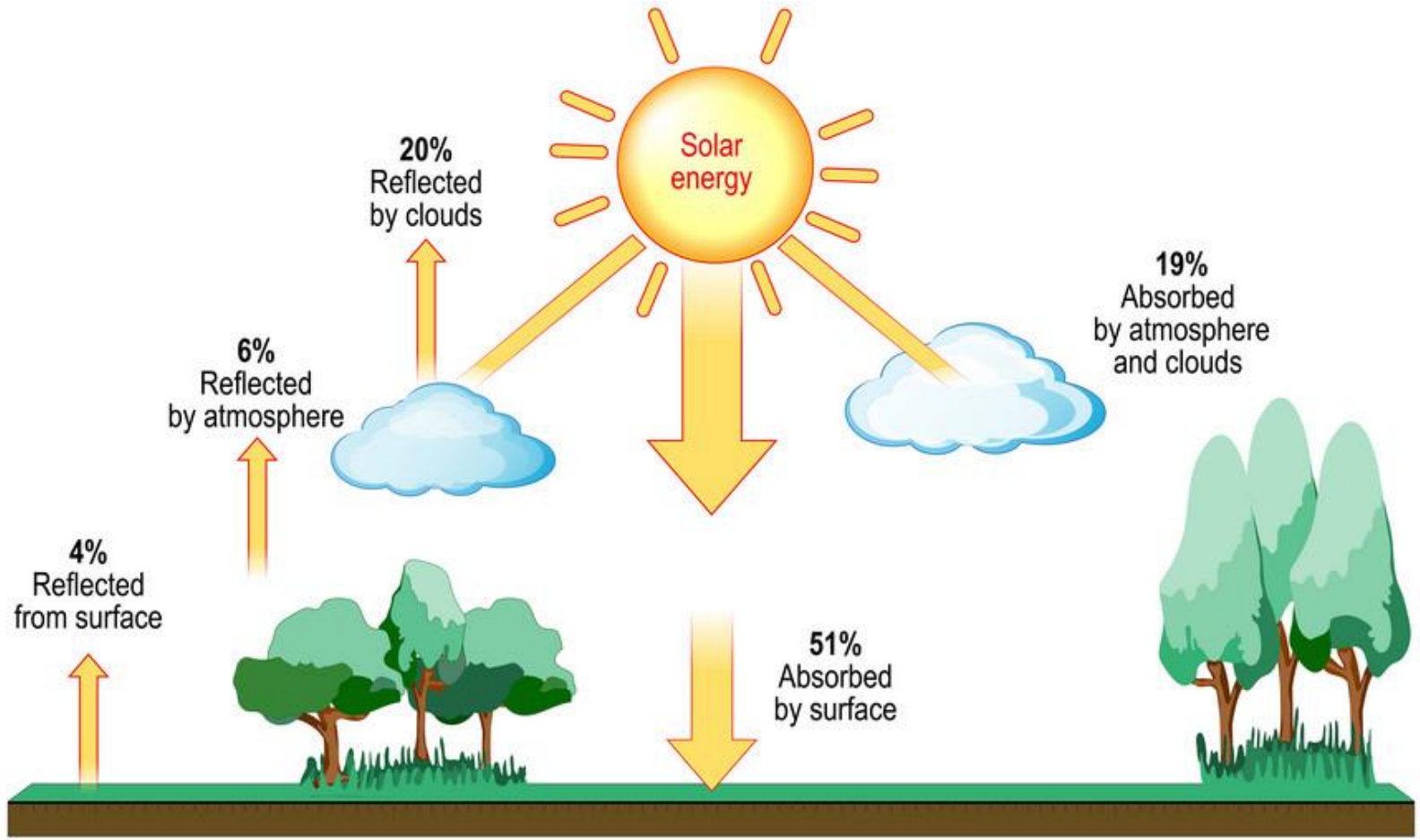
