
Arctic Climate
Change

"*Climate change*"

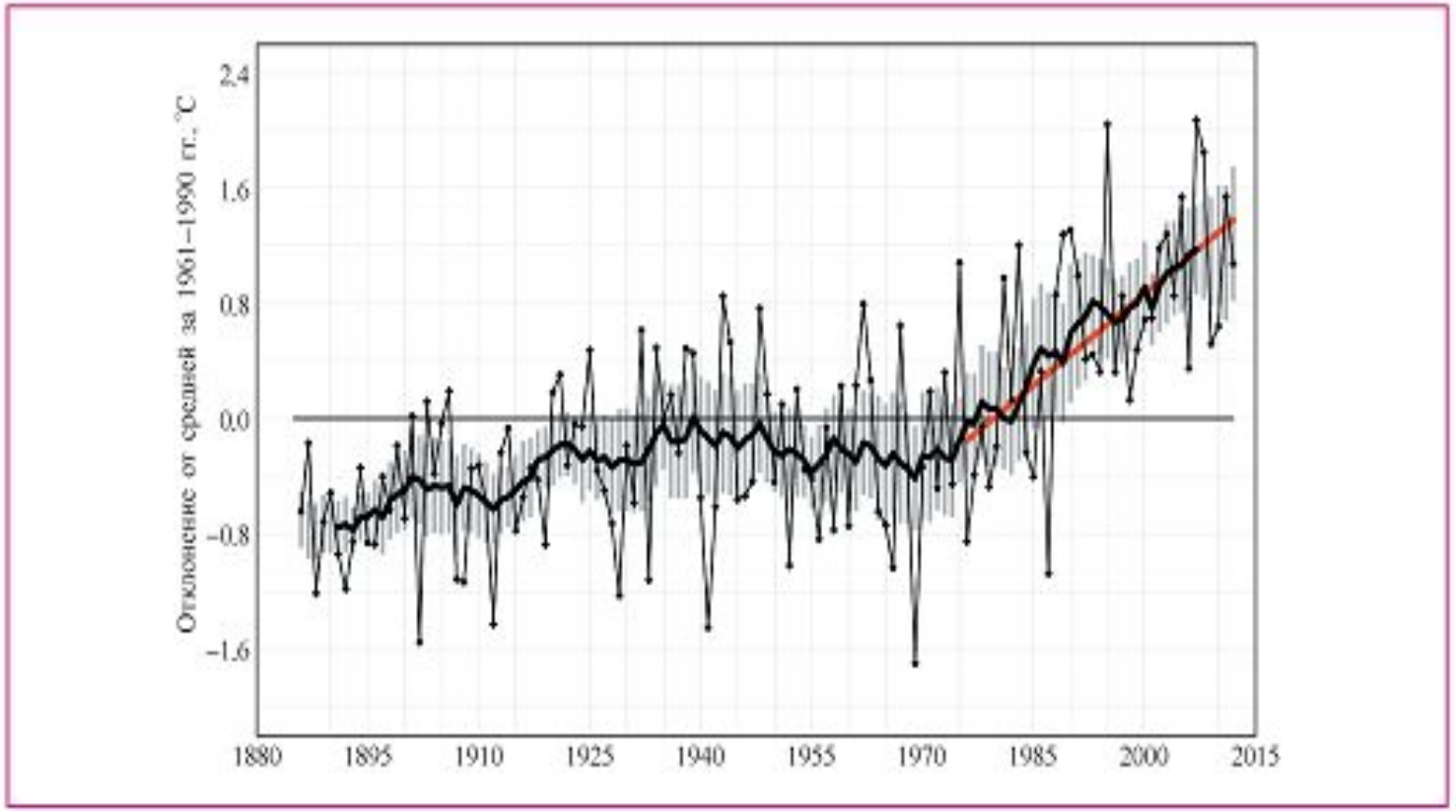
The meaning of the term "climate change" within this report is consistent with its definition by the United Nations Framework Convention on Climate Change:

"*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*."

«Global warming»

- *Global warming* is a term often used interchangeably with the term “climate change,” but they are not entirely the same thing. Global warming refers to an average increase in the temperature of the atmosphere near the Earth’s surface. Global warming is just one aspect of global climate change, though a very important one.

Change anomalies of annual surface air temperature averaged over the territory of Russia, during 1886-2012,

