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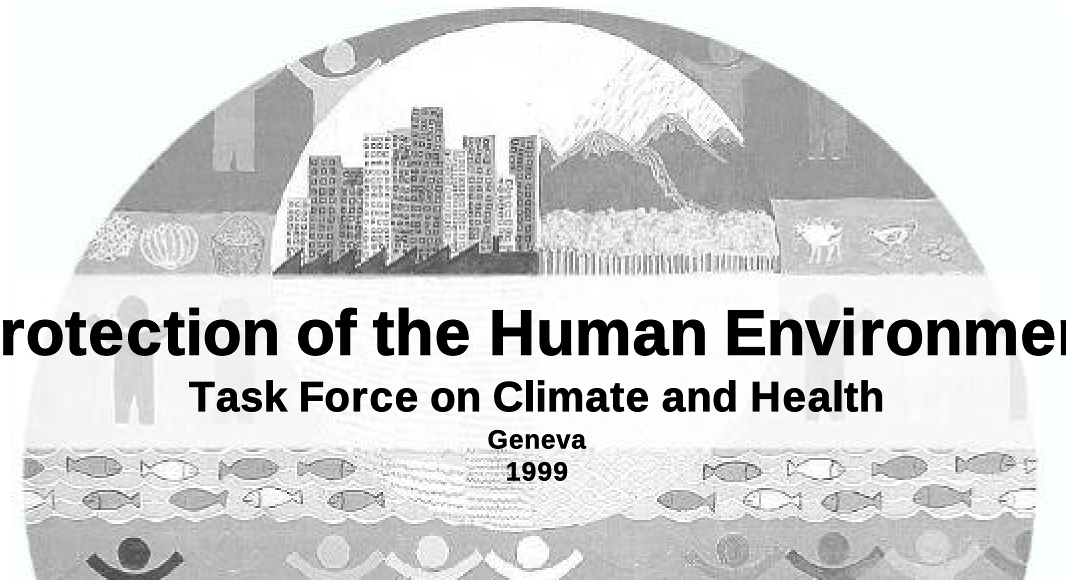

Protection of the Human Environment

Task Force on Climate and Health

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El Niño and Health

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PREFACE

This report was commissioned by the former Offices of Global and Integrated Environmental Health (EHG), and ICO (Intensified Cooperation with Countries in Greatest Need). It accompanies the report "Near-term Health Benefits of Greenhouse Gas Reductions" recently produced by WHO.

It was felt that there was a need to promote awareness at the global, regional and country level of the health impacts of climate variability, and the role of the health sector in addressing such impacts. Focussing attention on the impacts of inter-annual climate variability associated with the El Niño Southern Oscillation (ENSO) phenomenon would also help countries to develop the necessary capacity and preparedness to address the longer-term impacts associated with global climate change.

The report highlights the fact that the ENSO phenomenon has substantial effect on world climate. ENSO is associated with changes in the risk of weather-related disasters like hurricanes and tropical storms, floods and droughts, forest and bush fires, as well as increasing the risk for certain vector-borne diseases, most notably malaria.

The ENSO phenomenon provides opportunities for early warning which should improve disaster and disease outbreak preparedness in the future. Seasonal forecasting methods and information can be used to far greater effect by the health sector. For example the onset and progression of El Niño can now be forecast months ahead, and can give a timely seasonal indicator of malaria risk.

The ENSO phenomenon also provides opportunities to study the effects of longer-term climate change on human health. Long-term climate change may affect El Niño and is very likely to affect the frequency and intensity of weather events. Addressing the health impacts of El Niño can thus lead to reduced vulnerability to the potential health impacts of climate change.

It is hoped that this document will stimulate action regarding forecasting applications in the health sector in order to assist in disaster preparedness. Both the risk of natural disasters as well as that of disease outbreaks needs to be addressed. This will help to strengthen the role of the Ministry of Health in disaster preparedness programmes as well as in disease surveillance and monitoring.

Yasmin von Schirnding
Sustainable Development and Healthy Environments

EXECUTIVE SUMMARY

This report summarises the impacts of El Niño on health and the potential uses of such information. The first section provides background information on the nature of the ENSO phenomenon and the second section describes its impact on world climate in the form of weather-related disasters such as hurricanes and tropical storms, floods, drought and forest/bush fires. Section three summarises the current state of knowledge on the health impacts of El Niño. The relationship between weather-related events and health outcomes is explored with an evaluation of the epidemiological and biological evidence. Section four addresses the potential for seasonal (El Niño) forecasting and the issues in disseminating such forecasts to those who need to know, especially within the health sector. Section five describes some current international initiatives related to ENSO and climate change and section six discusses the conclusions of the report.

The report is aimed at people working in the health sector in developing countries that are affected by El Niño and La Niña. The objective of the report is to identify and promote the use of forecast information within the health sector. It is now possible to forecast the onset and progression of an El Niño months ahead. There is great potential to use these seasonal forecasts to improve public health. Seasonal forecasts are currently used to enhance agricultural productivity and disaster preparedness, particularly as part of famine early warning systems. There is a need for the health sector to improve its capacity in the use of meteorological and climate resources.

The El Niño Southern Oscillation (ENSO) comprises changes in sea surface temperatures in the Pacific Ocean (El Niño) and in atmospheric pressure across the Pacific basin (Southern Oscillation). El Niño events occur irregularly, every 2–7 years. El Niño is associated with extreme weather (floods, drought) in countries surrounding the Pacific and in other parts of the world through distant connections (teleconnections). El Niño begins when the prevailing winds in the Pacific weaken and there is a shift in rainfall patterns. Prolonged dry periods may occur in Indonesia, the Philippines and Northern Australia and heavy rainfall, sometimes associated with extensive flooding, may occur in Peru and Ecuador. El Niño also has an effect on the Asian monsoon and on hurricane activity. In some cases, El Niño (a warm event) is followed by La Niña (a cold event). Global climate anomalies associated with La Niña are generally less pronounced and tend to be the opposite of those that are associated with El Niño.

Changes in precipitation, temperature and hurricane activity all contribute to the effect of El Niño on human health. There is good evidence that El Niño is associated with an increase in the burden of natural disasters in some regions. The intensity of the effect is so great that it has a major effect on the global total of disaster victims.

A growing number of studies have shown that the El Niño cycle is associated with changes in the risk of diseases transmitted by mosquitoes, such as malaria and dengue and other arboviruses. Malaria transmission is particularly sensitive to climate variations. In areas of unstable malaria, populations lack protective immunity and serious epidemics may occur when the weather conditions make transmission possible. In Venezuela and Colombia, malaria cases increase by more than one third following dry conditions associated with El Niño. In south-west Sri Lanka, an historical analysis found a four-fold increase of malaria epidemics during El Niño. Changes in rainfall are probably the most important mechanism by which El Niño has an effect on vector-borne disease transmission. However, in highland areas, such as the Himalayas, higher temperatures may also be significant for malaria transmission, as has been shown in Northern Pakistan.

Preliminary studies have shown a relationship between ENSO and dengue activity in countries where ENSO has a strong effect on the weather, for example, some Pacific island nations and Indonesia. Many factors affect dengue activity in addition to mosquito abundance, such as the immune status of the population. There is evidence that some arboviral diseases in Australia, where El Niño has a strong effect on the weather, are effected by the ENSO cycle: Murray Valley (Australian) Encephalitis and Ross River Virus disease.

Outbreaks of Rift Valley Fever (RVF) (an arboviral disease primarily affecting cattle) in eastern Africa, always follow episodes of heavy rainfall. RVF outbreaks are associated with ENSO (SOI and SST anomalies). However, a high negative value of SOI is not always associated with heavy rainfall in the region. To improve the predictive value of this relationship, real-time satellite data can be used to identify the locality of RVF activity. A serious outbreak of RVF occurred following very heavy rainfall in north-eastern Kenya and southern Somalia during the 1997/1998 El Niño event. The rainfall patterns were unusually heavy for El Niño and the serious flooding was also associated with major outbreaks of malaria and cholera.

El Niño may affect rodent-borne diseases. Populations of some rodents have increased during El Niño, for example, the deer mouse (a reservoir for hantaviruses) in the southern US. There is suggestive evidence of an increase in hantavirus pulmonary syndrome in the US in association with El Niño.

There is an association between the cases of Ciguatera fish poisoning and El Niño in some islands in the South Pacific. Ciguatera poisoning is due to the accumulation of plankton biotoxins in reef fish and is sensitive to sea surface temperatures. Recent studies have further shown that plankton may act as a reservoir for cholera. Increased sea surface temperatures may therefore facilitate transmission of cholera in coastal areas. There is suggestive evidence that this has occurred in the Bay of Bengal. However, further studies are needed to elucidate a relationship between El Niño and cholera.

The majority of deaths and diseases that are associated with El Niño can be attributed to weather-related disasters. There is also often substantial damage to the public health infrastructure in affected countries. In Peru nearly 10% of all health facilities were damaged during the 1997/8 El Niño.

Large forest fires and the associated haze pollution are becoming an increasing problem that is associated with El Niño. Smoke inhalation from forest fires was a substantial health problem in Malaysia, Indonesia and Brazil in association with the 1997/98 event and caused increased visits to health facilities for respiratory problems.

There is thus good evidence that the ENSO cycle is associated with an increased risk of certain diseases and health-related events. Climate forecasts at seasonal and inter-annual lead times may be of great importance in mitigating future epidemics in regions where a relationship between disease and ENSO has been established. In many countries, vector control measures have failed or resources are too limited to maintain adequate levels of control of vector-borne diseases such as malaria. Seasonal forecasts can give a timely seasonal indicator of disease risk. Seasonal forecasts need to be used and promoted by the health sector in order to prevent disease occurrence and public health disasters in the future.

1. EL NIÑO SOUTHERN OSCILLATION

1.1 What is the El Niño Southern Oscillation?

At a Geography Society meeting in Lima, Peru in 1892, a Peruvian navy captain, Camilo Carrillo gave an account of how the El Niño (Christ child) current got its name… "Peruvian sailors from the port of Paita in northern Peru, who frequently navigated along the coast in small craft, named this current 'El Niño' without doubt because it is most noticeable and felt after Christmas" (Carrillo 1892, quoted in Glantz 1996a). The term El Niño is now reserved for exceptionally strong and prolonged warm periods which have implications for the global climate. This cycle of warming (and cooling) of the eastern Pacific waters is closely mirrored by air pressure deviations in the East and West Pacific — the Southern Oscillation, discovered earlier this century by Sir Gilbert Walker. Walker noticed that when pressure rises in the east Pacific, it usually falls in the west. Walker pioneered the use of statistical methods to link weather anomalies with the Southern Oscillation, including the Asian monsoon, and was one of the first to explore the possibility of seasonal forecasting (Walker, 1936). It was only in the 1960s, that the link was made between the atmospheric Southern Oscillation and the oceanic El Niño — now referred to as El Niño Southern Oscillation (ENSO).

The two extremes of ENSO are El Niño (warm event) and La Niña (cold event). ENSO terminology is often confusing. The term "El Niño" is frequently used to describe all aspects of the ENSO phenomenon. Global climate anomalies associated with La Niña are generally less pronounced and, in some areas, tend to be the opposite of those that are associated with El Niño.

An El Niño begins when the easterly winds, which normally blow from east to west in the Pacific, weaken. The major rain zone is shifted eastwards towards the central Pacific causing a prolonged dry period in Indonesia, the Philippines and northern Australia. The Pacific ocean is warmer along the western coast of South America. The coastal upwelling along this coast is reduced and the nutrient-rich cold waters from the deep ocean no longer appear at the sea surface. Due to the lack of nutrients, plankton production decreases. This has repercussions higher up the food chain, for both fish and sea bird populations. Sea levels on either side of the Pacific are also affected. The behaviour of ocean and atmosphere reinforce each other until a full-scale El Niño is under way.

ENSO events are a strong determinant of interannual climate variability in many countries in Africa, Asia, and in North and South America. During an El Niño, associated climate anomalies called "teleconnections" are felt beyond the Pacific region. These include regional land and sea surface warming, changes in storm tracks, and changes in precipitation patterns.

A significant proportion of the impacts of ENSO on human societies are mediated by precipitation anomalies, i.e. torrential rain or prolonged drought. The climate anomalies were comprehensively described by Ropelewski and Halpert (1987; 1989) following the early work by Walker (Walker and Bliss, 1932). The anomalies illustrated in Figure 1.1 (El Niño) and Figure 1.2 (La Niña) have been derived by scientists at the US National Oceanic and Atmospheric Administration (NOAA). The La Niña phase has been less well studied than the El Niño phase. Teleconnections are derived by averaging the data for several events, therefore, an individual event is unlikely to show all these characteristics. Only 100–150 years of climate station data are available for such analyses, with limited coverage in certain regions.

1.1.1 ENSO parameters

Weather is what we experience on a day-to-day basis. Climate means the "average weather" and its longer-term variability in a given area. ENSO is described as a *climate* phenomenon. However, the exposures for impact studies are meteorological or *weather* data. Studies of the impacts of ENSO use a variety of parameters, both raw meteorological station data (i.e. temperature, precipitation, humidity) or derived meteorological indices.

El Niño or La Niña years. El Niño does not run to the calendar year, and some events go on for more than 12 months. There are differences between climatologists in the definition of El Niño and in the designation of individual events. For example, some researchers have suggested that the 1991 El Niño spanned three calendar years 1991–3, others have suggested it continued into 1995 (Glantz 1996a). The definition of La Niña is even less clear, partly because there have been fewer events.

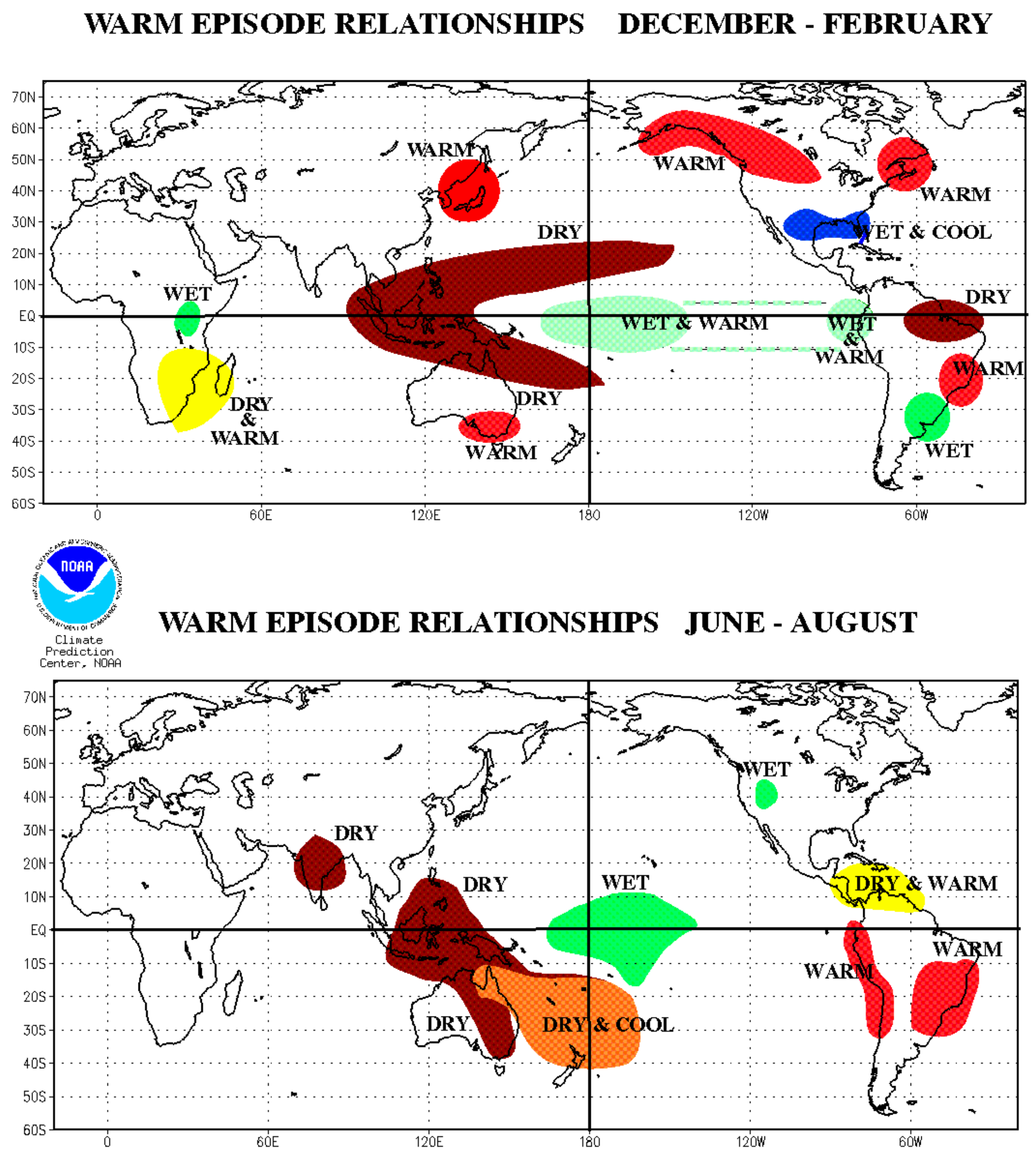


Figure 1.1. Climate anomalies associated with El Niño
These are averaged effects and are likely to differ from the impacts of individual events. These maps should not be used for planning purposes.
Source: NOAA

