Introduction to the principles of climate modelling

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Text in English corrected by Stephanie Hayes

Introduction

A large amount of the CO_2 that is released into the atmosphere as a result of human activities is absorbed by vegetation and the oceans, thus removing it from the atmosphere. If we know the quantity of CO_2 that is being emitted into the atmosphere, and the quantity that is being absorbed during the last 50 years, we can make some predictions about future atmospheric CO_2.

Aims

- To introduce students to the global carbon budget and to give them a first try at climate modelling.
- To estimate the amount of human CO2 emissions that is absorbed by vegetation and oceans.
- To make atmospheric CO_2 predictions for the next century.

Activity type: data manipulation and analysis

Prior knowledge required: none

Cost: none

Materials

- Computer room: ideally, students work in groups of two.
- Excel or openOffice file (calculs1) download on www.carboschools.org. Or data can be found here: http://lgmacweb.env.uea.ac.uk/lequere/co2/carbon_budget.htm (you will find at this address all explanations for data, but they are also in the file).

Summary of the activity

Students are introduced to the notion of a global carbon budget. They work with data from 1958 to 2008. The 1958 data gives the total amount of CO_2 present in the atmosphere, and the 1959 – 2008 data shows the amount of human-emitted CO_2 in the atmosphere.

All values are in billion tons of carbon. We begin in 1958 because it was the first year that atmospheric CO_2 was directly measured.

If pupils add annual amount of CO_2 emitted by human activities to the total quantity of CO_2 already present in the atmosphere, they will obtain a value that is superior to the one that is currently observed. As a result, the students understand and deduct that a certain amount of CO_2 is absorbed by the vegetation and the oceans.

The question for the students is: How much of atmospheric CO_2 is absorbed by the vegetation and the oceans? Students then find a suitable value for the natural absorption. The best idea is to use a percentage of the emissions. (In an extension to the activity, students can split natural absorption into absorption by the ocean and by the vegetation).

Using their natural absorption value, students try to obtain a calculated quantity of atmospheric CO_2 that is similar to the observed quantity. They now have a good simulation to explain the global carbon cycle.

It is now possible to include emission scenarios from the IPCC reports to make prediction for the next century (until 2100).

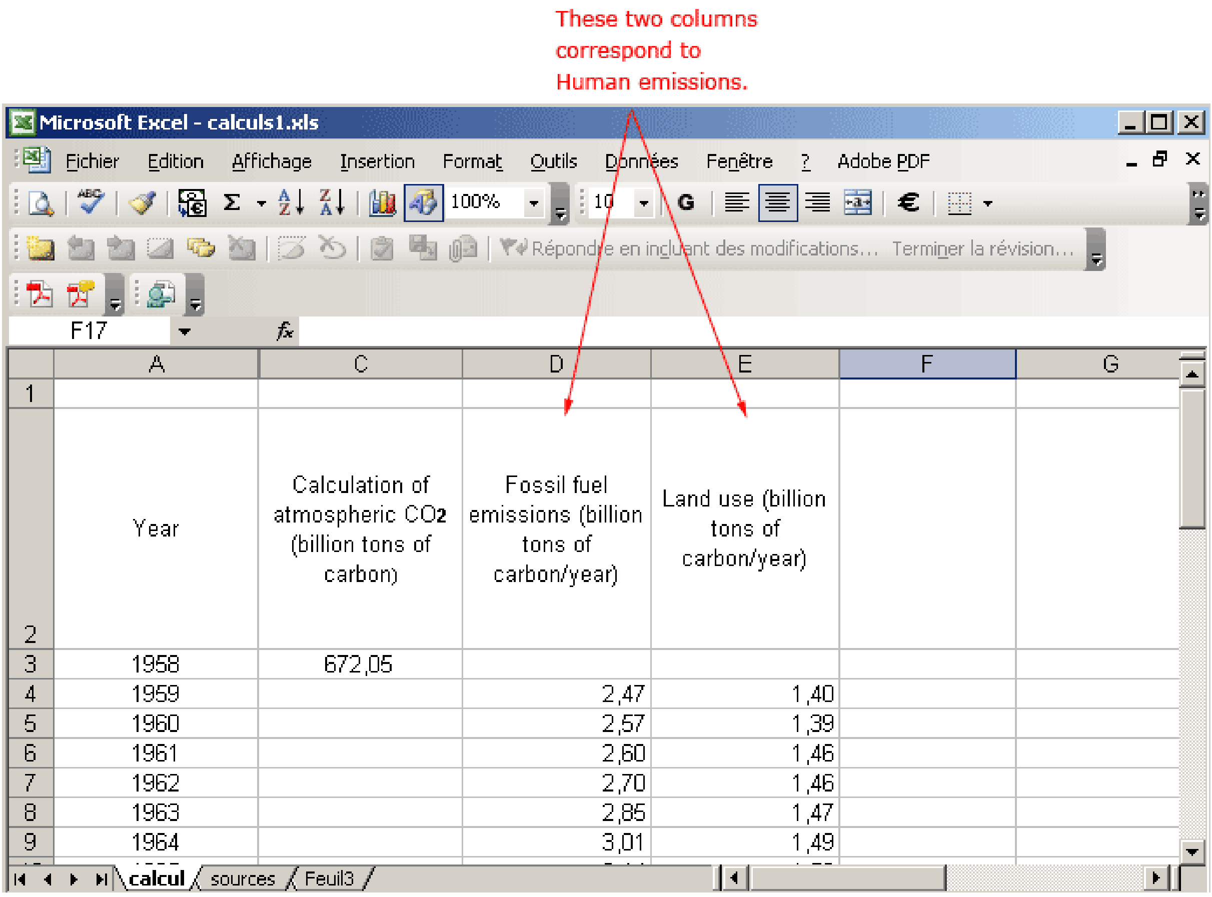
Students can play around with human CO_2 emissions data and the percentage of natural absorption in order to compare the effects of each parameter on the evolution of atmospheric CO_2. Each group of pupils will leave the classroom with its own evolution and its own prediction for 2100.

