Specific requirements of GEO orbit ocean color observation for China coastal sea

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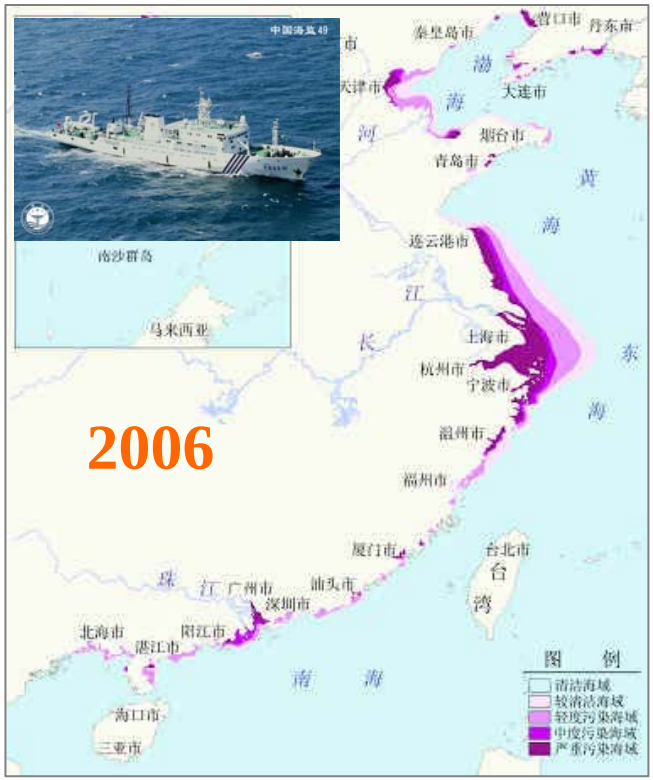
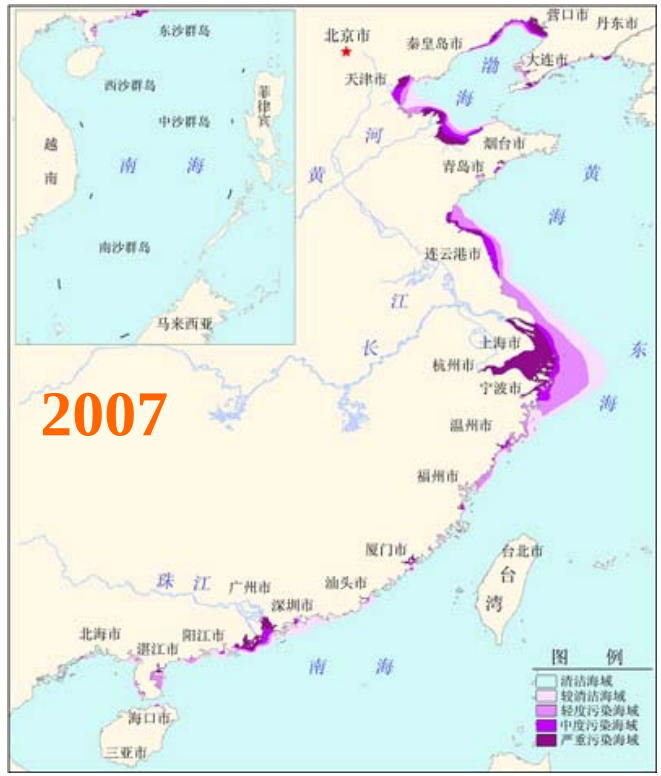
Outline

- Introduction
- Specific requirements of GEO OCRS in China coastal sea
- GEO remote sensing satellite plan of China
- Conclusion

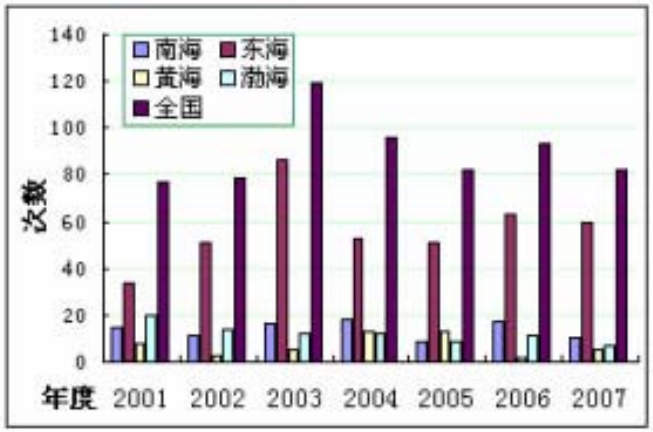
Introduction

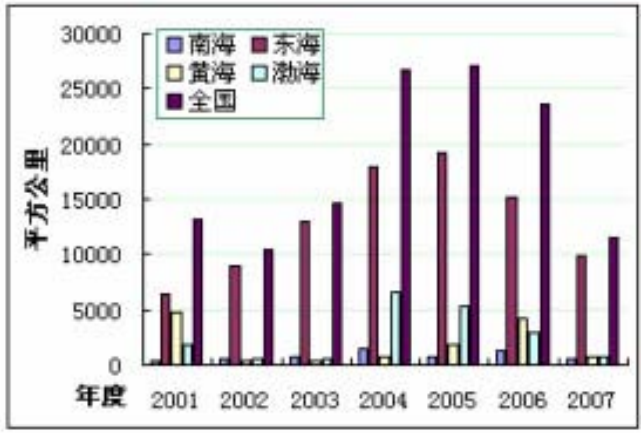
- Length of China coastal line is more than 38,000Km.
- Every year, more than 20,000 hours of ship measurement (more than 200 ships, 200000 miles cruise), and 800 hours airplane measurement (more than 300 sorties, 300000 miles cruise) must be used to monitor the coastal water environment.



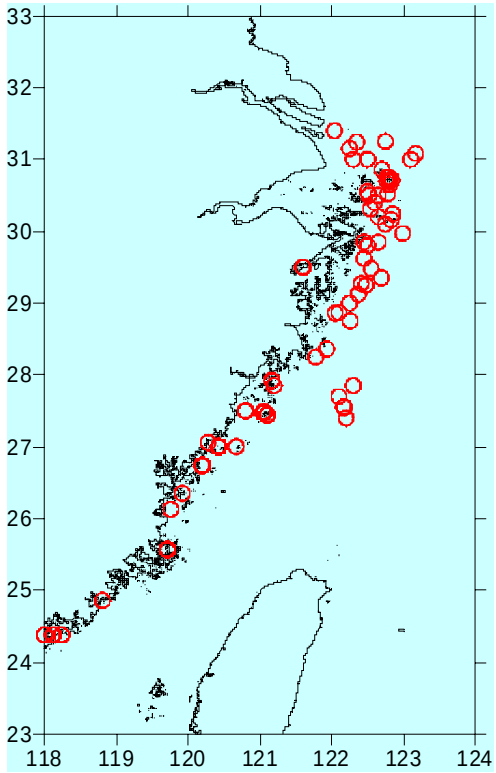


- **Every year, more than 100 red tides around China costal sea, especially in the coastal of East China Sea**



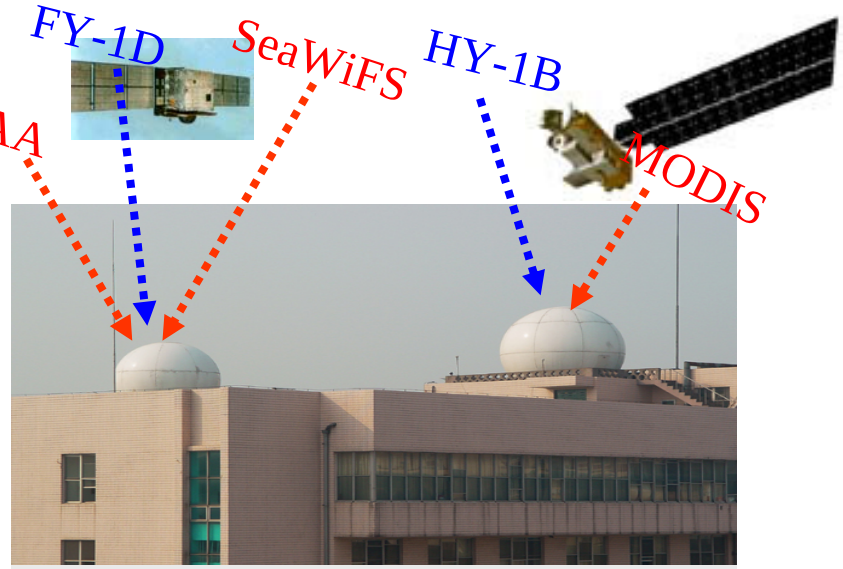


2001~2007 年全国赤潮发生次数及发生面积

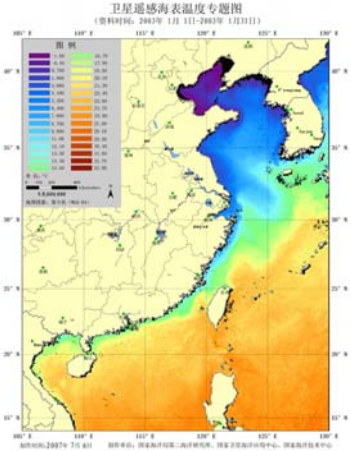


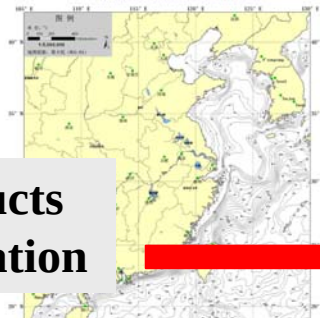
SIO Operational System of LEO OCRS Application

Data Processing System

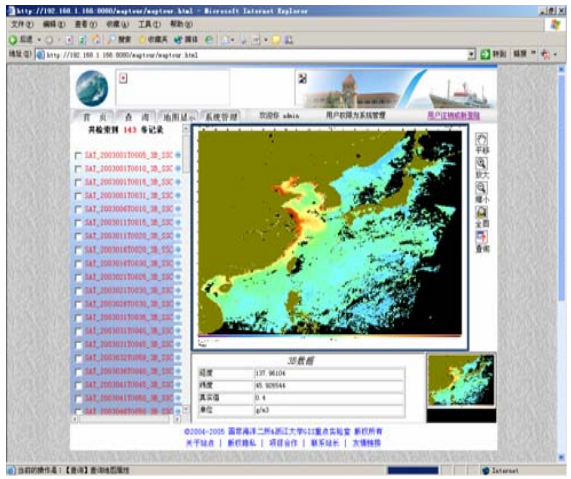


Data Receiving Ground Station

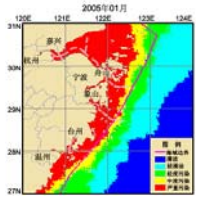




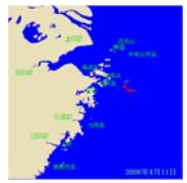
Products Generation



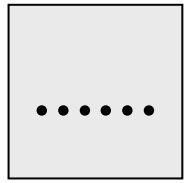
Data Distribution through internet



Water quality



Red Tide



Fishery
Carbon Cycle
Coastal engineering
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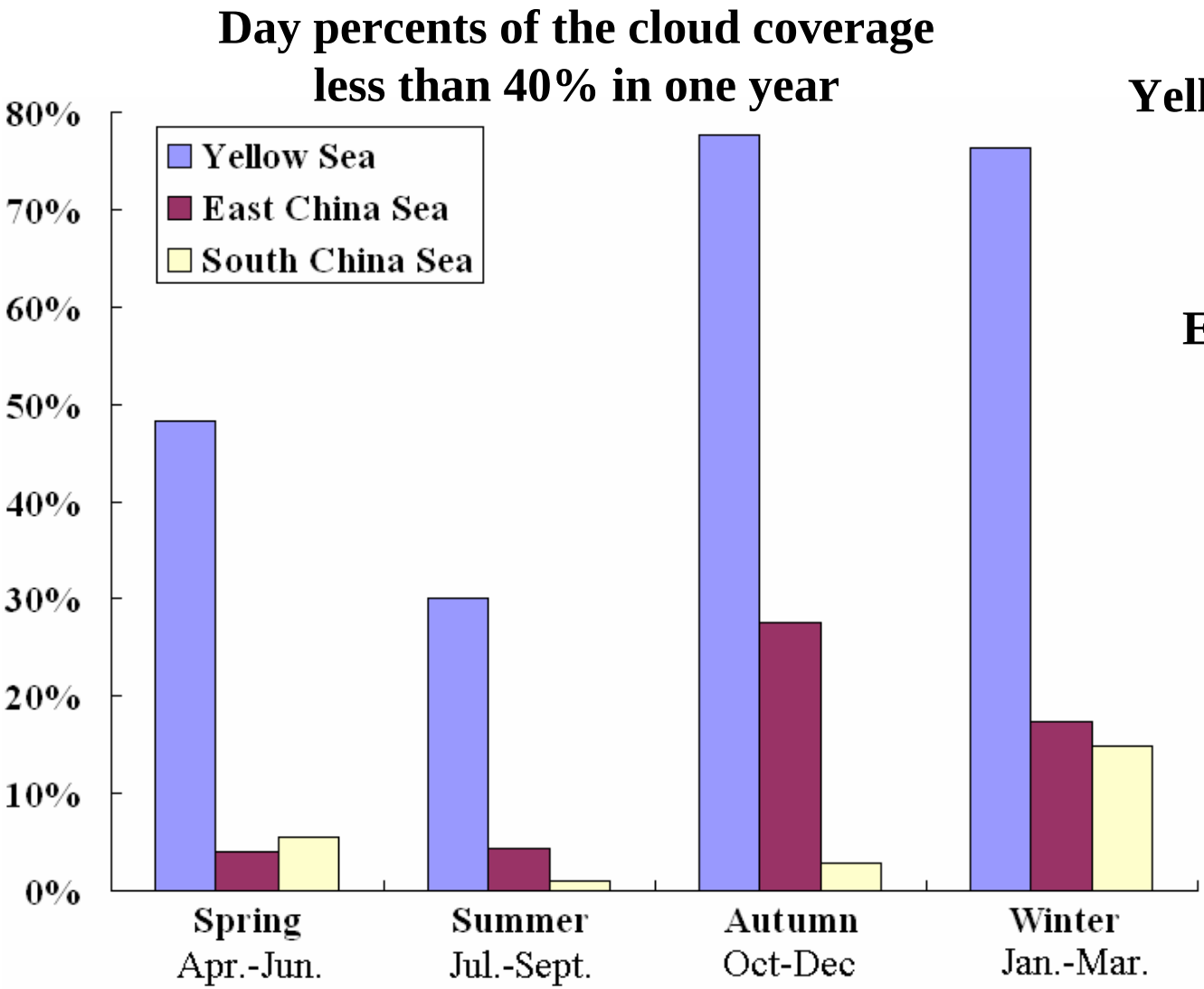
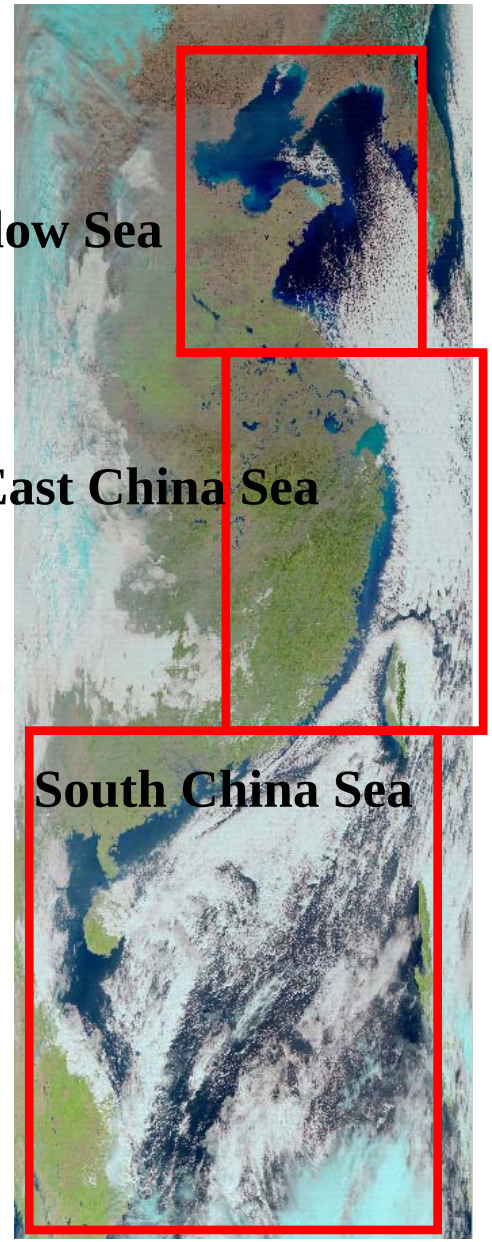
Application