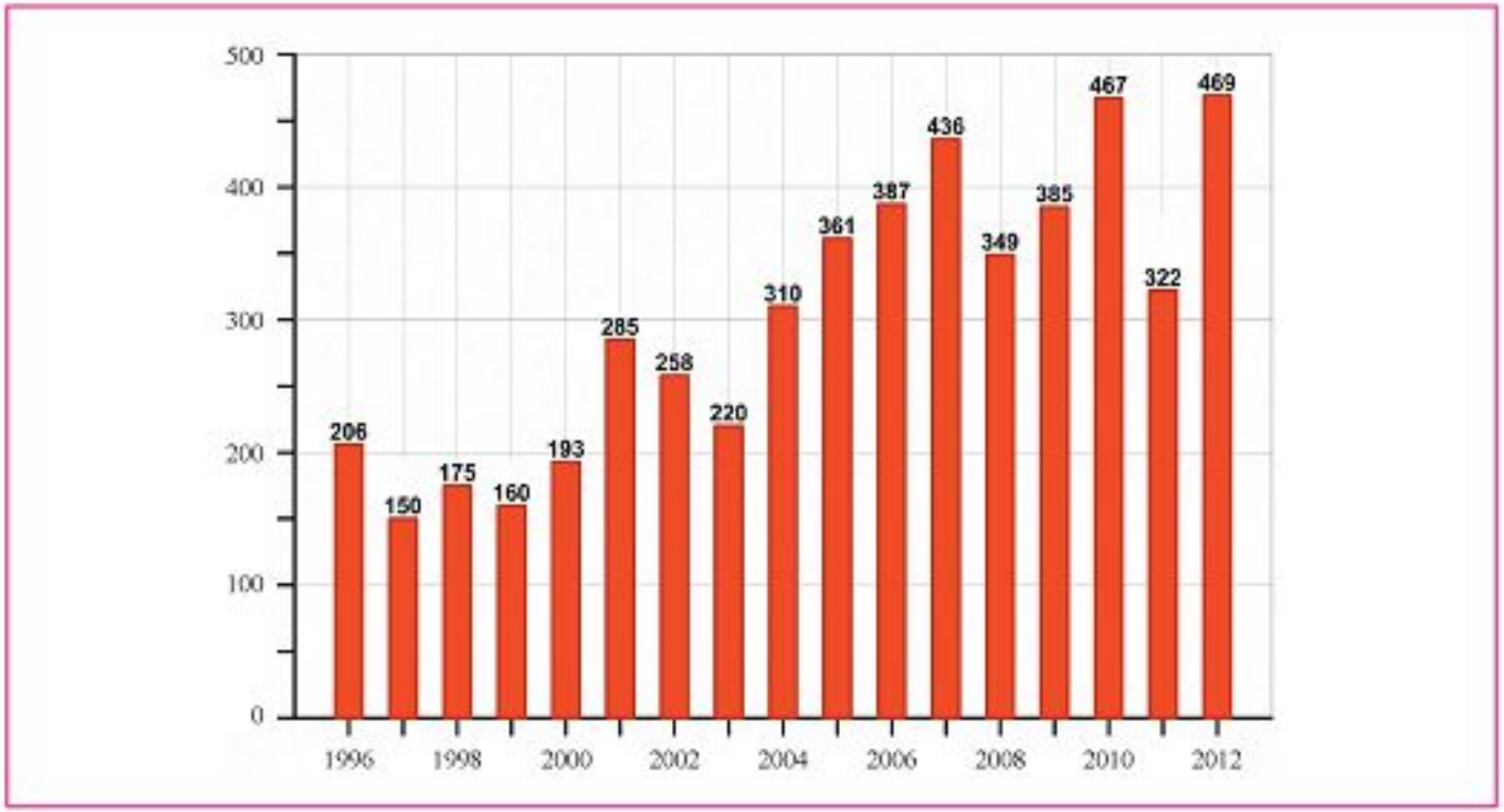


ВТОРОЙ ОЦЕНОЧНЫЙ ДОКЛАД РОСГИДРОМЕТА ОБ ИЗМЕНЕНИЯХ КЛИМАТА И ИХ ПОСЛЕДСТВИЯХ НА ТЕРРИТОРИИ РОССИЙСКОЙ ФЕДЕРАЦИИ

http://voeikovmgo.ru/download/2014/od/od2.pdf

The total (for the year) number of dangerous hydrometeorological phenomena on the Russia have caused considerable damage to the

economy and population, 1996-2012



ВТОРОЙ ОЦЕНОЧНЫЙ ДОКЛАД РОСГИДРОМЕТА ОБ ИЗМЕНЕНИЯХ КЛИМАТА
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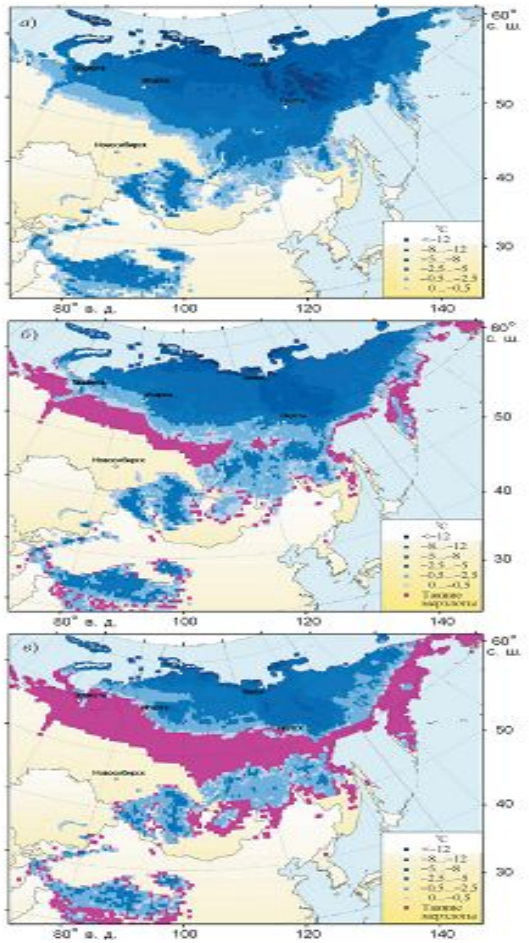
The average annual temperature of rocks in the lower part of the layer of seasonal thawing (freezing) in Northern Eurasia for three time

intervals: 1990-2000 (a), 2040-2050 (b) and 2090-2100, (c).



Thawed from the surface of the permafrost is shown in pink.

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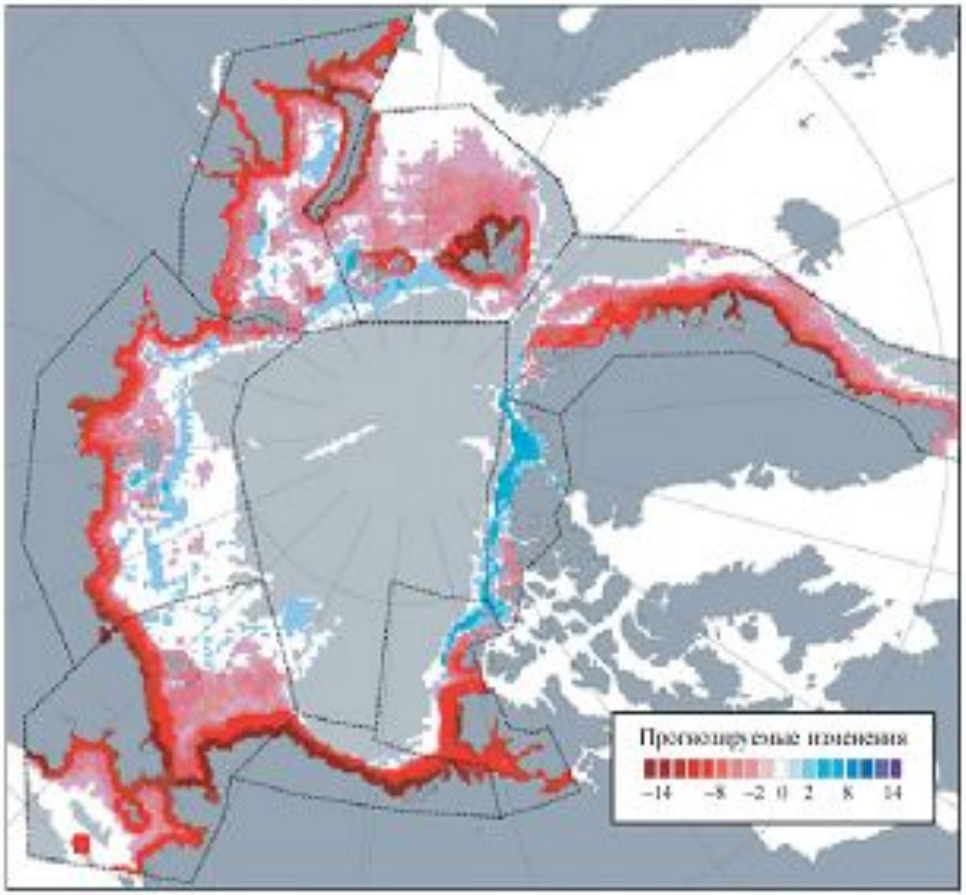
Changes in the polar bear habitats expected in 2041-2050 in relation to the 2001



color gradations shows at which decreased (red) or increased (blue) the duration of conditions that are optimal for polar bear; from

