



Riding the Climate Rollercoaster 1 T4 2025

1. Climate through Time

Malte Ebach

TESEP Regional Co-ordinator

Slides by Rob Kirk and Malte Ebach

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We wish to acknowledge the Traditional Owners of the land on which we meet today.

We also wish to pay our respects to Elders past, present and future.



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- Sydney Mineral Exploration Discussion Group (SMEDG)



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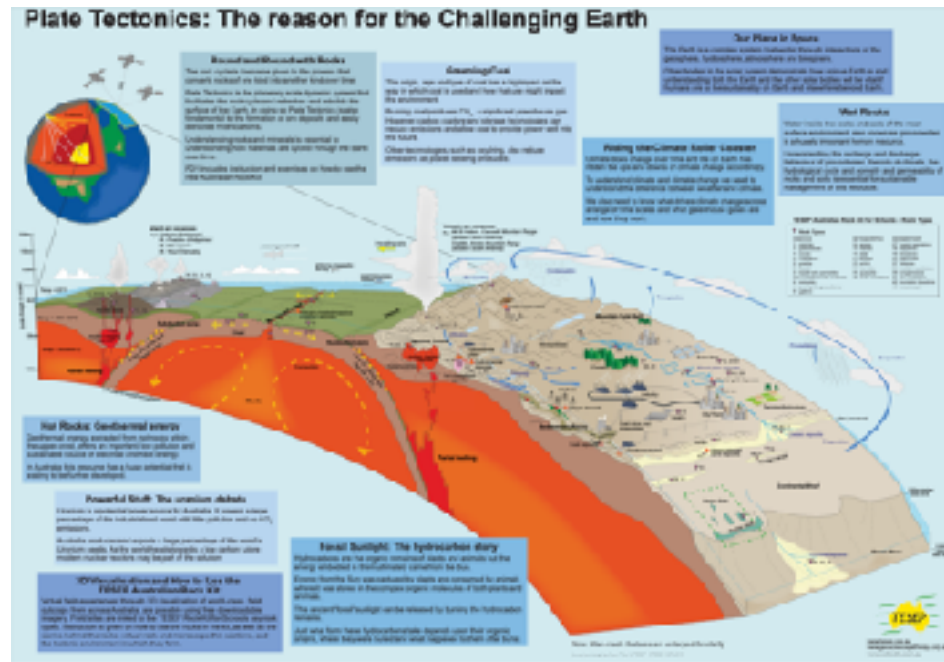
- BHP Olympic Dam
- South 32

BRONZE

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- Astron Corporation (Donald Mineral Sands)
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- Whitehaven Coal
- WIM Resource
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- To identify any misplaced specimens or valuable specimens (for display only)
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TESEP Australian Critical Minerals Kit



2 boxes with 26 minerals:

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- Rock forming minerals
- Moh's scale of hardness
- Online resources include:
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 - 3D renders



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Australian Curriculum v.9 (F-10)

We will be following the Australian Curriculum v.9 (2022):

- Curriculum content for Years 7-10 only
- Focus on the Earth and Space science sub-strand
- Will follow as many other sub-strands as possible

Australian Curriculum v. 9 (2022): Examples.

Year 10 (Earth and Space Sciences)

“They appreciate how energy drives the Earth system and how climate models simulate the flow of energy and matter within and between Earth’s spheres”.

- Use models of energy flow between the geosphere, biosphere, hydrosphere and atmosphere to explain patterns of global climate change (AC9S10U04).
- Explain how scientific knowledge is validated and refined, including the role of publication and peer review (AC9S10H01).
- Investigate how advances in technologies enable advances in science, and how science has contributed to developments in technologies and engineering (AC9S10H02).

Australian Curriculum v. 9 (2022): Examples.

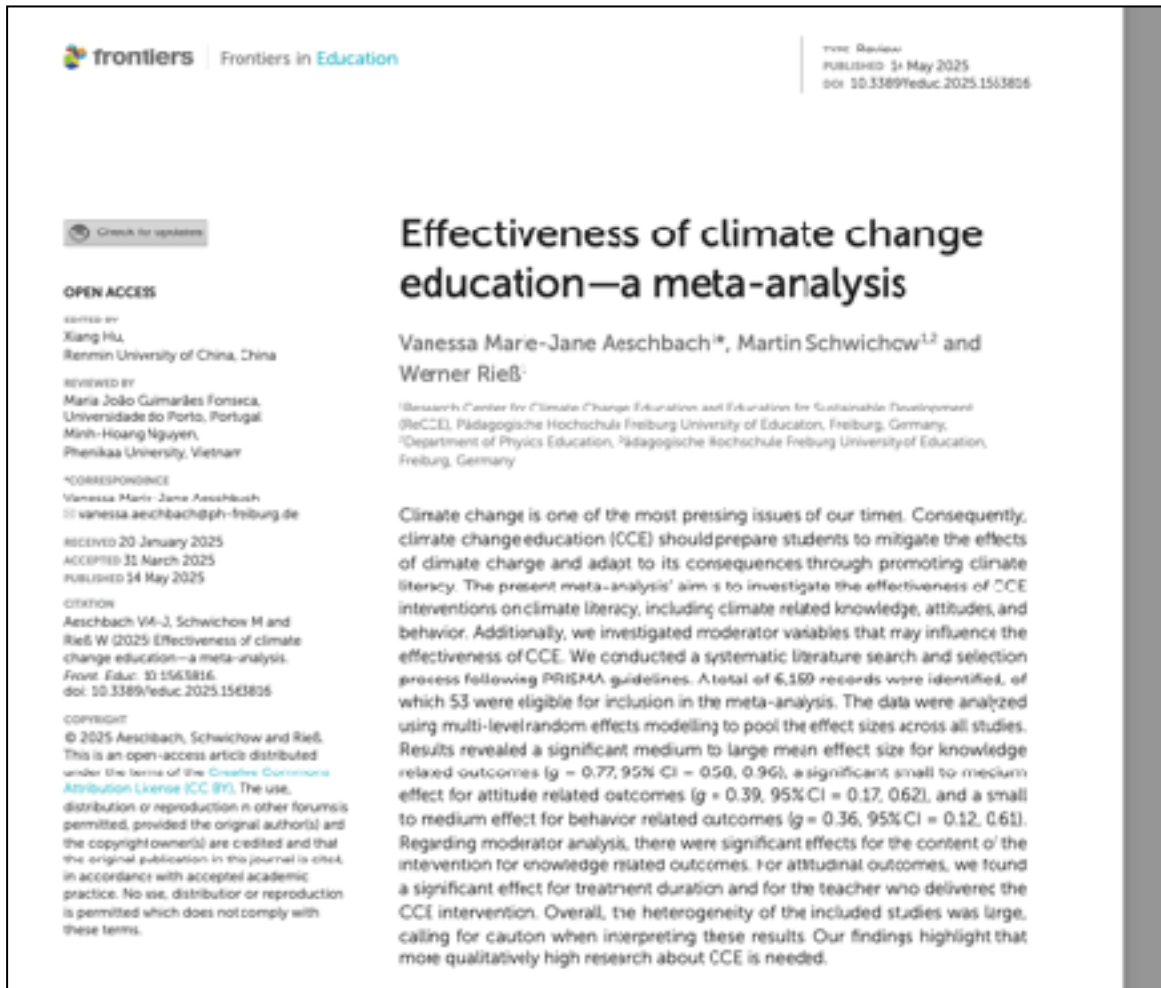
Year 10 (Geography)

“develop a range of questions for a geographical inquiry related to a phenomenon or challenge”.

- planning an investigation of a phenomenon or challenge being studied at a range of scales, using digital tools; for example, investigating the causes of human-induced climate change at the global scale and its impacts on Australia, Bangladesh and/or a Pacific Island country at the national scale (AC9HG10S01)

Climate in the news ...

Why teaching Climate Change is important



frontiers | Frontiers in Education

TYPE Review
PUBLISHED 31 May 2025
DOI 10.3389/educ.2025.1563806

[Check for updates](#)

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Effectiveness of climate change education—a meta-analysis

Vanessa Marie-Jane Aeschbach^{1*}, Martin Schwichow^{1,2} and Werner Rieß¹

¹Research Center for Climate Change Education and Education for Sustainable Development (ReCCE), Pädagogische Hochschule Freiburg University of Education, Freiburg, Germany, ²Department of Physics Education, Pädagogische Hochschule Freiburg University of Education, Freiburg, Germany

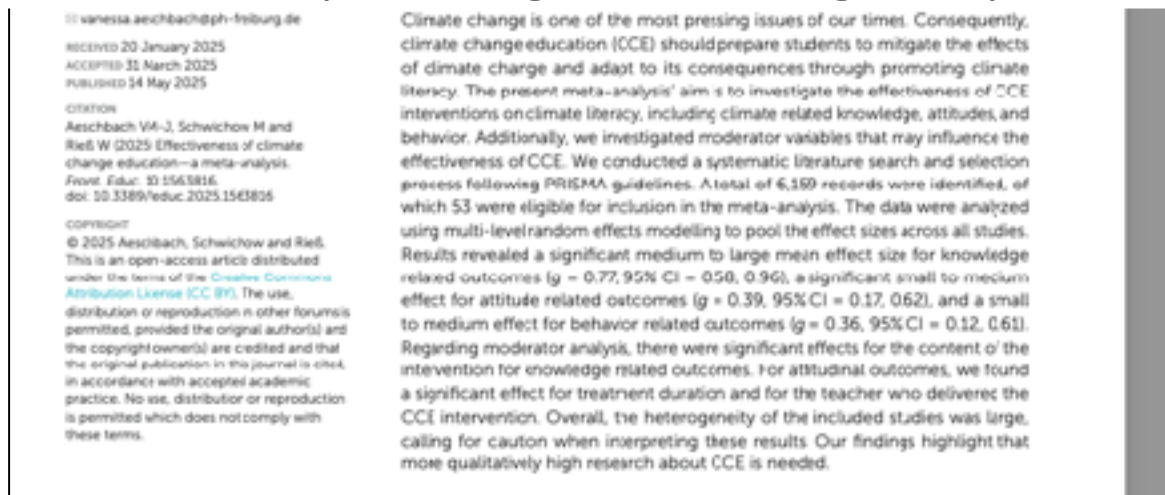
Climate change is one of the most pressing issues of our times. Consequently, climate change education (CCE) should prepare students to mitigate the effects of climate change and adapt to its consequences through promoting climate literacy. The present meta-analysis' aims to investigate the effectiveness of CCE interventions on climate literacy, including climate related knowledge, attitudes, and behavior. Additionally, we investigated moderator variables that may influence the effectiveness of CCE. We conducted a systematic literature search and selection process following PRISMA guidelines. A total of 6,169 records were identified, of which 53 were eligible for inclusion in the meta-analysis. The data were analyzed using multi-level random effects modelling to pool the effect sizes across all studies. Results revealed a significant medium to large mean effect size for knowledge related outcomes ($g = 0.77$, 95% CI = 0.50, 0.96), a significant small to medium effect for attitude related outcomes ($g = 0.39$, 95% CI = 0.17, 0.62), and a small to medium effect for behavior related outcomes ($g = 0.36$, 95% CI = 0.12, 0.61). Regarding moderator analysis, there were significant effects for the content of the intervention for knowledge related outcomes. For attitudinal outcomes, we found a significant effect for treatment duration and for the teacher who delivered the CCE intervention. Overall, the heterogeneity of the included studies was large, calling for caution when interpreting these results. Our findings highlight that more qualitatively high research about CCE is needed.

Climate in the news ...