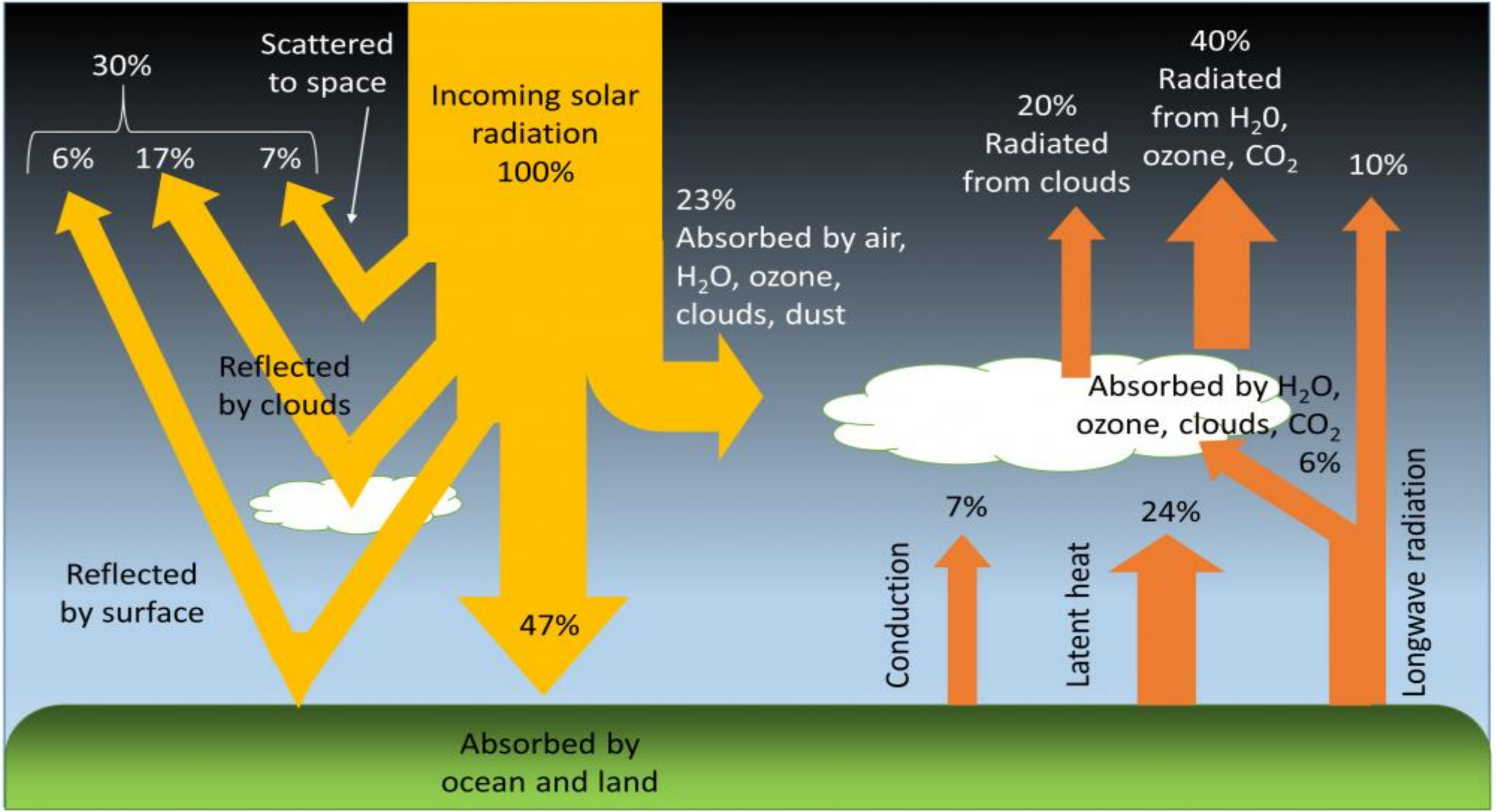
Earth-Atmosphere Energy Balance

