

# 2004 Prince William Sound Lagrangian Field Experiment

## **Funded jointly by**

Prince William Sound Science Center and Oil Spill Recovery Institute.

## **Participating organizations include:**

Prince William Sound Science Center, NOAA-Hazmat, University of Alaska Anchorage/ Alaska Experimental Forecast Facility, University of Miami/Rosenstiel School of Marine and Atmospheric Science, University of Alaska Fairbanks/ School of Fisheries and Ocean Sciences, and SINTEF Applied Chemistry

## Executive Summary

Prince William Sound Nowcast-Forecast (PWSNF) was a marine research program funded primarily through the Oil Spill Recovery Institute (OSRI) and housed within the Prince William Sound Science Center (PWSSC) during the years 1998 to 2004, when it was phased out in favor of the Prince William Sound Ocean Observing System (PWSOOS). PWSNF was directed at developing an ecosystem level understanding of the Prince William Sound and Copper River Delta regions. The foundation of PWSNF included an atmospheric circulation model coupled to an ocean circulation model and an oil spill trajectory model.

The Lagrangian Field Experiment (LFE) described within this document was developed to facilitate the identification of operational needs within the PWSNF (and eventually PWSOOS) system, as well as the development of external partnerships for long-term operational interactions. In the event of an oil spill, NOAA Hazmat scientific staff advise the U.S. Coast Guard on probable spill trajectories based on modeled scenarios using available wind and current data.

The primary goals of the 2004 Lagrangian Field Experiment (LFE) were:

- evaluate the PWSNF system's present accuracy in forecasting passive trajectories at the surface and at mid-mixing depth (both as predicted utilizing the OSCAR component of PWSNF and utilizing the General NOAA Oil Modeling Environment model (GNOME) in conjunction with PWSNF physical data),
- assess the information infrastructure and modeling suite of the PWSNF system for use in an operational oceanographic capacity, and
- develop collaborative relationships with other entities involved with modeling and observations in the region.

The 2004 Lagrangian Field Experiment (LFE) evaluation criteria are:

1. Ability of the PWSNF observation and modeling system to forecast the trajectory of Lagrangian particles as represented by a set of drifter buoys.
2. Evaluation of data utilization by partnering organizations – does this data provide a useful service to the partnering organization? (i.e., does it improve their ability to accurately predict a spill trajectory?)
3. Evaluation of the mechanics of data transfer, both internally (within PWSNF) and externally (e.g. PWSNF to NOAA Hazmat).
4. Evaluate for improvements in the understanding of dispersion in Prince William Sound.
5. Evaluate the expense of exercise versus benefits for feasibility of follow-on experiments.
6. Evaluate for timeliness of data and modeling activities – does PWSNF as presently constituted possess (or have the potential to reasonably develop) operational relevance?

7. Public Involvement - Extent to which this experiment increases public awareness of the PWSNF system and confidence in the quality of data available for public consumption.

**Evaluation criteria on a point by point basis:**

1. Ability of the PWSNF observation and modeling system to forecast the trajectory of Lagrangian particles as represented by a set of drifting buoys:

Results of the 2004 LFE indicate that the present configuration (August 2004) of the PWSNFS was unable to satisfactorily describe (model) the existing oceanic conditions in PWS required to forecast Lagrangian trajectories over a 48 hour period. The two Princeton Ocean Model domains utilized, the Standard (PWS) domain and the Extended (EPWS) domain, performed significantly different, with the EPWS domain able to approximate the general circulation pattern and drifter trajectories observed. The Regional Atmospheric Model (PWS-RAMS) and Oil Spill Contingency and Response (OSCAR) performed at acceptable levels though evaluation was hampered by atypical conditions featuring extended quiescence during the experiment period.

2. Evaluation of data utilization by partnering organizations – does this data provide a useful service to the partnering organization? (i.e., does it improve their ability to accurately predict a spill trajectory?)

NOAA-Hazmat Office of Response and Restoration personnel participating in the experiment stated, upon completion of the experiment, that the information provided by PWSOOS/PWSSC represented a significant benefit in conducting spill response and remediation activities. While the data from the ocean model failed to accurately represent currents in PWS *in this instance*, the ready availability of simulated conditions based on the best available information offers the potential to greatly aid the forecasting of trajectories and the parameterization of prevailing conditions.

3. Evaluation of the mechanics of data transfer, both internally (within PWSNF) and externally (e.g. PWSNF to NOAA Hazmat).

External data transferred worked remarkably well, a state of affairs which may be largely attributable to the pre-experiment collaboration between the PWSSC PI team and NOAA-Hazmat as well of the attendance of John Whitney at the PWSSC offices during the initial three days of the experiment. This interaction allowed for the development of a working relationship between the organizations and principals involved. Additional transfers included the USCG, with whom the trajectories and progress reports were shared.

