Review

UNITED NATIONS ENVIRONMENT PROGRAMME. 2007. *Global outlook for ice and snow*. Nairobi, United Nations Environment Programme. 235pp. ISBN: 978 9 2807 2799 9, paperback. $40.

One can hardly open a newspaper or magazine, tune into the wireless or even watch the evening news these days without witnessing the preoccupation that our society has with what is commonly referred to as 'global warming'. As in all polemical issues on the deprivation of resources and habitat through inconsiderate and reckless human practices, the changing climate that now threatens the equilibrium of ecosystems and the resulting capacity of the planet to sustain conditions for continued social progress and economic activity is subjected to the gamut of opinion from prediction of the direst consequences to outright denial that a problem exists. The media thus often shape our perception of what may, or may not, be the impact of such changes. Moreover, the diversity of the information and prognostication is understandable when one considers the disinclination and/or incapacity of certain media to examine closely the scientific evidence upon which researchers base their conclusions on the change in climate and the impacts it can bring to bear. On the other hand, many scientific organizations, governments and non-governmental organizations do publish works that attempt to bridge the gap between the complexity of the scientific studies and the need for adequate understanding by the public, including decision-makers, of the key issues that should give rise to policy definition and implementation.

An excellent example of such a publication is *Global outlook for ice and snow*, which is the second thematic assessment report of the Global Environment Outlook series from the United Nations Environment Programme. The book covers the interrelationship between the climate and the cryosphere (the planet's snow and ice systems) and how the interaction between the increase in temperature of the atmosphere, oceans and land masses will modify the surface of the Earth, the diversity of the biosphere and human activity itself. The authors (79 of them) are practically all internationally well known in their respective fields of cryospheric science and represent countries (18) with either significant reserves of snow and ice or an interest in the impacts of cryospheric change on national boundaries and land use. A team of experts on snow and ice has also reviewed the work, and in many ways another review may seem here to be superfluous. However, this current review does not address itself to an evaluation of the basic science of data collection and interpretation, but rather to the way in which the knowledge gained is presented to the target audience, which should cover not only educators and policy-makers but also legislators, media producers, writers, journalists and any other citizen who desires to be informed on the issue.

The book is really well produced and edited to transmit the 'state of the science' on the cryosphere and climate change to the 'targeted' reader. Overall, the text is clear and concise and the work is amply illustrated with photographs depicting cryospheric systems (e.g. forest snow cover; glacier calving and melt), changes that have taken place in the cryosphere (e.g. glacier retreat), the flora and fauna of cryospheric ecosystems (e.g. sea ice, snow cover) and human-activity–cryosphere interaction (e.g. permafrost thaw and infrastructure collapse). Tables have been kept to a minimum, and the large number of graphs and figures are extremely well drawn for clarity and colour-coded for distinction and ease on the eye. This reviewer appreciated particularly the figures based on satellite imagery showing the large-scale changes in the cryosphere (e.g. seasonal sea-ice extent; mass loss from ice sheets). Separate text boxes are included where information is required on certain more specific aspects of the subject under discussion. If a more detailed search of any subject is desired, the references are more than adequate and up to date (2007). The flyer for the work (www.earthprint.com) describes it as an educational and reference publication; however, no index is included to facilitate any search. On the other hand, the first chapter in the book, 'Highlights', succinctly reviews the individual chapters, which does help one to pick out quickly the salient points of each chapter.

After the first chapter, the eight other chapters in the volume may be divided into three themes. Chapters 2 and 3, 'Why are ice and snow important to us?' and 'Why are ice and snow changing?' respectively, treat the role that the cryosphere plays in the global climate and why that role is changing – due mainly to the melting of ice by the increase in temperature. A brief overview of the feedback mechanisms that accelerate the warming of polar regions and the resulting heat distribution by the global oceanic thermohaline circulation is given in chapter 2. The consequent melting of ice on land and the rise in sea level (presently about 3 mm a^{-1}) due to runoff and thermal expansion of the oceans is most preoccupant as significant population concentrations occupy coastal regions. Chapter 3 includes a discussion on the forces that drive the climate system and why the anthropogenic emissions of greenhouse gases are now causing the shift to overall warmer temperatures. The learning of past conditions from Antarctic ice cores and model simulation of Arctic temperatures into the mid-21st century suggest that the Arctic annual land temperature will rise by 2–4°C from the present level, the range representing the uncertainty in model projections. For the Antarctic the uncertainty is larger. The chapter also includes text and a well-thought-out conceptual figure that describe the relationships between positive and negative feedbacks in the warming of the high latitudes.

