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REPORT ON THE CURRENT STATUS OF THE HY-2 SATELLITE AND ITS PROSPECTS

The HY-2 satellite was successfully launched on 16 August, 2011. It carried three main microwave instruments into space for operationally observing dynamic ocean environment parameters on a global scale. The HY-2 satellite altimeter provides sea surface height, significant wave height, sea surface wind speed, while the HY-2 satellite scatterometer provides sea surface wind fields. At the same time, other oceanic and atmospheric parameters such as sea surface temperature and wind speed, water vapour and liquid water content can also be obtained by its onboard scanning microwave radiometer. Current status of HY-2 is put forward in this report. By comparison with the other satellite data, NDBC data and other data, the accuracy of the HY-2's data products is evaluated in this report also. In addition, some examples are given forward. These examples tell us that the HY-2 satellite data products can be used to monitor typhoon, mesoscale eddy, weather phenomenon, etc. Because of the low time and space resolution, HY-2 cannot be used to find all the details of the ocean phenomena. It is necessary to build satellite networking or to launch new type payloads to satisfy the need of ocean phenomena detection in the future.

CGMS Working Paper template - Report on the current status of the HY-2 satellite and its prospects

1 INTRODUCTION

The HY-2 satellite is the first dynamic environment satellite in China. It was successfully launched on August 16th 2011 with a sun-synchronous orbit at an altitude of ~970km. Repeat cycles of 14 days are planned for the first two years with oceanographic purpose and 168 days geodetic cycles will follow for the third year of the mission. The satellite is equipped with a Ku/C bands altimeter, a microwave scatterometer, a scanning microwave radiometer and the orbit is determined thanks to SLR, GPS and DORIS systems.

The HY-2 has the ability to image large planetary areas in all weather during day and night. The HY-2 satellite altimeter provides sea surface height, significant wave height, sea surface wind speed and polar ice sheet elevation, while the HY-2 satellite scatterometer provides sea surface wind fields. At the same time, other oceanic and atmospheric parameters such as sea surface temperature and wind speed, water vapour and liquid water content can also be obtained by its onboard scanning microwave radiometer.

Table 1 Main characteristic of the HY-2 satellite and its orbit

Orbit type	Sun-synchronous
Equator crossing local time	6:00AM
Altitude	970 km
Inclination	99.3
Period	104.46 min.
Attitude control	3 axes stabilized
Designed life time	3 years
Launch vehicle	CZ-4B
Launch site	Taiyuan

2 CURRENT SATELLITE SYSTEMS

2.1 Description of instruments

- Radar altimeter

The HY-2 satellite's radar altimeter is an active microwave remote sensor with a main objective to measure sea surface height with high accuracy, which lays the foundation for long-term ocean monitoring from space to an extent that will ultimately lead to improved understanding of the ocean's role in global climate change. The other objective of the HY-2 satellite radar altimeter is to measure significant wave height and wind speed along its nadir track.

- Microwave scatterometer

The microwave scatterometer is dedicated to determining the wind vector field (including wind speed and direction) of the ocean surface. Its swath is about 1,700 km and can cover above 90% of global open sea area within one day. The HY-2 scatterometer adopts two pencil beams to measure the backscatter energy, thus ground wind vector cells can be observed with four different views by conically scanning each. This geometry can resolve the nadir data gap that is exists in fan fixed beam scatterometers, such as ASCAT and NSCAT. The launch of the HY-2 scatterometer will certainly contribute to the continuity of global and regional ocean wind data.

- Scanning microwave radiometer

The scanning microwave radiometer operated on HY-2 is a multi-channel radiometer (RM). Intended to obtain ocean circulation parameters such as sea surface temperatures, sea surface winds, total water vapour and cloud liquid water content under all-weather conditions, the HY-2 RM is designed as a nine-channel instrument capable of receiving both horizontally and vertically polarized radiation, except on the 23.8 GHz channel, which only works with vertical polarization. The parabolic antenna reflects the 6.6 GHz and 10.7 GHz microwave emissions into a two-frequency feed horn and other channel emissions into a three-frequency feed horn.

