PICES17thA
(25minutes,OCT.27)
Oct.23-Nov.2, 2008
Dalian PR China

Marine Ecosystem Studies of Today and Tomorrow with emphasis on the western North Pacific Ocean.

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Frontier Research Center for Global Change
Japan Agency for Marine-Earth Science and Technology

At present, the tentative goal of global environmental studies is to provide clear-cut scientific scenarios to solve various kinds of environmental problems within the next 50 to 100 years under the reliable data base and simulation studies. Integrative studies involving observation, modeling and simulation may be connected to social management systems of the Plan-Do-Check-Action.

PART 1 . What kinds of ecosystem models are we developing?

PART 2. Ⅰ .What is Stable Isotope techniques ?
Distributions of δ15N-δ13C in marine ecosystems

ii. Application of SI techniques in future studies.

- Biome or Vegetation types or ISOSCAPE (Isotope Landscape)
  - L. Baikal & W. N. Pacific : Fish Scaleδ exhibits Synchronous Oscillation
- AMINO ACID Trophic Level → MEMURO.FISH + ECOSIM
  - Boreal area.→ Growth rate (μ) could be estimated from δ13C(phyto-)

Our Ecosystem Change Program,FRCGC has been developing several kinds of global ecosystem simulation models as indicated in this slide.

Terrestrial Ecosystem (30 Vegetation Types)

Sim-CYCLE for global carbon dynamics,

Sim-CYCLE-MATSIRO-AGCM

Spatially Explicit Individual Based -Dynamic Global Vegetation Model

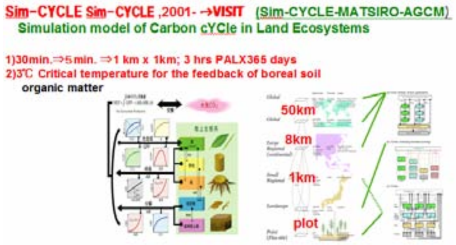
Marine Ecosystem (No Biome)

NEMURO model for a plankton dynamics

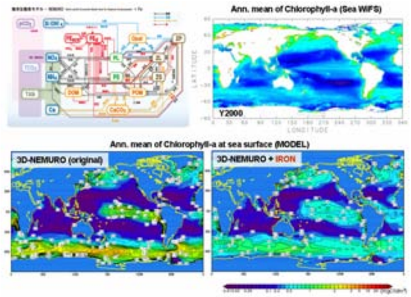
NEMURO.FISH mode l

Oceanic GCM for carbon dynamics(OFES)

Remote sensing for PAR, NDVI, 3D-forest model and pCO2 to refine above models in two systems.



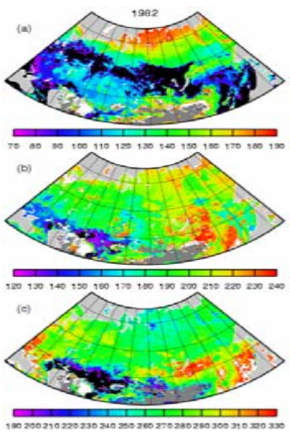
SEIB-DGVM



What is our Research Purposes ?

The major, mid-term goal of the Ecosystem Change Research Program (ECRP) is to develop the biosphere sub-model for the integrated model of global change.

In this context, our efforts have been focused on modeling of biogeochemical carbon cycles in both terrestrial and oceanic ecosystems.



Interannual change of daily

NDVIdata.

(a) Greenup date (NDVI exceeds 0.2)

(b) Mature date (annual maximum NDVI)

(c) Senescence date (NDVI drops below 0.2)

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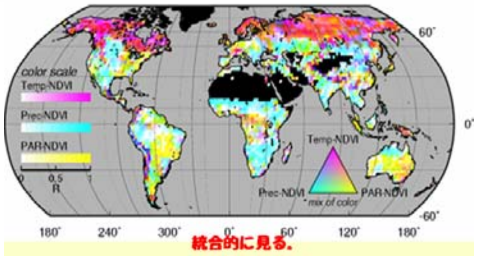


PAR, Temp. Precip.

PART 2. Nitrogen and carbon isotope ratios in the biosphere

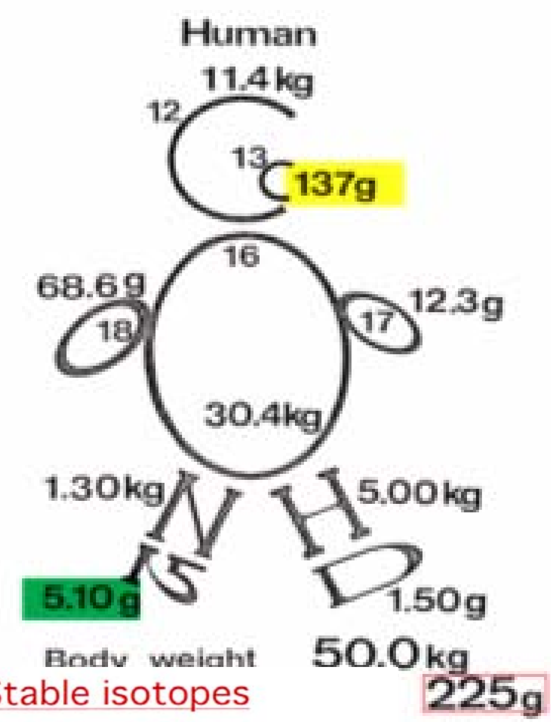
– From molecule to ecosystem

1)Whai is the SI method ?

2)Distribution in plant kingdom.

3)Isotopic map and human food web analysis.

4)Possible application for assessing the ecosystem models



Stable isotopes of light elements

		atom. %	weight%
Hydrogen H	$^{1}_{1}H$	99.9851	99.97023
	$^{2}_{1}D$	0.0149	0.02977
Carbon C	$^{12}_{6}C$	98.89	98.79825
	$^{13}_{6}C$	1.11	1.20175
Nitrogen N	$^{14}_{7}N$	99.635	99.60915
	$^{15}_{7}N$	0.365	0.39085
Oxygen O	$^{16}_{8}O$	99.763	99.736
	$^{17}_{8}O$	0.0372	0.03953
	$^{18}_{8}O$	0.1995	0.2245

Definition of parameters

$$\delta‰ = \left[\frac{R_{sample}}{R_{standard}} - 1\right] \times 1000$$

R : $^{15}N/^{14}N$ or $^{13}C/^{12}C$

standard : $N_{2\ air}$ or PDB

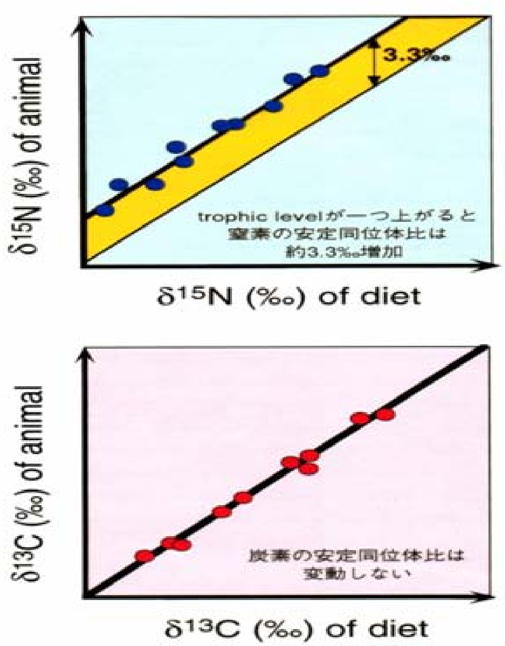
Empirical low of SI distribution

1） Plant $\delta^{13}C$ is determined by the dynamics of CO2 fixation during photosynthesis. C3 &C4 pant exhibit different 13C content.

