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Atmosphere

A Thin Line between Life and Death

Rayappa A. Kasi

An Appeal to Save the Atmosphere

Year of Priests 2009-2010

United Nations International
Year of Biodiversity - 2010

ATMOSPHERE
A Thin Line between Life and Death



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Illustration of the Jacket: Modern Art of Atmosphere
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Blue Color represents Nitrogen 78%; Yellow Color represents Oxygen 21%; Red Color represents Carbon Dioxide 0.04%; White Color represents Water Vapor 0.2%; Violet Color represents Argon 0.01%; also small amount of Methane and Nitric Oxide also present; the Circles represent the Ozone Hole in the Stratosphere.

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Preface

Our Earth is truly an amazing planet! Not only is it exactly the right distance from the sun to have temperatures that will support life, but it is also one of the only planets to have liquid water on its surface. In addition, our Earth has an Atmosphere that has just the right composition to allow life to exist. The Atmosphere is the layer of gases that surrounds the Earth. *We may not always be aware of them, but without these gases, life on Earth would definitely not be possible*. The Atmosphere provides the gases that animals and plants need for respiration and photosynthesis, it helps to keep temperatures on Earth constant and also protects us from the sun's harmful radiation. In this book, we are going to take a closer look at the chemistry of the Earth's Atmosphere and at some of the human activities that threaten the delicate balance that exists in this part of our planet.

Nature is fragile, environmentalists often tell us. The truth is far more worrying. Its revenge for man-made Global Warming will very probably unleash unstoppable planetary forces. And they will not be gradual. The history of our planet's climate shows that it does not do gradual change. Under pressure, whether from sunspots or orbital wobbles or the degredations of humans, it lurches—virtually overnight. We humans have spent 400 generations building our current civilization in an era of climatic stability—a long, generally balmy spring that has endured since the last ice age. But this tranquility looks like the exception rather than the rule in nature. And if its end is inevitable one day, we seem to be triggering its imminent and violent collapse. Our world may be blown away in the process.

This book is a reality check about the state of our planet. Along the way, I also learned about solar pulses, about the "ocean conveyor," *about how Indian village fires may be melting the Arctic ice*. It is hard to escape the sense that primeval forces lurk deep in the ocean, in ice caps, in rainforest soils, and in Arctic tundra. That state scares me, just as it scares many of my friends I have talked to—sober friends, with careers and reputations to defend, but also with hopes for their own futures and those of their children, and fears that we are the last generation to live with any kind of climatic stability.

It seems clear to me that no amount of lecturing from environmentalists will persuade society at large that consumer treadmill is not the quickest route to health and happiness. Most of my neighbors still shop in supermarkets, even though they have to drive to them in cars and end up depriving local shopkeepers of making a living in the process. An outdated view still prevails that a low-carbon lifestyle requires immense suffering and sacrifice. In my view, nothing could be further than truth. All the evidence shows that people who do not drive, do not fly on planes, do shop locally, do grow their own food, and do get to know other members of their community have a much higher quality of life than their compatriots who remain addicted to high-fossil-fuel-consuming lifestyles.

It seems to me that low-carbon society would be one that remembers that our planet is a unique gift—perhaps the only one of its kind in the entire universe—which we are indescribably privileged to be born into. It would be a society that could look back on the four-degree nightmare scenario as just that—a nightmare, one that humanity woke up from and avoided before it was too late. More than anything, it would be a society that survived and prospered and that passed on this glorious inheritance—clean Atmosphere, clean Hydrosphere, clean Lithosphere, and clean Biosphere with all its ice caps, rain forests, oceans, and thriving civilizations—to countless generations, far into the future.

We need to cut emissions and do so within a decade, to save Atmosphere. Indeed, carbon emissions might reach 500 ppm in two or three decades, indeed, a 500 ppm concentration would probably warm the globe by between three and four degrees Celsius, probably crossing both the carbon cycle and Siberian methane tipping points in the process. At present the carbon concentration is less than 400 ppm-mark. To stay within the 400-ppm, two-degree target, on the other hand, we need to knock another four or five wedges into the emissions graph. The addition is not impossible: We can double the quantity of wind turbines, and further reduce the numbers of vehicles on the roads. *But India and China are adding more cars on the road, adding more to the problem.* We can cut our need for energy by living less consumptive lifestyles, and by adopting more localized patterns of behavior. We already have the technologies and the social know-how to achieve this transition. But that still leaves the political question open: Is there a way to turn our society around, so that people work eagerly and collectively to achieve a two-degree target, rather than ignoring the whole issue or trying to find ways to justify their own damaging behavior?

Currently, socioeconomic pressure works in the other direction: Young children, for example, rather than eschewing consumerism, have to display

the latest consumer fashion gear so as not to be humiliated on the playground. Their parents save up to buy the latest jeep or SUV such as Tata Safari, Mahindra Bolero or Scorpio, in order to demonstrate their status and earning power to the neighbors. In India, Tata Nano has fulfilled the dream of at least 500 million Indians of at last owning a car. India has the best transport infrastructure in the world; there is no need for a car. Just owning a car, (not the driving part) is a prestigious part of many Indian lifestyles. Television programs equate speed with virility and driving freedom, cultural messages that are relentlessly reinforced by screen and billboard advertising. Hip-hop artists, Hollywood, Bollywood, and Kollywood movies reinforce these values by rapping about their expensive cars and producing videos with scantily clad models dancing sexily around them.

2003, heat wave in Europe, deluge in Mumbai in 2005, and Hurricane Katrina in 2005, all these events were, to differing degrees, windows into a changing world. Global Warming is making the hydrological cycle more intense, causing heavier storms and more intense hurricanes to brew up out at sea. Yes, extreme weather has always been with us, but the fact that rising levels of greenhouse gases trap the sun's heat means that more energy is available in the system—so the worst is happening more and more often. The misery suffered in New Orleans in August 2005 felt to me like an insight into what the 21st century may have in store for many more of us, in a thousand locations across the world, as climate change accelerates. Where next? What will happen as the world warms bit by bit? *With up to 6 degrees Celsius, of Global Warming in the cards over the next hundred years, according to the Intergovernmental Panel on Climate Change (IPCC), what will happen to our coasts, our towns, our forests, our rivers, our croplands, and our mountains?* Will we all, as some environmentalists suggest, be reduced to eking out a living from shattered remains of civilization in Arctic refuges, or will life go on much as before—if only a little warmer?

I thank to Fr. Jahn Samala, Fr. Joseph, Fr. Lourdu Xavier, Fr. Christian, Fr. Johnson, Fr. Maria Susai (USA), Fr. Stephen Pillai, Fr. Joemics, Fr. Roy Lazar, Fr. Daniel, Fr. D. F Bosco, Fr. Henry George, Sr. Eluru Rakkini Mangarpu, Sr. Elisa Samala FMA, Mr. Aruldoss and Stella Mangarpu, Fr. Arulraj Kasi SDB, Fr. Sagayaraj Kasi SDB, Fr. Earnest Pathy SDB, Fr. Praveen Samala SDB, Sr. Martina MBBS, Mr. Sathiaseelan and Balasamy Kasi. I would also like to thank those who helped me locate and use the many and various sources on which this book depends: Fr. Paul Ring, Francine Bell, Theresa Moses, for their library cards and the staff of Brockton Library in particular, where I spent many weeks and months buried in work down in the big room. I am very much indebted to LTD Media Publications for their neat and perfect

work. Thanks in particular to my publisher Mr. Sagayam Deva and Josephine, who also have provided helpful advice on a number of occasions.

This book makes an appeal first to priests and religious leaders around the world who are in an advantageous position to command any change in the future. *First these leaders should recognize that such problems of Global Warming and Climate Change are not myth, but they are real. Confident, then, they can proceed to make an appeal to their faithful.* The Year of Priests demands all the more to take a stand on environmental Matters. Atmosphere is wounded and bleeding. Poor people all over the world are affected by the consequences. The gospel proclaims God's love for every human being and calls us to love as God loves. *Yet recognition of Global Warming and Climate Change means taking a position, opposing certain groups of persons, rejecting certain activities, and facing hostilities. It is not possible to remain neutral in the face of poverty and the resulting just claims of the poor; the exploiting lifestyle of the west destroys the Atmosphere and damages the surroundings and ecosystems where the poor live.* We priest need to take a position. 'If You Want to Cultivate Peace, Protect Creation," wrote Pope Benedict XVI. The position we take under the inspiration of the gospel must be real and effective. For if we are convinced that peace indeed supposes the establishment of justice, as priests we cannot remain passive or indifferent when the most basic Earth's systems such as Atmosphere, Hydrosphere, Lithosphere, and Biosphere are at risk.

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24. 5.2004 – Feast of Mary Help of Christians
June 19, 2010 – End of the Year of Priests

Atmosphere – A thin Line between Life and Death

The Earth's early Atmosphere was very different from what it is today. When the Earth formed around 4.5 billion years ago, there was probably no Atmosphere. Some scientists believe that the earliest Atmosphere contained gases such as water vapor, carbon dioxide, nitrogen and sulfur which were released from inside the planet as a result of volcanic activity. Many scientists also believe that the first stage in the evolution of life, around 4 billion years ago, needed an oxygen-free environment. At a later stage, these primitive forms of plant life began to release small amounts of oxygen into the Atmosphere as a product of photosynthesis. During photosynthesis, plants use carbon dioxide, water and sunlight to produce simple sugars. Oxygen is also released in the process. The air is the part of the Atmosphere with which we are most familiar. Almost every moment of our lives is spent within it. We breathe its gases, walk, fly, or drive through them. Our world is seen from its depths. Yet most of the time, we forget we live at the bottom of an ocean of air. So familiar and so all-enveloping is it, we simply ignore it. Part of our forgetfulness may be because the air is odorless, tasteless, and impossible to feel. If we "smell" the air, it is not the air that we are sniffing, but its contaminants. If we "feel" the air, it is its heat or water vapor that affects us, not the air itself. If we "taste" the air, we are tasting — airborne substances. Yet the air exists. If it did not, the delicate system by which we breathe and through which we are able to use the gases of the Atmosphere would fail. Nor would there be a single blade of grass, tree, or any other form of life on the Earth. The existence of the Atmosphere and the constant recycling of its gases make it possible for living organisms to survive in the biosphere.



Year of Priests 2009-2010 – An Appeal to Save the Atmosphere

Pope Benedict XVI proclaimed a Year for Priests on the occasion of the 150th anniversary of the death of St. Jean Marie Vianney, the Cure of Ars.* The theme for the year will be "Faithfulness of Christ, Faithfulness of Priests." Pope has declared a "Year for Priests" beginning with the solemnity of the Sacred Heart of Jesus on June 19, 2009. The year will conclude in Rome with an international gathering of priests with the Holy Father on June 19, 2010. The theme of the Year of Priests: "Faithfulness of Christ, Faithfulness of Priests," should give all priests a confident role to play: to make an appeal to humanity to care, to protect, to love, and to conserve all life and all their life supporting systems such as Atmosphere, Hydrosphere, Lithosphere and Biosphere. Christian theology holds that the Earth is a gift from God that humans share with all other creatures, and it is obvious that our relationships with other beings, humans or not, are affected by the physical environment. *To show disregard for the air that others breathe and the quality of the water they drink is to sin against God and against other people, who disproportionately turn out to be the poor who tend to live in especially polluted areas. Such disregard for ecological degradation damages not only inanimate objects but also humankind's overall relationships with living things.* Wasting and polluting precious natural resources is justifiably deemed sinful, for it is an offence against all the things, living and inert, biotic and abiotic that God has blessed us with. Many people, parishes and dioceses have adopted programs to raise awareness of pollution and to organize efforts to preserve our fragile ecosystems. Projects and efforts to alleviate the environmental problems have made an important impact on the lives of many people of faith, feeding their spirituality and rekindling their commitment to the life of discipleship. Many people express hope that their grass-root efforts will capture the attention on high social and religious officials and make their way into the formulating of some environmental action, the social teaching of pontiffs.

Saving souls through pastoral care and the celebration of the sacraments is the primary function of the priest from the perspective of the cultic model. Recent decades have seen that perspective expand to the point where the communal dimension to salvation has received appropriate consideration. The people of God are redeemed and saved as a people. Without diminishing the essential role of personal surrender to the loving plan of God required of every individual, a renewed sense of belonging to a covenant people has led to a new awareness of social sin and institutional

**Saint John Mary Vianney is familiarly known as the Cure of Ars is the patron of all parish priests born in France in 1786 and died in 1859.*

evil. This, in turn, has evoked a keen awareness of the constitutive place that work for justice, peace, and liberation holds at the center of the Christian life. The community of faith and the social order surface as the enduring context for God's saving grace. Writer Joseph Bacik comments: *"Priests who have accepted and assimilated the social dimension of the Gospel are not comfortable in the cultic model … These priests experience added pressures and tensions if their parishioners do not accept this linkage and want to confine the clergy to church affairs."** Cardinal Suhard once wrote, *"One of the priest's first services to the world is to tell the truth."* So, we priests by telling the truth should awaken the faithful from their dream world to the frightful situation we are in. It is clear that we are inexorably moving towards a major catastrophe which we cannot stave off. We have poisoned our Atmosphere and temperatures are rising! Rich people can buy air-conditioners. But, poor are fried in the heat. In recent years, there has been questioning of pastoral action and theological reflection in the fields of global warming and climate change. Misunderstanding or limitedness in access to information on these two fields contributes more confusion. But recent message of His Holiness Pope Benedict XVI for the celebration of the world day of peace on the 1st January 2010, does contribute the needed confidence and clarity for further action.

"If You Want to Cultivate Peace, Protect Creation," wrote Pope Benedict XVI. He continues, "It should be evident that the ecological crisis cannot be viewed in isolation from other related questions, since it is closely linked to the notion of development itself and our understanding of man in his relationship to others and to the rest of creation. Prudence would thus dictate a profound, long-term review of our model of development, one which would take into consideration the meaning of the economy and its goals with an eye to correcting its malfunctions and misapplications. The ecological health of the planet calls for this, but it is also demanded by the cultural and moral crisis of humanity whose symptoms have for some time been evident in every part of the world. Humanity needs a profound cultural renewal; it needs to rediscover those values which can serve as the solid basis for building a brighter future for all. Our present crises – be they economic, food-related, environmental or social – are ultimately also moral crises, and all of them are interrelated. They require us to rethink the path which we are traveling together. Specifically, they call for a lifestyle marked by sobriety and solidarity, with new rules and forms of engagement, one which focuses confidently and courageously on strategies that actually work, while decisively rejecting those that have failed. Only in this way can the current crisis become an opportunity for discernment and new strategic planning.

**The "Instruction," approved by John Paul II on August 13, 1997, and signed by eight heads of Vatican dicasteries on August 15, 1997, was embargoed until November 1997.*

Is it not true that what we call "nature" in a cosmic sense has its origin in "a plan of love and truth"? The world "is not the product of any necessity whatsoever, nor of blind fate or chance… The world proceeds from the free will of God; he wanted to make his creatures share in his being, in his intelligence, and in his goodness." The Book of Genesis, in its very first pages, points to the wise design of the cosmos: it comes forth from God's mind and finds its culmination in man and woman, made in the image and likeness of the Creator to "fill the earth" and to "have dominion over" it as "stewards" of God himself (cf. Gen 1:28). The harmony between the Creator, mankind and the created world, as described by Sacred Scripture, was disrupted by the sin of Adam and Eve, by man and woman, who wanted to take the place of God and refused to acknowledge that they were his creatures. As a result, the work of "exercising dominion" over the earth, "tilling it and keeping it", was also disrupted, and conflict arose within and between mankind and the rest of creation (cf. Gen 3:17-19). Human beings let themselves be mastered by selfishness; they misunderstood the meaning of God's command and exploited creation out of a desire to exercise absolute domination over it. But the true meaning of God's original command, as the Book of Genesis clearly shows, was not a simple conferral of authority, but rather a summons to responsibility. The wisdom of the ancients had recognized that nature is not at our disposal as "a heap of scattered refuse". Biblical Revelation made us see that nature is a gift of the Creator, who gave it an inbuilt order and enabled man to draw from it the principles needed to "till it and keep it" (cf. Gen. 2:15). Everything that exists belongs to God, who has entrusted it to man, albeit not for his arbitrary use. Once man, instead of acting as God's co-worker, sets himself up in place of God, he ends up provoking a rebellion on the part of nature, "which is more tyrannized than governed by him". Man thus has a duty to exercise responsible stewardship over creation, to care for it and to cultivate it."

Unfortunately, "The Copenhagen Accord" on Climate change has proved that all the world's governments are not committed to preventing "dangerous" climate change. For some people, especially in the third world, dangerous climate change is already a reality. These places are inhabited by the poorest of the poor, but rich in biological diversity with endemic species of animals and plants. Majority of people who live in these areas are Christians and immediate action is required from their leaders and priests. Many victims of recent hurricanes, floods, and droughts blame climate change. Climate change is real, and it's not a myth. The 35,000 Europeans who died in the heat wave of 2003 were victims of an event that would almost certainly not have happened without the insidious increase in background temperatures that turned a warm summer into a killer. But, despite such local disasters, most would argue that the critical aim in the quest to prevent dangerous climate is to avoid crossing thresholds in the

climate system where irreversible global changes occur—especially changes that themselves trigger further global warming. There is no certainty about where such "tipping points" lie. But there is a growing consensus, especially in Europe that the world should try to prevent global average temperatures from rising by more than 3.5 degrees F above pre-industrial levels, or about 2.5 degrees above current levels.



After all that outcry and heat generated over saving the planet from Global Warming, Copenhagen ironically has done exactly the opposite. *The mammoth summit has itself turned out to be one of the highest polluting events of the year.* According to data with United Nations Framework Convention on Climate Change (UNFCC) and Deloitte Accounting, total carbon emission of the summit was around 46,200 tones. The numbers that make up that figure put into context mean the emission of this 12-day summit was more than what 600,000 Ethiopians emit in a year. The numbers include emissions caused by air travel, accommodation, local transport, electricity, paper, security, transport of goods and services etc. according to data from international agencies, around 30,000 people flew into Copenhagen for the summit, 140 private jets were used to carry delegates, 1,200 limousines were hired; nearly 800 km of computer cables were laid and close to 1.5 million sheets of papers were used for a summit which ended without a result. *Environmental campaigners have branded the summit an abject failure, saying it made progress on financing the battle against Climate Change but little else.* By delaying action, rich countries have condemned millions of the world's poorest people to hunger, suffering and loss of life as Climate Change accelerates. The blame for this disastrous outcome is squarely on the developed nations. A major bloc of developing nations called the draft climate deal in Copenhagen the "worst in history" and hinted it may try to block it. The deal locks developing countries and the poor of developing countries into a cycle of poverty forever.

The deal is not ambitious, is unfair, not legally binding and likely to put the world on a path to at least a 3 degrees Celsius temperature rise. World leaders had a once in a generation chance to change the world for good, to avert catastrophic Climate Change. In the end they produced a poor deal

full of loopholes big enough to fly Air Force One through. We have seen a year of crisis, but today it is clear that the biggest crisis facing humanity is a leadership crisis. *The agreement will be disastrous for the world, particularly the poor and the most vulnerable, as it will allow emissions to increase in the rich world.* Politics aside, what are the practicalities of stabilizing climate? Ultimately, it will be technologies, rather than politics, that solve the problem. The only question is what politics will best deliver the technologies that will allow us to *"decarbonize"** the world energy system. Those technologies fall into four categories: much more efficient use of energy; a switch to low carbon and carbon free fuels; capturing and storing or recycling some of the emissions that cannot be prevented; and finding new methods of storing energy, such as hydrogen fuel cells. Religions could join with politics or religions could make an appeal to their followers to cut down poisonous emissions on individual level. *Religion is a powerful tool.* If somehow, priests could make an appeal to Christians around the world, there are 2 billion followers who might take serious effort to do the right thing. Other religious leaders also urge their followers to join in the effort.

The task sounds daunting. But, in truth, much of it goes with the grain of recent economic and industrial development. In the past thirty years, global carbon dioxide emissions have grown only half as fast as the global economy—thanks mostly to improved energy efficiency. And many of the new energy technologies we will need are already in use, offering benefits such as cheaper or more secure energy. The replacement of coal with lower-carbon natural gas, oil with ethanol made from bio-fuels, the development of wind and solar power, the proposed expansion of nuclear energy, and investment in energy efficiency all fall into this category. What is needed first is faster progress in a direction in which we are already headed. Unfortunately, there is no certainty either above what limits on greenhouse gases will achieve that temperature target. We don't yet know how sensitive the climate system is. Current estimates suggest that to stack the odds in favor of staying below a 3.6 degree warming, we probably need to keep concentrations of man-made greenhouse gases below the heating equivalent of 450 parts-per-million carbon dioxide. In practice, that probably means keeping carbon dioxide levels themselves below about 400 ppm. Let's call this "safety-first" option.

Forgive me if I now abandon this language of parts per million. I find it an irritating and unnecessary abstraction. It seems to me much more sensible to talk in terms of tons carbon instead. Then we can establish how

** Moving towards Green energy, therby reducing gradually our dependency on fossil fuels.*

much there is in the Atmosphere and see more clearly how much we can afford to add before the climate goes pear-shaped. At the depths of the last ice age, there was about 440 billion tons of carbon dioxide in the Atmosphere. As the ice age closed, some 220 billion tons switched from the oceans to the Atmosphere, raising the level there to about 220 billion tons switched from the oceans to the Atmosphere, raising the level there to about 660 billion tons. That's where things rested at the start of the Industrial Revolution, when humans began the large scale burning of carbon fuels. Today, after a couple of centuries of rising emissions, we have added another 220 billion tons to the Atmosphere, making it about 880 billion tons. If we want to keep below the safety-first concentration, we have to keep below 935 billion tons. So we have only about another 55 billion tons to go.

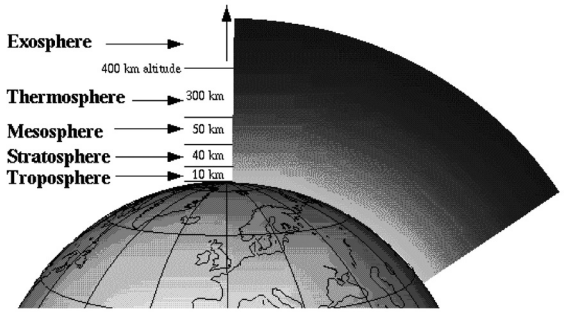
Currently, we pour about 8.2 billion tons of carbon into the Atmosphere annually. Of this, a bit over 40 % is quickly taken up by the oceans and by vegetation on land. The rest stays in the air, where its life expectancy is more than a century. So, for practical purpose, we are adding about 4.4 billion tons of carbon dioxide a year to the Atmosphere. Even at current rates of emissions, that means that we will be above our 935-billion-ton safety-first target before 2020; and assuming that emissions continue to rise at the current rate, we will be there in less than a decade. Frankly, barring some global economic meltdown, there is now very little prospect of not exceeding 935 billion tons. If we had acted quickly after 1992, we could have done it. But the world failed. *Big developing nations like China and India may have high national emissions. But measured in ratio to population, their emissions remain low.* While the U.S and Australia emit around 5.5 tons of carbon a year for every citizen, and European countries average around 3 tons, China is still around 1 ton, and India below half a ton. Most of the rich countries are Christian countries having the best institutional advantage for any action and change. Here is an opportunity for Christian leadership with their priests to make an appeal to their flocks, the ethical, moral, and theological need for sustainable development that would stop further damage to Atmosphere. Developing countries feel they are being asked to forego economic development to help clean up a mess they did not create. On the other hand, they increasingly see that climate change threatens their prospects for economic development.

Literally, whatever target we set will require drastic cuts in emissions. Nature will probably continue to remove a certain amount of our emissions. But experts on the carbon cycle say that we must reduce emissions to around a quarter of today's levels before nature can remove what we add each year.

Only then will Atmosphere levels stabilize; only then will climate start to stabilize. The quicker we can do it, the lower the level at which carbon concentrations in the air will flatten out. *Reaching the safety-first target of 935 billion tons of carbon dioxide would require an immediate and dramatic ditching of business as usual in the energy industry worldwide.* Global emissions would need to peak within five years are so, to fall by at least 50% within the next half century, and to carry on down after that. A trillion ton target could be achieved with more modest early cuts and greater reductions later. The significant reduction would be made possible by the initiative taken by different religions, such as religious leaders and priests.

History of our Atmosphere

Our Atmosphere has evolved from an earlier and quite different Atmosphere. Apart from a continuing removal of carbon dioxide, the composition of the air has not changed fundamentally over the last 600 million years, however, so it makes sense to think of the two Atmospheres separately. In addition to these, the Earth probably had yet another Atmosphere, its first, for a short time after the planet formed. The sun began as a cloud of gas and dust, which collapsed under its own gravitational attraction. Almost all of the matter became part of the new star—the sun itself—but a small amount remained in orbit about the central mass, and it is from this residue that the planets formed. Hydrogen and helium were the most abundant ingredients of the original cloud—they are the principal constituents of the sun and—also the lightest. It seems likely, therefore, that the newly formed Earth may have had an Atmosphere composed mainly of hydrogen and helium, possibly mixed with traces of other gases. The existence and composition of this very early Atmosphere can only be inferred from the most plausible theories about the way planets form, for it vanished long ago and left no trace of itself. The Earth's own gravitational attraction is strong enough to retain gases heavier than hydrogen and helium, but an Atmosphere composed of those gases would have leaked away into space. If it existed, the hydrogen-helium Atmosphere was probably lost fairly rapidly as pressures within the sun reached



the level at which atomic nuclei began to fuse together, and the star began to shine. Its warmth would have imparted enough energy to hydrogen and helium for them to have been swept away completely.