Part 1

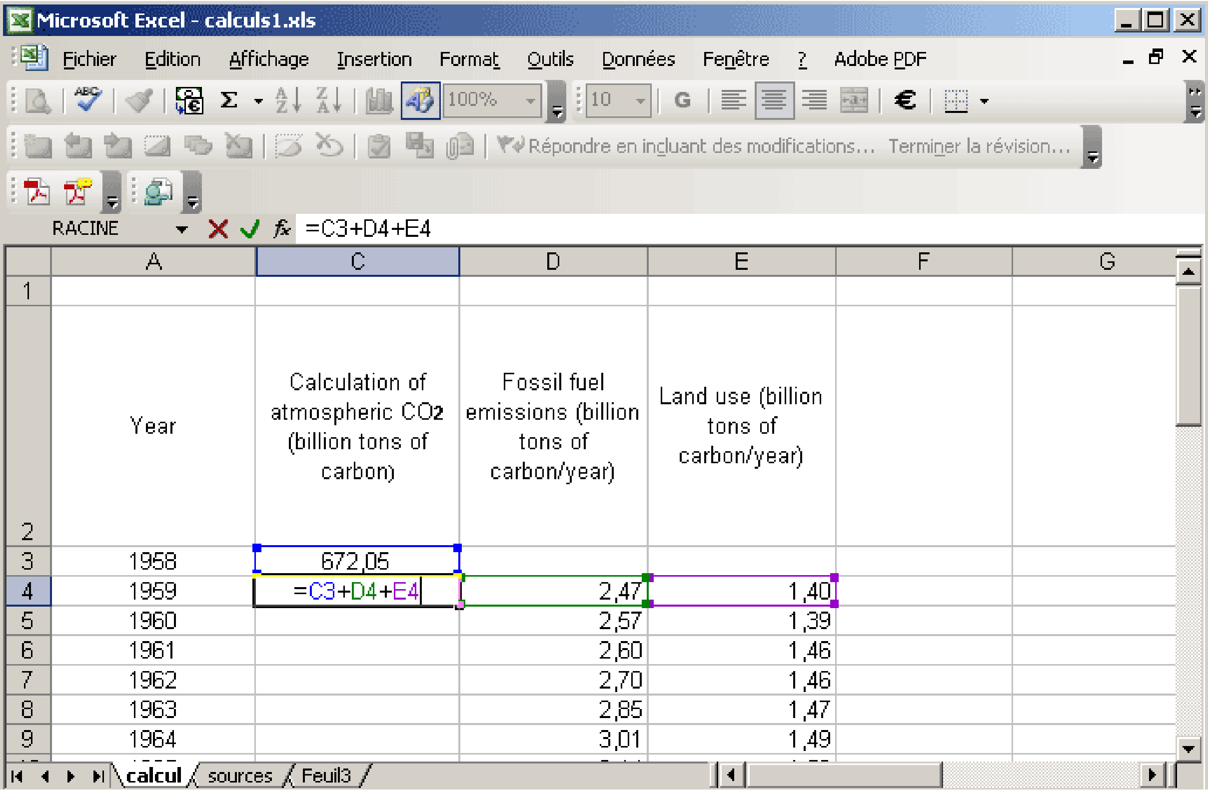
Here we compare the observed values for atmospheric CO_2 with the values obtained according to the hypothesis that all emissions stay in the atmosphere (atmospheric CO_2 for year **n** = atmospheric CO_2 year **n-1** + fossil fuel emissions year **n** + land use year **n**).

Procedure

1. Add together the values for fossil fuel emissions and land use in order to obtain values for total annual human CO_2 emissions.

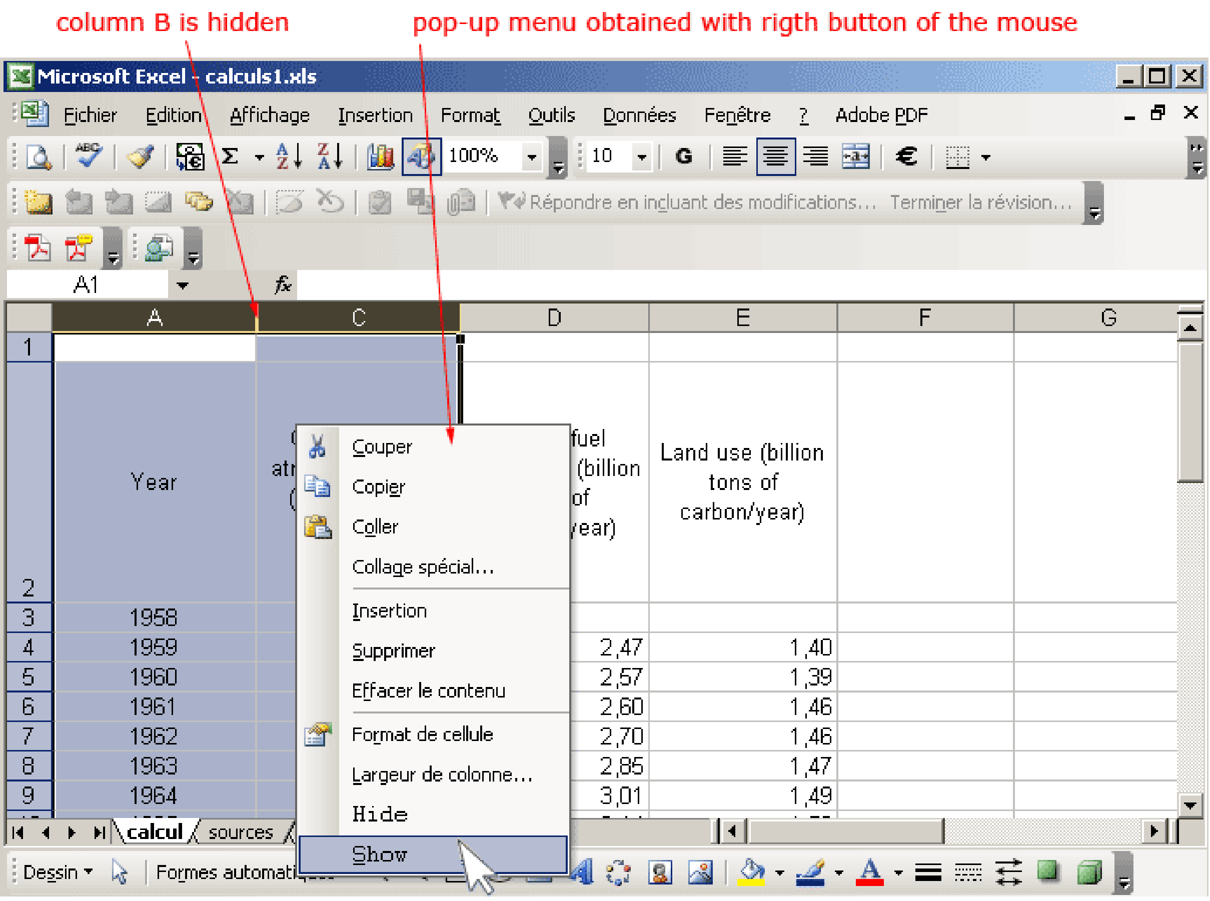


	A	C	D	E	F	G
1						
2	Year	Calculation of atmospheric CO2 (billion tons of carbon)	Fossil fuel emissions (billion tons of carbon/year)	Land use (billion tons of carbon/year)		
3	1958	672,05				
4	1959		2,47	1,40		
5	1960		2,57	1,39		
6	1961		2,60	1,46		
7	1962		2,70	1,46		
8	1963		2,85	1,47		
9	1964		3,01	1,49		

