WERA Ocean Radar Support for Tsunami Early Warning Systems

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High-frequency (HF) ocean radars give a unique capability to deliver simultaneous wide area measurements of ocean surface current fields and sea state parameters far beyond the conventional microwave radar coverage. Additionally it can contribute to the development and improvement of Tsunami Early Warning Systems. The WERA (Wavel E RAdar) HF radar system is an ocean radar installed at the coast. The system operation is based on electromagnetic wave propagation along salty water; it uses the radar frequency between 3 and 30 MHz to provide a large coverage of ocean surface that could extend to more than 300 kilometers in range. These maximum range values are of high interest for many applications including research in oceanography, tsunami monitoring, vessel tracking, as well as search and rescue support, distribution of pollutants, etc. These radar systems recently became an operational oceanographic tool for coastal monitoring worldwide.

Bragg-resonant backscattering by ocean waves with wavelength equal to a half of the electromagnetic radar wavelength allows measuring the ocean surface current velocity at far distances. Hence HF radar could identify a tsunami wave travelling towards the coastline following possible ocean surface current changes due to a tsunami event which are evaluated using a fast update of the radar backscattered spectra. The ocean backscattering effect on the received monostatic radar Doppler spectrum produces two large power peaks containing information about velocities of incoming and outgoing surface currents. Tsunami induced surface currents would cause additional shifts in the peak frequencies comparing to normal oceanographic situation. While the tsunami wave is approaching the beach, the surface current pattern changes slightly in deep water and significantly in the shelf area. This strong change of the surface current can be detected by a WERA system in real-time monitoring. This fact gives an opportunity to issue an automated tsunami watch during real-time monitoring by the WERA radars. If these radar systems have been already installed at the coast then their upgrade for tsunami observation is easy and inexpensive.

One of WERA systems was in operation on March 11, 2011, when the Great 2011 Japan tsunami waves hit the Chilean coast after 22 hours of propagation time throughout the Pacific Ocean. The radar was located near Rumenca, Chile, and supplied ocean surface monitoring in that region. The radar measurements were recording during several hours while the tsunami wave train was arriving at the coast. Bragg-resonant backscattering by ocean waves with a half of the electromagnetic radar wavelength allows measuring the ocean surface current velocity. The ocean surface current field changes due to a tsunami event were evaluated using the measured HF radar backscatter spectra. The unique chance to observe a natural tsunami event by means of WERA radar showed that such radars are capable to measure tsunami surface current velocity with a resolution of a few cm/s. Significant deviations in ocean current measurements were observed by this short-range radar system at distances up to 40 km off the coast. Clear periodic disturbances in surface currents due to the Japan tsunami were observed. To identify a tsunami induced signature in a measured current field, a moving-average filtering technique to remove regional surface currents was used. After applying this technique the unique tsunami wave train was clearly seen in radar measurements. Since the information about the bathymetric contours within the radar coverage was known using ETOPO1 global relief model, the tsunami induced signatures were found up to a water depth of more than 1000 meters. It is remarkable to notice that the tsunami currents were recognized far beyond the shallow water region of 200-m depth. Moreover, it can be clearly seen that the absolute tsunami current velocity becomes higher while the wave is entering the shelf region. The surface current pattern changes in the shelf area can be detected by the WERA system in real-time monitoring. The first appearance of such signatures can be monitored early enough to issue a watch message about an approaching tsunami wave.

The observed radar results were compared with water level measurements by the tide gauge located 50 km to the south from the radar site. The tsunami wave periodicity was estimated for measurement data. It showed agreement estimating two tsunami wave periods of 14 and 32 minutes for both tide gauge and radar measurements. Due to these values of tsunami period, it should be stated that the potential tsunami areas have to be monitored by the ocean radar in a continuous operation mode with a fast update of the ocean surface current measurements, for example at a 2-minute rate. It is also important to point out that it is necessary for the radar system to achieve high signal-to-noise performance and narrow beam directivity. These features can only be obtained using an array type WERA system or similar systems with beamforming technique. The use of compact ocean radars is not capable to provide the required performance for tsunami monitoring.