Cooling the Climate

How to Revive the Biosphere and Cool the Earth Within 20 Years

By

Peter Bunyard and Rob de Laet

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Acknowledgements

This book is the culmination of years of research, and countless conversations about the most pressing challenge of our time: the existential crisis facing humanity. Our concern for the future of humanity started in the 1960's for Peter and for Rob in the 1970's. This book was written by Peter Bunyard and Rob de Laet based on a publication that Peter first wrote in 2010.

We are standing on the shoulders of many brilliant and passionate people, some of whom hover over this book in spirit, such as the great scientist James Lovelock, and the Aborigine leader Guboo Ted Thomas, a crucial mentor for Rob.

A special thank you goes to the founders of Climate Change and Consciousness, Stephanie Mines, the chairperson of Biology for a Livable Climate, Philip Bogdonoff and the co-founder of EcoRestoration Alliance, Jon Schull and members of the EcoRestoration Alliance.

Last and not least, we want to express deep gratitude to Nature and Mother Earth, for giving us the greatest gift of all, Life. What a Wonderful Journey it is! ''You may say I'm a dreamer, But I'm not the only one. I hope someday you'll join us, And the world will live as one'' John Lennon, Imagine.

Together, we can make a difference and we must, because we are running out of time.

"Look closely at nature. Every species is a masterpiece, exquisitely adapted to the particular environment in which it has survived."

— Edward O. Wilson

Preface

The pressing question today is whether we can cool the planet and stabilize the climate within twenty years. The answer lies not just in reducing greenhouse gas emissions but in rethinking our approach to nature. The planet's water cycle, powered by plants, plays an underappreciated but crucial role in climate regulation. While carbon emissions dominate the conversation, the interaction between water, plants, and the atmosphere is equally essential in cooling the planet. If we can restore degraded ecosystems and revive natural processes like evapotranspiration, we can tackle the climate crisis.

Life on Earth has spent billions of years co-evolving with its surroundings, building ecosystems which, through multiple interactions, help maintain a stable climate. The planet has faced mass extinctions before, yet life has always found a way to rebalance itself. Today, with the climate crisis driven largely by human actions, we need to accelerate the restoration of natural systems to stabilize the climate.

A Call to Action: Reimagining Our Role in Planetary Health

In our book, we argue that to truly reverse the climate crisis, we must repair the planet's ecosystems and restore the balance between water, plants, and the atmosphere. This approach, inspired by the Gaia theory of James Lovelock, suggests that Earth is a self-regulating supra-organism and that, by working with natural processes—such as photosynthesis and water cycling - we can cool the planet more effectively than by focusing almost exclusively on carbon reductions.

The key lies in leveraging the power of nature. Regenerating forests, restoring water cycles, and expanding regenerative agriculture are critical strategies. These natural processes not only sequester carbon but also have a profound cooling effect on the planet. We propose a

strategic plan that involves both global and local actions to restore ecosystems and stabilize the climate.

Part I: The Science Behind Cooling the Planet

Our book begins by delving into the science of how the planet regulates its temperature through natural processes. Plants and ecosystems are central to maintaining this balance. When we destroy ecosystems—through deforestation, industrial farming, or urbanization—we disrupt these processes and accelerate global warming.

One crucial concept we explore is the biotic pump, originally a theory, but now a principle, that shows how forests generate rainfall and maintain atmospheric circulation. This process begins with evapotranspiration—plants releasing water vapour—which leads to cloud formation and rainfall. In the Amazon, for instance, this cycle is responsible for much of the rainfall across the continent and for the formation of atmospheric rivers of moisture. Deforestation breaks this cycle, leading to droughts, reduced rainfall, and ultimately ecosystem collapse.

In the appendix, we highlight research by Peter Bunyard, who proved experimentally that water vapour condensation in the formation of clouds leads to a measurable airflow, validating the biotic pump theory. His experiments demonstrated that forest evapotranspiration is key to maintaining rainfall patterns far from ocean sources, ensuring the survival of forests and farmlands even thousands of kilometres inland as is the case for the Amazon and Congo Basins.

The Role of Water in Cooling the Planet

Water is an essential part of the Earth's temperature regulation system. As we all know from watching a kettle boil, a lot of energy has to go into steam-making. Plants, in releasing water vapour from their leaves, use the sun's energy to bring about that vaporization. The evapotranspired water vapour rises into the atmosphere, where it cools,

condenses into clouds, and releases the latent heat energy needed for vaporization, which escapes into space as infrared radiation. This process not only cools the surface but also creates the necessary conditions for rainfall and climate stability.

