Report for University of Alaska Reporting Period: 15 September 2011 to 14 Sept 2013

Title: *Collaborative Project: Understanding the effects of tides and eddies on the ocean dynamics, sea ice cover and decadal/centennial climate prediction using the Regional Arctic Climate Model (RACM)*

Project ID: ER65371-1038744-0017588

Program Manager: *Renu Joseph*

Project Synopsis

The goal of this project is to develop an eddy resolving ocean model (POP) with tides coupled to a sea ice model (CICE) within the Regional Arctic System Model (RASM) to investigate the importance of ocean tides and mesoscale eddies in arctic climate simulations and quantify biases associated with these processes and how their relative contribution may improve decadal to centennial arctic climate predictions. Ocean, sea ice and coupled arctic climate response to these small scale processes will be evaluated with regard to their influence on mass, momentum and property exchange between oceans, shelf-basin, ice-ocean, and ocean-atmosphere. The project will facilitate the future routine inclusion of polar tides and eddies in Earth System Models when computing power allows. As such, the proposed research addresses the science in support of the BER's Climate and Environmental Sciences Division Long Term Measure as it will improve the ocean and sea ice model components as well as the fully coupled RASM and Community Earth System Model (CESM) and it will make them more accurate and computationally efficient.

The role of Jennifer Hutchings, University of Alaska Fairbanks, is to provide observational data for model validation and participate in developing metrics to evaluate the model ice-ocean interaction.

Primary Research and Development Activities

The main activities over the past 19 months were:

- Collating a database of GPS ice drifting data with sufficient quality for analysis of seasonality in tides and inertial fluctuations.
- Participating in joint analysis of this data with Andrew Roberts, Naval Postgraduate School. Developing metrics of to evaluate modeled high-frequency ice drift.
- Initiating collation of a database of time series data from coastal and pelagic tide stations for evaluation of tides in the 3-D coupled ice-ocean model.

Ice Drift Data

A through search has been made for ice drift data of high position accuracy and temporal resolution, suitable for time series analysis of tidal and inertial motion of the Arctic ice pack. In coordination with an NSF Arctic Observing Network project we are working with the IABP to clean up full temporal resolution buoy data (to date data from 2000 to 2010 has been processed), identify data quality including position precision and missing data. Time series data from the NSF funded effort will be incorporated into this projects database. Data has been collated that is unavailable through the International Arctic Buoy Program (IABP) from: France/Germany (Damocles), Canada (U. Manitoba), Japan (JAMSTEC), and Russia (AARI Ice camps). We also had to ask individual investigators for their highest resolution data that is not routinely provided by IABP, and have hourly or better data from IARC ice drifters, NPS flux buoys, WHOI ITPs and CRELL IMBs.

Developing an ice drift based metric to evaluate sea ice rheological model

Roberts and Hutchings are collaborating closely in developing a new metric for assessing the ability of sea ice models to reproduce energy dissipation due to ice mechanics. Mechanical processes in the ice pack (ridging, rafting and cracking) dissipate energy from the low frequencies that force the ice pack drift (synoptic/tidal/inertial) to higher frequencies. An initial investigation (fig. 1,2,3) shows that interannual variability is apparent in tidal and inertial motion of the ice pack. Spectral averaging over regions and a month provides sufficient signal to identify significant difference in seasonality of inertial motion between years and regions. Note that the seasonal cycle of inertial motion (12 hour in the clockwise component) is stronger in the Beaufort Sea (where the ice pack is less compacted a weaker), and has an increasing seasonality in the Beaufort from 2007 to 2009 that may be related to increasing cover of first year ice.

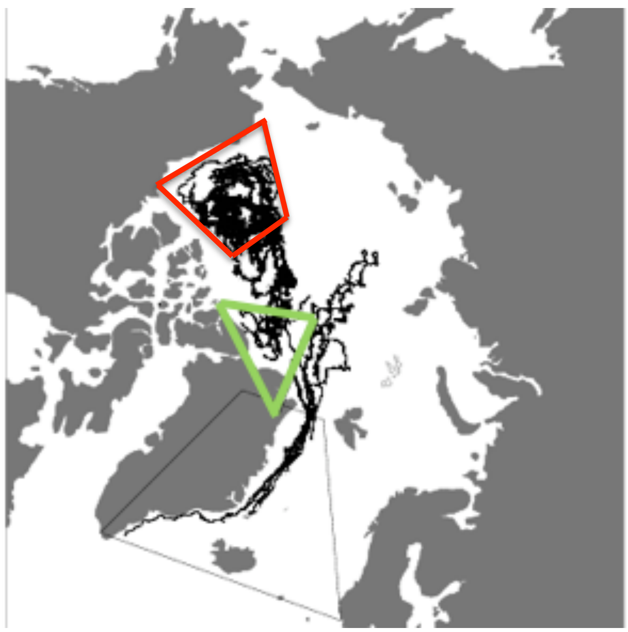

Figure 1. Map of drift tracks with GPS data available in 2007-2009. Regions outlined are the Beaufort Sea (red), Lincoln Sea (green) and GIN Sea (grey).

