the center passed. This change in atmospheric pressure was not noted nor mentioned by any of the occupants of the apartment. All, however, complained of the heat, especially during the earlier hours of the storm.

After the storm I found a live grouper, weighing perhaps 60 pounds, in a puddle three blocks back from the ocean. I also saw several fish, principally grouper, half buried in the sand that covered the Ocean Drive. I counted the following day above 300 dead fish on the beach in a distance of a quarter of a mile. Nearly all were bottom fish—groupers, snapper, sailor's choice, grunts, progies, sheepshead, toadfish, etc. Of the surface swimmers I saw perhaps a dozen mullet, but the halfbeaks (or ballyhoo), the needlefish, etc., were entirely absent.

The great majority of these fish had evidently washed ashore after the main storm had passed, as they lay down at the edge of the water where a small surf had left them. The heavy seas I saw breaking during the storm center had gone far higher.

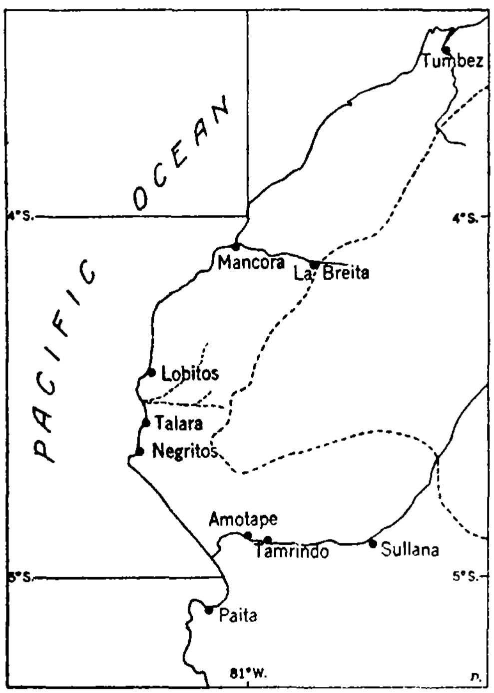
METEOROLOGICAL OBSERVATIONS AT NEGRITOS, PERU, DECEMBER, 1924, TO MAY, 1925

By E. WILLARD BERRY

[Dated Negritos, Peru, June 15, 1926]

The desert of northwestern Peru, better known locally as the Desert de Tumbez, is the center of the oil fields of Peru. In this northwestern region are located the fields of the International Petroleum Co. (Ltd.) of Canada, the Lobitas Co., and the Zorritos Co. Very little has been written of its climate, and of late years, its floods.

The Northwestern Desert of Peru is an area extending from Rio Tumbez on the north to Rio Chira on the south, in all about 140 miles long, and from the sea on the west to about the crest of the coastal mountain ranges on the east, roughly 50 miles wide. This desert under normal



conditions is one of the driest in the world. There is, during normal years no measurable rainfall. Along the coast a little mist collects on roofs and drips off, but this is all. Yet rains actually do occur here. The proximate reason for their occurrence seems to be the weakening or shifting of the Humboldt or Peruvian Current. The west coast of South America is washed by this cold current and by more or less upwelling of deep water along the coast due to the earth's rotation. The Humboldt Current runs northward at such a rate as to be appreciable in coastwise shipping. It flows along the coast as far north as the region of Cabo Blanco, where it is met by the warm Ecuadorian Current and turned westward to form the Pacific South Equatorial Current. The first of these, being cold, maintains a relatively low temperature in the air over it, so that when this air blows toward the land our temperatures are several degrees lower than they would otherwise be. The capacity of this air for water vapor is not high. Hence, even though the water vapor in it may be nearly or quite at the saturation point when the winds arrive over the hot land, they are soon raised to a temperature far above that of saturation, so they absorb quickly any moisture available on the land, causing desert conditions.

