CLIMATE CHANGE AND NATURAL RESOURCES POLICY AND MANAGEMENT

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Contents

1. Introduction

Climate can be considered a natural resource. Civilizations develop under the tacit assumption of the continuity of climate. Climate does vary, for example, from one century to another and from one year to the next. And humanity manages its affairs and its survival - as do flora and fauna, managed and unmanaged ecosystems - to varying degrees of success within such climate variability. Climate of the globe as a whole can change (above and beyond mere variability) for causes that are external to the system, such as changing Sun's radiation or volcanic eruption spewing ash and soot into the atmosphere - or for causes that are within the system - such as large scale conversion of forests to agricultural and pastoral lands. Climate can also change on smaller space scales by activities such as depletion of ground water and consequent decrease in soil moisture. Climate change can have dire consequences: it is known that the demise of some of the past civilizations was associated with prolonged climate stress including shifts in precipitation patterns (Obasi, 1999*b*).

Knowledge of climate variability from instrumental records extending back into the last two centuries has been derived largely from data that have been collected under the aegis of the World Meteorological Organization (WMO) and its predecessor, the *International Meteorological Organization*. In particular, these data have shown that over the last few decades, greenhouse gases (GHGs), particularly carbon dioxide (CO_2), have been accumulating in the atmosphere. Increases in atmospheric concentrations of the GHGs are largely the result of human activities, especially the use of fossil fuel. Recent studies including assessments by the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) (IPCC, 1995*a*,*b*) have shown that enhanced amounts of GHGs in the atmosphere can give rise to global warming with accompanying sea-level rise. Observational temperature records dating back to about 1860 are showing that the global mean temperature has risen during the period. Not all of this increase can be explained on the basis of natural variability alone. In fact, the IPCC concluded in 1995 (IPCC, 1995*a*) that the balance of (observational) evidence suggests a discernible human influence on global climate.

Policies on the exploitation and management of natural resources must be very carefully considered in the context of climate change in order to ensure availability of food, water, and clean and safe energy that would satisfy the current and future needs of the society, without harming the environment. This was recognized by the United Nations Conference on Environment and Development (UNCED) and is currently being addressed under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Several other conventions including the United Nations Convention to Combat Desertification, the Convention on Biodiversity and the Vienna Convention on the Protection of the Ozone Layer and its Montreal Protocol and its Amendments are also contributing to the protection of the environment.

This paper reviews our current understanding of the subject of climate change and the fundamental question of climate variability. The policy issue of sustainable use and management of natural resources are addressed in this context.

2. Climate change, climate variability and the greenhouse effect

To start with, we need to understand what climate is and what controls it. If you were planning a trip weeks or months in advance to some part of the world with which you were not familiar, you would probably want to know what type of "average" weather to expect or the climate of the place, for the time of the year. Weather conditions, including seasonal to interannual extremes and variations, locally, regionally or across the globe averaged over a period of time long enough to establish statistical properties for that period largely independent of any instantaneous atmosphere state, is considered climate. At any one location, weather can change very rapidly from day to day whereas its climate is more stable. In other words: "*climate is what you expect, weather is what you get*".

