1. PROJECT INFORMATION

GOA IERP Project Number:	G84
Title:	Exploring temporal and spatial variability in Gulf of Alaska groundfish dynamics with integrated biophysical models
Overall project duration	May, 2010 - February, 2015
Overall project funding	**$999,995**
Report period	May 1 2011 to November 1 2011
Report submission date	November 8th 2011
Lead Author of Report	Georgina Gibson and Sarah Hinckley (co-Lead PIs)

Principal Investigator(s), Co-Principal Investigators and Recipient Organization(s):

Georgina Gibson: gagibson@alaska.edu
Ken Coyle: coyle@ims.uaf.edu
Albert J Hermann: Albert.J.Hermann@noaa.gov
Carolina Parada: cparada@inpesca.cl
Sarah Hinckley: Sarah.Hinckley@noaa.gov
Carol Ladd: Carol.Ladd@noaa.gov
William Stockhausen: William.Stockhausen@noaa.gov
Kerim Aydin: Kerim.Aydin@noaa.gov
Kate Hedstrom: kshedstrom@alaska.edu

2. PROJECT OVERVIEW

A. BRIEFLY (4-5 SENTENCES) DESCRIBE THE CORE PURPOSE OF YOUR PROJECT, AND THE UNDERLYING NEED FOR THIS RESEARCH.

Groundfish recruitment in the Gulf of Alaska is thought to be controlled by physical processes (i.e. climate and transport) and biological processes (i.e. growth and predation) experienced between offshore spawning sites and the end of the young of year (YOY) stage. We will use the Regional Ocean Modeling System (ROMS), a Nutrient-Phytoplankton-Zooplankton (GOANPZ) model, and Individual-Based Models (IBMs) to examine recruitment mechanisms and derive indices related to recruitment for five ground fish species; arrowtooth flounder, walleye pollock, Pacific cod, Pacific Ocean perch, and sablefish. We will also incorporate the indices in a multispecies model (MSM) to explore the consequences of recruitment variability on the GOA ecosystem and fisheries. Indices produced, and conclusions about the effects of physical and biological processes on the GOA ecosystem under different physical regimes will aid in the management of these important fish stocks.

B. STATE THE SPECIFIC GOAIERP HYPOTHESIS OR HYPOTHESES THAT YOUR PROJECT IS ADDRESSING.

Our project will address two of the overarching GOAIERP hypothesis:

1) **The gauntlet**: The primary determinant of year-class strength for marine groundfishes in the GOA is early life survival. This is regulated in space and time by climate-driven variability in a biophysical gauntlet comprising offshore and nearshore habitat quality, larval and juvenile transport, and settlement into suitable demersal habitat.

2) **Regional comparison:** The physical and biological mechanisms that determine annual survival of juvenile groundfishes and forage fishes differ in the eastern and western GOA regions.

To achieve the objectives of our project we will address the following testable hypotheses with our suite of models:

1. *Historical environmental variability in the GOA can be characterized in terms of a few (≤ 6) distinct physical regimes and we can identify these regimes from ROMS simulations.*
2. *Recruitment variability of the five focal species is primarily influenced by variability in the proportion of young fish transported from offshore spawning areas to nearshore nursery areas (connectivity) due to interannual differences in the strengths of the physical regimes that characterize the GOA environment.*
3. *Recruitment variability is secondarily influenced by the survival of young fish successfully transported to nursery areas, which varies due to differences in physical factors (wind speed and direction, water temperature, runoff, mixing) and biological processes (prey abundance, competition, predation) encountered along the transport pathways.*

C. LIST THE SPECIFIC OBJECTIVE(S) OF YOUR RESEARCH PROJECT.

The objective of this project is to identify how recruitment of five target groundfish species in the GOA is affected by environmental variability in the region. We will project the effects of different environmental regimes, and the resulting recruitment variability, on upper trophic level ecosystem dynamics for the GOA under current fishing regimes.

- **NEP5 Regime Analysis:** Use Empirical Orthogonal Function (EOF) and other analysis tools to identify a small number (≤ 6) of distinct physical regimes that comprise the major components of environmental variability in the GOA. Categorize each year as representative of a particular regime.
- **IBM Connectivity:** Calculate the proportions of individuals that arrive at juvenile nursery areas from specific source areas (spawning regions or early larval distributions).
- **Trajectory analysis:** Examine the differences between survivors and non-survivors (or those who do not reach nursery areas) by examining correlations between physical and LTL variables and individual characteristics along individual trajectories from the IBMs through the YOY stage
- **Indices: C**alculate indices related to recruitment success from the IBM results for each of the five focal groundfish species. Transform indices into anomalies from mean recruitment biomasses.
- **MSM simulations:** Incorporate recruitment indices from the IBMs into the MSM model to test how the effects of the different environmental regimes on recruitment interact with population dynamics processes and fisheries.

