Contemporary global and high-latitude climate change

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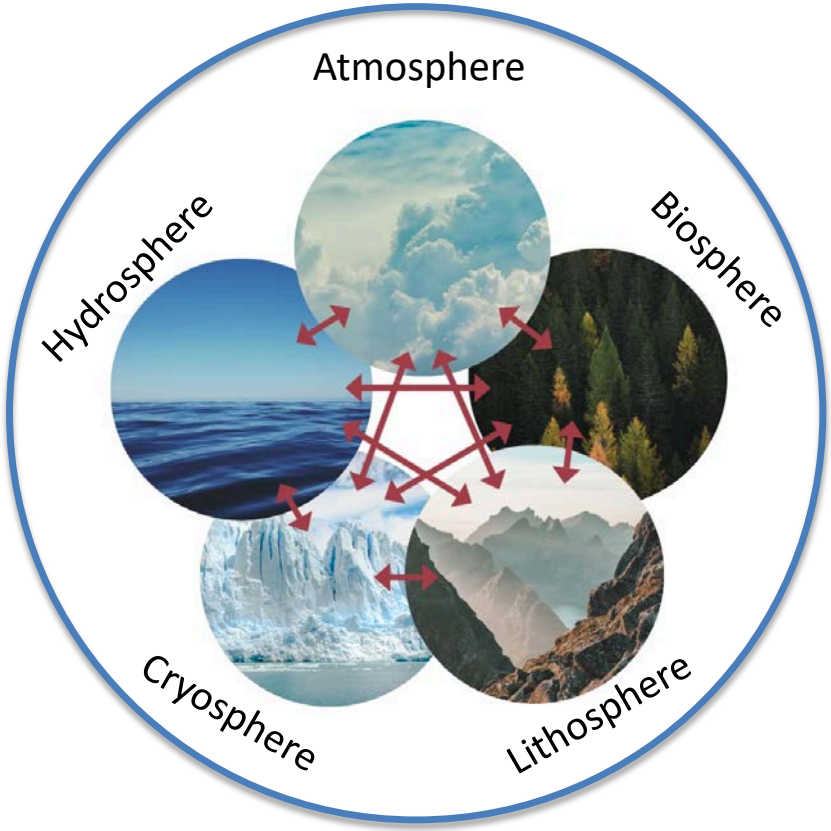
18th All-Russian open conference
'Contemporary problems of Earth remote sensing'
Lectures of the young scientists' school-conference on Remote sensing of vegetation at high latitudes in response to climate change and other disturbances

What is «climate change»?

Sustainable development Goal 13:
Take urgent action to combat climate change and its impacts

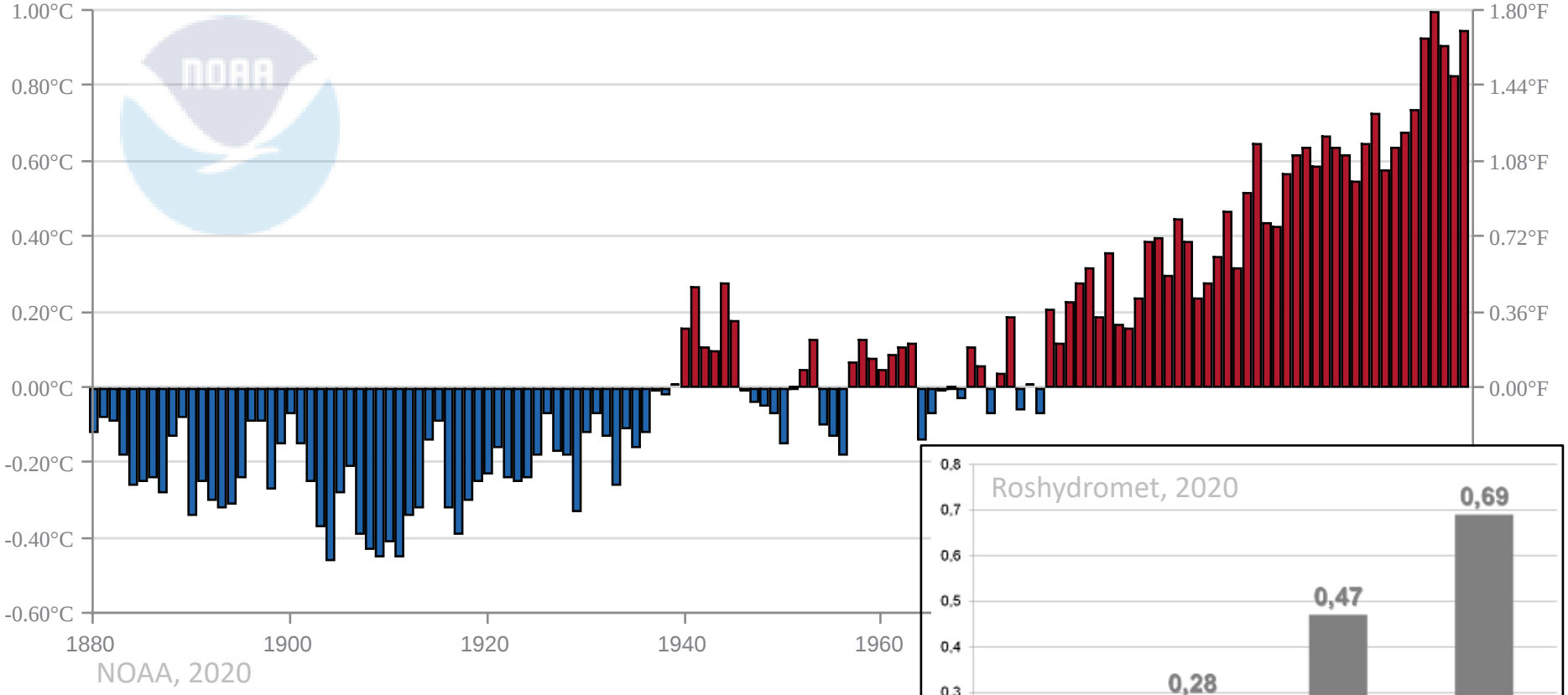
Climate change — contemporary global climate changes that are mostly consequence of anthropogenic activities (burning fossil fuels, land-use changes, etc.).

Climate is an ensemble of states of the Earth's climatic system (atmosphere, hydrosphere, biosphere, lithosphere, cryosphere) over a relatively long time interval (usually at least 30 years).



Contemporary warming

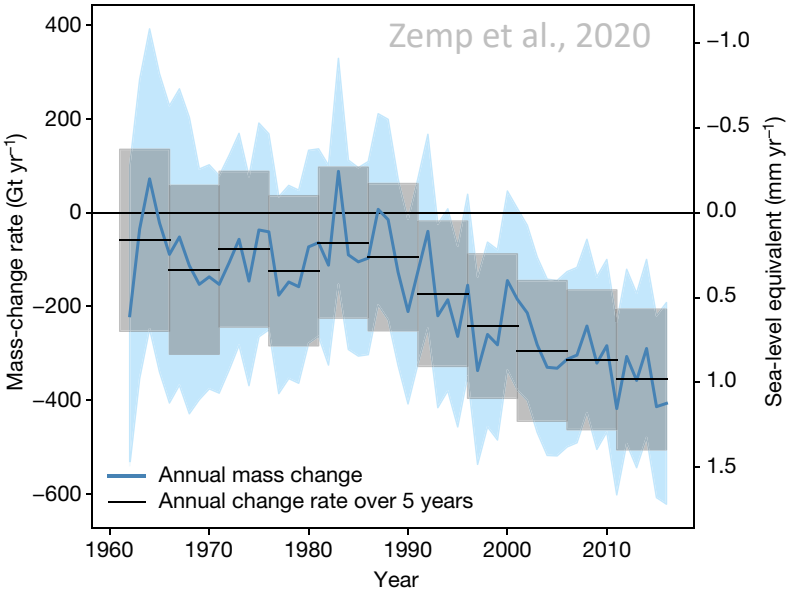
Global surface air temperature anomalies
(relative to the 1901–2000 mean)



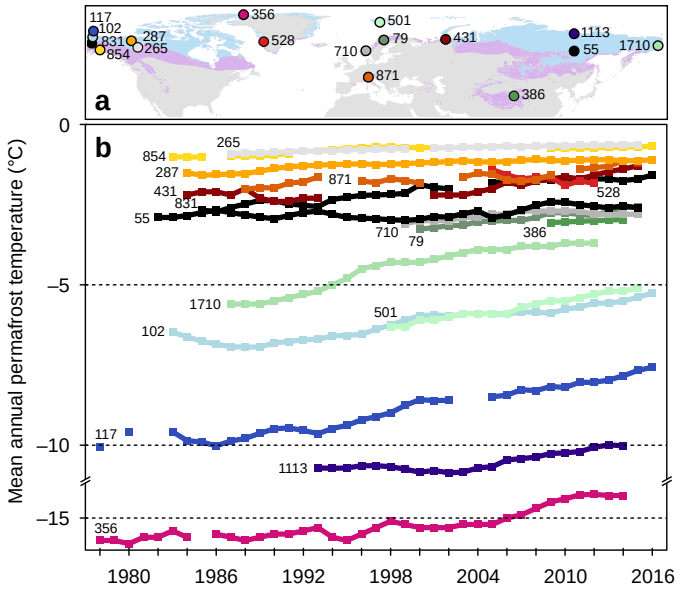
SAT trends (ºC/decade, 1976–2019)