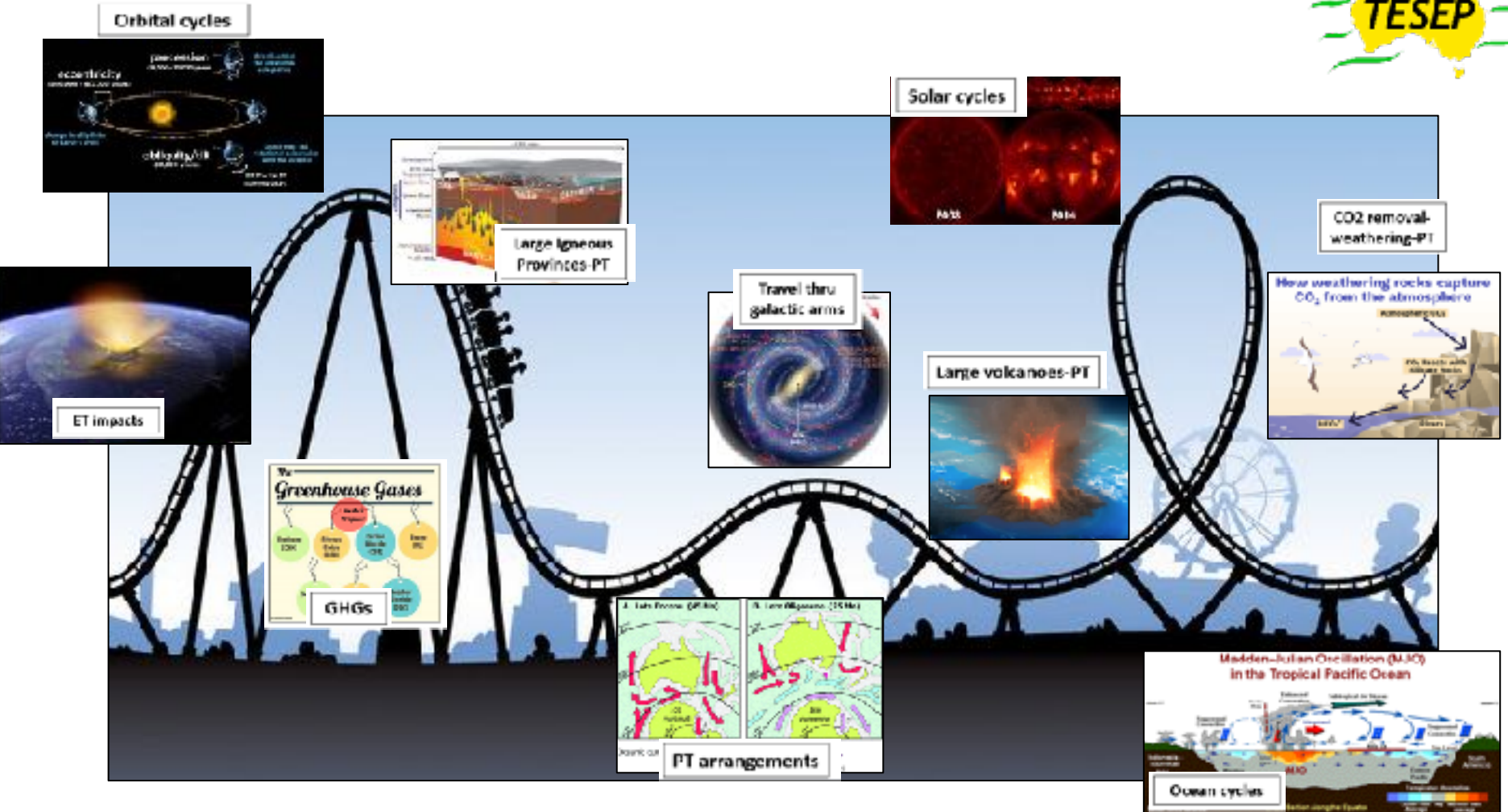
Why Climate Change Education (CCE) is important



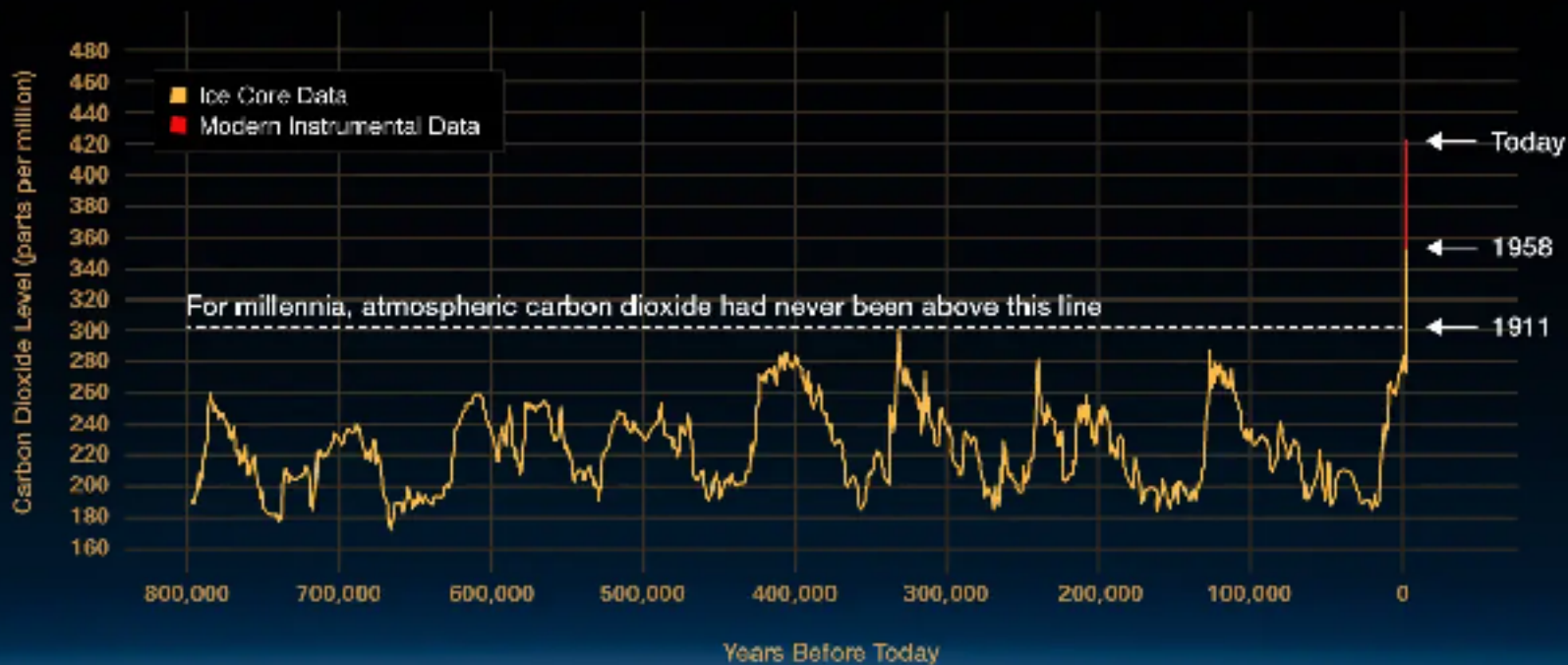
CCE education is effective for promoting the knowledge component of climate literacy



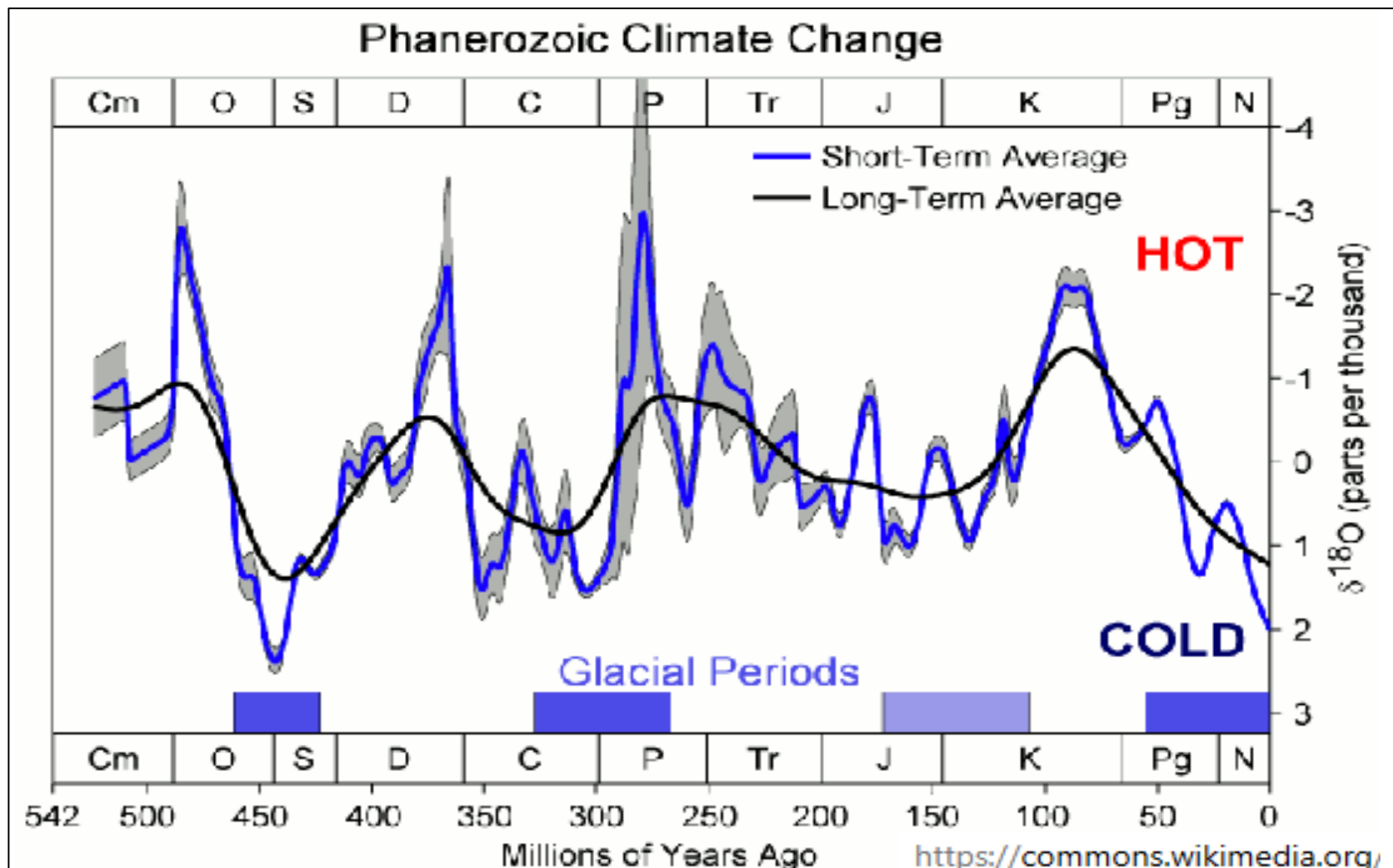
The Climate Rollercoaster



Climate change is due to many different processes operating on different time scales ... some reinforce each other and some diminish each other.



climate.nasa.gov



Climate Science in the Curricula

Australian Curriculum v. 9 (Year 10)

Use models of energy flow between the geosphere, biosphere, hydrosphere and atmosphere to explain patterns of global climate change (AC9S10U04)

Victorian Science Curriculum v. 2 (Year 10)

Carbon is cycled on Earth through key processes including photosynthesis, respiration, fire, weathering, vulcanism and the combustion of fossil fuels; these processes change the composition of Earth's interrelated systems (atmosphere, biosphere, hydrosphere and lithosphere) over time (VC2S10U10)

The dynamics of global climate change can be modelled and explained by examining the interactions between greenhouse gas emissions and energy exchanges within and between Earth's systems; mitigating human-induced climate change requires addressing various activities including power generation, deforestation, manufacturing, transportation, food production and resource consumption (VC2S10U11)

Western Australian Science Curriculum v. 8.1 (Year 10)

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)



NSW 2026 Syllabus > Science 7-10 >

Stage 4> Observing the Universe > Space Science >

- Distinguish between climate and weather
- Investigate data to determine what trends are evident in the world's climate
- Explain how the natural greenhouse effect influences global climate

Stage 5 > Environmental sustainability > [Impacts of present day climate change](#)>

- Identify the characteristics of climate change
- Investigate and report on the consequences of climate change
- Investigate how satellites collect global data, including data on ocean temperatures, sea levels, and forest and ice cover, and examine how this data is used to evaluate the impact of climate change

Teach Climate Change in Context

1. Compare recent changes over geological time

- Define
 - Climate
 - Weather
 - Geological time
- Examine
 - Known climate changes
 - Sources of geological information
 - Drivers of climate change (covered in episode 3)
 - Specific climatic events

Teach Climate Change in Context

2. The term “Climate Change” is not the best description

Rocks tell us global climate changes over time

- Sometimes colder
 - Ice ages
 - Snowball Earth
- Sometimes warmer
 - Polar dinosaurs
 - Ice free Earth
- Never constant over geological time
 - Stable long enough to allow evolution
 - Unstable enough to drive evolution

Teach Climate Change in Context

3. There are many compounding factors that control climate

What affects climate:

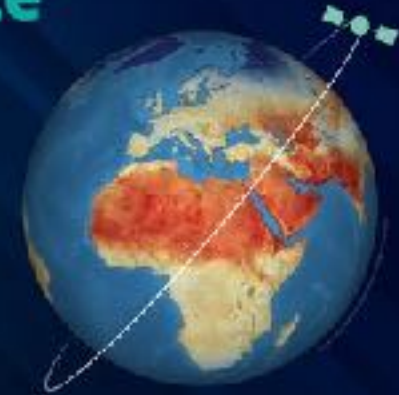
- Plate tectonics, volcanoes, ocean currents
- Cooling due to mountains ([carbonate-silicate cycle](#))
- Solar activity (e.g., low activity = cooling)
- Greenhouse gasses: CO₂, CH₄, H₂O
- Earth orbital parameters
- Evolution-biosphere
- Meteor impacts
- Galactic motion
- Human assisted: albedo, heat islands, GHG output, particulates

The oceans and their cycles also need to be understood

Weather versus Climate



The difference between weather and climate is a matter of time



Weather

refers to short-term changes in the atmosphere. It can change minute-to-minute, hour-to-hour and day-to-day

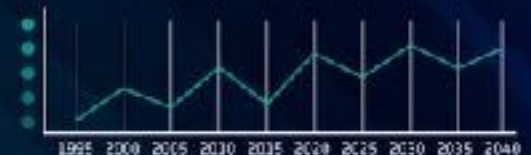


Climate

describes the average weather conditions in a specific area over a long period of time – 30 years or more



Satellites measure several aspects of Earth's weather as well as provide essential data over decades to monitor how our climate is changing