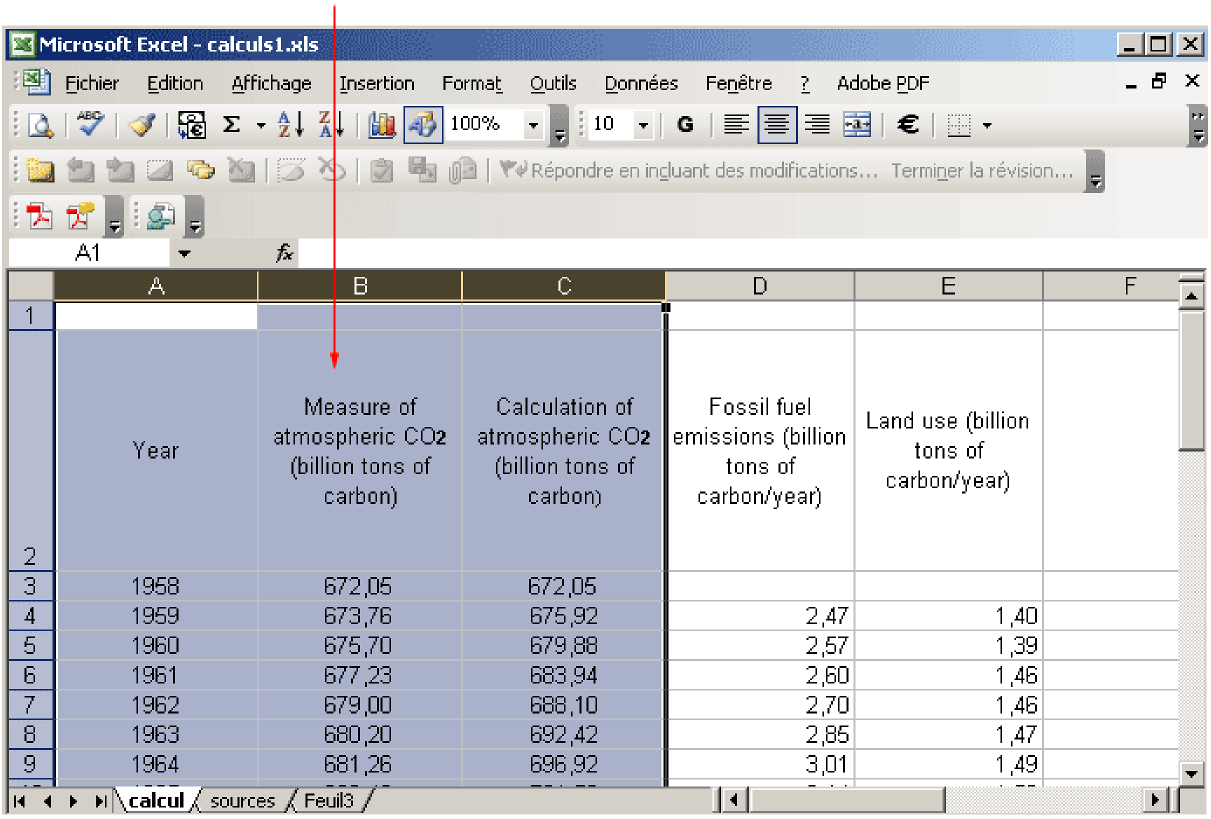


Calculation corresponding to the hypothesis that all Human emissions stay in the atmosphere.

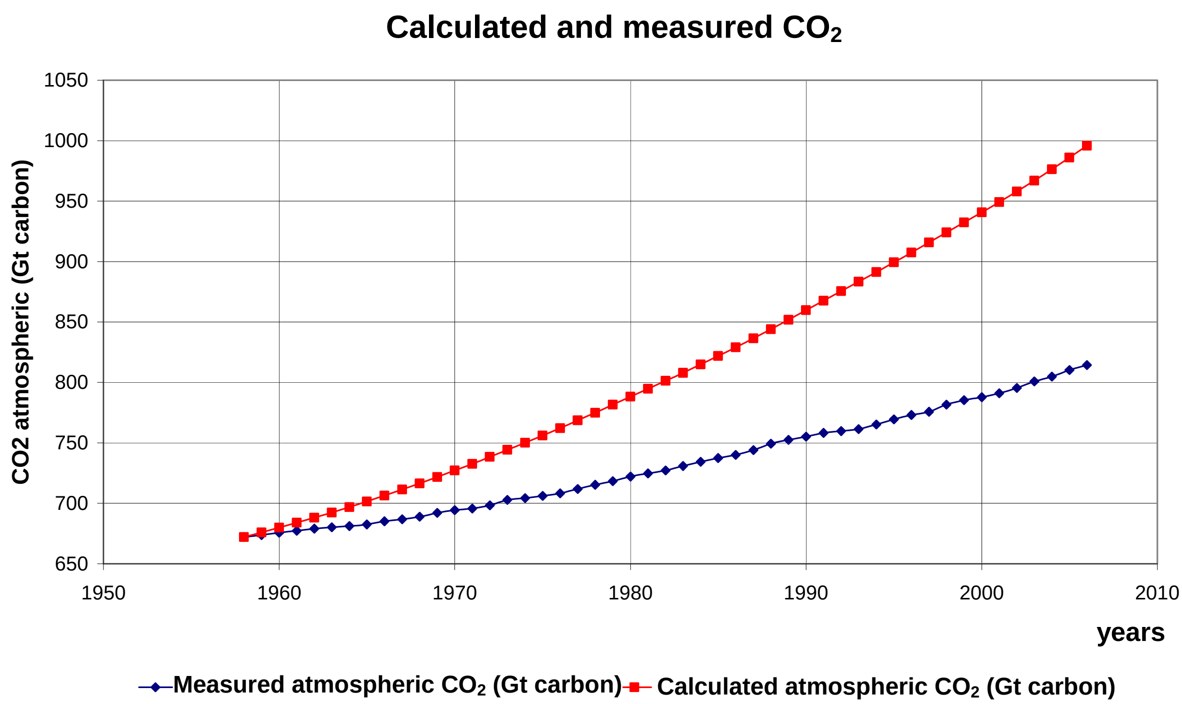
2. Column B, which gives the “real” values for atmospheric CO_2, is hidden. You can see below how to show the column by clicking on the right button of your mouse (ctrl+mouse left button on Mac).



Column B (measurements) is now visible and can be compared to column C (calculation)



3. Pupils can now compare measurements and calculation. Using column B and column C data, construct a graph to show measured atmospheric CO_2 and calculated atmospheric CO_2.



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4. Answer and discuss the following questions:
What conclusions do you draw from the curves in the graph?
What do you think is responsible for the absorption of the CO_2?
What in the terrestrial biosphere, what process is involved in the absorption of atmospheric CO_2?

Discussion
Calculated values are higher than the observed ones; therefore part of the atmospheric CO_2 is being absorbed by vegetation in the terrestrial biosphere and by the oceans. The process responsible for absorption of CO2 by vegetation is photosynthesis.

At this point, it might be a good idea to stop the activity, carry out experiments and other related work, and return to the next part later on.