- This refers to the **balance between the amount of incoming solar radiation and outgoing terrestrial radiation**.
- The Earth's temperature remains constant if incoming and outgoing energy remains balanced.
- Of all of the solar radiation reaching Earth, **70% is absorbed** while **30% is reflected** back to space.
- **Out of total 70%,** Earth's surface absorbs (47%) and atmosphere (23%).
- When incoming energy from the sun is absorbed the Earth warms and when energy is released from Earth into space, the planet cools.

Solar radiation

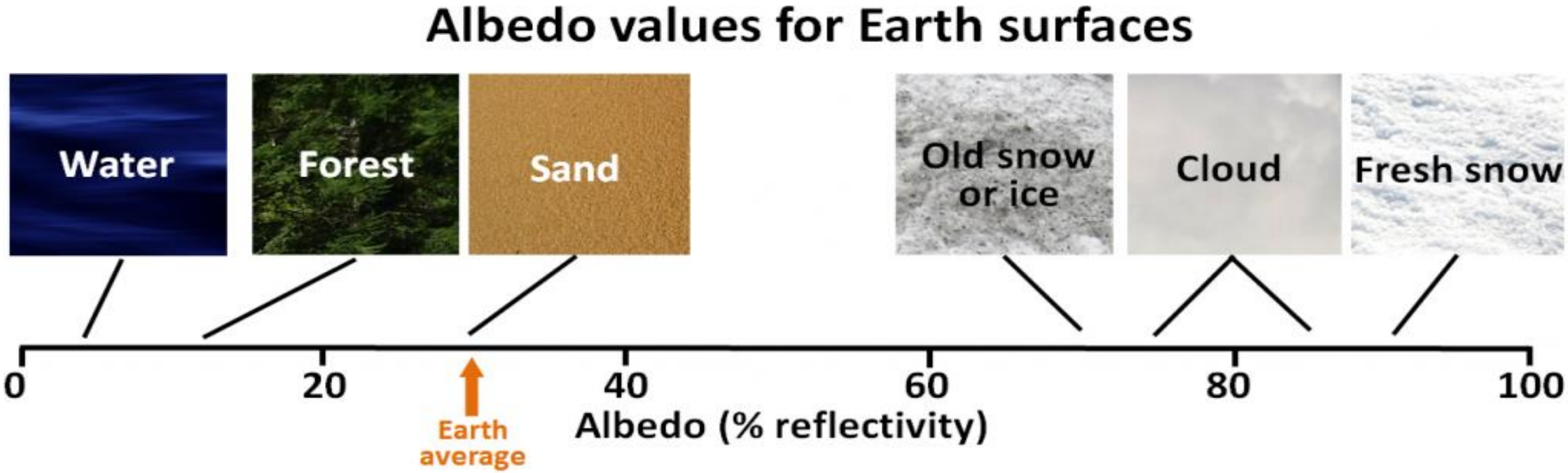



30%
Scattered to space
6%
17%
7%
Incoming solar radiation 100%
23% Absorbed by air, H_2O, ozone, clouds, dust
20% Radiated from clouds
40% Radiated from H_2O, ozone, CO_2
10%
Reflected by clouds
Absorbed by H_2O, ozone, clouds, CO_2 6%
Reflected by surface
47%
7%
Conduction
24%
Latent heat
Longwave radiation
Absorbed by ocean and land

Albedo

- The albedo refers to **reflectivity of a surface**, expressed as the percentage of light that is reflected back from a given material.

- Lighter surfaces are more reflective than darker surfaces and therefore have a higher albedo.



Factors affecting Energy Balance

- **Changes in the concentration of greenhouse gases**, which affects the amount of heat retained by Earth's atmosphere.
- **Variations in the sun's energy** reaching Earth.
- **Changes in the reflectivity** of Earth's atmosphere and surface.

Calculating Planetary Energy Balance & Temperature

The total amount of energy intercepted by Earth:

$$E_{intercepted} = K_S \times \pi {R_E}^2$$

Where, E = Total energy intercepted (W)

K_S = Solar insolation or solar constant = 1,361 W/m^2

R_E = Radius of Earth = 6,371 km = 6,371,000 m

$$E = 1361 \times 3.1416 \times (6{,}371{,}000)^2$$

$$E = 173.5 \times 10^{15}\ watts$$

Contd…

Since, some of this energy is reflected back, and albedo represents the light reflected away. Hence the **equation for total energy absorbed** is given by:

$$E_{absorbed} = K_S \times (1 - albedo) \times \pi {R_E}^2$$

From the Stefan-Boltzmann law the **energy emitted by the Earth** per unit area per unit time is given by:

$$E^* = \sigma T^4$$

Where,

- E* = energy flux = energy per unit time per unit area ($J/s/m^2$ or W/m^2)
- σ = Stefan-Boltzmann constant = 5.670373×10^{-8} W/m^2K^4
- T = Temperature (in Kelvin)

