International Symposium on Carbon Cycle in the North Pacific

Programme and Abstracts

J G F S
JOINT GLOBAL OCEAN FLUX STUDY
JAPAN

8-10, February 2000
Symposion Hall, Nagoya University

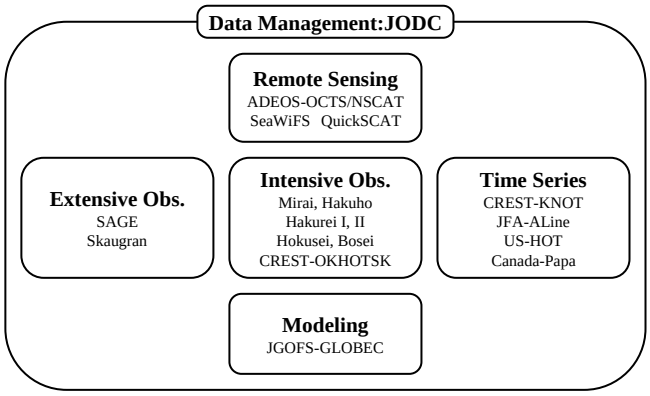
Hosted by

Institute for Hydrospheric-Atmospheric Sciences
Nagoya University

Welcome!

It is our honor to have this International Symposium on Carbon Cycle in the North Pacific here at Nagoya University. As stated in the first circular, the aim of this symposium is threefold; one is to facilitate exchange of the latest data and information among the various components of the Japanese JGOFS' activities, the second to locate Japanese JGOFS' results in the context of the JGOFS North Pacific Process Study, and the third to discuss the coordination of North Pacific Synthesis and modeling with JGOFS' other 4 regional synthesis and modeling groups. As of this writing, we have more than 90 registered participants and 34 poster presentations. Together with invited oral presentations, the poster presentations nicely cover various topics relating to Terms of Reference given to the North Pacific Task Team of JGOFS.

The JGOFS North Pacific Process Study started in a rather unusual way compared to the foregoing Process Studies in the North Atlantic, Equatorial Pacific, Arabian Sea and the Southern Ocean. The JGOFS Japan started the Process Study also in an unusual way. You will note that every Japanese activity being reported in this symposium does not have direct support to the JGOFS. The JGOFS Japan was lucky enough to find a lot of JGOFS-related activities being planned in the northern North Pacific to start from 1996 or 1997. Therefore the JGOFS Japan decided to take advantage of those activities by coordinating them, in order to make contribution to the JGOFS North Pacific Process Study. The coordination is depicted in the following figure.



The 2-year long intensive phase of the JGOFS Japan's North Pacific Process Study will be completed by the Mirai Cruise MR-00-01, which ends one day before this symposium. It is our expectation that we, including people who were on board Mirai, will be able to have fruitful discussion on the latest data and information, and to come up with an agreement in the direction toward the synthesis of the JGOFS North Pacific Process Study.

Toshiro Saino and Masashi Kusakabe,
Co-organizers

Program

International Symposium on Carbon Cycle in the North Pacific

8 Feb (Tue) ----------

Registration
10:00 Registration
Opening (Chair: Toshiro Saino, Nagoya U.)
10:30 Opening
Welcome: Takao Takeda (Director, IHAS, Nagoya U.)
Welcome: Masashi Kusakabe (Co-convener)
Meeting Objective: Toshiro Saino (Co-convener)
Current Status of Regional Synthesis (Chair: Nobuhiko Handa, Aichi Pref. U.)
11:00 Keynote: Kon-Kee Liu (Nat. Taiwan U.; JGOFS SSC Vice Chair)
11:30 NABE: David Siegel (U. of California, Santa Barbara; NA SMG Member)
12:00 EqPac: Robert LeBorgne (ORSTOM/France; EqPac SMG Chair)

Lunch (12:30-13:30)

Current Status of Regional Synthesis (Chair: Kon-Kee Liu, Nat.Taiwan U.,Taiwan)
13:30 Indian Ocean: Peter Burkill (Plymouth Marine Lab.; IO SMG Chair)
14:00 Southern Ocean: Urlich Bathmann (AW Inst. Polar Res., SO SMG Chair)
14:30 North Pacific: Alexander Bychkov (PICES; NPTT Co-Chair)
Break (15:30-16:00)
North Pacific Marginal Seas (Chair: Alexander Bychkov, PICES, Canada)
16:00 Continental Margin: C.T. Arthur Chen (Natl. San-Yat-Sen U., Taiwan)
16:30 Japan/East Sea: Kyung-Ryul Kim (Seoul Natl. U., Korea)
17:00 Okhotsk Sea: Masaaki Wakatsuchi (Hokkaido U.)

Welcome Buffet (18:00-)
Restaurant "Hana-no-Ki"

9 Feb (Wed) ----------

Time Series Observations (Chair: Steven Emerson, Univ. of Washington, USA)
09:00 HOT, David Karl (U. of Hawaii, USA)
09:30 PAPA, Paul Harrison (U. of British Columbia, Canada)
10:00 KNOT, Yukihiro Nojiri (NIES)
Break (10:30-11:00)
Extensive Survey (Chair: Shizuo Tsunogai, Hokkaido U.)
11:00 SAGE: Nobuo Suginohara (U. of Tokyo)
11:30 Ship of Opportunity: Yukihiro Nojiri (NIES)
12:00 Satellites Observation: Sei-ichi Saitoh (Hokkaido U.)

Lunch (12:00-13:30)

Poster Session (Chair: Toshiro Saino, Nagoya U., Japan)
13:30 Short Presentations for Posters
14:00 Posters

Dinner (19:00-)
Hotel "Rubrum Ohzan"

10 Feb (Thu) ----------

Plankton Dynamics (Chair: Paul Harrison, University of BritishColumbia, Canada)
09:00 Oyashio Monitoring: Hiroaki Saito and Atsushi Tsuda (Japan Fisheries Agency)
09:30 East-West Difference: Isao Koike (U. of Tokyo)
10:00 Seasonal Variability: Michio J. Kishi (Hokkaido U.)
Break (10:30-11:00)
Biogeochemistry (Chair: Isao Koike, U. of Tokyo)
11:00 COSMIC: Koh Harada (NIRE)
11:30 Mirai Cruises: Masashi Kusakabe (JAMSTEC)
12:00 Subtropical Nuts Flux: Steven Emerson (U. Wash., USA)

Lunch (12:30-13:30)

Toward NPPS Synthesis (Chair: Masashi Kusakabe, JAMSTEC)
13:30 Annual Variability: Toshiro Saino (Nagoya U.)
14:00 NOPACCS Synthesis: Joji Ishizaka (Nagasaki U.) & Yutaka Watanabe (NIRE)
14:30 CO_2 Budget: Shizuo Tsunogai (Hokkaido U.)
Break (15:00-15:30)
Discussion (Chair: Toshiro Saino, Nagoya U.)
15:30 Discussion Items (tentative)
Physical Pump, Biological Pump, Seasonal Variability, Annual Variability,
Comments for JGOFS-Synthesis, Assignment of Authors for Synthesis Volume,
Arrangement of Chapters, Coordination of North Pacific Activities
Etc.

17:30 Adjourn

JGOFS North Pacific Task Team Meeting

11 Feb. (Fri) ----------

09:30 – 15:00 Chairs: Alexander. Bychkov and Toshiro Saino
Venue: IHAS, Nagoya U. (Guests welcome)

Guests, please contact A. Bychkov or T. Saino if you plan to attend the NPTT meeting.

The Dynamic Ocean Carbon Cycle

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Freeman Dyson wrote in *Infinite in All Directions*, “So there are two styles of science ..., unifying and diversifying.” He asserted that physics is the domain of unifiers, while 99% of biologists are devoted to explore details of life’s diversity. I suspect this may have something to do with the view that the biogeochemical processes are secondary in importance as opposed to the physics in the climate study, because the biogeochemical processes may be only the details which need to be filled within the frameworks set up by the physics. However, Freeman Dyson cautioned that every science needs for its healthy growth a creative balance between unifiers and diversifiers. Such a balance was not appreciated for climate research until the late 1980s, when the science community realized that a full understanding of the earth’s climate system was not possible without knowledge of the interaction among biogeochemical and physical processes. The carbon cycle is undoubtedly the most important biogeochemical cycle related to the climate system. Since the ocean has the largest reservoir not only for heat but also for carbon in the climate system, the dynamic ocean carbon cycle must be central to any climate study.

Under such a belief, the Joint Global Ocean Flux Study (JGOFS) was first conceived in a meeting held by SCOR in Paris in 1987. Later on IGBP joined SCOR to co-sponsor JGOFS. The goals of JGOFS are (1) to determine and understand on a global scale the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the ocean, and to evaluate the related exchanges with the atmosphere, sea floor and continental boundaries; and (2) to develop a capacity to predict on a global scale the response of oceanic biogeochemical processes to anthropogenic perturbations, in particular those related to climate change. Incidentally, these two goals represent the diversifying and the unifying aspects within the project.

After ten years of study how close has JGOFS approached the goals it set? This is a very difficult question to answer. It may be safe to say that we have made pretty good progress towards the first goal, but the second goal still awaits the fruit of synthesis and modeling of a colossal database collected by all JGOFS-related projects throughout the world. I will try to highlight the most interesting JGOFS results from my own point of view.

By definition, JGOFS must deal with the oceanic uptake of anthropogenic CO_2 over the entire global ocean. Extensive studies of the air-sea exchange fluxes of CO_2 in a global survey provided an up-to-date map of the breathing of the oceans. The current estimate of the oceanic uptake rate is 2.2 Pg C/yr. However, this estimate is subject to large uncertainty due to its dependency on the gas exchange coefficient, which has estimates differing by a factor of two. Recently the GASEX98 study obtained very detailed observations of trace gas gradients within the boundary layers, both above and below the sea surface, in the hope of improving the accuracy of gas exchange coefficient.

However accurate the CO_2 flux may be determined, it does not exemplify how the CO_2 uptake is effected by the complex action of physical-biogeochemical processes in the ocean. The physical processes have been studied in projects undertaken by the World Climate Research Program. The biogeochemical processes have been examined by JGOFS intensive studies, which cover either a few critical regions in limited field campaigns (Process Studies) or rather long time-spans at a few fixed points (Time-series Observations). The transfer of atmospheric CO_2 into the deep ocean is via a biological pump and a physical pump. The former represents biological sequestration of carbon as organic matter that gets transferred to the deep ocean either by sinking of particulate matter or by convection of dissolved organic carbon; it constitutes about 10% of the total transfer. Although the biological pump is less effective than the physical pump, which represents uptake of CO_2 in the sinking dense water during formation of deep waters, it is the biological pump that makes the uptake

more efficient. Many scientists believe that the biological pump does not contribute much to the sequestration of anthropogenic CO_2 at present, but how biological pump may change in response to global climate change is a big question. The current feeling is that it will become more important as the physical pump slows down.

The JGOFS research made tremendous contribution to the understanding of the operation of the biological pump. The uniform steady-state carbon fluxes envisioned by the previous generation of marine biogeochemists are replaced either by temporally variable fluxes with pulsated transport events or by spatially heterogeneous fluxes with patches of hot spots. The North Atlantic Bloom Experiment (NABE) captured the spring bloom of phytoplankton and the concurrent enhanced air-to-sea CO_2 transfer and the slightly delayed surface-to-deep water particle flux. The Arabian Sea Expeditions demonstrated how monsoons control the circulation as well as the biogeochemical fluxes of the Arabian Sea. The export flux of organic carbon from the euphotic zone is called the new production or the export production. The previously held paradigm of a well-behaved relationship between the new production and the primary production was debunked, because the export does not only depend on primary production but also on the ecosystem structure which varies dramatically in different parts of the ocean.

The concept of nitrate-based new production breaks down in many areas of the ocean, such as the equatorial Pacific and the polar oceans, where the so called “high nitrate low chlorophyll” (HNLC) condition prevails. John Martin proposed that iron limitation is the culprit, while others suggested grazing as the main cause. Thanks to the ingenious Iron Experiments, which have been conducted twice in the equatorial Pacific and once in the Southern Ocean, and has unequivocally proved that iron limitation is indeed a major reason for the HNLC condition. Subsequently, new propositions suggest that the total primary production in the world oceans may be controlled by the aeolian dusts that pepper the ocean with iron, which controls not only carbon fixation but also nitrogen fixation.

Continental margins represent about 10% of the total area of oceans, but contributes almost 20% to the total marine primary production. Despite its high productivity, its role in CO_2 sequestration is poorly quantified, because the horizontal exchanges between open oceans and coastal oceans are critical but difficult to measure. Contrary to the conventional wisdom that the coastal oceans are a net source of CO_2, recent findings revealed several important marginal seas as net sinks. However, this part of the ocean carbon cycle may be most susceptible to perturbation, which may come directly from human disturbance or indirectly from climate change.

The ranges of scale in both time and space encompassed in JGOFS are unprecedented. The spatial scale ranges from the size of a single organism to an entire ocean basin viewed by satellites; the time scale ranges from the plankton turnover of less than a day to decadal trends observed by time-series stations. Data synthesis and modeling are the most difficult task, but they are the only way to unify all the information. Models of varying degree of complexity have been developed and more are in the make. The compartmented ecosystem model proposed by Mike Fasham and colleagues, when coupled with physical processes, has succeeded in simulating the first-order features of ocean biogeochemistry. New and improved techniques for coupled physical-biogeochemical models are emerging rapidly. I am confident that the paradigms and database left by JGOFS will enable the ocean biogeochemistry to evolve to such a state that may complement the physics for the new climate study in the 21 century.

