SACE Stage 2: Earth and Environmental Science

Topic 1: Earth Systems

"Earthrise": Earth from the Moon; image acquired by NASA on 12 October 2015

NASA Earth Observatory: *"On December 24, 1968, during a live Christmas Eve broadcast from orbit around the Moon, Apollo 8 astronauts shared a spectacular image of Earth rising on the lunar horizon. The image, known as Earthrise, offered us one of the first views of our planet as it appears from deep space. The photograph has become one of the most recognizable views of our home and is often credited with inspiring the nascent environmental movement to become a political force."*
(*https://earthobservatory.nasa.gov/IOTD/view.php?id=87233*)

Version 1 notes by Bernd Michaelsen

Monday_11_December_2017

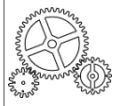
Topic 1: Earth Systems

This topic lays the foundation of scientific inquiry skills that students use in planning and implementing their Earth systems study. Students examine in detail the interaction between and within Earth systems — the atmosphere, hydrosphere, geosphere, and biosphere — and apply their learning to investigating their local area, as well as considering wider implications.

Students participate in field trips and use technology to develop their observational, recording, and analytical skills in preparation for the main study. They consider how their findings may provide advice to appropriate groups for future action.

NOTE TO TEACHERS:

*These notes have been designed to elaborate on the **Possible Contexts** provided in the Earth and Environmental Science subject outline. They are intended to provide further ideas and links to teaching and learning resources that address the **Science Understanding.** It is important to remember that you are not expected to cover all of the material included. Rather, these notes should be regarded as a 'smorgasbord' from which individual teachers might pick and choose, according to the needs and abilities of their students and according to the context of their externally assessed 'Earth Systems Study'.*

Science Understanding	Possible Contexts	
The four Earth systems are the geosphere, atmosphere, hydrosphere, and biosphere. • Investigate the components of each of the four systems. • Identify visible and 'hidden' system components and processes. • Identify interactions between system components. • Describe dynamic relations within and between systems. • Organise components and processes into a web of interactions.	Discuss an infographic about the systems of the Earth: http://visual.ly/fifty-unbelievable-facts-about-earth Examine an overview of Earth systems and their interconnections, including numerous teaching resources and student activities in EarthLabs, 'Earth System Science' unit and field study: http://serc.carleton.edu/earthlabs/climate/index.html	
	Investigate the interaction of the four Earth systems in the local area and construct a table to show how the four Earth systems can interact. www.ucmp.berkeley.edu/education/dynamic/session4/index.html Investigate a case study, for example, cleaning up an oil spill: http://response.restoration.noaa.gov/training-and-education/education-students-and-teachers	
	Use an example such as the *Exxon Valdez* oil spill to examine the contribution of science to the public debate on suitable methods to stimulate ecological recovery after an oil spill.	
A change in any one system can impact others at a range of temporal and spatial scales. • Explain how changes in systems can be caused by natural or human-induced factors. • Describe that changes within a system and between systems can occur over a variety of time-scales. • Identify patterns and changes over a variety of time-scales. • Discuss how a change in Earth systems can influence conditions at a range of spatial scales from local to global. Explain that changes in systems may have cyclic or unpredictable patterns.	Explore use of fieldwork apps, such as: • FieldMove Clino — free app for field notes, photos, map of sites, and recording dip and strike measurements: www.mve.com/digital-mapping • Evernote Sketch — a sketching app to complement field notes and photos: https://evernote.com/skitch/?var=c	

Science Understanding	Possible Contexts	
• Examine changes in interactions between Earth systems that have occurred in the past. Predict future changes within and between Earth systems in a given area.	Conduct a field activity in which students participate in a whole-class Earth systems study to develop appropriate science inquiry skills and make connections with science as a human endeavour. • Observe interactions among the systems in a local area. • Identify and record these interactions. • Analyse this primary data. • Identify an environmental issue, concern, initiative, or successful undertaking. • Hypothesise, control variables, predict, and gather new data. • Gather background information, such as from maps and satellite imagery, and/or research the outcomes of prior studies.	
	Provide recommendations for further work. Investigate the many factors that limit predictions about the effects of combustion of fossil fuels on global warming.	

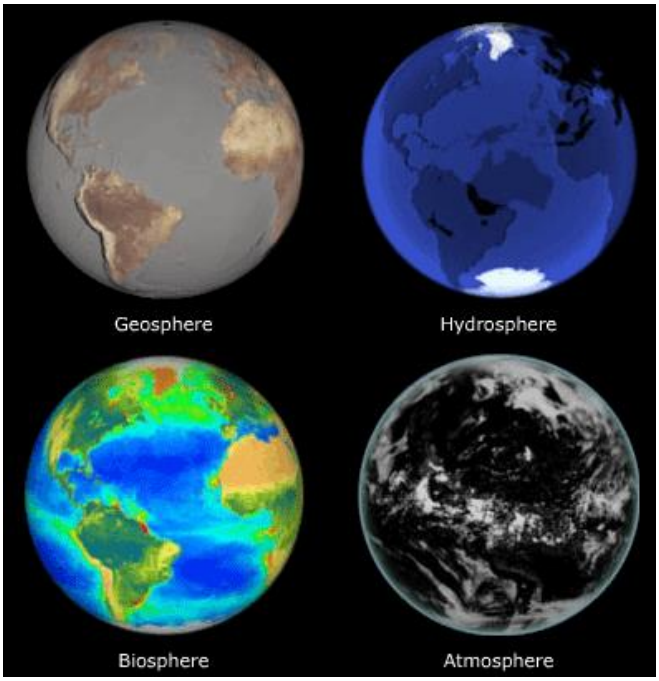
The four Earth systems are the geosphere, atmosphere, hydrosphere, and biosphere

Definition of "Earth Systems Science"

> ***"Earth system science is the study of processes that move energy and materials among the four spheres"***

In this *Earth & Environmental Science* course, we shall attempt to conceptualise the entire Earth "super system" as the superposition and interrelationships of four systems (spheres):

1. Geosphere
2. Atmosphere
3. Hydrosphere
4. Biosphere.



Earth's four "systems" or "spheres"
(https://d32ogoqmya1dw8.cloudfront.net/images/eslabs/climate/earths_four_spheres.gif)

Visual model of Earth's interacting systems

Visualisation of the four Earth systems at:
http://www.classzone.com/books/earth_science/terc/content/visualizations/es0102/es0102page01.cfm?chapter_no=visualization

Photo-timeline: How Earth formed

A tour of the geological record (a record of the interrelationship of the four Earth ststems at https://www.livescience.com/46593-how-earth-formed-photo-timeline.html?_ga=2.122104392.272616353.1512709818-1346314372.1508209500.

The Day the Oceans Boiled

The documentary film *"The Day the Oceans Boiled"* clearly explains how the four earth systems are intermeshed and interdependent. This has been the case since the advent of life on earth about 4 billion years ago.

