Ocean color remote sensing and application in China

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国家海洋局第二海洋研究所

Ocean color remote sensing and application in China

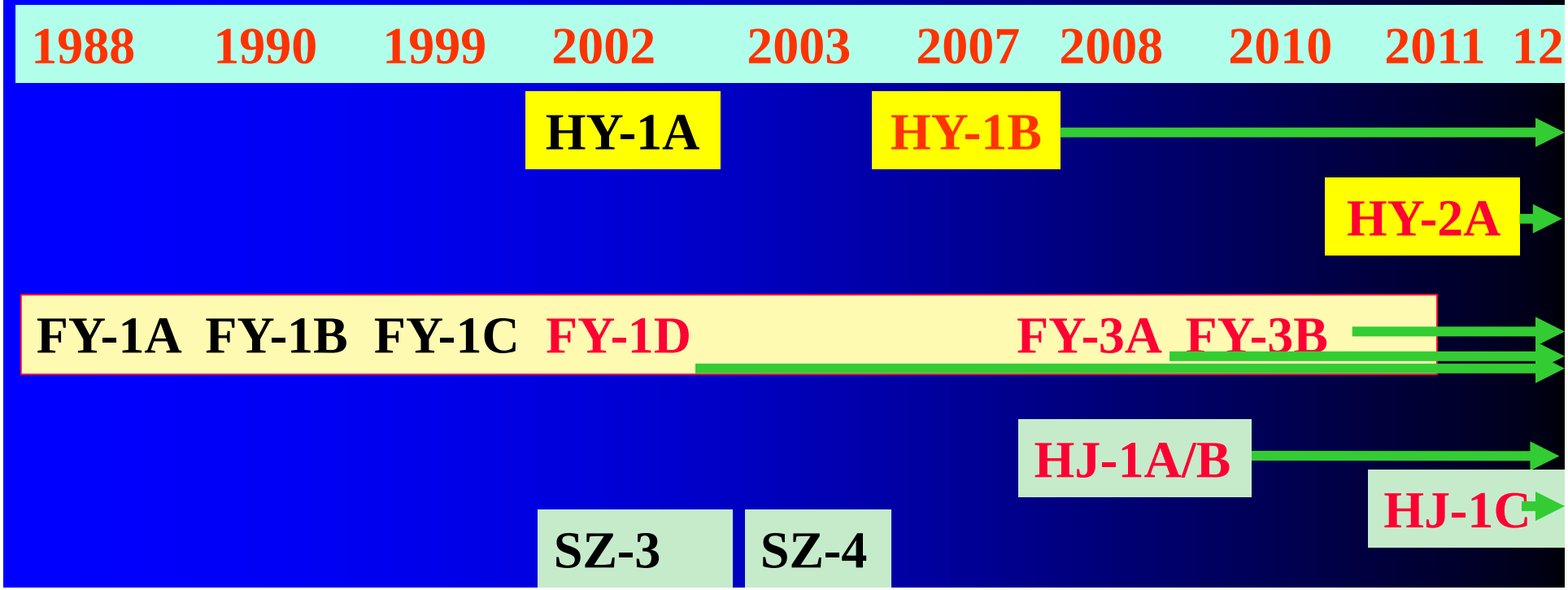
1、 Present Chinese satellite missions

2、 Future Chinese satellite missions

3 、Application of ocean color -derived sea surface pCO_2 in the ECS

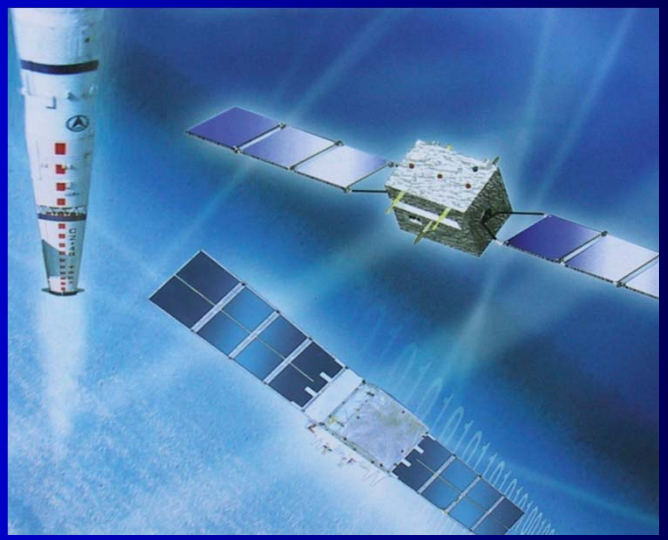
Four series of satellite for ocean color remote sensing in China

- **Ocean Observation Satellites (HaiYang,HY series)**
- **Meteorological Satellites (FengYun,FY series)**
- **Environment and Disaster Monitoring Satellites (HJ series)**
- **Spacecraft (SZ series)**



First Ocean Observation Satellite in China (HY-1A)

- China launched the first ocean satellite **HY-1A on 15 May,2002**, together with meteorological satellite FY-1D using same rocket
- HY-1A was an experimental ocean color satellite in China, and successfully operated for about two year (**2002.5-2004.4**)



HY-1B satellite

Second ocean color satellite of China, **HY-1B** was launched by Long March rocket, **in April, 2007.**

Sponsored by: State Oceanic Administration, (SOA) **Manufacturer**: the Chinese Academy of Space Technology (CAST)

HY-1B Satellite and orbit characteristics

Orbit type	Near Circular and near sun-synchronous
Equator crossing local time	10:30±30 min (descending node)
Altitude	798km
Inclination	98.8 deg
Period	100.8 minute
Repeat observation period	1days for COCTS, 7days for CZI
Mass	<400kg
Payload	COCTS and CZI
Attitude control	3 axis stabilized
Downlink frequency	X-band
TT&C link	S-band
Designed life time	3 years
Launch	2007 by using Long March 4
Manufacturer	CAST

HY-1A/B Sensors

1. COCTS- Chinese Ocean Color and Temperature Scanner (Ten bands)

2. CZI- Coastal Zone Imager (4 bands CCD Cameral)

Difference between HY-1B and HY-1A

1 . The Equator cross time delays from **8:35 am to 10:00 am**, in order to enhance the water leaving radiance.

2 . Enlarging field of view of COCTS from **90^{o} to 114^{o}**, so the coverage period reduce from **three days to one day**

3 . The oversea data storage capacity increases from **80MB to 250MB.**

4 . The COCTS band width are moved from **730-770nm to 740-760nm, for better atmospheric correction.**

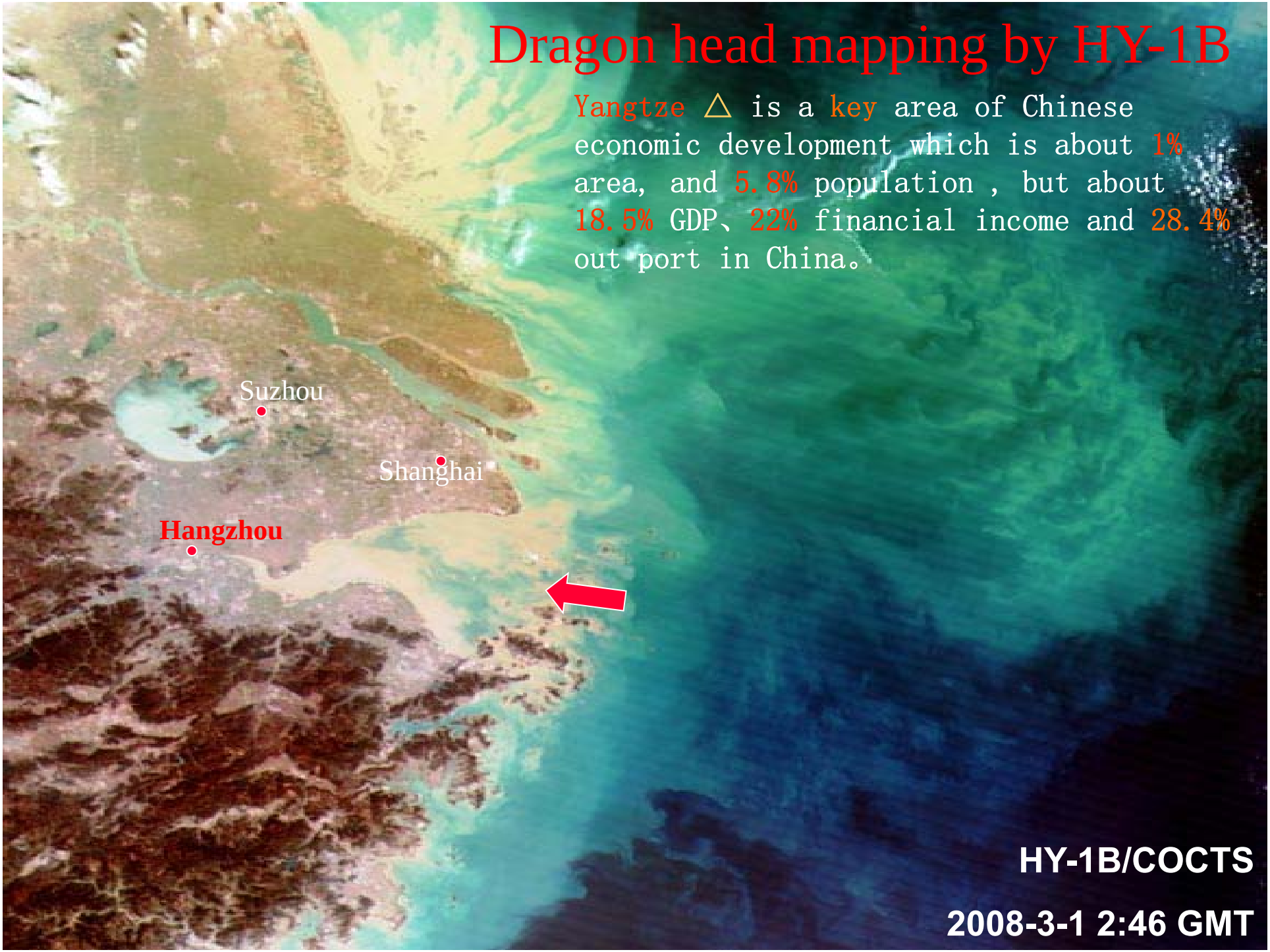
5. The CZI band's width are **narrow** to meet the requirements of ocean color inversion.

Major parameters of COCTS and CZI

Parameter	COCTS	CZI
Spatial resolution	1.1km	0.25km
Scan coverage	2900km	500km
Polarization sensitivity	5%	5%
Digitization	10bit/pixel	12bit/pixel
Pixels/Scan Line	1664	2048
Radiometer accuracy	10%	10%

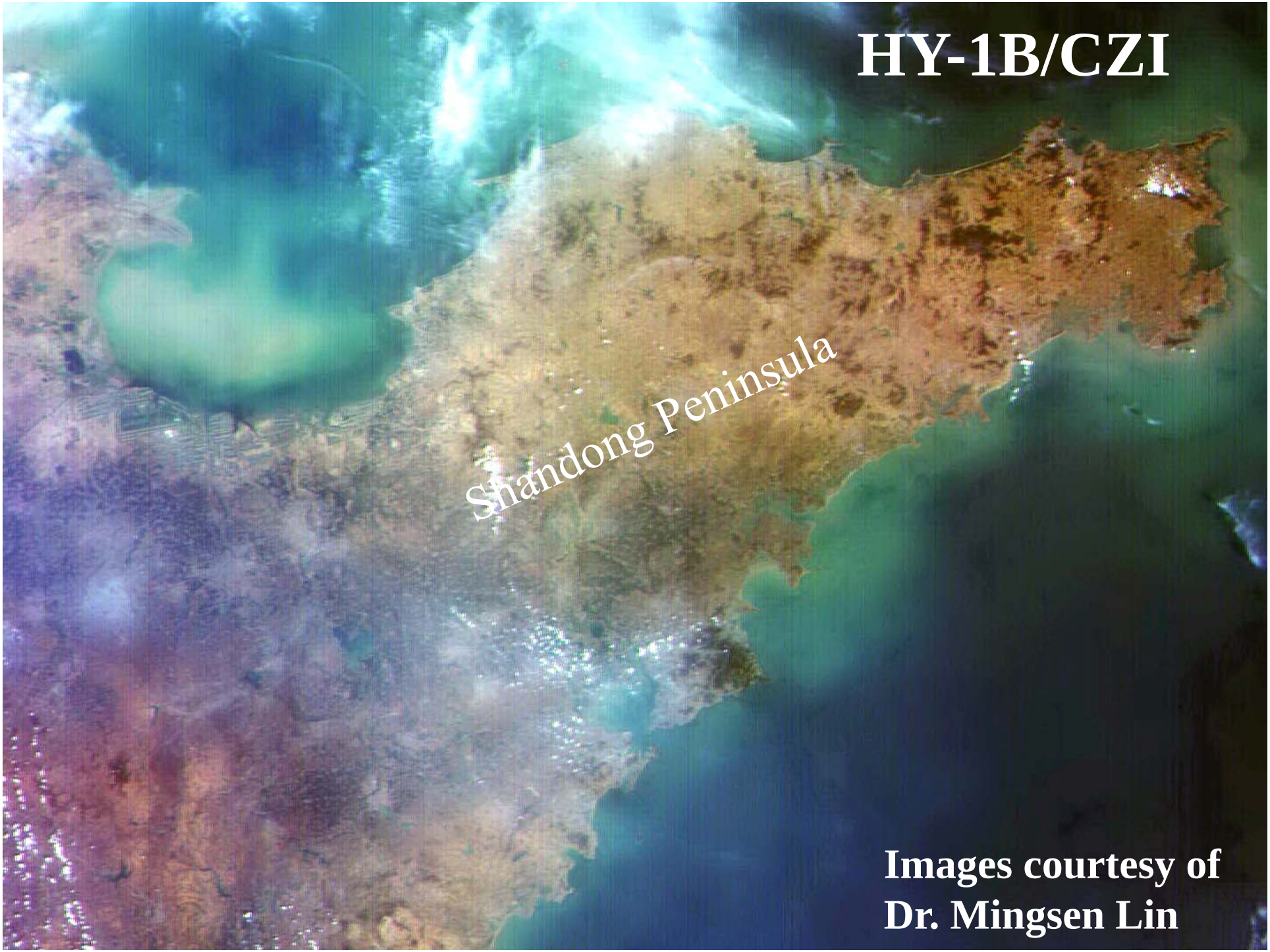
COCTS bands and detecting object

	Band (micro m)	Main detecting object
	0.402～0.422	Yellow substance、water pollution
	0.433～0.453	Chlorophyll absorption
	0.480～0.500	Chlorophyll、sea ice、pollutant
	0.510～0.530	Chlorophyll、water depth、pollutant、suspended sediment
	0.555～0.575	Chlorophyll、vegetation、sand
	0.660～0.680	Fluorescence、suspended sediment、atmospheric correction、aerosol
HY-1B	0.740～0.760	Suspended sediment、atmospheric correction、vegetation
HY-1A	0.730～0.770	
	0.845～0.885	Atmospheric correction、water vapor
	10.30～11.40	Surface temperature
	11.40～12.50	Surface temperature


Dragon head mapping by HY-1B
Yangtze △ is a key area of Chinese economic development which is about 1% area, and 5.8% population , but about 18.5% GDP、22% financial income and 28.4% out port in China。
Suzhou
Shanghai
Hangzhou
HY-1B/COCTS
2008-3-1 2:46 GMT