Other climate system variables' changes

Global glacier mass

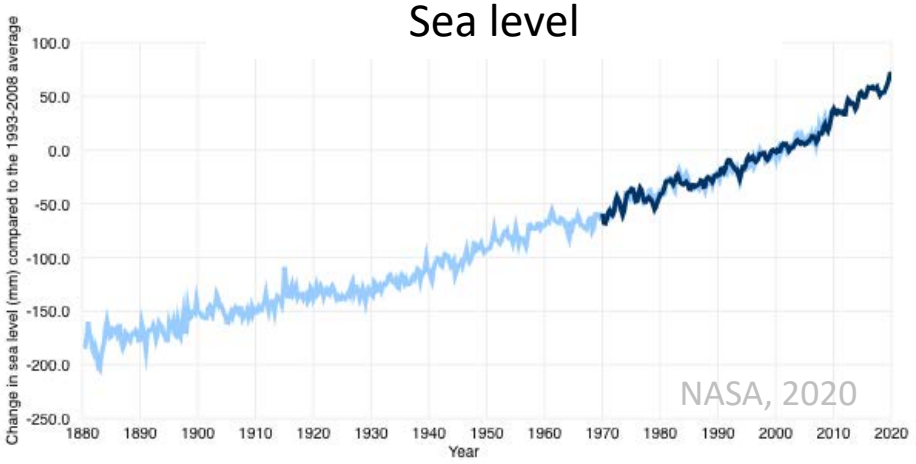


Permafrost temperature

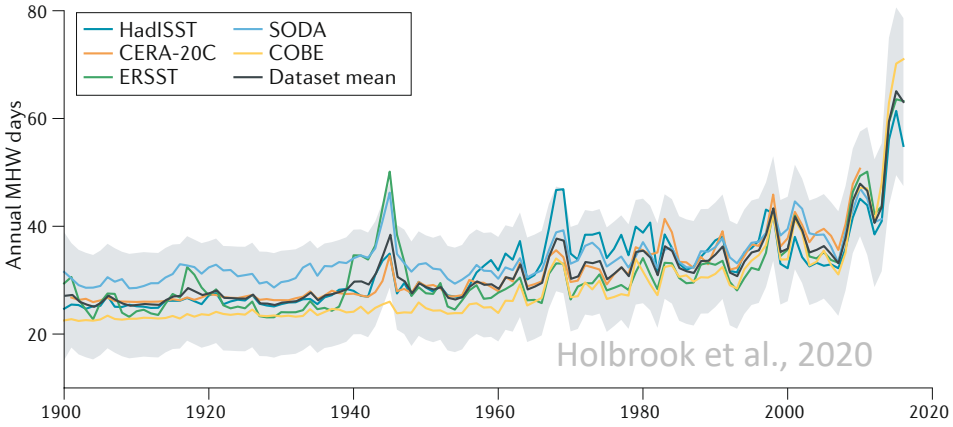


Biskaborn et al., 2019

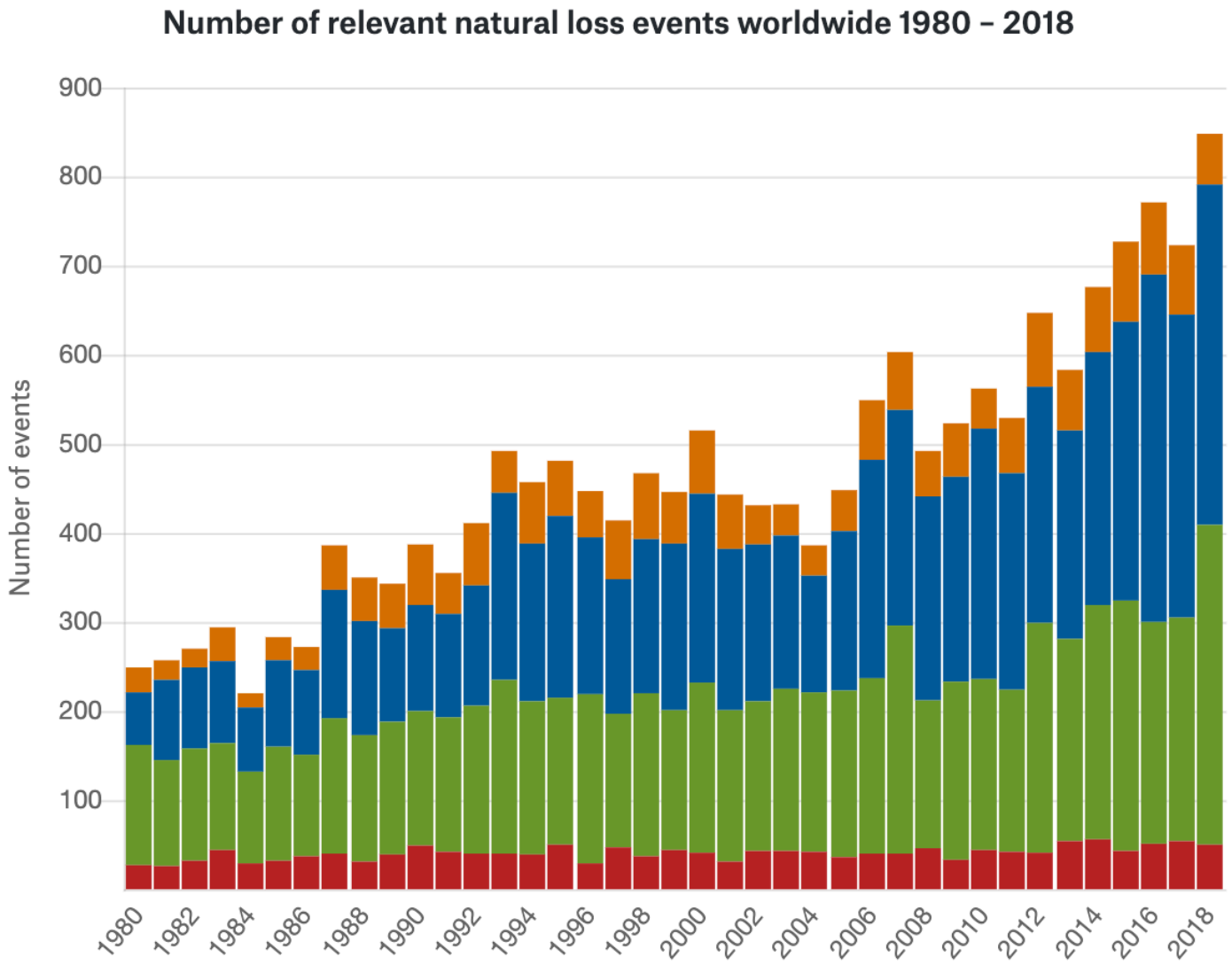
Sea level



Marine heat waves



Number of natural loss events (worldwide)



Climatological events (extreme temperature, forest fire, drought)

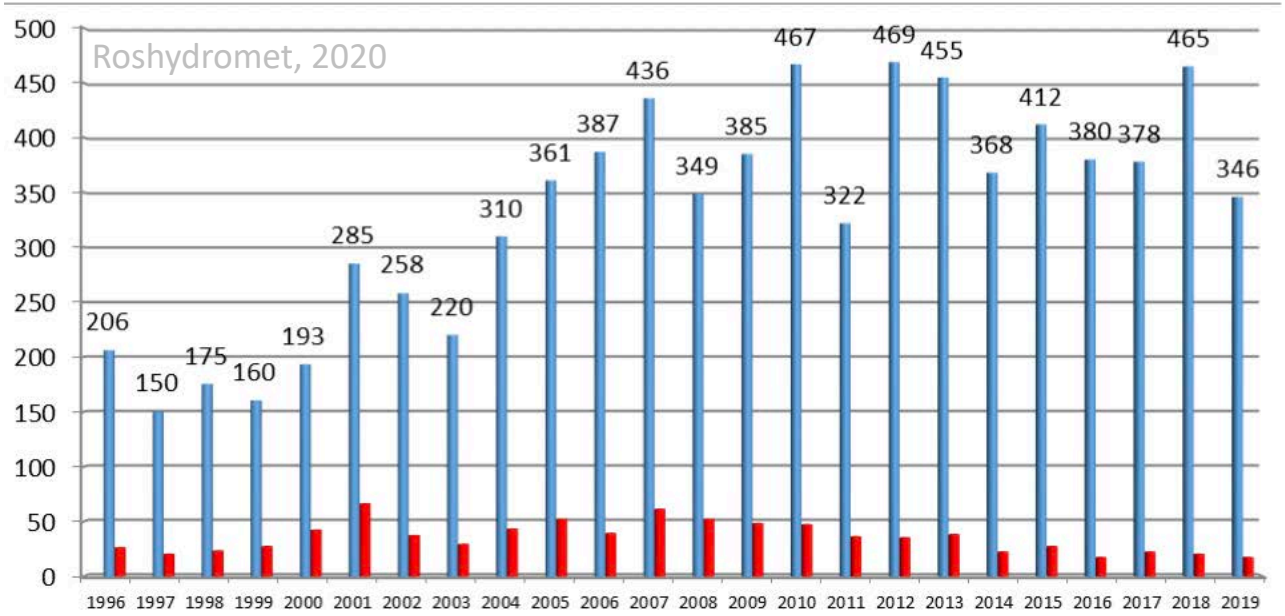
Hydrological events (flood, mass movement)

Meteorological events (tropical and extratropical storms, severe convective storm, local storm)

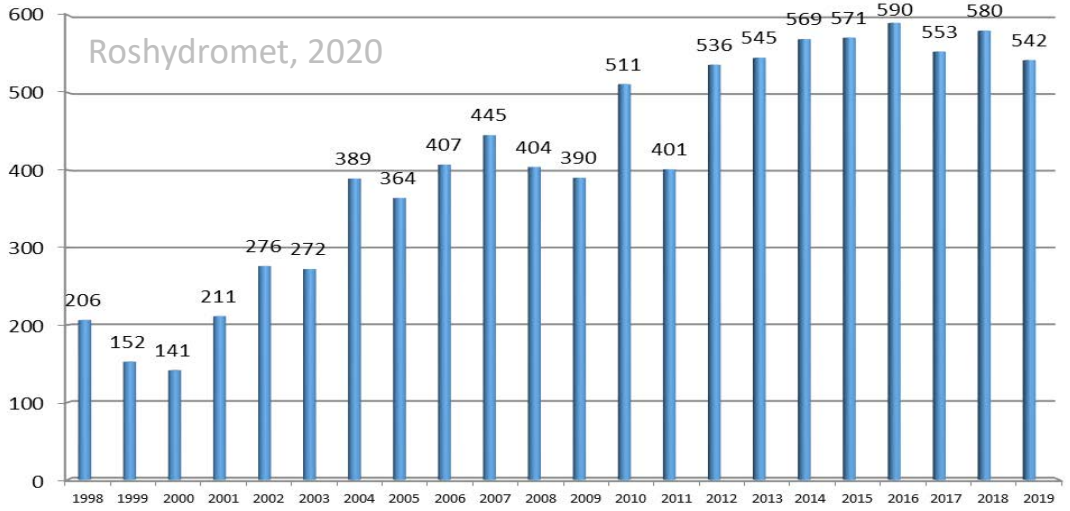
Geophysical events (earthquake, tsunami, volcano activity)

Munich RE, 2019

Number of natural loss events (Russia)

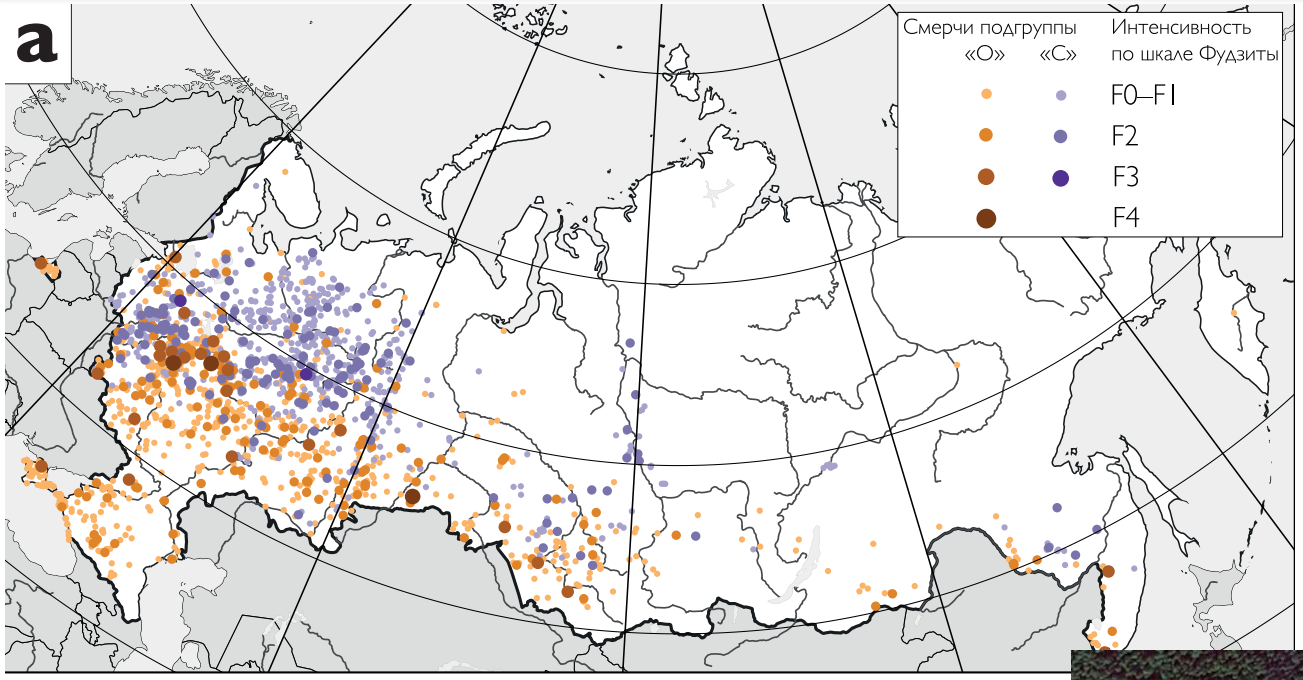


The number of hydrometeorological hazards in Russia that caused significant damage (blue - all events, red – non-forecasted)



