EL NINO PHENOMENON AND NATURAL DISASTERS IN PERU

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The El Nino phenomenon is an extraordinary recurrent set of climatic conditions produced by the alteration of the ocean and the atmosphere in the Equatorial Pacific. It is said that this is a macro scale phenomenon since it affects huge areas of the planet

It primarily affects the Pacific Ocean, especially the tropical and subtropical region, but also reaches the Indian Ocean and Atlantic Ocean. Its effects are perceived in large continental areas of Asia, Oceania, Europe and America, but mainly in America and the Pacific Ocean. The affects are particularly seen in the coasts of Peru and Ecuador.

Southern oscillation constitutes the climatic, oceanographic and meteorological event of highest economic, social, and biological impact for many countries in Latin America. Nowadays, it is considered as an event of global impact. For a long time El Nino was seen as a phenomenon that appears from time to time and that changes the life of mainly those countries of the south eastern basin: Colombia, Ecuador and Chile.

However, the impact of this climatic effect from 1997 to 1998 with the product of the equatorial pacific warming was severe and diverse in different regions of the world. Rain and floods were produced in Ecuador, Peru and the central zone of Chile. In Colombia, the climatic effect produced an important deficit of rains and droughts occurred

Manifestations and Evolution of the El Nino Event from 1997 to 1998 in Macro, Meso and Micro Scale

The evolution of the El Nino event was characterized by a north-south advance of tropical surface waters and Ecuadorian surface waters, which had little salinity (S<34,0 UPS), high temperature of sea water (T>27°C), and lack of inorganic nutrients that modified the typical environment of the Peruvian sea ecosystem.

During the development of the event in the phase of the post El Nino, a rapid and rough movement of Equatorial surface waters and tropical surface waters to their zone of origin was seen. Also, subtropical surface waters which are oceanic waters characterized for their high salinity and lack of inorganic nutrients, penetrated to the coastal areas; and as a result the ecosystem suffered a lack of environmental elements for the development of resources needed to create conditions for the normalization of environmental parameters.

Evolution of the Coastal Extension of the Cromwell Current

Among the sub-superficial conditions, we observed an obvious advance towards the south of the south extension of the Cromwell current registered from Puerto Pizarro to Ilo. The features that we saw were high content of oxygen· deepening of the isotherm of 15°C that had influence up to 250 m of depth. This sub-superficial flow of Equatorial origin water started to decline from March 1998 and has now recovered its normal conditions

The Oscillations of El Nino

The analysis of the oceanic and atmospheric index indicates that this index has a pendulous oscillation or some kind of cyclic movement where there are intervals of cold and hot events.

The analysis time series of this multi varied index show that the current event of El Nino had an origin in March 1997, reaching its peak in August 1997 and in February 1998. It started its decline in March 1998. This El Nino, had two cycles and was different from the majority of the previous El Nino events that occurred in this century.

Follow up of El Nino Event

- *Satellite images*

  Through satellite images of the sea temperature and their anomalies we have a synoptic view of the development of the current El Nino; what allows us to reach a prognostic for short and medium term.

- *Research cruises in Peruvian Sea*

  IMARPE during the development of El Nino, made a series of research cruises exploring 2,7000 nautical miles, totaling 203 days of navigation during the years 1997 to 1998. Some of those cruises traveled over 500 miles of the Peruvian sea with the intention of obtaining a synoptic vision in situ of the distribution of environmental parameters. Now we are able to show some of the results of these cruises

- *Peruvian Coastal Stations and Laboratories*

  For the follow up of the oceanographic conditions, IMARPE consulted with 8 laboratories of investigation along the Peruvian coastline where information on resources was obtained as well as oceanographic information following the path of the series of time data taken from these laboratories. From these measures of the superficial temperature of the sea, the development of the present El Nino event may be seen.

  The image shows the temporal distribution of the sea water temperature near the laboratories of Paita and Chimbote, which are zones sensitive to changes of sea temperature

Impacts on the coastal ecosystem and the resources

- *Peruvian Ecosystem feature*

  It has been frequently mentioned that the ecosystem of the Peruvian upwelling is one of the most diverse and productive in the world, because of its nature, its geographic position in the planet, the geomorphology of the continent, and the system of flows where it is merged.