If this is what happened, the lost Atmosphere was replaced very quickly by one that proved more substantial, and of this there is clear evidence. The decay of radioactive elements proceeds at a very precise rate, and allows scientists to discover the age of materials by analyzing the isotopes from which they are made. Radioactive dating has established that the formation of the Earth was completed about 4.5 billion years ago. The oldest rocks so far discovered in western Greenland are 3.8 billion years old, and they are sedimentary. This means they formed by the accumulation of sediment, a process that can occur only in water. *Liquid water must have been present while the rocks were being deposited and, if water was present, there must also have been an Atmosphere.* This is because the temperature at which water boils is inversely proportional to the Atmosphere pressure. If the air pressure is zero, water cannot exist at all as a liquid all—of it will vaporize. Had this happened, it is almost certain that the hydrogen and oxygen of the water molecules would have dissociated and been lost from the top of the Atmosphere. Not only would the Earth have lost its Atmosphere, it would also have lost all of its water.

It is quite certain, therefore, that the Earth had an Atmosphere at least 3.8 billion years ago. That much we know, but our understanding of its composition is largely conjectural, although we are not quite helpless. The Atmospheric gases must have been emitted by volcanoes—there seems no other way they can have originated and the Earth was much more volcanically active then than it is now. At that time more heat was generated by radioactive decay beneath the crust, and this is the principal cause of volcanism. Less heat is generated now because the process has continued for long enough for much of the original radioactivity to have decayed. *Living organisms were already present 3.8 billion years ago—chemical evidence of them has been found in the Greenland rocks.* They lived in water, because the evidence comes from sedimentary rocks, and they must have required particular chemical nutrients, especially carbon, nitrogen, sulfur and perhaps iron, all of which must have been present in the water, and some of which are most likely to have reached the water from the air.

Most scientists now accept that a "greenhouse effect" prevented the Earth from being extremely cold—with an average temperature below freezing, and perhaps far below. This suggests that the principal constituent of the

Atmosphere must have been carbon dioxide. There were also remaining from the earlier Atmosphere and, perhaps a little free nitrogen, although this is uncertain. Water vapor must have been present, and there may possibly have been a very small amount of methane as well as a little ammonia formed by the reaction between hydrogen and nitrogen. At this stage, the Atmosphere contained, at most the smallest traces of free oxygen, and probably it contained no oxygen at all. This means there was no formation of ozone (O3), and no ozone layer to provide a shield against ultra-violet (UV) radiation—although UV radiation is much less biologically damaging than many people suppose, and exposure to it is as likely to have accelerated the chemical reactions with which evolution began as to have hindered the process.

Although it is a gaseous ocean, with currents, eddies, and other similarities to the seas while cover the globe, the Atmosphere obviously is different from the Earth's water cover. The air is not as uniform as the oceans. Its concentration and weight varies with altitude from sea level and with the seasons of the year. Variations in the Atmosphere take place because the air is a combination of gases, rather than a liquid. The concentration of any gas is dependent on the closeness with which its atoms are held together by gravity, the force which affects all universe. Gravity's pull is greater on the Atmosphere close to the surface of the Earth, hence the concentration and pressure of gases is greater closest to the Earth's surface. As gravity diminishes with altitude, the pressure of the Atmosphere grows less. At sea level the Atmosphere exerts 14.7 pounds of pressure for each square inch of surface, but this rapidly diminishes with altitude, so that at even a mile above sea level, some persons have difficulty in breathing.

How does Atmosphere work?

The temperature of the air also varies from point to point above the Earth's surface. Air temperatures are dependent on a number of factors, altitude, the amount of water suspended as vapor in the Atmosphere, and the speed with which air is being circulated. At sea level, the temperature of the air rarely falls below 60 degrees below zero or rises above 120 degrees Fahrenheit. Air temperatures tend to decrease through the lower levels of the Atmosphere at about 1 degree Fahrenheit for each 100 feet of altitude. These are only generalizations, however, and other factors are important in determining air temperatures at higher levels of the Atmosphere. Insulation, also affects air temperatures, making the air generally warmer at the Equator and colder at the poles, because the sun's rays strike the Earth at greater angles at higher latitudes north and south of the Earth's middle.

Water also is a key factor in the temperature of the air. The oceans absorb heat from the sun during the day and release it during the night. Land, on the other hand, reflects the sun's rays during the day, making differences in both day and nighttime temperatures over land surfaces. In either case, the sun has an important effect on the temperature of the air. Water suspended in the air as vapor allows the air to absorb heat and also to release it as the water is turned into clouds, fog, snow, and rain.

A few high clouds sometimes are found in the stratosphere, but usually it contains very little water vapor and low gas concentrations. The stratosphere also is the home of the Ozone Layer. Vestiges of the troposphere's gases are also found in the stratosphere, but they are at such low concentrations that they could not support living creatures. In the higher layers of the stratosphere, the concentration of gases grows less, for there is less gravity to hold the atoms of gas together. The temperature of the gases in the stratosphere may grow higher, however. This also is true in the thermosphere and exosphere, the two highest levels of the Atmosphere. There air temperatures may rise to more than 1,000 degrees Fahrenheit, but because gas atoms are so far apart there, little of this heat is transmitted from one atom to another. The thermosphere and exosphere do have sufficient atoms within them, however, to create friction on meteorites as they fall toward the Earth from space, usually turning them to cinders before they reach the lower levels of the Atmosphere. The upper levels of the Atmosphere thus provide the Earth's surface with enough protection to prevent wholesale bombardment of the surface and its life by these travelers from space.

Water vapor in the Atmosphere is "expressed" or made visible in some form of precipitation, clouds, fog, rain, sleet, hail, or snow. In any of these forms, it becomes visible when it is sufficiently condensed to allow water droplets to form in the air and fall toward the Earth. The droplets condense around dust particles in the air. The additional weight of the dust particle also makes them fall toward Earth more rapidly than if they had been formed only from water. Whether it is visible, as clouds or other forms of precipitation, or invisible, as water makes up a sizable part of the Atmosphere, perhaps as much as 40 million tons. Much of it is invisible. Thus, simply because the air is clear is no guarantee that it is also dry. Clear air is as capable of carrying water as is cloudy or foggy air. Water vapor usually is visible from the surface, however, as clouds. Clouds are important not only because they bring moisture to the land surface of the Earth, but also because they make it possible to follow patterns of air movement. The movement of the air over the surface of the Earth is complex, because air

travels not only horizontally, but vertically as well, and because the gases of the air are constantly in motion. Air is never completely stagnant. The air which exists over one part of the Earth today will be in a completely different place by tomorrow.

At lower levels of the Atmosphere, it is often possible to chart air movements by watching how dust, smoke, and the products of volcanic eruptions are pushed this way and that by air currents. Clouds, however, are the chief way in which men have been able to chart and predict the weather, as the changes in air movement and precipitation are called. The formations of clouds can tell a great deal about what to expect from them. Indeed, with enough information, even nonscientists can make rough but fairly accurate predictions about the weather from cloud formations alone. In part this is because air currents in the Atmosphere follow generally predictable pathways over the Earth's surface. Any study of air currents must begin with the fact that the Earth is a turning sphere. Not only does the air move around our planet, but the Earth also turns beneath the air. Thus, even if air stood still, it would not be over the same point on the Earth's surface for very long. The Earth's rotation and the movement of the air help to create an apparent whirling of the air into circular pools called cyclones or anticyclones, depending on which direction they are moving. In the Northern Hemisphere, cyclones seem to be moving in one direction. In the Southern Hemisphere, they seem to be moving in the opposite direction. In either hemisphere, the apparent circular motion is called the Coriolis force,* in memory of Gaspard Gustave de Coriolis, a French scientist of the nineteenth century.

Cyclones and anticyclones result from vertical movements of air along the jet stream's path, interacting with its horizontal movement. As warm air forms near the surface, it has greater pressure than cold air and begins to rise. It also expands. Such a body of air is called a "high" because its pressure is higher than the air surrounding it. If it is colder than the air around it, with less pressure and is sinking, it is called a "low." In general, highs are an indication of fair weather, that is, weather without rain, fog, or snow, whereas lows may mean stormy weather is coming. The situation with regard to highs and lows is more complicated than this. However, it is not so much the appearance of a high or low that indicates stormy weather as it is the interaction between them. When highs and lows meet or come near

**The Coriolis force is an effect which causes the curving of things that travel long distances such as prevailing winds or ocean currents. The ocean currents and prevailing winds curve due to the rotation of the Earth. The Earth rotates once per day. Ocean currents and prevailing winds rotate to the right in the northern hemisphere and to the left in the southern hemisphere.*

enough to one another, air flows between them and the water vapor in the highs tend to be condensed into precipitation. Highs and lows interact with one another partly because of the stability or instability of air. Air is always rising or sinking. The rise or fall of pockets of air in the Atmosphere takes place because of differences in the moisture content and temperature of such bodies in relation to the air around them.

Warm, moist air tends to rise. Cold, dry air tends to sink. The rate at which air rises or falls also is dependent on whether or not the air is cloudy or clear. Cloudy air tends to cool more slowly than clear air, because it contains more water vapor and hence may continue to rise for a longer time than clear air. This is particularly true of the clouds of some thunderstorms, for example, which may soar thousands of feet into the air very rapidly before they are sufficiently cooled to become stable air. It is also important to remember that movement of the air always takes place in relation to the Earth's surface and that the Earth is constantly turning. Thus, even as the air is being churned around by differences in its temperature and water content, it also may be passing over a different place on the Earth's surface. Highs and lows seldom remain stationary, but move over the Earth, constantly changing their position.

Technology and Atmosphere

Modern technology can detect the happenings in the Atmosphere, with latest instruments. The collision of warm and cold air in highs and lows makes weather in one of three ways. When warm air rides out over a cold low, it tends to hold it in place, because the cold air cannot rise. This sometimes creates a kind of lock on the cold air and makes an air inversion. But more often, it causes some of the warm air to condense into rain or snow. This formation is called a warm front. The reverse also may be true. Cold air from a low may overwhelm a body of warm air, creating a cold front. Where the warm and cold air come together, rain or snow may form. Finally, cold and warm fronts may mix to create an occluded front. Precipitation also may form in places along an occluded front. To find highs and lows and hence to discover the possibility of interaction between warm and cold fronts, weather scientists must have some idea of the pressure and temperature of air within specific places in the air. To measure air pressure, it is necessary to have a standard against which to check it, and this is the

** Barometer is an instrument to measure atmospheric pressure. Barometer measures the weight of the column of air that extends from the instrument to the top of the Atmosphere. Invisible gases found in the Earth's Atmosphere have weight and exert a pressure on all of us. It is this pressure that barometer calculates. Mercury and aneroid are the main two types of barometer.*

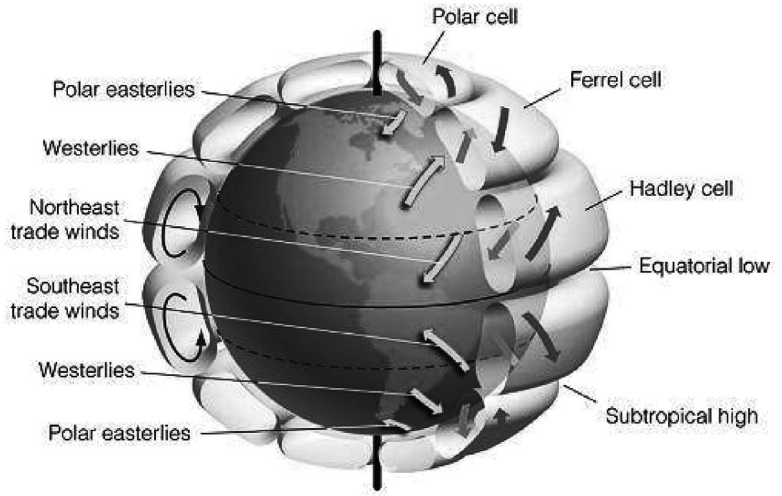
pressure of air at sea level, 14.7 pounds per square inch. Most barometers,* the devices used to measure air pressure, are calibrated at this figure. Some are made of glass tubes filled with mercury, whose columns are graduated from sea-level pressure, but some may be small tanks from which air has been removed, making it possible for the tank to reflect changes in the air pressing on it. In either case, barometers detect small but important changes in air pressure. Because they do, they make it possible to tell whether air pressure is rising or falling. In general, a falling barometer and a declining amount of air pressure indicate storms are likely to be on the way. A rising barometer means fair weather or clearing after a storm.

Barometer readings, of course, are only one of many bits of information weather scientists need to predict the weather. They also must measure the temperature of the air, the direction of the wind, its force, and many other factors that may affect weather changes. Technologically advanced nations of the world over the past half century have developed thousands of weather-observation stations to gather such information. Less developed nations have few such places and less ability to tell how the weather is going to change. A vast amount of such information now goes into weather forecasting. It is gathered from ships at sea, balloons flown into the Atmosphere, weather satellites, and ground measurements. Since the invention of computers, it has been possible to use such data to gain an ever-clearer picture of what is happening to the air, whether the air is visible as clouds or is invisible. It also should be clear that even though masses of cold and warm air are constantly shifting around in the Atmosphere as the Earth moves beneath them, the shape of the Earth's land surface also has important local effects on the weather. Ranges of mountains tend to force air upward. Mountains passes leak air into regions beyond the mountains. The oceans and inland bodies of water absorb heat. Deserts reflect it back into the air.

Weather and Global Wind Pattern

What makes weather? It is the sun. Through seasons, it heats the world, some parts more, some less. The Earth's yearlong trip around the sun creates a giant engine that drives the weather. Anyone who ever wilted on a sweltering summer day can easily understand that the sun creates hot weather. An equally important factor in the movement of the air is the sun's heat. Heat does not reach the Atmosphere in uniform amounts, nor is it reflected or absorbed in uniform amounts by the ocean. In general, however, both the air and water around the Earth's equator receive more heat than do the air and water near the poles. The equatorial air rises in an

effort to cool and because it has more pressure within it. Because the air over the temperate zones of the world is cooler, equatorial air flows both north and south over the Earth toward it. As the air grows cooler, it begins to sink back toward Earth again, first at about 30 degrees north and south latitude from the Equator, and then at about 60 degrees north and south latitude. As the air reaches these two areas, some of it flows back toward the Equator again forming a constantly moving convection cell of air, but some of it remains aloft and continues toward the poles. That which finally does reach the poles grows cold and sweeps back along the Earth's surface toward the temperate zones and the Equator. These six convection-cell movements make the general circulation of air over the face of the Earth, but they are not as neatly defined as this description would indicate. Rather, they are general patterns of circulation, and their general movement helps greatly in explaining the regular direction in which winds on the Earth's surface flow and how weather at higher elevations in the Atmosphere is created. One always has to keep in mind, too, that the Earth is turning beneath the cells as they move, adding an apparent direction to the wind.



The cells are the explanation for several wind phenomena: the trades, which blow in a constant direction across certain latitudes of the Pacific and the Atlantic; the doldrums, intervals between the cells at the Earth's surface where winds often are slight or almost nonexistent; Westerlies;* and the strong surface winds at the poles. More important, where the cooled

**Above the subtropical highs in the northern hemisphere, and below the subtropical highs in the southern hemisphere, winds blow from the west towards the east. The winds are known as westerlies.*

higher-altitude air begins to sink earthward, the jet stream forms. The jet stream is an intersection between two cells where the vertically moving air of the cells creates a stream of very swift air at high altitudes in the troposphere. Usually the jet stream travels at several hundred miles an hour. The stream affects North America by blowing across the northern Pacific to British Columbia or Washington State. It then dips down over the U.S. *Coincidentally, the jet aircraft traveling from west to east across the Pacific often "catch" the jet stream and use its tailwinds to reduce their fuel consumption. The stream is not named for them, however, but for the fact that it is a thin jet of fast-moving high-altitude air.* Jet streams seem to affect the location of cyclones and anticyclones as they travel across the Earth's surface. Both tend to follow the path of the jet stream, and hence its location on the Earth is an indication of where storms or fair weather are likely to occur. The jet stream is not always in the same place. During the winter months in the Northern Hemisphere, it tends to shift southward to bring winter storms to the United States, but sometimes this does not happen, and abnormal weather results.

Usually, there is also a pattern to the movement of air over coastal regions of the continents. During the day, the land radiates its heat into the air, causing it to rise and flow toward the ocean. During the night, the ocean, which has been absorbing solar heat in daylight hours, is free to release the heat into the now cool air above it, and the flow of air reverses itself and moves back toward the land. We know these air movements as on and offshore breezes, and usually they are as regular as the night and the day. Much of the same kinds of forces are often at work between mountains and valleys. During the day, air warms more rapidly over the surfaces of the mountains than in the valley, but it also cools down more rapidly there during the night. As it cools at night, it flows downhill into the valleys below. This causes the warm air the valleys have been holding to be pushed aloft and carried toward the mountains. Thus there is set up a strong up-and-down flow of air between mountains and valleys, particularly where there are large differences in altitude.

Trade Winds: Trade winds blow generally from northeast to southwest in the northern hemisphere. For hundreds of years, sailing ship captains—among them Christopher Columbus—sailed far enough south to catch the steady, easterly trade winds that pushed them westward to the Caribbean. To return to Europe, they sailed northwest close to the North American coast until they found the westerly winds that predominate in the temperate latitudes. The inter-tropical Convergence Zone, where the trade winds come together—converge— shows up on satellite photos as a band of white clouds near the Equator. Sailors know this zone as *"the doldrums."** Here the winds blow lightly or not at all. As the trade winds approach this area, they die out as air warmed by the tropical oceans begins rising. During the northern hemisphere summer, the inter-tropical Convergence Zone creeps northward especially over Asia. The zone moves more directly under the sun where it's hotter. In the fall it moves southward to the Equator, or, in some places, even south of the Equator. Air, rising from the ICZ thunderstorms, flows northward or southward in the upper Atmosphere and sinks when it gets about as far north as Florida or as far south as Australia. Then it forms huge high-pressure areas at the surface with light winds. On land these high-pressure areas help create the Earth's large deserts, such as in the southwestern U.S and across northern Africa and Saudi Arabia and India. At sea these high-pressure areas, where air is slowly descending, create calm or light, variable winds and mostly clear skies.

Polar winds: Around the poles, the winds are variable, but blow from the east on average. As cold air piles up, it creates strong high pressure at the surface. As cold air flows away from the North and South Poles, it warms slightly as it reaches about 60 degrees latitude, where the ocean is a little warmer. Warming causes the air to rise, which creates low-pressure areas. Meteorologists call these *"semi-permanent"* lows, since they are in the same places most of the time, but not always. Air flowing away from both the North and South Poles into these low-pressure areas causes easterly winds around the Polar Regions in both hemispheres. The clear skies of the high-pressure areas and cloudy skies of the lows are important global weather makers. The pattern of winds around the semi-permanent areas of high and low pressure also makes west winds dominate at the surface in the temperate zones. The flow of the wind around these big highs and lows is a weather predictor. In winter, oceans near the poles are warmer than the land. Air over the warm water is warmed more than air over land and begins rising, creating low pressure—and stormy weather. Areas such as the *Aleutian Low* spawn winter storms. In summer, as the land warms up, the contrast between land and ocean temperatures decreases and the low-pressure areas weaken. High-pressure areas in a particular latitude form where the surface is cooler. In the summer, the contrast between the hot, tropical land and the cooler oceans is greater than in winter. This is why the high-pressure areas over tropical oceans grow in the summer.

Local Winds – Sea Breeze: While global-scale winds, such as the trades, determine the weather over large areas, smaller winds create local weather. One of the most common local winds is a sea breeze along the ocean or

**Doldrums is a region of low pressure close to the Equator. Winds will be light or non-existent, the weather hot and sticky, and thunderstorms and squalls may appear with little warning.*

near large lakes. During the day the land heats up more than the water. Warm air rises over the land and cooler air flows in from the water to replace it. If the water is warm enough, such as off the coast of Florida, a land breeze can begin at night as the land cools.

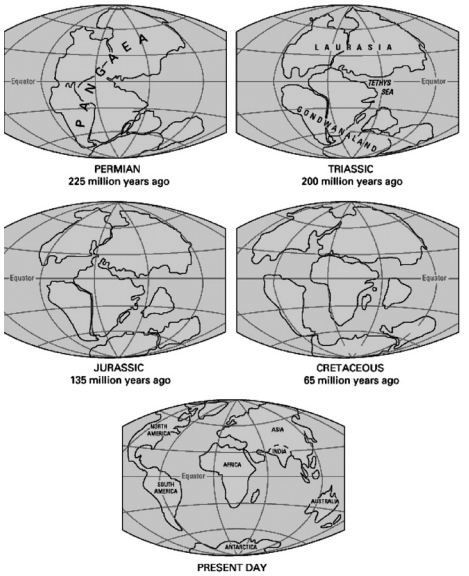
Mountain Winds: Mountains also create their own winds. During the day the sun can heat mountain slopes, especially bare rock. The warmed air rises above and more air flows upward from valleys to replace it. This creates a wind blowing up the mountain during the afternoon. As the mountain slopes cool at night, cold air, which is heavier than warm air, begins flowing down into the valleys. Winds, whether they're the jet streams racing overhead, the gales in the roaring, or the first warm breezes of spring, they definitely move masses of air around the Earth. The clash of these moving air masses creates the storms that dominate our ever-changing weather. Although much is known about the movement of the air, then, much remains to be discovered. The air is still filled with mysteries. Not the least of these is how man is to continue to survive within the invisible cloak of the Atmosphere, even as he continues to abuse the vital gases which gave him life. To learn these secrets before permanent damage makes the Atmosphere uninhabitable will require much more research and understanding than man now possesses, but it is a goal toward which much scientific dedication is now directed.

Tectonics and Climate

The positions of the continents also determined global climatic conditions. Over the last 100 million years, changes in climate have been largely controlled by plate tectonics.* When most of the land huddled near the equatorial regions, the climate was warm. When lands wandered into the Polar Regions, however, they grew cold and became covered with ice. Furthermore, during times of highly active continental movements, there is a greater amount of volcanic activity, especially at mid-ocean ridges and subduction zones. The amount of volcanism could affect the composition of the atmosphere and the rate of mountain building, which ultimately affect the climate. When all the lands were welded into the super-continent Pangaea around 250 million years ago, much of the land was located near the tropics, where more of the sun's neat could be absorbed, which contributed to higher global temperatures. Also, oceans in the high latitudes are less reflective than land. Therefore, they could absorb more heat, which further moderated the climate. Moreover, without land in the

**According to the theory of Plate Tectonics the Earth's crust is broken into at least a dozen rigid plates that move independently of one another.*

Polar Regions to interfere with the movement of warm ocean currents, both poles remained ice free year-around. This resulted in little variation in temperature between the high latitudes and the tropics.



When Pangaea* began to break up, the climate in the Cretaceous period was extremely warm, with average global temperatures 5 to 10 degrees Celsius warmer than they are today. When the continents drifted toward the poles by the end of the Cretaceous period, however, they disrupted the transport of poleward oceanic heat and replaced heat-retaining water with heat-losing land. As the cooling progressed, the land accumulated snow and ice, creating a greater reflective surface, which further lowered global temperatures and sea levels. The most important factor controlling the geographic distribution of marine species is ocean temperature. Therefore, climatic cooling is primarily responsible for most crises among seafaring creatures. The location of land in the Polar Regions is often the cause of extended periods of glaciations because high-latitude land has a higher albedo** and a lower heat capacity than the surrounding seas. This condition encourages the accumulation of snow and ice. The more land area in the higher latitudes, the colder and more persistent is the ice, especially when much of the land is at higher elevations, where glaciers can grow easily. Furthermore, replacing land in the tropics with oceans has a net cooling effect because land located in the lower latitudes absorbs more of the sun's heat, while oceans reflect solar rays back into space. Also, by increasing the land area in the high latitudes, where snow falls steadily with little melting, a permanent polar glacial climate is established.

**For almost one hundred million years, only one continent existed. It extended from the North Pole to the South Pole. Today, this land mass is known as Pangaea. It formed almost two hundred and fifty million years ago.*

***Albedo is the fraction of solar energy reflected from the Earth back into space. It is a measure of the reflectivity of the Earth's surface. Ice, especially with snow on top of it, has a high albedo.*

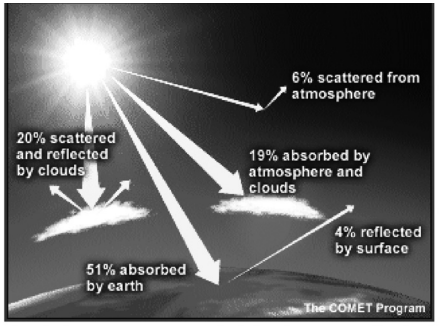
After the glaciers are securely in place, the high reflectivity of snow and ice tends to perpetuate them and sustain glaciations. This is true even if the once high land were to sink to the level of the sea due to a decrease in crustal buoyancy by the weight of the ice. Increasing the weight on the land can also interfere with the flow of mantle currents, possibly causing an increase in volcanism. The greater volcanic activity increases the amount of ash injected into the Atmosphere, which shades the planet and lowers global temperatures, maintaining glacial conditions. The ocean bottom influences how much heat is carried by ocean currents from the tropics to the poles. When Antarctica separated from South America and Australia and moved over the South Pole some 40 million years ago, a circumpolar Antarctic Ocean current was established. This current isolated the frozen continent, preventing it from receiving warm poleward flowing waters from the tropics, causing it to become a frozen wasteland. During this time, warm salty water filled the ocean depths, while cooler water covered the upper layers. In the large shallow Tethys Sea, which separated Eurasia from Africa, warm water became top-heavy with salt due to high evaporation rates and little rainfall, causing it to sink to the bottom. Meanwhile, ancient Antarctica, which was much warmer than it is today, generated cool water that filled the upper layers of the ocean, causing the entire ocean circulation system to run backward. Then around 28 million years ago Africa slammed into Eurasia turning off the tap of warm water flowing to the poles, placing Antarctica in a deep freeze. The cold air and ice cooled the surface waters and made them heavy enough to sink and flow toward the equator, providing the Earth with the ocean circulation system it has today.

