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| Historic greenhouse gas concentrations from Antarctic ice core sampling |
| Information Processing and Data Analysis |
| This document and its accompanying Excel workbook ‘Historic greenhouse gas concentrations ice core data” give students the opportunity to process and analyse authentic scientific data which provides ice core records of the concentration of greenhouse gases, carbon dioxide and methane, in the Earth’s atmosphere over the past 800,000 years.  **Students will:**   * construct graphs using MS Excel * interpret and analyse their graphs to determine the trends in the concentration of greenhouse gases, carbon dioxide and methane, over time * process information from suggested videos and background information to interpret the data and answer the questions provided.   The step-by-step instructions provided in this document for the construction of graphs using MS Excel are suitable for 2013 Excel and 2016 Microsoft Office Excel programs. |
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| **The activities provided address the following Australian Curriculum Content Descriptions:**  **Year 10: Earth and Space Science**   * Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere [(ACSSU189)](http://www.scootle.edu.au/ec/search?accContentId=ACSSU189) * investigating how human activity affects global systems * explaining the causes and effects of the greenhouse effect * People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people’s lives, including generating new career opportunities [(ACSHE194)](http://www.scootle.edu.au/ec/search?accContentId=ACSHE194) * considering the scientific knowledge used in discussions relating to climate change   **Senior Secondary Curriculum: Earth and Environmental Science**   * Unit 4: The Changing Earth - the cause and impact of Earth hazards   The cause and impact of global climate change  Anthropogenic climate change – what’s the evidence?  **The activities provided address the following Australian Curriculum Inquiry Skills:**   * Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies [(ACSIS203)](http://www.scootle.edu.au/ec/search?accContentId=ACSIS169) * Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204) * Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems [(ACSIS206)](http://www.scootle.edu.au/ec/search?accContentId=ACSIS172) * Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations [(ACSIS208)](http://www.scootle.edu.au/ec/search?accContentId=ACSIS208)   **Each activity requires a 60 minute lesson to complete. The activities are suitable for students in Years 10 to 12.** |
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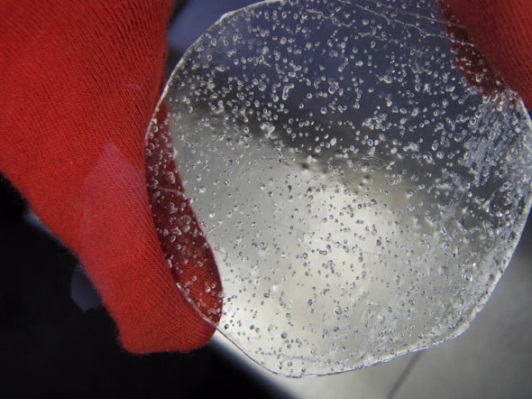
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**Investigating the concentration of greenhouse gases in the Earth’s atmosphere over time**

Ice core records provide the most direct and detailed way to investigate past climate and atmospheric conditions. Ice cores are cylinders of ice drilled out of an ice sheet or glacier. Airborne relics of Earth's earlier climate—including air trapped in bubbles, dust, sea salt, volcanic ash, and soot from forest fires—can end up trapped in ice. These relics tell climate scientists about how our planet's climate and atmosphere have changed over periods ranging from decades to many hundreds of thousand years.

The ice encloses small bubbles of air that contain a sample of the atmosphere – from these it is possible to measure directly the concentration of gases, including the greenhouse gases carbon dioxide and methane, as they were in the past atmosphere. More detailed information can be found by looking at the isotopes - the same elements but with differing masses – comprising these gases. Hence ice cores provide a vertical timeline of past climates stored in ice sheets. Most ice core records come from locations in Antarctica and Greenland. The oldest continuous ice core record to date comes from Antarctica - from a place called Dome Concordia (Dome C). That ice core has been drilled to a depth of 3200 m and provides a record that goes back 800,000 years. By looking at past concentrations of greenhouse gases, scientists can determine how modern amounts of carbon dioxide and methane compare to those of the past. ANSTO is involved in this work. ANSTO’s principal research scientist Dr Andrew Smith, in collaboration with atmospheric scientists and glaciologists, measures the amount of radiocarbon (14C), the radioactive isotope of carbon (C) in carbon dioxide (CO2) and in methane (CH4) extracted from polar ice sheets. The main sites are Summit and Pakitsoq in Greenland (Arctic) and Law Dome and Taylor Glacier in Antarctica. These measurements allow us to track the process of bubble formation in ice sheets and to understand where the atmospheric methane came from in past times. These studies have focused on the ‘Anthropocene’ which commenced ~ 1850 AD and marks the rapid rise of greenhouse gases in the atmosphere.