CZI bands and detection object

	Wavelength(μm)	Target
HY-1B HY-1A	0.433~0.453 (0.42~0.50)	pollution， vegetation, ocean, color ice, shallow sea topography
	0.555~0.575 (0.52~0.60)	Sediment, pollution, vegetation ice , coast zone
	0.655~0.675 (0.61~0.69)	Sediment, soil ,water vapor
	0.675~0.695 (0.76~0.89)	soil ,water vapor , atmospheric correction


HY-1B/CZI
Shandong Peninsula
Images courtesy of
Dr. Mingsen Lin

HY-1B SATELLITE GROUND STATION

(1)Beijing (NSOAS/SOA)
(2)Hangzhou (SIO/SOA)

Receive raw data in real time acquiring, processing, archiving and managing, distributing, applying and analyzing the HY-1 mission

(3) SanYa, NSOAS/SOA

Receive raw data in real time and transfer to Beijing

(4) Mudanjiang (under construction)

Mudangjian

Beijing

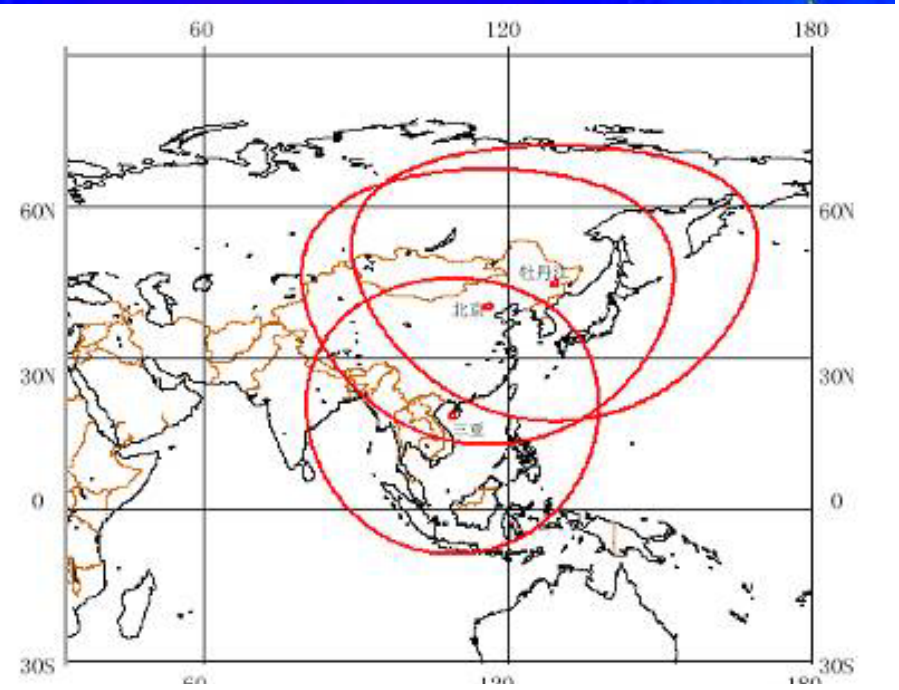
Hangzhou

海洋二所站

SanYa

Receiving Coverage of HY-1 Satellites Ground Stations

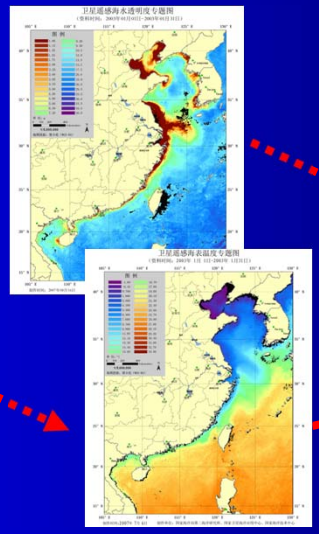
HY-1B卫星地面站接收区域



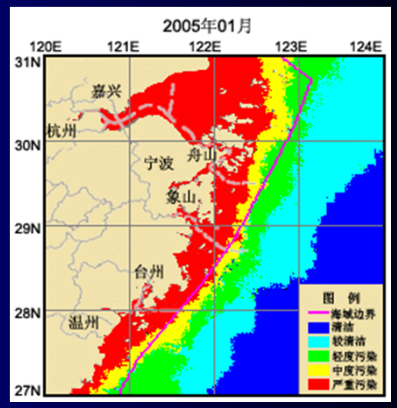
HY-1B data receiving and processing in Hangzhou SIO/SOA station

Data Receiving

Data Processing



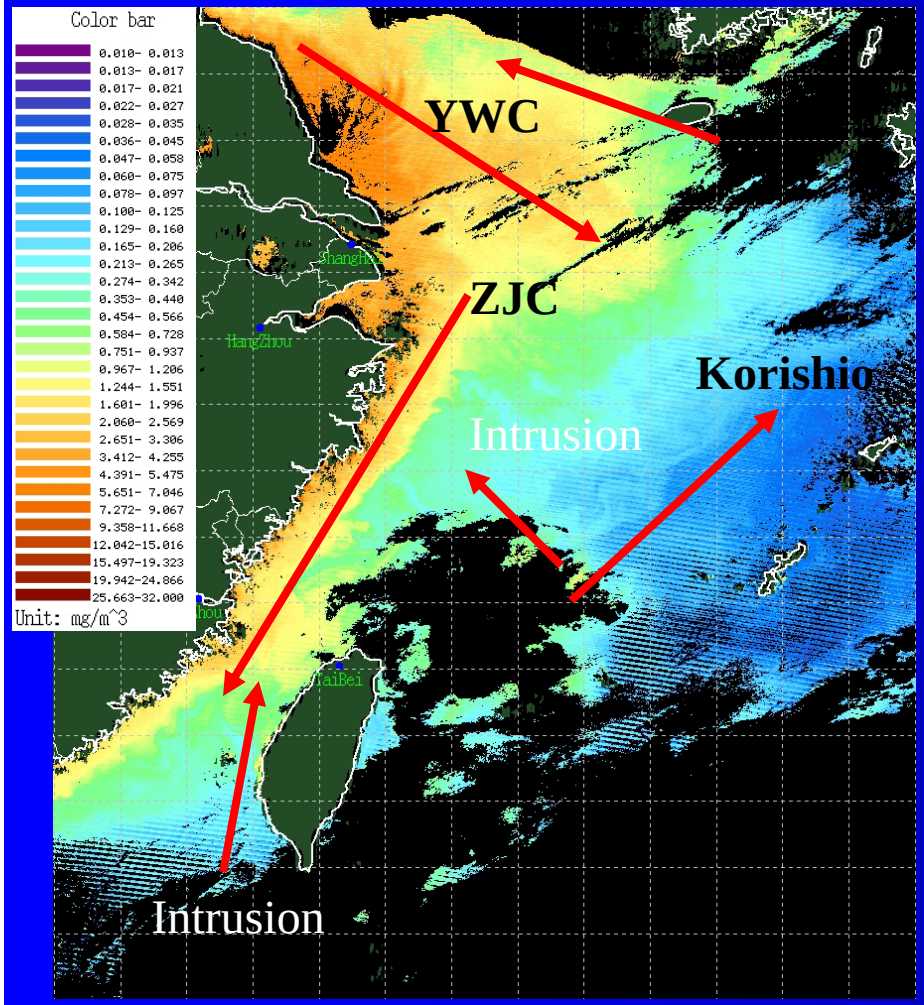
Basic OC and temperature Products



Data Application

2008-3-2 02:19 GMT

Chl_a concentration



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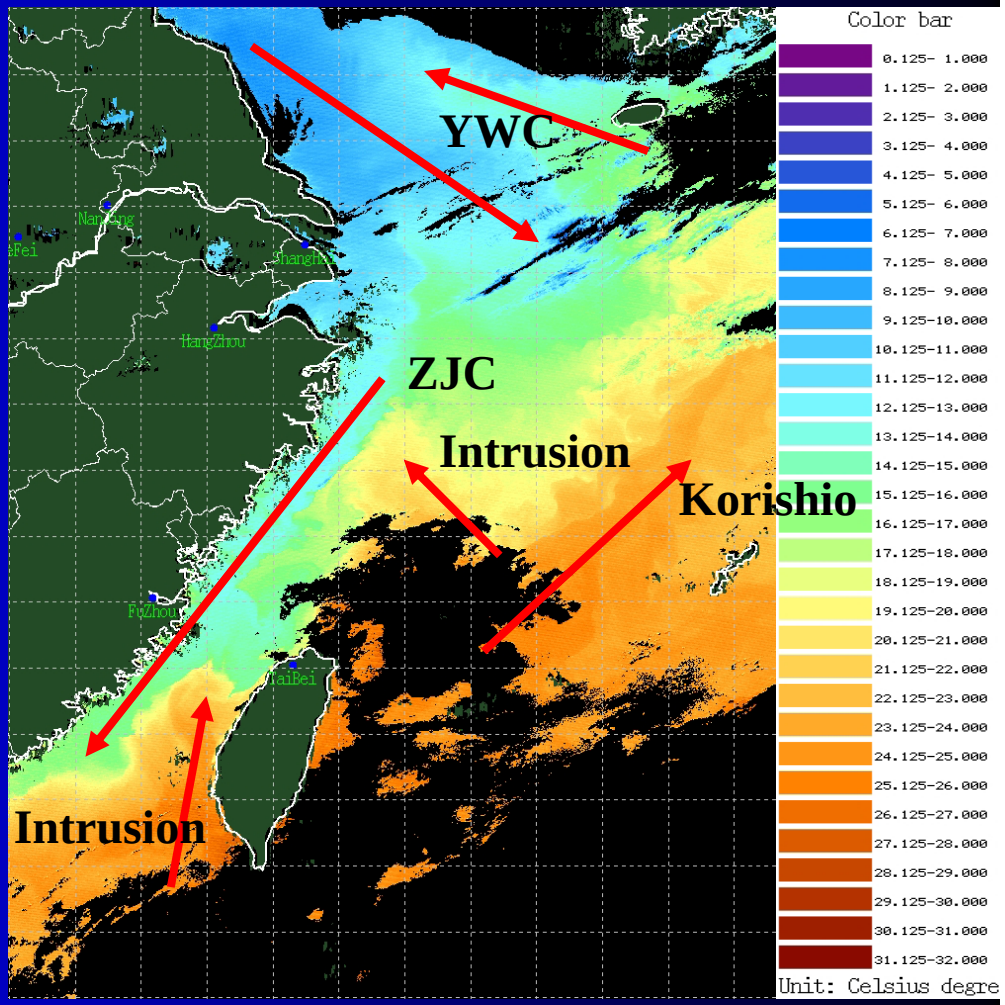

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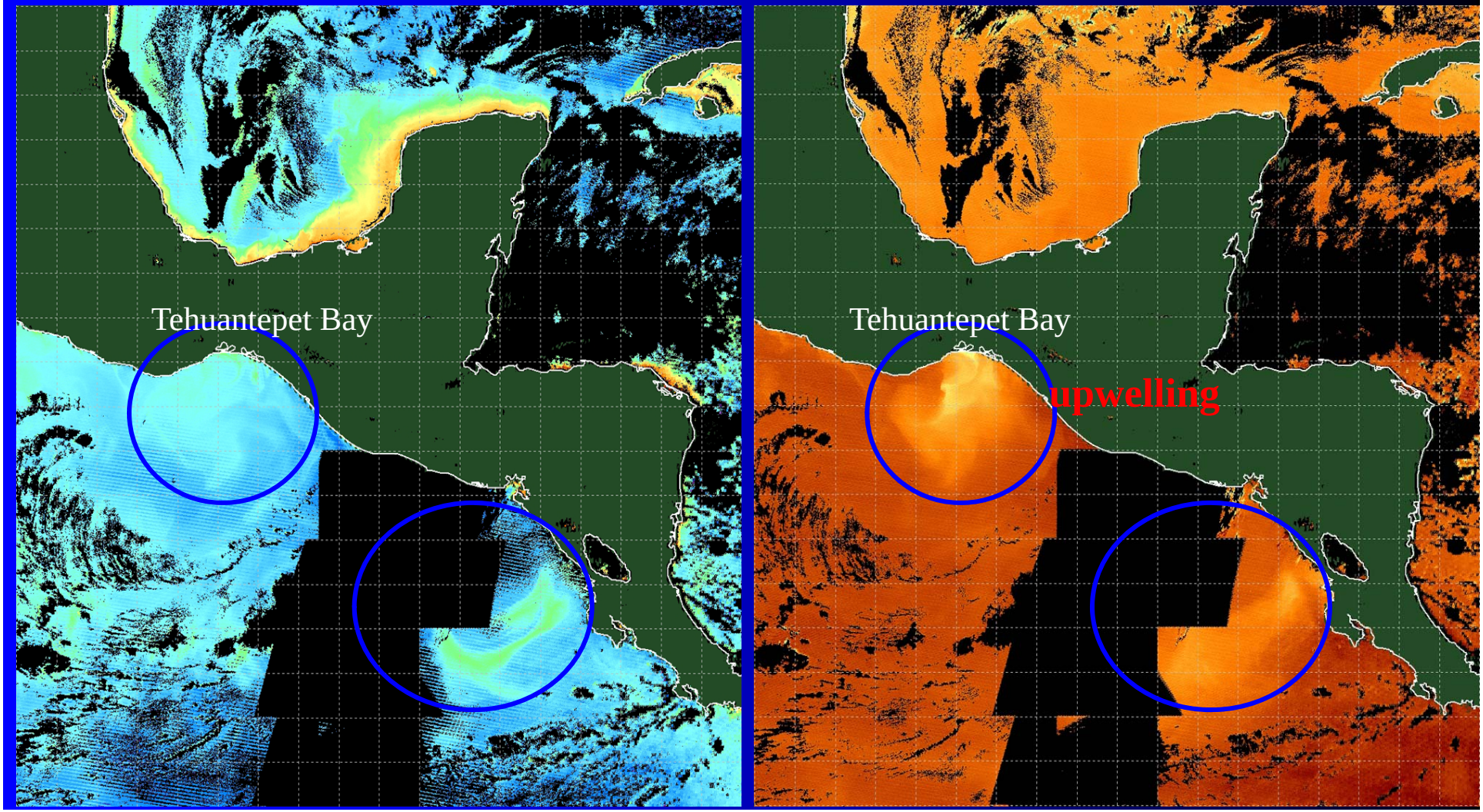
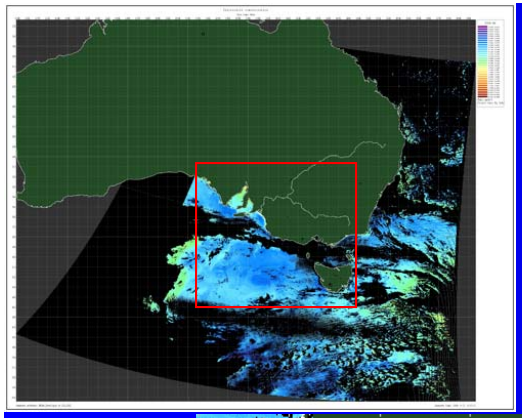
Chl_a concentration ***SST***