  For that reason, it is sometimes difficult to talk about a balanced ecosystem. It would be better if we mention that it is an ecosystem that contains multiple points or phases of balance which explains why sometimes it is difficult to make comparisons in relation with normal conditions It is better to talk about common conditions or average conditions

  Each of these phases of different scale of time and space that belong to the Peruvian marine ecosystem have specific features with a variety of alternatives resources that are joined together as part of the natural dynamics that we are learning to understand.

- *Impact on Resources and Fishing*

  Briefly, we are going to make a review of the main effects of the El Nino 19971998, the main components of the ecosystem, and the fishing resources.

  In the pelagic system the primary production was reduced to levels 25% (summer to fall 1997) of the value observed before the event.

  El Nino phenomenon has differential effects on differential subsystems. It favors one species and damages others

- *The Anchovy (Engraulis Ringens)*

  The anchovy is a pelagic species of cold coastal waters that is distributed geographically from Punta Aguja, Peru to Talcahuano, Chile It represents more than the 90% of the fishing resources in Peru.

  The distribution of the anchovy in 1991, a cold year, was wide and disperse; especially in fall and winter, reaching more than 100 mm of the coast.

In 1997, the incidence of the El Nino event modified the patterns of distribution and concentration of anchovy that of first was near the coast where it increased its concentration and was more accessible and available for fishing. Later on, the anchovy school movement was southward as well as a movement to the deepest zones of the sea.

In 1998, the biggest concentrations were registered in the south of Callao and then they returned to their normal place when condition got better.

In summer 1999, the redistribution of the resource towards habitual areas continued, and now there are small concentrations in front of Paita.

- *The Sardine (Sardinops Sagax)*

The sardine is distributed mainly in the north region of the Peruvian shore; it is very dispersed during winter and it is located near the coast during summer.

In 1996, it had a wide distribution reaching inclusively more than 200 nautical miles off the coast. In 1997 with El Nino, concentrations were near the coastline and then they moved to the central part of the area.

In 1998, there were in the central region and in fall and winter time they started to redistribute towards the northern region. In summer 1999, the distribution expanded along more than 80 nautical miles of the coast, indicating a movement towards oceanic areas

In the historic series of the anchovy biomes distribution from 1983 to 1999, it was observed that in normal environmental conditions, the placement of the four main sardine nuclei are between 07 - 09°S, 10° - 11°S, 13°S and 15° - 17°S. While in El Nino periods the nuclei of the northern region disappears and the presence of the nuclei of the central and south regions are more important.

Finally due to the El Nino of 1997-98, last year there was a reduction of the catch of anchovy and a slight recuperation in the fishing of sardine

The latitudinal distribution of the anchovy shows the movement towards the north, which during cruise 981112 (November - December), the anchovy was mainly distributed in the south.

In the graphics, it can be observed that the abundance of the anchovy, which has recuperated after El Nino 1997-1998 and which reached its lowest point during cruise 980809, is showing a level and distribution very similar to the one determined in cruise 970910 (BIC Olaya).

- *The Yellow Jack (Trachurus Picturatus Murphyi)*

The Yellow Jack is a fish species with a large distribution along the Peruvian coast.

In 1996, the highest concentrations were located mainly in the north and central regions.

In 1997, its distribution was reduced in the northern region while in 1998 just isolated nuclei were observed in summer and fall; with a progressive coming back to its habitual areas of distribution in the last months of the year.

In summer 1999, its distribution was located mainly in front of Paita and Chimbote in an extensive area that reached 120 nautical miles along the coast.

- *The Mackerel (Scomber Japonius)*

The major concentrations of mackerel are situated in the northern zone of the Peruvian coast.

In 1996, its distribution was wide and dispersed, located 200 nautical miles off the Peruvian coast.

