Global warming and its consequences

CHARACTER OF THE EARTH'S CLIMATE CHANGE

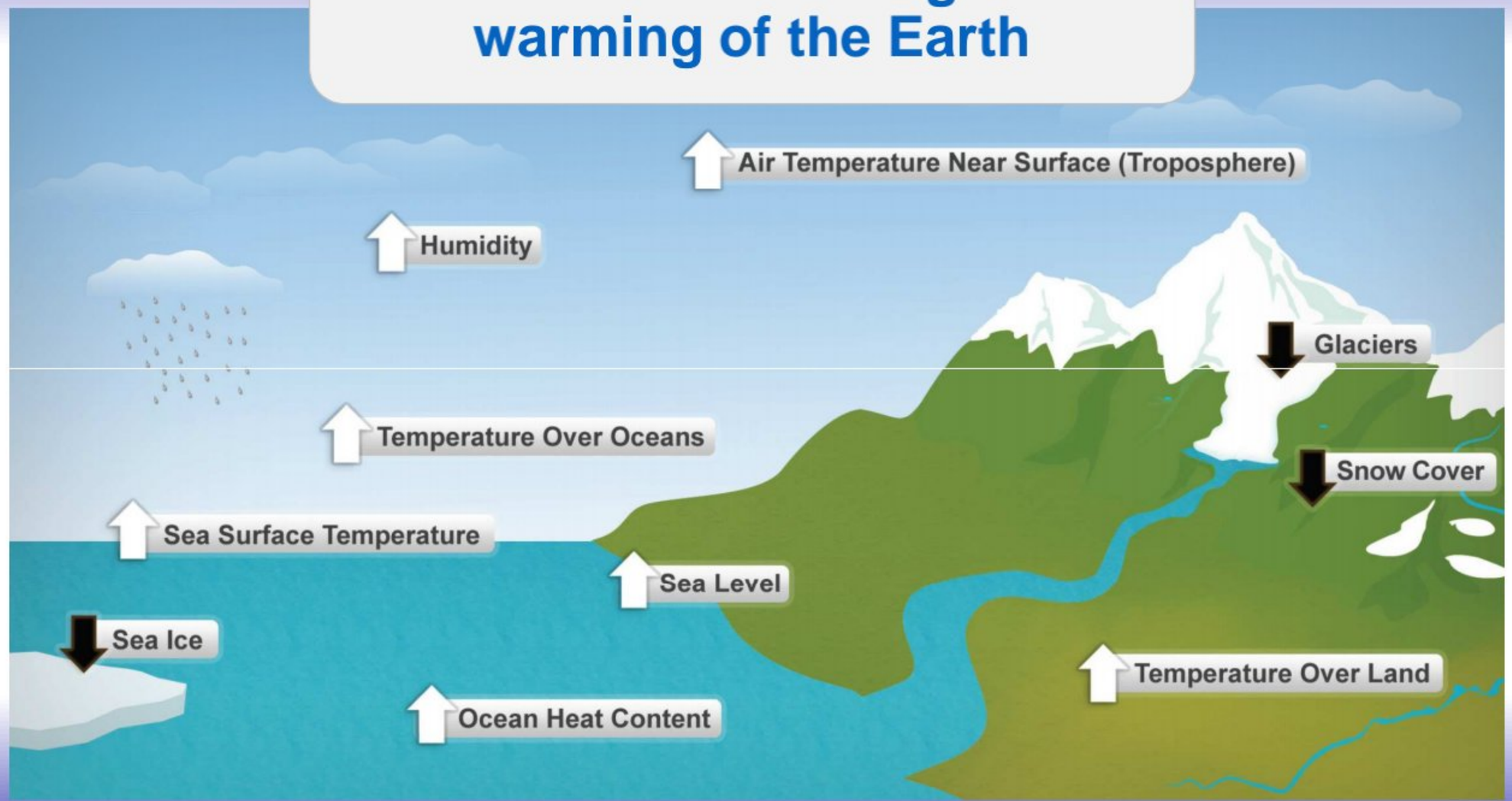
Analysis of the Earth's climate change trends provides evidence that over the last century the Earth's climate has changed significantly

Climate change is affecting both, overall parameters of the Earth and changes in the Earth's biophysical systems (such as nutrient cycling and flows etc.)

- **Temperature**
- **Precipitation**
- **Stability of snow cover in northern regions**

There is a reason to believe that the greenhouse gas emissions and concentration in the atmosphere is considered as a key factor that determines substantial change the Earth's climate – global warming

Ten indicators of a global warming of the Earth



The time period 1983-2012 has been the warmest period in the last 1,400 years in the Northern Hemisphere, where it was possible to make such climate reconstruction

The global average combined temperature above the land and oceans shows a linear growth trend for the period from 1880 to 2012

Each of the last three decades has had a higher temperature than any other decade since 1850

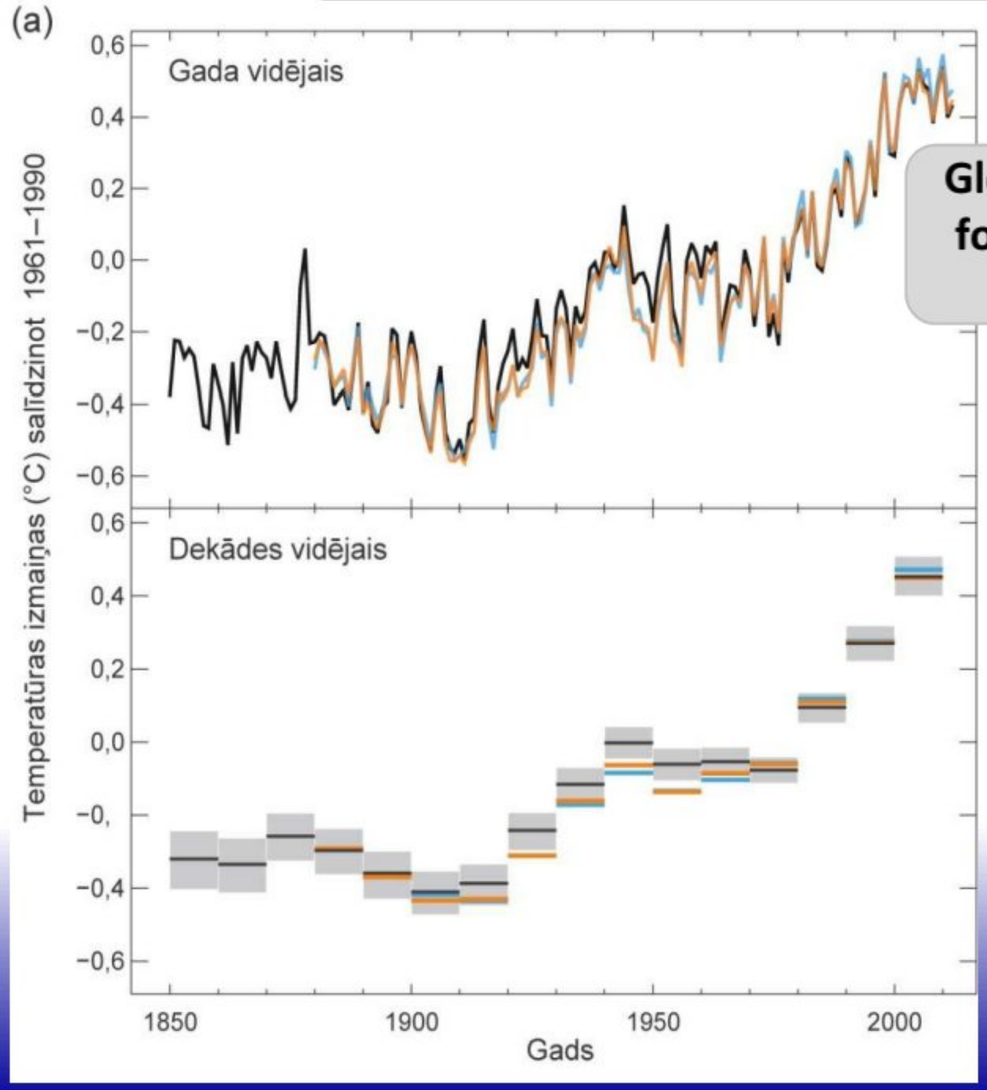
Global warming over the past 150 years has determined not only temperature increase, but also rise of sea level and reduction of snow cover area in the Northern Hemisphere

July 10, 2011 – Sampling Melt Ponds in Chukchi Sea, NASA

Decrease of ice cover in the Arctic Sea

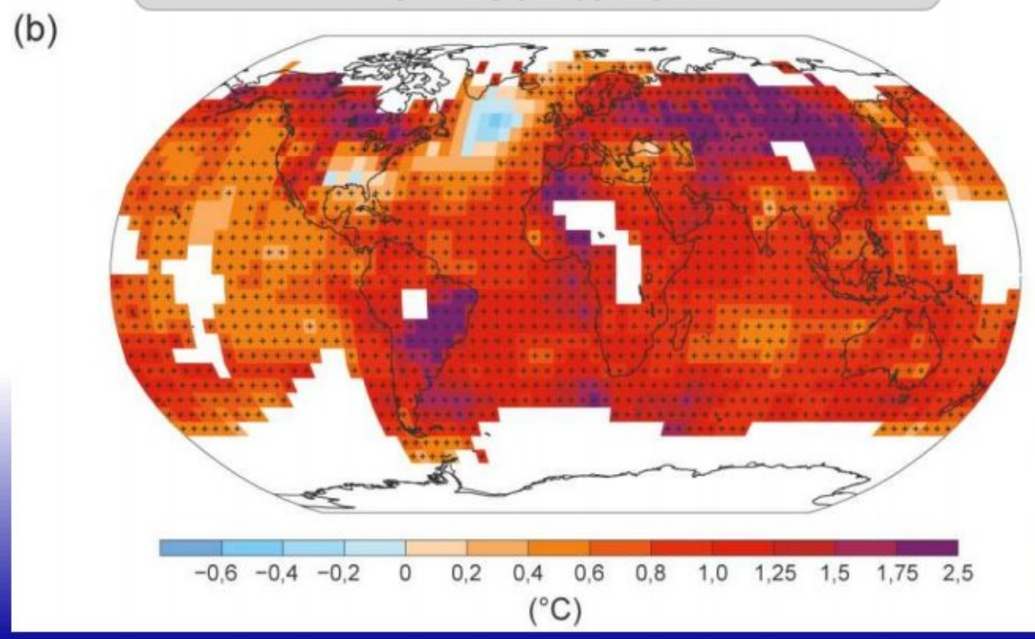
Melted ice = 2,917,000 km²; Argentina = 2,780,400 km²; EU = 4,324,782 km²

Deviations of global annual average air temperature (over land and oceans) for the time period 1850-2012



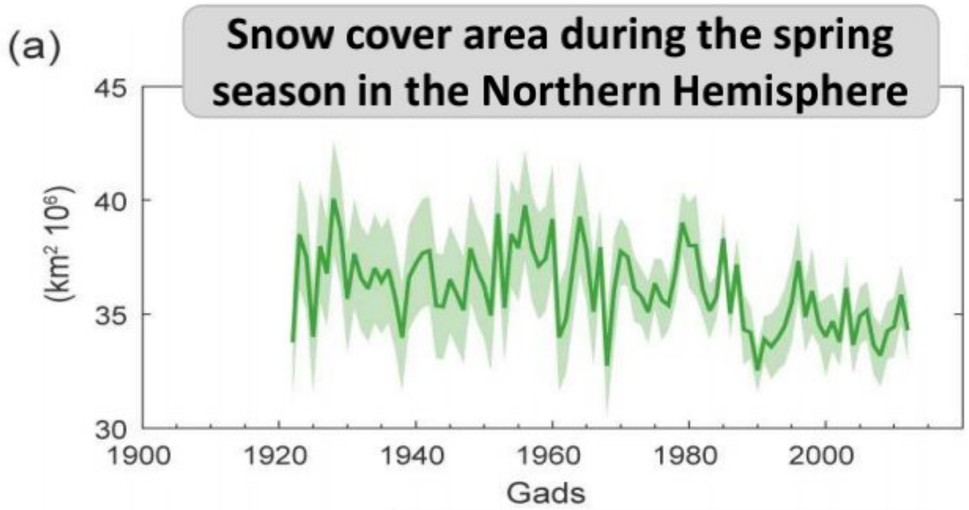
Global annual and decade average air temperature for the time period 1850-2012 (compared with an average temperature for 1961-1990)

Observed temperature changes from 1901 to 2012

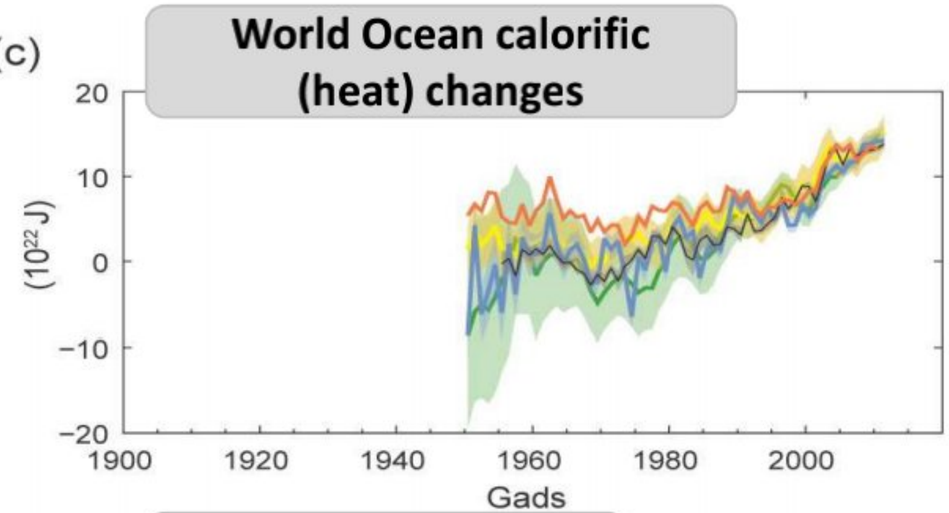


Variability of some important environmental parameters over the last hundred years

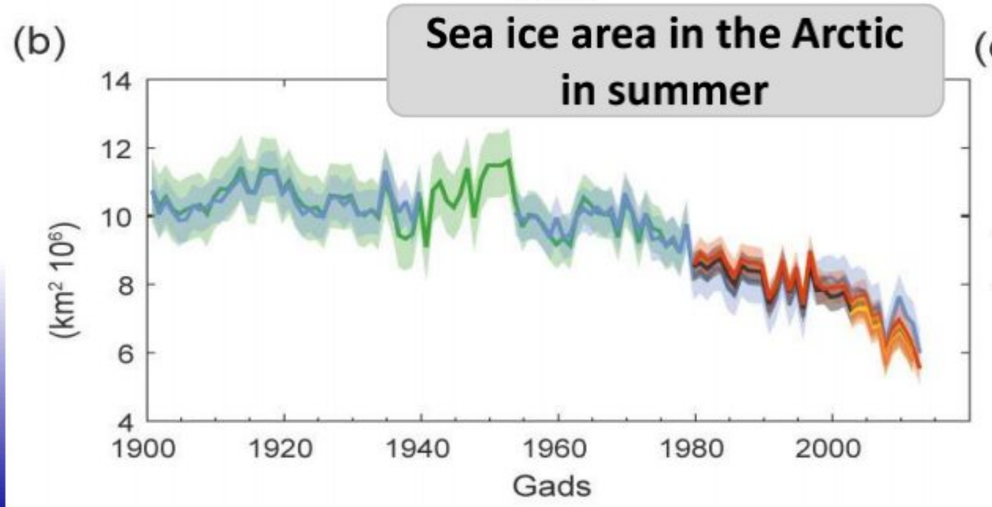
(a)



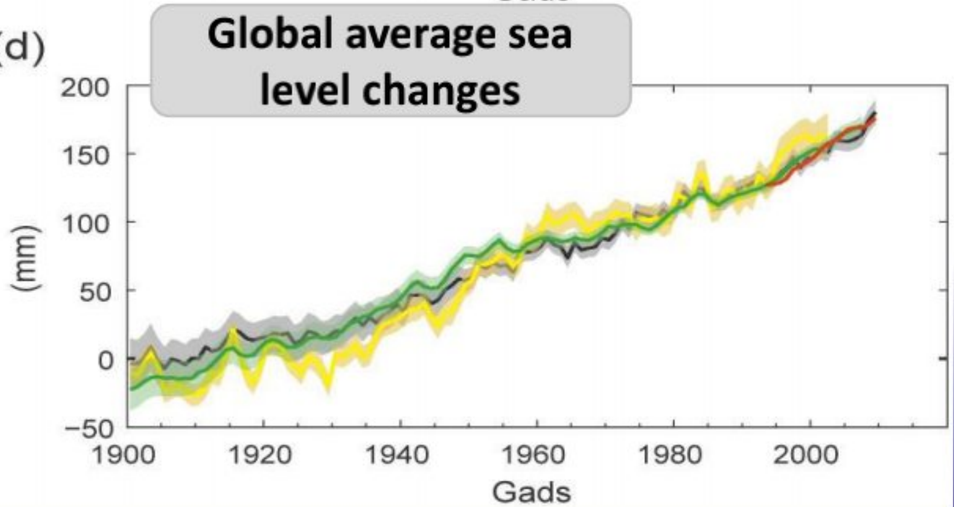
(c)



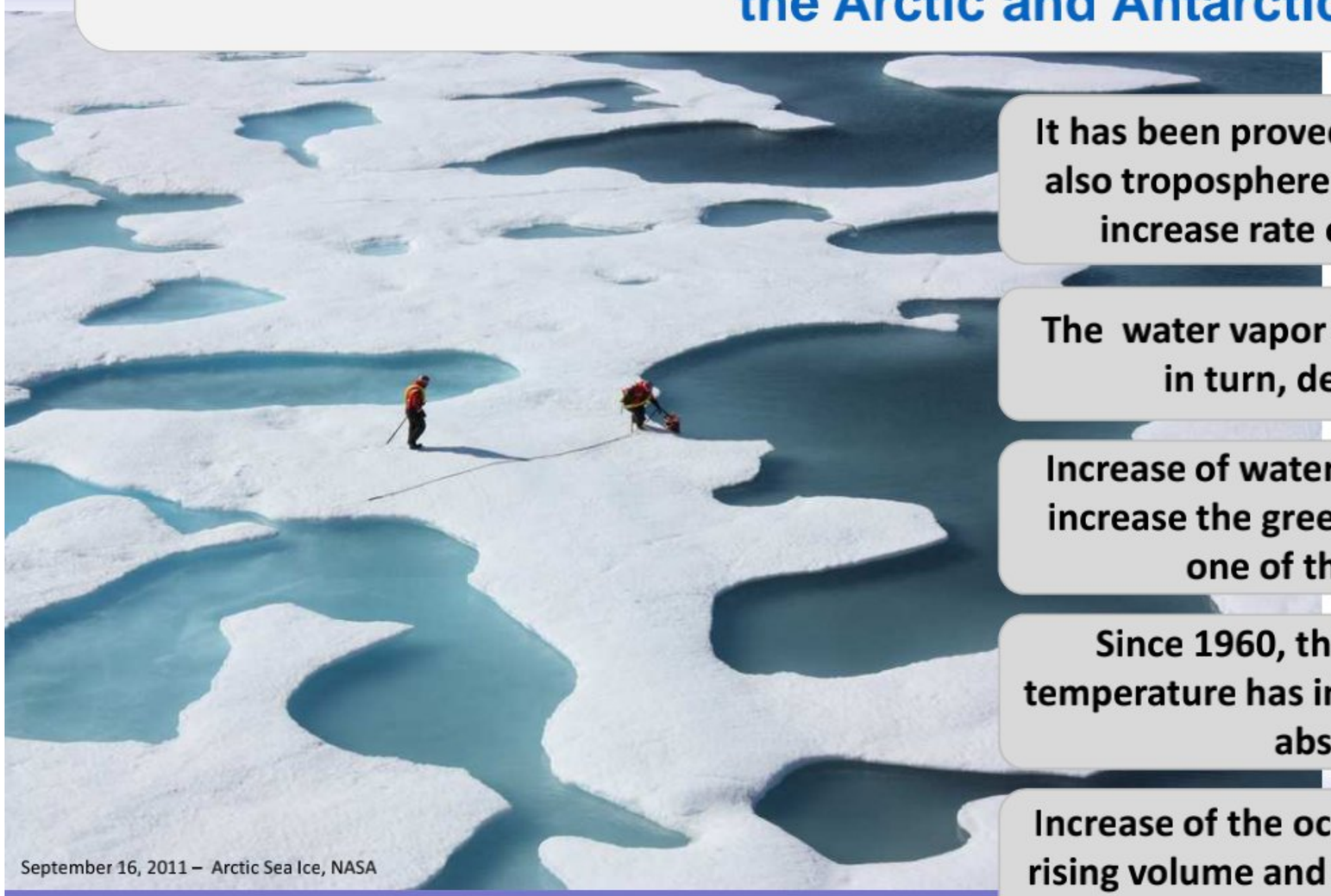
(b)



(d)



However, the rise in temperature on the Earth has been uneven – the fastest temperature increase is observed in the Earth's poles – **the Arctic and Antarctica**



September 16, 2011 – Arctic Sea Ice, NASA

It has been proved that not only ground-level temperature, but also troposphere temperature increases, and the temperature increase rate of the studied atmospheric mass is similar

The water vapor in the atmosphere also has increased, which, in turn, determines the increase of temperature

Increase of water vapor concentration in the atmosphere may increase the greenhouse effect in the future, because water is one of the greenhouse-enhancing substances

Since 1960, the measurements proved that ocean water temperature has increase in (up to 3000 m deep), because water absorbs most of the incoming heat

Increase of the ocean water temperature may contribute to the rising volume and levels of sea, as well as may affect the nature of water flows

Over the last century not only snow cover area of Northern Hemisphere, but also the mountain and continental glaciers, as well as the permafrost occupied area has reduced, which contribute to sea level rise

