Sparse Times in the Gulf of Tehuantepec – Evaluating the Effects of the 2015-2016 El Niño on the Wind-Mixed Productivity in the Eastern Tropical Pacific Ocean

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Subject / Statement of Problem

A unique seasonal pattern of primary productivity occurs off of the Pacific Coast of southern Mexico and Central America every winter. Strong winds that funnel through passes in the cordillera, caused by differences in atmospheric pressure on the eastern and western sides of the range, induce wind mixing in the surface ocean. This wind mixing brings colder water with increased nutrient concentrations to the surface, fostering episodic blooms of phytoplankton.

During a large El Niño event, however, the elevated sea surface temperature (SST) and concomitant increased depth of the thermocline reduce the effectiveness of wind mixing as a nutrient transport mechanism. During the 1997-1998 El Niño, a significant negative anomaly of chlorophyll-*a* concentration, indicative of lower phytoplankton concentration and growth, was observed in the wind-mixing zones by remote sensing. The strong El Niño event occurring in 2015-2016 would be expected to result in a similar pattern of reduced phytoplankton activity (NASA, 2016). With a larger suite of data variables than that employed in prior examinations of the El Niño effects in this region, it is possible to compare conditions between the generally average winter of 2014-2015 and the El Niño winter of 2015-2016.

Background

Satellite remote sensing can indicate the occurrence of a wind event in several ways. Frequently, the leading edge of a wind event is indicated by a thin arc cloud over the Pacific Ocean. Wind-induced mixing of the water column is detected by reduced SST, as colder subsurface waters are brought up to the surface. Because these colder waters also have higher nutrient concentrations than do surface waters, the wind events usually initiate phytoplankton blooms. These blooms are observed by satellite-borne sensors as an increased concentration of phytoplankton chlorophyll.

Objective

Our objective was to evaluate the effects of the 2015-2016 El Niño, by comparing oceanographic and meteorological conditions in December 2015 and January 2016 to conditions in December 2014 and January 2015.

Previous Work

Earlier studies of this oceanic region have documented the regular winter occurrence of the wind jets and the associated increased productivity they induce (Brenes et al., 2003; Chelton et al., 2000; Fiedler, 2000; Steenburgh et al., 1998; Trasviña et al., 1995). Because these events influence the physical and biological oceanography of the eastern Pacific Ocean, they can be simulated in ocean modeling (Liang et al., 2009; Sasai et al., 2007). They have been observed to exert a global influence (Schultz et al., 1998). The biological effects have been observed with ocean color remote sensing (NASA Earth Observatory, 2004), and associated cloud patterns have been seen in visible remotely sensed images (NASA Visible Earth, 2014).

What Was Done

Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite were used to generate SST and chlorophyll concentration images, using the NASA Giovanni analysis and visualization system (Acker and Leptoukh, 2007). Images were created for the large area encompassing the outflow region of three main wind areas (Tehuano, Papagayo, and Panama) by averaging the monthly data products for December 2014-January 2015 and December 2015-January 2016. Time-series plots of chlorophyll-*a* concentration and SST from September 2014 to January 2016 were also created for the Tehuano wind offshore zone, which showed the most striking difference between the two time periods. The geographical coordinates of the area used for the time-series are shown in the title of the following figures.

To evaluate the wind regime, northward and eastward component wind speeds from the Modern Era Retrospective-analysis for Research and Applications (MERRA) were plotted for the same period, and time-series for each component was generated for the Tehuano wind zone. These data were acquired from the reprocessed MERRA-2 data set, also available from Giovanni.

What Was Found

Figure 1 shows a comparison of SST for December 2014-January 2015 (Fig. 1a) and December 2015-January 2016 (Fig. 1b). Elevated SST attributable to El Niño, adjacent to much of the Pacific coast, can be clearly seen in Figure 1b. A clear SST difference in the wind mixing zones between the two periods is also evident, with SST for December 2015-January 2016 about two degrees C higher than that in December 2014-January 2015.

