Introduction to El Niño Phenomena:

A Peruvian Perspective†

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The recent interest in El Niño Phenomenon stems from: 1) our better understanding of the physical processes involved, which in turn has made possible its early prediction, 2) the realization that it affects the climate at a global scale, and 3) its unusual recent intense episodes and their higher frequency of occurrence. The behavior of El Niño during the 1997-98 cycle was successfully predicted with six or more months in advance. From an equatorial eastern-Pacific point of view, more specifically from the long tradition and historical records available in Piura, Peru (~5°S, 79°W), the 1997-98 and the 1982-83 El Niño have been the strongest recorded in the last 470 years, i.e., since the Spanish foundation of the city.

Piura is the oldest post-Hispanic city in the whole South American continent and the most sensitive to El Niño related climatic variations. While the phenomena have only recently caught the attention of the world, its existence was well known by the local population. In fact, the name, El Niño (Christ Child), was coined by the fishermen of the area, with the believe that the warm waters associated with the phenomena came with the northern current which appeared around Christmas time. The author was born and brought up in Piura. This may explain why an upper-atmospheric physicist has been invited to give a talk on the subject.

Climatologists have come to realize that, after the well-known seasonal variations, the most important "predictable" climatic variations are the inter-annual ones related to El Niño. Its statistical signature can be observed far beyond the coastal areas around the equatorial Pacific and includes the effects on the climate of the Australian and whole American continent, the Asian monsoons and the frequency and intensity of hurricanes in the Caribbean, to mention a few.

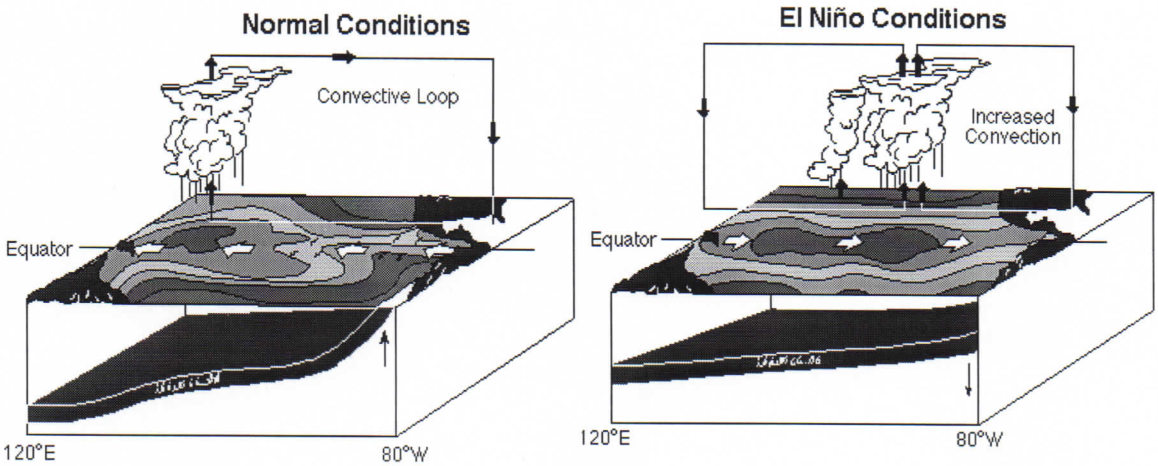

Figure 1. Schematic diagram of SST's during Normal and El Niño conditions

Tropospheric and oceanographic phenomena have not been included as a research topic of Equatorial Aeronomy nor of ISEA in particular. But, considering El Niño's current importance, both from a geophysical as well as political point of view, and because of its equatorial nature, the ISEA Organizing Committee has considered appropriate to include an introduction in this symposium. In fact, I hope we will discuss in this opportunity the formal inclusion of this subject in future International Equatorial Symposia. I doubt there is already a better forum than ISEA to gather atmospheric scientists from equatorial countries, especially developing countries. And El Niño is indeed an equatorial phenomenon. With no further justification, we should certainly start looking, as a research topic, for statistical signatures in the upper atmosphere that correlate with El Niño.

In this talk I will make a short introduction to El Niño- Southern Oscillation (ENSO) as a global phenomenon and present more specific and regional features of the phenomena, namely its principal manifestations along coastal Peru.

