<u>CRUISE REPORT FOR BERING STRAIT MOORING PROJECT 2007</u>

Russian Vessel SEVER ('North') – RUSALCA2007

Nome, 27th August 2007 – Nome, 5th September 2007

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Chief Scientist: *Terry Whitledge, University of Alaska, Fairbanks (UAF), USA*
Lead for Mooring Team: *Rebecca Woodgate, UW, USA*

As part of the joint US-Russian RUSALCA (Russian US Long-term Census of the Arctic Ocean) Program, a team of US and Russian scientists undertook an oceanographic cruise in summer 2007 on board the Russian vessel 'Sever'. The cruise started in Petropavlosk, Russian Federation, on 22nd August. It arrived in Nome, USA, on the evening of 26th August. There, it picked up the US science team and equipment on 27th August, and sailed for the Bering Strait on 28th August. A major objective of the cruise was mooring work in the Bering Strait region (recovery of 7 moorings, deployment of 8 moorings), related high resolution CTD sections with nutrient sampling, and some benthic grab work. This cruise report concerns the mooring and physical CTD work - for details of other programs, please contact the Chief Scientist.

Cruise Participants

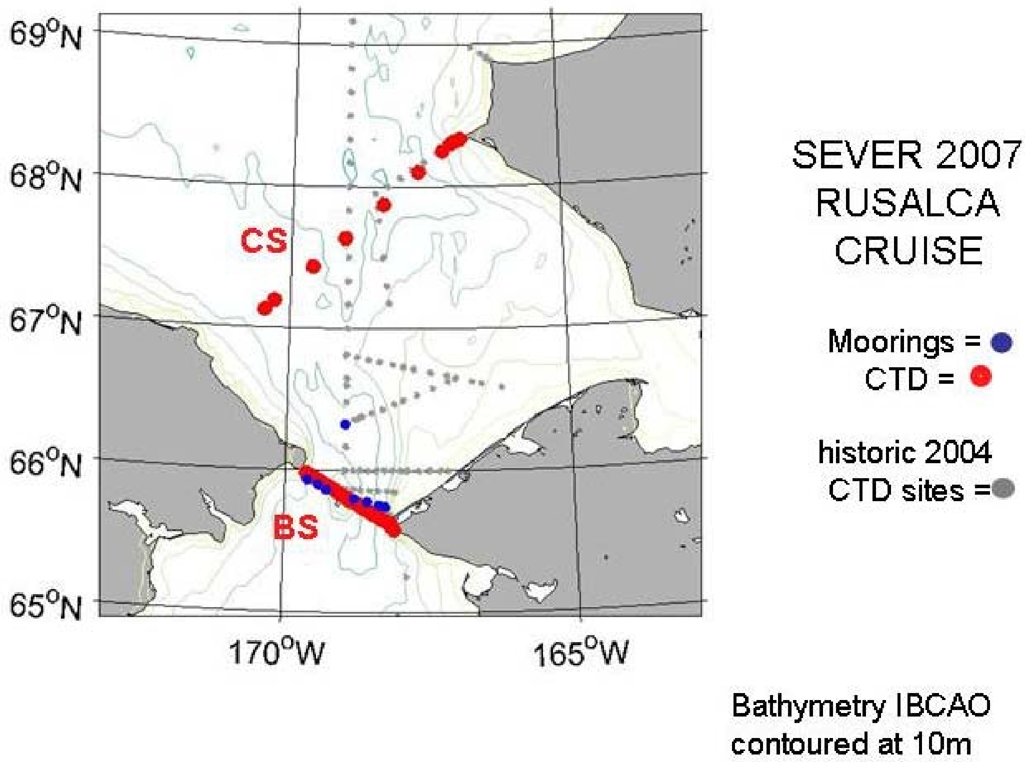
- US

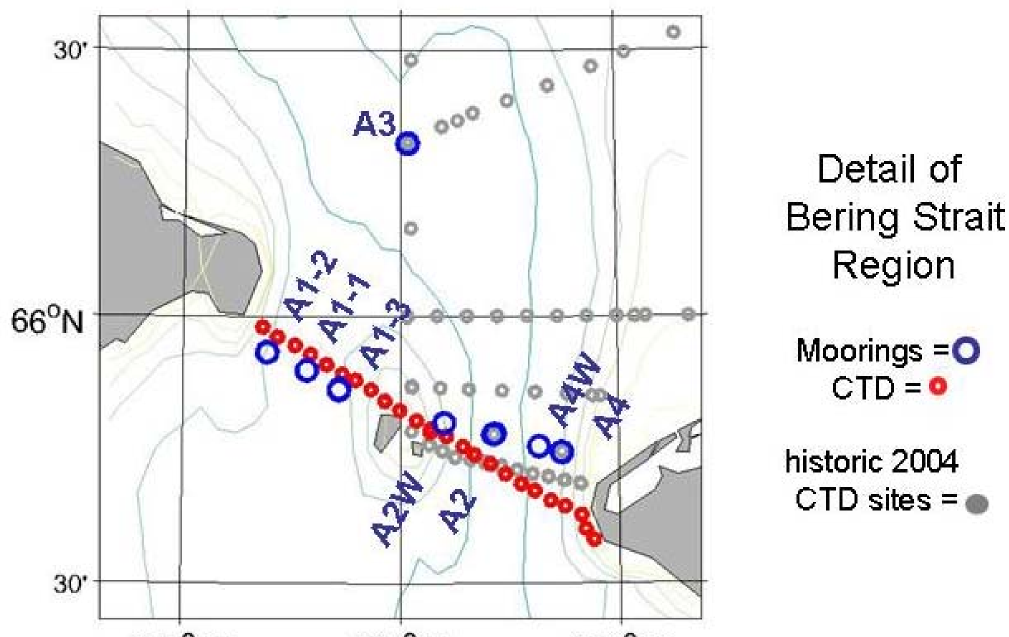
1. Terry Whitedge (M), UAF, USA – *Chief Scientist, nutrients, moored nutrient sampler*
2. Kevin Wood (M), NOAA/UW – *Science Liaison*
3. Rebecca Woodgate (F), UW – *Moorings*
4. Jim Johnson (M), UW – *Moorings*

- Russian

5. Vladimir Smolin (M), SRNHI, RF – *Science Liaison and translator*
6. Igor Lukashenko (M), Pacific Hydrographic Service- *Vladimir's assistant*
7. Konstantin Bachinsky (M), Pacific Oceanography Inst, RF
8. Valerian Golavsky (M), Arctic and Antarctic Research Institute (AARI), RF – *Moorings*
9. Vladislav Djurinsky (M), Zoological Institute (ZIN) , RF – *Benthic work*
10. Vladislav Potin (M), ZIN, RF – *Benthic work*
11. Igor Karnaushevskiy (M), RF Ministry of Defense

Cruise Map of Stations relevant to UW Mooring work





SEVER 2007 RUSALCA mooring (blue dots) and CTD (red dots) locations. The Bering Strait (BS) line was run contiguously from east to west with a 7 hour break at the Diomede Islands in the centre of the strait (one station was repeated after this break). The Cape Serdtse Kamen to Point Hope (CS) line was run contiguously from east to west. Small grey dots mark CTD stations from the Bering Strait Alpha Helix cruise in 2004 [Woodgate, 2004]. Contours from IBCAO every 10 m.