The most significantly are affected Antarctic and Greenland glaciers

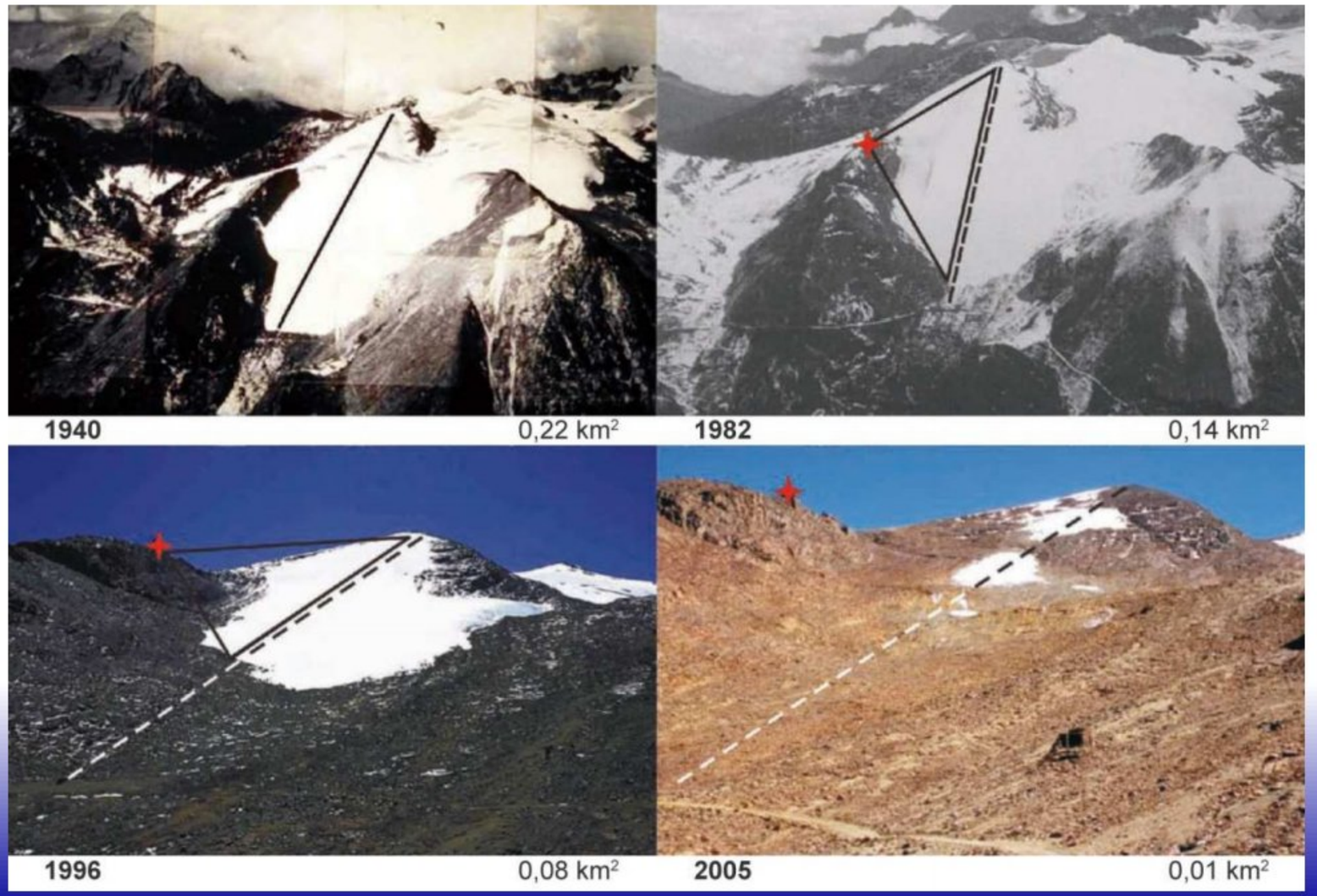
Mountain glaciers are becoming increasingly shorter and thinner, e.g., in Central Asia and the Southern Siberian mountains many glaciers have become smaller than 4 km over the last 200 years

Alpine glacier area has decreased by 30-40% compared with the area, which they took during the Little Ice Age

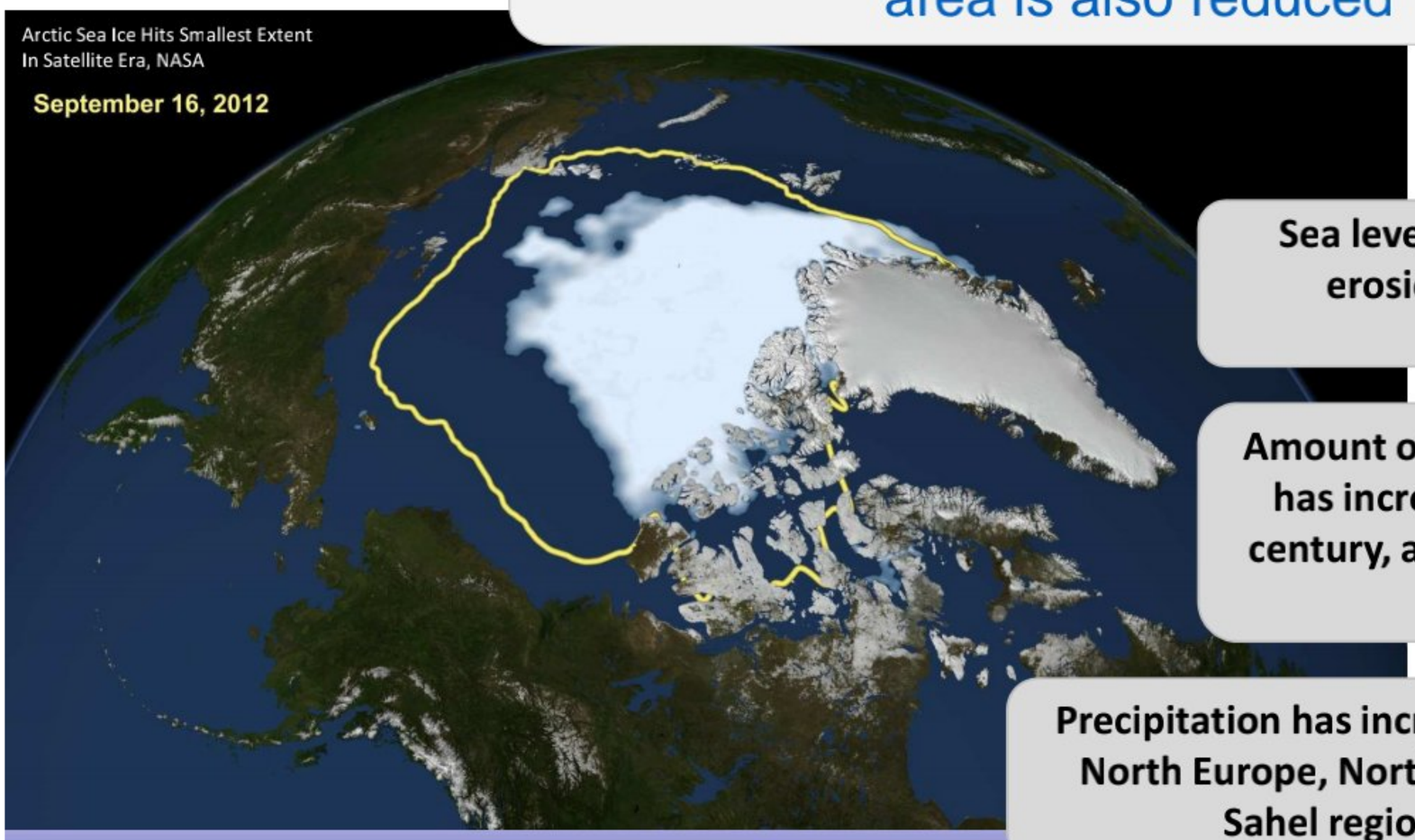
In Europe, sharp reduction of glaciers is directly related to the rapid climate warming in the Alps in 20th century; freezing permafrost areas are reducing as well

October 16, 2011 – Aerial View of Switzerland's Fast-Decreasing Glaciers, UN

Changes of mountain glacier area over 60 years



The temperature increase is significant in the polar regions of the Earth; the sea ice occupied area is also reduced



Sea level changes has significantly affected coastal erosion processes and has contributed to the degradation of coastal areas

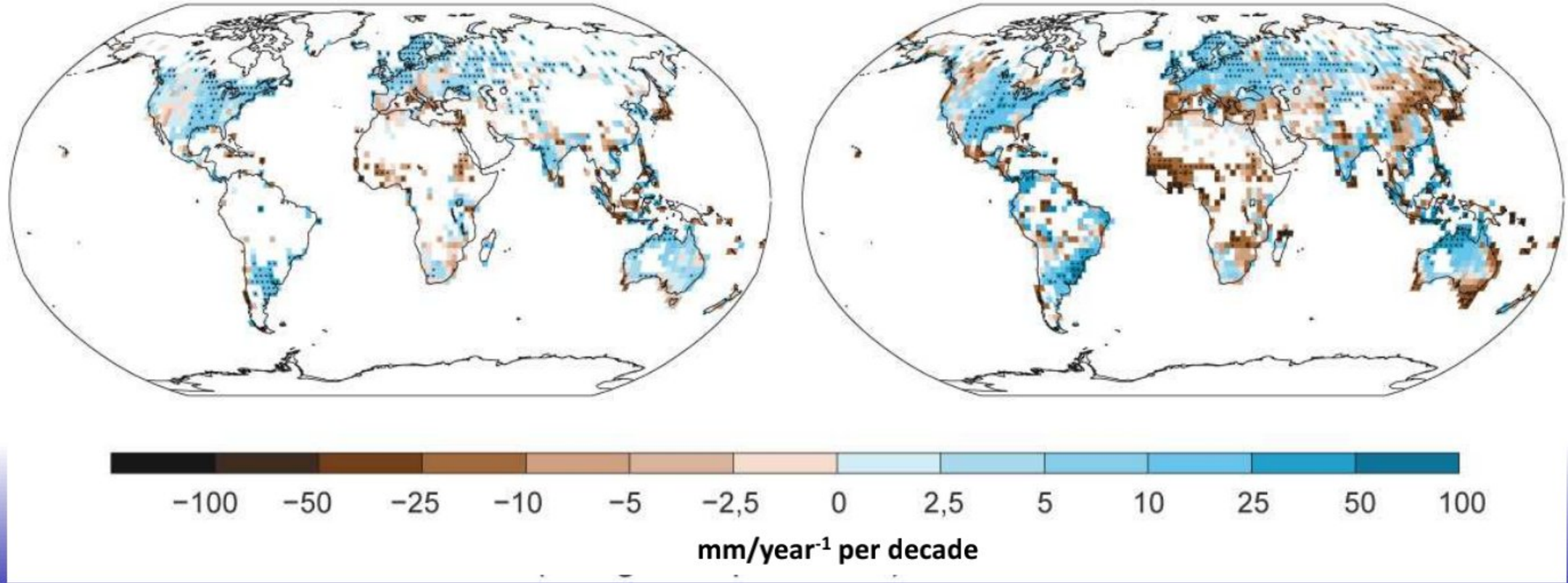
Amount of precipitation, although uneven, on average has increased by 2% since the beginning of the 20th century, as well as frequency of extreme precipitation has significantly increased

Precipitation has increased in North America and South America, North Europe, North Asia and Central Asia, but declined in the Sahel region, Mediterranean and South Africa

Observed changes in precipitation over the land

For the time period 1901-2010

For the time period 1951-2010



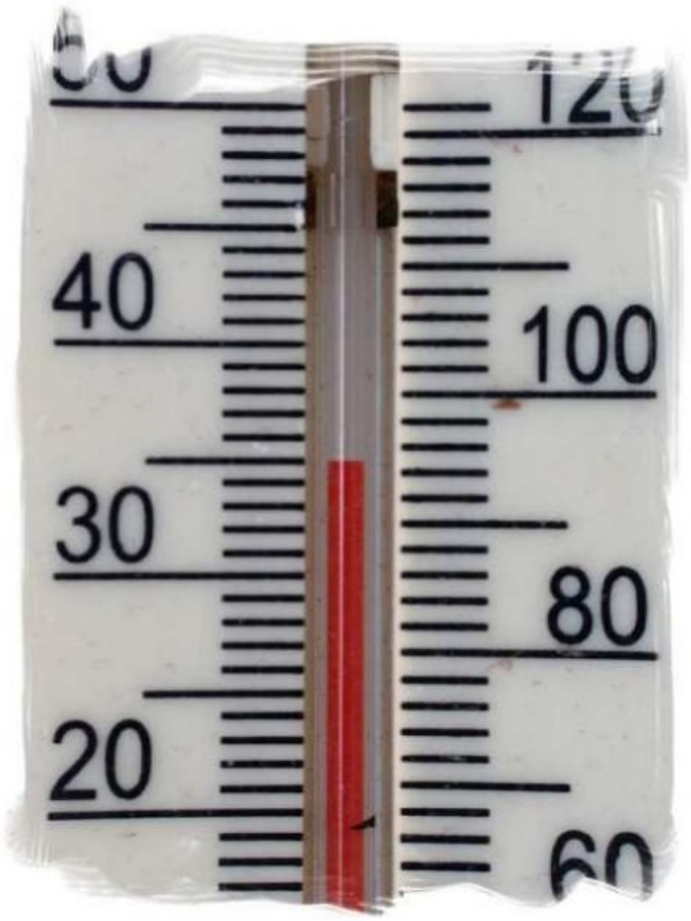
Global warming is also linked to **the stability of climate system and increase in frequency of extreme climatic events** - this applies to both, variability of tropical cyclones and hurricanes frequency and intensity of the Caribbean's, as well as to the monsoon rains in Asia

Climate change directly affects not only natural, but also the human environment, as well as possible invasion of unusual species for the region

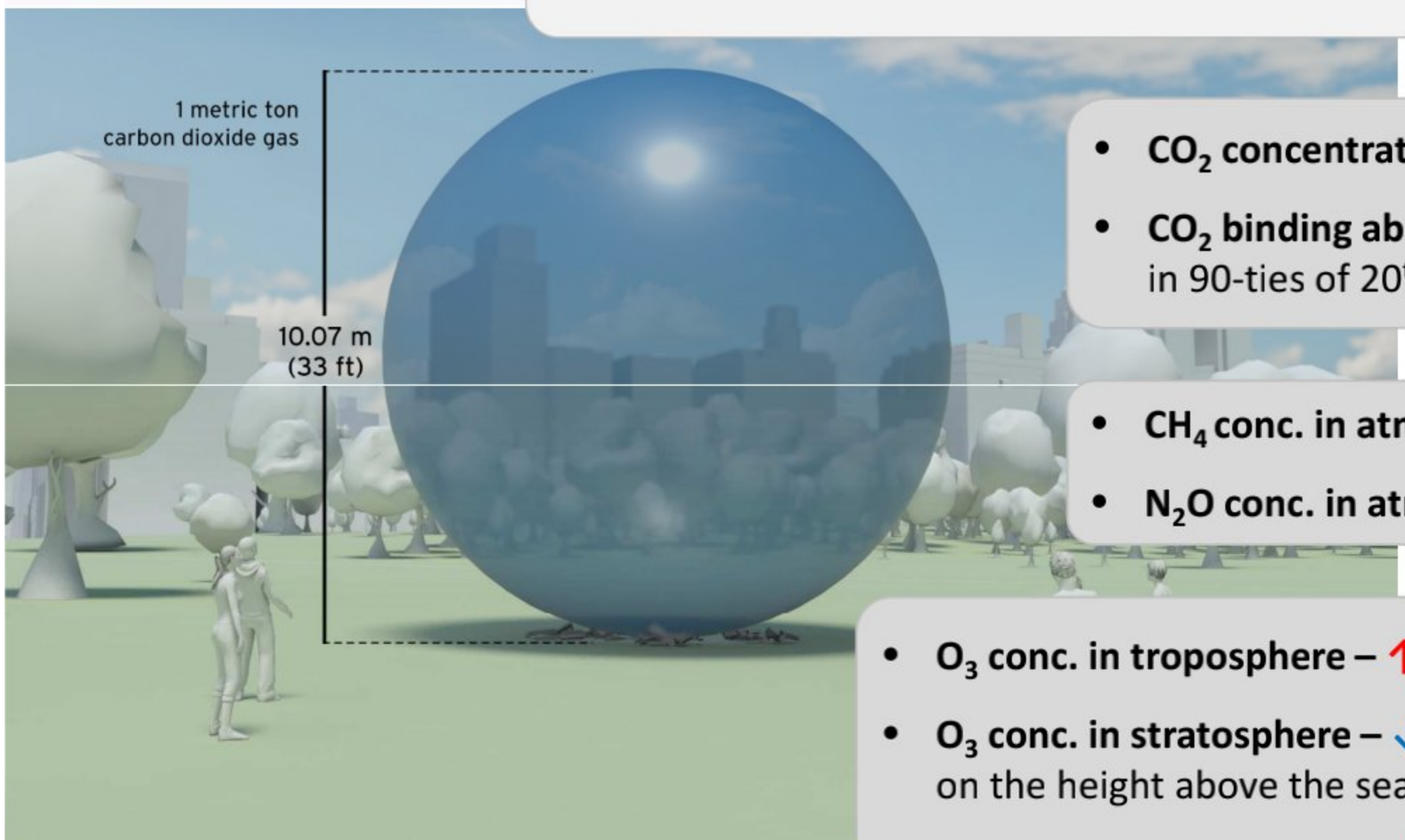
By impact of global warming summers in many regions have become warmer, and intensity of periods when observed extreme high temperature «heat waves» has increased

The negative impact of extremely hot summers is enlarged by the increasing humidity - it has been determined that in temperate regions at very hot weather the number of deaths a day is increasing

Heat waves in cities of the USA, France in 2003 and in Greece in 2007 claimed several hundreds of lives, but during the heat waves in London mortality increased by 15%



Observed changes in the atmosphere – **concentration indicators**



- **CO_2 concentration in atmosphere– ↑ increase** by 40±4%
- **CO_2 binding ability in biosphere – ↓ decrease** by 14±7 GtC in 90-ties of 20th century

- **CH_4 conc. in atmosphere – ↑ increase** by 151±25%
- **N_2O conc. in atmosphere – ↑ increase** by 20±5%

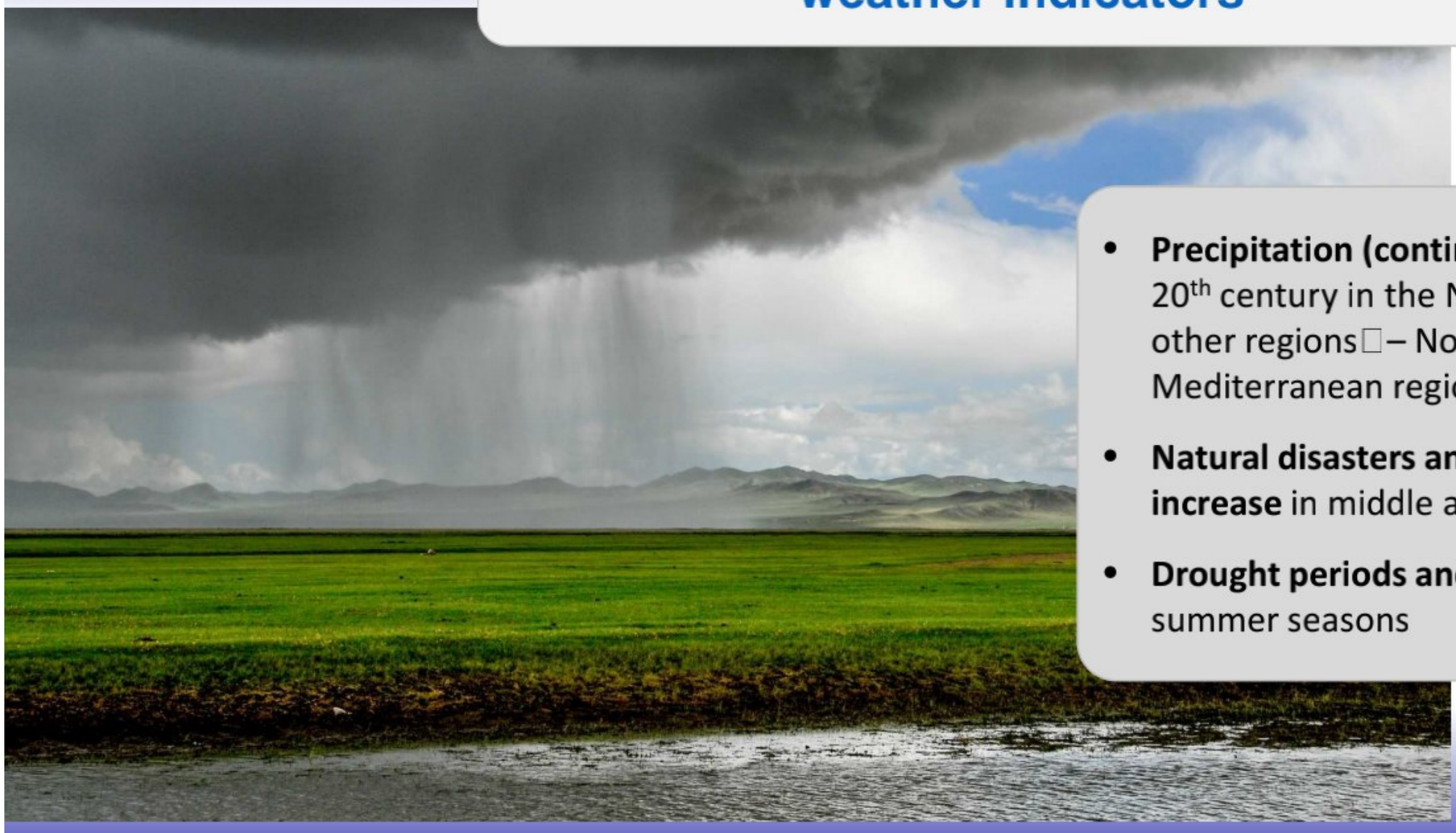
- **O_3 conc. in troposphere – ↑ increase** by 35±15%
- **O_3 conc. in stratosphere – ↓ decrease** during 1970-2012, depending on the height above the sea level and latitude
- **Other greenhouse gases – ↑ overall increase** during the last 50 years

