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REPORT OF THE PICES 2002 *VOLUNTEER OBSERVING SHIP* WORKSHOP

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EXECUTIVE SUMMARY

PICES and the Exxon Valdez Oil Spill Trustee Council's Gulf Ecosystem Monitoring (GEM) program presently sponsor a plankton monitoring program in the subarctic Pacific, that uses commercial "volunteer observing ships" (VOS) to tow a Continuous Plankton Recorder (CPR) along repeated routes from southern California to Alaska, and from British Columbia to Japan. Value of the CPR data would be greatly enhanced by additional underway measurements from the VOS.

A workshop to identify and evaluate potential add-on sensor and archival modules was held on April 4-5, 2002, in Seattle. The recommended system would include one group of instruments making measurements of water from the ship's engine room sea-water intake, and a second group of instruments (mounted on or near the bridge) making optical, acoustic, and sea-state measurements, and perhaps deploying expendable subsurface profiling probes (XBT or XCTD). Total price for the acquisition and testing of the first unit would probably be under US$250,000. Subsequent units could be assembled for about US$150,000.

Workshop participants recommend that a technical proposal for funding such a system be developed, and seek endorsement by PICES and approval to proceed with proposal development as an official PICES activity.

David L. Mackas
MONITOR Task Team Co-Chairman

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Workshop overview

On April 4-5, 2002, the PICES MONITOR Task Team, the PICES Continuous Plankton Recorder (CPR) Advisory Panel, and the Exxon Valdez Oil Spill Trustee Council's Gulf Ecosystem Monitoring (GEM) program convened a workshop in Seattle, U.S.A., to consider enhanced instrumentation for volunteer observing ships (VOS), particularly instruments to complement CPR data. Ships instrumented to gather oceanographic data secondarily to their main mission can range from fishing vessels to the largest commercial ships on long trans-oceanic runs. The focus of the workshop was the latter, with the expectation that suitably instrumented ships could obtain data from the farthest ocean reaches on a frequent and recurring basis for long periods.

The rationale is old, simple and excellent. The long time scales of significant oceanic environmental events, such as coupled changes of climatic and fishery regimes, require long time series of data to document them. There is also continuous need for "sea-truth" measurements for comparison to satellite observations. In the subarctic North Pacific, there are interannual variations in timing of seasonal events that are keys to understanding its ecology. At the present time, expedition style cruises aboard dedicated research ships are too expensive and too irregular to accomplish this, particularly far from shore where only reasonably large, expensive vessels can venture. Therefore, the workshop participants aimed to review developments in instrumentation that can be used to provide rich data sets when coupled to commercial vessel sea chests. Large vessels move many cubic meters of water per minute through their intake systems for cooling and other purposes. Our instrumental requirements will be liters per minute and can readily and safely be coupled to these larger flows.

Relevant experience was represented among the workshop participants (see group photo on the next page) as follows:

Drs. Sonia D. Batten and David W. Welch manage the PICES Continuous Plankton Recorder operations on tankers running between Valdez, Alaska, and Long Beach, California, and from Vancouver to Japan.

Dr. David Hydes has experience with the European Union "Ferry Box" program that instruments several ferries operating around Europe.

Dr. Akira Harashima is instrumenting ferries operating in Japanese waters and crossing to Korea, Hong Kong and Malaysia.

Dr. David Cutchin has experience with installing, maintaining and retrieving data from thermosalinograph and XBT systems on commercial ships.

Dr. Ronald Zaneveld is working with a range of optical instruments suitable for sea chest instrumentation.

Dr. Ricardo Letelier is familiar with fluorometers and fast repetition rate fluorometers which could be utilized on VOS.

Capt. Robert Decker manages data transfer communications for several NOAA operations.

Participants of the PICES MONITOR VOS Workshop: front row from left - Sei-ichi Saitoh (PICES MONITOR Task Team, University of Hokkaido, Japan), David Cutchin (Scripps Institution of Oceanography, U.S.A.), Ricardo Letelier (Oregon State University, U.S.A.), David Mackas (PICES MONITOR Task Team, Institute of Ocean Sciences, Canada, Workshop Chairman), Akira Harashima (National Institute for Environmental Studies, Japan); back row from left - Robert Decker (NOAA SEAS, U.S.A.), Phillip Mundy (Exxon Valdez Oil Spill Trustee Council, U.S.A.), Warren Wooster (University of Washington, U.S.A., local host), Ronald Zaneveld (Oregon State University, U.S.A.), Charles Miller (PICES CPR, Oregon State University, U.S.A.), David Welch (PICES CPR, Pacific Biological Station, Canada), Sonia Batten (PICES CPR, Sir Alister Hardy Foundation for Ocean Science, UK), David Hydes (National Environmental Research Council, Southampton Oceanography Centre, UK); Not in picture: Jeffrey Napp (National Marine Fisheries Service, U.S.A.).

Dr. Phillip Mundy is responsible for the EVOS Gulf Ecosystem Monitoring (GEM) initiative, concerned with the ecosystem health of the Gulf of Alaska.

Dr. Sei-ichi Saitoh is expert in satellite oceanography.

The other participants are oceanographers interested in time-series sampling.

The workshop opened with a presentation by Dr. Batten on the status of a PICES VOS program now in operation. That is the spring-summer CPR sampling aboard tankers of the Polar Corporation running from Valdez to Long Beach, and a once per year CPR tow from Seaboard International Ltd. ships running from Vancouver to Japan via the Bering Sea. Her written report on progress of the PICES CPR program is attached as Appendix 1. In brief, three years of CPR data from the Valdez-Long Beach line have shown large interannual variations in developmental timing and abundance of dominant Gulf of Alaska zooplankton species (principally copepods of the genus

Neocalanus). CPR results demonstrate extended seaward transport of coastal plankton stocks (*Acartia* spp., *Calanus marshallae*) by the Haida eddy and other large coastal eddies along the coasts of British Columbia and southeast Alaska. The CPR data also appear to represent plankton abundance changes associated with the possible regime shift of 1998-99.

A forthcoming addition to the east-west CPR run is a seabird observer to be directed by Dr. William Sydeman of the Point Reyes Bird Observatory (4990 Shoreline Highway Stinson Beach, CA). Subsequent to the VOS meeting, insurance considerations were successfully negotiated with Seaboard International Ltd. for placement of an observer. The primary concern is the possibility that ship time would be lost if an observer were to require diversion because of sickness or injury. From this experience we are learning the problems and possibilities of placing scientists on board VOS, which eventually may be as valuable as bird data.

In addition to producing some actual PICES science, the CPR program shows that shipping companies are willing to help with well-designed oceanographic observations which do not interfere with their transport operations. While the workshop was not convened to consider improvements to the CPR, the participants recognize that an expanded and improved CPR program has been endorsed by both PICES and LMR-GOOS. We heartily second this endorsement.

Next, currently active VOS instrumentation systems operating in Japan and Europe were reviewed. The Japanese program is managed by the Center for Global Environmental Research (CGER) and Marine Environmental Research Laboratory (MERL) of the Japanese National Institute for Environmental Studies (NIES). Dr. Harashima of MERL/NIES reported on instrument suites making continuous computerized records of data on a number of runs, including one from Tokyo to Malaysia. Instrumentation includes: temperature, salinity, pH, fluorescence, dissolved oxygen, periodic automated filtration and sample storage for shoreside analysis of nutrients (NO_3, NO_2, NH_4, PO_4, $Si(OH)_4$), and preserved whole water sampling for microscopic analysis of phytoplankton. Other than this work, CGER/NIES is conducting a monitoring program to evaluate the CO_2 flux across the surface of the North Pacific using a VOS. A report by Dr. Harashima on the Japanese VOS sampling program is presented as Appendix 2.

An important result of tow basin and numerical modeling research by Dr. Harashima and colleagues is that intake water on a large ship can be displaced downward from its original position near the ocean surface by several meters. That is, intakes do not sample water that was originally at their depth below the surface, but effectively sample somewhat higher in the water column. Appendix 3 details the model basin and numerical simulation of displacement of water approaching hull intakes.

Dr. Hydes reported that the European Union is supporting a wide array of different ferry instrumentation efforts, under an umbrella organization called the “E.U. Ferry Box Program”. The common effort is to examine data comparability and to push forward with addition of pollutant identification instrumentation. Various systems include: temperature, salinity, turbidity, fluorescence, and CO_2. A system under development by Dr. Hydes at the Southampton Oceanography Centre determines nutrients on a relatively high frequency basis, operating on water drawn from an intake stream with a reagent addition and colorimetry system comparable to autoanalyzers but compact and fully automated. Good stability has been achieved, but frequent checks with standards remain an essential part of establishing and sustaining data reliability. Indeed, the standard checks are included in his system's automation scheme. Such gear is becoming available from several other laboratories around the world and is nearly ready for commercialization. Details provided in writing by Dr. Hydes are presented as Appendix 4. Particularly interesting is the use of cell phone technology for data transfer in coastal regions. For U.S. applications access can probably be obtained from Iridium phone service.

Japanese and European ferry systems are also carrying various bridge instrumentation, including radiometers, both upward looking (sky and total downward radiance) and water-leaving radiance meters. The latter are much more problematic, according to Dr. Zaneveld, because the results are extremely sensitive to angle of the instrument relative to the sea surface (which is hard to hold constant) and to bubbles that are copiously, but variably, produced by both waves and the instrumented ship.

Dr. Cutchin and Capt. Decker reported on bridge wing XBT operations. These involve automated or manual launch from ships at regular locations along standard routes. One example is the WOCE program on ships running between Hawaii and Alaska. Expense of the expendable probes is a significant issue, with current prices of US$40 each for XBT probes and US$600 for XCT (conductivity) probes. The latter have proved prohibitive for all but very special operations.

Dr. Saitoh reported on satellite remotely-sensed data which could usefully be collated with the VOS trackline data. Examples include surface temperature and ocean color, surface roughness (a proxy for wind speed), and sea-surface elevation (a proxy for geostrophic current fields). Benefits of this collation are mutual: the remotely-sensed data provide a broader spatial view that greatly aids interpretation of features observed by the VOS, while the VOS provides valuable open-ocean sea-truth sampling needed for calibration of satellite algorithms.

The group discussed a wide range of issues regarding gear installation on VOS. Cabling between engine room instruments and bridge instruments to gather data in a common computer came in for particular attention. Experience (Cutchin, Hydes, Decker, others) shows that running cable can be difficult and, therefore, expensive. Cabling and all other aspects of installation depend upon excellent relations with the shipping company and ship's personnel at all levels. This takes negotiating skill and constant attention to relationships throughout any VOS program. Positive relationships are as important to success as reliable equipment and good maintenance when the ships reach port.

A highly specific discussion followed, of available instruments, the value of the data they produce and the problems they present. Potential instrumentation discussed divides into engine room (water intake) and bridge measurements. The following box shows the lists which appear to workshop members to be the practical, meaningful measurements available "off the shelf" at the present time. Participants felt that, if at all possible, the instruments at each location should be combined into two reasonably compact packages that could be transported, mechanically installed, and wired as modular units. In order to represent input and cooperation throughout PICES, we dubbed these the *PICES Ferry box* and *PICES VOS Wing Pod*. We will gladly name it after any agency or other entity willing to fund development (e.g., the *PICES/GEM Ferry Box*).