The Equatorial Pacific JGOFS Synthesis

Robert Le Borgne[1]
Chaiman of the Equatorial Pacific Synthesis Group

The equatorial Pacific is the main source of carbone dioxide on Planete Earth and was chosen for that reason, as one of the five JGOFS (Joint Global Ocean Flux Study) process study areas. The programme was launched at the Honolulu meeting in September 1989 and oceanographic cruises started the following year with Australian, French, Japanese and U.S. research vessels. Most of the field work ended in 1998, and included more than 32 cruises in the 1990-1998 period. Among the major results of the Equatorial Pacific JGOFS study are the following points: (1) evidence of the importance of the diurnal time scale in the functionning of the "warm pool" and HNLC (High Nutrient –Low Chlorophyll) ecosystems; (2) importance of the variability of the zonal extension of the HNLC area, as a result of the climatic situation, and consequences on carbon fluxes estimates; (3) influence of Tropical Instability Waves (TIW) on the spatial and temporal variabilities within the HNLC zone; (4) first measurements of new production and sinking rates on the whole equatorial zone; (5) first large-scale experiments on iron limitation during IronEx expeditions; (6) first description of the frontal zone between the "warm pool" and the HNLC area,…

Data interpretation was organized on both national and international levels and included workshops and publications in special journal issues. On the international level, former chairman of the Equatorial Pacific Group, Professor J. W. Murray, initiated a conference in Noumea (New Caledonia) in June 1995 and the edition of a special volume in Deep-Sea Research. Both presented the first conclusions of the international programme after 5 years of field activities. But the actual synthesis period started in 1998, after most of the field work had been completed. At that time, the JGOFS Equatorial Pacific Synthesis Group decided to put its effort on the collection of all existing JGOFS data on the region from national databases and to edit a special volume in Deep Sea Research. The volume will be made of 17 chapters, each of them presenting a synthesis on a particular topic dealing with the JGOFS scientific questions. Chapter are being written presently under the leadership of scientists of different nations and international co-authorship was sought as often as possible. Deadline of manuscript reception has been set to April 2000. Edition of the special volume will represent the contribution of the equatorial Pacific community to the global JGOFS synthesis.

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North Pacific Marginal Sea Exchanges

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The continental marginal zone is where rivers, land, ocean, atmosphere and sediments interact. Despite its relatively modest surface area, the marginal zone plays a considerable role in the biogeochemical cycles of C, N and P because it receives massive inputs of these elements through upwelling and riverine inputs. The marginal zone is also among the most biogeochemically active areas of the biosphere, and exchanges large amount of matter with the open oceans. It is the goal of this study to assess, specifically, the contribution of North Pacific continental margins and seas to CO_2 sequestration and horizontal flux of nutrients across the ocean-continental margin boundary. The penetration of anthropogenic CO_2 into these marginal seas is then described.

The continental marginal shelf systems are divided into two overlapping types: the recycling systems and the export systems. The inner shelves of the Bering Sea, the Sea of Okhotsk and the East and South China Seas belong to the recycling systems, often with large riverine inputs, but the outer shelves are more export oriented. With respect to the export, often ocean dominated systems such as the Californian Shelf, the northwestern American shelf, the western Canadian shelf and the shelves of the Sea of Japan, a dominant feature influencing the budgets is upwelling.

The marginal seas do serve as an important link in the global carbon cycle. Teleconnections between marginal seas have been detected. For instance, the western part of the Kuroshio Intermediate Water originates from the nutrient-rich South China Sea intermediate water which upwells onto the East China Sea (ECS) continental shelf and contributes a large amount of nutrients to the ECS. This contribution, especially for P, is far more than the inputs from the P-deficient Yangtze and Yellow Rivers.

Most of the shelves and estuaries appear likely to show denitrification. Mass balance calculations reveal that the denitrification rate in the ECS shelf is 0.1 mol N m^{-2} yr^{-1} ; whereas it is 0.042 mol N m^{-2} yr^{-1} for the entire SCS. The ECS has a new production rate of phytoplankton as 26 ± 10 mg Cm^{-2} day^{-1} and a new DOC production rate of 38 ± 15 mg $Cm^{-2}day^{-1}$ for a total of 64 ± 32 mg C mol $N^{-2}day^{-1}$, or 15% of the average primary production rate. In other words, 85% of the organic carbon produced on the shelf is regenerated. The downslope transport of modern particulate carbon is 93 ± 47 mg Cm^{-2} day^{-1} of which 27% is organic. The alkalinity budget indicates that there is a substantial amount of alkalinity generation in the sediments (3.9 ± 3.9 mmol m^{-2} day^{-1}) due to anaerobic respiration such as by iron and sulfate reductions.

Most marginal seas are undersaturated with respect to atmospheric CO_2 in the surface water. Further, deep marginal seas with a larger body of water, especially those with deep water formation, may be non-negligible sinks for excess CO_2 . It is estimated that seawater in the marginal seas in the North Pacific alone may have taken up 1.2 ± 0.3 Gt (10^{15}g) of excess carbon, including 0.21 ± 0.05 Gt for the Bering Sea, 0.18 ± 0.08 Gt for the Sea of Okhotsk; 0.31 ± 0.05 Gt for the Sea of Japan; 0.07 ± 0.02 Gt for the East China Sea and Yellow Sea; 0.43 ± 0.1 Gt for the South China Sea; and 0.015 ± 0.005 Gt for the Gulf of California.

More importantly, high latitude marginal seas such as the Sea of Okhotsk or the Bering Sea may act as a conveyer belt in exporting 0.1 ± 0.08 Gt C excess CO_2 into the North Pacific Intermediate Water per year. The upward migration of calcite and aragonite saturation horizons may also make the shelf deposits on the Bering Sea and the Sea of Okhotsk more susceptible to dissolution thus neutralizing excess CO_2 .

Biogeochemistry of CO_2 in the East/Japan Sea, a Miniature Ocean for Global Changes

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The role of ocean is very crucial in the overall geochemical cycle of CO_2 with its special pumping mechanisms such as solubility pumping at the air-sea interface, biological pumping in the surface waters, alkalinity pump associated with calcite deposition at the sea floor and dynamic pumping associated with ocean circulation. Therefore, the quantification of processes involved in the geochemical cycle of CO_2 is one of the most important research areas for understanding the effect of human perturbation on global climate in recent years.

The East/Japan Sea is one of a few ideal places to study these oceanic processes in small scales. Even though the East Sea is a typical marginal sea with her average depth of only 1700 meters, she has many oceanic characteristics such as deep basins over 3000 meters in depth, a very large seasonal variation in SST by more than 15 degrees in centigrade, active biological processes, and a deep convection system with relatively rapid replenishment time of less that 100 years (Kim and Kim, 1996; Kim et al., 1999). Furthermore, the East Sea has shown dramatic changes in her deep-water structures for more than last 30 years, which is apparently related to changes in mode of her own ventilation system from bottom water formation in the past to intermediate water formation in recent years. It is interesting to point out that the mode of changes resembles that in the open ocean very much, which is expected to happen in the next century if global warming continues. Thus, the East Sea could serve a natural miniature laboratory for the oceans in changes during the next century.

We have initiated researches on constructing overall CO_2 cycle in the East Sea. Our initial focus has been on solubility pumping at the air-sea interface. The fCO_2 in marine air and surface seawater were measured with an NDIR (Non Dispersive InfraRed , Licor 6252) CO_2 analyzer and a Weiss-type equilibrator. The fCO_2 of surface waters varied in a range from 350 to 400 μatm in summer and from 300 to 350 μatm in winter. Comparison of these concentrations with those in the atmosphere revealed that surface seawaters in the East Sea are, in general, supersaturated with respect to atmospheric CO_2 in summer and are undersaturated in winter.

A simple model was devised for explaining the variation of fCO_2 in surface waters in time and for estimating the annual flux of CO_2 at the air-sea interface (Oh et al., 1999). The model considers the

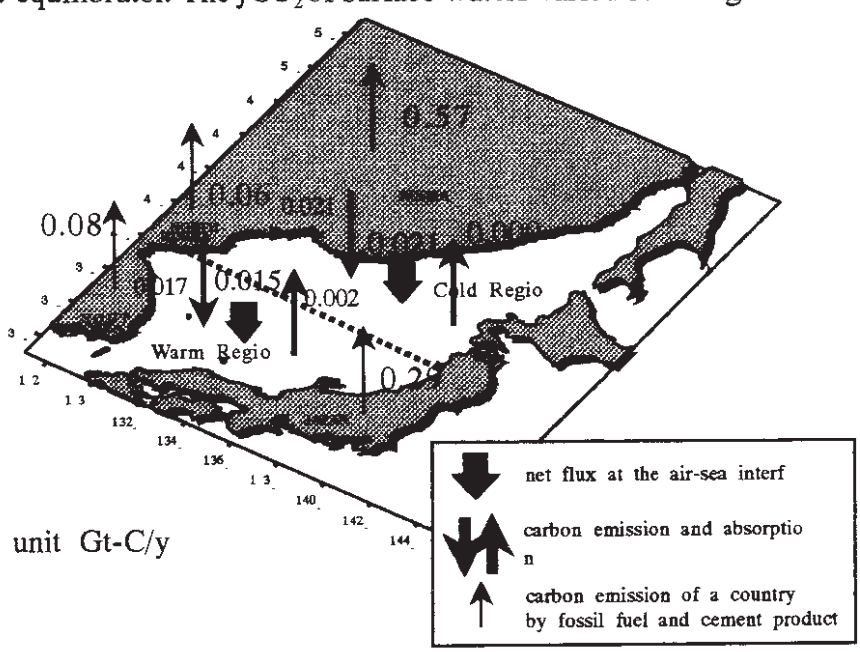

Fig. 1. The overall exchange fluxes of CO_2 at the East Sea. Anthropogenic emissions of CO_2 from nearby nations are also shown for comparison in the figure (Marland et al., 1994. Trends '93)

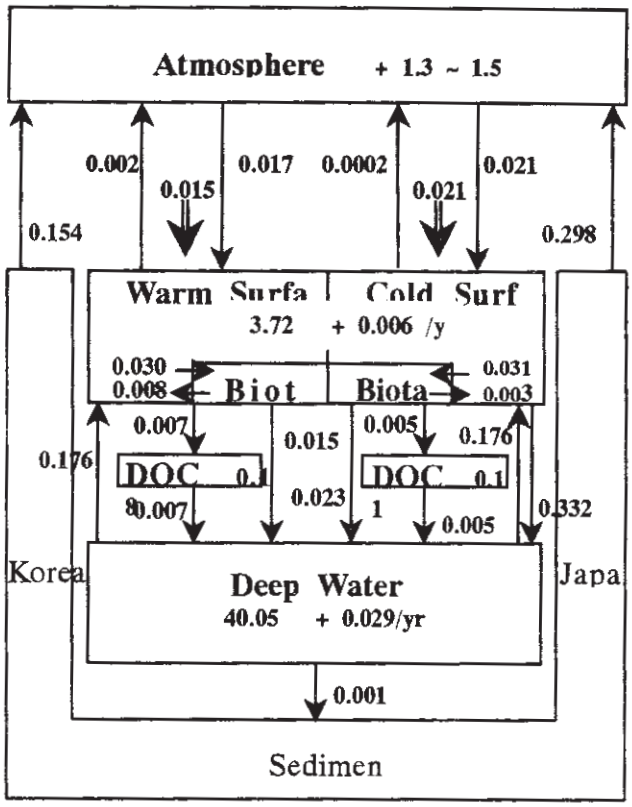

Fig. 2. The carbon cycle reservoirs and fluxes in the East Sea. The numbers denote sizes of reservoirs or fluxes in Gt-C and Gt-C a year, respectively.

annual variation of parameters such as the atmospheric CO_2 concentration, sea surface temperature(SST) and salinity, mixed layer depth(MLD), transfer velocity(kw) and biological activity. Due to differences in SST variations, the East Sea was divided into two regions (cold and warm region) at the 40°N in latitude: northern part represents the subpolar oceans and southern one subtropical ones. The annual flux at the East/ Japan Sea is summarized in Fig. 1.

Studies on the carbonate system in the East Sea were also carried out in order to construct a model for a total geochemical cycle of CO_2 in the East Sea. Total alkalinity and pH (total hydrogen ion scale) of seawaters from major Basins were measured on board and the total inorganic CO_2 was calculated using thermodynamic relationships. The data shows that there are excess CO_2 all the way to the bottom at the present time. In order to describe the dynamic pumping in the East Sea, a simple moving-boundary box model was designed, which also accommodates the recent changes in deep water structures in the East Sea. The initial results obtained on biogeochemical cycle of CO_2 in the East Sea are shown in Fig. 2.

The refinement of the dynamic model of the East Sea and the development of time-dependent carbon cycle model are underway and will be further discussed at the meeting.

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Biogeochemical Studies at the Hawaii Ocean Time-series (HOT) Station ALOHA

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In 1988, two deep-water, oceanographic time-series stations were established: one in the North Atlantic Ocean near the historical Panulirus Station (Bermuda Atlantic Time-Series, BATS) and the other in the North Pacific Ocean near Hawaii (Hawaii Ocean Time-Series, HOT). These programs were established and are presently operated by scientists at the Bermuda Biological Station for Research and the University of Hawaii, respectively, on behalf of the U.S.- JGOFS and the U.S.-WOCE ocean science communities. The primary objective of the HOT program is to obtain high-quality time-series measurements of selected oceanographic properties, including: water mass structure, dynamic height, currents, dissolved and particulate chemical constituents, biological rate processes and particulate matter fluxes. These data sets will be used to improve our description and understanding of ocean circulation and ocean climatology, to elucidate further the processes that govern the fluxes of carbon into and from the oceans, and to generate novel hypotheses. These are necessary prerequisites for developing a predictive capability for global environmental change.