The Amazon rainforest plays an outstanding role in this process. It acts as a giant natural heat pump, drawing moist air from the Atlantic Ocean and recycling it across the continent. However, deforestation threatens this delicate balance, potentially leading to the collapse of the rainforest and a significant disruption of global climate patterns. It may well be that the terrible droughts which afflicted the Amazon Basin during 2023 to 2024 can be tied, in part at least, to the spate of hurricanes and tornadoes which wreaked so much damage and loss of life during the autumn of 2024 in Florida. The lack of rain to the Amazon indicates a significant weakening of the Trade Winds which, in a normal year, are responsible for 40 per cent of Amazonian rainfall, the rest, some 60 per cent, being provided by a forest-led recycling. To provide the rainfall coming in with the Trade Winds, as much as the equivalent of 5.5 atomic bombs of energy per second are required of the Sun's radiation to warm the surface of the tropical Atlantic Ocean, such as to bring about evaporation. The faltering of the Trade Winds therefore results in a significant proportion of that heat being retained over the ocean. That extra energy is available for hurricane formation and not surprisingly we have Hurricane Milton following hard on the heels of Hurricane Helene.

Part II: Challenges and Solutions—A Global Blueprint for Restoration

In this section, we provide concrete strategies for large-scale ecosystem restoration. To cool the planet, we propose a combination of reforestation, regenerative agriculture, and the restoration of degraded lands and watersheds. These actions are urgently needed to address the ongoing destruction of ecosystems, which is contributing to climate chaos.

We emphasize the importance of focusing on bioregions and watersheds—natural boundaries defined by ecological and hydrological systems. Restoration projects based on watersheds can simultaneously improve water quality, regenerate biodiversity, and protect communities from the impacts of climate change. A great example is the Subak system in Bali, where communities manage natural resources collectively, leading to sustainable conservation and agricultural productivity.

Global Priorities: Large-Scale Restoration

1. Avert the tipping point in the Amazon: We call for a global effort to restore the Amazon rainforest, employing over a million workers to replant and regenerate the region. The Amazon's survival is critical not just for South America but for global climate stability.

2. Restore ocean ecosystems: A plan to revive ocean biology through projects like fertilizing ocean deserts to sequester carbon and increase cloud formation. Ocean restoration is vital to regulating climate and maintaining the planet's albedo.

3. Greening deserts: Initiatives to green areas from the Sahara to the Mediterranean can help rehydrate the land, draw in atmospheric moisture, and reverse desertification.

4. Reverse polar amplification: Although this is a more speculative project, we propose exploring both nature-based and technological solutions to reverse the melting of polar ice caps.

Part III: How We Can Solve the Climate Crisis Within Our Lifetime

The last part of the book focuses on the urgency of reversing climate chaos and the need for international cooperation to tackle these challenges. While local actions are critical, global coordination and financing are required for large-scale restoration efforts.

One of the most immediate actions we propose is a global movement to empower 500 million smallholder farmers to transition to regenerative agriculture. This transition would regenerate soils, restore small water cycles, and increase biomass, with the potential to mitigate climate change significantly. We estimate that this project alone would cost 0.5% of global GDP annually for the next twenty years.

In addition to land restoration, we propose a plan for large-scale ocean and marine ecosystem restoration. This could be achieved through international cooperation and funding, with the goal of restoring coastal ecosystems and reversing ocean degradation.

A Global Call to Action

Our book is a call to mobilize the best minds and resources to restore the planet's ecosystems and thereby stabilize the climate. By acting together—locally, regionally, and globally—we can create the conditions for the Great Turnaround. We must shift from an economy based on resource extraction to one that regenerates the planet and ensures long-term climate stability.

The stakes are high, but the potential for success is real. By restoring forests, watersheds, oceans, and agricultural lands, we can reverse much of the damage caused by human activities and create a sustainable future for all species on Earth.

We conclude by emphasizing that the solutions to the climate crisis are within reach. With the right strategies, financial support, and global cooperation, we can repair the climate and ensure a liveable planet for future generations.

Final Thought: Let's Repair the Planet Together!

This book is more than just a scientific exploration of climate solutions. It is a call for action—an invitation to work together to heal our wounded planet. By rethinking our relationship with nature and acting

now, we can reverse climate chaos and build a future based on abundance, balance, and respect for the Earth.