Cruise Time-schedule

Friday 24th Aug 2007	*mooring team arrive Nome.*
Saturday 25th Aug 2007	*prep mooring gear on shore in Nome.*
Sunday 26th Aug 2007	*prep mooring gear on shore in Nome, Sever docks in Nome in evening.*
Monday 27th Aug 2007	*loading, and mooring gear prep.*
Tuesday 28th Aug 2007	*cast off 8am, wait for freight, depart for Bering Strait pm, arrive at mooring site A1-3 ~ 10pm local time, recover A1-3-06.*
Wednesday 29th Aug 2007	*recover A1-1-06, fog at A1-2-06, deploy A1-1-07, wait out fog at A1-2-06, recover A1-2-06, deploy A1-3-07.*
Thursday 30th Aug 2007	*deploy A1-2-07, recover A2-06, recover A4-06, steam to A3-06.*
Friday 31st Aug 2007	*recover A3-06, deploy A3-07, deploy A2-07, deploy A2W-07, shelter over night on west side of strait.*
Saturday 1st Sep 2007	*deploy A4W-07, deploy A4-07, prep CTD gear, run half of BS line from east to the Diomede Islands (station BS12).*
Sunday 2nd Sep 2007	*continue BS line after 7hr break, redoing BS12, download data.*
Monday 3rd Sep 2007	*run CS line with mud sampling from east to west, not quite finishing line by midnight. Leave for Nome around midnight.*
Tuesday 4th Sep 2007	*data transfer and backup, packing, dock Nome ~8pm.*
Wednesday 5th Sep 2007	*offload, Sever leaves for Petropavlosk ~ 3pm, mooring team leaves Nome.*

Total: 8 days at sea,

Background to mooring and CTD program

Moorings: The moorings serviced on this cruise are part of a multi-year time-series (started in 1990) of measurements of the flow through the Bering Strait. This flow acts as a drain for the Bering Sea shelf, dominates the Chukchi Sea, influences the Arctic Ocean, and can be traced across the Arctic Ocean to the Fram Strait and beyond. The long-term monitoring of the inflow into the Arctic Ocean via the Bering Strait is important for understanding climatic change both locally and in the Arctic. Data from 2001 to 2004 suggest that heat and freshwater fluxes are increasing through the strait [*Woodgate et al.*, 2006]. The work completed this summer should tell us if this is a continuing trend.

An overview of the Bering Strait mooring work (including access to mooring and CTD data) is available at http://psc.apl.washington.edu/BeringStrait.html.

Six moorings were recovered on this cruise.

-- Three moorings (A2-06, A3-06, A4-06 in US waters) were deployed under an Alaskan Ocean Observing System (AOOS, http://www.aoos.org) grant to *Woodgate and Weingartner*.

-- The other three moorings (A1-1-06, A1-2-06, A1-3-06) were a joint US-Russian (*Weingartner and Lavrenov*) project, part of the NOAA-led RUSALCA (Russian-American Long-term Census of the Arctic, http://www.arctic.noaa.gov/aro/russian-american/) program.

A total of 8 moorings (in Russian waters – A1-1-07, A1-2-07, A1-3-07, in US waters – A2W-07, A2-07, A4W-07, A4-07, A3-07) were deployed in another joint US-Russian venture supported by RUSALCA and by NSF-OPP (*Woodgate, Weingartner, Whitledge, Lindsay, NSF-OPP-ARC-0632154*).

This is the highest resolution array ever deployed in the Bering Strait, (see map above). Three moorings were deployed across the western (Russian) channel of the strait (from west to east - A1-2-07, A1-1-07, A1-3-07). Four moorings were deployed across the eastern (US) channel of the strait (from west to east - A2W-07, A2-07, A4W-07, A4-07). A final 8th mooring (A3-07) was deployed ca. 35 nm north of the strait at a site proposed as a "climate" site, hypothesized to measure a useful average of the flow through both channels [*Woodgate et al.*, 2007]. Testing this hypothesis is a main aim of this work. All moorings measure water velocity, temperature and salinity near bottom (as per historic measurements). Additionally, 6 of the 8 moorings (i.e., all eastern channel moorings, the climate site mooring A3, and the mooring central in the western channel) also carried upward-looking ADCPs (measuring water velocity in 1-2 m bins up to the surface, ice motion, and medium quality ice-thickness) and ISCATS (upper level temperature-salinity-pressure sensors in a trawl resistant housing designed to survive impact by ice keels). Bottom pressure gauges were also deployed on the moorings at the edges of the eastern channel (A2W-07 and A4-07). (The preferred locations – A1-2-07 and A4-07 – were unavailable.) Two moorings (A2-07, central eastern channel; and A1-2, western part of western channel) also carried ISUS nitrate sensors and optical sensors for fluorescence and turbidity. Recovered moorings in the central eastern channel and at the climate site (A2-06 and A3-06) carried Upward Looking Sonars (ULSs) measuring high-quality sea-ice thickness. These instruments were not redeployed. For a full instrument listing, see the table below.

This coverage should allow us to assess year-round stratification in the strait and also to study the the physics of the Alaskan Coastal Current, a warm, fresh current present seasonally in the eastern channel, and suggested to be a major part of the heat and freshwater fluxes [*Woodgate and Aagaard*, 2005; *Woodgate et al.*, 2006]. The current meters and ULSs allow the quantification of the movement of ice and water through the strait. The nutrient sampler, the transmissometer and fluorometer time-series measurements should advance our understanding of the biological systems in the region.

CTD: The moorings are supported by annual CTD sections, with water samples for nutrients. The best coverage achieved to date was in 2004 from the Alpha Helix, although that cruise was limited to US waters. For reference, the 2004 Helix stations are indicated as small grey dots on the map above. The most important section is the high resolution CTD section run across the Bering Strait (named BS). This was completed in 2007 and included both US and Russian waters. There are two other lines which we attempt to maintain during this cruise. One (named CS) is a coast-to-coast section with high resolution near the coasts running from Cape Serdtse Kamen (RF) to Point Hope (US) – part of that line was completed during this 2007 cruise. The other is a high resolution line through mooring site A3 – this line was not taken during this 2007 cruise.

International links: Maintaining the time-series measurements in Bering is important to several national and international programs, e.g. NSF's Freshwater Initiative (FWI) and Arctic Model Intercomparison Project (AOMIP), and the international Arctic SubArctic Ocean Fluxes (ASOF) program. The mooring work also supports regional studies in the area, by providing key boundary conditions for the Chukchi Shelf/Beaufort Sea region; a measure of integrated change in the Bering Sea, and an indicator of the role of Pacific Waters in the Arctic Ocean. Furthermore, the Bering Strait inflow may play a role in Arctic Ocean ice retreat and variability (especially in the freshwater flux) is considered important for the Atlantic overturning circulation and possibly world climate [*Woodgate et al.*, 2005].

Mooring Operations during 2007 Sever cruise

Despite fog and certain challenges (see below), the mooring work was successfully completed. The acoustic hydrophone was deployed via the window in the aft lab. Once the mooring was released, the ship brought the floating mooring along the port side, where it was grappled by hook and brought aboard onto the foredeck using the Sever's substantial forward crane. The following issues are noteworthy:

1) On two moorings (A3-06 and A4-06), barnacles jammed the mechanism on the releases. In both cases, this problem was limited to one release of the double releases used, and thus the mooring was successfully released with the second release. In both cases, the drop link remained attached to the jammed release and was only freed on deck, in the A3 case by tugging the release and in the A4 case by chipping at the barnacle. These moorings had been in the water since July 2006, i.e., through two growing seasons). To prevent this, ***antifouling should be used on critical parts of the release mechanism.***

2) Several of the releases were found to require a special deckset, since a manufacturer's error made the acoustic circuits temperature dependent. With this deckset, codes normally starting with 4 can be retuned by changing the initial digit of the code. All recoveries except A1-3 (which had an older release) required this special deckset. For successful communication, by trial and error, the following pattern for the initial digit was found (relating somewhat to temperature) – A1-1-06 required 8, A1-2-06 required 8, A2-06 required 8, A4-06 required 9, A3-06 required 8 or 9 depending on the release. It was necessary to redeploy some of these releases – thus, ***for 2008, moorings A1-2-07 and A1-3-07 will require the special deckset.***

3) Release sn 32426 (recovered from A1-2-06 and redeployed on A1-2-07) was reported with the wrong enable code. The correct code is 474043 (with the first digit altered to 8 for the temperature dependence problem discussed above).

4) Although the weather was in general calm, fog delayed mooring recoveries in the western parts of the western channel, especially A1-2-06. It would be interesting to relate this to water properties.