Chapters 4–8 treat the different components of the cryosphere (theme two), namely 'Snow', 'Ice in the sea', 'Ice on the land', 'Frozen ground' and 'River and lake ice' respectively. Each chapter is structured more or less along the same lines: an introduction to the cryosphere component comprising the physical characteristics, geographical distribution and dynamics of the solid water phase, followed by a reconstitution of past trends, an outlook on future changes in the amount and distribution of ice, and finally the impacts that such changes may cause in ecosystems and on human activity. Each cryospheric component influences the climate and water bodies of the Earth in different ways depending on the extent and time of the ice accumulation and ablation phases. Seasonal snow cover (chapter 4), for example, contributes very little to sea-level rise but is a very significant factor in climate due to high reflectivity, insulation of

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underlying soils and cooling of the atmosphere. Snow is also an important source of fresh water for approximately one in every six human beings. Recent trends show that snow-cover extent in the Northern Hemisphere is declining at a rate of $1.3\%\,(10\,a)^{-1}$, and model simulations lead to rapid loss rates in the amount of snow (snow water equivalent (SWE)) through the next century when up to 60–80% of present SWE values in most mid-latitude areas will be lost. The impacts induced by a reduction in snow cover include the loss of habitat for chionophilic fauna and flora, and the availability of surface and soil water for agricultural use, industry and recreation. In a similar manner to that of snow cover, the extent of sea ice (chapter 5) in the Arctic is also decreasing; the current mean rate of decrease is $3.2\%\,(10\,a)^{-1}$, but regional rates vary from $10.6\%\,(10\,a)^{-1}$ for the Greenland Sea to $0.4\%\,(10\,a)^{-1}$ for the Canadian Arctic Archipelago. Projected changes into the latter half of this century show significant decreases in sea-ice extent, particularly during the summer months. Although sea-ice decrease does not contribute to sea-level rise, it will significantly affect climate due to decreases in reflectivity, as with snow-cover decrease. It will also significantly reduce the diversity of marine food webs, mammals and bird life, with concomitant repercussions for the culture and livelihood of indigenous peoples. In addition, there are already ominous political stirrings in the more southerly climes of North America and Eurasia, with sovereignty being claimed over the increased areas of open water because of the access it would bring to oil and gas reserves and the possibility of commercial sea passage.

