Providing SeaSonde High-Resolution Surface Currents for the America's Cup

Newell Garfield, Max Hubbard and Jim Pettigrew
Romberg Tiburon Center
San Francisco State University
Tiburon, CA USA
garfield@sfsu.edu

***Abstract*— The selection of San Francisco Bay as the venue for the 2013 America's Cup competition provides the opportunity to highlight the technology available for measuring surface currents over the entire proposed racecourse and to deliver current estimates in near real-time. Using an array of CODAR Ocean Sensors SeaSonde 42 MHz systems, the currents in Central San Francisco Bay can be mapped in high spatial resolution with a temporal resolution of 30 minutes.**

Keywords; HF radar, San Francisco Bay Currents, America's Cup;

I. RACE BACKGROUND

The America's Cup competition is designed to test both technology and racing skill. The boats to be used in the competition are built to a "rule" rather than one-design, which allows each competitor flexibility in the final configuration of the boat. Individual ships are tuned for the local wind and wave conditions to maximize the vessel speed. The 2013 competition will display significant changes to one of sport's oldest competitive challenges: the boats will be rule-designed catamarans with semi-rigid wing sails. During 2011 and into 2012 the lead-up races will be held in 45 foot catamarans, and in 2012 and for the final competition the multi-hulls will be 72 feet with a wing sail 130 feet high (Fig. 1). Another dramatic change is the venue. In the past the America's Cup competition has been held in open seas, away from headlands and removed from potential spectators. For this series, the races will be held near shore in bays and estuaries that will allow spectators to observe the speed and performance of these new ships. During 2011 and into 2012, there will be a series of America's Cup World Series races, to be held in different venues, to serve as training for the final competitions. The Louis Vuitton Cup series (July 13 – September 1, 2013) to determine the challenger, and the America's Cup challenge races (September 7 – 22, 2013) will be held in San Francisco Bay (Fig. 2). The final course will not be determined until later in the year; the presently proposed course covers an area of 30 km^2 in a roughly oval pattern. Each race would be multiple circuits of the course.

San Francisco Bay will demand technical skill by the racing teams; the boats will be extremely fast and the racecourse relatively short. In addition, the surface currents, waves and winds will likely be highly variable over the area. The proposed course is roughly an oval shape bounded on the west by the Golden Gate, north by Angel Island, east by Treasure Island, and south by the San Francisco waterfront. Currents

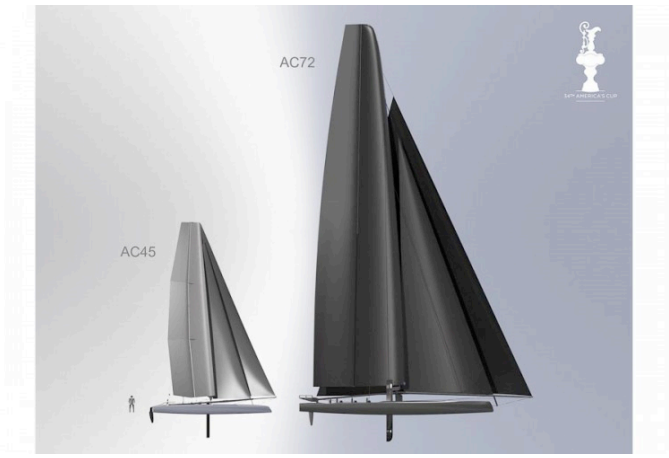

Figure 1. Schematic of the America's Cup 45 and 72 foot catamarans.

near the Golden Gate can reach speeds of nearly 3 m/s (6 knots) while to the east the currents usually don't exceed 1 m/s. Through the tidal cycle strong current fronts migrate across the region, and these are accompanied by changes in the waves. Likewise, the winds in the Bay vary in both space and time. A significant challenge for each boat's navigator will be to maneuver the vessel to obtain maximum benefit of this variation in the waves, winds and currents.

II. RADAR NEWORK

In 2005 California voters approved two water quality bonds; one provision in the bonds was to monitor the surface currents along the entire California coastal zone and inside bays. The consortia of nine institutions proposed to instrument the coast with shore-based radio Doppler remote sensors as the only solution to map surface currents over a large area with sufficiently high temporal and spatial resolution. The Coastal Ocean Currents Monitoring Program (COCMP) has deployed an array of over 60 CODAR Ocean Sensors SeaSonde systems in a nested configuration to create the monitoring array. Along the coast are eleven 5 MHz systems that have an average range of approximately 180 km and configured for a spatial

resolution of 6 km. Nested within this coverage are 12 and 25 MHz systems situated to cover the regions of high commercial traffic and large population centers. These systems have a range

Figure 2. A possible racecourse for the 2013 America's Cup Competition.

of 40 - 90 km and spatial resolution of 1-3 km. The region of increased resolution in northern California extends from Pt. Arena to Pt. Sur, and in southern California from Pt. Conception south to the Mexican border. The geometry of San Francisco Bay allowed deployment of 42 MHz systems that are not range limited and can be configured to have a spatial resolution of 400 m.

