2016

Development of Non-Traditional Detection Algorithms for Undersea Warfare

Radko, Timour; Joseph, John; Merriam, Christopher; Martin, Michael; Moody, Zachary

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/57737

MONTEREY, CALIFORNIA

Development of Non-Traditional Detection Algorithms for Undersea Warfare

Report Type: Final Report
Period of Performance: 10/01/2015-02/28/2017

Project PI: Associate Professor Timour Radko, GSEAS
Additional Author/Authors: Faculty Associate John Joseph, GSEAS
Student Participation:

Christopher Merriam, LCDR, Navy, Meteorology and Oceanography
Troy Benbow, LT, Navy, Oceanography
Michael Martin, LT, Navy, Meteorology and Oceanography
Zachary Moody, LT, Navy, Meteorology and Oceanography

Prepared for:
Topic Sponsor: N9
Research Sponsor Organization (if different): OPNAV, N97

Research POC Name: Jennifer S. Roberts
Research POC Contact Information: jennifer.roberts1@navy.mil , 571-256-8414

EXECUTIVE SUMMARY (3-5 PAGES, 600-800 WORDS)

Project Summary

This study addresses the problem of hydrodynamically-based detection of the surface and subsurface wakes generated by transiting submersibles. Our primary objective is to investigate the wake intensity, its thermal signatures and detection potential. Research activities involved numerical, laboratory and field experiments. Our work was aimed at providing a comprehensive and systematic analysis of stratified wakes in a realistic oceanic environment and will offer valuable operational guidance in this regard. This project is most timely since numerical modelling capabilities, and understanding of environmental influences, have only recently reached the level at which all key physical components can be fully represented. The identification of detection vulnerabilities will affect the tactics of undersea warfare by narrowing search areas for USW. These techniques became particularly appealing in view of continuous technological advances in remote sensing methods, which have dramatically improved the accuracy of measurements in the submarine wake.

Keywords: Non-traditional detection; Undersea Warfare; Battlespace environment; Submarine search, detection and avoidance

Background

Research into non-acoustic submarine detection methods, mainly supported in the US by the Office of Naval Research, has been ongoing since the 1960s. Several promising methods have been considered for airborne and submarine-based detection of the thermal and velocity signatures of submarine wakes. However, attempts to consistently implement non-acoustic methods on the operational level have yielded mixed results. The interest in hydrodynamically-based detection systems has been recently invigorated by: (i) continuous technological advances in remote sensing methods, which have dramatically improved the accuracy of measurements in submarine wakes and (ii) the proliferation of ultra-quiet air-independent propulsion submarines whose signal-to-noise levels fall significantly below the threshold of passive acoustic detection systems.

Findings and Conclusions (to include Process)

Since this project is directly based on student research activities, we summarize our key findings by referring to thesis projects supported by this NRP:

LCDR Merriam: The wake of a propagating, submerged body in a stratified fluid is fundamentally different from that of the same body in a homogenous fluid due to modification by buoyancy and gravity. The size of the wake, especially its vertical extent, is dependent upon the body's momentum and diameter and the stratification of the water. These parameters are captured by the Froude number which is the ratio of the inertial forces of a wake to the buoyancy forces. In a thermally stratified fluid it is possible to detect the wake of a submerged object by perturbations in temperature. This thesis identifies an additional parameter, the depth ratio, for the prediction of wakes that will reach the surface. Through laboratory experiments and numerical simulations we show that, for a given depth ratio, there exists a critical Froude number above which the wake can be detected at the surface by IR camera. A field study conducted in Monterey Bay shows that it is also possible to detect such wakes below the surface using a UUV and looking for a warming of the temperature profile. (Merriam, 2015)

