CONVECTION IN THE LABRADOR SEA
and
AN AUTONOMOUS OCEANOGRAPHIC INSTRUMENT ARRAY

Prof. Russ E. Davis
Physical Oceanography Research Division
Scripps Institution of Oceanography
La Jolla, CA 92093-0230
rdavis@ucsd.edu
Voice: 619-534-4415 FAX: 619-534-9820
Award No. N000149510686 and N000149710468

LONG TERM GOAL

Describe the process of deep oceanic convection well enough to provide critical tests of, and guidance to, models used to predict subsurface ocean conditions. Determine where the water involved in deep convection in the Labrador Sea comes from and where it goes.

SCIENTIFIC OBJECTIVES

Deep convection occurs in late winter in a few regions where atmospheric cooling is great enough, and ocean salinity is high enough, that cold water formed near the surface can sink many hundreds of meters into the ocean. Current models suggest the active agents for water mass modification are plumes of the O(100 m) wide in which vertical velocities are of O(5 cm/s). Convection plumes are apparently organized into regions of O(100 km) of weakly stratified water (called chimneys) which are surrounded by stratified water. Plumes act to mix the water in a chimney while slumping of the chimney, possibly associated with instabilities along its rim, is responsible for the transfer of modified surface water into the stratified ocean.

The objective of these projects is to define the statistics of plume processes, (typical vertical velocities, temperature fluctuations and the vertical heat flux) and develop a resolved picture of how the chimney scale evolves over two complete cooling seasons. This observational picture will be compared with model predictions that relate the plume properties to physical parameters (surface buoyancy flux, earth's rotation and the initial oceanic density stratification) and predict how chimney scale structures evolve.

APPROACH

Profiling Autonomous Lagrangian Circulation Explorer (PALACE) floats are used to observe deep convection in the Labrador Sea over the winters of 1996/97 and 1997/98. During each winter PALACEs measure temperature and salinity profiles every 4 days. Between these profiles they measure time series of vertical velocity, temperature fluctuations and in 1998 salinity fluctuations near 400 m depth. Lateral motion of the floats will define circulation on the chimney and basin scales. During the warming season the profiling interval will be doubled to extend life.

The array of floats will monitor evolution of the density and velocity fields on the chimney scale throughout each cooling season. This will show the preconditioning of the ocean before convection

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Convection in the Labrador Sea and An Autonomous Oceanographic Instrument Array**	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) **University of California, San Diego,Scripps Institution of Oceanography,Physical Oceanography Research Division,La Jolla,CA,92093**	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	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

begins, where convection occurs, how deep it goes, and the associated vertical velocity and density fluctuations. The array will also indicate the sources of waters entering the chimney and the fate of those escaping it, factors that determine how convection affects, and is affected by, larger scale ocean processes. These descriptions will be compared with local process models of convection and basin scale models of the seasonal evolution of interior ocean properties.

ACCOMPLISHMENTS

In preparation for deployments in February of 1997, the standard PALACE float was adapted to measure vertical currents. Using the float's vertical axis as a free-floating axle, vanes placed around the instrument turn it into a propeller that senses vertical flow. A field test of two new instruments was carried out off the California coast in 1996.

Sixteen floats Vertical Current Meter (VCM) floats, all reporting temperature profiles to 1500 m, and nine reporting salinity profiles as well, were prepared and deployed into the Labrador Sea in February 1997. Two were damaged in deployment and do not descend to their parking depth and one failed for unknown causes in March 1997. Figure 1 shows the trajectories of horizontal motion from the array of SIO floats deployed in February 1997. An additional 15 similar VCM floats deployed by B. Owens of Woods Hole Oceanographic Institution are in the same area; the total array of 31 VCMs is imbedded in a long-term array of floats profiling temperature and salinity as part of the World Ocean Circulation Experiment.

An additional fifteen floats capable of measuring vertical velocity, temperature and thirteen capable of measuring salinity have been constructed and are being calibrated for deployment in January 1998.

RESULTS

The measured VCM response to vertical flow is linear down to 1 mm/s where ocean variability confused the test and shows no hint of the asymmetric response implicated in older designs. The two floats deployed off California demonstrated an ability to accurately measure small vertical flows down to about 0.05 mm/s.

The horizontal motion of the floats deployed in 1997 shows that there is weak cyclonic flow in the gyre interior in winter; this is less clear in other times of the year. The trajectories also show how floats placed outside the boundary current along the Canadian coast can escape to the southwest in weak chaotic motion in the interior.

Sequential temperature and salinity profiles show that convection penetrated to 1400 m in March of 1997. Even during the period that convection was occurring the T and S profiles show considerable fine structure; the convecting layer is certainly more complicated than a deep mixed layer. These results suggest that lateral motion and potentially double diffusive turbulence play roles in Labrador Sea deep convection.

