

Implementation of an Ocean Circulation Model: A Transition from SEA (PWS) to GEM (GOA)

Project Number: 02603

Restoration Category: Research

Proposer: University of Alaska Fairbanks

Lead Trustee Agency: ADFG

Cooperating Agencies:

Alaska Sea Life Center: No

Duration: 1-year project

Cost FY 02: \$80,000

Geographic Area: GOA including PWS and Cook Inlet

Injured Resource/Service:

ABSTRACT

During this transition year (FY02), we propose to establish a 3-D ocean circulation model in the Gulf of Alaska (GOA) to lay down a foundation for GEM starting in 2003 in order to couple this model to a hydrological model and a biological model. This model will cover the entire GOA, including PWS and Cook Inlet. The horizontal resolution of this model is 4'x2' minutes (about 3.7km at 60° N). This model will be forced by tides, the Alaska Current inflow/outflow, freshwater discharge, and wind stress derived from NCEP (National Center for Environmental Prediction).

INTRODUCTION

In the SEA program, extensive observations of phytoplankton and zooplankton, as well as oceanography, have been made during 1995–1998 (Cooney, 1996, 1997; McRoy et al. 1997; Thomas et al. 1997). Fish larvae and schools of some kinds were also measured (Stokesbury et al. 1997). The 3-D ocean circulation model explains some mechanisms with a application to biology (Mooers and Wang 1998; Wang et al. 2001). For example, the oceanic advection and diffusion only can explain the existing phytoplankton and zooplankton movement, while the spring blooms and sometime the later summer blooms (i.e., second bloom in the year) due to the ecosystem dynamics cannot be explained by a physical only model.

Based the observed data collected from 1995–1998 in PWS and the forcing of tide, coastal current inflow/outflow, freshwater discharge, and wind stress, a 3-D PWS model developed from the SEA Project (Wang and Ikeda 1996; Mooers and Wang 1998; Wang et al. 1999, 2001) has been used to produce a continuous 4-year, 3-D fields of velocity, and temperature, salinity. In addition, the interannual variability of PWS ocean circulation, temperature and salinity due to interannually variable atmospheric forcing has been studied. Thus, we can identify the key environmental parameters in a long-term monitoring program (such as GEM) to assist resource managers through sensitivity studies. During 1998-2000 (SEA Project 00398), the substantial progress has been made for the PWS ocean circulation modeling:

1. We provided 3-D velocity fields to A. Brown for her research (Brown et al. 1999), because she found that physical forcing from the 3-D model fits well with her biological data. Thus, she strongly urges us to provide four consecutive years (1995–1998) of the 3-D current velocity, temperature and salinity for her continuous proposal to EVOS.
2. We have collected the wind data from 1995-1998 at mid Sound station (see Fig. 1) and other stations (not shown) with the efforts of Dr. Vince Patrick, Jenny Allen, and Stephen Bodnar (the first-year subcontract). These data have a 30min interval, which were averaged to hourly or 3-hourly interval to drive the model.
3. The year-to-year variability of the circulation due to wind forcing has been examined (Figs. 2-4).
4. We are preparing a manuscript on the sensitivity studies of PWS circulation with respect to the forcing functions: winds, freshwater runoff, ACC inflow/outflow, and tide (Jin and Wang 2001).

NEED FOR THE PROJECT

A. Statement of Problem

Since SEA project started more than five-year ago, physical oceanographers and modelers at IARC and IMS/UAF have developed a PWS circulation model (Wang et al. 2001) and a coupled biological-physical model (Jin et al. 2001). Because the PWS model has a limited region with two open boundaries, physical conditions are required to prescribe these boundary conditions into the model. This drawback was noticed during the course of the research. To overcome this drawback and to face the challenge of the GEM goals, we propose to develop a GEM-based 3D

circulation model (Fig. 1), covering the entire GOA including PWS and Cook Inlet. This model has a potential for future coupling with