Now when, for any reason, the northward flow of this cold Humboldt Current is interrupted or pushed further from the coast the warm Ecuadorian Current usurps its path and invades the coastal waters from the north. This usurping current is called El Niño, the Little One. It raises our land temperatures and also allows the winds to carry more moisture. When the winds thus enriched strike the land they are chilled, especially by the sudden radiation from the land after sunset, and the saturation point being lowered, rain occurs. This is what appears to have happened in 1925 and 1926.[1] There are references to other floods in 1856 and later in 1891.

Speed of El Niño.—On March 6, 1926, when the sea temperature at 12 o'clock was 90°, I noticed at about noon several large masses of drift in the sea. Such masses are uncommon, hence very noticeable. The night before had been rainy and the bridge at Quebrado Parinias, which is at least 15 miles to the north, had washed away. Of the 15 miles, 6 are in the quebrado and the other 8 are in open sea. The bridge went sometime during the night of March 5 and the drift beached about 1 p. m. on March 6. It had taken not more than 15 hours to make the 15 miles. A mass of drift that I timed made 4,000 feet in 50 minutes, or about 4,800 feet an hour. I believe this estimate to be nearly correct, as the material would travel faster in the quebrada than in the open sea. This is only one example of the way the currents went south this year. I have also picked up mangrove seeds on the beach. As far as I can ascertain there are none growing to the south and the nearest to

[1] It seems not likely that chilling of the warm, wet wind by contact with a radiation-cooled land surface could be more than a very minor cause of the precipitation described. The only air to be largely affected by such cooling is the thin surface stratum through which the very slow process of conduction could work, the stratum being only a very few feet thick even under the most favorable conditions of great calm. Turbulent mixing of this thin skin of cooled air with air not so cooled, above, would promptly reduce the effectiveness of the cooled air as a rainmaker. One must look for action on a far grander scale than this as the cause of the downpour described by the author.

Only violent convection can cause violent rain. There must have been present in the situation discussed at least two causes of violent convection: (1) The forced rising of warm and heavily moisture-laden air against the highland barrier; (2) the recognized tendency at sea, especially in warm latitudes, to the occurrence of nocturnal showers even in the absence of an obstructing land. These showers are the result of strong convection induced by nocturnal cooling aloft so greatly in excess of the restrained cooling at the sea surface that the resulting superadiatic lapse rate causes convectional overturning. Now, nocturnal showers over this coastal land were one of the characteristics of the rains described later in the present paper. The moisture for them may well have been brought inland from the sea, either as showers already *in process (in which case they would be strongly augmented by forced rising against the highland)* or as a vast supply not yet released by convection over the sea, but only awaiting the very effective trigger action of the forced rising to let loose the fierce cloudbursts described.—*B. M. V.*

the north are at Puerto Pizarro at the mouth of the Tumbez River.

I have found a few drift seeds similar to those called snuff or box beans and valued as charms by the women of the Shetland Islands, north of England. How far these may have come I have no means of telling, as I do not know the extent of their habitat, but I am sure they came from the north and not the south.

The coastal region.—This coast when seen from a steamer is sand, backed by steep hills cut by deep narrow valleys, all ending in a series of flat plains or tablazos, which are really Pleistocene wave-cut terraces. The entire landscape normally is a dull, lifeless, sandy brown. Here and there in the bottoms of the quebradas are green bits, where grow a few algarroba trees (*Prosopis*) and some grass and vines. The tablazos are barren, covered with sun-split pebbles. Few if any of the valleys or quebradas reach the sea. Sand dunes close them off and any water they have is lost in the sand.

Along the coast the cliffs rise suddenly from sand-covered flats. In the southern part of the region these flats form great salt fields or salinas, absolutely barren and usually show white with salt left by the evaporated sea water. However, from Point Pariñas northward there is an ever-increasing cliff dissected by narrow, deep valleys or quebradas. On top of the tablazos these valleys can not be seen until one has almost reached their edge. Then they remind one of the Grand Canyon of the Colorado on a small scale, or some of the Bad Lands of Montana. The land plant life near the shore on these tablazos is nil under normal conditions. Further inland there are a few stunted trees, and in the northern part of the desert one finds cacti.

