Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Greenhouse Earth Part 2 – The restless planet*.

This is the second of two podcasts on what astronomy can tell you about climate change and global warming.

Last episode we dealt with fairly modern Earth history looking at the causes of glaciation cycles in the last 800,000 years – which are sometimes mistakenly called ice ages – but really ice ages are measured in millions of years and we are in one now. It's called the Quaternary ice age, since it's in the current Quaternary geological period. Possibly the first ice age ever, the Huronian, is more hypothetical than evidence-based and is somewhat speculatively positioned around 2.7 to 2.3 billion years ago – and was probably caused by biology and a slightly cooler Sun.

When life, at least archaean and bacterial life, first took hold about 3.5 billion years ago, it's speculated that the Sun was around 10% cooler than it is today. However, Earth's atmosphere was very rich in carbon dioxide at the time. So, as cyanobacteria began to actively photosynthesise they began to change the atmosphere, by adding oxygen and extracting carbon dioxide – which after 800 million years or so resulted in an atmosphere a bit more like the one we have today. So a combination of low atmospheric CO_2 and a slightly cooler Sun may have brought about an ice age lasting hundreds of millions of years.

Apart from the Huronian, ice ages and the lack thereof – being those long periods of global warming that don't really get a name – all seem to be largely the result of continental drift – and its impact on ocean currents.

If we divide the Earth's surface into land, water and ice – we find ice has the highest albedo – reflecting back most of the Sun's radiation – while land is more likely to absorb some heat, but still reflect a bit back – and then water, having both a lower albedo and being a rapidly convective fluid not only absorbs more heat, but is also an excellent heat buffer – absorbing heat during the day and then releasing it at night. This is why you experience generally warmer nights on the coast than you would do further inland.

So – across the history of continental drift, it tends to be the case that if you have a lot of tropical oceans, Earth's mean global temperature is going to be warmer than if you have a lot of tropical continents. However, a bit of an exception to this rule is now – where we do have a fair share of tropical oceans, but we are still technically in an ice age – after all over 10% of Earth's surface is currently covered in permanent ice.

This is thought to be because the present configuration of continents limits the circulation of warm water from the equator out to the poles. If you look at a world map, the Arctic Ocean is semi land-locked by Siberia, Alaska, Canada and Greenland – and at the south pole, the large majority of the southern ice cap is on land.

Of course in earlier periods of Earth history, everything was different. There is thought to have been a cyclic pattern to continental drift – where you start with a single supercontinent which fragments and various continents spread out, but later on they tend to re-congregate to form another supercontinent.

So, what's really just the last of many supercontinents, Pangea formed around 300 million years ago – from a previous generation of continents which came from the fragmented Pannotia supercontinent formed about 600 million years ago – and before that was Rodinia about a billion years ago. Then – getting a little speculative here – there was Columbia sometime before 1.5 billion years ago, Kenorland more than 2 billion years ago, Ur at 3 billion and Vaalbara at around 3.6 billion – after which we are getting back towards the period of heavy asteroid bombardment and everything starts gets a bit molteny.

Across these sort of time scales, climate is largely influenced by what kind of surface the Sun is shining on and whether there is significant flow of ocean from the equator to the poles. Greenhouse gas formation from volcanic sources may also be significant as it's speculated that there is more volcanic out-gassing when the continents are being actively spread apart – than when they're all bunched together into one supercontinent.

The most severe known ice ages occurred in the aptly named Cryogenian period – which persisted for about 100 million years between the time the supercontinent Rodinia began to break up and transition to the Pannotia supercontinent. At that time, life was still limited to the oceans – with sponges being about the most complex life form found in the fossil record.
Ice ages in the Cryogenian period are hypothesised to have been severe enough to produce a Snowball Earth – where pretty much all land surface area was covered in ice and sea ice extended down to the equator. Some evidence for this comes from signs of glacial erosion from rocks considered to have been tropical at that time. Computer modelling suggests that a critical point is reached if ice gets to within 30 degrees of the equator – at which point a Snowball Earth, with total ice coverage, is inevitable as the high albedo of the ice reflects solar radiation back into space. Such an extreme might be achieved though continental drift of heavily glaciered continents to lower latitudes – well, maybe.

A reason to doubt the Snowball Earth hypothesis is that CO_2 levels in these early eras of Earth were still significantly higher than they are today. It wasn't until trees and forests really took off in the Jurassic period that CO_2 levels started to decline towards today's levels. Indeed during the Jurassic and Cretaceous periods oxygen levels were higher than today – perhaps due to the explosive growth of trees and forests which only became limited by the later evolution of species that could effectively live off them and limit their growth.

Something else we haven't really covered is the presumably major influence of ocean currents on ancient climates – but unfortunately the geological record doesn't have much to say on ancient ocean currents. It is however possible to predict their future movement from today. Climate change deniers point to the risk of a pending new glaciation cycle as a rationale for embracing anthropogenic greenhouse gas production as a good thing since we are otherwise going to experience loss of habitable land area and reduced crop production as the Earth ices over again.

However, there's another theory that states that if you melt all the Arctic ice in a carbon-driven global warming scenario it will dilute the far northern seas – stopping the normal downward movement of dense cooled water – and hence stopping the stream of warm water which is normally drawn up from the Equator to replace the cool water – and snap, instant ice age. Well, after all the ice has melted once and flooded lots of coastal real estate.

So look maybe everyone can come to Australia or just make a choice to embrace modern technologies and replace cheap but in all other respects dirty and inefficient technologies. It's time to move on. Let's fix this now and then start work on the asteroid defense system. Then it's time to thinking about the biggest climate change of all when the Sun becomes hot enough to evaporate all the oceans in about a billion years or so. If we can't save the planet – or at least its inhabitants – time is running low for something else to evolve that can.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where thinking globally can save you the Earth. No ads, no profit, just good science. Bye.