SOUTH PACIFIC CLIMATE VARIABILITY AND ITS IMPACT ON LOW-LYING ISLANDS

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1. THE IMPORTANCE OF CLIMATE IN THE PACIFIC

The Pacific is the world's largest ocean. With a surface area of 175 million km^2, it accounts for 40% of the planet's open waters. In the tropical latitudes, it spans more than half the globe's circumference.

In its western tropical regions, surface water temperature is always in excess of 28°C over a depth of several hundred meters. This constitutes the world's major store of thermal energy available for exchange with the atmosphere (Fig.1). This is where the interaction between ocean and atmosphere is the most intense, and what takes place there influences the climate not just regionally but planet-wide.

The nations of the Pacific are isolated pockets of human settlement immersed in this vast fluid universe. The ocean is by far the most important factor controlling the environment and all life in it. Thus any variation in oceanic conditions, and the resulting climatic changes, are of fundamental importance for the environment and the life of the inhabitants.

This article aims at presenting the major climatic phenomena affecting the Pacific Ocean (chapter 2) and their impact on the environment (chapter 3).

2. CLIMATE SIGNALS AFFECTING THE SOUTH PACIFIC

The most characteristic aspect of the mean climate of the Pacific region is that it is entirely ocean-dependent. Yet, above and beyond the seasonal fluctuations, it is subject to variations on a larger scale in which periods of intense drought alternate with period of extreme rainfall. Scientists have attempted to identify climate signals, which can be more or less distinct, and to determine the particular frequency (or rate of return) characteristic of each.

The best known among these is the phenomenon called ENSO (El Niño Southern Oscillation), which has a frequency of 2 to 4 years and affects the tropical regions in a spectacular manner.

A ten-year, or decadal, oscillation has also been observed; this affects each hemisphere in turn and is the subject of current research.

Global warming is not strictly speaking a signal, as it does not possess any identifiable frequency. This general warming trend has been observed since the beginning of the century, and appears to have been gathering speed over the last few years. At this stage, it is not possible to say whether this phenomenon is of natural origin or whether it is linked to man's increased industrial activity.

The study of **paleo-climatology** in the Pacific, using the evidence found in the build-up of coral formations, hopes to yield valuable information concerning longer-term oscillations of the region's climate. This kind of research may also help us understand better the currently observed shorter-term oscillations, and establish a relationship between climate and the large-scale migrations and the lifestyles of the people of the Pacific.

Before discussing these variations, or signals, let us consider the characteristics of the mean climate in the Pacific region.

2.1 - Mean climate conditions in the Pacific

The climate of a region is defined by averaging the conditions observed over a period of 30 years or more, taking into consideration all the parameters that constitute "weather" as it is felt by everyone and predicted by meteorologists. Among these parameters, the major ones are atmospheric pressure, temperature, wind conditions, rainfall and cloud cover.

As all inter-tropical regions, the South Pacific is bound by an area of low pressure near the equator (10°N to 10°S) and an area of high pressure centred around the 30°S parallel. Between these two areas, the resulting north-south pressure gradient generates the regular winds known as the South-East Trades.

Yet, within this overall pattern, there exist differences between the eastern and western parts of the region. Equatorial low pressures are lower in the west (around northern Australia and Indonesia), while the sub-tropical high pressures are higher in the east, reaching a maximum in an area south of French Polynesia and around Easter Island. This constitutes another pressure gradient, east to west, affecting the whole Pacific region between the equator and 30°S.

This east-west pressure gradient is one of the elements, in the equatorial zone, of what meteorologists call "Walker's cell". It is made up of a surface atmospheric flow generated by the above mentioned pressure gradient; this converges toward the low-pressure area of the equatorial western Pacific which covers northern Australia and extends to the whole of Indonesia. In this region, cloud cover is abundant and rainfall is intense. Above this warm and rainy region, very powerful ascending convection currents can be observed. Conversely, the wind circulation at higher altitudes (10,000 m, pressure 200 mb) follows a reverse pattern, i.e. from west to east. Over the area of high pressure at other end of the ocean, in the vicinity of Easter Island, the atmospheric circulation follows a downward flow.

closing the loop of the equatorial circulation cell (Walker's cell), which plays an essential role in the climate of the South Pacific. Disturbances in the flow of Walker's cell are associated with the ENSO phenomenon, which we shall discuss later.(Fig 2)

