2023 Dragon-5 Symposium, 11-15, Sep., Hohhot, China, ESA-MOST, NRSCC and ESA

Monitoring of marine disasters using CFOSAT, HY Series and Sentinel series satellite data (ID: 59310)

Jianqiang Liu[1,2], Jing Ding[1,2], Yingcheng Lu[3], Ying Xu[1,2], Daniele Hauser[4], Tao Zeng[1,2], Chao Liang[1,2], Maohua Guo[1,2], Xiaomin Ye[1,2], Xiuzhong Li[5], Wenming Lin[5], Lingling Xie[6], François Schmitt[7]

[1](National Satellite Ocean Application Service, MNR, Beijing, China)

[2](Key Laboratory of Space Ocean Remote Sensing and Application, MNR)

[3](Nanjing University, Nanjing, China)

[4](CNRS/LATMOS, Guyancourt, France)

[5](Nanjing University of Information Science & Technology, Nanjing, China)

[6](Guangdong Ocean University, Zhanjiang, China)

[7](CNRS/Laboratory of Oceanology and Geosciences ,Wimereux, France)

CONTENTS

Ocean Satellites Project in China

HY-1 launch site

New-EXP

- ❖CFOSAT (China-France), launched on 29th, Oct. 2018

GF-3

- ❖GF-3, launched on 10th, Aug.2016
- ❖C-SAR01, on 23th , Nov., 2021
- ❖C-SAR02, on 7th , Apr., 2022

HY-2

- ❖HY-2B, launched on 25th, Oct., 2018
- ❖HY-2C, launched on 21th, Sep., 2020
- ❖HY-2D, launched on 19th, May, 2021

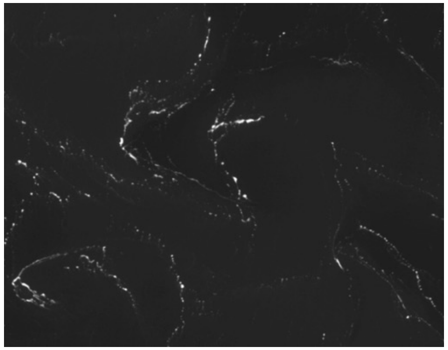
HY-1

- ❖HY-1C, launched on 7th, Sep., 2018
- ❖HY-1D, launched on 11th, Jun., 2020

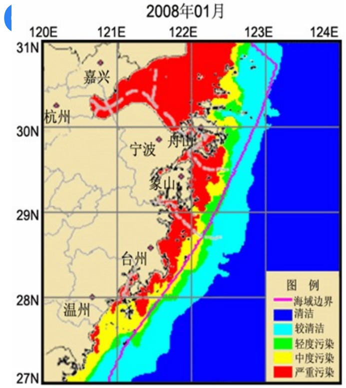
Main purposes of HY-1 satellites

- ◆Global ocean color and SST
- ◆Global climate change
- ◆Marine environment monitoring
- ◆Marine disasters prevention
- ◆Marine Rights and Interests Maintenance
- ◆Survey and supervision of natural resources
- ◆Utilization of Marine Resour

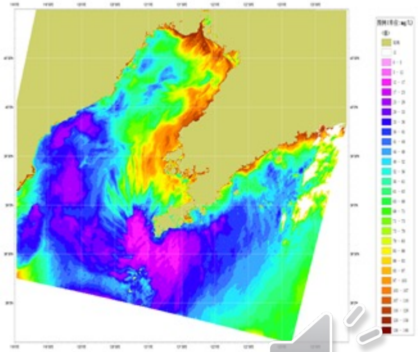
Sea-ice



green-tide



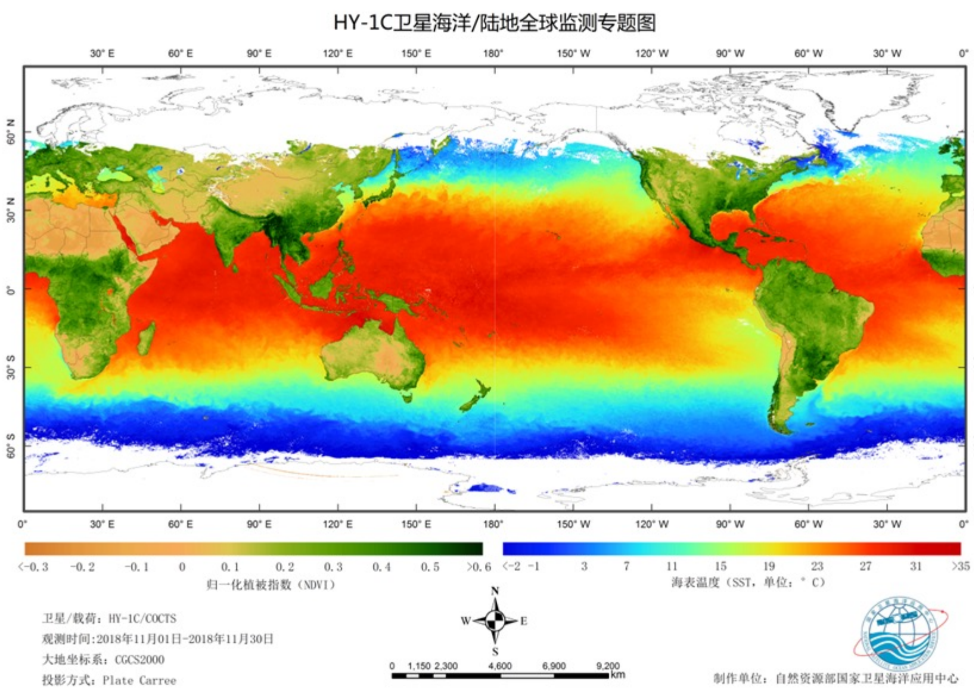
Water quality

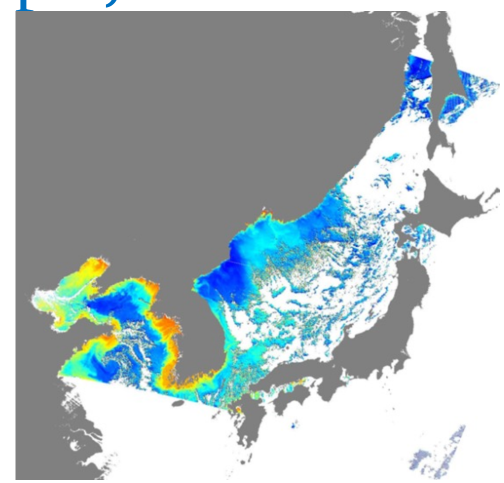


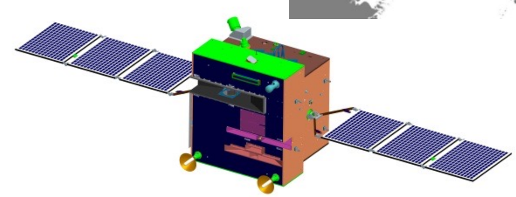
Coastal zones

HY-1C satellite

- Orbit: sun-synchronous orbit at 782 km
- Descending point: 10:30 AM
- HY-1C satellite launched successfully on Sep.7,







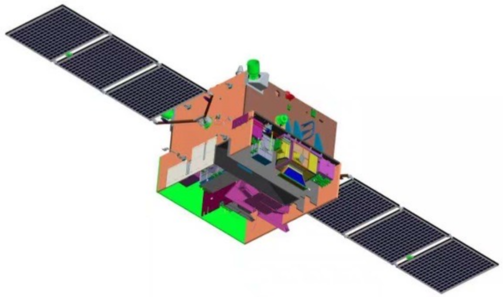
Global SST and NDVI distributions from HY-1C/COCTS

Main characteristics of HY-1C/D

- ✓ The first operational ocean color satellites in China
- ✓ to detect global ocean color and SST every day
- ✓ to monitor ecological environment of coastal regions
- ✓ to monitor marine disasters such as red-tide, sea-ice, oil spill, etc.
- ✓ global detection and 5 years life-span on -orbit as designed
- ✓ Ultra-violet imaging at global scale and on-orbit calibration
- ✓ High signal to noise ratio, large-width and quick revisit
- ✓ HY-1D satellite in ascending mode has been launched in 2020 to achieve satellite constellation with HY-1C in

Sensors on HY-1C/D satellites

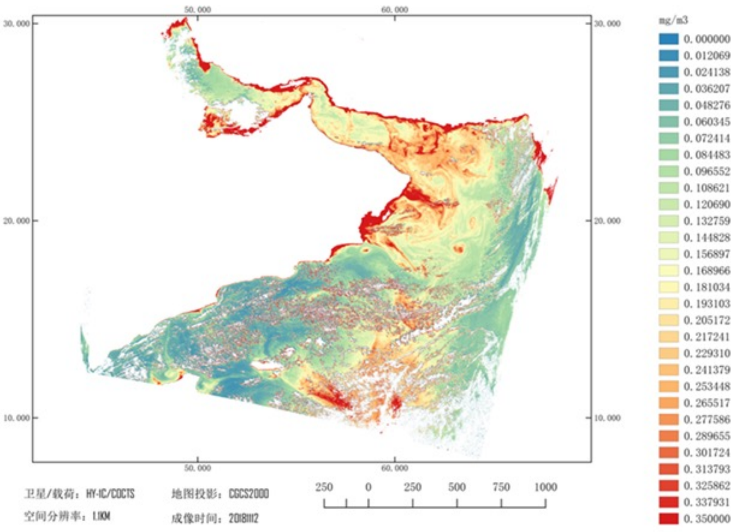
* 5 sensors in the same on board HY-1C /D satellites
- Chinese Ocean Color and Temperature Scanner(**COCTS**), 1-day revisit
- Coastal Zone Imager (**CZI**), 3days revisit
- Ultra-violet Imager (**UVI**), 1-day revisit
- Satellite-based Calibration Sensor (SCS)
- Automatic Identification System (AIS)



