RAND

Population Displacement and Migration in Developing Countries:

An Exploratory Study in the Development of an Early Warning Decision Support System

Allan N.D. Auclair

MR-1264.0-RC

November 1999

Prepared for RAND Science and Technology

RAND Science and Technology
National Defense Research Institute

This is a final report of a project performed within RAND Science and Technology and and RAND's National Defense Research Institute. It has been formally reviewed but has not been formally edited.

PREFACE

This report identifies and explores a method of predicting the risk of large-scale displacements of human populations using a set of key environmental indicators. It characterizes worldwide trends in population displacement over the past three decades in view of illustrating the enormity of the problem and in demonstrating why it poses a growing threat to international security and stability.

A number of R&D initiatives are in progress that build on the findings in the study. This report should be of particular interest to agencies whose responsibilities include issues of US national security, the planning and conduct of complex humanitarian operations such as disaster relief and peacekeeping, and to those agencies whose tasks are to assess the risk of economic and societal collapse leading to failed states and regional conflict.

This work was an exploratory study funded by the RAND Science and Technology and by RAND's National Defense Research Institute.

Population Displacement and Migration in Developing Countries
An Exploratory Study in the Development of an Early Warning Decision Support System

Allan N.D. Auclair, PhD
RAND, Environmental Sciences and Policy Center

ABSTRACT

International organizations are reeling from the strain of coping with natural disasters and with violent conflicts that have exploded or re-emerged in several countries. The number of humans killed, displaced or in some way affected by weather-incited disasters has risen 250% over the past three decades. The world is also experiencing an increasing volume of diffuse conflict, seen as one of the main causes of forced migration. The growing number of displaced persons and enforced migrants (450% increase since1964) is now perceived as a significant threat to global security.

The objective of this exploratory study was to test the concept that environmental stress, namely severe weather events, can predict large-scale episodes of population disaster and migration. NOAA's Multivariate ENSO Index, a measure of the strength of El Nino events associated with severe, chaotic weather, was correlated with the number of persons 'affected' world-wide by natural disasters and with the number of trans-boundary refugees and internally displaced populations (Schmeidl and Jenkins 1998) over the 1964 to 1995 period.

The NOAA Multivariate ENSO Index proved a particularly good indicator of acute weather events (e.g., droughts) that strongly impact on human societies in developing countries. A predictive, regression-based model showed a very highly significant correlation ($r = 0.954^{***}$ $p<0.001$) between disruptive weather and human disaster.

Flood and droughts accounted for 75-90% of all natural disasters. A significant shift in the nature of weather impacts occurred in 1987. Prior to 1987, droughts predominated with relatively few humans being affected by floods. In and after 1987, floods predominated with few drought victims. In terms of human impacts this shift was a *key event in human disaster chronology* since the effects of floods are far more immediate and severe.

Worldwide, the total cost of disaster relief from 1964 to 1996 inclusive was an estimated $23 billion and involved 8220 missions. A sequential progression was evident between the onset of severe climate events, the impact on humans, and relief in the form of food shipments. Whereas the impact of acute weather events on human populations was immediate, there was a lag of 3-4 years between the human impact and the relief in the form of food shipments.

The timing of the sustained surge in forced migration coincided with the onset of an especially severe and persistent El Nino in and after 1982. Hence, extreme climate was a good predictor ($r = 0.925^{***}$) of forced migration over the 1970 to 1985 period. Despite the strength of the link, the causal chain of events remains to be resolved.

Prediction at the regional scale, the use of NOAA 3-18 month advance climate forecasts, and attention to agency needs for early warning assessment, decision-making, and simulated learning exercises were future research directions suggested by the study.

INTRODUCTION

This paper explores two elements of the large suite of issues on human population displacement and migration. The first is the role of changing environmental conditions in triggering or exacerbating population displacement and migration in developing countries. The second element is the potential for better management of population disruptions by means of early warning and anticipatory planning. Humanitarian assistance, including relief missions of the US military, would benefit greatly from a set of predictive tools that provide important pre-event information that can be crucial to the success of humanitarian efforts.

Background. International organizations are reeling from the strain of coping with natural disasters and with violent conflicts that have exploded or re-emerged in several countries (Brecke 1998). The number of humans killed, displaced or in some way affected by weather-incited disasters has risen 250% over the past three decades (Fig.1). The world is also experiencing an increasing volume of diffuse conflict. This violence is widespread, difficult to isolate, and subject to much local variation (Kennedy 1998). Focusing on present war-torn countries, one "cannot fail to be struck by the repeated appearance of environmental change in the generative processes leading to conflict" (Dessler 1994). In the future, regional conflicts will increasingly be the result of environmental factors (Baechler 1998).

The time is past when any developed nation can safely ignore large-scale regional instability elsewhere. Emerging diseases and terrorism, for example, are exacerbated by migration, displaced populations, internal conflict, and collapsing civil infrastructures. It has become important to understand and to predict large population movements and to tie this to the development of an adequate global preparedness and response capability (Lyerly and LeDuc 1998). This is seen as a significant challenge.

Related Issues. There is considerable recent literature on the growing magnitude of human population movements. Displaced persons and enforced migration are perceived as significant threats to global stability. Even a cursory overview indicates clearly the numerous ramifications of the problem. There is a cluster of interrelated effects and justifiable concerns of being overwhelmed by an explosion of aftermaths tied to populations that have been weakened, displaced and/or forced to migrate. Some of the most striking elements of the issue include the following:

Link to accelerating environmental change. Environmental change is now rapid, marked, and unprecedented in scope. Given the fact that most change is anthropogenic, and the human population is expected to double in the next half century, the pace of environmental change is certain to accelerate. The character and rate of change will make the future vastly different from the past (Kennedy 1998). The rapidity and abruptness of environmental changes mean that there is a need to understand the basic causal links, and to improve our capacity for prediction of impacts and surprise events.

Links to diseases and health. Forced migration endangers the health and welfare of the migratory population through higher rates of mortality, malnutrition, post-traumatic stress, infectious diseases from overcrowding and inadequate water and sanitation, and vector-borne diseases; it is also socially, economically, and politically destabilizing (Greenough, G. per comm, JHU/SPH).

In addition, emerging infectious diseases now present one of the most significant health and security challenges facing the global community (Lyerly and LeDuc 1998). Global warming, environmental change, and the resurgence of resistant pathogens contribute to the problem.

Regional conflict. Major environmental disasters can lead to new conflicts between states, place new demands on the military, or otherwise radically change the economic and social context for defense planning (Mathews 1996). While the most powerful and wealthy states are suffering

from "donor fatigue", international and non-government organizations are reeling from the strain of coping with violent conflicts (Brecke 1998). While environment appears to be an essential element in certain types of conflict, the causal relationships are complex, making effective early warning models of regional conflict difficult to achieve (Homer-Dixon 1999).

New military needs and focus. There is a new emphasis on upgrading the military's preparedness for "operations other than war" (OOTWs). These operations are a new, more complex, and shifting array of non-state belligerents with different causes and strategies.

There is an interest in being able to anticipate likely hot spots both years ahead (risk assessment) and more precisely, weeks ahead (early warning alerts). There is also greater openness to collaboration with academic and other private sector analysts to better understand and anticipate crises, serve in a police capacity, and provide humanitarian aid. One way to achieve this is to develop specialized training in joint civilian-military crisis management (including EWS research and application, preparation, planning) (Davies and Gurr 1998).

Need for Early Warning Systems (EWS). Decreased number of lives lost to disasters over the past several decades (in the face of rising disaster costs) is largely due to advances in disaster indication and early warning (DITF 1997).

Pre-event information assembly activities are crucial to the success of disaster relief efforts (DITF 1997). There is a need to supplement field monitoring and expert analysis with systematic model-based early warning systems. In turn, this must be supported by dynamic data processing for filtering the enormous information flows available to analysts (Davies et al 1998).

Objective. The objective is to test the concept that climatic indicators of severe weather events can predict large-scale episodes of population disaster and migration.

A related goal is to identify and acquire existing data, and to characterize numerically the patterns and trends in relevant population and climatic parameters. It is also to develop a suite of early warning, predictive models. This is an exploratory study and these models will necessarily be preliminary. Nevertheless, they should test the concept, and identify some of the key factors to focus on in developing a comprehensive EWS.

DATA and METHODS

General Approach. The basic concept is that human communities in developing countries are particularly susceptible to high-impact, disruptive weather events. The criteria for a 'disaster' in this study is 100 million humans affected worldwide in a given year. This includes death, displacement and persons otherwise "affected" by the broad array of natural disasters tracked annually (OFDA 1999). The concept also applies to populations of internally displaced persons and trans-boundary migrants (USCR 1998). In this case, the numbers are considerably smaller than in weather-incited disasters, and there is no set numeric cutoff.

The strategy is to identify a set of global climate stressors that have, over the past three decades, resulted in significant levels of death, distress, displacement and/or forced migration of human populations. The intent is to do the analysis at the aggregate global level. Once the key links have been identified, it should be possible at a later date to test and refine these relationships at the regional level.

Simplifying assumptions were made regarding the vulnerability of human populations to stress. First, it was assumed that there are multiple conditions that now *compound* each other so that the number of humans at risk in developing countries is at an unprecedented level. The potential for interactions has become especially problematic under the current regime of significantly increased frequency and severity of weather events. Other conditions that increase vulnerability include weak infrastructure (few medical centers, roads, dams, water storages, etc) high and/or rapidly increasing

population density, and increased settlement on land sensitive to flooding, droughts, ocean surges, and other disastrous weather.

Second, severe, anomalous climate is one of the most pervasive and damaging environmental stressors of human communities. More than other environmental factors, global parameters (Table 2) are of special value since they are intensely and continuously monitored. Third, it is assumed that 'politically' forced migration can be triggered by external impacts, including large-scale climatic disasters. This will happen where the internal system is already highly stressed (Homer-Dixon 1999, Homer-Dixon and Blitt 1998). The hypothesis is:

Hypothesis 1: Extreme climatic events act to trigger 'politically' forced migration in countries and regions already under resource, economic, political, racial, religious, and/or ethnic tension.

Many countries of the developing world are marked by both limited resources and internal tensions. A severe climate event can act as the "final straw" that precipitates conditions forcing migration. The corollary is that severe climate can be an important predictor of forced displacement and migration episodes in developing countries.

The Data. *Population Levels*. Potential sources of data compiled on natural disasters, displacement, and forced migration of human populations is enumerated in Table 1. I accessed data for 1964 to 1995, inclusive, on the numbers of persons dead, made homeless, and 'affected' worldwide from the US Agency for International Development, Office of Foreign Disaster Assistance (OFDA 1999). These were estimates of the number of persons impacted by natural disasters annually in different nations. Data were stratified by 23 natural disasters and 4 human-caused disasters, including technological accidents, civil strife, displaced persons, and emergencies. The OFDA database was also the source of estimates on the annual costs and total tons of food shipped in relief missions.

The dataset of Schmeidl and Jenkins (1998a) on the number of trans-boundary refugees and internally displaced populations was used as a starting point. They had analyzed worldwide refugee statistics 1964 through 1995 using both the UN High Commissioner for Refugees and the US Committee for Refugees survey data. These two data sources were harmonized using a number of screening routines to ensure the most representative estimates (Jenkins per comm). "Refugees" were defined as political refugees, those hosted in refugee camps, or those who had made themselves available to the protection of aid organizations. They obtained the numbers of internally displaced persons from the US Committee for Refugees.

There are other sources of population refugee data (Table 1, files 1-7) that were not accessed in this study. Trends and statistics of total global population levels, numbers of refugees, and mortality levels from different causes are available at the United Nations Development Programme Web site *http://www.undp.org/popin/*.

Climate Indicators. Anomalies in global temperature are considered to be one of the best and most dependable indicators of change in climate. As a regional indicator, it has been often combined with a high frequency oscillation such as ENSO, NAO, the Monsoon Index or other ocean-atmosphere oscillation (Table 2) to give a sensitive index of the changing pattern of severe weather conditions in specific geographic regions.

El Nino-Southern Oscillation (ENSO) conditions are known to be particularly powerful predictors of climate anomalies both within and outside the tropics. The MEI or Multivariate ENSO Index (K. Wolter *per comm* NOAA/CDC) combines six related parameters (sea-level pressure, surface sea temperature, surface air temperature, zonal and meridional surface wind, total cloudiness) into one indicator. NOAA's new forecast technologies of regional anomalies in

temperature and precipitation make use of this feature, and of the fact that the ENSO ocean-atmosphere oscillation is both heavily monitored and modeled with considerable accuracy. As a generality (with many exceptional cases), El Nino conditions are associated with chaotic, severe climate events, and hence a good indicator of disastrous weather events. La Nina tends to be relatively benign until extreme MEI conditions are reached.