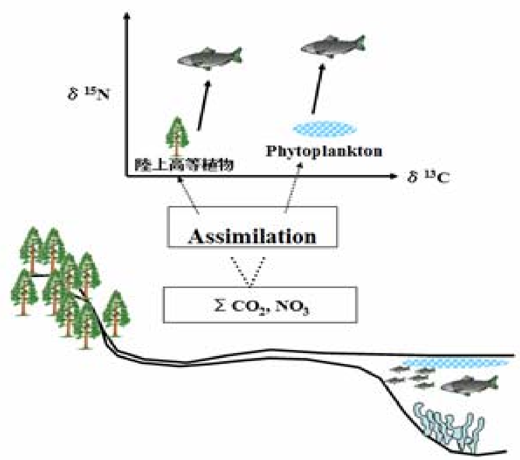
2） Food chain
$\delta^{15}N(\text{animal}) = 3.3\,(TL - 1) + \delta^{15}N(\text{plant})$
TL: Trophic level

3） Increase in ^{15}N in an ecosystem is caused by evapolation of NH_3 and denitrification ($NO3 \rightarrow N_2$).

Trophic effect during a feeding process

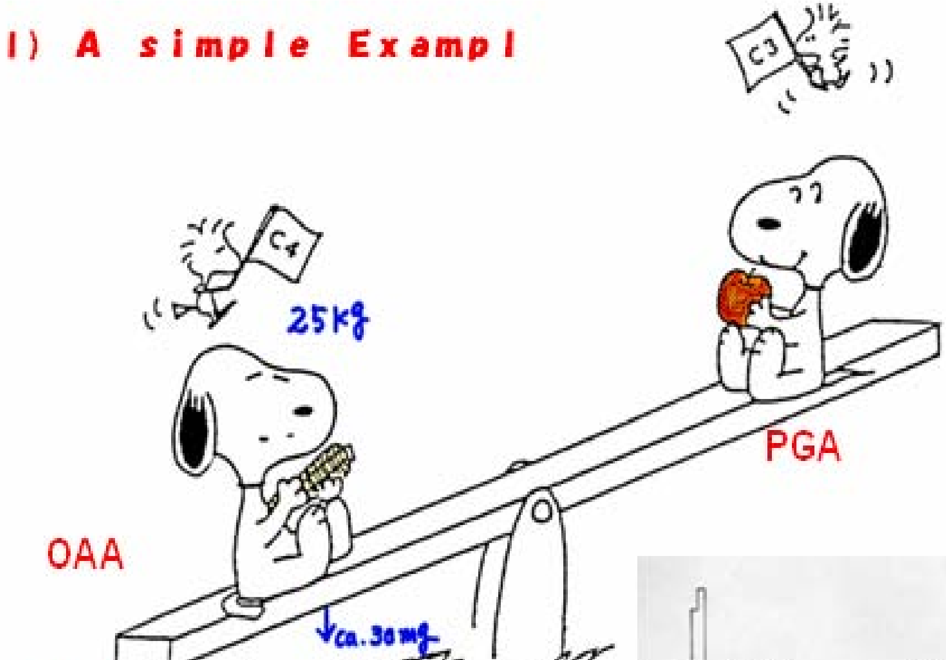


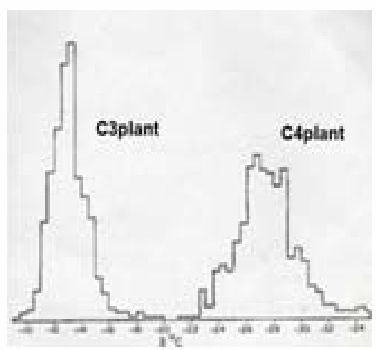
SI food web model in the watershed



A shematic illustration for analysis of a food web by a stable isotopic method.

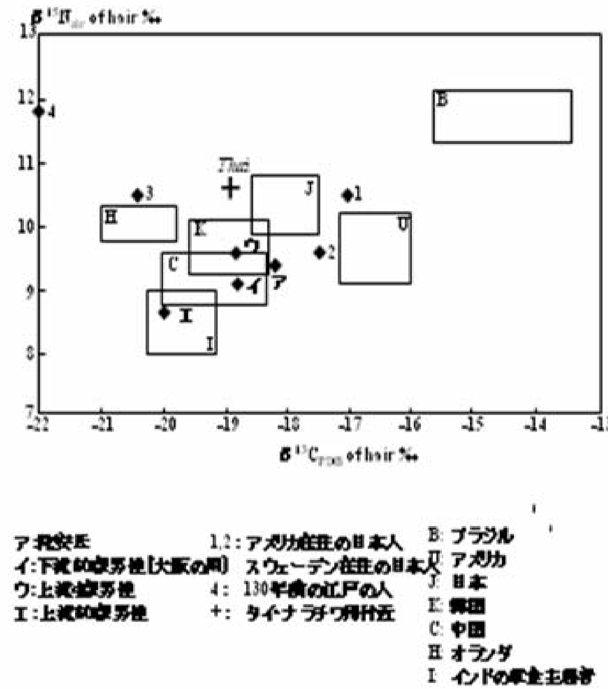
1) A simple Exampl





Examples of human Food habit

δ 15N-δ 13C SI-map of human hair



TOPICS

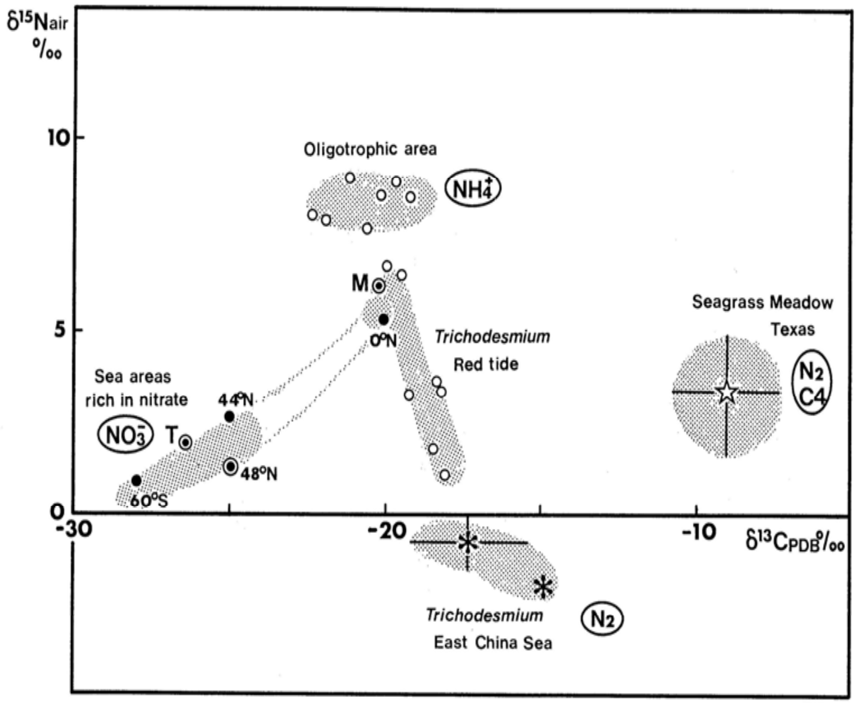
- **Topic 1.**
  Is δ15N-δ13C SI-map of phytoplankton useful to classify biome in the open ocean?
  1) Satellite Biome
  2) Stable Isotopes: ISOSCAPE or Isotope Landscape!

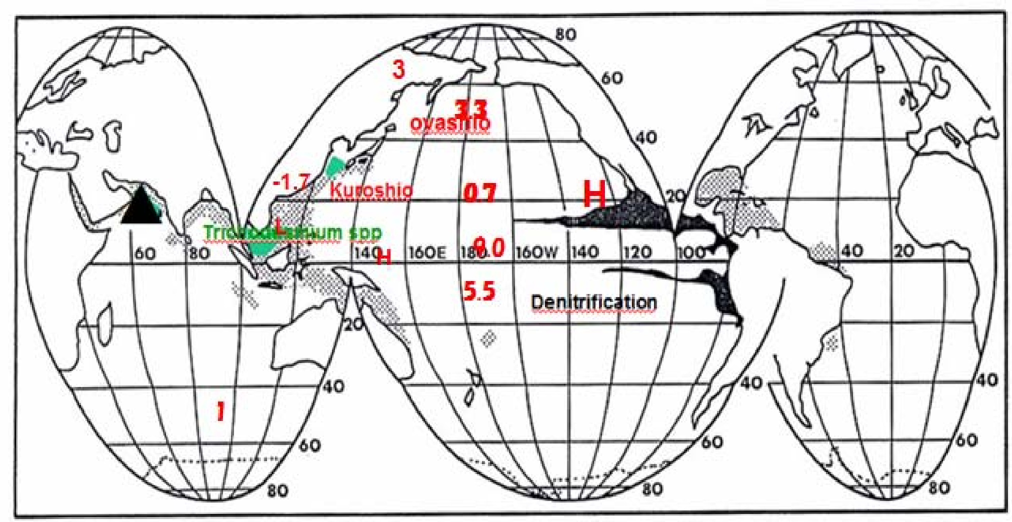
- **Topic 2.**
  Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific ?