Chinese Ocean Color and Temperature Scanner

band	wavelength（um）	Typical radiance[1]	S/N	Max radiance[2]	Main purpose
1	0.402～0.422	9.10	515	20.54	CDOM、water pollution
2	0.433～0.453	8.41	767	19.60	Chlorophyll absorption
3	0.480～0.500	6.56	668	19.60	CHL、ocean optics、seaice、Shallow sea topography
4	0.510～0.530	5.46	650	18.80	CHL、water depth、low SSC
5	0.555～0.575	4.57	637	17.86	CHL、low SSC
6	0.660～0.680	2.46	550	16.05	high SSC、atmospheric correction、aerosol
7	0.730～0.770	1.61	569	9.72/5.0[3] 9.79	atmospheric correction、high SSC
8	0.845～0.885	1.09	424	6.93/3.5[3] 7.83	atmospheric correction
9	10.30～11.30	0.06K（300K时NE∆T）		200-320K[4]	SST、sea-ice
10	11.50～12.50	0.08K（300K时NE∆T）		200-320K[4]	SST、sea-ice

Main parameters of HY-1C/COCTS



Chlorophyll concentration in the Gulf of Arden from HY-1C/COCTS

- **resolution： <1.1km；**
- **swath： ≥2900km；**
- **Stray-light： ≤1-2%；**
- **Out-of-band response： ≤5%；**
- **polarization： ±20° of FOV：**
- **≤1-2%；**

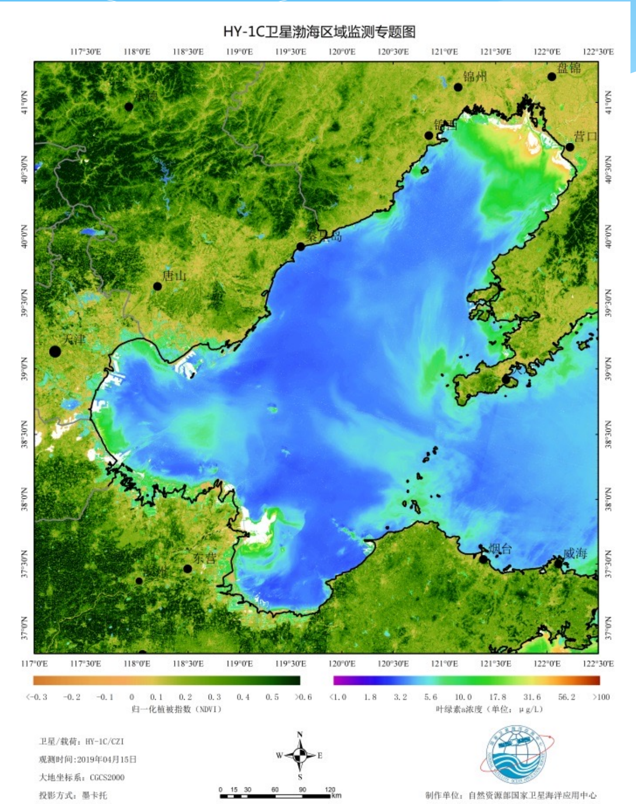
  ±57° of FOV： ≤1-3%；
- **MTF： visible/near-infrared bands: >0.2；**
- **thermal infrared bands: >0.1**

Coastal Zone Imager

No.	band (um)	Typical radiance[1]	S/N	Max radiance			Main purpose
				L：turbid water	M：35% reflectance	H：80% reflectance	
1	0.42-0.50	8.41	572	14.0	21.0	48.3	CHl、pollution、sea-ice、topography
2	0.52-0.60	4.57	475	14.0	21.0	47.0	CHL、low SSC, pollution、NDVI、sea-ice、beach
3	0.61-0.69	2.46	534	12.0	18.0	39.0	Moderate SSC、NDVI、soils
4	0.76-0.89	1.09	254	4	12	25	NDVI、high SSC, Atmospheric correction

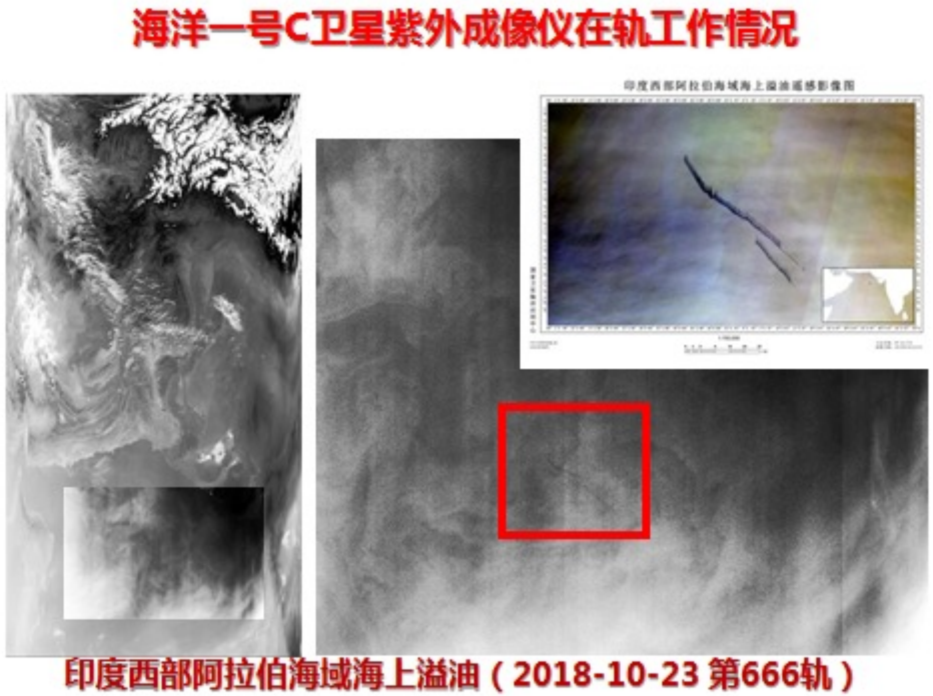
Main parameters of HY-1C/CZI

- resolution： <**50m**；
- swath： ≥**1000km**；
- Stray-light： ≤1.5%；
- Out-of-band response： ≤5%；
- polarization： ±10° of FOV： ≤1.5%；
  others of FOV： ≤2.5%；
- Calibration: ≤5%
- non-uniform correction: ≤1%；
- MTF： ~0.4