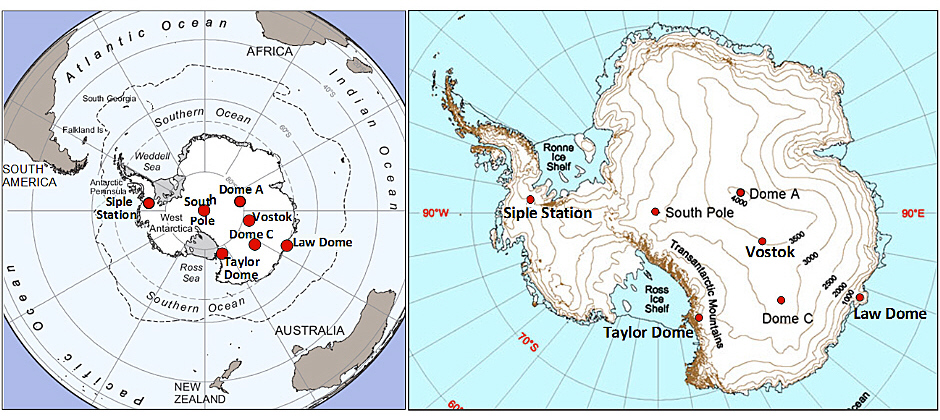
The data set provided in the Excel spreadsheet uses the EDC3 age scale, which relates the age of the trapped air to the depth in the ice core from which the air was extracted. EDC3 is the official age scale for the EPICA (European Project for Ice Coring in Antarctica) Dome C (EDC) ice core. The age of the trapped air is stated in ‘yrs BP 1950’. BP stands for ‘before present’ but present time changes, so it is standard practice to measure time from 1 January 1950.

The data set includes:

* a detailed methane record from the EPICA Dome C ice core that extends the history of this greenhouse gas to 800,000 yr before AD 1950.
* a composite record of atmospheric carbon dioxide levels over the past 800,000 years provided by records from the Antarctic Vostok and EPICA Dome C ice cores. The Antarctic ice-core records of carbon dioxide (CO2) extend back 800,000 years at Dome C and over 400,000 years at the Vostok site. A shorter record is provided from another Antarctic location, Taylor Dome.
* a temperature estimate, specifically the temperature difference from the average temperature of the last 1000 years (that is, -54.5oC), over the past 800,000 years. The temperature was estimated from analysis of deuterium in the ice cores, with various corrections.
* Law Dome carbon dioxide (CO2) and methane (CH4) records for 0 to 2000 AD

More detailed information about each of the data sheets provided is given in the *Acknowledgement for Data Sets* given at the end of these worksheets.

## Antarctic Ice-Core Stations



Maps of Antarctica showing locations and elevations in metres above sea level (masl) of: Law Dome (66°44'S, 112°50'E, 1390 masl), Dome C (75°06'S, 123°24'E, 3233 masl), Taylor Dome (77°48'S, 158°43'E, 2365 masl), Vostok (78°28'S, 106°52'E, 3500 masl), Dome A (80°22'S, 77°22'E, 4084 masl), the South Pole station (90°S, 2810 masl), and Siple Station (75°55'S, 83°55'W, 1054 masl).

Before beginning the information and data analysis tasks, read the articles listed below. Use the information presented in the articles to assist you in answering the questions in the tasks.

* “Man-made fossil emissions larger than previously believed”

<http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS162050>

* “Retrieving an Antarctic ice core more than a million years old presents challenges and opportunities”

<http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS171193>

* Australian Antarctic Division: Leading Australia’s Antarctic program – Ice cores

<http://www.antarctica.gov.au/about-antarctica/environment/climate-change/ice-cores>

**activity 1: Methane in the earth’s past atmosphere**

Information Processing and Data Analysis Exercises

1. From your reading of the articles, describe how scientists have been able to study the chemical composition of the Earth’s atmosphere over the past 800 000 years.

