Convection in the Labrador Sea

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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. Half the floats were still functioning in September 1999. Motion of these floats, and of others deployed as part of WOCE, was 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 infer the vertical flux of heat and freshwater through various levels by assuming negligible lateral advection. Time series of vertical velocity, temperature and salinity were used to define the times and positions of convection and to measure vertical eddy fluxes past the floats.

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

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along the Canadian coast to Flemish Cap. Offshore of this deep boundary is an unexpected counter-current that can carry newly formed Labrador Sea Water directly to the Irminger Sea. The basin interior has eddy variability but little mean motion. There is little seasonality to the boundary current or counter-current and little depth dependence between 600 and 1500 m.

Profiles show convection reached about 1400 m in early 1997 but only about 800 m in 1998. Judging from vertical velocities and mixed layer depths, deep convection was focused 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. While there is considerable disparity in the surface buoyancy fluxes between operational weather analyses but float profiles showing a flux focused where convection is deepest with a peaks monthly average of 600 W/m^2 .

The float-measured vertical temperature flux $<w'T'>$ based on fluctuations with periods less than 88 hours are only half that computed from profile changes. The probability distribution of velocity fluctuations w' are only slightly skewed toward infrequent strong upward motion. Low frequency (several day period or longer) variations of w and T are large enough to support the missing flux but their correlation cannot be well measured from the data quantity available.

Float results are being compared with numerical models to see if any can explain the small heat flux by the plume scale. Models predict that isobaric floats in the mid- to lower mixed layer will see a reduced heat flux and net upward motion 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. While float fluxes are small, no net upward motion is observed. Comparisons are underway with other models that simulate geostrophic eddies that themselves can support significant vertical buoyancy flux in the hope that these can explain our observations.

IMPACTS

In the conventional view, upright plumes that are rotationally modified analogues of those seen in laboratory convection carry convection fluxes. It is also possible for the vertical flux to be carried by slantwise convection, a process more closely related to baroclinic instability. Our observations of convection should be able to 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 float observations can show which operational products are accurate. 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 ability of autonomous floats to make sophisticated observations under the harshest winter conditions may point to their utility for other scientific and operational observations.

RELATED PROJECTS

The field operations were carried out in close collaboration with Brechner Owens (WHOI).

We are analyzing a series of model runs by John Marshall (MIT) and colleagues and comparing them our observations with the intent of defining the relative importance of plumes and geostrophic turbulence in vertically transporting buoyancy.

William Garwood and Ramsey Harcourt (NPS) have compared our observations with their Large-Eddy Simulations to elucidate the Lagrangian biases of floats.

PUBLICATIONS

Lavender, K., R.E. Davis and B. Owens. 1999. Direct velocity observations in the Labrador and Irminger Seas describe the pathways of Labrador Sea Water. Nature. submitted