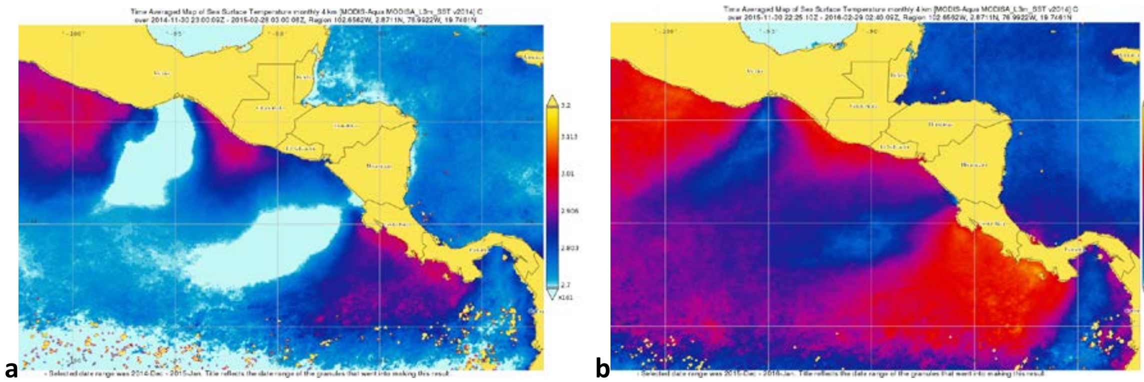


Figure 1. MODIS-Aqua sea surface temperature for (a) December 2014-January 2015 and (b) December 2015-January 2016.

The effects on the biological oceanography of the region are shown in Figure 2. All three wind zones show reduced chlorophyll-*a* concentrations in the El Niño 2015-2016 winter (Fig. 2b) as compared to the 2014-2015"normal" winter (Fig. 2a).

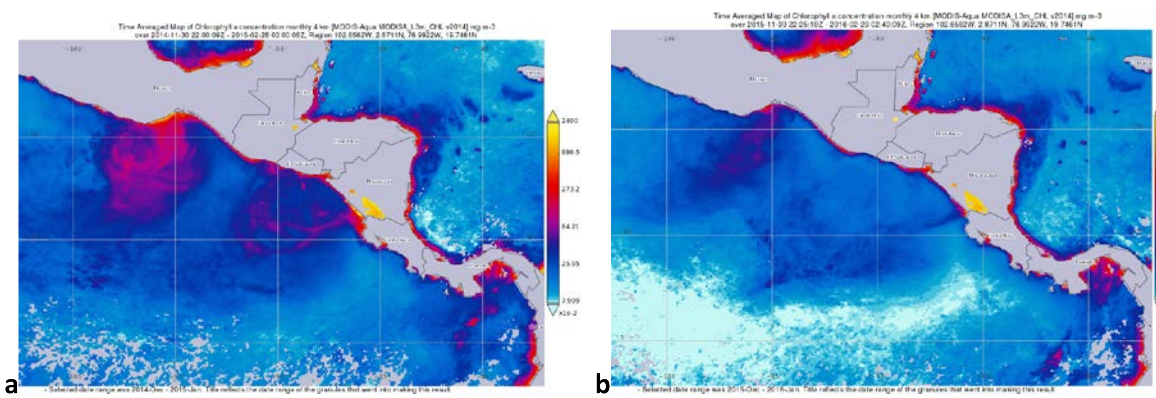


Figure 2. MODIS-Aqua chlorophyll-*a* concentrations for (a) December 2014-January 2015 and (b) December 2015-January 2016.

The wind speed component comparison is shown in Figures 3 and 4. The northward wind component is most significant for the Tehuano wind zone, where the winds blow almost directly south, resulting in <u>negative</u> northward wind component values. The Papagayo winds blow more toward the west, so their eastward wind component is negative. Figures 3 and 4 indicate that the wind regime during the 2014-2015 "normal" winter was slightly stronger than that during the 2015-2016 El Niño winter. Note that, because northward and eastward winds are indicated as negative values, the colors lower in the palette (greens) represent stronger winds.

