Global Warming and the Role of Physics in its Reduction - An Empirical Study

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Abstract

This paper investigates the role of physics especially thermodynamics, is at the heart of Global Warming. Global warming is the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere. The term is frequently used interchangeably with the term climate change, though the latter refers to both human- and naturally produced warming and the effects it has on our planet. It is most commonly measured as the average increase in Earth's global surface temperature. Physics lies at the core of the earth sciences. It is essential for understanding the deep structure of Earth and the natural phenomena that affect Earth's surface, such as earthquakes and volcanic eruptions. These topics, along with others aspects of the physics of Earth.

Physics also provides a basis for understanding the dynamic interactions between the atmosphere and the oceans and for the study of short-term weather and long-term climate change. This understanding is essential to stewardship of the environment: for addressing problems like urban air pollution and lake acidification and for dealing with natural hazards such as floods and hurricanes.

Much of physics is the study of energy and its transformation, and energy lies at the heart of important environmental issues. Climate is shaped by how the energy of the Sun affects movement of the atmosphere and oceans and how they in turn distribute energy around the world. Most of the impact of humans on the environment revolves around the need for energy production.

To understand the complexities of the environment and to address problems effectively, the underlying physics must be combined with chemistry, geology, atmospheric and oceanic science, and biology. The ocean-atmosphere system, environmental monitoring and improvement, and energy production and the environment are three areas where an understanding of the basic physics has played a central role and where it is crucial for further progress.In the years ahead, a continuing improvement in our understanding of the remarkable concentration of energy involved in severe weather patterns causing ***Global Warming***.

This progress will come from a combination of theoretical modeling, computer simulation, and direct measurement, each drawing on the tools of physics and each conducted by researchers schooled in the methods of physics. At that stage of understanding, it was thought that variability in the oceans and variability in the atmosphere were relatively independent of each other on time scales shorter than decades.

Key words: Global Warming. theoretical modeling, computer simulation, environmental monitoring

Introduction

Until the 1980s, atmospheric science had concentrated on the theory and practice of weather forecasting, which involved a time scale of 6 to 10 days. Weather forecasting was based on an understanding of the prevailing instability of large-scale, mid-latitude phenomena resulting from an analysis of the Navier-Stokes fluid dynamic equations. In the oceans, meanwhile, the emphasis was on attempting to understand the physical processes that accounted for mass and heat transport in cases such as the Gulf Stream and the circulations of the ocean basins. More recently, it has been realized that the ocean and the atmosphere are coupled on much shorter time scales. Climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates. These changes have a broad range of observed effects that are synonymous with the term.

Changes observed in Earth's climate since the early 20th century are primarily driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature. These human-produced temperature increases are commonly referred to as global warming. Natural processes can also contribute to climate change, including internal variability (e.g., cyclical ocean patterns like El Niño, La Niña and the Pacific Decadal Oscillation) and external forcings (e.g., volcanic activity, changes in the Sun's energy output, variations in Earth's orbit).

Scientists use observations from the ground, air and space, along with theoretical models, to monitor and study past, present and future climate change. Climate data records provide evidence of climate change key indicators, such as global land and ocean temperature increases; rising sea levels; ice loss at Earth's poles and in mountain glaciers; frequency and severity changes in extreme weather such as hurricanes, heatwaves, wildfires, droughts, floods and precipitation; and cloud and vegetation cover changes, to name but a few.

This realization emanated from the developing understanding of the El Niño phenomenon in the Pacific Ocean. A series of positive and negative feedbacks between the ocean and the atmosphere create this phenomenon, an oscillation on a grand scale, which is responsible for an instability of the climate system in the Pacific region. The understanding of this phenomenon, which rests on the joint fluid dynamics of the ocean and the atmosphere, suggests a predictability in the climate system. Predictability has been demonstrated not only on the weather time scale of 6 to 10 days but also on an interannual time scale of 6 months to 1 or 2 years, the time scale of the El Niño-coupled ocean-atmosphere instability. Since the pioneering work on the El Niño phenomenon, it has been shown that the great monsoon systems of the planet are also coupled ocean-atmosphere phenomena on the same time scale, so that their evolution depends on the same joint dynamics and thermodynamics of the atmosphere and ocean.

