Networking Multiple HF Radar Systems with Common Coverage Overlap

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Abstract - **Two older NOAA pulse-Doppler CODAR systems at Moss Landing and Monterey, CA have been providing real-time surface-current map coverage of Monterey Bay since 1991. Recently, this configuration has been extended. The older CODAR at Monterey has been replaced by a new lower-frequency, longer-range SeaSonde. SeaSondes have been brought on line at Santa Cruz and Granite Canyon, South of Monterey.**

This paper describes the operation of the multi-system network. Overlapping coverage between at least two systems is required to produce a total horizontal current vector, as each unit can measure only the vector component at any point that is radial to the radar. More systems results in greater coverage, accuracy and a more complex operation.

I. INTRODUCTION

The NOAA CODAR network began coverage of Monterey Bay in March, 1992. Since that time, a database consisting of maps of surface current velocity taken at 2-hour intervals, together with radial velocity files, have been collected, archived and disseminated to users. The network originally consisted of two first-generation CODAR systems at MBARI at Moss Landing and Stanford/Hopkins Marine Laboratory at Monterey, and was augmented in September by the installation of a SeaSonde system at the Long Marine Laboratory of the University of California at Santa Cruz. The older Hopkins system has been replaced by a SeaSonde system purchased by the Naval Postgraduate School. In addition, a fourth site has been purchased by Stanford University and installed at Granite Canyon, 12 miles south of Monterey. The coverage of the Granite Canyon system does not overlap Monterey Bay; therefore it is operated independently to give radial current velocities only. A SeaSonde is a small HF radar system, developed and manufactured by CODAR Ocean Sensors, which maps the radial components of the ocean surface current field, to distances of about 70 km, and also provides local directional wave information. The photographs show the SeaSonde in operation. This paper describes the operation of the Monterey Bay network. In the normal mode of operation, radial current vector files are measured by systems at two or more remote sites separated by 25-50 km, and sent by modem to a central site computer where they are combined to give a field of total current vectors. Routine diagnostic procedures are run to check the quality of the output data and to minimize system down-time. The total current vectors are displayed, archived, and disseminated to interested users.

II. MEASUREMENT OF RADIAL VELOCITIES AT THE REMOTE SITES

The SeaSonde radar systems at the remote sites have compact, three-element receive antenna units consisting of two crossed loops and a monopole. The transmit antenna is a 5-m vertical whip; it can be combined with the receive antenna unit or deployed separate from it, to best accommodate the electrical requirements and site constraints. Voltage time series from the antennas are windowed, Fourier transformed and the cross spectra formed and averaged. The average is continually updated every four minutes, resulting in near real time data. The method used to derive radial current vectors from the voltage cross spectra is described in [1]. Radial vectors are computed every hour for the SeaSonde and every two hours for the first-generation CODAR systems. They are stored on the remote computer, ready for transfer to the central site.

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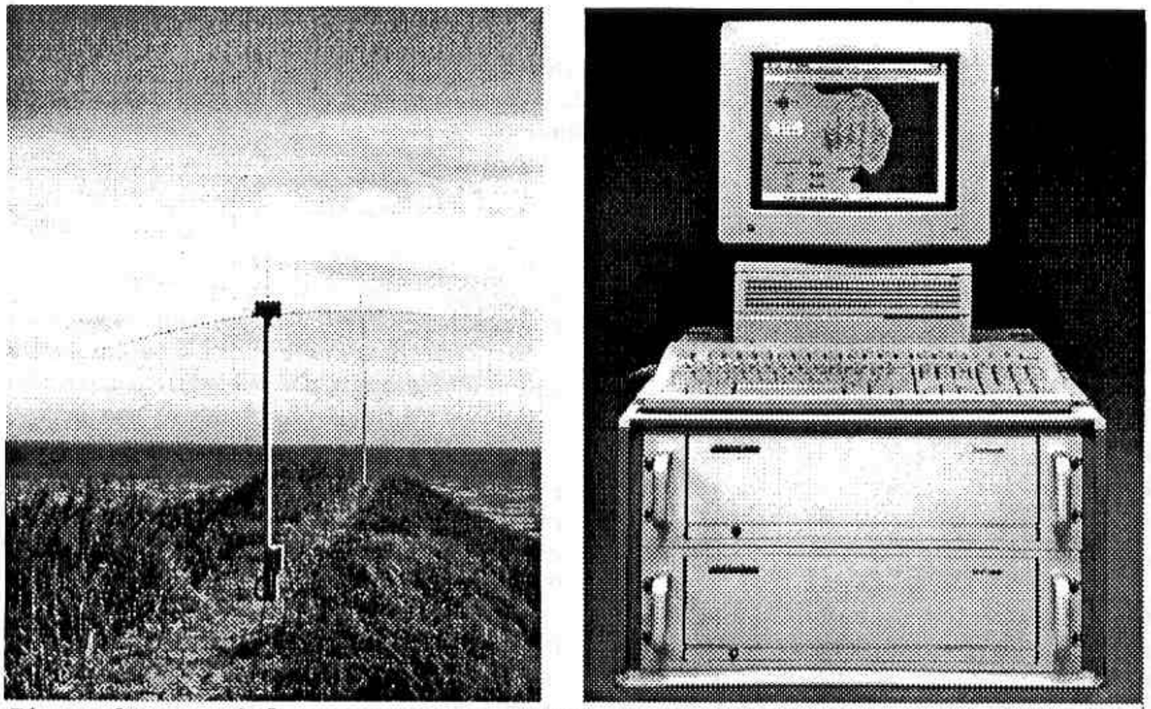


