Aviation Meteorology

Topic Objective:

At the end of this topic student will be able to understand:

- Weather occurrence
- Temperature and layers
- Pressure and thickness
- Composition

Definition/Overview:

Weather: The weather is a set of all the phenomena in a given atmosphere at a given time. Weather phenomena lie in the hydrosphere and troposphere. Weather refers to current activity, as opposed to the term climate, which refers to the average atmospheric conditions over longer periods of time. When used without qualification, "weather" is understood to be the weather of Earth.

Key Points:

1. **Introduction to Weather**

Weather occurs due to density (temperature and moisture) differences between one place to another. These differences can occur due to the sun angle at any particular spot, which varies by latitude from the tropics. The strong temperature contrast between polar and tropical air gives rise to the jet stream. Weather systems in the mid-latitudes, such as extratropical cyclones, are caused by instabilities of the jet stream flow. Because the Earth's axis is tilted relative to its orbital plane, sunlight is incident at different angles at different times of the year. On Earth's surface, temperatures usually range 40 C (72 F) annually. Over thousands to hundreds of thousands of years, changes in Earth's orbit affect the amount and distribution of solar energy received by the Earth and influence long-term climate. Surface temperature differences in turn cause pressure differences. Higher altitudes are cooler than lower altitudes due to differences in compressional heating. Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. The atmosphere is a chaotic system, so small changes to one part of the system can grow to have large effects on the system as a whole. Human attempts to control the weather have occurred throughout human history, and there is evidence that human activity such as agriculture and industry has inadvertently modified weather patterns. Studying how the weather works on other planets has been helpful in understanding how weather works on Earth. A famous landmark in the Solar System, Jupiter's *Great Red Spot*, is an anticyclonic storm known to have existed for at least 300 years. However, weather is not limited to planetary bodies. A star's corona is constantly being lost to space, creating what is essentially a very thin atmosphere throughout the Solar System. The movement of mass ejected from the Sun is known as the solar wind.

2. Temperature and layers

The temperature of the Earth's atmosphere varies with altitude; the mathematical relationship between temperature and altitude varies among five different atmospheric layers (ordered highest to lowest, the ionosphere is part of the thermosphere):

- Exosphere: from 500 1000 km (300 600 mi) up to 10,000 km (6,000 mi), free-moving particles that may migrate into and out of the magnetosphere or the solar wind.
- Ionosphere: the part of the atmosphere that is ionized by solar radiation. It plays an important part in atmospheric electricity and forms the inner edge of the magnetosphere. It has practical importance because, among other functions, it influences radio propagation to distant places on the Earth. It is located in the thermosphere and is responsible for auroras.
- Thermosphere: from 80 85 km (265,000 285,000 ft) to 640+ km (400+ mi), temperature increasing with height.
- Mesosphere: From the Greek word "μέσος" meaning middle. The mesosphere extends from about 50 km (160,000 ft) to the range of 80 to 85 km (265,000 285,000 ft), temperature decreasing with height. This is also where most meteors burn up when entering the atmosphere.

- Stratosphere: From the Latin word "stratus" meaning a spreading out. The stratosphere extends from the troposphere's 7 to 17 km (23,000 60,000 ft) range to about 50 km (160,000 ft). Temperature increases with height. The stratosphere contains the ozone layer, the part of the Earth's atmosphere which contains relatively high concentrations of ozone. "Relatively high" means a few parts per millionmuch higher than the concentrations in the lower atmosphere but still small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from approximately 15 to 35 km (50,000 115,000 ft) above Earth's surface, though the thickness varies seasonally and geographically.
- Troposphere: From the Greek word "τρέπω" meaning to turn or change. The troposphere is the lowest layer of the atmosphere; it begins at the surface and extends to between 7 km (23,000 ft) at the poles and 17 km (60,000 ft) at the equator, with some variation due to weather factors. The troposphere has a great deal of vertical mixing because of solar heating at the surface. This heating warms air masses, which makes them less dense so they rise. When an air mass rises, it does work against gravity. This work changes some of the thermal (kinetic) energy into gravitational potential energy, so the temperature of the air mass decreases. As the temperature decreases, water vapor in the air mass may condense or solidify, releasing latent heat that further uplifts the air mass. This process determines the maximum rate of decline of temperature with height, called the adiabatic lapse rate. The troposphere contains roughly 80% of the total mass of the atmosphere. Fifty percent of the total mass of the atmosphere is located in the lower 5 km of the troposphere.

The average temperature of the atmosphere at the surface of Earth is 15 C (59 F).

3. Pressure and thickness

The average atmospheric pressure, at sea level, is about 101.3 kilopascals (about 14.7 psi); total atmospheric mass is 5.148010^{18} kg. Atmospheric pressure is a direct result of the total weight of the air above the point at which the pressure is measured. This means that air pressure varies with location and time, because the amount (and weight) of air above the earth varies with location and time. However the *average* mass of the air above a square meter of the earth's surface is known to the same high accuracy as the total air mass of 5148.0 teratonnes and area of the earth of 51007.2 megahectares, namely 5148.0/510.072 = 10.093 metric tonnes or 14.356 lbs (mass) per square inch. This is about 2.5% below the officially standardized unit atmosphere (1 atm) of 101.325 kPa or 14.696 psi, and corresponds to the mean pressure not at sea level but at the mean base of the atmosphere as contoured by the earth's terrain. Were atmospheric density to remain constant with height the atmosphere would terminate abruptly at 7.81 km (25,600 ft). Instead it decreases with height, dropping by 50% at an altitude of about 5.6 km (18,000 ft). For comparison: the highest mountain, Mount Everest, is higher, at 8.8 km, which is why it is so difficult to climb without supplemental oxygen. This pressure drop is approximately exponential, so that pressure decreases by approximately half every 5.6 km, and about 50% of the total atmospheric mass is within the lowest 5.6 km. However, because of changes in temperature throughout the atmospheric column, as well as the fact that the force of gravity begins to decrease at great altitudes, a single equation does not model atmospheric pressure through all altitudes (it is modeled in 7 exponentially decreasing layers, in the equations given above).

Even in the exosphere, the atmosphere is still present (as can be seen for example by the effects of atmospheric drag on satellites).

The equations of pressure by altitude in the above references can be used directly to estimate atmospheric thickness. However, the following published data are given for reference:

- 50% of the atmosphere by mass is below an altitude of 5.6 km.
- 90% of the atmosphere by mass is below an altitude of 16 km. The common altitude of commercial airliners is about 10 km.
- 99.99997% of the atmosphere by mass is below 100 km. The highest X-15 plane flight in 1963 reached an altitude of 354,300 ft (108,000 m).

Therefore, most of the atmosphere (99.9997%) is below 100 km, although in the rarefied region above this there are auroras and other atmospheric effects.

4. Composition

[Fig 1: Composition of Earth's atmosphere as of Dec. 1987. The lower pie represents the least common gases that compose 0.038% of the atmosphere. Values normalized for illustration.]

Filtered air includes trace amounts of many of the chemical elements. Substantial amounts of argon, nitrogen, and oxygen are present as elementary gases. Note the major greenhouse gasses: water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Many additional elements from natural sources may be present in tiny amounts in an unfiltered air sample, including contributions from dust, pollen and spores, sea spray, vulcanism, and meteoroids. Various industrial pollutants are also now present in the air, such as chlorine (elementary or in compounds), fluorine (in compounds), elementary mercury, and sulfur (in compounds such as sulfur dioxide [SO_2]).

PPMV: PARTS PER MILLION BY VOLUME	
Gas	**Volume**
Nitrogen (N_2)	780,840 ppmv (78.084%)
Oxygen (O_2)	209,460 ppmv (20.946%)
Argon (Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO_2)	383 ppmv (0.0383%)
Neon (Ne)	18.18 ppmv (0.001818%)
Helium (He)	5.24 ppmv (0.000524%)
Methane (CH_4)	1.745 ppmv (0.0001745%)
Krypton (Kr)	1.14 ppmv (0.000114%)
Hydrogen (H_2)	0.55 ppmv (0.000055%)
Nitrous oxide (N_2O)	0.3 ppmv (0.00003%)
Xenon (Xe)	0.09 ppmv ($9x10^{-6}$%)
Ozone (O_3)	0.0 to 0.07 ppmv (0%-$7x10^{-6}$%)

Nitrogen dioxide (NO_2)	0.02 ppmv ($2x10^{-6}$%)
Iodine (I)	0.01 ppmv ($1x10^{-6}$%)
Carbon monoxide (CO)	trace
Ammonia (NH_3)	trace
Not included in above dry atmosphere:	
Water vapor (H_2O)	~0.40% over full atmosphere, typically 1%-4% at surface

[Table 1: Composition of dry atmosphere, by volume]

4.1. ppmv

The *parts per million by volume* figures above are by volume-fraction (V%), which for ideal gases is equal to mole-fraction (that is, the fraction of total molecules). Although the atmosphere is not an ideal gas, nonetheless the atmosphere behaves enough like an ideal gas that the volume-fraction is the same as the mole-fraction for the precision given.
By contrast, *mass-fraction* abundances of gases will differ from the volume values. The mean molar mass of air is 28.97 g/mol, while the molar mass of helium is 4.00, and krypton is 83.80. Thus helium is 5.2 ppm by *volume-fraction*, but 0.72 ppm by *mass-fraction* ([4/29] 5.2 = 0.72), and krypton is 1.1 ppm by *volume-fraction*, but 3.2 ppm by *mass-fraction* ([84/29] 1.1 = 3.2).

4.2. Heterosphere

Below the *turbopause*, at an altitude of about 100 km (62 mi; 330,000 ft) (not far from the mesopause), the Earth's atmosphere has a more-or-less uniform composition (apart from water vapor) as described above; this constitutes the *homosphere*. However, above the turbopause, the Earth's atmosphere begins to have a composition which varies with altitude. This is because, in the absence of mixing, the density of a gas falls off exponentially with increasing altitude but at a rate which depends on the molar mass. Thus higher mass constituents, such as oxygen and nitrogen, fall off more quickly than lighter constituents such as helium and hydrogen. Thus there is a layer, called the *heterosphere*, in which the Earth's atmosphere has varying composition. The precise altitude of the heterosphere and the layers it contains varies significantly with temperature.

: The Realm Of Flight

Topic Objective:

At the end of this topic student will be able to understand:

- Physics
- Types
- Study of flight
- In religion, mythology and fiction

Definition/Overview:

Flight: Flight is the process by which an object achieves sustained movement either through the air (or movement beyond earth's atmosphere, in the case of spaceflight) by aerodynamically generating lift, propulsive thrust or aerostatically using buoyancy.

