Visualization of Divergence and Vorticity of Ocean Currents in Monterey Bay

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Background

The divergence and vorticity (also known as the curl) of currents respectively describe the change in volume and the rotation of currents. In order to better understand the relationship between weather patterns and ocean currents in Monterey Bay, the divergence and vorticity of the currents were calculated and visualized. The data which was used was provided by the University of California Santa Cruz HF Radar lab. It was recorded once every hour from March 1, 2004 through June 30, 2004 at 328 different locations in Monterey Bay. Due to missing data, ocean currents from only 201 locations were used. Figure 1 shows the 328 locations, with the filled circles representing the 201 selected locations. The ocean current data had been run through a 33-hour filter to eliminate the effects of the tides and the sea breezes on the ocean currents.

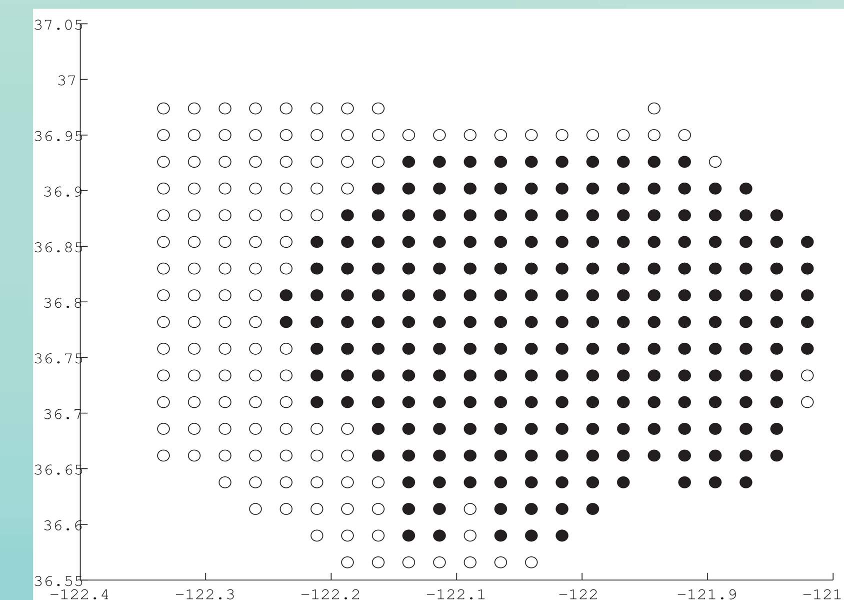

Figure 1

Calculations

The divergence and vorticity of the ocean currents were numerically approximated using equation 1 to calculate the divergence and equation 2 to calculate the vorticity given four locations arranged as in figure 2.

Eq. 1 $$\frac{1}{2}\left(\frac{U(2)-U(1)}{\Delta(x)}+\frac{U(3)-U(4)}{\Delta(x)}\right)+\frac{1}{2}\left(\frac{V(1)-V(3)}{\Delta(y)}+\frac{V(2)-V(4)}{\Delta(y)}\right)$$

Eq. 2 $$\frac{1}{2}\left(\frac{V(2)-V(1)}{\Delta(x)}+\frac{V(3)-V(4)}{\Delta(x)}\right)-\frac{1}{2}\left(\frac{U(1)-U(3)}{\Delta(y)}+\frac{U(2)-U(4)}{\Delta(y)}\right)$$

U(t) is the x (east/west) component of the current at position t in figure 2. V(t) is the y (north/south) component of the current at position t in figure 2. Δ(x) and Δ(y) represent the change in the x and y direction among the points in figure 2. These calculations were done for each set of adjacent locations that formed a square as in figure 2, which created a grid of 172 2x2 squares (see figure 4a). The divergence and vorticity of these squares were then taken in groups of four and an average over the four squares was calculated, creating a grid of 39 3x3 squares (see figure 4b).

