



National Centre for
Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

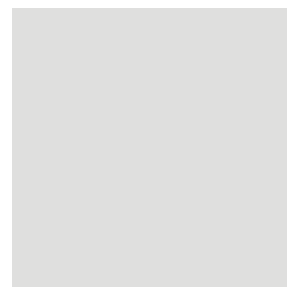
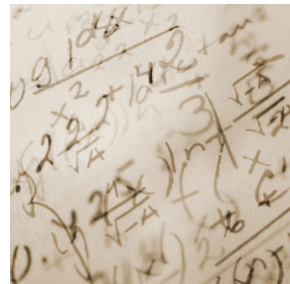


Royal Meteorological Society

Report for Geography Teachers

Climate Change Updates

*Evidence from the 2013 Intergovernmental Panel
on Climate Change (IPCC)*



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Glossary

This booklet and all the figures and Frequently Asked Questions referenced in this booklet may be downloaded from www.metlink.org

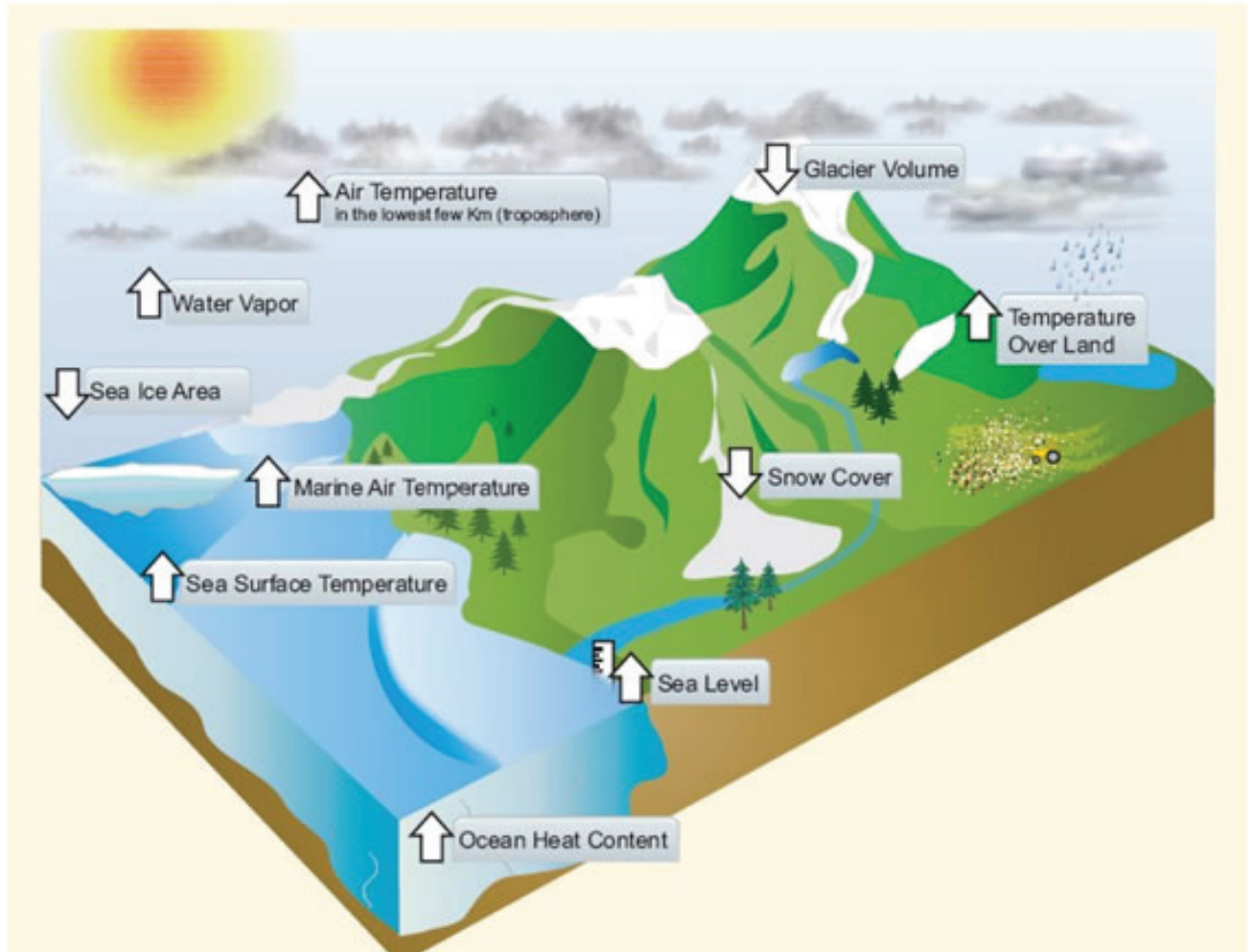
IPCC, 2013: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014: Climate Change 2014: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change.

1. Signs of a Changing Climate



Changes observed in the climate system which provide evidence of a warming world

What is the key evidence for climate change?

Evidence for a warming world comes from many independent indicators, from high up in the atmosphere to the depths of the oceans. They include increases in surface, atmospheric and oceanic temperatures; shrinking of glaciers; decreasing snow cover and sea ice; rising sea level and increasing atmospheric water vapour. Put together, we see that the evidence points unequivocally to one thing: **the world has warmed since the late 19th century.**

A rise in **global average surface temperatures** is the best-known indicator of climate change. Although each year and even decade is not always warmer than the last, global surface temperatures have warmed substantially since 1900.

Why is the cryosphere so important?

The **cryosphere** plays a major role in the Earth's climate system. It has an impact on the water cycle, primary productivity, the surface energy budget, surface gas exchange and sea level and is therefore a fundamental control on the environment over a large part of the Earth's surface. The **cryosphere** is sensitive to changing temperatures and provides some of the most visible signatures of climate change over time.

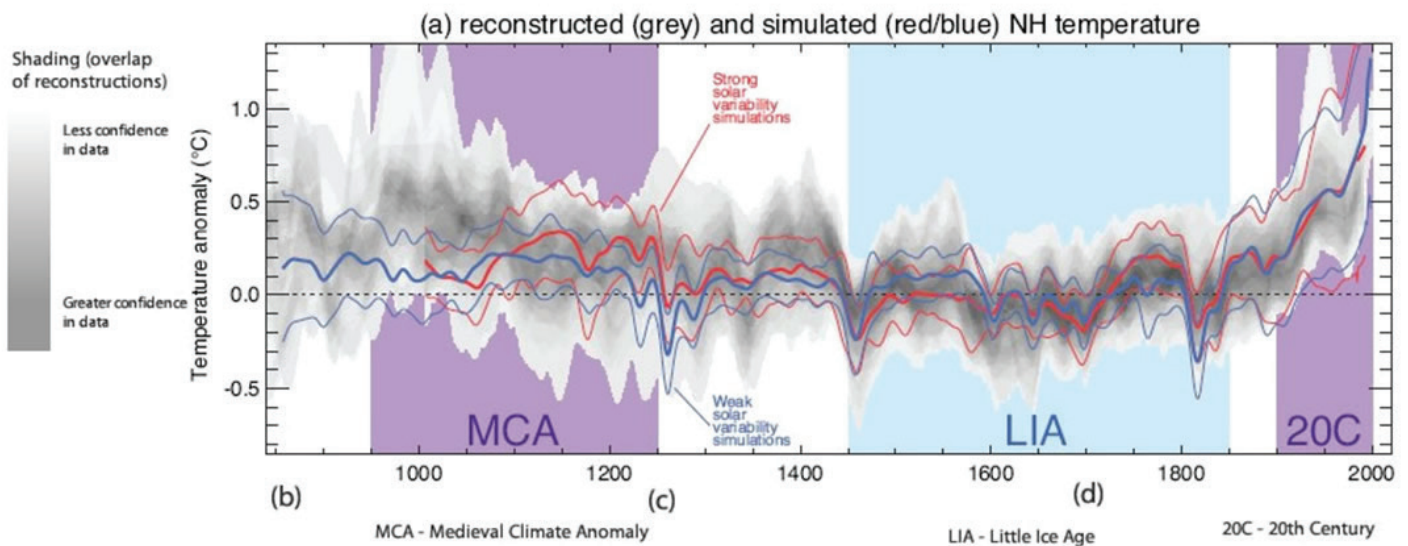
What evidence does the cryosphere reveal?