Key Points:

1. Physics

1.1. The physics of flight

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There are different approaches to flight. If an object has a lower density than air, then it is buoyant and is able to rise and float in the air without using energy; a lighter than air craft is known as an aerostat. A heavier than air craft, known as an aerodyne, includes flighted animals and insects, fixed-wing aircraft and rotorcraft. Because the craft is heavier than air, it must use the force of lift to overcome its weight. The wind resistance caused by the craft moving through the air is called drag and is overcome by propulsive thrust except in the case of gliding. Some vehicles also use thrust for flight, for example rockets and Harrier Jump Jets.

1.2. Forces for flight

Forces relevant to flight are:

- Propulsive thrust: (except in gliders)
- Lift: created by the reaction to an airflow
- Drag: created by aerodynamic friction
- Weight: (created by gravity)
- Buoyancy: for lighter than air flight

These forces must be balanced for stable flight to occur.

The stabilization of flight angles (roll, yaw and pitch) and the rates of change of these can involve horizontal stabilizers (i.e. 'a tail'), ailerons and other movable aerodynamic devices which control angular stability i.e. flight attitude (which in turn affects altitude, heading).

1.3. Lift to drag ratio

When lift is created by the motion of an object through the air, this deflects the air, and this is the source of lift. For sustained level flight lift must be greater than weight. However, this lift inevitably causes some drag also, and it turns out that the efficiency of lift creation can be associated with a lift/drag ratio for a vehicle; the lift/drag ratios are approximately constant over a wide range of speeds. Lift to drag ratios for practical aircraft vary from about 4:1 up to

60:1 or more. The lower ratios are generally for vehicles and birds with relatively short wings, and the higher ratios are for vehicles with very long wings, such as gliders.

1.4. Thrust to weight ratio

If thrust-to-weight ratio is greater than one, then flight can occur without any forward motion. If the thrust-to-weight ratio is greater than the lift-to-drag ratio then takeoff is possible.

1.5. Energy efficiency

To create thrust to push through the air to overcome the drag associated with lift takes energy, and different objects and creatures capable of flight vary in the efficiency of their muscles, motors and how well this translates into forward thrust. Propulsive efficiency determines how much thrust propeller and jet engines gain from a unit of fuel

1.6. Power to weight ratio

All animals and devices capable of sustained flight need relatively high power to weight ratios to be able to generate enough lift and/or thrust to achieve take off.

2. **Types**

2.1. Animal

The most successful groups of living things that fly are insects, birds, and bats. The extinct Pterosaurs, an order of reptiles contemporaneous with the dinosaurs, were also very successful flying animals. Each of these groups' wings evolved independently. The wings of the flying vertebrate groups are all based on the forelimbs, but differ significantly in structure; those of insects are hypothesized to be highly-modified versions of structures that form gills in most other groups of arthropods. Bats are the only mammals capable of sustaining level flight. However, there are several gliding mammals which are able to glide from tree to tree using fleshy membranes between their limbs; some can travel hundreds of meters in this way with very little loss in height. Flying frogs use greatly enlarged webbed feet for a similar purpose, and there are flying lizards which employ their unusually wide, flattened rib-cages to the same end. Certain snakes also use a flattened rib-cage to glide, with a back and forth motion much the same as they use on the ground. Flying fish can glide using enlarged wing-like fins, and have been observed soaring for hundreds of meters using the updraft on the leading edges of waves. It is thought that this ability was chosen by natural selection because it was an effective means of escape from underwater predators. The longest recorded flight of a flying fish was 45 seconds. Most birds fly (*see bird flight*), with some exceptions. The largest birds, the ostrich and the emu, are earthbound, as were the now-extinct dodos and the Phorusrhacids, which were the dominant predators of South America in the Cenozoic period. The non-flying penguins have wings adapted for use under water and use the same wing movements for swimming that most other birds use for flight. Most small flightless birds are native to small islands, and lead a lifestyle where flight would confer little advantage. Among living animals that fly, the wandering albatross has the greatest wingspan, up to 3.5 meters (11.5 ft); the great bustard has the greatest weight, topping at 21 kilograms (46 pounds). Among the many species of insects, some fly and some do not (See insect flight).

2.2. Mechanical

Mechanical flight is the use of a machine to fly. These machines include airplanes, gliders, helicopters, autogyros, airships, balloons, ornithopters and spacecraft. Gliders provide unpowered flight. Another form of mechanical flight is parasailing where a parachute-like object is pulled by a boat. In an airplane, lift is created by the wings; the shape of the wings of the airplane are designed specially for the type of flight desired. There are different types of wings: tempered, semi-tempered, sweptback, rectangular, and elliptical. An aircraft wing is sometimes called an airfoil, which is a device that creates lift when air flows across it.

2.3. Supersonic

Supersonic flight is flight faster than the speed of sound. Supersonic flight is associated with the formation of shock waves that form a sonic boom that can be heard from the ground, and is frequently startling. This shockwave takes quite a lot of energy to create and this makes supersonic flight generally less efficient than subsonic flight at about 85% of the speed of sound.

2.4. Hypersonic

Hypersonic flight is very high speed flight where the heat generated by the compression of the air due to the motion through the air causes chemical changes to the air. Hypersonic flight is achieved by reentering spacecraft such as the Space Shuttle and Soyuz.

3. Study of flight

In 8th century Cordoba, Ibn Firnas studied the dynamism of flying and carried out a number of experiments. After one of his flights he fell on his back and he commented that he now understands the role played by the tail when birds alight on the ground, telling his close friends that birds normally land on the root of the tail which did not happen in that occasion, hence a reference to the missing tail. Durant in his book the story of Civilisation, quoting Al-Makkari who mentioned that Ibn Farnas indeed constructed a flying machine. However, he does not elaborate on how the machine works nor whether it was the one Ibn Farnas used nor on its destiny. Leonardo da Vinci is one of the best-known early students of flight. He made many prototypes of parachutes wings and ornithopters.

4. In religion, mythology and fiction

In religion, mythology and fiction, human or anthropomorphic characters sometimes have the ability to fly. Examples include angels in the Hebrew Bible, Daedalus in Greek mythology, and Superman in comics. Two other popular examples are Dumbo, the elephant created by Disney who uses his ears to fly, and Santa Claus whose sleigh is pulled by flying reindeers. Other nonhuman legendary creatures, such as some dragons and Pegasus, are also depicted with an ability to fly. The ability to fly may come from wings or other visible means of propulsion, from superhuman or god-like powers, or may simply be left unexplained.

: Ever-Changing Weather

Topic Objective:

At the end of this topic student will be able to understand:

- Cause
- Shaping the planet Earth
- Effect on humans
- Forecasting
- Modification
- Extremes on Earth
- Extraterrestrial within the Solar System
- Space weather

Definition/Overview:

Ever-Changing Weather: In meteorology, the condensation and separation of the atmospheric water vapour as rain, snow, hail, fog, is called precipitation. We distinguish falling precipitation such as rain or snow, deposited precipitation, such as dew or fog, and accumulated precipitation in the form of hail or snow. When large clouds rise, they soon reach altitudes where temperatures are below freezing. These clouds are made up of ice crystals, water vapour, and droplets of water which, in spite of the below-freezing temperature have not yet crystallised into ice. Tiny small crystals coalesce into snowflakes, which fall to the ground. Snowflakes fall in the form of dry snow to the warm ground. If the snowflakes have to pass through a warmer layer of air, they melt and change into rain. Drops of water, which in our geographical latitudes fall to the earth, were in reality originally snowflakes. The droplets or ice crystals forming in the clouds are too light to fall to the ground. Only when millions of these droplets collide and coalesce into one drop, they are heavy enough to form precipitation. Some flat clouds create only smaller drops of water, which fall to the ground as drizzle. When drizzle falls on frozen ground, it immediately solidifies as ice. The ground is then covered by a thin layer of ice. This poses a great danger for drivers, because the colourless and transparent ice is not visible on the dark surface of the road. In the clouds that do not reach the altitude with freezing temperatures, air currents whirl millions of tiny droplets and join them together. These drops of water then fall to the ground as rain. An opposite electrical charge accelerates this coalescence. Snowflakes show a characteristic symmetry reflecting the coalescence of water molecules in ice. However, snowflakes deviate from this basic formula. The reason is, that the tips of crystals grow at different rate of speed. There are never two identical snowflakes. Individual ice crystals are so fine that when they fall, they touch and deform. These crystals reach the ground as deformed compounds. Tiny droplets of water and some ice crystals form in the higher layers of clouds. Moisture from the evaporating droplets combines with the ice, forming larger ice crystals. These later form snowflakes. Snowflakes fall as dry snow on cold ground or as wet snow on warm ground.

The nucleus of a grain of hail is either an ice crystal or a grain covered by a thin layer of ice. Many additional ice layers must form before the nucleus becomes a grain. Strong rising currents cause the nuclei to be in constant swirling motion, which allows the cool water droplets to adhere. The number of ice layers (up to 25) indicates, how many times the nucleus was swirled around in the cloud. The thickest ice layer forms during the descent, because the air humidity is higher in the lower layers of the air. When the air current cannot support the grain of hail any longer, it falls to the ground. Hail may cause considerable damage. Fog is a surface cloud layer. Tiny droplets of water are suspended in the air. This considerably decreases visibility and poses danger not only to air travel, but sea and road travel as well. Fog may even freeze (icy fog). If it combines with exhaust gases and dust particles, it may become a toxic smog. Similarly to fog, dew and frost are included in the deposited precipitation. When the earth's surface cools down below the dew point, dew forms at temperatures over the freezing point, while frost will form at temperature below the freezing point. The dew point is the temperature at which the air is saturated with water vapor. At one hundred percent air humidity, the dew point corresponds to the temperature of the moment. Dew is the transition stage from water vapor to water, while frost represents the transition stage of water vapor to ice. Dew and frost represent approximately 3 percent of the total amount of liquid precipitation. In regions with low amounts of precipitation (rain), dew may be the source of moisture for the scarce local vegetation, since the precipitation amounts differ greatly from one region of the earth to another.

