

BIO-PHYSICAL COUPLING OF PREDATOR-PREY INTERACTIONS

Thomas Osborn
Department of Earth and Planetary Sciences

Center for Environmental and Applied Fluid Mechanics

phone: (410) 516-7039

fax: (410) 516- 7933

email: osborn@jhu.edu

Charles Meneveau
Department of Mechanical Engineering

phone: (410) 516-7802

fax: (410) 516- 7254

meneveau@jhu.edu

The Johns Hopkins University
3400 N. Charles Street
Baltimore, MD 21218

Award #: N00014-97-1-0429

LONG-TERM GOAL

Our long term goal is to understand the dynamics of oceanic predator-prey interactions of copepods with feeding currents. Knowledge about the plankton and their oceanic environment will be incorporated into a framework of numerical simulations which includes behavioral aspects and their interactions in conjunction with the other biological processes and physical processes.

SCIENTIFIC OBJECTIVES

Predator-prey interactions and their relative motion cover a wide range of spatial scales. We wish to develop realistic models and simulations that include processes occurring at the relevant scales for a quantitative understanding of the bio-physical coupling in predator-prey interactions.

It is fundamental to understand the physics and the fluid mechanics for predator-prey interactions. At these scales, viscous effects are significant and many of the details of the feeding process are determined by the structure and shape of the organisms involved. Since the Reynolds number of the associated flow is small, it is possible to numerically calculate some of these deterministic aspects. These calculations will augment and extend the direct observations, making it possible to identify the fundamental aspects of the morphology and operation of the predators. Our objective is to understand the biological and physical processes involved in feeding in sufficient detail to quantitatively predict predator-prey contact rates. Such quantitative results will shed light on feeding strategies and rates responsible for the thin layers of high biological concentrations and production now being found in many oceanic environments.

APPROACH

Simulations of the flow, at millimeter scales, have been performed by employing a state-of-the-art, finite-volume code with curvilinear body-fitted coordinates (BFC). This code has the ability to handle complex boundary conditions and smoothly describe the body shape without the jagged edges that would arise with Cartesian coordinates. The feeding current of the copepod is simulated by specifying a force in the water adjacent to the body. Using this code, we obtain details of the feeding current and its interaction with flow non-uniformity. At present the objective is to model the feeding current around a copepod and diagnose the properties of the computed feeding current for comparison with direct observations. We will evaluate forces on the zooplankton due to interaction with externally imposed flow structures.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 30 SEP 1997	2. REPORT TYPE	3. DATES COVERED 00-00-1997 to 00-00-1997			
4. TITLE AND SUBTITLE Bio-physical Coupling of Predator-prey Interactions		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Johns Hopkins University, Department of Earth and Planetary Sciences, 3400 N. Charles Street, Baltimore, MD, 21218		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

Simulations at larger scales will be performed with a code for Large-Eddy Simulation (LES) of high Reynolds number turbulent flow. This code can include stratification. In those calculations the tracking of predators and prey will be based on solving appropriate Ordinary Differential Equations for each “particle”. We plan to track large samples of predator and prey trajectories, as they evolve with a three-dimensional unsteady turbulent velocity field.

WORK COMPLETED

Four cases considered to date in order to test the applicability of the code.

1. Stokes flow due to a point force was compared to the exact analytic result for $Re=0.008$.
2. Stokes flow due to a point force outside a solid sphere was compared to an exact analytic results for $Re=0.008$.
3. Flow due to a point force outside a solid sphere was calculated for $Re=0.8$, which is a realistic value for a copepod. No analytical solution is available for comparison with this result.
4. An artificial copepod shape was generated by adding appendages to the sphere in order to have a body that included the antennae and the tail. The feeding current around this artificial “copepod” was calculated for the realistic value of $Re=0.8$ (Figure 1). This result is compared to case 3 to show the effect of the additional details of body shape.

Having completed the testing of the code and calculated the feeding current around a sphere and an artificial “copepod” we are now performing calculations around realistic shapes for copepods.

RESULTS

In the completed preliminary calculations of the feeding current, we first assumed that a “copepod” was in a shape of sphere, then we added two antennae and one tail to the spherical “copepod” to make an artificial “copepod”. Comparing the feeding currents for the two “copepods”, we found that with modification of shape from “sphere” to “copepod”, the feeding current in front increased and water was drawn in from a greater distance. The more realistic artificial “copepod” would feed from a larger domain than the sphere, showing that the copepod’s morphology contributes to its feeding success.

IMPACT

Our work shows that the direct calculation of the feeding current around a copepod is possible. Preliminary calculations on simplified shapes shows that the details of the body shape are important in determining the paths of entrained particles. Computations of the feeding current give details that are difficult to obtain from direct observations. Thus, the calculations expand the value of the laboratory measurements by increasing the spatial and temporal resolution of the role of the feeding currents in the predator-prey interactions.

The study of the oceanic predator-prey interactions, by combining knowledge about plankton and oceanic environment within a framework of numerical simulations, furthers our understanding of the population dynamics in species specific settings. The work shows what is generic about shape, feeding strategy and feeding success.

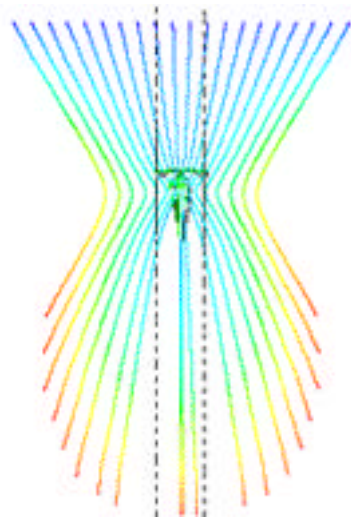


Figure 1. Particle tracks using the computed feeding current around the artificial “copepod”. Twenty particles are tracked. The color indicates the speed with the darkest blue color corresponding to the highest speeds and the darkest red to the lowest speeds.