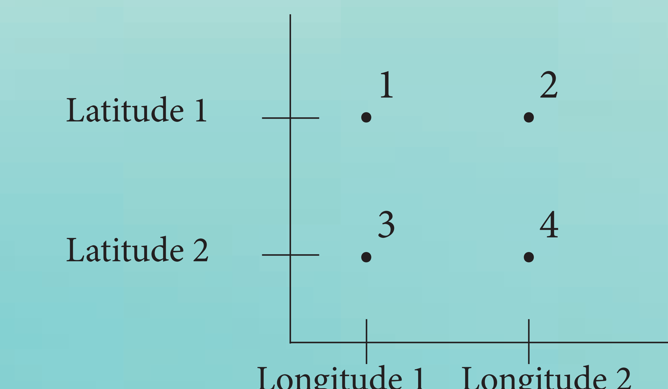

Figure 2

Visualization

All visualization was done using Matlab 6.5. The first visualization of the data was a 3D mesh grid (figure 3), but this proved to be too complicated to be of much use. The next method of visualization was a 2D grid with the color of each square directly proportional to the divergence/vorticity of that square. For both divergence and vorticity, red was mapped to the highest value, blue to the lowest value, and green to 0. Figures 4a and 4b are examples of the 2D color-coded visualization. Despite the fact that the 201 locations were selected based on their lack of missing data, there was still some data missing, but at these times the missing locations were simply ignored instead of all the data at that time being disregarded (figures 5a and 5b). The 2D color-coded grids proved to be relatively easy to interpret, so it was then filtered such that only the highest one-third and lowest one-third of the divergence and vorticity were mapped (figures 6a and 6b). Due to the fact that the ocean current data had been run through a 33-hour filter, the data did not vary much from hour to hour, so only one filtered graph was made for every 6 hours. Using a program called MakeQTMovie by Malcolm Slaney of Interval Research, these graphs were then made into QuickTime movies so that the movement of the high and low divergence and vorticity could be tracked and compared to weather patterns.