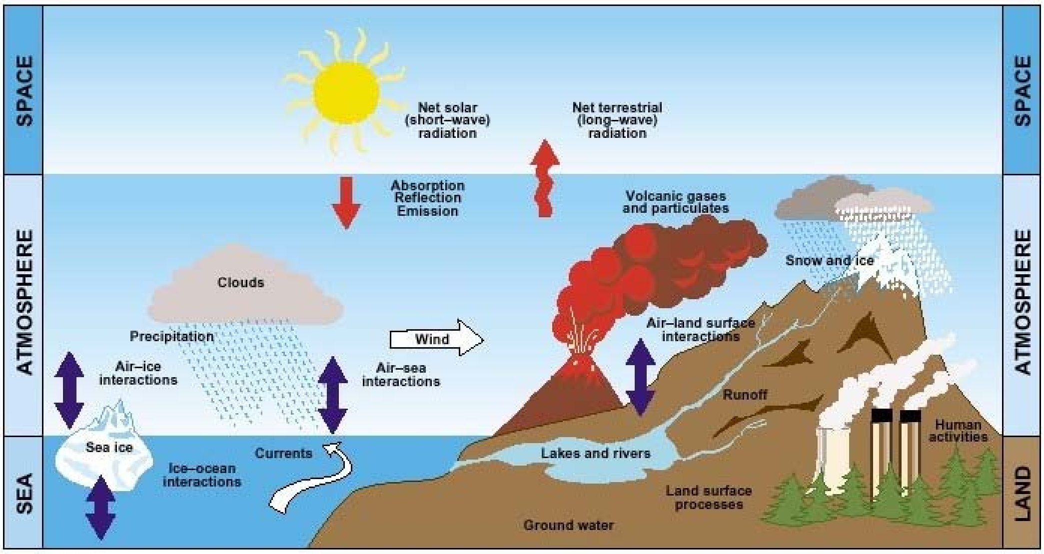

Figure 1 – The global climate sysem.

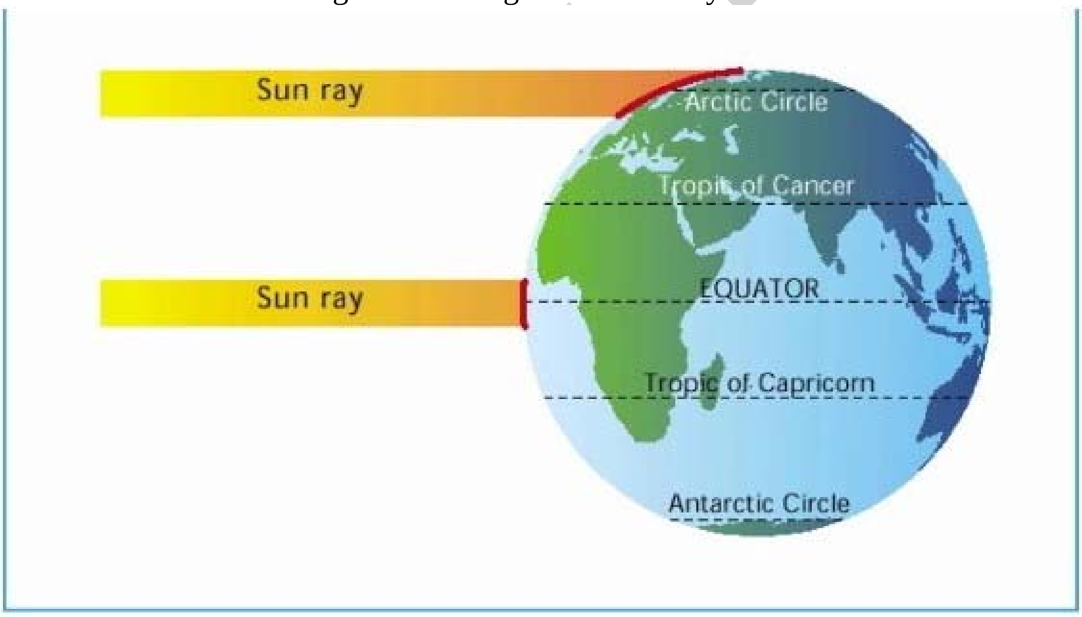

Figure 2 – The relative amounts of radiation received from the Sun.