	Average Rate of ice loss during 1992-2001 (Gt per year)	Average Rate of ice loss year during 2002-2011 (Gt per year)
Greenland Ice Sheet	34	215
Antarctic Ice Sheet	30	147

Gt = Gigatonnes

- The annual Arctic sea ice extent decreased over the period 1979–2012 by between 3.5 and 4.1% per decade. The extent has decreased in every season, and is most rapid in summer and autumn.
- In total, all the glaciers in the world, excluding those on the periphery of ice sheets, lost approximately 226 Gt/ year in the period 1971–2009, approximately 275 Gt/ year in the period 1993–2009, and approximately 301 Gt/ year between 2005 and 2009.
- Between 2003 and 2009, most of the glacier ice lost was from Alaska, the Canadian Arctic, the periphery of the Greenland ice sheet, the Southern Andes and the Asian Mountains.

2. Past Changes in Northern Hemisphere Temperature



Northern Hemisphere temperature changes over the last millenium

Is recent climate change similar to anything that has happened in the past?

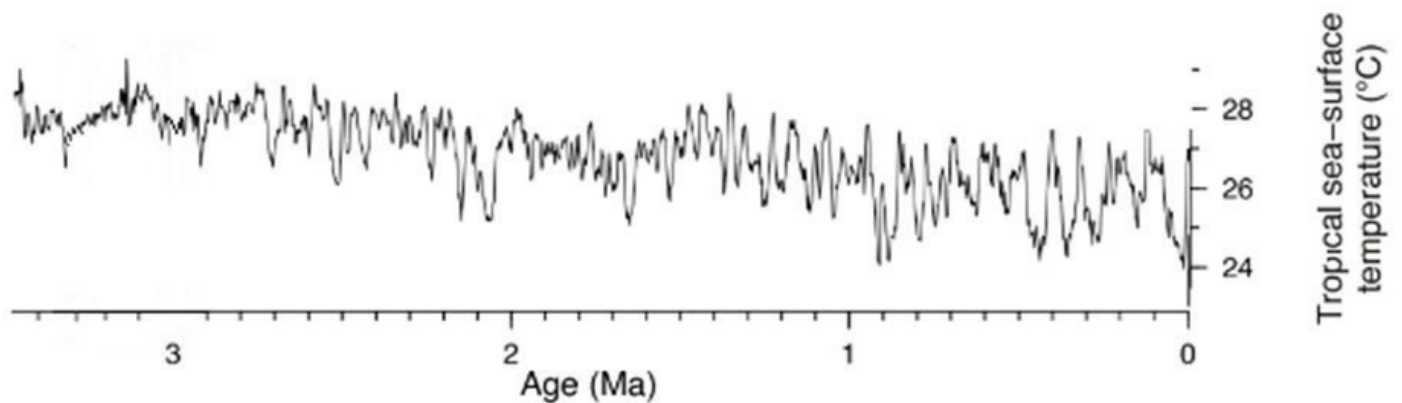
Many studies have confidently indicated that the mean Northern Hemisphere temperature of the last 30 years exceeded any previous 30- year average during the past 1400 years. The studies are based on proxy data (indirect measures of the climate) including tree ring widths, stalactites and stalagmites, glaciers, bore hole data and marine and lake sediments.

New **reconstructions** of **paleoclimates** differ on precisely when and where the warmer and colder conditions occurred, including which seasons were particularly warm or cool. There is agreement that there were mostly warmer conditions from about 950 to 1250 AD (Medieval Climate Anomaly) and cooler conditions from about 1400 to 1850 AD (Little Ice Age). The IPCC concluded that although some decades during the MCA were in some regions as warm as in the late 20th century, these warm periods did not occur as coherently across regions as the warming in the late 20th century.

What is Forcing?

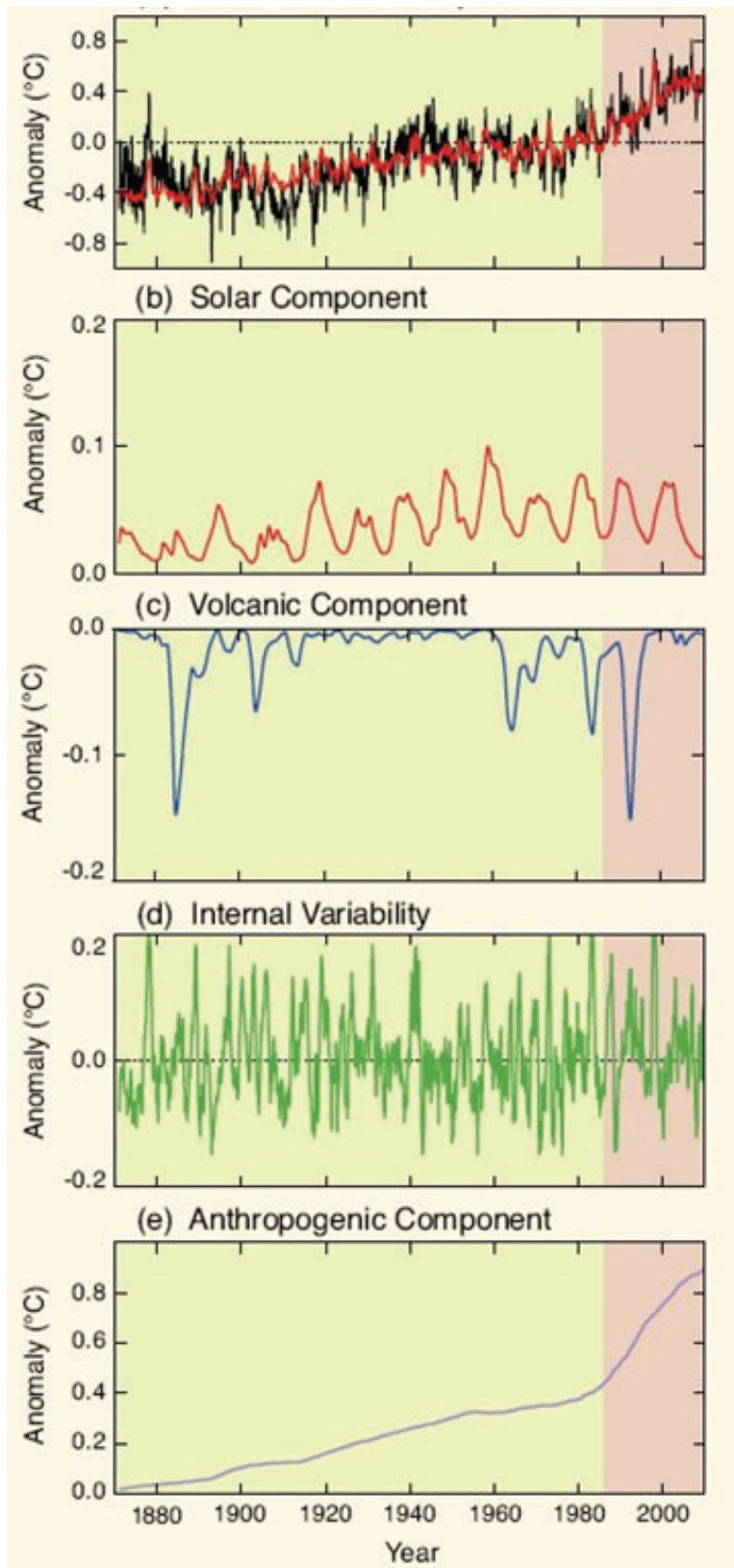
Forcing represents any factor that influences global climate by heating or cooling the planet. Examples of forcings are volcanic eruptions, solar variations and **anthropogenic** (human) changes to the composition of the atmosphere.