5) The moorings in the eastern channel and at the northern site were deployed last summer (as compared to the autumn deployment of the western channel moorings) and showed significantly more biofouling than instrumentation in the western channel. This likely reflects the longer deployment period, and possibly warmer waters. Barnacles up to 3 cm were common on these moorings – barnacle growth has becoming the dominant form of biofouling in the strait in recent years. Unusually small barnacles were also found on the lower parts of the release mechanisms. Other than impeding the release mechanism, it does not yet seem that the data is degraded by the biofouling. In all cases, salinity cells remained clear. A future recommendation is to use anti-fouling measures on the releases.

Very preliminary analysis of the mooring data show very good data return, apart from one flooded microcat (temperature, salinity instrument) on the eastmost mooring (A4). Some instruments – ULSs (Upward Looking Sonars, measuring ice thickness), and the AARI current meter and CTD – could not be downloaded at sea, but are expected to be read on return to their institutes.

The data show the usual large annual cycle in temperature and salinity. Many of the usual features are present, i.e. high variability in autumn, generally with freshening and cooling; salting (at the freezing point) in the winter; freshening and warming in the spring [*Woodgate et al.*, 2005]. Interestingly in the spring 2007 warming, A2 is distinctly colder than the western channel data – this unusual situation requires further investigation, as do the strong warming events at A2 in the warmest period of 2006. A more detailed analysis is necessary to seek for interannual signals. Also noteworthy is the persistence of northward flow for the last ~ 3 months of the record (i.e. summer 2007). The flow through the strait is believed to be driven by a sea-level difference between the Pacific and the Arctic, which drives a flow northwards towards the Arctic. Local winds (usually southward in the annual mean) tend to oppose this flow and may reverse it on timescales of days [*Woodgate et al.*, 2005b]. However, the recovered data suggest that reversals have been unusually uncommon this summer. (This is consistent with verbal reports from Nome about the extreme clemency of the weather.) Since the variability of northward fluxes of heat and freshwater are dominantly dependent on the variability of the volume transport [*Woodgate et al.*, 2006], this may imply further increases in this fluxes, with possible implications for the Arctic and beyond.

Details of mooring positions and instrumentation are given below, along with schematics of the moorings, photos of the mooring fouling and preliminary plots of the data.

CTD Operations during 2007 Sever cruise

Due to clearance issues, the 2007 cruise sailed without a UAF mooring technician. Lack of personnel delayed the mooring and limited the CTD sections which could be taken. Of the proposed 3 CTD lines, one (the Bering Strait line BS) was completed from east to west with a 7hr break during the run, and one (the Cape Serdtse Kamen line CS) was roughly ¾ completed from east to west.

Two internally sampling CTDs (an SBE25 and an SBE19) were deployed strapped together from the upper deck winch on the starboard aft deck. In addition CTD, the SBE 19 also recorded oxygen, fluorescence, and PAR. At each station up to three bottle samples were taken – nominally surface (by bucket), bottom and midwater column (by niskin). The bottom niskin was suspended ~ 2 m below the CTD on a bottom trip mechanism. The mid-water bottle was attached to the wire during the downcast and closed by messenger when the cast was estimated to be at the bottom. Bottom depths were estimated from the bridge depth sounder. On station 19, the CTD hit bottom, but mostly the cast did not appear to hit bottom. The table below gives CTD positions, LOCAL times (for GMT, add 8 hrs), estimated depth from the bridge depth sounder, and depth to which the CTD was lowered (calculated by wire out). The bottom bottle is likely from ~ 2 m deeper than the maximum CTD pressure (likely the MaxP here, but this should be checked against the CTD records). An estimate of the mid-water bottle depth is also given from wire out. This could also be extracted from the CTD data since the CTD cast was stopped to attach and remove the bottle.

Preliminary CTD sections are given below. These should be treated with caution as they are (a) blindly 1-m binned and (b) based on pre-calibrations.

Table of Bering Strait Mooring Positions (US GPS) and Instrumentation

ID	LATITUDE (N)	LONGITUDE (W)	WATER DEPTH /m (corrected)	INST.
RECOVERIES				
- Russian EEZ				
A1-1-06	65 54.000	169 25.783	50.5	ADCP, SBE37
A1-2-06	65 55.982	169 36.856	50.5	AARI, ISUS, SBE/TF, RCM9T
A1-3-06	65 51.764	169 16.956	50.5	AARI, RCM7, SBE37
- US EEZ				
A2-06	65 46.775	168 34.471	56	ULS, RCM9LW SBE/TF, ISUS
A3-06	66 19.543	168 58.009	58	ULS, RCM9LW SBE37
A4-06	65 44.73	168 15.67	49	ADCP, SBE37
DEPLOYMENTS				
- Russian EEZ				
A1-1-07	65 53.994	169 25.877	52	ISCAT, ADCP, SBE37
A1-2-07	65 56.019	169 36.763	53.3	ISUS, SBE/TF, RCM9T
A1-3-07	65 51.908	169 16.927	49	AARI, RCM9LW, SBE37
- US EEZ				
A2W-07	65 48.07	168 47.95	52	ISCAT, ADCP, SBE16, BPG
A2-07	65 46.87	168 34.07	56	ISCAT, ADCP, SBE/TF, ISUS
A4W-07	65 45.42	168 21.95	54	ISCAT, ADCP, SBE16
A4-07	65 44.77	168 15.77	50	ISCAT, ADCP, SBE16, BPG
A3-07	66 19.60	168 57.92	58	ISCAT, ADCP, SBE37

AARI = AARI Current meter and CTD
ADCP = RDI Acoustic Doppler Current Profiler
BPG=Seabird Bottom Pressure Gauge
ISCAT = near-surface Seabird TS sensor in trawl resistant housing, with near-bottom data logger
ISUS= Nutrient Analyzer
RCM7 = Aanderaa Mechanical Recording Current Meter
RCM9LW = Aanderaa Acoustic Recording Current Meter
RCM9T = Aanderaa Acoustic Recording Current Meter with Turbidity
SBE/TF = Seabird CTD recorder with transmissometer and fluorometer
SBE16 = Seabird CTD recorder
SBE37 = Seabird Microcat CTD recorder
ULS = APL Upward Looking Sonar

Table of Bering Strait CTD Positions (US GPS)

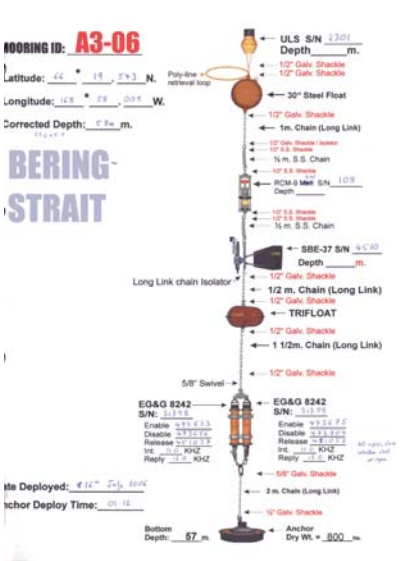
SEVER 2007 CTD POSITIONS - *recreated from written logs, start and endpositions also available*

