The Gippsland Coast in 2100
from scientific predictions on global warming to political action

"... if we fully 'develop' all of the world's coal, tar sands, shales and other fossil fuels we run a high risk of ending up in a few generations with a largely unliveable planet"
Steven Sherwood UNSW New Scientist 17.11.12

"Hope for the best, plan for the worst" Thomas Norton

by Peter Gardner(1)

Introduction

More than 12 years ago I wrote a political article entitled "Is Gippsland Going Under" which was published online. (2) This short essay briefly examined the work of geomorphologist Eric Bird on the possible subsidence of parts of the Gippsland coast and what would happen when this was combined with sea level rises predicted by global warming. In his book *Coasts* Bird noted a number of options combining sea level rise with vertical coastal land movement.(3). In 2008 the Gippsland Coastal Board published a report entitled *Climate Change, Sea Level Rise and Coastal Subsidence along the Gippsland Coast*. (GCBR) (4) This report has provided the most up to date information on coastal subsidence whilst the information on sea level rise it provided is already seriously out of date. The various predictions of average sea-level rise to the year 2100 range from 18 cm to about 2 metres.(5) Unfortunately the lower estimate as predicted by the 2007 Intergovernmental Panel on Climate Change (IPCC) is already being exceeded by the current average annual rise of 3.2mm which, if continued, would give an average global sea level rise of 28.5 cm by 2100. This estimate must be considered the bottom line and a most unlikely occurrence as all indications are that the rate of rise is increasing. In 2006 CSIRO climate scientist Barrie Pittock presented a paper entitled "Ten Reasons Why Climate Change May be More Severe than Projected" to the Washington Summit on Climate Stabilisation. Pittock concluded: "More rapid rise in sea level may be imminent(an acceleration has already been observed), and more rapid regional impacts may be expected"(6) Pittock's argument has recently been repeated in a New Scientist article by Michael Le Page who "gives seven reasons why things are looking even grimmer" than the 2007 IPCC worst case scenario. (7) Most of the Gippsland coast from Wilsons Promontory to the border is fronted by highly vulnerable coastal dunes - in particular the dune barrier that divides the Gippsland Lakes from Bass Strait. It is the purpose of this paper to examine the current state of affairs as regards subsidence, sea level rise and possible inundation and erosion along the Gippsland Coast, to offer three possible scenarios with rough time lines and briefly outline a political solution.

Coastal Subsidence

The 2008 GCBR noted that subsidence may occur with:

> "the extraction of underground water, oil or natural gas resulting in a relatively rapid collapse (compaction) of underlying strata and hence a lowering of the land surface - such as is the case surrounding the Latrobe Valley open pit coal mines where groundwater from the Latrobe Aquifer is extracted for dewatering purposes. The principal causes of the lowering of pressures in the Latrobe Aquifer, and hence any resulting subsidence, are extraction of oil and gas, dewatering of the Latrobe Valley open pit brown coal mines and extraction of groundwater for irrigation. Subsidence modelling was carried out by CSIRO for the years up to 2056" (8)

A summary of the CSIRO modelling can be seen in Table 1. The Coastal Board Report made a further 8 conclusions about subsidence along the Gippsland Coast including that

"subsidence is predicted to occur to differing degrees along the Gippsland Coast" and that the subsidence will "exacerbate the effect of sea level rise and future coastal erosion" but that "to date high resolution ground surveys have not detected any statistically valid land subsidence (other than at the valley open pit coal mines)." (9) The range of the subsidence predicted by the Latrobe CSIRO modelling published in the GCBR is 20 centimetres by 2031 up to 1.2m by 2056. The full range of subsidence predicted by the CSIRO - in both their realistic and pessimistic scenarios for both 2031 and 2056 - is from a minimum of 15.1cm to a maximum of 3.059 metres. The latter massive estimate was made for Golden Beach West.(10) The CSIRO estimates were in part based on the aquifer thickness. It is also of note that the estimates of subsidence were made from Corner Inlet to Bunga Arm and did not extend to Lakes Entrance. These estimates are far greater than any predicted sea level rise in the short to medium term and should the latter pessimistic worst case occur would almost certainly create a catastrophic changes to the Gippsland coast (see below) much earlier than otherwise estimated. One current unknown is whether the heaver rains of the last few years have replenished the aquifer to any degree. Because no measurable subsidence has been observed to date (2012) along the Gippsland coast this is currently not perceived as a threat.