Introduction

Greenhouse gases heat up the planet, but they are not the major driver of climate change. While carbon gets most of the attention, another huge factor is largely overlooked which concerns water in its movements and changes of state (ice, liquid water and vapour) as it interacts with plant life and the atmosphere. This interaction has enormous stabilizing and cooling effects. Once we understand the full force of plants and the water cycle, we can confront the climate crisis with a whole new set of powerful, additional measures. Plants, healthy soils, and healthy ecosystems stabilize weather, and help balance the climate temperature such as to reduce extremes.

Life, through its co-evolution with the surface of the planet, has evolved strategies over the course of 3.8 billion years to create the conditions for life to thrive, even though that has meant overcoming five great mass extinctions. Life has altered the composition of the atmosphere, constantly producing the oxygen we breathe and recycling carbon into the ground. The shells of microscopic skeletons of plankton have even formed whole landscapes, such as the White Cliffs of Dover! Life, with all its different ecosystems, has been balancing the climate for aeons and now, given all the destruction we humans have wreaked, we must help it to do so again. In fact, the whole planetary climate regulation has all the hallmarks of a self-regulating supra-being which, in a nutshell is what James Lovelock called the Gaia Theory. Frontloading vigorous protection and regeneration of nature around the world, together with massive increases in regenerative agricultural practices and agroforestry, will restore a balanced climate, calm the weather and cool the planet!

We can leverage these qualities to fight the climate crisis.

The book will show how we can stabilize the climate and even get on a trajectory of cooling. It shows that if we intervene with Nature's

intelligent methods, we may avoid average global temperatures exceeding the 1.5^{0}C limit of rising temperatures, set by the IPCC as the point beyond which climate change and the extremes will become increasingly unmanageable.

Regeneration of essential ecosystems, and in particular forests, will have enormous beneficial impacts, including fundamental changes to the flows of energy implicit in the restoration of nature, such that such beneficial changes will result in the Earth cooling, while simultaneously countering to a great extent the global warming caused by anthropocentric emissions of greenhouse gases. The shortest way to describe what we need to do is to stimulate the increase of biomass in the coming two decades in a strategic way to stabilize the climate. The book will also touch on the strategies that are meant for humanity to undertake this largest endeavour in history at the speed and scale needed for it to be successful.

The second part of the book came out of a six-month writing group of the EcoRestoration Alliance, a global network of several hundred scientists, earth stewards, storytellers and grassroots leaders working to accelerate the restoration of degraded lands and waters, foster biodiversity, and cool the planet. The group came together to write a blueprint for a complete regeneration of the Earth's biology to restore its metabolisms, temperature regulation. All biomes can be restored fast. Collectively we have the knowledge.

But we are running out of time. When fluctuations become too extreme, they break through the barriers of balancing that are key to the survival of all life. The authors are all too conscious that we are already at the tipping point of cascading collapse of the life systems upon which humanity is completely dependent. At the same time, we share the hope that nature is incredibly resilient and can bounce back from destruction in remarkably vigorous ways when given a chance and strategic support.

We start with an opening poem, to express our heartfelt pain and anguish for the young, who have inherited a damaged Earth. Do watch and listen. We hope that the knowledge in this book will contribute to reversing the existential threat.

Requiem for the Earth, the Children's Song, *Paco Peña,* original words in English by Peter Bunyard – https://youtu.be/boUu4pPfR6w

ALABANZA: RÉQUIEM POR LA TIERRA

Ay! de tí, hombre villano,	*What of you, uncaring Man*
¿Qué has hecho con la tierra?	*What have you done with the Earth?*
¿Dónde están las florestas,	*Where are the forests*
Los límpidos arroyos,	*The limpid streams*
el transparente mar?	*The transparent sea?*
Has truncado la vida	*You have truncated the life*
al árbol que,	*of the tree which,*
orgulloso,	*With pride, rose up*
de la tierra salía.	*from the Earth.*
Has pelado montañas;	*You have laid bare mountains,*
y los ríos majestuosos	*And the majestic rivers*
hoy ciénagas serán.	T*hey are becoming unpalatable swamps*
Ahora llegan torrentes	*Now, we bear the brunt of torrents*
que desbordan el río	*Which burst the banks of rivers*
y arrasan la ciudad.	*And wipe out the city,*
Las casas,	*Houses, cattle, men, women,*
el ganado,	*children.*
hombres, mujeres, niños	*If we don't take care of our*
todo perecerá.	*Sacred Mother, All will perish.*

Part One
The Science Behind Cooling the Planet

Chapter 1
The Urgent Need to Cool our Planet

"If you want to make major changes, you have to change the way you SEE things."

