Variations in the California Current

Upwelling and southward flow in the California Current supply cool and nutrient-rich waters to a highly productive ecosystem that once supported a major sardine fishery. This fishery collapsed mysteriously in the 1940s, leading to the establishment of the California Cooperative Oceanic Fisheries Investigation in 1949. Since then the physical and biological characteristics of the California waters have been monitored. Today more than 50 years of these ocean observations provide a unique opportunity to investigate long-term changes and variations in this eastern boundary current, which displays energetic variations in temperature, salinity, and biology. El Niño, for example, warms the water, depresses the thermocline, and is associated with a decline in zooplankton stock.

Taking advantage of these existing observations, **Niklas Schneider** (IPRC) and his collaborators **Emanuele Di Lorenzo** and **Peter Niiler** at Scripps Institution of Oceanography looked at decadal changes in salinity and temperature along the best observed section, which extends from Long Beach in California to over 600 km offshore. They included data from cruises conducted by the US Coast Guard and Harald Sverdrup in the 1930s, extending the data coverage further back in time.

Salinity measurements, in addition to being of scientific interest as one of the main ocean properties, are a useful way in the California Current to distinguish between fluctuations due to changes in upwelling and fluctuations due to changes in advection from the north. Upwelling brings saltier and cooler water to the surface from the halocline - the layer in the ocean that shows a sharp gradient in salt concentration - whereas transport of water from the north brings fresher and cooler water to the region. Moreover, unlike temperature, salinity variations do not affect the fresh-water flux between the atmosphere and ocean and therefore do not result in a feedback that affects the ocean over longer periods of time. Thus, any imbalance in the ocean's salt budget that is, for example, traceable to changes in advection will lead to a salinity trend and cause the largest salinity variations on time scales of several years to a decade.

The team's analyses of the above data sets show that in the California Current surface temperature varies differently from salinity. Temperature varies mostly in association with the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation and shows a warming since the 1980s, which has already been noted by others. Salinity, in contrast, varies mostly over decades, with variations that are in the order of 0.2 parts per thousand and that are independent of both ENSO and the Pacific Decadal Oscillation. The California Current was fresher during the early 1950s, around 1970, and since the mid-1980s; it was saltier in the late 1950s, the early 1960s, the mid-1970s, and the early 1980s.

In searching for the cause of these differences in variability between salinity and temperature, Schneider and his colleagues distinguished between variations that may result from vertical undulations of the ocean's stratification and variations that are independent of these undulations. They found that in the halocline, salinity varies mostly with vertical undulations, which are highly correlated inshore with ENSO: El Niño conditions in the tropical Pacific usually deepen the halocline, while La Niña conditions occasionally raise the halocline. On the other hand, the prominent salinity variations described above are found mainly in the surface layer and are little affected by variations in the halocline.

A comparison with the along-shore geostrophic current estimated from the observations indicates that the changes in salinity are roughly consistent with changes in the along-shore transport of water from the north. This suggests that an intensified California Current increases the transport of fresher water to the south, displacing the climatological along-shore salinity gradient southward; a weakened current, on the other hand, would have the opposite effect. In the 1990s, however, short salty bursts occurred, yet the current was flowing toward the equator and was fresher overall, indicating a new advective equilibrium with conditions upstream in the North Pacific.

