United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

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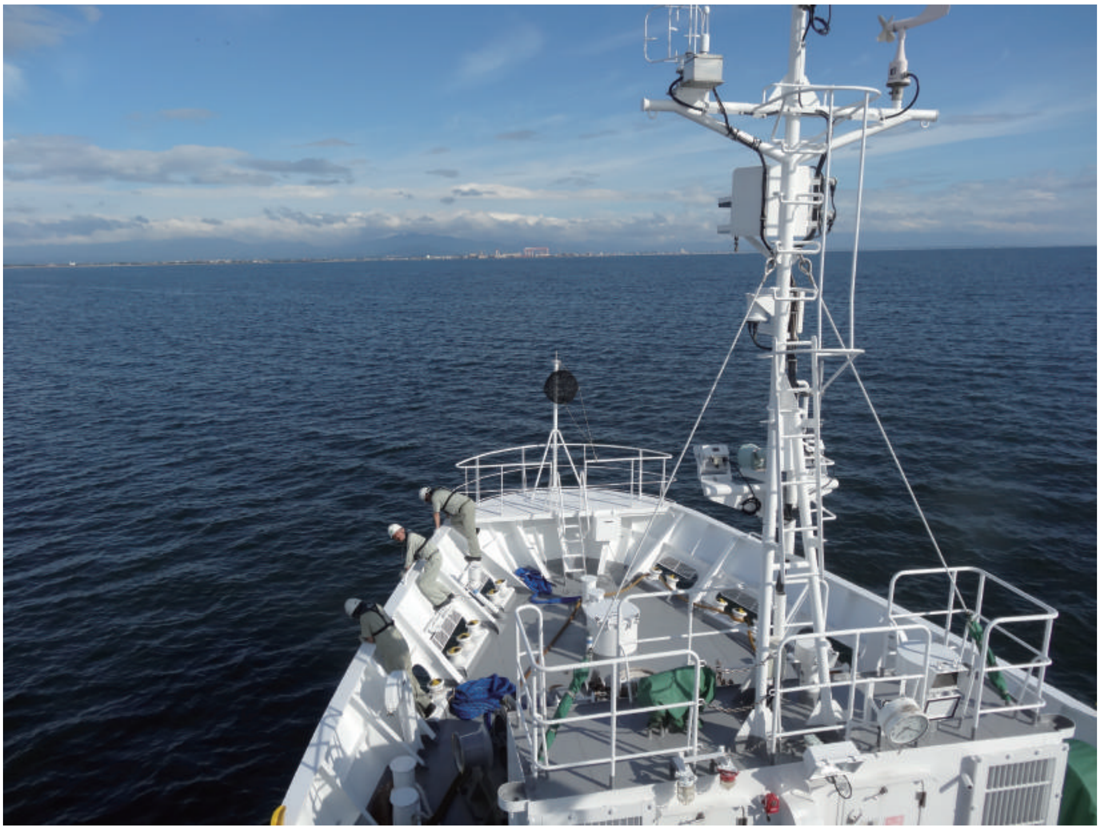
MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

International Hydrological Programme

Coastal Vulnerability and Freshwater Discharge

－The Twenty-six IHP Training Course－



Institute for Space-Earth Environmental Research, Nagoya University

Supported by

ISEE Institute for Space-Earth Environmental Research

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日本海洋学会 The Oceanographic Society of Japan

NOWPAP CEARAC

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MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

International Hydrological Programme

Coastal Vulnerability and Freshwater Discharge

The Twenty-six IHP Training Course

27 November - 10 December, 2016

Nagoya, Japan

Institute for Space-Earth Environmental Research, Nagoya University

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Outline

A short training course "Coastal Vulnerability and Freshwater Discharge" will be programmed for participants from Asia-Pacific regions as a part of the Japanese contribution to the International Hydrological Program (IHP). The course is composed of a series of lectures and practice sessions.

Objectives

Large number of population is living in coastal area of Asian countries. The area is also important for various human activities including fisheries, transportation, farming, and many other industries. The population explosion of the coastal area often makes pollution of waters, both fresh and salt waters, inducing environmental problems in the area. Freshwater input to the coastal area modified the circulation of waters. Large amount of materials are known to be discharged to the coastal water with the freshwater as natural, and they played important roles to keep the coastal ecosystem; however, the pollution of the freshwater also alternate the coastal ecosystem. River is known as a major source of freshwater, and more recently importance of underground discharge has been also recognized. Those freshwater discharges are also changing significantly by the climate change, construction of dams on the river, and use of freshwater. Coastal shallow area is often destructed to make a land for farming, industry or living area with reclamation and other human activities. Recently, it was shown that those coastal areas are vulnerable for tsunami caused by earthquake and storm surge caused by typhoon, and radical changes can be happened by those natural hazards. It is necessary to manage the area to make comfortable, productive and safe.

In this training course, the basic knowledge of physical, biological and chemical environments of coastal waters, and forcing including freshwaters from river and underground discharge, will be covered. Furthermore, interaction between nature of coastal area and human will be discussed. Technical training on-board of Training Vessel Seisui-Maru, Mie University, will cover the basic technics to sample waters, analyze the quality and interpret the data in large estuarine Ise and Mikawa Bay. Demonstration of satellite and numerical models will be also covered.

Key Note (Tentative)

K1: *Satoumi* Concept	YANAGI T.
K2: Melting Tibetan Ice Shield	CHEN A.

Lectures (Tentative)

L1: River Discharge	TANAKA K.
L2: Submarine Ground Water Discharge	TANIGUCHI M.
L3: Coastal Water Circulation	KASAI A.
L4: Nutrient Dynamics	UMEZAWA Y.
L5: Plankton Ecosystem	ISHIZAKA J.
L6: Influence to Fisheries	ISHIKAWA S.
L7: Tsunami and Disaster Prevention	TOMITA, T.
L8: Tidal Flat Conservation	YAMASHITA H.

Exercise

E1: Satellite Data Analysis	TERAUCHI G.
E2: Cruise Data Analysis	ISHIZAKA J.
E3: Coastal Model Output Analysis	AIKI H.

Field Workshop and Exercise

W1: Cruise in Ise Bay by T/V Seisui-Maru, Mie University	ISHIZAKA J., AIKI, H., and MINO Y.

Schedule (27 November to 10 December, 2016)

27 (Sunday)	Arrival at Central Japan International Airport and Move to Nagoya University
28 (Monday)	09：30-09：40 Registration & Guidance 09：40-12：10 Lecture 1 by TANAKA K. 13：30-16：00 Lecture 2 by TANIGUCHI M. 17：00-19：00 Welcome Party
29 (Tuesday)	09：30-12：00 Lecture 3 by KASAI A. 14：00-16：30 Keynote 1 by YANAGI T.
30 (Wednesday)	09：30-12：00 Lecture 4 by UMEZAWA Y. 14：00-16：30 Keynote 2 by CHEN A. (Move to Mie)
1 (Thursday)	Cruise in Ise/Mikawa Bay
2 (Friday)	Cruise in Ise/Mikawa Bay
3 (Saturday)	Tour to Ise Shrine (Back to Nagoya)
4 (Sunday)	Off
5 (Monday)	09：30-12：00 Lecture 5 by ISHIZAKA J. 13：30-17：00 Exercise 1 by TERAUCHI G.
6 (Tuesday)	09：30-12：00 Lecture 6 by ISHIKAWA S. 13：30-16：00 Exercise 2 by ISHIZAKA J.
7 (Wednesday)	09：30-12：00 Lecture 7 by TOMITA, T. 13：30-17：00 Exercise 3 by AIKI H.
8 (Thursday)	09：30-12：00 Lecture 8 by YAMASHITA H. 13：30-17：00 Making reports and discussions
9 (Friday)	09：30-11：30 Report presentations and discussions 11：30-12：00 Completion ceremony of this course 13：30-15：30 Farewell party
10 (Saturday)	Departure from Central Japan International Airport

K1: Concept and Practices of Satoumi in Japan and Lessons Learned

Tetsuo Yanagi (International EMECS Center, *Kobe*)

Abstract

The coastal seas in the world suffer from environmental problems such as eutrophication, natural disaster, fish resources decreasing, environmental degradation and so on. In order to solve such complicated problems, successful Integrated Coastal Management (ICM) is necessary. Method of ICM in Japanese SATOUMI (the coastal sea with high biodiversity and productivity under the human interaction such as the Seto Inland Sea, Shizukawa Bay and the Sea of Japan) is introduced in this lecture.

ICM is an increasingly important topic for the public, scientist, policy makers and NPO related to environmental problems in the coastal sea. ICM is also a very rapidly evolving field. Dissemination of ICM in Satoumi where high biodiversity and productivity are realized under the human interaction is very useful for the people interested in the environmental problems in the coastal seas of the world.

A new concept "Satoumi" was firstly proposed by Prof.T.Yanagi in 1998 and the first book "Sato-Umi" was published in 2006 and the second book "Japanese Commons in the Coastal Seas: How the Satoumi Concept Harmonizes Human Activity in Coastal Seas with High Productivity and Diversity" was published in 2010 with Springer.

This lecture will present the most advanced results on ICM in Satoumi. This lecture would target graduate students and advanced college students as well as stakeholders (such as policy makers and environmental organizations), oceanographers and economists.

Concept and Practices of Satoumi in Japan and Lessons Learned

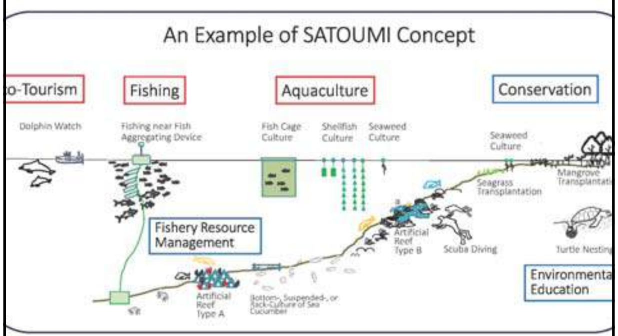
International EMECS Center
Professor Emeritus of Kyushu University
Tetsuo YANAGI

SATOUMI

"A coastal area where biological productivity and biodiversity has increased through human interaction"
By Dr. Yanagi

"Place to make profit, learn the importance of marine environment, and enjoy the richness of the nature"
By Shima Municipality, Mie Prefecture, Japan

Profit through Sustainable Use of Natural Resources and Farming

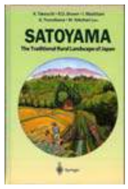


Satoyama and Satoumi

Satoyama : Forest with high productivity and bio-diversity under the human interaction

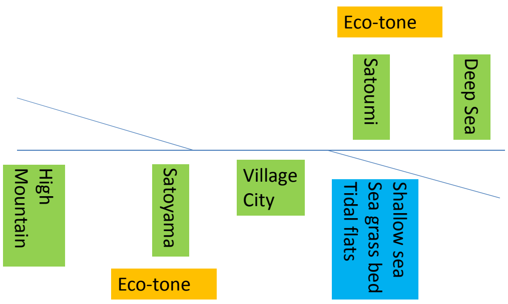
Satoumi : Coastal sea with high productivity and bio-diversity under the human interaction

Yanagi (1998, 2006)



2001

Satoyama - Satoumi



Claim of some ecologists

- Human interaction in Satoyama may increase bio-diversity,
- but human interaction in coastal sea may decrease bio-diversity

Bio-diversity and Human interaction

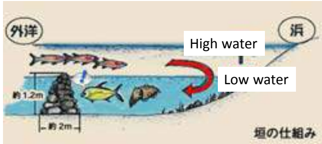
High bio-diversity =
Many kinds of habitat (nursery ground, feeding place, spawning ground) and
no-climax (climax=simple habitat)

1) Human interaction to arrange habitat – High biodiversity
2) Human interaction to stop the transfer to climax of flora – High biodiversity

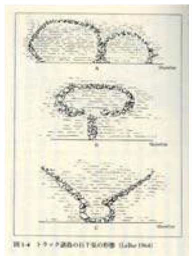
Yanagi (2009) Human interaction and bio-diversity. Ocenography in Japan, 18, 393-398 (in Japanese)

Example of increasing bio-diversity under the human interaction

Tidal stone weir (Nagaki, Kachi in Okinawa)



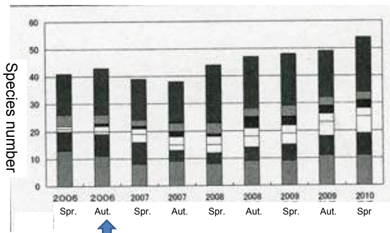
Siraho Conservation Organization HP



Tawa ed. (2007)

Nagaki at Shiraho, Ishigaki Island, Okinawa

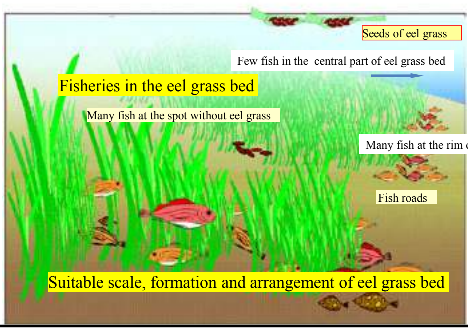
Data of Kamimura



2006 Autumn Reconstruction

Kamimura (2011)

Spot harvest in eel grass bed resulted in increasing bio-diversity

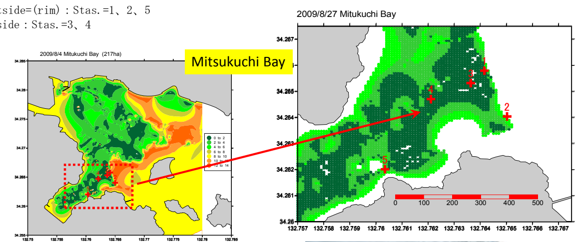


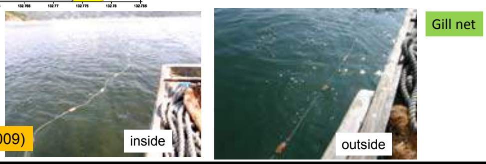
Tanimoto (2009)

Field=experiment=of=fish=catch=inside=and=outside=of=eel=grass=bed=in=Mitsukuchi Bay

2009/8/26～27

Outside=(rim) : Stas.=1、2、5
inside : Stas.=3、4

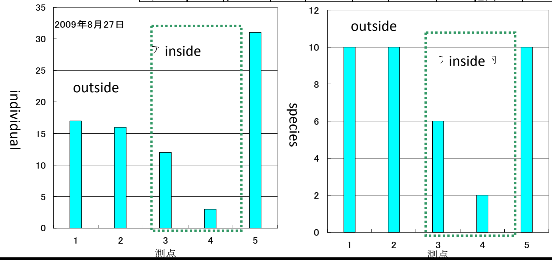




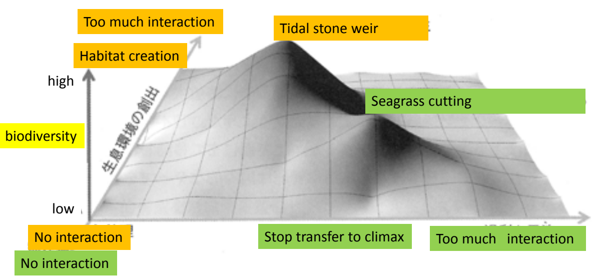
Tanimoto (2009)

Tanimoto (2009)

1		2		3		4		5	
魚種	数量	魚種	数量	魚種	数量	魚種	数量	魚種	数量
ギザミ	1	ギザミ	1	メバル	1	オコゼ	1	メバル	1
メバル	3	メバル	4	フグ	2	フグ	2	コノシロ	8
コノシロ	1	コノシロ	1	コノシロ	3			コチ	2
アイナメ	1	コチ	1	ネコサメ	2			サバ	1
タイ	1	タイ	1	ハゼ	1			キス	2
ハゼ	1	ハゼ	3	イシガニ	3			コイワシ	1
エソ	1	オコゼ	1					イシガニ	13
イシガニ	5	タナゴ	1					シャコ	1
ウニ	2	イシガニ	2					ニシ	1
ニシ	1	ナマコ	1					ヒトデ	1

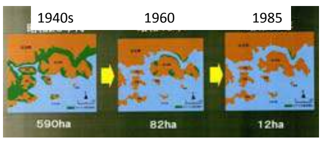


Biodiversity and human interaction



Hinase Fishermen's Union, Okayama

Decrease of eel grass beds
Decrease of fish catch



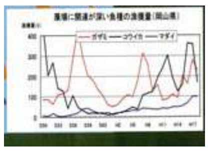
Due to agricultural chemical and increase of turbidity

Fishermen in Hinase Fishermen's Union began the eel grass bed creation in 1985 and continued until now

eel grass bed in 2011

more than 200ha

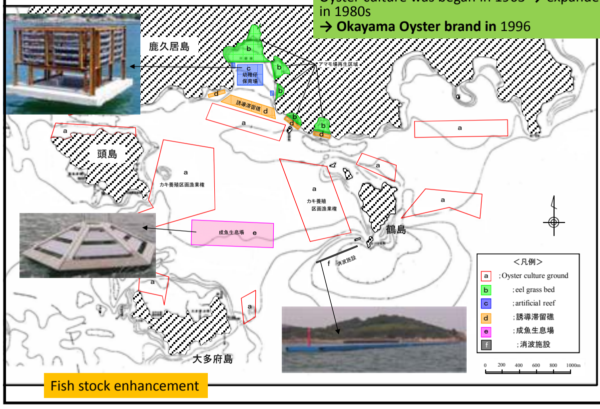
Recovery to 1/3 of eel grass bed in 1940s



Fish catch by set net

Oyster culture grounds

Oyster culture was began in 1963 → expanded in 1980s
→ **Okayama Oyster brand in 1996**



Fish stock enhancement

Oyster culture and eel grass bed win-win relation

- Decrease of water temperature in eel grass bed (due to leaves of eel grass)
  → decrease of mortality of oyster
- Attached diatom and small animal on the leaves of eel grass
  → increase of growth rate of oyster
- Decrease of wave height by oyster raft → decrease of eel-grass root damage
- Grazing of phytoplankton and detritus → Increase of transparency → Increase of eel-grass beds area

Recovery of sea bed litter and Direct selling of harvest

Fishery of Hinase Fishermen's Union

- Marine environment conservation: eel grass bed creation, recovery of sea bed litters、Sea bed cultivation
- Resources management: Release of juvenile、Days of prohibition of fishing
- Added values: Direct selling of harvest、Oyster baking restaurant, information from direct selling
  →Adjustment of fishing activity

Necessity of dissemination of fishermen's activities:
Consumer may pay extra money for the marine environment conservation

Fishery and Marine Ecosystem Conservation

- Fishery is said to be the worst environment destroying activity
- It may result in conservation of marine ecosystem to harvest all levels biota in marine food chain

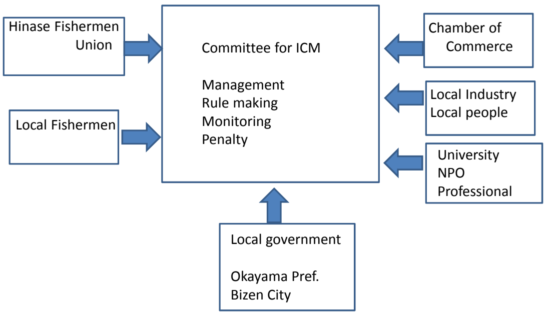
  Galcia et al. (2012) Reconsidering the consequences of selective fisheries. Science, 335, 1045-1047

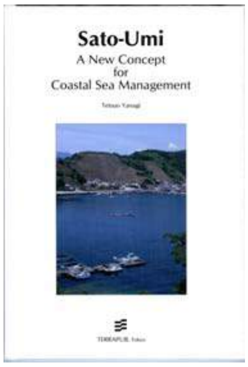
- Hinase set net＝ Selective fishing
- Cooking of all kinds of fish from small to large → Dissemination of Hinase culture – fishing and cooking

Agreement for Hinase Fisheries May 2012

1) Fishermen's Union
2) Okayama Prefecture
3) Okayama COOP
4) Research Institute for Satoumi Creation

Committee for management

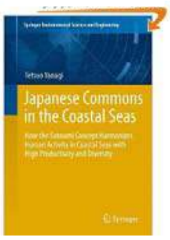




Terra Scientific Publishing Company
2007

Sato-Umi
－A new concept for coastal sea management－
1.Introduction
2.Mankind and coastal sea
2.1 Richness of the coastal sea
2.2 Crisis of the coastal sea
3. Mankind and the forest
3.1 Sato-Yama
4. Sato-Umi
4.1 Concept of Sato-Umi
4.2 Harvest of sea-glass bed
4.3 New technology
4.4 Stock enhancement and fish culture
4.5 Sea farming
4.6 Fish resources management
5. Environmental ethics
5.1 Environmental ethics and Commons
5.2 Preservation and Conservation
5.3 Environmental education
6. Concluding remarks

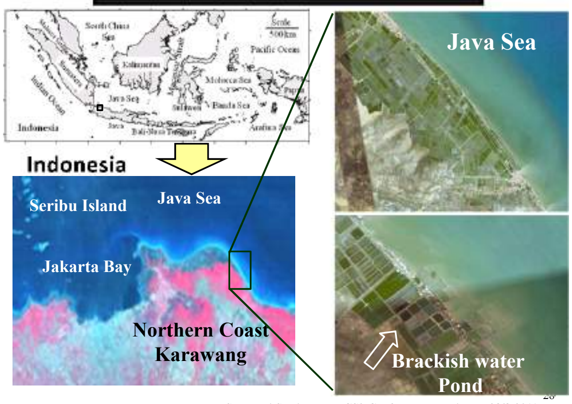
Satoumi: Japanese Commons in the Coastal Sea



12 examples of satoumi creation by Japanese fishermen and international activities on Satoumi creation are introduced

published in 2012 from Springer

SITE LOCATION

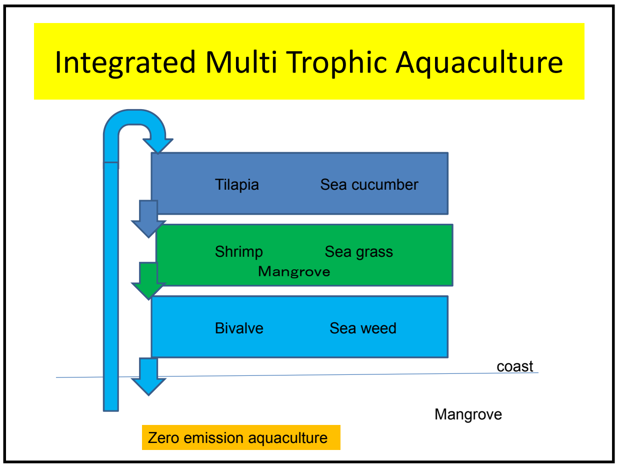


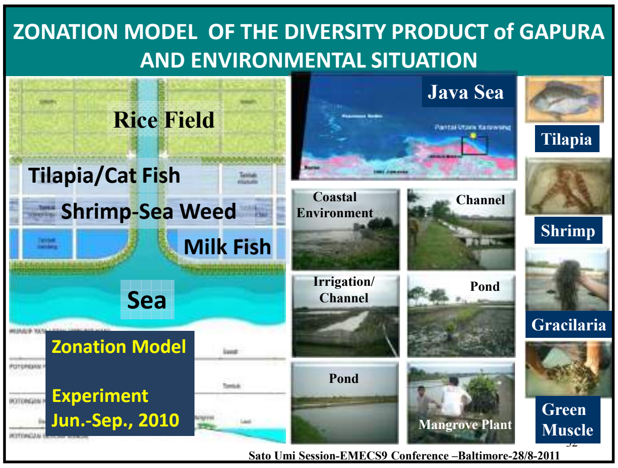
Sato Umi Session-EMECS9 Conference –Baltimore-28/8-2011

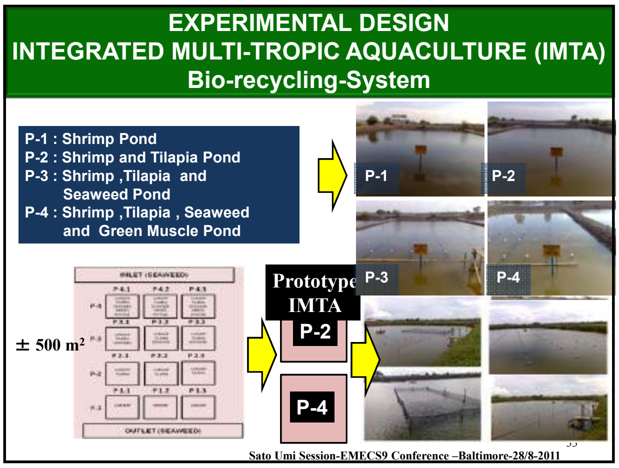
Aquaculture pond

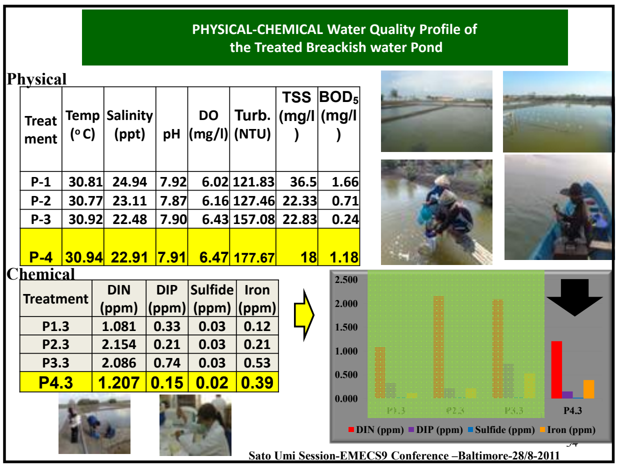
Consulting Activities in 2008

30
Sato Umi Session-EMECS9 Conference –Baltimore-28/8-2011







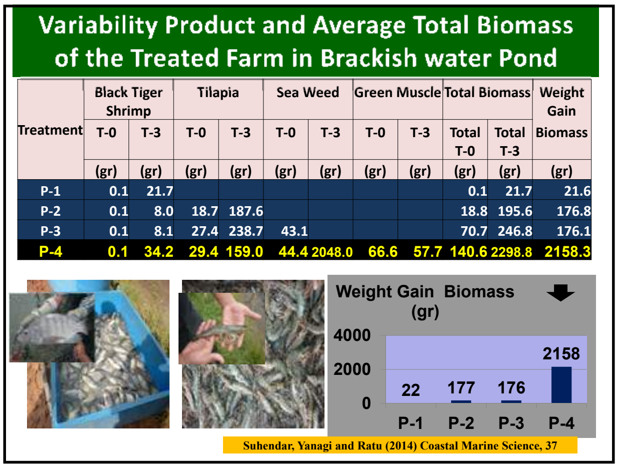


Physical

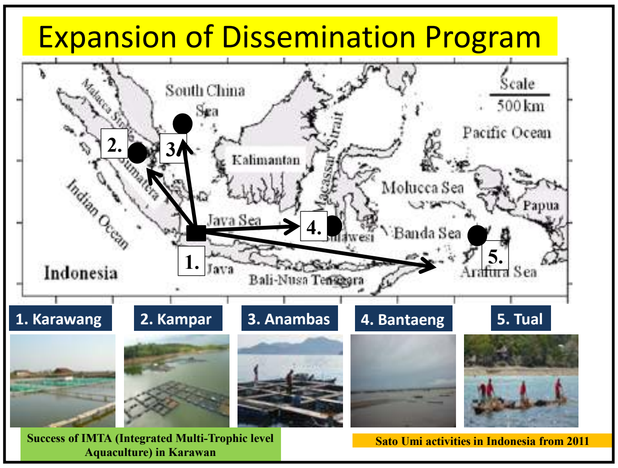
Treatment	Temp (°C)	Salinity (ppt)	pH	DO (mg/l)	Turb. (NTU)	TSS (mg/l)	BOD_5 (mg/l)
P-1	30.81	24.94	7.92	6.02	121.83	36.5	1.66
P-2	30.77	23.11	7.87	6.16	127.46	22.33	0.71
P-3	30.92	22.48	7.90	6.43	157.08	22.83	0.24
P-4	30.94	22.91	7.91	6.47	177.67	18	1.18

Chemical

Treatment	DIN (ppm)	DIP (ppm)	Sulfide (ppm)	Iron (ppm)
P1.3	1.081	0.33	0.03	0.12
P2.3	2.154	0.21	0.03	0.21
P3.3	2.086	0.74	0.03	0.53
P4.3	1.207	0.15	0.02	0.39



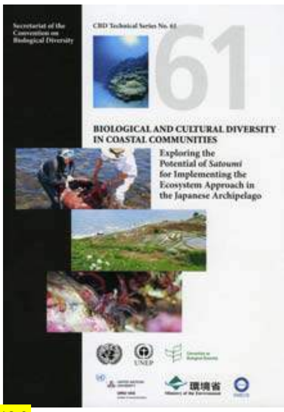
Treatment	Black Tiger Shrimp T-0 (gr)	Black Tiger Shrimp T-3 (gr)	Tilapia T-0 (gr)	Tilapia T-3 (gr)	Sea Weed T-0 (gr)	Sea Weed T-3 (gr)	Green Muscle T-0 (gr)	Green Muscle T-3 (gr)	Total Biomass Total T-0 (gr)	Total Biomass Total T-3 (gr)	Weight Gain Biomass (gr)
P-1	0.1	21.7							0.1	21.7	21.6
P-2	0.1	8.0	18.7	187.6					18.8	195.6	176.8
P-3	0.1	8.1	27.4	238.7	43.1				70.7	246.8	176.1
P-4	0.1	34.2	29.4	159.0	44.4	2048.0	66.6	57.7	140.6	2298.8	2158.3



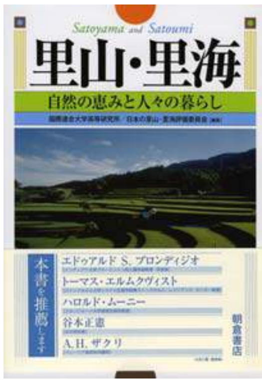
Satoumi-GAPRA International Workshop at Jakarta, Indonesia on 13-14 March, 2013

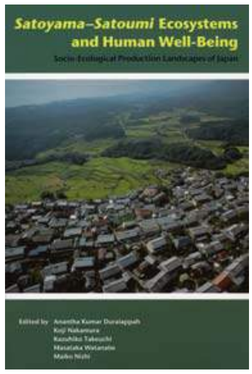
Establishment of Fisheries Management System based on Satoumi Concept in the Pan-Pacific Region (2012-2016)

- 0.12 million US dollars/year sponcered by JFA
- Western, central and eastern parts in the North-Pacific
- Manual, Workshops, Data-base
- Under the umbrella of PICES（Pacific ICES; International Council for the Exploration of the Sea）



2012.3





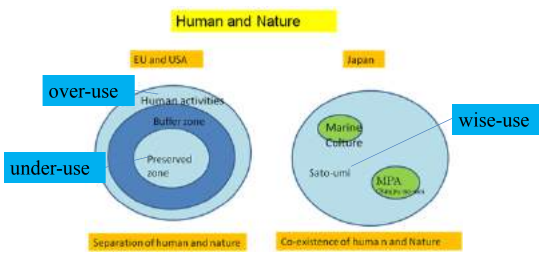
United Nation University

2012.3

International Workshop on Satoumi

- 1st Workshop in 2008 at Shanghai
- 2nd Workshop in 2009 at Manila
- 3rd Workshop in 2010 at Kanazawa
- 4th Workshop in 2011 at Baltimore
- 5th Workshop in 2012 at Hawaii
- 6th Workshop in 2013 at Marmaris (Turky)
- 7th Workshop in 2014 at Tokyo
- 8th Workshop in 2015 at Da Nang (Vietnam)
- 9th Workshop in 2016 at Saint Petersberg (Russia)
- 10th Workshop in 2017 at Bordeaux (France)

Difference of human-nature relation between Japan and Western Countries



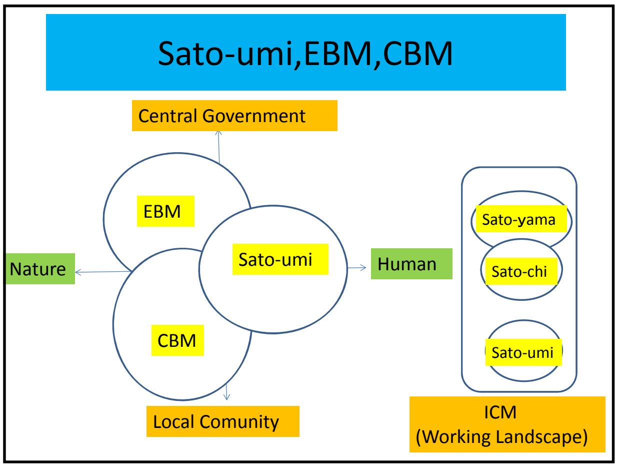
Japan with high population density cannot have preserved zone

Christianity and Buddhism

- God separately creates Human and Nature.
- Human cycles his life after his death :

  Human → animal → plant → human

Asian people think that gods live everywhere.



General Discussion on "Satoumi Creation"

- Science and Technology

  Habitat for marine biota: Artificial reef, Ishihimi (Tidal stone weir), Tidal flats, Sea- grass beds, Coral reef

  Local (indigenous) wisdom – heterogeneity of environment ＋ Scientific knowledge

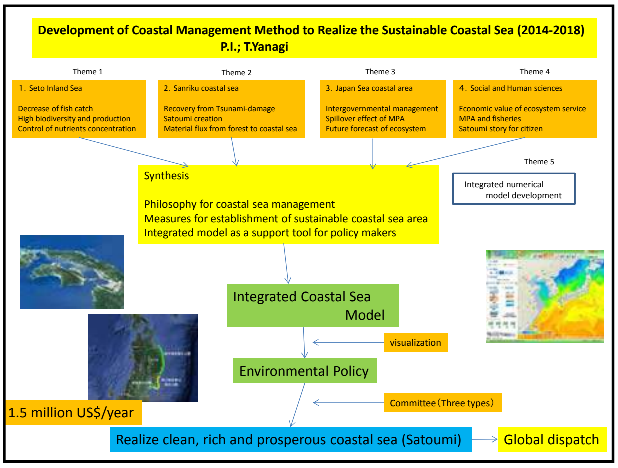
  Resilient ecosystem

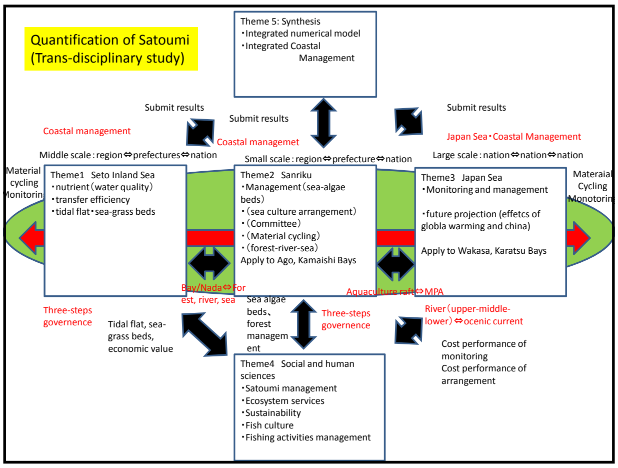
- Management

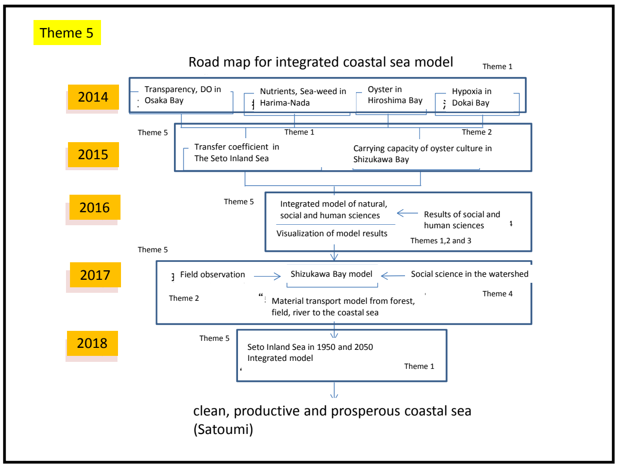
  Commons; fishermen, stakeholders, managers, scientists - agreement

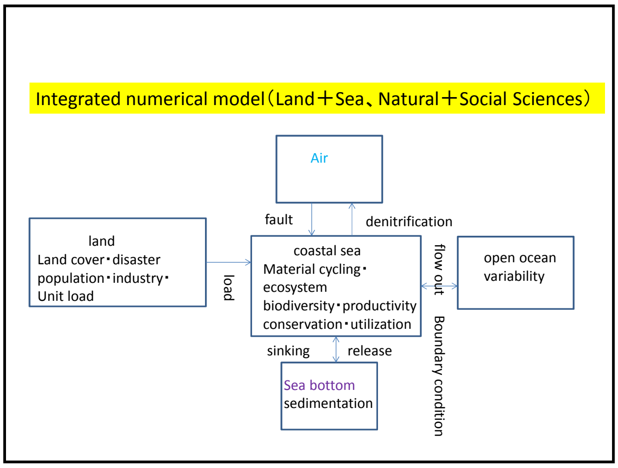
  Local (indigenous) wisdom – heterogeneity of culture

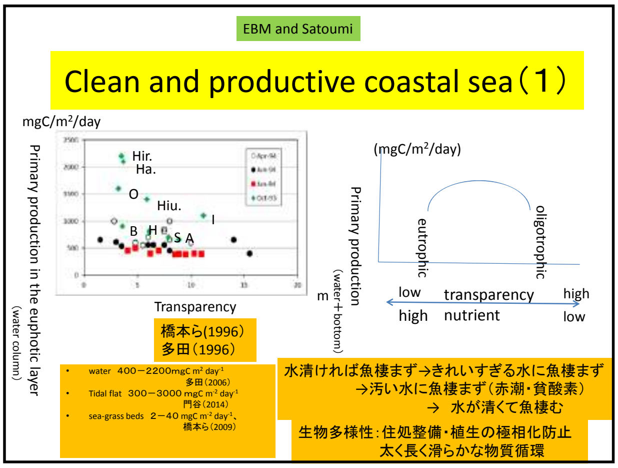
  local community, local government, central government – compensatory

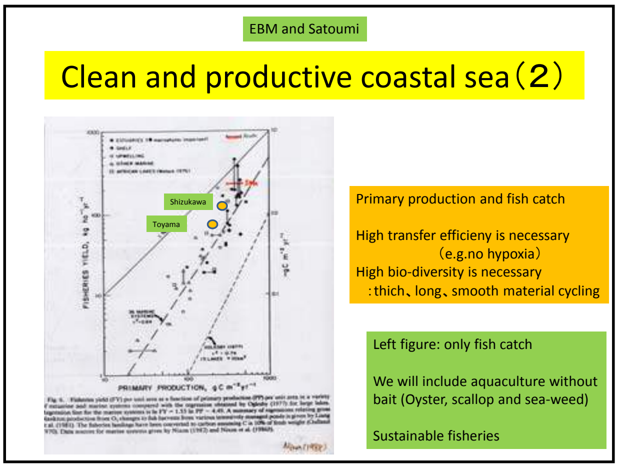


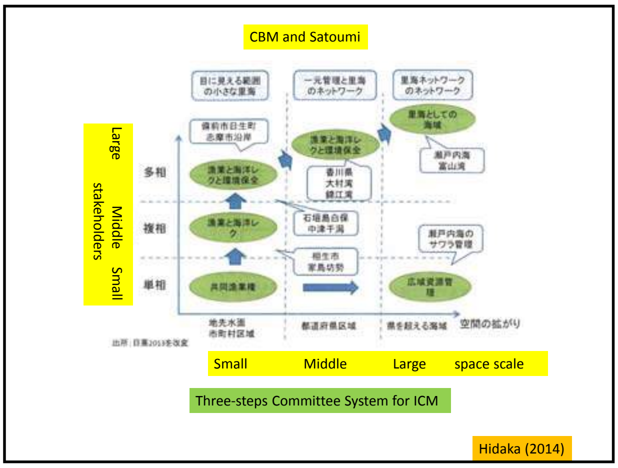


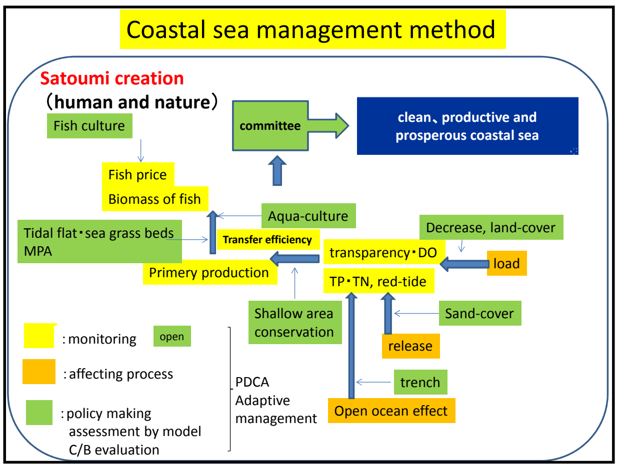


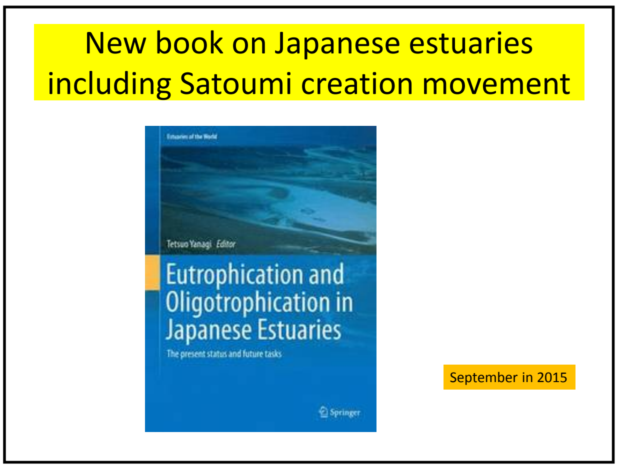

Integrated numerical model（Land＋Sea、Natural＋Social Sciences）
Air
fault
denitrification
land
Land cover・disaster
population・industry・
Unit load
load
coastal sea
Material cycling・
ecosystem
biodiversity・productivity
conservation・utilization
flow out
open ocean
variability
sinking
release
Sea bottom
sedimentation
Boundary condition


EBM and Satoumi
Clean and productive coastal sea（１）
mgC/m²/day
Primary production in the euphotic layer
（water column）
Hir.
Ha.
O
Hiu.
I
B
H
S
A
Transparency
橋本ら(1996)
多田（1996）
water 400－2200mgC m² day⁻¹ 多田（2006）
Tidal flat 300－3000 mgC m⁻² day⁻¹ 門谷（2014）
sea-grass beds ２－40 mgC m⁻² day⁻¹、橋本ら（2009）
(mgC/m²/day)
Primary production
（water＋bottom）
m
eutrophic
oligotrophic
low
transparency
high
high
nutrient
low
水清ければ魚棲まず→きれいすぎる水に魚棲まず
→汚い水に魚棲まず（赤潮・貧酸素）
→ 水が清くて魚棲む
生物多様性：住処整備・植生の極相化防止
太く長く滑らかな物質循環


EBM and Satoumi
Clean and productive coastal sea（２）
Shizukawa
Toyama
PRIMARY PRODUCTION, gC m⁻² yr⁻¹
FISHERIES YIELD
Primary production and fish catch
High transfer efficiency is necessary
（e.g.no hypoxia）
High bio-diversity is necessary
：thich、long、smooth material cycling
Left figure: only fish catch
We will include aquaculture without bait (Oyster, scallop and sea-weed)
Sustainable fisheries


CBM and Satoumi
Large
Middle
Small
stakeholders
多相
複相
単相
空間の拡がり
Small
Middle
Large
space scale
Three-steps Committee System for ICM
Hidaka (2014)


Coastal sea management method
Satoumi creation
（human and nature）
Fish culture
committee
clean、productive and prosperous coastal sea
Fish price
Biomass of fish
Aqua-culture
Decrease, land-cover
Tidal flat・sea grass beds
MPA
Transfer efficiency
transparency・DO
load
Primery production
TP・TN, red-tide
Shallow area conservation
Sand-cover
release
trench
Open ocean effect
：monitoring
open
：affecting process
：policy making
assessment by model
C/B evaluation
PDCA
Adaptive
management


New book on Japanese estuaries
including Satoumi creation movement
Tetsuo Yanagi Editor
Eutrophication and Oligotrophication in Japanese Estuaries
The present status and future tasks
Springer
September in 2015

K2: Relating accelerated melting of Tibetan ice shield with estuaries and continental shelves

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Abstract

All the world's mountains higher than 7,000m are in Asia and all peaks above 8,000m are in the Himalayas and Korakorams. With an average elevation of more than 4,000m, the Tibetan Plateau is the largest high-elevation region of the world, and contains as much ice and snow as each of the poles. The glaciers of the plateau are the source of most of Asia's great rivers: the Ganga, Indus, Brahmaputra, Ayeyarwadi, Salween, Mekong, Yangtze and Huanghe Rivers. Indeed, one of the most important services from mountain ecosystems is the provision of freshwater.

The mountain hydrology, and for that matter, the water supply to over a billion people downstream of rivers originated from the Tibetan Plateau, is directly affected by changes in climate, by land use and land cover change, and by variations in the cryosphere. Variations in the quality and quantity of freshwater and sediment supply to the adjacent areas impact on goods and services such as slope stability of river banks, biodiversity on land and in the riparian and aquatic systems, transportation, as well as food and energy production. Hence both climate variability and human pressure have an impact on the Tibetan Plateau and its role as "water towers" for the surrounding regions.

Precipitation is of course the primary driver for hydrological processes but here I focus on the effect of global warming and the retreat of glaciers. Increased runoff and sediments carried with it due to enhanced meting of ice are beneficial to many ecosystems and humans through increased water, energy and nutrient supplies. On the other hand, more floods, increased mud slides, and accelerated filling of dams and waterways downstream are envisioned.

Overall, increased discharge of melt water probably does not increase the flux of dissolved material to the estuaries and oceans very much because the concentration of many dissolved species is merely diluted by the meltwater. However, the flux of particulate matter is likely to increase, exponentially, due to increased melt water flux at the beginning of the snow-melt season, especially in the event of a breach of ice dam from a large lake. As a result, the downstream reparian system and the delta will receive increased sediment influx leading to enhanced deposition. But, as the snow and ice masses decrease both freshwater and particulate matter outflows will decrease to below the current level, resulting in greater pressure on water resources, food supply to aquatic biota, and on shoreline defense at the delta.

In addition, continental shelves are likely to be affected as well because more melt water results in higher buoyancy which tends to increase the outflow of surface water on the shelves. As a consequence, more nutrient-rich subsurface waters from offshore will be upwelled onto the continental shelves, hence inducing higher primary productivity and fish catch. Once the melt water dwindles, however, the buoyancy on the shelves will decrease, resulting in reduced primary productivity and fish catch.歗

Relating accelerated melting of Tibetan ice shield with estuaries and continental shelves

Chen-Tung Arthur Chen

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http://www.mgac.nsysu.edu.tw/ctchen/Publications--2015-0915v.htm

1

Coastal Zone:

- freshwater and food resources
- gentle terrain for settlements and agriculture transportation
- 40-60% of the global population

2

21st Century Water War

3

Tibetan Ice Sheet

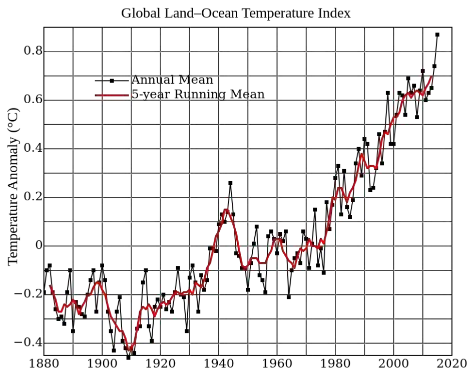
•Largest repository of freshwater after the two poles

•Sources of major rivers: Yellow, Yangtze, Mekong, Salween, Irrawaddy, Brahmaputra.

4

Taken from http://www.21stcentech.com/wp-content/uploads/2013/09/map_rivers_tibet11.png

5



Taken from https://en.wikipedia.org/wiki/Global_warming

Global mean surface temperature change from 1880 to 2015, relative to the 1951–1980 mean. The black line is the annual mean and the red line is the 5-year running mean. Source: NASA GISS.

6

Stronger and more frequent typhoons!

7

After Typhoon Morakot
(The hotel of Xiaolin Village collapsed into the river)
莫拉克颱風(小林村飯店倒下)

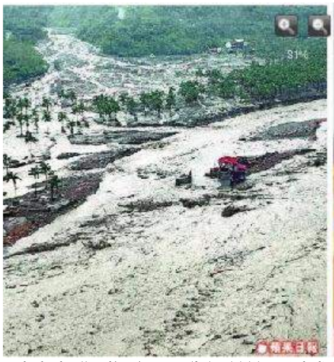
8

The circled area was totally destroyed.

Taken from http://ipobar.com/read.php?tid-75888.html

9

Xiaolin Village (小林村)



Taken from http://mag.chinareviewnews.com/doc/1010/4/4/6/101044672.html?coluid=23&kindid=292&docid=101044672&mdate=0811102225

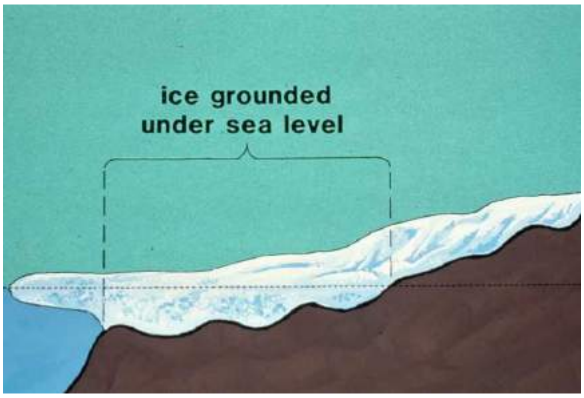
10

The flooding at Linbian Township
(林邊淹水)

11

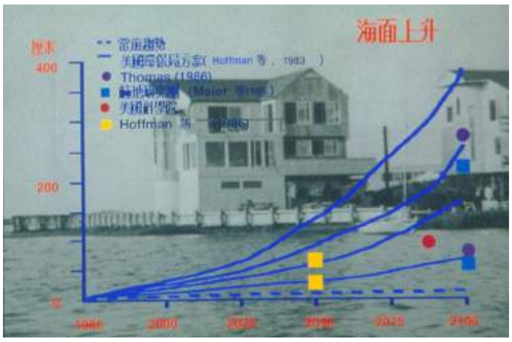
Taken from http://travel.xytcn.com/lyimg/%E7%8E%89%E9%BE%99%E9%9B%AA%E5%B1%B1_2.jpg

12



13

Sealevel Rise



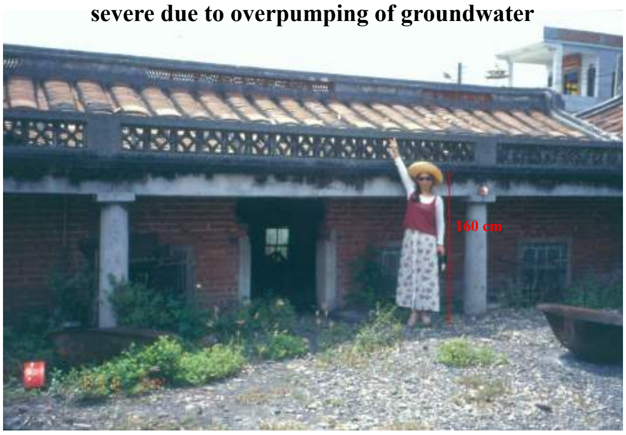
14

15

16

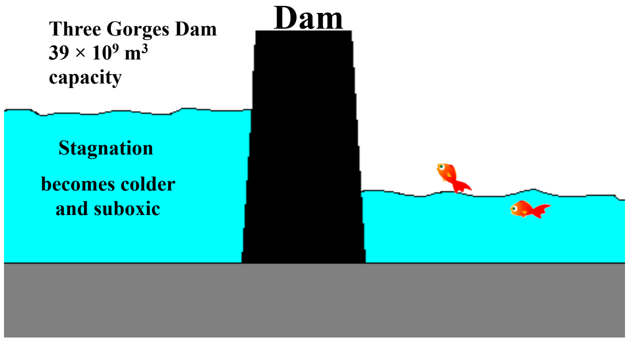
17

A house in an area where land subsidence is severe due to overpumping of groundwater



Qutang Xia Gorge, one of the Three Gorges (taken by the author in 1992)

19



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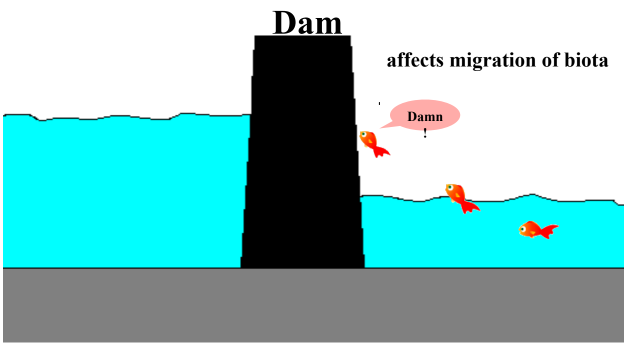
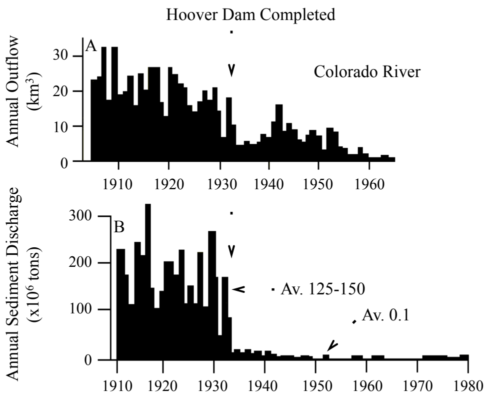


21

Severe denudation upstream of the Three Gorges Dam (taken by the author in 1998).

22



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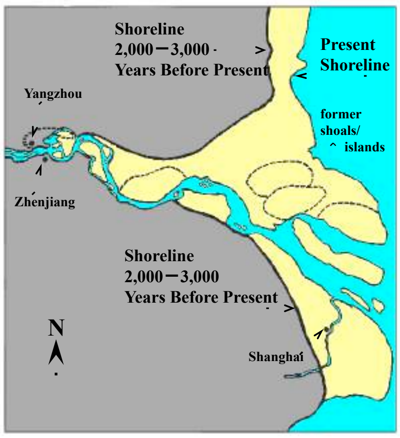


24

In the Near Future

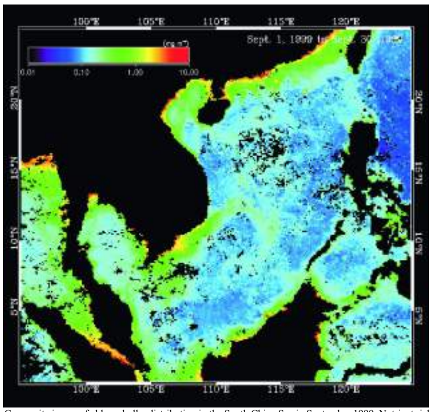
- Freshwater (Food/Energy): increased.
- Nutrients: dissolved, lower concentration but not much change in flux; particulate, increased concentration and flux.
- Sediments: increased concentration and flux, bad for dams but good for deltas.
- Burst of ice dams: flooding.
- Buoyancy effect on continental shelves: increased.

25

Longer Term

- Nutrients: dissolved, higher concentration but not much change in flux; particulate, decreased concentration and flux.
- Sediments: decreased concentration and flux, bad for deltas.
- Buoyancy effect on continental shelves: reduced.

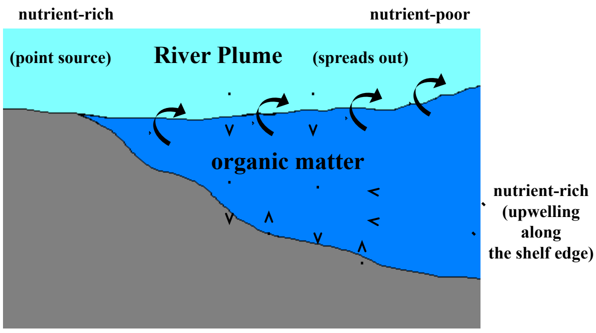
26



Composite image of chlorophyll a distribution in the South China Sea in September 1999. Nutrient rich waters, where primary production is high, are visible as green areas along the coasts of SE Asia. Derived from SeaWiFS data provided by NASA. Data and image processing done by C. Hu of USF and I-I Lin and C. Lian of National Center for Ocean Research, Taipei (courtesy K.K. Liu).

27

Buoyancy Effect



A typical river plume generates upwelling of nutrient-rich subsurface waters.

28

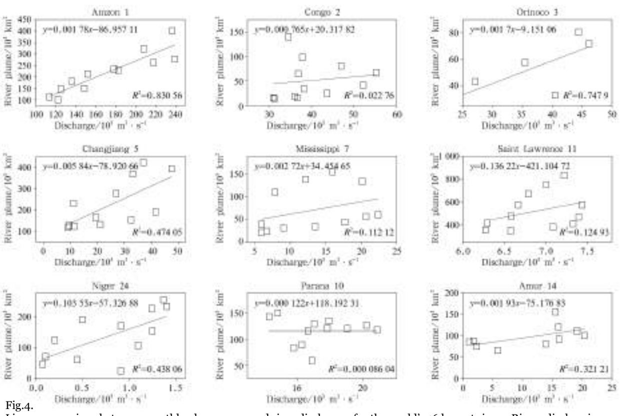


Fig.4.
Linear regressions between monthly plume areas and river discharges for the world's 16 largest rivers. Rivers discharging into the Arctic Ocean are excluded. The number next to the river name denotes its rank in terms of discharge.

Taken from: Kang, Y., D. L. Pan*, Y. Bai, X.Q. He, X.Y. Chen, **C.T.A. Chen**, D.F. Wang (2013), Areas of the global major river plumes, Acta Oceanologica Sinica, 32 (1), 79-88, doi: 10.1007/s13131-013-0269-5

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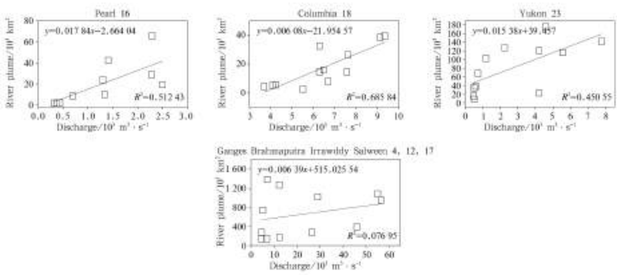

(Cont.) Fig.4.
Linear regressions between monthly plume areas and river discharges for the world's 16 largest rivers. Rivers discharging into the Arctic Ocean are excluded. The number next to the river name denotes its rank in terms of discharge.