Internal data transfers were largely successful, given that this field experiment represented the first attempt of this nature by PWSSC. Improved communications between the field crew (located onboard vessels in PWS) and the offices where telemetry and buoy tracking occurred are identified as an area for reevaluation. Cellular service proved unreliable, satellite phone service provided better coverage but was only available on one vessel. The primary communication issue was in tracking the buoys in the field, conditions were favorable throughout the experiment and all operational buoys were recovered – it was strongly felt by the entire team that significant losses would have occurred under more adverse weather conditions lacking better field tracking equipment.

4. Evaluate for improvements in the understanding of dispersion in Prince William Sound.

The dominant feature observed was a mid-sound cyclonic circulation pattern, or gyre, presumably resulting from isopycnal doming due to freshwater influx along the coast. This circulation pattern had been previously observed but was widely believed to establish itself later in the season and to be driven significantly by precipitation. The atypically depressed level of precipitation during the 2004 LFE, in addition to near continuous clear skies, created extremely warm and dry conditions which largely isolated the component of freshwater input attributable to melt-water. The observed persistent gyre suggests that under certain conditions the gyre may be driven almost exclusively by intra-PWS melt-water and during periods when the circulation pattern was not believed to exist. The existence of the cyclonic pattern, particularly when expressed to the depths observed by the 10 meter drogued buoys, represents a significant consideration for both spill response and ecological assessment.

The speed of the 10 m drogued SVP drifters was significantly slower than the speed of the surface Argosphere drifters. Although most of the SVP drifters eventually exited the central sound toward the end of the 12-day experiment, their stay in the gyre areas was much longer than what was observed for the surface drifters. This suggests that should dispersants be used following an oil spill in central Prince William Sound, the trajectory and fate of the subsurface oil would likely differ considerably from the trajectory and fate of untreated surface oil.

5. Evaluate the expense of exercise versus benefits for feasibility of follow-on experiments.

The experiment described by this document relied significantly on in-kind contributions from existing work being conducted in PWS. These costs include the expenses incurred in collecting the oceanic and meteorological data for the study area as well as the modeling activities for both the PWS-POM (Prince William Sound Princeton Ocean Model) and PWS-RAMS (Prince William Sound Regional Atmospheric Model). Assuming an estimate of \$400 - 500K per year budget for PWSNF activities, conducting the field experiment represents an additional 10-20% in funding requirements. This estimate is dependent upon factors which might vary from field experiment to field experiment based on success in recovering buoys and success in securing in-kind contributions for additional budget items, such as vessel time. Equipment purchased for this field experiment, such as the SVP drifters, tracking software, etc., is readily employable in future field experiments.

6. Evaluate for timeliness of data and modeling activities – does PWSNF as presently constituted possess (or have the potential to reasonably develop) operational relevance?

The PWSNF system, as it existed at the time of the 2004 LFE, was capable of transferring data concerning environmental conditions in PWS in a timely fashion (see section IV below). Methods for exchanging data between PWSNF and partnering organizations were developed both prior to and during the experiment. These “channels” of communication proved extremely valuable during the course of the field experiment and should be considered an asset to conducting future field experiments. In the event of an actual spill in PWS these channels facilitate exchange and provide access to local expertise and data, absent prior collaboration it seems unlikely that the highly technical data contained in the model outputs would find its way into data products for the decision makers with the same degree of success.

7. Public Involvement - Extent to which this experiment increases public awareness of the PWSNF system and confidence in the quality of data available for public consumption:

The LFE was featured in the local newspaper and on the radio. An article was written by the lead PI describing the project in laymans terms and was published during the first week of the experiment. Additionally, participation by the USCG, ADEC, NOAA-Hazmat likely served to increase awareness of the PWSSC/OSRI PWS observing efforts among likely end users.

## **I. Introduction**

Prince William Sound Nowcast-Forecast (PWSNF) was a marine research program funded primarily through the Oil Spill Recovery Institute (OSRI) and housed within the Prince William Sound Science Center (PWSSC). PWSNF was directed at developing an ecosystem level understanding of the Prince William Sound and Copper River Delta regions. Consisting of numerical models of the region's oceanic and atmospheric conditions as well as physical and biological monitoring programs, PWSNF was intended to provide information for evaluating oil spill response strategies, managing the region's coastal resources, and providing environmental information to local residents and industry.

PWSNF began in 1999 with the awarding of research grants to conduct oceanographic data collection and numerical modeling of Prince William Sound. PWSNF Phase I was designed as a five-year comprehensive research program which would expand ongoing oceanic research to include atmospheric and biological components. OSRI awarded grants to begin biological assessment of dominant fisheries in Prince William Sound and of the Copper River Delta ecosystem in 2000 and 2001 respectively. In 2002 OSRI awarded research grants for initiating atmospheric modeling and data collection efforts. Conceptually linked, the PWSNF projects varied in their level of integration and stage of development at the time of the 2004 LFE.

