Sea ice studies in the Weddell Sea aboard USCGC *Polar Sea*

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Our purpose was to investigate several of the characteristics of Weddell Sea pack ice that may affect the relative roles of dynamics and thermodynamics of pack ice development in this region. The total pack ice production and the movement of pack ice from its source area in the Weddell Sea is particularly important in modifying ocean-atmosphere exchange processes. These modifications affect both climate and water mass development in and beyond the Weddell Sea embayment. The pack ice area affected by Weddell Sea processes is 8–10 million square kilometers (Ackley 1979a), about one-third of the total around Antarctica at maximum extent.

We traversed the Weddell Sea during February and March 1980 sampling from helicopters based on board USCGC *Polar Sea*. Foster, Garrison, Michel, and Tørreson (this volume) describe the cruise track and the physical oceanographic programs conducted simultaneously with our program.

Our study had three major objectives: (1) to survey the physical and structural properties of pack ice using core samples; (2) to deploy drifting buoys to obtain pack ice drift and deformation data and also meteorological information; and (3) to study the relationship between pack ice and algal biomass production, an important primary food source for the living community in the southern ocean.

Surveying the physical and structural properties of pack ice was the central portion of our work. We used helicopters and obtained samples with U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) ice coring augers on the floes. This effort took 14 days of sampling flights, amounting to over 70 hours of flight operations. We sampled the Weddell Sea pack in a north-south transect covering about 600 nautical miles from 64° to 74°S latitude at roughly 40°W longitude. More than 60 floes were sampled with 138 meters of core retrieved. Most of the core was split in half on the ship where preliminary analyses of salinity content and some structural properties of the ice were made. The remaining half-cores as well as some whole-cores were returned frozen for analysis and archiving at the USA CRREL where more detailed studies will be made over the next year.

From horizontal thin section analysis of 16 cores, we find that the Weddell Sea pack ice contains significant amounts of *frazil ice* (see the figure) derived from small ice crystals that form in the water column, as opposed to *congelation* ice formed by the freezing of seawater directly onto the bottom of the existing pack ice. Of the 54 thin sections examined 26 percent are entirely composed of frazil ice while an additional 22 percent are composed of mixtures of frazil and congelation ice. Further laboratory analysis based on examination of entire core lengths rather than inferred from the point sampling reported here, will attempt to identify structural transitions in the cores to refine these percentages.

Frazil ice is related to strong turbulence events and forms probably as a result of the brine convection induced by the rapid freezing in leads and polynyas. If this formation of frazil is as widespread as we suspect, then the role of deformation (the opening and closing of leads and polynyas) may have a greater role in the formation of Weddell Sea pack than similar processes do in the arctic pack. For comparison, although the sampling is spotty, frazil ice formation in arctic pack ice is thought to account for only the top portion of drifting pack ice (Martin 1979) usually confined to the top 10 or 20 centimeters of ice and comprises only 5 to 10 percent of the ice structure with 90 to 95 percent being congelation ice.