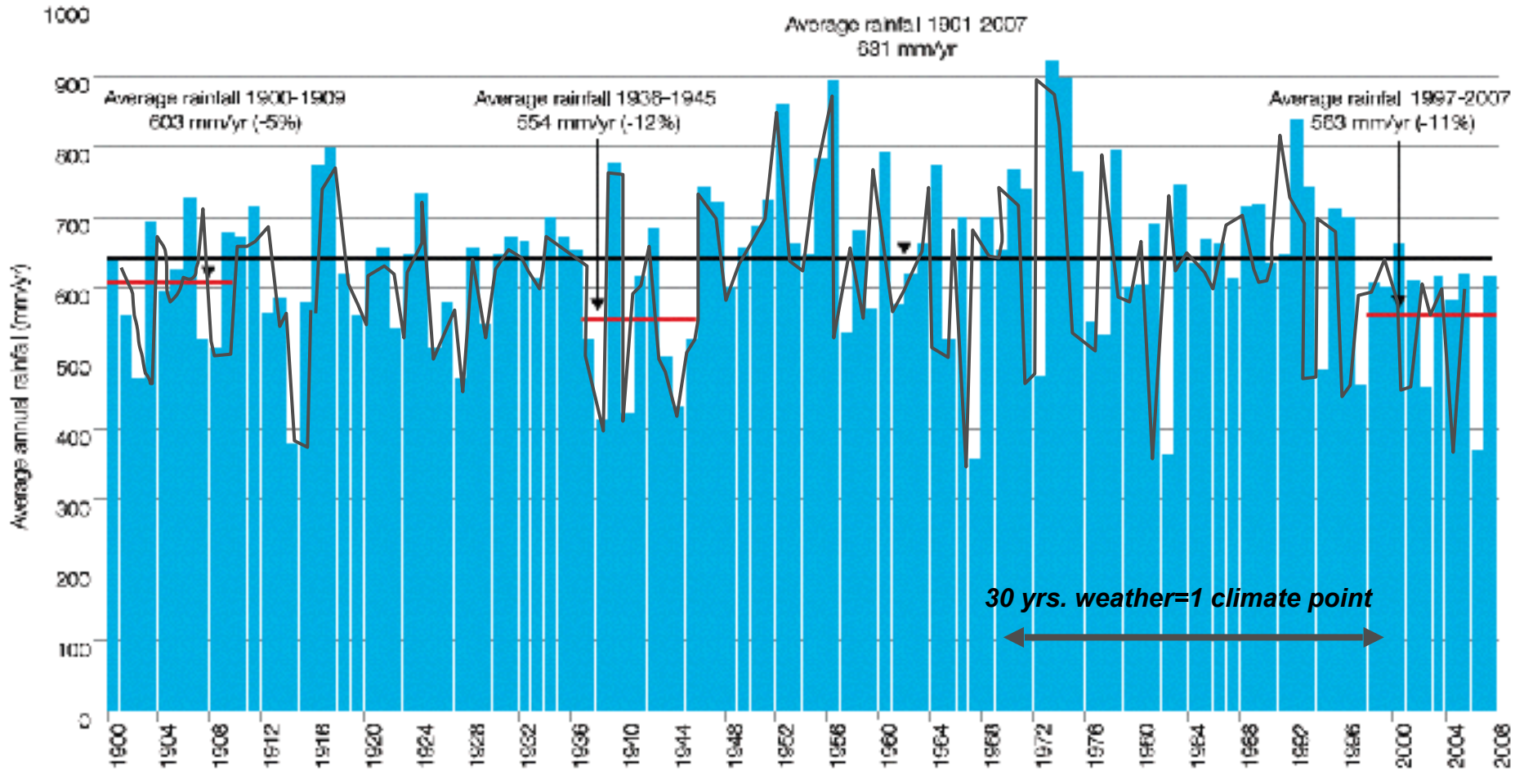
For more information, visit space for our climate:
www.esa.int/climate

ESA - Weather vs climate: What's the difference?

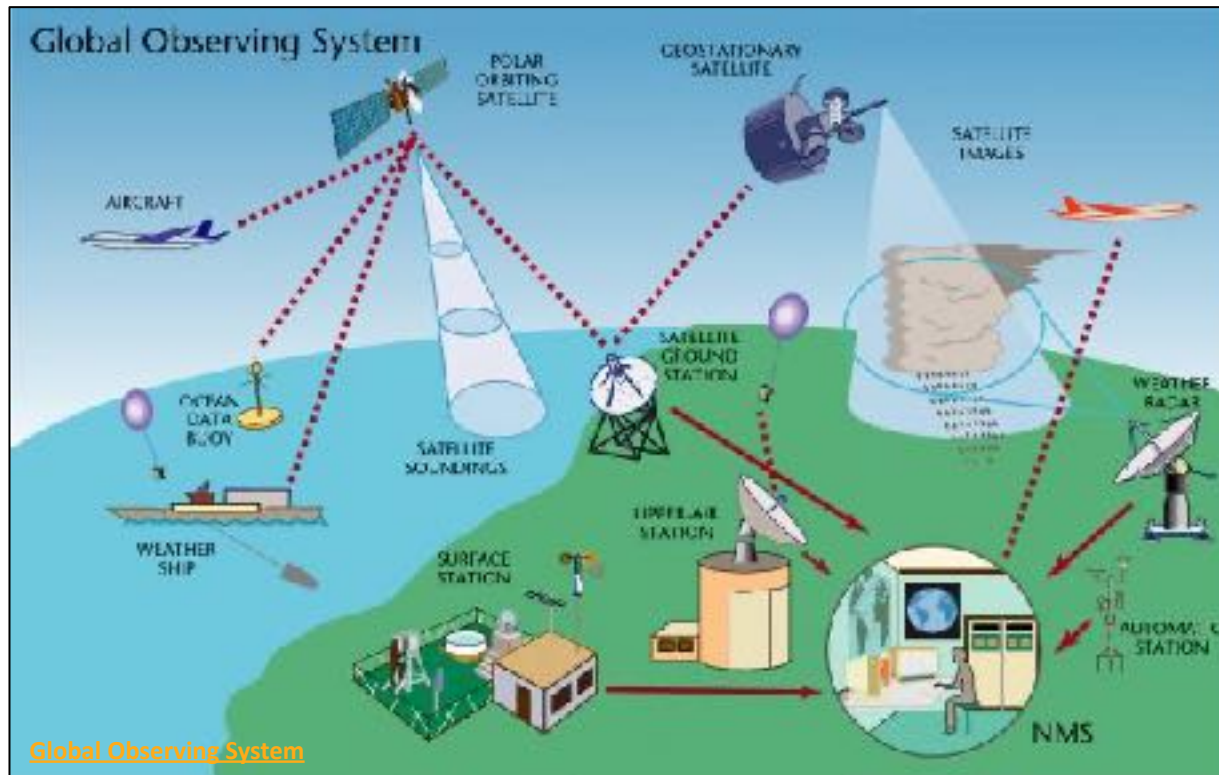
Weather (look out the window) vs Climate (weather of an area over time)

Climate versus Weather

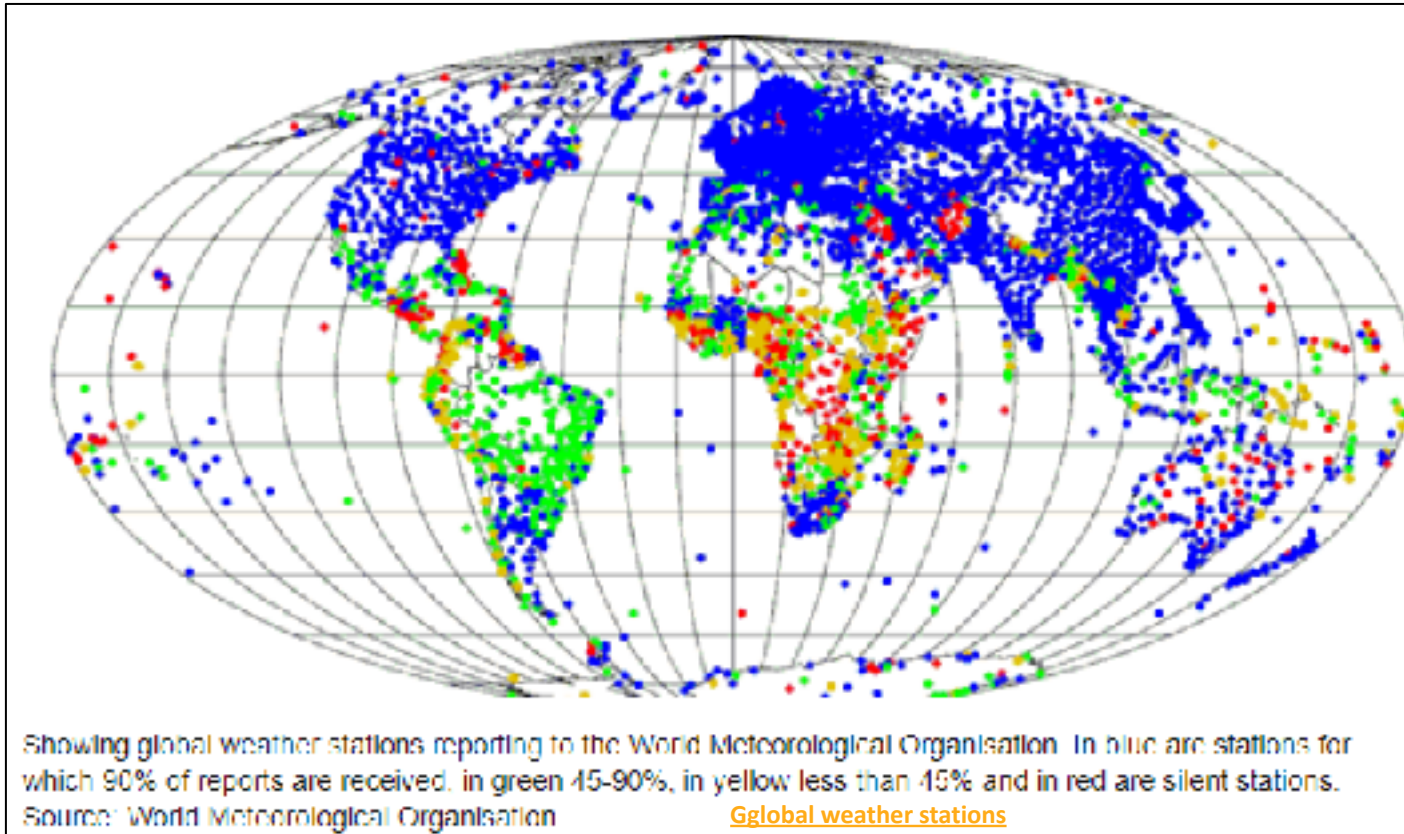
Annual rainfall across Victoria (with average rainfall in previous droughts compared with long-term average)¹⁰



How do we measure weather?



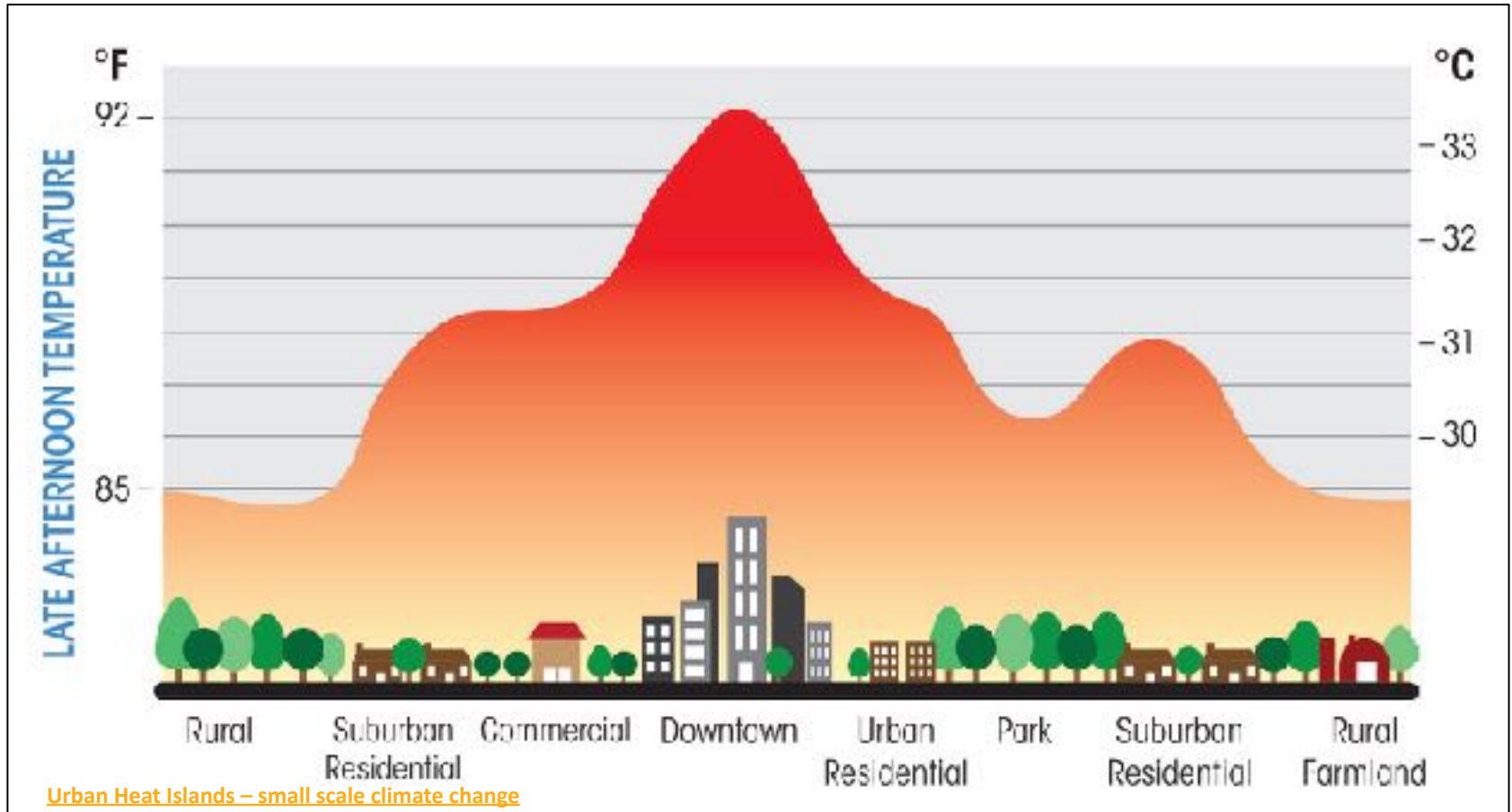
Worldwide Weather Measurements



Silent stations are equipped non-operation stations.

