PASSIVE ACOUSTIC DETECTION AND MONITORING OF ENDANGERED WHALES IN THE ARCTIC (BEAUFORT, CHUKCHI)

&

ECOSYSTEM OBSERVATIONS IN THE CHUKCHI SEA: BIOPHYSICAL MOORINGS AND CLIMATE MODELING

Catherine L. Berchok[1], Ph.D.
Phillip J. Clapham[1], Ph.D.
Jessica Crance[1], M.S.
Phyllis Stabeno[2], Ph.D.
Jeff Napp[3], Ph.D.
James Overland[2], Ph.D
Sue E. Moore[4], Ph.D.

[1]National Marine Mammal Laboratory
Alaska Fisheries Science Center

[2]Pacific Marine Environmental Laboratory

[3]Resource Assessment and Conservation Engineering Divison
Alaska Fisheries Science Center

[4]National Marine Fisheries Service
Office of Science & Technology

7600 Sand Point Way NE
Seattle, WA 98115

Quarterly Report

Submitted to Minerals Management Service

under Inter-Agency Agreement Number M09PG00016 (AKC 083)
July 2010

Executive Summary

Through an Inter-Agency agreement (IA) between the National Marine Mammal Laboratory (NMML) and the Minerals Management Service (MMS), NMML is conducting a dedicated multi-year study of the distribution and relative abundance of endangered whales in the Chukchi Sea Planning Area and relate variation in those parameters to oceanographic conditions, indices of potential prey density, and anthropogenic activities. This quarterly report covers the period between 16 April 2010 and 15 July 2010.

The major activities during this period consisted of planning and preparing for the upcoming Chukchi Sea Acoustics, Oceanography, and Zooplankton (CHAOZ) cruise that is scheduled for 24 August through 20 September 2010. The cruise will take place on the chartered fishing vessel R/V *Alaskan Enterprise*. The vessel was loaded on June 9-11, 2010, and left Seattle, WA on June 12, 2010 with a crew of four. Twelve scientists, technicians, and observers are scheduled to participate on the CHAOZ cruise. In addition, work has begun on the modeling component of the project, which aims to predict the impact of climate change on the sea-ice characteristics and physics variables in the Chukchi Sea.

Introduction and objectives

The western Arctic physical climate is rapidly changing. The summer minimum sea ice extent in 2007 and 2008 covered an area which was 37% less that the area coverage of two decades ago and 20% less than the previous minimum coverage in 2005 (Stroeve et al., 2008). The rapidity of these changes was unexpected, as the consensus of the climate research community just a few years ago was that such changes would not be seen for another 30 years, as expected from the CO_2 anthropogenic contribution alone (Wang and Overland 2009).

Baleen whales are subject to changes in environmental variables such as oceanographic currents, sea temperature, sea-ice cover, prey availability, and anthropogenic impacts. Furthermore, extreme ice-retreat and climate warming in the western Arctic over the last decade are expected to lead to changes in species composition and distribution, evidenced already through local knowledge and opportunistic observations.

In addition, the observed northward retreat of the minimum extent of summer sea ice has the potential to create opportunities for the expansion of oil and gas-related exploration and development into previously closed seasons and localities in the Alaskan Arctic. This change, coupled with steadily increasing abundance and related seasonal range expansion by the bowhead, gray, humpback, fin, and possibly other whales, indicates that more complete information on the year-round presence of large whales is needed in the Chukchi Sea planning area. Timing and location of whale migrations may play an important role in assessing where, when or how exploration or access to petroleum reserves may be conducted to mitigate or minimize the impact on protected species.

Acoustic monitoring and satellite-tracking in the Chukchi Sea Planning Area year-round for several years will provide a previously unattainable assessment of the seasonal occurrence of large whales in this region and their response to environmental changes (including climate and anthropogenic use of the area). These data, when integrated with data from concurrent monitoring of oceanographic conditions, will enhance the understanding of the finer-scale variability in whale occurrence and relative abundance. Moorings permit observations during long periods when ice covers the region, especially during the critical spring and early summer periods when spring phytoplankton blooms occur. Such measurements are virtually impossible to obtain from ships, because of the relatively short duration of cruises and severe limitations in the availability of ships able to work in ice-covered seas.

The overall goal of this multi-year IA study is to document the distribution and relative abundance of bowhead, humpback, right, fin, gray, and other whales in areas of potential seismic surveying, drilling, construction, and production activities and relate variation in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities. The proposed study will have four component projects: oceanography, passive acoustics, zooplankton, and climate modeling. Each component project is a technical discipline and will be coordinated by a Project Leader with extensive experience in that discipline.

The specific objectives are:

1. Assess the year-round seasonal occurrence of bowhead, gray, and other whale calls in the Chukchi Sea.

2. Estimate relative abundance of these whales.
3. Obtain two full years of biophysical measurements on the shallow Chukchi shelf utilizing moorings at three sites, and collect hydrographic and lower trophic level data during deployment/recovery of the moorings.
4. Evaluate the extent to which variability in environmental conditions such as sea ice, oceanic currents, water temperature and salinity, and prey abundance influence whale distribution and relative abundance.
5. Run the National Center for Atmospheric Research (NCAR) climate model (Community Climate System Model: CCSM) for future projections using the sea ice extents from 2007/2008 as initial conditions.
6. Analyze multiple ensemble members from the NCAR model and other IPCC models to assess the future variability of sea ice cover and extended sea ice free seasons during fall for the Chukchi Sea.
7. Evaluate whether changes in seasonal sea ice extent are resulting in a northward shift of Bering Sea cetacean species such as fin, humpback, and North Pacific right whales.
8. Provide long-term estimates of habitat use for large whale species and compare this with predictions about annual ice coverage in order to establish predictive variables to describe large whale occurrence.

Summary of work performed and overall progress made against the schedule:

Cruise planning summary

Equipment: A significant amount of scientific and safety equipment is required for this cruise. The cruise coordinator has been working to ensure that all of the cruise participants will have the necessary equipment (such as Big-eye binoculars, oceanographic sampling gear, laboratory van, satellite phones, mustang suits, survival suits, flares, air horns, etc.) for the cruise. Small boat safety inspections and maintenance have been completed. The vessel contract was awarded in May to the F/V *Alaskan Enterprise*, captained by Atle Remme.

