Glaciers—Science and Nonsense

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In these days of warnings about climate change, the ice sheets of Greenland and Antarctica play an important role. Alan Carlin wrote "Hansen et al. believe that the most likely and most critical of these dangerous effects is the possibility of substantial sea level rise due to the breakup of parts or all of the ice sheets covering Greenland and West Antarctica." (my emphasis).

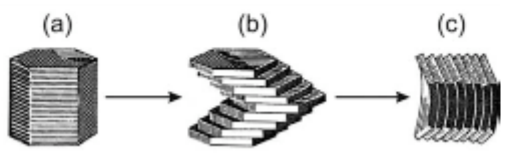
Alarm started with 'global warming' but since the Earth failed to warm in the past 10 years it changed to 'climate change" and most recently to "carbon pollution." But the most graphic scare is still of rising sea levels, so many articles continue appear describing sea level rise of many metres caused by the melting of the icesheets.

Like the original warming scares, the melting scares are based on models, and poor models at that. The commonest one is the notion that glaciers slide downhill, lubricated by meltwater, and that this can pass a threshold and lead to melting of all the icesheets and a runaway rise in sea level. The sliding hypothesis was the best available to De Saussure (1779), but we have learned a lot since then – but it has been forgotten again in many modern models.

The mechanism of glacier flow was long controversial, as observers tried to reconcile the solidness of ice with its ability to flow as a non-rigid body. Early experimenters placed lines of sticks across glaciers and found the middle moved faster than the edges – there was plasticity in the ice. Fierce controversies raged and brought in occasional new aspects of physics (such as regelation), but it was not until the crystallography of ice could be studied that real progress was made. The crystals in a glacier take on a preferred orientation as they travel down glacier. The crystals of ice at the glacier terminus may be a thousand times bigger than those at the source. How can this be? Scientist in the 1940s such as Max Perutz (a Nobel Prize winner in Physics, not Peace!) explained glaciers as being like a metamorphic rock consisting of one mineral, which flowed by a process called creep (and incidentally developed petrofabric properties not explained in other models).

It is also worth noting the geometry and age of the great icecaps. The Greenland, East Antarctica and West Antarctica ice sheets occupy kilometre-deep basins, and the ice cannot possibly slide downhill – it has to flow uphill. In simple numbers the Greenland icecap has existed for three million years and the Antarctic Ice sheets 30 million. Why such contrast between the two hemispheres? The idea that both simply respond to average temperatures of today is oversimplified.

Glacier budget



Glaciers grow, flow and melt continuously, with a budget of gains and losses. Snow falls on high ground. It compacts with time, air is extruded, and it turns into solid ice. More precipitation of snow forms another layer on the top, which goes through the same process, so the ice grows thicker by the addition of new layers at the surface. This stratified ice preserves data on temperature and carbon dioxide over hundreds of thousands of years. When the ice is thick enough it starts to flow under the force of gravity, and when it reaches a lower altitude or latitude where temperature is higher it starts to melt and evaporate (ablate).

If growth and melting balance, the glacier appears to be ‘stationary’. If precipitation exceeds melting the glacier advances: if melting exceeds precipitation the glacier recedes, but there will be a time lag between cause and effect.

In ice sheets it may take many thousands of years for ice to flow from the accumulation area to the melting area. The balance between movement and melting therefore does not relate to today’s climate, but to the climate thousands of years ago.

How glaciers move

Glacier flow is by a process called creep, essentially the movement of molecules from one crystal to another. Ice crystals are in the hexagonal system with glide planes parallel to the base. In lake ice, the c-axes are vertical and the glide planes all parallel to the lake surface, so a push parallel to the glide planes deforms the ice readily. Greater stress is needed to deform ice perpendicularly to these glide planes. In the absence of any stress, an individual grain of ice will lose as many molecules as it gains, and so remain unchanged. A stressed crystal will lose more molecules than it gains and so shrink, while a nearby unstressed grain will gain more than it loses, and grow. In this way glacier ice acquires a preferred petrofabric orientation. The ice crystals at a glacier snout have a volume about a thousand times greater than that of the first-formed ice crystals at the source of the glacier. These observations cannot be explained by mechanisms that ignore the creep mechanism of glacier flow.

