Physical and Historical Context of 2009 Ice Stations in the Bering Sea

What Were We Doing on the Ice?

Authors: [2]D.G. Kachel, [1]N.B. Kachel, [1]C.W. Mordy, [2]S.A. Salo, [2]P.J. Stabeno, [1]M.E. Sullivan

[1]JISAO, Univ. Washington, Seattle, WA / [2]NOAA, PMEL, 7600 Sand Point Way NE, Seattle, WA 98115

Introduction

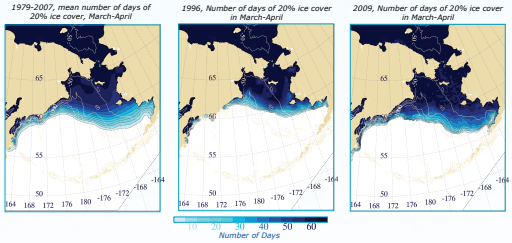
The eastern Bering Sea comprises an extensive shallow continental shelf, housing a rich fishery and the ecosystems that support these species. Annual ice cover is a dominant influence in the ecosystem, determining water-column structure and timing of the spring bloom. Extent and duration of ice has changed with warming Bering Sea water temperature.

In 2006 EcoFOCI collected ice core data from R/V *Thomas G. Thompson* at ice edges. In 2007-2009, we worked as part of the multi-disciplinary BEST/BSIERP research team on the ice breaker USCGC *Healy*, working further into the ice pack. The Eco-FOCI data includes vertical ice profiles for temperature, salinity, chlorophyll, phaeopigments, and nutrients (pigments and temperature from one core, salinity and nutrients from a second core); brine well sampling (same as ice-core parameters plus oxygen); and metadata for ice and weather conditions. Multiple CTD casts near each ice station location provide data for the ambient water column water properties at the time.

Samples from brine wells were analyzed for temperature, salinity, nutrients and chlorophyll. We measured time series of oxygen using an Aanderaa optode sensor. At the end of those experiments, samples were collected for Winkler analysis. In each of those wells, oxygen was super-saturated for the measured temperature and salinity values. We present an overview of our findings from a set of three ice stations visited in 2009.

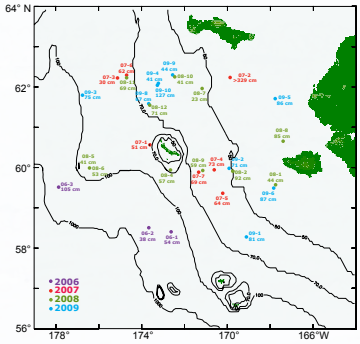
These observations are put into the context of climate variability by comparing satellite ice analyses from 1979-present for March and April, with conditions that existed during the field seasons of 2006-2009.

Satellite Ice Data



Images of ice duration were created from SSM/I ice data downloaded from the National Snow and Ice Data center (NSIDC). We use their GSFC bootstrap files from 1979 through 2007. These files are not yet available for 2008 and 2009, so for those years we used the Near Real Time NASA Team files, which are not as well quality-checked. The images depict the number of days locations are covered by ice of 20% concentration or higher. We also display the mean duration from 1979-2007 (we exclude 2008-09 to avoid mixing bootstrap and near-real-time data), and the anomaly from this mean for the years 2006-2009.

Ice Station Map and Metadata



Map of the Bering Sea showing all Ice Stations, 2006-2009, their distribution over the shelf, and average length of cores at each station (cm).

