Arctic Methane Emergency Group (AMEG) Presentation given by Chairman, John Nissen at the "Davos Atmosphere and Cryosphere Assembly DACA-13", July 12, 2013

"Countering strong positive feedbacks in the Arctic to avoid catastrophic climate change"

1. Intervention is sensible

This conference has underlined the extent of mankind's inadvertent interference with the Earth System, besides CO_2, both to produce positive forcing (i.e. heating) and negative forcing (i.e. cooling) in different places and at different times. The degree of cooling is shown by the fact that global surface temperature has not changed very much since 1998. But there are natural factors at play. Here, the negative forcing has been mainly provided by a combination of SO_2 from volcanoes, and SO_2 from industrial emissions. There is also a suggestion that aircraft contrails could be having a quantitatively similar cooling effect.

This gives hope that with deliberate interference, we can produce the necessary countermeasures by a combination of deliberate cooling, enhancement of natural cooling, and reduction of both manmade and natural forcing/warming agents. This has to be done carefully, with each ingredient produced in the right quantity, right place and right time to produce the required overall effect: ultimately to restore the Earth System to a state where it can maintain a temperature and climate condusive to agriculture and aquaculture, and allow our civilisation to flourish.

2. Breaking the vicious cycle

In the Arctic, a vicious cycle of warming and melting may have started in the 80s when the masking effect of SO_2 was reduced, producing a net warming of currents flowing from Atlantic and Pacific into the Arctic. This reduction was sufficient to start the cycle, but very soon the cycle became self-sustaining, such that we are now at a point that any reduction of greenhouse gases would have negligible effect on the rapid decline in sea ice. We have to find a way of introducing sufficient cooling power into the Arctic to break the cycle.

Looking at the albedo calculation, Hudson has 0.1 W/m2 in 2007, mounting to 0.3 W/m2 when sea ice goes at the end of summer, mounting to 0.7 W/m2 when sea ice is gone throughout the year. He says there is 90% cloud cover in summer - so I wonder whether the cloud LWR positive forcing effect is countering its SWR negative forcing effect.

Some of the extra heat each year is going into melting ice, but much is going into warming the Arctic Ocean water - to a considerable depth, because of the churning/mixing action of storms. Only a small amount of net heat is being carried away from the Arctic by atmospheric heat transport, though ultimately there will be a global warming effect. The heat added to the Arctic Ocean accumulates during the summer, producing further melting and a greater quantity of heat being added the next summer. If the sums are right, we should see an exponential trend in sea ice volume decline - and we do. There has been no other explanation for the observed exponential decline, that I know of.

The reduction in snow cover, most marked in June, has produced about as much extra heat per year from the albedo flip effect. Some of this extra heat goes into the ground and melting permafrost, but much goes straight into the atmosphere, contributing to the general warming of the Arctic. Thus there is a loose coupling between the vicious cycle of warming and retreat of sea ice with the cycle of warming and retreat of snow cover.

Peter Wadhams calculated that the warming effect by 2012 was roughly equivalent to forcing of 50 ppm of CO_2 or around 0.8 W/m2. It was as if 50 years of anthropogenic CO_2 emissions had been added to the atmosphere. As the sea ice retreats, it is equivalent to adding even more CO_2. By the time the sea ice is gone at end summer, and snow has retreated similarly, the heating will be equivalent to 100 years of CO_2 emissions. Cooling the Arctic should deserve a lot of carbon credit!

The work by Stephen Hudson (AGU, 2011) suggests that Wadham's calculation is on the pessimistic side, especially because of a high percentage of cloud cover in high summer, at the peak of the insolation. But Hudson calculation only takes account of sea ice albedo loss. If you double up on his end-summer-ice-free case of 0.3 W/m2, you get 0.6 W/m2.

Suppose we consider the loss of 2% of planet's area or 10 million square kilometres of sea ice reflecting power, at it is replaced by sea. The albedo change is from fresh snow 0.85 to open water 0.10, or 0.75. The peak insolation is 400 W/m2, averaged over the year gives approximately one third. If cloud cover halves this, we get a forcing of 0.75 * 400 / 3 /2 = 50 W/m2. Averaged over the planet, it is 1 W/m2. This could be doubled by including the snow retreat - giving 2 W/m2 globally, which, when multiplied by the area of the planet, gives you one petawatt. Thus we are now talking of requiring up to a total of 1 petawatt cooling power to be directed into the Arctic to start getting the snow and sea ice back, if most of it is allowed to go. The critical factor is the cloud cover. If we can make the clouds last longer or make them more reflective in the summer, we can have a big effect on snow and sea ice albedo loss. Thus cloud brightening and preservation techniques can have an important role in the Arctic.

