卫星海洋环境动力学国家重点实验室
STATE KEY LABORATORY OF SATELLITE OCEAN ENVIRONMENT DYNAMICS

MEMFiS
China Seas & Northwestern Pacific

IMBeR
Integrated Marine Biosphere Research

Integrated coastal observing and forecasting system - lessons learnt from the China Coastal Regions

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Second Institute of Oceanography, China
Xiamen University, China

May 4, 2023

Resources and productivity of the ocean











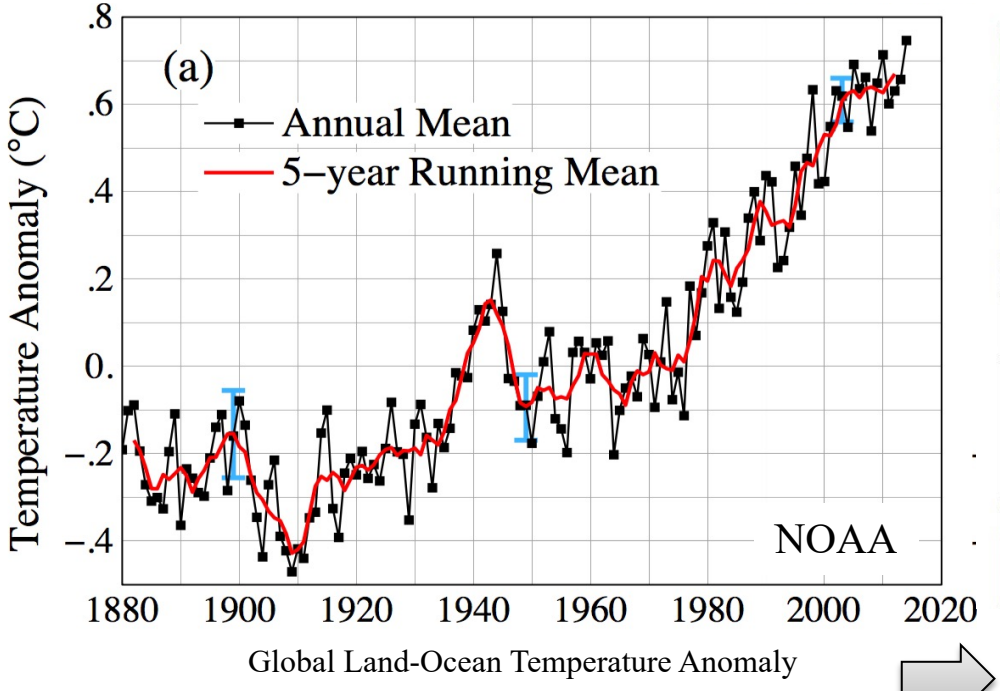

Coastal and Marine Ecosystem Stressors

Climate Change

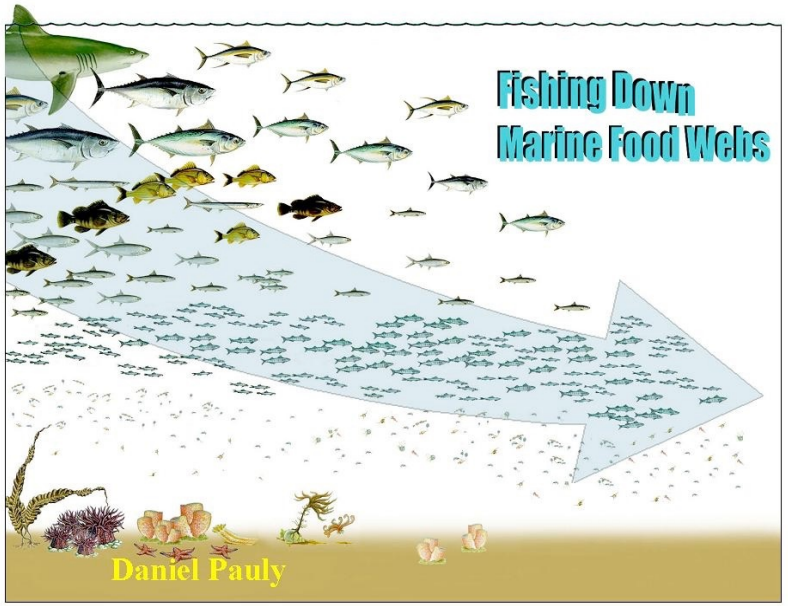
- Global warming
- Precipitation & runoff
- Sea-level rise
- Storms & extreme events
- Ocean acidification

Non-Climate

- Overfishing
- Eutrophication
- Loss of habitats
- Oil spill
- Land reclamation

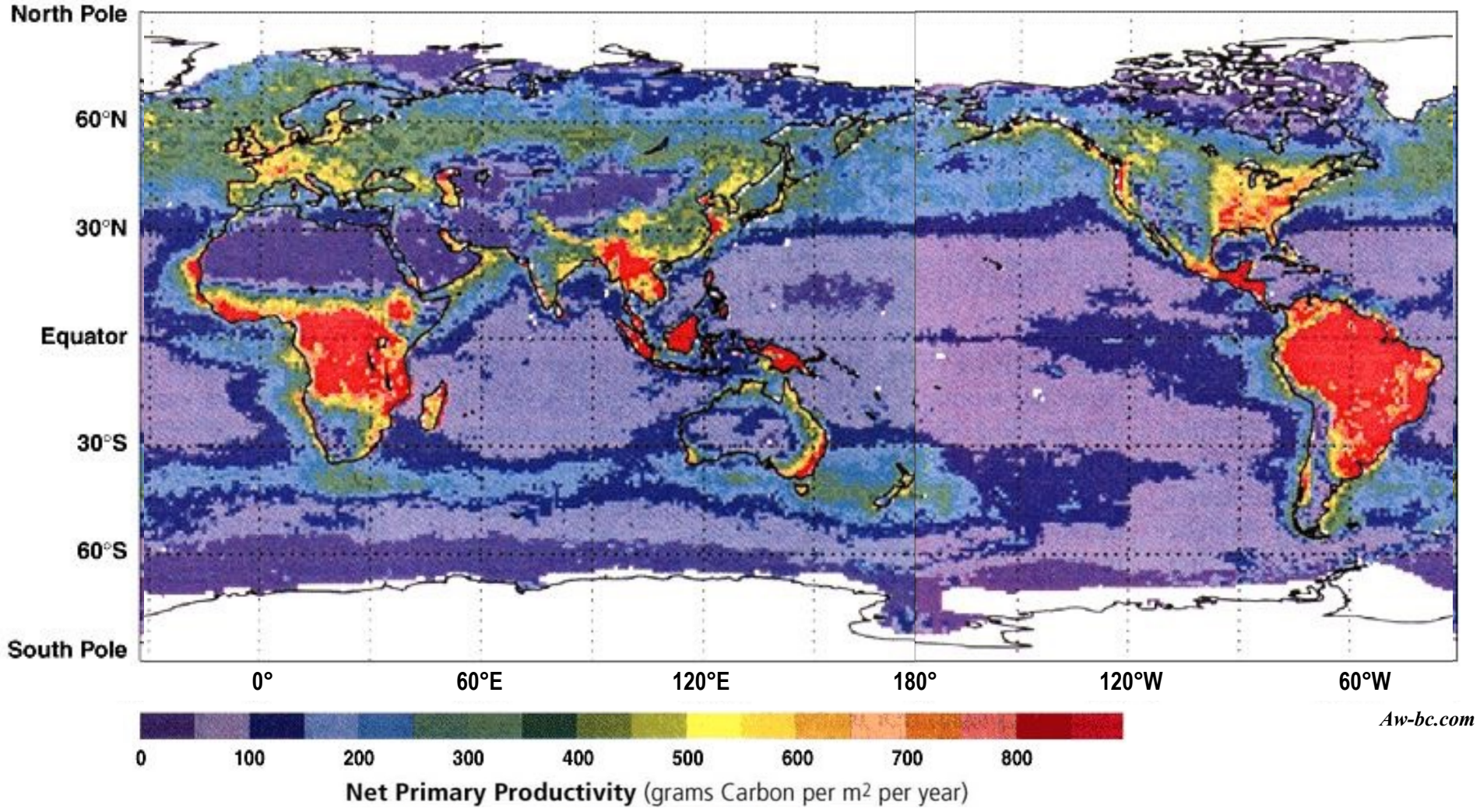


Global Land-Ocean Temperature Anomaly



Important to make prediction

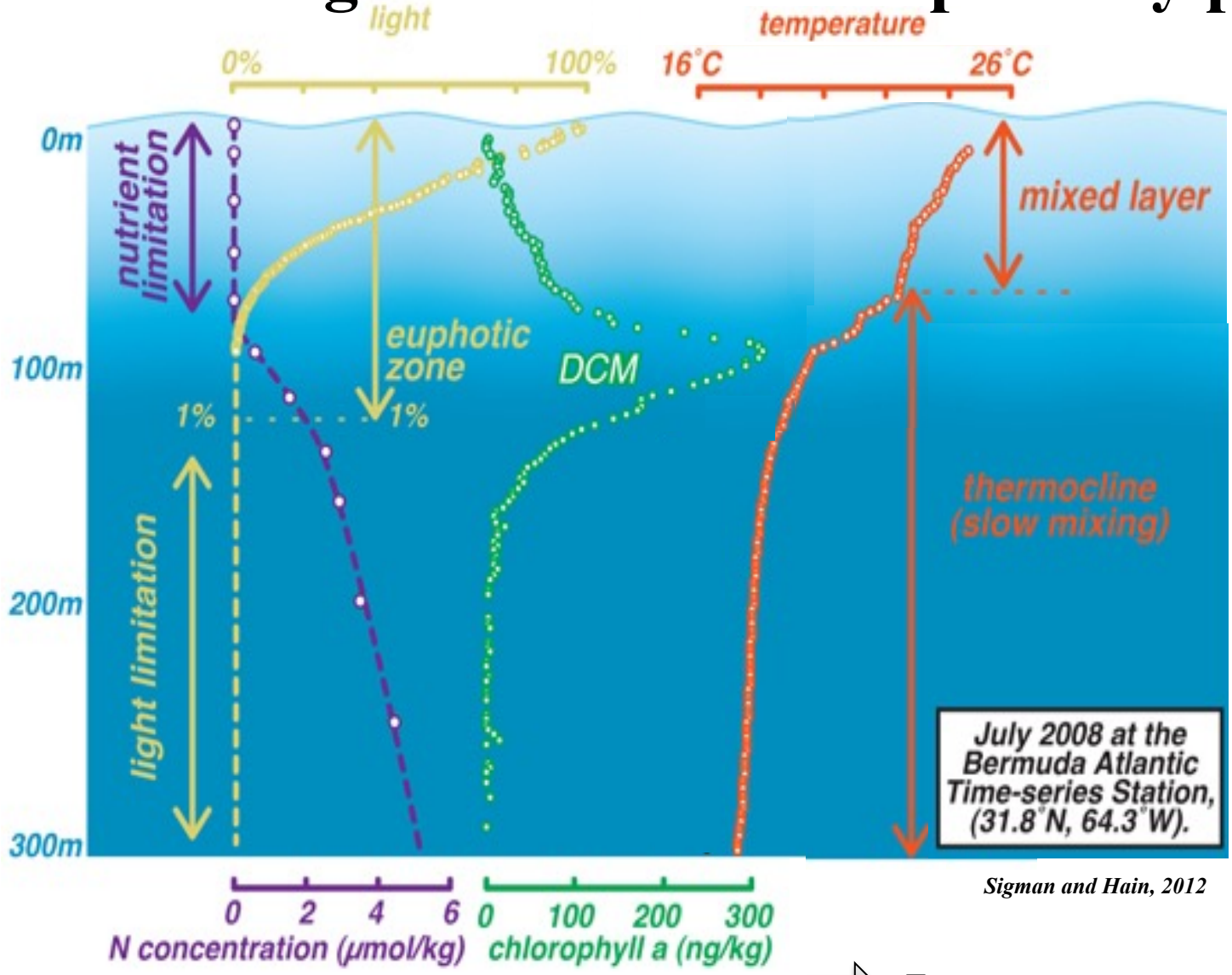
Distribution of global primary production



> 70% of the earth surface
~ 50% of total production

⇨ **Low unit production**

Limiting factor for marine primary production



Sigman and Hain, 2012

Surface
- Enough light
- None nutrients
- Mixed layer(ML)
- Low Chl-a

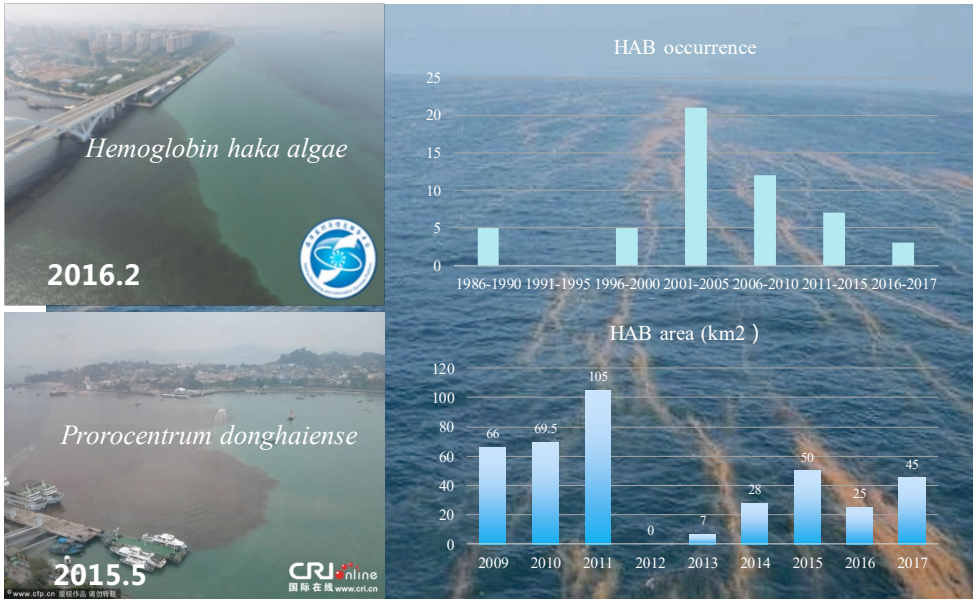
Subsurface
- Light
- Low nutrients
- Bottom of ML
- Maximum Chl-a

Deep-sea
- No light
- Sufficient nutrients
- Beneath ML
- Low Chl-a

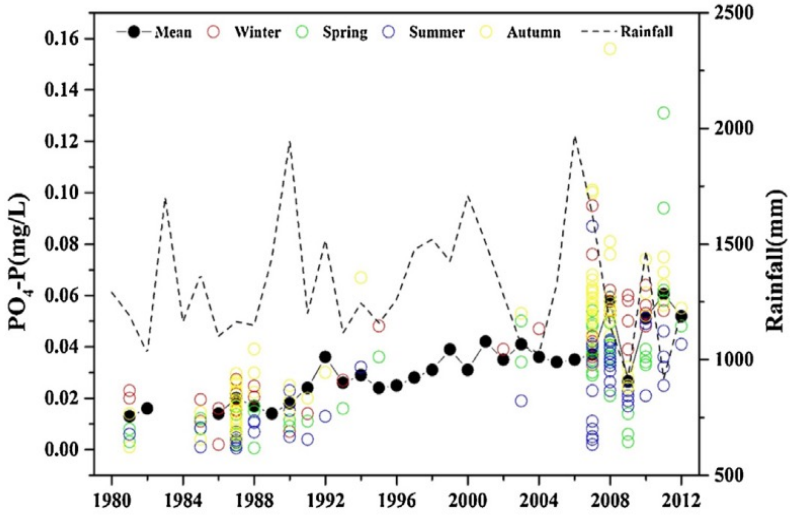
⇨ **Important to observe at depths**

Main environmental issues

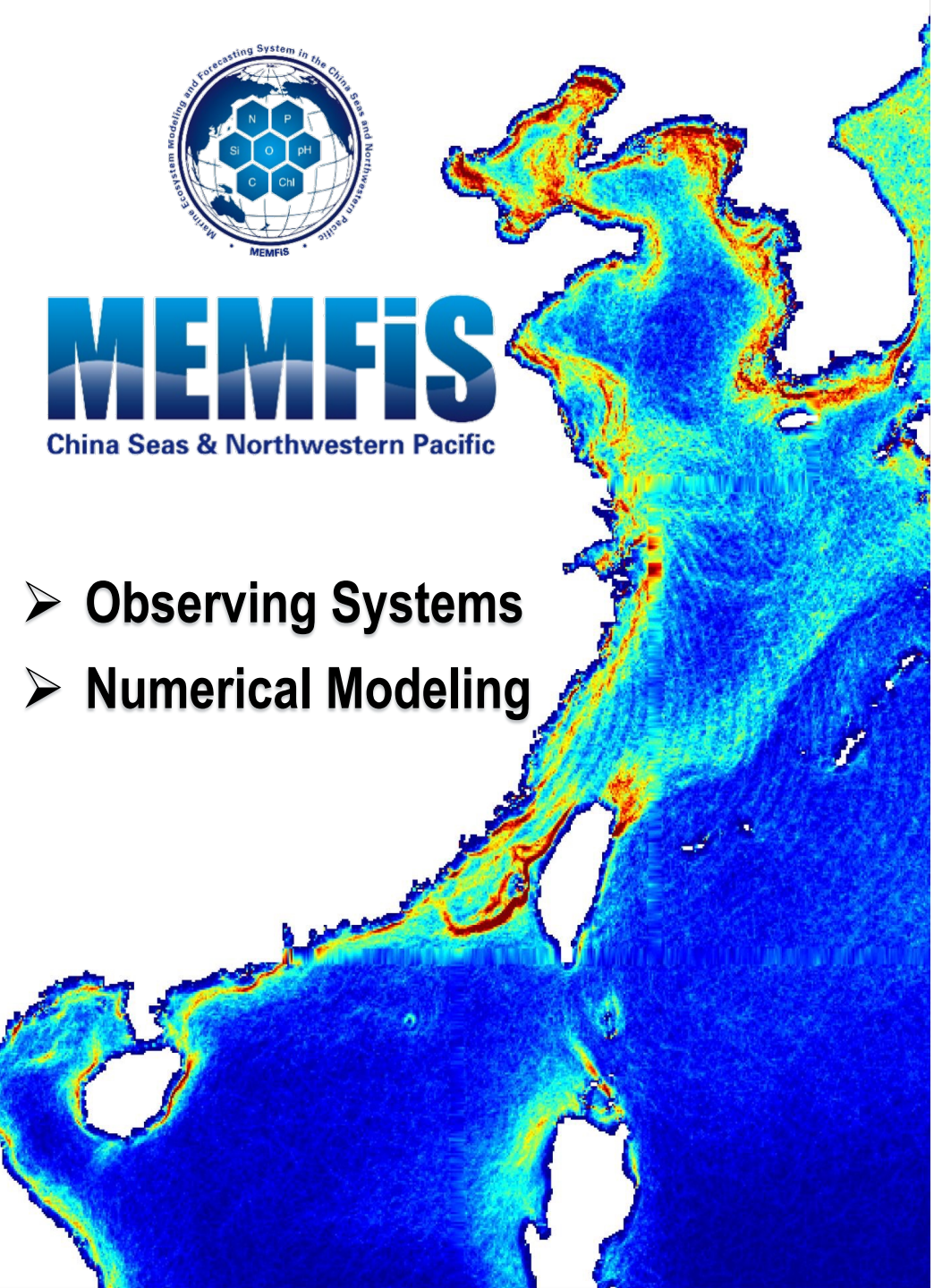
- Water quality degradation due to sewage, urban runoff and agriculture
- Eutrophication and HABs
- Loss of wetlands due to sea reclamation
- Increasing ecological risks under rapid urbanization, marine economy development and climate change



Red tides in Xiamen Bay



Concentrations of PO_4-P in Xiamen Bay (Cai et al., 2016)



MEMFiS

China Seas & Northwestern Pacific

- Observing Systems
- Numerical Modeling

Marine Ecosystem Modeling and Forecasting System in China Seas and NW Pacific

Supported by MoST

9/2016 – 8/2021

Prof. Fei CHAI

Second Institute of Oceanography, China

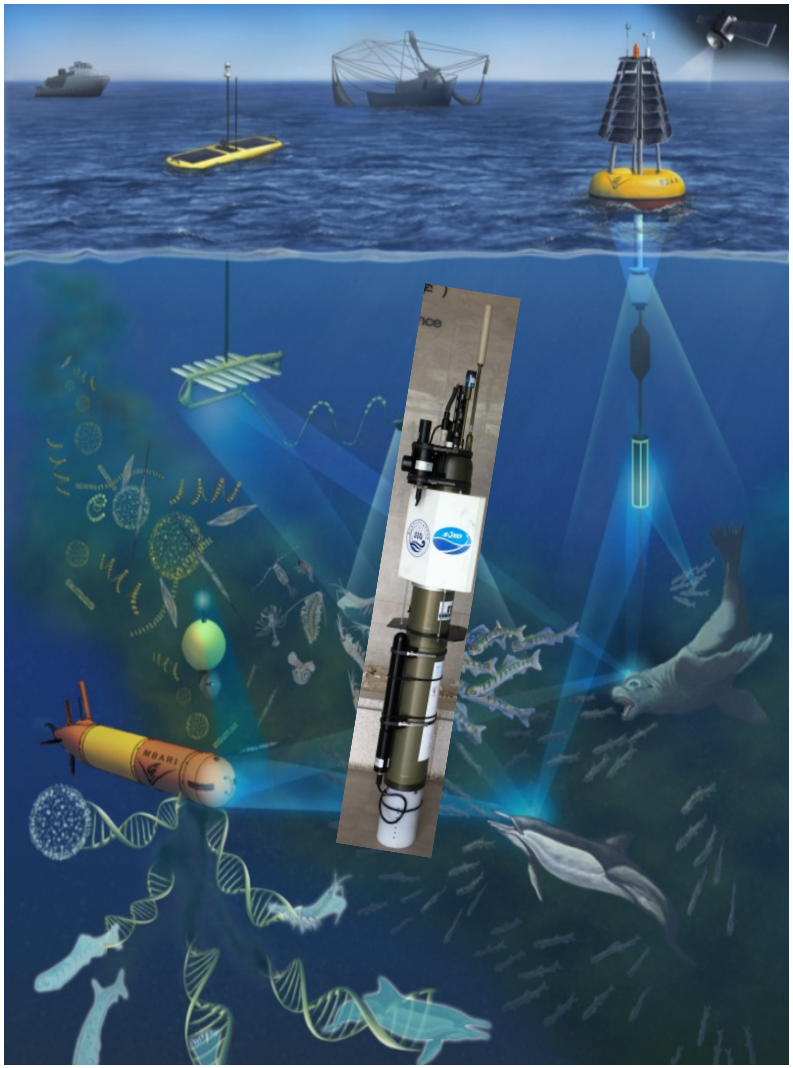
Xiamen University, China

Peng XIU (SCSIO), Feng ZHOU (SIO/MNR),

Hao WEI (Tianjin U.), Shan GAO (NMEFC)

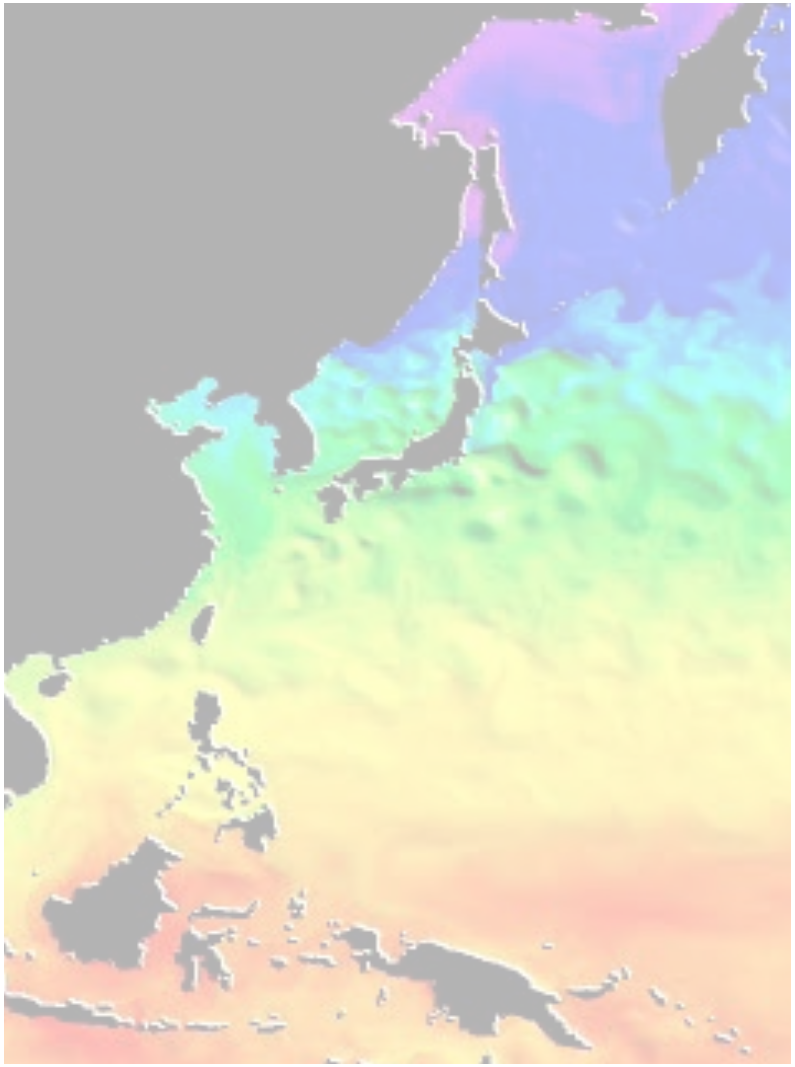
Yuntao Wang (SIO/MNR)

