THE EVOLUTION OF ADAPTATION IN RESPONSE TO CLIMATE CHANGE

Ian Burton
Environmental Adaptation Research Group
Institute for Environmental Studies
University of Toronto
33 Willcocks St.
Toronto, Ontario M5S 1A4

The research community of biometeorologists is familiar with the concept of adaptation as it applies to spontaneous changes in organisms in response to atmospheric stress. Indeed it may be argued that the fundamental paradigm of the interdisciplinary field of biometeorology is the theory of adaptation seen as the outcome of stress/response processes. Within this paradigm, biometeorology has made important contributions both to the theory of adaptive response, and in many practical applications. With the advent of anthropogenic climate change onto the research and policy agendas the concept of adaptation as traditionally used in biometeorology and biological sciences has been stretched to include socio-economic adaptation, and the interaction of natural ecosystems with human systems beyond their strictly biological elements. The United Nations Framework Convention on Climate Change, for example, refers to the capacity of ecosystems to adapt naturally in the face of climate change. At the same time the notions of setting aside north-south migration corridors to facilitate migration of organisms, and other forms of "assisted adaptation" are prominent in the literature on climate change and biodiversity. Thus land use policy and land resource allocation become part of the adaptation process for non-human species.

The main intent of this paper is to explore the concept of adaptation in this broader sense, and to stimulate some discussion on the biometeorology research agenda which may contribute to human understanding and the resolution of policy issues. Biometeorologists have been pioneers in the development of an interdisciplinary specialty. Now that climate change has become a prominent part of atmospheric science, the challenge is to rethink the nature of the interdisciplinary mix that is now required to further advance theoretical understanding, and to contribute to the growing scientific and policy effort to achieve a more sustainable relationship between biological systems, including human systems, and the restless and changing atmosphere. The concept of adaptation is central to this effort.

The concept of adaptation in this broader sense can be understood as part of the climate cycle and possible human interventions in that cycle (Figure 1). It is convenient to begin the description of the climate cycle with human economic and social activities (Oval 1). The growth of greenhouse gas emissions is a function of population, affluence or level of living, and technology, otherwise described as the well known I = P.A.T. formula. The greater the rate of population growth, the higher the material level of consumption, and the less sustainable or environmentally friendly the deployed technology, the greater will be the level and growth rate of greenhouse gas emissions. (Oval 2). The first human intervention in the cycle therefore is to measure and attempt to control these emissions (Box I-1).

The relationship between greenhouse gas emissions and greenhouse gas concentrations (Oval 3), in the atmosphere is still not adequately understood. Specifically when all known and estimated carbon sinks are taken into account, less carbon shows up in the atmosphere than is to be expected from the known level of emissions. This is the famous problem of the missing carbon. The second human intervention that is needed therefore is more atmospheric research to better define and understand the relationship between greenhouse gas emissions and greenhouse gas concentrations (Box I-2).
Knowledge of the level of concentrations does not by itself provide reliable forecasts of climate change. (Oval 4). It cannot yet be said with confidence how the climate will change in different regions of the planet, nor how fast such changes are likely to be. Nor can the likely changes in variability and the frequency and magnitude of extreme events be described with confidence. Another priority area for atmospheric research therefore is the relationship between greenhouse gas concentrations and climate (Box 1-3).

**Figure 1: The Climate Cycle and Human Interventions**

In order to begin the task of impact assessment (Box 1-4) it is necessary to characterize future climates in some consistent ways. A popular approach has been the development of climate scenarios derived from General Circulation Models (GCMs). These are commonly based on so-called 2xCO₂ equilibrium projections. The IPCC Guidelines for Impact and Adaptation Studies recommends such scenario based research. Among the many difficulties associated with this approach is the fact that the climate information so generated reflects poorly the experienced complexity of climate phenomena, and does not necessarily identify the elements of climate or the climate parameters that are crucial for assessing impacts. In the absence of reliable impact assessments the task of identifying adaptation measures appears to become rather speculative to say the least. If it cannot be specified in sufficient detail and complexity what it is that should be adapted to, then how are we to talk sensibly about adaptation at all?
Suggestions of ways to overcome this problem include the use of spatial and temporal analogues, (using the climate record from another time or place, or both, and transposing it onto the region, sector, economy, or ecosystem in question). They also include the use of a technique of forecasting by analogy (Glantz 1988), and empirical studies of the impacts of past extreme events and how socio-economic systems have responded (adapted). (Burton 1995).