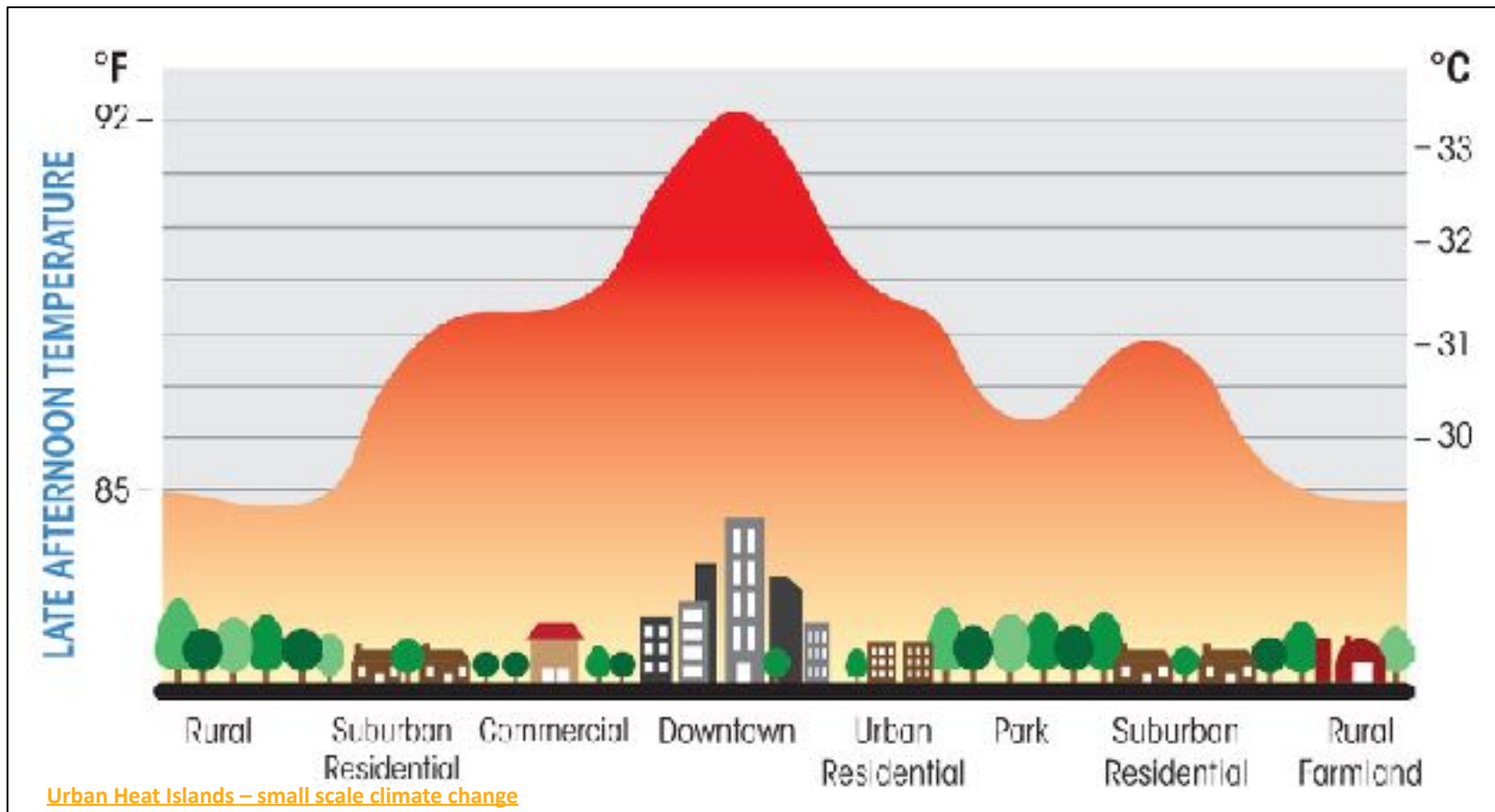
What continents don't provide the necessary data to measure regional climate change? Why?

Urban Heat Islands

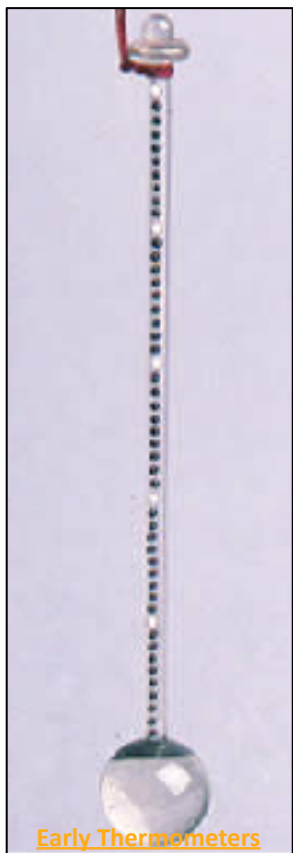


High albedo, low heat retention, low CO₂ Low albedo, high heat retention, high CO₂

Urban Heat Islands



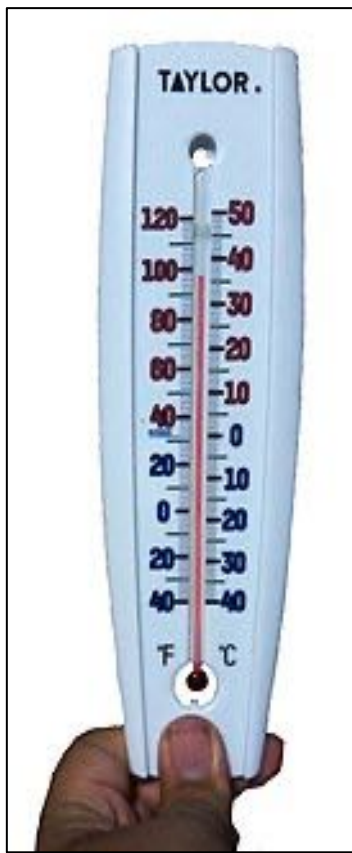
Other than albedo, high heat retention and high CO₂, what other factors can contribute to UHIs?



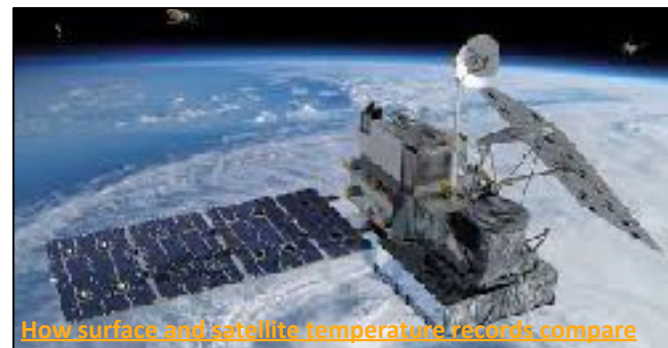
17th C



1780



20th C



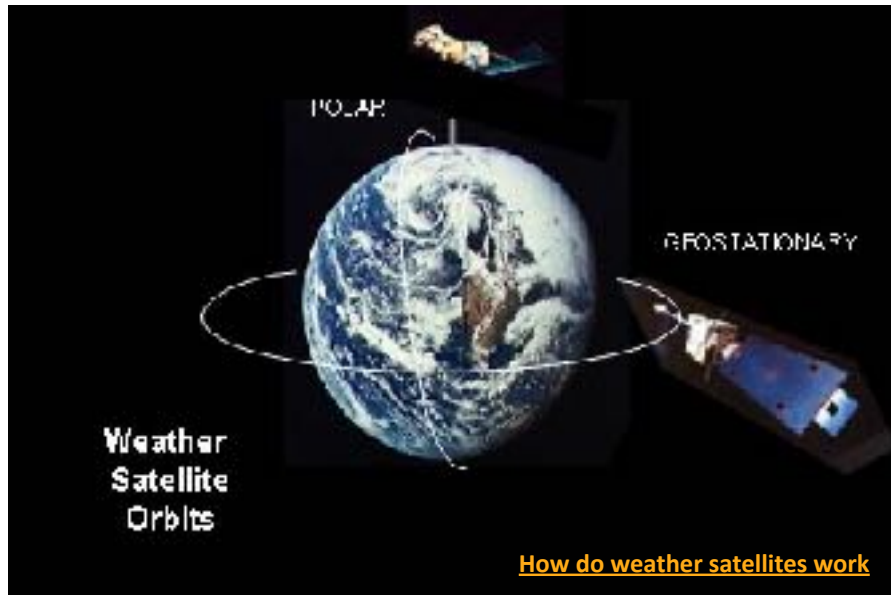
Scientists mark the start of modern global record-keeping at roughly 137 years ago, in 1880. That's because earlier available climate data doesn't cover enough of the planet to get an accurate reading, according to NASA. Most weather stations were established in the late 1800s.

Remote Sensing Measurements



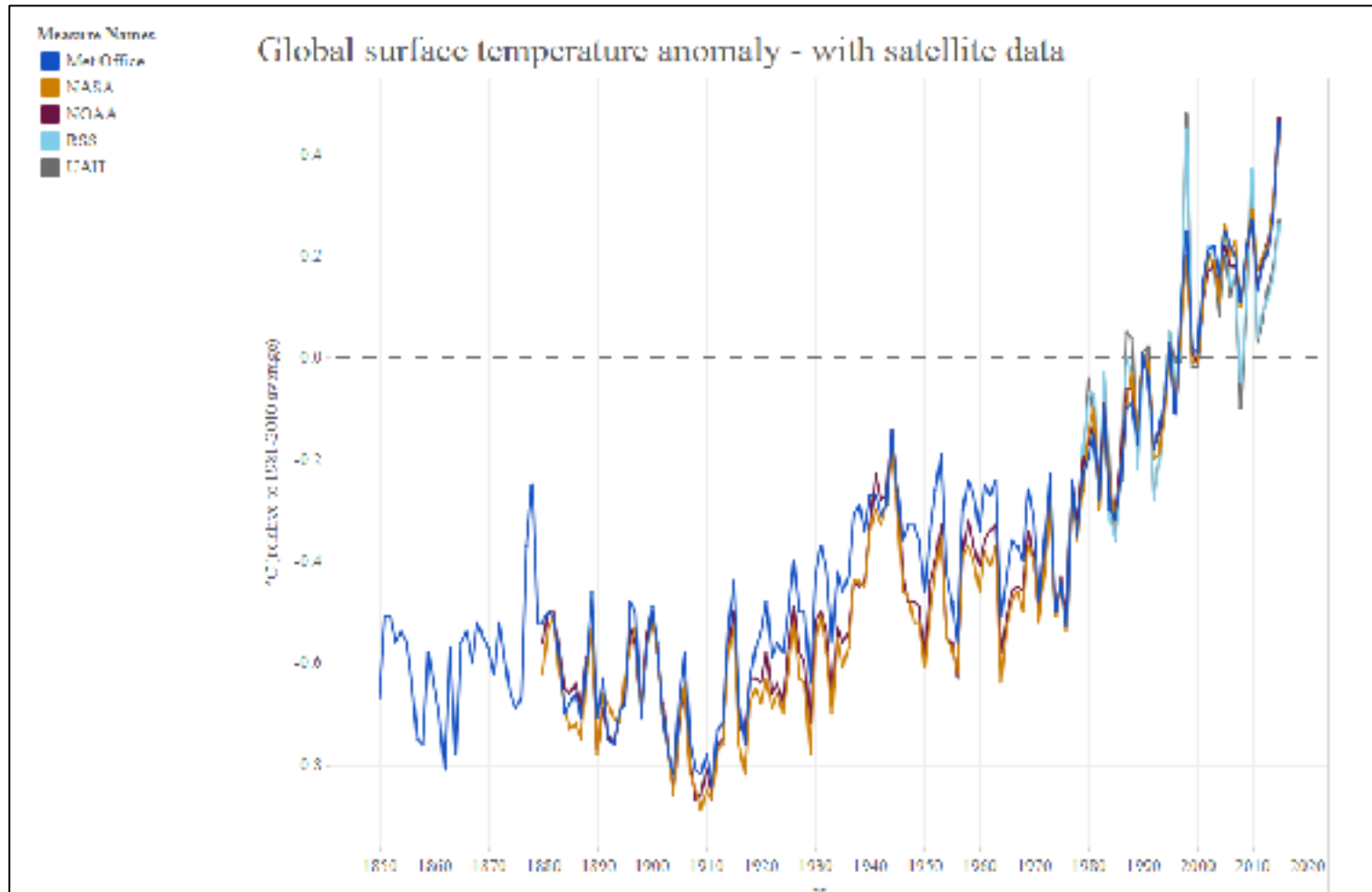
- Satellites in low orbit (100s kms) circle Earth 14 times a day
- Those in high orbit (36,000 kms) are geostationary: stay over the same point on the Earth
- Most electromagnetic emissions from the Earth can be measured from space
- Temperature can be measured using different parts of the electromagnetic spectrum
- Water vapour at different levels of the atmosphere
- Sea level can be measured using laser altimeters
- Clouds, precipitation and water vapour
- Indirectly measure wind direction and speed
- Chemical composition (e.g., ozone)

