Marine Science Lesson Enhancements
based on **Grade 11 & 12 curriculum** in
Physics, Chemistry & Biology

Climate Energy & Wind Masses

Ocean Explorer

Module 5

Bayworld Centre for Research & Education

BCRE

Overview

1 - What is "energy" ?

Energy is a property or characteristic (or trait or aspect) of matter that makes things happen, or has the "potential" to make things happen. Without energy, nothing would ever change, nothing would ever happen ! There are 2 main forms of energy : Kinetic energy and Potential energy.

Kinetic energy is the energy contained in a moving mass or in a moving particle. You might call this "happening energy". If you could look close enough, or small enough, you would see that when anything is "happening", work is being or has been done, and something is moving.

Potential energy is the energy contained within something immobile. This energy will be released at some point. For example, an apple hanging onto a tree has stored potential energy, the apple could fall if it wasn't attached to the tree ! And when the stalk breaks, the apple falls onto the ground, using its stored potential energy.

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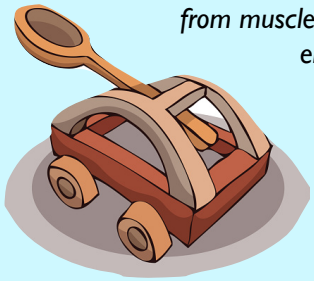
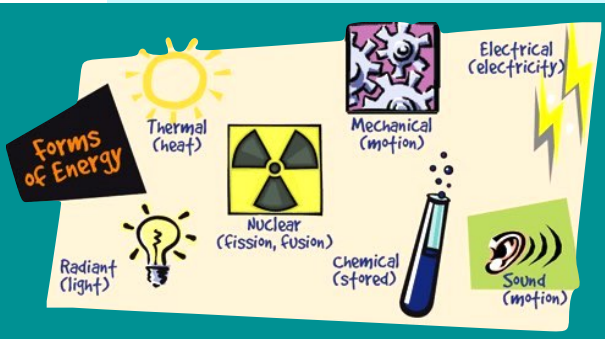
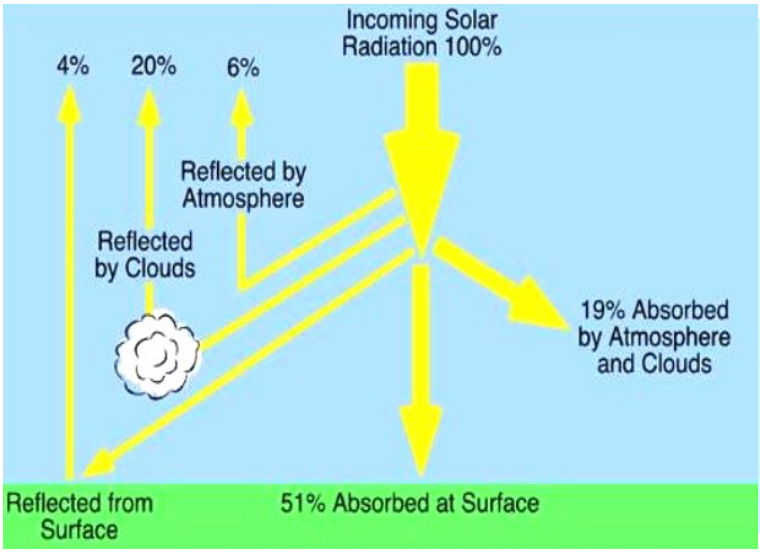
When potential energy is used, it becomes kinetic energy as the object/ mass is now moving or doing something ! Below : Device for converting work from muscles into potential energy and then converting that into kinetic energy.



Energy is a property of many substances. It is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. We often differentiate between all of these and call them different types of energy, but in reality all of them are the same kinetic or potential energy !



Essentially 100% of the energy that fuels the Earth comes from the sun. To maintain a constant global average temperature, all of the sun's radiation that enters Earth's atmosphere must eventually be sent back to space. This is achieved through Earth's energy balance.



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*The Earth's surface reflects part of the solar energy. This is called the **Albedo** effect and expressed as a fraction. The albedo of Earth depends on the geographical location, surface properties, and the weather. On average, it is around 0,3. The other 0,7 part of the incoming solar radiation is absorbed by our planet.*

100% of the energy entering Earth's atmosphere comes from the sun.