Objective:

This paper deals with global warming and the role of physics, The heart of the solution is replacement of every technology that causes emission of greenhouse gases, preferably at lower cost.

ENVIRONMENTAL MONITORING AND IMPROVEMENT

An ever-larger fraction of the environmental challenges facing humankind consists of problems requiring better management of human activity to reduce its deleterious impact on natural systems. Problems of this kind arise with increasing frequency because of the larger and more prosperous human population. But they can also be addressed with greater success because of our deeper understanding of the affected systems and an improved capacity. to detect the impact of human beings. These kinds of problems come at all scales: from an individual room whose air is degraded by radon or organic pollutants, to an urban airshed subject to the buildup of pollutants intensified in particular seasons, to the global stratosphere, whose chemical composition is being altered by chlorofluorocarbons and nitrogen oxides.

The discovery of the destruction of stratospheric ozone by chlorofluorocarbons is a classic example of the use of physical science to understand how human beings change a natural system. Working out the details of this problem has involved a blend of the chemistry of heterogeneous reactions and the physics of fluids and radiation transport.

Global warming is partly a consequence of altering the carbon cycle on the planet by the burning of fossil fuels. The increase of carbon dioxide appears to foster the growth of other greenhouse gases by alteration of the global hydrological cycle. An understanding of global warming and the associated climate change draws on a number of disciplines. Geophysical fluid dynamics is necessary to understand the structure of the basic climate system within which these climate changes occur. At the same time, chemical and biochemical cycles are active partners in the dynamics and thermodynamics of the climate system.

Effective management of human interaction with an environmental system requires simultaneous progress on several fronts: an understanding of the system in the absence of human impact; an understanding of the way human impact changes the system; and an understanding of measures available to reduce this impact, such as substituting one form of energy production for another. Much progress has been made over the past few decades in understanding the workings of those environmental systems that are particularly vulnerable to human impact, ranging from the thermal behavior of lakes to the chemistry of the stratosphere. Many of these systems are now well understood, through a combination of measurement, modeling, simulation, and theory.

One of the best tools for measuring human impact on climate is the identification of small concentrations of tracer atoms in environmental samples. Various long-lived radioactive nuclei serve as such tracers in much the same way that short-lived radioactive nuclei serve as tracers for the study of biological systems. The use of these tracers has grown out of the understanding of the formation of radioactive elements and their decay and detection. This method for environmental monitoring has become increasingly important as ever more sensitive detection techniques are developed (see sidebar "Monitoring the Environment").