Remote Sensing Measurements



First weather satellites were launched in 1959 (Vanguard 2)

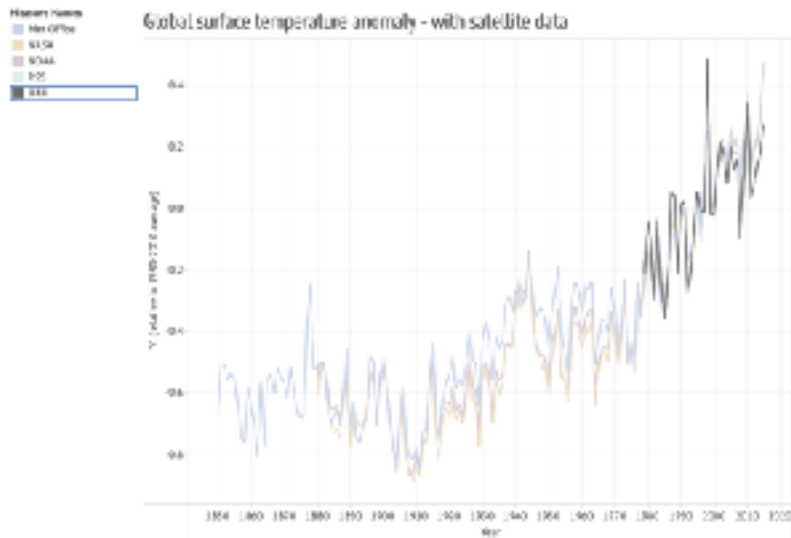
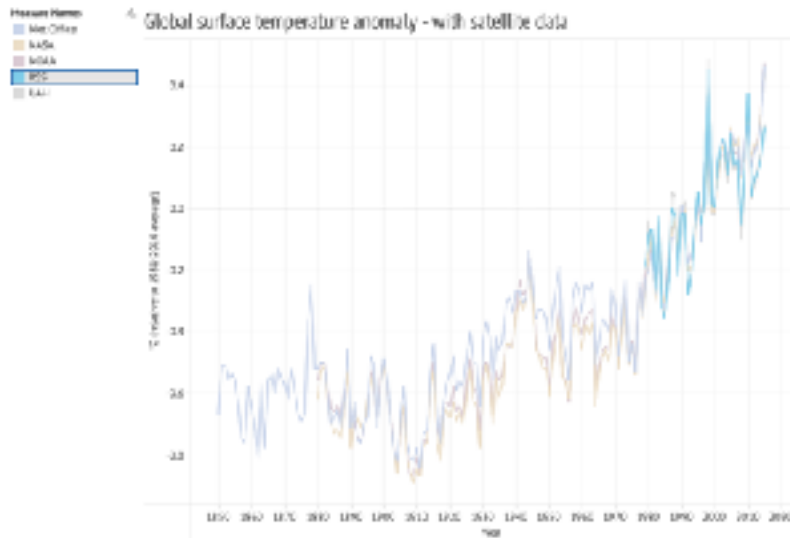
Surface versus satellite records



[How surface and satellite temperature records compare](#)

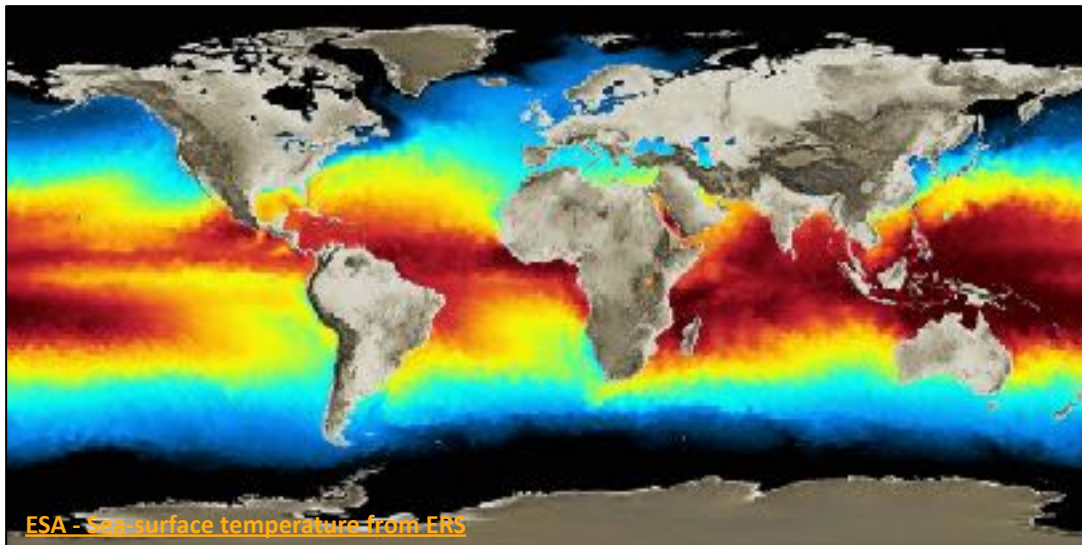
RSS and UAH (satellite data) differ to surface data

How we interpret the measurements (data)

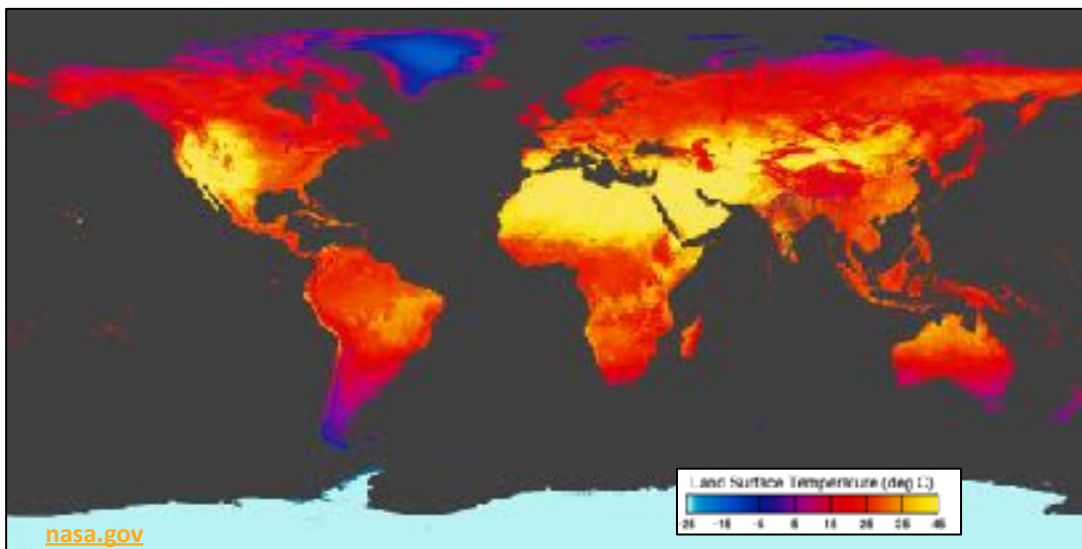


[How surface and satellite temperature records compare](#)

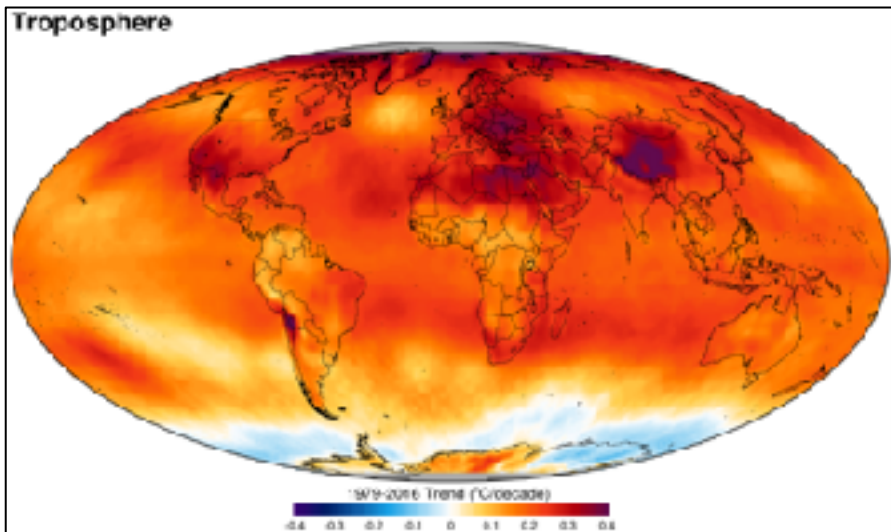
RSS and UAH (satellite data) use the same data, but different methods



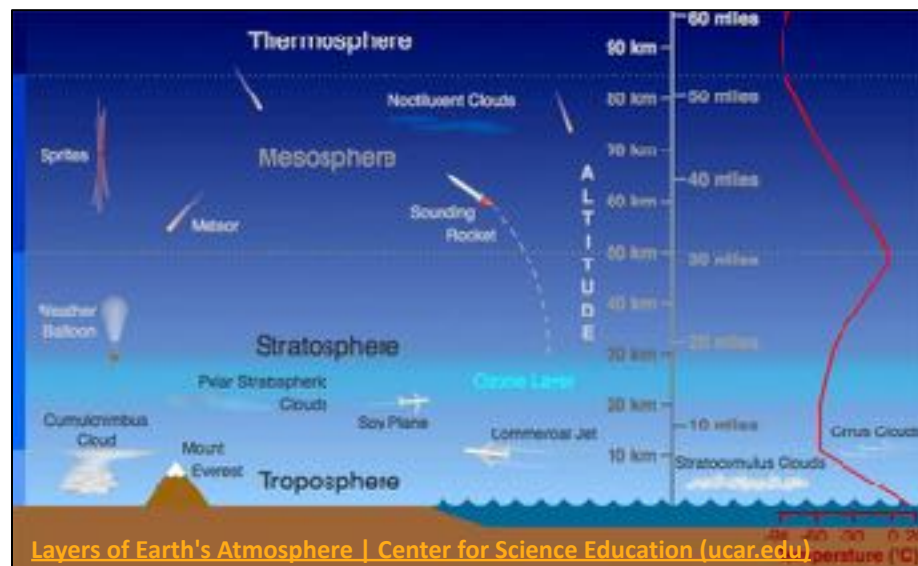
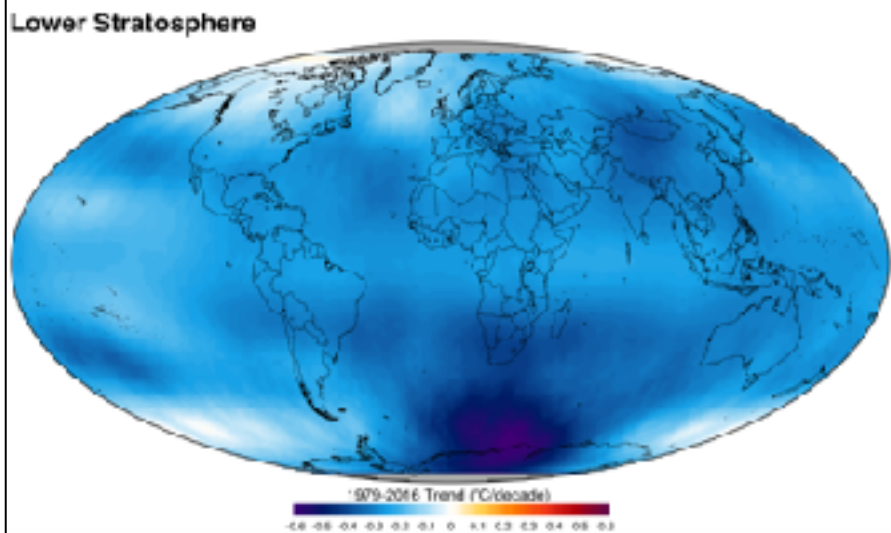
Satellite measurements of sea surface temperature



Satellite measurements of land surface temperature

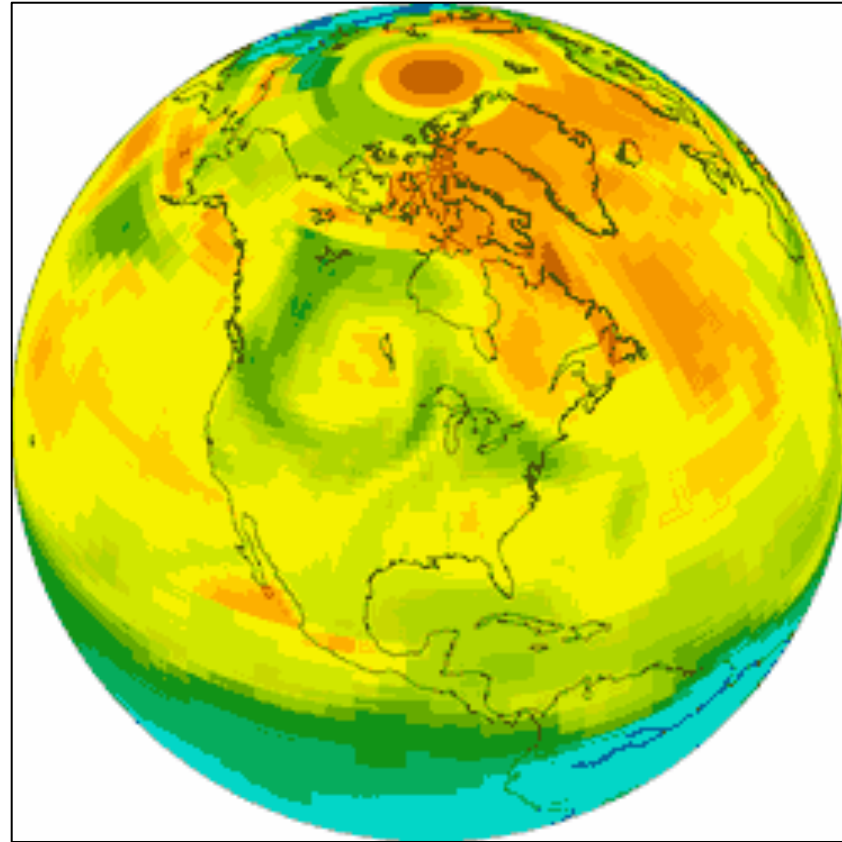


[RSS troposphere stratosphere trend - Satellite temperature measurements - Wikipedia](#)



Satellite measurements of atmospheric temperatures (for the period of 1979-2016).

