National Simultaneous Storytime ...from space!

NSS2021 Experiment - Information Sheet

The Science Challenge: Background on the Thermal Balance of the Earth

A worldwide controversy has been developing over the past few decades on global warming. Is it real or not? Does human activity contribute to it? The second question is relevant only if the answer to the first is that global warming is real.

The Earth science community has been studying the Earth's temperature for many decades and the research shows that we are experiencing global warming. The analysis of temperature trends also points to catastrophic effects if global warming continues. And it is quite clear that humans are having an impact. Scientists have been taking temperatures around the world over a long period of time and show an increase of the yearly average temperature of 0.8 degrees over the past 100 years and an increase in the temperature of the oceans of 1.1 degrees over this time period. The research also shows that human activity is having a significant impact at a global scale.

So why is there an apparent controversy? If the science community is claiming that global warming is real and that the human contribution is real, why would others question this, and on what basis?

Perhaps a simple answer to the first of those two questions is that many people might find it inconvenient to accept this warning from the science community. Perhaps for political reasons, perhaps for economic reasons, perhaps this comes as a threat that challenges long held beliefs of the place of man in the world system. Irrespective of the reason for not wanting to accept it, the fact is that global warming is real and human activity is contributing to it.

The research that has established global warming is based on a simple principle: measure temperatures over a great deal of the Earth and over a long time period. Simple arithmetic then shows what the average temperature is doing. But the Earth is so large that very many observations of temperature are required from locations all over the Earth and quite a bit of arithmetic is required to analyze the data. Millions of measurements have been made over large areas of the Earth. This has been ongoing for several centuries, and over the past six decades satellite observations have been

used to provide very complete temperature observations of the whole Earth. The overall result points to global warming and to human impact. Would anyone question that winter is colder than summer? How much colder is determined from similar observations taken over areas that are small compared to the area of the whole Earth; for example, the area of a country, or of a province within a country, or a city within a province.

The science principles are also quite simple: over a short time span the Earth is in thermal balance: that is, the heat coming in from the Sun is in short term balance with the heat that the Earth radiates to space. But that balance depends on three basic things: the energy radiated by the Sun, the temperature of deep space, and the nature of the surface of the Earth, which effects how well the Earth absorbs heat from the Sun and how well it radiates heat to space.

The Basic Principle of Thermal Balance

The temperature of any object is governed by just a few simple principles:

The rate of heat absorption by the object.
The rate of heat transmission from the object to its surroundings.
How much heat will required to change the objects temperature by, say, 1°C.

For example, you can feel heat transfer if you hold your hand close to but not touching a light bulb or other warm object. The heat is transferred by radiation. How warm will your hand get? This depends on the power of the light bulb and how close your hand is to the light bulb. But it also depends on how well your hand absorbs the heat and how well your hand transfers heat to its surrounding, mainly to the air surrounding your hand. As your hand warms it will transfer more heat to the air until there is a balance between the heat being absorbed and the heat being transferred to the air.

This basic principle of thermal balance is always at work in many daily activities.

What Governs the Temperature of the Earth?

The surface of the Sun is very hot, about 5770K (5500C), and it radiates energy in all direction. Part of this radiated energy arrives at the Earth. The Earth absorbs some of this energy and tends to warm up. But the Earth in turn radiates energy in all directions into space, which has a very cold background temperature of about 4K (-269C). **The temperature of the Earth comes from the balance of the Earth absorbing energy from the Sun and radiating energy to deep space.**

How well the Earth absorbs the energy received from the Sun depends on nature of the Earth's surface and on its atmosphere. How the Earth radiates energy into space also depends on the surface properties of the Earth and on what is in the atmosphere.

While the energy from the Sun is quite constant and space remains very cold, the temperature balance of the Earth thus depends on the characteristics of the surface

and on what is in the atmosphere. **If the surface characteristics of the Earth or the atmosphere change then the Earth's temperature will change**.

The Citizen Science Activity
The activity is designed to shed some light on this large and very important issue. We want to obtain a great number of temperature observations all around Australia and to share these measurements with all the participants. By plotting these on a map of Australia we can learn two key things: first, the measurements are quite easy and will lead us to better understand how temperatures around Australia vary; and second, we can obtain these only where people live, leaving out much of the land area of Australia, and almost all of the sea area around Australia. This makes it quite hard to obtain a good estimate for the average temperature of Australia.

We can compare the temperature obtained as part of this project to temperatures obtained from satellites that are in orbit around the Earth. These satellites have a much broader view of the Earth and can provide temperature estimates in areas where it is not possible to make ground based measurements. In the areas where the activity gives us observations, we can compare the temperatures observed on the ground to temperatures observed for the same areas from satellites. Satellite data provides temperatures over a much more extensive areas, essentially over all of Australia, and in actuality over the whole Earth. **Developing an understanding of issue such as global climate changes requires these extensive measurements and requires that these made over long time periods.**

The citizen science activity is designed to let student explore some of the things that effect how energy is absorbed and how scientists' study and monitor the thermal balance of the Earth. There are two main elements to the activity:

1. To explore how temperature varies across Australia by:
    a. Making temperature measurements across Australia and performing some of the arithmetic analysis required to explore large scale temperature variations.
    b. See how these compare to measurements made by satellites that monitor the temperature (and many other things) of the whole Earth.
2. Explore how the nature of the surface of the Earth effects the temperature that is reached by:
    a. Measuring the temperature over different surfaces: asphalt, grass, soil, water.
    b. Look at the Thermal Balance experiment done on the ISS which models the Sun-Earth-Space system.

Experiment Connection
The temperature of the Earth depends on the thermal balance of the Earth: the Earth absorbs heat from the Sun and radiates heat into space. The balance depends on the

surface characteristics of the Earth and its atmosphere. If these characteristics change then so will the average temperature.

The ISS experiment is an analogue for this balance. In the experiment the temperature/thermal balance depends on the properties of the balls in the experiment. If we change the properties of the surface of the balls, this changes the thermal balance of the balls.

The same principles are at play for the ball in the experiment as for the Earth. If we change the properties of the surface of the Earth and the atmosphere the temperature that gives thermal balance for the Earth will change.

On both our experiment and the Earth there is a heat source and a heat sink. For Earth, the heat source is the sun and the heat sink is space. For the experiment, the heat source is a light bulb and the heat sink is a cooling unit. The experiment system is a model for the Sun-Earth-Space system. In both cases, our ISS experiment and the Earth, the heat source and the heat sink do not change. The only thing that changes is what we do to the surface of the balls or the surface of the Earth.

When we change the surface of the ball in the experiment from white to black, we will get a different temperature on the surface of the balls. When we change the surface of the Earth from trees, oceans and dirt to concrete, bare fields and roads, and increase the CO_2 levels in the atmosphere; we will get a different temperature of Earth and its atmosphere.

Guideline for the Citizen Science
Learning Objectives:
We would like students to:

1. Become involved in science and learn from their involvement.
2. Learn that data is of key importance to gaining knowledge and understanding.
3. Obtain temperature data and share the data with other kids in Australia.
4. Learn about Satellite data- how does a satellite measure temperature of the Earth and how this helps develop understanding of the Earth.
5. Determine if their temperature readings are consistent with satellite data.
6. Learn that satellite data helps to give a full picture of what is happening with temperatures across Australia.
7. Use arithmetic to find average temperatures.
8. Use mapping skills to map temperatures around Australia.
9. Understand that global warming measurements have to be done over the whole Earth, over a long period of time, 100 and more years.
10. Understand that the science principles that govern the Earth's thermal balance can be studied locally.
11. Understand that when scientists talk about global warming, they are utilizing data gathered over a long period of time, actually much longer than 100 years.

Overview of the Citizen Science Project
We would like to see students in classrooms and kids all around Australia do the following:

- Take the temperature on 12 May 2021, in the morning between 10:00 and 11:00am local time.
- Determine the average temperature for the area around their school using the data gathered by their classmates.
- Determine the average temperature of a wider region using the average temperatures determined around several schools within their region, for example within a 50km radius.
- Enter the average temperature for a region into survey Monkey. This will be shared in a spreadsheet so that students around the country have access to.
- Students around the country can then write the regional temperatures on a map of Australia to see the variations in temperature around the country.

After students have done all this work, the satellite data can be overlapped. This will allow students to see the temperature variation over the entire country and surrounding oceans. They can check to see if their data is similar to the data from the satellite observations and learn that satellite data provides much more detail for understanding the Earth.

Guideline for Implementation
To ensure that observations are comparable:
Observations should be made outside at approximately the same time of day locally.

The temperature measurement should be at a height of 6 ft above the ground. This height should be recorded by the students. Their location should also be recorded.

We are trying to measure the air temperature. Observations should not be with direct sunlight on the thermometer. The observation could be made in a shady area where there is a bit of wind to keep air moving past the thermometer. If it is done in sunshine a sheet of white paper should be used to shield the thermometer from direct sunlight.

Have the students note what the area around them is like: is it over grass, over pavement, close to their home, etc. To have comparable measurements the ideal would be over grassed area, not over asphalt.

It may take several minutes for the thermometer to reach its own equilibrium to obtain a more accurate measurement.

We should not expect all measurements to be the same. The students should not let the result that others obtained impact their own observation. The temperatures could differ because of location, different surroundings, calibration of the thermometers, etc.

Effect of the Surface and Height on Temperature
The majority of the Sun's energy is absorbed by the surface, and this in turn affects the temperature of the air. We can expect that the temperature will vary with height. Some students could be asked to explore this.

While not part of the planned activity a follow on investigation could be to exploring this. You could have some students measure the temperature at several heights, in one foot increments from one foot to 6ft. The variation with height will depend on the surface, over asphalt in sunlight there will be more variation with height than over a grassed area. The height variation will also depend on time of day. Very early in the morning the temperature of the air will be lowest right next to the surface. At noon and mid-afternoon, the temperature will tend to be highest right next to the surface.

Analysis of the Data
The objective it to obtain an appreciation of how the temperature varies over large areas, in this case across the whole country. This requires doing some arithmetic on the observations. The analysis requires only basic arithmetic: adding and dividing.

Determine averages from several measurements:

a. Determine the average temperature for the area around the school: average the observations from all of the students in a classroom.

b. Determine the average temperature for a region: average the observations from several schools in a town, city or region. To do this all schools in an area need to share the average temperature for the area around the individual schools.

c. Plot the temperatures of the region on a map of Australia. They will need to:

Locate the regions on the map.

By hand print the regional temperatures on all regions based on the data obtained for all regions.

Try to draw lines that connect places of equal temperature, perhaps for every 2°C.

From the mapped temperatures estimate the average temperature of Australia.

Observations:

To get a good understanding of the temperatures of Australia requires a lot of measurements.

You need to do some arithmetic to determine the averages temperature from all the individual observations.

To obtain the average for a region the averages for a group of schools needs to be calculated.

To get an average temperature for Australia another average needs to be calculated.

By plotting the temperatures on a map, you can see patterns of how the temperature varies across the whole country.

Appendix A. Types of thermometers

There are many different types of sensors for measuring temperature. We all gain experience with some of these. For example, the mercury-based thermometer using when we have a fever, or the modern form for this that could be a digital thermometer. Any type of thermometer can be used in the project. A few examples are:

1. The mercury thermometer. How does this work?

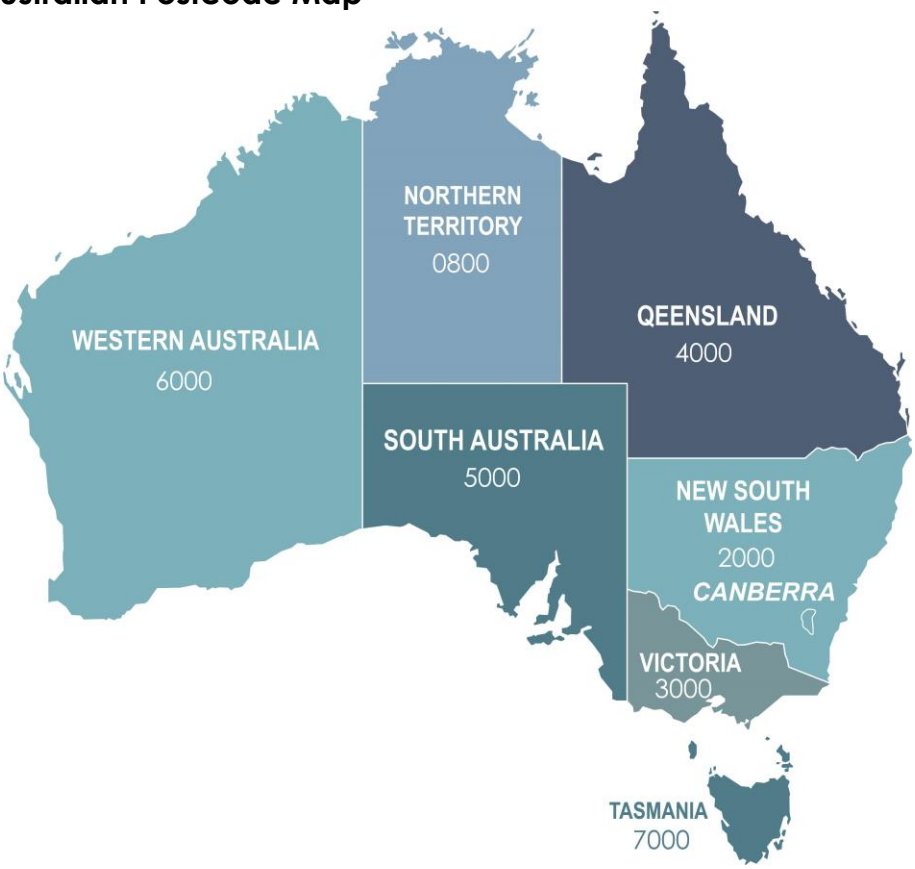
2. Bimetal strip thermometer; for example, a meat thermometer. How does this work?

3. Thermocouple thermometer. Simple and inexpensive. Requires some electronics but thermocouple-based thermometers can be purchased at quite low cost.

Any type of thermometer can be used. Most homes will have some type of thermometer, perhaps hanging outside. Some that can be purchased for few dollars are fine. For measurements taken at the school one thermometer can be shared by many students.

How can the temperature of the Earth's surface be measured from a satellite? None of the above type would work as they all need to be in contact with the object whose temperature is being measured. Satellites use infrared sensors to determine the surface temperature of the Earth.

Appendix B: Australian Postcode Map



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