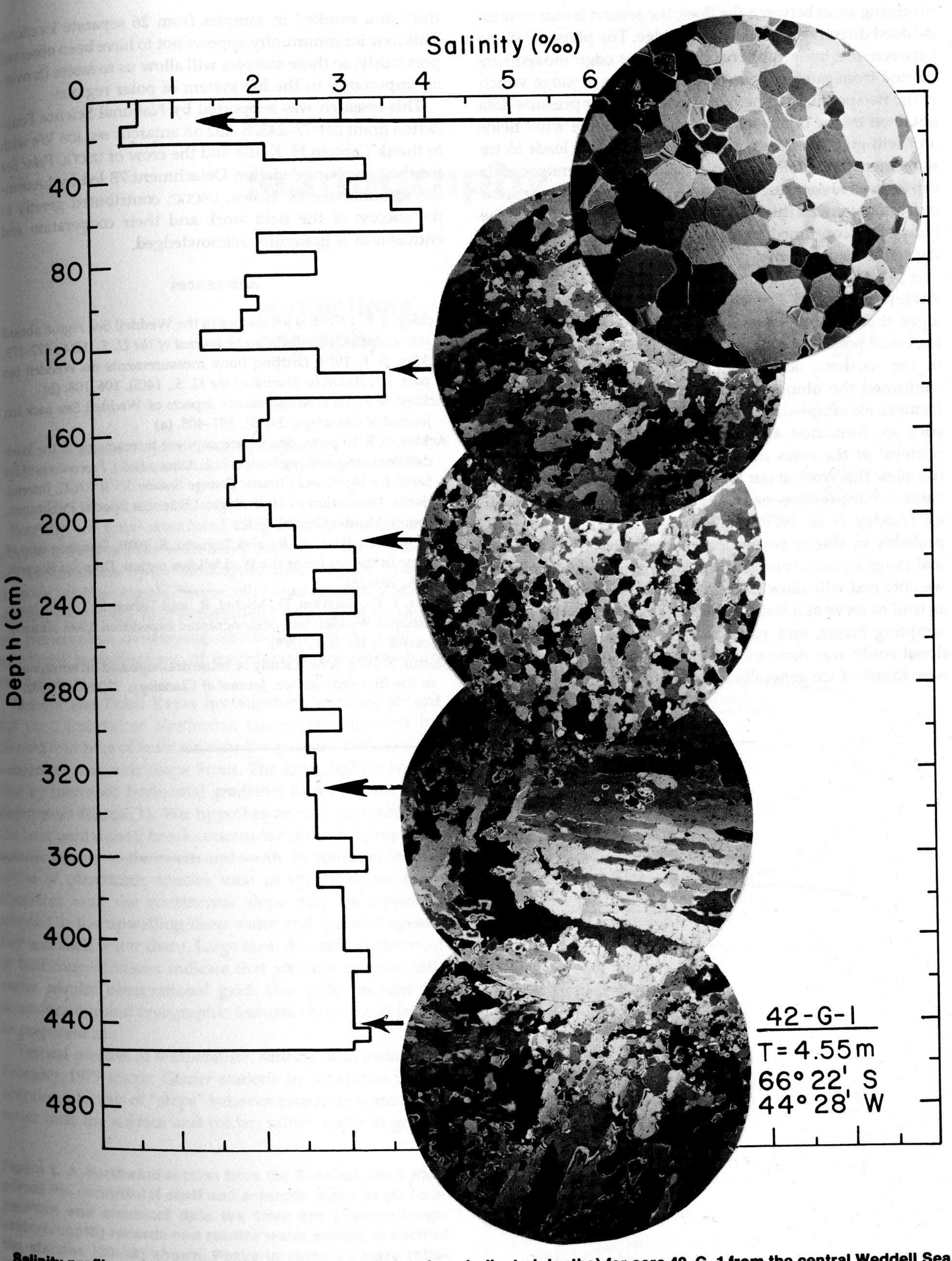
The floe salinity (see the figure) is also more comparable with winter ice than arctic summer ice of similar thickness, reflecting the interaction of two processes. The first of these is the low top-surface summer melt (Ackley 1979b) which allows the floe to retain more brine rather than flushing it out through melt processes. The second factor may be a relatively higher salinity due to the frazil ice formation, which tends to entrap more seawater into the ice strucure than occurs in congelation ice formation. The higher salinities observed here may also be associated with enhanced algal growth within the ice.

Four data buoys were deployed, similar to ones described in earlier reports (Ackley 1979a, 1980). These will transmit, via satellite, position information, air pressure, and temperature during 1980. The buoy data on position will be used to compute trajectories of ice floes or the advection of the ice from its origin in the southern Weddell Sea to its decay in the lower latitudes north and east of its origin. Relative distances between the buoys indicate the divergence and convergence of the ice and, therefore, the amount of ice involved in deformation processes. The initial locations of the buoys are shown in the table.

Buoy Deployment Data

	Buoy number	Location	Deployment date
a	0003	73°53′S 44°40′W	17 Feb 80
b	0621	72°07′S 42°03′W	23 Feb 80
c	1405	73°03′S 39°34′W	23 Feb 80
d	0035	70°28′S 39°54′W	28 Feb 80

Two of the buoys (c and d) were located relatively close (~30 miles) to the ice edge at that time, while the other two were in a line about twice as far in from the edge. Part of our study will be to see how the ice edge actually moves in this region, with two possibilities to be tested. One is that the ice floes move out, and new ice is formed in the



Salinity profile and ice thin section photographs (taken from indicated depths) for core 42–G–1 from the central Weddell Sea. Frazil ice is indicated most strikingly for depths 130 and 210 centimeters.

diverging areas between the floes; the second is that new ice is added directly onto the existing edge. The phase relations between the buoy motions and the ice edge movements plotted from satellite data should allow us to judge which of the two possibilities actually occurs. The air pressure data obtained by the buoys will be used to compute wind fields and will give one element of the forcing that leads to ice movement and deformation, while air temperature data can be used to compute ice growth rates in open water areas and under various thicknesses of ice. As of August 1980, the buoys had continued transmission for approximately 100 days after deployment.

A previous study on our cruise 3 years ago (Ackley 1977; Ackley, Buck, and Taguchi 1979) indicated that pack ice algae, that is, algae living and multiplying within the pack ice, could possibly be an important source in the food chain in the southern ocean. Our observations this trip have confirmed the ubiquitous presence of algae in nearly all forms of ice sampled and point to some close links between pack ice formation and enhanced algal production. The retrieval of the cores deployed this year will allow us to complete this work at our laboratory. Based on visual observations, our previous estimates of algal production in pack ice (Ackley et al. 1979) were under the actual amounts, probably by one or two orders of magnitude. The latitudinal range of this cruise and the large numbers of samples we obtained will allow us to quantify amounts of biomass, as well as serve as a statistical base to determine the range, sampling errors, and variability in the region. An additional study was done on the algal production in various new forms of ice generally less than about 20 centimeters thick and resulted in samples from 26 separate locations. This new ice community appears not to have been observed previously, so these samples will allow us to assess its overall importance in the life system of polar regions.

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