Major planning efforts for PWSNF include the December of 2000 *Prince William Sound Meteorology Workshop* in Anchorage, Alaska, the April of 2002 *Intensive Observing Period Workshop* in Cordova, Alaska, and the June of 2003 *Prince William Sound Nowcast-Forecast Workshop* in Anchorage, Alaska. These workshops included participants from a number of usergroups and stakeholders within the Prince William Sound region as well as researchers involved with the PWSNF program, developers of other operational oceanographic research efforts, and representatives from agencies and academia.

### **Background: The Prince William Sound Nowcast Forecast (PWSNF) Program**

Just after midnight on March 24, 1989 the tanker vessel *Exxon Valdez* ran aground on Bligh Reef releasing approximately 11 million gallons of Alaska North Slope crude oil into Prince William Sound. At the time little detail was known of the Prince William Sound ecosystem and the response to the spill proved both ineffective and controversial. The lack of information on the physical and biological systems of the region also complicated efforts aimed at assessing damage and evaluating restoration activities. Events such as the "crash" of the Prince William Sound herring population in the mid 1990's, while never definitively proven to be an aftereffect of the spill, further raised concerns over the potential for oil spills to produce long-term ecosystem level impacts.

The Sound Ecosystem Assessment (SEA) was an interdisciplinary research program focused on the Prince William Sound marine environment and funded by the Exxon Valdez Oil Spill Trustee Council. Elements of the SEA program focused on oceanographic data collection and numerical

ocean modeling of Prince William Sound, as well as acoustical assessment of dominant fish stocks, have formed the foundation of the PWSNF program.

As the SEA program came to a close in the late 1990's the Oil Spill Recovery Institute (OSRI) was just beginning to develop a research program, having been appropriated funding through the Coast Guard Authorization Act of 1996. OSRI chose to focus much of its energies on developing a Nowcast-Forecast system for Prince William Sound, the only major maritime oil shipping port in the U.S. Arctic or subarctic.

While OSRI integrated elements of the SEA program into the developing PWSNF program a significant difference in the approaches should be noted. PWSNF was predictive in nature and built on the emergence of operational oceanography and improvements in telemetry, computational capacity, and Internet connectivity developed over the preceding decade (1990's) to facilitate the efficient generation and rapid transfer of relatively large data sets over significant distances. PWSNF provided information on present (Nowcasts) and anticipated (Forecasts) conditions for the region's physical environment. PWSNF was also able to provide simulations of past events (Hindcasts) for evaluations of oceanic and atmospheric events of scientific or societal interest and for evaluating oil spill response simulations.

The physical PWSNF program was comprised of five primary components; 1) a Princeton Ocean Model implemented for the Prince William Sound region (also denoted as PWS-POM), 2) an Observational Oceanography program, 3) a Regional Atmospheric Modeling System (PWS-RAMS) implemented for the region, 4) a meteorological data collection network, and, 5) an implementation of the Oil Spill Contingency and Response (OSCAR) model for oil spill trajectory, chemical fates and effects, and biological exposure modeling. The three modeling components, PWS-POM, PWS-RAMS, and OSCAR, were linked in a preliminary, prototype configuration via automated Internet data transfers.

The Princeton Ocean Model served as the central component of PWSNF and was implemented by Professor C.N.K. Mooers of the Ocean Prediction Experimental Laboratory at the Rosenstiel School of Marine and Atmospheric and Science. PWS-POM is implemented on a ~1.1km grid utilizing 15 vertical sigma (terrain-following) layers with boundaries at Hinchinbrook Entrance and Montague Straits. A non-uniform freshwater runoff model (Simmons) provides freshwater input along the PWS coastline. Tidal forcing is provided from a Northeast Pacific tidal model (Foreman). Surface winds are derived from the PWS-RAMS (Prince William Sound Regional Atmospheric Modeling System) model, though prior to early 2003 they were treated as a spatially invariant field based on hourly-observed winds at the mid-sound buoy.

The Regional Atmospheric Modeling System was implemented by Dr. Peter Olsson of the University of Alaska's Alaska Experimental Forecast Facility (AEFF). RAMS for Prince William Sound (PWS-RAMS) is configured on a triple nested grid with 64km/16km/4km grid spacing and 36 vertical levels to 25km altitude. The National Centers for Environmental Prediction (NCEP) Eta model is utilized for initial and boundary conditions. At the time of the workshop the atmospheric modeling program had been in progress for approximately one year

and initial linkages between PWS-POM and PWS-RAMS had been developed. Initial model runs at 64km and 16km were conducted in fall of 2002 and winter 2003.