Figure 1 shows a schematic diagram of Sea Surface Temperature (SST) in the Pacific Ocean under two conditions: during El Niño or ENSO's Warm-phase, and during Normal conditions, which does not deviate much from the Cold-phase, now known as La Niña. The normal situation can be easily accepted on physical grounds. The warmest SST's are in the equatorial region where the solar radiation is a maximum and where there is a convergence of the solar heated superficial waters. The surface winds play an important role in the SST distribution and they in turn are affected by this distribution in a coupled atmospheric-oceanic process. Warmer SST temperatures produce atmospheric convective instabilities and, thus, heavy rains. The associated water vapor condensation process deposit the solar energy in the atmosphere above the warmest sea surface, producing an atmospheric upwelling which is accompanied by a convergence of surface airs coming from north and south of the equator. The Coriolis forces produce the large circulation cells in the north and south Pacific, with prevailing easterly winds in the equatorial belt. The convergent component of the winds produce convergence of warm waters, as mentioned before, and the easterly component sweep the warm waters from the eastern equatorial Pacific to the western Pacific where they accumulate. This explains the strong gradient in temperature along the equator increasing toward the west. Accompanying the warmer western SST there is a deepening of the thermocline (the surface that separates the warmer superficial waters from the cooler deep oceanic ones). One can say that there is a deep pool of warm waters in the western equatorial Pacific produced and maintained by the easterly equatorial winds. Above this warm pool we have the strongest vertical convection of the whole globe. It is also the region of highest precipitation and it is maintained there by the positive feedback mechanism just described.

The above situation is not completely stable. There are fluctuations as in all weather processes. If the eastern winds weaken there is a shift of the location of highest SST and precipitation. The shift is dynamic with some inertia. The deep warm waters try to reach its static equilibrium level and propagate in

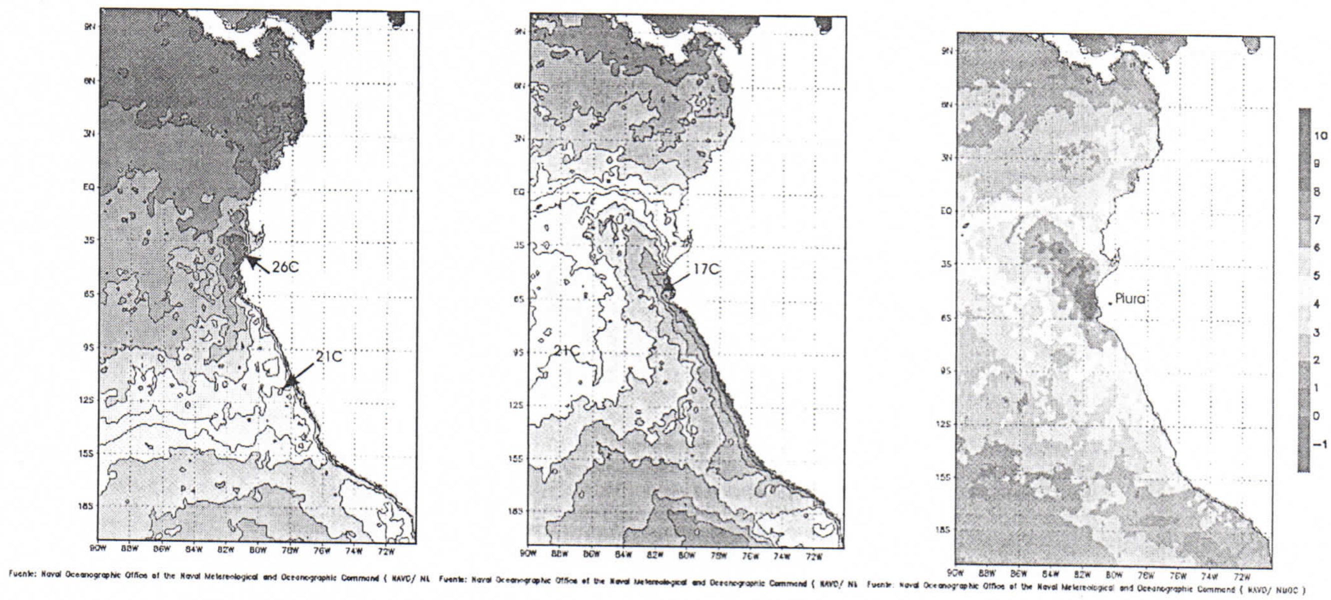

Figure2. a) SST's for the last week of November of 1997, b) the same for 1998, c) difference between the two previous conditions: El Niño minus La Niña