3. PROGRESS SUMMARY

A. PROVIDE A TABLE SHOWING THE TIMELINE AND MILESTONES FOR THE CURRENT REPORTING PERIOD ONLY.

	2011			
Research Activity Milestone	1	2	3	4
NEP5 Regime Analysis PI's: Ladd & Hermann.				
Comparison between Float Tracking Tools PI's: Parada, Stockhausen, Gibson				
Construction of IBMs for the 5 target species Dependency: LTL, MTL and UTL information PI's: Parada, Stockhausen, Gibson, Hinckley				
Develop experimental design for model runs Dependency: Regime Analysis, Recruitment timeseries, UTL retrospective analysis PI's: All PIs				
Run ROMS/GOANPZ model on NEP grid for boundary conditions for CGOA grid PI's: Hermann, Hedstrom,Coyle, Gibson				

B. DESCRIBE REPORT PERIOD PROGRESS.

NEP5 Regime Analysis: During this reporting period the pattern analysis work has been ongoing and the central focus of activity. Progress and results from this activity, which is near completion, are described in the Results section, below.

Comparison between Float Tracking Tools

During this reporting period we undertook experiments to compare the skill of the offline IBM tools ICTHYOP and DisMELS to track 'floats' relative to the ROMS online float tracking. We followed the model testing protocol outlined in the previous project report. Results from this activity are outlined in the results section. At present, the ICTHYOP tool is able to reproduce the online ROMS float trajectories reasonably well. Inconsistencies have been found with floats tracks produced by the DisMELS tool relative to online ROMS. Preliminary investigation indicates that this may be due to small inconsistencies with start timing and location of the floats between the two models or due to differences in the float tracking algorithm used in the two models. We are currently taking action to pinpoint the source of the problem and improve the comparability of the two tools.

During the past reporting period we identified that the ROMS output we were working with to compare the float tracking algorithms) included tidal aliasing because tidal effects were not being filtered out prior to writing output to the average files. This issue was rectified during the current reporting period. For future simulations, ROMS simulations will be filtered.

Construction of IBMs for the 5 target species:

Construction of the IBM models for each of the five target species are at different stages of development. The pollock IBM is a detailed model previously developed by S. Hinckley and C. Parada. This model is essentially fully developed, with only minor updates needed. The sablefish and Pacific cod IBMs will be much simpler due to the level of data availability on these species. Conceptual models for these species have been developed and construction of the code in NetBeans (Java) in under way. The Arrowtooth and POP IBMs are being developed using the DisMELS software. Some preliminary experiments with the Arrowtooth IBM have been conducted.

Develop experimental design for model runs:

Discussions on the exact years of model runs that will be undertaken with the ROMS/GOANPZ model (NEP and CGOA model grids) and IBMs are underway. This decision will be made following final analysis of the pattern analysis work. We anticipate that the experimental design will be finalized prior to the annual PI meeting in early March 2012.

Run ROMS/GOANPZ model on NEP grid for boundary conditions for CGOA grid

Preliminary discussions on the runs that will be required on the North East Pacific (NEP) grid in order to provide boundary conditions for the smaller Coastal Gulf of Alaska (CGOA) grid are underway. To date, no firm decision on which years will be run has been made. This decision will be made following final analysis of the pattern analysis work. According to our project timeline this activity is expected to be ongoing through the third quarter of 2012.

C. DESCRIBE PRELIMINARY RESULTS.

NEP5 Regime Analysis

We have examined the following parameters from the NEP5 model output to determine whether they co-vary and to what extent we can summarize variability of the physical state of the Gulf of Alaska using a limited set of patterns.

Velocities:
We extracted model velocities along three isobaths, 200m, 500m, and 1000m. These velocities were decomposed into along-shelf (U) and across-shelf (V) components. EOFs were calculated for both the combined U and V velocities as well as for U and V individually. In the along-shelf direction, velocities are influenced by El Niño. The two strong El Niños of 1983 and 1997/98 both resulted in gyre spin-up and stronger along-shelf flow. In the cross-shelf velocities at the 200m isobath, the first EOF mode (Fig. 1) shows up/downwelling circulation west of ~150°W and east of ~146°W with alternating bands of on/offshelf flow at the head of the gulf (between 150°W and 146°W). At the 500m isobath, the cross-shelf velocities are more constant with depth instead of exhibiting upwelling structure.

Stratification:
We examined both the timing of stratification set up in the spring and the strength of stratification in the summer. The date of stratification set up is defined as the day (after March 1) when mixed layer depth shoaling is maximum as long as the resultant mixed layer depth is less than 20m. Average date of stratification set up is mid-May around Kodiak Island and west of Shelikof Strait while it occurs in late April on the Kenai shelf and farther east (Fig. 2). EOFs of stratification date on the shelf show that the signal is strongest around Kodiak Island. Typical variability around Kodiak island is about 3 weeks earlier or later than average. The strength of August stratification varies most strongly seaward of Kodiak Island. The first EOF mode of the strength of August stratification is weakly but significantly correlated with the first EOF mode of spring stratification timing such that earlier spring stratification implies stronger August stratification.

Eddy Kinetic Energy:
We compared time series of average eddy kinetic energy from the eastern and the western Gulf of Alaska (Fig. 3). Both time series show a strong peak during the 1997/98 El Niño which has also been seen in satellite altimeter measurements.

Multivariate analysis:

We performed multivariate EOF analysis on a collection of monthly anomalies, to look for covarying patterns among oceanic and atmospheric quantities. Some of the resulting modes correlated strongly with the MEI (Multivariate El Nino Index) and PDO (Pacific Decadal Oscillation). A mode with especially strong correlations describes a simultaneous rise in SSH and coastal SST, along with a deepening of coastal mixed layer depths (Figure 4; note this is a subset of the total collection of variables used).