Key Points:

1. **Weather**

Weather is a set of all the phenomena occurring in a given atmosphere at a given time. Weather phenomena lie in the hydrosphere and troposphere. Weather refers to current activity, as opposed to the term climate, which refers to the average atmospheric conditions over longer periods of time. When used without qualification, "weather" is understood to be the weather of Earth. Weather occurs due to density (temperature and moisture) differences between one place to another. These differences can occur due to the sun angle at any particular spot, which varies by latitude from the tropics. The strong temperature contrast between polar and tropical air gives rise to the jet stream. Weather systems in the mid-latitudes, such as extratropical cyclones, are caused by instabilities of the jet stream flow. Because the Earth's axis is tilted relative to its orbital plane, sunlight is incident at different angles at different times of the year. On Earth's surface, temperatures usually range 40 C (100 F to −40 F) annually. Over thousands to hundreds of thousands of years, changes in Earth's orbit affect the amount and distribution of solar energy received by the Earth and influence long-term climate. Surface temperature differences in turn cause pressure differences. Higher altitudes are cooler than lower altitudes due to differences in compressional heating. Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. The atmosphere is a chaotic system, so small changes to one part of the system can grow to have large effects on the system as a whole. Human attempts to control the weather have occurred throughout human history, and there is evidence that human activity such as agriculture and industry has inadvertently modified weather patterns. Studying how the weather works on other planets has been helpful in understanding how weather works on Earth. A famous landmark in the Solar System, Jupiter's Great Red Spot, is an anticyclonic storm known to have existed for at least 300 years. However, weather is not limited to planetary bodies. A star's corona is constantly being lost to space, creating what is essentially a very thin atmosphere throughout the Solar System. The movement of mass ejected from the Sun is known as the solar wind.

2. Cause

On Earth, common weather phenomena include wind, cloud, rain, snow, fog and dust storms. Less common events include natural disasters such as tornadoes, hurricanes and ice storms. Almost all familiar weather phenomena occur in the troposphere (the lower part of the atmosphere). Weather does occur in the stratosphere and can affect weather lower down in the troposphere, but the exact mechanisms are poorly understood. Weather occurs primarily due to density (temperature and moisture) differences between one places to another. These differences can occur due to the sun angle at any particular spot, which varies by latitude from the tropics. In other words, the farther from the tropics you lie, the lower the sun angle is, which causes those locations to be cooler due to the indirect sunlight. The strong temperature contrast between polar and tropical air gives rise to the jet stream. Weather systems in the mid-latitudes, such as extratropical cyclones, are caused by instabilities of the jet stream flow. Weather systems in the tropics, such as monsoons or organized thunderstorm systems, are caused by different processes. Because the Earth's axis is tilted relative to its orbital plane, sunlight is incident at different angles at different times of the year. In June the Northern Hemisphere is tilted towards the sun, so at any given Northern Hemisphere latitude sunlight falls more directly on that spot than in December. This effect causes seasons. Over thousands to hundreds of thousands of years, changes in Earth's orbital parameters affect the amount and distribution of solar energy received by the Earth and influence long-term climate. Uneven solar heating (the formation of zones of temperature and moisture gradients, or frontogenesis) can also be due to the weather itself in the form of cloudiness and precipitation. Higher altitudes are cooler than lower altitudes, which are explained by the lapse rate. On local scales, temperature differences can occur because different surfaces (such as oceans, forests, ice sheets, or man-made objects) have differing physical characteristics such as reflectivity, roughness, or moisture content. Surface temperature differences in turn cause pressure differences. A hot surface heats the air above it and the air expands, lowering the air pressure and its density. The resulting horizontal pressure gradient accelerates the air from high to low pressure, creating wind, and Earth's rotation then causes curvature of the flow via the Coriolis Effect. The simple systems thus formed can then display emergent behavior to produce more complex systems and thus other weather phenomena. Large scale examples include the Hadley cell while a smaller scale example would be coastal breezes. The atmosphere is a chaotic system, so small changes to one part of the system can grow to have large effects on the system as a whole. This makes it difficult to accurately predict weather more than a few days in advance, though weather forecasters are continually working to extend this limit through the scientific study of weather, meteorology. It is theoretically impossible to make useful day-to-day predictions more than about two weeks ahead, imposing an upper limit to potential for improved prediction skill. Chaos theory says that the slightest variation in the motion of the ground can grow with time. This idea is sometimes called the butterfly effect, from the idea that the motions caused by the flapping wings of a butterfly eventually could produce marked changes in the state of the atmosphere. Because of this sensitivity to small changes it will never be possible to make perfect forecasts, although there still is much potential for improvement. The sun and oceans can also affect the weather of land. If the sun heats up ocean waters for a period of time, water can evaporate. Once evaporated into the air, the moisture can spread throughout nearby land, thus making it cooler.

3. Shaping the planet Earth

Weather is one of the fundamental processes that shape the Earth. The process of weathering breaks down rocks and soils into smaller fragments and then into their constituent substances. These are then free to take part in chemical reactions that can affect the surface further (such as acid rain) or are reformed into other rocks and soils. In this way, weather plays a major role in erosion of the surface.

4. Effect on humans

Weather has played a large and sometimes direct part in human history. Aside from climatic changes that have caused the gradual drift of populations (for example the desertification of the Middle East, and the formation of land bridges during glacial periods), extreme weather events have caused smaller scale population movements and intruded directly in historical events. One such event is the saving of Japan from invasion by the Mongol fleet of Kublai Khan by the Kamikaze winds in 1281. French claims to Florida came to an end in 1565 when a hurricane destroyed the French fleet, allowing Spain to conquer Fort Caroline. More recently, Hurricane Katrina redistributed over one million people from the central Gulf coast elsewhere across the United States, becoming the largest diaspora in the history of the United States. Though weather affects people in drastic ways, it can also affect the human race in simpler ways. The human body is negatively affected by extremes in temperature, humidity, and wind. Mood is also affected by the weather.

5. Forecasting

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. Human beings have attempted to predict the weather informally for millennia, and formally since at least the nineteenth century. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve. Once an all-human endeavor based mainly upon changes in barometric pressure, current weather conditions, and sky condition, forecast models are now used to determine future conditions. Human input is still required to pick the best possible forecast model to base the forecast upon, which involves pattern recognition skills, teleconnections, knowledge of model performance, and knowledge of model biases. The chaotic nature of the atmosphere, the massive computational power required to solve the equations that describe the atmosphere, error involved in measuring the initial conditions, and an incomplete understanding of atmospheric processes mean that forecasts become less accurate as the difference in current time and the time for which the forecast is being made (the *range* of the forecast) increases. The use of ensembles and model consensus helps to narrow the error and pick the most likely outcome. There are a variety of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property. Forecasts based on temperature and precipitation are important to agriculture, and therefore to commodity traders within stock markets. Temperature forecasts are used by utility companies to estimate demand over coming days. On an everyday basis, people use weather forecasts to determine what to wear on a given day. Since outdoor activities are severely curtailed by heavy rain, snow and the wind chill, forecasts can be used to plan activities around these events, and to plan ahead and survive them.

6. Modification

The wish to control the weather is evident throughout human history: from ancient rituals intended to bring rain for crops to the U.S. Military Operation Popeye, an attempt to disrupt supply lines by lengthening the North Vietnamese monsoon. The most successful attempts at influencing weather involve cloud seeding; they include the fog- and low stratus dispersion techniques employed by major airports, techniques used to increase winter precipitation over mountains, and techniques to suppress hail. A recent example of weather control was China's preparation for the 2008 Summer Olympic Games. China shot 1,104 rain dispersal rockets from 21 sites in the city of Beijing in an effort to keep rain away from the opening ceremony of the games on Aug 8, 2008. Guo Hu, head of the Beijing Municipal Meteorological Bureau (BMB), confirmed the success of the operation with 100 millimeters falling in Baoding City of Hebei Province, to the southwest and Beijing's Fangshan District recording a rainfall of 25 millimeters. Whereas there is inconclusive evidence for these techniques' efficacy, there is extensive evidence that human activity such as agriculture and industry results in inadvertent weather modification:

- Acid rain, caused by industrial emission of sulfur dioxide and nitrogen oxides into the atmosphere, adversely affects freshwater lakes, vegetation, and structures.
- Anthropogenic pollutants reduce air quality and visibility.
- Climate change caused by human activities that emit greenhouse gases into the air is expected to affect the frequency of extreme weather events such as drought, extreme temperatures, flooding, high winds, and severe storms.

The effects of inadvertent weather modification may pose serious threats to many aspects of civilization, including ecosystems, natural resources, food and fiber production, economic development, and human health..

7. Extremes on Earth

On Earth, temperatures usually range 40 C (100 F to −40 F) annually. The range of climates and latitudes across the planet can offer extremes of temperature outside this range. The coldest air temperature ever recorded on Earth is −89.2 C (−129 F), at Vostok Station, Antarctica on 21 July 1983. The hottest air temperature ever recorded was 57.7 C (135.9 F) at Al 'Aziziyah, Libya, on 13 September 1922. The highest recorded average annual temperature was 34.4 C (93.9 F) at Dallol, Ethiopia. The coldest recorded average annual temperature was −55.1 C (−67 F) at Vostok Station, Antarctica. The coldest average annual temperature in a permanently inhabited location is at Eureka, Nunavut, in Canada, where the annual average temperature is −19.7 C (−3 F).

8. Extraterrestrial within the Solar System

Studying how the weather works on other planets has been seen as helpful in understanding how it works on Earth. Weather on other planets follows many of the same physical principles as weather on Earth, but occurs on different scales and in atmospheres having different chemical composition. The CassiniHuygens mission to Titan discovered clouds formed from methane or ethane which deposit rain composed of liquid methane and other organic compounds. Earth's atmosphere includes six latitudinal circulation zones, three in each hemisphere. In contrast, Jupiter's banded appearance shows many such zones, Titan has a single jet stream near the 50th parallel north latitude, and Venus has a single jet near the equator. One of the most famous landmarks in the Solar System, Jupiter's *Great Red Spot*, is an anticyclonic storm known to have existed for at least 300 years. On other gas giants, the lack of a surface allows the wind to reach enormous speeds: gusts of up to 600 meters per second (about 2,100 kilometers per hour (1,300 mph)) have been measured on the planet Neptune. This has created a puzzle for planetary scientists. The weather is ultimately created by solar energy and the amount of energy received by Neptune is only about 1/900th of that received by Earth, yet the intensity of weather phenomena on Neptune is far greater than on Earth. The strongest planetary winds discovered so far are on the extrasolar planet HD 189733 b, which is thought to have easterly winds moving at more than 9,600 kilometers per hour (6,000 mph).

9. Space weather

Weather is not limited to planetary bodies. A star's corona is constantly being lost to space, creating what is essentially a very thin atmosphere throughout the Solar System. The movement of mass ejected from the Sun is known as the solar wind. Inconsistencies in this wind and larger events on the surface of the star, such as coronal mass ejections, form a system that has features analogous to conventional weather systems (such as pressure and wind) and is generally known as space weather. Coronal mass ejections have been tracked as far out in the solar system as Saturn. The activity of this system can affect planetary atmospheres and occasionally surfaces. The interaction of the solar wind with the terrestrial atmosphere can produce spectacular aurorae, and can play havoc with electrically sensitive systems such as electricity grids and radio signals.