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1. (i) Examine the “**CH4\_EDC**” MS Excel worksheet. Explain the unit used to measure the gas age. Why has this unit been chosen?

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1. To what **calendar year** is the air for the most recent methane reading in the table attributed?

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1. How can the age of a layer of ice be determined?

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1. Using the data, construct a scatter graph with smooth lines to show the **gas age versus the depth**. Include a graph title and axes titles.

**HINT**: You can use the following steps to create your chart:

1. In the **CH4\_EDC** MS Excel worksheet, highlight all the data in both **EDC1999 depth** and **gas age** columns. Do not include the column headings. To do this, click, hold and drag the icon from cell A3 to cell B2105, the last cell in column B.

Alternatively, you can use **Shortcut keys** to highlight each column separately. Click in cell A3 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column A. Scroll to the top of the spreadsheet and, holding down the CTRL button, click in cell B3. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in column B.

1. On the **Insert** tab, in the **Charts** group, select the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers**. 
2. Right click on the scale of the horizontal axis (x-axis) and select **Add Minor Gridlines** from the dialog box that opens.
3. Add **Chart Title** and **Axis Titles** for both Primary Horizontal axis and the Primary Vertical axis. To do this, select **Chart Design** from the top bar of the spreadsheet or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles,** both Primary Horizontal and Primary Vertical.
4. (i) Use your graph to state the depth at which the age of the methane gas is 100 000 years old.

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(ii) How old is the methane gas from air trapped in the ice core at a depth of 2700 m?

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1. Describe the trend shown by the graph.

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1. Give an explanation for the trend shown by the graph.

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1. What are some natural sources of methane in the atmosphere?

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1. Using the data, construct a scatter graph with smooth lines to show the **concentration of methane in ppbv versus the gas age**. Include a graph title and axes labels.

**HINT**: You can use the following steps to create your chart:

1. Highlight all the data in both **gas age** and **CH4 mean concentration** columns. Do not include the column headings. To do this, use **Shortcut keys** to highlight each column separately. Click in cell B3 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column B (gas age). Scroll to the top of the spreadsheet and, holding down the CTRL button, click in cell C3. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in column C (CH4 mean concentration).
2. On the **Insert** tab, in the **Charts** group, click the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers**. 
2. Right click on the scale of the horizontal axis (x-axis) and select **Add Minor Gridlines** from the dialog box that opens. Repeat for the scale of the vertical axis (y-axis)
3. Add **Chart Title** and **Axis Titles** for both Primary Horizontal axis and the Primary Vertical axis. To do this, select **Chart Design** from the top bar of the spreadsheet, or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles,** both Primary Horizontal and Primary Vertical.
4. (i) From your graph, state the **highest** **historical concentration** of methane that has been recorded between 10 000 years ago and 800 000 years ago. Approximately when did this occur?

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(ii) From your graph, state the **lowest** **historical concentration** of methane that has been recorded over the last 800 000 years. Approximately when did this occur?

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1. Describe what the graph shows about the methane concentration in the atmosphere over the last 800 000 years.

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1. Present-day atmospheric methane levels of 1,770 ppbv have been reported, which are well above the concentration of methane in the atmosphere for the entire time period of the last 800 000 years. How do scientists account for these present-day values?

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1. Why do Australian scientists want to drill a million-year ice core record in Antarctica? What new information could it provide?

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1. What criteria need to be met in choosing a site for the extraction of ice cores?

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**activity 2: carbon dioxide in the earth’s past atmosphere**

Information Processing and Data Analysis Exercises

**Task 1: Carbon dioxide in Earth’s atmosphere over last 800 000 years**

1. Using the Composite CO2 record (0-800 kyr BP) data set (“**CO2\_Composite\_record**” MS Excel worksheet), construct a scatter graph with smooth lines to show **the concentration of CO2 versus the gas age**. Choose a range of 160 – 320ppmv for CO2 concentration and a range of 0 – 800000 yrs for gas age. Include a graph title and axes labels.

**HINT**: You can use the following steps to create your chart:

1. Highlight all the data in both **gas age** and **CO2 concentration** columns. Do not include the column headings. To do this, click, hold and drag the icon **from cell A9 to cell B1104**, the last cell in column B.

Alternatively, you can use **Shortcut keys** to highlight each column separately. Click in cell A9 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column A. Scroll to the top of the spreadsheet and, holding down the CTRL button, click in cell B9. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in column B.