- Part 1: *The Day the Oceans Boiled* (various segments) (https://www.youtube.com/watch?v=G19Vg24motc)
- Part 2: *The Day the Oceans Boiled* (various segments) (https://www.youtube.com/watch?v=0FDvtFL0iYE)
- Part 3: *The Day the Oceans Boiled* (various segments) (https://www.youtube.com/watch?v=iDBt07skLbQ)

*What is the **missing carbon sink**? And why is it so critical to understand?*

- Natural changes in the carbon cycle have tracked Earth's ice ages during at least the last half a million years.
- There is a relationship between periods of ice age and the levels of carbon in the geosphere and biosphere *versus* CO_2 in the atmosphere.
- Proxy temperature data from ice cores indicate that dramatic changes of temperature (up to ~20 °C) can occur within a human lifetime.

What is the Paleocene-Eocene (55 Ma) event?

With respect to the temperature of Earth's oceans exactly what (spread over a couple of hundred years) happened at 55Ma?

What is a runaway greenhouse event?

Lighting a fire on a frozen lake with nothing but a chisel and one matchstick

Fun with burning methane (thawed methane hydrates) on a frozen lake – watch the video (3:52) at

https://www.nytimes.com/2016/03/08/science/methane-has-never-looked-so-beautiful.html.

- Humankind is now a major agent for biological, atmospheric, hydrological and geological change.

Methane hydrates

Crater left by methane hydrate burp within Russian permafrost (https://www.thinkglobalgreen.org/METHANE.html)

Abraham Lake, Alberta, Canada. Methane bubbles trapped in ice – the methane escapes entrapment in the lake sediment and moves slowly to the surface to escape into the atmosphere (http://www.dailymail.co.uk/news/article-2326862/What-bubbles-beneath-Beautiful-patterns-frozen-bubbles-trapped-Canada-lake-highly-flammable-methane-gas.html)

- **Methane hydrates** (**clathrates**) are produced when bacteria acting on organic matter as it sinks in an oxygen-poor (anaerobic) environment, which is then buried and preserved within the geological realm.
- The cycle of formation, preservation and release of methane from clathrates (methane hydrates) involves all four Earth systems. It is an excellent example of how a change in one system can have enormous consequences for the other systems.

An important video to watch, perhaps in your own time, is from the **2017 UN Climate Change Conference** (Bonn, Germany) at https://www.youtube.com/watch?v=S7z61UZoppM. The discussion in this video is driven by James Hansen, a renowned scientist, and is up-to-date, rational and backed-up by good science.

- **Proxy temperature data**: geochemical data from ice cores indicate that dramatic changes of temperature (up to ~20 °C) can occur within a single human lifetime.
- **Self-reinforcing loop**: warming leads to thawing of frozen organic matter and gas-hydrates, which releases more CO_2 and methane, that increases warming that increases the thawing. This is also called a **positive feedback loop**.
- Positive feedback loops such as **permafrost** thawing and the release of enormous quantities of **greenhouse gases** are <u>not</u> in present **climate models** because of the inherent conservatism of scientists – after all no scientist wants to be ridiculed by their peers.

Relax and be awe inspired by the "Earth from space" video (12:46) at https://www.youtube.com/watch?v=n4IhCSMkADc.

- **Investigate the components of each of the four systems**
- **Identify visible and 'hidden' system components**

Components of the atmosphere

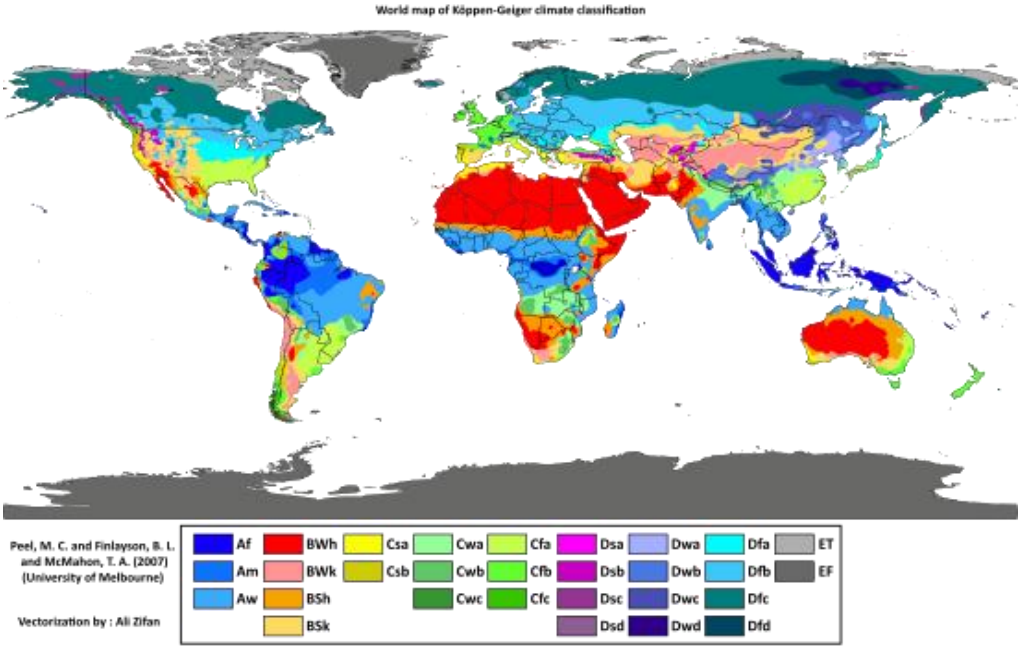
Photo-image (31 July 2011) taken aboard the International Space Station, showing Earth's atmosphere and moon (https://www.space.com/17683-earth-atmosphere.html)

- Nitrogen (N_2), 78%
- Oxygen (O_2), 21%
- Argon (Ar), ~0.93%
- Carbon dioxide (CO_2), 0.04% (~400 ppm)

Not only are CO_2 concentrations in the atmosphere rising; atmospheric O_2 concentrations are falling (https://www.space.com/34163-earth-atmospheric-oxygen-levels-declining.html). These changes have been caused by changes in the photosynthesizing capacity of Earth's ecosystems and anthropogenic causes such as the combustion of fossil fuels.

Atmospheric temperature and ocean temperature are the major control factors with respect to Earth's climate (see below).