- **Topic 3.**
  Newly developed SI method for Amino acid Trophic Level is useful to validate NEMURO.FISH model & ECOSIM.

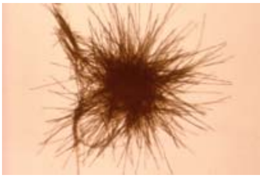
- **Topic 4.**
  Does δ13C inform you growth rate of phytoplankton in the ocean?

Topic 1. Possible BIOME on the del15N-13C map





Trichodesmium



Diatom 1permi, -25permil

Coccolithophorids

Pico-phytoplankton

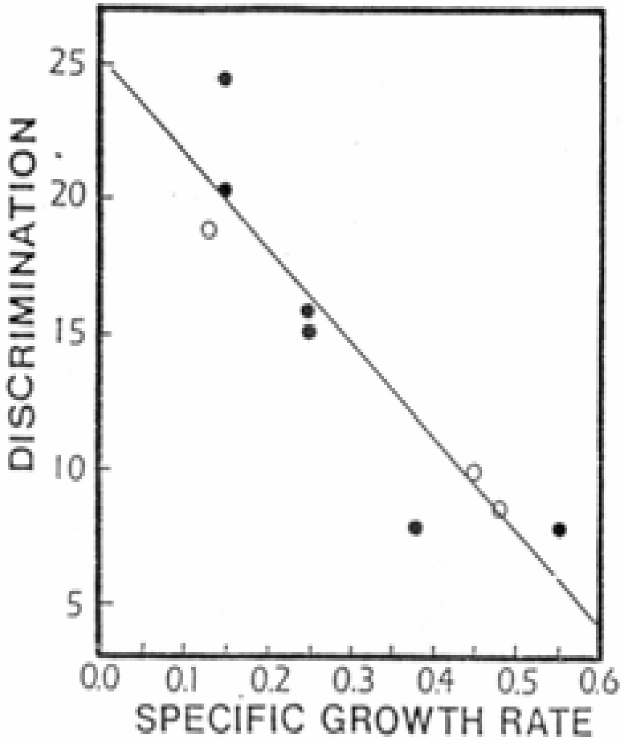
6<permil, -20permil

-2 permil

-13 permil

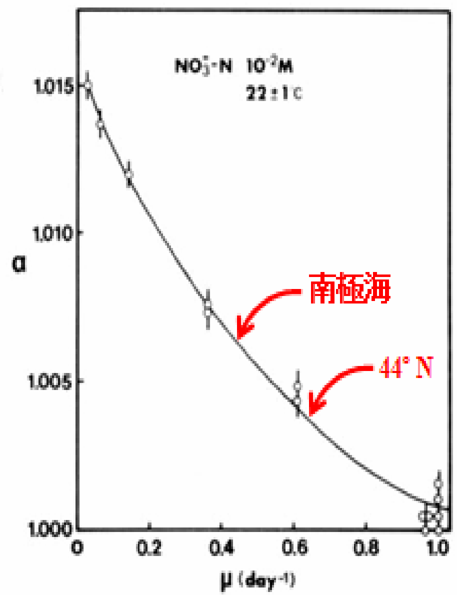
$\alpha = 1.002$

δ15N,δ13C (// μ)can inform a growth rate constant of phytoplankton !



Relationship between carbon isotope discrimination and the specific growth rate (μ) in green alga *Chlamydomonas reinhardtii* Dangeard (IAM C-238).
(●): Nitrate-limited condition.
(○): Light-limited condition.
Linear regression corresponds to:

$$\Delta\delta^{13}C = -35.4 \times \mu + 25.3 \quad (r = -0.92).$$



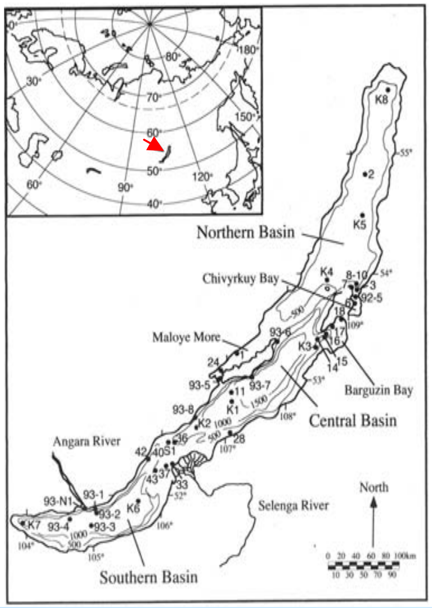
Relationship between the nitrogen-isotope fractionation factor in nitrate assimilation (α) and growth constant (μ) of *Phaeodactylum tricornutum*. (From Wada, E. and Hattori, A., *Geomicrobiol. J.*, 1, 97, 1978. With permission.)

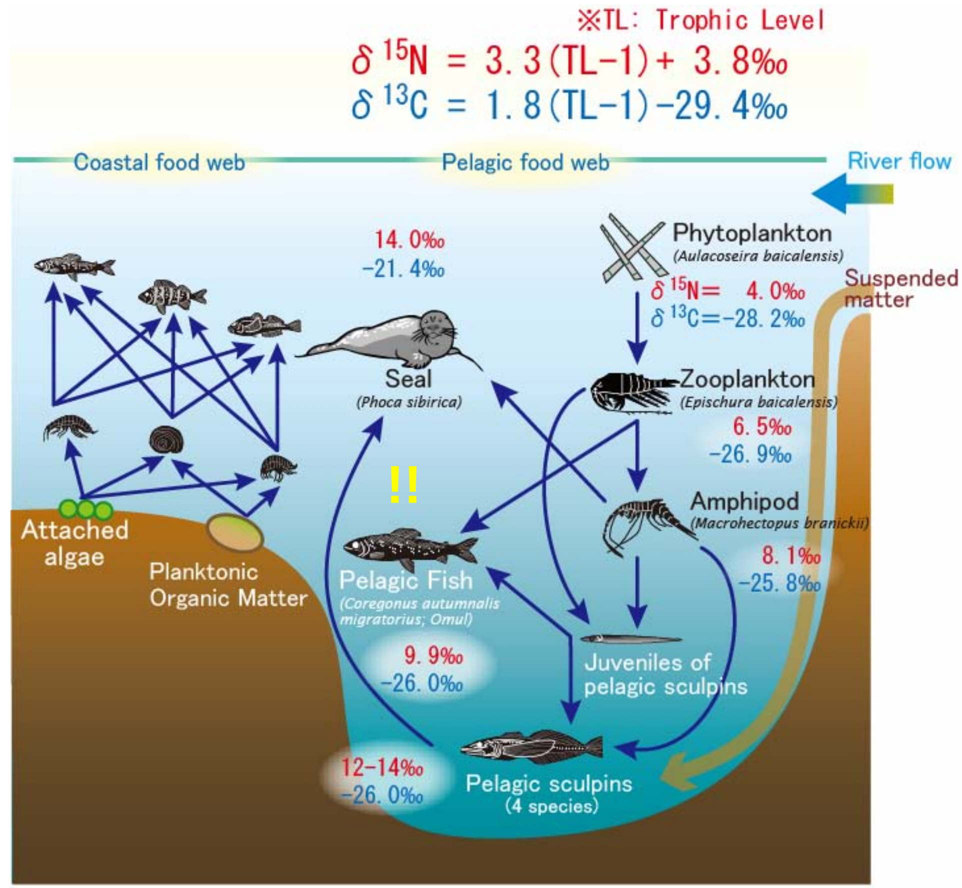
$N = No e^{\mu t}$

0.69 τ =1日
0.5 τ =1.5

Nt = No exp. (μ t) The higher the algal growth rate, the higher the δ13C value.

