The Climate-Science Year in Review 2019

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What's New?

Students are protesting, politicians are talking (and starting to act), and what are the scientists up to? Is there anything left to say? Wasn't the climate change puzzle solved long ago?

Yes, we know much, but there's still plenty to be learned and understood, even for the scientists. Whether physicists, biologists, geoscientists, sociologists, economists or political scientists, scientists are still working tirelessly to deepen the understanding of the complex links between climate, weather and biosphere (plants and animals, the living part of the Earth system,). Scientists also ask themselves which economic and societal changes can contribute to a more sustainable way of life; and how can we ensure that these changes are both fair and just?

It is becoming increasingly clear that many risks associated with climate change have been *under*- rather than *over*estimated. Shifts in how the "planetary machinery" works are happening faster than expected.

What is this text?

This is of the Top-10 moments climate science 2019. The original, more comprehensive version[1] was prepared by Future Earth and the Earth League and presented at the 25th UN climate conference in Madrid (Conference of the Parties, COP25), and delivered to the negotiators. The aim was to provide a high-quality and up-to-date scientific basis for their decisions.

This version is shortened and enriched by text boxes referring to material explicitly designed for application in schools. This is not a "starter course in climate", but offers a selective spotlight on the most recent science. It can therefore be used as a primer on different topics within the field of climate change. The references to all statements in this document can be found in the comprehensive version[1].

10 New Insights in Climate Science 2019:

1. The world is not on track
2. Climate change is faster and stronger than expected
3. Climate change leaves no mountain summit behind
4. Forests are under threat, with global consequences
5. Weather extremes – a "new normal" in 2019
6. Biodiversity – the guardian of Earth's resilience is under threat
7. Climate change threatens food security and the health and wellbeing of hundreds of millions
8. Most vulnerable and poor hardest hit by climate change
9. Equity and equality pivotal to successful climate change mitigation and adaptation
10. Time may have come for social tipping points on climate action

[1] Pihl, E., Martin, M.A., Blome, T., Hebden, S., Jarzebski, M.P., Lambino, R.A., Köhler, C., Canadell, J.G., Ebi, K.L., Edenhofer, O., Gaffney, O., Rockström, J., Roy, J., Srivastava, L., Payne, D.R., Adler, C., Watts, S., Jacobsson, L., Sonntag, S., 10 New Insights in Climate Science 2019, Future Earth & The Earth League, Stockholm, 2019

1. The World is not on Track

Infrastructure like power plants, pipelines, roads etc. depend on energy to operate, and much of this comes from fossil fuels, which come from under-ground and contribute to greenhouse gas emissions. Power plants are often built to operate for many decades. If all existing and planned fossil-based infrastructure operates this long, it would result in twice as much CO_2 emissions as the world can afford, if we are to halt global warming at 1.5°C. Greenhouse gas emissions continue to grow, even though an increasing amount of money is being divested (drawn) from fossil fuels (especially coal) in many sectors. Fossil-fuel industries overall continue to grow, especially oil and gas.

In order to meet the climate goals it will most likely be necessary to not just reduce the emission of CO_2, but to remove CO_2 from the atmosphere that has already been emitted – but it is tied to big risks and high costs. Among possible strategies, "nature-based solutions" are the most promising (and least risky) ones: preserving forests, planting trees and agricultural techniques that trap CO_2 in the soil. But there are caveats. Firstly, an area 12 times the size of France would be needed to grow additional forests until 2100 in order to comply with the climate goals (and could therefore not be used for food production). Secondly, such plans must come in addition to reducing emissions and not as a substitute – otherwise things just don't add up in the end.

2. Climate change is faster and stronger than expected

The past five years are all among the warmest since recording began, and the warming continues. Some scientists warn that the rate of warming could become even faster. This would mean that we might cross the 1.5°C limit within about 10 years, long before the current estimate of 2040.