Changes in the deep-ocean circulation also coincided with the late Eocene extinctions, in which all the archaic mammals abruptly disappeared. The extinctions also eliminated many European species of marine life, when the continent was flooded by shallow seas. The separation of Greenland from Europe during this time might have been responsible for the frigid arctic waters to drain into the Atmosphere, significantly lowering its temperature, and causing most types of foraminifera to disappear. In the ensuing Oligocene epoch, the seas were drained from the land as the ocean withdrew to perhaps its lowest level since that last several hundred million years, and the seas remained depressed for the next 5 million years. These cooling events removed the most vulnerable of species, so that those living today are more robust and capable of withstanding the extreme environmental swings that occurred during the last 2 million years, when glaciers spanned across much of the Northern Hemisphere. The ice ages came and went almost like clockwork about every 100,000 years. They will most likely continue for perhaps several more million years until all the

continents are once again gathered at the equator. This will alter the face of the planet, and the composition of its life, just as it has done for most of the Earth's history.

How Sun Creates Energy

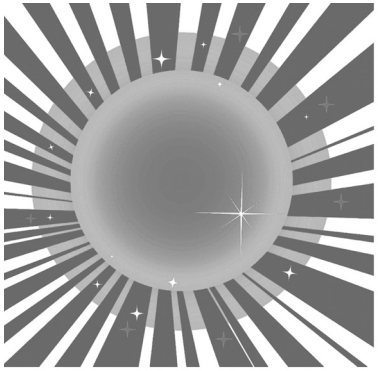
For centuries people thought of the sun as a giant object on fire, burning the way campfires burn. But imagine how much fuel would be needed to keep that fire going. If something the size of the sun were made of gasoline and had enough oxygen, it would burn about 10,000 years. That's a long time but far short of the four and a half billion years the sun and Earth have existed. Early in the 1900s, as scientists started learning about radioactivity, they conjectured that nuclear energy might explain the sun's power. In 1938, Hans Bethe of Cornell University and Charles L. Critchfield of George Washington University produced a theory explaining how nuclear fusion fuels the sun and other stars. A fusion reaction fuses atoms together, creating other kinds of atoms and giving off energy. Only a small share of the sun's tremendous energy reaches the Earth, but that's enough to maintain life and drive the weather.



The sun's electromagnetic energy, including light, ultraviolet energy and infrared energy, flows into the Atmosphere to warm the air, oceans and land. Besides the sun, the only source of heat on Earth is its molten core and radioactive rocks. While this heat supplies energy to slowly push the continents around and build mountains, it hardly affects the weather. As the seasons change, the sun bathes different parts of the Earth in widely varying amounts of energy. The result is a planet sharing frigid polar cold, sweltering tropical heat and all the temperatures in between, all at the same time. *This sets up a huge "heat engine" in the Atmosphere that powers the weather. A heat engine depends on hot-cold contrasts to produce power.* Your car is a good example. Power comes from the heat created by burning a mixture of gasoline and air in a cylinder. As the engine runs, its cylinders alternate between being hot and cooler. Power is produced. The Atmosphere is similar. The stronger the hot-cold contrasts, usually the stronger the storm.

More effects of the sun

Long before they began writing down history, our ancestors realized the sun gods. They celebrated the winter solstice, when the sun begins to spend more time in the sky each day until midsummer. The sun was a benign god that brought heat and light but no violence. In the far north, shimmering lights in the night sky inspired awe, but no one associated these auroras with the sun. In reality, the sun's atmosphere is an incredibly violent place that sends a "solar wind" of charged particles at speeds faster than 600,000 mph far into space, around and past the Earth. Earth's magnetic field shields us from the solar wind's particle bombardment. As we're being shielded, the solar wind molds our magnetic field into a comet-like shape with a long *"magnetotail"** stretching 4 million miles out from the Earth's dark side. Harmless auroras** in the northern and southern skies are the only visible signs of the solar wind's bombardment. The solar wind energizes electrons and other charged particles in the Earth's magnetic field. These particles follow the field's lies to the northern and southern magnetic poles. Here, more than 80 km above the ground, they collide with molecules of nitrogen and oxygen, making them glow as auroras. The more vigorous the solar wind, the bigger the auroras. Scientific understanding of all this has grown with the space age as researchers collect data from satellites and probes of the solar system.



This knowledge of "space weather" is becoming more important because what goes on inside and around the sun affects satellites, radio transmissions and even the electricity coming into our homes. On the night of March 12-13, 1989, a problem in the field of electricity caused total shut down for more than a week in Montreal, Canada. Some places were without power. The villain was a "geomagnetic storm," triggered when a huge blob of charges particles smashed into the Earth's magnetic field. The storm caused the magnetic field to bounce back and forth, creating or inducing currents in long

**Earth's invisible magnetic field is shaped like a comet. It has a long tail that stretches millions of miles behind Earth in the opposite direction from the sun.*

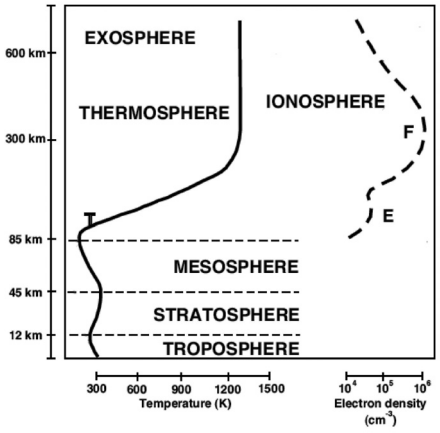
***Auroras are produced in the Atmosphere by the sunlight reflected from polar snow and ice, or refracted light similar to the light that produces rainbows. They are also known as Northern Lights.*

electrical conductors such as power lines, pipelines and railroad tracks. Moving an electrical conductor, such as a wire, through a magnetic field induces an electric current in the conductor. This is how generators and alternators make electricity. These currents are relatively weak, but they are enough to burn out electrical equipment and shut down power grids. In pipelines, they cause flow meters to give false readings. In railroad tracks, they can interfere with electrical devices that help locate trains. Satellites, especially the more than 600 geostationary satellites in orbits above the Equator, are in even more danger. These satellites include those that handle an increasing amount of the globe's communications as well as ones that watch the weather.

Structure of the Atmosphere

We often describe the Atmosphere as a kind of blanket enveloping the Earth. In some respects the image is misleading, however, because a blanket has a thickness you could measure, and this suggests that the Atmosphere should also have a definite thickness. For many years this was the conventional view, modified a little by the realization that at the top the Atmosphere does not end quite abruptly, but rather fades away through a region of increasing tenuousness. When plans were made to launch vehicles into space, no one doubted than the "space" they were to enter lay beyond the uppermost reaches of the Atmosphere, in what was essentially a vacuum. Part of the image has survived, but the information acquired through space research programs has necessitated a substantial revision of most of it. In particular, it has been revealed that the *"vacuum of space"* is by no means empty, and our atmosphere does not simply end, so that if you were launched from the surface in a space vehicle you could say that at one moment you were inside the atmosphere is like asking the length of a piece of string. Indeed, the concept of a "vacuum" is now considered to be of only theoretical importance.

The space shuttles, which orbit the Earth at altitudes between 250-300 km are clearly in space—but are they outside the Atmosphere? All gases, including air, are easily compressed. A planet retains its Atmosphere because of the gravitational force it exerts, but this force decreases rapidly with increasing distance from its source. The gradual "fading out" of the upper Atmosphere is due to the combination of these two factors. The air we breathe, through which we move and without which we cannot survive is a material substance. *We cannot see it, except as the blueness of the sky, but physically it is as real as any of the solid objects we see around us—as real as a house or a tree. Being a real substance, air has mass and it also has weight.* Mass and weight are not the same thing, although we commonly use the words as though they were synonymous. The mass of an object is a measure



of its inertia—of the force needed to move it if it is at rest. If two bodies of equal mass collide—picture two balls on a snooker or pool table—they will be affected equally by the collision. If the balls are of different masses, the one with the smaller mass will move faster and further than the one with the greater mass. At the same time, mass is a measure of the gravitational attraction a body exerts on other bodies within its range.

The Layers of Atmosphere

A space traveler, departing from Earth for a destination elsewhere in the solar system, would pass through all the layers of our Atmosphere. Unfortunately, such a passage would be far too brief to allow any examination or appreciation of the regions that were traversed. A more leisurely means of ascent is required. We are surface-dwellers, and bound to the surface more firmly than we may suppose in these days of air travel. The air with which we are familiar is contained in the troposphere. Many of us have flown through tropospheric air. And some of us may have crossed the tropopause—barely—but very few people have ventured beyond the lowest regions of the stratosphere, and only astronauts have visited the outer regions of the Atmosphere. A journey of a mere 161 km to the region directly above our heads is beyond us, and we know far less about what happens there than we do of events on the other side of the world, but at the surface. If you were to climb slowly and steadily through the Atmosphere, you would see everything, if you were inside an aircraft, so we must suppose that you could remain exposed to your surroundings—in the basket below a balloon, perhaps. You would need to take special clothing and equipment, for protection when conditions became intolerable, and you would also need instruments, to measure changes your senses would fail to register.

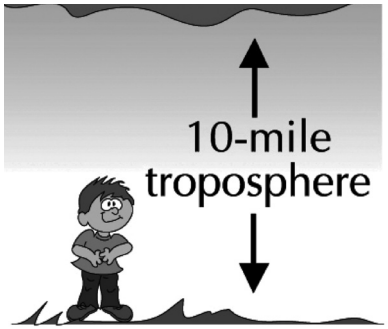
Your first impression, on an average day, might be of a sharp increase in the wind speed as soon as you were well clear of the surface. The air is seldom still, but it is slowed by friction as it passes across the ground and encounters obstacles such as trees and buildings. You would feel this change at a height of 200 feet or less, and you can often see it from ground

level. When the wind is too light to disturb even the smallest twigs on the trees and scraps of paper fall almost vertically, low-level clouds are often moving across the sky quite steadily and fairly rapidly. A little higher, perhaps you will approach the base of cloud. As you enter the cloud you will need to don waterproofs, because clouds are composed of water droplets and will soak you very quickly. The cloud, feeling like fog, will seem cold. The reason, you may think, is quite straightforward. If you cool water vapor it will condense. This is why the windows of a car "steam up" on a cold day—the passengers exhale water vapor which condenses on to the cold windows. This broadly true, but in a cloud matters are not quite so simple. The water droplets are cold, but the air between them is much warmer. At lower levels, the Atmosphere forms layers, which are distinct and separated by boundaries that tend to prevent the passage of molecules and solid particles in either direction. These layers form a set of concentric spheres surrounding the Earth and each has a name ending with the suffix-sphere. This structure is controlled by temperature.

Troposphere and Tropopause

The lowest layer is called the troposphere. Temperature is one of the ways in which scientists have been able to divide the Atmosphere into levels. The lowest level of the Atmosphere, the troposphere a region which extends from the Earth's surface to 40,000 or 50,000 feet, is the home of all life, almost all clouds, the majority of the water vapor in the biosphere, and almost all the changes in conditions we call weather. The upper limit of the troposphere is also about the limit to which jet aircraft can fly, and thus it is the practical limit to which most humans travel in the Atmosphere. Above the troposphere lies the tropopause, a dividing layer of air which separates the troposphere from the stratosphere. The word troposphere comes from the Greek *tropos*, meaning *turning* or *mixing*. *The troposphere is the most turbulent part of the atmosphere and is the part where our weather takes place.* Weather is the state of the air at a particular place and time e.g. if it is warm or cold, wet or dry, and how cloudy or windy it is. The Earth's surface provides its lower boundary and it extends upwards as far as the tropopause. The height of the tropopause varies from place to place and season to season—occasionally it can descend to surface level—but generally it is about 17 km over the Equator and sometimes as low as 8 km over the poles, although usually it is at about 10-12 km. The really huge storm clouds that bring thunder and lightning are more common in some parts of the world than others—they are especially common in the tropics—but if ever you have a good view of one, it will reveal the location of the tropopause. Such clouds are called "cumulonimbus," from the Latin

"cumulus," meaning "heap" and "nimbus," meaning "cloud," and they stand as great, threatening towers. The top of a big cumulonimbus is often flattened with what looks like a tail trailing to one side, giving the cloud top the approximate shape of a blacksmith's anvil—and these clouds are often called "anvil" clouds.



The flat top of the "anvil" marks the level of the tropopause, and demonstrates clearly that this is a real boundary which gas molecules and water droplets can rarely cross. If you wonder about the height of such a cloud, in middle latitudes the "anvil" probably marks an altitude of a little more than 15 km and is higher than most civil aircraft are able to fly. The existence of the tropopause is due, in the first place, to the fact that air in the lower part of our Atmosphere is transparent to all of the solar radiation to which it is exposed. The radiation passes through the air without affecting it and warms the land and sea surface. Contact with the warmed surface then warms the air. The *troposphere* is the part in which we live. An important characteristic of the troposphere is that its temperature *decreases* with an increase in altitude. In other words, as you climb higher, it will get colder. You will have noticed this if you have climbed a mountain, or if you have moved from a city at a high altitude to one which is lower; the average temperature is often lower where the altitude is higher. This is because the troposphere is heated from the 'bottom up'. In other words, places that are closer to the Earth's surface will be warmer than those at higher altitudes.

Gases, including air, can be compressed quite readily. We compress air every time we pump up a tire or a balloon—it is easy. The weight of the Atmosphere also compresses the air of which it is composed. The great mass of the Atmosphere is given weight by the gravitational attraction that draws it towards the center of the Earth but, because the molecules in a gas are not attached to one another, the force acts on each of them individually. At the bottom of the Atmosphere, the air molecules are closer together than they are at higher levels and, therefore, the density of the air decreases with increasing height. *The troposphere contains about three-quarters of the entire mass of the Atmosphere—but only a minor proportion of its total volume.* If you fly at an altitude of more than about 10,000 feet, oxygen must

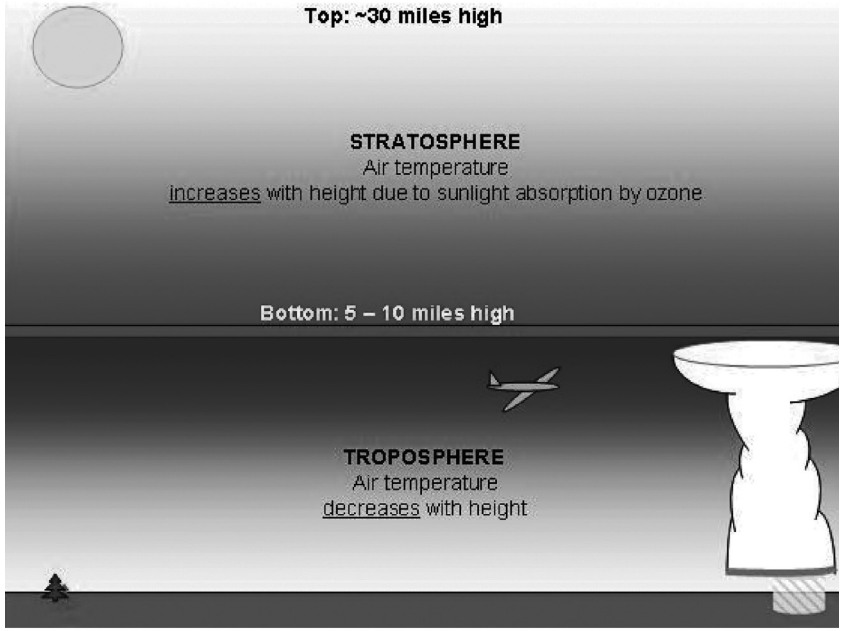
be added to the air you breathe, and you may need extra oxygen at lower levels if you are exerting yourself strenuously. This is not because the composition of the air changes at this height—it still contains about 21% oxygen—but because the air itself is less dense and a "lungful" contains fewer molecules of all the atmospheric ingredients, including oxygen. People who live at high altitudes adapt to the low air density by producing more haemoglobin,* so their blood compensates for the reduced amount of oxygen by making more efficient use of the oxygen available to them.

Stratosphere and Stratopause

The atmospheric layer above the tropopause is known as the stratosphere, and it extends upwards to a height of about 50 km above the surface. Temperatures in the stratosphere change according to the seasons but, in the lower stratosphere, there is no change in temperature with increasing height. This is because the stratosphere is effectively isolated from the principal source of atmospheric heating—contact with the ground surface. Above about 20 km, however, the situation changes and the temperature begin to increase with increasing height. This is especially marked in summer. The pattern is more complex in winter, when there is usually very cold air in the middle stratosphere over the middle latitudes. The relationship between temperature and altitude changes because, at this height, the Atmosphere begins to absorb some of the incoming solar radiation. Air is transparent to visible light, but oxygen absorbs and, therefore, is opaque to radiation in the ultraviolet part of the electromagnetic spectrum. As radiation passes through the Atmosphere, the chance that it will encounter an oxygen atom or molecules increases the further it travels because the distance between particles decreases as the density of the air increases. *At about 22 km UV is absorbed in significant amounts. This absorption produces a concentration of ozone, in the ozone layer, and it also warms the air, because the process transfers energy to the absorbing particle, thus raising its temperature.*

Stratosphere is the place where most long distance aircrafts fly. If you have ever been in an airplane and have looked out the window once you are well into the flight, you will have noticed that you are actually flying above the level of the clouds. As we have already mentioned, clouds and weather occur in the troposphere, whereas the stratosphere has very stable atmospheric conditions and very little turbulence. It is easy to understand

**The red blood cells contain a substance called haemoglobin, they are like tiny bubbles which combine with the air (Oxygen) in the lungs, carry round the body to all the body parts to keep the body tissues and organs alive. Haemoglobin gives blood its red color when it contains oxygen.*



why aircraft choose to fly here! The *stratosphere is different from the troposphere because its temperature increases as altitude increases. This is because the stratosphere absorbs solar radiation directly, meaning that the upper layers closer to the sun will be warmer.* The upper layers of the stratosphere are also warmer because of the presence of the *ozone layer.* Ozone (O_3) is formed when solar radiation splits an oxygen molecule (O_2) into two atoms of oxygen. Each individual atom is then able to combine with an oxygen molecule to form ozone. The two reactions are shown below:

$O_2 \rightarrow O+O$ (1)

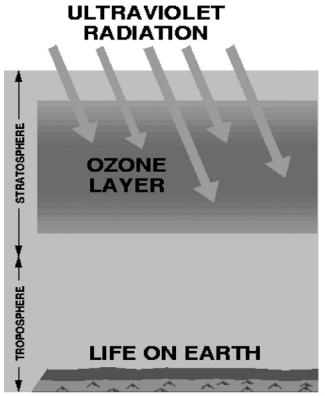
$O+O_2 \rightarrow O_3$ (2)

The change from one type of molecule to another produces energy, and this contributes to higher temperatures in the upper part of the stratosphere. An important function of the ozone layer is to absorb UV radiation and reduce the amount of harmful radiation that reaches the Earth's surface. *The upper boundary of the stratosphere is called the "stratopause," and the region above it is the mesosphere, extending to a height of about 80 km.* The air density continues to fall with increasing height, from about 1 mb at the stratopause to about 0.01 mb at the upper boundary of the mesosphere. It is also a region in which temperature once again

decreases with increasing altitude, from about 0 degree Celsius at the stratopause to minus 90 degrees Celsius at 80 km. You might think that the mesopause, the upper boundary of the mesosphere, marked the top of the Earth's Atmosphere, but "Meso" means "middle," and above the mesopause there lies the thermosphere. This is a layer in which the absorption of solar radiation causes the temperature to rise with increasing height, perhaps to about 930 degrees Celsius at 354 km. The gases at this height are so rarefied, however, that the air does not feel warm and orbiting satellites are not warmed by it. *The ionosphere forms part of the thermosphere above about 100 km.* At about 480- 755 km—there is no definite boundary—the thermosphere becomes the exosphere. This merges with the magnetosphere, where particles are dominated by the Earth's magnetic field, concentrated most densely between about 57,000. It is the magnetosphere which merges with the solar wind.

Extension: CFCs and the ozone layer

You may have heard people talking about *'the hole in the ozone layer'.* What do they mean by this and do we need to be worried about it? Most of the Earth's ozone is found in the stratosphere and this limits the amount of UV radiation that reaches the Earth. However, human activities have once again disrupted the chemistry of the Atmosphere. Chlorofluorocarbons (CFC's) are compounds found in aerosol cans, fridges and air-conditioners. In aerosol cans, it is the CFC's that cause the substance to be sprayed outwards. The bad side of CFC's is that, when they are released into the Atmosphere, they break down ozone molecules so that the ozone is no longer able to protect us as much from UV rays. *The 'ozone hole' is actually a thinning of the ozone layer approximately above Antarctica.* Let's take a closer look at the chemical reactions that are involved in breaking down ozone:



When CFC's react with UV radiation, a carbon-chlorine bond in the chlorofluorocarbon breaks and a new compound is formed, with a chlorine atom.

$CFCl_3+UV \rightarrow CFCl_2+Cl$(3)

The single chlorine atom reacts with ozone to form a molecule of chlorine monoxide and oxygen gas. In the process, ozone is destroyed.

$Cl+O_3 \rightarrow ClO+O_2$(4)

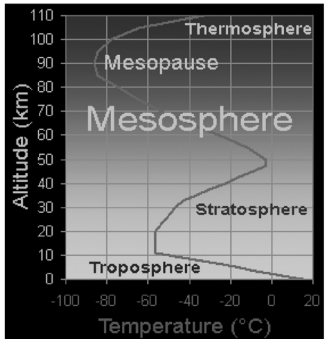
The chlorine monoxide then reacts with a free oxygen atom (UV radiation breaks O_2 down into single oxygen atoms) to form oxygen gas and a single chlorine atom.

$$ClO+O \rightarrow Cl+O_2 (5)$$

The chlorine atom is then free to attack more ozone molecules, and the process continues. A single CFC molecule can destroy 100,000 ozone molecules.

One possible consequence of ozone depletion is an increase in the incidence of skin cancer because there is more UV radiation reaching Earth's surface. CFC replacements are now being used to reduce emissions, and scientists are trying to find ways to restore ozone levels in the Atmosphere. The stratosphere extends upward for from 100,000 to 150,000 feet above the Earth's surface, depending on the time of year and the part of the Earth over which it lies. Both the stratosphere and troposphere may vary in thickness, depending on whether or not the Earth is enjoying summer or winter, being thicker at lower temperatures.

The mesosphere

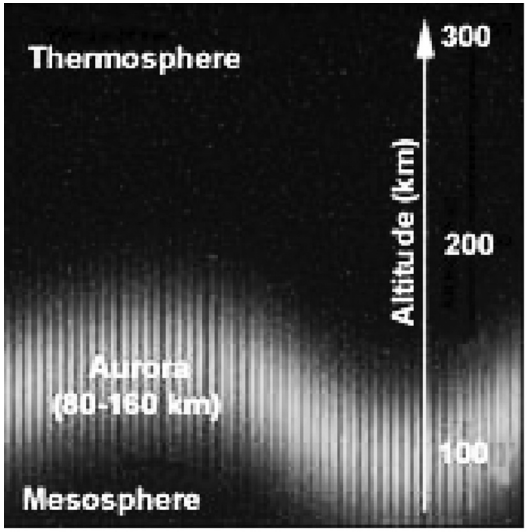


The mesosphere is located about 50-80/85km above Earth's surface. Within this layer, temperature decreases with increasing altitude. Temperatures in the upper mesosphere can fall as low as minus 100 degrees Celsius in some areas. Millions of meteors burn up daily in the mesosphere because of collisions with the gas particles that is present in this layer. This leads to a high concentration of iron and other metal atoms.

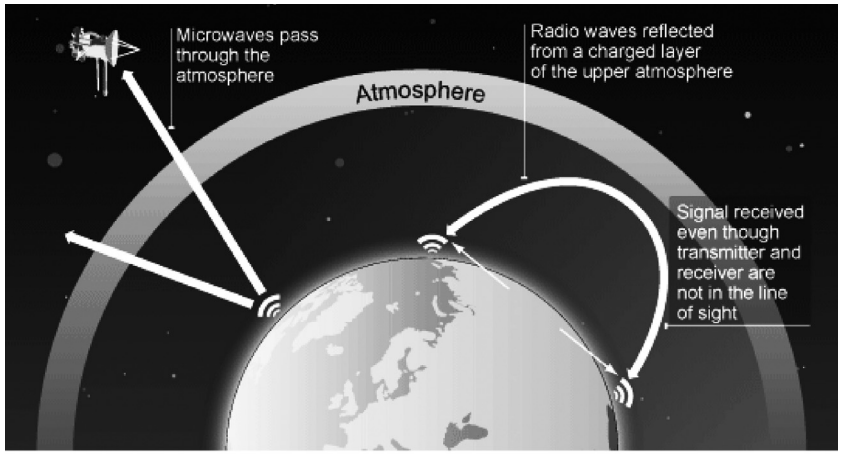
The Thermosphere

The thermosphere exists at altitudes above 80 km. In this part of the Atmosphere, ultraviolet (UV) and shorter X-Ray radiation from the sun cause neutral gas atoms to be *ionized*. At these radiation frequencies, photons from the solar radiation are able to dislodge electrons from neutral atoms and molecules during a collision. A *plasma* is formed, which consists of negative free electrons and positive ions. This part of the atmosphere is called the *ionosphere*. At the same time that ionization takes place however, an opposing process called recombination also begins. Some of the free

electrons are drawn to the positive ions, and combine again with them if they are in close enough contact. Since the gas density increases at lower altitudes, the recombination process occurs more often here because the gas molecules and ions are closer together. The ionization process produces energy which means that the upper parts of the thermosphere, which are dominated by ionization, have a higher temperature than the lower layers where recombination takes place. Overall, temperature in the thermosphere increases with an increase in altitude.