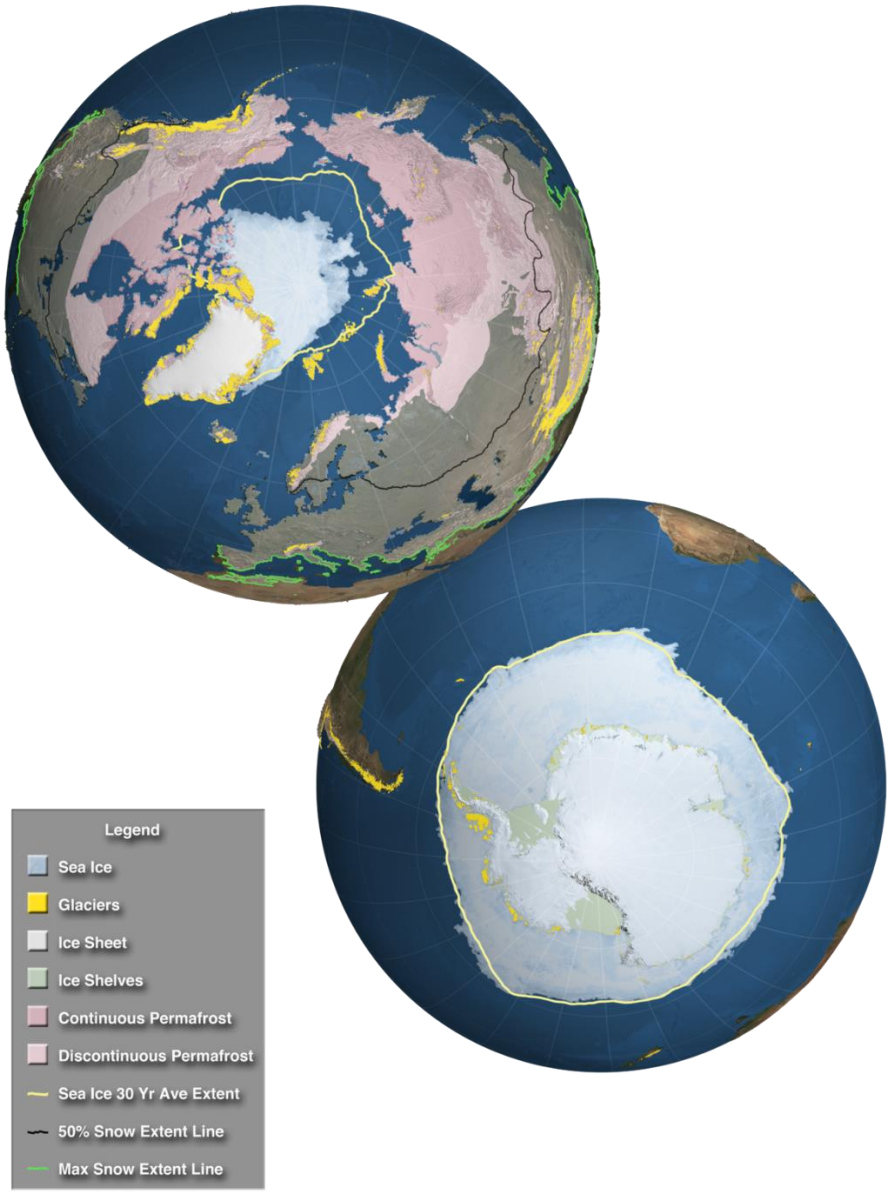
Variations in atmospheric temperature are largely "hidden" – we observe their manifestations (e.g. climate zones)



*Köppen climate classification map (https://socratic.org/questions/what-factors-are-used-to-classify-climate-in-the-k-ppen-climate-classification-s). **A** = Average temperature of 18 °C or higher; **B** = Low precipitation. Potential evaporation and transpiration are greater than precipitation; **C** = Temperatures for the coldest month average between 0–18 °C and at least one month of the year averages above 10 °C; **D** = At least one month on average below 10 °C and at least one month on average above 10 °C; **E** = Average monthly temperatures always below 10 °C.*

Read more about the Köppen Climate Classification at https://socratic.org/questions/what-factors-are-used-to-classify-climate-in-the-k-ppen-climate-classification-s and http://hanschen.org/koppen/#maps.

Components of the hydrosphere



Extent of regions affected by components of the cryosphere (https://en.wikipedia.org/wiki/Cryosphere)

- Liquid water beneath the planet's surface (aquifers)
- Liquid water above the surface (oceans, lakes, rivers)
- Water vapour in the atmosphere
- Frozen water (cryosphere) beneath the ground surface (permafrost)
- Frozen water (cryosphere) at the surface (continental & alpine glaciers)

Visible components of the biosphere

- Aquatic flora and fauna
- Terrestrial flora and fauna

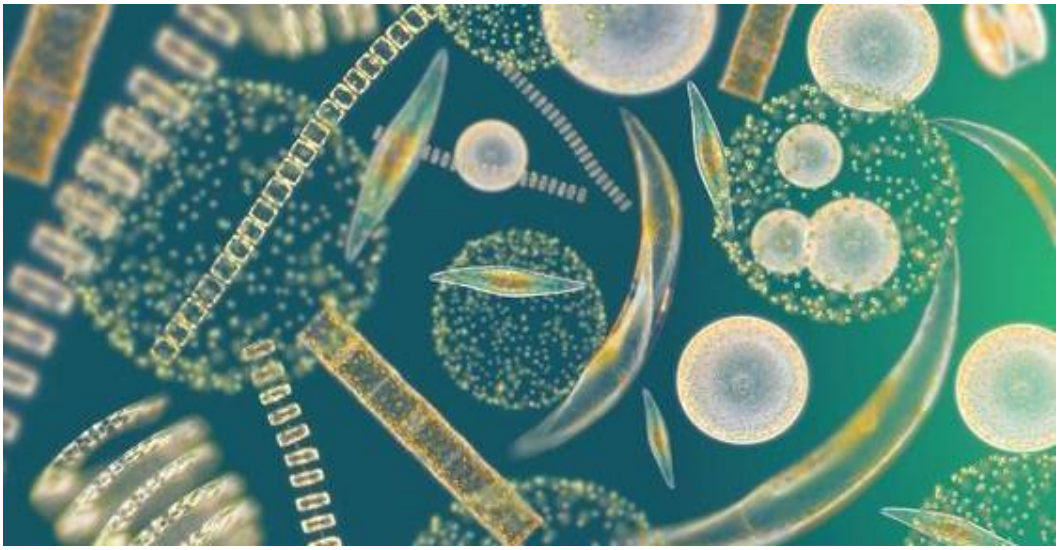
Table 12.1. Geographical area, mean plant biomass and net productivity in major world ecosystems

Major world ecosystems	*Geographical area* 10^6 *km*^{2}	*Mean plant biomass* (*t ha*$^{-1}$)	*Mean net primary productivity* (*t ha*$^{-1}$ *year*$^{-1}$)
1. Tropical rain forest	17	440	20
2. Tropical deciduous forest	8	360	15
3. Temperate deciduous forest	7	300	12
4. Temperate coniferous forest	12	200	8
5. Savanna	15	40	9
6. Temperate grassland	9	20	5
7. Desert shrub	18	10	0.7
t = ton = 1000 kg ; ha = 10,000 m^2			