Chapter 6, the longest chapter in the book, is divided into three sections: 6A, Ice sheets; 6B, Glaciers and ice caps; and 6C, Ice and sea-level change. The separate section on sea-level change is justified by the fact that ice on land is the cryosphere component that would be the major contributor of meltwater (99.9%) to the oceans in the event of complete ablation of the ice. Together, the two continental ice sheets of Greenland and Antarctica (chapter 6A) contain 98–99% (Greenland 11%, Antarctica 89%) of the freshwater ice on the Earth's surface. If both sheets were to melt completely, sea level would rise by approximately 64 m. Although the time frame for the complete ablation of the ice masses would be thousands of years, there are definite signs of melt and meltwater contributions to the recently observed rise in sea level. The Greenland ice sheet is undergoing increased mass loss as a result of surface ice- and snowmelt during the warmer summers and the discharge of ice from outlet glaciers to the sea, but losses from the Antarctic ice sheet are subject to much more uncertainty. Consequently, the outlook for both ice sheets is impossible to predict with any degree of confidence at the present time. In contrast to the paucity of data on the ice sheets, there is a wealth of data on glaciers and ice caps (chapter 6B). Although they contain a very small amount of ice relative to the ice sheets, glaciers and ice caps have been the subject of worldwide monitoring for over a century. Data collection by the World Glacier Monitoring Service, Zürich, Switzerland, has shown that decrease in the ice mass of glaciers since 1970 is now a global phenomenon, particularly at lower elevations and latitudes. Although glacier wastage is widespread, it varies from region to region. This loss of glacier ice forebodes dramatic long-term supply problems of fresh water for both agriculture and drinking-water supply in all those areas currently dependent on glacier runoff, and also increases the risk of glacier lake formation and catastrophic outburst floods. The disappearance of glaciers and ice caps would result in a sea-level rise of between 15 cm (rise based on the lowest estimated value of ice volume) and 37 cm (highest estimate). The rate of sea-level rise (chapter 6C) is presently $3.1\,mm\,a^{-1}$, which is almost double the average value of $1.7\,mm\,a^{-1}$ for the 20th century. Runoff from glaciers, ice caps and ice sheets accounts for about one-third of the change in level, while the remainder is due to thermal expansion. During the 21st century the same factors will prevail: thermal expansion will be dominant, while the meltwater will continue to come, in the majority of cases, from glaciers and ice caps. Most model projections foresee a sea-level rise of 0.3–0.5 m by 2100, but uncertainties in ice-sheet losses could significantly change these values. It is also pointed out that the frequency of extreme events will increase due to the change in sea level, thus effectively magnifying the overall impact of the rise itself. Impacts related to flooding, storm damage, erosion, saltwater intrusion into surface and ground waters, and impeded drainage, will be along coastal areas and exposed low-lying landforms. Asia would be especially at risk: it is estimated that a 1 m rise in sea level would encroach on $>2000\,km^2$ and affect a population of 145 million.

It is estimated that the ice in frozen ground (permafrost; chapter 7) could contribute approximately 7 cm to the change in sea level. Permafrost, which contains more ice than the Greenland ice sheet, covers up to approximately 24% ($22.8 \times 10^6\,km^2$) of the Northern Hemisphere. Recent warming of permafrost of up to 2°C in some areas has not, however, led to any appreciable large-scale thaw, but in certain locations increased subsidence and the formation of thermokarst due to soil collapse into drained subsurface melt zones has been recorded. Some model projections indicate that most of the present extent of the permafrost zone could be subject to a temperature rise of 4–8°C at the permafrost surface, and thus large areas of permafrost, particularly in southern Alaska, the Canadian subarctic and northwest Siberia, will be losing ice by the end of the century. The major impacts will be wetland replacement of boreal forest stands, infrastructure damage and the release of methane into the atmosphere. Methane is a powerful greenhouse gas and will contribute to increased rates of global warming through positive feedback processes. In chapter 8 ('River and lake ice') on cryosphere components, it is not so much the role that river and lake ice plays in influencing climate change that is discussed but rather the changes in freshwater ice regimes due to a warming of the climate. However, one can assume that snow cover on lake and river ice should react to incoming radiation in a similar way to snow cover on land, unless the snow cover is particularly thin. On a more regional scale, river and lake ice are extremely important to the productivity of ecosystems and human activity (e.g. transport) and human well-being (flooding). Recent changes in river ice from the Northern Hemisphere indicate that long-term temperature increases of 2–3°C in autumn and spring have both delayed freeze-up and advanced break-up by about 10–15 days each. In many areas of Canada, there is a significant trend in the shortening of the lake ice season due to earlier break-up. Projections generally indicate that the ice season will further shorten as temperatures continue to rise.

By the time the reader has reached the last chapter (the third theme, 'Policy and perspectives', chapter 9), he or she should have got the message that the relatively unbridled

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destructive exploitation of the planet and its resources is leading to increasing rates of climatic change, mass wasting of the cryosphere and rise in sea level. So mankind has a choice, i.e. do nothing and take the consequences, or get organized and start making intelligent policy decisions and implementing mitigation procedures. Even if intelligence does prevail, decision-makers could still face a quandary, in that, apart from the obvious global long-term mitigation of greenhouse gas emissions, trying to plan for future situations that are modelled by incremental change relies on concomitant adaptation, whereas unforeseen abrupt and catastrophic changes that may occur at tipping points along the way cannot be adequately addressed and could cause undue hardship.

Read the book, read your newspaper, and compare.

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