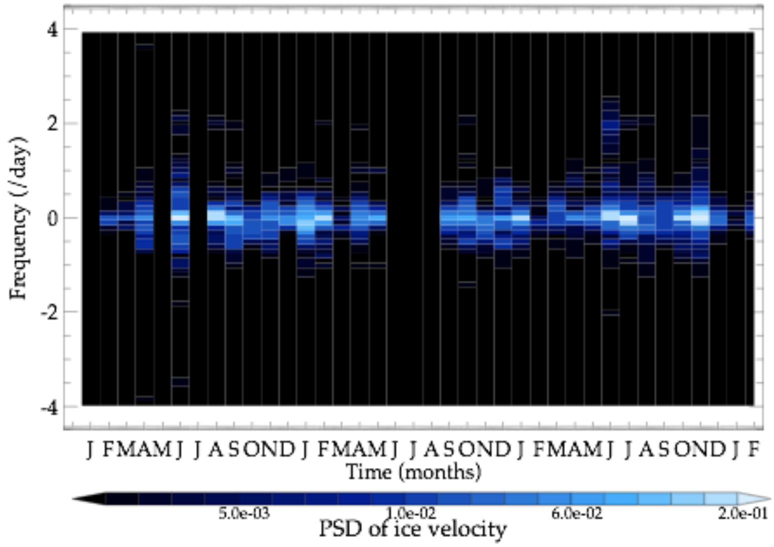

Figure 2: Monthly average spectra of rotary components of ice drift in the Lincoln Sea from 2007 to 2009. Clockwise component is positive, anti-clockwise negative.

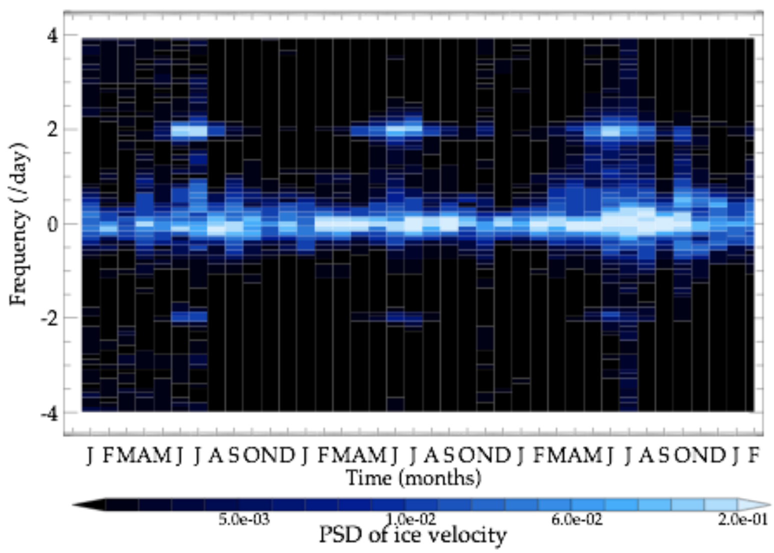

Figure 3: Monthly average spectra of rotary components of ice drift in the Beaufort Sea from 2007 to 2009. Clockwise component is positive, anti-clockwise negative.

Tide gauge data

Such a model could be used to investigate the impact of a changing sea ice pack (reducing ice strength and therefore increasing energy dissipation due to ice interaction) on tides in the Arctic. For evaluation of a 3-D coupled ice-ocean model with tides we desire time series data for tidal height and currents. Time series of tidal height data, at 3 hourly or higher resolution, could be used for assessing long term tidal variability, and whether this is related to changing seasonality and strength of the Arctic ice pack.

The last status report for Arctic tide gauges dates from 2000 (citation), and a compilation of tidal components (not time series data) from Arctic stations was compiled by Kowalik and Proshuntinsky (1994), which was used by Padman and Erofeeva (2004) in a 2-D assimilative tide model. Since 2000, many tide gauges have ceased reporting and additional tide gauges have been deployed. We present the results to date of a detailed survey of available tide time series data in table 1 (see appendix). Please note that this is a work in progress, and blank spaces represent data that is still be collated from various sources. We are actively pursuing data from Russia, and have begun the process of finding and requesting this data. This is not a trivial task, and previously only monthly mean sea level and tidal component data has been released from Russia.

Project Participants

Jennifer Hutchings, International Arctic Research Center, University of Alaska Fairbanks.

Close collaborators:
Wieslaw Maslowski, Andrew Roberts, Naval Postgraduate School, Monterey California.
Jennifer Lukovich, U. Manitoba, Canada (Collaborating to share data and evaluate sea ice dispersion properties in the expanding Arctic marginal ice zone).

