What Controls the Surface Temperature of Earth?

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(All temperatures Celsius and near approximations)

Earths surface temperature is determined by many factors, energy from the sun is its major source of heat, plus minor amounts of energy from its hot interior, and from cosmic rays. However, for any given input of energy its atmosphere determines its final temperature.
The temperatures of the earth and its moon amply demonstrate the importance of a planets atmosphere, as also do the temperatures of Mercury and Venus.
If the sun shut down earth's temperature would fall to about minus 254.5° C that's about 16° C above the temperature of space. It wouldn't fall to space temperature, as it would be warmed by heat leaking from its hot interior.

The earth and moon receive equal amounts of energy per sq m from the sun since on average they are both the same distance from it. Of this energy the moon absorbs 89% and earth only 69.4% the balance in both cases is reflected back into space, and plays no part in their warming. So the average temperature of the moon should be higher than earth's but this is not so, Earth's average temperature is about 15° and the moons about minus 20°. Earths average day and night temperatures are 20° and 10°, whilst the moon's are, plus 107° and minus 153°. Their atmospheres cause this anomaly, earth's atmospheric pressure at surface is about 1014 hecto Pascals or 14.7 lb/sq.in, in the old measure, the moon's is only 3 billionths of a hecto Pascal, virtually non existent, so its composition is irrelevant. Earths atmosphere consists mainly of nitrogen, oxygen and argon, these are not greenhouse gases, they take no part in warming the planet and only 1 to 4 % water vapour - near the surface - and 0.0383% CO_2 with minor amounts of methane, nitrous oxide and ozone, these are all green house gases and play an important part in earth's temperature regulation. (1,2,3)

Mercury is about 57.9 million kilometres from the Sun; Venus is 108.2 million kilometres, about twice the distance. So Venus receives only about quarter the amount of suns energy per sq.m, as mercury.
Of these amounts Mercury absorbs about 88% and Venus only about 25%. Mercury should be very much hotter than Venus, however, Mercury's average temperature is plus 167° and Venus' plus 464°. Mercury's day temp is 450°;its night temp is minus 170°. Venus' day and night temps are both about 464° because dense clouds of CO_2, which cover the planet, prevent sunlight from penetrating to its surface. Again this is due to their atmospheres. Mercury's atmospheric pressure at one billionth of a hecto Pascal is less than our moons, so its composition is irrelevant. However, Venus' atmospheric pressure is 92 times as great as earth's, a massive 92000 hecto Pascals, and is composed of carbon dioxide - 96.5%, nitrogen - 3.5%, water vapour - 0.002% with some minor gases. If it had a different atmosphere it could have a climate similar to earths. (1)

If Earth's atmosphere had no water vapour, carbon dioxide and other green house gases its average temperature would be about minus 18°. However, at about 15° the greenhouse warming is 33°, 30 degrees, is due to water vapour because of its greater abundance, 2 degrees are due to carbon dioxide and less than 1 degree to other greenhouse gases. (2) However, this could change. As the methane concentration increases due to exhalations from ruminant animals, from the warming of frozen methane hydrate in the Arctic Ocean, and thawing of permafrost, all of which is happening.
So you see what a difference these small amounts of greenhouse gases make, we meddle with our atmosphere at our peril.
How does the greenhouse work? In May 1859 John Tyndall in London set out to find if any of the gases found in the atmosphere, could trap heat rays i.e. infrared radiation. His careful laboratory measurements identified several gases that did just that. The most important being water vapour and carbon dioxide due to their abundance.
The greenhouse gases absorb various parts of the infrared radiation causing them to vibrate. This absorbed energy causes them to vibrate, the molecules have various ways in which they can vibrate, these vibrations involve the bending, and stretching of the bonds that hold

their atoms together and for some, rotation. These modes of vibration are activated by certain parts of the infrared spectrum, both by that incoming from the sun and that outgoing from earth. This absorbed energy registers in the molecules as increased temperature; the heated molecules then, radiate heat energy at this higher rate, both back to earth and into space.