To understand the particular climate of a particular place and the variability of that climate, study of the complete global climate system that includes the atmosphere, the hydrosphere (liquid water), the cryosphere (ice and snow), the lithosphere (rock and soil) and the biosphere (plant and animals, including humans) and the complex interaction between these components (Figure 1) are necessary. The climate system is basically driven by solar radiation received by the Earth which, in turn, depends on the rotation and orbital motion of the Earth around the Sun. The axis of rotation of the Earth is inclined at an angle of 66½ degrees to its orbital plane, and the angles of inclination of the parallel rays from the Sun falling on Earth are highest in the equatorial region and decrease polewards (Figure 2). The average solar energy per second falling on a surface one square metre in area on top of the atmospheric envelope is about 342 W. About 30 per cent of this energy is scattered or reflected back to space by air molecules, aerosols, clouds and the Earth's surface, which leaves 235 Wm^{-2} on average to warm the Earth's surface and the atmosphere. Like every other body in the universe, the Earth also radiates energy - only it does so in the form of heat rays. This outgoing "long-wave" Earth's radiation is distributed more evenly over the Earth's surface. On an annual mean basis, the result is an excess of absorbed solar radiation (predominantly "short-wave" or visible part of the electromagnetic spectrum) over the outgoing long-wave radiation in the tropics while there is a deficit in the higher latitudes (Figure 3*a*,*b*). In order the keep the average temperature of the Earth's surface more or less steady, heat has to be transported from the surplus regions namely equatorial and the tropical latitudes to the deficit regions - the higher latitudes. This transport occurs through a process known as the General Circulation of the atmosphere; climate, weather and weather systems are products of this circulation. In addition, the movement of the Earth around the Sun once every year causes the seasons (Figure 4).

With regard to the issue of global warming, one must first understand the "*greenhouse effect*" within the atmosphere. To maintain its average temperature, the Earth itself must radiate on average the same amount of energy (that it receives) back to space. It does this, as was stated earlier, by emitting long-wave radiation in the infrared part of the spectrum. For a surface to emit 235 Wm^{-2}, it should have a temperature of about -19°C. However, the annual average global mean temperature is about 15°C. This is because of the presence of various naturally-occurring gases in the lower part of the atmosphere such as ozone, methane, nitrous oxide and more importantly *carbon dioxide and water vapour*. These gases, known as the greenhouse gases, absorb some of the outgoing long-wave radiation from the Earth and reradiate a part of the radiation to space and a part back to the surface. The portion re-radiated to the surface warms the surface (in addition to the solar radiation received). This warming of the surface due to reradiated energy from the atmosphere to the surface is known as the "greenhouse effect".

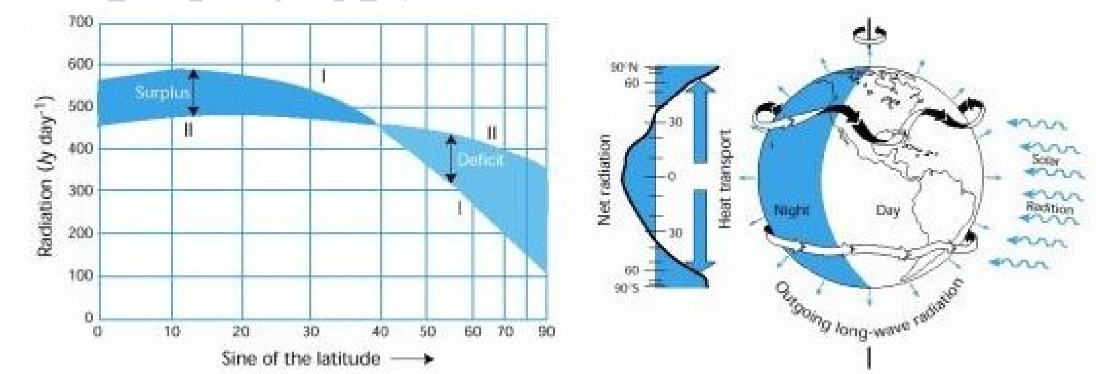

Figure 3*a* (left) – Curves I and II represent mean annual insolation and outgoing long-wave radiation, respectively, at the tropopause.(Source: Haltiner and Martin, 1957)