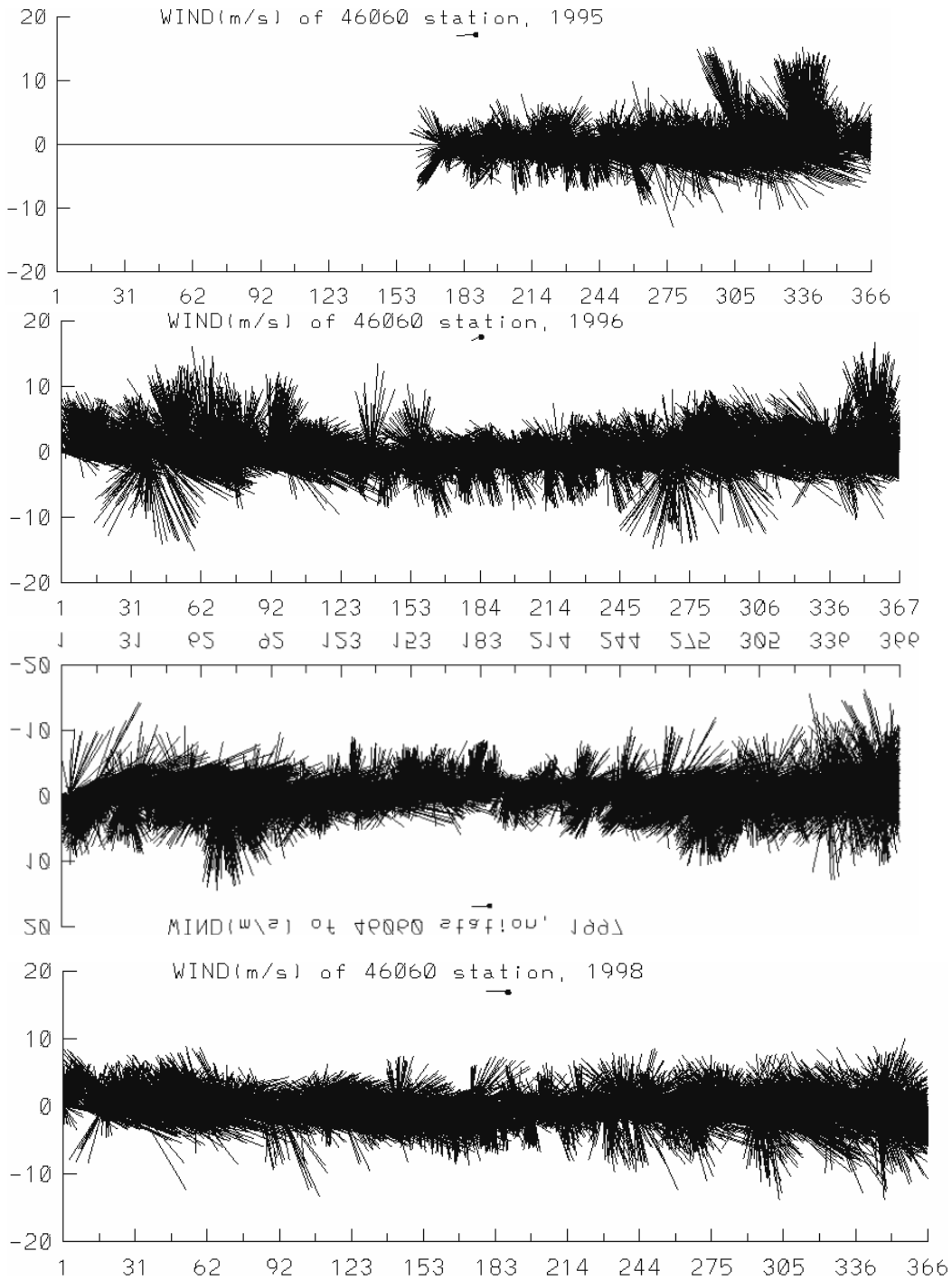


Fig 1. Wind vector at the mid-sound of PWS from 1995–1998.