The research conducted at Station ALOHA to date has provided an invaluable data set on unexpected physical and biogeochemical variability in the subtropical North Pacific Ocean. Some of these results have already been published, but others are part of the continuing time-series measurement program. Selected HOT-JGOFS program results include: (1) quantitative assessment of the CO_2 sink which, at Station ALOHA, averages 0.7 mol C/m2/yr, (2) quantitative assessment of a secular increase in total DIC, in response to rising atmospheric CO_2, at a rate of 1 µmol/kg/yr, (3) numerical dominance of photosynthetic (oxygenic) bacteria of the genera *Prochlorococcus* and *Synechococcus* in the surface waters at Station ALOHA and numerical dominance of Archaea in the mesopleagic zone, (4) ENSO-related changes in subtropical North Pacific community structure and biogeochemical cycling rates, (5) quantitative role of *Trichodesmium* and microbiological N_2 fixation in the nitrogen budget, (6) quantitative assessment of a secular decrease in the inventory of soluble reactive phosphorus in the upper water column (0-100 m) of ~1.1 mmol P/m2/yr, probably related to a shift from N to P limitation with the observed increase in N_2 fixation, (7) discovery of relatively high, but variable, annual rates of primary production (~15 mol C/m2/yr) compared to historical estimates of 4-5 mol C/m2/yr and (8) convergence of new (export) production estimation by three independent techniques (oxygen mass balance modeling, mixed-layer dissolved inorganic carbon and $^{13}C/^{12}C$ mass balance modeling and direct measurement of particulate matter export on a value of ~1 mol C/m2/yr.

A major scientific objective of the HOT program is to provide members of the scientific community with a high quality time-series data set of relevant physical and biogeochemical variables for model validation and other purposes. Each year we publish a HOT Program Data Report that presents data collected from the previous calendar year. In 1999 we produced our first HOT CD-ROM which contains data from the first decade of program operation, as well as other related materials. The full, updated data sets are also available, approximately 6-12 months after collection at our on-line web site: http://hahana.soest.hawaii.edu/hot/hot.html.

The HOT time-series program has already provided crucial data on the mean states of a representative open ocean ecosystem and on the natural variability therein. Selected biogeochemical trends were unexpected but are now understandable; others remain enigmatic. For example, the fact that dinitrogen appears to supply about 50% of the new nitrogen was not predicted by the existing conceptual frameworks. Other surprises are also probably in store.

As our understanding of the oligotrophic North Pacific gyre ecosystem expands, the core measurement research effort may require modification to accommodate new paradigms.

Station Papa Time Series: Insights into Ecosystem Dynamics

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The time series at Stn Papa at 50° N and 145° W in the NE subarctic Pacific, spans more than 40 years, making it one of the longest open ocean time series in the world. We are now able to examine a wide variety of temporal scales from seasonal and interannual to decadal variability.

Winds and solar radiation are the main factors influencing annual variability in physical and chemical properties of the surface layer. The intense low pressure system, the Aleutian Low, sits over the Gulf of Alaska in winter and produces winds of about 12 m/s. These winds mix the surface layer to 120 m, increase the salinity to 32.7, decrease the temperature to 6°C, and increase NO_3 and SiO_4 to 16 and 24 µM respectively (Si:N = 1.5). PO4 is about 1 µM, NH4 = 0.2 and urea <0.2µM. Winter chlorophyll is >0.2 µg/L (<15 ug/m2) and primary productivity is <10 µg C/L/d (300 mg C/m2/d). As light and temperature increase, the mixed layer depth decreases to 40 m in summer, temperature increases to 12C, and NO3 and SiO4 decrease to 8 and 12 µM respectively (Si:N = 1.5), PO4 = 0.3, NH_4 <0.2 µM, chl = 0.4 µg/L (30ug/m2), and primary productivity is 30-40 µg C/L/d (850 mg C/m2/d).

Interannual variability in the last decade is due to several El Nino events in the early 1990s (Whitney & Freeland 1999). Due to warmer surface waters, the winter mixed layer became more buoyant and the macronutrient supply decreased. The warmest year, 1994, had the lowest nitrate and silicate and surface NO_3 depletion extended to Stn 16 (about 600 km offshore). By the summer of 1996, silicate depletion was also observed along Line P. This broad area of nutrient depletion reduced primary productivity.

Long term trends indicate a near surface warming and a decline in salinity. This has resulted in a reduction of the mid-winter mixed layer depth (Freeland et al. 1998), and consequently, a reduction in the supply of macronutrients (e.g NO_3 and SiO_4) ((Whitney et al. 1998). We do not have a long enough record to state with certainty whether there has been an accompanying decrease in new production which is related to the variation in the iron supply which may be from the atmosphere rather than from vertical mixing. Detailed nutrient sampling by the weather ship in the 1970s clearly showed 2 summers where SiO_4 was probably limiting for diatom growth (Wong & Matear 1999). There are also several years where chl was up to 10 times normal concentrations, perhaps due to sporadic inputs of iron.

At Stn P, proposed sporadic fluctuations in iron supply likely influence carbon export and phytoplankton community composition. An increase in iron supply should increase the number on pennate diatoms (Boyd & Harrison 1999) and carbon export (Harrison et al. 1999). Variability in iron supply may be due to dust events (Boyd et al. 1998) and possibly large coastal eddies advected offshore (Thomson & Gower 1998).

Without this forty year time series, insights into the ecosystem dynamics at Stn P would not have been possible.

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Ocean Time Series Study in the Western North Pacific at 44°N, 155°E (station KNOT): Preliminary Results from 1998-1999 Time Series

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Station KNOT (Kyodo North pacific Ocean Time series, Kyodo means 'cooperative' in Japanese) has been started its intensive phase of study from June 1998. Thirteen visits in 1998 (June-December) and eleven visits in 1999 (May-October) were carried out by five different R/Vs (T/S Hokusei of Hokkaido University, T/S Bosei of Tokai University, R/V Mirai of Japan Marine Science and Technology Center, R/V Hakuho of Tokyo University and R/V Hakurei II of Metal Mining Corporation). The station locates at north of sub-arctic front and is usually occupied by surface water of Oyashio origin having lower salinity than 33 psu. Large new production in summer and intensive winter mixing at this location were confirmed by the results of M/S Skaugran program. Measurements under JGOFS protocol were carried out with reasonable consistency in the time series surveys by various R/Vs.

The 1998 time series gave the results of seasonal changes for dissolved inorganic carbon (DIC), alkalinity, nutrients and primary production from summer (June) to winter (December). The seasonalities of DIC and nutrients were clear, decreasing in summer and increasing in autumn, however, alkalinity showed smaller change than 4μmole/kg during the observation. The summer (from early June to middle August) new production estimated from the DIC change was about 200mgC/m^2/day. The primary production in July and August was about 300mgC/m^2/day and then decreased in autumn and winter to about 100 mgC/m^2/day.

The 1999 time series started from middle May survey, which encountered intensive phytoplankton blooming. High spatial variability was observed around station KNOT, which showed change of chlorophyll concentration from 0.5 to 13μg/L. The primary production inside and outside the blooming showed change from 1700 to 300mgC/m^2/day. The station was frequently occupied by Kuroshio-Oyashio mixture having higher salinity than 33 in the 1999 summer. This made the seasonal changes of DIC and nutrient less clear than 1998 time series.

The 2000 time series just start from January-February cruise by R/V Mirai and arrived at the station on 15th January, 2000. This will give true winter picture of the rough ocean in the western north Pacific. The spring/summer survey will be repeated in 2000, the last year of the intensive phase of the KNOT time series program.

The authors thank the R/Vs and participated scientists for the cooperation in the time series surveys.

Sub-Arctic Gyre Experiment in the North Pacific Ocean (SAGE) Programme

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SAGE (Sub-Arctic Gyre Experiment) programme, a research programme for Research Promotion Fund by Science and Technology Agency, started in 1997 and will continue for five years.In this talk, the background and outline of the SAGE programme are introduced, and some of the preliminary results are shown.

Outline of the programme

Major objectives of the SAGE programme are to estimate the formation rate of intermediate waters such as North Pacific Intermediate Water (NPIW), and to clarify their distribution processes and decadal / interdecadal variabilities. To accomplish the objectives, the following four core projects are set up.

CP 1: Observational study on the structure and variability of the subarctic gyre

a) Surface layer circulation (Thermal structure and current field)
Sea surface topography measured with satellite altimetry will be analyzed. We will keep a network of XBT and XCTD observation including TRANSPAC-XBT, and conduct Lagrangian measurements of the current field using surface and subsurface drifters.

b) Hydrographic structure of the subartic gyre (temperature, salinity, and tracers)
We will revisit one-time WHP lines such as P1 (47°N), P16N (152°W), and P13 (165°E) to detect decadal changes of the subarctic North Pacific.

CP 2: Research on the interaction between the subarctic and the subtropical circulation
- Formation and distribution of NPIW in the western North Pacific -

We will try to identify the formation processes of the origin water of NPIW in the Okhotsk Sea, interaction between the Okhotsk Sea and the subarctic gyre, and advection process of NPIW including cross-gyre flow.

CP 3: Behavior of CO_2 in the subarctic circulation system

We will map air-sea exchange of CO_2 in the subarctic North Pacific and estimate seasonal variations of TCO_2, pH, pCO_2, etc. in the mixed water region.

CP 4: Modeling of the subactic gyre

We will develop inverse models for the intermediate and deep layer circulation, assimilation models, and an eddy resolving model for the North Pacific. For an eddy resolving model, we try to reproduce the Kuroshio separation at a realistic latitude.

Participating organizations

Fisheries Agency, Agency of Industrial Science and Technology, Maritime Safety Agency, Meteorological Agency, Japan Marine Science and Technology Center, and some universities participate in the programme. They own many ships, which we will make full use of to accomplish the objectives of the SAGE programme.

Preliminary results

The programme is in progress according to plan. In this talk, preliminary results are shown on CP 2 and the revisit of WOCE -P1 line.

High Density Data set of pCO_2 in the North Pacific Measured by Cargo Ship Program

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NIES (National Institute for Environmental Studies) and IOS (Institute for Ocean Science) continued the ocean/atmospheric CO_2 monitoring study using a cargo ship, M/S Skaugran between US/Canada west coast and Japan for 4 and half years from 1995 March under Japanese/Canadian JGOFS. The ship sails between British Columbia, the US West Coast and Japanese ports at intervals of around 6 to 8 weeks. Two underway pCO_2 systems were operated by on board personnel and discrete samples were taken for chemical analysis in the 68 crossings from March 1995 to March 1999. More than one million data record of pCO_2 in the North Pacific, north of 34°N, gives spatially and temporally dense data set.

Seasonal function of ΔpCO_2 (ocean minus atmosphere) for each ocean grid in the north Pacific (north of 34°) was obtained only using the pCO_2 data, and then, monthly maps of ΔpCO2 were created. The maps clearly indicate that the pCO_2 variations near the Alaskan Peninsula and off Kril Islands are largest, having 100 μatm of seasonal amplitude with minimum pCO_2 in summer and maximum pCO_2 in winter. In the middle latitude eastern Pacific, seasonal warming and cooling of surface ocean caused decreasing pCO_2 in winter and increasing pCO_2 in summer.

Flux maps of CO_2 were constructed from ΔpCO2 maps and monthly wind velocities. The integrated net annual absorption of CO_2 by the monitoring area of $1.4\times107km^2$ was 0.20 GtC/y. Although the large seasonal amplitude of pCO_2 in the northern north Pacific was observed, the net annual absorption was close to zero, about 0.03 GtC/y for latitudinal zone between 45 and 55°N. A large net annual absorption of 0.17GtC/y was given by the mid latitude zone between 34 and 44°N. It is mainly due to the net absorption by the western mid latitude Pacific, where the winter pCO_2 is significantly lower than the atmosphere.

The seasonal change of temperature effect compensated pCO_2 is approximated for change of dissolved inorganic carbon. The seasonal changes of pCO_2 in the North Pacific are expressed by 75 grid functions for the north of 34°N. The integrated signal of temperature effect compensated pCO_2 change gives summer new production and its distribution is given using the 75 functions. The map expresses the difference of new production in the western and eastern Pacific. In the western North Pacific, high production area, larger than 150 $mgC/m^2/day$, covers from high latitude to 40°N. However, in the eastern Pacific, high production area appears only in the northern north, north of 50°N. The new production and its distribution well agreed with which expected by the amplitude of nutrient change measured by the same monitoring. The monitoring is continuing by a new instrumentation on board M/S Alligator Hope, servicing Tokyo and Seattle/Vancouver from November 1999.

Temporal and Spatial Variability of Chlorophyll *a* in the sub-arctic northwestern North Pacific, Using Multi-Sensor Remote Sensing and Ship Observation during 1996-1999

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The sub-arctic North Pacific is well known as one of the highest biological productivity region in the world. Understanding the role of biological pump in the ocean and monitoring variability of the chlorophyll *a* (chl-a) distribution is very important to clarify the geochemical carbon cycles.

Our objectives of this study are, to grasp the temporal and spatial variability of chlorophyll a (chl-a) distribution and primary productivity at the Japan JGOFS time series station KNOT(44N, 155E) and its adjacent waters in the Subarctic north-western North Pacific, and to understand the mechanisms of chl-a distribution during 1996-1999. We applied multi-sensor remote sensing data sets including ocean color (OCTS and SeaWiFS), sea surface temperature (SST) (AVHRR), sea surface height (TOPEX/Poseidon). Ocean color and SST images are applied to study interannual variability of primary productivity and front dynamics. Sea surface height is applied to study circulation and transport. In addition to these satellite data sets, we generated estimated-nitrate map by the new algorithm (Saino et al., 1999) which employs satellite chl-a and SST values. We attempt to calculate primary productivity by VGPM Model (Behrenfeld and Falkowski, 1997) using ocean color and SST satellite data sets. On the other hand, we examined estimation error of SeaWiFS in-water algorithm using bio-optical measurement data sets gathered by R/V Mirai and other research vessels.

As a result, SeaWiFS in-water algorithm is working well in this region with the error of less than about 40 percents. Relatively low chl-a concentration (about 0.3 – 0.8mg/m^3) dominated throughout the year at the Stn.KNOT, but remarkable peak was seen in bloom period (in May and October), winter (in November and December) and summer (in August 1998). In adjacent sea area, most remarkable high chl-a (more than 10mg/m^3) was seen northward to Stn.KNOT along the Kuril-Islands and adjacent waters in May 1999, moreover high concentration remain over a month during the bloom season. Year-to-year variability of chl-a was seen. Chl-a concentration at Stn.KNOT in May 1999 was higher than that in May 1998. Chl-a around the center of Western Subarctic Gyre(50N, 165E) in October 1998 was higher than that in October 1997. Primary productivity derived by VGPM Model tends to be larger than that measured by in-situ ^{13}C method, but there are some similarity between these temporal change patterns.