Sea levels are also rising faster than ever – even faster than the UN climate science panel, IPCC, predicted back in 2013. This means that floods, that statistically speaking, should only occur once every 100 years, could be happening every single year in many coastal cities by the time we hit 2050. Recent research has again confirmed that sea level will continue to rise for centuries, even if we start reducing emissions now. This is because sea water will continue to absorb heat and expand, and large masses of ice have a delayed reaction (i.e. melting) to warmer air and warmer seas.

In spite of all that knowledge, exact predictions like "X cm sea-level rise until year Y at location Z" remain difficult, because the now most important contribution to sea-level rise is caused by the melting of polar ice. Computer simulations that calculate how much ocean waters warm near the poles and how much the ice melts as a result are not yet precise enough. We can, however, do a good job of assessing the risks. If we continue on our current path, a globally averaged sea-level rise of 60-100cm until 2100 are expected. A child born today could very well live to see this situation.

IPCC – Summary for Teachers (OCE)

Summary for teachers based on the IPCC Special Report "Global Warming of 1.5°C"

Scientists in general, and especially climate scientists, often tend to be very conservative when assessing risks. At the same time, many of them agree that with bad luck (meaning that if the especially big risks, that we do not know enough about yet, are more probable than we can today know) mean sea-level rise could in principle be twice as large as the estimate mentioned above.

The situation is similar with the thawing of permafrost – ground that is normally frozen all year round – in the high North and in mountains. It is possible that the amount of greenhouse gases that are released due to permafrost thawing are higher than scientists have estimated.

3. Climate change leaves no mountain summit behind

Mountain glaciers, which feed into rivers, are enormously important because they contribute to the supply of clean drinking water for half the world's population. While in the coming decades more melt water is expected (and earlier in spring) due to increased and earlier melting worldwide, a decline is expected towards the end of this century. This also has consequences for the amount of water available for irrigation of agriculture. Except for on the poles, mountain glaciers were lost during the years 2006-2015 at a rate as if half a meter of the surface had been scraped off each year.

It is clear that climate change has already led to unprecedented redistribution and loss of native species of plants and animals, as local climates change and habitats disappear or transform. An important way to mitigate the consequences is – among many others - to pay attention to indigenous and local knowledge about nature, as well as to ensure a diversity of opportunities for local people to earn a living.

The climate in our hands - Ocean and Cryosphere (OCE)

Guide book supporting teachers in a range of activities on climate change and the ocean and cryosphere , targeting students of ages 9 to 15

4. Forests are under threat, with global consequences

Forests all over the world and the climate (global and regional) are interlinked through many different complex connections. Firstly, forests are an important carbon sink, because plants filter CO_2 from the atmosphere and use it to build stems, leaves etc. Almost one third of man-made CO_2 emissions from fossil fuels is reabsorbed by forests. Scientists also talk about a process called "CO_2 fertilization", by which plants grow faster when there is more CO_2 in the air. However, they probably do not live as long before releasing the stored carbon back into the atmosphere when they decay and are also limited in their growth by other factors (e.g. drought and the availability of phosphorus).

Secondly, forests are influenced by the local climate and its natural fluctuations, but are also themselves a decisive influencing factor! Here are some examples: Halving the forest cover in a tropical region can increase the mean temperature there by one degree. An irregular but strong natural climate fluctuation in the Pacific, called El Niño, changes weather patterns worldwide. In 2015-2016, this has dried out natural forests so strongly, that they could absorb much less CO_2 – the effect was so strong that it could be seen even when all absorption and release processes are summed up. At the same

The tropical rainforest (Medienportal Siemens Stiftung)

Interactive Whiteboard containing texts, pictures, videos and interactive elements. Can be used separately as well. For ages 6-10.

time, rainforests have earned their name: only through their existence, and the uptake of rainfall with later evaporation of water and further transport in clouds, can there be such lush vegetation as far inland as the Amazon.

Fighting deforestation and encouraging reforestation, along with sustainable forest management and other natural climate solutions are important and cost-effective options for reduced net emissions.

