Lecture 11: Out in the sun

Learning objectives

✓ Interpret power function models of real-world phenomenon

✓ Evaluate the effectiveness of various models for the same data

Scientific examples

✓ UV light and SPF

✓ Carbon dioxide in the atmosphere

Maths skills

✓ Understand the properties and shapes of various types of power functions

✓ Understand transformations of power functions and their graphs

Case Study 8: Ban the tan, man

- Earlier, we saw that temperature in the lowest atmospheric layer (Troposphere) decreases as altitude increases, but temperature in the next layer (Stratosphere) increases from altitude 20 km to 50 km.
- The rise in temperature is due to interactions between the ozone layer and ultraviolet (UV) light.
- UV light is electromagnetic radiation with wavelengths shorter than visible light, and can be divided into: UVA (wavelength 315 – 400 nm); UVB (wavelength 280 – 315 nm); and UVC (wavelength 100 – 280 nm).
- The following sequence of chemical reactions occurs in the ozone layer:

$$\begin{aligned}
O_2\ (g) &\xrightarrow{\text{UVC light}} 2O\ (g) \\
O_2\ (g) + O\ (g) &\longrightarrow O_3\ (g) \\
O_3\ (g) &\xrightarrow{\text{UVB light}} O_2\ (g) + O\ (g) \\
O_3\ (g) + O\ (g) &\longrightarrow 2O_2\ (g) \\
2O\ (g) &\longrightarrow O_2\ (g)
\end{aligned}$$

- The second and third reactions describe the *ozone-oxygen* cycle. The net result of the these reactions is that harmful UV radiation is converted to heat, and ozone is conserved (no net loss of ozone).

- The chemical reactions which occur in the ozone layer are extremely important to life on Earth:
  - UVC light is very damaging to life, but is completely absorbed.
  - Most UVB light is also absorbed; only around 1 part in 350 million reaches the surface of Earth. Exposure to this light causes sunburn, eye cataracts, visible ageing, genetic mutations in cells and skin cancer.
  - Almost all UVA light reaches the surface of Earth.

- The effectiveness of sunscreens at preventing UVB light from reaching the skin is measured by their *Sun Protection Factor*, SPF. When a product with SPF n is correctly applied to the skin, it blocks a fraction of $(n-1)/n$ of the usual amount of UVB light.

Question 4.4.7

Write a function for the proportion of UVB light that is **not** blocked by sunscreen with SPF n, and draw a rough sketch of the graph of the function.

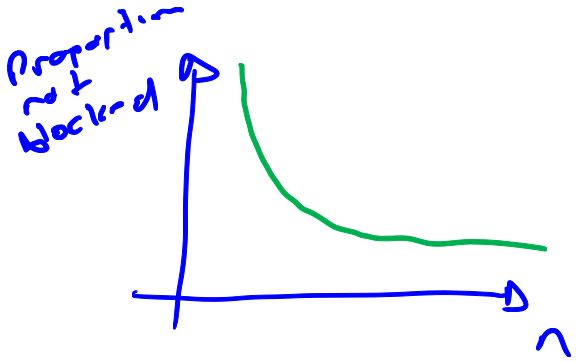
proportion blocked + proportion not blocked = 1

proportion not blocked = 1 − proportion blocked

$= 1 - \frac{n-1}{n} = \frac{n}{n} - \frac{n-1}{n} = \frac{n-n+1}{n}$

$= \frac{1}{n}$

$n \geq 1$



***Question** 4.4.7 (continued)*

What proportion of UVB light is not blocked by sunscreen with SPF 30? SPF 50? SPF 100?

SPF (n)	Not blocked ($1/n$)	%
30	0.033	3.3%
50	0.02	2.0%
100	0.01	1.0%

Should people buy sunscreen with SPF 100? Why or why not?

For
- more protection
- some sunlight is good (Vit D)
- Not much better
- cost ?

- There has been a substantial depletion of total atmospheric ozone in recent decades, including formation of the *ozone hole* over Antarctica.
- It is well-accepted that this has anthropogenic causes, particularly the release of ozone depleting substances such as *chlorofluorocarbons* into the atmosphere. These had been used as refrigerants and aerosol propellants.
- The *Montreal Protocol*, adopted in 1989 and ratified by around 200 states, is an agreement on phasing out the use of CFCs. It represents one of the most significant international climate agreements ever.

Successful.