Components of proposed VOS Data Systems

Ferry Box	***Wing Pod***
Flow-through T and S	XBT launcher
T via hull conductance ($\pm$0.1ºC)	Downwelling irradiance
Fluorometer Transmissometry	Recording of ship high frequency echosounder and Doppler speed log
OPC	Meteorology package
Spectral absorbance (AC-9)	Navigation (GPS)
Nutrient concentration Colored-DOM fluorescence	Accelerometer (sea state)

The *Ferry Box* and *Wing Pod* systems must be coupled with suitable and redundant computing and recording capability to archive the substantial data sets that will be produced, and to maintain accurate time marks for all observations, accounting for varying instrumental delays (those of automated nutrient analysis, for example). Several options for frequent or real-time telemetry of data to shore exist, including application of Iridium satellite phone technology. A variety of computational and communications hardware and software issues are involved in this aspect of the design. All of them have solutions. A rough cost estimate, with adequate engineering money included, suggested that the *first* system could be assembled for around US$250,000. Subsequent, installable copies of the Mark I would run about US$130,000 each.

Instrumentation and cost

Further evaluations of each component instrument and selections among available designs will be part of the engineering effort. Expertise available at the workshop provided preliminary knowledge of frequently used systems and costs. We list that preliminary data here (all costs are in US dollars):

PICES Ferry Box – An engine room system to be coupled to VOS sea chests:

Flow-through temperature and salinity (thermosalinograph)
SeaBird $8,000
SST via hull conductance ($\pm$ 0.1ºC) $500
Fluorometer, flowthrough - general level of phytoplankton biomass
Turner Designs $3,000
Transmissometer - light beam C (attenuation) and particle concentration
Seatech $3,000
Optical Plankton Counter - evaluation of zooplankton abundance and size distribution
Full description at http://www.focaltech.ns.ca/ product-opc.html
Focal Technologies $12,000
Spectral absorbance (AC9) - evaluation of relative abundance of absorbing pigments and, thus, of phytoplankton composition by measuring light absorbance at 9 wavelengths.
SeaLabs AC9 $16,000
Nutrient concentrations – NO_3, PO_4, $Si(OH)_4$, Several systems in test phases
$15,000
CDOM fluorescence – measure of colored dissolved organic matter; varies strongly in inshore-offshore direction, a measure of "neriticity". Measure is blue fluorescence excited with UV.
Adapted Turner Designs Fluorometer $3,000

Instrument component cost - $60,500

Pumps, plumbing, housing, safety alarms and other fittings will cost ~ $10,000.
Instrument control and data storage computer systems should cost about $5,000.

Total cost ~ $75,000

PICES Wing Pod – for deployment on the bridge wing:

XBT launcher – spaced vertical profiles of ocean temperature
Sippican $3,000
Downwelling irradiance – measure of light intensity above the ship
LiCor, several others $8,000
Recording of ship's high frequency echosounder – read out cable required
Recording of ship's Doppler log – readout cable required
Meteorology package - air temperature, humidity, apparent wind speed
Several systems $5,000
Navigation (dedicated GPS)
Many manufacturers $3,000
Vertical Acceleration (sea state) – response will vary from ship to ship
$5,000

Instrument component cost - $24,000

Attachments, housings, data storage ~ $10,000

Total cost ~ $ 35,000

Dr. Zaneveld has noted in reviewing a draft of this report, that a *FerryBox* system including an AC9 spectral absorbance system will not require a chlorophyll fluorometer. The AC9 will measure chlorophyll absorption as [a(676) - a(6650)], which is better correlated with extracted chlorophyll than standard fluorometer output, since the quantum efficiency of fluorescence is not involved. The AC9 transmission at 650 nm also replaces the standard transmissometer, which measures at 650 nm. He also stated that with some plumbing the AC9 can alternately pass water filtered at 0.2 m to obtain a measure of colored dissolved organic matter (CDOM), which by subtraction provides a measure of light absorption by particles. The AC9 can thus reduce costs by about $8,000.

In the future, the *PICES Ferry Box* could be upgraded to include fast repetition rate fluorometry (FRRF, potentially a photosynthesis rate measurement), a 100-wavelength spectro-photometer, a FlowCam for accumulating particle images and the pollutant sensors under development in Europe. The *PICES WingPod* could eventually include a downlooking LIDAR system to profile chlorophyll. Both *Ferry Box* and *Wing Pod* should include physical space and data capacity for new instrumentation not yet developed even in concept. It is possible that the biggest contribution of the PICES VOS systems could be stimulation of completely new measurements.

Workshop participants recognize that development of the PICES VOS systems must include careful computer hardware selection and detailed software design for data logging. Data formats suitable to NODC or other data archiving organizations should be used. Computer media and formats should adhere to standards likely to last or remain accessible long into the future. In addition to storing raw instrumental output (volts, counts, etc.), data streams logged at sea should, when possible, be converted to standard units (engineering, SI, or oceanographic such as PSU) for parallel storage. Data storage should be redundant. Calibration and data quality control protocols should be part of system design as well as operation. It may be desirable for the systems to provide regular telemetry to the deploying laboratories. For example, shore-based inspection of near-real-time data from the VOS would allow prompt detection and diagnosis of most foreseeable instrument faults, and would greatly aid on-board or "next port call" repair. Use of satellite phone (Iridium) facilities seems possible and likely to be inexpensive. (Iridium facilities were recently acquired by the U.S. government and are available for qualified scientific applications.)

Expertise to develop and assemble components and software is likely to cost in the order of $100,000. Initial deployments will require that the systems be accompanied at sea by a technical expert. This will incur costs for insurance, passage, sea pay, transport home, etc. This might run to $20,000. Unanticipated contingencies might cost $30,000. Thus, both **the *Ferry Box* and *Wing Pod* could be developed for approximately $250,000 or less**. Second and later copies could be produced for about $150,000 each, perhaps less.

Proposal development

Members of the PICES CPR Advisory Panel will prepare a detailed proposal to develop these VOS systems in the near future. It is our hope that PICES will take a strong interest in supporting development of the *PICES Ferry Box* and *PICES Wing Pod*. The currently active European and Japanese programs for ferry instrumentation show that complex, long-term and frequent data strongly indicative of ecosystem conditions can be generated by VOS programs. The full extent of the North Pacific can be sampled in this way at very reasonable cost.

Potential funding sources

It is obvious that sources of funding must be identified to develop and sustain VOS data collection in the North Pacific. The following agencies should be interested in this work:

U.S. NOAA, National Marine Fisheries Service
U.S. NOAA and other entities involved in Global Ocean Observing System development
U.S. NASA - SeaWIFS, MODIS, EOS and other programs needing comparative sea surface data
Fisheries and Oceans Canada
Environment Canada
Gulf Environmental Monitoring (GEM) program of the Exxon Valdez Oil Spill Trustee Council
Sloan Foundation Census of Marine Life
Packard Foundation
Japan Ministry of Education, Science and Technology (MEXT)
Japan Ministry of the Environment (MOE)

Since instrumentation will partly come from small business concerns, it is likely that some support can be obtained from the U.S. Small Business Innovative Research Program. It is possible that shipping (e.g., Maersk-SeaLand, Columbus Lines, Seaboard International) and ferry (Alaska Marine Highway) companies would assist with costs in return for publicity or shipboard data displays.

Appendix 1

Current status of the Pacific CPR program

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By the end of 2001, a total of 13 CPR deployments had been made along two transects (Fig 1). Sampling success was high and processing of selected samples for plankton abundance has now been completed.

Highlights of some of the data analyses were presented at the workshop. The monthly distribution of the copepods *Neocalanus plumchrus/flemingeri* (one of the most abundant copepods in surface waters during spring/early summer) along the Alaska to California transect were shown. A similar pattern was evident in both 2000 and 2001. Highest abundances occurred in May and throughout all months abundances were higher in the central portion of the transect. There was some evidence that the peak distribution had shifted further south in 2001. Stage composition analysis also suggested that development was faster, or occurred earlier, in 2001 than in 2000.

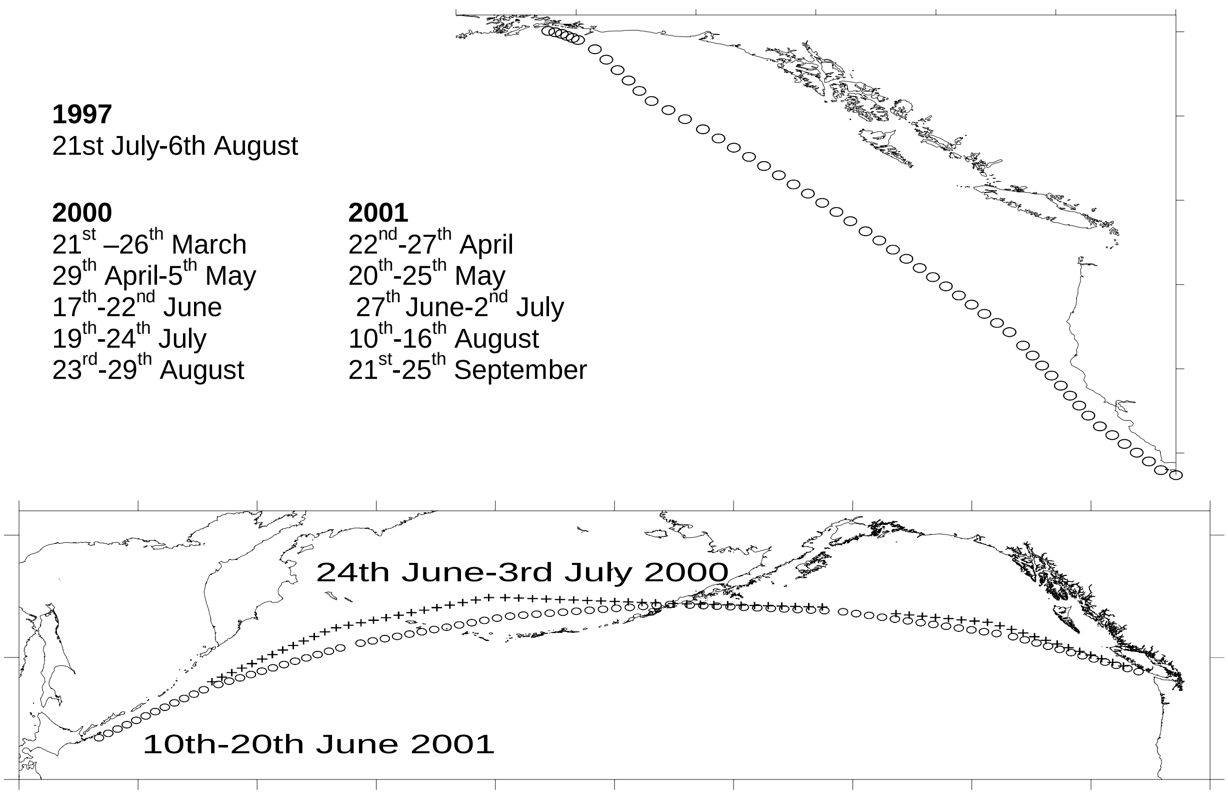

Fig. 1 Upper panel shows the N/S transect, run 5 times in 2000 and 2001, and once in 1997. Lower panel shows the E/W transect, run once in 2000 and 2001. Symbols indicate sample positions.