Air and ocean temperatures follow the same general pattern as that of atmospheric pressure and wind. A north-south thermal gradient exists between the equatorial areas, where average air and water temperatures never drop below 26°C and are little influenced by seasonal cycles, and the tropical regions where the temperatures are considerably cooler during the southern winter (for example 21°C for sea water and 19°C air temperature in New Caledonia). Similarly, there is also a temperature gradient between the western and eastern Pacific, particularly concerning sea surface temperature. The western end of the ocean (northern Australia, Indonesia) experiences sea-water temperatures in excess of 28°C all year round: this is the planet's boiler that we mentioned earlier (see Fig. 1). Conversely, the eastern equatorial regions can have comparatively much cooler waters (below 20°C in the vicinity of the Galapagos Islands); this is due to the upwelling of cooler water from the ocean's depths. This phenomenon is extremely important: it is one of the elements which drive the overall atmospheric circulation in Walker's cell, and its behaviour is responsible for the anomalies in this circulation associated with the ENSO cycle.

2.2 - ENSO : El Niño Southern Oscillation

ENSO is the dominant meteorological and oceanological phenomenon affecting the South Pacific. It is responsible for a large part of its inter-annual climate variability. "EL Niño" refers to the oceanological aspect of the phenomenon, and is characterised by an abnormal warming of the usually cool waters off the coast of Peru and Ecuador. "Southern Oscillation" is the atmospheric aspect of the event, characterised by a remote interaction between the atmospheric pressure fields of the eastern and western Pacific.

The German meteorologist J. Bjerknes was the first to establish a link between the warming of the ocean waters off the coast of Peru and a vast oscillation of the ocean-atmosphere system affecting the whole of the Indo-Pacific region. He also showed the existence of a negative correlation between the surface atmospheric pressure in the area of northern Australia / Indonesia and that of the region between Tahiti and Easter Island. He observed that when the atmospheric pressure is lower than average over several months in the Australia-Indonesia region, it is higher than average 10,000 km to the east in the central Pacific (near Tahiti and Easter Island). Such oscillations of atmospheric pressure have been shown to correspond to sea surface temperatures off the coasts of Peru and Ecuador, home of the El Niño phenomenon. When the Southern Oscillation Index (SOI), which is based on the difference in sea-level pressure between Darwin (northern Australia) and Easter Island, reaches a maximum, the warm anomaly characteristic of El Niño appears along the Peruvian and Ecuadorian coastlines.

Since the beginning of the 1950's, scientists have had at their disposal the necessary equipment for observation, and have been able to document fifteen El Niño events associated with the Southern Oscillation. The most pronounced El Niño recorded this century began during the summer of 1982 and intensified through 1983, reaching a magnitude never experienced before. Its impact on climate was spectacular, and was featured in the news media over a period of several months. Although the phenomenon does not always follow the same pattern, there are enough common features that a typical scenario can be described.

The most likely sequence of events is based on a simple mechanism (Fig. 3). The south-east trade winds, when they blow consistently over a long period of time, create an accumulation of warm waters and a rise in sea level in the western Pacific. As soon as the wind strength drops, the accumulated water tends to flow back eastward. This return flow can be accompanied by an equatorial wave (known as a Kelvin wave) resulting from the deformation of the interface between the surface warm waters and the cooler waters below.

In turn this eastward movement of warm waters, which constitute the El Niño phenomenon proper, influences the lower atmosphere resulting in a lowering of the atmospheric pressure, particularly in the Tahiti - Easter Island region where the pressure is normally high. The Southern Oscillation Index drops, as does the strength of the trade winds. Thus the phenomenon is further fuelled by its own self-reinforcing feedback, and reaches the warm phase of ENSO, the stage usually called El Niño. These warm waters then disperse north and south along the coasts of the American continent. Cold water reappears off the coast of Peru and Ecuador, bringing the atmospheric pressure back to normal for the area. Atmospheric pressure increases in the Tahiti - Easter Island zone, raising the Southern Oscillation Index and reinforcing the trade winds. The phenomenon moves then into its cold phase, sometimes erroneously called "normal", and the trade winds begin once more to push warm waters to the western edge of the Pacific (Indonesia and northern Australia).