Such studies lead in the first instance to gross impacts assessment (Oval 5). These impacts can give rise to potentially large feedback effects to earlier stages in the cycle (e.g. the thawing of permafrost and its consequent release of stored carbon dioxide and methane, resulting in positive feedback to the atmosphere). This and other feedback loops are not identified in this simplified climate cycle diagram. It is important for policy purposes to have assessments of the biophysical impacts of climate change in order that the economic costs may be compared with the costs of action to reduce emissions and control atmospheric concentrations. Realistic cost estimates cannot be based on gross biophysical impact assessments alone. The amount of successful adaptation has to be taken into account, including the rate at which various adaptation options can be adopted.

The issue of adaptation to climate change has given rise to some vigorous debate in the policy community. Some see adaptation potential as very high, so high in fact that they feel that little or nothing needs to be done in the short term at least, to curb greenhouse gas emissions. At the other extreme some of those convinced of the need to move as quickly as possible to the stabilization of greenhouse gas concentrations see the proponents of adaptation as a subversive movement attempting to sabotage the delicate process of international negotiations under the Climate Convention, and the development of national action programmes in energy conservation and the like.

So far the need for adaptation measures has been agreed in principle, but much remains to be done to formulate a consistent way of thinking about adaptation. The ideas presented in this paper are a contribution to that process. It is suggested that adaptation can take place at three levels in socio-economic systems. Level 1 adaptation refers to those tactical changes that can be adopted at the lowest exposure unit. By this is meant the firm or enterprise such as a farm, a business, a community, and including individual, family and households. Level 2 adaptation refers to strategic actions in sectors and collectivities, such as a farming region of system, a transportation system, or a sector such as manufacturing, forest industry, mining, fishing and so forth. Action on a system-wide basis necessarily involves government at least in proving the context for collective action, but also potentially in a pro-active role aimed at reducing vulnerability to climate change, and increasing response capacity. These levels of adaptation are shown in Figure 1 as boxes I-5 and I-6. After the implementation of such adaptation measures that may be feasible at levels 1 and 2 some residual damage or impacts will necessarily remain. Complete elimination of climate impacts is not possible in living systems. If the processes leading to the growth in emissions of greenhouse gasses are not radically changed, then over time the residual impacts will tend to increase, thus requiring further adaptive response. Adaptation in socio-economic systems, as in biological systems is an unending process.

This leads to an interesting question. If adaptation to climate is a continual process, how successful is the present level or pattern of adaptation? In one respect there is evidence that adaptation is failing, and that a process of maladaptation is underway. The rising costs of disasters associated with extreme events in the atmosphere (Figure 2), are strongly suggestive. Without so far any major identifiable change in the frequency or magnitude of the extreme atmospheric events themselves, greater damage is resulting from the human invasion of hazard zones, and failure to locate or build structures in such a way that they can withstand the elements. Patterns of development in many coastal zones, arid and semi-arid regions, mountainous regions and elsewhere are such that significant costs frequently arise from atmospheric extremes and in some cases there is reason to believe that a potential for more major disasters is being created. There is need therefore to consider adaptation in a more fundamental way than is suggested by the tactical and strategic measures likely to be generated at levels 1 and 2. The components of Level 3 adaptation (Box I-7) include more far reaching changes in lifestyle, changes in social values and behaviour, and in technology. Level 3 adaptation encompasses many of those reforms described by the Brundtland
Commission in its call for sustainable development. It is here that the distinction between control measures and adaptation measures becomes blurred, and a convergence develops. Many actions that can be taken under the rubric of sustainable development are both adaptive to the environment and serve to “control” it by reducing emissions, and hence reducing concentrations, the pace of climate change and the cost of impacts. Thus the circle is completed. At present it is a vicious circle both because emissions of greenhouse gasses continue to grow and because the adaptation process is not working well. It can become a virtuous circle in which effective adaptation measures have a key part to play.

Figure 2: The Rising Cost of Disasters

![Graph showing economic and insured losses due to great natural disasters (1960-1993), with trends extrapolated to 2000. Source: Munich Reinsurance 1994, cited in McCulloch and Etkin 1995; used with permission.]

If this is to happen ways are needed to identify and assess adaptation measures at all three levels, and mechanisms created to ensure that adaptation to climate change is factored into decision-making and policy-making. To this end a classification of adaptation measures is suggested in the form of a tree (Figure 3) (to be added).