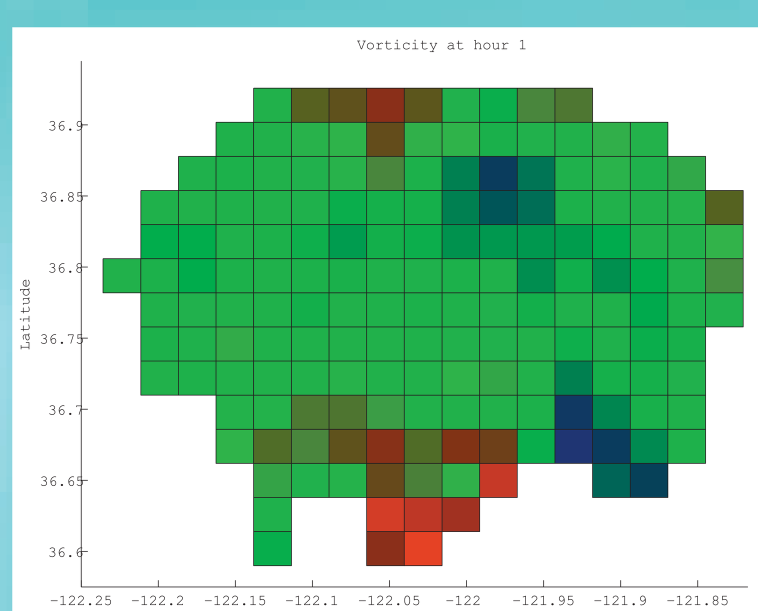

Figure 4a

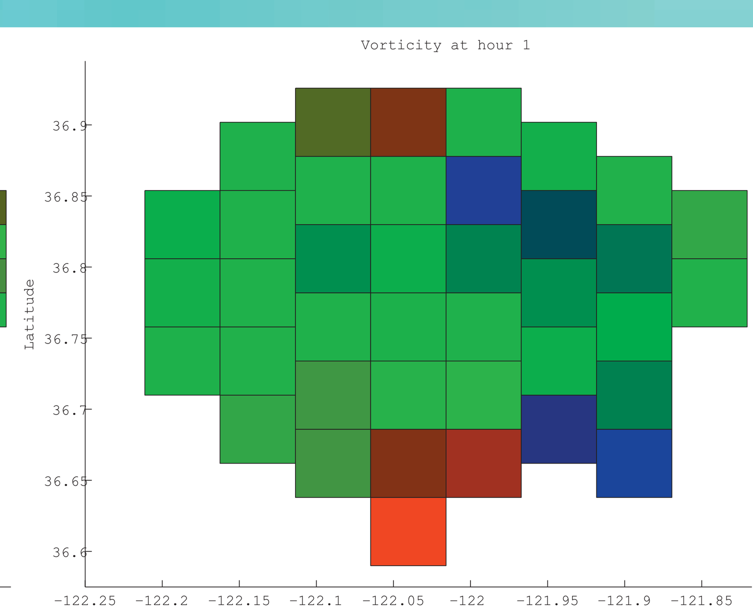

Figure 4b

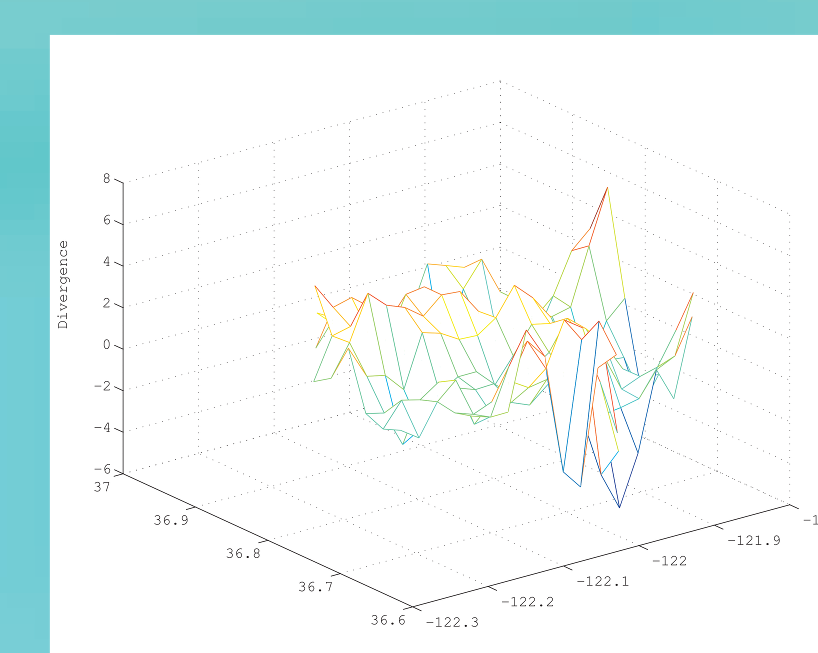

Figure 3

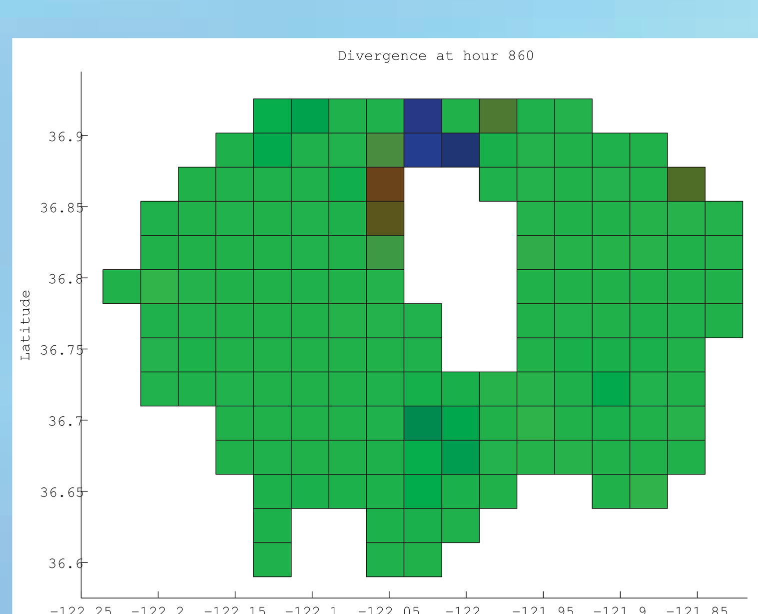