The number of meteorological hazardous events in Russia

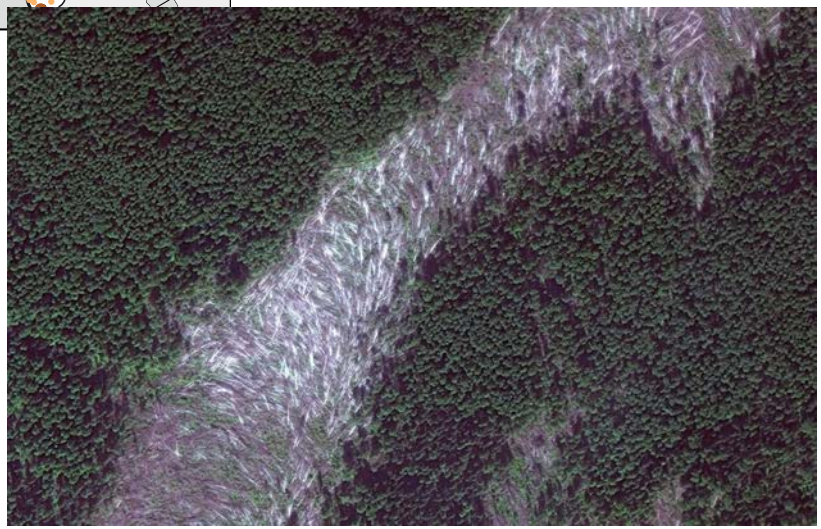
Underestimated threats: tornadoes



Chernokulsky et al, 2020, 2021

Tornadoes in Russia in 1900–2018

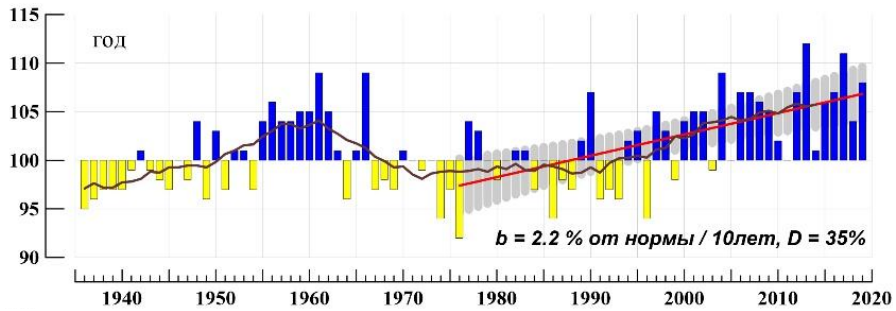
Details: tomorrow talk by Dr. Andrey Shikhov



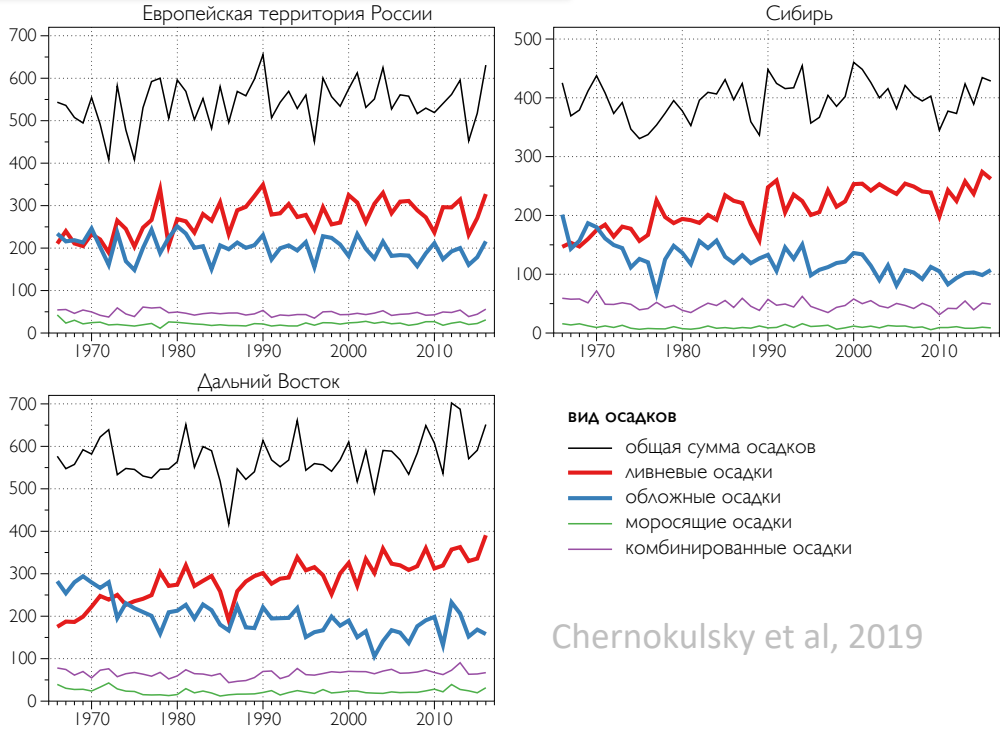
2017:
342 tornadoes (52 of them with ≥F2 intensity, wind speed > 50 m/s)

According to official statistics: only 1 tornado

Changes of precipitation character

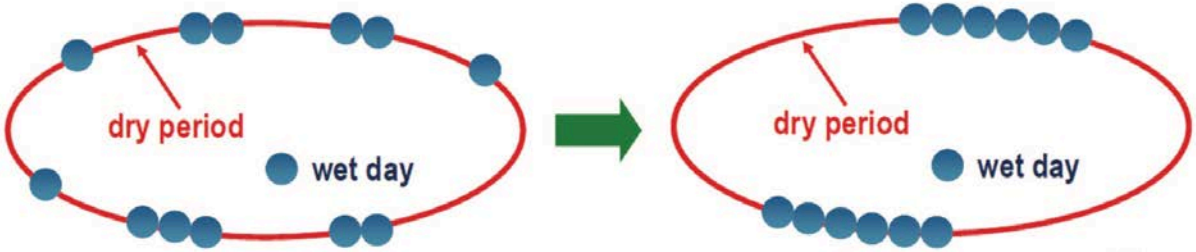


Dynamics of annual precipitation rate anomalies over Russia



Changes of total (black), convective (red) and large-scale (blue) precipitation over Russian regions

Chernokulsky et al, 2019



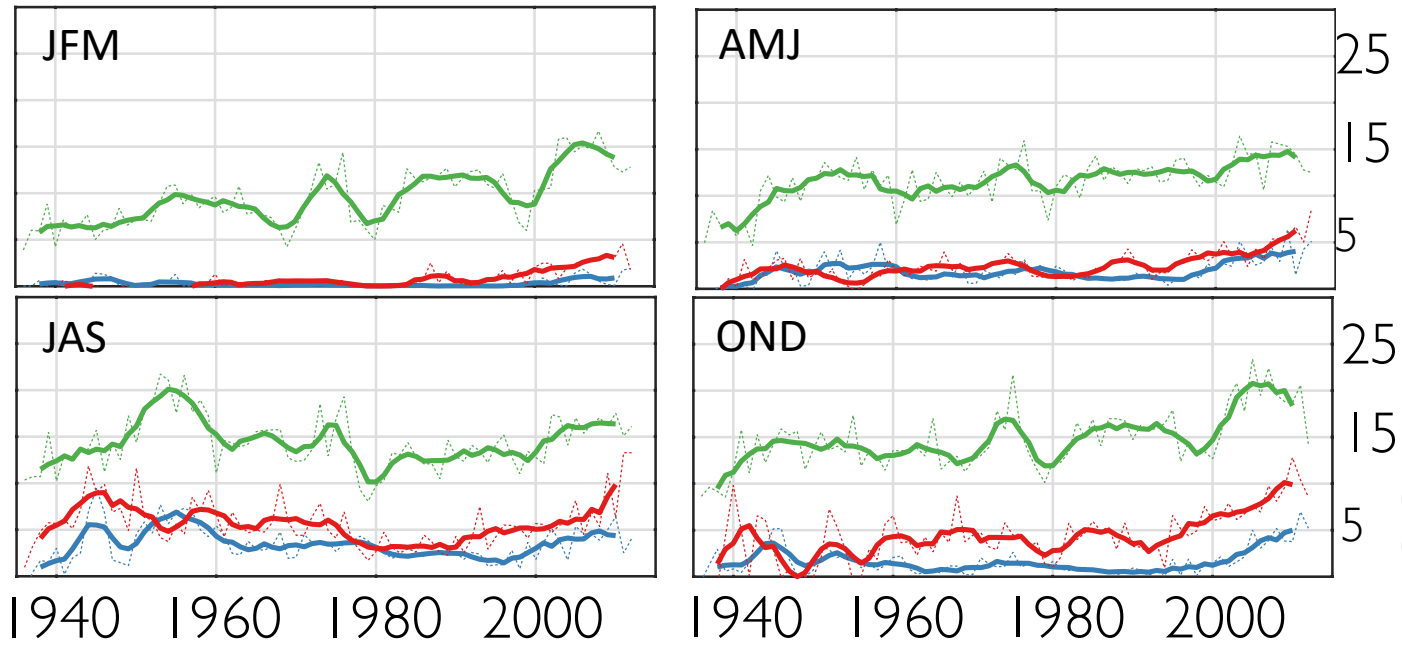
Zolina et al., 2013

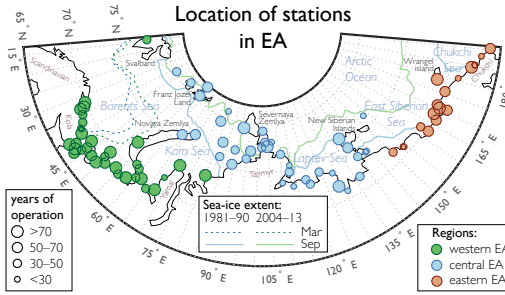
Longer dry period: more frequent and more drought

Clustering rainy days: increasing flood risk

The nature of precipitation is changing: there are more heavy showers

Convective clouds in the Russian Arctic





WEA
CEA
EEA

Chernokulsky et al, 2017
Chernokulsky and Esau, 2019

Variability of amount of convective clouds (%) over meteorological stations in the Russian Arctic

Rapid changes in the Arctic: temperature, sea-ice, snow cover, precipitation, etc…

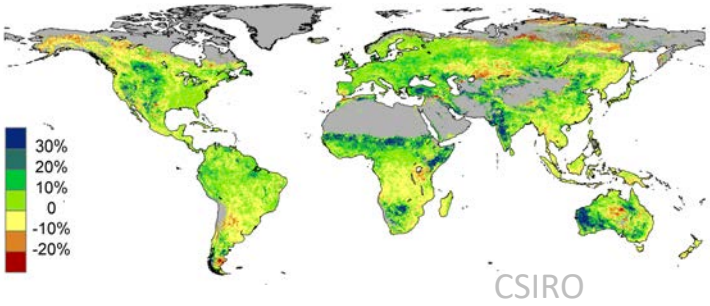
Details in the next talk by Dr. Gareth Marshall

Climate change and vegetation at high latitudes

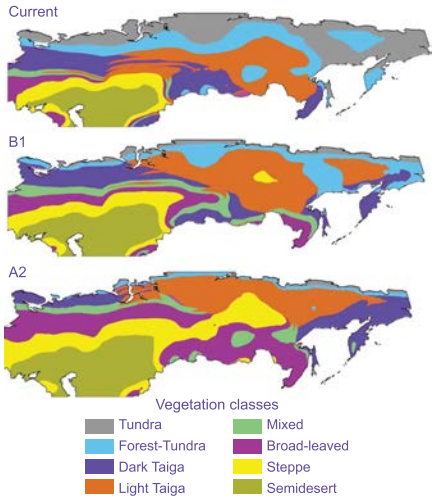
- CO2 increase — increase of plant primary production, ‘global greening’
- Temperature and precipitation changes — changes in plant species phenology and distribution area
- Forest fires
- Wind-related disturbances
- Invaders distribution changes
- Insolation and Photosynthetic active radiation (PAR) changes

etc…

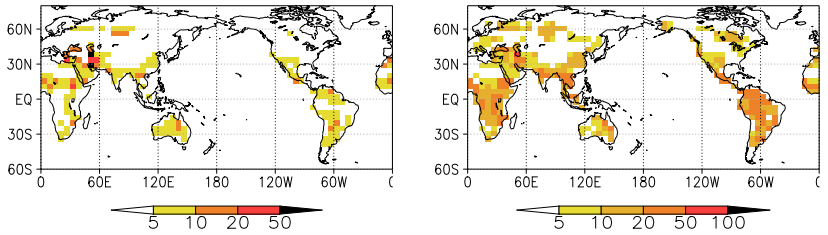
Details in the next talks…



CSIRO

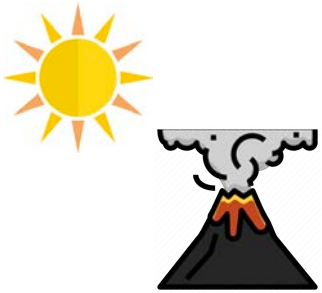


Tchebakova et al., 2016



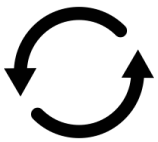
Eliseev et al., 2014

Drivers of climatic changes and variability



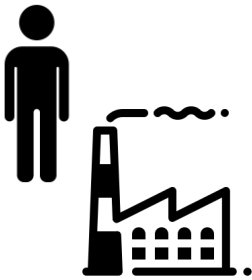
- External factors:

astronomical factors (solar activity and galactic rays); geological factors (volcanic eruptions).