Ionosphere and Radio Waves - The ionosphere is of practical importance because it allows radio waves to be transmitted. A radio wave is a type of electromagnetic radiation that humans use to transmit information without wires. When using high-frequency bands, the ionosphere is used to reflect the transmitted radio beam. When a radio wave reaches the ionosphere, the electric field in the wave, forces the electrons in the ionosphere into oscillation at the same frequency as the radio wave. Some of the radio wave energy is given up to this mechanical oscillation. The oscillating electron will then either recombine with a positive ion, or will re-radiate the original wave energy back downward again. The beam returns to the Earth's surface, and may then be reflected back into the ionosphere for a second bounce. What gives sky its color? On a bright, sunny day, you may wonder why the sky appears blue rather than other colors. The secret is the size of air molecules. They are the perfect size for scattering blue light out of the incoming sunlight. The sun appears yellow because the other colors of the incoming sunlight usually pass through the air uninhibited. If you were to look at the sun in outer space, it would appear white. Other particles in the Atmosphere such as dust and cloud droplets can team up to create beautiful sunrises and sunsets.



How Hurricanes Develop?

Hurricanes seem to develop when the Equatorial low-pressure area moves some distance from the Equator. The sea-surface temperature must be high—more than 27 degrees Celsius—over a large area that covers a region far enough from the Equator for the Coriolis "force" to be significant, but not so far from the Equator that it lies beneath the subtropical jet stream. There must also be an area of high atmospheric pressure, with air flowing from it, close to the tropopause. Most hurricanes begin 5-10 degrees from the Equator in the "doldrums" area. The combination of a very warm sea surface, calm winds and high pressure aloft cause strong convection and the development of a local area, up to about 640 km in diameter, of intensely low pressure. Warm, very moist air rises rapidly and, because of the Coriolis "force'" air drawn in at low level to equalize the pressure is deflected, so the whole system twists about its vertical axis, forming a vortex. The rising air cools, but the cooling is offset by the latent heat of condensation as its water vapor condenses to form massive cumulus and cumulonimbus clouds, towering to a height of 40,000 feet or more. The system "feeds on itself," producing a vortex of rising air increases the high-altitude pressure, increasing the rate at which air flows out from it, and this, in turn, intensifies the low pressure at the surface. Air is drawn downwards at the center, from high pressure above towards low pressure below, spills to the sides and is warmed at the surface and then rises again as the vortex of intense winds.

The "eye," at the center, has a diameter of 322-483 km. within it, the skies are clear and there is little or no wind. In the vortex, however, the wind speed is never less than 120 km per hour—by definition, the minimum

speed for a wind classified as "hurricane force"—and they often reach 193 km per hour. The most severe winds usually last for only a few days, after which the conditions producing the hurricane begin to break down, and the hurricane system moves as a whole, usually at up to about 24 km –per hour, the precise speed and direction depending on the movement of the warm upper air. When a hurricane crosses land, it causes extensive damage and, of course, it presents a major hazard to shipping while it is at sea. Even after it has crossed the Atlantic all the way to Europe, a particularly vigorous hurricane can bring storm-force winds that bring down trees and damage buildings.



Hurricane Katrina - The year 2005 had been an extraordinary one in the Atlantic. There were so many tropical storms that for the first time meteorologists ran out of names for them. Wilma became the most powerful Atlantic storm ever recorded. Katrina brought an entire U.S. city to its knees. Hurricanes are an established part of the climate system. There have always been hurricanes. They start off as clusters of thunderstorms that form as warm, humid air rises from the surface of the tropical ocean. As the air rises, the water vapor condenses, releasing energy that heats the air and makes it rise even higher. If conditions are favorable, a tropical storm can rapidly turn into a hurricane as wind speeds pick up. Worldwide there are about eighty five tropical cyclones each year, of which about sixty reach hurricane force. When Katrina went from a category 1 to a category 5 hurricane back in August 2005, the surface of the Gulf of Mexico was around 86 degrees Fahrenheit, which, is far as anyone knows, was a record. Whether or not climate change can be blamed for the record sea temperatures, those temperatures certainly helped Katrina strengthen as it slipped across the Gulf from Florida toward the Louisiana coast. The simple link between sea surface temperatures and hurricane formation and strength has encouraged the view that a warmer world will inevitably lead to more hurricanes, stronger hurricanes, and the formation of hurricanes in places formerly outside their range.

Tornado - Tornadoes are extremely severe storms that are highly destructive. They appear as a dark, funnel-shaped cloud of violently rotating air that extends down to Earth. The funnel appears dark as a result of sucking up debris. The power and destruction of tornadoes is mind boggling! Tornadoes pick up debris that includes rocks, tree limbs, parts of buildings, etc. When the edge of the tornado funnel, slams into a building, the debris acts like a circular saw ripping through everything it impacts. Tornadoes have been known to pick up automobiles, horses, and whole trees. In one very strange incident, a tornado in Minnesota (year 1931) lifted an 83-ton railroad car containing 117 passengers and moved it 80 feet. The car was dropped into a ditch and all the passengers survived. Tornadoes result from the interaction of contrasting layers of air within a heavy cumulonimbus cloud mass. Atmospheric conditions required for the formation of a tornado include great thermal instability, high humidity, and the mixing of warm, moist air at low levels with cooler, drier air above. The diameter of tornadoes can range from a few feet to a mile; most however are less than a quarter mile wide. Winds within a tornado can reach 320 to 480 km/hr. the updraft at the center may reach 320 km/hr. updraft is caused by centrifugal (i.e. spinning) force that throws the air away from the center and causes a very low pressure area in the center. The paths taken by tornadoes average about 25 km. some tornadoes, however, greatly exceed that. In May 1917, a tornado traveled across Illinois and Indiana leaving a path of destruction 469 km long! This tornado lasted 7 hours and 20 minutes. A tornado that passes over water is called a waterspout.

Cyclones - A cyclone is an area that is surrounded by a wind system and has a low atmospheric pressure. Tropical cyclones are intense low pressure systems that form over tropical oceans with sustained winds exceeding gale force 63 km/hr, surrounding the center. Their circular wind pattern has a clockwise rotation in the Southern Hemisphere and counter-clockwise in the Northern Hemisphere. At lower latitudes, tropical cyclones tend to be small in size, sometimes less than 100 km in diameter, but in higher latitudes they typically grow to more than 1000 km and occasionally to more than 2000 km in diameter. Severe tropical cyclones have maximum winds surrounding the center exceeding hurricane force 120 km/hr. in Asian countries bordering the Northwest Pacific severe tropical cyclones are called typhoons whilst in the USA and Caribbean they are known as hurricanes.

Subtropical cyclones are very similar to extra tropical and tropical cyclones but unlike most cyclones, subtropical cyclones can occur at any time of year. They are hybrid storms and it is very hard to find consistent characteristics

among them. The maximum wind intensity they can have is 420 km from the center of the cyclone. Subtropical cyclones have large centers, sometimes as big as 140 km in diameter. In the center there isn't much rain or pressure. They develop from cold-upper-level polar troughs. Sometimes the bottom portion of an upper-level trough cuts off and forms an upper-level-cold-core low. When this reaches the surface, it becomes a subtropical cyclone. They have a very high degree of symmetry and have high levels of persistence. Sub-tropical cyclones don't disappear; instead they hook on to another large storm. Many storms become subtropical cyclones as they decline which brings about many changes such as more rain and increased temperatures.

Typhoon - A typhoon is a tropical cyclone that has winds of 125 km /hr or more, and forms in the West Pacific Ocean. In order for a typhoon to form, there are several necessary things that must be in place. There must be warm waters, in order to fuel the heat engine of the typhoon; an Atmosphere that will cool fast enough with height, so that it is potentially unstable to moist convection; relatively moist layers near the mid-troposphere at 5km; a minimum distance of at least 500 km from the Equator; a pre-existing near-surface disturbance; and low values less than about 34 km of vertical wind shear between the surface and the upper troposphere. Vertical wind sphere is the magnitude of wind change with height. Typhoons begin near the Equator and move westward, gathering intensity and size. They advance slowly, usually at about 16-24 km per hour. But the circular winds around the center are very strong, often reaching speeds of 240 km per hour. Typhoon season runs from the first of July through the thirtieth of November. Typhoons are always given names when they are discovered.

Successive Ice Ages

We cannot draw a map of the world as it was more than 2000 million years ago, but there is some reason for supposing that large land areas were located in high latitudes. There is evidence that parts of what are now North America, South America and Australia were covered by ice sheets about 2300 million years ago. Much later, from about 950 million years ago until about 615 million years ago, parts of what are now Africa, Australia and Europe lay beneath the ice. It is probable, but not certain, that North Africa was covered by ice about 450 million years ago. South Africa, South America, India and Australia were partly covered by ice for a long time, between about 350 million years ago and about 250 million years ago, though not continuously. This episode was at the end of the Carboniferous and commencement of the Permian Periods, and it was at about the time

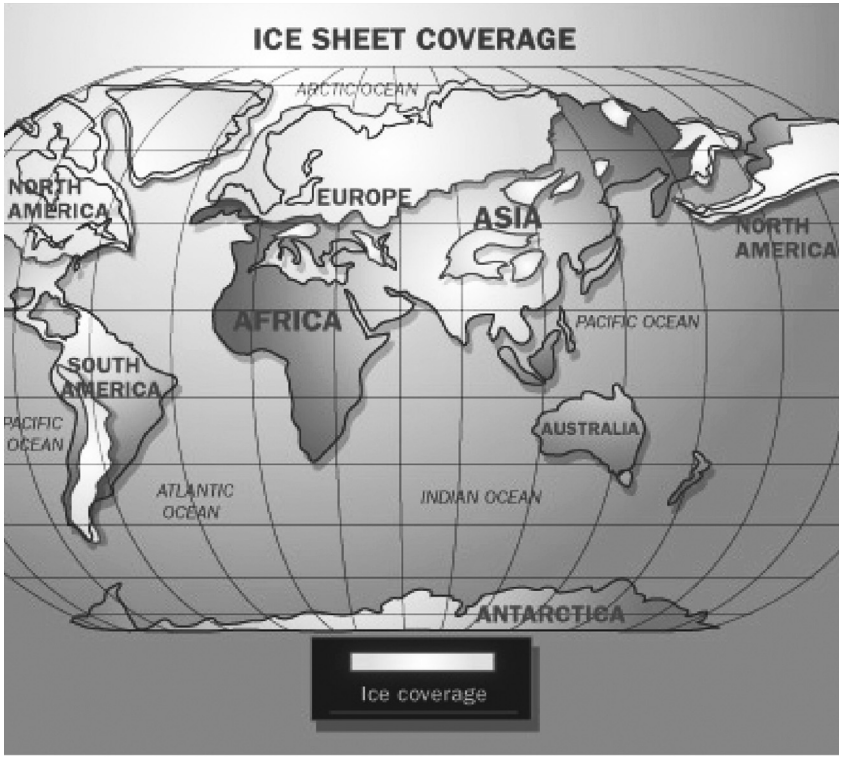
that Pangaea began to break into two super-continents. Both were moving northwards, but Laurasia* drifted more rapidly and the Tethys Sea inundated the land that, until then, had joined them. During the Permian, the climates of the northern hemisphere were mainly continental—dry, with extremes of temperature—and ice was widespread in the southern hemisphere.

It is tempting to suppose that the movement of continents was responsible for these large-scale changes in the climates of the world. Continental wandering did not necessarily trigger the changes, but it would certainly have predisposed the world to them. There are other "triggers," but pulling a trigger will not fire a shot unless the gun is loaded, and the location of continents represents the loading of the gun. Just as coal swamps occur only in low latitudes and the presence or absence of land near the poles makes ice sheets more or less likely to form. A period during which part of the Earth is covered by snow and ice which do not melt during the summer constitutes an "ice age." Technically, therefore, we are living in an ice age now. So far as anyone can tell, the great Carboniferous-Permian ice age that occurred around 290 million years ago was the last for a very long time. For most of its history, the Earth has been free from year-round ice and ice has covered the southern hemisphere more frequently than the northern hemisphere.

About 2 million years ago, or possibly a little earlier, with the continents more or less in their present positions—the world entered a new ice age. The period prior to that—the Pleistocene Epoch—had been generally warm but the Pleistocene Epoch (the name is from the Greek words "Pleistos" meaning "most" and "kainos," meaning "recent") brought dramatic changes. These led to an increase in the size of the Antarctic ice sheet—or its formation, because it may not have existed during the Pliocene. Apart from Antarctica, however, there is little land at high latitudes in the southern hemisphere and so the changes affected mainly the northern hemisphere. At its most extreme, ice covered about 28% of the land area of the Earth—at present it covers 10%.

Europe lay beneath the Scandinavian Ice Sheet, in places 10,000 feet thick, which extended as far south as Kiev in the Ukraine and covered Britain approximately to as far south as a line between the Severn Estuary and the Wash. Sea ice linked the Kamchatka Peninsula with the Aleutian Islands and

Laurasia was the northern half of Pangaea. The northern landmass formed 200 million years ago by the splitting of the single world continent Pangaea. The southern land mass known as Gondwanaland.



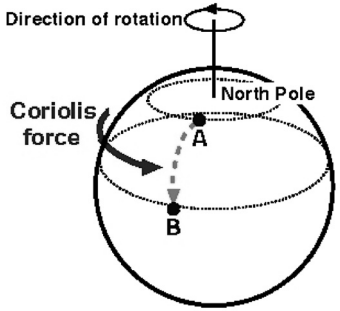
Alaska. North America lay beneath the Laurentide Ice Sheet,* extending from the Atlantic to the Rockies and as far as the latitude of New York, Cincinnati and Kansas City. Over most of this area the ice was between 5000 and 10,000 feet thick. Greenland and Iceland were almost completely covered by ice and sea ice extended across the Atlantic, linking Newfoundland with Ireland. There were also isolated ice sheets in various parts of Asia, western North America and Western Europe, including a large sheet around the Alps. The glaciers of Europe advanced during the Little Ice Age, but by only a short distance compared with their size during the ice ages. Apart from the episode, the ice sheets and glaciers have occupied their present positions throughout the whole of recorded human history, and the discovery that they had been much more extensive in the distant past came as a shock. Until then, the accepted view was that the world was

Ice began to accumulate in northern Canada to form the Laurentide ice sheet 120,000 years ago. This latest glaciation was initiated by a decrease in incoming solar radiation due to the elliptical nature of the Earth's orbit. Over the past 2.5 million years, variations in the axis of rotation and eccentricity of the Earth's orbit have caused many glaciations.

essentially unchanging. Scientists knew of the existence of deposits which resembled glacial deposits, but were far removed from amounts of it to the south of what are now the Great Lakes.

The ice sheets and glaciers began to retreat about 10,000 years ago. The dating of this retreat and the concept of the "great Ice Age" led to the idea that the ice age had ended. The Pleistocene Epoch, the ice age epoch, had come to an end and a new epoch had begun—called the Holocene, or Recent. Most geologists now believe the change of name may have been premature. There is still ice on the Earth, at both poles, and glaciers still exist. By definition, therefore, the ice age has not yet ended, and the discovery that during the "Great Ice Age" the ice advanced and retreated several times leads, inexorably, to the conclusion that we are living in an interglacial—which also has a name, the Flandrian.* If this interglacial resembles its predecessors, eventually it will end and the ice will advance once again. Indeed, the consensus among scientists who study the history of the ice ages is that the present interglacial is now very close to its end and a new ice age is due to commence at any time. To a geologist, "anytime" means within the next few thousand years, but starting now. There were four major ice ages during the Pleistocene, separated by inter-glacials. All of them are named after the geographical regions in which the evidence of them was obtained, and so there is something of a profusion of names but also much uncertainty, because ice sheets do not advance and retreat at the same time and by the same amount of all their fronts.

The Coriolis "Force"

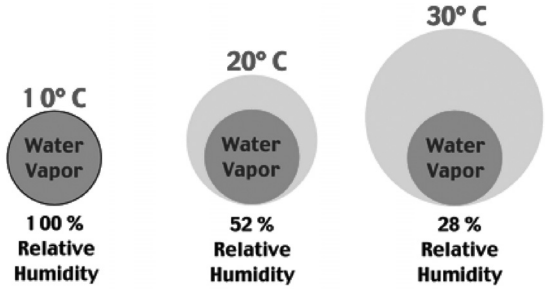


The Coriolis "force" was discovered, in 1835, by a French engineer, Gaspard Gustave de Coriolis (1792-1843). It explains why an object moving away from the right of its direction of movement in the northern hemisphere and to the left in the southern. The effect is proportional to the latitude and the horizontal speed of the moving object but it is not really a force at all. It is not the body that is deflected, but the Earth beneath it which has moved, because of its rotation, while the object was passing over it. You can demonstrate the effect with a disc, pivoted through its center. Rotate the disc slowly and, while it is rotating, try drawing a straight line from the edge towards the center. When the disc stops you will see the line is curved—but only because of the rotation of the disc. To either side of the Equator, the prevailing winds blow from the east—from the north-east in the northern hemisphere and from the south-east in the southern. Two hundred years ago, when international commerce relied on ships powered by wind, these reliable winds were of great importance. Mariners called them the "trade winds" and they have kept their name. They were also of great scientific interest.

The name "Flandrian" has been applied to the current sea level rise affecting the coastal regions around the globe which began approximately 18,000 years ago.

Humidity

The measure of humidity used most often is "relative humidity." To explain it, we'll start with some other ways of measuring the air's humidity and then show what relative humidity is all about. Meteorologists use various ways to describe how much water vapor is in the air. It describes how many grams of water are in the air for each kilogram of dry air when air at different temperatures is saturated. How much air is a kilogram? If the air is at a normal sea-level pressure and a temperate around 60 degrees Fahrenheit, a kilogram of air would fill about a cube yard of space; that is, a 3-by-3by-3-foot box. Using this information, we can see just how little water is in even the most humid air. If you condensed all of the water vapor in a kilogram of saturated 95 degrees Fahrenheit, you'd have only 37.25 Grams of water—not even a quarter cup.



If water vapor gets cooler, it will begin condensing into liquid water. Dew will form on the grass. In other words, 59 degrees Fahrenheit is the air's dew point. Hourly weather observations from around the world don't give the relative humidity; they give the dew point. The dew point temperature is based on how much water vapor is in the air. So while dew point is given in terms of temperature, it's really a measure of humidity. Relative humidity depends not only on how much water vapor is in the air but also on the air's temperature.

Effects of Water Vapor in the Air

Understanding how water acts as it evaporates into the air or condenses out of the air helps explain why a bathroom mirror fogs up when you take a hot shower. It also explains how dew, frost, and clouds form. The bathroom mirror fogs because some of the hot water spraying from the shower evaporates into the air, increasing its humidity, and therefore the air's dew-point temperature. The mirror's surface is cooler than the dew point of the now humid air in the bathroom. Some of the vapor in the air that touches the mirror condenses onto it, making tiny water drops. Dew has formed on the mirror. If the shower is hot enough and the air already humid enough, a light fog might form in the room. The vapor is condensing into tiny drops that float in the air. Fog or dew or frost is more likely to form on clear nights than on cloudy ones. The Earth is always radiating away infrared energy into the atmosphere. After the sun goes down, solar energy is no longer warming the ground, but the infrared energy keeps sending heat upward. The ground cools. On cloudy nights, the clouds absorb infrared energy from the Earth and radiate it back down. On clear nights, infrared energy is lost to space; the ground becomes cooler. The cold ground cools the air next to it. If the air cools to its dew point, dew, frost or fog forms.

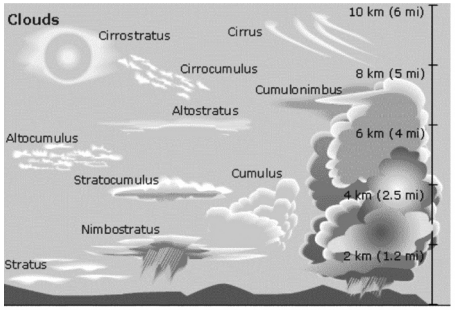
Stability and the Shape of Clouds



On a day when the Atmosphere is unstable, individual "bubbles" of air accelerate after they begin moving upward. Perhaps they've been shoved by an advancing cold front. Unless the air is very dry, water vapor will condense into clouds. Since individual bubbles of air are rising, the clouds will be bubbly or puffy. Their precipitation will be showery. If the layer of unstable air is only three or four thousand feet deep, it will produce small, puffy clouds. But if the air is unstable up to 20,000 or more feet above the ground, towering cumulus clouds or thunderstorms form. When the air is stable, bubbles won't rise. Instead, entire layers of air may be pushed upward. A warm front is a good example; warm air is being pushed up over cold air. Since the whole layer of air is being pushed upward, clouds that form are flat with a layered look. The distinction between stable and unstable air isn't always sharp. Sometimes one layer of air is stable while another above or below it is unstable. Or the air can be on the borderline between stable and unstable. This is why sometimes flat clouds typical of stable air and billowing clouds that mark unstable air can appear in the sky at the same time.

What goes on in the Clouds?

To someone who pays little attention to the sky, clouds might look simple, merely white puffs or gray smudges. When you begin looking closely at the sky, however, clouds present a bewildering variety of shapes and colors. As scientists came to learn more about clouds, they found them to be far more complicated than they first appear. Not many years ago key questions about clouds seemed unanswerable. Today, however, many of those questions are being answered by probing clouds with instrument-laden aircraft and Doppler radars* that measure hidden, internal motions. Scientists need to learn more about clouds so they can make computer models, which are central to weather forecasting and understanding Earth's climate. Clouds are made of tiny water droplets, tiny ice crystals, or both. Precipitation that falls from clouds is made up of larger water drops, ice crystals that have melted, or still-frozen crystals. Sometimes all three fall together.



Gravity pulls the cloud droplets toward the Earth like everything else. But, also like everything else, cloud droplets have a "terminal velocity," which is the speed they reach when the upward force of air resistance matches the downward pull of gravity. Small water drops have a slower terminal velocity than large drops. For an average-sized cloud droplet, the terminal velocity is less than tow feet per minute, about 0.02 miles per hour. The question of how a cloud

**The Doppler Radar is the state of the art weather measuring machine, was named after the scientist who invented it, this is the famous Christian Doppler.*

made of water could float in the air was a big puzzle through the early 19th century. Many scientists argued that clouds must be composed of bubbles because bubbles would be able to float on the air. They didn't have a good understanding of terminal velocity, which explains how air can hold up water drops. Even if the updrafts supporting the tiny drops stop and the droplets start falling, they're so tiny they quickly evaporate into the surrounding air. For rain to begin falling, the drops must grow much larger. While the average cloud droplet has a terminal velocity of only 0.02 miles per hour, an average raindrop falls at 14 miles per hour. As drops grow larger, their terminal velocity increases.

It might appear that condensation continues until the drops become big enough to start falling. But early in the 20th century scientists realized that condensation alone is too slow and could never produce rain-sized drops in a half-hour. Yet showers often began falling 30 minutes or less after the first wisps of a new cloud show up. Between 1911 and the 1930s, scientists developed the theory that ice is the answer. As we see above, if ice crystals and water drops are mixed together in a cloud, the ice crystals will grow at the expense of the water droplets. In such cases, researchers found, the ice crystals quickly could grow large enough to begin falling melt on the way down, and hit the ground as rain. Until World War II, meteorologists accept the ice-crystal theory as central to most precipitation. During the war meteorologists were sent to the tropics to study and forecast weather. Their research showed that plenty of tropical rain falls from clouds that never contain below-freezing temperatures. Ice crystals couldn't account for this rain.

This has forced scientists back to the question: How can cloud droplets grow big enough to fall? One answer is *"accretion,"* droplets bumping into each other and sticking together. This is how the planets were formed, when chunks of matter in space came together. In a cloud, drops that grow this way would start falling faster than others in the cloud. As they fell they would sweep up any smaller droplets they run into. But the questions remain. The air flowing around a falling drop would push many smaller drops out of the way, reducing the number that collide with and join the bigger drops. Scientists are still trying to discover just how efficient larger drops are at sweeping up smaller ones. They're also looking at how turbulence could mix up drops, causing them to collide and grow. Clouds without ice are called "warm clouds." If part of a cloud is below freezing, it's a "cold cloud." Many questions remain about exactly what goes on in warm and cold clouds. *The study of these questions constitutes an entire branch of meteorology called cloud physics.*

Climate Change

The human presence on the Earth has developed to the point where we have acquired the ability affect the Earth's climate. At one time, the gases our historical ancestors put into the Atmosphere by burning wood to cook the animals they hunted was insignificant. The small quantities of greenhouse gases they produced were absorbed and diluted by the air. Today, this is no longer the case. We find different kind of gases in the Atmosphere. Some of the components of the Atmosphere are natural. Some are contribution. Since all fuels—with the single exception of hydrogen gas—have carbon as part of their chemical makeup, every fuel produces carbon dioxide when it burns.