The *Victorian Coastal Hazards Guide* dealt with subsidence in a few brief paragraphs stating: "Recent studies have concluded that there is currently no evidence that the coastline in this area has begun to subside in any measurable way." (11) This conclusion appears to have been based on the same CSIRO study of 2007. Since subsidence may occur rapidly and/or be localised this outlook may be foolhardy.

Table 1
Predicted subsidence under a 'realistic' and a 'pessimistic' scenario (p.16 GCBR)

Time Period	'Realistic Scenario' Maximum Predicted Subsidence	'Pessimistic Scenario' Max. Predicted Subsidence
2031	0.51m Range 0.22 – 0.51m	0.87m Range 0.30-0.87m
2056	0.48m Range 0.2-0.48m	1.2m Range 0.47 – 1.2m

Sea Level Rise

As noted in the Introduction the sea level rise is currently an average of 3.2mm per annum with about four-fifths of this resulting from thermal expansion of the oceans and the rest from ice melt on land. It is of interest that the IPCC 2007 report had no ice melt on land in their minimum scenario of 0.18m to 0.59m. Their high emissions scenario of 0.26m to 0.59m plus a possible further .1m to .2m caused by melting ice sheets on land gave a maximum rise of .79m in 2100.(12) With current global annual average sea level rise of 3.2mm even if no increase in the rate of rise were to occur the minimum average rise by 2100 would be 28.5cm. The predictions of the IPCC 2007 and the GCBR are already out of date. In sharp contrast to these predictions James Hansen of Goddard Institute for Space Studies, NASA, has observed that the current rate of sea level rise is doubling every 10 years but concluded that there is not enough evidence yet to determine whether this alarming rate will continue. (13) Such an

exponential rate rise would certainly condemn the coastline to the catastrophic scenario in our children's lifetime. It should be noted that the average variability of sea level rise currently in Australia varies from about the global average on the south and east coasts and to up to 3 times the global average on north and west coasts.

Bruun's Rule and Coastal Retreat

This somewhat controversial rule states that coastlines will retreat by 50 to 100 times in distance for every unit rise in sea level.(14) Modelling by Eric Sjerp of Ethos in the GCBR used an average 1:75 for the retreat of the coastline. This was then used to calculate potential erosion and inundation at the Honeysuckles and Paradise Beach combining a 1:100 year storm (see below) with both .49m and .8m sea level rise by 2100. (15) As noted above the latter sea level rise estimates now appear to be unrealistic. It is significant that Sjerp did not include either the realistic or pessimistic estimates of subsidence in his 'Honesuckles' model. If these estimates are added to Sjerp's calculations the sea level rise is 3-4 times his estimate and thus the Bruun's Rule retreat of the coastline is of a similar amount. The question of 1 in 100 year events is also a problem as global warming science indicates that extreme events such as storm surges will increase at an increasing rate as the planet warms. (see below). Thus the 1 in 100 year events may become a 1 in 10 year event or even less. Computer images done by Peter Wheeler of Monash University in 2008 on coastal flooding depict the Lakes Entrance township with flood level rises of 0, 1 and 2 metres. (16) Applying Bruun's rule for a 2 metre sea level rise to this model would also see the entire foreshore between Bass Strait and Cunningham Arm disappearing.

Storm Surge, Wave Height and Inundation

The GCB Report noted: "Winds are likely to intensify in coastal regions of Victoria, particularly in winter as a result of more intense low pressure systems. Low pressure systems off the east coast of Australia may become more frequent." (17) These low pressure systems are generally associated with heavy rainfall events and flooding in East Gippsland. The increase in severity of winds will also mean an increase in wave heights and increasing coastal erosion. The GCBR predicted that the added water heights from storm surges would be minimal – up to 19% by 2070. (18) However when added to the sea level rise and accompanied by flooding due to heavy rains the effect will probably be substantial. All the low lying lakeside towns and villages should expect to be inundated on a regular basis until – perhaps as early as 2100 – they are permanently submerged.