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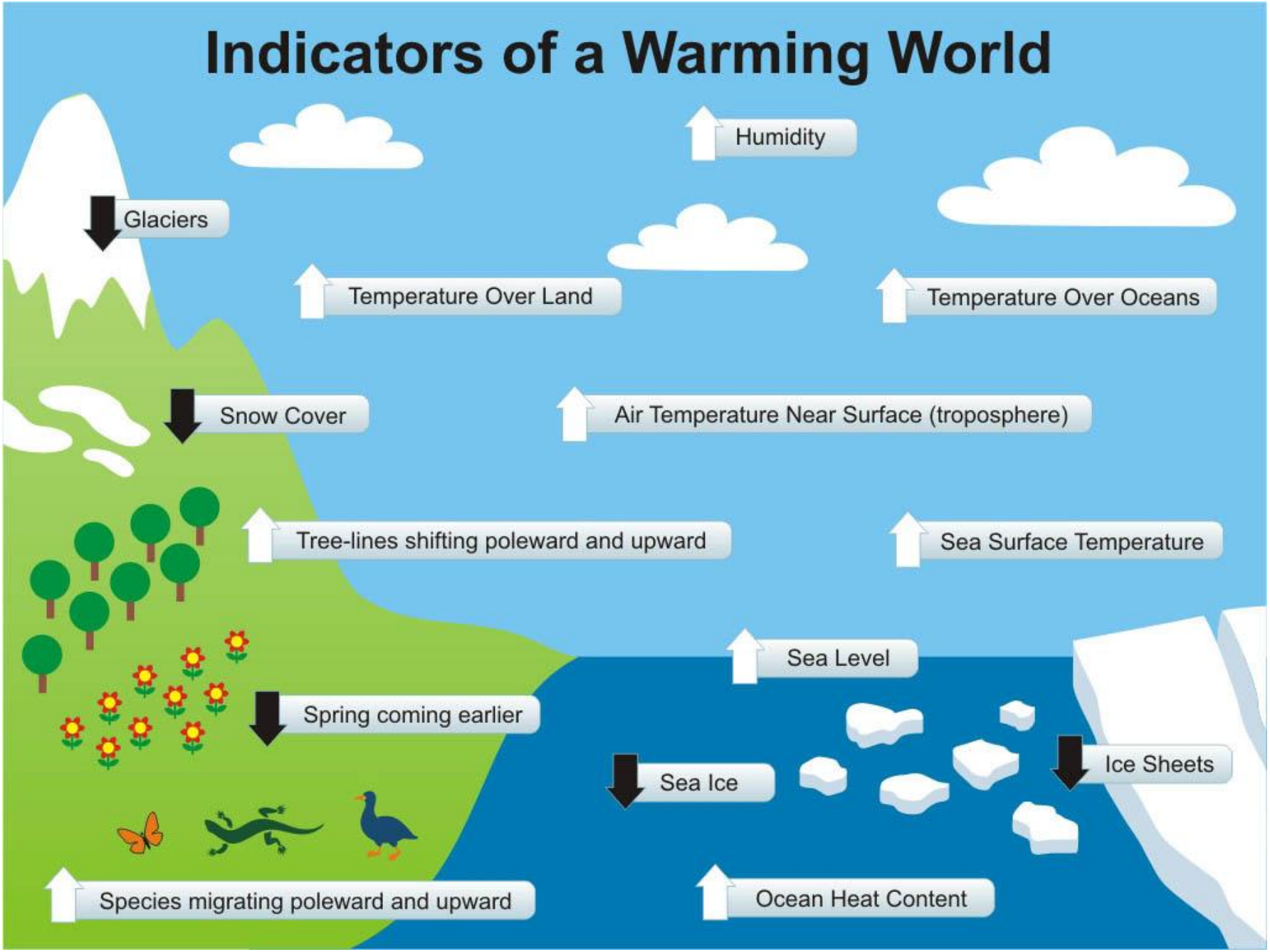
Arctic climate change

- The Arctic has some special features that make it an important focus for climate research. Physically, the Arctic islands are entirely snow-covered for more than half the year, and the region contains mountain glaciers, ice caps and extensive areas of permafrost. Arctic waters are also covered with sea ice for most of the year. Changes in the amount of sunshine are extreme since the Arctic experiences periods of 24-hour sunlight and 24-hour darkness at different times of year. Also, while large parts of the Arctic are essentially desert-like, large expanses of open water do occur during the short summer, making the Arctic a significant source for moisture and clouds. Northward-flowing rivers such as the Mackenzie empty their waters into the Arctic Ocean, influencing the ocean's physical characteristics. There are also important large-scale climate patterns, such as the Arctic Oscillation, where atmospheric pressure in the Arctic switches between high and low, causing shifts in climate and weather patterns in the Northern Hemisphere. These factors produce a complex interplay among climate processes in the Arctic.

RATIONALE FOR SELECTION OF INDICATORS OF CLIMATE CHANGE (Canada)

Valued Component	Key Indicators	Rationale
Climate Change	• **Changes in Temperature and Precipitation**	• demonstrated changes in the North due to climate change • directly linked to climate change predictions in Global Climate Models • direct local impacts on humans and the ecosystem
	• **Atmospheric CO_2 Concentrations**	• measured in Alert, NWT since 1976 • strongly linked to increasing greenhouse gas emissions and hence the greenhouse effect • concentrations have increased dramatically since industrialization

Indicators of a Warming World



- Concerns about climate change stem from the increasing concentration of greenhouse gases in the atmosphere. These gases keep heat from dissipating into space. According to the Intergovernmental Panel on Climate Change (IPCC), a continued increase at current rates could raise the average global air temperature between 1 and 3.5°C by 2100. The average rate of warming would likely be greater than any seen in the past 10 000 years.

- Climate change will not be evenly distributed over the globe. Its effects are likely to be greater in some areas and less significant in others, but current understanding of global climate patterns is insufficient for making reliable regional predictions.

- IPCC has drawn some general conclusions about the consequences of an increasing greenhouse effect. These include that sea level will rise somewhere between 15 and 95 centimeters by 2100. Sea-level rise is caused by a combination of melting glaciers and the fact that water expands as it warms. Another prediction is that there will be more extremely warm days and fewer extremely cold days. The probability of both droughts and floods is expected to increase. The largest temperature increases are predicted for winters in the northern part of the northern hemisphere.

High latitude climate is sensitive to changes

- The effects of global climate change on Arctic temperatures and precipitation patterns are very difficult to predict, but most studies suggest that the Arctic, as a whole, will warm more than the global mean.

Sea ice is critical to energy exchange between ocean and atmosphere

- Sea ice plays a critical role in the energy budget of the Arctic and thus in the region's climate. Snow-covered ice is highly reflective. If the ice extent decreases, more solar energy will be absorbed by the ocean as less is reflected back to space. Decreasing sea-ice cover can thus enhance a warming trend.
- Sea ice is also a physical barrier between the ocean and the atmosphere.

Precipitation has increased

- Precipitation has increased in high latitudes by up to 15 percent during the past 40 years.
- On the North American tundra, there is a trend toward earlier spring snowmelt. South of the subarctic, the area of land with continuous snow cover during winter, which follows both temperature and precipitation, has retreated by about ten percent during the past 20 years.