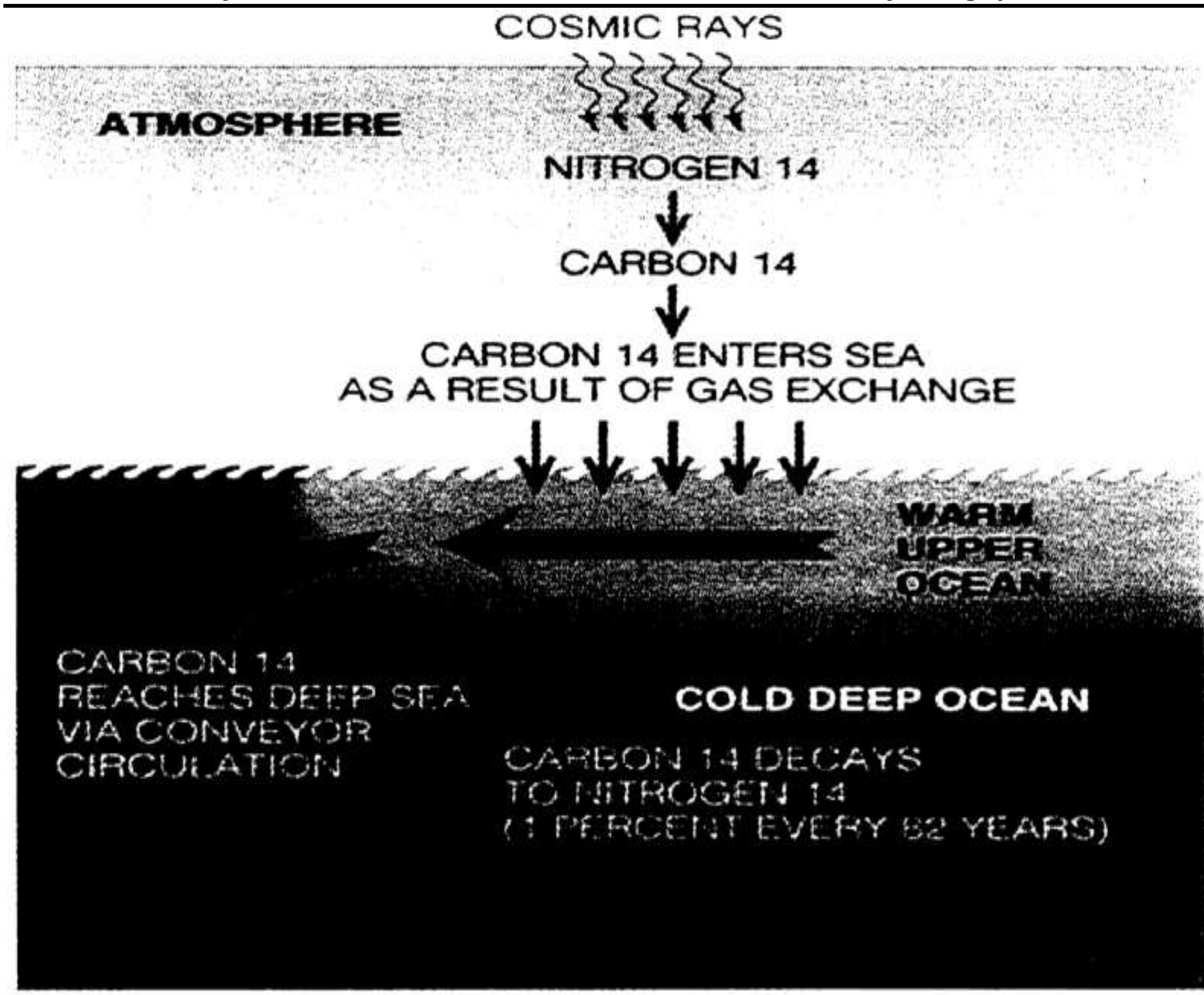
MONITORING THE ENVIRONMENT

Accelerator mass spectrometry (AMS) is an important tool for environmental measurements. AMS uses nuclear techniques to accelerate and identify small concentrations of tracer atoms in environmental samples. Measurements that would otherwise be difficult or impossible are made routine by its sensitivity.

Cosmic rays from elsewhere in the galaxy continually bombard Earth's atmosphere and surface, producing long-lived radioactive “cosmogenic nuclei.” Because carbon in organic objects is not replenished from the atmosphere once an animal or plant dies, the ^{14}C present decays with a 5700-year half-life, and the amount remaining provides a measure of the object's age. Other cosmogenic nuclei can be used in a similar manner to determine how long material that contains them has been shielded from cosmic rays and from the atmosphere. The concentration of the long-lived isotope ^{81}Kr in an aquifer of the Great Artesian Basin in Australia is measured and used to determine how long its water has remained uncontaminated by younger groundwater.

Cosmogenic nuclei are used to study large-scale environmental phenomena. The amount of ^{10}Be in ice cores has been measured by AMS and is found to be correlated with solar activity. This correlation may allow studies of solar activity backward 10,000 years in time, compared to the 400-year record currently available. It may then be possible to determine to what degree solar variation is responsible for climate variation.

Other AMS measurements are devoted to understanding the nature of oceanic circulation, which has a major influence on climate. If northward-flowing currents in the Atlantic were to cease, the temperature in northern Europe would decrease by 5 °C to 10 °C. There is a concern that increasing greenhouse gases could initiate such a change. Measured concentrations of oxygen isotopes in Greenland ice cores show that large changes were common near the end of the last ice age. Dating of organic glacial remains in New Zealand using ^{14}C indicates that these large changes were global in nature.