Earth's major terrestrial ecosystems: Geographic area, mean plant biomass and net productivity (http://www.biologydiscussion.com/ecosystem/3-main-components-of-biosphere/52947)

Hidden components of the biosphere

An example of a hidden component: Phytoplankton



Microscopic phytoplankton (https://www.sailorsforthesea.org/programs/ocean-watch/searching-phytoplankton)

Although phytoplankton are a "hidden" component of the biosphere, and they only comprise about 1% of Earth's photosynthetic biomass, their contribution to the Earth's carbon cycle is approximately the same as that of "visible" land plants. Some facts about phytoplankton:

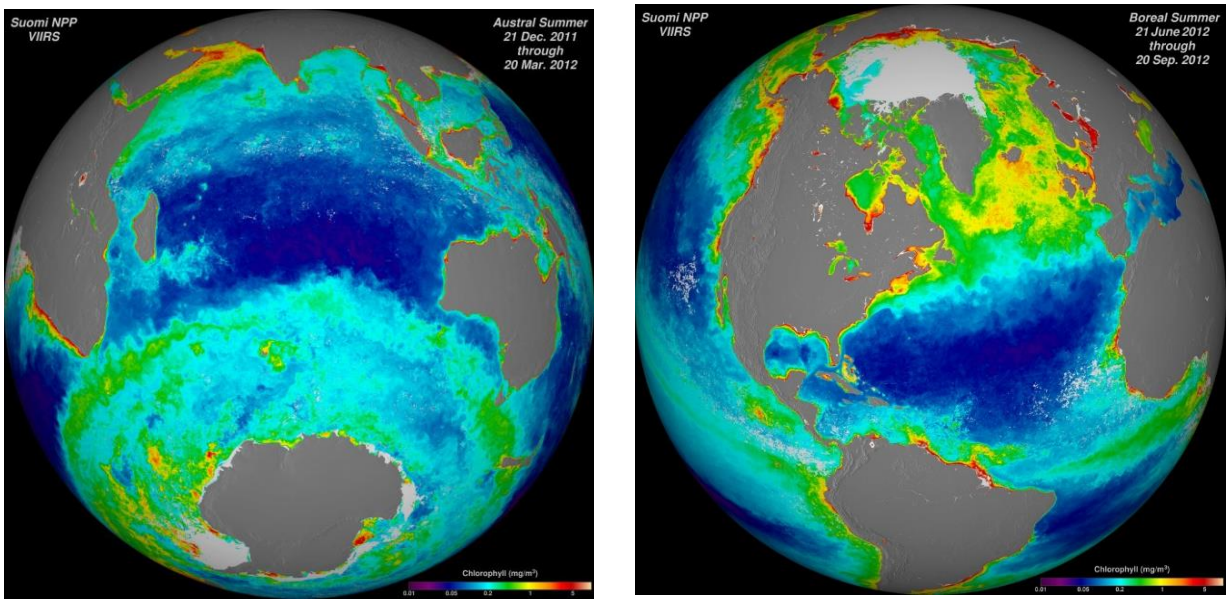
- Total mass of all the phytoplankton in Earth's oceans is < 10^9 tonnes
- Yet, 45 x 10^9 tonnes of new phytoplankton are produced each year
- Thus, phytoplankton reproduce themselves ~ 45 times a year.

Land-plants (presently), annually incorporate ~52 x 10^9 tonnes of inorganic carbon. So although the total biomass of all the world's oceans is miniscule compared to **vascular** land-plants, their contribution in the carbon cycle is roughly the same magnitude.

Information source: On-line 2012 paper by Paul Falkowski, "The Power of plankton. Do tiny floating microorganisms in the ocean's surface waters play a massive role in controlling the global climate?", Lenses on Biology: Outlook (https://www.nature.com/articles/483S17a.epdf)

Phytoplankton is the great "hidden" components of the biosphere

- Phytoplankton within Earth's oceans is the foundation of the **aquatic food web** (https://earthobservatory.nasa.gov/Features/Phytoplankton/page2.php).

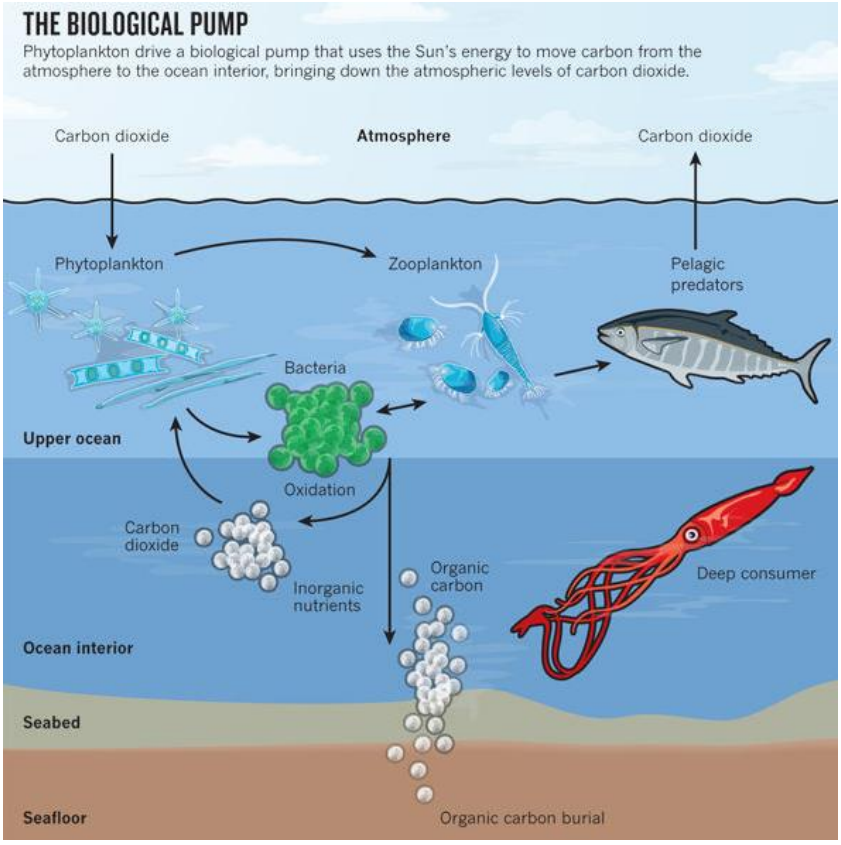


Left: Ocean chlorophyll concentrations, Sorthern Hemisphere;Austral summer, 21 Dec 2011 to 20 Mar 2012 (https://www.nasa.gov/mission_pages/NPP/multimedia/gallery/V20113552012080-NPP.html)

Right: Ocean chlorophyll concentrations, Northern Hemisphere; Boreal summer, 21 June 2012 to 20 Sep 2012 (https://www.nasa.gov/mission_pages/NPP/multimedia/gallery/V20121732012264-NPP.html)