2.2 Instrument Parameters

The HY-2 satellite's radar altimeter, operating at Ku and C bands simultaneously, is the primary sensor for the HY-2 mission. The measurements made at the two frequencies are combined to obtain altimeter height of the satellite above the sea (range), wind speed and significant wave height. The instrument and orbit parameters are listed in Table 2.

Table 2 Main parameters of the HY-2 radar altimeter

Frequency	13.58 GHz, 5.25 GHz
Pulse-limited footprint	<2 km
Frequency bandwidth	320 MHz
Pulse Repetition Frequency	2 KHz

In order to meet the requirements of wind vector retrieval with high precision and a wide swath, the following scatterometer specifications were proposed, as listed in Table 3.

Table 3 Main parameters of the HY-2 scatterometer

Frequency	Ku band (13.256GHz)
Transmit power	120 W
Pulse width	1.5 ms
Swath	1,350 km for inner beam; 1,750 km for outer beam
Polarization	HH for inner beam; VV for outer beam
Look angle	34.8 for inner beam; 40.8 for outer beam
Incidence angle	41 for inner beam; 48 for outer beam
Scanning mode	conically scanning
Antenna rotation rate	95 /s for low rate; 105 /s for high rate
$_0$ measurement accuracy	0.5 dB
$_0$ measurement range	-40 dB~+20 dB
Wind cell resolution	25 km
Wind speed accuracy	<2 m/s or <10%
Wind direction accuracy	<20 rms
Mission lifetime	3 years

The HY-2 satellite's RM instrument specification is listed in Table 4.

Table 4 Main parameters of the HY-2 radiometer

Frequency (GHz)	6.6	10.7	18.7	23.8	37.0
Polarization	VH	VH	VH	V	VH
Scan width (km)	1,600				
Footprint size (km)	100	70	40	35	25
Sensitivity (K)	<0.5	<0.5	<0.5	<0.5	<0.8
Dynamic range (K)	3-350				
Calibration precision (K)	1（180~320）				

3. Current data products

3.1 Radar altimeter

3.1.1 Levels of products

There are three levels of processed data: Level 0: Telemetry data (raw data),Level 1: Sensor Data Records (engineering units),Level 2: Geophysical Data Records (geophysical units).

Geophysical data records are sent as they become available to the wider scientific community. Geophysical data records include the interim geophysical data record (IGDR), the sensor geophysical data record (SGDR), and the geophysical data record (GDR).

The interim geophysical data record (IGDR), which is also a non-validated product but that uses a preliminary orbit and applies ground retracking, are available by pass with a latency of 2-3 days. The geophysical data record (GDR), which is a fully validated product that uses a precise orbit and applies ground retracking, are available by repeat cycle with a latency of 30 days. And the SGDR is essentially the same product as the GDR or IGDR, with the wave forms added to the product.

3.1.2 Accuracy

The sea surface height (SSH) differences within 3 days at crossovers between HY-2 Cycle22 ascending and descending tracks are analyzed using a common method. After a standard selection of crossover data (on latitudes, oceanic variability and bathymetry), the standard deviation at crossovers for Cycle22 is -2 ± 8.6 cm. Using this method, the Jason-2 data are valuated also. And the standard deviation at crossovers is 1.6 ± 6.6 cm (Cycle123).