Oyashio Monitoring

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Oyashio is the western boundary current of the subarctic circulation in the North Pacific. The Oyashio flows southwestward along Kuril Islands and Hokkaido, reaches to ca. 40°N and turns eastward. Various physical factors, e.g., wind stress, water exchange with the Okhotsk Sea, the warm core ring separated from Kuroshio current, etc., influence the velocity, path and water properties of the Oyashio.

Oyashio region is considered as a highly productive area, and the biological production is influenced of such variations of the Oyashio. In order to understand the physical and biological characteristics of the Oyashio, Hokkaido National Fisheries Research Institute began Oyashio monitoring in 1987 at 17 stations along the observation line named A-line. A-line crosses the Oyashio, extending to SSEward from southeast coast of Hokkaido off Akkeshi Bay. From 1990, biological observations were intensified, and five to seven cruises a year have been carried out.

Spring bloom dominated by diatom is one of the most characteristic events in the Oyashio region. At the end of the winter, nitrate and silicic acid concentration in the surface mixed layer reached 15-20 mM and 25-40 mM, respectively, and the concentrations decreased to ca. 5 mM or less at the end of the spring bloom. Decrease in nitrate concentration during spring bloom (1-2 months) was larger than annual variations in eastern and central subarctic Pacific. The ratio of $Si(OH)_4$: NO_3 in the surface mixed layer was 1.6 before and in the early phase of the spring bloom, and gradually decreased to 0.3-1.0 at the end of the bloom. These results suggest f-ratio of 0.4-0.6 assuming Si: N uptake ratio of diatom equal to the cellular ratio (ca.1). We reproduced silicic acid and nitrate dynamics in a simulation model and examined the factors controlling spring bloom in the Oyashio region.

Control of Biological Processes in the Subarctic Pacific - Comparison of Western and Eastern Domains-

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The subarctic Pacific, including marginal seas such as the Bering Sea and the Sea of Okhotsk, is known to its high biological productivity compared to middle and lower latitudes of the Pacific ocean, partially because of the presence of high nutrients supported by winter mixing of upper water column. At the same time, previous studies prevailed that primary production in the western side of the subarctic Pacific and marginal seas is high while the eastern side, the Gulf of Alaska, is regarded as a typical high nutrients and low chl a (HNLC) area. The gradient of possible micro-nutrients limitation was suggested from the western to eastern subarctic Pacific. Also, marked difference in community structure of planktonic assemblages between the western and eastern domains was reported. In this study, two aspects of western to eastern gradient of the subarctic Pacific in summer are discussed, i.e. the relative ratios of macro-nutrients and phytoplankton population in the upper layer, and microbial peptidase and glucosidase activities and their possible regulation by trace metals.

From the data of Hakuho-Maru Cruise in summer 1997 and two cruises of Skaugram on July and August 1997 (Y. Nojiri, unpublished), Si/N, Si/P. N/P of upper 200m in subarctic western Pacific, Bering Sea and the Gulf of Alaska were compared. During 1.5 month of interval in summer, significant decrease in nitrate (5 μM) and reactive phosphate was observed in the western subarctic and the Bering Sea, while the decrease in both nutrients in the Gulf of Alaska was much smaller than the former regions. Active silicate uptake relative to nitrate reduced Si/N ratio of the Bering Sea and the western subarctic down to 1.0-1.5, indicating active diatom growth in those regions. On the other hand, an opposite trend of Si/N ratio in the Gulf of Alaska suggested minor importance of diatoms in summer. Si/N and Si/P ratios in the upper layer of the central subarctic Pacific categorized into those of the Gulf of Alaska, suggesting that HNLC region occupies al least some 2/3 of total subarctic pacific.

Since hydrolytic activities of ectoenzyme can be used as a potential index of microbial degradation of polymeric organic matter in the ocean, depth profiles of aminopeptidase (LAPase) and glucosidase (BGase) measured by fluorescent substrates were compared in the upper layer of the subarctic Pacific and the Bering Sea. The vertical profiles of LAPase:BGase ratios indicated a systematic shift along the west-east transect of the survey area. The ratio decreased with depth by ca. 6-fold in the western area, which is consistent with general pattern in decomposition of sinking organic matter, i.e. degradation of protein is faster than polysaccharides. However, the ratio increased by over 10-fold with depth in the eastern Pacific, suggesting significant export of proteinaceous materials to the mesopelagic depth compared to polysaccharides. Since positive correlation between cell specific LAPase activity and concentration of dissolved zinc in the upper 100 m depth was observed along the west-east transect, LAPase activity in the euphotic layer of the eastern Pacific would be suppressed by deficiency of zinc as a catalytic element of proteases.

Preliminary Results from Mirai Cruises in 1997-1999

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The Japan Marine Science and Technology Center (JAMSTEC) began a biogeochemical study of the northern North Pacific and its adjacent seas in 1997 when JAMSTEC obtained the new research vessel, Mirai in the fall of 1997.

Goals of the project are:
a) To assess the spatial and temporal variation of flux of CO_2.
b) To understand the mechanisms that control the biological pump and its role in the carbon cycle.
c) To clarify transportation processes of dissolved materials in relation to the formation of intermediate water.
d) To evaluate the fluxes of carbon and other materials carried by particulate matter to the interior of the deep ocean, and their spatial and temporal variation.
e) To determine the past change of ocean environments from records in sediments.

From 1997 to 1999, we had 4 cruises in the northwestern North Pacific. Observations include (1) deployment of moored sediment traps (3 stations) and drifting sediment traps, (2) sampling of bottom sediment by a piston corer and multiple corer, (3) underway measurement of pCO_2, TCO_2, and nutrients in the surface water, (4) hydrocasts for carbonate species, nutrients, DO, ^{14}C, radioisotopes (^{234}Th), trace metals (Fe), and (5) collection of aerosol. In addition, underway measurements of pCO_2 were done piggybacking other cruises.

Results obtained during the cruises were not finalized and some samples are still being analyzed. Following are preliminary results from the cruises. Details of the results will be also given at a poster session.

(1) pCO_2 distribution

In the northwestern North Pacific, spatial variations of surface seawater pCO_2 in the early winter are characterized by three water types: North Pacific Subtropical Water (NPSTW), North Pacific Subarctic Water (NPSAW), and Transient Area. There existed a north-south pCO_2 gradient of 80 µatm between NPSTW and NPSAW (higher in NPSAW). Rates of the pCO_2 change against changes of water temperature (T), salinity (S), total CO_2 (TCO_2) and total alkalinity (TAlk) are calculated as:

$(\partial pCO_2/\partial TCO_2)(TCO_2/pCO_2) = 11.3$,
$(\partial pCO_2/\partial TAlk)(TAlk/p\,CO_2) = -10.6$,
$(\partial pCO_2/\partial T)/pCO_2 = 0.0478°C$,
$(\partial pCO_2/\partial S)(S/pCO_2) = 0.90$.

The calculations suggest that the north-south change of surface water pCO_2 is controlled by northward increases of TCO_2 (contributed by 400 µatm) and of TAlk (-83 µatm), and northward decreases of water temperature (-230 µatm) and of salinity (- 13 µatm).

(2) Sediment trap experiments

So far settling particles have been collected for 1.5 years at three stations (44°N/155°E, 50°N/165°E, and 40°N/165°E). Carbon fluxes started to increase from March and were the highest in summer at 44°N/155°E station, where fluxes of the biological materials were highest among the three

stations. Ratios of organic carbon to inorganic carbon were also highest at the station, implying the area has the most effective biological pump.

(3) Distributions of ^{14}C

Distributions of bomb radiocarbon in the western North Pacific show direct ventilation of upper intermediate water (above 26.6 sigma-theta surface). Formation of North Pacific Intermediate Water may occur in the transition area in the western North Pacific.

(4) Particulate organic carbon (POC) fluxes

Based on the ^{234}Th profiles in the surface water, POC fluxes were calculated. In the area studied (40-50°N, 155-170°E) during the cruise in 1997, POC fluxes in the surface water decreased gradually northwards from 350 mg C/m^2/day to 160 mg C/m^2/day. POC fluxes obtained during the cruise in 1998 (35-40°N, 145-160°E) showed a similar trend; the flux changed from 40 to 330 mg C/m^2/day.

(5) Spring bloom survey

Spring bloom occurred during the cruise in May 1999. Decrease of surface water pCO_2, and nutrients, and increase of chlorophyll, and DO were observed inside a patch of the bloom. Material balance during the bloom will be discussed.

N:P Ratios, Nutrient Limitation and Decadal Scale Changes in the Biological Pump in the Subtropical North Pacific Ocean

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It has been recently argued that the rate of productivity in the North Pacific Subtropical Gyre (NPSG) increased by about a factor of two in the mid-1980s, and that the system has changed from nitrate to phosphorus limitation since then. Climate forcing may have played a role in promoting the "regime shift" and the increase in importance of nitrogen fixation is suggested to have resulted in a system that is phosphorus limited (Karl, 1999). Since this area supports rates of primary production and carbon export that are similar to that in the nutrient-rich subarctic ocean and about half that at the equator (Emerson et al., 1997), changes in carbon and nutrient fluxes in the vast NPSG should have important global consequences.

Recent measurements of dissolved organic phosphorus indicate that lateral surface ocean mixing or intermittent upwelling events caused by eddies may be responsible for the phosphorus input to the euphotic zone (Abell et al., 2000; Emerson et al., 1999). We believe it is difficult to determine what nutrient limits production based on existing data; however, it is clear that the N:P ratio of the particulate biological material presently exiting the euphotic zone is enriched in N with respect to Redfield Ratios (N:P = 24), almost certainly as a result of nitrogen fixation (Karl et al., 1997). The nitrogen-rich flux is not matched by similar N:P ratios in the top of the thermocline (TDN/TDP = 15). Either the dissolved organic nitrogen (DON) and phosphorus (DOP) fluxes out of the euphotic zone are relatively nitrogen poor to compensate for the high N:P ratio of the particulate flux, or the system is not at steady-state. Our measurements of dissolved organic matter (DOM) in the eastern NPSG indicate that isopycnal DOP gradients are steeper than those of DON relative to Redfield ratios, but the phosphorus-rich dissolved organic flux is not enough to compensate for the excess particulate nitrogen export. (Abell et al., 2000). These results suggest the system is not in steady state.

A simple reservoir model of the upper subtropical ocean between 10° and 45° N illustrates the effects on the AOU of the upper thermocline that would result from an increase in carbon export under conditions of nitrogen and phosphorus limitation. If the export is driven by increased nitrogen fixation (the N limitation case) then there should be an easily-measurable AOU increase. Export production increase driven by circulation change (the P limitation case); however, would cause no change in AOU of the upper thermocline. We compared the AOU from four meridional sections that were taken in the eastern NPSG between 1980 and 1997. The integrated AOU between the winter mixed layer depth and 400 m (σ_θ = 26.4-26.6) from 24º to 44º N increased by about 20 % between 1984 and 1997. We suggest this is the maximum permissible increase in carbon export in response to increased nitrogen fixation over the last decade.

In addition to these studies of the eastern subtropical gyre of the north Pacific, we are presently measuring O_2, Ar and N_2 at the Japanese JGOFS time-series station (KNOT) in the eastern subarctic gyre. Preliminary results will be presented at this meeting. The data indicate that signal of net biological oxygen production is clearly measurable. Because the mixed layer is shallow and the oxygen gradients across the thermocline are strong, an upper ocean mixing model will be required to interpret the data in terms of net biological oxygen fluxes.

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NOPACCS Synthesis

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Northwest Pacific Carbon Cycle Study (NOPACCS) was one of the Japanese national project to survey the carbon related materials in the North Pacific and was conducted from 1990 to 1997. It was funded by the New Energy and Industrial Technology Development Organization (NEDO) under the support of the Ministry of International Trade and Industry (MITI). Survey and research activities were consigned to Kansai Environmental Engineering Center, Co., Ltd. (KEEC) with cooperation of the National Institute for Resources and Environment (NIRE) and Geological Survey of Japan (GSJ), and scientists from universities. For the quantitative evaluation of the carbon cycle in the ocean, meteorological, oceanographical and biogeochemical information was collected from the western North Pacific, mainly from 48°N to 15°S along 175°E, by using R/V Hakurei-Maru. One special volume of Journal of Oceanography was published on 1999 and, presently one CD-ROM is available from Japan Oceanographic Data Center (JODC). Studies of the upper ocean processes were focused on the latitudinal difference of the fugacity of carbon dioxide and detail plankton community structures. Intermediate water was studied with relation to the formation of North Pacific Intermediate Water and the estimation of the amount of accumulated anthropogenic carbon. Sedimentation process, past carbon cycle and coral reef were also studied during the project. Preliminary, overall view of the carbon cycle of the north Pacific was drawn with the results of the project and compared with the global values.

CO_2 budget in the Pacific Having a Large Potential Sink Capacity and Four Processes Absorbing much Anthropogenic CO_2

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The Pacific Deep Water can absorb anthropogenic CO_2 more than the North Atlantic Deep Water nor forming, when all nutrients contained in the waters are transformed into organic matter. This is due to the following three causes. (1) When the Pacific Deep Water forms from the upwelling deep water in winter of the Antarctic Ocean, the gas exchange at the surface causes the gain of O_2 and the loss of CO_2. This induces the fact that increase in its preformed C equivalent to preformed P or N is more than actual increase in preformed C of the Pacific Deep Water. The difference is a capacity of atmospheric CO_2 to be absorbed. (2) The dissolution of $CaCO_3$ increases the CO_2 absorption capacity of the water. The quantity can be calculated from the increase in alkalinity of the Pacific Deep Water. (3) The atmospheric CO_2 level has increased after forming the Pacific Deep Water in the preindustrial era. This increase also makes atmospheric CO_2 more absorbable. We define "Potential Sink Capacity" of water for absorbing anthropogenic CO_2 as a sum of these three components.