Expression for Earth's total energy emissions:

$$E_{emitted} = \sigma T^4 \times 4\pi {R_E}^2$$

From the law of conservation of energy, the energy absorbed must be equal to the energy emitted

$$E_{absorbed} = E_{emitted}$$

$$K_S \times (1 - albedo) \times \pi {R_E}^2 = \sigma T^4 \times 4\pi {R_E}^2$$

Or, $$K_S \times (1 - albedo) = 4\sigma T^4$$

Or, $$T = \sqrt[4]{\frac{K_S \times (1 - albedo)}{4\sigma}}$$

Contd…

Earth's overall, average albedo is about 0.31 (or 31%)

Hence, $$T = \sqrt[4]{\frac{1361 \times (1 - 0.31)}{4 \times 5.6704 \times 10^{-8}}} = 253.7\ kelvins$$

$$T_{Celsius} = T_{Kelvin} - 273.15 = -19.5°\ C$$

$$T_{Fahrenheit} = \frac{9}{5} \times T_{Celsius} + 32 = -3.1°\ F$$

Q:Why is Earth's temperature so much warmer than the calculated value?

Ans: GHGs in the atmosphere traps the heat and warms the planet. This is called the greenhouse effect.

Intergovernmental Panel on Climate Change (IPCC)

- The Intergovernmental Panel on Climate Change (**IPCC**) was established **jointly** by the **United Nations Environment Programme** (UNEP) and the **World Meteorological Organization** (WMO) in **1988.**

- Currently, the IPCC has **195 members**.

- The IPCC was created to provide the policymakers with:
  - **Regular scientific assessments on climate change**.
  - **Mitigation options and its potential future risk.**

Global Frameworks and Agreements

- **Sustainable Development Goals (SDGs).**
- **UN Framework Convention on Climate Change (UNFCCC).**
- **Kyoto Protocol.**
- **Paris Agreement.**

Sustainable Development Goals

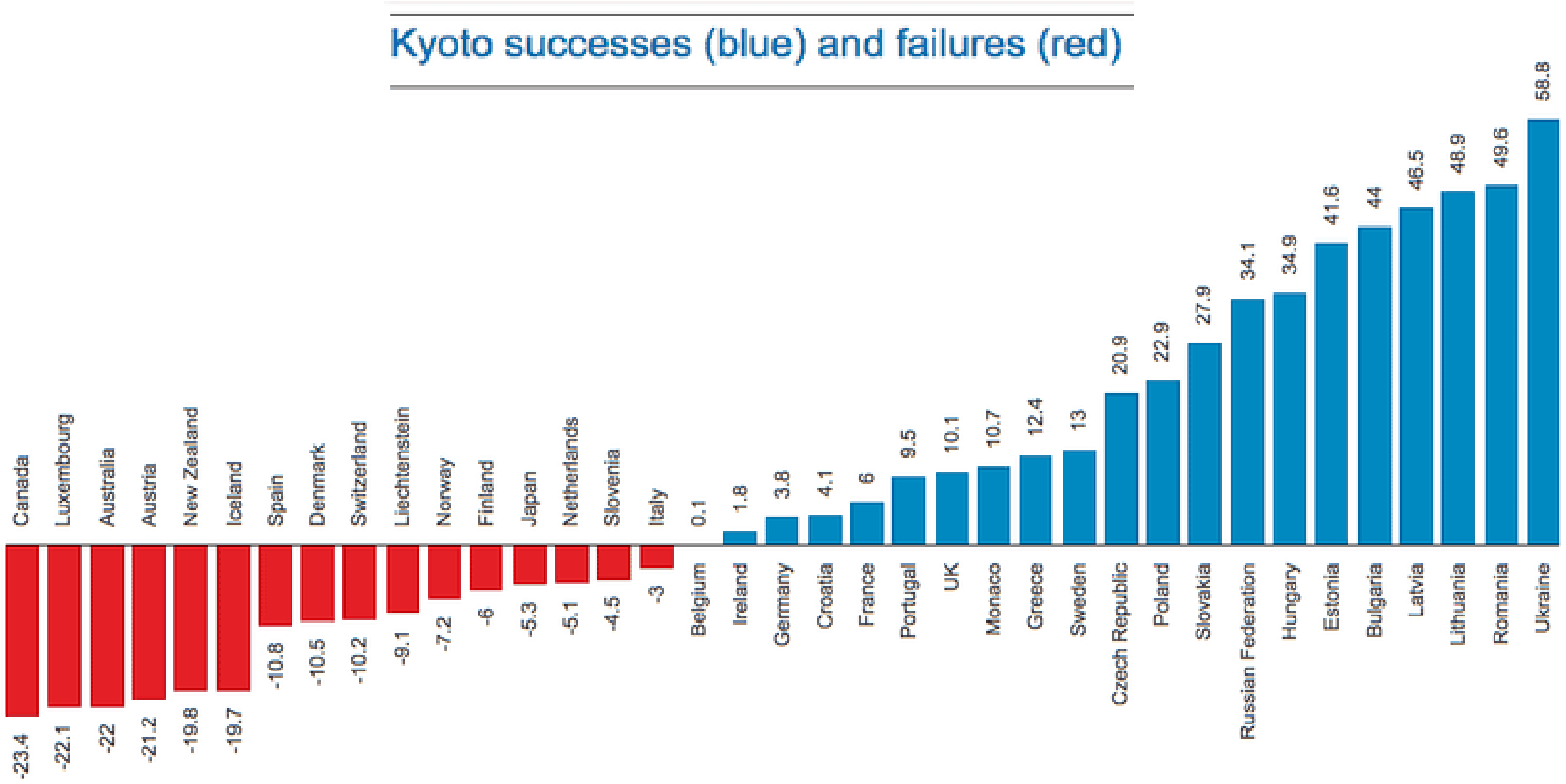
UN Framework Convention on Climate Change (UNFCCC)

