Quantify Lateral Dispersion and Turbulent Mixing by Spatial Array of χ-EM-APEX Floats

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LONG-TERM GOALS

Our long-term scientific goals are to understand the dynamics and identify mechanisms of small-scale processes—i.e., internal tides, inertial waves, nonlinear internal waves, vortical modes, and turbulence mixing—in the ocean and thereby help develop improved parameterizations of mixing for ocean models. Mixing within the stratified ocean is a particular focus as the complex interplay of internal waves from a variety of sources and turbulence makes this a current locus of uncertainty. Our focus is on observing processes that lead to lateral mixing of water properties.

OBJECTIVES

Our primary scientific objective is to improve our understanding and parameterization schemes of small- to submeso-scale oceanic processes. Dispersion due to lateral processes with vertical and horizontal shears could enhance turbulent mixing. Both internal waves and vortical motions exist at vertical scales smaller than order of 10 m and horizontal scales smaller than few km. They have distinct kinematics and dynamics. Internal waves propagate and may carry energy to remote regions before they break and dissipate via turbulent processes, whereas vortical motions do not propagate and are often long lived. Separation of these two motions is necessary to improve parameterization schemes.

APPROACH

Our approach is to measure the internal wave background, shear vector, vorticity vector, and turbulent mixing using a “swarm” of EM-APEX profiling floats that will profile simultaneously through the

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surface mixed layer and upper seasonal pycnocline every hour. These 3-D observations of turbulence, instability, and small-scale processes are vital to understanding the dynamics of the coupling between the diapycnal mixing and oceanic lateral processes. Our primary purposes are to quantify the time evolution of the complete horizontal and vertical structures of turbulence mixing and shear instability including thermal diffusion rate χ, vertical shear S, stratification N, shear instability gradient Richardson number Ri, Ertel's potential vorticity Π, and effective horizontal eddy diffusivity k_h on isopycnal surfaces from shear dispersion, and to quantify effects of internal waves and vortical modes on horizontal dispersion and diapycnal mixing.

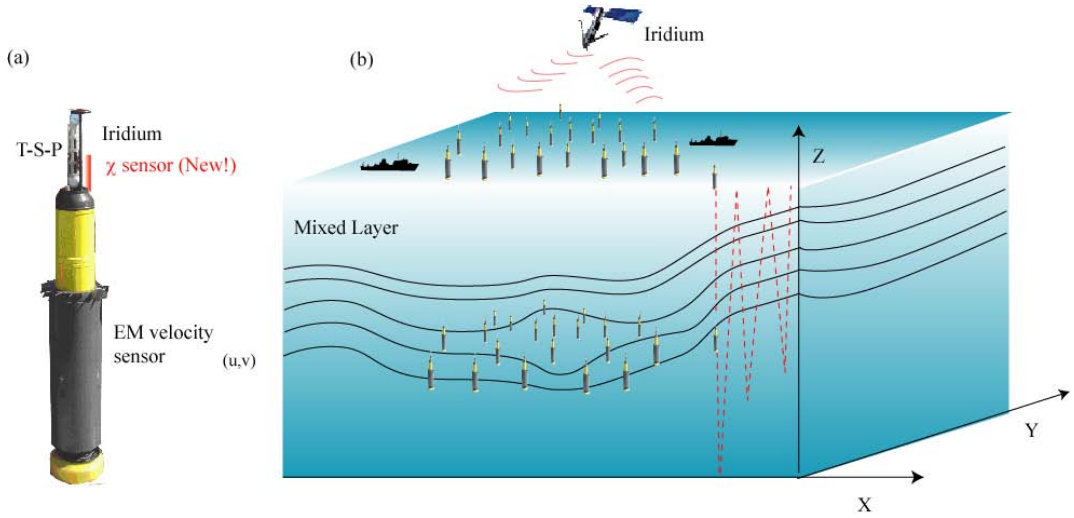

Fig. 1: (a) EM-APEX float with the proposed χ sensor. (b) Proposed experimental plan of a spatial array of 20-microstructure EM-APEX floats (χ-EM-APEX floats). N.B. The χ sensor will be mounted so as to be out of the wake produced by the Iridium antenna, which will be tilted to the side in the so-called "Mai Tai" mounting.