Observed changes in the atmosphere – **weather indicators**

- **Earth's surface temperature – ↑ increase** by 0,84±0,2% ºC in 20th century, more on land than on ocean surface
- **Temperature in the Northern Hemisphere – ↑ the greatest increase** in 20th century during the last 1000 years
- **Daily temperature amplitude – ↓ decrease** on land during the time period 1950-2012
- **Temperature minimum at night – ↑ double increase** if compared with daily maximum temperature

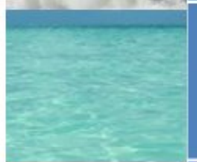
- **Hot days / heat index– ↑ increase**
- **Cold / freeze (days with temperature below 0 ºC) – ↓ decrease** on land in 20th century

Observed changes in the atmosphere – **weather indicators**

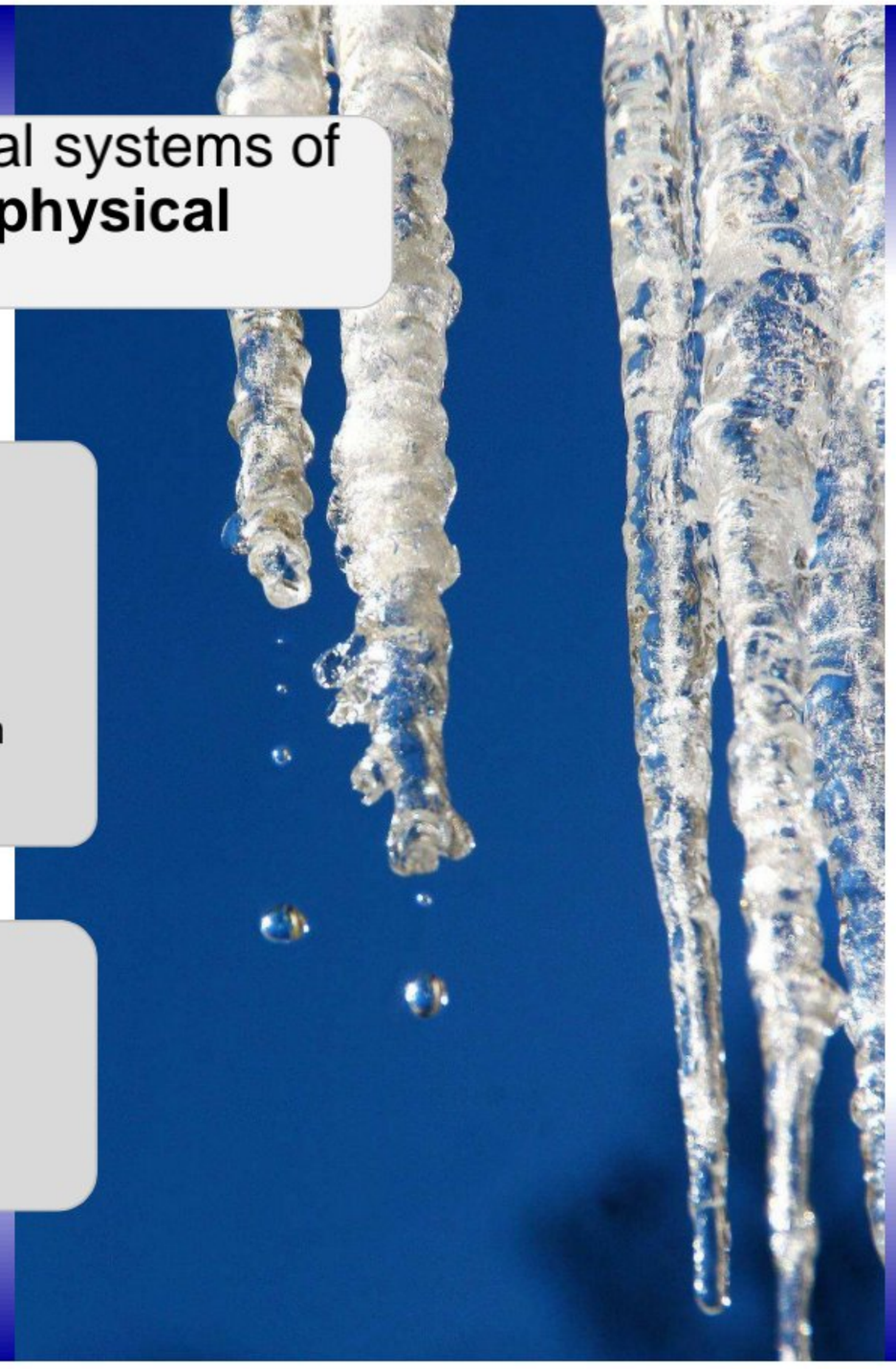


- **Precipitation (continental) – ↑ increase** by 5-10% in 20th century in the Northern Hemisphere, while in other regions – North and West Africa, Mediterranean regions – **↓ decrease**
- **Natural disasters and precipitation intensity – ↑ increase** in middle and upper northern latitude
- **Drought periods and intensity – ↑ increase** in summer seasons

Trends of global indicators indicating global warming

	Global Indicator	Period of Record	Long-term Trend	Trend Since 2000
	Ocean Heat Content	1955-2012	↑	↑
	Global Sea Level Rise	1880-2011	↑	↑
	Global Sea Surface Temperature	1880-2012	↑	↑
	Global Surface Temperature	1901-2012	↑	↑
	Arctic Minimum Sea Ice Extent	1979-2012	↓	↓
	Reference Glaciers Cumulative Mass	1945-2010	↓	↓
	Ocean Acidity	1983-2011	↑	↑

Observed changes in biophysical systems of the Earth – **biological and physical indicators**

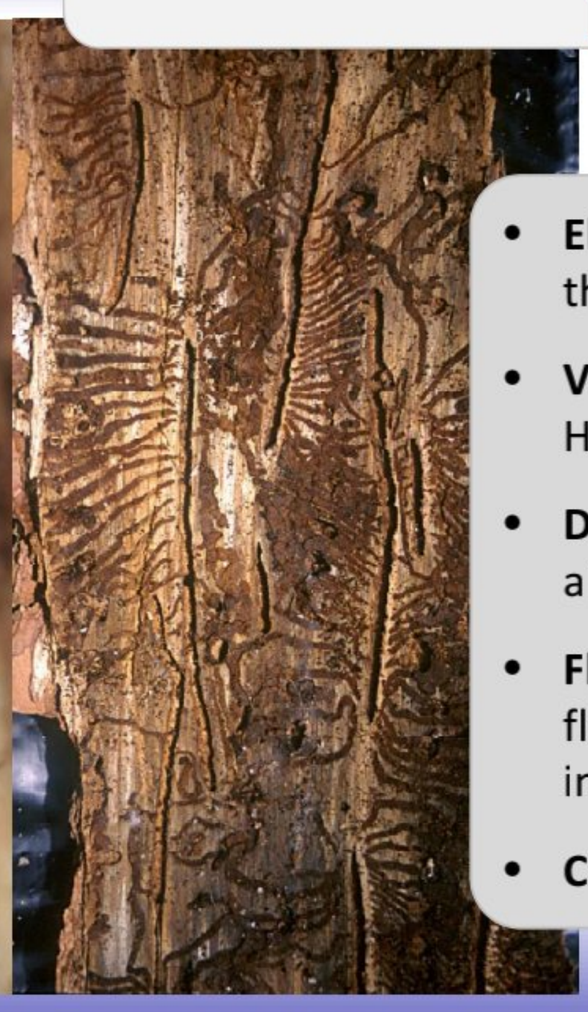


- **Sea level – ↑ increase** in 20th century by 1-2 mm a year
- **Period of ice cover on rivers and lakes – ↓ decrease** by ~2 weeks in middle and upper northern latitude in 20th century
- **Thickness and area of ice cover in Arctic Ocean – ↓ decrease** by 40% in summer-autumn seasons during the last decades

- **Glacier – ↓ decrease**
- **Snow cover – ↓ decrease** by 10% from the 60-ties of 20th century
- **Permafrost – ↓ decrease** in polar, sub-polar and mountain regions

Observed changes in biophysical systems of the Earth – **biological and physical indicators**

Egļu astonzobu mizgrauzis
Ips typographus



- **El Niño phenomenon – ↑ more frequent, persistent and strong** over the last 20-30 years, compared to the previous 100 years
- **Vegetation period– ↑ prolonged** by 1-4 days in the Northern Hemisphere over the last 40 years, especially at higher latitude
- **Distribution of flora and fauna – ↑ expanded** to the north and high-altitude areas (distribution range of plants, insects, birds and fish)
- **Flowering, breeding and migration period – ↑ earlier plant** flowering and bird arrival, earlier breeding period, rapid invasion of insects in the Northern Hemisphere
- **Coral reef fade– ↑ increased,** especially due El Niño

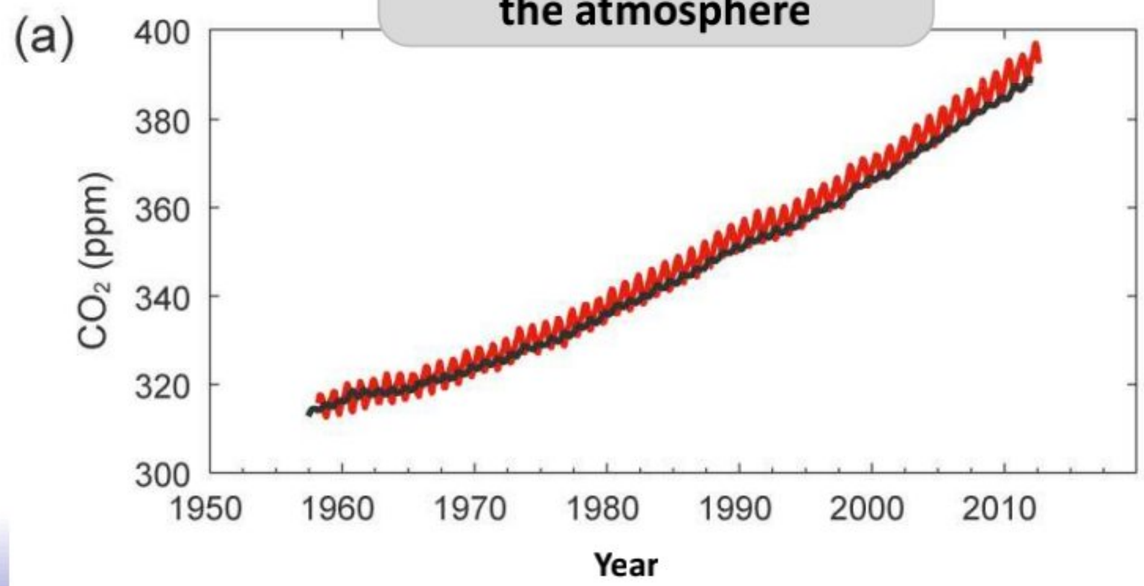
Increase of carbon dioxide concentration in the atmosphere affects not only the Earth's climate, but, by dissolving in water, it changes pH of water and subsequently the ocean becomes more acidic

The pH balance is essential parameter for the successful development of all the living organisms in seas and oceans

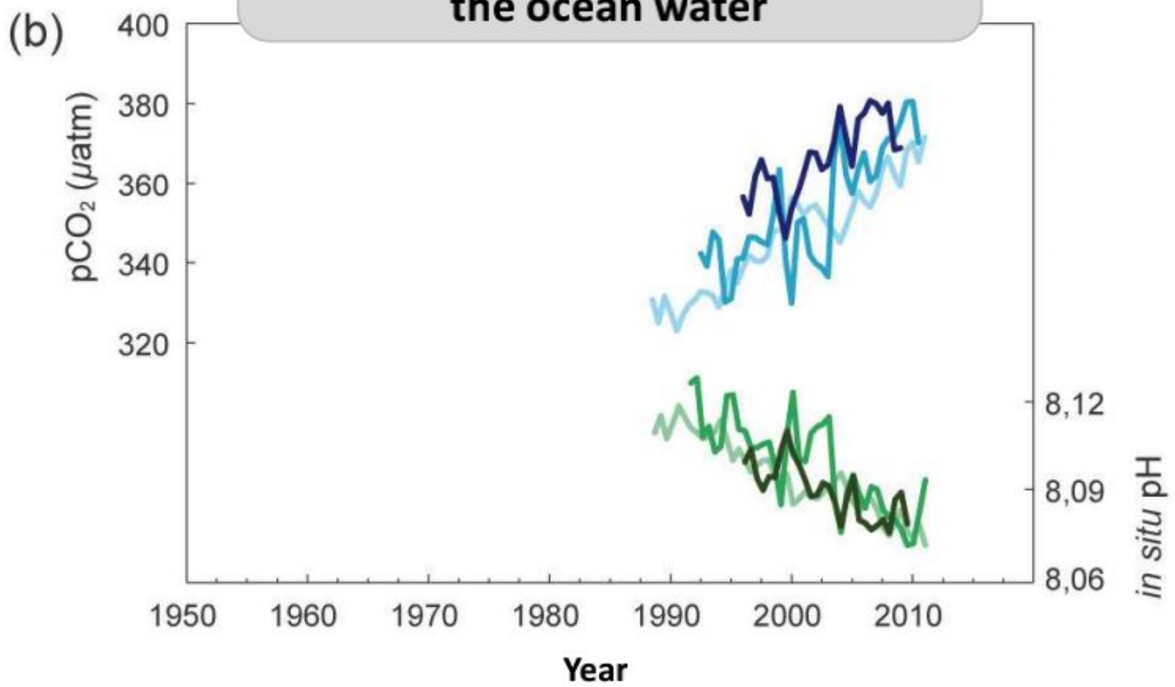
Such a changes can lead to direct consequences - the extinction of sensitive species and reduction in fish catches, but indirect changes may affect all community of living organisms

Character of changes in carbon dioxide concentration in the atmosphere and the ocean waters during 1950-2010

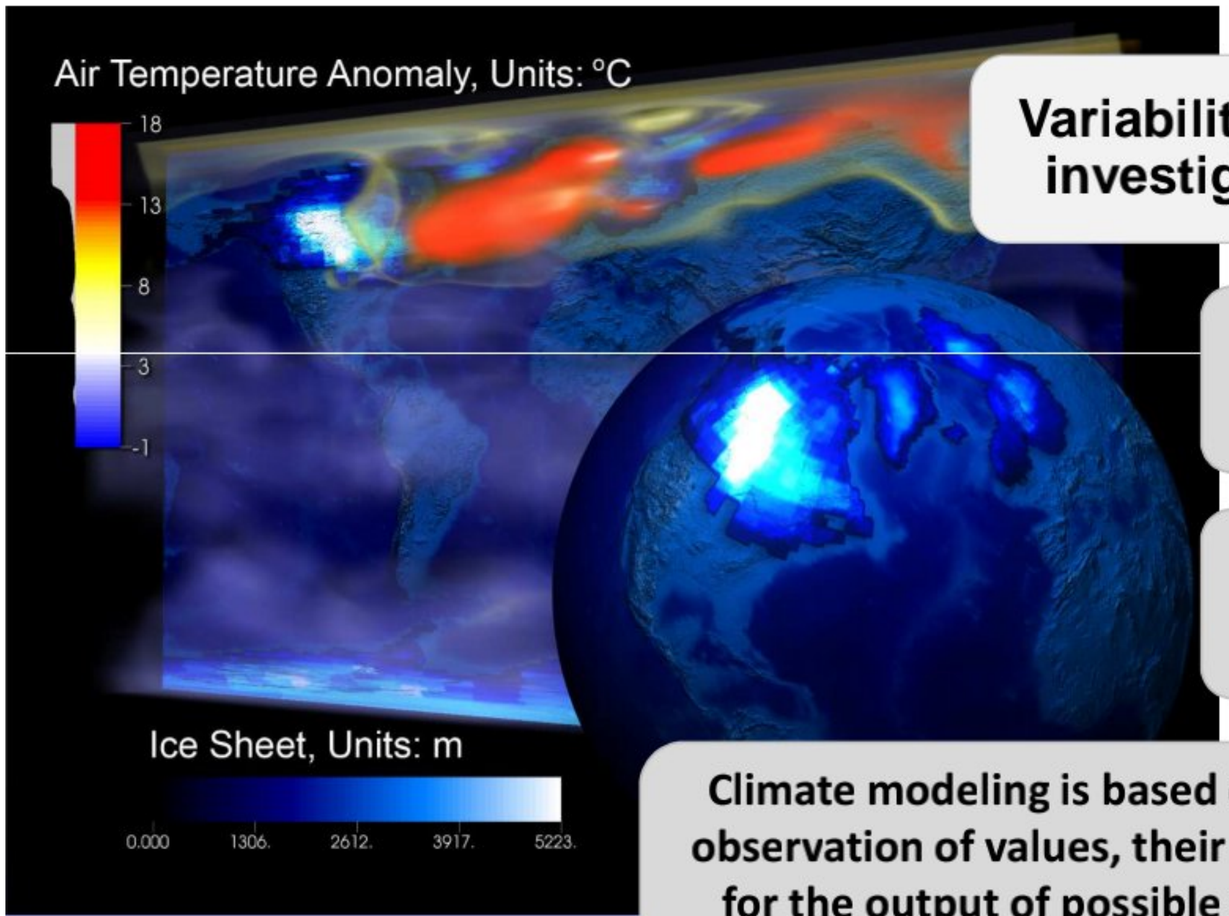
Changes in carbon dioxide concentration in the atmosphere



Changes in carbon dioxide concentration and pH reaction in the ocean water



MODELING OF THE EARTH'S CLIMATE AND SCENARIOS OF CLIMATE CHANGES



Variability of the climate system and its behavior can be investigated and predicted applying climate modeling

A model is a description or visual representation of processed, systems or activities using a mathematical equation assistance

Cognitive approach, replacing the research object by the model, is used when an object's direct investigation is difficult or impossible

Climate modeling is based on the relationship among the climate elements and on the observation of values, their changes and interactions in a certain time period to be used for the output of possible scenarios (modeling) in order to obtain the insight into the systemic changes as they might appear in the future or have occurred in the past

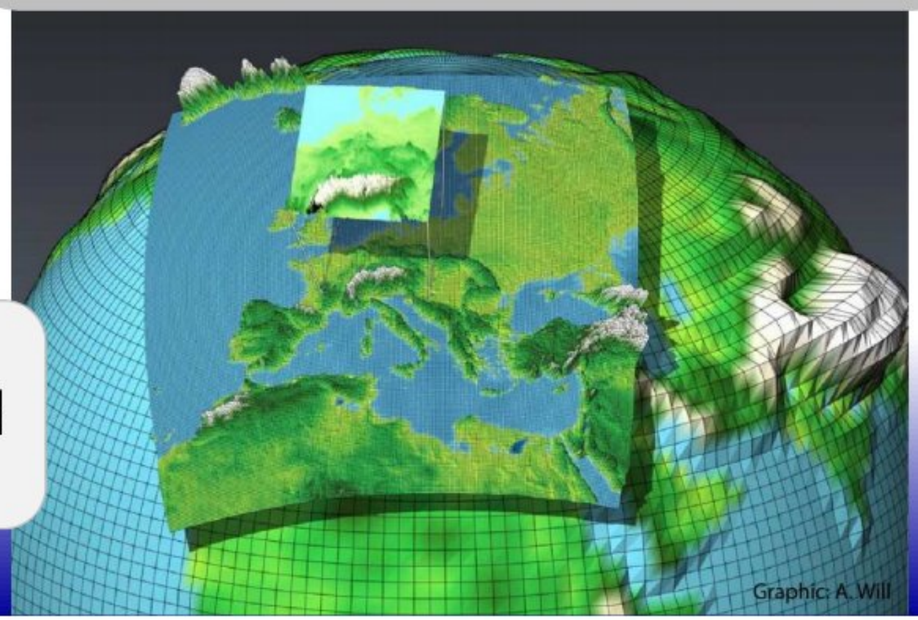
Perfect **climate model** must meet the following requirements:

1) **Complete understanding of all the factors involved in the climate formation, their interactions and relationship expressed as a mathematical formulation, including data on:**

- **Atmospheric circulation**
- **Land relief / topography**
- **Oceanic circulation**
- **Intensity of solar radiation**
- **Geological activities** (e.g., volcanoes, greenhouse gases released from soil)
- **External cosmic activities** (e.g., magnetic storms, meteorites)
- **Anthropogenic activities**
- **Interaction between the atmosphere and biosphere**