In this study, the MEI and global temperature anomalies were used both individually and in combination as logical and exceptionally powerful indicators of weather-incited human disasters. The diversity of other ocean-atmosphere oscillations in Table 2 have the potential to increase model accuracy, particularly of region-level predictions.

The approach of strategically combining different indicators is an important capability that could be developed, but was not explored in this study. The analysis was confined to globally aggregated data, and the question of region-level models was deferred to a future date.

Methods. The total numbers impacted by natural disasters (killed + homeless + 'affected'), and the numbers of internally displaced and trans-boundary refugees were plotted for the 1964 to 1995 period. The same was done for the MEI and global temperature anomalies. In each case, yearly values and five-year running means were computed and the timeseries plotted for comparison of trends. Flood and drought disasters together accounted for 75-90% of the total population affected by natural disaster. Floods have became conspicuously more important and droughts less important in the 1990s. For this reason, flood, drought, and flood+drought categories were retained and analyzed individually.

Regression-based predictive models were developed. Global climate parameters were explored as predictors of population impacts. Prior to correlation and regression, I calculated (i) the annual differentials of population levels of drought and flood-incited refugee groups. This was achieved by simply subtracting the current year values from that of the previous year for each parameter. (ii) Another procedure was to calculate for each parameter the deviation from the linear regression trend of the 1964 to 1995 period. This put exclusive focus on year to year variability. Without this step of calculating either the differentials or deviates, the three-decade trends of rising population numbers and climatic severity (each changing at varying rates) complicates the analysis. Five-year and nine-year centered means, and different lag times (from 2 up to 5 years lag between climate event and population response) were calculated and tested in subsequent correlations.

RESULTS and DISCUSSION

Long-Term Numeric Trends.

Population Disasters and Forced Migration

Human Disasters Due to Natural Causes. Three patterns were particularly evident in the 1964 to 1995 trend of human disasters: a highly episodic pattern with individual events lasting usually one, but up to several years duration, a consistent increase in severity and frequency of peak years, and a predominance of flood and drought events throughout the period (Fig. 1a). The 1996 to 1999 trend was assumed on the basis of reported disasters in the literature. It includes, among others, floods in Honduras and China (ca 250 million affected in the Yangtze River floods alone).

A significant shift in the quality of weather impacts occurred in the late 1980s and persisted through the 1990s. Prior to 1987, droughts predominated with relatively few humans being affected. In and after 1987, floods predominated with few drought victims (Fig. 1b). In terms of human impacts, this shift was a key event in the disaster chronology since the effects of floods are much more immediate and severe.

Internally Displaced Populations. Of particular interest in this study was *the sudden rise of internally displaced persons in the 1980s*. The annual rates remained more or less stable until 1982 but then increased dramatically, reaching unprecedented rates (27 million new internally displaced per year) by the early 1990s. This represented a 450% increase over the average pre-1980 rate of about 6 million new refugees per year (Fig. 2). Unlike natural disasters, the rates were not episodic, but rose progressively, and then fell (at least temporarily) in the mid-1990s.

Trans-Boundary Refugees. A surge of refugees occurred in the mid 1960s, decreased in the early 1970s, and rose to approximately three times the average pre-1980 rate (ca 5 million per year) to a peak in the early 1990s (ca 17 million per year).

The decrease in the 1970s was due to repatriation and self-settlement. The decrease after 1990 was largely due to repatriations from the largest displacements (Ethiopia, Ethiopia/Eritrea, and Mozambique) and new, short-term displacements from the former East Bloc. These decreases in trans-boundary refugees were matched by increases in the number of internally displaced, perhaps because of border controls in asylum countries, so that the problem shifted from international to internal domains (Schmeidl and Jenkins 1998a). Hence, it appeared logical to combine the two categories to obtain a full measure of the extent of forced migration.

Human Migration Due to Political Causes. The total numbers of internally displaced plus trans-boundary refugee populations rose sharply in the early 1980s, reflecting a simultaneous increase in both categories (Fig. 2). This was a conspicuous departure from more or less stable levels (ca 10 million per year) from 1964 to 1982. The drops in both displaced and trans-boundary refugees evident in 1995 were verified and found to continue to drop slightly in 1996 and 1997 (USCR 1997, 1998). It is unknown at this point whether this decrease was a short-term aberration of the longer-term increasing trend or not.

Humanitarian Assistance

Food Shipments. There has been an obvious, albeit episodic increase in the total monies allocated to disaster relief, and closely associated with it, the quantity of food shipped in relief missions (Fig. 3). Food shipments are clearly in response to increased numbers of political refugees (Fig. 4), and/or those affected by natural disasters (see Fig. 9). In all cases there has been a conspicuous increase in the 1990s.

Other Humanitarian Assistance. To illustrate the type and quantities of humanitarian assistance in addition to food, that involving the US Department of Defense missions were enumerated in Table 3. The primary DOD relief, apart from 'general relief supplies and support' involved airlift, medical supplies and assessment teams. The analysis of DOD contributions over the 33 years (1964-1996) indicated the 605 missions were effected and cost an estimated $884 million in direct expenditures. This was an average of about $27 million and 18 missions per year, or about $1.5 million per mission.

The total number of DOD relief missions and direct costs indicated large year to year differences. The number of missions peaked at times of high refugee and natural disaster levels. After 1990, the number of missions declined sharply; conversely the total costs increased suggesting a change in the DOD policy of managing relief operations (Fig. 5).

Table 4 indicated that DOD responded in a high percentage (ca 80%) of its relief missions to flood, hurricane, cyclone, and other weather-incited disasters. In contrast, over 90% of the total costs were attributed to forced migration, civil strife, and other human-caused emergencies.

Worldwide the total cost of disaster relief from 1964 to 1996, inclusive, was an estimated $23 billion and involved 8220 missions. On an annual basis this averaged $700 million per year, or about $3 million per mission.

Global Climate Stress

Multivariate ENSO Index (MEI). The predominance of El Nino conditions after 1975 is striking and contrasts to the normal oscillation between El Nino and La Nina events from 1950 to 1975 (Fig. 6). Particularly strong El Nino events in 1982-83, 1986-87 and 1997-98 suggested a high potential for disastrous weather conditions in those years. The 5 and 9-year mean trends showed a conspicuous rise in the severity and frequency of El Nino events since 1964 (Fig. 7).

Global Temperature Anomalies. The trend toward warming global temperatures is marked. The 5-year mean suggests a step-like pattern with jumps in temperature in the mid-1960s, mid-1970s, and mid-1980s. That in the 1976 to 1979 period was marked (Fig. 8).

There was a very highly significant correlation ($r = 0.794$***, $p<0.001$) between the 5-year means of El Nino / La Nina variations (i.e., the MEI) and global temperature. This is significant in that the incidence of severe weather events tied to El Nino and La Nina is closely associated with the global warming problem. Hence, international treaties attempting to regulate industrial emissions of greenhouse gases have an evident link to the health and stability of human populations.

Comparison of Trends

An example was chosen to illustrate the potential links between acute climate events, its impact on human populations, and its aftermath. The number of humans affected by natural disasters was compared to the onset and magnitude of the climate stress. It was evident that the trends parallel each other (Fig. 9). There was a close tie between climate stress (i.e. MEI^2) and number of persons affected by natural disaster from 1964 through 1990. From 1985 through 1990, the numbers of humans affected continued to rise. This occurred despite a decreased level of climate stress compared to a peak in 1985. The 1985 through 1990 interval, nevertheless, had a climate stress level that remained high enough to signal continued acute climate stress ($MEI^2 =$ 2.74 peak, vs an impact threshold of 0.46) so that populations were being adversely impacted. It was over this interval that floods, typically much more severe than droughts, became the predominant stress for the first time in several decades. Rather than a lag in response between climate and population response, there was a qualitative change in nature of the stress and a much increased vulnerability.

Food shipments followed the rise in disaster-affected population levels, in this case with a consistent 3 to 4 year lag. This time gap likely represents a period of deteriorating human condition, requests for relief, and the needed time to set up the logistics of delivering humanitarian assistance.

Predictive Models

Natural Population Disasters.

Regression-based Models. The Multivariate ENSO Index (in this case, positive values of MEI^2, see Fig. 10) accounted for 91% of the variation in the numbers of humans affected by natural disasters (all categories). The relationship is a proportional increase in the number of humans affected worldwide across the entire spectrum of El Nino severity (Fig.11).

The exceptionally high correlation ($r = 0.954$***, $p<0.001$) depended somewhat on an appropriate time lag (5 years), and the use of averages (9 year-centered mean). However, even without the time lag, the use of 9-year means was still very highly significant ($r = 0.870$***).

It was noteworthy the correlation dropped to $r = 0.726$*** with a shorter averaging period (5-year mean, 5-year lag). Without either the time lag or any averaging, the correlation remained highly significant ($r = 0.454$**). This testified to the strong basic nature of the link between

environmental stress and population response, and to the fact that this was not an artifact of the analytical procedures.

Two significant findings emerged in linking individually drought and flood disasters to MEI: (i) Droughts occurred under severe El Nino conditions, with a more or less linear increase in number of drought victims with increasing strength of the El Nino episode. Flood disasters occurred under moderate El Nino (positive MEI) and mild La Nina conditions (negative MEI), (ii) At any given MEI, floods appeared far more damaging than did droughts. At about MEI positive 0.7, both drought and flood disasters occurred but floods affected 3.5 times more humans than did drought.

Rule-based Models. By superimposing the distribution of El Nino events, as measured by the Multivariate ENSO Index, on the incidence of human disasters, it was apparent that the MEI values above a threshold of $MEI^2 = 0.46$ in the first year of an El Nino event accurately predicted the onset involving 100 million or more humans worldwide. The empirical model of Figure 12 shows this first-year - threshold relationship. In each case of a human disaster episode-year, the MEI is consistent in identifying the advent of high-impact, weather disturbances.

Where the levels beyond the first year of a multi-year disaster event have remained or risen above 100 million humans affected (e.g., 1988-1989, 1995), the disasters involved floods. The incidence of floods are not well predicted by the simple threshold relationship of Figure 12, and further study of the climate forcings of flood events is needed. They may, for example, be better indicated by La Nina conditions, or by anomalies in timing of the ENSO cycle.

'Politically' Forced Migration.

Regression-based Models. If Hypothesis 1 on acute climate stress is to be credible, the data must show a natural disaster - forced migration link. One-year data in Figure 13 give a better idea of the magnitudes of the natural disasters relative to the numbers of forced migrants. It is conceivable that the rapidity and severity of the disasters act as a "blow of the hammer" to finally break a societal or political system already under stress. When a 5-year average is used, there is a paralleled rise in both the number of natural disaster victims and those forced to migrate (Fig. 14). Figure 15 indicated a strong relationship between disaster and forced migration, particularly under conditions where more than 120 million disaster victims occurred worldwide. The exceptional correlation ($r = 0.939^{***}$) generally supports Hypothesis 1 but does not clarify the cause – effect nature of the link.

General Discussion

Summary of Initial Results. This was a short-term feasibility study (ca 55 man-days). The methods were exploratory and the results are at a preliminary stage. Some of the main initial findings to emerge in the study include the following:

(1) The incidence of human disasters involving 100 million or more humans affected worldwide was highly episodic and closely associated with disruptive, high-impact weather events. The NOAA Multivariate ENSO Index proved a particularly good indicator of acute weather events (e.g., droughts) that strongly impact on human societies in developing countries. A rule-based model accurately identified the onset of all major disasters over the 1964 to 1995 period. A predictive, regression-based model showed a very highly significant correlation ($r = 0.954^{***}$ $p<0.001$) between disruptive weather and human disaster.

(2) The mechanism of natural disasters is severe weather events resulting in human death, displacement, and persons otherwise affected, including a high incidence of infectious diseases. Among 27 categories of disasters, floods and droughts accounted for the large majority (75-90%). Both the severity of acute weather and the numbers of humans affected by disasters have

risen sharply over the past three decades (1964-1995). The fact that floods have dominated the 1990s, and are far more severe and immediate in their impacts than droughts indicates a change in the nature of disasters compared to the 1960s, 1970s, and 1980s.

(3) Worldwide, the total cost of disaster relief from 1964 to 1996 inclusive was an estimated $23 billion and involved 8220 missions. The US military was involved in 605 of these missions and contributed $0.9 billion in direct costs. The top three disasters involving DOD relief included flood events, civil strife, and hurricanes. The primary DOD relief, apart from 'general relief supplies and support' involved airlift, medical supplies and assessment teams.

(4) A sequential progression was evident between the onset of severe climate events, the impact on humans, and relief in the form of food shipments. The impact of natural disasters on humans was immediate (i.e., the same year). In contrast there was a lag of about 3-4 years between the year of the stress/impact and humanitarian assistance in the form of food shipments.