Topic Objective:

At the end of this topic student will be able to understand:

- How it works
- Application/Use
- Consumer products
- Dr. Oskar Heil's "Air Motion Transformer" (AMT) US Patents

- Components of wind
- Classification
- Wind terms
- Local winds

Definition/Overview:

The Air Motion: The Air Motion Transformer (AMT) is a loudspeaker mechanism, or audio transducer, invented by Dr. Oskar Heil. It operates on a different principle than both electrodynamic and electrostatic speaker drivers. The AMT moves air in an augmented, semi-perpendicular motion using a folded sheet (made of polyethylene, polyester or polyimide), structured around a series of aluminum struts positioned in a high intensity magnetic field.

Key Points:

1. How it works

The diaphragm pushes back and forward from itself in a similar physical motion pattern to what is observed when an accordion is squeezed in and out to pump air though the reed chambers, albeit over an exceedingly smaller motion range. The result is a dipole driver with an extraordinarily rapid response rate, caused both by the extremely low mass of the polyester driver, and by the far smaller motion range it undergoes on each swing compared to a dynamic driver. In this technical respect, it shares characteristics with the electrostatic driver. The discernible motion of each of these diaphragm flexes is very small, but because of the folded structure more air is moved than would be by a conventional cone or electrostatic driver of the same plotted surface area. As a matter of surface comparison, a standard one-inch-wide AMT strip has a functional driver area which is comparable to a circle-shaped dynamic cone with a diameter of eight inches. The folded driver design, combined with the small motive range, means that the AMT acts like a point source version of a larger driver, inherently resulting in lower distortion in sound reproduction. As a result of its motion pattern, the AMT "spits" the air out in a way which is compatible with what happens when, although you apply only a small amount of pressure to a slice of fruit, the pip inside shoots out at high speed. The motion of the air as it leaves the diaphragm is in fact around five times faster than the motion of the actual driver structure. Hence the name Air Motion Transformer. Although it is possible to operate the diaphragm without the magnetic field, using piezoelectric technology, this method has only been used by the Take for their headphone and tweeter products.

2. Application/Use

In the tweeter market the AMT must compete against electrostatic, ribbon, and electrodynamic tweeters. While apparently very good as a mid-tweeter or full tweeter, the AMT is not commonly employed as much as one may expect lower down in the speaker market. This is mainly as a corollary of their dipole sound radiation, which makes enclosure in traditional speaker cabinets difficult without sacrificing sound quality or employing sound reflex baffles. The AMT can also reproduce sound right down into the low midrange fully competently, making design decisions regarding crossover points difficult (depending on the model ESS was using a cut of frequency of 1 kHz, 1.5 kHz or 2.5 kHz). The last difficulty to design a loudspeaker with an AMT (midrange-tweeter) is to find a woofer that will be fast enough to be a good match to this very fast transducer.

3. Consumer products

The AMT was first used in 1970 by ESS (ElectroStatic Sound) a Californian company based near Sacramento. The first speaker was called ESS AMT-1. Looking like a truncated, four sided pyramid; the system combined the AMT driver with a 10 inch woofer and bass port.There were several models that followed. AMT-1a. This redesign of the AMT-1 replaced the smaller woofer with a 12 inch woofer and passive radiator. This gave the speaker better bass response characteristics. The AMT Tower was a speaker design with 1 AMT and a woofer and line transmission. The AMT 3, also called Rock Monitor; a design with 1 AMT, a 6.5 inch mid-range and two 10 inch woofers. At the end of the 70s, ESS and Dr. Heil introduced the ESS Transar using one AMT for the high frequency and one low frequency AMT. Until 2006 it was still possible to get ESS speakers from Sacramento on demand. The most common use for the AMT driver in consumer electronics today is as a midrange-tweeter or tweeter in high-end multi-driver speakers, sometimes paired with horns, or in the case of Precide's speaker products, with an upward-firing woofer driver. There are a couple of companies producing Heil AMTs: Precide (Switzerland) who calls their version the AVT (Air Velocity Transformer), ELAC (Germany) who calls their version of the transducer JET, ADAM (Germany, under the name Accelerating Ribbon Technology), FAL (Japan), ETON (Germany). In Germany it is also possible to get ESS speakers (new designs or classic ones) as well as the ESS AMT drivers (e.g., Great Heil). Recently the low frequency AMT technology was rediscovered by a company called Tymphany. Using what appears to be one of the embodiments of Dr. Heil patent US#4,039,044, the company tries to produce compact woofers and sub-woofers. Tymphany names this technology LAT (Linear Array Transducer). Precide also use an AMT driver for their top of the line headphone.

4. Dr. Oskar Heil's "Air Motion Transformer" (AMT) US Patents

- US#3,636,278 issued Jan 18, 1972.
  - (Describes the Heil AMTs variations some of which resemble the ELAC JET Transducer)
- US#3,832,499 issued Aug. 2, 1974.
  - (Describes the Heil AMT embodiment used in the ESS AMT series)
- US#4,056,697 issued Nov 1, 1977.
  - Movable diaphragm connector method flexible hinge diaphragm surround and...
- US#4,039,044 issued Aug 2, 1977.
  - (Low Frequency AMT. The patent also describes the principle used by Tymphany for their LAT transducer including the embodiment type)
- US#4,107,479 Aug 15, 1978.
  - (Further refinements of the Low Frequency AMT)
- US#4,160,883 Jul 10, 1979.
  - Acoustic transducer and method of making same

5. **Components of wind**

Winds defined by equilibrium of physical forces are used in the decomposition and analysis of wind profiles. They are useful for simplifying the atmospheric equations of motion and for making qualitative arguments about the horizontal and vertical distribution of winds. Examples are:

- Geostrophic wind (wind that is a result of the balance between Coriolis force and pressure gradient force; flows parallel to isobars and approximates the flow above the atmospheric boundary layer in the midlatitudes if frictional effects are low)
- Thermal wind (not actually a wind but a wind *difference* between two levels; only exists in an atmosphere with horizontal temperature gradients, i.e. baroclinicity)
- Ageostropic wind (difference between actual and geostrophic wind; the wind component which is responsible for air "filling up" cyclones over time)
- Gradient wind (like geostrophic wind but also including centrifugal force)

6. **Classification**

There are global winds, such as the wind belts which exist between the atmospheric circulation cells. There are upper-level winds which typically include narrow belts of concentrated flow called jet streams. There are synoptic scale winds that result from pressure differences in surface air masses in the middle latitudes, and there are winds that come about as a consequence of geographic features, such as the sea breezes on coastlines or canyon breezes near mountains. Mesoscale winds are those which act on a local scale, such as gust fronts. At the smallest scale are the microscale winds, which blow on a scale of only tens to hundreds of meters and are essentially unpredictable, such as dust devils and microbursts.

7. **Wind terms**

'Gusts' are inconstant winds. Unlike relatively constant winds, such as the Chinook wind, gusting winds are characterized by the apparent rapid change in the force and/or direction of the wind. The wind appears, to those who experience it, to come in *blasts* of varying strength with brief lulls between. Such a blast is known as a *gust*. A squall is a sudden, sharp increase in wind speed which usually is associated with active weather, such as rain showers, thunderstorms, or heavy snow. Squalls refer to an increase in the non-sustained winds over an extended time interval, as there may be lower gusts during a squall event.

8. Local winds

Some local winds blow only under certain circumstances, i.e. they require a certain temperature distribution. *Differential heating* is the motive force behind land breezes and sea breezes (or, in the case of larger lakes, lake breezes), also known as on- or off-shore winds. Land absorbs and radiates heat faster than water, but water releases heat over a longer period of time. The result is that, in locations where sea and land meet, heat absorbed over the day will be radiated more quickly by the land at night, cooling the air. Over the sea, heat is still being released into the air at night, which rises. This convective motion draws the cool land air in to replace the rising air, resulting in a land breeze in the late night and early morning. During the day, the roles are reversed. Warm air over the land rises, pulling cool air in from the sea to replace it, giving a sea breeze during the afternoon and evening. Mountain breezes and valley breezes are due to a combination of differential heating and geometry. When the sun rises, it is the tops of the mountain peaks which receive first light, and as the day progresses, the mountain slopes take on a greater heat load than the valleys. This result in a temperature inequity between the two, and as warm air rises off the slopes, cool air moves up out of the valleys to replace it. This upslope wind is called a *valley breeze*. The opposite effect takes place in the afternoon, as the valley radiates heat. The peaks, long since cooled transport air into the valley in a process that is partly gravitational and partly convective and is called a *mountain breeze*. Forested areas are less windy than plains and cities because the trees disrupt wind patterns. Trees are defined to have a dampening effect on wind speeds in that they reduce the partial derivative of pressure differences across non-infinitively occupying plain. Further effects of trees wind reducing capabilities is in the fact that trees bend in the wind. Considering the mass of a tree in comparison to air particles it is highly predicable that much of the total energy of the wind is lost in kinetic energy to the trees. Mountain breezes are one example of what is known more generally as a katabatic wind. These are winds driven by cold air flowing down a slope, and occur on the largest scale in Greenland and Antarctica. Most often, this term refers to winds which form when air which has cooled over a high, cold plateau is set in motion and descends under the influence of gravity. Winds of this type are common in regions of Mongolia and in glaciated locations.

Because *katabatic* refers specifically to the vertical motion of the wind, this group also includes winds which form on the lee side of mountains, and heat as a consequence of compression. Such winds may undergo a temperature increase of 20 C (68 F) or more, and many of the world's "named" winds belong to this group. Among the most well-known of these winds are the chinook of Western Canada and the American Northwest, the Swiss foehn, California's infamous Santa Ana wind, and the French Mistral. The opposite of a katabatic wind is an anabatic wind, or an upward-moving wind. The above-described *valley breeze* is an anabatic wind. A widely-used term, though one not formally recognised by meteorologists, is *orographic wind*. This refers to air which undergoes orographic lifting. Most often, this is in the context of winds such as the chinook or the fhn, which undergo lifting by mountain ranges before descending and warming on the lee side.

Topic Objective:

At the end of this topic student will be able to understand:

- High clouds (Family A)
- Middle clouds (Family B)
- Low clouds (Family C)
- Vertical clouds (Family D)
- Other clouds
- Cloud fields

Definition/Overview:

The topic overviews the high clouds, middle clouds, low clouds, vertical clouds, and other clouds formed. The topic also defines the cloud fields.

Key Points:

1. High clouds (Family A)

These generally form above 20,000 feet (6,000 m), in the cold region of the troposphere. In Polar Regions, they may form as low as 16,500 ft (5,030 m); they are denoted by the prefix *cirro*- or cirrus. At this altitude, water frequently freezes so clouds are composed of ice crystals. The clouds tend to be wispy and are often transparent.