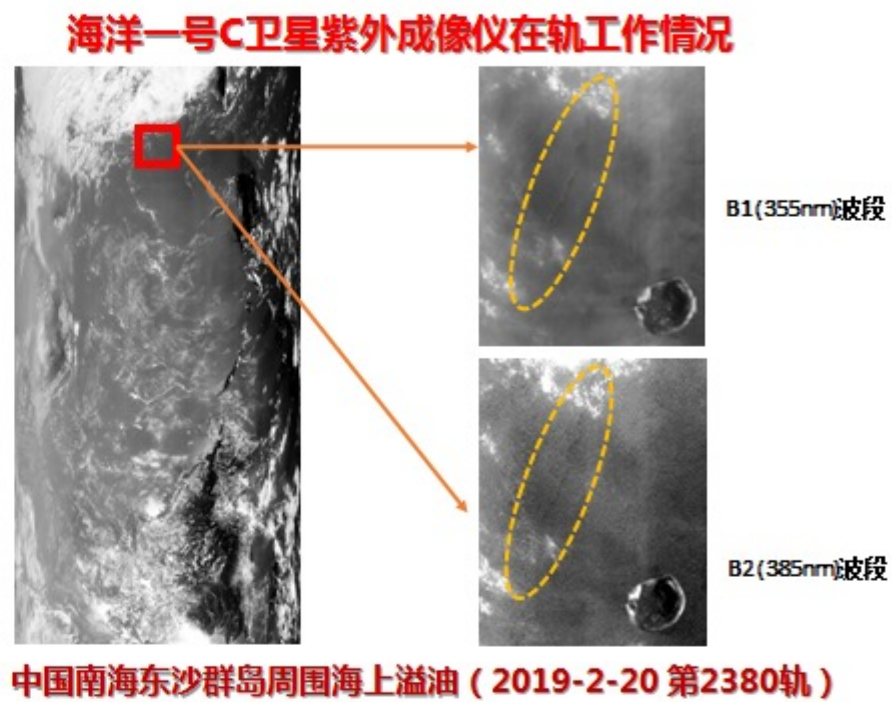


Chlorophyll and NDVI in Bohai sea from HY-1C/CZI

Oil spill monitoring with HY-1C satellite data

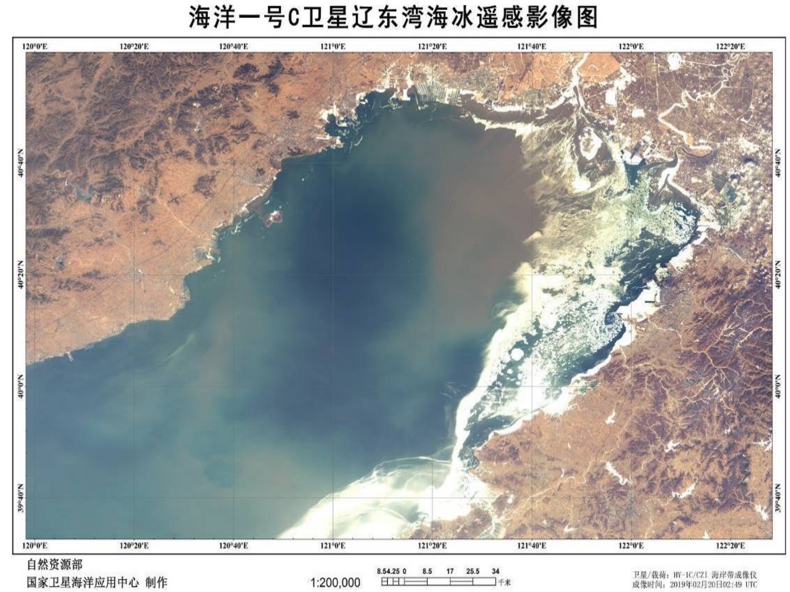


Oil spill detection from HY-1C/CZI

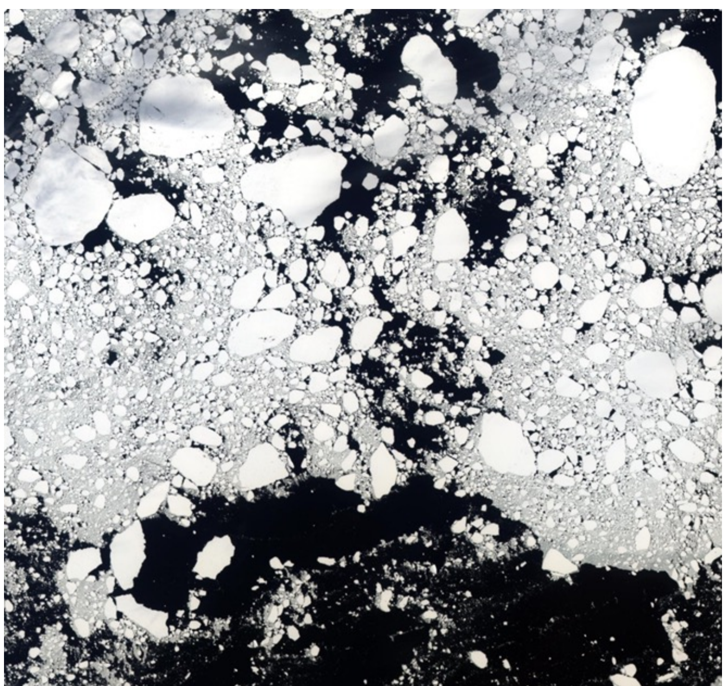


Oil spill detection from HY-1C/UVI

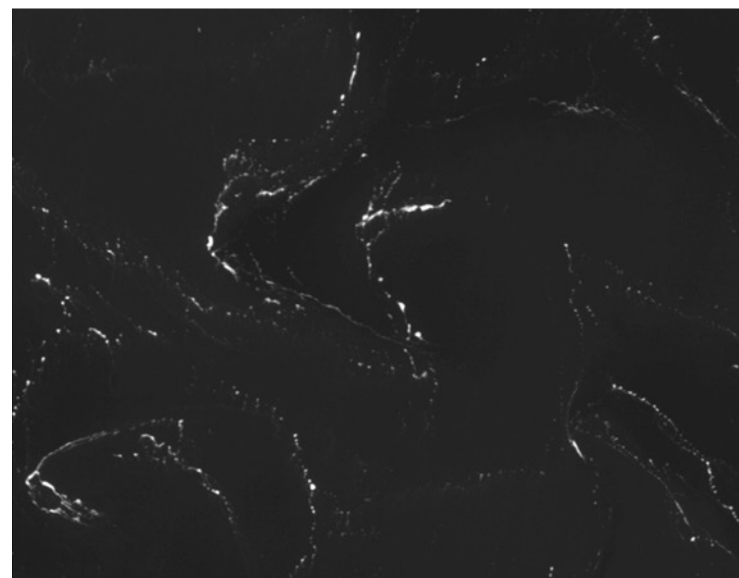
Sea-ice in Bohai Sea, 12.28, 2018



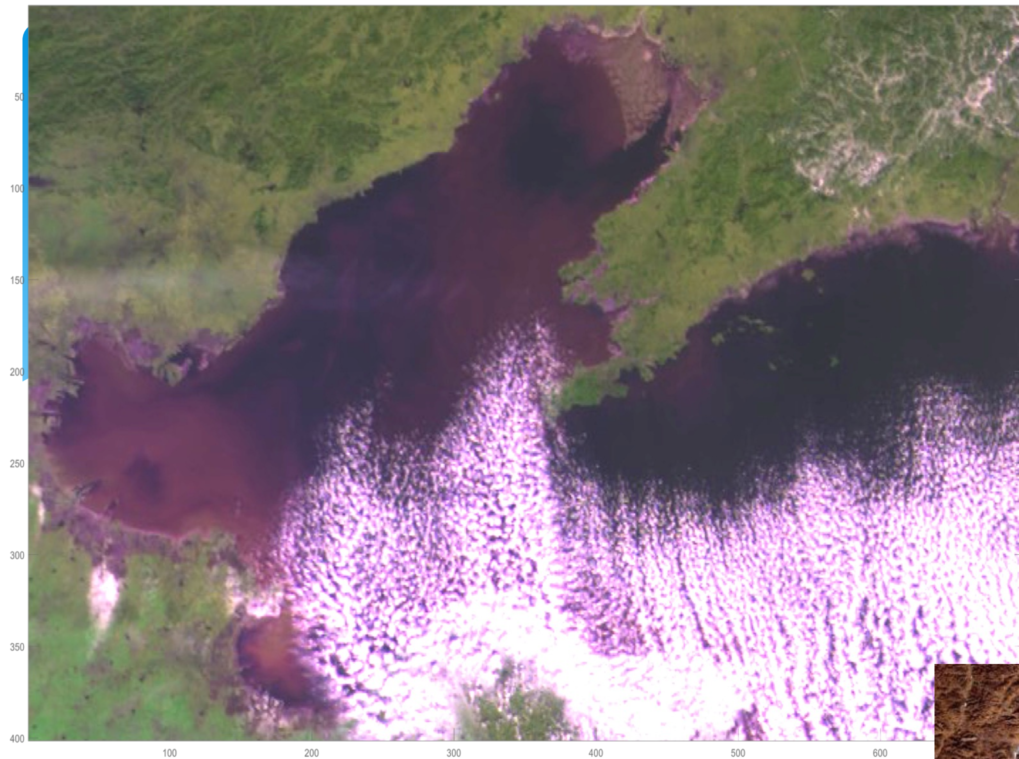
Sea-ice in Bohai Sea, 2.20, 2019