(5) The timing of the sustained surge in forced migration coincided with the onset of an especially severe and persistent El Nino in and after 1982. Hence, extreme climate was an excellent predictor ($r = 0.925^{***}$) of forced migration over the 1970 to 1985 period. Despite the strength of the link, the cause-effect relationship was not clear.

Prediction versus Explanation. The focus of this study was on prediction, and not on explanation. The approach contrasts with descriptive "case study" methods where the emphasis is on characterization and unraveling the details of cause-effect mechanisms (Homer-Dixon 1999).

The intended endproduct of this study is a series of straight-forward predictive models for practical application. Much has been written on the gap between warning and response (George and Hall 1997, Davies and Gurr 1998). The dilemma reflects the need on the part of (government) decision-makers to genuinely understand and put confidence in early warning models. There is a need for simplicity whereas warning models to date are rarely simple. They have typically been developed by the (academic) scientific community where the explanation afforded by causal mechanisms and the complexity of numerous driving and mediating factors have been important determinants of the approach.

Environmental Hypotheses on Forced Migration. Environmental factors are receiving renewed interest as potentially powerful drives on regional conflict and political instability. The idea that security is linked to environmental quality is not new. The link, however, remains *highly controversial.* There is both a large gap in the understanding of how environmental change generates conflict, and in the evolution of methods to quantify the link. Two recent authors exemplify the attempts at bridging this gap.

Kennedy (1998) postulates that we are now in a time of unprecedented environmental change, and the pace of change is certain to accelerate. Deteriorating environmental quality forces change in "conflict liability". In turn, conflict is seen as a major determinant of forced migration (Schmeidl and Jenkins 1998b). Environmental quality includes land use and land cover change (especially deforestation), global climate change, energy and economic growth, soil fertility and agriculture (food security), water, and other "common-pool" resources (e.g., fisheries). One of the primary indicators of environmental security in the Kennedy model is how the land is being used.

The Homer-Dixon (1999) model proposes that environmental scarcity (including environmental degradation, global warming, population growth, resource distribution) generates conflict by widening the disparity between rich and poor. In his model, human migration and the

failure of large-scale development projects are socially and economically disruptive. Mediators include "state capacity", vulnerability to external shocks, the "ingenuity gap", ability to cope with surprise, and the *rates* of environmental change.

Both Kennedy and Homer-Dixon note the potential importance of changing climate. Global warming has the potential for increasing resource scarcity through changes in agriculture, crop failure, and diminished water supply. US support for international agricultural research and early warning, as in the case of the Africa Famine Early Warning System (US AID 1999) are seen to be important prevention mechanisms for dealing with increased climatic variability. Kennedy (1998, p.61) poses the question "What are the likely secondary climate effects – changes in the intensity or frequency of violent storms, or in the occurrence of larger-scale events like El Nino? And what about the next layer of consequences: the spread of infectious disease, or the enforced movement of human populations?" Environmental deterioration or disruption due to severe climate is seen as one of the triggers of migration. This is the central question being addressed in this study.

Both authors argue that one of the best ways to deal with environmental security is to build research capacity to make better predictions. They note that the ability to deal with surprise has to be part of the prediction. Homer-Dixon's (per comm) current emphasis is on adaptability of human societies, and on identifying ways they can better cope with and mitigate for environmental scarcity. The general question is "Can we identify areas in which there are special prevention opportunities related to environment / population / resources?" (Kennedy 1998).

Future Research Directions. The initial results of this study appear to justify continuing research efforts to identify the environmental mechanisms and to model predictively the incidence of population displacement and migration. Kennedy (1998) perceived his study as "an experiment and a natural framework for thinking about the problem". As such, even if less than successful, his study, and other similar efforts could usefully inform future efforts.

What are these future efforts? Three topic areas that would benefit from continued research were indicated in this study: (i) Analysis and prediction at the regional and national scales. NOAA forecasts of climate anomalies are available at the scale of individual nations, or in the case of large countries such as the US or China, at the regional level. Downscaling to this level has the advantage of an assessment of changing risk levels for individual nation states and advance planning with specific national requirements in mind.

(ii) Since NOAA El Nino / La Nina seasonal (3-month) forecasts are made as much as 18 months in advance of actual events on the ground, true prediction is possible (in contrast to surveillance and timely reporting). A desirable objective is to push back the "warning envelop" as far as possible. Six to twelve months may be sufficient time to allow for requisitioning of funds and adequate logistic preparations.

(iii) There is a need to tailor predictive models to agency needs that include training assessment, decision-making, and learning exercises. A technical manual serving as a guideline to basic concepts and how to apply these would be valuable.

The manual could include a Web instruction site for simulated exercises in practicing the use of early warning. It could also include an assessment of the newest technologies (e.g., high resolution hyper-spectral satellite imagery, day-after gaming and military "what if" simulation, advance climate forecasting) on monitoring and modeling techniques, and a catalogue of international and non-government relief organizations with the potential for optimizing joint military-civilian and/or US-multilateral collaboration in disaster relief efforts.

LITERATURE CITED

Baechler, G. 1998. Early warning of environmentally caused conflicts. p. 131-141, *In* J.L. Davies and T.R. Gurr (ed). Preventive Measures: building risk assessment and crisis early warning systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

Brecke, P. 1998. A pattern recognition approach to conflict early warning. p.121-130, *In* J.L. Davies and T.R. Gurr (ed). Preventive Measures: Building risk assessment and crisis early warning systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

Davies, J.L., and T.R. Gurr 1998. Preventive measures: An overview. p. 1-14, *In* J.L. Davies and T.R. Gurr (ed). Preventive Measures: Building risk assessment and crisis early warning systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

Davies, J.L., B. Harff, and A.L. Speca 1998. Dynamic data for conflict early warning. p. 79-94, *In* J.L. Davies and T.R. Gurr (ed). Preventive Measures: Building risk assessment and crisis early warning systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

Dessler, D. 1994. How to sort causes in the study of environmental change and violent conflict. *In* N. Graeger and D. Smith (ed) E.P.C. Oslo: PRIO Report No. 2: 91-112.

DITF 1997. Harnessing information and technology for disaster management: The global disaster information network (GDIN). Disaster Information Task Force Report, November 1997, Office of the Vice-President, Washington, DC

Dmitrichev, A. 1998. The role of early warning in the Office of the High Commissioner for Refugees. p. 219-229 *In* J.L. Davies and T.R. Gurr (eds) Preventive Measures: Building Risk Assessment and Crisis Early Warning Systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

George, A.L., and J.E. Holl 1997. The warning-response problem and missed opportunities in preventive diplomacy. A Report to the Carnegie Commission on Preventing Deadly Conflict. Carnegie Corporation of New York. Washington, DC.

Homer-Dixon, T. 1999. Environment, Scarcity, and Violence. Princeton University Press, Princeton, NJ.

Homer-Dixon, T., and J. Blitt 1998. Ecoviolence: Links among environment, population, and security. . Rowman and Littlefield Publishers, Inc. Lanham MD.

Kennedy, D. 1998. Environmental quality and regional conflict. A Report to the Carnegie Commission on Preventing Deadly Conflict. Carnegie Corporation of New York. Washington, DC.

Lylerly, W.H., and J.W. LeDuc 1998. Emerging infectious diseases: An introduction. p. xv-xix, *In* A.M. Nelson and C.R. Horsburgh, Jr. Pathology of Emerging Infections 2. American Society for Microbiology, Washington, DC.

Mathews, J. 1996. Global drivers in 2010: The environment. Unpubl. Rpt. Carnegie Endowment for International Peace, Washington, DC.

NOAA 1998. NOAA Strategic Five-Year Plan. National Oceanic and Atmospheric Administration, Department of Commerce, Washington, DC.

OFDA 1999. Disaster History Database: Significant data on major disasters worldwide, 1900 to 1995. Office of Foreign Disaster Assistance, US Agency for International Development, Washington DC.

Schmeidl, S. and J.C. Jenkins 1998a Early warning indicators of forced migration. p. 56-69 *In* J.L. Davies and T.R. Gurr (ed) Preventive Measures: Building risk assessment and crisis early warning systems. Rowman and Littlefield Publishers, Inc. Lanham MD.

Schmeidl, S. and J.C. Jenkins 1998b The early warning of humanitarian disasters: Problems in building an early warning system. IMR 32(2): 471-486.

US AID 1999. The Africa Famine Early Warning System Network. Africa Bureau. US Agency for International Development, Washington DC.

USCR 1997. World Refugee Survey 1996: Annual assessment of conditions affecting refugees, asylum seekers, and internally displaced persons. US Committee for Refugees, Washington DC.

USCR 1998. World Refugee Survey 1997: Annual assessment of conditions affecting refugees, asylum seekers, and internally displaced persons. US Committee for Refugees, Washington DC.

Table 1. Institutions providing statistical information on annual levels of persons affected by natural disasters, and/or migrating or internally displaced due to political causes. In this study only files 8, 9, and 10 were accessed.

Institution

1. Center for Research on Epidemiology and Disasters**,
   University of Louvain, Belgium
2. International Center for Migration and Health, Geneva
3. International Organization for Migration, Geneva
4. Norwegian Refugee Council, Geneva
5. Refugee Policy Group, Washington DC
6. UN Department of Humanitarian Affairs, Geneva
7. UN Food and Agriculture Organization, Rome
8. UN High Commissioner for Refugees, Geneva
9. US Agency for International Development,
   Office of Foreign Disaster Assistance, Washington DC
10. US Committee for Refugees, Washington DC

**Disaster Events Database (EM-DAT) takes over compilation of the US AID/OFDA database from 1996 to present. Contact Ms. Below, Center for Research on Epidemiology and Disasters (CRED), School of Public Health, University of Louvain, 3034 Clos Chappelle Aux Champs, 1200 Belgium, Belgium. Tel. (01) 322 764 3823; Fax. (01) 322 764 3441; Eml. below@epid.ucl.ac.be

Table 2. Global climate parameters intensively monitored and commonly used as a basis for indicator development. Only global temperature and the Multivariate ENSO Index were used in this study.

Global Climatic Parameter	Description
Global Mean Annual Temperature	The global hemisphere annual mean land surface air temperature estimates of NASA/GISS. Gridded data are available for any specified geographic subsets or regions.
Global Mean Annual Precipitation	The global hemisphere annual mean land surface precipitation of NASA/GISS. Gridded data are available for any specified geographic subsets or regions.
Tropical Pacific Sea Surface Temperature	Sea surface temperature over the tropical Pacific region is available consistently from 1946 at the NOAA Climate Analysis Center, Washington, DC. It has been used with SOI as an indicator of El Nino-Southern Oscillation Index (ENSO) events. Tests indicate that although similar to SOI, it is more consistent (less noise) and potentially yields important differences in correlations with mid-latitude climatic fluctuations. Mean monthly values can be used to calculate annual and seasonal (winter, spring, summer, fall) means.
Southern Oscillation Index	The SOI represents the difference between the standard Tahiti sea level pressure anomaly and the standard Darwin anomaly divided by the monthly standard deviation. Mean monthly values can be used to calculate annual and seasonal (winter, spring, summer, fall) means.
Multivariate ENSO Index	The MEI or Multivariate ENSO Index (K. Wolter per comm NOAA/CDC) combines six related parameters (sea-level pressure, surface sea temperature, surface air temperature, zonal and meridional surface wind, total cloudiness) into a single indicator. El Nino-Southern Oscillation (ENSO) conditions are known to be particularly powerful predictors of climate anomalies, both within and outside the tropics.
Monsoon Index	Measures the strength of the Indian monsoons affecting eastern Africa and the Indian subcontinent.

Table 2 (cont'd). Global climate parameters intensively monitored and commonly used as a basis for indicator development. Only global temperature and the Multivariate ENSO Index were used in this study.

Global Climatic Parameter	Description
North Pacific America Pressure	The PNA is a low frequency variability mode that provides a more appropriate indication of regional climatic variability at mid-latitudes that the tropical SOI (Higuchi per comm). Although there is a high correlation between SOI and PNA, the PNA pattern is not always associated with SOI, which is an indicator of El Nino events. The PNA oscillation has a particularly strong influence on climatic variability over the western and southeastern parts of North America.
North Atlantic Pressure Oscillation	The NAO has a significant correlation with the SOI. It influences variability over the Northeast US and eastern Canada. The NAO is the normalized sea-surface pressure difference between Lisbon, Portugal winter. The NAO has been strongly positive since around 1980 (esp. 1983, 1989, 1990) and stronger than at any time in this century.
Pacific Decadal Oscillation	The PDO is related to fluctuations in SOI and sea surface temperatures (ENSO) of the tropical Pacific Ocean. It is used as a measure of the long-term oscillation in the ENSO It coincides with several periods this century of high levels of El Nino activity lasting approximately 25 to 30 years.