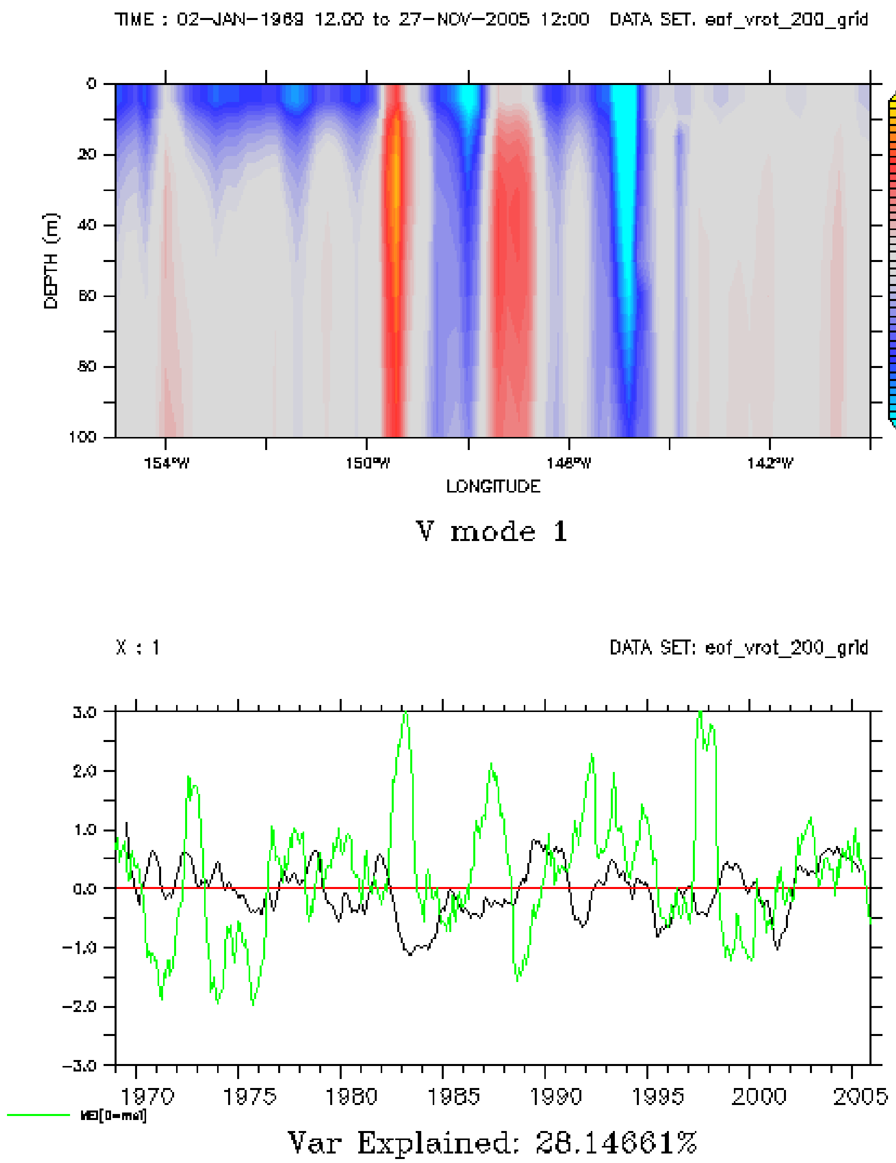

Figure 1. EOF of cross-shelf velocity at the 200m isobath.

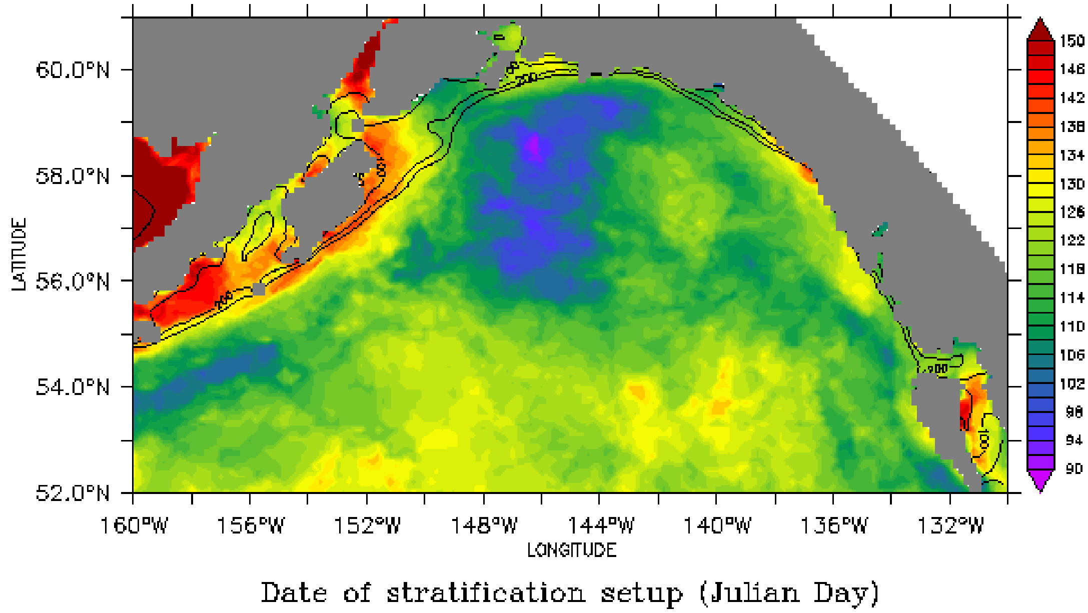

Figure 2. Mean Julian date of stratification setup.