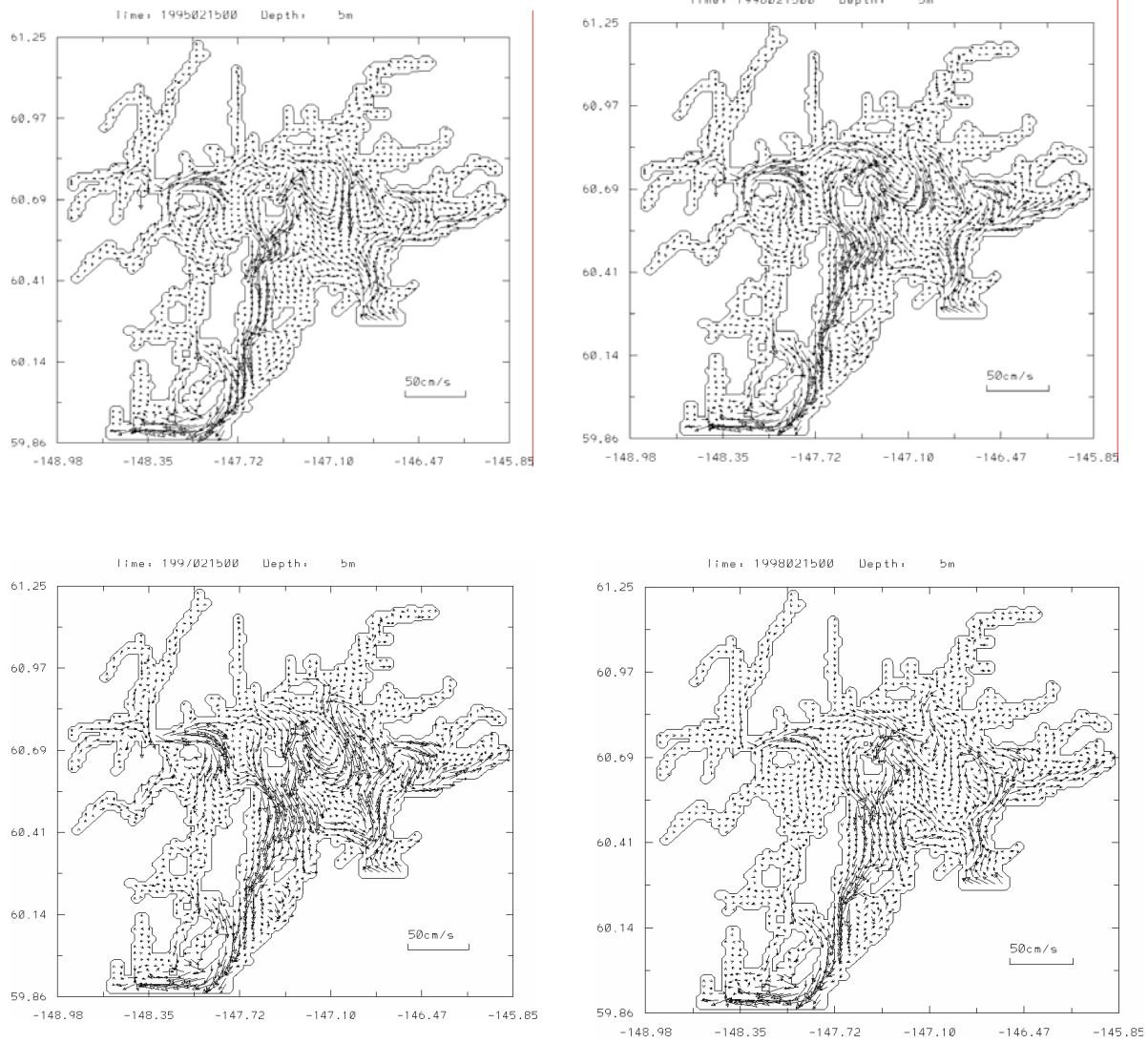


Fig. 2. Surface current of February 15 of 1995-1998.

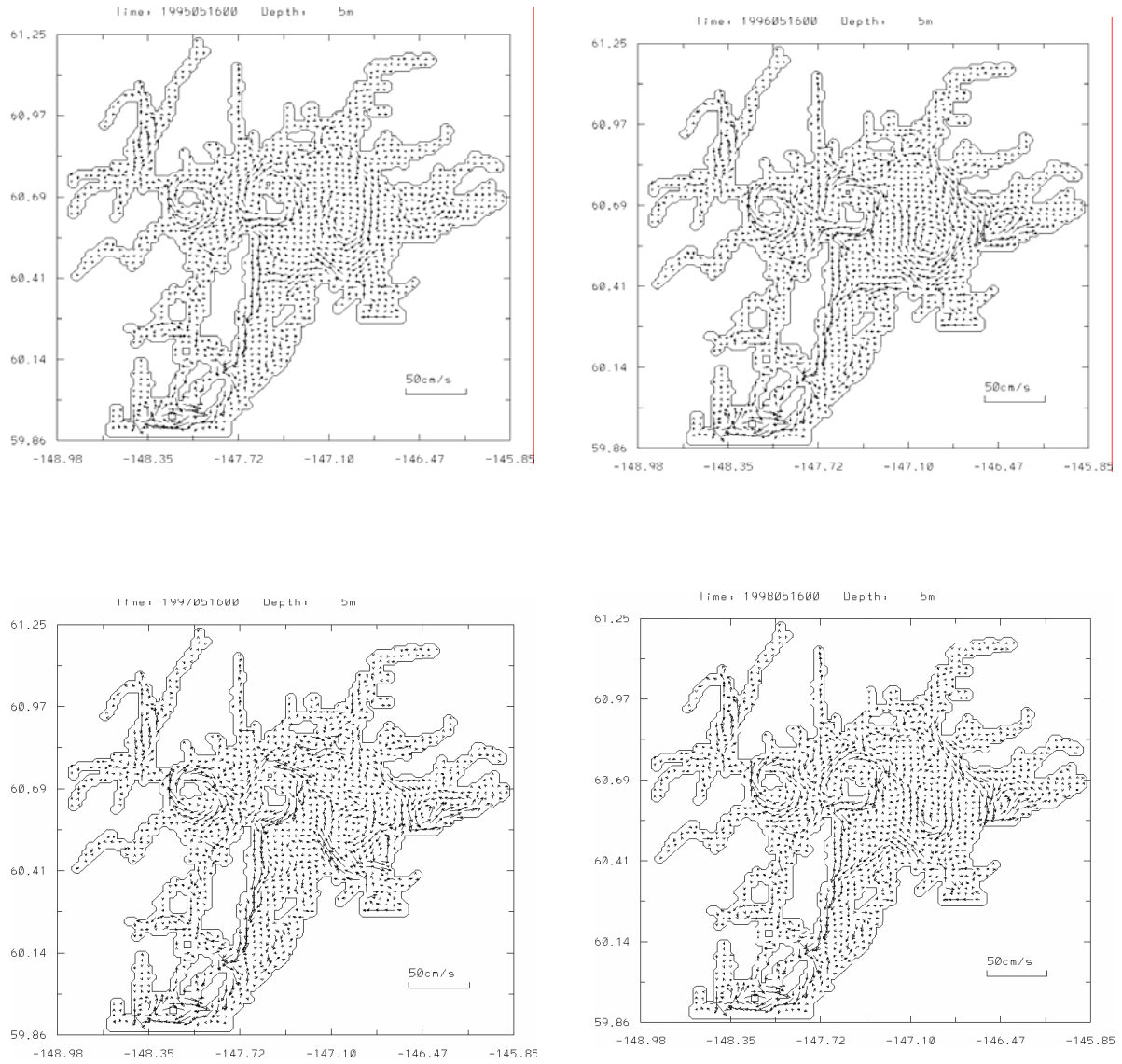


Fig. 3. Surface current of May 15 of 1995-1998.