Taking a longer term perspective shows the substantial role played by **anthropogenic** and natural forcings in driving climate variability on hemispheric scales prior to the twentieth century. It is very unlikely that Northern Hemisphere temperature variations from 1400 to 1850 can be explained by natural **internal variability** alone – something, such as changes in solar and/ or volcanic activity, must have driven the changes.



Tropical sea-surface temperature from 3.5 Ma (Million years ago) to present. This figure shows that there was a slow cooling of climate over the last 3 million years as polar ice sheets grew partly in response to continental drift. At the Mid-Pleistocene Transition around 1.2 million to 700,000 years ago, the Milankovitch cycles started interacting differently with a shift to a dominant 100,000 year climate signal.

3. Causes of Recent Changes in Global Surface Temperature



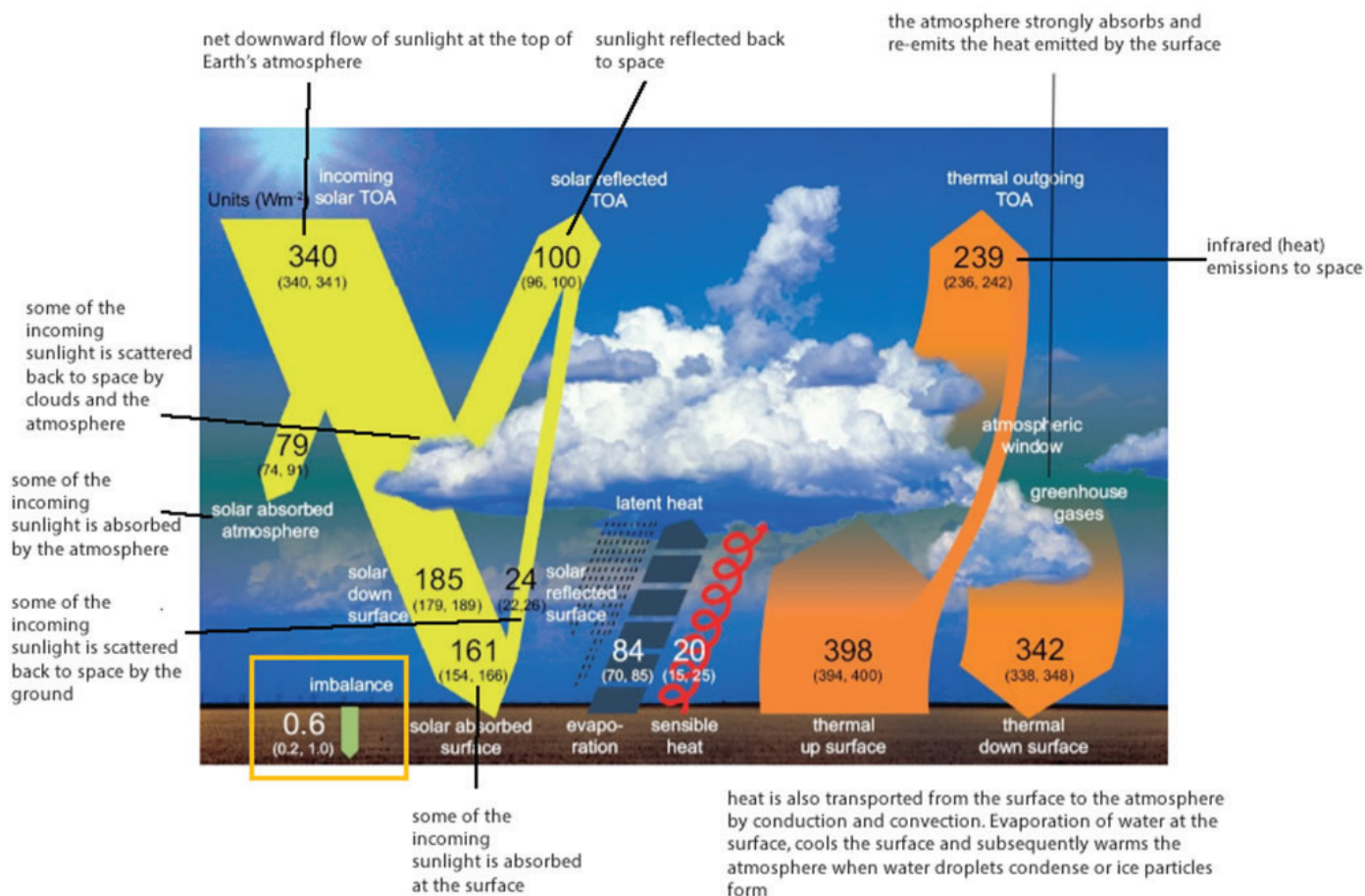
Left: Global surface temperatures from 1870 to 2010, (a) The black line shows global surface temperatures (1870–2010) relative to the 1961–1990 average. The red line shows climate model simulations of global surface temperature change produced using the sum of the impacts on temperature from natural (b, c, d) and anthropogenic factors (e). Note the different vertical scales.

The IPCC concluded that **“It is extremely likely that human activities caused more than half of the observed increase in global mean surface temperature from 1951 to 2010”** (0.08 to 0.14 °C per decade). Over this time period:

- Greenhouse gases contributed a global mean surface warming between 0.5°C and 1.3°C
- Other **anthropogenic forcings** (such as land use changes and other atmospheric pollution) contributed between -0.6°C and 0.1°C,
- Natural forcings (such as changes in the sun and in volcanic eruptions) contributed between -0.1°C and 0.1°C
- **Internal variability**, due to naturally variable processes within the climate system such as the El Niño-Southern Oscillation, contributed between -0.1°C and 0.1°C.

The observed global mean surface temperature increase has slowed over the past 15 years compared to the past 30 to 60 years with the trend over 1998–2012 estimated to be around one third to one half of the trend over 1951–2012. This **‘hiatus’** is probably due to the cooling influences from natural radiative **forcings** (more volcanic eruptions and reducing output from the sun as part of the natural 11-year solar cycle) and **internal variability** (fluctuations within the oceans unrelated to **forcings**). Even with this ‘hiatus’ in the surface temperature warming trend, 2000-2010 has been the warmest decade in the instrumental record, which began in the mid 19th century. The climate system has continued to accumulate energy, for example energy accumulation in the oceans has caused the global mean sea level to continue rising.

4. The Earth's Energy Balance



The Global annual average flows of energy under present day climate conditions. The numbers show the individual energy fluxes in W/m^2 and their range of **uncertainty** (in brackets). The net downward flow of sunlight at the top of Earth's atmosphere ($340 W/m^2$ incoming minus $100 W/m^2$ which is reflected back to space) is approximately balanced by the infra-red (heat) emissions to space ($239 W/m^2$).

Since the last IPCC report, knowledge of the magnitude of the energy flows in the climate system has improved as new space-borne instruments have supplied data measuring the energy exchanges between the Sun, Earth and Space.

It is harder to measure the energy budget at the surface than at the top of the atmosphere because they cannot be directly measured by passive satellite sensors and surface measurements aren't equally distributed across the earth's surface. New estimates for the downward flow of heat at the surface have been established which include information on cloud base heights.