a (Kelvin) wave fashion towards the east, shifting the center of precipitation towards the east. The easterly wind weakens. When this disturbance is sufficiently strong the center of precipitation moves to the central Pacific, the warm waters reach by inertia the east coast, new precipitation cells form in the east and the easterly winds can even reverse in direction with a further positive feedback effect. A situation as the one depicted in Figure 1b develops, and we say we have El Niño conditions. The whole event takes about a year. When it comes to normality it usually overshoots into an extreme cold condition.

The large shift in the center of precipitation is an important energetic disturbance of the atmosphere as a whole and its effects propagate much beyond the equatorial Pacific region. These disturbances are responsible for the change in the climate in regions far away from the direct and more local influence of the SST of the equatorial Pacific. One of the large atmospheric manifestations of this disturbance was studied independently and was known as the Southern Oscillations (SO) and it is characterized by few-year-scale deviations in the difference of the atmospheric pressure at Darwin and Tahiti. Now we know that this oscillation is a manifestation of the same global phenomena, and when we want to stress the global oceanic and atmospheric effects of El Niño (EN), we refer to it as ENSO.

As mentioned before, one of the most —if not the most— sensitive regions in the whole world to El Niño is the northern coast of Peru southern coast of Ecuador, including the desert region around Piura, in particular. Figure 2a) shows the SST in front of Peru during the last week of November for the El Niño conditions of 1997 (temperatures became higher later, in the austral summer months) and the La Niña conditions of 1998 (panel b). The third panel shows the differences between these two states. I doubt there is any other region in the world where the temperature for the same time of the year can vary as much as shown in the depicted region. It shows differences of more than 9°C. More local thermometer measurements in the port of Paita, in front of the difference maximum, register differences as high as 12-13°C.

The effects of the variations in SST in front of the northern coast of Peru are dramatic. This region goes from being one of the driest desert regions of the world to precipitation regimes that are comparable with the wettest tropics. The average rainfall around Piura is 50mm a year, including normal El Niño events that occur every 5-7 years. During El Niño of 1982-83 it recorded close to 3000mm in the rainy season. In three months it rained more than the accumulated amount of 25 years. Never in its 470 years of written history had occurred rains as heavy and with such a long lasting duration. But in less than 15 years another equally devastating El Niño occurred: the 1997-98 event.

During normal years the coastal Peruvian SST are cold, 15 to 22°C, depending on latitude and season. These cold temperatures are a consequence of the upwelling of cold deep oceanic waters in front of the coast. The upwelling is a consequence of the prevailing winds which blow parallel to the coast from south to north. The wind stress is therefore also parallel to the wind direction, but the Coriolis force produce a surface current response with an offshore component. The divergence produced by these component forces the deep and cooler waters to replace the surface waters that have moved offshore. As a consequence, the airs that cover the coast are cooled by their contact with these cool oceanic waters. They are humid and heavy. Aloft, we find warmer, drier and lighter airs that have not had any contact with the ocean. The contact between these two masses of air is almost discontinuous, producing a strong stabilizing temperature inversion with a temperature increase that can be as high as 15°C. This inversion prevents the convection necessary for rain to occur. As a consequence it does not rain and the Peruvian coast is a desert. On the other hand, the same (mineral rich) ocean upwelling responsible for this condition is the cause of the large fish population in front of the Peruvian shores, one of the riches fishing grounds in the world.

During El Niño conditions, warm equatorial waters from the west invade the Peruvian coast. In the northern coast they can reach 28-29°C with a thermocline as deep as 200 meters. Upwelling continues but the deep waters are warm as well (and nutrient poor). The atmospheric inversion layer disappears and the climatic conditions of this region do not differ much from normal maritime tropical conditions. Precipitation occurs at the same level of any tropical island. The mineral rich cold waters do not make it to the sunlight exposed surface, photosynthesis is poor, and the whole fish food chain collapses.