Time series of temperature and velocity near 400 m confirm that convection was active during February-April. Downwelling jets up to 10 cm/s, and somewhat weaker upwelling bursts, were observed during this period. Temperature fluctuations of 0.05^{o}C are common after the convective layer has extended below the float depth but these fluctuations show a complex and varied connection with vertical velocity. Examples of this complex behavior during convection are shown in Figure 2.

IMPACT

The ability of small autonomous floats to report submerged horizontal velocity, profiles of temperature and salinity to 1500 m, and time series of temperature and vertical velocity during the extreme winter conditions has been demonstrated.

When fully analyzed, the combination of a large-scale picture of where and how deep convection occurs coupled with a statistical picture of the associated temperature and vertical velocity fluctuations will provide stringent tests of numerical models of convection.

Improved understanding and modeling of deep convection will improve prediction of high latitude conditions in both the ocean and the overlying atmosphere. These processes are all central to predicting evolution of both the ocean and maritime atmosphere during the cooling season.

RELATED PROJECTS

The SIO effort is half of close collaboration with Breck Owens who has deployed similar floats in the same area. Both efforts are significantly aided by, and are aiding, the NSF/NOAA Atlantic Circulation and Climate Change Experiment (ACCE) which is fielding intensive observations in the subpolar gyre of the Atlantic. Data from ACCE and from a pair of Canadian hydrographic surveys of the Labrador Sea will be critical in putting the localized convection observations in context.

Under separate ONR funding R. Davis and B. Owens are collaborating to develop an underwater glider to carry out autonomous observations. This was motivated by a desire to carry out long-term observations of the sort made by PALACE floats, but with control of where they are made. It is hoped the prototype will be ready to observe convection in the Labrador Sea by the winter of 1997-98 and to provide description of the horizontal structure of the things PALACEs observe at isolated points.