"I speak as a planetary physician whose patient, the living Earth, complains of fever; I see the Earth's declining health as our most important concern, our very lives depending upon a healthy Earth. Our concern for it must come first, because the welfare of the burgeoning mass of humanity demands a healthy planet''

''We live on a live planet that can respond to the changes we make, either by cancelling the changes or by cancelling us."

— James E. Lovelock, *The Revenge of Gaia*

The main message of our book is that we are both much closer to sudden collapse than almost anybody thinks because of planetary organ failure, and with that the wholesale collapse of human societies. The good news is that nature is incredibly resilient and with the right treatment we might still be able to revive our planet's vitality fast. Our focus is entirely on nurturing the living planet back to health and save our societies in the process. If the damage to the biosphere is reversed, the planet will regain its capacity to regulate its own temperature. Ecological restoration can and must be done by everyone everywhere.

Figure 1: *Rob de Laet & Dall-E*

You and I are Part of a Living Planet

Indigenous cultures across the globe, including Native Americans, Aboriginal Australians, Andean peoples, and the Māori of New Zealand, share a profound belief in the Earth as a living, sacred entity. From the Native American concept of "Mother Earth" to the Andean "Pachamama" and the Aboriginal "Dreamtime," these cultures view the planet as a nurturing, spiritual mother figure deeply interconnected with all forms of life. This perspective fosters a strong sense of respect and stewardship for the environment, emphasising harmony and balance with the natural world. These beliefs are central to their cultural identity, spirituality, and environmental practices, underscoring a deep-rooted kinship with the Earth.

The authors have embraced James Lovelock's Gaia Theory, which revolutionises our perception of Earth within the Western body of science. We see the planet as a living, self- regulating entity. This ground breaking concept suggests that our planet functions like a single organism, with its diverse biological processes intricately interconnected and working in unison to maintain and sustain life. Through this lens, Earth's atmosphere, biosphere, oceans, and soil are not just separate entities but components of a larger, living system.

Lovelock shows that the planet has vitality through the interdependence of all species and biomes in the biosphere, highlighting the delicate balance required to sustain life. Like the Indigenous people and the authors of this book we acknowledge that we are part of a living being that needs care and respect. This makes us both offspring and stewards of our planet as we have a clear role to play in preserving this wonderful, living organism and the future generation of humans and other species, with which we have the honour to share this miraculous place in the universe. But, back to the reality of where we are today, because we are running out of time and much work has to be done fast to avert the worst-case scenarios of a dark future to where are now heading.

How Much Do We Have To Do To Reverse Climate Chaos?

Through a strategic plan, involving large parts of the global population to act locally with place-based solutions, we may still be able to reverse most damage fast. We call on people to organise themselves and focus on the restoration of natural bioregions and watersheds within their domain, all the while cooperating with local communities to bring about rapid improvements. The idea is to involve as many people of the region as possible.

As an appendix we have added a chapter in which we focus on the physical numbers associated with the energetics of evapotranspiration and cloud-forming condensation of water vapour. We show that a tropical humid rainforest, as in the Amazon, per square metre, effects a

surface cooling which is more than 100 times greater than the photosynthetic energy required to generate biomass from the carbon extracted from the atmosphere. Consequently, if we could regenerate the forests lost since World War 2 in the tropics and temperate zones, we would offset a good proportion of current global warming. Such expansion of forests would have the increased beneficial effect of reducing the concentration of carbon dioxide in the atmosphere.

Restoration along Bioregions

If nature were to draw a map of the world, what would it look like? We've grown accustomed to seeing the world divided into countries but there is another way to see, and better understand, the planet we call home. One Earth presents a novel biogeographical framework defined by 185 unique bioregions, which helps reveal the underlying ecological fabric of life that surrounds us.