The climatological consequences of these oscillations between a cold and a warm pole are very important for the South Pacific region. In a "normal" situation (cold pole of ENSO), the South Pacific regions enjoy plentiful rainfall. During the "El Niño" phase (warm pole of ENSO), the area of abundant rainfall shifts eastward toward the central and eastern Pacific. Thus in 1983, Indonesia and northern Australia suffered from the most severe drought ever observed in these regions. Conversely, torrential downpours drenched the central Pacific, particularly the Marquesas Islands which received 2400 mm of rain in three months (Fig. 4).

New Caledonia is affected by the cyclic influence of ENSO. Periods of drought, such as the one which began in 1992, correspond to the El Niño phase of the oscillation, i.e. the warm pole of ENSO.

2.3 - Global warming

Since the beginning of the century the earth's average temperature has increased by 0.5°C; this has been accompanied by a 10 cm rise in the level of the oceans. The rise in sea level is the result of thermal expansion of the surface layers of the oceans.

This long-term climate change is termed "global warming". The process has shown a tendency to accelerate, and computer modelling of the situation indicates that this warming may be the result of an increase in the "greenhouse effect", itself due to an increase in the atmospheric concentration of gases produced by industrial activities, such as carbon dioxide, methane and ozone.

Whatever the cause of the phenomenon, be it natural evolution or man's industrial activity, this warming trend in the atmosphere is transferred to the oceans, resulting in a world wide rise in mean sea level. Global warming is therefore of particular concern to the Pacific island communities who exist within this ocean environment. The rise in sea-water temperature affects marine life and increases the chances of cyclones. The rise in sea-level is a vital concern for many of the region's islands and nations.

We shall discuss the impact of global warming in more detail in Chapter 3.

2.4 - The ten-year (or decadal) oscillation

This climate signal, whose existence was recently discovered, is only mentioned here because it is likely to be the subject of research projects in the near future. It affects alternatively the whole of each hemisphere. It appears to be particularly noticeable in the Atlantic and might be one of the driving factors in the current persistent drought in the sub-Sahara regions of Africa. In the Pacific, it has been detected as a factor in oceanic water circulation in the vicinity of Kuro Shivo (Japan). It might affect climatic conditions in the Pacific on a ten-year cycle, and may have an influence on the effect of the shorter-cycle ENSO.

2.5 - The paleo-climates of the Pacific

Changes in climate have a significant influence on the biology of the reef ecosystems, on their morphology, structure and abundance.

Corals have a well documented response to environmental conditions, thus the study of coral reef structures makes it possible to determine with surprising accuracy the average surface temperature and level of the oceans during past periods, and even to detect and date annual and inter-annual climate variations, from the recent past all the way back to the close of the last ice-age (roughly 18,000 years ago).

Such studies are shedding light on long-term trends which have affected the Pacific since the last ice-age, and have led scientists to reconsider some previously accepted scenarios. They show for instance that in the region of Vanuatu, the surface temperature of the ocean may have been 5° to 7°C lower than at present at the time of the last ice-age. In New Caledonia, the water was also much colder, and the seasonal variation far more pronounced. The discovery of past occurrences of rapid changes in average ocean temperature (several degrees per century) and sea-level (a rise of over 1 cm/year during the thaw that followed the ice age) has raised questions about the human origin of the current warming, which is progressing at a much slower pace.

Past climate changes have profoundly influenced the life and settlement patterns of the early inhabitants of the region. A good understanding of the way in which human communities reacted and adapted to these variations is likely to be very relevant today.

Studies are currently being undertaken in this field, and further research programmes may soon be initiated focusing on the Pacific region, where ancient coral formations can readily be found.

3 - The impact of climate changes on the South Pacific environment

The impact of climate variability in the Pacific is linked to the evolution of the atmosphere and of the ocean waters, the major characteristic of the region being its oceanic nature.

Among the impacts of the evolution of oceanic waters we may list:

(i) The consequences of the rise in mean sea-level;
(ii) The consequences of the warming of surface waters for marine life and its harvesting for human consumption;
(iii) The consequences of the warming of surface waters on the frequency of catastrophic meteorological events, notably cyclones;

Among the impacts of the evolution of atmospheric conditions, we may list:

(iv) The consequences of climate variation on rainfall and the fresh-water supply;
(v) The consequences of climate variations on certain types of agricultural activities.

We may also consider types of impact which are linked to climate change, but which act through factors of purely human origin, such as over-population:

(vi) The consequences of warming and coastal pollution for lagoon environments: leaching of mineral salts and heavy metals, erosion.