The amount of the Sun's energy reaching the surface changed after 1950, with

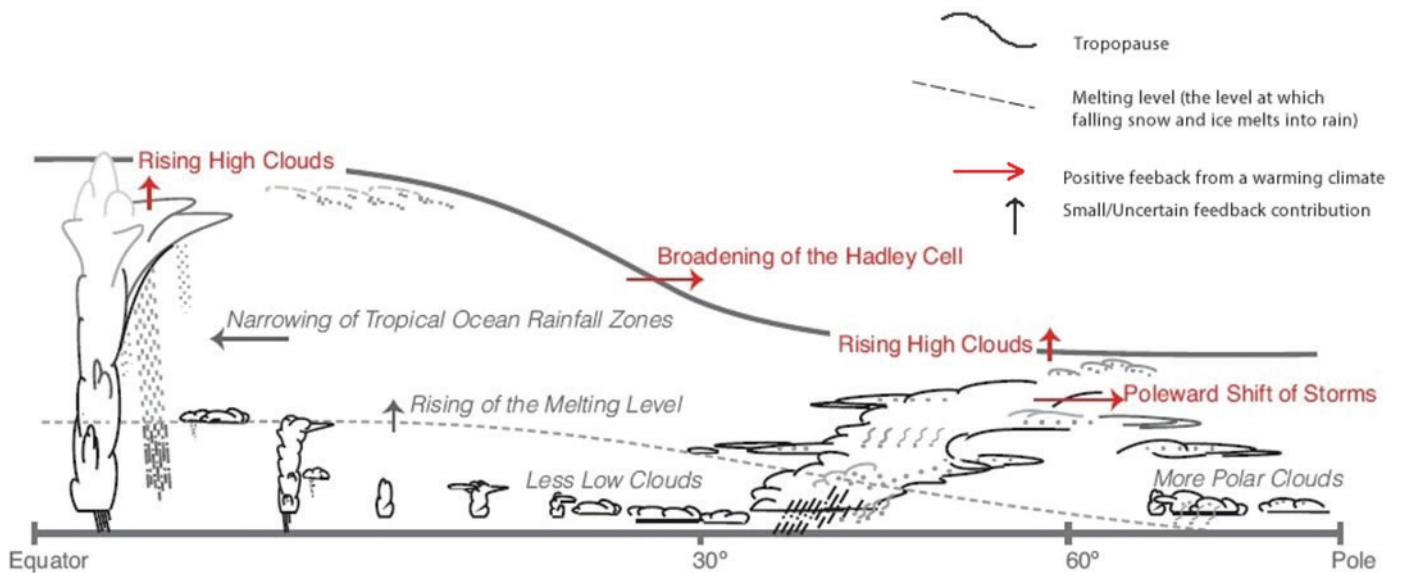
a) decreases ('**dimming**') until the 1980s, because atmospheric pollutants (**aerosols**) make the atmosphere more reflective and also clouds, by increasing the number of water droplets in the clouds, which in turn increases the amount of sunlight reflected, and subsequent

b) increases ('**brightening**') as national and international legislation in the 1980s reduced the amount of pollutants in the atmosphere which increased the amount of energy reaching the surface.

How do human activities affect the Earth's energy budget?

Human activities are continuing to affect the Earth's energy budget by changing the emissions and resulting atmospheric concentrations of important greenhouse gases and **aerosols** and by changing land surface properties. The result of this is that the sum of the energy leaving the top of the atmosphere is less ($239 + 100 \text{ W/m}^2$) than the energy entering it (340 W/m^2). Most of this excess energy is absorbed at the surface, as shown by the orange box, causing the observed increase in temperatures in the lower atmosphere and oceans.

5. Changes to the Global Atmospheric Circulation



Robust cloud responses to greenhouse warming. No mechanisms contribute a robust negative *feedback* (reducing the size of the warming). Changes include rising high cloud tops and melting level, and increased polar cloud, broadening of the *Hadley Cell* and poleward migration of storm tracks, and narrowing of rainfall zones such as the *Intertropical Convergence Zone (ITCZ)*.

How might precipitation change?

- Over the **mid-latitude land areas of the Northern Hemisphere**, precipitation has increased since 1901 (medium confidence before 1951 and high confidence after).
- **Tropical oceanic rainfall** is likely to increase with warmer oceans, particularly in the equatorial Pacific. As the ascending air associated with tropical rainfall drives the **Hadley Cell**, increasing tropical rainfall may intensify and broaden (poleward) the subtropical and mid-latitude dry zones that exist at the **Hadley Cell's** outer edges, reducing rainfall there and expanding deserts.
- In **wetter mid-latitude regions** and in **high latitudes**, average precipitation will likely increase, due to the poleward shift in the storm tracks and a greater atmospheric capacity for moisture at warmer temperatures. This increased moisture capacity will probably also produce more intense and frequent extreme precipitation events over most mid-latitude land masses and wet tropical regions.

How does cloud height affect climate?

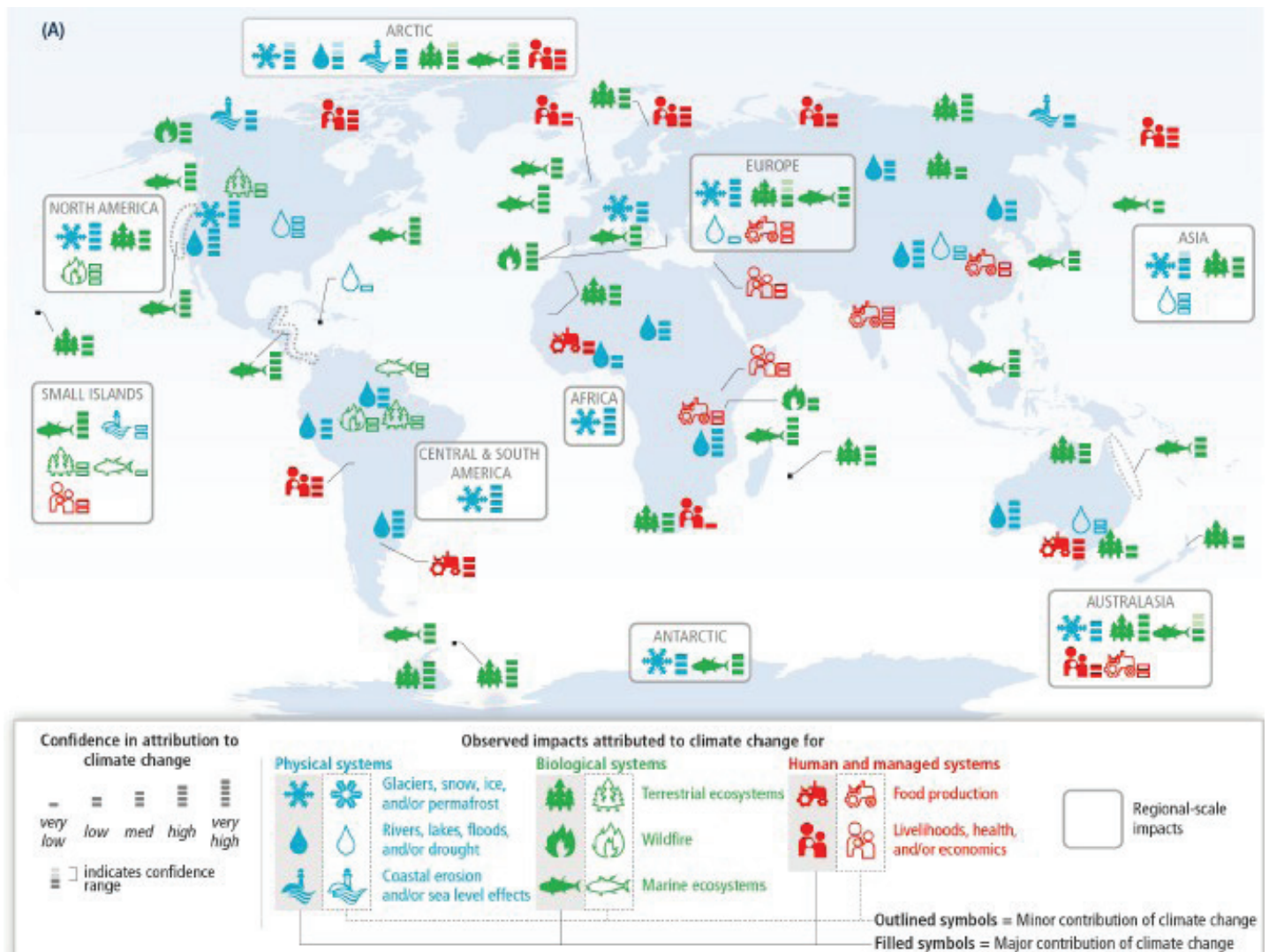
In general, high clouds cool the climate during the day, by reflecting the Sun's light, but warm it during the day and night by trapping heat lost from the Earth's surface – the net effect is one of warming. Low clouds, on the other hand, mainly cool the climate, so if there are more extensive low clouds, this cooling effect would become larger.

What is the outlook?