Clouds in Family A include:

- Cirrocumulus (Cc)
- Cirrostratus (Cs)
- Cirrus (Ci)
- Cirrus Kelvin-Helmholtz Colombia
- Cirrus uncinus
- Contrail, a long thin cloud which develops as the result of the passage of an aircraft at high altitudes.
- Pileus

2. Middle clouds (Family B)

These develop between 6,500 and 20,000 feet (between 2,000 and 6,000 m) and are denoted by the prefix *alto*-. They are made of water droplets and are frequently supercooled.

Clouds in Family B include:

- Altocumulus (Ac)
- Altocumulus castellanus
- Altocumulus lenticularis
- Altocumulus mackerel sky

- Altocumulus undulatus
- Altostratus (As)
- Altostratus undulates

3. Low clouds (Family C)

These are found up to 6,500 feet (2,000 m) and include the stratus (dense and grey). When stratus clouds contact the ground, they are called fog.

Clouds in Family C include:

- Cumulus humilis (Cu)
- Cumulus mediocris (Cu)
- Nimbostratus (Ns)
- Stratocumulus (Sc)
- Stratus (St)

4. Vertical clouds (Family D)

These clouds can have strong up-currents, rise far above their bases and form at many heights.

Clouds in Family D include:

- Cumulonimbus (associated with heavy precipitation and thunderstorms) (Cb)
- Cumulonimbus calvus
- Cumulonimbus incus
- Cumulonimbus with mammatus
- Cumulus congestus
- Pyrocumulus

5. Other clouds

A few clouds can be found above the troposphere; these include noctilucent and polar stratospheric clouds (or nacreous clouds), which occur in the mesosphere and stratosphere respectively. Some clouds form as a consequence of interactions with specific geographical features. Perhaps the strangest geographically-specific cloud in the world is Morning Glory, a rolling cylindrical cloud which appears unpredictably over the Gulf of Carpentaria in Northern Australia. Associated with a powerful "ripple" in the atmosphere, the cloud may be "surfed" in unpowered glider aircraft.

6. Cloud fields

A cloud field is simply a group of clouds but sometimes cloud fields can take on certain shapes that have their own characteristics and are specially classified. Stratocumulus clouds can often be found in the following forms:

- Actinoform, which resembles a leaf or a spoked wheel.
- Closed cell, which is cloudy in the center and clear on the edges, similar to a filled honeycomb.
- Open cell, which resembles a honeycomb, with clouds around the edges and clear, open space in the middle.

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Topic Objective:

At the end of this topic student will be able to understand:

- local winds
- local weather phenomena
- Seasonal winds
- Microburst

Definition/Overview:

Air or Earth Atmosphere: The Earth's atmosphere (or air) is a layer of gases surrounding the planet Earth that is retained by the Earth's gravity. Dry air contains roughly (by volume) 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, and trace amounts of other gases. Air also contains a variable amount of water vapor, on average around 1%. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night. There is no definite boundary between the atmosphere and outer space. It slowly becomes thinner and fades into space. An altitude of 120 km (75 mi) marks the boundary where atmospheric effects become noticeable during reentry. The Krmn line, at 100 km (62 mi), is also frequently regarded as the boundary between atmosphere and outer space. Three quarters of the atmosphere's mass is within 11 km (6.8 mi; 36,000 ft) of the surface.

Key Points:

1. **The list covers local winds and local weather phenomena including seasonal winds.**

- *Abroholos* (squall frequent wind that occurs from May through August between Cabo de Sao Tome and Cabo Frio on the coast of Brazil)
- *Alize* (northeasterly across central Africa and the Caribbean)
- *Aliz Maritime* (wet, fresh northerly wind across west central Africa)
- *Amihan* (northeasterly wind across the Philippines)
- *Bayamo* (violent wind on Cuba's southern coast)
- *Bora* (northeasterly from eastern Europe to northeastern Italy)
- *Cape Doctor* (dry south-easterly wind that blows on the South African coast in summer)
- *Chinook* (warm dry westerly off the Rocky Mountains)
- *Etesian* (Greek name) or *Meltem* (Turkish name) (northerly across Greece and Turkey)
- *Fhn* (warm dry southerly off the northern side of the Alps and the North Italy), the name gave rise to the *fn-fēng* of Taiwan

- *Fremantle Doctor* (afternoon sea breeze from the Indian Ocean which cools Perth, Western Australia during summer)
- *Gilavar* (south wind in the Absheron Peninsula of the Azerbaijan Republic)
- *Gregale* (northeasterly from Greece)
- *Habagat* (southwesterly wind across the Philippines)
- *Harmattan* (dry northerly wind across central Africa)
- *Halny* (in northern Carpathians)
- *Helm Wind* (north-easterly wind in Cumbria, England)
- *Khamsin* (southeasterly from north Africa to the eastern Mediterranean)
- *Khazri* (cold north wind in the Absheron Peninsula of the Azerbaijan Republic)
- *Kona* (southeast wind in Hawaii, replacing trade winds, bringing high humidity and often rain)
- *Koava* (strong and cold southeasterly season wind in Serbia)
- *Viento de Levante* (easterly through Strait of Gibraltar)
- *Libeccio* (southwesterly towards Italy)
- *Maestro* (cold northerly in the Adriatic sea)
- *Marin* (south-easterly from Mediterranean to France)
- *Minuano* (southern Brazil)
- *Mistral* (cold northerly from central France and the Alps to Mediterranean)
- *Monsoon* (mainly south-westerly winds combined with heavy rain in various areas close to the equator)
- *Nor'easter* (strong storm with winds from the northeast in the eastern United States, especially New England)
- *Nor'wester* (wind that brings rain to the West Coast, and warm dry winds to the East Coast of New Zealand)
- *Ostro* (southerly wind in the Mediterranean)
- *Pampero*, (Argentina), (very strong wind which blows in the Pampa)
- *Papagayo* (periodic wind which blows across Nicaragua and Costa Rica and out over the Gulf of Papagayo)
- *Passat*, (Tropic) (medium strong, constant blowing Wind in tropical Sea-Areas)

- *Rasha-ba* (strong wind in Iraq Kurdistan Region, particularly in Sulaimaniya. The word is Kurdish for Black-wind)
- *Santa Ana winds* (southern California)
- *Shamal (wind) (Kurdish term, signifying a summer northwesterly wind blowing over Iraq and the Persian Gulf states)*
- *Simoom* (strong, dry, desert wind that blows in the Sahara, Israel, Jordan, Syria, and the desert of Arabia)
- *Sirocco* (southerly from north Africa to southern Europe)
- *Southerly Buster* (rapidly arriving low pressure cell that dramatically cools Sydney, Australia during summer)
- *Sou'wester* (strong wind which blows from the southwest, and also a type of waterproof hat designed to protect from and repel wind and rain)
- *Squamish (wind)* (strong, violent wind occurring in many of the fjords of British Columbia)
- *Sundowner (wind)*, (strong offshore wind off the California coast)
- *Tehuano* (periodic wind which blows across the Isthmus of Tehuantepec in southern Mexico and out over the Gulf of Tehuantepec)
- *Tramontane* (cold northwesterly from the Pyrenees or northeasterly from the Alps to the Mediterranean, similar to Mistral)
- *Vendavel* (westerly through the Strait of Gibraltar)
- *Zonda wind* (on the eastern slope of the Andes in Argentina)

2. **MicroBursts**

The University of Illinois breaks the evolution of downbursts into three stages, the contact stage, the outburst stage and the cushion stage.

A downburst initially develops as the downdraft begins its descent from cloud base. The downdraft accelerates and within minutes, reaches the ground (contact stage). It is during the contact stage that the highest winds are observed.

During the outburst stage, the wind "curls" as the cold air of the downburst moves away from the point of impact with the ground.

During the cushion stage, winds about the curl continue to accelerate, while the winds at the surface slow due to friction.

In Section 2 of this course you will cover these topics: - Air Masses In Conflict - Where'S The Front? - Pilot Weather Resources And Services - Surface Observation (Metar) - Pilot Weather Reports - Satellite Images
You may take as much time as you want to complete the topic coverd in section 2. There is no time limit to finish any Section, However you must finish All Sections before semester end date.
If you want to continue remaining courses later, you may save the course and leave. You can continue later as per your convenience and this course will be avalible in your area to save and continue later.

Topic Objective:

At the end of this topic student will be able to understand:

- The Classification of Air masses

- Movement and fronts

Definition/Overview:

Air mass: Air mass is a large volume of air that have characteristics of temperature and water vapor content. Air masses cover many hundreds or thousands of square miles, and slowly change in accordance with the surface below them.

Key Points:

1. **The Classification of Air masses**

Air masses are classified according to their approximate environmental origin. An air mass is classified as Arctic, Polar, Tropical, or Equatorial. It is also classified as either maritime or continental. Maritime air is a moist air mass, whereas continental air is relatively dry. Air masses are noted on some weather charts using a particular system of notation. However, air mass terminology is somewhat subjective, that is, it is not defined by any definite, universally-accepted quantitative parameters. It is used primarily for general descriptive purposes in meteorological discussions. Air masses of oceanic origin are denoted with a lower-case "m" ("maritime"), while air masses of continental origin are denoted with a lower-case "c" ("continental"). Air masses are also denoted as either Arctic (upper-case "A", or "AA" for Antarctic air masses), polar (upper-case "P"), tropical (upper-case "T"), or equatorial (upper-case "E"). These two sets of attributes are used in combinations depending on the air mass being described. For instance, an air mass originating over the desert southwest of the United States in summer may be designated "cT". An air mass originating over northern Siberia in winter may be indicated as "cA". In older charts, an upper case "S" was occasionally used to denote something called a "superior" air mass. This was regarded as an adiabatically drying and warming air mass descending from aloft. In South Asia, an upper case "M" (for "monsoon") has been occasionally used to denote an air mass within the summer monsoon regime in that region. The stability of an air mass may be shown using a third letter, either "k" (air mass colder than the surface below it) or "w" (air mass warmer than the surface below it). An example of this might be a polar air mass blowing over the Gulf Stream, denoted as "cPk". Occasionally, especially on older charts, one may also encounter the use of an apostrophe or "degree tick" denoting that a given air mass having the same notation as another it is replacing is colder than the replaced air mass (usually for polar air masses). For example, a series of fronts over the Pacific might show an air mass denoted mPk followed by another denoted mPk'. Another convention utilizing these symbols is the indication of modification or transformation of one type to another. For instance, an Arctic air mass blowing out over the Gulf of Alaska may be shown as "cA-mPk". Yet another convention indicates the layering of air masses in certain situations. For instance, the overrunning of a polar air mass by an air mass from the Gulf of Mexico over the Central United States might be shown with the notation "mT/cP" (sometimes using a horizontal line as in fraction notation).