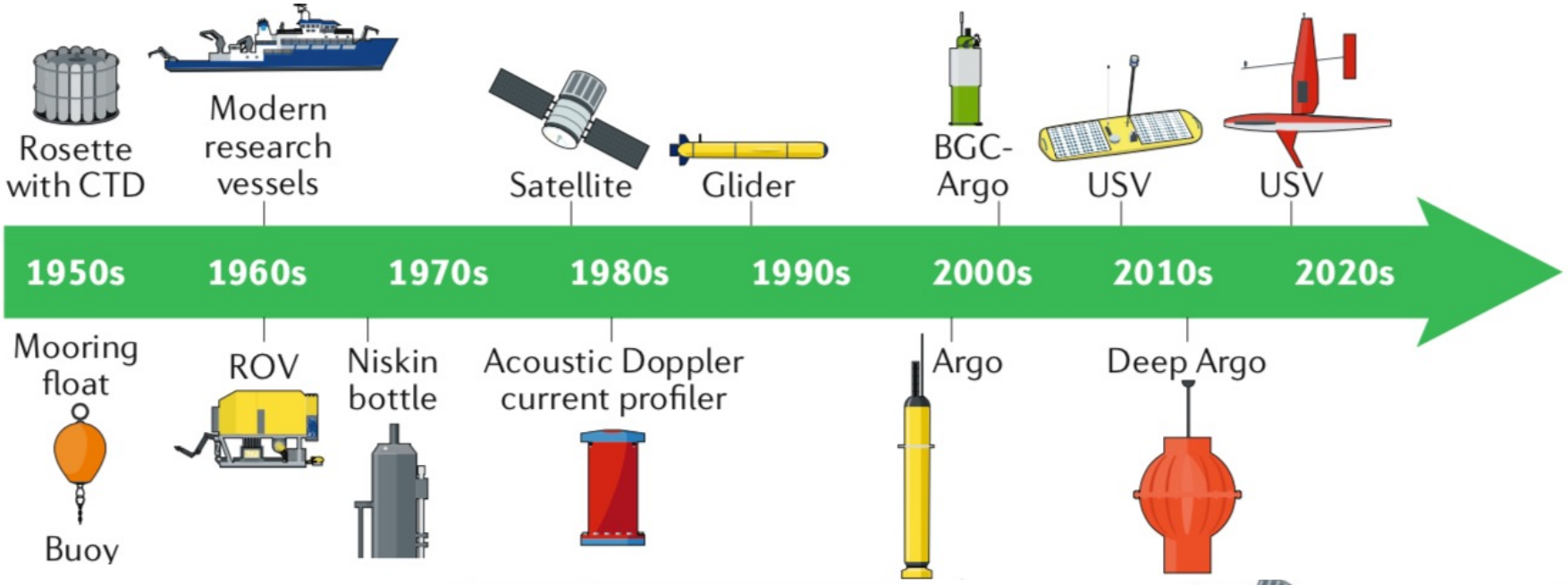
Observing system



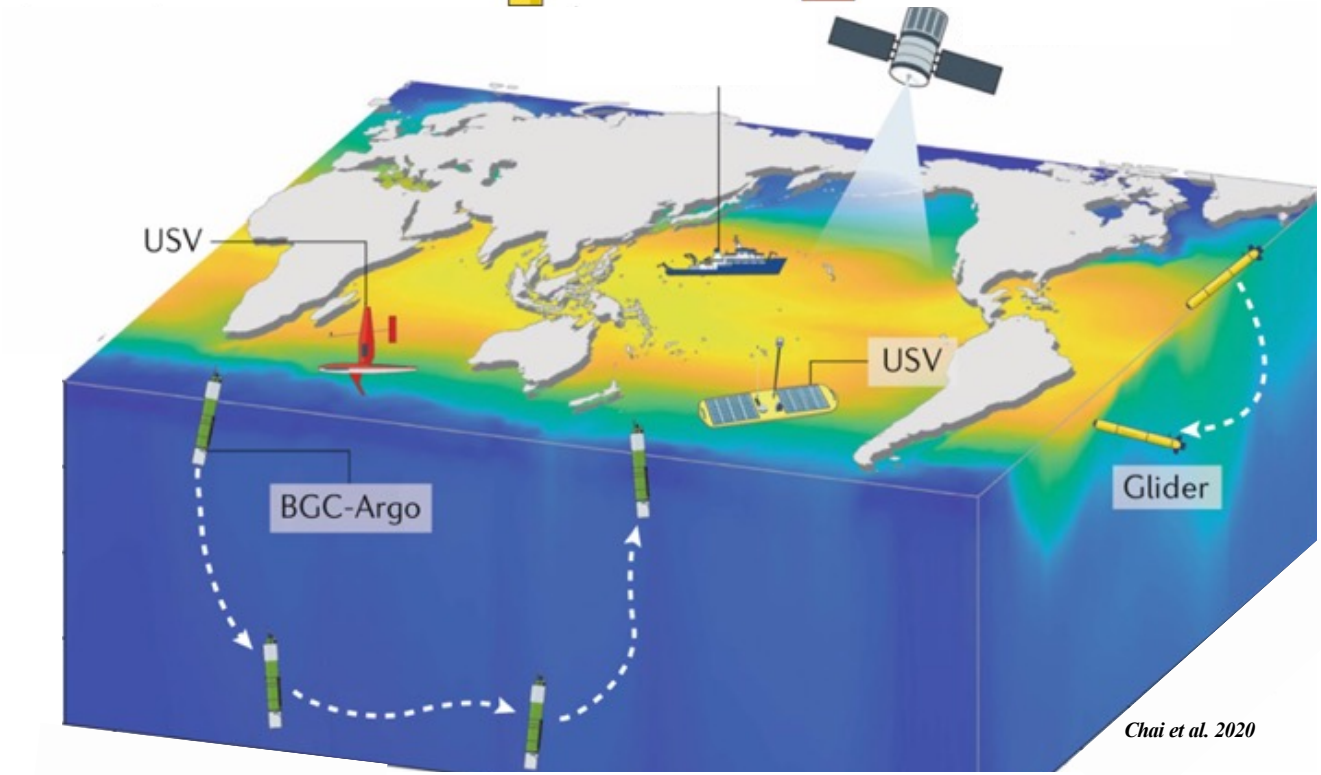
NOAA

Numerical modeling





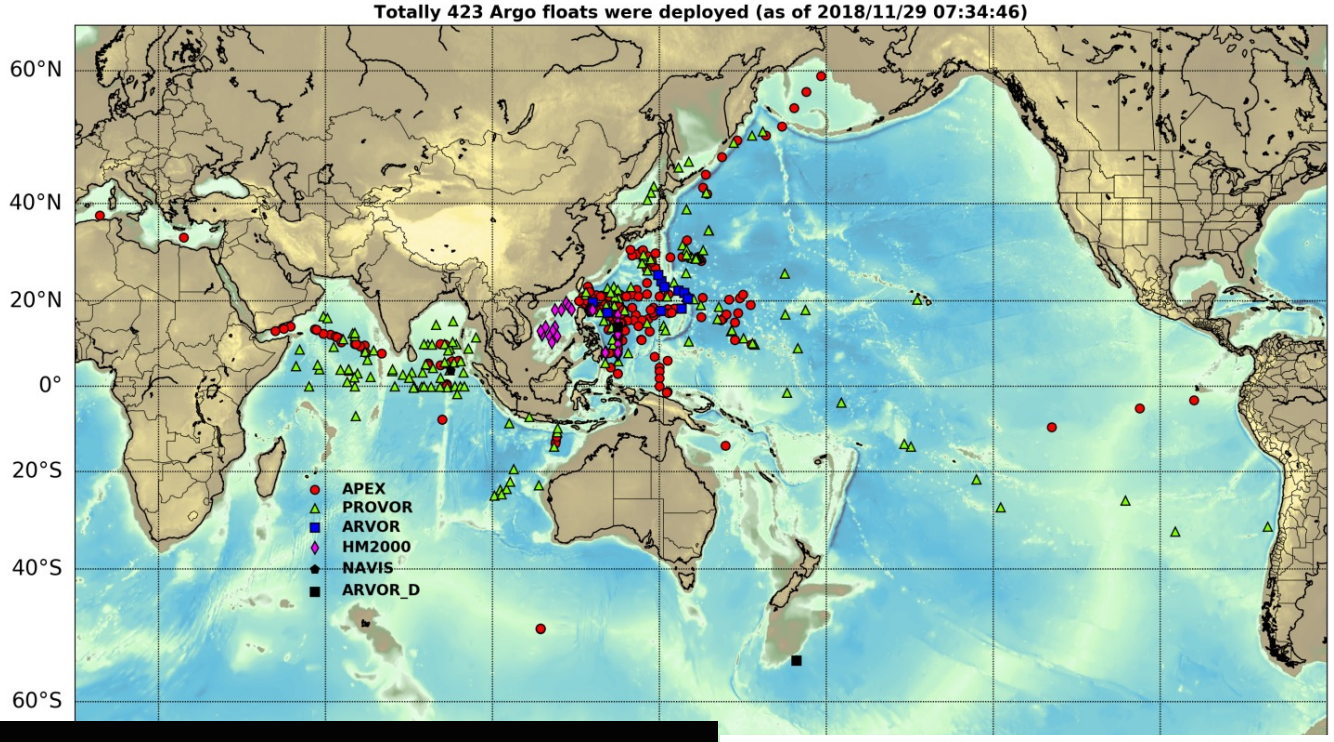
4D Observing System

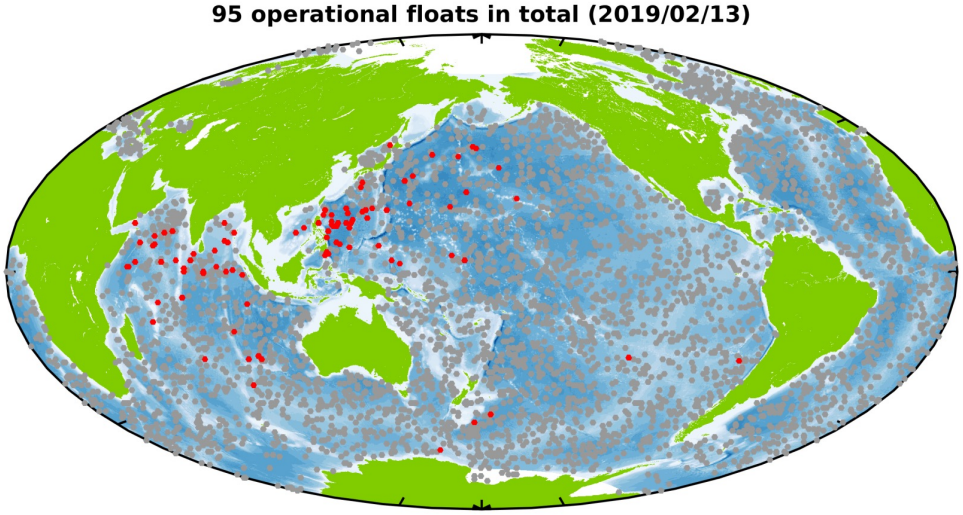


Chai et al. 2020

2002-2018, 11 PIs from 7 organizations
2.9% of the amount of the global deployment

Float deployment





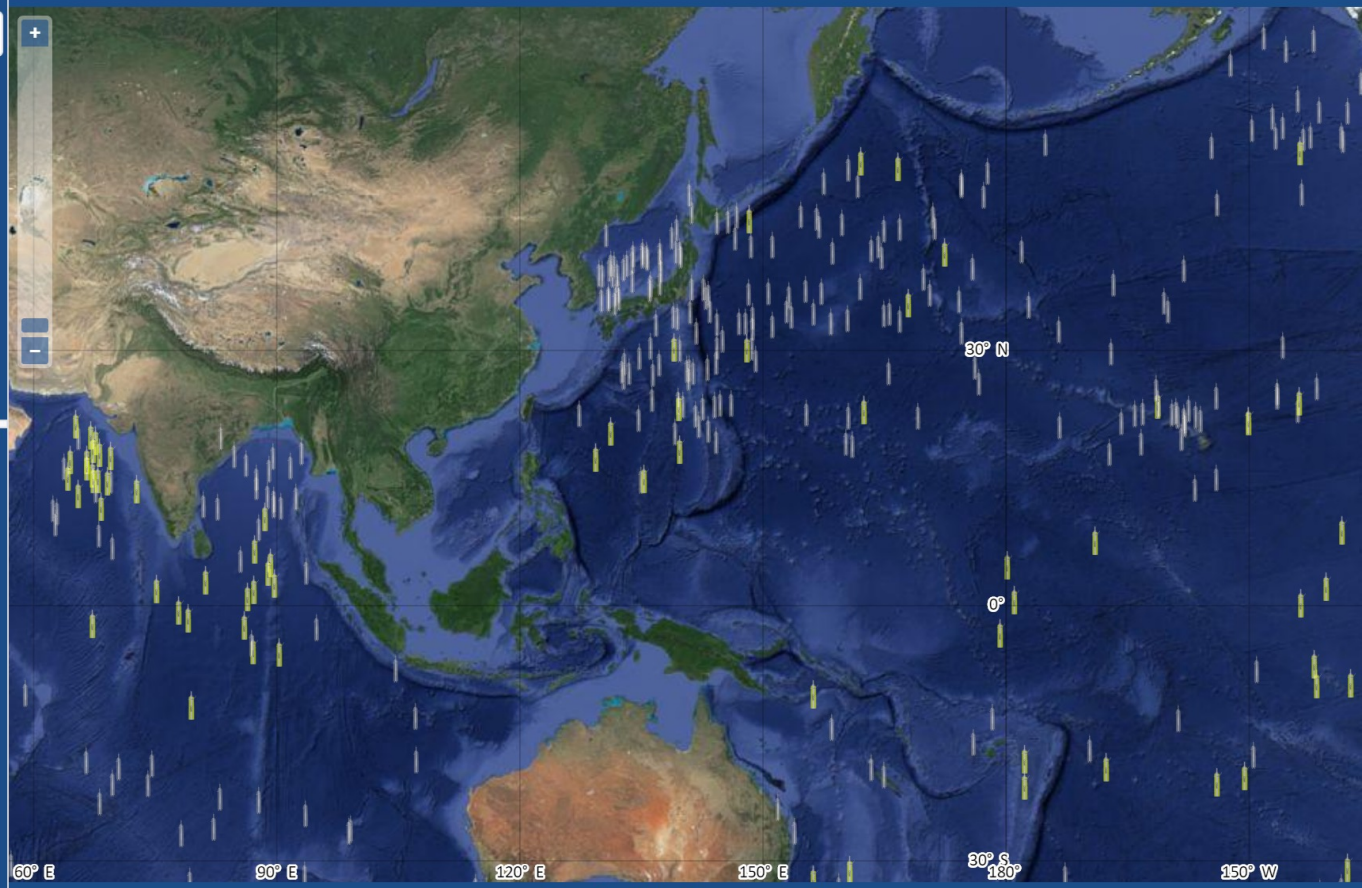
Global BGC-Argo Data View

Filter | All | + 11 | Status | All | Parameter | Please choose... | Query | Reset

Enter platformNumber

WMO	Launch Date	Details
3902122	2017-10-08	
2903394	2019-05-25	
6900878	2011-10-01	
2900961	2009-01-27	
Count:	1368	

[WMO] : 2902764
[DAC] : CSIO
[first profile] : 2019-11-12 00:45:00
[first profile location latitude] : 5.76
[first profile location longitude] : 89.96
[latest profile] : 2019-12-12
[project name] : CHINA ARGO EQUIVALENT
[BGC Parameter]: DOXY



Second Institute of Oceanography, MNR

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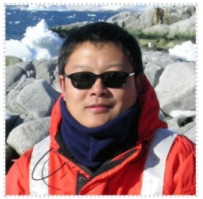

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Tetsuichi Fujiki
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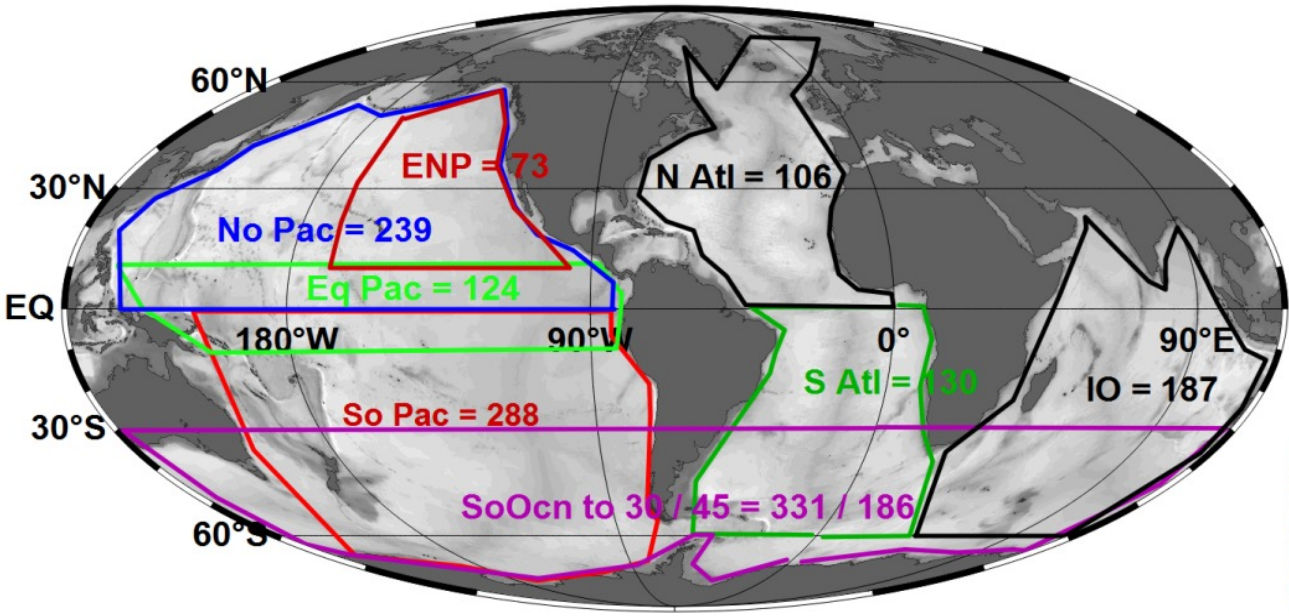
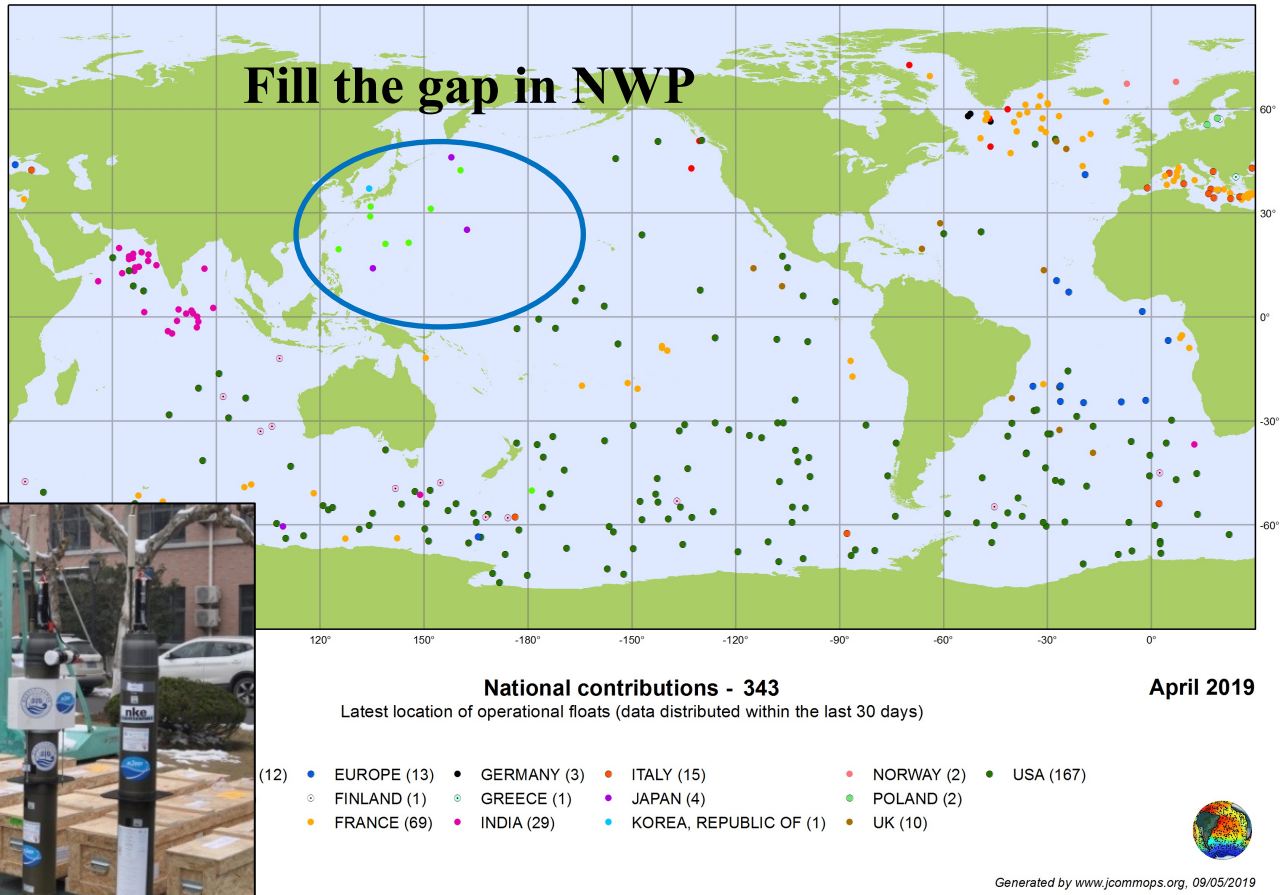
Katja Fennel
CANADA



1000 BGC-Argo in next ten years

China BGC-Argo development

Aiming to build up and maintain an array with 15-20 BGC-Argo floats in NWP (9 active now)

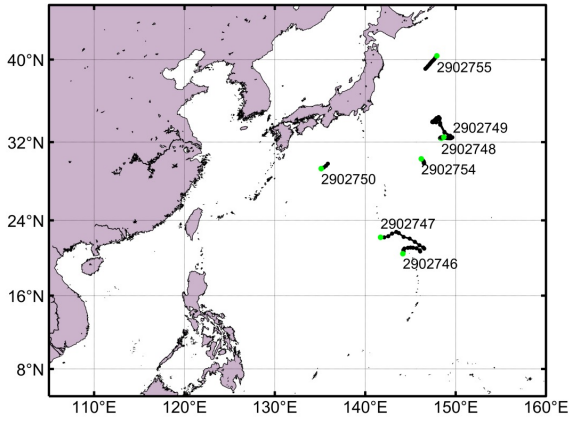


China Ongoing Argo and Bio-Argo Activities and Plans

18 Bio-Argo for the Western Pacific 2018-2019

9 has been deployed during May-Sept. 2018

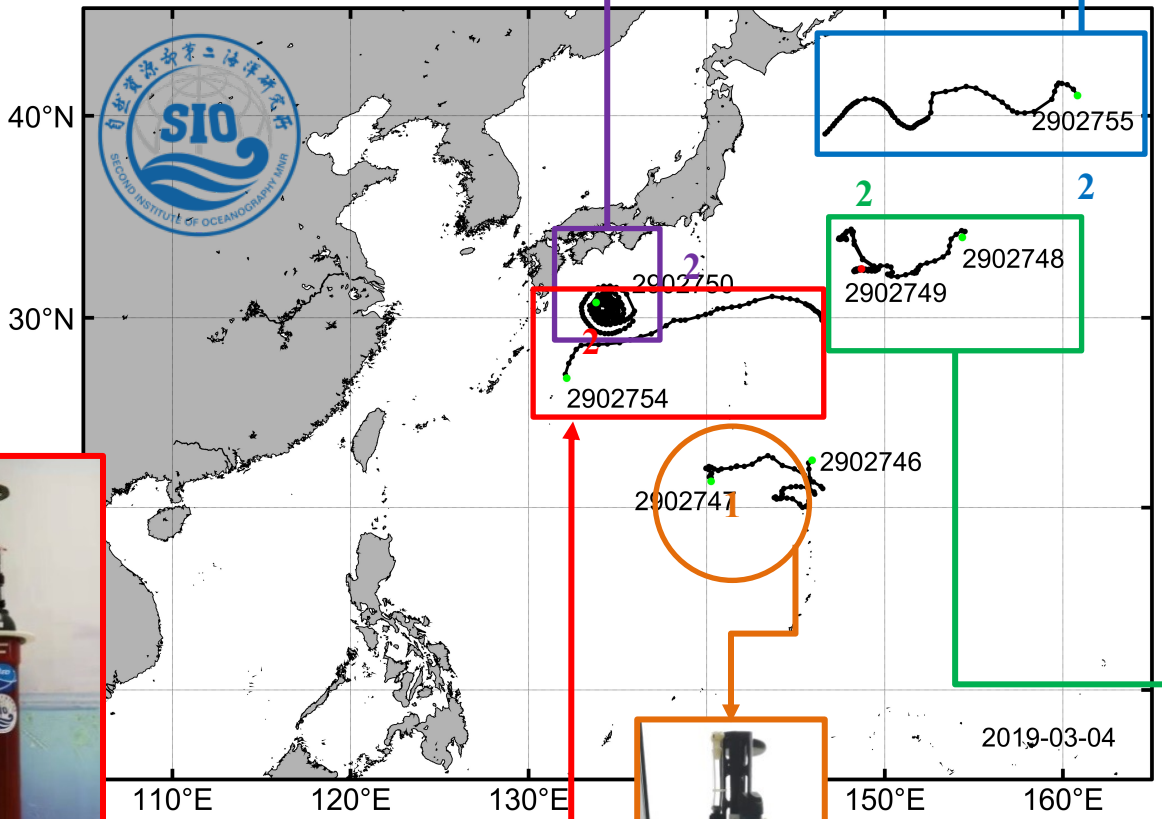
#	Type	Variables							
		$[O_2]$	[Chla]	FDOM	POC	$E_d(3\lambda)$	iPAR	$[NO_3]$	pH
2	Provor	√	√	√	√	√	√	√	√
4	Provor	√	√	√	√	√	√	√	
4	Provor		√	√	√				
2	Provor	√							
4	Navis-Trec	√	√	√	√	√	√	√	√



Deployment by SIO in 2019

Provor CTS4
(Chla/bbp/Ed/O2/NO3)

Provor CTS4
All-6-Variables (Chla/bbp/Ed/O2/NO3/pH)



HM2000-O2

APEX-O2

Navis SL1
All-6-Variables
Rechargeable
battery

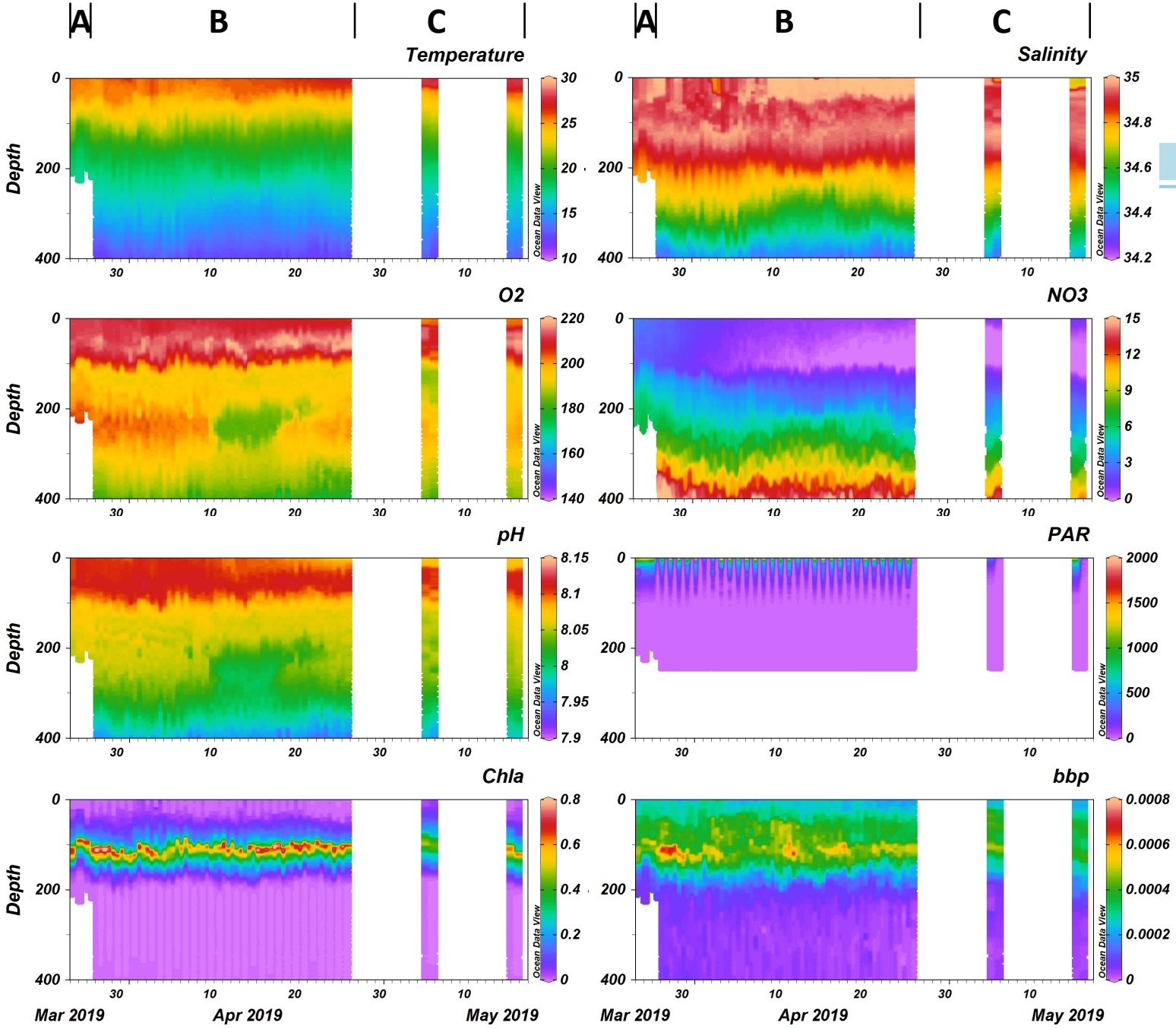
biogeochemical Argo

Float WMO 2902756

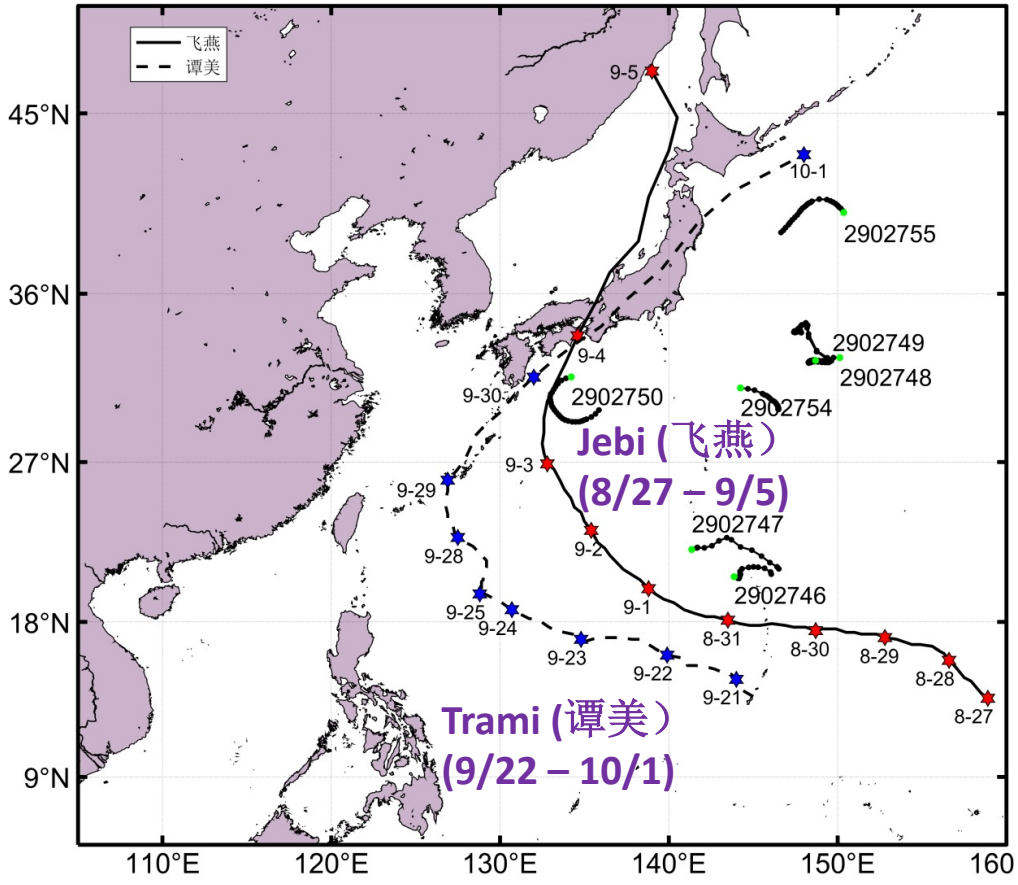
A: Test period

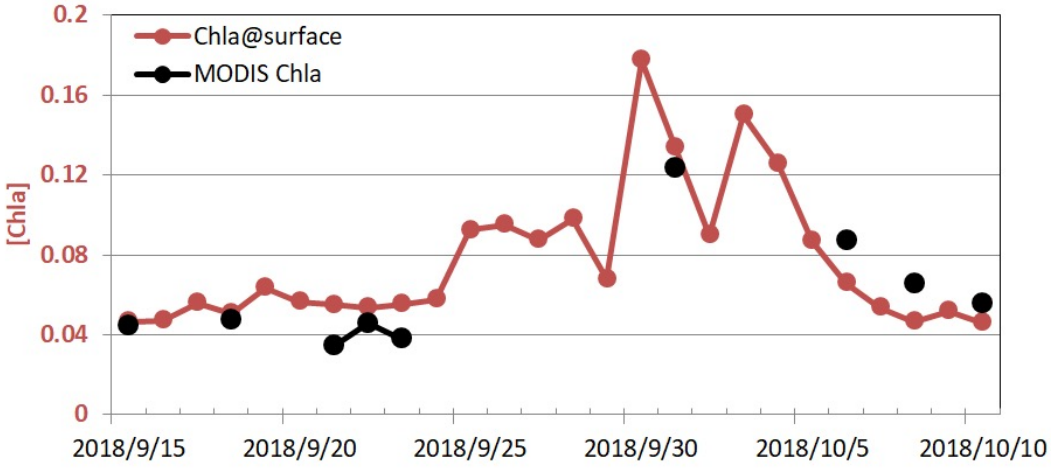
B: Twice per day (noon and midnight) for 1 month