Personnel: There will be a maximum of 12 scientists aboard the research vessels on the survey, including 3 acoustic scientists, 5 oceanographic (including a mooring specialist) and zooplankton scientists, 3 marine mammal observers, and one bird observer. Scheduling, contracting and observer hiring have been completed, and travel arrangements should be completed shortly.

Oceanographic mooring and sampling planning

- We investigated depth of ice in the region and found that the keel depth of ice can be as deep as 25 m. Since we are deploying moorings in water depths of less than ~40 m, we have designed all our moorings to be within 10 m of the bottom. This will entail deploying three moorings at one site and two moorings at the other two sites. There are three types of moorings: three moorings (one at each site) that have an upward looking 600 KHz ADCP as the top instrument (10CKP1a, 10CKP2a, 10CKP3a) shown in Appendix 1, Figure 1; three moorings with an instrument to measure ice-thickness as the top instrument (10CKIP1a, 10CKIP2a, 10CKIP3a) shown in Appendix 1, Figure 2; and a single mooring with a TAPS-8 as the top instrument (10CKT2a) shown in shown in Appendix 1, Figure 3.
- New equipment to be used on the moorings has been purchased. Most of the equipment that we are using from our pool has been calibrated and prepared for deployment. Some components of the moorings, including oceanographic instrumentation and mooring hardware, were prepared and loaded on board before the vessel departed Seattle. On July 14, most of the remaining instruments, CTD, a TAPS-6 and mooring hardware will be loaded in a container which will be shipped to Dutch Harbor. This equipment will be loaded on the ship during the last week of July. Because of the extensive ice in the Bering Sea this year, a few pieces of mooring equipment have just been recovered and will be sent to Nome to be loaded at the end of August.
- We have refurbished our CTD rosette and obtained 13 Niskin bottles (three bottles will be used as spares) for use on the cruise. We plan to measure temperature (dual sensors), salinity (dual sensors), oxygen (dual sensors), fluorescence, PAR and altimeter. A Seacat-19 will be sent as back-up
- The vessel had no suitable place to prepare instruments or position the deck units and computers, therefore a modified office container was purchased jointly by NMML and PMEL to work in. This container will be used by all parties on the cruise and is being customized to fit our scientific needs. It was loaded on the vessel before its departure from Seattle, WA.

- Noting the loss of moorings by several groups who worked in the area last year, we have decided to deploy a pop-up tag on each mooring. We have used these tags before. They are a relatively cheap form of insurance. The tags are programmed to pop to the surface on a predetermined date (September 10, 2011). If a mooring is dragged by ice or a ship then the tag will indicate the mooring's location. This is important on a shallow shelf, because the acoustic releases can only be "heard" over a relatively short distance. We have used these tags before and plan to use ones that we already own.
- We will deploy one TAPS 8 instrument from the Bering Sea on the Chukchi mooring and use a TAPS 6 instrument on the CTD (in profiling mode) during the cruise to determine the vertical distribution of potential prey items on all of the CTD transects. Both instruments were calibrated this past winter. The profiling instrument will help us interpret both the net data and the longer term mooring data.
- We are investigating methods and equipment necessary to obtain samples of inorganic suspended material near the bottom to assess its contribution to the scattering signal.
- Repairs and maintenance to our oceanographic winch were conducted in preparation for the cruise.
- On July 2, 2010 we received word from Tom Weingartner that they have secured space on an earlier cruise and will not be joining our cruise.
- We have been active letting the communities know about our summer plans, for instance, the goals and general sampling area was presented at a recent meeting of the North Slope Science Initiative (NSSI) by R. Angliss, S. Moore sent a two-page informational flyer introducing the CHAOZ cruise to residents of the North Slope in June, and Rachel Potter (UAF) will be presenting information about our cruise plans at the AEWC meeting in Fairbanks this July.

Passive acoustic mooring and monitoring planning

Passive acoustic arrays:

- Three five-unit arrays of AURAL recorder subsurface moorings (NMML) will be deployed.
- As per the first item of the oceanography planning, we will be using the mooring type designed for the Bering Sea lease area as it is compact, rugged, and low to the seafloor (Appendix 1, Figure 4). Most of the mooring equipment was loaded onto the vessel prior to its departure from Seattle. The acoustic release and calibration pingers arrived after the vessel departed and so they will be shipped to Dutch mid-July in the oceanography group's container. We borrowed 15 steel floats from PMEL, which we had sandblasted and repainted as suggested by PMEL.
- We received the AURAL passive acoustic recorders, and recorder batteries. All instruments have been cleaned and prepped, and the recorders have been programmed and each group of five time-synchronized for deployment.
- We have had some setbacks in our attempt to lease a self-contained trawling winch to use for dragging for the three AURAL moorings from the MMS funded BOWFEST project, that were unrecoverable off Barrow Canyon in 2009. Other possible lease or purchasing options are being explored. Since we have many moorings going in this year, the likelihood of needing to drag for these moorings next year is high. Therefore it makes the most sense to purchase a winch outright.
- We have finalized our plans for the locations of the arrays and have created a cruise schedule (Figures 1 & 2). We will place the pentagonal arrays around each of the oceanographic mooring clusters so that simultaneous acoustic recordings and oceanographic measurements can be collected.

Auto-Detection buoy:

- A mutual decision was made by NMML and Bioacoustics Research Program (BRP) at Cornell University to postpone deployment of their auto-detection buoy until the 2011 field season. WHOI altered their well-tested mooring design to make it more rugged for deployment in the harsher conditions of the Chukchi Sea. This new design will make it possible to deploy the buoy with sea ice present, but at the moment it is untested and risky to deploy. Furthermore, the power available for the onboard auto-detection algorithms has been halved and the BRP needs additional time to reconfigure their software. We are waiting for BRP to send a new proposal and budget for this revised plan.

- We will be deploying a double-bubble MARU (Marine Acoustic Recording Unit) for the BRP group in the original location chosen for the auto-detection buoy. As with the other moorings for this project, the MARU will be deployed for a full year. The BRP will use the data recorded on this unit to fine-tune their auto-detection buoy.

Modeling component planning

There are two types of modeling planned for this year: Climate modeling from the Overland group and Cumulative noise modeling from the Bioacoustics Research Program group at Cornell University.