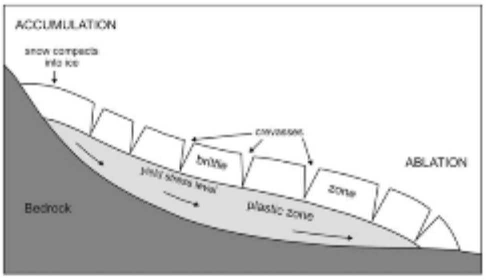
Creep—proportional to temperature

The closer the temperature comes to melting point, the greater the creep rate. In experiments at a fixed stress it was found that the creep rate at -1oC is 1000 times greater than at -20oC. In valley glaciers the ice is almost everywhere at the prevailing melting point of ice, because the latent heat of ice is very much greater than its specific heat. Very little heat is required to raise the temperature of an ice block from -1oC to 0oC - it takes 80 times as much heat to turn the same ice block at 0oC into water at 0oC. Because the temperature does not vary in valley glaciers, they are unaffected by this first law of creep.

Ice caps are very different. They are cooled at the surface to temperatures far below freezing point, which removes their capacity to flow. Ice caps can be kilometres thick, and their warmest part is actually the base, where the ice is warmed by geothermal heat, and where flow is concentrated. It is because only the lower part of ice sheets can flow that the great thicknesses of stratified ice found in ice cores can accumulate in the upper part.

At Vostok, Antarctica, during the month of July 1987 the surface temperature never rose above -72.2o C. At these temperatures ice cannot flow under the pressures that prevail near surface. Warming has no effect at such low temperatures because ice will not flow any faster at -60oC than at -70o C.

Creep—proportional to stress



Stress in this context is proportional to the weight of overlying ice. The greater the weight, the faster the flow. This explains why the stratified ice revealed in ice cores can only persist to a certain depth. When the weight of the overlying pile reaches a threshold, the ice starts to flow and the stratification is destroyed. In the Vostok cores the undisturbed ice continued to a depth of 3310 m when yield stress was reached and the ice flowed.

The threshold boundary between non-flowing ice and flowing ice marks the yield stress level. The brittle upper ice in an alpine glacier is a solid being carried along on plastic ice beneath. A valley glacier flows faster in the middle than at the edges, and the solid, brittle ice is broken up by a series of cracks called crevasses. The base of crevasses marks the position of the yield stress and the transition from brittle to plastic ice. In Antarctic and Greenland ice sheets crevasses occur where the ice is flowing towards the edge, but not in the areas of accumulation.

Meltwater can only penetrate through the ice if crevasses reach the base. If the yield stress level is reached before bedrock, meltwater cannot reach the base. All those theories based on ice sliding on a lubricated base have very limited application.

There is no surface melting of icecaps

The stratified ice is of great age. In Greenland, several ice-cores have more than 3km of undisturbed ice which go back in time for over 105,000 years - far less than the Antarctic equivalent. The Vostok cores in Antarctica provide data for the past 414,000 years before the ice starts to deform by flow. Dome F core reached 3035 m and Dome C core 3309 m, both dating back to 720,000 years. The EPICA core in Antarctica goes back to 760,000 years, and retains complete records of deposition, although temperatures at times during that period have been higher than today. They do not fit a model of surface melting, either now or in the past. After three quarters of a million years of documented continuous accumulation, how can we believe that right now the world's ice sheets are “collapsing”?

Glacial surges

Climate alarmists note some glaciers that have increased in speed, and attribute it directly to climate warming. It is much better explained, however, by known laws of creep. The speed of valley glaciers is rather variable. Sometimes a valley glacier will flow several times faster than it did earlier. Suppose we had a long period of heavy precipitation. This would cause a thickening of the ice, and more rapid glacial flow. The pulse of more rapid flow would eventually pass down the valley. The increase in flow rate is not related to present day air temperature, but to increased precipitation long ago. Hubbard Glacier surged in 1986, at the height of the global warming that took place between 1975 and 1998.

Pulling glaciers to the sea

A number of papers give the impression that melting of glacial ice at the sea somehow causes the glacier to flow faster. Hubbard Glacier is the largest tidewater glacier on the North American continent. Since it was first mapped in 1895 it has been thickening and advancing (at a rate of 25m per year), even though smaller glaciers in the vicinity have been retreating. Why?