Table 3. The type, quantities, and estimated costs of humanitarian assistance provided by US Department of Defense relief missions from 1964 to 1996 inclusive. Data are those compiled by the US AID Office of Federal Disaster Assistance, Washington DC. Costs are used to sequence the categories; only values for greater than $1 million per decade are shown. Values, in US dollars, are not adjusted for inflation.

Category	**Rank**	**Number *of* Missions**	**Costs** *(US$ Millions)*	**Costs / Decade** *(US$ Millions)*
Relief Supplies	1	32	488.3	147.976
Relief Support	2	2	160.8	48.739
Relief Projects	3	5	100.4	30.425
Airlift	4	217	44.7	13.537
Medical Supplies	5	46	15.6	4.737
Assessment Team	6	20	11.4	3.455
Construction Equipment	7	1	10.0	3.030
Food	8	17	7.5	2.259
Road Equipment	9	2	6.3	1.902
Spare Parts	10	1	5.0	1.515
Personnel Support	11	39	4.7	1.420
Tents	12	27	4.4	1.337
Aircraft	13	20	4.4	1.329

Table 4. Defense relief missions from 1964 to 1996 inclusive by the type disaster. The number of missions, direct costs and costs per mission of humanitarian assistance. Data are those compiled by the US AID Office of Federal Disaster Assistance, Washington DC. Number of missions are used to sequence the categories Values, in US dollars, are not adjusted for inflation. Weather–incited disasters account for 80% of the missions but less than 10% of the total costs.

Code	Category	Rank	Number *of* Missions	Costs *(US$ Millions)*	Costs / Mission *(US$ Millions)*
FL	Flood	1	148	22.7	0.153
CS	Civil Strife	2	63	184.5	2.928
HU	Hurricane	3	49	6.5	0.133
CY	Cyclone	4	37	23.2	0.627
EP	Epidemic	5	31	0.9	0.030
EQ	Earthquake	6	31	0.9	0.030
DR	Drought	7	24	2.4	0.100
VO	Volcano	8	20	12.8	0.639
DP	Displaced Persons	9	15	552.3	36.820
AC	Accidents	10	15	0.5	0.036
FI	Fire	11	13	0.8	0.058
TY	Typhoon	12	13	0.6	0.044
ST	Storm	13	12	0.1	0.008
EM	Emergency	14	9	30.8	3.420
IN	Infestation	15	6	0.4	0.071
LS	Landslide	16	5	0.1	0.023
PS	Power Shortage	17	4	0.4	0.102
UP	Unusual Phenomenon	18	4	0.1	0.028
EX	Expellees	19	1	0.0	0.005

Figure 1a. Total human population "affected" by natural disasters from 1964 to 1995. These include 27 different categories of natural (23) and human-caused disasters (4). Drought plus flood category alone accounts for 75-90% of all disasters. Data are based on worldwide compilation by US AID Office of Foreign Disaster Assistance. The levels for 1996 through 1999 are assumed on the basis of literature and new reports.

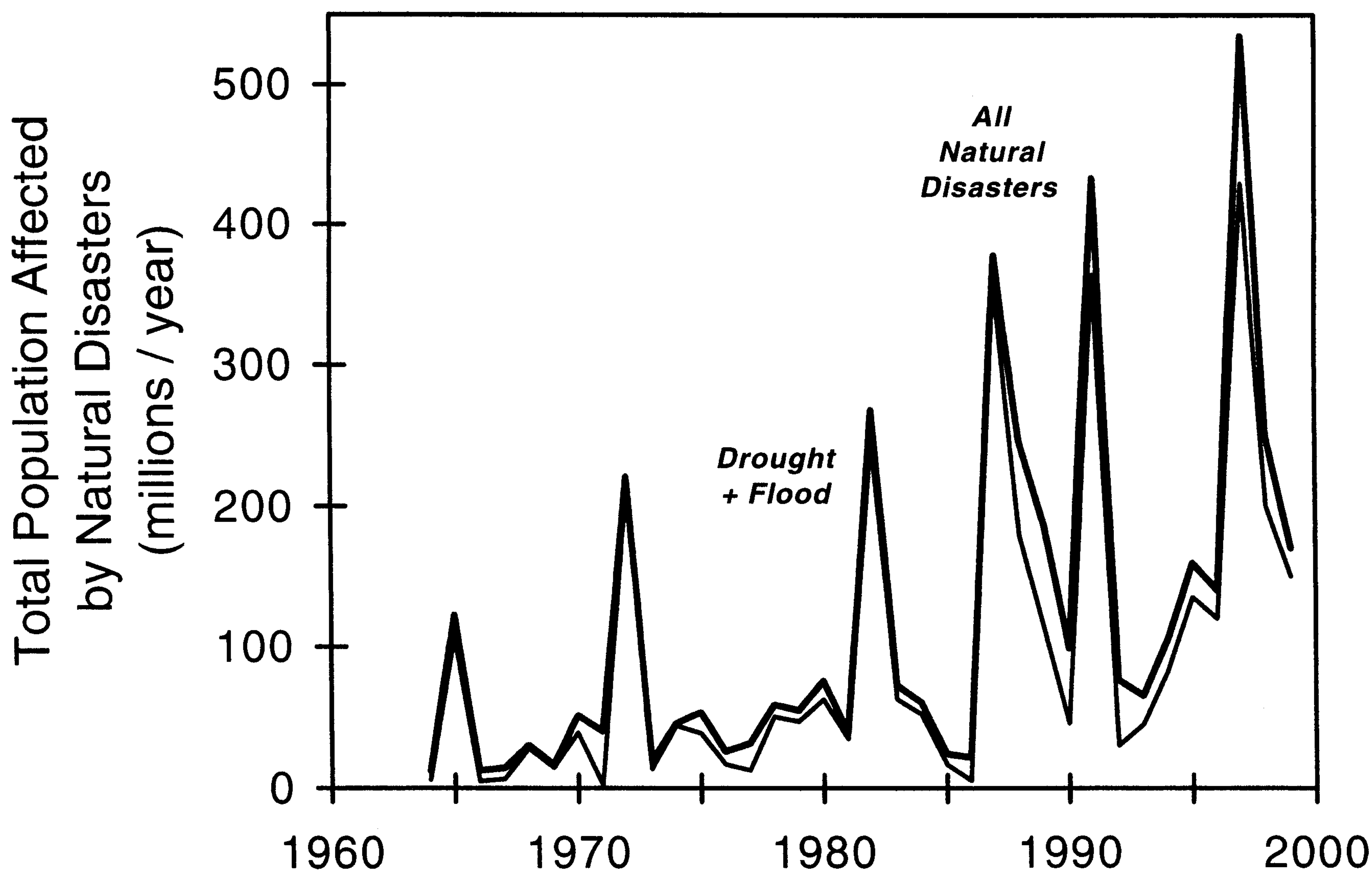


Figure 1b. Change in the quality of natural disasters since 1987. Droughts were the predominant acute weather stress through 1987. From 1988 on, flood events predominated as primary human impact. Data are the same as in Figure 1a.

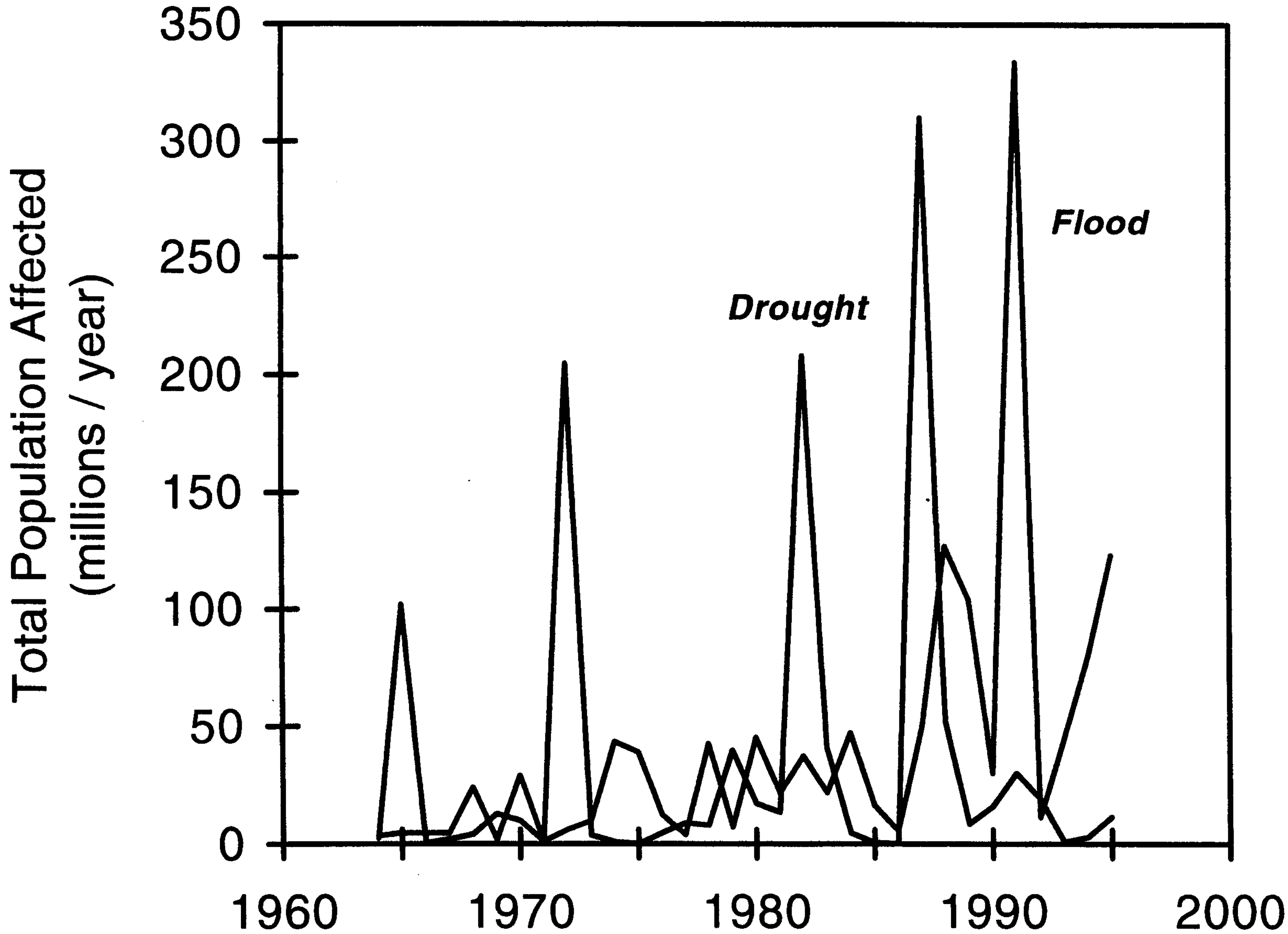


Figure 2. Total population of forced migrants from 1964 to 1995 inclusive. Total is the sum of the internally displaced population *plus* trans-boundary refugees due to political causes. The data are harmonized estimates of the UN High Commissioner for Refugees and the US Committee for Refugees published by Schmeidl and Jenkins (1998).