- Organise components and processes into a web of interactions

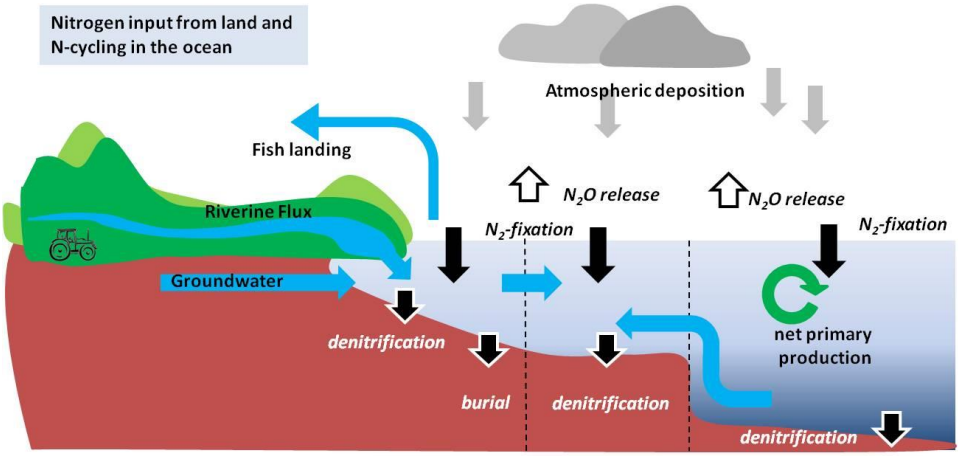
- The **biological carbon pump**, which annually transfers about 10 Gt of carbon from the atmosphere to the deep ocean. Thi aquatic pump incorporates "hidden" chemical and biochemical processes.



Schematic representation of the aquatic "biological carbon pump" (*http://www.nature.com/articles/483S17a*)

- **Describe dynamic relations within and between systems**

The marine **nitrogen cycle** is an example of a dynamic web of relations between all four Earth systems, and incorporates visible and "hidden" system components.



Marine nitrogen cycle (https://www.io-warnemuende.de/bio-ag-stable-isotopes.html)

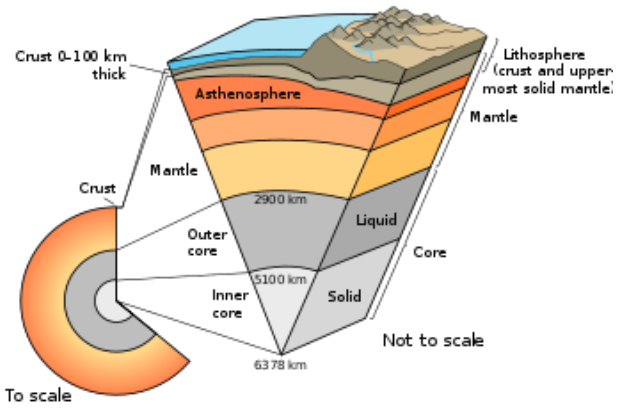
Earth and plate tectonics

Plate tectonics is a unifying theory that links all of Earth's systems and explains not only **tectonism**, mountain building and **volcanism**, but also

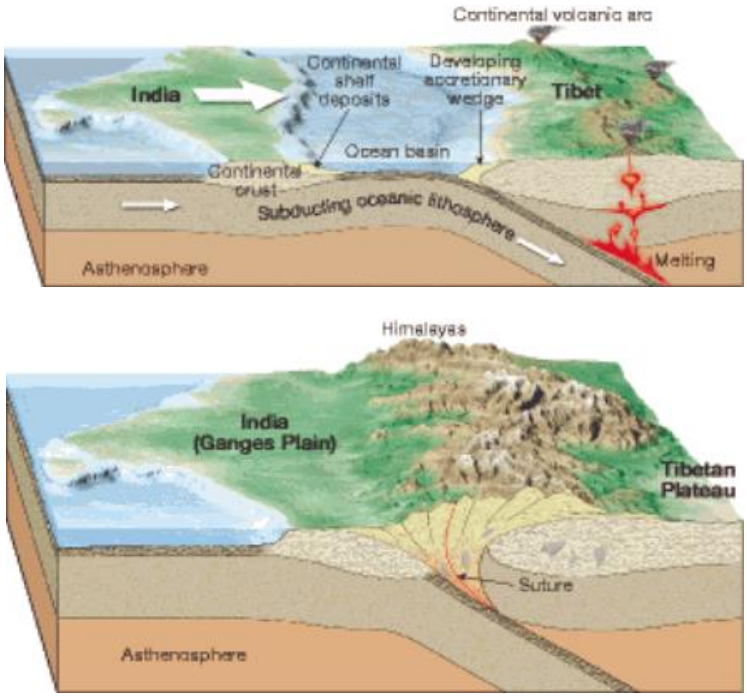
Earth's mineral resources, its past and present climates, and the evolution of Earth's atmosphere and life.

Hidden components and processes

The essence of plate tectonics is that heat from the decay of uranium drives **mantle convection** which in turn drives the movement of **tectonic plates** that comprise Earth's lithosphere. Heat energy is lost from Earth's core and the mantle through this process, which also produces volcanism along plate and **continental margins**.



Major layers of Earth (https://en.wikipedia.org/wiki/Asthenosphere)



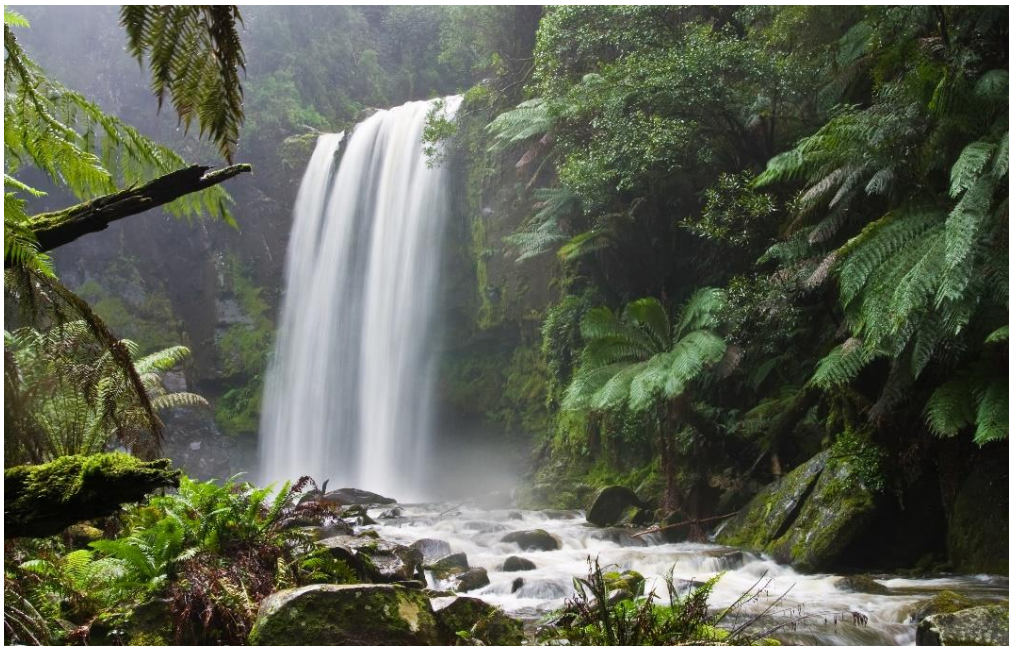
Reconstruction of the collision and subduction of the Indian Plate beneath the Eurasian Plate. (http://cosscience1.pbworks.com/w/page/8286031/Lesson%20105%20Convergent%20and%20Transform%20Boundaries)