- The UNFCCC came into force on **21 March 1994**.
- Currently **198 countries (Parties)** have ratified the Convention.
- The ultimate objective of the Convention is to **stabilize greenhouse gas** concentrations **"at a level that would prevent dangerous anthropogenic interference with the climate system".**
- **Industrialized countries** are expected to do the maximum **cut in GHGs emissions** on their home ground.

Kyoto Protocol

- This Protocol was adopted on 11 December 1997, however it came into force on **16 February 2005**.
- The Kyoto Protocol **operationalizes the UNFCCC** by committing **industrialized countries and economies in transition** to **reduce GHG emissions**.
- Currently, there are **192 Parties** associated with the Kyoto Protocol.

Actual Percentage Change in Emissions Between 1990 and 2010

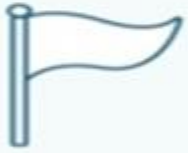
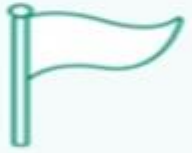


Paris Agreement

- This agreement was signed by the world leaders at the **UN Climate Change Conference (COP 21) in Paris** on **12 December 2015** to **tackle the climate change and its negative impacts**.

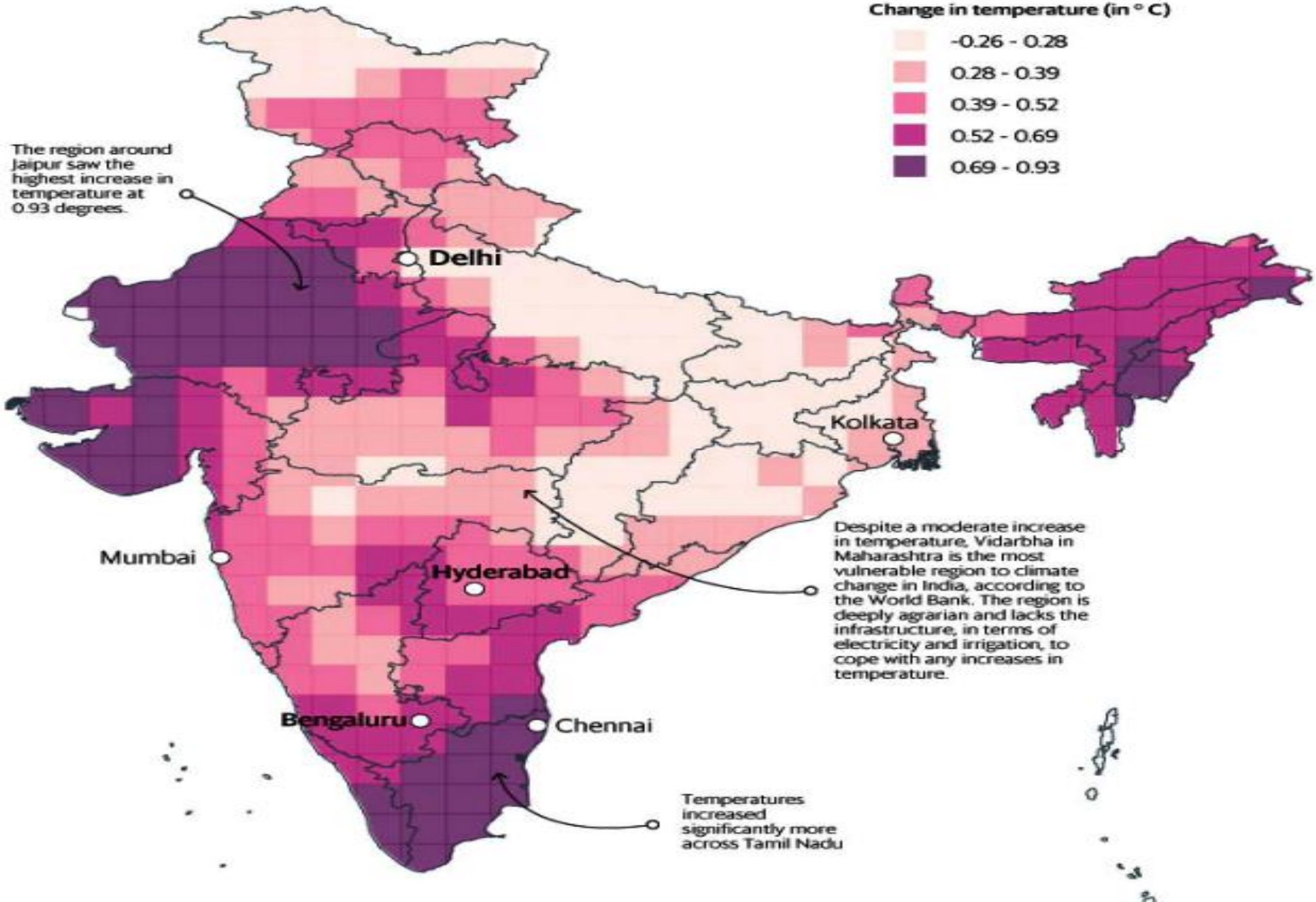
- The long-term goals of the agreement:

  - **Reduce GHG emissions** to **limit the temperature rise** in this century to 2^{o}C.
  - Putting efforts to limit the rise even further to 1.5^{o}C.
  - **Review countries' commitments** at every 5 years.
  - **Provide finance to developing countries** to **mitigate climate change**.

Kyoto Protocol	Paris Agreement
 Was created in 1997 and ratified in 2005. Had two periods from 1997-2020.	 Signed in December, 2015 . New commitments are due every 5 years