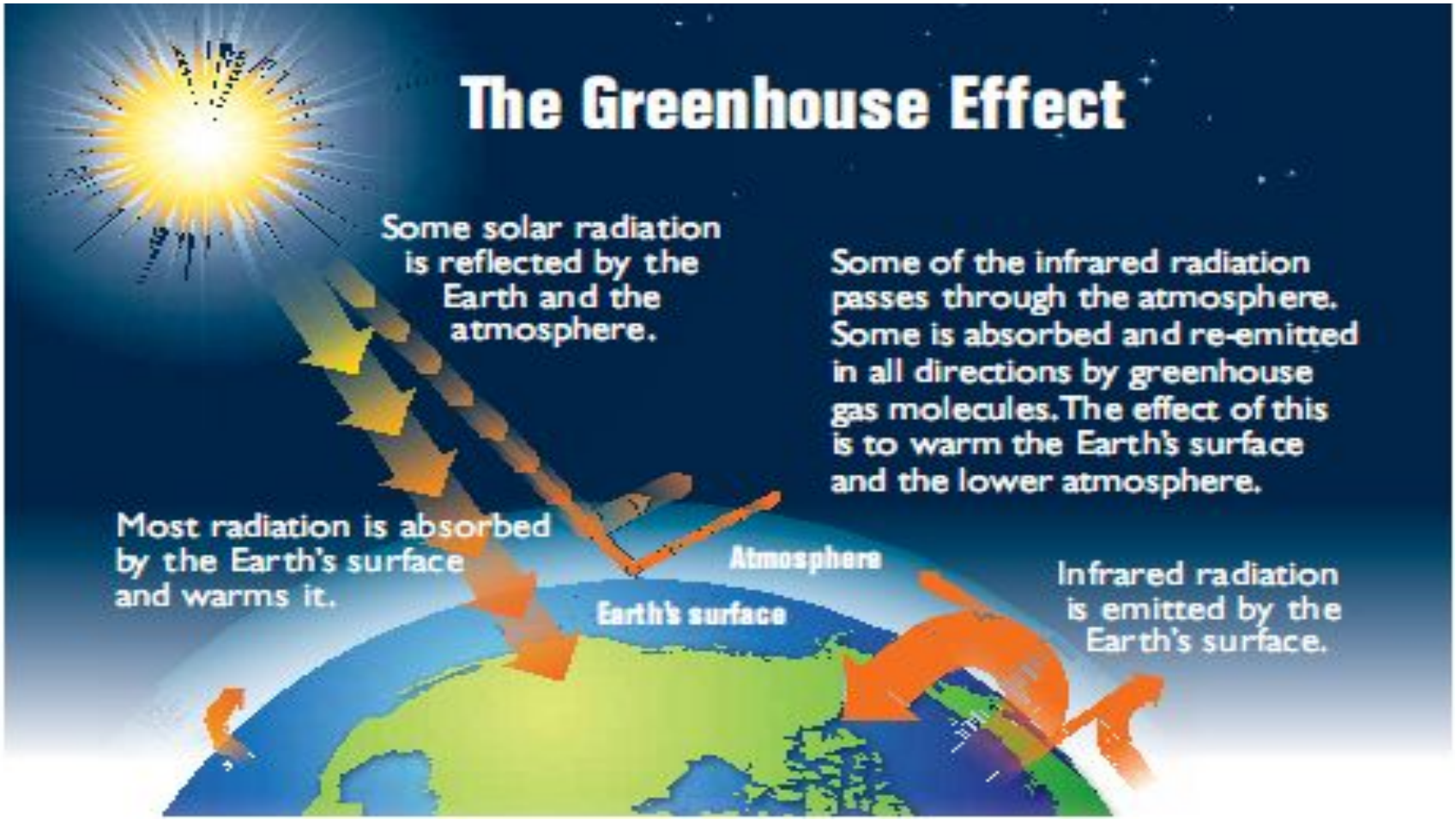
Future impact

- The impacts of climate change on the Arctic are difficult to predict because of the intricate interactions between physical and biological factors. The following section describes some of the potential changes that might occur if there is a significant warming of the region.

Future impact

- Melting ice caps and warmer water raise sea level
- Winds and water currents are likely to change
- Higher temperatures could disrupt permafrost
- Warmer soils may enhance nutrient cycling
- Southern invaders might out-compete native species
- Animals are sensitive to changing food supplies
- Lakes and ponds will have a longer growing season
- Northern fisheries will benefit from warmer seawater
- People depend on stable climate

HOW IS THE CLIMATE CHANGING?

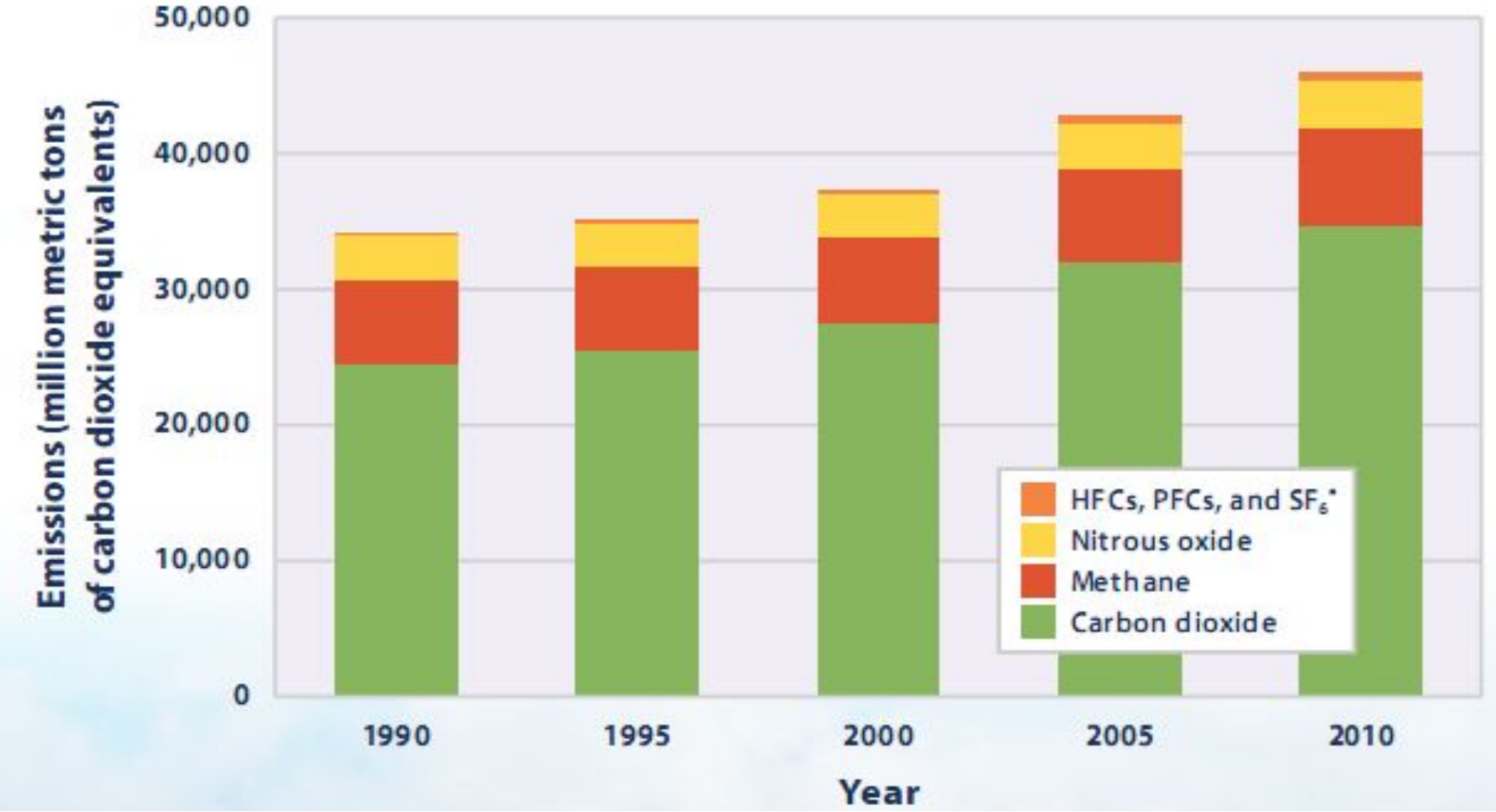


MAJOR GREENHOUSE GASES ASSOCIATED WITH HUMAN ACTIVITIES

Greenhouse gas	How it's produced	Average lifetime in the atmosphere	100-year global warming potential
Carbon dioxide	Emitted primarily through the burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Changes in land use also play a role. Deforestation and soil degradation add carbon dioxide to the atmosphere, while forest regrowth takes it out of the atmosphere.	see below*	1
Methane	Emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and agricultural practices and from the anaerobic decay of organic waste in municipal solid waste landfills.	12 years	28
Nitrous oxide	Emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.	121 years	265
Fluorinated gases	A group of gases that contain fluorine, including hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, among other chemicals. These gases are emitted from a variety of industrial processes and commercial and household uses, and do not occur naturally. Sometimes used as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs).	A few weeks to thousands of years	Varies (the highest is sulfur hexafluoride at 23,500)

* Carbon dioxide's lifetime cannot be represented with a single value because the gas is not destroyed over time, but instead moves among different parts of the ocean–atmosphere–land system. Some of the excess carbon dioxide will be absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.