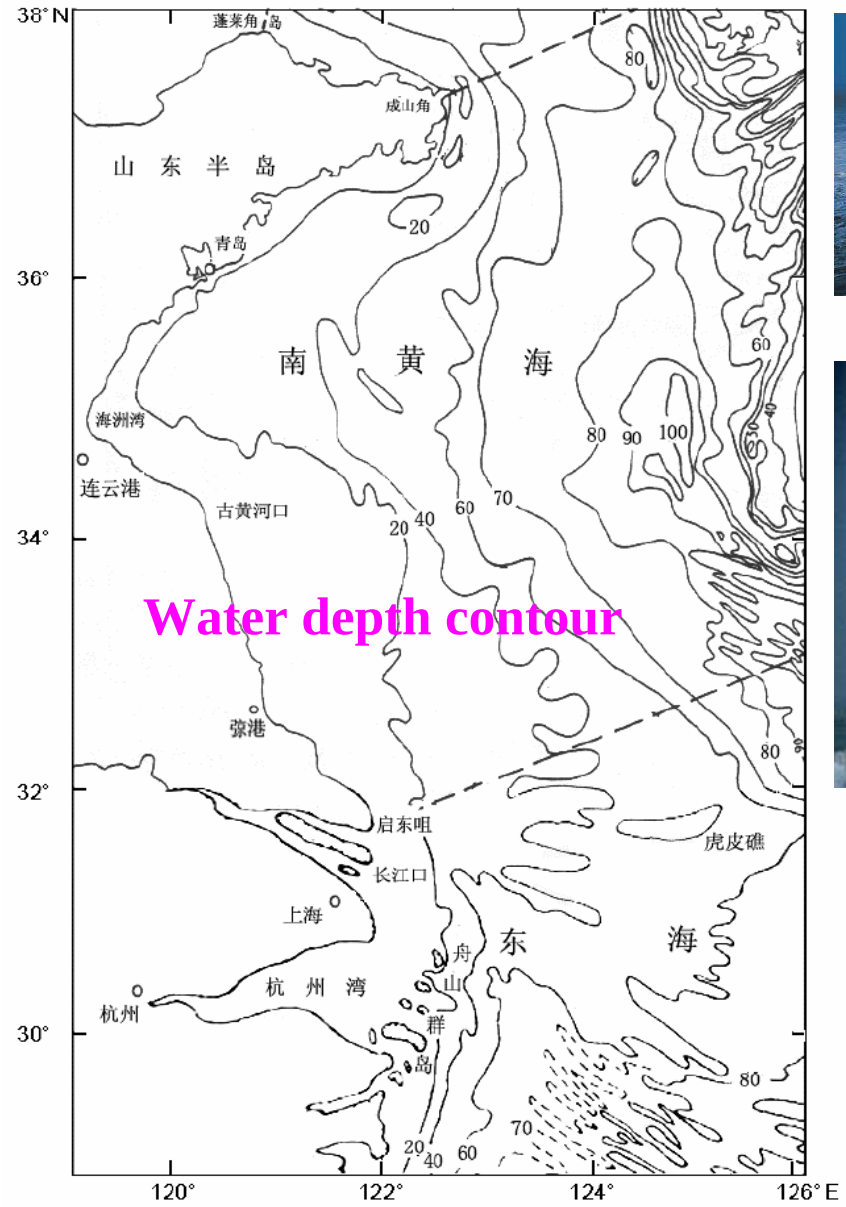
The challenges of LEO OCRS in China coastal sea

- The heavy cloud cover around the China coastal sea

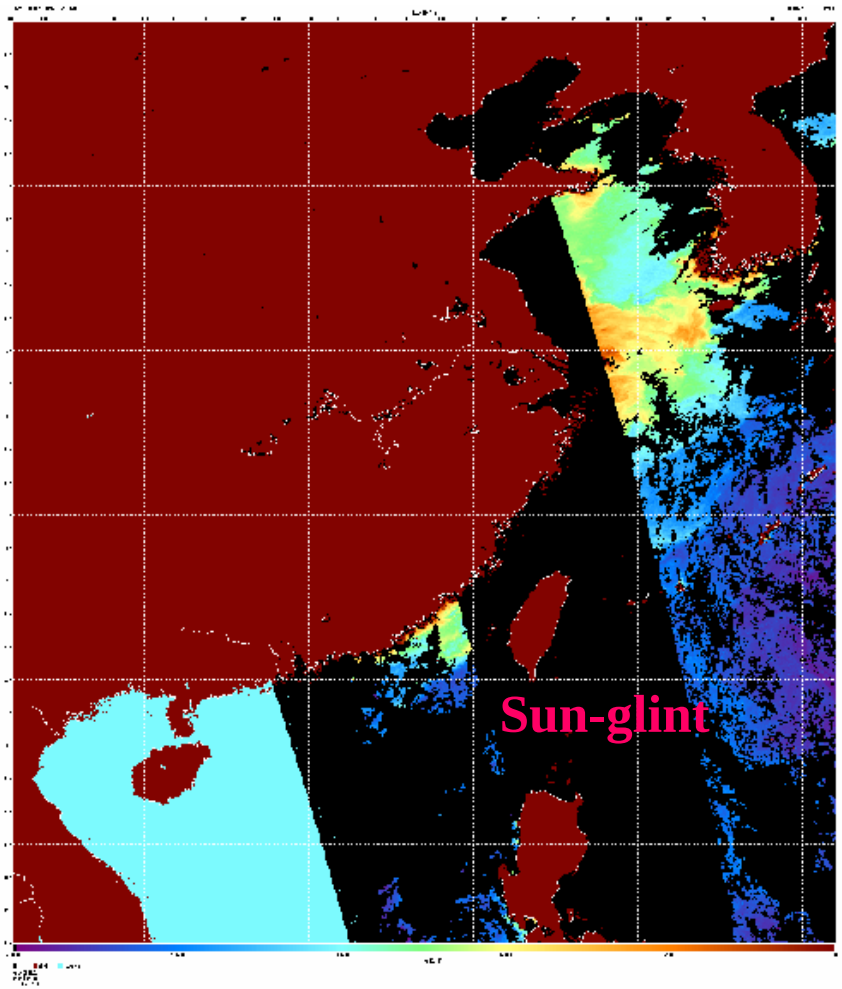




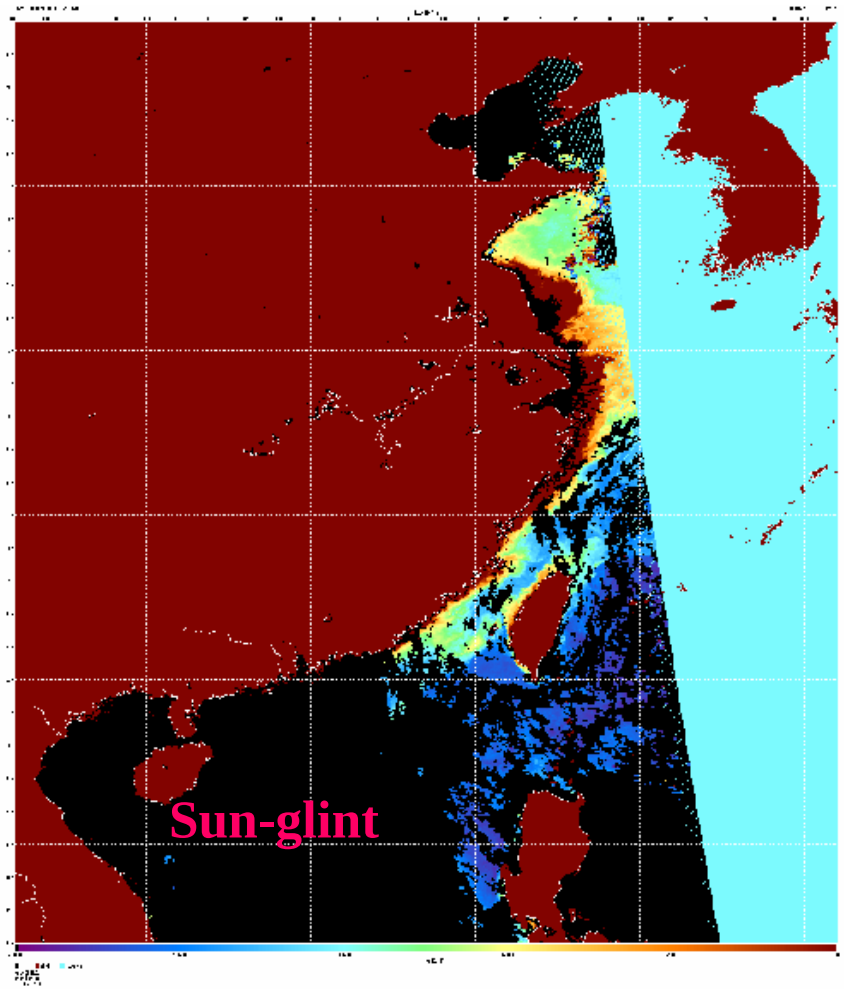
●The diurnal variation by tide mixing /storm tide mixing



- **The incompletely covered by LEO OC satellite for the daily variation of the orbit and sun-glint contaminated**



MODIS/Aqua 19/07/2004 04:59 UTC



MODIS/Aqua 20/07/2004 05:42 UTC

GEO OC satellite for China coastal sea

- **GEO OCRS has high temporal coverage, which could catch the diurnal variation phenomena. So, it is very useful for China coastal sea environment monitoring.**
- **Already seeing significant activities:**

  (1)ESA

  (2)Korea (COMS/GOCI,2009)

  (3)NOAA(GOES-R/HES-CW, *Cancel*)

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The specific requirement of bands

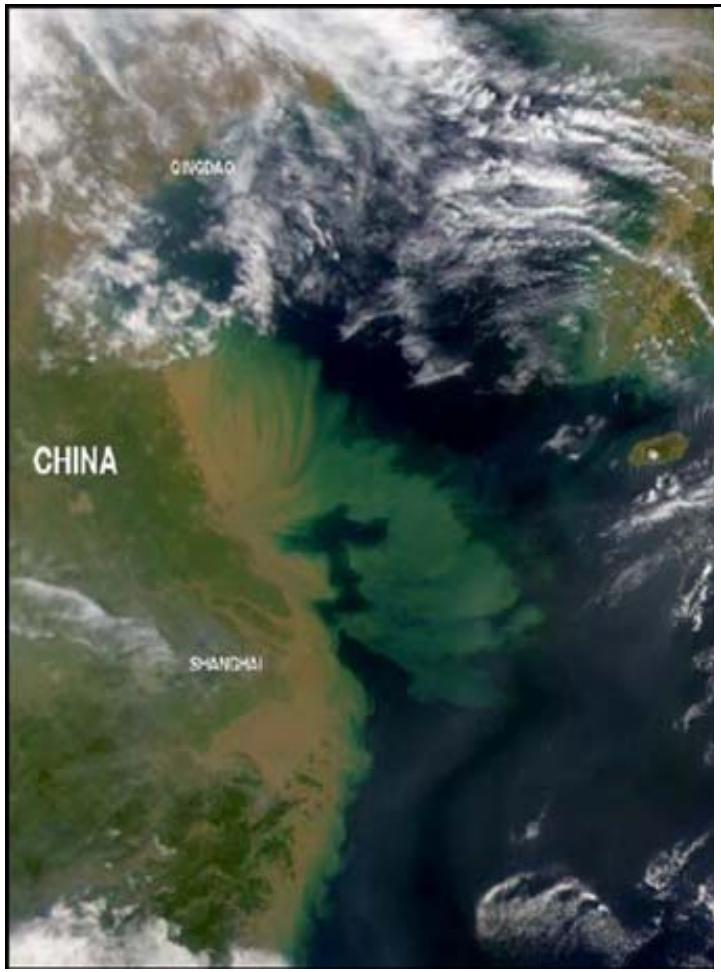
- **A minimum band set should includes two channels(such as 490nm/555nm or 443nm/555nm) in the visible and two channels (such as 750nm,865nm) in the near infrared with narrow bandwidth and high SNR.**

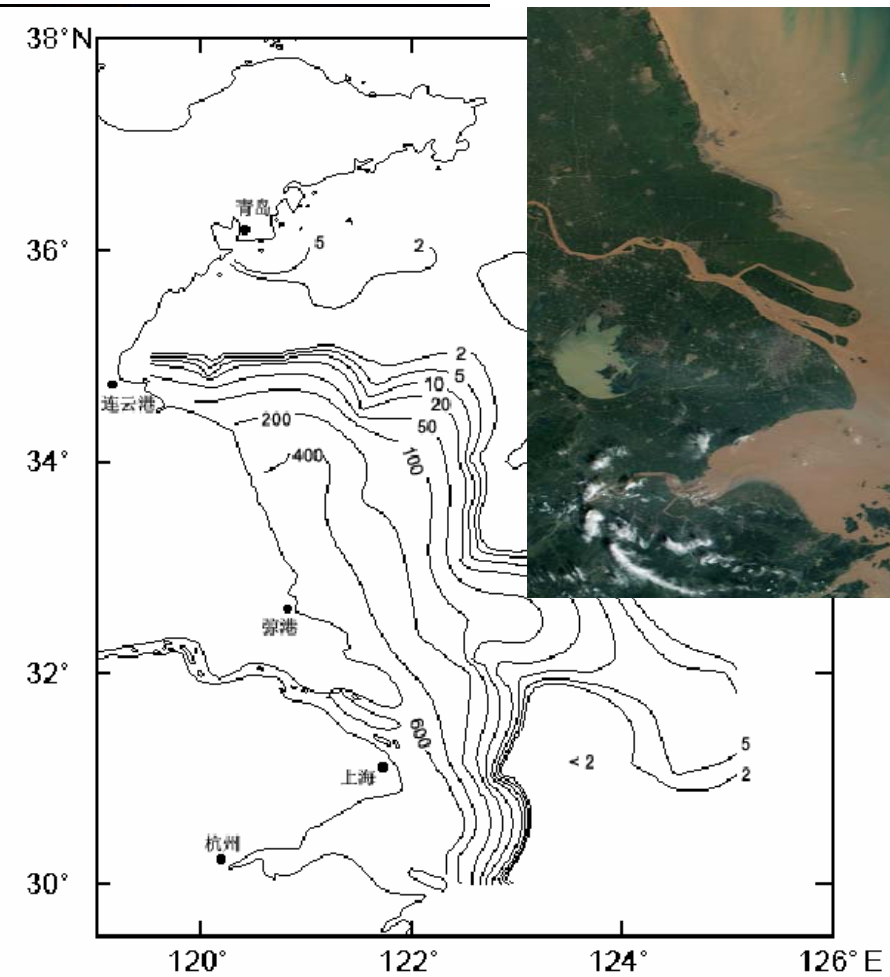
- **For coastal water, there should be more bands (likes 412nm for CDOM, 670nm for TSM/atmospheric correction, even chlorophyll fluorescence band 685nm) to separate different ocean color components.**

