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ABSTRACT

A different view of El Niño is proposed, namely, that it represents an approach towards the tropical equilibrium temperature of approximately 30°C, set essentially by evaporation, by the waters of the eastern tropical Pacific.

1. Introduction

The warmest surface water in the open ocean (30°C) occurs year-round in the western tropical Pacific. The temperature limit near 30°C is quite sharp as may be seen by inspection of histograms of monthly mean sea surface temperatures (Newell, Navato and Hsiung, 1978); both annual and interannual variations in that region are small (Newell, Selkirk, and Ebisuzaki, 1982). At this limiting temperature, there is a near balance between the incoming solar radiation and the sum of the net infrared radiative energy loss to the atmosphere and the evaporative energy loss, with the evaporative loss rising steeply with increasing temperature owing to the rise in saturation vapor pressure as expressed by the Clausius-Clapeyron relationship (see Priestley, 1966, for a discussion of the limit for a well-watered terrain; Edinger et al., 1968, for an application to lake surfaces; and Newell et al., 1978, and Hoffert et al., 1983, for an application to the ocean). The energy required to change this equilibrium is substantial—close to 30 W m⁻²°C⁻¹ according to Newell and Dopplick (1979), this quantity being relatively independent of wind speed in the range 3–6 m s⁻¹ typical of the region. There is some paleoclimatic evidence that a similar limit prevailed in the past (e.g., see Matthews and Poore, 1980) and this has been invoked to provide support for the evaporational limit (Newell and Dopplick, 1981).

Conditions in the eastern equatorial Pacific are quite different, with the lower temperatures there being maintained by a balance between horizontal advection, upwelling and surface flux (Wyrtki, 1981; Newell et al., 1982) except for the region north of the equator and off Panama which resembles the western Pacific. Reduction of the cooling factors, upwelling, or advection from the east, leads to warmer conditions as meridional advection of warmer water and local surface heating occurs.

The purpose of the present note is to extend the hypothesis of the equilibrium temperature to the El Niño phenomenon: it is argued that the El Niño is simply an approach towards the equilibrium temperature of approximately 30°C by the waters in the eastern tropical Pacific, as the cooling processes there are reduced in intensity.

2. Temperatures in the Eastern Pacific

Analyses of sea surface temperatures (SST) for the 1982–83 El Niño, made by Forrest Miller of Scripps Institution of Oceanography from ship reports, are reproduced in Fig. 1. Climatological mean maps of SST show a warm pool of water close to 30°C off the western coast of Central America at 10°–15°N in summer (Newell, 1979) and this expands westwards in the summer of 1982, while other warm areas appear at 10°N and 10°S in the Central Pacific. It is proposed that in all of these regions of close to 30°C water the conditions for the evaporative limit are met, namely, that incident solar energy is offset by infrared and evaporative losses.

What is it that reduces the normal cooling terms in the eastern Pacific, namely, upwelling and advection of colder water from the south and east, and permits this approach to equilibrium? First, there are purely atmospheric changes. For example, in the region 140°–170°W where normal conditions are strong easterlies on the equator, westerly 850 mb wind anomalies appeared in August 1982, reaching 8 m s⁻¹ by February 1983 and reducing to zero in June of 1983 (Arkin et al., 1983). Similar changes at the surface would, of course, diminish upwelling and advection of cold water from the east. The weaker winds also reduce the evaporational loss, thus tending to increase the equilibrium temperature. Second, there are changes within the ocean. Wyrtki (1975) suggested that Kelvin waves contribute to the warming in the eastern Pacific and this view has been cogently argued and the dynamical aspects modeled by Busalacchi and O'Brien (1981) and Busalacchi (1983) and has been applied in particular to some of the coastal changes in a recent review by Cane (1983). These waves appear to act by depressing
the thermocline so that any upwelled water is warmer than before. The wind changes that produce the waves are thought to occur in the central and west Pacific and the waves are propagated towards the east in the water so that one does not have to associate temperature changes with local wind changes. One major problem is that these considerations do not explain temperatures of 30°C at 10°N and 10°S as previously noted. However, as the cooling effect of that upwelling is normally spread away from the equator by the Ekman drift (Wyrski, 1981) and this is reduced because of weaker easterlies, then the Kelvin influence may indirectly reach to 10°N and 10°S.