3.1 - Consequences of the rise in mean sea-level for the nations of the South Pacific

The rise of the mean sea-level (ignoring the changes in level due to tides and meteorological events) affects all coastlines in the Pacific. Since the beginning of the century, the figures for this rise vary between island groups, going from 0.6 mm/year in Micronesia to 3.8 mm/year in the Hawaiian Islands. This observable rise in water level is not only due to a general increase in the level of the oceans, but also to "isostasic" movements of the seabed which supports the islands. Given the short period of time since the beginning of scientific observations of the phenomenon (often less than 20 years), it is difficult to establish a clear tendency independent of these tectonic movements. Nevertheless, we may estimate that the mean sea-level in the Pacific, and over the rest of the globe, rises at a rate of 0.5 mm/year. This is principally due to thermal expansion of the water as a result of global warming.

It is very difficult to say with confidence whether the current rising trend of the mean level of the oceans, a phenomenon which is tied to global warming and has now been observed for a full century, is the direct result of the increase in the greenhouse effect due to man's industrial activities, or whether it is a stage in a perfectly natural long-term evolutionary process.

Some nations are at risk

In any case, acting on the hypothesis that the rise in sea-level is a consequence of industrial activity, there has been much debate on the subject among the governments of the small island nations of the Pacific. The tendency has been to overestimate the danger, and to demand action (and compensations) from the industrialised nations of the northern hemisphere, considered to be the major producers of greenhouse-effect gases.

One must admit that some of the figures can be frightening. The more pessimistic models, given the continuing production of greenhouse gases at current rates, anticipate a rise in sea-level of the order of 0.5 m in the next 50 years (document published by the International Panel on Climate Changes). Some entire islands of the atoll type do not exceed a height of 3 m above mean sea-level. A rise of this magnitude would be enough to wipe such nations as the Marshall Islands, Kiribati, Tuvalu and Tokelau off the map within the next century. While it is true that the whole of the populations concerned represents only a few tens of thousands of individuals, and that these could be easily relocated on other islands, the impact on public consciousness of the disappearance of several sovereign states could be stupendous, particularly if it could be shown that their demise was directly attributable to the industrial activity of other nations.

Yet, paleo-climatology - the study of the climate patterns of ancient times - has shown that the Pacific has experienced several major changes in sea-level over the last few millennia. About 18,000 years ago, at the time of the peak of the last ice-age, the mean level of the ocean was approximately 120 meters below its current level. It then rose rapidly until 5000 years ago, when it reached a level higher than that of today. Over the last 2 to 3000 years, the general tendency has been to a decrease, but with ups and downs lasting several centuries. For example, between 750 and 1300 AD, the mean sea-level rose; then, during the mini-ice-age of 1300 to 1800 AD, it dropped again. Since 1800, we have been experiencing a period of rise in sea-level, which coincides with the development of the industrial age; but it is impossible to say whether this, or natural causes, is at the root of the phenomenon.

Compounded degradation of coastal areas

Not only would rising ocean levels mean the disappearance of low-lying lands, but it would also affect entire coastal areas above the level of flooding.
In atolls, any rise in salt-water level would tend to push the precious fresh-water lenses upwards, where they would evaporate faster.
The loss of coastal areas, combined with a reduction in available fresh-water, would could be very detrimental to the agricultural potential of the many islands where the coastal strip is the only area suitable for cultivation.
The temporary rise of water level which accompanies such events as cyclones or tidal waves would threaten and damage lands which had been previously out of reach of the sea.

3.2 - Consequences of the warming of surface waters on marine life and its harvesting

Life in the ocean is very much dependent on the thermal conditions of the water. Salinity is also important, but this is less affected by climate change. Ocean dynamics are another significant factor: strength of currents, turbulence, frontal and convergence zones, all of which are likely to be altered by climate change.

The life and death of corals - The phenomenon of "bleaching"

Corals grow successfully where the water is between 26° and 30°C. Above 30°C, corals become separated from the symbiotic algae which are the indispensable partners of their existence, and which give them their usual colouring.

Over the last few years in the Pacific, particularly the South Pacific, one has been able to observe a discoloration of corals, a phenomenon referred to as "coral bleaching". The coral colonies suddenly take on vivid colours, going from brilliant blue to pink and fluorescent yellow. They appear to bloom, while at the same time the tips of the branches start to turn totally white. In the space of a few weeks, this stark white colour extends to the whole structure, and filiform algae begin to grow over the coral, indicating without any doubt that the coral is now irreversibly dead.