- **For China coastal sea, because of the extreme turbidity, the atmospheric correction needs some additional bands.**

The bands requirement of atmospheric correction

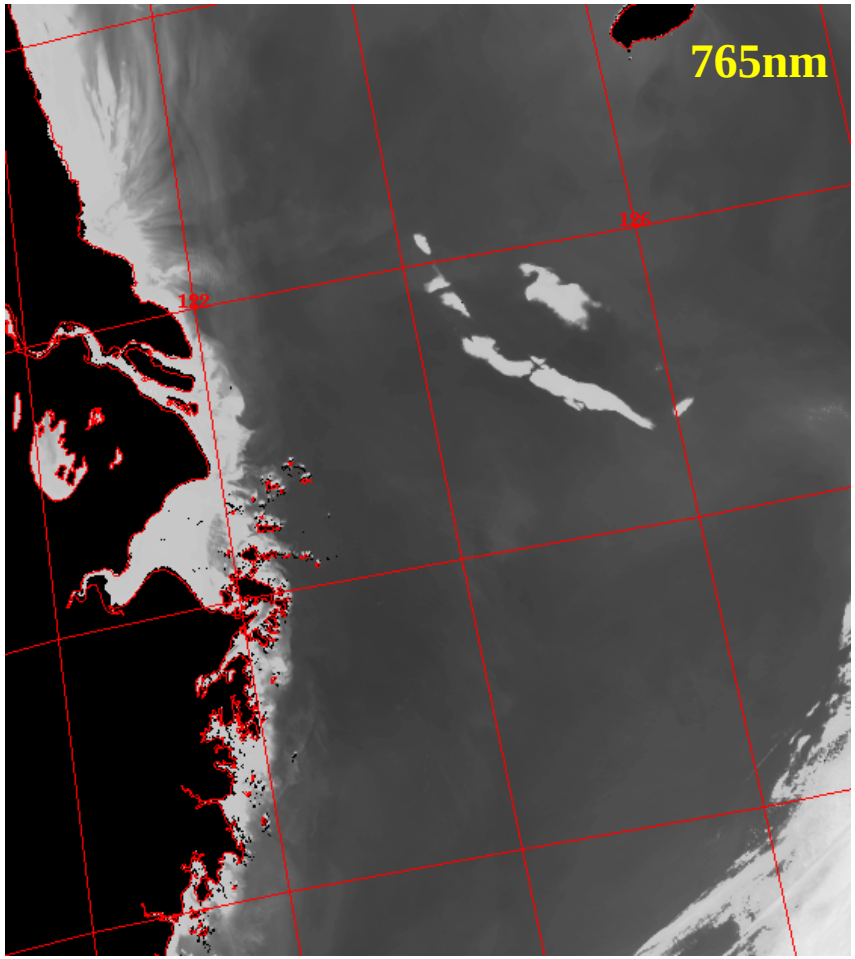
- China coastal sea is one of the most turbidity water around the global ocean, with the maximum concentration of total suspend matter more than 1000mg/L.

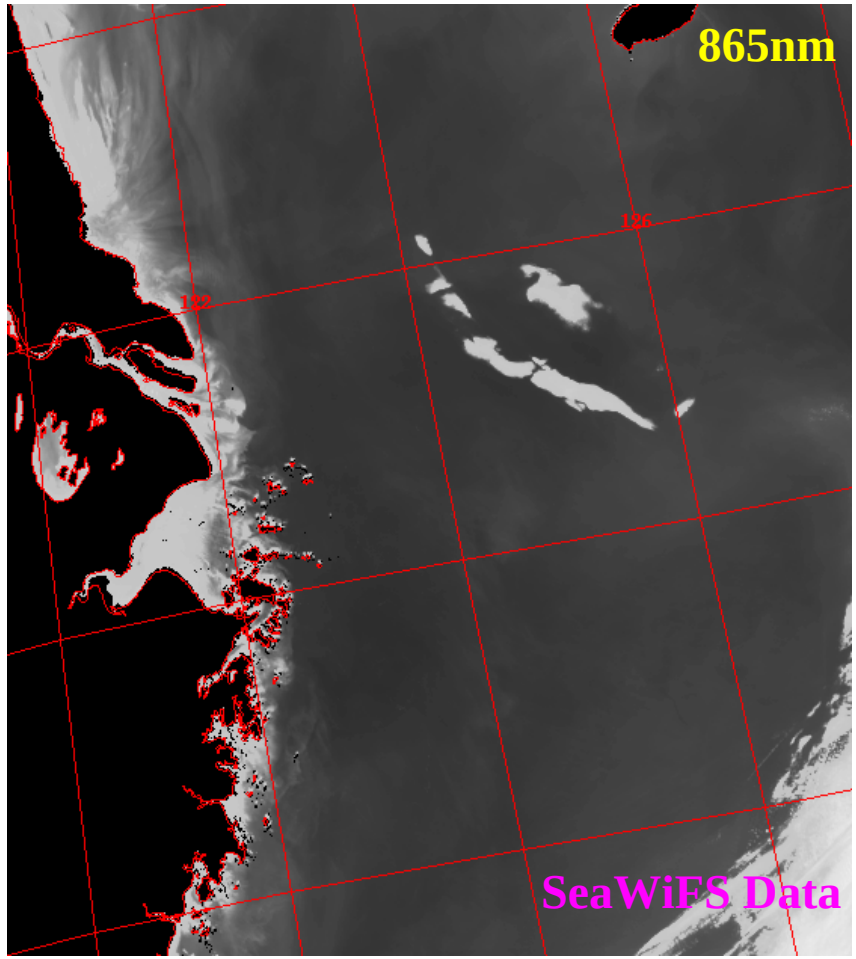




The non-neglect water-leaving radiance in China coastal sea

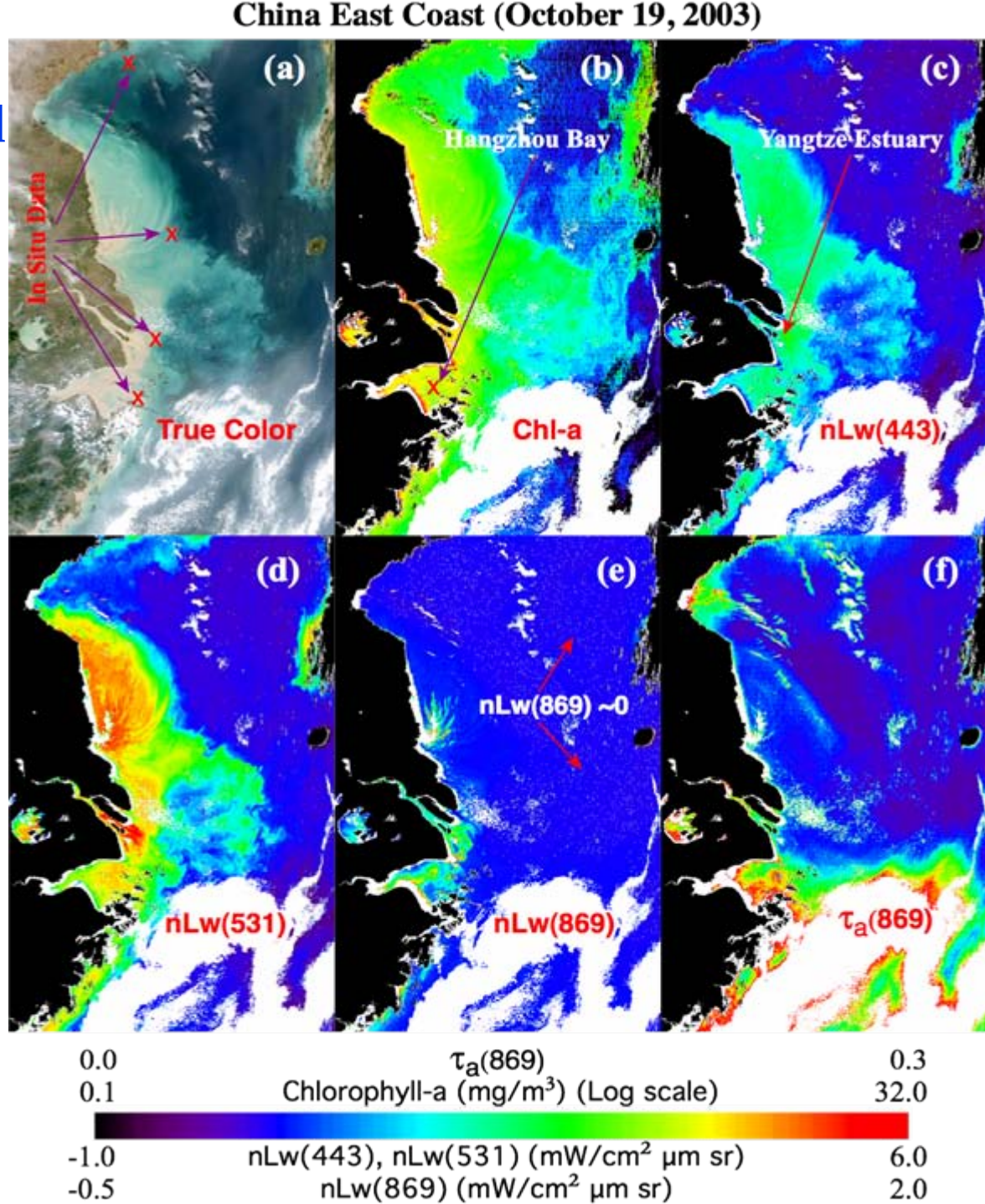
- Standard algorithm often fail to produce valid values in very turbid waters, e.g., Hangzhou Bay, Yangtze Estuary.





- **Wang using MODIS SWIR bands (1240 and 1640 nm) data**

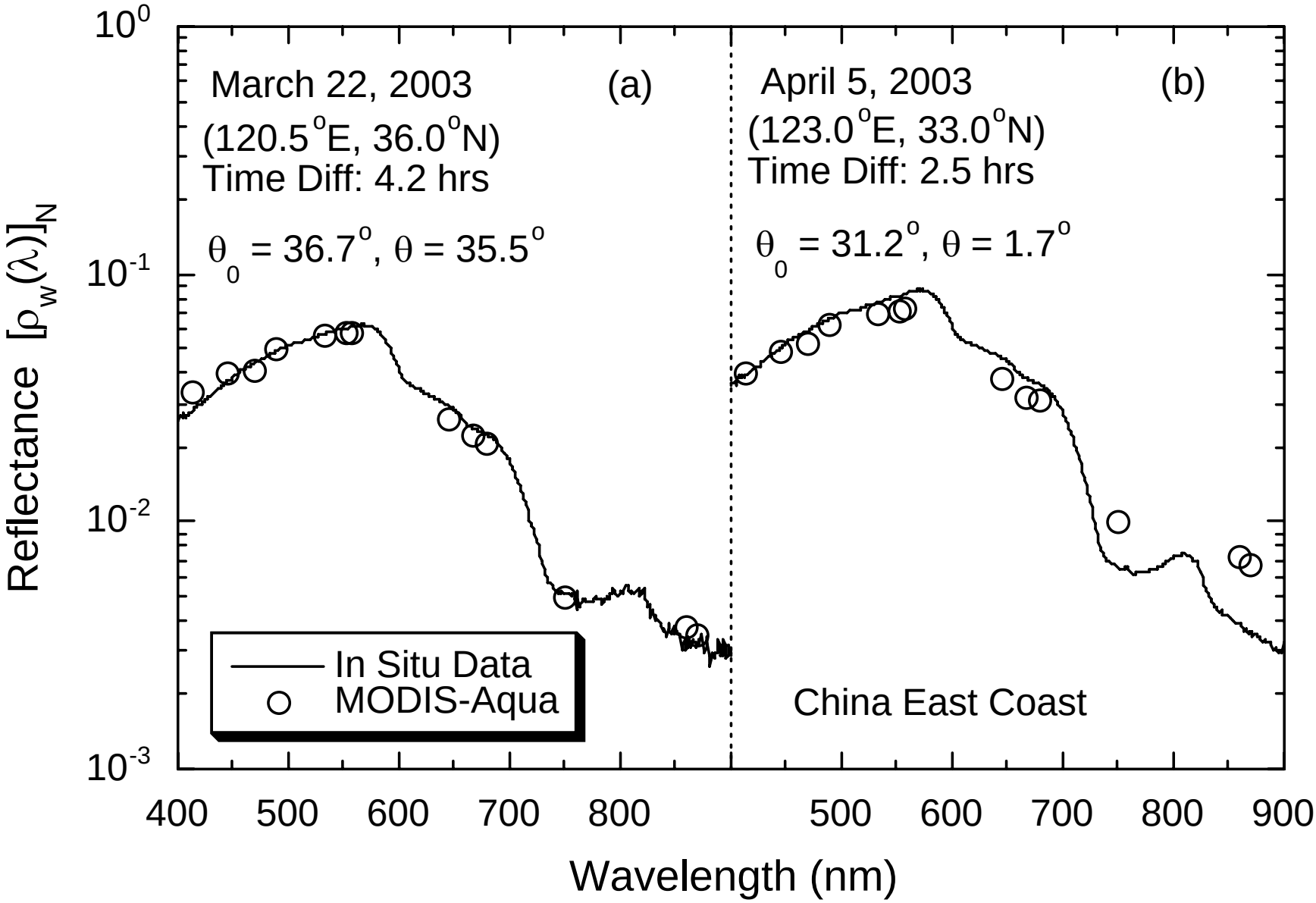
Results from SWIR Atmospheric Correction for turbid ocean waters