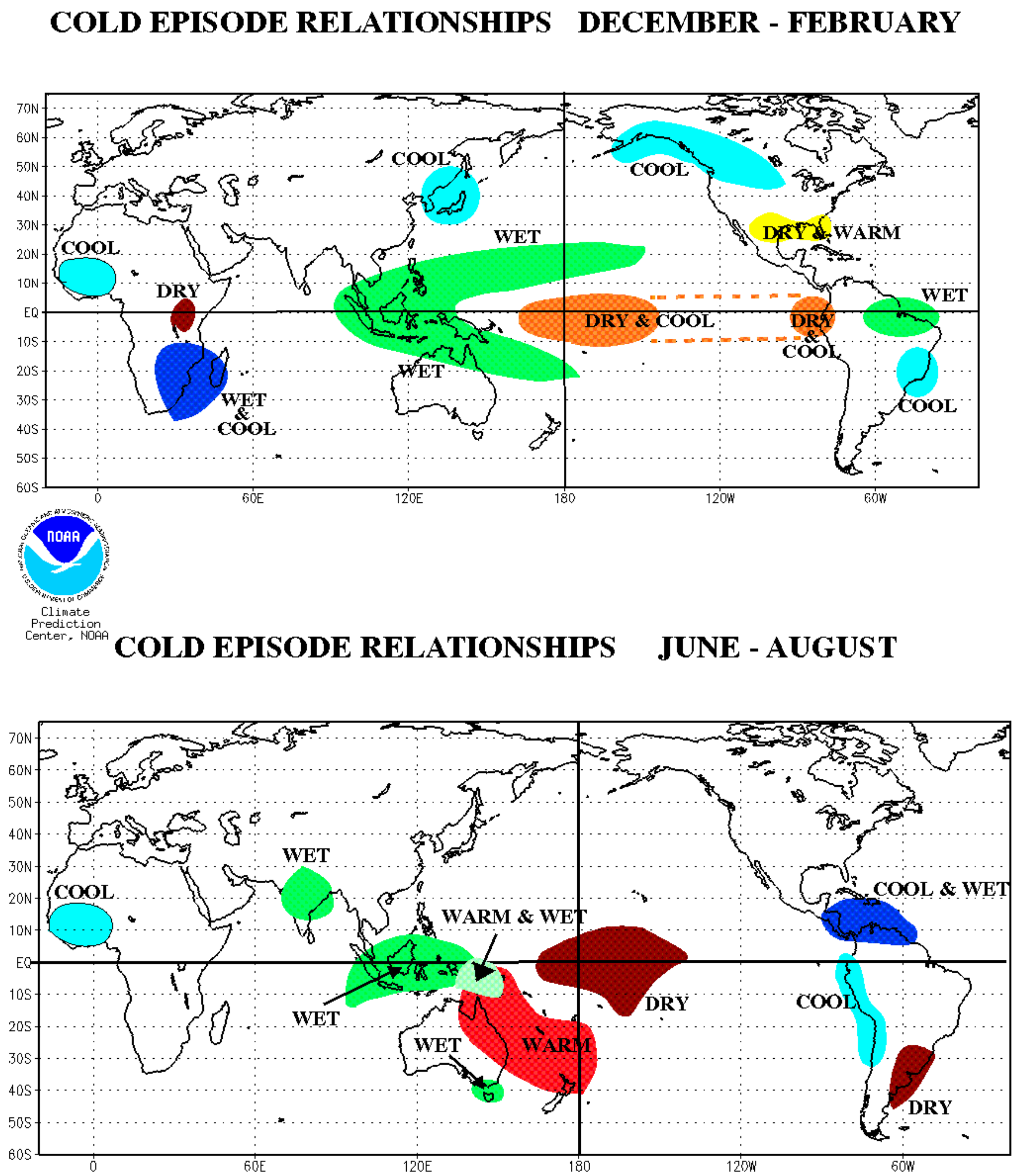


Figure 1.2. Climate anomalies associated with La Niña
Source: NOAA

Sea surface temperatures (SST) in the Pacific. Four geographical regions have been defined in the Pacific (named NINO1 to NINO4). Each region gives different kinds of information about the ENSO phenomenon. SST anomalies are defined as deviations for a specified region from the averaged climate for 1961–1990 (a standard recommended by WMO).

The *Southern Oscillation Index (SOI).* A simple index, defined as the normalized pressure difference between Tahiti, French Polynesia, and Darwin, Australia. There are several slight variations in the SOI values calculated at various centres. The SOI values illustrated in Figure 1.3 were calculated using the method of Ropelewski and Jones (1987). El Niño events are associated with large negative values and La Niña events are associated with large positive values. Although the relationship between El Niño year and SOI values is not perfectly correlated it is very strong.

The *Multivariate ENSO Index* (MEI) has recently been derived by Wolter (Wolter and Timlin, 1998). Bimonthly values from 1950 have been derived from meteorological variables (e.g. sea-level pressure, surface winds, SST, air temperature and total cloudiness). Large positive values are associated with El Niño events and large negative values are associated with La Niña events.

1.1.2 Frequency of El Niño

El Niño is not a new phenomenon. El Niños have been occurring for millennia and individual events have been described back to around 1500 (Quinn *et al.*, 1987; Whetton and Rutherfurd, 1994). No two El Niño events are alike, but most seem to follow a general pattern (Table 1.1). Events usually last for 12 to 18 months, and occur every 2–7 years. Some changes in frequency have been reported over the last 200 years. Events vary in frequency, time of onset, duration, and intensity. Scientists sometimes describe events as: very weak, weak, moderate, strong and very strong, depending on their impacts (Glantz, 1996a). Magnitude can be defined using the strength of ENSO parameters, such as SST deviations or the geographical area covered by the pool of warm water in the Pacific. Very strong events can result in temperatures up to 3.5 ºC above average in the eastern Pacific, with localised warming of up to 9 ºC (Webster and Palmer, 1997).

Table 1.2 lists El Niños this century. As there are no universally agreed criteria for an El Niño (or La Niña) event there is some disagreement between climatologists whether some weak events should be “counted”. The 1982/83 and 1997/98 El Niños were the largest events this century (see below). The catastrophic impacts of the former event, especially in South America, triggered governments and scientists to improve their understanding of the nature and predictability of the ENSO phenomenon. Forecasts of a major event in 1997 lead to collaborative international action including the creation of the UN Interagency El Niño Task Force (see page 28).

Table 1.1 Life cycle of El Niño

Phases of El Niño	Characteristics	Year
Precursor phase	SSTs in east Pacific have returned to normal, easterly trade winds weaken upwelling reduces. =>SSTs begin to increase	-1
Onset phase	Seasonal warming along coast of Peru persists to April or May	0
Growth and maturity phase	SSTs continue to increase. Changes in the Southern Oscillation Index, i.e. pressure drops at Tahiti, and increases at Darwin	0
Decay phase	SST decrease, coastal upwelling strengthens, easterly winds strengthen	1

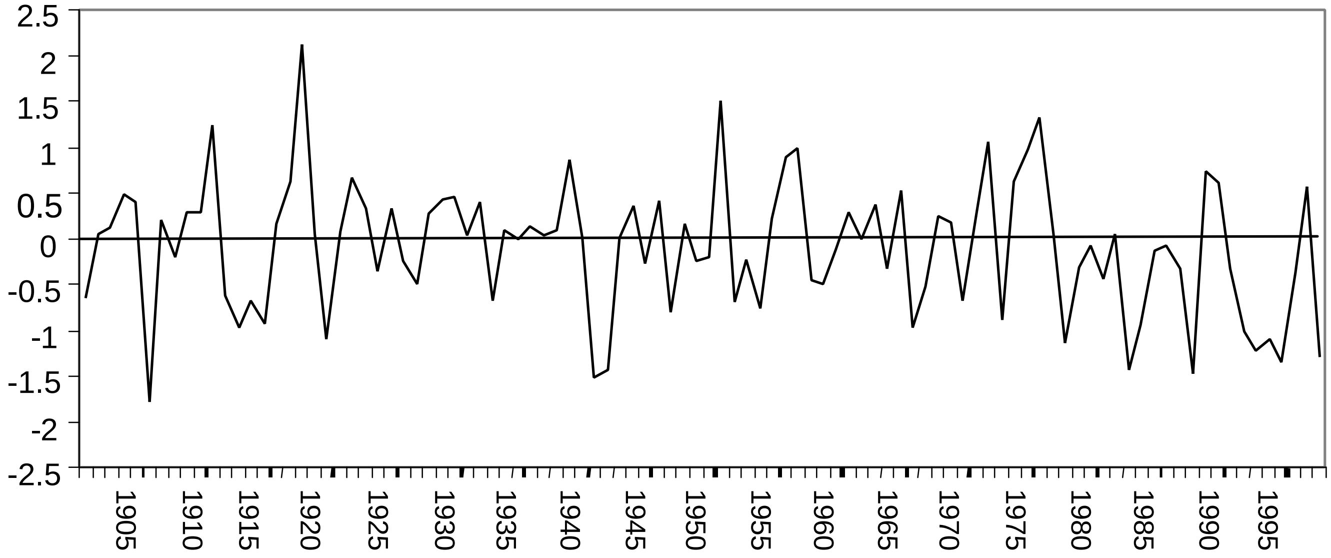
Based on Nicholls, 1987; Glantz, 1996a

Table 1.2 El Niño events this century. Strong events are indicated.

Year	Comments	Year	Comments
1899–1900	very strong	1951	
1902–03	strong	1953	
1905–06		1957–58	
1913–15	strong	(1963)	immature event
1918–20	strong	1965	
1923–24		(1969)*	immature event
1925–26		1972–73	strong
1930–31		1976–77	
1932–33		(1979)	immature event
1939–40		1982–83	very strong
1940–41	very strong	1987–88	strong
1941–42		1991–94	3 separate events?
1946–47		1997–98	very strong

*some disagreement about this event.

Figure 1.4. Southern Oscillation Index: annual values for the years 1900 to 1997.
El Niño events are associated with large negative values; La Niña events are associated with large positive values.
Data from Climatic Research Unit, UK



1.1.3 The El Niño of 1997/98

The 1997/98 El Niño dramatically illustrated the global character of the phenomenon and at the same time clearly demonstrated the promise of seasonal climate prediction. Table 1.3 describes some of the impacts of this event in four South American countries. However, this event was atypical of El Niño in some respects, for example, the monsoon in South Asia usually fails during El Niño but this did not occur.

Intense warming of ocean waters across the eastern and central tropical Pacific developed in March 1997 (WMO, 1998a). The El Niño developed very rapidly during April–May and reached a peak in June 1997. By January 1998, the El Niño began to weaken; the surface area of the warm water pool in the Pacific decreased by 40% since its maximum in the preceding November.

The El Niño was associated with anomalous patterns of rainfall and cloudiness over most of the global tropics, a nearly complete shutdown of the normal easterly winds across the entire tropical Pacific, and abnormal air pressure patterns throughout the global tropics. El Niño impacts were felt in the tropics and subtropics and across the eastern South Pacific and central South America. There was a dramatic decrease in tropical storm and hurricane activity across the subtropical north Atlantic and an expanded area of favourable conditions for tropical cyclone activity in the North Pacific. Kenya was particularly hard hit by flooding, and rainfall surpluses between October 97 and February 98 exceeded 1000 mm in some parts. Very heavy rainfall was also experienced along the coastal regions of Ecuador and Northern Peru. At the other extreme, Guyana, Indonesia and Papua New Guinea were severely affected by drought. The sea level in the Colombian Pacific coast rose by 20 cm.

Table 1.3 Deaths, injuries and disappearances in South America associated with the 1997/98 event and deaths attributed to 1982/83 event.

Country	Impact 97/98	Deaths 82/83	Deaths 97/98*	Injuries 97/98*	Disappeared 97/98*
Bolivia	Intense rains in the Cordillera with roads connecting the capital with Cochabamba and Santa Cruz washed out, freezing temperatures and hail. New outbreak of cholera in La Paz, Cochabamba, and Oruro.	50	43	400	40
Ecuador	Intense rains with flooding along the coast and bridges and roads destroyed. Cases of leptospirosis and cholera detected in the south.	220	183	91	35
Paraguay	Intense rains with flooding of the Paran and Paraguay Rivers. The capital stricken by a tornado accompanied by a storm. Major flooding in the areas, with flooding of homes schools and hospitals.	65	49	--	--
Peru	Intense rains in the northern and Amazon regions of the country with major flooding mudslides and damage to the roadways. Significant increase in the number of cholera cases in the northern region of the country.	380	203	107	No data

*Cumulative to March 1998

Source: PAHO 1998b/Web page. Programa desastres OPS/Ecuador. http://www.salud.org.ec/desastre/

1.2 Long-term climate change and ENSO

Climate change, due to human activities such as fossil fuel combustion, is anticipated to lead to an increase in global mean temperatures over the coming decades and beyond. The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to assess scientific information about climate change relevant for international and national policy formulation. The IPCC Second Assessment report concludes that anthropogenic climate change may have already begun — that there is “a discernible human influence on global climate” (IPCC, 1996). Climate change may affect El Niño and is very likely to affect the frequency and intensity of weather events around the world. Global climate change is likely to have serious impacts on human health (WHO/WMO/UNEP, 1996).

1.2.1 Observed trends

Historical and palaeoclimatic data indicate that ENSO is variable in frequency, duration, and intensity. ENSO teleconnections also vary substantially over time (Kiladis and Diaz, 1989). Assessment of the variability of ENSO is complex and reviewed elsewhere (Diaz and Markgraf, 1992; 1999). There is some evidence that the periodicity of ENSO has varied since the 1950s (IPCC 1996). Some recent ENSO behaviour, especially the long period of negative Southern Oscillation Index (SOI) from 1989 to 1996, is unusual in the 120 year-record (see Figure 1.4) (Trenberth and Hoar, 1996, 1997). However, there is no conclusive evidence that El Niño has become more frequent as a consequence of anthropogenic climate change.

1.2.2 El Niño in a warmer world

In the IPCC Second Assessment Report, climatologists were non-committal about future changes in the frequency and intensity of ENSO events, although it is anticipated the events will still continue to occur (IPCC 1996). However, there may be enhanced precipitation variability associated with ENSO events. The large uncertainty is due to the lack of confidence in representing spontaneous El Niño behaviour in global climate models. Climate model experiments generate ENSO-like SST variability in their simulations of present day climate and continue to do so in projecting climate with increased greenhouse gas concentrations (e.g. Tett, 1995). The results of an experiment where the model was forced with climate change conditions found that El Niño events became more frequent and La Niña events became stronger (Timmermann *et al.*, 1999). Lack of knowledge about future ENSO behaviour is a significant source of uncertainty in assessments of future climate.

2. NATURAL DISASTERS

2.1 Weather events and weather disasters

The criteria vary for determining whether a given event constitutes a disaster. WHO/IFRC/UNHCR (in press) distinguishes between emergencies and disasters. Thus an *emergency* represents a violent disruption of life in a community, and requires that the community affected take special measures to reduce loss of life, adverse impacts on human health, and damage to material goods, homes and infrastructure, and to return living conditions to normal. But a *disaster* occurs if the measures taken by the community fail to reduce losses and to enable a return to normality without substantial external assistance.

Although there are pronounced year-to-year fluctuations in the numbers of deaths due to disasters, a trend towards increased numbers of deaths and numbers of people affected has been observed in recent decades. The increase is likely to be due, in part, to improved reporting or, in some cases, to the desire of governments to attract foreign aid. The rise is also due to the increasing vulnerability of populations. High rates of population growth, which in some areas has led to the concentration of populations in disaster risk zones, is a major contributory factor to this vulnerability. Thus, in large shanty towns habitation is often flimsy and located on land subject to frequent flooding. In many areas, the only land available to poor communities may be marginal land that has few natural defences against weather extremes.

During the past two decades the human impacts of climate-related disasters have been considerable (IFRC, 1998). Floods are the second most frequent cause of a natural disaster after wind storms. However, the highest numbers of persons killed or affected by natural disaster are due to drought and famine. Very large numbers of people have been killed or affected by famines associated with drought, such as the Sahelian famines in Africa in the early 1970s and mid-1980s.