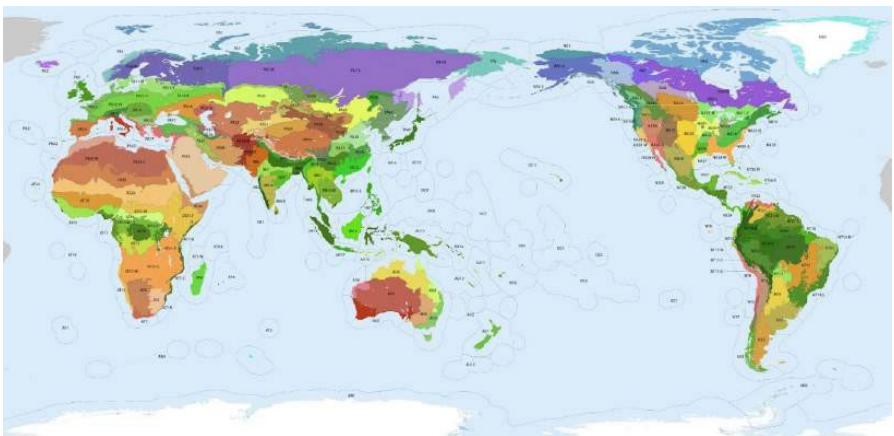

Figure 2: *Bioregion map of the World Courtesy One Earth*
https://www.oneearth.org/bioregion

Ecological Restoration Based on Watersheds

Ecological restoration founded on the concept of watersheds represents a holistic approach to environmental conservation and ecosystem rehabilitation. It revolves around the idea that ecosystems within a

given watershed are intricately interconnected, emphasising the need to consider the entire system as opposed to isolated components. Restoration will then contribute simultaneously to the well-being of both the environment and the community.

Figure 3: *Water – Photo of Trutta/Shutterstock*

One of the primary advantages of watershed-based restoration efforts is the significant improvement in water quality. By addressing the sources of pollution and runoff within a watershed, restoration projects lead to cleaner and healthier water bodies. This, in turn, has a positive impact on aquatic life and the communities that rely on these water resources for drinking water, recreation, and economic activities. All the diverse ecosystems within the watershed boundaries profit from this improvement, which can start at the level of alpine pastures and may include wetlands, forests, streams, rivers, deltas, coastal lagoons and marine ecosystems.

Watershed restoration projects include plans for biodiversity protection and regeneration, flood control, common water use and common infrastructure. Healthy watersheds are better equipped to face droughts, for instance.

Community engagement is a fundamental aspect of watershed-based restoration. A great example is the Subak system in Bali, Indonesia,

where watership councils are formed within communities to protect and manage natural resources, including forests and their biodiversity. The resulting cooperative structure leads to everyone becoming involved in a sense of ownership and stewardship. This engagement not only empowers communities, but also builds a long-term commitment to the sustainable conservation of the watershed. Well managed watersheds improve agricultural and fish production. They also build community cohesion and resilience.

While all people everywhere can become part of a regenerative movement, the damage is too large to leave it just to local forms of citizen action. For global-needed actions we need global organisations and finance.

The Large Emergency Priorities to Reverse Climate Chaos Fast

This is the list of points we think need to be addressed immediately:

- Avert the **tipping point resulting from die-back of the Amazon rainforest** and strategically reforest the biome to restore the full vigour of the surface-cooling function over the area, by encouraging fast regrowth. This rescue project must include probably more than a million workers getting paid to do the restoration and the finance must come from the whole world, given that all everywhere will be affected if this powerful, natural, cooling organ of the planet dies back.

Figure 4: *Healthy Amazon Rainforest – Photo of Theo Tarras/Shutterstock*

- A plan for the **fast revival of ocean biology** including the fertilisation of ocean deserts to sequester carbon, restore the ocean food chain, increase vertical mixing of the water column, increase planetary albedo through increased cloud formation. As this has to happen simultaneously in hundreds of places in the world's coastal marine ecosystems and deep oceans, this must be an internationally coordinated and financed effort.

- A plan to **green the desert areas** from the Thar desert to the Sahara and, through strategic ecosystem regeneration, to draw the Indian monsoon moisture streams all the way to the Mediterranean. In addition, the aim is to increase precipitation over the Third Pole, as the Himalayas and nearby mountain ranges are called because of the thousands of glaciers and snow-clad mountains they hold. Countries from India all the way to Senegal and around the Mediterranean must have a coordinated plan to bring back the atmospheric moisture streams over the areas, rehydrating the lands, regenerating soils and vegetation and cleaning up degraded coastal systems both above and below the water line.

Figure 5: *Permaculture food production in India – Photo of Dr. Chandrashekar Biradar*

– Organise the best minds around the world to **reverse polar amplification** by reversing the melt of polar sea ice on both sides of the planet. We may not yet know how to do that but plans are forming, both with nature-based solutions, as well as with some technical interventions.

Figure 6: *Sea Ice in the Weddell Sea – Photo of Steve Allen/Shutterstock*

Global Action

While restoration can and must be done everywhere by everyone, these large projects we describe need the support from powerful organisations like states, armies and large companies. By such means, we can stop the Earth from warming up within decades. Furthermore, such restoration actions will swiftly bring the number of weather extremes to drop significantly.