On the eastern edge of the desert near the mountains more vegetation is found. Orchids, cacti, and air plants, which look like misplaced pineapple tops, flourish, and there are several varieties of small trees growing in the foothills. One, a sort of poisonous sumac, is quite common in the northern part of the desert.

When the rains come the quebrados flow water. There are often floods where sand dunes left by the winds dam up the water until it gains sufficient force and the sand is broken through. Where this occurs everything is washed away—roads, bridges, wells, and houses are either completely demolished or badly damaged. The waters subside, leaving a muddy waste which after a few weeks of sunshine and growth blossoms into a new beauty. Everywhere plants spring up, not new or uncommon species, but millions more of the same kinds whose seeds have been accumulating since the last rains. Even the desolate and wind-swept tablazo turns green. Grasses grow 2 and 3 feet high. A sort of wild alfalfa, reeds, and many legumes predominate. The tablazo, once a barren plain, is clothed in verdure. Cattle are imported and wax fat on this luscious new diet. The burros, in the past hardly more than skin and bone, fatten until they almost overreach the limits of their crude crossed-stick pack saddles. Even the goats look as if their skins were too small. In the quebrado bottoms after the flood large crops are planted; cotton and table vegetables do well; areas near the streams are irrigated. On old dead trees, wild gourds and a wild prickly cucumber grow rank.

But let six months pass. The grasses are brown, dry, and sere. The cattle are killed and eaten, or driven to better pastures in the mountains. The burros are again thin and gaunt. The goats are climbing at the trees for bark. The irrigated crops have been harvested. The wild vines are dry and rustle as the breeze plays through their dead stems. Pools linger in the bottoms until the water, becoming more and more brackish, is finally so salt that a crust forms over it, and it, too, soon dries up.

The few people living here who are not under the control of the oil companies live either in small houses built of odd-shaped, gnarled bits of wood packed between uprights or in reinforced mud huts. Needless to say, they are not weatherproof. The roofs are built for shade rather than to turn water. Near the watercourses cane is grown and used for building.

These native houses were glutted by the rains. At Sullana, on the Chira River, the native market, built of adobe, had one side dissolved out and is still being repaired. In Amotape, a small town near the river, there were whole streets where the adobe houses had dissolved and the roofs caved in, presenting a spectacle of sad desolation. The small settlements in the river bottoms were literally destroyed. Pools forming in every slight depression became the breeding place of hordes of mosquitoes, and malaria became common. Natives died rapidly, weakened by exposure and discouraged by the destruction of their houses, gardens, and livestock. Food became scarce, gardens were washed out, and transportation was almost at a standstill. Normally, burros pack foodstuffs and the companies have rail and auto roads. All the roads became practically impassable. Burros could not go in 3 feet of mud; neither could autos. Railroads were not only undermined but covered with mud. Drinking water was polluted by cemeteries washing into the sources. Much property found its way to the sea.

Rains of 1925–26.—Negritos, where the following observations were made, is located about a mile northeast of Point Pariñas, the westernmost point of South America. As explained, the region is normally desert. Last year (1925), however, there were heavy rains which did considerable damage, a repetition of the rains of 1891. No record was kept here of rainfall and allied meteorological conditions except a record of land and sea temperatures taken at noonday by Mr. Frank Kroeger, of the Geological Department of the International Petroleum Co. This was published by Robert Cushman Murphy in the *Geographical Review* of January, 1926.[1] These records now cover a period of about three years.

In order to learn more, I augmented our observations with humidity and barometric readings. I also had a rain gauge made and placed in a good position. Table 1 will give some insight into meteorological conditions here from about the middle of December, 1925, to May 31, 1926.[2]

[1] See also by the same author: "Recent oceanic phenomena along the coast of South America." MO. WEA. REV. 53: 116–17.—ED.

