SeaWiFS and OCTS are effective in mapping phytoplankton distribution (Gordon *et al.*, 1985, Esaias *et al.*, 1986, Hooker *et al.*, 1993) However, a considerable portion of satellite data products are compromised by cloud cover. Moreover, the set of satellite data for the cloud-free conditions is not appropriate as a time series because it cannot be regarded as random sampling considering the variability of air-sea heat exchange and photosynthesis and their possible relationships to cloud cover. The satellite data are indirect signals of the *in situ* physical and biological conditions, which should be validated by direct measurements. We made a data base of ship-based biogeochemical data for the area around Japan (Harashima *et al.*, 1990) to retrospectively analyze the relation to the satellite data. However, the possibility of the coincidence of satellite and ship in time and space was small because the frequency of regular ship observations were insufficient. Therefore an *in situ* platform that can regularly scan the ocean (in this sense similar to satellite missions) is required even if the sampling is limited horizontally to the track of the ship route.

Regular research vessels are not suitable because we cannot use them exclusively for long-term monitoring programs. It is worth considering the fact that most of the merchant and passenger ships are taking sea water into their engine cooling systems and that any ships would be potentially ocean observation platforms as 'volunteer observation ships' or 'ships of opportunity' if the owners and their crews are cooperative. Among these vessels, the ferries are of special utility because they frequently sail in the fixed routes and their draft depths are stable compared to those of cargo ships or tankers.

Due to the importance of ocean margin processes (Holligan *et al.*, 1993, Smetacek *et al.* 1991, Mackenzie *et al.*, 1991, Wollast *et al.*, 1993), we selected the ferry route between Pusan, Korea and Kobe, Japan (Ship's name : Dan-Noh, Osaka International Ferry, Co. Ltd., see Fig.1). We decided to monitor temperature, salinity, pH, *in vivo* fluorescence (Turner-Design fluorometer) semi-continuously (every ten seconds) and take bottle and filter samples for dissolved nutrients, chlorophyll-a and pheopigments with automated filtration samplers. These procedures have been described in a previous report (Harashima, 1993c).

The present report describes the method not covered in the previous report, data processing and export to CD-ROM, the results and remarks on the malfunction of the first implementation of the monitoring system and useful points to be improved if a network of the biogeochemical monitoring network will be established on the ferry boat.

2.Methods

2.1. Continuous sensing and automated bottle and filter sampling

The regular monitoring menu consists of the analysis of T, S, pH, and *in vivo* fluorescence measurements every 10 seconds (hereafter termed continuously sensed data) and the bottles and filters collected automatically every two weeks (hereafter called the bottle and filter data).

The continuously sensed data were transformed from the raw electrical signals into the corresponding physical, chemical and biological parameters as are those from satellite missions (Fig. 2). The analog signals from the sensors were converted to 12 bit digital

