

# GLOBAL CLIMATIC CHANGE AND PAKISTAN'S WATER-RESOURCES

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## ABSTRACT

*The rapid growth in the use of water in the last half century has resulted in universal awareness of the limited stocks of fresh water and, in the light of the increasing demands, the need for conservation. There is also a realisation that international climate-change may have some influence on the water availability picture of the future.*

*Because of its geographical location, Pakistan is mostly an arid and semiarid country. However, it is fortunate to have 3 major rivers (the Indus, Jhelum and the Chenab) flowing from the bordering region to sustain irrigation and hence agriculture. The use and development of the potential of Indus River, the major contributor (above 60%), has been central to sustaining agriculture. The Indus is basically a snow-fed river; because of global warming, the extent of snow cover is rapidly decreasing, and this may affect its base-flow. A macro-scale hydrological model for river-flow suggests that the runoff of the Indus will decrease by 27% by the year 2050.*

*Pakistan's population is increasing at a rate of about 2.6% p.a. and the use and demand of water is increasing faster. Additional demand for water will come from the anticipated improvements in the standard of living, through greater economic activity. Increase in industrial activity will also require additional water. Our underground water-resources are already being exploited to the maximum. Increase in sustainable water-resources in the country can be achieved through a combination of groundwater-aquifers and large and small surface-water facilities. This combination will be critical to meeting the water needs of the twenty-first century.*

*Incorporating realistic scenarios of water-resources is a fundamental element of sustainable development. Water-resources and climate change not only affect agriculture, but they also affect urban centres, industry and human health. Management of water-resources requires a balanced and careful review of current knowledge under a comprehensive framework.*

## INTRODUCTION

The recent dry years, particularly in the south of the country, and the resulting water-crisis has raised our awareness of the changing climatic conditions in the country and in our region. It has also shown our weakness in understanding and anticipating climatic problems, especially when there is little or no indication of it in our past experience. Our behaviour, for the most part, has been reactive rather than anticipatory. The crisis cannot be addressed fully in the long-term, without some understanding of the dynamics and relationship between our water-resources, the local weather, the regional weather and the global climate change.

In this paper we will try to see if there is a perceptible climatic change; if so, how will it affect our present and future water-resources.

Before we move forward, it is necessary to define the climatic region in which Pakistan is situated. Pakistan is situated in the Near East region. According to the FAO Regional Office, the Near East extends from the Atlantic Ocean (Mauritania and Morocco) in the west to Pakistan and Kyrgyzstan in the east and from Turkey and Kazakhstan in the north to Somalia in the south<sup>1</sup>. It falls between longitudes 17° west and 80° east and latitudes 43° north and 2° south. The Near East comprises 29 countries, with a total area of 18.5 million km<sup>2</sup>, which is about 14% of the total area of the world. Because of the aridity prevailing in the region, the Near East is the poorest region in the world, in terms of water-resources. Irrigation covers 47.7 million hectares in the region. Pakistan alone, covering a little over 4% of the region, accounts for 33% of the irrigated areas. By adding Iran, Turkey, Iraq and Egypt, 72% of the areas under irrigation are controlled by five of the 29 countries, covering only 25% of the Near East. Pakistan and Egypt are fortunate countries because they have rivers flowing from the bordering and more humid regions, tropical Africa (the Nile) and Himalayan Asia (the Indus). Thus, Pakistan's water-resources are greatly influenced by climatic changes in its region and also in the neighbouring regions.

These water-resources are also affected by climate changes in the world at large.

The question is; is there a significant change in climate of Asia, in general, and near east, in particular, to warrant such a concern?