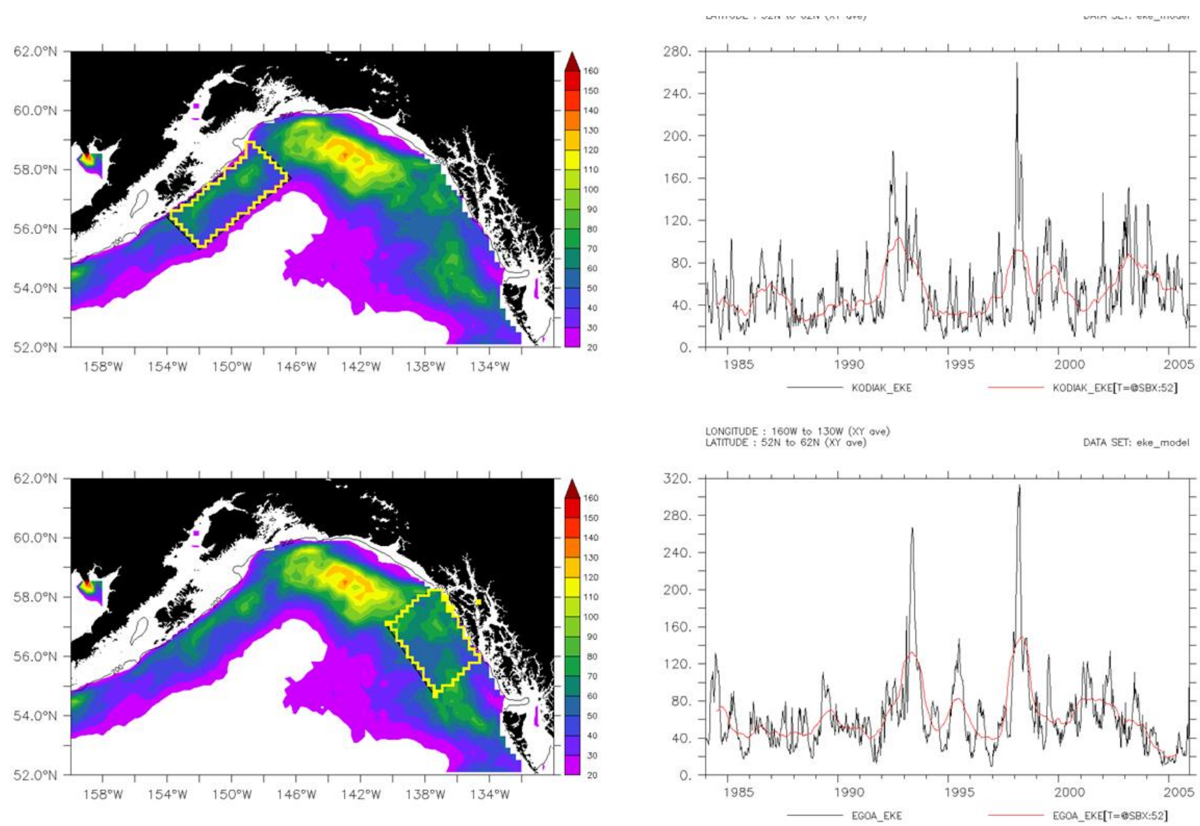

Figure 3. Average eddy kinetic energy showing two averaging regions (left). Time series of EKE averaged over the two regions (right).