At first, we have tried to quantify the "Potential Sink Capacity" (Θ). The capacity is an amount of CO_2 to be absorbed into a water mass when all nutrients contained in the water are transformed to organic matter and equilibrated at *in situ*;

$$\Theta = C_{STA} - (C_{obs} - C_P),$$

where C is the concentration of carbonate, and the subscripts, STA, obs and P refer to the quantities, respectively, equilibrated at *in situ* salinity, temperature and a present atmospheric CO_2 level, observed, and equivalent to its nutrient concentration. The potential sink capacity can be expressed approximately by a linear combination of the following three terms;

$$\Theta = \Theta_{org} + \Theta_{car} + \Theta_{atm} ,$$

where Θ_{org} is the capacity change due to the formation and decomposition of organic matter, Θ_{car} is that due to the formation and dissolution of carbonate test, and Θ_{atm} is that due to the atmospheric CO_2 concentration change.

We can get the following solutions;

$$\Theta_{org} = C_P - C_{ox} = R_{C/P}P_{pre}, \quad \Theta_{car} = \Delta A/2 \quad \text{and} \quad \Theta_{atm} = C_{STA} - C_{ST0} .$$

To minimize systematic errors and deviations from the real ocean conditions, we have obtained the potential sink capacity difference the North Pacific and the North Atlantic $\Delta\Theta_{p\text{-}a}$, which is given by

$$\Delta\Theta_{p\text{-}a} = \Delta\Theta_{org(p\text{-}a)} + \Delta\Theta_{car(p\text{-}a)} + \Delta\Theta_{atm(p\text{-}a)}.$$

We have calculated the above three terms using the GEOSECS and WOCE data sets besides ours and found that the three terms have nearly the same capacities of 30 – 60 μm/kg each and 160 μm/kg as a total, although they depend on the systematic errors and the Redifield ratio. The potential

sink capacity difference means that the Pacific Deep Water flowing northward can absorb anthropogenic CO_2 about 1 GtC/yr more than the surface water of the Atlantic, if it is 15 Sv and equilibrated with the present atmospheric CO_2 at the surface. The upwelling water first expels much CO_2 (mainly oxidative C) , especially in the warm eastern tropical and subtropical Pacific. After losing all the nutrients by photosynthesis and being cooled, the surface water can absorb such an amount of CO_2. This Pacific water's large capacity means reduction of the upwelling water during the El Nino events ultimately induces the decrease in the amount of CO_2 absorbed into the ocean.

Next we show our observed CO_2 system of the Pacific water. We have measured water column distributions of total carbonate, pH, alkalinity, nutrients, C-13 and f(CO_2), especially in the North Pacific and got the following results. (1) The subtropical gyre water contains most abundantly anthropogenic (excess) CO_2. (2) The North Pacific Intermediate Water down to 500-1000 m or more also contains considerable excess CO_2. (3) On the other hand, the warm equatorial surface water is deficient in CO_2. (4) The upwelling water in the northern North Pacific also contains little excess CO_2. (5) The excess CO_2 is accumulated more in the western North Pacific comprising younger and thicker North Pacific Intermediate Water than in the eastern North Pacific. A part of CO_2 absorbed in the Pacific should be carried out of the Pacific by the surface return flow and accumulated in the Atlantic.

Finally we consider the processes recovering the large potential sink capacity, because it takes more than two years as a mean to attain an equilibrium state in the surface water. We point out the following four processes. (1) The Intermediate Waters occupying a layer down to about 1000 m which are formed in the Pacific, containing much CO_2, and reside for a few tens to one hundred years. (2) The continental shelf system making the dense water containing much total dissolved carbonate and pumping it into the subsurface layer of the open ocean. (3) The large bubble induced gas transfer velocities at the surface in the high-latitudes in winter under heavy storms. (4) The ecosystem controlled by abundant silica in the western North Pacific, producing more and particles sinking quickly into the abyss with a larger organic-C/carbonate-C ratio.

Program: Poster Session

Subtropical Pacific, Carbon Dioxide

P-01 Data Management Support Provided by the Carbon Dioxide Information Analysis Center for the U.S. Department of Energy CO_2 Ocean Survey during WOCE/ JGOFS Cruises

A. Kozyr (U of Tennessee) and T. A. Boden (CDIAC)

P-02 A comparison of anthropogenic anomalies of TCO_2 and $\delta^{13}C$ in the upper layer of the subtropical North Pacific Ocean

Y. Takahashi (IHAS, Nagoya U; NIES) , E. Matsumoto (IHAS, Nagoya U) and Y. W. Watanabe (NIRE)

P-03 Variations in CO_2 Outflux from the Central and Western Equatorial Pacific over 1990s

H. Y .Inoue , M. Ishii , H. Matsueda , T. Tokieda , S. Saito (MRI), I. Asanuma, T. Kawano, A. Murata (JAMSTEC), K. Nemoto and T. Midorikawa (JMA)

P-04 Seasonal Variation in the Oceanic CO_2 and Its Controlling Factors in Surface Seawater of the Subtropical Western North Pacific

M. Ishii, H. Y. Inoue, H. Matsueda, S. Saito, K. Fushimi, A. Obata (MRI), T. Midorikawa, K. Nemoto, T. Yano and H. Nagai (JMA)

P-05 Seasonal and Interannual Variability as well as Long-tern Trends in Low Trophic Level Biological Environments in the Northwestern Part of the North Pacific Subtropical Gyre During 1950-1997

A. Limsakul, T. Saino (IHAS, Nagoya U) and T. Midorikawa (JMA)

Subarctic Pacific, Productivity and Flux

P-06 Distribution of Radiocarbon in the Western North Pacific in 1997

Y. Kumamoto, M. C. Honda, A. Murata, M. Kusakabe (JAMSTEC), K. Hayashi , N. Kisen (MWJ), M. Katagiri, K. Nakao (KEEC) and J. Southon (LLNL)

P-07 Fluxes of Silica, Carbonate and Excess CO_2 in the Surface Western Subarctic Pacific

A. Andreev, M. Kusakabe, M. Honda, A. Murata and C. Saito (JAMSTEC)

P-08 Seasonal change of phytoplankton assemblage at a station in the northwestern North Pacicic.

M. Mochizuki, N. Shiga (Fac. Fish., Hokkaido U) and K. Imai (CREST)

P-09 Seasonal variations of primary productivity at Station KNOT (44°N, 155°E) in the North western Pacific Ocean

K. Imai, N. Tsurushima, T. Egashira (CREST), Y. Nojiri (NIES, CREST), T. Saino (IHAS, Nagoya U) and Y. Maita (Fac. Fish., Hokkaido U)

P-10 Seasonal variability in the $\delta^{13}C$ of Particulate Organic Matter (POM) at Station KNOT (44°N, 155°E)

Y. Mino, T. Saino (IHAS, Nagoya U), K. Imai, N. Tsurushima (CREST) and Y. Nojiri (NIES, CREST)

P-11 Ocean Color Variability of Japan JGOFS Time Series Station KNOT and Its Adjacent Waters, Northwestern North Pacific Observed by OCTS and SeaWiFS During 1996-1999

K. Sasaoka, S. Saitoh (Fac. Fish., Hokkaido U), I. Asanuma, M. Honda (JAMSTEC), K. Imai (CREST), Y. Nojiri (NIES, CREST) and T. Saino (IHAS, Nagoya U)

P-12 Biological Pump in the Northwestern North Pacific: Preliminary Results of Sediment Trap Experiment During Dec, 1997 and May, 1999

M. Honda, M. Kusakabe, F. Hoshi (JAMSTEC) and T. Sugawara (MWJ)

P-13 Particulate Organic Carbon Fluxes in the Northwestern North Pacific Derived from Th-234 Profiles

M. Kusakabe, H. Kawakami (JAMSTEC) and Y. Yang (JAMSTEC, Qindao U)

Iron, East-West Difference, Misc.

P-14 Distribution of Trace Metals in the Subarctic North Pacific Ocean and the Bering Sea

Y. Sohrin, Y. Fujishima, K. Ueda (Fac. Tech., Kanazawa U), H. Koyama, H. Hasegawa, and M. Matsui (ICR, Kyoto U)

P-15 Seeking for Phytosiderophores from Marine Algae

M. Suzuki , H. Hasegawa, K. Naito (ICR, Kyoto U), I. Imai (G. School Agr., Kyoto U) and M. Matsui (ICR, Kyoto U)

P-16 Comparison of Iron Enrichment Experiments in the NE and NW subarctic Pacific Ocean

I. Kudo, T. Yoshimura, T. Nishida and Y. Maita (Fac. Fish., Hokkaido U)

P-17 Iron Limitation of Northeast Subarctic Pacific Phytoplankton During Winter

S. Takeda, J. Nishioka (CRIEPI), C. S. Wong and W. K. Johnson (IOS)

P-18 Phytoplankton Community Structure in the Northern North Pacific as Determined by Phytoplankton Pigments

Y. Obayashi, E. Tanoue, K. Suzuki (IHAS, Nagoya U), N. Handa (Aichi Pref. U), Y. Nojiri (NIES) and C.S. Wong (IOS)

P-19 Phytoplankton growth and microzooplankton grazing in the subarctic North Pacific Ocean and Bering Sea during summer 1999

H. Liu, K. Suzuki, and T. Saino (IHAS, Nagoya U)

P-20 Photosynthetic Characteristics of Phytoplankton in the Subarctic Pacific During Summer 1999 as Estimated by Active Fluorescence Technique

K. Suzuki, H. Liu, C. Minami, and T. Saino (IHAS, Nagoya U)

P-21 Geographical Variation of Body Size of Neocalanus cristatus, N. plumchrus and N. flemingeri in the Subarctic Pacific and Its Marginal Seas: Implication of the Origin of Large form N. Flemingeri in Oyashio Area

A. Tsuda, H. Saito, H. Kasai (HNFRI, JFA)

P-22 Detection and Identification of Particulate Proteins in North Pacific Surface Waters.

S. Saijo (IHAS, Nagoya U), T. Sakai, A. Tsugita (RIBS, Sci. U of Tokyo) and E.Tanoue (IHAS, Nagoya U)

P-23 1H - NMR Profiles of Dissolved and Particulate Lipids in Seawater

T. Nishida and E. Tanoue (IHAS, Nagoya U)

P-24 Production and Particulate Export of C37 Alkenones in the Surface Ocean

J. Hamanaka (IHAS, Nagoya U), K. Sawada (U of Tsukuba) and E. Tanoue (IHAS, Nagoya U)

P-25 Alkenone Temperature Variations During the Last Glacial Era Recorded in Sediments from the Northwestern North Pacific

N. Harada, T. Nakatani and M. Kusakabe (JAMSTEC)

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P-26 Responses to Climate Change of Coupled 1-D Mixed Layer / Planktonic Ecosystem Models

K. L. Denman and M. A. Peña (IOS)

P-27 An Ecological-Chemical-Physical Coupled Model Applied to Station KNOT

M. J. Kishi (Fac. Fish., Hokkaido U), Y. Yamanaka, N. Yoshie and M. Fujii (GSEES, Hokkaido U)

P-28 Primary Production Model using Satellite Data

I. Asanuma, K. Matsumoto, T. Kawano (JAMSTEC)

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P-29 The Carbon Budget in the East Sea (Japan Sea)

D. -J. Kang, K. E. Lee, S. K. Jung, J. H. Lee and K.-R. Kim (RIO, Seoul Nat. U)

P-30 An Estimation of the New Production in the Southern East Sea (Japan Sea) Using Helium Isotopes

D. Hahm, M. –K. Park, S. Kim and K. –R. Kim (RIO, Seoul Nat. U)

P-31 Factors Controlling the Dynamics of Dimethyl Sulfide and Dimethylsulfonio-propionate in Northwest Pacific Marginal Seas

N. Jiao, C.Liu (IO, CAS), H. Koshigawa, S. Harada and M. Watanabe (NIES)

P-32 Transport Processes of Foraminifera from the Shelf Edge to the Slope in the East China Sea: Evidence from Sediment Trap Experiment

M. Yamasaki, M. Oda (GSST, Kumamoto U) and Y. Tanaka (GSJ)

P-33 Dissolved and Colloidal Organic Carbon in the East China Sea

W. Zhao (IO, CAS), J. Wang (Ocean U of Qindao), and N. Jiao (IO, CAS)

P-34 Causes and Consequences of Changes in Nutrient Structure in a Typical Coastal Waterbody, with Special Reference to Silica-Limitation of Phytoplankton

N. Jiao, S. Zhao Y. Wang, Z. Shen and Y. Wu (IO, CAS)

P-01 Data Management Support Provided by the Carbon Dioxide Information Analysis Center for the U.S. Department of Energy CO_2 Ocean Survey during WOCE/JGOFS Cruises.

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The Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory provides data management support for the Joint Global Ocean Flux Studies (JGOFS) carbon dioxide (CO_2) measurements taken aboard research vessels during World Ocean Circulation Experiment (WOCE) Hydrographic Program cruises. The U.S. Department of Energy's Global Change Research Program (DOE GCRP) sponsors both the CO_2 measurement operation and CDIAC's data support activities, which include development of a data management plan, data archival, data checking and evaluation, preparation of data documentation, and data dissemination. All CO_2-related data are checked before documentation and distribution. Staff from Lamont-Doherty Earth Observatory (LDEO) assist CDIAC with data evaluations, particularly larger-scale CO_2 data assessments. Through the November 1999, DOE GCRP-supported investigators had collected CO_2 measurements on 42 WOCE cruises. As of today, CDIAC has received data from all of these cruises.