Taken from: Kang, Y., D. L. Pan*, Y. Bai, X.Q. He, X.Y. Chen, **C.T.A. Chen**, D.F. Wang (2013), Areas of the global major river plumes, Acta Oceanologica Sinica, 32 (1), 79-88, doi: 10.1007/s13131-013-0269-5

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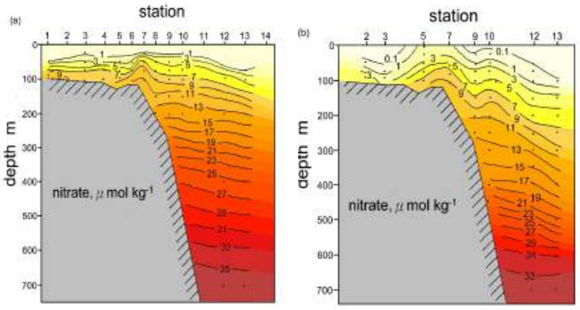
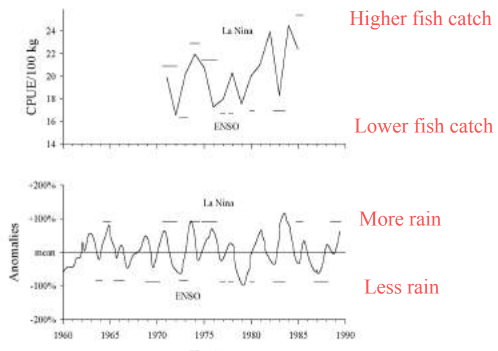


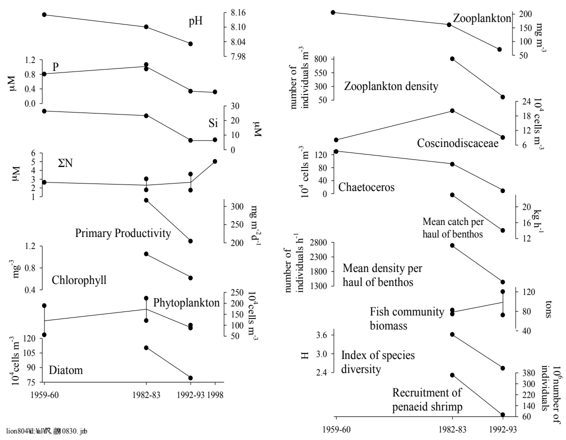
Cross-section of nitrate in (a) September 1988 and in (b) December 1989.

31



Anomalies of the Changjiang River outflow and the Catch Per Unit Effort in the East China Sea (modified from Lin et al., 1995)

32



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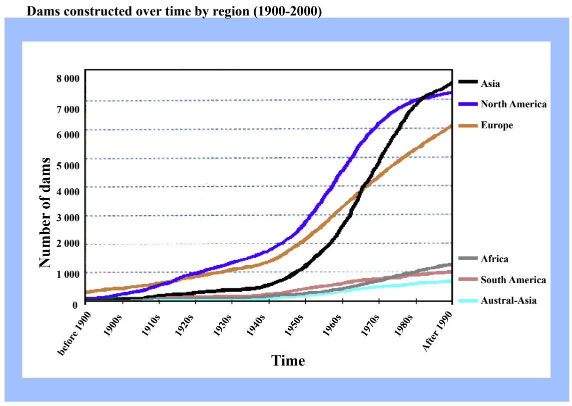


Source: ICOLD, 1998. Note: Information excludes the time-trend of dams in China

34

Xiaolangdi Reservoir, Yellow River,
05/19/2001

35

FACTS:

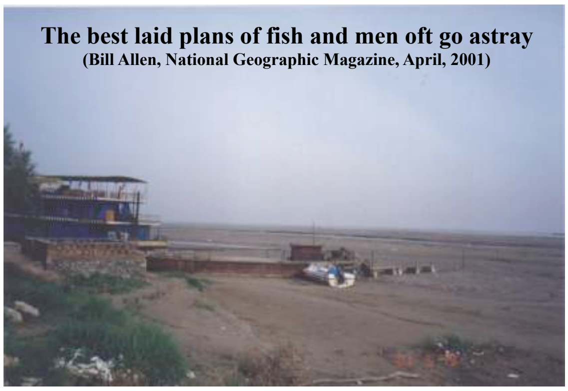
- The number of large dams has increased sevenfold since 1950 (Revenga et al., 2000)
- At least one large dam modifies 46% of the world's 106 primary watersheds (World Commission on Dams, 2000)
- More than 40% of global river discharge is already intercepted by the 663 of the world's largest reservoirs (Vorosmarty et al., 1997)

36

Resource Transfer

As a result of improvement by the Tucurui Dam in Amazonia, people downstream experienced a 45% drop in fish catches. In contrast, upstream and reservoir-area residents experienced 200 and 900% increases in fish catches respectively after commissioning of the dam.
(M. Niasse, 2002)

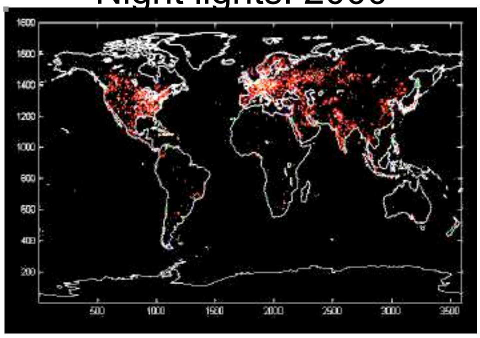
37



The last big bend where the southward flowing Yellow River turns eastward
(upstream of the Sanmenxia Reservoir, taken on 05/19/2001)

38

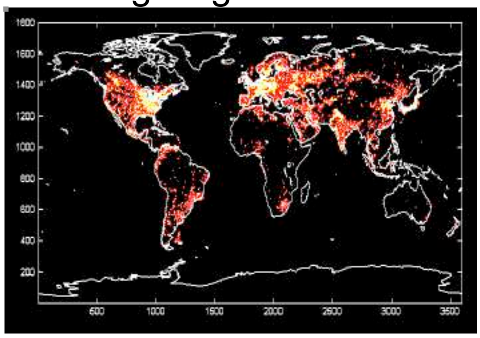
Night lights: 2000



Source: Nakicenovic et al., 2000, figure is on page 233.

39

Night lights: 2070



Source: Nakicenovic et al., 2000, figure is on page 233.

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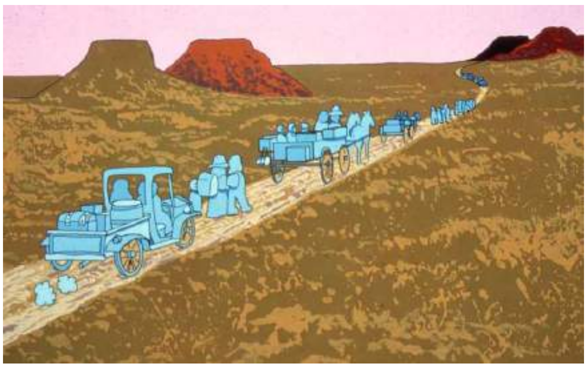

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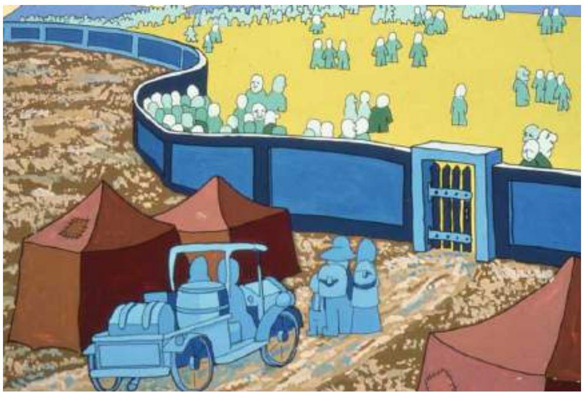

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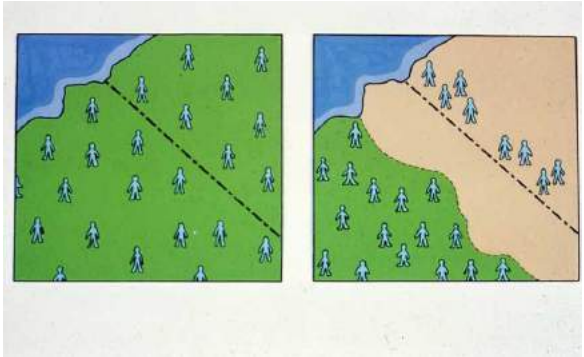

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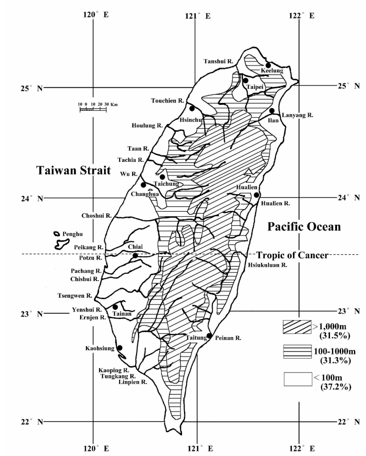

Fig. 1. Geographical map of Taiwan showing the terrain and major river.

Taken from Chen, C.T.A., Liu, J.T. & Tsuang, B. (2004). Regional Environmental Change, 4(1): 39-48. doi:10.1007/s10113-003-0058-3

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Table 1

Top 20 rivers ranked in terms of sediment yield for rivers originating from elevations above 3000 m.

River	Sed. yield (world rank[a]), T/km²/yr	Unit-area Runoff (world rank[a]), $\times 10^6$ T/km²/yr	River	Sed. yield (world rank[a]), T/km²/yr	Unit-area runoff (world rank[a]), $\times 10^6$ T/km²/yr
1. Peinan(Taiwan)	37,712(3)	1.900(99)	12. Ooi(Japan)	1462(63)	1.538(128)
2. Choshui(Taiwan)	32,278(4)	1.586(119)	13. Fly(Papua New Guinea)	1447(65)	2.368(47)
3. Taan(Taiwan)	30,562(5)	1.919(94)	14. Bengawan Solo(Indonesia)	1188(79)	938(280)
4. Kaoping(Taiwan)	22,468(7)	2.439(41)	15. Copper C. of Alaska(USA)	1111(84)	1.524(131)
5. Hoping(Taiwan)	21,454(8)	2.405(42)	16. Mira(Colombia)	1021(90)	2.842(22)
6. Tachia(Taiwan)	14,353(13)	1.998(88)	17. Chira(Peru)	1000(91)	250(N/A)
7. Lanyang(Taiwan)	6633(22)	2.857(21)	18. Rangitata(New Zealand)	889(100)	1.667(113)
8. Haast(New Ze aland)	6344(23)	6.452(3)	19. Bramaputra(Bangladesh)	806(107)	940(279)
9. Cimanuk(Indonesia)	4762(27)	1.048(233)	20. Tana(Kenya)	762(114)	112(N/A)
10. Tanshui(Taiwan)	4074(29)	2.593(31)			
11. Purari(Papua New Guinea)	2424(43)	2.576(32)	Pearl(China)[b]	97–328	531

[a] Numbers in parenthesis indicate world rankings for all rivers with a catchment area larger than 300 km² but regardless of the elevation at the source; Data taken from Lin (2010), Milliman and Farnsworth (2011).
[b] Listed for comparison (Zhang et al., 2008).

Taken from Lou, J.Y. et al. (2014). Comparison of subtropical surface water chemistry between the large Pearl River in China and small mountainous rivers in Taiwan. Journal of Asian Earth Sciences, 79 (A): 182-190, doi:10.1016/j.jseaes.2013.09.001.

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Table 2

Top 20 rivers ranked in terms of sediment yield for rivers with a unit-area runoff exceeding 1.8×10^6 T/km²/yr.

River	Sed. yield (world rank[a]), T/km²/yr	Unit-area runoff world rank[a]), $\times 10^6$ T/km²/yr	River	Sed. yield (world rank[a]), T/km²/yr	Unit-area Runoff (world rank[a]), $\times 10^6$ T/km²/yr
1. Jaba(New Zealand)	56,522(2)	2.826(23)	12. Lanyang(Taiwan)	6633(22)	2.857(21)
2. Peinan(Taiwan)	37,712(3)	1.900(99)	13. Haast(New Zealand)	6344(23)	6.452(3)
3. Taan(Taiwan)	30,562(5)	1.919(94)	14. Speel Pacific(USA)	4138(28)	5.345(4)
4. Hualien(Taiwan)	27,277(6)	2.191(55)	15. Tanshui(Taiwan)	4074(29)	2.593(31)
5. Kaoping(Taiwan)	22,468(7)	2.439(41)	16. Houlung(Taiwan)	3617(31)	1.915(95)
6. Hoping(Taiwan)	21,454(8)	2.405(42)	17. Rewa(Fiji)	3448(34)	2.069(73)
7. Hokitika(New Ze aland)	17,714(10)	8.857(1)	18. Wu(Taiwan)	3400(35)	1.850(103)
8. Hsiukuluan(Taiwan)	17,196(12)	2.145(61)	19. Skafta(Iceland)	2667(40)	2.400(43)
9. Tachia(Taiwan)	14,353(13)	1.998(88)	20. Motu(New Zealand)	2500(41)	2.000(80)
10. Tungkang(Taiwan)	11,064(14)	2.340(51)			
11. Linpien(Taiwan)	8,080(18)	2.517(35)	Pearl(China)[b]	97–328	531

[a] Numbers in parenthesis indicate world rankings for all rivers with a catchment area larger than 300 km² but regardless of the unit area runoff; Data taken from Lin (2010), Milliman and Farnsworth (2011).
[b] Listed for comparison (Zhang et al., 2008).

Taken from Lou, J.Y. et al. (2014). Comparison of subtropical surface water chemistry between the large Pearl River in China and small mountainous rivers in Taiwan. Journal of Asian Earth Sciences, 79 (A): 182-190, doi:10.1016/j.jseaes.2013.09.001.

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Table 3
Top 20 rivers[a] in the world ranked in terms of sediment yield (T/km²/yr).

River	Sed. Yield, T/km²/yr	River	Sed. yield (T/km²/yr)
1. Jaba(Bougainville)	56,522	12. Hsiukuluan(Taiwan)	17,196
2. Erhjen (Taiwan)	45,772	13. Tachia(Taiwan)	14,353
3. Peinan(Taiwan)	37,712	14. Tungkang(Taiwan)	11,064
4. Choshui(Taiwan)	32,278	15. Uawa(New Zealand)	9091
5. Taan(Taiwan)	30,562	16. Waitaha(New Zealand)	8750
6. Hualien(Taiwan)	27,277	17. Whataroa(New Zealand)	8136
7. Kaoping(Taiwan)	22,468	18. Linpien(Taiwan)	8080
8. Hoping(Taiwan)	21,454	19. Arawata(New Zealand)	7742
9. Waiapu(New Zealand)	20,588	20. Agrioun(Algeria)	7273
10. Hokitika(New Zealand)	18,000		
11. Tsengwen(Taiwan)	17,590	Pearl(China)[b]	97-328

[a] Only rivers with a catchment area larger than 300 km² are ranked; Data taken from Liu (2010) and Milliman and Farnsworth (2011).
[b] Listed for comparison (Zhang et al., 2008).

Taken from Lou, J.Y. et al. (2014). Comparison of subtropical surface water chemistry between the large Pearl River in China and small mountainous rivers in Taiwan. Journal of Asian Earth Sciences, 79 (A): 182-190, doi:10.1016/j.jseaes.2013.09.001. 49

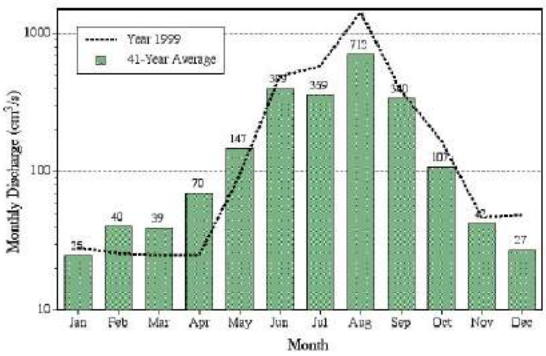


Fig. 2. Mean monthly discharge of the Kaoping River and the monthly discharge for 1999 and the first three months of 2000 (data from Water Resources Bureau).

Taken from Chen, C.T.A., Liu, J.T. & Tsuang, B. (2004). Regional Environmental Change, 4(1): 39-48. doi:10.1007/s10113-003-0058-3 50

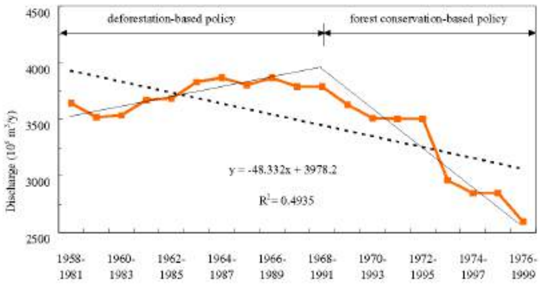


Fig. 5. Projected annual sediment discharge of a flood of 100-year return frequency on a tributary of the Kaoping River. The two solid lines show one increasing and one decreasing trend, and the dashed line shows the long-term decreasing trend.

Taken from Chen, C.T.A., Liu, J.T. & Tsuang, B. (2004). Regional Environmental Change, 4(1): 39-48. doi:10.1007/s10113-003-0058-3 51

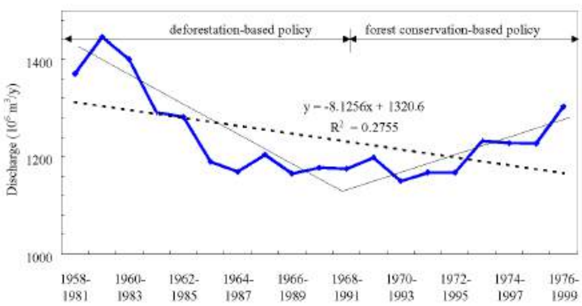


Fig. 6. Projected annual discharge of 100-yr drought on a tributary of the Kaoping River. The two solid lines show one decreasing and one increasing trend, and the dashed line shows the long-term decreasing trend.

Taken from Chen, C.T.A., Liu, J.T. & Tsuang, B. (2004). Regional Environmental Change, 4(1): 39-48. doi:10.1007/s10113-003-0058-3 52

Figure 7 Annual harvested volume of lumber (COA, 2000).

Taken from Chen, C.T.A., Liu, J.T. & Tsuang, B. (2004). Regional Environmental Change, 4(1): 39-48. doi:10.1007/s10113-003-0058-3 53

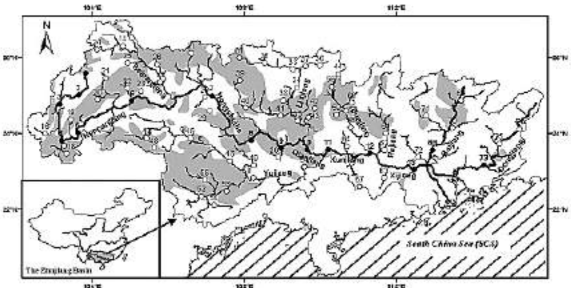


Figure 1.
The Zhujiang (Pearl River) Basin and the location of sampling stations. The thick lines represent the main channel of the three main rivers in the Zhujiang Basin, the Xijiang, Beijiang and Dongjiang, and the thin lines represent the tributaries. The solid circles represent the main channel stations (the Xijiang: 1. Zhanyi; 2. Xiqiao; 3. Gaoguma; 4. Xiaolongtan; 5. Jiangbianjie; 6. Bajie; 7. Longtan; 8. Du'an; 9. Qianjiang; 10. Wuxuan; 11. Dahuangjiangkou; 12. Wuzhou; 13. Gaoyao; the Beijiang: 68. Shijiao; the Dongjiang: 73. Boluo) and the open circles represent the tributary stations. The shadowed areas indicate the distribution of carbonate rocks in the basin.

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 54

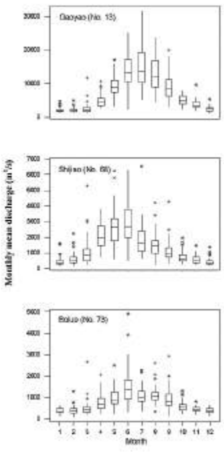


Figure 2.
Monthly variation of water discharge of the Zhujiang (average for the period of 1958–2002) at station Gaoyao (number 13), Shijiao (number 68) and Boluo (number 73), which are the most downstream stations of Xijiang, Beijiang and Dongjiang, respectively.

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 55

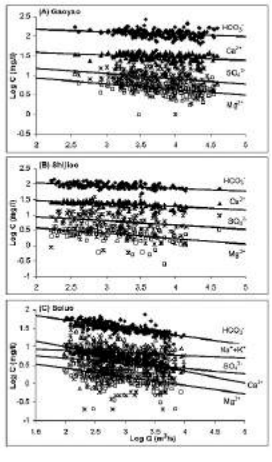


Figure 7.
Plots of the relationship between major ions and water discharge in logarithmic scales at (a) Gaoyao, (b) Shijiao, and (c) Boluo (only ions statistically significant at the significance level of 0.05 in Table 5 were plotted).

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 56

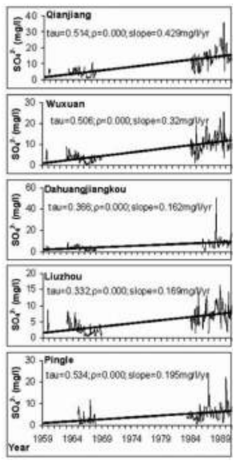


Figure 12.
Significant increasing trends of SO_4^{2-} at station Qianjiang (number 9), Wuxuan (number 10), Dahuangjiangkou (number 11), Liuzhou (number 35), and Pingle (number 57) during the period of 1958–1990.

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 57

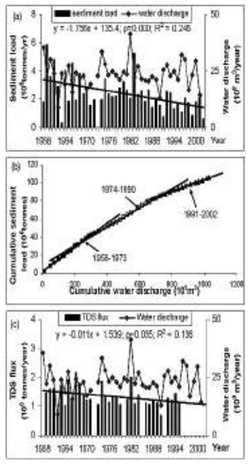


Figure 13.
(a) Long-term trend of annual sediment load at station Boluo, (b) double mass plot of cumulative annual sediment load versus cumulative annual water discharge at station Boluo, and (c) long-term trend of annual TDS flux at station Boluo.

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 58

Table 6. Summary Information of Large and Medium Reservoirs Constructed in the Zhujiang Basin[a]

	Large Reservoir[b]		Medium Reservoir[c]		Total	
Water System	Number	Storage Capacity, $10^9 m^3$	Number	Storage Capacity, $10^9 m^3$	Number	Storage Capacity, $10^9 m^3$
Xijiang	24	14.7	212	6	236	20.6
Beijiang	6	3.8	41	1.2	47	5
Dongjiang	4	17.2	35	0.8	39	18
the Pearl Delta	5	1.5	60	1.6	65	3.1
Total	39	37.2	348	9.6	387	46.7

[a]From Pearl River Water Resources Committee (PRWRC) Web site http://www.pearlwater.gov.cn/index.jsp).
[b]Capacity of large reservoirs is over 10^8 m^3.
[c]Capacity of the medium reservoirs is from 10^7 million to 10^8 million m^3.

Taken from: Zhang, S.-R., X. X. Lu, D. L. Higgitt, **C.-T. A. Chen**, H.-G. Sun, and J.-T. Han (2007), Water chemistry of the Zhujiang (Pearl River): Natural processes and anthropogenic influences, J. Geophys. Res., 112, F01011, doi:10.1029/2006JF000493. 59

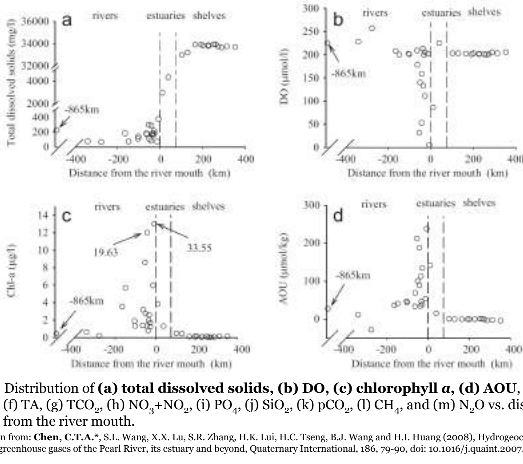
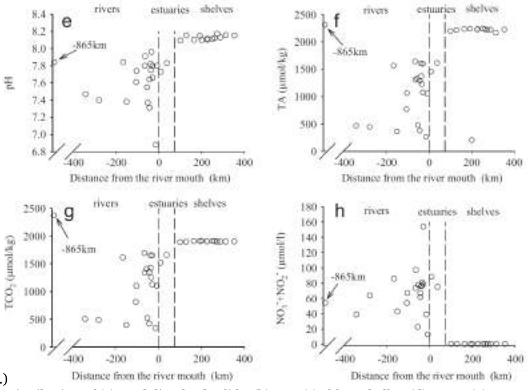


Fig. 3. Distribution of **(a) total dissolved solids, (b) DO, (c) chlorophyll *a*, (d) AOU**, (e) pH, (f) TA, (g) TCO_2, (h) NO_3+NO_2, (i) PO_4, (j) SiO_2, (k) pCO_2, (l) CH_4, and (m) N_2O vs. distance from the river mouth.

Taken from: **Chen, C.T.A.***, S.L. Wang, X.X. Lu, S.R. Zhang, H.K. Lui, H.C. Tseng, B.J. Wang and H.I. Huang (2008), Hydrogeochemistry and greenhouse gases of the Pearl River, its estuary and beyond, Quaternary International, 186, 79-90, doi: 10.1016/j.quaint.2007.08.024. 60



(Cont.)
Fig. 3. Distribution of (a) total dissolved solids, (b) DO, (c) chlorophyll *a*, (d) AOU, **(e) pH, (f) TA, (g) TCO_2, (h) NO_3+NO_2,** (i) PO_4, (j) SiO_2, (k) pCO_2, (l) CH_4, and (m) N_2O vs. distance from the river mouth.

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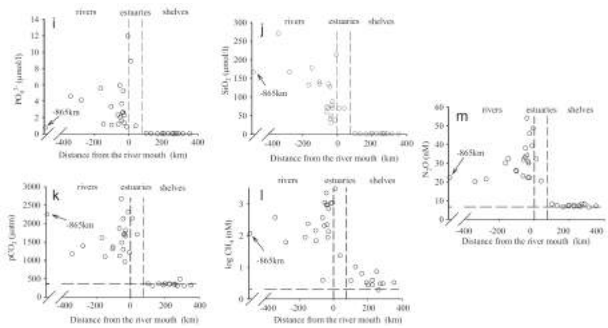


(Cont.)
Fig. 3. Distribution of (a) total dissolved solids, (b) DO, (c) chlorophyll *a*, (d) AOU, (e) pH, (f) TA, (g) TCO_2, (h) NO_3+NO_2, **(i) PO_4, (j) SiO_2, (k) pCO_2, (l) CH_4, and (m) N_2O** vs. distance from the river mouth.

Taken from: **Chen, C.T.A.***, S.L. Wang, X.X. Lu, S.R. Zhang, H.K. Lui, H.C. Tseng, B.J. Wang and H.I. Huang (2008), Hydrogeochemistry and greenhouse gases of the Pearl River, its estuary and beyond, Quaternary International, 186, 79-90, doi: 10.1016/j.quaint.2007.08.024. 62

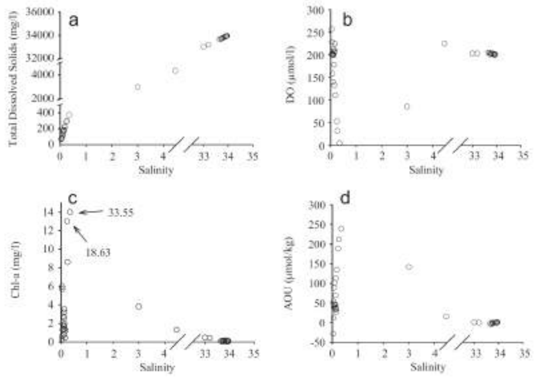
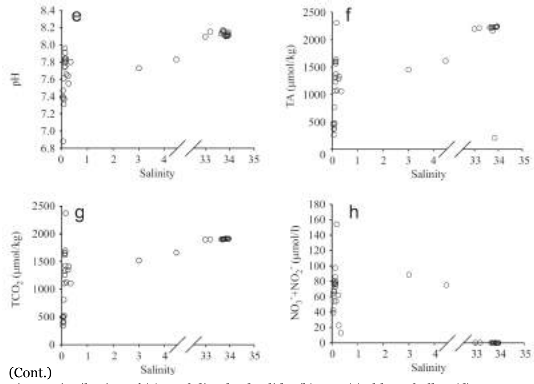


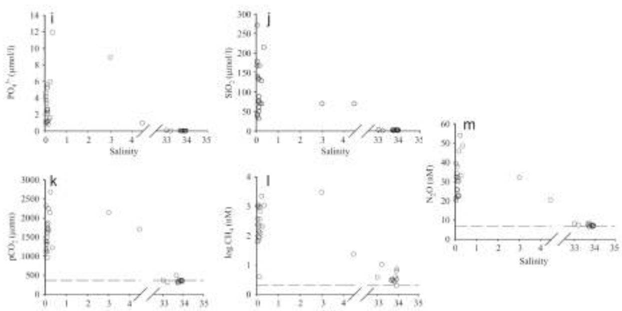
Fig. 4. Distribution of **(a) total dissolved solids, (b) DO, (c) chlorophyll *a*, (d) AOU**, (e) pH, (f) TA, (g) TCO_2, (h) NO_3+NO_2, (i) PO_4, (j) SiO_2, (k) pCO_2, (l) CH_4, and (m) N_2O vs. salinity from the river mouth.

Taken from: **Chen, C.T.A.***, S.L. Wang, X.X. Lu, S.R. Zhang, H.K. Lui, H.C. Tseng, B.J. Wang and H.I. Huang (2008), Hydrogeochemistry and greenhouse gases of the Pearl River, its estuary and beyond, Quaternary International, 186, 79-90, doi: 10.1016/j.quaint.2007.08.024. 63



(Cont.)
Fig. 4. Distribution of (a) total dissolved solids, (b) DO, (c) chlorophyll *a*, (d) AOU, **(e) pH, (f) TA, (g) TCO_2, (h) NO_3+NO_2,** (i) PO_4, (j) SiO_2, (k) pCO_2, (l) CH_4, and (m) N_2O vs. salinity from the river mouth.

Taken from: **Chen, C.T.A.***, S.L. Wang, X.X. Lu, S.R. Zhang, H.K. Lui, H.C. Tseng, B.J. Wang and H.I. Huang (2008), Hydrogeochemistry and greenhouse gases of the Pearl River, its estuary and beyond, Quaternary International, 186, 79-90, doi: 10.1016/j.quaint.2007.08.024. 64



(Cont.)
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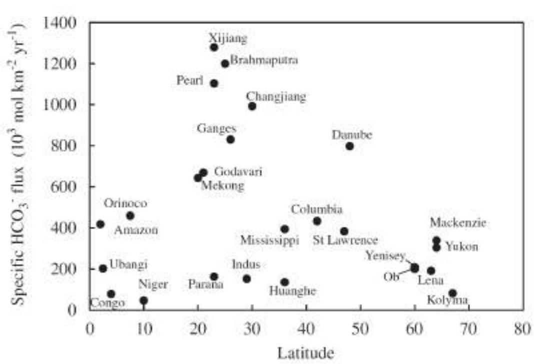

Fig. 2. Latitudinal distribution of specific fluxes of riverine bicarbonate.

Taken from: Cai, W.J.*, X.H. Guo, **C.T.A. Chen**, M.H. Dai, L.J. Zhang, W.D. Zhai, S.E. Lohrenz, K. Yin, P.J. Harrison and Y.C. Wang (2008), A comparative overview of weathering intensity and HCO_3^- flux in the world's largest rivers with emphasis on the Changjiang, Huanghe, Zhujiang (Pearl) and Mississippi Rivers, Continental Shelf Research, 28, 1538-1549, doi: 10.1016/j.csr.2007.10.014. 66

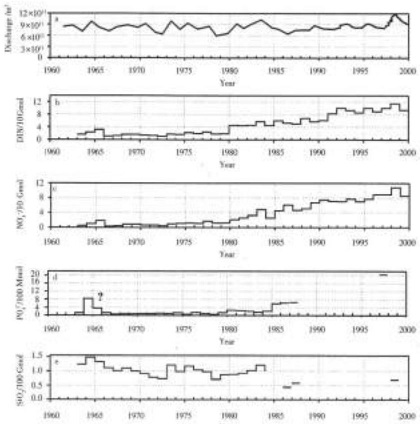

Fig. 1. Annual fluxes of (a) water; (b) DIN; (c) NO3; (d) PO4 and (e) SiO2 of the Changjiang (Data taken from Shen, 2000a, b; Shen *et al.*, 2001; Li *et al.*, 2007). Since the DIN data are not continuous but those of NO3 are, the latter is also shown.

Taken from: **Chen, C.T.A.* (Arthur, C.C.T) (2008),** Buoyancy leads to high productivity of the Changjiang Diluted Water: a note, Acta Oceanologica Sinica, 27 (6), 133-140.

67

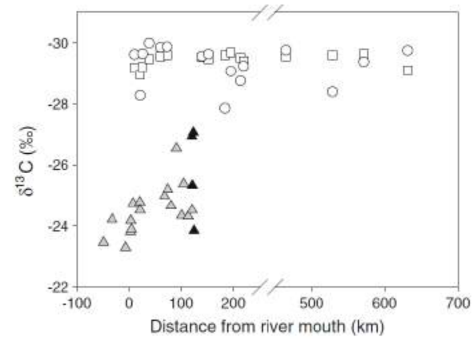

Fig. 3 δ^{13}C values for the Kaoping and Kapuas Rivers. Open squares represent the Kapuas River during June–July 2007 sampling; open circles represent the Kapuas River during Dec 2007–Jan 2008 sampling; filled triangles (black) represent the tributaries draining into the Kaoping River; and shaded triangles (gray) represent the mainstream of the Kaoping River and three locations along its coastal zone.

Taken from: Loh, P.S.*, **C.T.A. Chen**, J.Y. Lou, G.Z. Anshari, H.Y. Chen and J.T. Wang (2012), Comparing lignin-derived phenols, δ^{13}C values, OC/N ratio and ^{14}C age between sediments in the Kaoping (Taiwan) and the Kapuas (Kalimantan, Indonesia) Rivers, Aquatic Geochemistry, 18 (2), 141-158, doi: 10.1007/s10498-011-9153-0.

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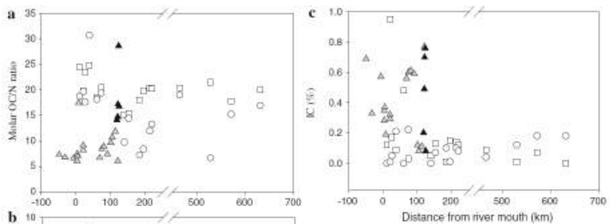

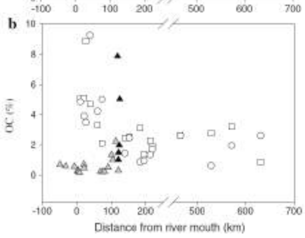

Fig. 4 a molar OC/N ratios,b %OC and c %IC for the Kaoping and Kapuas Rivers. Open squares represent the Kapuas River during June–July 2007 sampling; open circles represent the Kapuas River during Dec 2007–Jan 2008 sampling; filled triangles (black) represent the tributaries draining into the Kaoping River; and shaded triangles (gray) represent the mainstream of the Kaoping River and three locations along its coastal zone

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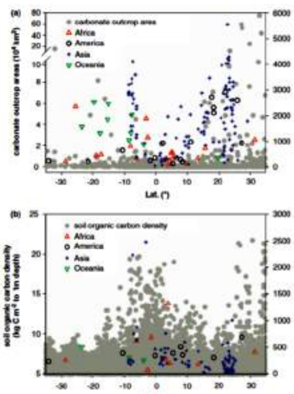

Figure 3.
Latitudinal distribution of (a) DIC and carbonate outcrop areas (data from http://web.env.auckland.ac.nz/our_research/karst/) and (b) DOC concentrations and soil organic carbon density.

Taken from: Huang, T.H., Y.H. Fu, P.Y. Pan and **C.T. A. Chen*** (2012), Fluvial carbon fluxes in tropical rivers, Current Opinion in Environmental Sustainability, 4 (2), 162–169, doi: 10.1016/j.cosust.2012.02.004.

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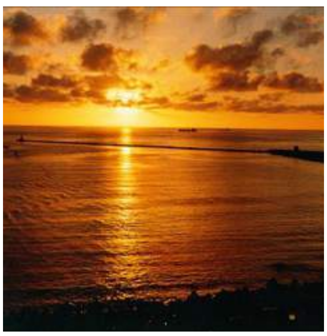
Welcome to visit National Sun Yat-sen University



Taken from http://www.uu1.com/sight/cq1486.html

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L1: River Discharge

Kenji Tanaka (*Disaster Prevention Research Institute, Kyoto University*)

Abstract

River discharge is an important source of freshwater supply to oceans. According to the global estimates, precipitation over oceans is approximately 391 thousand Gt per year, while river discharge is approximately 45.5 thousand Gt per year. Amount of river discharge changes greatly as consequences of climate, vegetation, soil type, drainage basin relief and the human activities, etc. As river discharge is not measured at all rivers, hydrological model is necessary to estimate the global freshwater supply from global land areas to oceans. There are various kinds of hydrological models to calculate river discharge. In some applications focusing on peak discharge analysis or flood forecasting, land surface processes can be neglected. As the time and spatial scale increases, land surface processes become more and more important, especially, in the area where evapotranspiration is a dominant component.

In this training course, in-land water cycle model which consists of land surface model, river routing model, irrigation model, reservoir operation model is introduced to show you how time and spatial distribution of river discharge is calculated. Current achievement, difficulties, new challenges in large scale model are introduced.

26th IHP Training Course (2016/11/28)

Lecture 1
River Discharge

Kenji Tanaka
Water Resources Research Center
Disaster Prevention Research Institute,
Kyoto University, Japan

River Discharge

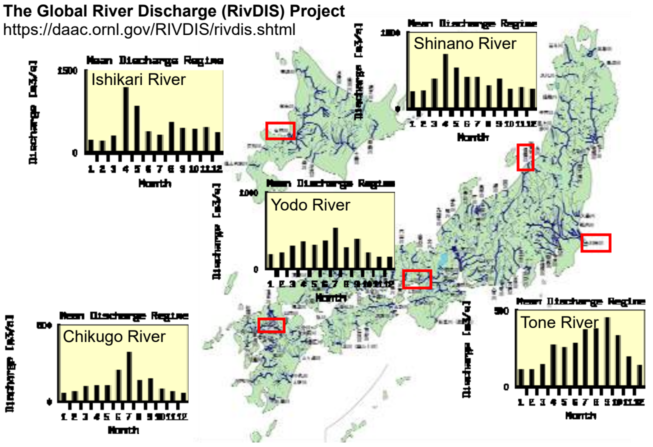
River discharge is the volume of water flowing through a river channel. This is the total volume of water flowing through a channel at any given point. The discharge from a drainage basin depends on precipitation, evapo-transpiration and storage.

Drainage basin discharge =
precipitation – evapotranspiration +/- storage change

The volume of the discharge will be determined by factors such as climate, vegetation, soil type, drainage basin relief and the human activities.

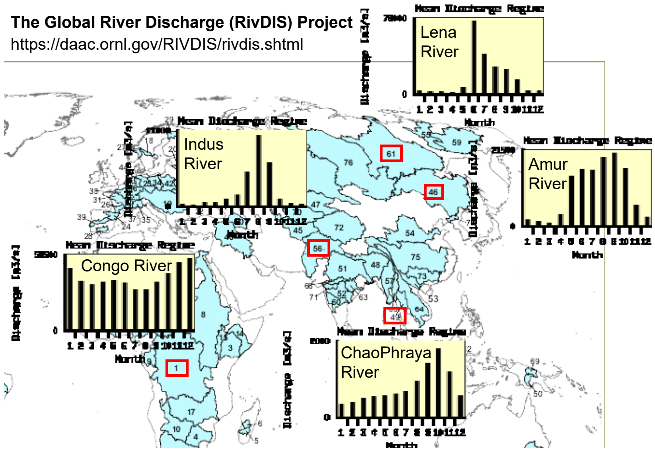
Example of monthly River Discharge (Japan)

The Global River Discharge (RivDIS) Project
https://daac.ornl.gov/RIVDIS/rivdis.shtml



Example of monthly River Discharge (World)

The Global River Discharge (RivDIS) Project
https://daac.ornl.gov/RIVDIS/rivdis.shtml



Climate Indicator
(Aridity Index & Evaporation Ratio)

Annual evapotranspiration approaches annual precipitation in arid and semi-arid regions where the available energy greatly exceeds the amount required to evaporate annual precipitation.

Evapotranspiration is a key information for water management in the region where available water resources are limited.

Aridity Index

Energy balance $\dfrac{R_{net}}{L\,P}$

Evaporation Ratio

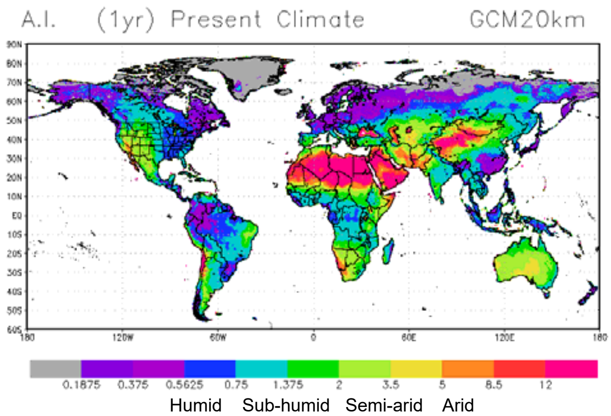
Water balance $\dfrac{E}{P}$

5 < AI < 12	Arid	
2 < AI < 5	Semi Arid	
0.75 < AI < 2	Sub Humid	
0.375 < AI < 0.75	Humid	

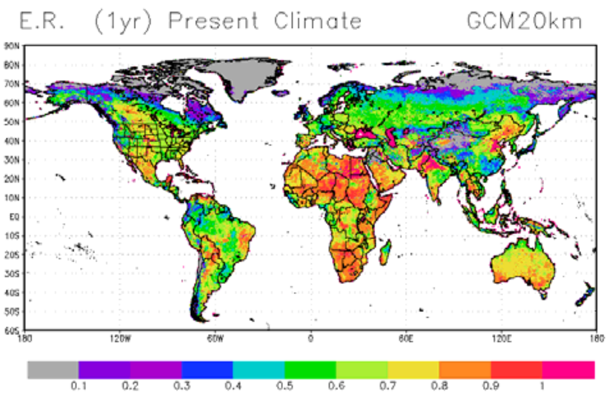
(Ponce et al. 2000)

R_{net}: annual mean net radiation
P : annual precipitation
L : latent heat of vaporization
E : annual evapotranspiration

Global Distribution of Aridity Index (AI)

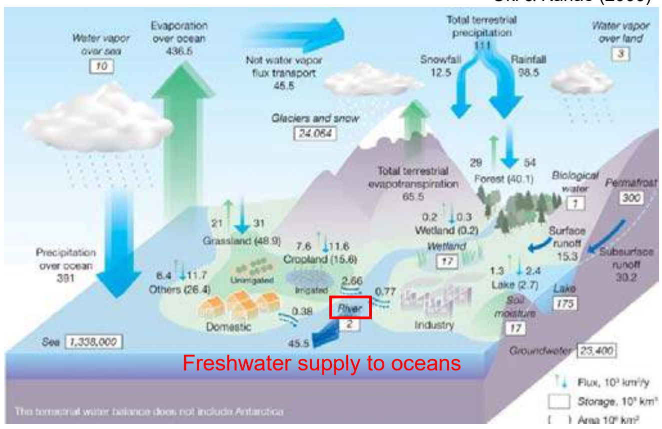


Global Distribution of Evaporation Ratio (ER)



Global Hydrological Cycle

Oki & Kanae (2006)



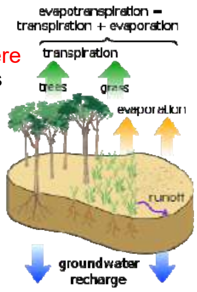
Land Surface Process

"Land surface processes are those associated with the exchange of water and energy between the land surface and the atmosphere and are, therefore, integral components of hydrologic and atmospheric sciences."
(by Bill Crosson (NASA MSFC))

integral components of hydrologic, atmospheric, and ocean sciences

Hydrological Cycle
from GEWEX home page

Water budget



- Water is exchanged between the atmosphere and the land surface through the processes of precipitation, evaporation, and transpiration.
- Water is exchanged between the land surface and ocean/lake through runoff.

- $\Delta S = P - E - R$

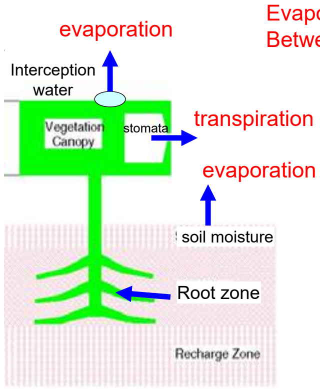
P : precipitation(rain/snow) input from atmosphere
E : water vapor flux by evaporation and transpiration
R : runoff flux by river system and ground water system
ΔS : change in the surface water and soil moisture

Energy budget

- Rn is partitioned into fluxes of sensible, latent, and ground heat.
- This partitioning is strongly dependent on both the land cover characteristics (landuse) and its hydrological state (wet/dry).
- Why energy partitioning is important?

$Rn = H + \lambda E + G$
H → heating lower atmosphere
λE → heating middle atmosphere
G → surface (time lag between RB & EB)

Evapotranspiration = Evaporation + Transpiration



Evapotranspiration is an interface
Between water cycle and energy cycle

Water cycle:
Rainfall reached to surface go back to atmosphere as water vapor.
Evaporation is a loss term in terms of water resources.

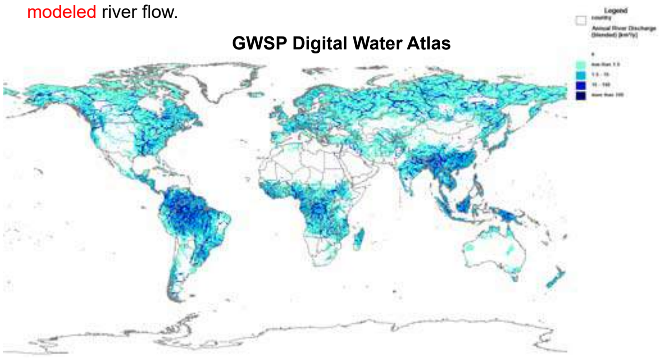
Energy cycle:
Transfer the energy of vaporization to atmosphere. Energy absorbed by surface is redistributed to atmosphere.

Water vapor from surface will condense
(latent heat release) and fall down again as rainfall.

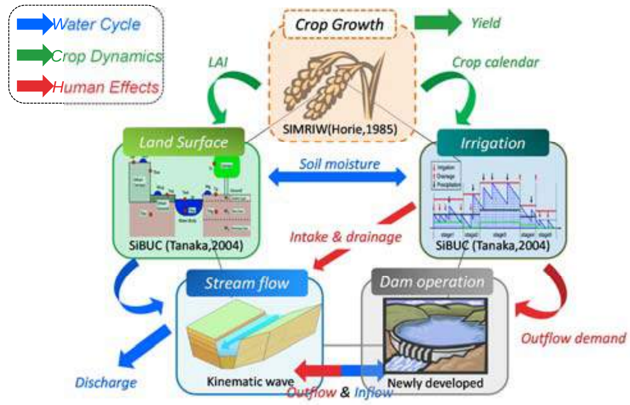
Annual River Discharge

This map shows annual river discharge for the globe on a 0.5 X 0.5 degree global river network. Blended river flow represents a composite of observed river discharge from the Global Runoff Data Centre and modeled river flow.

GWSP Digital Water Atlas



Integrated Water Resources Model



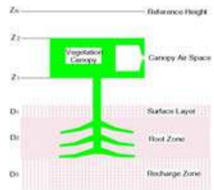
Land Surface (SiBUC)

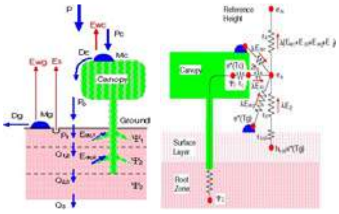
Grid box is divided into three landuse categories
1. Green Area
2. Urban Area
3. Water Body

1. Broadleaf-evergreen trees
2. Broadleaf-deciduous trees
3. Broadleaf and needle leaf trees
4. Needle leaf-evergreen trees
5. Needle leaf-deciduous trees
6. Short vegetation/C4 grassland
7. Broadleaf shrubs with bare soil
8. Dwarf trees and shrubs
9. Farmland (non-irrigated)
10. Paddy field (non-irrigated)
11. Paddy field (irrigated)
12. Spring wheat (irrigated)
13. Winter wheat (irrigated)
14. Corn (irrigated)
15. Other crops (irrigated)

Green area model (SiB)

- Prognostic variables
  temperature (canopy, ground, deep soil)
  interception water (canopy, ground)
  soil wetness (surface, root zone, recharge)
- Time invariant parameter
  geometrical parameter
  optical parameter
  physiological parameter
  soil physical properties
- Time varying parameter (LAI etc.)
  estimate from satellite data
- Physical processes
  radiative transfer
  interception loss
  soil hydrology
  canopy resistance
  transpiration
  turbulent transfer,
  snow, freezing/melting,… etc.





Prognostic equation of green area model

Temperature

Rn: net radiation
H : sensible heat
λE : latent heat

$$C_c \frac{\partial T_c}{\partial t} = R_{nc} - H_c - \lambda E_c$$
$$C_g \frac{\partial T_g}{\partial t} = R_{ng} - H_g - \lambda E_g - \omega C_g (T_g - T_d)$$
$$C_d \frac{\partial T_d}{\partial t} = R_{ng} - H_g - \lambda E_g$$

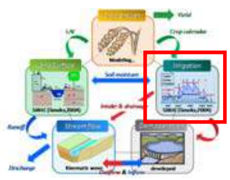
Soil Wetness

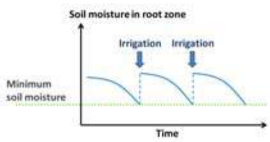
P1: infiltration
Qi,j : water exchange
Es : soil evaporation
Edc : transpiration
Q3 : drainage

$$\frac{\partial W_1}{\partial t} = \frac{1}{\theta_s D_1}\left[P_1 - Q_{1,2} - \frac{E_s}{\rho_w} - E_{dc,1}\right]$$
$$\frac{\partial W_2}{\partial t} = \frac{1}{\theta_s D_2}\left[Q_{1,2} - Q_{2,3} - E_{dc,2}\right]$$
$$\frac{\partial W_3}{\partial t} = \frac{1}{\theta_s D_3}\left[Q_{2,3} - Q_3\right]$$

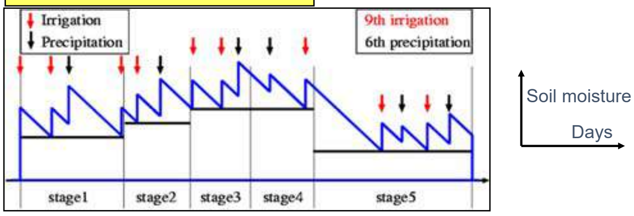
Irrigation

Basic concept is to maintain soil moisture/water depth within appropriate ranges for optimal crop growth.
Application to wheat, corn, soy bean, cotton etc…
New water layer is added to treat paddy field more accurately.

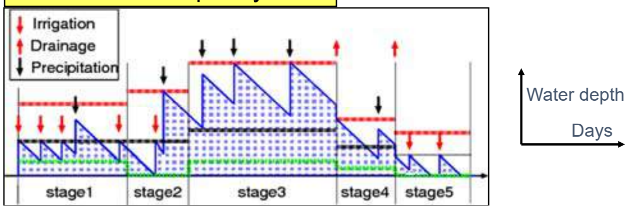




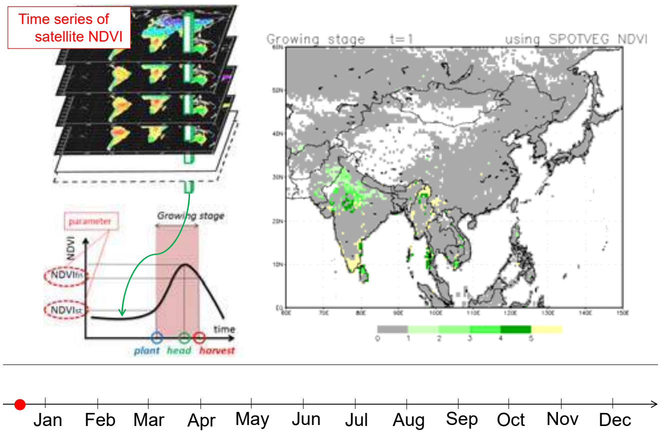
Water control in farmland



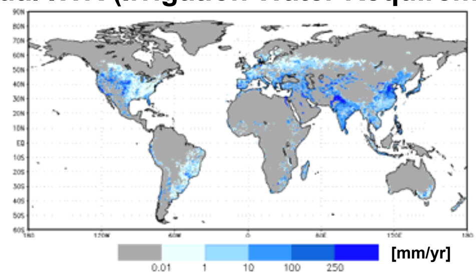
Water control in paddy field

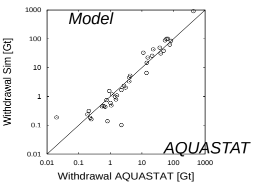


Crop Calendar (Growing stage)



Annual IWR (Irrigation Water Requirement)

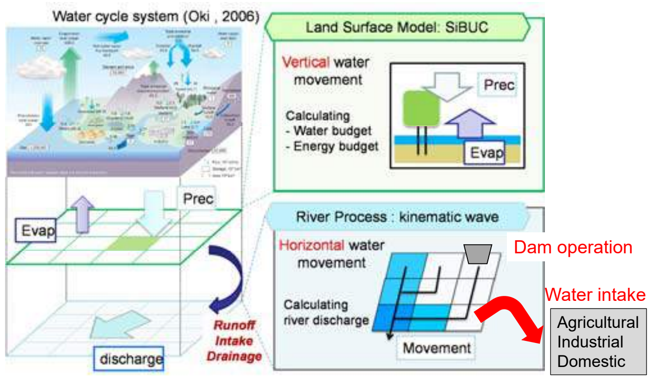




Annual IWR for each grids are aggregated into country, then compared with AQUASTAT

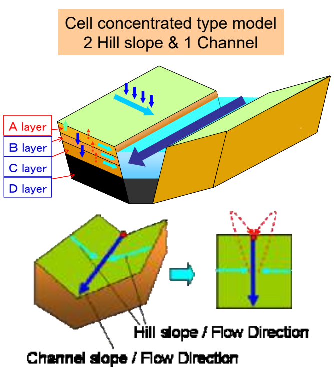
※ Using irrigation efficiency (Doll *et al*., 2002)

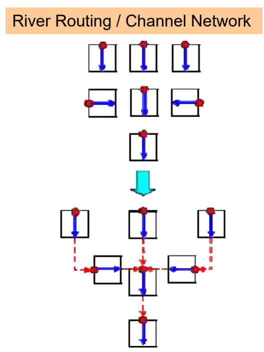
Land surface process and river routing process



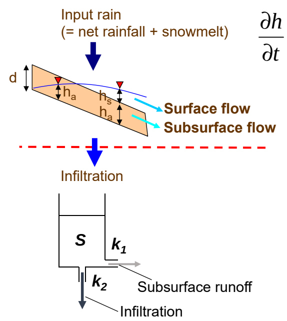
Hydro-BEAM

Hydrological river Basin Environment Assessment Model



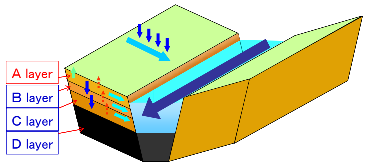


Basic Structure



Kinematic wave model

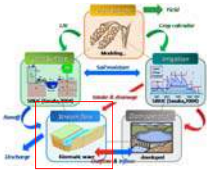
$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial x}=r \quad \begin{cases} q=f(h)=\alpha(h-d)^m+ah \\ h=h_s+h_a \end{cases}$$

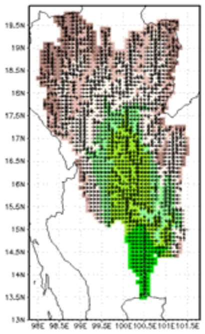


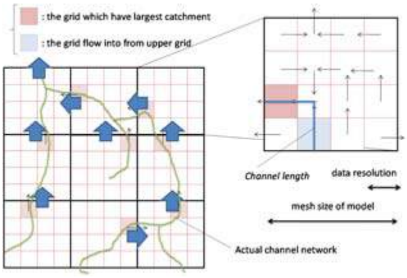
Multi-layer Storage function model

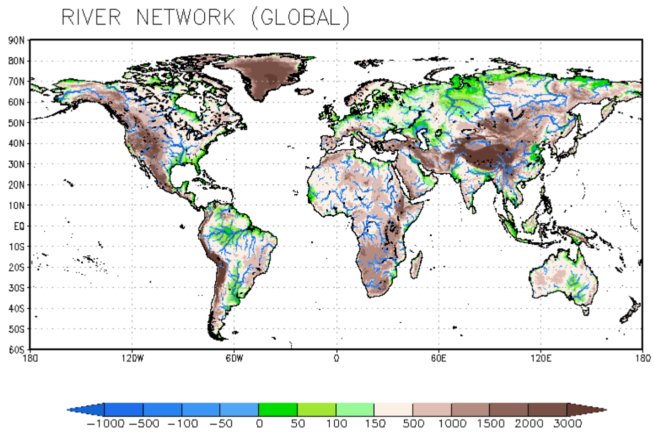
$$\frac{dS}{dt}=I-O \qquad O=(k_1+k_2)\cdot S$$

River

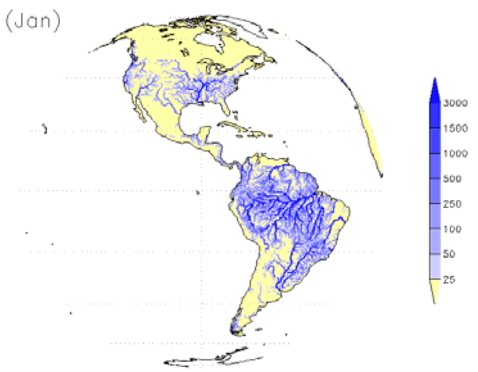




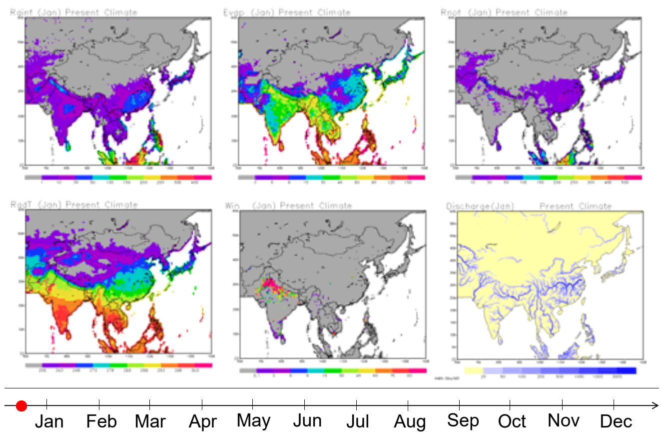




Monthly River Discharge

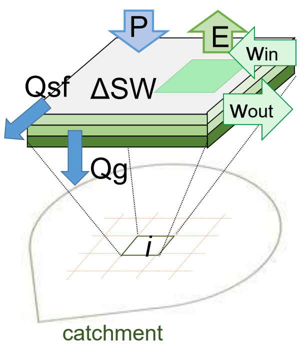


Seasonal Change (Asia)



Water Balance check

① WB
② PREC
③ EVAP
④ ROFF
⑤ TWS
⑥ delTWS

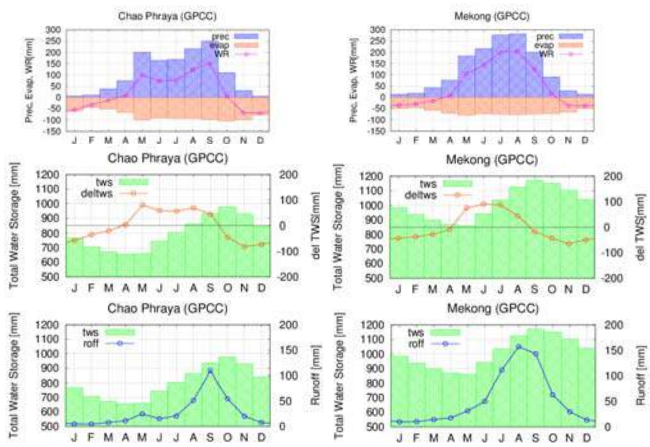


TWS (Total water storage)
=Soil moisture + surface water
(snow)

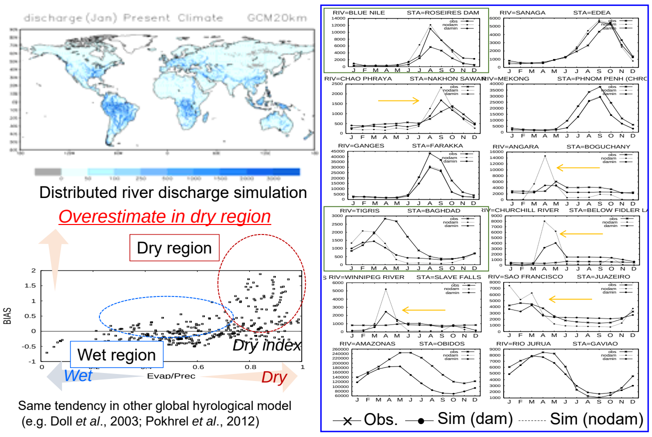
$$Roff_{i,t} = Qsf_{i,t} + Qg_{i,t}$$

$$WB_{i,t} = P_{i,t} - E_{i,t} + Win_{i,t} - Wout_{i,t} - \Delta S_i$$

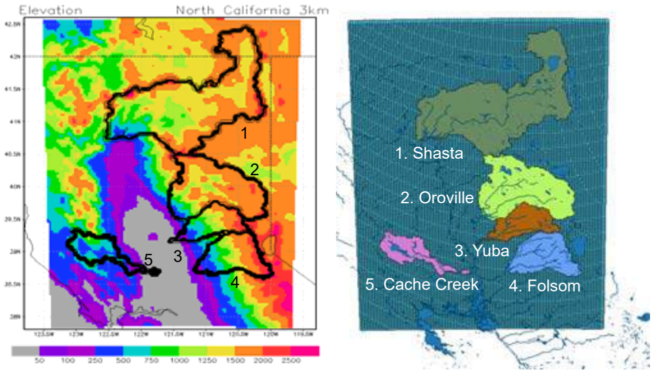
Water Balance (Chao Phraya & Mekong)



Validation of River Discharge (GRDC)

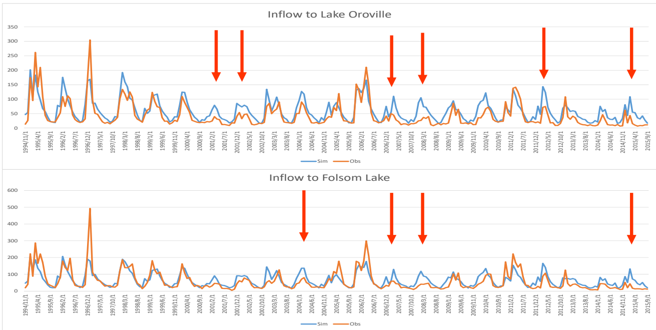


Historical hydrological simulation in North California



Joint research with Dr, Ishida @UC Davis

Simulated runoff is overestimated in drought year

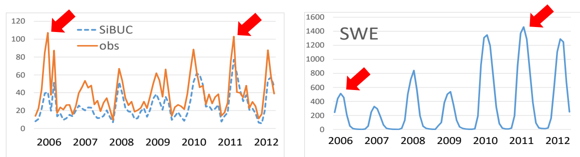


Simulated Evaporation might be too small .