[2] For convenience the daily readings have been combined in monthly averages, and these averages appear in Table 1. At the bottom of that table the differences between air and ocean temperatures are given. The monthly averages are based on from 24 to 27 observations per month. The greatest period of missing observations did not exceed four days.—ED.

TABLE 1.—*Summary of meteorological observations made at Negritos, Peru, December 18, 1925–May 31, 1926*

[Pressure and temperature at noon; humidity at 11 a. m.; precipitation measured in a home-made gage and given in inches and hundredths. E. Willard Berry, observer. As a rule observations were made on 20 to 25 days in each month]

	December	January	February	March	April	May
	PRESSURE (INCHES AND HUNDREDTHS)					
Mean	29.48	29.49	29.47	29.48	29.48	29.50
Maximum	29.55	29.55	29.53	29.55	29.56	29.57
Minimum	29.40	29.35	29.40	29.38	29.38	29.45
	AIR TEMPERATURE					
Mean	78.7	82.9	87.1	87.8	89.7	84.4
Maximum	90.0	91.0	92.0	92.0	96.0	91.0
Minimum	81.0	83.0	74.0	84.0	86.0	79.0
	WATER TEMPERATURE (SURFACE OF OCEAN)					
Mean	74.2	75.5	78.0	81.8	75.0	69.3
Maximum	76.0	80.0	81.0	85.0	83.0	71.0
Minimum	72.0	73.5	75.0	74.0	72.0	67.0
	RELATIVE HUMIDITY (PER CENT)					
Mean	68	60	71	73	59	61
Maximum	85	83	96	96	85	82
Minimum	57	38	60	55	49	56
	PRECIPITATION (INCHES AND HUNDREDTHS)					
Total	0.00	0.21	2.12	7.80	0.35	0.01
Number of days	0.00	4	10	14	4	1
	TEMPERATURE DIFFERENCE, AIR MINUS WATER					
Mean	+4.5	+7.4	+9.1	+6.0	+14.7	+15.1
Maximum	+14.0	+11.0	+11.0	+7.0	+13.0	+20.0
Minimum	+9.0	+9.5	−1.0	+10.0	+14.0	+12.0

1. *Barometric pressure.*—These readings were taken on a compensated surveying aneroid made by the Topley Company, Ottawa, Canada. On testing this barometer by means of the boiling point of water I find that it is 0.38 inch higher than the pressure at which water would boil at a given temperature. However, for most uses I believe it to be as nearly correct as any. All the readings were made at 12 o'clock noon, the barometer being fixed in the shade on my house wall. The elevation above mean sea level is about 50 feet.

[The following comments are a condensed summary of Mr. Berry's remarks upon Table 1.—*Editor.*]

The barometer readings are not corrected for elevation or difference of barometer reading and boiling point of water.

Humidity.—The readings were made beside the Geological Offices of the International Petroleum Co. at Negritos. I took them on wet and dry bulb thermometers which were in both draft and shade. They were made at 11 a. m., and the daily values were taken from Fox-Burough tables.

Air temperature.—Observations of air temperature were made at 12 o'clock noon, beside the wet bulb thermometer at the geological office. Mr. Kroeger began recording these readings about 3 years ago. I am indebted to him for both the air and water temperatures. The latter were taken off the end of the small steel mole extending about 50 feet beyond the mean tide mark. A heavy crock is heaved over and allowed to chill and fill with water. It is then pulled up and the temperature of the water read on a chemical thermometer.

Water temperatures.—The table shows a rise from December through March and a decided drop in April and a still lower temperature in May. However, during April the relation of land and sea temperature is not at all like their relation during the first two months of the year. For some reason the land temperatures were much higher than the sea temperatures; that is, they did not decline together.

