Program Summary
Timing Information
- Global Heat Budget 2:45
- Convection 5:20
- Coriolis Effect 6:47
- General Circulation of the Atmosphere 15:20
- Seasons 15:58
- Monsoons 17:31
- Synoptic Charts 19:50

Introduction
The Sun is the driving force behind all of the motions in the atmosphere. This incoming solar radiation is called "insolation". It is received and absorbed unevenly over the Earth's surface. The atmosphere's motions bring about a more even distribution of the energy.

The spherical shape of the Earth results in a big difference in energy receipts between the Equator and the Poles, leading to a big difference in temperature and resulting in high air pressures, and a flow of air away from the high pressure centres over the Poles (Polar Highs), and a flow of air towards low pressure systems near the Equator (Equatorial Lows).

The large size of the Earth results in the development of intermediate belts of air pressure - relatively low pressures in latitudes about 60 degrees (Sub-Polar Lows), and reactively high pressures in latitudes about 30 degrees (Sub-Tropical Highs), with more surface air movements (winds) from the all highs to all lows.

The rotating motion of the Earth produces a deflection of all air flows - the Coriolis Effect.

The revolution around the Sun with a tilted axis, causes the seasons and leads to a migration north and south of the Equatorial Lows following the apparent seasonal movement of the Sun, and forcing all of the pressure and wind belts to shift by an average of about 10 to 15 degrees of latitude.

The uneven distribution of land and sea disrupts the simple patterns of air pressure and air flows between them, as land and water surfaces absorb energy very differently in summer and winter, and result in greater pressure variations with some consequent different air movements that include the seasonal monsoons.

The Global Heat Budget
The Sun provides the energy that causes the atmosphere to be constantly moving. The Sun sends out into space waves of energy known as "electromagnetic radiation", travelling at 300,000 km per second.

The tiny fraction that is intercepted by the Earth is called insolation (incoming solar radiation) but the amount arriving each minute is approximately equal to the total of all electricity that the world's power stations generate in a year.

The insolation does not become "heat" until the rays are absorbed by the ground or greenhouse gases. The microwave energy in a microwave oven doesn't produce heat until it is absorbed by foods or liquids.

Solar radiation passes through the atmosphere at the speed of light and doesn't become heat until it is absorbed by the Earth's surface. However, because of the Earth's curvature, the insolation reaches the Earth unevenly. At the Equator, it arrives at or nearly perpendicular to the Earth's surface; near the Poles, it arrives at a low angle and is spread over, and has to be absorbed to produce heat.

Clouds, snow and light-coloured surfaces reflect a lot of the energy back into space, while dark surfaces will result in more absorption and greater heating. Reflection is greatest at low angles.
The atmosphere is transparent, so the Sun cannot heat the atmosphere directly. The atmosphere obtains its heat from the Earth's surface and is warmed from the bottom up. It is fortunate for us living at the bottom of the atmosphere, that the Sun doesn't heat the atmosphere from the top down like the oceans are heated by absorbing the Sun's rays mainly at the top, and where the sea at the bottom is at its coldest. Heat from the Earth's surface is passed up through the atmosphere as infrared radiation (heat radiation, like that coming from an electric radiator). For a time, the gases of the atmosphere hold onto the heat and pass it up slowly.

As a result the atmosphere remains fairly warm, even when the Sun is no longer shining at night. If the energy left our planet as quickly as it came to it (at 300,000 km per second) we'd all freeze to death at night. This slow movement of heat energy up through the atmosphere is called the "Greenhouse Effect" as it operates on the same principle as a glasshouse, or greenhouse, that keeps plants warm (the light easily comes through the glass and is absorbed and turned into heat which heats the air inside the glasshouse, but this heat had difficulty getting out through the glass).

As infrared radiation passes through some gases more slowly than it does through others, gases like carbon dioxide, methane and water vapour tend to hold onto heat longer and help to create more warmth in the atmosphere, than other gases like oxygen and nitrogen. It is fortunate that we have these "greenhouse gases" but if their quantities increase, as is our present concern, the atmosphere will become warmer in time.