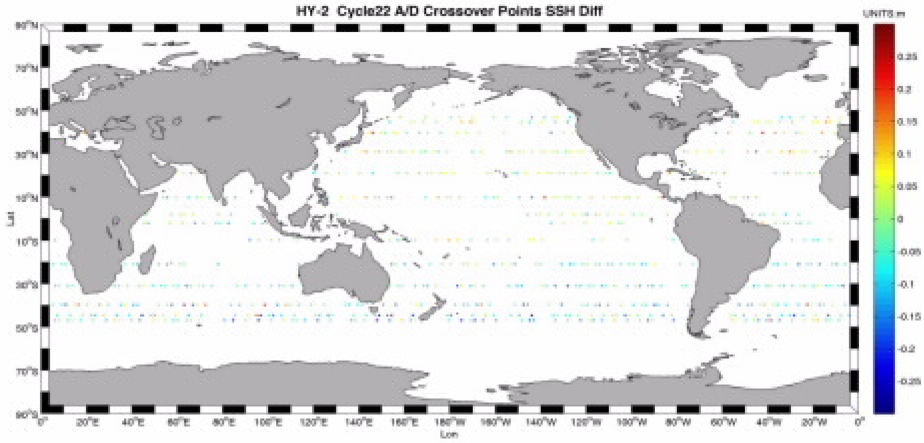


Fig 1. The difference at crossovers

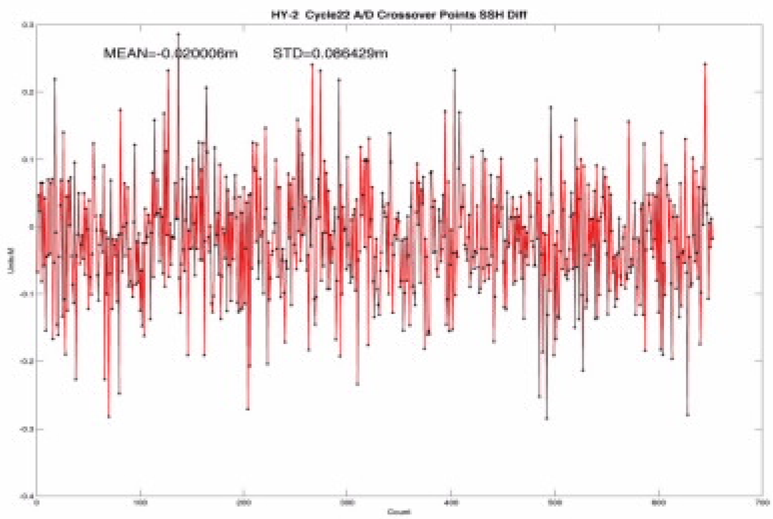


Fig 2. The mean and standard deviation at crossovers

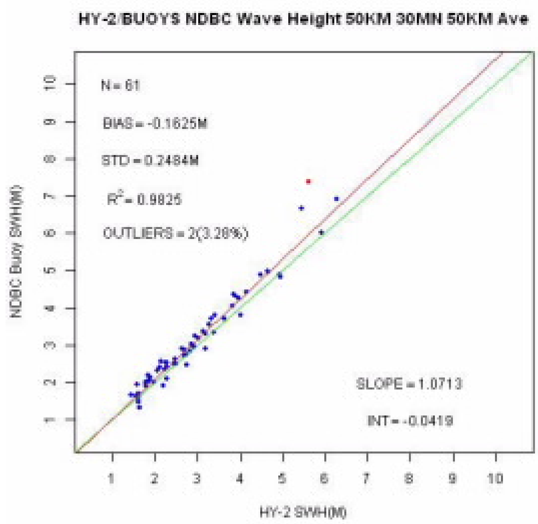


Fig 3. Comparison of significant wave height between HY-2 and NDBC

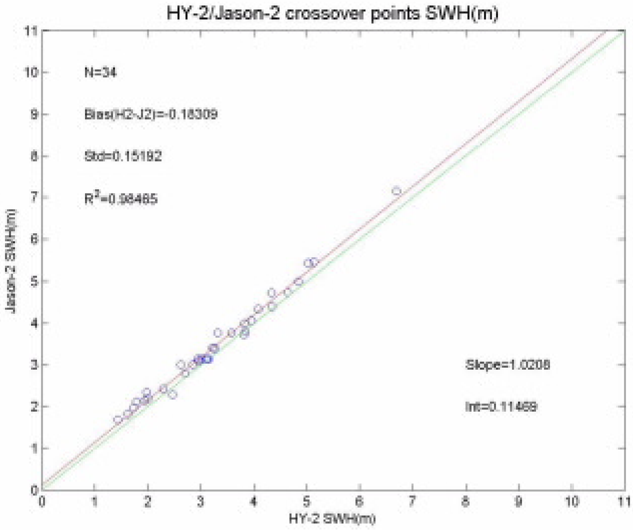


Fig 4. Comparison of significant wave height between HY-2 and Jason-2

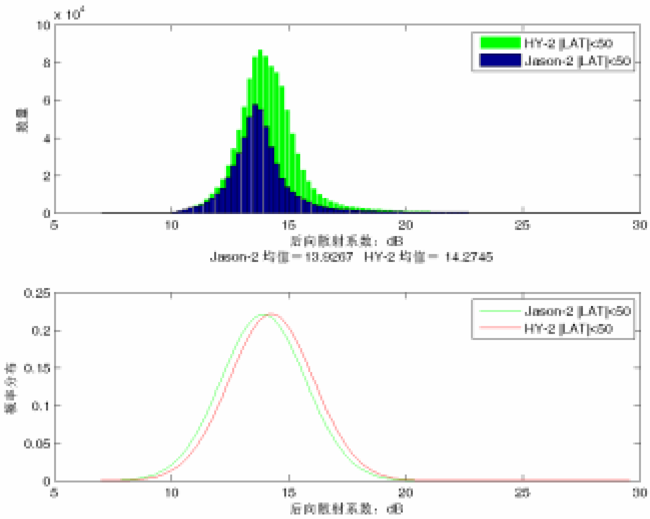