Climate Modeling:

- We have initiated contact with NCAR about using their system to project sea ice in the Chukchi Sea over the next year.
- We have inquired and learned that the next Intergovernmental Panel on Climate Change (IPCC) set of model results for their Fifth Assessment report will become available in early winter 2011. This set of models is the latest contribution from all of the modeling centers in the world which project future climate. Our group was a leader in evaluation of the last set of models from their Fourth Assessment Report, and one of our tasks will be an early comprehensive evaluation and analysis of these new results.
- We are in the process of purchasing the necessary hardware to store model output.
- We have established the priority of a) reviewing existing information for the Chukchi, b) working with the NCAR model, c) preparation in terms of computer analysis codes for the IPCC 5th assessment report.
- We are evaluating the available model runs, and prioritizing the years (future runs) we need and what variables we want. Considering that it takes 1 week of wall clock time to run the model for given year, this critical component of this program.
- Research has begun on the evaluation of model runs. There are two models, the CCSM3 and the CCSM4, that we will work with. The first was used in recent IPCC Report and model runs are available now, while the second is being tested now and results will be out in the winter of 2011.
- The runs from 25 climate models have been examined and 6 have been selected as the most realistic from historical perspective. A manuscript is being prepared using these 6 model runs in which we will present our best estimates for future sea ice and temperature in the Bering Sea and the Chukchi.
- A discussion of some of the accomplishment in modeling component is provided in Appendix 2.

Cumulative Noise Modeling (Bioacoustics Research Group at Cornell University):

NMML received this statement of work from BRP on April 30, 2010:

This project component's goals are three-fold: quantify the ocean noise "budget", quantify the contributions of anthropogenic sounds to the ocean noise budget, and assess the influence of anthropogenic sounds on the acoustic habitats of marine species.

To achieve these goals, well-established passive acoustic technologies and a mixture of existing and newly developed analytical methods will be applied. Basic data consist of acoustic recordings from previous or to-be-deployed autonomous seafloor acoustic recorders (recorders), sound propagation models informed by site-specific parameter values, estimates of numbers and distributions of selected marine mammal species, and numbers and distributions of sound generating industrial activities. Recorder data are used to calculate the spatial-temporal-spectral variability of the acoustic habitat and, when feasible, to detect and localize vocally active marine mammals. This project will take advantage of recently developed methodologies to calculate the noise budget contributions from different types of anthropogenic sound sources. Data on the distributions and acoustic behaviors of such sources and marine animals are then merged to investigate the potential impact of anthropogenic sounds on vocally-active species (e.g., masking of animal sounds), using custom software tools such as (a) the Acoustic Integration Model (AIM, Frankel et al. 2003) for estimating underwater sound propagation; (b) the open-source Extensible BioAcoustic Tool (XBAT, http://xbat.org/home.html, Figueroa 2008), a sound analysis algorithm development platform operating within MATLAB (The Mathworks, Inc. 2008); and (c) the open-source BioAcoustic Resource Network (BARN, Figueroa 2008), a distributed computing annotated sound library management platform.

Visual/ passive acoustics observations planning

Three marine mammal observers will be aboard to conduct a visual survey whenever the vessel is transiting between stations or ports during daylight hours. Two observers will use 25x Big-Eye binoculars to call out sightings, and the data recorder will have 7x50 hand-held binoculars to identify animals close to the vessel. Each position will rotate every 40 minutes. If a species of interest is located, the observers will collect as much information as they can on their current course and will only divert from track at the discretion of the Chief Scientist. While on station, the mammal observers will either take a break (depending on the duration of the previous transit) or will assist the Chief Scientist with the oceanographic data collection. If a right whale is spotted while on station, it may be possible to launch a small boat for biopsy and photo-identification purposes, but this is entirely situation-dependent and will not interfere with the main focus of the cruise. There will also be a seabird observer onboard from the US Fish and Wildlife Service.

Throughout the cruise there will also be passive acoustic monitoring using DiFAR (Directional Frequency Analysis and Recording) sonobuoys. Acoustics is a critical component as it can easily detect calling whales from 20 km away, even when visual observations are limited by darkness, high sea states, or fog. Once whale calls are detected and the bearing to the whale is calculated, a second sonobuoy can be deployed and a more accurate cross bearing location of the calling whale can be obtained. If time permits, the vessel can be diverted to that location.

The receiving gear necessary for sonobuoy operations was installed on the charter vessel prior to its departure from Seattle. Two antennae were installed on the vessel, one omni-directional and one directional Yagi antenna, with a selection switch on the bridge. The directional antenna should increase the reception range of the buoys during transit, thus extending the life of the buoy and increasing our detection range. Again, we received the sonobuoys at no cost to the project through a donation from the U.S. Navy.

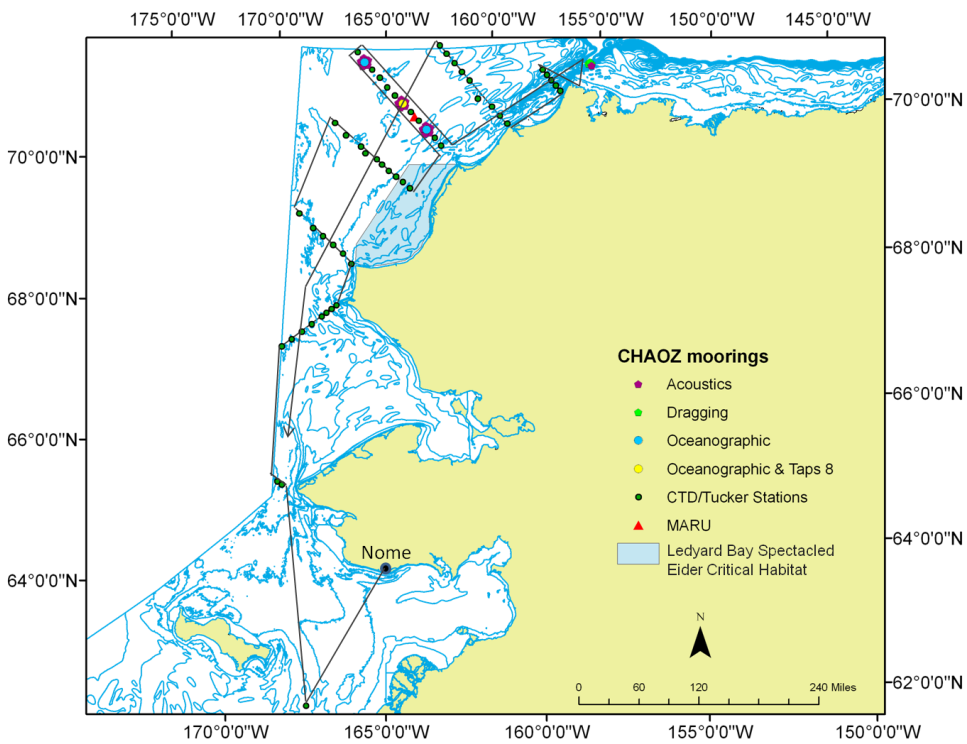


Figure 1. Proposed mooring locations for the oceanographic and passive acoustic moorings, as well as the CTD and net tow stations. The hydrographic lines (CTD, TAPS-6, and nets) will provide snapshots of water column structure and spatial patterns of lower trophic level (nutrients, chlorophyll, zooplankton) along six transects. We will occupy key sites on the return transit to Nome.

