KEYNOTE ADDRESS: THE BASIS OF CLIMATE CHANGE

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To understand the reasons and mechanisms behind climate change, it is crucial to recognize the role played by the atmosphere. The atmosphere is a complex system where various chemical, thermodynamic, and fluid dynamics processes occur. It's important to note that the atmosphere is not uniform; it becomes less dense as it extends from the Earth. Most of the mass of the atmosphere is within 30 km from the Earth's surface, and its fluid properties constantly change with time and location. This variability in the atmosphere is what we call "weather." Weather phenomena occur mostly within the first 10 km of the atmosphere. The lower edge of what could be considered outer space is approximately 100 km above the Earth's surface. However, the atmosphere extends to an altitude of about 10,000 km, into outer space.

So, What Do We Define as Weather?

Weather is the state of the atmosphere at a particular place during a short period of time. There are six main characteristics of weather, very well known to all. These are the temperature, atmospheric pressure, wind, humidity, precipitation/rain-snow, and cloudiness.

What Do We Define as “CLIMATE”?

The Earth’s climate is a complex dynamic system.

Climate is defined as an area's long-term weather patterns. The simplest way to describe climate is to look at average rainfall, temperature, snow, or any other weather condition over time. ***We usually define a region’s climate over a period of 30 years.***

Comparing weather and climate, we can say that weather changes over a short period of time, which can range from a few minutes to hours or even a few days. This is reported as a "**forecast**". Climate, on the other hand, takes a much longer time to change over a region, often measured in years. There are two main factors that determine climate: the energy coming from the Sun and the interaction between

different components of the Earth system. These components include atmospheric, oceanic, biological, and geological processes, which are all linked together within a vast number of nested subsystems. These subsystems are the Biosphere, Hydrosphere, Cryosphere, and Lithosphere, that drive the climate system and result in regional variations of climate. The atmosphere links all of these vital subsystems.

Climate change refers to alterations in the weather patterns, as well as changes in oceans, land surfaces, and ice sheets. These changes have a lasting impact on the local, regional, and global climates of the Earth and occur over periods of decades or even longer. **Human activities**, particularly the emission of greenhouse gases from burning fossil fuels, deforestation, and changes in land use, are the main drivers of climate change that we have observed in the industrial era. However, both natural processes and human activities can cause climate change.

Climate variability is a natural phenomenon that occurs due to the interaction of various climate components like the atmosphere, ocean, and sea ice. There are three main causes of **internal climate variability**. *Firstly*, the ocean circulation plays a crucial role in regulating the climate by storing and transporting heat, carbon, nutrients, and freshwater around the world. *Secondly*, the ocean and atmosphere form a complex coupled system and work together by exchanging gases, water (including water vapor), particles, momentum, and energy at the air-sea interface. These exchanges affect the physical, chemical, and biological processes of the ocean and influence the weather, water cycle, and climate. *Thirdly*, life itself, including all plants, humans, and animals, can also cause internal climate variability. **External forcing** is another type of natural cause of climate change. This refers to climate forcing agents that impact the climate system while being outside of the climate system itself. Examples of external forcing include the emissions of greenhouse gases, variations in the solar output, orbital variations of the Earth, and plate tectonics.

Let's discuss how **natural causes** such as shifts and wobbles in the Earth's orbit can affect the climate. The Earth makes a full orbit around the sun each year, tilted at an angle of 23.5° to the perpendicular plane of its orbital path. Even small changes in the tilt of the Earth can lead to important changes in the “strength” of the seasons and temperature. More tilt means warmer summers and colder winters, while less tilt means cooler summers and milder winters. Slow changes in the Earth's orbit over tens of thousands of years can lead to significant changes in the strength of the seasons. Climate feedbacks amplify these small changes, which can result in ice ages. Now, let's talk about how the Sun can trigger climate change. The Sun is a hot sphere of gases where nuclear reactions take place within its core, producing vast amounts of energy. The Sun is the primary source of energy for the Earth's climate system. Although the Sun's energy output may appear consistent from an everyday perspective, small changes over a long period can lead to significant

