ORIGINAL ARTICLE

Atmospheric science

The dynamics and chemistry of Earth Atmosphere

I.A. Aly

Independent Researcher and theorist-ORCID 0000-0002-9699-266X-ResearcherID: L-3923-2017

[1]Independent Researcher and theorist-ORCID 0000-0002-9699-266X-ResearcherID: L-3923-2017

Correspondence
RESEARCH, EG, 32511
Email: Islamatefaly5@gmail.com

Funding information

This paper overviewing the dynamics of the Earth atmosphere and the chemistry contents of the atmospheric layers including some experiments to describe some climate events like tornadoes, hurricanes, heat waves and thunder storm.

KEYWORDS

Atmospheric science, *Dynamics*, Ice age, origins of the universe

1 | INTRODUCTION

Earth is the only planet in the solar system with an atmosphere that can sustain life. The blanket of gases not only contains the air that we breathe but also protects us from the blasts of heat and radiation emanating from the sun. It warms the planet by day and cools it at night.

Earth's atmosphere is about 300 miles (480 kilometers) thick, but most of it is within 10 miles (16 km) the surface. Air pressure decreases with altitude. At sea level, air pressure is about 14.7 pounds per square inch (1 kilogram per square centimeter). At 10,000 feet (3 km), the air pressure is 10 pounds per square inch (0.7 kg per square cm). There is also less oxygen to breathe.

The atmosphere is a mixture of nitrogen (78 percent), oxygen (21 percent), and other gases (1 percent) that surrounds Earth. High above the planet, the atmosphere becomes thinner until it gradually reaches space. It is divided into five layers. Most of the weather and clouds are found in the first layer.

The atmosphere is an important part of what makes Earth livable. It blocks some of the Sun's dangerous rays from reaching Earth. It traps heat, making Earth a comfortable temperature. And the oxygen within our atmosphere is essential for life.

Over the past century, greenhouse gases and other air pollutants released into the atmosphere have been causing big changes like global warming, ozone holes, and acid rain.

Abbreviations: I.A. Aly, Scientific society; SS, Atmospheric and Earth chemistry; AEC, ResearcherID: L-3923-2017.

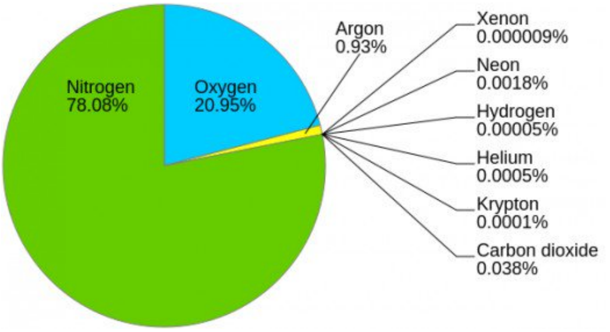

FIGURE 1 Composition of Earth Atmosphere

2 | CONCLUSIONS

The work includes topics that overviewing the Earth atmospheric layers and it's chemical composition, Weather and it's four fronts, clouds and it's 6 types and the effect of air pollution in the components of Aerosols, the types of fronts and give a quick introduction into the dynamics and chemistry of Earth atmosphere.

3 | OVERVIEWING

3.1 | Earth's Atmospheric Layers

fThe atmosphere is divided into five layers. It is thickest near the surface and thins out with height until it eventually merges with space.

Troposphere The troposphere starts at the Earth's surface and extends 8 to 14.5 kilometers high (5 to 9 miles). This part of the atmosphere is the most dense. Almost all weather is in this region.

Stratosphere The stratosphere starts just above the troposphere and extends to 50 kilometers (31 miles) high. The ozone layer, which absorbs and scatters the solar ultraviolet radiation, is in this layer.

Mesosphere The mesosphere starts just above the stratosphere and extends to 85 kilometers (53 miles) high. Meteors burn up in this layer

Thermosphere The thermosphere starts just above the mesosphere and extends to 600 kilometers (372 miles) high. Aurora and satellites occur in this layer.

Ionosphere The ionosphere is an abundant layer of electrons and ionized atoms and molecules that stretches from about 48 kilometers (30 miles) above the surface to the edge of space at about 965 km (600 mi), overlapping into the mesosphere and thermosphere. This dynamic region grows and shrinks based on solar conditions and divides further into the sub-regions: D, E and F; based on what wavelength of solar radiation is absorbed. The ionosphere is a critical link in the chain of Sun-Earth interactions. This region is what makes radio communications possible.

Exosphere This is the upper limit of our atmosphere. It extends from the top of the thermosphere up to 10,000 km (6,200 mi).[15]

4 | WEATHER

Weather is the state of the atmosphere at a given time and place. Most weather takes place in the troposphere, the lowest layer of the atmosphere.

Weather is described in a variety of ways by meteorologists, scientists who study and predict weather. Air temperature and pressure, the amount and type of precipitation, the strength and direction of wind, and the types of clouds are all described in a weather report.

Weather changes each day because the air in our atmosphere is always moving, redistributing energy from the Sun. In most places in the world, the type of weather events expected vary through the year as seasons change. While weather can change rapidly, climate changes slowly, over decades or more, in response to changes in the factors that determine our climate.

4.1 | Weather Fronts

When a front passes over an area, it means a change in the weather. Many fronts cause weather events such as rain, thunderstorms, gusty winds, and tornadoes. At a cold front passes there may there may be dramatic thunderstorms. At a warm front there may be low stratus clouds. Usually the skies clear once the front has passed.

A weather front is a border between two different air masses at the Earth's surface. Each air mass has its own characteristics such as temperature and humidity. Where two different air masses come in contact, the line between them is a front. Often there is turbulence where those different air masses come together. The turbulence can cause clouds and storms.

While many fronts cause storms and clouds, some fronts do not cause dramatic weather events, just a change in the temperature. However, a few fronts start Earth's largest storms. Tropical waves, fronts that develop in the tropical Atlantic Ocean off the coast of Africa, are able to develop into tropical storms or hurricanes if conditions allow.

Fronts move over time as the air masses move. The direction that fronts move is often guided by high winds such as Jet Streams. Landforms like mountains can also change the path of a front.

There are 4 different types of fronts: cold fronts, warm fronts, stationary fronts, and occluded fronts.

4.1.1 | Cold Fronts

A cold front is where a cold air mass is pushing into a warmer air mass. Cold fronts can produce dramatic changes in the weather. They move fast, up to twice as fast as a warm front. Cold air is dense so it is able to quickly plow a warm air mass ahead of it.

Commonly, when the cold front is passing, winds become gusty; there is a sudden drop in temperature, and heavy rain, sometimes with hail, thunder, and lightning. Lifted warm air ahead of the front produces cumulus or cumulonimbus clouds and thunderstorms. Atmospheric pressure changes from falling to rising at the front. After a cold front moves through your area you may notice that the temperature is cooler, the rain has stopped, and the cumulus clouds are replaced by stratus and stratocumulus clouds or clear skies.

On weather maps, a cold front is represented by a solid blue line with filled-in triangles along it, like in the map on the left (B). The triangles are like arrowheads pointing in the direction that the front is moving. Notice on the map that temperatures at ground level are warmer in front of the front than behind it.