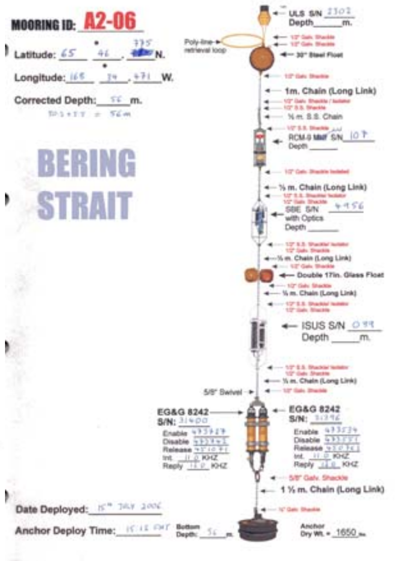
#	**Name**	**US Date** *year*	*mon*	*day*	**Time** *in*	**LOCAL** *bottom*	*out*	**Lat (N)** *Deg*	*min*	**&Long (W) at Bot** *Deg*	*min*	**WD** */m*	**MaxP** */m*	**MB** */m*
1	BS24	2007	9	1	1828	1834	1836	65	34.897	168	07.09	25	*23*	*13*
2	BS23	2007	9	1	1858	1902	1904	65	36.12	168	009.308	31	*26*	*11*
3	BS22	2007	9	1	1940	1942	1944	65	37.68	168	10.399	33	*29*	*14*
4	BS21	2007	9	1	*2042**	2044	2046	65	38.66	168	14.905	43	*39*	*19*
5	BS20	2007	9	1	2109	2113	2115	65	39.305	168	18.839	46	*42*	*19*
6	BS19	2007	9	1	2149	2153	2204	65	40.438	168	23.156	53	*49*	*24*
7	BS18	2007	9	1	2225	2229	2231	65	41.212	168	26.877	53	*49*	*24*
8	BS17	2007	9	1	2254	2258	2300	65	42.316	168	31.199	56	*52*	*27*
9	BS16	2007	9	1	2326	2330	2332	65	43.491	168	35.273	53	*49*	*24*
10	BS15	2007	9	1	2357	0001	0003	65	44.48	168	39.683	53	*49*	*24*
11	BS14	2007	9	2	0028	0032	0034	65	45.426	168	42.797	52	*48*	*23*
12	BS13	2007	9	2	0101	0106	0108	65	46.593	168	47.359	52	*48*	*23*
13	BS12	2007	9	2	0126	0130	0132	65	47.406	168	51.667	46	*42*	*17*
14	BS12	2007	9	2	0926	0929	0931	65	47.038	168	51.714	46	*42*	*17*
										redone after 2am-9ambreak				
15	BS11	2007	9	2	0952	0956	0958	65	48.338	168	55.559	47	*43*	*18*
16r	BS10	2007	9	2	1029	1033	1035	65	49.474	169	00.206	41	*38.5*	*18*
17r	BS9	2007	9	2	1057	1101	1102	65	50.549	169	04.304	46	*43.5*	*18*
18r	BS8	2007	9	2	1124	1127	1129	65	51.832	169	08.155	46.5	*43*	*19*
19r	BS7	2007	9	2	1241	1245	1247	65	52.903	169	12.426	49	*45*	*21*
										hit bottom, brought up 2 sea-urchins				
20r	BS6	2007	9	2	1311	1315	1317	65	53.577	169	16.039	49	*45*	*21*
										strumming, significant wire angle				
21r	BS5	2007	9	2	1344	1347	1349	65	54.653	169	20.429	50	*47*	*23*
										strumming, green/brown water				
22r	BS4	2007	9	2	1420	1424	1426	65	55.77	169	24.86	53	*49*	*25*
										water very brown				
23r	BS3	2007	9	2	1454	1458	1500	65	56.787	169	29.151	52.5	*49*	*25*
									lots of propwash, discharge off deck, foggy					
24r	BS2	2007	9	2	1537	1541	1542	65	57.721	169	33.983	51	*47*	*23*
										foggy				
25r	BS1	2007	9	2	1606	1610	1612	65	58.837	169	38.073	50	*46*	*22*
										foggy, but warmer and calmer				
26M	CS19	2007	9	3	1059	1102	-1104	68	19.975	166	52.112	27.5	*24*	-
27	CS18	2007	9	3	1129	1132	1133	68	19.047	166	57.801	34.5	*31*	-
										jellyfish				
28M	CS17	2007	9	3	1155	1159	1200	68	18.075	167	02.69	39	*36*	*16*
29	CS16	2007	9	3	1251	1255	1257	68	15.029	167	11.927	44.5	*41*	*17*
30M	CS14	2007	9	3	1421	1425	1427	68	6.126	167	39.85	53	*48*	*24*
31M	CS12	2007	9	3	1634	1639	1641	67	52.501	168	18.799	57	*54*	*30*
32rM	CS10	2007	9	3	1854	1858	1900	67	38.088	169	00.782	51	*47*	*23*
33rM	CS8	2007	9	3	2054	2058	2100	67	25.976	169	35.985	50	*46*	*22*
34rM	CS6	2007	9	3	2313	2317	2319	67	11.448	170	17.163	47.5	*44*	*20*
35rM	CS5.5	2007	9	4	0001	0005	0007	67	7.646	170	27.585	46	*42*	*19*

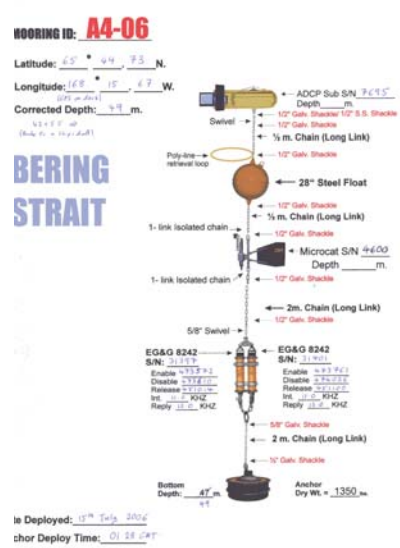
M=Mud samples were taken by Russian team. WD=water depth estimated by bridge. MaxP=distance CTD lowered from surface (bottom bottle ~ 2m deeper than this); MB=wire-out estimate of depth of middle bottle. *=estimated. r=in Russian EEZ.

SCHEMATICS OF MOORING RECOVERIES

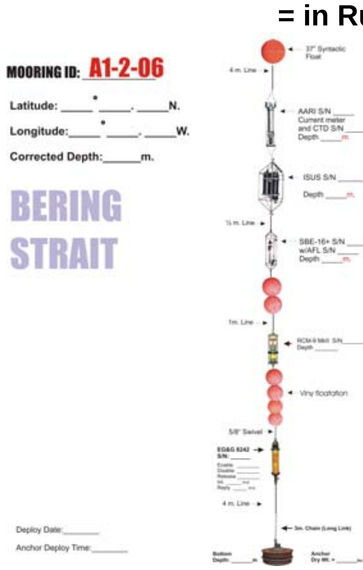
= in US waters (AOOS moorings)

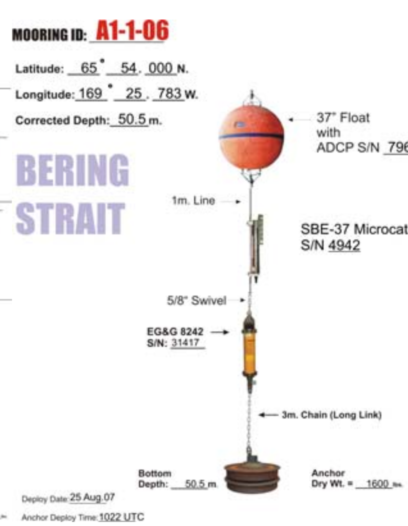


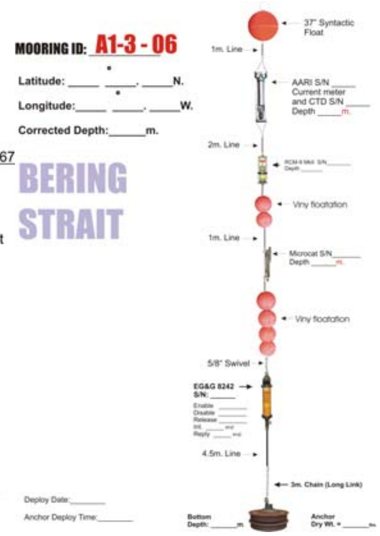




= in Russian waters (RUSALCA moorings)

