Sylvia Knight

Launching a balloon to the edge of space

This photo of the Earth was taken from 21 000 m up, just before the weather balloon burst.

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atmosphere
weather
pressure
gas laws

On 22nd May 2013, a weather balloon was launched from a school playing field in Chorley, Lancashire. The balloon travelled almost 21 km up and landed near Loughborough, 138 km away, carried by the wind. ***Sylvia Knight*** *explains what happens when a weather balloon is sent up.*

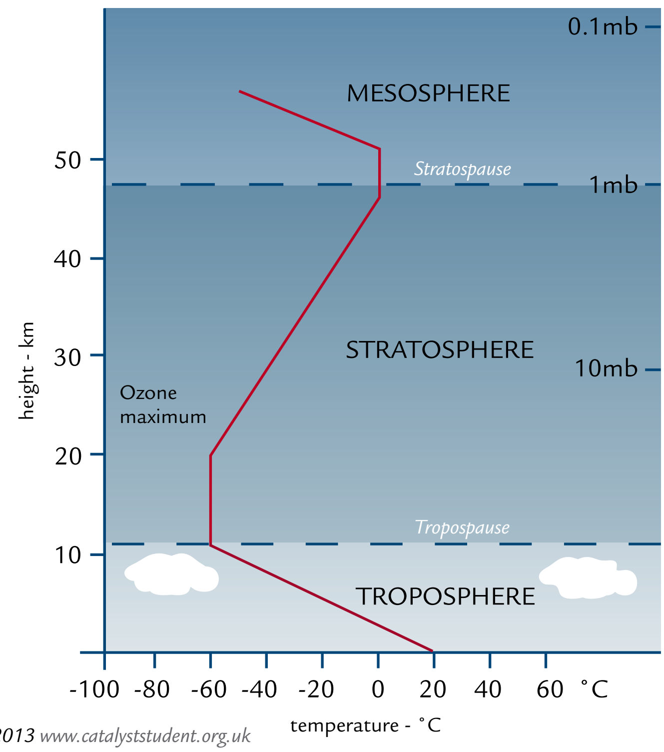
What is the edge of space? It is technically defined as being at the Karman Line, 100 km up. Weather balloons don't get anywhere near that high, but at an altitude of 21 km, which is much higher than aeroplanes normally fly, you can get a good view of the curvature of the Earth and the thinness of the atmosphere.

So what happens to a balloon as it rises through the atmosphere? Air pressure is simply a measure of how much air there is above you. As the balloon goes up through the atmosphere, the amount of air above it reduces, and so the pressure falls.

As the pressure falls, the balloon expands. Eventually it gets so big that it bursts, and falls back to the ground. Our balloon had a parachute attached so that the instruments didn't fall too fast, potentially damaging them and anything they might land on.

As the pressure falls, the temperature falls too. So, in the troposphere (the lower atmosphere, which contains all our weather), it gets colder as you go up. However, there is ozone in the stratosphere, which is the next layer up. Ozone absorbs the Sun's ultraviolet rays and re-emits them as heat, warming the stratosphere up. So it actually gets warmer again.

Have you ever thought about what it sounds like when a balloon bursts in space? Sound is a pressure wave that needs molecules to be transmitted. This means that there is no sound in Space. In the stratosphere, there are still air molecules but they are much further apart than they are near the ground. This means that sounds are a lot quieter. Also, because it is colder, the speed of sound is slower than it is near the ground.



Balloons and Boyle's law

As the balloon rises, the pressure p outside it decreases. If the temperature is constant, Boyle's law applies:

$p \times V$ = constant

where V is the volume of the balloon. So, if the pressure falls from 1000 mb to 100 mb, the volume of the balloon must increase by a factor of 10 – or, if you assume the balloon stays roughly spherical, the radius approximately doubles.

In fact, the graph on page 15 shows that the temperature drops as the balloon rises. The relatively warm air inside the balloon loses heat to the air outside the balloon. A decrease from 20 °C to -60 °C (293 K to 213 K) is a decrease of about 20%, so the balloon will expand less than predicted by Boyle's law.