- Internal factors:

slow elements of the climate system towards to fast elements; internal variability of climate (on large time scales).

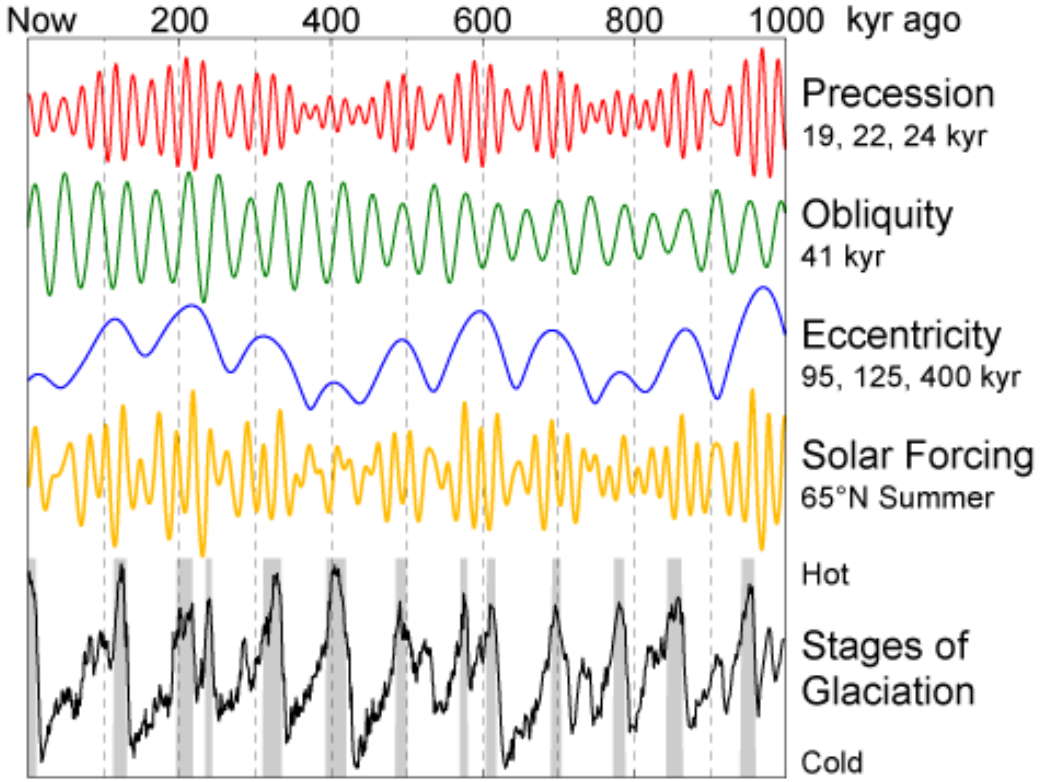


- Human (internal or external factor?):

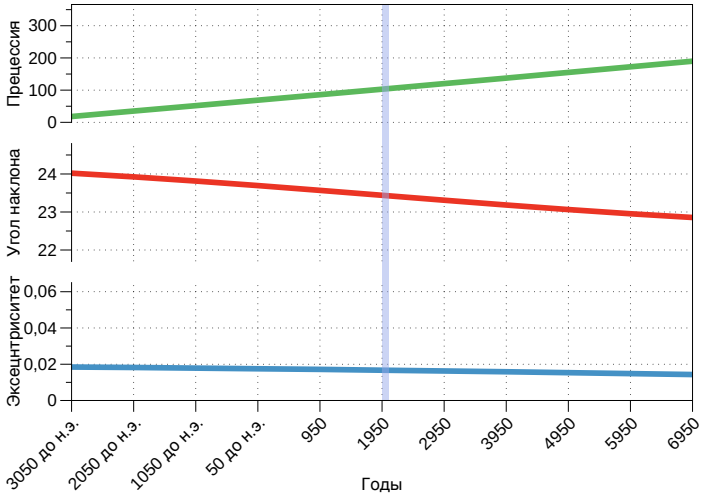
changes in the properties of the earth's surface (deforestation, land-use, wind and solar power plants), changes in the composition of the air (greenhouse effect, aerosols, impact on the ozone layer, etc.)

Astronomical factors

Milankovitch cycles are long-term fluctuations of solar energy arriving at the Earth's surface, caused by changes in astronomical characteristics.



Laskar et al, 2004



Solar activity

Change in solar activity (associated with the formation and decay of strong magnetic fields in the solar atmosphere).

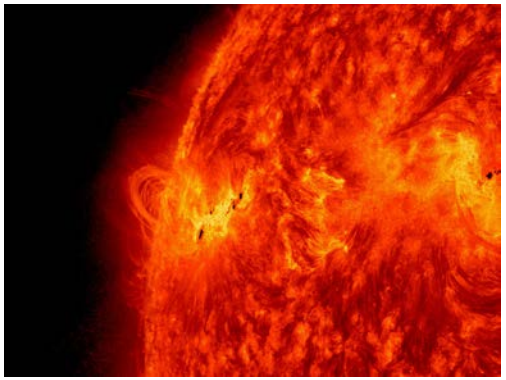
Solar activity can be estimated by the number of sunspots: the so-called. Wolf numbers. Also look at the group sunspot number.

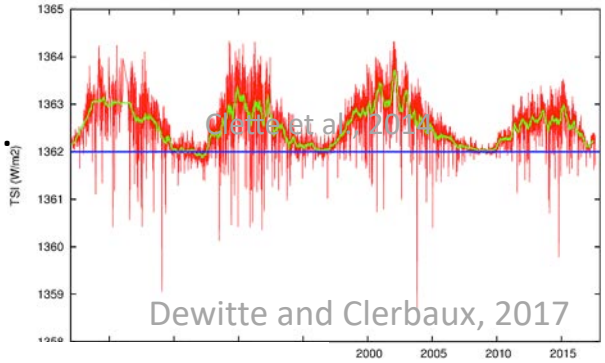
Since the late 1970s, energy from solar radiation reaching the TOA has been measured from satellite data (total solar irradiance)

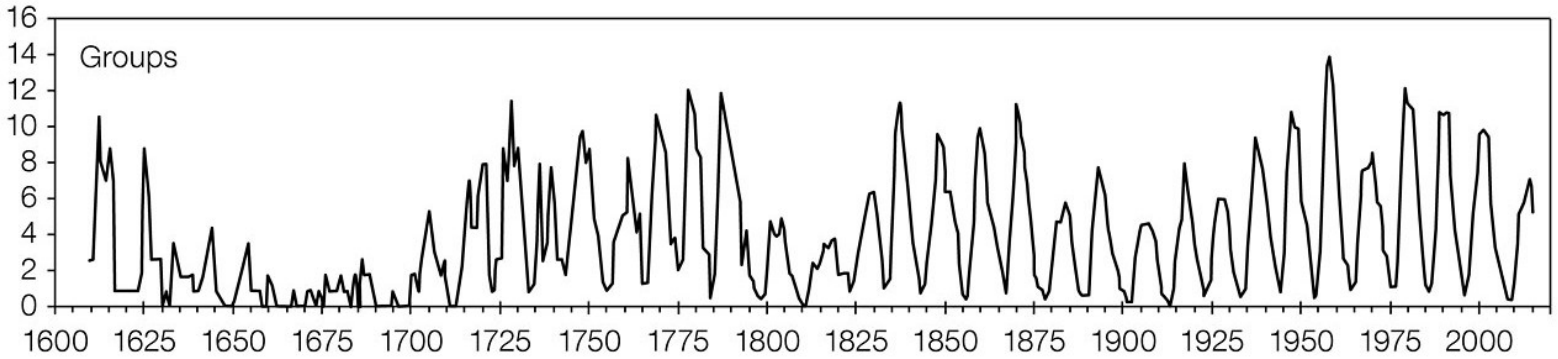
Cycles: 11 years (Schwabe cycle), 70-100 years (Gleisberg cycle).

Variability of solar activity: ~1 W / m^2

For the surface of the Earth: <0.2 W / m^2





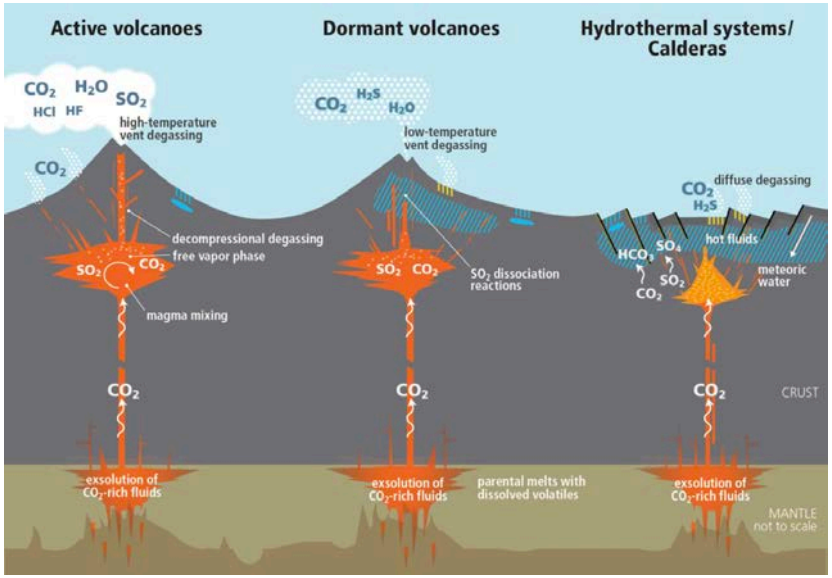


Clette et al., 2014

Geological factors: volcano activity

Major volcanic eruptions in the tropics: the release of a huge amount of sulfate aerosols into the stratosphere, which creates a kind of screen that reflects solar radiation.

This leads to cooling. Periods of increased volcanic activity -> cold climate.