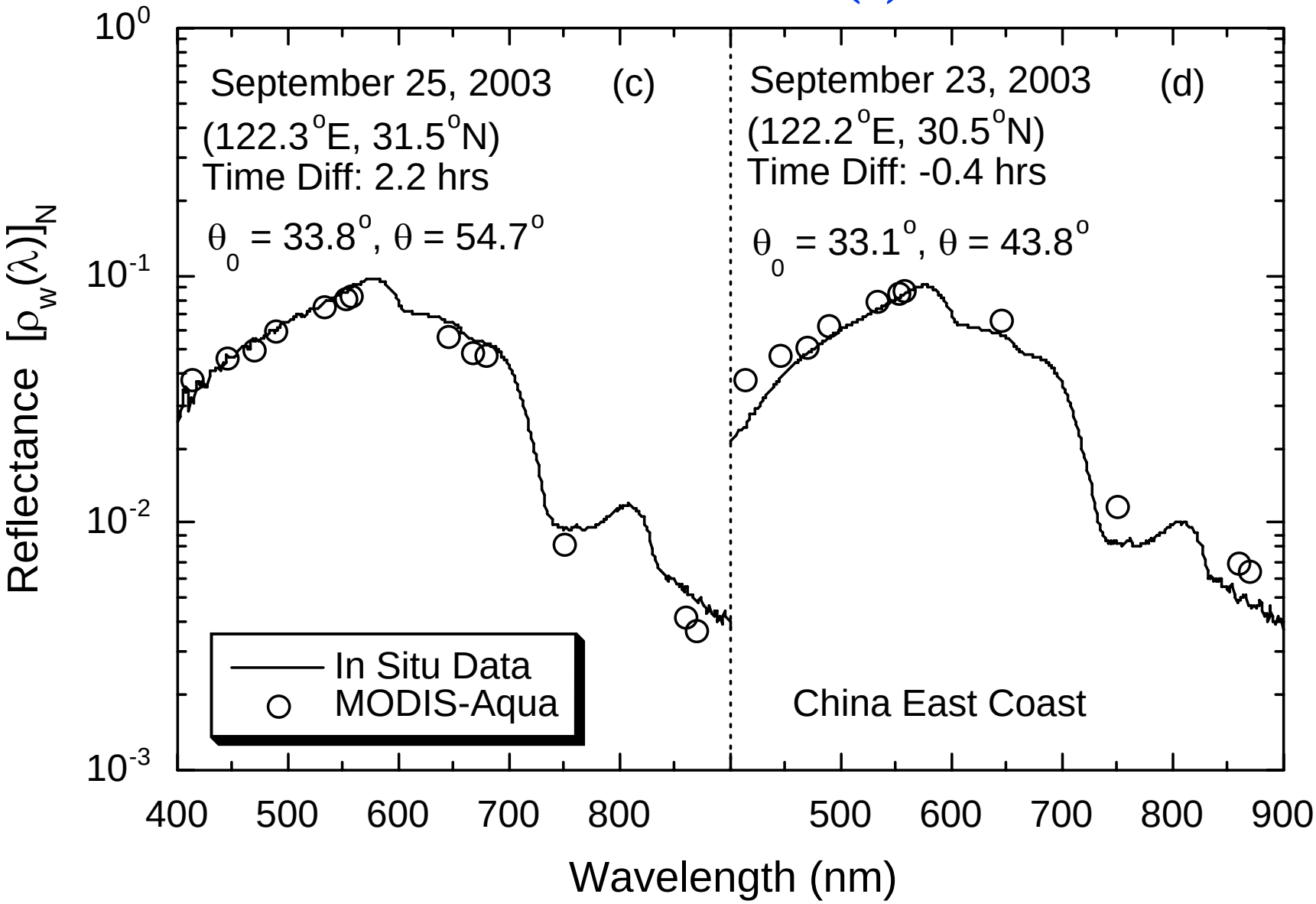
Wang, M. and W. Shi, "Estimation of ocean contribution at the MODIS near-infrared wavelengths along the east coast of the U.S.: Two case studies," Geophys. Res. Letters, 32, L13606, doi:10.1029/2005GL022917 (2005).

Wang, M., J. Tang, and W. Shi (2007), "MODIS-derived ocean color products along the China east coastal region," *Geophys. Res. Lett.*, 34, L06611, doi:10.1029/2006GL029724.

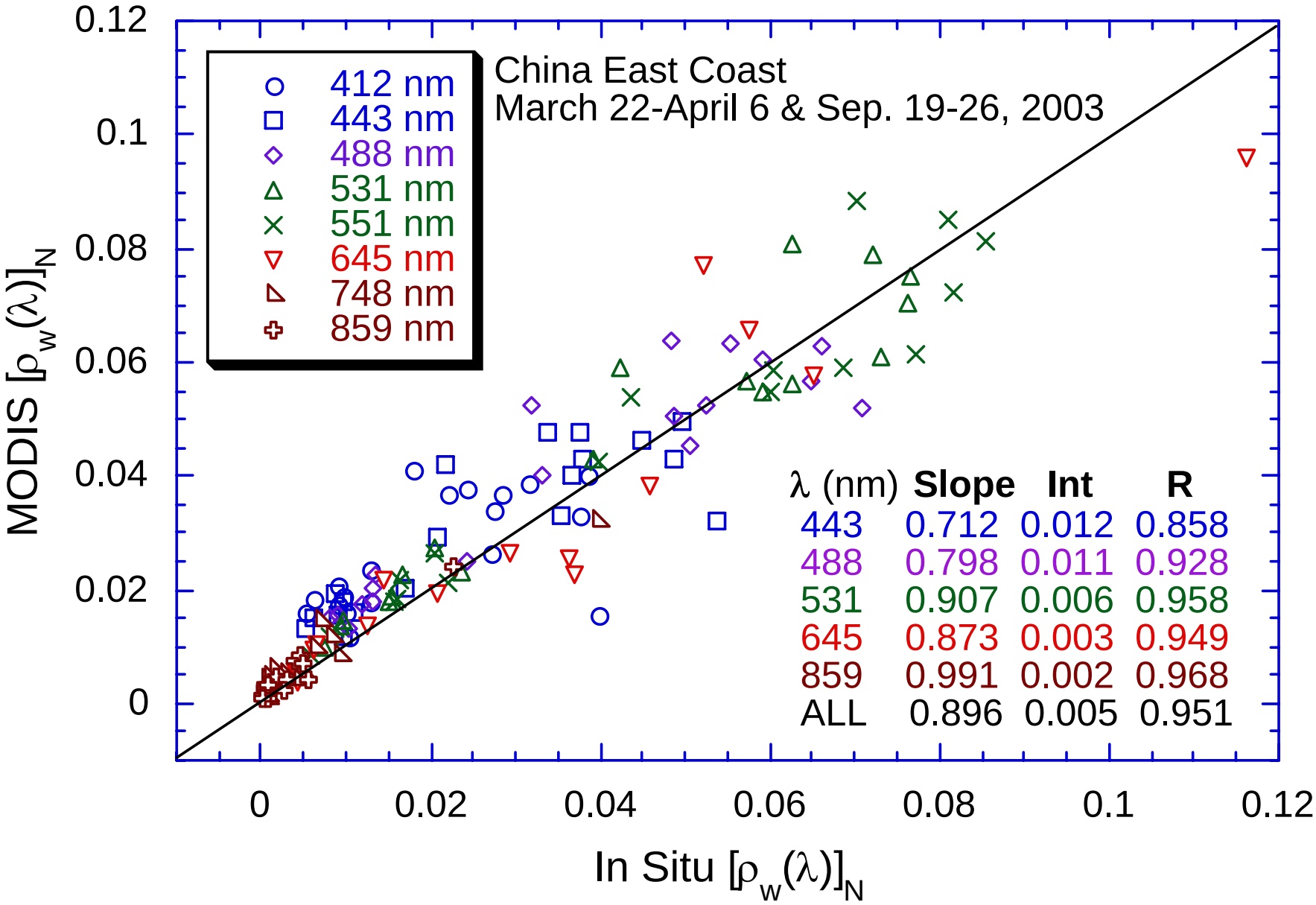
Validation Results (1)



Validation Results (2)

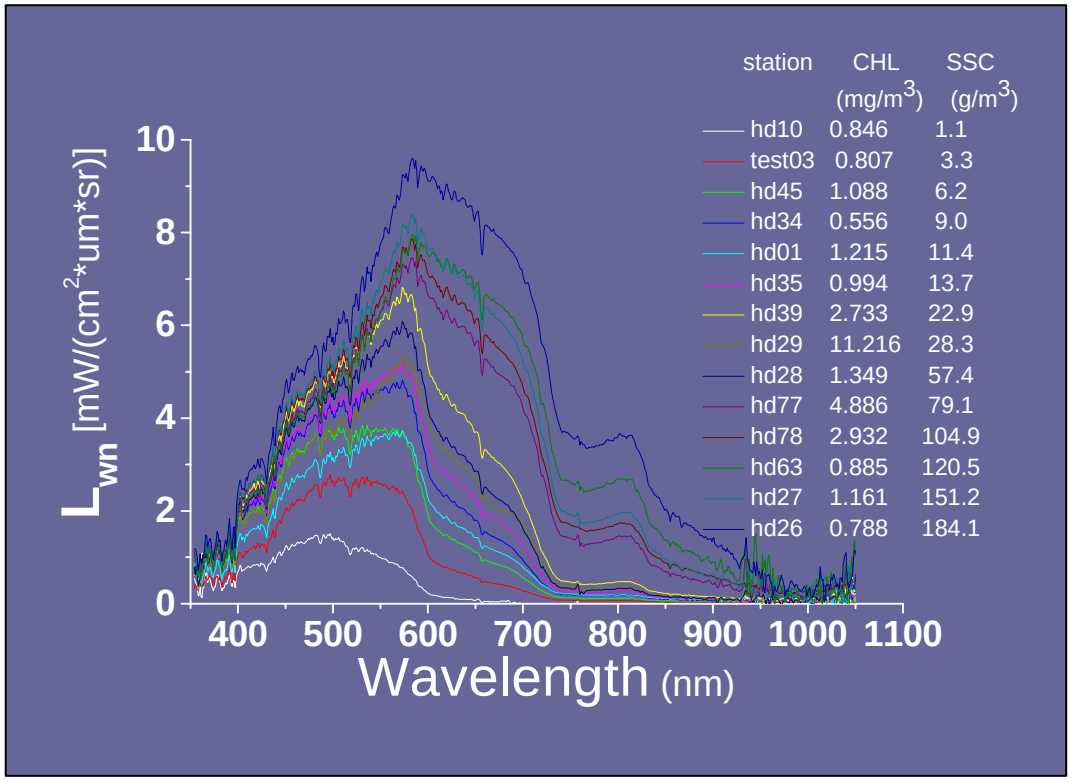


Validation Results (3)

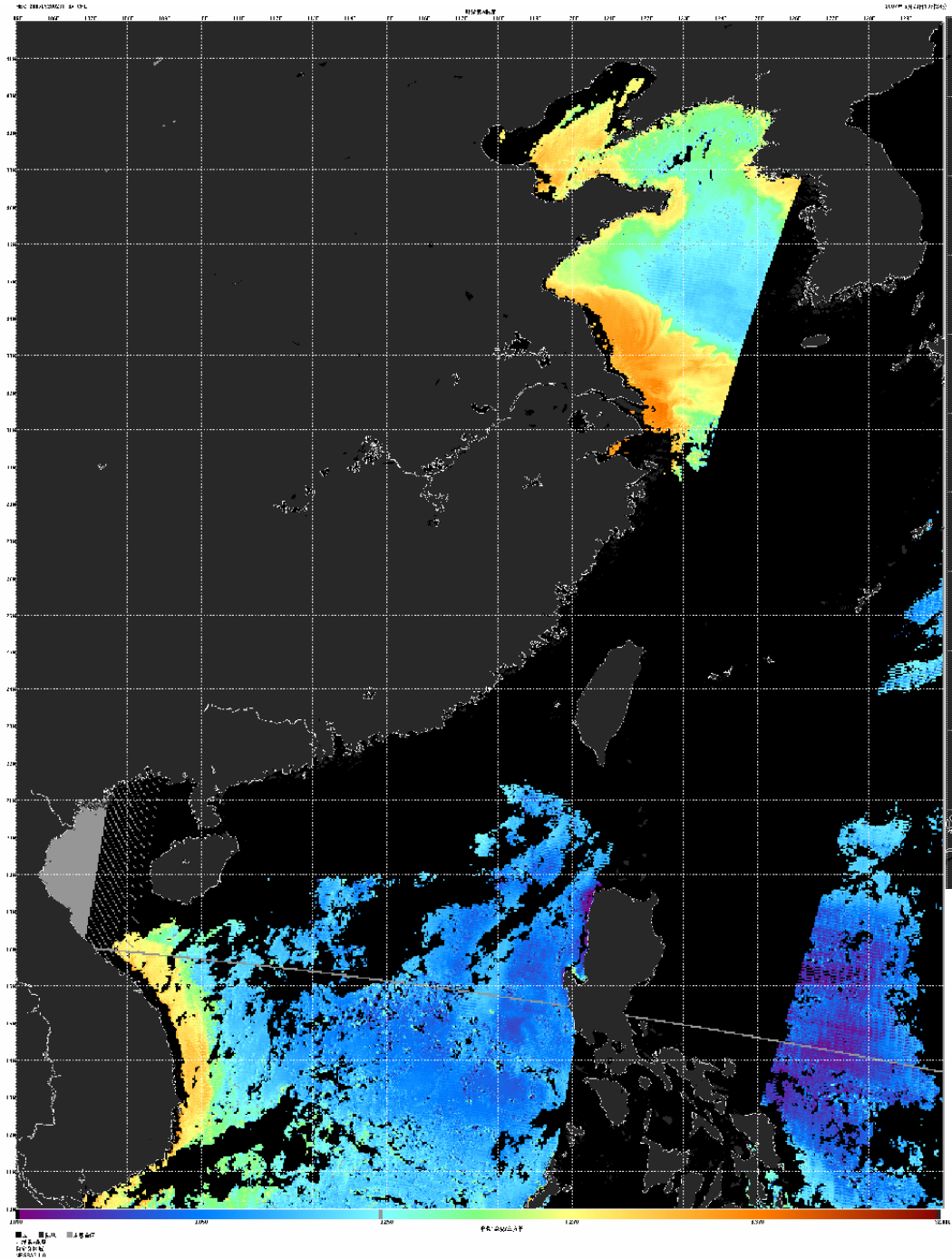


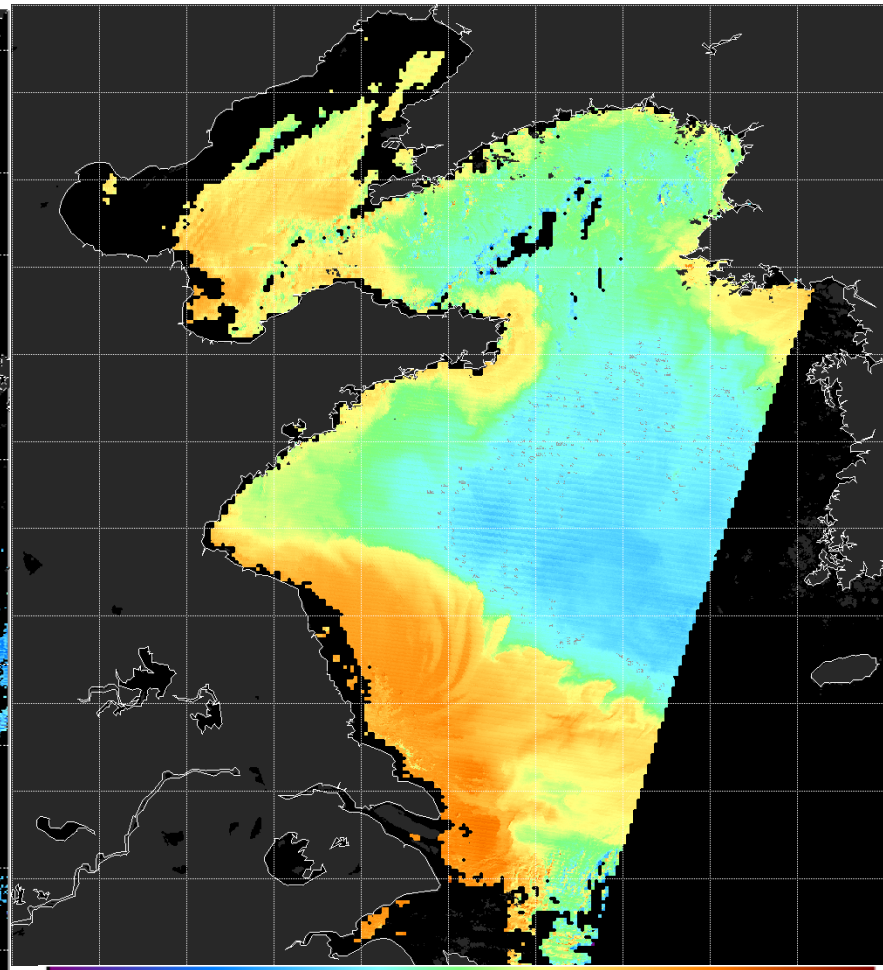
Atmospheric correction using UV band

- He&Pan(2004) developed a practical algorithm of atmospheric correction for turbid coastal and inland water.
- Water leaving radiance at UV increases little with increasing of turbidity. Thus, radiance at UV can be used to estimate aerosol scattering radiance.
- The performance of the algorithm is validated, and the error of the retrieved remote sensing reflectance less than 10% for the visible bands.