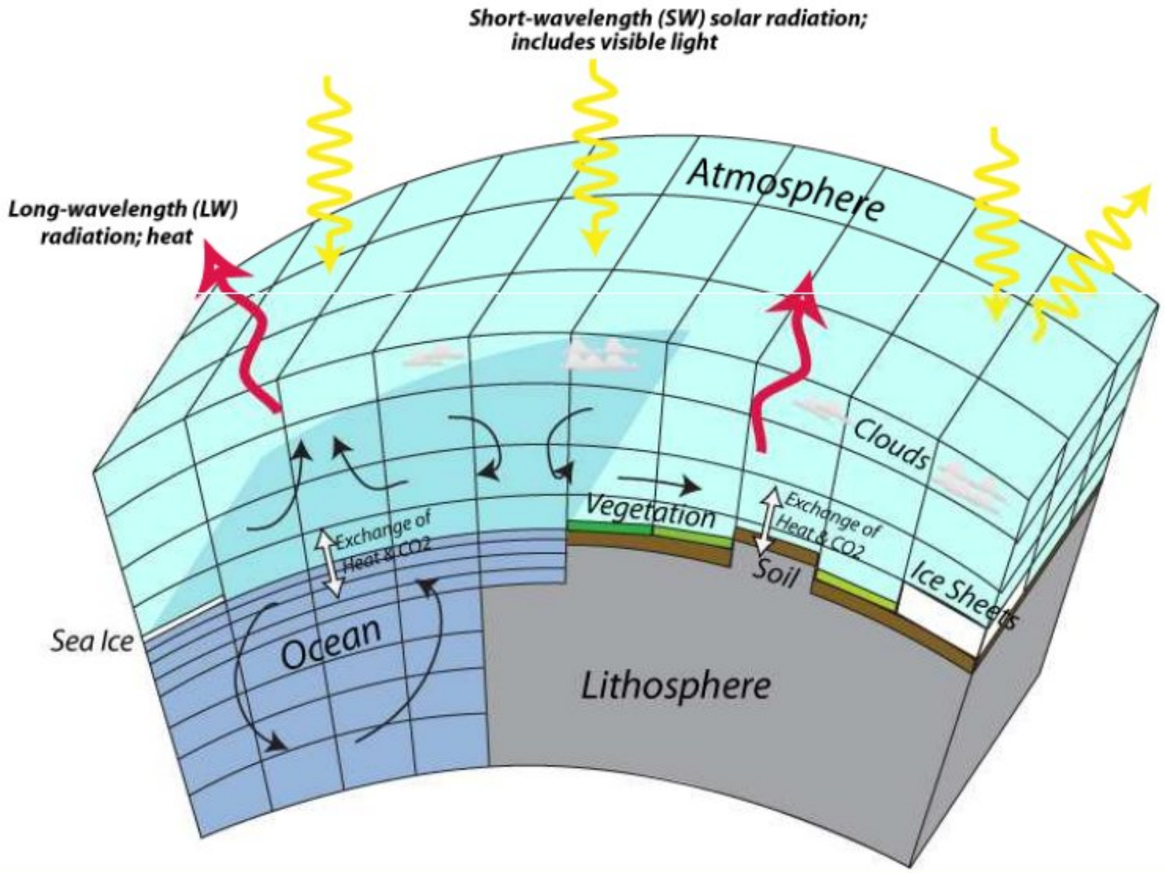
2) **Accurate data for these parameters at interest time periods throughout the studied area**

3) **Computing power, allowing to process the mathematical information (climate modelling is one of the leading supercomputing fields in the world)**



The potential of high resolution is significantly important in order to incorporate all the modelled data changes at various spatial scale

Although the climate system is very complex and it is difficult to gain undoubted achievements in modeling of climate and its variability, climate research is still at an active development stage



In climate modeling several types of models that are mutually interconnected are used

Usually, as the models of weather or climate prediction general circulation models or global climate models (GCM) are applied

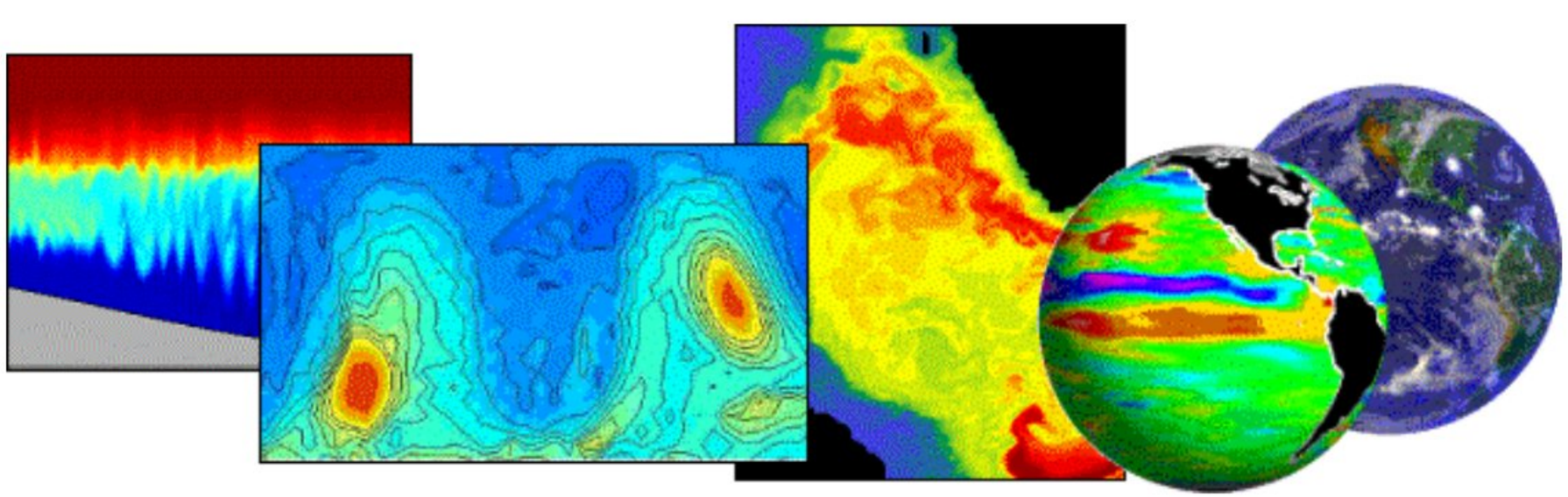
Simple general circulation models consist of basic equations that describe the flow of energy in a system and the algorithm of energy dissipation mechanism

With these models local processes in the atmosphere can be simulated and predicted

Atmospheric general circulation models typically cover the nature of interaction of processes occurring in the atmosphere and on the Earth's surface

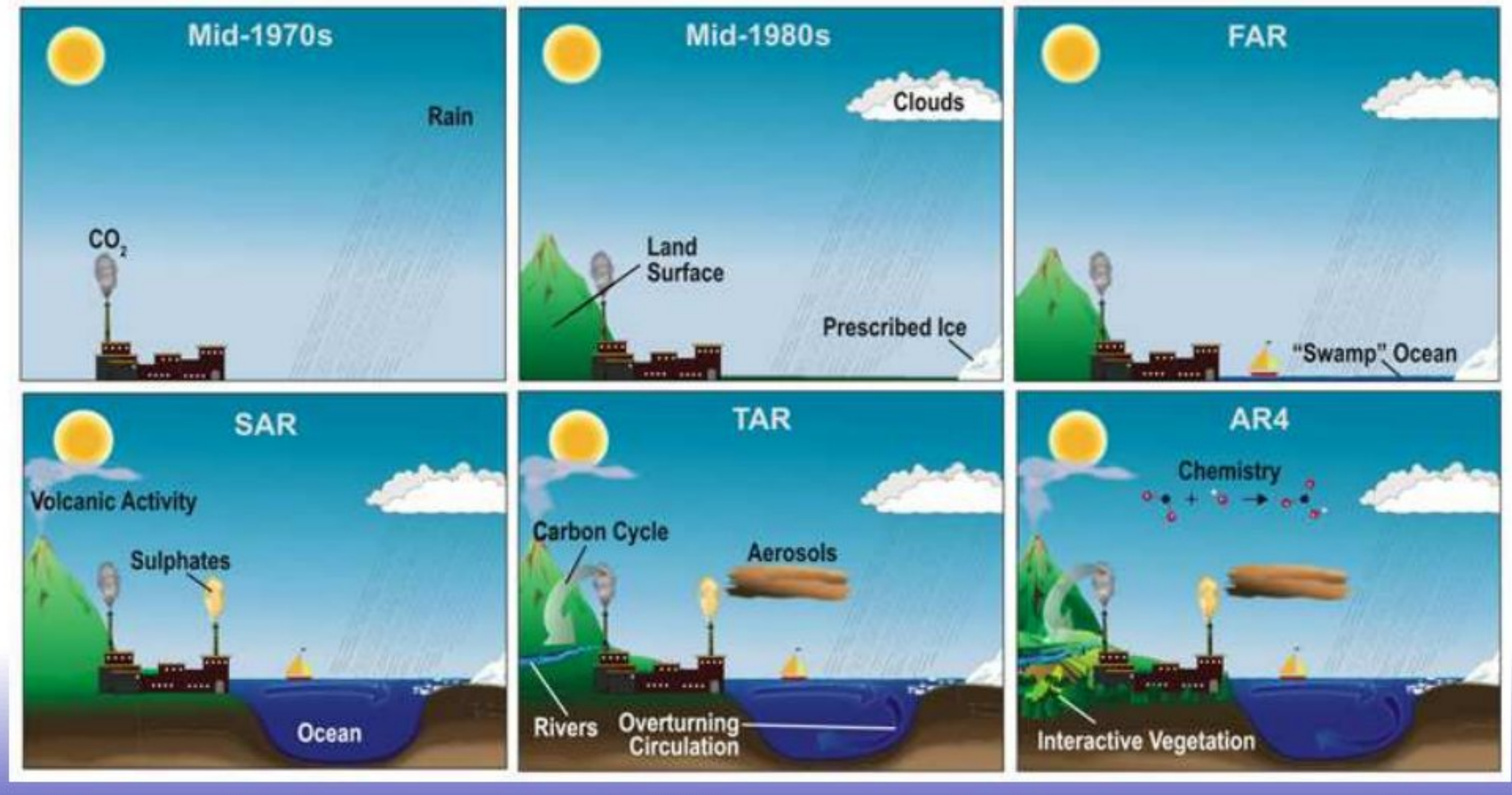
Complex or interconnected models include the preceding elements and more additional factors

Ocean models describe the interaction between the atmosphere and the surface of seas and oceans, related energy exchange, evaporation and condensation processes, as well as interactions induced by ice cover on the flows of air masses

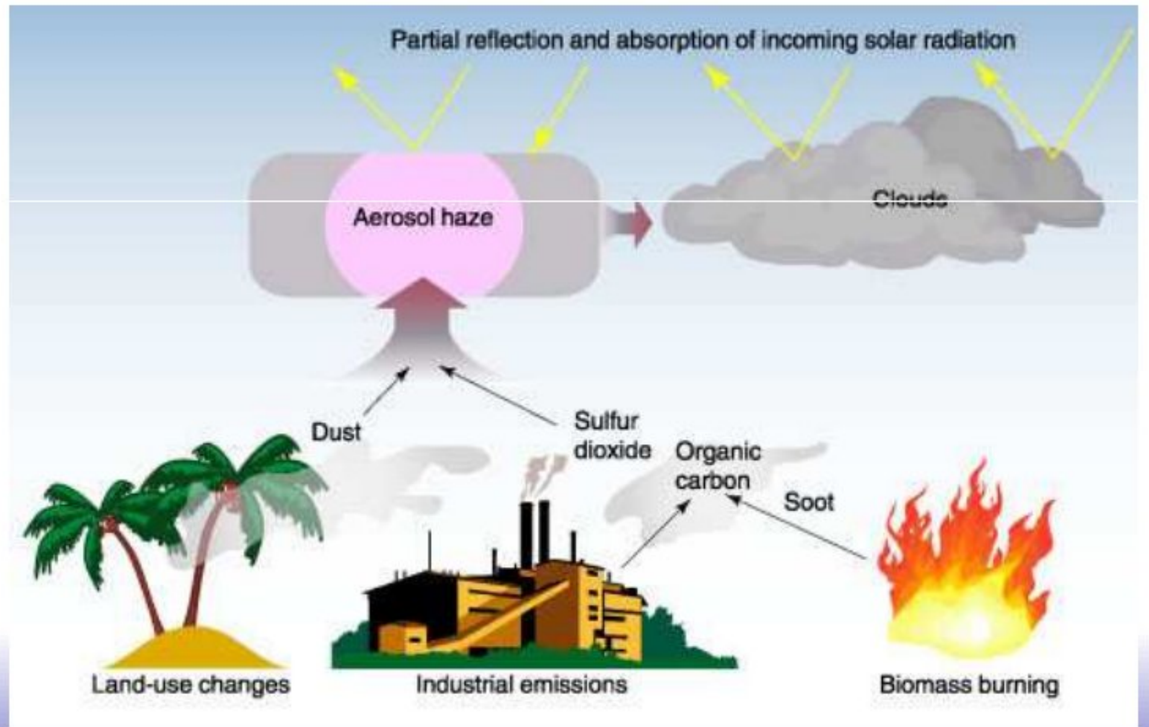


Climate modeling comes across with a wide variety of problems - there are too many factors in the environment that are mutually closely related and it is difficult to reflect them objectively in a unified model

In addition, there are problems concerning unpredictable factors of the impact of human activities that are associated with the development and speed of economic growth (for example, which scenario should be chosen for the modeling)



At development of models, firstly, the accuracy of the calculation techniques is tested describing the situation for which data are available for the certain meteorological observation period in the past

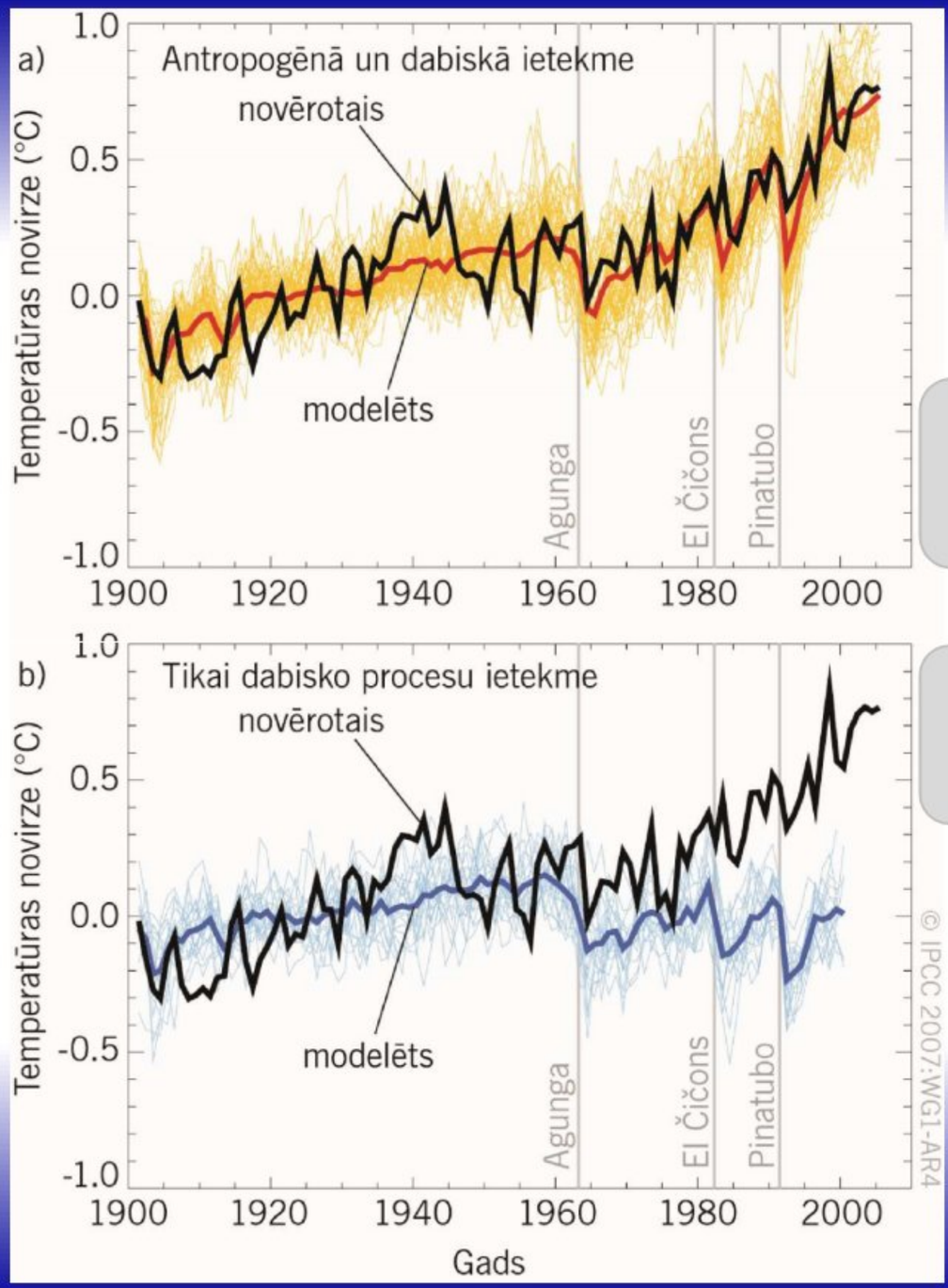


Future climate change modelling provides insight into possible climate variability in accordance with certain changes in the model input data, taking into account factors that can lead to climate alteration

A major role in a climate change modelling is paved to the assessment of anthropogenic factors and to analysis of natural climate variability and influencing factors

Although, currently used models do not cover all of the climate variability influencing processes, they allow to perform enough precise description of the changes that are happening now, and to assess the impacts of anthropogenic role as a major cause of climate change

Observed anomalies of average global temperature (1901-1951) and temperature variation character detected by modeling



↖ Changes taking into account natural and anthropogenic impact

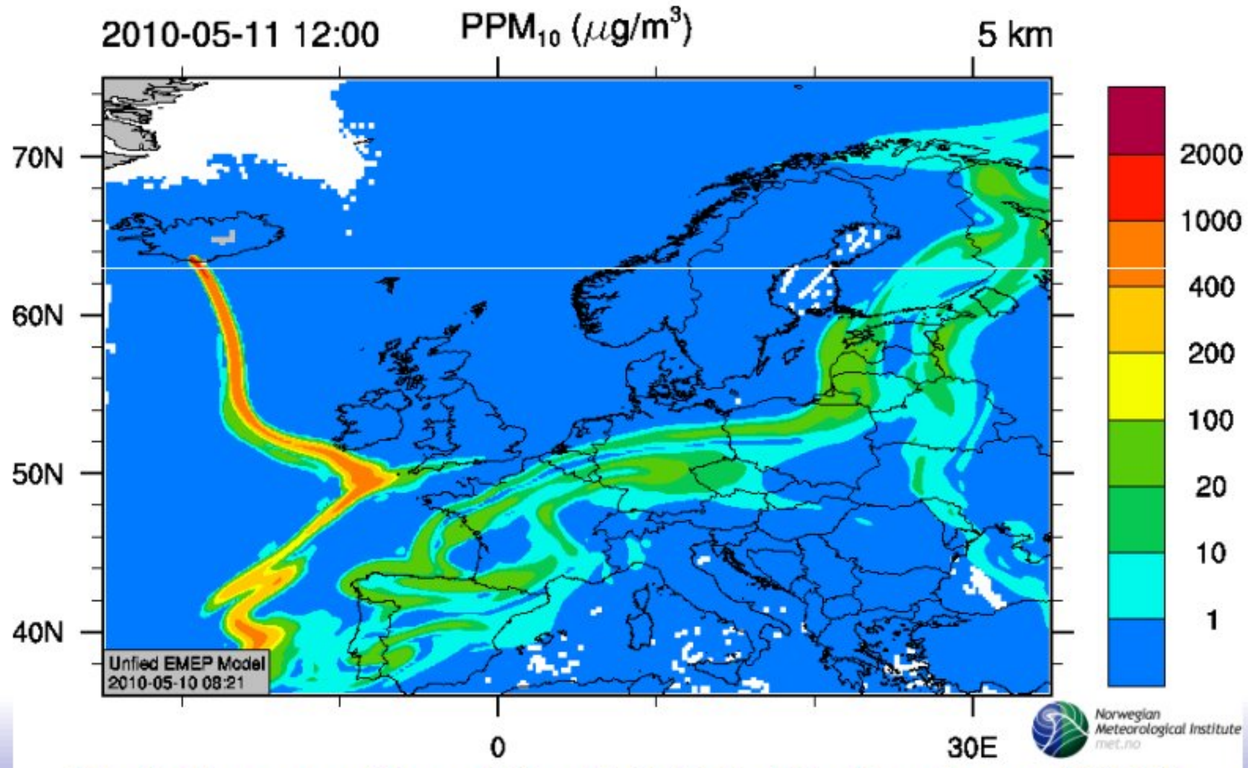
↙ Changes taking into account only natural impact

Short-term models are used for daily weather forecasts, supplementing the data by the latest observations from satellites and meteorological stations to gain as much as possible accurate predictions

Various economic sectors require precise weather forecasts, and therefore such models are very useful

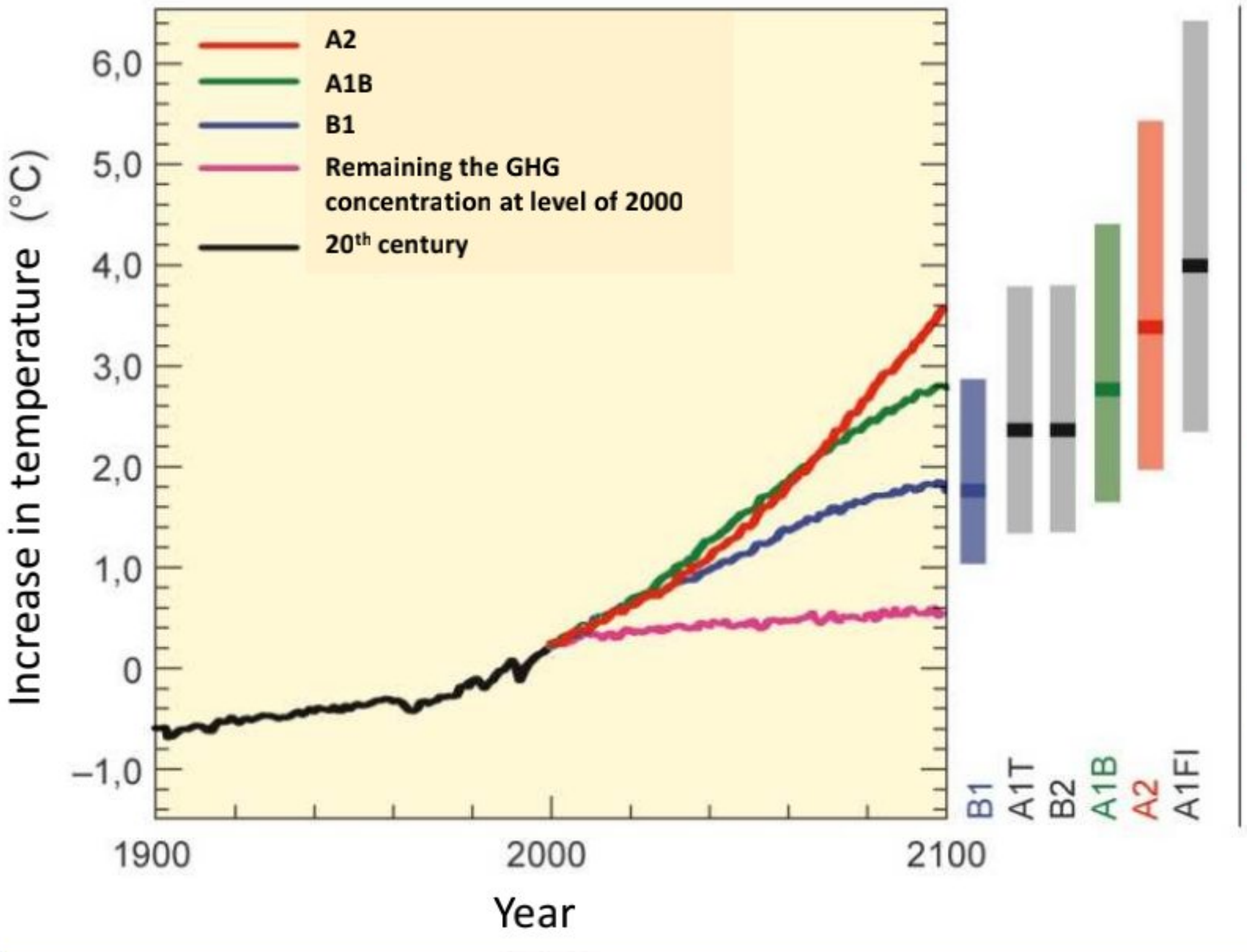
Climate change models allow to assess the impact of volcanic eruptions on climate