Estimates of total mesozooplankton abundance for 1°-latitude bands along the Alaska to California transect showed a recurring peak between about 39-42°N. The peak was sometimes an order of magnitude higher than the abundances at adjacent latitudes. Satellite images of chlorophyll concentration (from SeaWiFS) show a region of high chlorophyll on the shelf and extending over the slope, with a noticeable front perpendicular to the coast in this area. It is likely that the peak in abundance coincides with the point at which the CPR transect intersects this front, as it approaches the coast from the open ocean.

A trial sampling of the Alaska to California transect was carried out in summer 1997. Comparisons of abundance for the same periods in 2000 and 2001 show that abundances were much lower, particularly in the open Gulf of Alaska, and in fact at no time in 2000 and 2001 were such high abundances found along the whole transect as in 1997. The cause may be climate related, since 1997 was an El Niño year and 2000/2001 witnessed more normal conditions, however as yet a mechanism remains unclear. If estimates of biomass prove to be as variable as the abundances, then implications for other trophic levels will be considerable.

Community composition along the single, annual, Vancouver to Japan transect showed that distinct regional variations in community structure exist. Furthermore, the regional variability appears stronger than the interannual variability, at least in the two years sampled so far. Further funding should enable the sampling of this transect more frequently in 2002, so that within-year variability can be determined.

The Alaska to California transect sampled within, or close to, large (~200 km diameter) anticyclonic eddies that form along the western continental shelf edge in the winter. These eddies are clearly visible in sea surface altimetry maps from TOPEX/ POSEIDON/ERS satellites. Samples in the region of the eddies contained significant numbers of coastal or shelf-origin plankton taxa. The oceanic occurrence of these taxa appears to be related to the strength of these eddies, since occurrences on CPR samples were more frequent in 2000, when the eddy was stronger, than in 2001.

To summarise, the data analyses described show that the three years of CPR data (including the trial in 1997) have provided large-scale distribution data for key plankton taxa. Some information on within year variability is also available, at least for spring through summer. Interannual changes are already proving to be considerable. Satellite imagery has proved useful in linking the observed abundances and species distributions with the mesoscale features that may explain them.

Additional funding has been obtained for 2002, which will enable further sampling (autumn and winter baseline data can be acquired as well as additional east to west sampling) and further data analyses. It is also hoped that the CPR program will be supplemented in 2002 by the addition of a thermosalinograph (and fluorometer) to the vessel operating the Alaska to California transect. A trial Vancouver to Japan transect is also planned which will include a marine bird/cetacean observer on board.

Appendix 2

Marine environmental monitoring using ferries in Japan

Akira Harashima
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Since 1991, NIES has been conducting a marine monitoring program by deploying flow-through equipment on the continuous seawater intake system of the ships of opportunity, to get the temporal/spatial variation of marine environmental variables with high temporal/spatial resolution (Harashima *et al*. 1997), targeting the detection and the evaluation of anthropogenic impacts to the seas, as well as the development of monitoring techniques. The tracks (Fig. 1) and periods of each leg were:

Line-1: Kobe - Seto Inland Sea - Tsushima Strait - Pusan, 1991 - 1993;
Line-2: Osaka - Seto Inland Sea - Beppu, 1994 - ongoing;
Line-3: Osaka - Naha, 1994 - 1998;

We extended this program to the Asian marginal seas by using container ships, whose route was:

Line-4: Japan - Hong Kong - Singapore - Port Kelang.

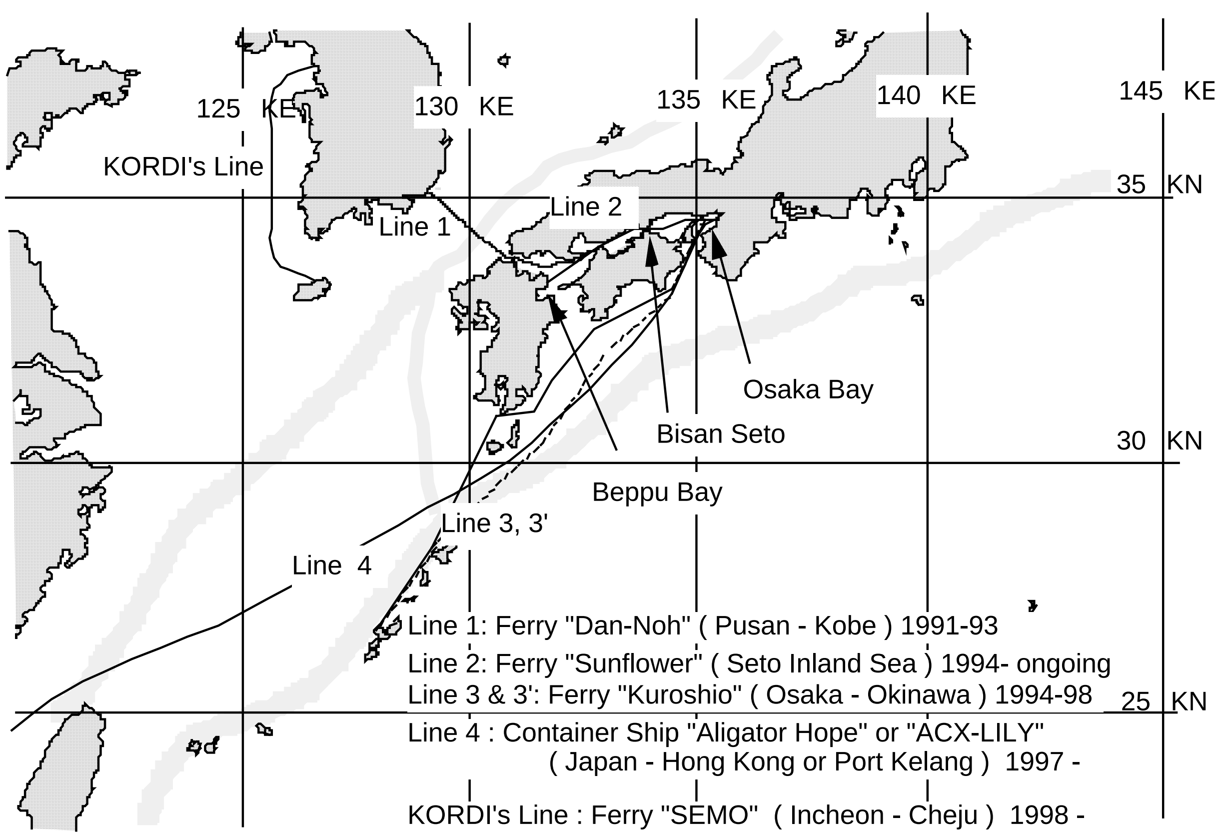

Fig. 1 Tracks of ferries used for monitoring.

One of the technical points worth special mention is that we constructed an opened system that consists of a measurement tank containing several sensors with free water surface in it, and a sampling faucet on a sink on Line-1, 2 and 3, and that we deployed automated filtration samplers to obtain filter papers and filtered water samples to be analyzed in the laboratory on Line-1 and 2, instead of the closed system usually designed for measuring only T, S and *in vivo* fluorescence. On Line-4, seawater was sampled manually by the ship crew following an instruction chart showing how to take and filtrate by expendable syringes, fix and reserve the samples for analyzing dissolved inorganic nutrients and phytoplankton community structures. These setups allowed us to investigate multiple kinds of items such as those described in the following papers by multiple authors compiled in a comprehensive report (Harashima and Kinugi, 2000):

Paper-1: Marine environmental monitoring and related studies using ferry boats - Description of the decadal experience and synthesis of the products

Paper-2: Technical points in designing and maintaining the unattended marine environmental monitoring system deployed on ferryboats

Paper-3: A model ship experiment on the original depth of the seawater taken for the monitoring system deployed on ferryboats

Paper-4: Inter-comparison between the ocean color from satellite mapping and the *in vivo* fluorescence from ferry monitoring

Paper-5: Advancement in the online evaluation of the health of the sea and the detection of plankton using ship of opportunity

Paper-6: Development of a flow-through measurement of pCO_2 with high time response

Paper-7: Temporal/spatial variation of nutrients and silica deficit

Paper-8: Method of phytoplankton analysis for evaluation of marine environmental quality

Paper-9: Measurement of size spectra of phytoplankton by a bio-particle counter

Paper-10: Measurement of biogenic sulfur compounds in the marine environment

Paper-11: Observation of the marine environmental change before and after the passage of a typhoon

Paper-12: Observation of marine pollution with hazardous chemicals using ferries

Paper-13: Monitoring of organo-tin species in seawater of the Seto Inland Sea

Paper-14: Comprehensive monitoring of the Seto Inland Sea to detect global change

Paper-15: Possibility of a short-term prediction model using biogeochemical data obtained by ferry monitoring

Results of Paper-3 by Ship Research Institute (Hinatsu *et al*. 2000) showed that the seawater taken into the flow-through system via the inlet comes from near the sea surface even if the inlet is located at around -5 m, because of the lowering of streamlines beside the hull with model ship experiments and CFD (Computational Fluid Dynamics), which is referred to here as one of the basics to evaluate the outcomes from flow-through systems.

References

Harashima, A. *et al.* (1997): Monitoring algal blooms and related biogeochemical changes with a flow-through system deployed on ferries in the in Kahru, M. and Brown, C. B. (eds.) *Monitoring Algal Blooms – New Techniques for Detecting Large Scale Environmental Change*-, 85-112, Springer.

Harashima, A. and Kunugi, M. (Eds.) *Comprehensive Report on Marine Environmental Monitoring and Related Studies Using Ferry Boats*, 38-45, CGER-Report CGER-M007-2000, Center for Global Environmental Research, National Institute for Environmental Studies, 180pages (in Japanese with abstracts and figure captions in English).

Hinatsu, M. *et al.* (2000): A model ship experiment on the original depth of the seawater taken for the monitoring system deployed on ferryboats, in Reference[2)], 38-45.

Appendix 3

Evaluation of upstream location of sampled water using model ship experiments

Munehiko Hinatsu[1], Yoshiaki Tsukada[1], Yoshimasa Minami[1], Hiroshi Tomita[1] and Akira Harashima[2]

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Abstract

In the monitoring of sea healthiness using a voluntary observation ship (hereafter abbreviated as VOS), information of the original depth of sampled water is very important for sampled water analyses. The objective of the research is to develop a method to estimate the original depth of sampled water. In order to do that, first of all, we use a model ship experiment. In the experiment, we inject a dye from the upstream of the ship and pick the water up from the inlet, then the occupation rate of dye in the picked up water is analyzed using a spectrophotometer. The occupation rate is mapped onto the position of dye injection and will thus show the original location of sampled water as a contour map. Further, numerical simulation of flow around the ship is done and streamline tracing is carried out. Thus the water trajectories that pass near the inlet are roughly estimated. These results agree with the experiment.

Introduction

Recently, the importance of environmental safeguards of the ocean has been recognized, and along this trend, the National Institute for Environmental Studies (NIES) has been carrying out sea healthiness monitoring using VOS, such as container ships and ferry ships, which are operated in Asia and the Seto Inland Sea. In the monitoring, sampled seawater is obtained through an inlet located on the ship hull. However, in order to evaluate the sea healthiness through the chemical analyses of sampled water, it is important to know the original depth of the sampled water.

This study is related to the experimental estimation of the original upstream location of sampled water which is obtained through an inlet set on the ship hull.