Gases in the Atmosphere: Nitrogen, 78%; Oxygen 21%, Water Vapor, 0.2%; Argon, 0.1%; Carbon Dioxide, 0.04% (280 parts per million (ppm), pre-industrial, 379 ppm in 2005); Methane, 0.0002% (715 parts per billion (ppb) pre-industrial, 1774 ppb in 2005); Nitrogen Dioxide, 0.00003% (270 ppb pre-industrial, 319 ppb in 2005); stratospheric ozone, in trace amount, and Tropospheric ozone in trace amount. Carbon dioxide enters the Atmosphere naturally by anaerobic bacteria that decompose other organic matter; animals that exhale carbon dioxide during respiration and; occasional volcanic activity. On the other hand, nature removes carbon dioxide from the Atmosphere by plants consuming it in the process of photosynthesis and water dissolving carbon dioxide.

Some of the carbon dioxide that is released into the air is removed by being dissolved in the oceans and other bodies of water. The amount of carbon dioxide that can dissolve in a volume of water depends on the temperature of the water and the concentration of carbon dioxide that is already dissolved in the water. *Warmer water dissolves less carbon dioxide than cooler water.* Water with a higher concentration of carbon dioxide also dissolves less carbon dioxide than water with little carbon dioxide. This process is self-limiting because as the greenhouse effect causes higher temperatures, the removal rate of the carbon dioxide decreases. As carbon dioxide dissolves in water, it also causes the water to become more acidic.

The fossil fuels are coal, oil, and natural gas. The name fossil fuel derives from the origin of these fuels from the remains of organic matter preserved from prehistoric times. Most of our energy used for electricity and transportation today comes from the burning of fossil fuels, which generates carbon dioxide as a by-product. As a result of fossil fuel combustion, carbon dioxide in the Atmosphere is now 35% higher than it

was a century and a half ago. Human puts carbon dioxide into the Atmosphere in other ways besides burning fossil fuels. *One example is the production of concrete, which involves the conversion of calcium carbonate rock (limestone) into calcium oxide. This process also produces carbon dioxide. Development of houses, buildings, cities and towns and industries contributes to global warming in at least three ways: it releases carbon dioxide to the air through the production of cement; it requires heat, which is likely to involve the combustion of fossil fuels; it often replaces vegetation that absorbs carbon dioxide from the Atmosphere. In cement manufacturing, carbon dioxide is released when limestone is heated to produce quicklime during the production of cement.*

Fossil fuels are a concern because they increase the absorption of incoming solar radiation above the amount absorbed naturally. *This is referred to as the enhanced greenhouse effect*. When a gas molecule absorbs energy, it has no place to store that energy other than in some form of movement of the molecule itself. According to the kinetic theory of matter, molecules are constantly in motion. The molecules move faster when their temperatures go up. Gas molecules in the Atmosphere can absorb energy passing through the Atmosphere in the form of visible light or invisible electromagnetic waves. Some molecules are able to move in more ways than others, enabling them to be better absorbers of certain kinds of light energy. Various chemical structures of some of the gases in the Atmosphere, allow them different ways to absorb light energy passing through the Atmosphere. The impact of increasing the amount of a greenhouse gas in the Atmosphere on global warming depends on how much of that greenhouse gas is present to begin with. Additional carbon dioxide will absorb only the infrared radiation that has not been absorbed by the carbon dioxide already present in the Atmosphere. Adding a few molecules of a trace gas such as CFCs, will have a proportionally greater impact because those molecules will not be competing with others of its type for the wavelengths that the gas most strongly absorbs.

CFCs are human-made chemicals that do not exist in nature. Since they become a vapor just below room temperature and are nonflammable and nontoxic, they were used widely in refrigeration systems, insulation, and as a propellant in spray cans in 1980s. Because they are highly stable chemically, once released into the Atmosphere, they can persist for a few hundred years. Like an unwelcome house guest, they are released into the Atmosphere and are pretty much there for good. All CFCs as a group have a concentration in the Atmosphere of around 1 ppb. This may seem like an insignificant presence, but it was enough to destroy ozone in the

stratosphere. Stratospheric ozone protects the inhabitants of the Earth by absorbing ultraviolet rays from the sun before they can enter the Atmosphere. Stratospheric ozone is like nature's sunblock.

In response to concerns about ozone depletion, many governments signed the Montreal Protocol in 1989, which required the phasing out of CFCs entirely. The industrial countries were given until 1996 to do this, and the developing countries had until 2006. *In terms of international cooperation, this is a success story. As a result of implementation of the Montreal Protocol, CFCs are no longer increasing in the Atmosphere.* Because of the very long lifetime of CFCs in the Atmosphere, though, they are expected to be present near current levels for hundreds of years. In terms of global warming, both ozone and CFCs are greenhouse gases. The presence of CFCs is partly compensated by their tendency to destroy ozone. The CFCs molecules make up for their relatively small abundance by being virtual "infrared sponges," absorbing 5000-10,000 times the amount of energy from the sun as a carbon dioxide molecule. On balance, they contribute about 20% of the overall atmospheric heating owing to the current mix of greenhouse gases.

The CFCs were replaced by a class of chemicals called halocarbons. These include *hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)*. The HCFCs are less destructive to ozone and are preferable for that reason. Both, however, are greenhouse gases, although they have shorter lifetimes on the order of decades rather than centuries. HCFCs are slated for being phased out by 2030. Other compounds in this group are the perfluourocarbons (CF4 and C2F6) and sulfur hexafluoride (SF6), which are used in industrial processes. Although they are present in the Atmosphere in small quantities, they have 1000-year lifetimes. Human activities also add solid suspended material—called aerosols—to the Atmosphere. These include suspended carbon (soot and ash), carbon in compounds, dust, and oxides of sulfur and nitrogen. Together, the aerosols produce a cooling effect by reflecting incoming sunlight back into space before it has a chance to enter the Atmosphere. Overall, the aerosols act to restrict some of the sunlight from heating the Earth. In some cases they absorb some of the incoming light. Aerosols also can influence cloud formation and precipitation.

Indus – A Victim of Climate Change

It is a curious geographical coincidence that the world's two highest mountains both straddle international borders. Everest forms the boundary between Nepal and Tibet, while K2 divides Pakistan from China's remote Xinjiang Province. K2 also forms the apex of the mighty Karakoram Range,

which boasts for peaks over 8,000 meters and another ten over 7,000. *One of the world's highest and most inaccessible mountain ranges, the Karakoram includes the largest glaciated area outside the poles.* Climbers must walk for a week up the Baltoro Glacier, for example, before they even get their first view of K2's forbidding pyramidal peak. *These glaciers represent a massive store of fresh water, and all three main rivers on the Indian subcontinent—the Indus, Ganges, and Brahmaputra—rise amongst the snows of the Karakoram, Himalaya, and the great Tibetan Plateau beyond.* Since the Mekong, Yangtze, and Yellow Rivers also have their sources in this gigantic upland area, it is no exaggeration to say that rivers rising on the slopes of these glaciated peaks *currently sustain half the world's population.*

Though waters from the Everest region eventually enter the Ganges, runoff from the north side of the Himalayan continental divide joins the Brahmaputra, which runs from west to east of Bhutan and south into Bangladesh. The Indus, meanwhile, derives much of its early flow from the 72-km-long Siachen Glacier, one of eight glaciers in the Karakoram region longer than 50 km. farther downstream, the Indus runs right past the towering 8,126-meter peak of *Nanga Parabat,** at the far western end of the Himalaya, where another cluster of glaciers adds further runoff. At this point the Indus Valley is already essentially arid, and views of the towering slopes of this giant mountain—ninth highest in the world—are a relief from the shimmering heat haze along the flat and stony valley floor. *All told, the Indus basin includes more than 3,500 individual glaciers, more than both the Ganges and the Brahmaputra put together.* Right along its length, however, the Indus experiences a more arid climate than the two other rivers, both of which gather more runoff from the summer monsoon rains in their lower reaches. The combination of aridity and a highly glaciated catchment makes the Indus particularly dependent on mountain water. And this is its Achilles heel: *The once timeless mountain snows are already melting. A quirk of atmospheric dynamics means that air temperatures in the highland region are rising and has been recorded high across all the major ice-capped ranges.* Even mighty Everest has been losing glacial mass: The Khumbu Glacier has retreated over five kilometers from the spot where Hillary and Tenzing set out to conquer the peak back in 1953.

As the glaciers at its source gradually recede over the century ahead, the Indus will change dramatically. In the early stages of this great transformation, the river will be swollen with extra melt as the glaciers

**Nanga Parbat, naked mountain in Hindi, boasts one of the highest mountain faces in the world. The Rupal Face rises 15,000 feet above its base, and to the north, somewhat more gently sloped Rakhiot Flank, rises 22,966 feet from the Indus River valley to the summit in just 27 kilometers. It is known as the killer mountain.*

continue their accelerated retreat. For a developing country with expanding agriculture and population, the increased freshwater supply may seem like a boon for Pakistan—but it will be short-lived. *In later decades, once the majority of the ice has gone, the river's flow will slow to little more than a tricks and the great, braided plain of the Indus River will lie empty for months at a time.* A study funded by Britain's Department for International Development, which used hydrological modeling to project changes in river flows over the century, confirms the grim forecast for the upper Indus. *Though, flows initially increase by between 14 and 90% depending on the speed of the warming, later in the century, the model projects decreasing water supplies by up to 90%.* At Skardu, gateway to the Karakoram and a major stopping point for high-altitude climbers heading to K2 and Broad Peak, modeled flows on the Indus River peak in 2030 but then drop by half by 2080, while farther upstream still, at Shyok in Ladakh, the river could be running dry by 2090. Down stream, meanwhile, where the Indus begins to leave the mountains at Bisham Qila, flows will have diminished by between 20 and 40 percent by 2080.

The disappearance of glacial melt-waters from the sources of the Indus will have a dramatic effect on downstream flows right the way through Pakistan. Little rain falls either in the east, on the Punjabi plains, or in the west, in the dry and lawless mountains of Balochistan, to augment the glacial flow. *With Pakistani agriculture almost entirely reliant on water from the Indus flowing into the irrigation canals that criss-cross the Punjab, the country faces the destruction of its key breadbasket once the river and its tributaries run dry.* Little help will be available abroad, as countries that border Pakistan are also likely to experience problems with declining water supplies. In China, for example, 23% of the population lives in western regions where glacial melt provides the principal dry-season water source. Even though it will be less affected than the Indus, as much as 70% of the dry-season flow of the Ganges, and half the flow of other major rivers, comes from melting glaciers. *In some ways, these are "fossil" water supplies, which have been stored for millennia when the glaciers were in relative balance, but will be released in decades to come as the world warms up.*

With India particularly dependent on hydroelectric power generation, dwindling summer flows may lead to blackouts and energy shortages during the hottest months of the year. Two of the Indus River's major tributaries—the Chenab and the Sutlej—arise in India and flow into Pakistan. Both will also be suffering the effects of deglaciation in their upper reaches. Conflicts may well break out between these two nuclear-armed countries as water supplies dwindle and political leaders quarrel over how much can be stored behind

dams in upstream reservoirs. Any crisis in food production could quickly escalate into a crisis for the whole Pakistani economy. The country depends heavily on cash-crop exports of rice and sugar, both of which are grown extensively in irrigated Punjab. Farther south, where the province of Sindh relies solely on the Indus for inflows into its canal system, farmers may find themselves outmatched by their more powerful Punjabi colleagues to the north. Farmers across the country may find themselves outmatched in turn by big cities like Lahore, Hyderabad, and Karachi, which each support populations in the millions.

As dry-season supplies from the Indus dwindle with the retreating ice upstream, a cascade of impacts may begin to pile up the pressure on Pakistani society, as people leave the land in huge numbers and flee to the overcrowded cities. With global food stocks already under pressure, little or no surplus capacity will remain to feed people displaced from formerly irrigated areas. *Further conflicts could arise with India if millions of Pakistani refugees cross the border in order to find sustenance in better watered areas served by the Ganges but already supporting dense human populations.* All of human history shows that given the choice between starving *in situ* and moving, people move. In the latter part of the century, tens of millions of Pakistani citizens may be facing this choice, as the river that has sustained their civilization for centuries runs dry and the breadbaskets that it supported are overcome by the spreading desert. Nuclear-armed *Pakistan may find itself joining the growing list of failed states, as civil administration collapses and armed gangs seize what little food is left. The rule of the gun would replace the rule of law. In the high mountains, meanwhile, the shimmering white of all but the highest snows will have given way to bare rock and sunbaked soil. Down below, valley glaciers that for millennia ground their way slowly between the peaks will have vanished into rubble. And somewhere in the remote wastes of the Tibetan Plateau, far away from any human habitation, a simple pile of stones will mark the spot that was once the source of one of the mightiest rivers in history.*

Acid Rain

Acid rain describes any form of precipitation with high levels of nitric and sulfuric acids. It can also occur in the form of snow, fog, and tiny bits of dry material that settle to Earth. Rotting vegetation and erupting volcanoes release some chemicals that can cause acid rain, but most acid rain falls because of human activities. *The biggest culprit is the burning of fossil fuels by coal-burning power plants, factories, and automobiles*. When, humanity burns fossil fuels, sulfur dioxide (SO2) and nitrogen oxides (NOx) are released into the Atmosphere. These chemical gases react with water, oxygen, and other substances to form mild solutions of sulfuric and nitric acid. Winds may spread these acidic solutions across the Atmosphere and over hundreds of miles. When acid rain reaches the Earth, it flows across the surface in runoff water, enters water systems, and sinks into the soil. *Acid rain has many ecological effects, but none is greater than its impact on lakes, streams, wetlands, and other aquatic envir onments.* Acid rain makes waters acidic and causes them to absorb the aluminum that makes its way from soil into lakes and streams. This combination makes waters toxic to crayfish, clams, fish, and other aquatic animals.

Some species can tolerate acidic waters better than others. However, in an interconnected ecosystem, what impacts some species eventually impacts many more throughout the food chain—including non-aquatic species such as birds. *Acid rain also damages forests, especially those at higher elevations. It robs the soil of essential nutrients and releases aluminum in the soil, which makes it hard for trees to take up water.* Trees' leaves and needles are also harmed by acids. The effects of acid rain, combined with other environmental stressors, leave trees and plants less able to withstand cold temperatures, insects, and disease. The pollutants may also inhibit trees' ability to reproduce. Some soils are better able to neutralize acids than others. In areas where the soil's *"buffering capacity"** is low, the harmful effects of acid rain are much greater. The only way to fight acid rain is by curbing the release of the pollutants that cause it. This means burning fewer fossil fuels. Many governments have tried to curb emissions by cleaning up industry smokestacks and promoting alternative fuel sources. These efforts have met with mixed results. But even if acid rain could be stopped today, it would still take many years for its harmful effects to disappear. Individuals can also help prevent acid rain by conserving energy. The less electricity people use in their homes, the fewer chemicals power plants will emit. Vehicles are also major fossil fuel users, so drivers can reduce emissions by using public transportation, carpooling, biking, or simply walking wherever possible.

Acidic Oceans

Greenhouse gases released over the last hundred years or so have not only changed the climate they have also begun to alter conditions in the largest planetary habitat of all: *the oceans. At least half the carbon dioxide released every time you or I jump on the plane or turn up the air-conditioning ends up in the oceans.* This may seem like a good place for nature to dump it, but ocean chemistry is a complex and delicate thing. The oceans are naturally slightly

**It is an ability to withstand, ability to recalibrate, and ability to resilience by neutralizing acids in the soil.*

alkali, allowing many animals and plants that inhabit the seas to build calcium carbonate shells. However, carbon dioxide dissolves in water to form carbonic acid, the same weak acid that gives you a fizzy kick every time you swallow a mouthful of carbonated water. *The most important life-forms to be affected by this are those that form the bedrock of the oceanic food chain: plankton.* Although individually tiny, photosynthesizing plankton like coccolithophores* are perhaps the most important plant resource on Earth. They compose at least half the biosphere's entire primary production—that's equivalent to all the land plants put together—often forming blooms so extensive that they stain the ocean surface green and can easily be photographed from space. The places where phytoplankton thrives: are the breadbaskets of the global oceans.

All higher species from mackerel to humpback whales ultimately depend on them. Yet coccolithophores have a calcium carbonate structure, and this makes them especially vulnerable to ocean acidification. *When scientists simulated the oceans of the future by pumping artificially high levels of dissolved CO2 into sections of a Norwegian fjord, they watched in dismay as coccolithophore structures first corroded and then began to disintegrate altogether.* Acidification will also directly affect other ocean creatures. Crabs and sea urchins also need their shells to survive, while fish gills are extremely sensitive to ocean chemistry, just as our lungs are to the air. Mussels and oysters, vitally important both as economic resources and as part of coastal ecosystems worldwide, will lose their ability to build strong shells by the end of the century—and will dissolve altogether if atmospheric CO2 levels ever reach as high as 1,800 ppm. Tropical corals, already badly hit by bleaching, will increasingly be corroded by this oceanic acid bath. Wiping out phytoplankton by acidifying the oceans is rather like spraying weed killer over most of the world's land vegetation, from rain forests to prairies to Arctic tundra, and will have equally disastrous effects. *Just as deserts will spread on land as global warming accelerates, so marine deserts will spread in the oceans as warming and acidification take their unstoppable toll.*

The year 2003 had not a normal summer, and the heat wave experienced in Europe during the three months of June, July, and August did not produce normal circumstances. The heat wave and drought devastated agricultural

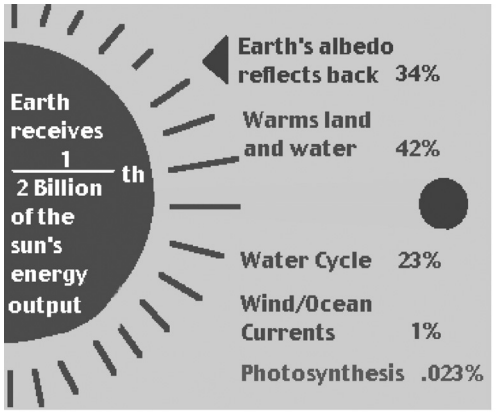
**Coccolithophores are small organisms in the oceans, with two smooth flagella and covered by calcareous plates called coccoliths. They dominate in regions of moderate turbulence and nutrients such as lid-latitudes in late spring in subpolar regions and in equatorial regions. Typical size is 5-10 micrometers in diameter. They are one of the world's primary producers, contributing about 15% of the average oceanic phytoplankton biomass to the oceans. The whit cliffs of Dover, England are made up mostly of coccoliths.*

sector, many people lost their lives almost 10,000 people had heat attacks in Paris alone. Crop losses totaled around 12 billion dollars while forest fires in Portugal caused another 1.5 billion dollars of damage. Major rivers such as the Po in Italy, the Rhine in Germany, and the Loire in France ran at record low levels, grounding barge traffic and causing water shortages for irrigation and hydroelectric production. Some glaciers lost 10% of their entire mass during the heat of that one summer in 2003. What will happen in future? This means that extreme summers in 2040 will be much hotter than 2003, and the death toll will rise in consequence—perhaps reaching the hundreds of thousands. Temperatures may soar to highs commonly experienced today only in Sahara desert, as rivers and lakes dry up and vegetation withers across the entire continent. Crops that require summer rainfall will bake in the fields and forests that are more accustomed to cooler climes will die off and burn. As a result, catastrophic wildfires may penetrate north into new areas torching broadleaved forests from Germany to Estonia.

The Seven Wonders of Atmosphere

1. Albedo Effect – First Wonder of Atmosphere

The word "albedo" is derived from the Latin "albus," meaning "white" and, it is numerical measure of whiteness or, more correctly, of the proportion of radiation a surface reflects in the short-wave band between 0.000s mm and 0.004 mm. In summer, many of us wear white clothes or at least light-colored ones and, in winter, we tend to favor darker colors. We believe that white clothes reflect heat and dark clothes absorb it. This is true, although the number of layers of clothes and the materials from which they are made are more important factors in keeping us warm or cool than their color. The Earth as a whole reflects about 31% of the solar radiation falling upon it. This figure, the Earth's total reflectiveness, is its "albedo" value. It can be expressed as a percentage (31 percent) or as a decimal fraction (0.31). It is important, because any change in this value represents an increase or decrease in the amount of solar energy that is absorbed. The climatic implications are obvious.



The albedo of the whole Earth is, obviously, a composite of different albedos for the many different surfaces the planet presents to the sun. Each type of surface has its own albedo value. The whole Earth has about the same albedo as sand, but this figure includes the albedo of the Atmosphere and its clouds. The surface of the Earth has an overall albedo ranging from about 0.14 to 0.16. Within regions, albedos change from time to time. Snow cover in winter increases albedo and the spring thaw reduces it again. Clouds form and clear. In the case of large expanses of water, the albedo depends on the wind and on the position of the sun above the horizon. If you watch the sun setting over the sea or a large lake, the light is reflected from the water may dazzle you—the albedo is very high—but only if the water is calm. Waves will reduce the glare greatly, because they present different angles to the sun. At midday, however, the water appears dark, because the sun is higher in the sky. The angle between the radiation and the water surface is larger and much of then radiation penetrates—water is fairly transparent to radiation in the visible light waveband—and is absorbed, principally by plankton and particles suspended in the water. The difference is very large. The albedo of water surfaces ranges from 0.06 for rough water to 0.20 for calm water, but is much higher when the sun is low.

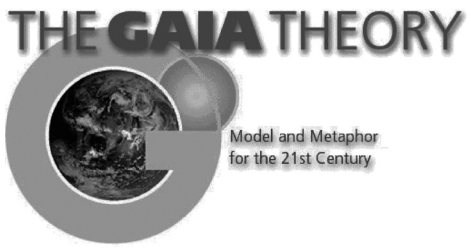
As you would expect, fresh snow is the surface with the highest albedo. Depending on how smooth and clean it is, its value lies between 0.8 and 0.9—between 80 and 90% of the radiation falling upon it is reflected. As the snow melts, its albedo falls to between 0.4 and 0.6. Sand comes next in the ranking, with an albedo of 0.30 to 0.35—desert sands tending towards the higher value. Grasslands and cereal crops on farms—which, botanically, are grasses—have an albedo of 0.18 to 0.25. Cereal crops are harvested, of course and, when the fields are ploughed, the albedo, assuming the ground surface is dry, falls to between 0.12 and 0.20. Wet soil is darker still, with an albedo of about 0.10. This helps the farmer, because it means the ground absorbs more warmth when it is bare and this assists seed germination. The albedo of forest depends on the type of forest. Deciduous forests, of the kind that grow naturally in temperate regions with seasonal climates, have an albedo of 0.15 to 0.18. Coniferous forest is darker, with an albedo of 0.09 to 0.15, and tropical rain forest is a little darker still. Its albedo is between 0.07 and 0.15.

Bare rocks have an albedo of 0.12 to o.18. The albedo of urban areas is the same as that of rocks. Buildings and roads are made from rock, after all. *The color of a surface has such a strong influence on the proportion of solar radiation that is reflected and absorbed that it is a major factor in determining the climatic conditions a region enjoys.* In fine weather, winter holiday makers often protect their eyes and skin against the glare of light reflected from the snow, but the ground temperature remains low. The snow and ice do not melt and the air is not warmed by its contact with them. The solar radiation is often intense, but almost all of it is reflected back into space and lost. The climatic consequences of altering the albedo are among the factors that concern scientists when large areas of land are converted from one use to another. Such changes often involve increasing albedo. When temperate forest is cleared for pasture, for example, the albedo of the surface increases from, say, about 0.16 to about 0.21— although, if the land is ploughed, it changes little, or even falls while the soil remains bare. The conversion of

tropical rainforest to pasture has an even larger effect, increasing the albedo from about 0.11 to 0.21, and the deterioration of grassland into sandy desert involves a still greater increase, from 0.21 to about 0.33. Albedo Effect keeps Atmosphere comfortable and it is the first wonder of Atmosphere.

2. Gaia Hypothesis – Second Wonder of Atmosphere

At certain times in Earth's history, volcanism has been so intense and so much ash has been put in the Atmosphere, little solar radiation could reach the surface. The planet should have become trapped in a runaway global icehouse, in which it was covered with ice, and from which it could not escape. *For billions of years, Earth has maintained its temperature and atmospheric composition in a narrow range that has permitted life to exist on the surface, and the planet has always managed to escape from periods of deep-freeze and global warming. Many scientists have suggested that this remarkable trait of the planet is a result of life adapting to conditions that happen to exist and evolving on the planet.* An alternative idea has emerged that the planet behaves as some kind of self-regulating organism that invokes a series of positive and negative feedback mechanisms to maintain conditions within the narrow window in which life can exist. In this scenario, organisms and their environment evolve together as a single coupled system, regulating the atmospheric chemistry and composition to the need of the system. *This second idea, known as the Gaia hypothesis, was pioneered by Dr. James Lovelock, an atmospheric chemist at Green College in Oxford, England. However, the idea of a living planet dates back at least to Sir Issac Newton.*



How does the Gaia hypothesis work? The Atmosphere is chemically unstable, yet has maintained conditions conducive for life for billions of years despite a 30 percent increase in solar luminosity since the Early Precambrian. The basic tenet of the hypothesis is that organisms, particularly microorganisms, are able to regulate the atmospheric chemistry and hence temperature to keep conditions suitable for their development. Although widely criticized, some of the regulating mechanisms have been found to exist, lending credence to the possibility that Gaia may work. Biogeochemical cycles of nutrients including iodine and sulfur have been identified, with increases in the nutrient-supply from land to ocean leading to increased biological production and increased emissions to the Atmosphere. Increased production decreases the flux of nutrients from the oceans to the land, in turn decreasing the nutrient supply and decreasing biological production and emissions to the Atmosphere. As climate warms, rainfall increases and the weathering of calcium-silicate rocks increases. The free calcium ions released during weathering combine with atmospheric carbon dioxide to produce carbonate sediments, effectively removing the greenhouse gas carbon dioxide from the Atmosphere. This reduces global temperatures in another self-regulating process.