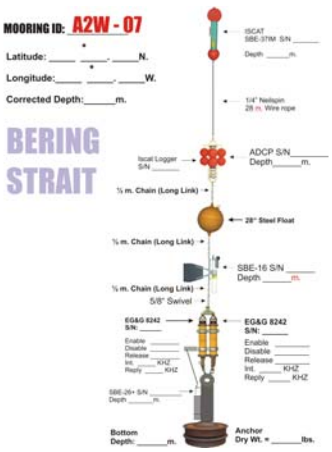


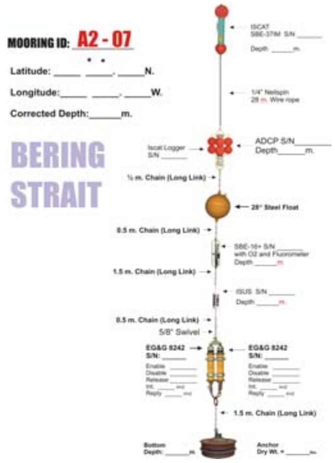


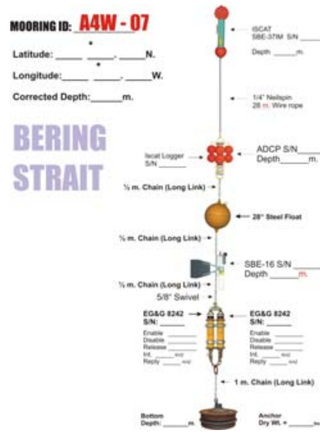


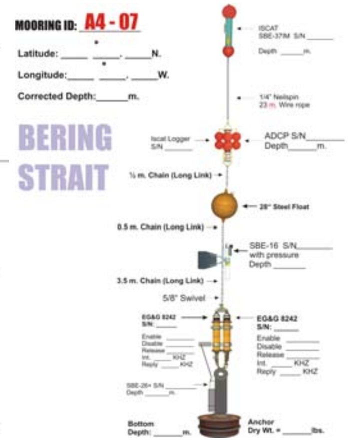
SCHEMATICS OF MOORING DEPLOYMENTS

= in the eastern channel of the Bering Strait

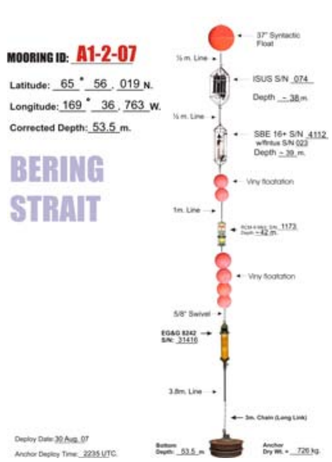


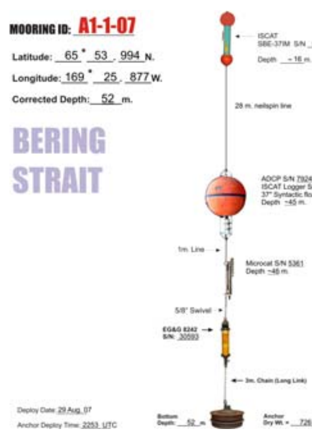


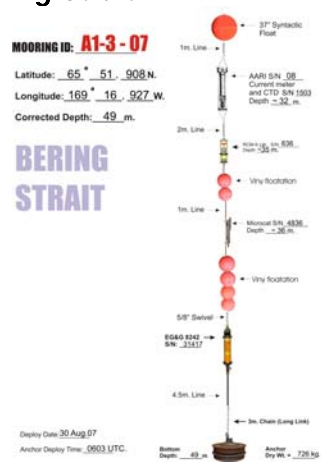




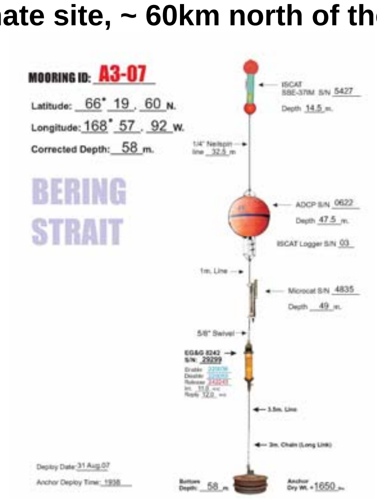
= in the western channel of the Bering Strait