2.2 The ENSO 'disaster cycle'

There is a widely held perception that El Niño and La Niña herald disaster and weather chaos. There is good evidence that ENSO events are associated with an increased risk of natural disasters in certain regions. Two studies have examined the relationship between ENSO and *disasters* associated with drought. Dilley and Heyman (1995) found that, worldwide, disasters triggered by drought are twice as frequent in the year following an El Niño (year +1) as during other years. Figure 2.3 illustrates countries which are more likely to have a drought-related disaster in the year following the onset of El Niño (year +1), based on USAID disaster data 1964–92 (Dilley and Heyman, 1995). Bouma *et al.* (1997a) found that, worldwide, the annual rate of persons affected by natural disasters (1964–93, EM-DAT data) is significantly associated with the ENSO cycle. There is no standard definition for a “disaster”, however, the EM-DAT criteria are at least 10 deaths and/or 200 people affected and/or an appeal for outside assistance. Figure 2.1 shows the total number of persons affected by natural disasters and El Niño years. All El Niño years, with the exception of 1976, are associated with an increase in the number of people affected by natural disasters. Figure 2.2 illustrates the El Niño disaster cycle, with low risk in the years before an El Niño and high risk years during and after an El Niño (years 0, +1). If the differences in the rates are applied to the current world population (1993), the change in population affected by natural disasters is 160 million people. This cycle of risk should be seen in the context of the trend in the increased vulnerability of populations to natural disasters.

Regional analyses show that the impact of ENSO on the number of persons affected by natural disasters is strongest in South Asia. This region contributes more than 50% of all disaster victims due to its high population density and high absolute population.

It is not possible, however, to attribute an individual extreme event with any certainty to El Niño. El Niño increases the likelihood of extreme events occurring
Webster and Palmer, 1997). Regional factors can mitigate or amplify the influences of ENSO events on local conditions. In addition, ENSO-related anomalies are quite localized and inappropriate aggregation of data can easily mask an ENSO signal (Gregory, 1989).

Figure 2.1. Total number of persons affected by natural disasters and El Niño years
El Niño years are indicated by grey bars.
Source: Bouma *et al.*, 1997a.

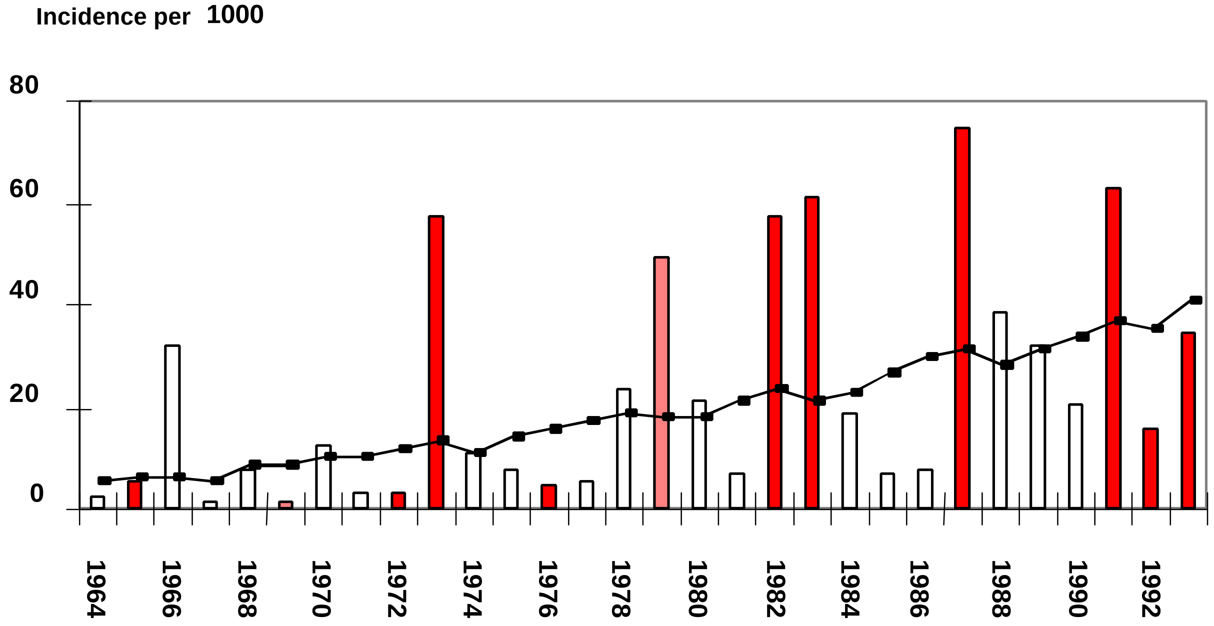


Figure 2.2. ENSO-related disaster cycle.
Deviations from detrended global rates of disaster-affected persons per 1000 population during the six El Nino events between 1964 and 1993 and two years before and two years after the onset of El Nino. Bars represent mean deviation for all six events.
Source: Bouma *et al.*, 1997a.

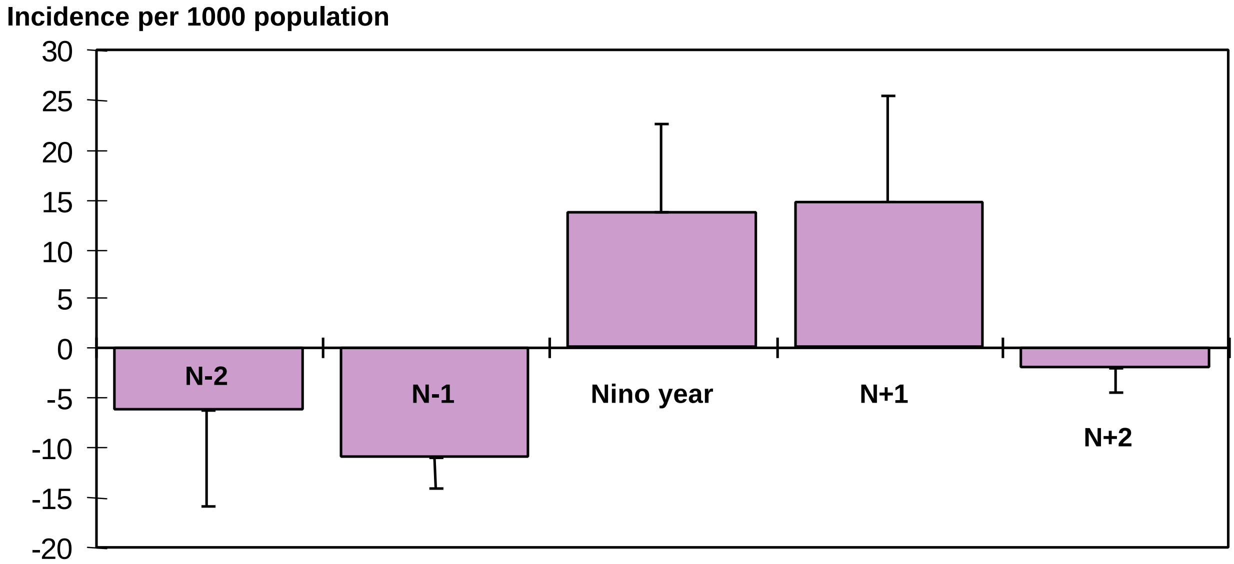


Figure 2.3. Areas which are vulnerable to drought. Countries where drought disasters are more frequent during the second year of El Nino (year +1).
Source: Dilley and Heyman, 1995.

2.3. Drought, food shortages and famine.

Worldwide, rates of persons affected by drought/famine account for about half of all disaster victims, and these show a significant association with the ENSO cycle (see above). Food production is most susceptible to drought in arid regions where the precipitation pattern is markedly seasonal, or is otherwise highly variable. El Niño is important because it is associated with drought in many vulnerable regions at the same time. This aggregate effect has even lead to several world food crises (Dyson, 1996). For example, in 1972, drought hit several of the major grain-producing regions of the world, including northern and west parts of South Asia and north-east China. The most effected populations were in Ethiopia, the Sahel and in parts of India and China. The world food crisis of 1982–83 was also linked to the El Niño, when famines struck populations in Ethiopia and the Sahel, which were also badly affected by the civil war.

Food shortages and famine have complex social and environmental causes but climate variability is a still significant factor in many modern famines (Dyson, 1996). Vulnerability to climate variability can be reduced with appropriate action, such as early warning systems that include climate forecasts (see Section 4). For example, famine was averted following the severe drought in Southern Africa in 1992 despite 80% crop failure rates in some of the worst affected regions (Yip, 1997).

Historically, the impacts of ENSO have been very substantial (Nicholls 1991; Diaz *et al.*, 1999). About 8 million people perished in India due to famine in the 1877 El Niño and in many districts a quarter of the population died. Severe famine was reported in north-east Brazil in the El Niño of 1877–78 (Kiladis and Diaz, 1986). The 1888 event again affected India and Brazil, but the greatest effect was on Ethiopia where about one-third of the population died.

There is good evidence that droughts in Papua New Guinea and Indonesia have been associated with El Niño for well over a century (Nicholls, 1993a). There is also evidence that some droughts in the Philippines are related to ENSO (Jose *et al.*, 1996). The 1997/98 El Niño was associated with the most serious drought in 50 years in Papua New Guinea and the government declared a state of emergency. Many small island states in the Pacific were also seriously affected, such as the Marshall Islands (Lewis *et al.*, 1998).

Countries in north-eastern South America (north-east Brazil, French Guyana, Surinam, Guyana and Venezuela) experience drier-than-normal conditions during an El Niño, between July (year 0) and March (year +1) (Ropelewski and Halpert, 1987). A link between El Niño and drought in north-eastern Brazil has been described for many years (e.g. Hastenrath and Heller, 1977). The periodic occurrence of severe drought in this agriculturally rich region (Nordeste) associated with El Niño has resulted in occasional famines (Hastenrath, 1995). Severe food shortages have occurred in this region in 1988 and 1998.

2.3.1 Southern Africa

Southern Africa is subject to recurrent droughts which cause severe food shortages. There is an increased risk of drought during El Niño in a region encompassing parts of Zimbabwe, Mozambique and South Africa. The 1991-92 El Niño was accompanied by the worst drought in southern Africa this century, affecting nearly 100 million people (Dyson, 1996). In 1992, 20 million people needed food relief in the Southern African Development Community (SADC) region. These problems were exacerbated by the war in Mozambique and related refugees in Zimbabwe. In the previous year, Zimbabwe had been forced to sell some of its grain reserves by the World Bank. At this time, an El Niño had been forecast but this forecast was not communicated to the government (Dyson, 1996). If the Zimbabwean government had been aware of the forecast, they might have acted otherwise.

Several studies have shown a relationship between ENSO and food production in southern Africa. Cane *et al.* (1994) found a strong relationship between SOI and maize yields in Zimbabwe. SOI and SST parameters are both related to seasonal rainfall in the SADC region (Matariria and Unganai, 1995; Mason *et al.*, 1994). A comparison of ENSO-related SST anomalies and NDVI (Normalised Difference Vegetation Index, a satellite-derived vegetation index) shows that remote sensing can be used to identify specific locations in Africa where ENSO activity has an important effect on vegetation (Anyamba and Eastman, 1996; Kogan, 1998).

Seasonal rainfall forecasting capability is being developed in Southern Africa (see section 4). Forecasting ability is good because climate variability is linked to the tropical atmospheric circulation (Mason *et al.*, 1996; Makaru and Jury, 1997). Highest forecasting ability occurs in the summer rainfall region during the peak rainfall months (December to February) and is particularly high in areas that are strongly affected by ENSO. Rainfall forecast skill is relatively low, however, during the first half of the summer season. Several initiatives are underway to improve the use of seasonal forecasting to aid food security in the southern Africa region (SADC/NOAA/NASA, 1996; Glantz, 1994).

2.4 Forest and bush fires

Drought increases the susceptibility of some forests and rangelands to fires. The widespread “Ash Wednesday” bushfires in Australia in 1983 were due partly to the preceding drought (associated with the 1982–1983 ENSO) which had depleted moisture in vegetation and soil.

Indonesia suffers recurrent drought associated with El Niño (see above). Such drought in association with slash-and-burn methods of land clearance can trigger uncontrolled forest fires. Every El Niño since at least 1982 has been associated with fires in Kalimantan, with consequent public health implications. Smoke from the 1997 forest fires in Kalimantan and Sumatra affected surrounding countries including Malaysia, Singapore, the Philippines and southern Thailand. The air pollution episode caused elevated levels of particulates for approximately two months from late July 1997. Levels were particularly high in September and then rose again in October (Brauer, 1998). The public health implications of “haze”-type air pollution are great due to the large number of people who may be exposed.

2.5 Floods and landslides

Flooding can be triggered by heavy rainfall events. Table 2.1 describes some of the meteorological events associated with flooding. Landslides are triggered by heavy rainfall and saturation of the soils. In many countries, deforestation has increased the risk of landslides. Rainfall anomalies associated with El Niño are described in Figure 1.1. (see also Ropelewski and Halpert, 1987, 1989; Kiladis and Diaz, 1989).

Global analyses have shown no association between ENSO and the number of flood disasters (Dilley and Heyman, 1995) or ENSO and the number of persons affected by floods and landslides (Bouma *et al.*, 1997a). However, the number of persons affected by landslides, particularly in South America, increases in the year after the onset of El Niño (year +1) (Bouma *et al.*, 1997a).

Analyses by country by Dilley and Heyman (1995) found that flood disasters (1964–92) were significantly more frequent in El Niño year +1 in the following countries: Madagascar, Papua New Guinea, Cuba, Guatemala and several countries in Europe. The climatological evidence for teleconnections of ENSO in these regions is variable. There is some evidence of weak ENSO connections in southern Europe.

While floods are very localized in time and space, droughts are long-term events that usually affect a greater area. Floods are also much more frequent than droughts. Thus, floods and flood disasters have high natural variability in time and space. The geographical aggregation of data may have been inappropriate in the studies described above.

The effect of El Niño along the western coast of South America is very strong, particularly in Peru and Ecuador. Nearly every El Niño event, whether weak or strong, is associated with heavy rainfall in this region. In 1997/8 El Niño, very heavy rainfall was experienced along the coastal regions of Ecuador and Northern Peru. In the Piura region of Peru, there were 12 separate days with at least half its annual rainfall and in Talara, Peru, five times the normal annual rainfall fell in a single day. The Peru-UNICEF programme reported that 22 of the 24 departments in the country were badly affected. It was estimated that 67,068 families were affected with over 20,000 homes destroyed.

During El Niño, countries in eastern equatorial Africa experience wetter-than-normal conditions in the winter period (Ropelewski and Halpert, 1987). The impact of 1997/98 El Niño was very severe and catastrophic flooding occurred in East Africa. Flooding was caused by exceptionally heavy rainfall in Somalia, northern Kenya, Ethiopia and Tanzania. Severe flooding in China in 1998, killing more than 5,500 and leaving at least 21 million homeless, was possibly associated with El Niño (Kriner, 1999).

2.5.1 Asian Monsoon

ENSO has an important effect on the character of the annual monsoon in Asia. Accurate summer monsoon forecasting remains a difficult task because many factors are involved in monsoon development (O'Hare, 1997). During a typical El Niño (year 0), the monsoon is weakened and displaced towards the equator. Thus, during many but not all El Niño years, India experiences summer (June to August) drought in the north-west and central regions and heavy rains in the north-east (Gregory, 1989). Enhanced winter-monsoon rainfall has also been linked to El Niño in the extreme south of India and Sri Lanka (Ropelewski and Halpert, 1987). La Niña events are often associated with flooding in parts of India.

Table 2.1 Mechanisms of flooding

Cause	Mechanism	Link to ENSO
Heavy rainfall	Flash flooding - heavy rainfall on land that cannot absorb it (e.g. due to drought). Slow-rise flooding also occurs after prolonged rainfall has waterlogged the ground.	Only in regions where ENSO affects rainfall, e.g. Indian subcontinent, South America
Glacial melt water	Annual melt of mountain glaciers is more rapid than usual.	Highland regions where ENSO affects temperature, e.g. Himalayas/Hindu Kush
Tropical storms	Flooding due to combined effect of heavy rainfall and storm surge.	Possible link where ENSO has affected storm tracks.
Tsunamis	Earthquakes in the ocean floor	Earthquakes are not associated with El Niño events

2.6 Hurricanes and tropical storms

Tropical cyclones (also known as typhoons in the Pacific and hurricanes in the Caribbean) are severe tropical storms that originate between 5°N and 20°S of the equator. Tropical cyclones usually occur during the summer and autumn. Many of the impacts of tropical cyclones are due to flooding associated with the “storm surge” when it reaches the land.

During a typical El Niño (year +1), tropical cyclone activity is:

- reduced in the Atlantic basin - Caribbean, southern USA, central America (hurricanes)
- reduced in the western part of the north-west Pacific (typhoons)
- reduced off north-east Australia and slightly reduced off western and northern Australia (cyclones)
- increased in the eastern part of the north-west Pacific (typhoons)
- increased in the south and central Pacific (>160° E) (cyclones/hurricanes)
- slightly increased in the eastern north Pacific (hurricanes)

An unpublished study by Saunders and Roberts (1999) found that landfalling hurricanes in the Caribbean, Gulf of Mexico, and Queensland (Australia) are a factor of two to three less common during El Niño months than during La Niña months. This reduced storm activity seems to be the main positive benefit of El Niño on weather-related disasters. It should be remembered, however, that the most expensive natural disaster ever in terms of insured losses, Hurricane Andrew, occurred in an El Niño year (1992).