~50% of the incoming energy is absorbed by the earth's surface i.e. the land and oceans.

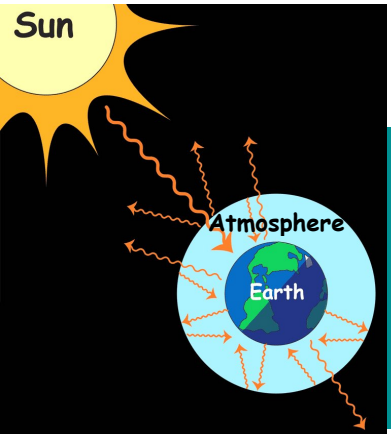
~30% is directly reflected back to space by clouds, the earth's surface and different gases and particles in the atmosphere (the earth's albedo is 0.3 on average).

~20% is absorbed by the atmosphere and clouds.

The 70% of the sun's energy that is absorbed by the earth's surface, clouds, and atmosphere causes warming. Any object or gas that has a temperature emits radiation outward, and this is ultimately re-radiated back into space.

Energy emission from the Earth

Consider a stove. If you were cooking, you'd have the stove turned on so it would heat up. The burner is like the earth and the heat source is like the sun. When you're done cooking you turn off the burner, but it stays hot for a long while even after the heat source is gone. Turning off the burner is like the sun going down. Even though there is no more energy input, there is still energy output in the form of infrared radiation. The burner stays hot because it's still emitting the energy it absorbed earlier, just like the Earth. This time delay is called *thermal inertia*.



During the day, the Sun's energy reaches Earth's atmosphere. Most of it goes through, and some bounces off back to space.
At night, most of the Sun's energy escapes back into space. Some energy remains trapped inside the atmosphere by the greenhouse gases, further warming the Earth.

Greenhouse gases and keeping the energy into the atmosphere

Most of the energy emitted from the earth's surface does not go directly out to space. This emitted energy is reabsorbed by clouds and by the gases in the atmosphere. Some of it gets redistributed by convection. Even more energy is released into the atmosphere through condensation. The majority of the energy is reabsorbed by the greenhouse gases such as methane, nitrous oxide, ozone, carbon dioxide and water vapour. These gases constantly emit the sun's energy back into the atmosphere and keep the earth a habitable temperature. Eventually, most of the energy makes its way back out to space and

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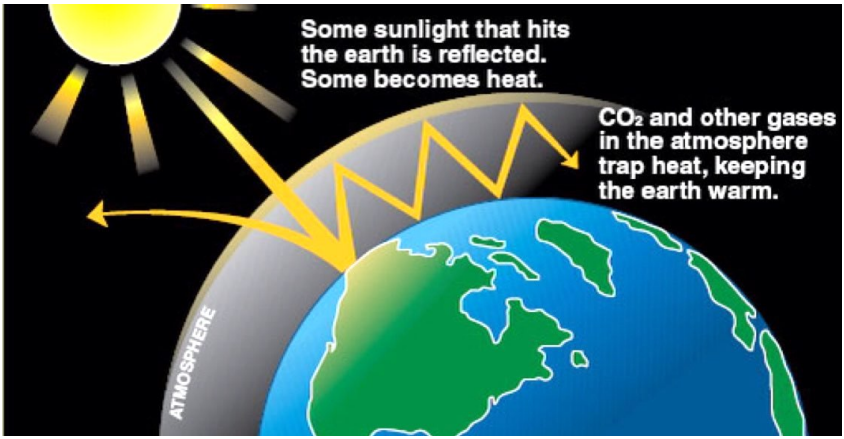
Convection *is the transfer of heat through fluids (gases or liquids) from a warmer spot to a cooler spot.*

Earth's energy balance is fairly well maintained. The energy that doesn't escape is responsible for global warming.



3 - Air masses

Air masses bring a variety of weather. Fronts form the boundaries of air masses with differing properties. The most severe weather usually occurs when dry-cold continental polar air clashes with warm-humid maritime tropical air.

The nature of air masses is determined by three factors: the **source region**, the **age** and the **modifications** that may occur as they move away from their source region across the earth's surface. An air mass that forms over an equatorial region would be warm and moist. An air mass forming over a polar region would be cold and dry.