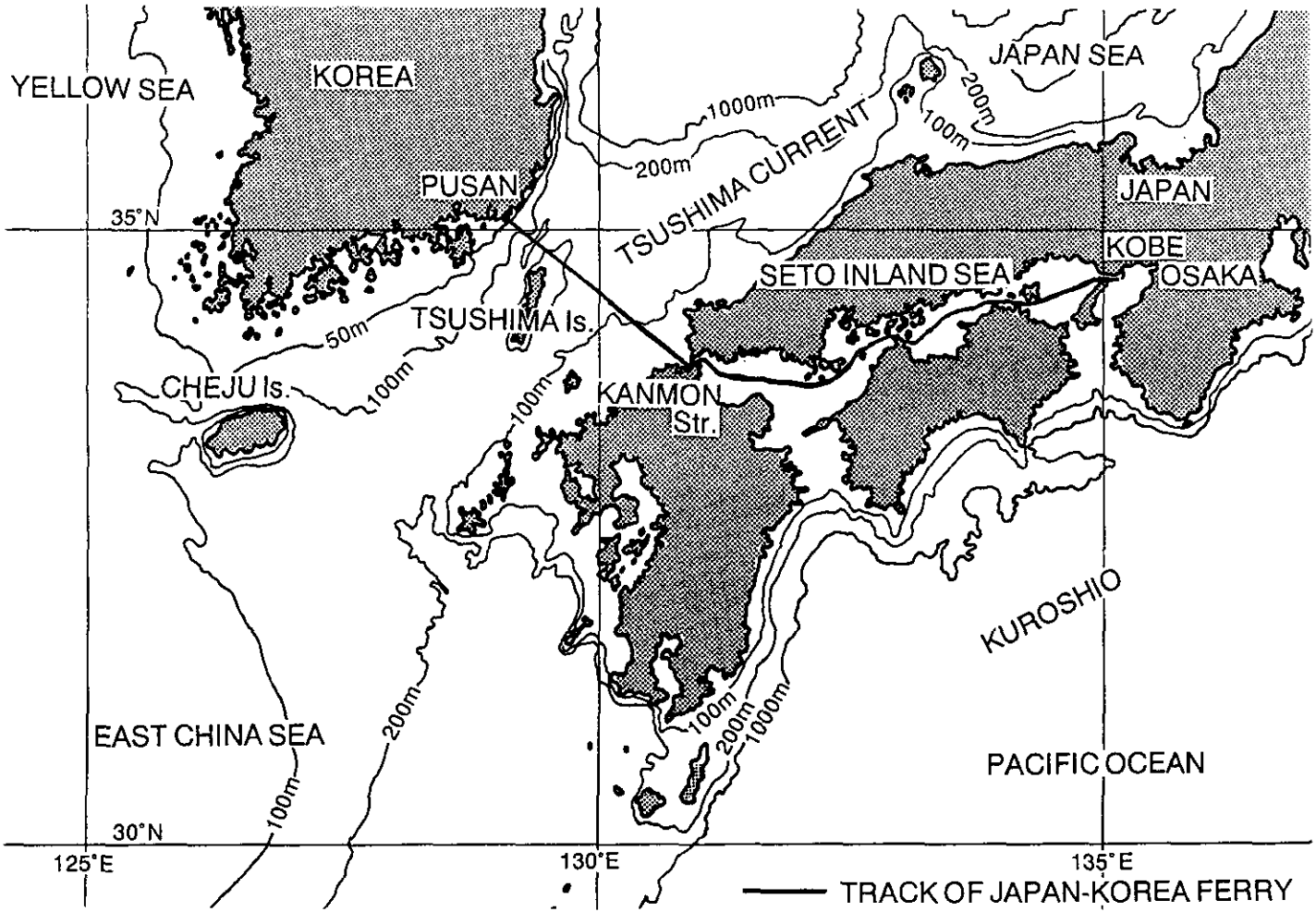

Fig. 1 Track of the Japan-Korea Ferry

(binary) form, recorded on floppy disks (Level-0 data) and subsequently converted into DOS text file format called level-1 data. Level-1 data is appropriate for quickly viewing the data features although it includes slight departures from the true values created either in the process of AD-conversion or by output drift due to fouling of the sensors.

The Level-1 data are converted into Level-2 data through the computation of the time to location transformation using ship's log book information and a linear sensor drift correction using pre- and post-cruise calibration information. The ship position is to be obtained directly from GPS and recorded in the new monitoring program beginning in 1994 (Harashima *et al.*, 1994b).

The drift of the temperature and salinity data were corrected assuming that the sensors drifted linearly with time during one week intervals between calibrations. The fluorometer was calibrated using four fluorescein standards (0, 10, 20, 30 μg/l) and the values in the Level-2 data are shown as ppb units of equivalent fluorescein concentration.

solutions. Two types of corrected data series have been produced. One data series, denoted pH_1 was calculated correcting only for the difference between the pH of the buffer solutions and the digitally recorded values during calibration before the cruise by adding this difference to the Level-1 data values. Another data series, denoted pH_2, was calculated by correcting the cruise pH data for drift using the calibration data from both before and after the one week period and transforming the cruise values to pH at 25°. An inventory of the Level-2 Data files is listed in Appendix 2.

The automated filtration sampling was performed approximately every two weeks. The number of bottle and filter samples are averagely 30 per cruise on average. After recovering bottle and filter samples at Kobe, they were forwarded to the laboratory for chemical analysis. In May 20 1992, the method of nutrient analysis was changed from manual analysis (Strickland *et al.*, 1968) to autoanalyser (Bran Luebbe). The detection limits of the data value before May 20, 1992 are 1.0, 0.2, 0.5, 0.25, 0.25 for Dissolved-Si, PO_4-P, NH_4-N, NO_2-N, NO_3-N, respectively. They have been improved to 1.0, 0.03, 0.20, 0.05, 0.05 (μM), respectively since the sifting to the autoanalyser. Chlorophyll-a and pheopigments were analyzed by multi-wavelengths type fluorometer after extraction of the filters in acetone. Their detection limits are 0.2 (μg/l). The accuracy of the measurements were defined by sampling two bottles simultaneously at twelve points in April and July and by calculating the square roots of the mean squared differences in the results for each station. They were 0.73, 0.016, 0.072, 0.039, 0.080, 0.14, and 0.10 for Dissolved-Si, PO_4-P, NH_4-N, NO_2-N, NO_3-N, chlorophyll-a and pheopigments, respectively. The bottle and filter data results are contained in MS-DOS text files, whose format is shown in Fig. 2.

2.2. Mapping of temporal and spatial variation

The data for each variable has time (date) and space (position along the ship route) axes, so a two-dimensional representation using computer graphics is more comprehensible. Such plots were found to be useful for checking data quality or even for identifying latent malfunction of the system.