The 42 MHz systems broadcast a 7 m electromagnetic wave that produces a coherent Bragg scatter return from surface gravity waves of half that length, or 3.5 m (Fig. 3). In San Francisco Bay these 3.5 m waves are modulated by currents to a water depth of 1.8 m. Over the entire proposed racecourse, the Bragg waves travel as deep water waves with known Doppler shift. When their phase velocity is subtracted from the total Doppler-determined velocity a precise estimate of the surface currents is obtained. Each radar station consists of two compact electronics chassis and a single antenna mast for transmit and receive, as shown in Fig. 3. [1] discuss the recent calibration of these systems in San Francisco Bay; overall current estimates are accurate to about 8.45 cm/s.

For the America's Cup competition we plan to have an array of six stations that will provide redundant coverage of the racecourse. This overlap gives more accurate, robust coverage and will allow a reduction of spatial resolution to 200 m. Fig. 4 shows the location of the four existing operational systems and the location of the additional two units that will go in shortly. Total current vectors in Fig. 4 were produced by the existing stations. The new additional stations will fill in and improve the coverage over the race area.

The radial configuration of the signal and processing for each station allows a one degree angular grid and 400 m in range resolution. With the overlapping coverages of the six systems, the spatial scale for the vector maps becomes 200 m. In the dynamic currents of San Francisco Bay, a time averaging of 30 minutes is the correct compromise to reduce the unwanted random turbulence seen in the surface flows but short enough to track the movement of the fronts. For the America's Cup competition, and for all sailors on the Bay, the goal is to compute the currents with minimal lag time and then develop projections for "real time" and short term forecasts.

III. APPLICATIONS

The COCMP array was established to assist with environmental, regulatory and emergency issues; however it has proved equally useful to the recreational community. The

Figure 3. The 42 MHz SeaSonde antenna located at Crissy Field.

statewide array has improved our understanding of tidal variability over the shelf, the role of eddy motion over the shelf and slope, including the large persistent eddy off Cape Mendocino, and the large scale connectivity of shelf circulation. During both the Cosco Busan (2007) and the Dubai Star (2009) fuel spills in San Francisco Bay the HF radar was used in the response to track the transport of the oil. Similarly, HF radar current measurements have been used to estimate the trajectories of pollutants off San Francisco, San Diego and Los Angeles. HF radar current measurements are also being incorporated into the US Coast Guard Search and Rescue operations.

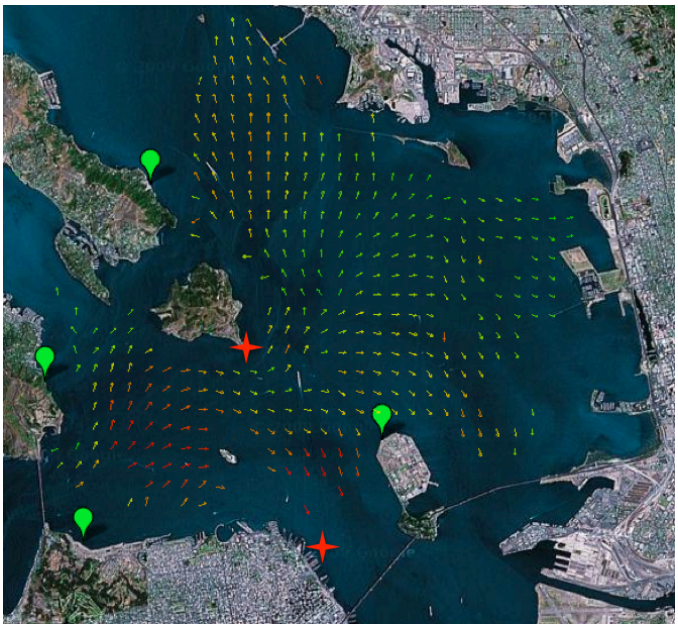

Figure 4. Presently deployed HF radar systems in San Francisco Bay and the locations of two proposed additional systems (red crosses). Vectors are shown at 500 m resolution.

HF radar data at two kilometer resolution were available to sailors in the 2008 Summer Olympics off Qingdao. Analysis of winds and currents before the 2008 Newport to Ensenada race was credited by the navigator of one boat for winning their class. In prior America's Cup competition, spatial variation of the currents did not play a significant role; in the open ocean the currents were spatially relatively constant. This is not the case in San Francisco Bay; the shape of the Bay and bathymetric changes combined with the strong tidal currents and wind variations help create a very complex current regime that changes over the tidal cycle. The array of 42 MHz HF radar systems has already been used to verify the tidal constituents throughout the central Bay. The addition of two more systems, one on Angel Island's Blunt Point and one potentially on Pier 17 will allow mapping the Bay currents in unprecedented detail. Our present goal is to improve the spatial resolution of the currents down to 200 m. This should allow mapping the tidal fronts and translation of these tidal fronts in the central Bay. These data will be made available to the racers to assist with race planning.

REFERENCES

[1] M. Hubbard, N. Garfield, D. Barrick, "Surface Current Variability Statistics in the Tidally Dominated San Francisco Bay,"IEEE/CWTM Conference Proceedings", 2011.