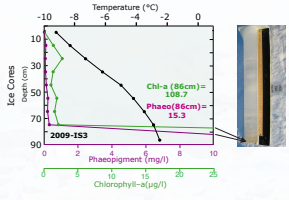
Ice Stations and Conditions, 2006-2009

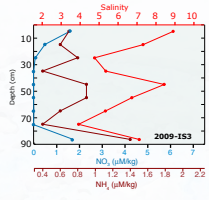
Cruise ID/ Ice Sta ID	Date Taken	Start Time (GMT)	Snow Temp. (°C) Average	Snow depth (cm) Average	Free-board (cm) Average	Ice Thickness (cm) Average	Air Temp. (°C)	Sea Surface Temp. (°C)	Floe Description
TN193 -01	29-Apr-2006	2104		1	7	54	-5.7	0.4	SmaLL at ice edge
TN193 -02	30-Apr-2006	21:53		8.3	7	38	-6.3	-0.2	SmaLL at ice edge
TN193 -03	03-May-2006	3:29		27	12	105	-2.2	-0.6	SmaLL at ice edge
HI1701 -01	17-Apr-2007	3:30	-8.6	1	6	53	-9.8	-1.5	Massive, some ridges
HI1701 -02	19-Apr-2007	4:24	-4.6	1	N/A	>329	+1.6	-1.7	Large, with ridges. Incomplete core
HI1701 -03	21-Apr-2007	0:34	-2.3	4	3.5	30	-1	-1.2	
HI1701 -04	24-Apr-2007	17:48	-1.1	3	6.5	73	-3.8	-1.7	
HI1701 -05	30-Apr-2007	3:48	-0.3	26	5	65	-1.8	-1.7	Massive floe
HI1701 -06	06-May-2007	18:00	-0.6	2	4.7	62	-1	-1.7	Massive, ridges
HI1701 -07	08-May-2007	23:50	1.1	0	5.2	69	2.6	-0.9	Medium, with ridging
HI1802 -01	03-Apr-2008	18:25	-1.5	5	-1	44	0.9	-1.7	Drifting snow, slush-covered 5-
HI1802 -02	04-Apr-2008	20:19	-8	-50	-1	92	-10	N/A	Extensive, some ridging
HI1802 -04	06-Apr-2008	19:57	-8.9	8	2	57	-4.5	-1.7	Large, much ridging. Brown on
HI1802 -05	08-Apr-2008	18:52	-15.1	8.5	1	41	-13.8	-1.7	Very Large,wet on surface
HI1802 -06	12-Apr-2008	20:54	-4.2	3.5	13	53	-8	-1.7	Massive, with blowing snow
HI1802 -07	13-Apr-2008	17:52	-5.9	8	-3	23	-8.8	-1.7	Massive, snow-covered, flooded
HI1802 -08	15-Apr-2008	1:01	-4.6	17	0	85	-9.4	-1.7	Large, with deep snow
HI1802 -09	16-Apr-2008	20:20	-0.1	10	0	59	-1	-1.7	Large floe, wet to snow/ice
HI1802 -10	28-Apr-2008	22:35	-2.4	5	5.5	41	-2.5	-1.6	Continuous, with snow cover
HI1802 -11	29-Apr-2008	19:10	-2.5	7	3	69	-2.8	-1.7	Extensive, some ridges.
HI1802 -12	30-Apr-2008	17:55	-2.7	5	7	71	-3.8	-1.7	Extensive, with powdered snow
HI1902 -01	05-Apr-2009	19:58	-0.8	4	10	81	1.8	1.1	Consolidated, with ridges
HI1902 -02	07-Apr-2009	20:40	-2.6	17	0	71	-0.2	-1.71	Extensive, flat.
HI1902 -03	14-Apr-2009	18:38	-11.8	5	8	75	+0.6	-1.72	Massive, with snow.
HI1902 -04	16-Apr-2009	20:58	-4.9	3	1	41	-3.6	-1.71	Massive, ice wet in places
HI1902 -05	18-Apr-2009	19:59	-3.9	27	-2	86	-5.3	-1.72	Massive, ridged
HI1902 -06	20-Apr-2009	18:25		30	-2	87	-3.6	-1.63	Extensive, but rafted at ~140cm
HI1902 -08	01-May-2009	18:25	-0.6	16	-1	67	0.5	-1.65	Blocks~100m, snow, surrounded by
HI1902 -09	02-May-2009	19:51		4	1	44	1.2	-1.66	Massive, dome ridging
HI1902 -10	03-May-2009	20:24	-0.8	21	10	127	-0.6	-1.7	Massive, heavy ridges~150m ahead