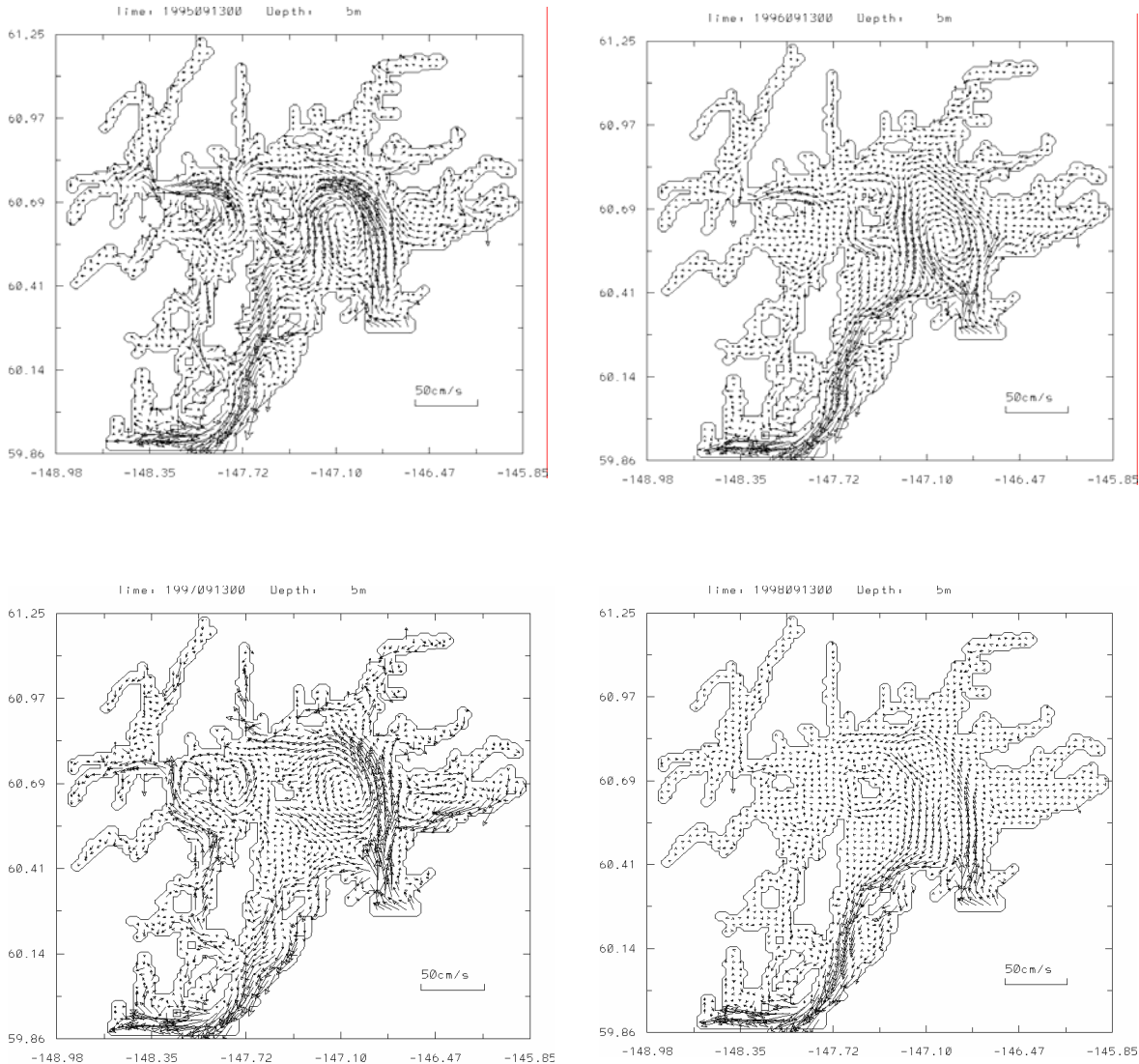


Fig. 4. Surface current of September 15 of 1995-1998.

1. Hydrological model to calculate freshwater runoff of the point source (rivers) and line source, because the line source was at least comparable to the point source.
2. Biological model with nutrients, phytoplankton, zooplankton, and detritus, which describe the primary and second productivity in the region.
3. Developing a nowcast/forecast system (Wang 1999, 2001) to provide prediction of the ocean states to users, such as environmental policy makers, managers, and fishing fleets, with sophisticated data assimilation of satellite-sensed sea surface height (SSH), SST, biological variables, surface current, as well as in situ oceanographic dataset of any type.

Therefore, it is essential to establish a 3D, high-resolution ocean circulation model at the very beginning of GEM to provide necessary physical setting/forcing/information to biological and

other disciplines. This model also can provide boundary conditions to the PWS model.

B. Rationale/Link to Restoration

The Gulf of Alaska (GOA) including PWS and Cook Inlet is located in the northeastern Pacific. A systematic numerical simulation (study) of the physical oceanography and ecosystem in the region is essential and timely to understand the physical-biological system in order to provide scientific knowledge and information to the state government, local community, etc. Because of its rich resources in sea birds, mammals, salmon, forage fish, and many other animals,

Possibly because the North America's largest oil spill by T/V Exxon Valdez on March 24 1989 in PWS seriously damaged the ecosystem in PWS and the adjacent downstream waters in GOA, such as Cook Inlet and Kachemak Bay, extensive observational programs have been carried out in PWS and GOA. The SEA (Sound Ecosystem Assessment) project was a major effort since. This interdisciplinary project started in 1994 with major focus on pink salmon, Pacific herring habitat, ecology, and physical oceanography. As the physical component, the effort was placed on field program and numerical modeling.