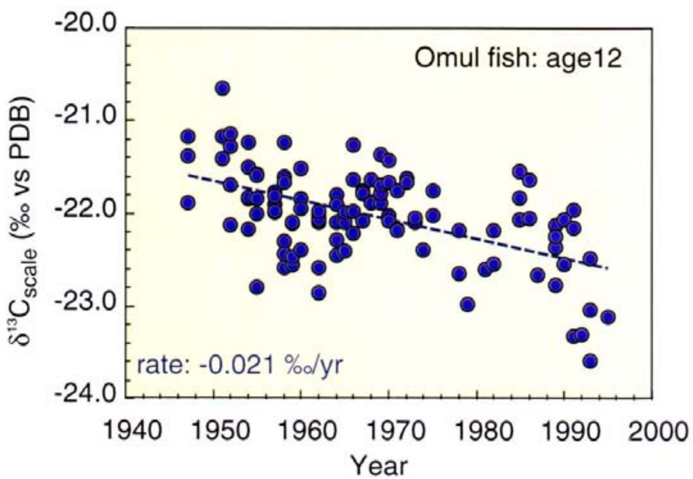
Topic 2. Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific ? YES !

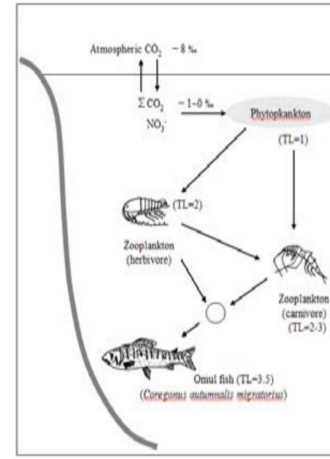


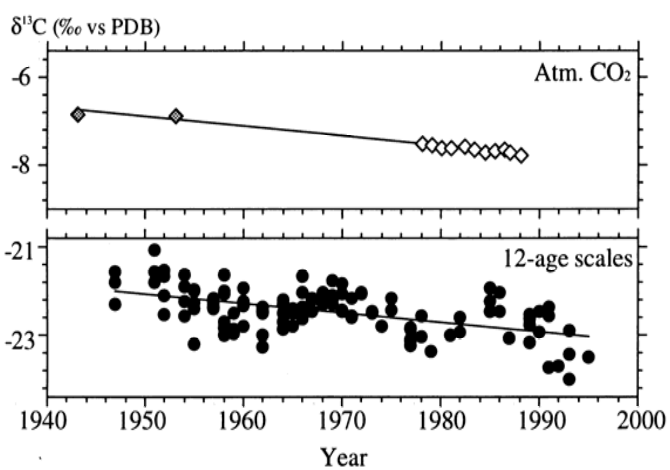


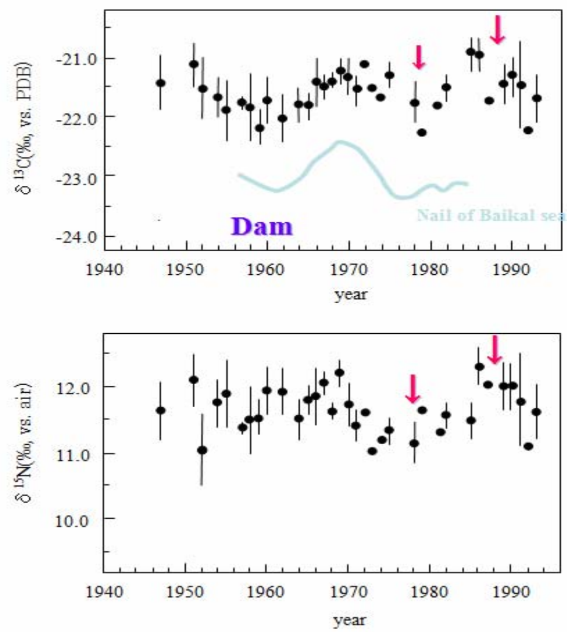
Schematic illustration of Lake Baikal food webs

δ¹³C records of Omul scale specimens from Lake Baikal: 1947-1995









Annual variations of δ ¹³C and δ ¹⁵N in omul scale.
Correction for the change in δ ¹³C of atmospheric CO_2 was made for δ ¹³C value of omul scale.

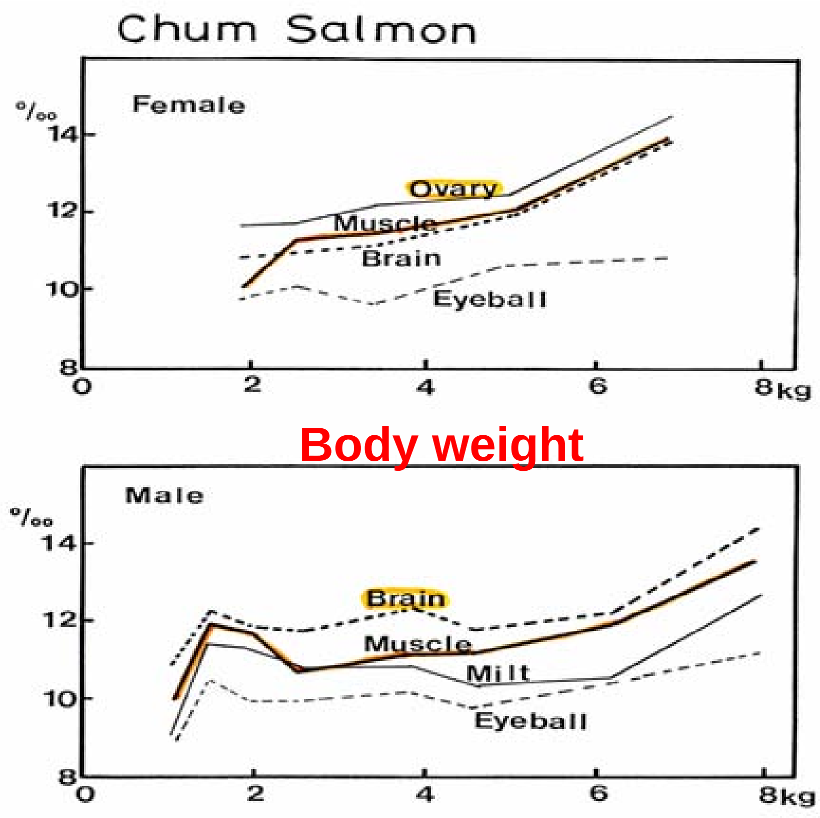
Decrease in δ13C is similar.

Topic 3. Amino acid TL

Chikaraishi et al. suggested that glutamic acid is systematically enriched in 15N toward the upper levels of the food chain (8.0 ± 1.2‰ at each trophicstep) as a result of metabolic processes; in contrast, phenylalanine shows little enrichment in 15N because of the absence of nitrogen-involving reactions in its dominant metabolic processes. Therefore, trophic level is estimated based on the δ15N values of glutamic acid and phenylalaninevia the following equation, termed the "Amino acid Trophic Level (ATL):"