Survey design

The tentative cruise track is provided in Figure 1 (with a detailed zoom of the main research area in Figure 2. The vessel will depart Nome on August 24, arriving in the study area by August 27. We will work for 18 days, then transit back to Nome for a touch-and-go on September 16, arriving back in Dutch Harbor on September 20. Three bad weather days have been included in the planning, plus the three unused Weingartner days. If time permits, additional activities such as more CTD/net tow stations, visual/sonobuoy transects, or small boat operations (biopsy, photo-id, satellite tagging) will be included. If time becomes critically short, the oceanography group will begin to cancel some of the CTD /net tow stations as needed.

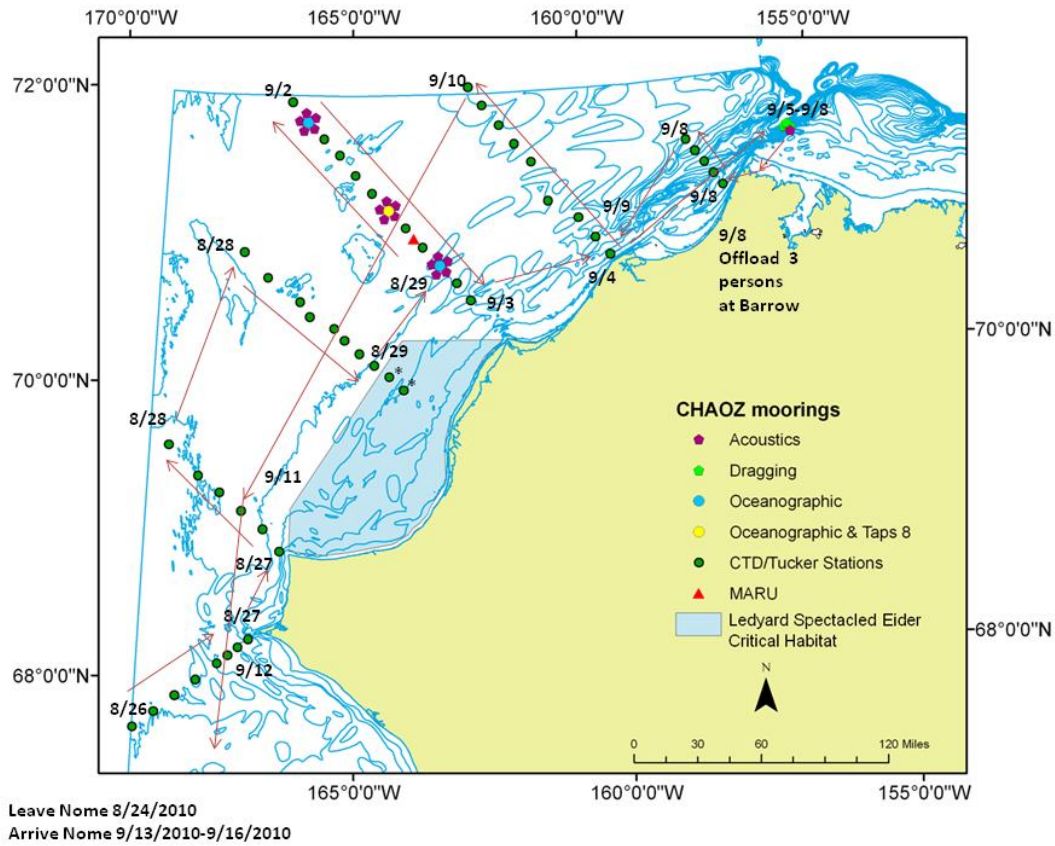


Figure 2. Detailed map of the main research area of the study showing the location of the mooring deployments and CTD/net tow stations. Approximate time line of the cruise track is included, but subject to change.

Significant meetings held or other contacts made

Berchok, Crance, Stabeno, and Napp have met several times to discuss cruise planning and coordination progress and set-backs. Personnel, equipment, logistics, and budget issues were discussed. Stabeno has met with Overland to discuss modeling progress.

Following a presentation at the international State of the Arctic (SoA) meeting in March, Moore provides introductory presentations of the Distributed Biological Observatory (DBO) in the Pacific Arctic region to

colleagues at the Alaska Fisheries Science Center (4/12/10), the North Pacific Research Board (NPRB) Scientific Panel (4/15/10) and the NPRB Board (5/6/10). Positive feedback on including the CHAOZ cruise in the DBO pilot study received from Dee Williams (MMS).

05/13/10 meeting with Berchok, Crance, Stabeno, Napp and Moore to integrate the CHAOZ cruise within the framework of the DBO. Specifically, stations on transects offshore Pt. Hope and across Barrow Canyon are included as part of the 11-cruise DBO 2010 Pilot Season to assess biological response to physical changes in the Chukchi Sea associated with climate change.

5/17/10 Moore follows up on previous discussions and consults (via telecom) with Alaska Ocean Observing System (AOOS) colleagues (McCammon/Dugan) to insure the CHAOZ cruise is included in the all-activity mapping effort undertaken by AOOS.

06/07/10 Conference call between BRP and Berchok about the postponement of the autodetection buoy.

06/09/10 Mooring information is sent to both Darcy Dugan (AOOS) and Rachel Potter (UAF) for their online Arctic Research Assets maps.