Publications

Roberts, A., and J. K. Hutchings, Seasonality of tidal and inertial oscillations in the Arctic perennial ice pack, in preparation for J. Phys. Oceanogr.

Presentations / Meetings Attended

Nov 2011 Collaborative meeting in Monterey with Wieslaw Maslowski, Andrew Roberts, Jackie Clement-Kinney and Robert Osinski.
May 2012 Attended project meeting and RASM workshop in Monterey. Presented data available for model validation, including novel metrics for validating sea ice deformation.
Dec 2012 Project meeting with Andrew Roberts during AGU Fall Meeting.

References

Padman, L. and S. Erofeeva, 2004: A barotropic inverse tidal model for the Arctic Ocean, Geophys. Res. Lett., 31(2), L02303, doi:10.1029/2003GL019003.

Kowalik, Z., and A. Yu. Proshutinsky, 1994. The Arctic Ocean tides. In: The Polar Oceans and Their Role in Shaping the Global Environment, Geophysical Monograph, American Geophysical Union, **85,** pp. 137–158.

Pleg, H., 2000: Arctic Tide Gauges: A Status Report, Intergovernmental Oceanographic Comission of UNESCO, IOC/INF-1147, 26 pages.

Appendix

Table 1: Current status of Tide gauge data search, including location of tide gauges and dates hourly data is available. Pelagic gauges (bottom pressure recorders) are not on this list, however this data has been requested from Proshutinsky (Beaufort Sea, 4 moorings), Morison (North Pole, 1 mooring), Winegartner (Chukchi Sea, 1 mooring), Woodgate (Bering Strait). We are searching for pelagic data that was collected in the Fram Strait (Norsk Polar Institute/AWI), and time series of Russian coastal tide gauges (Dr. Vyacheslav I. Smirnov, Obninsk data center).

Station	Sea	Data Source	Latitude	Longitude	Station ID	Operational	Contact
Stations with hourly data downloaded for 1989-2010							
Nain	Labrador	Canada, DFO	56.55° N	61.683333° W	1430	1963-2010	http://www.isdm-gdsi.gc.ca/
Churchill	Hudson Bay	Canada, DFO	58.766667° N	94.183333° W	5010	1929-2010	http://www.isdm-gdsi.gc.ca/
Qikiqtarjuaq	Baffin Bay	Canada, DFO	67.5167° N	64.0667° W	3980	1958-2012	http://www.isdm-gdsi.gc.ca/
Alert	Lincoln	Canada, DFO	82.491866° N	62.3173° W	3765	1960-2012	http://www.isdm-gdsi.gc.ca/
ULUKHAKTOK	NW Passage	Canada, DFO	70.736283	117.76115	6380	2002-2010	http://www.isdm-gdsi.gc.ca/
Little Cornwallis Island	NW Passage	Canada, DFO	75.383333° N	96.95° W	6758	1986-1994	http://www.isdm-gdsi.gc.ca/
Tuktoyaktuk	Beaufort	Canada, DFO	69.438226° N	132.994402 ° W	6485	1961-2010	http://www.isdm-gdsi.gc.ca/
Stations I want data for							
Prudhoe Bay, AK	Beaufort	USA, NOAA	70 24.7 N	148 31.9 W	9497645	1989 -	co-ops.userservices@noaa.gov
Red Dog Dock	Bering	USA, NOAA	67 34.6 N	164 3.9 W	9491094	2003 -	co-ops.userservices@noaa.gov
Nome	Bering	USA, NOAA	64 30.0 N	165 25.8 W	9468756	1992 -	co-ops.userservices@noaa.gov
Adak, Aleutian Is.	Bering	USA, NOAA	51 51.8 N	176 37.9 W	9461380	1991-2012	co-ops.userservices@noaa.gov
Village cove, St. Paul Island	Bering	USA, NOAA	57 7.5 N	170 16.5 W	9464212	2006 -	co-ops.userservices@noaa.gov
Port Moller	Bering	USA, NOAA	55 59.4 N	160 33.7 W	9463502	1984-2008	co-ops.userservices@noaa.gov
Surf Bay, Akutan Bay	Bering	USA, NOAA	54 9.0 N	165 36.9 W	9462711	2008-2011	co-ops.userservices@noaa.gov
Unalaska	Bering	USA, NOAA	53 52.8 N	166 32.4 W	9462620	2005-	co-ops.userservices@noaa.gov
Nikolski	Bering	USA, NOAA	52 56.4 N	168 52.3 W	9462450	2006-	co-ops.userservices@noaa.gov
Atka	Bering	USA, NOAA	52 13.9 N	174 10.4 W	9461710	2006-	co-ops.userservices@noaa.gov
King Cove	Bering	USA, NOAA	55 3.6 N	162 19.6 W	9459881	2005-	co-ops.userservices@noaa.gov
Sand Point	Bering	USA, NOAA	55 19.9 N	160 30.3 W	9459450	2005-	co-ops.userservices@noaa.gov
Ammassalik	N. Atlantic	Denmark, RDANH	65 37N	37 37W		1990-	Palle Bo Nielsen <pbn@dmi.dk>
Sisimiut/Holsteinsborg	Davis Strait	Denmark, RDANH	66 56N	53 45W		1991-	Palle Bo Nielsen <pbn@dmi.dk>
Nuuk/Godthab	Labrador	Denmark, RDANH	64 11N	51 45W		1992-	Palle Bo Nielsen <pbn@dmi.dk>
Qaqortoq/Julianehab	Labrador	Denmark, RDANH	60 43N	46 02W		1991-	Palle Bo Nielsen <pbn@dmi.dk>
Ilulissiat/Jacob	Labrador	Denmark, RDANH	69 13N	51 06W		1992-1997	Palle Bo Nielsen <pbn@dmi.dk>