Listed below are some of the facts that have been making headlines in recent years in Asia:

1. Lhasa, Tibet: Warmest June on record, 1998. Temperatures hovered above 77 degrees Fahrenheit for 23 days.
2. Himalayas, India: Glacial retreat at record pace. The Dokriani Barnak Glacier retreated 66 feet in 1998, despite a severe winter. The Gangorti Glacier is retreating 98 feet per year. At this rate, scientists predict the loss of all central and eastern Himalayan glaciers by 2035.
3. Tien Shan Mountains, China: Glacial ice reduced by one quarter in the past 40 years.
4. Middle East: Severe drought has affected many parts, including Iran, Iraq and Jordan. Rainfall in parts of Iran is down by 25% compared to 1999; eighteen of the country's twenty-eight provinces are suffering.

In Iraq the Tigris and Euphrates rivers have fallen to around 20% of their average flow, with serious consequences for irrigated farming. Jordan's agricultural production has been severely damaged by two years of drought.

Most countries in Middle East are suffering the consequences of prolonged water-shortages, dating from last two years. The evidence listed above shows that the recent dry years in Pakistan were not individual events; the whole Near East region is suffering. It is also implied that whatever changes are taking place have reasons beyond the immediate zone. Before evidence of overall global change is considered, it is important to understand that to explain climate change it is important to have:

- a. A picture of what happened over the whole earth, as against a single country, or region, or hemisphere;
- b. Weather-data from at least several years, to allow temporal and geographic patterns to be distinguished; and
- c. A perspective that encompasses all aspects of the weather.

## GLOBAL CLIMATE CHANGE

### The Global Temperature Increase

Globally, the 1990s were the warmest decade and 1998 the warmest year in the instrumental record, since 1861. New analyses of proxy data for the Northern Hemisphere indicate that the increase in temperature in the 20th century is likely to have been the largest of any century, during the past 1,000 years. Because fewer data are available, less is known about annual averages prior to 1,000 years before the present.

On the average, between 1950 and 1993<sup>2</sup>, nighttime daily minimum air temperatures over land increased by about 0.2°C per decade. This is twice the rate of increase in daytime daily maximum air temperatures (0.1°C per decade). This has lengthened the freeze-free season in many mid- and high latitude regions. The increase in sea-surface temperature over this period is about half that of the mean land-surface air temperature. Arctic sea ice has decreased since 1973, when satellite measurements began. Since the start of the satellite record in 1979, both satellite and weather balloon measurements show that the global average temperature of the lowest 8 kilometers of the atmosphere has changed by +0.10°C ± 0.05 per decade, but the global average surface temperature has increased by +0.15 ± 0.05°C per decade. The record shows a great deal of variability; for example, most of the warming occurred during the 20th century, during two periods, 1910 to 1945 and 1976 to 2000.

The Earth may have warmed by an average of more than 1.7 degrees over the past 150 years, according to an analysis of the University of Wisconsin study of the freeze-and-thaw records for lakes and rivers in the Northern Hemisphere. Researchers found that the annual freeze of 26 bodies of water in North America, Asia and Europe shifted *later* by about 8.7 days over the last century and a half, while the spring ice break-up came an average of about 9.8 days *earlier*. The study found very strong evidence of a general warming from 1845 to 1995 in areas where there is ice cover. The change in the ice-on and ice-off days found in the study corresponds to an air temperature warming of about 1.8°Cdegrees over the 150-year period.

## Reasons For Global Temperature Increase

### (i) *Variation of Solar output*

The Sun is the primary source of energy responsible for governing both the weather and the climate of Earth. For that reason, the amount and type of energy the earth received from the Sun could alter weather and climate on the earth. Our Sun is not a constant star and variations in the energy that the Earth receives from the Sun, both in the form of total electromagnetic radiation and other types of energy, such as outflows of charged particles, are well documented. The variations in solar energy outflow are generally cyclic, with periodic times ranging from the 27-day solar rotation period, through the 11-year and 22-year solar activity periods. Solar luminosity is closely linked to sunspot activity, which waxes and wanes over a cycle that lasts 10 to 11 years. Research shows that total solar irradiance, or the total radiant power received by the Earth from the sun, was about 0.036 percent higher in 1996 than in 1986.