Antarctic Glacier images

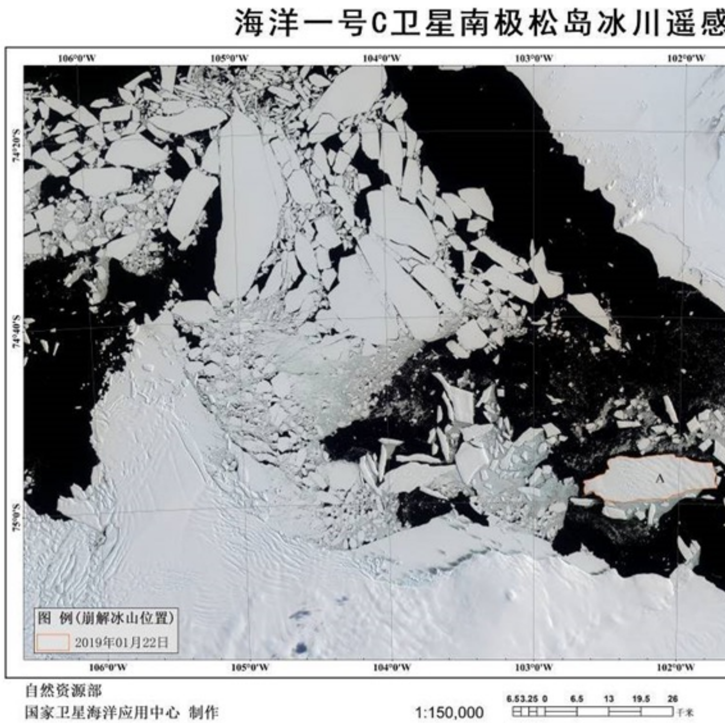


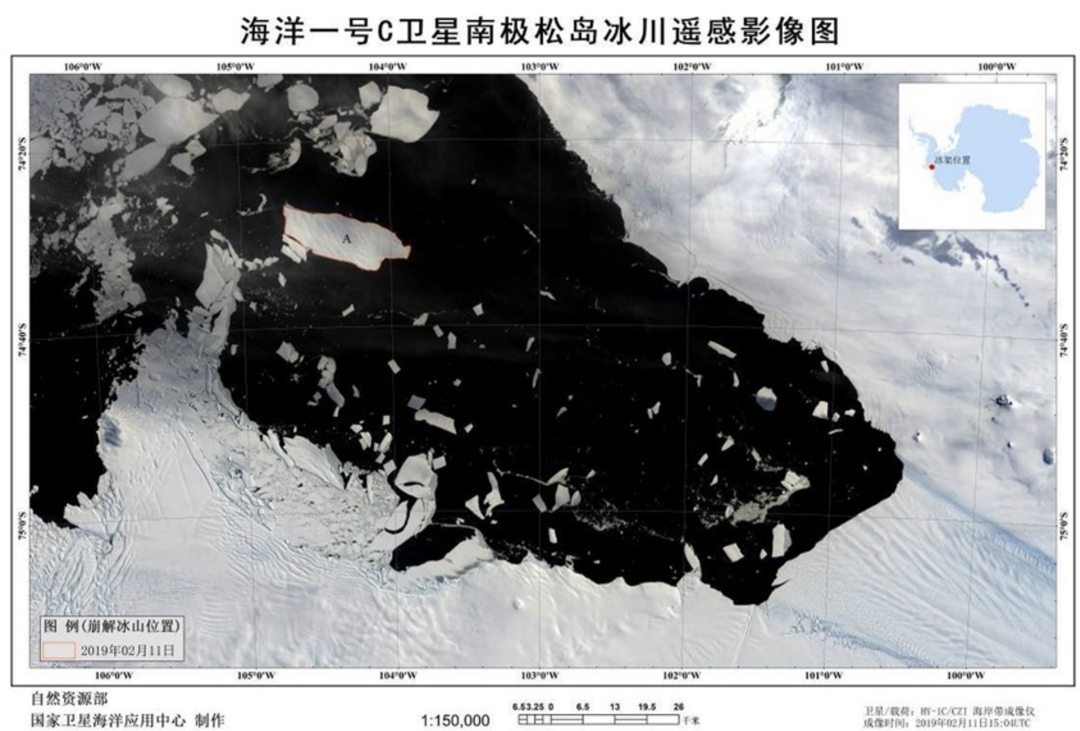
3.17, 2019, green-tide image



HY1C/COCTS sea-ice monitoring
（12.28, 2018）

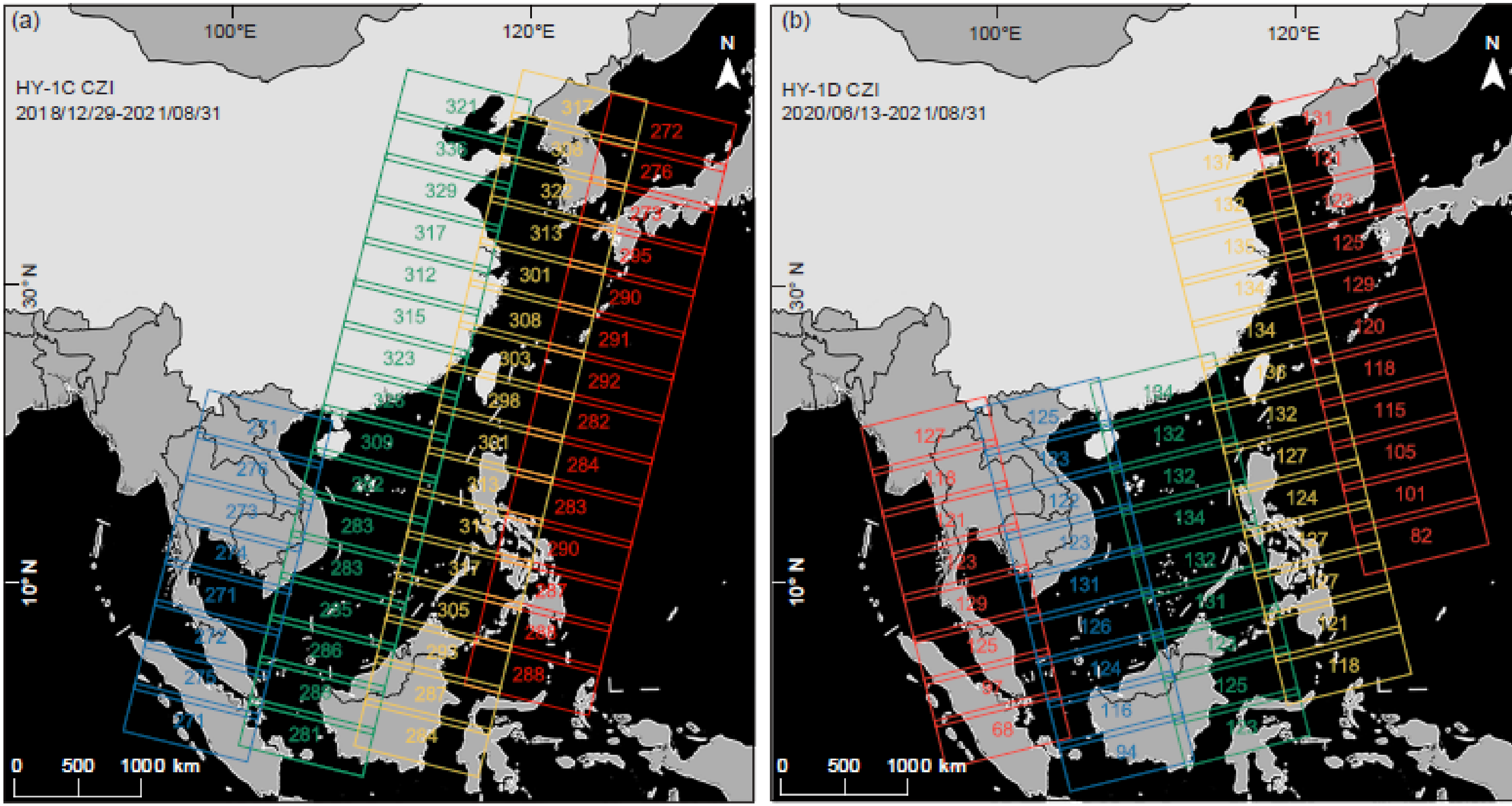
HY1C/CZI sea-ice monitoring
（12.28, 2018）



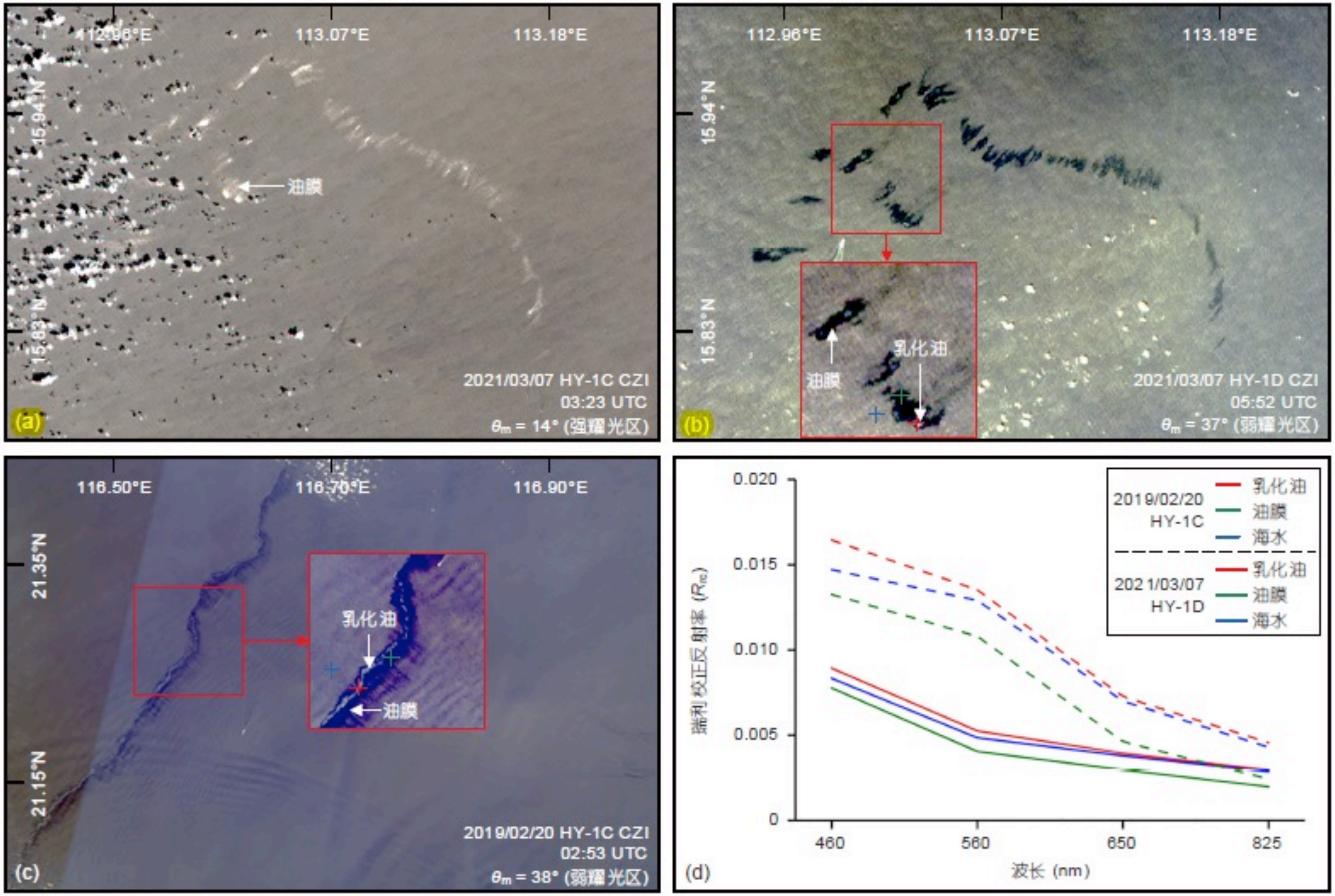


Matsushima Glacier break apart

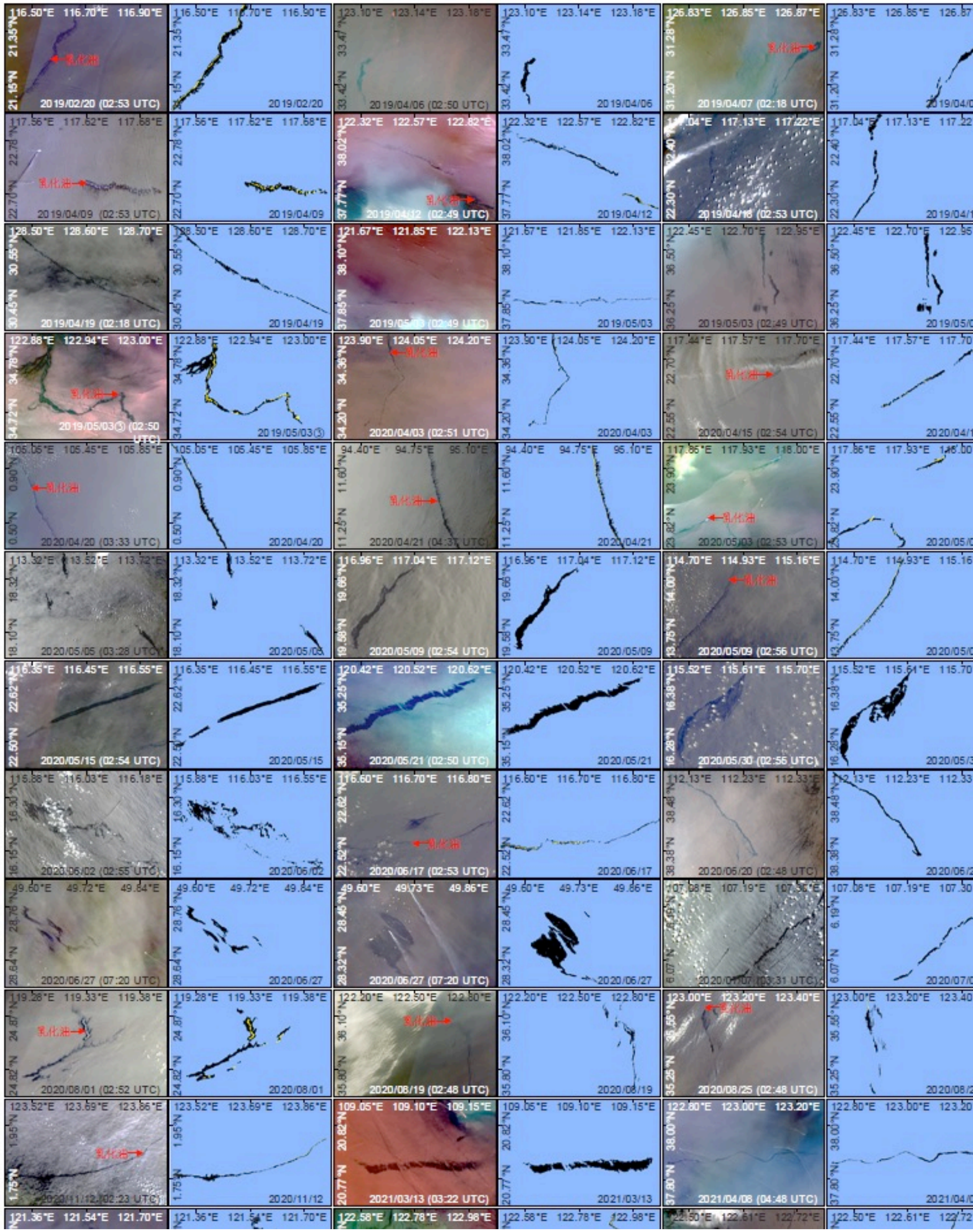
Monitoring of oil spills using HY-1C/D satellite data in China coastal oceans