Here are the global priorities that cannot be done without international cooperation:

1. To bring finance, information, organisation and tools to the 500 million smallholder families around the world to restore their lands and transition to regenerative agroforestry food production. This will restore the small water cycles, recover degraded soils and substantially increase living biomass. A plan for this has been written. Estimate cost 0.5% of Global GDP per year for a period of twenty years.
2. As such, we invite large networks of organisations such as the Rotaries, WVF (World Veterans Federation), Red Cross, CARE, The Nature Conservancy, Oxfam, WWF, Peace Corps, climate action groups and so on to support communities everywhere to regenerate the ecosystems in their area and improve their economy and well-being.
3. To bring about a programme of ocean and coastal marine ecosystems restoration. Cost of the total programme is in the tens of billions of dollars with almost immediate results.
4. We call for support to assemble in a very short time a Digital Gaia to support all these restoration processes. An outline has been written, almost all parts already exist. Cost to launch first viable product 5 million USD. Let's build this fast!
5. The planetary restoration project will be financed through several revenue streams from governments, philanthropy, investment programmes, green bonds and carbon credit finance.

Reducing emissions must continue, but the main focus needs to shift to the repair of nature and water cycles around the world together with massive increases in regenerative agricultural practices and agroforestry to make landscapes climate resilient. Combined with reviving ocean biology, such efforts will restore a balanced climate, calm the weather and cool the planet! Tens of gigatons of CO_2 per year will be sequestered in the fast-increasing living biomass around the world. The transition of an area of 2.5 million square kilometres in the tropical belt from open field to forest, combined with strategically-sited agroforestry, will increase the cooling capacity through the atmospheric water cycle enough to stop the planet from heating up further.

This book, Cooling the Climate, is a proposal to restore the health of our planet fast and with that restore the future of the generations that want to live a happy life on a benign planet that provides enough for everybody's needs (but not everybody's greed!). But first we start with a comprehensive overview of Earth's intricate living systems. The following chapters delve into the science of our living planet, atmosphere, biosphere, climate, and weather, laying a solid foundation for understanding how we can get ourselves out of the climate mess fast.

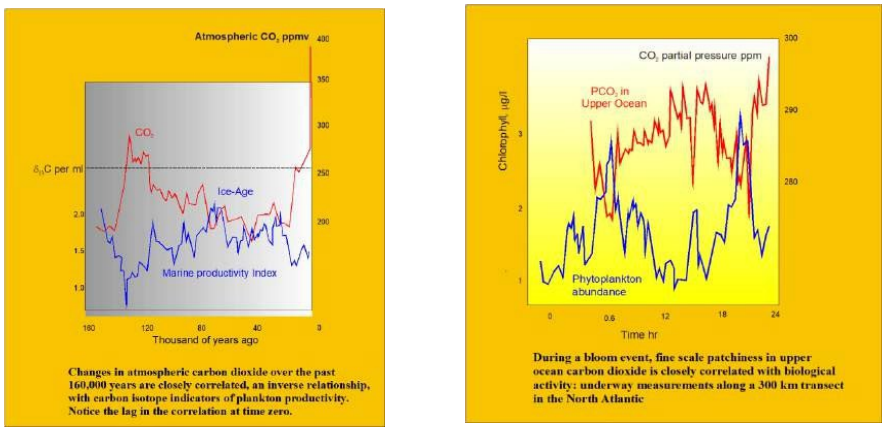

Figure 7: *Atmospheric and Ocean C0₂ values over time – Graphs by Peter Bunyard from the Plymouth Marine Biological Laboratory. The graphs show the role of oceanic phytoplankton, both on a daily basis and over thousands of years in reducing atmospheric CO_2.*

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Chapter 2
Honouring the Earth's Protective Shield

"We have a choice. Collective action or collective suicide. It is in our hands."

Quote from the Secretary General of the UN Antonio Guterres, talking to a group of ministers from 40 countries on 18 July 2022.

Figure 8: *Sunrise over the planet showing how thin our protective atmosphere really is. Courtesy: NASA*

The Earth is the only known planet where life thrives, and its complex biosphere has played a critical role in shaping the atmosphere that sustains us. Life has transformed the Earth's atmosphere into a delicate balance of nitrogen, oxygen, water vapour, and greenhouse gases that make human existence possible. This balance, carefully managed by nature over millions of years, has allowed life to flourish. Without the contribution of life to create this atmosphere, human evolution, and survival would have been impossible. We have inherited an atmosphere that not only provides us with breathable air but also protects life on Earth.