Rain.—Last year during the "floods," so called hereabouts, no good record of rainfall was taken. Mr. Blogett, a driller, living at La Brea, about 12 miles to the east, told me that an empty metal barrel had 37 inches of water in it after the rains. How much evaporated no one can say.

I am told by several people that a locomotive, mired 5 or 6 miles south of here, had a common galvanized pail about 10 inches deep, 9 inches in diameter at the bottom, and 12 inches in diameter at the top, placed upright in the stack. The next day the pail was found overflowing with rain water.

This year the rains were not so heavy, judging from the damage done to roads, houses, and the like. Starting on the night of January 18 and raining now and then until the night of May 24 a total of 10.446 inches of rain fell. The greater part of this fell in March.

March had the highest humidity, the highest sea temperature, and the most rain.

The following observations extend over this period of rains.

The rains seem to have been of a very local character. On February 6 I drove to Catalinas, in Quebrado Mancora, about 35 miles to the north. Leaving there about 12:30 p. m. I started back to Negritos and had gone only a little way, about a mile, when I ran into a shower. We were apparently running with the storm, but after several miles we changed our direction. The road ran over steep hills and they were wet and slippery, so our progress was necessarily slow. In spite of this in 5 miles we were ahead of the shower and in open sunlight.

Heavy showers were often to be seen further inland in the Amotape Mountains. These showers seldom come far from the foothills. During Easter (April 1–4) I was camping in the foothills of the mountains. On April 2 at 7 o'clock it was a sapphire night. In about 10 minutes a fog was about us and shortly afterwards it began to rain extremely hard and continued to do so for an hour. To the best of my knowledge it rained over an inch during this shower. A straight-sided cook pot was left in the open contained an inch of water the next morning, so, allowing for evaporation, which is rapid, fully an inch must have fallen. I inquired next day at a place a mile distant and was told no rain had fallen there.

On the night following I came out to the coast and camped on Point Arena about 4 miles north of Negritos. That night also started out clear, so clear in fact that I did not put up a tent. However, at 12:30 a. m. we were awakened by a downpour which lasted about 25 minutes, the rest of the night interrupted by showers of a second or two. On returning to Negritos the next afternoon (April 4) I was told there was one very slight shower during the night. For the days of April 1, 2, and 3 my rain gage registered a total of only 0.15 inch of rain. This indicates how local the rainfall was.

One night in Negritos it rained about a half an inch in about five minutes. The same night a culverted railroad embankment about 3 miles inland was completely washed out and much other damage was done.

Some of the rains were accompanied by lightning, but so far as I know no damage was done by that agency.

Quite often before rains I noticed clouds over the sea. These clouds were not the fairly common cloud banks which one can observe off many coasts. They were low lying, though not touching the horizon—flat bottomed and almost stationary, very like the common flat-bottomed clouds of the trade-wind areas.

Prevailing winds here are from the south. A north wind was frequently the forerunner of rain, although this was not always the case.

When I arrived here last November small briny pools were still to be found inland. This year there are some, but I very much doubt whether they will be left five months from now.

Parinas, a dry stream under normal conditions, has been flowing now since the rains in 1925. Mr. Oscar Haught tells me, however, that it does not seem to be flowing as much water as it did this time last year.

Last year the country hereabouts blossomed forth with large numbers of plants. In December, 1925, the desert was bare and brown, but after the rains started grass and many legumes came up and grew both fast and rank. One of the legumes has a yellow flower and a long seed pod with almost cylindrical seeds. It often grows so high that you can not see over it from the seat of a Ford car.

These same rains also made pools on the Tablazo which attracted many wild ducks, affording our hunters much sport. The pools also bred mosquitoes, which are absent here under normal circumstances.

Discussion.—The almost complete absence of meteorological observations from Peru, save only from Lima, makes it difficult to visualize the meteorological changes that were associated with the extraordinary rains of February–April, 1925. The southward extension of the El Niño current in that year, seems to have taken place as early as the middle of January or a few days later. In 1926 the water temperatures as measured at the end of the steel pier at Negritos, Peru, first reached a height of 80° on January 27; the temperature then sank slightly below that figure and remained below about two weeks, again reaching 80° on February 11 and continuing close to that figure until the end of the month.