NOAA CarbonTracker



[Carbon Cycle \(noaa.gov\)](https://noaa.gov)

CarbonTracker is a global model of atmospheric carbon dioxide with a focus on North America, designed to keep track of CO₂ uptake and release at the Earth's surface over time.

Warm colours equals high CO₂ and cool colours equals low CO₂

Notice that CO₂ goes down in summer growing season

Geological Climate Measurements



What are the ancient sources of temperature and climate?

- Rocks
 - Red beds
 - Tillites
 - Some minerals
- Fossils
 - Key families, genera, species
 - Distributions
- Isotope ratios
 - $^{16-18}\text{O}$ xygen
 - Minerals, fossil hard parts and ice cores



Remember the Principle of Uniformitarianism?

The present is the key to the past

Geological Climate Measurements

Direct evidence of climate change

- Evaporites, such as halite, gypsum, anhydrite (hot, arid)
- Red beds (hot, arid)
- Tillites (cold, glacial)
- Ikaite, a hydrohalite (cold)



[Tillite: Source wikipedia](#)

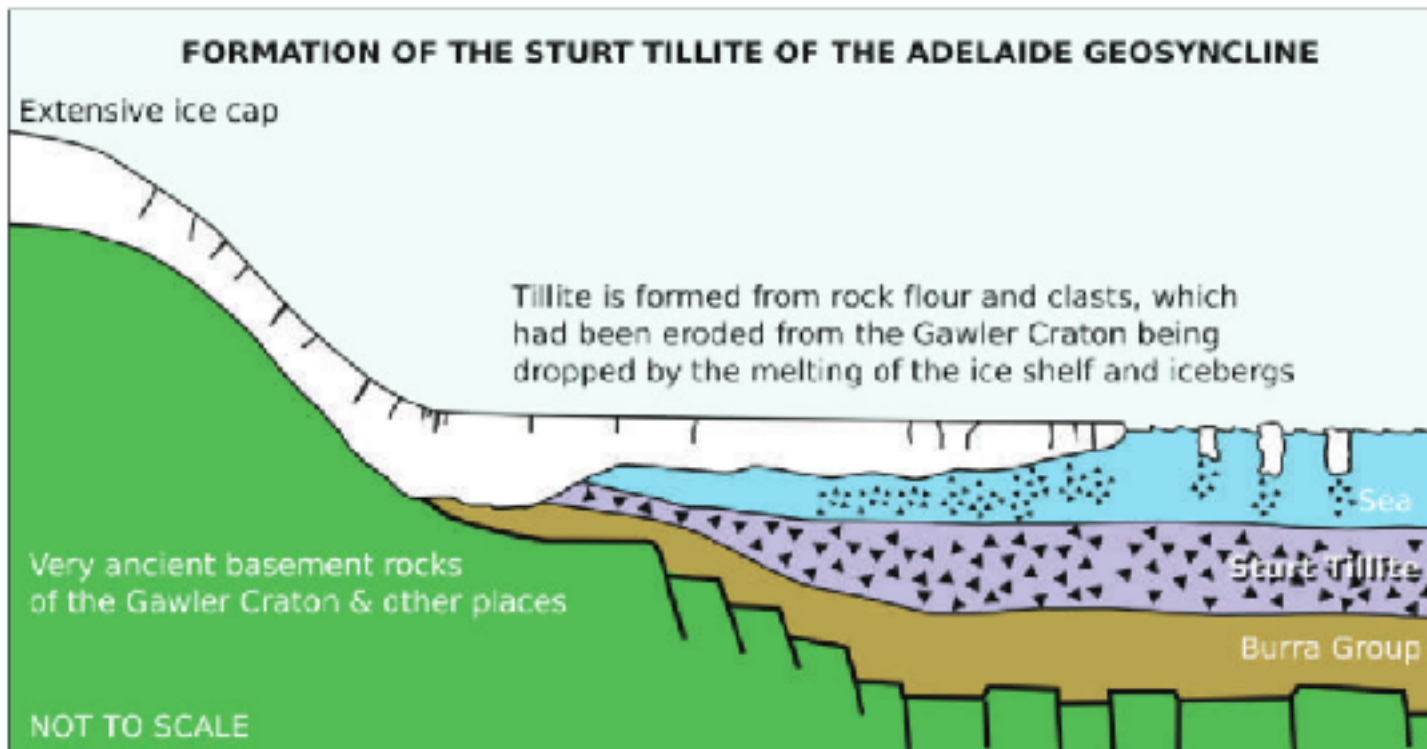


Ikaite: an unusual carbonate mineral

http://commons.wikimedia.org/wiki/Image:Concretion_and_crystals.jpg



Wirrina, South Australia- Sturt tillite from 800 million year old Snowball Earth glaciation.
Notice the clast or drop stones?



Wirrina, South Australia- Sturt tillite from 800 million year old Snowball Earth glaciation.

Halite, or rock salt, is an evaporite mineral



The Salt Range in Pakistan, where you get Himalayan rock salt from was an evaporite basin 800Ma



Lake Eyre is an evaporite basin in which halite forms



Climate proxies

Preserved data that can be measured to interpret past climate (indirect evidence for climate change)

Samples include:

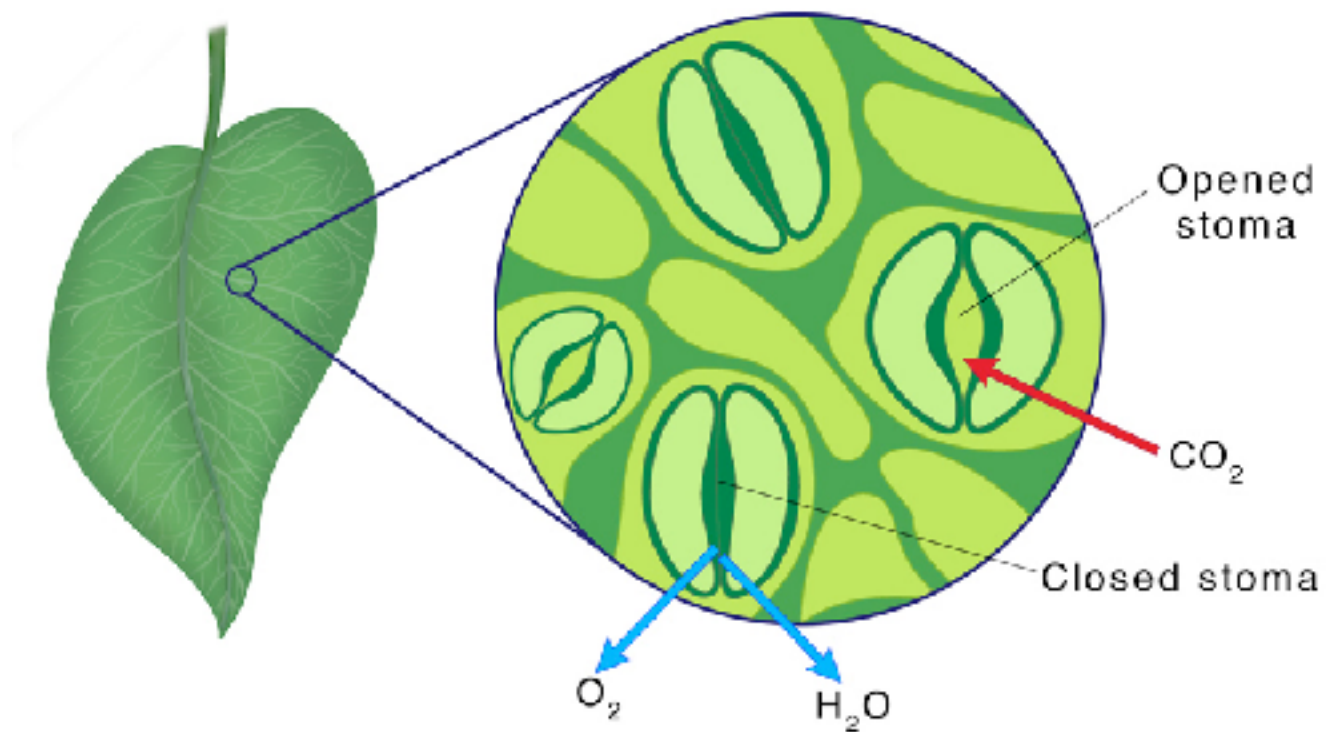
- Fossil Stomatal Index in plants
- Oxygen and carbon isotopes, CO₂ and CH₄ in ice cores
- Chemical ratios in the shells of marine organisms
- Tree ring growth
- Pollen

[How Do We Know the Temperature On Earth Millions of Years Ago? » Science ABC](#)