Liu Jianqiang, Lu Yingcheng, Ding jing, et al., 2022, Science Bulletin in China

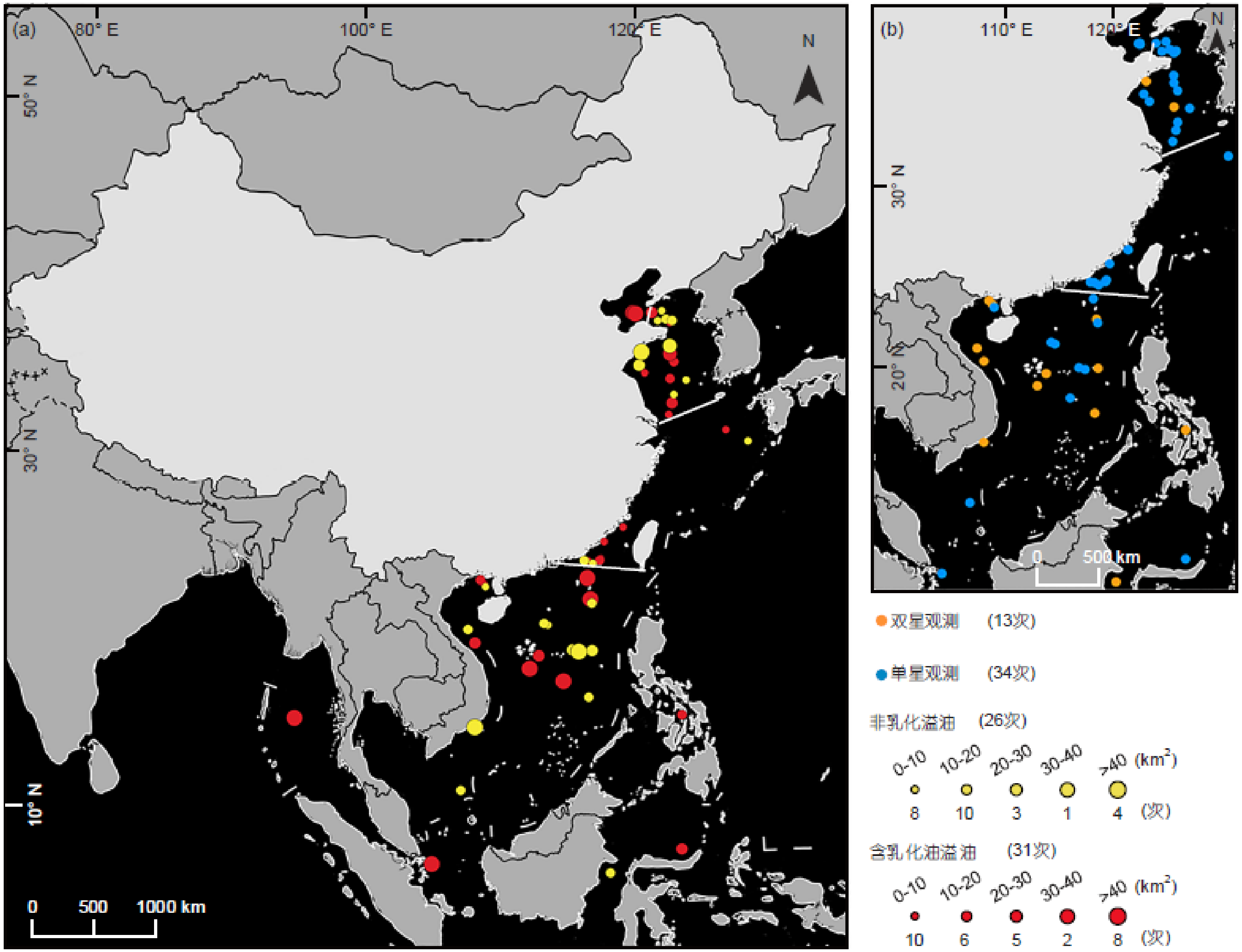


a: strong glint area; b: faint glint area; c: faint glint area
d: Rayleigh-corrected reflectance for emulsified oil(red); oil slick(green);and sea water (blue)

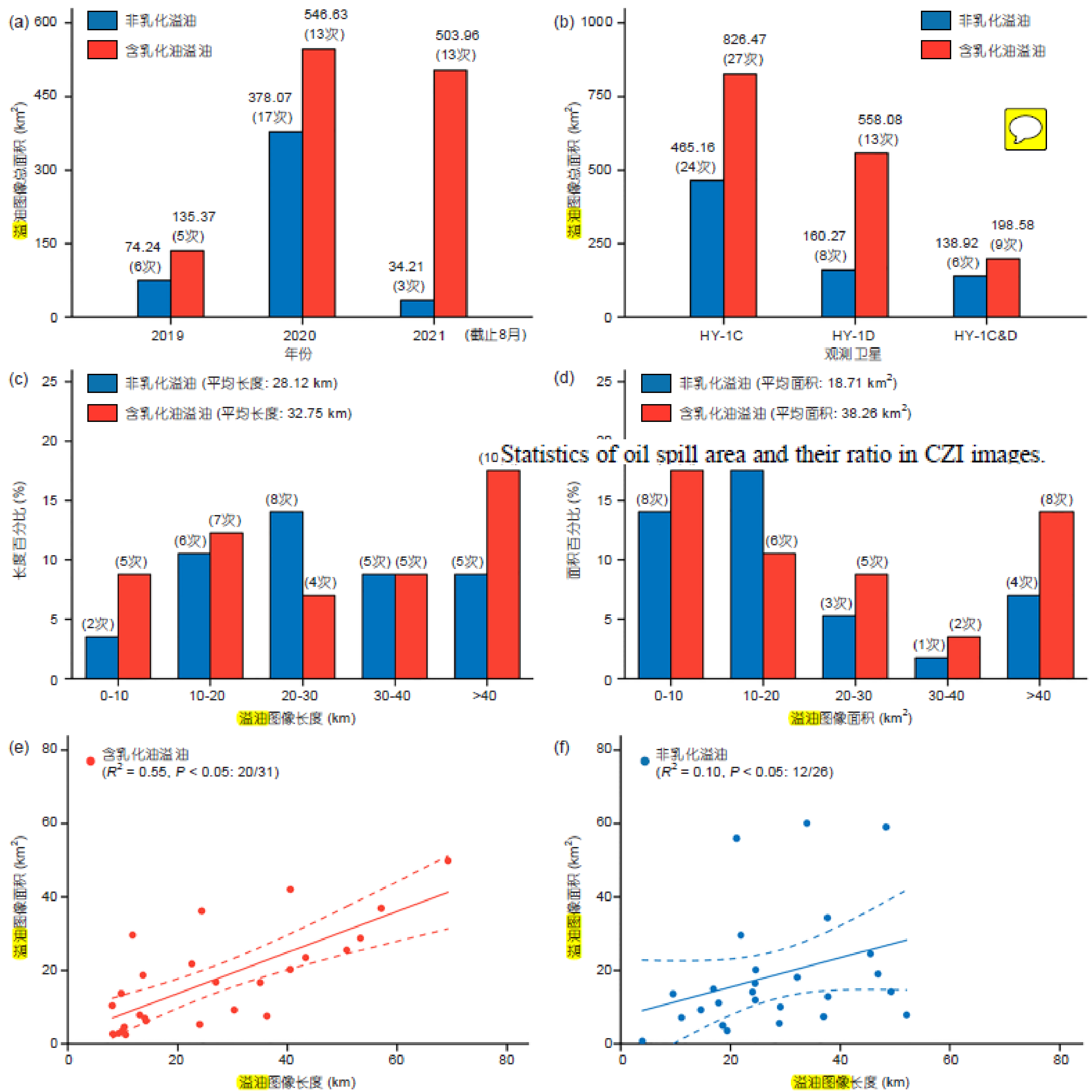


The oil spill detection as well as the type determination by HY-1C/D-CZI images in recent 3 years displays the excellent performance of satellites.

The two satellites constellation have enhanced the efficiency of oil spill remote detection in China coastal areas.



The oil spills detection:
13times(red) by two satellites;
34 times(blue) by one satellite;
26 times(non – emulsified oil)
31 times (emulsified oil)



Statistics of oil spill area and their ratio in CZI images.