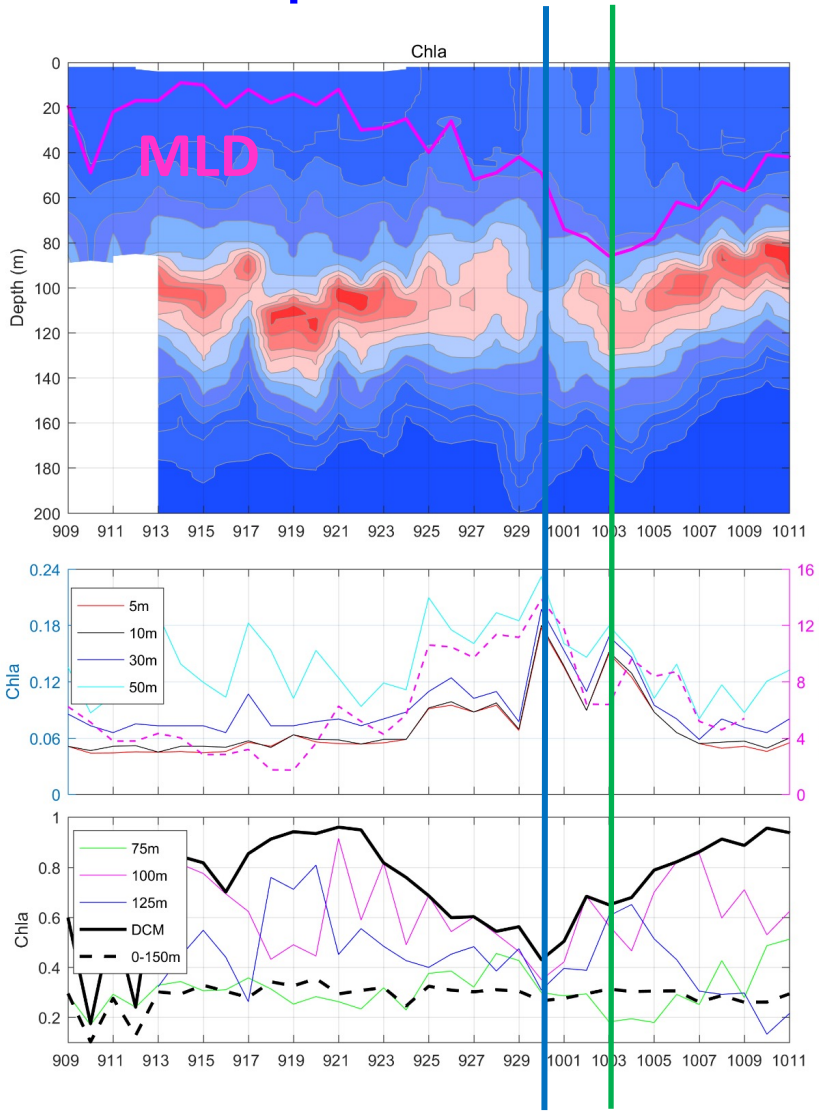
C: Once per 10 days for 20 days



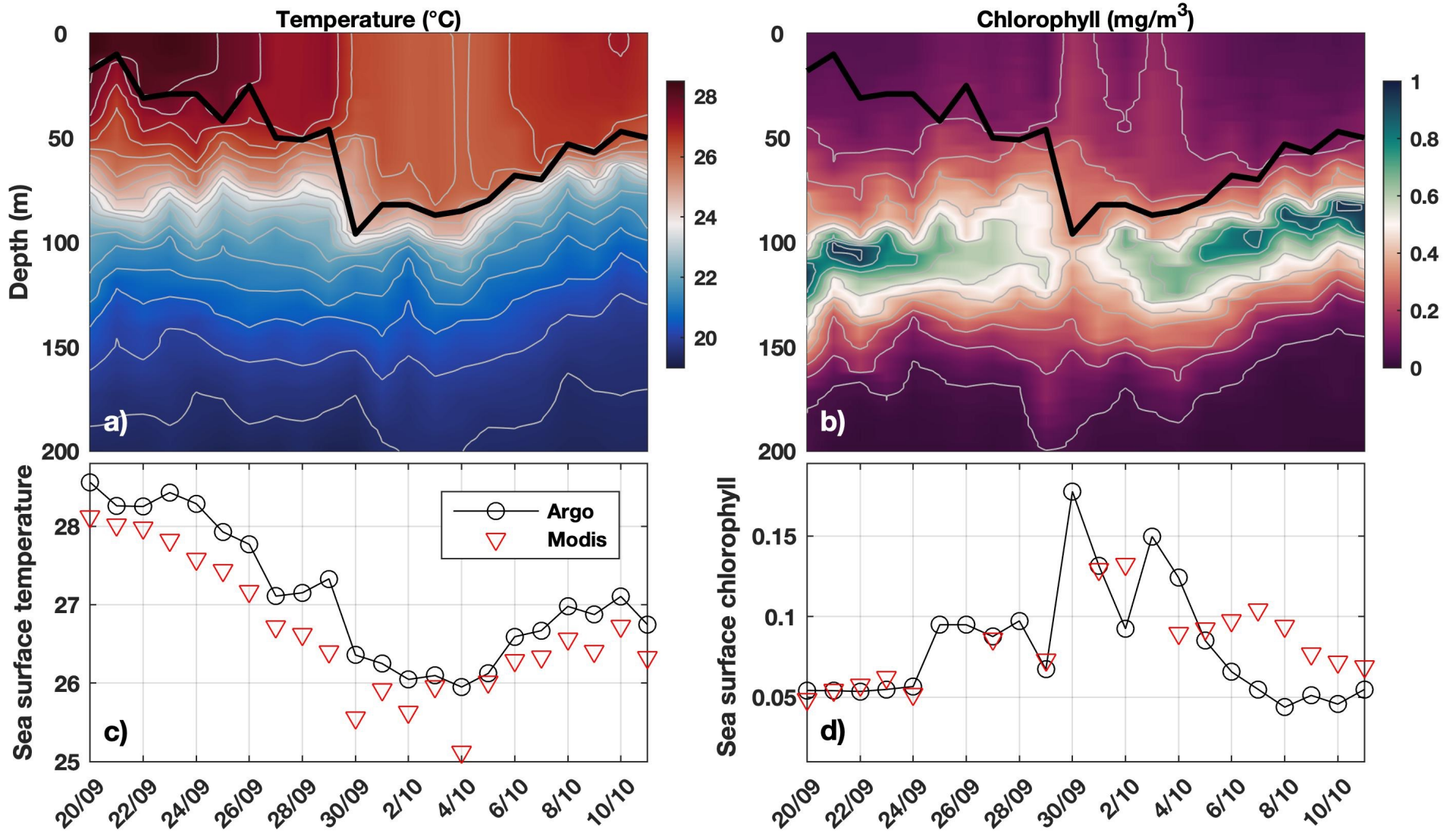
Two peaks of surface Chl-a
Sep 30 & Oct 03





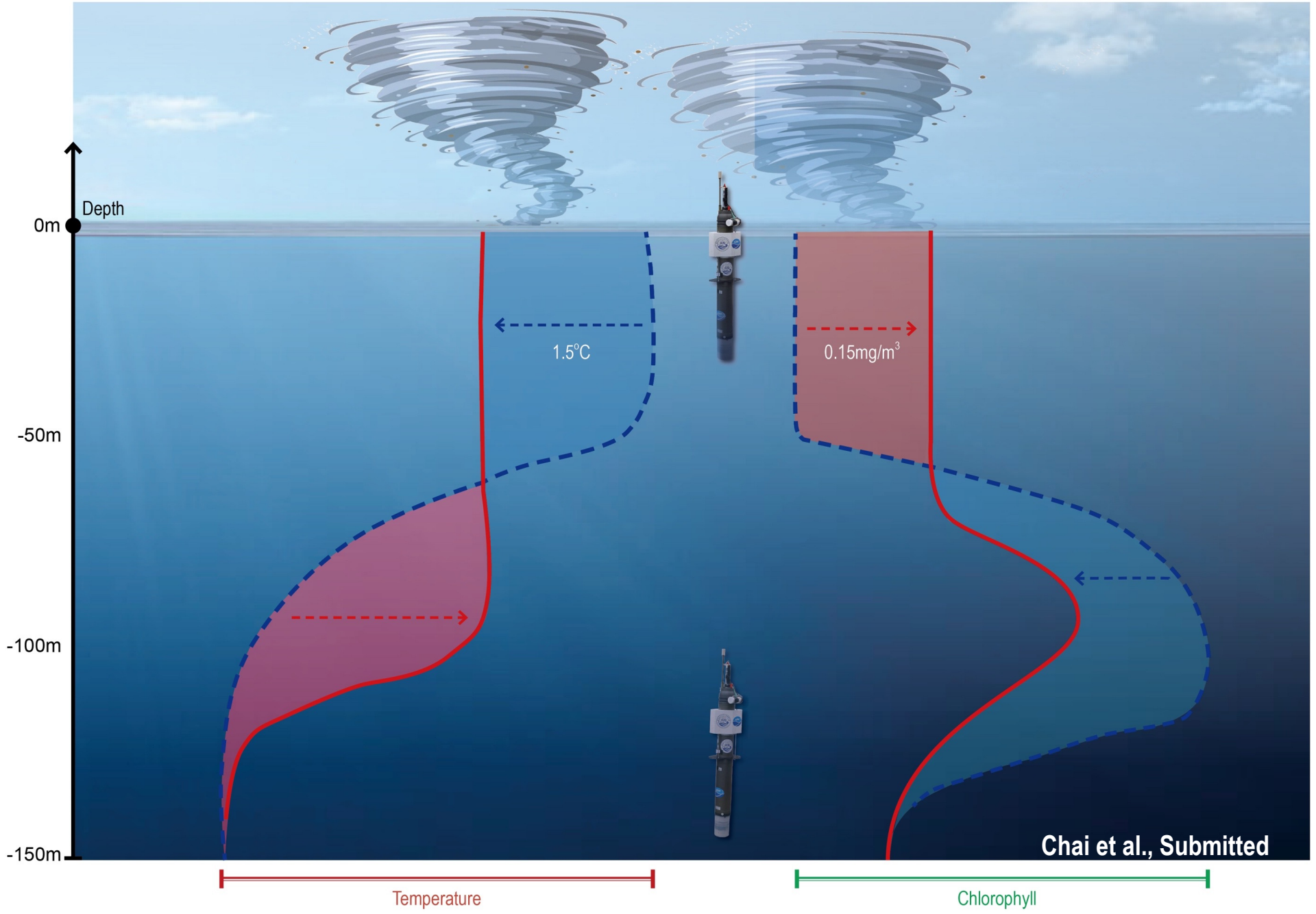


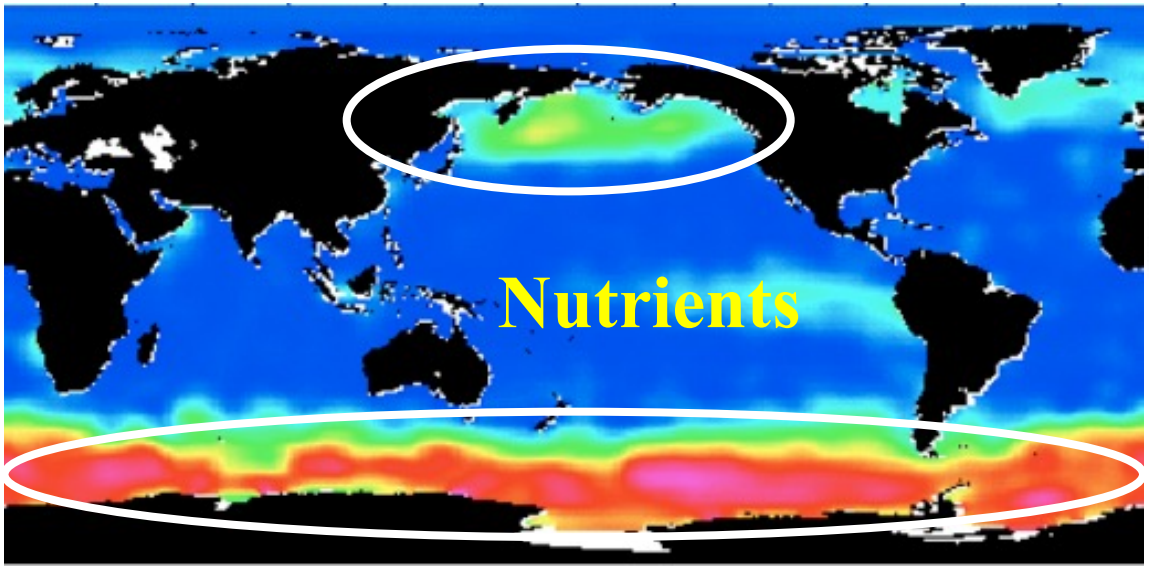
BGC-Argo Sections

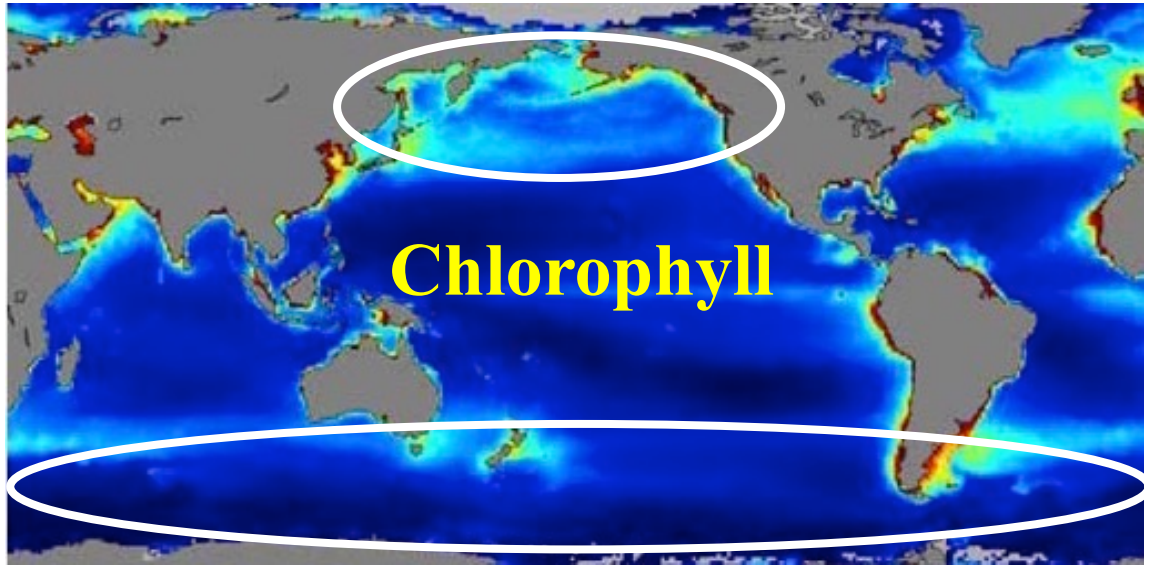


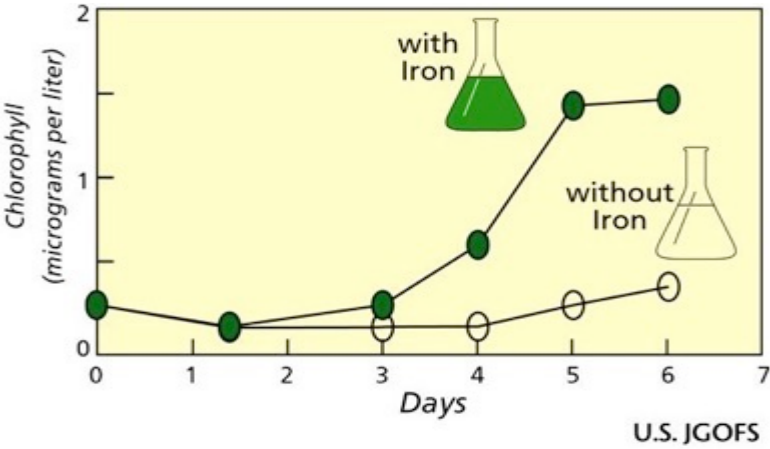
Chai, Wang et al. 2021

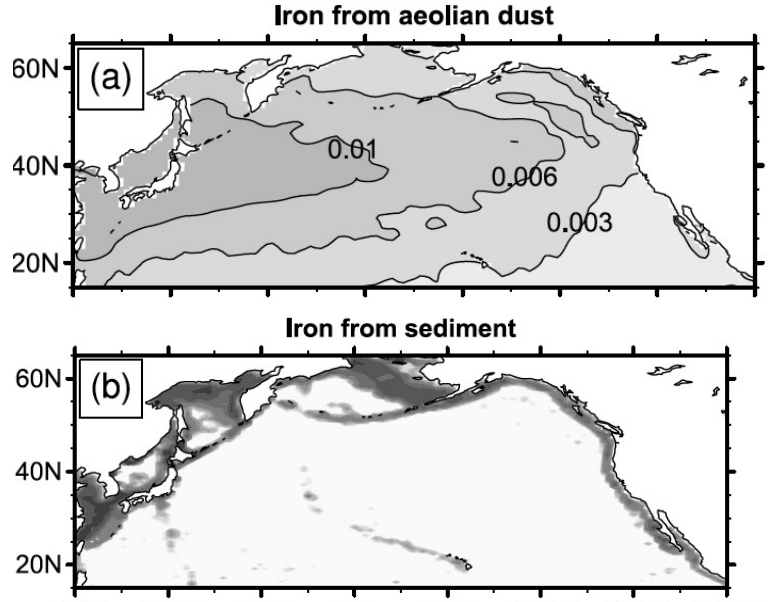
Limited Effect of Sub-Tropical Typhoons on Phytoplankton Dynamics



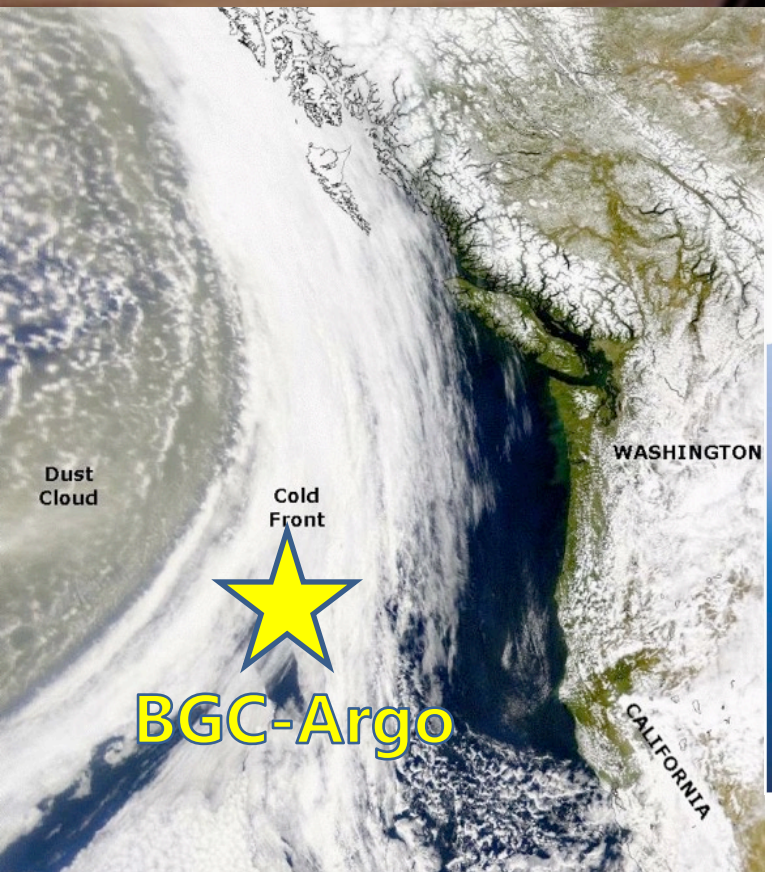

Nutrients

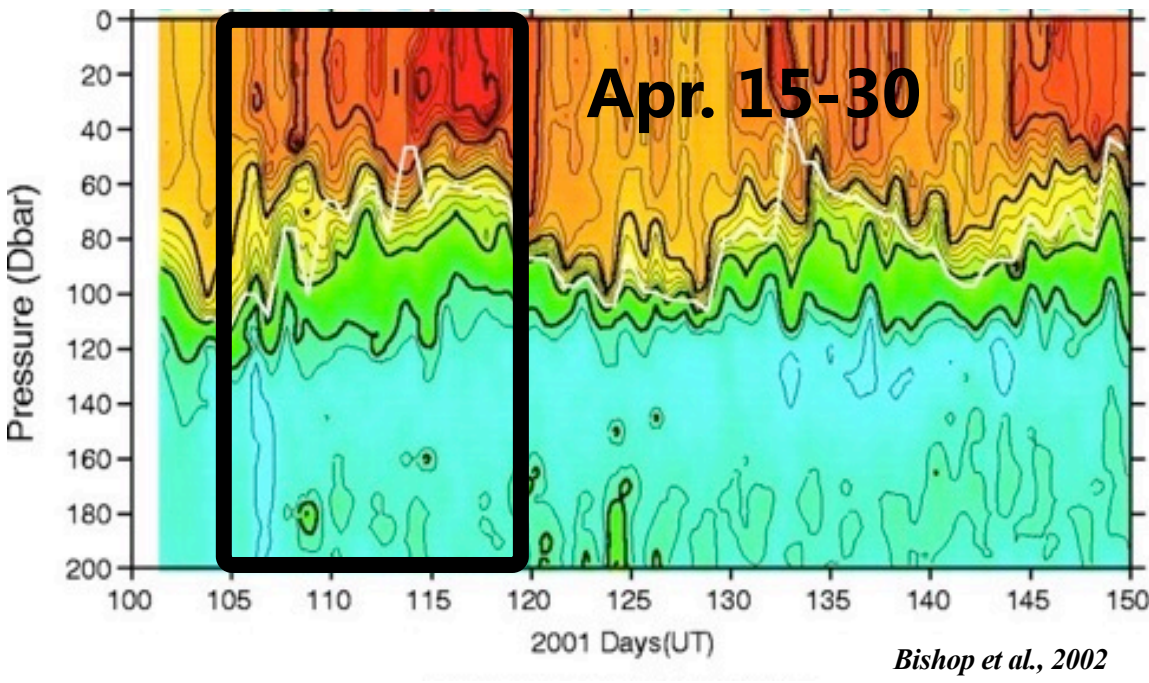

Chlorophyll


Chlorophyll
(micrograms per liter)
with
Iron
without
Iron
0
1
2
0
1
2
3
4
5
6
7
Days
U.S. JGOFS

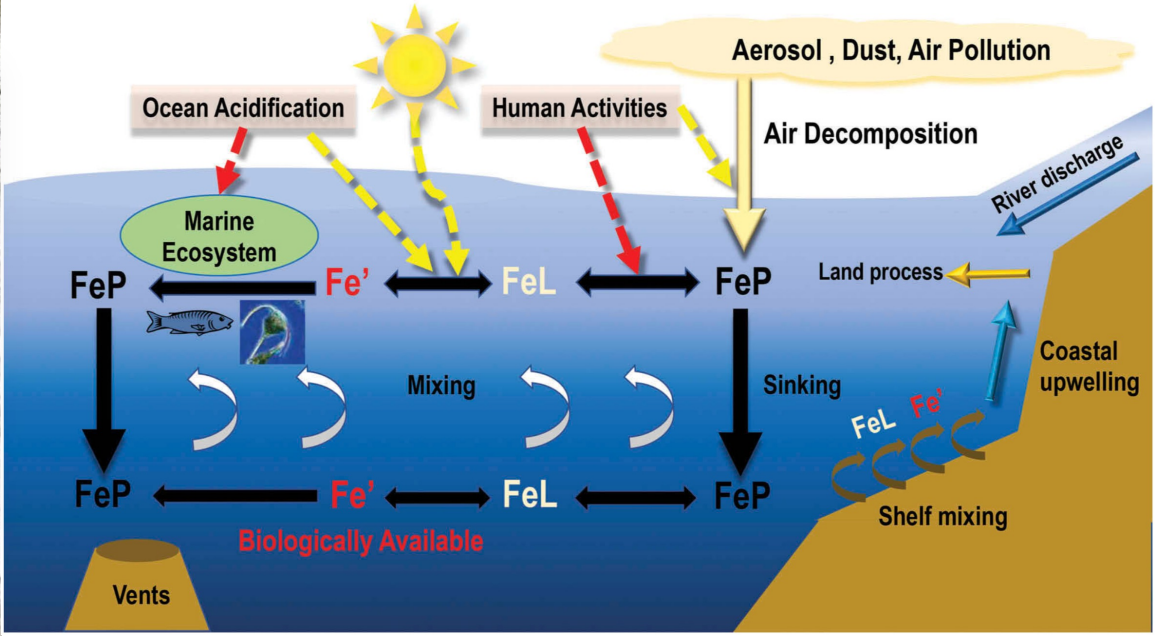

Iron from aeolian dust
60N
40N
20N
(a)
0.01
0.006
0.003
Iron from sediment
60N
40N
20N
(b)

Martin, 1990



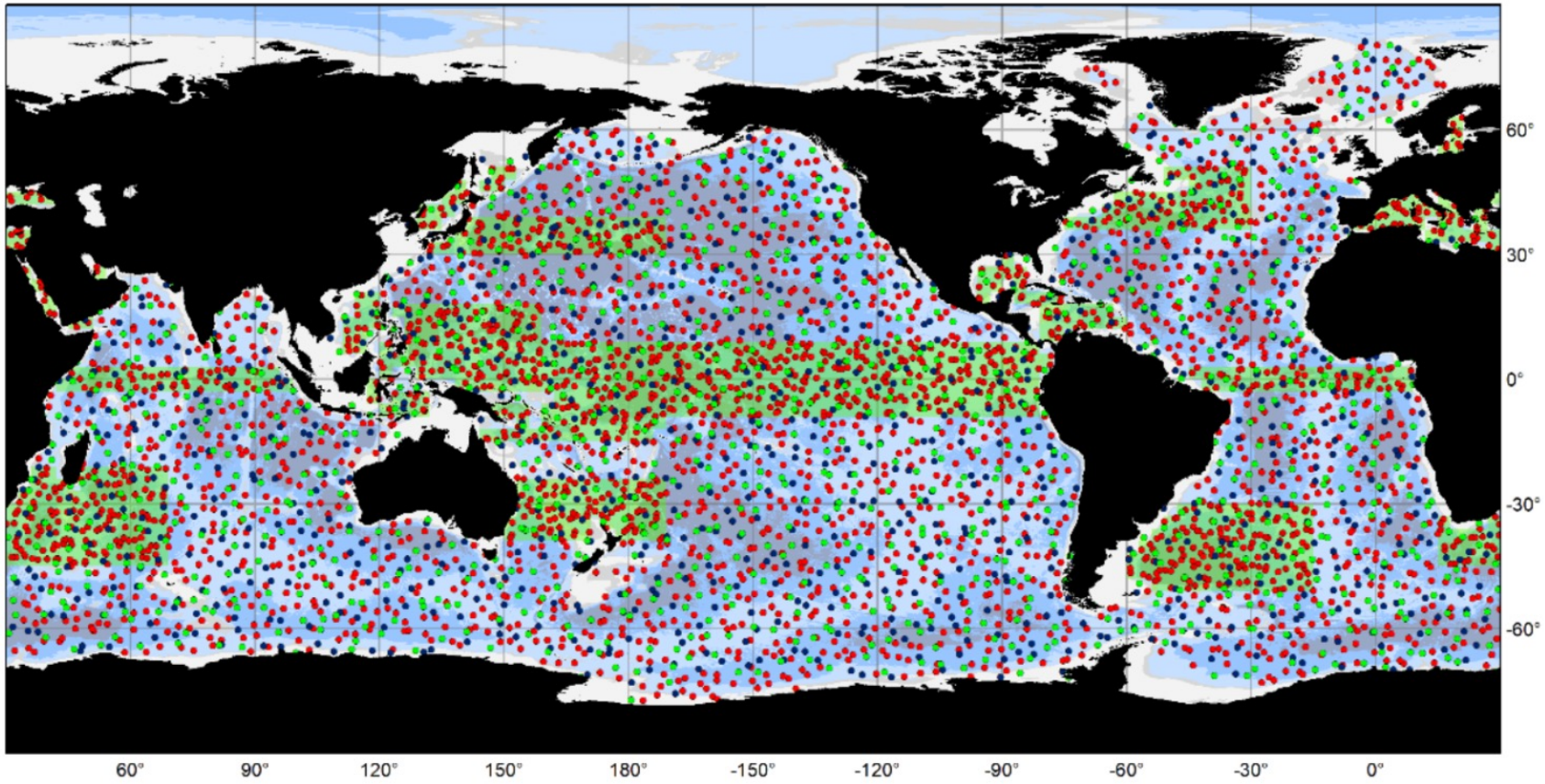


Bishop et al., 2002



Wang et al., 2018

Blueprint of “Argo 2020” Program



Argo

Argo 2020 Design: 4535 floats

To complete and sustain such array, considering a 150 cycles lifetime,
678 core, 260 deep and 222 BGC floats are required every year