Fig 5. Comparison of backscattering coefficient between HY-2 and Jason-2

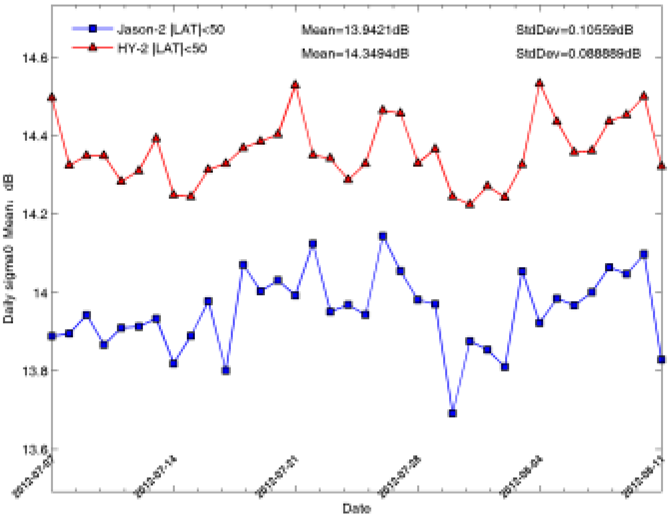


Fig 6. Comparison of daily sigma0 between HY-2 and Jason-2

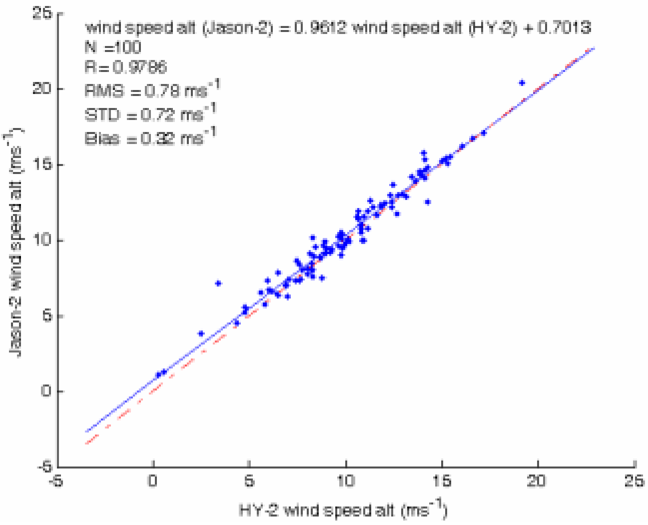


Fig 7. Comparison of wind speed between HY-2 and Jason-2

3.1.3 Applications

- Sea surface height

Sea surface height (SSH) is the height of the sea surface above the reference ellipsoid. It is calculated by subtracting the corrected range (see above) from the Altitude:

Sea Surface Height = Altitude - Corrected Range

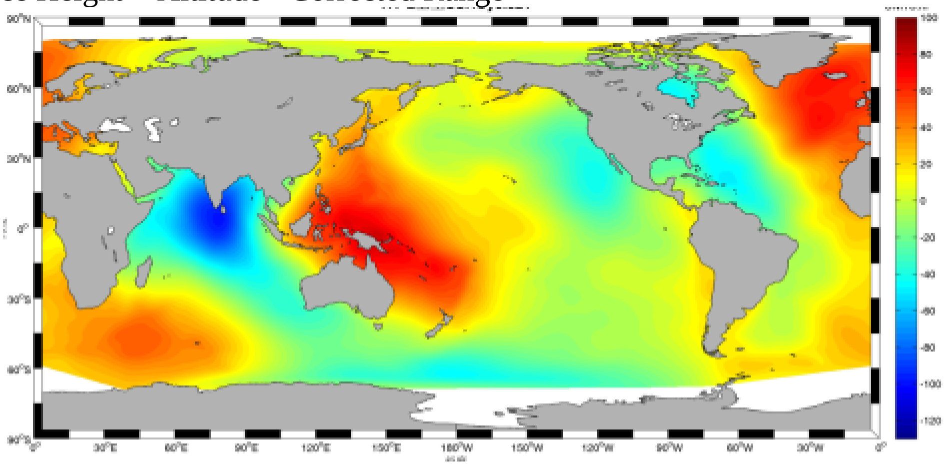


Fig 8. Map of SSH

The SLA is the difference between the observed sea surface height and the mean sea level. The SLA allows us to monitor ocean variability due to seasonal variations and climatic phenomena.

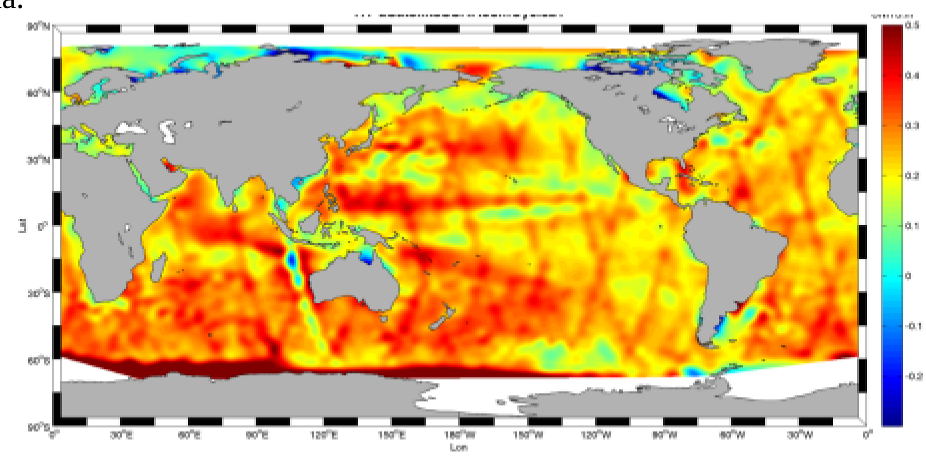


Fig 9. Map of SLA

- Significant wave height

The significant wave height is obtained by analyzing the shape and intensity of the altimeter radar beam reflected from the sea surface (radar echo). A long time delay in the return signal indicates that waves are high, whereas conversely, a short delay indicates that the sea surface is calm.