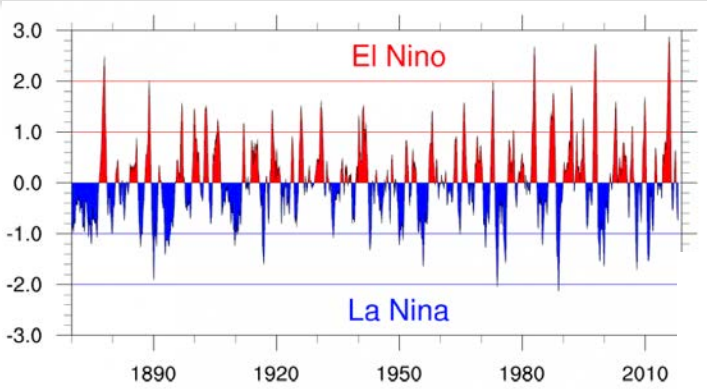


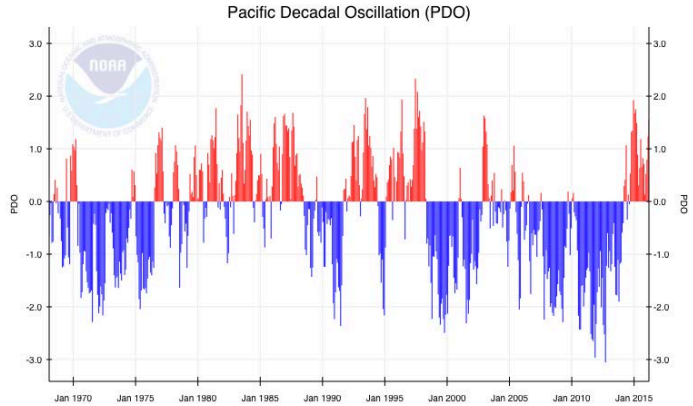
CO_2 fluxe from volcanoes :
~300–400 mln tonn CO_2/year
Anthropogenic activity:
~35 bln tonn CO_2/year

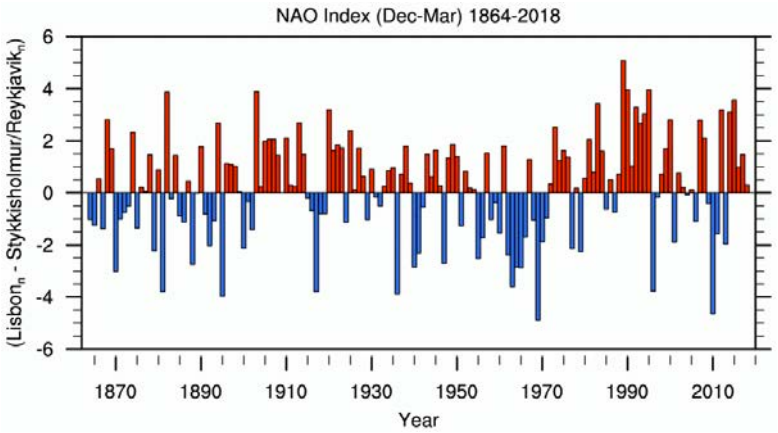
Pinatubo eruption (1991):
~42 mln tonn CO_2
Anthropogenic activity in 1991:
~23 bln tonn CO_2

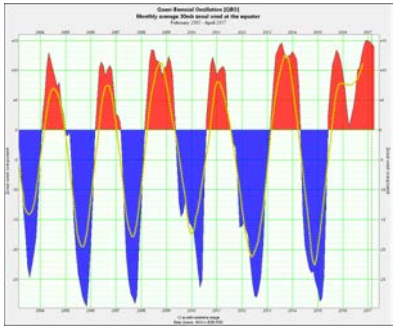
Internal variability

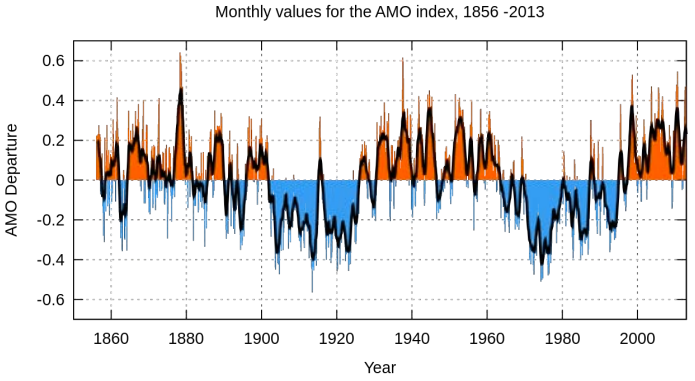
ENSO, PDO, NAO, AMO, QBO, etc…







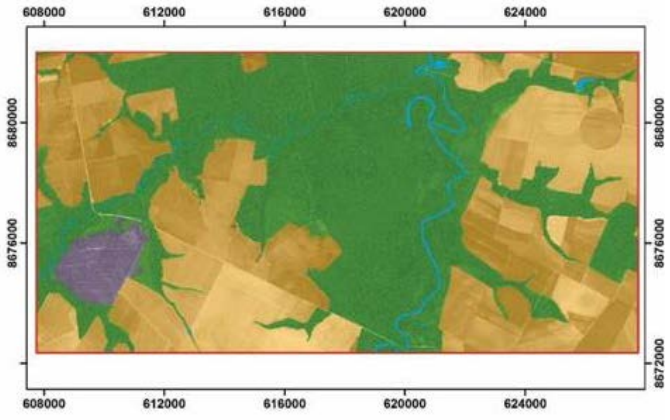




NCAR/UCAR, NOAA

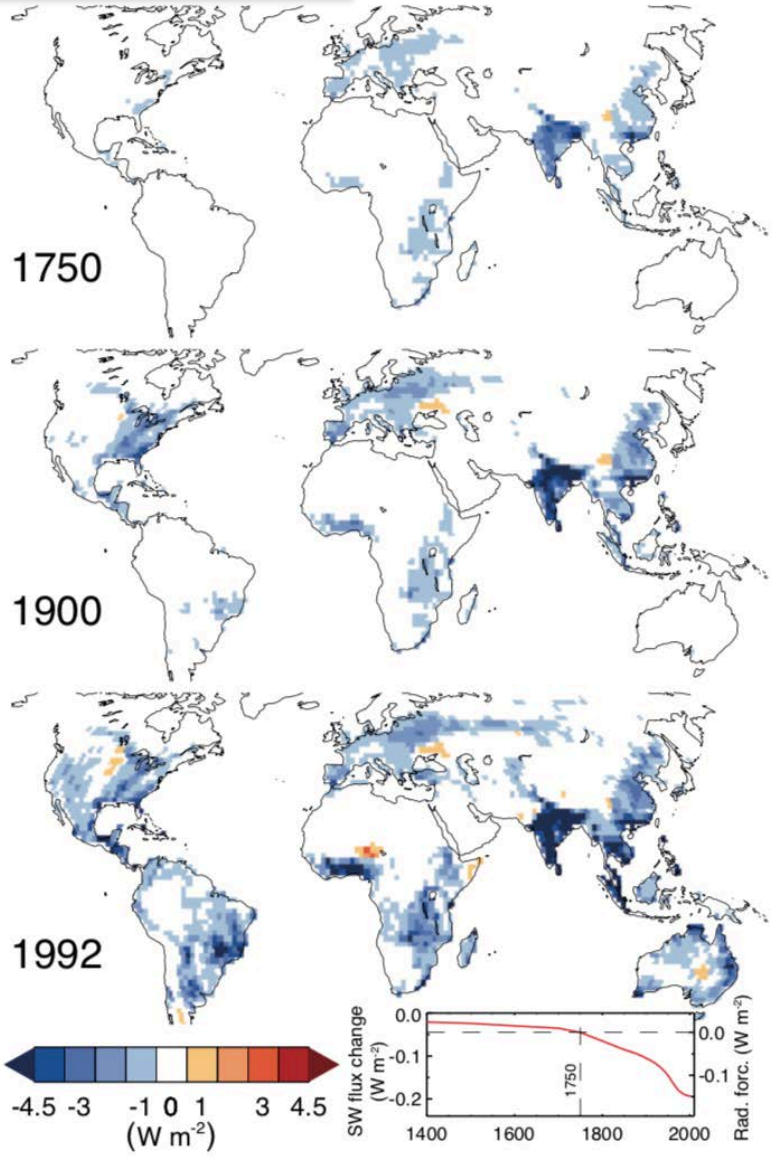
Human-caused changes: land-use

Deforestation impacted on climate (changes in surface albedo).



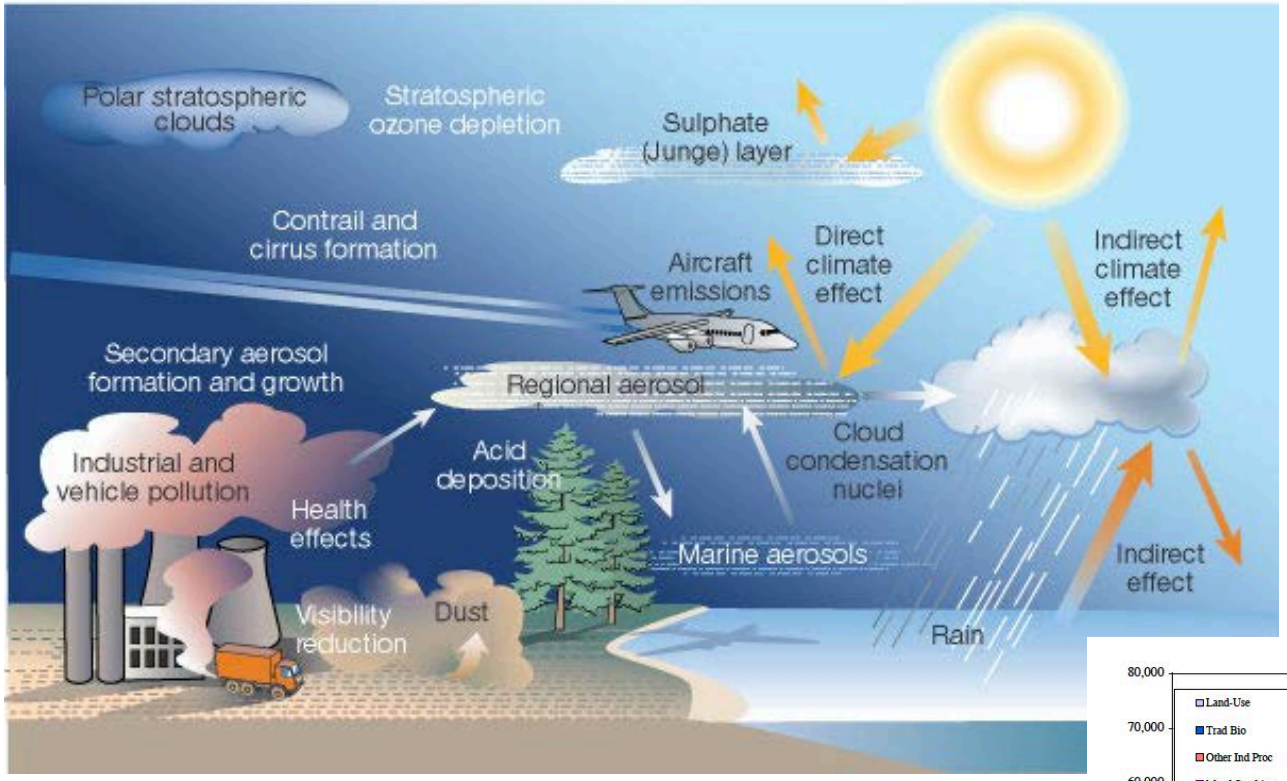
=> man began to influence the climate several thousand years ago!

Changes in the SW outgoing radiation as a result of changes in land-use



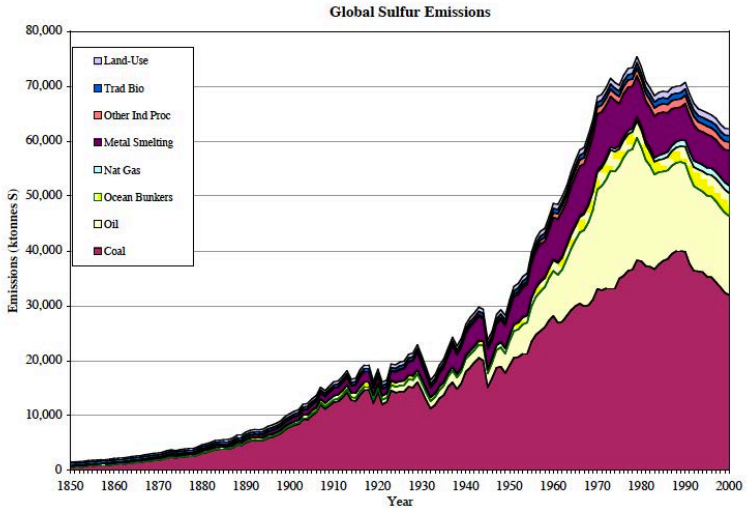
IPCC, 2014

Human-caused changes: aerosols



Aerosols in the climate system

Sulfur aerosol emissions



Sulfur aerosols: multiple effects (direct, indirect) – mainly cooling effects
Black carbon – warming and cooling effects

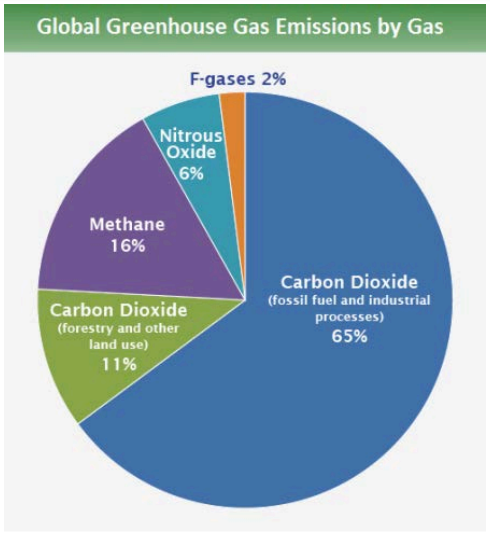
IAS, PNNL

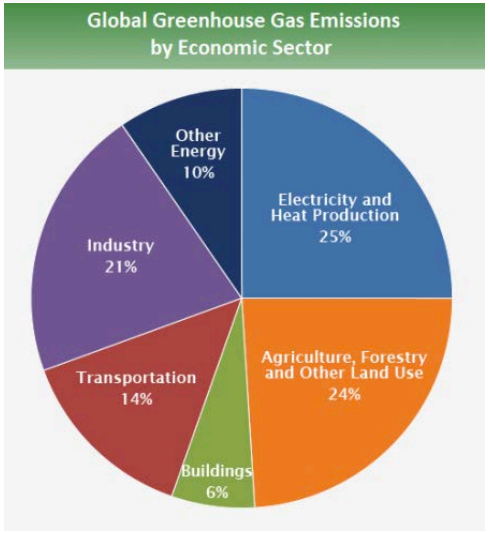
Human-caused changes: green-house gases

CO2 emissions, primarily due to combustion of fossil fuels - impact on the greenhouse effect. Also CH4, N2O, freons (land-use, industry etc.)