Experiment

In order to evaluate the original location of sampled water, we shed dye tracer from the upstream of the ship and suck water from the inlet hole set on the ship hull. Sampled water is then analyzed through a spectrophotometer, so the concentration of dye in the sampled water can be determined. The contour map of the concentration of dye contained in the sampled water and the location of the dye shedding position show the original location of sampled water. Figure 1 shows the setup of the experiment. In the study, we used potassium permanganate ($KMnO_4$) as dye tracer. Here we name this method the "dye concentration method".

The 2 m-long model ship used in the experiment is in a training ship hull form, not exactly the same as the VOS hull form, a car ferry ship operating in the Seto Inland Sea - because the hull form of VOS is confidential. The location of inlet is roughly the same as that set on the VOS, that is 22.5% of ship length in front of the A.P. (rudder post) and 52% of draft upper from the bottom. We also added another inlet at the bottom in the same lengthwise location.

The model ship is towed with the velocities of 0.5 m/sec and 1.377 m/sec. Sampled water is sucked by a computer-controlled injector.

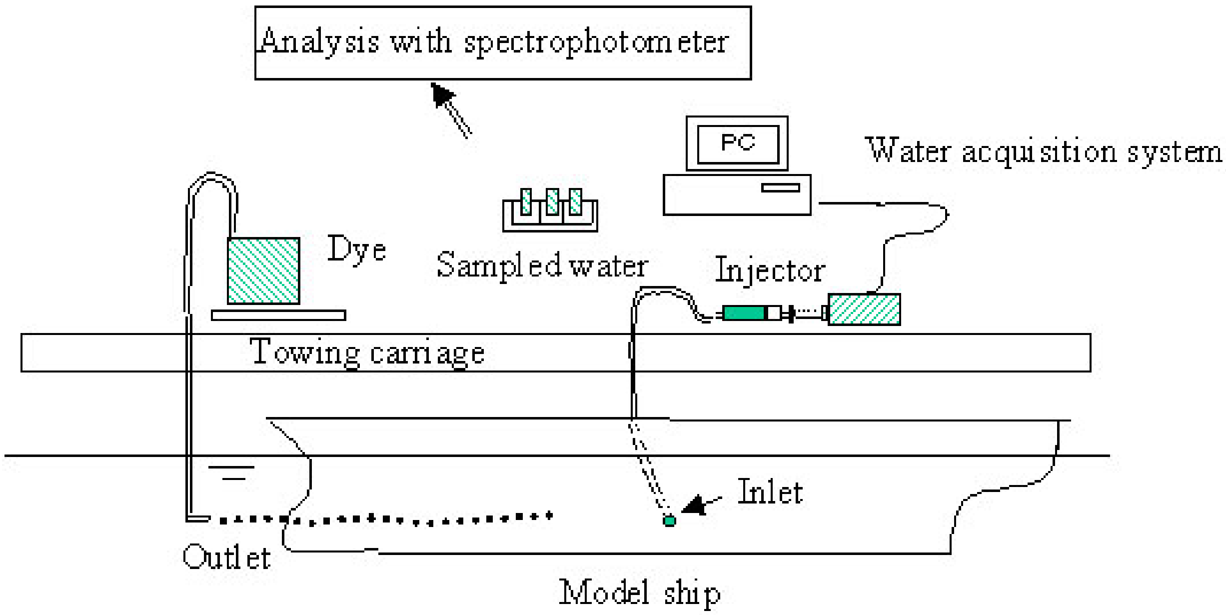

Fig. 1 Schematic setup of experiment.

The rate of suction is set to 0.536 ml/sec and the injector and the inlet are connected with the pipe whose inner diameter is 1 mm. Dye is shed through 3 mm-diameter pipe. The dye is stored in a container set on the towing carriage of the model ship, and it is shed only by gravitational force. The outlet of dye is set at 5% of the ship length upstream from the bow (F.P.).

Estimation of ship flow

The flow around the model ship is computed using CFD, and streamlines that start near the bow are simulated as shown in Figure 2. In the figure, we look up the ship from an oblique angle beneath the ship stern. The tracers shed around the ship bow near the waterplane go down to the bottom around midship, and go up toward the waterplane around the stern. This is a general trend for ship flows. Therefore, we can roughly expect that the sampled water sucked from the mid-draft at the stern would originally exist near the waterplane.

Result of experiments

Preliminary investigation on dye diffusion

At first, in order to investigate to what extent the dye diffuses, we shed dye and suck it in a uniform flow without the model ship. The distance between the dye-shed outlet and inlet for dye-suck is set at 1650

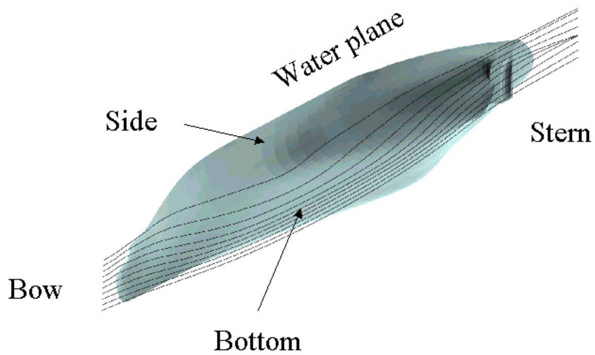

Fig. 2 Trajectories of streamlines starting from around ship bow.

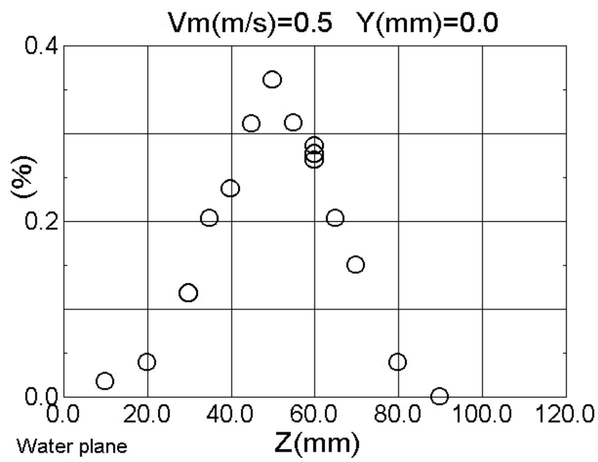

Fig. 3a Vertical distribution of diffused dye under uniform flow.

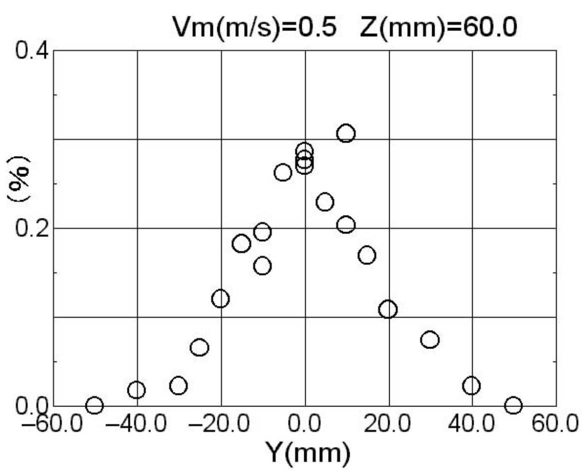

Fig. 3b Horizontal distribution of diffused dye under uniform flow.

mm, corresponding to the distance between the dye outlet and the inlet set on the hull in the model ship test. In Figure 3, result of the diffusion is shown. Here the velocity of uniform flow is 0.5 m/sec and the depth of outlet is 60 mm. The vertical and horizontal diffusion are shown in Figures 3a and 3b, respectively. The vertical axis means the ratio of concentration of dye in %. The area of diffusion can be estimated to be not more than a circle of a 50 mm radius.

Original location of sampled water collected through side inlet

The results are shown in Figures 4 to 7. Figures 4 and 5 show the result at a ship speed of 0.5 m/sec and Figures 6 and 7 are at 1.377 m/sec. In Figure 4, we show the contour map of the concentration of dye in the sampled water. The peak point of this map means that we can recover the dye most when the dye is shed from that point. In other words, we can say that the sampled water must come from around the peak point in all probability.

In the figure, the center of the circle is the gravitational center of the concentration of the dye, and the area of the circle is equivalent to that obtained by dividing the total amount of dye concentration by the maximum value of concentration. In Figure 5, the arrows show the horizontally integrated values of the concentration. Therefore the vertical position of the longest arrow shows the most probable location where the sampled water comes from. From these figures, we can find out that the sampled water collected at the side inlet mainly exists near the free surface originally. This result is consistent with the result of CFD.

In case of higher ship speed, the same trend can be obtained as shown in Figures 6 and 7.

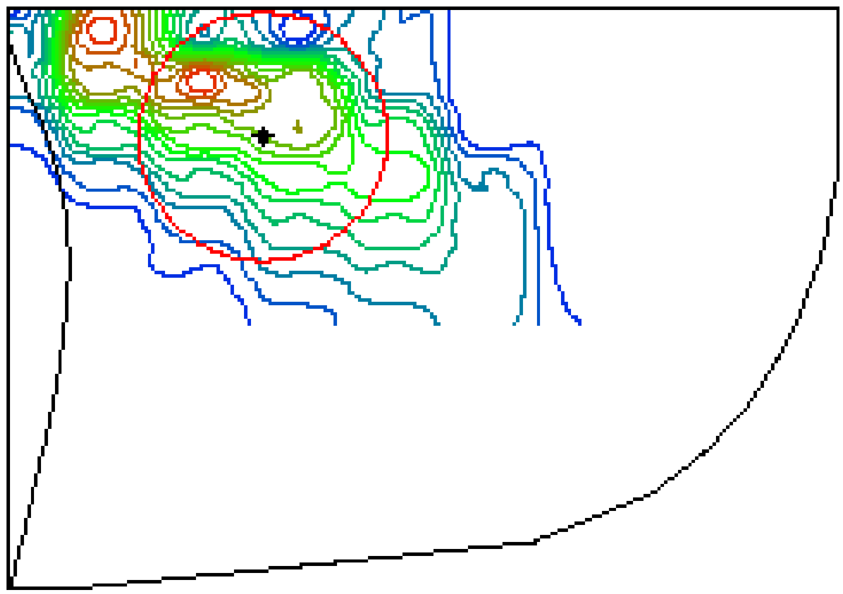

Fig. 4 Contour of percentage of dye in sample water picked up from side inlet (V_m=0.5 m/s, thick line 0.1%, contour interval 0.02%).

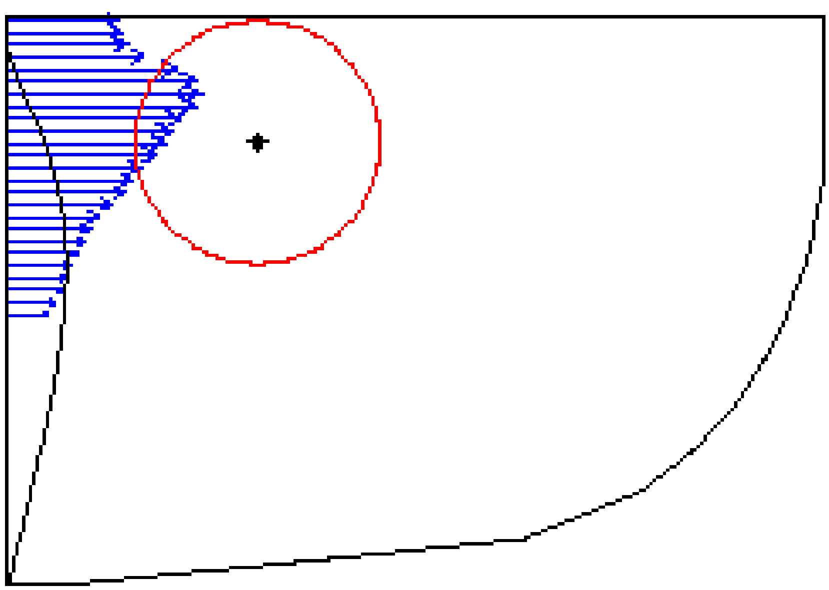

Fig. 5 Integrated percentage of dye in sample water along horizontal direction (side inlet, V_m=0.5 m/s).

