DARPA Questions

- ***What are the unknowns in the ocean reservoir relevant to national security?***

The DARPA Ocean Synoptic Sensing Roundtable covered multiple themes relevant to oceanographic science, technology, data integration, and advanced modeling. This roundtable emphasized the need for innovative ocean sensing technologies and improved models to better understand the ocean's complex dynamics, while balancing military needs with scientific exploration.

Key Findings and Conclusions

Unknowns in Oceanography

A major theme was the lack of understanding of ocean processes on various timescales and how this affects national security. The ocean's role in climate impact and fluid dynamics needs better modeling and observation across both short-term (weather) and long-term (climate) scales.

Modeling Ocean Dynamics

Carl Wunsch highlighted the need for high-resolution models to cover large-scale energy dynamics down to centimeter-scale dissipation. Ocean circulation is a key area of study, and future ocean sensing requires improved computational power and space-based observations (e.g., altimetry, gravity sensing). Small scale experiments are needed, as the ocean is 'regional'. The Arctic is both essential to our national security and an excellent candidate for basin-scale experiments that would provide essential parameters for models. With the anticipated further sea ice melt, it is critical to accurately model this strategic environment, which is a growing concern for national security. Link to **Kerr DoD 2024 Arctic Strategy Document**.

Models like NOAA's MOM6 are advancing in sea-level rise predictions and regional observations. However, fundamental physical processes and boundary conditions (e.g., coastlines, carbon budgets) remain unresolved, requiring more data to refine ocean models.

Emerging Technologies for Ocean Sensing

Acoustic thermometry, remote sensing, and satellite communications were discussed as critical tools for improving ocean current and thermal data collection. Acoustic "GPS" may well be quite important. A lot of ocean observations are drifters. Acoustic GPS can locate a vehicle with an accuracy of 1-10m. ARGO floats greatly understate temperature changes by a factor of 2, based on seismic measurements from stations like the IDA Network operating since the 70's.

Acoustics can measure temperature profiles and resolve mixing layers in the Arctic, while satellite data enhance global ocean monitoring systems.

Tomographic sensing and reconstruction have been valuable understanding the solid earth and thereby improving model fidelity. Similarly, Acoustic Tomography employing the hydrophones in the International Monitoring System (CTBT) has proven valuable.

National Security Implications

Randy Pugh, Director of Naval Warfare Institute, emphasized the importance of competitive advantage in ocean sensing for military operations, including underwater systems for tracking submarines and anti-ship missile threats. The Arctic was identified as a key strategic area, with ice melt presenting both challenges and opportunities for adversarial activity.

Ocean Discovery and Exploration

A key concept discussed was the need for collecting, integrating and making accessible Ocean data from various platforms (fixed, floating, historical) to users such as the military, civilian agencies, and scientific communities. While building operational systems is not within DARPA's primary mission, a proof of concept is needed to support follow-on research and demonstrate its proof of concept. Other funding agencies philanthropic and commercial funding sources are needed to explore and discover the ocean, 70% of the planet.

Challenges in Data Integration and Sharing

Oceanographic data, particularly classified data, faces bureaucratic obstacles in sharing between military and scientific communities. Improved coordination between data collection systems, including the integration of acoustic data, was proposed to enhance modeling and prediction efforts. A testbed to collect experimental data from a variety of sensors, integrate them into a database and make the available for testing is an essential tool. Some work has started to develop a Concept for such an Operational Testbed, illustrated in Figure 1. on the next page.

Focus Areas Recommended to DARPA

- High-resolution, region-specific ocean current predictions.
- Acoustic thermometry for deeper ocean monitoring.
- Integrating advanced AI models for adaptive ocean sensing systems.
- Testbed to evaluate research and data from experiments.

An *Ocean Challenge*, with specific well-defined parameters, modeled after previous DARPA Grand Challenges, fits well within DARPA's de-risking mission and is highly recommended.

(Note: Such a challenge and future oceanographic modeling research would build on results and lessons learned from DARPA's previous Ocean of Things program, which conducted a small challenge in 2021 called Forecasting Floats in Turbulence.)
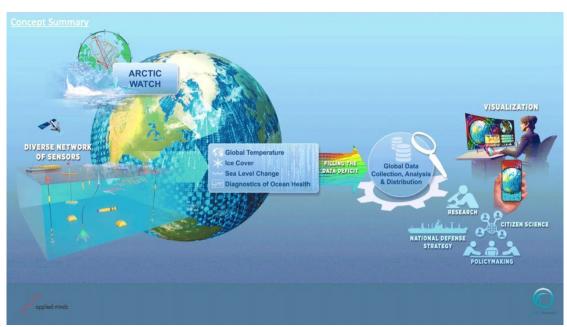
Figure 1: Concept for Ocean Watch Operational Testbed