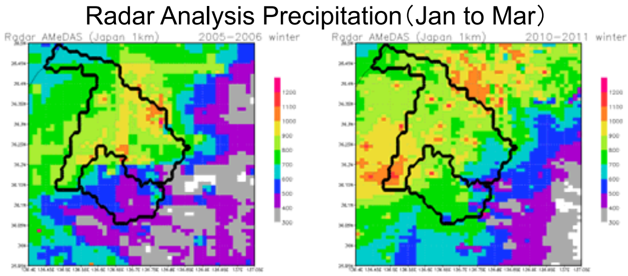
Physiological parameter (dry tolerant)?? Need more study

Deep root zone??

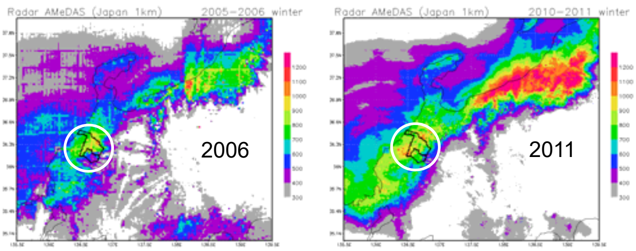
Runoff Simulation is still difficult even in Japan (snow region)



Radar Analysis Precipitation (Jan to Mar)



Radar Analysis Precipitation (Jan to Mar)



Basically due to the quality of Input snowfall data

Recently, many rain gauge information by local government were added for analysis.

River Discharge in Snowy Region

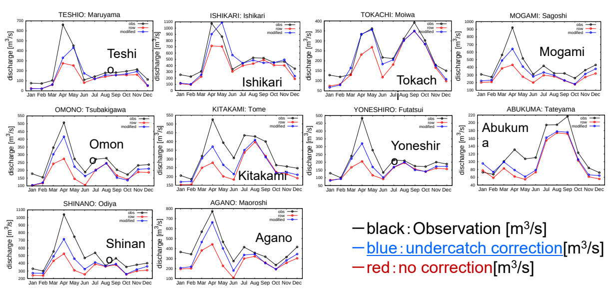
Undercatch correction can improve the acculacy of river discharge

$$Rs = 1/(1+0.213 \cdot Ws)$$

Undercatch correction *Wind speed*

$$Tc = 11.01 - 1.5e$$

Critical temperature *Vapor pressure*



— black : Observation [m³/s]

— blue : undercatch correction [m³/s]

— red : no correction [m³/s]

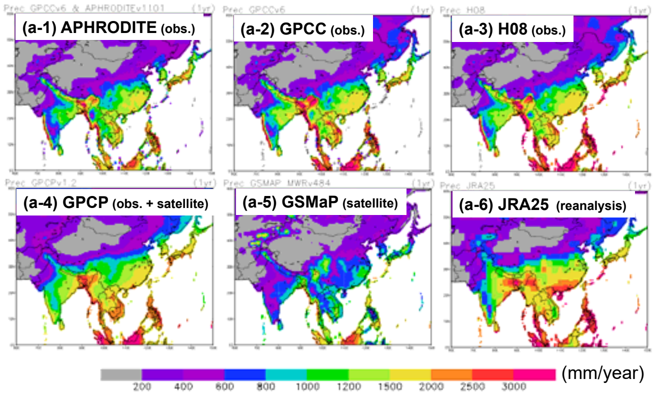
Validation of River Discharge (MLIT)

Water Balance $Budget = \sum (Q_{sim} - Q_{obs}) / \sum Q_{obs}$

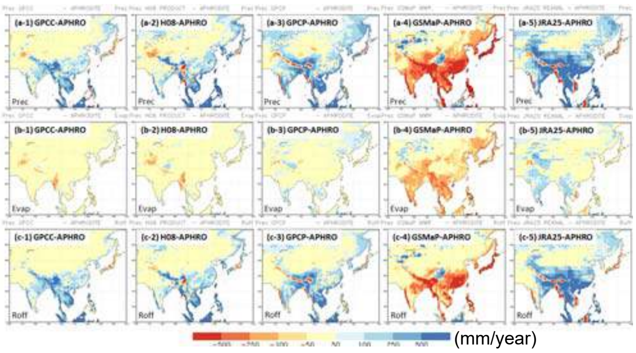
Nash Efficiency $Nash = 1 - \frac{\sum (Q_{sim} - Q_{obs})^2}{\sum (Q_{obs} - \overline{Q_{obs}})^2}$

No.	River	Station	Budget[%]	Nash	No.	River	Station	Budget[%]	Nash
1	Teshio	Maruyama	-24.5	0.613	11	Tone	Kurihashi	+ 9.7	0.892
2	Ishikari	Ishikari	- 4.0	0.674	12	Naka	Noguchi	- 9.6	0.852
3	Tokachi	Moiwa	- 8.1	0.882	13	Fuji	Kitamatsuno	+56.9	0.666
4	Mogami	Sagoshi	-19.8	0.721	14	Tenryu	Kashima	- 1.3	0.878
5	Omono	Tsubakigawa	-18.4	0.801	15	Kiso	Inuyama	+ 1.1	0.915
6	Kitakami	Tome	-18.8	0.742	16	Katsura	Katsura	-14.6	0.692
7	Yoneshiro	Futatsui	-20.9	0.685	17	Kizu	Yawata	-21.7	0.786
8	Abukuma	Tateyama	-16.0	0.834	18	Gono	Kawahira	-23.1	0.685
9	Shinano	Ojiya	-22.0	0.594	19	Yoshino	Ikeda	+ 9.3	0.876
10	Agano	Maoroshi	-19.8	0.729	20	Chikugo	Senoshita	-15.2	0.941

Precipitation products over Eastern Asia

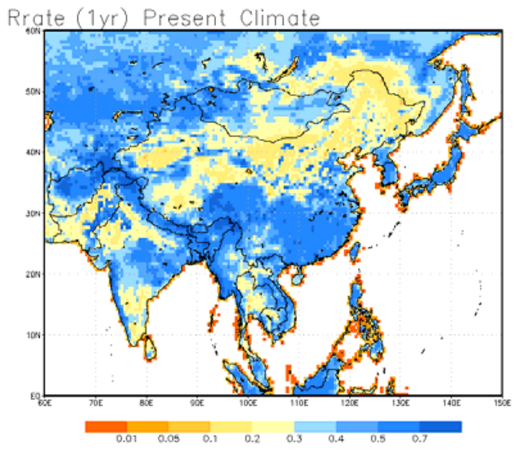


Precipitation products over Eastern Asia

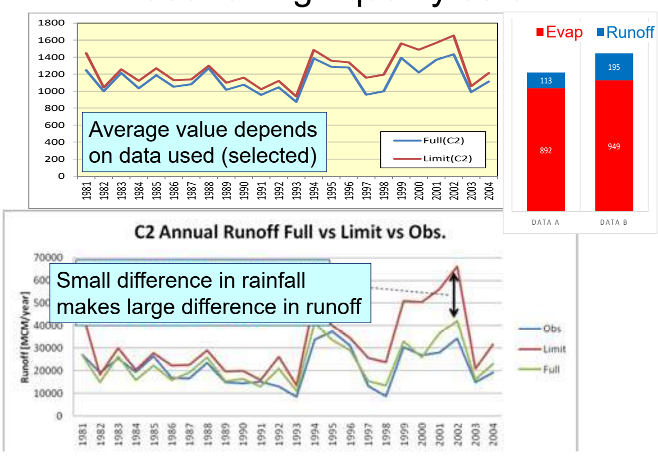


While precipitation has large difference between products, simulated evapotranspiration using products has small difference. Most of difference in precipitation translates to difference in runoff. Any error in the precipitation translates to approximately the same absolute error in runoff over the Eastern Asia.

Runoff Ratio

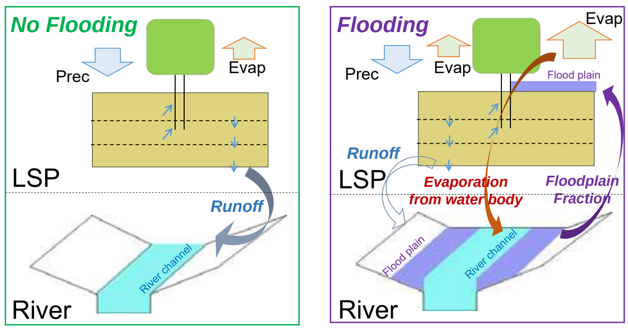


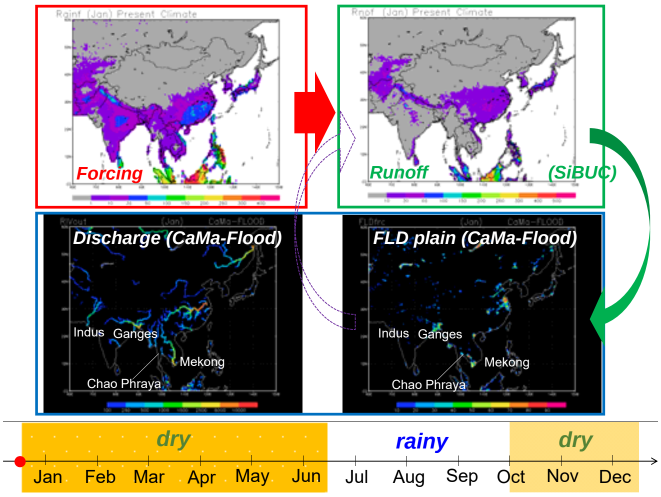
Need for high quality data



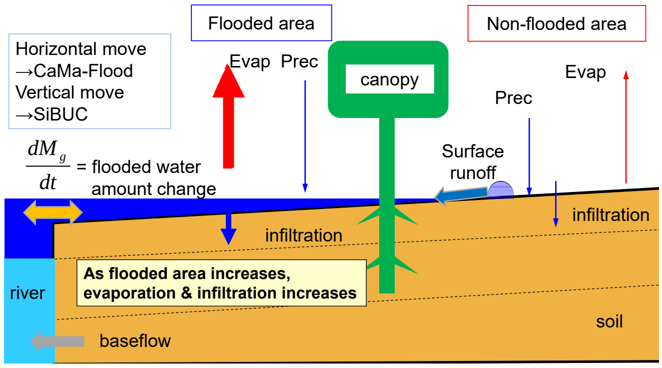
New Challenges

Online-coupling is required to consider dynamic land cover change caused by flooding.

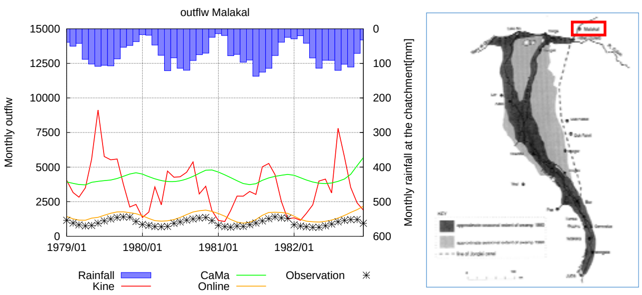




Dynamic (Online) coupling SiBUC & CaMa-Flood



Application to White Nile (Sudd wetland effect)



Absolute value and seasonal change are greatly improved

Summary

- River discharge is an important source of freshwater supply to oceans.
- The volume of the discharge will be determined by factors such as climate, vegetation, soil type, drainage basin relief and the human activities.
- As the time and spatial scale increases, land surface processes become more and more important, especially, in the area where evapotranspiration is a dominant component.
- In-land water cycle model is introduced.
- Current achievement, difficulties, new challenges in large scale model are introduced.

L2: Submarine groundwater discharge from land to the ocean

Makoto Taniguchi (*Research Institute for Humanity and Nature, Kyoto, Japan*)

Submarine groundwater discharge (SGD) is a hidden pathway of water and dissolved material from land to the ocean. Interdisciplinary research by hydrologists and oceanographers during the last decay revealed less terrestrial SGD but huge material flux by total SGD including re-circulated SGD. Spatial and temporal variations in SGD were evaluated in site by direct measurements including seepage meters, ^{222}Rn, resistivity and others, as well as numerical simulations. Global estimates of SGD and evaluations of impact of SGD on coastal ecosystem and fisheries are next future research areas which are related to SGD.

Submarine Groundwater Discharge

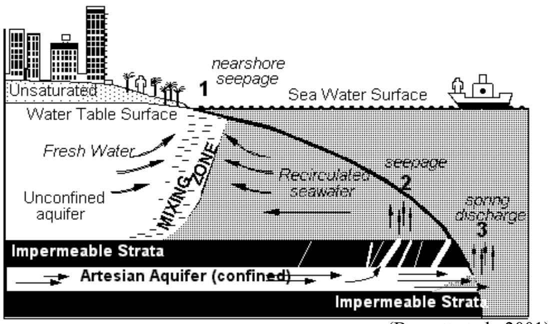
- Another pathway of water and dissolved materials from land to the ocean -

Makoto Taniguchi
Research Institute for Humanity and Nature (RIHN)

Reviews of global SGD rate

Authors	*Role of SGD*	*Method*
Berner and Berner [1987]	**6 %** of the total water flux	Literature
Church [1996]	**0.01–10%** of Surface R.	Literature
COSODII [1987]	**0.3 %** of Surface Runoff	Hydrological assumptions
Garrels and MacKenzie [1971]	**10 %** of Surface Runoff	Water balance
Lvovich [1974]	**31%** of the total water flux	Water balance
Nace [1970]	**1 %** of Surface Runoff	Hydrogeologic assumptions
Zektser et al. [1973]	**10 %** of Surface Runoff	Water balance etc.
Zektser and Loaiciga [1993]	**6 %** of the Total water flux	Hydrograph separation

Freshwater → **Coastal water** **← Seawater**
(Hydrologists) **(Oceanographers)**



(Burnett et al., 2001)

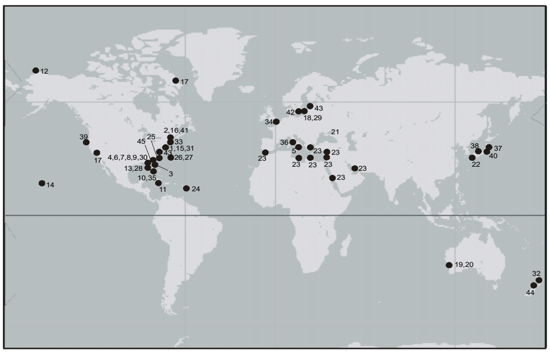
Reviews of SGD

(1) ～7% of total discharge may be SGD

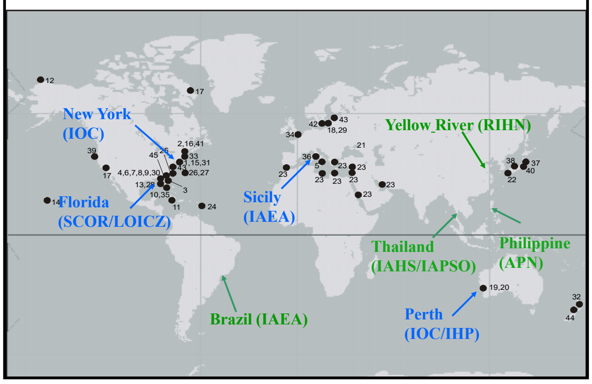
(2) SGD occur in continental scale, but quantitative evaluations are limited

(3) Intercomparisons are needed

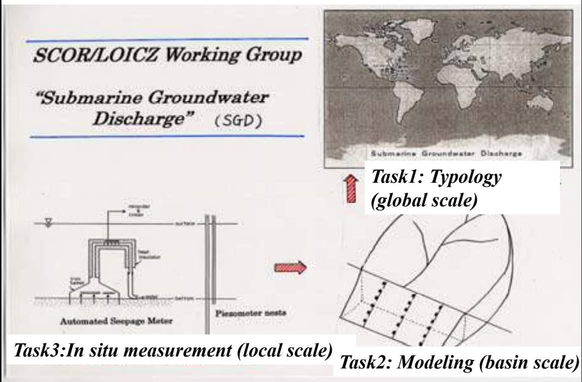
Locations of SGD measurements (Taniguchi *et al.*, 2002)



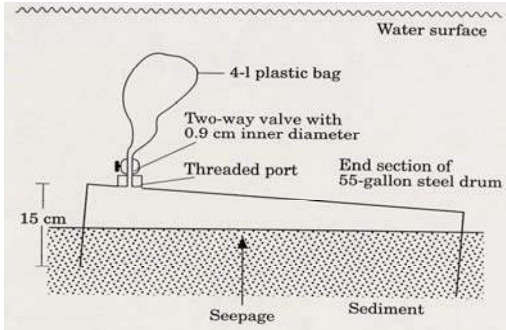
Intercomparisons of SDG in the world (2000-2009)



Methods for evaluating SGD



Various types of seepage meters (1)



Lee – type manual seepage meter

Methods for evaluating SGD (1)

(1) Typology

(2) Modeling and calculations
  2-1 numerical simulations
  2-2 water balance method

(3) Direct measurements
  3-1 seepage meters
  3-2 piezometers
  3-3 tracers (Rn-222, Ra-226, CH_4 etc.)

Problems of Lee –type manual seepage meters

(1) the resistance of the tube and bag

should be minimized to the degree possible to prevent artifacts ; (1cm diameter, prefilled water in bag)

(2) the effects of current and wave on the bag

use of a cover for the collection bag may reduce the effect of surface water movement due to wave, current or streamflow activity

(3) a seepage meter detection limit

of approximately 3 to 5 mL m^{-2} min^{-1} (0.4 to 0.7 cm/day) should be applied (Cable et al. 1997), and

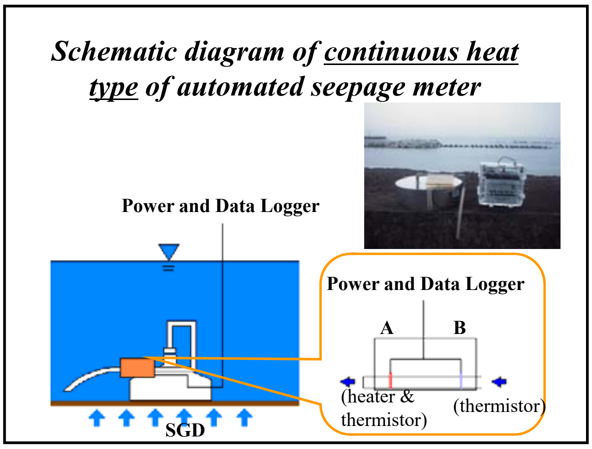
Labor Intensive !!!

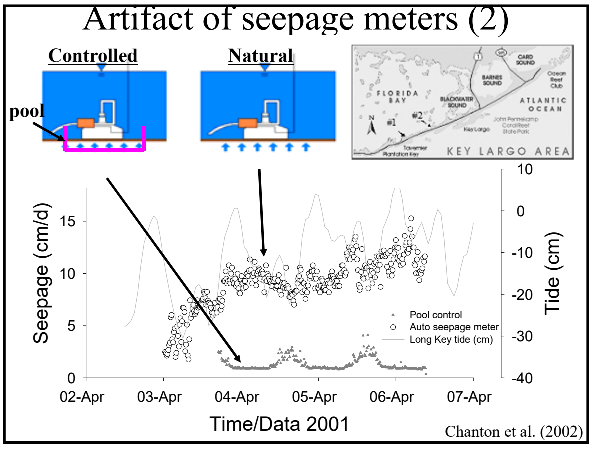
Methods for evaluating SGD (2)

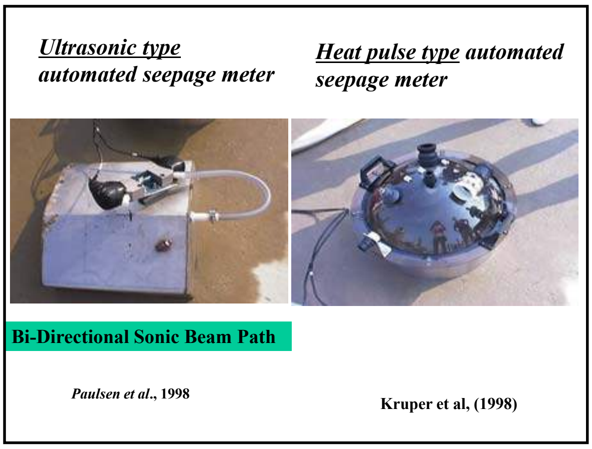
(1) Typology → need P, E, R, vegetation, geology etc.
(2-1)Water balance method → need P, E, R
(2-2) Numerical simulations →need several model parameters
(3-2) Piezometers → need hydraulic conductivity
(3-3) Tracers (Rn-222, Ra-226, CH_4 etc.) →need wind speed etc. for modeling
(3-1) Seepage meters→ only direct method for SGD flux

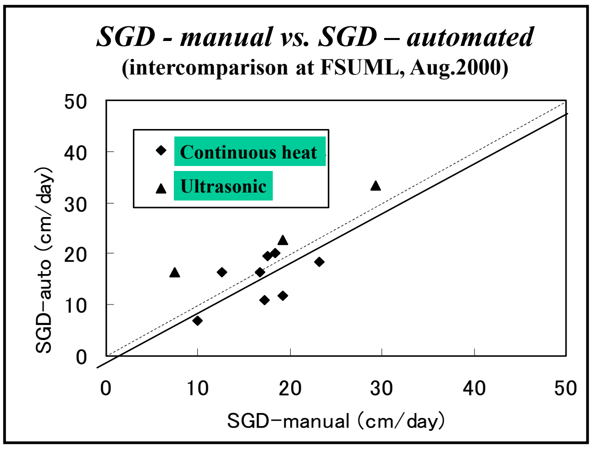
Various types of seepage meters (2)

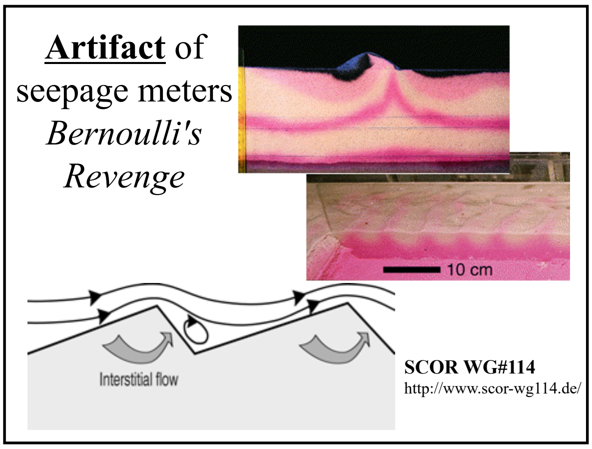
automated seepage meters

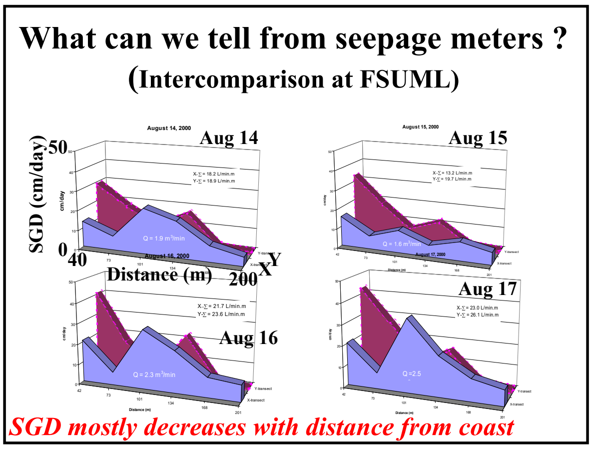

Schematic diagram of continuous heat type of automated seepage meter
Power and Data Logger
Power and Data Logger
A
B
(heater & thermistor)
(thermistor)
SGD


Artifact of seepage meters (2)
Controlled
Natural
pool
FLORIDA BAY
ATLANTIC OCEAN
KEY LARGO AREA
Seepage (cm/d)
Tide (cm)
Pool control
Auto seepage meter
Long Key tide (cm)
02-Apr
03-Apr
04-Apr
05-Apr
06-Apr
07-Apr
Time/Data 2001
Chanton et al. (2002)


Ultrasonic type automated seepage meter
Heat pulse type automated seepage meter
Bi-Directional Sonic Beam Path
Paulsen et al., 1998
Kruper et al, (1998)

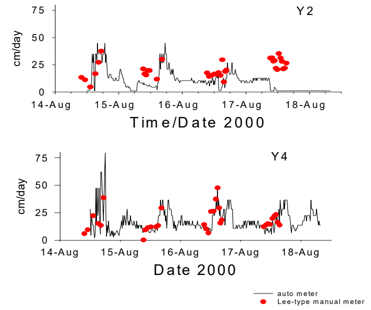

SGD - manual vs. SGD – automated
(intercomparison at FSUML, Aug.2000)
Continuous heat
Ultrasonic
SGD-auto (cm/day)
SGD-manual (cm/day)


Artifact of seepage meters
Bernoulli's Revenge
10 cm
Interstitial flow
SCOR WG#114
http://www.scor-wg114.de/

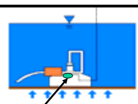

What can we tell from seepage meters ?
(Intercomparison at FSUML)
SGD (cm/day)
Aug 14
Aug 15
Aug 16
Aug 17
Distance (m)
SGD mostly decreases with distance from coast

What can we tell from seepage meters ?

Automated seepage meters can tell us continuous changes of SGD with long term & high resolutions

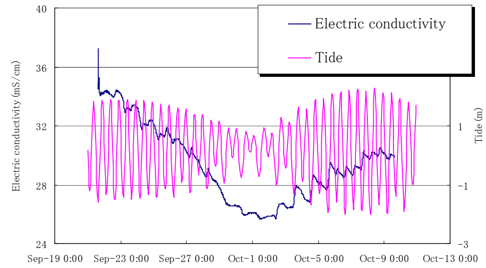


Why is the high SGD during spring tide ?



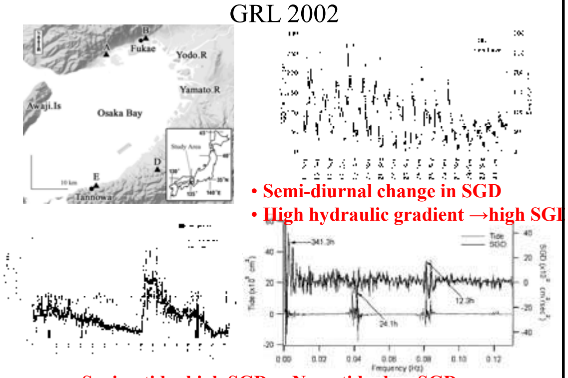
Relationship between fresh SGD and recirculated saline SGD (1)

Conductivity meter



Spring tide: high recirculated saline SGD due to tidal pumping

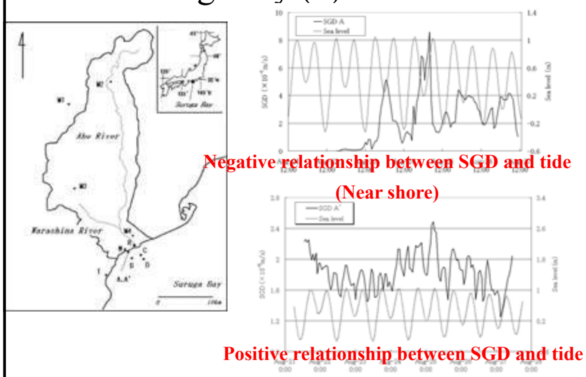
Long term changes in SGD at Osaka Bay, Japan GRL 2002



- Semi-diurnal change in SGD
- High hydraulic gradient →high SGD

Spring tide: high SGD, **Neap tide**: low SGD

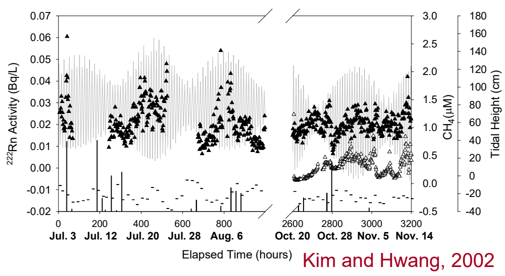
Suruga bay (1) *GW2005*



Negative relationship between SGD and tide (Near shore)

Positive relationship between SGD and tide (Offshore)

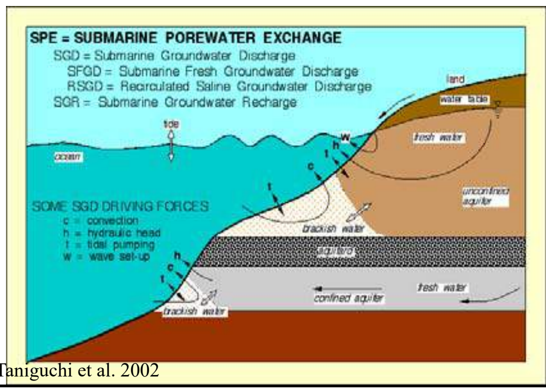
Semi-monthly changes of SGD confirmed by not only seepage meter but also by Rn and CH_4



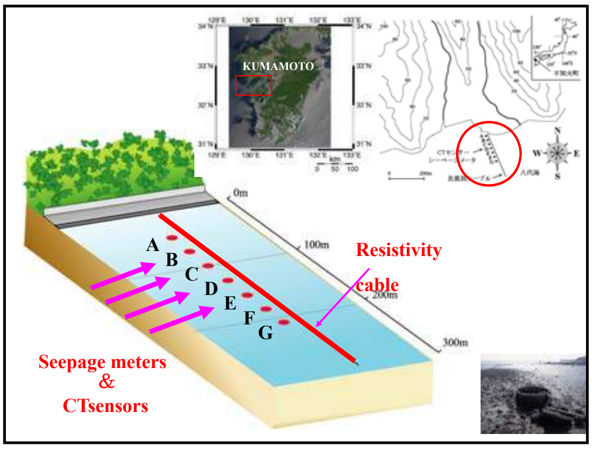
Kim and Hwang, 2002

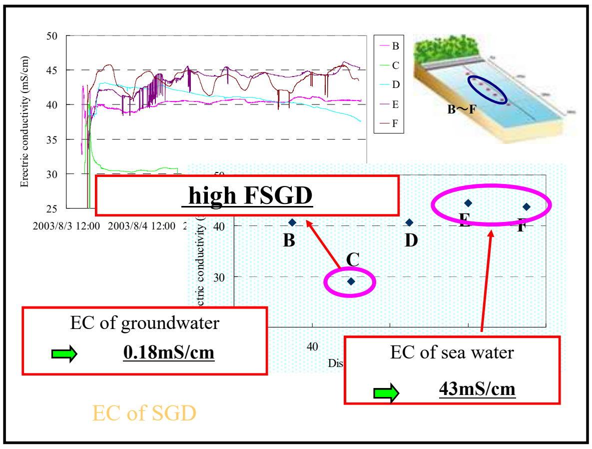
Spring tide: high SGD, **Neap tide**: low SGD

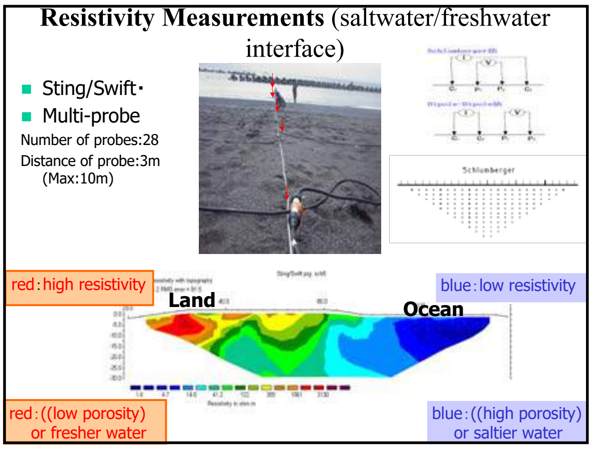
SGD=SFGD+RSGD

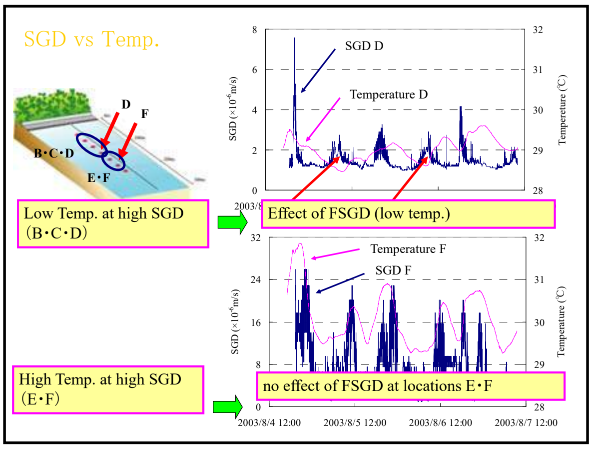


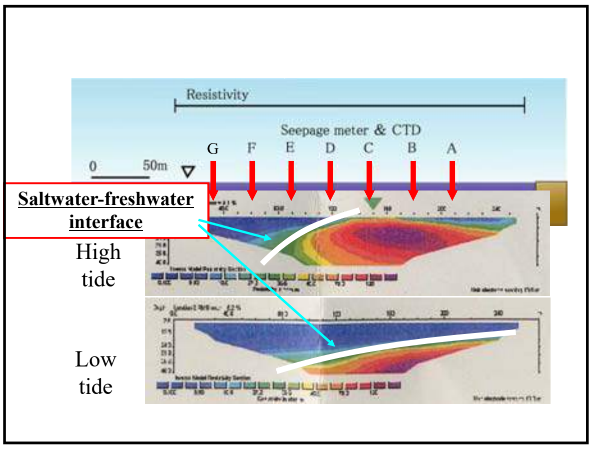
Taniguchi et al. 2002

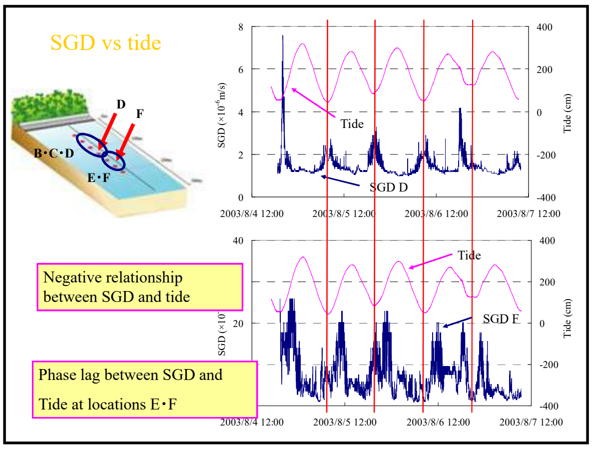

KUMAMOTO
0m
100m
200m
300m
A
B
C
D
E
F
G
Resistivity
cable
Seepage meters
&
CTsensors

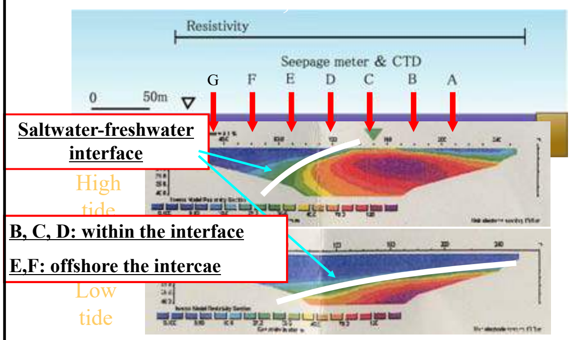

Erectric conductivity (mS/cm)
50
45
40
35
30
25
2003/8/3 12:00
2003/8/4 12:00
B
C
D
E
F
B〜F
high FSGD
B
C
D
E
F
EC of groundwater
0.18mS/cm
EC of sea water
43mS/cm
EC of SGD


Resistivity Measurements (saltwater/freshwater interface)
Sting/Swift･
Multi-probe
Number of probes:28
Distance of probe:3m
(Max:10m)
Schlumberger
red:high resistivity
blue:low resistivity
Land
Ocean
red:((low porosity)
or fresher water
blue:((high porosity)
or saltier water


SGD vs Temp.
D
F
B･C･D
E･F
SGD D
Temperature D
SGD (×10⁻⁶m/s)
Temperature (℃)
Low Temp. at high SGD
(B･C･D)
Effect of FSGD (low temp.)
Temperature F
SGD F
High Temp. at high SGD
(E･F)
no effect of FSGD at locations E･F
2003/8/4 12:00
2003/8/5 12:00
2003/8/6 12:00
2003/8/7 12:00


Resistivity
Seepage meter & CTD
G
F
E
D
C
B
A
0
50m
Saltwater-freshwater
interface
High
tide
Low
tide


SGD vs tide
D
F
B･C･D
E･F
Tide
SGD D
SGD (×10⁻⁶m/s)
Tide (cm)
Negative relationship
between SGD and tide
Tide
SGD F
Phase lag between SGD and
Tide at locations E･F
2003/8/4 12:00
2003/8/5 12:00
2003/8/6 12:00
2003/8/7 12:00



Conclusions

1. Diurnal and semi-diurnal changes of SGD due to tidal changes were found.
2. SGD increase from neap tide to spring tide due to increase of recirculated submarine groundwater discharge
3. SGD rate, EC and Temperature of SGD are different between within interface and offshore interaface.
4. Fresh submarine groundwater discharge rate can be estimated using Bokuniewicz (1992) within the freshwater-saltwater interface.
5. SGD increases from neap tide to spring tide because recirculated seawater due to tidal pumping increases.
6. Saltwater-freshwater interface move toward offshore during spring tide at Shiranui bay, Japan.

Comparisons between observed and calculated SFGD

Separation of SGD into SFGD and RSGD

SGD | fresh | saline

SGD= SFGD+ RSGD

SGD× Csgd= SFGD× Csfgd+ RSGD× Crsgd

EC of SGD | EC of groundwater | EC of seawater

Analyses using Bokuniewicz (1992)

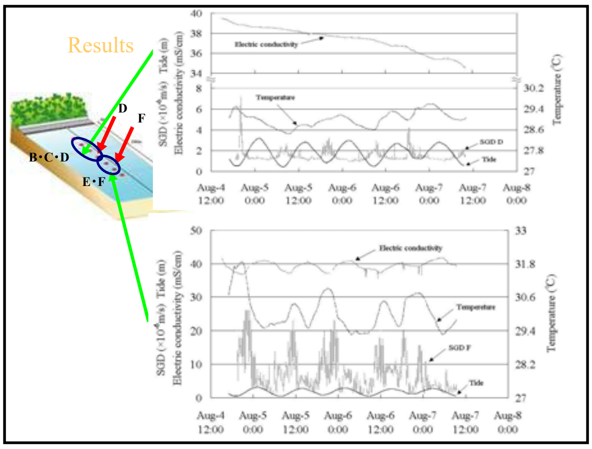
SFGD | Hydraulic conductivity | Hydraulic gradient

$$q = \frac{K_v \cdot i}{\pi k} \ln \left(\coth \frac{\pi x k}{4l} \right)$$

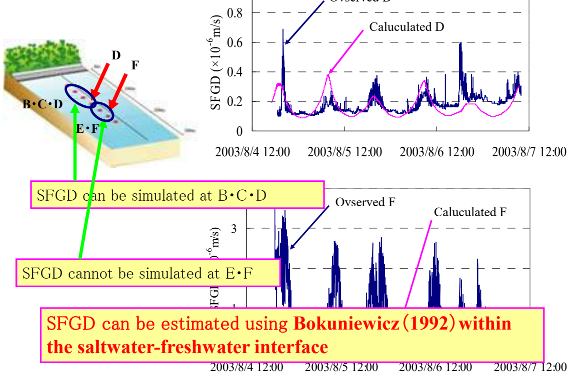
SGD was simulated with independent X

$$\left(k = \sqrt{\frac{K_v}{K_h}} \right)$$

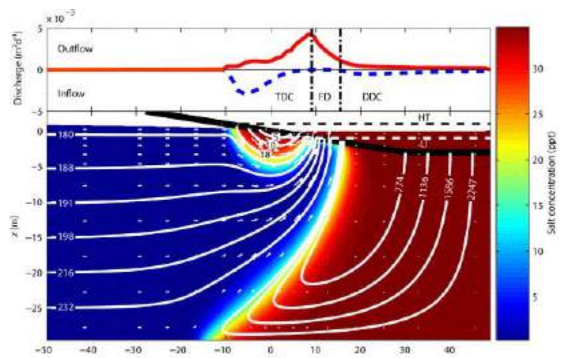
Thickness of aquifer | Horizontal hydraulic conductivity | Distance from the coast

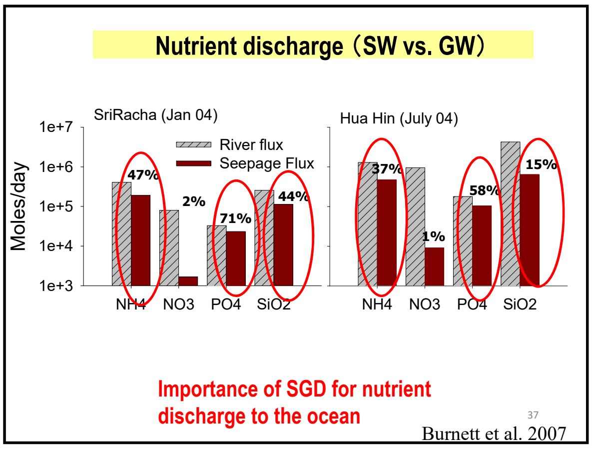


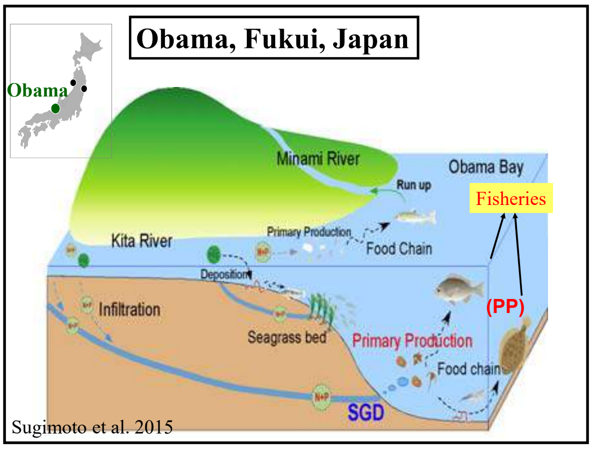
Results

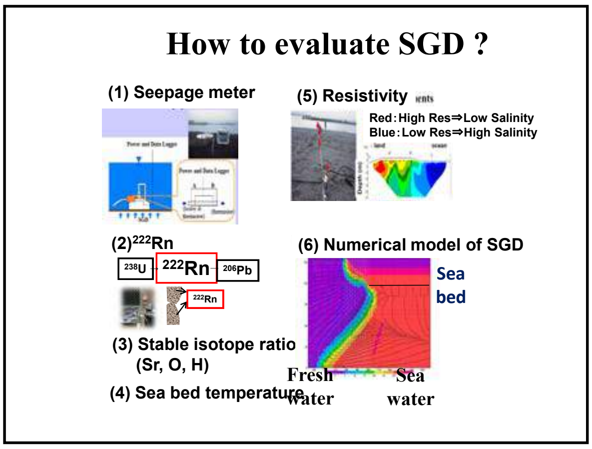


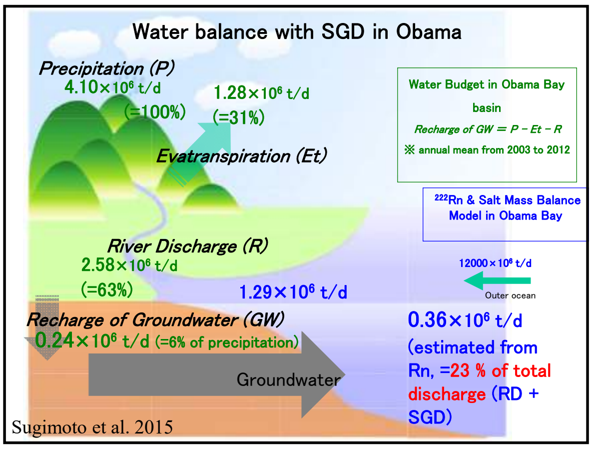
Robinson et al. 2007

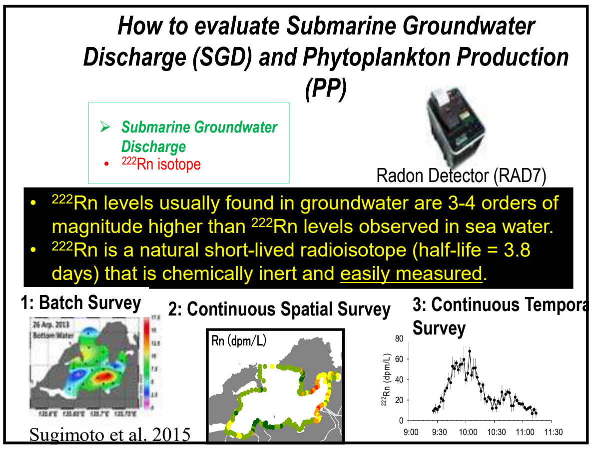


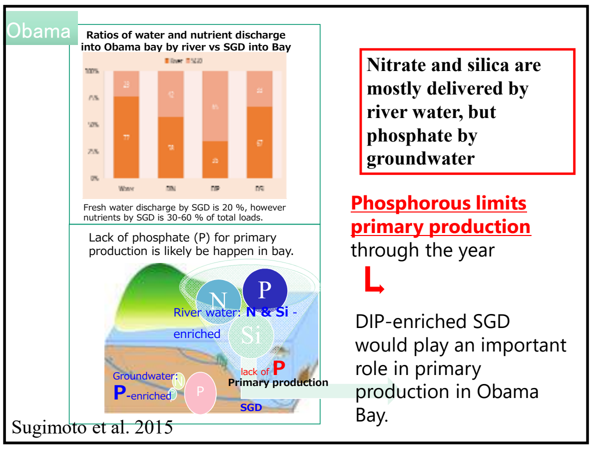

Nutrient discharge（SW vs. GW）
SriRacha (Jan 04)
Hua Hin (July 04)
Moles/day
1e+7
1e+6
1e+5
1e+4
1e+3
River flux
Seepage Flux
47%
2%
71%
44%
37%
1%
58%
15%
NH4
NO3
PO4
SiO2
Importance of SGD for nutrient discharge to the ocean
37
Burnett et al. 2007

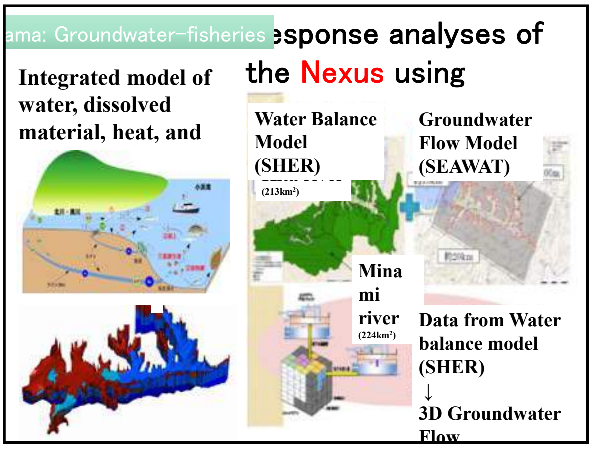

Obama, Fukui, Japan
Obama
Minami River
Obama Bay
Run up
Fisheries
Kita River
Primary Production
Food Chain
Deposition
Infiltration
(PP)
Seagrass bed
Primary Production
Food chain
SGD
Sugimoto et al. 2015


How to evaluate SGD ?
(1) Seepage meter
(5) Resistivity
Red:High Res⇒Low Salinity
Blue:Low Res⇒High Salinity
(2)222Rn
238U
222Rn
206Pb
222Rn
(6) Numerical model of SGD
Sea bed
(3) Stable isotope ratio (Sr, O, H)
(4) Sea bed temperature
Fresh water
Sea water


Water balance with SGD in Obama
Precipitation (P)
4.10×10⁶ t/d
(=100%)
1.28×10⁶ t/d
(=31%)
Evatranspiration (Et)
Water Budget in Obama Bay basin
Recharge of GW = P − Et − R
※ annual mean from 2003 to 2012
222Rn & Salt Mass Balance Model in Obama Bay
River Discharge (R)
2.58×10⁶ t/d
(=63%)
1.29×10⁶ t/d
12000×10⁶ t/d
Outer ocean
Recharge of Groundwater (GW)
0.24×10⁶ t/d (=6% of precipitation)
Groundwater
0.36×10⁶ t/d
(estimated from Rn, =23 % of total discharge (RD + SGD)
Sugimoto et al. 2015


How to evaluate Submarine Groundwater Discharge (SGD) and Phytoplankton Production (PP)
Submarine Groundwater Discharge
222Rn isotope
Radon Detector (RAD7)
222Rn levels usually found in groundwater are 3-4 orders of magnitude higher than 222Rn levels observed in sea water.
222Rn is a natural short-lived radioisotope (half-life = 3.8 days) that is chemically inert and easily measured.
1: Batch Survey
2: Continuous Spatial Survey
3: Continuous Temporal Survey
Rn (dpm/L)
9:00
9:30
10:00
10:30
11:00
11:30
Sugimoto et al. 2015


Obama
Ratios of water and nutrient discharge into Obama bay by river vs SGD into Bay
Fresh water discharge by SGD is 20 %, however nutrients by SGD is 30-60 % of total loads.
Lack of phosphate (P) for primary production is likely be happen in bay.
River water: N & Si - enriched
Groundwater: P-enriched
lack of P
Primary production
SGD
Nitrate and silica are mostly delivered by river water, but phosphate by groundwater
Phosphorous limits primary production through the year
DIP-enriched SGD would play an important role in primary production in Obama Bay.
Sugimoto et al. 2015



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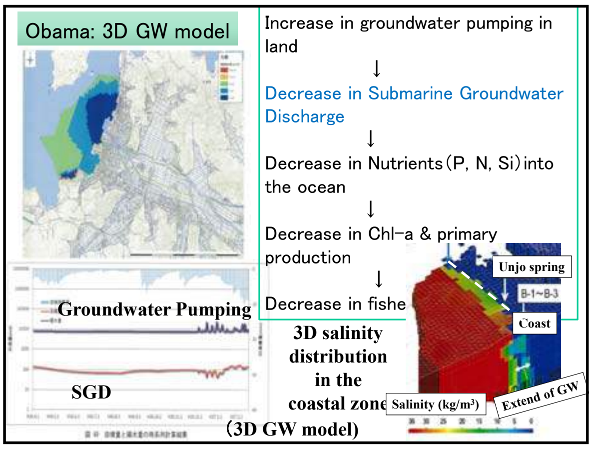
Burnett WC, Aggarwal PK, Aureli A, Bokuniewicz H, Cable JE, Charette MA, Kontar E, Krupa S, Kulkarni K M, Loveless A, Moore WS, Oberdorfer JA, Oliveira J, Ozyurt N, Povinec P, Privitera A MG, Rajar R, Ramessur RT, Scholten J, Stieglitz T, Taniguchi M, Turner JV. Quantifying submarine groundwater discharge in the coastal zone via multiple methods. *Science of the Total Environment* 2006; 367: 498–543.

Taniguchi M, Burnett WC, Cable JE, Turner JV. Assessment methodologies for submarine groundwater discharge, M. Taniguchi et al eds: *Land and Marine Hydrogeology*, Elsevier. 2003; 1-24.

Taniguchi M, Ono M, Takahashi M. Multi-scale evaluations of submarine groundwater discharge, *IAHS publication* 2014; 365: 66-71, doi:10.5194/piahs-365-66-2015



Kwon EY, Kim G, Primeau F, Moore WS, Cho H-Mi, DeVries T, Sarmiento JL, Charette MA, Cho Y-Ki. Global estimate of submarine groundwater discharge based on an observationally constrained radium isotope model, *Geophys. Res. Lett.* 2014; DOI: 10.1002/2014GL061574.

Sugimoto R, Honda H, Kobayashi S, Takao Y, Tahara D, Tominaga O, Taniguchi M. Seasonal Changes in Submarine Groundwater Discharge and Associated Nutrient Transport into a Tideless Semi-enclosed Embayment (Obama Bay, Japan), *Estuaries and Coasts* 2016; 39: 13–26.

Utsunomiya T, Hata M, Sugimoto R, Honda H, Kobayashi S, Tominaga O, Shoji J, Taniguchi M. Higher species richness and abundance of fish and benthicinvertebrates around submarine groundwater discharge in Obama Bay, Japan. J Hydrol. in press; DOI: doi:10.1016/j.ejrh.2015.11.012.

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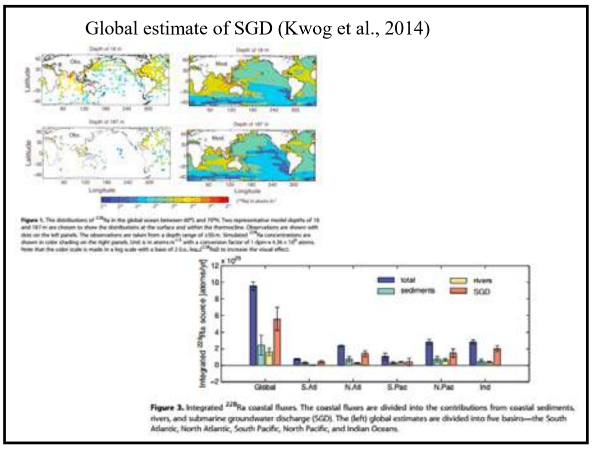


L3: Coastal Water Circulation

Akihide Kasai (*Graduate School of Fisheries Sciences, Hokkaido University*)

Abstract

There are many factors that control coastal water circulation. The strength of tidal currents, river runoff, meteorological conditions (winds) and flow pattern of the outer sea are particularly important, as well as shoreline structure and bottom topography. In general, the salinity of coastal water is low and variable, with surface waters showing reduced levels compared with the open ocean, because of the freshwater input via river discharges and groundwater influx from lands. However, as each coastal area has its own characteristics, circulation pattern in the coastal basin varies from one locality to another. It also changes with time, because the factors fluctuate with various time scales.

Coastal area of California is famous for upwelling. Northwesterly winds blowing parallel to the coastline drive surface water to the right of the wind flow (westward) through the Ekman transport. Deep cold water upwells to compensate the offshore movement of surface water. This region draws considerable attention not only because of the physical process, but also its importance in generating high production. The deep cold waters contain a lot of nutrients and thus stimulate primary production in the euphotic layer. The coastal area of California is thus one of the most productive regions on earth.

In the regions of freshwater influence, surface lighter water flows toward outer sea, while bottom denser water flows toward inner bay. This is called 'estuarine circulation', a type of density currents. The main force that drives the estuarine circulation is a horizontal pressure gradient caused by the density difference between the fresh water from rivers and the salty water from outer seas. As the water flux by the estuarine circulation is several to more than 10 times larger than the river discharge, it significantly influences water exchange between inner and outer seas and material circulation.

Tides are most familiar as a rise and fall of seawater level once or twice a day in littoral area. Tides considerably change the strength and direction of currents in coastal waters. The tidal currents often dominate coastal circulation, and determine the strength of water stratification. Tides in Ariake Bay are the largest in Japan because of the resonance of tidal wave, while those in the Sea of Japan are generally small because the tidal waves damp at the entrance of the sea (Tsushima strait).

The combined effects of winds, freshwater discharge, tidal currents, and oceanic forces result in a unique circulation in each coastal area. It is important to conduct a preliminary survey and find out the characteristics of the target area, if you want to know the water circulation.