The PWSSC Observational Oceanography program, led primarily by Dr. Shari Vaughan, supported the Ocean Modeling program through seasonal hydrographic cruises and passive drifter studies in Prince William Sound. The cruises consist primarily of Acoustic Doppler Current Profiler (ADCP) surveys for measuring ocean currents in the mid sound, Hinchinbrook Entrance and Montague Straits, as well as conductivity, temperature, and depth (CTD) profiler measurements at three stations (northern PWS, mid-sound, and Hinchinbrook Entrance). The OSRI funded program was supplemented by an EVOSTC-funded moored ADCP in Hinchinbrook Entrance from 1999 through 2002.

The Meteorological Data Collection effort supported the overall PWSNF program by providing meteorological data for the modeling efforts, for use in the event of a spill, and use by the general public. Meteorological monitoring stations were established at seven locations throughout the PWS region; the Cordova Boat harbor, Tripod hill (elevated site in Cordova), Tatitlek, Chenega Bay, Pigot Point, Applegate Rocks, Port Etches, Kolenhenic Island (a Copper River Delta barrier island). Data collected included temperature, wind speed and direction, relative humidity and barometric pressure.

The Oil Spill Contingency and Response (OSCAR) modeling effort, led by PI Dr. Mark Reed of SINTEF Applied Chemistry, provided oil spill trajectory, chemical fates and effects, and biological exposure modeling capacity to the PWSNF system. Processes calculated by the OSCAR model include surface spreading, emulsification, dispersion (both natural and chemically enhanced), dissolution, evaporation, sedimentation, resurfacing, degradation, and stranding. Trajectories are derived from PWS-POM current predictions and surface winds (presently surface wind files are manually created for a scenario). Chemical processes are calculated based on 27 components and pseudo-components. Spatially explicit biological models ported to interact with OSCAR should be able to provide exposure estimates through interactions with OSCAR. Advance planning for this capacity is critical in the development of biological modeling components within PWSNF.

## **Goals & Objectives**

The 2004 Lagrangian Field Experiment (LFE) for the Prince William Sound Nowcast/Forecast (PWSNF) observation and modeling system is described within this document. The experiment is intended to meet both Scientific and Programmatic goals and objectives:

### **A) Scientific**

- Evaluate the temporal variability of a point source release within the Prince William Sound marine environment.
- Estimate the horizontal (and possibly) vertical advective transports of neutrally buoyant, passive particles at the surface and in the upper layer of PWS under different forcing regimes.

-Evaluate the sensitivity of PWSNF modeled parameters in predicting Lagrangian trajectories.

## B) Programmatic

-Advance the understanding of Prince William Sound physical processes within research, regulatory, industrial and residential interests within the region.

-Foster working relationships between organizations engaged in observation and numerical modeling activities within PWS, particularly those organizations involved with oil spill modeling and spill response activities.

-Development of PWS environmental information products by PWSNF to be made available to NOAA-Hazmat, spill response organizations, the USCG and other agencies involved with emergency response activities in PWS.

## Scientific Rationale

The importance and complexity of PWS upper ocean dynamics for the physical transport of oil spills, biota, vessels and personnel adrift, etc. dictates that observational and simulated Lagrangian experiments be performed to quantify the temporal and spatial variability of surface and near-surface particle displacements, and the skill of the simulations compared to observations. August 2004 was chosen for the first experiment because the likelihood of benign weather conditions prevailing then was relatively high. The middle of Central Sound was chosen as the drifter release point of various for the following reasons:

1. Substantial datasets exist from CFOS-13 (hydrostation) and mid-Sound NDBC (meteorological) buoy over the past several years.
2. It is located in relatively deep (ca. 400m) open water, thus allowing a reasonable opportunity for the deployed buoys to travel freely without grounding excessively.
3. It is an oceanographically significant location for PWS.
4. It adjoins the tanker lane and, thus, enhances the societal relevance.

The importance of tidal and synoptic wind-forcing of the upper ocean circulation in mid-Sound suggest that intensive sampling and a fortnightly duration are highly desirable in order to resolve and cover, respectively, a spring-neap tidal cycle and one or two weather cycles. The vertical density and velocity structure of the upper ocean (ca. 20m) in mid-Sound in mid-summer suggest that Lagrangian flow observations are required at the very surface, near-surface (ca. 1m), and mid-mixed layer (ca. 10m). Supporting observations (e.g., shipboard CTD, towed ADCP, and dye release, plus pre-deployed moorings and meteorological and tide gauge stations) were performed to develop an understanding of prevailing oceanic conditions. Similarly, coupled predictive circulation modeling is an essential component of the experiment; for example, the PWS Regional Atmospheric Model (PWS-RAMS), the PWS Princeton Ocean Model (PWS-POM), and the General NOAA Oil Modeling Environment (GNOME) were all included in planning exercises and real-time application during the experiment.