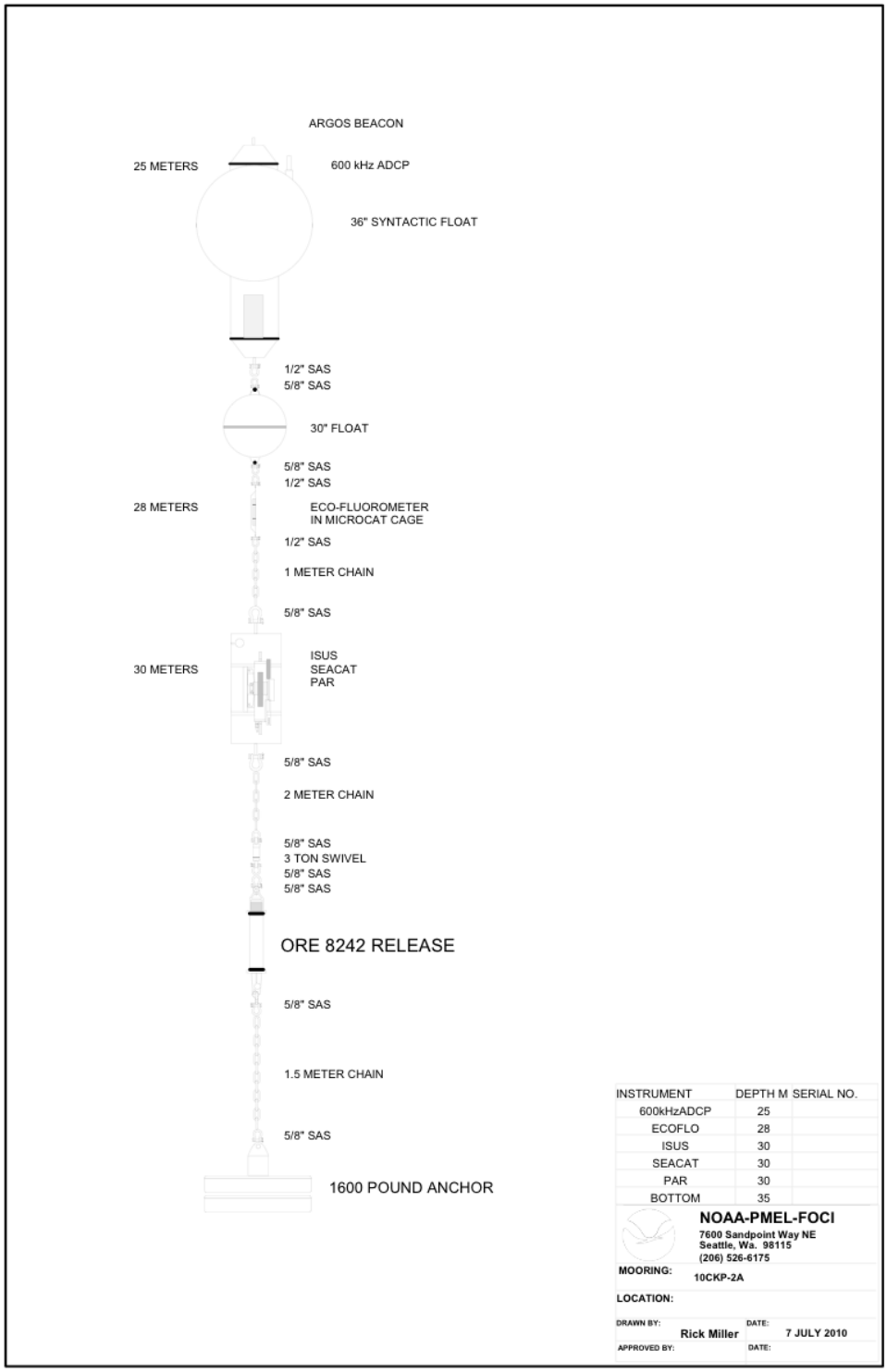
06/21/10 Moore sends two-page informational flyer introducing the CHAOZ cruise to residents of the North Slope. Hard copies of the flyer were sent to the Village Coordinators along the North Slope (Barrow, Wainwright, Pt. Lay & Pt. Hope) and an electronic version was sent to North Slope Borough e-mail users.

6/16/10 Phyllis Stabeno and Jeff Napp discussed zooplankton acoustic sampling strategy with Charles Monnett via phone. A slightly modified sampling strategy was presented and accepted for the first year whereby a TAPS-6 (CTD) and a TAPS-8 (mooring) instruments will be used instead of (2) moored TAPS-8 instruments.

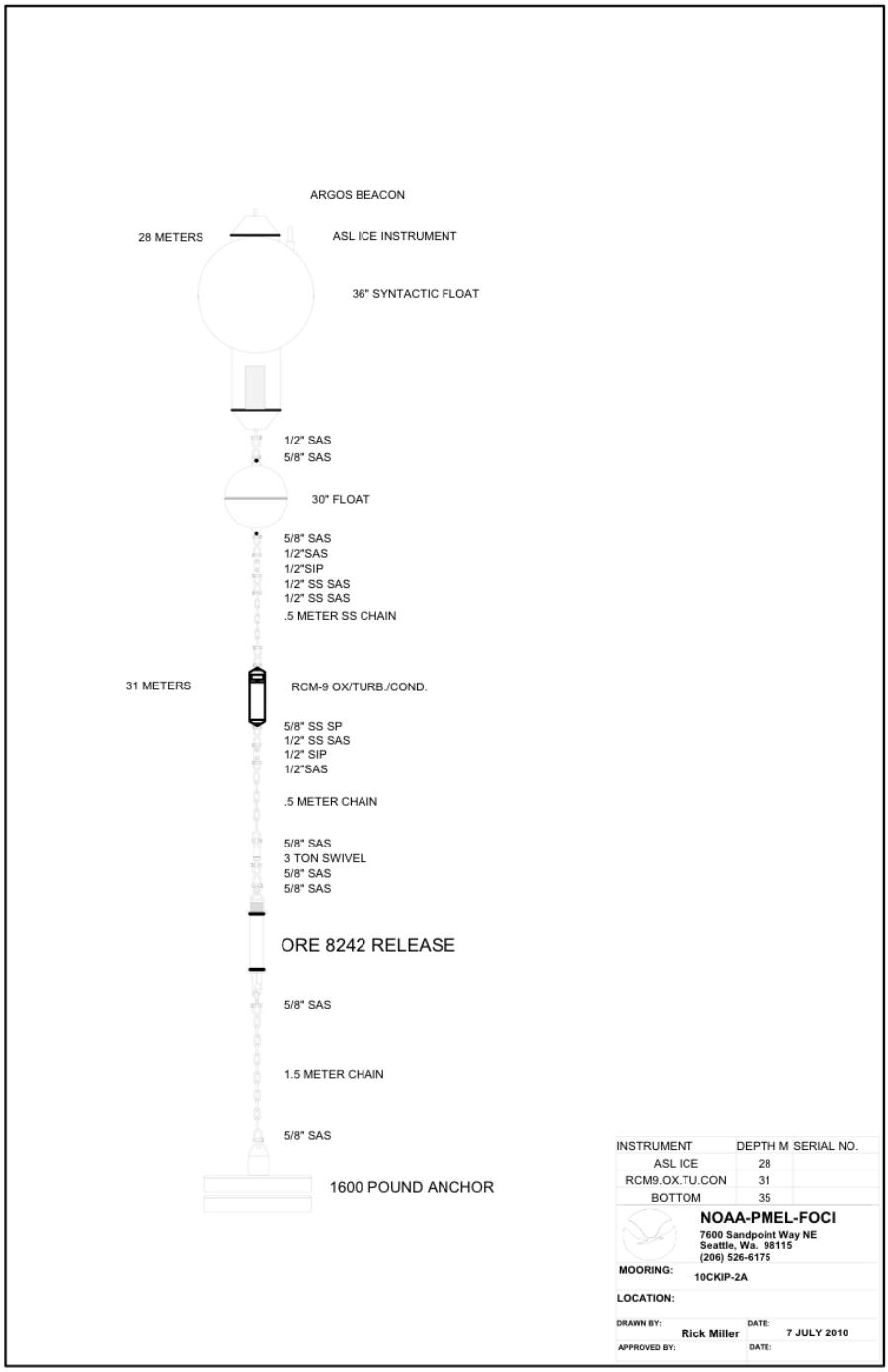
06/23/10 Tom Weingartner (UAF) sent his powerpoint presentation to Glenn Sheehan (BASC) as part of the formal request process of being placed on the AEWC agenda in July. Rachel Potter (UAF) will be making the presentation.

