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Chavez, Francisco P.

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Editorial

El Niño along the west coast of North America

"No hay dos Niño iguales (Romulo Jordan, circa 1970)"

1. Introduction

The fisherman of northern Peru coined the name El Niño in the late nineteenth century for a warm southward current that appeared every year around Christmas (the Christ child – El Niño). Years of unusually high rainfall in northern Peru were associated with an intensification of the annual current. It was not until the 1960s that Bjerknes (1966) linked warming of the coastal ocean off Peru (and the equatorial Pacific) with larger scale climatic phenomena. It was then that a relatively small and inoffensive coastal current (Chavez, 1986) was associated with dramatic global weather disturbances. Over the last 30 years the influence of El Niño on oceanic and atmospheric conditions throughout the globe has been well documented (Rasmusson and Wallace, 1983; Philander, 1990). More recently, in the 1980s, Peruvian scientists coined the name La Niña for anomalously cool temperatures along Peru. This phenomenon also has significant climatic impacts.

Even though El Niño has been extensively studied it remains an enigma. We are not yet able to accurately predict the timing and intensity of the phenomena. Once started, the developmental sequence of events in the equatorial Pacific and along the coast of Peru is relatively well understood. Westerly wind bursts initiate Kelvin waves that propagate along the equator, raising sea level and deepening the thermocline. The deep thermocline then influences a variety of physical, chemical and biological processes. Along the South American coast the importance of thermocline displacements associated with equatorial Kelvin waves has been well documented. At higher latitudes of the eastern Pacific, and off the western coast of North America in particular, the developmental sequence has not been as clear. In some cases, oceanic warming and anomalies associated with El Niño have been ascribed by some authors primarily to local meteorological anomalies caused by atmospheric teleconnections (e.g. Simpson (1984) while other authors ascribed them primarily to propagation through the oceanic wave-guide.

During late 1997 and early 1998 the coastal ocean off the west coast of North America was anomalously warm. The anomalous warming was accompanied by dramatic ecological changes, including reductions in primary and secondary production, and redistribution and disappearance of species from their typical habitat. These perturbations were associated with one of the strongest episodes of El Niño ever recorded. Serendipitously there were a number of programs making oceanographic measurements from Baja California to Canada during this period. On December 6–9, 1999 scientists involved in these programs (Figure 1) met at the Monterey Bay Aquarium Research Institute to share their experiences. The papers in this volume are the result of this workshop.

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Fig. 1. Photograph of the workshop participants.

2. Papers in the volume

The in situ observations during 1997–98 are shown in Figure 2 relative to the 1950 California Cooperative Oceanic Fisheries Investigations (CalCOFI) grid. The volume is organized geographically beginning from

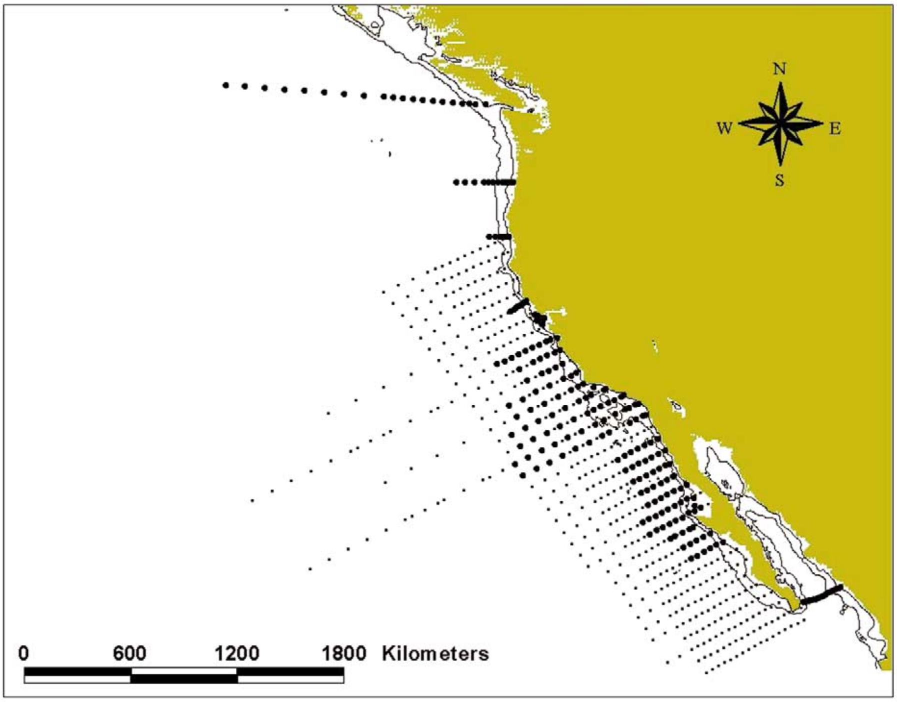

Fig. 2. Map showing the locations of in situ measurements collected during 1997–98 (large filled circles) relative to the basic CalCOFI pattern established in 1950 (small circles).