In the Society Islands, scientists from the ORSTOM Centre of Tahiti observed coral bleaching over 500 km of barrier reef. Other regions of the Pacific are also affected. Similar observations had been made during the warm periods of the 1982-83 El Niño, at a time when sea surface temperatures in the central and eastern Pacific were 4°C above normal. The same phenomenon has also been noted in the Atlantic Ocean since the 70's, when temperature anomalies affected the Caribbean region.

Thus it is possible to associate the bleaching syndrome and death of coral with the general warming of surface waters in the tropical oceans, itself a consequence of global warming, although at this time the information is too sketchy for an exact mapping of the extent of the phenomenon and for establishing with precision its relationship with the warming of the waters and of the climate in general. Other factors, linked or not with climate change, may well be involved in the process.

Impact on fishing resources

Life within the ocean is directly dependent on the conditions it finds there and, near the surface, on certain atmospheric influences such as the effect of the wind.

Of the two climate signals which affect the South Pacific, ENSO and global warming, only the former has significant and reasonably well understood effects on life in the ocean. Our understanding of the biological consequences of global warming have not progressed beyond speculation.

The impact of ENSO on marine ecosystems has been known to fishermen off the coast of Peru, Ecuador and Chile for centuries. The warm waters associated with the phenomenon interfere with the upwelling of cold, nutrient-rich waters, inhibit the development of plankton, and thus limit the supply of nutrition available to the food-chain. This means fewer fish to catch for human consumption. Furthermore, the temperature anomalies which accompany ENSO affect the behaviour of many fish species, which will tend to seek waters where the temperature is more to their liking and where food is more plentiful. During an El Niño occurrence, these fish migrations take place north and south along the American coast, shifting the traditional fishing grounds by hundreds, if not by thousands, of kilometres.

At times, this may lead to large congregations of fish within a very limited area where water temperature is favourable, making them vulnerable to massive over-fishing. This may represent "miraculous catches" to some fishermen, but in the long term this can be dangerous for the population dynamics of the particular species, and a threat to the sustainability of the resource.

Another physical factor associated with El Niño and capable of negative impact on marine life is the disruption of the rhythm of the seasons. Both flora and fauna rely on this cycle to time the stages of their life-cycle and any disturbing of the pattern is certain to be detrimental to their development.

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The impact of global warming on marine ecosystems is not expected to modify their composition, but only to alter their zone of expansion following the shifting of the isotherms. Global warming generally tends to shift these in latitude, which implies a progressive expansion of marine habitats from the tropics toward higher latitudes. Nevertheless, if the warming trend accelerates, it is debatable whether the various ecosystems will be able to adapt to such rapid change.

The distribution and the abundance of the different marine populations will be more affected by modifications in ocean dynamics (currents) than by the warming itself. It is thus difficult at this time to predict the evolution of marine ecosystems in the South Pacific under the influence of the warming of ocean waters (excepting in the case of corals - see earlier paragraph).

Global warming will also have consequences for the carbon exchange process at the interface between ocean and atmosphere. Generally speaking, oceans act as receptor for excess atmospheric carbon dioxide, and thus contribute to the regulating of the global carbon cycle, which is an important factor in climate change. However, the equatorial regions of the Pacific actually give out carbon dioxide to the atmosphere through a release of the CO_2 dissolved in the surface layers. Nevertheless, the equatorial Pacific plays and essential role in the balancing the global carbon budget, which amply justifies the amount of research which is currently being carried out on the subject (JGOFS - FLUPAC, Chapter 4.2.2).

3.3 - The consequences of the warming of surface waters for catastrophic meteorological events

Tropical cyclones are an important feature of the climate of the South Pacific; their destructive power affects agriculture, housing, and the whole of the living conditions of the many island groups which lie within the cyclone belt.

One of the necessary conditions for the formation of cyclones is sea surface temperatures in excess of 27°C. Thus any warming up of surface temperature, whether temporary as during an ENSO event or more lasting as a result of global warming, will contribute to an increase in the risk of cyclones. This was demonstrated clearly during recent ENSO occurrences; in 1983, during what was termed "the El Niño of the century", French Polynesia, an area not normally prone to cyclones, was battered by six particularly violent cyclonic storms which devastated a number of atolls, notably Muroroa. Temperature anomalies of 4 to 5°C above normal were observed in this region, resulting in favourable conditions for the formation of tropical cyclones (water temperatures of 28 to 30°C).