1. On the **Insert** tab, in the **Charts** group, click the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers.** 
2. Add **Chart Title** and **Axis Titles** for both Primary Horizontal axis and the Primary Vertical axis. To do this, select **Chart Design** from the top bar of the spreadsheet or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles,** both Primary Horizontal and Primary Vertical.
3. (i) From your graph, state the highest historical concentration of carbon dioxide that has been recorded between 137 yrs Bp 1950 and 798 512 yrs Bp 1950. Approximately when did this occur?

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(ii) From your graph, state the **lowest** historical concentration of carbon dioxide that has been recorded between 137 yrs Bp 1950 and 798 512 yrs Bp 1950. Approximately when did this occur?

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1. Describe what the graph shows about the carbon dioxide concentration in the atmosphere between 137 yrs Bp 1950 and 798 512 yrs Bp 1950.

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1. The most recent data provided in the CO2 data set shows the concentration of CO2 in the Earth’s atmosphere 137 yrs Bp 1950.

Find out the **current concentration** of carbon dioxide in the atmosphere. The following NASA website regularly updates the concentration of carbon dioxide in the Earth’s atmosphere.

[Carbon Dioxide | Vital Signs – Climate Change: Vital Signs of the Planet (nasa.gov)](https://climate.nasa.gov/vital-signs/carbon-dioxide/)

Concentration of carbon dioxide in Earth’s atmosphere (ppm) …………………………………………………..

Date of measurement: ………………………………………………………………………………………………………………..

1. What conclusion can you draw from a comparison between the range of carbon dioxide concentrations from the graph you have constructed and the concentration of carbon dioxide in today’s atmosphere?

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**Task 2:** **Comparing carbon dioxide data from different Antarctic sites**

1. Using the Vostok-TD-Dome C record data set (“**Dome C-Vostok-Taylor\_CO2**” excel worksheet), construct a scatter graph with smooth lines to show the **gas age versus the concentration of CO2**for Vostok (0-440 kyr BP), Taylor Dome (19-63 kyr BP), Dome C (0-22 kyr BP) and Dome C LGGE in Grenoble on the same set of axes.

Choose a range of 160 – 320ppmv for CO2 concentration and a range of 0 – 450000 yrs for gas age. Include a graph title and axes labels.

**HINT**: You can use the following steps to create your chart:

1. For the Vostok data, highlight all the data in both **gas age** and **CO2** columns. Do not include the column headings. To do this, you can use **Shortcut keys** to highlight each column separately. Click in cell F8 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column F Vostok gas age. Scroll to the top of the spreadsheet and, holding down the CTRL button, click in cell G8. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in column G Vostok CO2.
2. On the **Insert** tab, in the **Charts** group, click the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers**.



1. Right click in the plot area of the chart and choose **select data**.
2. The **Select Data Source** dialog box appears. In the dialog box, select **edit** and, in the second dialog box that opens, type in the **series name** **“Vostok (0 – 440 kyr BP)”**. Click OK.
3. Select **Add** in the **Select Data Source** dialog box.
4. In the second dialog box that opens type in the **series name** **“Taylor Dome (TD)”**.
5. Click in the **Series X values,** type **=** then highlight the Taylor Dome **gas age** data in column I. Do not include the column headings. Alternatively, click in the **Series X values** then click in cell I8 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column I Taylor gas age.
6. Click in the **Series Y values**, delete {1} and highlight the **CO2 ppmv** for Taylor Dome in column J. Alternatively, click in the **Series Y values** then delete ={1} in Series Y Values box. Click in cell J8 and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column J Taylor CO2 ppmv. Click OK.
7. Repeat steps 6, 7, 8 and 9 to add the “**Dome C (0-22kyr BP)**” data series to the graph, highlighting data in **column B** for the Series X values, and data in **column C** for the Series Y values.
8. Repeat steps 6, 7, 8 and 9 to add the “**Dome C (393-664kyr BP) LGGE in Grenoble**” data series to the graph, highlighting data in **column Q** for the Series X values, and data in **column R** for the Series Y values.
9. Add **Chart Title** and **Axis Titles** for both Primary Horizontal axis and the Primary Vertical axis. To do this, select **Chart Design** from the top bar of the spreadsheet, or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles,** both Primary Horizontal and Primary Vertical.
10. Add a **legend** to show the names of the different series. To do this, click on **Add Chart Elements** on the left-hand side of the tool bar, and scroll down to **Legend.** Choose **Right.** You may also need to increase the size of your graph.
11. To change the data range of each axis, right-click the **scale on the axis** you want to format and click **Format Axis** to fix **minimum** and **maximum** range values. For CO2 concentration on the y axis, type a minimum of 160 and a maximum of 320 ppmv, and for gas age on the x axis type a minimum of 0 and a maximum of 450000 yrs.
12. Compare the plots for each of the sites – Taylor Dome, Dome C (0-22kyr BP), Dome C (393-664kyr BP) LGGE in Grenoble - with the plot of the Vostok site data.

