HF Radar Observations of Currents, Winds and Waves

John F. Vesecky, P.I., Lorelle A. Meadows, Calvin C. Teague, Pete Hansen, Jeff Paduan,
Dan Fernandez and Yolanda Fernandez

Goals

The objective of this portion of the EEGLE research program is to obtain real-time measurements of key air and water variables. These parameters are necessary for the identification and quantification of the physical processes generating cross-margin transport of biologically important material during episodic events. In particular, the HF Radar has been utilized to provide observations of near-surface current and current shear (leading to estimations of wind direction and wave energy) over an area of about 1000 square km adjacent to the Lake Michigan shoreline near St. Joseph/Benton Harbor, Michigan (Fig. 1).

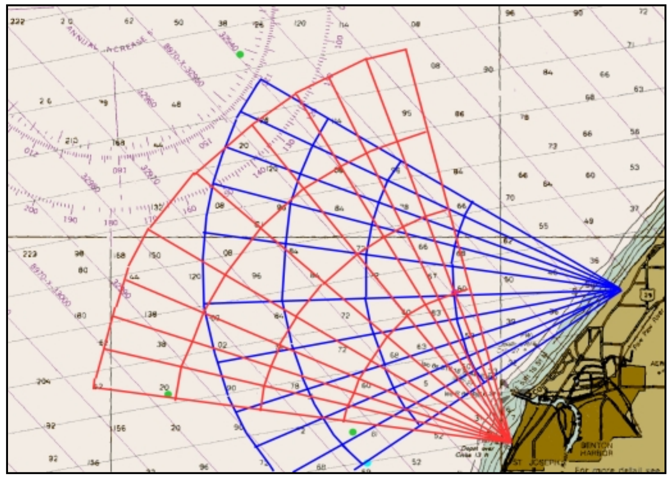

Fig. 1. HF Radar deployment locations and partial antenna patterns

1998 Pilot Experiment

In 1998, the feasibility of utilizing the University of Michigan Multi-frequency Coastal Radar (MCR) units to detect near surface currents over fresh water was tested and proven. This two week pilot deployment, during low energetic wind and wave conditions showed the capability of the radar to detect near-surface current and current shear consistent with ADCP measurements and wind forcing conditions (Vesecky, et al, 1999; Fernandez, et al, 2000).

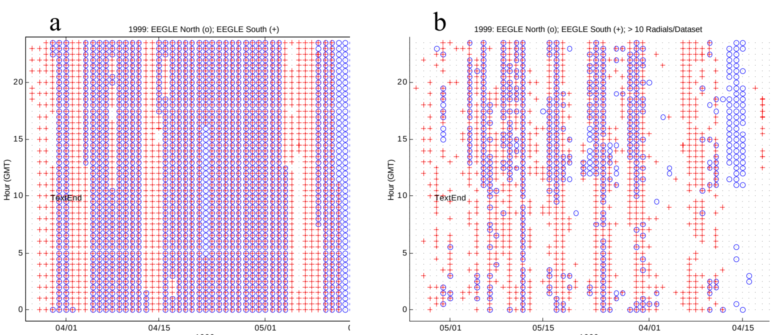

Fig. 2. 1999 HF Radar data sets (a) and data return (b)

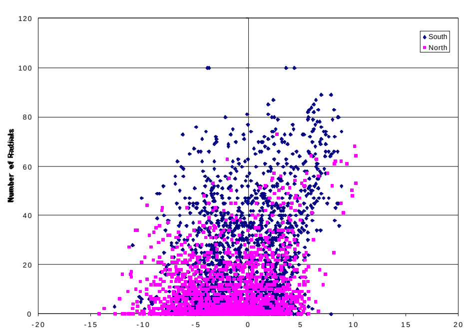

Fig. 3. 1999 data return vs radial wind component

1999 Deployment

In 1999 two MCR units were simultaneously deployed near St. Joseph, Michigan with observational ranges designed to encompass several moored current meters and other in-situ instrumentation (27 March through 18 May). In addition, an Aanderaa Coastal Monitoring (UM Met) buoy was also deployed to measure surface and atmospheric environmental characteristics (25 February through 15 June). This suite of instrumentation provided a coherent package with which to observe changes in environmental parameters and surface dynamic characteristics during the early spring. In particular, the HF Radars were capable of obtaining near surface current and current shear measurements during small episodic sediment suspensions events as well as the progression of the vernal thermal front (Meadows, et al, 2000). Due to the wave conditions during this time period, the northern site had data return of only 32%, further limiting vector current recovery to 20% (Fig. 2 and 3). Despite the small data set, good comparisons were made with ADCP near-surface current measurement (Teague, et al, 2000).

2000 Deployment

Hardware enhancements of the MCR's were completed for the 2000 deployment (1 March to 15 April). Preliminary data analysis reveals stronger return signals at both sites. In addition, stronger onshore wind components during the deployment time (Fig. 4), suggest an improved data return and vector current recovery of 60% for the 2000 deployment.