→ MEMURO.FISH –**saury and herring + ECOSIM**

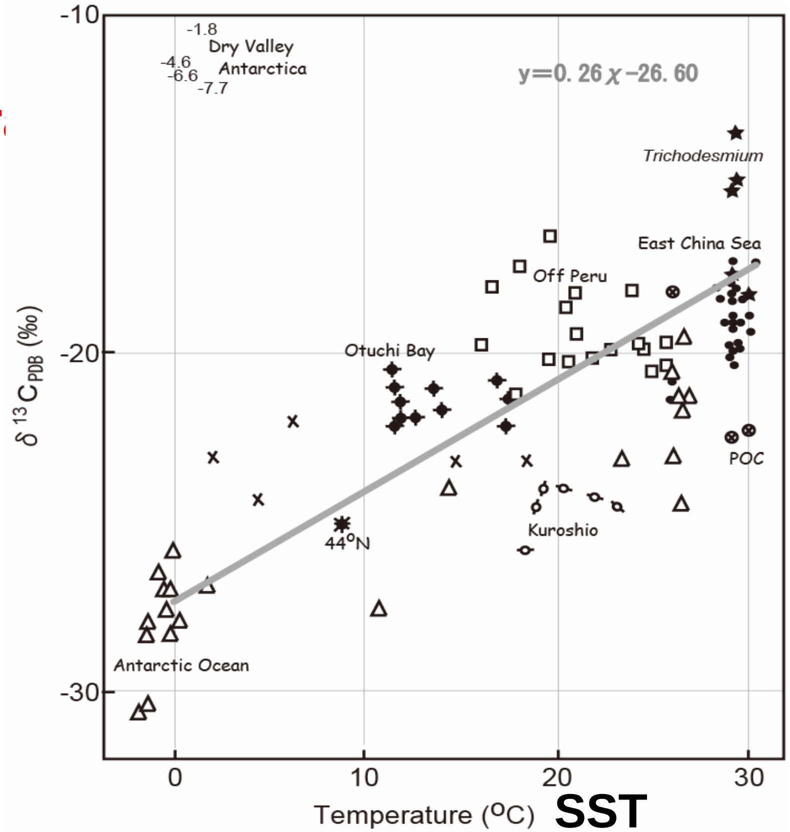
where δ15NGlu and δ15NPhe are the nitrogen isotopic compositions of glutamic acid andphenylalanine, respectively.



(submitted to *Limnology and Oceanography*
Yuichiro Kashiyama1**, Nanako O. Ogaw**
Yoshito Chikaraishi1**, Napussakorn**
Kashiyama1**, Saburo Sakai**1**, Kazushig**
Tanabe2**, and Naohiko Ohkouchi**1(2007
1Japan Agency for Marine-Earth Science an
Technology

Topic 4. Possible Idea !!

δ15N,δ13C (// μ)can inform a growth r constant of phytoplankton !



Estimation of SST, chl.a, Nitrate by using satellite data
(T.Saino、Sasaoka et al.,)

μcould be estimated by δ13C of phytoplankton or Possibly SST → **Daily PP** → **Dynamics of plankton biomass at intervals of Day-Night cycle**

Validation is conducted by using a new buoy system for NPP (In situ quantum irradiance spectra) in Euphotic Zone. T.Saino

C o n c l u s i o n !

Topic 1.

Is δ15N-δ13C SI-map of phytoplankton useful to classify biome in the open ocean?

POSSIBLE!

1) Satellite Biome

2) Stable Isotopes: ISOSCAPE or Isotope Landscape!

- **Topic 2.**

Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific ? **YES!**

Topic 3.

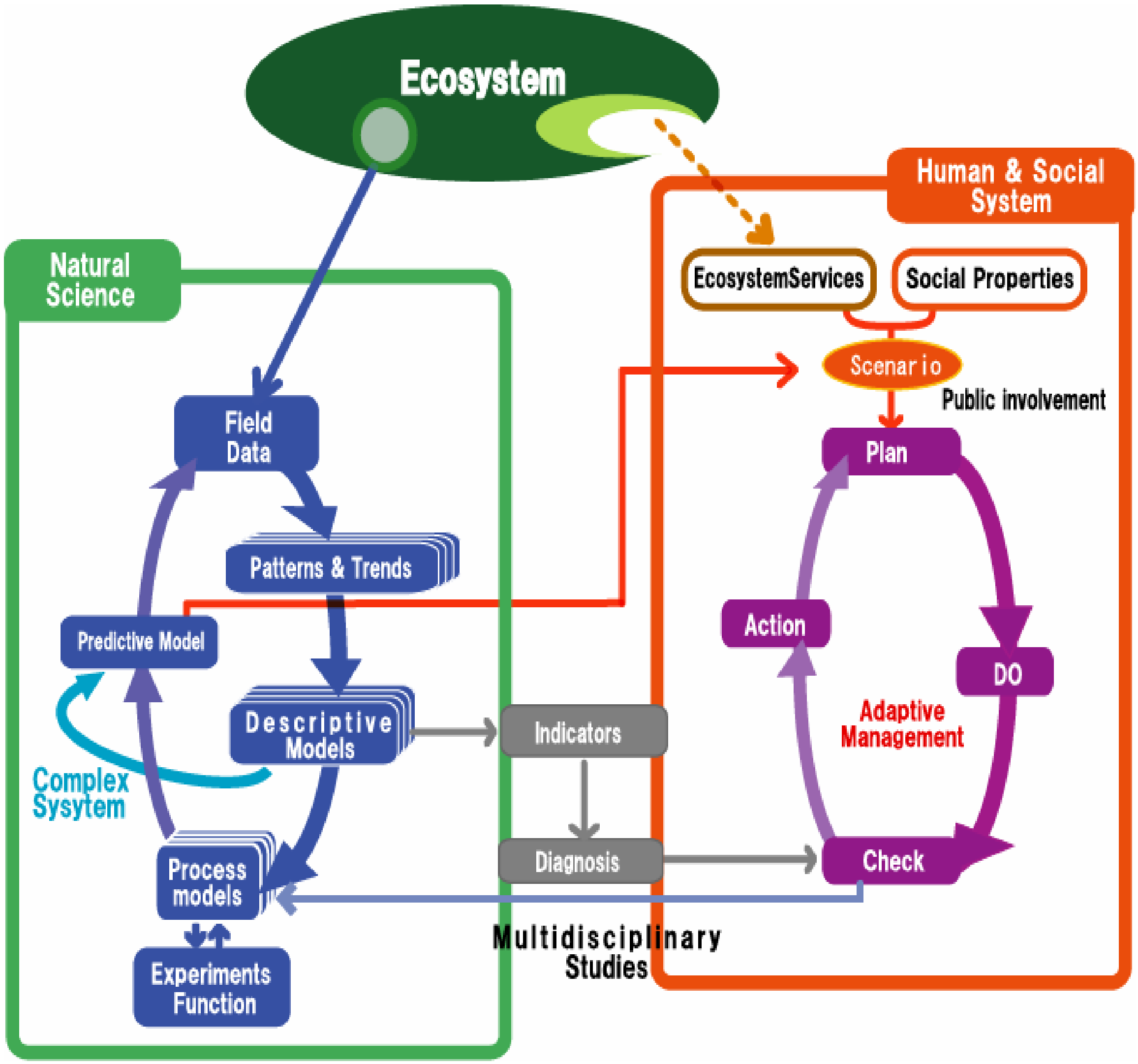
Newly developed SI method for Amino acid Trophic Level is useful to validate NEMURO.FISH model & ECOSIM. **YES !**

Topic 4.

Does δ13C inform you growth rate of phytoplankton in the ocean?

POSSIBLE!