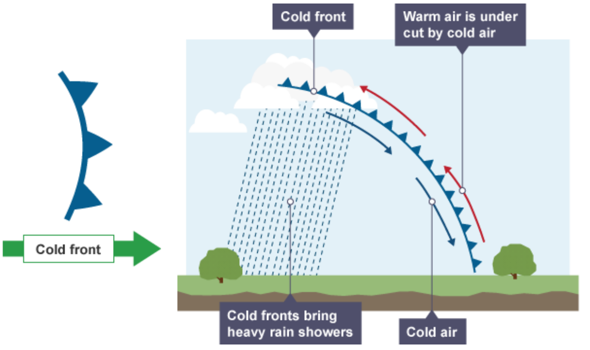

FIGURE 2 A side view of a cold front and how it is represented on a weather map

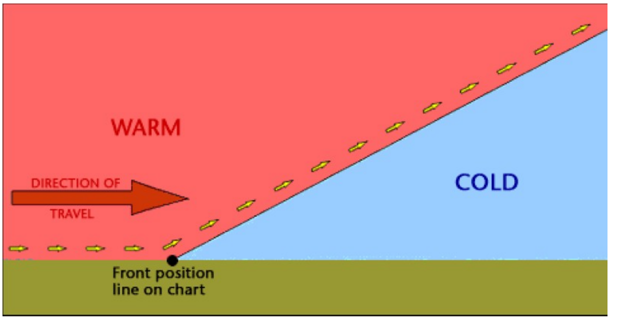

FIGURE 3 A side view of a warm front and how it is represented on a weather map

4.2 | Warm front

A warm front is where a warm air mass is pushing into a colder air mass. Warm fronts move more slowly than cold fronts because it is more difficult for the warm air to move against the cold, dense air.

You will often see high clouds like cirrus, cirrostratus, and middle clouds like altostratus ahead of a warm front. These clouds form in the warm air that is high above the cool air. As the front passes over an area, the clouds become lower and rain is likely. There can be thunderstorms around the warm front if the air is unstable.

On weather maps, the surface location of a warm front is represented by a solid red line with red, filled-in semicircles along it, like in the map on the left (B). The semicircles indicate the direction that the front is moving. They are on the side of the line where the front is moving. Notice on the map that temperatures at ground level are cooler in front of the front than behind it.

4.2.1 | Stationary front

A stationary front forms when a cold front or warm front stops moving. This happens when two masses of air are pushing against each other but neither is powerful enough to move the other. Winds blowing parallel to the front instead of perpendicular can help it stay in place.

A stationary front may stay put for days. If the wind direction changes the front will start moving again, becoming

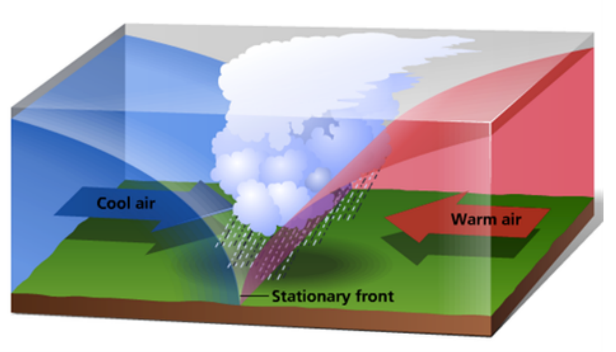

FIGURE 4 A side view of stationary front and how it is represented on a weather map

either a cold or warm front. Or the front may break apart.

Because a stationary front marks the boundary between two air masses, there are often differences in air temperature and wind on opposite sides of it. The weather is often cloudy along a stationary front and rain or snow often falls, especially if the front is in an area of low atmospheric pressure.

On a weather map, a stationary front is shown as alternating red semicircles and blue triangles like in the map at the left. The blue triangles point in one direction and the red semicircles point in the opposite direction.

4.2.2 | Occluded Fronts

Sometimes a cold front follows right behind a warm front. A warm air mass pushes into a colder air mass (the warm front) and then another cold air mass pushes into the warm air mass (the cold front). Because cold fronts move faster, the cold front is likely to overtake the warm front. This is known as an occluded front.

At an occluded front, the cold air mass from the cold front meets the cool air that was ahead of the warm front. The warm air rises as these air masses come together. Occluded fronts usually form around areas of low atmospheric pressure.

There is often precipitation along an occluded front from cumulonimbus or nimbostratus clouds. Wind changes direction as the front passes and the temperature changes too. The temperature may warm or cool. After the front passes, the sky is usually clearer and the air is drier.

On a weather map, like the one on the left, an occluded front looks like a purple line with half triangles and half semicircles along it pointing in the direction that the front is moving. It ends at a low pressure area shown with a large 'L' on the map, and at the other end connects to cold and warm

4.3 | Clouds

Clouds can come in all sizes and shapes, and can form near the ground or high in the atmosphere. Clouds are groups of tiny water droplets or ice crystals in the sky and are formed by different processes. They can make different kinds of precipitation depending on the atmosphere's temperature.

Cloud types are classified by height and appearance. The shape depends on the way the air moves around the cloud. If air moves horizontally, clouds form spread-out layers. Clouds grow upward if air is moving vertically near the cloud.

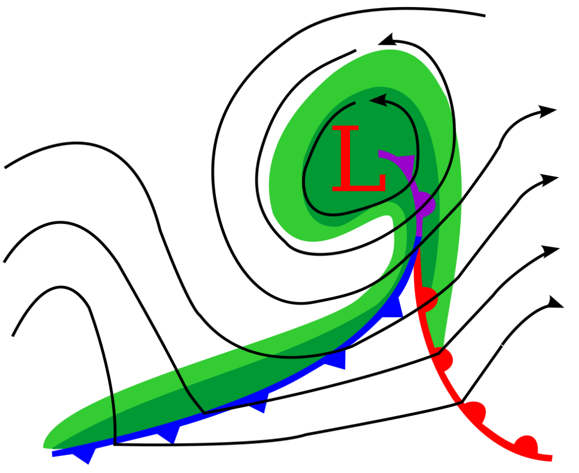

FIGURE 5 A side view of occluded front and how it is represented on a weather map

TABLE 1 This is a table. Tables should be self-contained and complement, but not duplicate, information contained in the text. They should be not be provided as images. Legends should be concise but comprehensive – the table, legend and footnotes must be understandable without reference to the text. All abbreviations must be defined in footnotes.

Cloud groups and hight	Cloud types
High Clouds 5,000-13,000m	Cirrus Cirrocumulus Cirrostratus
Middle Clouds 2,000-7,000m	Altocumulus and Altostratus
Low Clouds Surface-2,000m	Stratus Stratocumulus Nimbostratus
Clouds with Vertical Growth Surface-13,000m	Cumulus Cumulonimbus
Unusual Clouds	Lenticular Kelvin-Helmholtz Mammatus
Contrails 5,000-13,000m	Contrails

At any given time, clouds cover about 50 percent of the Earth. We would not have rain, thunderstorms, rainbows, or snow without clouds. Clouds make up some of the atmospheric optics we can see in the sky. The atmosphere would be boring if the sky was always clear! Did you know that Earth is not the only planet with clouds? Other planets, like Venus, Mars, Jupiter, Neptune, Uranus, and Saturn, have clouds too.

4.3.1 | Clouds types

Most clouds are associated with weather. These clouds can be divided into groups mainly based on the height of the cloud's base above the Earth's surface. The following table provides information about cloud groups and any cloud classes associated with them. In addition, some clouds don't fall into the categories by height. These additional cloud groups are listed below the high, middle, and low cloud groups.

[bt]

Cirrus clouds are the most common of the High Cloud (5000-13000m) group. They are composed entirely of ice and consist of long, thin, wispy streamers. They are commonly known as "mare's tails" because of their appearance. Cirrus clouds are usually white and predict fair weather.

Cirrocumulus clouds belong to the High Cloud group (5000-13000m). They are small rounded puffs that usually appear in long rows. Cirrocumulus are usually white, but sometimes appear gray. Cirrocumulus clouds are the same size or smaller than the width of your littlest finger when you hold up your hand at arm's length.

If these clouds cover a lot of the sky, it is called a "mackerel sky" because the sky looks like the scales of a fish. Cirrocumulus are usually seen in the winter time and indicate fair, but cold weather.