The moment the balloon burst

The team from Manchester University and the Royal Meteorological Society launch the balloon with the school STEM club watching. You can see the balloon, the red parachute and the box containing the camera and GPS tracker underneath.

The balloon travelled from Chorley to Loughborough in 90 minutes, an average speed of almost 100 km/h.

Hugo Ricketts with the parachute and the box containing the camera and GPS tracker, before the launch

Sylvia Knight asked Dr Hugo Ricketts, Research Scientist at Manchester University, to describe what we can learn using weather balloons.

Weather balloons can give us detailed information about the structure of the atmosphere and how its temperature, pressure and humidity change as you go up. We need this information to feed into the computer models which we use to make weather forecasts, and to improve our understanding of how the atmosphere works. We also get information about the atmosphere from weather instruments on the ground, on ships, on buoys and aircraft, and from radar and satellites.

What is a radiosonde?

A radiosonde is a collection of instruments which is usually attached to a weather balloon. It includes a thermometer, a humidity and pressure sensor, and a GPS antenna which transmits the data back to a receiving station on the ground, as long as there is a line of sight between the radiosonde and the receiving station. As soon as a hill or building gets in the way, we lose contact with the balloon. You can work out the wind speed from the GPS too. The radiosonde transmits data once every second. We don't normally find the radiosondes once they come back to Earth, although they are quite valuable, so they have a note on them asking anyone who finds one to post them back.

How well did the radiosonde work on this launch?

We didn't get data back from the radiosonde all the time, but we got enough to show how the temperature, pressure and humidity changed through the atmosphere.

You can see the data from the radiosonde on page 15.

Teacher Sean Hardeley collects the parachute and camera box where the balloon landed in a field near Loughborough, Leicestershire.

Sylvia Knight asked Sean Hardley, science teacher, to explain why the project was organised.

This was a joint project between the STEM club from Holy Cross School in Chorley and the North West Local Centre of the Royal Meteorological Society. The balloon was carrying a camera, a GPS transmitter and a radiosonde, an instrument which transmits measurements by radio waves back to Earth.

Why did you want to launch a balloon?

We have a very active school STEM club, and we wanted to do something completely different from anything that the students were already likely to cover in class.

What did the STEM club do prior to the launch?

The students took part in a range of activities in the after-school STEM club. These included demonstrations with different gases, experiments on the effects of pressure and learning about how pressure changes with altitude. We looked at trajectories with PE equipment and learnt how to calculate landing sites, taking wind speed and direction into account.

What weather were you hoping for?

We were hoping for clear skies, so that the camera would get good pictures of the Earth. However, more importantly, we had to have the right wind conditions. To be able to launch a balloon, you have to have permission from the Civil Aviation Authority. Our permission said that the balloon couldn't go anywhere near Manchester Airport, so that was one concern. Also, we didn't want it to land too far away, in the sea or anywhere else we couldn't retrieve it, so we used trajectory forecasts. These combine the wind forecast with information about how fast the balloon rises and what altitude it bursts at, to predict roughly where the balloon will go. The forecast we had was very accurate, which helped us find the balloon.

What were the risks?

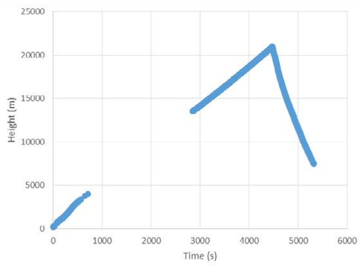
Not being able to find the balloon and the camera! Although we would still have the data which the radiosonde had transmitted, what we really wanted were the images the camera had captured.

Was it worth doing?

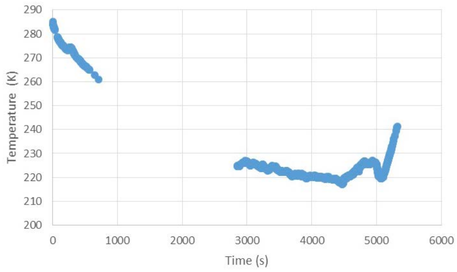
Yes, it was so exciting to watch the balloon's progress, and then use the GPS tracker to find it – its location was less than 5m from where the tracker said it was. We couldn't believe it when we downloaded the photos and they were so good.