During a typical La Niña (year +1), tropical cyclone activity is:

- increased in the Atlantic basin (hurricanes)
- increased in the western part of the north-west Pacific (typhoons)
- increased off north-east Australia and slightly reduced off western and northern Australia (cyclones)
- reduced in the eastern part of the north-west Pacific (typhoons)
- reduced in the south and central Pacific (>160° E) (cyclones/hurricanes)

Hurricane Mitch in 1998 was one of the most devastating storms in recent history. Mitch occurred in an Atlantic hurricane season that began late (under the influence of El Niño) but was also under influence of the rapid transition to La Niña. As a consequence, more storms than usual did occur which is also consistent with the La Niña pattern. However, the specific storm (Mitch) has not been indicated to have been caused, or to have been made more intense or to have travelled west to Central America, because of La Niña (Llanso, pers. com.).

The shifting of storm tracks has particular importance for small islands which lie in those tracks. Thus, typhoons are 2.6 times more likely to occur near the Marshall Islands, Pacific Ocean, during an El Niño (Spennemann and Marschner, 1995) because El Niño events shift storm tracks to the West in the Pacific. During the 1982/83 El Niño, severe typhoons hit both Hawaii and Tahiti. The number of tropical cyclones observed in the north Australian cyclone season is related to ENSO and forecast by monitoring an ENSO index (Darwin pressure) in the months preceding the cyclone season (Nicholls, 1985).

It is fairly well understood how tropical cyclones are affected by ENSO (Landsea, 1999; Saunders *et al.*, 1999). Due to their large natural variability, it is not yet possible to predict when an individual storm will occur. However, forecasts of hurricane and tropical cyclone activity for the forthcoming season are available for the Atlantic and other regions. Once generated, it is now possible to forecast the area of landfall of a cyclone within 1–5 days, and therefore timely warnings may be issued. Such short-term weather forecasting has greatly reduced the death toll of cyclones in recent decades.

3. HEALTH IMPACTS

3.1 Relationships between weather and health outcomes

It is the extremes of weather that have the most devastating impacts on human health and well-being (Epstein *et al.*, 1998). Storms, hurricanes, and floods kill many thousands of people every year. However, non-catastrophic weather can also have varied and significant impacts on human health. For example, the relationships between rainfall events, the abundance of mosquitoes and outbreaks of malaria have been well documented. The links between climate, weather and disease are also illustrated by the seasonality of many diseases and by the distribution of diseases that are transmitted by cold blooded vectors.

Epidemiology is the principal scientific discipline used to study how disease relates to weather and climate. Recent advances in the understanding of ENSO, as well as the threat of global climate change, have now made this an expanding field of research. There are many potential benefits to public health from such research, in particular, the prediction of disease distribution and interannual disease intensity.

3.1.1 Mechanisms

As described in the previous sections, El Niño is associated with changes in local temperature and rainfall patterns in selected regions around the Pacific and beyond. Several mechanisms can explain an association between rainfall anomalies (drought, heavy rain, flood) and disease incidence. There is a well-studied relationship between rainfall and diseases spread by insect vectors which breed in water and are therefore dependent on surface water availability. The main species of interest are mosquitoes which spread malaria and viral diseases such as dengue and yellow fever. There is a wealth of evidence linking mosquito abundance to rainfall events - both wet and dry conditions. These studies show that the ecology of the local vector species needs to be understood in order to determine the epidemiology of the disease and attempt some measure of control.

Vector-borne disease transmission is also sensitive to temperature fluctuations. Increases in temperature decrease the intrinsic incubation period of the pathogen (e.g. malaria parasite, dengue or yellow fever virus) and vectors become infectious more quickly (MacDonald, 1957). Increases in temperature also accelerate vector life cycles or allow the vector to colonise areas that were previously too cold. Temperature may also affect the behaviour of the human population with regard to exposure.

The relationships between rainfall and water-washed or water-ingested diseases have been less well-studied. These are principally faecal-oral diseases that are spread via water or food that is contaminated with faecal material. Examples of such diseases include cholera, typhoid, and diarrhoeal diseases. Outbreaks of such diseases can occur after flooding if the floodwaters become contaminated with human or animal waste. Drought reduces the water available for washing and sanitation and also increases the risk of disease.

There is some analogous evidence from the impacts of ENSO on plant diseases. Time series data of rust disease outbreaks in North America show a correlation with the ENSO cycle (Scherm and Yang, 1995, cited in Yang and Scherm, 1997). Two studies have also shown a possible association between ENSO and mosquito-borne viral diseases in animals in Australia (Ward and Johnson, 1996) and South Africa (Baylis *et al.*, 1999). The authors have found no studies which have examined the relationship between vector abundance and ENSO. This is likely to be because data on vector abundance are not typically collected over long periods of time.

Outbreaks of infectious disease are often associated with catastrophic events not only due to the initial cause (e.g. flooding) but also due to population displacement and overcrowding. Sections 3.2 to 3.5 focus on the non-catastrophic aspects of the relationship between ENSO and epidemic disease, principally vector-borne diseases. Section 3.6 addresses the health impacts of disasters.

3.1.2 An evidence-based approach

Several factors must be considered when assessing a causal relationship between El Niño and changes in human health. Evidence needs to be examined in relation to the following factors:

1. *Climatological* evidence of appropriate teleconnections or direct effects of ENSO in the area of interest, e.g. precipitation or temperature anomalies, as derived by climatologists.

2. *Biological* evidence that the diseases or other health impacts of interest have a plausible biological link with weather exposures (precipitation, land surface temperature, sea surface temperature), e.g. field studies of vectors which examine their abundance in relation to the ENSO cycle.

3. *Epidemiological* evidence:

- Statistical analyses are needed to show that disease incidence or epidemics vary over time with the ENSO cycle. This requires a long (e.g. 20 year) data series due to the small number of ENSO events. Such analyses should demonstrate that disease incidence or epidemics vary over time with the weather pattern (e.g. rainfall) that is associated with ENSO.
- The analyses should take into account potential confounding factors over the time period which may account for the observed association, for example, changes in land use which may affect vector abundance. Confounding factors are unlikely to vary coincidentally with the ENSO cycle over long periods and therefore the likelihood of confounders explaining the observed relationship is greater for short time series or single event case studies.
- Changes in population vulnerability to climate variability may also occur. For example, changes in public health infrastructure including changes in vector control, may change vulnerability and therefore enhance or reduce the magnitude of the relationship. Again, these are more likely to be important to the interpretation of single event case studies.

The periodic nature of epidemics may be due to many non-climate factors, the most important of which is the waxing and waning of herd immunity. Thus, the size of the susceptible (non-immune) population increases as children (who have no immunity) are born into the population. These changes in population immune status are an important factor for the periodic epidemics of measles and many other diseases (Anderson and May, 1979a; 1979b).

The geographical area of analysis is important. Health researchers must necessarily rely on the assessment by climatologists of the teleconnections in the region of interest. Teleconnections do not respect national boundaries. Aggregation of data at the national level may lead to a loss of information. In most countries that are affected, local data are necessary to evaluate the impact of El Niño. Unfortunately, good quality long time series of surveillance data at such resolution may not be available. Additional factors which may also be addressed in studies investigating links between ENSO and health include (PAHO, 1998a): disease ecology (existing vector reservoirs, host/parasite interactions); magnitude of the El Niño/La Niña events; other climatic influences; social change (such as lack of access to health care services); and increased case detection.

The authors have reviewed the literature on ENSO and health up to January 1999. It should be noted that there are relatively few studies on ENSO and health. There may also be a publication bias as studies which present a positive association between climate and disease are more likely to be published.

3.2 Vector-borne diseases

Epidemics of vector-borne disease occur in unprotected populations which lack sufficient immunity and/or effective public health measures. Many regions in the tropics are without an effective public health infrastructure. In these regions, the transmission of vector-borne diseases has a natural boundary where ecological or climatological conditions limit the distribution of the pathogen or vector. Often pathogen and vector share the same ecological niche having shared their evolutionary pathway. In these “unstable” or “fringe” areas, small changes in weather between years may dramatically change the conditions for disease transmission.

Zoonotic infections (e.g. yellow fever, plague) become epidemic when the pathogen changes to a vector which prefers to bite humans (e.g. *Aedes aegypti* for yellow fever) or which co-habits with humans (e.g. the black rat and flea for plague). Ecological disturbances, which are often weather driven, may account for these excursion of the pathogen outside its normal habitat. Thus, epidemics can be triggered by weather events in areas that are next to endemic regions or when the disease is present in a non-human host reservoir.

Few generalizations can be made about vector-borne disease transmission and weather patterns. Local transmission is dependent on the ecology of the local vector species which may respond to rainfall events differently. Mosquito vectors which breed in brackish water in coastal areas or urban-adapted vectors which breed in plastic containers are less sensitive to rainfall than sylvatic vectors. The timing of rainfall in the year (season) can be important as well as the amount of rainfall.

3.2.1 Malaria

Malaria is the most important vector-borne disease. WHO estimates that 2400 million people live in malarious regions. Each year, 300–500 million new cases occur each year and more than one million children die. Malaria transmission is sensitive to weather and climate conditions. Indeed, it is perceived as the vector-borne disease most likely to be affected by global climate change (WHO/WMO/UNEP, 1996; McMichael *et al.*, 1996). A changing climate is likely to change transmission dynamics in many regions.

The gradual increase of malaria worldwide, and the re-invasion of territory where the disease was previously controlled are reasons for grave concern. There are currently several global initiatives underway to revitalize malaria control efforts. WHO has recently launched a new initiative to combat malaria mortality and morbidity world-wide. The "Roll Back Malaria" initiative will be implemented in close co-operation with the World Bank and other international agencies. The increasing cost of effective insecticides and the development of drug resistance are likely to contribute to increasing prevalence of malaria in the coming decades. Targeting control efforts to high risk years increases the cost effectiveness of malaria control and the more judicious use of insecticides can delay the development of resistance. Early warning and epidemic preparedness are therefore elements in the renewed global efforts to control malaria.

In the epidemiology of malaria, there are desert and highland fringes, where rainfall and temperature, respectively, are critical parameters for disease transmission (Bouma, 1995). In such highland fringe areas, such as the Himalayas, higher *temperatures* associated with El Niño particularly during the autumn and winter months may increase transmission of malaria in the high altitude/latitude areas of Asia. This has been shown for Northern Pakistan (Figure 3.1, Bouma *et al.,* 1994) and is also likely for the other parts of the sub-Himalayan belt.

Effective malaria control in most higher latitude regions means that the latitudinal borders of malaria are not limited by temperature. Malaria epidemics may occur at these "control" fringes when public health infrastructure deteriorates. In areas of "unstable" malaria in developing countries, populations lack protective immunity and are prone to epidemics when weather conditions facilitate transmission (Table 3.1). Many such areas across the globe experience drought or excessive rainfall due to ENSO teleconnections (see section 2).

Table 3.1 Characteristics of endemic and epidemic malaria

Endemic malaria	Epidemic malaria
"stable malaria"	"unstable malaria"
Climate conditions are very favourable for transmission	Conditions for transmission are marginal
Not much variation between years in malaria incidence.	Much variation between years in malaria incidence
Good population immunity. Morbidity and mortality mainly in children and pregnant women.	Low population immunity and therefore highly vulnerable.
	Transmission limited by temperature or rainfall but other human factors also important, e.g. migration, breakdown of vector control.

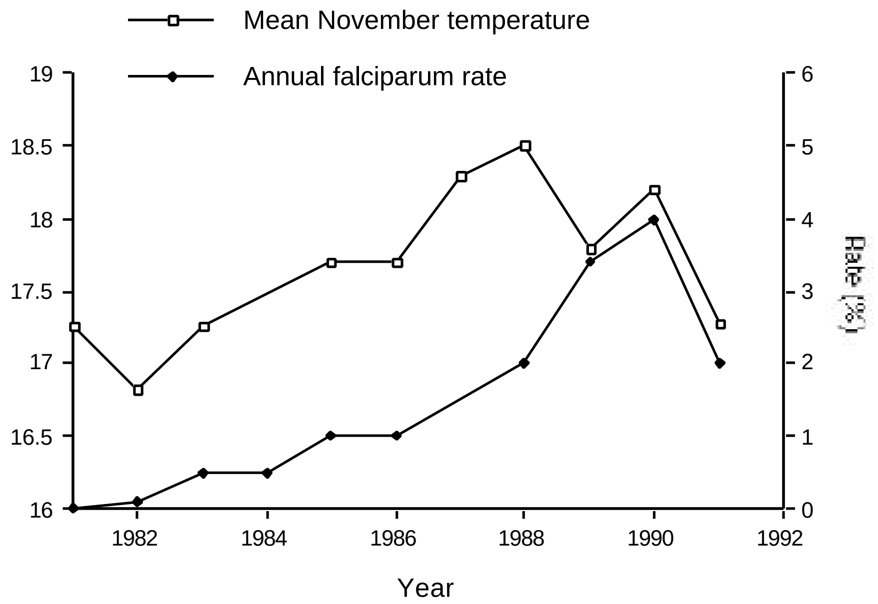


Figure 3.1. Relationship between malaria and November temperature (°C) in North-West Frontier Province of Pakistan. Source: Bouma *et al.,* 1994

South Asia

Earlier this century, periodic epidemics of malaria occurred in the Punjab region (now north-east Pakistan and north-west India). This plain, irrigated by the five rivers that give the province its name, borders the Thar desert. Excessive monsoon rainfall has been firmly identified as a major epidemic factor since 1908 through its effect on the vector (increased breeding and a longer lifespan due to higher rainfall-related humidity) (Christophers, 1911). Since 1921, forecasts of malaria epidemics in the districts of Punjab have been issued based on established relationships between rainfall and malaria mortality (Gill, 1923). This system was probably the first mathematically-supported malaria early warning system ever used (Swaroop, 1946).

Several factors allow for a robust historical analysis of malaria in relation to ENSO. There are good records of the malaria epidemics in the Punjab. Further, the ability to forecast the economically important monsoon was a major incentive for the careful recording of accurate climate data. Monsoon forecasting ability was based on the strong relationship between rainfall and the Southern Oscillation. Indeed, the global effects of ENSO on rainfall were first discovered in India (Walker and Bliss, 1932, see section 1.1). Historical analysis (1868–1943) of malaria in the semi-arid Punjab shows that the risk of a malaria epidemic increased five-fold during the year following an El Niño (+1 year) (Bouma and van der Kaay, 1994, 1996). The risk of an epidemic is greater in a year with excess rain in critical months.

The Punjab no longer experiences malaria epidemics due to economic and ecological changes. Epidemic malaria is still a serious problem in the more arid areas in Western Rajasthan and Gujarat in India, and Pakistan where malaria epidemics are linked to excessive rainfall. Strong correlations are found between annual rainfall on the one hand and the number of rainy days on the other and malaria incidence in most districts of Rajasthan and some districts in Gujarat (Akhtar and McMichael, 1997; Bouma *et al.*, unpublished). Years with a high risk of malaria and excessive monsoon rainfall can be expected in years following El Niño (+1 year) and during La Niña years (Bouma *et al.,* 1994).

In very humid climates, periods of drought may turn rivers (usually not conducive to vector breeding) into strings of pools. In such regions, opportunistic breeding of vectors during droughts can provide epidemic conditions. The south-west part of Sri Lanka which receives two monsoons is one of these areas. An historical analysis of malaria (1870–1940) found a 4-fold increase of the epidemic risk during El Niño. This risk was associated with the failure of the south-west monsoon, often combined with failure of the north-east monsoon in the preceding year. The association between drought compounded by irrigation and increased malaria risk in the “wet” part of the island may be of operational value to the malaria programme in Sri Lanka.

South America

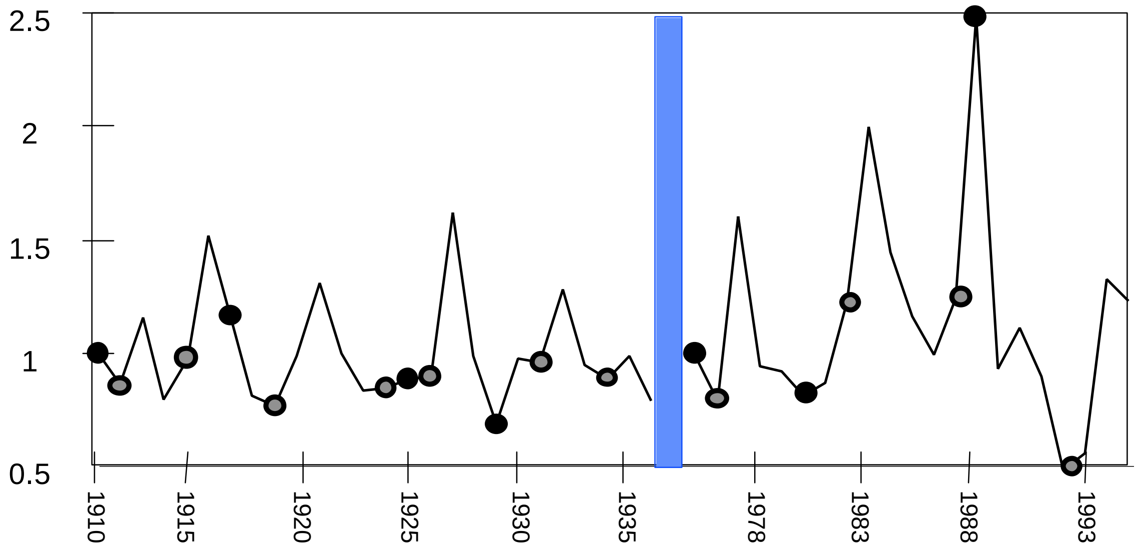
Many parts of South America show ENSO-related climate anomalies. Serious epidemics in the northern countries of South America have mainly occurred in the year after El Niño (year +1). Epidemics of malaria were observed in 1983 in Ecuador, Peru and Bolivia and were associated with heavy rainfall associated with the strong event (Cedeño, 1986; Russac, 1986; Nicholls, 1993b). The malaria epidemic in Ecuador was exacerbated by population displacement caused by the flooding.