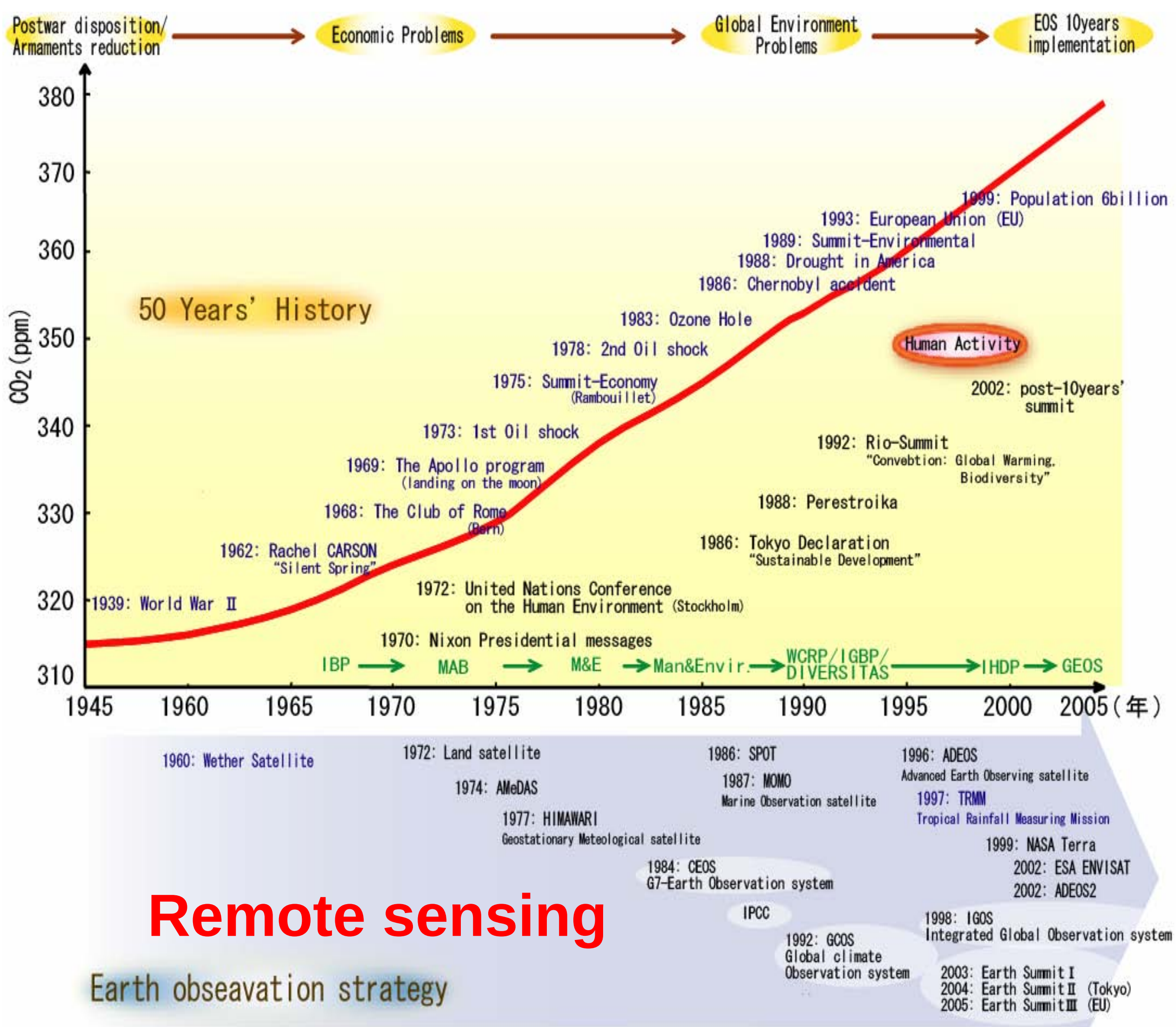
Finally a new framework of environmental studies is required to deepen the interactive cycles between nature and humanity.



Integrative studies of the observation, modeling and simulation are possibly connected to social management systems of the Plan-Do-Check-Action as indicated .

Introduction

50 years` progress of ecosystem studies is summarized with emphasis on the various kinds of international cooperative research programs under global environmental issues. These programs are IBP,MAB,IGBP, DIVERSITAS and HDP. At the beginning of 21st century,integration of WCRP, IGBP and IHDP are highly required to provide significant practical solution and scenarios to social sciences and public involvement .



Computer Simulation, SI techniques

PART 1

Introduction of our Program

Several process model have been integrated to several dynamic models of biophilic elements in the fields of biogeochemistry and ecosystem ecology.
Based on these data base ,our Ecosystem Change Research Program, FRCGC has been developing several kinds of global ecosystem models as indicated in the following slides.

Ecosystem Change Research Program
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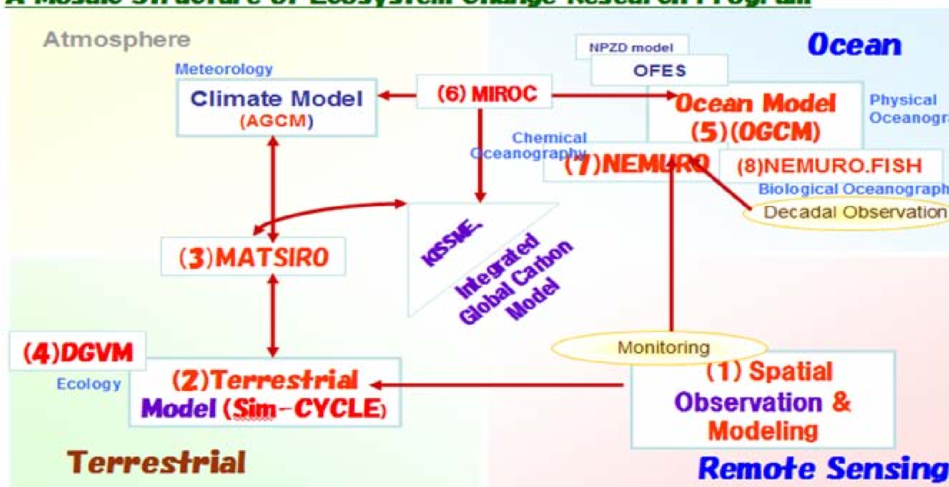
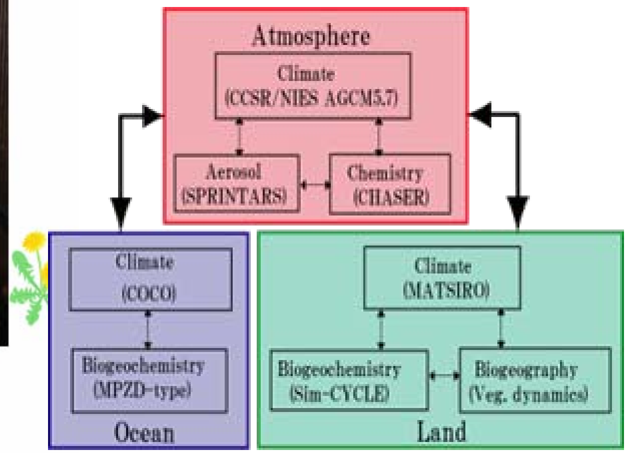
What is our Research Purposes？

The major, mid-term goal of the Ecosystem Change Research Program (ECRP) is to develop the biosphere sub-model for the integrated model of global change.
In this context, our efforts have been focused on modeling of biogeochemical carbon cycles in both terrestrial and oceanic ecosystems.

A Mosaic Structure of Ecosystem Change Research Program

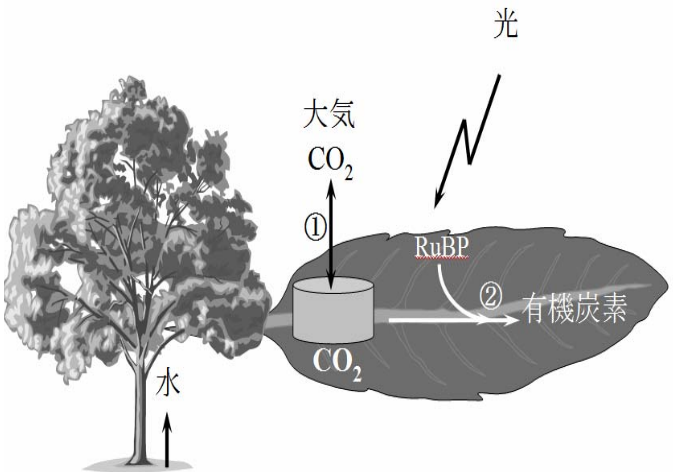


Our purpose : Development of Global Carbon Model

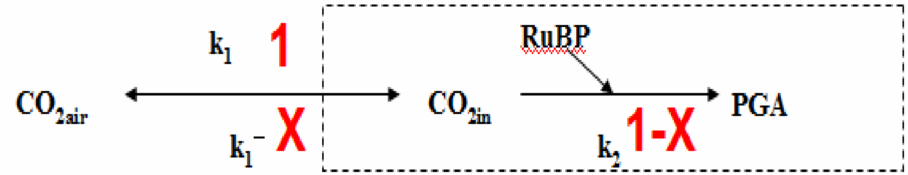


Comprehensive ESM (MIROC・KISSME)・ An integratede Earth system model (ESM) has **been developed by coupling biogeochemical sub-system models to an AOGCM (MIROC). A result from the ESM contributed to the IPCC AR4 (2007) for the assessment of feedbacks between climate change and carbon cycle.**