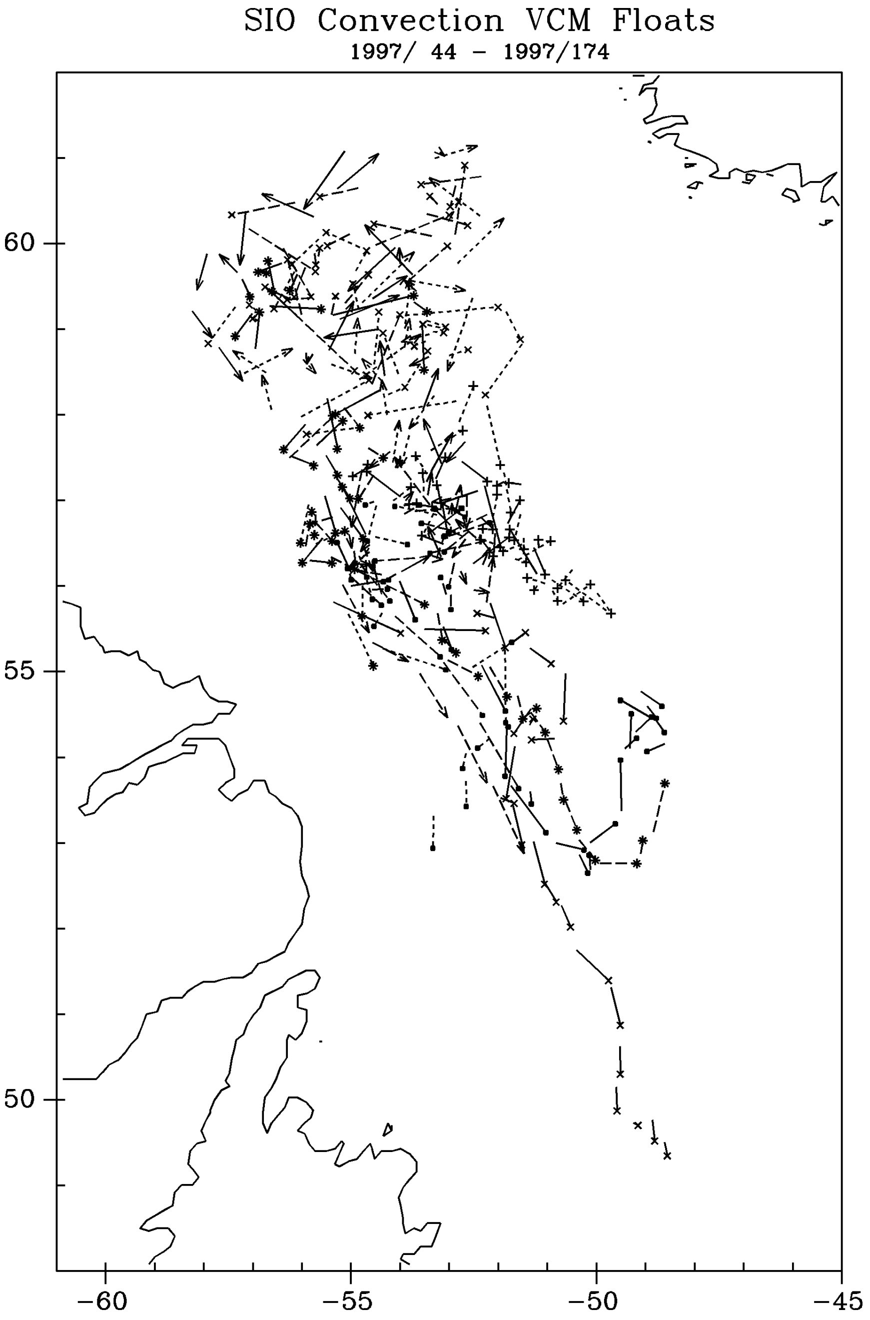

Figure 1. Trajectories of SIO CTD-profiling and Vertical Current Meter floats in the Convection Experiment. Each arrow represents the float displacement over 3.5 days while submerged near 400 m depth. Spaces between arrows represent surface drift while data is relayed through Argos satellites.

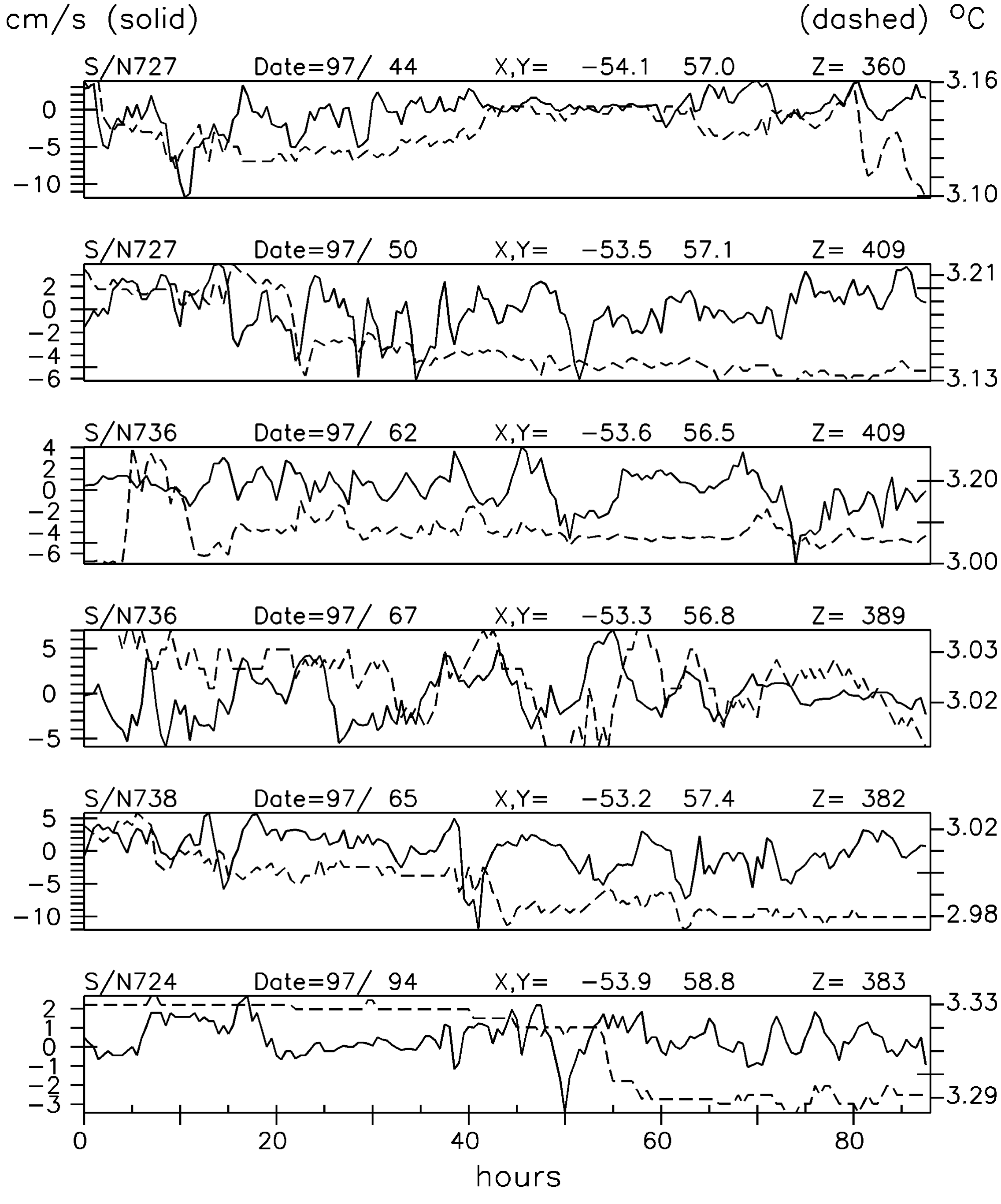

Figure 2. Time series of vertical velocity (solid line, left scale) and temperature (dashed line, right scale). Scales show float ID, date, position and depth. These series were selected from the convection period when vertical velocities are a factor of 5 bigger than after convection stopped.