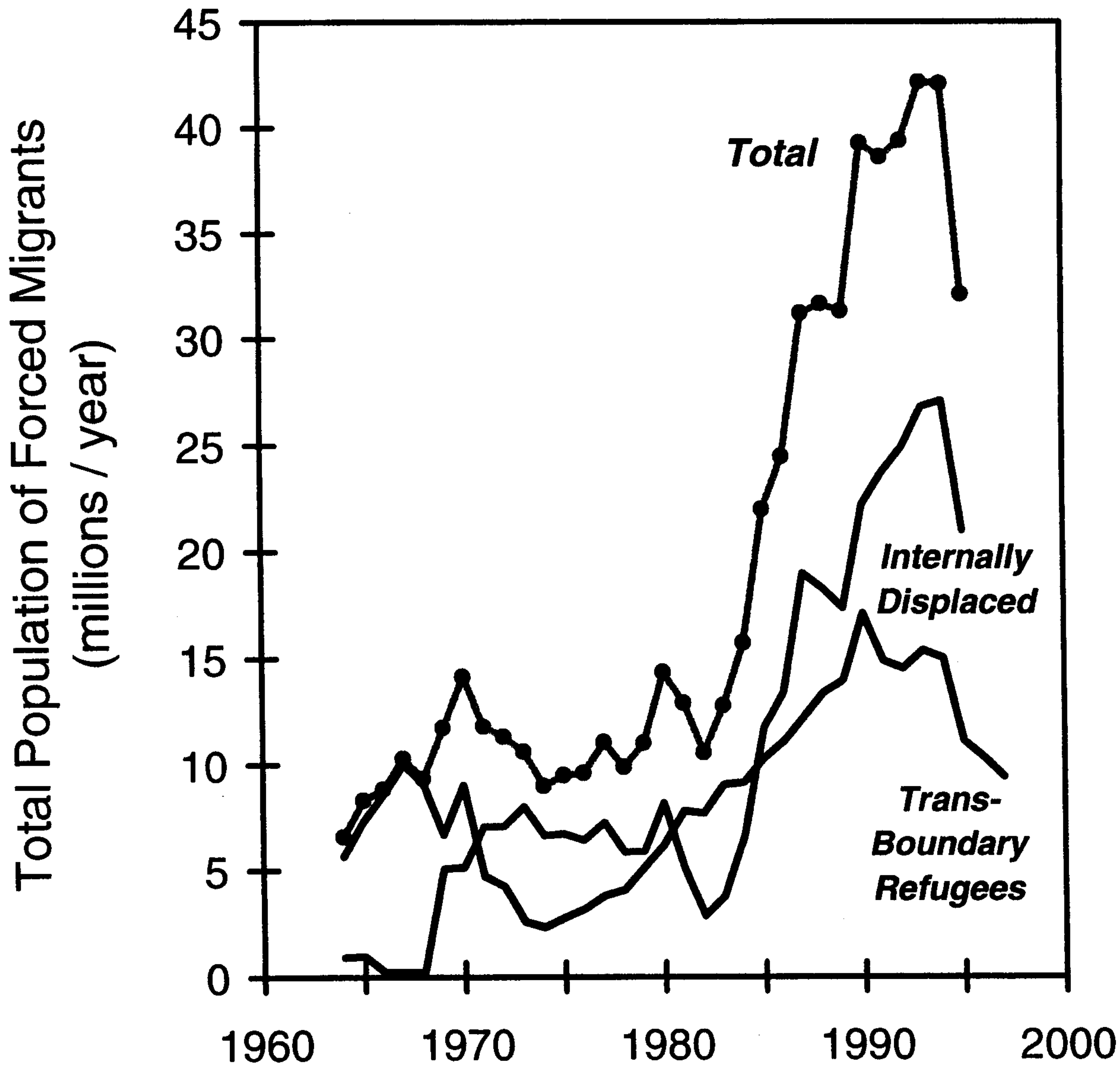


Figure 3. Total costs of humanitarian relief efforts and food shipments made from 1964 to 1995. Data are compiled by the US AID Office of Foreign Disaster Assistance. Note costs are not adjusted for inflation.

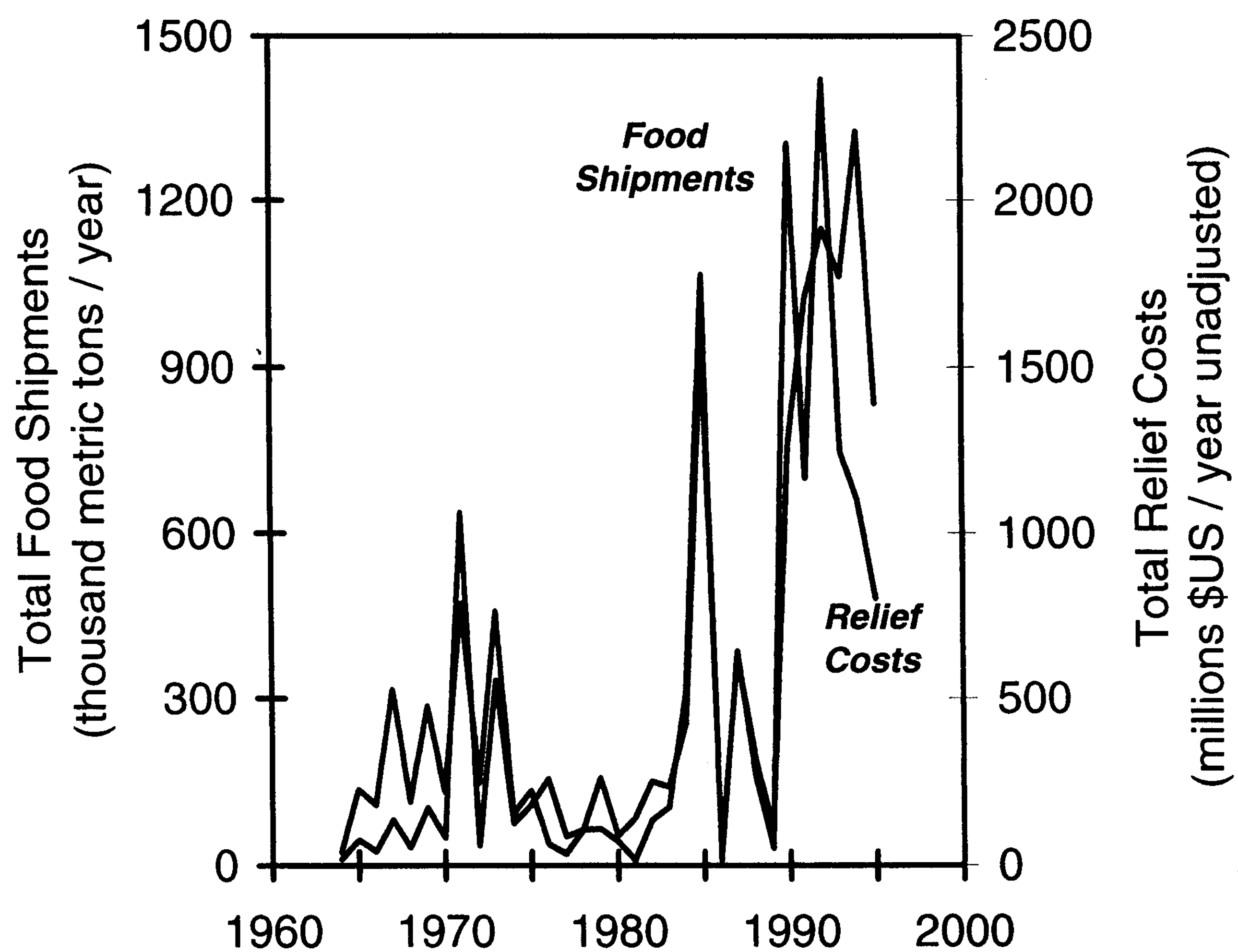


Figure 4. Global food shipments in relation to the number of forced migrants, 1964 to 1995 inclusive. Data are one-year values based on US AID Office of Foreign Disaster Assistance (food shipments), the UN High Commissioner for Refugees and the US Committee for Refugees (internally displaced persons *plus* trans-boundary migration).

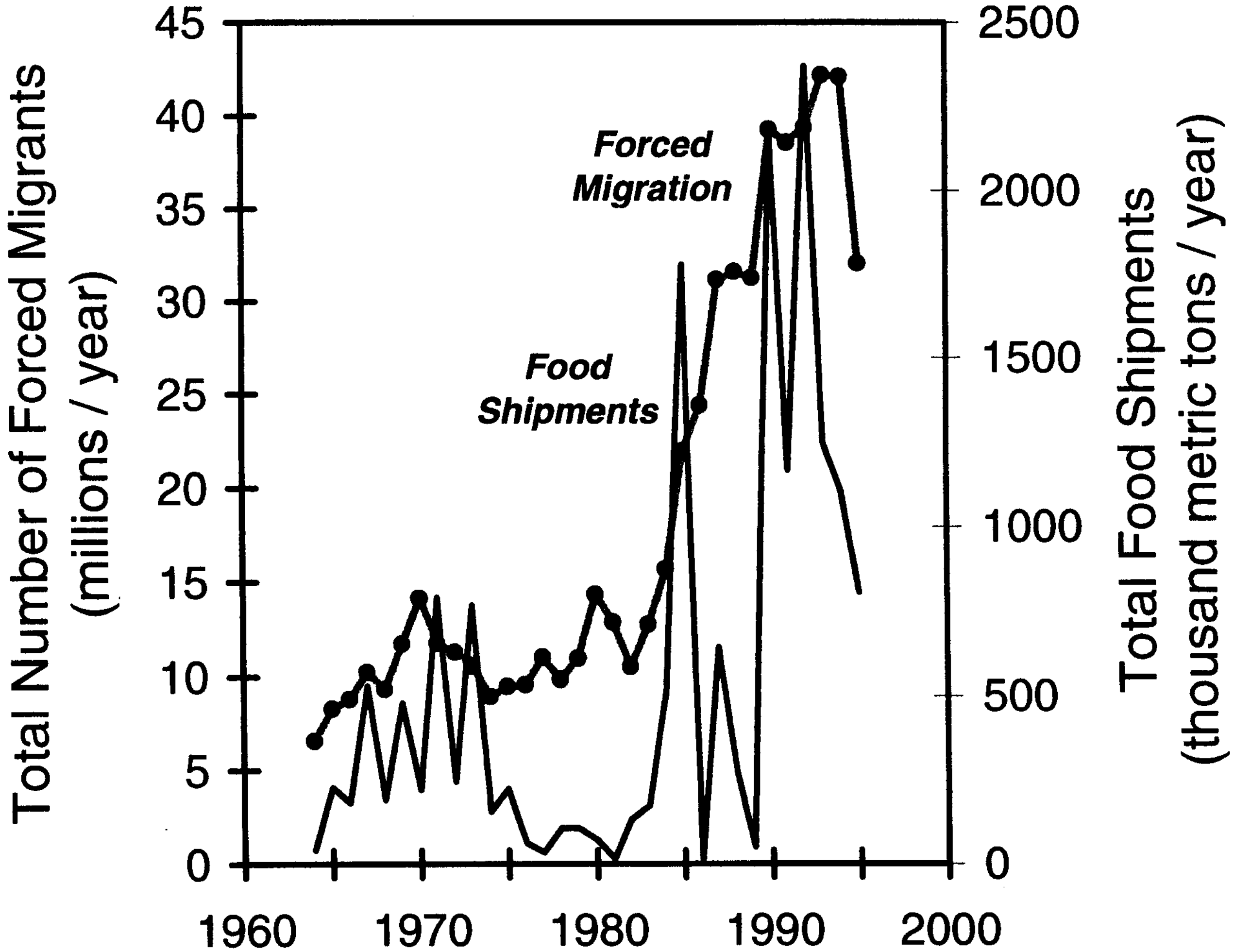


Figure 5. Number of missions and direct costs of missions undertaken by the US Department of Defense from 1964 to 1995 inclusive. Data are 1-year values based on compilation by the US AID , Office of Foreign Disaster Assistance. Costs are not adjusted for inflation.

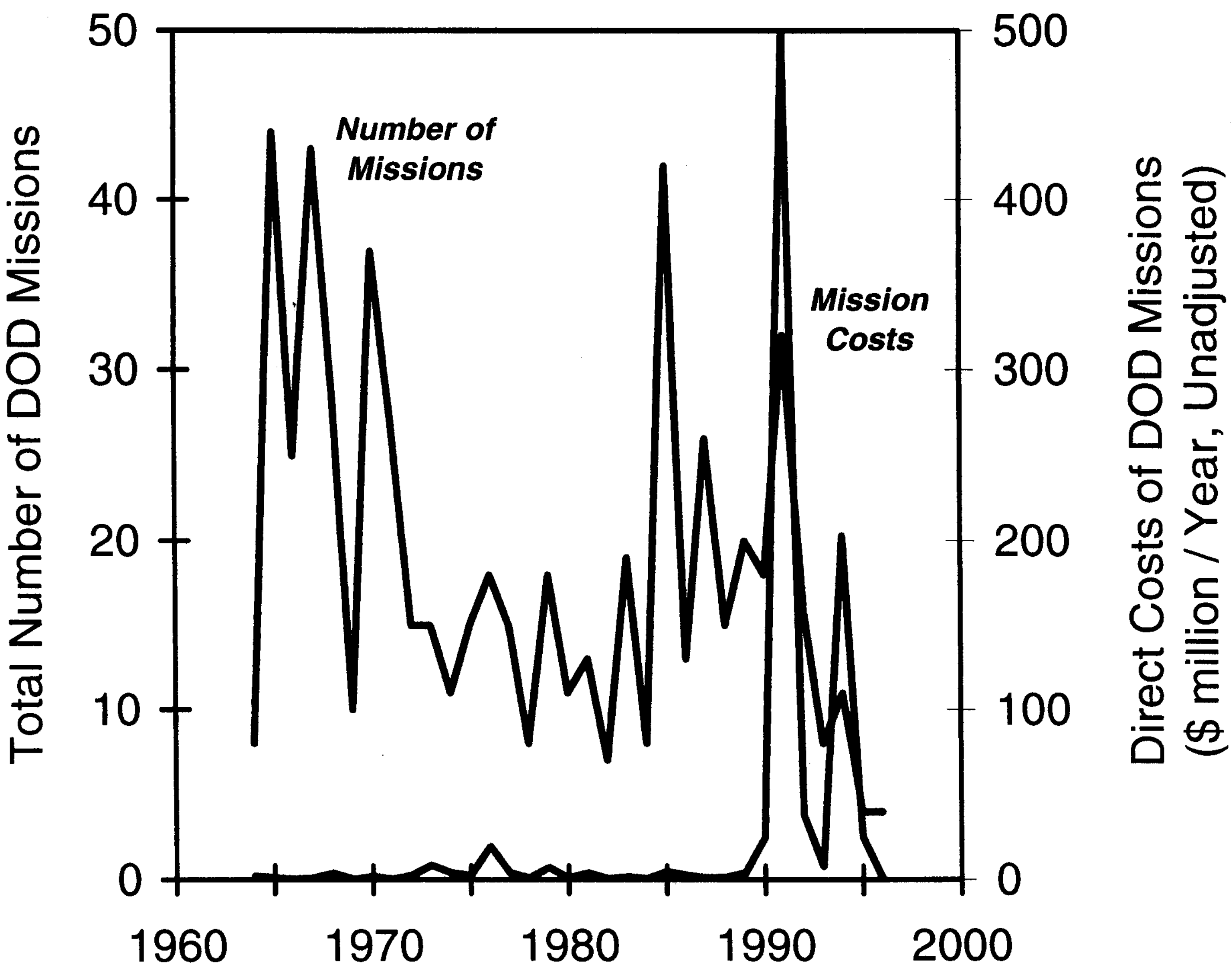


Figure 6. The Multivariate ENSO Index monthly values from 1950 to present. Values are based on NOAA / Climate Diagnostic Center analysis by K. Wolter, and are available as monthly updates at http://www.cdc.noaa.gov/~kew/MEI/