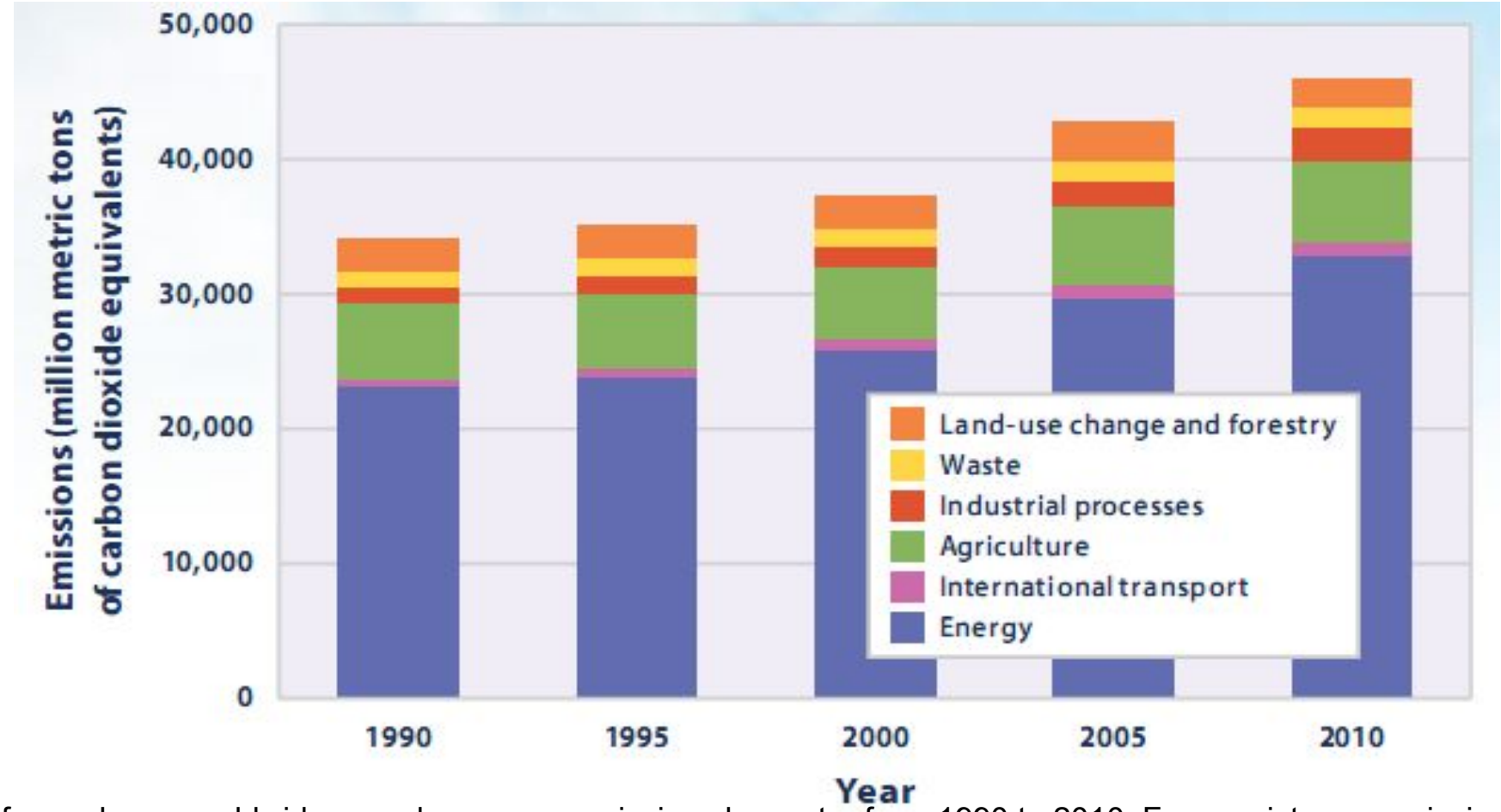
Figure. Global Greenhouse Gas Emissions by Gas, 1990–2010



This fgure shows worldwide emissions of carbon dioxide, methane, nitrous oxide, and several fuorinated gases from 1990 to 2010. For consistency, emissions are expressed in million metric tons of carbon dioxide equivalents. These totals include emissions and sinks due to land-use change and forestry. * HFCs are hydrofuorocarbons, PFCs are perfuorocarbons, and SF6 is sulfur hexafuoride.