An additional feedback mechanism was discovered between ocean algae and climate. Ocean algae produce dimethyl sulfide gas, which oxidizes in the Atmosphere to produce nuclei for cloud condensation. The more dimethyl sulfide that algae produce the more clouds form lowering temperatures and lowering algal production of dimethyl sulfide in a self-regulating process. That the Earth and its organisms have maintained conditions conducive for life for four billion years is clear. *However, at times the Earth has experienced global icehouse and global hothouse conditions, where conditions extend beyond the normal range. Lovelock relates these brief intervals of Earth history to fevers in an organism and notes that the planet has always recovered.* Life has evolved dramatically on Earth in the past four billion years, but this is compatible with Gaia. Living organisms can both evolve with and adapt to their environment, responding to changing climates by regulating or buffering changes to keep conditions within limits that are tolerable to life on the planet as a whole. However, there are certainly limits, and the planet has never experienced organisms such as humans that continually emit huge quantities of harmful industrial gases to the Atmosphere. It is possible that the planet, or Gaia, will respond by making conditions on Earth uninhabitable for humans, saving the other species on the planet. As times goes on, in about a billion years, the sun will expand and eventually burn all the water and Atmosphere off the planet, making it virtually uninhabitable. By then humans will hopefully have solved the problem of where to move to and have developed the means to move global populations to a new planet. Gaia means, Mother Earth and Earth is the second wonder of Atmosphere.

3. Aurora Borealis – Third Wonder of Atmosphere

Travel to the northern Canada or Alaska, or cross the sea between Norway and Iceland and, on most clear, dark nights, you will be treated to the most spectacular sight the Atmosphere can produce. You have entered an

approximately circular belt, about 483 km wide, called the *"auroral zone"*—there is a similar zone in the southern hemisphere. In Arctic, this is where aurora most often to be seen and they quite often occur simultaneously in both hemispheres. If you are close to the auroral zone, but outside it, you are most likely to see an aurora in the direction of the zone, but they fade as you move closer to the poles or into lower latitudes. Near to their low-latitude limit you are most likely to see them in spring or autumn. The sky will be illuminated by vast, draped curtains and arcs of light, usually white, yellow or green, with red near the edges. When aurora becomes visible in lower latitudes, they are often much redder. There may be one "curtain" or more. Sometimes there are as many as seven. Usually they appear to be waving gently, as though in a light wind, but they can move rapidly.

They are named after the Roman goddess of the dawn, *Aurora* and, because they occur close to the poles, the phenomenon is known technically as the "Aurora polaris" or more commonly, *as "aurora borealis" or "northern lights" in the northern hemisphere*. Despite being named after a Roman goddess, aurora is seen only very rarely in the Mediterranean region. Some Greek and Roman writers had heard of them, but few had witnessed them. At one time, people believed they were seeing fire or the reflection of sunlight from snow. They are caused by the sun, but they are neither sunlight nor fire. Captain Cook (1728-79) the English navigator was the first person to report seeing the aurora australis, in the Indian Ocean in 1773. The apparent height of the "curtains" depends on the position of the person seeing them. From a distance of about 1126 km they can seem to touch the horizon and, from still further away, they may seem to arise from below it. Their actual dimensions have been calculated trigonometrically by photographing them simultaneously from several different points. The base of the lights is between 80-105 km above the surface and they extend upwards, commonly for about 160 km, but sometimes much further, and rays from them can extend for several hundred miles above the upper edges. Of the "drapes" are moving slowly they may be about 3 km thick but, if they are moving rapidly, they will be much thinner. In fact, they mark the location of the "geomagnetic poles."

The magnetic field of the Earth—the geomagnetic field—is of the kind of the Earth, there were a dipole magnet. A compass needle will identify a magnetic pole. It follows magnetic field lines, which run from one pole to the other. The poles themselves are in the core of the Earth and, therefore, when the needle is directly above the pole it points either vertically downwards, at the north magnetic pole, or directly upwards, at the south magnetic pole. These are known as the "dip poles"—because the compass

needle dips— and, because of the distortions in the magnetic field, there are many of them and their positions wander. This is of little importance for most people, but when it matters—in navigating ships and aircraft, for example—magnetic compass readings must be corrected and the data used to correct them must be upgraded regularly. Away from the surface of the Earth, the geomagnetic field becomes regular and relates directly to the geomagnetic poles, not to the "compass" poles.



Cosmic radiation, principally the solar wind, showers the Earth with protons and electrons. As they enter the geomagnetic field, the associated electrical field accelerates them, so they gain energy, although scientists are not yet certain why this should happen. Then trapped in the magnetic field they spiral around them and oscillating between north and south geomagnetic poles. The lines of force and, therefore, the path of the electrically charged particles, sweep out far from the Earth over the Equator, but descend to the surface at the geomagnetic poles. A constant stream of charged particles is being drawn downwards at these points in both hemispheres. The stream descends from all directions, as though the particles were being drawn down a funnel or cone. This is why the auroral zones are approximately circular in shape and, although the "curtains" may appear to rise vertically, in fact they are slightly inclined. As they descend through the outer Atmosphere, the particles encounter the atoms and molecules of the atmospheric gases—at this height, principally atomic oxygen and atomic nitrogen, the Atmosphere is very tenuous and an incoming particle can

travel an average of 10 km before it encounters one, but the deeper it penetrates, the more closely packed the atmospheric atoms become—at the surface, a particle can travel an average 0.00008 inches, before colliding with one. Sooner or later, therefore, collisions are inevitable.

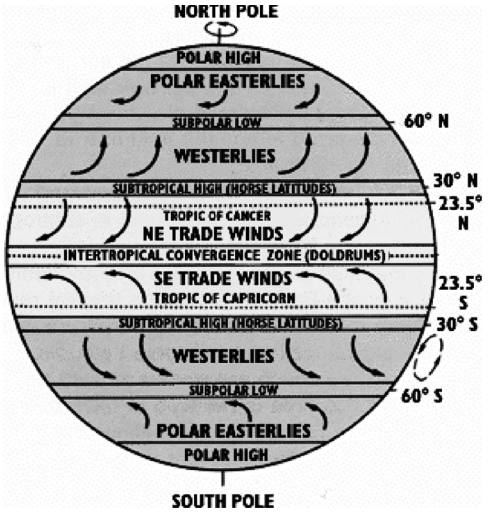
Aurora is produced more by electrons than by photons. When an electron collides with an atom it may dislodge an electron from the atom, and it also transfers some of its own surplus energy to the electrons around the atomic nucleus. They become "excited," but very quickly return to their former energy levels and, as they do so, the atom emits radiation—photons. This is called "excitation radiation" and its wavelength is characteristic for atoms of each element. Some of the protons, meanwhile, capture free electrons. An electron that is bound to a proton has less energy than a free electron and so this, too, causes an electron to fall to a lower energy level, again with the emission of radiation. In this case, the wavelength is characteristic of hydrogen because the nucleus of a hydrogen atom consists of a single proton, and one proton with one electron from a hydrogen atom. Aurora has been produced artificially, thereby confirming the reason they occur. In the days when atomic bombs were tested in the Atmosphere, a few were exploded at very high altitudes over the Pacific Ocean and the consequences monitored. Electrons flew upwards, were trapped by the geomagnetic field, and descended over the geomagnetic pole in the opposite hemisphere. The aurora they produced was visible in lower latitudes than most natural aurora, because the electrons had more energy than those arriving from above, by satellites, which confirmed their shape.

Sometimes, however, the upper regions of aurora are visible from much lower latitudes because the aurora extends to much greater heights. They have often been seen in Europe, occasionally even as far south as the Mediterranean, and in Mexico. These rare events occur during periods of increased solar activity. The solar wind intensifies— increasing the density of the particle stream—during sunspot maxima* and decreases during sunspot minima. This causes particles to collide at a greater altitude. Some of the electromagnetic radiation the Earth receives from the sun is absorbed, some is reflected and some is scattered. Over long periods, the climates of the Earth remain fairly constant, and changes of just a degree or two in average temperatures bring dramatic changes. It follows, therefore, that the amount of energy leaving the Earth must equal the amount arriving. Without any doubt in my mind, "Aurora Borealis" is the third wonder of Atmosphere.

**The sun goes through an 11 year sunspot cycle. It actually takes the sun 22 years to complete one cycle, but this cycle includes two sun spot: maxima and minima.*

4. Trade Winds – Fourth Wonder of Atmosphere

The trade winds are a part of the Hadley Cell circulation. This circulation is an extremely important element in the distribution of the global climate belts. This rising warm air at the tropics is transported in the higher tropospheric levels towards the northern hemisphere, where it descends we find the permanent high pressure belt, for example the permanent anticyclone of the Azores.* *When reaching the surface level the descending airflow spreads out horizontally, on the southern side of the Azores High resulting in quasi-permanent northwesterly wind, better known as the Trade* Winds. Blowing from the subtropical highs, or Horse Latitudes, towards the low pressure of the Inter Tropical Convergence Zone (ITCZ), they are often used by sailors crossing the Atlantic Ocean or heading south. The name Trade Winds originate back from the age that trade ships traveled by sail from Europe to the Americas, Africa, southeast-Asia relying on these permanent winds. Trade Wind is the fourth wonder of Atmosphere.



5. The Hadley Cells – Fifth Wonder of Atmosphere

In 1735, a London lawyer and part-time scientist called George Hadley believed he had found the answer, and presented it as a paper to the Royal Society of London. Hadley proposed that warm, equatorial air rises, moves away from the Equator as it does so and cools at a great height. Its place

**Discovered in the 15th century by navigators en route to the New World the Portuguese islands of the Azores are an archipelago of nine beautiful islands set in the Atlantic Ocean approximately 1450 km west of Portugal.*

near the surface is taken by cooler air, drawn in from a higher latitude, and so the air occupy the whole of each hemisphere—the cooling air returns to the Equator, the rotation of the Earth deflects it, so the winds blow from the north-east and south-east, rater than directly from the north and south. Hadley thought the deflection was due to what came to be called the Coriolis "force" but, in fact, the conservation of angular momentum is probably more influential—it accelerates objects in an easterly direction when they move away from the Equator, but in a westerly direction, when they move towards the Equator. The Earth spins on its axis at a constant rate. This means that, over the world as a whole, the energy that is expended in driving easterly winds must be balanced by force acting in a westerly direction. If this were not so, the Earth would be slowing down and we would need to replace our clocks and watches at regular intervals, because of the steady increase in the length of the days. The balancing westerly winds occur in the middle latitudes.

The movement Hadley described forms what are now known as "Hadley cells" and they are driven by convection. They are rather more complex than they sound. In the first place, their center is not the geographical Equator, but the thermal Equator—the line around the Earth joining points of highest average temperature. Its position varies from time to time but, on average, it lies at about 5 degree north. The cells are not continuous right around the Earth, partly because the surface is not heated evenly and, despite their reputation, the trade winds do not blow everywhere, all the time. Pairs of Hadley cells, on either side of the Equator, occur only in spring and autumn and the cells that forms in winter—first on one side of the Equator, then on the other—is the strongest of them all, some of its air crossing the Equator at a low level, into the summer hemisphere. In summer, the Hadley cells help to produce the monsoon rains. The mechanism is complicated, and linked to changes in the pattern of high-altitude winds and the jet streams, but essentially it is convective, of the Hadley-cell type.

Land warms more quickly than the oceans and in summer, therefore, the air over the continents is warmer and less dense than the air over the sea. This reduces the atmospheric pressure over the continents, especially over north-western India. Condensation in the rising air leads to spectacular cloud formations and dramatic storms, but the land is arid after its dry winter and, therefore, the total rainfall is slight. The weather becomes very hot—between March and May, the average temperature in Delhi increases from 28 to 45 degrees Celsius—and there are dust storms. The surface atmospheric pressure continues to fall until there is a very marked

difference between the low pressure over northwestern India and high pressure over the Indian Ocean to about 10 degree South—in the southern hemisphere. Then, by around the end of May, the gradient of pressure between the continent and the ocean becomes so strong that air is drawn from the high-pressure region, across the Equator, to fill the continental low-pressure region. This air is also warm and it is very humid, carrying water that has evaporated into it from the Indian Ocean and as it crosses the Arabian Sea.

The air arrives, in late May and early June, as south-westerly winds. As they cross into western India they encounter high ground which forces the air to rise—this is called *"orographic lifting."** As the air rises it cools, its water vapor condenses, and intensely heavy rain falls along the western side of the country and there are fierce storms, caused by convection, further inland. Local areas of low pressure—depressions—associated with this weather system then move westwards across India, bringing rain to more distant regions. *The weather in early summer is so predictable, and so dramatic, that Arabic speakers have called it "mausim," which means "fixed season," the word we have altered to "monsoon."* Strictly speaking, it refers to the whole season, not simply the rains. We tend to associate the monsoon with India, but it also occurs in West Africa, southern China, and northern Australia. The air in the Hadley cells descends at about latitude 30 degree, to form areas of high pressure in the subtropics. Of the world's total evaporation of moisture, 60% occurs between 25 degree north and 25 degree south and 60% of that moisture is "squeezed" out of it, condensing and falling in the humid tropics. Not surprisingly, the subsiding air is associated with the belts of deserts that circle the world in the subtropics of both hemispheres.

In the middle latitudes, beyond the easterly trade winds, the prevailing winds blow from the west—mainly from the south-west in the northern hemisphere and the north-west in the southern. In general, they blow away from the subtropical areas of low pressure which surround both poles. Areas of high pressure lie above both poles, surrounded by belts of mainly easterly winds. The Coriolis "force" exerts no effect at the Equator, but its influence increases with increasing latitude. *For this reason, it is only in low latitudes that the circulation of the Atmosphere is governed mainly by convection*. The overall circulation leads, nevertheless, to the transfer of energy away from the Equator and towards the poles, and two more systems of cells, much weaker than the Hadley cells, occur in higher

**Hydrologists have long recognized that clouds dispel greater amounts of moisture over highland areas, due to a phenomena known as "orographic lifting."*

latitudes, one direct, the other indirect, in that it is driven by the cells to its north and south. *This is known as the "three cell model."* The subsidence of very cold air, which produces the area of high pressure at each pole, causes an easterly outward flow from polar into subpolar regions. There, at about latitude 60 degree, the low-level cold air mixes with middle-latitude air of the Hadley cells marks a region of general air subsidence, and so the combination of air moving away from the Polar Regions in very high latitudes, and moving towards the Equator in the tropical cells drives a middle-latitude system of cells. This very general outline greatly simplifies a pattern that is subject to countless local variations—and about which much remains to be discovered. It is no more than a summary of the overall effect, and you should not regard it as an accurate description of what is happening in any particular place or at any particular time. Hadley Cells is responsible for the variations in Atmosphere and a hero of Atmosphere.

6. Hydrologic Cycle – Sixth Wonder of Atmosphere

The hydrologic cycle is a description of the generic reservoirs of forms that water resides in and on the Earth, the interconnections between these reservoirs, and how water in its various forms moves between the reservoirs. *The world's water is in constant motion, flowing downhill by gravity, pumped into the Atmosphere by evaporation fuels by sun's heat, and returned as rain and snow.* Except for the oceans, most of it moves underground. Water at the surface such as wetlands, lakes, rivers, and oceans evaporates into the Atmosphere, leaving impurities behind. Moisture moves around the globe with the weather patterns, and rain and snow condense from it. Some of the precipitation runs back to surface water bodies and some percolates into the ground to become soil moisture. Micro-organisms are constantly purifying this water as it moves in streams, wetlands, and soil. Plants transpire some of this back to the Atmosphere, and some continues to percolate down to the water table where it becomes ground water.

Ground water flows slowly through the Earth, and eventually returns to surface water bodies or to the oceans to start the cycle all over. Almost all parts of the hydrologic cycle are interconnected: for example, *the Atmosphere and surface water reservoirs are directly interconnected via precipitation, evaporation and plant transpiration; some of the water that infiltrates into the ground returns relatively quickly to the Atmosphere via transpiration and evaporation; surface waters can infiltrate into the ground to become ground water or can be fed by ground water.* In some cases, ground water extraction from shallow aquifers that naturally discharges into rivers and sustains stream flow in drought years may be responsible for decreased

stream flows and inadequate flows for surface water users. Human intervention in the hydrologic cycle can cause similar and related problems. For example, diversions of river water for flood irrigation have had a major impact on local ground water tables, by replenishing aquifers locally by leakage from canals and irrigated fields; as flood irrigation has given way to sprinkler irrigation over recent decades, artificial replenishment from flood irrigation has waned, ground water levels have declined, and conflicts have arisen. Hydrological cycle is very important for life and it is the sixth wonder of Atmosphere.

7. International Space Station – Seventh Wonder of Atmosphere

The International Space Station (ISS) is an international program with NASA in creating an International Space Station. It is the largest space project to date. It is a joint collaboration of 16 countries: United States, Russia, Brazil, Canada, Japan, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden and United Kingdom. The following modules are present in orbit:

1. Zarya Module (FGB) – Zarya as the first ISS module to be placed in orbit. It was launched November 20, 1998.
2. Unity Module (Node Module 1) – It was carried by STS-88 Endeavour on December 4, 1998.
3. Zvezda (Service Module) – Zvezda Module was launched on 12th July, 2000 on a Proton rocket.
4. Destiny Laboratory Module – It was carried by STS-88 Atlantis on February 1, 2001.
5. Joint Airlock (Quest Airlock) – It was carried on STS-104 Atlantis on July 12, 2001.
6. Docking Compartment (Pirs Airlock) – It was delivered on August 14, 2001 by a Russian Progress-M spacecraft.

Crews are delivered to the ISS by the Space Shuttle, such as Atlantis, Endeavour, Discovery, and Challenger, also Russia's Soyuz Spacecraft is used. Before 2005, the Soyuz functions as the only crewed space vehicle and was the Emergency Crew Vehicle. NASA planned to use X-38 as a Crew Return Vehicle however it was cancelled in 2001 due to budgetary reasons. Cargo is delivered by the US Shuttle and Russia's Progress Spacecraft and in the future by Europe's ATV and Japan's HTV. Dennis Tito visited the ISS as the first space tourist in 2001. French Astronaut Claudie Haignere was the first

European woman to serve aboard the ISS. The French-Russian flight blasted off to the ISS on October 21, 2001. At last the ISS is coming into function! The ISS will be 5 times larger than Mir when complete.

Indians will never forget the ill-fated shuttle Columbia of *Kalpana Chawla* of Indian origin. On January 16, 2003, Shuttle Columbia blasted off on NASA's 113th shuttle mission, to International Space Station. Engineers watching a video of the launch noticed a piece of foam insulation falling off the shuttle's fuel tank and hitting the left wing. The impact was not considered a hazard. On February, 2003, upon re-entering Earth's Atmosphere, Columbia broke apart over central Texas, claiming lives of commander Rick Husband, pilot William McCool, flight engineer Kalpana Chawla, mission specialist Laurel Clark, Michael Anderson and David Brown, and Israel's first astronaut Ilan Ramon. Debris recovery operations began immediately. Shuttles Discovery, Atlantis and Endeavour were grounded indefinitely. From the 480 km littered with debris, searchers recovered a critical flight data recorder in Hemphills, Texas. The box helped accident investigators piece together the sequence of events leading to the shuttle's destruction. Three years after Kalpana Chawla, *Sunita Williams,* 37 year old, is the next woman of Indian origin to make a space odyssey. She was selected as part of the 14th crew for the six-month long International Space Station Expedition. Indeed International Space Station is the seventh wonder of Atmosphere.

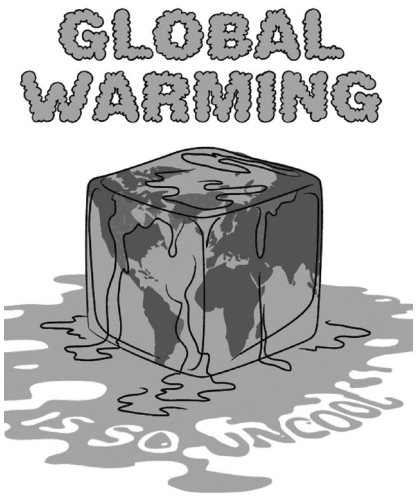
Seven Mega Disasters of Atmosphere

1. Global Warming – First Mega Disaster of Atmosphere

Earth has been habitable for most of its long history, even in its youth when the sun was far fainter than it is today, approximately 30% less than at present. If the sun were suddenly to become as faint as it originally was, temperatures on Earth would drop so much that all the water would freeze. The geological record nonetheless indicates that our planet has had plentiful water in liquid form, and hence has maintained a moderate range of temperatures, practically since birth. This paradox of the faint sun but warm Earth—a clear indication that ours is a resilient planet, capable of maintaining benign conditions in spite of adversities—is a blessing to our species, Homo sapiens, because today we thrive on conditions that could have evolved only on a planet that has favored life for billions of years. *It is as if elaborate preparations preceded the advent of mankind. We are the beneficiaries of gradual evolutionary processes that unfolded to the rhythms of cyclic phenomena including the repeated buildup and erosion of mountains and the periodic opening and closing of ocean basins.* Today our varied landscape, its spectacular mountains, vast plains, lush tropical jungles, and barren deserts, is but a snapshot of a continually changing panorama. Homo sapiens has been present for such a brief period, a million years or so, that we have witnessed only one possible arrangement of the continents. Our predecessors, however, have seen many changes because life, in one form or another, has been present on this planet practically since its birth.

Earth's inhabitants, far from being passive guests, have influenced conditions on this planet throughout its history. We are indebted to earlier life-forms for contributions that range from the oxygen in the air we breathe to the fossil fuels on which our civilizations have become dependent. During the evolution of the conditions that suit us so well, many species became extinct. The geologic record provides ample evidence of catastrophic extinctions of numerous species on several occasions. Some probably contributed to their own demise. Certain primitive forms of life that thrived in Earth's original Atmosphere produced oxygen as a waste to such an extent that an enormous amount was accumulated in the Atmosphere. We, too, could be causing ourselves considerable inconvenience with our carbon emissions. We have been here for but a blink of an eye on geologic time scales, but, because our development has been favored by easy access to fuels, minerals, and

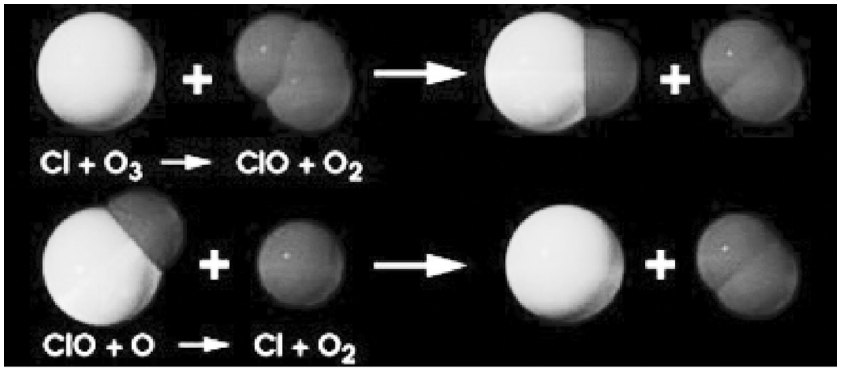
metals, we have grown in numbers and in prowess with incredible rapidity. We have become an important geologic agent are in the process of interfering with the processes that make this planet habitable. *For example, we are modifying the composition of the global Atmosphere significantly because of the fossil fuels we are burning at a furious rate. Soon our actions will cause the Atmospheric concentration of greenhouse gases to increase, not by tiny percentage, but by a factor of two at least.*



It is unlikely that the biosphere as a whole will be endangered by our actions; it has survived bigger calamities in the past. The Global Warming that we are likely to cause has been exceeded in earlier epochs. The present cold era our planet has been experiencing for some two million years was preceded by a period during which the poles were free of ice. At different times in the past, temperatures have been much higher and much lower than they are today, but because of fortuitous factors such as our distance from the sun and the size of Earth, temperature extremes on this planet never approached those that prevail on our neighbors Venus and Mars. In the long run, these factors will enable our planet to continue maintaining habitable conditions; our actions will be of little consequence over the next thousands and millions of years. That is scant comfort to humans, however, because we are vulnerable to even modest climate changes that persist for only a few years or decades. We Homo sapiens can ill afford something as trivial as an increase in the frequency of hurricanes, or prolonged droughts in some regions and repeated devastating floods in others. Our planet may seem robust from the perspective of the entire biosphere—like has been on Earth for more than three billion years—but it can nonetheless appear fragile from the perspective of individual species, especially us. That is why there is cause for concern about the global environmental consequences of our agricultural and industrial practices. The matter has generated lively debates, but they often end in stalemates; for example, some insist that Earth is robust, others that it is fragile. In reality it is both! Global Warming is wrecking the planet and it is the first mega disaster of Atmosphere.