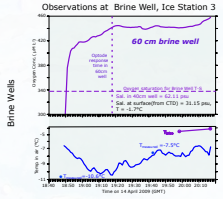
Photos from the Field

Ice Core and Brine Well Samples 2009

Ice Stations 03, 05, and 06. Top plots and image are ice core data. Bottom plots are brine well data. Net Community Production (NCP) = oxygen supersaturation x Redfield ratio (C:O2 117:170; Anderson, 1994*)



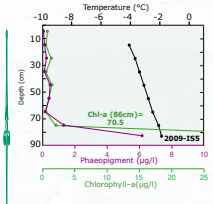


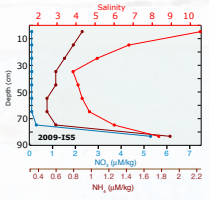


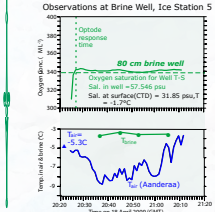
	IS03
air temp (°C)	-10.6
brine temp (°C)	-4.4
brine salinity	62.11
NCP* (µmol C/m^2)	523

* NCP calculated by integrating to depth of brine well

IS-03 was very cold with light snow cover, a steep ice-core temperature profile, and high NCP that was measured 20 cm above an intense algal layer at core bottom.



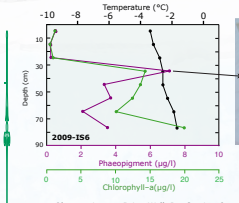


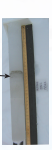


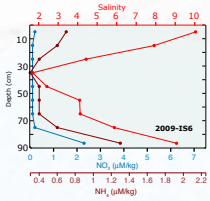
	IS05
air temp (°C)	-5.2
brine temp (°C)	-3.3
brine salinity	57.546
NCP* (µmd C/m^2)	29

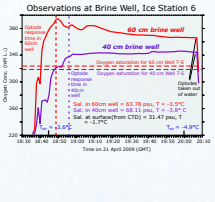
* NCP calculated by integrating to depth of brine well

IS-05 was warmer with thick snow, classic ice-core salinity and ammonium profiles, and depleted nitrate. NCP is extremely low, though still with a significant algal layer at bottom.







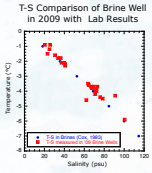


	IS06 40 cm	IS06 40 cm
air temp (°C)	-3.6	-3.6
brine temp (°C)	-3.8	-3.5
brine salinity	68.11	63.78
NCP* (µmd C/m^2)	81	261

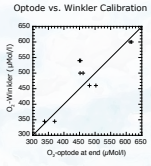
* NCP calculated by integrating to depth of brine well

IS-06 conditions are similar to IS-05 with warmer temperatures, thick snow and similar nutrient profiles. Most notable was a band of sediment and corresponding high pigment near 40cm. NCP was moderate with the 60cm brine well more than twice as high as the 40-cm brine well.

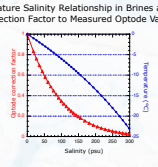
Analysis and Intrepretation



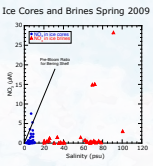
To verify our methods and results, we have plotted temperature vs. salinity from our brine well sampling (red) compared to laboratory values (blue) (Cox, 1983*).



At the end of each optode experiment, two Winkler samples were collected from the base of the brine well. The second sample value was always lower, suggesting that brine in the upper part of the well had degassed. This sampling was difficult in this environment.



Optode corrections are large, therefore it is important to make discrete measurements of oxygen to verify this data. Blue points are from lab results (Cox, 1983*). Red data points are the calculated correction factor from the optode



In the absence of biology, nitrate and salinity should be conserved. Nitrate is depleted in both ice and brine, but more so in the brine.

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*Anderson and Sarmiento (1994), Global Biogeochemical Cycles; Cox and Weeks (1983), Journal of Glaciology