Photo of SeaSonde® Antennas at Santa Cruz, CA on Left: (receive unit in foreground; transmit whip to rear). On Right, Photo of Macintosh Real-Time Current-Map Processor, on Top of SeaSonde Transmitter and Receiver Chassis.

III. RETRIEVING RADIAL DATA FROM THE REMOTE SITES

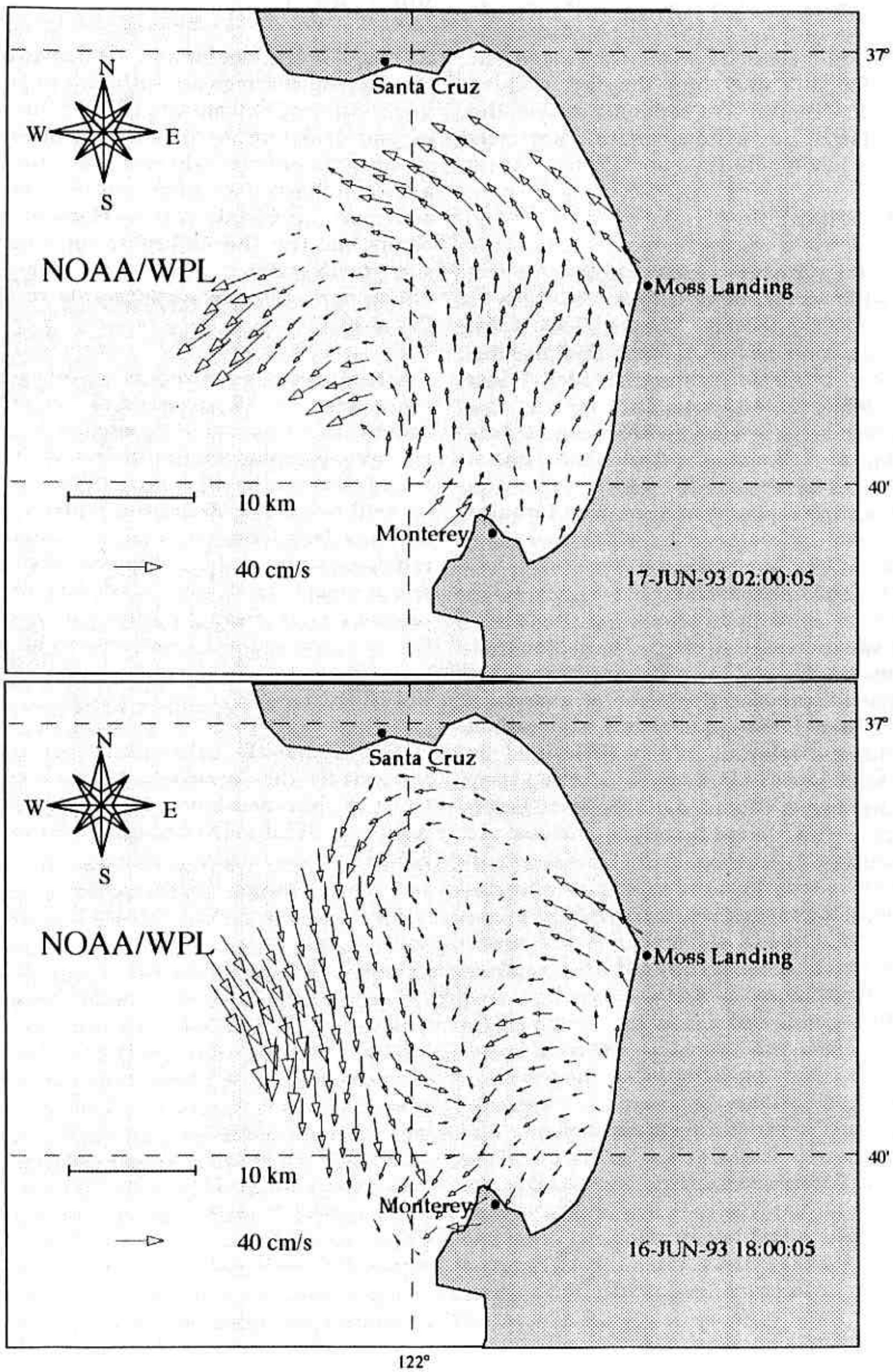
This is done remotely and automatically by dialing from the central computer and transferring all radial files that are not presently resident on the central site computer. Radial data is now being transferred every two hours throughout the day.