Figure 3*b* (right) – This radiation distribution results in warm conditions in the tropics but cold at high latitudes, and the temperature contrast results in a broad band of westerlies in the extratropics of each hemisphere in which there is an embedded jet stream (shown by the "ribbon" arrows) at about 10 km above the Earth's surface. The flow of the jetstream over the different underlying surface (ocean, land, mountains) produces waves in the atmosphere and adds geographic spatial structure to climate.(Source: Trenberth and Solomon (1994))

Increases in the concentrations of the greenhouse gases will strengthen the greenhouse effect and could therefore be expected to result in increases in the temperature of the Earth's surface. The Earth system is quite complex and the temperature rise that may occur depends on many factors such as feedbacks and interactions in the various parts of the climate system. For example, any increase in small particles in the atmosphere, either from the burning of fossil fuels, or as a result of volcanic activity, tend to cool the atmosphere because these particles, called aerosols, scatter and absorb radiation from the Sun before they reach the Earth surface. Any change in the radiation balance of the Earth, including those caused by greenhouse gas increases or aerosols, will alter the temperatures of the Earth surface, the oceans and the lower part of the atmosphere, thereby affecting weather patterns and climate. These could be accompanied by changes in the hydrological cycle (clouds, precipitation, evaporation, etc.) which would impact life forms and ecological and socio-economic systems on the planet.

From a climatological point of view, the term ***climate change*** refers to the difference between the mean values of a climate parameter or statistics, that is the difference between climatic states, which is outside the normal range of natural climate variability, whatever the cause may be. The term ***climate variability*** denotes deviation or anomalies of climate parameter over a given period of time e.g. a specific month, season or year from the long-term climate averages. In the most general sense, however, climate variability can be described by the differences between long-term statistics of meteorological elements calculated for different periods.