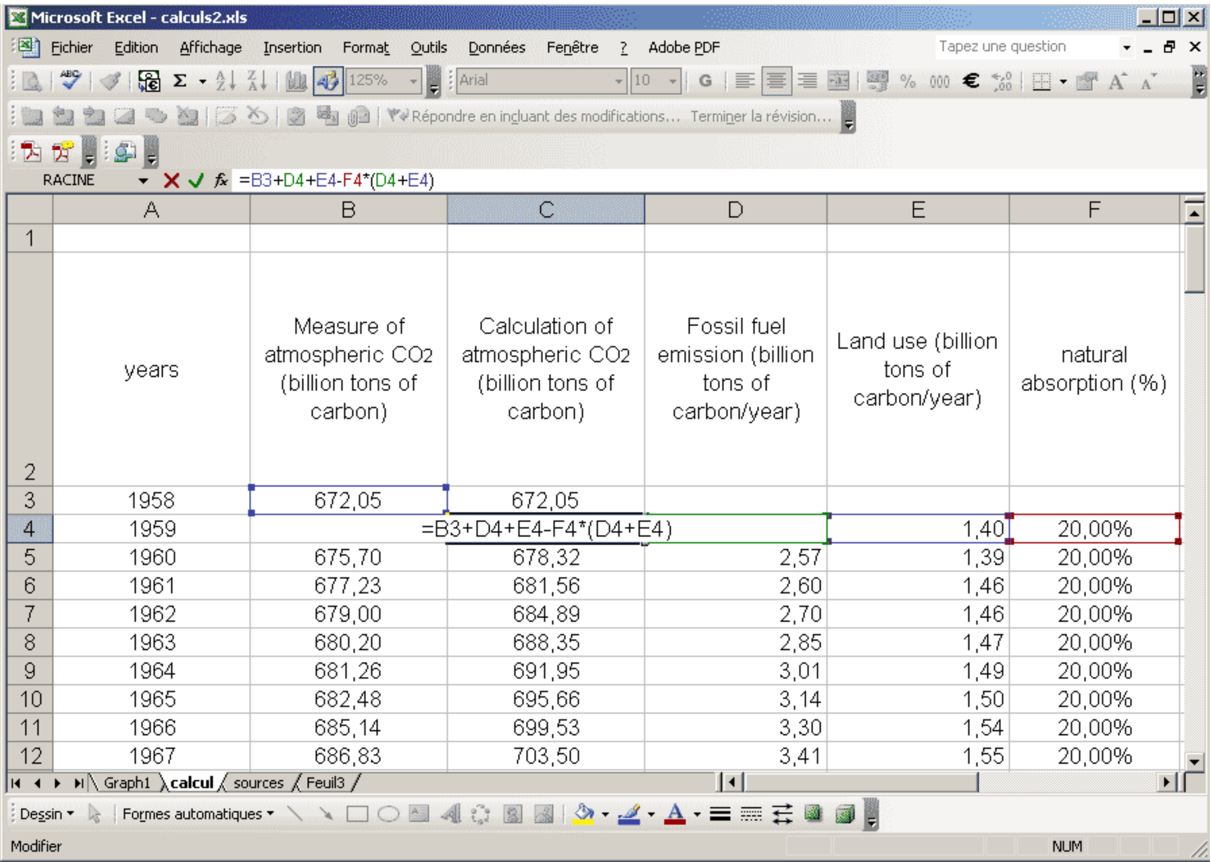
Part 2

Students now work out the percentage of atmospheric CO_2 that is taken up by vegetation and oceans.

This is the difficulty of the activity. You can suggest a file with a percentage already done (download calculs2.xls).

The formula is:
Amount of atmospheric CO_2 in 1959 = amount of atmospheric CO_2 in 1958 + amount of CO_2 emitted by Human activities in 1959 – percentage of CO_2 emitted by Human activities absorbed by natural sinks.

1. Apply the above formula to the calculated values in column C as shown below (example with a natural absorption of 20%):



	A	B	C	D	E	F
1						
2	years	Measure of atmospheric CO2 (billion tons of carbon)	Calculation of atmospheric CO2 (billion tons of carbon)	Fossil fuel emission (billion tons of carbon/year)	Land use (billion tons of carbon/year)	natural absorption (%)
3	1958	672,05	672,05			
4	1959		=B3+D4+E4-F4*(D4+E4)		1,40	20,00%
5	1960	675,70	678,32	2,57	1,39	20,00%
6	1961	677,23	681,56	2,60	1,46	20,00%
7	1962	679,00	684,89	2,70	1,46	20,00%
8	1963	680,20	688,35	2,85	1,47	20,00%
9	1964	681,26	691,95	3,01	1,49	20,00%
10	1965	682,48	695,66	3,14	1,50	20,00%
11	1966	685,14	699,53	3,30	1,54	20,00%
12	1967	686,83	703,50	3,41	1,55	20,00%

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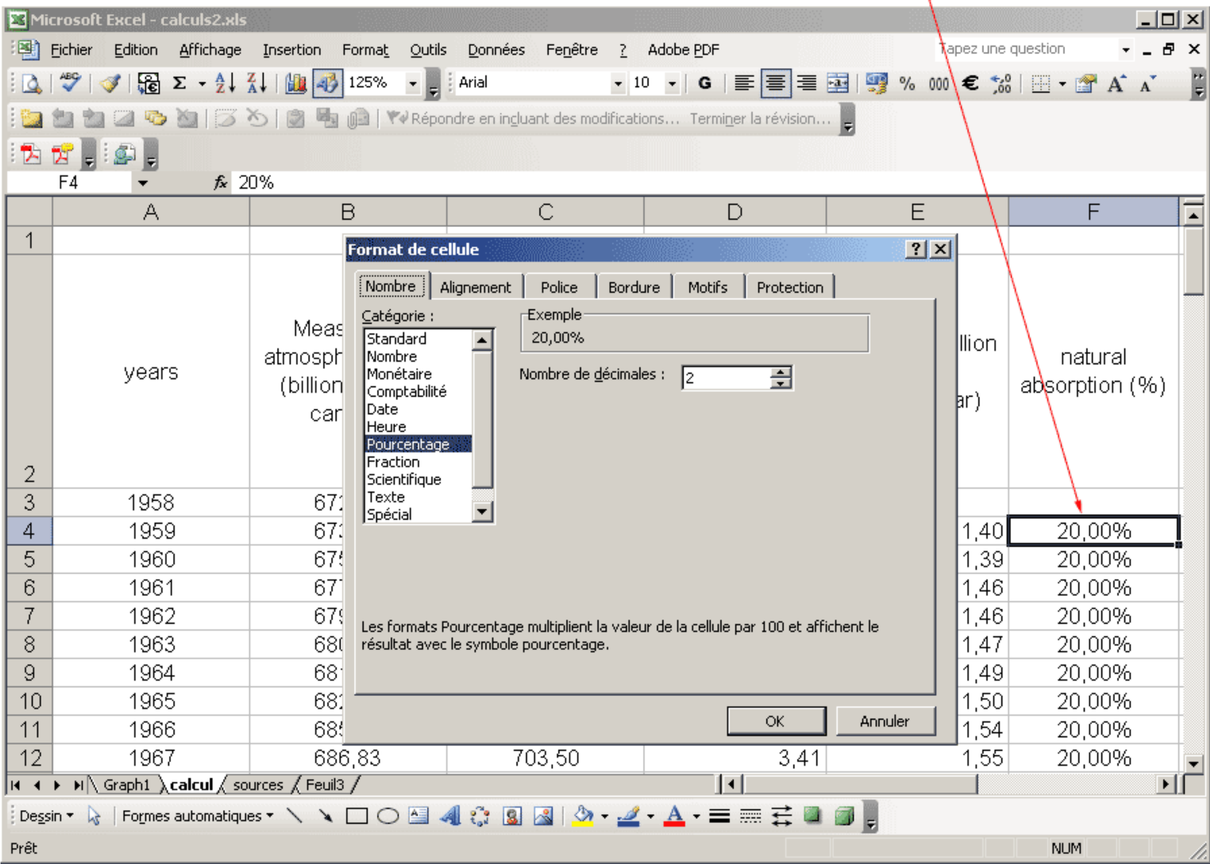
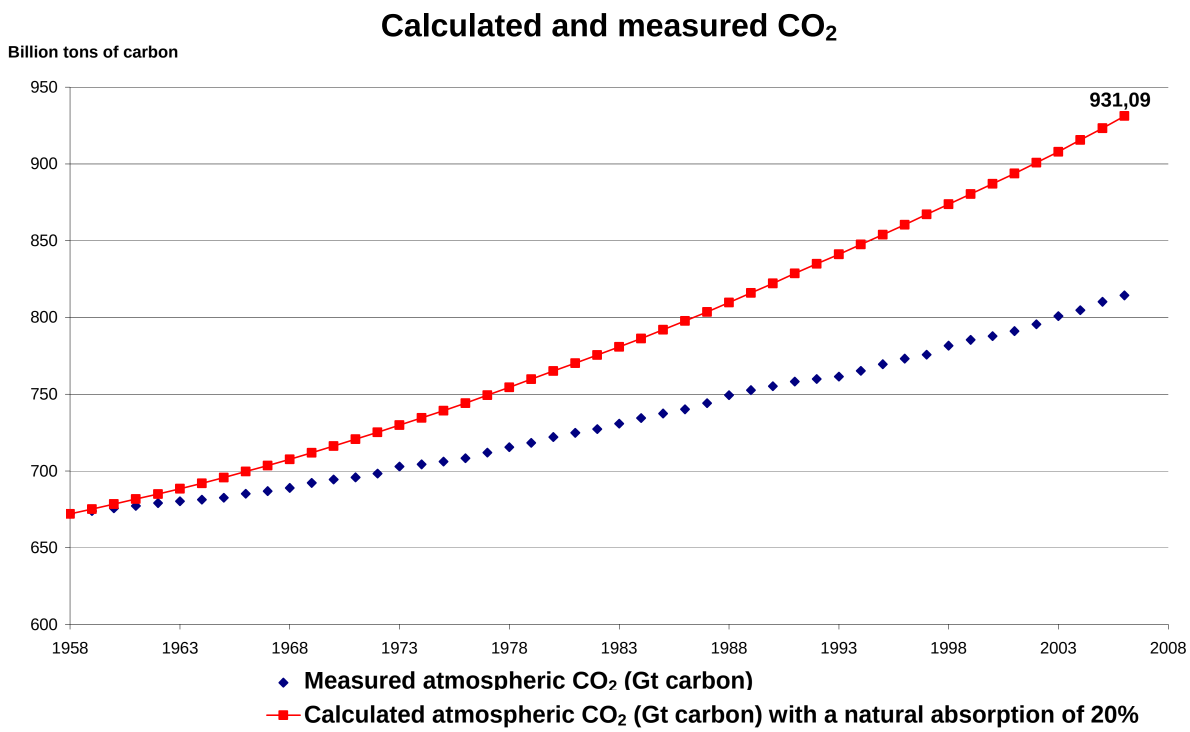
Value of this cell is 0.2 but when you change the format in "percentage", you will see 20%