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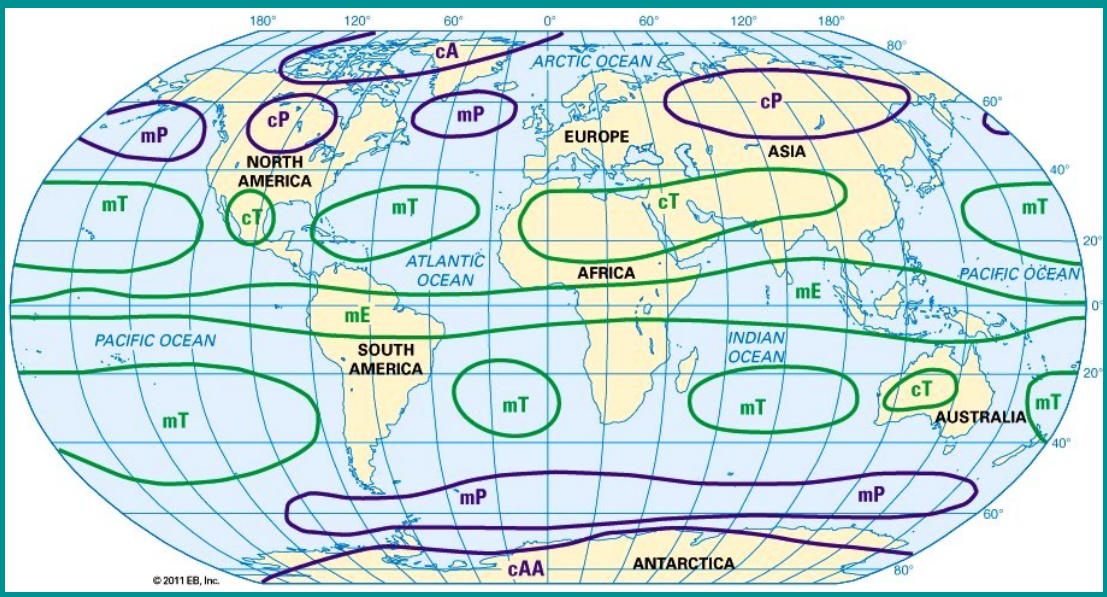
Air *is the mixture of gases that make up the earth's atmosphere. The principal gases that compose dry air are Nitrogen (N2 - 78%), Oxygen (O2 - 21%), Argon (A - 0.9%), Carbon Dioxide (CO2 - 0.03%). One of the most important variable constituents of air and most important gases in meteorology is water vapour (H2O), which may vary between 0 and 4%.*

Other components are traces of Neon (Ne), Helium (He), Methane (CH4), Krypton (K), Hydrogen (H), Nitrous Oxide (N2O) and Xenon (Xe).

The primary classification of air masses is based on the characteristics of the source region, giving **Arctic (A -** over arctic regions**)**, **Polar (P -** farther from the poles, i.e. Siberia, Canada, northern Atlantic and Pacific Oceans**)** or **Tropical air (T -** in the tropics**)**, and on the nature of the surface in the source region : **continental (c)** or **maritime (m)**. In addition, a large variety of secondary types of air masses are defined. For example, **Equatorial air (E)**. Sometimes there is a letter (k) or (w) attached to the two-letter initials indicating whether the air is warmer or colder than the surface. The former becomes more stable, and the latter more unstable.

An **Air mass** is a large body of air, whose properties - temperature, humidity and lapse rate - are largely homogeneous over an area several hundred kilometres across.



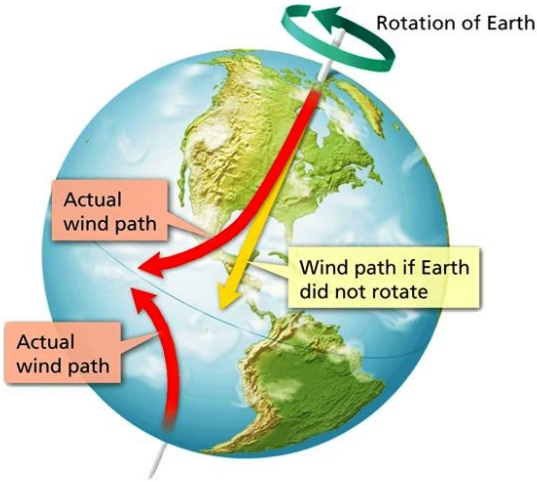
Air masses on Earth. Tropical and Equatorial air masses are in green, Arctic and Polar air masses are in purple.