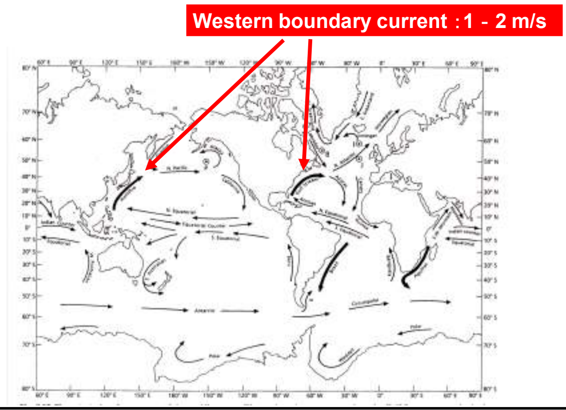
29 Nov. 2016 Coastal Vulnerability and Freshwater Discharge

Coastal Water Circulation

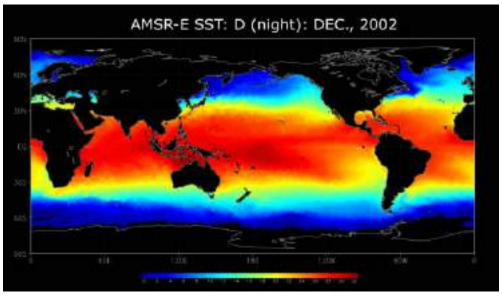
Akihide Kasai

(*Graduate School of Fisheries Sciences, Hokkaido University*)

Ocean circulation in the surface layer

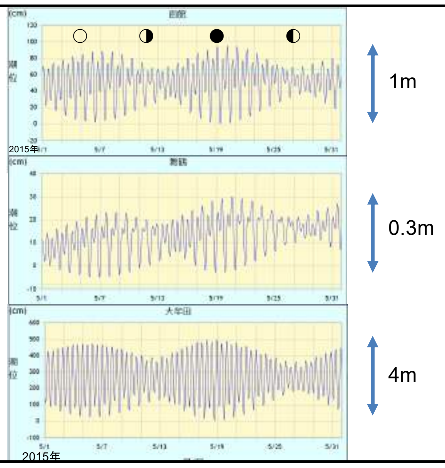


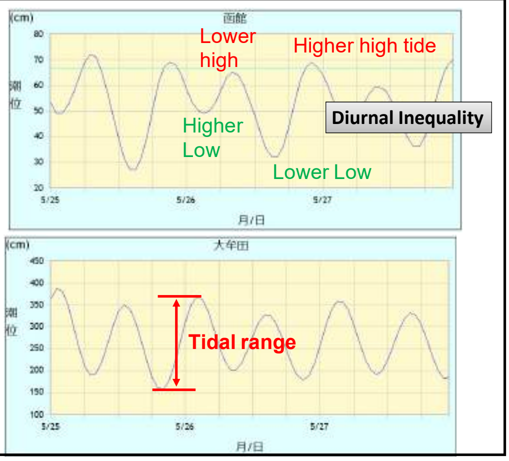
Sea surface temperature



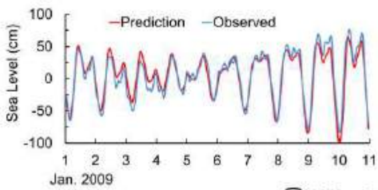
(From NASDA HP)

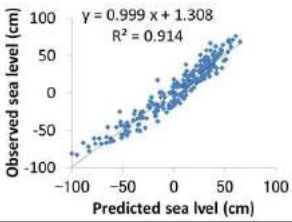
Tides



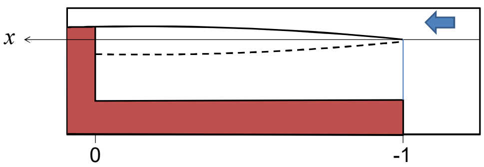


Prediction of tide in Osaka Bay

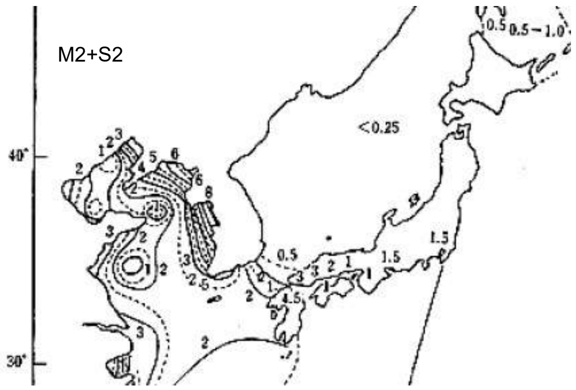




Tidal resonance



Standing wave in a bay

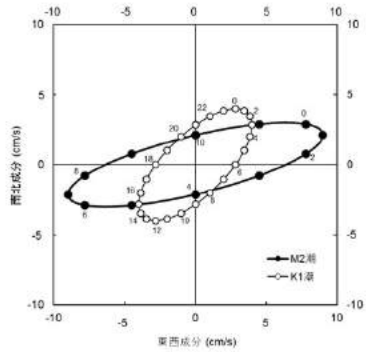


Primary tidal components

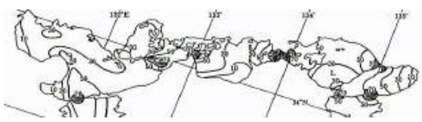
	description	period	amplitude (cm)	Phase (°)
K_2	Luni-solar	11h58m	4.36	227.50
S_2	Principal solar	12h00m	16.88	227.82
M_2	Principal lunar	12h25m	29.71	215.47
N_2	Larger lunar elliptic	12h39m	6.34	209.64
K_1	Luni-solar diurnal	23h56m	26.06	203.77
P_1	Principal solar diurnal	24h04m	8.00	201.91
O_1	Principal lunar diurnal	25h49m	19.60	181.31

※Amplitudes and phase are in Osaka Bay

Tidal ellipse

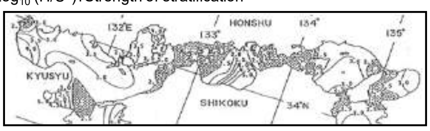


Amplitude of M2 tide



(Yanagi and Higuchi, 1981)

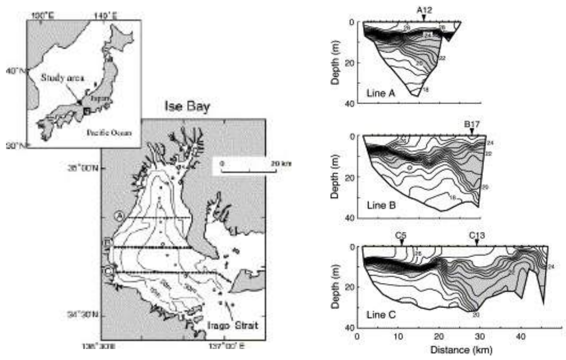
Log_{10} (H/U^3) : Strength of stratification



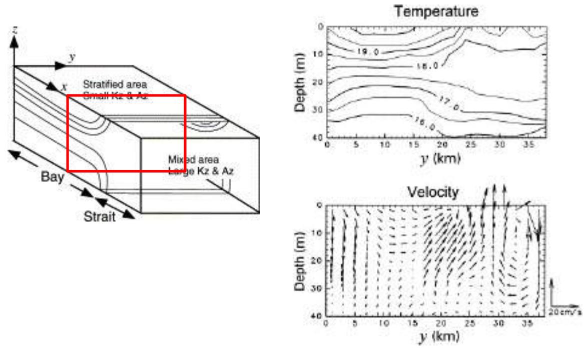
(Yanagi, 1990)

SST in Summer

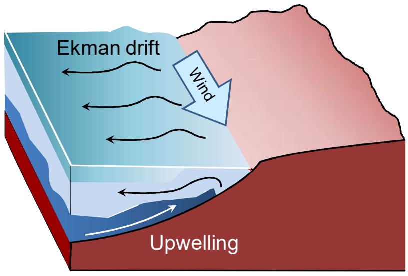
Circulation and temperature in Ise Bay



Circulation model

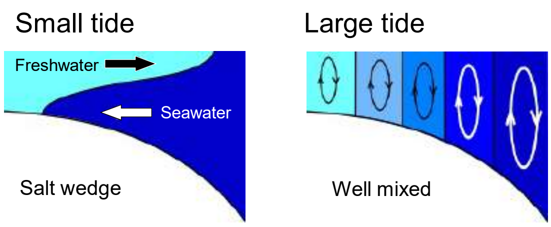


Upwelling caused by alongshore wind

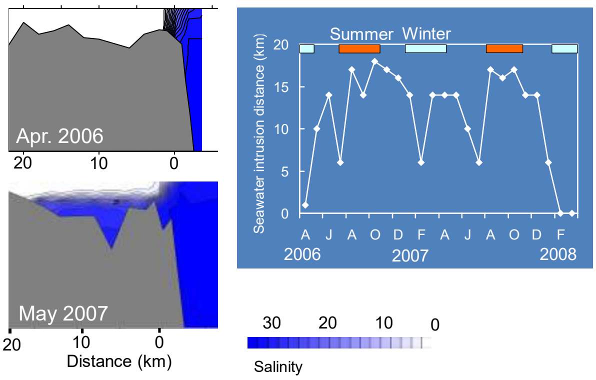


Upwelling of hypoxic water

Estuarine circulation



Yura River Estuary



Front in Akkeshi Bay

L4: Nutrient Dynamics

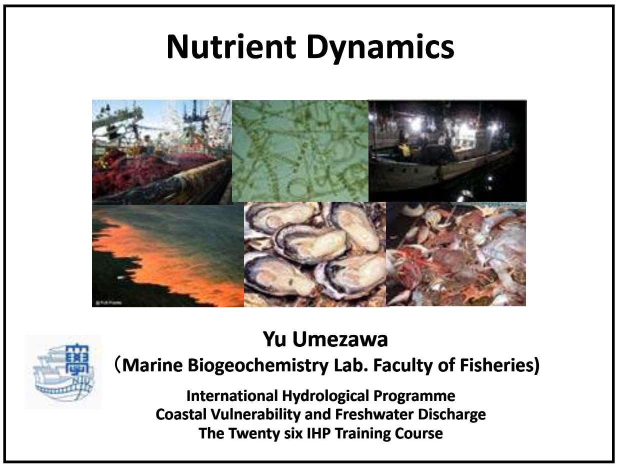
Yu Umezawa
(*Graduate School of Fisheries and Environmental Sciences, Nagasaki University*)

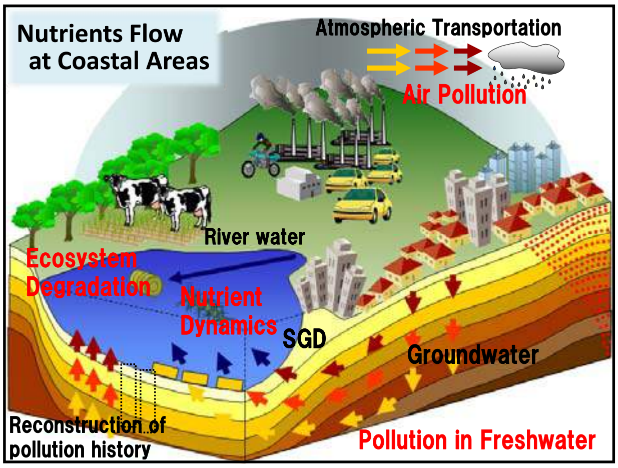
Abstract

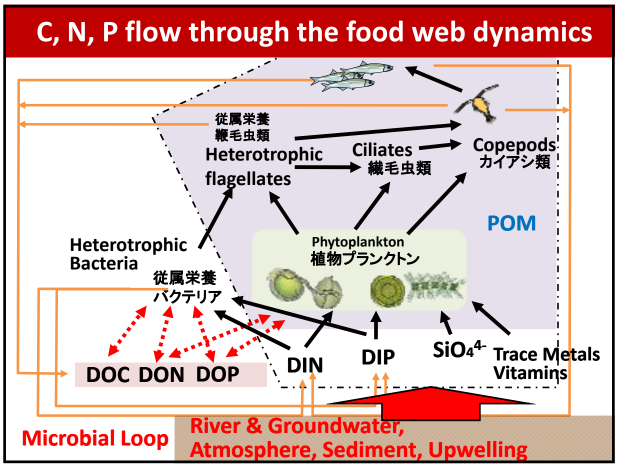
Understanding nutrient dynamics (i.e., nutrient concentration of each species, distribution, source, and movement etc.) in aquatic ecosystem are indispensable, when we study about phytoplankton species composition, primary production, and environmental problems such as red tide and green tide at coastal areas and lakes. In the oligotorphic waters at pelagic ocean and coral reefs, nutrients are tightly recycled in the ecosystems. Then, remineralization from particulate and dissolved organic matter (POM, DOM) is also important nutrient sources, as well as nitrogen supply through nitrogen fixation. Some species of phytoplankton have higher ability to uptake DOM for their growth. Therefore, POM and DOM are also categorized into nutrients in a broad sense, although component of nutrients are generally nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), phosphate (PO_4^{3-}) and silicate (SiO_4^{4-}) in a narrow sense. The analytical protocol of POM and DOM are briefly lectured in this lecture.

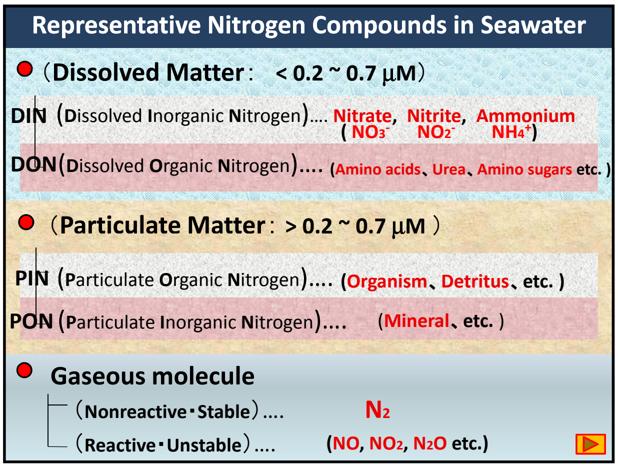
In the coastal areas and marginal seas, main nutrient sources are terrestrial water including groundwater, atmospheric depositions, upwelling waters and currents from adjacent areas. To identify the source of nutrients, stable isotopes techniques are often effectively used as well as other physical parameters (e.g., salinity and temperature), when stable isotopes values of nutrients from each source are distinctively different. Nutrient dynamics based on stable isotopes are introduced with examples of studies at groundwater in Asian mega cities, East China Sea, and Coral Reefs.

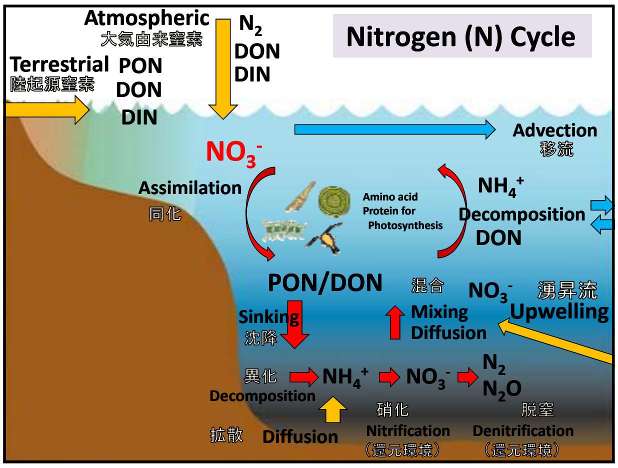
Stable isotopes techniques are also applicable to check actual uptake of each source of nutrients by the primary producers. For example, chemical compositions in macroalgal tissue record time-averaged information of water quality at the exact locations during algal growing period, because most of macroalgae are growing at exact locations, and uptake nutrients only from water column. Therefore, stable nitrogen isotope ($\delta^{15}N$) and nitrogen contents (%) in macroalgal tissue are effectively used to trace nutrient sources for the primary producers at shallow coastal areas. Transplanting experiments using macroalgae and bivalves in cages and associated shift of chemical composition in their tissue are also introduced in this lecture as an effective tool to check spatial variation in nutrient dynamics.

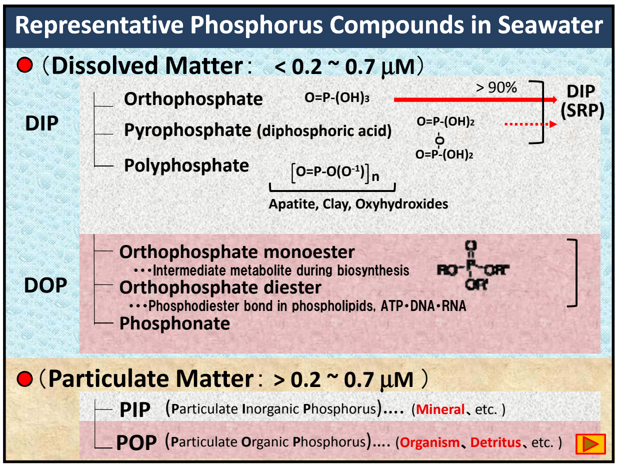

Nutrient Dynamics
Yu Umezawa
(Marine Biogeochemistry Lab. Faculty of Fisheries)
International Hydrological Programme
Coastal Vulnerability and Freshwater Discharge
The Twenty six IHP Training Course

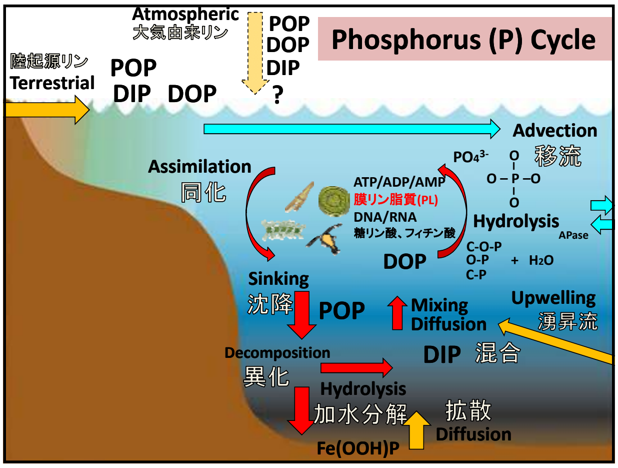

Nutrients Flow
at Coastal Areas
Atmospheric Transportation
Air Pollution
River water
Ecosystem
Degradation
Nutrient
Dynamics
SGD
Groundwater
Reconstruction of
pollution history
Pollution in Freshwater

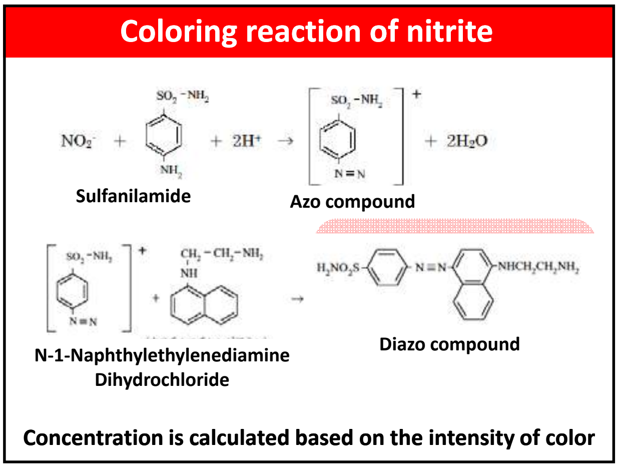

C, N, P flow through the food web dynamics
従属栄養
鞭毛虫類
Heterotrophic
flagellates
Ciliates
繊毛虫類
Copepods
カイアシ類
POM
Heterotrophic
Bacteria
従属栄養
バクテリア
Phytoplankton
植物プランクトン
DOC DON DOP
DIN
DIP
SiO4 4-
Trace Metals
Vitamins
Microbial Loop
River & Groundwater,
Atmosphere, Sediment, Upwelling

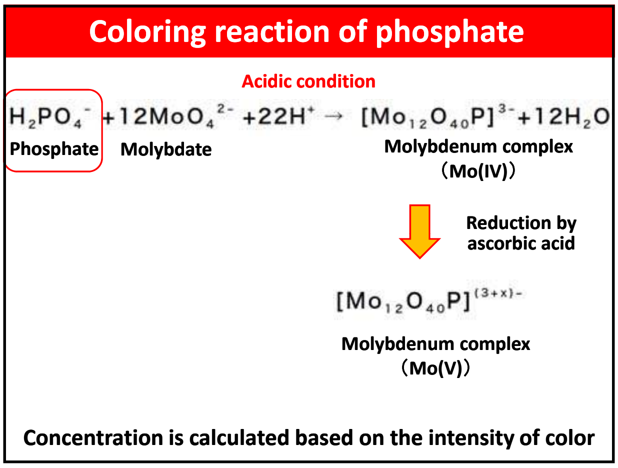

Representative Nitrogen Compounds in Seawater
(Dissolved Matter: < 0.2 ~ 0.7 μM)
DIN (Dissolved Inorganic Nitrogen).... Nitrate, Nitrite, Ammonium
(NO3- NO2- NH4+)
DON (Dissolved Organic Nitrogen).... (Amino acids、Urea、Amino sugars etc.)
(Particulate Matter: > 0.2 ~ 0.7 μM)
PIN (Particulate Organic Nitrogen).... (Organism、Detritus、etc.)
PON (Particulate Inorganic Nitrogen).... (Mineral、etc.)
Gaseous molecule
(Nonreactive・Stable).... N2
(Reactive・Unstable).... (NO, NO2, N2O etc.)

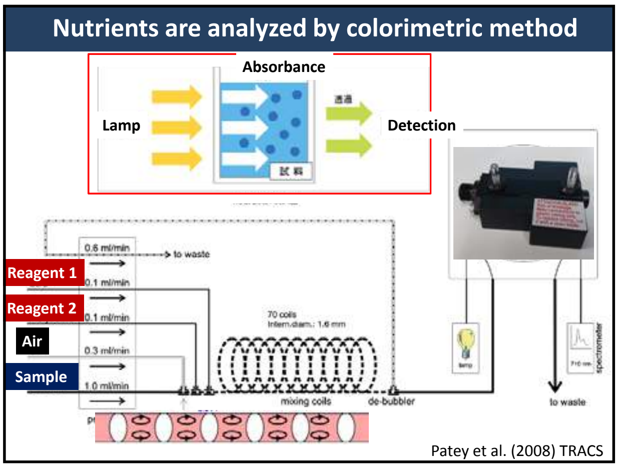

Atmospheric
大気由来窒素
N2
DON
DIN
Nitrogen (N) Cycle
Terrestrial
陸起源窒素
PON
DON
DIN
Advection
移流
NO3-
Assimilation
同化
Amino acid
Protein for
Photosynthesis
NH4+
Decomposition
DON
PON/DON
混合
NO3-
湧昇流
Upwelling
Sinking
沈降
Mixing
Diffusion
異化
Decomposition
NH4+
NO3-
N2
N2O
硝化
Nitrification
(還元環境)
脱窒
Denitrification
(還元環境)
拡散
Diffusion

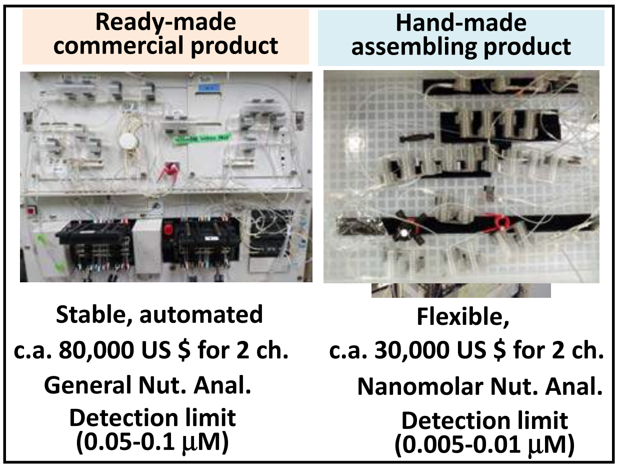

Representative Phosphorus Compounds in Seawater
(Dissolved Matter: < 0.2 ~ 0.7 μM)
DIP
Orthophosphate O=P-(OH)3
Pyrophosphate (diphosphoric acid)
Polyphosphate
> 90%
DIP
(SRP)
Apatite, Clay, Oxyhydroxides
DOP
Orthophosphate monoester
・・・Intermediate metabolite during biosynthesis
Orthophosphate diester
・・・Phosphodiester bond in phospholipids, ATP・DNA・RNA
Phosphonate
(Particulate Matter: > 0.2 ~ 0.7 μM)
PIP (Particulate Inorganic Phosphorus).... (Mineral、etc.)
POP (Particulate Organic Phosphorus).... (Organism、Detritus、etc.)

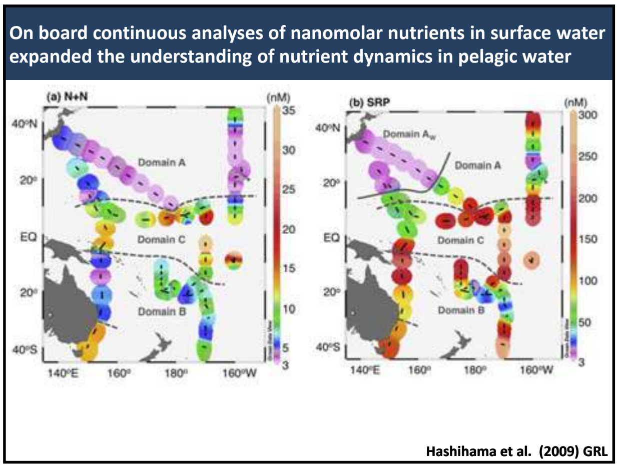

Phosphorus (P) Cycle
Atmospheric
大気由来リン
POP
DOP
DIP
?
陸起源リン
Terrestrial
POP
DIP DOP
Advection
移流
Assimilation
同化
PO4 3-
ATP/ADP/AMP
膜リン脂質(PL)
DNA/RNA
糖リン酸、フィチン酸
Hydrolysis
APase
C-O-P
O-P
C-P
+ H2O
DOP
Sinking
沈降
POP
Mixing
Diffusion
Upwelling
湧昇流
Decomposition
異化
DIP 混合
Hydrolysis
加水分解
拡散
Diffusion
Fe(OOH)P


Coloring reaction of nitrite
Sulfanilamide
Azo compound
N-1-Naphthylethylenediamine
Dihydrochloride
Diazo compound
Concentration is calculated based on the intensity of color


Coloring reaction of phosphate
Acidic condition
H2PO4- +12MoO4 2- +22H+ → [Mo12O40P]3- +12H2O
Phosphate
Molybdate
Molybdenum complex
(Mo(IV))
Reduction by
ascorbic acid
[Mo12O40P](3+x)-
Molybdenum complex
(Mo(V))
Concentration is calculated based on the intensity of color


Nutrients are analyzed by colorimetric method
Absorbance
Lamp
Detection
Reagent 1
Reagent 2
Air
Sample
0.8 ml/min
to waste
0.1 ml/min
0.1 ml/min
0.3 ml/min
1.0 ml/min
mixing coils
de-bubbler
to waste
Patey et al. (2008) TRACS

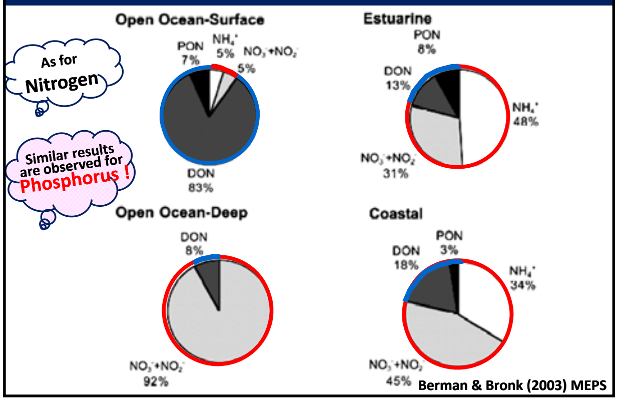

Ready-made
commercial product
Hand-made
assembling product
Stable, automated
c.a. 80,000 US $ for 2 ch.
General Nut. Anal.
Detection limit
(0.05-0.1 μM)
Flexible,
c.a. 30,000 US $ for 2 ch.
Nanomolar Nut. Anal.
Detection limit
(0.005-0.01 μM)


On board continuous analyses of nanomolar nutrients in surface water
expanded the understanding of nutrient dynamics in pelagic water
(a) N+N
(b) SRP
(nM)
Domain A
Domain C
Domain B
Hashihama et al. (2009) GRL

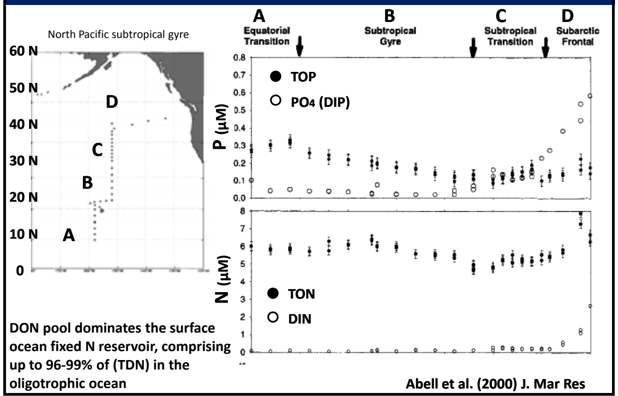
Importance of DOM, POM and remineralized nutrients

Remineralized nutrients through the decomposition of POM and DOM support primary production at ologotrophic waters.

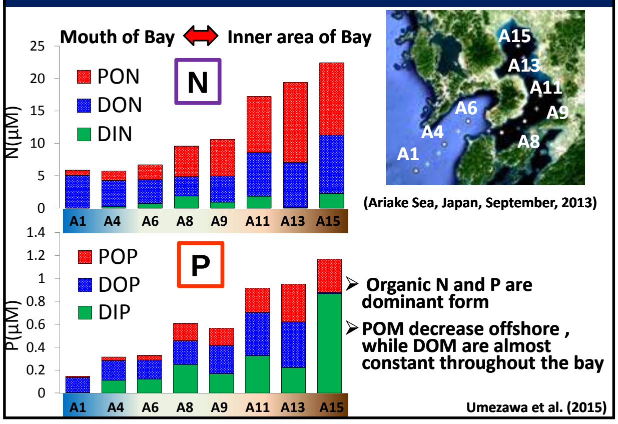
Average composition of nitrogen pools (except dissolved N2) In open ocean (surface & deep), coastal & estuarine waters



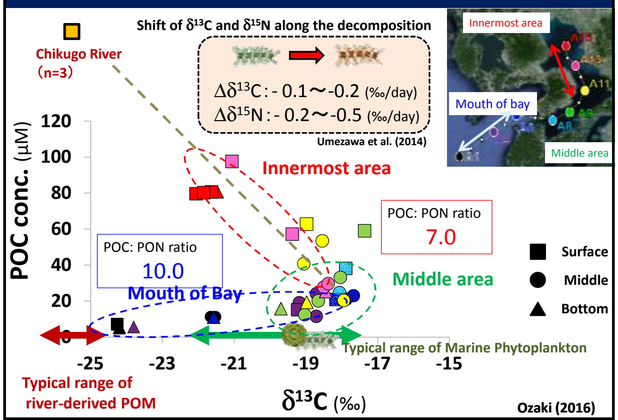
DON pool dominates the surface ocean fixed N reservoir, comprising up to 96-99% of (TDN) in the oligotrophic ocean



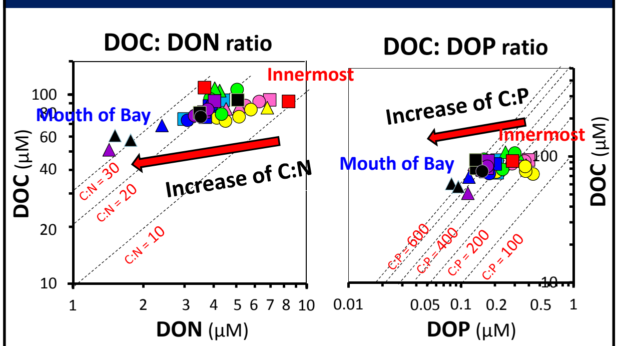
Composition of each form of N and P in the bay



Identification of POC based on $\delta^{13}C$ value

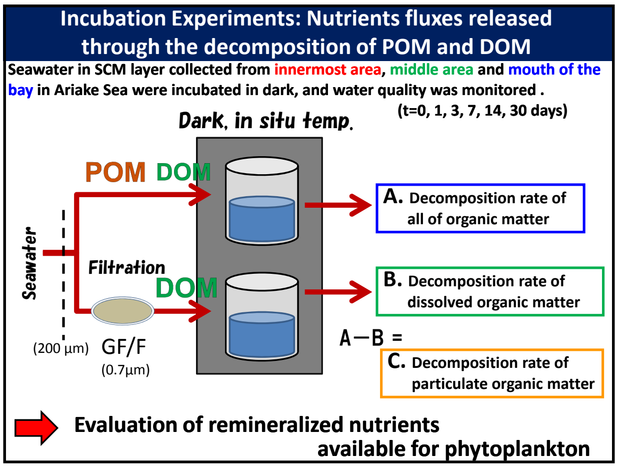


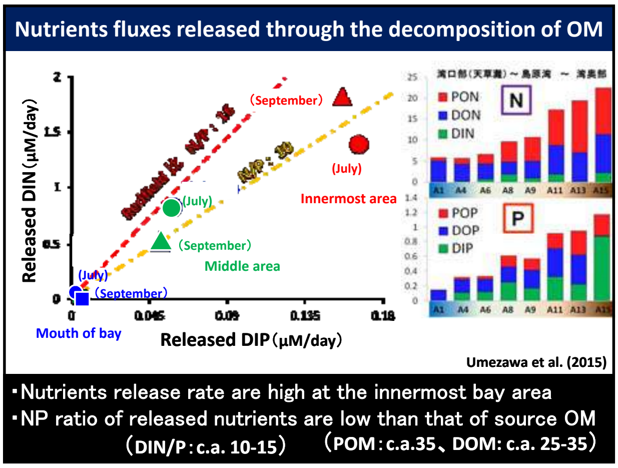
C/N, C/P ratios increase with distance from the river

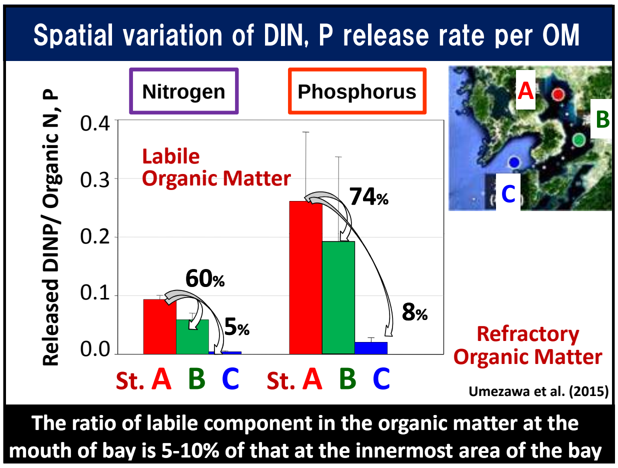


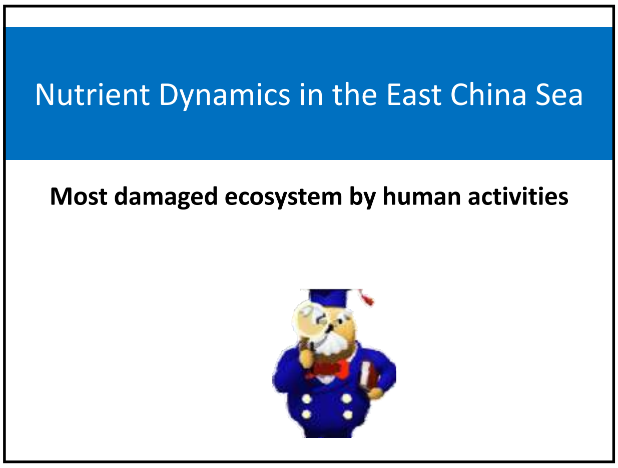
The quality of POM decreases from innermost area to the mouth of bay, in the viewpoint of the source of DIN & DIP

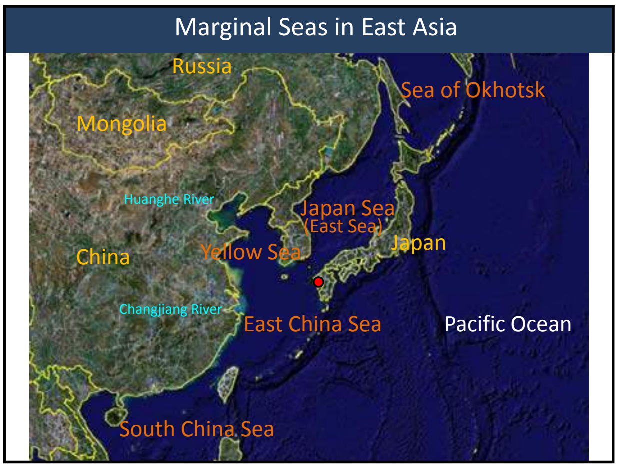
Ozaki (2016)

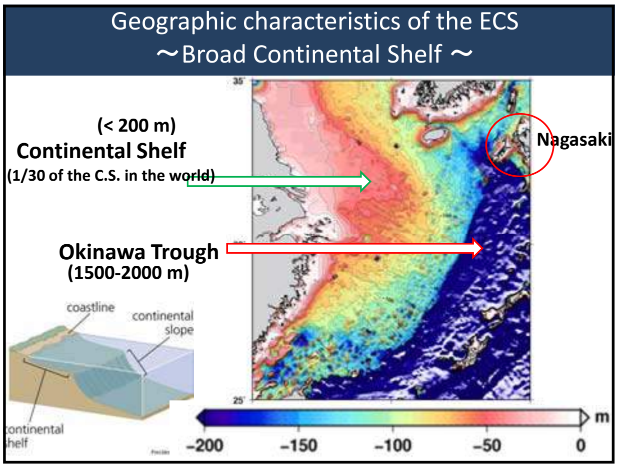

Incubation Experiments: Nutrients fluxes released through the decomposition of POM and DOM
Seawater in SCM layer collected from innermost area, middle area and mouth of the bay in Ariake Sea were incubated in dark, and water quality was monitored .
(t=0, 1, 3, 7, 14, 30 days)
Dark, in situ temp.
POM DOM
Seawater
Filtration
DOM
(200 μm) GF/F
(0.7μm)
A. Decomposition rate of all of organic matter
B. Decomposition rate of dissolved organic matter
A−B =
C. Decomposition rate of particulate organic matter
Evaluation of remineralized nutrients available for phytoplankton

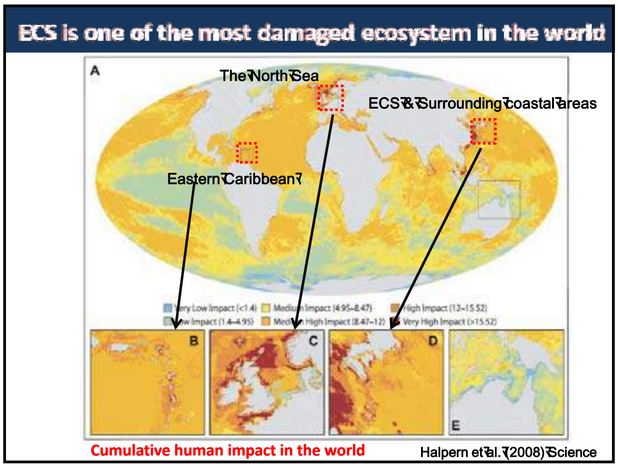

Nutrients fluxes released through the decomposition of OM
Released DIN (μM/day)
Released DIP (μM/day)
(September)
(July)
Innermost area
(July)
(September)
Middle area
(July)
(September)
Mouth of bay
PON
DON
DIN
N
POP
DOP
DIP
P
Umezawa et al. (2015)
・Nutrients release rate are high at the innermost bay area
・NP ratio of released nutrients are low than that of source OM
(DIN/P : c.a. 10-15) (POM : c.a.35、DOM: c.a. 25-35)

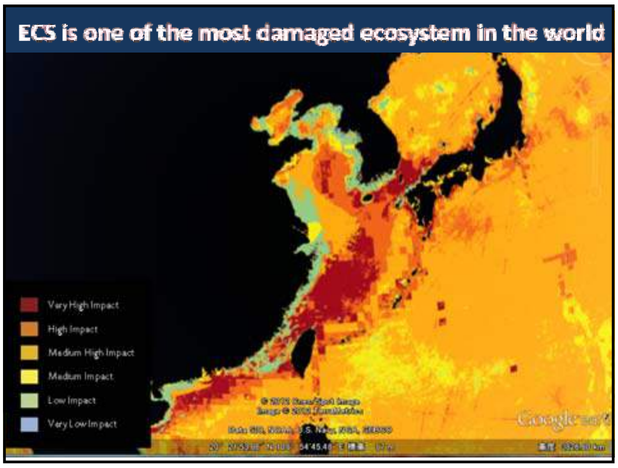

Spatial variation of DIN, P release rate per OM
Nitrogen
Phosphorus
Released DINP/ Organic N, P
0.4
0.3
0.2
0.1
0.0
Labile Organic Matter
60%
5%
74%
8%
Refractory Organic Matter
St. A B C St. A B C
A
B
C
Umezawa et al. (2015)
The ratio of labile component in the organic matter at the mouth of bay is 5-10% of that at the innermost area of the bay

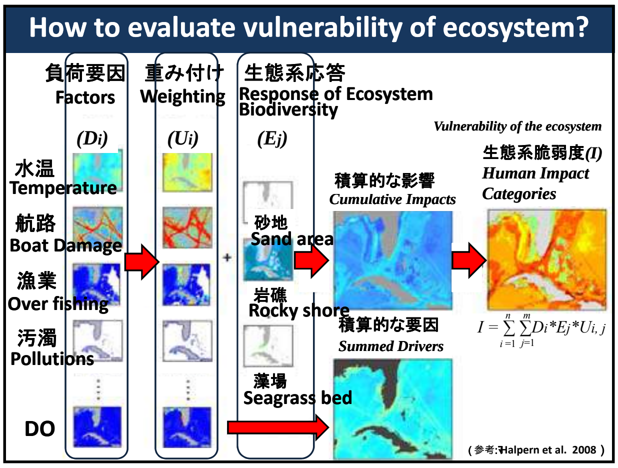

Nutrient Dynamics in the East China Sea
Most damaged ecosystem by human activities

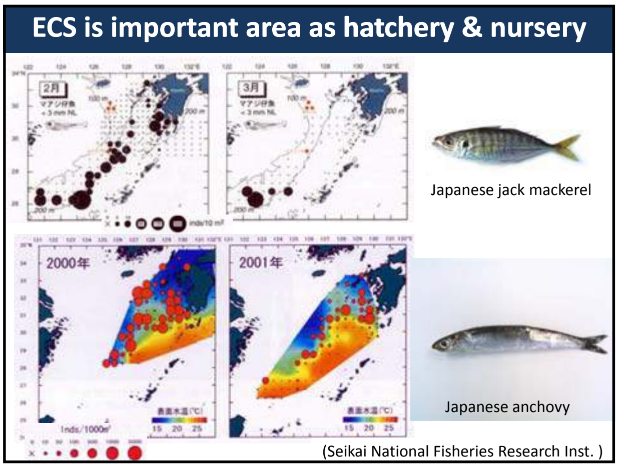

Marginal Seas in East Asia
Russia
Sea of Okhotsk
Mongolia
Huanghe River
Japan Sea
(East Sea)
Japan
China
Yellow Sea
Changjiang River
East China Sea
Pacific Ocean
South China Sea

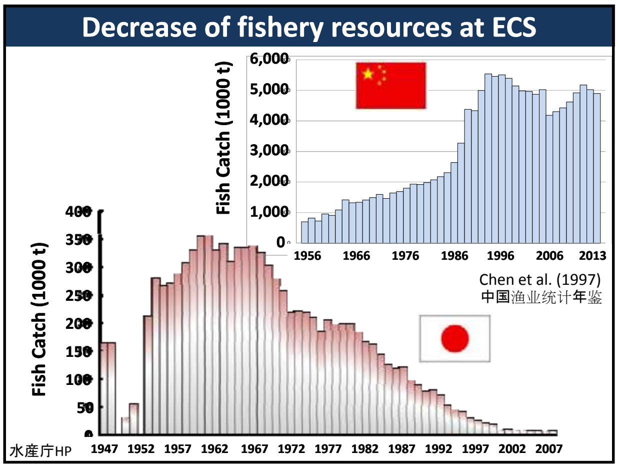

Geographic characteristics of the ECS
〜Broad Continental Shelf 〜
(< 200 m)
Continental Shelf
(1/30 of the C.S. in the world)
Okinawa Trough
(1500-2000 m)
Nagasaki
coastline
continental slope
m
−200 −150 −100 −50 0

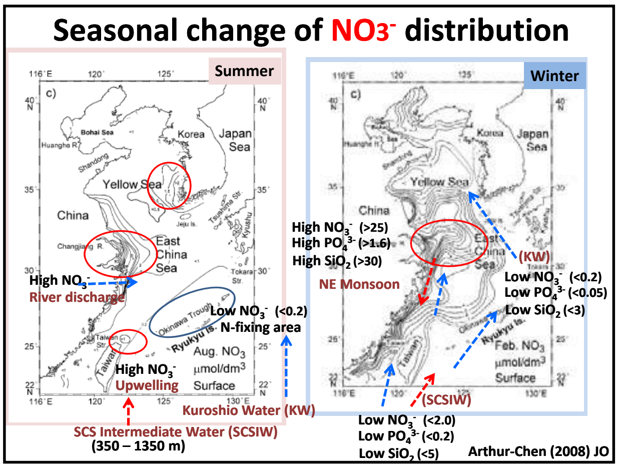

ECS is one of the most damaged ecosystem in the world
The North Sea
ECS & Surrounding coastal areas
Eastern Caribbean
Cumulative human impact in the world
Halpern et al. (2008) Science


ECS is one of the most damaged ecosystem in the world
Very High Impact
High Impact
Medium High Impact
Medium Impact
Low Impact
Very Low Impact

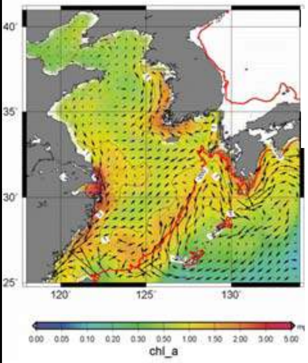

How to evaluate vulnerability of ecosystem?
負荷要因
Factors
重み付け
Weighting
生態系応答
Response of Ecosystem
Biodiversity
(Di)
(Ui)
(Ej)
Vulnerability of the ecosystem
生態系脆弱度(I)
Human Impact
Categories
積算的な影響
Cumulative Impacts
水温
Temperature
航路
Boat Damage
漁業
Over fishing
汚濁
Pollutions
DO
砂地
Sand area
岩礁
Rocky shore
藻場
Seagrass bed
積算的な要因
Summed Drivers
$I = \sum_{i=1}^{n} \sum_{j=1}^{m} Di*Ej*Ui,j$
（参考:Halpern et al. 2008）


ECS is important area as hatchery & nursery
2月
3月
2000年
2001年
Japanese jack mackerel
Japanese anchovy
(Seikai National Fisheries Research Inst.)


Decrease of fishery resources at ECS
Fish Catch (1000 t)
6,000
5,000
4,000
3,000
2,000
1,000
0
1956
1966
1976
1986
1996
2006
2013
Chen et al. (1997)
中国渔业统计年鉴
Fish Catch (1000 t)
400
350
300
250
200
150
100
50
0
水産庁HP
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007


Seasonal change of NO3- distribution
Summer
Winter
Korea
Japan Sea
Yellow Sea
China
East China Sea
High NO3- River discharge
Low NO3- (<0.2)
N-fixing area
High NO3- Upwelling
Aug. NO3 μmol/dm3 Surface
Kuroshio Water (KW)
SCS Intermediate Water (SCSIW)
(350 – 1350 m)
High NO3- (>25)
High PO4 3- (>1.6)
High SiO2 (>30)
NE Monsoon
(KW)
Low NO3- (<0.2)
Low PO4 3- (<0.05)
Low SiO2 (<3)
Feb. NO3 μmol/dm3 Surface
(SCSIW)
Low NO3- (<2.0)
Low PO4 3- (<0.2)
Low SiO2 (<5)
Arthur-Chen (2008) JO

Impact of terrestrial material input from China

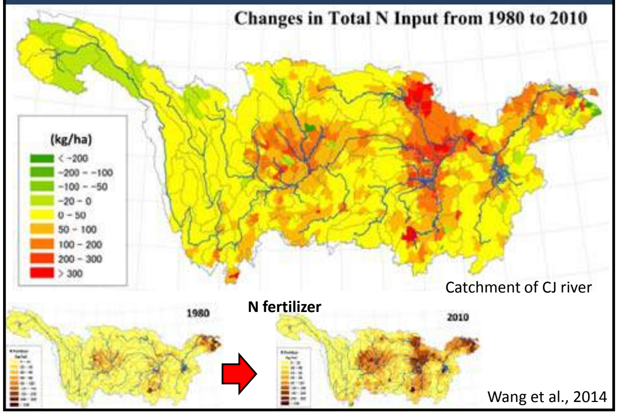


Primary production at ECS is highly supported by material fluxes from China.

Phytoplankton
植物プランクトン

Chlorophyll a distribution simulated based on satellite data & model

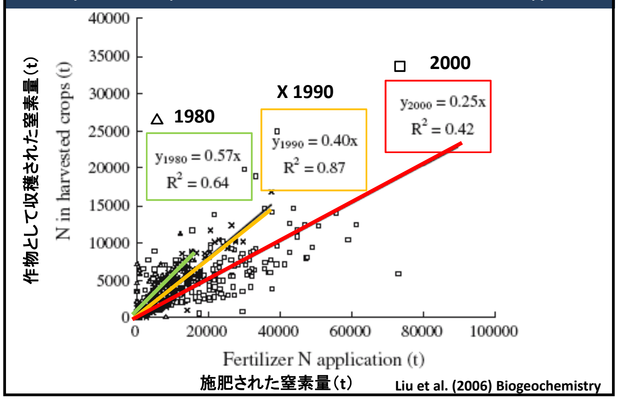
Increase of annual nutrients discharge through CJ River



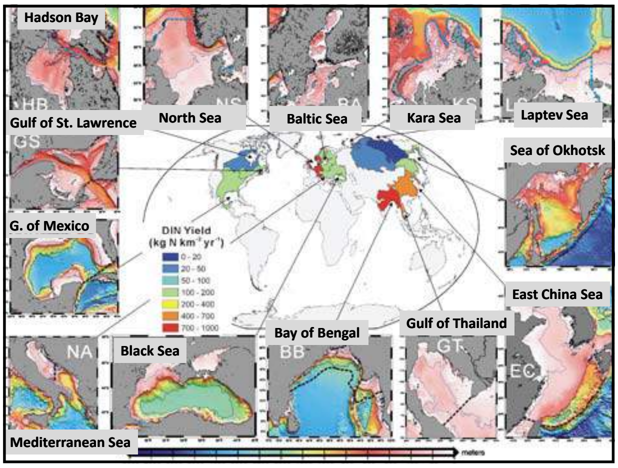
Wang et al., 2014

Increase of fertilizer input & discharge excess N

Efficiency of fertilizer uptake have decreased with an increase of fertilizer N application



Liu et al. (2006) Biogeochemistry



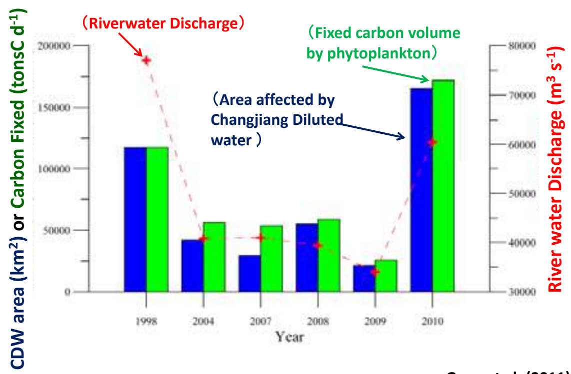
Riverine nutrient fluxes (Gmol/yr) at Major Marginal Sea

based on NEWS model (Seitzinger et al., 2005)

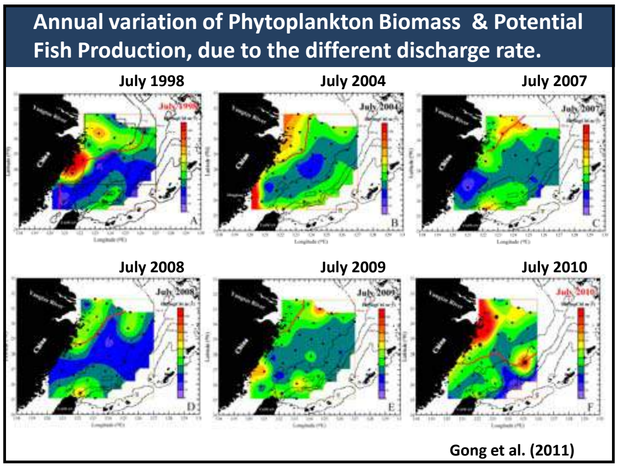
Name	DIN	DIP	DON	DOP	PN	PP	POC
Baltic Sea	19.8	0.68	7.5	0.22	4.7	0.86	49
Bay of Bengal	222.5	3.54	51.8	1.58	99.0	24.37	1396
Black Sea	23.6	1.47	10.5	0.38	8.8	1.75	100
East China Sea	122.7	2.55	25.3	1.03	71.6	13.72	783
Gulf of Mexico	77.2	1.28	17.1	0.54	29.7	5.96	340
Gulf of St. Lawrence	15.7	0.29	17.5	0.47	5.3	0.96	55
Gulf of Thailand	10.4	0.22	6.1	0.17	8.9	1.74	100
Hudson Bay	8.3	0.14	11.8	0.27	6.7	1.21	69
Kara Sea	16.0	0.47	17.1	0.42	18.7	3.51	200
Laptev Sea	3.4	0.09	7.8	0.17	10.6	1.98	113
Northern Adriatic Sea	11.9	0.50	3.3	0.10	4.5	1.06	61
North Sea	58.4	2.44	13.8	0.47	7.4	1.40	80
Sea of Okhotsk	19.9	0.58	8.5	0.21	8.7	1.63	93

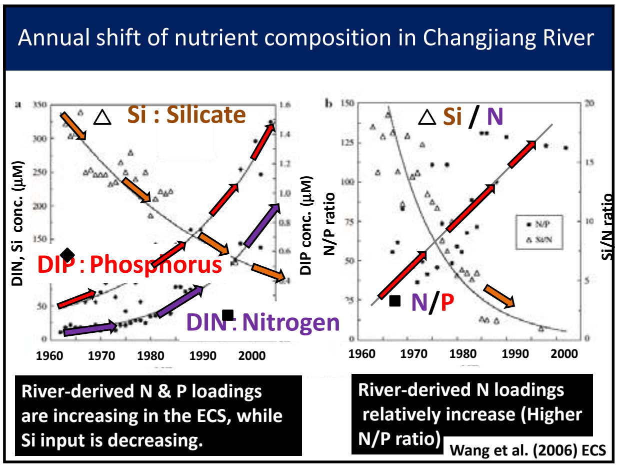
DIN: Dissolved Inorganic Nitrogen
DIP: Dissolved Inorganic Phosphorus
DON: Dissolved Organic Nitrogen
DOP: Dissolved Organic Phosphorus
PN: Particulate Nitrogen
PP: Particulate Phosphorus
POC: Particulate Organic Carbon

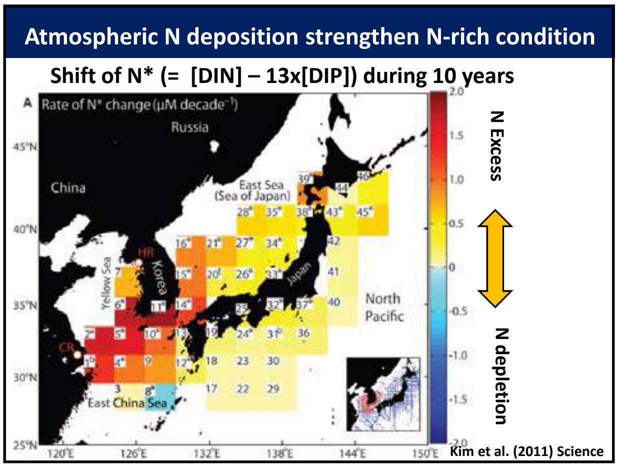
Yangtze River Floods Enhance Coastal Ocean Phytoplankton Biomass & Potential Fish Production

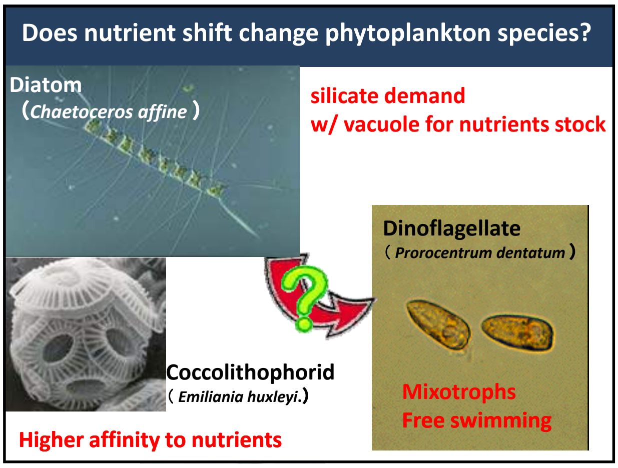


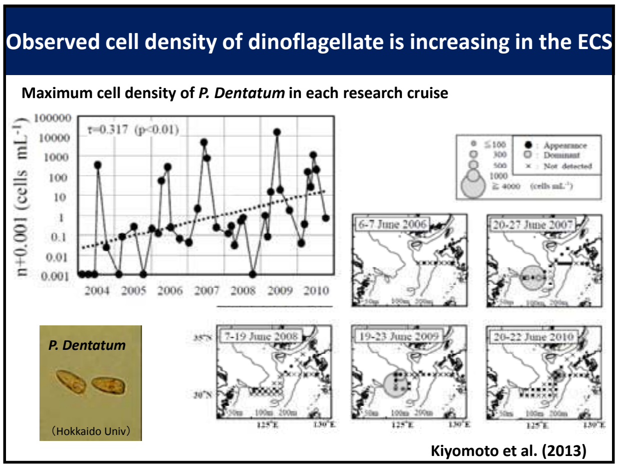
Gong et al. (2011)

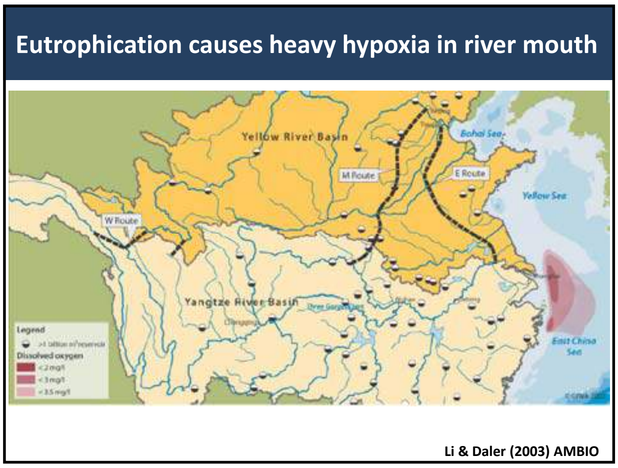

Annual variation of Phytoplankton Biomass & Potential Fish Production, due to the different discharge rate.
July 1998
July 2004
July 2007
July 2008
July 2009
July 2010
Gong et al. (2011)