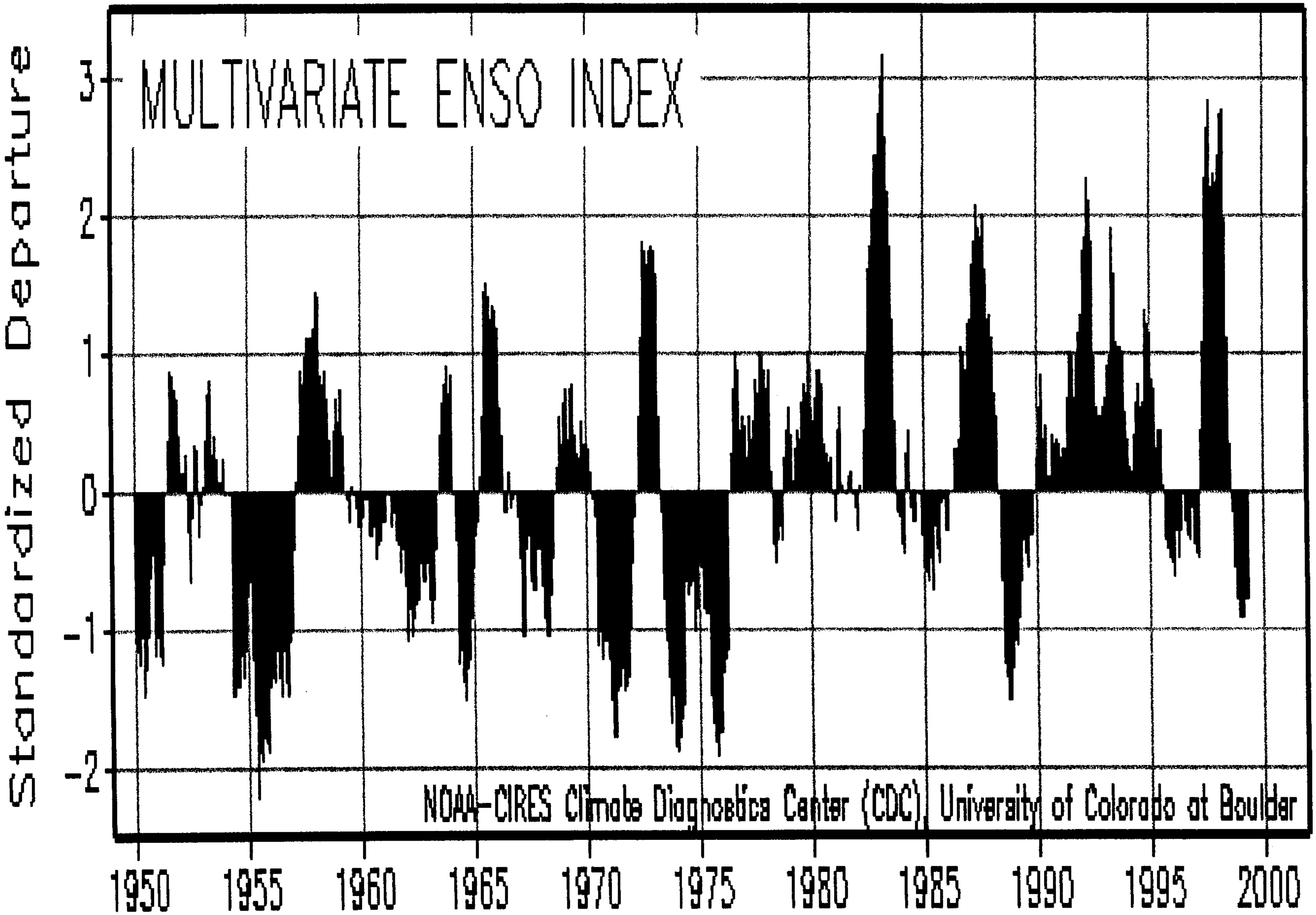


Figure 7. Trends in the 5-year and 9-year centered means of the Multivariate ENSO Index (*MEI*),1964 to 1995 inclusive. The MEI is based on models of K. Wolter, NOAA Climate Diagnostic Center in Boulder CO.

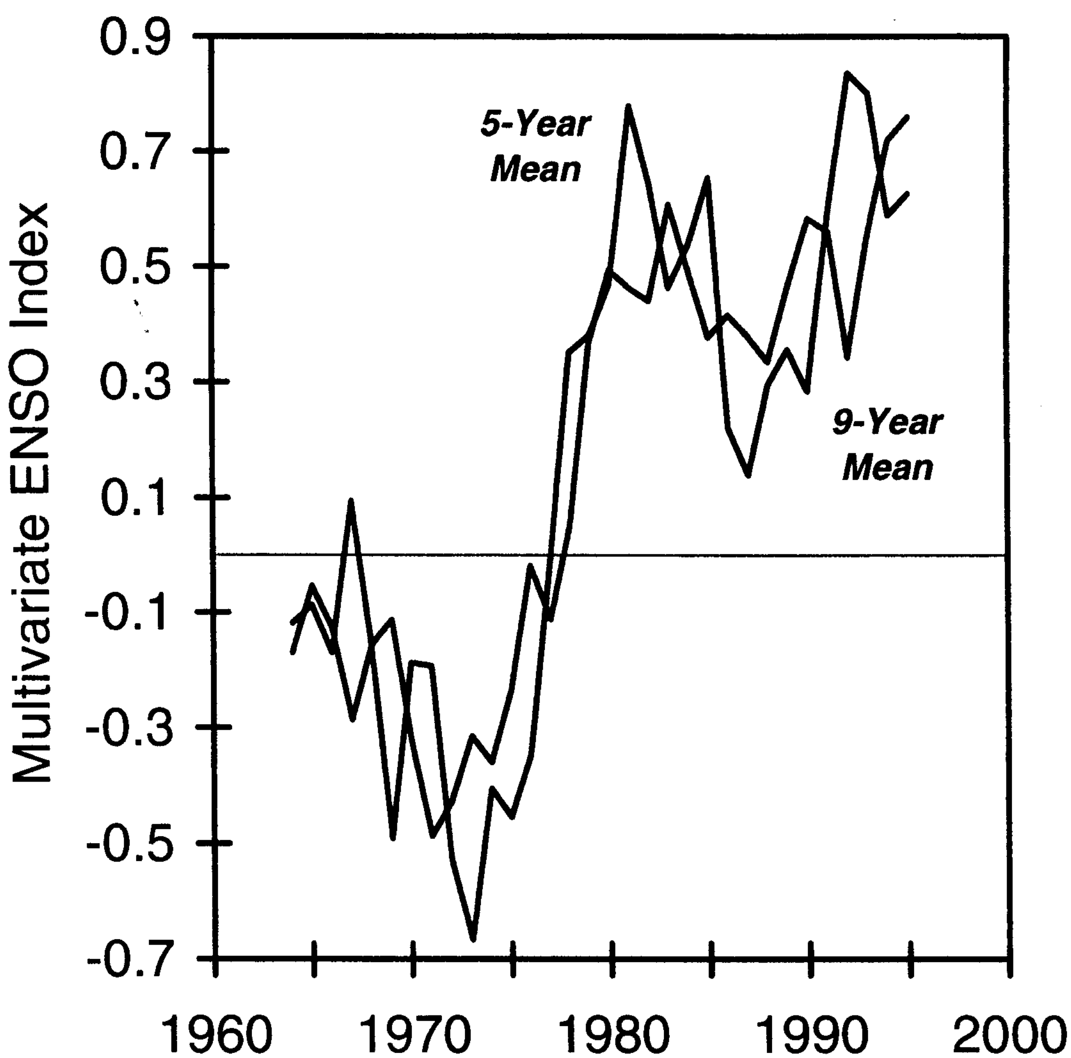


Figure 8. Trends in the annual, five -year, and nine-year means of global temperature. Values are anomalies from the long-term (1880-1980) mean. Data are based on NASA / Goddard Institute for Space Studies analysis of temperature of trends.