2. Movement and fronts

Air mass terms refer to the fact that air masses acquire characteristics from a given region which they may occupy for any significant length of time. For example, Polar air masses form during the northern winter as intense nighttime radiation and loss of daylight chills the air to great depths, and maritime air masses generally form over oceans and seas where widespread evaporation occurs. When air masses move into regions with different environmental conditions, they are modified. Even without movement, air masses can vary gradually over distance, with one type gradually becoming another. The boundary between two air masses can also be comparatively sharp. Where it is, the boundary is termed a "front". Fronts are often characterized by inclement weather, and are usually associated with areas of low atmospheric pressure termed frontal systems

Topic Objective:

At the end of this topic student will be able to understand:

- The Classification of Air masses

- Movement and fronts
- Movement
- Surface weather analysis
- Cold front
- Warm front
- Occluded front
- Stationary front and shearline
- Dry line
- Squall line
- Tropical waves
- Precipitation produced
- Cold and occluded fronts

Definition/Overview:

A **weather front:** A weather front is a boundary separating two masses of air of different densities, and is the principal cause of meteorological phenomena. In surface weather analyses, fronts are depicted using various colored lines and symbols, depending on the type of front. The air masses separated by a front usually differ in temperature and humidity. Cold fronts may feature narrow bands of thunderstorms and severe weather, and may on occasion be preceded by squall lines or dry lines. Warm fronts are usually preceded by stratiform precipitation and fog. The weather usually clears quickly after a front's passage. Some fronts produce no precipitation and little cloudiness, although there is invariably a wind shift.

Key Points:

1. **Cold and occluded fronts**

Cold fronts and occluded fronts generally move from west to east, while warm fronts move poleward. Because of the greater density of air in their wake, cold fronts and cold occlusions move faster than warm fronts and warm occlusions. Mountains and warm bodies of water can slow the movement of fronts. When a front becomes stationary, and the density contrast across the frontal boundary vanishes, the front can degenerate into a line which separates regions of differing wind velocity, known as a shearline. This is most common over the open ocean. The Bergeron classification is the most widely accepted form of air mass classification. Air mass classification involves three letters. The first letter describes its moisture properties, with c used for continental air masses (dry) and m for maritime air masses (moist). The second letter describes the thermal characteristic of its source region: T for tropical, P for polar, A for arctic or Antarctic, M for monsoon, E for equatorial, and S for superior air (dry air formed by significant downward motion in the atmosphere). The third letter is used to designate the stability of the atmosphere. If the air mass is colder than the ground below it, it is labeled k. If the air mass is warmer than the ground below it, it is labeled w.

2. **Surface weather analysis**

A surface weather analysis is a special type of weather map which provides a view of weather elements over a geographical area at a specified time based on information from groundbased weather stations. Weather maps are created by plotting or tracing the values of relevant quantities such as sea-level pressure, temperature, and cloud cover onto a geographical map to help find synoptic scale features such as weather fronts. Surface weather analyses have special symbols which show frontal systems, cloud cover, precipitation, or other important information. For example, an *H* may represent high pressure, implying fair weather. An *L* on the other hand may represent low pressure, which frequently accompanies precipitation. Various symbols are used not just for frontal zones and other surface boundaries on weather maps, but also to depict the present weather at various locations on the weather map. In addition, areas of precipitation help determine the frontal type and location.

3. Cold front

A cold front is located at the leading edge of the temperature drop off, which in an isotherm analysis shows up as the leading edge of the isotherm gradient, and it normally lies within a sharp surface trough. Cold fronts can move up to twice as fast and produce sharper changes in weather than warm fronts, since cold air is denser than warm air and rapidly replaces the warm air preceding the boundary. On weather maps, the surface position of the cold front is marked with the symbol of a blue line of triangle-shaped pips pointing in the direction of travel, and it is placed at the leading edge of the cooler air mass. Cold fronts come in association with a low pressure area. When a cold front moves through, the air with greater density wedges under the less dense warmer air, lifting it, which can cause the formation of a narrow line of showers and thunderstorms when enough moisture is present. This upward motion causes lowered pressure along the cold front.

4. Warm front

Warm fronts are at the leading edge of a homogeneous warm air mass, which is located on the equatorward edge of the gradient in isotherms, and lie within broader troughs of low pressure than cold fronts. A warm front moves more slowly than the cold front which usually follows because cold air is more dense and harder to remove from the earth's surface. This also forces temperature differences across warm fronts to be broader in scale. Clouds ahead of the warm front are mostly stratiform, and rainfall gradually increases as the front approaches. Fog can also occur preceding a warm frontal passage. Clearing and warming is usually rapid after frontal passage. If the warm air mass is unstable, thunderstorms may be embedded among the stratiform clouds ahead of the front, and after frontal passage thundershowers may continue. On weather maps, the surface location of a warm front is marked with a red line of semi-circles pointing in the direction of travel.

5. **Occluded front**

An occluded front is formed when a cold front overtakes a warm front. The cold and warm fronts curve naturally poleward into the point of occlusion, which is also known as the triple point. It lies within a sharp trough, but the air mass behind the boundary can be either warm or cold. In a cold occlusion, the air mass overtaking the warm front is cooler than the cool air ahead of the warm front and plows under both air masses. In a warm occlusion, the air mass overtaking the warm front is warmer than the cold air ahead of the warm front and rides over the colder air mass while lifting the warm air. A wide variety of weather can be found along an occluded front, with thunderstorms possible, but usually their passage is associated with a drying of the air mass. Occluded fronts are indicated on a weather map by a purple line with alternating half-circles and triangles pointing in direction of travel. Occluded fronts usually form around mature low-pressure areas.

6. **Stationary front and shearline**

A stationary front is a non-moving (or stalled) boundary between two air masses, neither of which is strong enough to replace the other. They tend to remain essentially in the same area for extended periods of time, usually moving in waves. There is normally a broad temperature gradient behind the boundary with more widely spaced isotherm packing. A wide variety of weather can be found along a stationary front, but usually clouds and prolonged precipitation are found there. Stationary fronts either dissipate after several days or devolve into shear lines, but they can transform into a cold or warm front if conditions aloft change. Stationary fronts are marked on weather maps with alternating red half-circles and blue spikes pointing in opposite directions, indicating no significant movement. When stationary fronts become smaller in scale, degenerating to a narrow zone where wind direction changes significantly over a relatively short distance, they become known as shearlines. A shearline is depicted as a line of red dots and dashes.

7. Dry line

A similar phenomenon to a weather front is the dry line, which is the boundary between air masses with significant moisture differences. When westerly winds aloft increase on the north side of surface highs, areas of lowered pressure will form downwind of northsouth oriented mountain chains, leading to the formation of a lee trough. Near the surface during daylight hours, warm moist air is denser than dry air of greater temperature, and thus the warm moist air wedges under the drier air like a cold front. At higher altitudes, the warm moist air is less dense than the dry air and the boundary slope reverses. In the vicinity of the reversal aloft, severe weather is possible, especially when a triple point is formed with a cold front. A weaker form of the dry line seen more commonly is the lee trough, which displays weaker differences in moisture. When moisture pools along the boundary during the warm season, it can be the focus of diurnal thunderstorms. The dry line may occur anywhere on earth in regions intermediate between desert areas and warm seas. The southern plains west of the Mississippi River in the United States are a particularly favored location. The dry line normally moves eastward during the day and westward at night. A dry line is depicted on National Weather Service (NWS) surface analyses as a orange line with scallops facing into the moist sector. Dry lines are one of the few surface fronts where the pips indicated do not necessarily reflect the direction of motion.

8. Squall line

Organized areas of thunderstorm activity not only reinforce pre-existing frontal zones, but can outrun cold fronts in a pattern where the upper level jet splits apart into two streams, with the resultant Mesoscale Convective System (MCS) forming at the point of the upper level split in the wind pattern running southeast into the warm sector parallel to low-level thickness lines. When the convection is strong and linear or curved, the MCS is called a squall line, with the feature placed at the leading edge of the significant wind shift and pressure rise. Even weaker and less organized areas of thunderstorms lead to locally cooler air and higher pressures, and outflow boundaries exist ahead of this type of activity, which can act as foci for additional thunderstorm activity later in the day. These features are often depicted in the warm season across the United States on surface analyses and lie within surface troughs. If outflow boundaries or squall lines form over arid regions, a haboob may result. Squall lines are depicted on NWS surface analyses as an alternating pattern of two red dots and a dash labelled SQLN or SQUALL LINE, while outflow boundaries are depicted as troughs with a label of OUTFLOW BNDRY.

9. Tropical waves

Atlantic tropical waves develop from disturbances which drift off the continent of Africa onto the Atlantic Ocean. They are generated or enhanced by the African Easterly Jet. The clockwise circulation of the large transoceanic high-pressure cell or anticyclone centered near the Azores islands moves easterly waves away from the coastal areas of Africa towards North America. Tropical waves cause approximately 60% of Atlantic tropical cyclones and 85% of intense Atlantic hurricanes (Category 3 and greater).

Tropical cyclones sometimes degenerate back into a tropical wave. This normally occurs if upper-level wind shear is too strong. The storm can redevelop if the upper level shear abates. If a tropical wave is moving quickly, it can have strong winds of over tropical storm force but is not considered a tropical storm unless it has a closed circulation. An example of this was Hurricane Claudette in 2003, where the original wave had winds of 45 mph (72 km/h) before developing a circulation. Tropical waves are depicted with a solid orange line on the U.S. National Weather Service Unified Surface Analysis.

10. Precipitation produced

Fronts are the principal cause of significant weather. *Convective precipitation* (showers, thundershowers, and related unstable weather) is caused by air being lifted and condensing into clouds by the movement of the cold front or cold occlusion under a mass of warmer, moist air. If the temperature differences of the two air masses involved are large and the turbulence is extreme because of wind shear and the presence of a strong jet stream, "roll clouds" and tornadoes may occur. In the warm season, lee troughs, breezes, outflow boundaries and occlusions can lead to convection if enough moisture is available. *Orographic precipitation* is precipitation created through the lifting action of air moving over terrain such as mountains and hills, which is most common behind cold fronts that move into mountainous areas. It may sometimes occur in advance of warm fronts moving northward to the east of mountainous terrain. However, precipitation along warm fronts is relatively steady, as in rain or drizzle. Fog, sometimes extensive and dense, often occurs in pre-warm-frontal areas. Although, not all fronts produce precipitation or even clouds because moisture must be present in the air mass which is being lifted.