He Xianqiang, Pan Delu, Mao Zhihua. Atmospheric correction of SeaWiFS imagery for turbid coastal and inland waters. Acta Oceanologica Sinica, 2004, 23 (4): 609-615.

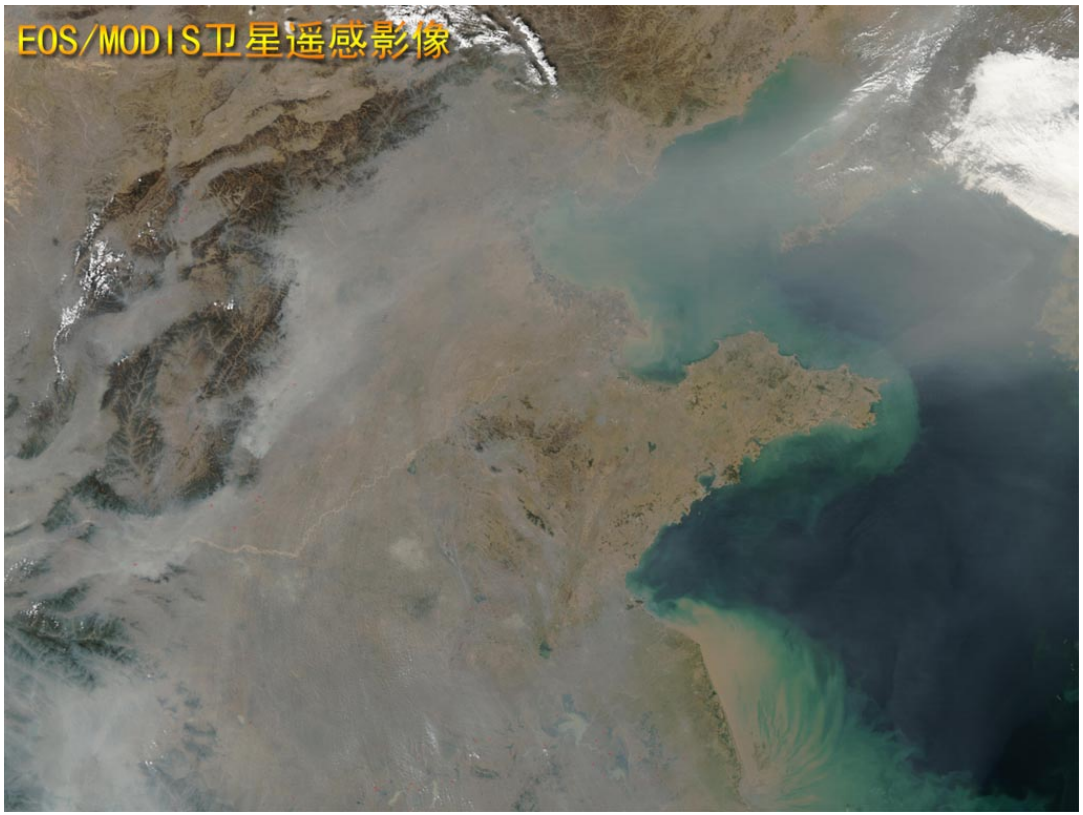




20 May, 2007. HY-1B/COCTS Chlorophyll concentration

Requirement of AC bands for China coastal sea

- One UV band (<400nm)
- Two shortwave IR bands
- Additional absorption aerosol detection band



The specific requirement of sensitivity

- **We use the RT model PCOART to simulate the TOA radiance with different chlorophyll concentration.**

  He Xianqiang, Pan Delu, Bai Yan, Zhu Qiankun, Gong Fang. Vector radiative transfer numerical model of coupled ocean-atmosphere system using matrix-operator method. Science in China Series D: Earth Sciences, 2007, 50(3): 442-452.

- **PCOART was an exact numerical model to deal with the vector radiative transfer problems of the coupled ocean-atmosphere system with rough sea-surface.**

- **The simulated cases:**

  (1)Sun zenith angles were 60^0 and 80^0, respectively;

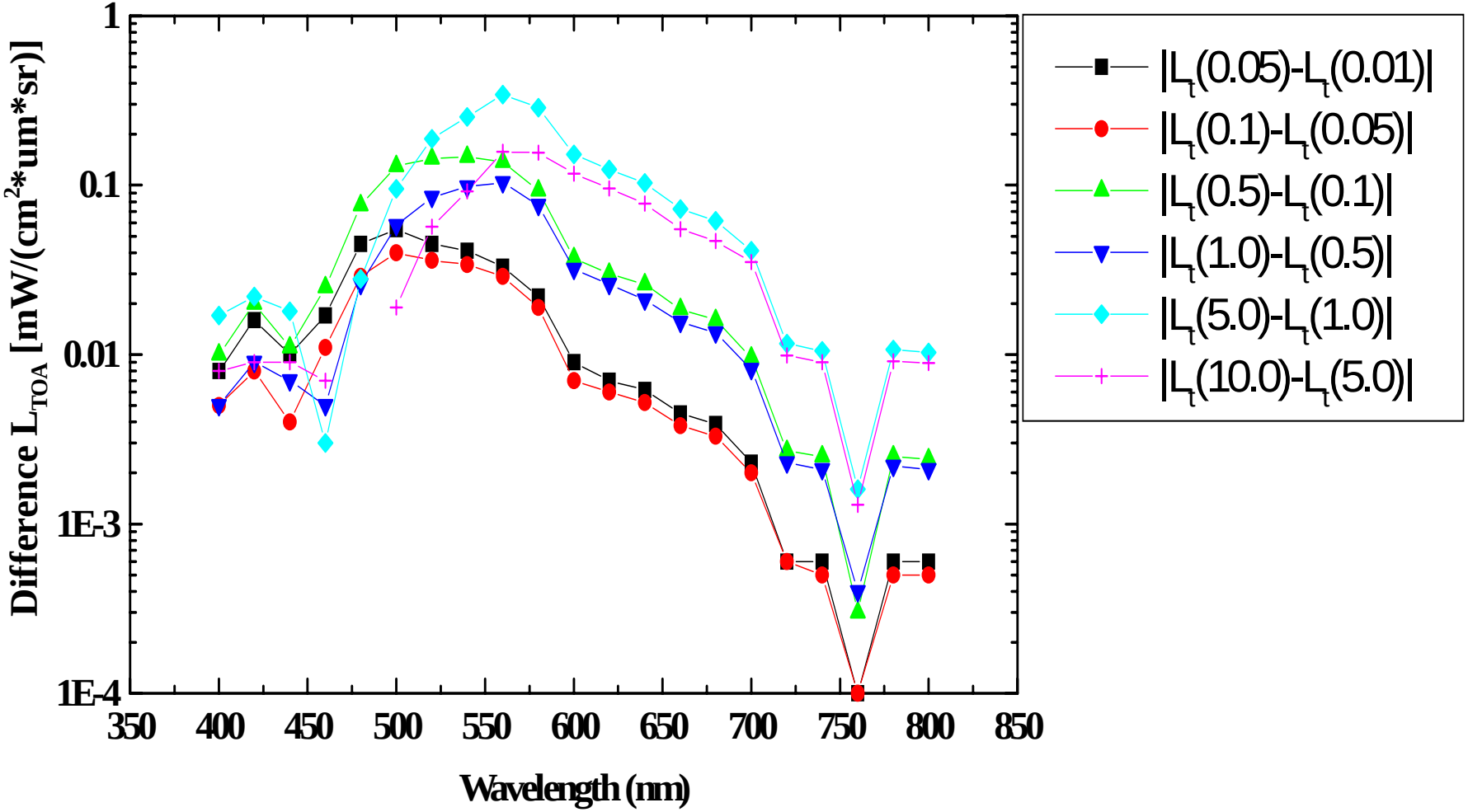
  (2)Senor viewing zenith angle was 0^0;

  (3)Chlorophyll concentrations were 0.01,0.05,0.1,0.5,1.0,5.0,10.0, respectively;

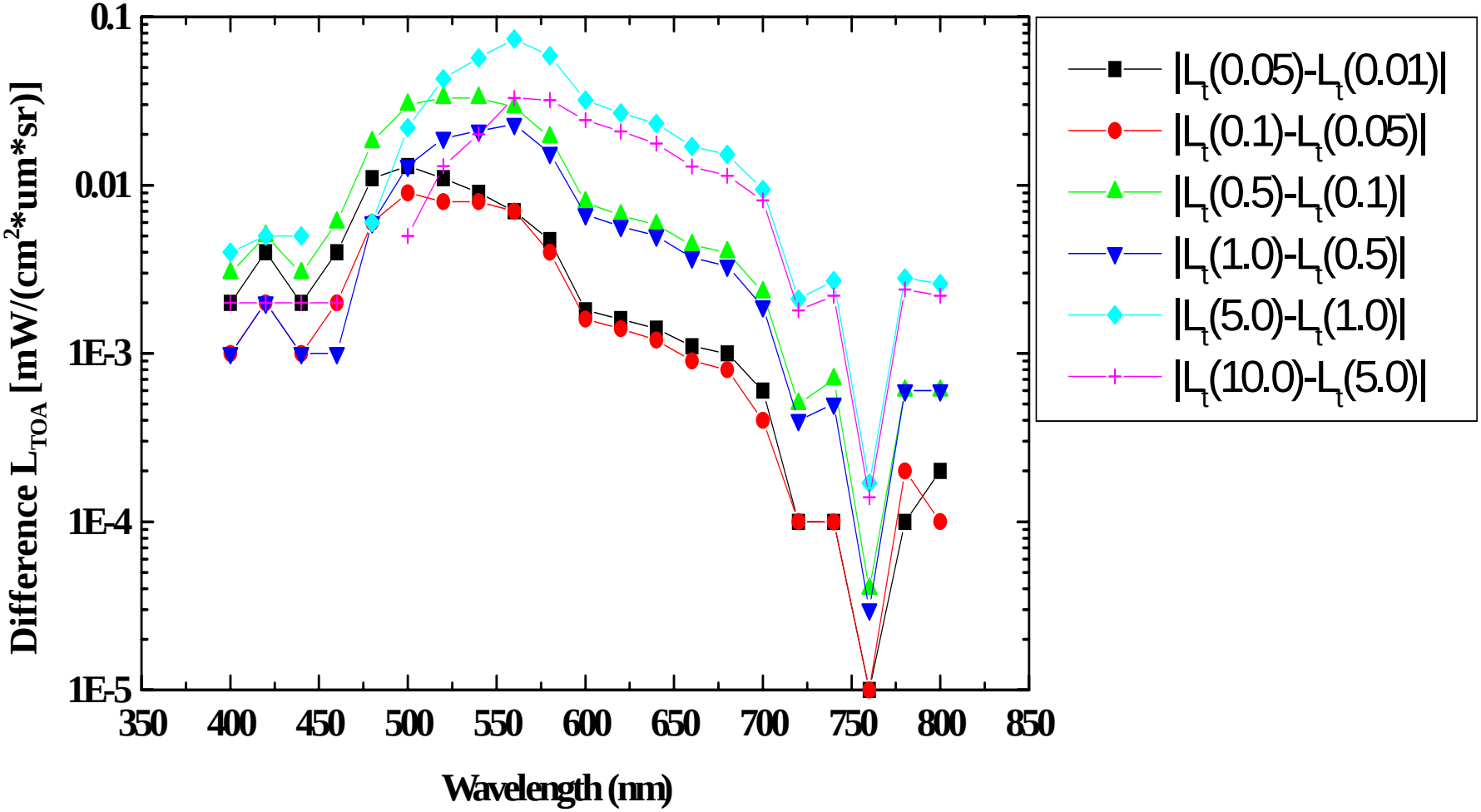
  (4)Wind speed was 7.23m/s;

  (5)550nm aerosol optical thickness was 0.2;

The difference of Lt with variation of chlorophyll concentration (Sun zenith angle is 60^0)



The difference of Lt with variation of chlorophyll concentration (Sun zenith angle is 80^0)



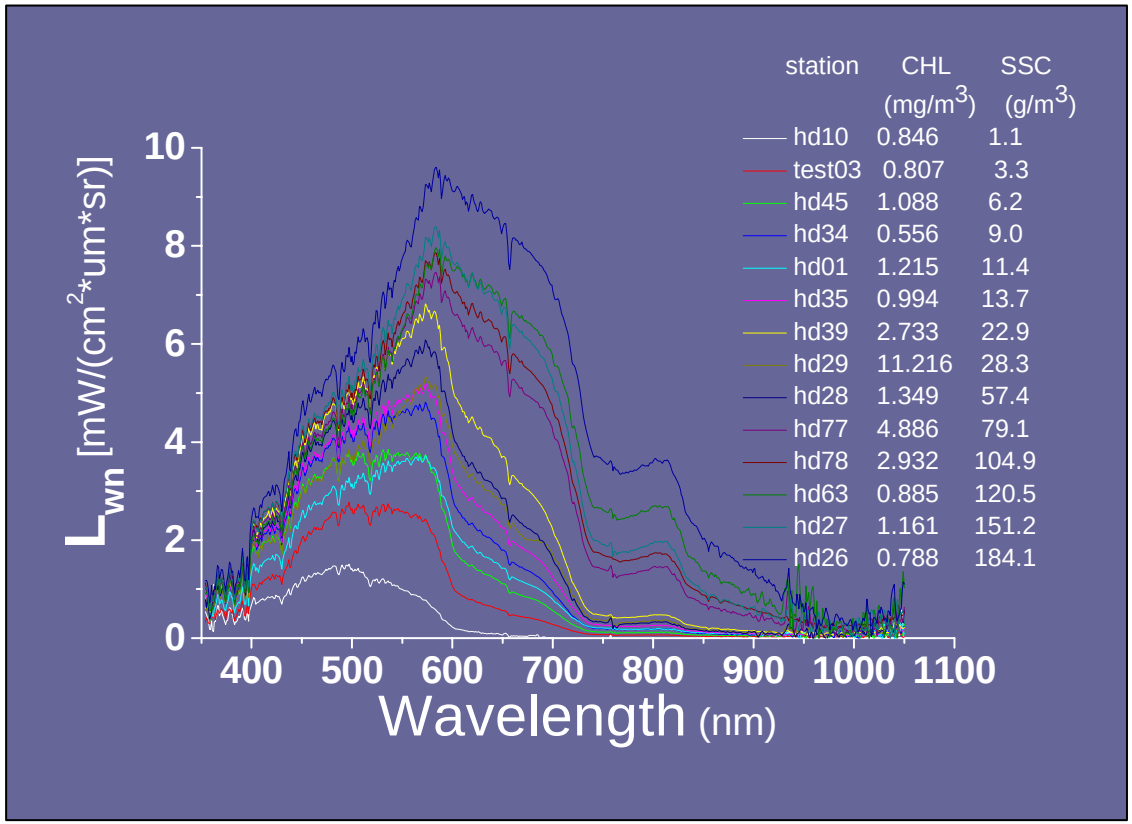
The requirement of the sensitivity (Radiance per-DC)