Emulsified oil(red)
Non-emulsified oil (blue)

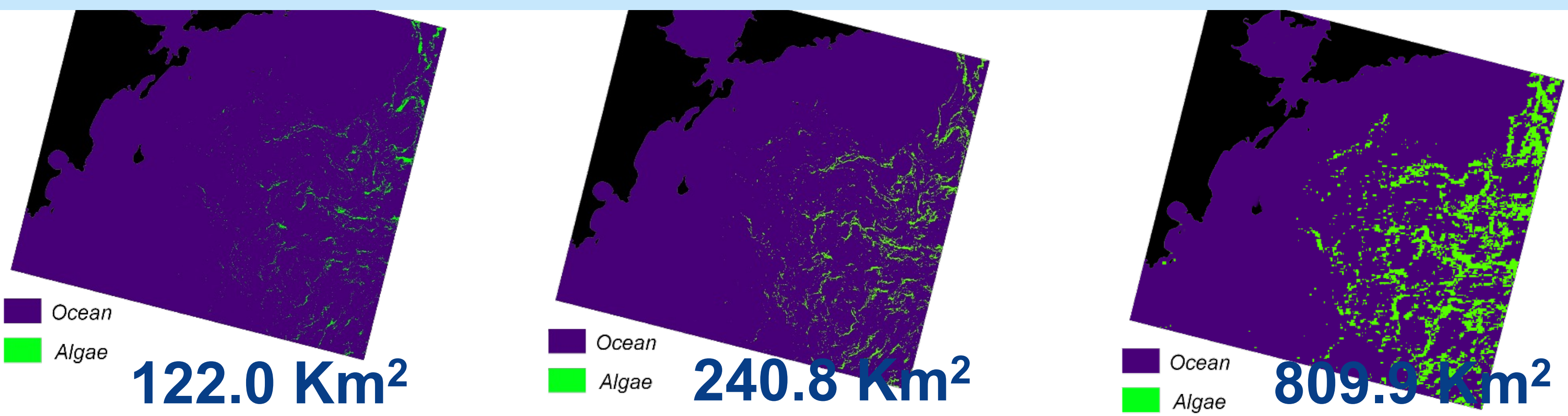
Statistics of oil spill length and their ratio in CZI images(Fig.c)

Statistics of oil spill area and their ratio in CZI images(Fig.d)

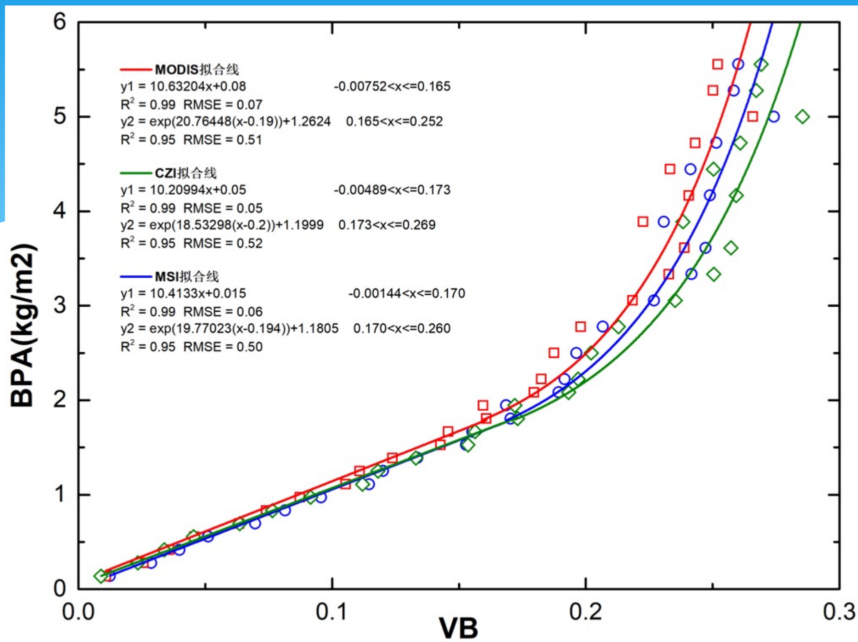
Monitoring of green-tides using multiple satellite data in coastal regions

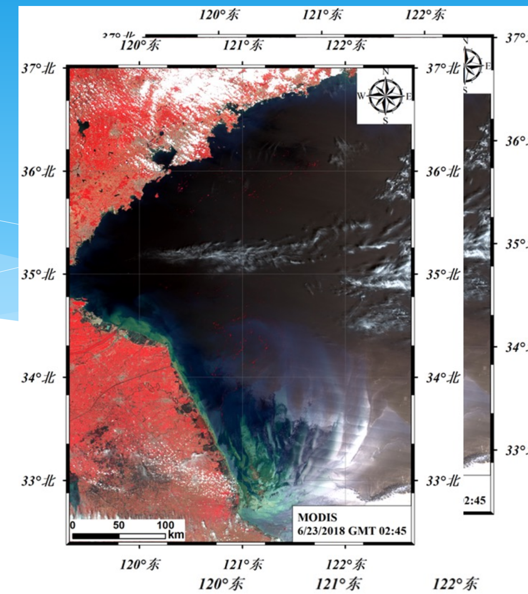
16m 50m 250m

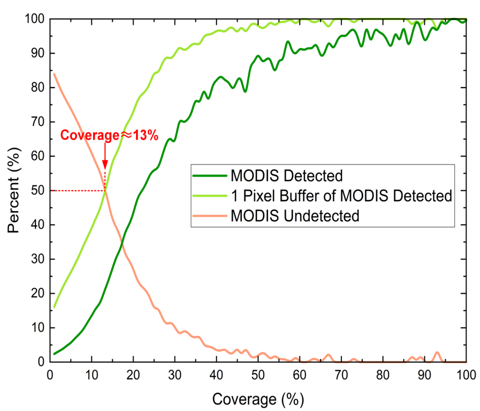
resolution→ algae pixels area≠ algae area

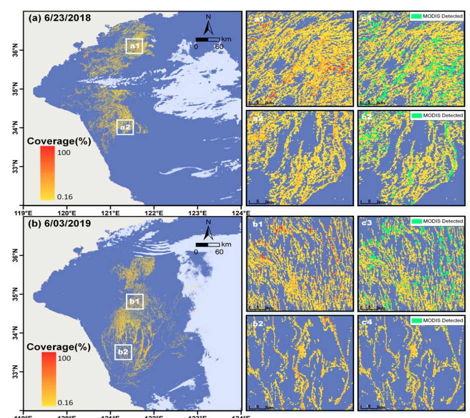


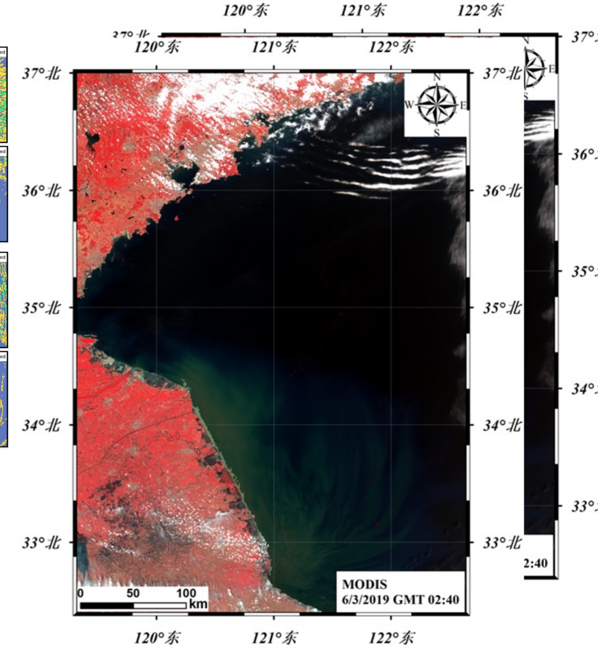
122.0 Km^2 240.8 Km^2 809.9 Km^2



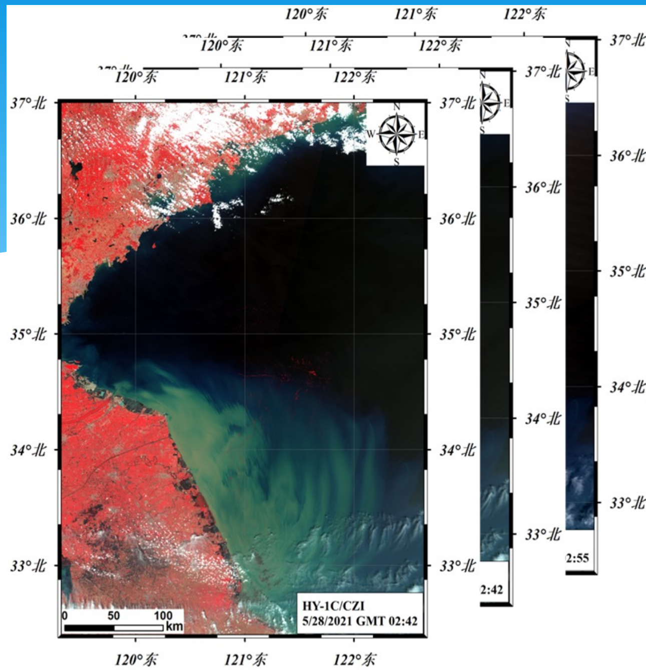


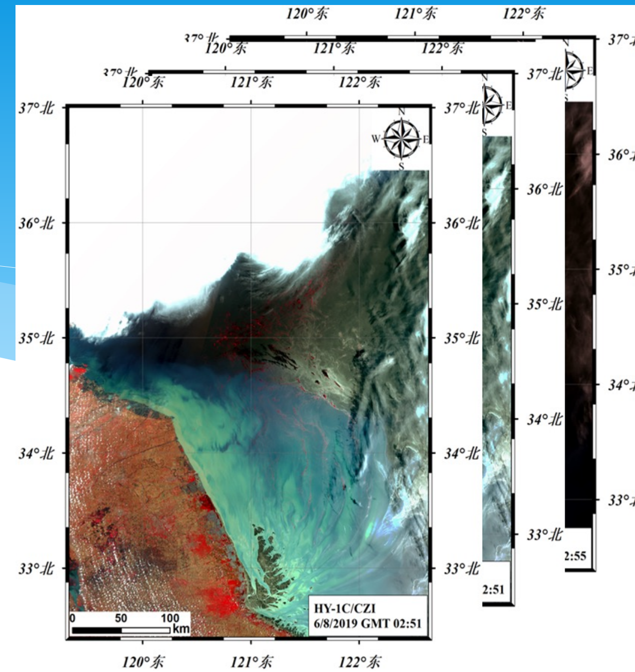


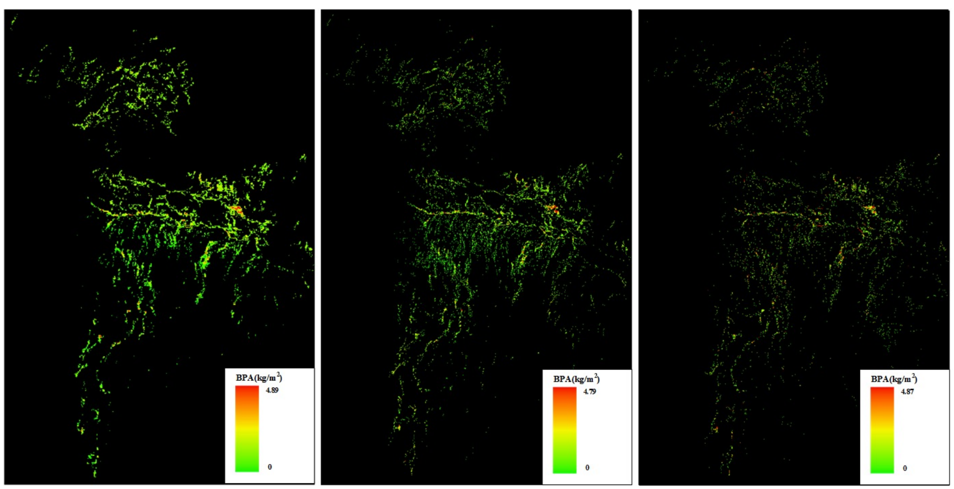




For different resolution images， it's more reasonable to choose the same areas for algae detection by various satellites to evaluate the biomass







