

## **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 TABP, and have hourly or better data from TARC 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).

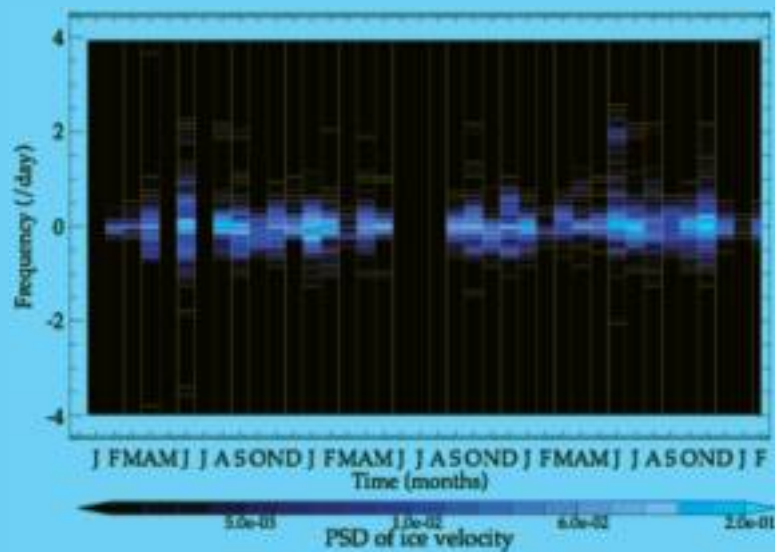


Figure 2: Monthly average spectra of rotary components of ice drift in the Lincoln Sea from 2007 to 2009. Clockwise component is positive, anti-clockwise negative

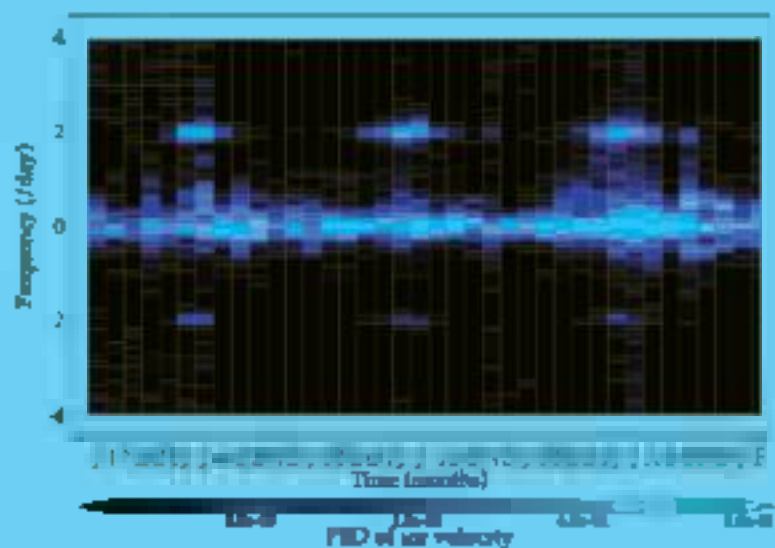


Figure 3: Monthly average spectra of rotary components of ice drift in the Beaufort Sea from 2007 to 2009. Clockwise component is positive, anti-clockwise negative.

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

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>
Danmarkshavn	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 <a href="mailto:pk@space.dtu.dk">pk@space.dtu.dk</a>
Hafnafjordur	Icelandic	Iceland, IMA	64°04'N	21°57'W	1994-	
Grundartangi	Icelandic	Iceland, IMA	64°21'N	21°47'W	1994-	
Akranes	Icelandic	Iceland, IMA	64°19'N	22°06'W	1994-	
Ólafsvik	Icelandic	Iceland, IMA	64°54'N	23°42'W	1994-	
Patreksfjordur	Icelandic	Iceland, IMA	65°35'N	24°00'W	1994-	
Skagastrond	Icelandic	Iceland, IMA	65°49'N	20°20'W	1994-	
Dalvik	Icelandic	Iceland, IMA	65°58'N	18°31'W	1994-	
Husavik	Icelandic	Iceland, IMA	66°02'N	17°21'W	1994-	
Hvanney	Icelandic	Iceland, IMA	64°14'N	15°11'W	1994-	
Skinneyjarhofdi	Icelandic	Iceland, IMA	64°13'N	15°29'W	1994-	
Porl	Icelandic	Iceland, IMA	63°51'N	21°22'W	1994-	
Vestmanneyjar	Icelandic	Iceland, IMA	63°27'N	20°13'W	1994-	
Grindavik	Icelandic	Iceland, IMA	63°50'N	22°26'W	1994-	
Sandgerdi	Icelandic	Iceland, IMA	64°02'N	22°43'W	1994-	
Keflavik	Icelandic	Iceland, IMA	64°00'N	22°33'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?resen
Vardo	Norwegian	Norway, Kartverket	70 20N	31 06E	1947-	Tor T?resen
Honningsvag	Norwegian	Norway, Kartverket	70 59N	25 59E	1970-	Tor T?resen
Hammerfest	Norwegian	Norway, Kartverket	70 40N	23 41E	1957-	Tor T?resen
Tromso	Norwegian	Norway, Kartverket	69 39N	18 58E	1952-	Tor T?resen
Andenes	Norwegian	Norway, Kartverket	69 19N	16 09E	1991-	Tor T?resen
Harstad	Norwegian	Norway, Kartverket	68 48N	16 33E	1952-	Tor T?resen
Narvik	Norwegian	Norway, Kartverket	68 26N	17 25E	1931-	Tor T?resen
Kabelvag	Norwegian	Norway, Kartverket	68 13	14 30E	1988-	Tor T?resen
Bodo	Norwegian	Norway, Kartverket	67 17N	14 23E	1949-	Tor T?resen
Rorvik	Norwegian	Norway, Kartverket	64 52N	11 15E	1969-	Tor T?resen