After the implementation of 3D-PWS model and a passive tracer simulation were accomplished (Mooers and Wang 1998; Deleersnijder et al 1998), a seasonal simulation (12 consecutive months) has been followed up by Wang et al. (2001) using the SEA observations of 1996 only. However, the field observations in physical and biological oceanography from 1995–1998 during the SEA program have not fully validated. In addition, the interannual variability as observed can not be explained by PWS model only, unless a large region is included. Thus, after the SEA has been synthesized (SEA Synthesis Volume, 2001), it is necessary to step up to develop a large-scale, 3D, high-resolution ocean circulation model (<http://www.frontier.iarc.uaf.edu:8080/~jwang>) for the GEM research themes (<http://www.oilspill.state.ak.us/future/gem.html>), such as coupled biological-physical modeling, coupled hydrological-physical modeling, and towards a nowcast/forecast system for GOA (Wang 2001).

The simulated results will be valuable to assist resources managers to forecast pink salmon and Pacific herring abundance and to anticipate or understand changes in the ecosystem. In addition, key elements will be identified that will be pertinent to include in a long-term monitoring program, leading to an establishment of a nowcast/forecast system in GOA using this 3D-GOA model.

C. Location

The research is conducted for the ecosystem of GOA (Fig. 1) that will help understanding the basic physical environment and forcing to the biological research community and resource managers.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

Not only the research institutions (such as IMS and IARC of UAF), but also the local community (Regional citizens' Advisory Council, RCAC, at Cordova and Cook Inlet) will be involved. They are concerned with possible long-term oil spill impact on the ecosystem and local community as well.

PROJECT DESIGN

A. Objectives

1. Implement a 3D-GOA model to simulate ocean circulation, T, S, vertically mixing coefficients using 2.5 turbulence closure model. The model validation will be conducted using actual observations in the future.
2. Provide biologists and resource managers the 3-D fields (longitude, latitude, and depth) of velocity, T, S, etc. of the ocean states.
3. Put the simulation results in a new server at IMS-IARC/UAF to enhance the information exchange and scientific communication with Alaskan citizens and local community.

B. Methods

The above objectives will be accomplished using a 3D-GOA ocean circulation model (Fig. 5).

1. Forcing data
 - i. Winds: The daily wind speeds and directions will be obtained from NCEP reanalysis, available from 1957-2000 (we need to purchase the data.)
 - ii. Tides: Oceanic tidal harmonic constants for 6 major tides (M_2 , S_2 , S_2 , K_1 , P_1 , O_1) will be specified in the southern boundary (Schwilerski 1980).
 - iii. Freshwater runoff: The hydrological model for freshwater discharge into GOA will be implemented in year 2003 (GEM project) to provide runoff discharge. At the present time, the surface temperature and salinity will be restored to the NODC (National Oceanographic Data Center) Levitus T and S dataset.
 - iv. Daily heat flux for the same period will be extracted from the NCEP reanalysis.
 - v. The monthly inflow/outflow of Alaska Current and Alaska Stream will be fixed to the observations of Onishi and Ohtani (1999).