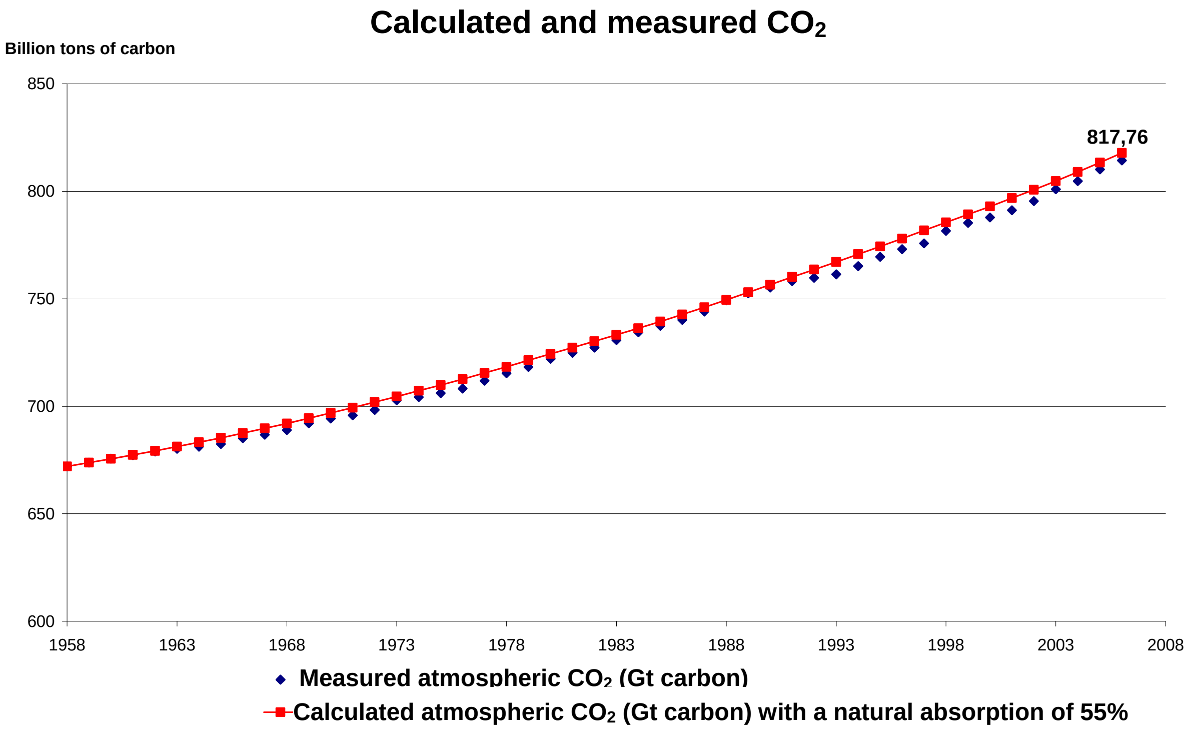
Graphic representation of the calculation using a natural absorption of 20%. It shows a natural absorption too small to explain observations.



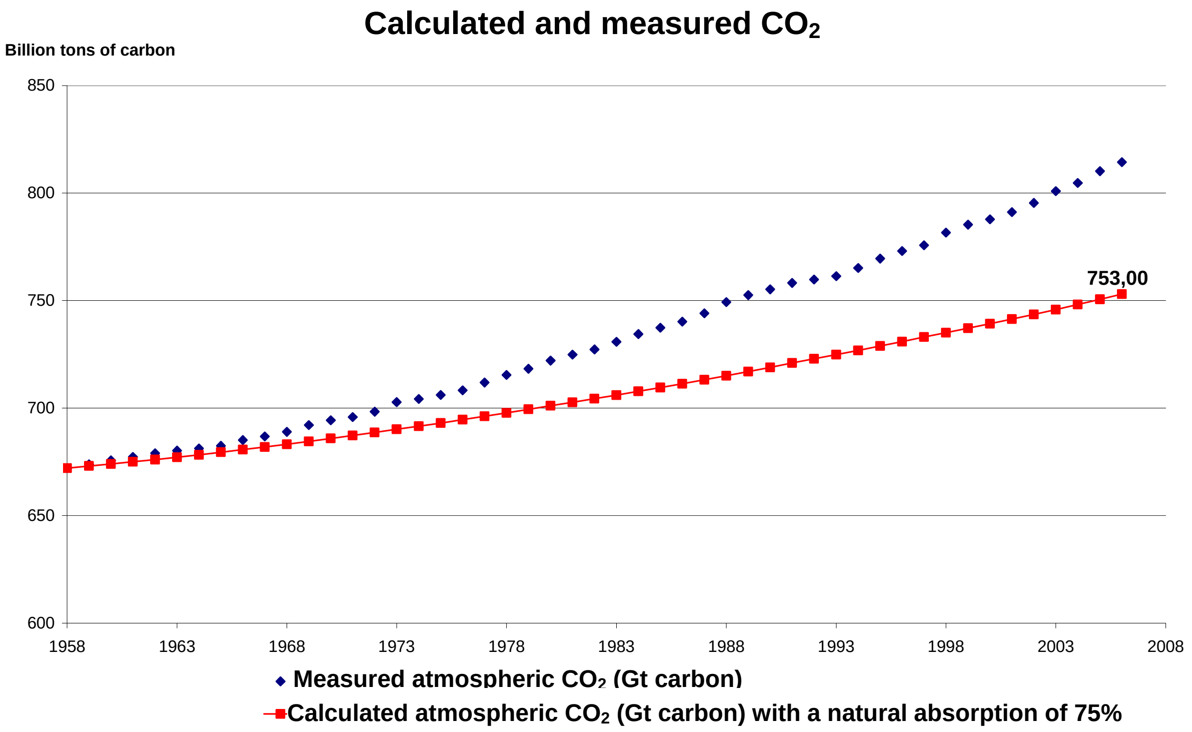
2. Use different percentages to produce graphs in order to find a "best fit". In other words, reproduce a curve that is similar to the observed curve.