The relationship between ENSO and malaria has been examined in detail for Venezuela (Bouma and Dye, 1997) and Colombia (Bouma *et al.,* 1997b; Poveda and Rojas, 1996; 1997). These countries usually have below average rainfall during El Niño. In Venezuela, malaria increased on average 37%, in the post-Niño year (+1) (see Figure 3.2). However, the analysis used aggregated data and does not reflect the dramatic focal surges of malaria during these years.

In Colombia, malaria cases increased by 17.3% during El Niño (year 0) and by 35.1% in the post-Niño year (+1) (Bouma *et al.,* 1997b; Anon, 1996). El Niño is associated with a reduction of the normal high rainfall regime in much of the country (Poveda and Mesa 1997). Reduced runoff and streamflow may increase mosquito abundance by increasing the number of breeding sites (Poveda *et al.,* 1997; 1999a). Higher temperatures during El Niño episodes may also favour malaria transmission (Bouma *et al.*, 1997b; Poveda et al 1999b).

The reasons that malaria increases after a dry period are not completely understood. However, this strong relationship between malaria and ENSO in Venezuela and Colombia can be used to predict high and low-risk years for malaria with sufficient time to mobilise resources to reduce the impact of epidemics. Further studies are required to elucidate the mechanisms which underlie these associations. Regional studies relating climate and vector ecology to malaria incidence may further improve an ENSO-based early warning system. Other countries in the region with similar ENSO related rainfall anomalies appear to exhibit similar malaria-ENSO relationships. For example, five-yearly epidemics were first described in the Guyanas and Surinam. These relationships should be investigated.

Figure 3.2 Malaria mortality and morbidity in Venezuela.
Malaria increases by 36.5% on average in years following recognised El Nino events. Relative change in mortality (deaths 1910–1935) and morbidity (cases 1975–1995), calculated as cases in year n divided by cases in year n-1. El Niño events are indicated by grey circles and La Niña events are indicated by black circles.
Source: Bouma and Dye, 1997.



Box 3.1 Drought, famine and malaria

Drought in the previous year has been identified as a factor contributing to increased malaria mortality. There are several possible reasons for this relationship. Drought-related malnutrition may increase an individual's susceptibility to infection (Gill, 1923). Drought may also reduce malaria transmission which results in a reduction in herd immunity in the human population. Therefore, in the subsequent year, the size of the vulnerable population has increased (Bouma and Dye, 1997). Alternatively, a change in ecology of the natural predators may affect mosquito vector dynamics, i.e. mosquito populations recover more quickly following a dry year than their predator populations.

Famine conditions may have contributed to excess mortality during historical epidemics of malaria in the Indian Punjab, Ethiopia and Swaziland (Yacob and Swaroop, 1946; Fontaine *et al.,* 1961; Packard, 1984). Such mechanisms may have also contributed to the large outbreak of malaria in India following the 1877 El Niño in India (Nicholls, 1998). Many deaths occurred after the end of the drought and the proximate cause was malaria when drought-breaking rains increased vector abundance and this was exacerbated by population movement and the concentration of people in feeding camps (Diaz *et al.,* 1999).

Africa

Africa has desert fringe malaria around the Sahara (e.g. Sudan) and the Kalahari (Namibia, Botswana). Of these areas, southern Africa and a region east of the Sahara show ENSO-related rainfall anomalies (see Section 2.2). Several studies that are investigating the relationship between malaria and ENSO in the highlands of East Africa and the drylands of southern Africa are in progress at the time of writing (NOAA, 1998). Unpublished results from Ethiopia show an increase of epidemic malaria associated with El Niño (year 0, +1) (Tulu *et al.*, Bouma *et al.*, unpublished). Data from tropical and south-west Africa indicate that epidemics tend to correlate with higher seasonal temperatures and annual rainfall, some of which might be associated with the ENSO.

The 1997/98 El Niño was associated with heavy rainfall and flooding in north-eastern Kenya. The subsequent malaria epidemics in this area were attributed to El Niño. From January to May 1998, a major epidemic of *falciparum* malaria occurred in a population that had no immunity as it was the first such outbreak since 1952. Two years of drought had preceded the outbreak. Brown *et al.* (1998) reported an attack rate of approximately 40% in the town of Wajir, Kenya. Mortality and morbidity due to malaria was coincident with a Rift Valley Fever (RVF) epidemic in the same region (see below). Three districts in Kenya reported a 6-fold increase in malaria cases in the first 2 months of 1998 compared to the same period in 1997 (Allan *et al.,* 1998). The malaria epidemic was compounded by widespread food shortages. The late recognition of the outbreak and a nurse strike at the beginning of 1998 also contributed to the severe public health problem.

3.2.2 Dengue

Dengue is the most important arboviral disease for humans. In recent decades, the disease has undergone a dramatic resurgence worldwide due to factors which include: ineffective vector and disease surveillance; inadequate public health infrastructure; population growth; unplanned and uncontrolled urbanization; and increased air travel (Rigau-Pérez *et al.,* 1998). The main vector of dengue is the domesticated mosquito *Aedes aegypti* which breeds in urban environments in artificial containers that hold water. Dengue is also transmitted by *Aedes albopictus* which is similarly adapted to urban environments.

Dengue incidence is seasonal and is usually associated with warmer, more humid weather. There is some evidence to suggest that increased rainfall in many locations can affect the vector density and transmission potential (Foo *et al.,* 1985). ENSO may also act indirectly by causing changes in water storage practices brought about by disruption of regular supplies (WHO, 1998a).

Many countries in Asia experienced an unusually high level of dengue and dengue haemorrhagic fever in 1998, some of which may be attributable to El Niño-related weather (WHO, 1998b). Epidemics of dengue in islands in the South Pacific (aggregated data, 1970–1995) were positively correlated with the Southern Oscillation Index

(SOI) a parameter of ENSO (Hales *et al.*, 1996). Hales *et al.* (1999a) examined the relationship between ENSO and monthly reports of dengue cases in 14 island nations in the Pacific. There were positive correlations between SOI and dengue in 10 countries. In five of these (American Samoa, Nauru, Tokelau, Wallis and Western Samoa) there were positive correlations between SOI and local temperature and/or rainfall. During La Niña, the five islands mentioned above are likely to experience wetter and warmer than normal conditions.

Unpublished studies have investigated the relationship between epidemic dengue activity and El Niño in Puerto Rico, Indonesia, and Thailand because these countries have good dengue surveillance data (Gubler, unpublished). In Puerto Rico, which has a relatively neutral ENSO signal, no correlation with ENSO was found. In Indonesia, which has a strong El Niño signal (drought), dengue epidemics consistently occurred in the year after El Niño (year +1). In Thailand, which does not have a strong ENSO signal, there was no correlation. However, a study of dengue in Viet Nam, found that the number of cases was correlated with the SOI negative values — El Niño years (Lien and Ninh, 1996 cited in Glantz, 1996b). These studies do not identify the environmental risk factors for increases in dengue cases unequivocally. Higher temperatures are associated with increased transmission of arboviral diseases. Rainfall may affect vector abundance but this may be less significant in urban areas, as the vector is a container breeder and dengue is primarily an urban disease.

Generalizations should not be made about the association between ENSO and dengue transmission. Whether or not an epidemic occurs depends not only on mosquito abundance but also on the history of dengue in that region (Gubler, 1998). Although weather conditions may be favourable for dengue transmission in one area, increased transmission may not be apparent if the local population is already immune to the prevalent serotype. Regional studies are needed to determine whether El Niño is associated with a change in dengue activity (Gubler, pers. com.).

3.2.3 Yellow fever

Yellow fever occurs in tropical regions of South America and Africa. It is maintained in a transmission cycle involving forest-dwelling mosquitoes and monkeys. The death rate ranges from 5% to more than 50% in epidemics. Yellow fever has been eradicated from north America and Asia. However, an historical epidemic in the southern US in 1878 may have been associated with El Niño (Diaz and McCabe, 1999). It was one of the most severe US outbreaks, with an estimated 20,000 deaths and 100,000 cases. The 1877–78 event was one of the strongest El Niño episodes on record. All reported yellow fever pandemics between 1880 and 1890 began in years with El Niño features (Bouma, unpublished).

Unlike most other tropical diseases, yellow fever vaccine generates very strong immunity lasting more than 10 years. It is therefore a powerful tool to prevent epidemics. After the major drives in the 50s and 60s against the main urban vectors of the disease in the Americas (except the US and Canada) and the early mass vaccination campaigns, vaccination coverage has slipped in recent decades. For example, vaccination coverage has dropped to 24% of the population in the Amazon region. Global climate change is expected to have some effect on the distribution of yellow fever (WHOWMO/UNEP, 1996).

Preliminary investigations have shown that the average number of annual epidemic foci (defined as the notification of cases in one area during a year) in Western Africa between 1950–1988 is doubled during the El Niño year or the following year (years 0, +1) (Bouma, unpublished data).

Many years after being confined to West Africa and South America, yellow fever epidemics have surfaced in recent years in Kenya. There is concern that the disease may expand into Asia where mosquito vector *Aedes aegypti* is present and human population density is high. Yellow fever has been identified by many public health specialists as one of the potentially re-emerging infections (IOM, 1992). It is a zoonosis, with endemic regions in the rain forests of South America and West Africa. Human cases result from exposure to the “sylvatic” reservoir and vectors, which rarely bite humans. The real danger of yellow fever outbreaks lies in the virus entering urban areas and being transmitted by the urban vector *Aedes aegypti*, resulting in serious epidemics with considerable mortality in a vulnerable population.

3.2.4 Murray Valley Encephalitis in Australia

Murray Valley Encephalitis (MVE), also known as Australian Encephalitis, is an arboviral disease reported, to date, only in Australia. Interannual rainfall variability in eastern and northern Australia are closely related to the Southern Oscillation. Frequent small epidemics of MVE occur in tropical Australia. However, infrequent but severe epidemics of MVE have occurred in temperate south-east Australia, after well above average rainfall and flooding associated with La Niña episodes. Thus, years with MVE cases in south-east Australia are positively correlated with Darwin pressure in the preceding year, another index of the Southern Oscillation (Nicholls, 1988).

Models for predicting outbreaks of MVE using the Southern Oscillation have been described (Nicholls, 1986, 1988). The Australian government undertakes vector control measures in high risk years only (i.e. years in which SOI is positive) (Glantz, 1996b). There has not been a major outbreak of MVE since 1974.

3.2.5 Ross River virus disease in Australia

Epidemic polyarthritis is caused by infection with several arboviruses, of which Ross River virus is the most important. Ross River virus is transmitted by a wide range of mosquito species in complex transmission cycles with several possible mammal and bird intermediate hosts. The disease is distributed throughout Australia and elsewhere in the South Pacific.

In northern and central Queensland, south-east Australia, cases are reported throughout the year. Tong *et al.* (1998) demonstrated that notified cases of epidemic polyarthritis (1986–95) in one district in Queensland, were positively associated with monthly SOI. The number of cases were also positively associated with temperature, rainfall and humidity. In other regions of Australia, virus activity tends to be epidemic following spring and summer rains (Mackenzie and Smith, 1996). In arid areas of Australia, the virus is thought to persist in mosquito eggs for considerable time (Lindsay *et al.,* 1993). When environmental conditions become favourable, such as with heavy rain or flooding, the eggs hatch into infected mosquitoes and a localised outbreak of the disease may occur. In coastal regions with salt marsh habitats (principally south-western Australia), sporadic cases may occur at anytime of year. In these areas, sea level rise and tidal effects have been shown to be more important than rainfall patterns for determining changes in local vector abundance.

Outbreaks of Ross River virus disease are linked to discrete vector/virus cycles in different parts of the country. Therefore, local studies are needed to determine a consistent relationship with the ENSO cycle. Harley and Weinstein (1996) found no relationship between La Niña events and epidemic polyarthritis outbreak “years” or notified cases in Australia as a whole. La Niña is associated with above average rainfall in certain parts of Australia. Infection with Ross River virus confers life-long immunity, and time since last outbreak is an important factor affecting the risk. Major outbreaks have occurred every 3–4 years despite years of high rainfall in between.

Although the relationship with ENSO is less certain than for MVE, the public health impact of Ross River virus infection is greater in terms of number of people affected. Some outbreaks of Ross River virus disease may be linked to weather patterns associated with ENSO. A strong relationship has not been proven with the exception of the study described above (Lindsay and Mackenzie, 1997).

3.2.6 Rift Valley fever

Rift Valley fever (RVF) is an arboviral disease that primarily affects cattle. Outbreaks of RVF in humans have occurred in East Africa following heavy rainfall (WHO, 1998a). In Kenya, outbreaks in the usually dry grasslands are always associated with periods of heavy rain. An analysis of RVF outbreaks between 1950 and 1982 in Kenya found a strong and consistent relationship with an aggregated measure of rainfall, i.e. persistent rainfall at a number of sites (Davies *et al.,* 1985). It is thought that the eggs of the mosquito vector are present in large numbers in the grassland depressions (Fontenille *et al.,* 1995). These eggs are already infected with the virus. Flooding in this habitat enables the mosquitoes to develop and appear in high enough densities to cause an epidemic.

Linthicum *et al.* (1999) found an association between RVF activity (1950-1998) monthly SOI, and SST anomalies in the Pacific and Indian Oceans. However, these relationships were not found to be sufficiently predictive for operational use. The authors recommended the additional use of satellite data for the development of an early warning system. A vegetation index (NDVI) could identify more localised areas where heavy rainfall had occurred and RVF activity was likely to be present.

The 1997/1998 El Niño event has been linked to very heavy rainfall in north-eastern Kenya and southern Somalia, from October 1997 to January 1998. The rain was 60-100-fold heavier than normal. In December 1997, there was a large outbreak of RVF in the North Eastern Province of Kenya and Southern Somalia. The outbreak also killed a large number of cattle in the affected regions. Livestock owners reported losses of up to 70% of their stock from RVF and flood-related diseases. This may be the largest outbreak of RVF, in both humans and cattle, ever recorded. In cross-sectional surveys, 9% of the total population (ie. 89,000 people) were infected with over 500 deaths due to bleeding disease. There are some concerns that a new pathogen may be involved in the outbreak due to the unusually high case fertility rate. The outbreak is still being investigated by WHO at the time of writing.

3.3 Rodent-borne diseases

Rodents, whether as intermediate infected hosts or as hosts for arthropod vectors such as fleas and ticks, are reservoirs for a number of diseases. Rodent populations are sensitive to weather conditions. For example, populations have been shown to increase in temperate regions following mild wet winters (Mills and Childs, 1998). ENSO may also act indirectly on rodent ecology, for example by causing changes in predator–prey interactions.

3.3.1 Hantavirus pulmonary syndrome in the United States

Rodent populations are reservoirs for hantaviruses. People become infected mainly by inhaling aerosolized rodent excreta. The emergence of the disease hantavirus pulmonary syndrome (HPS) in the early 1990s in the southern US has been linked to changes in local rodent density (Wenzel, 1994). Drought conditions had reduced populations of the rodents' natural predators. Subsequent high precipitation increased food availability in the form of insects and nuts. These combined effects lead to a ten-fold increase in the population of deer mice from 1992 to 1993. A comprehensive study by Engelthaler et al. (1999) in the Four Corners Region, US, concluded that above-average precipitation during the winter and spring of 1992–1993 may have increased rodents populations and thereby increased contact between rodents and humans and viral transmission. By 1995, rodent populations and the number of HPS reported cases had returned to previous endemic levels.

In 1998, an increase in cases of HPS was linked to increased rodent populations which, in turn, were attributed to two wet, relatively warm winters in the southern US associated with 1997/98 El Niño (ProMed digest, 1998). Between March 1997 and March 1998, rodent numbers (*Peromyscus* spp.) in parts of Arizona, New Mexico and Colorado increased 10 to 20-fold (Bonn, 1998). By the end of August 1998, 14 cases of HPS were reported, in contrast to an average of 4 cases per year (Rodriguez-Moran *et al.*, 1998). This evidence is suggestive of a link between El Niño and HPS. Predictive models of disease risk are being developed based on long-term studies of reservoir populations using data on environmental factors and disease surveillance (Mills *et al*., 1999).