March opened with ocean water temperature at 82° and fell to 79° on but a single day until the 20th. A water temperature on the 21st is missing but on the 22d a temperature of 74° was registered—a drop of 9° from the 20th; on the 23d it had returned to 79° and continued about that figure until the end of the month.

On April 9 it registered 83° for a single day and then sank to 78° on the 10th.

These figures seem to indicate that the retreat of the warmer water proceeds irregularly and that fragmentary incursions of warm water may be experienced some days after the cessation of the warm current.

The meteorological statistics with the exception of the land and sea temperatures throw no light upon the cause of the extraordinary rains over the normally desert areas of northwestern coastal Peru.

The outstanding features of these statistics are the high ocean temperatures of March and the heavy rains of that month and the cessation of the rains so soon as the ocean temperature fell to approximately normal values in April and May. The high ocean temperature would increase the air temperature locally both by conduction and convection, and the contact of these local masses of warm air with the adjacent Peruvian highlands would doubtless cause the rains as observed. The drift of overlying ocean air landward must occur with some regularity, especially during the night hours, and there must have been a countercurrent seaward during the daytime hours; wherefore it is inferred that the disturbed air conditions were local rather than general and due to the unusual extension of El Niño current to the southward.—*A. J. H.*

In connection with Mr. Berry's paper and the above discussion, the following reprint from the Bulletin of the National Research Council, Volume II, part 2, No. 56, November, 1926, is of interest:

INVESTIGATIONS OF THE AMERICAN MUSEUM OF NATURAL HISTORY IN THE HUMBOLDT CURRENT REGION

From December, 1924, until March, 1925, the writer, accompanied by Mr. Van Campen Heilner, conducted marine zoological investigations for the American Museum on the coasts of Peru and Ecuador. A report on the oceanographic phases has since been published (Oceanic and Climatic Phenomena along the West Coast of South American during 1925, Geographical Review, vol. 16, pp. 26–54, 1926). This paper is supplemented, moreover, by another of more popular nature (Equatorial Vignettes, Natural History, vol. 25, pp. 431–449, 1925).

The problem on the arid west coast of South America is highly complex. In their incipience, the factors which produce the periodical changes are doubtless purely meteorological, while the end stages, because of the peculiar topography of the western watershed of the Andes, involve profound geographic effects. The intervening phenomena in the grand sequence are, however, distinctly oceanographic. The notably stable physical characteristics of the littoral ocean of this coast, and the consequently undue disturbances which occur during the rare cycles in which such characteristics are altered, are alike unequaled elsewhere. In no other part of the world does a simple reversal in direction of the coastwise oceanic circulation lead to such spectacular climatic, biological, and economic results.

The writer worked entirely from launches and other small craft, and his equipment was limited to surface apparatus. His data, therefore, do not lead to an understanding of the extent in breadth or depth of the warm countercurrent which for many weeks during the winter and spring of 1925 replaced the Humboldt Current, at least at the surface, bringing about the cessation of cool upwelling and preparing the way for perhaps unprecedented rainfall along the desert coast. Even as regards simple surface temperatures, all the tables thus far obtained from the pertinent section of the Pacific, record conditions only along coastwise tracks, within a few miles of shore. The data urgently needed are routine observations made at right angles to the trend of the coast, and extending for a thousand miles or more along any parallel between the equator and latitude 30° S. Such data, especially if accompanied by subsurface records, might reveal whether the counter-current known as El Niño was in the nature of a restricted coastal tongue or whether the phenomenon represented a surface movement of colossal extent in the wake of retreating high-pressure areas. A search for figures which may throw light upon this question is now being made, with the aid of Doctor Littlehales, of the U. S. Hydrographic