Chlorophyll concentration
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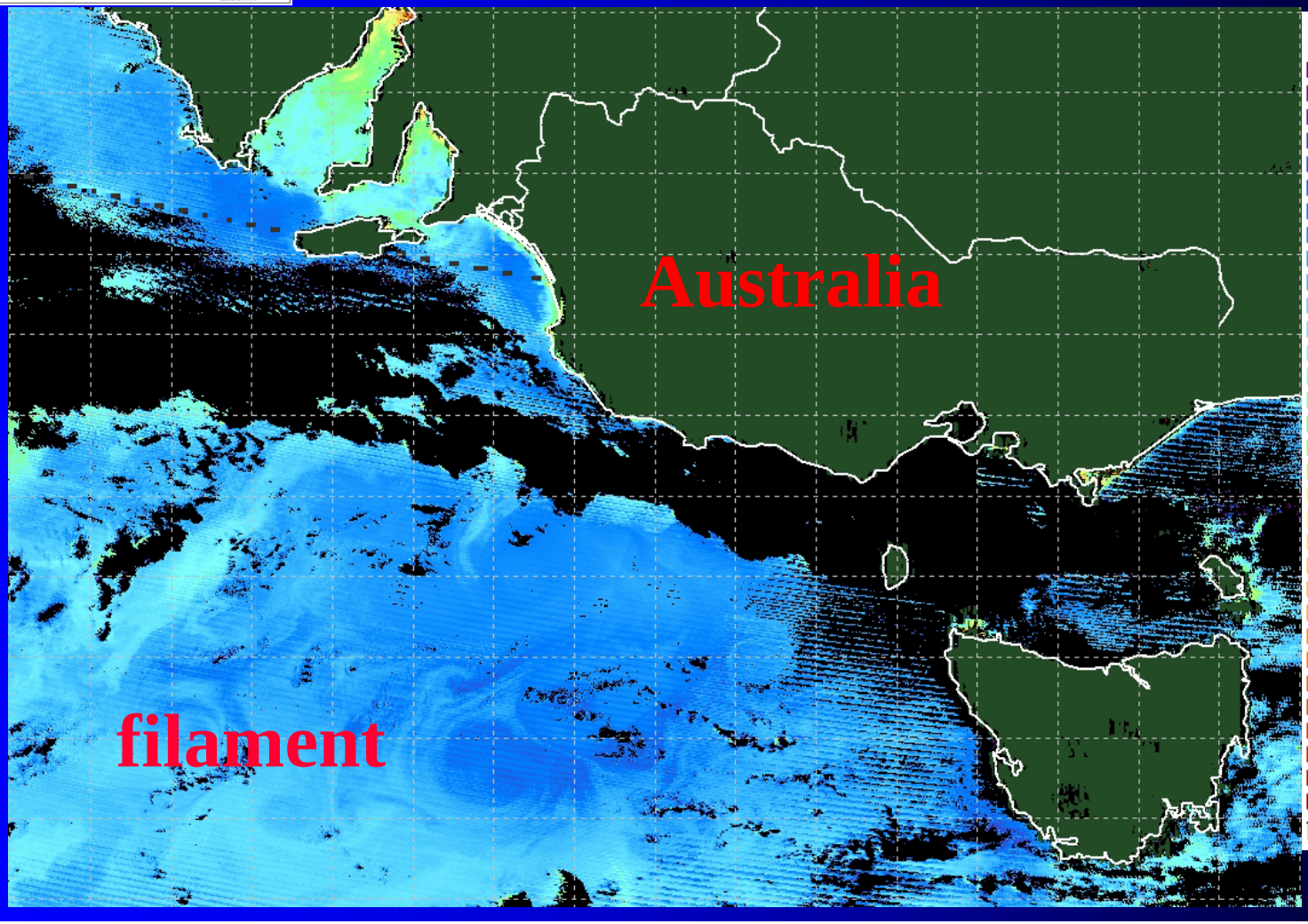
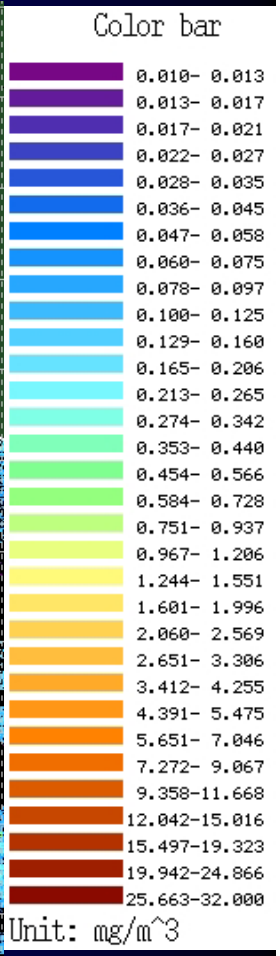
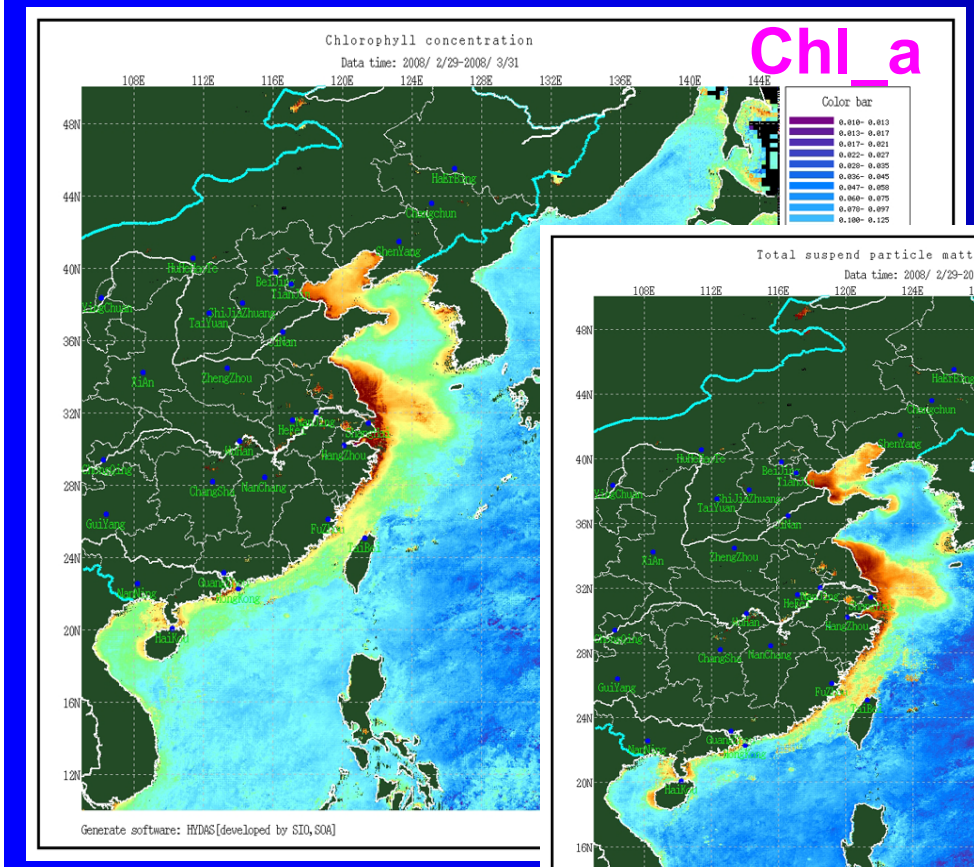
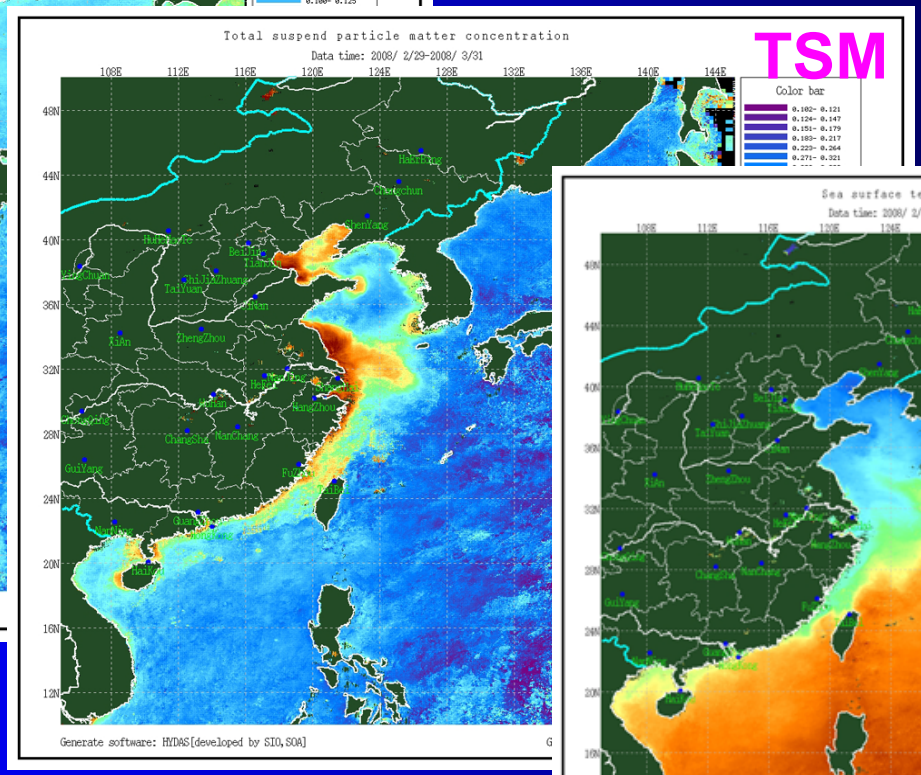




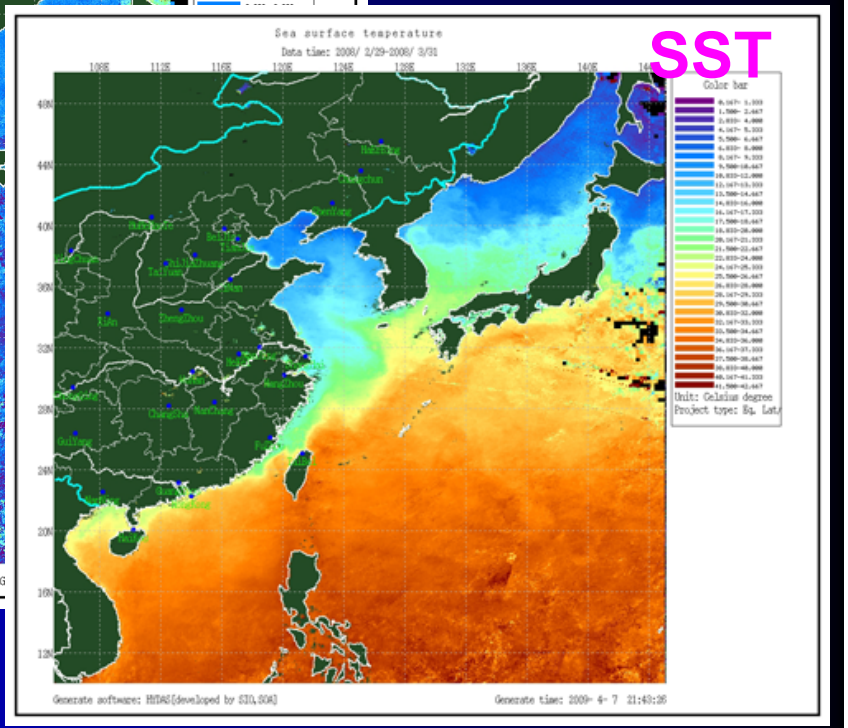
HY-1B/COCTS
Monthly averaged products(2008-3)



Chl_a

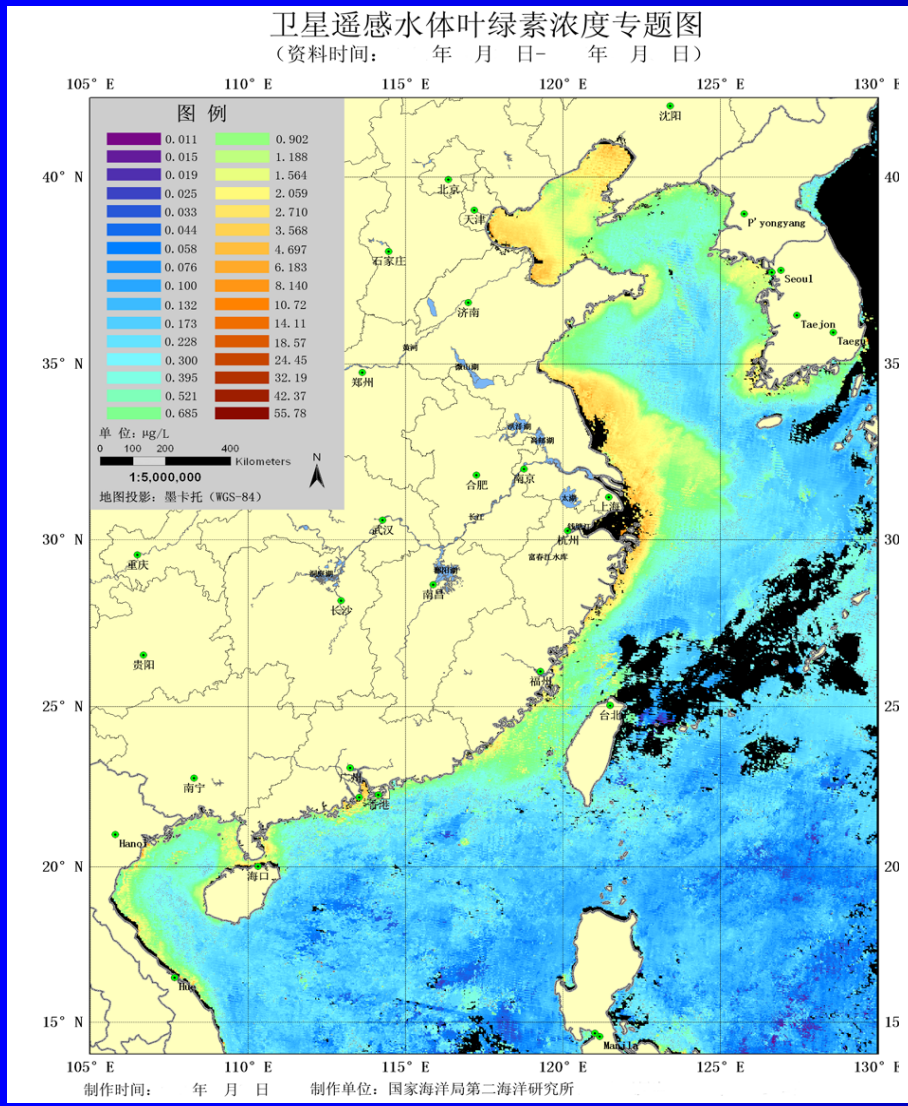


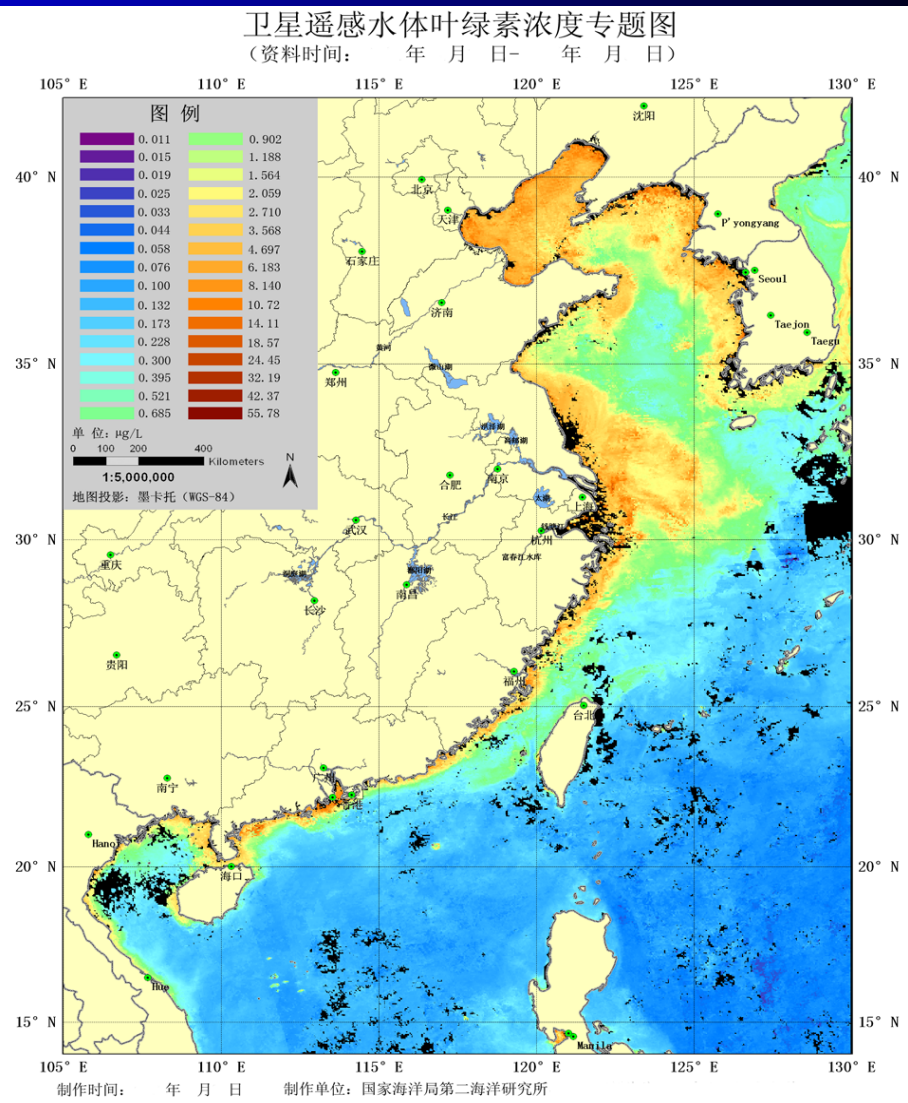
TSM



SST

Comparing of HY-1B/COCTS and Aqua/MODIS (Chl_a)