Appendix 1:

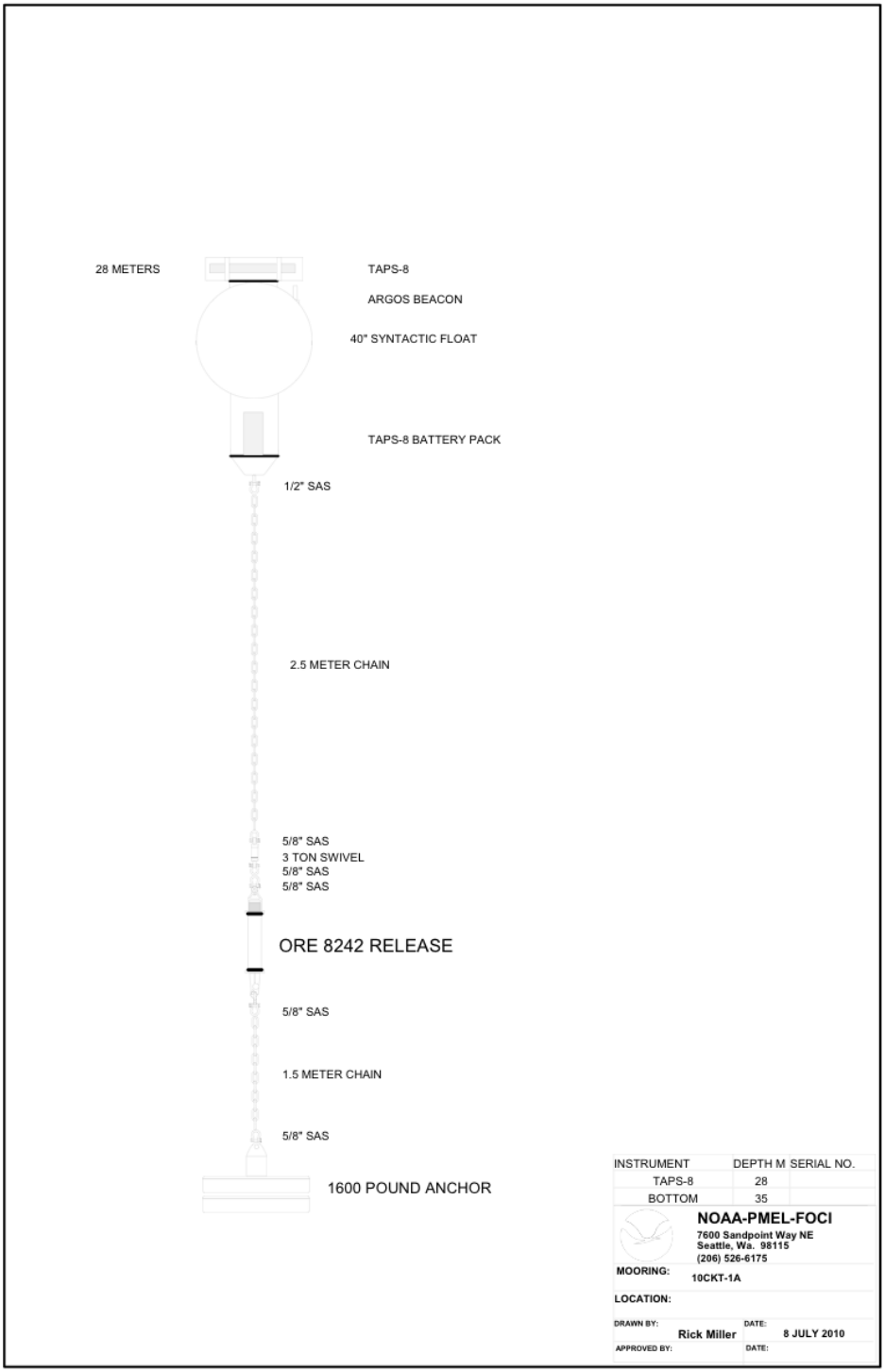
Mooring Designs



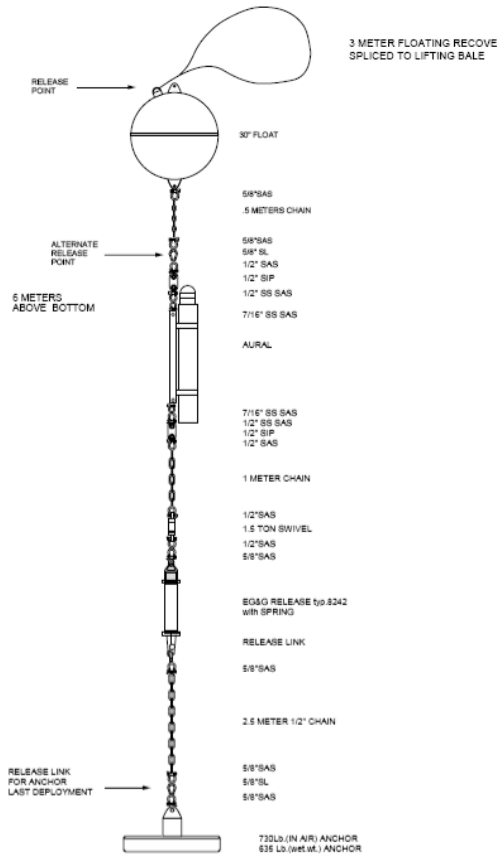
Appendix 1, Figure 1. Mooring design for 10CKP1a, 10CKP2a and 10CKP3a. In addition to the 600 kHz ADCP (currents), this mooring contains instruments to measure nitrate (ISUS), temperature and salinity (Seacat), fluorescence (EcoFluorometer) and Photosynthetically active radiation (PAR).



Appendix 1, Figure 2. Mooring design for 10CKIP1a, 10CKIP2a and 10CKIP3a. In addition to the ASL ice instrument (measures ice thickness), this mooring contains RCM9 that measures currents at one depth, temperature, oxygen, and turbidity.



Appendix 1, Figure 3. Design for mooring 10CKT. The TAPS-8 is an instrument that acoustically measures zooplankton bio-volume.



Appendix 1, Figure 4: Mooring design for the passive acoustic moorings. Moorings designs were provided by Rick Miller from PMEL mooring shop.

Appendix 2:

Report on Modeling Component

Chukchi Sea: Modeling Component

Comprehensive Atmosphere-Ocean General Circulation Models (AOGCMs) comprise the major objective tool that scientists use to account for the complex interaction of processes that determine the climate and climate change. In the process of preparing the Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007a) simulations from 23 AOGCMs developed by 17 international