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Convection in the Labrador Sea

Russ E. Davis
Scripps Institution of Oceanography
La Jolla CA 92093-0230
rdavis@ucsd.edu 619-534-4415
N00014-98-10065

LONG TERM GOALS

We hope to describe deep oceanic convection well enough to critically test and guide models used to predict subsurface ocean conditions.

OBJECTIVES

Our objective is to use neutrally buoyant float observations to define statistics of convection plume processes (vertical velocity, temperature fluctuations, etc.) over two cooling seasons. These observations will be compared with model predictions relating typical plume properties to physical parameters (surface buoyancy flux, density stratification. etc.) thereby providing an observational test of the models' realism and allowing inadequacies to be identified.

APROACH

Autonomous floats were used to observe deep convection in the Labrador Sea over the winters of 1996/97 and 1997/98. During each winter, floats measured temperature and salinity profiles to 1500 meters depth every 4 days. Between profiles, time series of vertical velocity, temperature and in 1998 salinity near 400 m depth were recorded. Lateral motion of the floats defined patterns and velocities

WORK COMPLETED

Sixteen Vertical Current Meters (VCMs) based on the ALACE float were deployed in the western Labrador Sea in the Winter of 1996/97. The next year fourteen VCMs based on the new SOLO float were deployed in the same general region. The floats functioned well; the most common problem was mechanical failure of blades in the VCM propeller. Motion of these floats, and of others deployed as part of WOCE, were used to directly map mean velocity between 600 and 1500 m. Profiles of temperature and salinity were used to map evolving mixed layer depths, describe the fine structure apparently associated with the collapse of convection plumes, and measure the vertical flux of heat and freshwater through various levels. Time series of vertical velocity, temperature and salinity were used to define vertical eddy fluxes past the floats and the Lagrangian mean vertical velocity.

RESULTS

Maps of horizontal velocity show a mid-depth boundary current flowing northwestward along the coast of Greenland, following isobaths across the northern Labrador Sea and then flowing south along the Canadian coast to Flemish Cap. The basin interior has eddy variability but little mean motion. There is no evident seasonality to the flow and very little depth dependence between 600 and 1500 m.

Three O(100 km) cyclones are found around the basin just offshore of the boundary current. One cyclone northwest of Weather Station B appears to precondition convection. Another just west of Cape Farewell is associated with floats that "retroflect" out of the West Greenland Current and recirculate back to the Irminger Basin.

Profiles show convection reached about 1400 m in early 1997 but only about 800 m in 1998. Deep convection was focused in the cyclone west of Station B but was found sporadically over much of the basin. The deepest mixed layers were found in April, by which time the net surface buoyancy loss had essentially ceased. There is considerable disparity in the buoyancy fluxes from different operational analyses. Float profiles accurately measure these fluxes, showing a flux focused where convection is deepest that peaks at a monthly average 600 W/m^2 .

Float apparent heat fluxes $\langle w'T' \rangle$ are only half that computed from profile changes and there is a net upwards vertical motion during the convection period. Low frequency (several day period or longer) variations of w and T are large enough to support the missing flux but are not well enough correlated. In numerical models the heat flux is carried mainly by plumes with lateral dimension of O(1 km). These models predict that isobaric floats in the mid- to lower mixed layer will see a reduced heat flux and net upward motion. This occurs because plumes are horizontally divergent in the lower mixing layer and isobaric floats are preferentially detrained into the surrounding flow where the net motion is upward, thereby avoiding the extreme cold T and downward w that carry much of the vertical flux.

IMPACTS

In the conventional view, convection fluxes are carried by upright plumes that are rotationally modified analogues of those seen in laboratory convection. It is also possible for the vertical flux to be carried by slantwise eddies in a process more closely related to baroclinic instability. Our observations of convection can distinguish between these mechanisms and will impact which models are accepted as describing oceanic convection. Accurate meteorological analyses of surface conditions are scientifically and operationally important and our observations show which operational products are accurate now and could allow them to be improved. Labrador Sea Water is found throughout much of the North Atlantic and these observations show directly how this water escapes the convection region and show, in particular, that there is a relatively rapid connection between the Labrador and Irminger basins that does not involve the western boundary current.

TRANSITIONS

Knowledge gained by integrating float observations and model runs will lead to improved models of the convection process. The success of autonomous floats in making sophisticated observations under the harshest conditions points to the utility of autonomous floats for various scientific and operational uses.

RELATED PROJECTS

This effort was closely coordinated technically and scientifically with a companion project led by Brechner Owens of WHOI. It is part of the Deep Convection ARI and is closely related to all programs in that program.