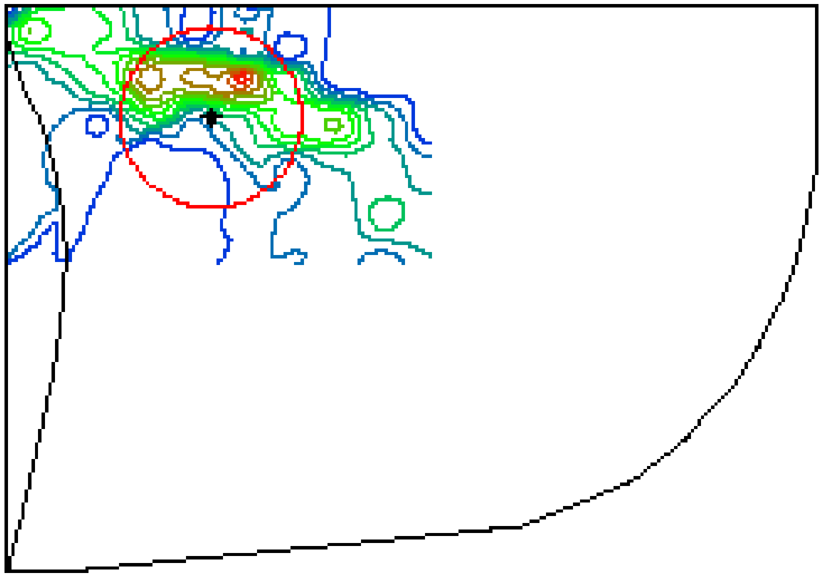

Fig. 6 Contour of percentage of dye in sample water picked up from side inlet (V_m=1.377 m/s, thick line 0.1%, contour interval 0.02%).

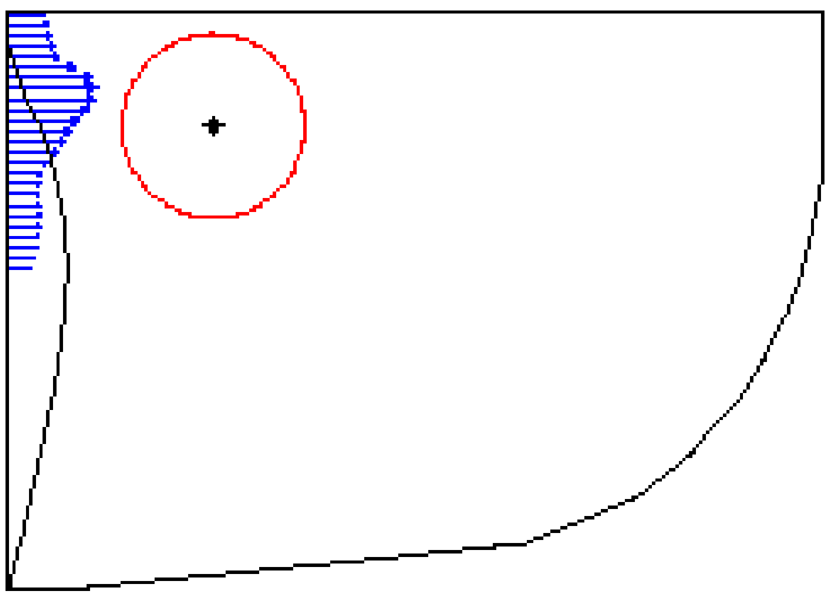

Fig. 7 Integrated percentage of dye in sample water along horizontal direction (side inlet, V_m=1.377 m/s).

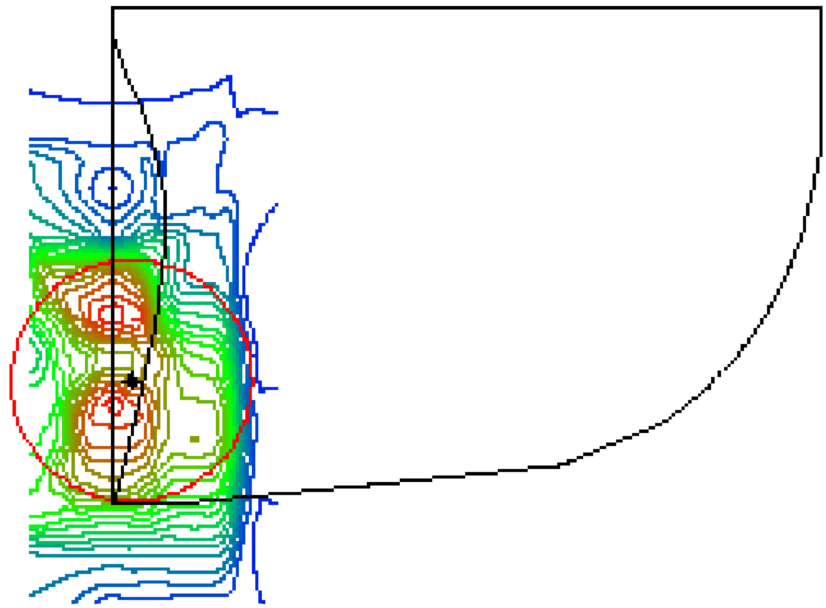

Fig. 8 Contour of percentage of dye in sample water picked up from bottom inlet (V_m=0.5 m/s, Thick Line 0.1%, contour interval 0.02%).

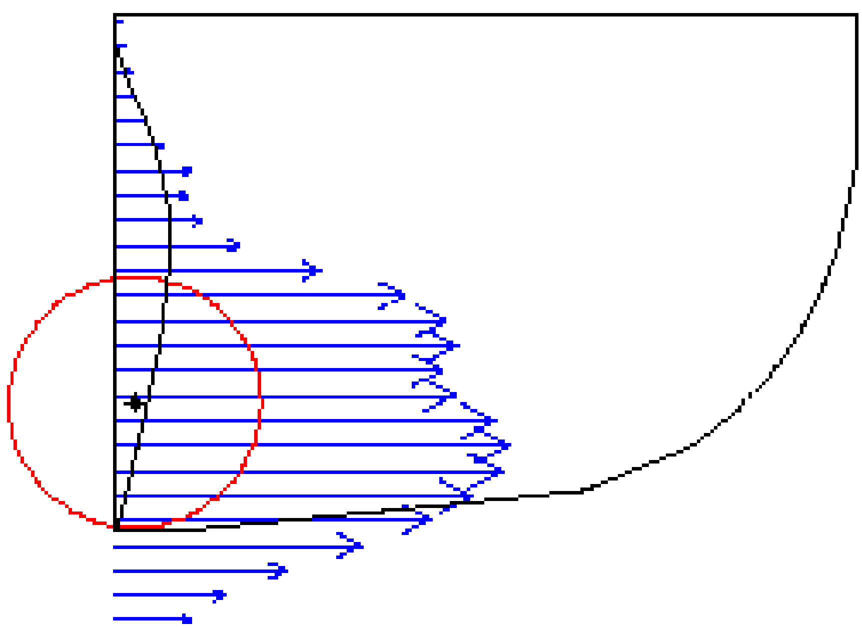

Fig. 9 Integrated percentage of dye in sample water along horizontal direction (bottom inlet, V_m=0.5 m/s).

Original location of sampled water collected through bottom inlet

In Figures 8 and 9, contour maps of the concentration of dye in the sampled water are shown. The ship speed is 0.5 m/sec in this case. Since the streamlines starting from under the bulbous bow run beneath the bottom along the symmetry plane of the ship, much more dye is recovered when dye is shed near the bulbous bow. Further, the contour map is narrower than that in the case of the side inlet. This trend holds even when the ship speed is higher. From this, we may say that the inlet to collect sample water should be set on the centerline of the bottom because the original location of sampled water must be much more limited.

Concluding remarks and future work

Through the experiment to estimate the original location of sampled water, we got the following results:

1. The original location of sampled water can be estimated quantitatively by use of the “dye concentration method”.

2. When we use the side inlet, mostly water at the depth of 13.1% of draft was recovered. This depth may correspond to 0.71 m for VOS, although the shape of the model ship hull is different from VOS operating in the Seto Inland Sea.

We still have the following future works to consider:

1. The dependence of Reynolds number on the result must be considered.

2. The development of an estimation method based on CFD technique is also necessary.

3. The effect of ship motion in waves on the result must be evaluated.

Appendix 4

Summary of the operations of the EU FP5 project "Ferry-Box"

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Introduction

This document briefly outlines the plans of Southampton Oceanography Centre and the European FerryBox consortium, to work with the operators of merchant vessels to install scientific instrumentation onto ferries with the aim of greatly increasing our knowledge and the stability of the marine ecosystem. It is essential to have the knowledge to be able to separate variability in the marine system from permanent change.

The European FerryBox consortium

The European FerryBox consortium is a group of 11 partners who are working together to develop operational oceanographic products based on data collected from ferries. They are: GKSS - Research Centre Geesthacht GmbH, Southampton Oceanography Centre, Netherlands Institute for Sea Research, Finnish Institute of Marine Research, National Centre for Marine Research (Greece), Proudman Oceanographic Laboratory, Norwegian Institute for Water Research, HYDROMOD Scientific Consulting (Germany), Chelsea Instruments (England), Instituto Español de Oceanografía, and Estonian Marine Institute. The consortium combines SMEs, scientific, operational and policy-oriented institutions. By collaborating in the FerryBox project, the partners will be setting about the task of defining the relative variability of important ecosystem components in the whole range of European marine environments. This will encompass the oligotrophic eastern Mediterranean to hyper-nutrified northern European estuaries, as well as the full range of physical forcing from low (Mediterranean and Baltic) to high tidal mixing (North and Irish Seas), and from low (coastal, Baltic) to high (Mediterranean) salinity waters.

FerryBox routes

The selection of the FerryBox lines (Fig. 1) is based on representing the wide range of European marine systems from oligotrophic to hyper-nutrified, and the large range in hydrodynamic conditions and processes. Each of the routes has end users who will be making use of the products of the FerryBox project.