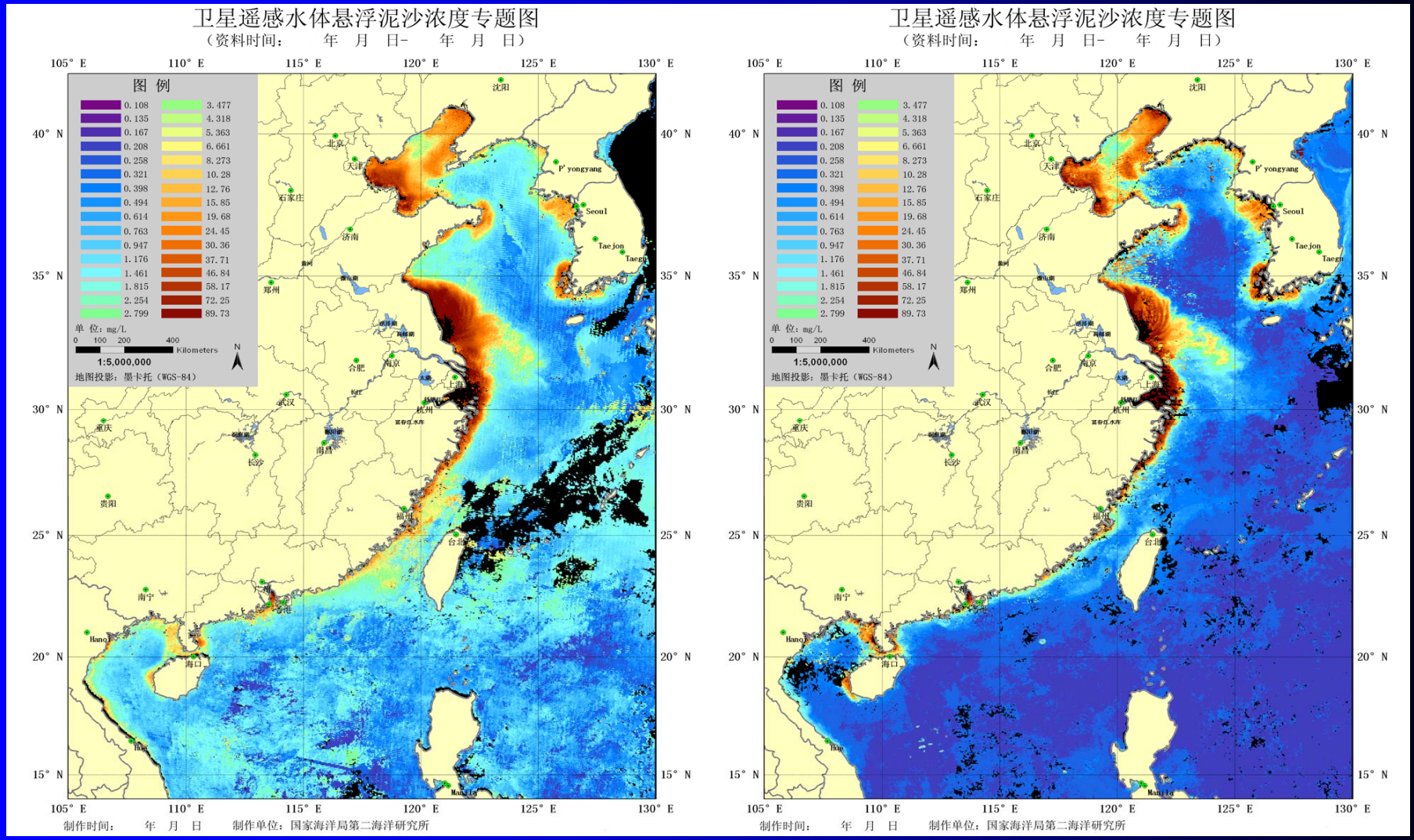




May, HY-1B/COCTS

May, Aqua/MODIS

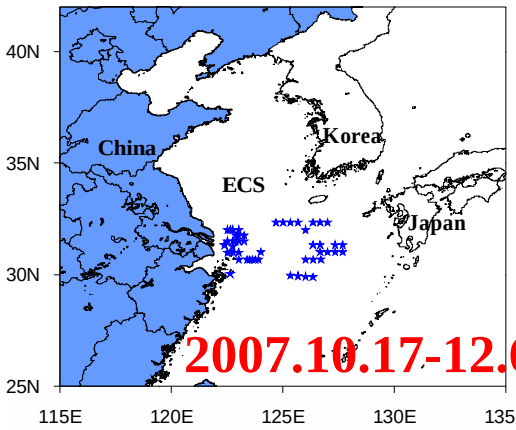
Comparing of HY-1B/COCTS and Aqua/MODIS (TSM)

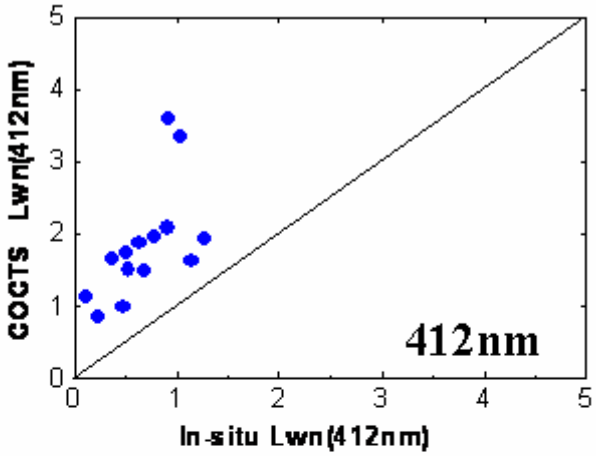


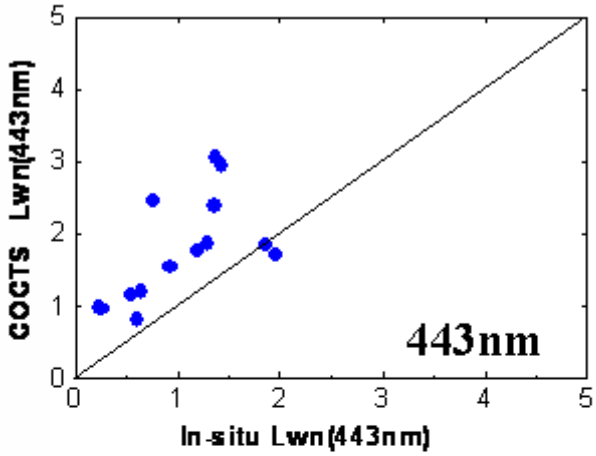
May, HY-1B/COCTS

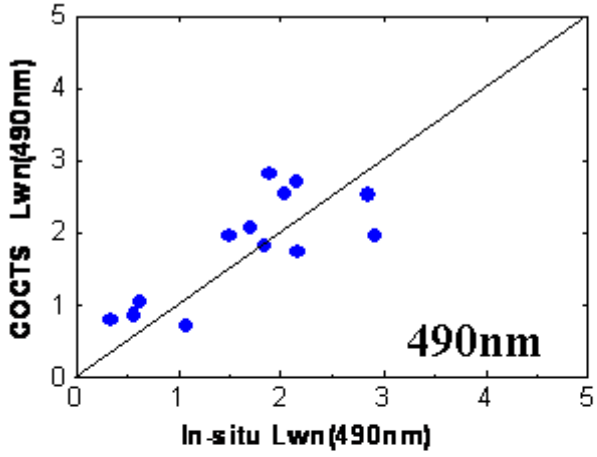
May, Aqua/MODIS

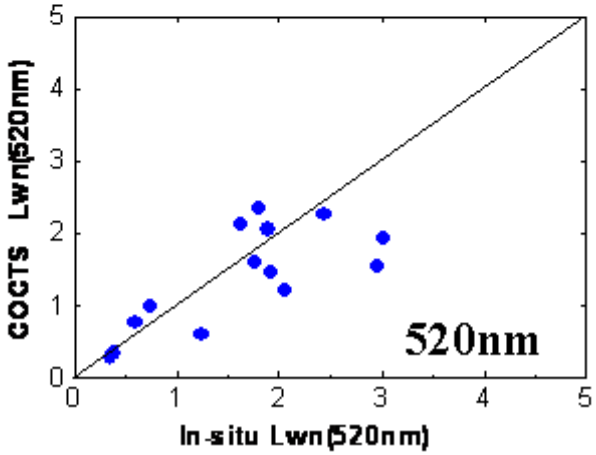
Validation of normalized water-leaving radiance