- In a warmer climate, high clouds are expected to rise in altitude and thereby exert a stronger greenhouse effect.
- Jet streams and storm tracks shift poleward, in part due to the tropical **troposphere** warming by more than the mid-latitude **troposphere**; the temperature difference between these two regions controls the location and speed of the jet stream. The shift in jet stream will dry the subtropics and moisten the high latitudes. In turn, this causes further positive (amplifying) feedback (i.e. enhancing the greenhouse effect) via a net shift of cloud cover to the higher latitudes, thereby allowing more sun light in at low latitudes, where the sun's light is more concentrated, to warm the surface.
- Low cloud amount will decrease, especially in the subtropics, according to most **climate models**.

The most likely combined effect of changes to all cloud types is to amplify the surface temperature warming (a positive feedback).

6. Impacts of Climate Change Already Observed



Global patterns of impacts in recent decades attributed to climate change (natural and **anthropogenic**).

Systems

In recent decades, changes in climate (including both **anthropogenic** and natural changes) have caused impacts on natural and human systems on all continents and oceans. The evidence of impacts is greatest for natural systems. Some impacts on human systems have also been attributed to climate change.

Terrestrial, freshwater, and marine species

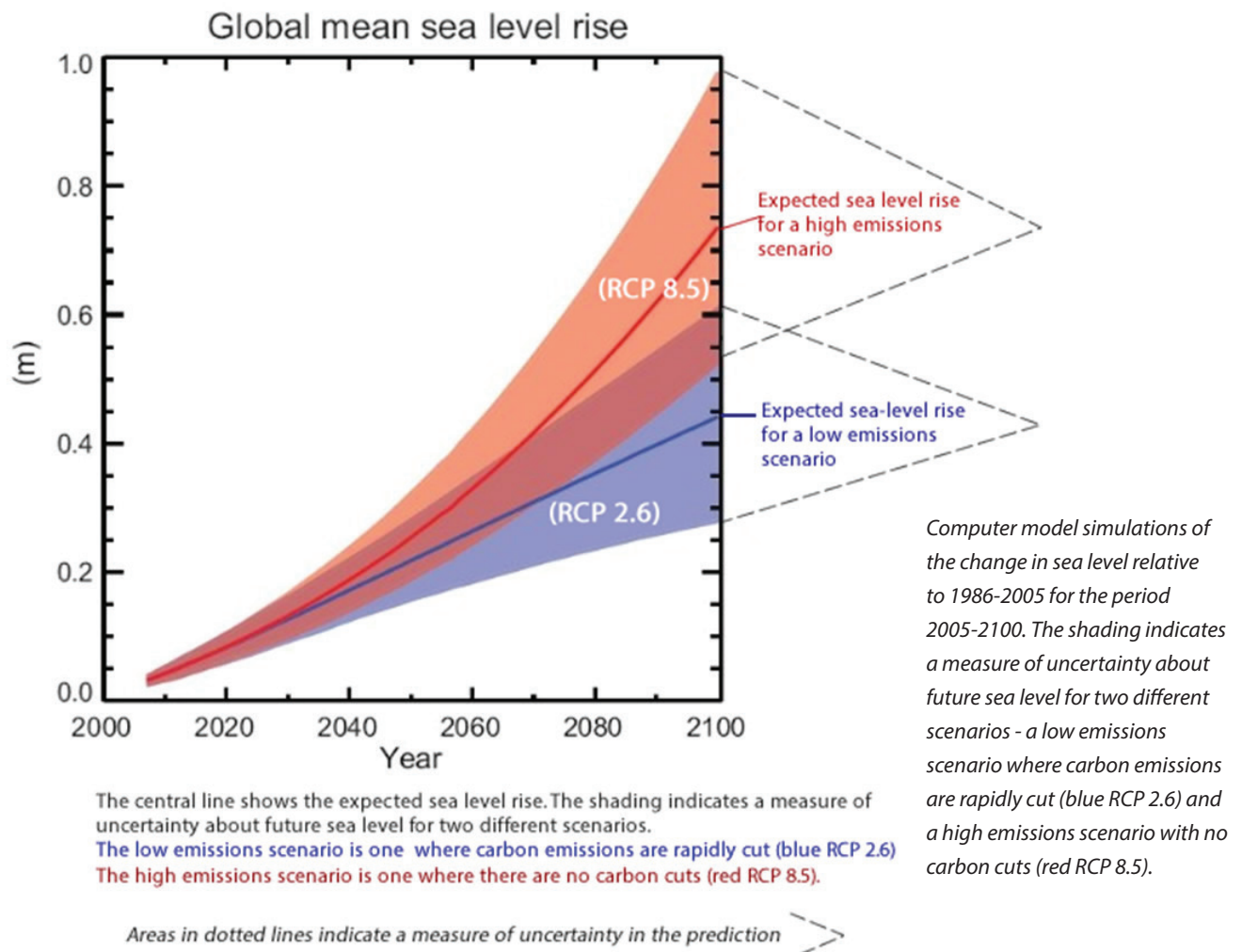
Many have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change. In the oceans, the distribution of phytoplankton and zooplankton has changed most.

While only a few recent species extinctions have been attributed to climate change, natural global climate change at rates slower than current **anthropogenic** climate change caused significant ecosystem shifts and species extinctions in the past millions of years.

Water

In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Glaciers continue to shrink almost worldwide due to climate change, affecting runoff and water resources downstream. Climate change is causing permafrost warming and thawing in high-latitude regions and in mountainous regions.

7. Sea Level and Marine Ecosystems



Sea Level

Global mean sea level is measured using tide gauge records and also, since 1993, satellite data.

- Between 1901-2010, it has risen 0.19m at an average rate of 1.7mm/ year.
- The rate increased to 3.2mm/year between 1993-2010.
- Global mean sea level will continue to rise through the 21st century at an ever increasing rate, due to increased ocean warming and expansion and melting of glaciers and ice sheets.



The Environment Agency in Britain has recently developed the Thames Estuary 2100 plan to manage the future flood threat to London. The motivation was a fear that due to accelerated sea level rise as the climate changed it might already be too late to replace the Thames Barrier (completed in 1982) and other measures that protect London, because such major engineering schemes take 25 to 30 years to plan and implement.



Rocky shores are one of the few ecosystems for which field evidence of the effects of ocean acidification is available. The community structure of a site in the NE Pacific shifted from a mussel to an algal-barnacle dominated community between 2000 and 2008, as the pH declined rapidly.

Ocean Circulation

As the temperature and precipitation at high latitudes increase over the 21st century, it is very likely that the **Atlantic Meridional Overturning Circulation** and its individual components (such as the North Atlantic Drift) will weaken but it is very unlikely that it will undergo an abrupt transition or collapse.