Meteorological and climatic data suggest that there are significant responses in the Earth's atmosphere and oceans to the variability of the Sun, in the form of drought cycles, variations in global sea-surface temperatures, etc., but the direct relation of the Earth's response to solar variations cannot be proven.

The energy received from the sun (The solar constant  $S$ ) varies due to a number of reasons; these include changes in the average distance between the Earth and the Sun, the tilt of the earth and precession. The eccentricity expresses to what extent the Earth's orbit around the Sun differs from a circle. The angle of tilt of the earth's axis of rotation varies between  $22^\circ$  and  $24.5^\circ$ , with a periodicity of about 40,000 years. The maximum change in energy received from the sun  $S$  associated with variation in eccentricity is about 0.1%. The eccentricity is just one of three orbital parameters that influence seasonal and latitudinal changes in short-wave radiation reaching the Earth. Precession is another one; it is the change of direction in space of the earth's axis of rotation. The axis changes direction with a periodicity of about 22,000 years

All the above-mentioned components of the orbit vary because of the gravitational attraction between the earth and the other planets. The orbital changes are known as Milankovich orbital changes<sup>3</sup>. He did put

forward the theory that the periodic changes of climate between glacial and interglacial are related to the orbital changes of the earth. However they are only important for climate changes on very long timescales. Hence, when modelling for short time-scales, solar constant (energy received from the sun) can be handled as a true constant.

### (ii) *The Greenhouse Effect*

The greenhouse effect is produced as certain gases allow incoming solar radiation to pass through the Earth's atmosphere, but prevent part of the outgoing infrared radiation from the earth's surface and lower atmosphere from escaping into outer space. Greenhouse gases include water vapour, carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), halogenated fluorocarbons (HCFCs), ozone ( $\text{O}_3$ ), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs). Major sources of greenhouse gases include the burning of fossil fuels (gas, oil, and coal), forest destruction, and agriculture. The average concentration of  $\text{CO}_2$  was about 290 ppm (parts per million) in pre-industrial times; in 1990 it was about 350 ppm and is increasing steadily at a rate of 0.3-0.4%/yr. Since  $\text{CO}_2$  is chemically inert, the photochemical or chemical processes in the atmosphere do not destroy it; it is either lost by transfer into the ocean or biosphere, or it builds up in the atmosphere. The concentration of methane, another greenhouse gas, has more than doubled in the same period.

To predict climate change, one must make a model of the climate. One test of the validity of predictions is the ability of the climatic models to reproduce the climate, as we see it today. Elements of the models, such as the physics and chemistry of the processes that we know or think we know, are essential to represent in the models. Therefore, the models have to embody the characteristics of the land and the oceans that serve as boundaries of the atmosphere represented in the models. Models also have to take into account the radiative characteristics of the gases that make up the atmosphere, including the key radiative gas, water vapour that is so variable throughout the atmosphere.

A number of climatic models have been developed and one of the most detailed is a General Circulation Model (GCM) developed by the Goddard Institute for Space Studies (GISS). A GCM uses extremely high-speed computers to solve the basic equations

governing atmospheric motions and processes by numerical techniques. One test of the model occurred in June 1991; the Mount Pinatubo volcano erupted and sent 25 to 30 million tons of sulphur dioxide into the stratosphere. There, the sulphur dioxide reacted with water vapour to produce a long-lasting haze of sulphuric acid droplets. The GISS group inserted the new information into the model, estimated how much sunlight the Pinatubo aerosol cloud would block, and predicted that the global temperature would drop about 0.3 degree Centigrade. The predicted change actually occurred. Although these successful climate predictions are encouraging, most scientists agree that much remains to be done to improve climate models before we will be able to predict future climate in a credible manner.

(iii) *EL Niño and LA Niña*

El Niño phenomenon is the result of persistent higher Sea Surface Temperatures (SSTs) in the central and eastern tropical Pacific; the magnitude of the warming determines the magnitude of El Niño. In 1997, Sea Surface Temperatures recorded in some of these tropical Pacific waters were more than 5°C (9° F) higher than their average value. Records of past climate reveal that El Niños have been a recurring feature of the earth's climate for thousands of years; however they have now become more persistent.