Volcanism during the Hadean and Archean eons formed Earth's early atmosphere, and ongoing volcanism continues to add volcanic gas to its present-day atmosphere.

What are the volcanic gases that present-day volcanoes add to earth's atmosphere?.

A change in any one system can impact others at a range of temporal and spatial scales

- **Explain how changes in systems can be caused by natural or human-induced factors**



Hopetoun Falls, Otway Ranges, Victoria (https://en.wikipedia.org/wiki/Natural_environment)

Unique mountain forests of south-eastern Australia

Natural or anthropogenic factors will effect changes to systems. Take for example the vegetation within the immediate vicinity of Hopetoun Falls (above figure), a waterfall located on the Aire River, within the southern Otway Ranges, Victoria.

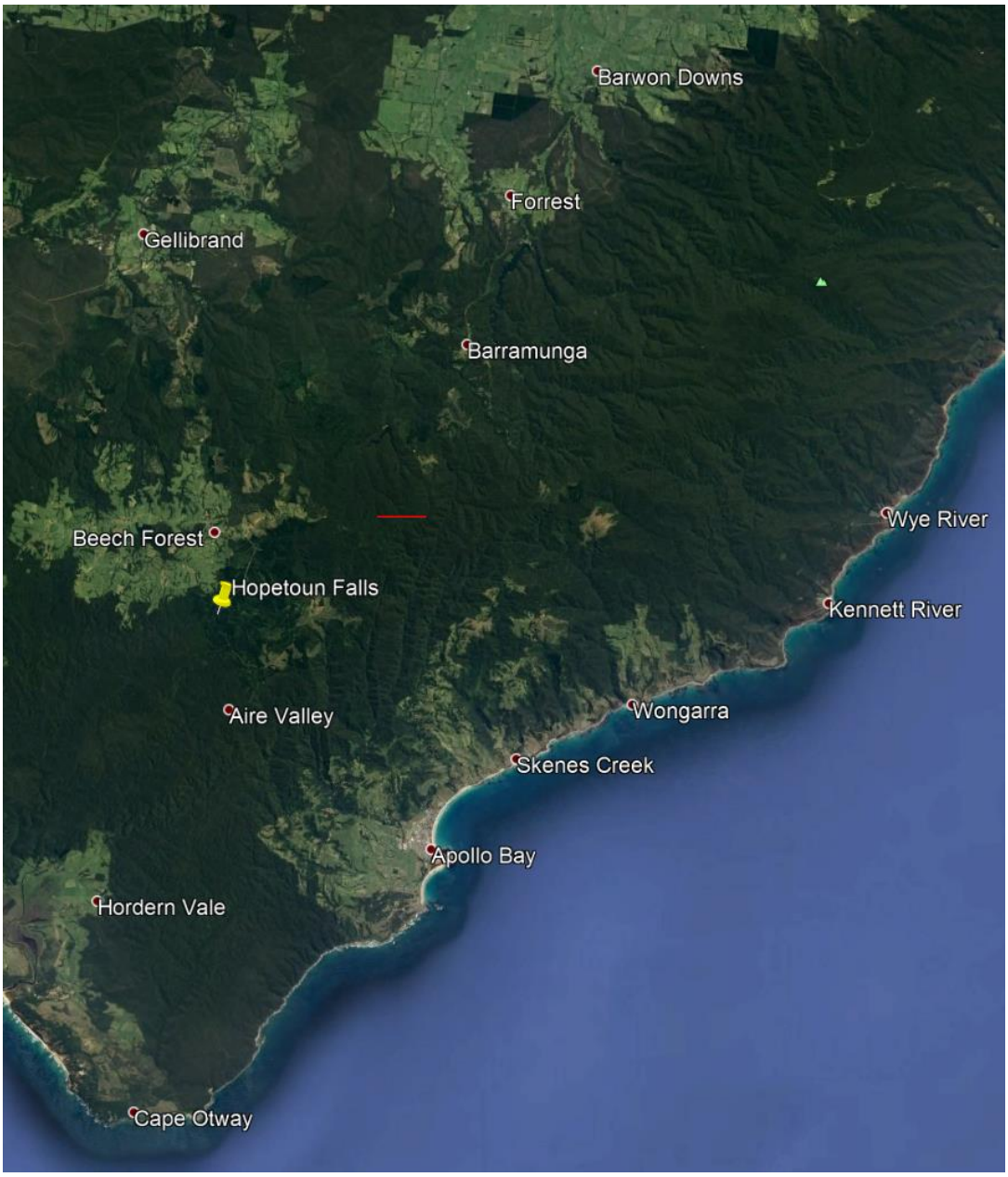
The area around the falls is vegetated with a canopy of ~80 metre-tall mountain ash *(Eucalyptus regnans)*, an understory of rainforest plants, with pockets of myrtle beech *(Nothofagus cunninghamii)*, tree ferns (*Dicksonia antarctica*) and a ground cover of ferns, lichen and moss.

Mountain ash are the world's tallest **angiosperms** (flowering plants) restricted to Victoria and Tasmania have been known to reach heights of over 100 metres.

This floral association is plentiful in western Tasmania and still common in parts of eastern Victoria. It is a typical temperate wet **sclerophyll forest** containing pockets of so-called cool temperate **rainforest**. The forest is very sensitive to changes in rainfall and river discharge – too little rainfall and the

flow of water in the Aire River will slow – the river will act more like a sump attracting groundwater flow into it – but not along the water course itself.

Firstly, the distribution of **lichen**, **moss** and ground ferns will shrink, especially on the north-facing slopes that present in full sunlight. Secondly, tree ferns exposed to direct sunlight will perish then the rainforest middle-canopy vegetation (myrtle beech and blackwood) dies off, leaving only *E. regnans*. Finally, after decades, or even centuries, *E. regnans* (that requires cool and moist climate) will be replaced by eucalyptus species more suited to dryer conditions, such as the stringy-bark eucalypts and **exotic** vegetation like radiata pine (*Pinus radiata*), similar to the vegetation in the Mount Lofty-Stirling area of the Adelaide Hills.