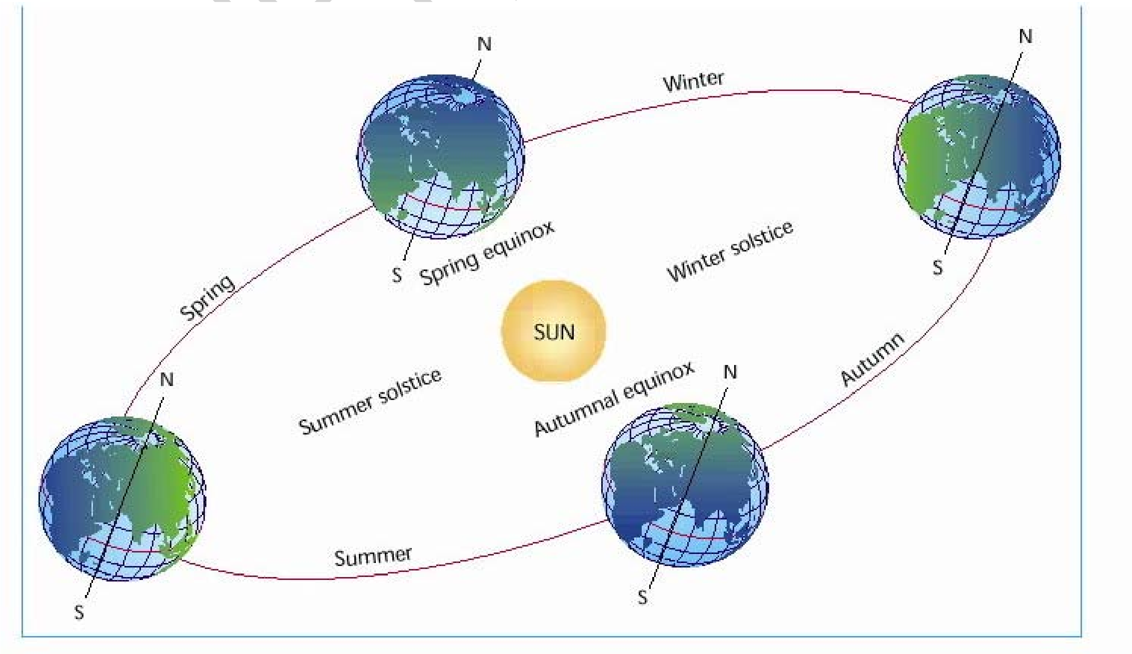

Figure 4 – As the Earth orbits the Sun, the tilt of its axis gives rise to seasons. During the spring and autumn equinoxes, the Sun is overhead at the Equator. During the summer solstice, the Sun is at the most northern position (23.4ºN) and the winter solstice at its most southern position (23.4ºS).

3. Observed climate variability and change

3.1. Long time-scale climate variability and changes

To a large extent, human societies have become attuned to the current climatic conditions, that is, the conditions over the last 30 to 50 years. However, considering the much longer period, one sees that the Earth's climate has never been static. Climate is a dynamic regime subject to changes on all time scales from decades to millennia to millions of years. Many scientific clues can be found in *glacial records* that indicate that past climates have been quite different from the present. Putting all available evidence together, one can deduce the global temperature variations in the past few thousand years. Evidence from paleo-climatological records (Figure 5) show:

(a) Recurrent glacial-interglacial cycles of periods of about 100 000 years, associated with alterations of the Earth's orbital parameters (Milankovitch Hypothesis), when climate was mostly cooler than at present, with global mean surface temperature variations of 4 to 5°C through these ice age cycles;

(b) The period since the end of the last glaciation (about 10 500 years ago) has been characterized by smaller changes in the global average temperature in the range of about 2°C;

(c) Large regional, long-term episodic changes in hydrological conditions have occurred, particularly in the tropics, e.g. wetter conditions occurred in the Sahara from 12000 to 4000 years before present. North-west India was particularly humid by today's standards with frequent floods in the period 8000 to 2500 before present;

(d) The late tenth to early thirteenth centuries (950-1250 AD) having been exceptionally warm in western Europe, Iceland and Greenland - a period sometimes known in Europe as the "*Medieval Climatic Optimum*"; and,

(e) Periods which were cooler and warmer than the normal periods during the last 1 000 years. The most recent cooler period, the "*Little Ice Age*" from the sixteenth to nineteenth centuries, witnessed marked advances of glaciers in almost all Alpine regions; glaciers were much more extensive 100-200 years ago than now. Since around 1850, most glaciers have been retreating rapidly (Obasi 1996*a*, 1998 and 1999*a*). Furthermore, there has been unprecedented increase in the mean global temperature during the last part of the twentieth century.