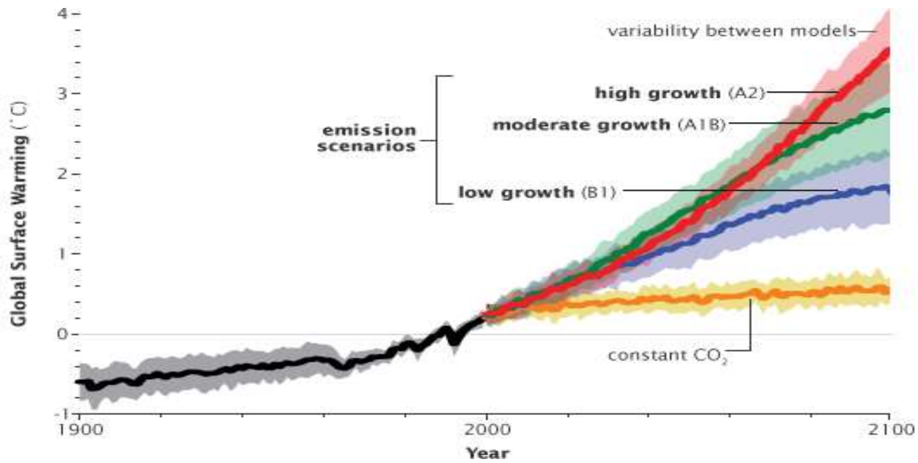
As cold, salty water sinks to great depths, as shown above, it carries radioactive ^{14}C out of the atmosphere and into the abyss, where it slowly decays. Radiocarbon dating is used to measure the state of the oceanic current system.

To further explore the causes and effects of global warming and to predict future warming, scientists build climate models—computer simulations of the climate system. Climate models are designed to simulate the responses and interactions of the oceans and atmosphere, and to account for changes to the land surface, both natural and human-induced. They comply with fundamental laws of physics—conservation of energy, mass, and momentum—and account for dozens of factors that influence Earth's climate.

Global warming in physics perspective

Though the models are complicated, rigorous tests with real-world data hone them into powerful tools that allow scientists to explore our understanding of climate in ways not otherwise possible. By experimenting with the models—removing greenhouse gases emitted by the burning of fossil fuels or changing the intensity of the Sun to see how each influences the climate—scientists use the models to better understand Earth's current climate and to predict future climate.

The models predict that as the world consumes ever more fossil fuel, greenhouse gas concentrations will continue to rise, and Earth's average surface temperature will rise with them. Based on a range of plausible emission scenarios, **average surface temperatures could rise between 2°C and 6°C by the end of the 21st century.**



The largest feedback is water vapor. Water vapor is a strong greenhouse gas. In fact, because of its abundance in the atmosphere, water vapor causes about two-thirds of greenhouse warming, a key factor in keeping temperatures in the habitable range on Earth. But as temperatures warm, more water vapor evaporates from the surface into the atmosphere, where it can cause temperatures to climb further.

The question that scientists ask is, how much water vapor will be in the atmosphere in a warming world? The atmosphere currently has an average equilibrium or balance between water vapor concentration and temperature. As temperatures warm, the atmosphere becomes capable of containing more water vapor, and so water vapor concentrations go up to regain equilibrium. Will that trend hold as temperatures continue to warm?

The amount of water vapor that enters the atmosphere ultimately determines how much additional warming will occur due to the water vapor feedback. The atmosphere responds quickly to the water vapor feedback. So far, most of the atmosphere has maintained a near constant balance between temperature and water vapor concentration as temperatures have gone up in recent decades. If this trend continues, and many models say that it will, **water vapor has the capacity to double the warming caused by carbon dioxide alone.**

On land, changes in the carbon cycle are more complicated. Under a warmer climate, soils, especially thawing Arctic tundra, could release trapped carbon dioxide or methane to the atmosphere. Increased fire frequency and insect infestations also release more carbon as trees burn or die and decay.

On the other hand, extra carbon dioxide can stimulate plant growth in some ecosystems, allowing these plants to take additional carbon out of the atmosphere. However, this effect may be reduced when plant growth is limited by water, nitrogen, and temperature. This effect may also diminish as carbon dioxide increases to levels that become saturating for photosynthesis. Because of these complications, it is not clear how much additional carbon dioxide plants can take out of the atmosphere and how long they could continue to do so.