Data source: WRI, 2014; FAO, 2014

Figure. Global Greenhouse Gas Emissions by Sector, 1990–2010

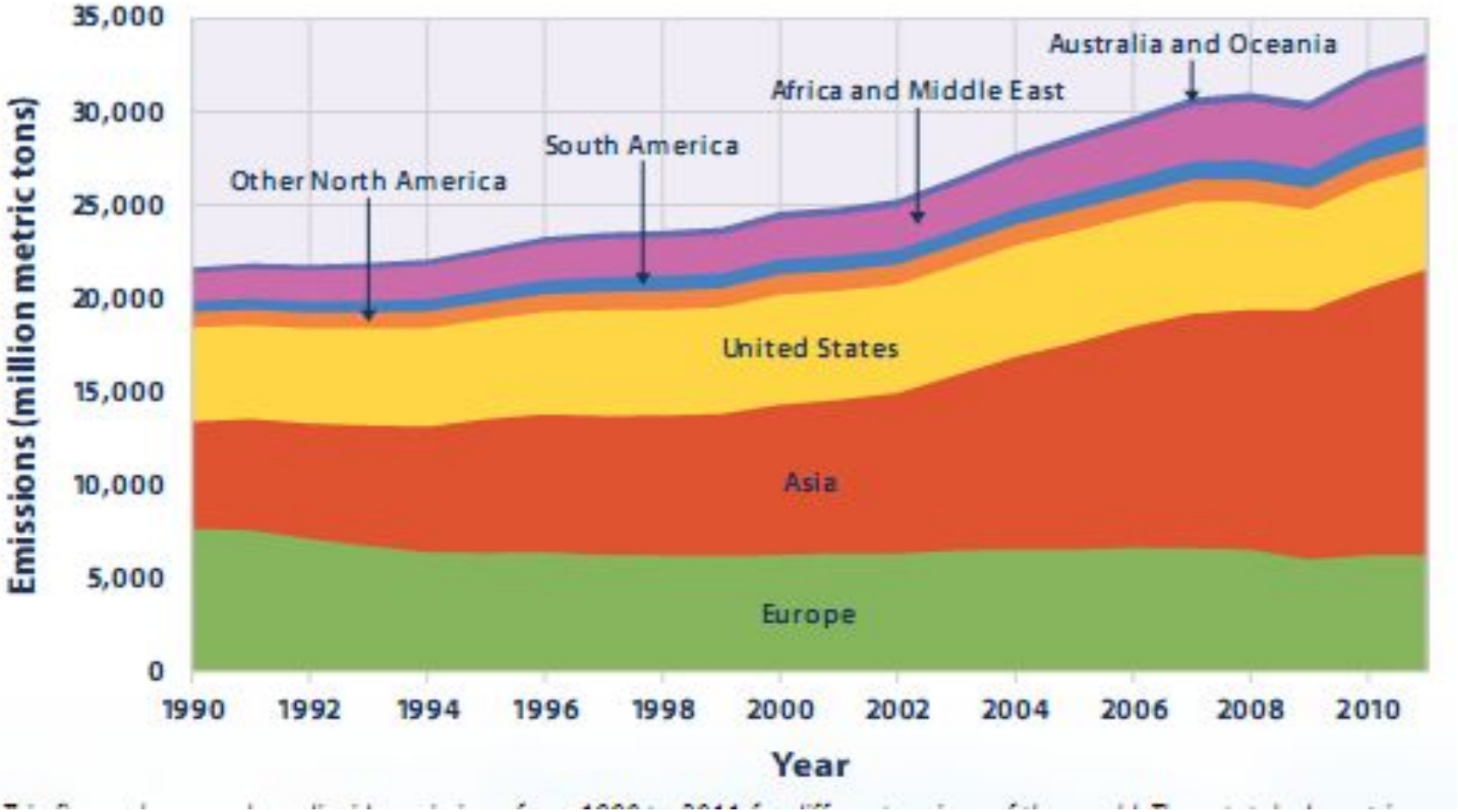


This fgure shows worldwide greenhouse gas emissions by sector from 1990 to 2010. For consistency, emissions are expressed in million metric tons of carbon dioxide equivalents. These totals include emissions and sinks due to landuse change and forestry.

Note that the sectors shown here are different from the economic sectors used in U.S. emissions accounting (see the U.S. Greenhouse Gas Emissions indicator on p.14). Emissions from international transport (aviation and marine) are separate from the energy sector because they are not part of individual countries' emissions inventories. The energy sector includes all other transportation activities.

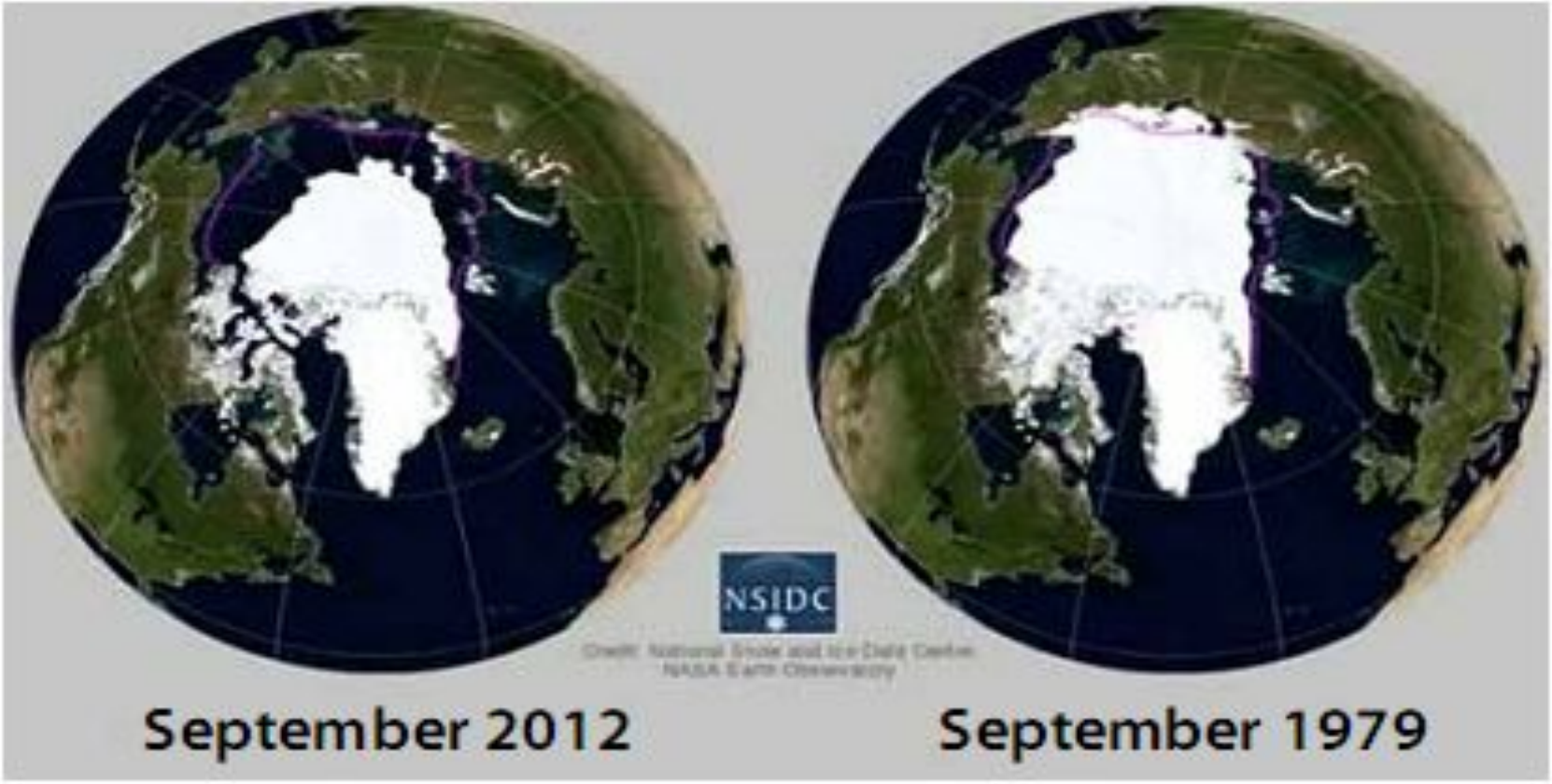
Data source: WRI, 2014; FAO, 2014

Figure. Global Carbon Dioxide Emissions by Region, 1990–2011



This figure shows carbon dioxide emissions from 1990 to 2011 for different regions of the world. These totals do not include emissions or sinks related to land-use change or forestry. Inclusion of land-use change and forestry would increase the apparent emissions from some regions while decreasing the emissions from others.