As shown in Fig. 2, The Level-2 data of the continuously sensed variables were transformed into text tables, in which each line and column correspond to one day and 30 seconds of longitudinal range, respectively. In this process, the original Level-2 data that fell within each 30 seconds' range (approximately 750 m) were gathered and averaged, excluding missing or abnormal data.

Thus, tables of 720 columns (129°E to 135°E : Pusan to Kobe) x 365 lines (1 to 365 day of year) partitioned by [TAB] and [CR] were generated for each variable. These text tables were imported into ™SPYGLASS-TRANSFORM graphics software to generate color sections shown in Figs. 5 to 8. The data series from each cruise is represented by a horizontal stripe in each figure. Missing data are expressed as -99.999 in the text file and black in the computer-generated images.

The bottle and filter data were transformed into a similar tabled text and imported to SPYGLASS-TRANSFORM to generate the color sections, shown in Figs. 9 to 15.

SPYGLASS-TRANSFORM to generate the color sections, shown in Figs. 9 to 15.

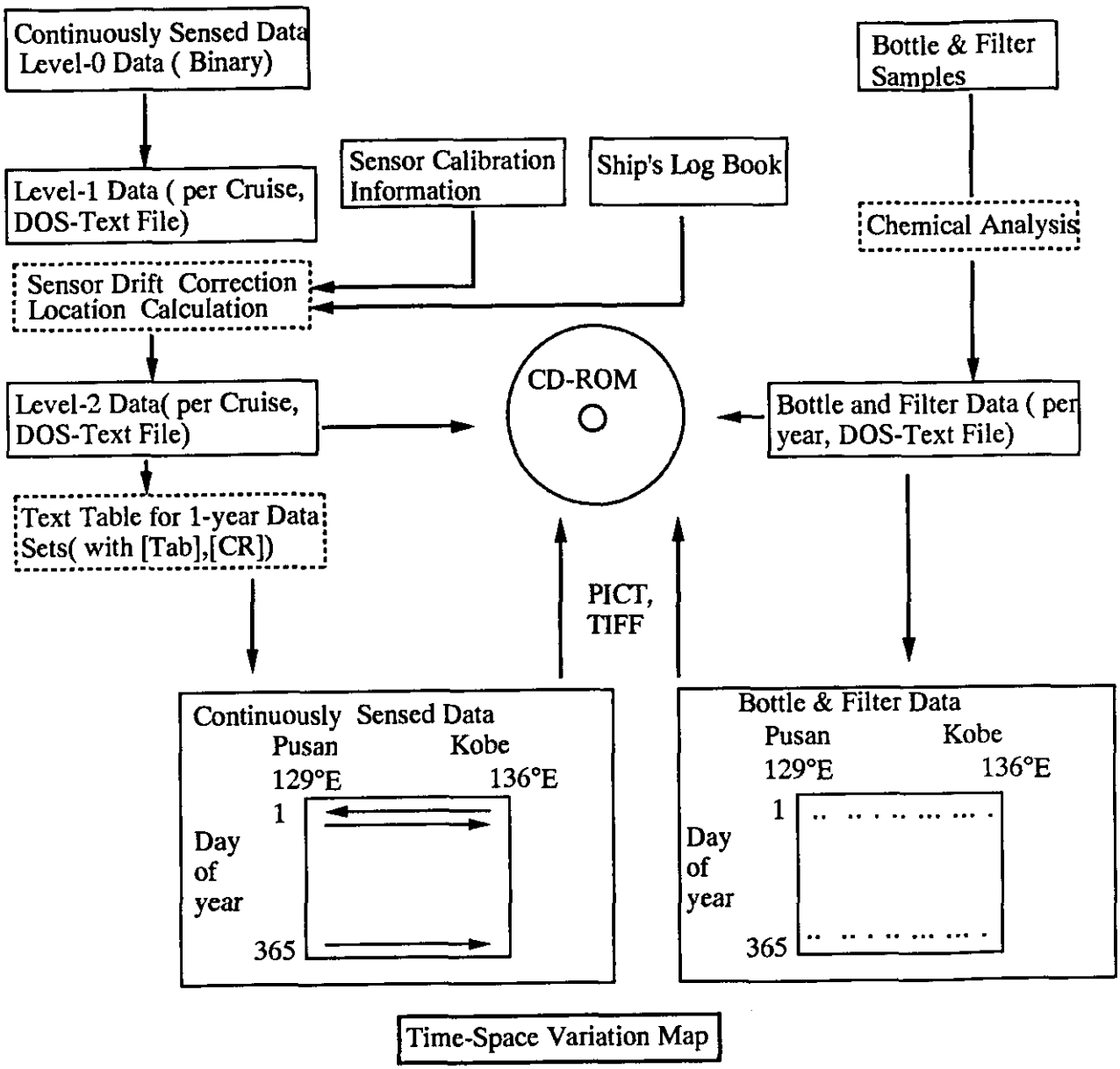

Fig. 2 Data Flow Diagram

```
Column   1        10        20        30        40        50        60
                  I         I         I         I         I         I
Data     92/ 6/ 5!12:30:14!  8.3982!  8.3429! 31.9881! 19.3804! 38.66
Item     Date       Time      pH1       pH2       S          T Fluores.
                                                        (µg/l-Eq.Fluorescein.)

Column   61       70        80        90        100       110
                  I         I         I         I         I
Data     19!157.5209954!135.1687366! 34.6273110! 14.571#
Item          Day of year  Longitude  Latitude  Cumulative distance from
                 (Day)      (°E.)      (°N.)     the departure port (km)
```

Fig.3 Record format of one data line of Level-2 Data. One file (per cruise, averagely 22 hours) consists of averagely 8000 data lines (800kbyte). Symbols ! and # denote [Tab] and [CR], respectively.

```
YYMMDDhhmmLtmm.mLonmm.m Vol   DTSi  PO4-P  NH4-N  NO2-N  NO3-N  Clo-a  Feo-a  Bo.NO

92061812303429.713436.4 480   14.9   0.20   0.57   1.41   3.10   1.10   0.23  C-11
92061813003433.213447.0 484   14.9   0.21   0.52   1.37   3.49   1.84   0.39  C-12
92070118003459.012916.1 479    5.0   0.06   0.54   0.51   0.02   0.24   0.14  A-1
92070119003448.912932.2 471    2.9   0.06   0.29   0.10   0.00   0.16   0.06  A-2
```

Fig.4. Record format of Bottle and Filter Data File. The 1st line shows the data items. The data line consists of Date, Time, Latitude (degree by I2+ minutes by F4.1), Longitude (degree by I3 + minutes by F4.1), Filtered water volume (ml), and concentration of the nutrients (mM), pigments (mg/l) and the bottle number (A-1, A-2, ...), respectively. The $<x$ in the data before May 20, 1992 shows that the value is below detection limits x. Since May 20, 1992, the value below detection limits are shown as 0.00. Missing data are shown by 999.9. Symbol* denotes abnormal values.