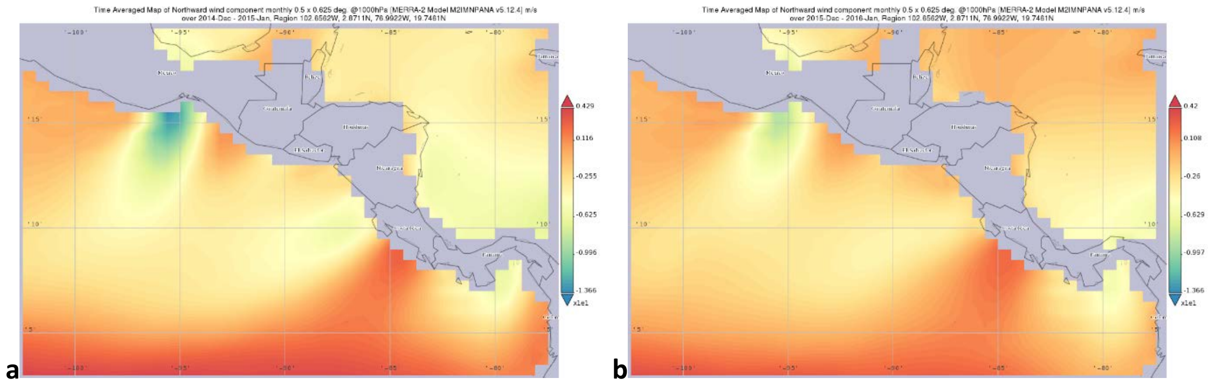


Figure 3. Northward wind component, (a) December 2014-January 2015 and (b) December 2015-January 2016.

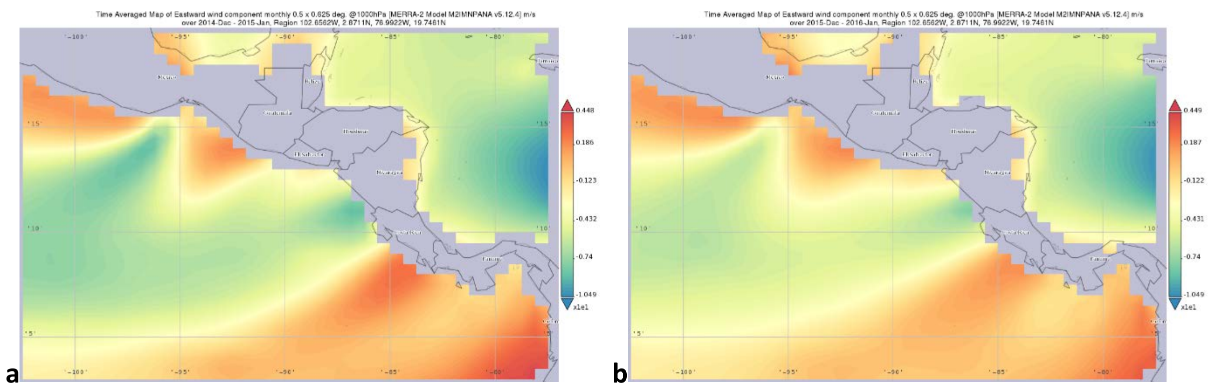
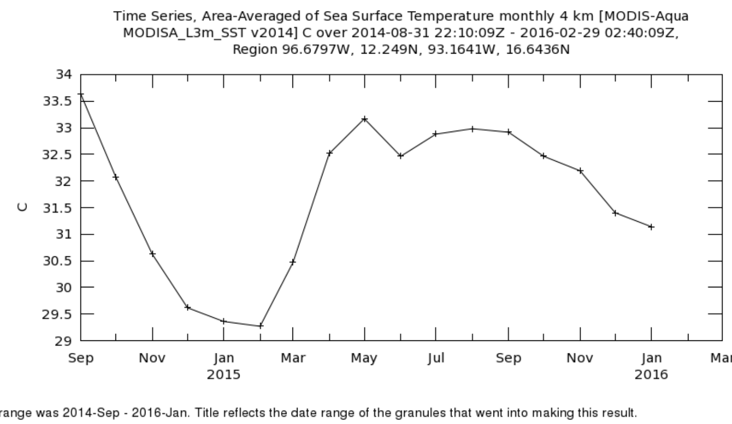


