Quantum Ocean: Resetting Ocean Science with Advances in Fiber Optics and Quantum Sensors

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UNESCO has designated the 2025 International Year of Quantum Science and Technology (IYQ) and the UN Decade of Ocean Science for Sustainable Development (2021-2030), *i.e.*, "the Ocean Decade". When coupling the Ocean Decade objective (to develop the scientific knowledge and the partnerships needed to better understand the ocean system) with the IYQ climate objective (for quantum physics to inform next-generation sensors for environmental monitoring and quantum computing to improve the accuracy of long-term climate models), we arrive at a unique place in scientific history. Namely, the potential for quantum technology to provide observational solutions of the subsurface ocean with unprecedented accuracy and precision, which will advance understanding, innovation, and lead to improved prediction of the natural world (Fig. 1). The present measurement of temperature and salinity, key metrics of ocean conditions, are antiquated, especially subsurface, and are limited to ship-based and floating/drifting/autonomous observation platforms. Essential ocean variables (EOV's) are the collection of ocean properties selected to provide the best, most cost-effective data that enable the quantification of key ocean processes. They are selected based on their Relevance, Feasibility and Cost Effectiveness. Defining properties of seawater, salinity and temperature are at the top of the EOV list. Oceans, particularly the deep ocean, is a vast and inhospitable environment. The present accuracy of oceanographic temperature and salinity sensors is 10^{-2} (°C and S). Remote sensing of the ocean interior (deeper than 5 m) using satellite systems is either impossible or inefficient; above 5 m, the precision is ∼0.1°C. The **Quantum Ocean** concept is identifying, developing, and applying cutting-edge quantum sensors and measurement techniques to improve the accuracy and precision of EOV's, underwater imaging, navigation, and communication can usher a new era of quantum ocean observing systems that can improve predictions of long- (climate) and short-term (weather) processes that will benefit human society by improving resiliency, sustainability, and well-being. A potential achievable starting point is to increase the present accuracy of subsurface specific volume of seawater estimates by three orders of magnitude. The integrated approach of combining Raman and Brillouin spectroscopy can be applied to independently measure water temperature and salinity. For example, an on-board platform delivering laser beams through a window and performing optical detection and ranging with specificity afforded by laser spectroscopic measurements. These quantum measurement systems integrated into ocean observing systems have the potential to fundamentally change our understanding of the ocean environment. The application of quantum technologies to observe and image the ocean interior will require new and innovative collaboration between several scientific and engineering disciplines. A strong stakeholder program is the pathway to sustainability.

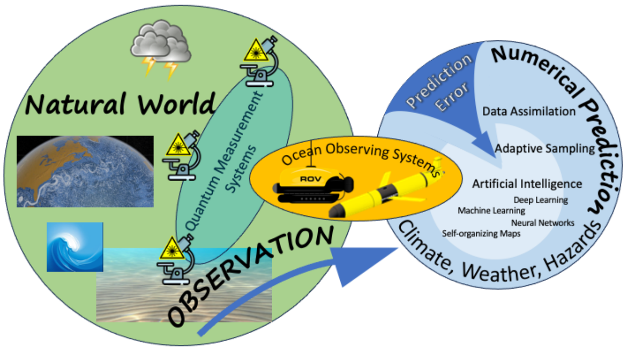

Figure 1: Quantum Ocean conceptual diagram depicting Quantum enhanced Observations of the Natural World lead to more accurate Prediction