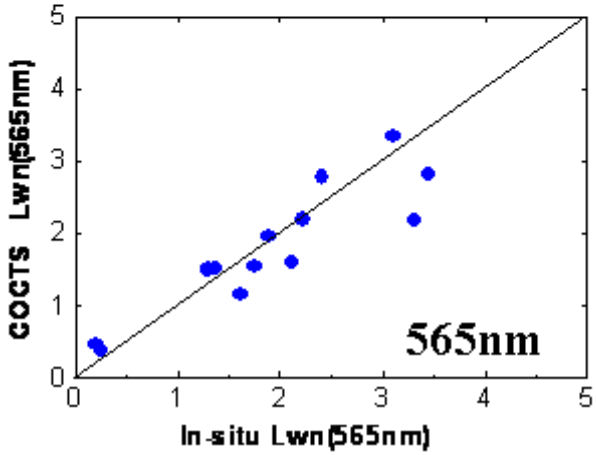


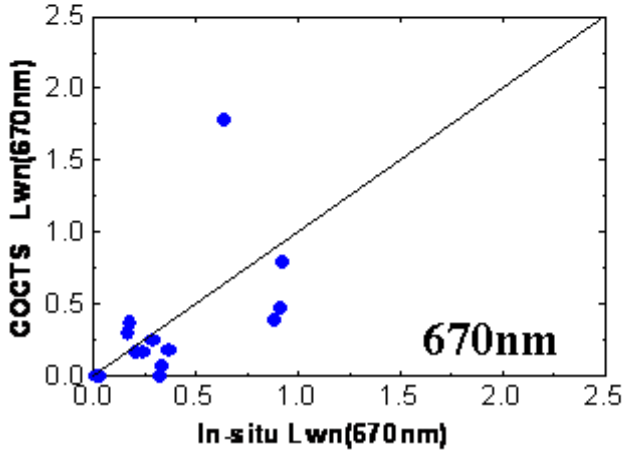




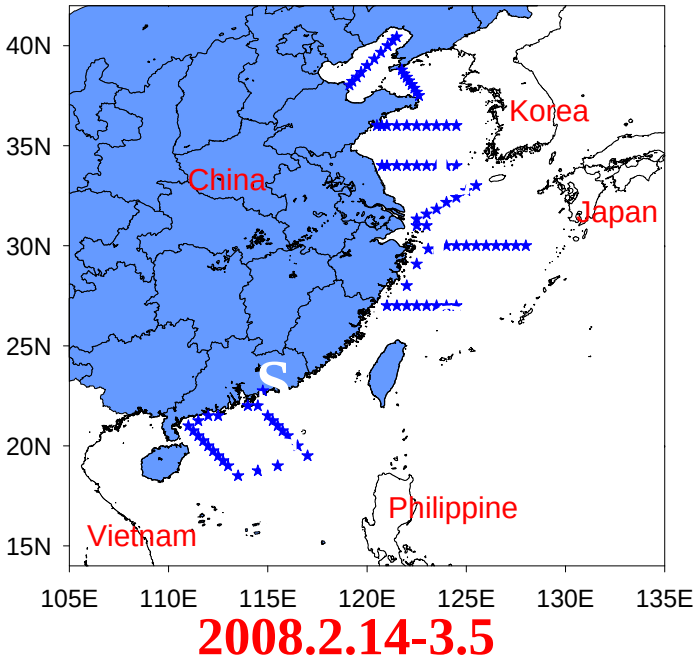


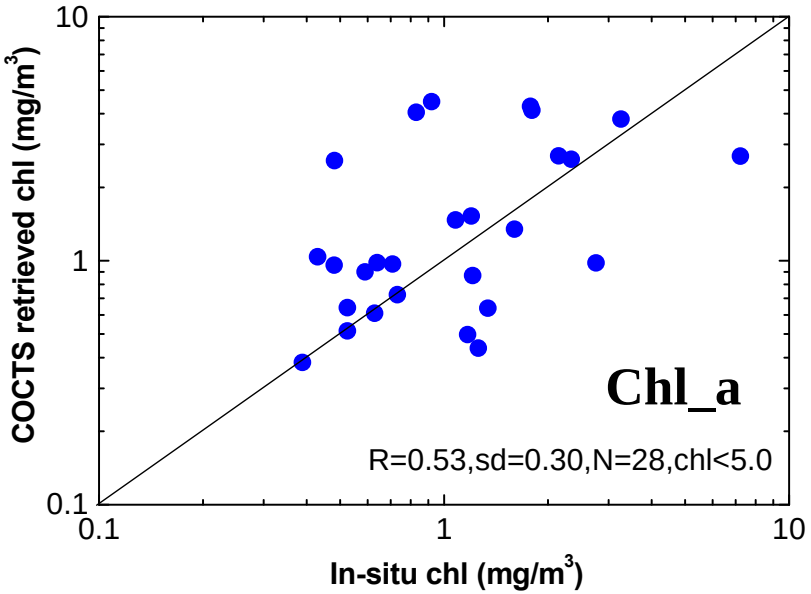


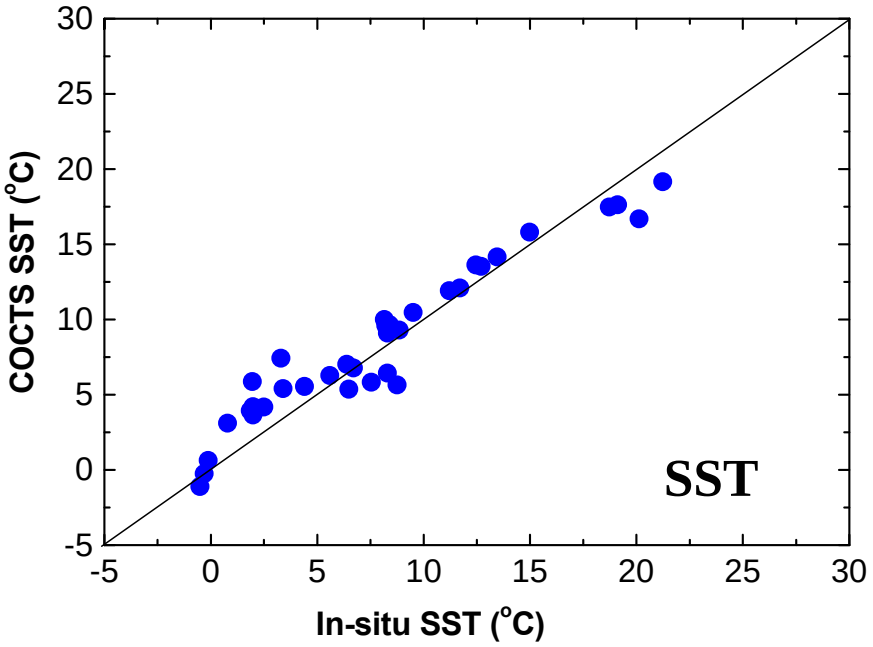


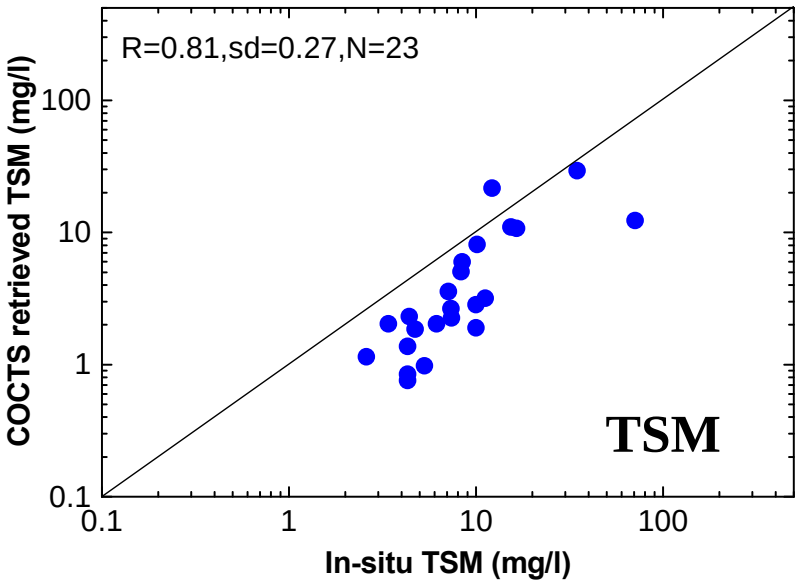


Validation of oceanic parameters









Access the HY-1/HY-2 satellite data

国家卫星海洋应用中心

National Satellite Ocean Application Service

http://www.nsoas.gov.cn

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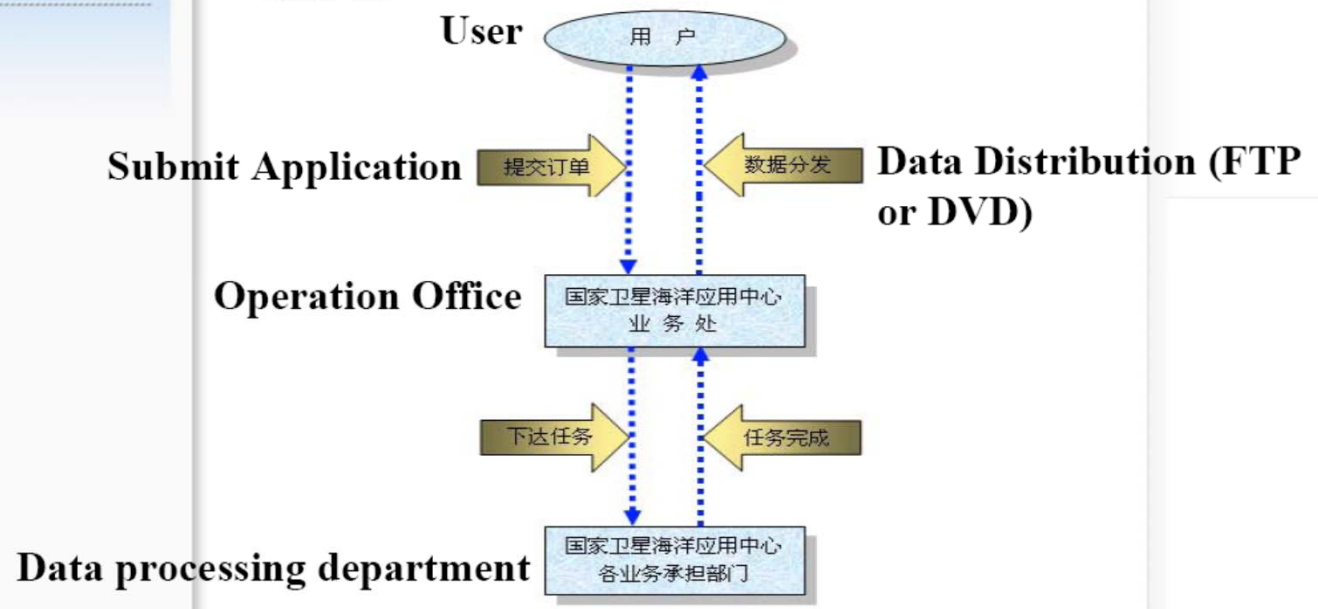
首页 > 定向服务 >数据分发

数据分发流程

国家卫星海洋应用中心业务处负责组织中心对外的卫星数据分发业务。用户根据自己的需求，向业务处提出申请，经业务处审核并报中心领导批准后，与用户签订协议。业务处根据用户的需求向中心各业务部门下达任务单。任务完成后，由业务处通知用户办理取货手续。具体步骤如下：

1. 数据查询。查询方式有两种：第一，用户登录到国家卫星海洋应用中心网站（www.nsoas.gov.cn），查询有关产品数据信息，确定自己的数据需求；第二，用户直接到国家卫星海洋应用中心来查询需求数据。
2. 订单提交。用户根据需求，填写《卫星数据分发申请表》（该表可在中心网站上获取），向中心业务处提出申请，经中心业务处审核并报中心领导批准后办理相关收费手续。
3. 任务下达。中心业务处向各业务部门下达任务。承担任务部门根据订单要求安排人员进行产品制作。
4. 数据分发。承担部门完成任务后即通知业务处，最后由中心业务处与用户联系，将数据交付到用户手中。



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Liu Cigui, Administrator of the State Oceanic Administration

Dr.Zhang Haisheng
the Director of the Institute

The second Institute of Oceanography which was established in 1966 is a non-benefit oceanographic research institute directly under the State Oceanic Administration (SOA). It is mainly engaged in the ocean scientific research on China seas, oceans and polar regions as well as the R& D of the high technology for the oceanic environment and resources investigation and survey. The institute owns one national key lab and three key labs of SOA, five scientific research and technological R&D centers with different type of superior equipments and advanced exploration techniques and methods. There are 3 academicians of Chinese Academy of Sciences and Chinese Academy of Engineering, 1 super specialist of Zhejiang Province and more than 300 scientists and technicians in the institute. In the recent years, closely around the international ocean scientific fronts and the national demands, the institute has lunched various ocean scientific research movements, undertaken and fulfilled numerous national and local significant ocean scientific research projects as well as the projects on ocean engineering survey, design and evaluation.....Click here for more information.


Marine Science Research


Marine Engineering and Technology


R & D of Marine Technology


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ZIP:310012

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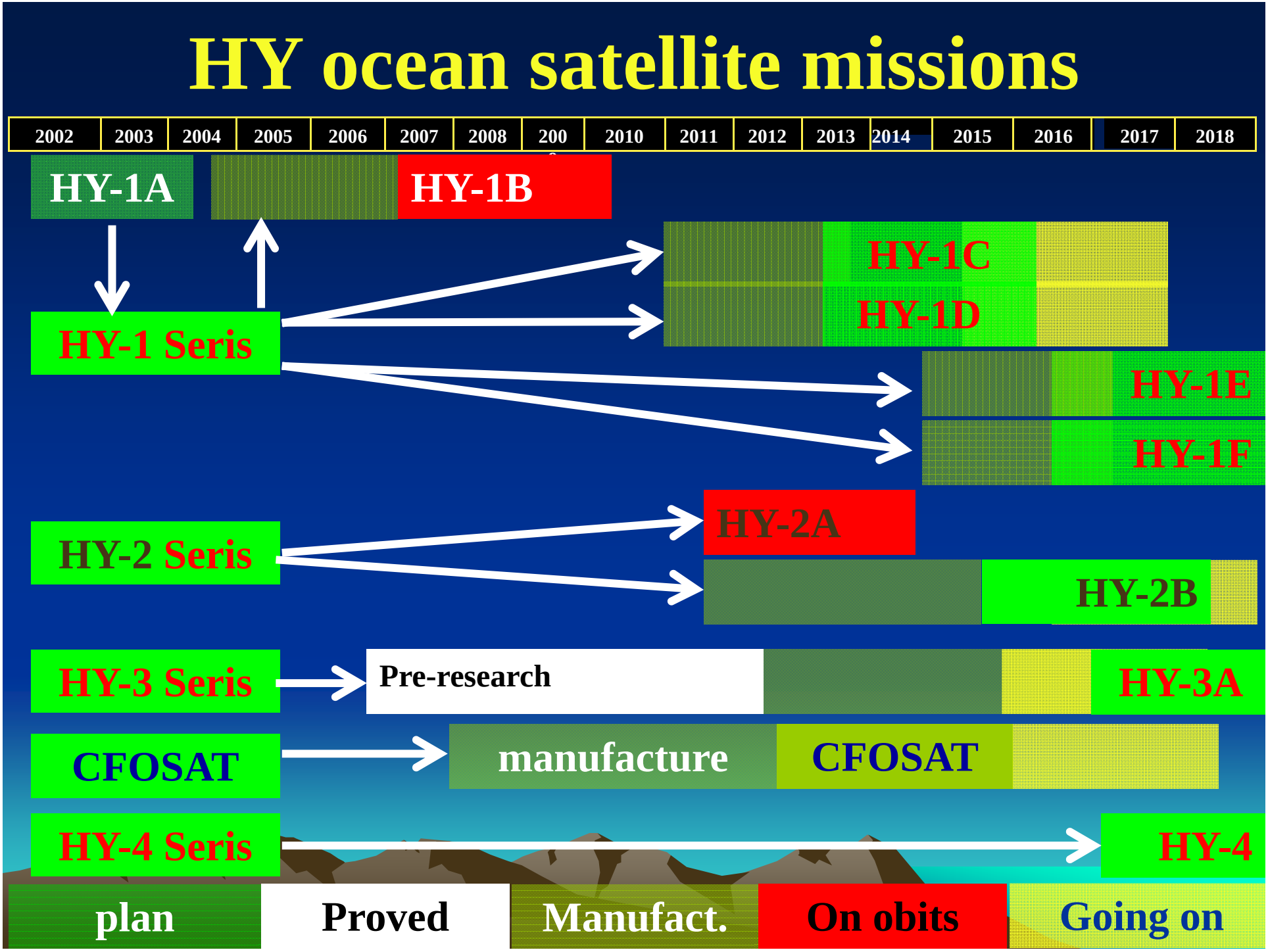
2、 Future Chinese satellite missions

3 、Application of ocean color -derived sea surface pCO_2 in the ECS

HY ocean satellite missions



中国海洋水色卫星计划

Future satellite mission for ocean color remote sensing in China

HY-1C/D series satellite

- HY-1C and HY-1D will establish a virtual satellites like Terra and Aqua, which enable two times global ocean color and SST observation in a day.
- Beside COCTS and CZI similar on the HY-1B, A new sensor UICS (Ultraviolet Imager and Calibration Sensor, not the final name) is planed on HY-1C/D to get two ultraviolet wavelength images for the CDOM retrieval and atmospheric correction in high turbid waters. In addition, UICS can help the on-orbit calibration of the COCTS.

Comparison between HY-1C/D and HY-1B (1)

	properties	HY-1B	HY-1C/D
Satellite platform	Revisit time	3 days (COCTS) 7 days (CZI)	1 day (COCTS) 3 days (CZI)
	Orbit altitude	798km	782km
	Pixel geo-location accuracy		<2km (nadir)
	Satellite life	3 yr	5 yr
	Infrared sensor life	2500 h	3 yr
	Tilt observing capacity	No	±20°
	Swing observing capacity	No	Yes
	Global observing capacity	partly	Yes
	Data storage capacity	250MB	512Gb
	Data rate	6.654Mbps	190Mbps
	Attitude accuracy	≤0.5°	≤0.1°
	Attitude stabilization	≤0.01°/s	≤0.005°/s

Comparison between HY-1C/D and HY-1B (2)

COCTS	properties	HY-1B	HY-1C/D
	VIS/NIR absolute calibration accuracy	<10%	<7%
	IR absolute calibration accuracy	1K (300K)	0.7K (300K)
	SNR	309-472	309-472
	Out-band response		<5%
	Polarization sensitivity	<5%	<2% (±20°)
	Stray light sensitivity		<2%
	Digitization	10bit	12bit
	Swath width	1800km	2900km

Comparison between HY-1C/D and HY-1B (3)

CZI	properties	HY-1B	HY-1C/D
	Bands	No NIR band	Adding NIR band
	Band width	20nm	80nm
	Spatial resolution	250m	50m
	Calibration accuracy		<7%(absolute) <2%(relative)
	Swath width	500km	950km
	SNR	232-340	250-470
	Out-band response		<5%
	Polarization sensitivity	<5%	<2.5% ($\pm 10^{o}$) <5%(full field of view)
UICS	Bands		2
	On-board calibration		Yes

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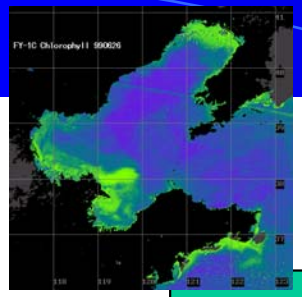
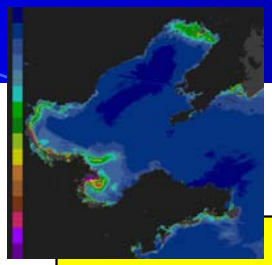
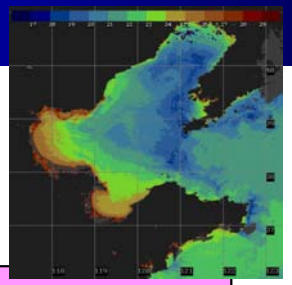
遥感的应用
OCR application
In 1979-2013 in China



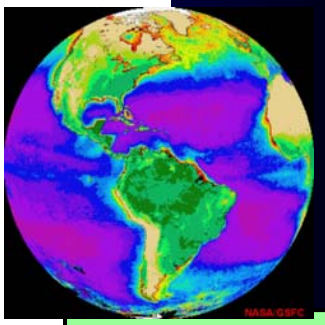
Chlorophyll



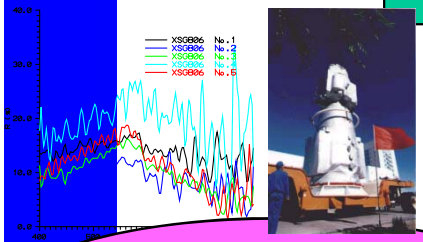
SSP



Temperature

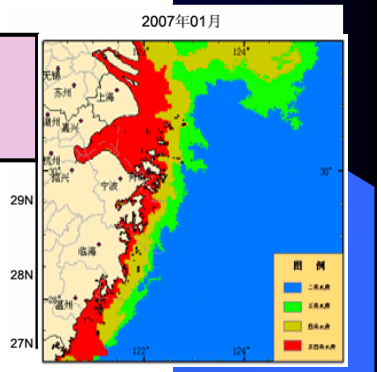


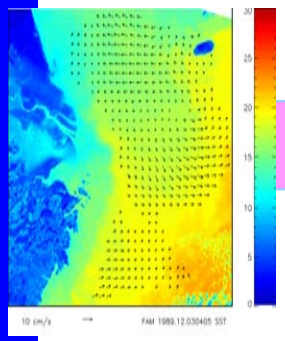
Global Environ.