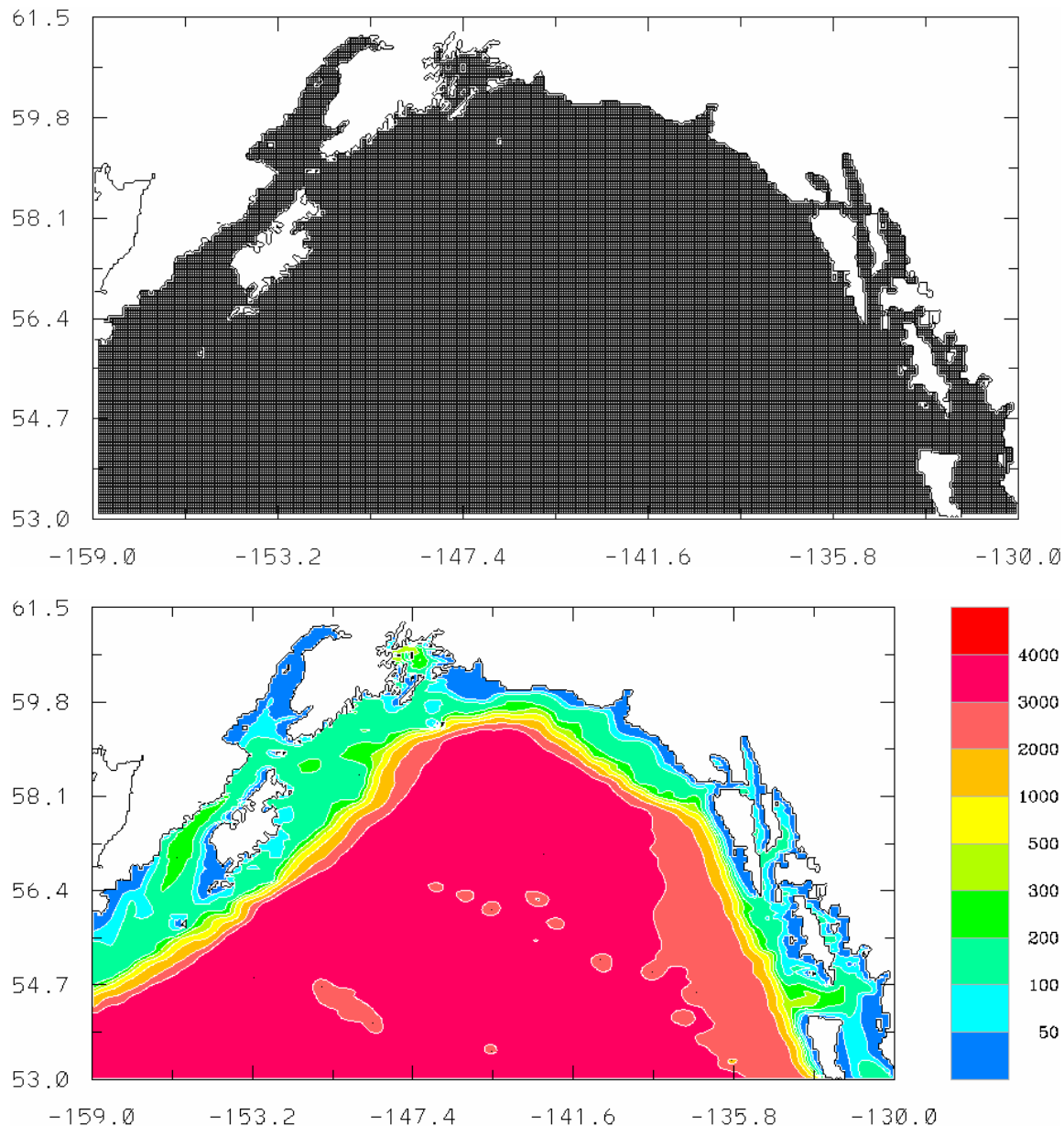


Fig. 5. Proposed 3D-GOA ocean circulation model for GEM: (upper) model grids and (bottom) topography).

2. Model simulations

The model resolution is about 3.75km and time stepping is 5mins/10secs for the internal/external mode. There are 20 levels in the vertical with 8 levels in the upper 50 meters to resolve the upper mixed layer. The purpose of this setting is to resolve the biological onset of the blooms in the upper mixed layer. Thus, the ocean model setting is suitable for the future biological model coupling.

Figure 6 shows the model run only under forcing of tides of six constituents. The model shows very strong tidal current in Cook Inlet, but weak tidal current in PWS, consistent with the observed information and previous tidal simulation in PWS (Wang et al 1997).

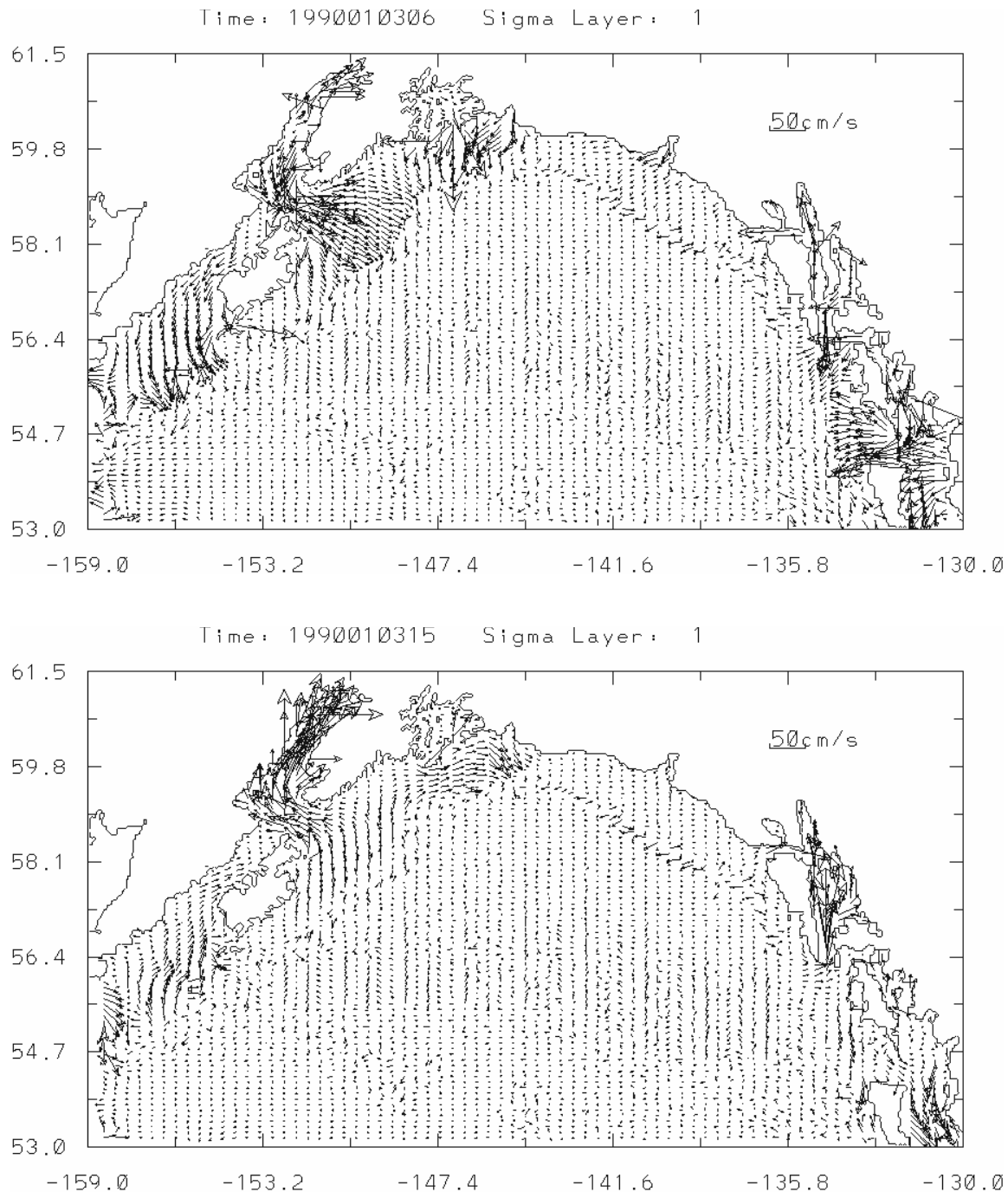


Fig. 6. Surface current at 6h (ebb) and 15h (flood) on 01/03/1990

A annual cycle (12-month) simulation will be conducted under the climatological (44-year mean) forcing described above (wind, heat flux, inflow/outflow with restoring to surface T and S) and tidal forcing. The outputs will be validated based on observations at coastal tide gauges, moorings, and CTD transects, etc.). Then, the model outputs (velocity, T, S, mixing coefficients, etc.) in 3D grids will be provided to biologists who need these outputs to verify their phytoplankton and zooplankton data. The monthly climatology for above mentioned variables will be produced.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