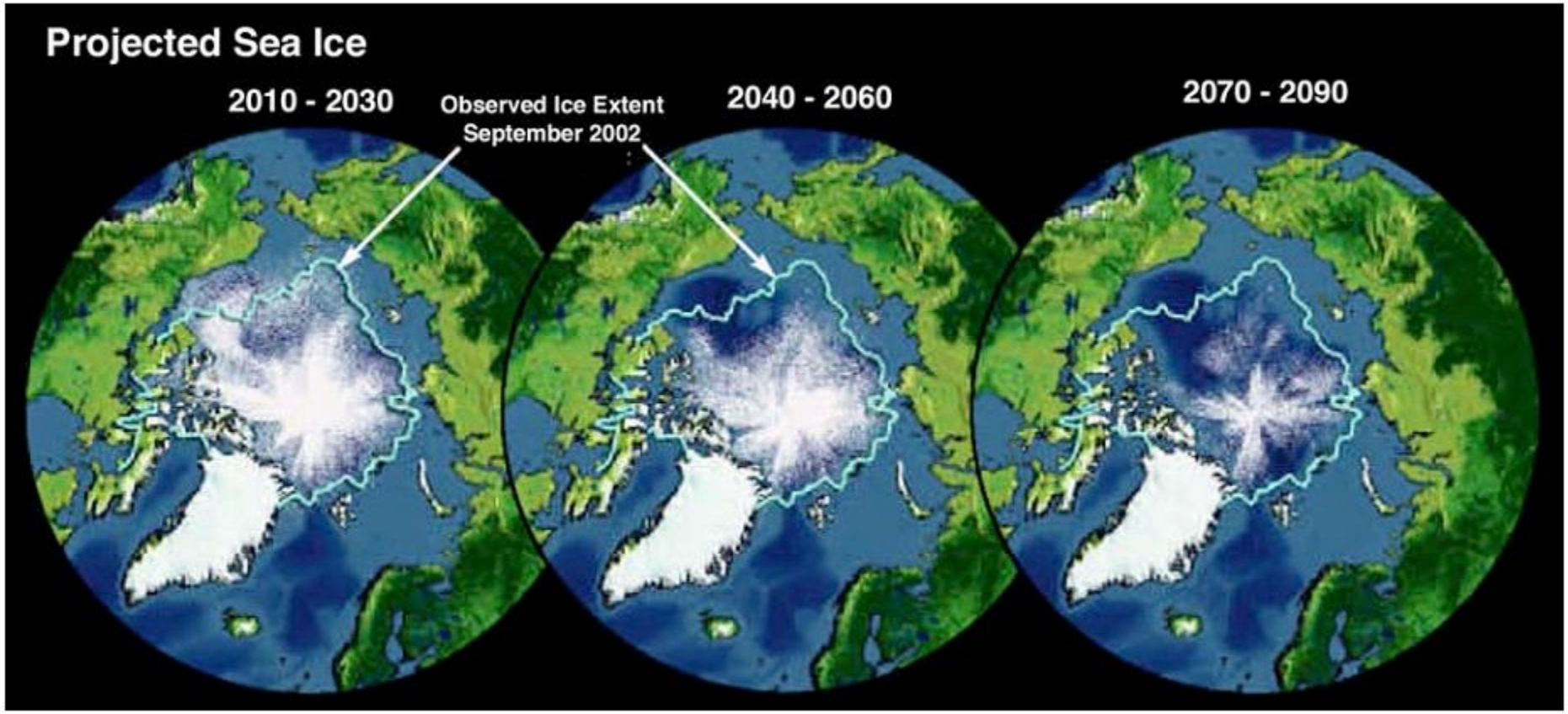
Data source: WRI, 201414



Rapid changes in the Arctic require urgent responses within the region and from the wider world. Since climate change dominates the current transformation of the Arctic environment, reducing global greenhouse gas emissions is the most important action that needs to be taken.

Permafrost

- Permafrost is a layer of frozen soil at some depth below the surface, where the temperature has continuously been below 0°C for at least several years. It has been retreating northwards in many places in the Arctic as the climate warms. Permafrost soils often contain large volumes of organic carbon. As these soils thaw, irreversible releases of some of the carbon in the form of greenhouse gases (CO_2 and methane) will occur, thereby reinforcing climate change.


Projected Sea Ice
2010 - 2030
Observed Ice Extent
September 2002
2040 - 2060
2070 - 2090

Key Findings of the Arctic Climate Impact Assessment

1. Arctic climate is now warming rapidly and much larger changes are projected.

- Annual average arctic temperature has increased at almost twice the rate as that of the rest of the world over the past few decades, with some variations across the region.
- Additional evidence of arctic warming comes from widespread melting of glaciers and sea ice, and a shortening of the snow season.
- Increasing global concentrations of carbon dioxide and other greenhouse gases due to human activities, primarily fossil fuel burning, are projected to contribute to additional arctic warming of about 4-7°C over the next 100 years.
- Increasing precipitation, shorter and warmer winters, and substantial decreases in snow cover and ice cover are among the projected changes that are very likely to persist for centuries.
- Unexpected and even larger shifts and fluctuations in climate are also possible.

Key Findings of the Arctic Climate Impact Assessment

2. Arctic warming and its consequences have worldwide implications.

- Melting of highly reflective arctic snow and ice reveals darker land and ocean surfaces, increasing absorption of the sun's heat and further warming the planet.
- Increases in glacial melt and river runoff add more freshwater to the ocean, raising global sea level and possibly slowing the ocean circulation that brings heat from the tropics to the poles, affecting global and regional climate.
- Warming is very likely to alter the release and uptake of greenhouse gases from soils, vegetation, and coastal oceans.
- Impacts of arctic climate change will have implications for biodiversity around the world because migratory species depend on breeding and feeding grounds in the Arctic.

Key Findings of the Arctic Climate Impact Assessment

3. Arctic vegetation zones are very likely to shift, causing wide-ranging impacts.

- Treeline is expected to move northward and to higher elevations, with forests replacing a significant fraction of existing tundra, and tundra vegetation moving into polar deserts.
- More-productive vegetation is likely to increase carbon uptake, although reduced reflectivity of the land surface is likely to outweigh this, causing further warming.
- Disturbances such as insect outbreaks and forest fires are very likely to increase in frequency, severity, and duration, facilitating invasions by non-native species.
- Where suitable soils are present, agriculture will have the potential to expand northward due to a longer and warmer growing season.

Key Findings of the Arctic Climate Impact Assessment

4. Animal species' diversity, ranges, and distribution will change.

- Reductions in sea ice will drastically shrink marine habitat for polar bears, ice-inhabiting seals, and some seabirds, pushing some species toward extinction.
- Caribou/reindeer and other land animals are likely to be increasingly stressed as climate change alters their access to food sources, breeding grounds, and historic migration routes.
- Species ranges are projected to shift northward on both land and sea, bringing new species into the Arctic while severely limiting some species currently present.
- As new species move in, animal diseases that can be transmitted to humans, such as Wes Nile virus, are likely to pose increasing health risks.
- Some arctic marine fisheries, which are of global importance as well as providing major contributions to the region's economy, are likely to become more productive. Northern freshwater fisheries that are mainstays of local diets are likely to suffer.

Key Findings of the Arctic Climate Impact Assessment

5. Many coastal communities and facilities face increasing exposure to storms.

- Severe coastal erosion will be a growing problem as rising sea level and a reduction in sea ice allow higher waves and storm surges to reach the shore.
- Along some arctic coastlines, thawing permafrost weakens coastal lands, adding to their vulnerability.
- The risk of flooding in coastal wetlands is projected to increase, with impacts on society and natural ecosystems.
- In some cases, communities and industrial facilities in coastal zones are already threatened or being forced to relocate, while others face increasing risks and costs.

Key Findings of the Arctic Climate Impact Assessment

6. Reduced sea ice is very likely to increase marine transport and access to resources.

- The continuing reduction of sea ice is very likely to lengthen the navigation season and increase marine access to the Arctic's natural resources.
- Seasonal opening of the Northern Sea Route is likely to make trans-arctic shipping during summer feasible within several decades. Increasing ice movement in some channels of the Northwest Passage could initially make shipping more difficult.
- Reduced sea ice is likely to allow increased offshore extraction of oil and gas, although increasing ice movement could hinder some operations.
- Sovereignty, security, and safety issues, as well as social, cultural, and environmental concerns are likely to arise as marine access increases.