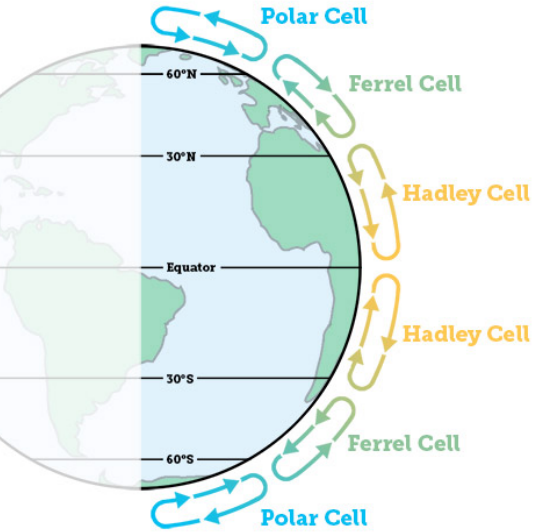
The global circulation is the world-wide system of winds by which the necessary transport of heat from tropical to polar latitudes is accomplished.

This is done through the 3 convection cells (**Hadley cell**, **Ferrel cell** and **Polar cell**) and the Coriolis effect.

The Coriolis effect

The Earth spins on its axis, which affects the direction of the wind. In the Northern hemisphere, winds are swung to the right, and in the Southern to the left.





In each hemisphere there are 3 cells (**Hadley cell**, **Ferrel cell** and **Polar cell**) in which air circulates through the entire depth of the **troposphere**.

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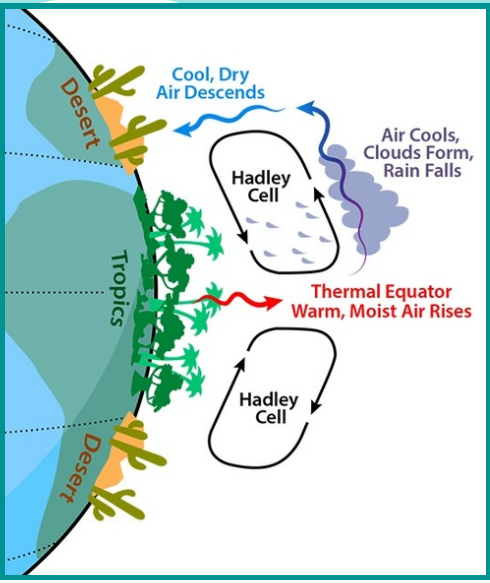
Troposphere *is the name given to the vertical extent of the atmosphere from the surface, right up to between 10 and 15 km high. It is the part of the atmosphere where most of the weather takes place.*

Hadley cells : They are the largest cells. They extend from the equator to between 30° and 40° north and south.

Within the Hadley cells, the trade winds blow towards the equator, then ascend near the equator as a broken line of thunderstorms, which forms the Inter-Tropical-Convergence-Zone (ITCZ).

From the tops of these storms, the air flows towards higher latitudes, where it sinks to produce high-pressure regions over the subtropical oceans and the world's hot deserts, such as the Sahara desert in North Africa.



High and Low pressure

The Earth's atmosphere exerts a pressure on the surface. Areas of high and low pressure are caused by ascending and descending air. As air warms up, it ascends leading to low pressure at the surface. As air cools down, it descends leading to high pressure at the surface.

- **High-pressure areas**, or anticyclones, are associated with cold air masses. Winds flows from the center of these high-pressure areas to the outside where the pressure is less. The air is descending, which reduces the formation of cloud and leads to light winds and settled weather conditions.
- **Low-pressure areas**, or depressions, form over hot areas, such as deserts or warm waters. Their formation is called cyclogenesis. As the air rises and cools, water vapour condenses to form clouds and perhaps precipitation. This is why the weather in a depression is often unsettled.