Topic 4. δ15N,δ13C can provide growth rate constant of phytoplankton



光合成炭酸固定の炭素同位体分別（C3植物の例）



$$\frac{d[CO_{2in}]}{dt} = k_1[CO_{air}] - (k_1^- + k_2)[CO_{2in}] = 0 \quad \text{(Steady State)}$$

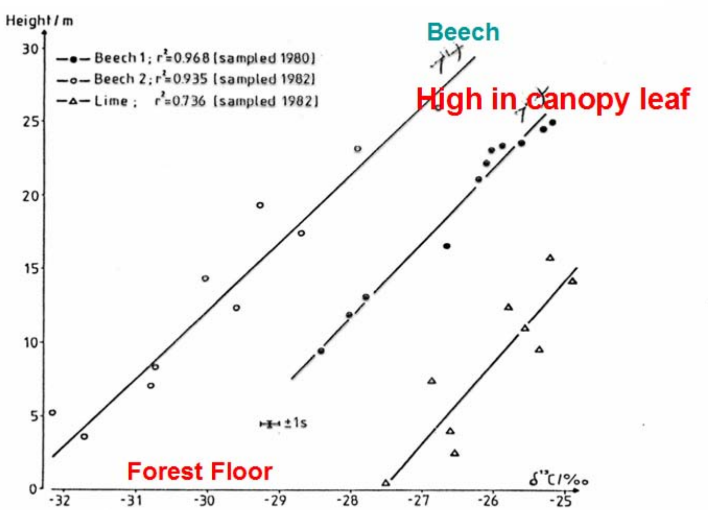
$$[CO_{2in}] = \frac{k_1}{k_1^- + k_2}[CO_{2air}] \quad ①$$

$$\alpha_{CO_2 \to PGA} = 1 + \Delta k_1 + (\Delta k_2 - \Delta k_1^-)X \quad ②$$

$$[CO_2]_{air} = 340\text{ppm}$$

$$X = \frac{k_1^-}{k_1^- + k_2} = \frac{[CO_{2in}]}{[CO_{2air}]}, \quad \Delta k_1 = \frac{{}^{12}k}{{}^{13}k} - 1, \quad k_1 = k_1^-$$

$$\Delta k_1^+ = \Delta k_1^- = 0.0044, \quad \Delta k_2 = 0.030$$



$\delta^{13}C$ values of leaf material from different heights. Two beeches of a forest and a solitary standing lime have been analyzed

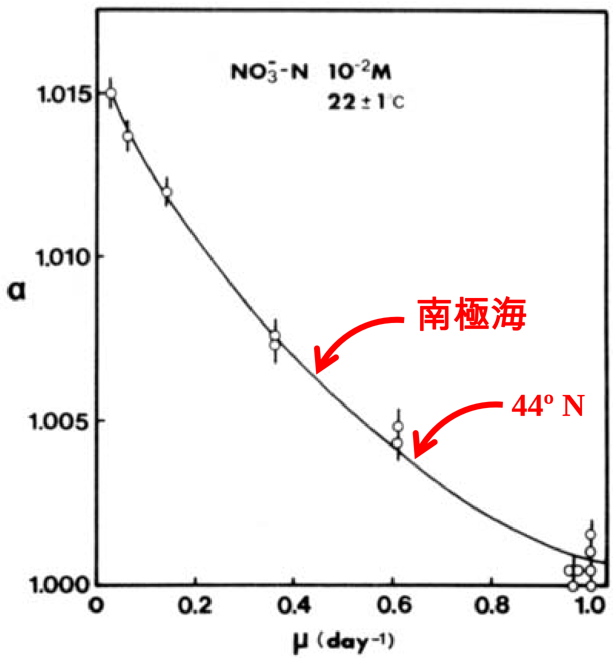
The variation of $\delta^{13}C$ between forest height levels.

In case we can measure the difference in $\delta^{13}C$ between CO_{2air} and plant leaf ($\alpha_{CO_2 \to PGA}$), we can calculate the value X. Then $[CO_{2in}]$ can be also calculated by using the X in Equation ①.

$$\delta^{13}C_{CO_{2air}} = -7‰, \quad [CO_{2air}] = 340\text{ppm}$$

Plant	α	X	PCO_{2in}	$\delta^{13}C\ CO_{2in}$
-27	1.020	0.61	201	3‰
-20	1.013	0.34	111	10 ‰
-37	1.030	1.0	330	-7 ‰
-11	1.004	0	0	-11 ‰

Reaction dynamics in the phytosynthetic CO_2-fixation by C3 plants



Relationship between the nitrogen-isotope fractionation factor in nitrate assimilation (α) and growth constant (μ) of *Phaeodactylum tricornutum*. (From Wada, E. and Hattori, A., *Geomicrobiol. J.*, 1, 97, 1978. With permission.)

$N = N_0 e^{\mu t}$

0.69 τ =1日
0.5 τ =1.5日

Steady state kinetics

$$S_0 \underset{k_1^-}{\overset{k_0^+}{\Leftrightarrow}} S_i$$

$$S_i + E \underset{k_1^-}{\overset{k_0^+}{\Leftrightarrow}} ES$$

$$ES + AH_2 \xrightarrow{k_2} E + A + P$$

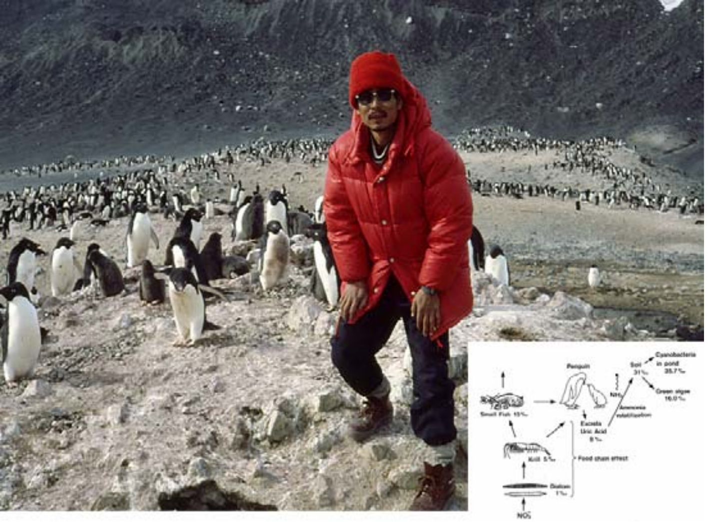
$$\alpha = 1 + \Delta k_0^+ + (\Delta k_0^+ - \Delta k_0^-)X + (\Delta k_0^+ - \Delta k_0^-)XY,$$

where

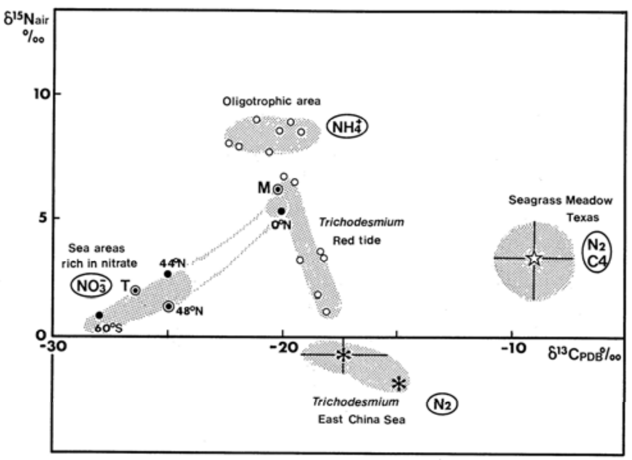
$$\Delta k = k_{14}/k_{15} - 1, X = \frac{k_0^-[Si]}{k_0^+[So]} and Y = \frac{k_1^-[ES]}{k_1^+[Si][E]}$$