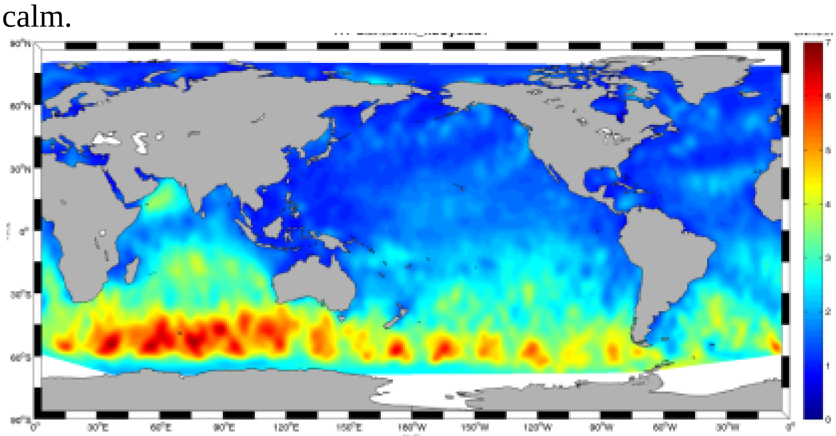


Fig 10. Map of SWH

- Wind speed

The model functions developed to date for altimeter wind speed have all been purely empirical. The model function establishes a relation between the wind speed, and the sea surface backscatter coefficient and significant wave height. A wind speed is calculated through a mathematical relationship with the Ku-band backscatter coefficient and the significant wave height using the Vandemark and Chapron algorithm. The wind speed model function is evaluated for 10 meter above the sea surface, and is considered to be accurate to 2 m/s.

3.2 Microwave scatterometer

The instrument of HY-2 scatterometer (SCAT) uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.256 GHz across broad regions on Earth’s surface. The instrument will collect data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band centred on the spacecraft’s nadir subtrack, covering 90% of earth’s surface each day. The instrument is active microwave radar designed to measure electromagnetic backscatter from wind roughened ocean surface.

HY-2’s scatterometer is aconically scanning pencil-beam scatterometer. A pencil-beam scatterometer has several key advantages over a fan-beam scatterometer; it has a higher signal-to-noise ratio, is smaller in size, and it provides superior coverage.

2.2.1 Levels of products

There are four levels of processed data can be distributed: Level 1B, Level 2A, Level 2B and Level 3.

2.2.2 Accuracy

- Zonal wind component

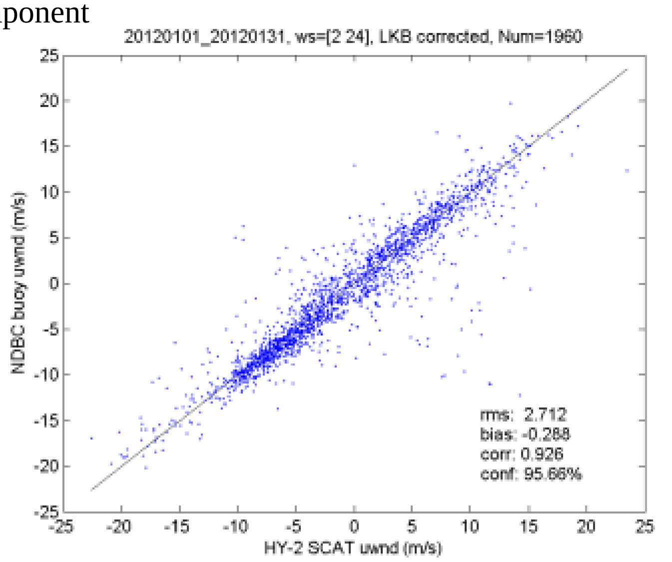


Fig 11. Comparison of zonal wind speed between HY-2 SCAT and NDBC, using all data in January 2012