5. Weather extremes – a "new normal" in 2019

Many weather events that used to be called extreme (i.e. very unusual), now occur on a regular basis. When records are broken over and over again, this is a sign of a changing "normality". Heat waves as rare as those in Europe in the summer of 2019 would have been about 4°C cooler 100 years ago. This means that extreme heat today is hotter than it was a century ago.

Extreme weather is particularly dangerous when several of them come together - such as simultaneous drought and heat. In California, for example, where this combination then leads to air pollution and agricultural, property and even human losses due to fires, the probability of both occurring simultaneously has doubled in comparison to the second half of the 20th century.

The duration of an extreme event is also very important. For example, very short, heavy rainfall can trigger landslides, and prolonged periods of rain can contribute to flooding. But the way climate change exactly influences the duration of extremes varies among different regions of the planet.

And that influence is also very complex. For example, it is observed that the jet stream - a wavy wind stream that meanders around the northern hemisphere at an altitude of 11 km above the Earth - has increasingly often stalled in the same wave pattern in recent years. As a result, the weather situation in a certain location, whether cool or warm, does not change for a long time. This may lead to extreme weather in several places: a heat wave in one place and continuous rain or cold spells in another place. Scientists suspect that this is related to climate change and the particularly strong warming of the Arctic. The matter is still a subject of intense research.

There are also "extreme weather" conditions in the ocean. In just under 40 years, the number of days with "marine heat waves" has already doubled, and there are estimates that this number can increase by a factor of 23 for 2°C warming. Ocean heatwaves are killing coral reefs and reducing fish harvests.

6. Biodiversity – the guardian of Earth's resilience is under threat

The biodiversity of plants and animals is a crucial property of ecosystems. It strengthens the ability of ecosystems to cope with changes in the environment so that they can continue providing humans with services such as food, timber, clear air and water. Global warming has led to the extinction of species and loss of their habitat, which globally threatens the biodiversity on land and in the oceans. An increase in global temperature by just 1.5°C to 2°C would result in a substantial extinction of local species in individual ecosystems (although these species might still exist in other parts of the world).

The current emission trend, which would result in an increase in temperature by 4°C in 2100, could cause a local extinction of one third of the species and a loss of half of their original habitat.

Biodiversity is threatened by changes in human land use (e.g. agriculture), by fisheries and cutting of forests, and pollution, in addition to climate change. The interaction between these many factors can cause even more damage than the sum of each individually.

Not only warming air, but also warming oceans will affect biodiversity. Different species will react differently, which could influence marine life cycles: the annual food cycle of predator and prey populations for example, could be pushed out of its natural balance. Coral reefs are especially threatened by the warming and acidification of the oceans. An increase in temperature of 2°C would leave only 1% of the original extent of the coral reefs. This is alarming since coral reefs are a crucial part of many ecosystems, which sustain the livelihood of half a billion people.

7. Climate change threatens food security and the health of hundreds of millions

Two things are crucial for a healthy diet of the human population: Firstly, there must be enough food and secondly, the food must be good and nutritious.

Climate change affects food production in many places. Droughts in particular are critical, as they already cause more than 80% of the damage and food loss in agriculture today. Irrigation is not always possible and often there are other interests in the use of water: for example for power plants. In southeast Asia, where population growth has to be taken into account, even the "best case" scenario, which would mean an increase in global temperature of 1.5 to 2°C, would lead to food production per capita decreasing by one third.

Natural forces: Erosion (Medienportal Siemens Stiftung – Experimento)

Experiment about erosion – for children from 4-7 years.

Food quality is important because even today almost half of the child mortality below five years of age is caused by a lack of micronutrients like iron and zinc. Children who experience severe malnutrition may have to live with lifelong damages to their health: whether due to growth deficiencies, diseases like diabetes or even brain damage. An increase in CO_2 in the air can accelerate plant growth (the CO_2 fertilization mentioned earlier) but also decreases the nutritional value of important grain varieties, including rice.