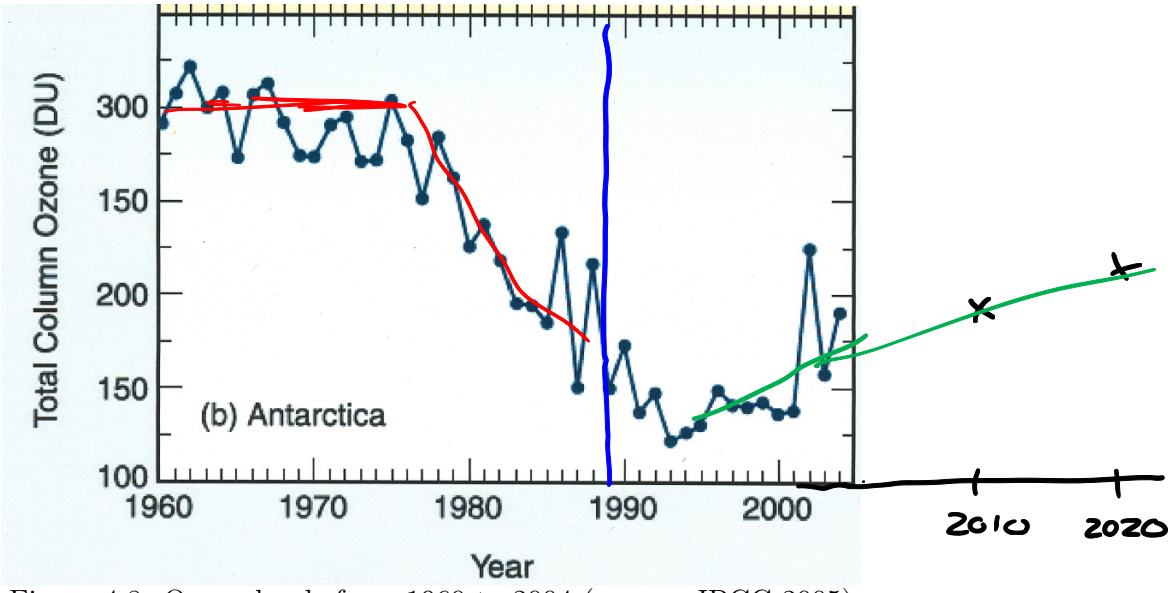


Figure 4.8: Ozone levels from 1960 to 2004 (source: IPCC 2005)

- There is evidence that the ozone layer has started repairing. Scientific modelling predictions made in 2005 suggested the ozone layer would return to its 1980 values by the year 2050 (see Figure 4.9).

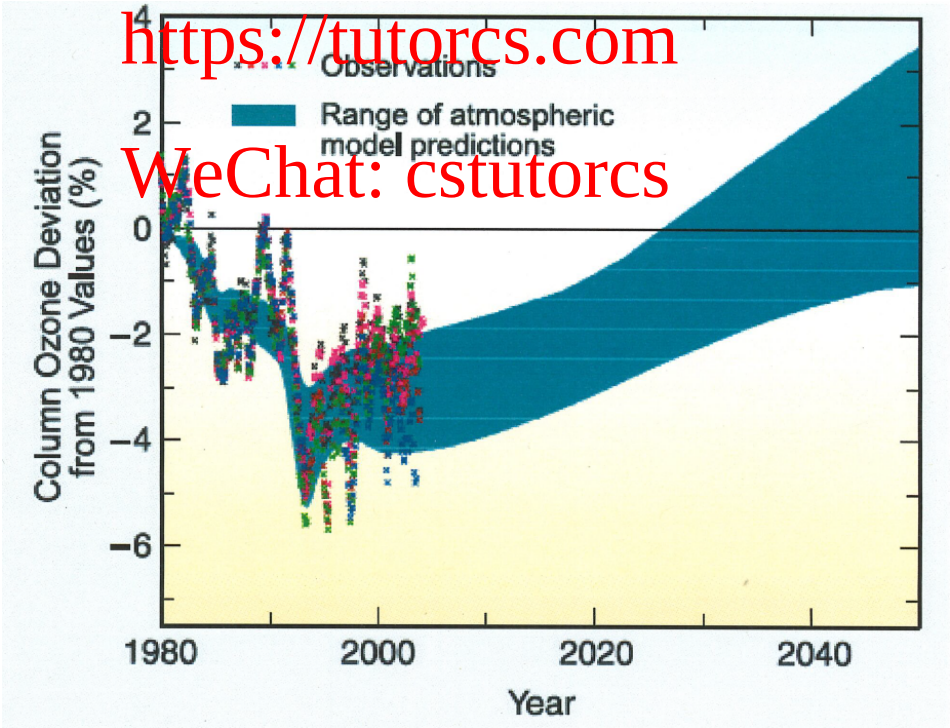


Figure 4.9: Ozone levels predictions (source: IPCC 2005)

- More recent evidence suggests the ozone layer will recover by the year 2075.

2009

Question 4.4.8

In [38], fourteen authors asked the following question. *What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated?*. With some sophisticated modelling, they developed simulations to predict what would have happened if CFC's had not been regulated, and called this situation the "world avoided" scenario (see Figure 4.10). Note: The *Dobson unit* is often used to measure the amount of a gas in a vertical column of Earth's atmosphere, and 1 DU = 0.4462 mmol/m^2.