If the current warming trend persists, the frequency of cyclones in the central South Pacific can be expected to increase. This frequency is not proportional to the rise in temperature, but can actually accelerate with warming. Furthermore, a larger area of the ocean will become likely to experience cyclones, as the 27-28°C isotherm shifts poleward and toward the central Pacific, increasing the risk, among other islands, for French Polynesia.

Over the last few years, a striking increase in cyclonic activity has been observed in the region of French Polynesia, where such tropical storms used to be virtually unknown.

3.4 - The consequences of climate change on rainfall and fresh-water resources

The pattern of rainfall over the whole of the South Pacific, up to fairly high latitudes (30°S), is to a great extent governed by the ENSO phenomenon. The warm phases of ENSO, the ones usually referred to as El Niño, correspond to below-normal rainfall throughout the western Pacific, which includes the east coast of Australia, Indonesia, Papua New Guinea, Solomon Islands, Vanuatu and New Caledonia. Conversely, the central Pacific, including Tuvalu, Kiribati and French Polynesia, experiences heavier rainfall than normal. The actual quantities of water may vary by a factor of 3 between a dry and a wet year, with significant consequences for agriculture and fresh-water reserves. Therefore, the ability to predict the behaviour of the Southern Oscillation a few months to a year in advance could be of extreme importance to the planning and management of resources, particularly among the regions' smaller nations where the availability of fresh-water is critical and traditional agriculture represents a sizeable factor in the economy.

Global warming will also affect rainfall, and thus the region's fresh-water resources. The fresh-water cycle, and notably the rate of evaporation and rainfall, will be intensified by the combined warming of air and sea-water. Rainfall statistics have not been kept long enough in the South Pacific region to assess any trend toward increase in average rainfall, as this evolution would be a long-term, low amplitude phenomenon, and would be overshadowed by the more dramatic influence of ENSO, far the strongest influence on South Pacific rainfall.

3.5 - The consequences of climate changes on agriculture

Here again, we shall consider the difference between short-term fluctuations, such as those linked to ENSO and which result in alternating periods (or years) of heavy rainfall and of pronounced drought and which are potentially predictable, and the long-term warming trend whose effect on the rainfall patterns is much less dramatic, to the point of being barely measurable.

In many countries, the ENSO cycle is already the subject of government concern and involvement. Farmers are advised of predicted upcoming wet or dry periods, so that they may plan accordingly. This is the case in Peru, in Ecuador, in Brazil, and in other Pacific countries. In Peru, for instance, farmers are encouraged to alternate the growing of cotton (during dry periods) and rice (wet periods). Improvements in production, measurable in economic terms, have been achieved this way, and while such predictions are still at the experimental stage, they should soon become an operational tool for the whole Pacific region.

Concerning any need to adapt the agricultural practices in the Pacific on account of the consequences of global warming, one can only speculate at this stage. It can only be said that some regions will be wetter, others dryer, and that the differences over space (between regions) and over time (between periods for any given region) will be more pronounced, raising the risk of persistent drought in certain cases, and of chronic flooding in others. Furthermore, if the concentration of atmospheric carbon dioxide continues to increase, this will have a positive influence on the growth of plants, but may be detrimental to their physiology (too rapid a rate of growth may result in improper maturing).

Generally speaking, the adaptation of agricultural practices in response to changing climatological parameters (fresh-water supply, temperature, amount of sunlight, carbon dioxide levels, wind strength....) will follow two major directions:

- switching to different crops (as is done in Peru by switching between cotton and rice in harmony with the ENSO cycle), and
- modifying cultivated species through genetics, as is already being done industrially for maize (Indian corn).

Two extremely important negative factors resulting from a general trend toward a warmer climate should also be noted:

- Increase erosion and leaching of soils due to increased rainfall and intensification of climatic contrasts, and
- Increased pest activity (insects, bacteria, etc.) resulting from increased humidity.

3.6 - The consequences of climate changes and demographic growth on coastal and lagoon areas

Human activity is responsible for major alterations to coastal marine environments. If this influence reinforces that of climate change in the direction of warmer conditions, this can be highly detrimental to the health and balance of lagoon habitats through the impact of such phenomena as leaching of chemicals into lagoon and coastal waters, and sharp increase in sedimentation.