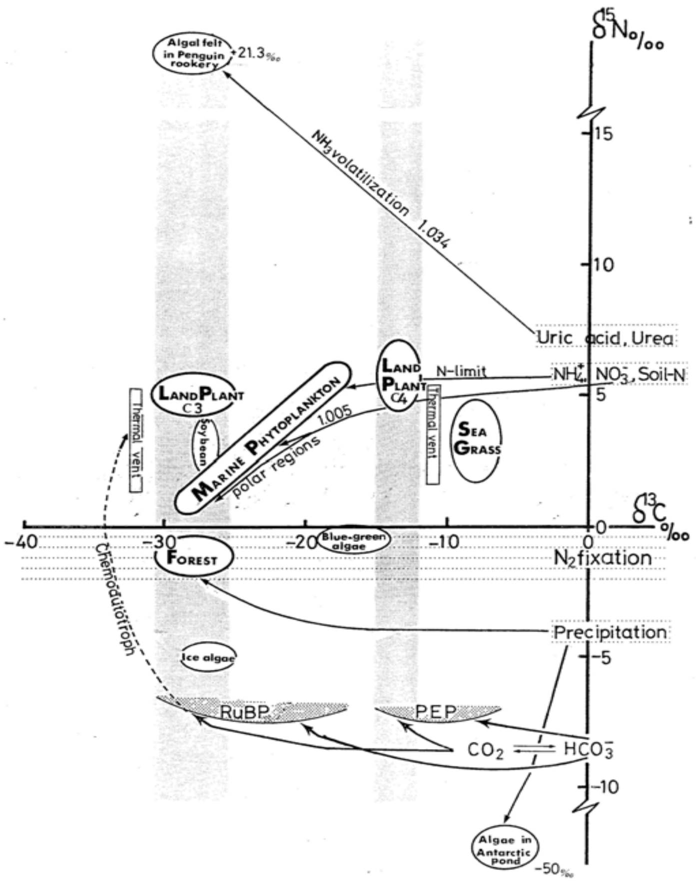
The cleavage of the N-O bond in nitrate and the transport of nitrate across the cell membrane might from, respectively, primary and secondary key steps where nitrogen isotope fractionation takes place. Then Equation 69 reduces to

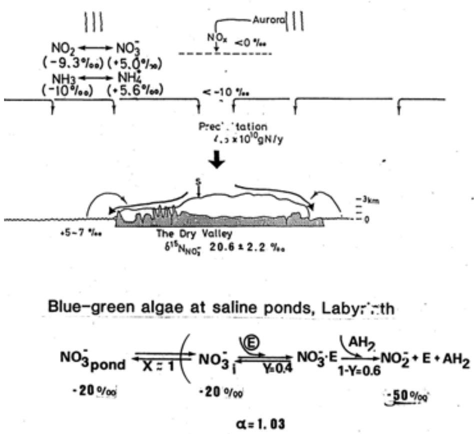
$$(\alpha - 1) = \Delta k_0^+ + (\Delta k_2 Y - \Delta k_0^-)X$$



The highest





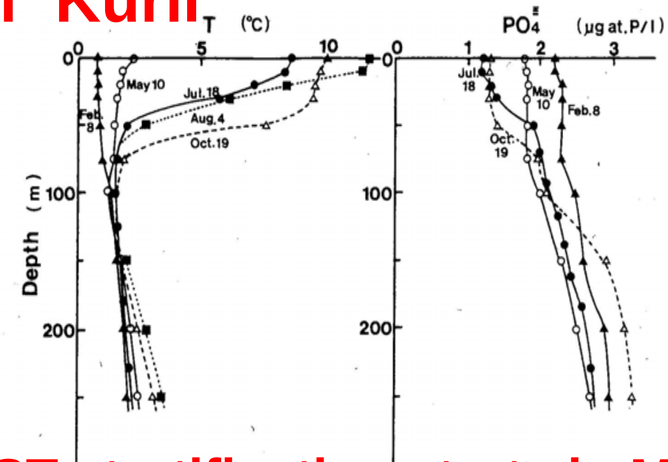


The lowest

δ15N-δ13C SI-map of plants

南極ドライバレー、ヴァンダ湖、底は30℃程度！

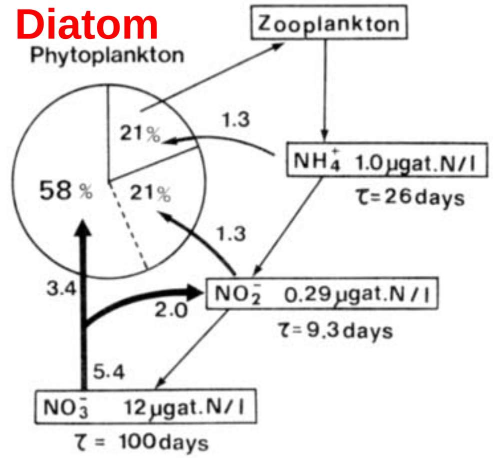
1)Off Kuril



2)SST stratification starts in May.

FIGURE 1. Seasonal variations of vertical profiles of both temperature and phosphate in seawater in the Oyashio area off the Kuril Islands, 1971. (From Wada, E., *Isotope Marine Chemistry*, Goldberg, E. D., et al., Eds., Uchida-Rohkakuho, Tokyo, 1980, 375. With permission.)

Diatom



Nitrogen fluxes in the surface water in the Oyashio area off the Kuril Island (44°N, 154°E) in the summer of 1971. Fluxes are estimated from data obtained by a ^{15}N tracer experiment and given in ng at.N/l/h. τ denotes the residence time of each component. (From Wada, E. and Hattori, A., unpublished data.)

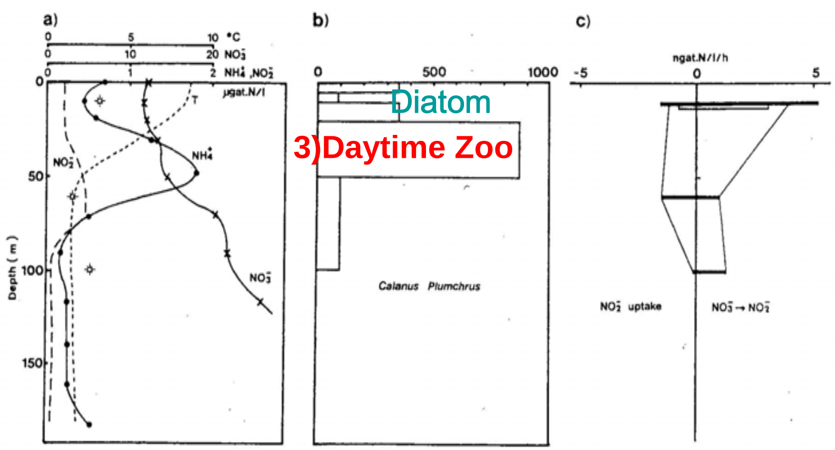
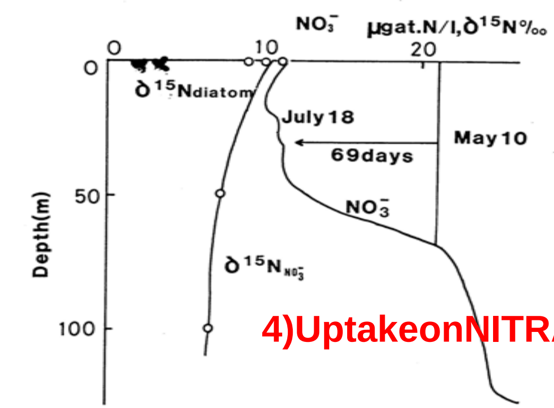


FIGURE 2. (a) Vertical profiles of temperature, nitrate, nitrite, and ammonium. (b) Average standing stock of *Calanus plumchrus*. (c) Production and consumption of nitrite. Taken at 44°N and 154°E, July 22, 1971. (From Hattori, A., Cruise Report of KH-71-3, Ocean Research Institute, University of Tokyo, 1983, and Miyasaki, T., et al., *Mar. Sci. Comm.*, 1, 381, 1975. With permission.)

STA19(44°N,154°E)



4)UptakeonNITRATE:1.005

Euphotic zone was regarded as a semiclosed system:

$$D\frac{\partial^2[NO_3^-]}{\partial z^2} - W\frac{\partial[NO_3^-]}{\partial z} \Leftarrow NO_3^- \text{ uptake}$$

$$\alpha_{NO_3^- \rightarrow diatom} = 1.0056$$