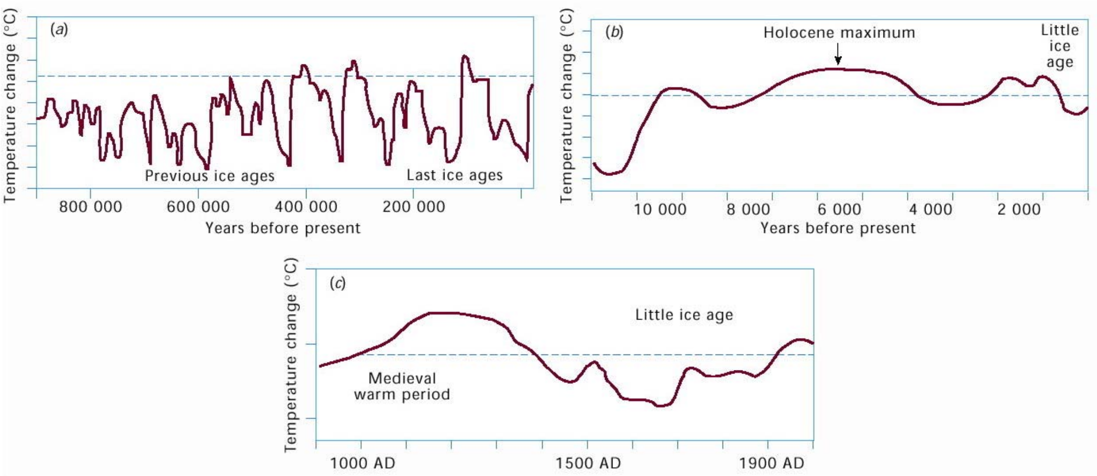

Figure 5 – Schematic diagrams of global temperature variations since the Pleistocene on three time-scales: (*a*) the last million years; (*b*) the last ten thousand years; and (*c*) the last thousand years. The dotted line nominally represents conditions near the beginning of the twentieth century.

3.2. Anthropogenic influences

The climate variations of the past, as described in the previous section, except probably the recent glacier retreats, have been essentially natural, with little or no human influence. However, the present day concern is that for the first time in history, the human element has been added to the climate equation. Emissions of some of the greenhouse gases into the atmosphere from human activities have now modified the concentrations of these gases quite significantly compared to pre- industrial levels. The gases include carbon dioxide, methane, nitrous oxides and halocarbon compounds. For example, for over 160 000 years up to about 1800, the atmospheric concentration of carbon dioxide (CO_2) did not exceed about 280 parts per million by volume (ppmv). Today carbon dioxide has increased by 31 per cent and is at 368 parts per million by volume (Figure 6 (a) and (b)). Similarly other gases such as methane (CH_4) and nitrous oxide (N_2O) have increased by 145 and 15 per cent respectively. The natural greenhouse effect has operated in the Earth's atmosphere for millions of years. The emerging threat of climate change is based on a *human-induced enhanced greenhouse effect* caused by increases in the atmospheric concentrations of the GHGs. Land use changes, and more recently the burning of fossil fuels, have injected into the atmosphere a total of about 180 billion tonnes of carbon dioxide as carbon since the 1860s (Obasi, 1991).

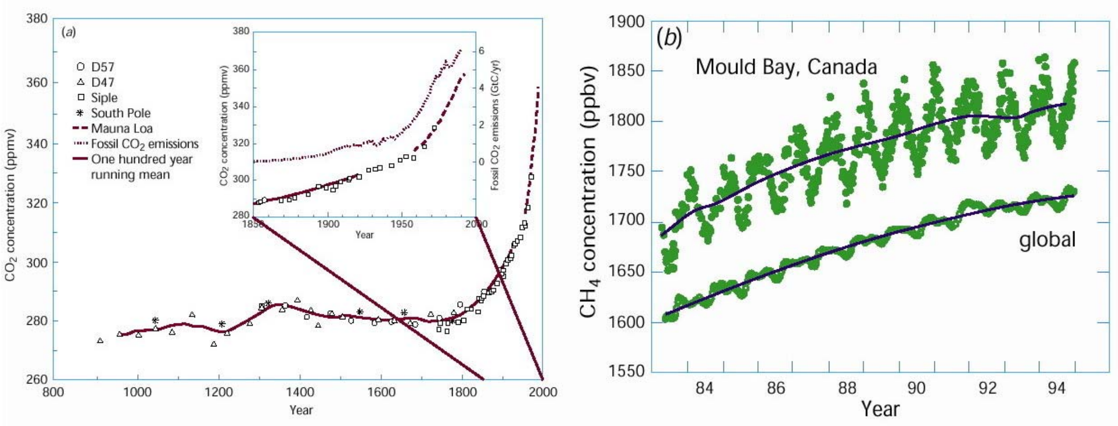

Figure 6*a* (left) – Carbon dioxide concentration over the past 1000 years from ice-core records (D47, D57 Siple and South Pole) and (since 1958) from the Mauna Loa, Hawaii measurement site. The smooth curve is based on 100-year running mean. The rapid increase in CO_2 concentration since the onset of industrialization is evident and has followed closely the increase in CO_2 emissions from fossil fuels (see inset of the period from1850 onwards). Figure 6*b* (right) – Global methane concentrations (ppbv) for 1983 to 1994. Concentrations observed at Mould Bay, Canada are also shown. (*Source*: IPCC, 1995*a*)