The data preparation will be conducted by Dr. Jin and a M.Sc. student (Yongmei Qin). The PI got funded from OSRI (Oil Spill Recovery Institute) for one-year (2000-2001) term (50K) of the proposal entitled "A 3-D coupled biological-physical model for the ecosystem in PWS, Alaska" to support 6-months of salary for Dr. Jin. This project will benefit the present proposed research by paying half of the time for Dr. Jin to focus on the intensive modeling work and data analyses.

SCHEDULE

A. Measurable Project Tasks for FY 02 (October 1, 2001 – September 30, 2002)

December 31:	Complete tide simulation and preparation of the NCEP climatological forcing
January 18–28 (3 of these days):	Attend Annual Restoration Workshop (Wang, Jin, maybe student as well)
March 31:	Start to implement the forcing data to the 3D-GOA model
August 31:	Complete the modelling of the seasonal cycle
September 15:	Put the simulation to the website

B. Completion Date

September 30, 2002

PUBLICATIONS AND REPORTS

Manuscript (entitled "Tidal current and tidal residual current in GOA" will be prepared and submitted to a refereed journal for formal publication. I may present the results and publish another paper in the book entitled "Computer Modeling of Seas and Coastal Regions, V, 2002" in which I serve as a member of the International Advisory Committee for three years now.

PROFESSIONAL CONFERENCES

The PI and Dr. Jin plan to attend the annual EVOS meeting, 2002 Ocean Science Meeting in Hawaii, presenting the updated research results. This is an excellent way to communicate with our colleagues and to get recognised in the ocean science community. We also encourage the student (research assistant) to attend the scientific meeting and EVOS workshop.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This proposed research will be co-ordinated with 1) E. Brown's project (if her proposal gets funded) by providing her with the model outputs; 2) B. Norcross's proposal for EVOS by providing our 3-D model outputs, and other potential proposals for the restoration effort for GEM. We are willing to provide our simulation outputs to all EVOS-funded proposals by putting our simulation results on our website in both digital and graphic formats.

PROPOSED PRINCIPAL INVESTIGATOR

Jia Wang
Institute of Marine Science and IARC
University of Alaska Fairbanks
P.O. Box 757335
Fairbanks, Alaska 99775-7335
907-474-2685
907-474-2643
jwang@iarc.uaf.edu

PRINCIPAL INVESTIGATOR

Dr. Jia Wang, the PI, will be involved in the entire course of the project, providing scientific guidance to the project, without claiming salary. The PI needs one graduate student to conduct forcing data from NCEP reanalysis.

OTHER KEY PERSONNEL

Dr. Meibing Jin, who is currently working on this EVOS-funded project awarded to the PI (Wang), will continue conducting the simulation, and will partially supported by the OSRI fund for six months, plus UAF overhead (25%), benefit, and travel to scientific conferences/workshops.

LITERATURE CITED

- Brown, E.D., J. Wang, S.L. Vaughan, and B.L. Norcross, 1999. Identifying seasonal spatial scale for the ecological analysis of herring and other forage fish in Prince William Sound, Alaska. *In Ecosystem Approaches for Fisheries Management*, Alaska Sea Grant College Program AK-SG-99-01 (in press)
- Cooney, T. 1996. SEA—An Integrated Science Plan for the Restoration of Injured Species in Prince William Sound. EVOS FY 1996 Annual Report.
- Cooney, T. 1997. SEA—An Integrated Science Plan for the Restoration of Injured Species in Prince William Sound. EVOS FY 1996 Annual Report.
- Deleersnijder, D., J. Wang, and C. Mooers. 1998. A two-compartment model for understanding the simulated three-dimensional circulation in Prince William Sound, Alaska. *Cont. Shelf Res.*, 18: 279–287.
- Eslinger, D.L., R.T. Cooney, C.P. McRoy, A. Ward, T. Kline, E.P. Simpson, J. Wang and J.R. Allen, 2001. Plankton dynamics: Observed and modeled response to physical forcing in Prince William Sound, Alaska. *Fisheries Oceanography* (in press).
- Jin, M. and J. Wang, 2001. Sensitivity studies of impacts of forcing functions on circulation in Prince William Sound, Alaska (in prep.)
- Jin, M., J. Wang, P. Simpson, P. McRoy, and G. Thomas, 2001. A 3-D coupled biological-physical model of the ecosystem in Prince William Sound, Alaska. (submitted to *J. Geophys. Res.*).
- McRoy, C.P. 1997. Sound ecosystem analysis: phytoplankton and nutrients. *In* Chapter 3, SEA—An Integrated Science Plan for the Restoration of Injured Species in Prince William Sound. T. Cooney (ed.). EVOS FY 1997 Annual Report.
- Mooers, C.N.K. and J. Wang. 1998. On the implementation of a 3-D circulation model for Prince William Sound, Alaska. *Cont. Shelf Res.*, 18: 253–277.
- Niebauer, H.J., T.R. Royer, and T.J. Weingartner, 1994. Circulation of Prince William Sound, Alaska. *J. Geophys. Res.*, 99: 14,113–14,126.
- Sea Synthesis Volume, 2001. Fisheries Oceanography (in press).
- Stokesbury, K.D.E., E.D. Brown, R.J. Foy, and B.L. Norcross. 1997. Juvenile herring growth and habitats. *In* Chapter 11, SEA—An Integrated Science Plan for the Restoration of Injured Species in Prince William Sound. T. Cooney (ed.). EVOS FY 1997 Annual Report.