Gill and Rasmussen (1983) suggest advection of the warm pool eastwards. They ask, Why did the warm pool migrate—a question that already assumes that the pool did migrate—and answer that eastward migration of the warm pool occurred because of anomalous advection from the west Pacific with the anomalous currents again being related to Kelvin waves. Gill and Rasmussen use 29°C to define the warm pool; their analysis source is different from that used here. They quote Kelvin wave speeds of about 60° per month along the equator but their warm pool migration speed is only about 10° per month. It is clear from Fig. 1 that the 30°C water in the east is not continuous with that in the west as would have to be the case if advection were the process. Simply joining the 30°C patches in

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**Fig. 1.** Maps of sea surface temperature from ship reports for the eastern Pacific, manual analysis by Forrest Miller of the Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography.
successive months suffices to convince one that the resultant advective velocities would constitute an impossible set.

One can make a better case for advection from the 28°C isotherms as these do extend eastward between September 1982 and March 1983. But this apparent advection could be due to a decrease in the cooling factors of upwelling and cold water advection from the east. It is worth noting that the net heat gain through the surface of the ocean is greater in the eastern equatorial Pacific than in the west: for example, Weare et al. (1981) report annual mean values of 60 W m\(^{-2}\) at 140°E and 120 W m\(^{-2}\) at 100°W. There is by no means universal agreement on these numbers and Hsiung (private communication, 1985) finds areal changes for the tropical west and east Pacific of 17 and 43 W m\(^{-2}\). It is, therefore, hard to claim that the energy necessary to heat the eastern Pacific enters the water through the surface in the western Pacific and is then carried eastwards. Wyrtki (1981) has analyzed the heat budget of the eastern equatorial Pacific and shows that the surface gain is offset by cold water advection and upwelling in the normal case. For the oceanic sector between 5°N and 5°S and from 100°W to 170°E, Wyrtki finds a surface energy gain of 85 W m\(^{-2}\), cold advection from the east representing an energy loss of 38 W m\(^{-2}\) and upwelling representing a loss of 84 W m\(^{-2}\). The heat capacity of this section down to 50 meters is 2.2 \times 10^8
and if the advection and upwelling were both stopped the surface energy gain would yield a heating rate of approximately 1.0°C per month. Smaller rates would occur if the upwelling were not stopped but originated from shallower depths. As temperatures approach 30°C the surface energy gain would gradually reduce to zero if the equilibrium concept is correct. Hence the apparent advection of the 28°C isotherm could equally well be explained by a continuation of surface heating with a diminution of upwelling and cold advection.

The situation in 1972 was similar as may be seen from inspection of maps from the Southwest Fisheries (NOAA 1971–73). The west Pacific warm pool of 30°C water extended to about 160°W and the secondary warm pool off Central America was more extensive than usual but only once did a patch of 30°C water appear in the region in between (in October 1972 at 10°N, 135°W). Again an interpretation in terms of an approach to equilibrium by reduction of the cooling factors seems more able to account for the observations than advection by itself.

3. Surface flux estimates and temperature anomalies

There have been three recent attempts to relate anomalies in local heating at the ocean surface to sea surface temperature anomalies; Leetmaa (1983) and Reed (1983) studied the 1972 El Niño and Weare (1983) studied the period 1956–76. Leetmaa found that
local heating rates were higher than average in the early stages of the 1972 El Niño, while Reed found no relationship between changes in heat content and departures from average of net surface flux. Weare, for the longer period that includes four El Niño events, finds greater than average surface heating in the early stages in the eastern Pacific. From the present perspective it is the absolute rather than the relative surface heating that is important. It should reduce towards zero in the warm pools.

From the present viewpoint, a maximum sea surface temperature anomaly exists given by the difference between the climatological mean temperature and 30°C and maps of these maxima have been presented by Newell and Hsiung (1984). The 1982–83 anomalies were quite close to these maxima.

4. Concluding comments

It has been suggested that the 30°C water in the eastern Pacific in the 1982–83 El Niño results from a relaxation of conditions that normally prevent this region from achieving this tropical equilibrium temperature. This is quite different from the hypothesis that the warm pool of the west Pacific migrates eastward. It is not basically different from the idea that Kelvin waves are the predominant factor involved, for if they act to cause a reduction of upwelling then this, in turn, permits local heating towards the equilibrium temperature. Ship reports when available may be evaluated to see if the energy balance at the surface is sufficient to heat the water to 30°C, when temperature advection and upwelling are reduced, rather than moving warm water bodily from elsewhere as is implied by the migration hypothesis.

The fact that the recent El Niño in the eastern Pacific produced temperatures limited to about 30°C like those of the western Pacific at a variety of locations, with different cloudiness and wind conditions, gives observational evidence in favor of the idea of a natural limit.

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REFERENCES