Cirrostratus clouds belong to the High Cloud (5000-13000m) group. They are sheetlike thin clouds that usually cover the entire sky.

The sun or moon can shine through cirrostratus clouds . Sometimes, the sun or moon will appear to have a halo around it when in the presence of cirrostratus. The ice crystals from the cloud refracts the light from the sun or moon, creating a halo. This halo is the width of your hand when you hold it out at arm's length.

Cirrostratus clouds usually come 12-24 hours before a rain or snow storm. This is especially true if Middle group clouds are associated with it.

Altocumulus clouds are part of the Middle Cloud group (2000-7000m up). They are grayish-white with one part of the cloud darker than the other. Altocumulus clouds usually form in groups and are about 1 km thick.

Altocumulus clouds are about as wide as your thumb when you hold up your hand at arm's length to look at the cloud.

If you see altocumulus clouds on a warm humid morning, then expect thunderstorms by late afternoon.

Altostratus belong to the Middle Cloud group (2000-7000m up). An altostratus cloud usually covers the whole sky and has a gray or blue-gray appearance. The sun or moon may shine through an altostratus cloud, but will appear watery or fuzzy.

An altostratus cloud usually forms ahead of storms with continuous rain or snow. Occasionally, rain will fall from an altostratus cloud. If the rain hits the ground, then the cloud becomes classified as a nimbostratus cloud.

Stratus clouds belong to the Low Cloud (surface-2000m up) group. They are uniform gray in color and can cover most or all of the sky. Stratus clouds can look like a fog that doesn't reach the ground.

Light mist or drizzle is sometimes associated with stratus clouds.

Stratocumulus clouds belong to the Low Cloud (surface-2000m) group. These clouds are low, lumpy, and gray. These clouds can look like cells under a microscope - sometimes they line up.

4.3.2 | Cloud form

A cloud is composed of tiny water droplets or ice crystals that are suspended in the air. A series of processes have to happen in order for these water droplets or ice crystals to form into clouds in the atmosphere, and different types of clouds form from different processes. The four main ways that clouds can form are:

Surface Heating Mountains and Terrain Air Masses Being Forced to Rise Weather Fronts (cold or warm)

All of these processes involve the cooling of air. Warm air is able to hold larger amounts of water vapor than cool air, so when air cools it is no longer able to hold all of the water vapor it was able to hold when it was warm. This extra water vapor begins to condense out of the air into liquid water droplets.

Typically, water vapor needs some sort of particle, such as dust or pollen, to condense upon. These particles are called condensation nuclei. Eventually, enough water vapor will condense upon condensation nuclei to form a cloud. The water droplets in the cloud may eventually fall down to Earth in the form of rain or snow (or other forms of precipitation).

5 | AEROSOLS

When you look up at the sky, you are looking at more than just air. There are also billions of tiny bits of solid and liquid floating in the atmosphere. Those tiny floating particles are called aerosols or particulates.

Some aerosols are so small that they are made only of a few molecules – so small that they are invisible because they are smaller than the wavelength of light. Larger aerosols are still very small, but they are visible.

There are hundreds or thousands of little aerosols in each cubic centimeter of air. Some of them are natural and others are released into the air by humans. Natural sources of aerosols include dust from dry regions that is blown by the wind, particles released by erupting volcanoes or forest fires, and salt from the ocean.

We, humans, add aerosols to the atmosphere too. Aerosols are a part of air pollution from cars, power plants, and factories that burn fossil fuels.

Some aerosols are released into the atmosphere, others are made in the atmosphere. For example, sulfate aerosols are made in the atmosphere from sulfur dioxide released from power plants.

In general, the smaller and lighter a particle is, the longer it will stay in the air. Larger particles tend to settle to the ground by gravity in a matter of hours whereas the smallest particles (less than 1 micrometer) can stay in the atmosphere for weeks and are mostly removed by precipitation.

For several reasons, aerosols affect climate. Aerosols help clouds to form in the sky and the number and types of clouds affects climate. Certain types are able to scatter or absorb sunlight, which affects climate. Aerosols that scatter light can make interesting distortions in the sky, called atmospheric optics.

The aerosols that are from air pollution are hazardous to human health. When the little particles get deep into a person's lungs it can make him or her very ill. Aerosols can also limit visibility, causing haze in many parts of the world.

6 | THUNDERSTORM

Thunderstorms are one of the most thrilling and dangerous types of weather phenomena. Over 40,000 thunderstorms occur throughout the world each day.

Thunderstorms form when very warm, moist air rises into cold air. As this humid air rises, water vapor condenses, forming huge cumulonimbus clouds.

There are two main types of thunderstorms: ordinary and severe. Ordinary thunderstorms are the common summer storm and usually last about one hour. The precipitation associated with these storms includes rain and occasionally small hail. With ordinary thunderstorms, cumulonimbus clouds can grow up to 12 kilometers high.

Severe thunderstorms are very dangerous. They are capable of producing baseball-sized hail, strong winds, intense rain, flash floods, and tornadoes. Severe thunderstorms can last several hours and can grow 18 kilometers high. Several phenomena are associated with severe thunderstorms, including gust fronts, microbursts, supercell thunderstorms, and the squall lines.

6.1 | Thunderstorm Formation

Most thunderstorms form by a cycle that has three stages: the cumulus stage, mature stage, and dissipating stage.

Cumulus Stage The sun heats the Earth's surface during the day. The heat on the surface and warms the air around it. Since warm air is lighter than cool air, it starts to rise (known as an updraft). If the air is moist, then the warm air condenses into a cumulus cloud. The cloud will continue to grow as long as warm air below it continues to rise.

Mature Stage When the cumulus cloud becomes very large, the water in it becomes large and heavy. Raindrops start to fall through the cloud when the rising air can no longer hold them up. Meanwhile, cool dry air starts to enter the cloud. Because cool air is heavier than warm air, it starts to descend in the cloud (known as a downdraft). The downdraft pulls the heavy water downward, making rain.

This cloud has become a cumulonimbus cloud because it has an updraft, a downdraft, and rain. Thunder and lightning start to occur, as well as heavy rain. The cumulonimbus is now a thunderstorm cell.

Dissipating Stage After about 30 minutes, the thunderstorm begins to dissipate. This occurs when the downdrafts in the cloud begins to dominate over the updraft. Since warm moist air can no longer rise, cloud droplets can no longer form. The storm dies out with light rain as the cloud disappears from bottom to top.

The whole process takes about one hour for an ordinary thunderstorm. Supercell thunderstorms are much larger, more powerful, and last for several hours.

6.2 | Thunder and Lightning

Lightning is the most spectacular element of a thunderstorm. In fact it is how thunderstorms got their name. Wait a minute, what does thunder have to do with lightning? Well, lightning causes thunder.

Lightning is a giant spark. A single stroke of lightning can heat the air around it to 30,000 degrees Celsius (54,000 degrees Fahrenheit)! This extreme heating causes the air to expand at an explosive rate. The expansion creates a shock wave that turns into a booming sound wave, better known as thunder. This explains why it has the name thunderstorm.

Thunder and lightning occur at roughly the same time, although you see the flash of lightning before you hear the thunder. This is because light travels much faster than sound.

6.2.1 | Lightning Formation

The sky is filled with electric charge. In a calm sky, the positive (+) and negative (-) charges are evenly spaced throughout the atmosphere. Therefore, a calm sky has a neutral charge.

Inside a thunderstorm, the electric charge is spread out differently. A thunderstorm is made up of ice crystals and hailstones. The ice crystals have a positive charge, and the hailstones have a negative charge. An updraft pushes the ice crystals to the top of the thunderstorm cloud. At the same time, the hailstones are pushed to the bottom of the thunderstorm by its downdraft. These processes separate the positive and negative charges of the cloud into two levels: the positive charge at the top and the negative charge at the bottom.