Eventually, all energy that came to the Earth as insolation must be returned to space, although in a different form, and there is a continuous natural balance known as the "Heat Budget".

**Air pressure and air movement**

Air over hot surfaces will become hot and it will expand and become lighter, producing less pressure on the Earth - an area of low air pressure. Air inside this "low" will rise in convection currents. Air over cold surfaces will become cold and it will contract, become heavy, and produce an area of high air pressure where air is pushing downwards onto the Earth. To bring about a balance, air will move from the high pressure to the low pressure areas, and this horizontal air movement is called a "wind".

Winds therefore are found blowing out of the cold Polar regions, and towards the hot Equatorial regions, but they are prevented from moving in direct paths. Because of the Earth's rotation, there is a "Coriolis Effect", and winds are deflected because the Earth's surface is moving at different speeds beneath the moving air. This causes all winds to be deflected to the right of their expected paths in the Northern Hemisphere, and to the left of their expected paths in the Southern Hemisphere (Ferrel's Law).

Because of the Earth's large size and the wind's deflection in each hemisphere, intermediate belts of air pressure develop with three circulating donut-shaped cells of atmosphere (eg the Hadley Cells) on each side of the Equator. As air spreads out from the Polar Highs, relatively low pressures form in latitudes about 60 degrees (the Sub-Polar Low Pressure Belt), and as air rises in convection currents near the Equator, moves back towards the Poles in the upper atmosphere, and deflects into a west-to-east flow (the Jet Streams), it builds up into relatively high pressures in latitudes about 30 degrees (the Sub-tropical High pressure Belt). The Earth ends up with alternating belts of high and low pressure spaced about 30 degrees apart.

Between each of these belts of air pressure there is surface air movement from all highs to all lows, with deflections to the right north of the Equator and to the left south of the Equator, and a returning flow of air into the upper atmosphere in the opposite direction with similar deflections. Between the Polar Highs and Subpolar Lows, there are surface Polar Easterlies. Between the Subpolar Lows and the Subtropical Highs there are strong Westerlies or Roaring Forties. Between the Subtropical Highs and the Equatorial Lows, there are the prevailing Northeast and Southeast Trade Winds.

Storm belts occur in each of the low pressure belts where there is converging air. Where the Westerlies meet the Polar Easterlies in the Subpolar Lows or Polar Front, the reactively warm Westerlies will be forced to rise over the heavy cold Polar air and much rain will result. Dry weather is typical of the high pressure belts. Most of the world's deserts occur in the Subtropical High zone around 30 degrees. Here, air is pressing down and becoming warmer. Water evaporates producing very dry weather.

**The General Circulation of the Atmosphere**

If the Earth had a totally uniform surface (eg all land, or all water) it would have continual motions of air in its donut-like atmospheric cells, and the simple set of alternating bands of high and low air pressure with the surface wind belts in between that we call the "General Circulation". However, because of great variations in surface absorption of energy, the real-world situation is only an approximation of the pattern as described, although we can easily recognise belts of pressure like the Equatorial lows and Subtropical Highs (Horse Latitudes), and wind belts like the Trade Winds and Westerlies in all parts of the world. The simple pattern of the General Circulation is affected by the Earth having a tilted axis as it revolves annually around the Sun, and by the fact that its surface is an uneven mix of land and water.

**Monsoons**

With its tilted axis the hottest part of the Earth changes its position through the year (23.5 degrees north in July, and 23.5 degrees south in January). The Equatorial Lows that form over the hottest areas of the Earth tend to follow this...
seasonal change, and they cause all of the wind and pressure belts to shift slightly by an average of about 10 degrees in the year. As land surfaces become hotter than bodies of water, these lows are most intense over land areas. If there is mainly ocean at or near the Equator, as there is in the area between Asia and Australia, there will be little heating of surfaces there, but the continents well to the north and the south will build up a great deal of heat when the Sun is overhead each summer. On these occasions, intense low pressures will form over lands well away from their normal equatorial latitudes, and cause the normal circulation of the atmosphere to be totally disrupted.