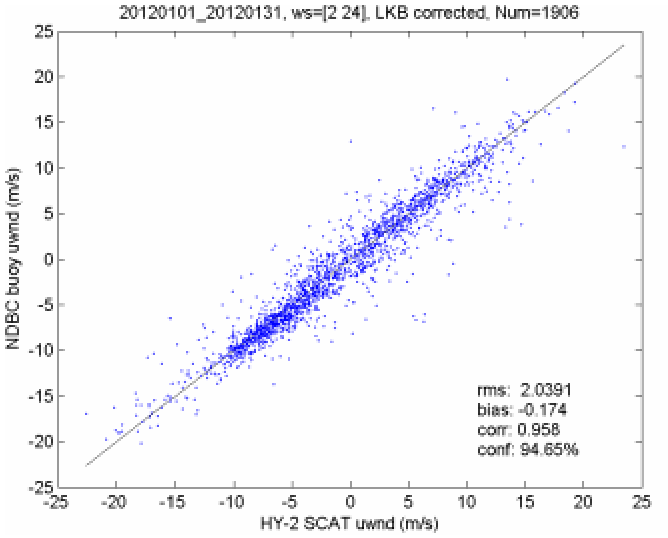


Fig 12. Comparison of zonal wind speed between HY-2 SCAT and NDBC, using after abnormal removal data in January 2012

- Meridional wind component

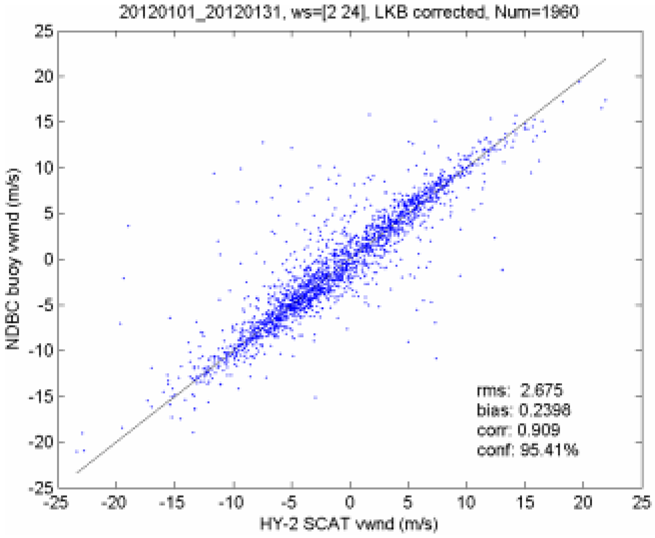


Fig 13. Comparison of meridional wind speed between HY-2 SCAT and NDBC, using all data in January 2012

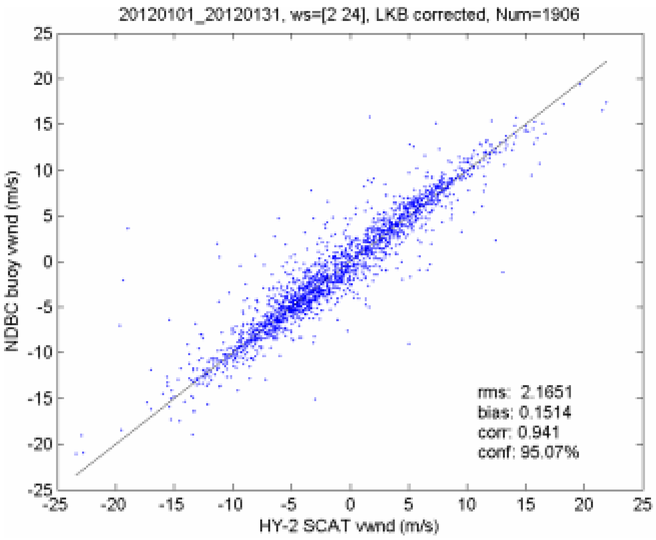
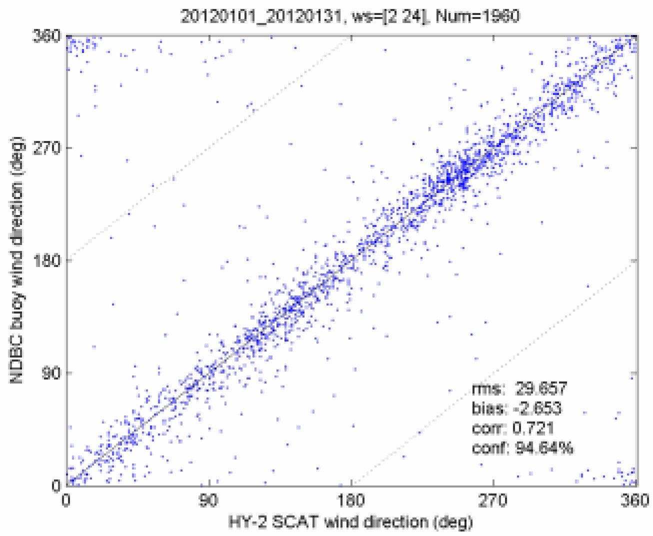