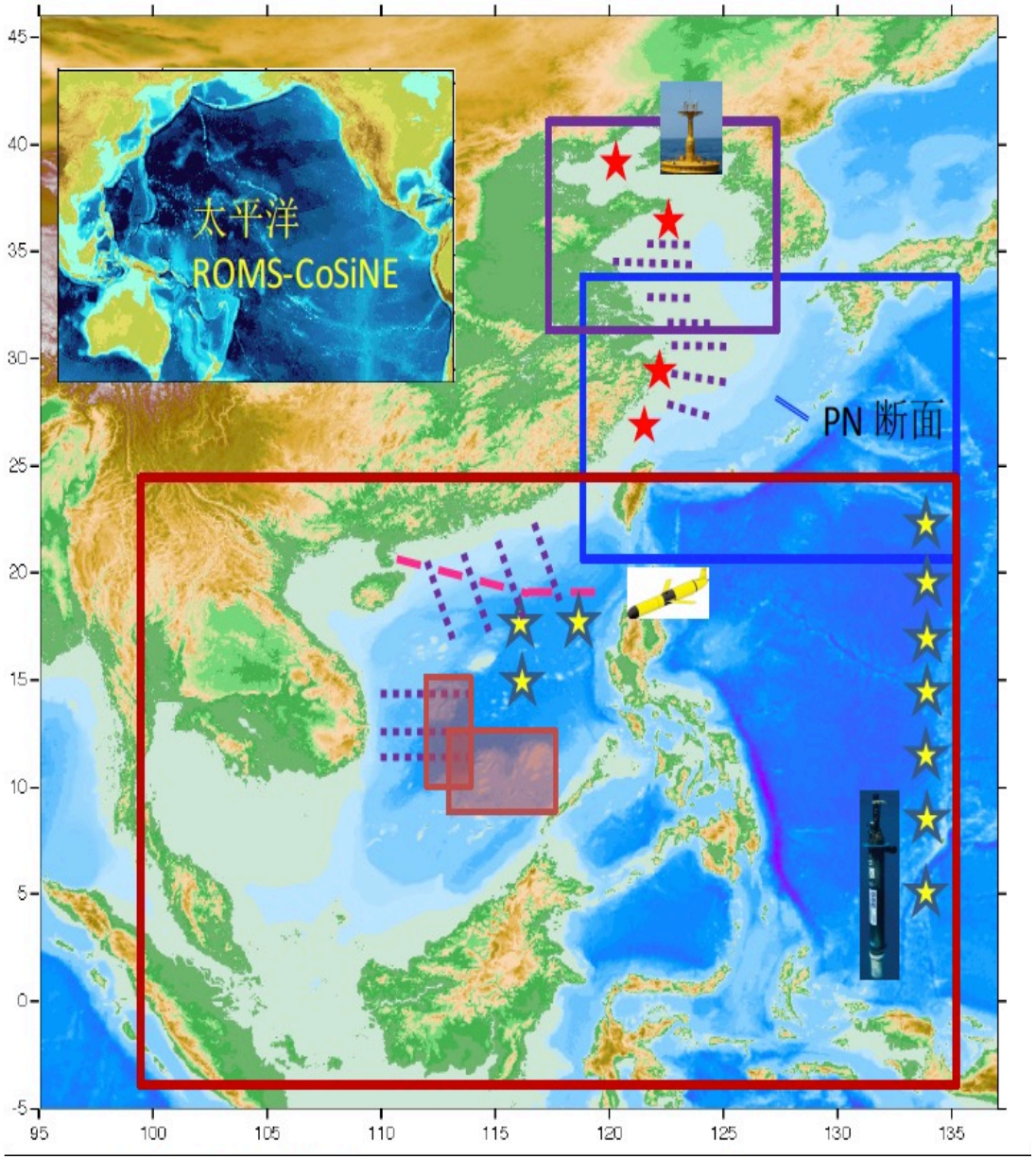
- BGC Floats, 911
- Deep Floats, 1069
- Core Floats, 2555 (including 226 for Marginal Seas, 636 for Equatorial , 922 for WBC)

Target density doubled

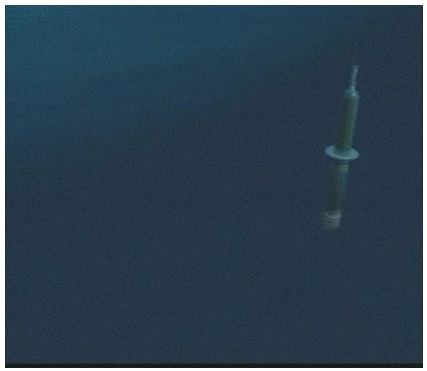
Generated by www.jcommops.org, 07/03/2019

2500 Core Argo+1000 BGC Argo+1000 Deep Argo

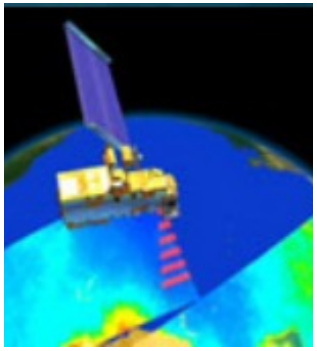
Regional assets for observations



Cruise of NSFC
Glider
BGC-Argo
Coastal moorings
Historical Fishery Survey

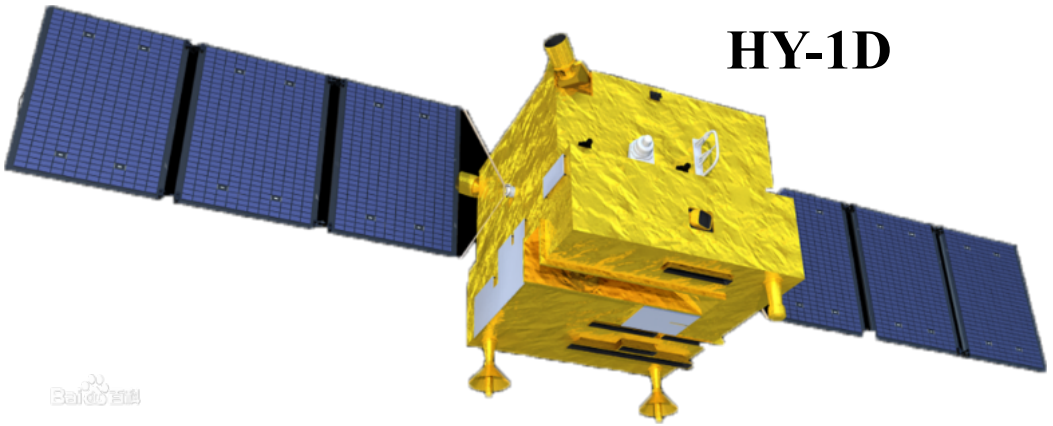


NASA U.S.A.
Coastal Scanner
1978-1986

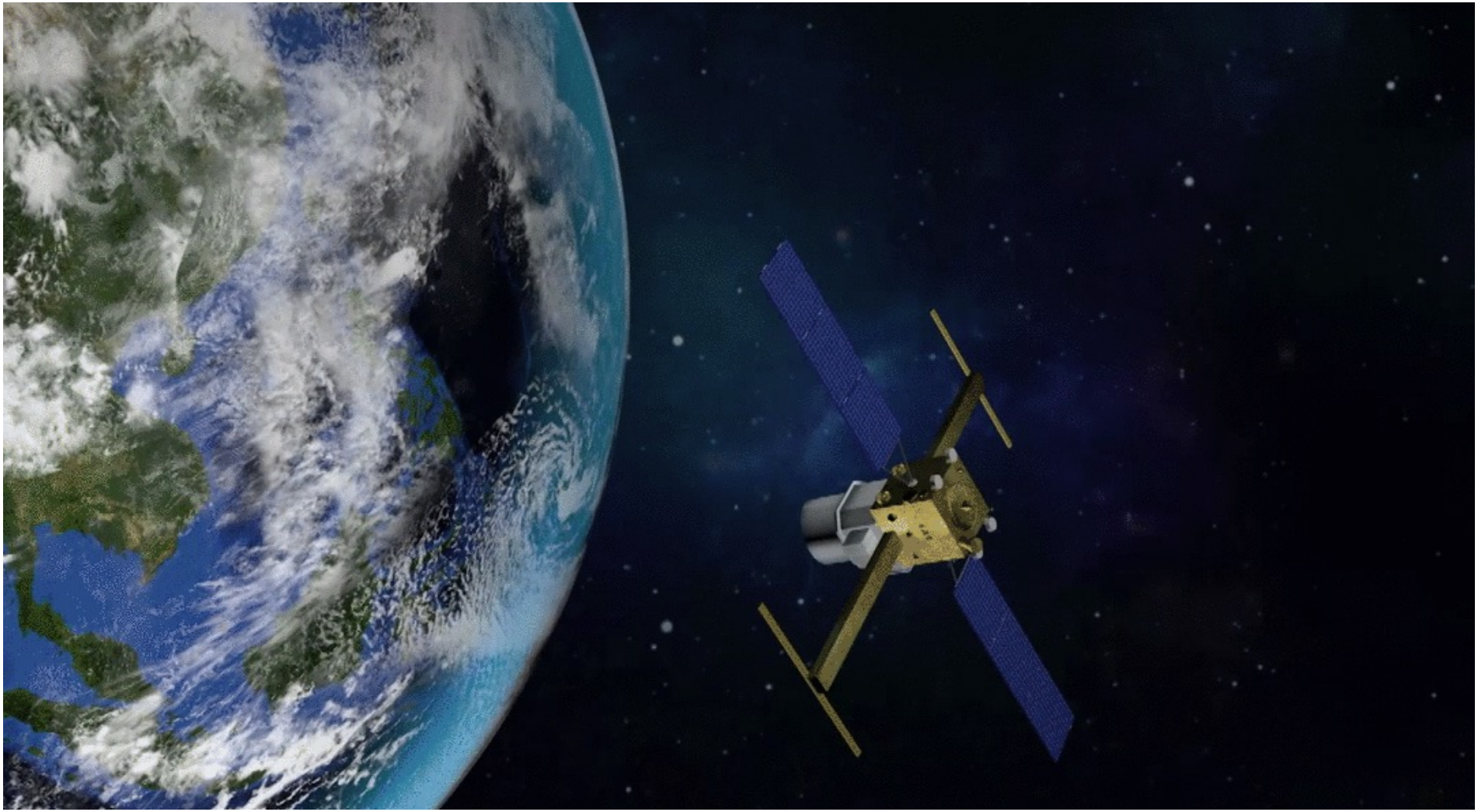


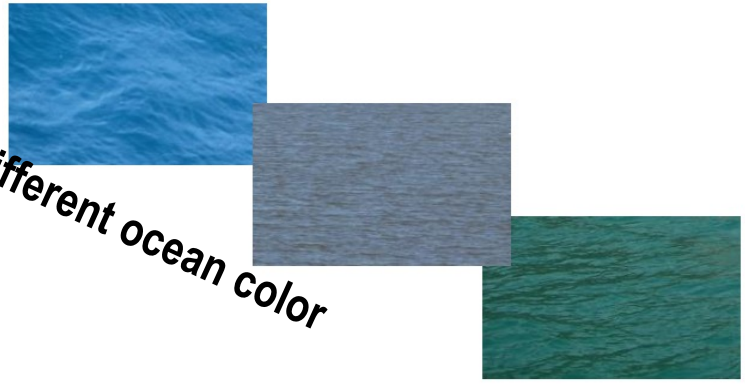
MODIS
Terra (1999~)
Aqua (2002~)

SeaWiFS
(1997-2009)



HY-1D

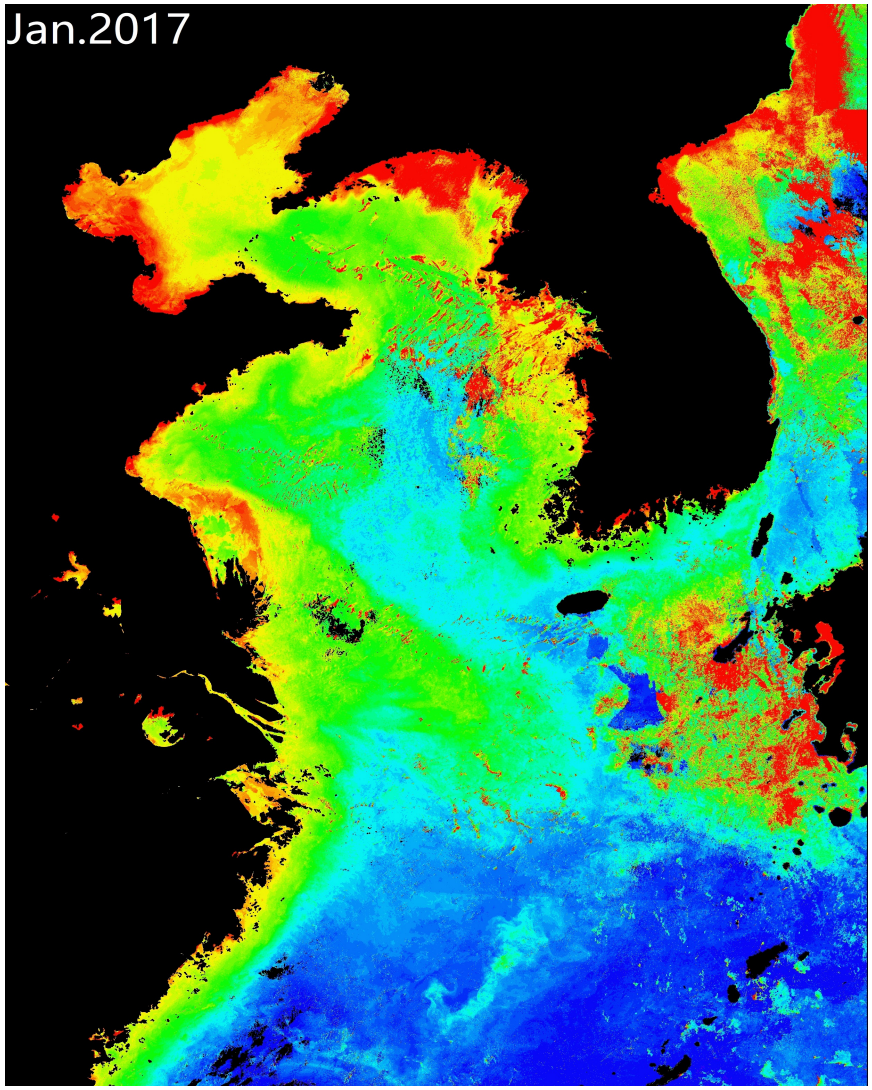



Different ocean color

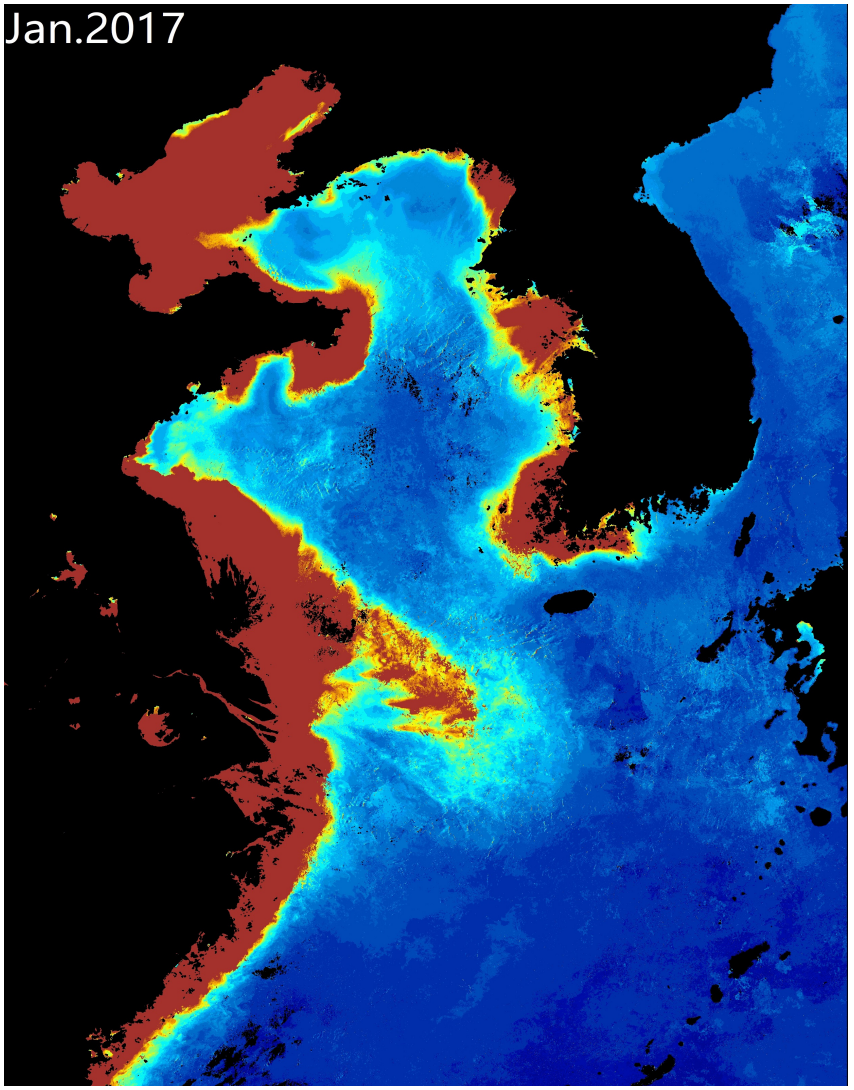

Oil Spill

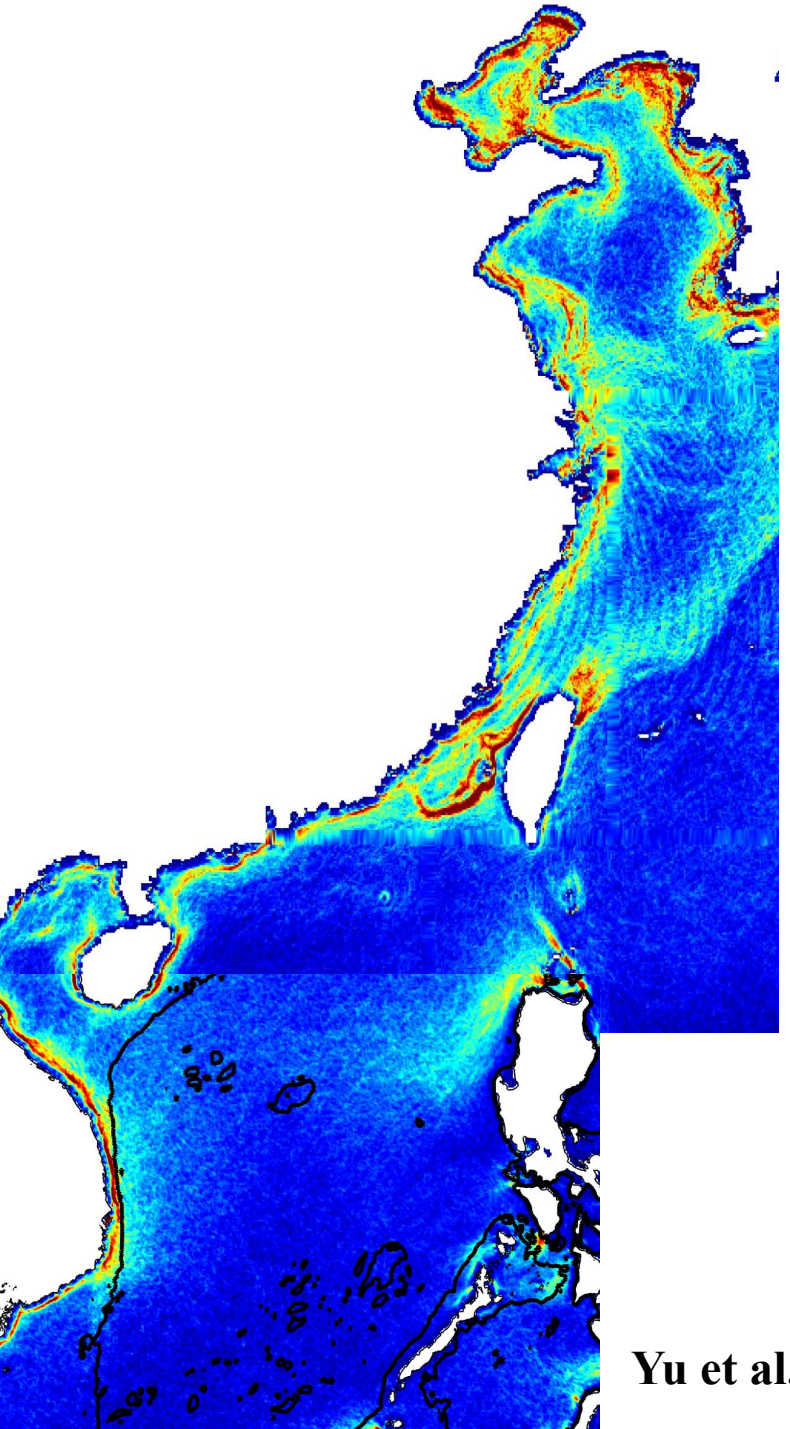

HAB

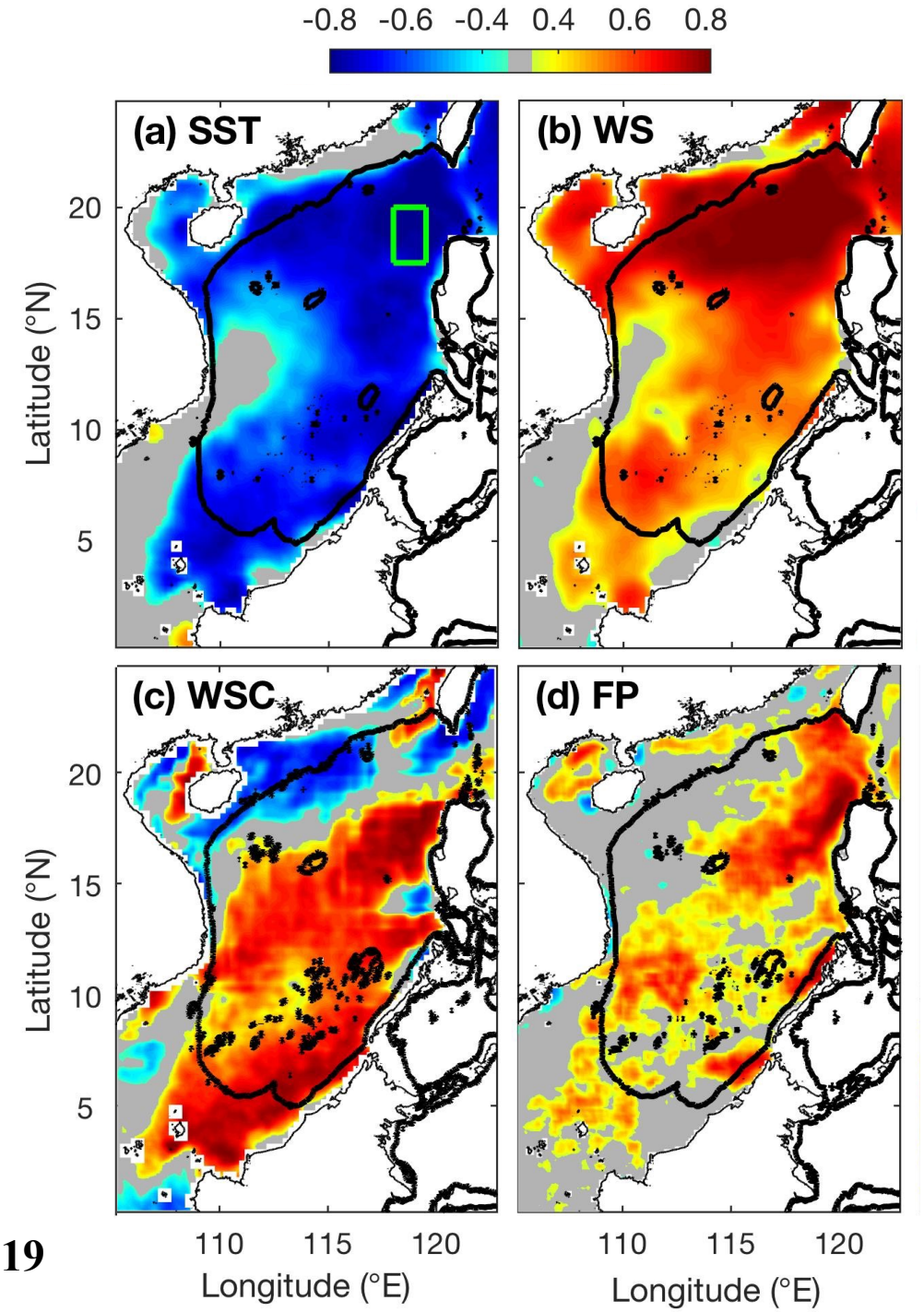
Chlorophyll



Suspended sediment



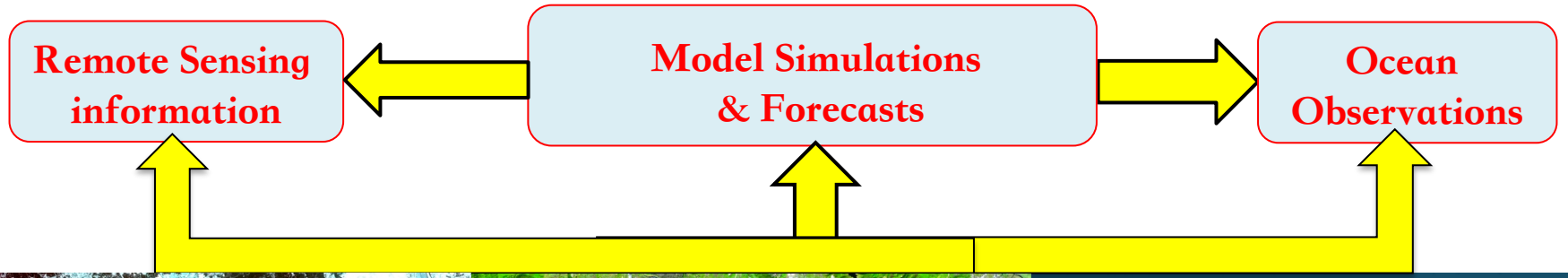


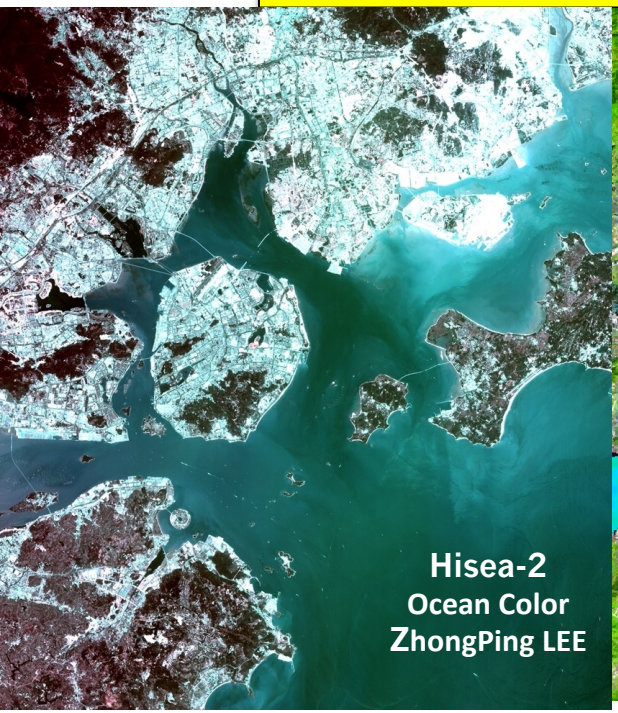

-0.8 -0.6 -0.4 0.4 0.6 0.8
(a) SST
(b) WS
(c) WSC
(d) FP
Latitude (°N)
20
15
10
5
110
115
120
Longitude (°E)

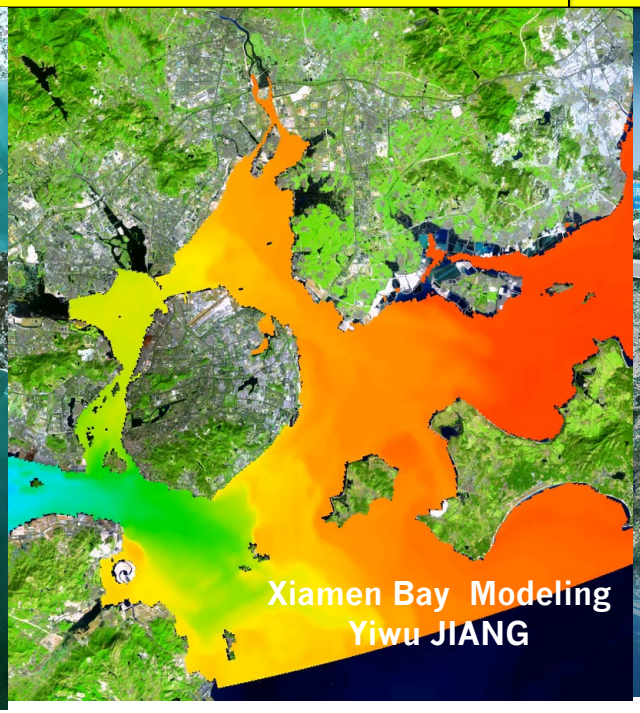
Yu et al., 2019

Essential Components of Digital Twin Ocean

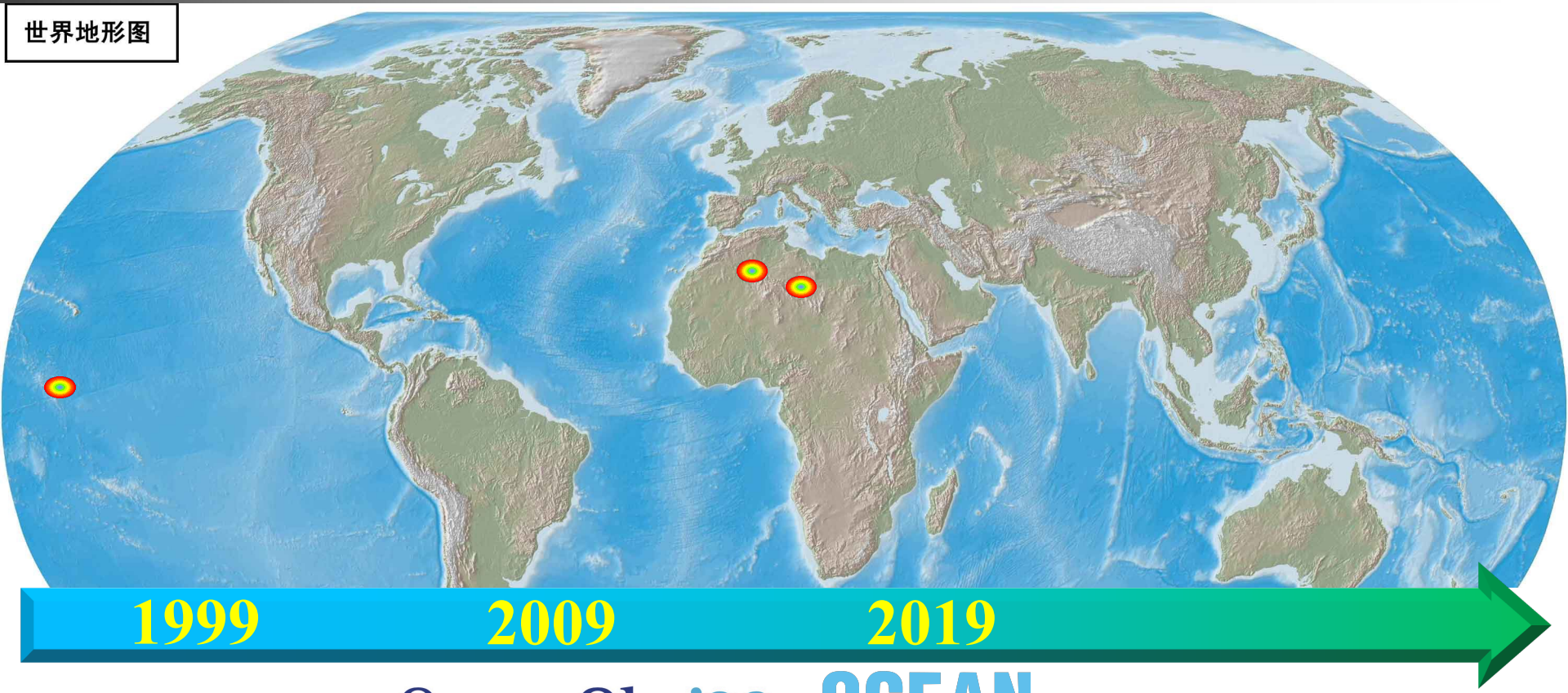
More observations and detailed modeling results