One 'explanation' (USGS 2007) says: "This atypical behaviour is an important example of a calving glacier cycle in which glacier advance and retreat is controlled more by the mechanics of terminus calving than by climate fluctuations." But glaciers are pushed by the weight of the glacier, not sucked by the calving at the ice front, and destruction at the ice front does not depend on present day climate. And why should calving cause an advance?

The cause of the advance is most likely that the glacier has been thickening since 1895, a feature described since the first observations were made.

Related false notions

The breakup of ice sheets

Wherever ice sheets or glaciers reach the sea, the ice floats and eventually breaks off to form icebergs. It is part of the glacial budget: the glaciers never flowed on to the equator. Icebergs have always been with us, and Captain Cook saw icebergs on his search for the great south land.

Yet we are shown many movies of ice sheets collapsing, and are told it is a sign of global warming. In fact although the break-up of ice sheets is simply part of the glacier budget, observers seem surprised by the size and suddenness of what they see. In 2007, when a piece of the Greenland ice shelf broke away, interviewed scientists said they were surprised at how suddenly it happened. How else but suddenly would a piece of ice shelf break off? The actual break is inevitably a sudden event – but one that can easily be built into a global warming horror scenario. The point to remember is that the release of icebergs at the edge of an ice cap does not in any way reflect present-day temperature.

The Hubbard Glacier in Alaska has long been a favourite place for tourists to witness the collapse of an ice front 10km long and 27m high, sometimes producing icebergs the size of ten-storey buildings. One tourist wrote "Hubbard Glacier is very active and we didn't have long to wait for it to calve." Yet the Hubbard Glacier is advancing at 25 metres per year!

It is easy to raise alarms over a large break. In 2009 Peter Garrett [Australian Minister for the Environment] claimed the break-up of the Wilkins ice shelf in West Antarctica "indicated sea level rises of six metres were possible by the end of the century, and that ice was melting across the continent". Actually, when floating ice melts there is no change in sea level (by Archimedes' Principle).

Ice sheet "collapse"

Claims that ice sheets 'collapse' are based on false concepts. Glaciers do not slide on their bellies, lubricated by meltwater. Ice sheets do not melt from the surface down – they melt only at the edges. Once the edges are lost, further loss depends on the rate of flow of the ice. The rate of flow of ice does not depend on the present climate, but on the amount of ice already accumulated, and the ice sheet will keep flowing for a very long time. The ice cores show that the stratified ice has accumulated over half a million years and has not been deformed, remelted or 'collapsed'. Variations in melting around the edges of ice sheets are no indication that they are collapsing, but reflect past rates of snow and ice accumulation in their interior. Indeed 'collapse' is impossible.

The modern scene

All this suggests that the present climate has limited effect on melting ice and rising sea levels, but since the Alarmists keep up their horror stories it is good to know that even the present times are not all bad. A recent paper is entitled "A doubling in snow accumulation in the western Antarctic Peninsula since 1850 (Thomas et al. 2008). Another reports that "The East Antarctic ice-sheet north of 81.6oS increased in mass by 45 ± 7 billion metric tonnes per year from 1992 to 2003 … enough to slow sea-level rise by 0.12 ±0.002 millimetres per year" Davis et al. 2005. Wingham et al. (2006) wrote: "We show that 72% of the Antarctic ice sheet is gaining 27 ± 29 Gt yr-1, a sink of ocean mass sufficient to lower global sea levels by 0.08 mm yr-1."

References and further reading

Christoffersen and Hambrey (2006) published a typical alarmist paper on the Greenland ice sheet, and their predictions are based on the concept of an ice sheet sliding down an inclined plane, on a base lubricated by meltwater, which is itself increasing because of global warming. The same misconception is present in textbooks such as Wilson et al. (2000), popular magazines like National Geographic (2007) and scientific articles such as Bamber et al. (2007), which is a typical modelling contribution. Alley et al. (2008) wrote a paper optimistically entitled Understanding Glacier Flow in Changing Times which is all about the role of meltwater reaching the base of the Greenland Glacier and speeding up ice flow, and also delivering heat to the glacier bed. If you can find it, the early article by Perutz is brilliant.

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