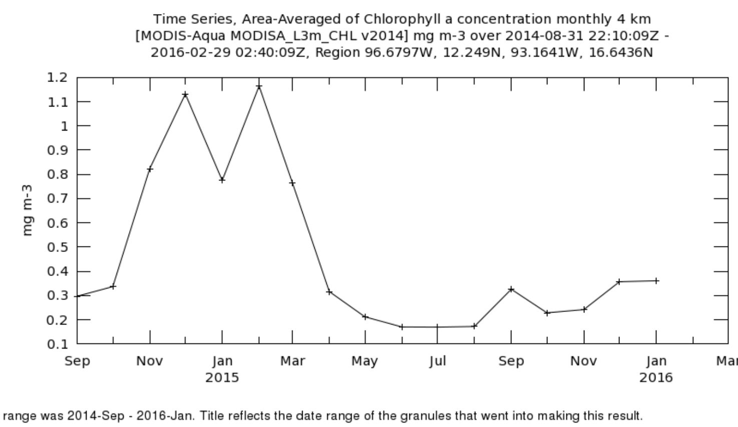
Figure 4. Eastward wind component, (a) December 2014-January 2015 and (b) December 2015-January 2016.

The time-series plots for SST, chlorophyll-*a* concentration, and the northward and eastward wind components, in the Tehuano wind zone region, are shown in Figure 5. The time-series plots all are consistent with the previous figures (1-4), i.e., showing higher SST, reduced chlorophyll-*a* concentrations, and slightly reduced wind components in the El Niño winter (Figs. 5a-d).

The average northward wind speed (Fig. 5c) is less negative (i.e., weaker) in January 2016 than in January 2015 but is approximately equal to the wind speeds in the other winter months. The eastward wind component (Fig. 5d) is also slightly less negative from November 2015 – January 2016 compared to the same period a year earlier. Intriguingly, April 2015 shows a distinct one-month increase in the positive eastward wind speeds, which corresponds roughly to the initiation of definitive El Niño conditions in the Pacific Ocean. During this period, atmospheric parameters began to display responses to the elevated SST that has already been prevalent for several months. It is not certain, however, if this increase in wind speed is related to the onset of El Niño.



a



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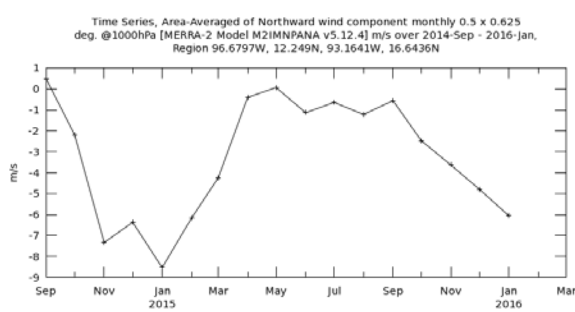

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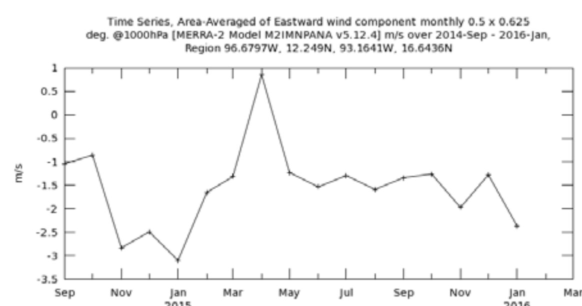

d

Figure 5. Time-series of (a) monthly sea surface temperature, (b) monthly chlorophyll-*a* concentration, (c) monthly northward wind component, and (d) monthly eastward wind component.

Conclusions

A comparison of SST, chlorophyll-*a* concentration, and wind speed data between “normal” winter conditions of 2014-2015 and El Niño winter conditions of 2015-2016, for the wind-mixed zones of the eastern tropical Pacific Ocean (off of the Pacific Coast of Central America and Mexico),confirmed the patterns consistent with the expected influence of El Niño oceanographic conditions. The El Niño water mass with elevated SST in this region reduced the effect on SST of the wind-mixing zones caused by high wind events. Higher SST in the wind-mixed zones during the El Niño winter was attributed to the increased depth of the thermocline. The latter reduced the effectiveness of wind-mixing for bringing subsurface water to the surface. The decreased effectiveness of wind mixing apparently suppressed phytoplankton productivity, due to reduced nutrient availability from subsurface waters. The northward and eastward wind components exhibited only a small decrease in wind speed during the El Niño winter as compared to normal winter conditions. The Tehuano, Papagayo, and Panama wind events continue to take place during an El Niño winter. However, their effect on the physical and biological oceanographic environment of the adjacent Pacific Ocean is significantly reduced, because of the overriding influence of El Niño.

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