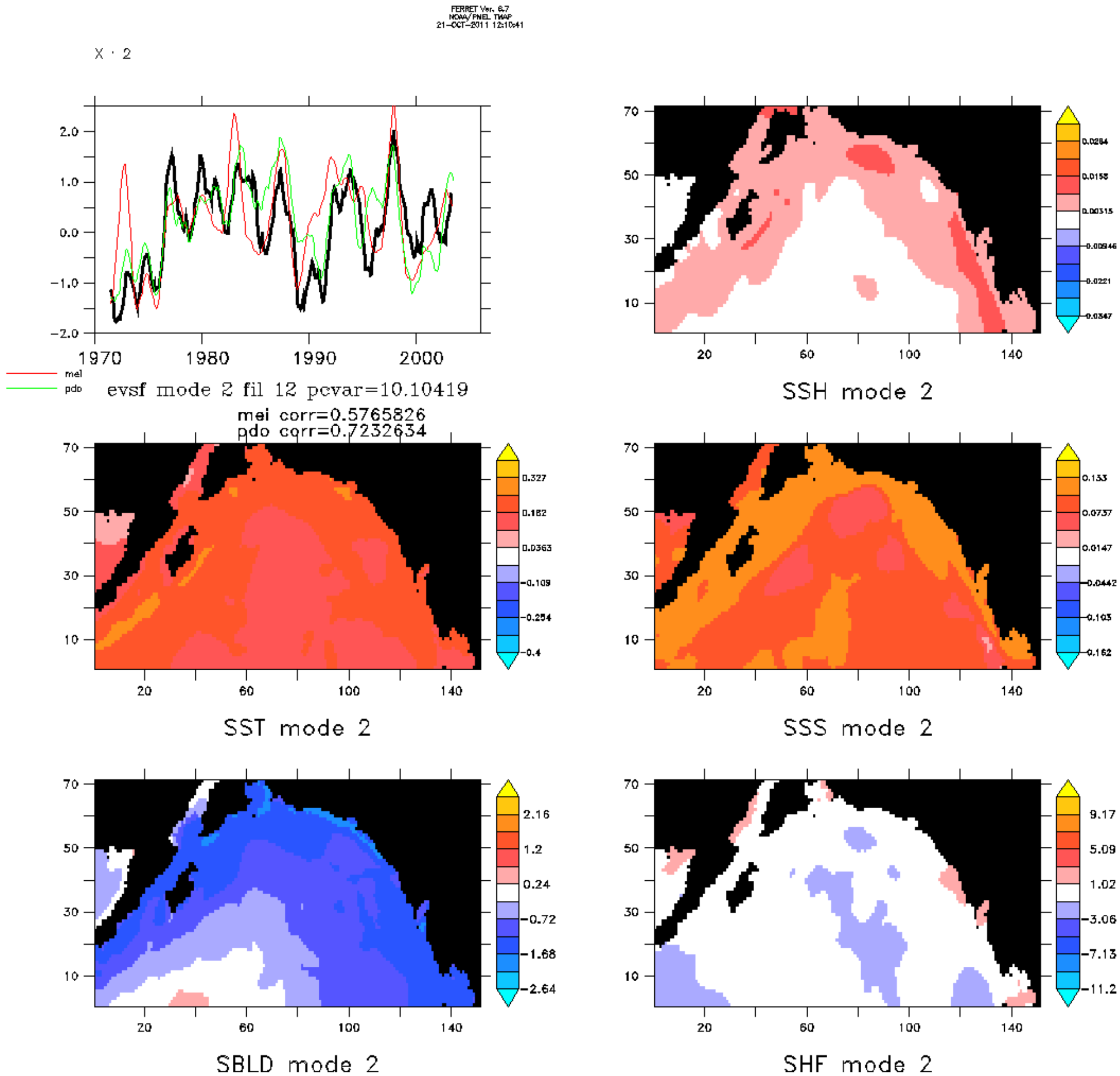

Figure 4. Results from a multivariate EOF analysis of model-derived monthly anomalies. Shown are the second mode amplitude (upper left figure), compared with MEI and PDO indices (rsquared=.57 and .72, respectively). Spatial patterns for this mode are shown for a subset of the variables used. SSH=sea surface height (m), SST=sea surface temperature (deg C), SSS=sea surface salinity (psu), SBLD=mixed layer depth (m; negative numbers denote mixed layer deepening), SHF=surface heat flux (W/m^2; positive numbers denote heat flux into the ocean).

Comparison between Float Tracking Tools

Float tracking experiments comparing offline float tracking tools ICTHYOP and DisMELS to ROMS online float tracking was undertaken to test the performance of the offline tools. In the tests, the offline tools were driven by daily tidally-averaged output from the ROMS CGOA model for 2001. In all three models 191 floats were released throughout the model domain at a set of pre-determined sites at 8 different depths (0,10,20,40,60,100,200,400 m) on 3 different release days (Feb. 3, 2001 00:00:00 GMT, April 3, 2001 00:00:00; and June 3, 2001 00:00:00) and tracked over time for 180 days. With all three models, release depth and date had a substantial effect on both individual float trajectories and on final locations (i.e. Fig. 5). The influence of significant mesoscale activity was evident in the simulated trajectories.