11. Movement

Fronts are generally guided by winds aloft, but do not move as quickly. Cold fronts and occluded fronts in the Northern Hemisphere usually travel from the northwest to southeast, while warm fronts move more poleward with time. In the Northern Hemisphere a warm front moves from southwest to northeast. In the Southern Hemisphere, the reverse is true; a cold front usually moves from southwest to northeast, and a warm front moves from northwest to southeast. Movement is largely caused by the pressure gradient force (horizontal differences in atmospheric pressure) and the Coriolis Effect, which is caused by Earth's spinning about its axis. Frontal zones can be slowed down by geographic features like mountains and large bodies of warm water.

Topic Objective:

At the end of this topic student will be able to understand:

- Origination
- Regulation
- METAR conventions
- International METAR codes

Definition/Overview:

METAR: METAR (aviation routine weather report) is a format for reporting weather information. A METAR weather report is predominantly used by pilots in fulfillment of a part of a pre-flight weather briefing, and by meteorologists, who use aggregated METAR information to assist in weather forecasting.

Key Points:

1. **Origination**

METAR reports typically come from airports or permanent weather observation stations. Reports are typically generated once an hour; if conditions change significantly, however, they can be updated in special reports called SPECI's. Some reports are encoded by automated airport weather stations located at airports, military bases, and other sites. Some locations still use augmented observations, which are recorded by digital sensors, encoded via software, and then reviewed by certified weather observers or forecasters prior to being transmitted. Observations may also be taken by trained observers or forecasters who manually observe and encode their observations prior to transmission.

2. **Regulation**

METAR code is regulated by Federal Meteorological Handbook No. 1 (FMH-1) and the World Meteorological Organization (WMO) aviation routine weather reports (FM-15 METAR) and aviation selected special weather reports (FM-16 SPECI) codes.

3. **METAR conventions**

Although the general format of METAR reports is a global standard, the specific fields used within that format vary somewhat between general international usage and usage within North

America (specifically the United States and Can ada). The two examples which follow illustrate the primary differences between the two METAR variations.

4. International METAR codes

The following is an example METAR from Burgas Airport in Burgas, Bulgaria, and was taken on 4 February 2005 at 16:00 Coordinated Universal Time (UTC).

METAR LBBG 041600Z 12003MPS 310V290 1400 R04/P1500N R22/P1500U +SN BKN022 OVC050 M04/M07 Q1020 NOSIG 9949//91=

- METAR indicates that the following is a standard hourly observation.
- LBBG is the ICAO airport code for Burgas Airport.
- 041600Z indicates the day of the month is the 4th and the time of day is 1600 Zulu time, 4:00PM Greenwich Mean Time, or 6:00PM Eastern European Time.
- 12003MPS indicates the wind direction is from 120 degrees true (east-southeast) at a speed of 3 meters per second.
- 310V290 indicates the wind direction is varying from 310 degrees true (northwest) through 120 degrees true (east-southeast) to 290 degrees true (west-northwest).
- 1400 indicates the prevailing visibility is 1400 metres.
- R04/P1500N indicates the Runway visual range (RVR) along Runway 04 is 1500 meters and not changing significantly.
- R22/P1500U indicates RVR along Runway 22 is 1500 meters and rising.
- +SN indicates snow is falling at a heavy intensity.
- BKN022 indicates a broken cloud layer at 2,200 feet above ground level (agl).
- OVC050 indicates an unbroken cloud layer (overcast) at 5,000 feet above ground level.
- M04/M07 indicates the temperature is minus 4 degrees Celsius and the dewpoint is minus 7 degrees Celsius.
- Q1020 indicates the current barometric pressure extrapolated to sea level is 1020 millibars.
- NOSIG is an example of a TREND forecast which is appended to METARs at stations while a forecaster is on watch. NOSIG means that no significant change is expected to the reported conditions within the next 2 hours.

- 9949//91 indicates runway status. Format: abcdefgh ab=runway heading, c=nature of coating (4=dry snow), d=surface covered in percent (9= 51-100% of rwy covered), ef=thickness of coating in millimeters (// stands for either not measurable or not affecting usage of rwy) gh=braking index (91=bad braking index i.e grip on rwy)
- CAVOK abbreviation for Ceiling And Visibility OKay indicating no cloud below 5,000 feet and no cumulonimbus at any level, a visibility of 6 Statute Miles (10 km) or more and no significant weather. As of 5 November 2008 this will be amended to include towering cumulus
- = indicates the end of the METAR report

Topic Objective:

At the end of this topic student will be able to understand:

- Data Reported
- Surface weather observations

Definition/Overview:

Surface weather observations: Surface weather observations are the fundamental data used for safety as well as climatological reasons to forecast weather and issue warnings worldwide. They can be taken manually, by a weather observer, by computer through the use of automated weather stations, or in a hybrid scheme using weather observers to augment the otherwise automated weather station. The ICAO defines the International Standard Atmosphere, which is the model of the standard variation of pressure, temperature, density, and viscosity with altitude in the Earth's atmosphere, and is used to reduce a station pressure to sea level pressure. Airport observations can be transmitted worldwide through the use of the METAR observing code. Personal weather stations taking automated observations can transmit their data to the United States mesonet through the use of the Citizens weather observer program, or internationally through the Weather Underground web site. A thirty-year average of a location's weather observations is traditionally used to determine the station's climate.

Key Points:

1. **Surface weather observations**

A meteorological observation made on the Earth's surface in contrast with an upper-air observation). Surface weather observations have traditionally been taken at airports due to safety concerns during takeoffs and landings. The ICAO defines the International Standard Atmosphere (also known as ICAO Standard Atmosphere), which is the model of the standard variation of pressure, temperature, density, and viscosity with altitude in the Earth's atmosphere. This is useful in calibrating instruments and designing aircraft, and is used to reduce a station's pressure to sea level pressure where it can then be used on weather maps. In the United States, the FAA mandates the taking of weather observations for safety reasons. To help facilitate the purchase of an automated weather observing system, such as ASOS, the FAA allows federal dollars to be used for the installation of certified weather stations at airports. The airport observations are then transmitted worldwide using the METAR observing code. METAR reports typically come from airports or permanent weather observation stations. Reports are generated once an hour; however, if conditions change significantly, they may be updated in special reports called SPECI's.

2. Data Reported

Surface weather observations can include the following elements:

- The Station Identifier, or Location identifier, consists of four characters for METAR observations, with the first representing the region of the world the station lies within. For example, the first letter for areas in and around the Pacific ocean is P, and for Europe is E. The second character may represent the country/state the location lies within. For Hawaii, the first two letters are "PH" while for Great Britain, the first two letters of the station identifie are "EG". Canada and the contiguous United States are an exception, with the first letters C and K representing the regions, respectively. The final two or three letters normally represent the name of the location or airport.

- Visibility, measured in meters for most sites worldwide, except in the United States where statute miles are reported.
- Runway visibility, measured in meters in many locations worldwide, or feet within the United States.
- Temperature is a measure of the kinetic energy of a sample of matter. Temperature is the unique physical property that determines the direction of heat flow between two objects placed in thermal contact. If no heat flow occurs, the two objects have the same temperature; otherwise heat flows from the hotter object to the colder object. Temperature, within meteorology, is measured with thermometers exposed to the air but sheltered from direct solar exposure. In most of the world, the degree Celsius scale is used for most temperature measuring purposes. However, the United States is the last major country in which the degree Fahrenheit temperature scale is used by most lay people, industry, popular meteorology, and government. Despite this, METAR reports from the United States also report the temperature in degrees Celsius.
- Dew Point is the temperature to which a given parcel of air must be cooled, at constant barometric pressure, for water vapor to condense into water. The condensed water is called dew. The dew point is a saturation point. When the dew point temperature falls below freezing it is called the frost point, as the water vapor no longer creates dew but instead creates frost or hoarfrost by deposition. The dew point is associated with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. If the relative humidity is 100%, the dew point is equal to the current temperature. Given a constant dew point, an increase in temperature will lead to a decrease in relative humidity. At a given barometric pressure, independent of temperature, the dew point determines the specific humidity of the air. The dew point is an important statistic for general aviation pilots, as it is used to calculate the likelihood of carburetor icing and fog. When used with the air temperature, a formula can be used to estimate the height of cumuliform, or convective, clouds.
- Wind speed and direction is determined using anemometers located a standard 10 metres (33 ft) above ground level. Average wind speed is measured using a two-minute average in the United States, and a 10 minute average elsewhere. Wind direction is measured using degrees, with north representing 0 or 360 degrees, with values increasing from 0 clockwise from north. Wind gusts are reported when there is variation of the wind speed of more than 10 knots (5.1 m/s) between peaks and lulls during the sampling period.

- Sea level pressure is the pressure at sea level or (when measured at a given elevation on land) the station pressure reduced to sea level assuming an isothermal layer at the station temperature. This is the pressure normally given in weather reports on radio, television, and newspapers or on the Internet. When barometers in the home are set to match the local weather reports, they measure pressure reduced to sea level, not the actual local atmospheric pressure. The reduction to sea level means that the normal range of fluctuations in pressure is the same for everyone. The pressures which are considered high pressure or low pressure do not depend on geographical location. This makes isobars on weather map meaningful and useful tools.
- Altimeter setting is a term and quantity used in aviation. The regional or local air pressure at mean sea level is called the altimeter setting, and the pressure which will calibrate the altimeter to show the height above ground at a given airfield.
- Present weather, which present restrictions to visibility or presence of thunder or squalls, are reported in observations to indicate to aviation any possible threats during landings and takeoffs from airports. Types included in surface weather observations include precipitation, obscurations, and other weather phenomena such as, well-developed dust/sand whirls, squalls, tornadic activity, sandstorms, volcanic ash, and duststorms.
- Intensity of precipitation is primarily measured for meteorological concerns. However, it can be of concern to aviation as heavy precipitation can limit visibility. Also, intensity of freezing rain can determine how hazardous it is for pilots to fly nearby certain locations since it can be an in-flight hazard by depositing ice on the wings of aircraft, which can be detrimental to flight.
- Precipitation amount over the past 6 or 24 hours is of particular interest to meteorologists in verifying forecast amounts of precipitation and determining station climatologies.
- Snowfall amount during the past 6 hours is taken for meteorological and climatological concerns.
- Snow depth is measured for meteorological and climatological concerns once a day. However, during periods of snowfall, it is measured each six hours to determine amount of recent snowfall.

Topic Objective:

At the end of this topic student will be able to understand:

- Included data
- Body
- Soliciting PIREPs
- Examples of PIREPs

Definition/Overview:

PIREP: A pilot report or PIREP is a report of actual weather conditions encountered by an aircraft in flight. This information is usually relayed by radio to the nearest ground station. The message would then be encoded and relayed to other weather offices and air traffic service units.