Ocean Acidification

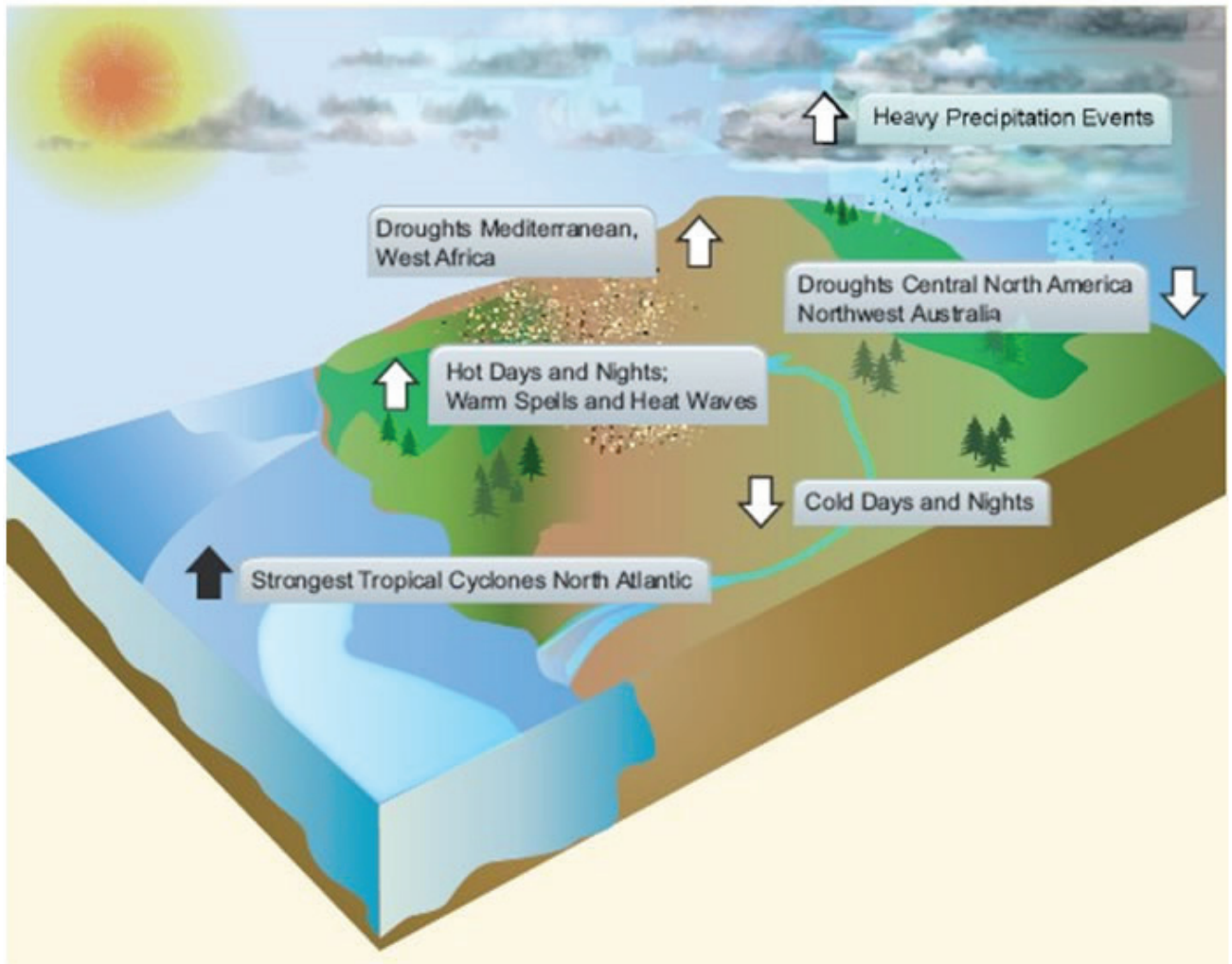
Anthropogenic CO₂ emissions cause the oceans to absorb more CO₂, which increases the acidity of the water. The pH of surface seawater has decreased by 0.1 since the beginning of the industrial era. By the end of the 21st century, the additional decrease in surface ocean pH is projected to be in the range of 0.06 – 0.32. The consequences of changes in pH for marine organisms and ecosystems are just beginning to be understood.

The effect on marine ecosystems and coastal economies.

- Rapid changes in the physical and chemical conditions within ocean sub-regions have already affected the distribution and abundance of marine organisms and ecosystems. As the oceans warm, marine organisms are moving to higher latitudes to maintain a constant temperature, with fish and zooplankton migrating at the fastest rates.
- Changes to sea temperature have also altered the **phenology** or timing of key life-history events such as plankton blooms, and migratory patterns and spawning in fish and invertebrates.
- 30 years of temperature increases have been partly responsible for boosting high latitude fisheries in the North Pacific and North Atlantic.
- Climate change will result in more frequent extreme weather events and greater associated risks to ocean ecosystems.
- Projected changes pose significant uncertainties and risks to fisheries, aquaculture and other coastal activities. In some cases (e.g. mass coral bleaching and mortality), projected increases will eliminate ecosystems, increase risks to food security and the vulnerability of coastal communities.
- Climate related risks to the sustainability of capture fisheries and aquaculture, adding to the threats of over-fishing and other non-climate stressors. Shifts in the distribution and abundance of large **pelagic** fish stocks will have the potential to create 'winners' and 'losers' among island nations and economies.

Practical adaptation options (e.g., strengthening buildings and coastal defences, expanding areas of coastal vegetation) and supporting international policies (e.g., cooperative efforts to regulate fisheries, managing shared river systems to avoid erosion) can minimize the risks and maximize the opportunities.

8. Extreme Weather Hazards



Trends in the frequency (or intensity) of various climate extremes (arrow direction denotes the sign of the change) since the middle of the 20th century (except for North Atlantic tropical cyclones where the period covered is from the 1970s).

Impact of Climate and Weather

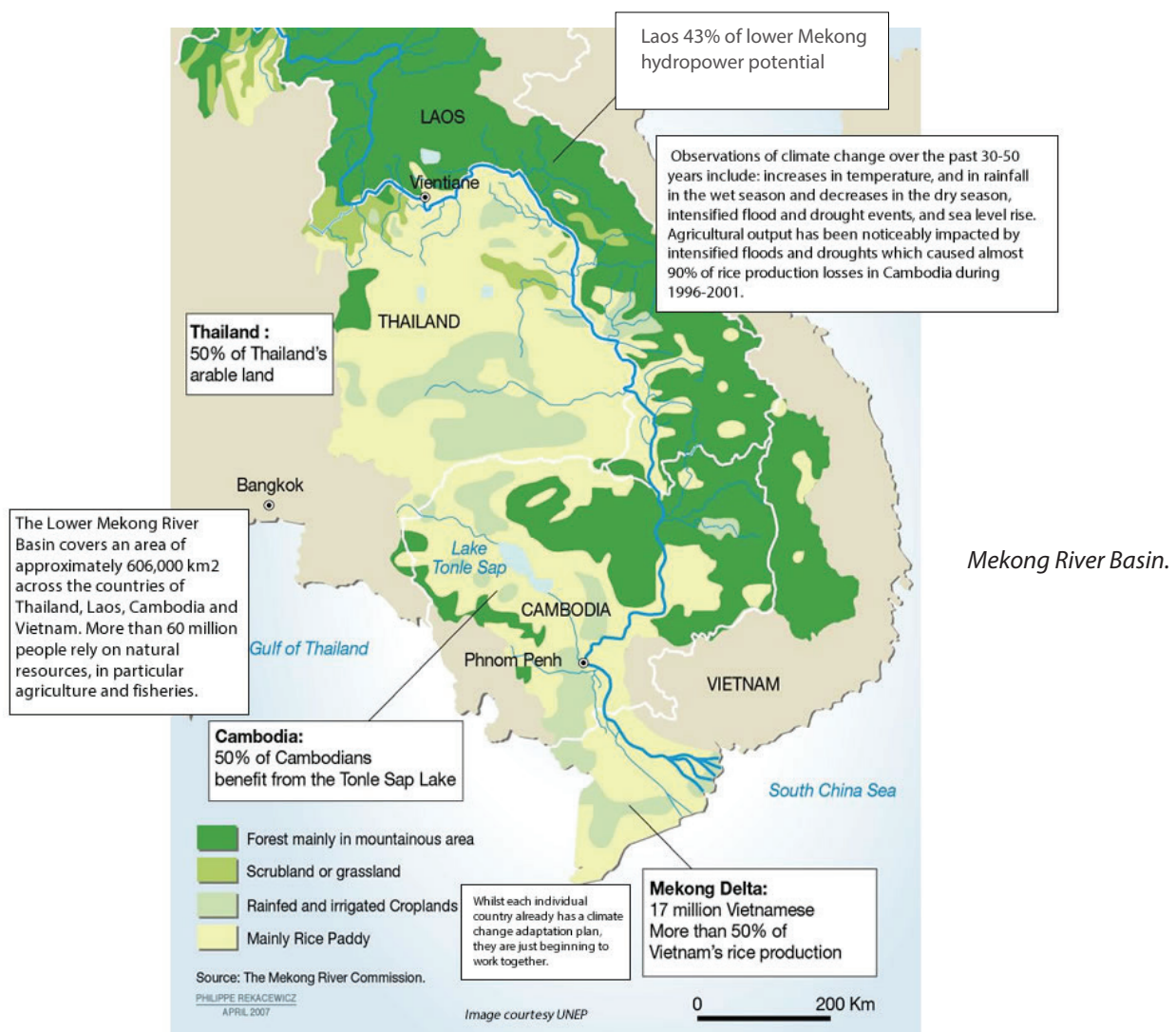
People and ecosystems across the world experience climate in many different ways. Average climate conditions give a starting point for understanding what grows where, tourist destinations and other business opportunities.