3. According to your models, what percentage of natural absorption best explains the global carbon cycle for the second half of the century? Answer: 55.6%

Graphic representation of the calculation with a natural absorption of 55%, which shows a good estimation of the natural absorption.



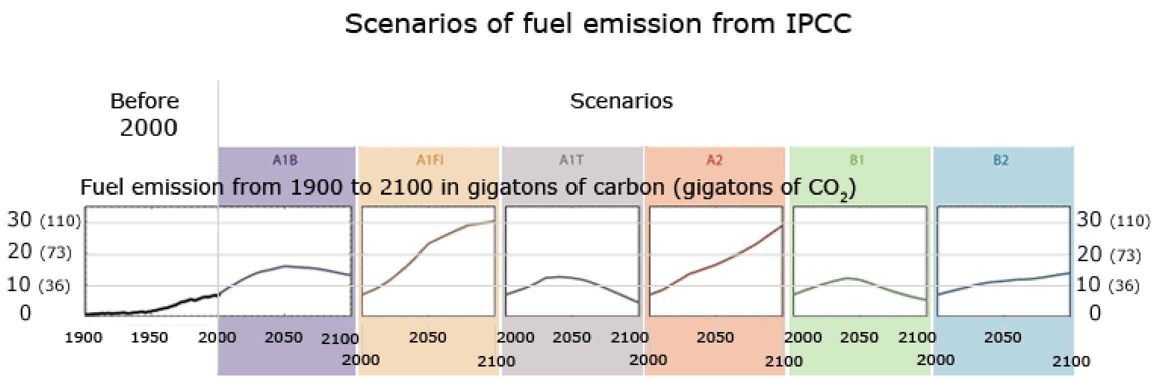
Graphic representation of the calculation with a natural absorption of 75%, which shows a higher estimation of the natural absorption.



Part 3

A natural absorption of 55% is a good model simulation to explain global carbon cycle for the second half of the second century. It is now possible to manipulate the data in order to produce different scenarios until the year 2100, as in the IPCC scenarios shown below (download or show scenariosCarbone.gif).

ScenariosCarbone.gif



Procedure

1. Decide what type of scenario you would like to create: Pessimistic? Optimistic? Intermediate?

2. Now you need to extend your column D (fossil fuel emissions) according to type of scenario. For example:

   - **Pessimistic**: highlight the last **two** cells in column D, place your pointer on the black square on the bottom right-hand side of the cell, left click on your mouse and drag down to 2100. Excel will calculate the difference between the values in the last two cells and will adjust the following quantities accordingly.

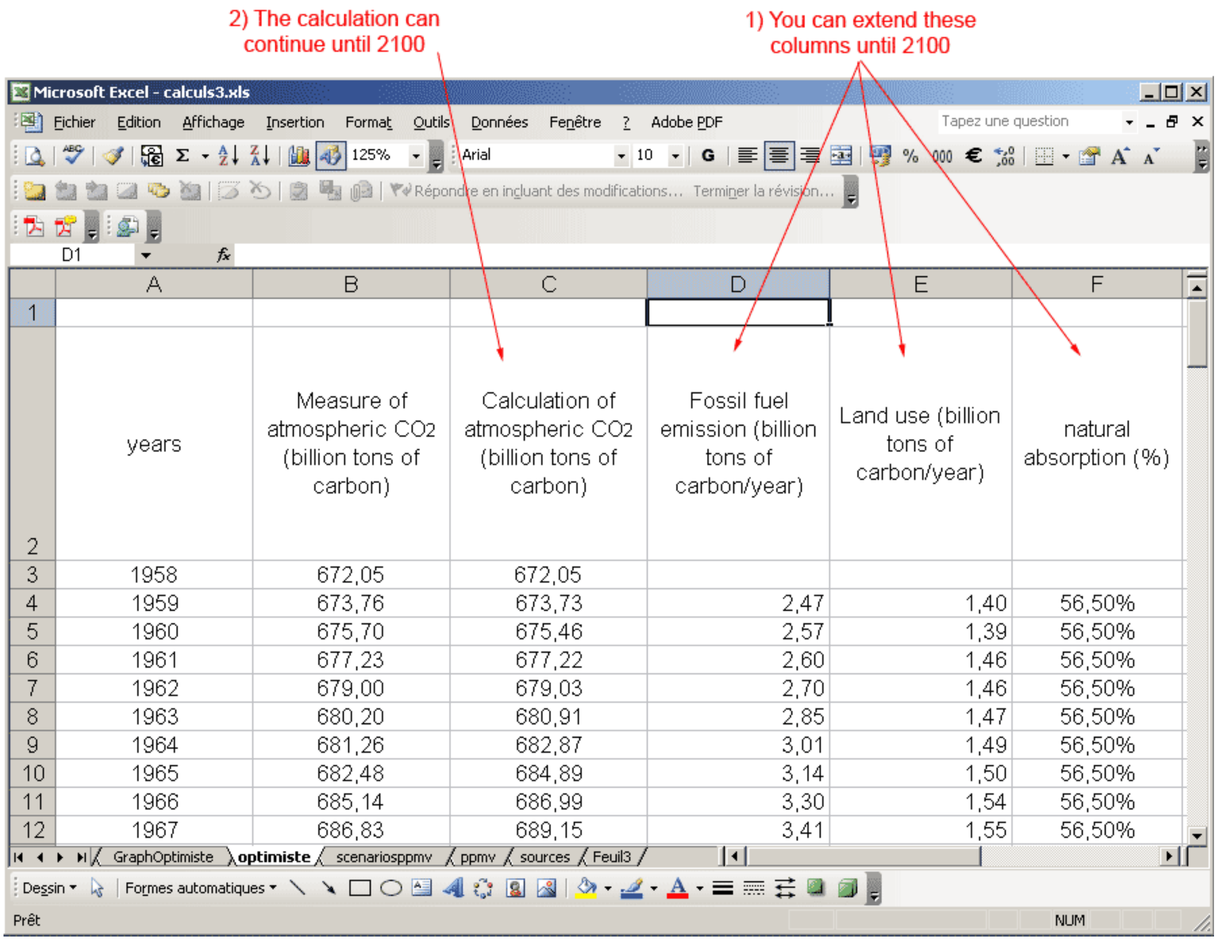
   - **Intermediate**: highlight (for example) the last ten cells in column D, and proceed as above. Your values until 2100 will not be so high because in the previous 10 years the difference in values from year to year was not so high as in the last two or three years.