 Legally binding agreement to decrease GHG	 Not legally binding commitment to reduce emissions
 Original commitment to decrease overall emissions by 5% from 1990 levels	 Overall goal to limit global temperatures to 1.5 degrees celcius
 Only required developed nations to reduce emissions	 Asked all nations to reduce emissions
 Targets are set but no determined time	 New set of targets declared after 5 years

India's Stand on Climate Change

- Indian government had released its first **National Action Plan** on Climate Change in 2008.
- Indian government has taken up steps to **scale up clean energy production.**
- India adopted the **National Electricity Plan in 2018,** and remains on track to comply with the **targets of Paris Agreement**.
- India is expecting to **achieve its goal of 40% non-fossil fuel-based power capacity by 2030**.
- Various Indian states have agreed to adopt '**Heat Action Plans**' that includes installation of cool roofs and shift the public transport system to electric buses.


Change in temperature (in ° C)
-0.26 - 0.28
0.28 - 0.39
0.39 - 0.52
0.52 - 0.69
0.69 - 0.93
The region around Jaipur saw the highest increase in temperature at 0.93 degrees.
Delhi
Kolkata
Mumbai
Hyderabad
Bengaluru
Chennai
Despite a moderate increase in temperature, Vidarbha in Maharashtra is the most vulnerable region to climate change in India, according to the World Bank. The region is deeply agrarian and lacks the infrastructure, in terms of electricity and irrigation, to cope with any increases in temperature.
Temperatures increased significantly more across Tamil Nadu

Thank you