However, changes in average (climate) conditions are often closely linked to changes in the frequency, intensity or duration of extreme weather events. Extreme weather places excessive and often unexpected demands on systems unable to cope and leads to losses and disruption. For example;

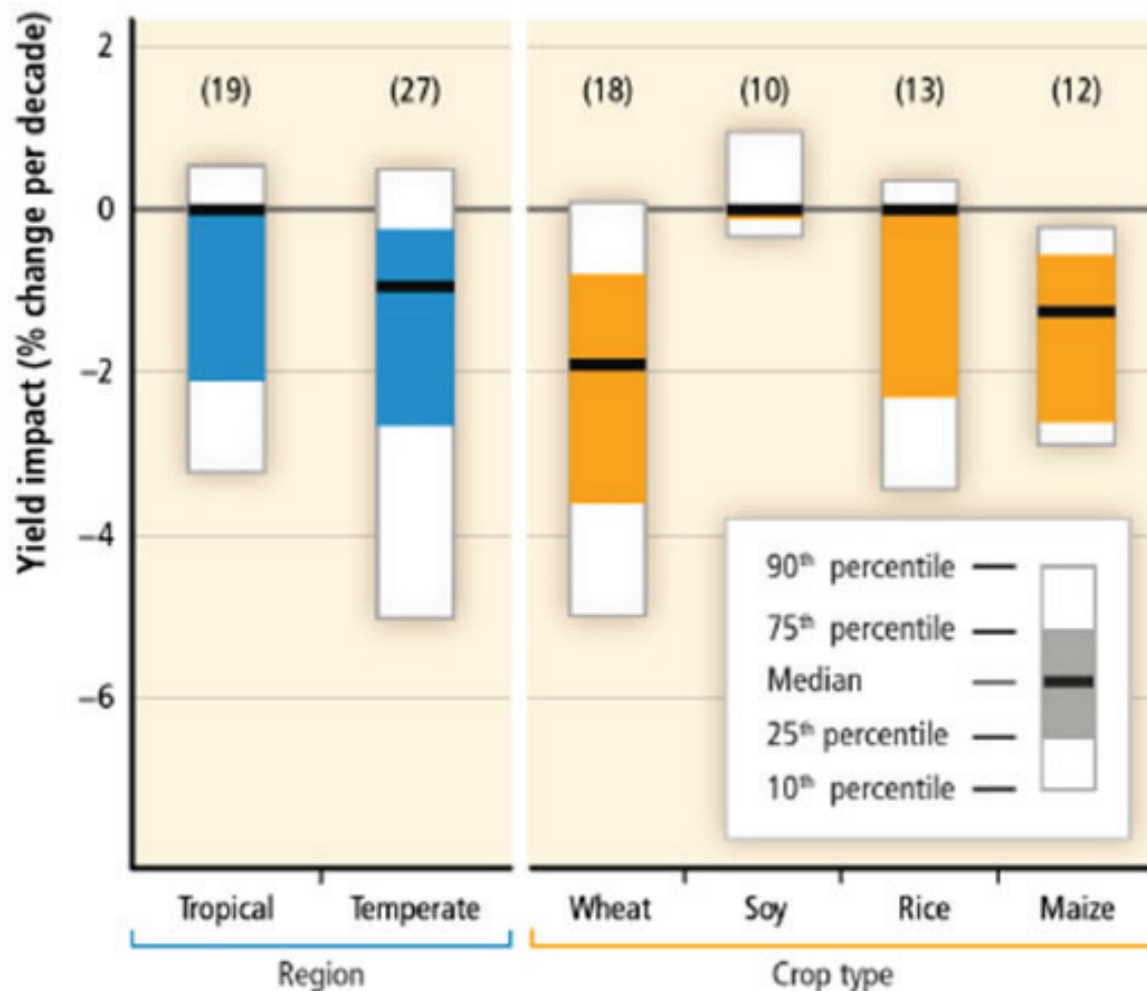
- wet conditions lead to flooding when storm drains and other infrastructure for handling excess water are overwhelmed;
- buildings fail when wind speeds exceed design standards;
- **drought** can cause crop failure;
- heat waves can cause sickness and death.

Changes in Extreme Weather

- There is strong evidence that warming has led to changes in temperature extremes—including heat waves—since the mid-20th century. In some locations, the occurrence of heat waves has more than doubled due to human influence.
- Increases in heavy precipitation have probably also occurred over this time, but vary by region. It is likely that the number of heavy precipitation events over land has increased in more regions than it has decreased in since the mid-20th century. In North America and Europe, the frequency or intensity of heavy precipitation events has probably increased.
- In the Near East, India and central North America modern large floods are probably comparable to or surpass historical, pre-industrial floods in magnitude and/or frequency.
- In some other regions (including northern and central Europe), historical floods were larger than those recorded since 1900.
- There is less certainty about other extremes, such as tropical cyclones, due to a lack of historical data. In the North Atlantic, tropical cyclone numbers and intensity have increased but it cannot yet be said whether these are related to climate change or not. In the future, it is likely that the global frequency of tropical cyclones will decrease or stay the same, although maximum wind speeds and rainfall will increase.
- There has been a poleward shift and intensification of the mid-latitude depressions in the North Atlantic from the 1950s to the early 2000s, which is linked to a poleward shift in Northern Hemisphere jet streams.