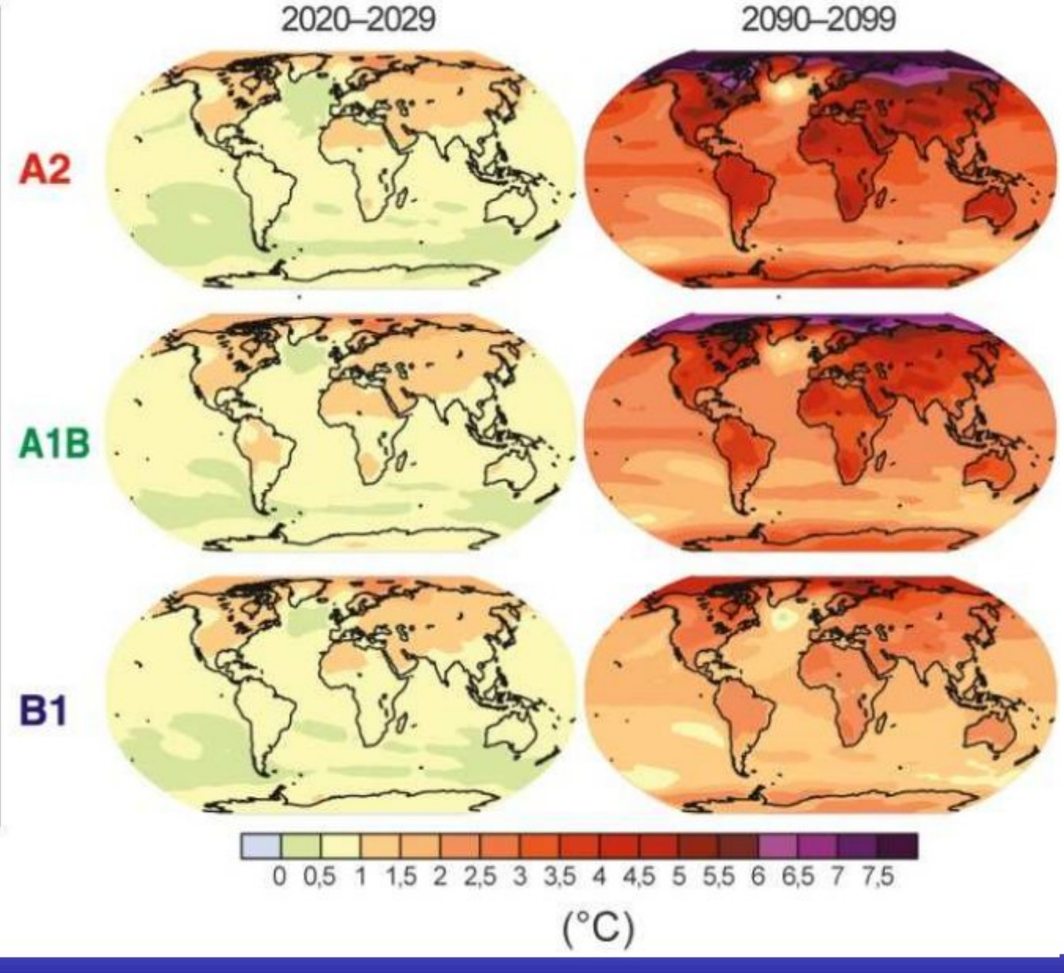
This proves that the ongoing climate variability can not be explained only by natural factors, but anthropogenic influence is considered as the main factor influencing the climate change since the beginning of 20th century



Modelling eruption of the Eyjafjallajökull volcano (2010)

Character of the increase in the Earth's average temperature depending on the growth of greenhouse gas emissions and society development scenarios

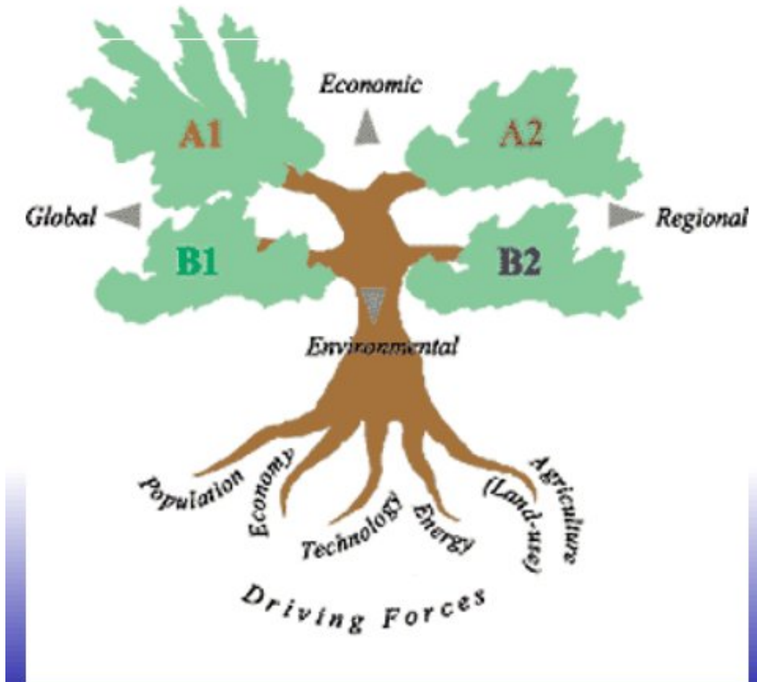




Depending on the amount of GHG emissions and other forms of anthropogenic pressure, during the 21st century, the character of temperature increase can significantly change

Consequently, in the climate research it is essential the understanding of how to develop the world and society in general

According to the United Nations Intergovernmental Panel on Climate Change, there are several possible scenarios of society development and climate change:



1. **A1 scenario. Remaining the GHG concentration at level of 2000, with an absence of population and economic growth, the changes in global temperature will be determined be the run-out of climate system**

2. **B1 scenario (sustainable development) provides that the world population will increase until the middle of the 21st century, but afterwards the decline in population will start**

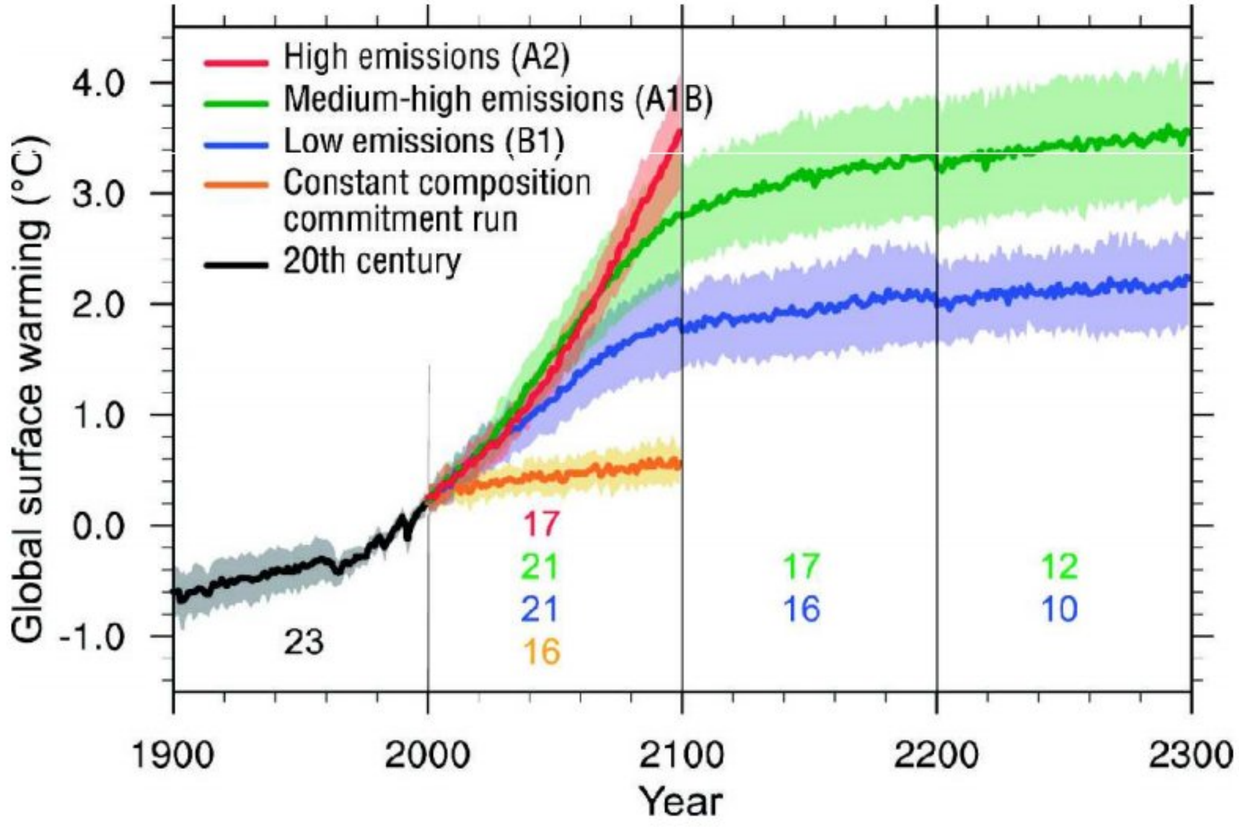
By decrease in material-intensive technologies and by introduction of resource-friendly technologies, the development is provided that contributes to decline of inequality and global solutions for environmental protection, economic growth and social welfare

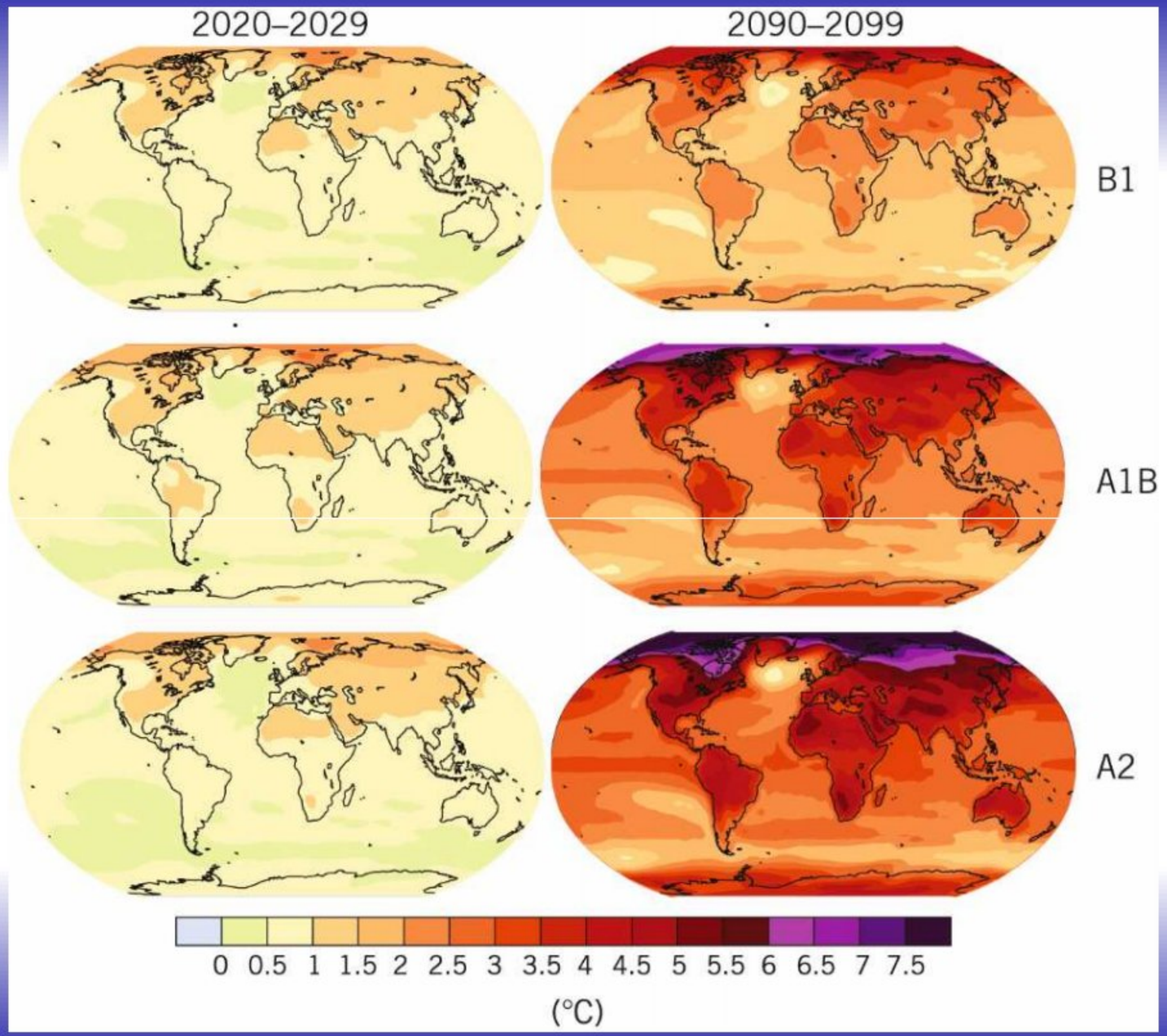
3. **A2 scenario (business as usual) describes quite heterogeneous world in which the main subject of interests is self-reliance and resources**

The world's population continues to grow, thereby setting an increasing consumption of resources and energy – economic development and technological progress mainly occurs in some regions

4. **A1B scenario describes the future world, which is characterized by both, rapid economic and population growth and technological progress (especially in power production) that in the second half of the century allows to reduce consumption growth of materials and resources**

The development of society is characterized by the reduction of inequalities among regions and the interaction of different cultures



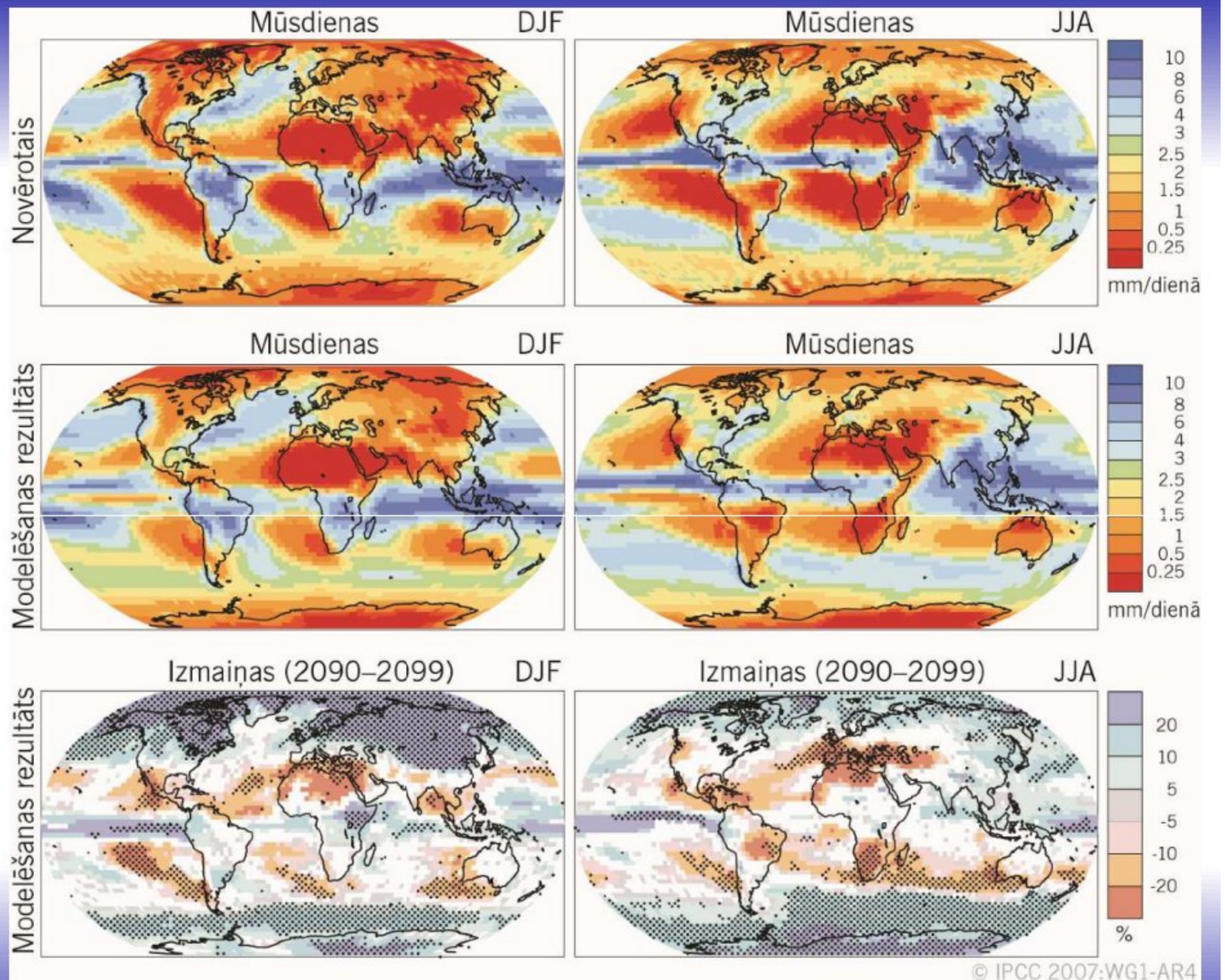


Predicted increase in **the Earth's average temperature** for the time periods 2020-2029 and 2090-2099 in relation to temperature between 1980 and 1999

According to the possible climate change scenarios: B1, A1B and A2

Predicted **precipitation variability** for the time periods 2020-2029 and 2090-2099 in relation to the amount of precipitation during the period from 1980 to 1999

According to the possible climate change scenario A1B



DJF – December, January, February / JJA – June, July, August

Future climate change scenarios predict that **the global average temperature will increase by 1.4-5.8 ºC** and the expected rate of warming will be much faster than it was observed in the 20th century and over the past 10,000 years

Regarding the amount of greenhouse gas emissions the Earth's temperature may increase significantly, moreover, the temperature rise is highly uneven and the maximum may be increased in the Arctic and equatorial areas

Global warming will inevitably affect the amount and intensity of precipitation, and climate change models predict that, during the 21st century, the global average water vapour concentration in the atmosphere and amount of precipitation will increase

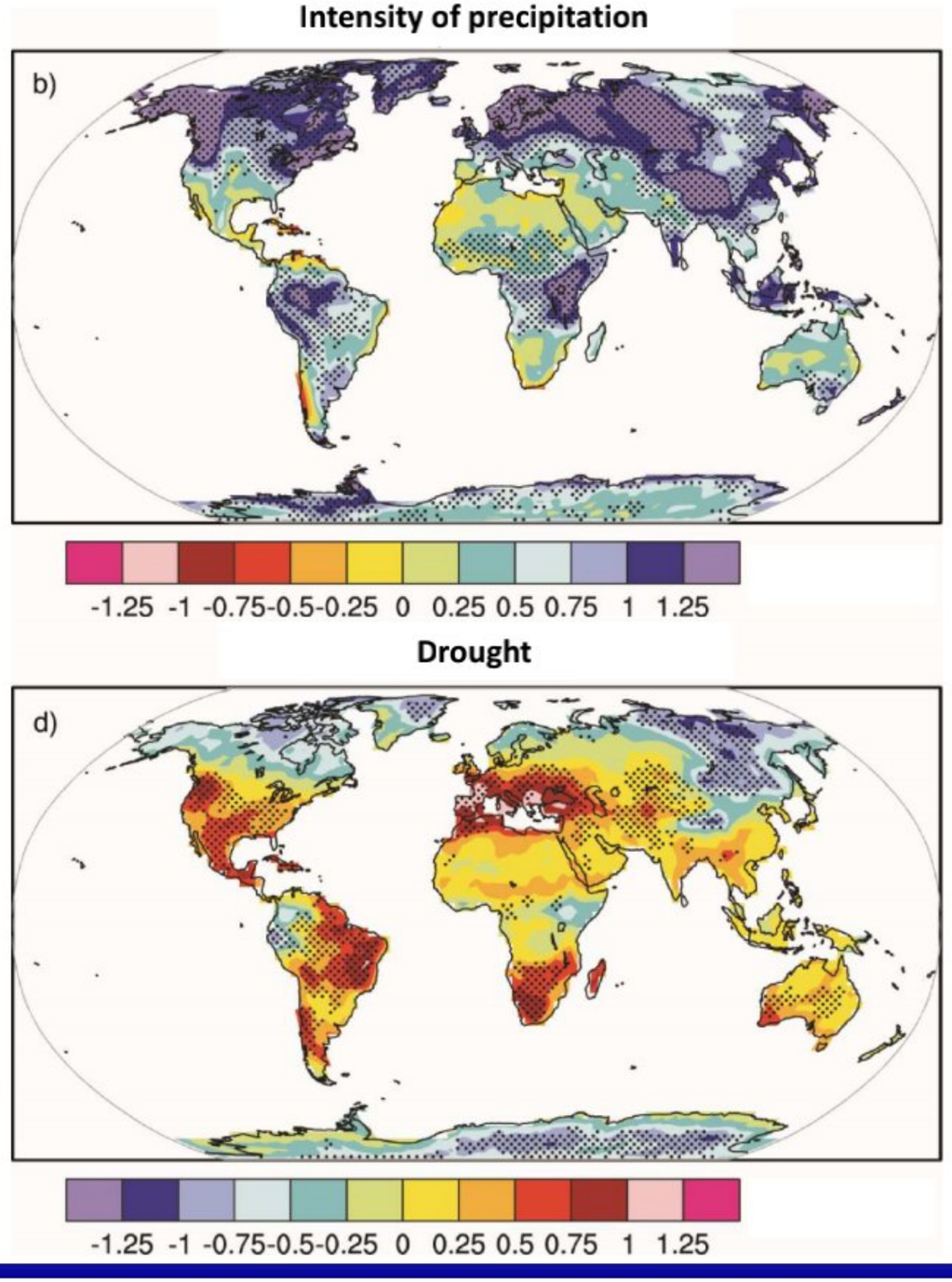
Furthermore, it is expected that greater precipitation variability from year to year will be in areas with increasing forecasted amount of precipitation