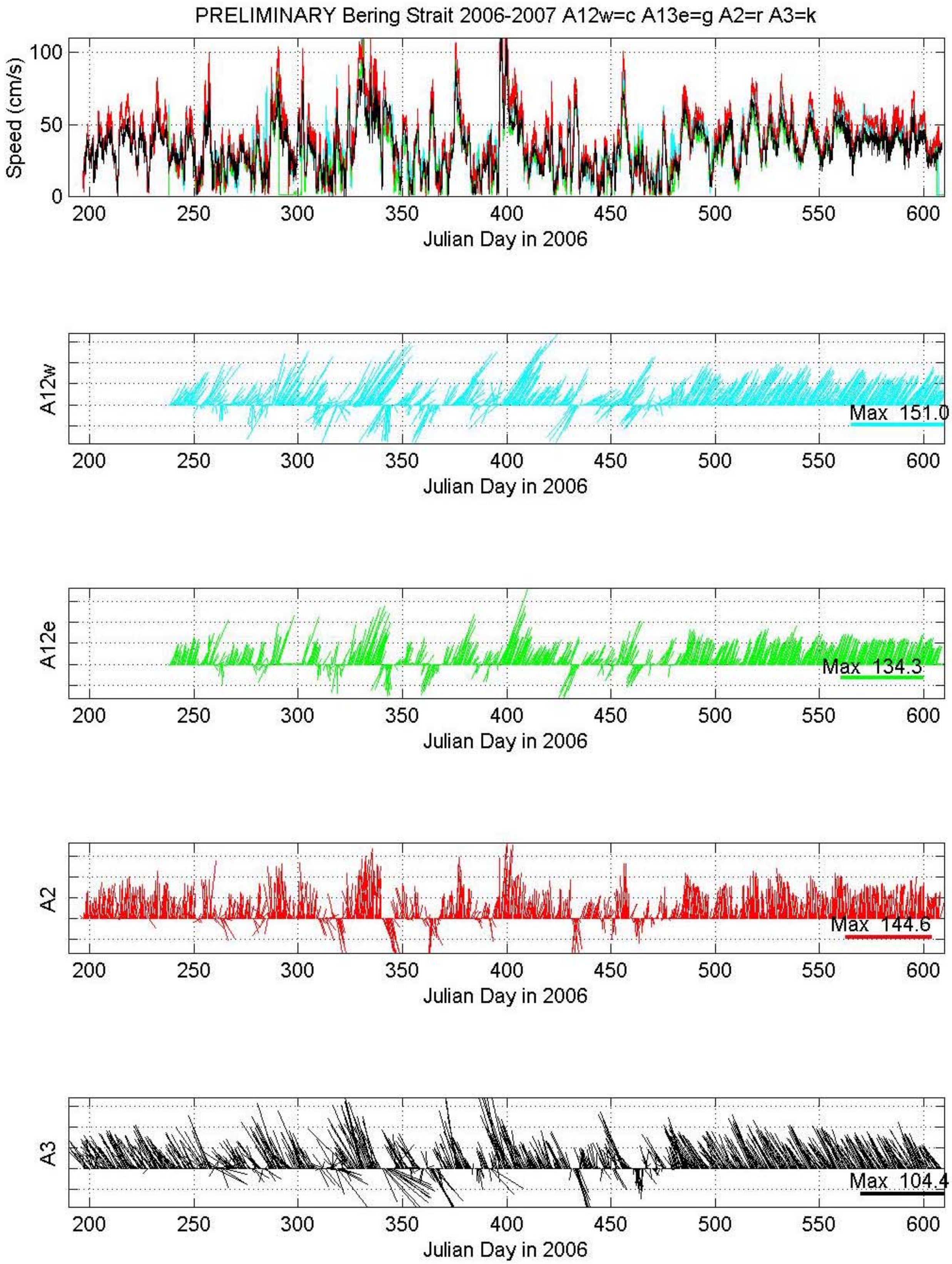




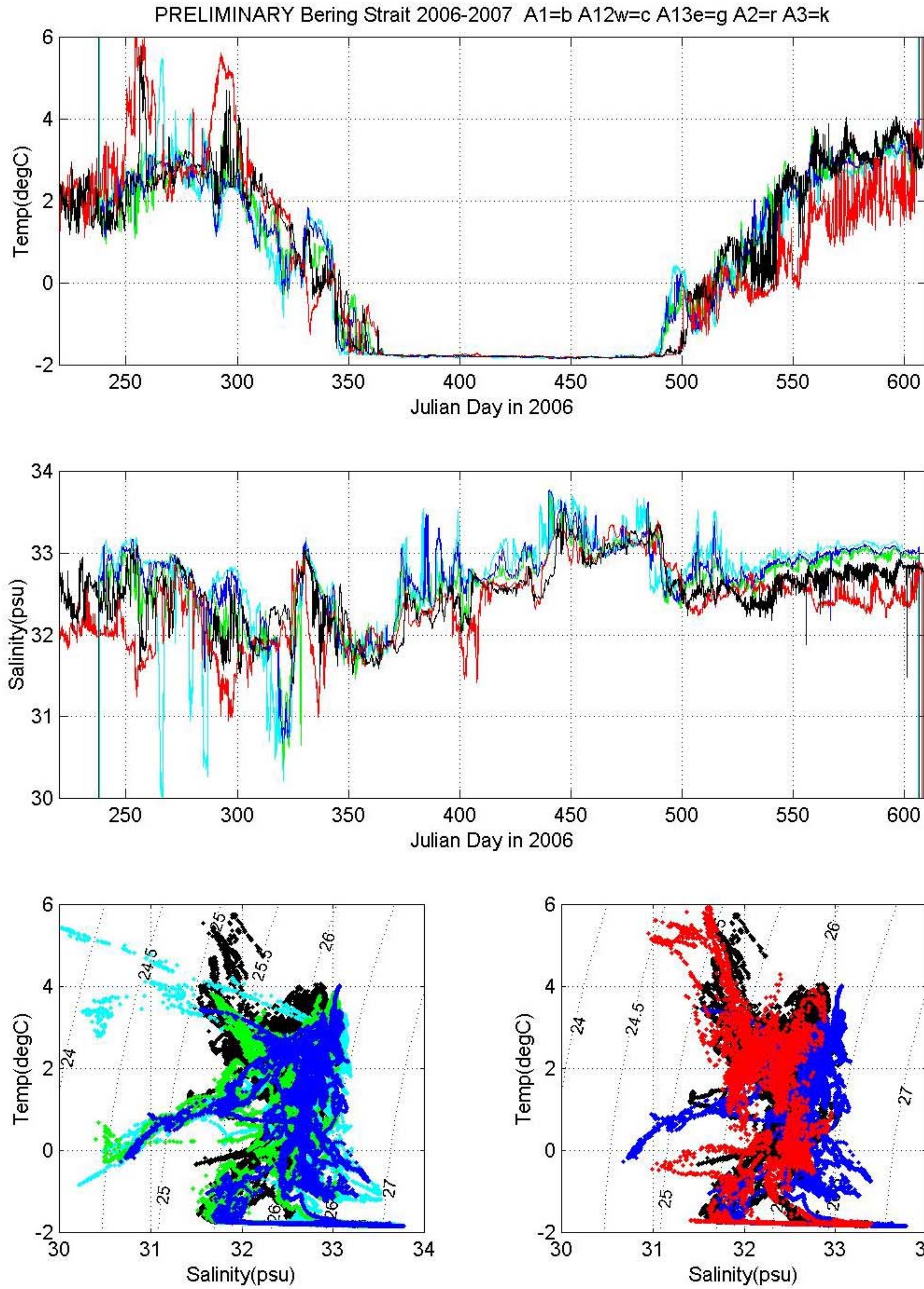
= at the climate site, ~ 60km north of the Strait