LT Benbow: A numerical study has been performed to investigate the feasibility of hydro-dynamically based detection of propagating submersibles. Of particular concern is the possibility of utilizing microstructure measurements as a means of wake identification. The simulations are based on the Massachusetts Institute of Technology General Circulation Model (MITgcm), which has been modified for wake analysis. The dissipation of a turbulent wake produced by a sphere uniformly propagating in a doubly stratified environment is examined for three scenarios: (i) quiescent regime, (ii) double-diffusive regime, and (iii) a flow with pre-existing turbulence. The analysis of the numerical models was based on two quantities, the dissipation of turbulent kinetic energy (ε), and the dissipation of thermal variance (χ). This analysis indicates that wake signatures generated by a 1-meter wide object are detectable for 0.4 and 1.2 hours, depending on regime, and the detection interval is not strongly sensitive to the density ratio. Double-diffusive convection plays a significant role in the duration of submarine wakes. The extrapolation of the simulations to objects of ~10m propagating with speeds ~10m/s suggests that microstructure-based detection is feasible for at least two hours after the passage of a submersible and significantly longer outside the double-diffusive regime. These results indicate that microstructure-based observations of stratified wakes offer a viable method for the non-acoustic detection of submerged objects. (Benbow, 2016)

LT Martin: Submerged bodies propagating in stratified fluids frequently create disturbances in temperature, salinity, and momentum that are detectable at the air-sea interface. This project includes the addition of momentum excess in order to model the fundamental differences between signatures generated by towed and self-propelled bodies in various ocean states. In cases where the body forces, form drag and thrust were balanced, fewer and less expansive surface signatures were observed. In cases where the balance was disturbed by either lack or excess of self-propulsion, a greater perturbation was achieved, particularly in the ocean interior. Discovering the significance of the internal, intermediate-range wakes has transformed the focus of the entire study. With the increasing employment of unmanned underwater vehicles, it is equally imperative to research the internal ocean dynamics as it is to study the physics at the surface. This study was focused on direct numerical simulations. However, the data collected in this investigation have produced new insights into the dynamics of stratified wakes, which can be used on the operational level for developing and improving algorithms for non-acoustic signature prediction and detection. (Martin, 2016)

LT Moody: A hydrodynamically-based predictive model for the detectability of submarines will greatly enhance the U.S. naval advantage over adversaries within the battlespace environment. The ability to detect a thermal wake at depth using an autonomous underwater vehicle (AUV) is tested. Primary investigation consisted of real-world ocean experiments using a scaled towed body to mimic a self-propelled submerged body (SB). The impacts and bias from a tow ship on the thermal signature are considered. Direct numerical simulations (DNS) and laboratory experiments are used to complement field work findings. Similar thermal deviations were found between applied ocean observations and theoretical research. Two measurement methods were used to discern water column regions that had experienced the passage of a submerged body. This thesis concludes that thermal wake detection at depth in a stratified fluid is very possible, and an AUV is well suited for employment as a measurement platform. Additional research is necessary in order to capture different SB and environmental parameters, along with the testing of various sensors. (Moody, 2016)

Recommendations for Further Research

The project can and should be further developed in several directions. Additional experiments are necessary in order to explore different submerged body characteristics and environmental parameters which will ultimately lead to development of a general predictive algorithm. The maneuvering and acceleration of the submerged body was not taken into consideration, but would most likely result in the amplification of both interior and surface signatures of the wake. Extending the period of observation into the late wake regime, while continuing to monitor the interior thermal signal, will make it possible to quantify the decay rates of turbulent patches – an important problem of general oceanographic significance. The proposed critical conditions for the surfacing of a wake need further refinement and inter-comparison between numerical, observational and laboratory analogues. Nevertheless, even our preliminary results indicate that detection based on thermal wake signatures is highly promising as a means of non-acoustic target recognition.

References

Benbow, T. (2016). *The effects of double-diffusion and background turbulence on the persistence of submarine wakes.* Monterey: NPS, thesis.

Martin, M. (2016). *Influence of the momentum excess on the pattern and dynamics of intermediate-range stratified wakes.* Monterey: NPS, thesis.

Merriam, C. (2015). *Laboratory experiments on stratified wakes.* Monterey: NPS, thesis.

Moody, Z. (2016). *Stratified wakes induced by submerged propagating objects: detection using UUVs.* Monterey: NPS, thesis.