Extreme Event Frequency

The use of the term 1 in 100 to describe the frequency of any unusual event is to some extent subjective. The problem of how to categorise the extreme bushfires in Victoria over the last decade is an example. In terms of either size or ferocity it can be argued that Victoria has seen three 1 in 100 year bushfire events over the last decade – in 2003, 2006/7 and 2009. (19) On the ABC Science show Catalyst CSIRO scientist Dr John Hunter of Antarctic Climate and Ecosystems noted that storm surge flooding events will increase by a factor of 3 for every 10cm rise in sea level. (20)

Climate Scientist James Hansen has worked on the probability of extreme events occurring – notably with his recent work on the relationship between temperature increases and the increasing number of heat wave events. The NASA website notes:

> On one of the six-sided dice, Hansen painted two sides blue, two sides white, and two sides red to represent the chance of a cold, average, or warm summer season, respectively. That's how the dice would have rolled from 1951 to 1980, when climate was relatively stable. On the other die – this one loaded – Hansen painted one side blue, one side white, and four sides red. That's how climate models suggested the dice would

> roll by the first decade of the 21st century, should the increase of greenhouse gases in the atmosphere play out as it ... [has].(21)

On extreme events Hansen noted:

> The question of whether these extreme hot anomalies are a result of global warming is often answered in the negative, with an alternative interpretation based on meteorological patterns. For example, an unusual atmospheric "blocking" situation resulted in a long-lived high pressure anomaly in the Moscow region in 2010, and a strong La Niña in 2011 may have contributed to the heat and drought situation in the southern United States and Mexico. However, such meteorological patterns are not new and thus as an "explanation" fail to account for the huge increase in the area covered by extreme positive temperature anomalies. Specific meteorological patterns help explain where the high pressure regions that favor high temperature and drought conditions occur in a given summer, but the unusually great temperature extremities and the large area covered by these hot anomalies is a consequence of global warming...(22)

Hansen claims that the frequency of extreme temperature events has increased by a factor of more than 10 compared with last century. This frequency probably applies to storm surges, flooding, coastal erosion and inundation as well. Thus instead of expecting these events every 100 years we can now expect them every 10 or even more frequently. It is of note that storms in Gippsland are often accompanied by floods caused by east coast and Tasman Sea lows.

Business as Usual

Worldwide it would seem that countries will proceed with ‘business as usual’ regardless of global warming. Politically both major parties appear in the thrall of big coal and are now trumpeting gas as a ‘green’ solution. The Victorian Liberal government is doing its best to discourage alternative energy - both solar and wind. And as the previous Labour government has done, it is doing its best to promote brown coal and Coal Seam Gas (CSG). It should be remembered that CSG is a fossil fuel and thus still contributes to climate change. If the energy used to extract it is also counted along with methane emissions and leakage it may be no better than coal and certainly not a ‘green’ solution. Likewise the current state government seems intent on promoting brown coal – the worst solution in terms of greenhouse gas – with new and bigger open cuts removing more water from the aquifer. One also wonders where all the water required for the fracking process for CSG will come from. Internationally all attempts at agreement so far - Kyoto, Copenhagen and now Doha - have achieved very little. With Liberal/National parties in control of most state governments and with a federal opposition, with few policies on climate and a guarantee to repeal the carbon tax, poised to gain power we can expect business as usual for the next few years. It is just possible that further financial downtowns may slow the growth of greenhouse gases in the atmosphere. On the other hand recent news on the melting permafrost – a feedback process still not included in IPCC modelling – seems to be condemning humanity to the worst case scenarios.(23)

Three Possible ‘Business as Usual’ Scenarios

1.Conservative – this combines a minimum ‘realistic’ coastal subsidence of about 20cm with a doubling of the rate of sea level rise every 30 years. This would give an estimated sea level rise of 133cm to which can be added the subsidence constant which would bring it to 153cm by 2100. The effects of this scenario are startling. By 2030 the combined effect of subsidence and sea level begins to be felt. Increasing erosion along the 90 Mile beach continually blocks the artificial entrance of the Lakes. The coastline has retreated by 30 metres and in a few places much further. By 2070 with a half metre total sea level rise the dune barrier to the Lakes has been breached in several places between Jack Smith Lake and Lakes Entrance. The coastline has retreated an average of 70 metres and with increasing severe storms the

townships of Seaspray, Golden Beach, Paradise Beach, Loch Sport, Paynesville and Lakes Entrance are regularly inundated. By 2100 all these townships are partly or completely inundated continuously and large parts of the dune barriers to the Lakes system have been washed away. The ocean has advanced on average about 150 metres and the Life Saving Clubs of Seaspray and Lakes Entrance have disappeared. The sewage system of low lying parts of Lakes Entrance fails.