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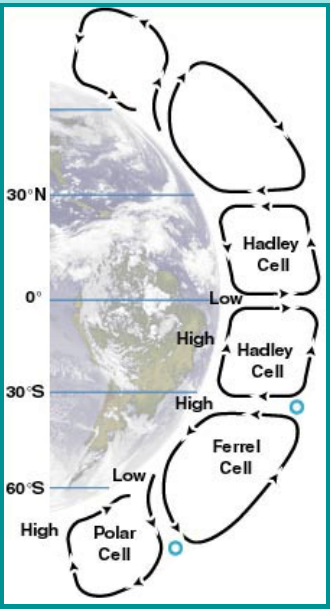
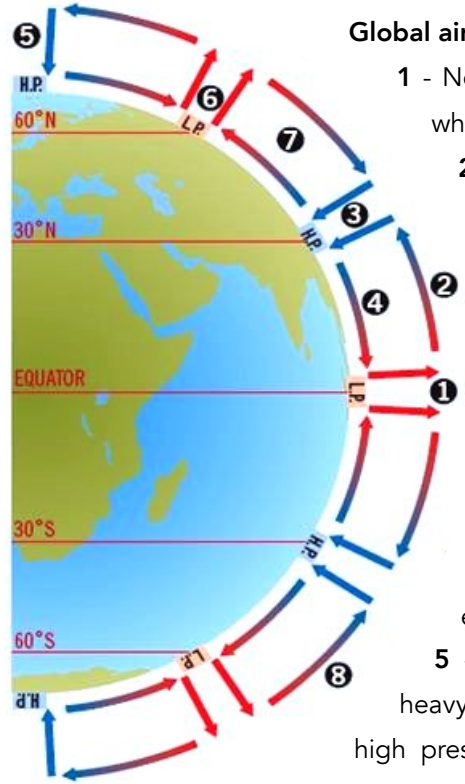
Air moves along the surface of Earth from high-pressure areas toward low-pressure areas. This moving air produces wind.



Ferrel cell : In the middle cells, which are known as the Ferrel cells, air converges at low altitudes to ascend along the boundaries between cool polar air and the warm subtropical air that generally occurs between 60° and 70° north and south. The circulation within the Ferrel cell is complicated by a return flow of air at high altitudes towards the tropics, where it joins sinking air from the Hadley cell.
The Ferrel cell moves in the opposite direction to the two other cells (Hadley cell and Polar cell) and acts rather like a gear.

Polar cell : The smallest and weakest cells are the Polar cells, which extend from between 60° and 70° north and south, to the poles. Air in these cells sinks over the highest latitudes and flows out towards the lower latitudes at the surface.



Global air circulation "step by step"

1 - Near the equator, the air is heated and rises, which creates a belt of low pressure.

2 - The warm air begins to move towards the poles and begins to cool.

3 - The air is cooler and heavier now. It begins to press downwards. This creates an area of high pressure at about latitude 30°.

4 - The cool air blows along the surface of the Earth outwards from this area of high pressure. Some of it blows back towards the area of low pressure at the equator.

5 - The extremely cold air in polar areas is heavy and presses down. This forms an area of high pressure. Winds begin to blow out from this

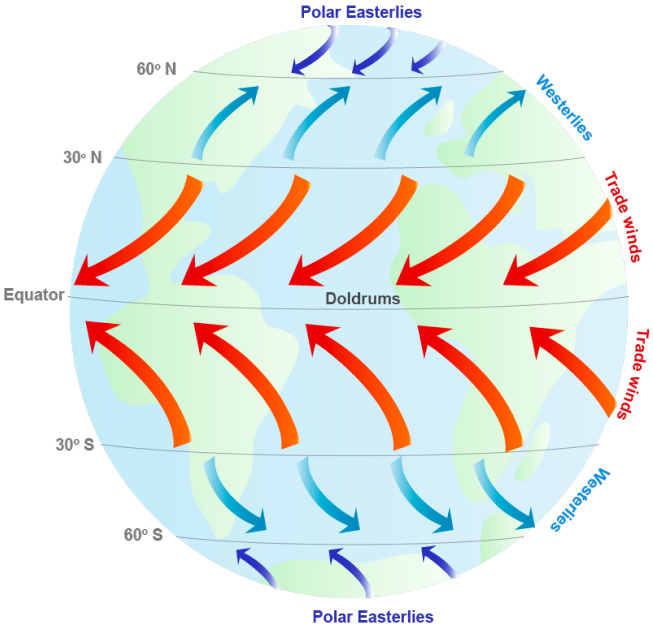
high-pressure area.

6 - At about 60°N, the cold wind from the north meets the warm wind from the south. The air rises to create another area of low pressure.

7 - A third wind system develops between the high-pressure belt at latitude 30° and the low-pressure belt at latitude 60°.