Wavelength	Sun_zen=60^0	Sun_zen=80^0
400	0.005	0.001
420	0.008	0.002
440	0.004	0.001
460	0.003	0.001
480	0.03	0.006
500	0.02	0.005
520	0.04	0.008
540	0.03	0.008
560	0.03	0.007
580	0.02	0.004
600	0.007	0.002
620	0.006	0.001
640	0.005	0.001
660	0.004	0.001
680	0.003	0.001
700	0.002	0.0005

CZCS		SeaWiFS		MODIS/AQUA	
		412	0.0109	412	0.01068
443	0.021	443	0.0105	443	0.00579
		490	0.0082	488	0.00394
520	0.015	510	0.0071	531	0.00290
550	0.012	555	0.0057	551	0.00233
670	0.005	670	0.0032	667	0.00074
		765	0.0023	748	0.00092
		865	0.0016	869	0.00085

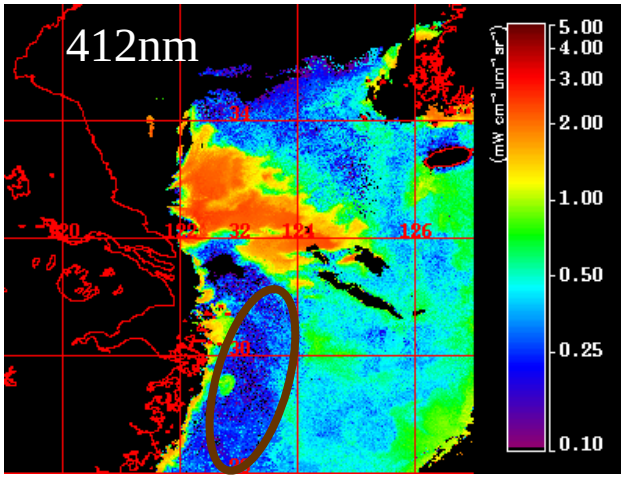
Specific requirement of radiance dynamic range

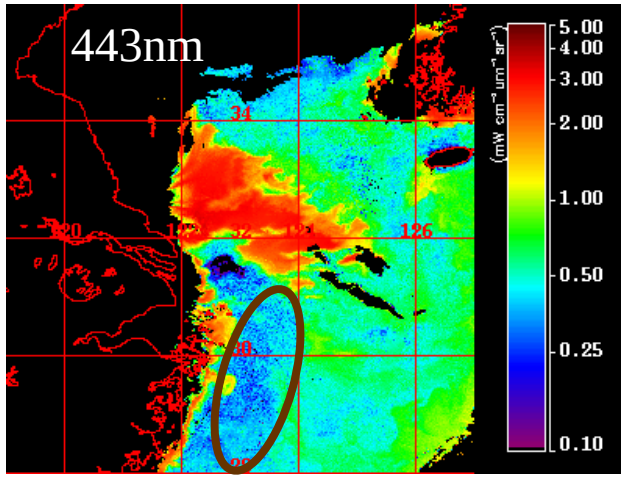
- **For the fixed bit number per-pixel, the dynamic range and sensitivity is conflict. High sensitivity causes low dynamic range.**
- **The water-leaving radiance in China coastal sea varied largely, especially at the red/NIR bands.**

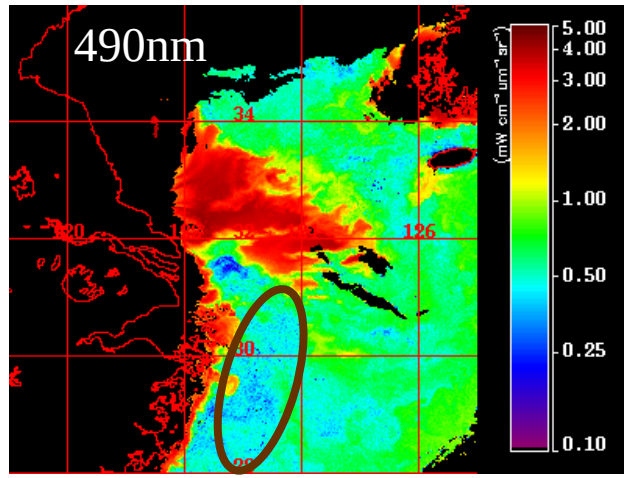


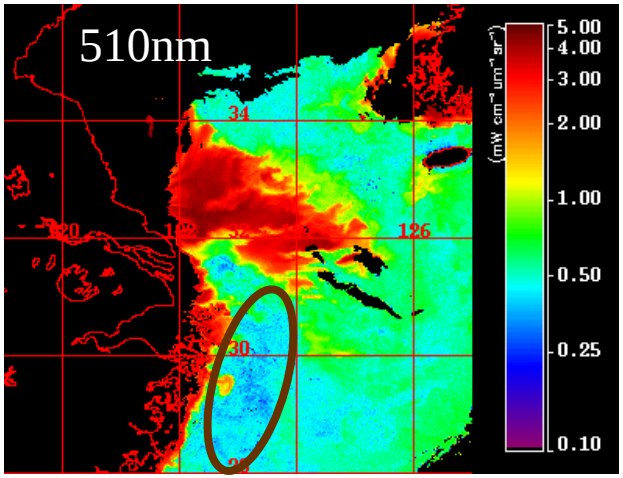
The black water around East China Sea coastal

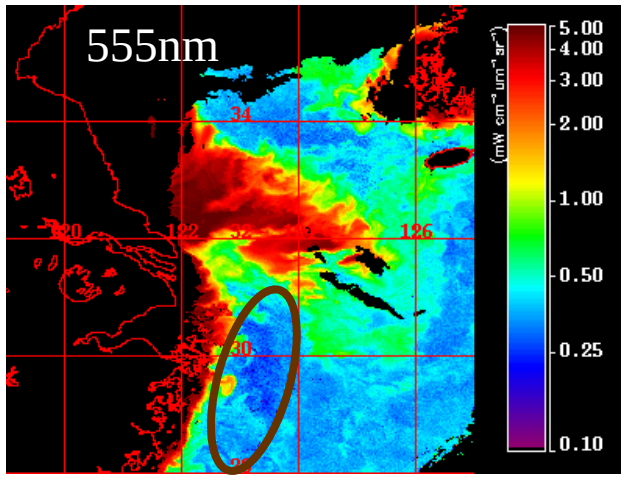
- **Normalized water-leaving radiances of SeaWiFS, 15/04/2003**

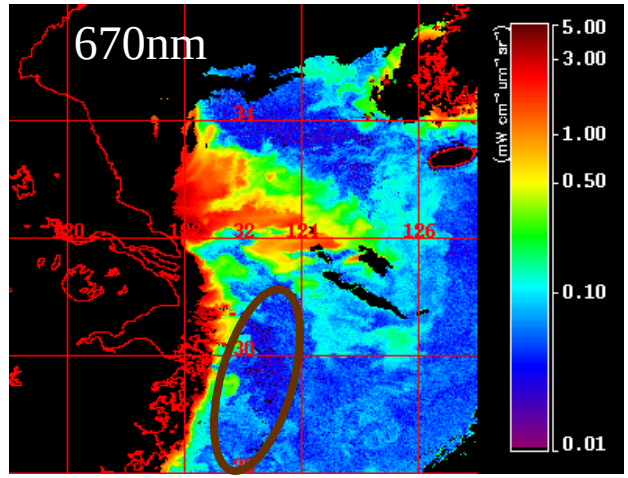




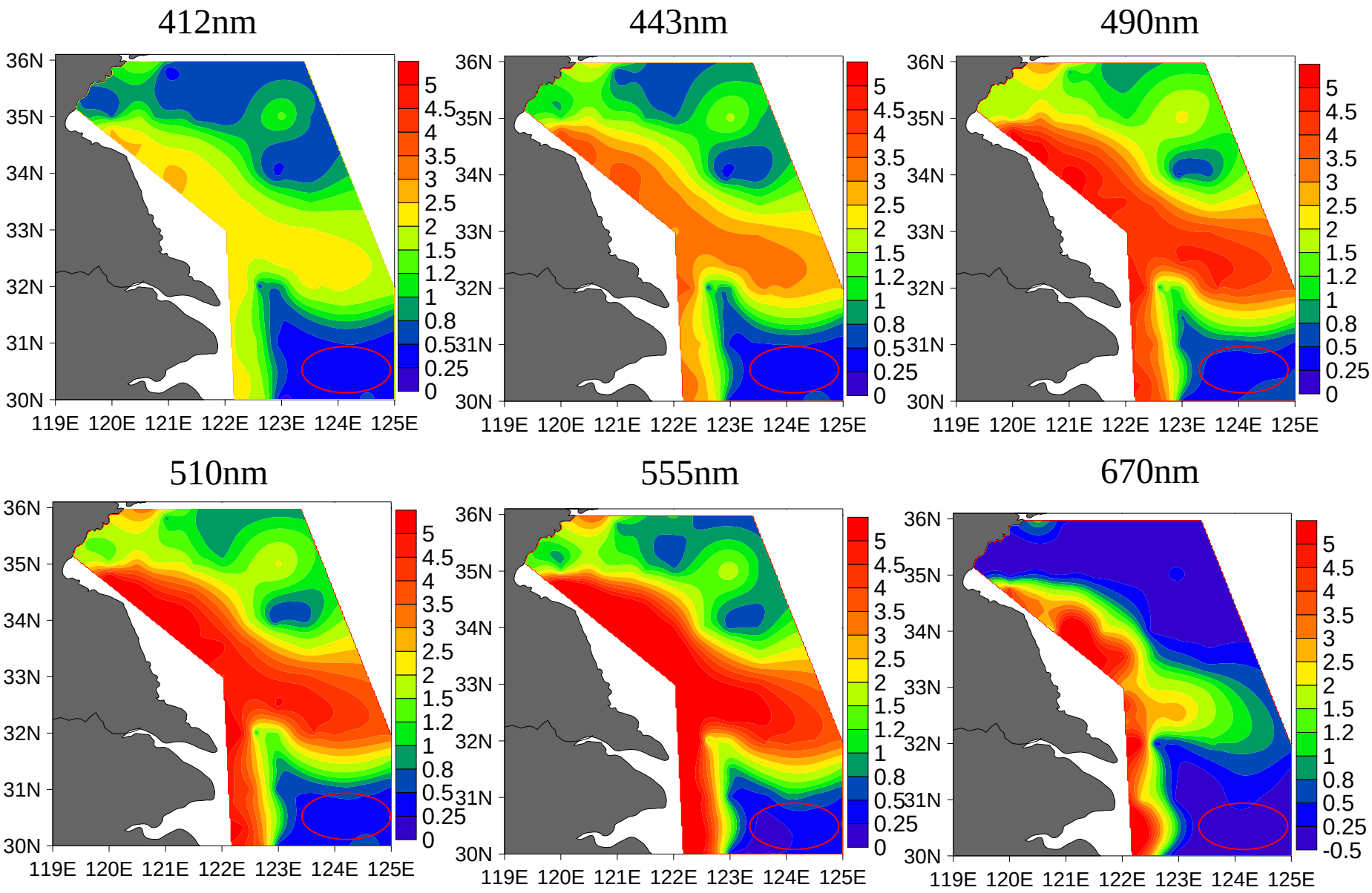




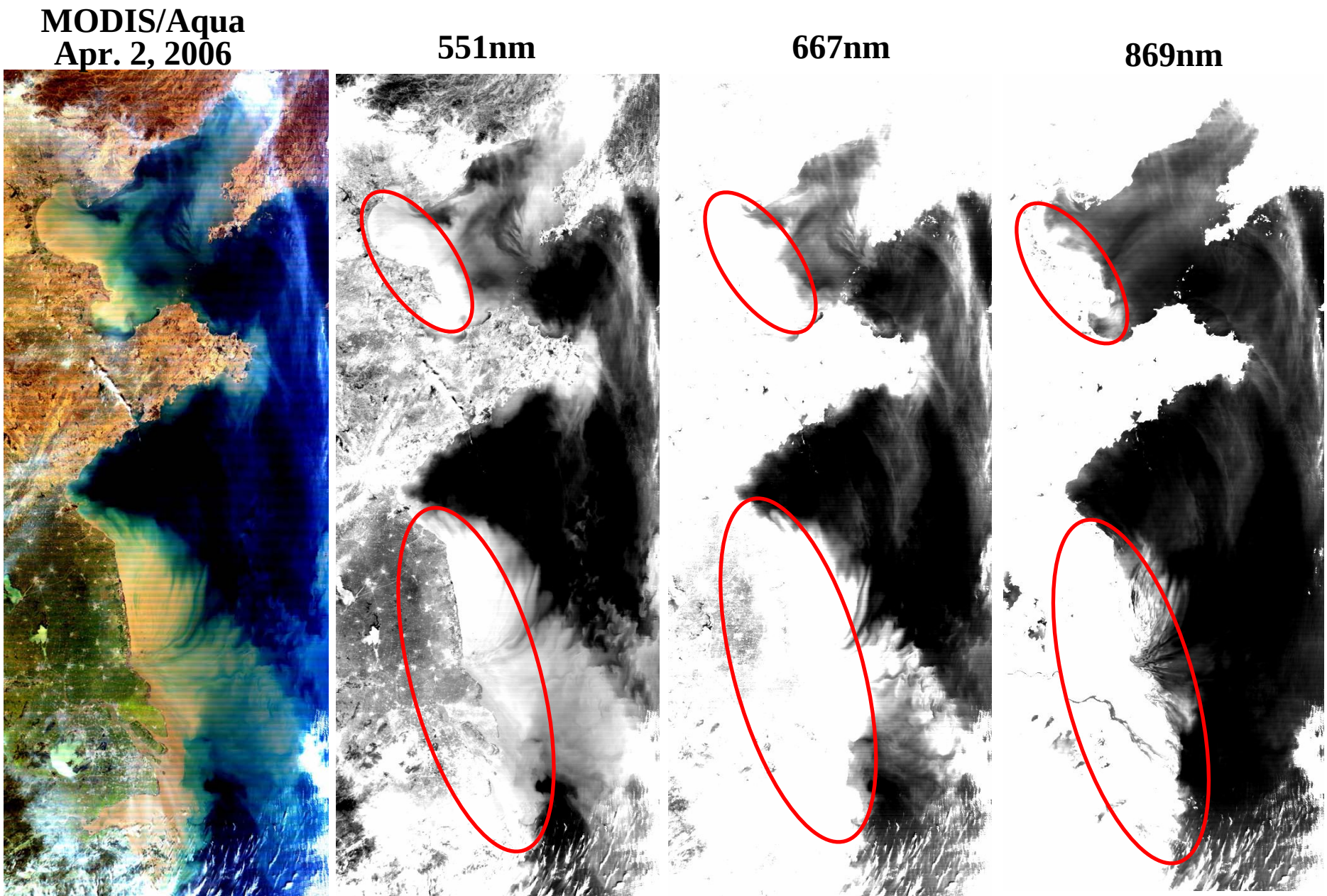




●In-situ measured Lwn distribution (22/03/2003-23/04/2003)