In 1997, the resource moved to the south of Paita and in 1998 it was observed to be progressively coming back to its common areas of distribution, it needs to be mentioned that the concentration detected in spring generated important captures of the species.

In the summer of 1999, its distribution was wide and it was located mainly from Paita to Huarmey, up to 150 nautical miles off the coast

The landings of yellow jack and horse mackerel showed an increasing tendency due to the availability and increase of fishery efforts in the last years.

- *The Hake (Merluccius Gayi Peruanus)*

The Hake is a demersal species, what means that it lives in the deep ocean of the continental platform and in the shore of the ocean slope. It represents more than 80% of the catch of demersal fishery resources in Peru

Hake lives in the north extreme of Peru until 14 degrees south and reaches depths of 600 to 800 meters. Its main areas of concentration are in the north but during the El Nino phenomenon it can be located in the southern part of Peru. During the El Nino of 1997-1998 there was a movement of this resource until 08 degrees south between July and December 1997 For 1998, the return to its common areas of concentration was observed.

The catch in the period from 1985 to 1998 showed an increasing trend with maximums in the years 1990 and 1994-1996; with catch reductions associated to the event of the El Nino of 1991 and 1997-1998.

- *Other resources*

The scallop catch during the period 1953-1998 were less than the 2,000 tons reached in normal years. With rises related with El Nino events, specifically in the year 1985 when the catch was of 47,000 tons and after the extraordinary El Nino of 1982-1983. In 1998. a new rise in the catch was observed (22,000 tons). In both cases Pisco Bahia Independence was the place of greatest abundance.

The catch of giant squid (Dosidicus gigas) were low in the period 1953-1990, due to the lack of a fishing policy directed towards this resource that was captured by chance while fishing. Since 1991, the development of new fishing technology of high scale with the participation of a foreign fleet of specialized fishing boats was implemented This allowed the maximum capture of 190,000 tons of this resource in the year 1994.

The fishing of giant squid needs small scale and industrial fleets whose major annual landings were like the one of the year 1994.

The small-scale fishery of the giant squid captured 100,245 tons in the period 1991-1998, being the best years: 1991 and 1994 because of their better catch, with a maximum of 9,000 tons in June 1994. A relation exists between positive anomalies of the surface water temperature and the volumes that were landed.

Industrial fishing captured 552,783 tons in the period 1991-1998 with maximum values in the years 1991 and 1994 which fluctuated between 60.000 and 165,000 tons per year The most important monthly catches were in June and December of each year, with a maximum value of 52,000 tons in July 1994. Like in small-scale fishing, the biggest volumes were related with the years of positive thermal anomalies of +5°C.

- *El Nino Phenomena from the Year 1525 until the Present*

It is important to point out that we have historical records of the El Nino events since 1525 thanks to different sources such as chroniclers, archeologists, historians, and others.

For this century, there have been 25 events until 1998.

We have a table of the El Nino phenomena produced in the Peruvian Sea from 1525 to this year. Each event is identified with its year of appearance, its intensity, and classification.

With this historical data, we reaffirm that the events are recurrent in time and that it is necessary to intensify the studies of the causes and effects as well as to publication of knowledge about the topic in order to obtain adequate tools for prediction.

- *The Multi Sectorial Committee for the Study of El Nino Phenomenon*

  Due to the fact that the El Nino events have great importance for the South-eastern Pacific Region, our country in 1973 presented to the Permanent Commission of the South Pacific Intergovernmental Institution for Maritime Affairs of Colombia, Ecuador, Peru and Chile, an initiative to create a regional program for the study of the El Nino event.

  The initiative was approved and in 1974 the scientific committee ERFEN was created (Regional Study of El Nino Phenomenon). The ERFEN is a program of scientific research about El Nino that includes Colombia, Ecuador, Peru, and Chile; in other words all the southeastern pacific countries.

  With the current event that started in March 1997, the sea started to show an abrupt warning that produced a new event El Nino. As it was public knowledge due to its very strong intensity, it made the government and society take important actions of prevention in order to reduce negative effects.