Changes in monsoon climate areas are associated with warming and increased variability of precipitation during the summer monsoons in Asia. In Africa and the Mediterranean region, precipitation is expected to decrease

These modeled results coincide with already observed precipitation variability trends in the 20th century, confirming the developed climate change models are able to predict future climate

Total precipitation variability is associated with its intensity, but at the same time with the drought risk - in this case the impact is highly regional, but in the most affected regions changes can be very significant

For example, increase of precipitation in polar regions may affect the stability of the glacier and, therefore, the character of water streams in oceans, but in the Mediterranean and southern part of Africa decline of precipitation may result with desertification processes



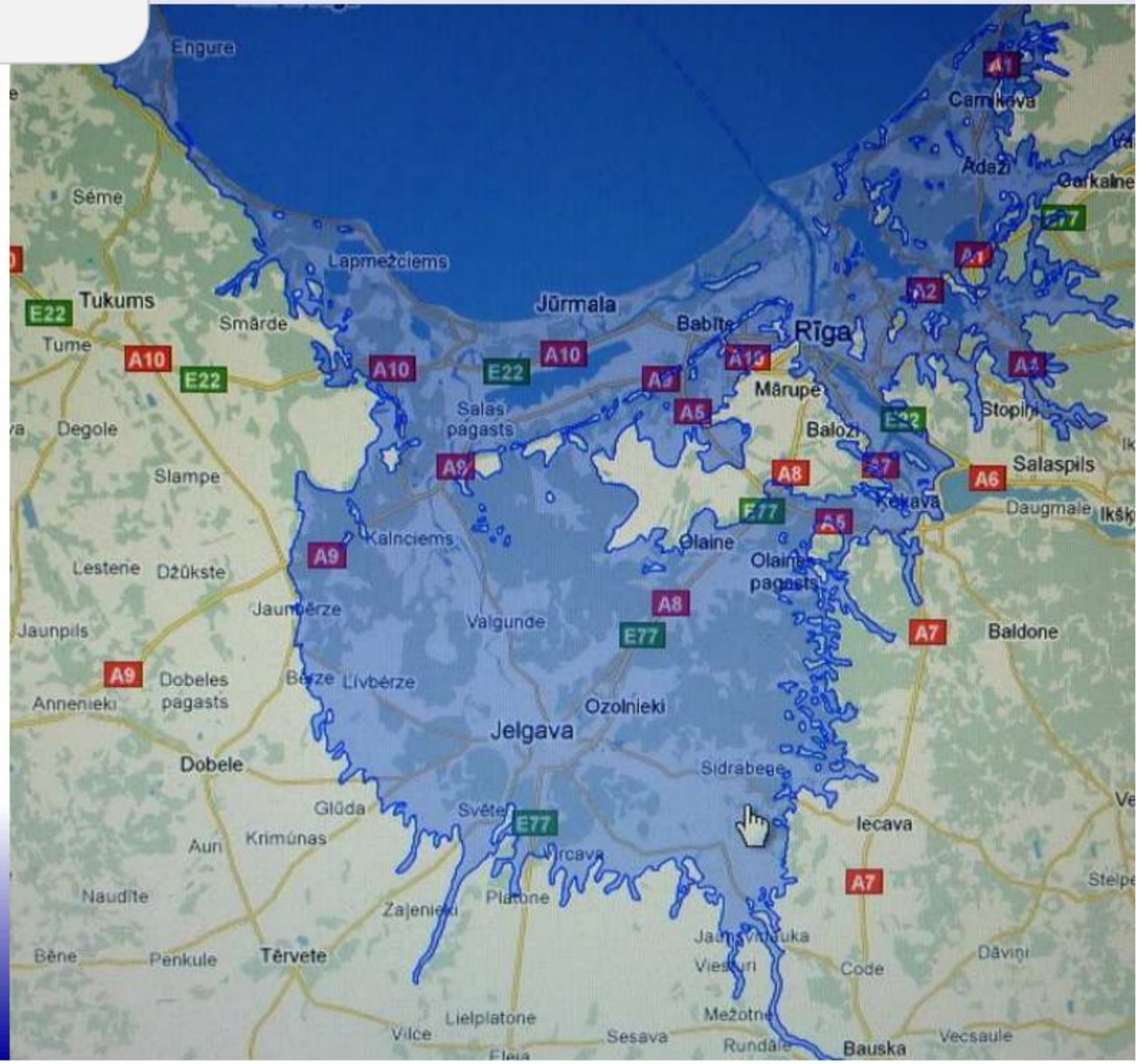
Predicted **intensity of precipitation and drought changes** for the period until 2100, relative to the situation in 1980 to 1999

According to the possible climate change scenario A1B

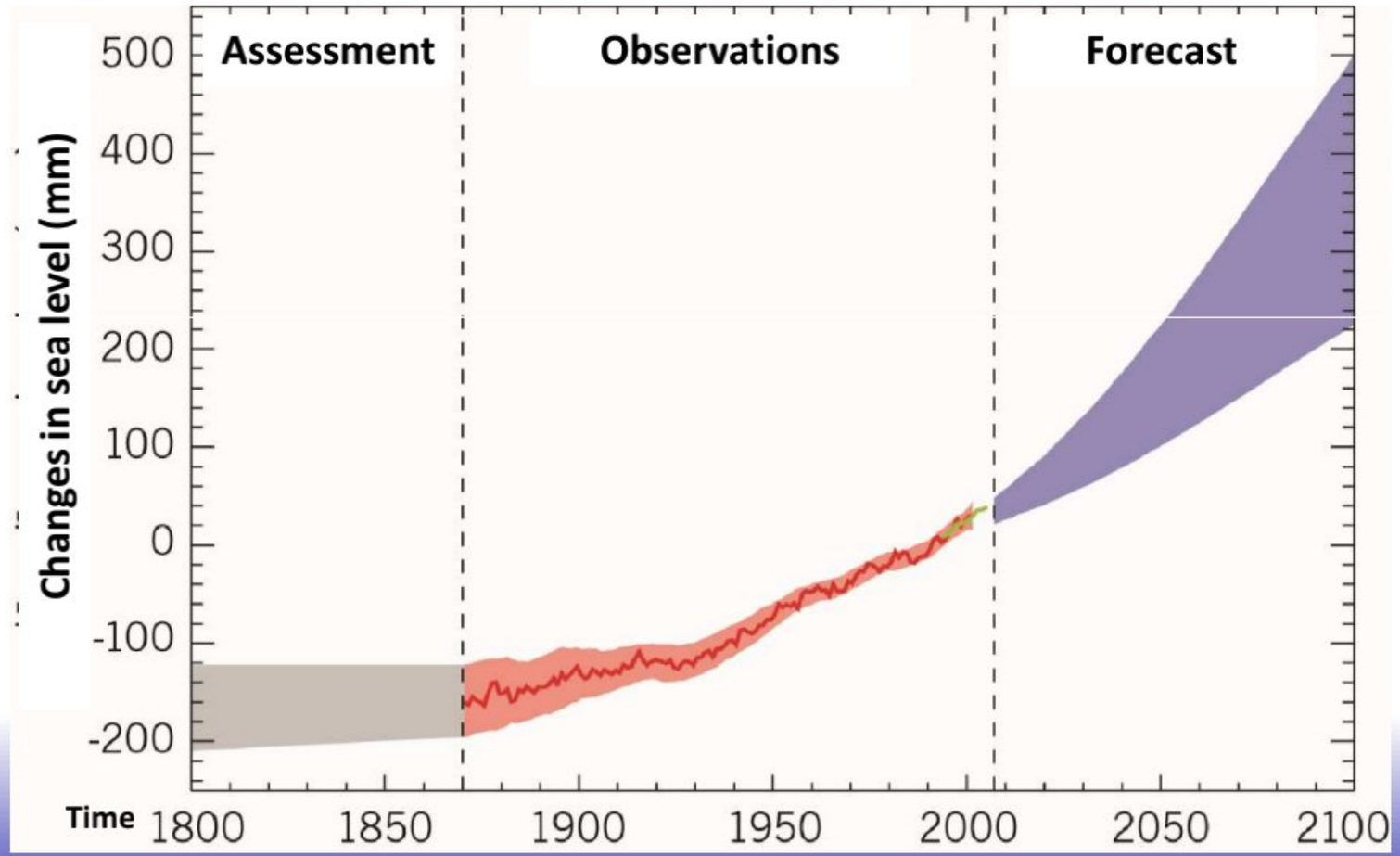
Climate change models predict that **the flow-up of sea and ocean levels is possible by 0.09 to 0.88 m** until the year 2100

Increase of the global average temperature of sea and ocean surface water and rise of sea level due to the expansion of warmth in the ocean will continue even for hundreds of years after the period of greenhouse gas stabilization (even if GHG concentration will remain at current level)

At the same time, the existing models do not provide a complete termination of thermohaline circulation until the year 2100, which could lead to rapid climate changes

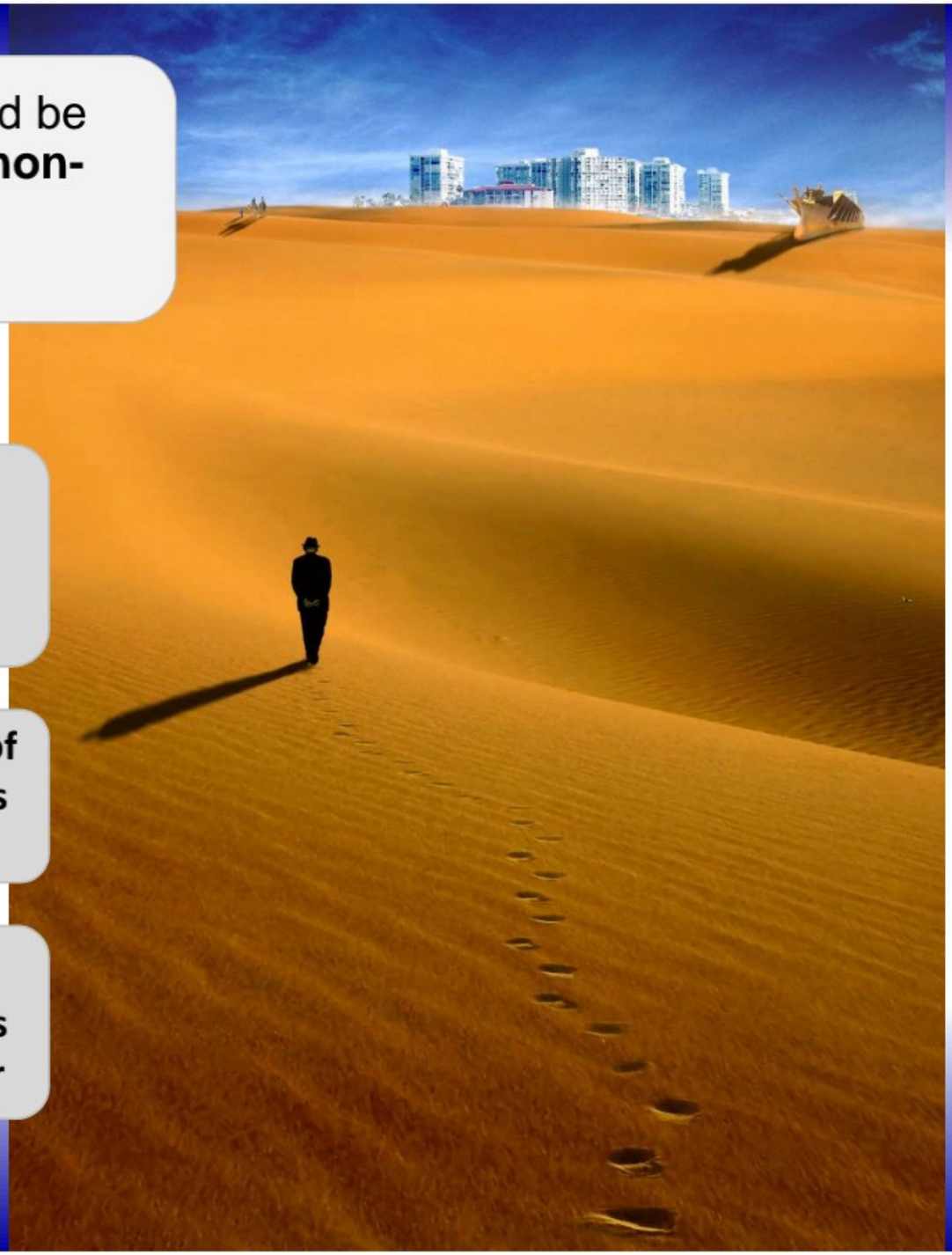


Expected changes in the sea level (deviation from the mean sea level during 1980-1999)



According to the possible climate change scenario A1B

In assessing the climate change forecasting, it should be noted that the climate system is considered to be **a non-linear system, i.e., small effects can lead to significant consequences**

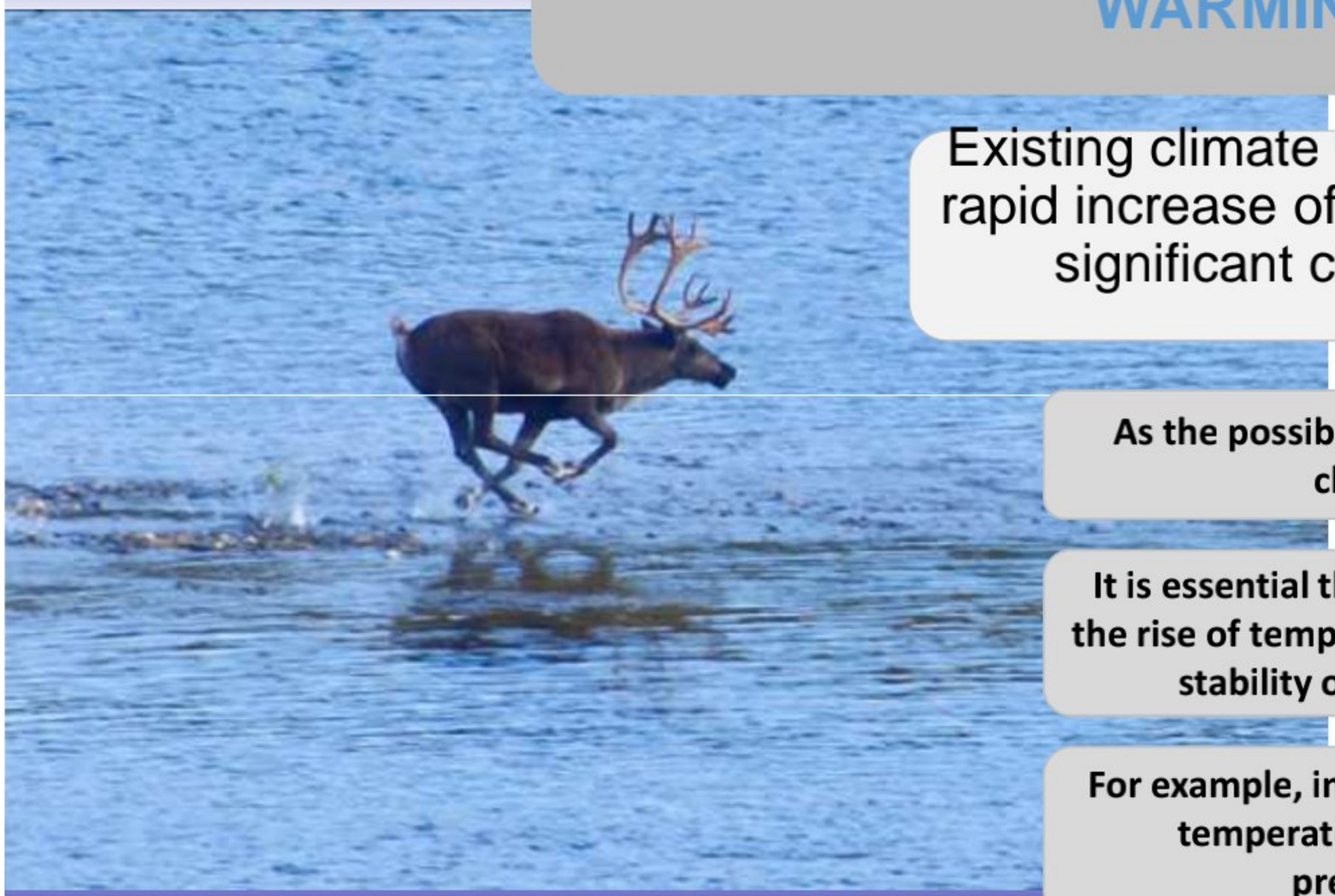


Thereof, like the weather forecasting also the modeling of climate changes does not provide by 100% accurate results, thus, the terms «probability», «possible» or «very likely» should be used

The fact that climate changes can be rapid, is proved by loss of species that has occurred historically several times, as well as fast climate changes during the last Ice Age

Rapid climate change may incorporate, for example, the changes in the ocean circulation, release of dust and aerosols into the atmosphere from volcanic activities or a nuclear war

POSSIBLE CONSEQUENCES OF GLOBAL WARMING



Existing climate variability is characterized by a rapid increase of temperature which can lead to significant changes in our surrounding environment

As the possible negative effects significant weather changes are the most likely

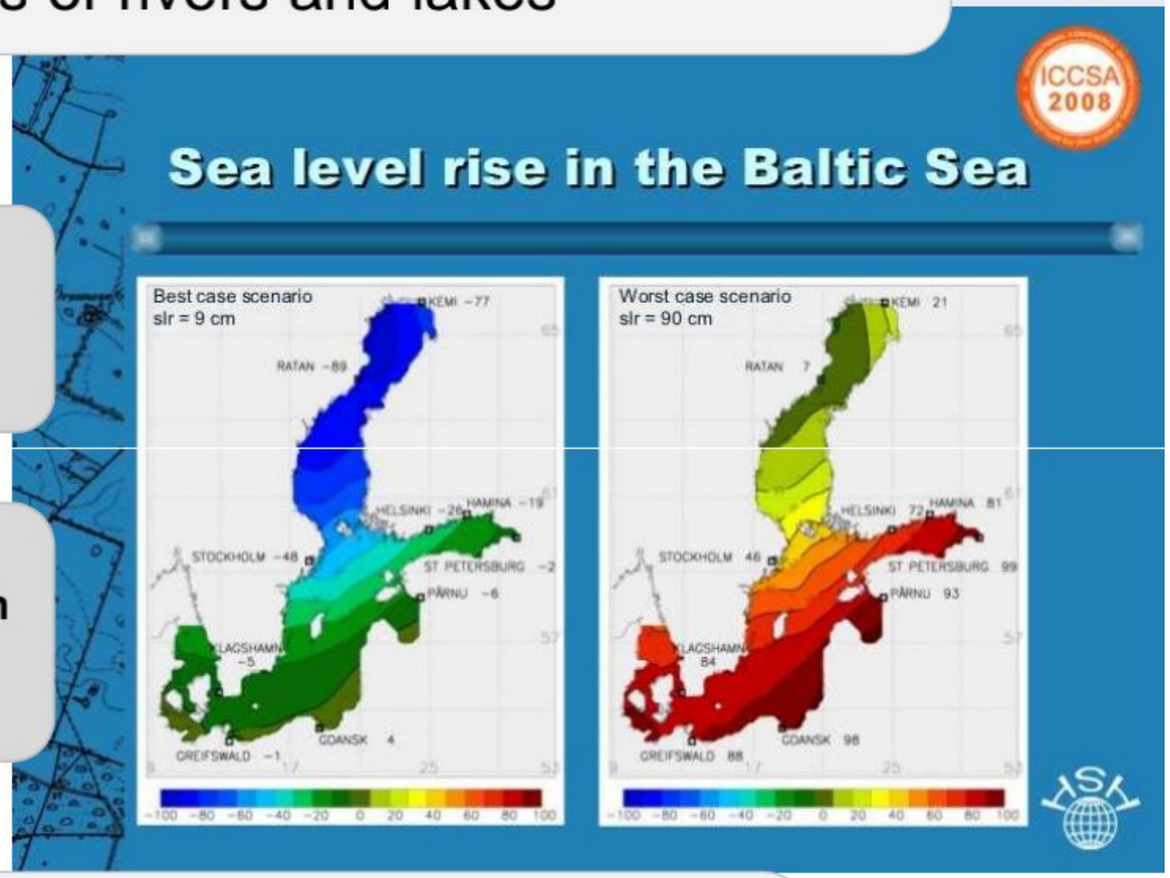
It is essential that the global warming means not only the rise of temperature, but its effects are related to the stability of the whole global climate system

