WITH CRACKS AND HOLES IN THE GREENLAND ICE SHEET, WE MAY WELL HAVE TO "GEO-ENGINEER" THE CLIMATE

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Next week, policy-makers, scientists and activists from around the world will gather in Bali, Indonesia, to try to produce a climate-change agreement that will take us beyond the 2012 expiration of the Kyoto Accord. This meeting will take place in an atmosphere of sharply heightened unease among leading climate scientists.

A few years ago, these scientists regarded global warming as a matter of serious concern; now many appear to think that it's a matter of grave urgency – that we may be running out of time. The recent Intergovernmental Panel on Climate Change (IPCC) reports are increasingly viewed as out of date.

Because the IPCC reports incorporate only scientific findings published up to about mid-2005, they don't reflect almost two years of extraordinarily important results from multiple streams of research. Immediately after the Working Group 1 report was released (last February), many scientists said it significantly underestimated sea-level rise this century. Since then, we've seen sharply higher global carbon dioxide emissions than the IPCC expected (2006 emissions were almost half a billion tonnes above the worst-case IPCC prediction), while the absorptive capacity of ocean and land-based carbon sinks appears to be decreasing more rapidly than predicted.

Two issues particularly exercise climate scientists: positive feedbacks and ice-sheet dynamics.

A positive feedback is a causal cycle – essentially a vicious circle – in which warming causes a series of changes that reinforces warming. One feedback of special importance to Canada is the ice-albedo feedback in the Arctic. The sea ice floating on the Arctic Ocean is white, so it reflects a large proportion of the sun's radiation back into space. As this ice melts from global warming, it leaves behind open water that absorbs about 80 per cent more of the sun's radiation. This ocean water becomes warmer. Then, after the summer passes and fall comes, the water releases its heat back into the atmosphere, which impedes refreezing. So winter generates thinner ice, which melts more easily the next summer.

This feedback is one of the reasons why the planet is warming, and will continue to do so, much more rapidly in its northern reaches. The IPCC predicts about 3°C average warming by 2100, and in the neighbourhood of 6°C to 7°C across much of Canada. Some people say we will benefit. Well, we may have lower heating bills in the winter for a few years, but because we're a northern country, warming here will be about twice as fast and the ultimate magnitude will be twice as great as the planet's average. The consequences will be immense for our flora and fauna, for our forests that can't adapt and die en masse, for our grain-growing regions that could turn to desert, for the Great Lakes as their levels fall, for transportation in the St. Lawrence Seaway and for northern permafrost that melts.

This summer, melting of Arctic sea ice sharply diverged from the trend of the past decade – which suggests feedbacks in the north are gaining enormous force. By mid-September, we'd lost about a third of the Arctic ice cap compared to the 1979-2000 average and about 50 per cent compared to the 1950s. Scientists now expect a completely ice-free Arctic Ocean in summer by the end of the next decade, perhaps as early as 2013.

The ice-albedo feedback is an example of one of two main kinds of positive feedback: the kind that operates more or less directly on energy flows and temperature. Feedbacks of this kind are reasonably well built into current climate models. But there's another kind that operates on the carbon cycle. In these cases, warming produces a change in the amount of carbon in the atmosphere. Carbon cycle feedbacks are not so well understood, but it's becoming increasingly clear that they could literally be deal-breakers for humanity. We may be quite close to creating circumstances in which the biosphere releases huge quantities of carbon into the atmosphere. At that point, warming could become its own cause; it would no longer really matter what we do to mitigate our emissions of carbon dioxide. The global ecosystem would take over.