9. The Impact of Climate Change on Food Production

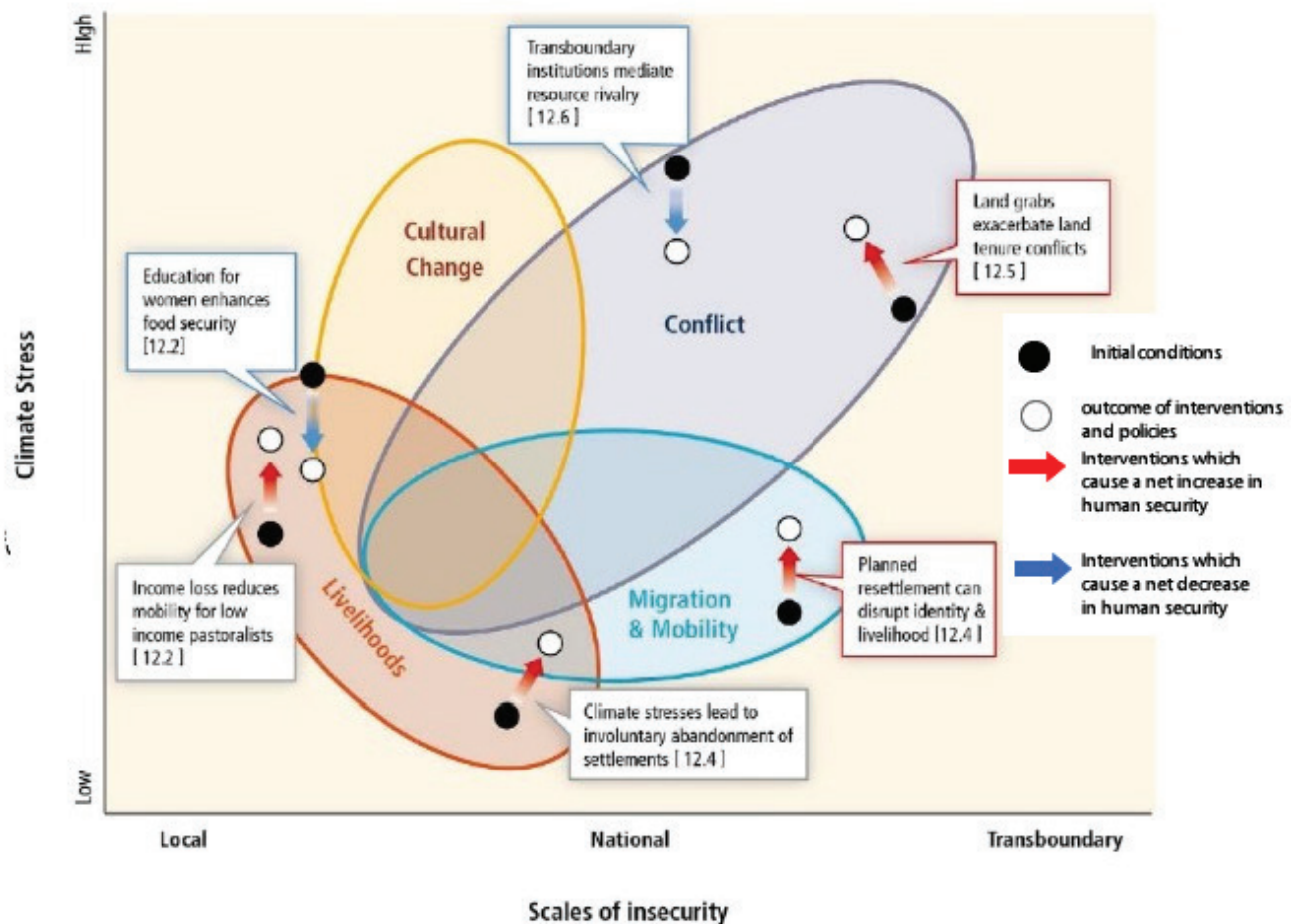


Summary of estimated impacts of observed climate changes on yields over 1960-2013 for four major crops in temperate and tropical regions. The number of data points analysed for each category are given in brackets.

- Negative impacts of climate change on crop yields have been more common than positive impacts (some positive trends are evident in some high latitude regions).
- Climate change has negatively affected wheat and maize yields for many individual regions and globally since 1960. The effects on rice and soybean yield have been smaller in major production regions and globally, with particularly few studies available of soy.
- The majority of the impact has been on food production, however food access, utilization, and price stability could be affected. In recent years, several periods of rapid food and cereal price increases following climate extremes in key producing regions indicate a sensitivity of current markets to climate extremes.

- There is a large negative sensitivity of crop yields to extreme daytime temperatures at around 30°C. Temperature trends are therefore important for determining both past and future impacts of climate change on crop yields at sub-continental to global scales.
- Local temperature increases in excess of about 1°C above pre-industrial are projected to have negative effects on yields for the major crops (wheat, rice and maize) in both tropical and temperate regions, although individual locations may benefit. It is more difficult to predict the future effect of changes in local precipitation, and the interactions between CO₂ and mean temperature, extremes, water and nitrogen.

10. The Impact of Climate Change on Security



Synthesis of evidence on the impacts of climate change on elements of human security and the interactions between livelihoods, conflict, culture, and migration.

Human security will be progressively threatened as the climate changes. Human insecurity almost never has single causes, however climate change is an important factor through:

- increasing migration that people would rather have avoided,
- undermining livelihoods,
- challenging the ability of states to provide the conditions necessary for human security,
- compromising cultural values that are important for community and individual well-being.

Migration and mobility are ways people adapt to climate variability in all regions of the world. In the past, major extreme weather events have led to significant population displacement, and changes in the incidence of extreme events will amplify the challenges and risks of such displacement. However, many vulnerable groups, particularly in rural and urban areas in low and middle-income countries, do not have the resources to be able to migrate to avoid the impacts of floods, storms and droughts. Migration may be undesirable, and can lead to changes in important cultural expressions and practices, and, in the absence of institutions to manage the settlement and integration of migrants in destination areas, can increase the risk of poverty, discrimination, violent conflict and inadequate provision of public services, public health and education.

Future challenges of climate change:

- **Physical impacts:** Sea level rise, extreme events and hydrologic disruptions pose major challenges to vital transport, water and energy infrastructure and can weaken states socially and economically.
- **Territorial impacts:** For example those highly vulnerable to sea level rise.
- **Transboundary impacts:** Changes in sea ice, shared water resources and the migration of fish stocks, have the potential to increase rivalry among states.
- **Violent conflict** can in turn undermine livelihoods, impel migration and weaken valued cultural expressions and practices.
- **Adaptation and mitigation strategies**, such as those which develop large infrastructures or resettle communities against their will to reduce exposure to climate change, carry risks of disrupted livelihoods, displaced populations, deterioration of valued cultural expressions and practices, and in some cases violent conflict.

In summary, climate change is one of many risks to the vital core of material well-being and culturally specific elements of human security that varies depending on location and circumstance.

On the basis of current evidence about the observed impacts of climate change on environmental conditions, climate change will be an increasingly important cause of human insecurity globally in the future. The greater the impact of climate change, the harder it is to adapt.

Glossary

Aerosols

A suspension of airborne solid or liquid particles, with a typical size between a few nanometres and 10 μm that reside in the atmosphere for at least several hours.

Anthropogenic

Resulting from or produced by human activities.

Atlantic Meridional Overturning Circulation

A major current in the Atlantic Ocean, characterized by a northward flow of warm, salty water in the upper layers of the Atlantic, and a southward flow of colder water in the deep Atlantic. It includes the North Atlantic Drift and the Gulf Stream.

Attribution

The process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence

Climate

The average weather, or more rigorously, the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind.

Climate Change

A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate Model

A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and interannual climate predictions.

Cryosphere

All regions on and beneath the surface of the Earth and ocean where water is in solid form, including sea ice, lake ice, river ice, snow cover, glaciers and ice sheets, and frozen ground (which includes permafrost).

Drought

A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion.

Feedback

An interaction in which a perturbation in one climate quantity causes a change in a second, and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is one in which the initial perturbation is weakened by the changes it causes; a positive feedback is one in which the initial perturbation is enhanced.

Forcings

Forcing represents any external factor that influences global climate by heating or cooling the planet. Examples of forcings are volcanic eruptions, solar and orbital variations and anthropogenic (human) changes to the composition of the atmosphere.

Greenhouse Gas

Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds.

Hadley Cell

A direct, thermally driven overturning cell in the atmosphere consisting of poleward flow in the upper troposphere, subsiding air into the subtropical anticyclones, return flow as part of the trade winds near the surface, and with rising air near the equator in the so-called Inter-Tropical Convergence Zone.

Internal variability

Variations in the mean state and other statistics (such as the occurrence of extremes) of the climate on all spatial and temporal scales beyond that of individual weather events, due to natural unforced processes within the climate system because, in a system of components with very different response times and complex dependencies, the components are never in equilibrium and are constantly varying. An example of internal variability is El Niño, a warming cycle in the Pacific Ocean which has a big impact on the global climate, resulting from the interaction between atmosphere and ocean in the tropical Pacific.

Inter-Tropical Convergence Zone

The Inter-Tropical Convergence Zone is an equatorial zonal belt of low pressure, strong convection and heavy precipitation near the equator where the northeast trade winds meet the southeast trade winds. This band moves seasonally.

Paleoclimate

Climate during periods prior to the development of measuring instruments, including historic and geologic time, for which only proxy climate records are available.

Pelagic

Any water in a sea or lake that is neither close to the bottom nor near the shore.

Phenology

The study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate, as well as habitat factors.

Mitigation

A human intervention to reduce the amount of climate change for example by reducing the sources or enhance the sinks of greenhouse gases.

Reconstruction

Approach to reconstructing the past temporal and spatial characteristics of a climate variable from predictors. The predictors can be instrumental data if the reconstruction is used to infill missing data or proxy data if it is an indirect measure used to develop paleoclimate reconstructions.

Stratosphere

The highly stratified region of the atmosphere above the troposphere extending from about 10 km (ranging from 9 km at high latitudes to 16 km in the tropics on average) to about 50 km altitude.

Troposphere

The lowest part of the atmosphere, from the surface to about 10 km in altitude at mid-latitudes (ranging from 9 km at high latitudes to 16 km in the tropics on average), where clouds and weather phenomena occur. In the troposphere, temperatures generally decrease with height.

Uncertainty

A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour.



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Report for Geography Teachers