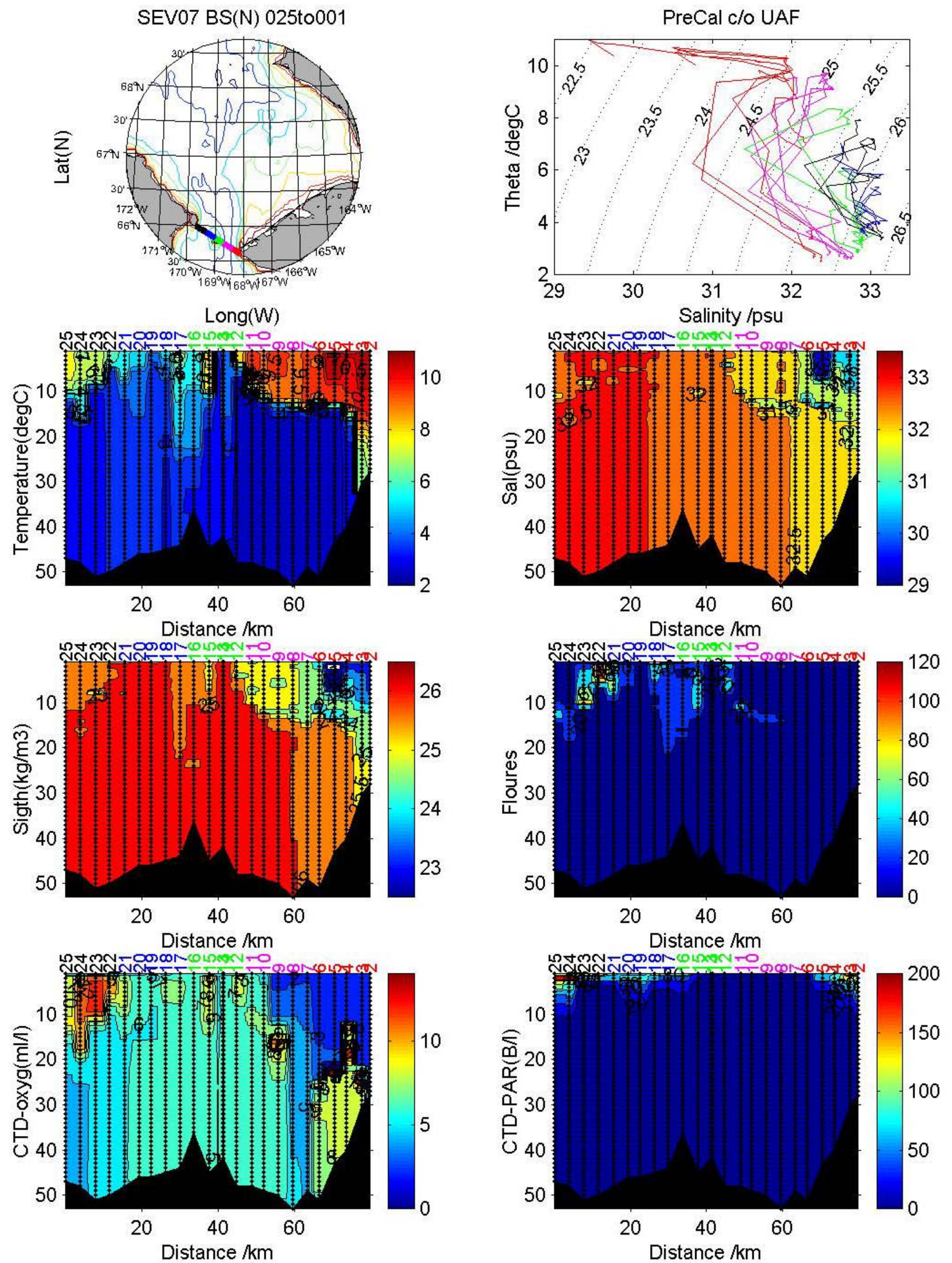
PRELIMINARY CURRENT METER RESULTS



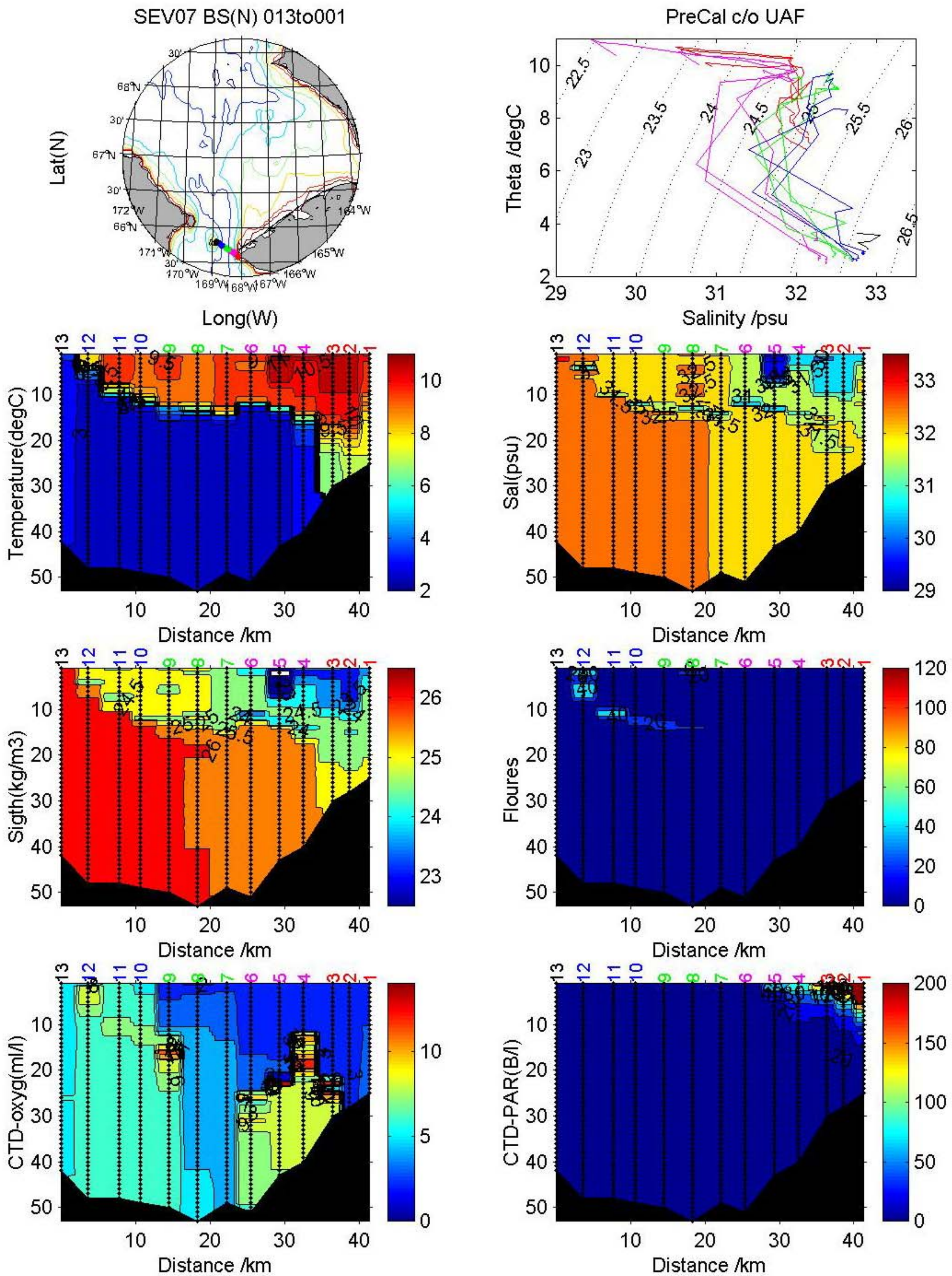
PRELIMINARY SEACAT RESULTS



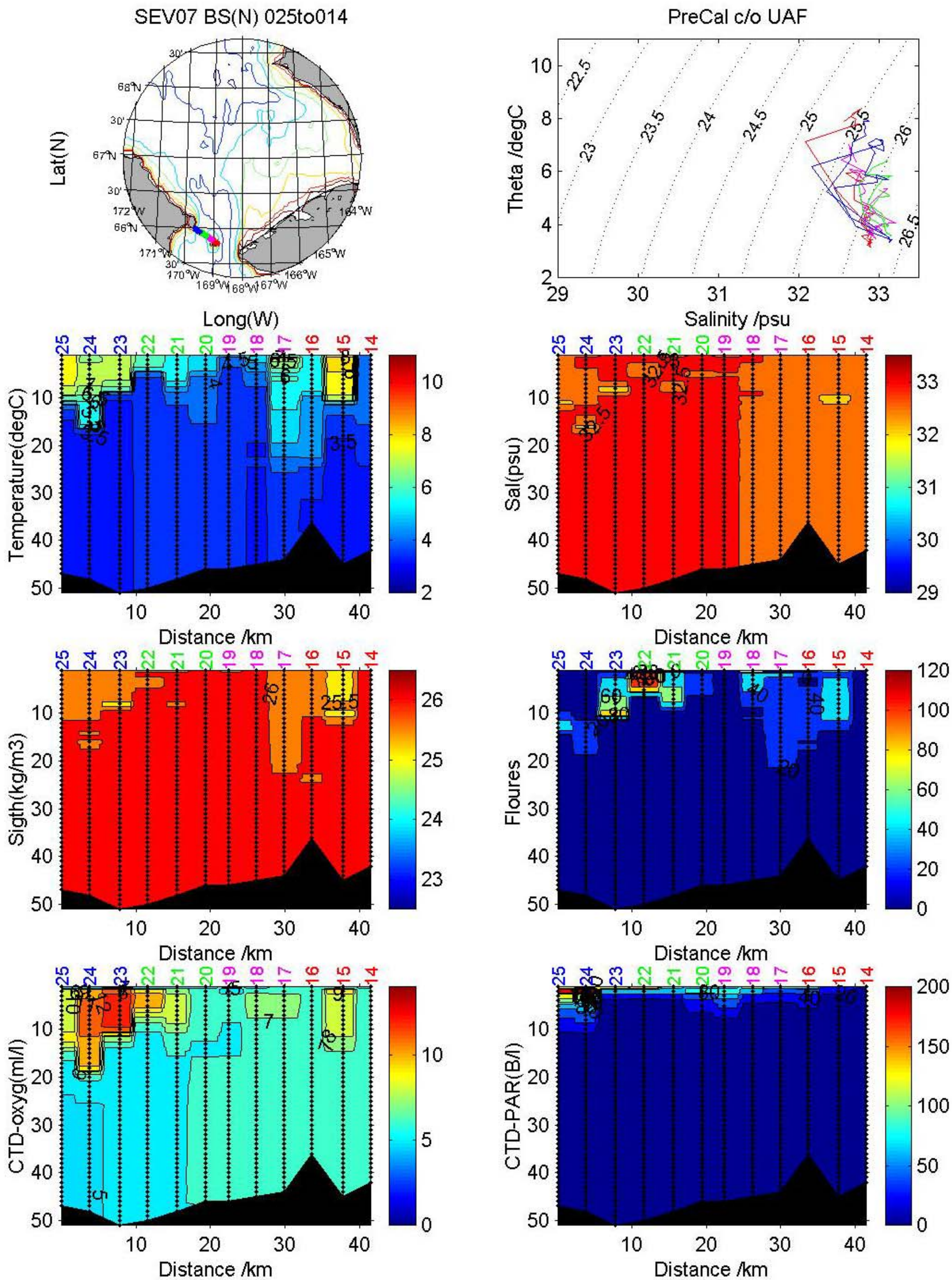
PRELIMINARY CTD SECTIONS - BERING STRAIT (whole section, except cast 1)