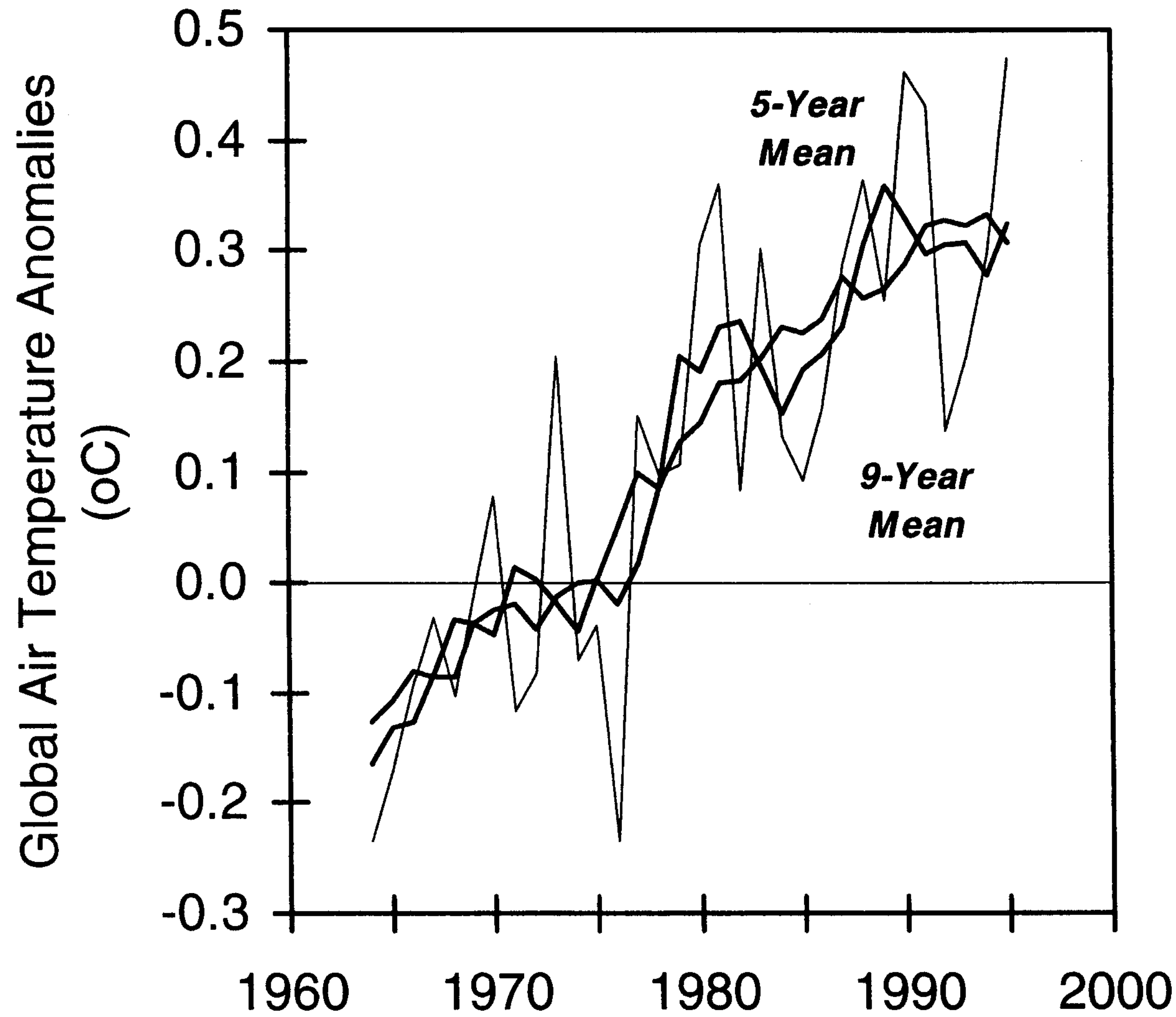
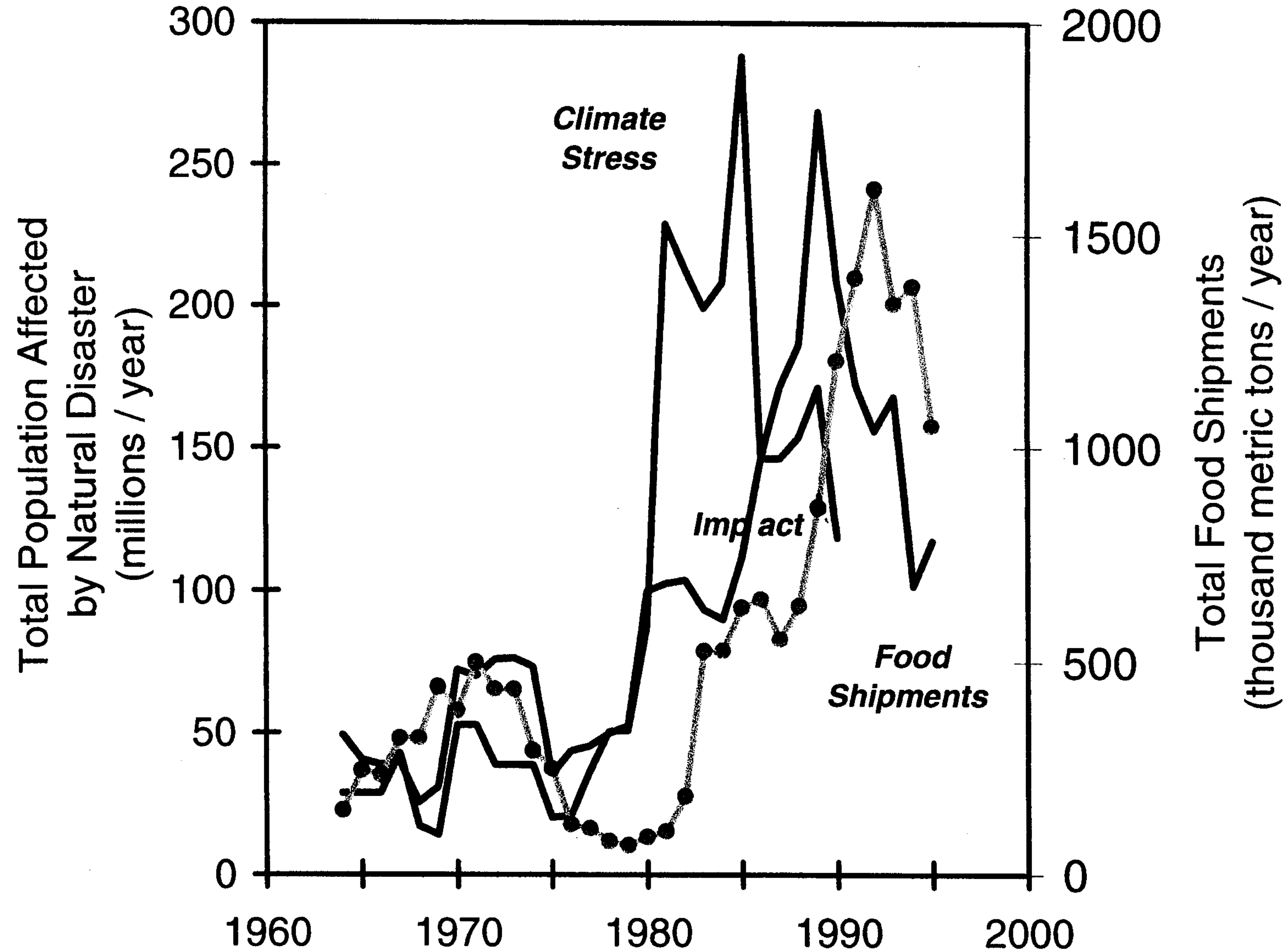


Figure 9. Sequential incidence of acute climate stress, population disaster, and subsequent humanitarian assistance in the form of food shipments. Climate stress is estimated by the NOAA Multivariate ENSO Index (*MEI **2*), and is adjusted to be 1 / 275th of the value on the left axis. Data on population impact and food shipment are based on that compiled by US AID , Office of Foreign Disaster Assistance. All values are five year-centered means.



Figuge 10. The 'El Nino" index based on positive values of the NOAA Multivariate ENSO Index(MEI). MEI values were squared to represent fully the severity of El Nino conditions at high MEI levels.

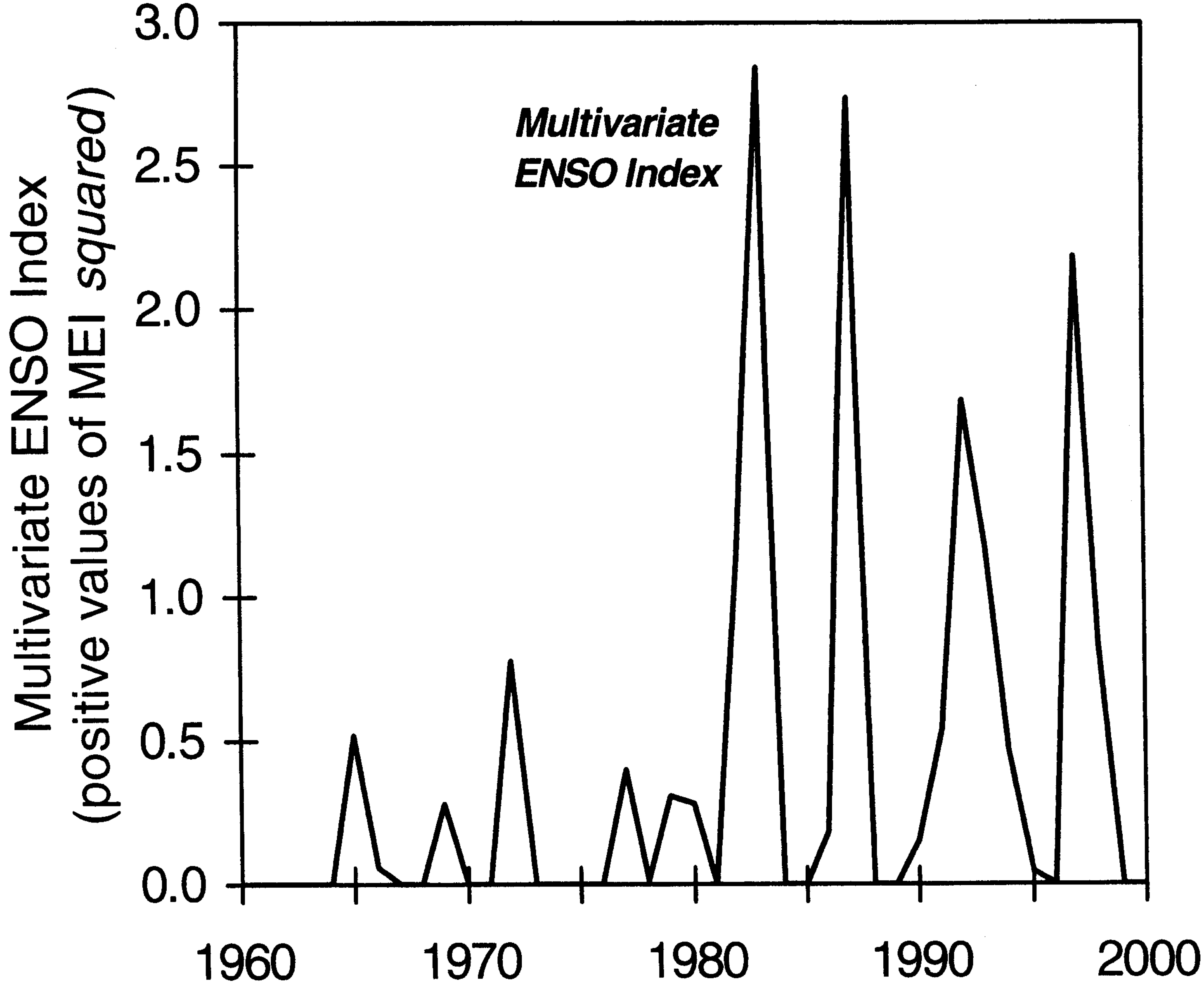


Figure 11. Predictive model of the total population affected by natural disasters worldwide. El Nino events (positive values of the NOAA Multivariate ENSO Index squared) account for 91% of the variation; the correlation (r) is very highly significant (p<0.001). Population disaster data is that compiled by the US AID Office of Foreign Disaster Assistance. Values are nine year-centered means, 1964-1995, with a five-year lag.

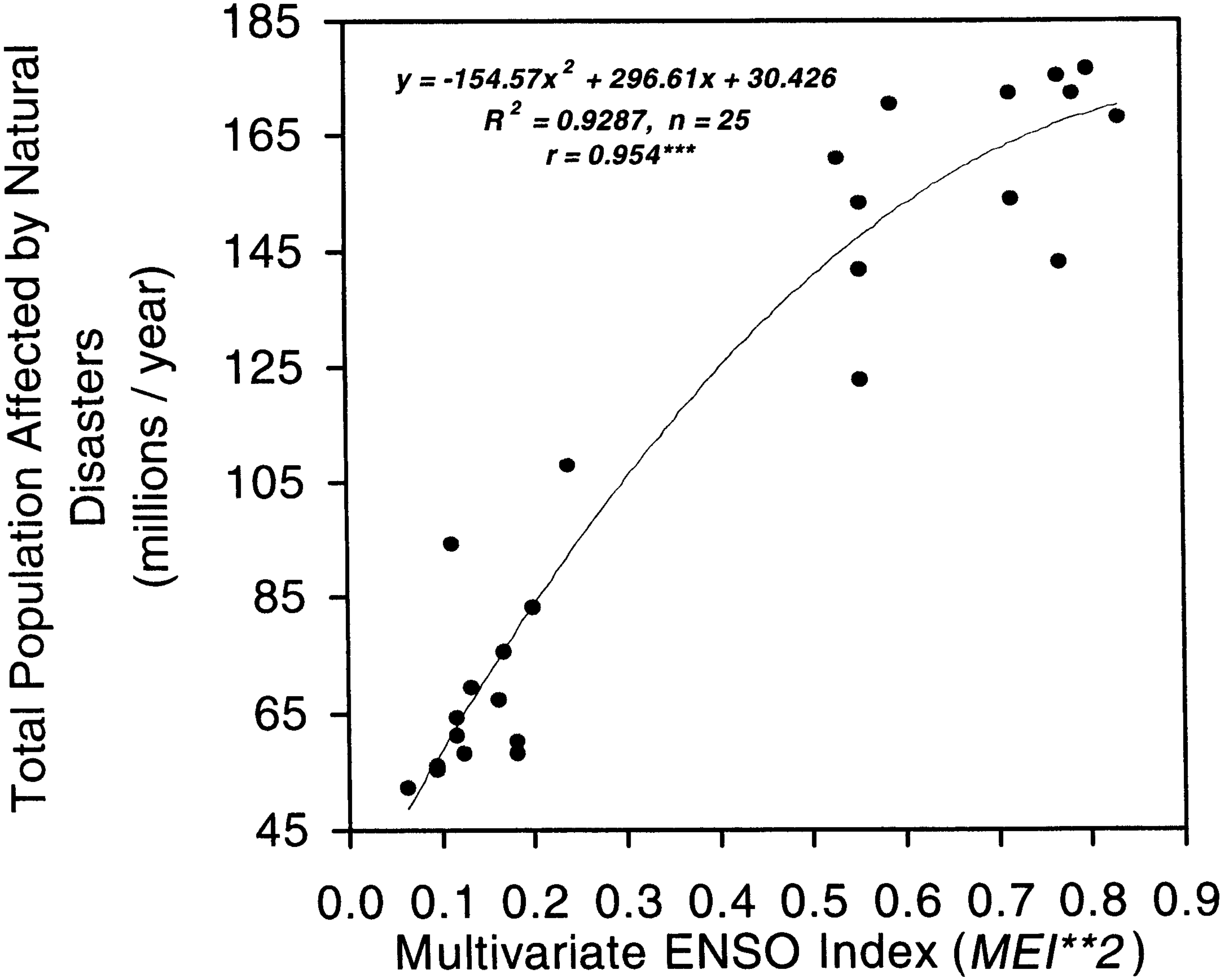


Figure 12. Rule-based model of population disasters. The first year of an El Nino event above threshold of MEI**2 = 0.46 (NOAA Multivariate ENSO Index positive values squared) predicts the onset of a disaster affecting more than 100 million persons worldwide. In cases where population disaster levels are greater that 100 million without an El Nino indicator (i.e., 1988-1989, 1995), floods predominated and were not predicted by the model.

