Meteorology

Anomalous El Niño of 1982–83

from S.G.H. Philander

An El Niño event, during which anomalously warm surface waters cover the central and eastern tropical Pacific Ocean, occurred between May 1982 and June 1983. The event was exceptionally intense and was associated with several natural disasters which received extensive coverage in the press. Ecuador and northern Peru had catastrophic floods because of unusually heavy rainfall. (Guayaquil had nearly 3 m of precipitation above normal between October 1982 and June 1983.) The neighbouring regions to the north and south, however, experienced severe droughts. Several hurricanes devastated islands in the central tropical Pacific, a region where such phenomena are extremely rare. Marine life practically disappeared from the upper ocean in the central and eastern equatorial Pacific[1]. This, together with the flooding of bird nests, caused a decimation of the bird population on Christmas Island[2]. Discussions of the meteorological and oceanographic aspects of this El Niño attracted considerable attention at a recent meeting* and can be summarized as follows.

The 1982–83 event evolved in an unusual manner. During a typical event[4] exceptionally warm surface waters first appear off Ecuador and northern Peru in February and March and then expand westwards over the next several months. In 1982, however, the warm water in the western Pacific gradually spread eastwards into the normally cold eastern Pacific (R. Reynolds, NOAA, Washington DC)[3]. Not until September did sea-surface temperatures in the eastern tropical Pacific increase sharply to values as much as 6°C above normal. These conditions persisted through June 1983, whereas a typical event would have ended in March or April.

Rainfall estimates derived from satellite measurements by O. Garcia (NOAA, Boulder)[3] indicate that the eastward expansion of the unusually warm surface waters was accompanied by an eastward displacement of the atmospheric convective region which is normally near Indonesia. This contributed to the drought in the far western Pacific and the late monsoons over the Indian Ocean. During a typical El Niño the convective region moves to the neighbourhood of the dateline, but during the past year it moved much further east, into the central and eastern Pacific so that the Southern Oscillation Index, the pressure difference between Darwin and Easter Islands, fell to record low values. A. Krueger (NOAA, Washington DC)[3] described how, because of the convergence of the surface air into the convective region, the trade winds were replaced by westerly winds over a region which at first was confined to the west but which expanded eastwards concurrently with the eastward movement of the convective zone and high sea-surface temperatures. This convergence caused an intensification of the trade winds over the Atlantic Ocean and probably contributed to the drought in northeastern Brazil.

The convection not only modified the zonal circulation in the tropics, but intensified the meridional atmospheric circulation (the Hadley Cell). The rising air in the equatorial convective region of heavy rainfall descended between latitudes 10° and 25°N and 25°S so that southern Peru and Bolivia south of the Equator, and central America north of the Equator, experienced severe droughts. The unusual convective activity near the Equator, in addition to intensifying the Hadley Cell, excited disturbances that radiated polewards into the extratropics. This affected the atmospheric variability in higher latitudes so that El Niño can be implicated in the unusual weather over large parts of the United States earlier this year (J. Horel, Scripps Institute of Oceanography)[3].

The increase in sea-surface temperatures in the central and eastern tropical Pacific Ocean was caused by an enormous flux of heat from the warm western tropical Pacific to the normally cool eastern tropical Pacific (A. Leetmaa, NOAA, Miami; D. Halpern, NOAA, Seattle)[3]. The depth of the thermocline and the sea level decreased west of the dateline but increased in the central and eastern Pacific. (Off South America the thermocline deepened by as much as 70 m and sea level rose by as much as 40 cm)[5]. Anomalous currents advected the heat eastwards[5]. Hansen's[5] measurements with drifting buoys reveal that, within 5° latitude of the Equator, the normally westward surface flow was predominantly eastwards. (Halpern's[3,5] measurements by means of current meters on a mooring at 110°W on the Equator show that the westward surface flow there reversed direction in August 1982.)

The zonal redistribution of heat in the equatorial Pacific caused the eastward pressure force associated with the zonal density gradients to weaken and even to vanish for a while[6]. As a result the eastward equatorial undercurrent, which is driven by this pressure force, disappeared temporarily[3,5,6]. This is the first time that measurements have failed to reveal the presence of this normally intense jet in the equatorial Pacific.

Interactions between the ocean and atmosphere are of central importance in El Niño events. The ocean responds primarily to the surface winds. Normally the easterly trade winds drive westward surface currents at the Equator, expose cold water to the surface in the eastern Pacific and accumulate warm water in the west. When the trade winds relax during El Niño anomalous eastward surface currents redistribute the heat zonally. The warming of the eastern tropical Pacific can therefore be attributed to the weakening of the trade winds. But the relaxation of the trade winds, in turn, is a consequence of the exceptionally high sea-surface temperatures in the east because the surface winds converge into that region where the atmosphere is heated. The symmetry of these arguments implies that unstable interactions between the ocean and atmosphere are possible and can cause the amplification of modest initial anomalies simultaneously in the ocean and atmosphere[4]. The instability is readily initiated in equatorial regions where sea-surface temperature gradients are large — off the coast of South America for example — but on infrequent occasions, such as 1982, can also be initiated in the western tropical Pacific where such gradients are small. A crucial feature of this theory is that anomalously warm surface waters must cause a local heating of the atmosphere. This requires that there be rising air over the anomaly. The large-scale atmospheric circulation, and the seasonal movements of its convergence zones, therefore modulate the instability. Initial amplification of a modest anomaly depends on favourable large-scale conditions, but once perturbations have attained a sufficiently large amplitude they can significantly alter the large-scale flow and can induce conditions favourable for their persistence. Hence the persistence of the 1982–83 event could be a consequence of its intensity.

The explosion of El Chichon deposited a large amount of volcanic dust in the upper stratosphere. There is no reason to believe that this directly affected motion in the lower troposphere or that it influenced the evolution of El Niño.

In summary, El Niño of 1982–83 was unusual in several respects: it first appeared in the western tropical Pacific and expanded eastwards; it attained an exceptionally large amplitude; and it persisted longer than the more common events. El Niño of 1982–83 is the best documented one yet. Further analysis of the data will permit a critical examination of the proposed explanations for these events. □

*A meeting of the American Geophysical Union was held in Baltimore on 1 June 1983.

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