WORK COMPLETED

- Design preparations for adding the χ sensor to the EM-APEX float.
- Ordered EM-APEX floats from support provided by DURIP grants.
- Developed method to synchronize many floats to fall and rise. It is most likely that each float will have a depth vs. time mission in its firmware and make internal adjustments of fall and rise rates to remain in step.
- Participated in LatMix meeting in Boston on 22–23 July 2010.
- Participated in email discussions for LatMix Site 1 planning.

RESULTS

Cruise planning has focused on the expected sea operations, such as how to rapidly deploy and recover a distributed array of 20 floats. It is expected that the array will be moved several times to sample new dye and environmental conditions.

Preparations have been made to build and install χ sensors on the 10 newest EM-APEX floats. The combination of density, velocity, and turbulence sensors on the APEX floats is an important

component of the LatMix experiment. FY10 funding was anticipated but not received. Early FY11 support is vital to the design, construction, and installation of these sensors.

IMPACT/APPLICATION

The use of autonomous vehicles operating in a coordinated way is able to separate temporal and spatial variability. In contrast, observations at a single site consist of fluctuations caused by both time and space dependencies. The use of a swarm of UUVs, all programmed to operate in unison, is now possible and surely will provide much more information than obtained by the more traditional methods. For example, on the recent ONR study NE of Taiwan, 452 EM-APEX float profiles were obtained in the same period that 164 CTD casts were made from the research vessel. The UUVs free up the vessel to do other work or provide valuable information about the context in which the vessel observations were made.

TRANSITIONS

The EM-APEX float resulted from a SBIR contract from ONR to Webb Research. This instrument has already begun to have an impact on a variety of experiments. The recent ONR DRI projects that the PI has been involved in have EM-APEX components. Other investigators, including James Girton, Mike Gregg, and Helen Phillips (U. Tasmania), have purchased and used these floats.

The installation of the χ sensors on the EM-APEX floats is a significant enhancement of the capabilities of these useful vehicles. It is expected that other investigators will benefit from the installation and use of the χ sensors on EM-APEX floats.

RELATED PROJECTS

Study of Kuroshio Intrusion and Transport using Moorings, HPIES and EM-APEX Floats (N00014-08-1-0558) as a part of QPE DRI: The primary objectives of this observational program are 1) to quantify and to understand the dynamics of the Kuroshio intrusion and its migration into the southern East China Sea (SECS), 2) to identify the generation mechanisms of the cold dome often found in the SECS, 3) to quantify the internal tidal energy flux and budgets on the SECS and study the effects of the Kuroshio front on the internal tidal energy flux, 4) to quantify NLIWs and provide statistical properties of NLIWs in the SECS , and 5) to provide our results to acoustic investigators to assess the uncertainty in acoustic predictions. Results of this DRI program will increase understanding of oceanic physical processes in the SECS, e.g., the cold dome. Typhoons may modulate the Kuroshio, the Kuroshio intrusion, and other oceanic processes, and result in cold pools on the continental shelf of the SECS.

Process Study of Oceanic Responses to Typhoons using Arrays of EM-APEX Floats and Moorings (N00014-08-1-0560) as a part of ITWP DRI: We will study the dynamics of the oceanic response to and recovery from tropical cyclones in the western Pacific using long-term mooring observations and an array of EM-APEX floats. Pacific typhoons may cause cold pools on the continental shelf of the East China Sea. The cold pool dynamics are likely related to the Kuroshio and its intrusion as well as the shelf/slope oceanic processes. The cold pool could produce a significant acoustic anomaly.

HONORS/AWARDS/PRIZES

Awarded The Henry M. Stommel Research Award from the American Meteorological Society, January 2010

Elected Fellow of the American Meteorological Society, January 2010