An initial distinction is made between adaptation in socio-economic and technological systems and natural ecosystems. No further attempt is made here to elaborate upon the anatomy of adaptation in natural systems. It would be a potentially creative exercise to develop such ideas in comparison with the processes of socio-economic adaptation. Perhaps the important points here are that there is an anatomy of adaptation, and that adaptation is not a fixed immutable process but also evolves. The stored genetic experience or “genetic memory” of a species implies that response to each new perturbation will be different depending upon the nature of the stress and the accumulated capacity of the species to respond.

A parallel to this in socio-economic systems is accumulated wealth or social capital. The richer a community or society the greater the capability to absorb shocks. This helps to account for the widely accepted view that those regions where the climate is expected to change least are most vulnerable. Projected changes in temperature are least in the low latitudes and greatest in the high latitudes. Nevertheless it is the low latitude (and generally poorer) countries that are expected to suffer the greatest losses and be least able to cope.

The next division of socio-economic adaptation is into the three levels described earlier. These are the tactical or enterprise level, the strategic or sectoral level, and the level of sustainable development here characterized as the metabolic level.
Since socio-economic systems are at least in part self-conscious systems with a capacity to conceptualize and to behave in anticipation of stress, the timing of adaptive response is highly significant. There is much policy debate about the urgency of responding to climate change. Some view the threat as so uncertain and remote that a wait-and-see attitude is justified. Others while acknowledging the uncertainty believe the threat is so serious that precautionary and “no regrets” measures should be taken immediately. Broadly expressed adaptive actions can be taken before, during or after an event. For this purpose climate change is not a single event but a long-term process of change composed of a pattern of weather events. It is the specifics of these events and their changing frequency, magnitude and spatial distribution to which people adapt.

In the literature on human response to natural hazards (Burton, Kates, and White 1993) a classification of actual measures has been developed on the basis of considerable empirical field study of hazard and disaster situations.

The four fold typology presented here can be further subdivided and additional “modes” added.

For this purpose an analysis of the contents of the recent IPCC Working Group II report (1996) has been made. With the help of a contact disk and a word search programme a comprehensive list has been compiled of all the adaptation measures mentioned in the report (Burton and McKay, unpublished report). Some 228 measures have been identified. These are listed by Chapter in Table 1.

Table 1: Typology of Adaptation Measures

<table>
<thead>
<tr>
<th>NATURAL</th>
<th>SOCIO-ECONOMIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Prevent Loss</td>
</tr>
<tr>
<td>Biological</td>
<td>Tolerate Loss</td>
</tr>
<tr>
<td></td>
<td>Spreading or Sharing Loss</td>
</tr>
<tr>
<td></td>
<td>Change Use / Activity</td>
</tr>
<tr>
<td></td>
<td>Change Location</td>
</tr>
<tr>
<td></td>
<td>Restoration and Protection</td>
</tr>
<tr>
<td></td>
<td>Research, Education, Training</td>
</tr>
<tr>
<td></td>
<td>Multiple Stress Alleviation</td>
</tr>
</tbody>
</table>

An attempt has been made to develop a more complete typology of these measures for classification purposes. It is also believed that the development of a more consistent typology across different sectors (chapters) would result in the identification of many more potential measures.

In this more elaborate typology, shown in Table 1, 8 categories of socio-economic adaptation are proposed, plus the two standard categories of natural adaptation, physical and biological.

The amount of attention given to adaptation varies widely from chapter to chapter as shown in Table 2. The Fisheries chapter mentions more adaptation measures than any other (33), followed by the chapters on land degradation and desertification, (28), financial services (21) and coastal zones and small islands (20). Deserts, mountain regions and the cryosphere provide the smallest number of suggested adaptation measures.

There seems to be little logic behind this distribution. The most likely explanation for the differences is attention to adaptation is that no guidelines for the treatment of adaptation were agreed among the lead authors of the different chapters.

In terms of the levels of adaptation suggested in Figures 1 and 3, the large majority of measures identified fall into Level 1, with fewer in Level 2 and least in Level 3. This is not surprising, since the concept of adaptation has been used to refer mainly to small scale, tactical actions, and not to broader country-wide actions at the policy or strategic levels. Nevertheless such broader measures are not absent as illustrated,