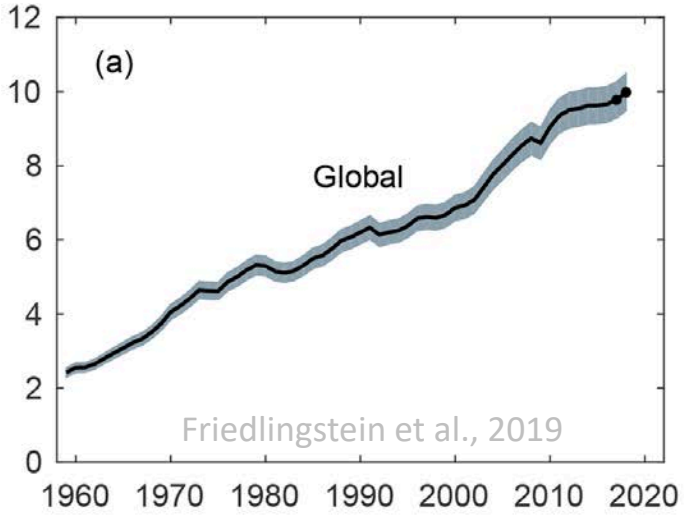
Emissions:
~35 bln tonn CO_2/year
~10 bln tonn C/year

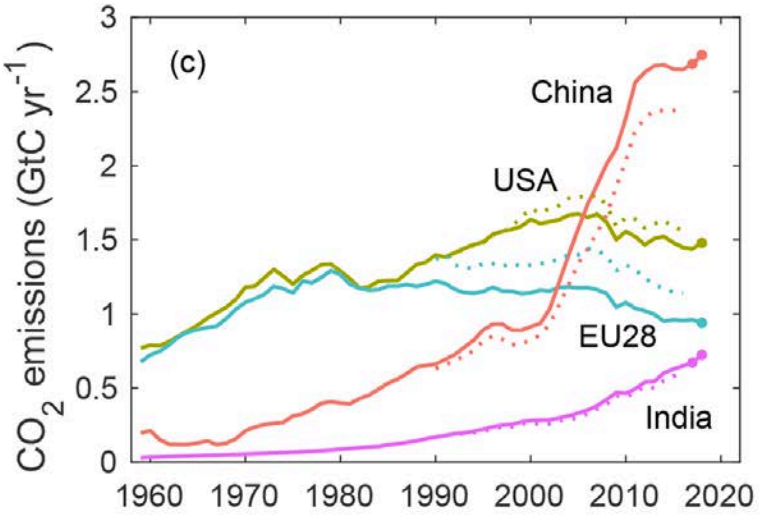
(1 bln tonn– 1 Gt or 1 Pg)





IPCC, 2014

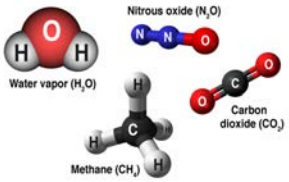




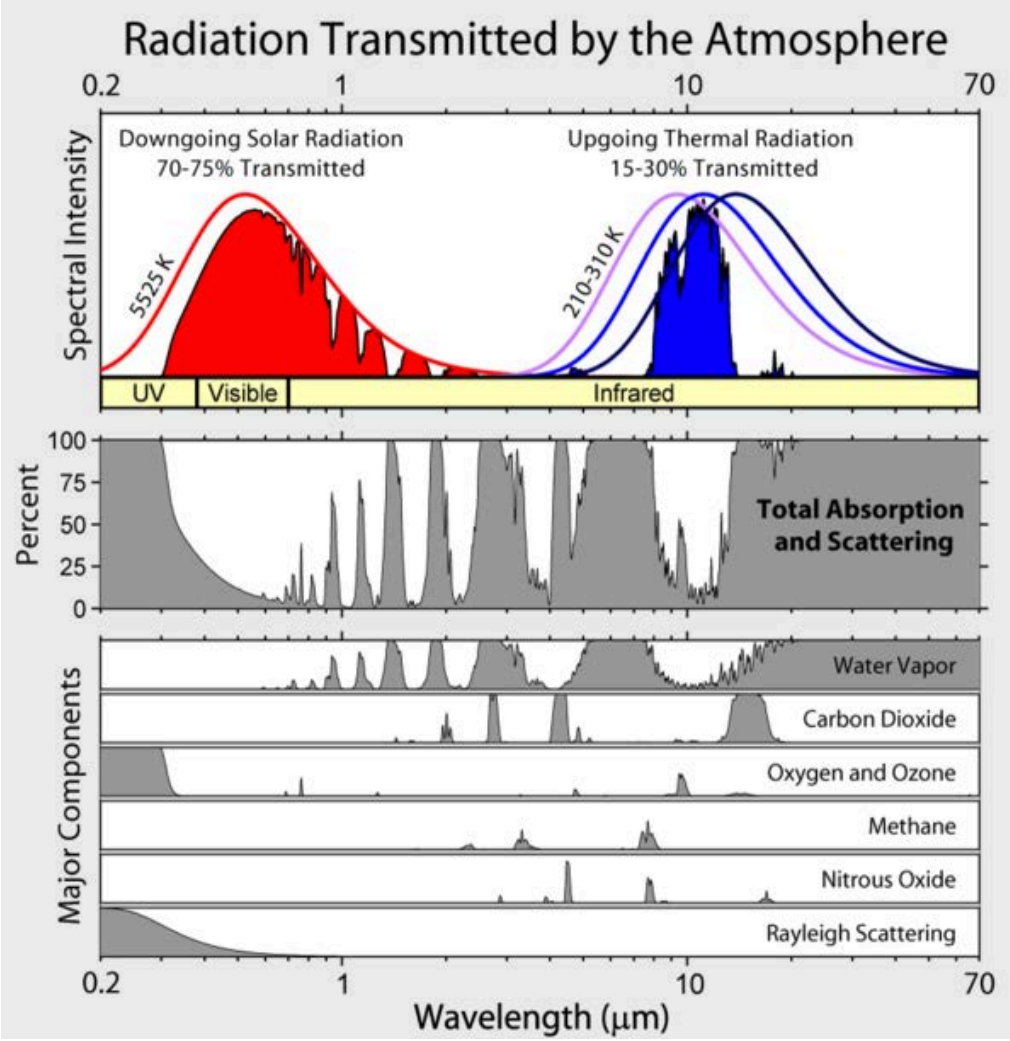
Greenhouse effect

The greenhouse effect of the Earth's atmosphere is an increase in the temperature of the lower layers of the atmosphere due to the absorption and scattering of long-wave radiation by the main greenhouse gases (these gases have a dipole charge).

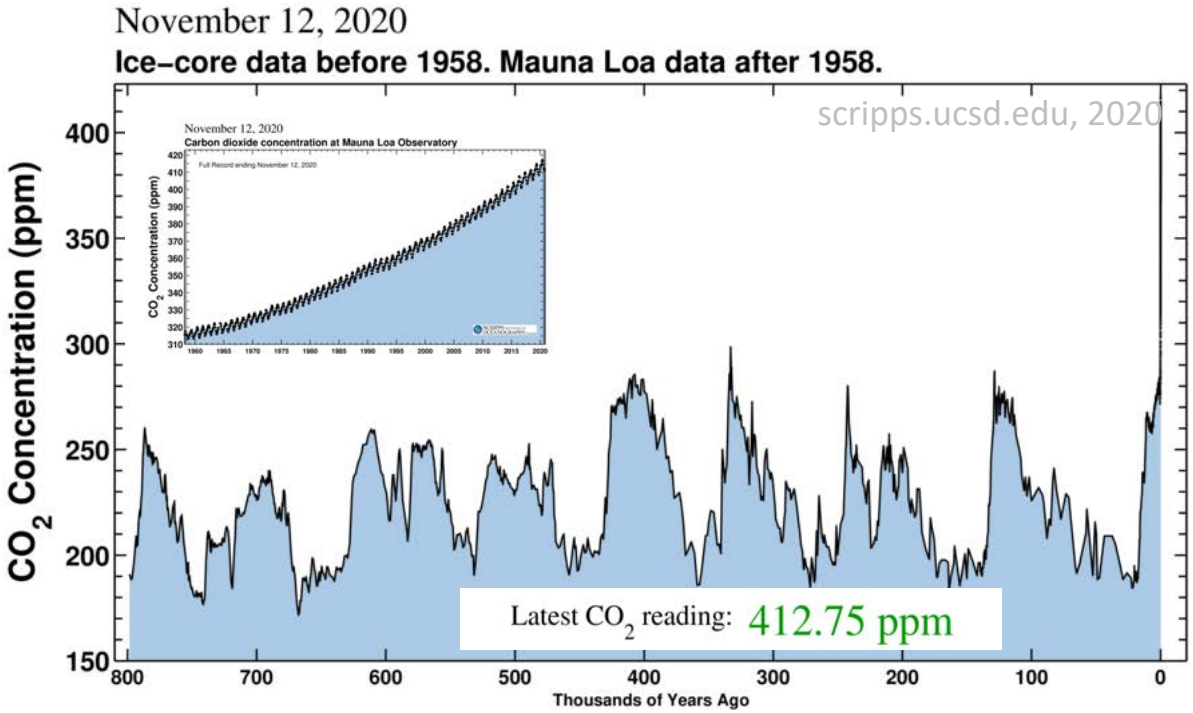
The main greenhouse gases:
Water vapor (H_2O) – 67%
Carbon dioxide (CO_2) – 24%
Methane (CH_4)
Ozon (O_3)
Nitrous Oxide (N_2O)

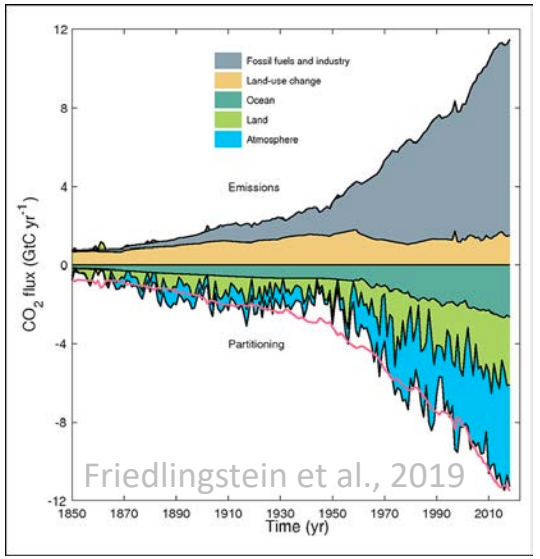


Global temperature of the Earth:
With GHE: +15ºC
Without GHE: –18ºC



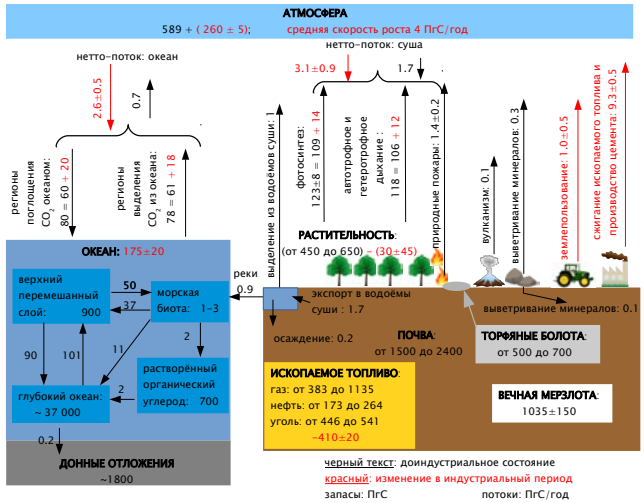
Warming attribution: unprecedented rise in CO2





Unprecedented rise in greenhouse gas concentration (over the last 1 million years)

Anthropogenic carbon flux: approx. 10 billion tons per year (about half is absorbed due to increased sink into the ocean and biosphere).