History of OceanObs meeting



1999 2009 2019

OCEANOBS99

Saint-Raphaël, France

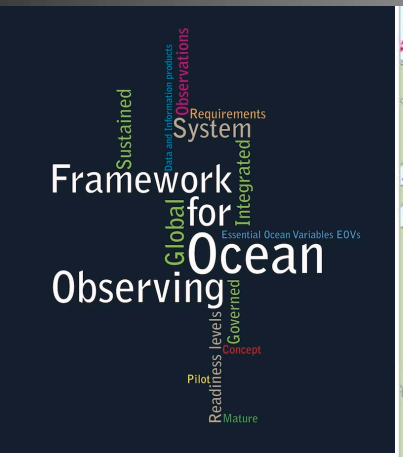
OceanObs'09

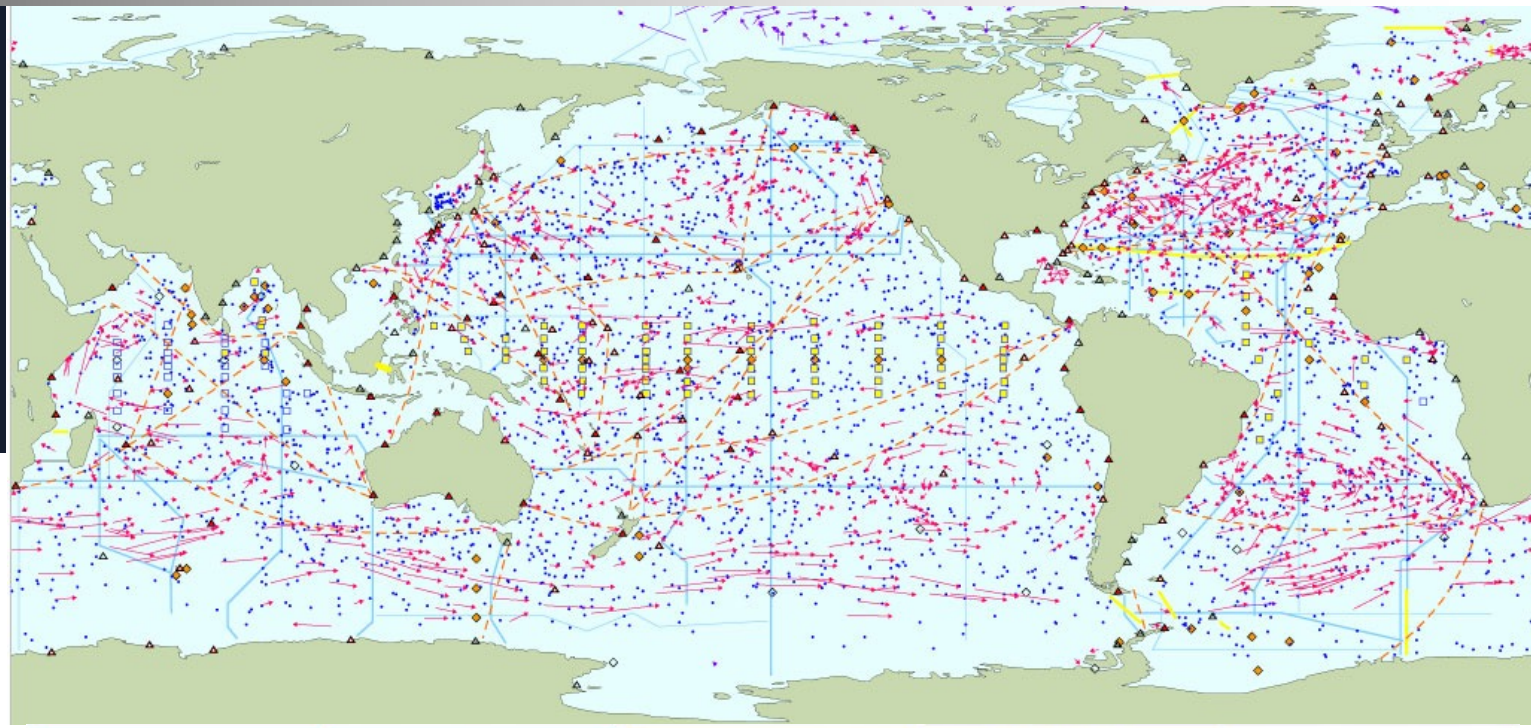
Venice, Italy

OCEAN OBS'19

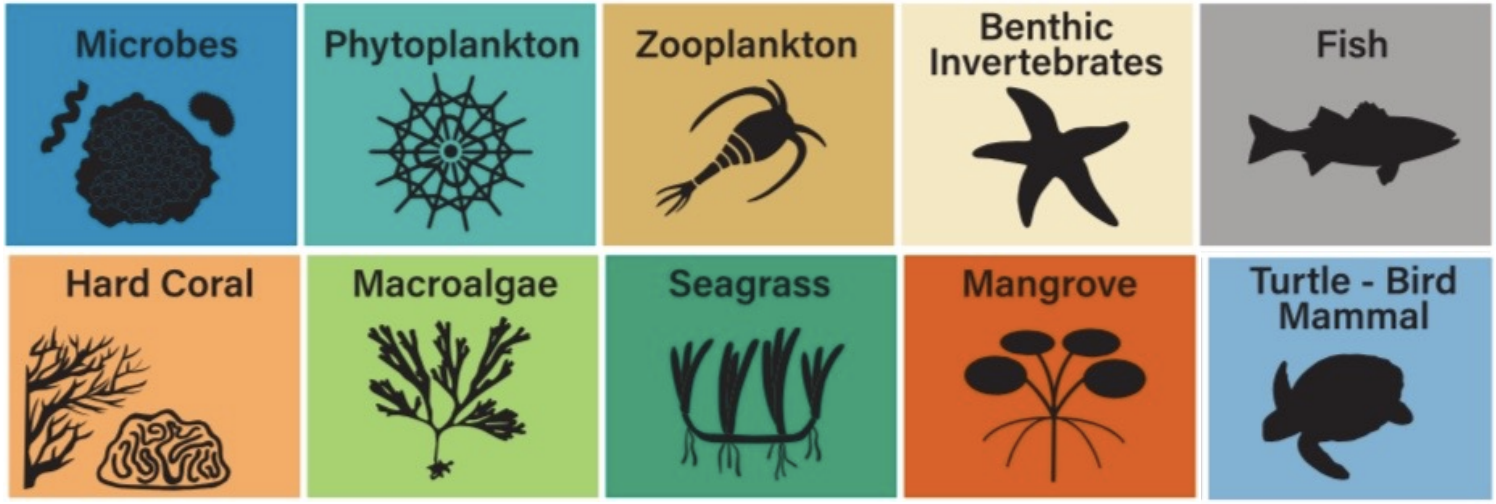
Honolulu, USA

History of OceanObs meeting





Global HF Radar Network

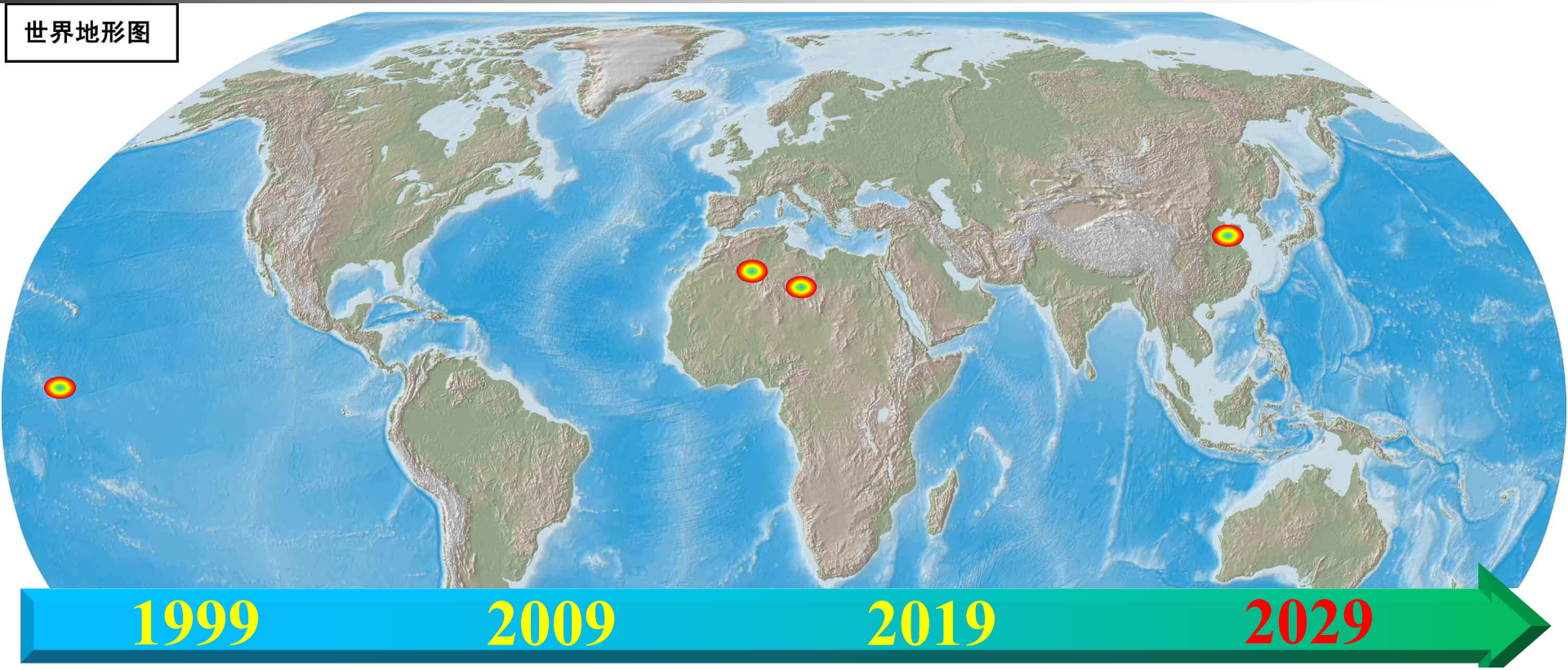


Ocean Gliders

Next OceanObs meeting in China

Ongoing preparation activities

Upcoming OceanObs meeting



OCEANOBS99

Saint-Raphaël, France

OceanObs'09

Venice, Italy

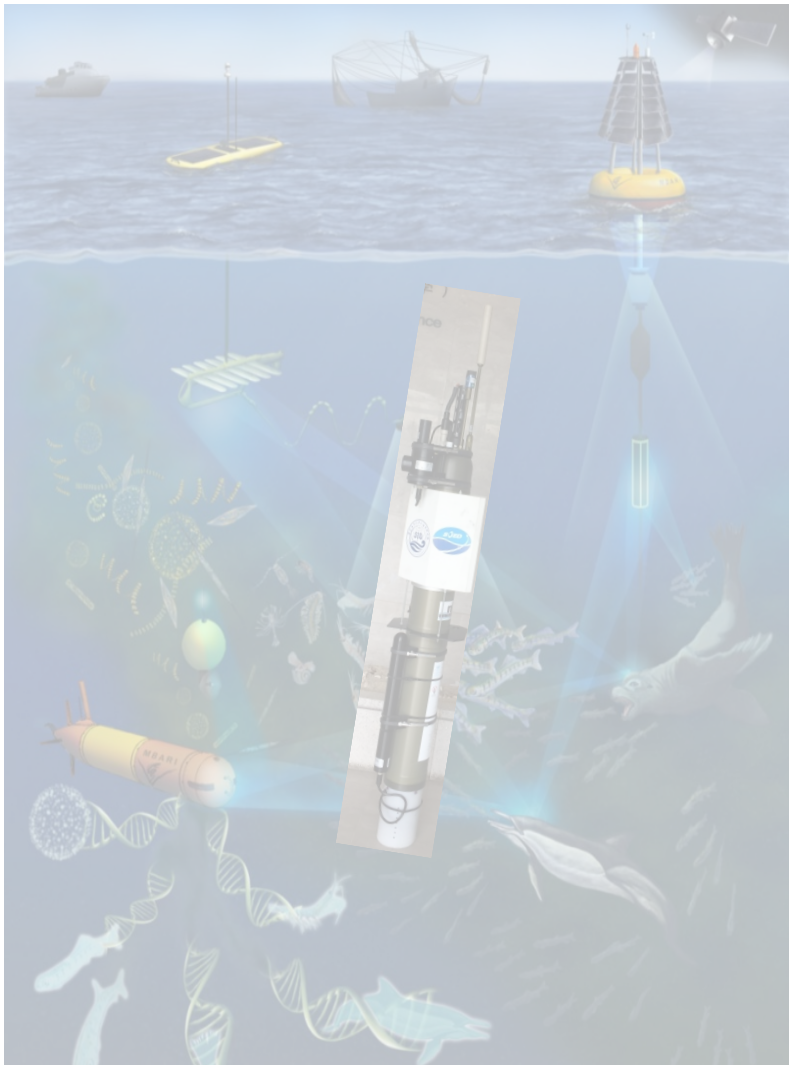
OCEAN OBS'19

Honolulu, USA

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

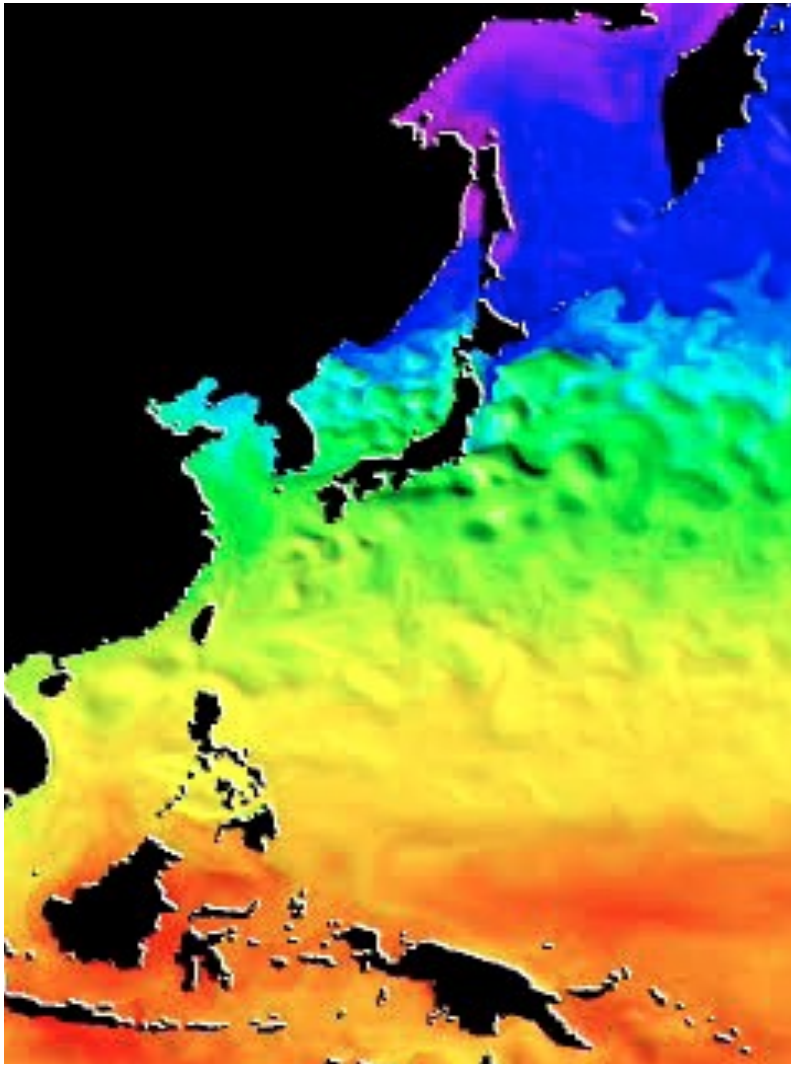
Qingdao, China

Observing system

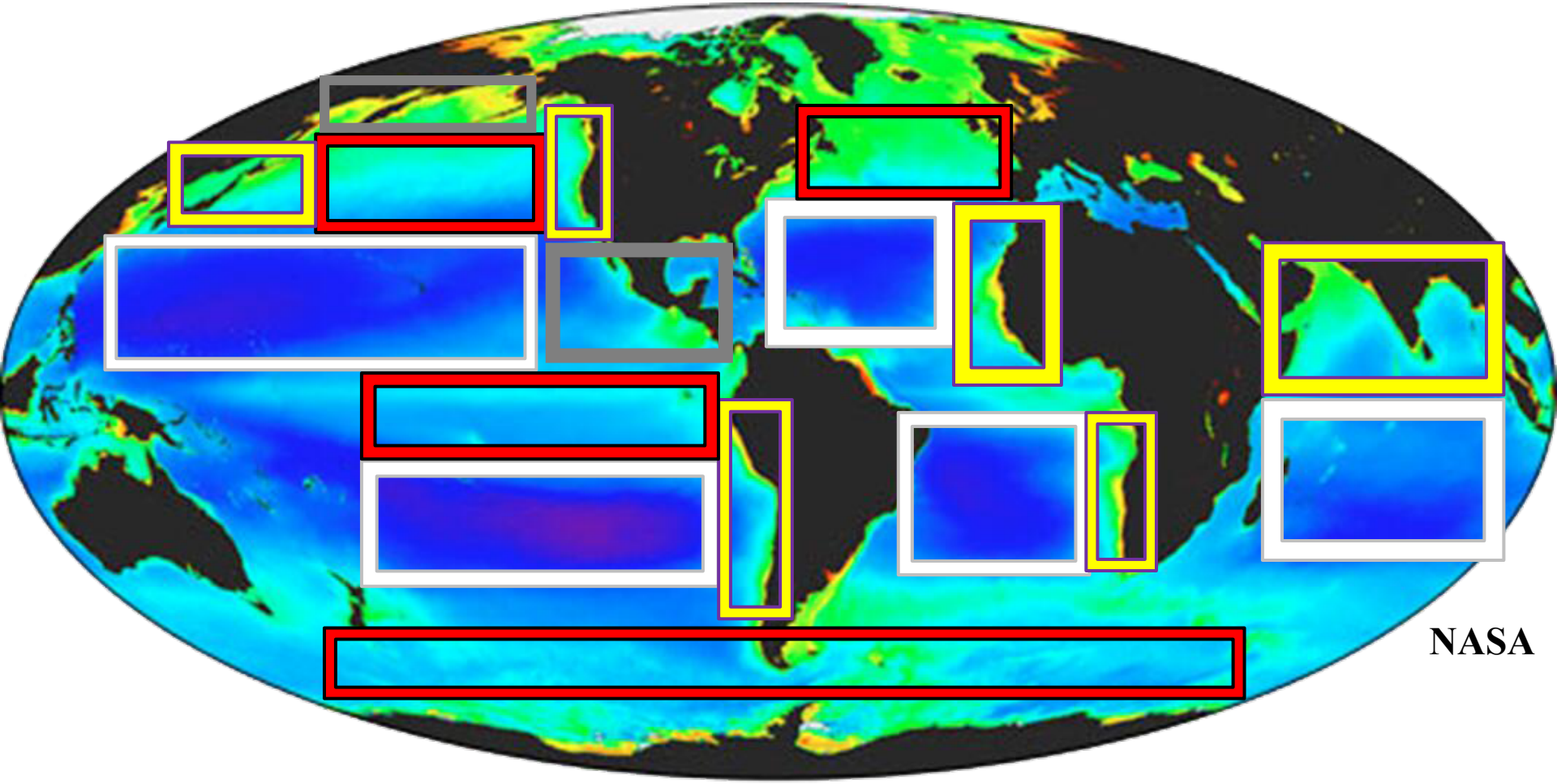


NOAA

Numerical modeling



Major pattern of chlorophyll distribution



NASA

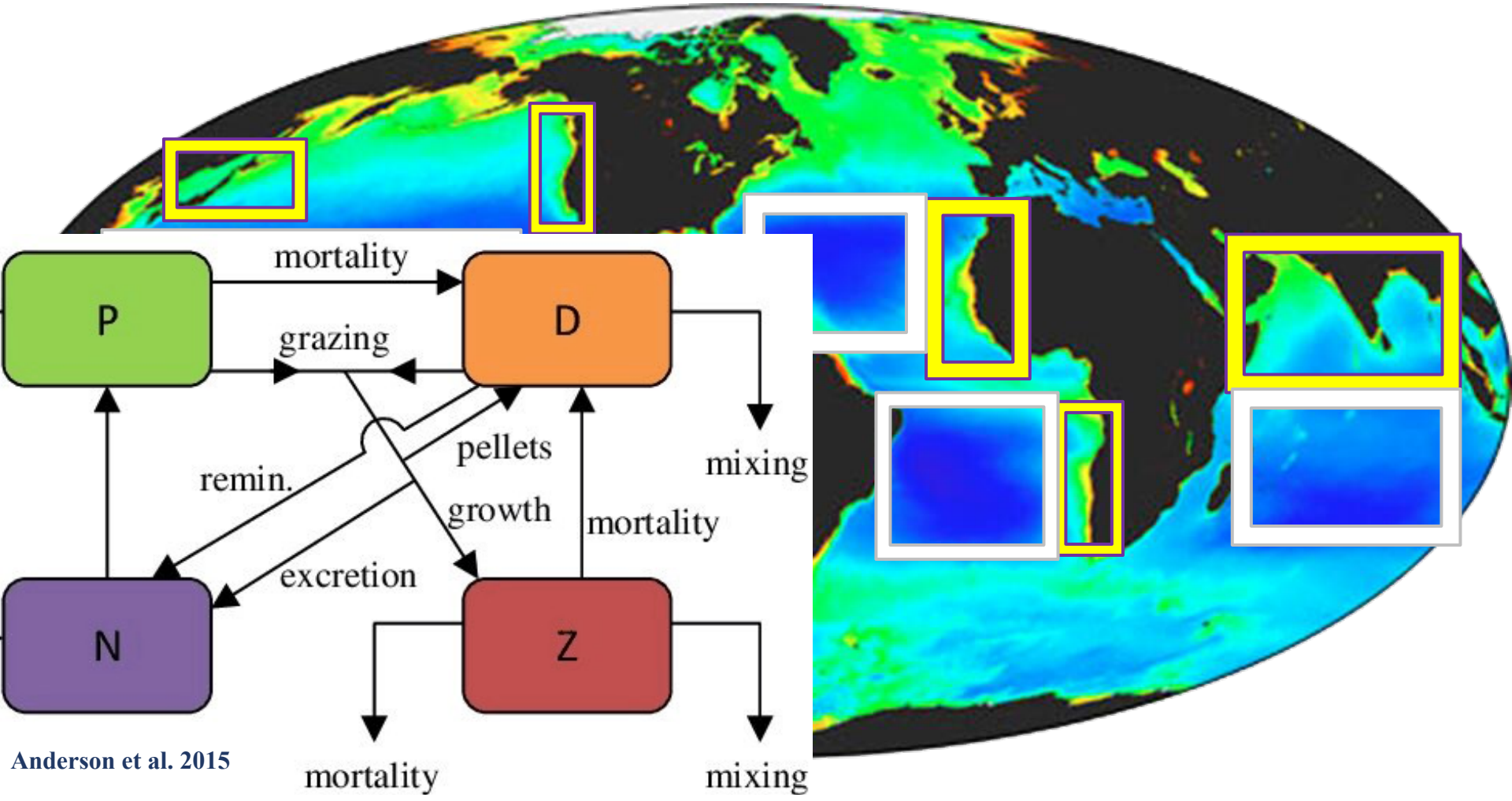
Low-Nutri
Low Chl-a

High Nutri
Low Chl-a

High Nutri
High Chl-a

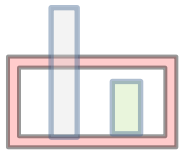
Low-Nutri
High Chl-a

Basis of BGC model



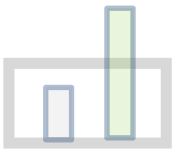
Anderson et al. 2015

Low-Nutri
Low Chl-a



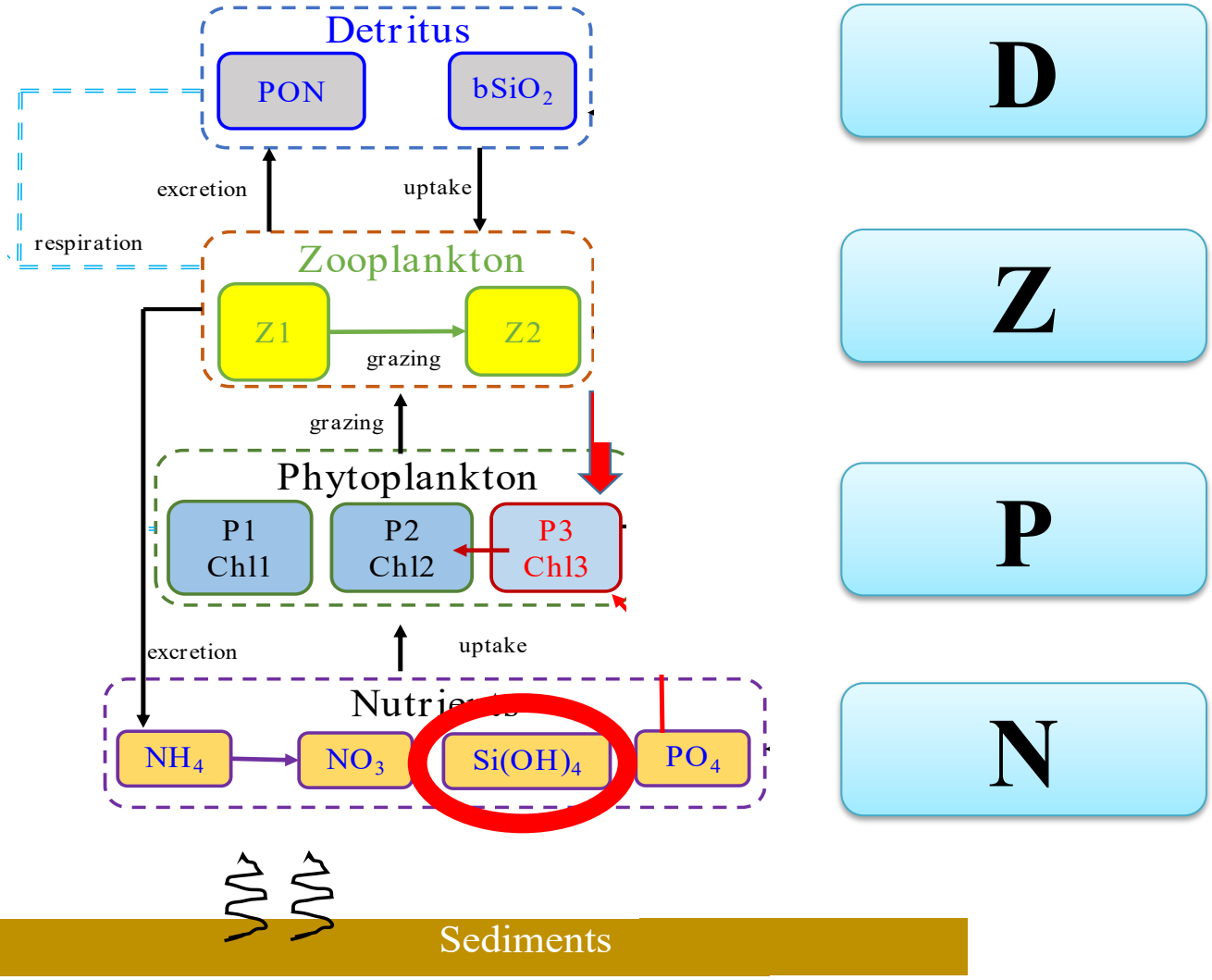
High Nutri
Low Chl-a

High Nutri
High Chl-a



Low-Nutri
High Chl-a

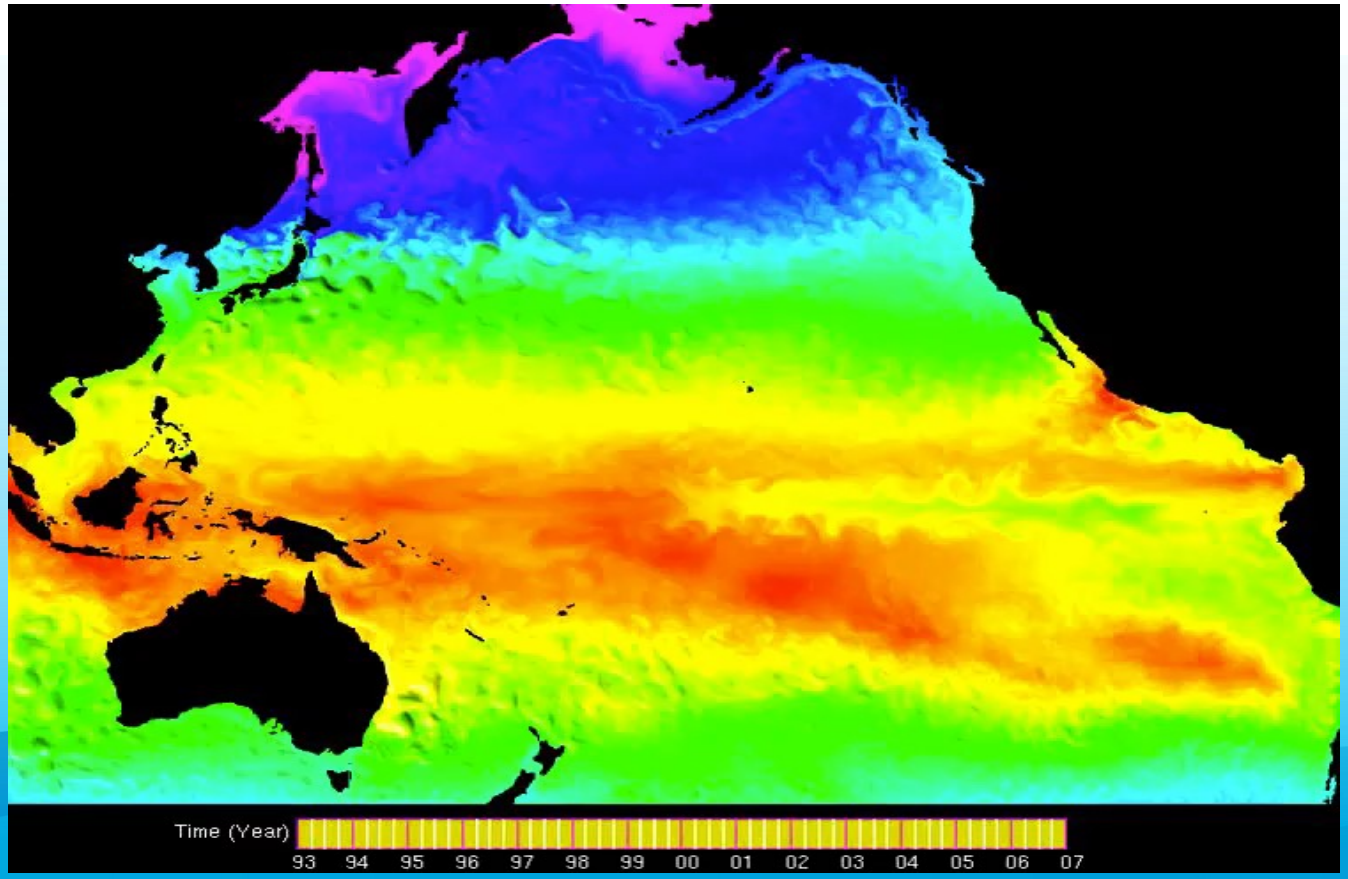
Development of CoSiNE model



- Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE-11)