What can you say about the plots from each of these different sites when compared to the plot from Vostok site?

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1. Refer to the map of the sites in Antarctica on page 5. Explain why it is necessary to gather data from different sites.

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**Task 3:** **Comparing carbon dioxide concentration with Antarctic temperature difference**

1. Using both the Temperature-EDC3 age scale data set (“**Temperature-EDC3 timescale**” MS Excel worksheet) and the CO2 composite data set (“**CO2­\_Composite\_Record**” MS Excel worksheet), construct a scatter graph with smooth lines to show the gas age versus the temperature and the gas age versus the concentration of CO2 for the same x-axis scale but having different y-axis scales.

Choose an x-axis range of 0 – 800000 yrs BP 1950 for gas age.

Choose a y axis range for CO2 concentration of 0 – 350 ppmv and a y-axis range for temperature of -20oC – 20oC.

Include a graph title and axes labels.

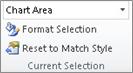
**HINT**: You can use the following steps to create your chart:

1. For the **Temperature-EDC3 timescale** MS Excel worksheet, highlight all the data in both **gas age** and **temperature** columns. Do not include the column headings. To do this, use **Shortcut keys** to highlight each column separately. Click in **cell D3** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column D gas age. Scroll to the top of the spreadsheet and, holding down the CTRL button, click in **cell E3**. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in **column E Temperature**.
2. On the **Insert** tab, in the **Charts** group, click the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers**. 
2. Right click in the plot area of the chart and choose **select data**.
3. The **Select Data Source** dialog box appears. In the dialog box, select **edit** and, in the second dialog box that opens, type in the **series name** “Temperature difference”. Click OK.
4. Select **Add** in the **Select Data Source** dialog box.
5. In the second dialog box that opens type in the **series name** “CO2 concentration”.
6. Click in the **Series X values:** box, then click the **CO2 \_Composite\_record** MS Excel worksheet, and highlight the CO2 composite **gas age** data, that is, click in **cell A9** and, holding the button depressed, drag to cell A1104. Alternatively, use **Shortcut keys** to highlight the data in column A gas age. To do this, click in **cell A9** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys.
7. Click in the **Series Y values**:, delete {1} and highlight the **CO2 concentration** data in column B on the **CO2 \_Composite\_record** MS Excel worksheet, that is, click in **cell B9** and, holding down the button, drag to cell B1104. Alternatively, use **Shortcut keys** to highlight the data in column B gas age. To do this, click in the **Series Y values**:, delete ={1}, then click in **cell B9** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys.
8. Click OK, and then OK for the original dialog box. The chart appears near the bottom of the data in the **Temperature-EDC3 timescale** worksheet.
9. Click the chart, then select **Format** from the tool bar at the top of the spreadsheet.
10. In the **Current Selection** group in the top left-hand corner, select **series “CO2 concentration”** from the drop down menu.