For senor development

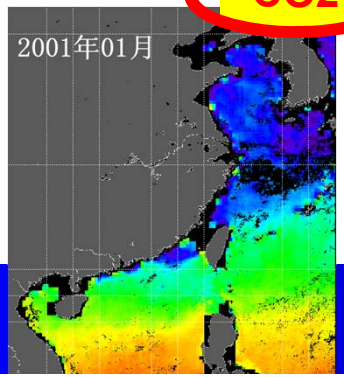
Water Quality





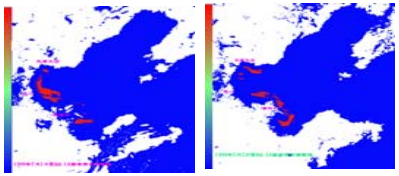
Oceanography

CO2



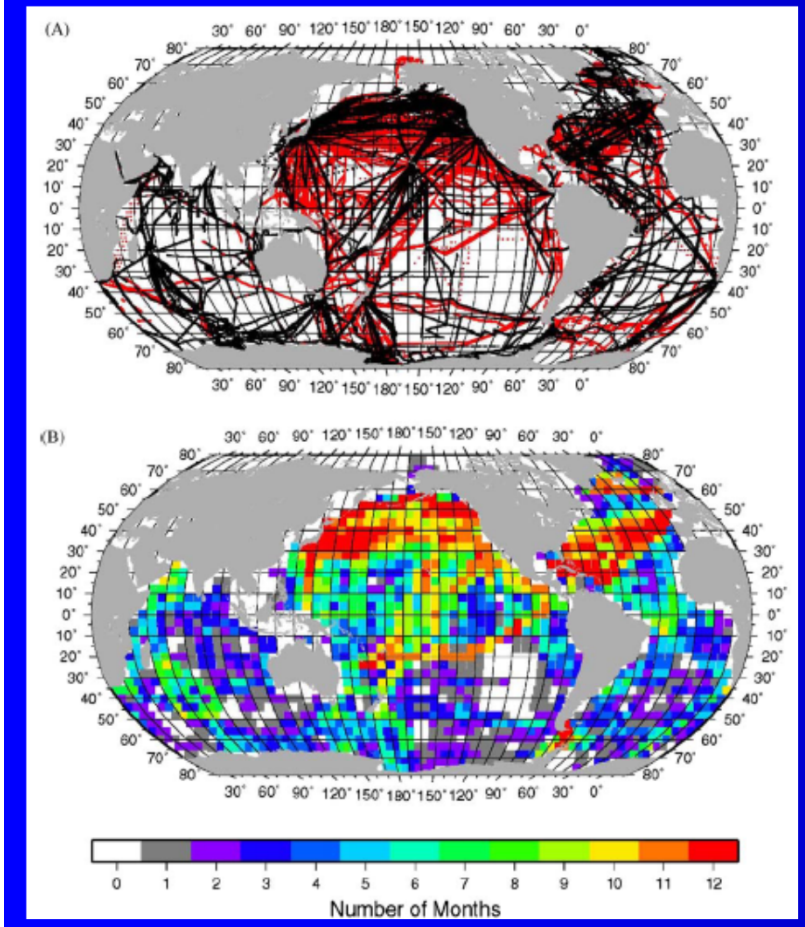
hazards detection

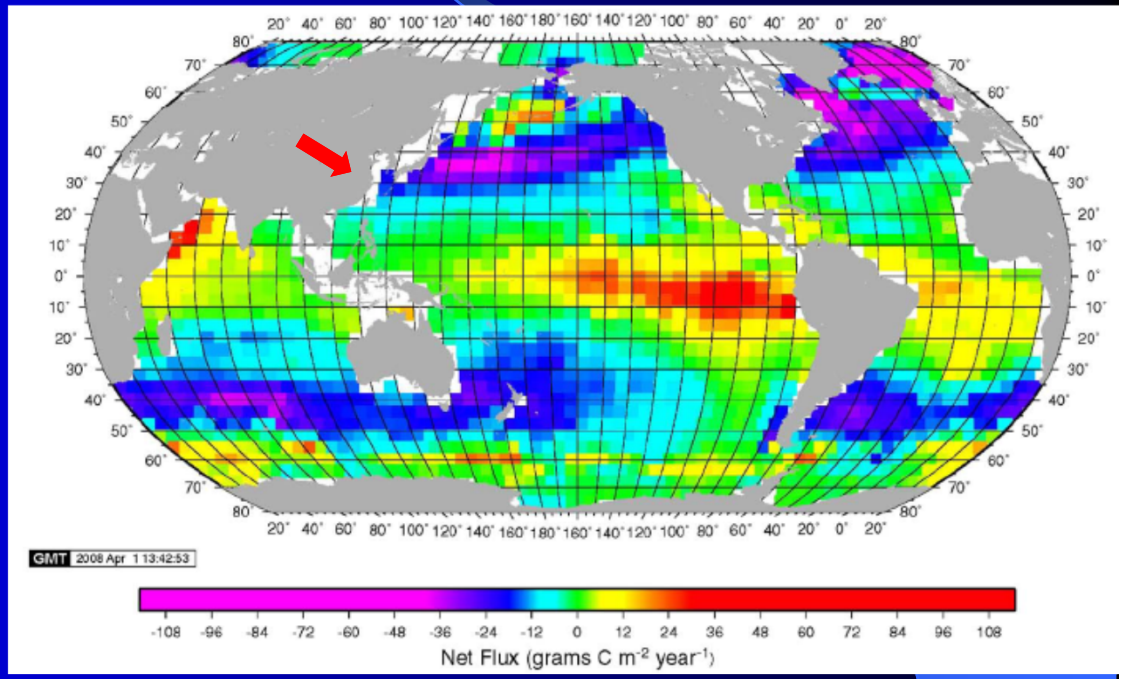
1999.7.2渤海黄河口赤潮
1500平方公里球形棕囊藻



Fishery

Sea surface partial pressure of carbon dioxide (pCO_2) and global air-sea CO_2 flux





Takahashi, T., ., et al. (2009). Climatological mean and decadal change in surface ocean pCO_2, and net sea–air CO_2 flux over the global oceans, Deep-Sea Research II , Deep-Sea Research II 56 , 554–577

1968-2006， more then 40yr, 3million data

Remote sensing algorithm of Aquatic pCO_2

Sea-air flux of CO_2 in the North Pacific using shipboard and satellite data

Mark P. Stephens, Geoffrey Samuels, Donald B. Olson, and Rana A. Fine
Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida

Taro Takahashi
Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 100, NO. C7, PAGES 13,571–13,583, JULY 15, 1995

pCO_2 vs. SST

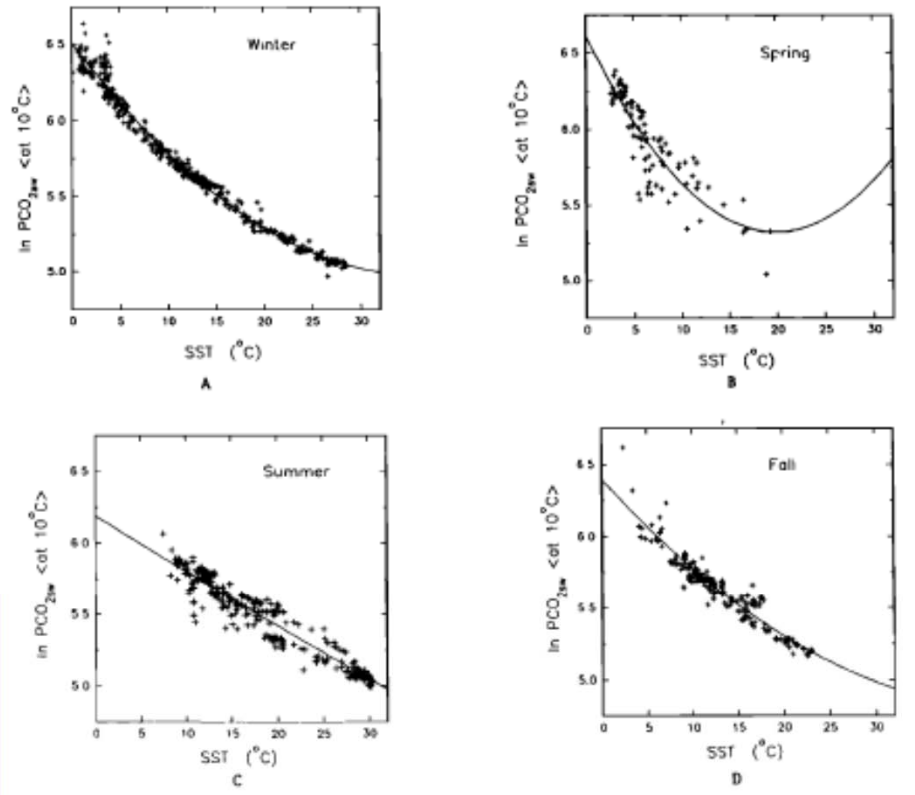
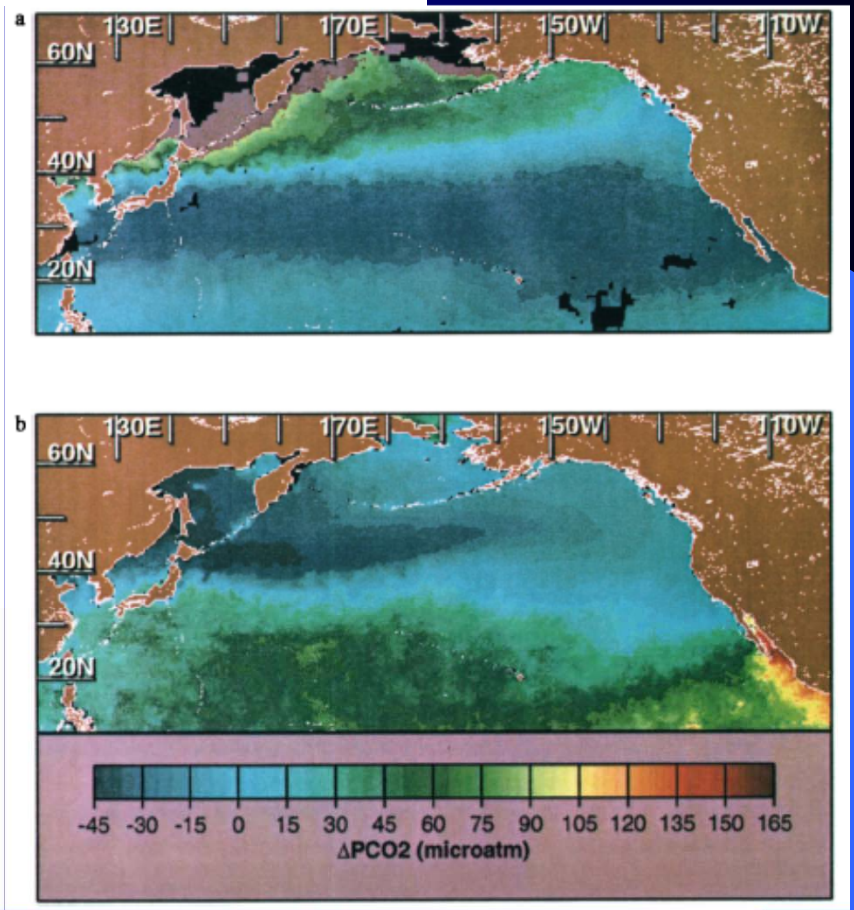


Figure 4. Seasonal relationship between ln $pCO_{2(t=10°C)}$ and SST. The curves represent the least squares fits of ln $pCO_{2(t=10°C)}$ to SST. The curves for (a and b) winter and spring represent the equations used to calculate ln $pCO_{2(t=10°C)}$ from satellite SST, but the equations for (c and d) summer and fall include a longitude term, not included in these curves.



Empirical algorithms

Aquatic pCO_2

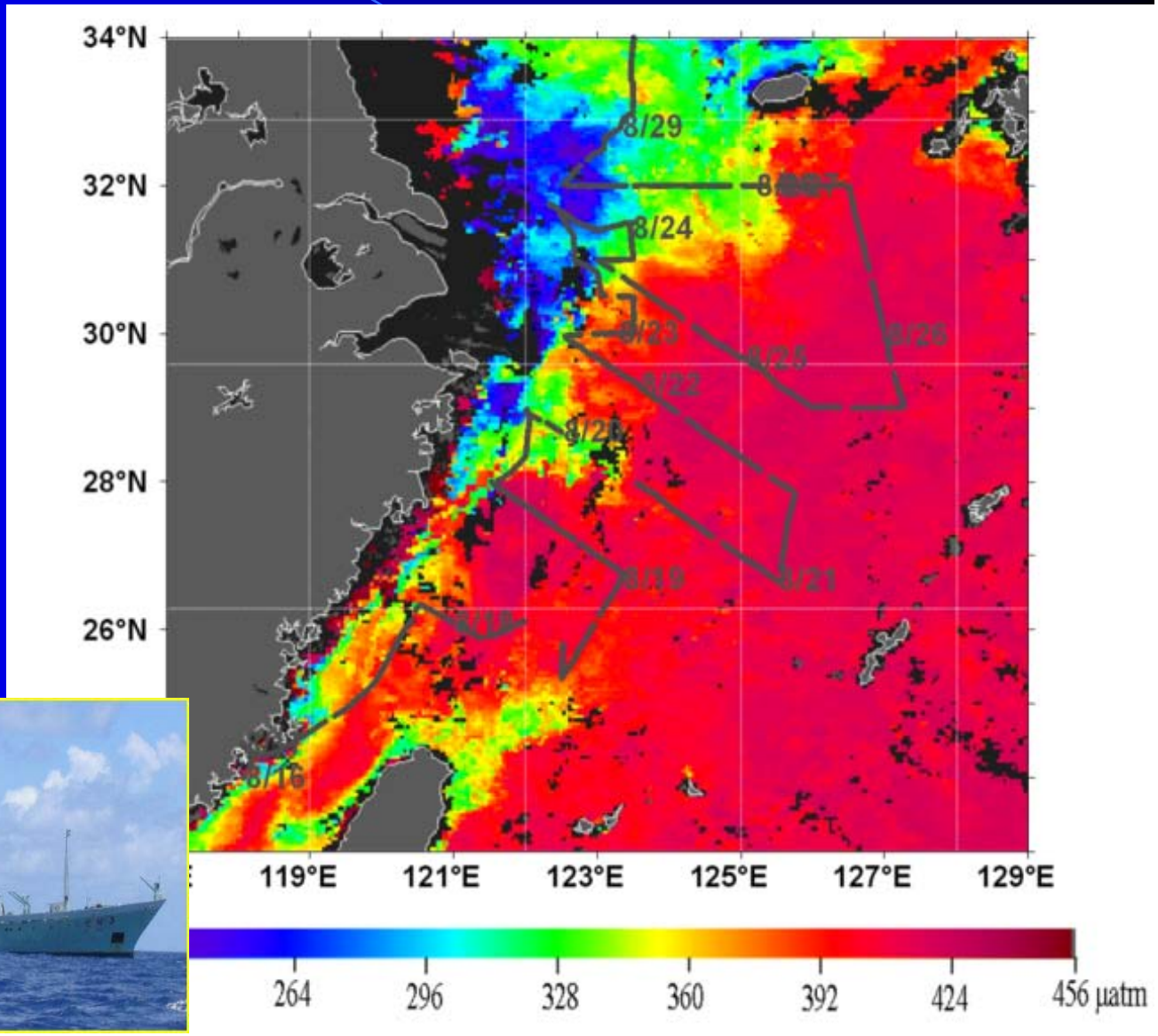
Proxies: SST, Chla, Lon, Lat, Salinity, Mixing Layer Depth, etc.