Chai, 2002

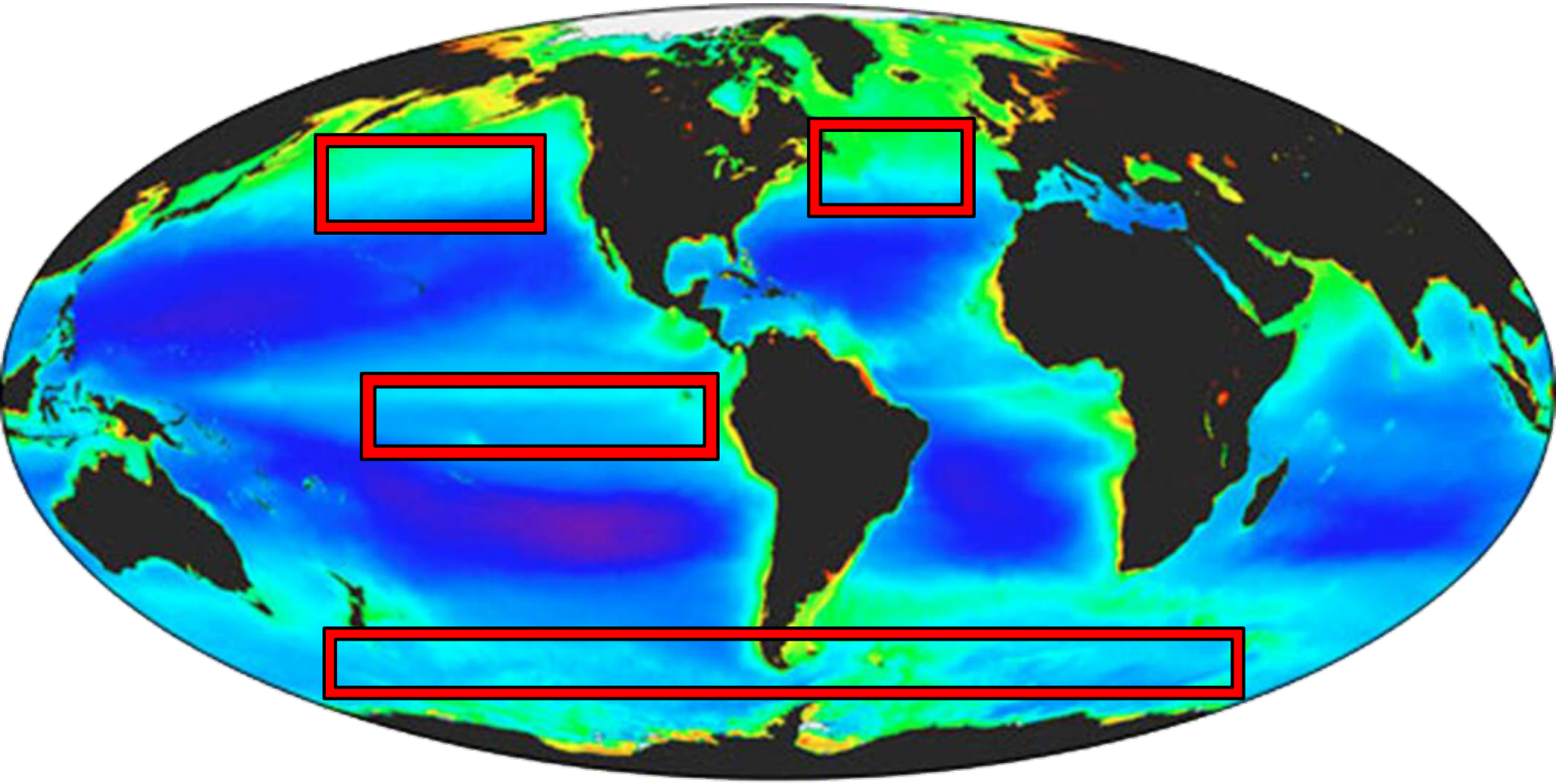
Regional Ocean Model System (ROMS)



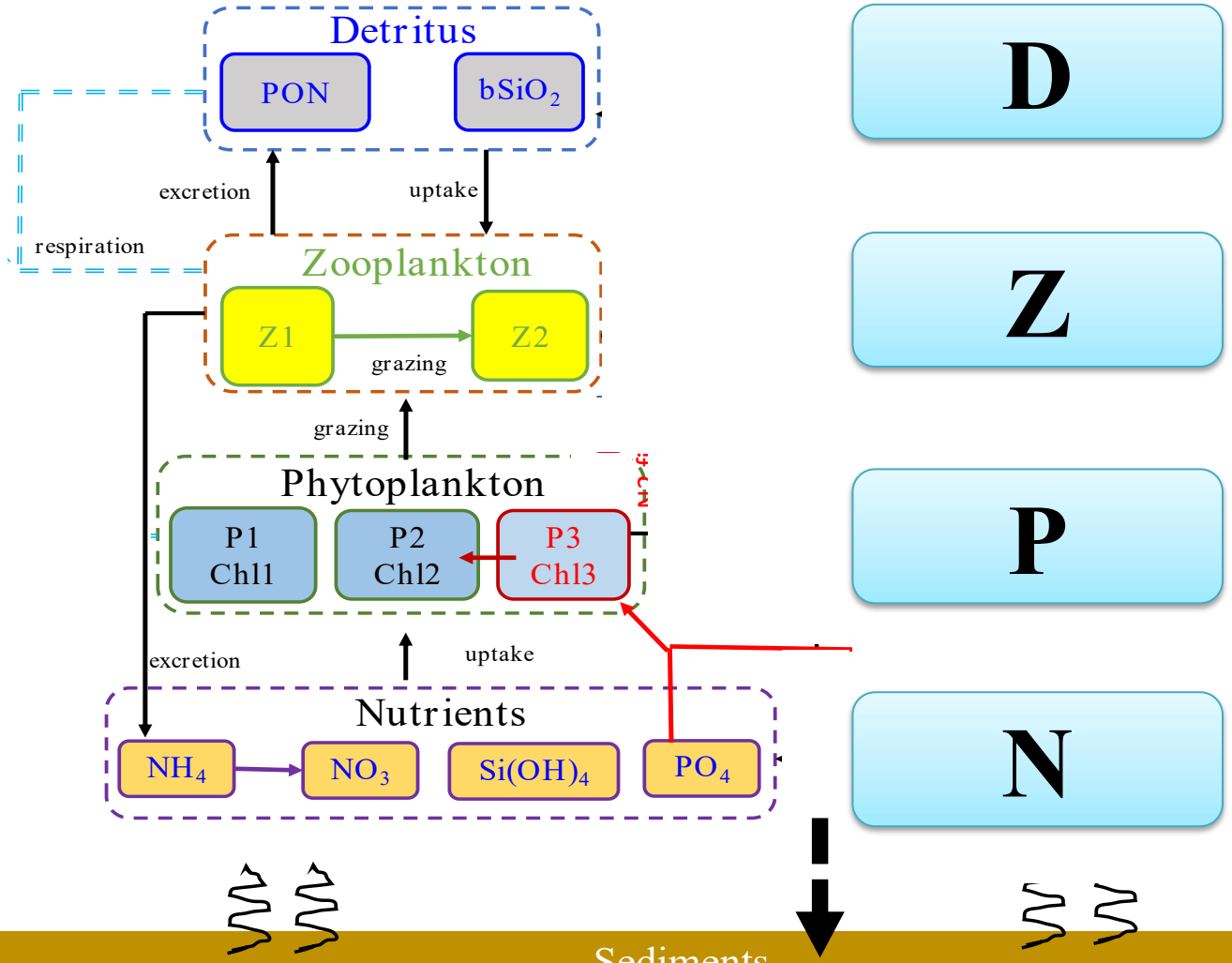
- 1/12° ~1/8° (7-12km)
- Period 1: 1991-2017
- Period 2: 1958-2017

(Chai et al., 2002, 2003, 2007, 2009; Fujii and Chai, 2007; Liu and Chai, 2009; Xiu and Chai, 2011, Palacz et al., 2011, Xu et al., 2013, Xiu and Chai, 2013, 2014, Guo et al., 2014; 2015; Zhou et al., 2017; Liu et al, 2018)

HNLC region simulation



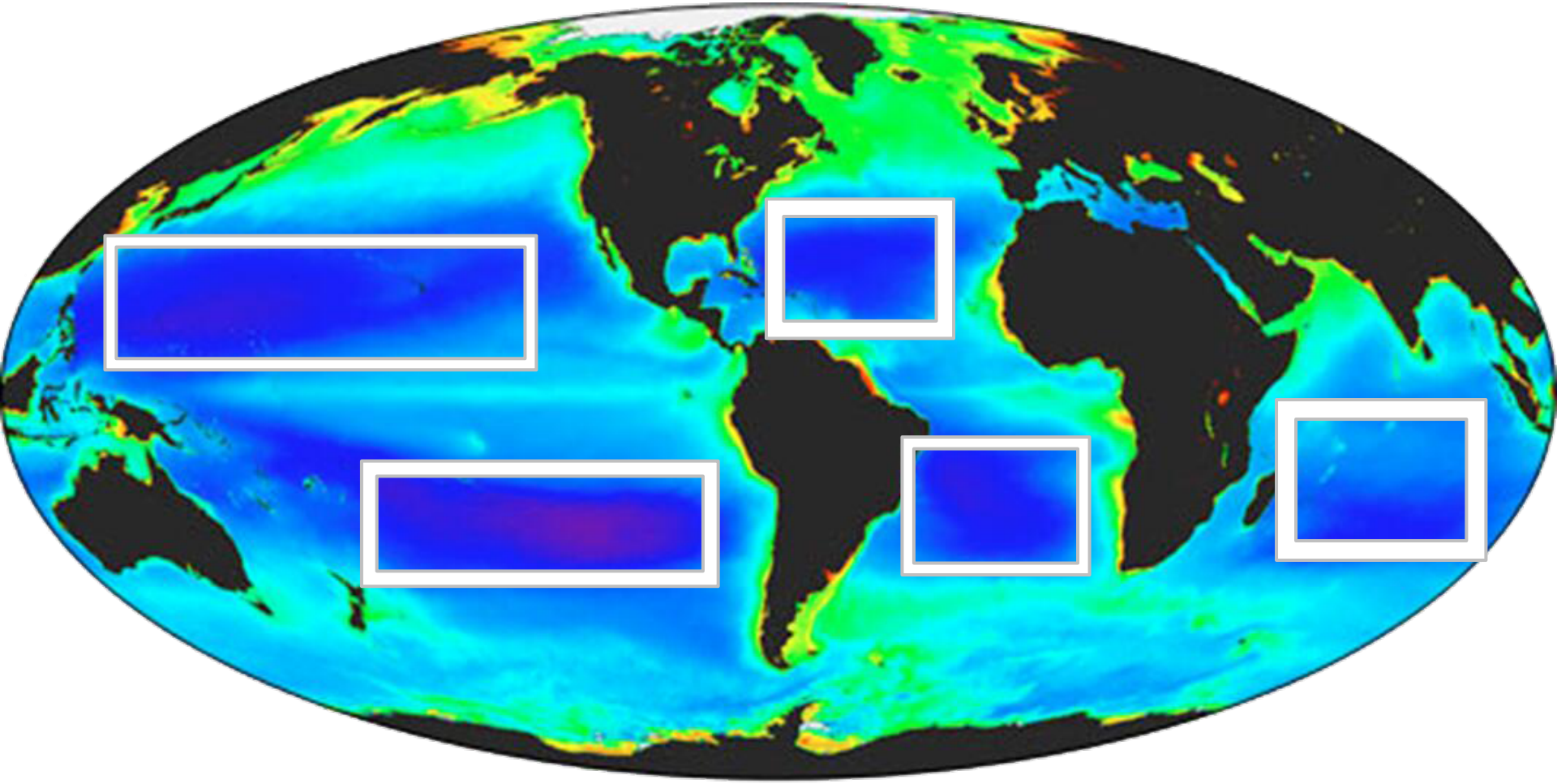
Development of CoSiNE model



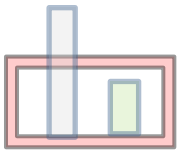
- Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE-13)

Chai, 2002

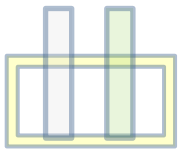
Nitrogen fixation module development



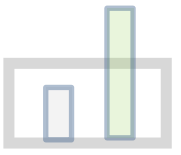
Low-Nutri
Low Chl-a



High Nutri
Low Chl-a

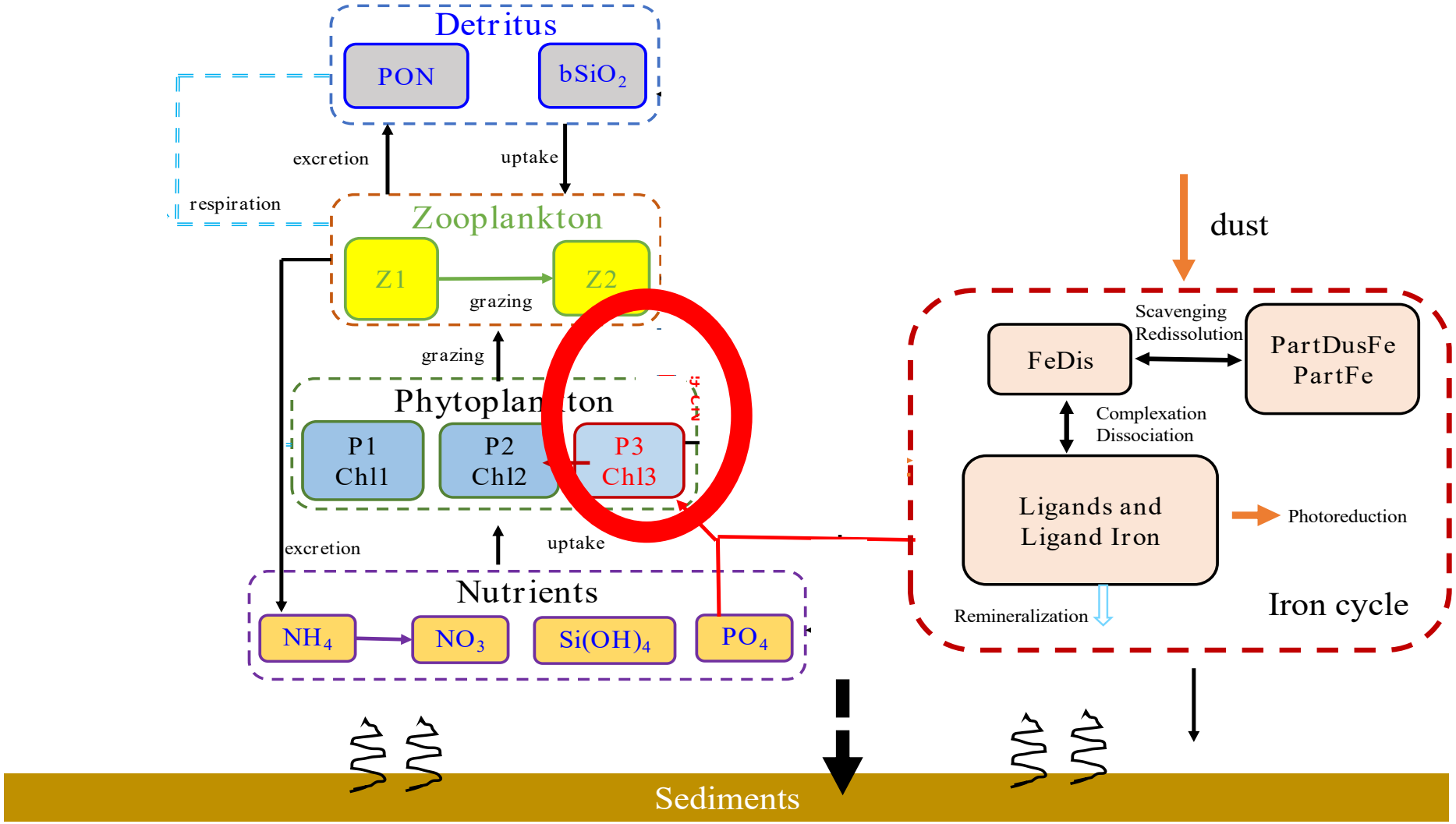


High Nutri
High Chl-a



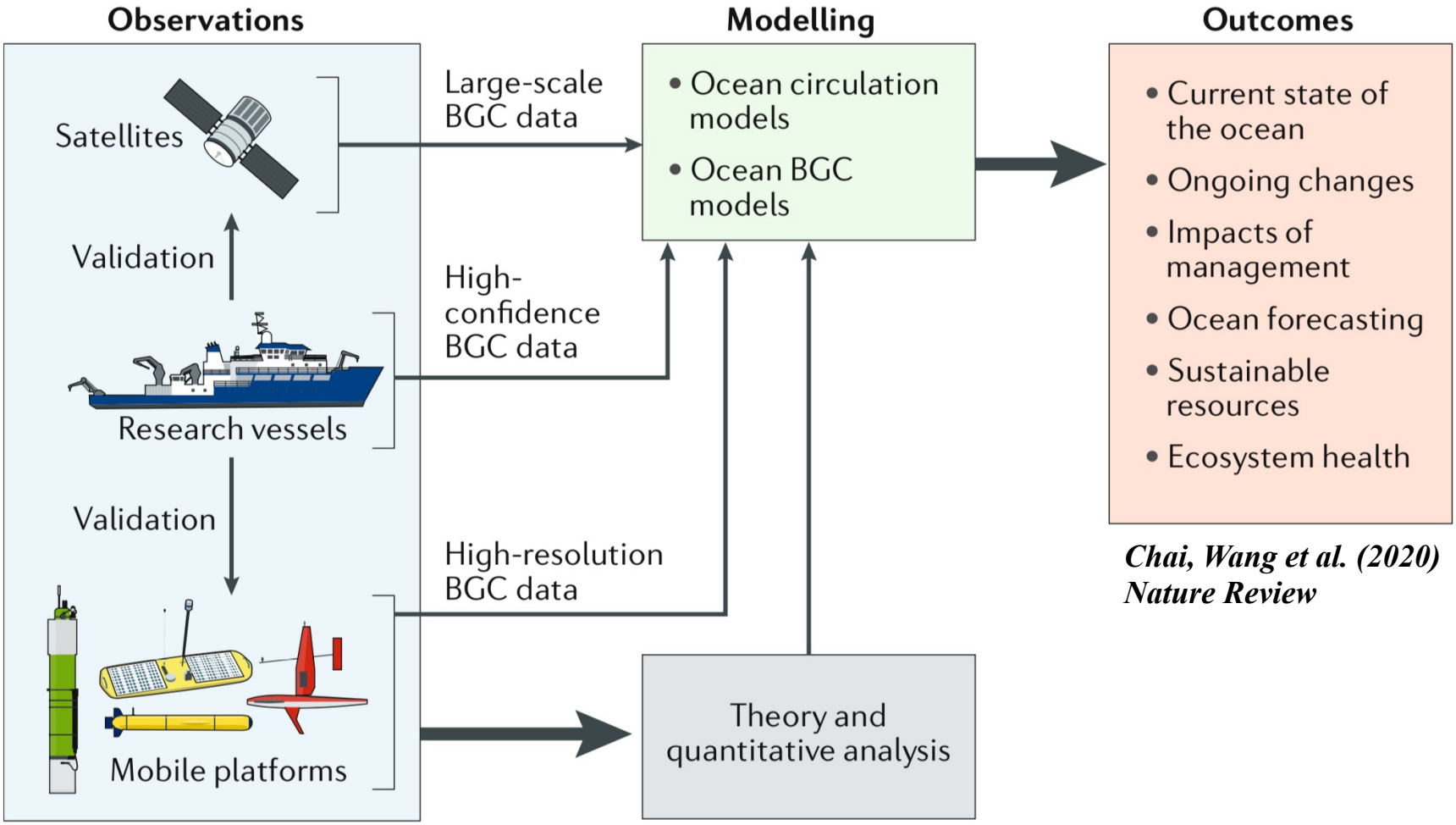
Low-Nutri
High Chl-a

Development of CoSiNE model



- Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE-31)

Flowchart from observations to modeling



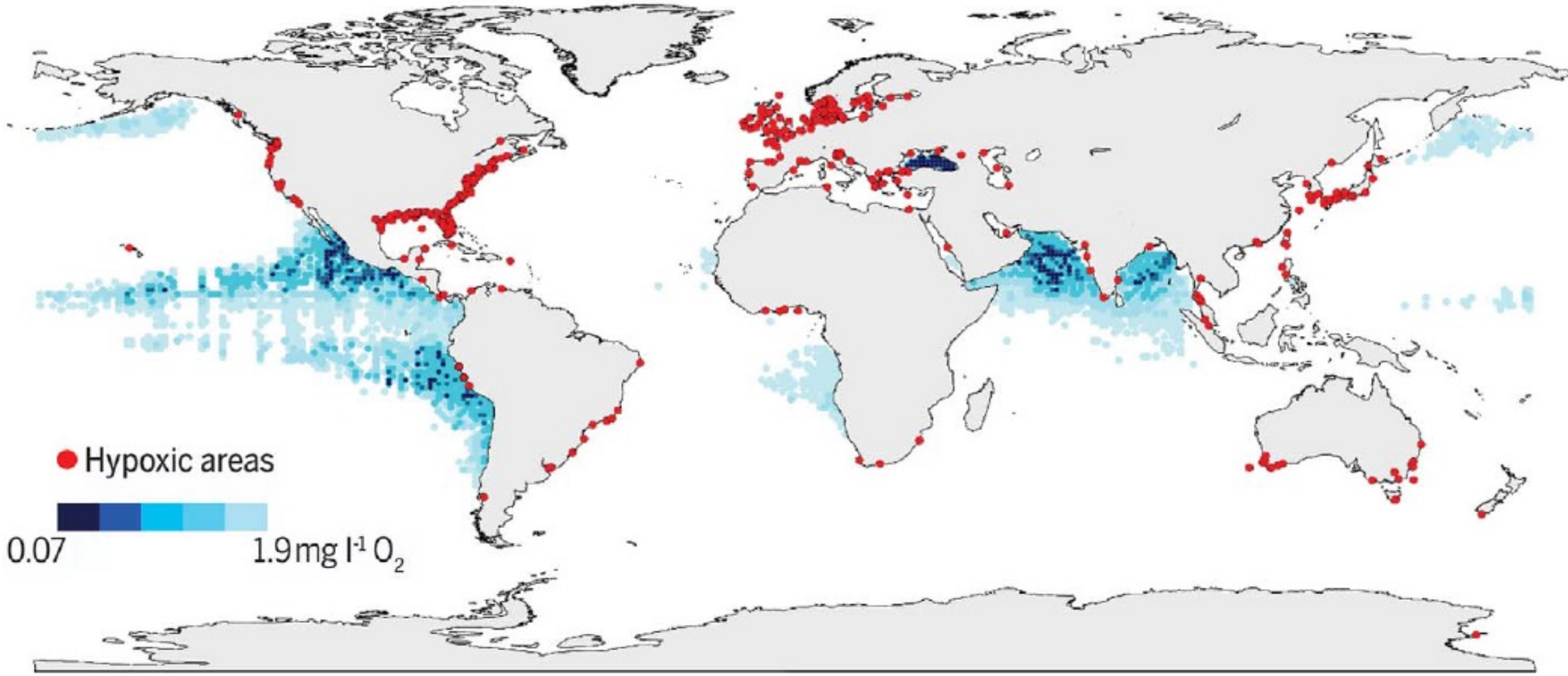
Chai, Wang et al. (2020) Nature Review

Multiple observations

Numerical modelling

Marine ecosystem health

Declining Oxygen and Hypoxia due to Coastal Eutrophication

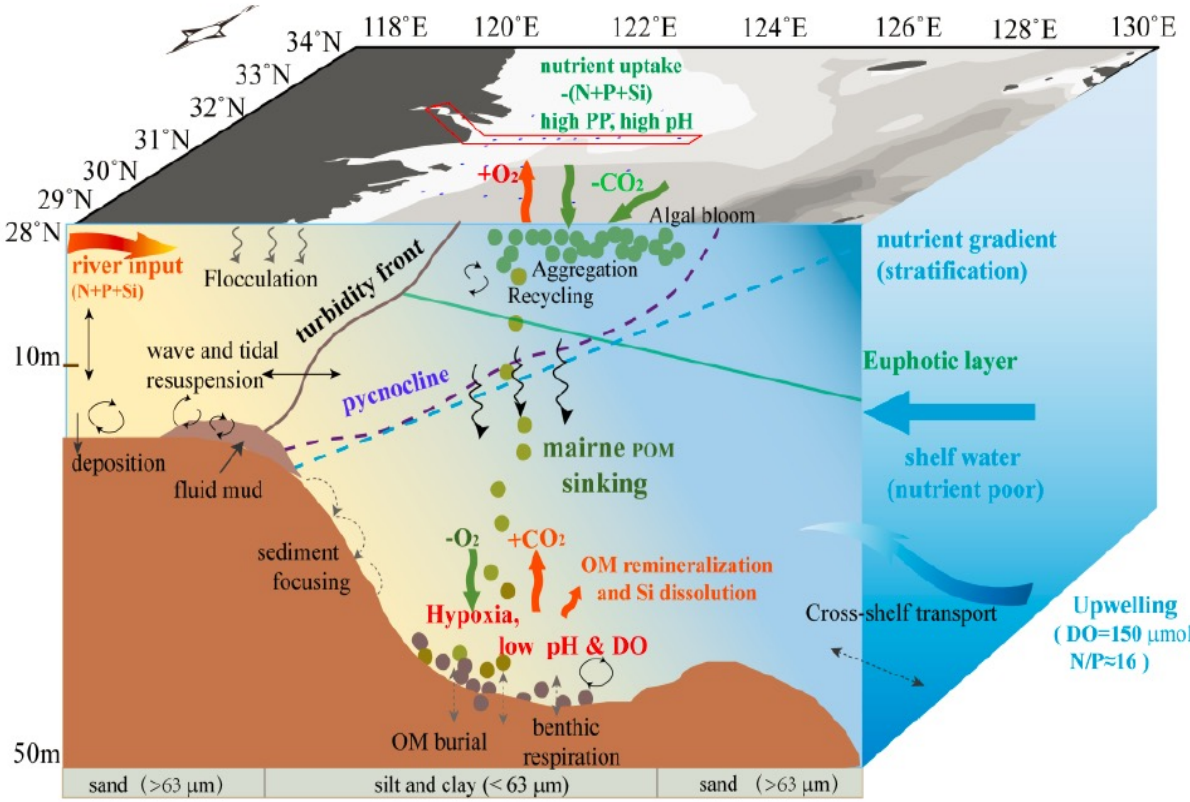


Low and declining oxygen levels in the open ocean and coastal waters affect processes ranging from biogeochemistry to food security. The global map indicates coastal sites