Figure 5a

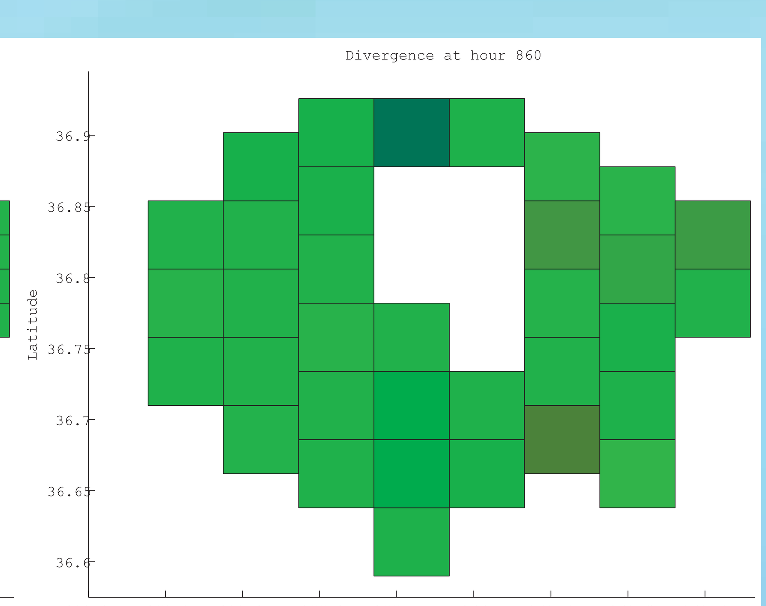

Figure 5b

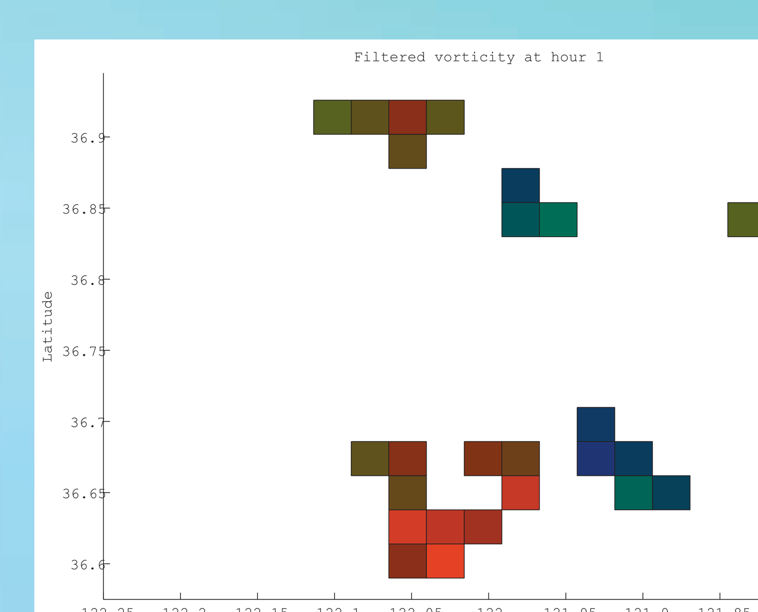

Figure 6a

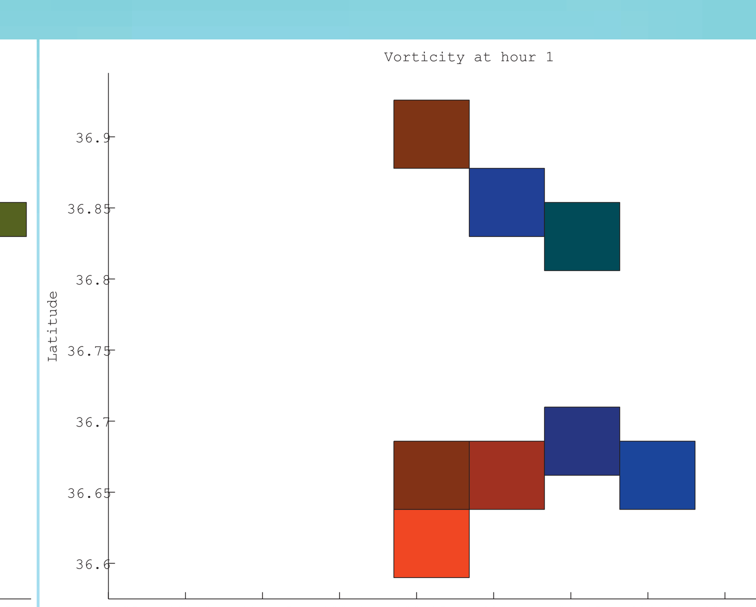

Figure 6b

Sponsored by the NSF