El Niños are often preceded or followed by the opposite phase, dubbed La Niña, when surface temperatures in the tropical Pacific Ocean are systematically lower than the long-term average. A corresponding modulation in the general circulation of the global atmosphere – called the Southern Oscillation – is also closely allied with these ocean changes. The name, which is widely used by scientists to refer to the three together, is the El Niño-Southern Oscillation phenomenon, or ENSO.

El Niño is the warm phase of ENSO, and La Niña the cold. Both involve the tropical oceans and the atmosphere, and the exchange of energy between the ocean surface and the air above it. The ocean and the atmosphere are linked together, interactively, and each affects the other. Atmospheric winds push the ocean currents and help determine the patterns of sea surface temperature. But Sea Surface Temperatures, at the same time, help determine the force and direction of winds and atmospheric circulation, by adding heat or

taking it away, chiefly by shifting the places where tropical thunderstorms preferentially occur. The warmest large-scale pool of ocean water in the world is normally found in the vicinity of Indonesia – south of China and north of Australia. El Niño shifts the location of the warm water pool over 3200 km (2000 miles) eastward. When water vapour condenses and falls as rain, the heat that was stored when the water was originally evaporated is released into the air. Because of this, the major shift in the location of tropical pacific rainfall that accompanies an El Niño alters the heating patterns of the whole atmosphere; their effects reach beyond the tropics into mid-latitude regions. In the end, winds and storm tracks and the jet stream are all perturbed, in ways that affect, to some degree, almost everyone on Earth.

When La Niña takes control, the situation changes. Areas with drier than normal or even drought conditions during El Niño, such as Indonesia, the Philippines, Australia, Southeast Asia, Hawaii, and parts of Africa, Asia and Brazil, are apt to experience heavy rains during La Niña. Meanwhile, areas that have experienced El Niño floods, such as Peru, Ecuador, Uruguay and northern Argentina in South America, parts of Africa, and southern parts of the U.S. in winter, are apt to be drier than normal during the ensuing La Niña phase. We know from past occurrences that what might be called a "mini global warming" accompanies each El Niño, with the highest air temperatures typically occurring a few months after the peak in ocean surface warming. The record-breaking and long-lasting El Niño of 1997-98 began in April of the first year and persisted until May of the next. It almost certainly contributed in establishing 1998 as the world's warmest year on record. It is estimated to have cost a staggering sum of \$89 billion<sup>4</sup>. In addition to material losses; these weather-related events had taken an estimated 32,000 lives, while displacing 300 million people. These estimates do not include the losses incurred because of the ensuing drought in Asia.

**Changes in Climate Due to Temperature Increase**

(i) *Effect on Rain Fall*

Although the precipitation has increased by 0.5 to 1% per decade in the 20th century, over most mid- and high latitudes of the Northern Hemisphere continents, and the rainfall has increased by 0.2 to 0.3% per decade over the

tropical (10°N to 10°S) land areas, rainfall has decreased over much of the Northern Hemisphere sub-tropical (10°N to 30°N) land areas during the 20th century by about 0.3% per decade (this is in the region in which most of Pakistan is situated). In contrast to the Northern Hemisphere, no comparable systematic changes have been detected in broad latitudinal averages over the Southern Hemisphere. There are insufficient data to establish trends in precipitation over the oceans.

In the mid- and high latitudes of the Northern Hemisphere over the latter half of the 20th century, there has been a 2 to 4% increase in the frequency of events of heavy precipitation. Increases in heavy precipitation events can arise from a number of causes, e.g., changes in atmospheric moisture, thunderstorm activity and large-scale storm activity. In most areas, there is an observed decrease in daily temperature range. Since 1950, there has been a reduction in the frequency of extreme low temperatures, with a small increase in the frequency of extreme high temperatures.