MODIS GMT 2:55 | CZI GMT 2:42 | MSI GMT 2:35

Satellite	Biomass (kg)	Algae pixels area (km^2)
MODIS	$3.5257*10^8$	884.7
CZI	$3.6202*10^8$	621.7
MSI	$3.6991*10^8$	349.7

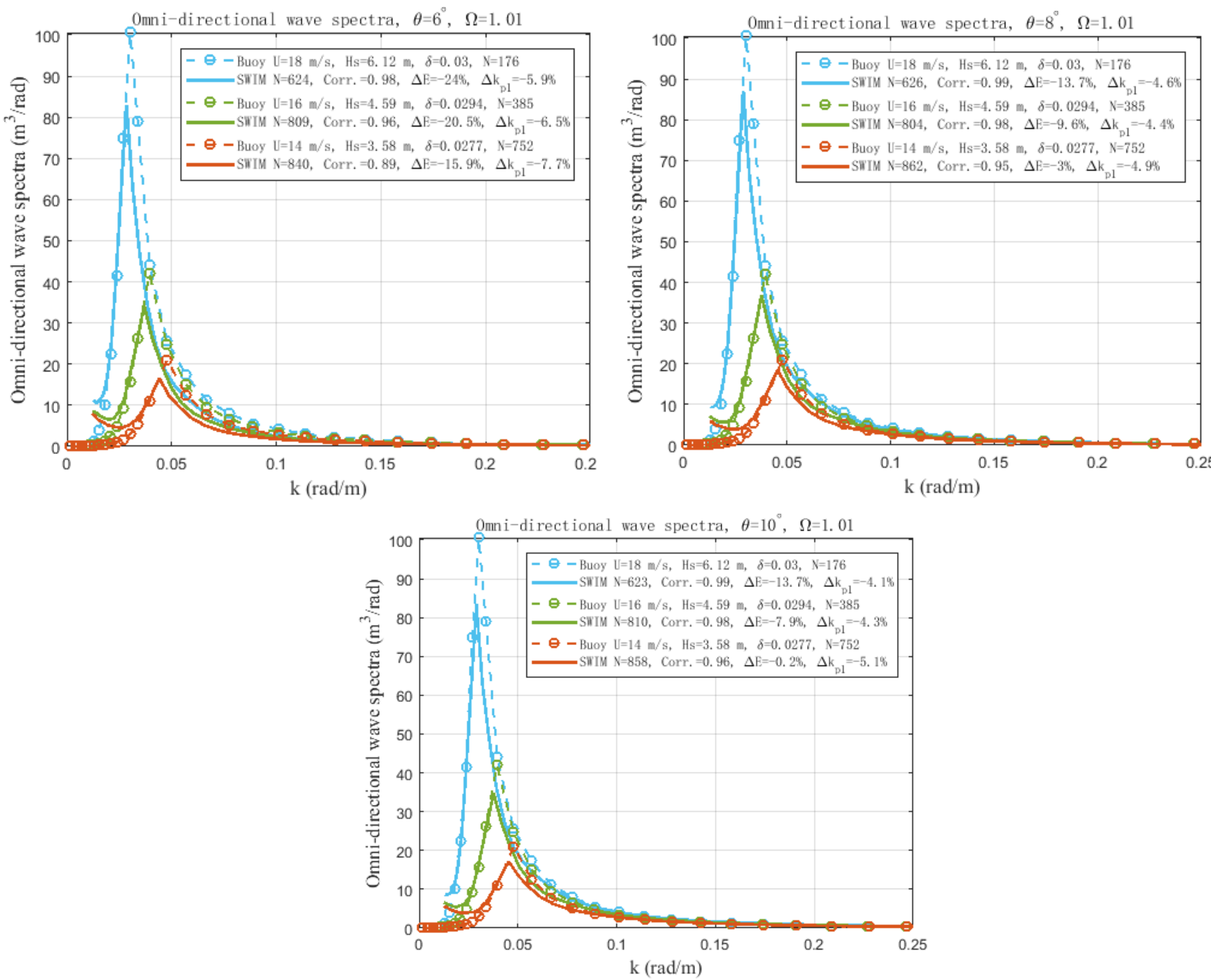
The point： large difference in algae pixels area but almost the same biomass

Lu Yingcheng, et al., 2022, in review

Performance for SWIM on CFOSAT

SWIM(for ocean surface wave observations)	
Frequency	13.575 GHz
Antenna incident angle	0° -2.43° -4° -6° -8° -10°
Spatial resolution	50x50 km^2 - 70x70 km^2
Accuracy of nadir wave beam retrieval	SWH: <**10%** or <**0.5**m WS:<±**2m/s** or <**10%** (for the larger one)
Range of wave-length detection	70-500m
Errors of wave detection	<15°
Errors of energy density spectra for wave height	<15%, (the goal for **10%**), width for peak of wave:**3dB**
Mean radar back-scattering coefficient	Absolute error: <±**1 dB** Relative error: <±**0.1 dB** (after the big data-sets reprocessing)

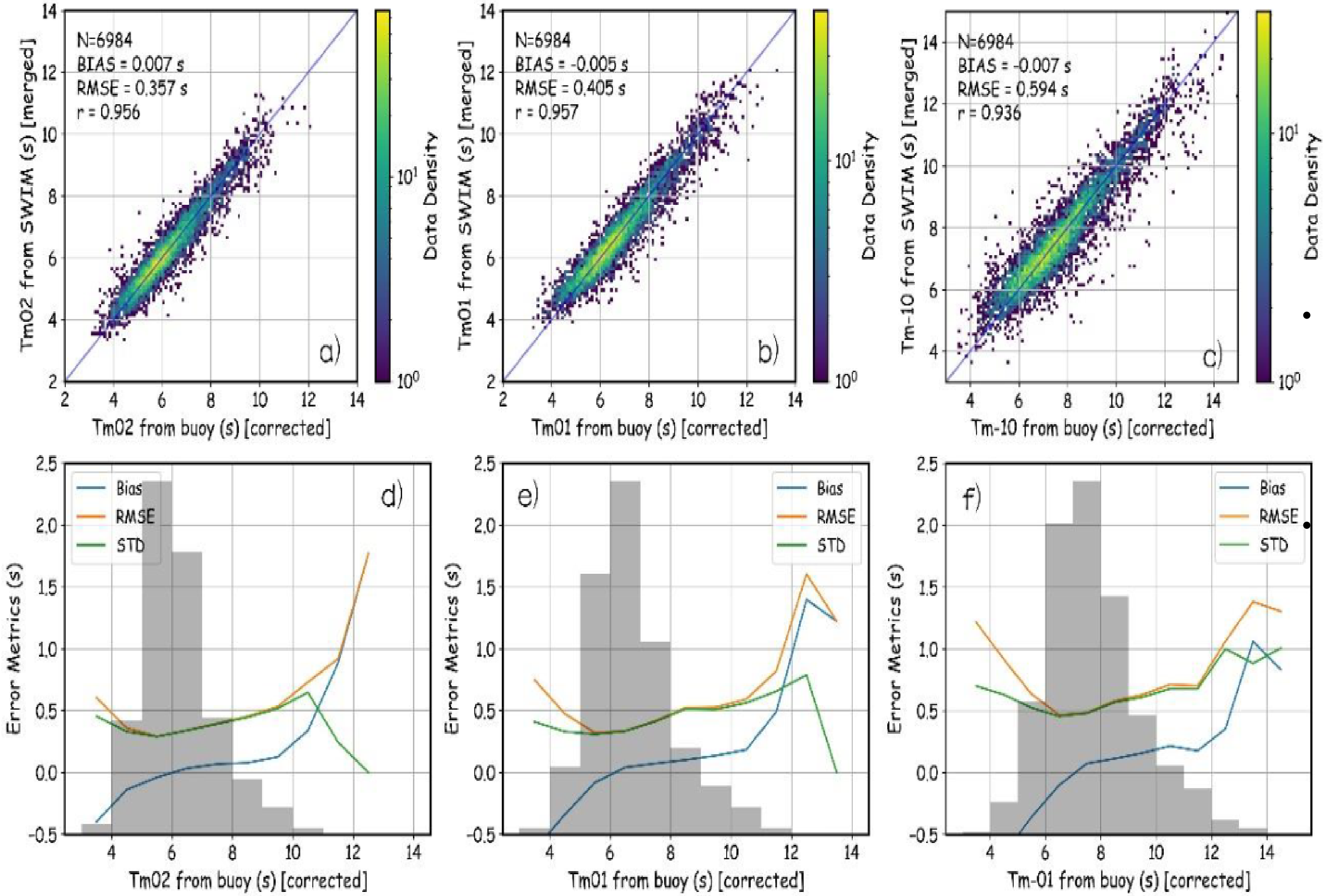
Statistical comparison of ocean wave directional spectra derived from SWIM/CFOSAT satellite observations and from buoy observations