The main interests of the FerryBox lines are:

R1 Baltic Sea (closed sea)
  Eutrophication, (blue)-algal blooms, sampling strategy

R2 Skagerrak (shelf sea)
  Validation of satellite data, combination *in situ* and satellite data (RS)

R3 Southern North Sea
  Nutrient input, eutrophication, algal classification, ground truth

R4 Wadden Sea (tidal sea)
  Water currents, sediment transport

R5 Irish Sea (shelf sea)
  Transport and mixing on western Scottish shelf, algal growth

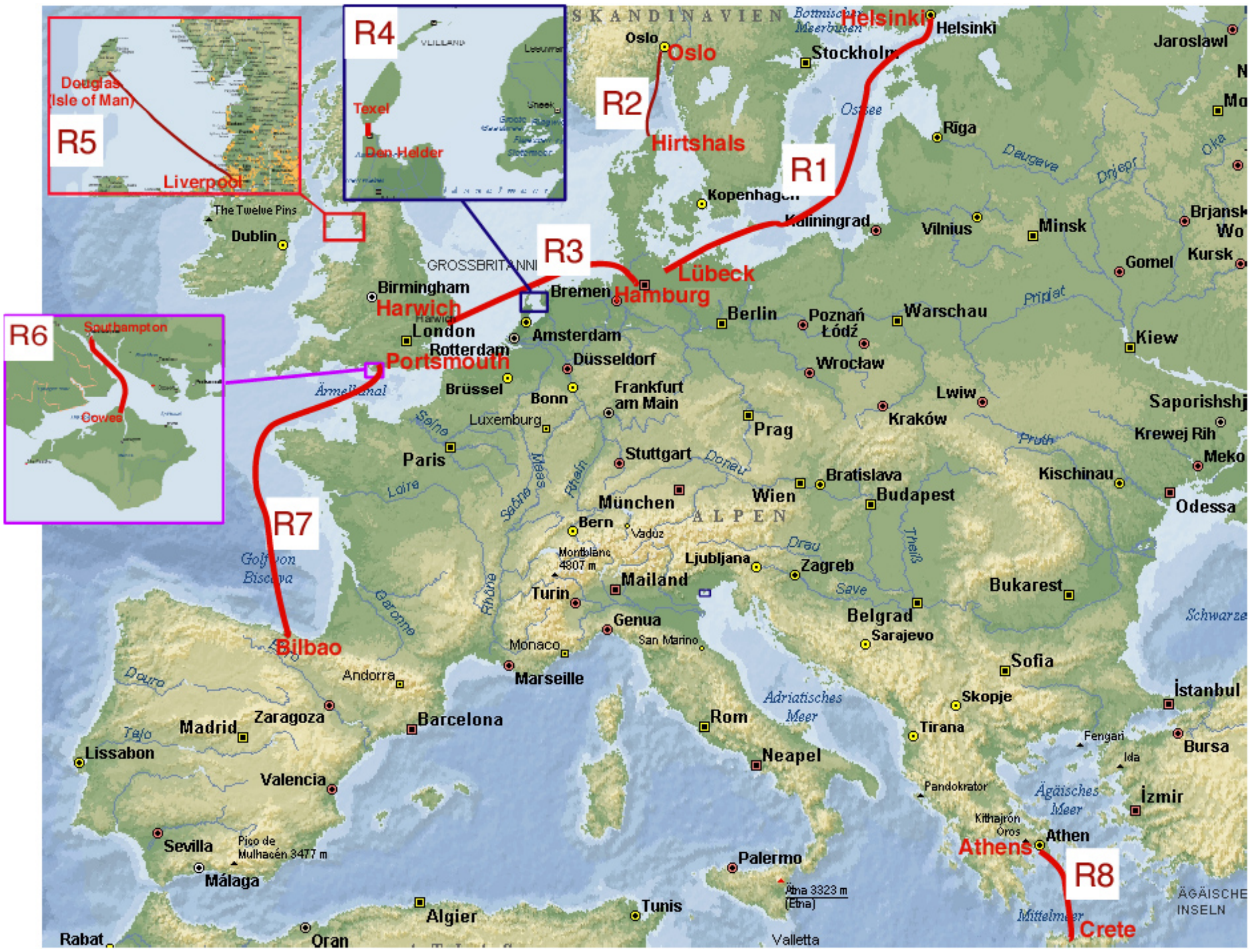

Fig. 1 Map of routes to be operated in the Ferry-Box project.

R6 Solent (UK) (estuary)
: Transport from river to sea, estuarine eutrophication

R7 Bay of Biscay (oceanic)
: Water mass exchange shelf - ocean, range of plankton environments

R8 Mediterranean Sea (oligotrophic)
: Nutrient gradients, upwelling, data assimilation with buoys systems

Definitions: Operational oceanography, GOOS, EuroGOOS and FerryBox

Operational oceanography is best described by the diagram on the next page (Fig. 2). It is essentially the systematic and long-term collection of oceanographic data in ways that minimises aliasing in the observations. The data is then fed directly into an established system to provide useful products. These may be nowcasts of present conditions or it is assimilated into numerical models to produce forecasts. Such systematic collection of data is essential for distinguishing climate and ecosystem variability from permanent change.

GOOS (Global Ocean Observing System): The aim of the organisations signing up to the GOOS concept is to contribute to establishing a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services world-wide.

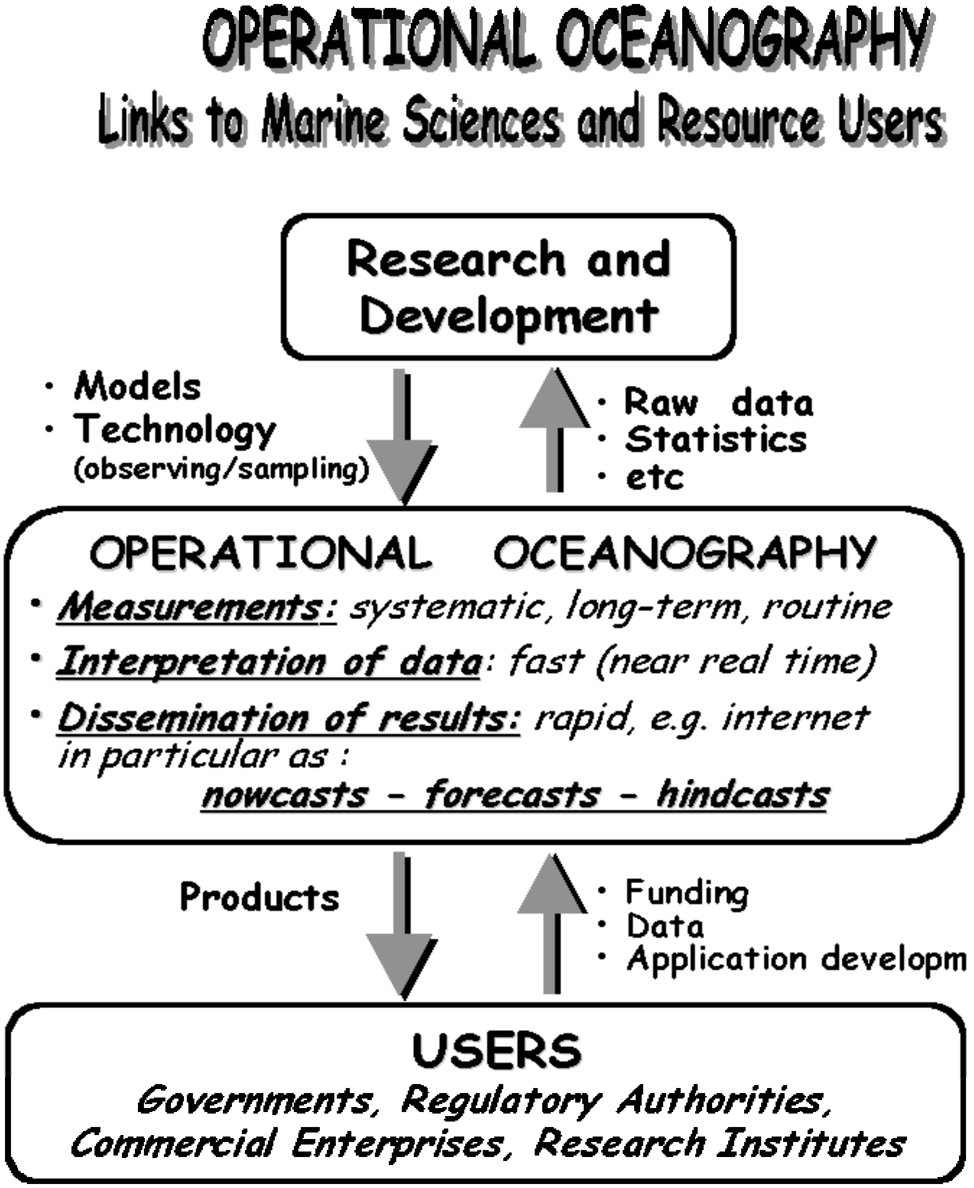

Fig. 2 Elements of operational oceanography.

GOOS will provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change (IOC 1998, IOC 2000).

EuroGOOS is the European division of GOOS. It is subdivided into action groups. The best developed of these is BalticGOOS which has started work on the strong base of activities co-ordinated by HELCOM. A MediterraneanGOOS pilot project is underway and a scheme for a North West European Shelf was published in November 2001, as the NOOS action plan (Droppert et al., 2000)

FerryBox: A practical approach to the establishment of cost effectively monitoring systems is the use of ships-of-opportunity to carry sets of scientific instruments (boxes). The most useful data are those which are collected in a regular fashion. They are easier to interpret and are suitable for assimilation into numerical models. Ships which travel in this manner are ferries - hence FERRYBOX. EuroGOOS has highlighted the fact that over 800 ferry routes are operating in European waters.

Aims and objectives of the FerryBox consortium

A serious hindrance to understanding marine systems is the lack of monitoring systems that provide continuous observations. Currently observations mostly lack spatial coverage and temporal resolution required to determine a true view of the state of the marine environment and changes within it. Moves to overcome this problem are being championed world-wide by the GOOS initiative and in Europe by EuroGOOS.

The FerryBox consortium plans to show how ferries can be used for automatic high quality measurements of environmentally important parameters. Emphasis is on the comparability of the data, and on the use of data to solve scientific and applied problems. The main problems that will be addressed in the first stage are eutrophication and its effects on water quality, and water and sediment transport. It will show that the accuracy of prognostic numerical models (such as those predicting storm surge) can be improved by assimilation of FerryBox data. It will demonstrate the reliability of the system for monitoring at all times of year, and the potential for improving management of European waters of different oceanographic character. It will recommend to the European marine community how future FerryBoxes can be operated and show the benefits to operational services of additional sensors, enhanced coverage and information density. It offers opportunities for the European marine industry to exploit.

The project will demonstrate that ship-borne instrumentation packages (FerryBoxes) can cost effectively deliver information of immediate scientific value, based on a co-ordinated approach and the development of standardisation procedures. It will quantify environmental variability on a European-wide scale and improve understanding of water quality-related processes, specifically eutrophication, transport of water sediments and contaminants.

Programme of work

A key element of the GOOS approach is that data is easily and rapidly available after collection to the user community whether they are scientists, managers or the general public. Data are worthless if their quality are unknown. Therefore before the partners exchange data, all partners will collaborate on developing a standard scheme for validating the accuracy and precision of all data that is used in the FerryBox project, both from Ferry Boxes, other collection methods or archived records. It is important that FerryBox data are data “that can stand the test of time”. We will set up the procedures for the rapid exchange of data that is accompanied by all the appropriate meta-data. This will be web based and use “Marine XML”.

We will concentrate on 3 scientific areas relevant to issues of water quality, ecosystem dynamics and climate variability and change. These will be:

1. Eutrophication including plankton productivity and variability in productivity in relation to physical and bio-geochemical constraints.