8 - The same wind patterns develop in the southern hemisphere.

Global Winds



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Doldrums : *the Inter-Tropical Convergence Zone, (ITCZ), is a belt around the Earth extending approximately five degrees north and south of the equator. Here, the prevailing trade winds of the northern hemisphere blow to the southwest and collide with the southern hemisphere's driving northeast trade winds, causing a windless zone.*

- **Trade winds :** They blow out from the Subtropical High Pressure belts. In the northern hemisphere, they blow towards the equatorial low and called North East Trade Winds. In the Southern hemisphere they blow towards the equatorial low and become the South East Trade winds. The trade winds are most regular winds of all kinds on earth. They blow with great force and in constant direction that is why they are preferred by the sailors. The trade winds bring heavy rain falls and sometimes contain intense depressions.
- **Westerlies :** They are opposite to trade winds. Westerlies blow in the middle latitudes between 30° and 60° latitude, and originate from the

high pressure area in the horse latitudes (or subtropical highs) towards the poles. Under the effect of the Coriolis force, they become the south westerlies in the northern hemisphere and Northern westerlies in the southern hemisphere. Because there is more of ocean and less of land in the southern hemisphere, the westerlies blow with much greater force than in the northern hemisphere. This also has implications in the Ocean currents. The currents in the Northern Hemisphere are weaker than those in the Southern Hemisphere due to the differences in strength between the Westerlies of each hemisphere.

- **Polar Easterlies :** They blow from the polar high pressure belts towards the temperate low pressure belts. These are extremely cold winds that come from the Tundra and Icecap regions of the poles. These polar cold winds converge with the warm easterlies near 60° latitudes and form the Polar front or Mid Latitude front. This mid-latitude front becomes the centre of the origin of the Temperate Cyclones.

Circulation of energy

On a global scale, the atmosphere's circulation and weather is an attempt to balance differences in solar energy that the earth receives across the globe. Sunlight at the tropics is intense and direct and a lot of heating of land, atmosphere, and oceans occur there. Sunlight in the polar regions is weak and indirect and does not do a good job of heating up the region. Currents in wind and ocean water carry energy from the tropics toward the poles to help balance out the energy differences across the globe.

Meteorologists are able to predict the changes in weather patterns by using several different tools. They use these tools to measure atmospheric conditions that occurred in the past and present, and they apply this information to create educated guesses about the future weather. They observe past and present atmospheric patterns and data, and apply this information to what we think will happen in the future.

Meteorologists use many different tools for different purposes. Most people are familiar with thermometers, barometers, and anemometers for measuring temperature, air pressure, and wind speed, respectively. But meteorologists use other tools as well, such as weather balloons or sea buoys for more insight into special locations, such as the troposphere or the bottom of the sea.

Meteorologists also use satellites to observe cloud patterns around the world, and radar is used to measure precipitation. All of this data is then plugged into super computers, which use numerical forecast equations to create forecast models of the atmosphere.

It's also important to observe previous weather conditions in order for meteorologists to know what to expect in the future. Meteorologists often describe the weather as a set of "patterns", because similar weather conditions tend to repeat themselves.

Now, with all that you have learnt regarding the weather on Earth, it is time for you to create your own weather forecast !

Method

Find the most recent satellite maps of your region (any weather website will show them). Study the map to understand what is happening at the moment and how the weather will change.

Tips and tricks

Blue lines are cold fronts and red lines are warm fronts.

L : Low pressure system, H : High pressure system

A blue "H" means a center of high pressure (usually calm, sunny weather).

A red "L" means low pressure (which can mean storminess). Most fronts extend from low-pressure centers.

See if you can find any lines that go around centers of high and low pressure. They are called isobars; they connect stations with equal barometric pressure, so you can see where the highs and lows are. The wind usually follows the isobars, with a slight trend in the direction of the low pressure area.

Satellite images show the amount of cloud cover. Clouds can act like a blanket helping to keep night warmer if the sky is clear. But clouds during the daytime can block the sun and keep temperatures cooler.

Questions

1 - What does the image show? Is there much cloud cover? Do you think it will increase or decrease, based on what you have learned from the weather maps?

2 - Look at the wind direction around your forecast city. Is the air blowing from colder areas toward your city, or is warmer air moving in?

3 - Will clouds or precipitation be coming, and if so, a lot or a little?