3.4 Water-borne diseases

Floods are associated with an increased risk of disease. Such health impacts occur irrespective of whether the flood is linked to El Niño. Heavy rainfall is often an important factor in the contamination of surface water with sewage or slurry (see Table 3.2). Common causes of diarrhoea linked to contaminated water supplies and flooding are: cholera, typhoid, shigellosis (a type of dysentery), and hepatitis A and E. Rodent borne diseases associated with flooding include leptospirosis, tularaemia and viral haemorrhagic diseases (Correa, 1975). Drought conditions can also lead to hygiene-related diseases and the increased concentration of pathogens in surface water (Table 3.3). Higher temperatures are also associated with an increase in gastro-intestinal infections (Madico *et al.*, 1997). For example, the number of patients with diarrhoea and dehydration admitted to a Rehydration Unit in Lima, Peru, was 25% higher than usual during 1997 when temperatures where higher than normal due to the emerging El Niño (Salazar-Lindo *et al.*, 1997).

Table 3.2. The many pathways by which above-average rainfall can effect health

Event	Type	Description	Potential health impact
Precipitation anomaly	meteorological	precipitation anomaly, % wetter than baseline conditions	
Heavy precipitation event	meteorological	"extreme event"	• increased mosquito abundance or decreased (if breeding sites are washed away)
Flood	hydrological	river/stream over tops its banks	• changes in mosquito abundance • contamination of surface water
Flood	social	property or crops damaged	• changes in mosquito abundance • contamination of water with faecal matter and rat urine (leptospirosis).
Flood	catastrophic flood /"disaster"	persons killed, injured >10 killed, and/or 200 affected, and/or government call for external assistance.	• changes in mosquito abundance • contamination of water with faecal matter and rat urine and increased risk of respiratory and diarrhoeal disease • deaths (drowning) • injuries • health effects associated with population displacement • loss of food supply • psychosocial impacts

Table 3.3. The many pathways by which below-average rainfall can effect health

Event	Type	Description	Potential health impact
Precipitation anomaly	meteorological	precipitation anomaly, % drier than baseline conditions	
Drought	meteorological	evaporation exceeds water absorption, soil moisture decreases. Several indices have been developed based on meteorological variables, e.g. Palmer Drought Severity Index.	• changes in vector abundance if vector breeds in dried up river beds, for example.
Drought	agricultural	drier than normal conditions leading to decreased crop production	• depends on socioeconomic factors, i.e. other sources of food available and the means to acquire them.
Drought	social	reduction in food supply or income, reduction in water supply and quality	• food shortage, illness, malnutrition (which increases risk of infection) • increased risk of disease associated with lack of water for hygiene.
Drought	food shortage/ famine/drought disaster	food shortage leading to deaths >10 killed, and/or 200 affected, and/or government call for external assistance.	• deaths (starvation) • malnutrition (which increases risk of infection) • health impacts associated with population displacement

3.4.1 Cholera

Attention has focused on cholera and ENSO because several outbreaks occurred in 1997 following heavy rains. Countries in East Africa were severely affected: major cholera outbreaks occurred in Tanzania, Kenya, Guinea-Bissau, Chad and Somalia (WHO, 1998a). Outbreaks were also reported in Peru, Nicaragua and Honduras (WHO, 1998c). However, the total number of cholera cases reported to WHO in 1997, globally and by region, were similar to that in 1996. Those countries that experienced increased cholera incidence in 1997 are at risk of increases in cholera in subsequent years.

In 1997, the regional WHO cholera surveillance team was aware of the forecasts of an El Niño-related drought in south-east Africa. The team was able to institute measures to help reduce the severity of a cholera outbreak in Mozambique by increased monitoring and heightened preparedness of health care institutions (WHO, 1998a).

Cholera is traditionally viewed as a strictly faecal–oral infection but increased attention is again being paid to the environmental determinants of this disease. The discovery of a marine reservoir of the cholera pathogen and its long term persistence with various marine organisms (in the mucilaginous sheath of blue-green algae and copepods) helps to explain the endemicity in certain regions, such as the estuaries of the Ganges and Bramaputra in Bangladesh (Colwell, 1996). Recent work has suggested relations between the seasonality of cholera epidemics and seasonality of plankton (algal blooms), and the marine food chain. A study of *Vibrio cholerae* 01 in Bangladesh (1987–90) found that abundance increases with the abundance of copepods (which feed on the phytoplankton) in coastal waters (Colwell, 1996). A relationship has also been found between cholera cases in Bangladesh and sea surface temperatures in the Bay of Bengal. El Niño events raise sea surface temperatures around the globe and may therefore increase the risk of outbreaks far beyond the endemic regions. It has been suggested that high SSTs during El Niño in 1992 may have contributed to the spread of cholera to South America. Evidence for an association between cholera and sea surface temperatures is limited but suggestive.

3.5 Biotoxins: fish and shellfish poisoning

Higher temperatures increase the growth of microorganisms, particularly in aquatic or marine ecosystems. Algal blooms are caused by rapid proliferation of dinoflagellates, diatoms, and blue-green algae, some of which produce potent toxins. Certain "harmful" blooms are associated with paralytic, diarrhoeal, and amnesic shellfish poisoning when planktonic biotoxins enter the food chain via clams and mussels (HEED, 1998). Some may cause illnesses without consumption because they release aerosolised toxins that can result in illness to many animals, including humans, when inhaled. High sea surface temperatures are thought to be a trigger in some bloom occurrences. However, environmental pollution is a major factor in the observed increase in the occurrence of blooms in recent years.

There is some evidence that the occurrence and distribution of harmful coastal algal blooms is associated with El Niño (Tester, 1994; Hallegraeff, 1993; HEED, 1998). Cases of human poisoning can occur in the absence of algal blooms, however. Outbreaks of human poisoning are rare events in developed countries but some notable poisoning outbreaks have occurred in El Niño years. For example, the first outbreak of amnesic shellfish poisoning occurred on Prince Edward Island, Canada in 1987 (HEED, 1998). A consistent relationship between shellfish poisoning cases and El Niño has not yet been investigated.

Ciguatera is the most frequent cause of human illness caused by ingestion of marine toxins. The toxins are eaten by herbivorous fish and are then passed up the food chain to humans who eat the predatory reef fish. It is an important health problem in the Pacific Islands where fish is a major source of protein. Hales *et al.* (1999b) have found a relationship between the annual incidence of reported ciguatera fish poisoning and the SOI in some islands in the South Pacific where El Niño is associated with higher SSTs. The risk of fish poisoning was found to increase during El Niño in Tuvalu, Rarotonga (Cook Islands), Kiribati and Western Samoa.

3.6 Health impacts of disasters

The majority of deaths and disease that are associated with El Niño can be attributed to weather-related disasters. This is illustrated by the impacts of torrential rain, landslides and flooding in South America during the major El Niño event of 1997/98 (see Table 1.3). In Peru, the impacts of El Nino in 1983 increased total mortality by 39.79% and infant mortality by 103% (Toledo Tito, 1997).

3.6.1 Drought

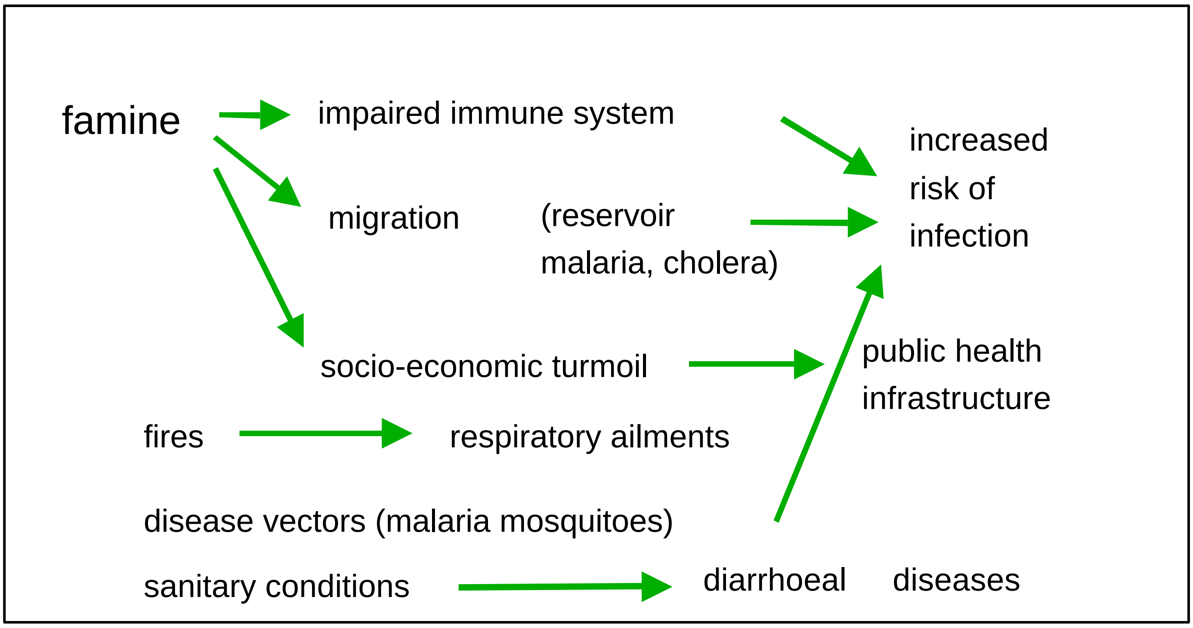
The relationship between drought disasters and ENSO is described in Section 2.3. High seasonal and year-to-year variability in food supplies, often the result of unreliable rainfall and insufficient water for crop and livestock production, is a major contributor to chronic undernutrition and food insecurity.

There are several pathways by which drought affects health (Figure 3.3). In the most extreme case, famine, the number of deaths associated with insufficient food consumption increases substantially. Famine often occurs when a pre-existing situation of malnutrition worsens. The health consequences of drought include diseases resulting from lack of water. Studies have shown that in times of shortage, water is used for cooking rather than hygiene. In particular, this increases the risk of faecal–oral (primarily diarrhoeal) diseases and water-washed diseases (such as trachoma, scabies). Malnutrition also increases susceptibility to infection.

Factors which contribute to famine include the inability of the population to produce food because of adverse climatic or other environmental conditions and/or absence of appropriate food aid. The latter may include a collapse in the marketing system due to political, environmental or economic crises. Additionally, these factors may have a cumulative or synergistic effect. For example, a breakdown in the reserve food supply system due to the sale of grain or livestock reserves might be exacerbated by conflict and breakdown in law and order.

El Niño events have been linked to droughts in otherwise humid environments. A study of the impact of drought in small villages in West Kalimantan, Indonesia, found increased health problems and damage to the rural economy (Salafsky, 1994). The total cost of drought was estimated to be between approximately one-quarter and one-half of annual township income.

Figure 3.3. Drought can affect human health via several pathways.
Source: Bouma



3.6.2 Floods

The impacts of catastrophic flooding on human health are significant. The relationship between flood disasters and ENSO is described in Section 2.5. Many health consequences were recorded after flooding in South America associated with the major El Niño of 1982/83. Increases in the incidence of acute diarrhoeal diseases and acute respiratory diseases were recorded in Bolivia (Telleria, 1986) and in Peru (Gueri *et al.*, 1986). Flooding in the Horn of Africa associated with the El Niño of 1997 was linked with an upsurge of cholera deaths due to affected sanitation and contaminated water supplies (WHO, 1998a).

3.6.3 Damage to public health infrastructure

The local infrastructure can be severely affected during a natural disaster. El Niño-related damage may include:

- flood damage to buildings and equipment, including materials, and supplies;
- flood damage to roads and transport systems.
- problems with drainage and sewerage systems;
- damage to water supply system.

PAHO (1998a) described several major impacts to the health care infrastructure during the 1997/98 El Niño in South America. In Peru, 9.5% (437) of health facilities had been damaged, including 2% of the hospitals (9) and 10% of other health centres (428). Approximately US$ 1500 000 was allocated to keep these facilities in operation by waterproofing roofs, installing drains, digging ditches, protecting equipment, installing generators, and building alternative water supply systems. In Ecuador, 2.3% (7) of the hospitals were damaged, mainly by flooding, mud, damage to the already defective sewerage systems and problems with drinking water supply.

3.6.4 Forest fires and "haze" air pollution episodes

The direct effects of fires on human health occur from burns and smoke inhalation. Loss of vegetation on slopes may lead to soil erosion and increased risk of landslides. Such a process is often exacerbated when an urban population expands into surrounding hilly and wooded areas.

The health impacts of biomass smoke episodes have been reviewed by WHO (e.g. Brauer, 1998). Elevated levels of particulates are known to be linked to increased mortality and morbidity in susceptible persons, and increased risk of hospital and emergency admissions. Increases in respiratory and eye symptoms were reported in Malaysia and Indonesia during the air pollution episode. In Malaysia, surveillance data indicate a 2–3 fold increase in number of outpatient visits for respiratory disease during episodes. A 14% decrease in lung function in school children during the episode was also reported. In Alta Floresta, Brazil, there was a 20-fold increase in outpatient visits for respiratory disease in 1997. Further assessments are being undertaken of the short-term impacts on mortality and morbidity associated with the 1997 episode. However, such assessments are often limited by lack of baseline data. Following the 1997 events, WHO has published health guidelines for episodic vegetation fire events (WHO, 1999).

3.7 Discussion

There is good evidence that the ENSO cycle is associated with the increased risk of certain diseases. This relationship is particularly strong for malaria but is suggestive for other mosquito-borne and rodent-borne diseases. Table 3.6 summarises for malaria some of the relationships that have been found in the literature. More research is needed to determine the nature of the climate drivers or mechanisms of these relationships. At present there are too few studies on this topic.

A report by PAHO (1998b) concludes that, at present, "no concrete data are available that demonstrate that the incidence of infectious diseases is consistently and reliably related to El Niño events". This conclusion was based upon analyses of aggregated national disease data for malaria in South America (1970–97). Such geographical aggregation of data irrespective of known ENSO-related climate anomalies was unlikely to find an ENSO "signal". Similar analyses performed for yellow fever in Peru and Bolivia also found no association with ENSO. Further, in infectious disease epidemiology, it is rare for a disease to be consistently and reliably related to a single factor.

Table 3.6 High risk years for malaria in relation to the ENSO cycle

Country/District	Time period	Relative risk		Reference
Sri Lanka (SW)	1870–1945	3.6	Niño year (0)	Bouma and van der Kaay, 1996
India + Pakistan (Punjab)	1867–1943 pre-DDT	4.5	post-Niño year (1)	Bouma and van der Kaay, 1996
Pakistan (NWFP)	1970–93	*		Bouma *et al.*, 1994
India (Rajasthan)	1982–1992	*	Niño year (0)	Bouma *et al.*, 1995
Venezuela	1910–35 deaths	5.0	post-Niño year (1)	Bouma, unpublished
Venezuela (Carabobo)	1975–90 cases	*	post-Niño year (1)	Bouma and Dye, 1997
Colombia	1960–1992	*	post-Niño year (1)	Bouma *et al.*, 1997
Colombia	1959–1993	*	post-Niño year (1)	Poveda et al. 1999b

* Relative risk not calculated

ENSO is associated with seasonal anomalies in climate in certain regions and not with individual weather events. Therefore, individual outbreaks of disease should not be attributed to El Niño or La Niña. The 1982/83 and the equally strong 1997/98 events have limited use as “case studies” for the impacts of ENSO precisely because they are such large events and therefore atypical. Analyses of single epidemics, or case studies, can provide important information about the meteorological conditions that triggered the outbreak. However, the causes of single epidemics may be different to the causes of *cyclic* epidemics. The authors recommend that time series be used to evaluate the relationship between the disease outcome and ENSO. Therefore, there is a need for long-term monitoring and surveillance to collect these data.

4. SEASONAL FORECASTING AND APPLICATIONS IN THE HEALTH SECTOR

4.1 Forecasting seasonal and inter-annual climate variability

The El Niño of 1997/98 may be the first time that reasonably successful seasonal forecasts have been made available globally by the scientific community and have been received with some confidence by the public and decision makers. The climate system is non-linear and the predictability of ENSO lies in its influence on the probabilities associated with atmospheric states. Forecasts are most robust for strong El Niño or La Niña events. Forecasts do not predict particular weather events. Rather, the probability of such weather occurring is increased or decreased by El Niño/La Niña. Individual weather systems are themselves chaotic and this is why the weather is inherently unpredictable beyond 7–9 days.

"Seasonal forecasts" are used to predict major climate trends over a period of several months to a few seasons. They indicate areas where there is an increased likelihood of some deviation from the climatic mean, such as wet or dry, warm or cold conditions. A seasonal forecast is usually limited to the probability of temperature or rainfall being above, near, or below normal, without quantifying the deviation. Predictions are better for some seasons than for others. At the moment, seasonal forecasts are only available for certain regions and for certain months, however, there is clearly the potential to extend such forecasts to other regions (Carson, 1998).