2. Transport of sediments (and associated contaminants) over long and short spatial and temporal scales.

3. Determination of the stability and transport of water masses in the Mediterranean, Baltic, and on and adjacent to the Western European shelf.

The work will be based on analysis of FerryBox data in conjunction with other time series data in adjacent waters, including remote sensing observations where this exists by: (i) statistical presentation of the data, and (ii) recognition of patterns in the data which test our hypotheses about specific processes.

There will be emphasis on the quantification of horizontal gradients and their variability in space and time, and on seasonal variations and events. The latter in particular, for instance, blooms or the effects of storms / high river discharges, have not in general been adequately sampled.

An important aspect of the GOOS initiative is the development of prognostic numerical models for marine systems, that can be run using the assimilation of observations to improve their accuracy as is the practice in weather forecasts. Work on numerical models will involve experiments in data-assimilation of FerryBox data into existing models, to produce recommendations on the strengths and weaknesses of assimilation schemes and their benefits. In addition, coupled hydrodynamic-biological models will be used in studies to explore interactions between processes (e.g. spring-neap tidal modulation of coastal plume stratification; algal blooms triggered by mixing events), and enhance the interpretative studies carried out by direct data analysis.

Advances expected from the FerryBox project

Major advances

1. The project will move of the study of water quality issues from national efforts to a truly pan-European effort. The FerryBox project will demonstrate the feasibility of, and provide the basis for, a trans-European operational co-operative network of operators and end-users. This is a very major advance. For the first time, data free from the aliasing inherent in normal infrequent spot surveys will be replaced by high frequency data of known comparability across European waters.

2. A Europe-wide assessment of variability in process relating to eutrophication, water, sediment and contaminant transport will be done. This will provide a baseline against which future and past changes in ecosystem stability can be judged.

3. The accuracy of pre-operational models will be improved by the assimilation of FerryBox data. Improved scientific understanding of processes (particularly eutrophication, sediment resuspension and water mass mixing) will be derived through the use of a combination of data analysis and process modelling.

Examples of other advances

1. Demonstration of the benefits of being able to link FerryBox data (which gives wide area and detailed cover) to existing less frequent time series measurements.

2. Detailed measurement of sediment transport in relation to water flow and forcing by weather (storms).

3. Measurement of production and biomass in a range of environments - near shore

plumes, open waters and at fronts, effects of storm stirring.

4. Contribution to the development of Ecological Quality objectives for eutrophication (EEA, OSPAR).

5. Database for a pilot project for the North Sea on the Ecosystem approach to Fisheries management (under the guidance of ICES, IOC and EuroGOOS).

6. An effective system for calibration and verification of Ferry-Box and related data, and recommendations for maintenance anti-fouling procedures.

7. An effective procedure for the rapid transfer of meta-data and quality controlled data using a web based approach.

Forward look

In addition to its value in supporting the development of prognostic models, the future expansion of the FerryBox concept has two natural developments. Firstly, an increase in the numberof routes operated. New routes will arise from user (scientific and management) requirements for additional data. Experience gained in the FerryBox project will enable the choice of future routes to be optimised. Secondly, an increase in the number of standard variables measured. A range of new sensors have and are being developed, some of which, e.g. sensors for O_2, CO_2, nutrients and active fluorescence, will be tested by FerryBox operators during this project. Future applications will be determined by the type of information needed by the data users. Water quality managers within the EU water framework directive might be expected to require measurements of nutrients and dissolved oxygen in waters which are, or are potentially, eutrophic. A combination of measurements of plankton productivity and algal type may enable harmful algal blooms to be forecast.

Southampton Oceanography Centre's (SOC) first FerryBox operation: Southampton-Isle of Wight Ferry on the Red Funnel - *Red Falcon*

FerryBoxes are packages of instruments (Boxes) mounted in the engine rooms of merchant ships working regular routes (mostly ferries). They sub-sample the ships' cooling water intake. Standard measurements on a number of European FerryBoxes are temperature, salinity, transmission (clarity/suspended solids), and chlorophyll-fluorescence (plankton). These are the instruments on the SOC's first FerryBox installed in 1999, on the Red Funnel Group ferry the *Red Falcon*. The purpose of this system is to provide detailed monitoring of the growth of plankton in Southampton Water and the Solent. A big question mark against many scientific findings is - were enough observations made for the data to represent the true situation? This is a common problem in oceanography where the costs of using purpose built research vessels to gather data are very high. The FerryBox systems can provide a cost-effective solution to this problem. We can now see when plankton really grows in Southampton Water gather than having to gathering data when we think it might in growing.

Relatively calm water, plentiful sunlight and supplies of dissolved nitrogen compounds and phosphate in the water are essential for the growth of plankton. The Southampton water system receives large loads of the essential chemical nutrients for plant growth nitrogen and phosphorus from run off of agricultural fertilisers and from discharges from sewage works. The Southampton

Water/Solent system is hypernutrified but it is debatable at the moment whether or not the system is “eutrophic”. Eutrophic is a term that implies that the ecosystem is being damaged by an excessive supply of nutrients. Signs of “eutrophication” (very noticeable prolonged blooms of plankton and reduced concentration of oxygen in the water) were seen in the 1980’s but have not occurred recently.

Data from the *Red Falcon* are being used to look in greater detail than has previously been possible, at how the growth of plankton in the spring and summer is controlled by the complex relationships between sunlight, concentrations of nutrients and the tidal energy of the system, that controls the rate at which growing colonies of plankton are stirred up and dispersed. The FerryBox data show that plankton growth starts in late spring in the less tidally stirred and clearer waters of the Solent. The first bloom will occur when good weather at this time of year coincides with neap tidal conditions. Then throughout the summer into September, significant accumulations of plankton will occur during neap tides. In exceptional circumstance of good weather, plankton will continue to accumulate more quickly than they are dispersed during a spring tide. The area of the estuary affected moves into Southampton Water in the summer towards the source of nutrients being supplied by the rivers.

Southampton Oceanography Centre’s second FerryBox operation: Portsmouth to Bilbao on the P&O European Ferries - *Pride of Bilbao*

In April 2002, SOC started running a second FerryBox on the P&O European Ferry’s vessel, the *Pride of Bilbao*. This ferry operates all year round between Portsmouth and Bilboa. It will link the observations we are now making in Southampton Water to the Atlantic Ocean - the source of the high salinity waters in the English Channel. The wealth of data that will be collected on the ferry has the potential to improve our understanding of a wide range of oceanographic processes occurring in the Atlantic Ocean and the English Channel. An important objective is to set up a durable, reliable and cost effective system that will have a sufficiently long life to provide baseline information on the influence of climatic variability through the region.

Scientific tasks of the Portsmouth Bilboa Ferry Box extend from the local to the global. They include:

<u>Local</u>

- Dispersion of sediments, nutrients and other contaminants from the Solent into the English Channel.
- The occurrence and movement of plankton blooms between open channel waters and the Solent.

<u>Wider area</u>

- Scaling of the patchiness of plankton blooms in regions with different hydrographic characteristics along the route. Including the influence of fronts in maintaining blooms.
- Scaling of the frequency and intensity of the features related to internal waves.
- Assessment of the transport of water masses from the shelf break into the English Channel, and the control of transport processes on the supply of nutrients from the Atlantic Ocean into shelf sea waters.

Global

Study of the winter mixing processes which:

- Transfer heat from the oceans.
- Control the amount of nutrients in the surface layer of the ocean controlling the productivity of the spring bloom and the draw down of carbon.
- Provide the nutrient supply to shelf waters.

Technical development associated with the SOC FerryBoxes

Technical development associated with the SOC FerryBoxes include:

1. Rapid ship-to-shore communication of data from ship to shore so that it can be used operationally in numerical models and for guiding detailed sampling by research ships.

2. Extension of the analyses performed automatically to include surveying of biologically produced green house gasses. A major problem in assessing the role of these gasses in global warming is a lack of knowledge about variability through the year of their production rates in the oceans.

3. Use of advanced fluorometric techniques to gather physiological information about plankton. On the base of which blooms may be predicted and detailed estimates of the variation in productivity can be made.

References

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Details of EU FerryBox project routes

(The numbering follows the map on Figure 1.)

R1 Routes of the FIMR (Finland) Algaline project

FerryBox measurements have been made operationally by FIMR since 1992. The Algaline project has three sets of FerryBox equipment on merchant ships and one on a Coast Guard vessel. FerryBoxes are run in co-operation with other research institutes. Algaline (FIMR) is co-ordinating the project. Each institute is responsible for the maintenance of a given system, practical work and laboratory analyses. FIMR provides help on technical problems. The equipment is owned chiefly by FIMR and by the other institutes.

The amount of data collected on the ferries in the framework of Algaline project is large (1.5 million observations annually). Data is quality controlled and inter-calibrated annually within the project.

On the ships, salinity, temperature and chlorophyll-a fluorescence are measured at ca. 5 m depth and in ca. 100 m intervals. The samples are considered to represent the upper layer.

Route: Helsinki-Travemunde
Ship: cargo ship *Finnpartner*
Responsible institute: FIMR
Parameters measured onboard: S, T, Chl-*a* fluorescence

Lab analyses: Phytoplankton species, Chl-*a*, nutrients (PO_4, NO_3, NH_4, Si, Total P, Total N)

Route: Helsinki-Stockholm
Ship: passenger ship *Silja Serenade*
Responsible institute: Uusimaa Regional Environment Centre, Finland
Parameters measured onboard: S, T, Chl-*a* fluorescence
Lab analyses: Chl-*a*, nutrients (PO_4, NO_3, NH_4, Si, Total P, Total N), turbidity, phytoplankton species from some samples

Route: Helsinki-Tallinn-Rostock-Tallinn-Helsinki (samples taken between Tallinn and Helsinki)
Ship: passenger ship *Finnjet*
Responsible institutes: City of Helsinki Environment Centre, and Finland, Estonian Marine Institute (phytoplankton analyses)
Parameters measured onboard: S, T, Chl-*a* fluorescence
Lab analyses: Phytoplankton species, Chl-*a*, nutrients (PO_4, NO_3, NH_4, Si, Total P, Total N), turbidity

Route: Archipelago Sea (2001 first year of measurements, good data from two months)
Ship: Finnish Coast Guard vessel *Telkkä*
Responsible institute: Southwest Finland Regional Environment Centre
Parameters measured onboard: S, T, Chl-*a* fluorescence
Lab analyses: Chl-*a*

Potential operations
Southeast Finland Regional Environment Centre is in the project and has FerryBox equipment, but does not have them on a ship. Was used on a route in the Eastern Gulf of Finland, and they are trying to find a new ship.

West Finland Regional Environment Centre is also in the project and has FerryBox equipment but no ship at present. They will receive EU-Life "Bothnian Bay Project" funding for three years starting 2002, this should be enough to set up a new route in the Gulf of Bothnia. Equipment was bought to the Environmental Centre by local industrial companies.

Zooplankton
FIMR tested a traditional CPR in zooplankton monitoring on the route Hanko-Lubeck in years 1998-1999. In 2001, the shipping company Transfennica bought a traditional CPR to FIMR. It will be used on the route Lubeck-Hanko or Trelleborg-Hanko starting 2002. The ship crew can operate the CPR, but one scientist or technical assistant has to take care of the maintenance and get the samples. The goal is to have operational zooplankton monitoring, which Juha Flinkman is developing. Additionally, U-tow is used on the research vessel Aranda. From 2000 and 2001, there is data on vertical distribution of zooplankton in several sea regions of the Baltic.