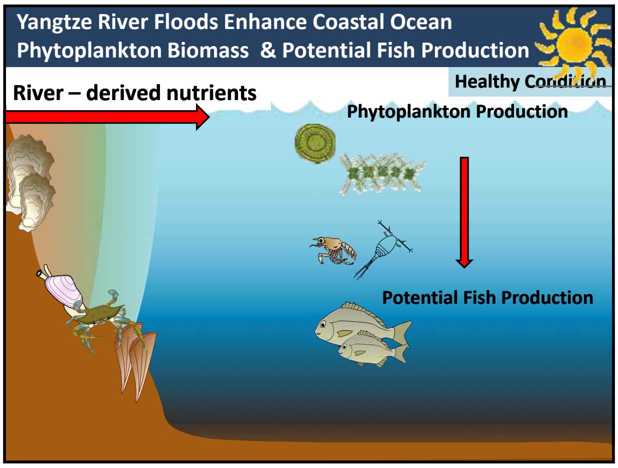

Annual shift of nutrient composition in Changjiang River
Si : Silicate
DIP : Phosphorus
DIN: Nitrogen
DIN, Si conc. (μM)
DIP conc. (μM)
N/P ratio
Si/N ratio
Si / N
N/P
1960
1970
1980
1990
2000
River-derived N & P loadings are increasing in the ECS, while Si input is decreasing.
River-derived N loadings relatively increase (Higher N/P ratio)
Wang et al. (2006) ECS

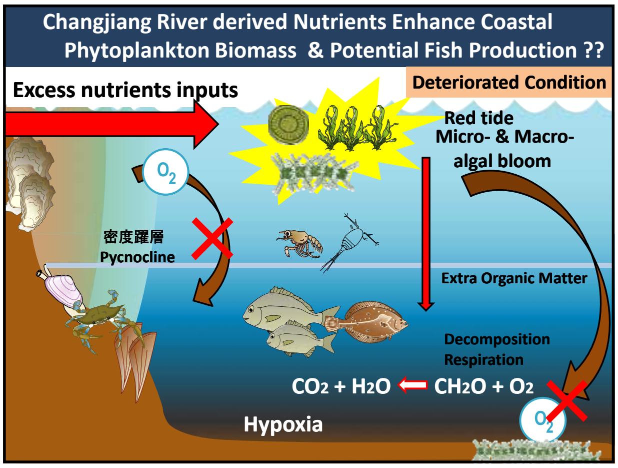

Atmospheric N deposition strengthen N-rich condition
Shift of N* (= [DIN] – 13x[DIP]) during 10 years
Rate of N* change (μM decade⁻¹)
Russia
China
East Sea (Sea of Japan)
Korea
Japan
Yellow Sea
East China Sea
North Pacific
N Excess
N depletion
Kim et al. (2011) Science


Does nutrient shift change phytoplankton species?
Diatom
(Chaetoceros affine)
silicate demand
w/ vacuole for nutrients stock
Dinoflagellate
(Prorocentrum dentatum)
Coccolithophorid
(Emiliania huxleyi.)
Mixotrophs
Free swimming
Higher affinity to nutrients


Observed cell density of dinoflagellate is increasing in the ECS
Maximum cell density of P. Dentatum in each research cruise
n+0.001 (cells mL⁻¹)
τ=0.317 (p<0.01)
2004
2005
2006
2007
2008
2009
2010
6-7 June 2006
20-27 June 2007
7-19 June 2008
19-23 June 2009
20-22 June 2010
P. Dentatum
(Hokkaido Univ)
Kiyomoto et al. (2013)


Eutrophication causes heavy hypoxia in river mouth
Yellow River Basin
Yangtze River Basin
Yellow Sea
East China Sea
Li & Daler (2003) AMBIO

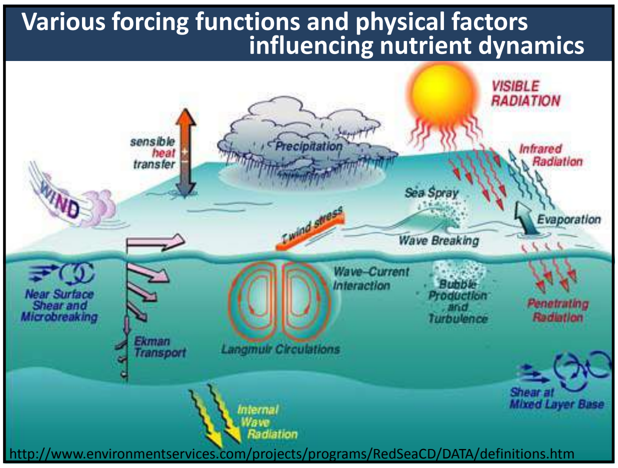


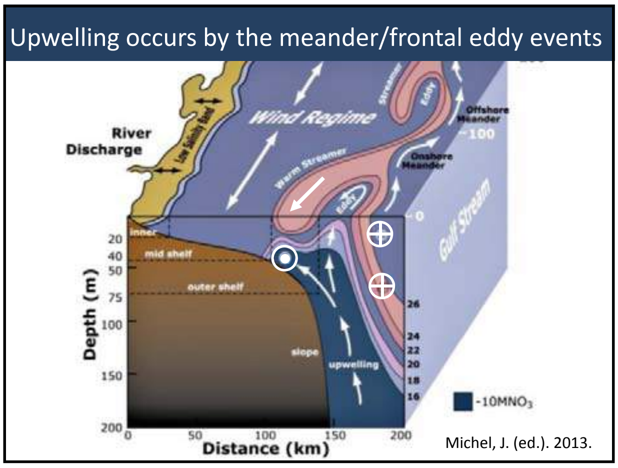


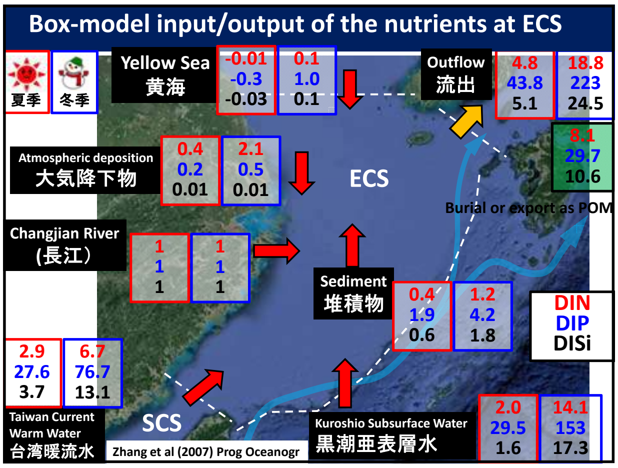
Marginal Seas categorized by forcing function

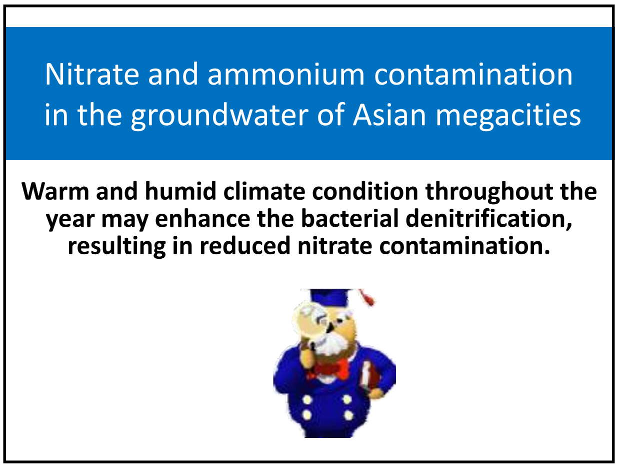
	Thermo haline	Deep Con - vection	Ice Form- ation	River Runoff	Wind	Tropical Storms	Tides	Bound- ary Currents	External Forcing
Red Sea	5	5	0	0	3	0	1	0	0
Med. Sea	5	5	0	1	1	0	1	0	0
Black Sea	3	0	0	5	3	0	1	0	0
G. of Mexico	1	0	0	3	1	3	1	5	0
Japan Sea	3	3	3	1	3	1	1	3	1
Indonesian Seas	1	0	0	1	1	1	3	3	5
South China Sea	1	0	0	1	3	5	?	?	3
Caribbean Sea	1	0	0	1	3	3	1	3	3
Yellow Sea	1	0	1	3	5	1	5	0	1
East China Sea	1	0	0	1	3	3	1	5	1
Sea of Okhotsk	3	3	3	3	3	0	3	1	3
Bering Sea	3	3	3	1	3	0	3	0	3

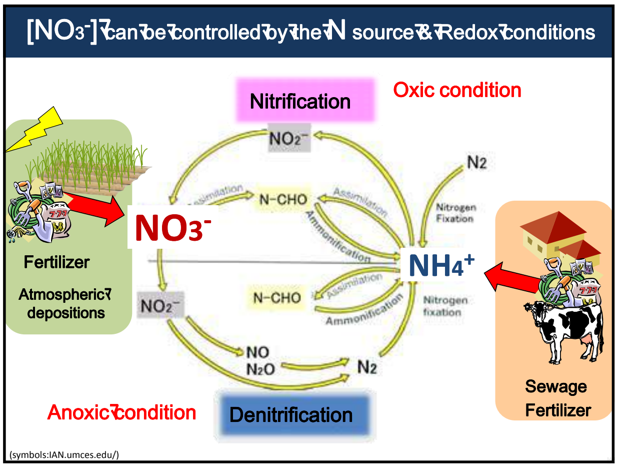
[0 = Not Happening; 1 = Minor Factor; 3 = Important; 5 = Dominant Factor]
Ramp. S.R. (1997)

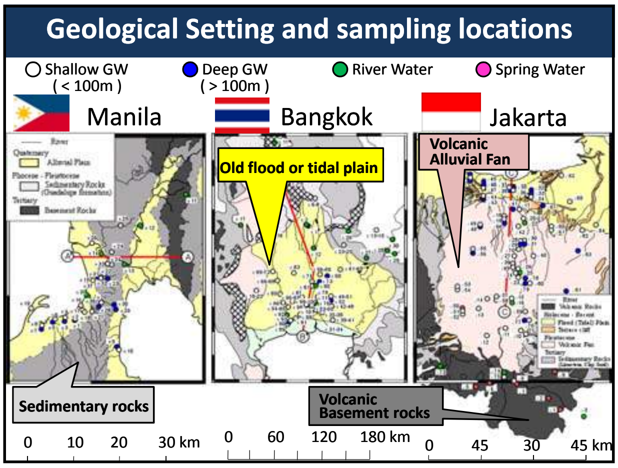


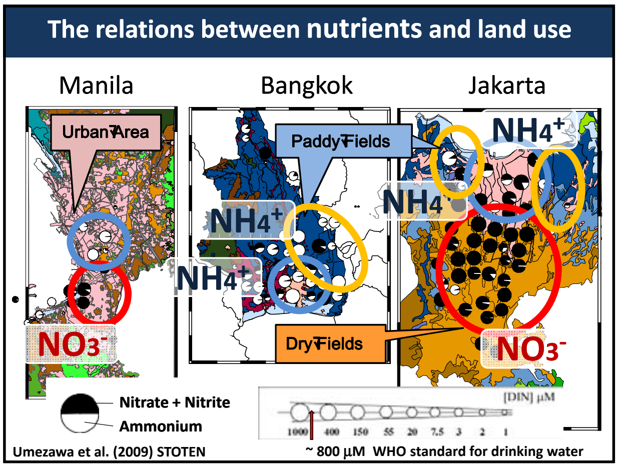


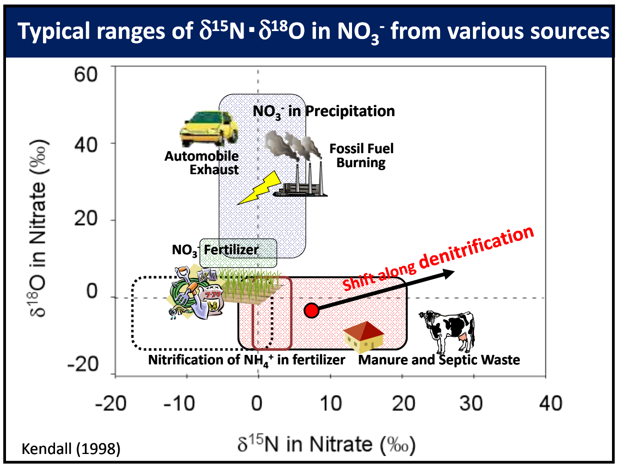


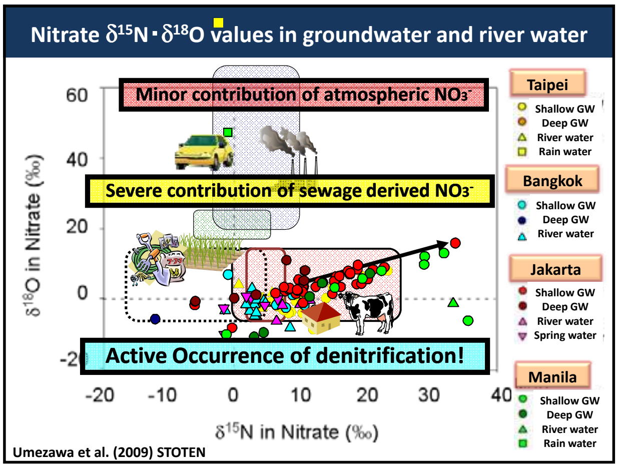

Nitrate and ammonium contamination in the groundwater of Asian megacities
Warm and humid climate condition throughout the year may enhance the bacterial denitrification, resulting in reduced nitrate contamination.

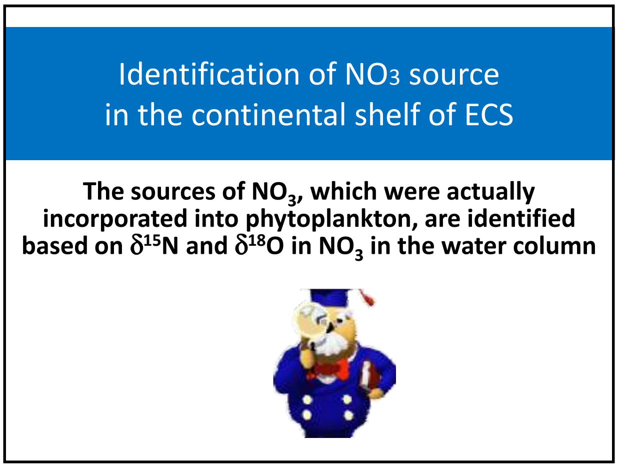

[NO3-] can be controlled by the N source & Redox conditions
Nitrification
Oxic condition
NO2-
N2
N-CHO
Assimilation
Ammonification
Nitrogen Fixation
NO3-
NH4+
Fertilizer
Atmospheric depositions
NO2-
N-CHO
Nitrogen fixation
NO
N2O
N2
Sewage
Fertilizer
Anoxic condition
Denitrification
(symbols:IAN.umces.edu/)

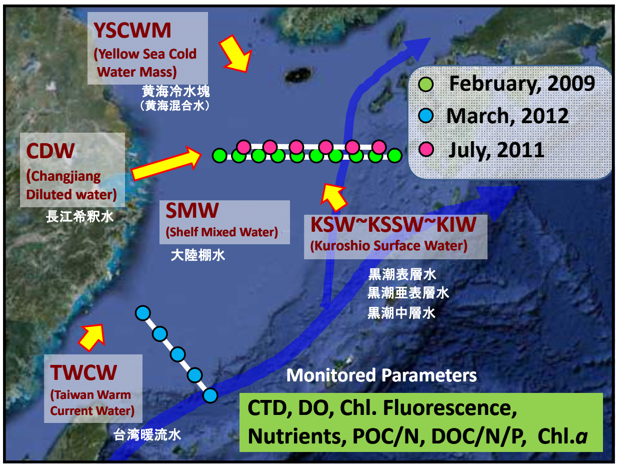

Geological Setting and sampling locations
Shallow GW (< 100m)
Deep GW (> 100m)
River Water
Spring Water
Manila
Bangkok
Jakarta
Old flood or tidal plain
Volcanic Alluvial Fan
Sedimentary rocks
Volcanic Basement rocks
0 10 20 30 km
0 60 120 180 km
0 45 30 45 km

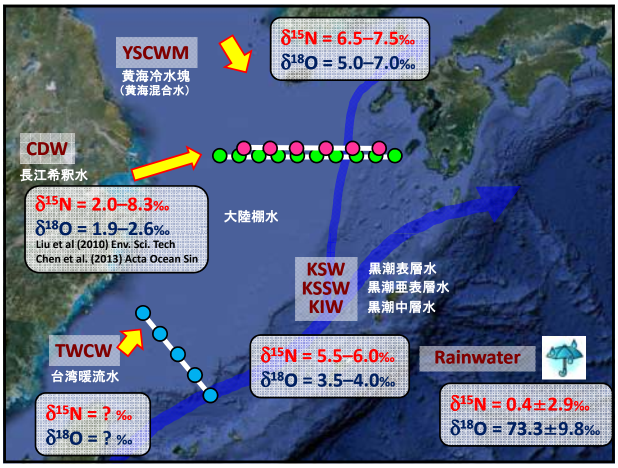

The relations between nutrients and land use
Manila
Bangkok
Jakarta
Urban Area
Paddy Fields
NH4+
NH4+
NH4+
NH4+
NO3-
Dry Fields
NO3-
Nitrate + Nitrite
Ammonium
[DIN] μM
1000 400 150 55 20 7.5 3 2 1
Umezawa et al. (2009) STOTEN
~ 800 μM WHO standard for drinking water

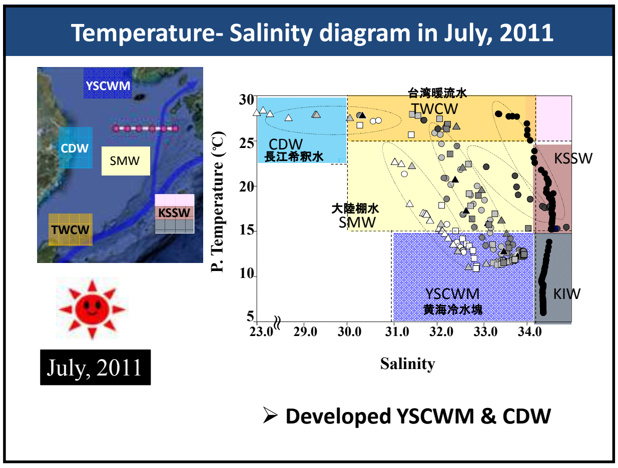

Typical ranges of δ15N・δ18O in NO3- from various sources
NO3- in Precipitation
Automobile Exhaust
Fossil Fuel Burning
NO3- Fertilizer
Shift along denitrification
Nitrification of NH4+ in fertilizer
Manure and Septic Waste
δ18O in Nitrate (‰)
δ15N in Nitrate (‰)
60
40
20
0
-20
-20 -10 0 10 20 30 40
Kendall (1998)

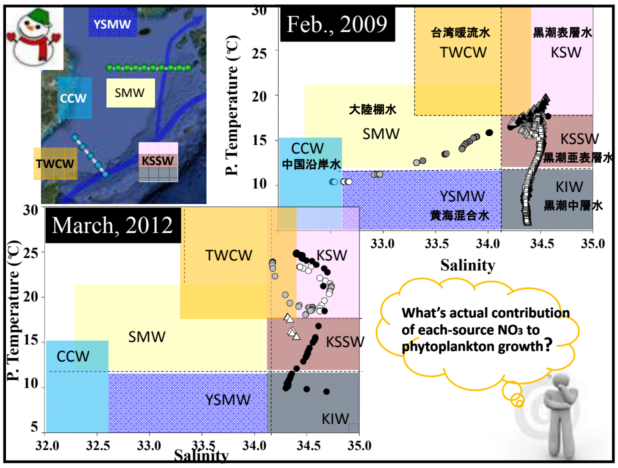

Nitrate δ15N・δ18O values in groundwater and river water
Minor contribution of atmospheric NO3-
Severe contribution of sewage derived NO3-
Active Occurrence of denitrification!
δ18O in Nitrate (‰)
δ15N in Nitrate (‰)
60
40
20
0
-20
-20 -10 0 10 20 30 40
Taipei
Shallow GW
Deep GW
River water
Rain water
Bangkok
Shallow GW
Deep GW
River water
Jakarta
Shallow GW
Deep GW
River water
Spring water
Manila
Shallow GW
Deep GW
River water
Rain water
Umezawa et al. (2009) STOTEN

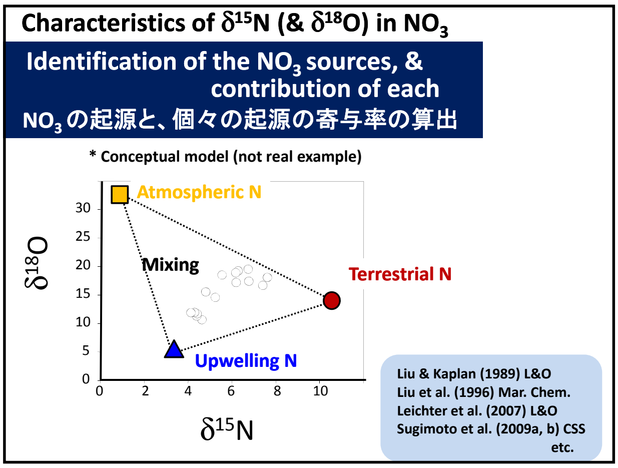

Identification of NO3 source
in the continental shelf of ECS
The sources of NO_3, which were actually incorporated into phytoplankton, are identified based on $\delta^{15}N$ and $\delta^{18}O$ in NO_3 in the water column

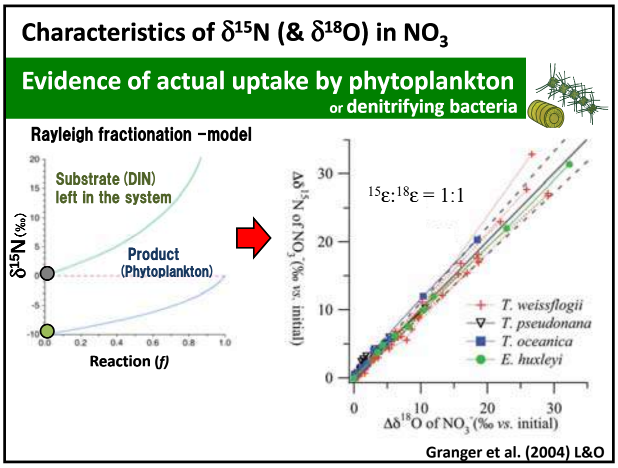

YSCWM
(Yellow Sea Cold Water Mass)
黄海冷水塊
（黄海混合水）
February, 2009
March, 2012
July, 2011
CDW
(Changjiang Diluted water)
長江希釈水
SMW
(Shelf Mixed Water)
大陸棚水
KSW~KSSW~KIW
(Kuroshio Surface Water)
黒潮表層水
黒潮亜表層水
黒潮中層水
TWCW
(Taiwan Warm Current Water)
台湾暖流水
Monitored Parameters
CTD, DO, Chl. Fluorescence,
Nutrients, POC/N, DOC/N/P, Chl.a

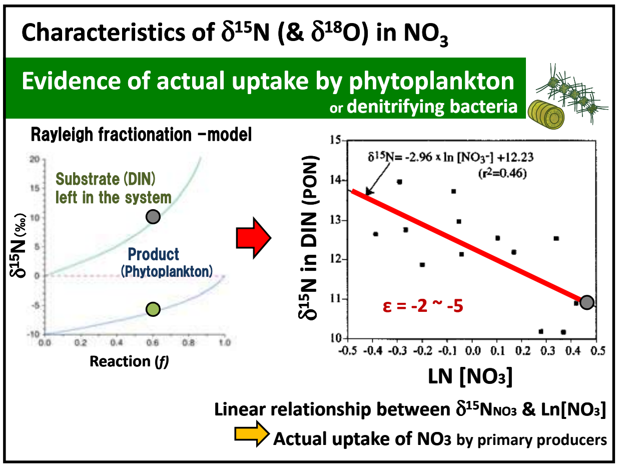

YSCWM
黄海冷水塊
（黄海混合水）
$\delta^{15}N$ = 6.5–7.5‰
$\delta^{18}O$ = 5.0–7.0‰
CDW
長江希釈水
$\delta^{15}N$ = 2.0–8.3‰
$\delta^{18}O$ = 1.9–2.6‰
Liu et al (2010) Env. Sci. Tech
Chen et al. (2013) Acta Ocean Sin
大陸棚水
KSW
KSSW
KIW
黒潮表層水
黒潮亜表層水
黒潮中層水
TWCW
台湾暖流水
$\delta^{15}N$ = 5.5–6.0‰
$\delta^{18}O$ = 3.5–4.0‰
Rainwater
$\delta^{15}N$ = 0.4±2.9‰
$\delta^{18}O$ = 73.3±9.8‰
$\delta^{15}N$ = ? ‰
$\delta^{18}O$ = ? ‰

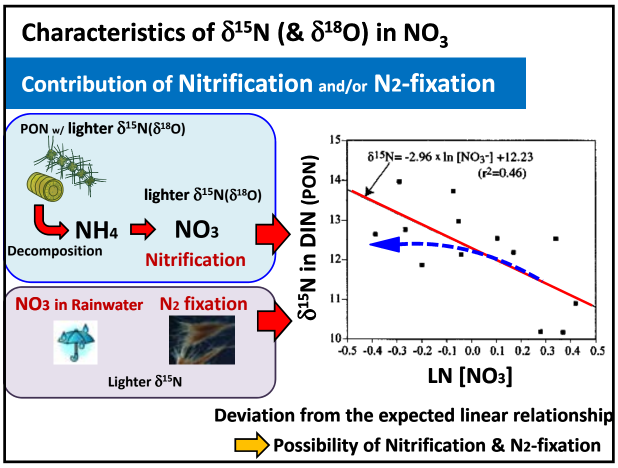

Temperature- Salinity diagram in July, 2011
YSCWM
CDW
SMW
TWCW
KSSW
台湾暖流水
TWCW
CDW
長江希釈水
大陸棚水
SMW
KSSW
YSCWM
黄海冷水塊
KIW
P. Temperature (℃)
Salinity
July, 2011
➢ Developed YSCWM & CDW

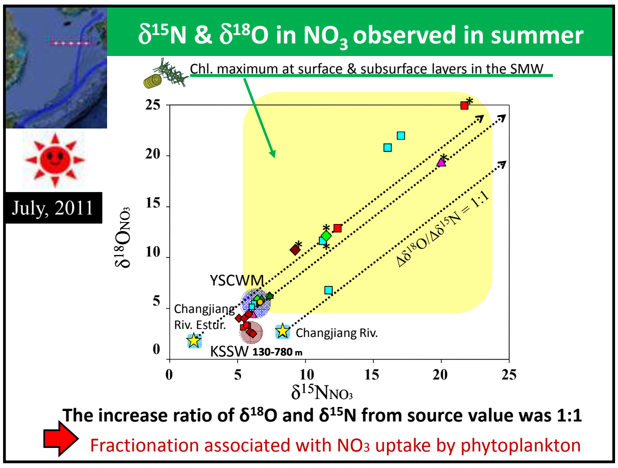

YSMW
CCW
SMW
TWCW
KSSW
Feb., 2009
台湾暖流水
TWCW
黒潮表層水
KSW
大陸棚水
SMW
CCW
中国沿岸水
KSSW
黒潮亜表層水
YSMW
黄海混合水
KIW
黒潮中層水
P. Temperature (℃)
Salinity
March, 2012
TWCW
KSW
SMW
CCW
KSSW
YSMW
KIW
What's actual contribution of each-source NO3 to phytoplankton growth?

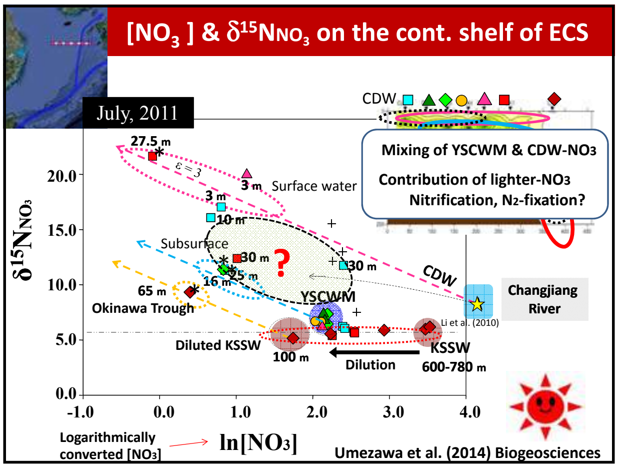

Characteristics of $\delta^{15}N$ (& $\delta^{18}O$) in NO_3
Identification of the NO_3 sources, & contribution of each
NO_3の起源と、個々の起源の寄与率の算出
* Conceptual model (not real example)
Atmospheric N
Mixing
Terrestrial N
Upwelling N
$\delta^{18}O$
$\delta^{15}N$
Liu & Kaplan (1989) L&O
Liu et al. (1996) Mar. Chem.
Leichter et al. (2007) L&O
Sugimoto et al. (2009a, b) CSS
etc.

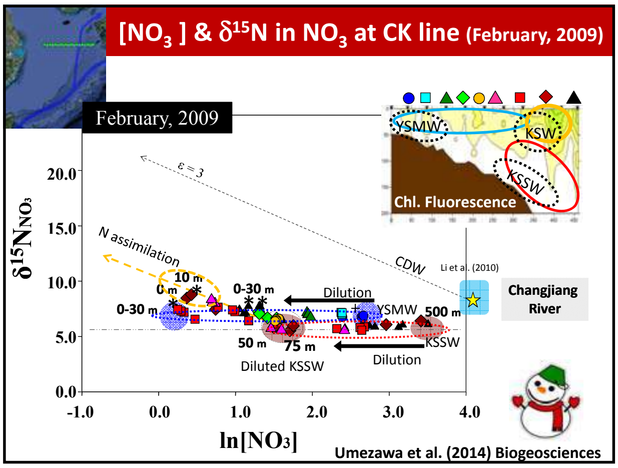

Characteristics of δ15N (& δ18O) in NO3
Evidence of actual uptake by phytoplankton
or denitrifying bacteria
Rayleigh fractionation –model
Substrate (DIN)
left in the system
Product
(Phytoplankton)
δ15N (‰)
Reaction (f)
15ε:18ε = 1:1
Δδ15N of NO3- (‰ vs. initial)
Δδ18O of NO3- (‰ vs. initial)
T. weissflogii
T. pseudonana
T. oceanica
E. huxleyi
Granger et al. (2004) L&O

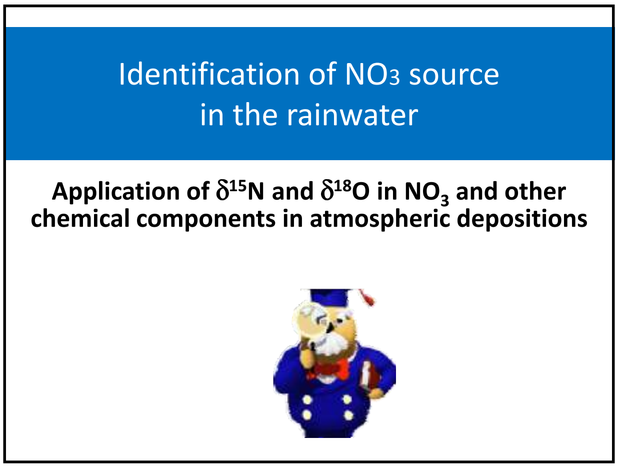

Characteristics of δ15N (& δ18O) in NO3
Evidence of actual uptake by phytoplankton
or denitrifying bacteria
Rayleigh fractionation –model
Substrate (DIN)
left in the system
Product
(Phytoplankton)
δ15N (‰)
Reaction (f)
δ15N= -2.96 x ln [NO3-] +12.23
(r2=0.46)
δ15N in DIN (PON)
ε = -2 ~ -5
LN [NO3]
Linear relationship between δ15NNO3 & Ln[NO3]
Actual uptake of NO3 by primary producers

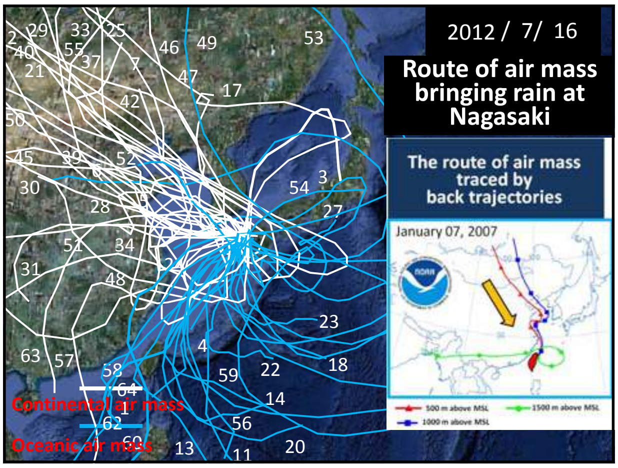

Characteristics of δ15N (& δ18O) in NO3
Contribution of Nitrification and/or N2-fixation
PON w/ lighter δ15N(δ18O)
lighter δ15N(δ18O)
NH4
NO3
Decomposition
Nitrification
NO3 in Rainwater
N2 fixation
Lighter δ15N
δ15N= -2.96 x ln [NO3-] +12.23
(r2=0.46)
δ15N in DIN (PON)
LN [NO3]
Deviation from the expected linear relationship
Possibility of Nitrification & N2-fixation

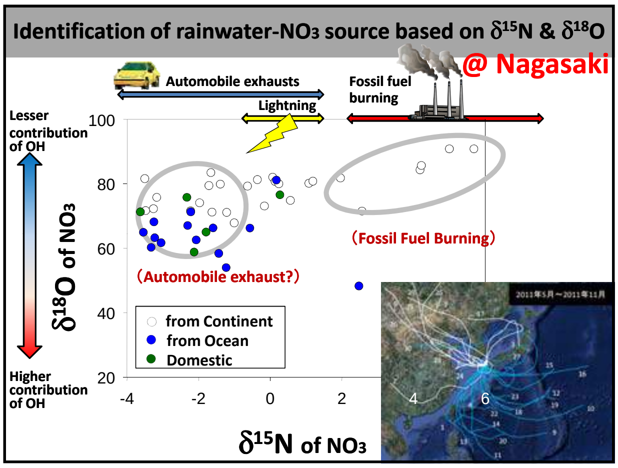

δ15N & δ18O in NO3 observed in summer
Chl. maximum at surface & subsurface layers in the SMW
July, 2011
δ18ONO3
δ15NNO3
Δδ18O/Δδ15N = 1:1
YSCWM
Changjiang Riv. Estur.
Changjiang Riv.
KSSW 130-780 m
The increase ratio of δ18O and δ15N from source value was 1:1
Fractionation associated with NO3 uptake by phytoplankton

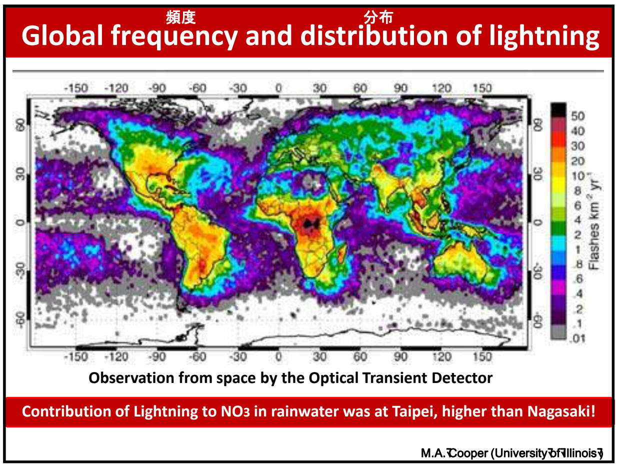

[NO3] & δ15NNO3 on the cont. shelf of ECS
July, 2011
CDW
Mixing of YSCWM & CDW-NO3
Contribution of lighter-NO3
Nitrification, N2-fixation?
27.5 m
3 m
Surface water
10 m
Subsurface
30 m
16 m
25 m
65 m
Okinawa Trough
YSCWM
Changjiang River
Diluted KSSW
100 m
Dilution
KSSW
600-780 m
Li et al. (2010)
δ15NNO3
Logarithmically converted [NO3]
ln[NO3]
Umezawa et al. (2014) Biogeosciences

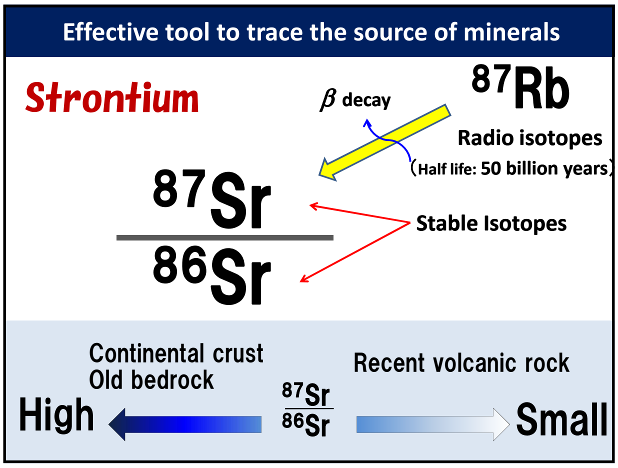

[NO3] & δ15N in NO3 at CK line (February, 2009)
February, 2009
YSMW
KSW
KSSW
Chl. Fluorescence
N assimilation
ε = 3
CDW
Li et al. (2010)
Changjiang River
10 m
0-30 m
Dilution
YSMW
500 m
50 m
75 m
Diluted KSSW
δ15NNO3
ln[NO3]
Umezawa et al. (2014) Biogeosciences

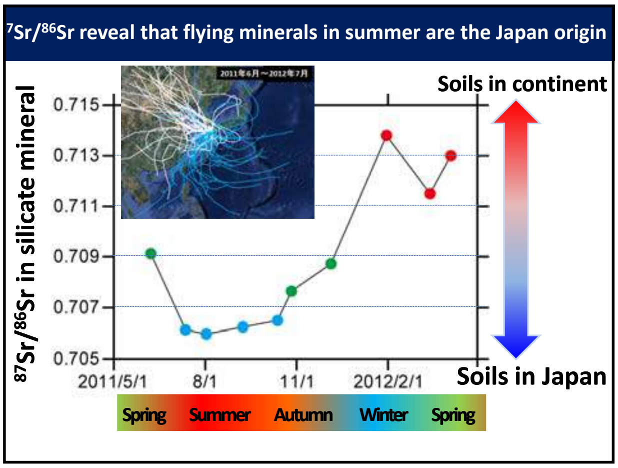

Identification of NO3 source
in the rainwater
Application of δ15N and δ18O in NO3 and other chemical components in atmospheric depositions

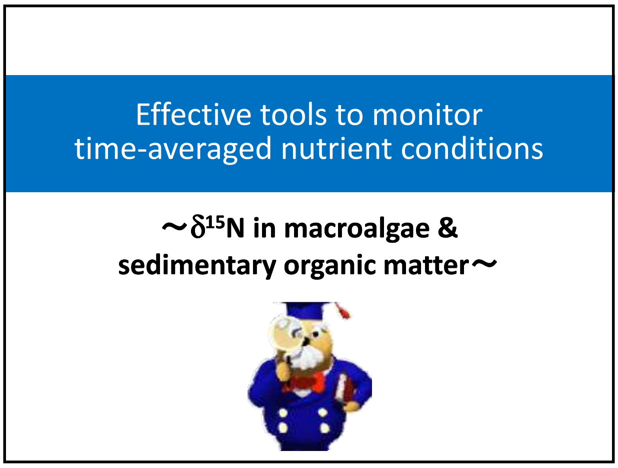

2012 / 7/ 16
Route of air mass bringing rain at Nagasaki
The route of air mass traced by back trajectories
January 07, 2007
Continental air mass
Oceanic air mass

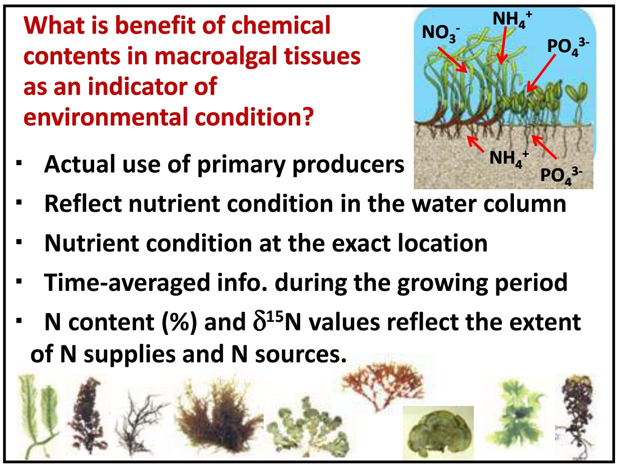

Identification of rainwater-NO3 source based on δ15N & δ18O
@ Nagasaki
Automobile exhausts
Lightning
Fossil fuel burning
Lesser contribution of OH
Higher contribution of OH
δ18O of NO3
δ15N of NO3
(Automobile exhaust?)
(Fossil Fuel Burning)
from Continent
from Ocean
Domestic

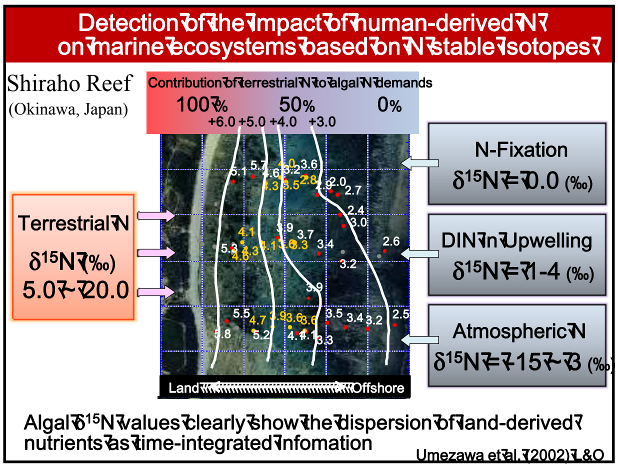

頻度
分布
Global frequency and distribution of lightning
Flashes km-2 yr-1
Observation from space by the Optical Transient Detector
Contribution of Lightning to NO3 in rainwater was at Taipei, higher than Nagasaki!
M.A. Cooper (University of Illinois)

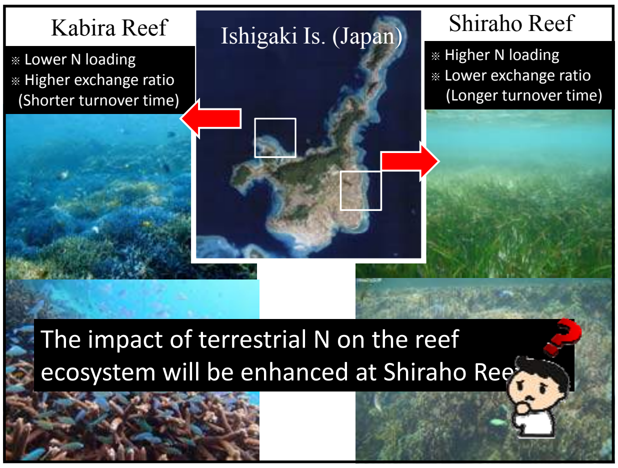

Effective tool to trace the source of minerals
Strontium
β decay
87Rb
Radio isotopes
(Half life: 50 billion years)
87Sr
86Sr
Stable Isotopes
Continental crust
Old bedrock
Recent volcanic rock
High
87Sr/86Sr
Small

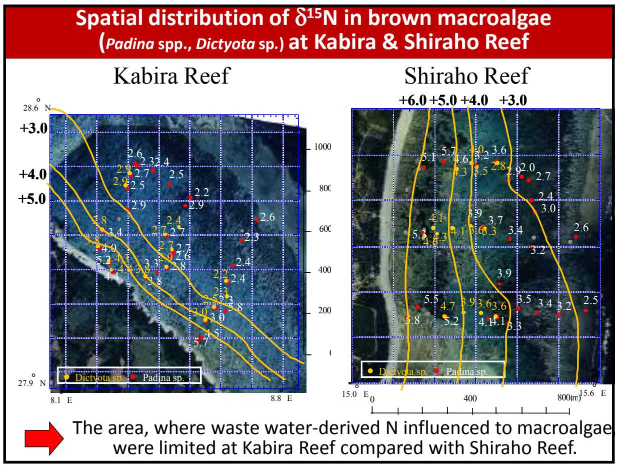

7Sr/86Sr reveal that flying minerals in summer are the Japan origin
87Sr/86Sr in silicate mineral
Soils in continent
Soils in Japan
2011/5/1
8/1
11/1
2012/2/1
Spring
Summer
Autumn
Winter
Spring

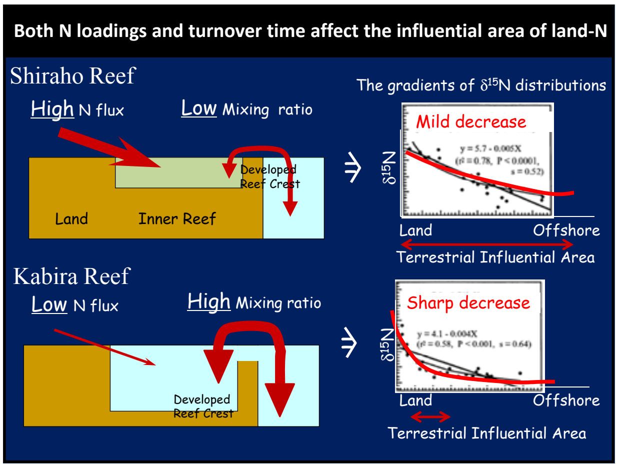

Effective tools to monitor
time-averaged nutrient conditions
～δ¹⁵N in macroalgae &
sedimentary organic matter～

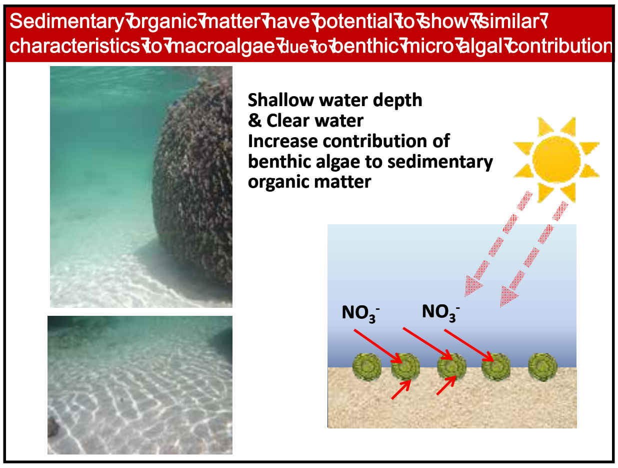

What is benefit of chemical contents in macroalgal tissues as an indicator of environmental condition?
NO3-
NH4+
PO43-
NH4+
PO43-
▪ Actual use of primary producers
▪ Reflect nutrient condition in the water column
▪ Nutrient condition at the exact location
▪ Time-averaged info. during the growing period
▪ N content (%) and δ15N values reflect the extent of N supplies and N sources.

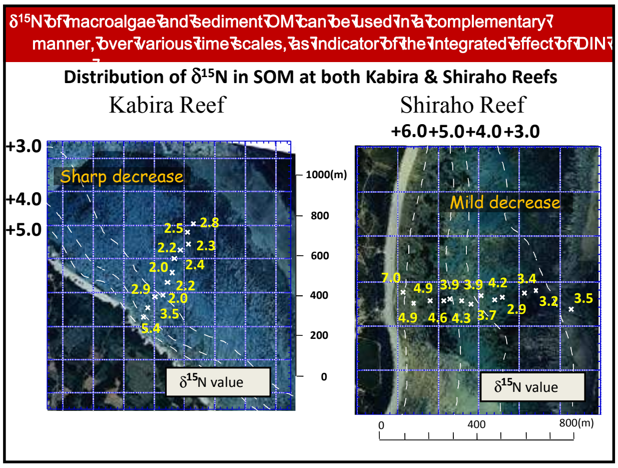

Detection of the impact of human-derived N on marine ecosystems based on N stable isotopes
Shiraho Reef
(Okinawa, Japan)
Contribution of terrestrial N to algal N demands
100% 50% 0%
+6.0 +5.0 +4.0 +3.0
Terrestrial N
δ15N (‰)
5.0 - 20.0
N-Fixation
δ15N = 0.0 (‰)
DIN in Upwelling
δ15N = 1-4 (‰)
Atmospheric N
δ15N = -15 - 3 (‰)
Land Offshore
Algal δ15N values clearly show the dispersion of land-derived nutrients as time-integrated infomation
Umezawa et al. (2002) L&O

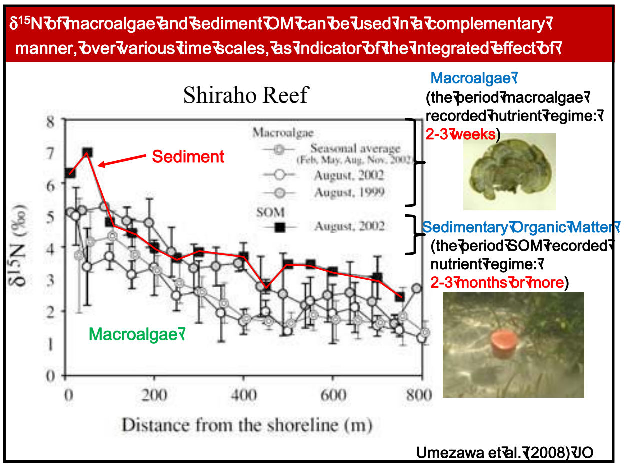

Kabira Reef
※ Lower N loading
※ Higher exchange ratio
(Shorter turnover time)
Ishigaki Is. (Japan)
Shiraho Reef
※ Higher N loading
※ Lower exchange ratio
(Longer turnover time)
The impact of terrestrial N on the reef ecosystem will be enhanced at Shiraho Reef

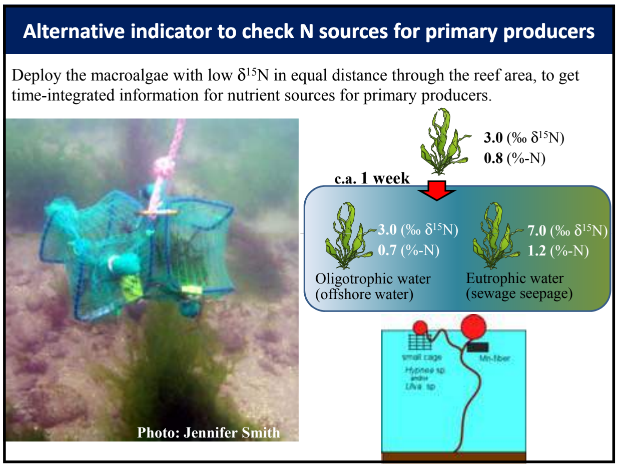

Spatial distribution of δ15N in brown macroalgae
(Padina spp., Dictyota sp.) at Kabira & Shiraho Reef
Kabira Reef
Shiraho Reef
+3.0
+4.0
+5.0
+6.0 +5.0 +4.0 +3.0
Dictyota sp.
Padina sp.
The area, where waste water-derived N influenced to macroalgae were limited at Kabira Reef compared with Shiraho Reef.

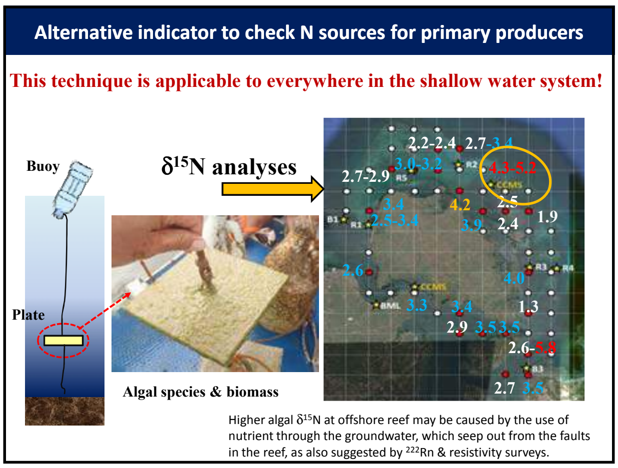

Both N loadings and turnover time affect the influential area of land-N
Shiraho Reef
High N flux
Low Mixing ratio
Developed Reef Crest
Land
Inner Reef
The gradients of δ15N distributions
Mild decrease
Land
Offshore
Terrestrial Influential Area
Kabira Reef
Low N flux
High Mixing ratio
Developed Reef Crest
Sharp decrease
Land
Offshore
Terrestrial Influential Area

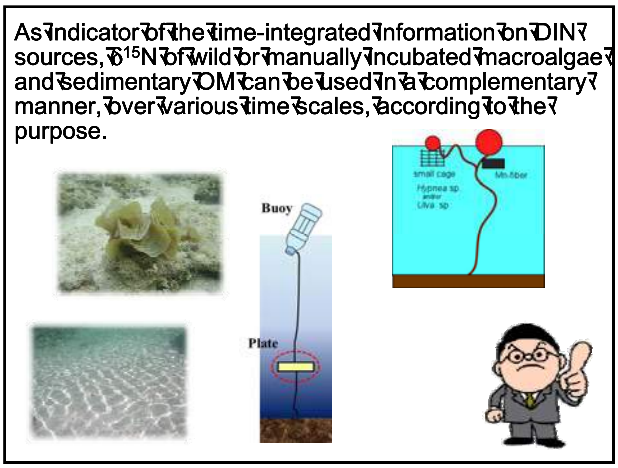

Sedimentary organic matter have potential to show similar characteristics to macroalgae due to benthic micro algal contribution
Shallow water depth
& Clear water
Increase contribution of benthic algae to sedimentary organic matter
NO3-
NO3-


δ15N of macroalgae and sediment OM can be used in a complementary manner, over various time scales, as indicator of the integrated effect of DIN
Distribution of δ15N in SOM at both Kabira & Shiraho Reefs
Kabira Reef
Shiraho Reef
+3.0
+4.0
+5.0
+6.0+5.0+4.0+3.0
Sharp decrease
Mild decrease
δ15N value
δ15N value
1000(m)
800
600
400
200
0
400
800(m)


δ15N of macroalgae and sediment OM can be used in a complementary manner, over various time scales, as indicator of the integrated effect of
Shiraho Reef
Macroalgae
(the period macroalgae recorded nutrient regime:
2-3 weeks)
Sediment
Macroalgae
Seasonal average
(Feb, May, Aug, Nov, 2002)
August, 2002
August, 1999
SOM
August, 2002
Sedimentary Organic Matter
(the period SOM recorded nutrient regime:
2-3 months or more)
Macroalgae
δ15N (‰)
Distance from the shoreline (m)
Umezawa et al. (2008) JO


Alternative indicator to check N sources for primary producers
Deploy the macroalgae with low δ15N in equal distance through the reef area, to get time-integrated information for nutrient sources for primary producers.
3.0 (‰ δ15N)
0.8 (%-N)
c.a. 1 week
3.0 (‰ δ15N)
0.7 (%-N)
7.0 (‰ δ15N)
1.2 (%-N)
Oligotrophic water
(offshore water)
Eutrophic water
(sewage seepage)
Photo: Jennifer Smith

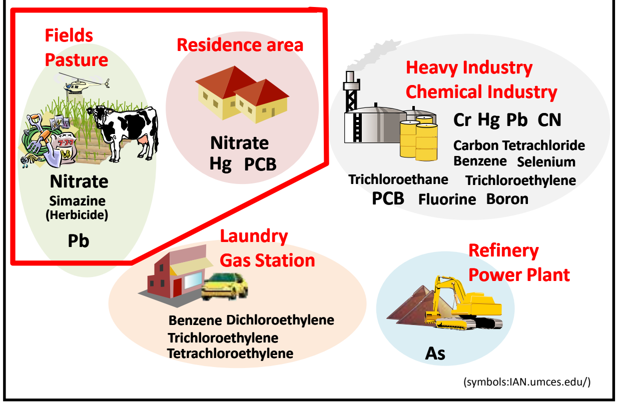

Alternative indicator to check N sources for primary producers
This technique is applicable to everywhere in the shallow water system!
Buoy
Plate
δ15N analyses
Algal species & biomass
Higher algal δ15N at offshore reef may be caused by the use of nutrient through the groundwater, which seep out from the faults in the reef, as also suggested by 222Rn & resistivity surveys.