During a thunderstorm, the Earth's surface has a positive charge. Because opposites attract, the negative charge at the bottom of the thunder cloud wants to link up with the positive charge of the Earth's surface.

Once the negative charge at the bottom of the cloud gets large enough, a flow of negative charge rushes toward the Earth. This is known as a stepped leader. The positive charges of the Earth are attracted to this stepped leader, so a flow of positive charge moves into the air. When the stepped leader and the positive charge from the earth meet, a strong electric current carries positive charge up into the cloud. This electric current is known as the return stroke and humans can see it as lightning.

7 | TORNADOES

Tornadoes form from severe thunderstorms. They have a very high energy density which means that they affect a small area but are very destructive to that area. They also don't last very long which makes it hard to learn about them. Since they're hard to study, they're also hard to forecast. People know even less about tornadoes, which is why there are a lot of different myths that aren't true. Tornadoes can occur anywhere in the world. About 75 percent of them happen in the United States, most in an area know as Tornado Alley. There are also some other interesting facts about tornadoes. People who are interested in tornadoes sometimes become trained tornado spotters for their community. Others chase tornadoes, either to research these incredible storms, or to photograph them. After a tornado touches down, scientists try and figure out how strong it was by using the Enhanced Fujita Tornado Scale.

8 | SIZE OF TORNADOES

Tornadoes come in three different sizes, each with different characteristics. The three sizes are: weak, strong, and violent. Their size is based on how large the tornado is as well as the time that the tornado lasts and how it compares to the Enhanced Fujita Scale.

A weak tornado is the most common type of tornado and makes up 69 percent of all tornadoes. The least number of deaths happen from this type of tornado, and the longest they can last is a little more than 10 minutes. Winds within this category of tornado are less than 100 mph (161 kph). Weak tornadoes are part of the first two categories of the Fujita Scale. Damage from a weak tornado can include broken tree branches and peeling off the roofs from houses and buildings.

Strong tornadoes include 29 percent of all tornadoes. This type of tornado causes 30 percent of all deaths from tornadoes. Wind speeds for strong tornadoes are between 110-205 mph (177-330 kph). These tornadoes can last 20 minutes or even longer. Demolished mobile homes and overturned trains are part of the damage that could happen from a strong tornado.

While a violent tornado is the least common, it is very deadly. Violent tornadoes make up 70 percent of all tornado deaths. This type of tornado can last over an hour. Wind speeds for violent tornadoes are typically greater than 205 mph (330 kph). A violent tornado is part of the last two categories on the Fujita Scale. These tornadoes can do a lot of damage, including throwing cars and picking up well built houses and carrying them for miles.

9 | HURRICANES

As a strong hurricane heads towards the coast, people prepare - boarding up houses, packing the car, and evacuating. These storms can spell disaster for people in hurricane prone areas, so they are taken very seriously. They are the most powerful of all weather systems and they are huge - an average of 340 miles across.

Hurricanes form in the tropics over warm ocean water and die down when they move over land or out of the tropics. These storms are called hurricanes in the Atlantic and typhoons or tropical cyclones in other areas of the world. In the Northern Hemisphere the storms rotate counterclockwise and in the Southern Hemisphere they rotate clockwise because of the Coriolis Effect. At the center of the rotating storm is a small area of calm weather and clear skies called the eye.

Hurricane damage in coastal areas is often due to storm surge, which floods coastal areas. Strong waves and wind also batter coastal areas. Hurricanes also cause a tremendous amount of rain. Not all storms are the same. Large and strong storms cause much more damage than small storms. In the Atlantic and Eastern Pacific, the Saffir-Simpson Hurricane Scale is used to describe the size of a hurricane.

As hurricanes move, scientists try to forecast where and when the storm will reach land in order to warn people. Hurricanes are tracked over large distances with weather satellites. Computer models that take into account factors of the storm and the atmosphere are used to predict where the storm will go. Since 1953 each hurricane has been given a name to help warn people that a storm was on its way.

Hurricanes usually happen at a particular time of year called hurricane season. The timing of hurricane season is different in different regions of the world. In the North Atlantic, hurricane season is from June 1st to November 30th each year.

10 | HEAT WAVES

It's the middle of the summer and it's hot – hotter than normal. The heat lasts for days. It's hot at night too.

Has that ever happened where you live? Unusually hot summer weather that lasts for several days is called a heat wave.

Not all heat waves are the same. Some have high humidity. Others do not. Some last for a week or more. Others last only a few days. Heat wave temperatures will be much hotter in a region that is usually hot than in a region that is usually cool. For example, temperatures during a heat wave in southern California, where summers are usually hot, may climb to 100-130 degree F (38-54 degree C), while temperatures during a heat wave in London, England, where summers are usually mild, may be only 90-95 degree F (32-35 degree C).

Heat waves are a danger to human health – causing heat stroke, heat exhaustion, cramps, and other ailments. They also cause crops to fail and can help start wildfires in dry areas.

How do they form? Sometimes, the jet stream, a flow of air through the mid-latitudes, can bring unusually warm air into a region. If the warm air stays put for a while, it can cause a heat wave. The heat is able to persist if there aren't rain and clouds to cool things off. The heat-trapping ability of cities, known as the urban heat island effect, can make a heat wave warmer and longer.

There are more heat waves today that there were in the past. According to the Intergovernmental Panel on Climate Change, the number of heat waves has risen, especially in Europe and Asia, and heat waves are expected to become more common during the this century.

11 | BLIZZARDS

Can you image winds blowing at 75 mph (120 kph), snowfall of 43 inches (1 meter), lost electrical power, and roofs collapsing due to the weight of the snow? These events were part of the Blizzard of 1993 that hit the entire East Coast of the United States.

The National Weather Service defines a blizzard as a storm with large amounts of snow or blowing snow, winds greater than 35 mph (56 kph), and visibility of less than 1/4 mile (0.4 km) for at least three hours. Some blizzards have no falling snow. Instead, snow that had fallen before the blizzard is blown around or drifts in a way to create these conditions. This type of blizzard is called a ground blizzard. Conditions for a blizzard usually will build up on the northwestern side of a powerful storm system. The strong winds are from the difference in pressures between two systems. This means the difference in the low pressure system which is causing the stormy weather and the high pressure system to the west of the low.

The word blizzard was first used in the United States during the 1870's when a snowstorm in Iowa was described as a blizzard. This word has been used throughout the United States and England ever since.

Blizzards are most common in the United States mostly the upper Midwest and the Great Plains according to the National Weather Service. Other countries that have blizzards include Canada and Russia. Russia uses a different name for blizzards, "purgas". Blizzards can occur all over the world. Iran experienced a blizzard in January of 2008 where the temperatures reached -11^{o}F (-24^{o}C), and record snowfalls were recorded. Places near the equator can experience blizzards especially at high altitudes.

Conditions of a blizzard can be severe. Travel becomes dangerous when the blowing snow causes whiteout conditions and sky and ground look white. Roads can be partially or fully blocked by drifts of snow that have been caused by the blowing snow. Many times cold temperatures are part of blizzard conditions. The cold temperatures can cause frostbite or hypothermia.

12 | WEATHER IN URBAN AREAS

Heavy rainfall often occurs around cities. In fact, cities themselves can affect the weather. Scientists have several different hypotheses that may explain how cities impact rain.

One hypothesis is that the urban heat island effect, which causes warmer temperatures in cities, creates unstable air which leads to rain. Air is unstable when it is warmer than the air around it. The warm, unstable air starts to rise. The air cools as it rises, which allows water vapor within it to condense and form clouds. If the warm, rising air was carrying enough water vapor, those clouds can grow into rainclouds.

Another hypothesis is that when wind hits the skyscrapers and other tall buildings in a city, it is pushed up higher in the atmosphere. This makes unstable air. The unstable air flows upward and cools, allowing water vapor to condense, forming clouds, which can lead to rain.