Table 2
Conservative Scenario: rate of rise doubling every 30 years +minimum subsidence
Figures rounded to 1 decimal point

Date to	Rate sea level rise pa mm	Total Cm	Cum. Total Cm	Plus Subsidence Cm	Total Rise cm
2040	6.4	19.2	19.2	20	39.2
2070	12.8	38.4	56.6	20	76.6
2100	25.6	76.8	133.4	20	153.4

2. Moderate - this combines a 'minimum' coastal subsidence of about 20cm with a doubling of the rate of sea level rise every 25 years. On current evidence this seems a fair assumption. This would give a total of over 2 metre sea level rise with subsidence added totalling 2.4m. By 2030 severe erosion of coastal dunes is occurring the full length of the Gippsland coast and the average retreat of the coastline is 40 metres. This is about the same as scenario 1. By 2050 the rise is over half a metre and the dune barrier has already been breached in the vicinity of Golden Beach. Class actions begin against Esso and the brown coal miners and generators as the major contributors to and cause of the subsidence. By 2080 the rise is over 1 metre and many of the low lying parts of the coastal and lakes towns are regularly or completely inundated. Large parts of the barrier have been completely washed away including the foreshore at Lakes Entrance. By 2100 all the low lying buildings of the coastal towns are permanently inundated the ocean front having advanced 200 metres. Breakers now tumble over the Esplanade at Lakes Entrance. The famous silt jetties of Lake Victoria have almost completely gone. See Table 3

3. Catastrophic - this combines an 'average' coastal subsidence of about 30cm with a doubling of the rate of sea level rise every 20 years. This gives a rise by 2090 of just over 2.4 metres with subsidence bringing the total to 2.7m. Initially the effects of the sea level rise appear about the same or even slightly less than the moderate scenario. By 2070 the infrastructure of all the low lying towns – roads, power supplies, sewage and water - is overwhelmed. By 2090 all the dune barriers and sand barrier islands along the entire coast have disappeared. The ocean has advanced on average 200 to 250m. Storm records both for frequency and intensity keep getting broken. The Gippsland Lakes have disappeared along with every island in them as have all the islands around Corner Inlet. A reactive coastal retreat by Gippslanders - forced on them by subsidence and climate change - has begun in earnest. An exceptionally wet winter creates a lush undergrowth in the hinterland. Murray Valley encephalitis and Ross River fever reach epidemic proportions straining the health system. An early November heatwave bakes the bush dry and heatstroke causes a large number of

fatalities amongst the young and elderly. In December dry electrical storms set the bush alight from Warragul to the border. The north winds drive the fires through the whole of Gippsland to the advancing ocean. See Table 4

Table 3
Moderate Scenario: rate of rise doubling every 25 years +minimum subsidence
Figures rounded to 1 decimal point

Date to	Rate of sea level rise mm	Total Cm	Cum. Total Cm	Plus Subsidence cm	Total Rise Cm
2030	6.4	18	18	20	38
2055	12.8	32	50	20	72
2080	25.6	64	114	20	134
2100	51.2	102.4	216.4	20	236.4

Table 4
Catastrophic Scenario: rate of rise doubling every 20 years + average subsidence
Figures rounded to 1 decimal point

Date to	Rate of Seal Level Rise mm	Total Cm	Cum. Total Cm	Plus Subsidence cm	Total Rise Cm
2030	6.4	11.5	11.5	30	41
2050	12.8	25.6	37	30	67
2070	25.6	51.2	88.2	30	118.2
2090	51.2	102.4	190.6	30	220.6
2100	102.4	102.4	293	30	323