As indicator of the time-integrated information on DIN sources, δ15N of wild or manually incubated macroalgae and sedimentary OM can be used in a complementary manner, over various time scales, according to the purpose.
Buoy
Plate

Reconstruction of the history of nutrient dynamics (source and eutrophication)

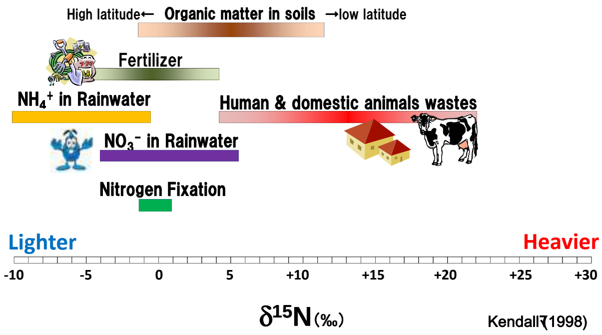
The use of chemical components in the sediment core samples

Anthropogenic contaminants into aquatic ecosystems



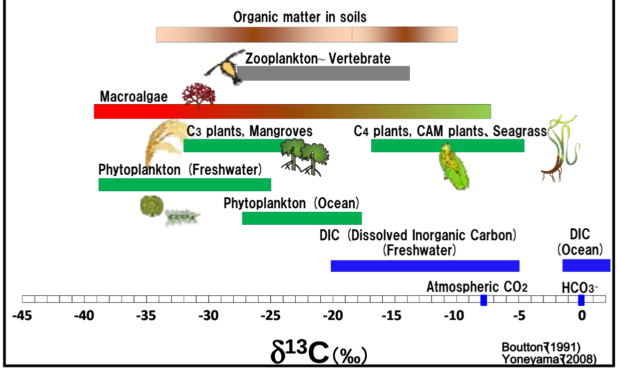
Variation of $\delta^{15}N$ value in N compounds

- $\delta^{15}N$ in organic matter and DIN (Dissolved Inorganic Nitrogen)

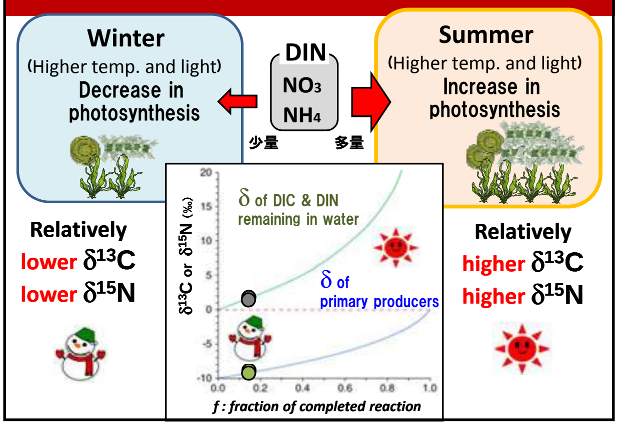


Variation of $\delta^{13}C$ value in C compounds

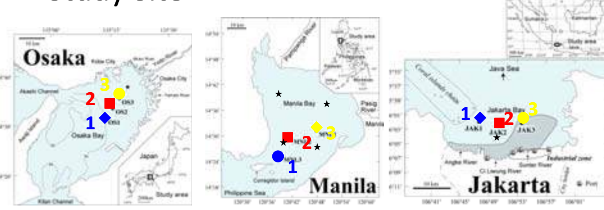
- $\delta^{13}C$ in organic matter and DIC (Dissolved Inorganic Carbon)



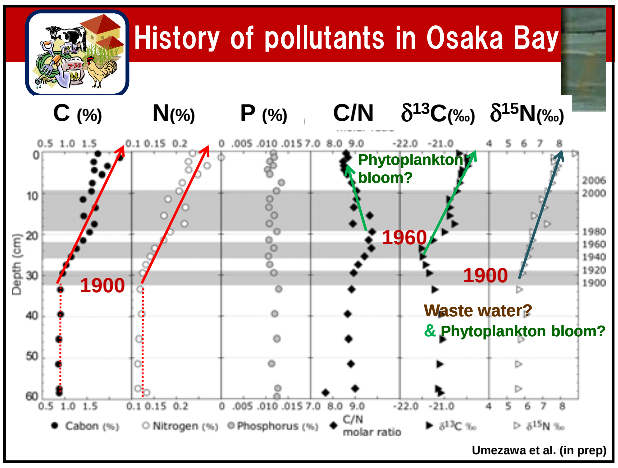
Response of $\delta^{13}C$ & $\delta^{15}N$ in primary producers to growth rate



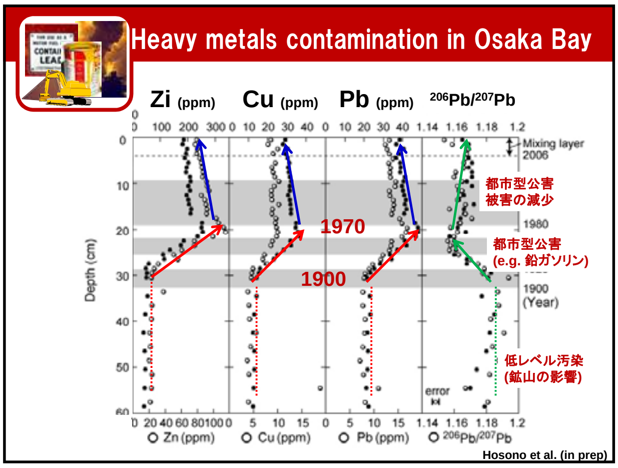
Study Site



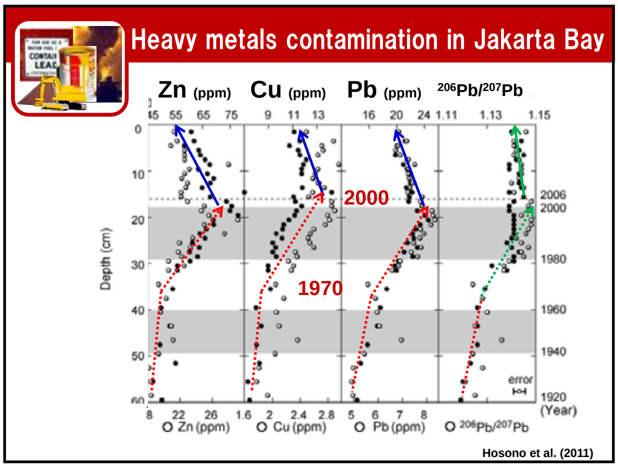
	Osaka	Manila	Jakarta
Area (km^2)	[a]1,530	[d]1,700	[f]514
Width of the mouth (km)	[a]4 + 7	[d]22	37.5
Ave. Depth (m)	[a]27.5	[d]17	[k]15
Volume (Km^3)	[a]41.8	[d]28.9	—
Residence Time	[a]5 month	[e]31 days	—
Closeness Index	3.6	1.9-4.1	0.6



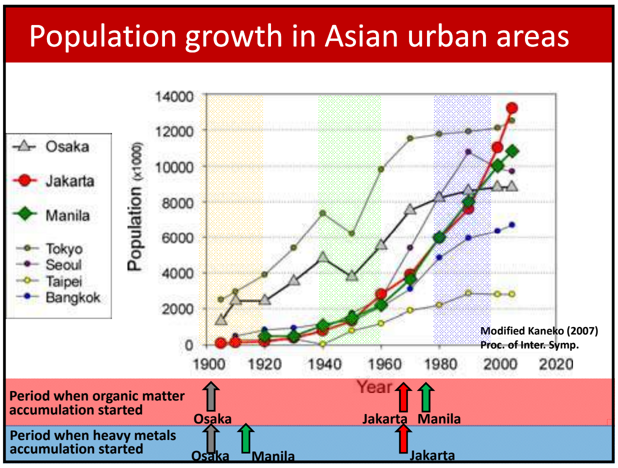
History of pollutants in Osaka Bay
C (%)
N(%)
P (%)
C/N
δ13C(‰)
δ15N(‰)
Phytoplankton bloom?
1960
1900
1900
1900
Waste water?
& Phytoplankton bloom?
Depth (cm)
Cabon (%)
Nitrogen (%)
Phosphorus (%)
C/N molar ratio
Umezawa et al. (in prep)



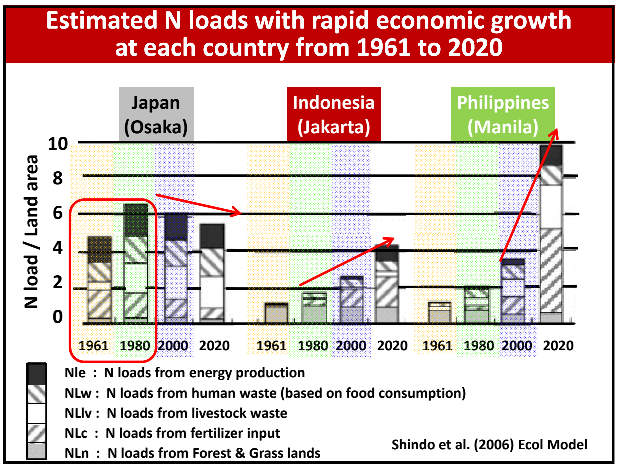
Heavy metals contamination in Osaka Bay
Zi (ppm)
Cu (ppm)
Pb (ppm)
206Pb/207Pb
Mixing layer
2006
1980
1900
(Year)
1970
1900
都市型公害
被害の減少
都市型公害
(e.g. 鉛ガソリン)
低レベル汚染
(鉱山の影響)
Depth (cm)
error
Zn (ppm)
Cu (ppm)
Pb (ppm)
206Pb/207Pb
Hosono et al. (in prep)



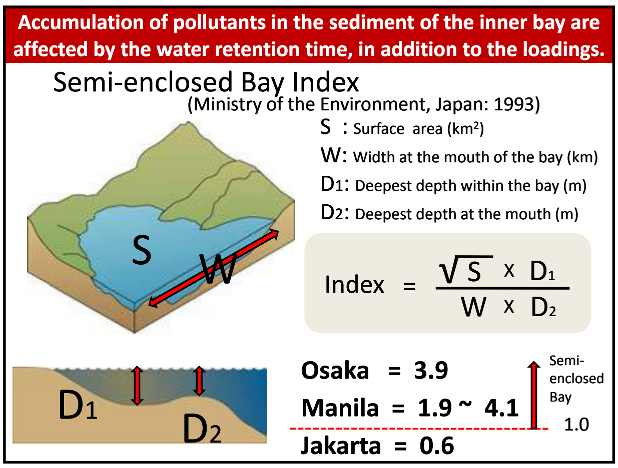
Heavy metals contamination in Jakarta Bay
Zn (ppm)
Cu (ppm)
Pb (ppm)
206Pb/207Pb
2000
1970
2006
2000
1980
1960
1940
1920
(Year)
Depth (cm)
error
Zn (ppm)
Cu (ppm)
Pb (ppm)
206Pb/207Pb
Hosono et al. (2011)



Population growth in Asian urban areas
Osaka
Jakarta
Manila
Tokyo
Seoul
Taipei
Bangkok
Population (x1000)
Year
Modified Kaneko (2007) Proc. of Inter. Symp.
Period when organic matter accumulation started
Osaka
Jakarta
Manila
Period when heavy metals accumulation started
Osaka
Manila
Jakarta



Estimated N loads with rapid economic growth at each country from 1961 to 2020
Japan (Osaka)
Indonesia (Jakarta)
Philippines (Manila)
N load / Land area
1961
1980
2000
2020
NIe : N loads from energy production
NLw : N loads from human waste (based on food consumption)
NLlv : N loads from livestock waste
NLc : N loads from fertilizer input
NLn : N loads from Forest & Grass lands
Shindo et al. (2006) Ecol Model



Accumulation of pollutants in the sediment of the inner bay are affected by the water retention time, in addition to the loadings.
Semi-enclosed Bay Index
(Ministry of the Environment, Japan: 1993)
S : Surface area (km2)
W: Width at the mouth of the bay (km)
D1: Deepest depth within the bay (m)
D2: Deepest depth at the mouth (m)
S
W
Index = √S x D1 / W x D2
D1
D2
Osaka = 3.9
Manila = 1.9 ~ 4.1
Jakarta = 0.6
Semi-enclosed Bay
1.0

L5: Plankton Ecosystem

Joji Ishizaka
(*Institute for Space-Earth Environmental Research, Nagoya University*)

Abstract

Freshwater discharge influences to plankton ecosystem of the coastal area. Freshwater is less saline and often low density, and the buoyancy effect makes the low salinity water is not easily mixed with seawater; however, entrainment and tidal pumping eventually mix the upper low salinity water with lower high salinity water. Freshwater discharge also supplies various organic and inorganic materials to coastal water. Loading of nutrients makes coastal water productive. Coastal area is also known as high population and activities by human. Large amount of nutrients loading and many constructions in shallow areas often caused eutrophication, red tides, hypoxia and other problems in the coastal area.

In this lecture, examples of changes of plankton ecosystem in coastal area by anthropogenic activities will be given. As the observation tool, satellite remote sensing technology is also summarized, and examples of the usage will be shown. One of the examples is the East China Sea which is the radically changing environment. One of the largest river in the world, Changjiang, influences to phytoplankton abundance and the taxonomic groups in the East China Sea. Increasing anthropogenic nutrient loading as well as large sediment discharge and accumulated sediment seems to be very important for the ecosystem.

Plankton Ecosystem

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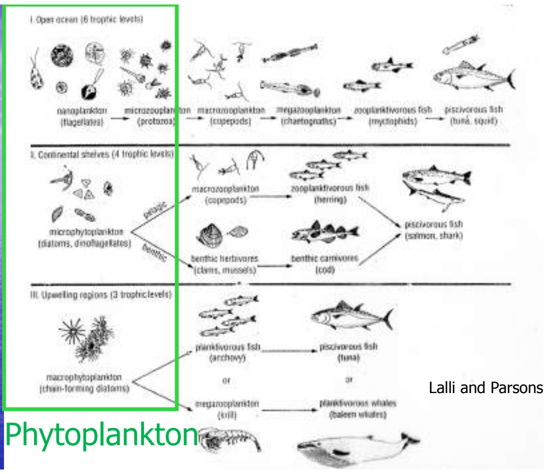
IHP
2016.12.5

Contents

- Plankton ecosystem and freshwater discharge
- Satellite Observation
- East China Sea/Yellow Sea and Changjiang River Discharge
- Phytoplankton Community Variation
- Satellite-based phytoplankton Community

Food Chain



Lalli and Parsons

Characteristics of Satellite Remote Sensing

- Synoptic Coverage of Large Area
- Frequent and Steady Time Coverage

- Only Surface Information
- Limited Parameters

- Combination with Ship and Buoy Observations is necessary

Methods of Ocean Remote Sensing

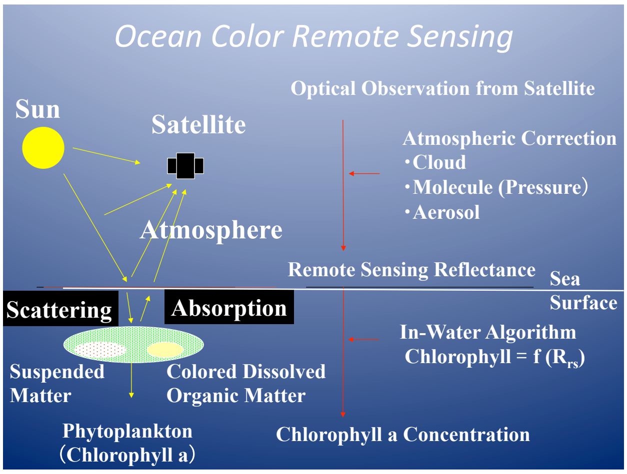
- Passive Visible (Ocean Color, Bottom Condition)
- Passive Infrared (SST)
- Passive Microwave
  (Wind Velocity, Rain, SST, SSS, Ice)

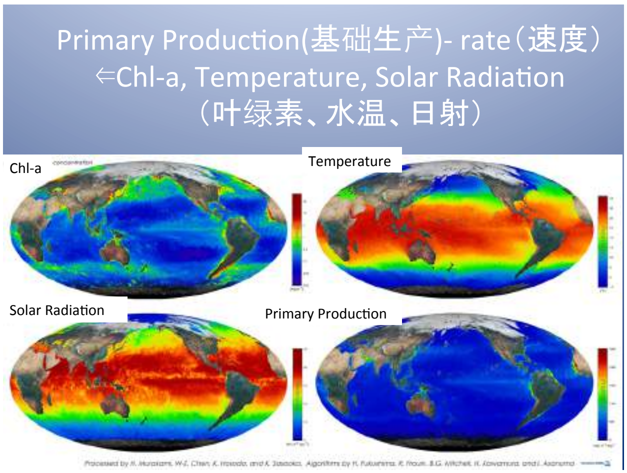
- Active Microwave
  Scatterometer (Sea Surface Wind Direction & Velocity)
  Altimeter (Sea Surface Height, Geostrophic Current)
  Synthetic Aperture Rader
  (Sea Surface Roughness - Oil Spill, Internal Wave)

Ocean Observations by Satellite

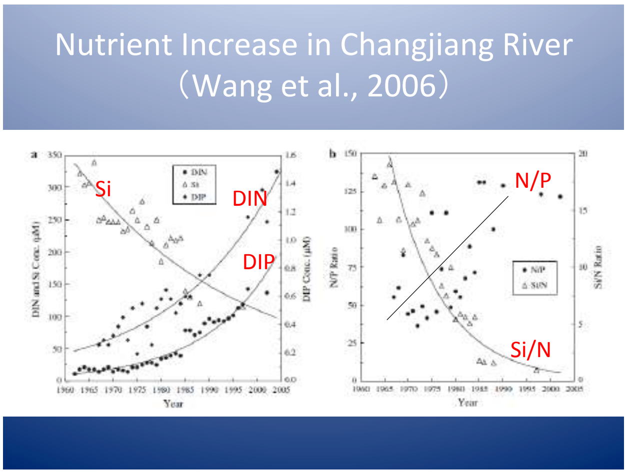
- Sea Surface Temperature
- Ocean Color→Phytoplankton, SS, CDOM
- Sea Ice
- Sea Surface Roughness (Oil Slick, Internal Wave)

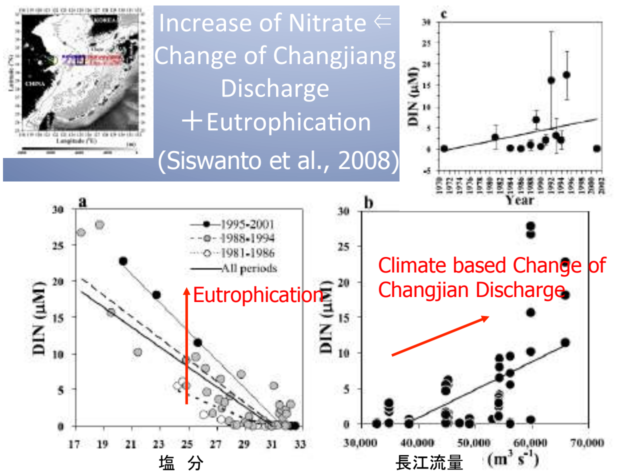
- Sea Surface Height (Current)
- Sea Surface Salinity
- Sea Surface Wind
  →Presentely difficult to use for coastal area

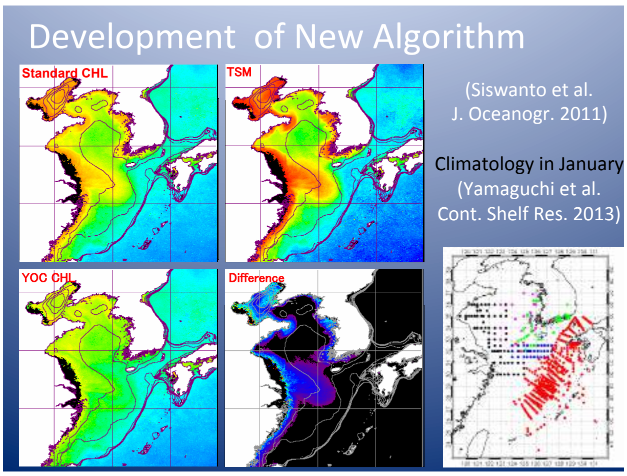

Ocean Color Remote Sensing
Optical Observation from Satellite
Sun
Satellite
Atmospheric Correction
・Cloud
・Molecule (Pressure)
・Aerosol
Atmosphere
Remote Sensing Reflectance
Sea Surface
Scattering
Absorption
In-Water Algorithm
Chlorophyll = f (Rrs)
Suspended Matter
Colored Dissolved Organic Matter
Phytoplankton (Chlorophyll a)
Chlorophyll a Concentration

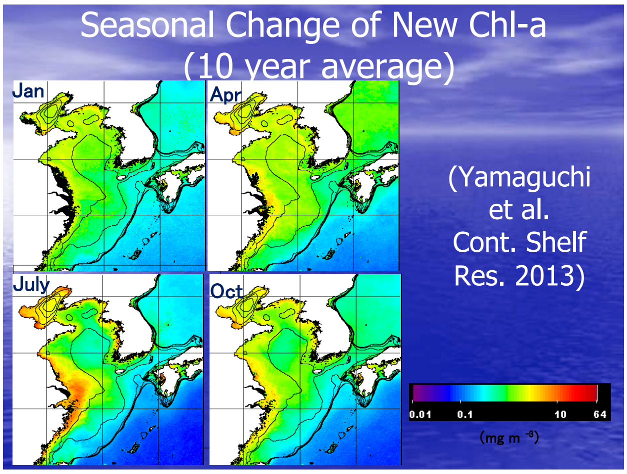

Primary Production(基础生产)- rate（速度）
⇐Chl-a, Temperature, Solar Radiation
（叶绿素、水温、日射）
Chl-a
Temperature
Solar Radiation
Primary Production

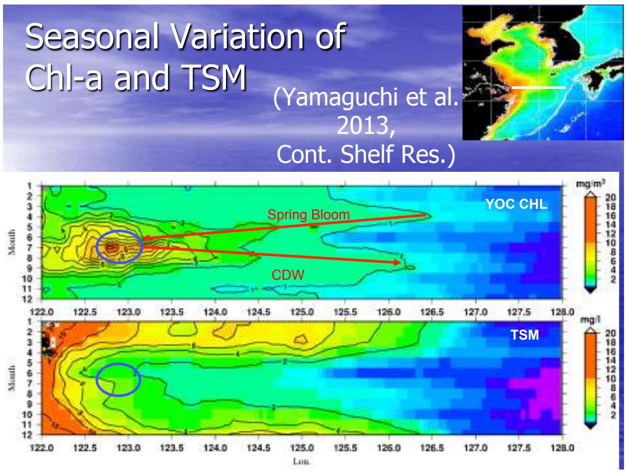

Problems in YECS and possible causes
Red tide (Choclodinium polykrikoides) 1988-
Red tide (Prorocentram shikokuense) 2000-
Giant Jellyfish (Nemopilema nomurai) 2002-
Green tide (Enteromorpha prolifera) 2008-
Eutrophication (River, Atmos.)
Climate Change
Dam Construction
Overfishing
More
Iwataki
Chugoku News

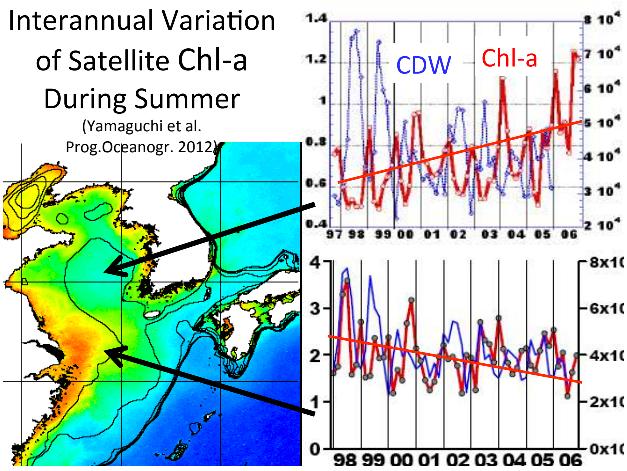

Nutrient Increase in Changjiang River
（Wang et al., 2006）
Si
DIN
DIP
N/P
Si/N
Year

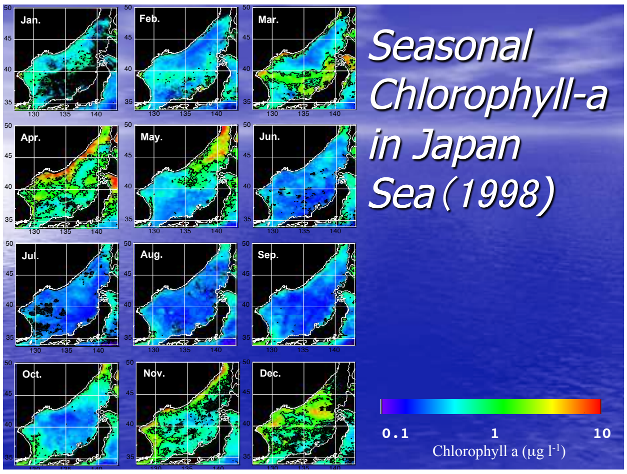

Increase of Nitrate ⇐
Change of Changjiang Discharge
＋Eutrophication
(Siswanto et al., 2008)
DIN (μM)
Year
1995-2001
1988-1994
1981-1986
All periods
Eutrophication
塩 分
Climate based Change of Changjian Discharge
長江流量 (m³ s⁻¹)

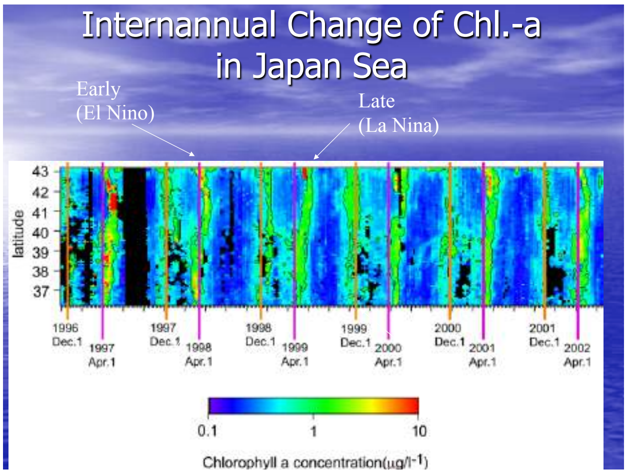

Development of New Algorithm
Standard CHL
TSM
YOC CHL
Difference
(Siswanto et al. J. Oceanogr. 2011)
Climatology in January
(Yamaguchi et al. Cont. Shelf Res. 2013)

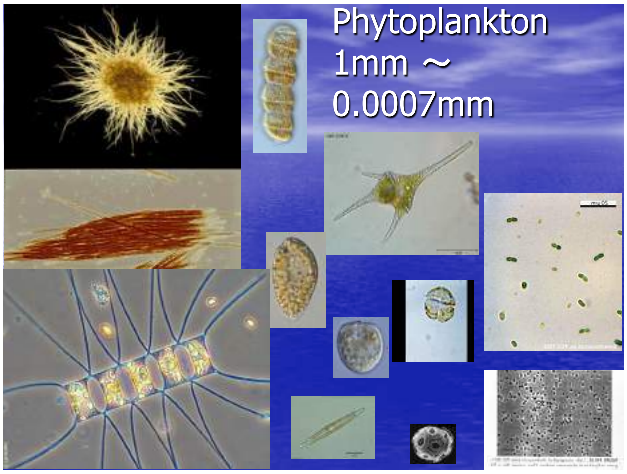

Seasonal Change of New Chl-a
(10 year average)
Jan
Apr
July
Oct
(Yamaguchi et al. Cont. Shelf Res. 2013)
0.01 0.1 10 64
(mg m-3)


Seasonal Variation of Chl-a and TSM
(Yamaguchi et al. 2013, Cont. Shelf Res.)
Spring Bloom
CDW
YOC CHL
TSM
Month
Lon.

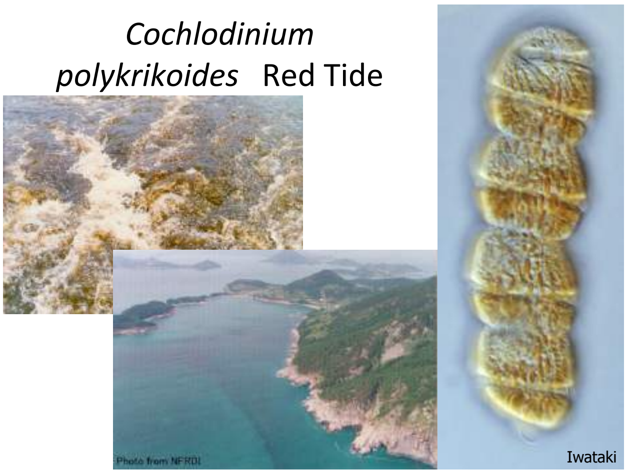

Interannual Variation of Satellite Chl-a During Summer
(Yamaguchi et al. Prog.Oceanogr. 2012)
CDW
Chl-a
97 98 99 00 01 02 03 04 05 06
98 99 00 01 02 03 04 05 06


Seasonal Chlorophyll-a in Japan Sea (1998)
Jan.
Feb.
Mar.
Apr.
May.
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
0.1 1 10
Chlorophyll a (μg l-1)

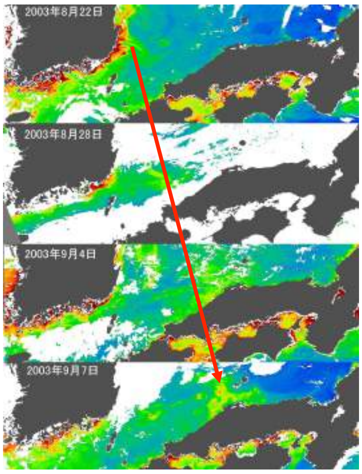

Internannual Change of Chl.-a in Japan Sea
Early (El Nino)
Late (La Nina)
latitude
1996 Dec.1
1997 Apr.1
1997 Dec.1
1998 Apr.1
1998 Dec.1
1999 Apr.1
1999 Dec.1
2000 Apr.1
2000 Dec.1
2001 Apr.1
2001 Dec.1
2002 Apr.1
0.1 1 10
Chlorophyll a concentration(ug/l-1)


Phytoplankton
1mm ~ 0.0007mm

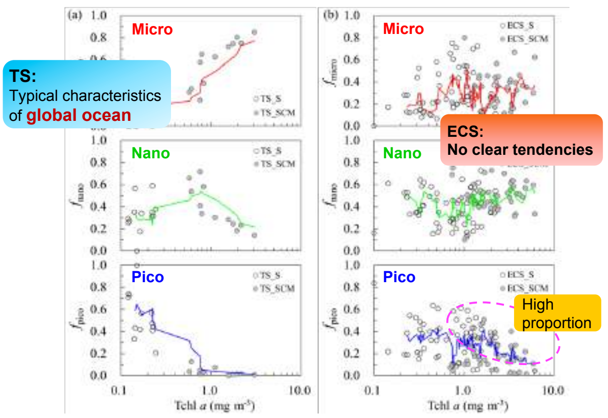
Cochlodinium polykrikoides Red Tide



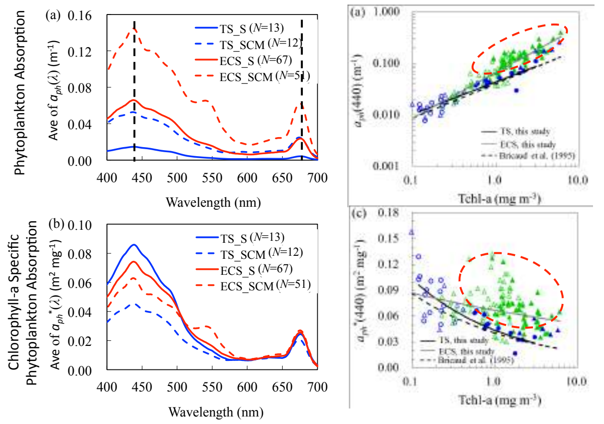
Transport of C. polykrikoides (2003)



Clear difference between TS and ECS

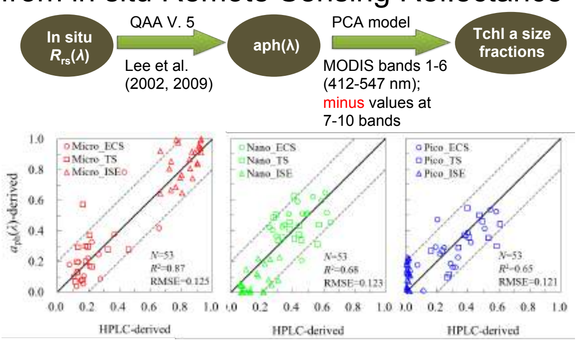


(Wang et al., BG-2013)



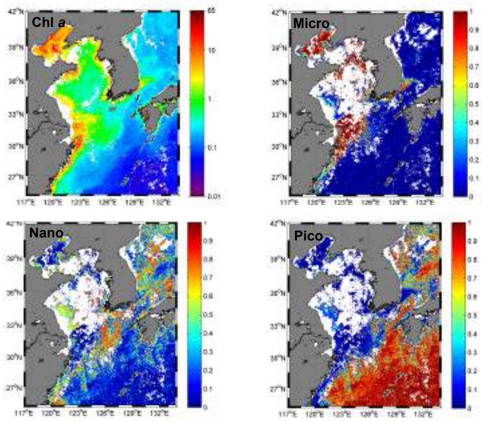
(Wang et al., BG-2013)

Verification of Absorption-based Phytoplankton Size from in situ Remote Sensing Reflectance



(Wang et al., Opt. Express-2015)

Absorption-based Phyto-plankton Size method



July 2011

Pixels with minus $a_{ph}(443)$ were removed

L6: Influence to Fisheries

Satoshi Ishikawa (*Research Department, Research Institute for Humanity and Nature*)

Abstract

In East Asia including Southeast Asian countries, approximate 72 % of 2 billion people living in rural and urban areas in coastal zone. Livelihoods in rural area are based on various ecosystem services provided from coastal nature that has high productivity and biodiversity, e.g., Mangrove trees are utilized for building materials and fuels, fisheries resources has important roles as protein and income sources. On the other hands, residents in urban area need some foods from rural areas, and a market in a city is quite important for both rural and urban people. Therefore, the connectivity and logistics between of them and economic activities are also important elements when we think the sustainable developments in a coastal area.

Land use change associated with urbanization affects on freshwater discharges, and subsequently on carrying capacity and biodiversity in coastal area, because most part of minerals and materials for primary production being provided from lands with freshwater. Besides, chemical contamination and increase of bacteria of freshwater in urban area can endanger the food safety of fisheries products in coastal area. Keep sea food safety is quite important for economic growth and improve quality of life in coastal zone.

Fisheries resource management is indispensable for sustainable development in coastal area. However, high biodiversity and multiple fishing gears utilization make statistical data collection difficult, even it is necessary for stock assessments. In addition, conservation of coastal habitats of fisheries species are required for reproduction of the resources. Therefore, alternative way of stock assessments and simultaneous conservation activities on coastal ecosystems are needed. In this connection, community based fisheries resource utilization with scientific evaluation of ecosystem health under collaboration among fisher folks, researchers and local governments are proposed as a new approach for coastal development, names as “Area-capability (AC)” approach.

In the AC approach, “care” of a target resources and its habitat, not management, is treated as major activity. The care includes three aspects as follow, 1) cultivate interests on nature supporting the target resources, 2) monitor the stock status based on daily utilization of the resources, 3) cure actions on injured part of nature. Biological and ecological researches can contribute to the cultivation of the interest of users, monitor of stock status and evaluation of cure activities. The balance between community based utilization and care is most important in coastal development. And the care of habitats should touch material flow, sanitation, logistics, biodiversity, carrying capacity, cultural diversity, and education with human resource

development. This comprehensive development strengthen the resilience of areas against natural disasters.

Influence to Fisheries in Southeast Asian coastal area

Research Institute for Humanity and Nature
Satoshi ISHIKAWA

In East Asia (including ASEAN), 72% of 2 billion people live in Coastal Zone.

- In rural area, many residents conducts fishery and fishery related activity as main jobs.
- Urban residents need some foods from rural area.

Urbanization change river flows, subsequently material flows to coastal ecosystems.

Land use changes also affects on fisheries resources status and reproductions.

Markets in Urban area are necessary for Rural fishery.

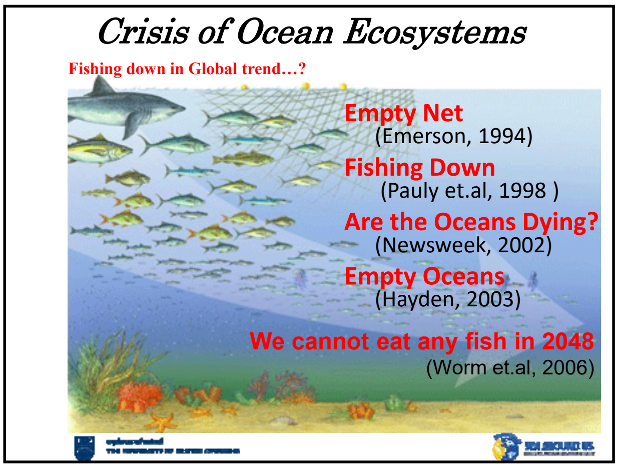
Connectivity and linkage between urban and rural should be taken into account in sustainable development in Coastal Zone.

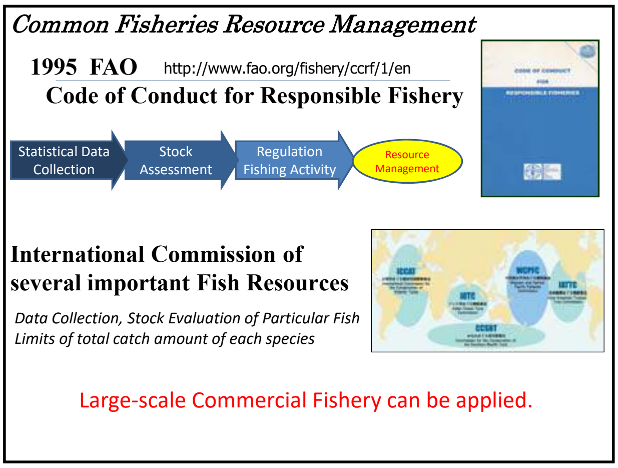
Garbage and waste control and sanitation improvements link to water quality and sea food safety, and Prices (Values) of them.

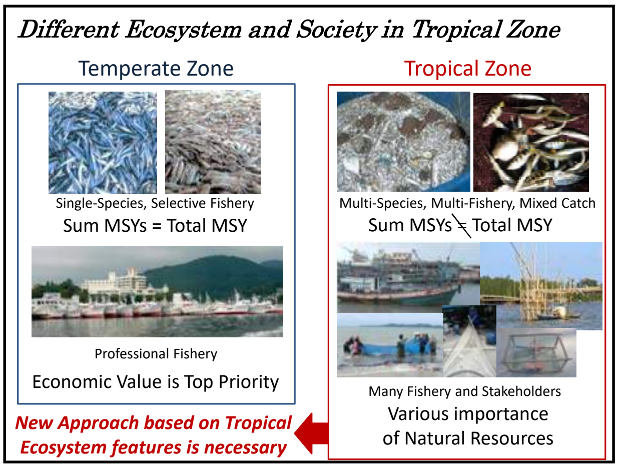
Regarding the linkage between land and coastal ecosystems via water flows, quantity, and quality should be taken into account.

Fisheries Resource managements and Food Safety control are necessary for sustainable development in coastal zone.

However, the differences of nature and society should be taken into account to come up with the management and control measures.

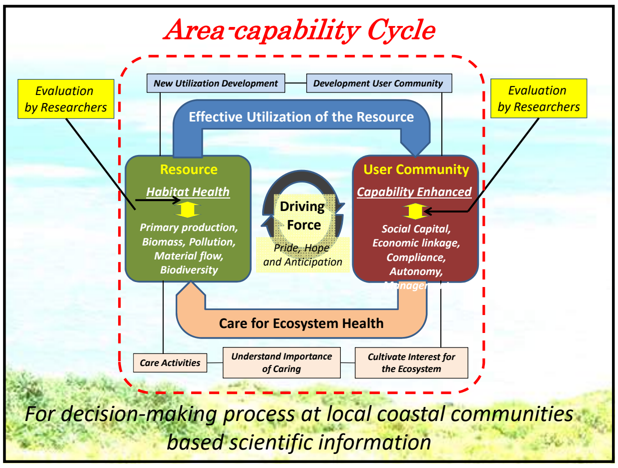

Crisis of Ocean Ecosystems
Fishing down in Global trend…?
Empty Net
(Emerson, 1994)
Fishing Down
(Pauly et.al, 1998)
Are the Oceans Dying?
(Newsweek, 2002)
Empty Oceans
(Hayden, 2003)
We cannot eat any fish in 2048
(Worm et.al, 2006)


Common Fisheries Resource Management
1995 FAO http://www.fao.org/fishery/ccrf/1/en
Code of Conduct for Responsible Fishery
Statistical Data Collection
Stock Assessment
Regulation Fishing Activity
Resource Management
International Commission of several important Fish Resources
Data Collection, Stock Evaluation of Particular Fish
Limits of total catch amount of each species
Large-scale Commercial Fishery can be applied.

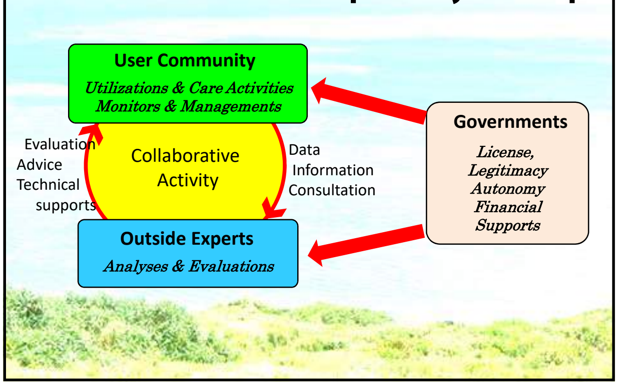

Different Ecosystem and Society in Tropical Zone
Temperate Zone
Tropical Zone
Single-Species, Selective Fishery
Sum MSYs = Total MSY
Multi-Species, Multi-Fishery, Mixed Catch
Sum MSYs ≠ Total MSY
Professional Fishery
Economic Value is Top Priority
Many Fishery and Stakeholders
Various importance
of Natural Resources
New Approach based on Tropical
Ecosystem features is necessary


Other issues for sustainable fishery in Asia
Haphazardly
Over Fishing
Illegal Activity
Bad Waste Management
Deterioration of Ecosystem Services
Vicious Cycle
Deterioration of Productivity, Livelihoods
Aggravation of Poverty
Inefficient Use
Merely target resource managements
based on regulation of fishing activities are not function.


Towards sustainable development
of East Asia
• Conservation and Care actions for Marine Ecosystems are necessary!
• However, conservation actions is usually not attractive for coastal people.
• And imposed care activity dose not have sustainability.
Care should be packaged with utilization


Area-capability Cycle
Evaluation by Researchers
New Utilization Development
Development User Community
Evaluation by Researchers
Effective Utilization of the Resource
Resource
Habitat Health
Primary production, Biomass, Pollution, Material flow, Biodiversity
Driving Force
Pride, Hope and Anticipation
User Community
Capability Enhanced
Social Capital, Economic linkage, Compliance, Autonomy,
Care for Ecosystem Health
Care Activities
Understand Importance of Caring
Cultivate Interest for the Ecosystem
For decision-making process at local coastal communities
based scientific information

Framework of Implementation and Evaluation in Area-capability concept



Stock enhancement of the tiger shrimp in Hamana Lake

Water area = 6,880ha
Periphery = 128km
Depth = 5m
10th in Japan

- There are traditional and modern fisheries, including both capture and aquaculture activities.
- Fishermen have been conducted as commercial activity but in small scale.

What changes occurred?

1978 Stock enhancement Center Established and the public project of larval prawn release started.
1979 Intermediate aquaculture of larvae failed.
1980 Researcher conducted catch data collection, prawn size measurement at landing sites, Examined the appropriate bait for prawn larvae, clarified food web around prawn, determined the best size for release, determined the best place and month for release, and continue the intermediate aquaculture.
1981 Young fishermen of Shirasu village started collaboration. And First Release (ca. 3million).
1983 Second release (more than 10 million)
Murakushi, Iride, Yutho joined the collaboration
Washizu Maisaka Arai joined the collaboration
1985 Public project terminated

> No appropriate aquaculture technology.

> Environmental information and stock status are quite limited. Researcher could not decide the release point and timing, and evaluate the impact of the project

Scientific data were collected by researcher, but not utilized by fishermen

> No gain from release work but collaboration stated

> Prawn catch increased. They realized the impact of release.

What changes occurred?

1983 Second release (more than 10 million)
Murakushi, Iride, Yutho joined the collaboration
Washizu Maisaka Arai joined the collaboration

1985 Public project terminated
Release activity were carried over by fishermen
1990 14million release
Release activity is continued by fishers.

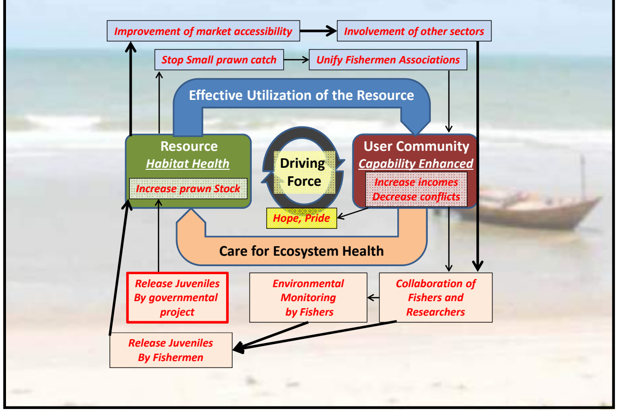
> Conflict decreased.
> Trade system improved.
> Incomes increased.
> They knew lake environments
>
> All activities were done by Fishermen

Prof. Fushimi, H
He was a researcher at SE center and took in charge of the prawn release wrok.

"After everything was finished," fishers knew how and what to do for Kuruma prawn intermediate culture. There was no need to explain anything to them." (Prof. Fushimi said)

Work together is Key to improve confidence of scientific data.

Area-capability cycle of stock enhancement of Kuruma prawn in Hamana Lake



From Case studies,

1. *New technology is key for establishment of new community.*
2. *Community activities make scientific data collection possible.*
3. *Scientific data improve community understanding of nature.*
4. *Evaluation from others sustains community activities.*

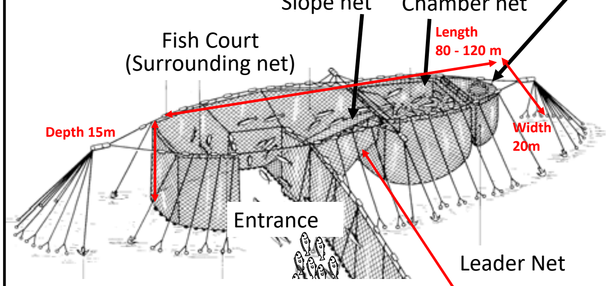
1. *Data of the important resources can attract users interests.*
2. *Collaboration of users and researchers enhance users' understanding of scientific data and information.*
3. *Improvement of livelihoods foster conservation minds and actions of users.*
4. *Evidences of resource improvement sustains community conservation activities.*

These events and phenomenon are closely linked.

Community based Set-net fishery

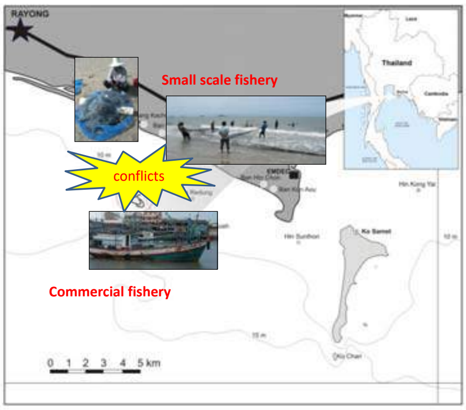
By TD/SEAFDEC and DOF/Thailand in Rayong

Set-net (Teichi-ami)

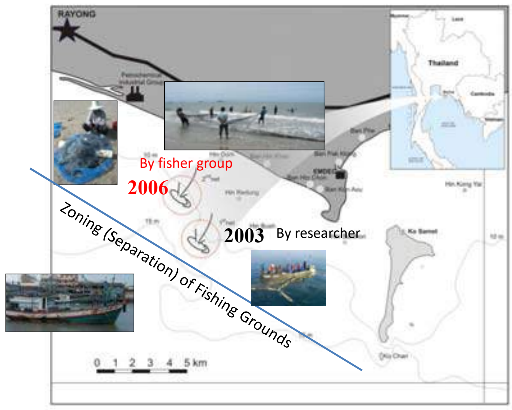


Passive Type of Gear, fixed in costal water
Large-scale trap net with compound design
Waiting for the migrating fish schools,
and entrapping them in the chamber net

Location of Rayong set-net project



Location of Rayong set-net project



History of Set-net Installation into Thailand

2001 ASEAN-SEAFDEC Millennium Conference on Sustainable Fisheries for Food Security in the Region in Bangkok

2002 International Set-Net Fishing Summit in Himi

2003-2005 Rayong Set-Net Project SEAFDEC- EMDEC-Fishermen Group

2005-2007 JICA grass-root project by SEAFDEC, TUMSAT and Himi City

2007-Present Operated and Managed by fishers group

2008 Training course for Practices and Theories Choko-ami in Chonburi, by Kasetsart Univ.

2010 New challenge in Southern Gulf of Thailand steered by DOF, Thailand

Got Idea

Start Project!

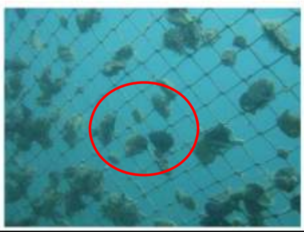
Mr. Aussanee Munprasit
Senior Officer of SEAFDEC

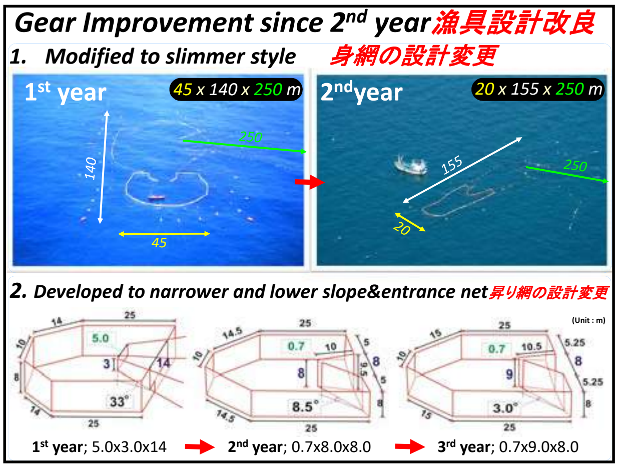
SEAFDEC: Southeast Asian Fisheries Development Center
JICA: Japan International Cooperation Agency
TUMSAT: Tokyo University of Marine Science and Technology, Japan
EMDEC: Eastern Marine Fisheries Research and Development Center, Department of Fishery, Thailand
Himi city: Located in Toyama Prefecture, in Japan Very famous as Set-net fishery

Problems and Difficulties in the 1st year

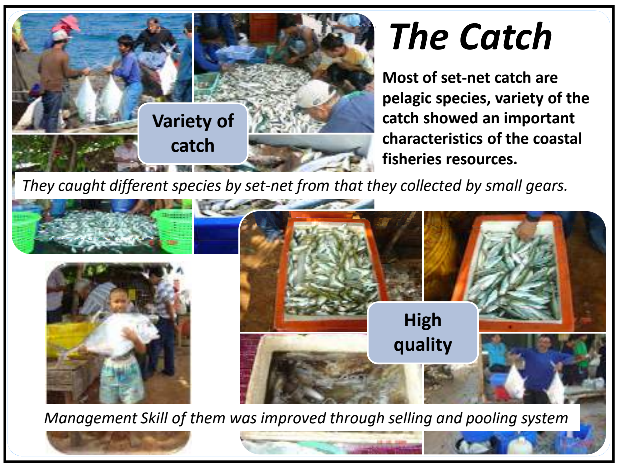
- **Strong current**
- **Bad Design of Net**
- **Anchors entangled with net**
- **Bad Operation of fishing**

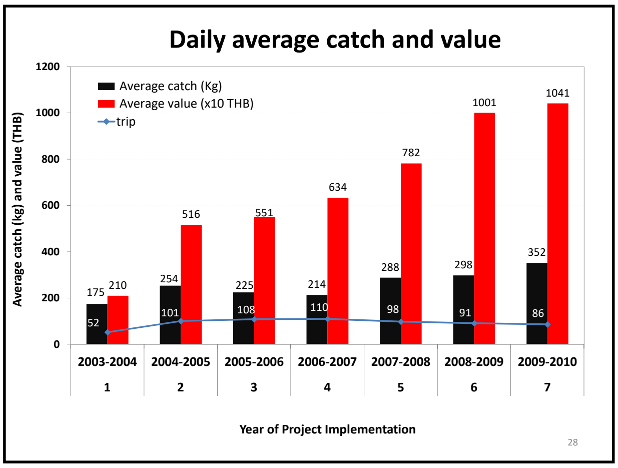
Fish Catch was not good!

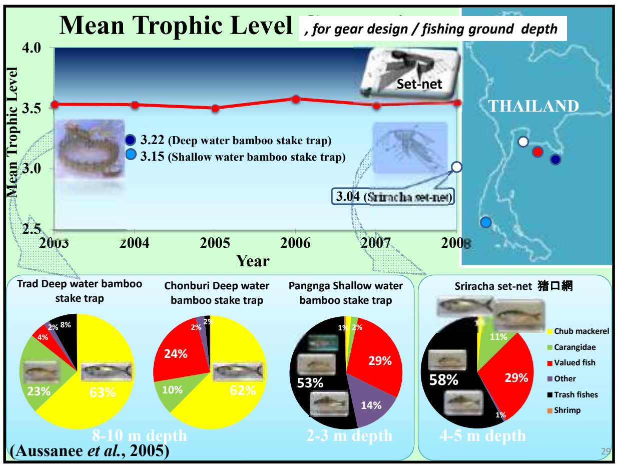


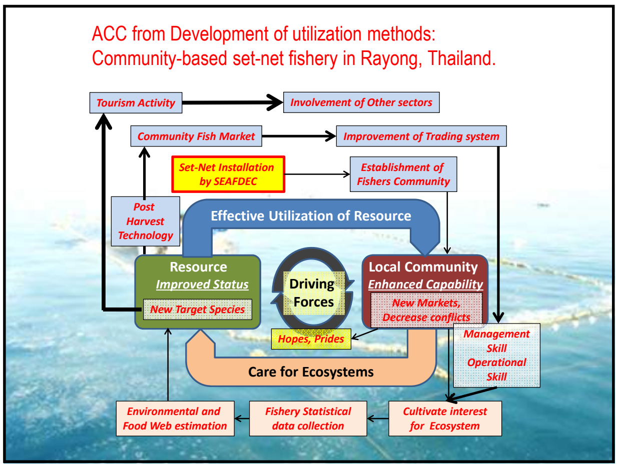

Gear Improvement since 2nd year漁具設計改良
1. Modified to slimmer style 身網の設計変更
1st year 45 x 140 x 250 m
2ndyear 20 x 155 x 250 m
250
140
45
155
250
20
2. Developed to narrower and lower slope&entrance net昇り網の設計変更
(Unit : m)
1st year; 5.0x3.0x14
2nd year; 0.7x8.0x8.0
3rd year; 0.7x9.0x8.0

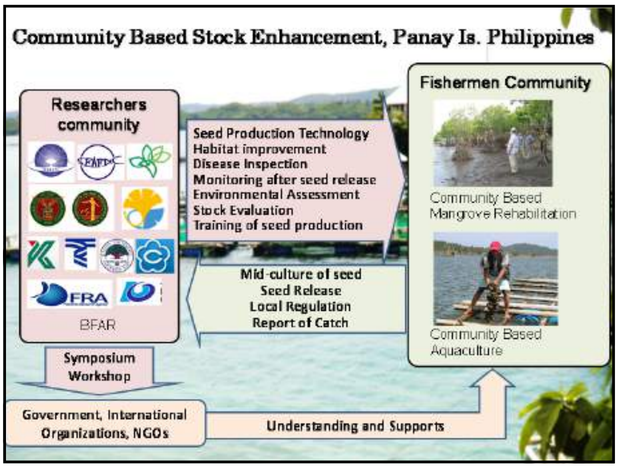

Fishing Operation in Rayong
Man-power hauling
Morning hauling
Every 2 days
3-4 boats, 10-12 fishermen
0.5-1.5 hours 20-30 min
September-April
Himi 2

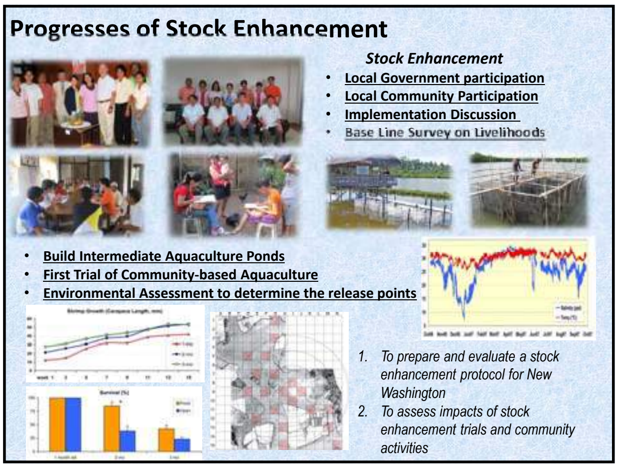

The Catch
Most of set-net catch are pelagic species, variety of the catch showed an important characteristics of the coastal fisheries resources.
Variety of catch
They caught different species by set-net from that they collected by small gears.
High quality
Management Skill of them was improved through selling and pooling system

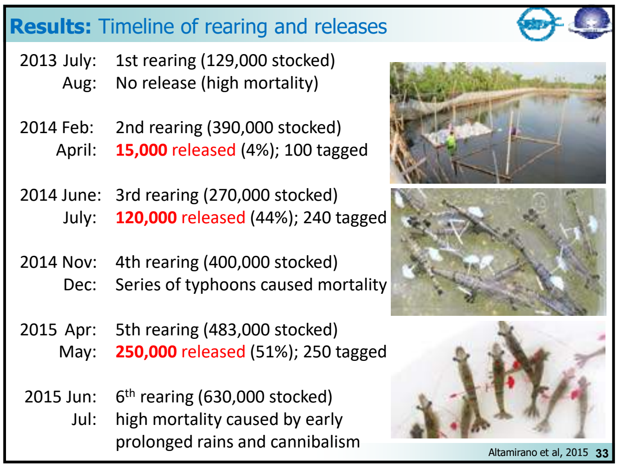

Daily average catch and value
Average catch (Kg)
Average value (x10 THB)
trip
Average catch (kg) and value (THB)
Year of Project Implementation
2003-2004 1: 175, 210, 52
2004-2005 2: 254, 516, 101
2005-2006 3: 225, 551, 108
2006-2007 4: 214, 634, 110
2007-2008 5: 288, 782, 98
2008-2009 6: 298, 1001, 91
2009-2010 7: 352, 1041, 86
28

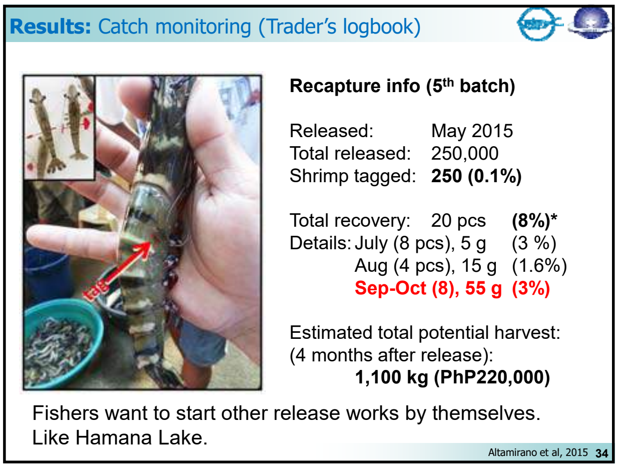

Mean Trophic Level
, for gear design / fishing ground depth
Mean Trophic Level
Year
Set-net
THAILAND
3.22 (Deep water bamboo stake trap)
3.15 (Shallow water bamboo stake trap)
3.04 (Sriracha set-net)
Trad Deep water bamboo stake trap
Chonburi Deep water bamboo stake trap
Pangnga Shallow water bamboo stake trap
Sriracha set-net 猪口網
Chub mackerel
Carangidae
Valued fish
Other
Trash fishes
Shrimp
8-10 m depth
2-3 m depth
4-5 m depth
(Aussanee et al., 2005)

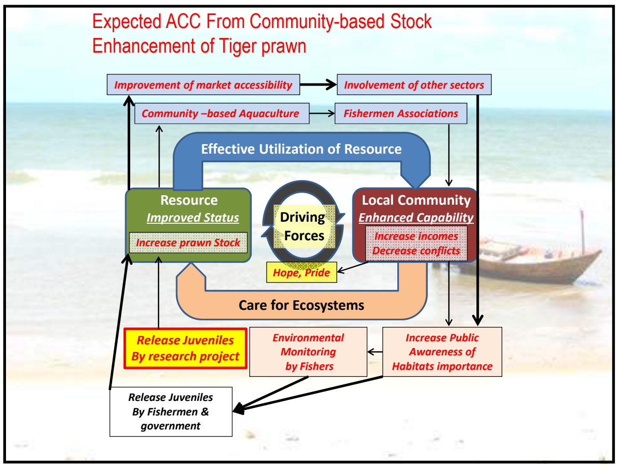

ACC from Development of utilization methods:
Community-based set-net fishery in Rayong, Thailand.
Tourism Activity
Involvement of Other sectors
Community Fish Market
Improvement of Trading system
Set-Net Installation by SEAFDEC
Establishment of Fishers Community
Post Harvest Technology
Effective Utilization of Resource
Resource Improved Status
New Target Species
Driving Forces
Local Community Enhanced Capability
New Markets, Decrease conflicts
Hopes, Prides
Management Skill
Operational Skill
Care for Ecosystems
Environmental and Food Web estimation
Fishery Statistical data collection
Cultivate interest for Ecosystem

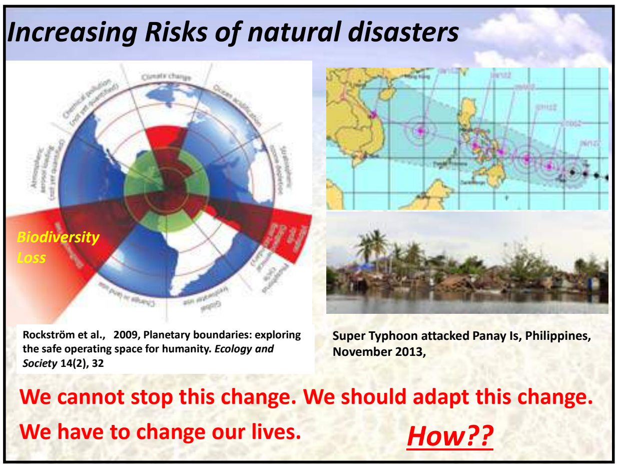

Community Based Stock Enhancement, Panay Is. Philippines
Researchers community
BFAR
Seed Production Technology
Habitat improvement
Disease Inspection
Monitoring after seed release
Environmental Assessment
Stock Evaluation
Training of seed production
Fishermen Community
Community Based Mangrove Rehabilitation
Mid-culture of seed
Seed Release
Local Regulation
Report of Catch
Community Based Aquaculture
Symposium Workshop
Government, International Organizations, NGOs
Understanding and Supports


Progresses of Stock Enhancement
Stock Enhancement
Local Government participation
Local Community Participation
Implementation Discussion
Base Line Survey on Livelihoods
Build Intermediate Aquaculture Ponds
First Trial of Community-based Aquaculture
Environmental Assessment to determine the release points
1. To prepare and evaluate a stock enhancement protocol for New Washington
2. To assess impacts of stock enhancement trials and community activities

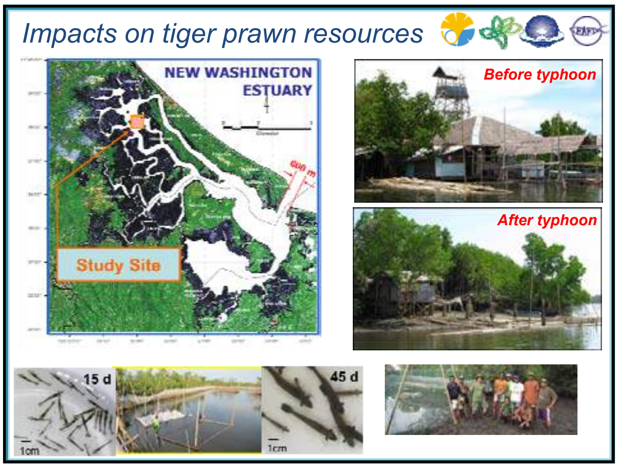

Results: Timeline of rearing and releases
2013 July: 1st rearing (129,000 stocked)
Aug: No release (high mortality)
2014 Feb: 2nd rearing (390,000 stocked)
April: 15,000 released (4%); 100 tagged
2014 June: 3rd rearing (270,000 stocked)
July: 120,000 released (44%); 240 tagged
2014 Nov: 4th rearing (400,000 stocked)
Dec: Series of typhoons caused mortality
2015 Apr: 5th rearing (483,000 stocked)
May: 250,000 released (51%); 250 tagged
2015 Jun: 6th rearing (630,000 stocked)
Jul: high mortality caused by early prolonged rains and cannibalism
Altamirano et al, 2015 33

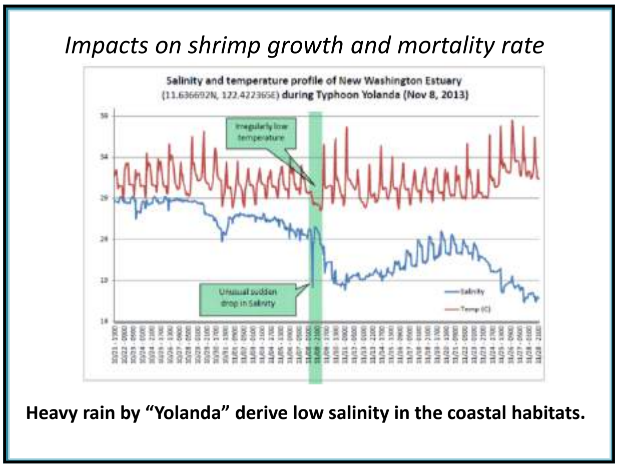

Results: Catch monitoring (Trader's logbook)
Recapture info (5th batch)
Released: May 2015
Total released: 250,000
Shrimp tagged: 250 (0.1%)
Total recovery: 20 pcs (8%)*
Details: July (8 pcs), 5 g (3 %)
Aug (4 pcs), 15 g (1.6%)
Sep-Oct (8), 55 g (3%)
Estimated total potential harvest:
(4 months after release):
1,100 kg (PhP220,000)
Fishers want to start other release works by themselves.
Like Hamana Lake.
Altamirano et al, 2015 34

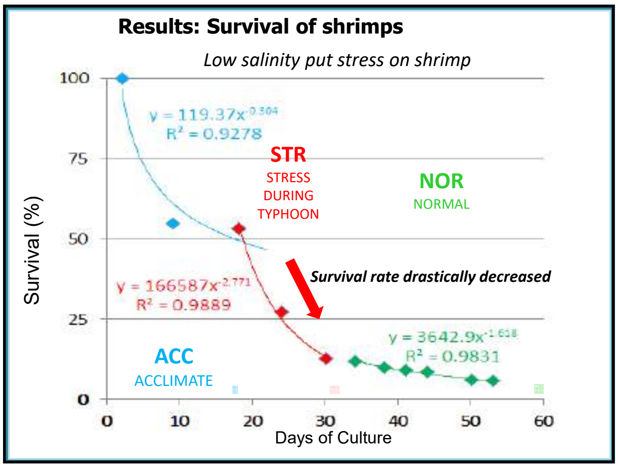

Expected ACC From Community-based Stock Enhancement of Tiger prawn
Improvement of market accessibility
Involvement of other sectors
Community –based Aquaculture
Fishermen Associations
Effective Utilization of Resource
Resource Improved Status
Increase prawn Stock
Driving Forces
Hope, Pride
Local Community Enhanced Capability
Increase incomes
Decrease conflicts
Care for Ecosystems
Release Juveniles By research project
Environmental Monitoring by Fishers
Increase Public Awareness of Habitats importance
Release Juveniles By Fishermen & government

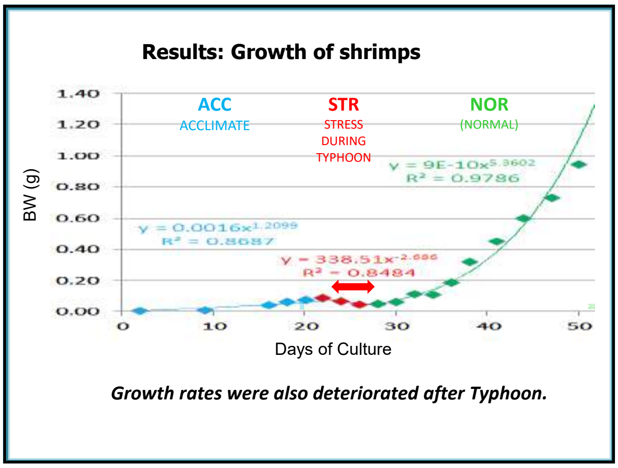

Increasing Risks of natural disasters
Biodiversity Loss
Rockström et al., 2009, Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2), 32
Super Typhoon attacked Panay Is, Philippines, November 2013,
We cannot stop this change. We should adapt this change.
We have to change our lives. How??

