Introducing Climate Prediction

Find out what happens to radiation from the Sun when it reaches the Earth and what this means for the temperature of the planet.

Use a simple climate model that predicts changes in temperature given a change in conditions on the planet.

Predicting the climate

- Why do you think understanding about the temperature of the Earth is important?

- Who might be affected by changing temperatures, and why?

The Earth from Space

- The Earth's climate is suitable for life.
- What governs the temperature of the Earth? List as many factors as you can.
- Think about the radiation that arrives from the Sun. What happens to it?

What happens to solar radiation

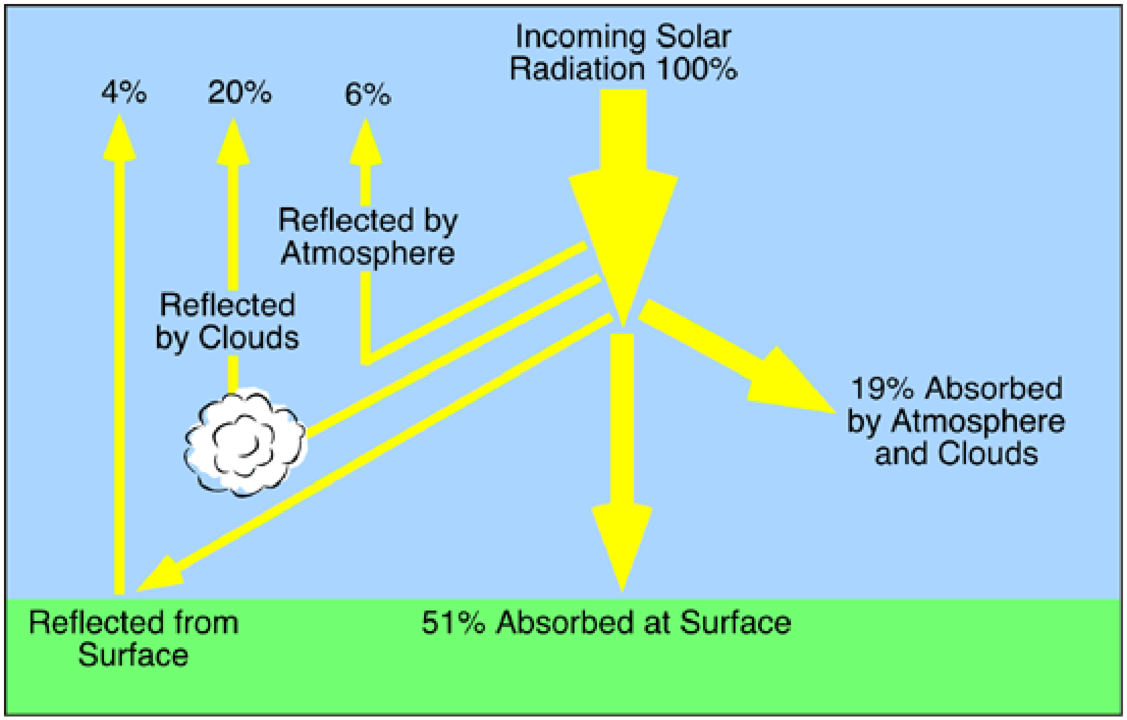
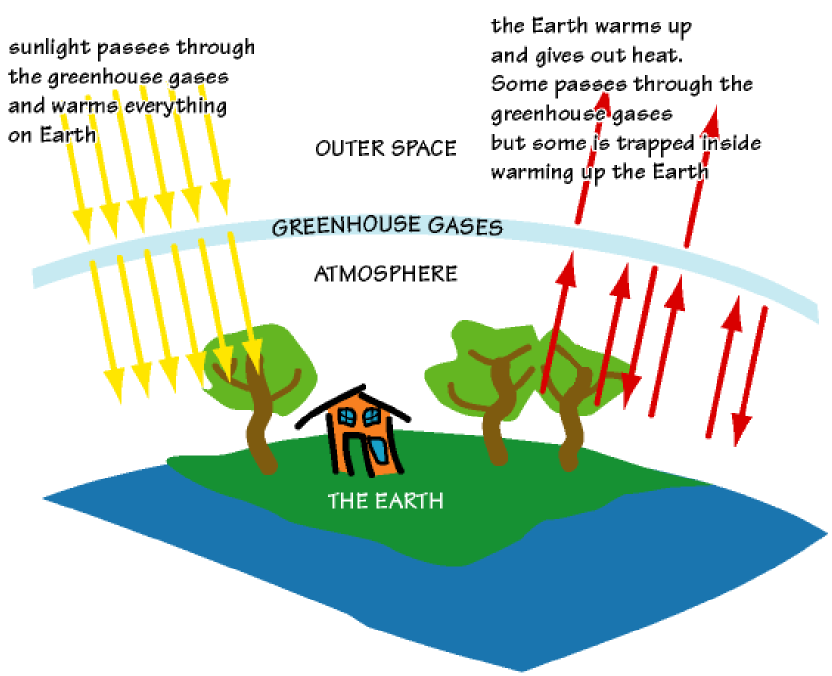


Diagram from physicalgeography.net

- What wavelengths does the Sun emit?
- How does the incoming solar radiation vary with time, and from place to place?

The Greenhouse Effect



- The Earth is warm; it gives off infrared radiation. Some of this is absorbed by the atmosphere.
- The atmosphere re-radiates as much energy as it absorbs. Some of this radiation warms up the Earth, keeping it at a comfortable temperature.
- With no atmosphere, the temperature of the Earth would be 33°C cooler than it is now. England would be at the temperature of a freezer!