  One of the first actions taken by the Peruvian government in dealing with the El Nino of 1997 has been the reconstruction of the national committee of ENFEN making for this purpose some changes in its structure in order to concentrate the needs of national sectors.

Objectives of the ENFEN Committee

The Multi Sectorial Committee for the Study of El Nino Phenomenon has the task to coordinate the prevision of these natural events and to mitigate its disaster effects in coordination with other government institutions.

IMARPE again has taken the chair of the reconstructed committee of ENFEN, that as a special action of the state has the following objectives:

- Study of El Nino phenomenon to understand its origin, describe its development at short term (3 months), and anticipate as much as possible the probable consequences (mainly sea temperature, rains, and droughts in the continent)
- Coordinate, recommend, and help in activities related with the phenomenon with national (Domestic institutions) and at the international level (ERFEN, CPPS, international agencies, COI, OMM NOAA, IAI, IRI, etc.).

Enfen Conformations

The multi sectorial committee is formed by: IMARPE, Peruvian Marine Research Institute; SENAMHI, National Service of Meteorology; DHNM, Hydrographic and Navigational Direction of the Marine; INRENA, Institute of Natural Resources; and INDECI, Civil Defense National Institute.

Among the actions taken by the committee are the preparation of specialized technical reports on the oceanic and atmospheric environment, and on its effects in the distribution of fishing resources, as well as in participation in the execution of scientific cruises related with the El Nino.

- *Improvement of the Prognostic Capacity and Evaluation of El Nino Phenomenon for the Prevention and Mitigation of Disasters in Peru (World Bank Project)*

  The objective of this project is to improve the prognostic capacity and evaluation of the recurrent El Nino event through the implementation of a modern system of disaster prevention (oceanic and atmospheric) for institutional parties of ENFEN that accomplishes tasks based on the study and modeling of the main physics and dynamic processes of the ocean, the atmosphere, and its intervention.

- *Economical Maintenance of the Project*

  One of the adverse meteorological phenomena that considerably affects the quality of life of citizens is the El Nino phenomenon. It produces loss of human and economical lives in our country; these damage can be mitigated if the prevention institutions responsible for the reporting of trustworthy and reliable alerts about El Nino become stronger. For this, it is necessary that the project of improvement of the prognostic capacity and evaluation of the El Nino phenomenon becomes operational.

The investment is funded as follows:

Equipment	$ 4,970,780
Installation	$ 165,000
Training	$ 375,000
Technical aid	$ 110,000
Total US$	**$5,570,780**

Project Components

- *Atmospheric Component*

It encompasses all the activities related to the prediction of time and climate in the different regions of Peru. The time prognostics as well as weekly, monthly, and seasonal climate predictions are included approximately 72 hours in advance.

- *Numeric Model of the Atmosphere*

There is an ideal of operating 3 numeric models, two of them for the prediction of climate changes over time in the continent; and the last one for the prediction of the climate in our country.

Capacities of global climatic prediction will be taken into account a study for North America designed to model the region of the tropical pacific.

A regional numeric model for the prognostics of time in the continent is operating right now, but it needs real time data. This data comes from automatic data stations which are divided with an space of approximately 150 by 150 km to obtain national level coverage, as well as with satellite data of high resolution for its validation.

These models will be used to forecast rain, temperature, pressure, and winds in the Peruvian territory 24, 48 and 72 hours in advance.

- *Hydrological Numeric Model*

For hydrological prediction for the short term, the strategy to be used consists basically on changing the rain forecasted to the atmospheric model in a hydogram of flows, and then to move this wave through other flows.

The selection of technical procedures and of the models for the disposable supply depends on the complexity of each flow and on hydro-meteorologic and topographic data, among other factors.

According to these models, the requirements of the data changes. It is imperative to use automatic stations of water level and flow, as well as meteorological stations and a system of quick and reliable communication.

It is necessary to previously identify the paths of rivers to find out if they are historically sensitive to floods and to include the topographic data from the rivers

- *The Oceanographic Component*

The objective of this component is to establish a system of oceanic safety in real time of the main process that modulates the marine dynamics and the interaction between ocean and atmosphere. This will improve the diagnostics and prognostics of oceanic and climatic conditions for use in the management of productive activities in the country.