2. Ozone Hole in Stratosphere – Second Mega Disaster of Atmosphere

In the 1970's, scientists discovered that chemicals known as CFCs, which stands for chlorofluorocarbons, can reach the stratosphere and destroy ozone gas. This was weighty discovery with worldwide implications because most of us rely on several products and appliances that, when manufactured or used release CFCs into the Atmosphere. Aerosol spray cans, Styrofoam, air conditioner units and refrigerators are a few items that make the list. The scientists began claiming that CFCs contribute to the formation of "holes" in the ozone. How could this happen? And how could CFCs be partly responsible? We know that chlorine and bromine are both substances that can destroy ozone. *It turns out that some natural and man-made chemical compounds containing chlorine and bromine are able to rise up to the stratosphere where the conditions allow them to react with and destroy ozone.* The Earth's natural production of these substances accounts for 17% of the chlorine and 30% of the bromine in the stratosphere. The above mentioned appliances we use contain chlorine.

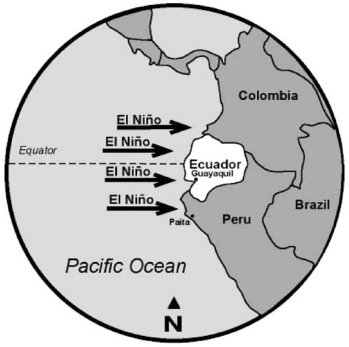


When chlorine encounters ozone, chlorine monoxide and an oxygen molecule form, destroying the ozone. When chlorine monoxide encounters an oxygen atom, the chlorine is released to wreak havoc on more ozone. When scientists and popular media refer to a "hole" in the ozone, what they really mean is an area with low density, or where the vertical column of ozone layer includes little ozone gas compared to the other areas. In one sense, the ozone "hole" can be understood as a "thin" area of the layer because if we collected all the ozone in that vertical area, it would be thinner than other places over the Earth. Specifically, scientists are worried that production of CFCs will lead to a "hole" over Antarctica. Most of the dramatic ozone disaster happens at the poles. We all know the ozone hole was found on Antarctica. However, no hole formed in the Arctic ozone layer

in 2005, because the sun did not rise when the air was at its coldest. But the spring of 2005 nonetheless saw the largest Arctic ozone loss in forty years of record-keeping. More than a third of the ozone disappeared, and losses reached 70% in some places. Air masses with reduced ozone levels spread south across Scandinavia and Britain, and even as far south as Italy for a few days. It was becoming more dangerous and Ozone hole is the second mega disaster of Atmosphere.

3. El Nino – Third Mega Disaster of Atmosphere

In 1988, and continuing into 1989, there was a severe drought in North America. Crop yields were reduced, and the water level in navigable rivers fell to such an extent that cargo-carrying river vessels were marooned, sometimes literally stuck in the mud. In Kansas, dust storms closed interstate highways. The western USSR suffered a drought, and 1988 was also the year in which there were unusually heavy rains in Australia and serious flooding in Bangladesh, southern China and Sudan. In India, the monsoon, which failed in 1987, returned to bring the heaviest rains in 70 years. Some people believed the freak weather was a manifestation of the *"greenhouse effect,"** but a thorough investigation of the weather in that year, and of the climatic events which preceded it, drew scientists very firmly to a different conclusion. The weather of 1988 was caused, at least partly, by "La Nina."



Early in 1989, and based on certain observations made late in 1988, it was predicted that Britain would enjoy a fine summer. Indeed, in 1989 there was a drought in Britain. This, too, was associated with "La Nina." "La Nina" is the opposite of "El Nino. "El Nino" is linked to world-wide climatic aberrations, its opposite to an intensification of the kind of weather that occurs normally. The severity of these events varies, and so does the weather associated with them. The most intense "El Nino" of this century occurred in 1982-3, but there were also major "El Ninos" in 1925, 1941, 1957, 1965 and 1972. "El Nino" is the Spanish for "the male child," and this climatic phenomenon earned its name in South America because it occurs at around Christmas. The reference is to

**Greenhouse effect is a warming of the lower Atmosphere and surface of a planet by a complex process involving sunlight, gases, and particles in the Atmosphere.*

the Christ child. "La Nina," meaning "the female child," is a name invented by some climatologists, and not one that is used by ordinary people in South America. More technically, *"El Nino" is known as an "El Nino-Southern Oscillation Event," or "ENSO,"* and it is only in recent years that it has received the full attention of scientists. Much remains to be learned about it, but what is known demonstrates rather dramatically the extent to which changes in the surface waters of one part of one ocean although a big part of a big ocean can produce climatic effects over many thousands of miles.

Because of the intense warming of the Equatorial surface waters, the South Equatorial Current carries warm water westwards. The deeper water of the Equatorial Undercurrent is much cooler. The result is that warm water is constantly being moved towards the west, so the depth of warm water is much greater around Indonesia than it is near the South American coast. The Peru (or Humboldt) Current, another component of the Pacific gyre, flows northwards, parallel to the South American coast, carrying water from the Antarctic. By the time it reaches the tropics, the water of the Peru Current is some 6 degrees Celsius cooler than the water of the South Equatorial Current. It wells up to the surface, contributing to the relatively low temperature of the surface waters, but also bringing oxygen and a rich load of nutrients close to the surface. The upwelling* stimulates vigorous biological activity. The vast shoals of fish, mainly anchovies, associated with upwelling of the Peru Current, used to sustain one of the largest commercial fisheries in the world, and the fish fed a large population of marine birds. The birds' droppings formed guano, which was the raw material for a large nineteenth-century fertilizer industry in Peru and Chile.

No one knows why, but from time to time, apparently at intervals of between two and seven years, the atmospheric pressure regime changes. The difference in pressure between the eastern Pacific and Indian Oceans decreases, and the Inter-tropical Convergence Zone. The prevailing winds of the north and south hemispheres, the region which they converge in the ocean, is usually known as the Inter-tropical Convergence Zone, or ITCZ. moves south. This is a "southern oscillation." It is associated with, and perhaps, causes a slackening of the southern trade winds and, because it is these winds which drive the South Equatorial Current, a slackening in the westward movement of warm water. In effect, the warm water accumulated

**Upwelling is a process that draws deep salty water, rich in nutrients up to the surface replacing warmer waters that have been pushed offshore by prevailing winds. In upwelling regions these nutrients can be utilized by phytoplankton with CO2 and energy from the sun to produce organic compounds through photosynthesis. The upwelling regions support a very high level of primary productivity and fix carbon from CO2 in the Atmosphere. Primary production of phytoplankton forms the base of the food chain which supports the world's largest fisheries.*

around Indonesia flows back towards South America. The depth of warm surface water increases off the South American coast, and the cold upwelling of the Peru Current cease to reach the surface waters. This, or rather its climatic consequences, is "El Nino." The two together comprise an ENSO event.

An ENSO event brings un-seasonally heavy rain and storms to coastal regions of Peru and Chile. These often cause flooding and damage crops, but offshore the effect is no less severe. With the disappearance of the rich upwelling, the biological productivity of that part of the ocean declines rapidly. The fish disappear, starved or migrated and this brings real hardship to communities whose livelihoods depend on fishing. The popular name for the phenomenon, linking it to a season for Christian rejoicing, is ironic for there is little rejoicing when this "child" is the Christmas visitor. In 1970, Peruvian fishermen caught more than 12 million tons of fish, about 17 percent of the total world catch in that year. In 1972, an "El Nino" year, they caught less than five million tons and, in 1973, the catch was still lower. Further afield, the strange weather, and sometimes the suffering continue. The start of an ENSO event was detected late in 1986 and intensified into 1987. In southern Alaska, western Canada and the northwestern United States, the period from December to April was unusually mild, and parts of the United States enjoyed the mildest winter and spring for more than 50 years. Parts of South America had very wet weather, but in the Philippines and Australia, on the other hand, the weather, summer and early fall in Australia, of course was extremely dry, and in India and Pakistan the monsoon largely failed.

During "La Nina" episode, the distribution of pressure in the Pacific and Indian Oceans intensifies, the southern trade winds blow more strongly, and more warm water flows westwards across the Pacific. The climatic effect is generally to exaggerate the normal weather, if rainfall is customary, there will be more of it, and if fine weather is usual, it will be warmer and last longer. It is impossible to do more than generalize, however, because, like all climatic phenomena, "El Nino" and its opposite develop in a non-linear, chaotic fashion, so that very small differences in the conditions at their start lead to very different outcomes. El Nino caused bizarre weather patterns around the world and it is the third mega disaster of Atmosphere.

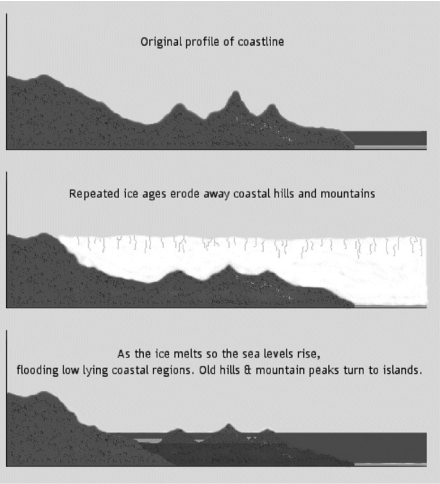
4. Ice Age – Fourth Mega Disaster of Atmosphere

An ice age is a period of cooling, marked by the presence of glaciers and ice sheets, such as those currently found in Antarctica and Greenland. Ice ages contain both cold periods, known as glacials, and warm periods, known as

interglacials. Ice ages may be as old as the Earth itself. Imagine what would happen if, one year, the average summer temperature were just a degree or two lower everywhere north of, say, New York. Some distance further to the north, in Canada, some of the snow that had fallen in the preceding winter would fail to melt. Snow would cover ground that had been free from snow in previous years and, because it is white, it would reflect sunlight. This would prevent the ground from absorbing warmth and, at the same time, the snow would chill air that passed over it. The following winter, more snow would fall on ground that had been prevented from warming during the summer. The following summer, the air would remain cold, because of the snow, and the area covered by summer snow would increase. The entire process would develop as a kind of vicious spiral, feeding on itself. This is called "positive feedback" and it affects air and, therefore, climate strongly.

It can happen only if there are large land areas in high latitudes. Snow that falls into the sea melts at once and the sea does not freeze readily. The freezing point for salt water is much lower than the fresh water, and winds and currents keeps the sea surface in constant motion, which inhibits the formation of ice. The sea freezes only where it is exposed to continental polar air—air that has been severely chilled over land. There is no land at the North Pole, but the ice cap is surrounded by continents on all sides. The feedback mechanism also works the other way, just as strongly. Suppose there is a series of unusually mild winters, with no change in summer temperatures. Snow would cover a smaller area in winter and would melt in summer. The period, during which the ground would absorb more warmth and therefore the air over the ground, would be warmer. The effect of the first mild winter would continue through the summer and into the following winter and, probably fairly quickly, the area of permanent snow would decrease. There are several ways in which such a process might be initiated, but a general warming would certainly be more strongly influenced by the heat-retaining capacity of the oceans.

There may be other effects. When a land mass breaks into two sections, for example, a new seaway is opened. This may allow currents to convey warm or cold water into formerly inaccessible sea areas. Just as the formation of air masses is altered, so is the circulation of ocean currents. The geographical distribution of the continents and oceans determines the characteristics of the air masses and, therefore, of the general circulation of the Atmosphere. Now that we know the continents have not always been in the positions they occupy today, and that they are still moving, we can amuse ourselves by imagining the climates of a world in which the continents were arranged very differently. What would happen, for example, were we to tow Africa and



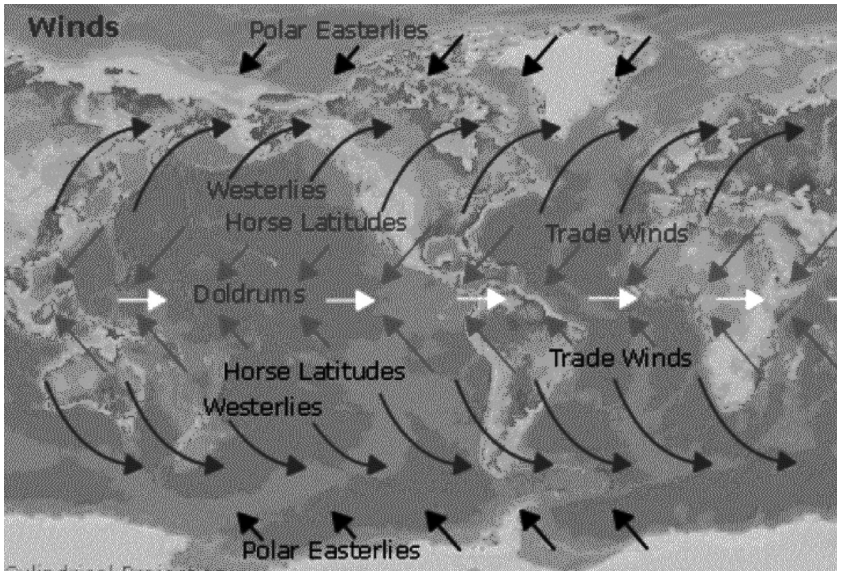
Eurasia southwards, so the Equator ran just north of the Himalayas and, at the same time, to tow Antarctica northwards into the Pacific—where there is room for it—so it lay across the Equator?

A map of the world would then show the Equator passing mainly over land, rather than in sea as it does now. There would be less land in high latitudes and none at the poles. The atmospheric circulation in the tropics would, presumably, continue to be dominated by the Hadley cells, but its air would be much drier. The tropics would probably be semi-arid and deserts would still cover much of the subtropics. Of Polar ice caps existed, they would be much smaller than those of today and, consequently, Polar Regions would be warmer. The temperature gradient between the Equator and poles would be shallower; the jet streams would be more settled. Weather of a particular kind—wet or dry, warm or cool—would remain constant for longer than it does at present and might end with a spell of fairly violent weather—storms and gales—as one type of weather gave way to another. This is pure speculation, of course, and could be quite wrong, but serves to illustrate the great climatic significance of the distribution of land and sea at different latitudes. It is easy to see that while land lies in the tropics it will experience a tropical climate and that this can explain the presence of coal. Similarly, the desert which supplied the sand of what is now Devon probably lay in the subtropics. The sandstone is now red because metals forming part of its mineral structure were oxidized when the sand was exposed to a more humid climate. It is less obvious that a large change in the area of land near the Equator or near either pole also produces climatic affects which are felt throughout the world. Ice Age played many roles in the making of our planet and it is the fourth mega disaster of Atmosphere.

5. Mumbai's Monsoon – Fifth Mega Disaster of Atmosphere

The crops of 60% of the world's population depend on a single recurrent weather feature: the Asian summer monsoon. Millions go hungry in years when the monsoon fails to bring its promised rains, and millions more lose

their homes to flooding when the monsoon brings more of a deluge than the land can hold. Daily totals of 40 centimeters of rain are not uncommon during these intense tropical downpours, and in Mumbai's record-breaking cloudburst in July 2005 nearly a meter of rain fell in less than 24 hours—the resulting floods causing a thousand deaths. But without this annual watering, the fertile plains of India and Bangladesh—which support some of the world's densest populations—would be arid and lifeless. The reliability of the monsoon in a warmer future is therefore a matter of life and death for billions of people



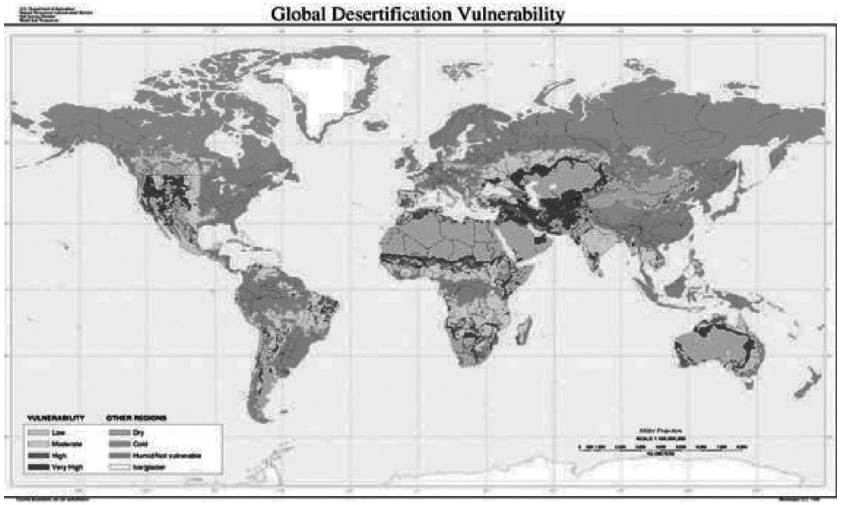
Monsoons depend on heat differentials between land and the surrounding ocean. These land-ocean contrasts will intensify in a warmer world, meaning that a total collapse of the Indian summer monsoon is unlikely over the next century. Indeed, times in the past when the monsoon has been weaker tend to be associated with colder periods, such as the height of the last ice age. Modern-day pollutants like aerosols, mostly sulfur dioxide and particulates released by fires, can also have a cooling effect, and in the absence of global warming the so-called Asian Brown Cloud might severely disrupt the monsoon, according to one study. Today same story continues, cooling pollutants weaken the monsoon. But many different studies—looking at the impact of greenhouse gases alone— have reached the firm conclusion that heavier monsoon rainfall is the most likely outcome, especially given the fact that a warmer Atmosphere holds more water vapor.

An intensification of the monsoon presents two problems. First, an increase in average rainfall during the monsoon will mean more heavy events and associated extreme flooding, thanks to this warmer, wetter Atmosphere. Second, the monsoon is also likely to become more viable. Some years it may fail altogether in some areas, only to return with renewed vigor the following season. Forecasters already struggle to predict the monsoon's annual ebb and flow, and this job will become even more difficult as the world's weather shifts into new patterns. These new weather patterns may affect areas a surprisingly long distance away from the Indian subcontinent. Studies of old corals off the coast of Indonesia have shown that 6,000 years ago, during an era of strong monsoons, Sumatra and other Indonesian islands were struck by harsh drought, thanks to changing wind-flow patterns across the tropical Indian Ocean. This history suggests that drought may once again become perennial in this densely populated country of the Indian monsoon gets stronger, as many climate models predict. Drought years in Indonesia can already be disastrous, with food shortages and forest fires so sever that huge areas of the country—and neighboring Malaysia—disappear underneath heavy palls of smoke for weeks at a time. Areas even as far away as southern Australia may also suffer reduced rainfall as a result of the changing Indian monsoon.

In India itself, farmers will struggle to grow successful crops if the monsoon's onset becomes less reliable. In more intense years, flooding will become catastrophic, submerging vast areas. The areas that already get the heaviest rains—the Indian west coast, the Bay of Bengal and Bangladesh, and northeast India—will be particularly affected. It is almost like a biblical adage: To them that already have, more will be given. And the reverse is also true: Rainfall may be reduced in areas that currently receive scanty amounts, such as northern India and southern Pakistan. And it is to Pakistan that we look next, because as world temperatures climb toward three degrees, *this country will be on the brink of a crisis without parallel in recent human history.* And as is so often the case, this disaster will flow not from the direct effects of the increased heat, but from its indirect consequences. Pakistan stands to lose massive quantities of the most precious resource of all: water.

6. Garden of Eden and Desertification – Sixth Mega Disaster of Atmosphere

According to some historians, the greener Sahara of 6,000 years ago was the geographical basis for the mythical Garden of Eden, its original inhabitants expelled not by God for bad behavior but by a devastating drying of the climate. While scientists continue to argue over the specifics of the likely climatic future of the Sahara and Sahel, one thing seems clear: Humanity will not be returning to Eden any time soon. Desertification might have been the cause for expulsion from the Garden of Eden. Scientists wonder that how the once fertile Sahara with cool temperatures, bustling with life turned to be hellish. The same story was repeated in different cultures, in various times. Desertification is the expansion of dry lands due to poor agricultural practices, overgrazing, degradation of soil fertility and structure, improper soil moisture management, salinization and erosion, forest removal, and climate change. Two misconceptions prevail about desertification, that it spreads from a desert core and drought is responsible. Desertification spreads outward from any where excessive abuse of the land occurs and far from any climatic desert. Droughts do increase the possibility of desertification if the carrying capacity of non-irrigated land is exceeded. Well-managed land can recover from the effects of drought. Combining drought with land abuse sets the stage of desertification.



Desertification comes about by a complex interaction between the natural environment and human activities. The cause may vary from region to region on account of economic conditions, population pressure, agricultural practices, and politics. Human activities, that destroy surface vegetation, degrades soil structure and fertility, impedes water infiltration, and causes soil drying promotes desertification. This is especially true for the fragile transition zone between arid and semiarid land where human activity has stretches the ecosystem to its limit causing expansion of

deserts. Population growth and its demand on agricultural resources had promoted the desertification process. Over cultivation, for example, causes declining soil fertility leading to falling crop yields. Over use leads to crusting of exposed topsoil by rain and sun that increases runoff, water erosion and gullying. Soil drying promotes wind erosion and encroachment of sand dunes on arable land. Forest cutting for fuel wood has deforested large tracks of land in Africa and Asia encouraging desertification. Overgrazing has several effects. It causes a decline in pasture vegetation and palatable grass species; it replaces perennials with short-lived annual species that do not hold soil against erosion; it compacts soil under trampling hoofs, and; it destabilizes dunes when crest vegetation is eaten.

Desertification is a global problem occurring in many places but is prevalent along the margins of semiarid and arid lands in Asia, central Australia, portions of North and South America, and Africa. Africa has been significantly impacted by desertification. Almost three quarters of Africa's agricultural drylands are already degraded to some degree. The impact on desertification on the greatest number of people occurs in Asia. Degraded regions include the sand dunes of Syria, the eroded mountain slopes of Nepal, and the deforested and overgrazed highlands of Laos. The Northern Mediterranean region is the cradle of civilization and has borne the effects of poor agricultural practices. Salinized, infertile soils are the result of natural hazards e.g. droughts, floods and forest fire, as well as over-tilling and overgrazing. Soil degradation is high through much of Central and Eastern Europe, and very high in some areas, for example along the coast of the Adriatic Sea. Poor irrigation practices and the unsustainable exploitation of water resources are contributing to chemical pollution, soil salinization and aquifer depletion. Nearly a quarter of the inhabitants of Latin America and the Caribbean live below the poverty line fueling practices that lead to land degradation. Erosion and water shortages are intensifying in many East Caribbean islands.

Monsoons are based on the simple principle that land surfaces heat up quicker in the summer than the surrounding oceans. This creates an area of low pressure as the hot air in the continental interior rises, sucking in cooler, moister air from the neighboring seas. These rain-bearing winds bring torrential summer downpours to monsoonal climates such as India's, where agricultural life revolves with this annual cycle. The African summer monsoon is weaker and less generally recognized, but is still the only source of reliable rainfall for the Sahel. Climate models project that land surfaces will warm much faster than the oceans during the 21st century, potentially adding boost to summer monsoons. So with one degree global warming,

this monsoon could begin to gain power and penetrate once again far into the African continent, greening the Sahara. Like Africa and the Indian subcontinent, northern China is subject to an annual monsoon cycle. In summer, moist air blows in from the ocean, bringing heavy rainfall to the south. In winter, however, the pattern reverses and strong winds sweep down from the north, bringing dust and freezing temperatures.

7. Drought – Seventh Mega Disaster of Atmosphere

Drought actually refers to a shortage of water that occurs when the available supply can't meet the demand. Weather contributes to the problem of drought but is not only factor in determining one. An increased demand for water or a change in water quality due to issues like contamination can also result in drought. There are three common types of drought:

Meteorological drought: This type of drought is determined by calculating the lack of precipitation from normal amounts, as well as the length of the dry spell. To classify official drought based on lack of precipitation, the area in question must typically be one that experiences precipitation on a year-round basis such as a rainforest. Areas where precipitation is seasonal cannot be classified the same way since dry periods aren't uncommon in these regions.

Agricultural drought: Though this type of drought may be caused by a lack of precipitation, the official explanation classifies is when the moisture present in soil is not sufficient for the crops growing in the area. While lack of rain or snowfall may be one factor, reduced ground water or reservoir levels can also be responsible. Agricultural drought also looks at the different stages of crops and how a lack of water will affect them in a given stage. This helps determine if a reduction in the final crop yield should be expected, dependant at what stage of the growing process the water shortage occurred in.

Hydrological drought: Another drought that occurs due to lack of precipitation, hydrological drought refers to a shortage of surface and subsurface water supplies such as stream flow or levels of ground water, lakes, or reservoirs. While this drought is caused by a lack of moisture as the others are, it's timing is often different as it usually occurs later since it takes longer for a lack of moisture to become evident in these water sources. Factors such as landscape or land use changes can also contribute to this type of drought.

In south India, in the state of Tamil Nadu, districts of Vellore, Kancheepuram, Dharmapuri, South Arcot and other surrounding areas would experience a global environmental disaster, desertification, which is spreading rapidly with the aid of a fickle climate and the mere trickle of a shrinking water table, incapable of supporting the millions of people who live there. Indeed, of all natural resources, the most tenuous, most threatened, and most precious worldwide, freshwater ranks number one. In these areas the age of drought and devastation has already come. It is estimated that all these places will experience a critical shortage of fresh water resources in 20 to 30 years if demand remains the same. This makes environmental awareness of this issue critical for all people of these areas. New technologies and simple changes in behavior can reduce the amount of water that we waste without significantly changing our individual lifestyles. It is possible to maintain agriculture by growing water-resistant crops, while reducing the amount of water used. Wasting valuable water must be avoided at all costs. It is well recognized that droughts in Africa have increased in frequency and severity in recent years. This devastating drought has once again set in the African continent, putting over 35 million people out of total 85 million, at risk of starvation and malnutrition in the coming months. Poor harvests over the past three years have worn away food surpluses and incomes in the region.