shavn							
Aasiaat	Labrador	Denmark, RDANH				1997-	Palle Bo Nielsen <pbn@dmi.dk>
Maniitsoq	Labrador	Denmark, RDANH				1997-	Palle Bo Nielsen <pbn@dmi.dk>
Uumannaq	Labrador	Denmark, RDANH				1993-1997	Palle Bo Nielsen <pbn@dmi.dk>
Danmarkshavan	Greenland Sea	Denmark, DMI	76 46N	18 45W		1993-1998	Palle Bo Nielsen <pbn@dmi.dk>
Scoresbysund	Greenland Sea	Denmark, DMI				1993-1998	Palle Bo Nielsen <pbn@dmi.dk>
		DTU SPACE					Per Knudsen pk@space.dtu.dk
Hafnafjordur	Icelandic	Iceland,IMA	64º04'N	21º57'W		1994-	
Grundartangi	Icelandic	Iceland,IMA	64º21'N	21º47'W		1994-	
Akranes	Icelandic	Iceland,IMA	64º19'N	22º06'W		1994-	
Ólafsvik	Icelandic	Iceland,IMA	64º54'N	23º42'W		1994-	
Patreksfjordur	Icelandic	Iceland,IMA	65º35'N	24º00'W		1994-	
Skagastrond	Icelandic	Iceland,IMA	65º49'N	20º20'W		1994-	
Dalvik	Icelandic	Iceland,IMA	65º58'N	18º31'W		1994-	
Husavik	Icelandic	Iceland,IMA	66º02'N	17º21'W		1994-	
Hvanney	Icelandic	Iceland,IMA	64º14'N	15º11'W		1994-	
Skinneyjarhofdi	Icelandic	Iceland,IMA	64º13'N	15º29'W		1994-	
Porl	Icelandic	Iceland,IMA	63º51'N	21º22'W		1994-	
Vestmanneyjar	Icelandic	Iceland,IMA	63º27'N	20º13'W		1994-	
Grindavik	Icelandic	Iceland,IMA	63º50'N	22º26'W		1994-	
Sandgerdi	Icelandic	Iceland,IMA	64º02'N	22º43'W		1994-	
Keflavik	Icelandic	Iceland,IMA	64º00'N	22º33'W		1994-	
Reykjavik	Icelandic	Iceland, IHS	64 09N	21 56W		1951-	
Longyearbyne	Greenland Sea	Norway, NPI					
Jan Mayen	GIN Sea	Norway,NMA					
Ny-Alesund	Greenland Sea	Norway, Kartverket	78 56N	11 57E		1976-	Tor T?rresen
Vardo	Norwegian	Norway, Kartverket	70 20N	31 06E		1947-	Tor T?rresen
Honningsvag	Norwegian	Norway, Kartverket	70 59N	25 59E		1970-	Tor T?rresen
Hammerfest	Norwegian	Norway, Kartverket	70 40N	23 41E		1957-	Tor T?rresen
Tromso	Norwegian	Norway, Kartverket	69 39N	18 58E		1952-	Tor T?rresen
Andenes	Norwegian	Norway, Kartverket	69 19N	16 09E		1991-	Tor T?rresen
Harstad	Norwegian	Norway, Kartverket	68 48N	16 33E		1952-	Tor T?rresen
Narvik	Norwegian	Norway, Kartverket	68 26N	17 25E		1931-	Tor T?rresen
Kabelvag	Norwegian	Norway, Kartverket	68 13	14 30E		1988-	Tor T?rresen
Bodo	Norwegian	Norway, Kartverket	67 17N	14 23E		1949-	Tor T?rresen
Rorvik	Norwegian	Norway, Kartverket	64 52N	11 15E		1969-	Tor T?rresen