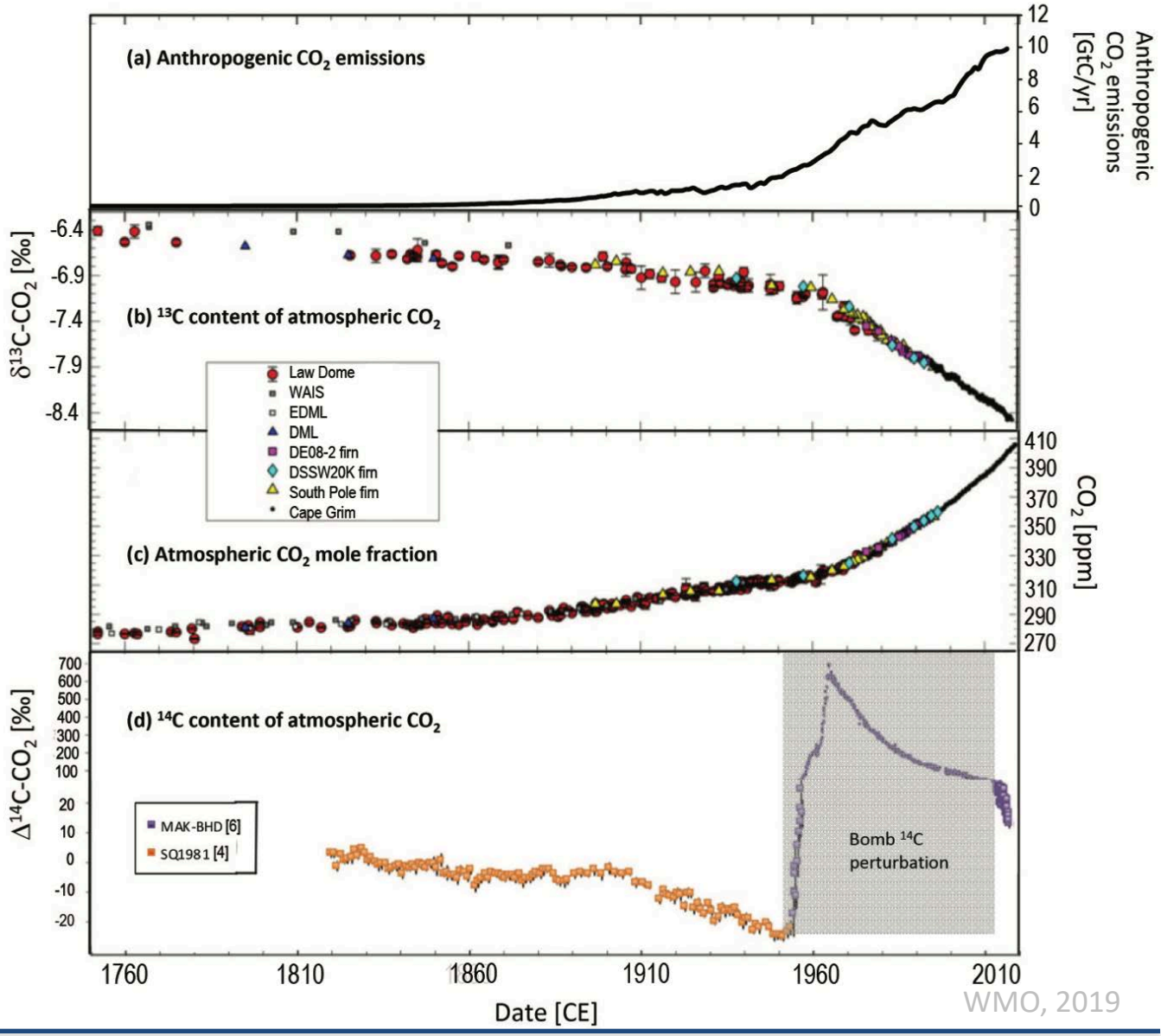


Eliseev, 2017

Warming attribution: CO2 isotope composition

The ‘Suess Effect’ (discovered in the 1950s): a decrease in ^{14}C concentration (formed in the upper atmosphere and does not depend on natural climatic variability) due to an increase in ^{12}C content (released into the atmosphere as a result of burning fossil fuels (does not contain ^{14}C).

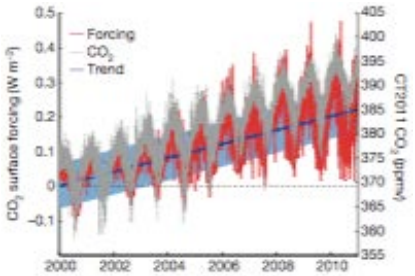
After nuclear bomb perturbations scientists are looking at the $^{13}C/^{12}C$ ratio (it is lower in plants due to the peculiarities of photosynthesis).



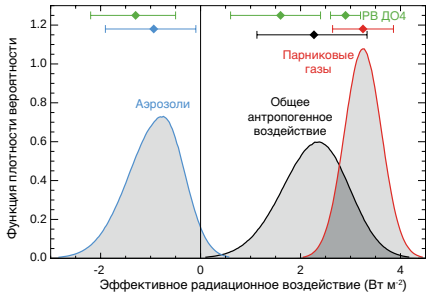
WMO, 2019

Warming attribution: set of observations

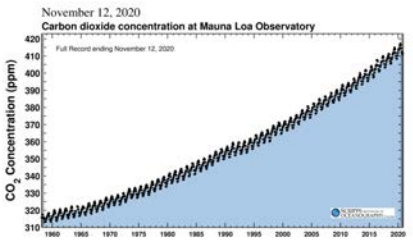
1. Increase of concentration of greenhouse gases, increase of anthropogenic CO2 emissions, direct measurements of the radiation effect of CO2, ocean acidification.



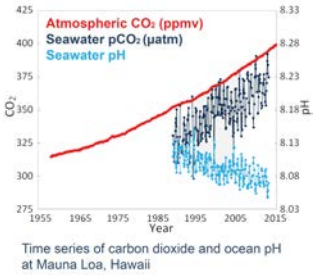
Fieldman et al., 2015



IPCC, 2014

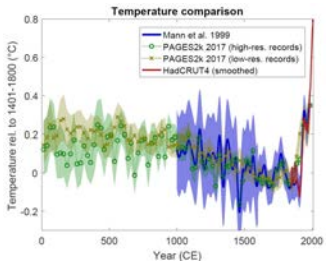


scripps.ucsd.edu, 2020

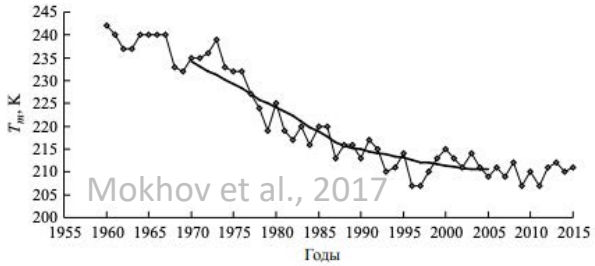


NOAA

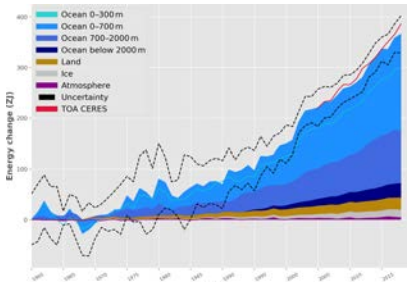
2. Changes of different climate variables (temperature of troposphere vs. stratosphere/mesosphere, atmospheric moisture content, heat accumulation, ocean level rise, glacier shrinkage, etc.)



PAGES2K, 2019

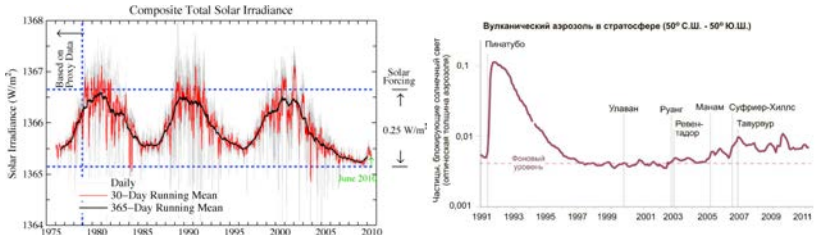


Mokhov et al., 2017



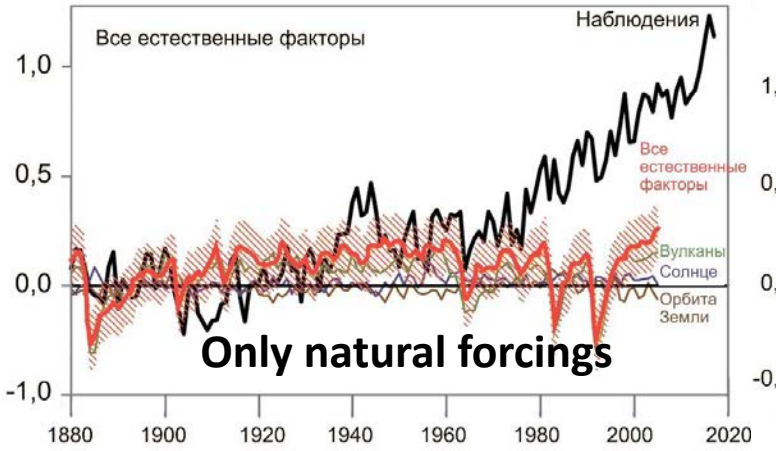
von Schuckmann et al., 2020

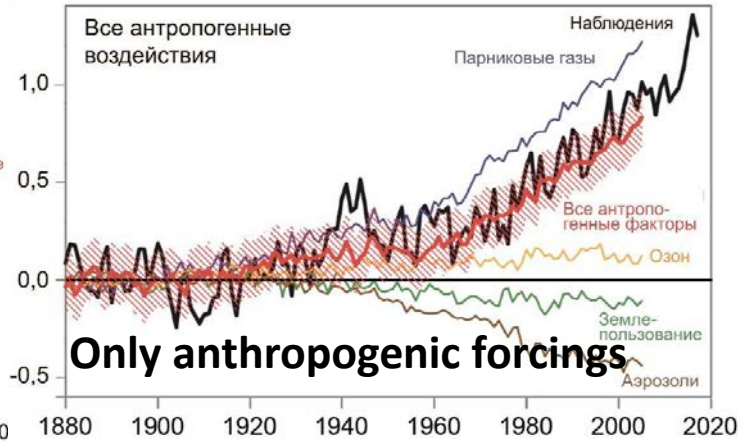
3. Lack of trends in the series of other factors of climatic variability

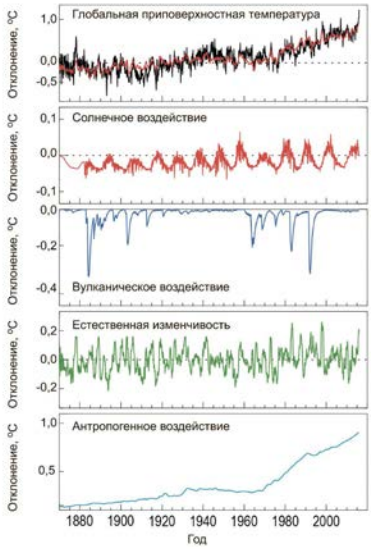


Warming attribution: climate model simulations

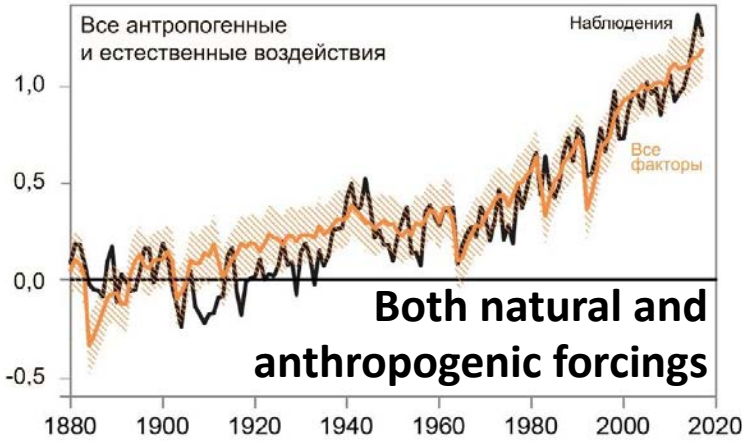
Failure of climate models to reproduce contemporary climate changes without taking into account anthropogenic forcing: emissions of greenhouse gases and aerosols, changes in land use.