Tall buildings might have another effect that causes clouds and rain. As wind approaches the buildings, it may be divided with some of it blowing around one side of the city and some of it blowing around the other side. Past the city, the wind comes back together. It collides, flows upward, cools, and releases water vapor forming clouds.

Air pollution in cities may also affect cloud formation and rain. Water vapor condenses on tiny particles in the air pollution, forming the droplets that make a cloud.

13 | THE URBAN HEAT ISLAND EFFECT

The air in urban areas can be 2 - 5 degree C (3.6 - 9 degree F) warmer than nearby rural areas. This is known as the urban heat island effect. It's most noticeable when there is little wind. An urban heat island can increase the temperature and length of a heat wave. And city heat can influence the weather - changing wind patterns, clouds, and precipitation.

What makes cities warmer? There are many factors that can influence the urban heat island effect. Changes to the land surface that are made in urban areas have a large impact on whether a heat island forms. For example, many cities have fewer trees than surrounding rural areas. Trees shade the ground, preventing the Sun's radiation from being absorbed. Without them, the ground surface heats up. Dark rooftops and pavement absorb more radiation too. Automobiles, which make heat from their engines and exhaust, also contribute to the heat island effect. Fewer plants in urban settings mean that less evapotranspiration occurs, a process that cools the air.

Some people have wondered whether growing cities have caused global warming because of their urban heat islands. There is very strong evidence that this is not the cause of global warming. According to the Intergovernmental

Panel on Climate Change, global warming is very unlikely to be affected significantly by growing urban areas.

Today, many cities are making an effort to combat the urban heat island effect. White or reflective materials are being used for roofing and roads. Trees are being planted along city streets. And, in many areas, green roofs - living plants on rooftops – are being installed.

14 | CLIMATE AND GLOBAL CHANGE

Warm near the equator and cold at the poles, our planet is able to support a variety of living things because of its diverse regional climates. The average of all these regions makes up Earth's global climate. Climate has cooled and warmed throughout Earth history for various reasons. Rapid warming like we see today is unusual in the history of our planet. The scientific consensus is that climate is warming as a result of the addition of heat-trapping greenhouse gases which are increasing dramatically in the atmosphere as a result of human activities.

14.1 | What Is Climate?

The climate where you live is called regional climate. It is the average weather in a place over more than thirty years. To describe the regional climate of a place, people often tell what the temperatures are like over the seasons, how windy it is, and how much rain or snow falls. The climate of a region depends on many factors including the amount of sunlight it receives, its height above sea level, the shape of the land, and how close it is to oceans. Since the equator receives more sunlight than the poles, climate varies depending on distance from the equator.

However, we can also think about the climate of an entire planet. Global climate is a description of the climate of a planet as a whole, with all the regional differences averaged. Overall, global climate depends on the amount of energy received by the Sun and the amount of energy that is trapped in the system. These amounts are different for different planets. Scientists who study Earth's climate and climate change study the factors that affect the climate of our whole planet.

While the weather can change in just a few hours, climate changes over longer timeframes. Climate events, like El Nino, happen over several years, small-scale fluctuations happen over decades, and larger climate changes happen over hundreds and thousands of years. Today, climates are changing. Our Earth is warming more quickly than it has in the past according to the research of scientists. Hot summer days may be quite typical of climates in many regions of the world, but global warming is causing Earth's average global temperature to increase. The amount of solar radiation, the chemistry of the atmosphere, clouds, and the biosphere all affect Earth's climate.

14.1.1 | What control the climate changes

Some of the factors that have an affect on climate, like volcanic eruptions and changes in the amount of solar energy, are natural. Others, like the addition of greenhouse gases to the atmosphere, are caused by humans. Some of the main ones are listed below.

The Sun Affects Climate Climate can change if there is a change in the amount of solar energy that gets to Earth. Changes to the cycle of solar activity, called the 11-year solar cycle, can cause a small impact on climate, too small to be the cause of recent climate change. Over thousands of years, changes in the way Earth orbits the Sun can cause large changes in climate.

Volcanic Eruptions Affect Climate When volcanoes erupt they spew more than hot red lava and ash. They release tiny particles made of sulfur dioxide into the atmosphere too. These particles get into the stratosphere and reflect solar radiation back out to space. This causes cooling. The cooling is temporary, lasting usually a year or two.

Greenhouse Gases Affect Climate Greenhouse gases have a strong affect on climate. These gases trap heat through a process called the greenhouse effect. While greenhouse gases are a natural part of the atmosphere, the amount has increased over the past 150 years as fossil fuels have been burned and the amount of forests, which naturally take up the greenhouse gas carbon dioxide during photosynthesis, has shrunk.

Snow and Ice Affect Climate Because the snow and ice of the cryosphere are light in color, they have a large albedo – the ability to reflect most solar radiation back out to space. When snow and ice melt as Earth's climate warms, less energy is reflected and this causes even more warming.

There are also other aspects of our planet that have an impact on climate too. Scientists are studying the impact of clouds and the impact of aerosols on climate. Scientist are studying the oceans too because melting Arctic sea ice could change ocean circulation, causing regional climate to change.

14.2 | Climates of the Past

Earth's climate has been changing for billions of years. It warmed and cooled many times long before humans were around.

There weren't any people on Earth millions and billions of years ago to describe what climate was like, but the Earth kept records of past climates in special ways. Sediments and fossils deposited millions of years ago provide a record of ancient environments. Thin layers of mud and sand that form at the bottom of lakes record seasonal changes. Bubbles of ancient air trapped inside glaciers record what the atmosphere was like. Tree rings show what climate was like for each year of a tree's life.

If climate has always changed, then why are people concerned about global warming? People are concerned because the Earth is warming faster now than it has in the past as more greenhouse gases are released into the atmosphere. Warming is happening faster and life on Earth, including humans, may not have time to get used to the warming planet.

14.2.1 | Climate changes during the Paleozoic Era (545-248 Million Years Ago)

Time:

545 to 248 million years ago (See the geologic timescale!)

Geography:

Early in the Paleozoic the continents were far apart, but moving tectonic plates caused continents to move together into one large continent (a supercontinent!) called Pangaea.

Climate:

Glaciers formed 430 million years ago. They may have only lasted one or a few million years. During this time, ice covered the northern part of Africa, which was located over the South Pole. Climate models have been used to help understand weather and regional climates of the supercontinent Pangaea. The models suggest that monsoons affected the subtropical east coast and that interior of Pangaea was dry.[3]

Evolutionary Events:

According to fossils, a large number of animals (including the distant ancestors of many modern animals) evolved between 530 and 520 million years ago. Invertebrates (animals without backbones) such as corals, brachiopods, mollusks, and arthropods such as trilobites ruled the oceans in the early and middle parts of the Paleozoic. Vertebrates (including fish, amphibians, and reptiles) began to flourish in the later Paleozoic. Animals and plants populated the land (but many still lived in the ocean!). About 440 million years ago the Late Ordovician Mass Extinction occurred. It was the second largest mass extinction of all time. Over 10 million years, many marine species became extinct including those that built reefs. At the end of the Paleozoic, about 250 million years ago, as many as 96 percent of species in the oceans became extinct. They didn't die all at once. It took over 8 million years for the mass extinction to wipe out all those species. This was the largest mass extinction of all time.

14.2.2 | Climate changes during the Mesozoic Era (248-65 Million Years Ago)

Time: 248 to 65 million years ago (See the geologic timescale!)

Paleogeography: At the start of the Mesozoic, the continents were all joined together forming one large continent called Pangaea. During Mesozoic time, they pulled apart from one another. Continents move due to plate tectonics.