(ii) *Snow Cover And Ice Extent*

Satellite data show that there have been decreases of about 10% in the extent of snow cover since the late 1960s. Ground-based observations show that there is very likely to have been a reduction of about two weeks in the annual duration of lake and river ice cover in the mid- and high latitudes of the Northern Hemisphere, over the 20th century. There has been a widespread retreat of mountain glaciers in non-polar regions during the 20th century. Northern Hemisphere spring and summer sea-ice extent has decreased by about 10 to 15% since the 1950s. There has been a decline in Arctic sea-ice thickness of about 40% in recent decades and a considerably slower decline in winter sea-ice thickness.

It may be remembered that increase and decrease in ice-cover does not depend on winter temperature. It is the summer temperature that determines the extent of ice cover. If the summer is warm, all the accumulated ice is melted and the ice cover decreases or remains constant, however, if the summer is mild, the previous season's ice is carried over to the next season and the ice cover increases.

(iii) *Sea Level Rise and Ocean Heat Content:*

Tide-gauge data show that global average sea-level rose between 0.1 and 0.2 meters during the 20th century. Global Ocean heat-content has increased since the late 1950s, the period for which adequate observations of sub-surface ocean temperatures have been available. The average temperature of the Atlantic, Pacific and Indian Oceans has risen 0.06 degrees C since 1955.

## EFFECT OF GLOBAL WARMING ON WATER-RESOURCES

**G**lobal weather changes and water-resources are deeply inter-related. The largest source of freshwater is rain. Global climatic changes will have major effects on precipitation and runoff. In the relatively arid and semi-arid regions, modest changes in precipitation can have proportionally large impacts on water supplies. In mountainous watersheds, higher temperatures will increase the ratio of rain to snow, accelerate the rate of spring snowmelt, and shorten the overall snowfall season, leading to more rapid, earlier, and greater spring runoff. Because the temperature projections of climate models are less speculative than the projections of precipitation, temperature-induced shifts in the relative amounts of rain and snow and in the timing of snowmelt in mountainous areas are considered highly likely. Climate-induced changes in hydrology will affect the magnitude, frequency, and costs of extreme events, which produce the greatest economic and social costs to humans. Flooding could become more common and extreme. Recent reports of the Intergovernmental Panel on Climate Change (IPCC) suggest that a greenhouse warming is likely to increase the number of intense-precipitation days as well as flood-frequencies in northern latitudes and snowmelt-driven basins. These reports also suggest that the frequency and severity of droughts could increase in some areas, as a result of a decrease in total rainfall and more frequent dry spells.

## EFFECTS OF GLOBAL WARMING IN THE ASIAN REGION

**T**he Asian region that spans polar, temperate, and tropical climates and is home to over three billion people, is a particular concern as far as effects of global warming are concerned. As climate warms,

many mountain glaciers may disappear and the northern forests may shift further north. A report by Intergovernmental Panel on Climate Change (IPCC) sponsored by UNEP predicts that the major impacts in Temperate Asia under global climate change are projected to be: large shifts of the boreal forests, the disappearance of significant portions of mountain glaciers and shortages of water supply. The most critical uncertainty in these estimates stems from the lack of credible projections of the hydrological cycle under global climate change scenarios.

The effects of climate change on the Asian monsoon and the El.Niño/Southern Oscillation (ENSO) phenomenon are among the major uncertainties in predicting the water picture in the region. The positive ENSO phase of the pattern (wet south and dry north) is promoted by warm Sea Surface Temperatures in the tropical Pacific and Indian Oceans. A rather abrupt change in the El Niño - Southern Oscillation behavior occurred around 1976/77 and the new regime has persisted. There have been relatively more frequent El Niño episodes, compared to La Niña. This behavior is highly unusual in the last 140 years (the period of instrumental record).

Although global temperature increase has occurred over the last century, clear signs of its effects appeared in the late 1970s, with the more frequent appearance of El Niños. A given explanation is that, although present, the global warming influence was, until that time insufficient to perturb the normal working of the climate system: its capacity to affect the overall behavior of the climate system was reached only after a certain threshold had been passed.