modeling centers are collected and archived as part of the Coupled Model Intercomparison Project-Phase 3 (CMIP3) at the Program for Climate Model Diagnosis and Intercomparison (PCMDI) in Lawrence Livermore National Laboratory (LLNL). This archive has resulted in more than 500 publications that include studies of regional climate change and future projection.

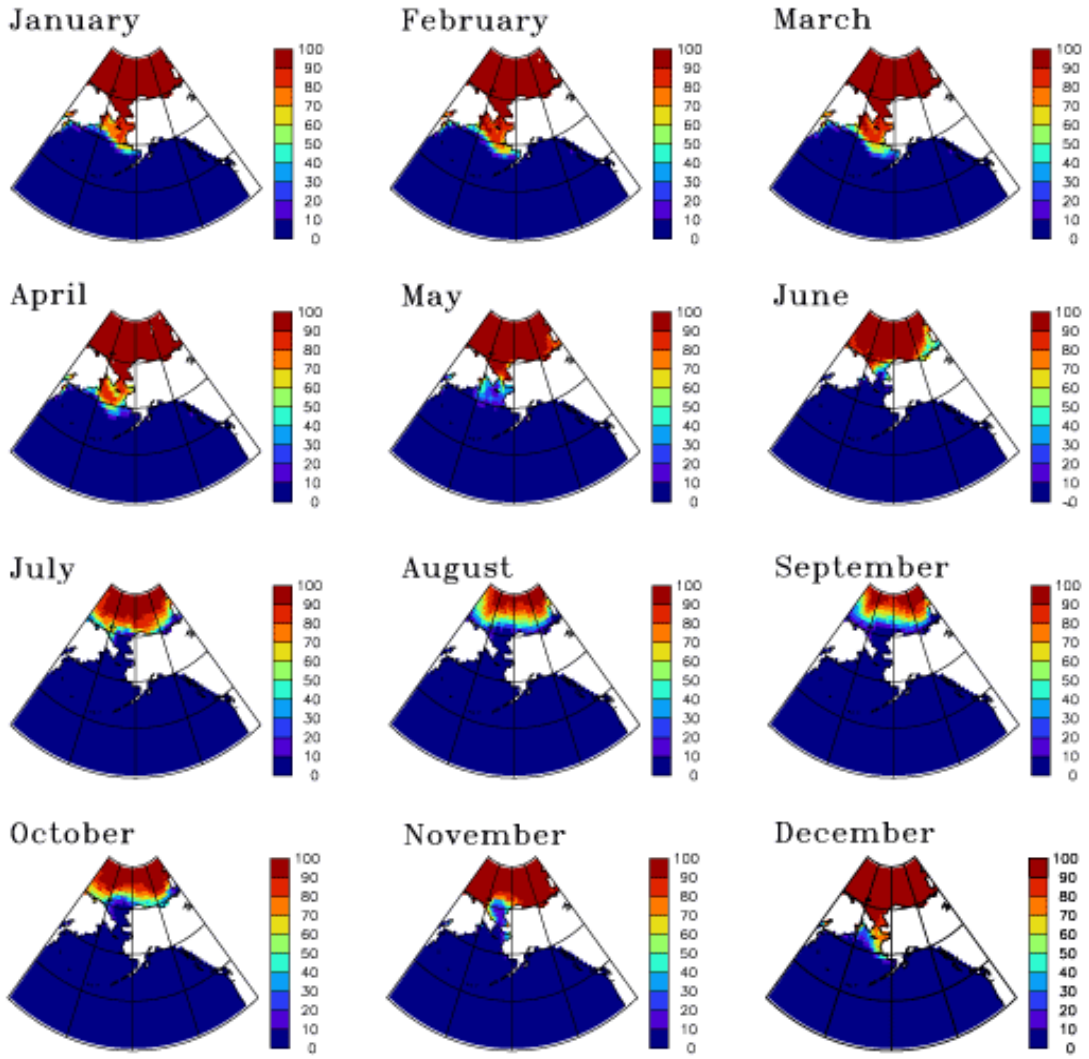
Models are built on well-known dynamical and physical principles and many large scale aspects of present-day climate are simulated quite well by these models (Randall et al. 2007, Knutti et al. 2008). The IPCC's AR4 emphasizes that current generation AOGCMs provide credible quantitative estimates of future climate change at continental scales and above (IPCC 2007). Further, some biases in simulated climate by different models are often unsystematic (Räisänen 2007, Jun et al. 2008), that would be cancelled out when ensemble means are considered. While there is emerging evidence of the utility of some regional climate model projections, users should strive to evaluate uncertainties in the multiple model simulations. There are three main sources of uncertainty in the use of AOGCMs for climate projections: large natural variations (both forced and unforced), the range in emissions scenarios, and across-model differences (Hawkins and Sutton 2009).

