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A Measurement-Based Analysis of the Hydrokinetic Energy in the Gulf Stream

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This study uses ocean current measurements made off the East Coast of the United States to evaluate the ocean current-based electricity production potential in the Gulf Stream. Drifter data from the World Ocean Circulation Experiment (WOCE) are used to map the energy density from South Florida to North Carolina, showing that the most energy-dense areas exist off the east coast of Central Florida. Bottom- and vessel-mounted Acoustic Doppler Current Profiler (ADCP) measurements are used to conduct a more detailed study near 26°N and 27°N, respectively. These results quantify the energy profiles in these regions, suggesting that 54% more energy-dense currents are available at 27°N than at 26°N.

INTRODUCTION

The world demand for electric power is increasing every day due to the economic and population growth of humanity. The International Energy Agency (IEA) released a study predicting that the world demand for energy will increase by 37% by 2040 (IEA, 2014). To satisfy this need for increased power production, both traditional and renewable forms of energy are being pursued. Offshore energy has some advantages over traditional sources. It is renewable and clean, it contributes to the decrease in the greenhouse effect as well as in toxic gas emissions, and it brings new prospects for jobs and economic development (Soukissian et al., 2012). The western boundaries of the world's oceans offer renewable energy (VanZwieten et al., 2013). The power density at a depth of 50 m is calculated through the use of the Hybrid Coordinate Ocean Model (HYCOM), as shown in Fig. 1 (VanZwieten et al., 2013). While the HYCOM numerical model has been shown to significantly underpredict the average energy density in several areas (VanZwieten et al., 2014), it is still valuable for visualizing regions containing ocean current resource.

To produce electricity from ocean currents, devices that can convert the hydrokinetic power in these currents to electrical power are being developed and tested (DOE, 2015). It has been calculated that on average about 19 GW of electrical power generation is technically feasible from ocean currents located in waters off the East Coast of the United States (Georgia Tech, 2013). This is equivalent to 4.07% of the 467.24 GW of electricity consumed in the U.S. during the year 2014 (EIA, 2015b). The U.S. electricity need is expected to grow. In the year 2013, the total electricity consumption was 3.836 billion kWh, and it is predicted to increase to 4.797 billion kWh in 2040 (EIA, 2015a).

This paper focuses on providing a purely measurement-based analysis of the ocean current resource of the U.S. East Coast with a focus on S.E. Florida. Ocean current velocities measured by drifters that are part of the World Ocean Circulation Experiment (WOCE) are used to map the energy density of surface currents from South Florida to North Carolina. After this, ADCP data are used to assess the energy potential at approximately the northern and southern ends of the primary area that is being considered for ocean current energy extraction off Florida. Vessel-mounted ADCP measurements are used to assess the ocean current resource throughout the water column at 27°N, while bottom-mounted ADCP data are used to assess the ocean current resource near 26°N between Florida's east coast and the Bahama Islands, as shown in Fig. 7.

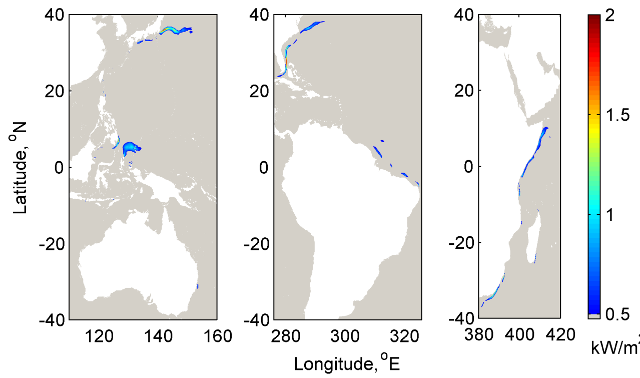

Fig. 1 HYCOM-calculated area with time-averaged power densities greater than 0.5 kW/m^2 at 50 m depth (2009–2011) for the western boundary of the Pacific (left), Atlantic (center), and Indian (right) Oceans

SEA SURFACE CURRENT ENERGY

To explore and collect ocean sea surface data, a global network of drifters was deployed as part of the WOCE. These data have been collected since 1990 and are publicly available on the Fisheries and Oceans Canada website (Fisheries and Oceans Canada, 2015).

Drifter Data

Drifter data collected by the WOCE include the following sea surface characteristics along the drifter's path: temperature, latitude, longitude, east component of the current, north component of the current, and year, month, day, hour, and minute in which the specific data were gathered. The Surface Velocity Program (SVP) drifters used in this study are made up of spherical surface buoys that maintain their shape even in high shear flow. Data from two sizes of SVP drifters are available: the original size weighs 45 kg,

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KEY WORDS: Resource, assessment, hydrokinetic, ocean, energy, Gulf Stream.