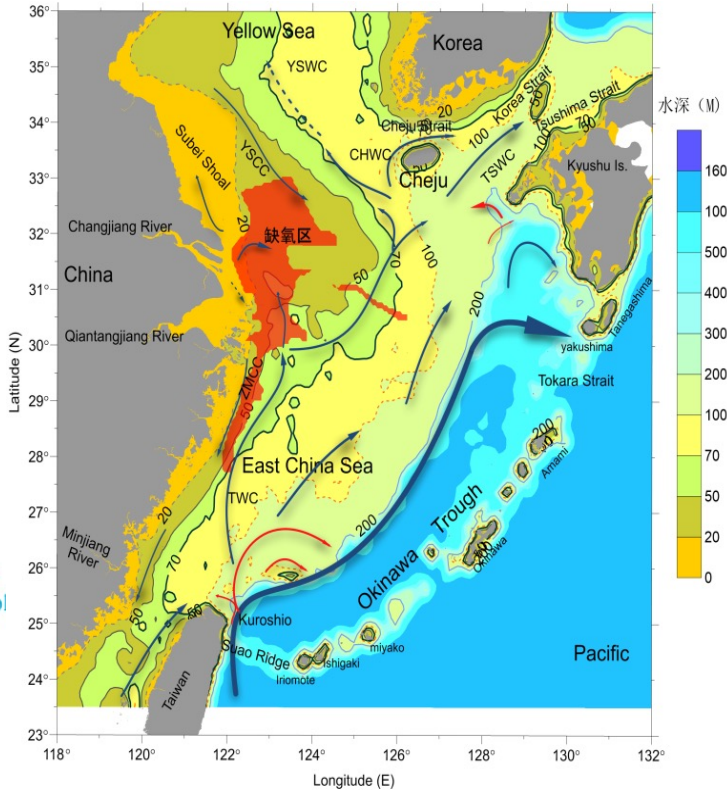
Breitburg et al., Science (2018)

Complex system in the Changjiang Estuary

Physical, River discharge, Phytoplankton blooms, Hypoxia, OA



Wang, B. et al., 2017, *L & O*



Biogeochemical processes:

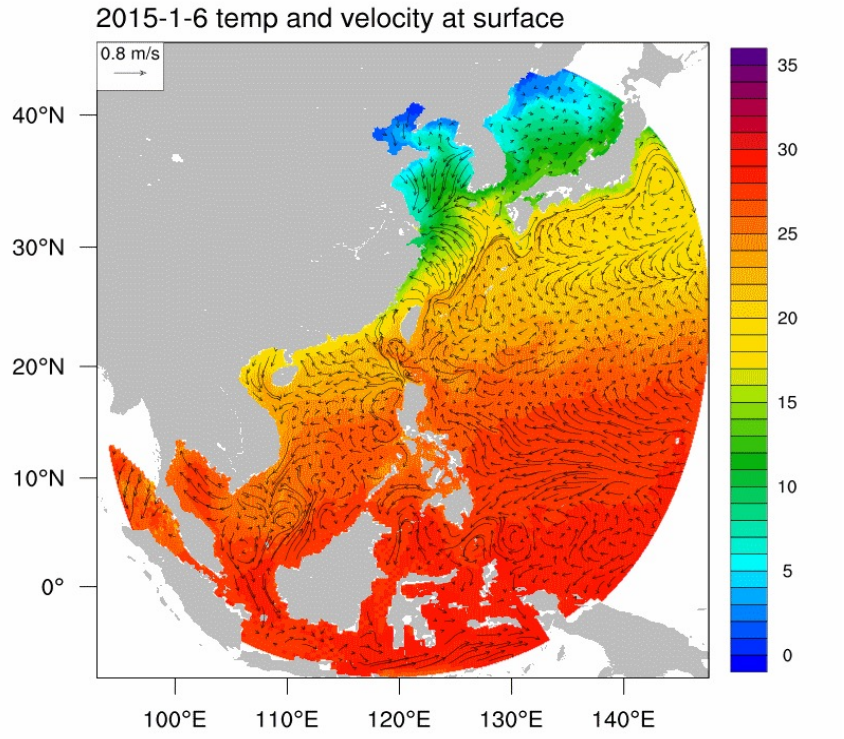
Nutrient loading/ratio, production, sinking, Respiration…

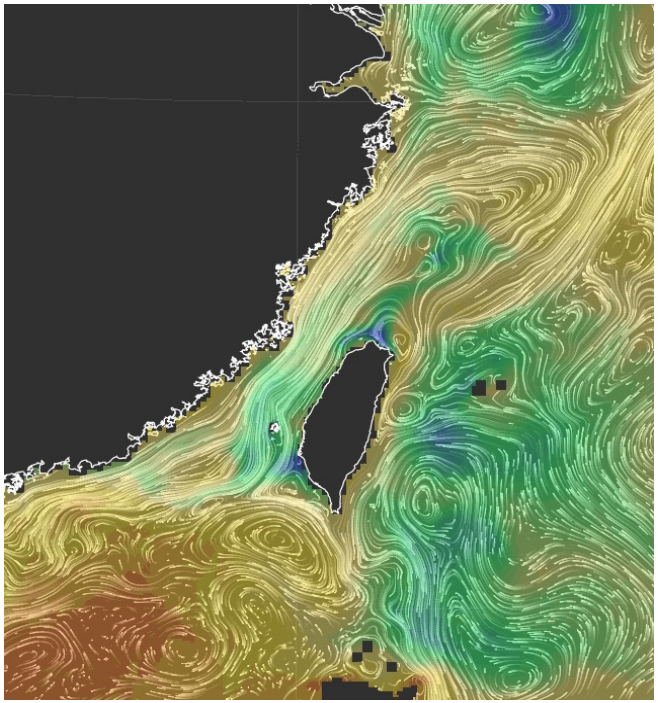
Physical processes:

Mixing + Advection

Zhou and Chai, et al. (2017), *Prog. Oceanogr.*

Numerical Models



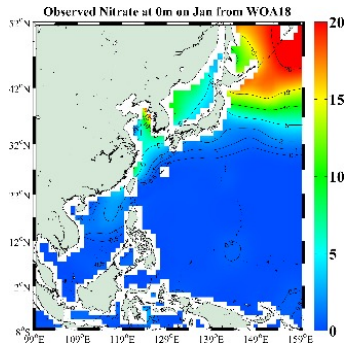


The current and SST for the northwestern Pacific Ocean and the Taiwan Strait

Lin, Yan, Jiang & Zhang 2016 OM

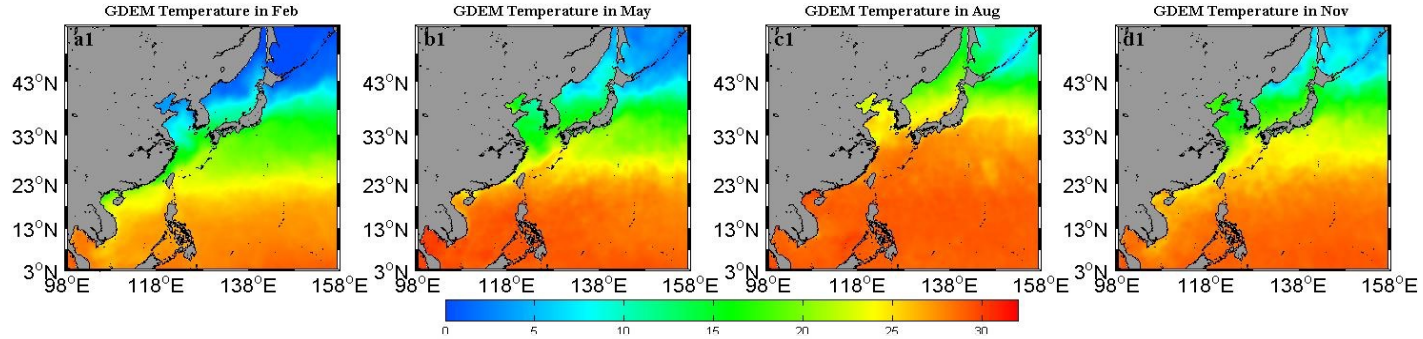
Dataset of model input

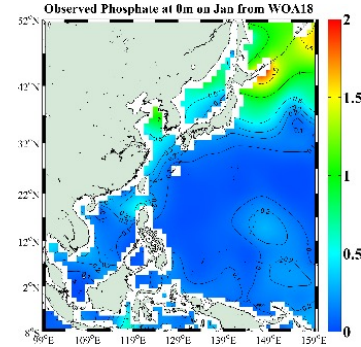
WOA18
1° ×1° ×57
Monthly average



NO_3

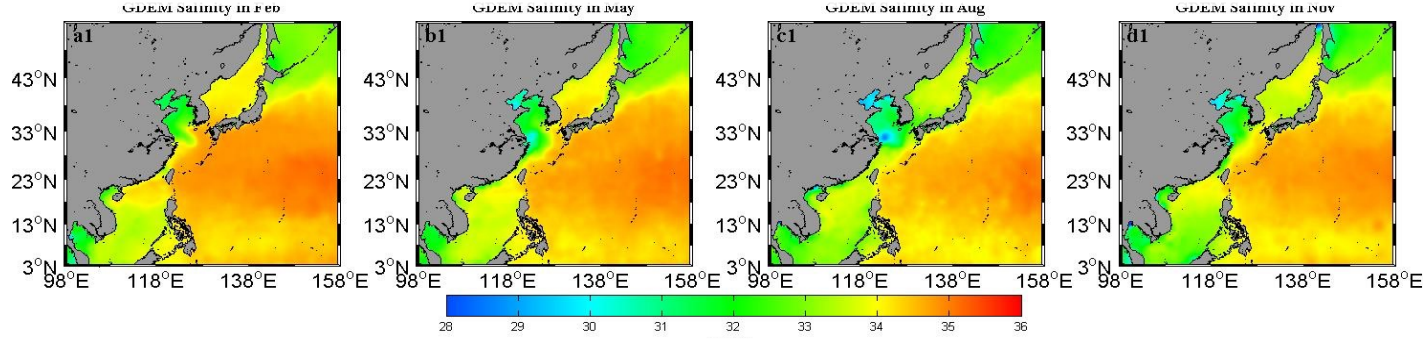
GDEM Temperature 0.25° ×0.25° ×78 Monthly Average

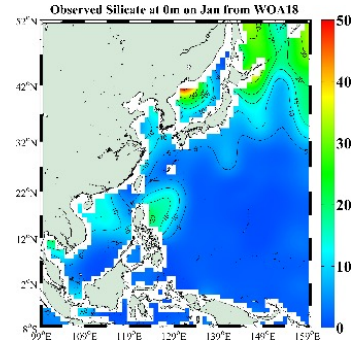




PO_4

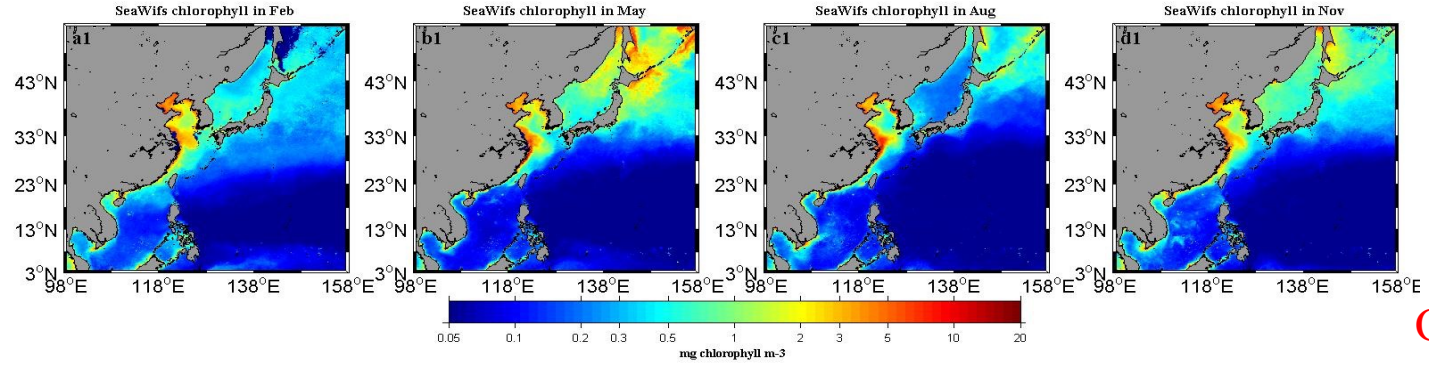
GDEM Salinity 0.25° ×0.25° ×78 Monthly Average

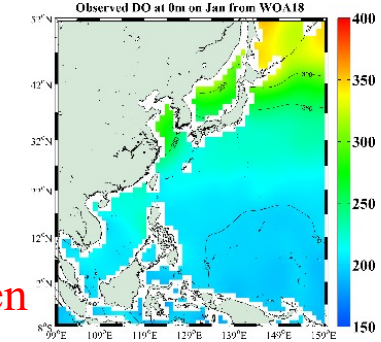




SiO_4

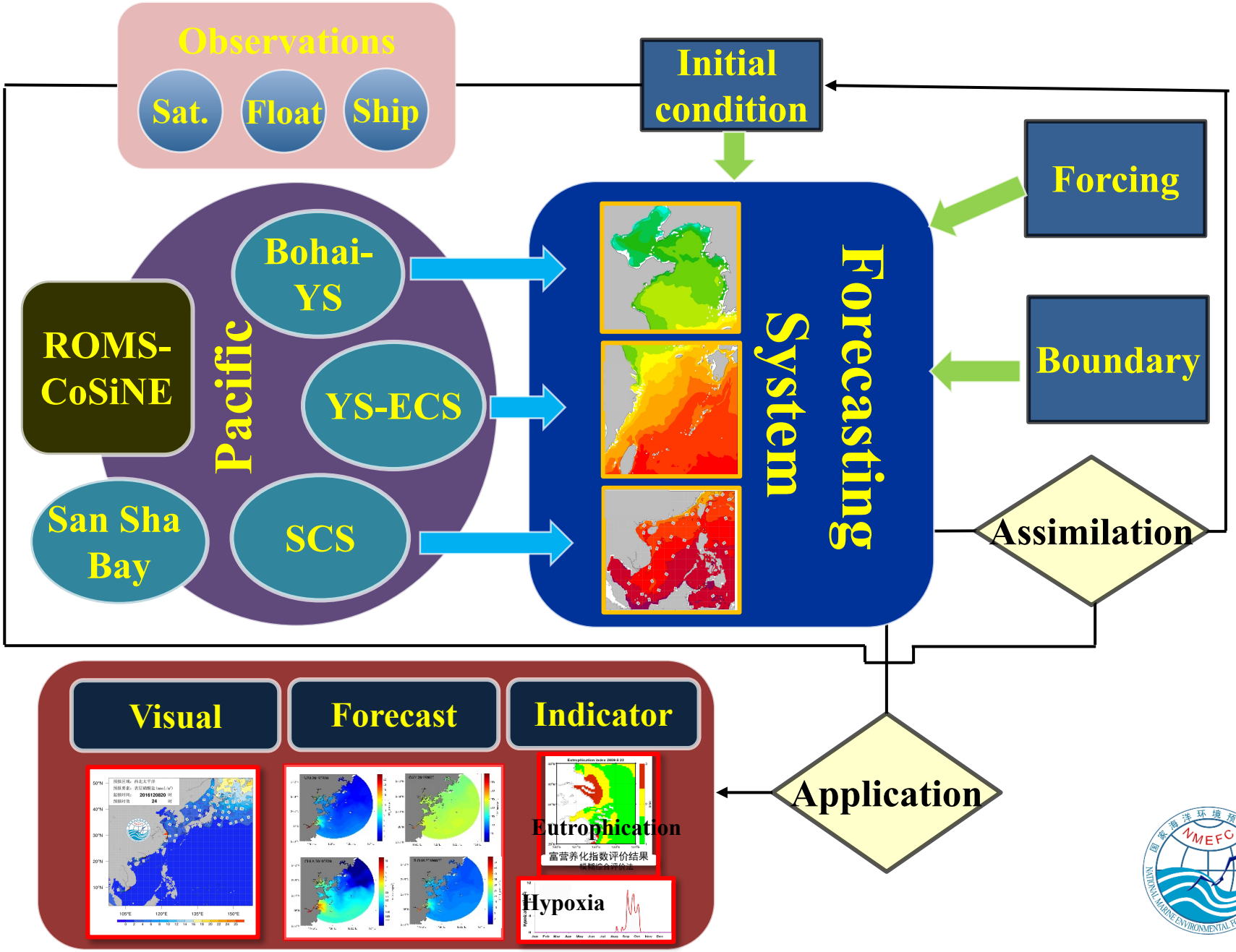
Merged satellite chlorophyll 4-9km Surface Monthly Average



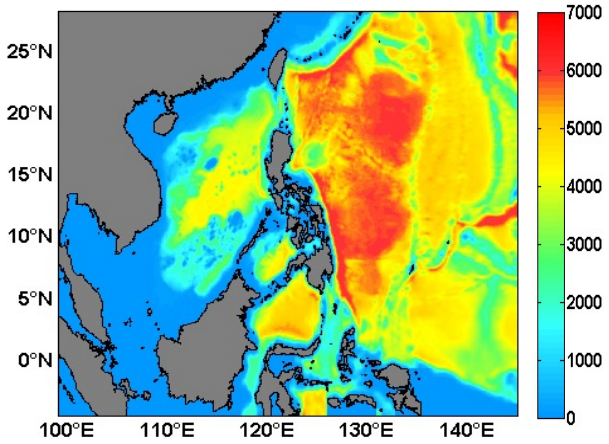


Oxygen

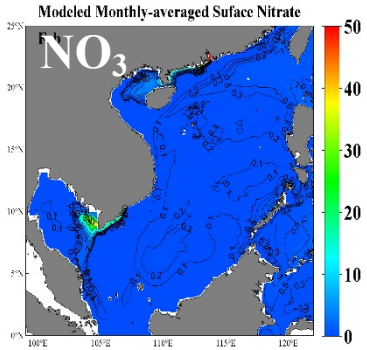
Development of operational forecasting system in Chinese Seas

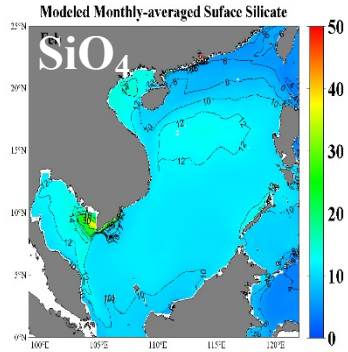


Model development in South China Sea

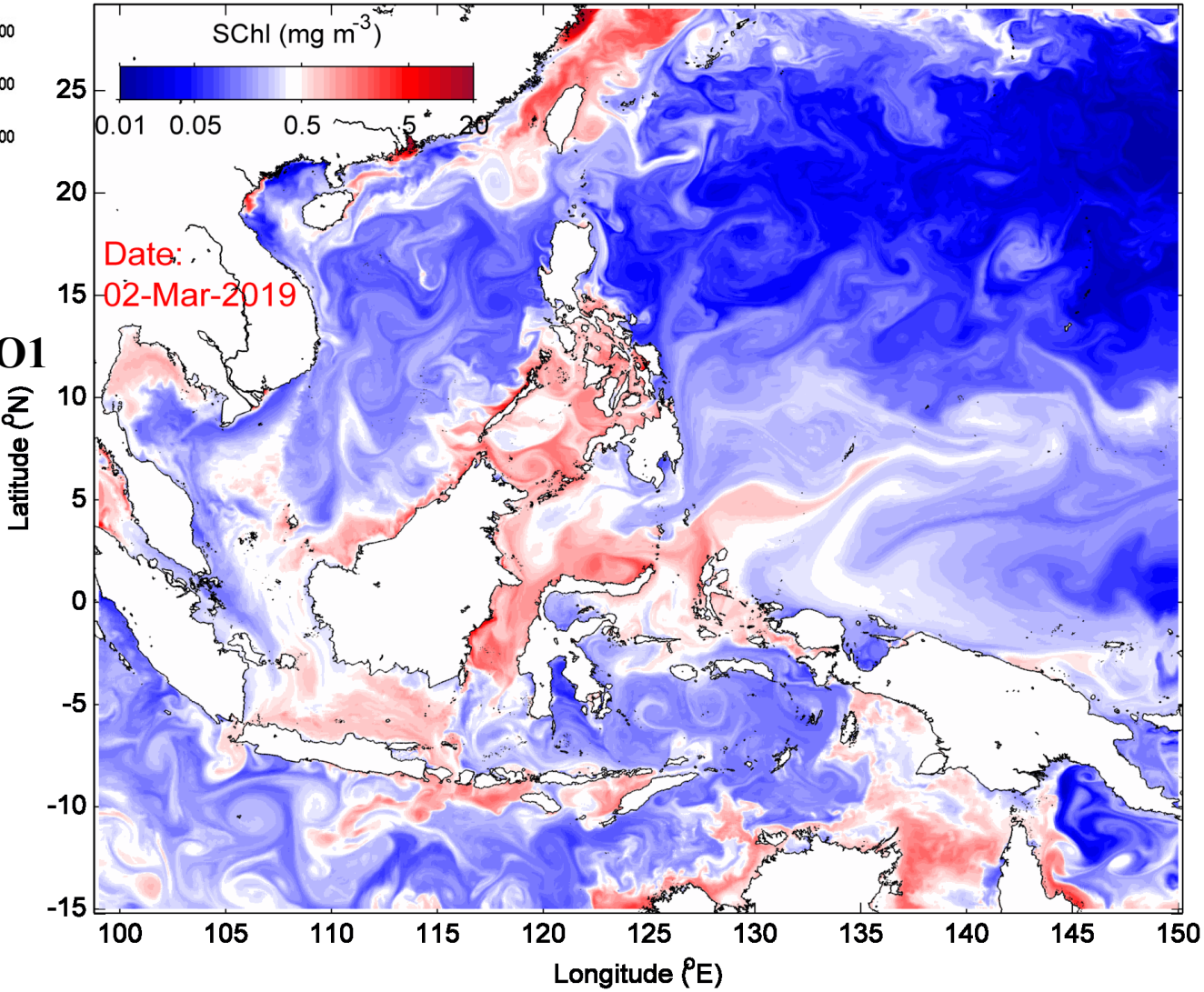


- 1/30°, 36 Layers
- Open boundary
- 6 tides: M2,S2,N2,K2,K1,O1
- Pearl, Mekong River





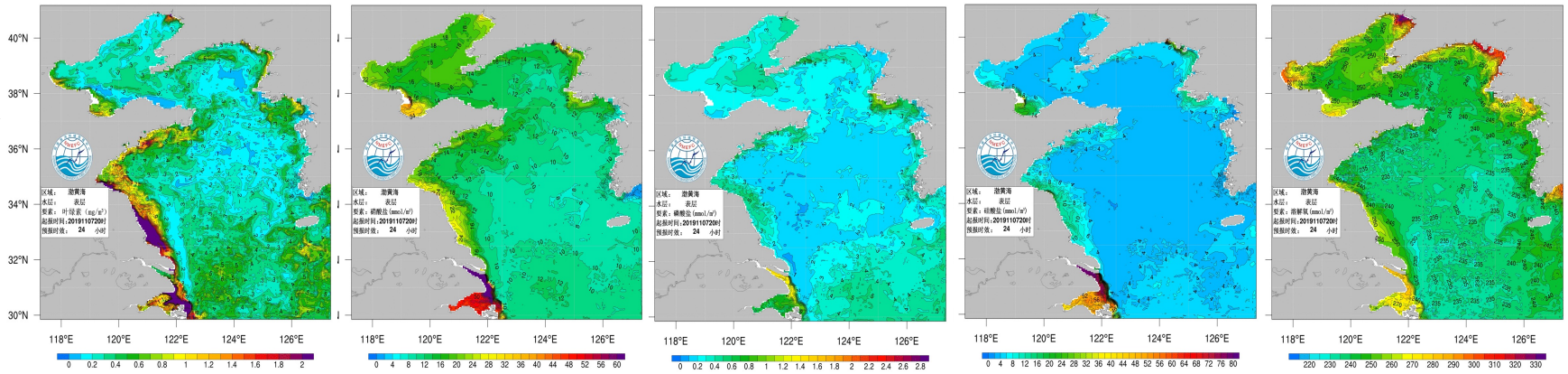
Output of Surface Chlorophyll



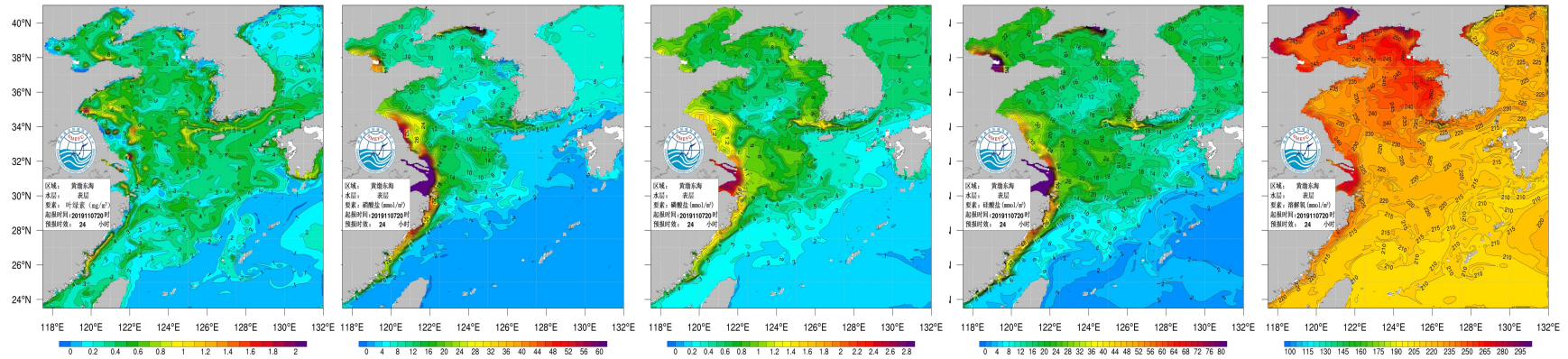
Daily forecasting products

CHL NO_3 PO_4 SiO_4 DO

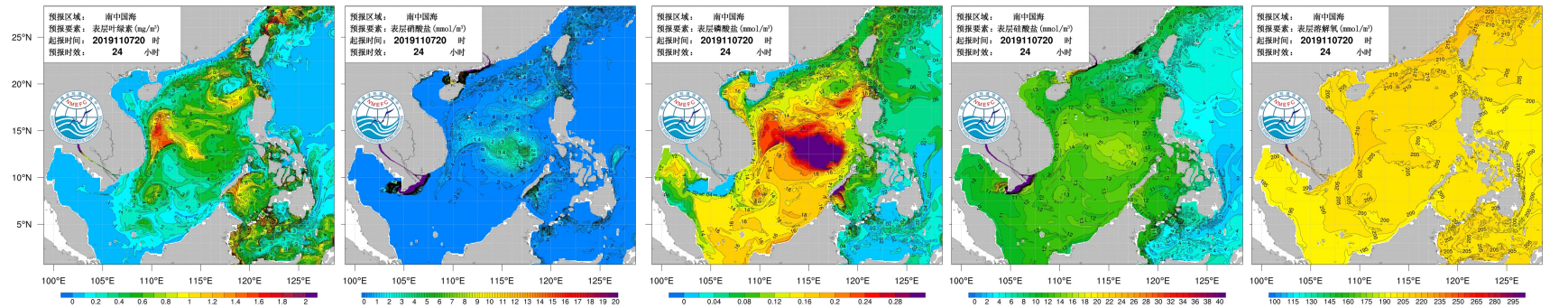
Bohai YS



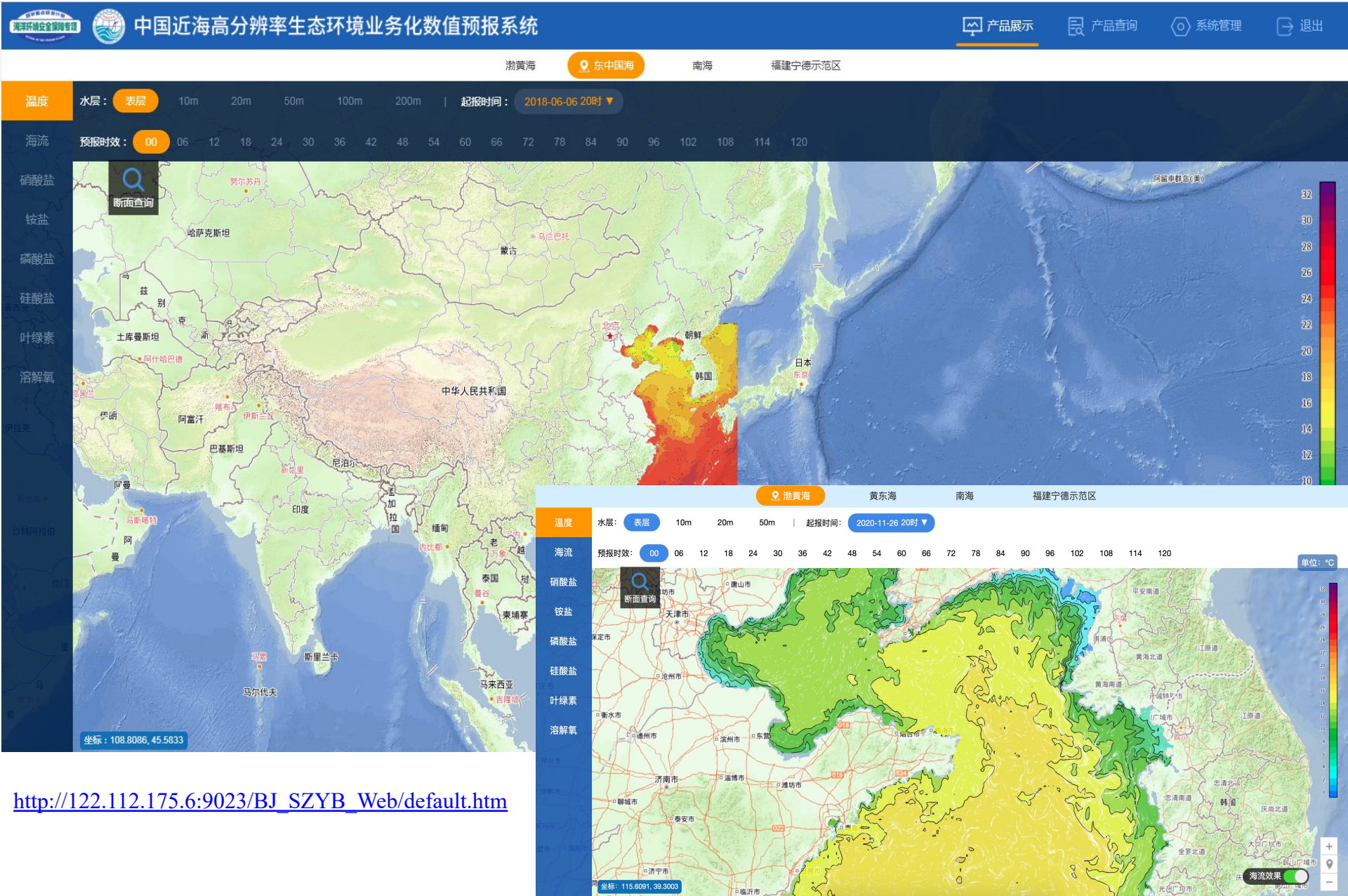
YS ECS



SCS



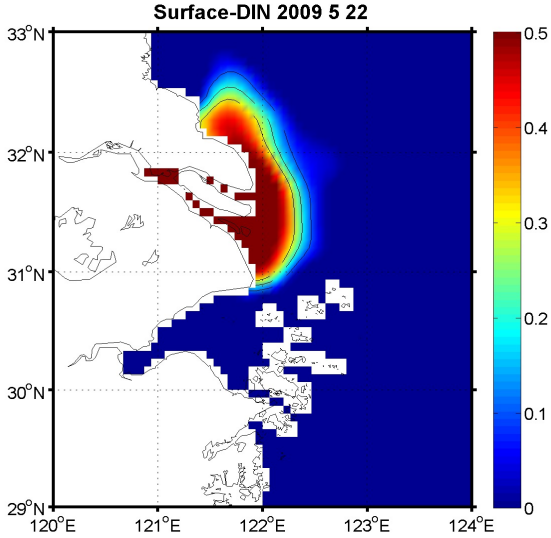
Online forecasting system



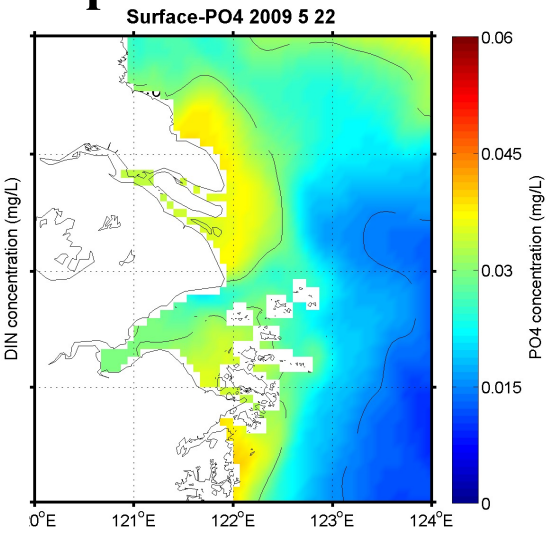
http://122.112.175.6:9023/BJ_SZYB_Web/default.htm