The major risk from the climate change in south Asia is increased summer precipitation intensity in temperate regions; this may increase flash-flood prone areas. Of all natural disasters, floods are the most destructive; in terms of human life they account for over 50 % fatalities (58% deaths were due to floods in the decade 1988-1997). In terms of economic loss, they account for one third. On the other hand, the arid and semi arid regions would be drier in summer, which could lead to severe droughts.

The Himalayas have a critical role in the provision of water to continental monsoon in Asia. Increased temperatures and increased seasonal variability in precipitation are expected to result in increased recession of

glaciers and increasing danger from glacial lake outburst floods. A macro-scale hydrological model for river-flow suggests that the runoff of the Indus will decrease by 27% by the year 2050<sup>5</sup>. This implies that the availability of fresh water in Pakistan is highly vulnerable to climate change.

A reduction in average flow of snow-fed rivers, coupled with an increase in peak flows and sediment-yield would have major impacts on hydropower generation and agriculture. Availability of water from snow-fed rivers may increase in the short term, but decrease in the long-run. Runoff from rain-fed rivers may also change in the future. A reduction in snowmelt water will put the dry-season flow of these rivers under more stress than is the case now, especially in Pakistan where one major snow-fed river, the Indus, accounts for as much as 80 % of the normal water flow. Increased population and increasing demand in the agricultural, industrial and hydropower sectors will put additional stress on water-resources.

## RIVER-FLOW DATA OF PAKISTAN

According to the global warming scenario presented earlier, the global warming should be reflected in the river-flow data of Pakistan, especially in the nineties. From the data available from 1975 to 2000<sup>6</sup>, the following picture emerges. In the post-Tarbela era, the water diverted from the rivers to the canal system has remained constant around 104 MAF per year (128  $\text{km}^3$ ). The fresh-water outflow to the sea may, therefore, be considered to be a good indication of the total river flow for this period. From the year 1975/76-1989/90 the average flow into the sea per year has been 34.13 MAF/year. However from the year 1990/91 to 1999/2000, this flow has been 47.88 MAF/year i.e. about 40 % greater. (Table-1) For the winter season for the same period, the average flow into the sea from the year 1975/76-1989/90 was 1.86 MAF/year. However from the year 1990/91 to 1999/2000, this flow has been 3.28 MAF/year, i.e. about 76 % greater. Although other factors may also be contributing, nevertheless the change visible in this time-frame is quite large. This increased river-flow could be taken as evidence for local effect of global warming. The global warming is expected to initially cause the river-flow to increase as the glaciers melt, then decrease as they recede. One more fact that emerges from the data listed in table-1 is that when there is an excessive amount of water in kharif season, the succeeding rabi season also has more water than usual; this

increased water-availability in rabi could be of greater moisture.  
due to increased rains because of local effect

**Table – 1: Fresh-Water Outflow to the Sea**

Year	Kharif	Rabi	Total
1975-76	37.8	1.5	39.3
1976-77	64.1	5.0	69.1
1977-78	29.0	1.4	30.4
1978-79	75.0	5.6	80.6
1979-80	29.4	0.4	29.8
1980-81	18.7	1.4	20.1
1981-82	35.5	0.3	35.8
1982-83	9.4	0.3	9.7
1983-85	43.5	2.1	45.6
1984-85	25.1	0.9	26.0
1985-86	10.9	0.0	10.9
1986-87	26.7	0.2	26.9
1987-88	17.5	0.1	17.6
1988-89	44.2	8.7	52.9
1989-90	16.9	0.4	17.3
Average flow till 1990	<b>34.13</b>	<b>1.86</b>	<b>34.13</b>
1990-91	38.2	4.1	42.3
1991-92	50.1	3.2	53.3
1992-93	69.2	12.3	81.5
1993-94	28.5	0.6	29.1
1994-95	88.2	3.7	91.9
1995-96	44.8	1.6	46.4
1996-97	61.1	0.7	61.8
1997-98	16.6	3.8	20.4
1998-99	32.6	0.1	35.3
1999-00	8.7	0.1	8.8
<b>Average for the 90's</b>	<b>47.88</b>	<b>3.28</b>	<b>47.88</b>
<b>Overall Average for 25 years</b>			<b>39.3</b>