Confidence that climate models provide credible quantitative projections of future climate is built upon their demonstrated ability to reproduce observed features of recent climate (Gerdes and Köberle 2007). Our study (Wang and Overland 2009, Overland et al. 2010) showed that culling models based on their fidelity of simulated past climate to the observations can reduce the uncertainty in the future projections. The result of culling is regional and variable dependent.

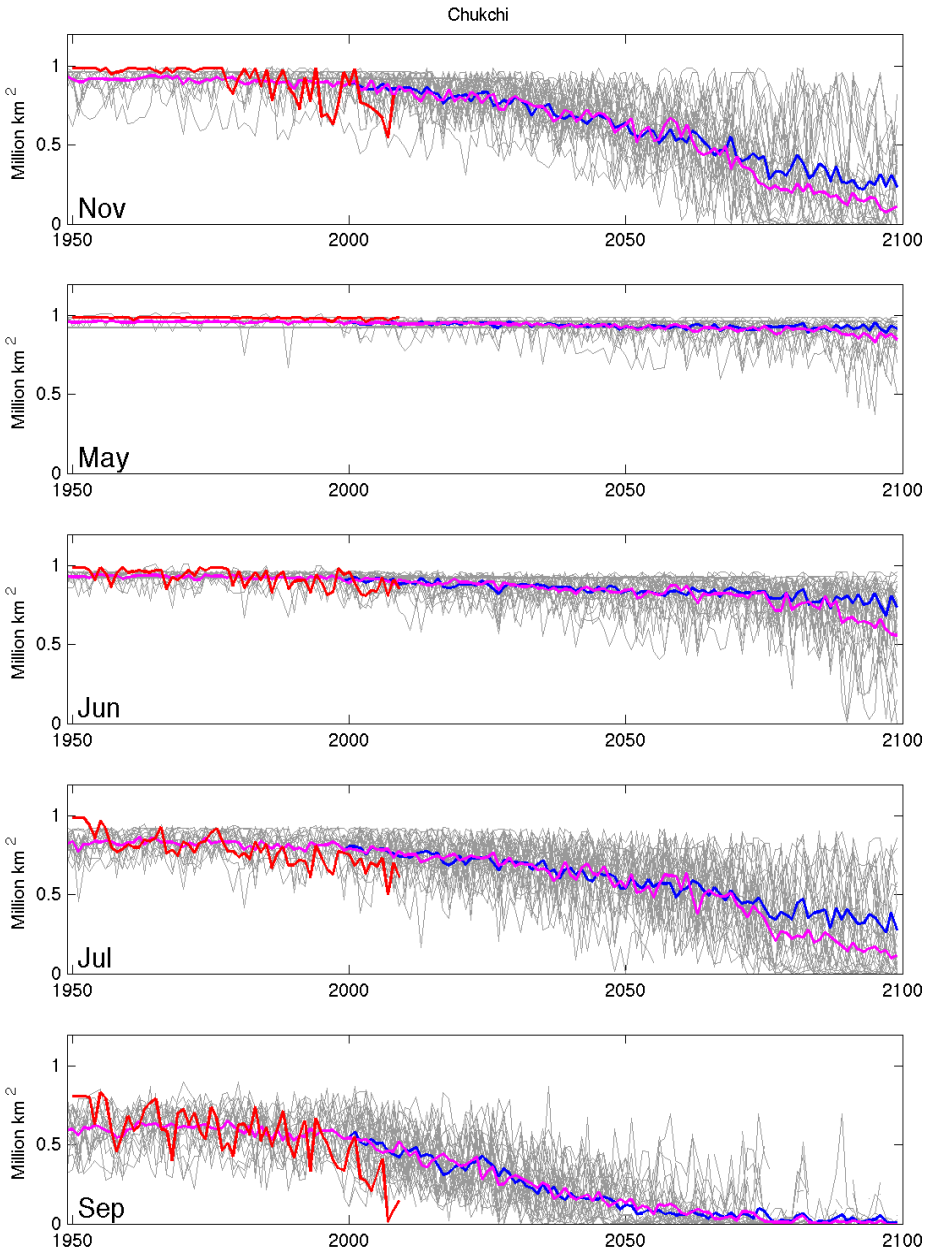
The Chukchi Sea is located well north of the Arctic Circle, with its northern boundary adjoining the Arctic Ocean. Sea ice starts to retreat in late May or later, and part of the region will be covered by ice during summer. The ice edge advances south in October, and by December the entire Chukchi Sea is covered by ice normally (Appendix 2, Figure 1).

In order to get the projection of Chukchi Sea sea ice conditions, we start with the six models identified by Wang and Overland (2009), and further evaluate these models' performance over the Chukchi Sea. There are several sources of sea-ice data available; we chose to use the gridded sea-ice concentration analysis from the Hadley Center (http://hadobs.metoffice.com/hadisst/) as the observed values in this study. Sea-ice extent was then defined as the area where the ice concentration is more than 15% in a grid box. Our constraints are based on comparisons to the HadISST sea ice concentration analysis, which was made more homogeneous by compensating satellite microwave-based sea ice concentrations for the impact of surface melt effects in the Arctic (Rayner et al. 2003). All the six models CCSM3, CNRM, ECHO-G, IPSI, MIROC (med) and UKhadGEM1 are doing a satisfactory job in terms of simulating the mean and seasonal cycle of the Chukchi Sea (66-80°N, and 180-157°W) sea ice extent comparing with the observations .

The projections of the sea ice extent by these six models (Appendix 2, Figure 2) show significant decline by mid-century in the fall (November) and summer (July). However the changes in winter and spring sea ice extent is negligible (May).



Appendix 2, Figure 1. Decadal mean sea ice concentration over Chukchi and Bering Sea for each month based on Hadley Sea ice analysis.



Appendix 2, Figure 2. Simulated sea ice extent by the climate models for selected month in the last part of 20th century and the 21st century. Each grey line represents one realization from the model. The thick blue line is the ensemble mean based on A1B emission scenario, and the magenta line is the ensemble mean based on A2 emissions scenario. The thick red line is based on Hadley sea ice analysis.