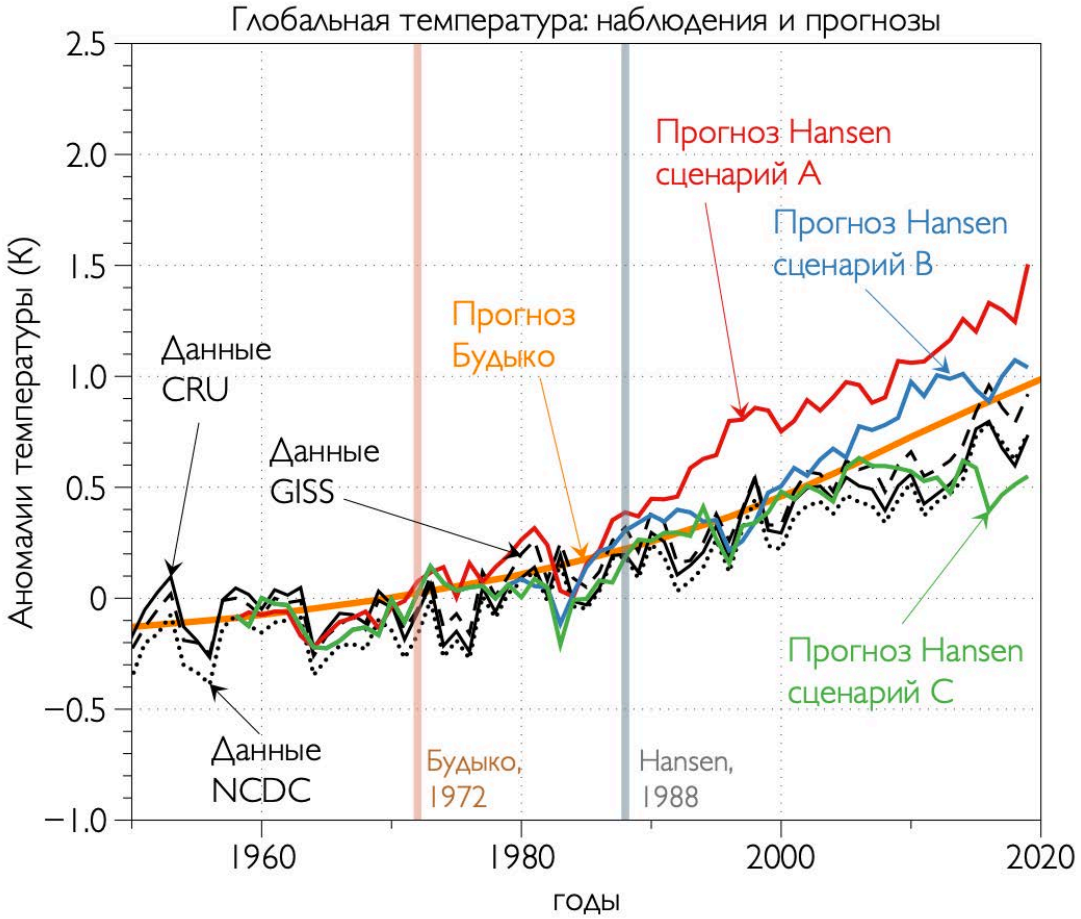


Global SAT based on model simulations with different forcings

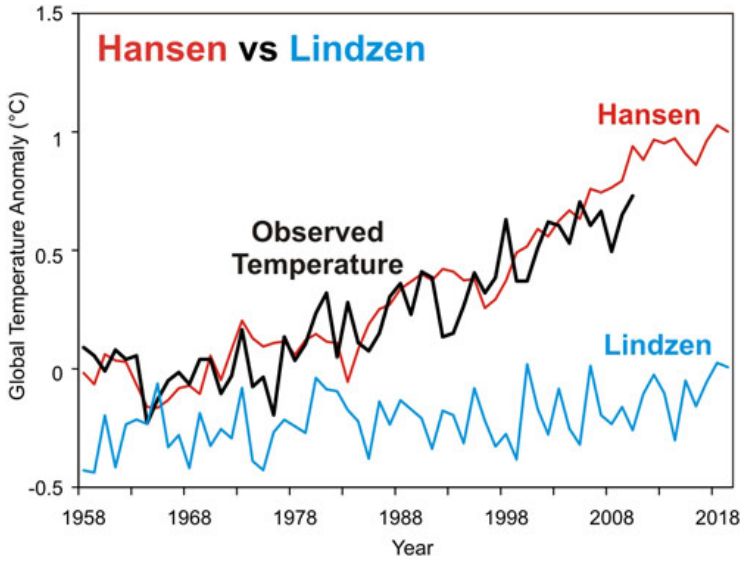


USGCRP, 2019

Do model predict recent warming?



The climate projection by Michael Budyko (1972), and three climate projections (with different scenarios) by Jim Hansen (1988) compare to observations



Hansen's (accounting for anthropogenic impact) and Lindzen's (denial of anthropogenic impact) climate projections

Climate change consequences

- Sea level rise (by 0.4–0.9 m by the end of the 21st cent.), storm surges increase.

Flooding of regions and entire countries, salinization of coastal areas, disappearance of islands, an increase in the number of refugees.

- Temperature warming, frequency of heat waves increase, aridity changes.

More people will live in extreme conditions; reduction of heating costs, increase in air conditioning costs.

- Changes in precipitation distribution: dry places will become even drier, humid - even more humid.

The impact on agriculture (positive only in the northern countries, in the world as a whole - negative), food security.

- Melting of glaciers, sea ice, permafrost.

Reduced access to fresh water, a problem for construction sites and infrastructure in the northern regions, access to the Arctic (northern sea-route, mineral resources).

- Increasing of ocean acidity, decreasing of oxygen content in sea-water.

Loss of marine ecosystems, decline in fish populations, decline in fisheries (increase in the Arctic).

- Increase in intensity and frequency of extreme weather events

Economic losses, an increase in the number of casualties.

The need for adaptation

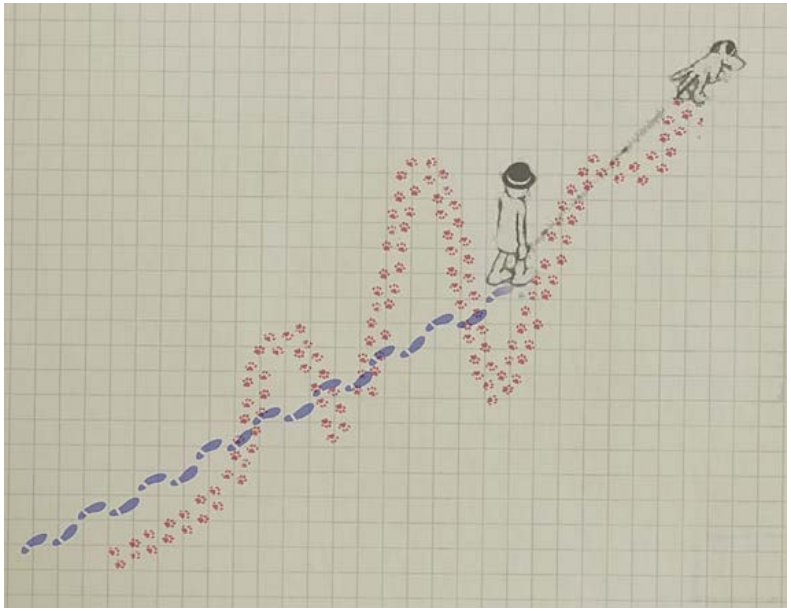
Key industries where adaptation is needed:

- Agriculture, food security and water resources
- Health care
- Energy industry, transport, construction, forestry, etc.

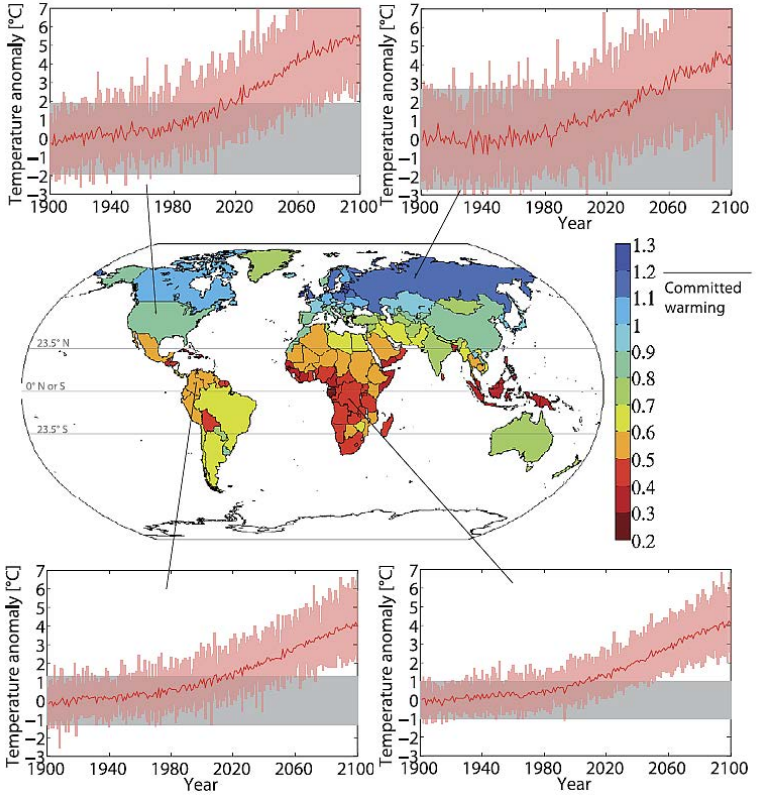
Key areas of adaptation:

- **Scientific tasks:** identifying risks, clarifying observations and model forecasts, improving the quality of warnings about extreme events, etc.
- **Social tasks:** informing and educating the population, behavioral capabilities, early warning systems, etc.
- **Technological tasks:** new varieties of plants, technologies for the protection of roads and facilities, protection of coasts, etc.
- **Institutional tasks:** financial incentives and insurance, legislative changes (e.g. building standards and practices), national and regional adaptation plans, etc.

Can we perceive the climate change?



People in their regular life are able to analyze weather changes, not climate changes. The more amplitude of weather changes, the harder to see climate change.



The expected year when the excess of the observed climatic anomalies will become obvious to the “man in the street” (the red line will leave the gray zone on the graphs for different regions)

Mahlstein et al., 2011

Problems of scientific communication

The British Embassy project:

Scientific and Public Expertise and dialogue on crucial Russian And woRldwide climatE issues - towards to COP26 (SPERARE)

The Round table "Promoting knowledge about climate: how to educate the population about the climate crisis in the face of uncertainty forecasts and postponed risks? " (16 October 2020, in the frame of the 4th Conference of science communicators)

The British-Russian round-table "COVID-19, climate, and environment: direct and indirect linkages" (9 or 16 December 2020) (Can the public response to the threat of a pandemic be a proxy indicator for assessing the public response to the threats associated with the climate change?)

Social polling with Levada-center on society awareness on climate changes and adaptation strategies (December 2020 – January 2021)