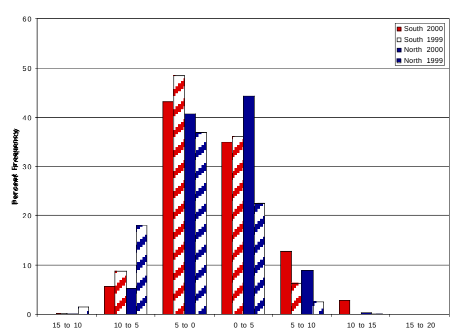

Fig. 4. 1999 vs. 2000 radial wind climate

University of Michigan ***HF Radar Laboratory***

IEEE Conference on Current Measurement Technology Proceedings, March, 1999.

Surface Current Measurements by HF Radar over Fresh Water at Lake Michigan and Lake Tahoe

John F. Vesecky, Lorelle A. Meadows, Jason M. Daida, Peter E. Hansen, Calvin C. Teague, Daniel M. Fernandez, Jeffrey D. Paduan

HF radar is widely used over salt water to measure surface currents, winds and waves. We report results over fresh water in Lakes Michigan and Tahoe. Although these pilot experiments were brief, they established that useful HF radar observations of surface currents can be obtained out to ranges of about 10 to 15 km with wave heights corresponding to wind speeds of about 3 to 7 m/s. Ranges 2 to 3 times larger and often more would be expected over salt water due to improved ground wave propagation. The currents measured by HF radar closely tracked in-situ current measurements by an acoustic Doppler current profiler. These encouraging results demonstrate the utility of HF radar in freshwater applications, but with significantly less spatial coverage than over salt water.

IEEE Journal of Oceanic Engineering, in press, 2000.

Surface Current Measurements by HF Radar in Fresh Water Lakes

Daniel M. Fernandez, Lorelle A. Meadows, John F. Vesecky, Calvin C. Teague, Jeffrey D. Paduan and Peter Hansen

HF radar has become an increasingly important tool for mapping surface currents in the coastal ocean. However, the limited range, due to much higher propagation loss and smaller wave heights (relative to the salt-water ocean), has discouraged HF radar use over fresh water. Nevertheless, the potential usefulness of HF radar in measuring circulation patterns in fresh water lakes has stimulated pilot experiments to explore HF radar capabilities over fresh water. The Episodic Events Great Lakes Experiment (EEGLE), studying the impact of intermittent strong wind events on the resuspension of pollutants from lake bottom sediments, provided an excellent venue for a pilot experiment. A Multifrequency Coastal HF Radar (MCR) was deployed for 10 days at two sites on the shore of Lake Michigan near St. Joseph, Michigan. Similarly, a single -frequency CODAR SeaSonde instrument was deployed on the California shore of Lake Tahoe. These two experiments showed that when sufficiently strong surface winds ($\geq$ about 7 m/s) exist for an hour or more, a single HF radar can be effective in measuring the radial component of surface currents out to ranges of 10 to 15 km. We also show the effectiveness of using HF radar in concert with acoustic Doppler current profilers (ADCPs) for measuring a radial component of the current profile to depths as shallow as 50 cm and thus potentially extending the vertical coverage of an ADCP array.

IEEE-IGARSS Proceedings, July, 2000.

Multi-Frequency HF Radar Observations of the Thermal Front in the Great Lakes

Lorelle A. Meadows, John F. Vesecky, Calvin C. Teague, Yolanda Fernandez, and Guy A. Meadows

In large fresh water lakes in temperate regions, the spring transition from weak to strong stratification is characterized by the formation of a coastal thermal front. This transition is dominated by high gradients in temperature, nutrient and plankton fields. A combination of solar warming, boundary heat flux, coastal bathymetry and surface wind stress causes the frontal system to develop such that a surface convergence forms at the nearly vertical 4°C isotherm (the temperature of maximum density). This isotherm propagates offshore as warming of the nearshore water increases and as storms provide a mechanism by which the two water bodies (warm stratified nearshore waters and cold isothermal offshore waters) mix. As part of the NSF Episodic Events • Great Lakes Experiment (EEGLE), HF Radar observations were obtained during the development and progression of the vernal thermal bar in Southern Lake Michigan in April 1999. Two Multi-Frequency Coastal Radars (MCR's) were utilized to provide observations of near-surface current vectors and vertical current shear adjacent to the Lake Michigan shoreline near St. Joseph, Michigan. MCR measurements of near-surface currents show evidence of theoretical vernal thermal front circulation supported by in-situ measurements of thermal and dynamic structure. A two-week study of surface dynamics in the vicinity of the thermal front is presented and compared with in-situ measurements.

IEEE-IGARSS Proceedings, July, 2000.

HF Radar Observations of Surface Currents on Lake Michigan During EEGLE 1999

Calvin C. Teague, Lorelle A. Meadows, John F. Vesecky and Yolanda Fernandez

The University of Michigan Multifrequency Coastal Radar (MCR) was used as part of the 1999 Episodic Events Great Lakes Experiment (EEGLE) to measure surface currents on Lake Michigan near St. Joseph, Michigan. High surface-wave loss over fresh water and generally calm wind and wave conditions during the 8-week experiment limited the radar range to less than 10 km. The radar measurements which were obtained showed good agreement (to within about 5 cm s^{-1}) with nearby acoustic Doppler current profiler (ADCP) current meter measurements at 2 m depth. Measurements from the MCR, ADCP and a wind buoy are compared.