Application: Indicator product

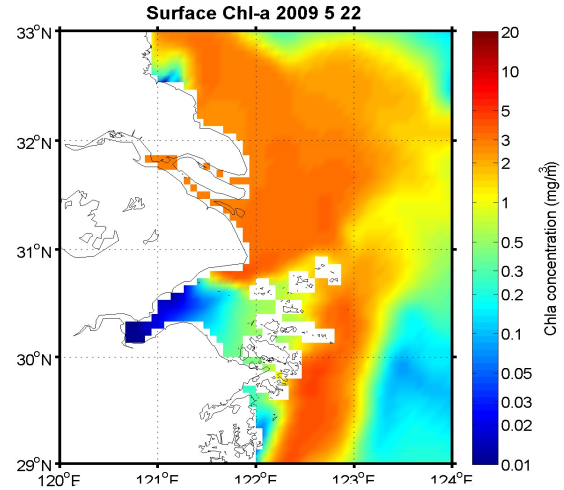
Model output



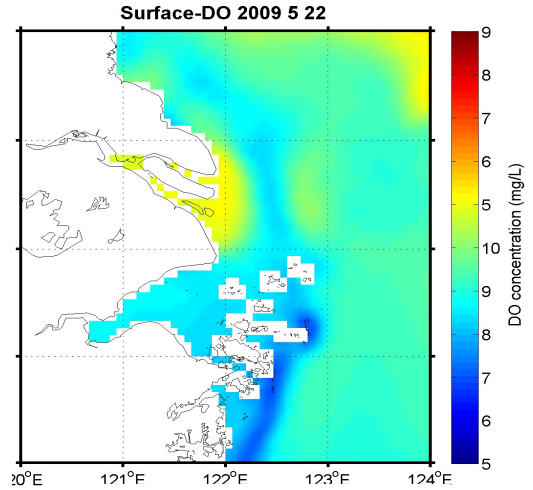
NO_3



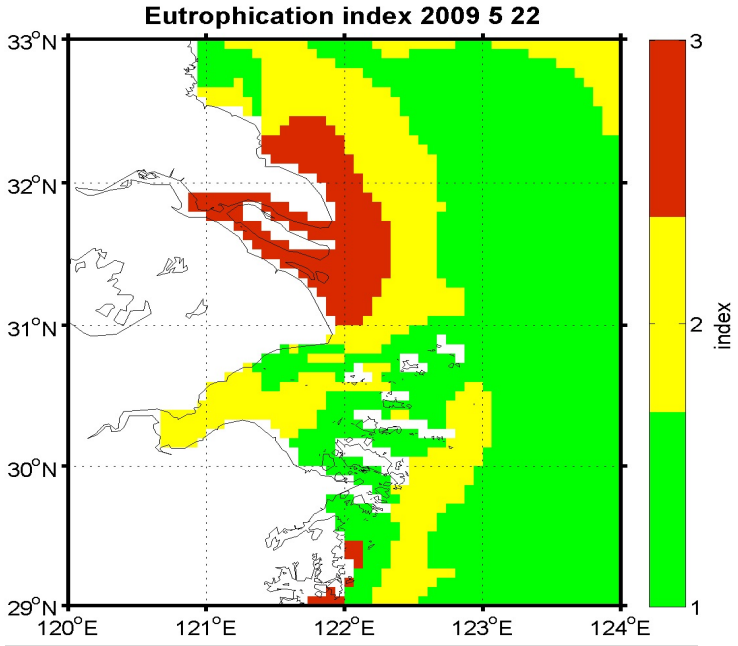
PO_4



CHL



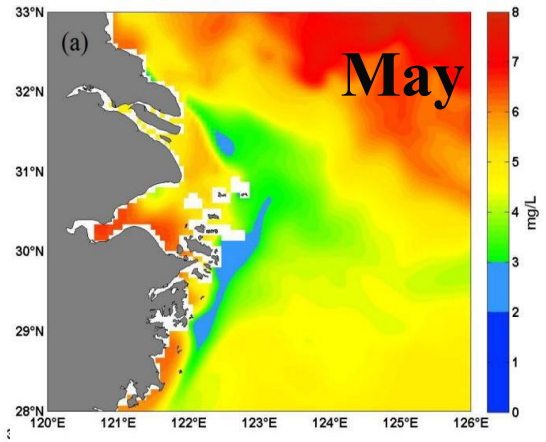
DO

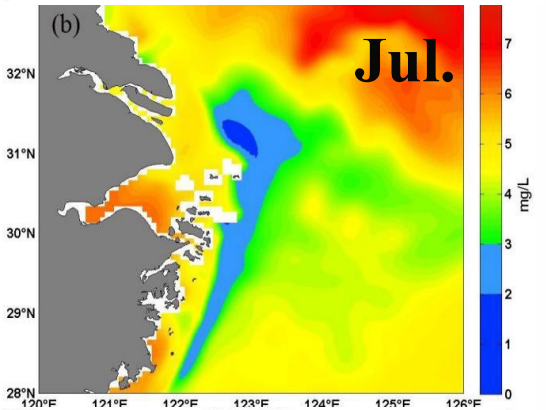


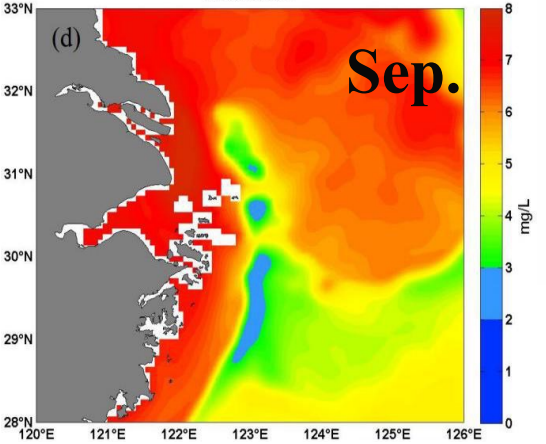
Eutrophication、Moderate、Oligotrophication

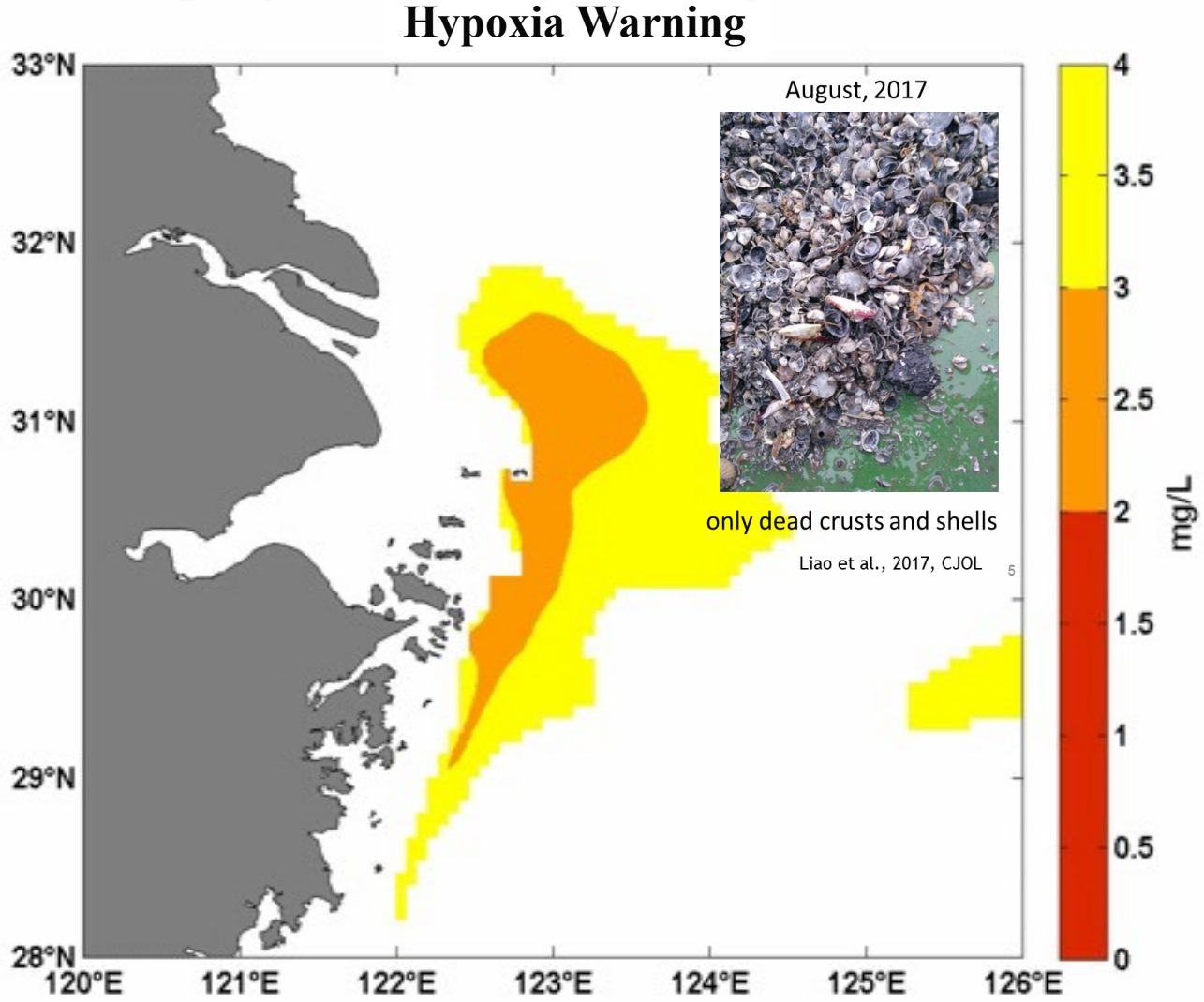
National Water Quality Report

Application: Altering system for ecosystem disaster

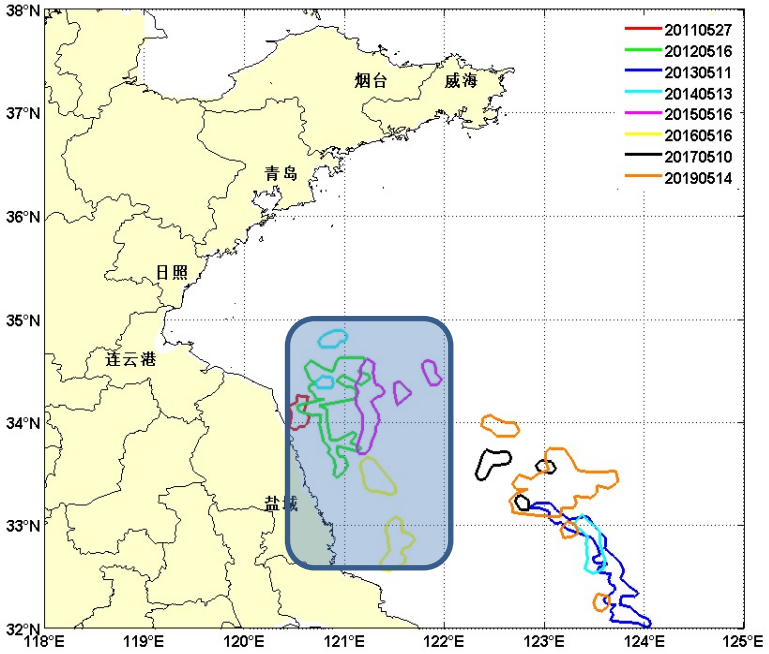


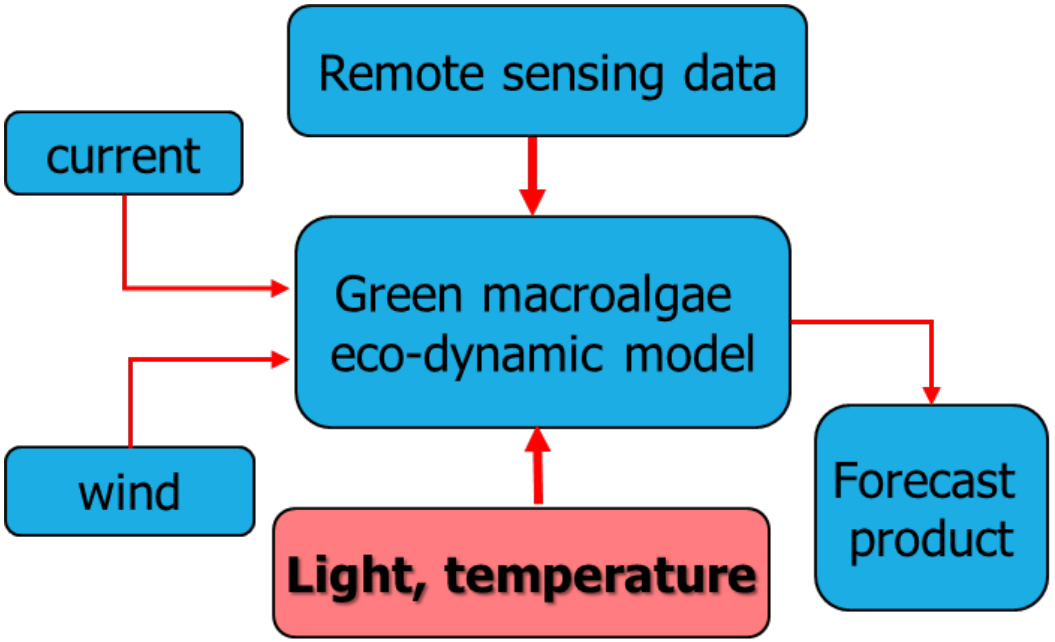


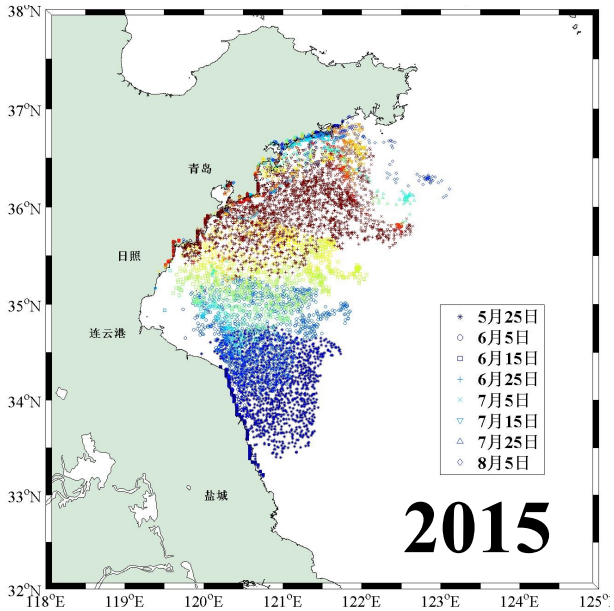


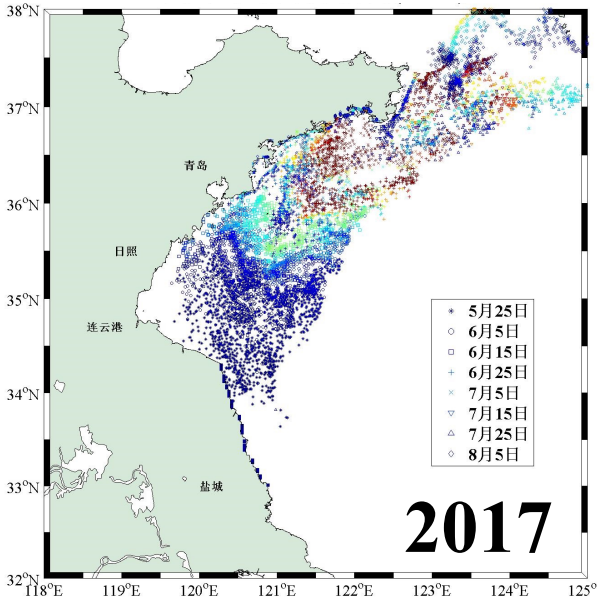


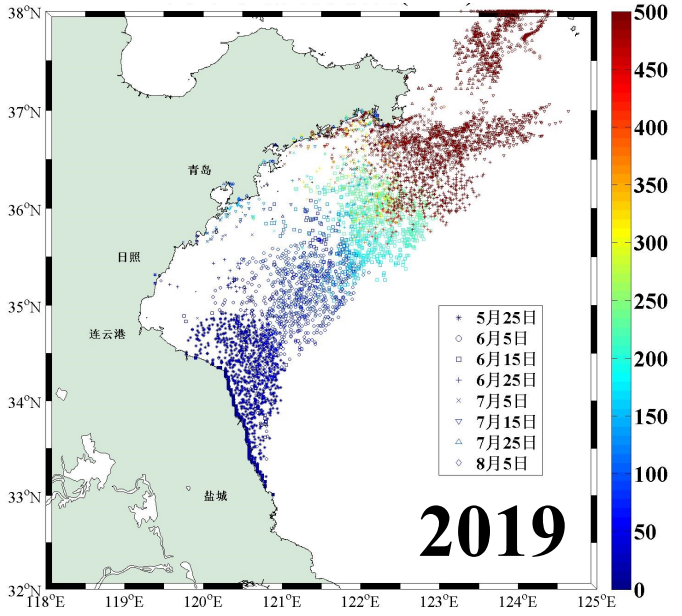
Application: Forecasting for harmful algal bloom





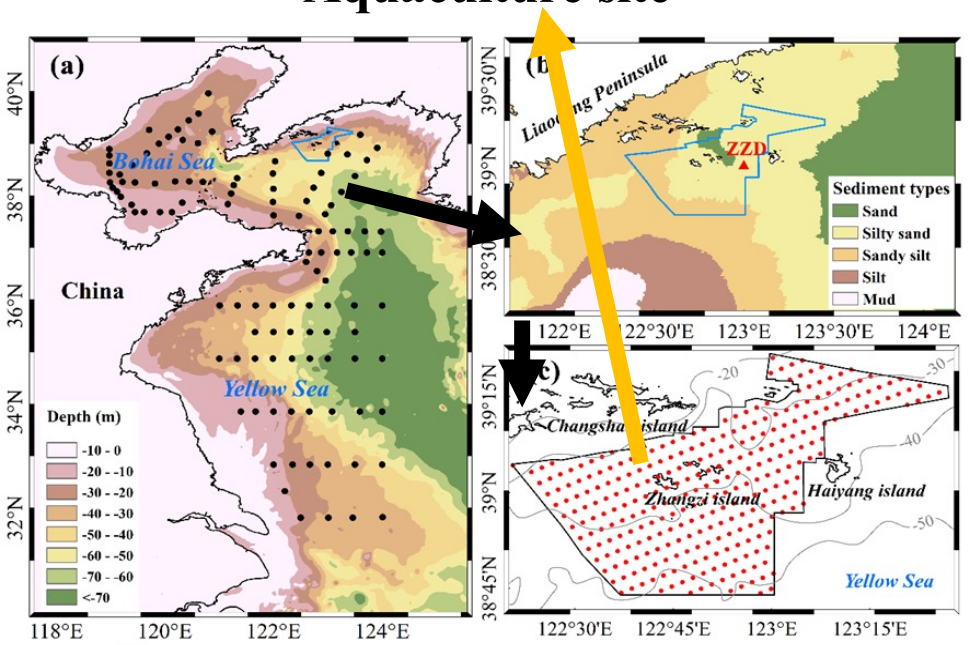




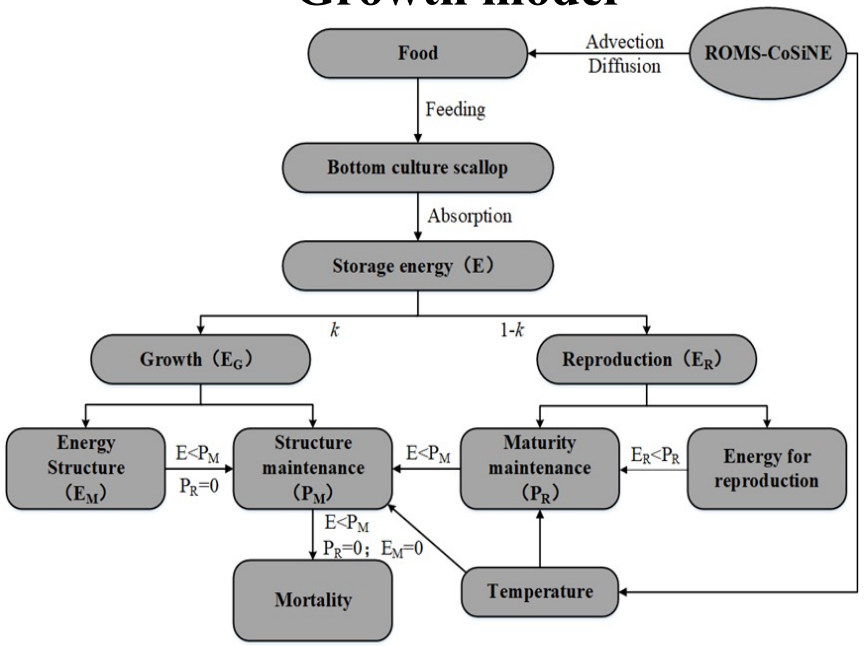


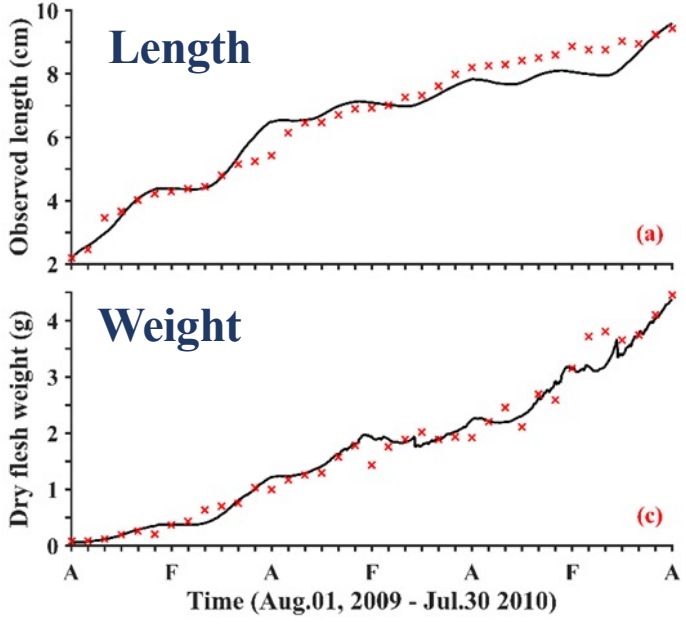
Application: Assessment for aquaculture

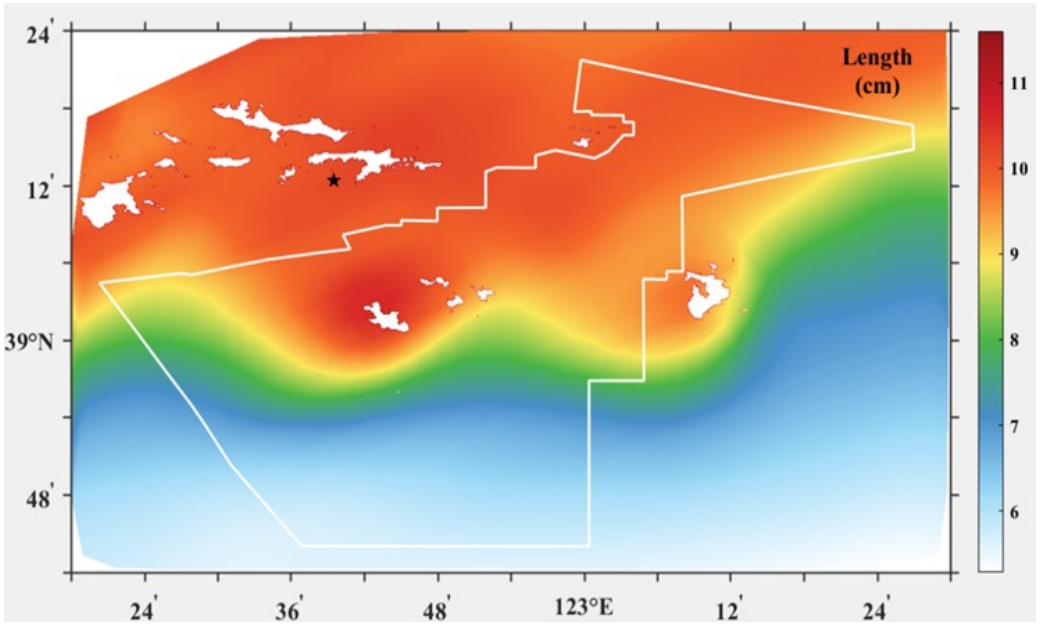
Aquaculture site



Growth model







The United Nations
Decade of Ocean Science
for Sustainable Development
(2021-2030)

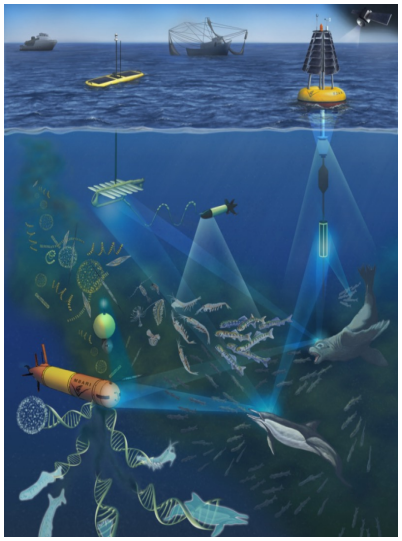
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Seven Societal Goals

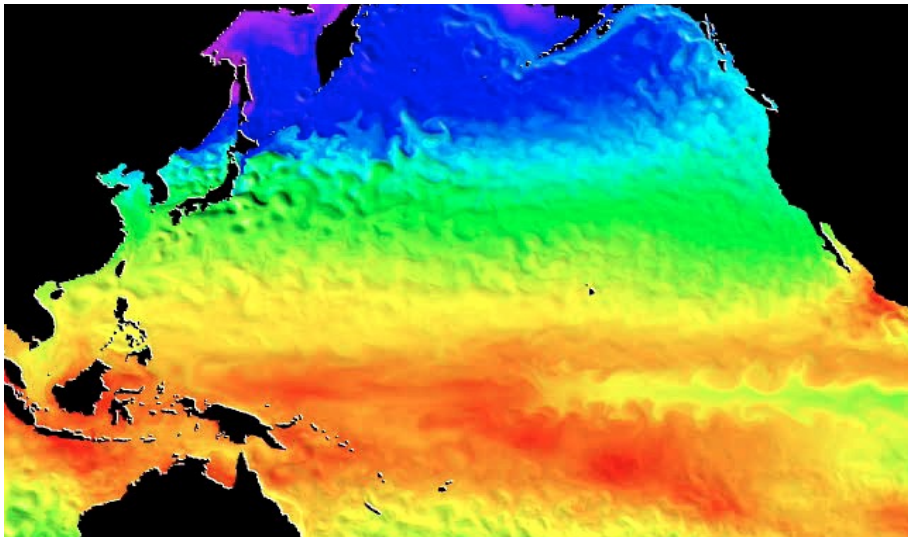
1. ***A clean ocean*** where sources of pollution are identified and removed
2. ***A healthy and resilient ocean*** where marine ecosystems are mapped and protected
3. ***A predictable ocean*** where society has capacity to understand current & future ocean conditions
4. ***A safe ocean*** where people are protected from ocean hazards
5. ***A sustainably harvested ocean*** ensuring the provision of food supply
6. ***A transparent ocean*** with open access to data, information & technologies
7. ***An inspiring and engaging ocean*** where society understands and values the ocean

Summary

Observing system



Numerical modeling



❖ Observe more

❖ Predict better

Knowing the ocean for now and future

A Sustainable Marine Ecosystem


Thank you!