On the other hand, if we can reduce them in late autumn and winter, we can allow more outgoing thermal radiation - long wave radiation (LWR). So we could consider cloud seeding techniques with most of the snow falling into the sea. However, if much snow falls on sea ice, it could have an undesirable insulation effect, such as to dampen the freezing of water on the underside of the floating ice. The best time for a lot of snow is at the end of winter and early spring, so that the cold is locked in by the snow's insulating effect, and albedo is enhanced as the sun rises in the sky.

Arctic air temperature, which has to be below freezing for forming sea ice, is much dependent on the cooling by convection from the planet surface. As the Arctic Ocean becomes sea ice free, the air temperature will rise above freezing, drawing in cold air from the continents. So it is critical that, at end summer, the continental land surface can cool quickly. It will be important also to prevent a churning of the ocean water and keep the surface water relatively fresh and conducive to freezing. Physical methods can be deployed to produce or encourage the formation of thick ice, mimicking the tough-to-melt multi-year ice, which has all but disappeared in the Arctic. Ice can be piled up or it can be thickened by spraying water on the surface. In the late winter or early spring, the thicker ice can be insulated by spraying snow or seeding clouds to produce snow.

There are physical methods which can also be used for strengthening the ice and preventing it breaking up in the spring. The melt rate increases dramatically once the sea ice is less than half a metre thick and subjected to breaking up from wave action, followed by wind dispersion. Much ice disappears each year through the Fram Strait and quickly melts away.

One technique which can be considered is to add wood chippings or similar material to ice to form what is known as pykrete - from its inventor Pyke and its concrete-like properties. For example, a long curved floating barrage of pykrete could be used to prevent flow of broken ice between islands. Pykrete could also be used to dampen wave action and allow sea ice formation more readily in the autumn and early winter. There could be many other applications.

3. Dealing with the methane

We have to consider methane from the Arctic seabed, escaping from hydrate (or 'clathrate') deposits or from bubbles in sediment, or from permafrost decomposition, or from free methane beneath the heavily perforated permafrost. It seems that there is a non-linear increase in methane to such a point that a general cooling of the seabed is required. We may require more specific measures than a general cooling of the Arctic to prevent an escalation of methane emissions. There is a danger that these emissions could reach a point when they cause some kind of thermal feedback to produce more methane. There is also a danger of instability in the structures holding the methane, which could become destabilised, e.g. by submarine slump or earthquake. There is over a thousand gigatonnes of methane trapped under the ocean, for release if the permafrost thaws. Some researchers are concerned that a pulse of 5 gigatonnes of methane, suddenly or over a few years, would double the atmospheric burden of methane, resulting in triggering methane feedback and even thermal runaway - the so-called clathrate gun effect, which may have caused previous extinction events in the Earth's history.

We also have to consider methane from terrestrial permafrost, which contains enough carbon for tripling the carbon content of the atmosphere. Some of the permafrost carbon will be vegetation decaying to produce CO2. However much is under water, in thermokast lakes and ponds, such that it decomposes to produce methane, seen bubbling up and getting trapped under the ice in winter. Fortunately there are good biological approaches to suppressing methane in these conditions, especially using diatoms. Diatoms photosynthesise, absorbing carbon dioxide and producing oxygen. They are foodstuff for the methanothrophs - methane digesting organisms. The water is purified and a food chain can be started, e.g. to allow fish farming.

4. Food security

There is mounting evidence that the warming of the Arctic relative to the tropics is resulting in a weakening of the jet stream, causing it to meander and get stuck in so-called blocking patterns. This is resulting in an increase in climate extremes, a reduction of food productivity, an increase in the food price index and an increase in unrest, especially when already a billion people are at near-starvation level. This has implications on food security for even the richest nations. Farmers rely on reasonably predictable weather, and this predictability is vanishing because the jet stream gets stuck in different places at unpredictable times. The warming of the Arctic is non-linear, currently at over a degree per decade - a rate which could double within a few years. This non-linearity is reflected in the global food price index, which has sharply increased since 2007, and is now at the crisis level of 210. Last year a prediction was made by Complex Systems Institute that there would be riots this year, because of the trend in this index towards the crisis level. They were right!

5. Conclusion

Thus there is a great deal that can be done. We are facing a precipitous decline in sea ice, which is having non-linear repercussions. Only by reacting very quickly do we have a good chance to break the sea ice cycle and prevent irreversible consequences.

What we need is for the international community, especially of nations around the Arctic, to recognise this situation as an opportunity for collaboration on behalf of all nations, to cool the Arctic, save the sea ice and suppress methane. There can be direct local benefits, especially in methane suppression, to smooth the political way forward.