Scenario Discussion

1. In the short term subsidence rather than sea level rise may be the problem for the coast from Seaspray to Lakes Entrance.
2. The transport of eroded sediment along the coast may in the short to medium term block the artificial entrance to the Gippsland Lakes and overwhelm the dredges.
3. If above average subsidence occurs the dune barrier may be breached as early as 2030. This is most likely to occur in the approximate vicinity of Golden Beach and break through to Lake Reeve.
4. The dune barriers will succumb to the rising sea levels at any time and possibly as early as 2050. The retreat of the dunes will be variable and influenced initially by subsidence rather than the rising sea levels. Once the dune barriers have been breached it is unlikely that the Gippsland Lakes system will survive in anything remotely resembling its current form. This also applies to the Corner Inlet/Port Albert coast which is also extremely vulnerable and unlikely to survive like anything remotely resembling its current form.
5. As most of the current indicators are tracking along the worst case scenario of the IPCC 2007 predictions then it is highly likely that by 2100 the coast of Gippsland will be nothing like it is now. Most, if not all, of the barrier dunes will have disappeared and many of our coastal villages will be partially or completely inundated.
6. All but the most benign scenarios are in reality catastrophic.
7. It should be clearly understood that many other changes – mostly harmful to human beings - will be happening around the same time as a result of global warming. These include various health threats including heat stroke and the increasing prevalence of vector born diseases like Ross River fever. We should also be aware of that there will almost certainly be many unpredictable results from the warming. (24)

Political Summary

It is becoming clear that we are in a climate emergency and with "business as usual emissions" we should prepare for the 'worst-case' scenario of warming. To try to prevent this drastic action must be taken at all levels of government to both mitigate and adapt to the warming. Emergency governments will override the power of both vested interests and the status quo. Emergency governments can implement the massive transition from fossil fuel based economy to renewable energy sources by implementing a "Snowy Mountains" type program on a vast scale. The conversion to full renewable energy should be on an urgent timetable of ten years. (25) This can only be done by governments with overriding powers similar to that of the Australian federal government during World War 2.

With regards the Gippsland coast no new developments should occur within 2m of the spring high tide level. Once the rate of sea level rise is more firmly established Authorities can plan an orderly retreat from the coast.

Postscript May 2014

Sea Level rise around the earth is currently rising at a slow but steady rate on average of 3.5 mm per annum. The crucial question for sea level rise is the rate at which the increase doubles. Astonishingly teams using satellite data have discovered that the rate of increase of ice melt has doubled in the last 3 years in some parts of Antarctica. But what could upset even the worst case scenario above is a surprise or abrupt change. One distinct possibility for such an abrupt change has recently been publicised on the internet – volcanic activity under the Antarctic ice. As the ice melts the weight on top of the land surface is reduced and the land rises causing other earth deformities. A study by Newcastle University in the UK has measured as much as 5 cm pa land surface rise – far more than the study predicted – on the Antarctic Peninsula and concluded that such drastic earth movements would cause an increase in volcanic activity under the ice. One of the researchers, Professor Mark King, now at the

University of Tasmania said “It’s one of the big unknowns: If something starts to happen with one of those volcanoes, our estimates of what sea levels might be like in the future may have a significant revision” and “It’s a big ‘if’ - but if a volcano erupted from underneath the ice sheet, it would dramatically accelerate the ice melt and the flows into the oceans.”(26)

Coincidentally, and almost simultaneously, another study has discovered a seismically active volcano under the most vulnerable West Antarctic ice sheet near the dormant volcano Mt Sidley. A Mail Online article of 22 May stated:

> “Even a sub-glacial eruption would still be able to melt ice, creating huge amounts of water which could flow beneath the ice and towards the sea - hastening the flow of the overlying ice and potentially speed up the rate of ice sheet loss.
>
> 'Numerous volcanoes exist in Marie Byrd Land, a highland region of West Antarctica,' said Amanda Lough, of Washington University in St Louis in the team's paper on the subject, published in the Nature Geoscience journal.
>
> 'High heat flow through the crust in this region may influence the stability of the West Antarctic Ice Sheet.' (27)

Similar volcanic activity has been identified a number of times since 2008. The consequences for the Gippsland coast following any large eruption under the West Antarctic ice sheet will ensure sea-level rise approaches the worst case scenarios.