The Protective Role of the Atmosphere

The atmosphere regulates the energy from the Sun, allowing just the right amount to reach Earth for life to thrive. The Sun, a powerful star producing immense energy through nuclear fusion, emits radiation that is harmful to life. Thankfully, the stratosphere acts as a protective shield, filtering out deadly ultraviolet (UV) radiation. Oxygen produced by plants through photosynthesis plays a key role here, as it rises into the stratosphere and interacts with UV-C radiation, the most dangerous form of UV light. This interaction prevents UV-C from reaching Earth's surface, where it could harm life. Additionally, the formation of ozone from this process helps block less harmful but still dangerous UV-B radiation.

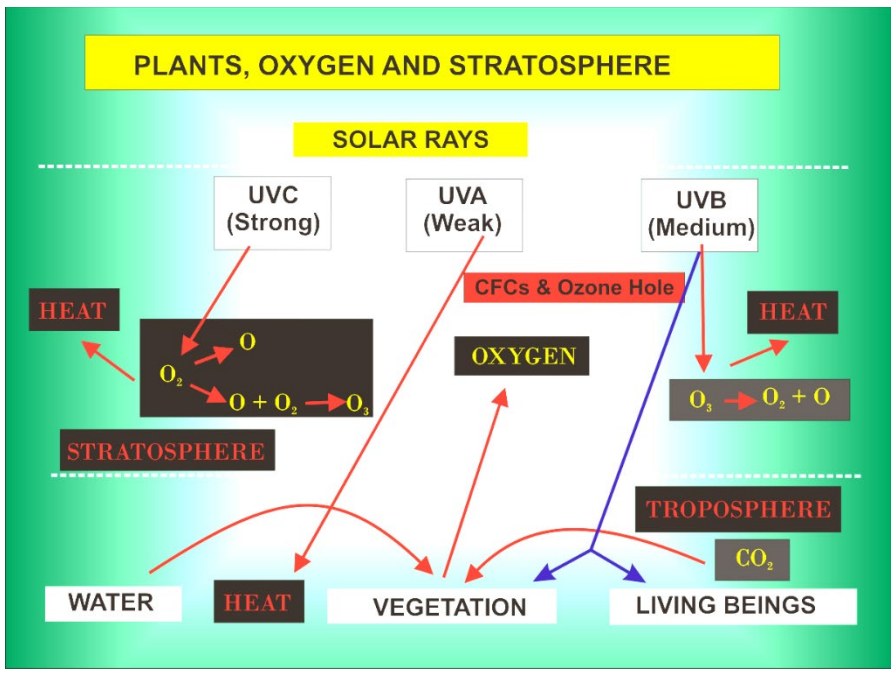

Figure 9: *Schematic overview of the interaction between sunlight, the atmosphere and the biosphere. Oxygen generated by plants protects life on the surface from harmful ultraviolet Sun rays – Peter Bunyard*

Another critical component of the atmosphere is the ionosphere, a layer filled with charged particles that interact with Earth's magnetic field. This interaction deflects harmful solar wind and cosmic radiation, protecting life on the planet. The atmosphere also acts as a barrier against space debris like meteors, burning them up before they can reach the surface, although it does not offer complete protection from large meteor impacts. The last major extinction event, which wiped out the dinosaurs 66 million years ago, was caused by a massive meteor strike in what is now the Yucatan Peninsula in Mexico.

The Impact of Human Activities on the Atmosphere

Human civilization has only been possible because of a stable climate, which began after the Last Ice Age around 12,000 years ago, marking the start of the Holocene epoch. During this time, favourable conditions allowed for the development of agriculture, settlements, and complex societies. However, as we have increasingly exploited natural resources, we have significantly altered the atmosphere, leading to climate change.

The impacts of human activities on the atmosphere are wide-ranging. These include the emission of greenhouse gases like carbon dioxide (CO_2) and methane, which trap heat and contribute to global warming. Industrialization has also increased aerosol pollution, and the use of chemicals like chlorofluorocarbons (CFCs) has depleted the ozone layer, further compromising our protection from harmful UV radiation. Land-use changes, particularly deforestation, have disrupted natural water cycles, thus reducing humidity and altering precipitation patterns.