For example, in certain areas also decrease of regional temperature and considerable variability of precipitation can be observed

The consequences of global warming can be the rise of sea and ocean levels, erosion of coastal areas and flooding of wetlands, changes in vegetation, runoff and levels of rivers and lakes

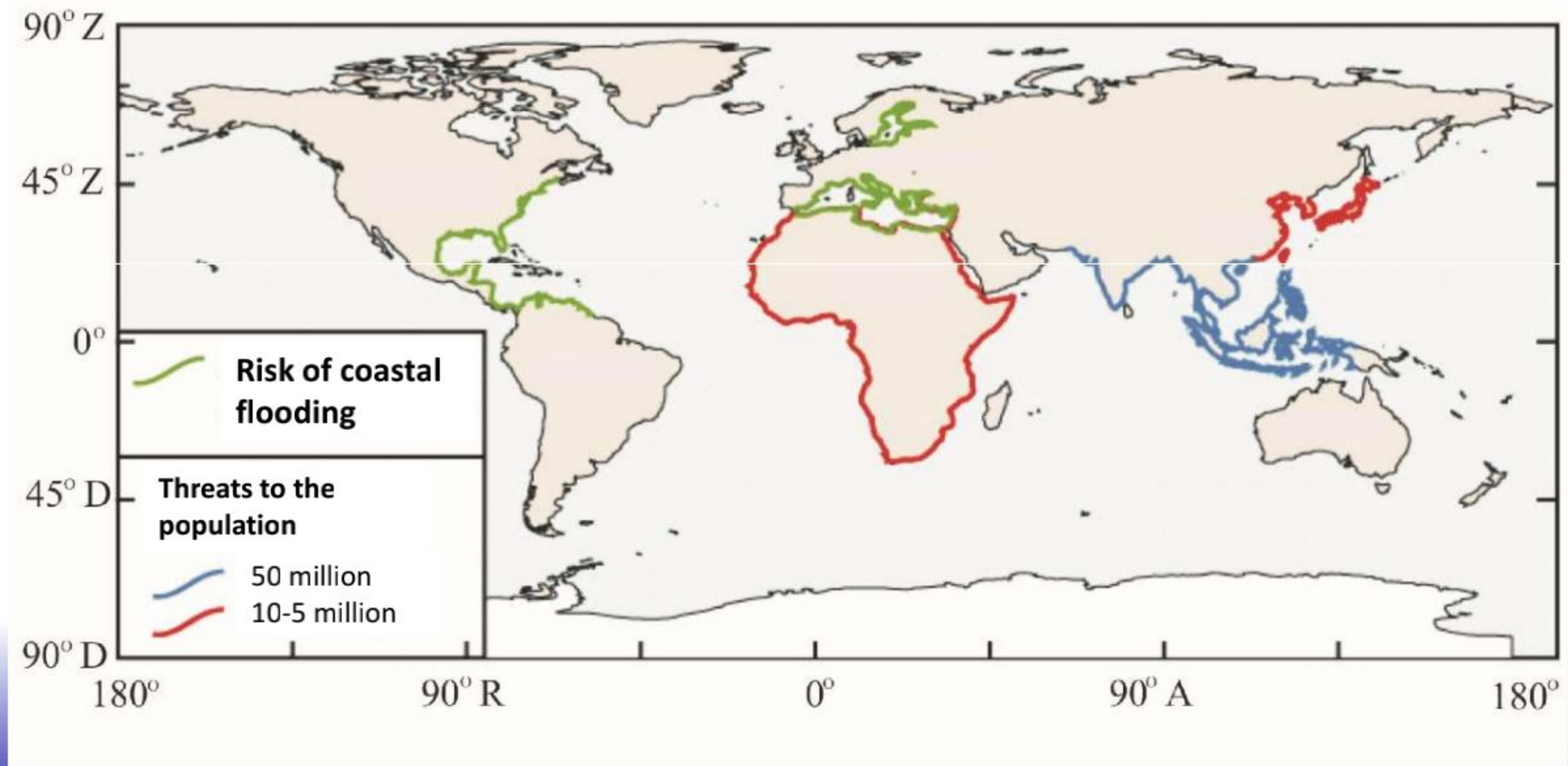
Mentioned changes of environment may affect human health, processes ongoing in the society, industrial production, agriculture, fisheries, forestry, ports and transport routes etc.

Particularly dramatic climate change impacts can occur in lowland areas (also in Latvia) and in tropical regions of the Earth where increase of desert area can significantly affect survival of local people

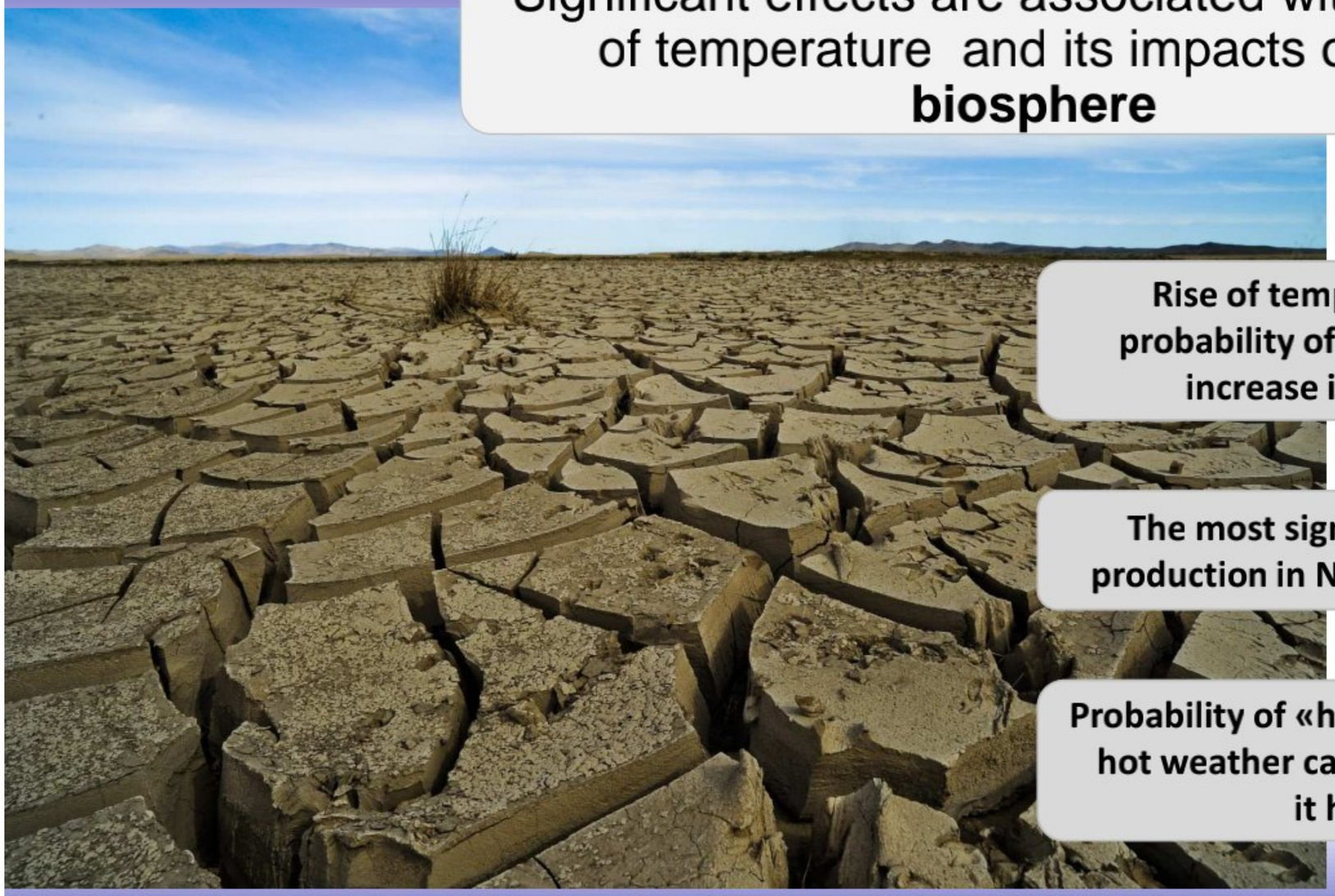


Also in the Baltic Sea region climate changes and its consequences are a subject of research and modeling, as well as possible climate change models are developed

Impact of climate change on coastal processes



Significant effects are associated with change of temperature and its impacts on **the biosphere**



Rise of temperature, first of all, will reduce the probability of frosts and will lead to a considerable increase in the length of vegetation period

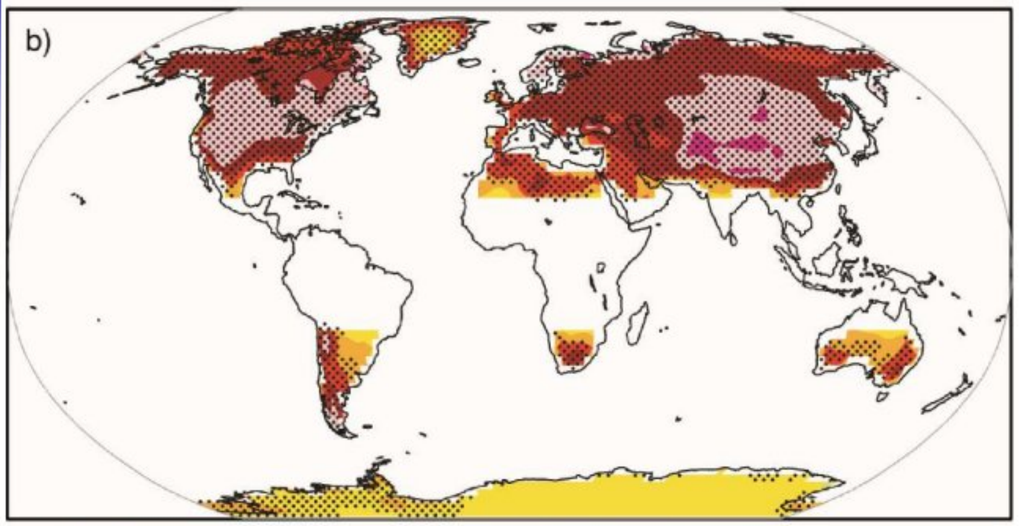
The most significantly will be affected agricultural production in North America and the northern Eurasia

Probability of «heat waves» may increase, but extremely hot weather can become typical in areas where so far it has not been characteristic

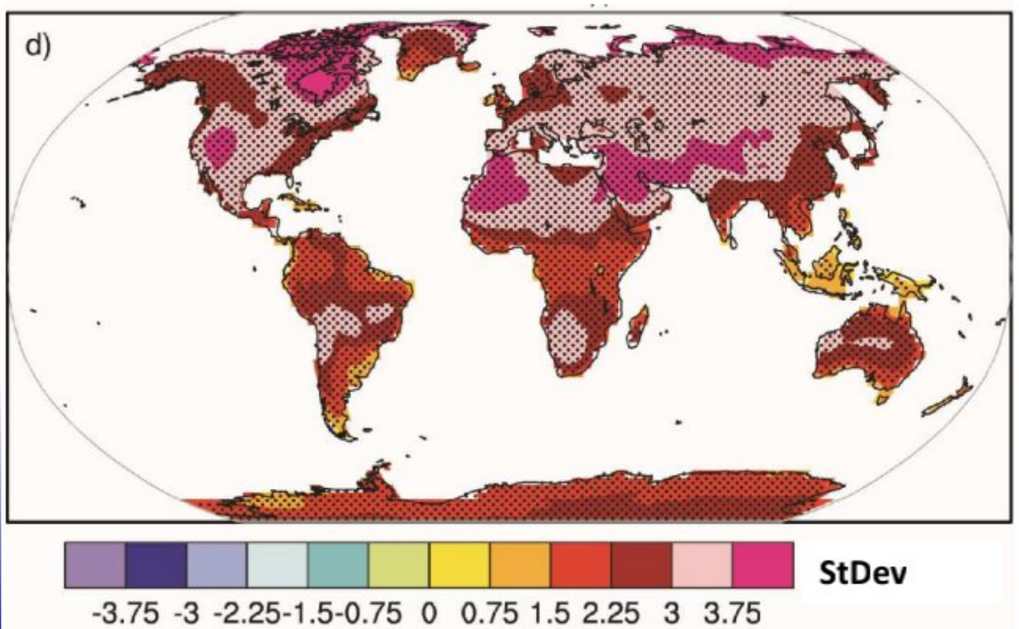
Expected changes in the number of days with frost, heat waves and length of vegetation period in 2100, in comparison with the situation during the period from 1980 to 1999

According to the possible climate change scenario A1B

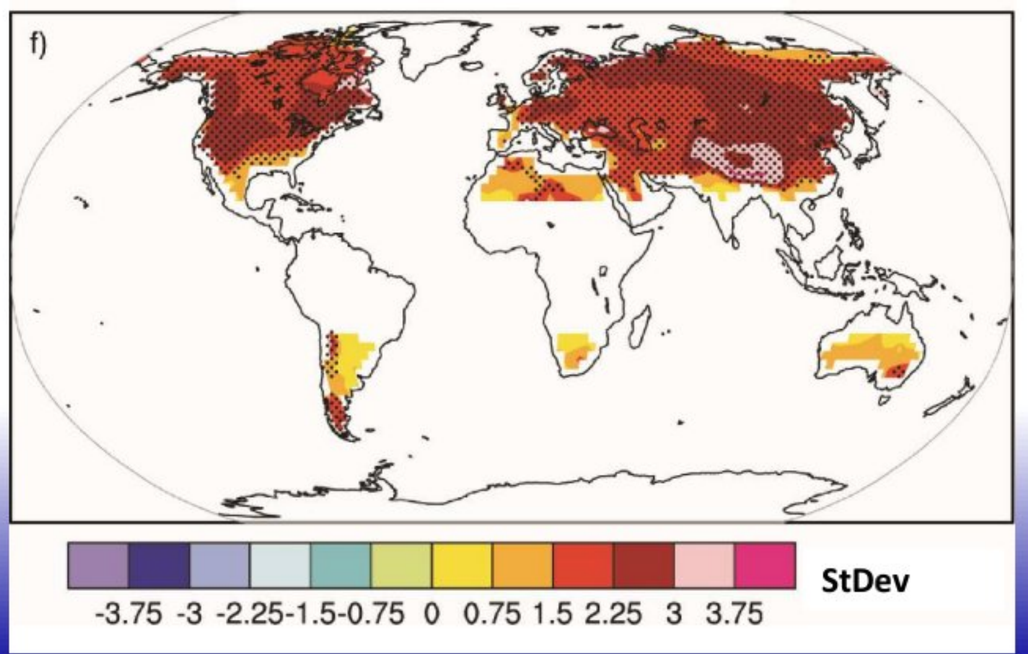
Days with frost



Heat waves



Vegetation period



Warmer temperature in summer can contribute to the ablation process, therefore, mountain glaciers in the areas of low and medium high mountains can significantly decrease

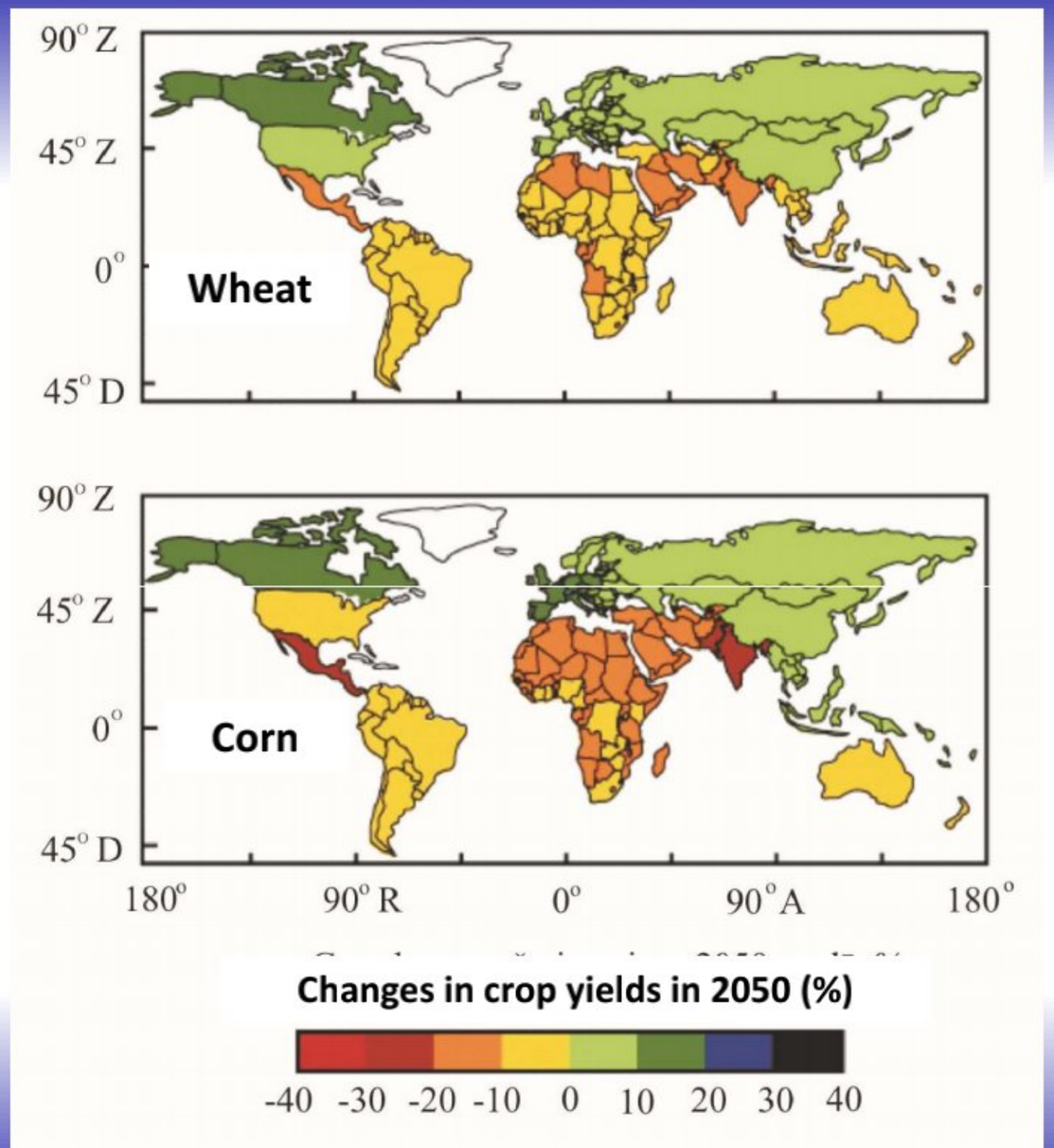
Polar sea ice is characterized by high albedo, but depletion of the ice area will reduce the reflection of short-wave solar radiation into space, thereby increasing the amount of heat absorbed by the ocean

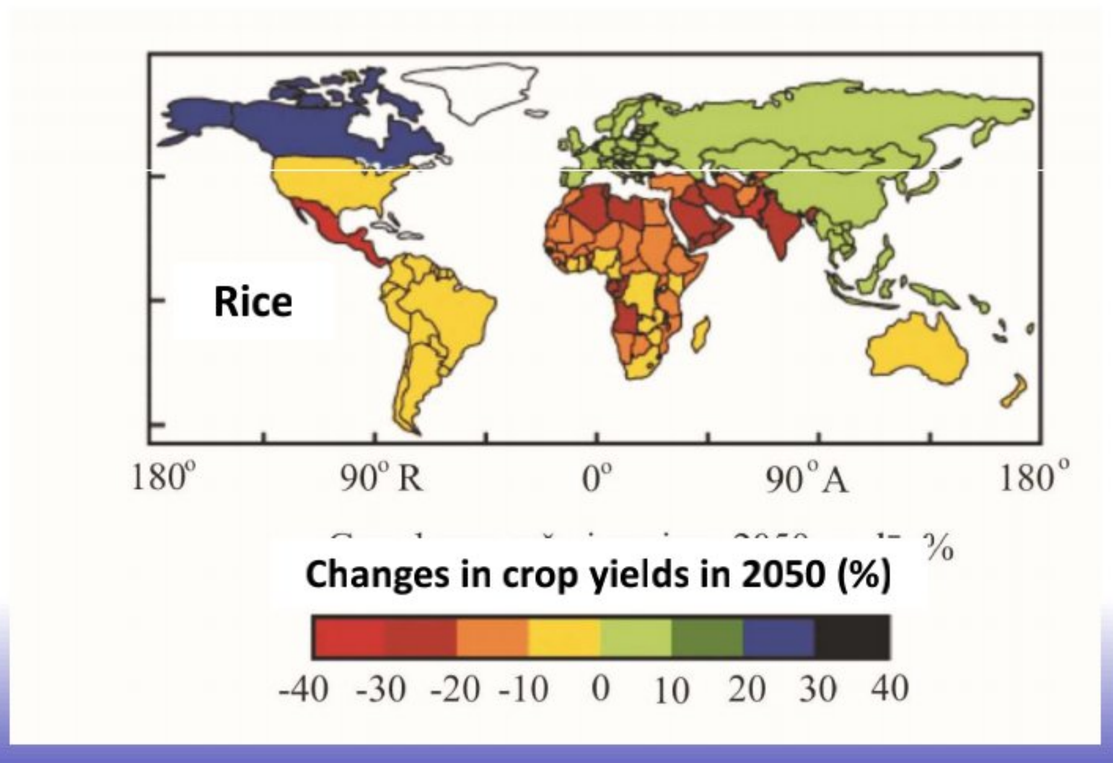
Changes of climatic indicators can have a significant impact on **agricultural production** and on the major agricultural crop yields

It is expected that, for example, crop yield in the Northern Hemisphere can significantly increase, while it will substantially decrease in Africa and south part of Asia

Climate variability can contribute to the spread of invasive species and migration of pests affecting survival, productivity and yield of agricultural crops