The dependence of precipitation on SST in front of the coast can be put in quantitative terms. Figure 3a shows the monthly average discharge of the Piura River. The Piura river basin includes the desert area around the city and the low western mountainous slopes of the Andes. In Figure 3b we show the accumulated monthly precipitation in the city of Piura. Both figures show the last eighteen years for which accurate SST satellite measurements are available. In the same figures we have plotted the result of a multivariable regression fits to the variation of SST in a selected number of points about 50 to 100km from the coast. The month of the year has also been included as an input variable. The agreement is impressive.

It is so good that suggests the use of the Piura river discharge or the precipitation over the city as a proxy index for the El Niño intensity, with the advantage that there are instrumental records for the last 75 years, and qualitative and semi-quantitative ones for the last 470 years.

Considering the success in predicting SST's in the equatorial Pacific several months in advance, the close correlation between this variable and precipitation opens the possibility of predicting the climate in the northern Peruvian coast with the same anticipation, a very difficult task in any other part of the world. Unfortunately, the important chain of oceanic and meteorological instruments displayed by the TOGA program stops at the Galapagos Is. and the fine structure of the upwelling is too fine for the coarse resolution of the current numerical predictive models. Thus, the performance of the models is not as good in this part of the Pacific as they are in the 120-170°W longitudes. Scientific Peruvian institutions, the Instituto Geofísico del Perú included, are embarked in a project to correct these deficiencies and develop regional numerical models that would improve upon the global predictions of El Niño related SST deviations.

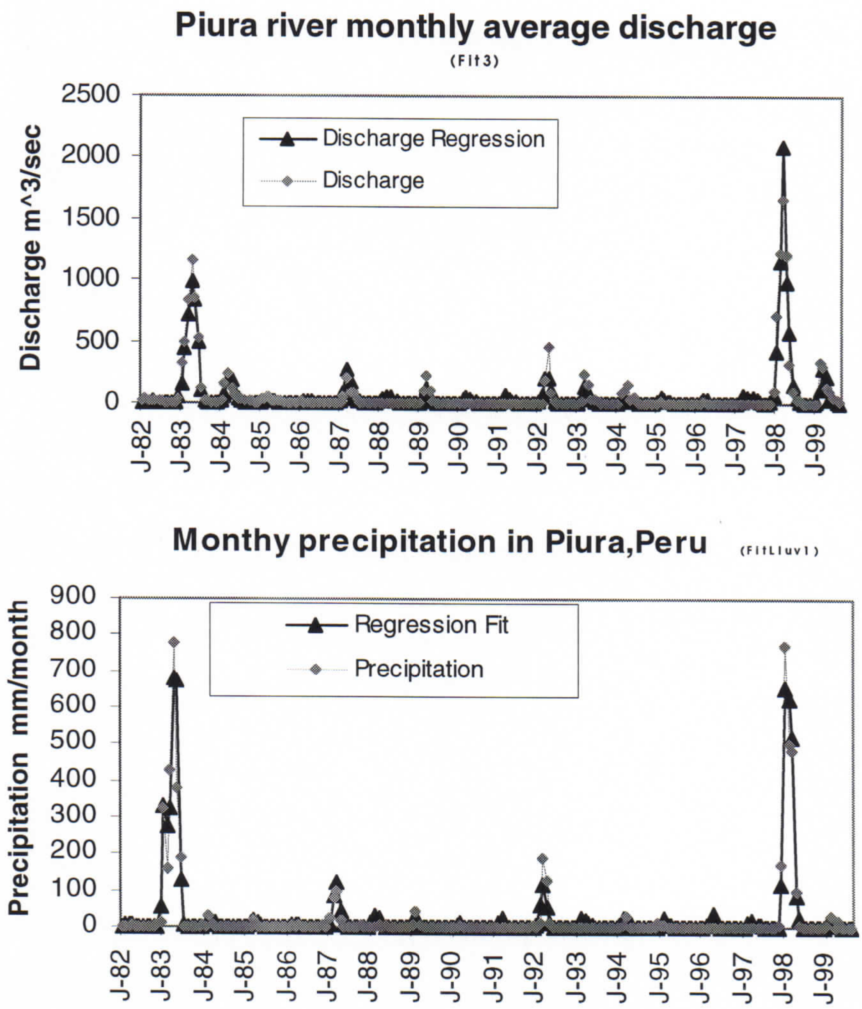

Figure 3a and b. As indicated

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