Thirty of these data sets have been checked and 11 fully documented. This presentation will describe CDIAC's data management plan, detail the quality checks performed by CDIAC and LDEO and offer sample results from their use, describe CDIAC's data documentation, and identify the JGOFS CO_2 data currently being processed by and available from CDIAC. The end products of the data management plan are CDIAC numeric data packages or NDPs. Each NDP contains written documentation and machine-readable data. CDIAC makes these NDPs available to anyone without charge in a variety of forms, including floppy diskettes, CD-ROM, eight-millimeter tape and quarter-inch tape cartridges. The data packages are also available from the CDIAC anonymous file transfer protocol (FTP) area via Internet or World Wide Web URL: http://cdiac.esd.ornl.gov/oceans/home.html.

P-02 A comparison of Anthropogenic Anomalies of TCO_2 and $\delta^{13}C$ in the Upper Layer of the Subtropical North Pacific Ocean

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In seawater, decomposition of organic matter, dissolution of $CaCO_3$, and anthropogenic CO_2 penetration would cause the variation of both TCO_2 and $\delta^{13}C$ of TCO_2. We examine horizontal distribution of TCO_2 and $\delta^{13}C$ along isopycnal surfaces of 25.6, 26.0 and 26.4 sigma-theta in the central North Pacific along 175E. The effects from the dissolution of $CaCO_3$ and the mixing of different water masses were both insignificant in the subtropical region between 33N and 19N on these isopycnal surfaces. We corrected the effect of the decomposition of organic matter and then determined preformed values of TCO_2 and $\delta^{13}C$. The preformed values of TCO_2 and $\delta^{13}C$ show significant variations in this region. These variations involve the penetration of anthropogenic CO_2. We compared the variation of preformed value of $\delta^{13}C$ with that of TCO_2 on the isopycnal surfaces. The data showed linear correlation between the preformed values of TCO_2 and $\delta^{13}C$ of TCO_2. Using TCO_2 variation as a time-dependent tracer, we calculated the apparent decreasing rate of $\delta^{13}C$ due to anthropogenic CO_2 penetration. We found that the apparent decreasing ratio of $\delta^{13}C$ is -0.022 ‰/yr.

P-03 Variations in CO_2 Outflux from the Central and Western Equatorial Pacific over 1990s.

H. Y .Inoue[1], M. Ishii[1], H. Matsueda[1], T. Tokieda[1], S. Saito[1], I. Asanuma[2], T. Kawano[2], A. Murata[2], K. Nemoto[3], and T. Midorikawa[3]

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In the central and western equatorial Pacific, temporal and spatial variations in partial pressure of CO_2 in surface seawater (pCO_2w), macro nutrients (NO_2^-+NO_3^-), and SSS are strongly dependent on the east-west advection of western Pacific warm water. Longitudinal distributions of pCO_2w and SSS show steep changes at the eastern boundary of the western equatorial Pacific warm water, which is characterized by low del-pCO_2, low SSS, depleted nutrients, and high SST. East of the boundary del-pCO_2 increases with the increase of SSS, nutrients, and the decrease of SST, mainly due to the equatorial upwelling.
A good relationship between the pCO_2w/SSS boundary and the SOI has been reported (Inoue et al., 1996), which allows us to estimate variations in CO_2 outflux from the central and western equatorial Pacific (Inoue et al., 1999). The CO_2 outflux in the central and western equatorial Pacific (5.5^{o}S-5.5^{o}N, 130°E-160°W) was estimated for cruises conducted over the period from 1987 to 1999. Because of prolonged El Niño events over 1990s, the average annual flux from the central and western equatorial Pacific was estimated to decrease considerably as compared with that of 1980s, that could be linked to decadal changes in climate throughout the Pacific basin (Trenberth and Hoar, 1996).

P-04 Seasonal Variation in the Oceanic CO_2 and Its Controlling Factors in Surface Seawater of the Subtropical Western North Pacific

M. Ishii[1], H. Y. Inoue[1], H. Matsuda[1], S. Saito[1], K. Fushimi[1], A. Obata[1], T. Midorikawa[2], K. Nemoto[2], T. Yano[2] and H. Nagai[2]

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Long-term increase in pCO_2 in surface seawater (+1.8 μatm/year on the average) has been observed in winter since 1984 in the subtropical western North Pacific along 137 ^{o}E. Large seasonal variation in pCO_2 due to seasonal variations in SST and $NTCO_2$ has also been observed in this region. We computed monthly values of surface pCO_2 and TCO_2 for each 1-degree latitudinal zone between 15N and 30N using the empirical relationships between pCO_2 and SST, a constant NTA derived from concurrent measurements of pCO_2 and TCO_2 we made several times in this region, and climatological monthly data sets of SST and salinity. Controlling factors on the seasonal $NTCO_2$ variation including vertical mixing, horizontal advection, air-sea CO_2 exchange and biological activities were then analyzed using the CO_2 flux evaluated from pCO_2, vertical section of TCO_2 along 137°E observed in July 1994, climatological monthly data of the mixed layer thickness, and the surface current velocity obtained by the MRI's OGCM. The result suggests that the decrease in surface $NTCO_2$ from February to August (ca. -30 μmol/kg) is attributable to the biological production and the northward lateral advection, and its increase from August to February is mainly attributable to the vertical mixing.

P-05 Seasonal and Interannual Variability as well as Long-tern Trends in Low Trophic Level Biological Environments in the Northwestern Part of the North Pacific Subtropical Gyre During 1950-1997.

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2) Japan Meteorological Agency

A long-term change, including seasonal and interannual variability, of lower trophic level biological environments in the region between 28°-31°N and 133°-137°E in the subtropical western Pacific was examined. Data set utilized was obtained quarterly by the Japan Meteorological Agency (JMA) from 1950 to 1997.

The results reveal that mixed layer depth (MLD) deepening is prominent in winter due to strong winter monsoon. This causes a transient increase of nutrients in near surface waters and results in increase of phytoplankton abundance. The MLD, the mixed layer nitrate (MLN) and the total chlorophyll-*a* in epipelagic ecosystem (0-200m) show clear interannual variations in winter. This corresponds to year-to-year variability in the strength of the winter monsoon, as well as the ENSO events.

On longer time scales, it is also found that the winter and spring MLDs during 1976-1988 were deeper than average, coinciding with a decade-long intensified Aleutian Low Pressure System in the North Pacific. As a result of the prolonged deepening of the MLD, an increased MLN was also observed in winter. Furthermore, during this decade, a linear and increasing trend in total chl-*a* was evident in spring.

Based on our observations, we believe that large-scale atmospheric fluctuations in different time scales play a significant role to alter physical and chemical oceanographic conditions on those time scales, which in turn may influence the abundance, and perhaps production, of phytoplankton in the study area on the different time scales.

P-06 Distribution of Radiocarbon in the Western North Pacific in 1997

Y. Kumamoto [1], M. C. Honda [1], A. Murata[1], M. Kusakabe[1], K. Hayashi [2], N. Kisen[2] , M. Katagiri[3], K. Nakao[3] , and J. Southon[4]

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In Nov., 1997, vertical distributions of radiocarbon at seven stations in the transition area between the subarctic and subtropical regions in the western North Pacific were clarified by AMS radiocarbon measurement. The distributions of bomb radiocarbon show direct ventilation of upper intermediate water (above 26.6 sigma-theta surface). Comparing our results and GEOSECS radiocarbon in the transition area, temporal radiocarbon increment in the intermediate water, namely in the North Pacific Intermediate Water (NPIW) is not obvious, which is inconsistent with the reported radiocarbon increasing in the eastern North Pacific. These results positively suggest that NPIW is formed in the transition area in the western North Pacific.

P-07 Fluxes of Silica, Carbonate and Excess CO_2 in the Surface Western Subarctic Pacific.

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Japan Marine Science and Technology Center.

Western subarctic Pacific water structure is characterized by main (or permanent) pycnocline, located at 100- 150 meters depth. The vertical profiles of chlorophyll show that the lower boundary of euphotic layer is coincide with location of upper boundary of main pycnocline. The study of distribution of salinity, nutrients and excess CO_2 in the western subarctic Pacific has shown that there is linear relation between concentration of silicate, nitrate, potential alkalinity (total alkalinity, normalized to salinity 35 psu, plus concentration of nitrate), excess CO_2 and salinity in the 100- 200 meters depth interval (33.2 -33.8 psu salinity range). Using these linear relations the vertical fluxes of salinity, nutrients and excess CO_2 through the main pycnocline can be related with each other. We have determined that annually averaged export fluxes of silica and carbonate from euphotic layer are equal to, respectively, 1.7 $mol \cdot m^{-2}$ $(year)^{-1}$ and 0.5 $mol \cdot m^{-2}$ $(year)^{-1}$ and uptake of the excess CO_2 in the study region is equal to 0.8 $mol \cdot m^{-2}$ $(year)^{-1}$

P-08 Seasonal Change of Phytoplankton Assemblage at a Station in the Northwestern North Pacicic

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2) Core Research for Evolutional Science and Technology

Standing stock and species structure of phytoplankton were investigated using monthly water samples collected at Stn. KNOT (Kyodo North Pacific Ocean Time Series; 44°N, 155°E) in the western subarctic Pacific Ocean through June 1998 to June 1999 (except January - April, 1999). The 1-liter water samples were preserved in 1% neutrally buffered formalin. Identification and enumeration of phytoplankton were made with a inverted microscope (magnification: 300 - 600 X).
Nutrients seemed not to be depleting for phytoplakton growth for entire season. Vertical distribution of phytoplankton was primarily restricted to the euphotic depth (*ca*. 50 m) rather than the mixing depth (*ca*. 15-30 m) during early summer to fall. In addition, comparable amount of senescent cells were observed at 200 - 250 m depth in summer. Phytoplankton cell abundance clearly showed a spring maximum (*i.e*. spring phytoplankton bloom) in May. Its seasonal change, however, did not so much coincide with the change of chlorophyll a concentration. Centric diatoms which were composed of *Thalassiosira*, *Chaetoceros* and *Coscinodiscus*, predominated all the year round, with their temporal succession. Pennate diatoms (mostly *Neodenticula seminae* and *Fragilariopsis*) increased only at the spring bloom. Dinoflagellates (mostly *Gymnodinium* and *Prorocentrum*) remained in low abundance, although their dominancy increased in summer when phytoplankton standing stock was low. Silicoflagellate abundance was extremely low.

P-09 Seasonal Variations of Primary Productivity at Station KNOT (44°N, 155°E) in the North Western Pacific Ocean

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1) Core Research for Evolutional Science and Technology,
2) NIES
3) Nagoya University
4) Hokkaido University

The time series observation has been started at Station KNOT (Kyodo North Pacific Ocean Time series) in the north western Pacific since June 1998. Eighteen measurements of primary production were carried out in the two periods, June-December in 1998 and May-October in 1999. ^{13}C uptake was measured after 24 hours of incubation (*in-situ* and/or simulated *in situ*) of seawater with clean sampling techniques. The primary productivity (range; average) for spring (May), summer (June–August), autumn (October–November) and winter (December) were 497-549; av. 518, 158-293; av. 216, 101-164; av. 133 and 83-121; av. 102 mgC m^{-2} d^{-1}, respectively. The seasonally averaged primary productivity was highest in spring and decreased with season. The lower productivity at Station KNOT compared with Station P can be characterized, in part, by shallower depth of euphotic zone, 50 m in average in summer, and also by smaller assimilation ratio, averaging 1-3 μgC μgChl-a^{-1} h^{-1} for summer in the surface mixed layer.
A large phytoplankton bloom was observed not exactly at Station KNOT but in its close vicinity in May 1999. The maximum chlorophyll-*a* concentration in the water column was 13.0 μg l^{-1} and the productivity was 1,667 mgC m^{-2} d^{-1}. The high spatial and variability of primary productivity in the blooming season makes the accurate estimation, by means of conventional shipboard observation, of averaged productivity difficult.

P-10 Seasonal Variability in the $\delta^{13}C$ of Particulate Organic Matter (POM) at Station KNOT (44N, 155E).

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Biological processes, playing important roles in the carbon cycle in open oceans, have the seasonal cycles that depend on the variability in upper-ocean water properties resulted from physical processes.In order to evaluate seasonal characteristics of biological processes using stable isotopic information of particulate materials, we have made year-long (Nov.1998-Oct.1999) observations for carbon isotopic compositions of suspended POM in the euphotic zone and sinking POM just below the euphotic layer (60m) at JGOFS Japan time-series station KNOT in the northwestern North Pacific.

The averaged $\delta^{13}C$ of suspended POM in the upper layer (0-40m) exhibited the changes of about 7‰ during the observation period with lowest value (-27.6‰) found in late-spring and highest value in late-summer (-20.4‰). The $\delta^{13}C$ of sinking POM varied in parallel with that of suspended POM which had lower value. The remarked negative correlation between the $\delta^{13}C$ of POM and the concentration of dissolved carbon dioxide in mixed layer was observed. This indicated that the fractionation of carbon isotope during phytoplankton photosynthesis (ε_p) governed the $\delta^{13}C$ of suspended and sinking POM in upper layer through the variability in CO_2 availability.

In the presentation, we will discuss about the factors controlling ε_p and the seasonal changes in phytoplankton physiological conditions estimated following the approach of Laws et al.(1995).

P-11 Ocean Color Variability of Japan JGOFS Time Series Station KNOT and Its Adjacent Waters, Northwestern North Pacific Observed by OCTS and SeaWiFS During 1996-1999

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The objective of this study is to grasp the temporal and spatial variability of chlorophyll a (chl-*a*) distribution and primary productivity at the Japan JGOFS time series station KNOT (44°N, 155°E) and its adjacent waters in the Subarctic north-western North Pacific using ocean color images of OCTS, SeaWiFS and ship observation data during 1996-1999. We attempt to calculate primary productivity by VGPM Model (Behrenfeld and Falkowski, 1997) using ocean color and SST satellite data sets.