   - **Optimistic**: add your own values for two or three cells with a lower difference between them than in the previous cells. You can do this at any point. For example, you could do an intermediate or pessimistic scenario until 2040 and then add your own values to create a subsequent more optimistic scenario.

3. Assuming that land-use will more or less remain the same, you can extend column E by using the same value in each cell: for example with the value in 2006, or with an average from 1958 till 2006.

4. Extend column F, Natural Absorption, with the same percentage. We will assume that it will be the same until 2100.

5. Now you have all the data in D, E and F, you can extend column C by using the same calculation.



	A	B	C	D	E	F
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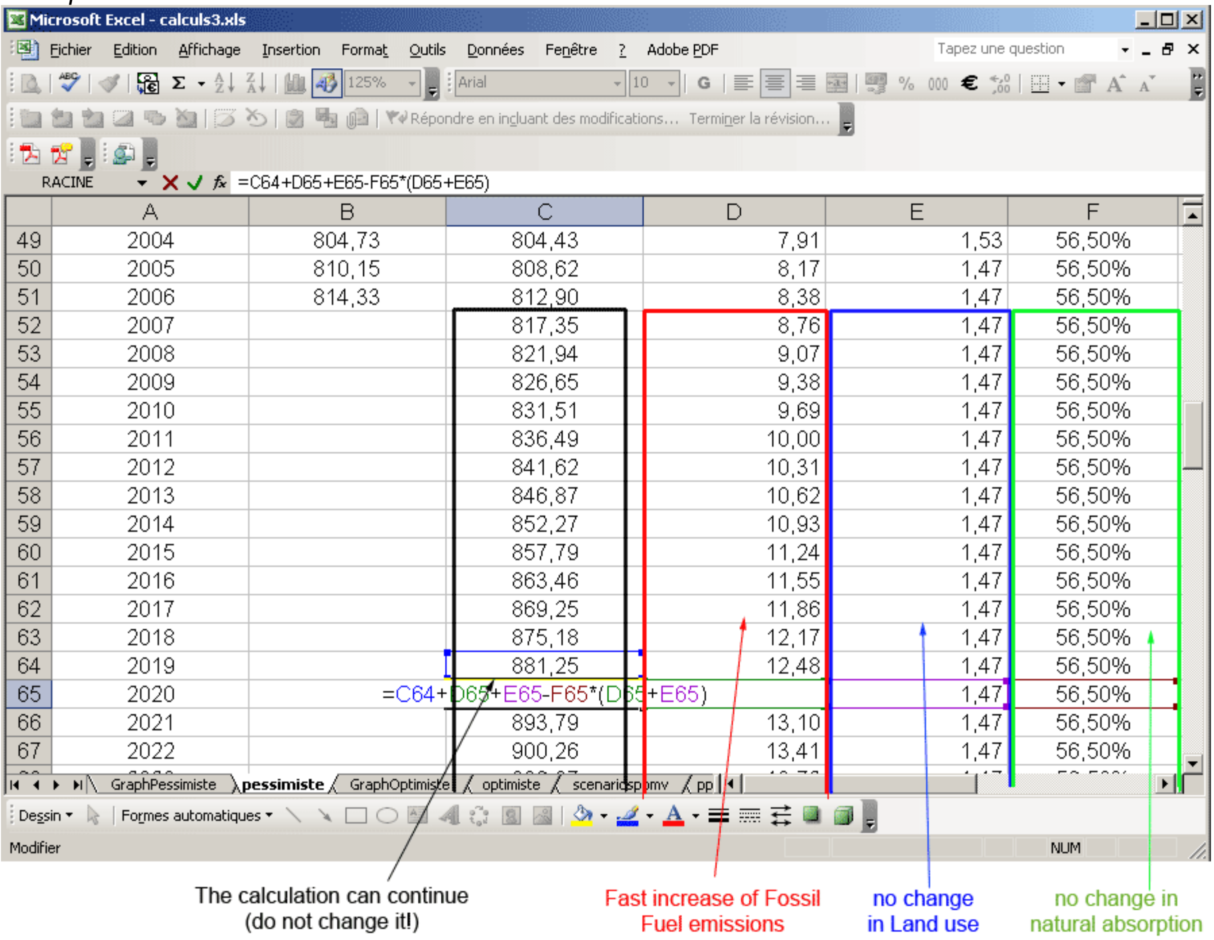
2	years	Measure of atmospheric CO2 (billion tons of carbon)	Calculation of atmospheric CO2 (billion tons of carbon)	Fossil fuel emission (billion tons of carbon/year)	Land use (billion tons of carbon/year)	natural absorption (%)
3	1958	672,05	672,05			
4	1959	673,76	673,73	2,47	1,40	56,50%
5	1960	675,70	675,46	2,57	1,39	56,50%
6	1961	677,23	677,22	2,60	1,46	56,50%
7	1962	679,00	679,03	2,70	1,46	56,50%
8	1963	680,20	680,91	2,85	1,47	56,50%
9	1964	681,26	682,87	3,01	1,49	56,50%
10	1965	682,48	684,89	3,14	1,50	56,50%
11	1966	685,14	686,99	3,30	1,54	56,50%
12	1967	686,83	689,15	3,41	1,55	56,50%

6. Create scenario graphs using your data.

7. Compare your scenarios with other pupils' in the class. Which do you think could be the most likely? Give reasons and discuss the implications of such a scenario really happening.

Example of an extension



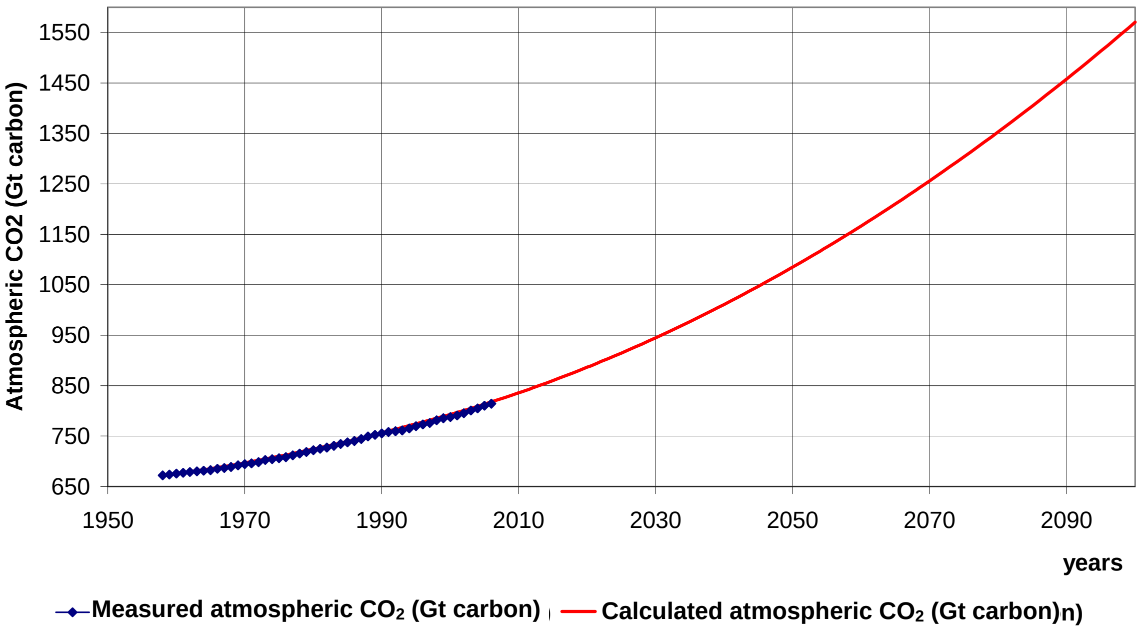
Microsoft Excel - calculs3.xls

RACINE =C64+D65+E65-F65*(D65+E65)