The Earth's temperature regulation depends heavily on water. The movement of water in its various forms—liquid, vapour, and ice—transports solar energy from the surface to the atmosphere, where it is eventually released back into space. This natural cooling process has allowed life to thrive despite the Sun being 30% more powerful than when Earth first formed. However, by altering ecosystems and, thereby,

reducing the energy exchange in the atmosphere, humans are disrupting this cooling mechanism, leading to rising surface temperatures and climate instability.

Meanwhile, we must be grateful that life, by means of its metabolism, has put into the atmosphere just the right concentrations of greenhouse gases for capturing and retaining an appropriate amount of the Sun's heat to maintain a stable and liveable climate on Earth.

Without the atmosphere and its greenhouse gases, temperatures would swing from being excessively hot to excessively cold. Quite aside from there being no air to breathe, the planet would hardly be habitable. On the Moon, the temperatures on the side facing the Sun can peak at approximately 127^{0}C (260^0 Fahrenheit), while on the lunar night-side temperatures as low as minus 173^{0}C (minus 279^0 Fahrenheit) have been observed. And as we saw earlier, if life did not keep the current mix of gases more or less constant, temperatures on Earth would either become lethally high, as on Venus or lethally low as on Mars. We can see how much the atmosphere regulates the Earth's temperature from the following graph.

Imagine the Earth as a 'black body' without an atmosphere and imagine that it is January, when Antarctica is having its summer and the North Pole its winter. The temperature at the North Pole would be -140°C and in Antarctica +40°C. With the current atmosphere, that sharp contrast between the two Poles is smoothed out and the temperature becomes not so different from one to the other, despite the seasonal shifts in exposure to the Sun.

Human civilizations have developed in the last ten thousand years or so during a period of very stable climate just after the Last Ice Age. It is known as the Holocene epoch. During this time, favourable conditions allowed for agriculture, settlement, the rise of complex societies with surplus food production, and with it all the increasing division of labour. One result was the creation of more and more specialised forms

of expertise and with that the wonders of technology, which we experience daily throughout the world.

However, our use of natural resources, as if nature was expendable and exploitable, has had severe consequences which we are now beginning to experience with a vengeance and which have come under the seemingly benign guise of 'climate change'. Climate change now poses significant threats to various aspects of human life. They include risks to food security, to water resources, to all ecosystems, to human health, and to the economy. In essence, changes in temperature, precipitation patterns, and extreme weather events disrupt agriculture, lead to water scarcity, intensify natural disasters, disrupt ecosystems and biodiversity, contribute to the spread of diseases, and have economic implications.

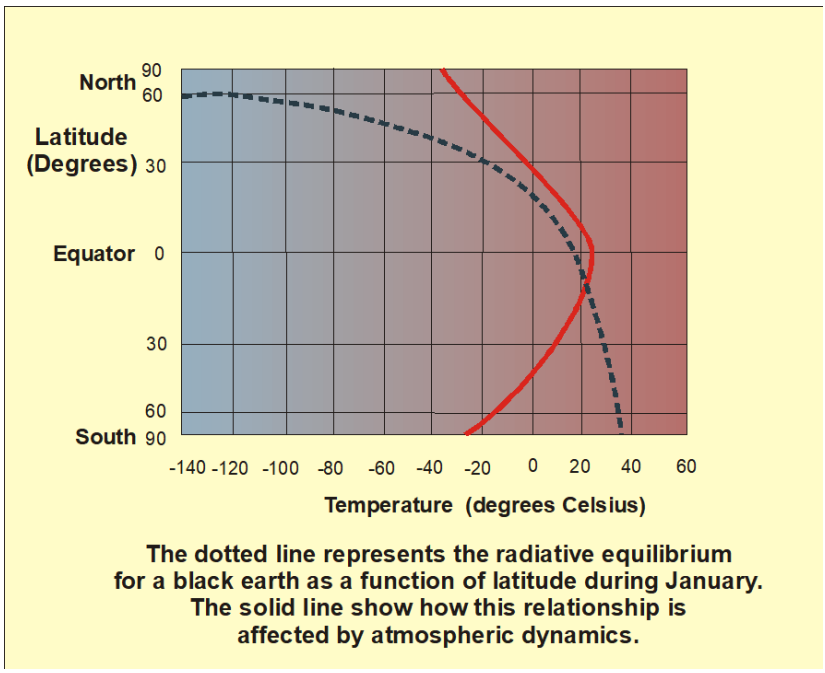

Figure 10: *Actual and calculated temperature if there was no atmosphere – Graph Peter Bunyard.*