310 "with intervention"

220 "world avoided"

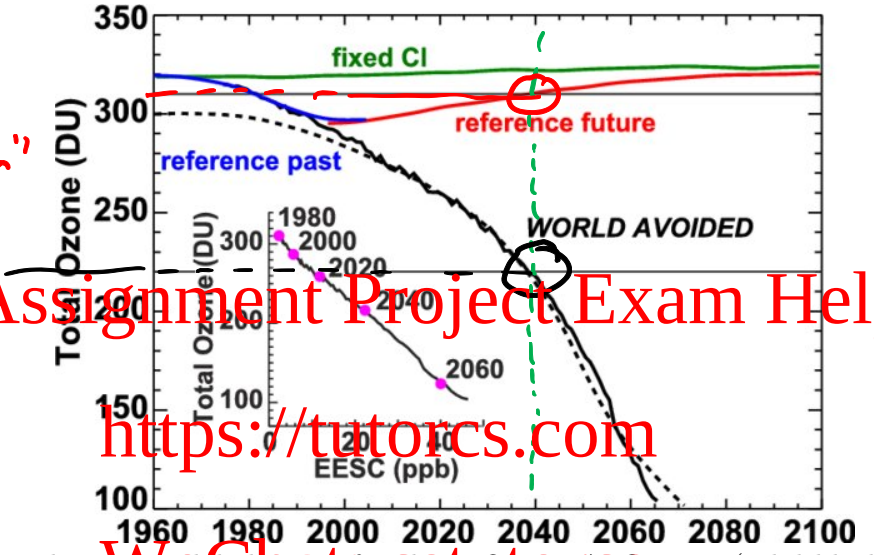


Figure 4.10: Annual average global ozone for the WORLD AVOIDED (solid black), reference future (red), fixed chlorine (green), and reference past (blue) simulations.

Consider the predictions for the year 2040 and comment on the relative percentage drop in ozone we would have faced if interventions had not been implemented.

with intervention conc. = 310 DU

"world avoided" conc = 220 DU

Reduction (drop) of 90 DU

Relative % drop = $\frac{90}{310} \times 100\%$.

$\simeq$ 29 %.

End of Case Study 8: Ban the tan, man.

- linear

Question 4.4.9

Keeling Model 2: Figure 4.11 shows two plots: a graph of the function $y(t) = 1/3 \times t^{1.37} + 315$, and the Keeling curve.

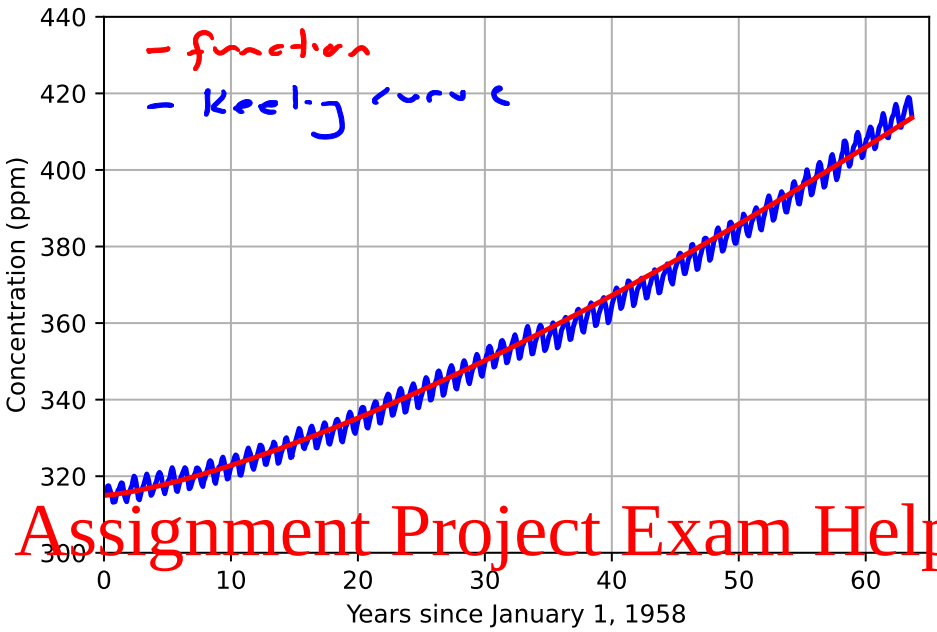


Figure 4.11: The Keeling curve (blue) and the power function model (black).

(a) Explain how each term in $y(t)$ impacts on the graph.

$y(t) = \frac{1}{3} t^{1.37} + 315$

vertical scale

curvature
$p > 1$
curves upwards

vertical shift
On Jan 1, 1958
conc = 315 ppm

(b) Discuss the limitations of this model of the Keeling curve.

No oscillations;

Phenomenological