Google Earth image of the southern Otway Ranges, Victoria, showing the location of Hopetoun Falls. The red horizontal line is a scale bar representing 2 km.

In summary, if the quantity of water flowing in Aire River drops significantly, there will be consequences for the health of the ecosystem.

Google Earth image of Victoria and parts of NSW and South Australia. The area of the southern Otway Ranges in the previous figure is indicated by the red rectangle, showing the location of Hopetoun Falls. The red horizontal line is a scale bar representing 200 km.

From the Google Earth image in the above figure, it is apparent that:

- Most of south-eastern mainland Australia has been deforested.
- Only the most difficult (elevated, steep, rocky) terrane his preserved as native forest.

Note: A closer look at the forested area of the Otway Ranges demonstrates that much of the so-called forests are in fact man-contrived plantations.

Prior to the introduction of European agriculture to Victoria (post-1835) and South Australia (post-1836), distinct ecological and floral communities were able to "migrate", i.e. geographically relocate over millenia as climate evolved.

? *Suggest why south-eastern mainland Australia is particularly susceptible to rapid changes to its ecology.*

Why will the indigenous floral communities (e.g. wet sclerophyll forest and cool temperate rainforest) be unable to migrate across the Australia landscape in response to future climate change?

Since the arrival of Europeans, huge areas of Victoria and South Australia have burned during countless bushfires. The following is a non-exhaustive list of the well-known major fires:

- **Black Friday** bushfires (71 deaths in Vic) burnt 20,000 km^2 in Victoria, 13 January 1939.
- **Ash Wednesday** bushfires (47 deaths in Vic, 28 deaths in SA), burnt 2100 km^2 in Victoria and 2080 km^2 in SA, 16 February 1983; total of 5200 km^2 burnt in 1982/83 season.
- **Black Saturday** bushfires (173 deaths in Vic), burnt 4500 km^2 in Victoria; 7 February 2009.

This list is not exhaustive, and only includes bushfire events that resulted in the loss of multiple lives. Indeed, large bushfires occur annually throughout SE Australia, but especially in Victoria.

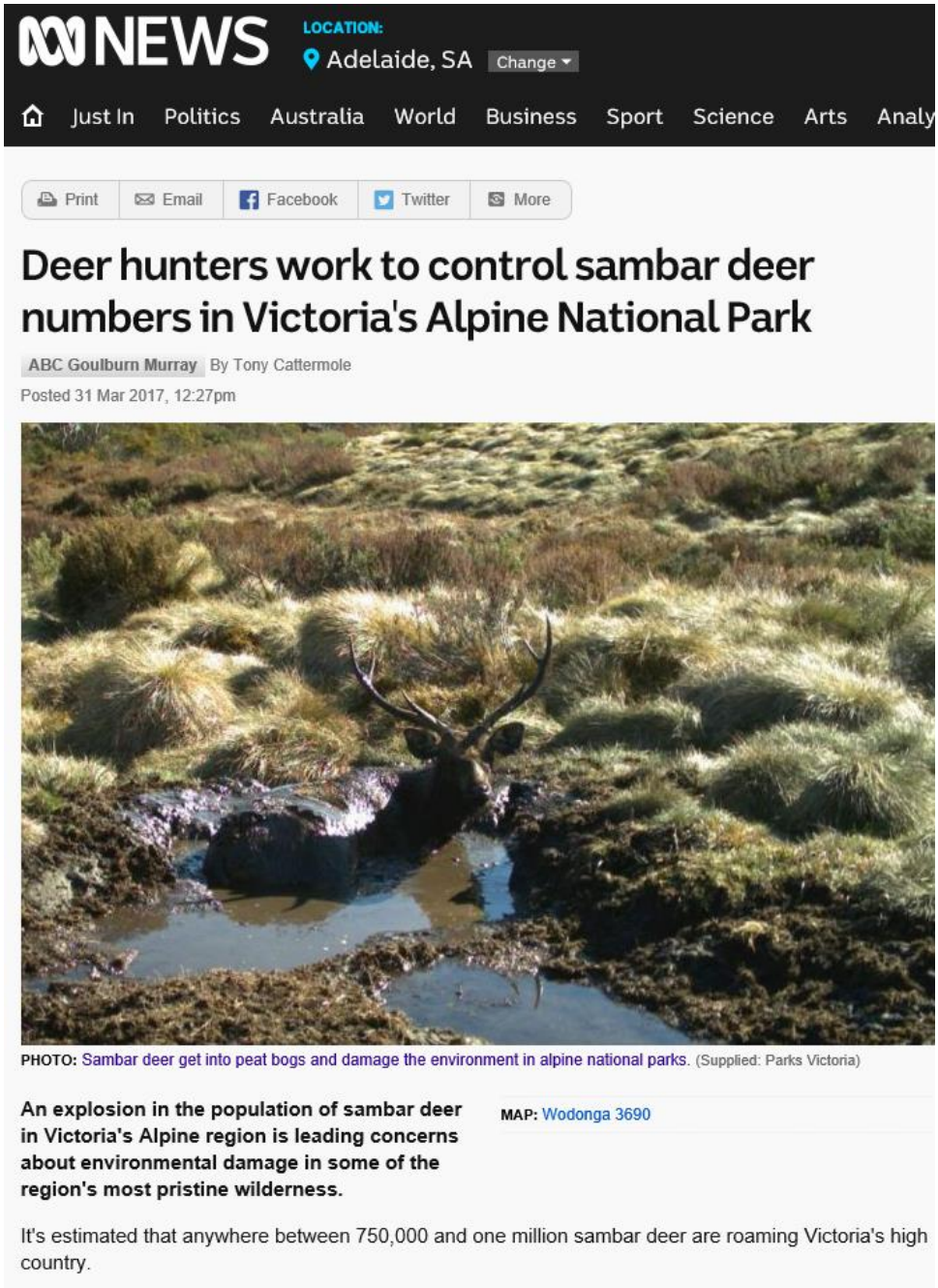
The Black Friday (1939) bushfires in Victoria burnt 20,000 km^2 of forest and rural properties. What does 20,000 km^2 look like represented on the Google earth image in the above figure?

Burnt forest after the Black Saturday (2009) Victorian bushfires (http://www.nma.gov.au/online_features/defining_moments/featured/black-saturday-bushfires)

Use the internet to research the amount of CO_2 produced by the Black Saturday (2009) fires. Don't stop at the first answer that you get – produce a list (or table) of the various estimates. Record your answers in tonnes and/or equivalent years of Australia's greenhouse gas/CO_2 emissions. Why are there such a wide range of estimates for the amount of CO_2 produced in Bushfires?