Climate:

The climate most likely remained warm throughout the Mesozoic. No evidence of glaciations has been found in Mesozoic age rocks and abundant evidence of tropical species has been found in Mesozoic age fossils. During the last part of the Mesozoic (called the Cretaceous period) the climate warmed very much. Earth was several degrees warmer than it is today. There was much less variation in temperature between the equator and the poles at this time. There is strong evidence that global cooling occurred at the end of the Mesozoic. The cooling may have been caused by either a huge asteroid impact near the Yucatan Peninsula, a large amount of volcanic eruptions in the area that is today India and Pakistan, or by a combination of both the asteroid and volcanoes. The Sun would have been blocked for some time by the debris spewed into the atmosphere.

Evolutionary Events:

Dinosaurs evolved and became abundant! Some were herbivores (eating plants) while others were carnivores (eating meat). Dinosaurs were reptiles, however there is some evidence that they may have been warm-blooded. Birds: During the late Mesozoic, birds evolved from a group of small carnivorous dinosaurs. Plants: Conifer trees evolved at the beginning of the Mesozoic. The first flowering plants evolved towards the end of the Mesozoic. Mammals evolved during the Mesozoic but there were relatively few species and they were small in size. During the Mesozoic, mammals were eaten by carnivorous dinosaurs. At the end of the Mesozoic, the Cretaceous-Tertiary Mass Extinction occurred. This was the extinction event that killed the dinosaurs (among others). Many of the animals and plants that survived the extinction event (such as mammals and birds) went on to become very abundant afterward. Likely causes of the extinction event include a large asteroid impact, erupting volcanoes, and climate change. There is evidence that all three of these happened.

14.2.3 | Climate changes during the Cenozoic (65 Million Years Ago to Present)

Time:

65 million years ago to today (and continuing!) (See the geologic timescale!)

Paleogeography:

The Atlantic Ocean continues to widen as new ocean crust is formed at the Mid Atlantic Ridge. India collided with the Asian continent forming the Himalayan Mountains which continue to grow higher today. The African plate pushed into Europe forming the Alps. In North America, the Rocky Mountains formed and the Colorado Plateau was uplifted. [2]

Climate:

Early Cenozoic climate was warm and humid and the climate cooled gradually during the Cenozoic. During the past two million years, Earth's climate has cooled and warmed over and over again. The cool times are called Ice Ages because large amounts of ice formed on land. The last time that these sheets of ice were very large was 20,000 years ago. Most of the sheets of ice melted by about 10,000 years ago. Whenever climate cooled and ice sheets formed on land, there was less water left in the oceans, thus lower sea level. Sometimes lower sea level caused land that is usually underwater to connect continents. These areas of land, called land bridges, allowed animals to migrate to other continents. [8]

Evolutionary Events:

Mammals, which had been small and few during the Mesozoic, became more diverse. New mammal species evolved and were able to live in areas and eat foods that had been used by dinosaurs during the Mesozoic. Grass evolved and was well adapted to the cooler climates of the late Cenozoic. Horses and other species of grazing animals evolved and ate the newly-evolved grass. The first horses were small, about the size of a labrador retriever. Modern humans and their recent ancestors are called hominids. Thousands of fossils of hominids have been found; the oldest is more than 6 million years old. Fossils of hominids that are similar to modern humans are called Homo sapiens. Fossils of Homo sapiens are as much as 400,000 years old.

14.2.4 | The Little Ice Age

The Little Ice Age was a time of cooler climate in most parts of the world. Although there is some disagreement about exactly when the Little Ice Age started, records suggest that temperatures began cooling around 1250 A.D. The coldest time was during the 16th and 17th Centuries. By 1850 the climate began to warm.

During the Little Ice Age, average global temperatures were 1-1.5 degree Celsius (2-3 degrees Fahrenheit) cooler than they are today. The cooler temperatures were caused by a combination of less solar activity and large volcanic eruptions. Cooling caused glaciers to advance and stunted tree growth. Livestock died, harvests failed, and humans suffered from famine and disease.

The Little Ice Age was not a true ice age because it did not get cold enough for long enough to cause ice sheets to grow larger. The cooling likely affected areas around the world but we have the most records of how it changed daily life from Europe. Some of the records and events that occurred during the Little Ice Age are listed below.

Fur trappers reported that southern Hudson Bay remained frozen for about 3 weeks longer each spring. Fishermen reported large amounts of sea ice floating in the North Atlantic. British people saw Eskimos paddling canoes off the coast of England. Alpine (mountain) glaciers grew larger. In some cases, the ice engulfed mountain villages. Winters were longer and growing seasons shorter according to tree ring data and records of cherry tree flowering. Wet weather caused disease that affected people, animals and crops including the bubonic plague (also called the Black Death). This disease killed more than a third of Europeans. Farms and villages in Northern Europe were deserted because the farmers couldn't grow crops in the cooler climate. During the harshest winters, bread had to be made from the bark of trees because grains would no longer grow. Limited crops and unhealthy livestock caused famine in areas of northern and Eastern Europe. Unlike today, there was no way to transport food around the world to areas where crops had failed and people were hungry. [14]

14.2.5 | The Year Without a Summer

Odd things happened during the summer of 1816. Snow fell in New England. Clouds and gloomy cold rains covered Europe. The weather didn't seem like summer weather at all. It was cold and stormy and dark. The year became known as "The Year Without a Summer."

The reason for the lack of summer weather in Europe and North America could be found on the other side of the planet - at Indonesia's Mount Tambora.

On April 5, 1815, Mount Tambora, a volcano, started to rumble with activity. Then, it erupted for four months, the largest eruption in recorded history. Many people close to the volcano lost their lives. Mount Tambora ejected so much ash and aerosols into the atmosphere that the sky darkened and people could not see the Sun. These particles spread through the atmosphere over the following months and had a worldwide effect on climate. Earth's average global temperature dropped three degrees Celsius. The effect was temporary. Eventually, ash and aerosols released by the volcano fell out of the atmosphere, allowing the sunshine through.

The change in climate during the year without a summer had many impacts in Europe and North America. The cold weather and lack of sunshine made it difficult to grow crops, increasing the price of food. The price of oats increased making it more expensive for people to feed their horses. Since horses were the way people got from one place to another, expensive oats meant that the cost of travel increased. This may have helped inspire a German man named Karl Drais to invent a way to get around without a horse: the bicycle.

The gloomy summer weather also inspired writers. During that summer-less summer, three British writers were on vacation in Switzerland. Trapped indoors by constant rain and gloomy skies, the writers described the bleak, dark environment of the time in their own ways. Mary Shelley wrote Frankenstein, a horror novel set in an often stormy environment. Lord Byron wrote the poem Darkness, which begins, "I had a dream, which was not all a dream. The bright sun was extinguish'd." [13] [11]

15 | EFFECTS OF CLIMATE CHANGE TODAY

Over 100 years ago, people worldwide began burning more coal and oil for homes, factories, and transportation. Burning these fossil fuels releases carbon dioxide and other greenhouse gases into the atmosphere. These added greenhouses gases have caused Earth to warm more quickly than it has in the past.

How much warming has happened? Scientists from around the world with the Intergovernmental Panel on Climate Change (IPCC) tell us that during the past 100 years, the world's surface air temperature increased an average of 0.6 degree Celsius (1.1 degree F). This may not sound like very much change, but even one degree can affect the Earth. Below are some effects of climate change that we see happening now.