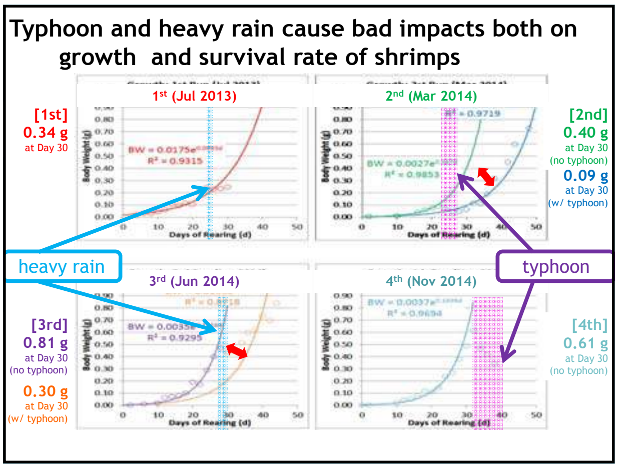

Impacts on livelihoods
FRA


Impacts on tiger prawn resources
NEW WASHINGTON ESTUARY
Study Site
Before typhoon
After typhoon
15 d
45 d
1cm


Impacts on shrimp growth and mortality rate
Salinity and temperature profile of New Washington Estuary
during Typhoon Yolanda (Nov 8, 2013)
Irregularly low temperature
Unusual sudden drop in Salinity
Heavy rain by "Yolanda" derive low salinity in the coastal habitats.


Results: Survival of shrimps
Low salinity put stress on shrimp
y = 119.37x-0.304
R² = 0.9278
STR
STRESS
DURING
TYPHOON
NOR
NORMAL
y = 166587x-2.771
R² = 0.9889
Survival rate drastically decreased
y = 3642.9x-1.618
R² = 0.9831
ACC
ACCLIMATE
Survival (%)
Days of Culture


Results: Growth of shrimps
ACC
ACCLIMATE
STR
STRESS
DURING
TYPHOON
NOR
(NORMAL)
y = 9E-10x5.3602
R² = 0.9786
y = 0.0016x1.2099
R² = 0.8687
y = 338.51x-2.686
R² = 0.8484
BW (g)
Days of Culture
Growth rates were also deteriorated after Typhoon.


Typhoon and heavy rain cause bad impacts both on growth and survival rate of shrimps
1st (Jul 2013)
2nd (Mar 2014)
[1st]
0.34 g
at Day 30
[2nd]
0.40 g
at Day 30
(no typhoon)
0.09 g
at Day 30
(w/ typhoon)
heavy rain
typhoon
3rd (Jun 2014)
4th (Nov 2014)
[3rd]
0.81 g
at Day 30
(no typhoon)
0.30 g
at Day 30
(w/ typhoon)
[4th]
0.61 g
at Day 30
(no typhoon)
Days of Rearing (d)

Fishery is a Safety Net in rural area

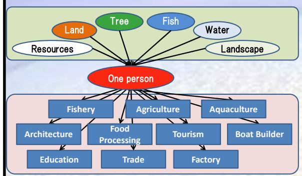
(Photos, 8:29am, 9th Nov. 2013)

- After 2 days from Yolanda Passed, fish market was sold fish and shrimps.
- This small scale fishery provided food and incomes to local residences.

Coastal ecosystem and small scale fishery have important roles as safety net for rural area.

This fact should be taken into account for disaster management.

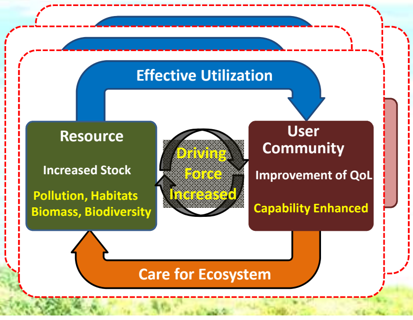
From Sustainability To Capability



- In high bio-cultural diversity area, People utilize a lot of resources for many purposes.
- Under this occasion, each resource is small and vulnerable.
- Efforts to keep sustainability of each resource are enormous.

- ACC is established for each resource.
- One Person get a place on plural communities according resources use.
- If one resource is deteriorated, other ACC can support his live.
- Cares for habitats in ACC contributes non-target resource reproductions.

Increasing AC cycles
= Sustainable Development
= High resilience against disasters

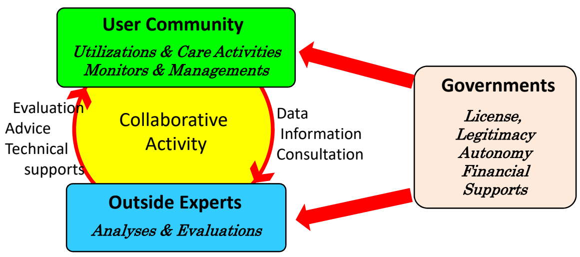


As AC cycle is drawn at each resource, number of it shows number of resources

Numbers of AC cycles show numbers of resources, local communities, utilization methods, jobs and cares on ecosystems.

Academic research can contribute to create Area-capability cycle in collaboration with local community. This is one of the solution toward sustainable development in coastal areas.

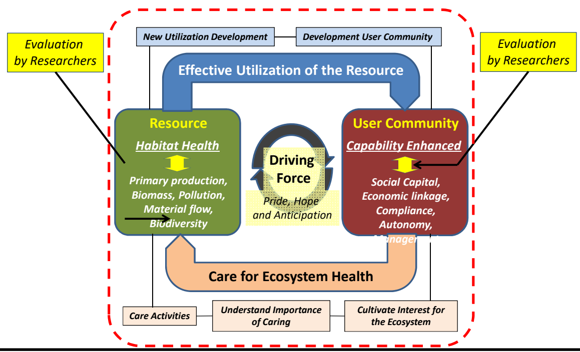
Transdisciplinary Research
Solution Oriented Academic activity

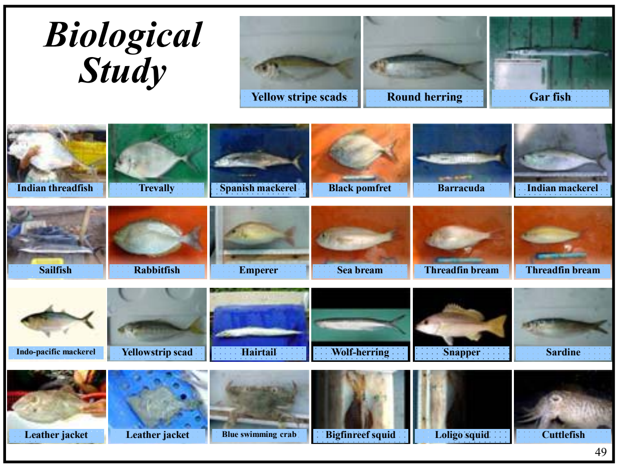


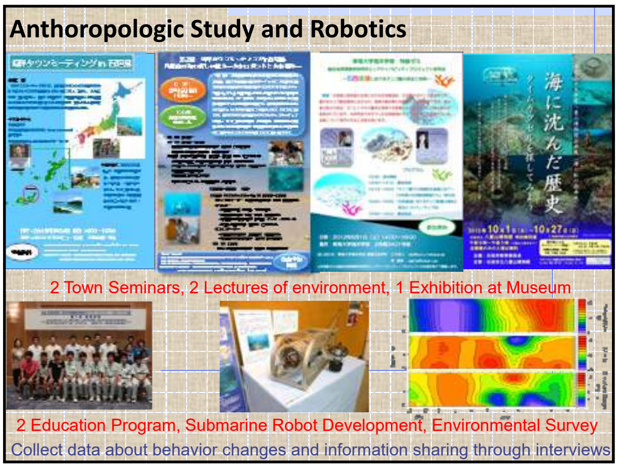
In some times, this collaboration is quite difficult for Scientist, because they can not find their roles based on their repartees.

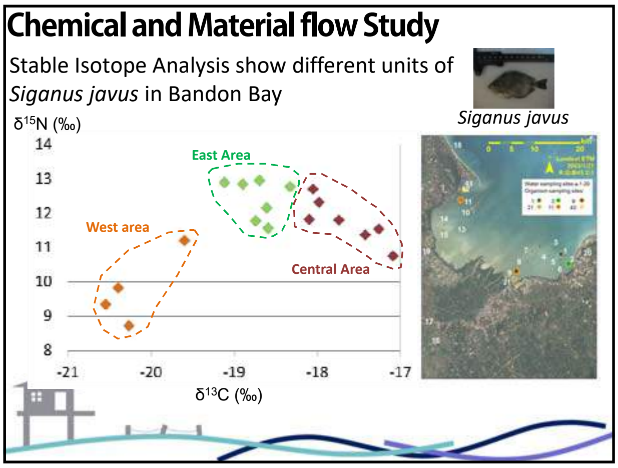
They can find their roles and places in the evaluation processes of Ecosystem health and Society in AC cycle

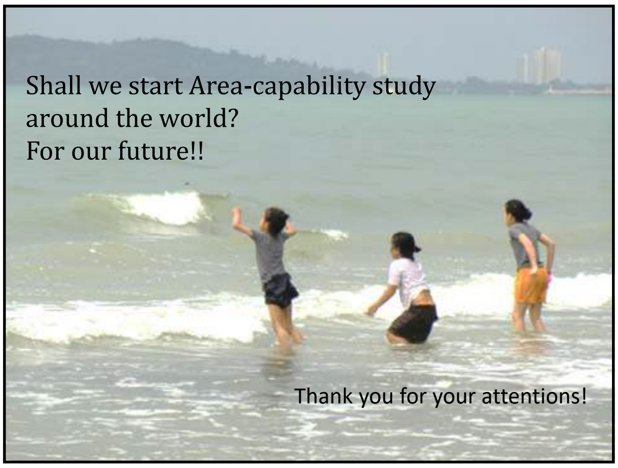
Area-capability Cycle




Biological Study
Yellow stripe scads
Round herring
Gar fish
Indian threadfish
Trevally
Spanish mackerel
Black pomfret
Barracuda
Indian mackerel
Sailfish
Rabbitfish
Emperor
Sea bream
Threadfin bream
Threadfin bream
Indo-pacific mackerel
Yellowstrip scad
Hairtail
Wolf-herring
Snapper
Sardine
Leather jacket
Leather jacket
Blue swimming crab
Bigfinreef squid
Loligo squid
Cuttlefish
49


Anthoropologic Study and Robotics
海に沈んだ歴史
2 Town Seminars, 2 Lectures of environment, 1 Exhibition at Museum
2 Education Program, Submarine Robot Development, Environmental Survey
Collect data about behavior changes and information sharing through interviews


Chemical and Material flow Study
Stable Isotope Analysis show different units of *Siganus javus* in Bandon Bay
Siganus javus
δ15N (‰)
14
13
12
11
10
9
8
East Area
West area
Central Area
-21
-20
-19
-18
-17
δ13C (‰)


Shall we start Area-capability study
around the world?
For our future!!
Thank you for your attentions!

L7: A Japanese experience of Tsunamis

Takashi Tomita

(*Education and Research Center for Sustainable Co-Development, Graduate School of Environmental Studies, Nagoya University*)

Abstract

Japan have learned many lessons from the 2011 Tohoku tsunami disaster: for example, multi-level scenarios for disaster management and multi-layered measures to reduce possible disasters. Through international cooperative research project, the Japanese experiences of tsunami disasters have been introduced into Chile that is also in high risk areas of tsunamis. These Japanese experiences will be introduced in the seminar.

L7: Tsunami and Disaster Prevention

Takashi Tomita

Graduate School of Environmental Studies, Nagoya University

What I want to talk

- Disaster risk reduction can provide not only to reduce mortality, the number of affected people, and economic loss, but also to create sustainable society and economy.
- Structural infrastructure is a measure to reduce tsunami impact to society and economy, while the priority measure to protect human life from tsunamis is evacuation.
- To develop structural infrastructure for tsunami disaster mitigation, tsunami damage to them is illustrated and how to plan and design them is introduced.

Global Trend

Disaster Risk Reduction

Sendai Framework for Disaster Risk Reduction 2015-2030

adopted at the Third United Nations World Conference on Disaster Risk Reduction held in Sendai Japan in March 2015.

- **Outcome over the next 15 years:**

  The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.
- **Goal to attain the expected outcome:**

  Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience.

Sendai Framework for Disaster Risk Reduction

Global targets:

- To reduce global disaster mortality,
- To reduce the number of affected people globally
- To reduce direct disaster economic loss
- To reduce disaster damage to critical infrastructure and disruption of basic services

Priorities for action:

Priority 1: Understanding disaster risk.

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for **resilience**.

Priority 4: Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

Disaster Risk Reduction for Resilience

Priority 3: Investing in disaster risk reduction for resilience

29. Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and reduce losses and ensure effective recovery and rehabilitation.

Important activities at national and local levels:

(c) To strengthen, as appropriate, disaster-resilient public and private investments, particularly through structural, non-structural and functional disaster risk prevention and reduction measures in critical facilities, in particular schools and hospitals and physical infrastructures;

(e) To promote the disaster risk resilience of workplaces through structural and non-structural measures;

(f) To promote the mainstreaming of disaster risk assessments into land-use policy development and implementation;

Disaster Risk Reduction for Resilience

Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

32. --- the recovery, rehabilitation and reconstruction phase, which needs to be prepared ahead of a disaster, ---

Important activities at national and local levels:
(c) To promote the resilience of new and existing critical infrastructure, including water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities, to ensure that they remain safe, effective and operational during and after disasters in order to provide live-saving and essential services

Sustainable Development & Disaster Risk Reduction

The 2030 Agenda for Sustainable Development
adopted at a UN Summit in September 2015 at an UN Summit

The 17 Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development

Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation

Investments in infrastructure – transport, irrigation, energy and information and communication technology – are crucial to achieving sustainable development and empowering communities in many countries. It has long been recognized that growth in productivity and incomes, and improvements in health and education outcomes require investment in infrastructure.

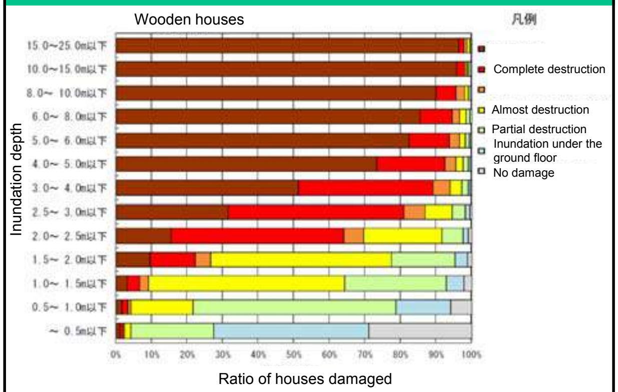
Goal 11: Make cities inclusive, safe, resilient and sustainable

Considering cities are hubs for ideas, commerce, culture, science, productivity, social development and much more, a goal is:

- By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters.

Experiences of the 2011 Tohoku Tsunami

Damage to Wooden Houses

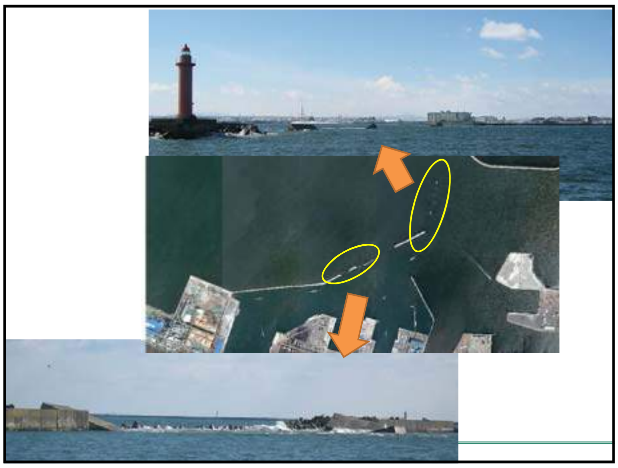


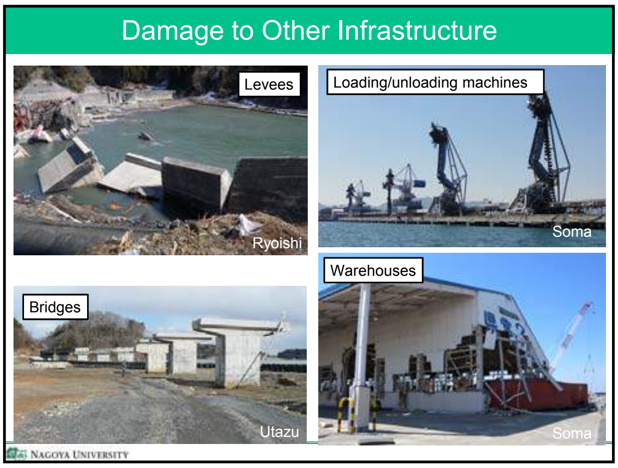
国土交通省都市局 平成23年10月4日プレスリリースより

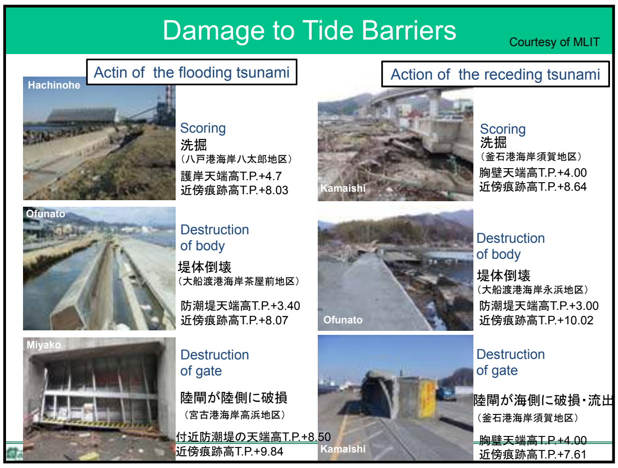
Damage to Breakwaters

Port of Hachinohe

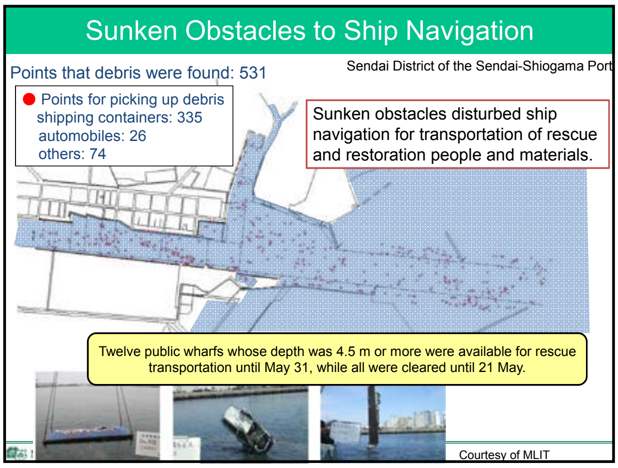
The section of 1,400 m among the Hattaro North breakwater of total length 3500 m was destroyed by the 9 m tsunami.



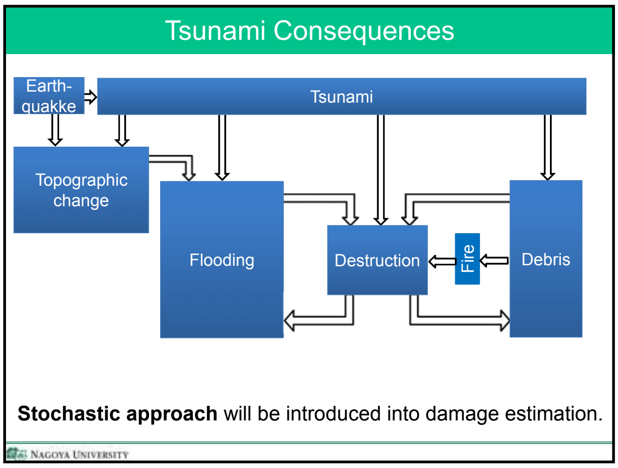

Damage to Other Infrastructure
Levees
Ryoishi
Loading/unloading machines
Soma
Bridges
Utazu
Warehouses
Soma
NAGOYA UNIVERSITY


Damage to Tide Barriers
Courtesy of MLIT
Actin of the flooding tsunami
Hachinohe
Scoring
洗掘
（八戸港海岸八太郎地区）
護岸天端高T.P.+4.7
近傍痕跡高T.P.+8.03
Ofunato
Destruction of body
堤体倒壊
（大船渡港海岸茶屋前地区）
防潮堤天端高T.P.+3.40
近傍痕跡高T.P.+8.07
Miyako
Destruction of gate
陸閘が陸側に破損
（宮古港海岸高浜地区）
付近防潮堤の天端高T.P.+8.50
近傍痕跡高T.P.+9.84
Action of the receding tsunami
Kamaishi
Scoring
洗掘
（釜石港海岸須賀地区）
胸壁天端高T.P.+4.00
近傍痕跡高T.P.+8.64
Ofunato
Destruction of body
堤体倒壊
（大船渡港海岸永浜地区）
防潮堤天端高T.P.+3.00
近傍痕跡高T.P.+10.02
Kamaishi
Destruction of gate
陸閘が海側に破損・流出
（釜石港海岸須賀地区）
胸壁天端高T.P.+4.00
近傍痕跡高T.P.+7.61


【on Feb. 20, 2011】
【on Mar. 13, 2011】
NAGOYA UNIVERSITY
Courtesy of MLIT


Sunken Obstacles to Ship Navigation
Points that debris were found: 531
Sendai District of the Sendai-Shiogama Port
Points for picking up debris
shipping containers: 335
automobiles: 26
others: 74
Sunken obstacles disturbed ship navigation for transportation of rescue and restoration people and materials.
Twelve public wharfs whose depth was 4.5 m or more were available for rescue transportation until May 31, while all were cleared until 21 May.
Courtesy of MLIT


Fire Incidence
Kesen-numa
Oil tanks damaged
NAGOYA UNIVERSITY
Courtesy of MLIT


Tsunami Consequences
Earth-quakke
Tsunami
Topographic change
Flooding
Destruction
Fire
Debris
Stochastic approach will be introduced into damage estimation.
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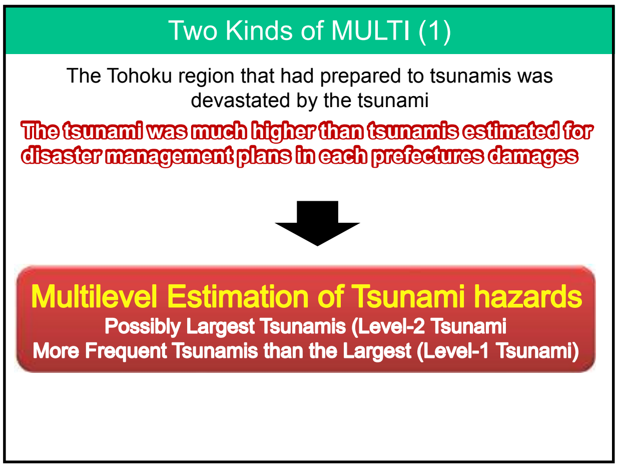
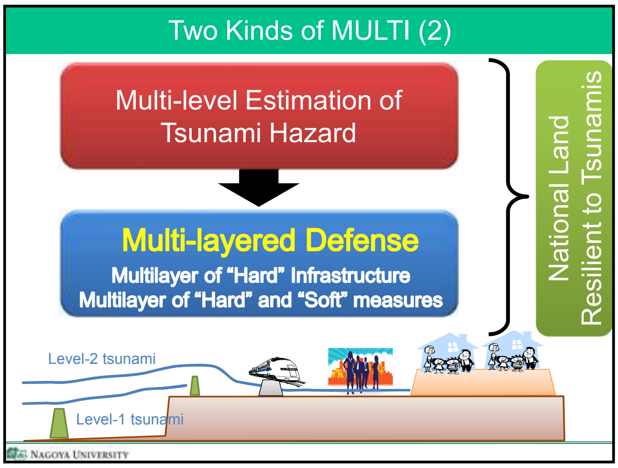

Two Kinds of MULTI (1)
The Tohoku region that had prepared to tsunamis was devastated by the tsunami
The tsunami was much higher than tsunamis estimated for disaster management plans in each prefectures damages
Multilevel Estimation of Tsunami hazards
Possibly Largest Tsunamis (Level-2 Tsunami
More Frequent Tsunamis than the Largest (Level-1 Tsunami)


Two Kinds of MULTI (2)
Multi-level Estimation of Tsunami Hazard
Multi-layered Defense
Multilayer of "Hard" Infrastructure
Multilayer of "Hard" and "Soft" measures
National Land Resilient to Tsunamis
Level-2 tsunami
Level-1 tsunami
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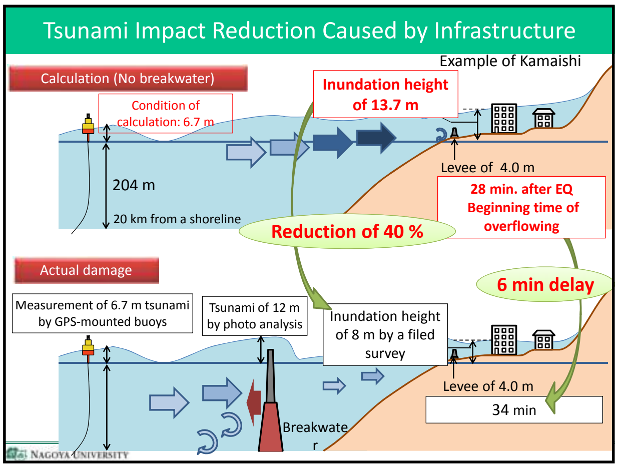
Tsunami Impact Reduction Caused by Infrastructure
Example of Kamaishi
Calculation (No breakwater)
Inundation height of 13.7 m
Condition of calculation: 6.7 m
204 m
20 km from a shoreline
Levee of 4.0 m
28 min. after EQ Beginning time of overflowing
Reduction of 40 %
Actual damage
6 min delay
Measurement of 6.7 m tsunami by GPS-mounted buoys
Tsunami of 12 m by photo analysis
Inundation height of 8 m by a filed survey
Levee of 4.0 m
34 min
Breakwater
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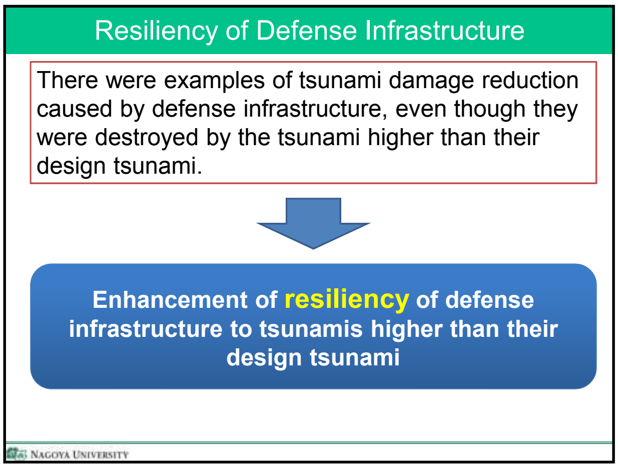
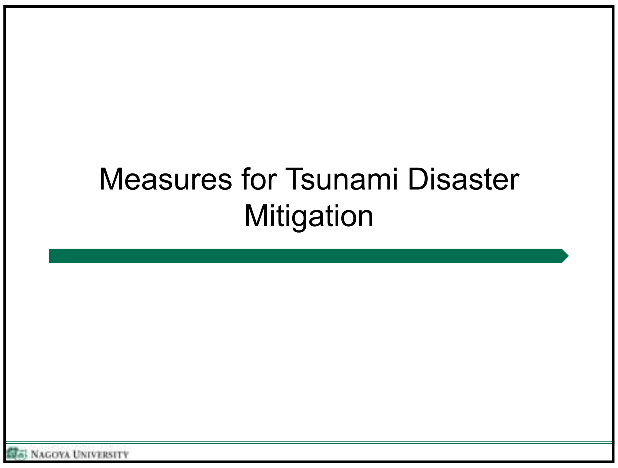
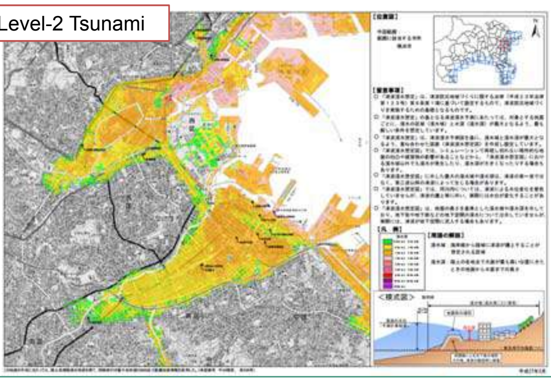

Resiliency of Defense Infrastructure
There were examples of tsunami damage reduction caused by defense infrastructure, even though they were destroyed by the tsunami higher than their design tsunami.
Enhancement of resiliency of defense infrastructure to tsunamis higher than their design tsunami
NAGOYA UNIVERSITY


Measures for Tsunami Disaster Mitigation
NAGOYA UNIVERSITY

Estimation of Tsunami Risk Areas

Level-2 Tsunami



出典：神奈川県ホームページ，津波浸水想定図

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Integration of “Hard” and “Soft” Measures

- Preparation for protecting human life at least even though the worst case scenario of disasters happens

➔ **“Soft” measures** for protecting human life ＋ **“Hard” measures to reduce inundation and others**

  – Horizontal evacuation outside the inundation areas
  – Vertical evacuation in nearby RC buildings
  – Relocation to higher place

- Reduction of tsunami impacts ➔ **”Hard” measures**
  – Height is the key for tsunami measures

In case of sea waves, Areal defense causing wave energy dissipation can be available for wave disaster mitigation: i.e. artificial reef inducing wave breaking.

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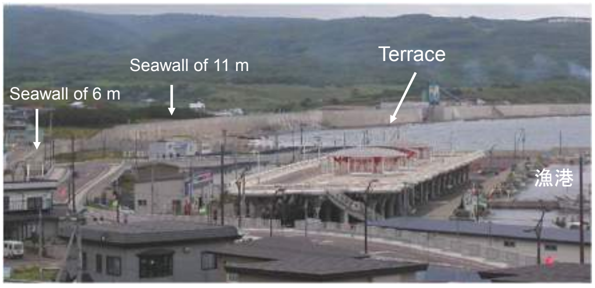
Emergency evacuation terrace in a port

Terrace has been utilized for fish works in the normal time.



Aonae in Okushiri Island, Japan damaged by the 1993 Okushiri Tsunami

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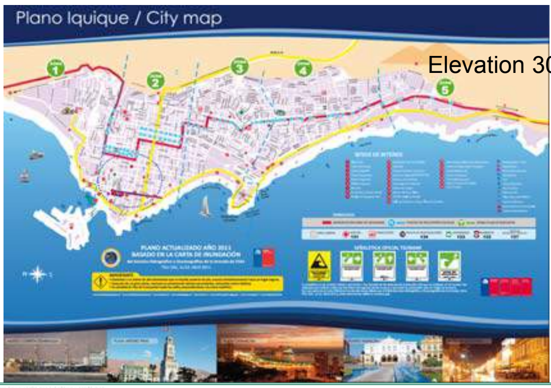
Safe Zone in Chile



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Coastal forest

Pine trees of 150-300 m wide

写真：国土地理院

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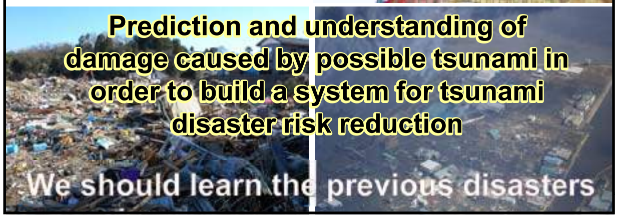
Damage Estimation in Detail

Tsunami hazard mapping can provide estimation of
- inundation areas
- mortality and the number of affected people
- the number of houses destroyed
- and others



Key points for numerical simulation of tsunami

- Accuracy of numerical simulation results depends on that of the used numerical models as well as bathymetric and topographic data.
- We should prepare appropriate numerical models and suitably-accurate bathymetry, topography and structure data to obtain the expected results.
- If the suitable data is not available at present, we need to proceed the simulation step by step depending on preparation of the data.

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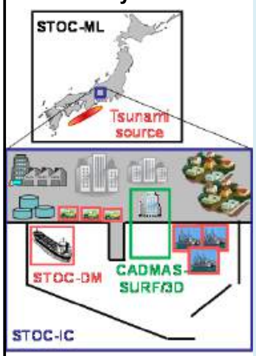
Simulation System for Tsunami Damage Estimation

STOC System



- **STOC-ML**
  - ✓Quasi-3d (multilevel) model with hydrostatic assumption
  - ✓Applying to tsunamis propagating in a wide ocean
- **STOC-IC**
  - ✓3d model with turbulent model and no hydrostatic assumption
  - ✓Water surface detection by the vertically-integrated continuity equation
  - ✓Applying to tsunamis affected by structures
- **STOC-DM**
  - ✓Model for debris motion
  - ✓Using output from STOC-ML and STOC-IC
  - ✓Estimating blocking effects of debris through direct connection with STOC-ML
- ***CADMAS-SURF/3D***
  - ✓ *3d model with the VOF model that detects the water surface*
  - ✓ *Connecting with STOC-IC*

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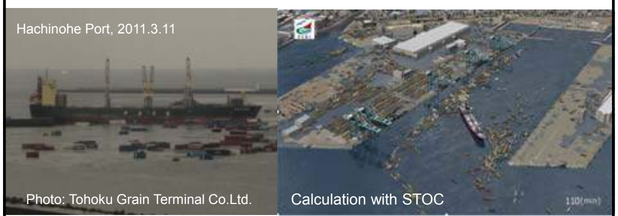
Example of Tsunami & Debris Calculation



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International Cooperation

Nagoya University

SATREPS Research Project supported by JST andJICA

SATREPS

Enhancement of Technology to Develop Tsunami-Resilient

PROJECT PURPOSE: Development of Technologies and Measures to Improve Communities and People in Chile, Japan and other countries to be Well-Prepared for and Resilient to Tsunamis

G 4: Proposal of Programs to Create Well-Prepared/Resilient People and Community
- Education method
- Method to utilize ports and harbors in emergency period
- Planning method for local government system to be functional after the disaster

G 1: Development of Mathematical Simulation Methods
- Database on tsunami damage
- Mathematical models
- Improvement of structure design methods

G 2: Proposal of Tsunami Disaster Estimation Method and Mitigation Measures
- Guideline for disaster estimation
- Estimation of damage in Japan and Chile
- Mitigation measures

G 3: Development of Precise Tsunami Warning Method
- Precise tsunami prediction method with seismometers and offshore tsunami-meters
- Information dissemination method

Building National Resilience to Disasters

High Damage Cost in Capital: Japan Case

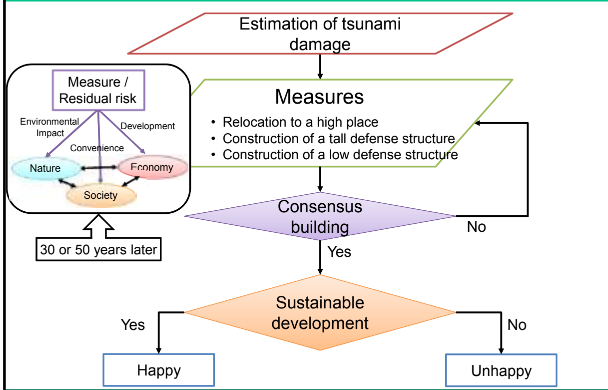
- Estimated damage in the 2011 Tohoku event
  - 154 billion US$ approx.
  - Death toll: 20,000
  - Complete destroyed buildings: 130,000
- Possible earthquake disaster in the Capital
  - 431 billion US$ approx.
  - Death toll: 23,000 max.
  - Complete destroyed buildings: 610,000 max.

If an big incident occurs in the Capital area that population and assets are concentrated in Japan, its disaster can become severe

Building National Resiliency: Japan Case

- Aging population and birthrate declining
  - Lack of persons who are responsible for taking care of handicap persons, and working rehabilitation and restoration activities
    - → Necessary for keeping and increasing population of productive age
- Building environment to easily live as well as to be safety and security
- Balance of natural hazard resiliency, industry development, and sustainable environment
  - Natural disasters, society and economy, and environment highly depending on local characteristics

National Land Use Design for Building Resiliency to Tsunamis



Summary

Summary

- Strengthening of critical infrastructures including defense structures, transportation systems, lifelines, schools, hospitals to build national land resilient to natural disasters such as tsunamis.
- Multi-level estimation of hazards to build integrated and inclusive measures for enhancement of resiliency of people, society and economy.
- Multi-layered defense system to protect people from unexpected tsunamis
- Understanding of geographical and social vulnerability, and previous disasters in the area and in the world.

L8: Tidal Flat Conservation

Hiromi YAMASHITA, PhD. (*Ritsumeikan Asia Pacific University: APU, Japan*)

Abstract

A tidal flat is a curious place where mud appears in shallow areas of coastal water when the tide is low. It supports not only an immense variety of wildlife, but also has an economic value, including providing a source of food, water purification, erosion control, and reducing damage from tsunamis. Among conservationists, tidal flats are regarded as one of the most important areas to conserve for the health of the wider coastal and oceanic environments. International convention documents, such as those produced by Ramsar, emphasize this (e.g. Ramsar Convention Secretariat 2008).

In this context, cities within 60 km of the sea are growing. Some 60 % of the world's population lives within 60 km of the sea and current trends suggest that this figure will rise to 75 % by the year 2025. Three quarters of the world's megacities are coastal, even though coastal regions harbour many of the Earth's most diverse, complex, and productive ecosystems (UNESCO 1997). Many of the city developments in coastal areas have utilized tidal flats to expand available land to use for living, transportation, and infrastructure. At the present time, in many countries more than half of the population lives in a coastal zone, a percentage that is increasing.

Although the ecological importance of wetlands and tidal flats has been widely communicated in recent years (e.g. Smardon 2009), they are still under great pressure from urban and coastal development projects in Japan and abroad. In Japan, between the 1940s and 1980s nearly 40 % of the natural tidal flats were lost through reclamation, and currently it is said to be 50 % or more (e.g. Baba et al. 2003).

There is little detailed study on how wetlands and tidal flats are perceived by people who have not had direct contact with them. However, it is well observed by wetland conservationists in many countries that wetlands and tidal flats have often been referred to as "wastelands" by the general public.

This course looks at the importance of tidal flats; existing tidal flat management arrangements and issues for the conservation and sustainable use of the areas; and how the ecological importance of tidal flat can be communicated effectively.

Lecture 9

Tidal flat Conservation

(selected slides only)

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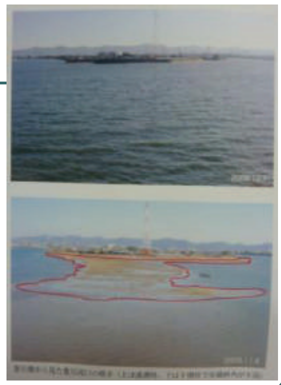
2016.12.08.

Tidal flats 干潟

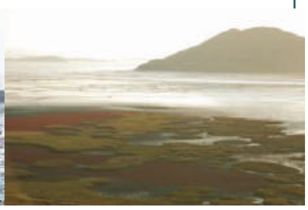
" Shallow, often muddy, part of seashore, which are covered and uncovered by the rise and fall of the tide "



Toyohashi Museum of Natural History 2010

Tidal flat

- 水の「熱帯雨林」" **Rain forests in the water**" **(rich biodiversity)**
- 海の子宮 " **Womb of the sea**" **(nursery for fish)**
- 地球の腎臓 " **Kidney of the earth**" (water purification mechanisms)



Cities within 60km from the sea (world)

- Around year 1500 – 25% of cities
  ⇨ Currently – **70%**

Population:

- Currently 70% of the world population
  ⇨ **75%** in Year 2025

In Japan, since 1945, 50% or more of tidal flats have been lost through "reclamation"

Isahaya Bay

Management of seashores

(according to Seacoast law［海岸法］1956, then updated in 1999)

Types of coasts	Management responsibility	Purpose
Shore for agriculture（農地海岸）	Ministry of Agriculture, Forestry and Fisheries	**To protect agricultural land and activities behind the shore** from erosion and natural disasters
Shore for fisheries（漁港海岸）	Ministry of Agriculture, Forestry and Fisheries	**To protect fishing ports and fishing activities**
Shore for ports（港湾海岸）	Ministry of Land, Infrastructure, Transport and Tourism（旧運輸省）	**To protect port infrastructures** and related business
Other protected shores（その他海岸保全区域）	Ministry of Land, Infrastructure, Transport and Tourism（旧建設省・農林水産と旧運輸省管轄外）	**To protect people's lives and possessions** behind the shore line

Existing tidal flat management arrangements

A. Tidal flats not being visible

- **Tidal flats are invisible on various planning maps: No names = no existence?**
- **Being under the water sometimes, and seasonal and daily changes** not being noted on maps and designing processes
- **Living creatures look less significant** due to small sizes or under the mud
- **Out of people's minds** by being not so 'attractive'

B. Not connected management mechanisms, and different purposes for the coastal management, although the implications are linked

Challenges in landscape planning

A. **How 'invisible landscapes' can be turned into attractive landscapes for people**, decision makers and planners' minds?

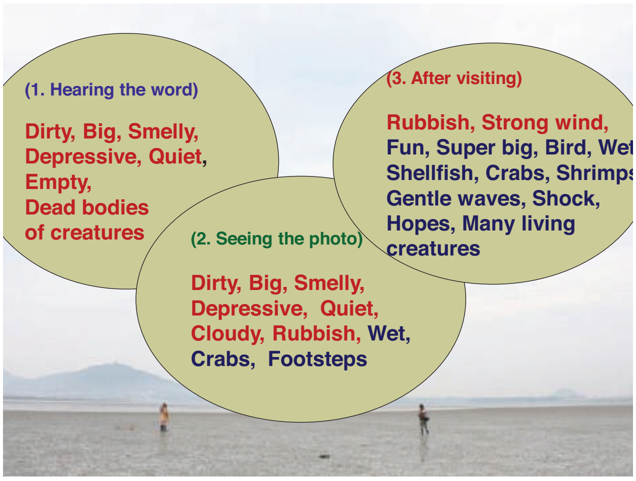
B. **How to conserve the places that do not have names** on the planning maps?

C. How can planning be aware of **3 dimensional landscapes, and changes** in days and seasons, more effectively?

D. How would it be possible to create **'joined-up thinking'** between different management bodies? (e.g. creating over-riding local mechanisms or regulations)

Invisibilities of tidal flats in landscape planning

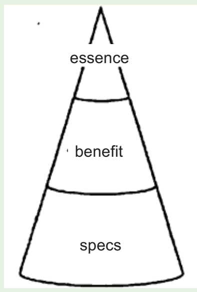
1. **In planners' and people's minds**
2. **On maps**
3. **In the existing management mechanisms**



Conventional ways to explain about tidal flats

Need a new approach in CEPA (Communication, Education, Participation and Awareness)?

Marketing Product cone	
1. Essence	Images, characteristics of products (personification: great, scary, beautiful etc)
2. Benefit	Something beneficial (ecological service, benefits to human beings)
3. Specs	Description of products, specs (places, names of living creatures and plants, ecology)

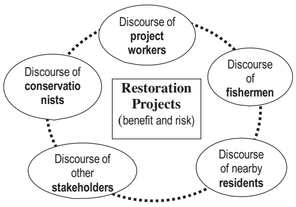


Marketing Product Cone (Mori 2000)

"Environmental Risk Communication and Social Perceptions of the Risk and Benefits of Tidal Flat Restoration Projects"

(3 year funded project: April 2011 ~ March 2014)
(extended study April 2015 ~ March 2019)

1) What kinds of **environmental information on tidal flat restorations are produced and communicated** by project contractors and other stakeholders in the community?
2) How do **various stakeholders perceive the 'benefits' and 'risks'** of their local restoration projects?
3) How the findings could make a **contribution to future decision making and support** for coastal wetland restorations?



Analysis of the 'benefits' and 'risks' of restoration projects presented by different stakeholders, and its implications for effective environmental communications

Discussion

Other elements to consider in the future

- Restoration project is about a local community regaining "commons" →
- **How shall it take into account "stakeholders" who existed in the past, but not there currently** (but **the success of the project means those people coming back to the area** in the future)
- For example, in the UK and Netherlands cases, fishermen are completely "forgotten stakeholders" for tidal flat restoration projects.

- Joint work. Yamashita, H. and Yasufuku, T. (2016) Coastal planning: Biodiversity conservation and ownership, in Shimizu, H. and Takatori, C. (2016 in print) ***Labor forces and landscape management***. London: Springer.
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- Joint work. Kato, H., Shimizu, H., Kawamura, N., Hirano, Y., Tashiro, T., Yamashita, H., Tomita, K., Tomiyoshi, M. and Hagihara, K. (2014) A Prospect Toward Establishment of Basic and Clinical Environmental Studies by ORT (On-Site Research Training), in Shimizu, H. Murayama, A. (eds) ***Basic and Clinical Environmental Approaches in Landscape Planning. Urban and Landscape Perspectives, Volume 17***. London: Springer. p.133-143
- Individual work. Yamashita, H. (2016) 'Discourse of risks and benefits towards tidal flat restoration: Case study of "opening a water gate" of Isahaya Bay land reclamation in Ariake Sea, Wetland Research. 山下博美(2016)「干潟再生に対するリスク・ベネフィット言説：有明海諫早湾干拓排水門『開門』をケースに」『**湿地研究**』6巻1号、3-17
- Individual work. Yamashita, H. (2015) Problems of the 'Fact'-Focused Approach in Environmental Communication: Examples of Environmental Risk Information on Tidal Flat Developments in Japan. ***Environmental Education Research***, Vol.21(4), pp.586-611. DOI: 10.1080/13504622.2014.940281
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- Joint work. Hockings, C., Cooke, S., Yamashita, H. McGinty, S. and Bowl, M. (2009) 'I'm neither entertaining nor charismatic…' Negotiating university teacher identity within diverse student groups. ***Teaching in Higher Education***, Special Issue: purposes, knowledge and identities, 14(5):470-483. http://www.tandfonline.com/doi/abs/10.1080/13562510903186642
- Individual work. Yamashita, H. (2009) Making Invisible Risks Visible: Education, environmental risk information and coastal development. ***Ocean & Coastal Management***, 52:327-335. http://www.sciencedirect.com/science/article/pii/S0964569109000258

E1: Analysis of satellite data for monitoring and assessment for coastal eutrophication

Genki Terauchi (NOWPAP CEARAC)

Abstract

Marine eutrophication has recently become a concern for all the world's oceans. There are over 415 areas worldwide identified as manifesting symptoms of eutrophication. Eutrophication causes deterioration of the coastal environment and often leads to the formation of harmful algal blooms and depletion of bottom oxygen, which may subsequently induce fish kills and/or ecosystem damage. Eutrophication was originally used in limnology to describe the natural process of nutrient enrichment concomitant with the aging of lakes and ponds. However, it is known that humans, through various activities, can greatly accelerate this natural process by increasing nutrient input into bodies of water.

Northwest Pacific region, which includes parts of northeast China, Japan, Korea and southeast Russia, is one of the most densely populated areas of the world, and its coastal systems are under pressure from human activities. In deed, a significant number of red tides and hypoxic conditions have been reported in coastal waters - possibly due to anthropogenic influences such as extensive chemical fertilizer use and sewage effluent.

In this training course, case studies of use of remotely sensed chlorophyll-*a* concentration (satellite Chl-*a*) in Toyama Bay, Japan will be introduced. Preparing a consistent long-term time series satellite Chl-*a* data sets and a methodology for quality assurance processes will be included. Interannual and seasonal variability of satellite Chl-a and its changes associated with fresh water discharge will then be discussed. Use of Google Earth Engine, a cloud-computing platform for processing satellite imagery, for detection of changes in coastal habitats will also be introduced.

Analysis of satellite data for monitoring and assessment of coastal eutrophication:
a case study in Toyama Bay

Genki Terauchi
NOWPAP CEARAC

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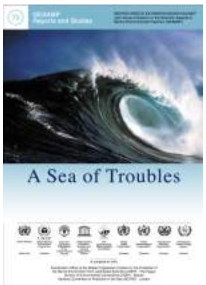
Marine Eturophication as a global concern

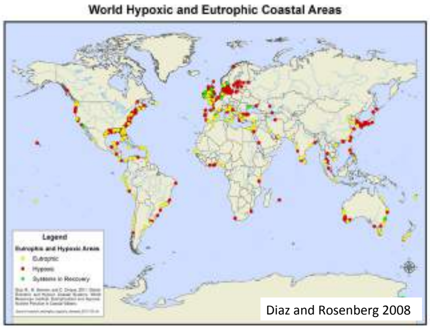


Increasing Eutrophication

Excessive growth of marine plant life, is seriously Disrupting ecosystems and threatening health throughout the worlds: coral reefs, seagrass beds and other vital habitats are suffering.
And it can trigger explosive blooms of toxic algae Which can blight tourism, contaminate seafood And poison people.