2.3. Data products on CD-ROM

The data products are to be distributed by CD-ROM due to this medium's large capacity. Appendix 1. shows the directory structure and the files included on the disk. The README.TXT file is a synopsis of this monitoring program, including this and previous reports. The ship's route map and schematic diagram of the monitoring system are contained in the FIGURE-directory. These files were saved in both PICT (*.PIC) and TIFF (*.TIF) formats for use in Macintosh, DOS and UNIX systems. The directory NUMDATA contains the subdirectory BTFL, which contains the bottle and filter data and the sub-directories L2Y91M06, ..., L2Y93M02, each of which contains the Level-2 data for each month. Macintosh computer users can transform DOS-text to Mac-text by changing [CR LF] to [CR] with the Apple File Exchange utility. The directory IMAGE contains the PICT and TIFF files of the sections of Level-2 data of the continuously sensed data, which corresponding to Figs. 5 to 8, and bottle and filter data, corresponding to Figs. 9 to 15, respectively.

3. Additional manned investigations

Manned investigations were performed seven times during the period from 1991 to 1993 (see Appendix 2). The main purpose of these investigations was to perform research-oriented experiments or additional measurements of sea water properties. Another purpose was to check for malfunctions during the cruise and explore ways to develop and improve the automatic sampling system. These additional measurements were performed on samples taken from an auxilliary sampling faucet branching from the sea water supply pipe feeding the automatic measurement system. We attempted to draw water for the additional measurements simultaneous with the automatic measurements.

Zooplankton and phytoplankton abundance and composition were analyzed by optical microscope and the nanoplankton and picoplankton by fluorescence microscope. Part of the plankton count data were transformed to values of carbon biomass in each size fraction with the data for size class and taxonomical classification to the genus level (Furusawa *et al.*, 1993) based on the method of Strathmann (1967).

The phytoplankton size spectra were measured with a Laser Particle Counter. This instrument detects the fluorescence signals of the chlorophyll-containing particle in a flow cell excited by the laser light via glass fiber and counts the number of fluorescence events in each size-fraction (Tsuda *et al.*, 1991, Tanaka *et al.*, 1993).

The distribution of the sea water CO_2 partial pressure was measured on five cruises (see Appendix 2) with a sea water CO_2 analyzer (Kimoto *et al.*, 1993), which made use of a newly developed bubble-based equilibrator for better time response and minimizing change of sea water temperature compared to the traditional shower-based types.

The results of these additional measurements are introduced briefly in the following sections as they will be published elsewhere.