The impact of climate change on the land carbon cycle is extremely complex, but **on balance, land carbon sinks will become less efficient** as plants reach saturation, where they can no longer take up additional carbon dioxide, and other limitations on growth occur, and as land starts to add more carbon to the atmosphere from warming soil, fires, and insect infestations. This will result in a faster increase in atmospheric carbon dioxide and more rapid global warming. In some climate models, carbon cycle feedbacks from both land and ocean add more than a degree Celsius to global temperatures by 2100.

Emission Scenarios

Scientists predict the range of likely temperature increase by running many possible future scenarios through climate models. Although some of the uncertainty in climate forecasts comes from imperfect knowledge of climate feedbacks, the most significant source of uncertainty in these predictions is that scientists don't know what choices people will make to control greenhouse gas emissions.

The higher estimates are made on the assumption that the entire world will continue using more and more fossil fuel per capita, a scenario scientists call "business-as-usual." More modest estimates come from scenarios in which environmentally friendly technologies such as fuel cells, solar panels, and wind energy replace much of today's fossil fuel combustion.

It takes decades to centuries for Earth to fully react to increases in greenhouse gases. Carbon dioxide, among other greenhouse gases, will remain in the atmosphere long after emissions are reduced, contributing to continuing warming. In addition, as Earth has warmed, much of the excess energy has gone into heating the upper layers of the ocean. Like a hot water bottle on a cold night, the heated ocean will continue warming the lower atmosphere well after greenhouse gases have stopped increasing.

These considerations mean that people won't immediately see the impact of reduced greenhouse gas emissions. **Even if greenhouse gas concentrations stabilized today, the planet would continue to warm by about 0.6°C over the next century** because of greenhouses gases already in the atmosphere.

ENERGY PRODUCTION AND THE ENVIRONMENT

Improvements in energy efficiency contribute directly to environmental quality, and many of these improvements are applications of physics. Lighting efficiency has increased dramatically, progressing from the kerosene lamp to the incandescent bulb to the fluorescent light. Window thermal resistance, with its direct effect on the energy required for space heating and cooling, has been greatly increased by the use of thin-film coatings that embody insights from atomic physics. The oxygen sensor in the automobile exhaust, which permits far lower emissions of hydrocarbons, carbon monoxide, and nitrogen oxides, is another application of physics. Metal recycling is also in this category: The increasing competitiveness of secondary metals production, or recycling, relative to primary metals production resurfed in part from numerous innovations in materials science.

The substitutability and attractiveness of alternative forms of energy production are also important. Fossil fuels inevitably produce carbon dioxide as a by-product of energy extraction. The two principal alternatives are nuclear power (both nuclear fission and nuclear fusion) and renewable energy (in many forms, including wind, hydropower, photovoltaic cells, and solar thermal energy). Research and development efforts on all of these alternative technologies are under way around the world. Each has its strengths and weaknesses. The sustainability of industrialized society is much more likely if humanity continues to pursue a broad portfolio of energy production options.

As long as fossil fuels continue to dominate energy production, the global energy system will require the sophisticated management of carbon. Carbon management strategies are already being considered and are attracting the attention of physicists around the world. An important class of strategies involves separating the carbon content from the energy content of fossil fuels by chemically processing the fossil fuels into carbon dioxide and hydrogen. The carbon dioxide would be treated as a waste product requiring sequestration from the atmosphere; for example, it might be piped to deep underground saline aquifers. The world would run its vehicles and buildings and appliances and factories on some combination of electricity and hydrogen, the two most environmentally preferred secondary energy carriers. The challenge of making a hydrogen economy safe and affordable will demand much progress in areas where physics is indispensable, ranging from molecular strategies for hydrogen storage to advanced materials for hydrogen fuel cells.

Conclusion

Throughout its long history, Earth has warmed and cooled time and again. Climate has changed when the planet received more or less sunlight due to subtle shifts in its orbit, as the atmosphere or surface changed, or when the Sun's energy varied. But in the past century, another force has started to influence Earth's climate: humanity. Environmental science is highly interdisciplinary. The life sciences, chemistry, applied mathematics, geology, oceanography, and physics are all front and center. Physics plays a broad role, contributing directly to energy production and environmental projects and indirectly through basic research, providing technological spin-offs from research programs, and helping to educate a technically literate population capable of responding to environmental issues. Basic research in atmospheric and oceanic physics provides the foundation.

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