Data from the radiosonde

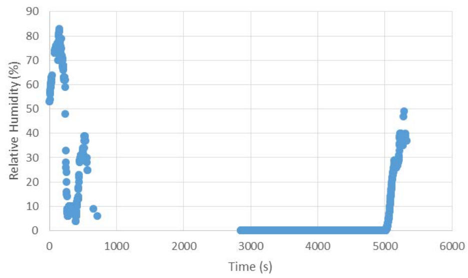
Instruments attached to the balloon gather data during the flight. The radiosonde transmits this data back to the ground station. In these graphs you will see that there were periods of time when the radiosonde lost contact with the receiving station.



The balloon rises at a pretty constant velocity (the line is straight) before bursting at about 21 000 m, then falling much faster. Notice how the balloon slows down as it falls and the atmosphere becomes denser.



The temperature falls as the balloon rises through the troposphere. In the lower stratosphere, the temperature is pretty constant at 220 K (-53 °C). The temperature rises again once the balloon starts falling.



The relative humidity is a measure of how much water is in the air. Cloud droplets can form when the relative humidity is close to 100%, so here you can see that the balloon reached the cloud base at about 150 s into the flight, or 1km up. There is virtually no water vapour in the stratosphere.

Look here!

You can see some video highlights from the launch, and find out how to arrange your own, on MetLink *http://www.metlink.org*

Sylvia Knight is Head of Education Services at the Royal Meteorological Society. She has a PhD in meteorology from the University of Reading and has worked in climate science. You can read Sylvia's article about cloud formation in Catalyst Vol 21 no 4.

Make your own aneroid barometer

A barometer is any device that measures atmospheric pressure. Weather forecasters use changes in pressure to help predict the weather.

What to do

Find a large, open-mouthed jar or tin – avoid sharp edges.

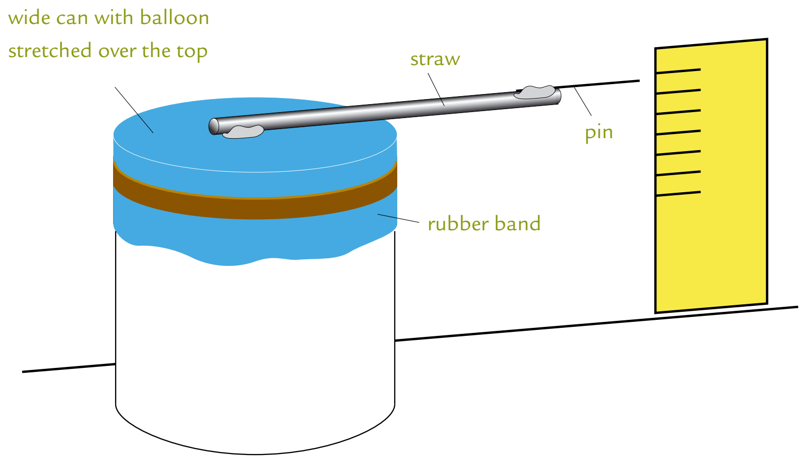
Cut a sheet of rubber from a balloon, stretch it over the mouth of the jar or tin and fix it in place with a rubber band.

Glue one end of a drinking straw to the centre of the rubber. Cut the other end (which will stick out beyond the rim) to form a point.

What happens

As the atmospheric pressure changes, it presses down more or less strongly on the rubber sheet, causing the free end of the pointer to move up or down.

Arrange a ruler next to the pointer to act as a scale. Look at predicted pressures in a local weather forecast – can you see changes in the position of the pointer as the pressure changes?



Aneroid means without fluid – many barometers use a liquid, usually mercury, but this one uses a trapped volume of air and no liquid.