Estimation the Aquatic pCO2 from Empirical algorithms (e.g. Linear Regression)

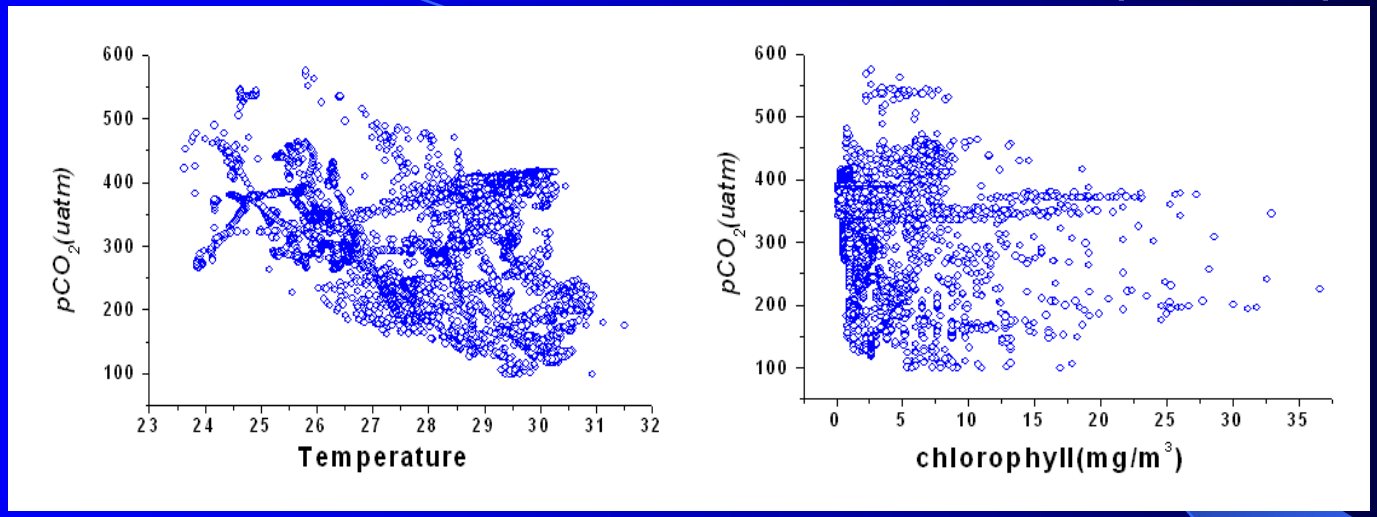
Proxy	Equation	Research area (References)
SST	f(T)	e.g.North Pacific(Stephens et al. 1995; Olsen et al., 2003, 2004;), Green land(Hood, et al., 1999;), Sargasso Sea(Nelson, et al., 2001), Caribbean Sea(Cosca et al., 2003;), Chile coastal(Levefre et al., 2002), sub-Antarctic Ocean(Metzl et al., 1999;), North Atlantic(Lefèvre et al., 2004;)
Chloraphyll a	f(T and/or Chla)	e.g. North Pacific (Ono et al., 2004) Southern Ocean (Rangama, et al., 2005) Northern SCS (Zhu, et al., 2009)
Location (Lon, Lat)	f(T, Lon, Lat)	e.g. Caribbean Sea (e.g. Wanninkhof, et al., 2007; Lueger, et al.,2009)
Mixing layer depth	f(T, MLD, Lon, Lat)	e.g. North Atlantic (Lueger, et al.,2009)
CDOM	f(T, aCDOM)	e.g. Hudson Bay (Else, et al., 2008),
Salinity	f(S, etc.)	e.g. North Pacific(Sarma et al., 2006)
Neutral Network (T, S, Chlorophyll, ect.)		e.g.Northern SCS (Yan et al., 2011)
Principal Component analysis		e.g.Northern Gulf of Mexico (Lohrenz and Cai, 2006)
Satellite data with Model		e.g.Mediterranean (D'Ortenzio)

CHOICE-C summer cruise in ECS (2009-08)

A case Study by RS



CHOICE-C summer cruise in ECS (2009-08)



$$pCO_2 = f(\text{thermodynamic}, \text{mixing}, \text{biology}, etc....)$$

Proxy

$$pCO_2 = f(\text{SST}, \text{salinity}, \text{Chla}, Vmixing, etc....)$$

It is generally difficult to find a straightforward, significant relationship between pCO_2 and salinity, temperature, *chla*, or other parameters using a regression analysis method. Mechanistic interpretations need to be involved in the satellite algorithm development to develop more accurate quantitative expressions.

Mechanistic-based Semi-analytic Algorithm (MSAA) for estimating the sea surface pCO_2 in coastal waters

Taylor expression:

$$\Delta pCO_2 = \left(\frac{\partial pCO_{2@\text{therm}}}{\partial V_{\text{therm}}}\right)\Delta V_{\text{therm}} + \left(\frac{\partial pCO_{2@\text{mix}}}{\partial V_{\text{mix}}}\right)\Delta V_{\text{mix}} + \left(\frac{\partial pCO_{2@\text{bio}}}{\partial V_{\text{bio}}}\right)\Delta V_{\text{bio}}$$
$$+ \left(\frac{\partial pCO_{2@\text{flux}}}{\partial V_{\text{flux}}}\right)\Delta V_{\text{flux}} + \ldots\ldots + \left(\frac{\partial pCO_{2@\text{factor-n}}}{\partial V_{\text{factor-n}}}\right)\Delta V_{\text{factor-n}} + \varepsilon$$

The variation of pCO_2 is analytically expressed as the sum of the first-order partial-difference of individual pCO_2 components contributed by each process or controlling factor.

Take the ECS during summer for example:

1. pCO_2 thermodynamic effect.

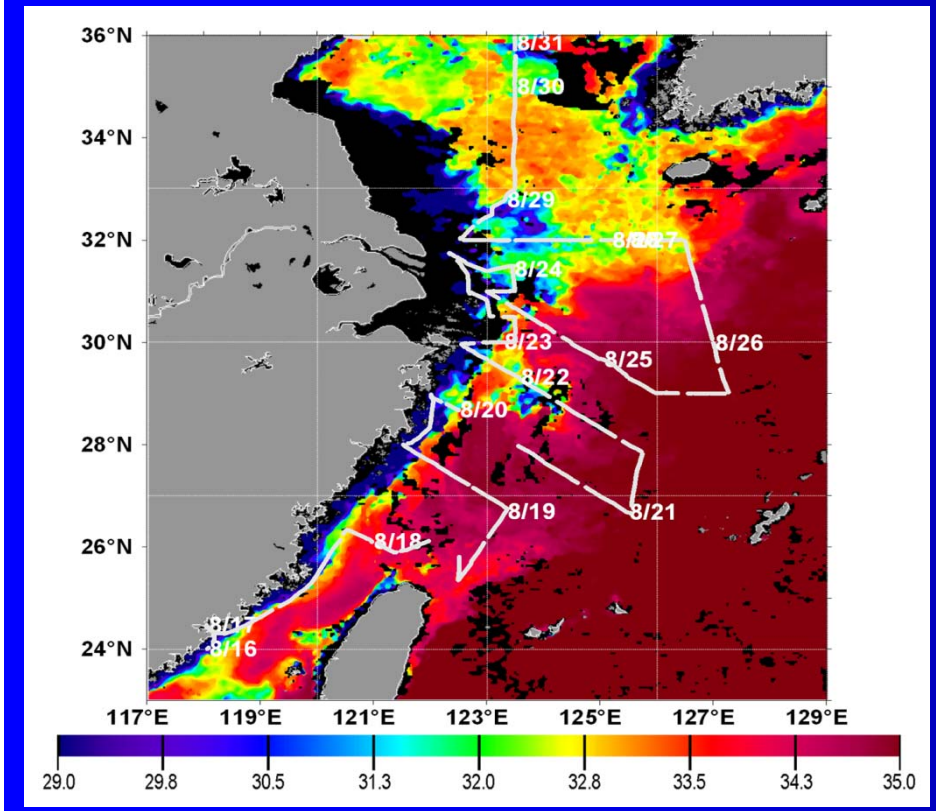
2. The two end-member mixing between Changjiang fresh water and Kuroshio water.

3. pCO_2 drawdown by biological effect.

Satellite Result and validation

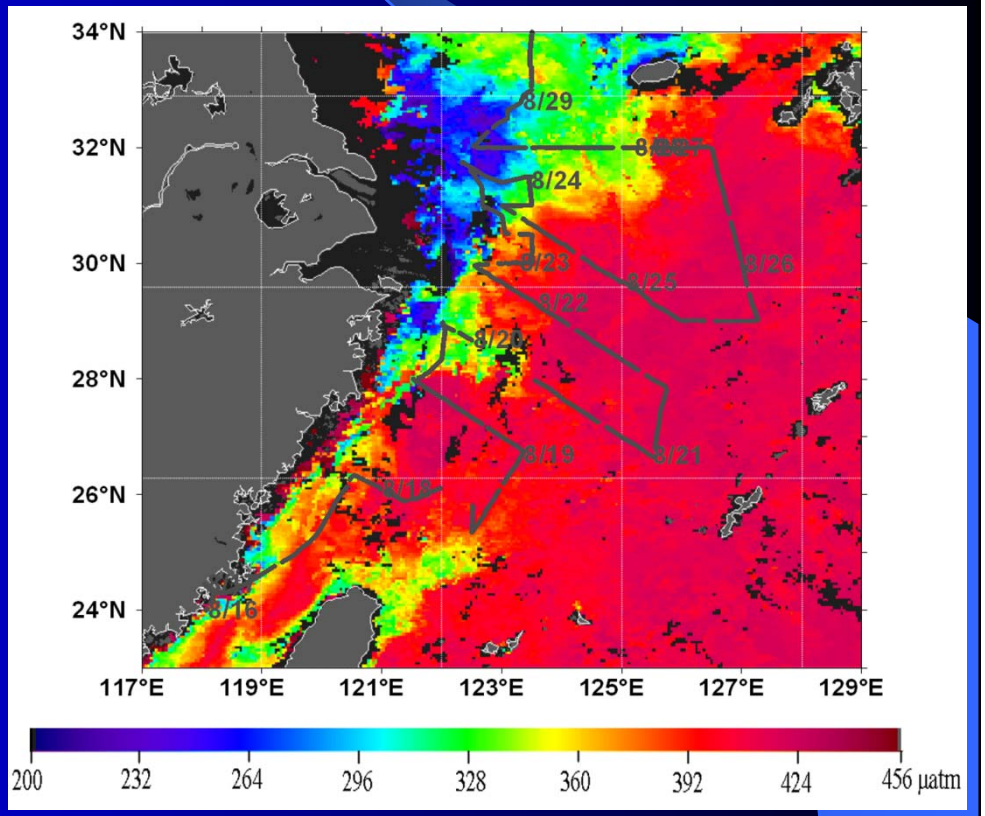
The inputs of MSAA include satellite products of *chla*, SST, salinity, and DIC and Alkalinity (TA) values for two pairs of end-members.

Satellite *salinity* in August 2009



Bai, et al., 2013, JGR
Salinity vs. aCDOM(355)

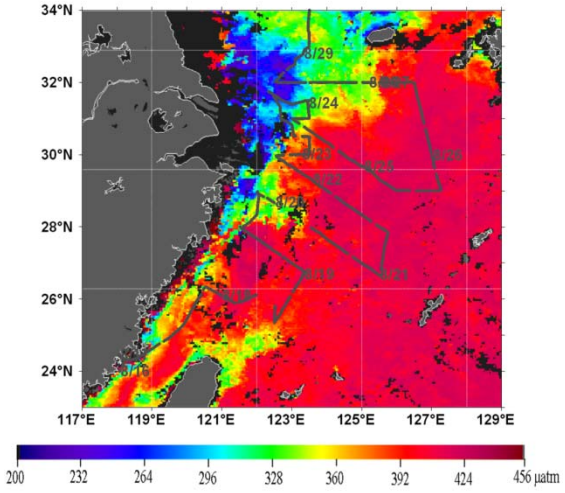
Satellite pCO_2 in August 2009

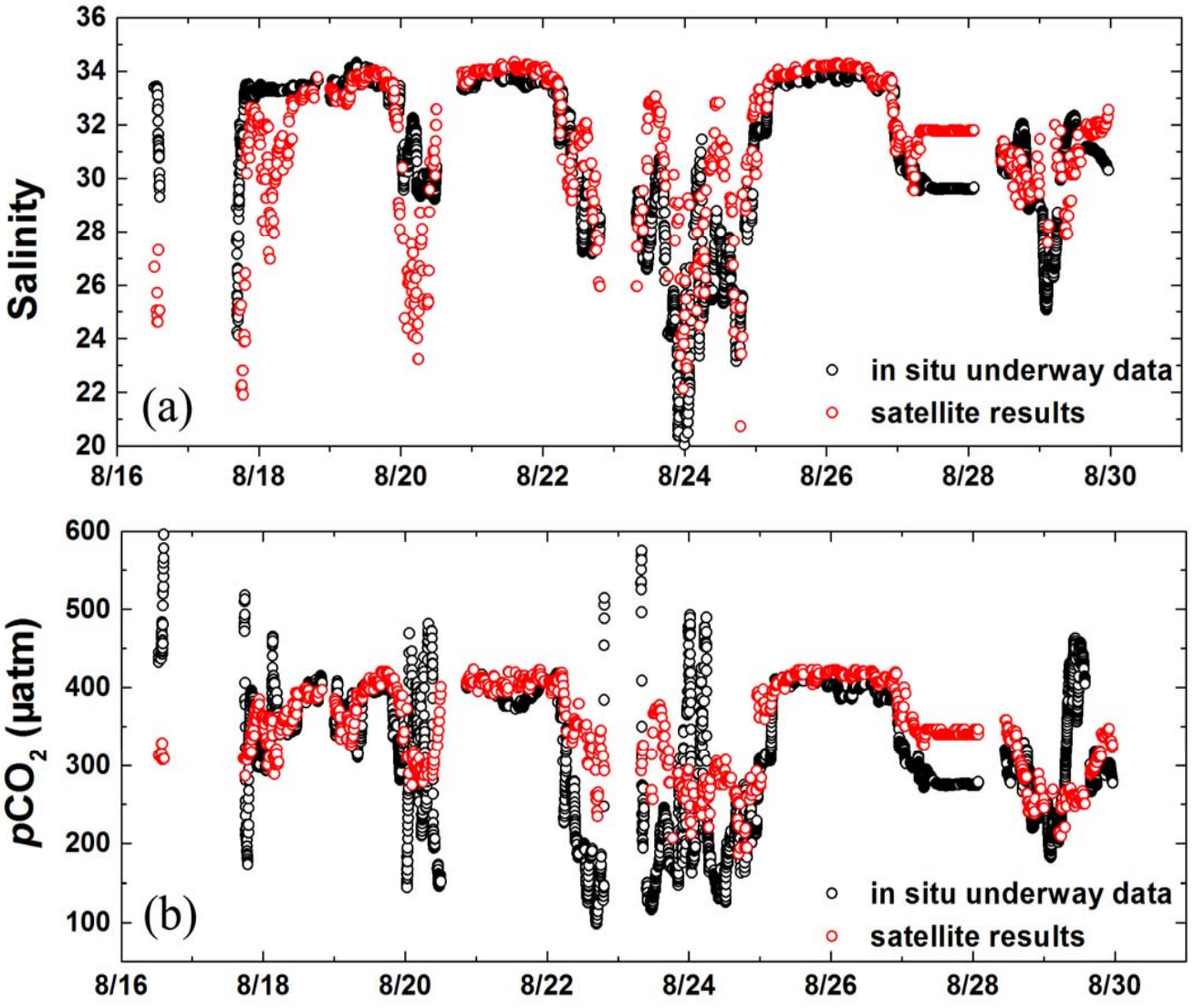


Bai, et al., 2013, Submitted
MSAA for ECS in summer

Satellite Result and validation

Satellite pCO_2 in August 2009 16 day composite during the cruise





Air-sea CO_2 flux estimated by RS

- pCO_{2SW} = Estimated by RS, Critical parameter

$$\text{Flux} = s(\text{solubility}) \times k\,(\text{gas transfer velocity}) \times (pCO_{2sw} - pCO_{2atm})$$