The island environments of the Pacific are particularly vulnerable to these risks, which are only partly the result of climatic change, but also that of a human factor which characterises our times: rapid demographic growth. A general warming of the climate would only amplify the dangers, and the impact of climate changes must be taken into account in future studies concerning the problems of leaching and over-sedimentation.

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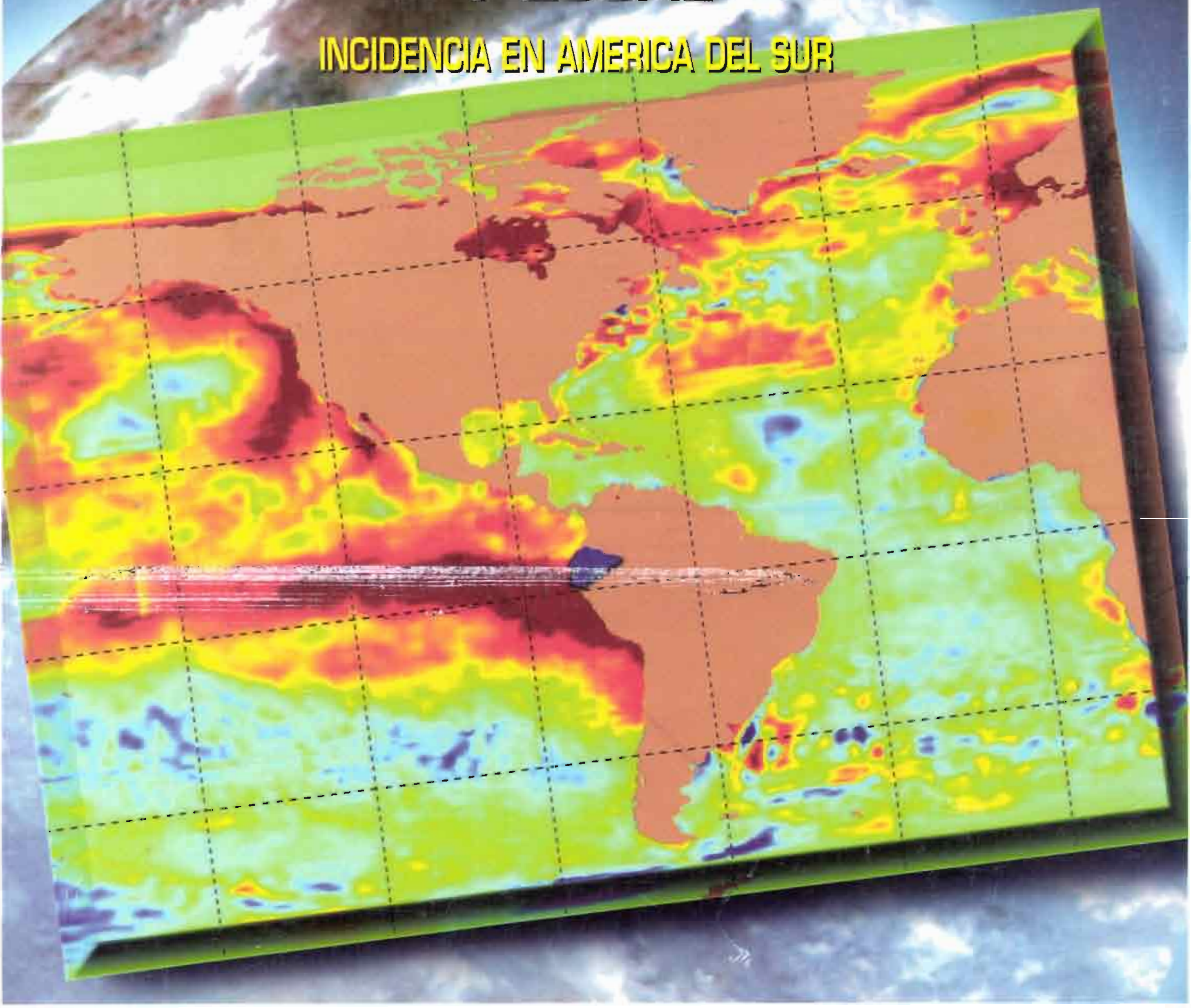

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