Comparison of Omni-Directioanal spectra (Wind wave conditions-mature wind wave)

- **A new comparison method of SWIM and buoy observations including omni spectrum and directional function at peak wave number, in different classes of sea-state.**
- **Under medium and high sea conditions, 8 ° and 10 ° SWIM spectra have a high consistency with buoy observations.**
- **Under low sea conditions, bias between SWIM and buoy observation mainly due to parasitic peak, non-linear surfboard effect and a slight underestimation of speckle noise spectral density.**

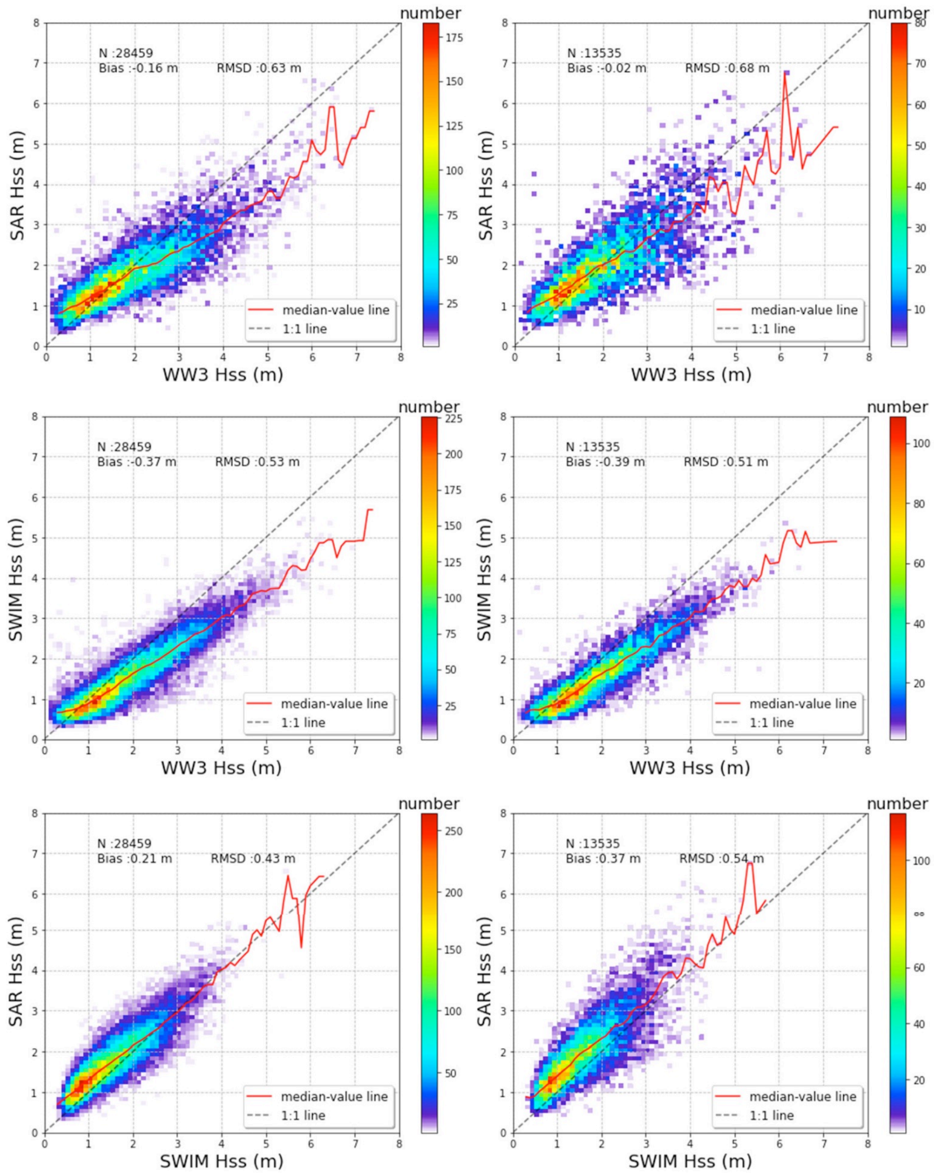
Accurate Mean Wave Period from SWIM On-Board CFOSAT



- A merged MWP retrieval model combining the nadir U10-SWH and the MWP from the spectrum of SWIM using an artificial neural network.
- Accuracy for MWP retrievals (RMSEs of ~0.36 s for zero up-crossing periods, 0.38 ~0.41 s for mean periods, and ~0.60 s for energy periods), demonstrating the usefulness of SWIM in the studies of ocean waves.

Comparison of the SWIM MWPs from the ANN merged retrieval model against buoy measurements

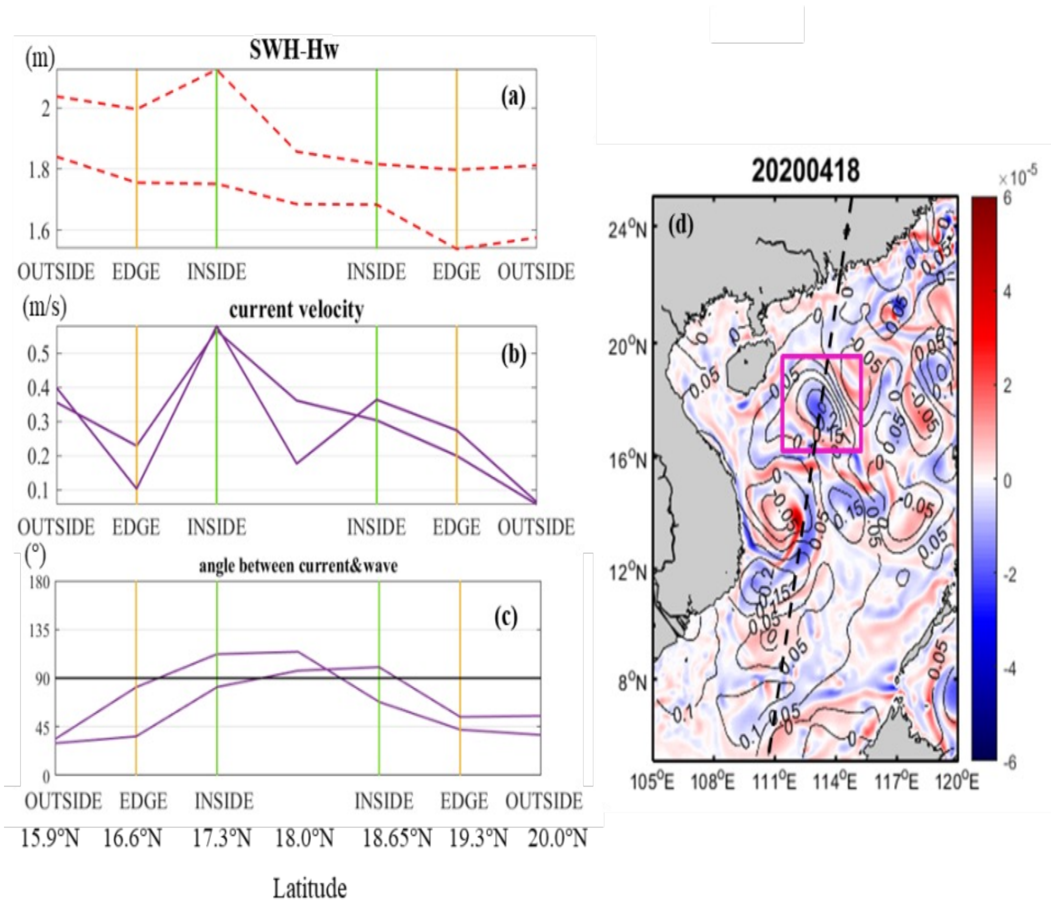
Quantifying Uncertainties in the Partitioned Swell Heights Observed From CFOSAT SWIM and Sentinel-1 SAR via Triple Collocation



- Quantifying Uncertainties in the Partitioned Swell Heights Observed From CFOSAT SWIM and Sentinel-1 SAR via Triple Collocation.

- CFOSAT has the least uncertainty (0.2-m RMSE, 11% SI, and 11-dB SNR) in terms of Hss

Modulation effects of mesoscale eddies on sea surface wave fields in the South China Sea derived from wave spectrometer onboard CFOSAT



Variation of wind-eliminating SWH, surface current velocity and angle between current and wave directions across warm eddy

- Using the SWIM, examine modulation effects of mesoscale eddies on sea surface wave fields in the South China Sea (SCS) .
- The wave energy analysis indicates that the deformation term of eddy current is a dominant term affecting SWH at the eddy edge.
- The model results show the wave parameter variations crossing the eddy are close to that interpreted by the SWIM data.

Conclusions and Prospects

1、The signal-to-noise ratio of CZI is much better than expected which could be up to 500 with 50m resolution and 1000km swath.

2、According to the characteristics of different spatial resolution data, we develop a comprehensive method to classify the difference of monitoring results using various satellite data which could improve the accuracy of greed-tide detection and coherence the bio-mass evaluations resulted from different satellite data.

3、it’s possible to distinguish the various spill types, for example the emulsified and non-emulsified oils, using the CZI satellite data in the condition of different sun-glint reflections. According to the 3 years data analysis, the spatial patterns of oil spill distributions have been conducted for the first time in the China Seas.

Conclusions and Prospects

4、 A merged MWP retrieval model combining the nadir U10-SWH and the MWP from the spectrum of SWIM using an artificial neural network which demonstrated the usefulness of SWIM in the studies of ocean waves.

5、 Using the SWIM, we examine modulation effects of meso-scale eddies on sea surface wave fields in the South China Sea. The wave energy analysis indicates that the deformation term of eddy current is a dominant term affecting SWH at the eddy edge. The model results show the wave parameter variations crossing the eddy are close to that interpreted by from the SWIM data.

6、It is deserved to use HY-1 series and CFOSAT data to monitor the marine environment disasters with high frequency and qualified data service.

DATA SERVICE

- All data from L1b to L2 open to worldwide users
- Official website: www.nsoas.org.cn
- Data distribution website: https://osdds.nsoas.org.cn
- Welcome to use HY-1C/D and CFOSAT satellite data and provide your valuable suggestions !!!

THANKS!