Eutropjhication as a global concern -Spreading Dead Zones-

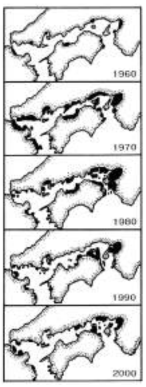
World Hypoxic and Eutrophic Coastal Areas



Diaz and Rosenberg 2008

Eutrophication as a threat in the Northwest Pacific

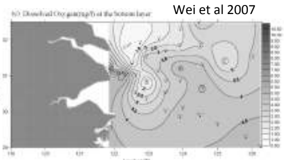
Imai and Hori 2006



Liu *et al.*, 2010

Dong *et al.*, 2010

Wei et al 2007



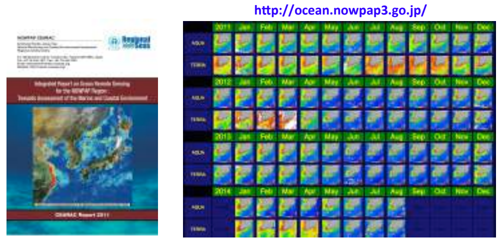
- Northwest Pacific Action Plan (NOWPAP) -

- Regional Sea Program (RSP)
  - Launched in 1974 by UNEP to address the accelerating degradation of the world's oceans and coastal areas.
  - RSP covers 18 regions across the world today
- NOWPAP
  - Adopted in 1994
  - China, Japan Korea and Russia
  - Latitude 33 - 52°N
  - Longitude 121 – 143E

Mission of NOWPAP CEARAC

- Mission
  - Assessment of the state of the marine, coastal associated fresh water environment
  - Development of tool for environmental assessment
- Activities
  - Harmful Algal Blooms (HAB)
  - Remote Sensing of Marine Environment
  - Assessment of eutrophication
  - Marine Litters
  - Marine biodiversity

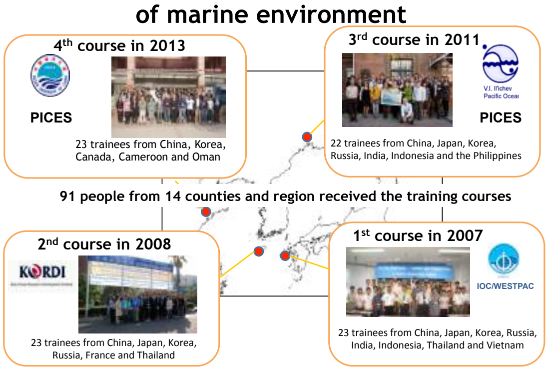
Publications and databases



Ocean remote sensing in the Northwest Pacific Region

Ocean color data time series in the Marine Environmental Watch

Training Courses on remote sensing of marine environment



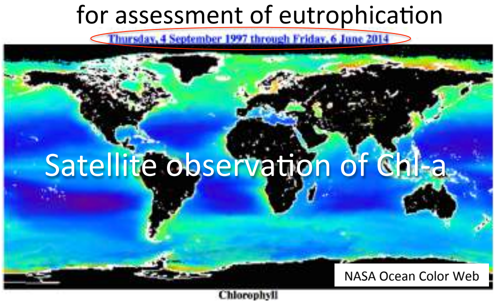
Initiatives to address or mitigate eutrophication -NOWPAP Common Procedure for eutrophication assessment

- Developed from a case study in Toyama Bay
- Eutrophication is assessed by

Category	Parameters
I	Parameters that indicate degree of nutrient enrichment (e.g. T-N/T-P load, DIN/DIP, N/P ratio)
II	Parameters that indicate direct effects of nutrient enrichment (e.g. Chlorophyll-a, red tide)
III	Parameters that indicate indirect effects of nutrient enrichment (e.g. DO, fish kill, COD)
IV	Parameters that indicate other possible effects of nutrient enrichment (e.g. Shellfish poison)

Chl-*a* is one of indicator among the others (Harding and Perry 1997; Bricker et al. 2003)

Potential of remotely sensed Chlorophyll-a for assessment of eutrophication



- Regular monitoring start from after the launch of NASA SeaWiFS in 1997.
- More than 16 years of remotely sensed Chl-a data available

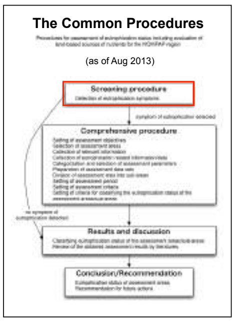
Strength and weakness of satellite and shipboard measurements

Means of observation	Strength	Weaknesses
Satellite Remote Sensing Preliminary Assessment for screening	•Wider area and higher temporal coverage •Objectively detect relative change •Free data access over the Internet	•Low accuracy in estimation of Chl-a in coastal area •No data obtained under cloud •Data is available only at sea surface
Ship board measurements Holistic Assessment	•Obtain data under sea surface •Can obtain actual measured value	•Data represent only point of information •Analysis of Chl-a need expertise •Costly

Development of procedure for eutrophication assessment

- Procedures for assessment of eutrophication status including evaluation of land-based sources for nutrients for the NOWPAP region (June, 2009 and refined in 2013)

Use of **remote sensing** is proposed as a screening tool

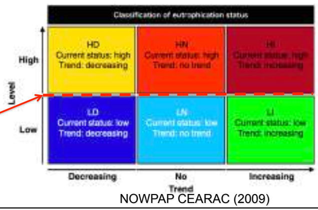


Assessment of eutrophication by the NOWPAP Common Procedure

Level	Trend
Help plan immediate mitigation intervention action	Help plan preventive management action
Chl-*a* level of 5ug l^{-1} is used as value for early warning	Annual maximum value in monthly mean

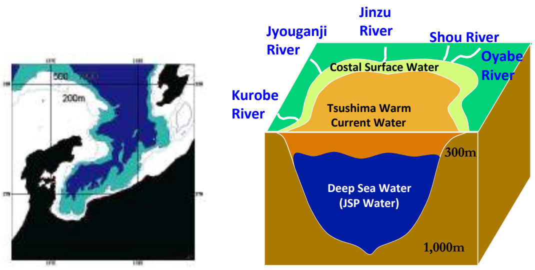
Level of Chl-*a* for eutrophication assessment proposed by Bricker et al. (2003)

Hypereutrophic (>60ug l^{-1})
High (>20, ≤60ug l^{-1})
Medium (>5, ≤20ug l^{-1})
Low (>0 and ≤5ug l^{-1})



NOWPAP CEARAC (2009)

2. Preliminary Assessment of eutrophication by remotely sensed chlorophyll-a in Toyama Bay

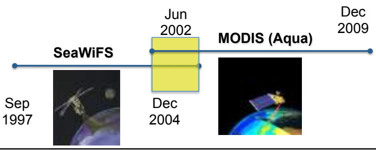


Toyama Bay and its characteristics

Material and method

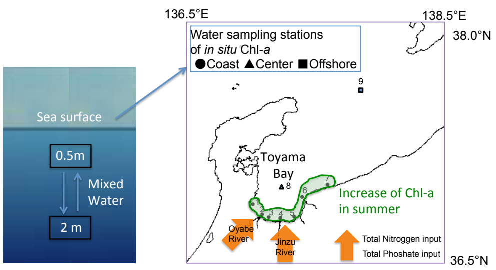
- Satellite Chl-a data

Sensor	**NASA SeaWiFS on Orbview 2** **NASA MODIS on Aqua**
Algorithm	**R2009 NASA standard datasets**
Duration	**12 Years from Jan 1997 to Dec 2009**
Data	**Monthly composite**
Area	**Toyama Bay (36.5 to 38^{O}N, 136.5 to 138.5^{O}E)**



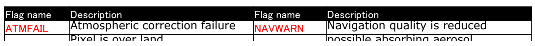
Material and method

- In situ data



Location of Toyama Bay

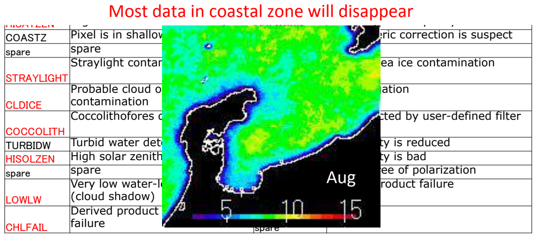
Uncertainty of satellite Chl-a and Level 2 flag



If you use the 17 level 2 flags are being applied in the NASA global data sets in coastal zones

↓

Most data in coastal zone will disappear



Validation of satellite Chl-a with in situ Chl-a

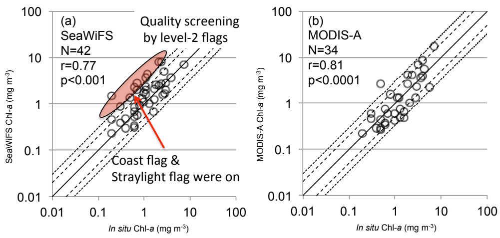


Fig 2.3 Comparison of satellite and *in situ* Chl-*a* during the studied period
(a) Level-2 data for SeaWiFS Chl-*a* from 1997 to 2004 and (b) MODIS-A Chl-*a* from 2002 to 2009 were compared with *in situ* Chl-*a*, with a time difference ≤3 hours. *In situ* data were obtained at 9 water sampling stations located at the coast, center and offshore of Toyama Bay. The solid line is a 1:1 ratio; dashed lines show 1:2/2:1; dotted lines show 1:3/3:1 ratios.

Evaluation of consistency between SeaWiFS and MODIS-A Chl-a

log(MODIS-A Chl-*a*) = -0.900 + 0.932 log(SeaWiFS Chl-*a*)
r^2 = 0.81, N = 137173

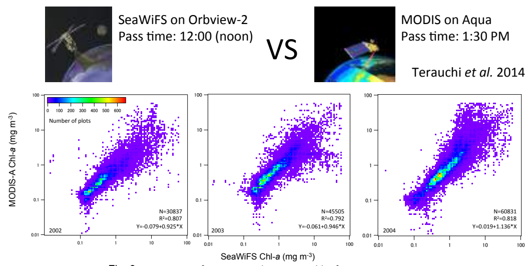
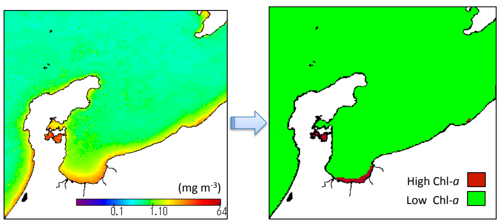


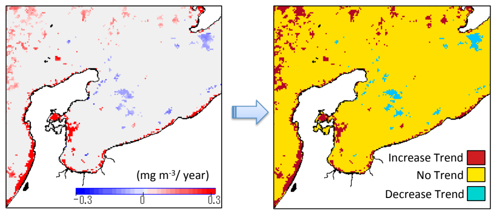
Fig. 3 Comparison of SeaWiFS and MODIS-A Chl-*a* from 2002 to 2004.
Pixel-to-pixel comparison of daily composite data between SeaWiFS and MODIS-A Chl-*a* was made from 2002, 2003 and 2004.

Determination of high and low Chl-a area



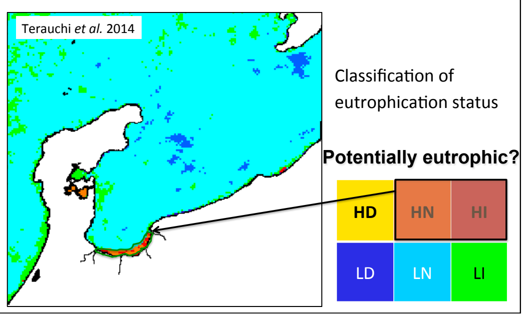
Detection of High and Low Chl-*a* area in Toyama Bay.
(a)13-years overall mean of satellite Chl-*a*. (b) High and Low Chl-*a* area determined by the Chl-*a* level more than 5 *ug* l⁻¹ referring to the Medium Chl-*a* condition (>5, <20 *ug* l⁻¹) of Bricker *et al.* (2003).

Detecting interannual Chl-a trend

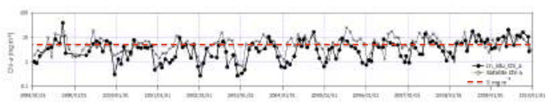


12-years of satellite Chl-*a* trend.
(a) The trend of annual Chl-*a* max in monthly mean Chl-*a* and its significance were estimated at pixel wise by the Sen Slope test at 90% confidence level. (b) Increase Trend, No Trend and Decrease Trend area were then detected.

Preliminary assessment of eutrophication in Toyama Bay

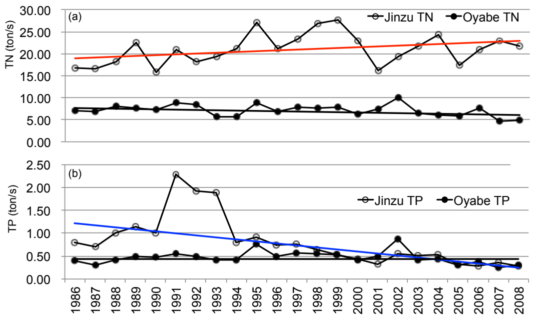


Interannual change of monthly satellite and in situ Chl-a in the detected potential eutrophic zone



Monthly mean of merged satellite Chl-*a* in the detected eutrophication zone and mean *in situ* Chl-*a* obtained at 3 water-sampling stations (Stations 3, 4 and 5) in the detected potential eutrophic zone.
Dashed red line is 5 mg m⁻³ which is the threshold condition to determine High or Low Chl-*a* level.

Interannual change of monthly satellite and in situ Chl-a in the detected potential eutrophic zone

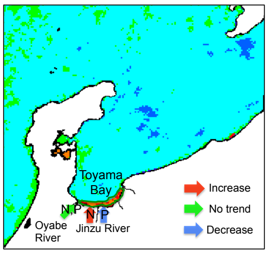


Summary of preliminary eutrophication assessment with satellite Chl-*a*

- Past studies based on spatially and temporally limited (sprase) data
  - Increased Chl-*a* in summer in Toyama Bay coastal area as a cause of water quality degradation
- Preliminary assessment of eutrophication by spatially and temporally intensive remotely sensed Chl-a
  - Illustrated boundaries of the potentially eutrophic zones in Toyama Bay coastal area, where mitigation of water quality is necessary.
  - Increasing TN input from Jinzu River as a cause of eutrophication

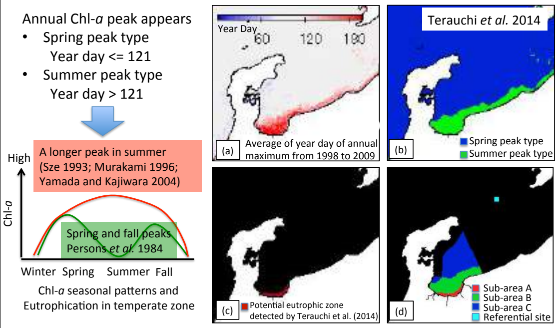
3. Influence of river discharge on seasonal and interannual variation of Chlorophyll-a in Toyama Bay

- Influence of river discharge on seasonal and interannual variability of Chl-a in Toyama bay?
- Causes of potential eutrophication in Toyama Bay?

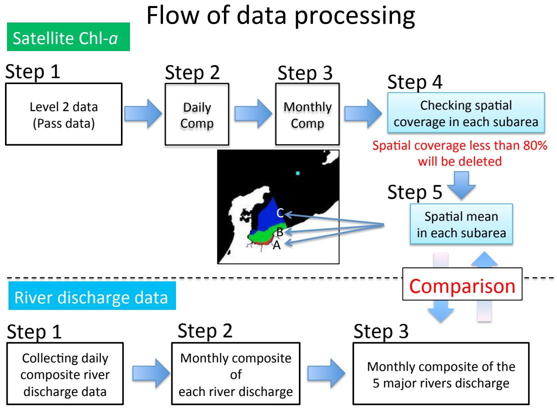


Material and method

- Chl-*a* increased after spring (Nagata and Nakura 1993)

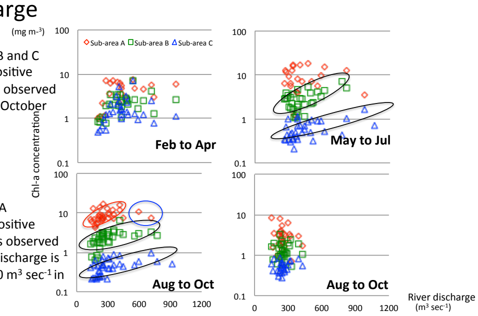


Flow of data processing

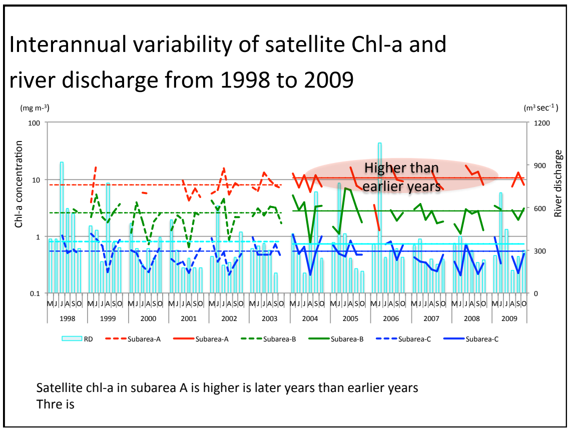


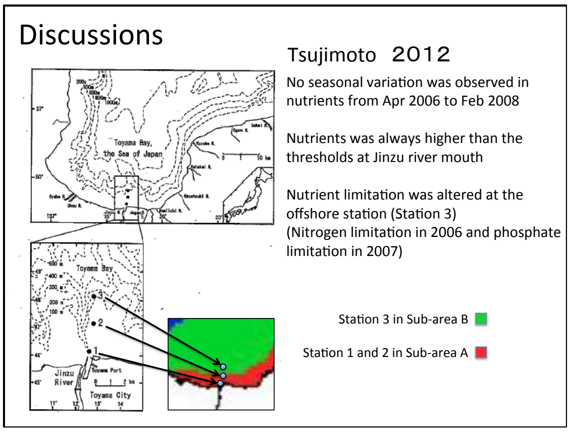
Seasonal variability of satellite Chl-a and river discharge

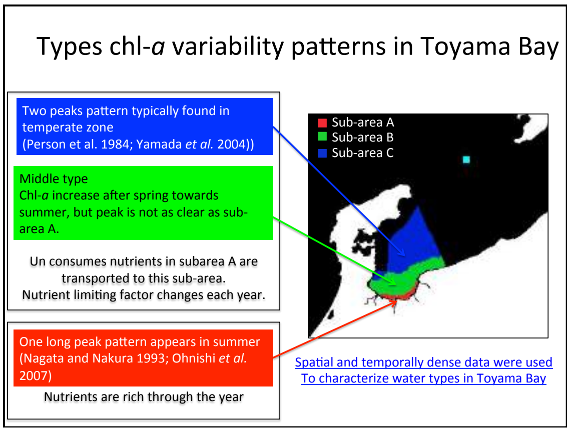
- Sub area B and C Significant positive correlation is observed from May to October
- Sub area A Significant positive correlation is observed when river discharge is less than 500 m³ sec⁻¹ in Aug to Oct

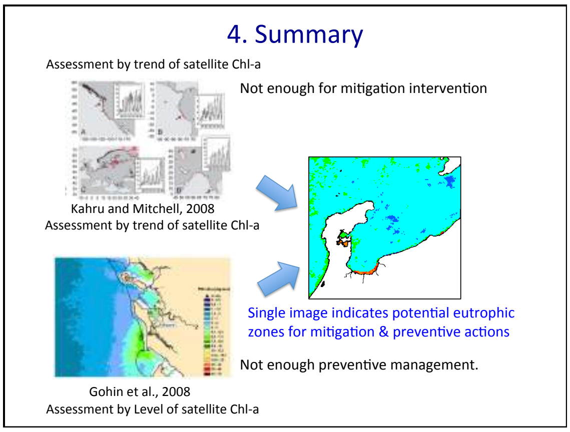


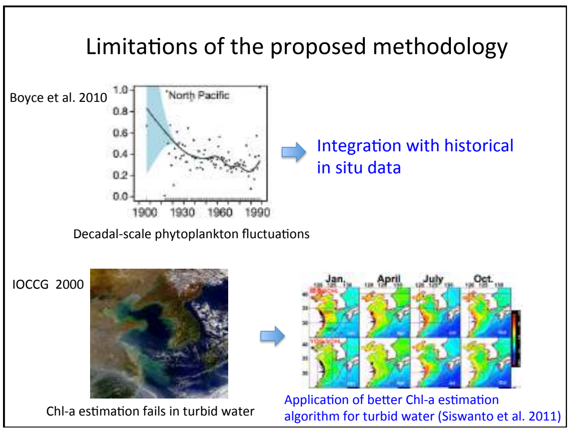
Comparison of monthly means of satellite Chl-a in each sub-area and the reference site, and sum of monthly mean river discharge in the 5 Class-A rivers from 1998 to 2009.

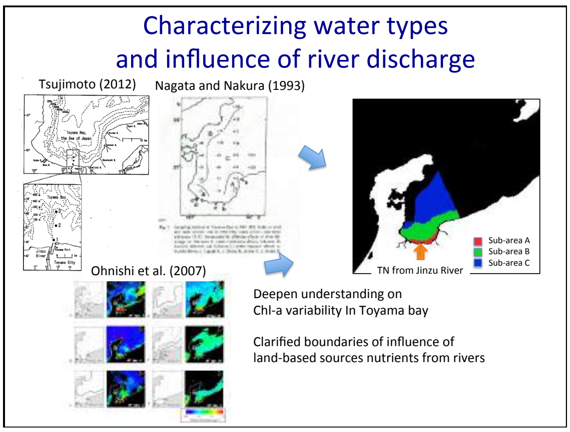

Interannual variability of satellite Chl-a and river discharge from 1998 to 2009
Chl-a concentration
River discharge
Higher than earlier years
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
RD
Subarea-A
Subarea-B
Subarea-C
Satellite chl-a in subarea A is higher is later years than earlier years
Thre is


Discussions
Tsujimoto 2012
No seasonal variation was observed in nutrients from Apr 2006 to Feb 2008
Nutrients was always higher than the thresholds at Jinzu river mouth
Nutrient limitation was altered at the offshore station (Station 3)
(Nitrogen limitation in 2006 and phosphate limitation in 2007)
Toyama Bay, the Sea of Japan
Toyama Bay
Jinzu River
Toyama Port
Toyama City
Station 3 in Sub-area B
Station 1 and 2 in Sub-area A


Types chl-a variability patterns in Toyama Bay
Two peaks pattern typically found in temperate zone
(Person et al. 1984; Yamada et al. 2004))
Middle type
Chl-a increase after spring towards summer, but peak is not as clear as sub-area A.
Un consumes nutrients in subarea A are transported to this sub-area.
Nutrient limiting factor changes each year.
One long peak pattern appears in summer
(Nagata and Nakura 1993; Ohnhishi et al. 2007)
Nutrients are rich through the year
Sub-area A
Sub-area B
Sub-area C
Spatial and temporally dense data were used
To characterize water types in Toyama Bay


4. Summary
Assessment by trend of satellite Chl-a
Not enough for mitigation intervention
Kahru and Mitchell, 2008
Assessment by trend of satellite Chl-a
Single image indicates potential eutrophic zones for mitigation & preventive actions
Not enough preventive management.
Gohin et al., 2008
Assessment by Level of satellite Chl-a

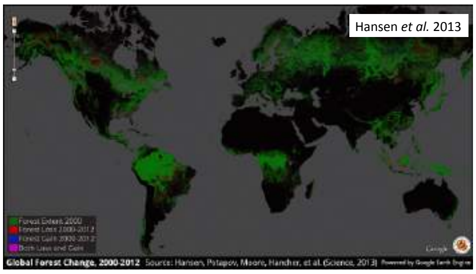

Limitations of the proposed methodology
Boyce et al. 2010
North Pacific
1900
1930
1960
1990
Integration with historical in situ data
Decadal-scale phytoplankton fluctuations
IOCCG 2000
Jan.
April
July
Oct.
Chl-a estimation fails in turbid water
Application of better Chl-a estimation algorithm for turbid water (Siswanto et al. 2011)


Characterizing water types and influence of river discharge
Tsujimoto (2012)
Nagata and Nakura (1993)
Ohnhishi et al. (2007)
Sub-area A
Sub-area B
Sub-area C
TN from Jinzu River
Deepen understanding on Chl-a variability In Toyama bay
Clarified boundaries of influence of land-based sources nutrients from rivers

5. Introduction to Google Earth Engine

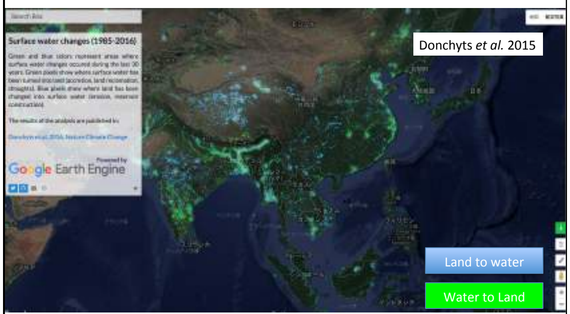
https://earthengine.google.com/

Detection of Global Forest Change at 30 m resolution

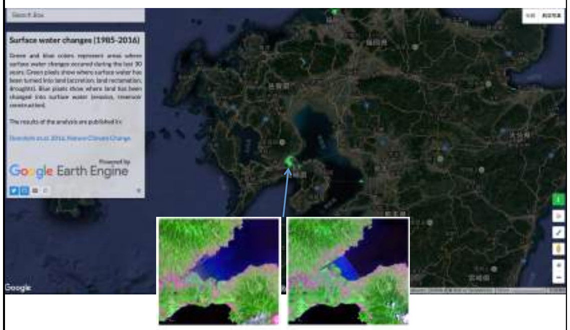


This is the first map of forest change that is globally consistent and locally relevant. What would have taken a single computer 15 years to perform was completed in a matter of days using Google Earth Engine computing.
- Professor Matt Hansen, University of Maryland

Analysis of surface water changes globally at 30m resolution

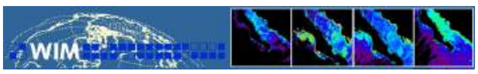


Land reclamation in Isahaya Bay, Japan



Hands on

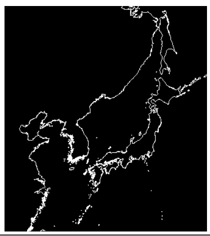
- Analysis of time series Chl-*a* using WIM Software



http://wimsoft.com

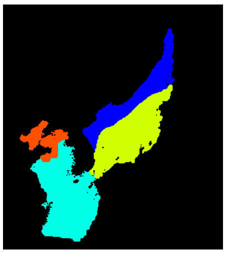
#1. Create image for your area of interest

- References
  - C:\Program Files\WimSoft\Course\3
    - Tutorial_time_series_of_areal_statisics.pdf
- Input
  - Projection: Linear
  - Pixel in size 9,000 meters
  - Input latitude and longitude for your area of interest
  - Apply coastal line overlay
- Output
  - Save output as hdf file



#2. Create mask images for your area of interest

- References
  - C:\Program Files\WimSoft\Course\3
    - Tutorial_time_series_of_areal_statisics.pdf
- Input
  - Draw masks to be used for time series with Edit-Draw function
  - Replace coast line value 255 with 0 by Transf-Replace Values
- Output
  - Save output as hdf file



#3. Create time series chart

- References
  - C:\Program Files\WimSoft\Course\3
    - Tutorial_time_series_of_areal_statisics.pdf
- Input
  - Remapped merged L3 Monthly Chl_9 images with WIM liner projection by wam_series (save the files in "cut" directory)
  - List of monthly Chl-a image under C:\Sat\Merged\L3\Monthly\CHL_9
  - Your created mask image for time series
- Output
  - Run wam_statis for monthly timeseries and save output as .csv file and then create time series chart with MS excel

Save your output in Z (share drive)

- #1. Creating directory with your name
- #2. Save your output in MS power point and put in the directory

E2: Cruise Data Analysis

Joji Ishizaka
(*Institute for Space-Earth Environmental Research, Nagoya University*)

Abstract

Ise Bay is one of heavily used coastal environments in Japan. Surrounded by the large city of Nagoya and Tokai industrial regions, many cargo ships transported large amount of materials through the bay. Because of the anthropogenic activities, both atmosphere and marine environments had been heavily polluted during 1970/80s, and hypoxia condition of the bottom water has been still often observed during summer, even the loading of the pollutant has been reduced. On the other hand, Ise Bay and the surrounded area have been also known as high fisheries production areas, and some of fish/clam catches, such as Manila clam, is top level in Japan.

Using the T/V Seisui-Maru in Mie University, we will observe marine environments of Ise Bay including water mass structure, phytoplankton abundance, and optical properties. We also demonstrate to take plankton samples by net and sediment with grab. Observations will be conducted in the western Ise Bay (narrow definition of Ise Bay) and in the eastern Ise Bay (Mikawa Bay). It is possible to see how people are using the bay and surrounded areas.

During the excise of cruise data analysis, we are planning to plot environmental data, such as temperature, salinity, chlorophyll-a, from the cruise during the training course and from cruises during different seasons to check the special and temporal changes of the environments. We are going to use Ocean Data View, which is a free software developed by NOAA. We are also planning to verify the chlorophyll-a concentrations estimated by optical measurements and satellite using the observed data during the cruise.

E3: Coastal model output analysis

Hidenori Aiki
(*Institute for Space-Earth Environmental Research, Nagoya University*)

Abstract

Ocean models have been used for understanding the three-dimensional structure and the continuous time evolution of coastal ocean circulations that are affected by the seasonal and interannual variations of general ocean circulations, such as the Kuroshio Current. Recent advances in atmosphere-ocean modeling and in-situ and satellite observations have enabled to take into account both the realistic structure of the Kuroshio Current and the high-resolution variations of atmospheric and tidal forcing for ocean circulations. The first part of this exercise gives a short lecture on basic understanding for (i) ocean models, (ii) classification of model experiments, and (iii) available model outputs and forcing. Then the second part of this exercise illustrates how to use a visualization tool suitable for analyzing model outputs and explain useful metrics for understanding the dynamics of coastal ocean circulation.

Exercise 3, December 7 (Wednesday), 13:30-17:00 26th IHP TC, 2016 1

Coastal Model Output Analysis

Hidenori Aiki, ISEE, Nagoya Univ.

2

Governing Equation System for an Ocean Model

$$u_x + v_y + w_z = 0$$ Incompressible

tendency, advection, Coriolis, pressure gradient, turbulent viscosity

$$\rho_0 \left[u_t + (uu)_x + (vu)_y + (wu)_z - fv \right] = -p_x + mixing$$

$$\rho_0 \left[v_t + (uv)_x + (vv)_y + (wv)_z + fu \right] = -p_y + mixing$$

Boussinesq

hydrostatic $$0 = -p_z - g\rho$$ buoyancy

$$p = \int_z^\eta g\rho \, dz$$

$$T_t + (uT)_x + (vT)_y + (wT)_z = mixing$$

$$S_t + (uS)_x + (vS)_y + (wS)_z = mixing$$

tendency, advection, turbulent viscosity

$$\rho = \rho(T, S, p)$$ equation of state

u	zonal
v	meridional
w	vertical
η	sea surface height
T	temperature
S	salinity
ρ	density
f	Coriolis
g	gravity

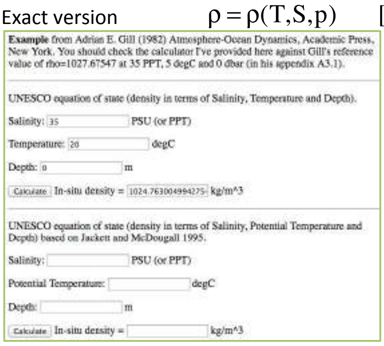
3

Density of sea water

Simplified version

$$\rho \approx 999.8 - 0.0752T + 0.8244S \qquad [kg/m^3]$$

Exact version $\rho = \rho(T, S, p)$ $[kg/m^3]$



Example from Adrian E. Gill (1982) Atmosphere-Ocean Dynamics, Academic Press, New York. You should check the calculator I've provided here against Gill's reference value of rho=1027.67547 at 35 PPT, 5 degC and 0 dbar (in his appendix A3.1).

UNESCO equation of state (density in terms of Salinity, Temperature and Depth).

Salinity: 35 PSU (or PPT)

Temperature: 20 degC

Depth: 0 m

Calculate In-situ density = 1024.763004994275 kg/m^3

UNESCO equation of state (density in terms of Salinity, Potential Temperature and Depth) based on Jackett and McDougall 1995.

Salinity: PSU (or PPT)

Potential Temperature: degC

Depth: m

Calculate In-situ density = kg/m^3

http://co2.hyarc.nagoya-u.ac.jp/
/labhp/member/aiki/density.html

4

Density of sea water

Simplified version

$$\rho \approx 999.8 - 0.0752T + 0.8244S \qquad [kg/m^3]$$

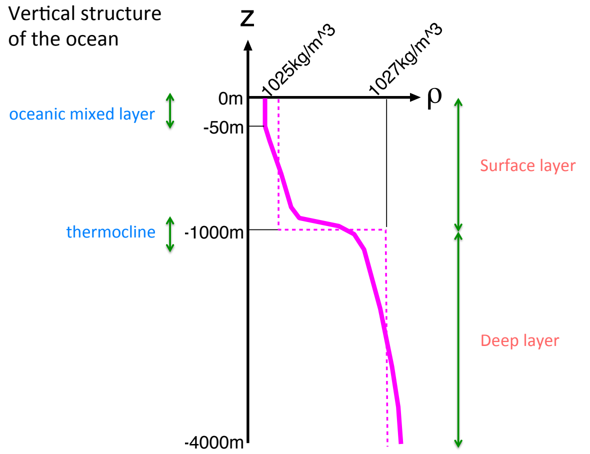
Exact version $\rho = \rho(T, S, p)$ $[kg/m^3]$

z=0m	T=0 ℃	T=10 ℃	T=20 ℃	T=30℃
S=0 g/kg	999.8	999.7	998.2	995.6
S=30 g/kg	1024.0	1023.0	1020.9	1017.9
S=35 g/kg	1028.1	1026.9	1024.7	1021.7
S=40 g/kg	1032.1	1030.8	1028.5	1025.4

z=-4000m	T=0 ℃	T=10 ℃	T=20 ℃	T=30℃
S=0 g/kg	1001.8	1001.6	1000.0	997.4
S=30 g/kg	1025.9	1024.8	1022.7	1019.6
S=35 g/kg	1030.0	1028.7	1026.5	1023.4
S=40 g/kg	1034.0	1032.6	1030.3	1027.1

5

Vertical structure of the ocean



6

E3.1 Ocean Models

US

ROMS (Regional Ocean Modeling System) http://www.myroms.org/

POM (Princeton Ocean Model) http://www.ccpo.odu.edu/POMWEB/

FVCOM (Finite-Volume, primitive equation Community Ocean Model) http://fvcom.smast.umassd.edu/

HYCOM (Hybrid Coordinate Ocean Model) https://hycom.org/

MITgcm (MIT general circulation model) http://mitgcm.org/

MOM (Modular Ocean Model) https://www.gfdl.noaa.gov/mom-ocean-model/

Europe

NEMO (Nucleus for European Modelling of the Ocean) http://www.nemo-ocean.eu/

Japan

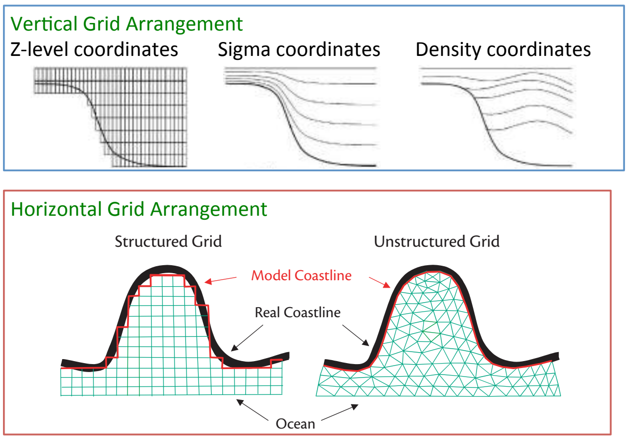
MRI.COM (Meteorological Research Institute Community Ocean Model) http://www.mri-jma.go.jp/

COCO (CCSR Ocean Component model) http://ccsr.aori.u-tokyo.ac.jp/~hasumi/COCO/

Ocean modelling activities in the East Asia Region:
http://www.clivar.org/sites/default/files/documents/wgomd/tsujino_report.pdf

E3.1 Ocean Models

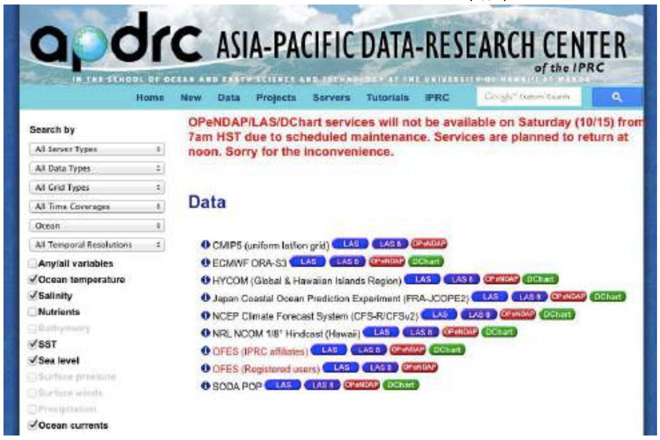
7



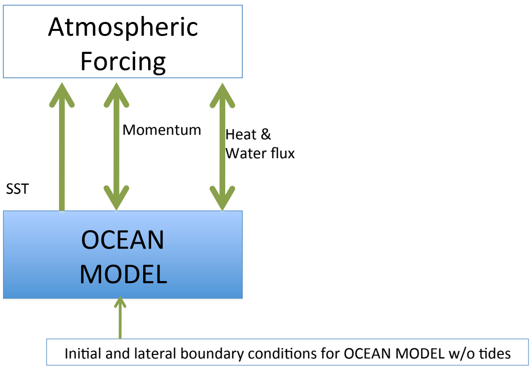
E3.2 Available Model Outputs and Forcing

8

http://apdrc.soest.hawaii.edu



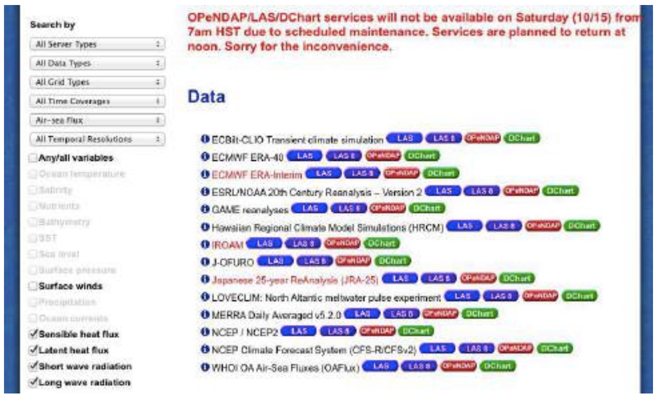
9



E3.2 Available Model Outputs and Forcing

10

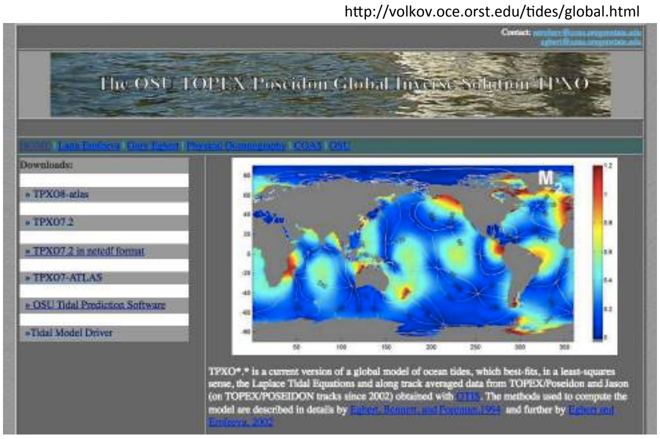
http://apdrc.soest.hawaii.edu



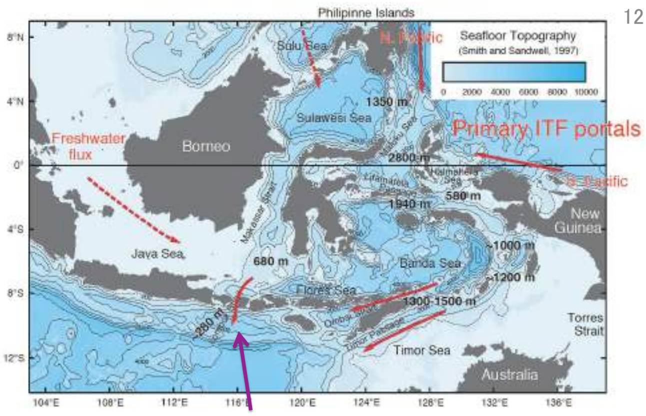
E3.2 Available Model Outputs and Forcing

11

http://volkov.oce.orst.edu/tides/global.html

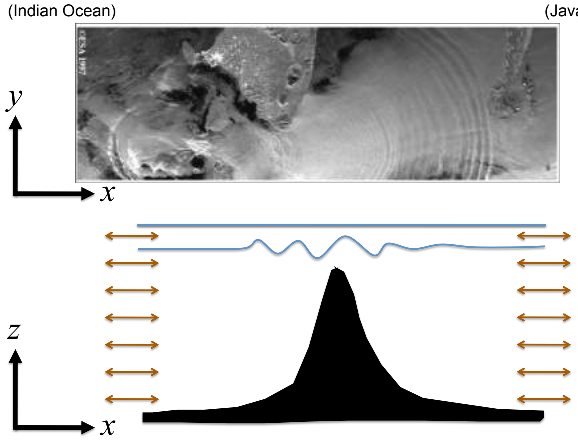


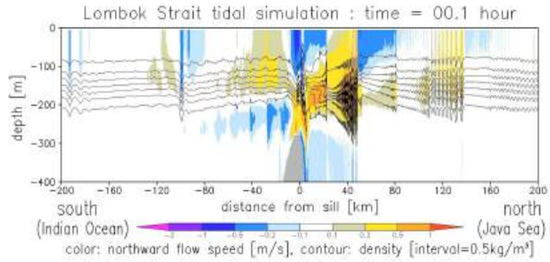
12



Lombok Strait

Gordon et al. (2005)





Forcing checkpoints

Atmospheric forcing
source: Satellite remote sensing (dx=20km) or
Atmospheric model outputs
(global: dx=200km, regional: dx=5km)
time-evolution: Climatology, Monthly, Daily-mean,
3-hour interval, Hourly

River discharge
included or not included

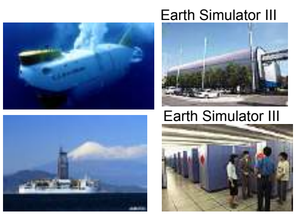
Tidal forcing
included or not included
constituents: M2, S2, M1, O1 …

E3.3 Classification of model experiments

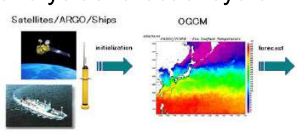
Ocean Model
- Hindcast experiments w/o tides
- Reanalysis (data assimilation) w/o tides
- Nowcast experiments w/o tides
- Forecast experiments w/o tides

Coupled Atmosphere-Ocean Model
- Hindcast experiments
- Reanalysis (data assimilation)
- Nowcast experiments
- Forecast experiments

JAMSTEC 国立研究開発法人 海洋研究開発機構
JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY



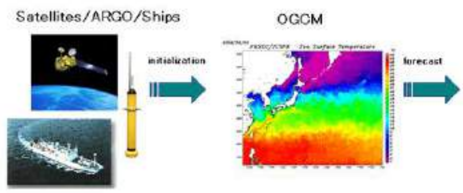
JCOPE (Japan Coastal Ocean Predictability Experiment)
reanalysis / forecast system

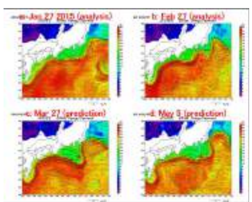


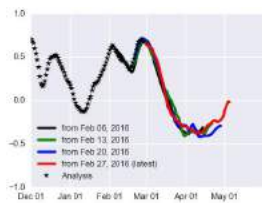
Reanalysis
(1993-, dx=1/12 deg, 108-180E, 10.5-62N)

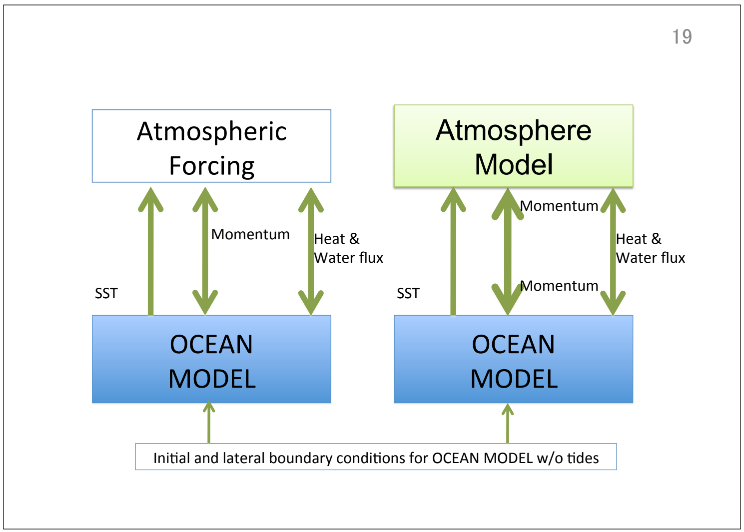
JCOPE (Japan Coastal Ocean Predictability Experiment)
reanalysis / forecast system

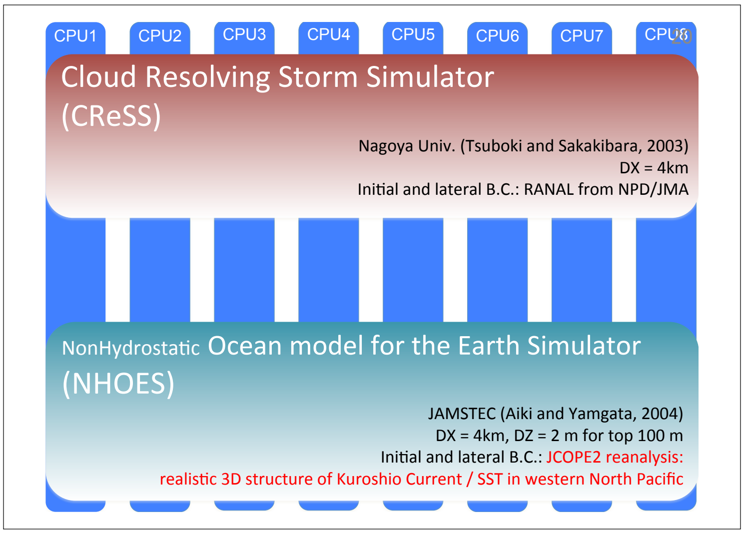
Miyazawa and Yamagata (2003)
Miyazawa et al. (2009)
Varlamov et al. (2015)

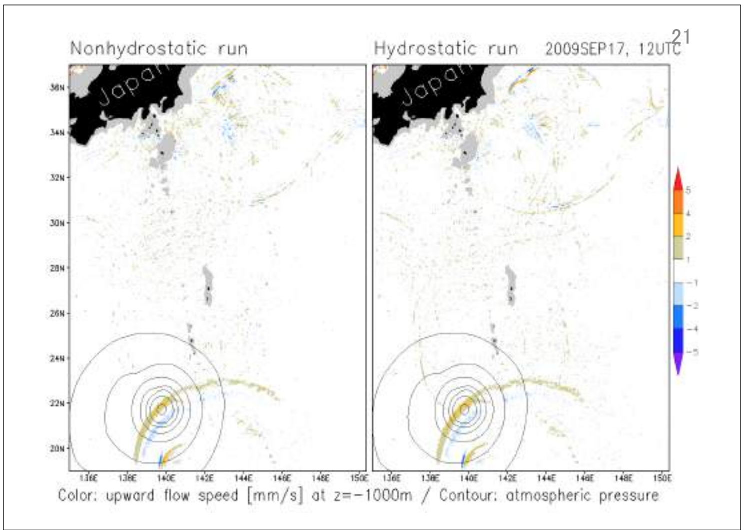


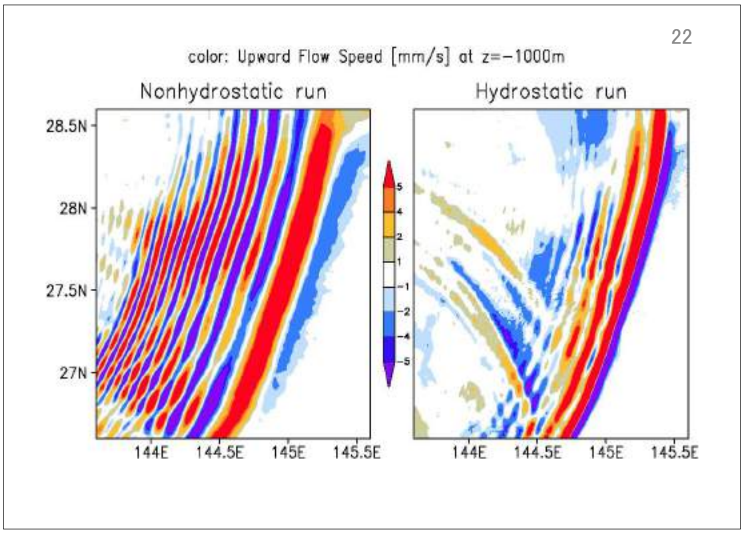


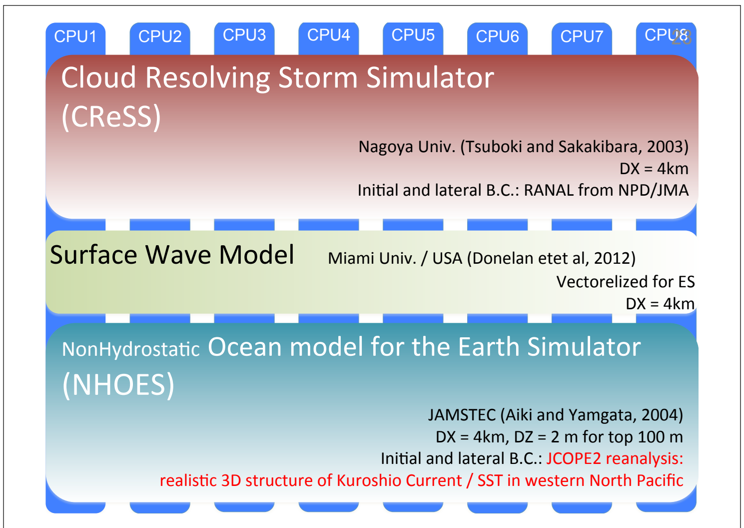


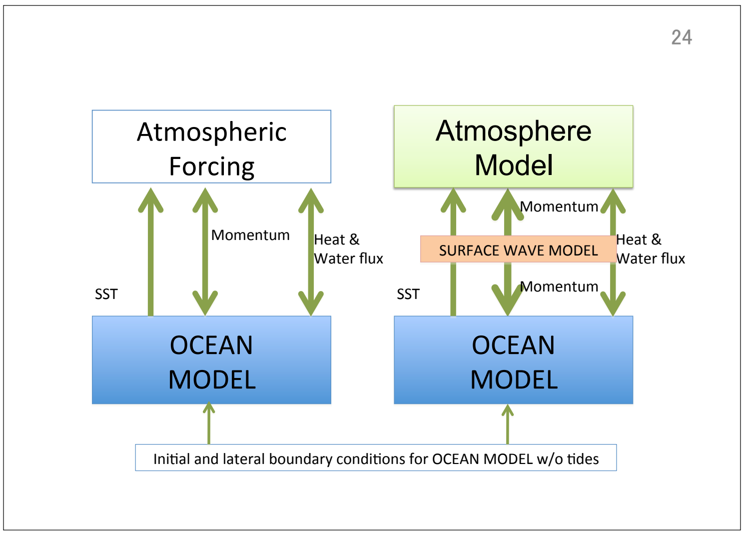

19
Atmospheric Forcing
Momentum
Heat & Water flux
SST
OCEAN MODEL
Atmosphere Model
Momentum
Heat & Water flux
SST
Momentum
OCEAN MODEL
Initial and lateral boundary conditions for OCEAN MODEL w/o tides

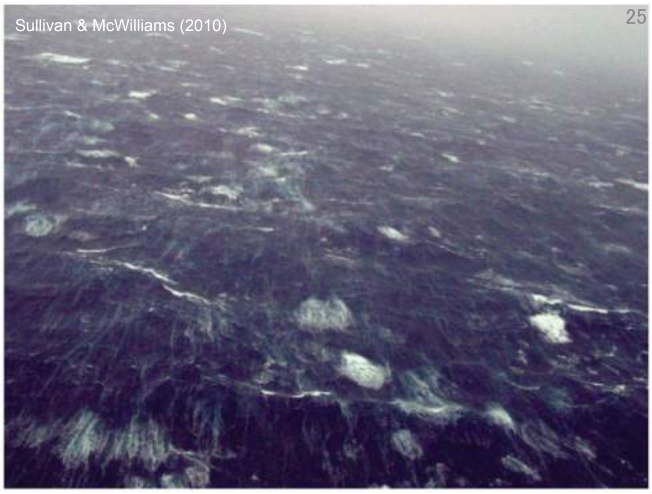

CPU1 CPU2 CPU3 CPU4 CPU5 CPU6 CPU7 CPU8
Cloud Resolving Storm Simulator (CReSS)
Nagoya Univ. (Tsuboki and Sakakibara, 2003)
DX = 4km
Initial and lateral B.C.: RANAL from NPD/JMA
NonHydrostatic Ocean model for the Earth Simulator (NHOES)
JAMSTEC (Aiki and Yamgata, 2004)
DX = 4km, DZ = 2 m for top 100 m
Initial and lateral B.C.: JCOPE2 reanalysis:
realistic 3D structure of Kuroshio Current / SST in western North Pacific


21
Nonhydrostatic run
Hydrostatic run
2009SEP17, 12UTC
Japan
Color: upward flow speed [mm/s] at z=−1000m / Contour: atmospheric pressure


22
color: Upward Flow Speed [mm/s] at z=−1000m
Nonhydrostatic run
Hydrostatic run
28.5N
28N
27.5N
27N
144E 144.5E 145E 145.5E


CPU1 CPU2 CPU3 CPU4 CPU5 CPU6 CPU7 CPU8
Cloud Resolving Storm Simulator (CReSS)
Nagoya Univ. (Tsuboki and Sakakibara, 2003)
DX = 4km
Initial and lateral B.C.: RANAL from NPD/JMA
Surface Wave Model
Miami Univ. / USA (Donelan etet al, 2012)
Vectorelized for ES
DX = 4km
NonHydrostatic Ocean model for the Earth Simulator (NHOES)
JAMSTEC (Aiki and Yamgata, 2004)
DX = 4km, DZ = 2 m for top 100 m
Initial and lateral B.C.: JCOPE2 reanalysis:
realistic 3D structure of Kuroshio Current / SST in western North Pacific


24
Atmospheric Forcing
Momentum
Heat & Water flux
SST
OCEAN MODEL
Atmosphere Model
Momentum
SURFACE WAVE MODEL
Heat & Water flux
SST
Momentum
OCEAN MODEL
Initial and lateral boundary conditions for OCEAN MODEL w/o tides



26

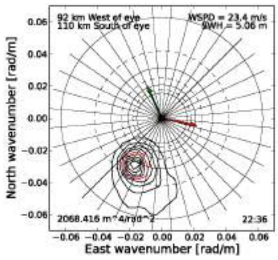
Surface Wave Model

Donelan et al. 2012 / Miami Univ.

$$E(x,y,\theta,\sigma)$$

distributed in 4-dimensional space:
high computational cost

E	Wave energy	
θ	Wave direction [rad]	24 grid
σ	Wave frequency [1/s]	36 grid



Spectral distribution of wave energy at a fixed point southwest of a hurricane translating north-westward (green arrow)

Wave direction (contour) is not the same as wind direction (red arrow)

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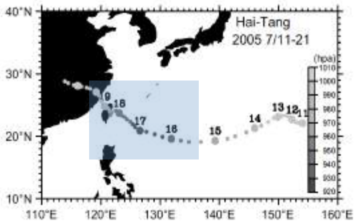
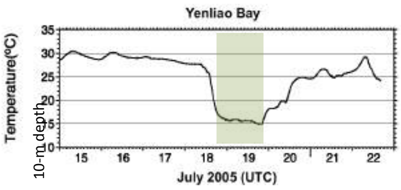
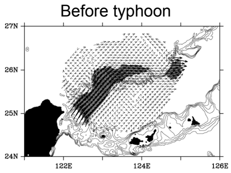




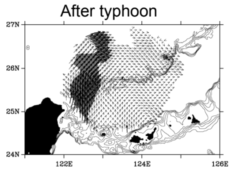
Observed Temperature

Observed Current Speed

Before typhoon



After typhoon



Morimoto et al. (2009)

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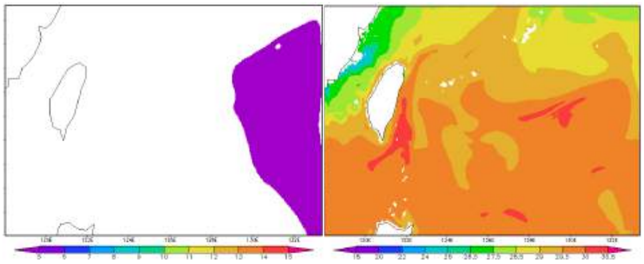
Simulation with wave

T0505 Haitang
(2005.07.14-)



Color: Significant Wave Height (m)
Contour: Wind Speed

Color: SST
Contour: Sea Surface Pressure

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E3.4 Visualization

Open-source Software

GrADS (Grid Analysis and Display System)

Supported file formats: binary (stream or sequential), GRIB, NetCDF etc.
Supported remote-access protocol: OPeNDAP

http://cola.gmu.edu/grads/

Minimum start
- data file + control file
- type each command

Medium start
- data file + control file
- exec command-set file (no loop)

Experienced start
- data file + control file
- run program file (with loop)

Smart start
- remote access to data
- without control file

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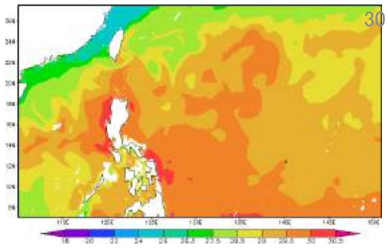
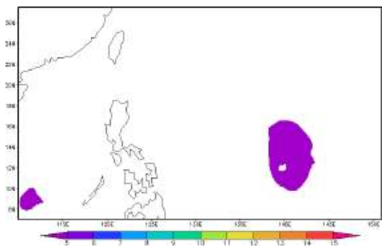
Simulation with wave

T1013 Megi
(2010.10.14-)

Color: SST
Contour:
Sea Surface Pressure



Color:
Significant Wave Height (m)
Contour: Wind Speed



Color: 6-day Change of SST
Contour: Sea Surface Pressure

T1013 Megi
(2010.10.14-)

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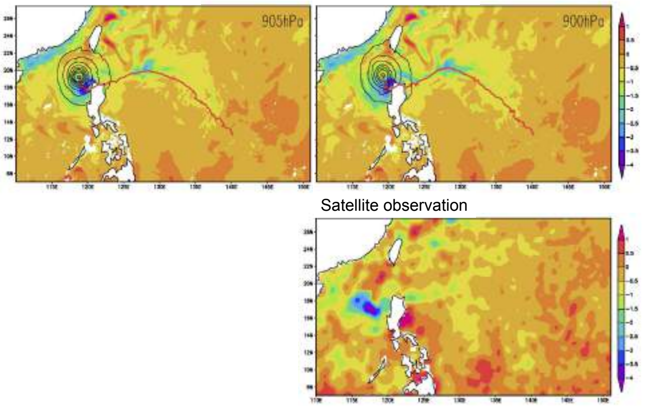
Simulation without wave

Simulation with wave

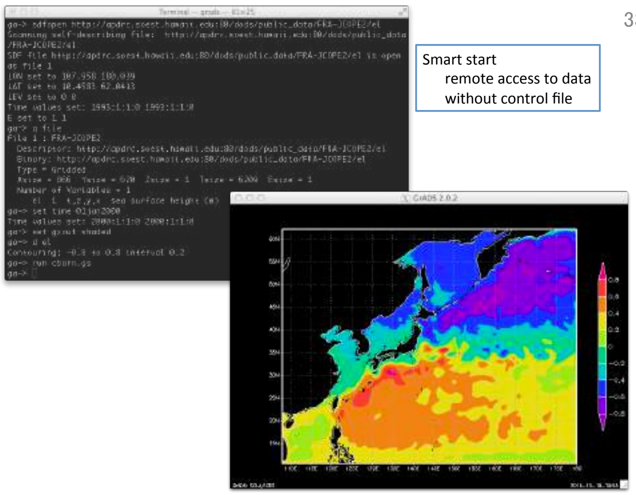
Satellite observation



32

http://apdrc.soest.hawaii.edu

33



Smart start
remote access to data
without control file

E3.6 Useful metrics

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Wind velocity (QuickSCAT, Atmosphere Model)
Significant wave height (WAVEWATCHIII)
understand wind wave

Sea surface temperature (OISST, HadSST, NGSST, Ocean Model)
Sea surface height (TOPEX/ERS/Jason 1, Aviso, Ocean Model)
understand geostrophic velocity

Ekman transport (QuickSCAT, Atmosphere Model)
understand coastal upwelling/downwelling

$$uh_{mix} = \tau^{x}_{wind} / f$$
$$vh_{mix} = -\tau^{y}_{wind} / f$$

E3.6 Useful metrics (continued)

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High-pass filtered ocean current velocity (Ocean Model)
understand inertial oscillation, tidal internal wave

Mixed layer depth (Argo, Ocean Model)
definition: ΔT=0.5 ℃ or Δρ=0.03 kg/㎥

Heat content (Argo, Ocean Model)
understand tropical cyclone

$$HC \equiv \rho_0 C_p \int_{z_{26}}^{0} (T - T_{26}) dz$$
$$C_p = 4178 \quad [JK^{-1}kg^{-1}]$$

Bottom topography (ETOPO, GEBCO)

E3.7 How to make animation

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```
'reinit'
'open cmodel_result.ctl'
'set display color white'
t=37
while ( t<150 )
'c'
'set parea 0.4 5.4 0.5 8.0 '
'set t 't
'set gxout shaded'
'set lev -1000'
'set clevs -5 -4 -3 -2 -1 0 1 2 3 4 5'
'd vel_wp*1000'
'printim tmp.gif x1600 y1200'
if (t < 100)
'!mv tmp.gif im-0't
else
'!mv tmp.gif im-'t
endif
t=t+3
endwhile
'!convert -loop 0 -delay 20 -colors 11 im-* anime.gif'
'!rm im-*'
```