Design and Purpose in Climate Change.

John G Lockwood

Climate distribution across the Earth's surface, and climate changes within that distribution, are controlled by the so-called climate system. The climate system is a composite system consisting of five major interactive adjoint components: the atmosphere, the hydrosphere, including the oceans, the cryosphere, the lithosphere, and the biosphere. All the subsystems are open and non-isolated, as the atmosphere, hydrosphere, cryosphere and biosphere act as cascading systems linked by complex feedback processes. The climate system is a dissipative, highly non-linear system, with many sources of instabilities. The whole climate system can be regarded as continuously evolving, as solar radiation at the Earth's surface changes on diurnal, seasonal and long-term time-scales. Starting with a given initial state, the solutions of the equations that govern the dynamics of a non-linear system such as the atmosphere, result in a set of long-term statistics. If all initial states ultimately lead to the same set of statistical properties, the system is ergodic or transitive. If, instead, there are two or more different sets of statistical properties, where some initial states lead to one set, while the other initial states lead to another, the system is called intransitive. If there are different sets of statistics that a system may assume in its evolution from different initial states through a long, but finite, period of time, the system is called almost intransitive. The climate system may be considered as almost intransitive, this arises because of internal feedbacks, or instabilities involving the different components of the climate system. Because of this, it may not be possible to produce a single set of long-term average values, which are of significant use in describing the climate. Aspects of Australian/Pacific Ocean

climates, among others, provide examples. It also makes detecting longer-term changes extremely difficult against this very noisy background.

Further, and perhaps most important, it sets limits on the detail with which it is possible to predict future climates. The limit on detail weather forecasts is about 20 days ahead. Past this limit it is only possible to describe climatic events in terms of probabilities of occurrence. This has another important consequence, because the details of future climatic events are not fixed. Modern Christians rarely pray about the weather, droughts, storms, etc., partly because they tend to assume that God can have no influence on such events! As Christians we believe that God created, is committed to his creation, and has given us the task of being good stewards of creation. Further interesting properties of dissipative, highly non-linear systems, such as the atmosphere/oceans, are observed as they evolve under changing solar input at the Earth's surface due to Earth orbital variations or changing atmospheric greenhouse gas composition. These include abrupt or sudden jumps from one climatic state to another, variations in the strength of teleconnections, non-stationary statistical relationships and persistent oscillations.

Much of the climatic change observed on the Ice Age/Interglacial scale is driven by the so-called Milankovitch mechanism of Earth orbital variations. The Ice Age/Interglacial record shows numerous examples of sudden jumps or oscillations in climate as the climate system evolves under the influence of the Milankovitch mechanism. Some of the major jumps in climate appear to have occurred on the decadal time scale. In short the climate system is not stable under changing radiation input conditions.

Carbon dioxide and methane are two important greenhouse gases, which trap heat in the atmosphere and cause surface temperatures to rise. By examining air bubbles trapped in deep ice cores from East Antarctica it is possible to produce records of atmospheric carbon

dioxide and methane extending over the last 750,000 years. These records show that the modern atmosphere is highly anomalous. At no time in the past 750,000 years is there evidence for levels of carbon dioxide or methane significantly higher than just before the beginning (around 1750) of the Industrial Revolution. Since the Industrial Revolution, atmospheric Carbon dioxide concentrations have risen by 33% and Methane concentrations by 100%, mainly due to the burning of fossil fuels and the spread of intensive agriculture. If no action is taken to curb these emissions, the carbon dioxide concentration will rise during the 21st century to two or three times the preindustrial level. These increases in greenhouse gas concentrations are continuing and rapidly taking the atmosphere into a climatic state of which we have no direct experience. Over the 21st century the global average temperature is projected to rise by between 2 to 6 ^{o}C from its preindustrial level. For comparison, the equivalent difference between the middle of an ice age and an interglacial warm period is only between about 5 to 6 ^{o}C. With a highly non-linear atmosphere/ocean system, the change to a warmer world could take the form of a very abrupt jump over a time period perhaps as short as a decade. Thus there is very much a need for Christians to be stewards of God's creation, and this includes a need for a deeper understanding of the nature and design of the climate system.

John Lockwood B.Sc., Ph.D., F.R.Met.S. 4 Woodthorne Croft, Leeds, LS17 8XQ.
E-mail jglockwood@clara.co.uk

Figure Legends:

Figure 3. Probability of changes in England and Wales rainfall in a world where atmospheric carbon dioxide is doubled. Copyright Met Office Hadley Centre.

Figure 4. Climate-model simulated England and Wales precipitation. Copyright Met Office Hadley Centre.

Figure 6. Temperature measurements deduced from ice cores drilled from the Greenland Ice sheet and analysed by the British Antarctic Surrey. Figure courtesy Eric Wolff, BAS.

Figure 11. Temperature simulations from a climate model driven by changes in natural factors but not including increases in atmospheric carbon dioxide. These do not agree with temperature observations due to the neglect of increases in atmospheric carbon dioxide. Copyright Met Office Hadley Centre.

Figure 12 Ocean circulation in the North Atlantic.

Figure 13. Temperature changes resulting from a hypothetical collapse of North Atlantic circulation. Copyright Met Office Hadley Centre.