Drop down menu



1. Click **Format Selection** in the **Current Selection** group. The **Format Data Series** dialog box is displayed on the right-hand side of the spreadsheet.
2. Select **Secondary Axis** from Series Options and press **enter**. This will create a new vertical scale for the CO2 concentration on the right-hand side of your chart.
3. Add **Chart Title** and **Axis Titles** for both Primary Vertical axes and the Primary Horizontal axis. To do this, To do this, select **Chart Design** from the top bar of the spreadsheet, or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles.** ForPrimary Vertical type **Temperature difference (oC)** and for Secondary Vertical type **CO2 concentration (ppm)**. For Primary Horizontal type Gas Age (years BP 1950).
4. Add a **legend** to show the names of the different series. To do this, click on **Add Chart Elements** on the left-hand side of the tool bar, and scroll down to **Legend.** Choose **Right.**
5. Change the data range of the **Temperature difference y axis** by right clicking the Temperature difference y-axis and selecting **format axis** in the dialog box that opens. Type  **-20** in the **minimum** box, and type **20** in the **maximum** box under **Bounds** in the box on the right hand side.
6. To move the x-axis to the bottom of the chart, go to **Horizontal axis crosses** in the box on the right hand sideandselect **Axis value** then type -20 in the box. Press **enter**.
7. Compare the temperature plot and the Carbon dioxide plot shown on the chart. Comment on the patterns of the plots. What can you conclude from these plots?

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**activity 3: carbon dioxide and Methane over the last 2000 years**

1. Using the **Law Dome \_CO2\_CH4\_0-2000AD** MS Excel worksheet, construct a scatter graph with smooth lines to show the Year AD versus the concentration of carbon dioxide (ppm) and the concentration of CH4 (ppb)using the same x axis scale but having different y-axis scales.

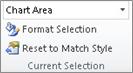
Include a graph title and axes labels.

**HINT**: You can use the following steps to create your chart:

1. For the methane data, highlight all the data in both **Year AD** and **CH4 (ppb)** columns. Do not include the column headings. To do this, use **Shortcut keys** to highlight each column separately. Click in **cell A2** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column A (Year AD). Scroll to the top of the spreadsheet and, holding down the CTRL button, click in cell B2. Whilst still depressing the CTRL button, simultaneously hold down the SHIFT + (Down Arrow) keys to highlight all the data in column B (CH4, ppb).
2. On the **Insert** tab, in the **Charts** group, click the **Scatter** symbol.



1. Click **Scatter with smooth lines and markers**. 
2. **Right click** in the plot area of the chart and choose **select data**.
3. The **Select Data Source** dialog box appears. In the dialog box, select **edit** and in the second dialog box that opens type in the **series name** “CH4 concentration”. Click OK.
4. Select **Add** in the **Select Data Source** dialog box.
5. In the second dialog box that opens type in the **series name** “CO2 concentration”.
6. Click in the **Series X values:** box, type **=** then highlight the **Year AD** data in column A. Alternatively, click in the **Series X values:** box, then click in **cell A2** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column A (Year AD).
7. Click in the **Series Y values**:, delete {1} then highlight the CO2 (ppm) data in column C. Alternatively, Click in the **Series Y values**: and delete ={1} then click in **cell C2** and simultaneously hold down CTRL +SHIFT + (Down Arrow) keys. This will highlight the entire column of data in column C.
8. Click OK and then OK for the original dialog box.
9. To create a **secondary vertical axis for carbon dioxide concentration**, click the chart area, then click **Format** at the top of the tool bar.
10. In the **Current Selection** group in the top left-hand corner, select **series “CO2 concentration”** from the drop down menu.



Drop down menu

1. Click **Format Selection** in the **Current Selection** group. The **Format Data Series** dialog box is displayed on the right-hand side of the spreadsheet.
2. Select **Secondary Axis** from Series Options and press **enter**. This will create a new vertical scale for the CO2 concentration on the right-hand side of your chart.
3. Add **Chart Title** and **Axis Titles** for both Primary Vertical axes and the Primary Horizontal axis. To do this, select **Chart Design** from the top bar of the spreadsheet, or double click on your graph. **Add Chart Elements** appears on left hand side of tool bar. Click here and scroll down to **Chart Title.** Choose **above chart**, click in the box at the top of the spreadsheet and type the title of your graph.Press **ENTER.** Repeat for **Axis Titles.** ForPrimary Vertical type **CH4 concentration (ppb)** and for Secondary Vertical type **CO2 concentration (ppm)**. For Primary Horizontal type **Year AD**.
4. Add a **legend** to show the names of the different series. To do this, click on **Add Chart Elements** on the left-hand side of the tool bar, and scroll down to **Legend.** Choose **Right.**
5. State the trend shown by each of the plots.

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1. Account for the changes in the concentration of carbon dioxide and methane in recent times (last 200 years).