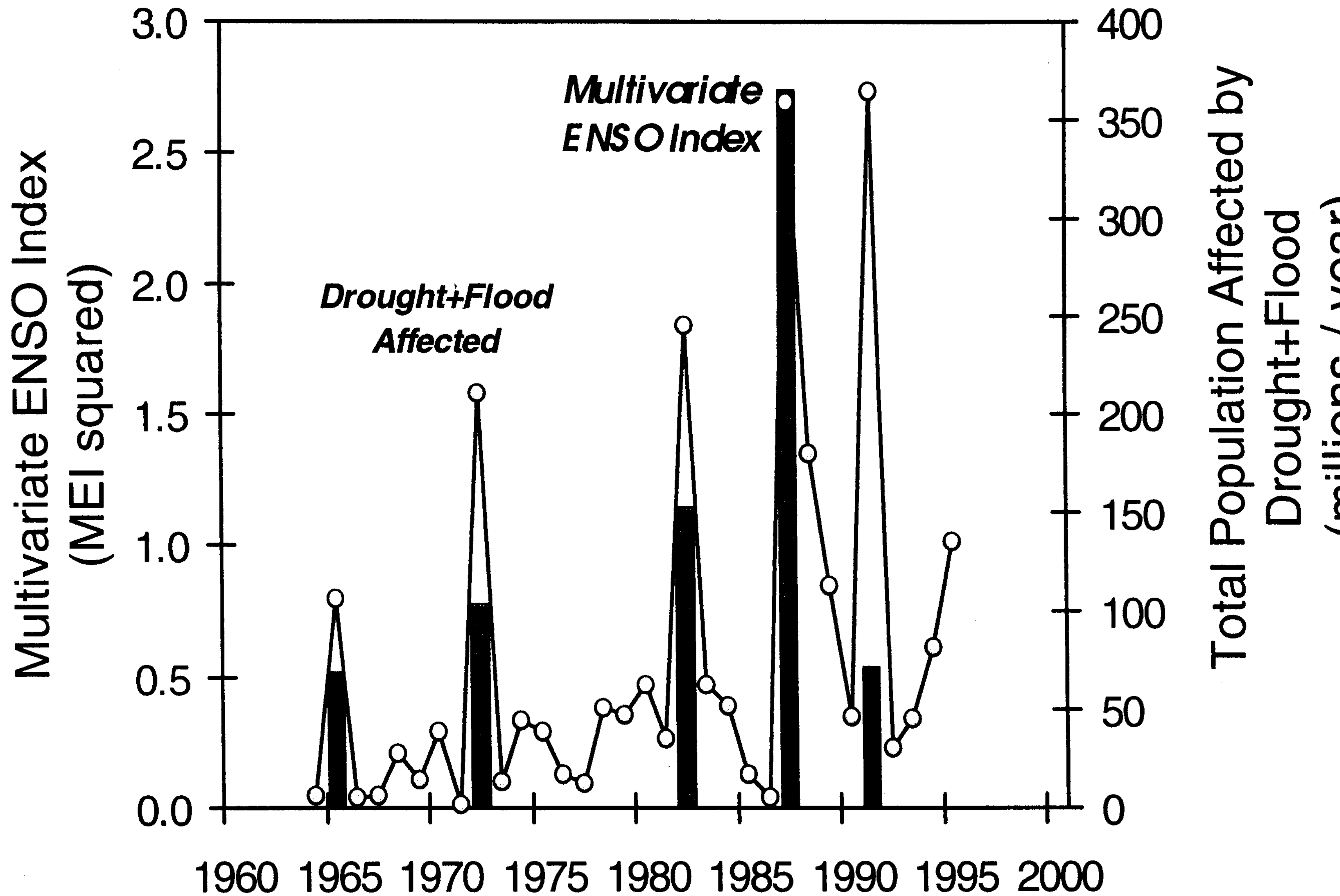


Figure 13. Trends in populations affected by natural disaster based on data compiled by the US AID Office of Foreign Disaster Assistance, 1964 to 1995, and the number of forced migrants (internally displaced persons *plus* trans-boundary migration) based on the UN High Commissioner for Refugees and the US Committee for Refugees . Disaster levels for 1996 to 1999 are estimated from literature.

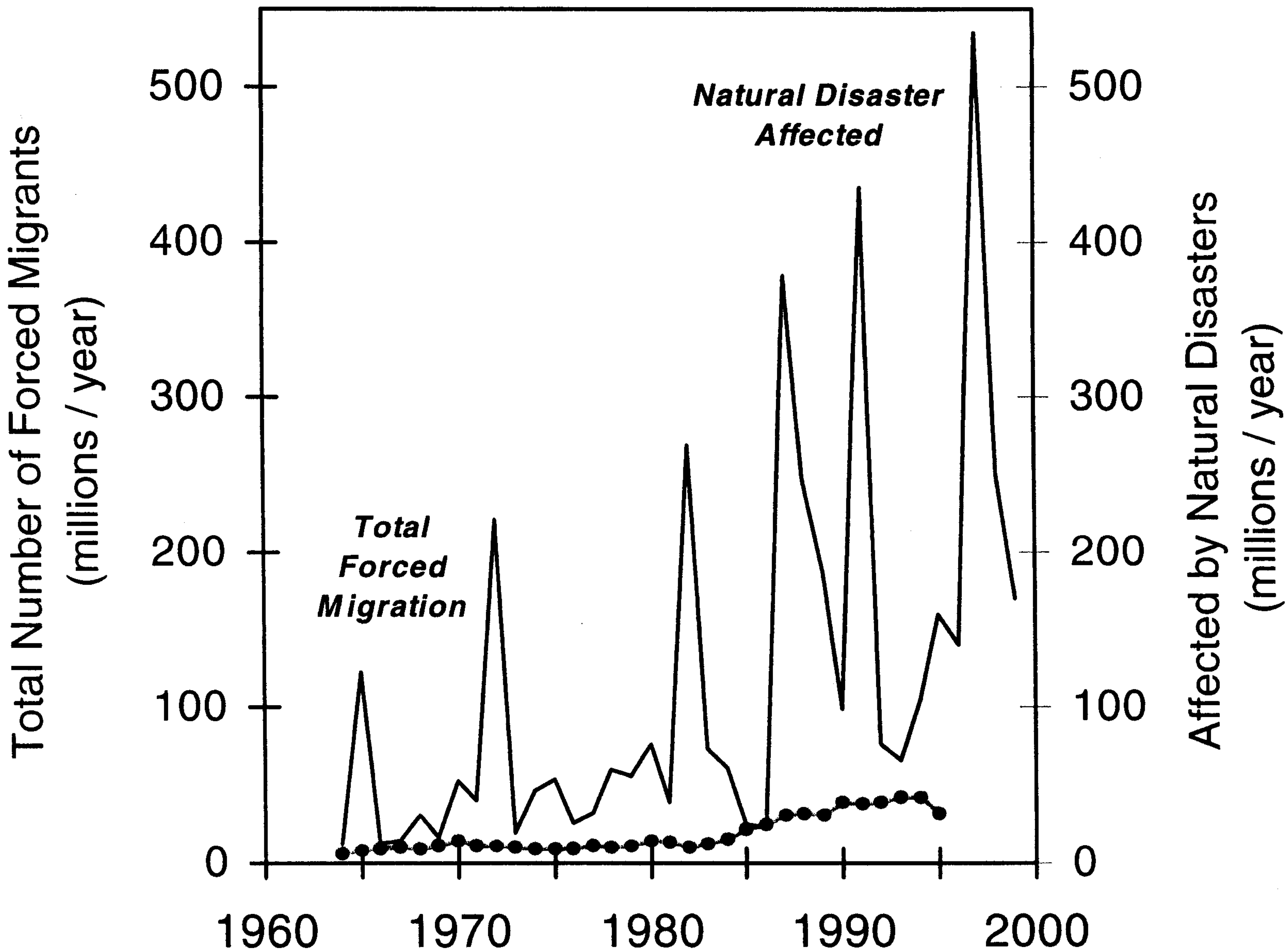


Figure 14. Population disaster and forced migration as in Figure 13. Values are five-year centered means.

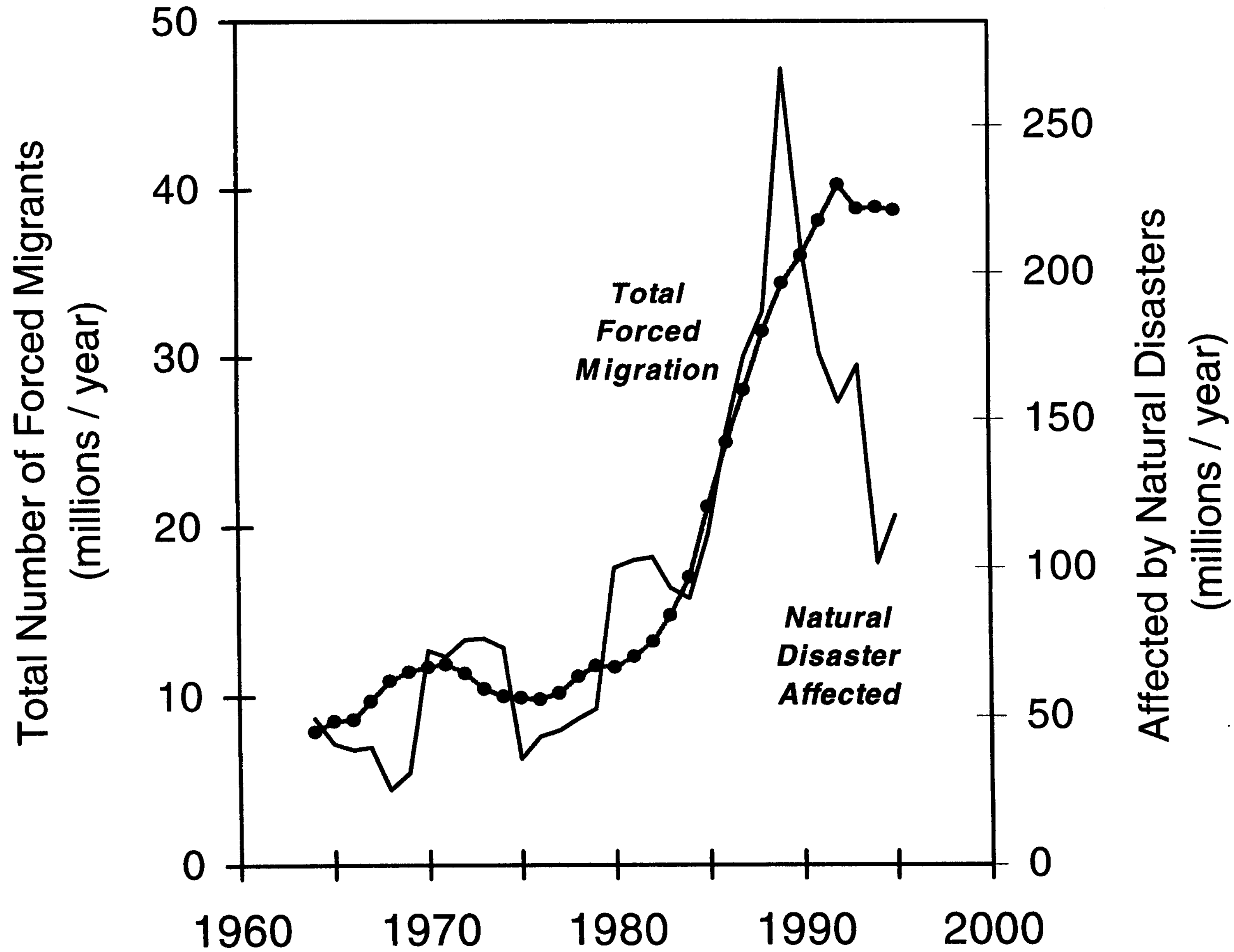


Figure 15. Predictive model of the total number of forced migrants (internally displaced persons *plus* trans-boundary migration) worldwide. The NOAA Multivariate ENSO Index accounts for 86% of the variation; the correlation (r) is very highly significant (p<0.001). Data are harmonized values of UN High Commissioner for Refugees and US Committee for Refugees (Schmeidl and Jenkins 1998a). Values are nine year-centered means, 1964-1995, with a five-year lag.