Possible impact of climate change on crop yields worldwide



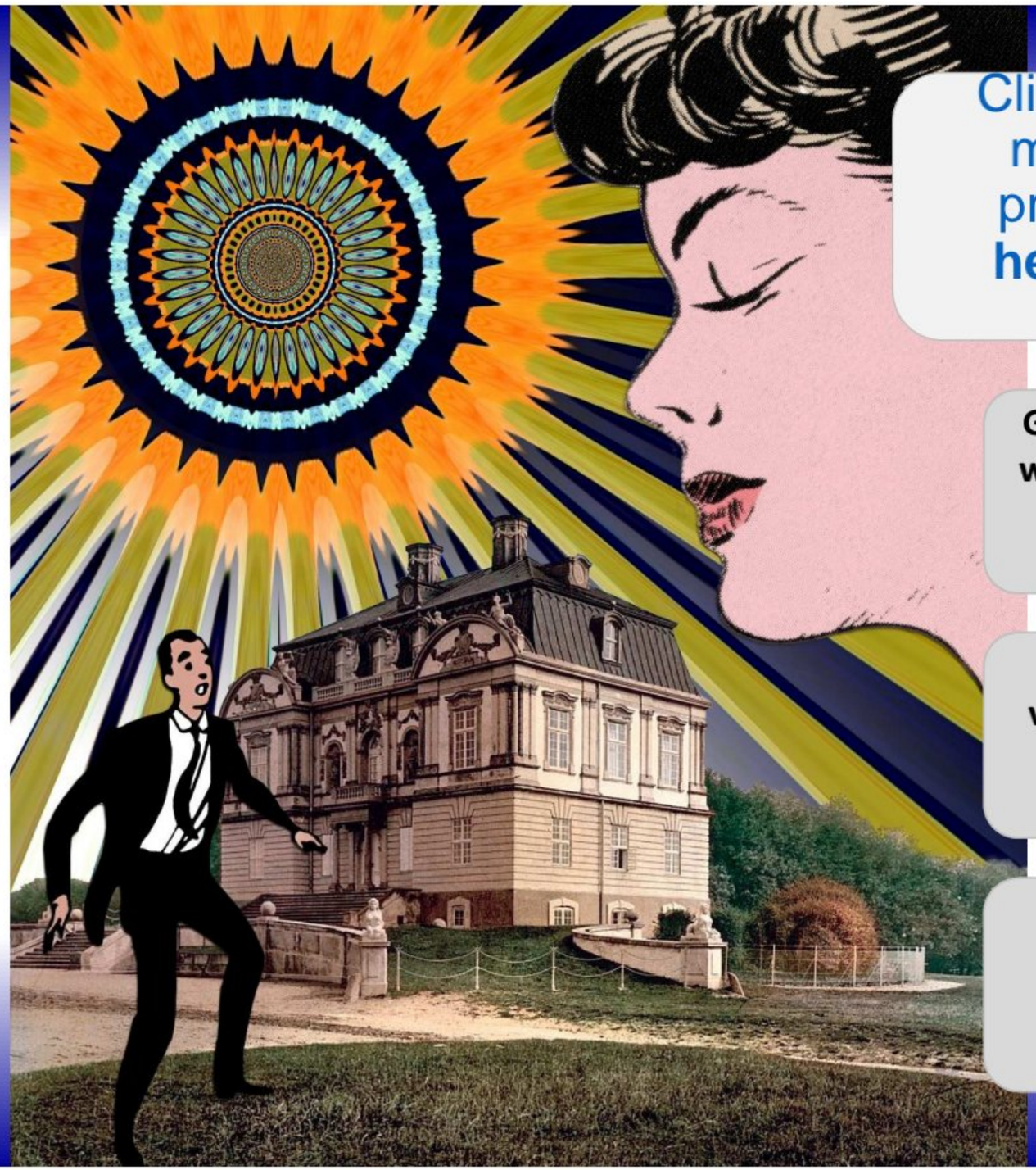


Impact of global warming on biodiversity still has been poorly researched

There is a reason to assert that due to the rapid climate changes and climate warming, big changes are expected in wetlands that occupy 4-6% of land

In wetlands hydrological regime will change, natural processes will be affected by seasonality and biological, biochemical and hydrological functions of wetlands will be influenced

It is possible that there will occur remarkable redirection of natural areas to direction of poles and changes of vertical direction in mountains



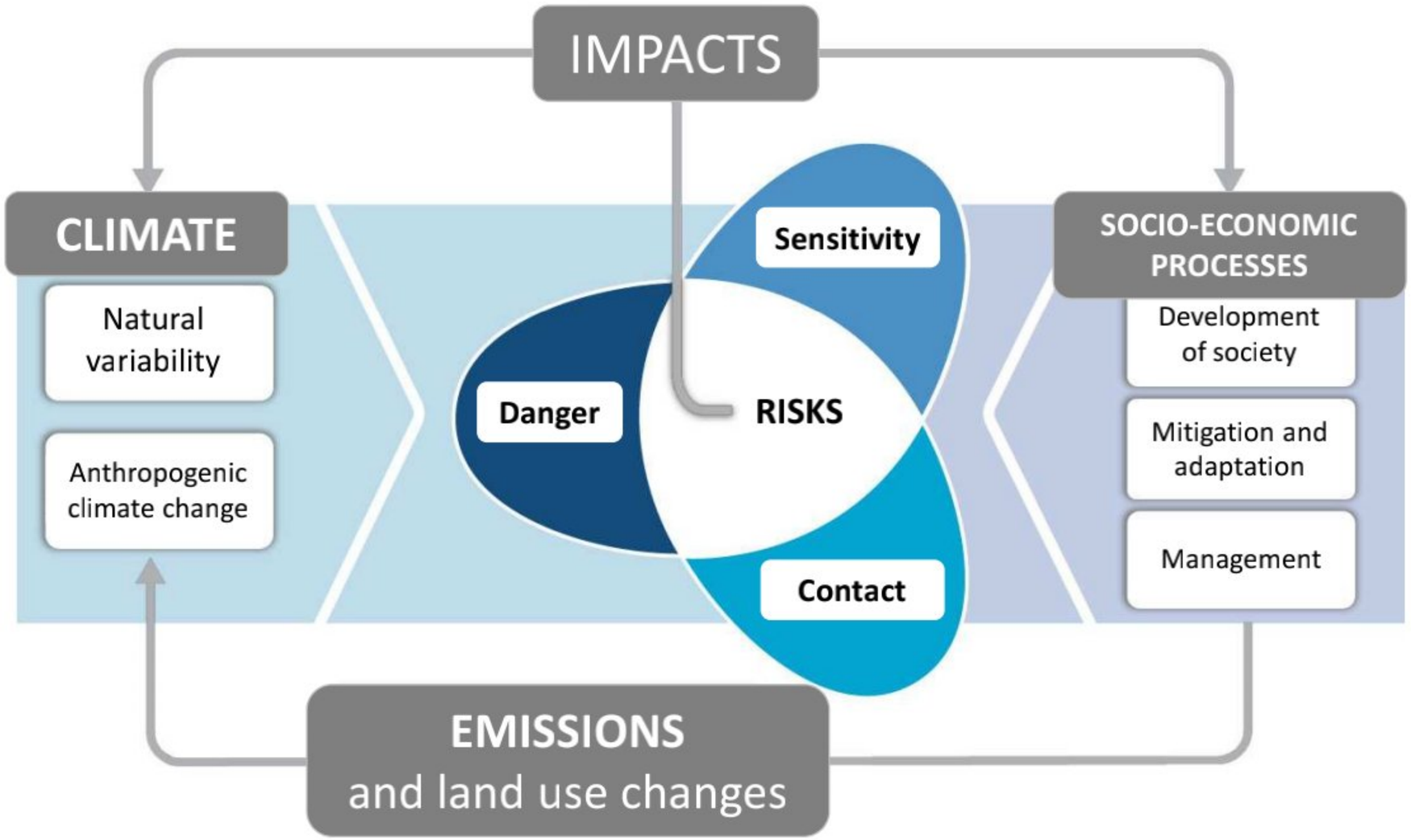
Climate change has become one of the most important global environmental problems that may also affect **human health** and contribute to the spread of various diseases on the Earth

Global warming may have a significant impact on a wide range of spheres of human life, and hence the already identified effects can become apparent in unexpected ways

Climate change primarily will affect socially vulnerable populations and the poorest countries, thus deepening socio-economic crisis and contributing to an increase in poverty

In countries with favourable environmental and socio-economic conditions, stable health care system and technologies adaptation to climate changes will happen more easily

Effects of climate change on society and necessary actions to mitigate the impacts



Impacts of climate change on human health can be divided into three main groups:

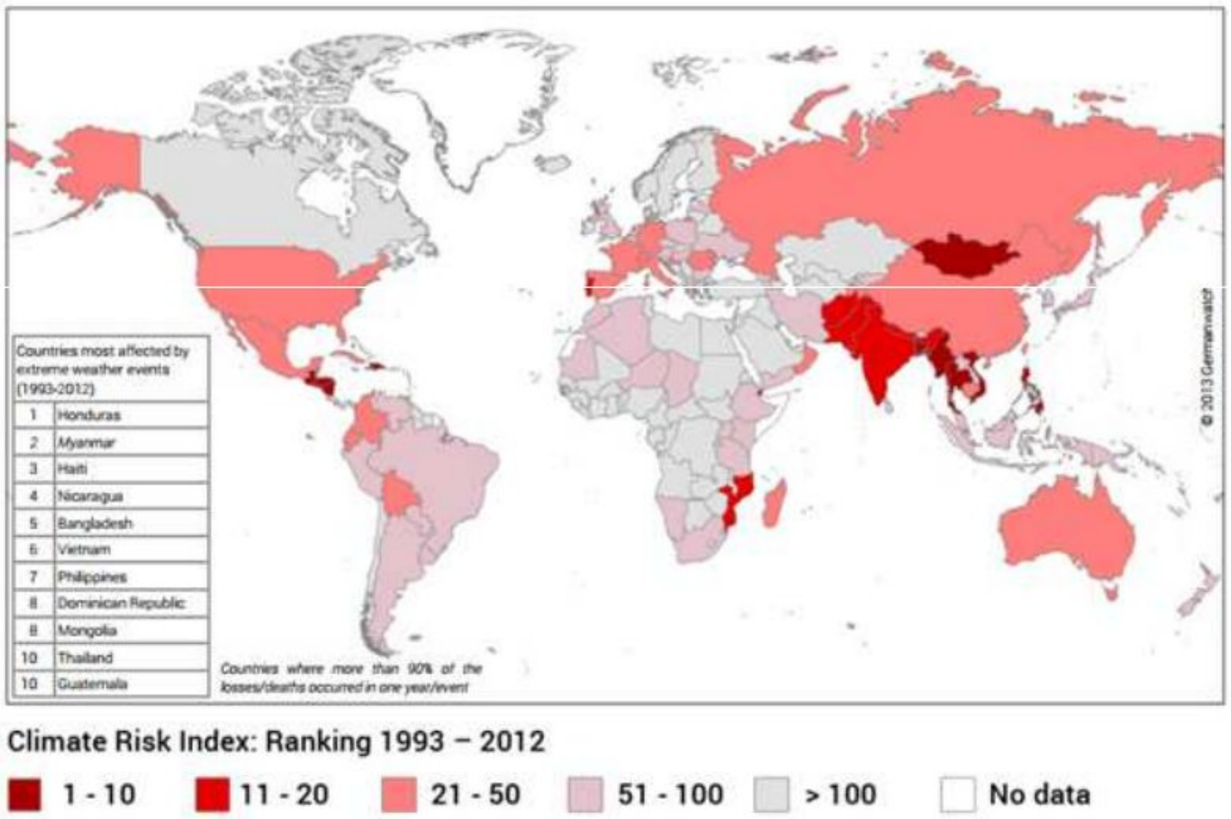
- **Direct impact on human health, usually caused by natural cataclysms (physical injuries, death)**
- **Impacts associated with changes in the environment and surrounding environmental conditions**
- **A variety of health problems, diseases related to critical situations caused by climate change such as an evacuation of people, instability of the economics**

In order to integrally assess climate impacts and risks, **the Global Climate Risk Index (GCRI)** has been developed characterizing national sensitivity and exposure to extreme weather events and their intensity, thus allowing the assessment of potential risks in the future

Climate risk determination is based on quantifiable assessment of climatic events in terms of caused human deaths, as well as in attained material and economic loss

According to the GCRI, during 1994-2013 more than 530,000 people have died due to the result of about 15,000 extreme climate events, but material losses for this period constitutes 2.2 trillion US dollars

Highest climate risks are characteristic to developing countries such as Honduras, Myanmar, Haiti, the Philippines, Bangladesh, but highest number of deaths is a result of floods and famine caused by a prolonged drought



Serious human health risk factor is the impact of **increased temperature**

During hot weather elderly people are exposed to higher risks, especially people older than 75 years, people with chronic health problems, people suffering from respiratory or cardiovascular diseases, as well as infants and toddlers

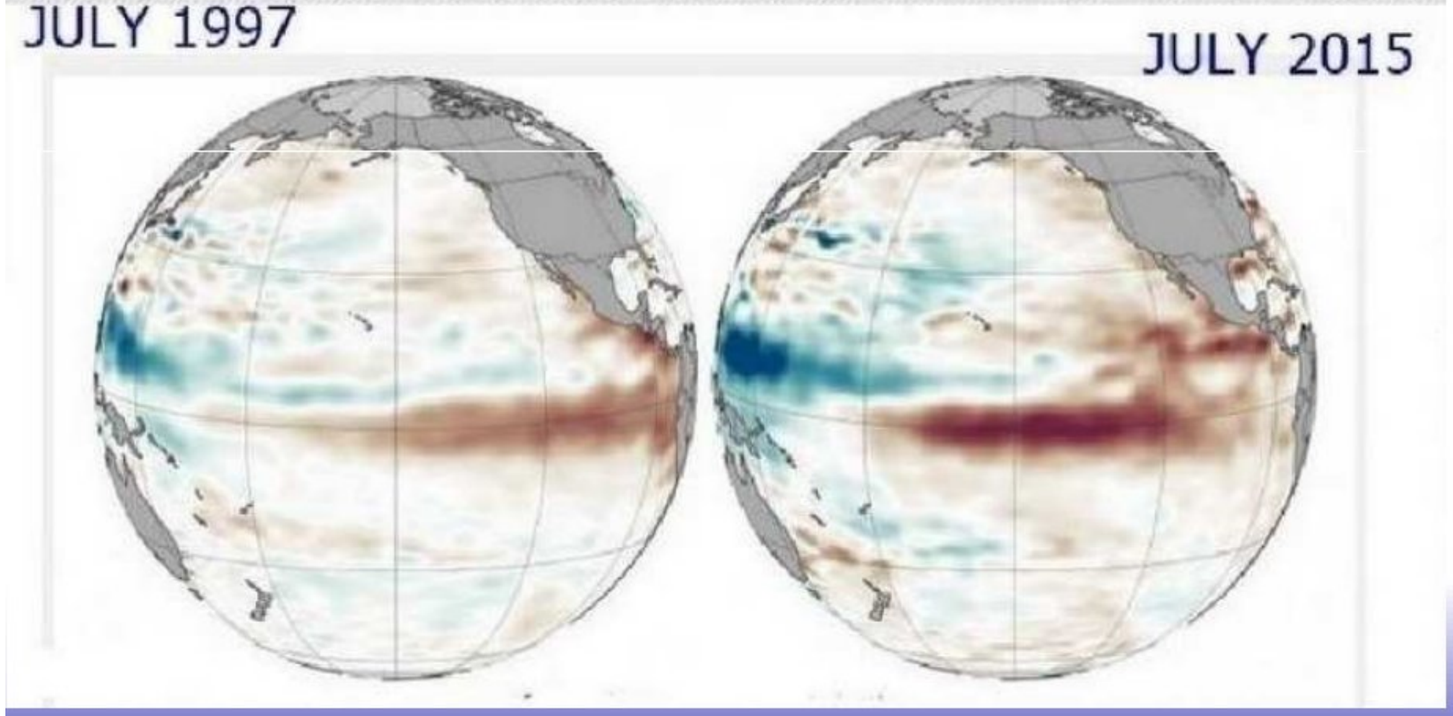
Heat may be the cause of heat strokes and sunstrokes, which in some cases can lead to death

Inhabitants of cities and urban settlements are more susceptible to negative impact of heat than people living in rural areas

Air pollution, which is usually higher in urban areas, enhance the negative effects of heat

Global warming can also affect the frequency and intensity of environmental cataclysms - part of these climate anomalies are associated with the **El Niño phenomenon**, e.g., unusually intense rains, hurricanes and floods

El Niño typically peaks between December and April



The most destructive consequences of these environmental phenomena will become apparent in poor and developing countries

Readiness for critical situations of rescue services in poor countries and medical infrastructure in industrialized countries have reduced the number of human deaths caused by natural disasters

Global warming can contribute to the rapid spread of vector-borne diseases such as malaria, dengue fever, yellow fever

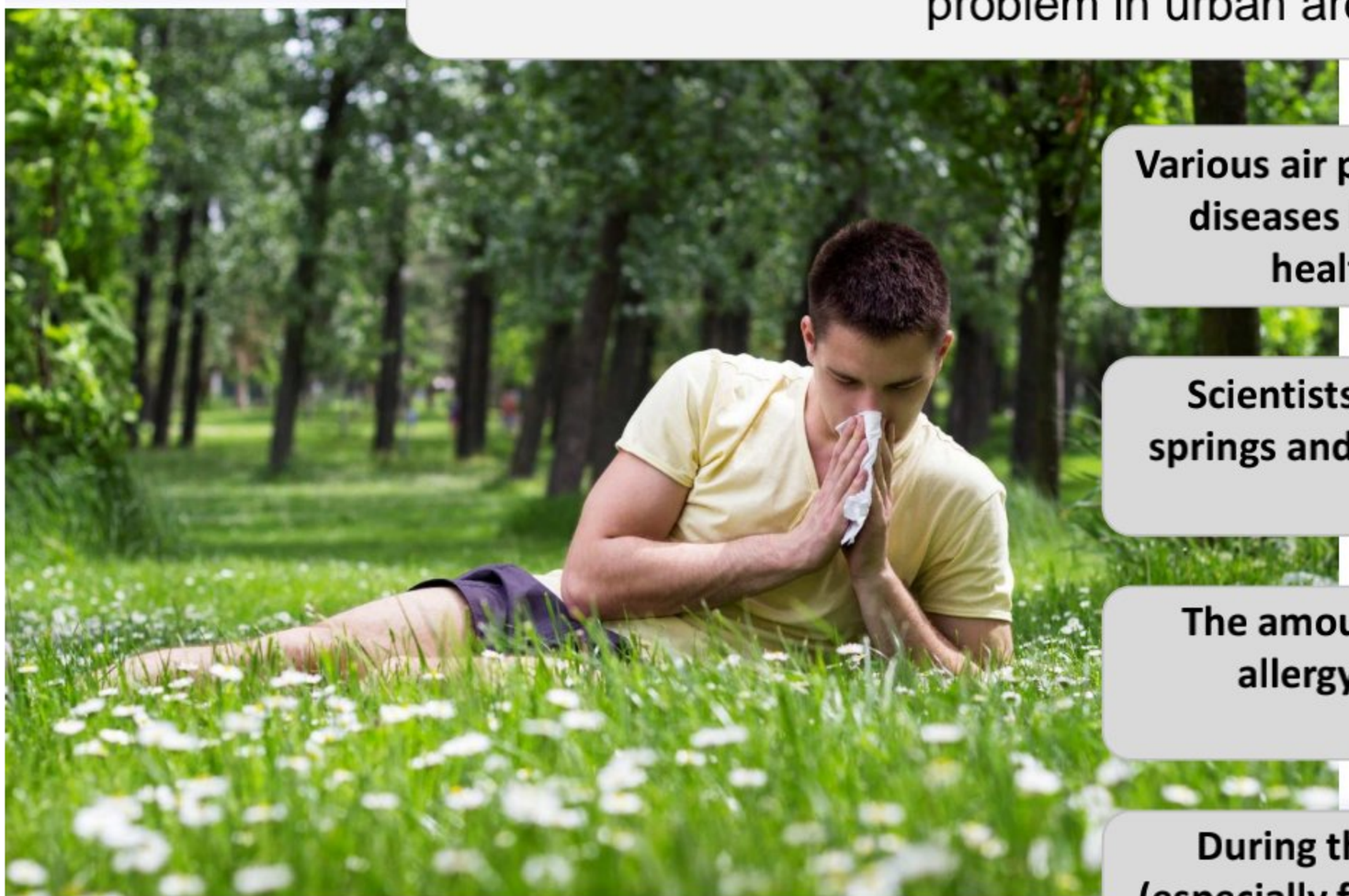
Approximately 40% of the world's population are living in areas where there is a risk of malaria infection; every year worldwide about 1 million people, mostly children, are dying from malaria

Scientists forecast that the temperature increase by 2-3 ºC (by 3-5%), will influence increase of the number of people (several hundred million people) living in malaria-risk areas

During large environmental cataclysms in step with rising temperature, deterioration of water quality and mixing of drinking water with rain water and soil particles pathogen microorganisms can expand causing various diseases and epidemics, e.g., diarrhea, dysentery, cholera, typhus, hepatitis A

In areas with existing problem of shortage of drinking water, probability of diarrhea caused by climate change will increase by 10% until the year 2030

Also **anthropogenic air pollution and dust** seriously affect and threaten human health - particularly it is an acute problem in urban areas



Various air pollutants can cause worsening of the respiratory diseases leading to death; serious problems for human health are posed by allergens (such as pollen)

Scientists forecast that due to the occurrence of earlier springs and tardy autumns, there will be a longer flowering season of allergy-causing species

The amount of birch pollen (the main cause of seasonal allergy in north Europe) increases with increasing of seasonal temperature

During the drought periods, will be a high risk of large (especially forest) fires that pollute the air and consequently may cause respiratory disease and eye inflammations

Interconnections among the climate change impacts, potential consequences and required actions