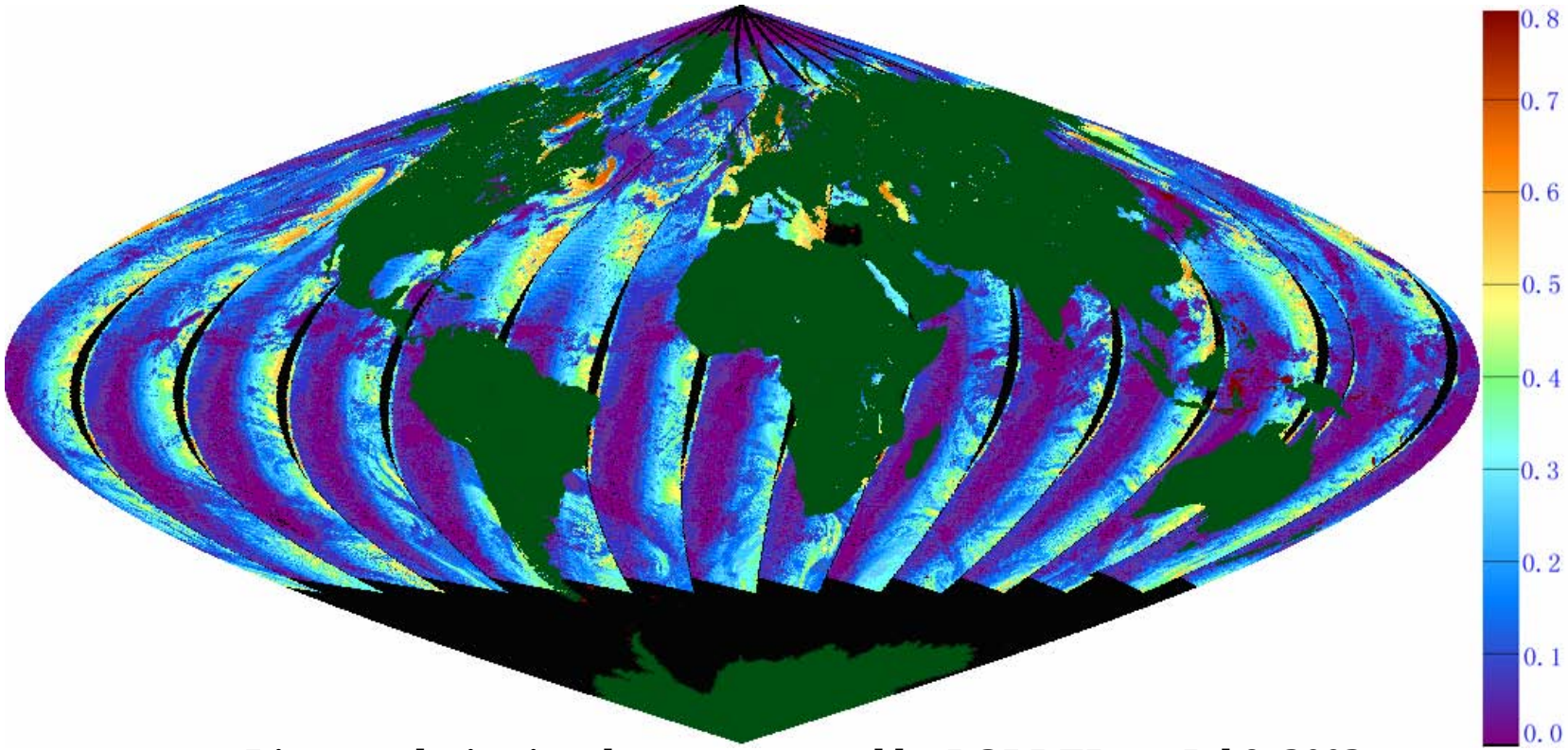


- **High water-leaving radiance may cause the saturation of the sensed signal**



Specific requirement of polarization sensitivity

- **Degree of polarization of the top of atmosphere (TOA) could approach 70% , If sensor polarization sensitivity is 5%, the measured TOA radiance should be corrected by as much as ±3% (5%×70%×90%, 90% is the ratio of the atmosphere scattering radiance to the total radiance received by sensor)**



Linear polarization degree measured by POLDER on Jul.9, 2003

Specific requirement of polarization sensitivity

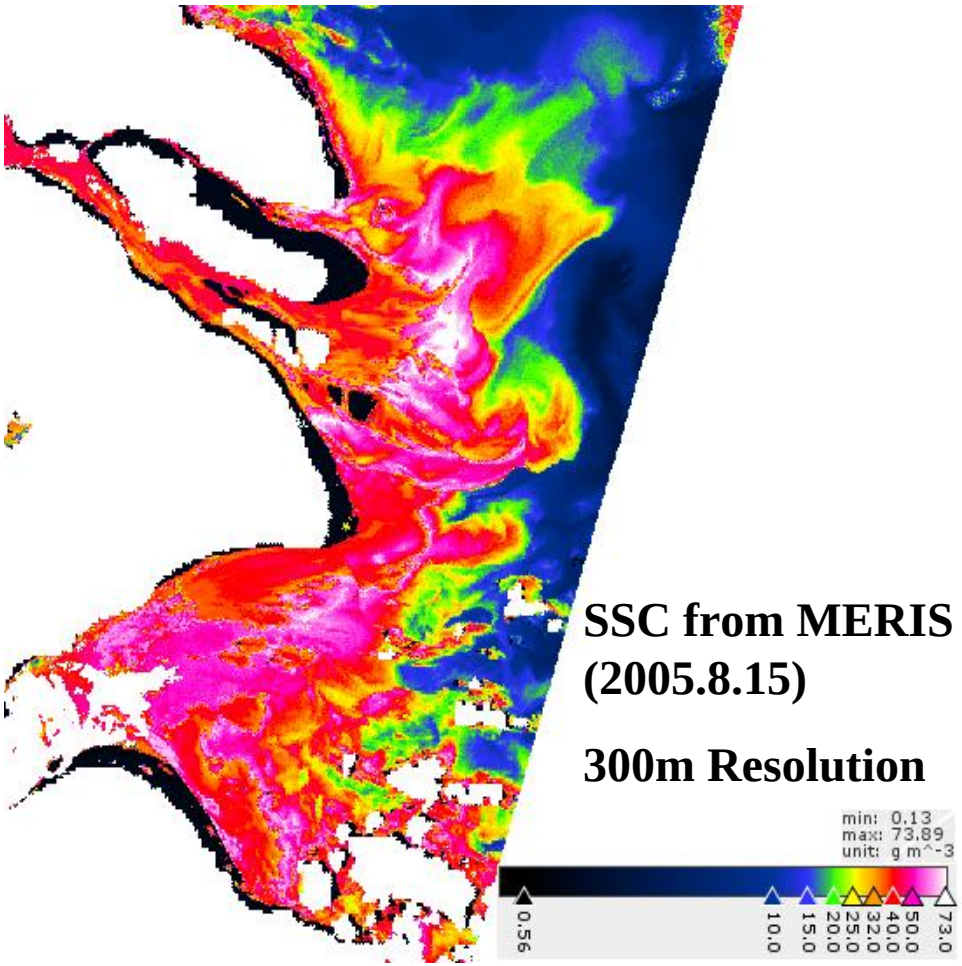
- Gordon(1988) derived a requirement for future ocean color sensor to have polarization sensitivity less than 2.5%.
- According to this requirement, most of the launched ocean color sensors was designed with the polarization sensitivity less than 2.5%, but the actual measured polarization sensitivity may as high as 6%

Sensor	Launched date	Country	Designed polarization sensitivity	Measured polarization sensitivity
SeaWiFS	Aug.,1997	USA	<2%	<0.3%
MODIS TERRA	Dec.,1999	USA	<2%	<6%
MODIS AQUA	May,2002	USA	<2%	<6%
MERIS	Mar.,2002	Europe	<0.3%	
GLI	Dec.,2003	Japan	<2%	<6%(band 1-2) <2%(other bands)
OCTS	Aug.,1996	Japan	<5%(412nm) <2%(>412nm)	
COCTS HY-1A	May,2002	China	<5%	
OCM	May,1999	India	<2%	

Specific requirement of the spatial resolution

- **100m~300m spatial resolution is preferred**

River plume



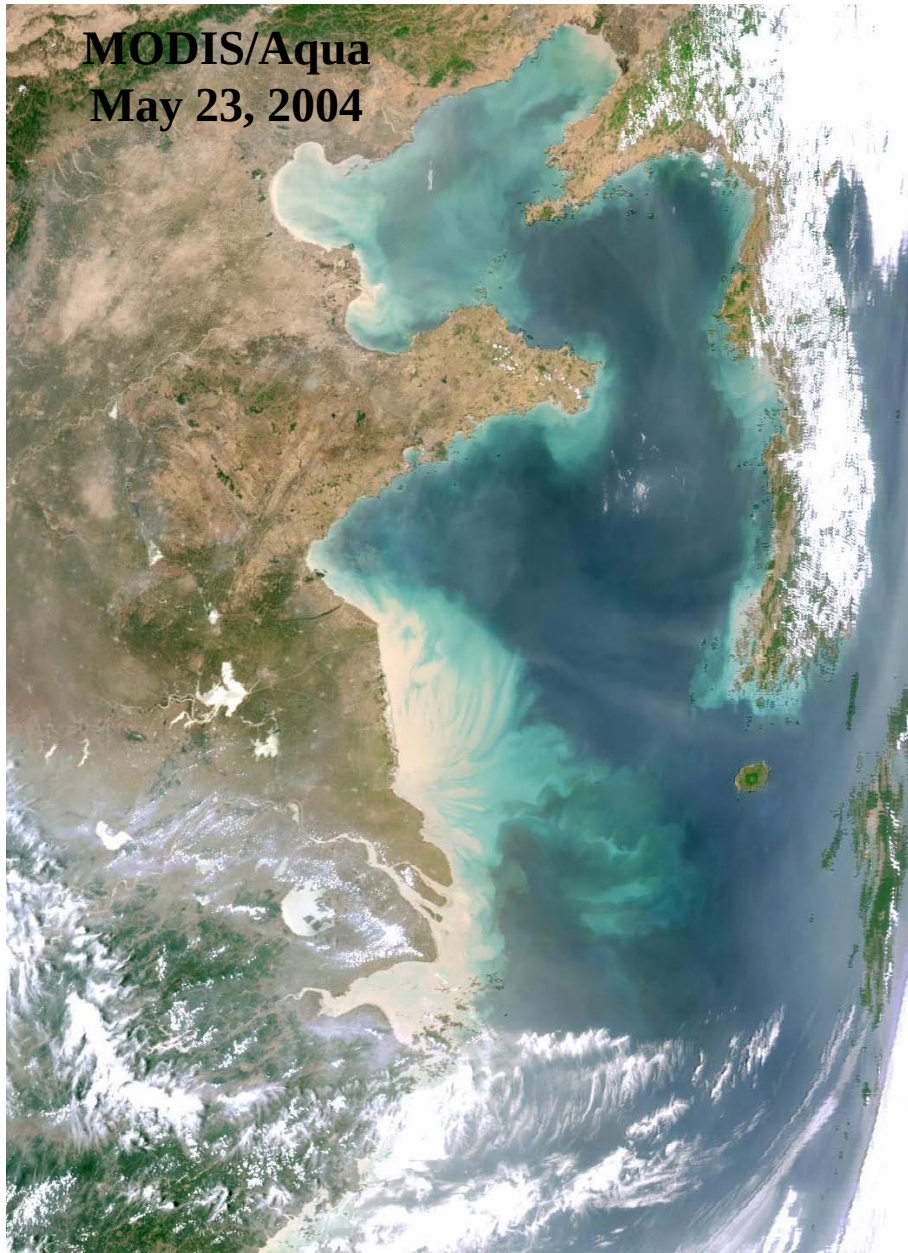
SSC from MERIS (2005.8.15)

300m Resolution

Red tide in ECS

The specific requirement of cloud detection

- Traditional, OCRS uses the 865nm bands to detect the cloud, such as SeaWiFS/MODIS/OCTS/POLDER/ OSMI process in SeaDAS.
- For China coastal sea, 865nm reflectance of water may larger than thin cloud. Traditional method may mask the coastal water as the cloud which reduces the available data.
- For GEO OCRS, because of the variation of the sun zenith angle as the time, exactly operational cloud detecting method should be developed.



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The total status of the OCRS in China

- China has draw out the three series special ocean remote sensing satellite with sun-synchronization orbit, including Ocean Color Satellite (HY-1 Series), Ocean Dynamic Satellite (HY-2 Series) and Ocean Watch & Monitor Satellite (HY-3 Series).
- Up to now, there are no formal plan to launch the special GEO OCRS satellite in China.

HY-1 Satellite Series

- **The main use of HY-1 is ocean color satellite and to detect the chlorophyll concentration, suspended sediment concentration, and dissolved organic matter, pollutants, as well as sea surface temperature.**
- **HY-1A, launched at 15 May,2002.**
- **HY-1B, launched at 11 April, 2007.**
- **HY-1C/D, will be launched 2009/10 on time-stable.**
- **It will be launched 2(AM/PM) HY-1 satellites every 3-4 years up to 2020.**
- **2002, 2007, 2009, 2013, 2017.**

COCTS bands and detecting object

- **Spatial resolution is 1100m**

Band (μm)	Main detecting object
0.402～0.422	CDOM
0.433～0.453	Chlorophyll
0.480～0.500	Pigment, diffuse attenuation coefficient
0.510～0.530	Chlorophyll, suspended sediment
0.555～0.575	Chlorophyll, suspended sediment
0.660～0.680	Atmospheric correction, suspended sediment
0.740～0.760	Atmospheric correction, aerosol
0.845～0.885	Atmospheric correction, aerosol
10.30～11.40	Sea surface temperature
11.40～12.50	Sea surface temperature

