The use of models to predict climate: **Climate*prediction*.net results so far**
Teacher's notes

This worksheet introduces students to a more complex model of the climate, one that is used to produce day-to-day weather forecasts as well as climate forecasts. It explains briefly how the model is tested in three stages before being used to actually predict future climate. It could form the basis of a teaching session on the use of models.

Students could work through the sheet, discussing the answers in pairs before a class discussion of the main points covered.

1. What is a model?
A way to represent a system for the purposes of reproducing, simplifying, analyzing, or understanding it (sometimes on a smaller scale).

2. All these factors might have an effect on climate.
   distance of Earth from Sun yes
   dust in the atmosphere yes – either by reflecting incoming solar radiation or by absorbing outgoing infrared radiation (acting like a greenhouse gas)
   concentration of carbon dioxide yes – greenhouse gas
   Sun's output yes – main source of Earth;s energy
   wind strength the wind is an aspect of the climate. The wind strength is related to temperature gradients, and the wind itself can affect the weather (by advecting weather systems) at a given place at any point in time.
   cloud cover - yes – either by reflecting incoming solar radiation or by absorbing outgoing infrared radiation (acting like a greenhouse gas)
   ice cover yes – by reflecting incoming solar radiation
   area covered by trees yes, either by substantially changing the colour of the land surface and therefore the amount of solar radiation, or by absorbing carbon dioxide (a temporary sink unless the trees do not decay)
   concentration of water vapour in the atmosphere yes – water vapour is a very powerful greenhouse gas
   ocean currents yes – by affecting the speed at which heat is removed from the atmosphere and advected into the deep oceans, which have a very large heat capacity
   ozone concentration yes – both by affecting how much solar UV reaches the Earth's surface and because ozone is a greenhouse gas (it absorbs radiation both at UV and IR wavelengths)
   volcanic eruptions yes – ash forced high into the atmosphere can reflect incoming solar radiation and cool the Earth e.g. Pinatubo 1993 negated the general warming trend for a couple of years.
   temperature of the Earth's core not really – the amount of heat that reaches the surface of the Earth from the core is negligible compared to the energy received from the Sun
   concentration of oxygen no – oxygen (O2) is not a greenhouse gas.

3. **For the factors in bold type suggest whether an increase would result in warming or cooling.**

The greater the distance between Earth and Sun the cooler the Earth

The more energy the Sun emits, the warmer the Earth

The greater the ice cover, the more incoming solar radiation is reflected back into space without warming the Earth.

4. **Climate change is often discussed in terms of average global temperature. How many temperature measurements would you need to take to know the average global temperature? Where would these measurements have to be taken?**
A very large number, at least several thousand. They would have to cover different continents and oceans, different latitudes and altitudes, urbanised and non-urbanised space.

5. How accurately do you think we can know the average global temperature?
We can never know the average temperature totally accurately but if temperatures are measured in the same places from year to year changes can be spotted fairly accurately. Traditional, thermometer-based measurements were concentrated on land, in the developed world. Today, satellites can give much more evenly spaced data, but there are issues associated with correlating satellite measurements to ground-based measurements.

6. **Do all the answers in Phase 2 look equally realistic for the period before carbon dioxide increased? How do we know that some of them must be wrong?**
7. **What does this mean about the parameters that were put into the models?**

In most of the models, the global mean temperature stays constant in phase 2. In a few models, the temperature cools dramatically. This is an indication that those models have a bad combination of parameters and the model Earths have flipped into an unnatural, unphysical and unrealistic climate. They are said to be *numerically unstable* and are rejected.

8. **What do the results so far show happens at the beginning of phase 3?**
At the beginning of phase 3, all models warm rapidly.

9. By the end of phase 3, what is the spread in global mean temperatures?
13-22˚C. However, some models are still getting warmer at the end of phase 3 i.e. they have not reached a new equilibrium temperature. The lines have to be extrapolated in order for the climate sensitivity to be calculated.

10. What can *definitely* be said from Figure 2 about global mean temperature when CO_2 is doubled, assuming the results so far are representative of the final results?
The climate does not warm to more than 22˚C or cool

11. What can be said from Figure 2 is *most likely* about global mean temperature when CO_2 is doubled, assuming the results so far are representative of the final results?
The global mean temperature is most likely to warm to between 15-19˚C.

12. In what ways is phase 3 like, or unlike, the real world?
Current predictions suggest that CO_2 will probably double in the atmosphere by 2050. However, CO_2 levels will never remain constant for a period of 15 years, as they do in phase 3 of the experiment, so the real climate will never reach an equilibrium.

13. If a headline based on Figure 3 said
"Scientists say temperature set to warm by 8^oC"
explain as you would to a friend why this headline somewhat misrepresents what scientists say.

The climate*prediction*.net results show that the climate could warm as much as 8^oC, but there is only a relatively small probability of that actually happening. There is a much bigger chance that the climate will warm by 2-5˚C.