Seasonal forecasting is still in its experimental phase but rapid improvements are anticipated within the next decade. The 1997/98 El Niño provided both new data and the chance to test and refine scientific understanding and evaluate forecasting techniques. This was the first event to be observed with the full array of TAO (Tropical Atmosphere–Ocean) buoys recently established in the Pacific Ocean.

The predictability of El Niño months ahead is possible because the oceans and the atmosphere continually interact and because the oceans have a persistent influence (memory) on weather systems. Several prediction schemes have been developed, including both statistical and physical models but they are all based on predicting tropical sea surface temperatures (SSTs). Over the last few years, the coupled ocean–atmosphere general circulation models have been providing the most accurate forecasts (Latif *et al.*, 1994; Stockdale *et al.*, 1999). All models rely on real-time climate data from monitoring stations in and around the Pacific.

Box 4.1: Sources of Seasonal Forecasts

WMO regularly summarises the outputs of several models [http://www.wmo.ch]. *Climate Prediction Center* (NOAA) disseminates special climate summaries which monitor current and developing climate variations, including an ENSO Diagnostic Advisory which is generally updated monthly and an ENSO Update which is generally updated weekly. *Office of Global Programmes* (NOAA) provides collections of predictions from the major operational and research climate centres as well as background information on El Niño. *International Research Institute for Climate Prediction (IRI)* was established to develop seasonal-to-interannual climate forecasts and address all aspects of end-to-end prediction, including model development, climate monitoring and dissemination, applications research, and training, in coordination and collaboration with the international climate research and the end user community. The IRI core facility is jointly at the Lamont-Doherty Earth Observatory in Columbia University, and the Scripps Institute of Oceanography, University of California.

Experimental forecasts are also issued by the following prediction centres:

- European Centre for Medium-Range Weather Forecasting (ECMWF), based at Reading University UK [http://www.ecmwf.int]
- UK Meteorological Office [http://www.meto.gov.uk]
- Australian Bureau of Meteorology, Australia [http://www.bom.gov.au]
- Lamont Doherty Earth Observatory at Columbia University, USA [http://rainbow.ldeo.columbia.edu]
- Centre for Ocean-Land-Atmosphere Studies (COLA/IGES) [http://grads.iges.org]

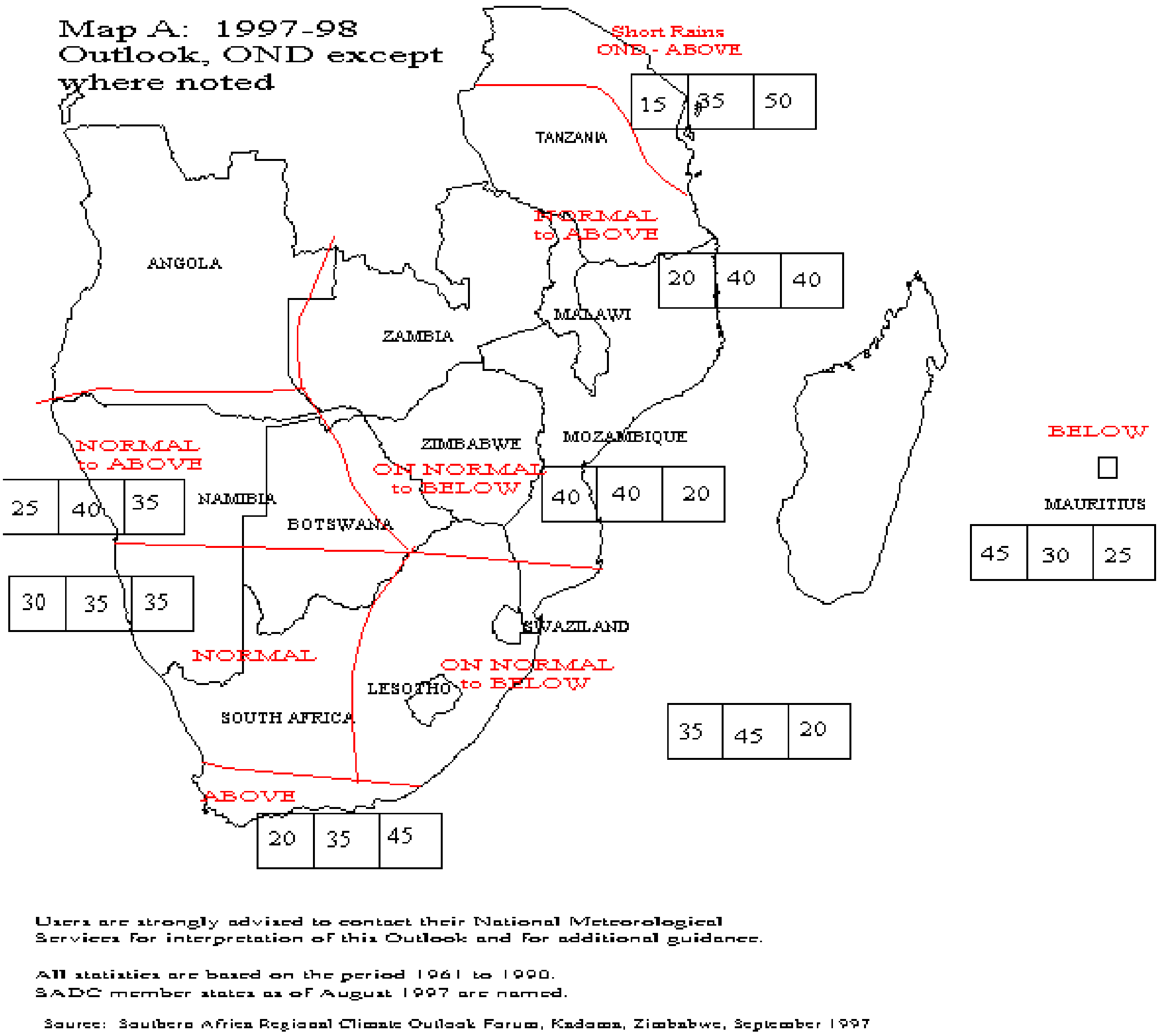


Figure 4.1. Example of forecast for the Southern Africa region for October–December season (OND)
All statistics are based on the period 1961 to 1990. SADC member states as of August 1997 are named.
Source: Southern Africa Regional Climate Outlook Forum, Kadoma, Zimbabwe, September 1997.
Key: B = below average rainfall, N = near-normal rainfall, A = above-average rainfall.

B	N	A

4.2 Disseminating forecasts

Seasonal forecasts are only of value if they are shown quantitatively to be reliable and if intermediate and end users have access to them and the capacity to respond. This requires effective communication between all parties along the linkages between prediction centre, to intermediate user (usually the National Meteorological and Hydrological Service, NMHS) to the end user. End users of seasonal forecasts are typically considered to be:

- Farmers: to maintain agricultural productivity under conditions of drought or heavy rainfall/floods;
- Water resource managers: to maintain water supplies in times of drought, limit flood damage and maintain water quality;
- Fishermen: to maintain fishery productivity;
- Foresters: to mitigate the impacts of drought on forests and reduce the risk of fire.

The dissemination of seasonal forecasts is a sensitive and difficult issue that is currently being addressed by the national and international agencies engaged in these activities (see Glantz, 1995). There are clearly political and socio-economic concerns about who is using the forecasts and why. For example. they can give unfair advantage to business competitors. For such reasons, forecast groups send their forecasts first to the local National

Meteorological Services, then to other relevant national and international agencies (including NGOs) before they are placed in the public domain.

Peru provides a good example of the application of seasonal forecasts (NOAA, 1994a). Peru suffers an increased risk of flooding and perturbations in the coastal fisheries during El Niño. El Niño forecasts are provided in early November *each* year for the following rainy season. Forecasts are given for the following contingencies:

- near normal conditions;
- a weak El Niño with slightly wetter than normal growing season;
- a full blown El Niño with flooding;
- cooler than normal waters offshore with higher than normal chance of drought (La Niña conditions).

Representatives of farmers and government then meet to decide on the selection of crops to maximise yield. Other countries which use seasonal forecasts for agricultural planning include: Brazil; Australia; India; United States; Zimbabwe; and Ethiopia. Australia has the longest track record in such applied El Niño research.

The International Research Institute for Seasonal-to-Interannual Climate Prediction (IRI) is mandated to improve application of seasonal forecasts for the explicit social benefit of both developing and developed nations (NOAA, 1994b). The Climate Information and Predictions Service of WMO (CLIPS) supports national meteorological agencies to develop their capacity for climate prediction. The CLIPS project was very active in ensuring that UN agencies were kept up to date with the development and the expected course of the 1997/98 El Niño through the regular publication of an El Niño update and the holding of interagency and press briefings.

As seasonal forecasting becomes more reliable, it will be more useful. There is also much work to be done to ensure equal, timely and appropriate access to forecast information. However, it is also important to note that because El Niño events evolve over several months, it is *now* possible to give advance warning of many impacts once the onset of an event has been confirmed.

4.2.1 Regional Climate Outlook Fora

A main problem for communities and decision makers is to decide which forecast to act upon. There can be significant differences between individual forecasts. The NOAA Office of Global Programmes and other agencies have therefore convened *Regional Climate Outlook Fora* in the following regions: Southern Africa; Greater Horn of Africa; South East Asia; Pacific South America; southeast South America; northeast South America; and Indonesia and Australia. Presentations are made by representatives of the prediction centres and world climate institutions. The objectives of each of the fora are to:

- discuss the current state of global and regional climate;
- produce consensus seasonal forecasts for the region in question;
- develop adaptation plans based on this seasonal forecasts.

The consensus forecasts are for several homogenous zones within each region, with probabilities for above, near and below normal rainfall (see Figure 4.1 above).

4.3 Disaster mitigation

El Niño is not itself a disaster but can be considered as a "hazard spawner" (Glantz, 1998). The information presented in Section 2 demonstrates that the relationship between ENSO and natural hazards is sufficiently strong to use seasonal forecasts as early warning of the increased risk of natural disasters in certain regions. Knowledge of general weather patterns a few months in advance can be used in all stages of handling natural disasters: awareness and education, preparedness and prevention, and prediction and mitigation. The forecasting of El Niño events allows preparations to be made in the health sector, e.g. the setting up of an epidemiological surveillance system to reduce the risk of disease outbreaks.

Specific strategies for preventing, mitigating, or adapting to ENSO-related disasters depend on prevailing socioeconomic conditions and institutional resources in each region (Dilley, 1997). In those regions where teleconnections pose a high risk of exposure to climatic hazards, vulnerability assessments can be undertaken. For example, those populations or sub-groups most at risk could be identified. Vulnerability assessments would provide information for targeting development and mitigation activities.

Community actions can reduce the risk of drought, wildfire, epidemics, and floods. The UN Disaster Management Training Programme has produced *A Guide for Community Action for El Niño*. Table 4.1. list some of the actions by which community groups can prepare themselves for the various types of disasters associated with El Niño. PAHO has helped establish the *Center of Communication and Information for Disaster Mitigation* in Peru, to work with the mass media to improve mass communication campaigns to encourage communities to adopt basic prevention and control measures (PAHO, 1998b). The success of any forecast will depend on the perceived benefits of early warning by the local community, as well as by governmental organizations.

Many governments are beginning to involve relevant sectors in the application of seasonal forecasts to disaster mitigation. Details can be obtained from national and regional agencies (e.g. FEMA, USDA, Peruvian Ministry of Interior, Asian Disaster Preparedness Centre (1998), etc.). PAHO has a long-standing and successful Emergency Preparedness and Disaster Relief program which has also addressed the impacts of ENSO.

Seasonal forecasting is only one potential component of a disaster early warning system. Seasonal forecasting can assist with medium-term planning and the optimization of resources. The conclusions of the 1998 IDNDR Early Warning Conference for natural disasters are particularly relevant for the use of seasonal forecasting (IDNDR Secretariat, 1998):

- Early warning represents a cornerstone of disaster reduction. It should therefore become a key element of future disaster reduction strategies for the 21st Century.
- Effective early warning depends upon multisectoral and interdisciplinary collaboration among all concerned actors.
- While early warning capabilities are strengthened at the global level, it is important that greater emphasis be given to developing capacities that are relevant and responsive to the needs of local communities.

Table 4.1. Community Action for El Niño as recommended by UN Disaster Management Training Programme

Disaster type	Action
Drought	• identification of emergency logistics facilities; • identification of vulnerable population groups; • development of water rationing plans; • establishment of local nutritional surveillance capacity; • establishment of local cereal banks and buffer stocks; • dissemination of water harvesting and fuel conservation techniques; • promotion of drought resistant agricultural techniques
Epidemics	• promotion of basic hygiene; • setting up emergency stockpiles of medicines, blankets, and other necessary equipment; • advocacy for maintenance of water and sanitation systems.
Fires	• promotion of reforestation with fire-resistant species; • promotion of awareness of the dangers of burning; • advocacy for burning ban enforcement.
Floods	• identification of emergency logistics facilities; • development of emergency response systems; • advocacy for land-use planning; • identification of vulnerable areas and population groups; • hill-side planting to reduce the risk of landsides and flooding; • construction of retaining walls and levees; • capacity building for infrastructure maintenance and repair.

4.3.1 Drought and famine early warning

At present, seasonal forecasts are of most use in the mitigation of drought, food shortages, and famine disasters. The onset of drought is long-term compared to the onset of other types of disasters. The timely application of mitigating measures is strongly dependent on being able to determine the drought's course, extent and likely severity at the earliest stage possible. Climate forecasts are often combined with other types of indicators (social and physical data, including satellite data) in Famine Early Warning Systems (FEWS).

Seasonal forecasts have already been included into many local and regional famine and drought early warning systems. These include:

- Global Information and Early Warning System (GIEWS) of FAO. GIEWS monitors continuously crop and food supplies worldwide to assist governments in taking timely action. Satellite data are used extensively to monitor crop conditions.
- FEWS (Famine Early Warning System) set up by USAID. FEWS covers the following countries in Africa: Chad; Burkina Faso; Ethiopia; Niger; Mali; Mauritania; Mozambique; and Sudan.
- Southern Africa Development Community (SADC) Regional and National Early Warning System.
- Drought prediction service provided by the Ethiopian National Meteorological Service Agency (Glantz, 1996a).

The World Food Programme (WFP) established a Global Task Force to tackle the effects of El Niño on food supply (FAO, 1998). The task force evaluated the world-wide impact of El Niño in the poorest countries, prioritises and co-ordinates response strategies and mobilises resources from donor countries.

Early warning systems should include ENSO/seasonal forecasts in order to build a system to intervene at different stages. In particular, community-based approaches are needed to reduce the adverse impacts of drought. Participants at a Workshop on Food Security, Early Warning and El Niño (Glantz, 1994) confirmed that it is important to make decision-makers understand the strengths and weaknesses of meteorological information and to show them how to use the information to mitigate potentially adverse impacts.

4.4 Forecasting applications in the health sector

Seasonal forecasts may assist in epidemic preparedness and to target the use of scarce resources. The health sector and research community need to address both the risk of natural disasters and disease outbreaks. Table 4.2 lists the stages of the various activities that are currently undertaken by the health sector to reduce the health impacts of disasters. During El Niño in 1998, the main activities and recommendations of PAHO (1998b) were directed toward the following actions:

- Training workshops in the health services network in high risk areas for the strengthening of entomological surveillance, vector control, and prevention activities. Support for the development of a project to introduce treated mosquito netting. Active surveillance was focused on the areas at greatest risk.
- Upgrading of health personnel to reduce mental health impacts of disasters in the most hard-hit subregions (prevention, assistance, and rehabilitation).
- Implementation of the Supply Management Project in the Aftermath of Disasters (SUMA) to strengthen the logistical information process at the national level and in the affected subregions, through workshops and follow-up for the Ministries of Health, NGOs, and UN agencies.
- Provision of basic supplies for water storage and treatment.
- Local workshops to find solutions to environmental sanitation problems.
- Training of members of the community in the hardest-hit departments (the local authorities, community leaders, neighbourhood representatives, school health monitors, health promoters) in preparedness for El Niño.
- Identification of shelter sites and requirements for their installation, and control of food distribution.
- Characterization of rodents and vectors of public health significance in disaster areas.
- Strengthening of laboratory diagnosis for leptospirosis and hantavirus.
- Vaccination of the affected population against whooping cough, tetanus, and diphtheria to guard against potential outbreaks.

Table 4.2. Public health activities for disasters.

Activity	Description	Examples
Mitigation	Reduction of harmful effects of the disaster limiting its impacts on human health and well-being.	Planning, building legislation, coastal defences, etc.
Early Warning and Preparedness	Communication of forecasts to appropriate officials in health sector	Severe weather watch/warnings systems, hurricane forecasts
Needs Assessment	Rapid needs assessment to determine the health and other needs of the affected population.	Surveys by public health department
Surveillance	Mortality and morbidity surveillance to determine	

	preventative actions in the future.	
Response and Recovery	Activities relating to public health and safety in the aftermath of the event	Water treatment, food safety, immunization campaigns, counselling for victims and rescuers, etc.