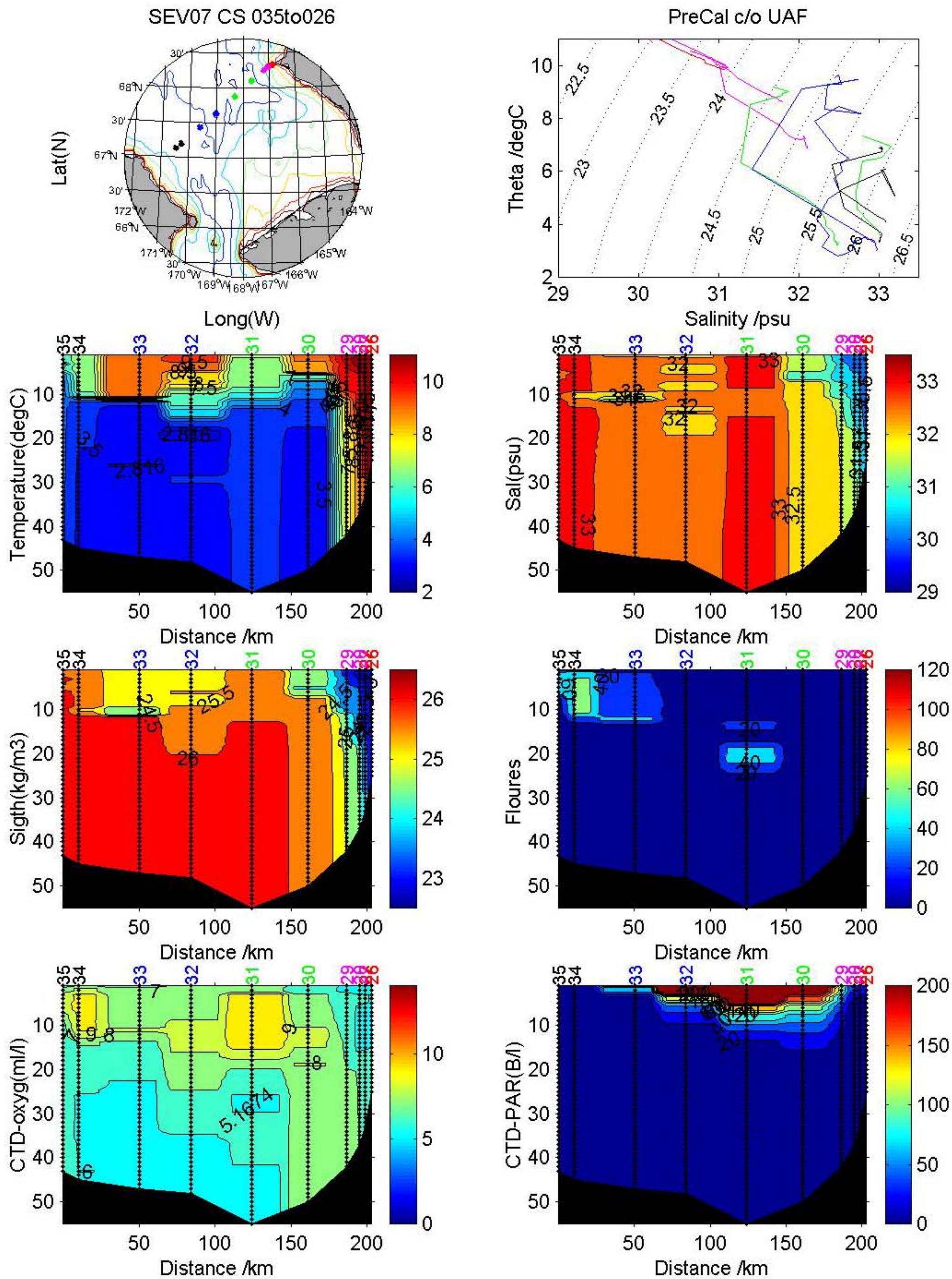
PRELIMINARY CTD SECTIONS - BERING STRAIT (eastern channel)



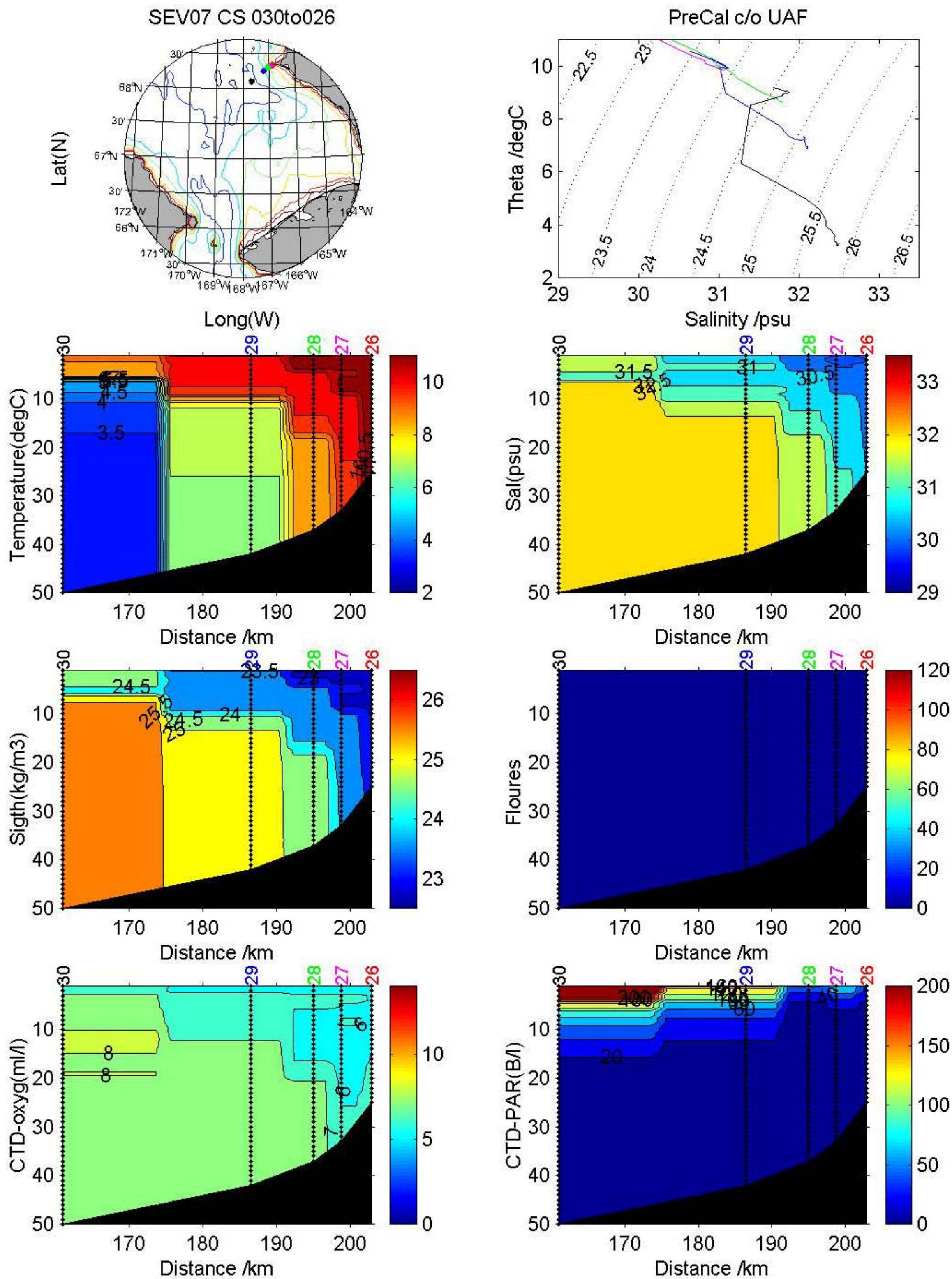
PRELIMINARY CTD SECTIONS - BERING STRAIT (western channel)



PRELIMINARY CTD SECTIONS - CAPE SERDTSE KAMEN to POINT HOPE LINE



PRELIMINARY CTD SECTIONS - CAPE SERDTSE KAMEN to POINT HOPE LINE (eastern end)



REFERENCES

Woodgate, R. A. (2004), Alpha Helix HX290 Cruise Report, Bering Strait Mooring Cruise August-September 2004, available at http://psc.apl.washington.edu/BeringStrait.html, University of Washington, Seattle.

Woodgate, R. A., and K. Aagaard (2005), Revising the Bering Strait freshwater flux into the Arctic Ocean, *Geophys. Res. Lett.*, *32*, L02602, doi:10.1029/2004GL021747.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner (2005), Monthly temperature, salinity, and transport variability of the Bering Strait throughflow, *Geophys. Res. Lett.*, *32*, L04601, doi:10.1029/2004GL021880.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner (2006), Interannual Changes in the Bering Strait Fluxes of Volume, Heat and Freshwater between 1991 and 2004, *Geophys. Res. Lett.*, *33*, L15609, doi:10.1029/2006GL026931.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner (2007), FIRST STEPS IN CALIBRATING THE BERING STRAIT THROUGHFLOW: Preliminary study of how measurements at a proposed climate site (A3) compare to measurements within the two channels of the strait (A1 and A2). 20 pp, University of Washington.