In contrast, the aerosols put into the atmosphere by human activities have a cooling effect on climate, but this cooling occurs over or close to regions of industrial activity, such as the eastern United States, central Europe and eastern China, and is much more variable in space and time. On the other hand, the heating from greenhouse gases is more or less the same around the world. The combination of both warming and cooling processes gives a general pattern of warming, though to varying degrees around the world, as has actually been observed (Figure 7).

An outstanding issue is how to adequately distinguish the human-induced effects from the natural climate variability. Progress is now being made in resolving this issue and the evidence attributing the recent changes to human influence is becoming stronger. In particular, it may be noted that the twentieth century global mean surface temperature was at least as warm as any century since 1400 AD.

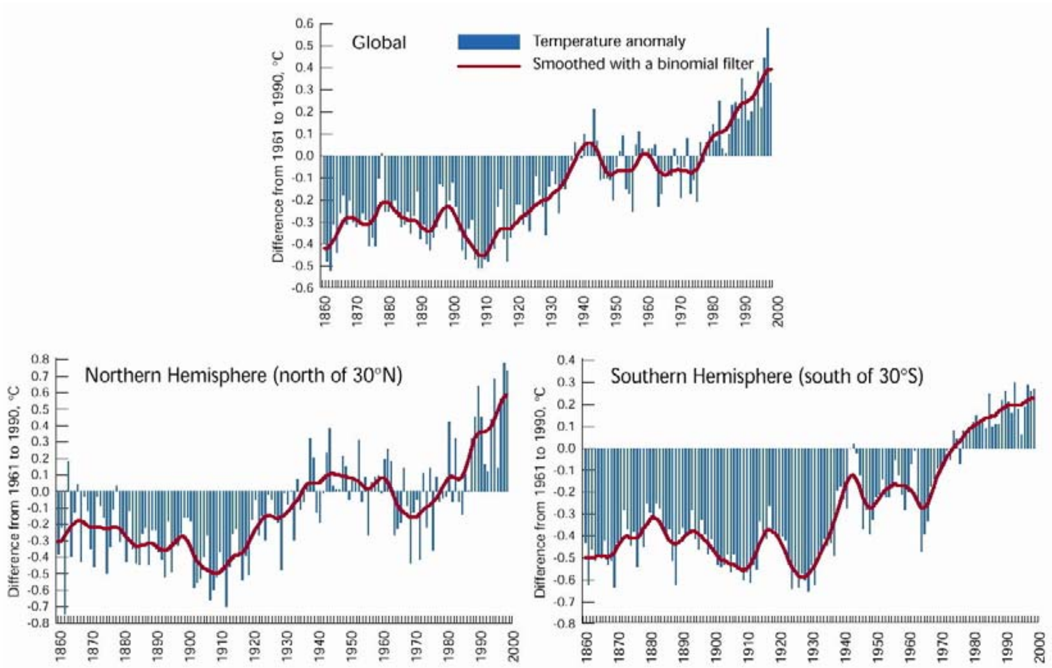

Figure 7 – Air and sea-surface temperature anomalies 1860-1999. (*Source*: P.D. Jones, Climate Research Unit, University of East Anglia; Hadley Centre, United Kingdom Meteorological Office)

Available observational records spanning through the period since industrial era have shown that:

(a) The global mean temperature has increased by between 0.3-0.6°C since the 19th century, with a global mean sea-level rise of between 10 and 25 cm;

(b) Night-time minimum temperatures over land have generally increased more than the daytime temperatures;

(c) The last two decades are the warmest of the last century, and the 12 warmest years of the last century have all occurred since 1983 with 1998 currently standing as the warmest year since the 1860s; and the twentieth century is the warmest century in the last 1 000 years; and

(d) Some regional changes are also evident in precipitation distribution over land in high latitudes of the Northern Hemisphere, especially during the cold season.