Ten Heroes of Atmosphere

1. Sun- Hero Number One of Atmosphere

We have always used the energy of the sun as far back as humans have existed on this planet. As far as 5,000 years ago, people "worshipped" the sun, Ra, the sun-God, who was considered the first king of Egypt. In Mesopotamia, the sun-God Shamash was a major deity and was equated with justice. In Greece there were two sun deities, Apollo and Helios. The influence of the sun also appears in other religions. Zoroastrianism, Mithraism, Roman religion, Hinduism, Buddhism, the Druids of England, the Aztecs of Mexico, the Incas of Peru, and many Native American tribes. We know today, that the sun is simply our nearest star. Without it, life would not exist on our planet. We use the sun's energy every day in many different ways. When we hang laundry outside to dry in the sun, we are using the sun's heat to do work—drying our clothes. Decaying plants millions of years ago produced the coal, oil and natural gas that we use today. So fossil fuels is actually sunlight stored millions and millions of years ago. Indirectly, the sun or other stars are responsible for all our energy. Even nuclear energy comes from a star because the uranium atoms used in nuclear energy were created in the fury of a nova—a star exploding.

Did you know that the sun is actually a star? The sun is the closest star to Earth and is about 149.6 million km away. It is a huge bright sphere of mostly ionized gas and is the largest object in the solar system; it is big enough to hold over a million Earths! Without the sun, the Earth would be a dark and cold place incapable of supporting human life. The sun provides the Earth with many things like heat, light, food, and even the air we breathe! A process called photosynthesis occurring when green plants use the sun's rays to turn carbon dioxide and water into carbohydrates releasing the oxygen that we need to breathe in order to survive. *Therefore, life on Earth, as we know it would not exist without the sun.* The sun has been producing its radiant and thermal energies for the past four or five billion years. It has enough hydrogen to continue producing for another four billion years. *Chhath Puja* is one of the holiest festivals in Hindu religion. It is especially celebrated by people originating from Bihar. Chhath Puja is the worship of sun God, who is the source of all life forms in the world. Chhath is also an eco-friendly festival as only unprocessed natural products are used in it, as puja material.

2. Precipitation – Hero Number Two of Atmosphere

Precipitation is any form of water that falls to the Earth's surface. Following is some interesting information on the various forms of precipitation.

Hailstones: Hailstones are balls of ice that range in size from raindrop size up to 2 or more inches in diameter. Hailstones as large as tennis balls have been reported. Scientists believe that they form by repeated up and down trips, caused by violent updrafts in a thunderstorm. Hailstone becomes larger and larger with each up and down trip, until they become so heavy that they drop to the surface.

Rain: Raindrops can range from small size to large size. It is generally believed that rain drops initially form with the help of a condensation nuclei (e.g. a particle of dust, smoke, or salt).Once a small drop forms, it grows into a bigger drop by collision with other small drops. When the drop becomes large enough, it falls from the sky as rain.

Sleet: Sleet is formed when rain passes through a layer of freezing air. The droplets freeze before they reach the Earth's surface. This occurs when a warm air mass is above a cold air mass.

Drizzle: Drizzle is a very slow fall of small water droplets. Drizzle is formed in low-lying stratus clouds.

Snow: Snow is formed when water vapor turns directly into ice crystals. Snowflakes are hexagonal in shape (six sided) and are quite beautiful.

3. Lightning – Hero Number Three of Atmosphere

Most of us have experienced the unbelievable power and awesome visual experience of a lightning strike. Some of us have experienced it too closely. The formation and discharge of lightning is a very interesting topic. I will discuss what happens, step-by-step, since it is a complicated process.

A. Inside of a thundercloud there is a variety of severe conditions including rain fall, air currents rising and falling, and water droplets freezing. As a result of this activity, some drops of water in the cloud become positively charged.

B. Ice Crystal that forms in the cloud obtains a negative charge.

C. The positively charged particles group together in the upper part of the cloud to form a positive-charge center, and a negative-charge center forms at the lower part of the cloud due to the heavier weight of the ice crystals.

D. A positive charge builds up on the ground just beneath the cloud to counteract the negative charge that formed on the lower part of the cloud.

E. The positive charge on the ground and the negative charge on the lower part of the cloud continue to build until there is sufficient energy to jump the gap between the cloud and the ground.

F. A small electrical discharge, called a pilot streamer moves from the negative part of the cloud to the positive Earth.

G. A stronger discharge, called a stepped leader immediately follows and ionizes the air in its path.

H. When the pilot streamer touches the Earth, a high powered return streamer jumps from the ground and travels towards the cloud by the ionized air path caused by the stepped leader. This is the bright flash that we see during a lightning storm.

I. Since there are usually multiple negatively charged areas within a thundercloud, these negative charges quickly move to the area that just discharged.

J. A dart leader from the newly formed negative-charge center will discharge down the same path as the first discharge.

K. A second return streamer travels up to the cloud. This process continues until all the charges in a cloud have been discharged.

As you can see, there is a lot more to a lightning strike than meets the eye! How about I give you some more interesting tidbits about Lightning?

- The thunder that follows a lightning strike is caused by the super heating of air. As the air is heated, the gases expand rapidly which causes compression waves (sound).
- Sheet lightning is caused when lightning jumps from cloud to cloud.
- Ball lightning is a ball shaped electrical discharge. Ball lightning often produces whistling sounds as it moves through the air.
- Heat lightning is the reflection of distant lightning on clouds.
- Lightning has been observed on other planets including Jupiter, Venus, Saturn, Uranus, and Neptune.
- About 3,500 thunderstorms occur at any one time on the Earth.
- About 100 lightning strikes hit the Earth every second.
- Lightning produces chemical compounds (nitrates) that eventually fall to Earth and supply nutrients to the soil. Lightning believed to be the starter of life and also the producer of ozone in stratosphere, and he is a true hero of Atmosphere.

4. Clouds – Hero Number Four of Atmosphere

Even though they sometimes look as if you could walk on them, clouds are actually a collection of billions of tiny water droplets, ice crystals, or mixtures of both. A air rises into the upper Atmosphere, it cools. When this happens, the water vapor that is present in the air reaches saturation and begins to form very small droplets. The droplets begin to slowly fall. As they reach the lower part of the cloud they evaporate. Therefore a cloud is a continuous cycle of droplets falling and then evaporating. Clouds are classified according to their appearances and height. Let's start from the ground and work our way up: Low clouds are, Cumulonimbus, Cumulus, Stratus, Stratocumulus.

Low Clouds - Low clouds occur ground level up to 6,500 feet. Cumulonimbus, or storm clouds, and generally have flat bases and rounded domes. Cumulus clouds vary in size from the small puffball-like clouds to huge dome-clouds that often develop into thunderclouds. Stratus clouds are usually dark shapeless clouds that appear as streaks across the sky or as gray layers hanging above the Earth. Stratocumulus clouds are large, round and lumpy and usually cover the entire sky.

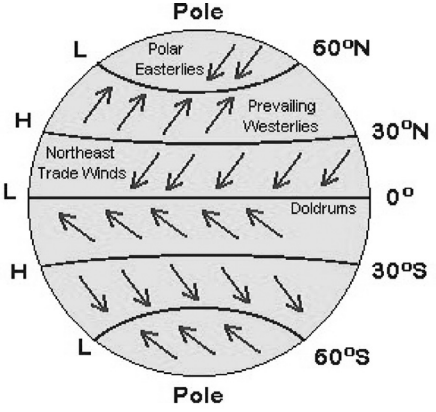
Mid-level Clouds - Mid-level clouds are, Nimbostratus, Altostratus, and Altocumulus. Mid-level clouds occur from 6,500 to 23,000 feet. Nimbostratus clouds are thick, dark, and shapeless and usually bring rain or snow. Altostratus clouds usually cover the sky with a partially transparent layer that you may see the sun through (as a bright spot). Altocumulus clouds appear as large rounded puffy clouds.

High Clouds - High clouds are Cirrostratus, Cirrocumulus, and Cirrus. High clouds occur from 16,500 to 45,000 feet. Cirrostratus clouds often look tangled webs or thin whitish sheets. When they cover the sky, you may see a large ring or around the sun or moon which is caused by the bending of light rays as they pass through the ice particles in the clouds. Cirrocumulus clouds look like very small round balls or flakes. Cirrus clouds are white and look like bands of feathers.

5. The Wind – Hero Number Five of Atmosphere

Some days it is perfectly still. Other days it will turn your umbrella inside out, blow shingles off your roof, and push you all over the road. The power of the wind is amazing. All wind is caused by differences in the temperature of the Atmosphere and by the rotation of the Earth. Have you ever noticed at the beach on a nice day that the wind usually blows on-shore during the day and off-shore during the evening? This is a perfect example of the effect of temperature differences. The sun heats land and water differently. Oceans and lakes absorb much of the heat energy from the sun and the air above them tends to be relatively cool. The land, however, absorbs much less heat than water, and as a result the air above it is heated more. Hence the air over land tends to be warmer than the air over the water. The warmer air over the land expands and becomes lighter. This creates a low pressure situation. The air over water is cooler and denser (heavier), than the land air and this creates a high pressure situation. The high pressure air over the water pushes into the low pressure area on the land. The air moving in from the water toward the land pushes the lighter land air up and out of its way. This movement is what causes a sea breeze. When night comes the opposite occurs because the air over the land cools more rapidly than the air over the sea. This causes the breeze to blow out to sea during the night.

All winds near the Earth's surface are caused by differences in atmospheric pressure brought about by uneven heating. Air moves from regions where pressure is high toward regions where pressure is low. Generally, the larger the difference between the low and high pressure areas, the harder the wind blows. This is why there is often very strong wind when a cold or warm front moves into an area. Differences in temperature and pressure are also responsible for large scale winds called planetary winds. The huge difference between the heated air in the tropics and the cold air in the Polar Regions is a primary contributor to planetary winds. In the area of the Equator, there is a low pressure area called the doldrums. This is an area of relatively calm weather. Here the air rises upward from the surface of the Earth and toward the poles.



The high pressure air that moves into the Equator area creates winds that are known as the Northeast Trade Winds. The trade winds do not blow directly toward the Equator. They are deflected by the Earth's rotation. Beyond the regions of the trade winds, there are two other calm areas, known as the Horse Latitudes (at about 35 degrees north and 30 degrees south latitude). The air which moves

upward at the Equator settles down to the Earth in these areas. Since the air settles nearly straight down in this region, there is little wind and a high pressure area. Some of the air which settles into the horse latitudes goes back immediately into the trade winds. The rest moves toward the poles to form the Prevailing Westerlies. The Polar Regions tend to send strong winds toward the Equator. These winds are called the Polar Eaterlies. Cyclonic storms frequently are formed where the Prevailing Westerlies meet the Polar Easterlies and where the Northeast Trade Winds collide.

6. Haemoglobin and Oxygen – Hero Number Six of Atmosphere

The red blood cells contain a substance called haemoglobin, they are like tiny bubbles which combine with the air (Oxygen) in the lungs, carry round the body to all the body parts to keep the body tissues and organs alive. Haemoglobin gives blood its red color when it contains oxygen. These haemoglobin bubbles or molecules stay freely flowing in the red blood cell. There are different types of normal haemoglobin flowing in red blood cell, Adult haemoglobin, Fetal haemoglobin and minor adult haemoglobin (A2).

The word oxygen was coined in 1777 by Antoine Lavoisier. The most plentiful element in the Earth's crust, about 46.6% by weight, oxygen is a nonmetallic element which, in its pure form is colorless, odorless, tasteless gas. It's most important compound is water. Oxygen constitutes about 21% of the Earth's Atmosphere and about 89% of weight of sea water. About 3 parts per hundred of the freshwater in rivers and lakes is also oxygen at 20 degree centigrade. For over 1 billion years photosynthetic organism bacteria, algae and later the plants, have been producing oxygen gas as a waste product of photosynthesis. Almost all the molecular oxygen in our Atmosphere today is the result of this process. Animals, plants and some bacteria take in oxygen and use it as the final acceptor of electrons in respiration. They return carbon dioxide to the Atmosphere. Oxygen dissolved in water is essential for respiration of fish and other water dwelling organisms.

Pure oxygen in the Atmosphere consists of molecules in which two atoms of oxygen are held together by a double covalent bond. High up in the Atmosphere oxygen molecules with three atoms are produced. Called ozone, this molecular arrangement protects life on this planet from the harmful effects of the sun's ultraviolet radiation. At very low temperatures about 183 degrees centigrade, oxygen becomes a pale blue liquid and even becomes a solid at about minus 218 degrees centigrade. Atomic oxygen has a half filled outermost energy level. It has four electrons in a level which

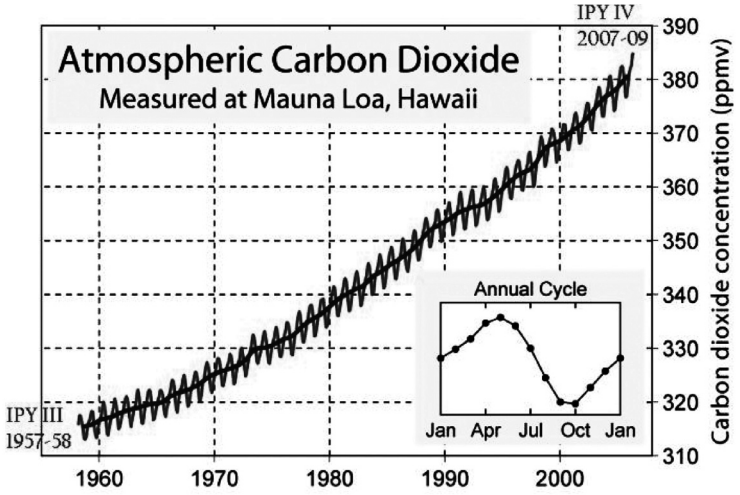
holds eight electrons. Oxygen, therefore, forms a large number of compounds in which it shares electrons. This sharing however, it rarely equal, oxygen has a high affinity for electrons, it is electronegative. The covalent bonds formed by oxygen are Polar with slight negative charges on the oxygen atom and slight positive charges on the other, sharing atom. Water is a good example of a molecule with polar covalent bonds. Oxygen is the third most abundant element in the universe by mass after hydrogen and helium and the most abundant element by mass in the Earth's crust.

7. Carbon Dioxide – Hero Number Seven of Atmosphere

Carbon dioxide contributes to plant growth as part of the miracle of nature known as photosynthesis. This enables plant to combine carbon dioxide and water with the aid of light energy to form sugar. Some of the sugars are converted into complex compounds that increase dry solid plant substances for continued growth to final maturity. However, when the supply of carbon dioxide is cut off, or reduced, the complex plant cell structure cannot utilize the sun's energy fully and growth or development is curtailed. Although carbon dioxide is one of three main components which combine to produce the products necessary for plant growth, the amount of carbon dioxide in the air is only 0.03% (250 to 330 parts per million). This compares to 78% nitrogen, 21% oxygen and 0.97% trace gases in normal air. Numerous tests have proven that during the winter months carbon dioxide concentrations inside greenhouses is invariably much lower than in outside air. The carbon dioxide molecule, like the water molecule, has three atoms. These atoms, rather than being bent, are arranged in a straight line. Because of its molecular structure, carbon dioxide happens to be especially well suited to absorb certain wavelengths, mostly the invisible infrared radiation emitted by the Earth. It does not absorb the light energy coming from the sun. Carbon dioxide lets sunlight through the Atmosphere but does not let the energy emitted by the Earth pass back into space. In this way, carbon dioxide acts a greenhouse gas.

Charles David Keeling, the world's leading authority on atmospheric greenhouse gas accumulation and climate science pioneer at Scripps Institution of Oceanography, University of California, San Diego (UCSD), died Monday, June 20, 2005, while at his Montana home, of a heart attack. He was 77 years old. Keeling has been affiliated with Scripps since 1956. Keeling was the first to confirm the rise of atmospheric carbon dioxide by very precise measurements that produced a data set now known widely as the *"Keeling Curve."* Prior to his investigations, it was unknown whether the carbon dioxide released from the burning of fossil fuels and other industrial

activities would accumulate in the Atmosphere by the oceans and vegetated areas on land. *In winter Carbon dioxide level went up in the northern hemisphere due to the winter season, no leaves to remove the excessive carbon from the Atmosphere, but in summer carbon dioxide level went down, because trees having leaves, removed the CO2 from the Atmosphere*. The Keeling Record of the increase in atmospheric carbon dioxide measured at Mauna Loa, Hawaii, and at the "pristine air" locations, represents what many believe to be the most important time-series data set for the study of global warming and climate change. The picture at the bottom, you may find in winter and spring months such as January to April CO2 level goes up, but in summer and fall months such as May to November CO2 level goes down.



8. Stratospheric Ozone Layer – Hero Number Eight of Atmosphere

Ozone can be good or bad depending on where it is in the Atmosphere. No matter where it is found in the Atmosphere, ozone is made of the same oxygen atoms that make up oxygen gas. Instead of the two oxygen atoms that bond together to form oxygen gas (02), however, three oxygen atoms bond together to form ozone (03). There is a naturally occurring layer of ozone in the stratosphere that absorbs harmful ultraviolet light before it can enter the Atmosphere. Without this filter, there would be epidemics of skin cancers, cataracts, and many other diseases, as well as damage to vital ecosystems. Life on Earth has evolved to live under its protection, and would find things much harder without it. Chemicals used for spray cans and refrigerants, which contain chlorine and fluorine, tend to decompose ozone in the stratosphere. This effect was most notable over Antarctica, where a hole appeared in the ozone layer.

When scientists recognized that this was happening, a ban was placed on the use of these chemicals. Since then, the ozone layer has been recovering. This resulted in a slight atmospheric cooling as additional ultraviolet light again began to be absorbed in the upper Atmosphere, leaving less to be absorbed closer to the Earth's surface. This is the "good" ozone. The "bad" ozone is the product of combustion and a complex chemical reaction that occurs in the lower layer of the Atmosphere, or the troposphere. Ozone in the troposphere is a greenhouse gas that absorbs a small amount of infrared radiation. Compared with the other heavy hitters in the Atmosphere, ozone, despite its notoriety of the stratospheric ozone hole, plays only a small role in changing the global temperature. Natural processes such as lightning convert oxygen gas to ozone. Ozone is also found in tailpipe and smokestack emissions resulting from a more complex photochemical reaction.

9. Carbon Sink – Hero Number Nine of Atmosphere

About half of the carbon dioxide that humans add to the Atmosphere is removed by nature in *what is called a sink*. Had this not occurred, the carbon dioxide levels and the enhanced greenhouse effect would be even greater than it is currently. Nature removes carbon dioxide from the Atmosphere by dissolving it in seawater. Dissolved carbon dioxide forms a mild acid called carbonic acid that slightly decreases the PH level of the water in which it is dissolved. The amount of carbon dioxide that can be absorbed by the oceans reaches a saturation level depending on water temperature. Warm water can hold less carbon dioxide than cold water. There is a limit as to how much carbon dioxide can dissolve, and since there is not very much vertical mixing in the oceans, it can take centuries for the dissolved carbon dioxide to penetrate below the surface layers. Although the oceans have an enormous capacity to absorb much of the carbon dioxide that is being added to them, only a small part of the oceans near the surface is available to accomplish this. Consequently, injection of carbon dioxide deep into the oceans has been proposed as a possible way to remove carbon dioxide from the Atmosphere.

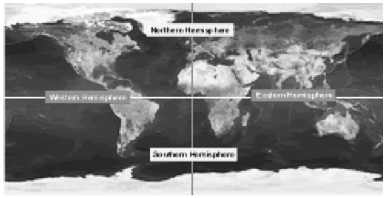
10. The Tilt of the Earth – Hero Number Ten of Atmosphere

Axis of the Earth: An imaginary straight line running through the center of the Earth from North Pole to the South Pole. The Earth is said to rotate on this axis, which is "tilted" in relation to the sun. This causes our seasons.

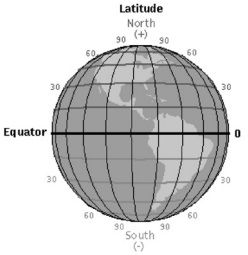
Equinox: The word means "equal night." It refers to the two moments each year when the sun appears to cross the Equator. The spring (vernal) equinox is around March 21 and the fall (autumnal) equinox is around September 23.

Almost all places on Earth have about 12 hours of daylight and 12 hours of night on the equinoxes. The sun doesn't really move, but it looks like it does to us. That's because our Earth is tilted as it revolves around the sun once a year.

Greenwich Mean Time (GMT) or Universal Time (UT): An international time-keeping standard based on the local time in Greenwich, England (0 degrees longitude. GMT or UT enables us to refer to things that happen at the same moment in different time zones. (It would be confusing to use "local time") At any moment, GMT/UT is the same everywhere on Earth. That's why it is called universal time.

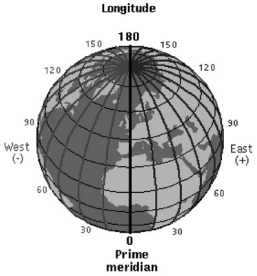


Hemisphere: A mapping division meaning half of the Earth (sphere). First, cutting the Earth in half at the Equator (0 degrees latitude), this divides the Earth into Northern Hemisphere and the Southern Hemisphere. Second, cutting the Earth in half at the Prime Meridian (0 degrees longitude), this divides the Earth into the Western Hemisphere and the Eastern Hemisphere.



Latitude: Imaginary horizontal mapping lines of the Earth. They are known as "parallels" of latitude because they run parallel to the Equator. The number of degrees of latitude shows how far north or south of the Equator a specific location is.

Longitude: Imaginary vertical mapping lines on Earth known as "meridians" of longitude. The number of degrees of longitude shows how far east or west of the Prime Meridian a specific location is.



Meridian: An imaginary line that runs vertically, north and south, from the North Pole to the South Pole. All points on a meridian have the same longitude.

Prime Meridian: The Prime Meridian serves as the starting point for longitude measurement, so is indicated as degrees longitude. The Prime Meridian passes directly over the British Royal Observatory in Greenwich, England.

Revolution of the Earth: The yearly 365 ¼ days trip the Earth takes around the sun. We experience different seasons as the titled Earth revolves around the sun.

Solstice: The word means "sun stop." It refers to the two moments each year when the sun appears to be farthest from the Equator. On the winter solstice in our hemisphere (around December 22), the sun seems to reach its most southerly point. It is our shortest day of the year. From there, it seems to head north until it reaches its most northerly point. That is our summer solstice (around June 21): the longest day of the year. When the Northern Hemisphere has its winter solstice, the Southern Hemisphere has its winter solstice, and vice versa. The sun doesn't move, but it looks like it does to us. That's because our Earth is tilted as it revolves around the sun once a year.

The Ten Commandments of Atmosphere

- Thou shall not pollute the Atmosphere, take care of the Atmosphere.
- Thou shall not disrespect the Atmosphere, especially the air which other people breathe.
- Thou shall not use fossil fuels which contribute poisonous gases in the Atmosphere.
- Thou shall keep the Atmosphere holy and friendly.
- Thou shall honor Atmosphere by honoring Earth and its systems, such as Hydrosphere, Lithosphere, and Biosphere.
- Thou shall not damage the Ozone Layer by using chlorofluorocarbons which damage the Ozone in the Atmosphere.
- Thou shall not burn plastics, tires, leaves, and paper.
- Thou shall not use aerosols and sprays.
- Thou shall plant trees which supply fresh oxygen to Atmosphere.
- Thou shall save the Atmosphere by living sustainable lifestyle.

Finally … New Horizons

We agree that the planet needs our help, but we disagree on what to do? By the end of this century, the planet will heat up between 1.4 degrees and 5.8 degrees Celsius, according to the Intergovernmental Panel on Climate Change. Six-degree rise in Earth's temperature would be enough to reshape our world almost beyond recognition. Homo sapiens had come through the last ice age as a mere novice on the planet then we could make it this time,

too. We need to get hold of the controls or risk disaster. Fifteen years on, the urgency of the climate crisis is much clearer, even if the story has grown a little more complicated. *But we are showing no signs yet of acting on the scale necessary.* The technology is still straightforward, and the economics is only easier, but we can't get the politics right. We know too well, what happened in Copenhagen, Denmark in December, 2009. *Even at this late hour, I do believe we have it in our power to set Spaceship Earth back on the right course.* But time is short. The ship is already starting to spin out of control. We may soon lose all chance of grabbing the wheel.

Humanity faces a genuinely new situation. It is not an environmental crisis in the accepted sense. It is a crisis for the entire life-supporting system of our civilization and our species. During the past 10,000 years, since the close of the ice age, human civilization have plundered and destroyed their local environment, wrecking the natural fecundity if sizable areas of the planet. Nevertheless, the planet's life-support system as a whole has until now remained stable. As one civilization fell, another rose. But the rules of the game have changed. In the Atmosphere, human influences on planetary systems are global and pervasive.

In the past, if we got things wrong and wrecked our environment, we could pack up and move somewhere else. Migration has always been one of our species' great survival strategies. Now we have nowhere else to go. No new frontier. We have only one Atmosphere; only one Planet.

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