#### Variation of Rainfall Between 1931-90

An overall increase in rainfall of 50-150mm<sup>7</sup> has been observed in the monsoon belt for the period 1931-90. However, a decrease in rainfall was seen in the rest of the country. The decrease is 50-100 mm in western and northern mountains, whereas in the southeastern and central parts it is 25-50 mm. These variations are in line with the predictions made on the expected effects of global warming. Global warming is expected to cause drier south and wetter north.

Changes in El.Nino/Southern Oscillation (ENSO) also affect Asia, especially the monsoon. Based on the monsoon rainfall pattern from 1901 to 90, a strong El Niño event causes poor or below normal rainfall in Pakistan. However, when a strong El Niño year is followed by another strong El Niño year, the rains return to normal or above

average. When a strong El Niño is followed by a moderate El Niño in the succeeding year, the monsoon activity is reduced. Most of the floods in Pakistan were recorded in the La Niña years (Appendix-1). The predominance of El Niño in recent years may be one of the causes of the recent dry years.

#### Identifying the Crisis Facing Pakistan

The persistent failure of rains in recent years has lead to persistence of droughts in most of the country. Droughts in one country or region also effects neighbouring regions that otherwise are supposed to make surplus water available for inter-basin transfers in the flood seasons. Increase in persistency of drought requires a re-examination of our assumptions, operating norms and contingency measures for existing and planned water-management measures. Droughts produce the additional burden of migration of population from

neighbouring regions into lands that are already stretched to the maximum. Besides the social disruptions, there is the cost of the degradation of the natural resources due to the over-exploitation.

A United Nations report in 1997 determined each member country's ratio of water-consumption to water-availability, in order to gauge the overall pressure on its water-resources. The report predicts that moderate to high water-stress translates to consumption-levels that exceed 20 per cent of available supply. In Pakistan, this ratio has already exceeded 65 percent! Water-use in agriculture is projected to increase as our food-demand rises. World-wide, agriculture accounts for about 70 per cent of water-consumption; in Pakistan, its share is already 95%. Future projects show a 50- to 100-percent increase in demands for irrigation water by 2020.

Better management of water-resources is the key to mitigating water-scarcities in the future in the short-term, and avoiding further damage to aquatic ecosystems. More efficient use of water could dramatically expand the available resources. In the longer term, however, the looming water-crises must be addressed through hard policy-decisions that reallocate water to the most economically and socially beneficial uses. Far greater emphasis on water-efficient technologies and control of pollution is also essential. In Pakistan, about 50 per cent of irrigation-water never reaches the crop and is lost to evaporation or runoffs. However, even with measures to contain the growth of demand and use of water more efficiently, new supplies will be needed. The financial and environmental costs of tapping new supplies will be, on average, two or three times those of existing investments, because most of the low-cost, accessible water reserves have mostly been exploited.

If the problems facing Pakistan, with respect to water, were to be *short-listed* they would constitute the following main points:

- a. Resource deficit
- b. Depletion of aquifers, by lowering of water-tables;
- c. Wastages, in the form of runoffs;
- d. Climate change;
- e. Wasteful agricultural practices;
- f. Water-logging and salinity;
- g. Low level of awareness to importance of fresh water;
- h. Water shortages in the urban areas.

Any water policy that fails to address these concerns will be piecemeal and, in the end, may aggravate the situation.