In its special report on climate change and land use, the IPCC warned that the occurrence of toxins caused by mold, so-called mycotoxins, which also survive the processing of plants into food, could triple in north-western Europe in the coming decades as temperatures go up. The problem is now most severe in Africa. Such poisoning can cause immune deficiencies or cancer in the long term.

8. *Most vulnerable and poor hardest hit by climate change*

Increasing and intensifying droughts, floods and heat waves will increase poverty and vulnerability in the Global South. Vulnerability describes the susceptibility of a society or region that is particularly affected by global warming, and unable to cope with adverse effects. Poor states in particular are very vulnerable, but inhabitants of rich states living in poverty are vulnerable as well. Hundreds of millions of people and large regions of the world are exposed to the consequences of climate change without having the necessary resources and capacities to do anything about it.

Vulnerability and poverty depend on each other. 100 million people are at immediate risk of falling below the UN poverty line of 1.9 dollars a day in 2030 if no climate protection measures are taken. Inadequate climate protection measures will lead to malnutrition and a shortage of clean drinking water by 2050. An additional challenge to coastal locations and cities is posed by sea-level rise.

Migration generally has multiple causes and often there is not one single reason for a person's decision to move. Initial estimates using computer models suggest that due to climate change between 31 and 143 million people in Sub-Saharan Africa, South Asia and Latin America will have to find a new home within their countries by 2050. This is roughly equivalent to the combined populations of Venezuela (32 million), Germany (82 million) and Italy (59 million). Sea-level rise especially threatens countries in Asia, where many people live very close to the coast.

9. *Equity and equality pivotal to successful climate change mitigation and adaptation*

The abolition of coal subsidies (i.e. funding for coal mining) and the introduction of a CO_2 price (putting an additional price on everything that releases CO_2) are examples of suitable political action to fight climate change. However, the success or failure of climate policy depends on whether people accept it. Studies show that fairness and trust in government, as well as the effectiveness and efficiency (relating efforts to outcomes) of policy measures are very important for this. Measures that are perceived as socially unjust can provoke protests like the yellow vests movement in France. Profound reform efforts and transformations must therefore be communicated openly and transparently, discussed and developed discursively, and be inclusive and socially just.

If there is no political control over climate change and its effects, inequality among people will continue to rise. The basic rules for fair and just climate policy must be negotiated with all parts of society, because there is no universal solution that suits everyone. Climate protection measures must be adapted to local conditions so as not to exclude rural areas that are remote from the places where the big policy is made. Politicians must consider intergenerational justice, recognizing that future generations have the right to an intact natural environment and must live with the lifelong consequences of climate change.

How can we act? (OCE)

Multimedia activity, displaying actions that have been or are being carried out around the world to address climate change issues.

10. Time may have come for social tipping points on climate action

What is a social tipping point? It is the moment when large-scale social patterns and behaviour development embark on a fully new path. In the context of climate change, this could mean that social, economic and political changes combine and reinforce in such a way that the $C0_2$ emissions stop to increase and start to fall, turning from fossil fuels to renewable energy and from meat-eating to plant-based diets - in other words, the moment when *de*carbonization of our way of life begins on a massive scale. These and many other profound and long-lasting radical changes are necessary to meet the goals of the Paris Climate Convention of 2015 and the Sustainable Development Goals (SDGs) of the United Nations.

A democratic transformation cannot start if the people merely change their habits of consumption. They need to understand their strategic and political power as citizens. Historical studies suggest that only 3.5% of the population need to assemble in non-violent resistance to create system change, even when it requires bringing down a brutal dictatorship. Indeed, non-violent protest is generally more effective than violent protest. Actual changes of habit by at least a quarter of the population are necessary in order for the transformation to pervade the whole system or society.

An analysis of the German arm of the Fridays-for-Future movement - an international, independent and decentralized organized climate-strike movement - shows that activism by young people influences not only politics, but also parents, who can then influence the political process. Such movements show that education on climate change, which is much more present in schools today than it was twenty years ago, is now a force within social dynamics.