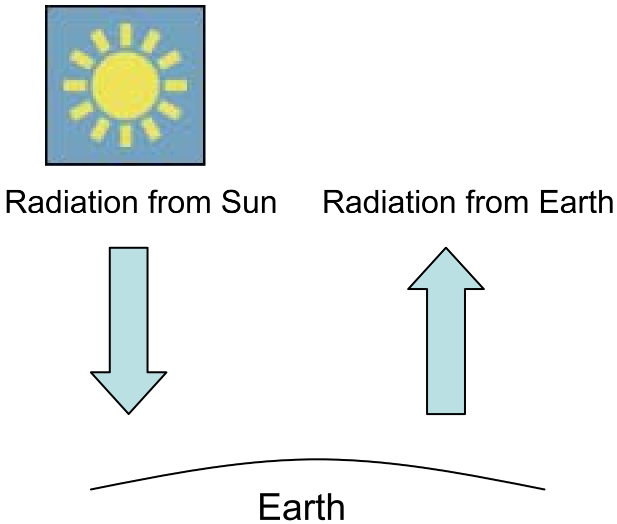
What is a model?

- **What do you understand by the word *model*?** What scientific models have you come across?
- A way to represent a system for the purposes of reproducing, simplifying, analyzing, or understanding it (sometimes on a smaller scale).
- A simplified description of a complex entity or process.
- Models can be made of any ‘substance’ such as clay, paper, abstract mathematics, or concepts.
- A representation of a set of components of a process, system, or subject area, generally developed for understanding, analysis, improvement, and/or replacement of the process. A representation of information, activities, relationships, and constraints
- A model can be descriptive or predictive. A descriptive model helps in understanding underlying processes or behaviour. For example, an association model describes consumer behaviour. A predictive model is an equation or set of rules that makes it possible to predict an unseen or unmeasured value (the dependent variable or output) from other, known values (independent variables or input).
- A visual, mathematical or real, three-dimensional representation, in detail, of an object or design, often smaller than the original. A model is often used to test ideas, to make changes to a design, or to learn more about what would happen to a similar, real object.

What is a model?

- Models are simplified representations of real systems.
- To predict and understand the climate of the Earth, we can use a model.
- In the case of climate prediction, what we mean by a model is **a set of equations** that represent how the atmosphere and oceans behave – how temperature patterns develop, how winds blow, and so on.

The energy balance model



- In this simple model, the Earth and its atmosphere absorb energy from the Sun, and lose energy to space. If energy is absorbed and lost at the same rate, the planet stays at a constant temperature – it is in a 'steady state'.
- Radiation arrives from the Sun at a (fairly) steady rate. Some gets reflected straight back out to space without heating the Earth.
- The rate at which the Earth radiates depends on the Earth's temperature. The hotter the Earth is, the faster it radiates.

Putting this into practice

a simple energy balance climate model

- Assume radiation falls on the Earth at a rate of 364 $Js^{-1}m^{-2}$.
- (What do these units mean? What does this quantity tell us?)
- The relationship between outgoing radiation and temperature is:
- Radiation out = $\sigma \times T^4$
  where $\sigma = 5.67 \times 10^{-8}\ Js^{-1}m^{-2}K^{-4}$
- Find the outgoing radiation of the Earth if the temperature is 283K
- Radiation out $= 5.67 \times 10^{-8} \times 283^4$
  $= 364\ Js^{-1}m^{-2}$
- Any temperature change depends on the difference between radiation in and out, and the **heat capacity** of the Earth.
- Change in temperature in 1 year =

  $$\frac{\text{net energy falling on 1 } m^2 \text{ in 1 year}}{\text{heat capacity}}$$
- The *heat capacity* is the amount of energy that has to fall on 1 m^2 of the Earth for it to heat up by 1K.
- heat capacity = $4.0 \times 10^8\ JK^{-1}m^{-2}$

Putting this into practice

- If 364 J come in and 364 J go out, then the Earth's temperature won't change – steady state.

- But what if the solar radiation increases by, say, 5%? We can use the same process to find the new temperature of the Earth.

- Key information:

Previous radiation in = 364 $Js^{-1}m^{-2}$

Initial temperature = 283K

$\sigma = 5.67 \times 10^{-8}\ Js^{-1}m^{-2}K^{-4}$

Radiation out = $\sigma \times T^4$

Change in temperature in 1 year =

$$\frac{(364 - 364) \times (60 \times 60 \times 24 \times 365)}{4.0 \times 10^8}$$

= 0K.

Radiation in = 364 x 1.05

= 382.2 $Js^{-1}m^{-2}$

Radiation out = 364 $Js^{-1}m^{-2}$

Change in temperature in 1 year =

$$\frac{(382.2 - 364) \times (60 \times 60 \times 24 \times 365)}{4.0 \times 10^8}$$

= 1.43 K

So the new temperature after 1 year is 284.4 K

Putting this into practice

- Our model show that an increase of 5% in the rate at which we receive radiation from the Sun increases the Earth's average temperature by 1.43 K in one year.
- The following year, the temperature will rise again, but by a smaller amount. (Why?)
- Eventually, the temperature will reach a new equilibrium value when, once again, energy in = energy out.
- It's easier to work out this new equilibrium temperature using a spreadsheet.