- Lns = f (sss, sst) (Weiss, 1974)

SSS – climatology

SST – satellite data

- k =f(U_{10}^2, sst)

(e.g. Wanninkhof, 1992)

U_{10} – Satellite data

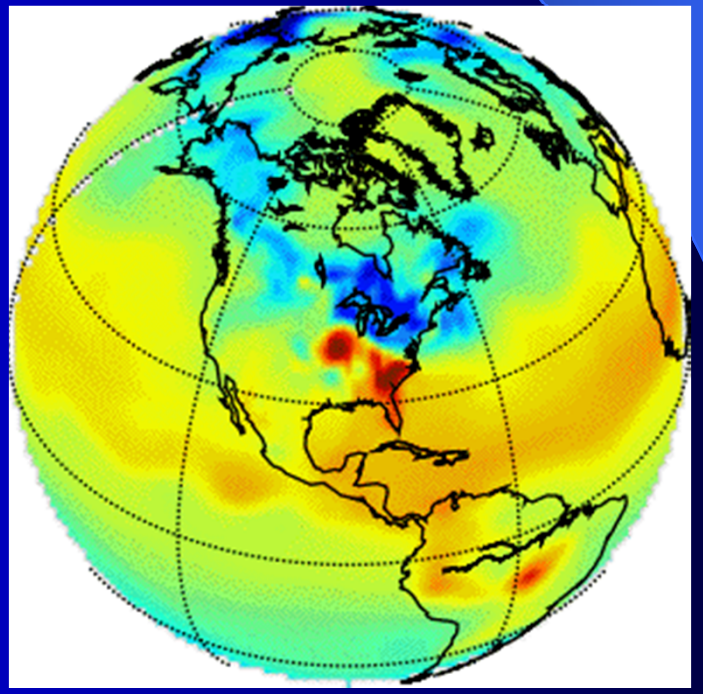
- pCO_{2atm}
- XCO_2 – NOAA/ESRL
- CO_2 satellite

Partial Pressure of CO_2 in the atmosphere

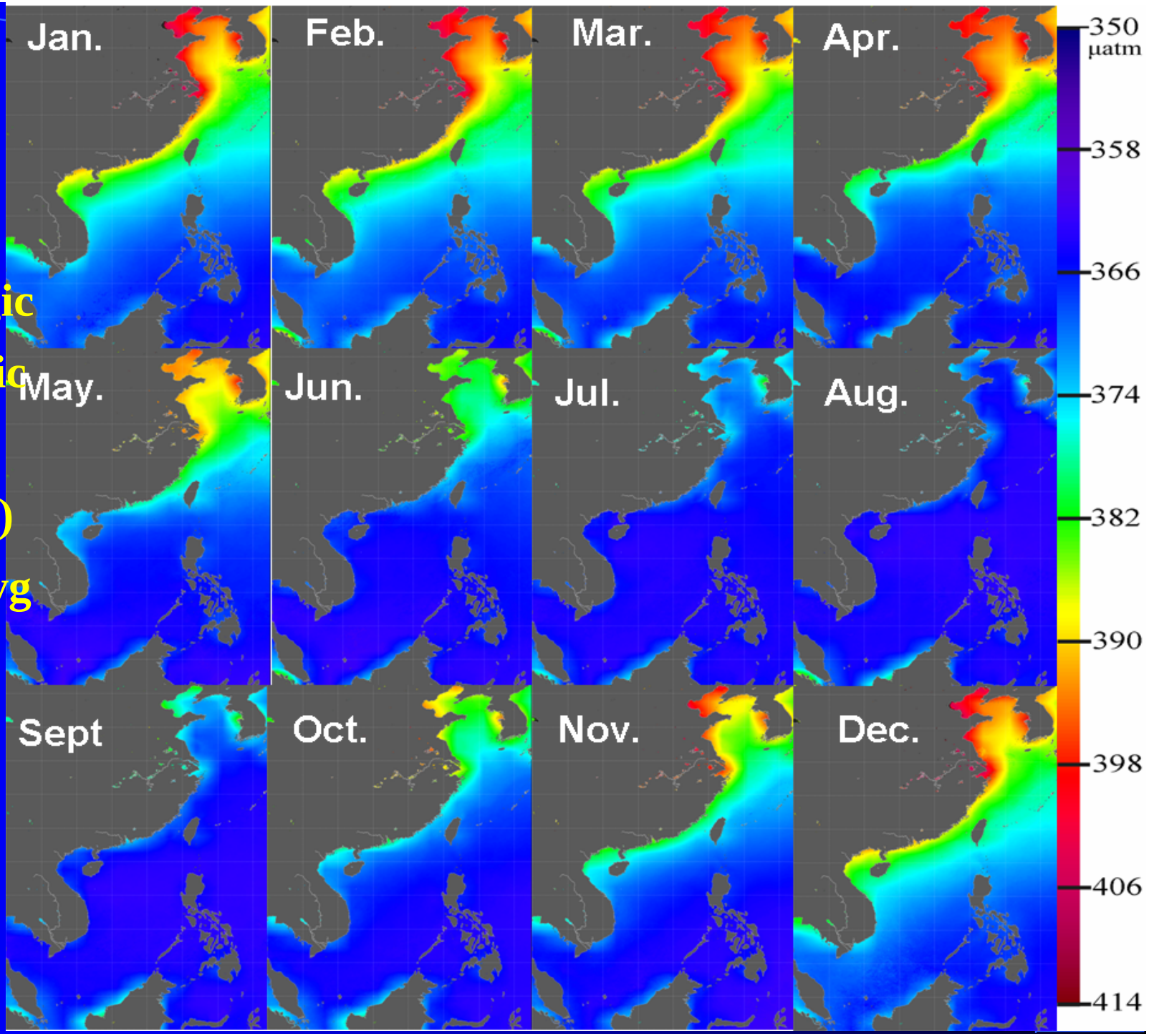
$$pCO_{2atm} = xCO_{2atm} \times (P_{atm} / 1013.25 - pH_2O)$$

xCO_{2atm} = CO_2 Dry Air Mole Fraction

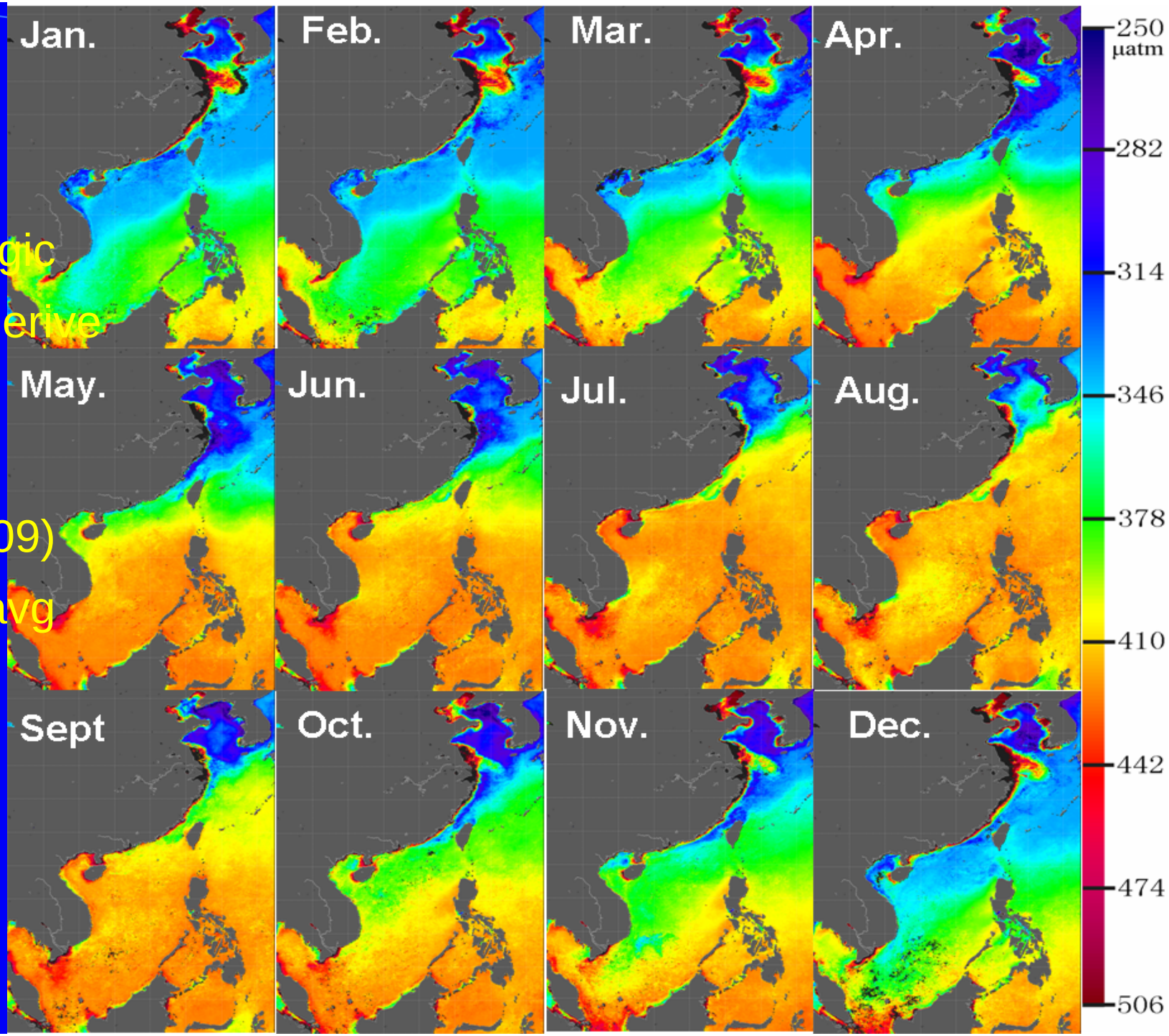
NOAA/CMDL/Carbon Tracker, CT2011_molefrac_glb 3×2 Data



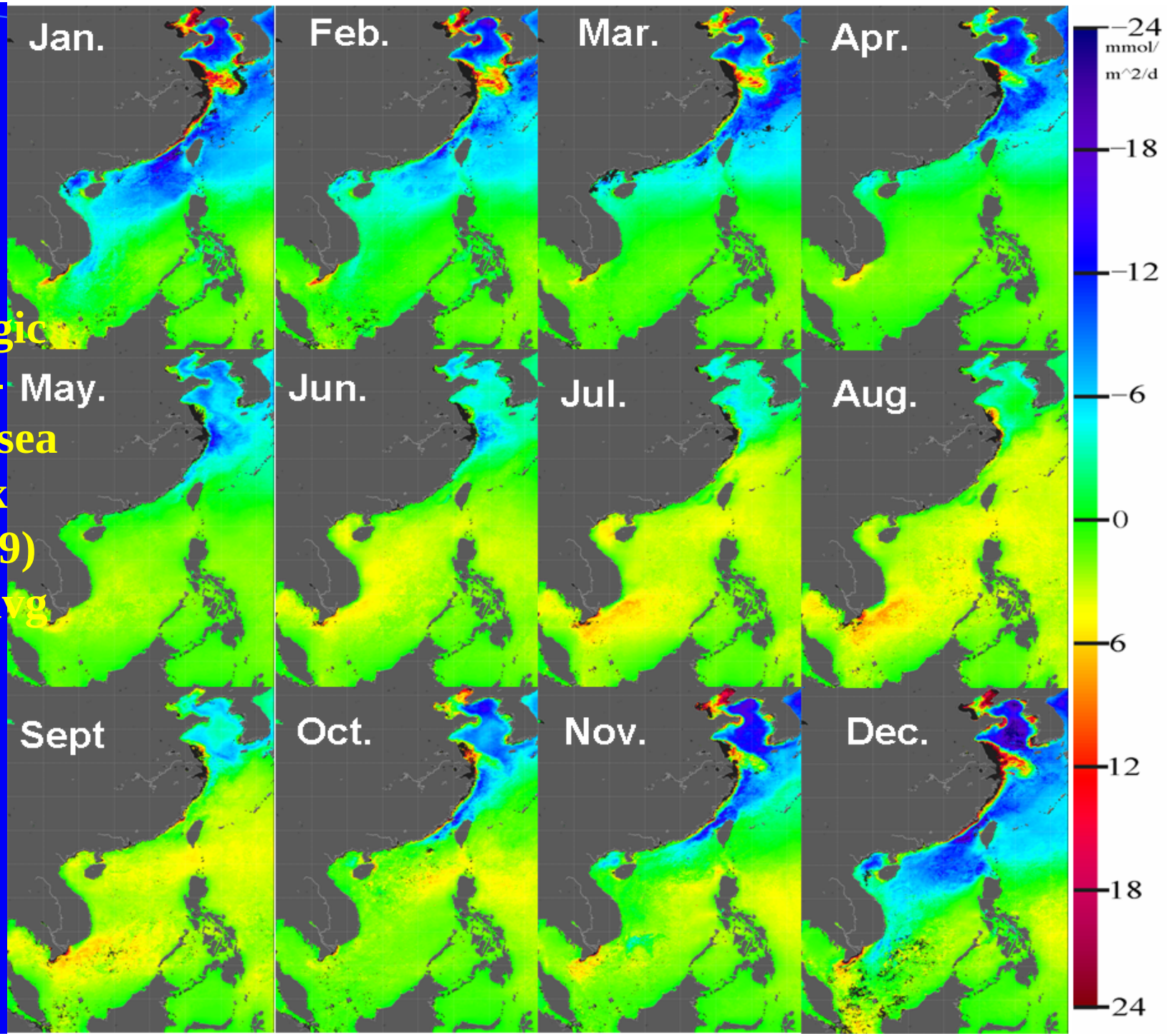
Climatologic atmospheric pCO_2 (2003-2009) monthly-avg



Climatologic satellite-derive Aquatic pCO_2 (2003-2009) Monthly-avg



Climatologic satellite-derive Air-sea CO_2 flux (2003-2009) Monthly-avg



Summary (1)

1) Presently, the Chinese second ocean color satellite **HY-1B is still operational running.**

2) Future mission, **HY-1C/D** are planned to be launched before 2016.

3) Ocean color sensors will be involved on **HY-3 Sea-watch** and **HY-4 Sea-Geo** ocean satellite series until to 2025

Summary (2)

The high frequently observing OC data are useful to study the air-sea CO_2 flux. But More in situ optical measurements are needed to improve models.

谢谢!

Thanks for your attention!