4.4.1 Malaria

Climate forecasts at seasonal and inter-annual lead times may be of great importance in mitigating future epidemics in regions where a relationship between disease and ENSO has been established (see Section 3). In many countries, vector control measures have failed or resources are too limited to maintain adequate levels of control of vector-borne diseases such as malaria. Seasonal forecasts can give a timely seasonal indicator of malaria risk.

Significant developments have been made in mapping and modelling techniques to forecast malaria “risk” in time and space (e.g. Hay *et al.,* 1996). In particular, attention has focused on the use of satellite data for the short-term forecasts of epidemics (Beck *et al.,* 1997). Satellite data can provide proxy ecological variables such as rainfall estimates or vegetation indices (e.g. NDVI - normalised difference vegetation index) to map areas suitable for certain disease vectors (Connor *et al.,* 1998).

There is potential to develop models for medium term forecasts of malaria risk, based on seasonal climate forecasts. For example, the “Malaria Forecasting Project” in southern Africa is being developed by le Sueur and colleagues at the National Malaria Research Program, South Africa (Le Sueur and Sharp, 1996). Previous studies have demonstrated the relationship between climate fluctuations and vector abundance and malaria transmission. A process-based model has been developed in the initial pilot study to predict the severity of malaria transmission for a given season, based on climate forecasts. Long term data on disease incidence are required for the validation of such a model. Unfortunately, such data are largely unavailable in southern Africa.

A pilot study on the application for seasonal forecasting for malaria control was undertaken in the SADC region (Cresswell *et al.,* 1998). This study made critical assessment of the forecast and climatological products that were produced at the southern Africa regional climate fora (ENSARCOF - Southern Africa Regional Climate Outlook Forum). Table 4.3 lists those climate products identified as most suitable for epidemic forecasting. However, the infrastructure does not yet exist in this region for the incorporation of seasonal forecasts into a prospective operational disease forecasting system. The IRI, in collaboration with NOAA/OGP and other agencies, is developing a program in Africa to train multi-disciplinary teams in developing regional malaria models and applying climate data and forecasts.

Early warning based on seasonal forecasts can assist in improving vector control and personal protection. In countries relying on residual house spraying with insecticides, increasing the efforts during high risk years and decreasing spraying during low risk years will improve cost-effectiveness of operations. Lead times of a year or more offer sufficient time to adjust procurement of insecticides to assessed risk. Countries relying on the use of insecticide impregnated bednets anticipating an increase of malaria could increase awareness through the public health system and launch special actions, for example, to re-impregnate nets. An early warning system can also assist in improving diagnosis and treatment. Most serious morbidity and mortality during malaria epidemics stems from late recognition of the epidemic and shortages of antimalarial drugs. For example, the epidemic in the highlands of Madagascar in 1987–88 was slow to be recognised and many delays occurred in the distribution of anti malarials to the epidemic region.

Table 4.3. Attributes of forecasts that are desirable for epidemic forecasting

Characteristic Required	Rationale
1 monthly forecast bulletins rather than seasonal	Dynamics of epidemics requires constant updating
2 month lead time, or 1 month if accuracy significantly greater	2 month permits health sector to make necessary plans
60–100km spatial resolution	Better resolution allows resources to be used more effectively
Rapid notification of “anomalous” events - like flooding	Many epidemics are due to these unusual events
Improved estimation of El Niño effects on climate	Rainfall and length of season of primary importance
Forecasts supplied as digital maps	Integration of forecasts to existing models will be easier

Source: Cresswell *et al.,* 1998

Malaria control programmes anticipating an increase in malaria in the following year can increase vigilance, e.g. by alerting district health office, filling vacant positions of health staff, requesting more frequent reporting to facilitate early identification of problem areas. Central country stock management and regional distribution of anti-malaria drugs can also be tailored to the assessed epidemic risk.

4.5 Discussion

There is clearly great potential in the use of seasonal forecasts to improve public health. More research is needed to establish the climate/health relationships upon which forecasts can be based. Although the science of forecasting is developing rapidly, there is still much progress to be made in intersectoral collaboration between forecasters and the users of the forecasts. At present the health sector is not considered a "user" of forecast information. The general needs for the "user" community include (NCAR. 1998):

- improved public understanding of how La Niña and El Niño events bring about probability shifts in terms of potential impacts in distant locations of extreme climate-related impacts about which societies are likely to be concerned;
- agreed-upon definitions of El Niño and La Niña events;
- more and better weather data at the local level, as opposed to the more generalized regional level for impact assessments;
- reductions in societal constraints, including institutional ones, on forecast use;
- more collaboration between users of ENSO information and more involvement early in the ENSO forecast process.

Many developing countries currently lack the infrastructure for a prospective operational disease forecasting system. Basic research is also required to establish the climate–health relationships and the appropriate forecast tools but some progress has been made in this area - see Table 4.3 above. It is clear that the needs of the health sector need to be identified and communicated to the forecast providers. Capacity building is clearly necessary to begin or improve the use of seasonal forecasts in the health and welfare sectors.

5. CURRENT INITIATIVES

5.1 Current initiatives on ENSO relevant to health

5.1.1 UN Task Force on El Niño

UN General Assembly on 18th Dec. 1997 adopted the resolution A/52/200 entitled "*International co-operation to reduce the impact of El-Niño phenomenon*" which calls upon the relevant intergovernmental bodies and others to actively support IDNDR activities to reduce the impact of the then current El Niño. The Inter-Agency Task Force has a dual approach: scientific on the one hand and social, economic and operational development on the other. The Task Force aims to develop strategic approaches towards prevention, preparedness and mitigation of El Niño-induced disasters. WHO is a member of the Task Force (see Table 5.1).

The Task Force is co-ordinated in the IDNDR Secretariat. The IDNDR focuses on the prevention of disasters rather than relief operations, and stresses the importance of disaster early warning systems. IDNDR intends to promote strengthening of national and local capacity to cope with disasters, particularly with respect to vulnerable groups and communities.

World Meteorological Organization (WMO) prepares the scientific and technical information for the Task Force. This will include input from several climate and forecasting fora that have been conducted to devise more effective ways of applying global forecasts to local regions. A major report is being prepared at the time of writing by WMO, "*The Scientific and Technical Retrospective of the 1997/98 El Niño Event*".

5.1.2 The Climate Agenda

The Climate Agenda is a UN interagency programme which integrates all major international climate-related activities. The Climate Agenda was adopted by the WMO Congress in June 1995 and provides a framework for governments, international organizations and NGOs can plan their contributions to climate-related programmes, allocate resources, benefit from complementary activities etc. It identifies climate services for sustainable development.

The InterAgency Committee on the Climate Agenda (IACCA) is the mechanism by which activities are co-ordinated under the Climate Agenda. The Committee recommended at its Second Session that "issues related to climate and human health should be given a very high priority in projects related to impact and adaptation within the framework of the Climate Agenda" (WMO, 1998b, p.6). A collaborative programme on climate and human health, outlined by WHO, WMO and UNEP was also approved by IACCA. Potential areas of work include:

1. assistance to Member States to promote vulnerability assessment, adaptation strategies, and the adoption of technologies to promote health and reduce greenhouse gas emissions;
2. the exchange and provision of information on the health impacts of climate change and of mitigation strategies as well as effective approaches to adaptation;
3. the promotion of research on the above topics.

The IHDP (International Human Dimensions of Global Change Programmes) has stressed, through IACCA, the need for social, economic, health and other human dimensions of El Niño events to be effectively integrated within the scope and outputs of the UN Task Force and its meetings.

5.2 Research and monitoring

There is a need to develop a scientific agenda that will examine the impact of ENSO on human and on health infrastructure and services. Attention should be paid to the vulnerability of populations to ENSO, how disease incidence will respond to extreme climatic events, and how health programs will adjust to changes in morbidity and mortality caused by climate change (PAHO, 1998b).

A workshop on the health impact of the El Niño phenomenon in Central America was held in November 1997 (PAHO, 1998b). Ministries of Health, water companies, disaster agencies and IDNDR were represented.

Recommendations were made for actions at the local, national and subregional levels. The workshop identified the following needs:

- to facilitate the sharing of knowledge and experience in areas such as environmental sanitation, epidemiology and information and communication systems;
- to strengthen the role of ministries of health in disaster preparedness programmes;
- to improve the identification of potential sources of funding for El Niño-related projects;
- to strengthen epidemiological surveillance systems at every level;
- to improve access to epidemiological and meteorological information including support for the human and material resources to strengthen the regional information network.

PAHO has called for national monitoring programmes of the most important environmental parameters of human disease (PAHO, 1995). Climate data are, in general, more easily accessible than health data. Major regional and global datasets can be accessed through several international programs that were specifically created to co-ordinate data collection and distribution. Improved monitoring and surveillance are also needed for potential health impacts of global climate change (Haines *et al.*, 1993).

Pilot projects to determine the usefulness of seasonal forecasts for epidemic mitigation should also be used to foster collaboration between researchers, discipline and between institutions (Diaz *et al.*, 1998). A Cooperative Research Network Program addressing climate variability and ENSO has been funded from 1999 by the InterAmerican Institute as a joint effort between the following countries: Brazil, USA, Colombia, Mexico, Venezuela, and Jamaica. The programme will investigate climate-health linkages in the Americas and implement a central clearinghouse for these data. The program also aims to develop conceptual frameworks and methodological approaches to climate/health studies.

NOAA Office of Global Programs is currently co-ordinating an interdisciplinary research effort, “The ENSO Experiment”, to assess the impact of the 1997-98 ENSO event on human health (NOAA, 1998). The programme also aims to enhance dialogue between the climate, ecology and health research communities and identify additional research and monitoring needs. The outcomes of the ENSO Experiment are expected in 1999/2000, no results or analyses were available at the time of writing.

Table 5.1. Members of the El Niño Task Force

- the Food and Agriculture Organization of the United Nations (FAO);
- the United Nations Educational, Scientific and Cultural Organization/International Oceanographic Commission (UNESCO/IOC);
- the World Health Organization (WHO);
- the World Bank;
- the International Atomic Energy Agency (IAEA);
- the World Meteorological Organization (WMO);
- the United Nations Development Programme (UNDP);
- the World Food Programme (WFP);
- the United Nations Department for Humanitarian Affairs (DHA);
- the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP);
- United Nations University (UNU);
- the Asian Disaster Preparedness Centre (ADPC).
- the United Nations Children's Fund (UNICEF);
- the United Nations Environmental Programme (UNEP);
- the United Nations Centre for Human settlements (Habitat);
- the United Nations Economic Commission for Europe (ECE);
- the United Nations Office for Project Services (UNOPS);
- the United Nations Research Institute for Social Development (UNRISD);
- the International Civil Defense Organization (ICDO);
- the International Council of Scientific Unions (ICSU).

6. CONCLUSIONS

There is good epidemiological evidence that El Niño is associated with an increased risk of certain diseases in specific geographical areas where climate anomalies are linked with the ENSO cycle. The associations are particularly strong for malaria but suggestive for other mosquito-borne and rodent-borne diseases. More research is needed to determine the nature of the ecological mechanisms of these relationships. Reports that link disease outbreaks to a single El Niño event are difficult to interpret because there are a number of potential confounding factors that may be responsible for the observation. Therefore, in this report, more emphasis has been placed on the results of analysis which have included a number of events or a long data series.

The ENSO phenomenon provides good opportunities to study effects of climate variability on human health and, in particular, to elucidate complex disease dynamics. Population vulnerability to climate variability is affected by factors such as socio-economic deprivation and public health infrastructure. Greater understanding of the impacts of climate on health could help reduce vulnerability to the potential health impacts of global climate change.

There are many initiatives associated with ENSO and climate variability. The majority of such initiatives focus on seasonal climate prediction and natural disaster mitigation. Seasonal forecasting is being increasing used to provide early warning of drought, particularly in the agricultural sector. The development of health early warning systems is an area where collaboration between the meteorological and health sectors can improve disaster and disease outbreak preparedness. Early warning for likely upsurges in vector-borne diseases would allow the health sector to target vector control programmes and other activities. The effective implementation of such systems requires closer collaboration between researchers, health professionals and meteorological services. Recent assessment of the health impacts of hurricanes George and Mitch have emphasised the benefits of early warning systems for natural disasters. In order to be successful, such systems need to reach the communities that are most likely to be affected. Systems should be part of a programme to strengthen the capacity of local communities to identify ways in which they are vulnerable to extreme weather and to enhance their preparedness to reduce impacts. There is an urgent need for the co-ordination of early warning and preparedness activities at the level of national governments.

The impacts of ENSO have demonstrated the importance of the ecological basis for many diseases and underscores the importance of understanding how ecosystems respond to climate influences. These linkages need to be more fully appreciated by many health professionals, policy-makers and the general public.

ABBREVIATIONS AND ACRONYMS

ADPC	Asian Disaster Preparedness Center
CERED	Center for Environment Research, Education and Development, Viet Nam
CLIPS	Climate Information and Prediction Services (WMO)
ENSARCOF	South African Regional Climate Outlook Forum
ENSO	El Niño/Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FEWS	Famine Early Warning System
HEED	Health and Ecological Dimensions of Global Change Program
HPS	Hantavirus pulmonary syndrome
GIEWS	Global Information and Early Warning System (FAO)
IACCA	InterAgency Committee on the Climate Agenda
IAI	Inter-American Institute for Global Change Research
IDNDR	International Decade of Natural Disaster Reduction (UN)
IHDP	International Human Dimensions of Global Change Programme
IFRC	International Federation of the Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Seasonal-to-Interannual Climate Prediction
MEI	Multivariate ENSO Index
MVE	Murray Valley encephalitis
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration, US
NMHS	National Meteorological and Hydrological Service
PAHO	Pan American Health Organization
ProMED	Program for Monitoring Emerging Diseases
RVF	Rift Valley Fever
SADC	Southern Africa Development Community
SOI	Southern Oscillation Index
SST	Sea surface temperature
UNEP	United Nations Environment Programme
USAID	US Agency for International Development
US NSF	US National Science Foundation
WFP	World Food Programme (FAO)
WHO	World Health Organization
WMO	World Meteorological Organization

ENSO GLOSSARY

El Niño is a term originally used to describe the appearance of warm (surface) water from time to time in the eastern equatorial Pacific region along the coasts of Peru and Ecuador. It was once suggested that minor El Niño events occurred about every two to three years and major ones about every eight to 11 years. Today, El Niño has a return period of four to five years. When an El Niño event occurs, it often lasts from 12 to 18 months. There is sometimes disagreement about what constitutes an "event".

La Niña refers to the appearance of colder-than-average sea surface temperatures (SSTs) in the central or eastern equatorial Pacific region (the opposite to conditions during El Niño). Many scientists do not like the use of the term and prefer to call it a cold event (described below). La Niña is also sometimes called El Viejo.

A **warm event** refers to the anomalous warming of SSTs in the central and eastern equatorial Pacific. This term is being used to avoid confusion over the use of other terms like ENSO and El Niño. A warming in the regions mentioned is accompanied by a relative cooling in the western equatorial Pacific.

A **cold event** is one where the SSTs become anomalously colder compared to the long-term average for the central and eastern equatorial region. (It is the opposite of a warm event in that region.) It has been referred to in the past as anti-El Niño and, more recently, as La Niña. La Niña, however, unlike the restrictive view of El Niño, is applied to Pacific basinwide phenomena.

The **Southern Oscillation** is a see-saw of atmospheric mass (pressure) between the Pacific and Indo-Australian areas. For example, when the pressure is low in the South Pacific high pressure cell and high over Indonesia and Australia, the Pacific trade winds weaken, upwelling of cool water on the Pacific equator and along the Peruvian coast weakens or stops, and SSTs increase in these areas where the upwelling weakens.

The **Southern Oscillation Index (SOI)** has been developed to monitor the Southern Oscillation using the difference between sea level pressures at Darwin, Australia, and Tahiti, although other stations have sometimes been used. Large negative values of the SOI indicate a warm event, and large positive values indicate a cold event (also referred to as La Niña). It is important to note that there is not a one-to-one correspondence between the occurrence of Southern Oscillation events and El Niño events, using the spatially restrictive original definition of El Niño.

ENSO is the term currently used by scientists to describe the full range of the Southern Oscillation that includes both SST increases (a warming) as well as SST decreases (a cooling) when compared to a long-term average. It has sometimes been used by scientists to relate only to the broader view of El Niño or the warm events, the warming of SSTs in the central and eastern equatorial Pacific. The acronym, ENSO, is composed of El Niño-Southern Oscillation, where El Niño is the oceanic component and the Southern Oscillation is the atmospheric component of the phenomenon. The broader definition of El Niño has sometimes been used interchangeably with ENSO, because ENSO is less well known in the popular media.

Teleconnections can be defined as atmospheric interactions between widely separated regions. They have been identified through statistical correlations (in space and time). Some of these correlations have been used to generate hypotheses about geophysical processes related to teleconnections. Most countries in the world are affected in some way by this aspect of the Southern Oscillation.

Based on: Glantz, 1996a [ESIG, 1997 http://www.dir.ncar.edu/esig/]

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