As we increase the amounts of carbon dioxide, methane and nitrous oxide in the atmosphere, causing its temperature to rise, its ability to hold greater amounts of water vapour also increases, because of the ready availability of water from the oceans, rivers, lakes and transpiration, recent observation show this is happening. This additional atmospheric water vapour traps more heat in the atmosphere, further increasing the planets surface temperature. This could lead to a run away greenhouse, if hot rising air didn’t cool, causing some water vapour to condense into rain and snow and fall to earth, to stabilise the atmospheres water content at the appropriate level.

Earth’s greenhouse works like a microwave oven in which water and perhaps other molecules in food, that are susceptible to microwave energy, vibrate and grow hot under the influence of electromagnetic microwaves generated in the oven, you may have noticed that in a tomato sandwich placed in a microwave oven the wet tomato becomes very much hotter than the drier bread.

The sun radiates both electromagnetic and magnetic energy their intensity varies during the eleven-year sunspot cycle being at a maximum when there is a sunspot maximum. The electromagnetic spectrum comprises gamma rays, x-rays, far ultra violet and ultra violet C, B and A, visible light, infrared, microwave, and radio waves. All this radiation is the same stuff, pure energy; it is distinguished only by its wavelength, frequency and energy. Gamma rays are at the high energy, shortest wavelength and highest frequency end and radio waves at the lowest energy longest wavelength and lowest frequency end. Gamma rays, x-rays, far ultra violet, ultra violet C and part of the B are trapped in the upper atmosphere, making life on Earth possible.

The remaining radiation passes through to earth's lower atmosphere and surface.
Solar radiation reaching the top of the atmosphere comprises, visible light 43%, infra red 49%, ultraviolet C, B and A 7%, and less than 1% gamma, x-rays and radio waves. At sea level these percentages change to, visible light 44%, infra red 53%, and ultraviolet A and B, 3%.
Because of its temperature the earth radiates mainly in the infrared band. (4)

For a planet to have a stable temperature it must radiate into space, as much energy as it receives, for example, if the suns radiation increased earth would store the excess energy thereby increasing its temperature and the heat it radiated back into space until balance was once again restored, albeit at a higher temperature.

On average1360 w/sq m of Suns energy reaches the top of our atmosphere.
That averaged over the whole planet (including nightside and oblique effects) equals 340 w/sq.m.
About 100-watts/sq m are reflected back into space. Only 240-w/sq m reach the surface were they are absorbed.

To maintain a stable temperature Earth must radiate these 240-w/sq m back into space. If Earth only radiated at 240 w/sq.m its temperature would be minus 18°. However, Earths average temperature is 15° and so radiates 390-w/sq.m.
The extra amount comes from the greenhouse gases in the atmosphere.
They receive 390 w/sq.m from Earth's surface; radiate 150 w/sq.m back to earth and 240 w/sq.m, out into space.
Earth receives 240 w/sq.m, from the sun and 150 from greenhouse gases in its atmosphere giving it the 390 w/sq.m, needed to reach 15°, which it radiates from its surface, 150 w/sq. m of which is trapped by greenhouse gases and is radiated back to Earth. The atmosphere radiates the remaining - 240-w/sq. m. out into space, which together with the 100 w/sq.m, reflected maintains energy balance of 340 w/sq.m, with the sun. (2)

To sum up earth's surface temperature is determined by the amount of energy it receives and the nature of its atmosphere. If the sun increases or decreases it's energy output with constant greenhouse gases earth's temperature will respond by increasing or decreasing. If the incident radiation is constant and its greenhouse gases are increased or decreased earth's temperature will also go up or down.
Should the suns energy output decrease as it has done in the past earth's temperature will go down but with the increased amounts of greenhouse gases we are putting into the air it would not fall as low as it would have with pre industrial levels of greenhouse gas.

References

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2. **NPL – Climate Change – What determines surface temperature of Earth? (NPL = National Physical Laboratory)**
3. **NASA.**
4. **Dr Craig Barnes 2006 – Lecture Notes, ENV12112, Semester 2.**

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