IV. RADIAL COMBINATION AND DATA ARCHIVAL

The radial vectors at a particular location are weighted by their calculated variances and vector combination is performed to produce a total vector map which is automatically displayed when generated on the central site computer. Uncertainties in the total vectors are calculated and when they exceed a selected threshold, the corresponding vectors are not displayed, although they are stored. High uncertainties occur, for example, when radials from two sites fall on the baseline joining the sites, and there is no data from the third site. This instability happens because the two sites are both measuring the same component of surface current parallel to the baseline, and there is no estimate of the perpendicular component. When the baseline lies close to shore, we have used the approximate condition that the component of the current normal to the shore is zero at the coast to allow interpolation of the normal component across the baseline. The component of current parallel to the baseline, however, is measured accurately. Examples of total vector maps are given in the following figure.

V. QUALITY CONTROL

Hardware diagnostic factors are computed from the cross-spectra at the remote sites and stored in the radial files which are sent to the central site. These include signal levels, signal to noise ratio vs. range, antenna phase and amplitude correction factors. In addition, the appearance of the radial map is a powerful diagnostic-- is the map filled in? Are there wild vectors due to the inclusion of second-order or ship echoes in the analyzed data? Are vectors confined to the sea, or do some fall over land? Then there is the baseline check: the radial vectors along the baseline between each pair of the three sites must agree, as seen from each site of the pair. In addition for a three site setup, the total maps obtained by combining radial data from each of the



Surface circulation of Monterey Bay obtained by combining radial vectors measured at the remote sites shown at Santa Cruz, Moss Landing and Monterey.

three site pairs and the complete three site combination should be consistent. A diagnostic computer program runs daily to generate diagnostic parameters for all sites and display warning messages on the central site computer and in the Central Site Log, if any system or data parameters fall outside the range considered acceptable.

VI. DATA ARCHIVAL

Radial and total vector files are stored on an optical disk drive with removable cartridges, each of will holds approximately 500 days of stored 3-site data. Each cartridge contains two folders: Radial Files and Total Vector Files. The radial files folder contains sub-folders for each site. Data is stored in a different folder for each week, with the start date included as part of the name and with the Central Site Log in the Total Vector Files folder. When the cartridge fills, it is replaced and archived for later use.

VII. DATA DISSEMINATION

The central site computer is connected to the Internet. Qualified users with any type of computer can use the file transfer protocol (ftp) free of charge to transfer data files. If the required data is more than 500 days old, the relevant folders (identified by name) are placed on the ftp server, allowing easy access to the user. Stored data in even larger quantities can be transferred for offline analysis via magnetic media.

VIII. CONCLUSION

Although it has long been known that two sites with overlapping coverage are sufficient to produce total vectors, distinct advantages of three sites are: (i) an expanded total vector coverage; (ii) more accuracy at geographic points where three-site data are available; (iii) elimination of the "baseline ambiguity" problem over much of the areas where it occurs; and (iv) the ability to continue to produce some total-vector coverage when one of the sites either partially malfunctions or is completely off the air.

The Monterey Bay network is a working example of continuous CODAR coverage of complex coastal ocean surface currents. At present it is used mainly for oceanographic studies of surface currents. It would obviously be of great utility in the event of an oil spill for guiding cleanup operations. Since this is the first long-term real-time operation of any HF radar network, it has become a testbed for the development, trial and evolution of diagnostic procedures. Interested parties can visit Monterey Bay and observe this NOAA network in operation.

REFERENCE

[1] B. J. Lipa and D. E. Barrick (1983), 'Least-squares methods for the extraction of surface currents from CODAR crossed-loop data: Application at ARSLOE', IEEE J. Oceanic Engineering, vol. OE-8, 226-253.