One worrying carbon feedback involves the permafrost in Siberia, Alaska and northern Canada. As the permafrost melts, it emits large quantities of methane, a very powerful greenhouse gas that, in turn, causes

more warming. And then there's the matter of pine bark beetles. As the climate warms, they reproduce through two generations during the summer, and their mortality is lower during the winter. Both these changes mean that beetle populations become much larger overall. We've already lost swaths of pine forest in British Columbia and Alaska to bark-beetle infestation. If they cross the Rockies into the boreal forest that stretches from Alberta to Newfoundland, and kill much of it, the forest will be susceptible to fire that could release astounding quantities of carbon dioxide. When I asked Stephen Schneider, a leading climate scientist at Stanford, about the implications, he just shrugged and said, "Well, we're talking about billions of tonnes of carbon."

Our climate has many positive and negative feedbacks. The positive ones are self-reinforcing, while the negative ones counteract the warming tendency. The big question for climate scientists then is: What is the balance is between the positive and negative feedbacks? A consensus appears to have emerged over the last two years – not yet reflected in the recent IPCC reports – that the positive feedbacks are much stronger and more numerous than the negative ones.

The second issue that particularly concerns climate scientists is ice-sheet dynamics. The Greenland ice sheet is the second largest mass of ice in the world, after Antarctica's. If we melt Greenland entirely, the sea level rises by seven metres. The recent IPCC estimate of sea-level rise by 2100 was only 20 to 60 centimetres, because the report assumed Greenland's melting would take many centuries. In the last two years, though, two studies using very different methods have suggested that the ice sheet is now melting much faster than expected – at a rate of 200 to 250 cubic kilometres a year. According to the most recent study, which used satellite measurements of Earth's gravity to estimate changes in Greenland's mass of ice, that rate has doubled in the past 10 years.

Climate scientists now recognize that the ice-sheet melting models in the IPCC reports were radically inadequate. These models were "static"; they assumed that atmospheric warming melts the ice, and the resulting water then runs off the surface of the ice sheet into the ocean. Scientists now know that these ice sheets have cracks in them. In the summer, melt water runs down the cracks, and as these expand into wide gaps, millions more tonnes flow downwards. This water takes heat to the bottom of the ice sheets and also lubricates the movement of glaciers into the ocean.

Commenting on the Ilulissat glacier in northwest Greenland just a few weeks ago, Robert Corell, chairman of the Arctic Climate Impact Assessment, said, "We have seen a massive acceleration of the speed with which these glaciers are moving into the sea. The ice is moving at two metres an hour on a front five kilometres long and 1,500 metres deep." He had flown over the glacier and seen "gigantic holes in it through which swirling masses of melt water were falling. I first looked at this glacier in the 1960s and there were no holes. These so-called moulins, 10 to 15 metres across, have opened up all over the place. There are hundreds of them."

The consensus now emerging is that oceans will rise by a metre this century and perhaps even two. A two-metre rise would have enormous effects on coastal areas of Canada – on places where people live in Victoria and Vancouver (especially on Delta and Richmond in the Lower Mainland) and on the ports of Vancouver, St John's and Halifax. With such a rise, concerns about rebuilding infrastructure and moving people inland will – in a few decades – become real, even urgent.

In light of these two trends, climate scientists are now beginning to discuss a topic that only two years ago many fervently hoped they'd never have to discuss: geoengineering, or the intentional human modification of the planet's climate to arrest or slow global warming. Geoengineering would involve, for example, putting sulphate aerosols into the atmosphere or putting mirrors into space to try to block a fraction of incoming solar radiation.

Today the topic is at the margins of the public-policy dialogue about climate change, but I expect it will be at the centre of public discussion within five years. In 10 years, we will see demands from some segments of the public and many opinion leaders that we carry out geoengineering. And we'll probably start doing it within 20 years, likely when it becomes apparent that the Greenland ice sheet is starting to collapse.

We will do it, because by then we'll be experiencing major socio-economic impacts of climate change – for instance, shortfalls in global food supply, as droughts and heat waves affect grain-growing regions. At that point, we will wonder about what kind of world we've created for our children and grandchildren. We'll recognize that we're facing an emergency unlike anything humankind has ever faced before, and we will demand that our leaders and experts do something, anything, to stop the slide.