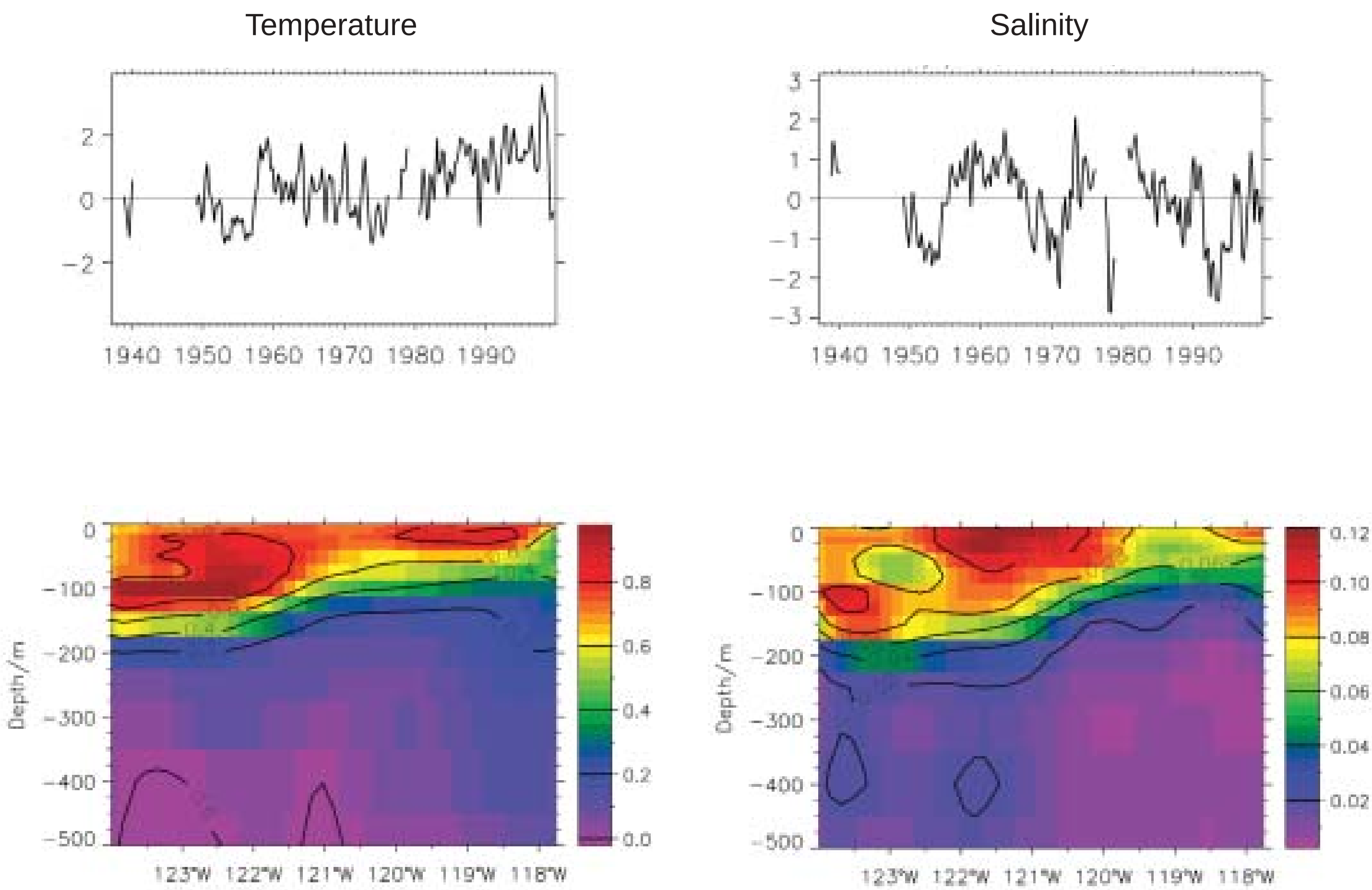

Figure 1. *(Left) Leading EOF (empirical orthogonal function) of temperature at CalCOFI line-90. Top panel shows the principal component as a thick black line over time in years. The bottom panel shows the spatial loading pattern (in °K) as a function of depth (in m) and longitude. Contour interval (color) is 0.02°K. This EOF accounts for 47% of the variance of the seasonally averaged temperature anomalies. (Right) Leading EOF of salinity. Contour interval in the bottom panel is 0.02 psu. The EOF accounts for 38% of the variance in the seasonal salinity anomalies. This salinity signal is independent of the leading EOF and does not correlate with El Niño-Southern Oscillation and Pacific Decadal Oscillation indices. Rather, the salinity anomalies, which are largest in the California Current, are consistent with changes of along-shore advection due to fluctuations in the current. Line-90 extends from Long Beach, California, about 600 km offshore, approximately perpendicular to the coast. The coast is on the right with the southern California Bight located east of 119°W; the California Current flows equatorward west of 119°W.*