- Thomas, G.L., K. Jay, G. Steinhart, and N. Peters. 1997. Nekton-plankton acoustics. *In* Chapter 10, SEA—An Integrated Science Plan for the Restoration of Injured Species in Prince William Sound. T. Cooney (ed.). EVOS FY 1997 Annual Report.
- Wang, J., 1999. A nowcast/forecast system for coastal ocean circulation (NFSCOC). International Arctic Research Center-Frontier Research System for Global Change. IARC/Frontier Tech. Rep. No. 99-1. University of Alaska Fairbanks, 97pp.
- Wang, J., 2001. A nowcast/forecast system for coastal ocean circulation using simple nudging data assimilation. *J. Atmos. Oceanic Tech.* (in press).
- Wang, J. and M. Ikeda. 1996. A 3-D ocean general circulation model for mesoscale eddies-I: meander simulation and linear growth rate, *Acta Oceanologica Sinica*, 15: 31–58.
- Wang, J., C.N.K. Mooers, and V. Patrick. 1997. A three-dimensional tidal model for Prince William Sound, Alaska. *In* Computer Modelling of Seas and Coastal Region III, J.R. Acinas and C.A. Brebbia (eds.), Computational Mechanics Publications, Southampton, pp 95–104.
- Wang, J., V. Patrick, J. Allen, and M. Jin. 1999. Modeling seasonal ocean circulation of Prince William Sound, Alaska using freshwater of a line source. *In* Computer Modelling of Seas and Coastal Region IV, C.A. Brebbia, et al. (eds.), Computational Mechanics Publications, Southampton (in press).
- Wang, J., M. Jin, V. Patrick, J. Allen, D. Eslinger, and T. Cooney. 2001. A simulation of the seasonal ocean circulation patterns and thermohaline structures of Prince William Sound, Alaska, 1996. *Fisheries Oceanography* (SEA Synthesis Volume, in press).

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		\$0.0						
Travel		\$0.0						
Contractual		\$74.8						
Commodities		\$0.0						
Equipment		\$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		\$74.8	Estimated FY 2003					
General Administration		\$5.2						
Project Total		\$80.0						
Full-time Equivalentents (FTE)		1.4						
Dollar amounts are shown in thousands of dollars.								
Other Resources								
Comments:								

FY02

Prepared:

Project Number: 02603
 Project Title: Implementation of an Ocean Circulation Model:
 A transition from SEA (PWS) to GEM (GOA)
 Agency: Alaska Department of Fish and Game

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		\$54.1						
Travel		\$2.8						
Contractual		\$0.0						
Commodities		\$3.0						
Equipment		\$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		\$59.9	Estimated FY 2003					
Indirect		\$14.9						
Project Total		\$74.8						
Full-time Equivalents (FTE)		1.4						
Dollar amounts are shown in thousands of dollars.								
Other Resources (tuition)								
<p>Comments:</p> <p style="margin-left: 40px;">The indirect rate is 25% TDC, as negotiated by the Exxon Valdez Oil Spill Trustee Council with the University of Alaska.</p> <p style="margin-left: 40px;">Student personnel costs include non-resident tuition of \$6,246 per year.</p>								

FY02

Prepared:

Project Number: 02603
 Project Title: Implementation of an Ocean Circulation Model:
 A transition from SEA (PWS) to GEM (GOA)
 Name: Jia Wang

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Personnel Costs:			Months Budgeted	Monthly Costs	Overtime	
Name	Position Description					
Wang, J.	PI		0.0	0.0		
Jin, M.	Research Assistant Professor		6.0	5.0		
TBA	M.S. Student		9.3	1.8		
Musgrave, D.	Associate Professor		1.0	7.4		
		Subtotal	16.3	14.2	0.0	
Personnel Total						
Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	
Description						
Fairbanks to Anchorage (workshop)		500.0	1	3	187.0	
Fairbanks to Hawaii (Ocean Science meeting)		700.0	1	7	142.0	
Travel Total						

FY02

Prepared:

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 A transition from SEA (PWS) to GEM (GOA)
 Name: Jia Wang

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

Contractual Costs:		
Description		
Contractual Total		
Commodities Costs:		
Description		
Project supplies Data purchase		
Commodities Total		

FY02

Prepared:

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 Name: Jia Wang

2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

New Equipment Purchases:		Number of Units	Unit Price	
Description				
Those purchases associated with replacement equipment should be indicated by placement of an R.			New Equipment Total	
Existing Equipment Usage:		Number of Units		
Description				

FY02

Project Number: 02603
 Project Title: Implementation of an Ocean Circulation Model:
 A transition from SEA (PWS) to GEM (GOA)
 Name: Jia Wang

Prepared: