Temperatures and Space
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Science Time From Space

There were many really good questions from a great many students. Many questions were quite similar. In the following I provide a response in three areas where many questions were asked. I could not answer all of the questions due to the limited time I could devote to this.

Temperature Balance: of the ISS, of parts of the ISS, and of You
There were quite a few questions about temperatures on the ISS. The ISS must achieve thermal balance just as does the Earth. Look at a photograph of the ISS: you will see the large solar panels. These absorb sunlight and generate the electricity required to run all the equipment on the ISS: it is almost a fully electric space craft. But every bit of energy absorbed by the station must be radiated back out of the station. Otherwise the ISS would overheat. Look again at photographs of the ISS. Do you see anything on the ISS that might help it radiate energy out to deep space? Spend time studying photos of the ISS to try to figure that out before reading further.

You might have found some gray panels attached to the ISS structure. These gray panels are the radiators that radiate energy out space to keep the ISS in thermal balance.

The electricity used by the equipment inside the ISS all ends up as heat. You have probably noticed that a TV, a telephone, an iPad or a computer all become warm as you use them. In the ISS most electronic items are mounted onto metal plates that have cool water running through tubes within the plate. The heat is transferred to the water which flows through pipes to heat exchangers that transfers the heat to an external cooling system that used another liquid to pump the heat to the external radiators. These radiate the energy to space. There are many things in the ISS that have to be in thermal balance. For example the radiator panels by themselves must be in thermal balance: the heat coming in through the Freon flow is transferred to the material of the panels and is radiated to space. There is a balance between the energy coming into the panels and that radiating from the panels out to space. The Freon flow is controlled to keep the radiating panels at a good working temperature as they radiate energy to space. These panels also receive heat from the sun and from the Earth, They must

radiate all the energy they receive to maintain their own balance. These panels keeps the ISS as whole in thermal balance, where the energy coming in from the Sun through the solar panels and from direct sunlight is radiated to space by the radiator panels. Just as the Earth does, the ISS reflects some of the sunlight, which is how we can sometime see it going overhead and how we can see it in photographs.
The bottom line: every object must be in thermal balance to stay at a constant temperature, even you. How do you regulate your temperature? Measure your temperature over several days. Does it change? How much? If it is cold outside how do you maintain your temperature? If it is hot outside how do stay cool? So all objects at constant temperature are in thermal balance with their surroundings. That does not mean they are all at the same temperature.

By controlling the thermal balance the temperature inside the ISS is kept constant, much as your heating system in your house keeps it at a constant temperature. We should think about the Earth in the same way: we need to control what we do to the Earth so that it can keep its temperature fairly constant for a very long time: hundreds of years.

Temperature in the Vacuum of Space
There were many good questions about the temperature of space itself. These are really good questions, and not quite simple to address.
The first thing we must consider is: what is space? It is easy to just use that word. But what does it mean? What image do you have in your mind what you use the word 'space'; or when you ask a question about the temperature of space? It is a valid and good question. We just need to be clear about what we are asking.

We can explore this is several ways. If you have a small globe of the Earth in your classroom you could ask the questions of that as well. The answer may come a little easier: that globe is pretty small and is surrounded by the air in your classroom. So what temperature will that little model Earth take? How about the temperature of the air? Use a thermometer to measure the air temperature. Then place the thermometer in contact with the globe. Are they at the same temperature? Try the following experiment: using scotch tape attach a small temperature sensor against one side of the globe. Cover it with some foam to insulate it from the air. Then use a hair dryer to heat the other side of the globe. Does the temperature of the globe change? Does it change on the side getting air from the hair dryer? On the opposite side? It may take some time but the globe will reach a balance, with one side quite warm, the other side will also be warmed, but not as warm. It will settle into thermal balance, even a balance with one side warmer than the other.

Then turn the hair dryer off and keep measuring the temperature on both sides of the globe. The globe will settle back to thermal balance with the air, with the whole globe at room temperature. This may take some time, perhaps a half hour. Try to explain what you observe when you are heating the globe and when you are letting it cool.

So what about the Earth as a whole? While it orbits the sun it is surrounded by…. space. You may have heard that space is completely empty. That is a common myth. Space is not completely empty. There are a great many molecules in the space surrounding the Earth. When we ask what the temperature of space is, we should be thinking of this as the temperature of the 'space atmosphere' surrounding the Earth. There is a lot less air on space compared to near the ground, but it is not empty.

The Earth in its orbit around the sun is surrounded by the 'space atmosphere' and the ISS in its orbit around the Earth is also surrounded by the same space atmosphere. That atmosphere is actually quite hot: about 1,600 ^{o}C. While hot the space atmosphere is so thin it has little effect on the ISS. The thermal balance for the Earth and also for the ISS is the balance between radiation from the Sun and radiation out to deep space.

The gases (mainly hydrogen and oxygen) that make up the space atmosphere are quite 'hot'. But when the astronaut is outside the ISS in a space suit his or her temperature is mainly affected by the balance of solar radiation coming in and IR radiation going out.

Normal thermometers would not be much good at measuring the temperature of the gases that make up the space atmosphere. Any normal thermometer will also achieve a balance between radiation from the sun and its own radiation to deep space. To measure the temperature of the gases requires a device that can sense and measure the energy of specific types of molecules. There are a number of ways this can be done. A simple way could be to place a flat plastic surface outside the ISS and measure how the surface is worn away by interaction with the gas molecules. The surface will degrade when it is bombarded by the high energy molecules. Many tests would be required on the ground to calibrate this slow acting 'thermometer'.

Climate Change and its Importance

Climate refers to how weather changes over very long periods of time, such as hundreds of years. The sun and deep space remain quite constant over hundreds of years. The main thing that affects climate is what happens on the surface of the Earth and in the Earth's atmosphere. To track climate change we need to study the whole Earth over long time periods. Scientists have been doing this for more than 100 years and have determined the history of the Earth's temperature for many thousands of years. We know that there have been ice ages in the past and periods of much higher temperatures than we have now. We also know that the cold and warm periods can last for thousands of years. We also know quite a bit about natural contributions to these changes, but we need to know a lot more. We also know that humans have and are having a big impact on the Earth's temperature especially over the past two hundred years, and we know that this human effect is increasing. And we know that this is affecting many species, for example polar bears are threatened because sea ice in the Arctic is decreasing in area.

To really understand the Earth and its climate requires a great amount of data over a long period so that long term changes of global temperatures can be determined to a fraction of 1 °C even as daily changes in local temperatures may by 20 °C and variations over a year in a small area such as a city may be 50 °C or more.

Unless we come to understand the Earth's climate much better than we do now we will not be able to make the important and difficult decisions to avoid global warming. We must change what we have been doing. We must start thinking of the Earth as the most important place to look after so that humans and the many other species on the Earth can continue to live healthy lives for centuries to come.

The future of the Earth is your future. The more you learn about the Earth and about science the better you will be prepared to look after the Earth and your own future.

The only way to change the human contribution to global warming is to change what humans are doing.