Sea level is rising. During the 20th century, sea level rose about 15 cm (6 inches) due to melting glacier ice and expansion of warmer seawater. Models predict that sea level may rise as much as 59 cm (23 inches) during the 21st Century, threatening coastal communities, wetlands, and coral reefs. Arctic sea ice is melting. The summer thickness of sea ice is about half of what it was in 1950. Melting ice may lead to changes in ocean circulation. Plus melting sea ice is speeding up warming in the Arctic. Glaciers and permafrost are melting. Over the past 100 years, mountain glaciers in all areas of the world have decreased in size and so has the amount of permafrost in the Arctic. Greenland's ice sheet is melting faster too. Sea-surface temperatures are warming. Warmer waters in the shallow oceans have contributed to the death of about a quarter of the world's coral reefs in the last few decades. Many of the coral animals died after weakened by bleaching, a process tied to warmed waters. The temperatures of large lakes are warming. The temperatures of large lakes world-wide have risen dramatically. Temperature rises have increased algal blooms in lakes, favor invasive species, increase stratification in lakes and lower lake levels. Heavier rainfall cause flooding in many regions. Warmer temperatures have led to more intense rainfall events in some areas. This can cause flooding. Extreme drought is increasing. Higher temperatures cause a higher rate of evaporation and more drought in some areas of the world. Crops are withering. Increased temperatures and extreme drought are causing a decline in crop productivity around the world. Decreased crop productivity can mean food shortages which have many social implications. Ecosystems are changing. As temperatures warm, species may either move to a cooler habitat or die. Species that are particularly vulnerable include endangered species, coral reefs, and polar animals. Warming has also caused changes in the timing of spring events and the length of the growing season. Hurricanes have changed in frequency and strength. There is evidence that the number of intense hurricanes has increased in the Atlantic since 1970. Scientists continue to study whether climate is the cause. More frequent heat waves. It is likely that heat waves have become more common in more areas of the world. Warmer temperatures affect human health. There have been more deaths due to heat waves and more allergy attacks as the pollen season grows longer. There have also been some changes in the ranges of animals that carry disease like mosquitoes. Seawater is becoming more acidic. Carbon dioxide dissolving into the oceans, is making seawater more acidic. There could be impacts on coral reefs and other marine life. [7]

16 | THE POLAR ATMOSPHERE

There are some unique phenomena that happen in the atmosphere that is above the Earth's polar regions. Read on to discover more about some of the unique parts of the polar atmosphere.

Aurora:High in the thermosphere layer of Earth's atmosphere, energized particles that come from the Sun follow Earth's magnetic field lines toward the Poles. The gases of the upper atmosphere light up with the added energy. The display is called the aurora. It can only be seen at high latitudes and is called the Northern Lights in the Northern Hemisphere and the Southern Lights in the Southern Hemisphere.

Noctilucent Clouds: In the mesosphere layer of Earth's atmosphere, below the thermosphere and above the stratosphere, noctilucent clouds form in the polar regions. This is much higher in the atmosphere than typical clouds, but noctilucent clouds are not typical clouds. The word noctilucent means to glow, and these clouds do glow blue in color when they are lit from below by the setting Sun.

Less Ozone: The ozone layer, located in the stratosphere layer of the atmosphere, shields our planet from harmful UV radiation. However, during the 20th Century pollutants that were used in aerosol cans and refrigeration destroyed a large amount of ozone. Most of the ozone destruction happened in the part of the stratosphere that is over Earth's polar regions. There are now a number of ozone holes, areas where the amount of ozone is only about a third of what it used to be, including a very large hole over Antarctica.

Cold Weather: Less solar energy gets to the poles making for lots of cold weather. However, even though both poles get the same amount of sunlight, the North Pole is less cold and has different weather than the South Pole. This is because the North Pole is over the Arctic Ocean, which is less cold than Antarctica and its thick layer of ice. Antarctica is the coldest continent on Earth. It has some of the harshest weather on the planet with high winds and low precipitation. Weather events happen in the troposphere layer of Earth's atmosphere, which is about half as thick at the poles as it is at the equator.

Patterns of the Polar Atmosphere

Changing patterns of high pressure are found in both polar regions. In the north polar region, the Northern Annular Mode is an area of high atmospheric pressure that moves between a location over the North Pole and a ring around the Pole at 45 degree N latitude. The changing location of the high-pressure zone causes changes in wind patterns and affects weather patterns from year to year such as how cold it will get in North America and Europe during a winter. In the south polar region, the Southern Annular Mode is similar. It involves a zone of high pressure that moves its location between the South Pole and a ring around the pole at 45 degree S latitude. [4]

17 | EARTH'S POLAR REGIONS

17.1 | Geography of Earth's Polar Regions

Location

The polar regions are the areas that surround Earth's geographic North and South Poles. The area surrounding the North Pole is called the Arctic and includes almost the entire Arctic Ocean and northern areas of Europe, Asia, and North America. The area surrounding the South Pole is called the Antarctic and includes the continent of Antarctica and parts of the surrounding Southern Ocean. Earth's geographic poles are in a slightly different location than the magnetic poles

The Arctic region extends from the North Pole to the Arctic Circle (66.5 degree N latitude). The Antarctic region extends from the South Pole to the Antarctic Circle (66.5 degree S latitude).

Day and Night

If you live in a place that is far from the equator, you may have noticed that during winter there are fewer hours of sunlight than during summer. This is because of the tilt of Earth's axis. Earth's tilt is the reason for the seasons. The closer you are to one of Earth's poles, the less sunlight there is during winter days. At the Arctic and Antarctic Circles there is one full day when the Sun does not set and one day when it does not rise. The Sun does not set on the summer solstice (June 21 in the north and December 21 in the south) and does not rise on the winter solstice (December 21 for the north and June 21 for the south). In the weeks prior to the winter solstice, the number of hours with sunlight become fewer and fewer until on the winter solstice when the Sun does not rise at all for a day. After the winter solstice the amount of daylight increases each day until the summer solstice when the Sun does not set at all for one day.

Right at the Poles, the Sun shines for half the year and it is dark for the other half of the year. This makes a year like one long day. The Sun rises in spring, reaches its highest point in the sky in summer, and sets in autumn. So the Sun is visible only during the warmer months of the year. When the Sun is visible during summer at the South Pole, it is the dark winter months at the North Pole. The time when the Sun is continuously in the sky is called Polar Day. [9]

17.2 | Earth's Magnetic Poles

Earth has a magnetic field. If you imagine a gigantic bar magnet inside of Earth, you'll have a pretty good idea what Earth's magnetic field is shaped like. Of course, Earth DOESN'T have a giant bar magnet inside it; instead, our planet's magnetic field is made by swirling motions of molten iron in Earth's outer core.

Earth has two geographic poles: the North Pole and the South Pole. They are the places on Earth's surface that Earth's imaginary spin axis passes through. Our planet also has two magnetic poles: the North Magnetic Pole and the South Magnetic Pole. The magnetic poles are near, but not quite in the same places as, the geographic poles. The needle in a compass points towards a magnetic pole. When you are far away from a pole a compass is very helpful if you want to find your way around. The compass needle points pretty much due North (or South if you live in the Southern Hemisphere!). However, if you are near either pole, a compass becomes useless. It points towards the magnetic pole, not the true geographic pole. Those two poles could be quite far apart, and in different directions. Think how hard it must have been for early explorers to find their way around in the Arctic and Antarctic without being able to use a compass!

Earth's magnetic field is tilted a little bit. If we pretend that Earth's magnetic field is made by a giant bar magnet, that bar magnet would make an angle with Earth's spin axis. That angle is about 11 degree. That's why the magnetic poles and the geographic poles are not in the same place. If you were standing at one of the magnetic poles, the magnetic field lines would be straight up and down. If you were holding a compass and turned it sideways, its needle would aim straight up and down!

Earth's magnetic poles are actually pretty far from its geographic poles. In 2005, the North Magnetic Pole (NMP) was about 810 km (503 miles) from the Geographic North Pole. The NMP was in the Arctic Ocean north of Canada. The South Magnetic Pole (SMP) was about 2,826 km (1,756 miles) from the Geographic South Pole. The SMP was off the coast of Antarctica in the direction of Australia.