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**ACKNOWLEDGEMENTS FOR DATA SETS**

**EXCEL Sheet 1: CH4\_EDC**

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| --- | --- |
| Name of Data Set | EPICA Dome C Ice Core 800 KYr Methane Data |
| Contributors | Laetitia Loulergue, et al.  IGBP PAGES/WDCA CONTRIBUTION SERIES NUMBER: 2008-054 |
| Original Reference | Loulergue, L., A. Schilt, R. Spahni, V. Masson-Delmotte, T. Blunier, B. Lemieux, J.-M. Barnola, D. Raynaud, T.F. Stocker, and J.Chappellaz. 2008.  Orbital and millennial-scale features of atmospheric CH4 over the past 800,000 years.  Nature, Vol. 453, pp. 383-386, 15 May 2008. doi:10.1038/nature06950 |
| Description | Methane record from the EPICA (European Project for Ice Coring in Antarctica)  Dome C ice core covering 0 to 800 kyr BP. The air from polar ice-core samples of about 40g (Bern) and 50g (LGGE) is extracted with a melt-refreezing method under vacuum, and the extracted gas is then analysed for CH4 by gas chromatography. |
| Source | <ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc-ch4-2008.txt> |
| Data presented | Column A: EDC1999 depth (m)  Column B: Gas Age (EDC3 gas age, years before 1950 AD)  Column C: CH4 mean (ppbv)  Column D: 1-sigma uncertainty (ppbv)  Column E: Laboratory (b=Bern, g=Grenoble) |

**EXCEL Sheet 2: Dome C-Vostok-Taylor\_CO2 and EXCEL Sheet 3: CO2 Composite**

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| --- | --- |
| Name of Data Set | EPICA Dome C Ice Core 800 kYr Carbon Dioxide Data |
| Contributors | Dieter Luthi, et al.  IGBP PAGES/WDCA CONTRIBUTION SERIES NUMBER: 2008-055 |
| Original Reference | Luthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, and T.F. Stocker. 2008.  High-resolution carbon dioxide concentration record 650,000-800,000 years before present.  Nature, Vol. 453, pp. 379-382, 15 May 2008. doi:10.1038/nature06949 |
| Description | Carbon dioxide record from the EPICA (European Project for Ice Coring  in Antarctica) Dome C ice core covering 0 to 800 kyr BP |
| Source | <https://www1.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc-co2-2008.txt> |
| Data presented | 1. **Antarctic CO2 data from Vostok, Dome C, and Taylor Dome**  * Depth in metres * Gas age scale: EDC3\_gas\_a (tentatively synchronized for Taylor Dome) * CO2 concentration and CO2 sigma error in ppmv  1. **Composite CO2 record (0-800 kyr BP)**  |  |  | | --- | --- | | 0-22 kyr BP | Dome C (Monnin et al. 2001) measured at University of Bern | | 22-393 kyr BP | Vostok (Petit et al. 1999; Pepin et al. 2001; Raynaud et al. 2005) measured at LGGE in Grenoble | | 393-416 kyr BP | Dome C (Siegenthaler et al. 2005) measured at LGGE in Grenoble | | 416-664 kyr BP | Dome C (Siegenthaler et al. 2005) measured at University of Bern | | 664-800 kyr BP | Dome C (Luethi et al. (sub)) measured at University of Bern |   Timescale EDC3\_gas\_a: Using EDC3 gas age, BP (before present) means years before 1950 AD |