Baja California and moving northward towards Canada. The Baja papers stem from the Investigaciones Mexicanas de la Corriente de California (IMECOCAL) program, a re-establishment of some of the early southern CalCOFI lines (Figure 2). Durazo and Baumgartner describe the infusion of warm and salty waters into the Baja region associated with an expansion in the volume of California Undercurrent and Subtropical Surface Waters. Lavaniegos et al. report that chlorophyll and zooplankton were not unusual off Baja during 1997–98. The high zooplankton biomass during El Niño was associated with salps.

Lynn and Bograd describe the perturbations in the region currently sampled by CalCOFI from the US-Mexico border to Point Conception. They document a dramatic increase in poleward flow that they ascribe primarily to propagating disturbances from the tropics. Dever and Winant use moored observations from Santa Barbara to Point Conception to describe perturbations to the temperature and flow fields. These were qualitatively similar to those described by Lynn and Bograd. Shipe et al. describe the relationship between surface characteristics and material collected in sediment traps. Lower surface nutrient and chlorophyll during El Niño did not translate into lower fluxes, rather these increased possibly due to the lateral advection of increased riverine input. The central California observations anchored in Monterey Bay are the most comprehensive. Collins et al. describe the physical anomalies and suggest the importance of poleward propagating disturbances as the primary mechanism for the El Niño warming; they also note the anomalous inshore position of the California Current during early 1998. Ryan and Noble focused on the coastal sea level along central California. They suggest that sea level had a strong signature from remotely generated waves even though there were also influences from alongshore wind stress anomalies. Castro et al. document the dramatic reduction in nutrient supply driven primarily by a deepening of the nutricline. Friederich et al. show that sea surface pCO2 is dramatically reduced during El Niño and also document the impact of increased El Niño runoff on pCO2 levels. Wilkerson et al. focus on changes in hydrographic conditions during the 1997–99 winters in the Gulf of the Farallones. The relative contribution of San Francisco Bay waters to coastal nutrients increased significantly during El Niño as oceanic sources diminished. Chavez et al., describe the biological response of primary producers to physical forcing and find that the biological and chemical fields were tightly coupled to the physical disturbances. Spatially averaged primary production was reduced four-fold at the height of El Niño even though a narrow productive band was retained along the coast. Kudela and Chavez modeled new production using moored and satellite observations. They predicted significant decreases (increases) during El Niño (La Niña) and show that these are most notable offshore. Hopcroft et al. show that smaller copepods populations were surprisingly stable during and after El Niño with most of the variability occurring within the large-bodied forms. Marinovic et al. describe a strong depression of euphausiid populations during El Niño and the clear influence of the advective disturbances on the relative abundance of krill species. The increased poleward flow 'washed out' the typically dominant species and replaced them with southern species. Benson et al. describe changes in cetacean communities. They suggest that cetacean populations concentrated in the narrow productive region close to shore during El Niño.

The Oregon coast was also well observed. Huyer et al. report on the hydrographic anomalies. They compare observations during 1997–98 to normal conditions and to 1983. They suggest that warm surface waters during mid-1997 were associated primarily with local conditions while subsurface warming was due to wave propagation of El Niño signals; late in the year the warming at all depths could be unambiguously associated with El Niño. El Niño was associated with strongly depressed isotherms close to the coast and increased poleward flow. Kosro reports on coastal sea level and temperature along the U.S. west coast and on alongshore currents off Oregon and northern California. He shows that positive anomalies in coastal sea level in 1997 and 1998 can be traced to the tropics and propagate at reasonable wave speeds. He also shows the enhancement of poleward flow during these same periods. Corwith and Wheeler studied the effects of El Niño on chlorophyll and nutrients. They show that during El Niño there was severe nitrogen limitation relative to normal upwelling seasons and that the enhanced poleward flow brought waters with anomalously low nitrate-to-phosphate ratios to Oregon. Peterson et al. collected hydrographic, nutrient, chlorophyll and zooplankton data during and after El Niño. They describe how the Oregon shelf was occupied with low nutrient waters and warm water copepods during El Niño. Pearcy describes the changes in marine nekton off Oregon during El Niño. Many warm-water, oceanic fishes invaded Oregon during 1997 but fewer species were noted than the 1982–83 El Niño.