Relatively low chl-*a* concentration (about 0.3 - 0.8mg/m^3) dominated throughout the year at the Stn. KNOT, but remarkable peak was seen in bloom period (in May and October), winter (in November and December) and summer (in August 1998). In adjacent sea area, most remarkable high chl-a (more than 10mg/ m^3) was seen northward to Stn.KNOT along the Kuril-Islands and adjacent waters in May 1999, moreover high concentration remain over a month during the bloom season. Year-to-year variability of chl-*a* was seen. Chl-*a* concentration at Stn.KNOT in May 1999 was higher than that in May 1998. Chl-*a* around the center of Western Subarctic Gyre (50°N,165°E) in October 1998 was higher than that in October 1997. Primary productivity derived by VGPM Model tends to be larger than that measured by *in-situ* ^{13}C method, but there is some similarity between these temporal change patterns.

P-12 Biological Pump in the Northwestern North Pacific: Preliminary Results of Sediment Trap Experiment During Dec, 1997 and May, 1999

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In order to study the role of biological pump in the uptake of atmospheric CO_2 in the northwestern North Pacific, we have conducted time-series sediment trap experiment at three stations (KNOT, 50°N, 40°N). Total Mass Flux increased in the late spring to summer at Stns. KNOT and 50°N, and in the early spring at Stn. 40°N. Collected materials consisted of, mainly, biogenic materials (organic matter, $CaCO_3$, and opal), and opal was major component, annual average of which was ~ 50 % for Stns. KNOT and 50°N. The ratio of organic carbon flux to inorganic carbon flux (Co/Ci ratio) increased in summer at Stns. KNOT and 50°N and in autumn at Stn. 40°N(Fig.4). Opal flux at Stns. KNOT and 50°N increased drastically from the late spring to summer, and seasonal variability in opal flux was larger than that in $CaCO_3$. Opal/$CaCO_3$ ratio correlated well with Co/Ci ratio. It implies that the increase of Co/Ci ratio was attributed to the increase of plankton with opal test such as diatom during the period with high Co/Ci ratio. Average values of carbon flux, Co/Ci ratio and opal/$CaCO_3$ ratio at Stn. KNOT were the highest among three stations , which is indicative of that the biological pump at Stn. KNOT works most efficiently for the uptake of atmospheric CO_2 in this region. Judging from the relatively high flux of Al at Stn. KNOT, the input of terrestrial materials (nutrients or micro nutrient such as Fe) might be associated with the high biological activity.

P-13 Particulate Organic Carbon Fluxes in the Northwestern North Pacific Derived from Th-234 Profiles

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Concentrations of dissolved and particulate Th-234 in surface water (<300 m) were measured in the northwestern North Pacific during the cruises of MR97-02 (Nov. - Dec., 1997), MR98-K01 (Nov.-Dec.,1998), and MR99-K02 (May-Jun.,1999). In addition, concentrations of organic carbon in particulate matter were also measured. Th-234 deficiencies with respect to its parent nuclide, U-238, were found in all profiles measured, that enabled us to estimate the removal rates of Th-234 from the surface water. Based on the Th-234 removal from the surface water and organic carbon concentration in particulate matter, fluxes of particulate organic carbon (POC) were estimated. In the area studied (40°-50^oN, 155°-170^oE) during the MR97-02 cruise, POC fluxes in the surface water decreased gradually northwards from 350 mg C/m^2/day to 160 mg C/m^2/day. POC fluxes obtained during the MR98-K01 cruise (35°-40^oN, 145°-160^oE) showed a similar trend; the flux changed from 40 to 330 mg C/m^2/day. During the MR99-K0 cruise, a spring bloom was observed, in which POC fluxes were calculated to be 490 mg C/m^2/day. In addition, excess Th-234 appeared at subsurface layer (60-150m) in the bloom patch. Dynamics of particulate matters in the surface water will be discussed.

P-14 Distribution of Trace Metals in the Subarctic North Pacific Ocean and the Bering Sea

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A column concentration-high resolution ICP-MS determination was applied to determining the dissolved concentrations of Fe, Co, Ni, Cu, and Zn in seawater collected from the subarctic North Pacific (~45^oN) and the Bering Sea in July-September, 1997. The vertical profiles for Fe, Ni, and Zn were nutrient-like. The deep water concentration of Fe was ~0.5 nM in the northeast Pacific (180°-140^oW) and increased to ~1 nM in the northwest Pacific (161^oE) and ~2 nM in the Bering Sea (57^oN, 180^oE). The deep water concentration for Ni and Zn in the Bering Sea was also 1.3-2 times higher than that in the subarctic North Pacific. The profiles for Co and Cu in the subarctic North Pacific were consistent with previous reports.
Fe and Zn were depleted in surface water of the subarctic North Pacific. The relationship between these trace elements and nutrients suggests that these elements may be a limiting factor of primary production. In the Bering Sea, surface water contained ~0.3 nM of Fe. The Zn concentration, which was less than the detection limit in surface water, increased at shallower depth compared with that in the subarctic North Pacific. These results suggest that high flux of Fe and Zn to surface water in the Bering Sea. This in turn may cause the Bering ecosystem characterized by dominance of diatoms and high regenerated production.

P-15 Seeking for Phytosiderophores from Marine Algae

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The availability of iron to marine algae has received considerable attention since iron may regulate productivity in many regions of the world ocean. Under iron-limited conditions, many microorganisms have a specific strategy that they release high affinity and low molecular weight ligands called siderophores. Siderophores solubilize Fe(III) extracellularly and facilitate its transport into the cell. Although a large number of siderophores for bacteria and fungi have been characterized, direct confirmation of siderophore production by marine algae is limited.
In this study, we examined several species of marine algae for siderophore production in batch culture. Four of marine algae (*Rhodomonas ovalis*, *Heterosigma akashiwo*, *Chattonella antiqua* and *Oltmannsiellopsis viridis*) produced CAS-positive compounds which are detectable by CAS assay for the detection of siderophores when grown under iron-deficient conditions. The algal growth was followed by decreases in iron concentration during the exponential phase. CAS-positive compounds began to increase at the initial term of the exponential phase, and showed maximum concentrations at the end of the exponential phase. In the *R. ovalis* culture, CAS-positive compounds remained steady during the stationary phase. These results may suggest that some marinealgae can produce phytosiderophores in analogy with other microorganisms.

P-16 Comparison of Iron Enrichment Experiments in the NE and NW Subarctic Pacific Ocean.

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It is recognized that Fe plays a key role in controlling phytoplankton growth and primary productivity in the ocean, especially in HNLC (high nutrient, low chlorophyll) regions. Subarctic Pacific ocean is one of them. We conducted three iron enrichment experiments on board in the summer of 1999 at St. Knot (NW) and St. P (NE) in the Pacific and one station in the Bering Sea. The original surface seawaters (5m) were at HNLC condition with different nutrient compositions. We added Fe at two concentrations into each bottles and some of them were also enriched with Zn. Size fractionated chl *a*, nutrients, dissolved Fe were measured at 2 days interval. The measurement of NRA (nitrate reductase activity) and APA (alkaline phosphatase activity) and the flowcytometric analysis for phytoplankon and bacteria were also conducted for several occasions. The results indicated that productivity at three stations seemed to be Fe-limited, but the response to the enrichment was not the same.

P-17 Iron Limitation of Northeast Subarctic Pacific Phytoplankton During Winter

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In the subarctic North Pacific, iron deficiency has been proposed to be one of the limiting factors for the growth of phytoplankton such as large diatoms, while irradiance and temperature may place strong controls on phytoplankton productivity during winter. To test the iron hypothesis in winter, surface seawater with resident phytoplankton assemblage was incubated in the bottles with and without added iron at Ocean Station P in February 1998. Concentration of total dissolvable iron in the surface water was very low (0.07 nM). Addition of 1 nM iron, however, did not show significant increases in Chl-*a* concentration compared to the controls. On the other hand, Chl-*a* production was up 1.5 fold by increasing irradiance. Increase in both irradiance and temperature also resulted in a 2.3 fold increase in Chl-*a* concentration, and the increase was mainly observed in <5 micron size fraction. Iron-enriched bottles subjected to high-temperature and high-irradiance showed the greatest effects (15.5 fold) on Chl-*a* biomass both in <5 micron and >5 micron size fractions. Although irradiance, temperature and iron appear to be co-limiting, the availability of irradiance may be considered as a primary controlling factor for the phytoplankton productivity during winter.

P-18 Phytoplankton Community Structure in the Northern North Pacific as Determined by Phytoplankton Pigments

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Intensive observations of phytoplankton community structures using phytoplankton pigments (chlorophylls and carotenoids) during 11 trans-Pacific cruises from April 1995 to June 1996 revealed the following spatial and temporal variabilities in the phytoplankton community structures of the eastern and western subarctic Pacific and the southern Bering Sea.

1) In the Alaskan Gyre, there were few seasonal or spatial variabilities in the total chlorophyll-*a* biomass, while in the Bering Sea and the sea off the Kuril Islands, drastic seasonal changes in chlorophyll a biomass were noticed.
2) Such drastic changes are mainly due to the elevation of the fucoxanthin-containing diatom population.
3) Chlorophyll *b*-containing green algae were one of the important algal groups throughout the year in the northern North Pacific as were fucoxanthin-containing diatoms and 19'-hexanoyloxyfucoxanthin-containing prymnesiophytes.
4) The results give new insights into the phytoplankton community structure of the subarctic North Pacific, namely, an ubiquitous basic structure made up of rather diverse algal groups, and a flourishing diatom population limited by area and season and superimposed on the basic structure. These two structures are thought to play their respective roles in the biogeochemical cycle in the surface of the northern North Pacific.

P-19 Phytoplankton Growth and Microzooplankton Grazing in the Subarctic North Pacific Ocean and Bering Sea during Summer 1999

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In order to assess the phytoplankton growth rate and microzooplankton grazing rate in the subarctic North Pacific Ocean, dilution experiments were conducted at 15 stations along a western-eastern transect during summer 1999. Average growth rates without added nutrients (μ_0) were 0.36, 0.41, 0.25 and 0.49 d^{-1} for the 4 regions that represents stations in the Western Gyre, the Bering Sea, the Gulf of Alaska gyre and stations along the Aleutian Trench. Average grazing mortality (m) were 0.34, 0.27, 0.20 and 0.49 d^{-1} for above regions, respectively. Limitation of phytoplankton growth by macro-nutrients, such as NO_3^- and SiO_2, was only spotted at fewer stations, with μ_0/μ_n (μ_n is nutrient-enhanced growth rates) averaged 0.9. Phytoplankton growth and microzooplankton grazing were balanced, as indicated by high m/μ_0 ratio, except in the Bering Sea where m/μ_0 ratio was 0.66, indicating the relative importance of the diatom-macrozooplankton grazing food chain and possible higher export flux in this region. Flow cytometric samples from the dilution experiments are currently being analyzed, and taxon specific growth and grazing rates will be discussed.

P-20 Photosynthetic Characteristics of Phytoplankton in the Subarctic Pacific During Summer 1999 as Estimated by Active Fluorescence Technique

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To estimate the difference in photosynthetic characteristics of phytoplankton between the eastern and western subarctic Pacific, we measured variable fluorescence using a fast repetition rate fluorometer during a R/V Hakuho-Maru cruise from Tokyo to Seattle (June 25-July 21, 1999). Water samples for the fluorescence measurements were collected continuously from a depth of about 7m, and usually analyzed every 15-30 minutes. A few minutes dark adaptation period was used to ensure complete opening of reaction centers in photosystem II before the measurements. Midday decreases in the photochemical quantum efficiencies (Fv/Fm) and functional absorption cross sections of photosystem II (sigma-PSII) were often appeared, which were probably caused by photoinhibition. Large nocturnal decreases in Fv/Fm and sigma-PSII appeared in the South Pacific (Behrenfeld and Kolber, 1999, Science, 283, 840-843) were not observed in the subarctic Pacific. When we compared station KNOT (44°N, 155°E) in the eastern subarctic Pacific and station P (50°N, 145°W) in the western, daily maximum and minimum values of Fv/Fm at the station KNOT were 1.25 times and twice as high as those at the station P, respectively. The mean values of sigma-PSII in the daytime at the stations KNOT and P were almost the same. These results suggest that physiological condition of phytoplankton for photosynthesis at the station KNOT was better than that at the station P. We will discuss the changes in photosynthetic parameters with phytoplankton (pigment) composition, and physical and chemical parameters such as light and nutrients.

P-21 Geographical Variation of Body Size of *Neocalanus cristatus*, *N. plumchrus* and *N. flemingeri* in the Subarctic Pacific and Its Marginal Seas: Implication of the Origin of Large form *N. Flemingeri* in Oyashio Area.

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Size distributions of *Neocalanus cristatus*, *N. flemingeri* and *N. plumchrus* were investigated in the eastern and the western subarctic gyres and three marginal seas during the diapause period to examine the geographical variation in body size of *Neocalanus* species and to clarify the origin of the large biennial *N. flemingeri*. There were significant local variations in the body sizes for three species of *Neocalanus.* Generally, the body sizes of the copepods were larger in the marginal seas and marginal areas of the open ocean. In the open ocean, the body sizes increased westward. These patterns of variation in the body sizes were roughly agreed with local variation of food availability. Distribution of biennial *N. flemingeri* was restricted to the Japan Sea, the Okhotsk Sea and the Oyashio region. Large-sized biennial *N. flemingeri* was abundantly observed in the Okhotsk Sea, and medium-sized biennial one was observed in Japan Sea. These facts strongly suggest that the large biennial *N. flemingeri* in the Oyashio region is advected from the Okhotsk Sea.

P-22 Detection and Identification of Particulate Proteins in North Pacific Surface Waters

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Particulate combined amino acids (PCAA) are the largest identified fraction of particulate organic matter and they were considered to be proteinaceous materials in the sea. It has been demonstrated that some of PCAA in surface waters are derived from a complex mixture of proteins. We applied the two-dimensional polyacrylamide gel electrophoresis (2D-PAGE) for separation of such proteins. Proteins are separated according to isoelectric points in the first dimension, and then separated according to molecular weight in the second dimension. By using 2D-PAGE, we detected 14 spots of particulate proteins from subarctic Pacific (45°N, 165°E) and 17 spots from subtropical Pacific (25°N, 165°E). The detected spots of particulate proteins were subjected to the N-terminal amino acid sequence analysis and one of such proteins was successfully analyzed the 9 residues from N-terminus. The homology search revealed that the amino acid sequence of this protein was similar to a protein in cyanobacteria as well as a protein in chloroplast of higher plants.