**EXCEL Sheet 4: Temperature-EDC3 timescale**

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| --- | --- |
| Name of Data Set | EPICA Dome C Ice Core 800KYr Deuterium Data and Temperature Estimates |
| Contributors | Valérie Masson-Delmotte, LSCE/IPSL  IGBP PAGES/WDCA CONTRIBUTION SERIES NUMBER: 2007-091 |
| Original Reference | Jouzel, J., V. Masson-Delmotte, O. Cattani, G. Dreyfus, S. Falourd, G. Hoffmann, B. Minster, J. Nouet, J.M. Barnola, J. Chappellaz, H. Fischer, J.C. Gallet, S. Johnsen, M. Leuenberger, L. Loulergue, D. Luethi, H. Oerter, F. Parrenin, G. Raisbeck, D. Raynaud, A. Schilt, J. Schwander, E. Selmo, R. Souchez, R. Spahni, B. Stauffer, J.P. Steffensen, B. Stenni, T.F. Stocker, J.L. Tison, M. Werner, and E.W. Wolff. 2007.  Orbital and Millennial Antarctic Climate Variability over the Past 800,000 Years.  Science, Vol. 317, No. 5839, pp.793-797, 10 August 2007. |
| Description | High-resolution (55cm.) deuterium (dDice) profile from the EPICA Dome C Ice Core, Antarctica (75º 06' S, 123º 21' E), from the surface down to 3259.7 m. Delta deuterium data is a [proxy](https://en.wikipedia.org/wiki/Proxy_(climate)) for temperature: more negative values indicate lower temperatures. (This file now includes EDC3 age model)  Temperature estimated after correction for sea-water isotopic composition (Bintanja et al, 2005) and for ice sheet elevation (Parrenin et al, 2007) on EDC3 age scale (Parrenin et al, 2007) |
| Source | <ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc3deuttemp2007.txt> |
| Data presented | Column A: depth (m)  Column B: dD data (per mille with respect to SMOW, Standard Mean Ocean Water)  Column C: EDC3 ice age scale (years before year 1950)  Column E: Temperature estimate (oC)(temperature difference from the average of the last 1000 years, −54.5 °C) |

**EXCEL Sheet 4: Temperature-EDC3 timescale**

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| Name of Data Set | EPICA Dome C Ice Core Timescales EDC3 |
| Contributors | Frederic Parrenin, LGGE, Grenoble, France, parrenin@ujf-grenoble.fr  Laetitia Loulergue, LGGE, Grenoble, France, loulergue@lgge.obs.ujf-grenoble.fr  Eric Wolff, British Antarctic Survey, Cambridge, UK, EWWO@bas.ac.uk  IGBP PAGES/WDCA CONTRIBUTION SERIES NUMBER: 2007-083 |
| Original Reference | Parrenin, F., J.-M. Barnola, J. Beer, T. Blunier, E. Castellano, J. Chappellaz, G. Dreyfus, H. Fischer, S. Fujita, J. Jouzel, K. Kawamura, B. Lemieux-Dudon, L. Loulergue, V. Masson-Delmotte, B. Narcisi, J.-R. Petit, G. Raisbeck, D. Raynaud, U. Ruth, J. Schwander, M. Severi, R. Spahni, J. P. Steffensen, A. Svensson, R. Udisti, C. Waelbroeck, and E. Wolff. 2007.  The EDC3 chronology for the EPICA Dome C ice core.  Climate of the Past, vol. 3, pp. 485-497.  Loulergue, L., F. Parrenin, T. Blunier, J.-M. Barnola, R. Spahni, A. Schilt, G. Raisbeck, and J. Chappellaz. 2007.  New constraints on the gas age-ice age difference along the EPICA ice cores,  0–50 kyr.  Climate of the Past, vol. 3, pp. 527-540. |
| Description | Timescale EDC3 for the EPICA Dome C ice core, both for the ice matrix and gas bubbles.  The file gives the depth versus age timescale that has been adopted as official for the EPICA Dome C ice core. Depth refers to the official log depth of the drilling. |
| Source | <ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc3-timescale.txt> |
| Data presented | Column A: Depth (metre)  Column D: gas age on EDC3 timescale / years before 1950 AD |

**EXCEL Sheet 5: CO2\_CH4\_0-2000AD**

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| --- | --- |
| Name of Data Set | Law Dome Ice Core 2000-Year CO2, CH4, and N2O Data |
| Contributors | David Etheridge, CSIRO Marine and Atmospheric Research  IGBP PAGES/WDCA CONTRIBUTION SERIES NUMBER: 2010-070 |
| Original Reference | Ice Core results:  Law Dome CO2 and CH4 records of the last 1000 years first published in Etheridge et al., 1996 and 1998. Newer results which fill in gaps, extend record to 2000 BP and include N2O, were published and explained in detail in MacFarling Meure  et al. 2006 and MacFarling Meure 2004. Some new CH4 results were also published in Ferretti et al. 2005. |
| Description | Law Dome ice core, firn air, and Cape Grim instrumental (deseasonalised archive, insitu and flask) records of CO2, CH4 and N2O concentrations for the past 2000 years. |
| Source | <ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/law/law2006.txt> |
| Data presented | Column A: Year AD  Column B: CH4 Spline (ppb)  Column C: CO2 Spline (ppm) |