Extreme Winter Weather and Global Warming

One frequently hears, these days, expressions of global warming skepticism based on recent instances of extreme winter weather at various locations around the world. These expressions are based on a lack of understanding of the nature of global warming. Individual, local weather events are sufficiently complex and sensitive, as regards their causal analysis, as to make it impossible to relate any one of them to long term global trends. On the other hand, the average frequency and severity of extreme weather events *of all kinds* throughout the globe *can* be related to long term global trends and, in the case of global warming, are expected to and have been observed to be increasing. In the last decade or so we have seen record breaking rainfall, record breaking snowfalls and low temperatures, record breaking heat waves and droughts, record breaking ocean storms and at increased frequencies at various locations and various times. All of that is to be expected from global warming! That increased frequency and severity of weather events *of all kinds at various locations and times* will continue and will continue to worsen so long as global warming continues. The reasons, very broadly, are as follows.

Complex dynamical systems

The global climate system is what is called a *complex dynamical system*. That's not just a descriptive phrase, but a technical term which refers to the fact that the system is characterized by many interconnected parameters, or measurable quantities, with extremely complicated interactions which determine the evolution of the system. Serious, detailed study of such systems has been ongoing for some decades now, but we still understand far less about such systems than is desirable. There are, however, some general features of such systems that we do understand.

Among the parameters that characterize the state of the system, there are some that dominate the governing of the behavior of the rest of the parameters. Such parameters are called forcing parameters. The forcing parameters of greatest concern for the global climate system at present are the rate of energy interception from the Sun, the atmospheric concentrations of so-called greenhouse gases and the reflectivity of the Earth's atmosphere and surface. They dominate the determination of the Earth's response to the energy Earth receives from the Sun.

When the forcing parameters of a complex dynamical system are stable, or stably cyclical, the system settles into a pattern of behavior characterized by 'modest' or normal oscillations of the rest of the parameters around more or less constant average values. The frequencies and amplitudes represented in these oscillations will be quite varied but they will tend to lie within stable limits. In the case of the global climate system these oscillations would comprise what we would call normal weather with occasional extreme events.

But when the forcing parameters of a complex dynamical system change, and especially if they persist in changing in a long term drift, then the system responds by, first, stretching the previously stable limits of the 'normal' oscillations and then breaking free of recognizable limits while the averages about which the oscillations occur acquire a corresponding drifting behavior of their own. In effect, if an anthropomorphic metaphor may be permitted, the complex dynamical system responds as if it were 'hunting' for a new stable regime into which it could settle and resume a form of 'normal, modest' oscillatory behavior about stable averages. But, of course, so long as the forcing parameters continue their drift no such stable regime can be located and the 'hunting' continues with increasingly severe oscillations.

The global climate system

In the case of the global climate system the single most important forcing parameter is the rate of energy intercepted from the Sun. This displays oscillatory cycles of its own which are wholly independent of anything that happens on Earth. But the parameters of greenhouse gas concentrations in the atmosphere and atmospheric and surface reflectivity determine how much of the intercepted solar energy is retained. The solar energy is received in relatively high frequency form. In that form much of it is reflected back into space either by the atmosphere or by the Earth's surface. The rest is absorbed by plant life, the land surface and the oceans. Much of what is absorbed is later re-emitted in relatively low frequency form, so-called infra-red heat radiation. In that form the molecules of certain gasses (the greenhouse gasses) in the atmosphere can absorb the radiation on its way out and re-emit much of it back to Earth, thereby trapping the energy within Earth's system. A certain amount of this trapping effect is very desirable to maintain stable and tolerable global temperature averages and climate for the biosphere as presently constituted. But for quite some time now an upwards drift in the global concentrations of certain greenhouse gasses, predominantly carbon dioxide, has taken place, starting slowly after the beginning of the industrial revolution and increasing steadily at an accelerating rate. This is trapping increasing heat radiation to slowly raise the global average temperature of the Earth's oceans. The significance of this stems not so much from the temperature increase per se, which is small, only a few degrees, but from its implications for the enormous quantities of thermal energy increase in the water of the oceans and the water vapor of the atmosphere. It is this increased energy content that fuels extreme weather events, regardless of whether the events themselves are wet or dry, hot or cold. The small change in global average temperature of the oceans corresponds to enormous changes in thermal energy content because the oceans contain so much water and because it takes more energy to raise the temperature of a given mass of water by one degree than for almost all other substances of the same mass.

Furthermore, as the oceans warm, on average and even though the temperature change is small, this does, by evaporation, warm the atmosphere, on global average and by small amounts. This, in turn, results in increased rates of melting of the Earth's large deposits of ice and snow. Glacial systems recede, polar ice caps dwindle, and the replacement of ice and snow covered surface by liquid water and land decreases reflectivity, further increasing the absorption and retention of solar energy. Furthermore, permafrost, in Alaska, Canada, Siberia and elsewhere, has started to thaw. This has begun to release the enormous quantities of methane gas trapped in the permafrost for thousands of years from organic decay. But methane is a much more potent greenhouse gas than carbon dioxide. Far more methane is contained in the ocean floors than in the world's permafrost layers and there is evidence that ocean warming is already increasing the release of these methane deposits. These secondary effects of the initial and continuing increases of atmospheric greenhouse gasses provide positive feedback loops which will greatly aggravate the processes of generating extreme weather events of increasing severity and frequency.

Climate after global warming stops?

Lets assume that we're not so stupid, as a species, to never get our rates of greenhouse gas generation under control. So stupid, that is, as to trigger a true *runaway* greenhouse effect which could annihilate all life on Earth and turn our planet into a duplicate of the planet Venus where, although it absorbs only about 14% more solar energy than Earth, lead melts on the surface. Let's also optimistically assume, that if we do get greenhouse gas generation under control, then, with luck, global warming will stop not too long after the end of this century. The oceans will, on average, be several degrees warmer than now. Sea level will be quite a few feet higher than now and roughly a billion people will have relocated inland (what fun!). 'Normal' weather will be returning but with norms for 'normal' that far exceed our current norms (the climate will still have all that extra thermal energy to play with). It will then still be quite likely that some places on Earth will be subject to *colder* climates, possibly *much* colder than they enjoyed before our present global warming adventure!

A likely candidate is the British Isles and Northern France which have enjoyed balmy weather for quite a long time. This is primarily due to the Atlantic Ocean current, known as the Gulf Stream and North Atlantic Drift, which transports thermal energy from the Gulf of Mexico to the Northeast Atlantic and, by evaporation into the prevailing westerlies, Midwestern Europe. When warm, it flows along the surface from the Southwest to the Northeast Atlantic, and then, cooled, sinks to return Southwest at depth. But this closed loop river within the ocean can be stopped! Its existence depends critically on the buoyancy of the salty ocean compared to the less saline waters of the Gulf Stream. Sufficient desalination of the Arctic and North Atlantic oceans by fresh water deposition from ice cap and glacial melt water can snuff the Gulf Stream in its tracks. Oceanographic and bio-geological evidence suggest it has happened before, and, quite possibly, very quickly when the right conditions prevail. Should it happen again, London and Paris could acquire a climate more like Moscow!

So global warming *does not* mean that all locations on Earth at all times get steadily warmer. What it *does* mean is that the long term global scale *average* temperatures will slowly drift upwards while the fluctuations in temperature, pressure, humidity, wind speed, precipitation and electrical activity that constitute weather will continue erratically oscillating around their more local averages with increasing severity and frequency. The increasing severity of both *winter* and summer weather in many locales is to be *expected* as a consequence of global warming.