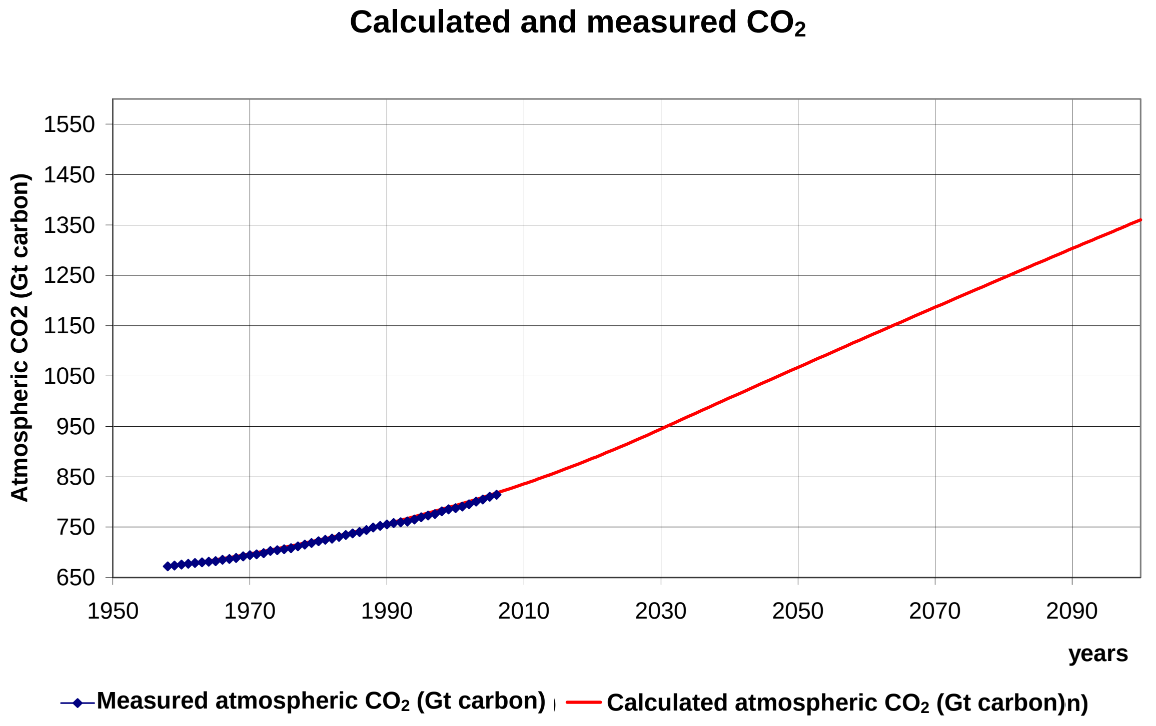
	A	B	C	D	E	F
49	2004	804,73	804,43	7,91	1,53	56,50%
50	2005	810,15	808,62	8,17	1,47	56,50%
51	2006	814,33	812,90	8,38	1,47	56,50%
52	2007		817,35	8,76	1,47	56,50%
53	2008		821,94	9,07	1,47	56,50%
54	2009		826,65	9,38	1,47	56,50%
55	2010		831,51	9,69	1,47	56,50%
56	2011		836,49	10,00	1,47	56,50%
57	2012		841,62	10,31	1,47	56,50%
58	2013		846,87	10,62	1,47	56,50%
59	2014		852,27	10,93	1,47	56,50%
60	2015		857,79	11,24	1,47	56,50%
61	2016		863,46	11,55	1,47	56,50%
62	2017		869,25	11,86	1,47	56,50%
63	2018		875,18	12,17	1,47	56,50%
64	2019		881,25	12,48	1,47	56,50%
65	2020		=C64+D65+E65-F65*(D65+E65)		1,47	56,50%
66	2021		893,79	13,10	1,47	56,50%
67	2022		900,26	13,41	1,47	56,50%

Example with a pessimistic scenario

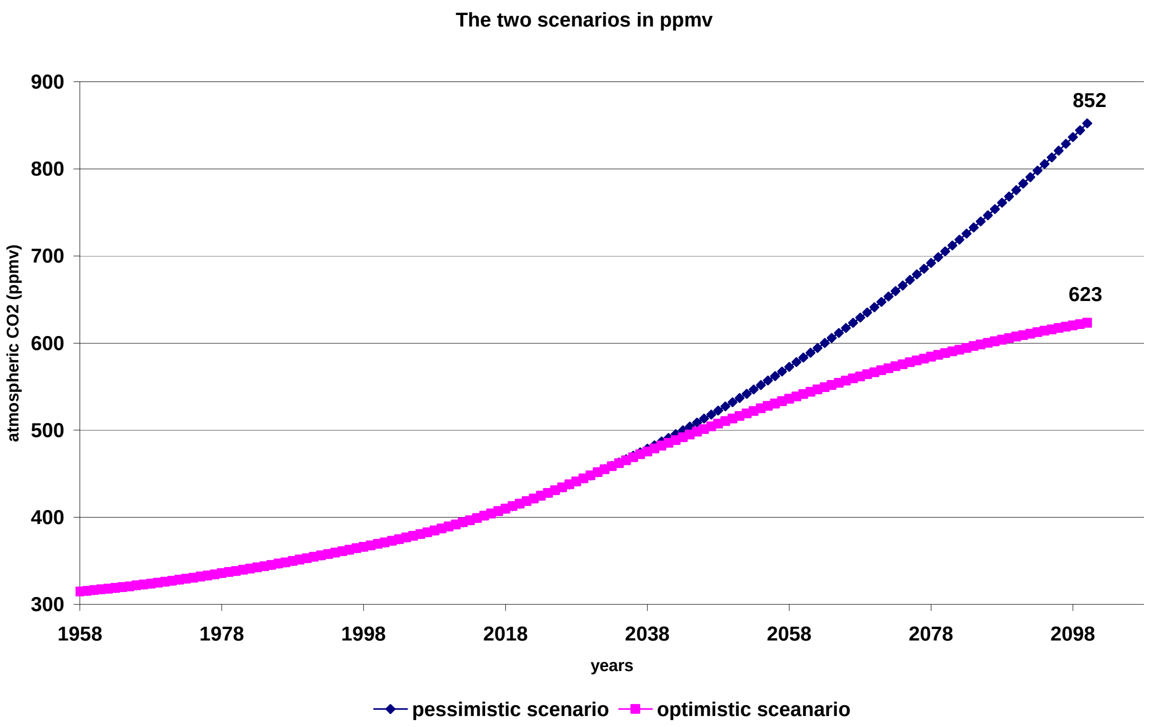
Calculated and measured CO_2



Example with an intermediate scenario



Comparison of two scenarios in ppmv



You can find different scenarios in calculs3.xls, downloadable on the website.

You can go further:

- To work with natural absorption data between 1958 and 2008, see “**Global carbon budget between 1958 and 2008**”
- To explore natural absorption year by year in billion tons of carbons, with the same file, see “**Estimation of natural carbon sinks**”

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