Whitney and Welch report on nutrient surveys from British Columbia to Station P in the Gulf of Alaska. They show that compared with normal years nutrients and chlorophyll were significantly lower during El Niño. Mackas and Galbraith focus on zooplankton along the coastal portion of the Station P survey. During El Niño there was both a decrease in biomass and shifts in community composition. The responses were similar to Oregon with increases in mid-California neritic and oceanic species.

Although spiciness has been used frequently to describe water mass properties in the California Current, and is used repeatedly in the physical papers in this volume, Flament's paper is the first formal refereed publication describing this variable in detail, and includes the algorithm to compute its value. Schwing et al. describe the large-scale evolution of ocean temperature and atmospheric pressure anomalies. They suggest that regional atmospheric anomalies were important in generating temperature and sea level anomalies during the 1997-98 El Niño. Strub & James analyze altimeter data along North, Central and South America. They show symmetry in two episodes of high sea level during May-July and October-December 1997 propagating poleward into both hemispheres and asymmetry in the manner they are altered by local topography, local winds and currents. The hydrographic data (including nutrients and chlorophyll) was compiled into an atlas described by Castro et al.

3. Conclusions

El Niños that also strongly impacted the West Coast of North America occurred in 1957–8 and 1982–3. The earlier El Niño occurred during the first decade of the CalCOFI program and was documented at the June 2–4, 1958, symposium on 'The Changing Pacific Ocean in 1957 and 1958' at Rancho Santa Fe, CA (Sette and Isaacs, 1960). Probably as a consequence of our scientific understanding at the time of the 1958 meeting, oceanic changes along the West Coast of North America were not interpreted as interannual changes associated with El Niño but as a beginning of a shift in climate conditions. By 1982–83, the changes in conditions along the West Coast were clearly associated with El Niño and these were summarized in Wooster and Fluharty (1985). Wooster had described the Peruvian El Niño at the 1958 Symposium. Differences between conclusions reached at Rancho Santa Fe, in Wooster and Fluharty (1985) and those contained in this volume are due to in large part to scientific progress and new measurement techniques. But it is wrong to assume that all the differences are only a result of our increased understanding. El Niños are not all the same, as the Peruvians recognized early on (see quotation above). The reader should keep this in mind when going through these papers and when studying future El Niños. The atmospheric and oceanic consequences of El Niño will vary widely depending upon intensity and the state of the climate regime.

The recognition of the importance of an equatorial oceanic connection is notable in many if not most of the papers in this volume. Earlier papers suggested a dominant role for the 'local' climate forcing, primarily related to the changes in the position of the Aleutian low. While the role of the oceanic connection via remotely forced equatorial waves has been established, there is still some debate over the role of local atmospheric forcing. Local effects are confounded by their relationship to large-scale anomaly patterns (teleconnections) that will need longer time series and further study. There was also clear recognition that nutrient supply, through thermocline displacements, was strongly curtailed during El Niño, leading to a sharp decrease in primary production. Concomitantly there was strong evidence of large-scale redistributions of animals either via migrations or advection by anomalous current patterns. These redistributions make it very difficult to evaluate the consequences of the decreases in primary production on secondary and higher production. To achieve a quantitative assessment of bottom up regulation of the lower trophic levels will require large-scale integrated efforts.

The collation of the 1997–98 hydrographic data into an Atlas (Castro et al., this volume) provides an example of spatial integration. It is hoped that the atlas will be useful for modeling efforts as well as comparisons with future El Niño events. It also highlights the relatively sparse (in time and space) and uneven regional distribution of observations. These problems of sparse and uneven data are worse for zooplankton and larger animals. Future observational efforts will require a full regional perspective, will benefit greatly from better coordination and from an observational network that, in addition to shipboard surveys, will necessarily rely heavily on developing technologies.

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Francisco P. Chavez,
Monterey Bay Aquarium Research Institute, Moss Landing, California USA

Curtis A. Collins,
Naval Postgraduate School, Monterey, California USA

Adriana Huyer,
Oregon State University, Corvallis, Oregon USA

David L. Mackas,
Institute for Ocean Sciences, Sidney, British Columbia USA