Did you notice how we said where the magnetic poles were in 2005? Guess what; the magnetic poles actually move around! Remember, swirling motions of molten metal in Earth's outer core make our planet's magnetic field. Those swirling motions are changing all the time. That means the magnetic field is changing, so the magnetic poles move! In the first part of the 20th century, the poles usually moved about 9 km (5.6 miles) per year. Then, around 1970, they started moving faster. In recent years they have been moving about 41 km (25 miles) per year!

Sometimes Earth's magnetic field even flips over! The North and South Magnetic Poles trade places. This doesn't happen very often; usually at least a few hundred thousand years pass between these flips.

Speaking of flipping, did you know that Earth's North Magnetic Pole is actually a south pole? Huh, what? When compasses were first invented, people noticed that one end of the compass pointed towards the North. They called the end of the compass needle that pointed North the "north end" of the needle (makes sense!). Later, people learned more about magnets. They learned that like ends (a north and a north OR a south and a south) push away from each other. They learned that opposite ends (such as a north and a south) pull toward each other. The needle of a compass is a tiny bar magnet. The north end of the needle is pulled toward Earth's North Magnetic Pole. So the North Magnetic Pole is actually the south pole of Earth's magnetic field. Doesn't that just make your brain ache!

The aurora (Northern and Southern Lights) mostly happen near the magnetic poles. That's because the charged particles (mostly electrons and protons) that cause the aurora follow along magnetic field lines towards the magnetic poles. When the particles run into air in Earth's atmosphere, the air glows in pretty colors - making the beautiful aurora. [1] [5]

18 | AIR POLLUTION

What do smog, acid rain, carbon monoxide, fossil fuel exhausts, and tropospheric ozone have in common? They are all examples of air pollution. Air pollution is not new. As far back as the 13 th century, people started complaining about coal dust and soot in the air over London, England. Since the beginning of the industrial revolution in the late 1700s, we have been changing the Earth's atmosphere and its chemistry. As industry spread across the globe, so did air pollution. Air pollution has many effects. In addition to being ugly, it can cause illness and even death. It damages buildings, crops, and wildlife. The worst air pollution happened in London when dense smog (a mixture of smoke and fog) formed in December of 1952 and lasted until March of 1953. 4,000 people died in one week. 8,000 more died within six months.

Air pollution is made up of solid particles and chemicals. Natural processes impacting the atmosphere include volcanoes, biological decay, and dust storms. Plants, trees, and grass release volatile organic compounds (VOCs), such as methane, into the air. We are more concerned with human-made pollution since we have the ability to control it. The pollutants include carbon monoxide, sulfur dioxide, VOCs, and nitrogen oxides. The largest source of human-made pollution is the burning of fossil fuels, including coal, oil, and gas, in our homes, factories, and cars.

Air pollution is either primary or secondary. Primary pollution is put directly to the air, such as smoke and car exhausts. Secondary pollution forms in the air when chemical reactions changes primary pollutants. The formation of tropospheric ozone is an example of secondary air pollution.

The atmosphere is a complex, dynamic and fragile system. Concern is growing about the global effects of air pollution, especially climate change. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health. [10]

19 | OZONE HOLE

The Ozone Hole is a major "thinning" of the ozone layer in Earth's atmosphere. It was first noticed in the late 1970s. The hole appears in the winter over the poles, especially the South Pole. Various chemicals that humans release into the atmosphere help cause the hole. Special weather patterns near the poles in winter also help cause the holes to form.

Ozone in the stratosphere protects us from ultraviolet radiation in sunlight. The ozone layer is sort of like sunscreen for planet Earth. That's why holes in the ozone layer are bad news.

Ozone is an unusual type of oxygen molecule. Normally, there are higher concentrations of ozone at various altitudes in the stratosphere. Sometimes, under the right conditions, chemical reactions in the ozone layer can destroy most of the ozone, creating an ozone "hole".

People from many countries have agreed to stop emitting most of the chemicals that destroy ozone. Scientists are hopeful that ozone holes will disappear sometime in the future if we continue to stop emissions of the problematic chemicals. [12]

20 | MODELING BY CMMAP

Clouds are an important part of Earth's weather and climate. Scientists use computer models to study our planet's climate. These computer models include models of clouds. It's hard to model clouds because these models need to include both large and small things. Some parts of cloud models need to explain very big things like hurricanes that can be more than a hundred miles across. Other parts of cloud models need to explain very small things like raindrops and snowflakes.

CMMAP (pronounced "see-map") stands for the Center for Multi-Scale Modeling of Atmospheric Processes. CMMAP scientists are working on a new way to model the climate that will help us to better understand the roles clouds play today and in the future as our climate changes. Climate model grid cells are usually about the size of the state of Delaware. The problem with modeling clouds is that they are much smaller than this, and there could be thousands of clouds in an area the size of Delaware at any given time.

One solution that CMMAP scientists are working on is to make the grid cells small enough to simulate clouds. This has been done using cells the size of city blocks. Although these models do a good job simulating clouds that are realistic, they are very slow. Even the fastest computers in the world are too slow to simulate global climate with city-block-sized cells. Someday this will be possible, but that is many years away.

We need better climate models today, so CMMAP is developing a radical new approach that bridges the gap between the city-block-sized grid cells and the Delaware-sized grid cells. This "middle ground" involves adding small grid cells to a tiny part of each Delaware-sized cell, which provides a representative sample of the grid cell rather than including all of the information involved. [6]

ACKNOWLEDGEMENTS

This work was partially supported by family. I thank Scientists from NASA Glenn center for research who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions

of this paper.

LIST OF FIGURES

LIST OF TABLES

REFERENCES

[1] Baker, K. and Wing, S. (1989) A new magnetic coordinate system for conjugate studies at high latitudes. *Journal of Geophysical Research: Space Physics*, **94**, 9139–9143.

[2] Berggren, W. A. and Hollister, C. D. (1974) Paleogeography, paleobiogeography and the history of circulation in the atlantic ocean.

[3] Berner, R. A. (1993) Paleozoic atmospheric co2: importance of solar radiation and plant evolution. *Science*, **261**, 68–71.

[4] Brekke, A. (2012) *Physics of the upper polar atmosphere*. Springer Science & Business Media.

[5] Dungey, J. W. (1961) Interplanetary magnetic field and the auroral zones. *Physical Review Letters*, **6**, 47.

[6] Foster, S., Johnson, R., Randall, D., Denning, A., Burt, M., Gardiner, L., Genyuk, J., Hatheway, B., Jones, B., La Grave, M. et al. (2009) Hands-on, online, and workshop-based k-12 weather and climate education resources from the center for multi-scale modeling of atmospheric processes. In *AGU Fall Meeting Abstracts*.

[7] Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J., Kleypas, J. et al. (2003) Climate change, human impacts, and the resilience of coral reefs. *science*, **301**, 929–933.

[8] Lamb, S. and Davis, P. (2003) Cenozoic climate change as a possible cause for the rise of the andes. *Nature*, **425**, 792–797.

[9] Nagata, T. and Kokubun, S. (1962) A particular geomagnetic daily variation (sqp) in the polar regions on geomagnetically quiet days. *Nature*, **195**, 555–557.

[10] Seinfeld, J. H. and Pandis, S. N. (2016) *Atmospheric chemistry and physics: from air pollution to climate change*. John Wiley & Sons.

[11] Skeen, C. E. (1981) " the year without a summer": A historical view. *Journal of the Early Republic*, **1**, 51–67.

[12] Stolarski, R. S. (1988) The antarctic ozone hole. *Scientific American;(USA)*, **258**.

[13] Stommel, H. and Stommel, E. (1979) The year without a summer. *Scientific American*, **240**, 176–186.

[14] Tkachuck, R. D. (1983) The little ice age. *Origins*, **10**, 51–65.

[15] Wayne, R. P. (1993) Chemistry of atmospheres.