Notes

1. the author is a Gippsland regional historian and climate change agitator. See http://petergardner.info/ He is currently the secretary of the Global Warming Action Party Australia http://globalwarmingaction.org.au/ and has contested recent elections as a ‘Climate Change Emergency Independent’.
2. Gardner, P.D. “Is Gippsland Going Under” Mountain Echoes No. 60 originally published on the Anarchist Media Institute website http://anarchistmedia.org in July 2000.
3. Bird, E.C.F. *Coasts: an Introduction to Coastal Geomorphology*, ANU Press, Canberra 1984 p.34
4. Gippsland Coastal Board (GCBR) *Climate Change, Sea Level Rise and Coastal Subsidence along the Gippsland Coast*, July 2008
5. The bottom estimate is from the Intergovernmental Panel on Climate Change Fourth Assessment on Climate Change (IPCC) 2007 - the higher levels in Le Page, M. Global Warming New Scientist 17.11.2012
6. Pittock, A. Barrie. “Ten Reasons Why Climate Change May be More Severe than Projected” http://washingtonsummit.climate.org/abstracts/pittock_tenreasons.html
7. Le Page, M. Op.cit. The seven areas Le Page identified were as follows i) the Arctic is warming faster than predicted ii) Extreme weather is getting more extreme iii) Food production is taking a hit iv) Sea levels will rise faster than expected v) Greenhouse gas levels could keep rising even if our emissions stop vi) We’re emitting more than ever vii) Heat stress means big trouble
8. GCBR op.cit. p.15
9. Ibid p.16
10. Freij-Ayoub, R. et al. Simulation of Coastal Subsidence and Storm Wave Inundation Risk in the Gippsland Basin, CSIRO, 2007
11. *Victorian Coastal Hazards Guide*, Dept. of Sustainability & Environment, Melb. 2012 p.29

12. IPCC 2007 is a document of over 3000 pages (approximately150,000 words) with less than 15 errors(all minor except for one) so far discovered giving the document an accuracy of 99.99%. However it is a conservative document which, with its consensus approach, has tended to underestimate many of the changes caused by warming. In particular by underestimating the drastic decline in Arctic summer ice and not accounting for land ice melt in Greenland and West Antarctica the sea level rise is already 60% above their predictions. It is the feedback mechanisms in the polar regions – particularly melting permafrost – that may assist in the acceleration of sea level rise. See http://www.skepticalscience.com/rahmstorf-foster-cazenave-2012.html for latest estimates of sea level rises of 3 foot to 1m. The main criticism of the IPCC by Rahmstorf et al is that they did not include dynamic ice melting in their model. See also http://www.climatespectator.com.au/commentary/new-ice-melt-benchmark for the latest in ice melt evidence.
13. Le Page, M. Op cit.
14. United Nations Framework Convention on Climate Change. "The first and best known model relating shoreline retreat to an increase in local sea level is that proposed by Per Bruun (1962). The IPCC reports that 1 cm rise in sea level erodes beaches about 1 m horizontally. This becomes a large issue for developed beaches that are less than 5 m from the ocean (IPCC, 1998).The Bruun rule states that a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth. The Bruun rule can be applied to correlate sea-level rise with eroding beaches. The Bruun rule estimates the response of the shoreline profile to sea-level rise. (SCOR, 1991)." http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5315.php
15. GCBR op.cit. p.78. In all probability the parameters of Sjerp's model were set by the GCB.
16. Ibid p.36
17. Ibid p.67
18. Ibid p.57
19. an oral account from a reliable source has a Tasmanian ecologist categorising the 2003 fires as a 1:1000 year event. This is unconfirmed.
20. http://www.acecrc.org.au/Our%20People/Researchers/Dr%20John%20Hunter
21. http://blogs.nasa.gov/cm/blog/whatonearth/posts/post_1344022702866.html
22. http://www.giss.nasa.gov/research/briefs/hansen_17/
23. Le Page, M. Op.Cit.
24. Mike Tidwell *The Ravaging Tide: strange weather, future weather and the coming death of America's coastal cities* (Free Press NY 2006) Tidwell predicted the damage to New York caused by Hurricane Sandy (pp.102-5) He also called unexpected results of warming his Law of Unintended Consequences.
25. Such a program has already been mapped out by Beyond Zero Emissions http://beyondzeroemissions.org/
26. Article by Peter Hannam at http://www.theage.com.au/environment/fire-and-ice-melting-antarctic-poses-risk-of-volcanic-activity-study-shows-20140520-zrj06.html
27. http://www.dailymail.co.uk/news/article-2625583/Newly-discovered-active-volcano-erupt-underneath-ice-Antarctica-add-effects-global-warming-say-scientists.html

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