Each of these bushfire events was preceded by extreme **drought** that dried-out the forests and made them particularly vulnerable. On their respective days, the fires were triggered by hot northerly winds and extremely low **atmospheric humidity**. It is therefore logical that if climate change causes a general decrease in humidity during summer across SE Australia, we should expect an increase in the frequency and severity of bushfires.

Unforeseen: Small marsupials supplanted by large exotic mammals



Male sambar (stag) rolling in a muddy wallow diring the rut (http://www.abc.net.au/news/2017-03-31/deer-hunters-cull-sambar-deer-in-alpine-national-park/8396774)

European farming and cultural practices have caused the extinction of dozens of marsupial and reptile species. Large-scale bushfires, especially the 1983 and 2009 fires have altered the vegetation and ecosystems of eastern Victoria. Especially after major bushfires since the year 2000, feral deer populations

have exploded, and they have moved into areas where they have never been seen before.

- It is estimated that up to one million **sambar deer** (native to south – eastern Asia) now inhabit the steep forested country of eastern Victoria and NSW.

- In hindsight, the proliferation of sambar deer in the years following the 2009 bushfires has been aided by thick dense new-growth vegetation, excess of food sources and an absence of natural predators.

Use the internet to learn what environmental damage is being caused by sambar deer?

- **Describe that changes within a system and between systems can occur over a variety of time-scales**

- **Identify patterns and changes over a variety of time-scales**

Two snow gum communities. Left: Healthy and unburnt. Right: Snow gums that have been burnt three times in ten years (https://phys.org/news/2017-09-recurring-threatening-iconic-gum.html)

Experience from the high country of eastern Victoria (above figure) shows that high frequencies of bushfires destroy not only the vegetation itself, but also the seed bank within the soil. Consequently, many Alpine areas that previously contained healthy snow gums are never expected to fully recover post the 2009 bushfires.

Bushfires continue to burn large areas Victoria's wet and dry sclerophyll forests every few years. Bushfires may have "natural" causes; however, many are deliberately lit.

What are the short-term consequences of the ongoing (year-in-year-out) bushfires? And what are the long-term consequences measures in decades or centuries?

- **Discuss how a change in Earth systems can influence conditions at a range of spatial scales from local to global**

Example: A new study estimates frequency of volcanic eruptions

When Iceland's volcano of Eyjafjallajökull volcano erupted it caused chaos in Iceland and in Europe. Air travel was suspended due to the ash cloud that was pushed across Europe with the prevailing winds. Ten million air passengers were stranded and the European economy lost the equivalent of ~A$7 billion.

Eruptions of volcanic ash at Eyjafjallajökull volcano between 14-20 April 2010 (http://www.dailymail.co.uk/travel/travel_news/article-2729797/Tourists-forced-flee-fifth-day-seismic-activity-Iceland-s-largest-volcano-heightens-fears-eruption-disruption-European-flights.html)

- Recent work by researchers from the University of Leeds (UK) indicates that volcanic ash clouds across Europe are more common than previously envisaged. They found evidence of 84 ash clouds spanning a period of 7000 years, all linked to Icelandic eruptions (https://phys.org/news/2017-01-frequency-volcanic-eruptions.html).

- Put into the context of Earth's entire geological history, the Icelandic eruptions are very small and inconsequential: The 1883 eruption of Krakatoa, a small island between the main islands of Java and Sumatra (Indonesia) resulted in the deaths of at least 36,000 persons and possibly as high as 120,000.

- Prior to the eruption, Krakatoa Island was ~9 km long; after the explosion, 70% of the area of the island was removed. In terms of energy, the Krakatoa eruption was equivalent to 200 Mt of TNT (https://en.wikipedia.org/wiki/1883_eruption_of_Krakatoa)

- The Krakatoa eruption affected Earth's atmosphere for years. Amongst other gases, sulphur dioxide (SO_2) was injected into the atmosphere creating a sudden increase sulphuric acid within high-level clouds. The reflectivity (**albedo**) of earth's cloud cover increased and Earth's temperatures dropped – especially in the Northern Hemisphere, where the summer temperature dropped by an estimated 1.2 °C. This dramatically affected crop yields and the biosphere generally.

See the video (3.28) on the Krakatoa eruption at https://www.youtube.com/watch?v=UORtQFZejeg.

Explain that changes in systems may have cyclic or unpredictable patterns.

- **Examine changes in interactions between Earth systems that have occurred in the past**

It has been estimated that there are many hundreds of thousands of frozen pre-historic mammals within the Siberian permafrost – many are mammoths, and even pygmy mammoths on some Artic islands. There is both evidence for and against a "quick-freeze" hypothesis to explain this. However, the answer to this question continues to perplex palaeontologists and climatologists. An interesting discussion regarding this subject can be found at https://answersingenesis.org/extinct-animals/ice-age/were-siberian-mammoths-quick-frozen/.

- 

- *Six to eight-month-old wooly mammoth in situ within thawing tundra near Kirgiljach River, north-eastern Siberia (http://www.maropeng.co.za/news/entry/new_mammoth_find_gives_insight_into_early_human_hunting_methods)*

- A short video (1:49) *"Boy discovers perfectly preserved wooly mammoth"* (http://www.dailymail.co.uk/video/sciencetech/video-5697/Boy-discovers-perfectly-preserved-woolly-mammoth.html).

- Read about the "left over mammoth" at https://www.archaeology.org/issues/202-1601/trenches/3934-trenches-michigan-mammoth.
- Find-out what else is trapped within Siberian permafrost at https://www.wired.com/2016/12/global-warming-beneath-permafrost/.

During this course on earth and Environmental Science we shall study the mechanism of climate change" and hopefully have time to reflect on the question of whether the Siberian mammoths were indeed quick-frozen, and how that may have happened.

Predict future changes within and between Earth systems in a given area

The film *"Crude Impact"* questions Earth's future and mankind's future with diminishing liquid hydrocarbons.

The trailer for Crude impact is at https://www.youtube.com/watch?v=EwyAA2Zt8CI.

Watch the full film on Vimeo at https://vimeo.com/33552646.

The *Crude Impact* suggests:

- Fossil fuels are most critical to humanity in the production of food, and have underpinned humanity's population explosion, and its material assets
- Fossil fuels have underpinned the manufacturing and the explosion of consumerism.
- Earth's resource base is finite.
- Consumption of fossil fuels is the driver of all environmental degradation – degradation of the: atmosphere, hydrosphere, biosphere and geosphere.
- Consumption of fossils fuels could lead to climate change, and ultimately the shutdown of the oceanic conveyor belt – the North Atlantic Ocean current, leading to dramatic drop in temperatures in Europe and North America.
- The present rate of extinction of species is between 100 and 10,000 times that before the Industrial revolution.
- Use of energy resources is undermining Earth's entire ecosystem.