CZI bands and detecting object

- **Spatial resolution is 250m**

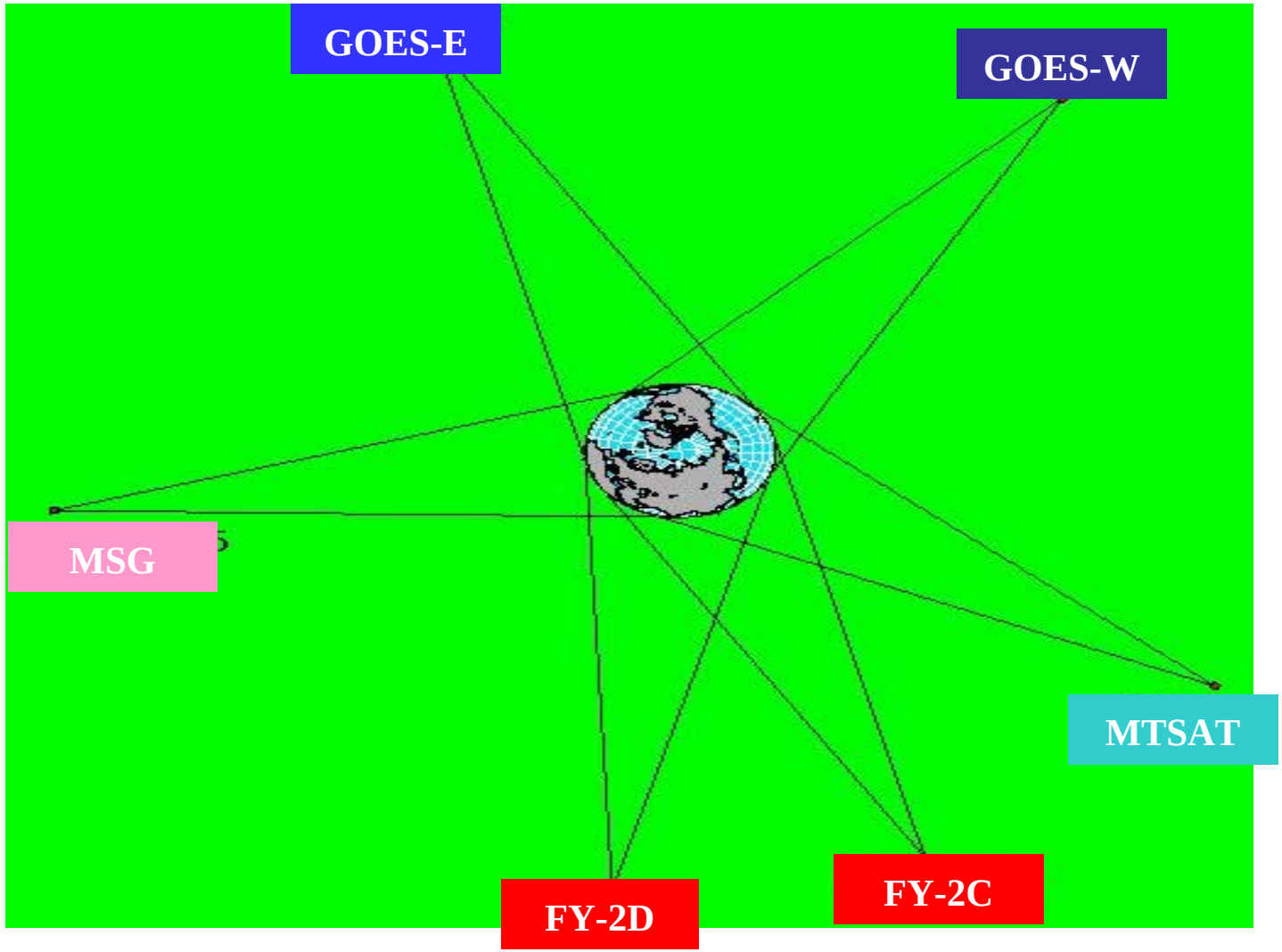
Band (μm)	Main detecting object
0.433～0.453	Pollutant, ocean color, sea ice, topography
0.555～0.575	suspended sediment, Pollutant, *ice, beach*
0.655～0.675	Atmospheric correction, suspended sediment
0.675～0.695	Atmospheric correction, chlorophyll fluorescence

Geostationary meteorological satellite program of China

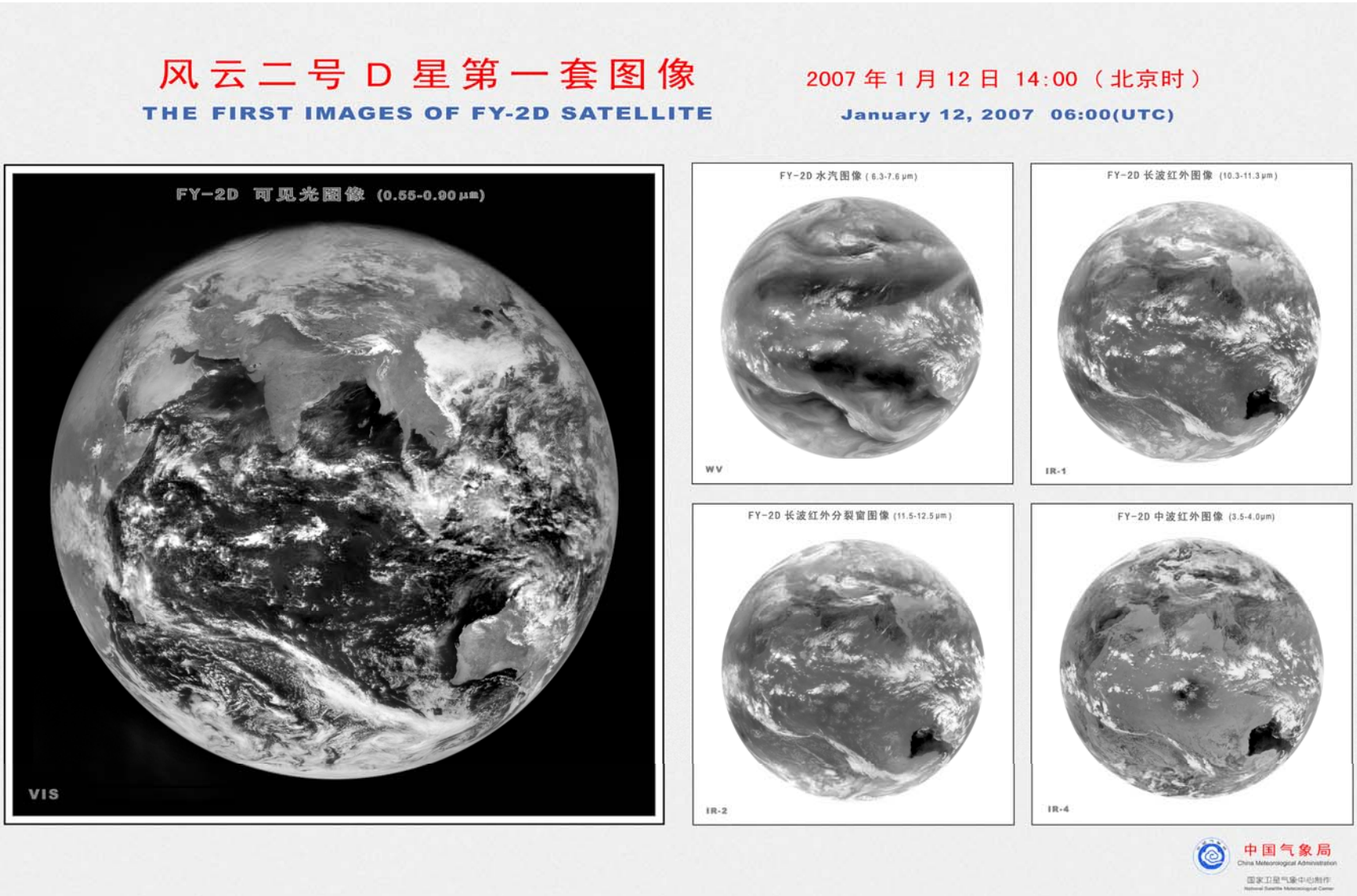
- **The first generation geostationary meteorological satellite of China (FY-2 Satellite Series)**

Launch time	Satellite Name	Type
1997.06.10	FY-2A	Experimentation
2000.06.25	FY-2B	Experimentation
2004.09.19	FY-2C	Operation
2006.12.08	FY-2D	Operation
2008	FY-2E	Operation,Plan
2010	FY-2F	Operation,Plan
2012	FY-2G	Operation,Plan

Two FY-2 operational satellite configuration (Every 15min)



●Image of Multi-channel Scanning Radiometer onboard FY-2D (Five channels)

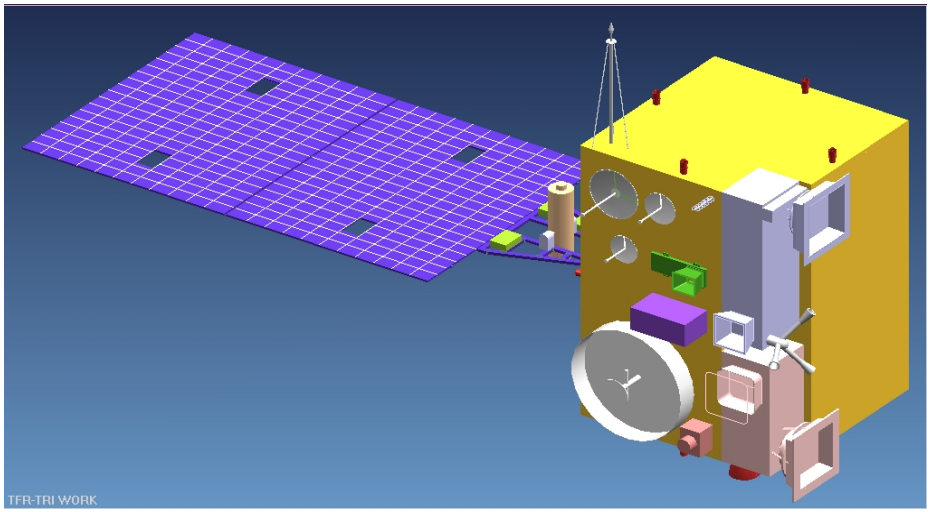


The next generation geostationary meteorological satellite of China (FY-4 Satellite Series)

- **Development:**
  - **FY-4 Phase A:2007-2008**
  - **FY-4 Phase B:2009-2010**
  - **FY-4 Phase C:2011-1012**
- **R&D/Operation**
  - **FY-4A/B : 2012-2014(R&D)**
  - **FY-4C/D/E/F: 2016 beyond (Operation)**

FY-4 Satellite configurations

- **Main payload considerations**



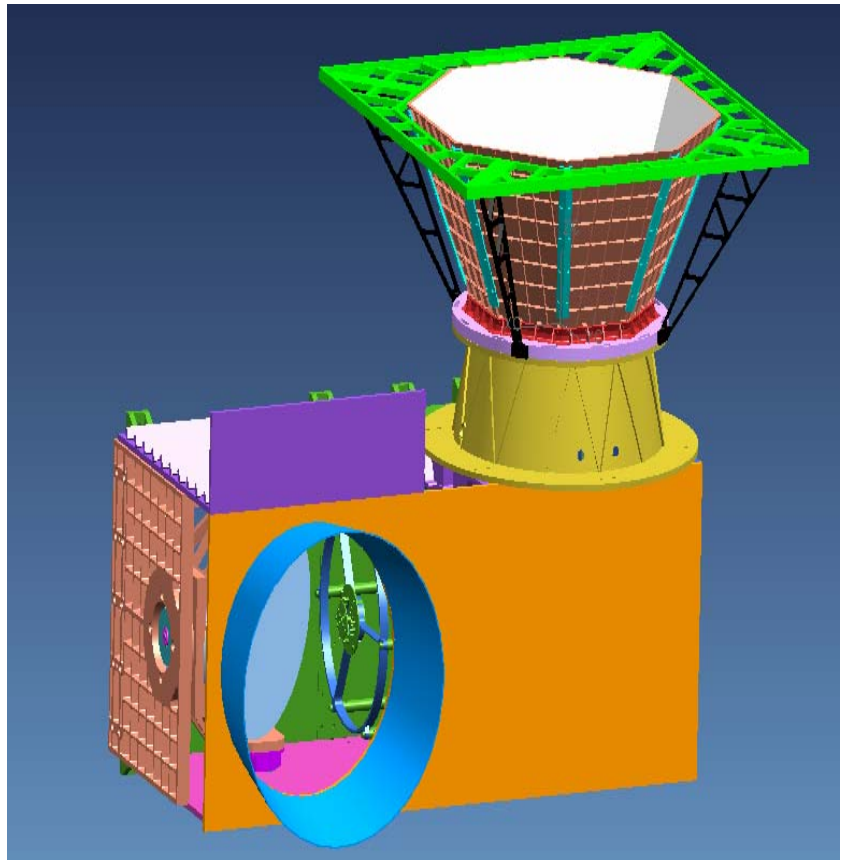
- Imaging Radiometer
- CCD Imager (option)
- Infrared Sounder
- Lightning Maper
- Solar X-ray Imager
- Space Environment Monitor Suite

Estimated weight: 3200Kg

Estimated power : 2000W

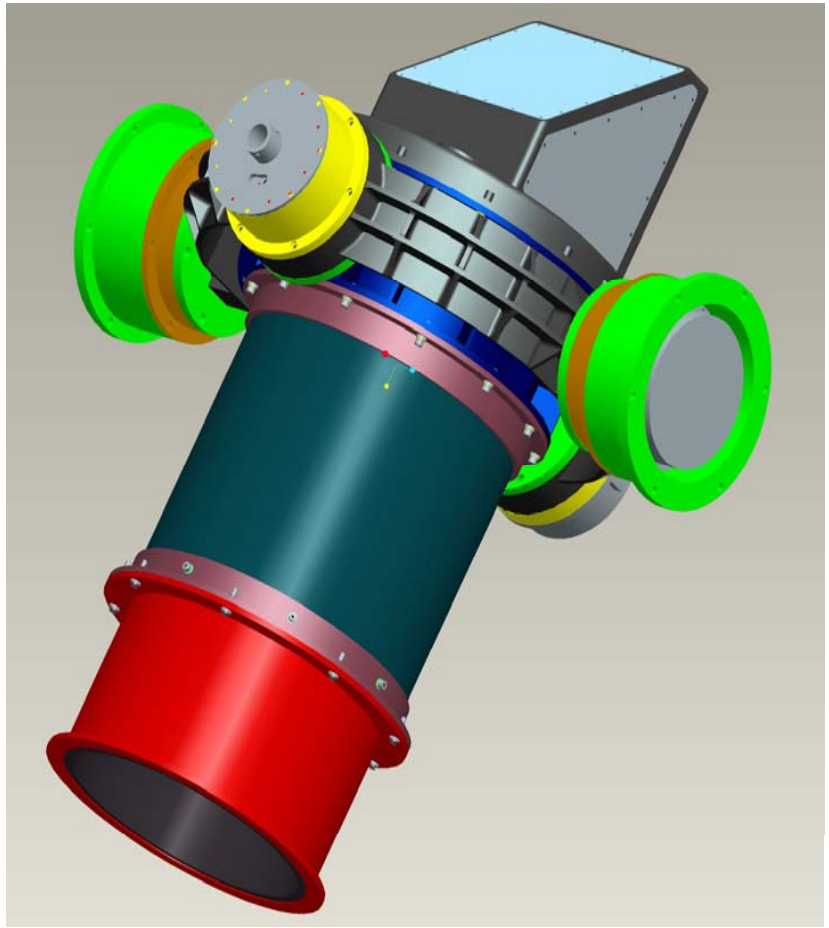
FY-4 Imaging Radiometer

- **Currently 12 channels, reference to MSG and GOES-R**
- **Imaging channels with higher spatial resolution and frequent observation (China territory: 5 minutes)**
- **Radiometric channel: higher radiometric performance.**



FY-4 CCD Imager

- **Broadband visible at 500Km×500Km area with spatial resolution between 50 and 100meters rapid refresh**



Conclusion

- **GEO OCRS is important for China coastal sea environment monitoring**
- **Because of the extreme turbidity in China coastal sea, it needs UV/SWIR bands for the accuracy atmospheric correction.**
- **In order to deriver the ocean color information in the early morning or nightfall, the GEO sensor should has high sensitivity.**
- **The dynamic range of GEO sensor should be large enough in order to avoid the signal saturation in high turbid water.**
- **The polarization sensitivity should be considered.**
- **The 100-300m spatial resolution is prefer.**
- **China has no formal GEO OCRS plan now, but it has GEO meteorological satellite program which may be used to measure the ocean color.**


谢谢
Thanks
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