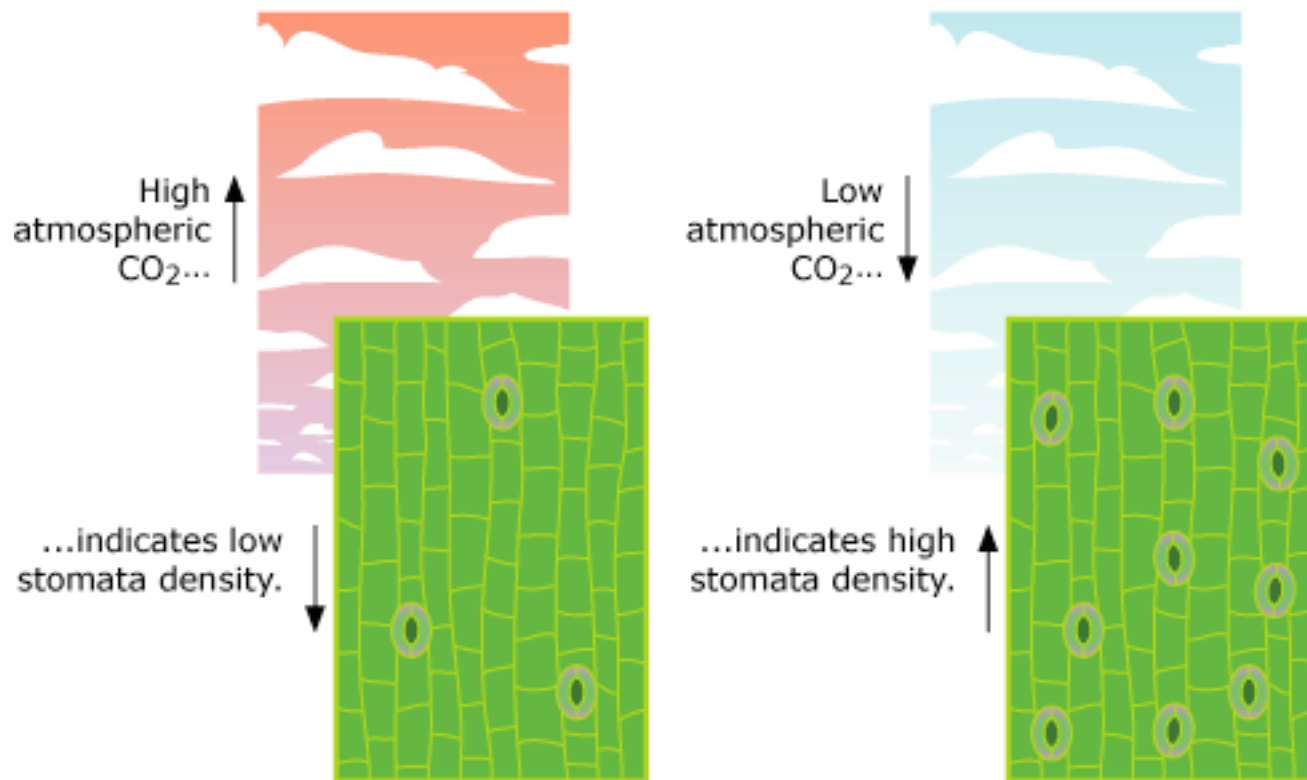
Plant Stomata

Stomata

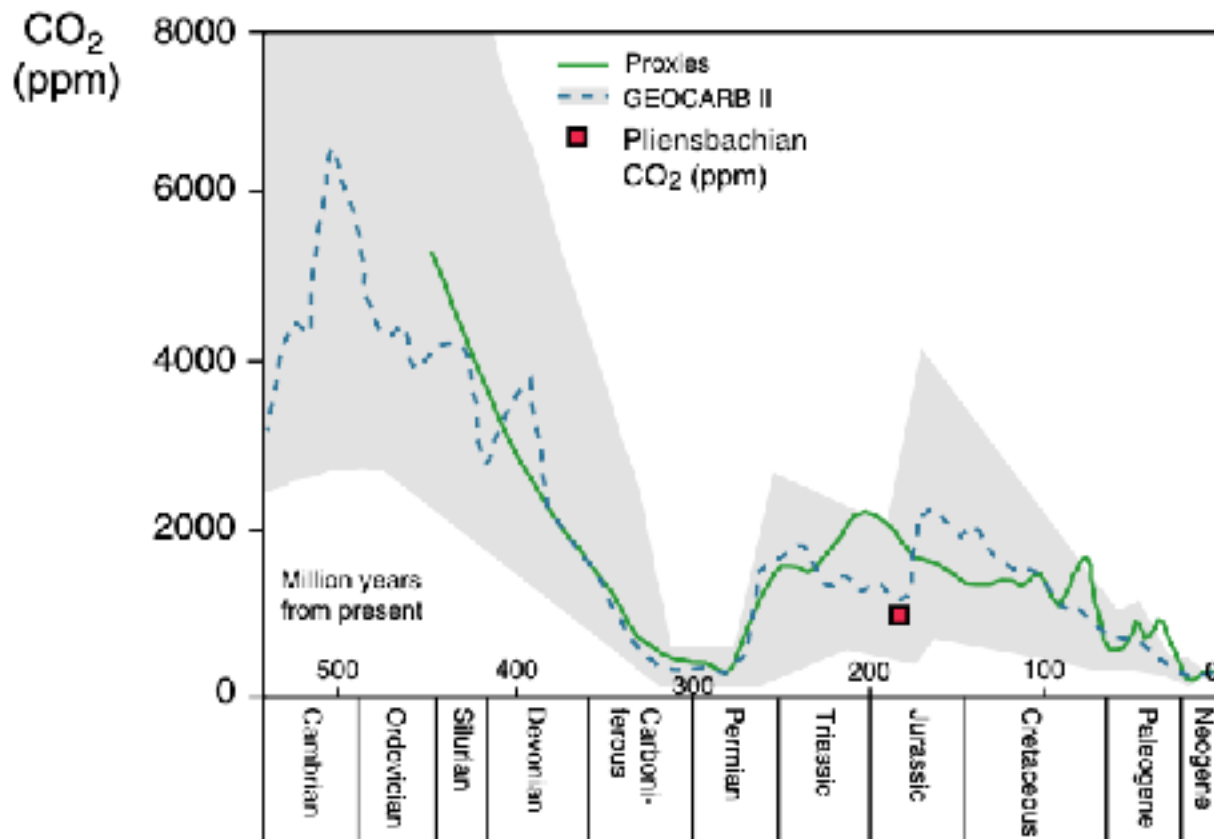
ScienceFacts.net



Stomatal Index



[Using plant stomata to determine CO₂ over the past 15,000 years](#)

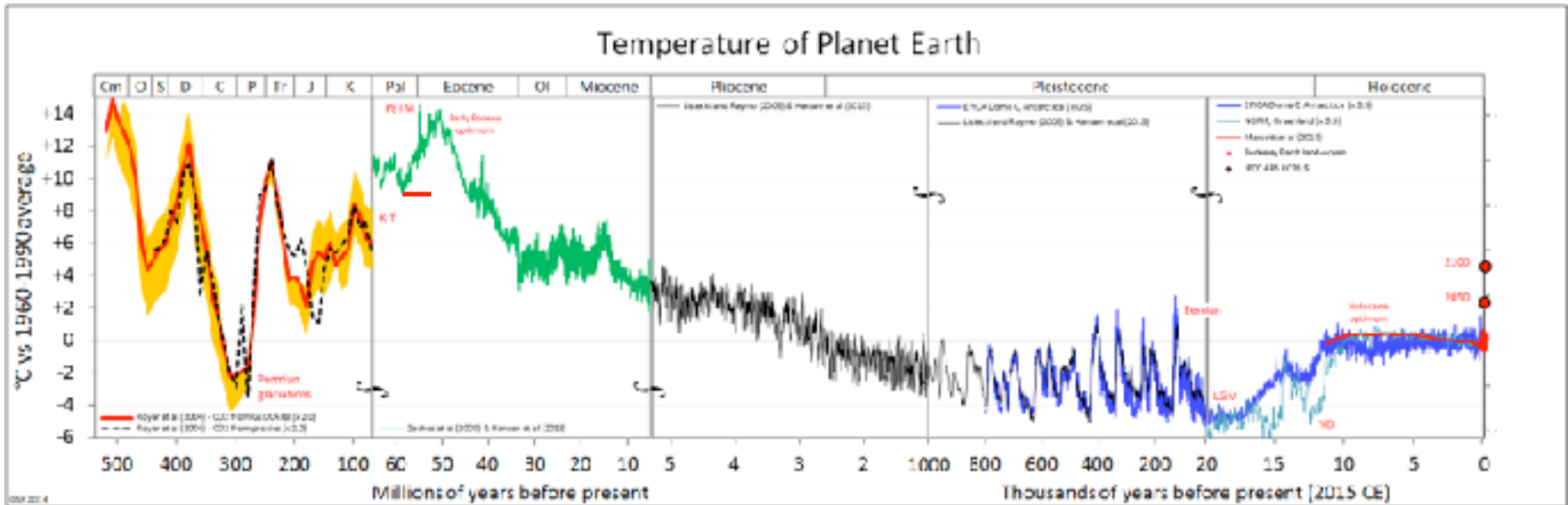


Stomatal proxy-based CO₂ estimate of ~900ppm, using Australian fossil conifer leaves, is shown (red box) relative to the Phanerozoic pCO₂ obtained by the GEOCARB models (GEOCARB II of Berner (1994) as adjusted in GEOCARB III of Berner and Kothavala (2001) (blue line with gray error envelope) and various additional proxies (green line) ([Steinthorsdottir and Vajda 2015, fig. 4](#)).

Temperature



- Reliable thermometer measurements since 1850
- Reliable satellite measurements since 1970's
- Oxygen isotope ratios-measure these in fossils, such as forams
- Ice cores

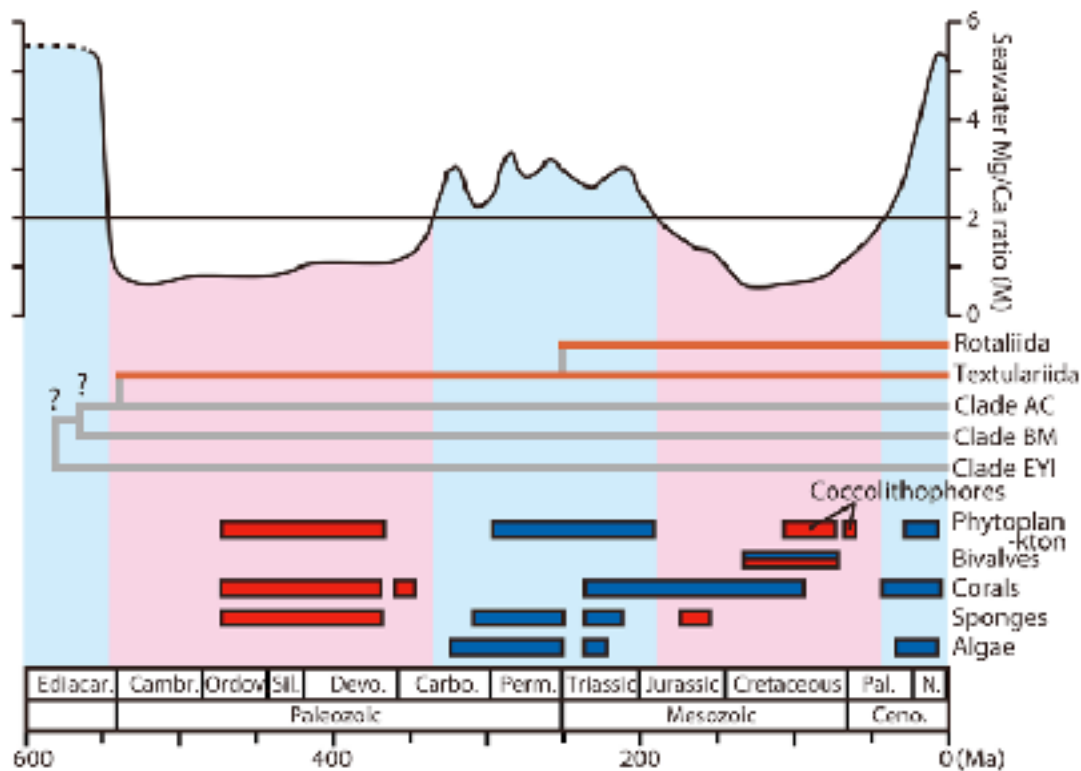


Source Wikimedia [Here's How Scientists Reconstruct Earth's Past Climates](#)

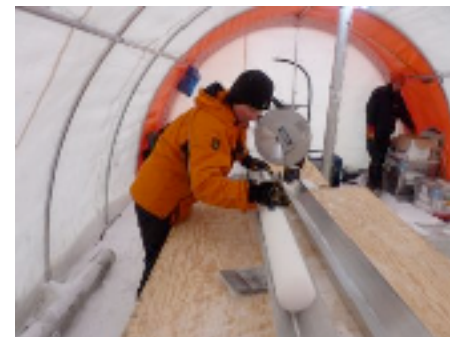
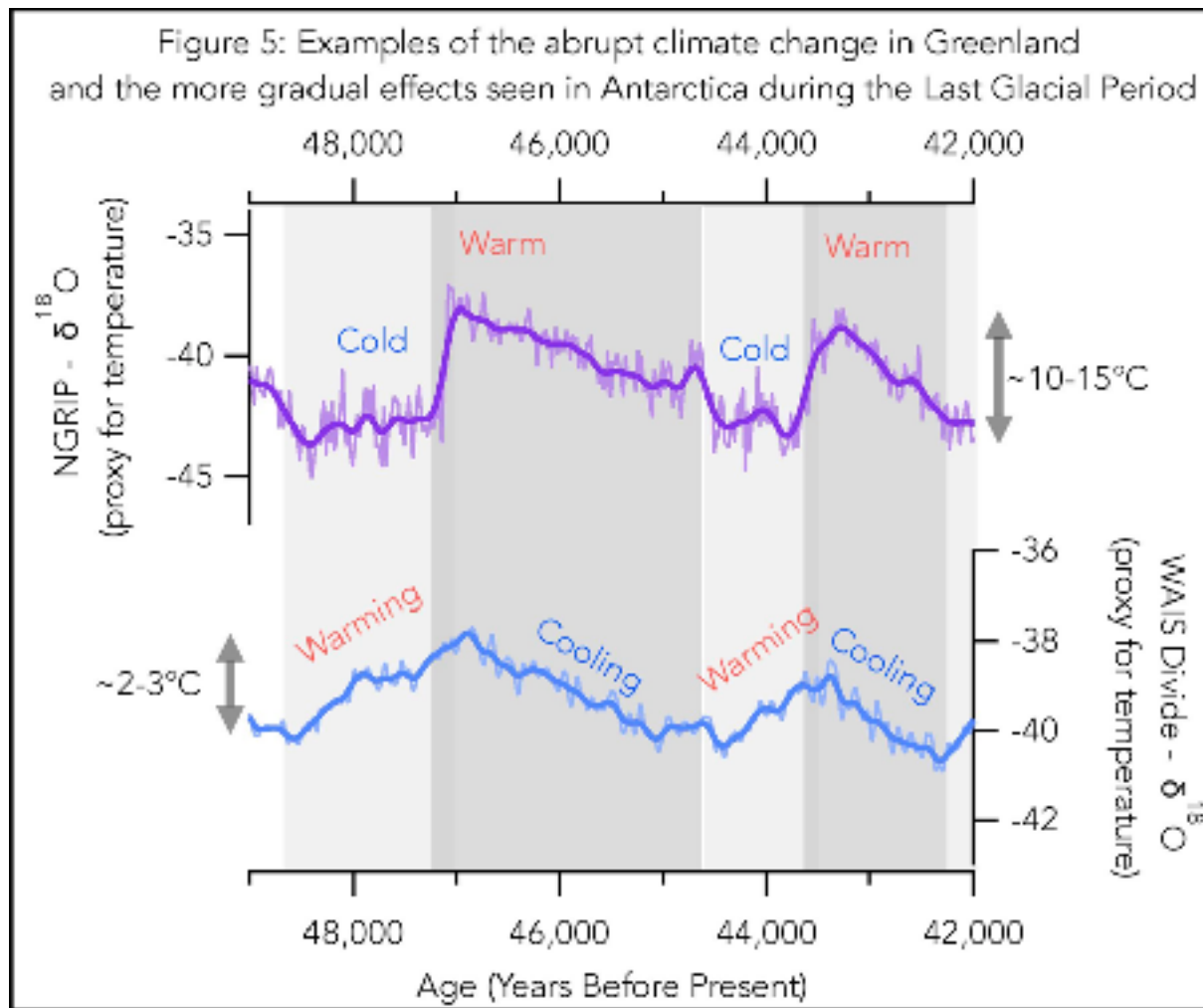
Paleocene–Eocene Thermal Maximum (PETM, 58Ma) saw global temperatures rise between 5-8 °C, which caused a mass deep-sea extinction that lasted 200,000 years. What will the predicted global temperature will be in 2100?