climate changes. As the Sun is the fundamental source of energy that drives our climate system, it's reasonable to assume that changes in the Sun's energy output would cause the climate to change. Scientific studies have revealed that solar variations have played an essential role in past climate changes. For instance, the Sun was "quiet" for an extended period, resulting in a solar output decrease. This decrease is believed to have triggered the Little Ice Age, which peaked in the 17th and early 18th centuries and was characterized by extremely severe winters that arrived early and lasted well into spring.

Volcanic eruptions can also cause natural climate changes. Though they may last for only a few days, their effects can influence climate patterns for years. The principal impact of volcanic eruptions on climate is short-term cooling. This is because they release clouds of ash and dust that block out some sunlight. These ash particles are relatively heavy and fall to the ground within three months, so their cooling effect is short-lived. However, volcanic debris also contains sulfur dioxide, which combines with water vapor and dust in the atmosphere to form sulfate aerosols. These aerosols are lighter than ash particles and can remain in the atmosphere for a year or more. They reflect sunlight away from the Earth's surface, resulting in a cooling effect that outweighs the warming caused by volcanic greenhouse gases. For instance, the Mount Pinatubo eruption in 1991 caused a 0.5°C drop in global temperature. Although volcanic eruptions emit lava, carbon dioxide, ash, and particles, their average CO2 emissions are less than 1-2% of emissions from current human activities. The release of large volumes of gases and ash can influence climatic patterns for years, by increasing planetary reflectivity, which causes atmospheric cooling.

The greenhouse effect is a natural process that helps keep the Earth's temperature stable and suitable for life. Greenhouse gases like carbon dioxide, methane, water vapor, and nitrous oxide occur naturally in the atmosphere in low concentrations. When the Sun's energy enters the atmosphere, some is reflected back by the clouds and the Earth's surface. However, the greenhouse gases absorb some of this energy and warm up the atmosphere, much like a blanket. Without the greenhouse effect, the average temperature of the Earth would be about -18 degrees Celsius, and life as we know it would not exist. However, human activity has increased the concentration of greenhouse gases in the atmosphere, mainly through the burning of fossil fuels. This increase in greenhouse gases is causing the Earth's temperature to rise, which is leading to climate change. Carbon dioxide is the primary greenhouse gas responsible for climate change, and its concentration in the atmosphere has increased by 40% since pre-industrial times. Other greenhouse gases, such as methane, are even more potent than CO2, and their concentration is also increasing. Therefore, while the greenhouse effect is essential for life, the excessive release of greenhouse gases by humans is causing significant environmental problems and needs to be addressed.

Deforestation and human activities, such as manufacturing, industry, transport, and agriculture, are major sources of greenhouse gas emissions. Deforestation refers to the permanent removal of trees for various purposes, including agriculture, grazing, or using timber for fuel, construction or manufacturing. Trees absorb carbon dioxide (CO2) from the atmosphere, and when they are cut down, they release all the carbon stored in them into the atmosphere, adding to the greenhouse effect. Deforestation, logging, clear-cutting, fires, and other forms of forest degradation contribute up to 20% of global carbon emissions. Greenhouse gases are also released by human activities, such as fertiliser use, livestock production, transportation, and energy generation from burning fossil fuels like coal, oil, and gas. Road vehicles are the largest contributors of greenhouse gases, followed by ships and airplanes. In fact, transportation accounts for almost one quarter of global energy-related carbon-dioxide emissions. Coal mining also releases methane (CH4), a potent greenhouse gas. Manufacturing and industry are also significant contributors to greenhouse gas emissions, mostly from burning fossil fuels to generate energy for producing cement, iron, steel, electronics, plastics, clothes, and other goods. Generating electricity and heat by burning fossil fuels also causes a large amount of global emissions. The transport and energy sectors are responsible for the highest greenhouse gas emissions in the European Union (EU), and the EU has committed to reducing its greenhouse gas emissions by more than half by 2030. Since 1991, the production of greenhouse gases has reduced by around 30% in the EU, mainly due to imposed rules in the industry. Each European member state must report its annual emissions to ensure compliance with the reduction targets.