Key Findings of the Arctic Climate Impact Assessment

7. Thawing ground will disrupt transportation, buildings, and other infrastructure.

- Transportation and industry on land, including oil and gas extraction and forestry, will increasingly be disrupted by the shortening of the periods during which ice roads and tundra are frozen sufficiently to permit travel.
- As frozen ground thaws, many existing buildings, roads, pipelines, airports, and industrial facilities are likely to be destabilized, requiring substantial rebuilding, maintenance, and investment.
- Future development will require new design elements to account for ongoing warming that will add to construction and maintenance costs.
- Permafrost degradation will also impact natural ecosystems through collapsing of the ground surface, draining of lakes, wetland development, and toppling of trees in susceptible areas.

Key Findings of the Arctic Climate Impact Assessment

8. Indigenous communities are facing major economic and cultural impacts.

- Many Indigenous Peoples depend on hunting polar bear, walrus, seals, and caribou, herding reindeer, fishing, and gathering, not only for food and to support the local economy, but also as the basis for cultural and social identity.
- Changes in species' ranges and availability, access to these species, a perceived reduction in weather predictability, and travel safety in changing ice and weather conditions present serious challenges to human health and food security, and possibly even the survival of some cultures.
- Indigenous knowledge and observations provide an important source of information about climate change. This knowledge, consistent with complementary information from scientific research, indicates that substantial changes have already occurred.

Key Findings of the Arctic Climate Impact Assessment

9. Elevated ultraviolet radiation levels will affect people, plants, and animals.

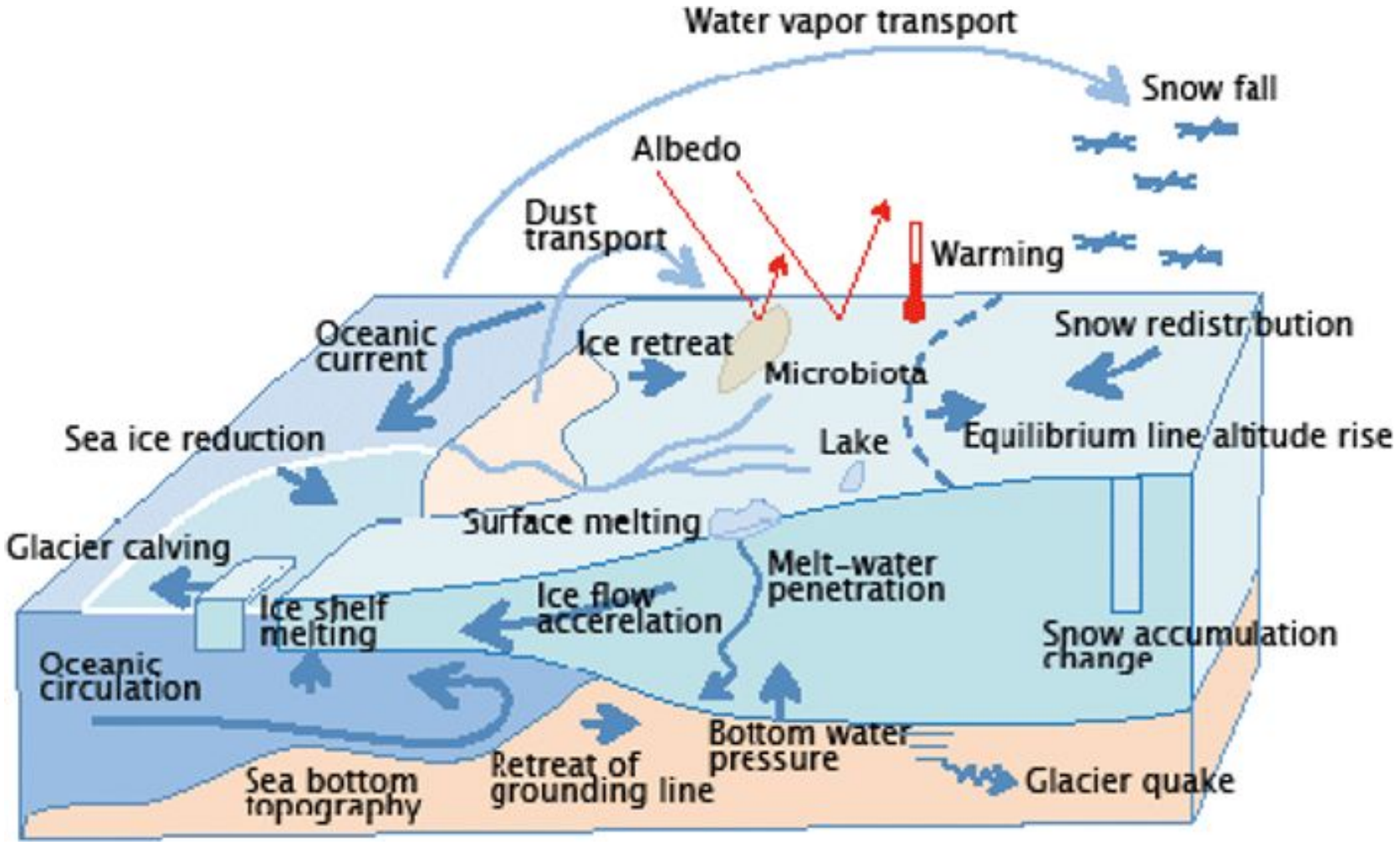
- The stratospheric ozone layer over the Arctic is not expected to improve significantly for at least a few decades, largely due to the effect of greenhouse gases on stratospheric temperatures. Ultraviolet radiation (UV) in the Arctic is thus projected to remain elevated in the coming decades.
- As a result, the current generation of arctic young people is likely to receive a lifetime dose of UV that is about 30% higher than any prior generation. Increased UV is known to cause skin cancer, cataracts, and immune system disorders in humans.
- Elevated UV can disrupt photosynthesis in plants and have detrimental effects on the early life stages of fish and amphibians.
- Risks to some arctic ecosystems are likely as the largest increases in UV occur in spring, when sensitive species are most vulnerable, and warming-related declines in snow and ice cover increase exposure for living things normally protected by such cover.

Key Findings of the Arctic Climate Impact Assessment

10. Multiple influences interact to cause impacts to people and ecosystems.

- Changes in climate are occurring in the context of many other stresses including chemical pollution, overfishing, land use changes, habitat fragmentation, human population increases, and cultural and economic changes.
- These multiple stresses can combine to amplify impacts on human and ecosystem health and well-being. In many cases, the total impact is greater than the sum of its parts, such as the combined impacts of contaminants, excess ultraviolet radiation, and climatic warming.
- Unique circumstances in arctic sub-regions determine which are the most important stresses and how they interact.

- http://www.ipcc.ch/index.htm The Intergovernmental Panel on Climate Change (IPCC)
- http://www.ipcc.ch/report/ar5/wg1/
- http://www.climatefinancelandscape.org/?gclid=CPaW39PqussCFUgMcwodQ6EHeg **-The Global Landscape of Climate Finance**
- **http://climate.nasa.gov/causes/**


Water vapor transport
Snow fall
Albedo
Dust transport
Warming
Oceanic current
Ice retreat
Microbiota
Snow redistribution
Sea ice reduction
Lake
Equilibrium line altitude rise
Surface melting
Glacier calving
Melt-water penetration
Ice shelf melting
Ice flow accerelation
Snow accumulation change
Oceanic circulation
Bottom water pressure
Retreat of grounding line
Glacier quake
Sea bottom topography