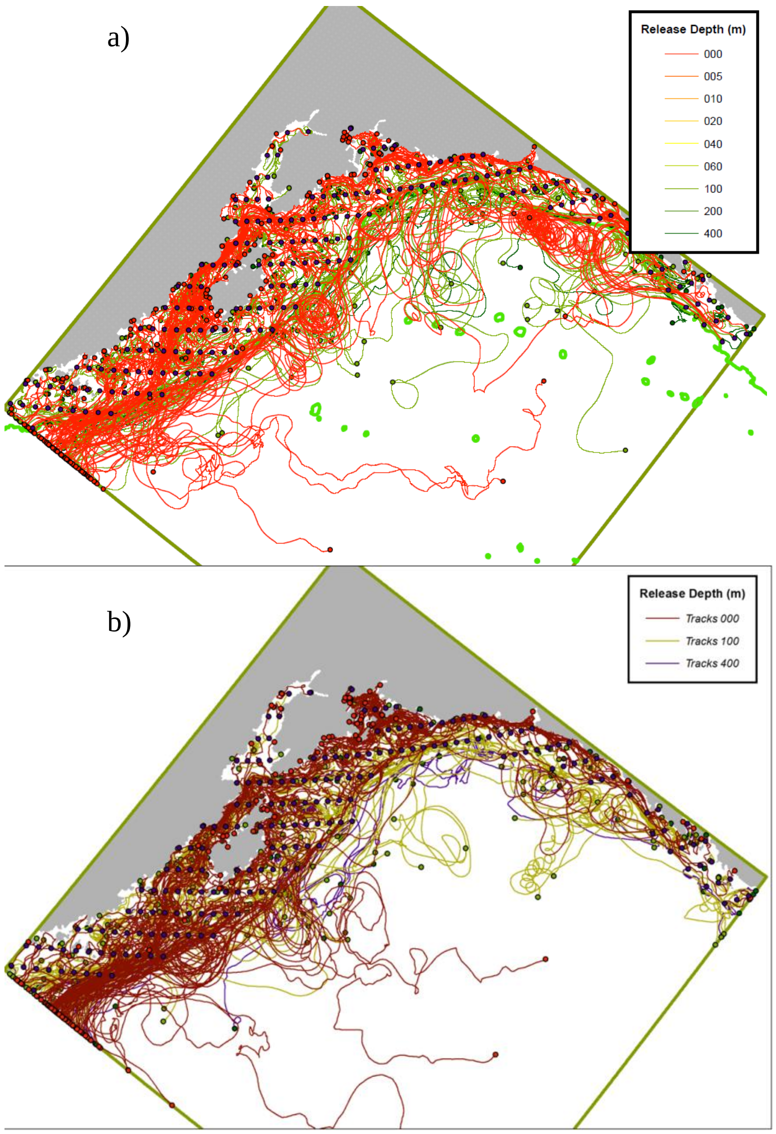

Figure 5. Float trajectories from preliminary DisMELS float tracking experiments: a) Feb. 3 release; b) April 3 release. Only trajectories for floats released at the surface (0 m), 100 m and 400 m depths are shown. Purple dots represent release sites; final locations are represented by dots with the same color-coding as the corresponding trajectory, which is color-coded by release depth (red: 0 m, green: 100 m, blue: 400 m).

In general, there was good agreement between ROMS and ICTHYOP float tracking capabilities. Figures 6 (a-i), for example, shows that often the two models produce very similar trajectories. The horizontal trajectories in particular are very comparable. However, there were several cases when the distance the between ROMS and ICTHYOP float tracks was relatively large (800 km in the worst case).