What is the Evidence of Climate Change?

Climate change is believed to be caused by human activities. The levels of carbon dioxide (CO2) concentrations in the atmosphere have increased over the last 800,000 years. Pre-industrial CO2 levels were around 280 parts per million (ppm), but today we are close to 420 ppm. Scientific findings show that concentrations of carbon dioxide, methane, and nitrous oxides have reached unprecedented levels in at least the last 800,000 years. The estimated levels of CO2 from 500 million years ago during the Ordovician period are the most distant in time. Carbon dioxide from human activities is increasing about 250 times faster than it did from natural sources after the last Ice Age. The last glacial period lasted from about 100,000 years ago until 25,000 years ago, and today we are in a warm interglacial period.

There is overwhelming proof that the Earth is undergoing a rapid warming process. It is an undeniable fact that human activities have led to the release of greenhouse gases that have trapped more of the Sun's energy in the Earth's system. This increased energy has caused warming of the atmosphere, ocean, and land, leading

to significant changes in the atmosphere, ocean, cryosphere, and biosphere. Thanks to Earth-orbiting satellites and new technologies, scientists are now able to collect many different types of information about our planet and its climate, revealing the signs and patterns of a changing climate. The heat-trapping nature of carbon dioxide and other gases was demonstrated by scientists in the mid-19th century, and there is no question that increased greenhouse gas levels are responsible for warming the Earth in response to their measured impacts.

The planet's average surface temperature has risen by 1 degree Celsius since the late 19th century. This change is primarily due to increased greenhouse gas emissions into the atmosphere. Most of the warming has happened in the past 40 years, with the last seven years being the warmest. Heat has been absorbed by the ocean, with the top 100 meters of ocean showing warming of 0.33 degrees Celsius since 1969. The Greenland and Antarctic ice sheets have lost mass, with Greenland losing an average of 279 billion tons of ice per year between 1993 and 2019, and Antarctica losing about 148 billion tons per year. Glaciers around the world, including in the Alps, Himalayas, Andes, Rockies, Alaska, and Africa, are retreating. Satellite observations show that spring snow cover in the Northern Hemisphere has decreased over the past five decades, and the snow is melting earlier. Climate change is causing our oceans to warm and glaciers to melt, resulting in sea level rise. The extent and thickness of Arctic sea ice have declined rapidly over the last few decades. Extreme weather events are happening more frequently and can have far-reaching impacts on communities, causing critical system failures. The impacts of extreme events are not confined to the place where they occur and can cause a sequence of climate hazards that cover large regions, such as flooding, droughts, and wildfires.

"**Is it possible to reverse global warming**?" is a question that may arise. If we completely stop all global net emissions, the warming that we've caused will gradually begin to reverse. However, it may take several decades for this to happen. Unfortunately, other changes induced by climate change will persist for decades, if not centuries. For instance, the rise in sea levels will likely take thousands of years to reverse its course.

The younger generation needs to be equipped with knowledge and critical thinking skills to effectively handle the inevitable obstacle of climate change and its impacts. Education plays a crucial role in the urgent global fight against climate change. Providing knowledge to children regarding climate change can help them in the following ways:

1) Understand the magnitude of the problem and deal with the consequences of global warming.
2) Motivate them to modify their daily activities and lifestyle to reduce the effects of climate change.

3) Enable them to adapt to the global emergency that is already upon us.

Teaching climate science and raising awareness about climate change in schools is a crucial step in combating climate change in the upcoming years. Today's youth will eventually become the decision-makers and policy-makers of tomorrow, and it is therefore their responsibility to shape a brighter future for humanity.

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