Although the actual form used to record the PIREP may differ from one country to another, the standards and criteria will remain almost the same. At a minimum the PIREP must contain a header, aircraft location, time, flight level, aircraft type and one other field.
The term PIREP is used, also, to describe a defect report entered into an aircraft's technical log by an aircraft's flight crew (in contrast to a defect report entered by maintenance crews).

Key Points:

1. **Included data**

- **Mandatory**
- UA or UUA used to identify the PIREP as routine or urgent.
- /OV location of the PIREP.
- /TM time the PIREP was received from the pilot. Coordinated Universal Time.
- /FL flight level or altitude above sea level at the time the PIREP is filed. Essential for turbulence and icing reports.
- /TP aircraft type. Essential also for turbulence and icing reports.

- **Optional (at least one is required)**
- /SK sky cover
- /TA ambient temperature. Important for icing reports.
- /WV wind velocity referenced in terms of True North (ICAO), or magnetic north (in the United States).
- /TB turbulence. Intensity, whether it occurred in or near clouds, and duration.
- /IC icing
- /RM remarks
- /WX flight visibility and weather.

2. Body

The message identifier "UA" is used when the PIREP contains non-hazardous weather information. If the PIREP contains a report of a tornado, funnel cloud, waterspout, severe turbulence, severe icing, hail, or a low level wind shear hazard, the identifier "UUA" would be used. The location (/OV) can be reported in one of three ways: as a direction and distance from a navigation aid (NAVAID), as a direction and distance from an airport, or as the latitude and longitude of the aircraft. The time (/TM) used is the UTC time that the PIREP is reported.
The flight level (/FL) is reported as either a three digit value that indicates the altitude of the aircraft above sea level in hundreds of feet or can one of three abbreviations: DURD (during descent or on approach), DURC (during climb or after takeoff) and UNKN (unknown).
Aircraft type (/TP) will be the approved ICAO designator or UNKN if not reported. Sky cover (/SK) is used to report the cloud layer amounts and the height of the cloud base. The tops of the cloud layers can also be included, as can more than one layer of cloud. Heights are in hundreds of feet above sea level and are three digits. Abbreviations used in this group are "CLR" (clear), "FEW" (few), "SCT" (scattered), "BKN" (broken) and "OVC" (overcast). Temperature (/TA) is the air temperature in whole degrees Celsius as a two-digit value, with negative temperatures preceded by a minus (-) sign. Wind velocity (/WV) must contain both the wind speed and direction. Direction is reported as a three-digit value in whole degrees true and the wind speed in knots also in three digits. Turbulence (/TB) and the intensity are reported in a PIREP based on the aircraft and occupants reaction to the turbulence. The altitude of the turbulence should be included using three-digit groups. When the top or the base of the turbulence is unknown then

the abbreviation BLO (below) or ABV (above) should be used. Turbulence should be reported as LGT (light), MDT (moderate) or SVR (severe). Clear-air turbulence is reported as CAT.
Icing (/IC) is reported by type and the intensity or rate of accretion. The type of ice is reported as "CLR" (clear), "RIME", or "MXD" (mixed). The intensity is reported as "TR" (trace), "LGT" (light), "MDT" (moderate), and "SVR" (severe). Remarks (/RM) report on other weather conditions that are not covered in the rest of the PIREP may include such things as icing in precipitation, thunderstorms, St Elmo's fire and frontal conditions. There are many other types of weather conditions that could be reported in a PIREP. The above explanation of PIREP fields is Canadian. The United States version may also include a weather (/WX) group; and other countries may use other groups and measurements.

3. Soliciting PIREPs

In the US, Air Traffic Controllers are required to solicit PIREPs upon request of other facilities or pilots, or when any of the following conditions exists or is forecast in their area:

- Ceilings at or below 5,000 feet
- Visibility at or less than 5 miles
- Thunderstorms and related phenomena
- Turbulence of moderate degree or greater
- Icing of light degree or greater
- Wind shear
- Volcanic ash clouds
- Braking Action reports (if fair or less)

At least once hourly, terminal controllers must obtain a descent/climb-out PIREP, including cloud information and other related phenomena.

Example/Case Study:

4. Examples of PIREPs

These examples are taken from the Canadian MANOBS (Manual of Surface Weather Observations) published by Environment Canada.

UACN10 CYQT 192128
YZ WG
UA /OV YSP 090025 /TM 2120 /FL050 /TP BE99 /SK 020BKN040 110OVC /TA -14 /WV 030045 /TB MDT CAT 060-080 /IC LGT RIME 020-040 /RM LGT FZRA INC
Decoded is
Routine Upper Air, Aircraft report from Thunder Bay, Ontario issued at 2128 UTC on the 19th
YZ is Toronto and WG is Winnipeg. This is the Flight Information Region where the PIREP was issued
Aircraft observation was 25 nautical miles (46 km) east (090 degrees magnetic) of the Marathon, Ontario VOR/DME at 2120 UTC. The aircraft was at 5,000 ft (1,524 m)and is a Beech 99. The clouds were broken at 2,000 ft (610 m) AMSL with tops at 4,000 ft (1,219 m) and an overcast layer at 11,000 ft (3,353 m) AMSL. The temperature is -14 Celsius and the winds are from the NE (030 degrees true) at 45 knots (83 km/h). There is moderate clear air turbulence between 6,000 ft (1,829 m) and 8,000 ft (2,438 m). There is light rime icing between 2,000 ft (610 m) and 4,000 ft (1,219 m). Note this would indicate that the icing is picked up in the cloud. The remarks section says that light freezing rain was encountered in the cloud.
UACN10 CYXU 032133
YZ
UA /OV YUX 09010 /TM 2120 /FL030 /TP C172 /TB MDT /RM MDT TURB BLO 050 CYKF CYXU
Routine message from London Ontario, issued at 2133 UTC on the 3rd
The Flight Information Region is Toronto
The aircraft was 10 nautical miles (18.5 km) east (090 degrees true) of the London VOR at 2120 UTC. The aircraft was at 3,000 ft (914 m) and was a Cessna 172. The pilot reported moderate turbulence. Then in remarks went on to say that the turbulence was below 5,000 ft (1,524 m) between Kitchener/Waterloo and London.

Topic Objective:

At the end of this topic student will be able to understand:

- Introduction to Satellite images
- Resolution and data

- DigitalGlobe
- GeoEye
- Disadvantages
- Moving images

Definition/Overview:

Satellite imagery: Satellite imagery consists of photographs of Earth or other planets made by means of artificial satellites.

Key Points:

1. Introduction to Satellite images

Satellite images have many applications in agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence and warfare. Images can be in visible colours and in other spectra. There are also elevation maps, usually made by radar imaging. Interpretation and analysis of satellite imagery is conducted using software packages like ERDAS Imagine or ENVI. Some of the first image enhancement of satellite photos was conducted by the U.S. Government and its contractors. For example ESL Incorporated developed some of the earliest two dimensional Fourier transforms applied to digital image processing to address NASA photos as well as national security applications.

2. Resolution and data

There are two different types of resolution when discussing satellite imagery; radiometric and geometric. Radiometric resolution refers to the effective bit-depth of the sensor (number of greyscale levels) and is typically expressed as 8-bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (0-65,535). Geometric resolution refers to the satellite sensor's ability to effectively image a portion of the earth's surface in a single pixel and is typically expressed in terms of Ground Sample Distance, or GSD. GSD is a term containing the overall optical and systemic noise sources and is useful for comparing how well one sensor can "see" an object on the ground within a single pixel. For example, the GSD of Landsat is ~30m, which means the smallest unit that maps to a single pixel within an image is ~30m x 30m. Contrast this with the latest commercial satellite (GeoEye 1) with a GSD of 0.41m (effectively 0.5 due to govt restrictions). 3600 pixels from a GeoEye image of the same area of the earth will fit into a single Landsat pixel. The resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit. For example, the Landsat archive offers repeated imagery at 30 meter resolution for the planet, but most of it has not been processed from the raw data. Landsat 7 has an average return period of 16 days. For many smaller areas, images with resolution as high as 10 cm can be available. Satellite imagery is sometimes supplemented with aerial photography, which has higher resolution, but is more expensive per square meter. Satellite imagery can be combined with vector or raster data in a GIS provided that the imagery has been spatially rectified so that it will properly align with other data sets.

3. DigitalGlobe

DigitalGlobe's WorldView-1 satellite provides the world's highest resolution commercial satellite imagery. The 50 cm resolution of WorldView-1's panchromatic images allows the satellite to distinguish between objects on the ground that are at least 50 cm apart. Similarly DigitalGlobe's QuickBird satellite provides 2.4 meter resolution multispectral images.

4. GeoEye

GeoEye's GeoEye-1 satellite is scheduled for launch Aug. 22, 2008 . The GeoEye-1 satellite will have the highest resolution of any commercial imaging system and be able to collect images with a ground resolution of 0.41-meters or 16 inches in the panchromatic or black and white mode. It will collect multispectral or color imagery at 1.65-meter resolution or about 64 inches, a factor of two better than existing commercial satellites with four-band multispectral imaging capabilities. While the satellite will be able to collect imagery at 0.41-meters, GeoEye's operating license from the U.S. Government requires re-sampling the imagery to 0.5-meter for all customers not explicitly granted a waiver by the U.S. Government.

5. Disadvantages

Because the total area of the land on Earth is so large and because resolution is relatively high, satellite databases are huge and image processing (creating useful images from the raw data) is time-consuming. Depending on the sensor used, weather conditions can affect image quality: for example, it is difficult to obtain images for areas of frequent cloud cover such as mountain-tops. Commercial satellite companies do not place their imagery into the public domain and do not sell their imagery; instead, one must be licensed to use their imagery. Thus, the ability to legally make derivative products from commercial satellite imagery is minimized. Privacy concerns have been brought up by some who wish not to have their property shown from above. Google Maps responds to such concerns in their FAQ with the following statement: "We understand your privacy concerns... The images that Google Maps displays are no different from what can be seen by anyone who flies over or drives by a specific geographic location."

6. Moving images

In 2005 the Australian company Astrovision (ASX: HZG) announced plans to launch the first commercial geostationary satellite in the Asia-Pacific. It intended to provide true color, real-time live satellite feeds, with down to 250 metres resolution over the entire Asia-Pacific region, from India to Hawaii and Japan to Australia. They were going to provide this content to users of 3G mobile phones, over Pay TV as a weather channel, and to corporate and government users. Unfortunately, the market response to the AstroVision concept fell into the classic chicken-egg problem: potential customers were excited by the possibilities offered, but they were unwilling (or, in government cases, generally unable) to sign contracts for a service that would not be delivered for 3-4 years (the length of time required to build and launch the satellite). AstroVision ran low on funds and was forced to shut down the program in 2006.