- Future development in Pakistan may be severely constrained, because we have neither the extra water nor the financial resources to shift development away from intensive irrigation and into other sectors that would create employment and generate income to import food. The present water-scarcity gives an idea of the future vulnerability of Pakistan to absolute a water-scarcity. Under all scenarios, including the most optimistic, there is a dearth of fresh water. Climate change, as a result of global warming will further constrain our resources.
- This thirst for water necessitates broad thinking and drawing up a research agenda that would address these concerns and would contribute towards agricultural productivity, sustainable use of groundwater, introduction of modern technology to expand resources, and making our agriculture more productive with less water.
- The IPCC third assessment on climate change, published in July 2001, states that global warming is happening, and at a much faster rate than was expected, global temperatures are rising nearly twice as fast as previously thought. Their prediction, based on computer models, is that temperatures could rise by as much as 5.8°C by the end of the century. The report stresses that human activity is responsible for this crisis and that industrial pollution, and, in particular, green-house gases emissions are the worst offenders.

## CONCLUSION

**I**n conclusion, it is generally thought that Climate change is a very slow process and the Earth has always been a temperate world. This is far from the case. The Earth has been much hotter and much colder than it is now; actually the past eight thousand years have been a period of unusually stable climate. The current atmosphere that blankets the planet helps to keep the globally averaged surface temperature up to about 15 degrees Celsius. But there is geological evidence that this figure has been down to about 7°C and possibly as high as 27°C<sup>8</sup>. Although we are

currently in a not-so-cold phase of an ice age, "the Quaternary Ice Age", there is evidence from Arctic ice and palaeontological studies that the earth has heated up to as much as

12°C in a span of less than a hundred years a number of times in the past.

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## APPENDIX-1

### La Niña (Cold) and El Niño (Warm) Episodes By Years.

The following published list of cold (La Niña) and warm (El Niño) episodes provides a season-by-season breakdown of conditions in the tropical Pacific. Intensity is classified for each event by focusing on a key region of the tropical Pacific (along the equator from 150°W to the date line). The process of classification is based on using reanalysed sea surface temperature analyses produced at the National Centers for Environmental Prediction/ Climate Prediction Center and at the United Kingdom Meteorological Office. In the following table, weak periods are designated as C- or W-, moderate strength periods as C or W, and strong periods as W+ or C+. A column has been added to the published list to identify flood or high flow years in Pakistan to establish a relationship with these events.

We should note that heavy rainfall is but one of several factors that determine whether or not a flood occurs. The spatial extent of the storm, the total amount of rain, and the rainfall rate are also important, as are the nature and condition of the terrain on which it falls. Geophysical, topographical and vegetation conditions are all involved. Because of these factors, flood records in themselves are not reliable indicators of changes in rainfall.

YEAR	JFM	AMJ	JAS	OND	
1950	C	C	C	C	Floods
1951	C			W-	
1952					
1953		W-	W-		
1954			C-	C	
1955	C	C-	C-	C+	Floods
1956	C	C	C	C-	Floods
1957		W-	W-	W	
1958	W+	W	W	W	
1959	W-				
1960					
1961					
1962					
1963			W-	W	
1964			C-	C	
1965	C-		W	W+	
1966	W	W-	W-		
1967					
1968				W-	
1969	W	W-	W-	W-	
1970	W-			C	
1971	C	C-	C-	C-	
1972		W-	W	W+	
1973	W		C-	C+	Floods
1974	C+	C	C-	C-	
1975	C-	C-	C	C+	High discharge
1976	C			W-	Floods
1977				W-	
1978	W-				Floods
1979					
1980	W-				
1981					High discharge
1982		W-	W	W+	
1983	W+	W		C-	High discharge
1984	C-	C-			
1985	C-	C-			
					<b>Continue....</b>

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1986			W-	W	
1987	W	W	W+	W	
1988	W		C	C+	Floods
1989	C+	C			
1990			W-	W-	
1991	W-	W-	W	W	High discharge
1992	W+	W+	W-	W-	Floods
1993	W	W	W	W	
1994			W	W	Floods
1995	W			C-	High discharge
1996	C-				High discharge
1997		W	W+	W+	
1998	W+	W	C	C	
1999	C+	C	C	C	
2000	C	C-		C-	