Recent records show that a number of unprecedented extremes have also occurred over the recent past. For instance, the El Niño/Southern Oscillation (ENSO) phenomenon (warm phase) has been more frequent than La Niña (cold ENSO phase) since the early 1970s. This may have resulted in changes in the frequency and intensity of floods, droughts, cyclone activities, and other extreme climate events in some regions where *El Niño* signals are strong (Obasi 1999a). It certainly appears that extreme weather- and climate-related events resulting in extensive economic damage and human suffering have increased in recent years, with industry (insurance) concerns as to whether the frequency and distribution of extreme weather events around the world are changing (Figure 8).

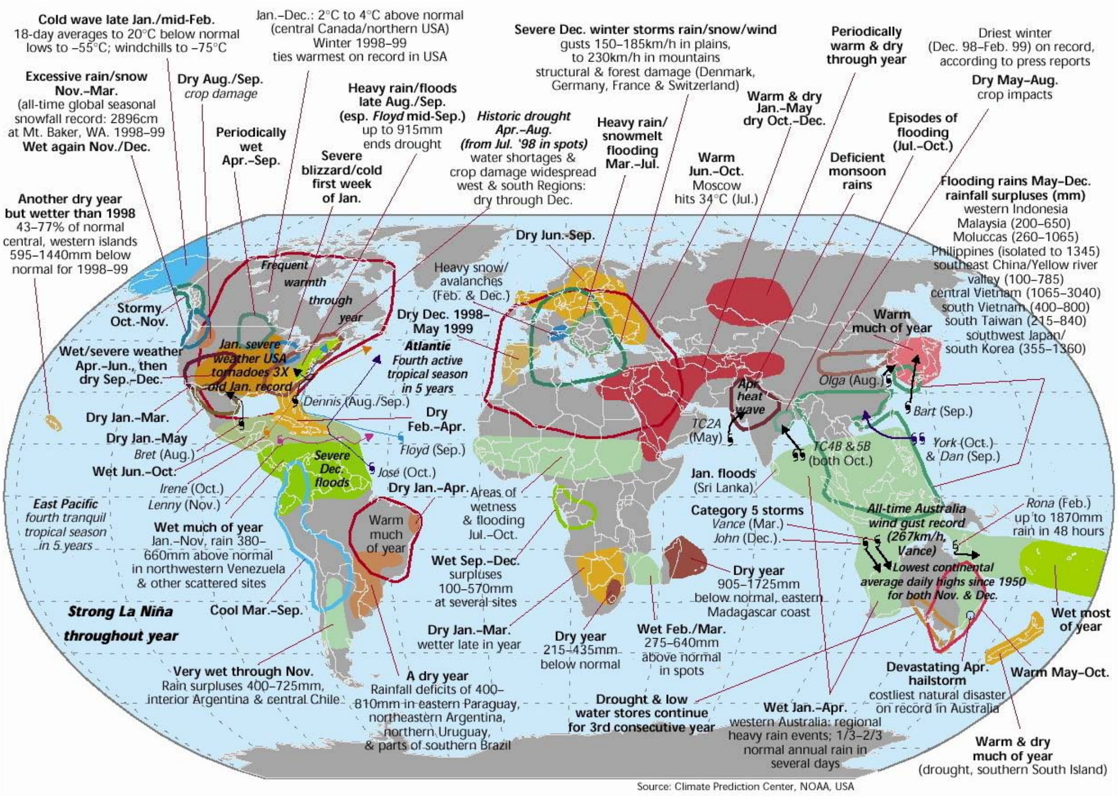

Figure 8 – Major global climate anomalies and episodic events in 1999.

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