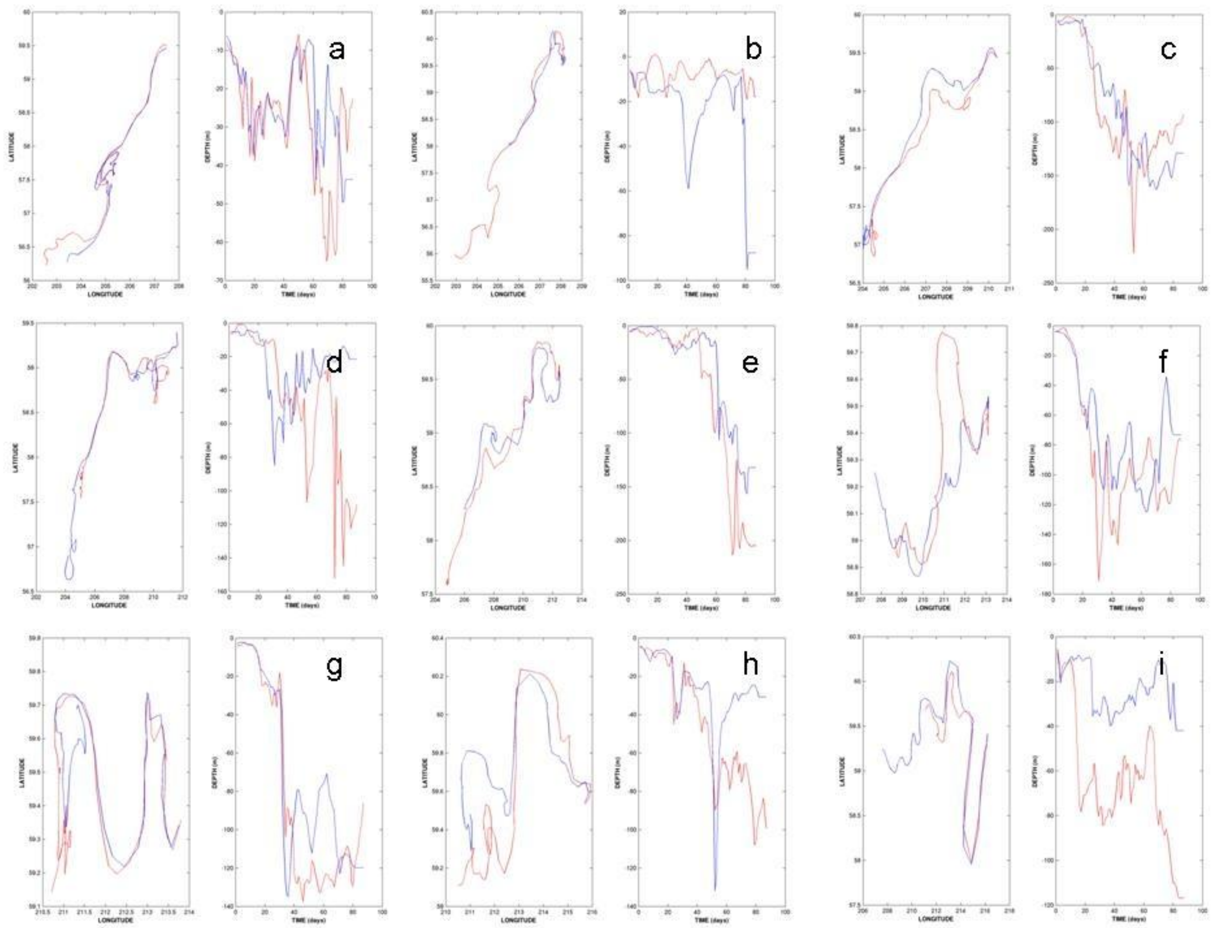

Figure 6. Examples of particle tracking comparison between ROMS and ICTHYOP. The double panels are for horizontal (left) and vertical (right) location of particles from initial to final positions. Red lines represent ROMs trajectories and blue lines ICTHYOP trajectories.

Close inspection of the horizontal and vertical trajectories, revealed that the initial positions set for ROMS and ICTHYOP and DisMELS were not always identical as should have been the case. The initial position setting in ICTHYOP and DisMELS uses geographical coordinates, which are subsequently transformed to ROMS coordinates. The two models appear to use somewhat different algorithms for converting initial real world coordinates to model grid coordinates, resulting in discrepancies in initial locations. In ICTHYOP, for example, the initial horizontal deviance was as much as 4 km in some instances while the initial vertical deviance approached 2 m. (Figure.7a). In some cases, large divergences in initial horizontal and vertical initial positions may correspond with a large drift between the final positions of the ROMS and ICTHYOP trajectories. However, Hovmuller plots showed no clear relationship between the initial distances in the initial vertical and horizontal directions and the final deviance. Most of the ending locations were less than 100 km apart (Figure 7b) and most of the deviances actually occurred when the initial vertical and horizontal deviance were small. Therefore, we conclude that the differences in starting location are likely not causing most of the divergence in trajectories between ROMS and ICTHYOP. It seems more likely that the intensity of physical processes, which will vary as positions drift apart, may be effecting final positions. So far, our experiments have been very encouraging with regards ICTHYOP's performance, however, it is important that we work towards minimizing the initial position differences between ICTHYOP and ROMS in order to mitigate this potential source of error.

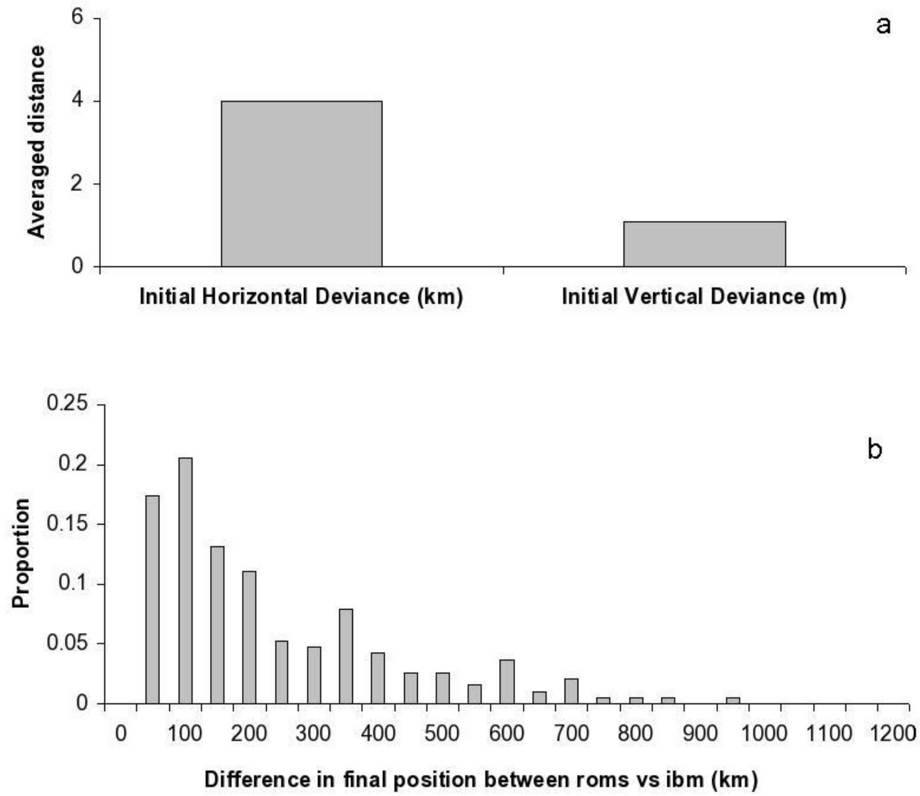

Figure 7. Deviance in trajectories as simulated by ROMS and ICTHYOP (a) and histogram of trajectory deviances (b).

