Activity description

In this activity students use graphic calculators to model what would happen to the temperature of the Earth if there were to be a sudden change in the amount of radiation entering or leaving the planet.

Students then investigate polynomial and exponential functions to find the best model.

Suitability

Level 3 (Advanced)

Time

1–2 hours

Resources

Student information sheet
Graphical calculators
Optional: slideshow

Key mathematical language

Model, constants, initial conditions, function, quadratic, cubic , quartic, exponential.

Notes on the activity

This version of the activity, Climate B, is paper-based activity and requires a graphic calculator. Climate A is an alternative activity in which students need access to Excel.

Either version can be used independently, or students can use both – this would allow them to compare the methods used.

Before doing this activity, students will need to have learnt how to use a graphic calculator to:

- draw graphs
- use trendlines to find polynomial regression lines.

If students already know how to substitute data values into exponential functions and solve the resulting equations, they could be asked to find their own exponential functions to model the temperature data.

During the activity

The work may be shared between students if you wish.

Points for discussion

Check that students can calculate the outgoing radiation = σT^4 = 364 J $s^{-1}m^{-2}$ (to 3sf), and that they know the connection between Kelvin and Celsius temperatures.

Discuss, in general terms, how students expect the Earth's temperature to change after a sudden increase in radiation input.

At the end of the activity, discuss why an exponential function gives a better long-term prediction than any of the polynomials.

Extensions

If students have time, they could find models for other percentage increases and decreases.

Students could also try using different time increments.

They could investigate an ongoing small percentage increase in radiation input – or decrease in radiation loss.

Climateprediction.net: information and acknowledgement

This is an adaptation of an activity written by Sylvia Knight (University of Oxford Atmospheric, Oceanic and Planetary Physics) and Jon Gray (Banbury School) for a Nuffield project linked to the climateprediction.net project.

Although this activity does not require that students have any detailed knowledge of climate or of the climateprediction.net project, they could be encouraged to find out more by visiting www.climateprediction.net.

Further activities linked to the project and information for teachers are also available from www.climateprediction.net/schools.

Climateprediction.net is a joint research project funded by the Natural Environment Research Council (NERC) and the Department of Trade & Industry. Its aim is to use the large number of idle computers worldwide and the power of the internet to predict and understand the climate. Your students can find out more and take part by visiting www.climateprediction.net and downloading their own unique simulation model of the Earth's climate. The downloaded program runs as a background process (it does not affect normal computing) to generate data for a climate model. The graphics packages supplied with the model show how weather patterns develop. Results from these experiments were contributed to the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and will help policy makers plan for the effects of climate change.

Answers

5% increase

Time x **(years)**	**Incoming radiation ($Js^{-1}m^{-2}$)**	**Outgoing radiation ($Js^{-1}m^{-2}$)**	**Change in temperature (K)**	**Temperature of Earth** y **(K)**
0	364	364	–	283
1	382.2	363.6878571	1.459497345	284.4594973
2	382.2	371.2485893	0.8634092225	285.3229066
3	382.2	375.7764999	0.506428751	285.8293353
4	382.2	378.4515222	0.2955299886	286.1248653
5	382.2	380.0191339	0.1719394816	286.2968048
6	382.2	380.9334091	0.09985802897	286.3966628
7	382.2	381.4651533	0.05793531696	286.4545981
8	382.2	381.773914	0.0335926201	286.4881908

Polynomial functions given by a graphic calculator are listed below:

Quadratic: $y = -0.0869374x^2 + 1.07138397x + 283.282031$

Cubic: $y = 0.01405968x^3 - 0.2556537x^2 + 1.58034468x + 283.045828$

Quartic: $y = -0.001717x^4 + 0.04153642x^3 - 0.3923014x^2 + 1.79427067x + 283.004613$

Graphs can be used to show that the cubic and quartic function given above and the given exponential function, $y = 283 + 3.53(1 - e^{-0.54t})$ all give values close to the temperature values for the first 8 years, but the values given by the quadratic function are not so good.

In later years, only the exponential function gives values likely to model what happens in practice. That is, the temperature approaches a new equilibrium value higher than the original 283 K.

The quadratic model predicts a temperature fall after 6 years.

The quartic model predicts a temperature fall after 7 years.

The cubic model predicts a steep rise in temperature after 10 years.

5% decrease

Time (years)	Incoming radiation ($Js^{-1}m^{-2}$)	Outgoing radiation ($Js^{-1}m^{-2}$)	Change in temperature (K)	Temperature of Earth (K)
0	364	364	–	283
1	345.8	363.6878571	– 1.410278655	281.5897213
2	345.8	356.4923798	– 0.8429872245	280.7467341
3	345.8	352.2426262	– 0.5079366515	280.2387975
4	345.8	349.700378	– 0.3075058016	279.9312917
5	345.8	348.1679988	– 0.1866930238	279.7445986
6	345.8	347.2401205	– 0.1135391021	279.6310595
7	345.8	346.6767304	– 0.06912142492	279.5619381
8	345.8	346.3340803	– 0.04210688713	279.5198312

Polynomial functions given by a graphic calculator are listed below:

Quadratic: $y = 0.08360494x^2 - 1.0476658x + 283.736059$

Cubic: $y = -0.0131113x^3 + 0.24094152x^2 - 1.5222978x + 282.95633$

Quartic: $y = 0.0016173x^4 - 0.0389895x^3 + 0.36963939x^2 - 1.7237781x + 282.995147$

The cubic and quartic function given above, and the given exponential function $y = 279.45 + 3.55e^{-0.5t}$, all give values close to the temperature values for the first 8 years.

The values given by the quadratic function are not so good.

In later years, only the exponential function gives values likely to model what happens in practice. The temperature approaches a new equilibrium value lower than the original 283 K.

The quadratic model predicts a temperature rise after about 6 years.

The quartic model predicts a temperature rise after 8 years.

The cubic model predicts a steep fall in temperature after 9 years.