Foraminifera

- Microscopic single celled organisms that live in seawater
- Foram shells or “tests” contain a ratio of magnesium to calcium
- Seawater temperature affect the Mg/Ca ratio in the test
- Mg increases in warmer sea water (aragonite forms in warmer water)
- Fossil forams can be used as palaeothermometers!

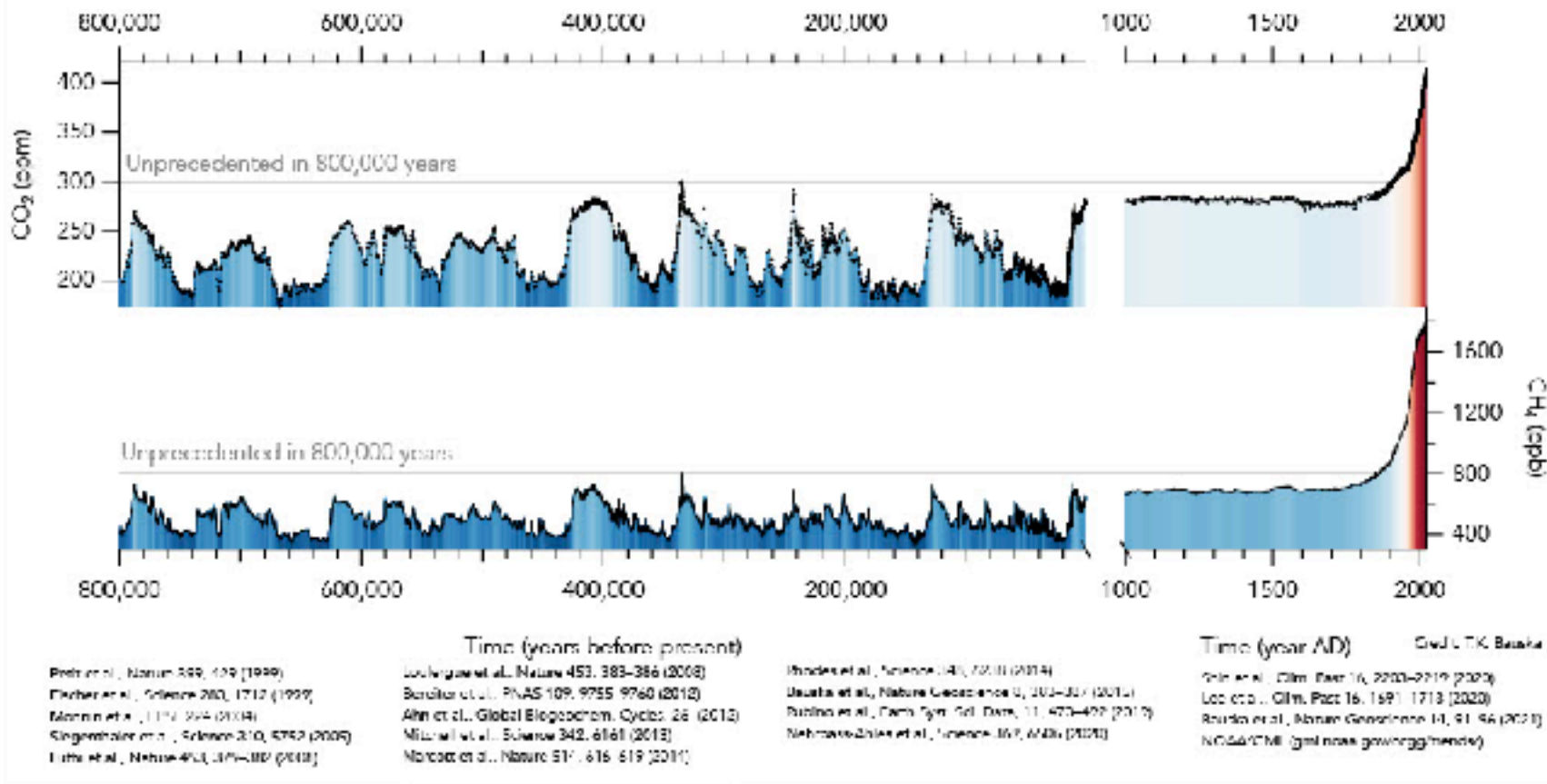


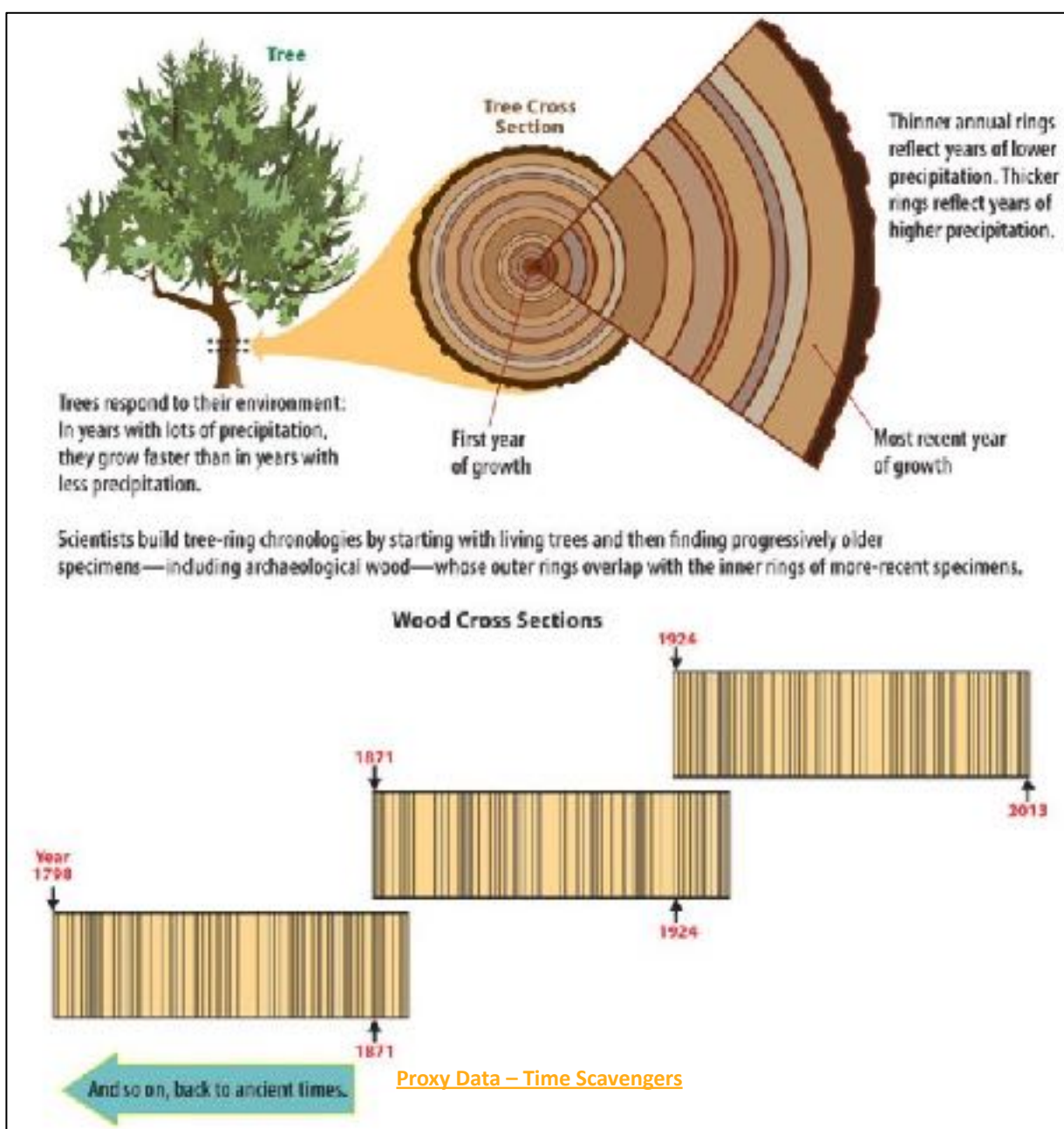
Forams!



Over time ice traps bubbles, which can be measured for CO_2 and CH_4 , and show the progression of ice ages.

Figure 2: 800,000 years of atmospheric CO₂ and CH₄ as recorded in ice cores and atmospheric sampling



The diagram illustrates the relationship between a tree and its growth rings. On the left, a green tree is shown with a yellow cone of light projecting from its trunk to a circular 'Tree Cross Section'. This section shows concentric rings, with the innermost labeled 'First year of growth' and the outermost 'Most recent year of growth'. A larger, wedge-shaped section of the tree trunk is shown to the right, with a text box stating: 'Thinner annual rings reflect years of lower precipitation. Thicker rings reflect years of higher precipitation.' Below this, a paragraph explains: 'Trees respond to their environment: In years with lots of precipitation, they grow faster than in years with less precipitation.' A second paragraph states: 'Scientists build tree-ring chronologies by starting with living trees and then finding progressively older specimens—including archaeological wood—whose outer rings overlap with the inner rings of more-recent specimens.' Below this is a 'Wood Cross Sections' diagram showing three overlapping horizontal bars representing wood samples. The top bar is labeled '1924' at its left end and '2013' at its right end. The middle bar is labeled '1871' at its left end and '1924' at its right end. The bottom bar is labeled 'Year: 1798' at its left end and '1871' at its right end. A green arrow at the bottom left points left with the text 'And so on, back to ancient times.' A blue link 'Proxy Data – Time Scavengers' is located at the bottom center.

Tree Rings

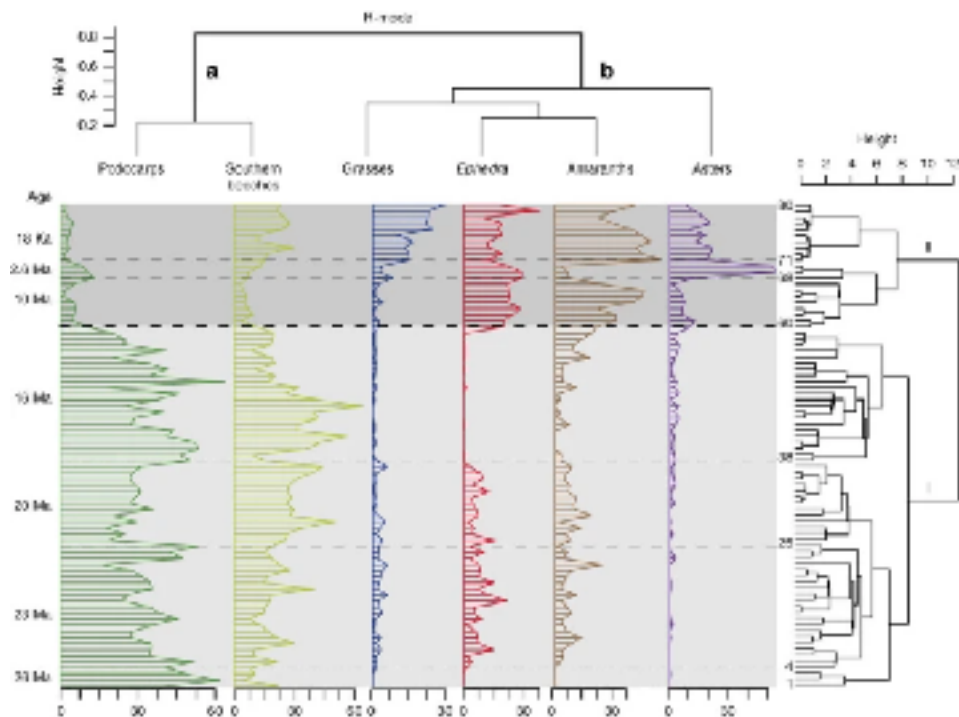
The thickness of tree rings varies according to precipitation

Pollen



Ancient pollen can be compared to living species

- Living species tell us about climate
- Pollen is preserved in lakes, bogs and marine environments
- Pollen can be problematic because species adapt over time
- Pollen is also light and can move over great distances



Podocarps and Southern Beeches are found in wet rainforest environments.

Grasses, amaranths and asters (daisies) are found in open woodland and meadows.

[Proxy Data – Time Scavengers](#)

Oxygen Isotopes



$\delta^{18}\text{O}$

One useful isotope for reconstructing past climates is oxygen-18. It is another stable isotope of oxygen along with oxygen-16, and its incorporation into water and carbon dioxide/carbonate molecules is strongly temperature dependent. Higher temperature implies more incorporation of oxygen-18, and vice versa. Thus, the ratio of $^{18}\text{O}/^{16}\text{O}$ can tell something about temperature.

- Measuring $\delta^{18}\text{O}$ is a proxy for global temperature
 - As the ratio for glacial ice decreases, the ratio for ocean water increases
 - As the ratio for glacial ice increases, the ratio for ocean water decreases
 - As atmospheric temperature decreases, the $^{18}\text{O}/^{16}\text{O}$ ratio for glacial ice decreases and the $^{18}\text{O}/^{16}\text{O}$ ratio for ocean water increases
 - As atmospheric temperature increases, the $^{18}\text{O}/^{16}\text{O}$ ratio for glacial ice increases and the $^{18}\text{O}/^{16}\text{O}$ ratio for ocean water decreases
 - Measure ratio in glacial ice to create a temperature vs time profile