P-23 1H - NMR Profiles of Dissolved and Particulate Lipidsin Seawater

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Lipid is one of the major components in dissolved and particulate organic materials in seawater. Chemical nature of marine lipids (*e.g.* fatty acids, hydrocarbons *etc.*) have been investigated, however chemical characteristics of lipid class are not well known. We applied 1- and 2-dimensional high-resolution NMR spectroscopic analyses to qualify the chemical characteristics of marine lipids. Based on the chemical shifts of 1-dimensional NMR analyses, major constituents of dissolved and particulate lipids were similar to each other being comprised phosphatidylcholine, diacylglycerol and carbohydrate groups. However, relative intensity of signals assigned to double bond (-CH=CH-) of fatty acids were quite different, high in particulate lipids and low in dissolved lipids. The spectrum of 2-dimensional NMR analyses indicated the most of signals assigned to the glyceryl moiety in 1-dimensional NMR spectra were allowed the spin connectivities for phosphatidylcholine and/or carbohydrate groups. Based on 1- and 2-dimensional NMR spectra, carbohydrate-linked lipids and phosphatidylglycerolipids were predominant and these lipids comprise approximately 30% of total dissolved and particulate lipids, respectively.

P-24 Production and Particulate Export of C37 Alkenones in the Surface Ocean

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The long-chain unsaturated ketones (alkenone) are molecular indicators of some Haptophycean algae (family *Gephyrocapsaceae* and *Isochrysidaceae*). A knowledge of dynamics of alkenones in the water column are essential for application of alkenones to the paleoenvironmental proxies as well as the fingerprint of such algae to biogeochemical carbon cycles. However, there have been very few studies for understanding the productivity, chemical stability and a relationship between production and export flux of alkenones in oceanic environments.

To elucidate dynamics of alkenones in the surface ocean, the production rate and the sinking flux of alkenones were evaluated using combination of two methods, namely, the ^{13}C tracer and gas chromatography-mass spectrometry (^{13}C-GC-MS) method and surface sediment traps. From the comparison with alkenone-specific productivity, sinking flux and standing stock, we discuss production and vertical transport of alkenones at coastal and oceanic waters in the North Pacific.

P-25 Alkenone Temperature Variations during the Last Glacial Era Recorded in Sediments from the Northwestern North Pacific

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The aim of this study is to understand the past environmental changes such as sea surface temperature (SST) and biogeochemical cycle in the northwestern North Pacific. A piston core was collected at St. 8s (45°N, 170°E: water depth 1,780m) situated on the Suiko seamount beneath the arctic front during the R/V MIRAI MR97-02 cruise. The sediment mainly consisted of light gray diatom, and foraminifera bearing calcareous nanno ooze. Age of the core was estimated to be about 110,000 yr. SST was estimated by using long-chain alkenones. SST changed from the minimum of 3°C at the last glacial maximum (LGM, *ca*. 20,000 yrBP) to the maximum of 18°C during the period of 80,000-110,000yrBP. The temporal change of SST implies that the arctic front drastically shifted northward during lower SST and southward during higher SST as compared with the modern SST. While accumulation rate of the organic carbon varied ranging from 5 to 50 mg/cm^2/kyr, that of the inorganic carbon varied from 10 to 400 mg/cm^2/kyr. However, the accumulation rate of the organic carbon did not change in accordance with the inorganic carbon through the past 110,000yr, except for the LGM when both fluxes were high.

P-26 Responses to Climate Change of Coupled 1-D Mixed Layer / Planktonic Ecosystem Models

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How marine planktonic ecosystems might respond to a changing climate is important to the carbon cycle because marine plankton affect the transformations and transport of carbon between the surface ocean and the ocean interior, thereby influencing atmospheric CO_2 concentrations. We have conducted simulations of two possible changes associated with the climate: increasing ocean temperatures by 2°C, and changing the supply of iron to phytoplankton in the subarctic Pacific. The simulations have been performed with a series of 1-dimensional mixed layer / planktonic ecosystem models of increasing complexity. Development of the models and results of the simulations will be presented.

P-27 An Ecological-Chemical-Physical Coupled Model Applied to Station KNOT

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A vertical one-dimensional ecosystem-chemical-physical coupled model was constructed and applied to Station KNOT (Kyodo North Pacific Time series). The model has two categories of phytoplankton, zooplankton , DOM and POM together with nitrate, phosphate, silicate and also includes carbon cycles. The model was coupled with mixed layer model for calculating diffusion coefficient. The mixed layer model was driven by SST, SSS data observed by KNOT time series which was interpolated using climatological data. The seasonal cycles of phytoplankton and zooplankton showed good agreements with observations and also incoming and outgoing of carbon dioxide was calculated which followed the tendency of observed values.

P-28 Primary Production Model using Satellite Data

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A vertically resolved primary production model was proposed for a satellite remote sensing using a ocean color sensor and an infrared thermal sensor. A vertical distribution of photosynthetically available radiation (EdPAR) in percentage to the surface (EdPAR%) is given by an empirical equation as a function of chlorophyll-*a* concentration in the surface (Chl(0)). A vertical distribution of chlorophyll-*a* concentration is given by an empirical equation as a function of Chl(0), EdPAR%. A primary production is given by an empirical equation as a function of sea surface temperature (SST), and EdPAR at the surface. These empirical equations were developed from the *in-situ* observation along the Equator from the warm water pool to the equatorial upwelling and the past data observed over the world. By substituting the Chl(0) by an ocean color measurement, EdPAR by a model simulation using MODTRAN4.3 and a cloud distribution estimated from MCSST, a primary production of the water was computed by integrating a primary production along the water column. The primary production computed from SeaWiFS data showed a temporal change related to a climate change.

P-29 The Carbon Budget in the East Sea (Japan Sea)

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The East Sea (Japan Sea) is one of the ideal natural laboratories for studying the oceanic pumping mechanisms of CO_2 such as solubility, biological, alkalinity, and dynamic pumps. It's based on recent observations that the East Sea shows many open ocean characteristics including her own conveyer system and that her ventilation system has been changing for the last 30-40 years, which may resemble the mode of change expected in the global oceans associated with global warming. Studies on carbon cycle in the East Sea were carried out during CREAMS expeditions. Necessary CO_2 parameters (pCO_2 in surface waters and marine air, alkalinity, pH, chlorophyll) have been measured along with the general oceanographical parameters. Using a simple gas-exchange model at the air-sea interface and a moving-boundary box model for the East Sea in change, a first-order carbon budget in the East Sea was developed.

The East Sea absorbs 0.036 Gt-C from the atmosphere annually by solubility pump. About 17% and 83% of this input contribute the increase of total CO_2 in the surface and deep waters, respectively. A time-dependent carbon budget model is being developed and will be further discussed at the meeting.

P-30 An Estimation of the New Production in the Southern East Sea (Japan Sea) Using Helium Isotopes

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Biological pump is one of the important pumping mechanisms absorbing CO_2 from the atmosphere into the ocean and can be quantified by estimating new production. To investigate the new production in the southern East Sea, helium isotopes were measured by mass spectrometry from seawater samples recovered from the Ulleung Basin during 4 expeditions in 1999. Through the year excess ^3He occurs in the mixed layer except slight depletion in summer.

The seasonal variation of gas-exchange rates was obtained using the relationship between wind speed and piston velocity. The ^3He flux of 13 ‰·md^{-1} associated with the concentration gradient at the air-sea interface was calculated from the product of the piston velocity and the excess ^3He. Tritium decay within the mixed layer could support only 2 ‰·md^{-1} of the flux. Thus, the rest 11 ‰·md^{-1} could be attributed to the flux of tritiugenic ^3He from the water below the mixed layer.

NO_3^- and ^3He were positively correlated within the thermocline layer with the slope of 0.21 μmol kg^{-1} $‰^{-1}$. The annual nitrate flux estimated from the upward flux of ^3He and NO_3^--^3He relation was 0.8+-0.2 mol(N)$m^{-2}yr^{-1}$. This flux corresponds to an annual new production of 64g(C)$m^{-2}yr^{-1}$, which is consistent with that of Atlantic subtropical ocean.

P-31 Factors Controlling the Dynamics of Dimethyl Sulfide and Dimethylsulfoniopropionate in Northwest Pacific Marginal Seas

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Dimethyl sulfide (DMS) and dimethylsulfonium propionate (DMSP) in Northwest Pacific marginal seas-the East China Sea, Jiaozhou Bay and Zhifu Bay- was investigated during 1994 to1998. DMS levels in the coastal waters ranged from 0.27 to 52.25 nM with highest values occurring in aquaculture areas. DMS production was obviously associated with biological activity. Unlike situation in oceanic waters, diatoms may play a central role in total DMS or DMSP production in coastal waters, especially in bloom periods. Nitrate was found to have a two-phased relationship with DMSP or DMS concentrations. The relationship was positive when nitrate concentrations were lower than 1 μM, and negative when nitrate was more abundant. The former case suggests that low nutrient availability limited the growth of the phytoplankton and thereby the production of DMSP. The latter case was considered to be due to the inhibition of nitrogen as a source of glycine betaine, a competitor of DMSP as an osmoregulating substance in the cells. Furthermore, significant correlation was found between nitrogen concentration and the ratio DMSP:Chl.*a* in different marine environments. The DMSP:Chl.*a* values in oligotrophic waters were higher than in eutrophic waters.

P-32 Transport Processes of Foraminifera from the Shelf Edge to the Slope in the East China Sea: Evidence from Sediment Trap Experiment.

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Under the MASFLEX project, we studied 11 sediment trap samples at three stations from the continental shelf edge to the slope in the East Chine Sea. The sediment trap experiments revealed that a large number of foraminifers in the bottom sediments were resuspended. The benthic foraminiferal fluxes were observed at 10m above the sea floor in all three stations. In these three traps, a number of planktic foraminifers with primary apertures or sutures being filled with mud and adherent particles were also recognized. The benthic foraminiferal fluxes in the upper continental slope station (water depth 301m) were low, in contrast with the continental shelf edge (132m) and the lower slope (604m) stations. Besides, the benthic foraminiferal assemblages were very different between the continental shelf edge and the slope station. These facts suggest that the sources of the resuspended foraminifers are different. By utilizing time series sediment traps at the continental slope, a great number of foraminiferal fluxes were observed at the first two days during the experiment (about 8 days). The fluxes were characterized by benthic foraminifers and planktic foraminifers with poorly preserved tests. These results suggest that the resuspension of benthic and planktic foraminifers occurred during a short period.

P-33 Dissolved and Colloidal Organic Carbon in the East China Sea

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Cross-flow ultrafiltration techniques was employed to extract colloidal organic carbon (COC) from seawater and high-temperature catalytic oxidation (HTCO) method was used for DOC and COC measurements in the East China Sea, July 1998. The DOC concentration varied from 165μmol/L in the surface water near Changjiang estuary to 39μmol/L at 1000m depth in the slope of the southern region. There was significant negative correlation between DOC and salinity in the mixing area of the northern shelf region of the sea. DOC distribution in this area seemed to be controlled by water mixing. Re-suspension of sediment caused increase of DOC concentration at the bottom layer around the cold eddy area in the northern region of the Sea. Concentration of COC (1000Dalton-0.7μm) ranged from 11 to 38μmol/L, comprising about 23% of the initial DOC. Averaged over the whole study area, the mass concentration of colloid was 0.7 mg/L. In vertical distribution, COC and COC/DOC decreased with increasing depth in the water column except for the cold eddy area where resuspension caused COC and COC/DOC increase.

P-34 Causes and Consequences of Changes in Nutrient Structure in a Typical Coastal Waterbody, with Special Reference to Silica-Limitation of Phytoplankton

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Long-term variation of nitrate and ammonium (N), phosphate (P), and silicate (Si) concentrations and their ratios in a typical coastal water, the Jiaozhou Bay, China, was followed for 3 decades. The N/P ratio increased but Si/N and Si/P ratios decreased substantially during this period. Seawater nitrate concentration was basically controlled by agriculture fertilization, precipitation, population and city drainage. Ammonia level was less related to rainfall but more to anthropogenic factors such as shipping activities, population and city drainage. Less of the variation in phosphate was explainable, but it was associated with shipping capacity, gross agricultural production, population and chemical fertilization. Si was correlated with precipitation and farming area. Stoichiometric calculations and *in situ* experiments both indicated that N was no longer a limiting factor since the 1980s. The probability of P limitation increased and could have occurred occasionally in autumn and summer; The probability of Si-limitation increased dramatically from the 1980s to the 1990s.

Phytoplankton species composition in the bay has changed remarkably as a consequence of the changes in nutrient structure. Abundance of large diatoms has been firmly decreasing and smaller species' increasing. Changes in phytoplankton size and species composition as a result of Si depletion may ultimately lead to various functional and structural changes at the system level.

P-35 Seasonal Changes in Settling Fluxes of Biogenic Materials in the Shikoku Basin, Western North Pacific.

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There has been few long-term observation of settling particle fluxes in the subtropical area of the western North Pacific with low productivity. Sediment traps were deployed at 500 m and 4000 m depths at a station in the Shikoku Basin, western Pacific (29° 30'N, 135° 15'E, 4500m WD) from February till April 1999 and from April till December 1999. Oceanographic observations were conducted at the station in April 1999 (SE99-01 Cruise of T/V Seisui Maru) and in December (KT99-17 Cruise of R/V Tansei Maru). Temperature, depth, current speed and direction, and salinity were monitored at 20 m above the upper trap. Its preliminary results will be reported. The observation will be continued at least for more three years.