Uses and dissemination
Data are used for monitoring and assessments, scientific projects, calibration and verification of models, and for interpreting satellite images. Quick dissemination of information on HABs and phytoplankton species in general to the public via faxes, Internet etc., has been very important. Results are presented on the Internet in four languages (Finnish, Swedish, English and Estonian) on the web site made in co-operation with several research institutes (for details see http://meri.fimr.fi). Web site will be renewed in spring 2002.

Linked operations

FIMR has co-operation with Finnish Coast Guard. In addition to the flow-through system onboard *Telkkä*, CTD measurements are made and samples for oxygen concentration analysis are taken in the Gulf of Finland on guard ship *Merikarhu*. Additionally, Coast Guard pilots and crew of several guard ships make visual observations of algal blooms. Visual observations of algal blooms are also made by the crew of Transfennica cargo ships. At FIMR, the Ice Service takes care of sea surface temperature measurements using hull thermometers in cargo ships.

Contact:

Phytoplankton: Johanna Argillander and Algaline group (E-mail: algaline@fimr.fi)

Zooplankton: Juha Flinkman (E-mail: juha.flinkman@fimr.fi)

http://meri.fimr.fi

http://meri.fimr.fi/Algaline/eng/EnPublicAlgalineDB.nsf/ByMeasurementParameter/52A9CE436C3D8969C22567A1003A44F7?OpenDocument

http://meri.fimr.fi/Algaline/eng/EnPublicAlgalineDB.nsf/cdee4ceb7a446ce6c22565d0003d850e/02ebb944bbb8479ac22567eb0034e8e2?OpenDocument

R2 Norwegian Institute for Water Research (Norway)

Route: Oslo (Norway) to Hirtshals (Denmark)

Ship: Color line *Color Festival*

First installed September 2001.

Measurements continuous since start (approx.).

Journey time: 8-12 hours; Oslo-Hirtshals 18:30 - 7:00 (night), return 9:00 -17:00 (day).

Measurements: T and S (Seabird), turbidity and chlorophyll-fluorescence (Seapoint), light (PAR) (Li-Cor).

Logging interval is 1 per minute. Remote data transfer continuous over satellite link (Internet) (1 obs./minute).

Instrument control: about 1 per week.

Calibration interval is not decided yet (testing).

Automatic water sampler (ISCO) released at pre-installed waypoints and is used for control measurements and sampling of phytoplankton and nutrients etc.

Purpose

Constructing and testing the system. Use it in combination with satellite observations (calibration of sensors). Explore the system as an early warning system for toxic algae blooms.

Contact

Project leader: Jan Magnusson (E-mail: jan.magnusson@niva.no)

Co-operator: Kai Sørensen (E-mail: (kai.sorensen@niva.no)

http://www.niva.no

R3 GKSS – Research Centre Geesthacht GmbH (Germany)

Route: Cuxhaven (D) to Harwich (GB) (before March 2002 from Hamburg to Harwich)

Ship: Scandinavian Seaways (Copenhagen, DK) *Admiral of Scandinavia*

First on installed November 2001

Journey time: 16h 45min (600 km) (before March 2002 - 20h (700 km)). 3-4 return voyages per week. Measurement season year around.

Measurements: T and S (FSI; USA), turbidity (Endress&Hauser; D + Turner;USA), pH and O_2

(Endress&Hauser; D), fluorescence (Turner; USA)
Algae Classes (bbe; D), NO_3, NH_4, PO_4, SiO_2 (pump photometer: ME; D), NO_3 (UV detection; TRIOS; D)
Measurement rate 0.1 Hz (exception nutrients: 10-15 min time interval). Logged on board, remote control and download (several times per week) by cell phone link
Special features: Automatic start/stop of the system controlled by GPS position, extensive cleaning procedures (after each voyage: high pressure flushing of certain sensors (O_2, pH, fluorometer) and flushing with acidified water of the whole system), storage of housekeeping data (pressure, flow rates etc.)
Instruments serviced: 1 per week and calibration samples collected.

Purpose
Monitoring of nutrient load, algae blooms (including algae classes) in the southern North Sea, validation of remote sensing (ENVISAT), calibration of ecological models

Developments in 2002
Check and improvement of algorithms for algae classes and calibration with laboratory measurements, test of UV-NO_3 detection, test of long time stability, optimisation of maintenance intervals

Contact
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http://www.gkss.de
http://coast.gkss.de/projects/ferrybox/

R4 Netherlands Institute for Sea Research (The Netherlands)

Route: Texel (Wadden Sea island) to den Helder (mainland of the Netherlands)
Ship: TESO ferry *Schulpengat* (since 1998)
Distance: 4 km
Travel time: 15 minutes; Ferry runs from 06.00 am to 22.00 pm, each 30 minutes, thus 30 transects per day
Sensors in a throughflow system measure temperature, salinity and fluorescence at 1Hz
ADCP attached near the keel measures currents and echo-intensity with a frequency of 2 Hz
Data are transferred to the nearby research institute by telemetry each time when the ferry is in the harbour on Texel.
Data are directly shown to the public on a screen in the passenger lounge

Contact
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Software manager: Frans Eijgenraam (E-mail: eijg@nioz.nl)
Scientist in charge: Herman Ridderinkhof (E-mail: rid@nioz.nl)
http://www.nioz.nl/en/deps/fys/niozteso/enhtml/niozteso.html
http://www.nioz.nl/en/deps/fys/niozteso/enhtml/results.html

R5 Proudman Oceanographic Laboratory (Liverpool, UK)

Plans for 2002/3
Route: Liverpool – Douglas (Isle of Man)
Ship: Isle of Man Steam Packet Company *Lady of Mann*
Winter months only (October - March)
Journey time: 4 hours, twice per day, 5 days a week (not mid-week)

Instruments: Idronaut CTD, Sea-Point turbidity and Chelsea Instruments MINItracka II fluorimeter & Flow rate monitor.
Status of equipment - being installed

Plan to transmit data (+GPS) by GSM phone / Iridium, instrument a Sea-Cat, measure nutrients.

Purpose
Monitoring of blooms and Mersey plume in the eastern Irish Sea

Contact
Scientist in charge: John Howarth (E-mail: mjh@pol.ac.uk)
http://www.pol.ac.uk

R6 Southampton Oceanography Centre (UK)

Route: Southampton to Cowes (Isle of Wight)
Ship: Red Funnel Lines *Red Falcon*
First installed on April 1999
Measurement season: April to October
Journey time: 1 hour (17 miles), up to 8 return voyages per day.
Measurements: Temperature, conductivity, and turbidity (pressure to check flow in system) (WS Ocean Systems UMI data sonde), Chlorophyll-fluorescence (CI Aquatraka)
Measurement rate: 1 Hz logged on board down loaded weekly
Remote data transfer: Sample of data averaged for 1 minute sent ashore by cell phone link at 15-minute intervals
Instruments serviced: 1 per week and calibration samples collected

Plan to extend measurements to nitrate using solid state UV based method.

Purpose
Monitoring of intensity, timing and duration of algal blooms in a hyper-nutrified estuary

Contact
System manager: Susan Hartman (E-mail: suh@soc.soton.ac.uk)
http://soc.soton.ac.uk
http://www.soc.soton.ac.uk/GDD/Sonus/animation.htm

R7 Southampton Oceanography Centre (UK) with Instituto Español de Oceanografía Santander, Spain

Routes: Portsmouth (UK) – Bilbao (Spain) (& Portsmouth - Cherbourg)
Ship: P & O Eurpean Ferries Ltd *Pride of Bilbao*
Installed 12 April 2002
Measurement season: year round except January when ship in refit
Journey time: Portsmouth – Bilbao - 34 hours, 2 per week; Portsmouth – Cherbourg - 10 hours, 1 per week
Measurements: Temperature, conductivity, Chlorophyll fluorescence (Chelsea Instruments Mini-Pack), water flow, turbidity (from May 2002)
Measurement rate: 1 Hz logged on board down loaded weekly
Remote data transfer and control: Data will be transferred to shore using an ORBCOMM satellite link. The effective data transfer rate will depend on the efficiency of connection to the satellites and will only be known when the system is operational. The interface unit being developed will allow remote control of the instruments – (remote re-boot and changes in sampling rates)
Instruments serviced: 1 per week and calibration samples collected

In 2002, samples for nutrients and chlorophyll will be collected manually on 1 crossing per month.

Plan to extend measurements to nitrate using solid state UV based method.

Purpose

Monitoring of intensity, timing and duration of algal blooms, detailed observations of mixing events particularly in winter and "up-welling" at shelf break front in summer. Ground truthing of satellite observations of frontal features and changes in "bio-mass". Estimation of events producing significant water movement on shelf and the through the English Channel.

Developments in 2002

Development of data interface and satellite communications

Testing of use of a Fast Repetition Rate Fluorimeter (Chelsea Instruments Fasttraka)

Work on autonomous (wet chemical) nutrient measurements

Contact

Scientist in change: David Hydes (E-mail: djh@soc.soton.ac.uk)

Data manager: Susan Hartman (E-mail: suh@soc.soton.ac.uk)

Control system developments: Nick Crisp (E-mail: ncr@soc.soton.ac.uk)

Satellite communications: Jon Campbell (E-mail: joc@soc.soton.ac.uk)

Pride of Bilbao section will be complemented by monthly surveys along the Northern Iberian Shelf.

Scientists in chage: Alicia Lavin and César González-Pola (Spain) (E-mail: Cesar.Pola@gi.ieo.es)

R.V. *José Rioja*. Instituto Español de Oceanografía (Santander, SPAIN).

To be installed spring-early summer 2002. Monthly track along coast and three standard perpendicular to coast sections.

Route: Santander-Gijón-Cudillero (~260 km)

Measurements: Temperature and conductivity (SBE21), Chlorophyll-fluorescence and spectral algae class determination (Bbe Fluoroprobe, Moldaenke)

Data will be downloaded monthly when finishing the cruises (no real time data transmission).

Purpose

Study physical features at the southern Bay of Biscay (thermohaline fronts due to upwelling processes, runoff, poleward winter current, eddies shedding, etc.) and also algal monitoring.

R8 National Centre for Marine Research (Greece)

Route: Athens – Heraklion (Crete)

Ship: *Minoan Lines*

Scheduled for mid-2003

Journey time: 9 hours (160 miles)

Measurements: Temperature, conductivity, turbidity, Chlorophyll-fluorescence

Measurement rate: 1 Hz logged on board down loaded weekly. Cell-phone data telemetry

Instruments serviced: 1 per week and calibration samples collected.

Contact

Scientists in charge: Haris Kontoyiannis (hk@ncmr.gr) and Kostas Nittis (knittis@ncmr.gr)

http://www.ncmr.gr

Other associated routes

Route: Kiel-Oslo by FTZ - Universitaet Kiel (Buesum, Germany)

Using "Blue Box" system developed with Go-Systems gmbh

http://www.go-sys.de/start/start_englisch.htm

Includes development of algal species monitor

Contact: K. H. Vanselow (E-mail: vanselow@ftz-west.uni-kiel.de)

EU Cavasoo project

Development of CO_2 monitoring systems on 4 trans Atlantic routes

http://envsol.env.uea.ac.uk/temp/tracer/e072/welcome.htm

Appendix 5

List of participants

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