- *Oceanographic Model*

Two oceanic models can be used.

1. A regional numeric model to simulate and forecast the coastal upwelling.

2. A regional numeric model to forecast waves.

The coastal upwelling is associated with a high primary production in fisheries. In these areas there are large concentrations of fish. In Peru the abundance of anchovy is due to this fact. This abundance changes depending on the intensity and duration of upwelling.

For this prognostic, a system of early alert is elaborated with the model of prediction of 12, 24, and 48 hours in advance, based in the theory of propagation of the spectra of frequency of waves at Brechtneider or Jonswap; and by regulating and adjusting the constants in the features of this part of the ocean in front of our shores as help to several activities including entertainment, sport security, etc.

The knowledge of the thermal structure upto 500 m of depth and of the currents at different levels will allow us to evaluate the processes of the warming of the subsurface and the future identification of the propagation of internal waves

- *Biological and Fishing Component*

This encompasses all the activities related with the study of the marine species to the environmental conditions near the coastline of Peru. For this , the distribution of the different marine species of the Peruvian sea must be analyzed.

- *Biological Numeric Model*

The experience obtained by IMARPE for events of previous years has demonstrated that during these events we captured more marine species.

These biological sensors can be used as tracers or indicators of the physical behavior of the sea, but an investigation program is needed to realize these features.

What is expected in this proposal is modeling numerically the relationship between the migrations of marine species and the physical condition of the ocean

This model will allow simulation of behavior of different species as a response of the changes in the physical variables of the ocean.

- *Biological and Fishing Research*

The task of this conception is reinforced by the measurement of the biological variables, the determination of the seasonable patterns, and the analysis of the changes of them in function with variable non-biotic conditions.

The quantitative features of some variables will contribute to the development of models of prediction; the emphasis of the investigation will be focused on determining the quality of biological variables as early indicators of the event.

Researche on knowledge at different scales of the vital cycle of a limited group of organisms whose antecedents show that they are good indicators of El Nino will be developed

Some areas have been selected because of their strategic location and or for the series of data that exist about them. These areas will allow studies about movement of biological communities and their association with oceanographic variables

Other Effects of El Nino Phenomenon in Different Sectors of the Peruvian Economy

In Peru, the effects of El Nino affect all our territory. The northern part of the country suffers the most severe damage: in the south droughts are a problem; in the highlands between 100 and 2,800 m of altitude above sea level, mudslides or floods increase; and the Pacific river flows rise.

When the El Nino phenomenon appears, it causes the modification of the coastal river streams, and produces important damage in urban and agricultural areas located near the ocean shores

Furthermore, it produces the erosion of the riverbeds in slope areas, affecting in this way the stability of the river banks as well as roads. It also accumulates solid materials (such as gravel, sand, and sediments) by taking them to the areas of gentle slope and by depositing them in valleys and in agricultural areas along the coast.

During this century, before 1997, the El Nino phenomenon has appeared in several episodes in Peru. The strongest events were the ones of 1925 and 1983.

In 1925, the departments of the northern part of Peru suffered from the effects of the El Nino. Even though, there aren't many graphics records from this period, it is known, thanks to others sources, that it seriously affected the agriculture in the area.

In 1982-83 the El Nino event appeared and strongly affected the population and the productive infrastructure; and also the economical activities of the north of Peru. As a consequence of this, there was a lack of products in Lima as well as in the affected areas, because there was no road movement due to the interruption of the road system. It is estimated that the damage produced by this phenomenon generated a direct loss of US$ 1.2 million: US$ 0.4 million of which, the highest percentage, were to the transport infrastructure, US$ 0.33 million were to the major and minor irrigation infrastructure, US$ 0.2 million were to the educational infrastructure, US$ 80 thousand impacted energy, US$ 64 thousand caused sanitation damage, and US$ 59 thousand affected health care, among others.