Instead of Trade Winds flowing towards the Equator from either side, there will be a flow of air across the Equator from the Subtropical Highs in the hemisphere experiencing winter (Australia in July). With this air movement being deflected by the Coriolis Effect, the winds take a path towards the left (to the west) while coming out of the Hemisphere, but they “hooked” to the right (to the east) after crossing the Equator and moving towards Asia in the Northern Hemisphere.

These winds are called “Monsoons” - seasonally reversing winds. They blow from Australia to Asia in the months of June, July, August and they blow from Asia to Australia in December, January, February.

They are dry winds leaving the highs of the winter continent, but they pick up moisture as they travel, over water, towards the summer continent and bring rain as they move in over these lands. Because of this unusual air flow, lands experiencing the Monsoons are very wet in summer and very dry in winter.

A world map shows the location of the intertropical Convergence Zone (the location of the Equatorial Lows) in January and July.

The Monsoon System operates where these belts are most widely separated, and where there is mainly water in between. As the map suggests, there is likely to be little or no monsoonal effect in South America, a slight effect in parts of Africa, but major effect in the Australasian region.

**Synoptic Charts**

From what is demonstrated in the video, it will be obvious that air pressure controls air movement over the surface of the Earth. It is important therefore to know what patterns of air pressure exist over a country at any certain time.

Air pressure is measured several times a day at all meteorological stations, and from these records, air pressure maps are drawn (called “synoptic charts” or “weather maps”) with patterns like the contour lines of a topographic map.

Having established the air pressure patterns, we can work out how the wind will blow. They will always move out of highs and into lows, but the Coriolis Effect will cause them to be deflected and they will always spiral out of highs (anticlockwise in the Southern Hemisphere) and spiral into lows (clockwise in the Southern Hemisphere), with the directions reversed in the Northern Hemisphere.

Knowing how the air will move around the patterns of highs and lows allows us to see where there may be rain coming in with winds from the sea, or dry weather from the interior of the land, or cold weather being brought up from southern areas, or hot weather from the tropical north. The synoptic chart allows us to make some predictions about our weather.
ATMOSPHERIC CIRCULATION

Listen carefully to the video and fill in the blank spaces.

1. All planets with ______________________ have winds depending on how much ____________ they receive from the Sun.

2. The _________ provides all of the energy leading to ________________ in our weather.

3. ________________ shade the Earth and so keep our atmosphere ________________.

4. Sunlight warms the __________________ of the Earth which then radiates ____________ up into the atmosphere.

5. When air is cooled over __________ it sinks forming a ________________ ____________.

6. Because of the Earth’s ________________ no wind can move in a ________________ line.

7. So, due to ________________, winds coming from the Poles are ________________.

8. Different parts of the Earth’s surface are ________________ at different _________.

9. In the ________ atmosphere as air from the _______________ heads towards the ________, it has to squeeze into a smaller ________.

10. __________ are traditionally named according to the ________________ they come from.

11. High pressure systems form over the __________ in this region and this means very ____________ ____________.

12. All of the ________________ and ________________ systems form what is known as a general ________________ of the atmosphere.

13. On Earth we have ________________ because the __________ is tilted at ________ degrees from the vertical

14. So as the Earth changes its ________________ to the ________, the seasons ________________.

15. The various ________________ ____________ stay aligned with the sun as the Earth ____________.

16. Monsoons are seasonally ________________ winds.

17. This causes the tropics to have only two seasons, the ________ and the ________.

18. ________________ ________________ deflects wind coming from the equator.

19. The ________________ cyclones and anti cyclones spiral, depend on which _________ of the equator it is on.

20. Despite sophisticated _________________, it’s still a ________________ to predict our weather.