Initial comparison between ROMS online and DisMELs offline float trajectories were not terribly favorable. Comparisons improved substantially when DisMELS was run using temporal interpolation of the ROMS model output at a 20 minute time step, rather than a 1-day time step (as in the results shown). Once it was recognized that initial locations for the floats were not the same between DisMELS and ROMS, as should have been the case, further investigation revealed that the DisMELS algorithm for converting initial real world coordinates to model grid coordinates is presently based on an earlier version of ROMS than is used currently for the ROMS CGOA model simulations. It appears the DisMELS algorithm should be updated to reflect the current ROMS algorithm. This realization has also prompted an unanticipated comparison of other DisMELS algorithms (lagrangian tracking, interpolation schemes), that were also based on the earlier version of ROMS, with the current ROMS algorithms. The float tracking experiments will be finalized after this review is done.

Eddy Tracking

One of the goals of the modeling component is to examine conditions along the simulated trajectories of larval and juvenile fish, to see whether the environment (acting on the fish) differs significantly between those that reach the nursery areas and those that do not. Entrapment in eddies has been thought to affect larval survival through either enhanced transport to suitable nursery areas, and/or through modification of the food and predator environment. Dr. Parada (and her team at INPESCA) have developed a method of identifying eddies in the output of the ROMS model, using the Okubo parameter. Sequential snapshots of ROMS output with the eddies identified are then linked, so as to trace the trajectories of the different eddies. Prior to this, the linking of eddies in sequential snapshots has been a manual operation and very time and labor intensive. Dr. Parada has begun to develop a program to automate this process, and, though this is a difficult problem, progress to date is encouraging.

Construction of IBMs for the 5 target species

Development of all five IBMs has been ongoing during this reporting period.

d. Describe integration activity.

- All PIs attended a face-to-face GOAIERP modelers meeting on August 23rd 2011. We have additionally conducted monthly PI telephone calls. Francis Weise and Danielle Dickson have participated in the GOAIERP modelers monthly PI calls and the in person modelers PI meetings.
- Gibson, Parada and Hinckley worked together extensively on developing the IBMs during a three day model development workshop in August.
- Many of the GOAIERP modeler PIs regularly attend the All PI GOAIERP monthly phone meetings.
- Coyle participated in the April-May 2011GOAIERP cruise to collect field samples around Kodiak as well as the Fall Seward Line cruise. The material from the fall cruise may be used to help interpret GOAIERP related data.
- Hinckley has participated in numerous discussions with PIs from the other GOAIERP components with respect to survey results i.e. fish distributions and predator stomach samples collected
- Hinckley has had extensive discussions with Miriam Doyle with regards the information she is putting together from the FOCI database: quarterly distributions of five focal species eggs, larvae, juveniles; summary of depth information, the grid she uses to plot distributions on, her plans for future work.
- Hinckley has had discussions with Miriam Doyle and Ann Matarese with regards life histories of target fish species that are being modeled.
- Hinckley has participated in GABI and Retrospective Team activities.

e. Describe any concerns you may have about your project's progress.

In our previous progress report we detailed a concern with regards the tidal aliasing that was present in the ROMS output daily average files. Since that time this issue has been rectified and the output now used to run the offline IBMs has been tidally filtered. By this stage in our project we had hoped to have finalized the comparison of the off-line float tracking tools to the ROMS online model. Although not complete, this activity is near completion and we anticipate that it will have been finalized prior to the end of the year. All other project activities are proceeding according to our timeline.

f. Poster and oral presentations at scientific conferences or seminars

The only presentations that have been made thus far have been for GOAIERP internal meetings. Several posters showcasing the GOAIERP modeling effort are planned for the upcoming Alaska Marine Science Symposium in January 2012.

g. Education and outreach

Sarah Hinckley met with teacher Dr. Kama Almasi to discuss the role of the modeling effort in the overall GOAIERP program to contribute towards the success of the Gulf of Alaska Teacher workshop.

4. PROGRESS STATUS

We are pleased with the progress of our project to date. With the exception of the slight delay in finalizing the comparison of offline float tracking tools to the ROMS online model the activities that we were working on during this reporting period are well under way but are not due to be finalized until subsequent reporting periods. The comparison of the offline and online tools is an important step and building block for the remainder of the project so we feel that it is well worth spending the additional time to ensure adequate behavior of the offline tools. During this reporting period we lost Sarah Gaichas and Heather Galindo from the project due to new employment opportunities. The work that Sarah Gaichas would have undertaken on the MSM model will now be undertaken by Kerim Aydin, another expert in this field. The genetics modeling work is not due to be undertaken until 2013. Prior to this Heather Galindo has indicated that she will work with us to find a suitable replacement to conduct this work.

5. FUTURE WORKPLAN and DATA DELIVERY

Workplan

What	*Who*	*Start and end dates*	*Other key dates*
NEP5 regime analysis	Hermann, Ladd	Oct 2010-Dec 2011	
Comparison between Float Tracking Tools	Parada, Stockhausen, Gibson	Oct 2010-Sept 2011	
Construction of IBMs for the 5 target species	Parada, Stockhausen, Gibson, Hinckley	Oct 2010-Sept 2012	
Develop experimental design for model runs	Coyle Hermann, Ladd, Parada, Gaichas,Stockhausen, Gibson, Hinckley	May 2011-March 2012	
Run ROMS/GOANPZ model on NEP grid for boundary conditions for CGOA grid	Hermann, Hedstrom,Coyle, Gibson	Oct 2011-Dec 2012	

Data delivery.

GOAIERP Data Delivery Table		
Data type for delivery	Delivery Month & Year	Person sending data, with email address
NONE		