Fig 14. Comparison of meridional wind speed between HY-2 SCAT and NDBC, using after abnormal removal data in January 2012

- Wind direction



Comparison of wind direction between HY-2 SCAT and NDBC, using all data in January 2012

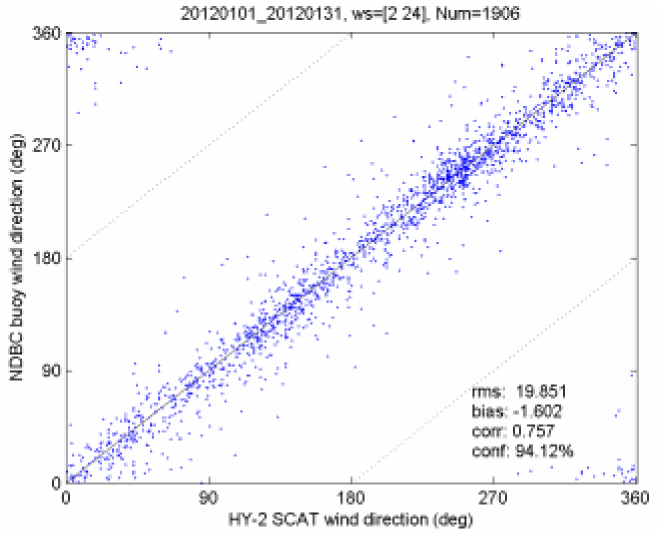


Fig 15. Comparison of wind direction between HY-2 SCAT and NDBC, using after abnormal removal data in January 2012

Using all the data (before abnormal removal), the error of different parameters is follow:

Time range (YYYYMM)	**Statistical parameter**	**Wind speed**	**Wind direction**	u_{wnd}	v_{wnd}
201111 No. of obs. : 2046	RMS	1.373	33.446	3.418	3.054
	Bias	-0.194	-0.614	-0.391	0.191
201201 No. of obs. : 1960	RMS	1.338	29.657	2.712	2.675
	Bias	0.118	-2.653	-0.288	0.240
201202 No. of obs. : 2106	RMS	1.257	29.593	2.754	2.617
	Bias	0.005	-1.169	-0.125	0.098
201203 No. of obs. : 1241	RMS	1.492	35.539	3.423	2.822
	Bias	-0.021	-1.000	-0.458	0.039

Using after abnormal removal, the error of different parameters is follow:

Time range (YYYYMM)	**Statistical parameter**	**Wind speed**	**Wind direction**	**uwnd**	**vwnd**
201111 No. of obs. : 1973	RMS	1.235	22.415	2.462	2.369
	Bias	-0.144	-0.870	-0.249	0.060
201201 No. of obs. : 1906	RMS	1.305	19.851	2.039	2.165
	Bias	0.137	-1.602	-0.174	0.151
201202 No. of obs. : 2043	RMS	1.126	19.524	1.950	1.938
	Bias	0.045	-0.769	-0.074	0.065
201203 No. of obs. : 1187	RMS	1.368	20.562	1.999	1.979
	Bias	0.063	-0.447	-0.234	0.049

3.2.3 Applications

- Typhoon

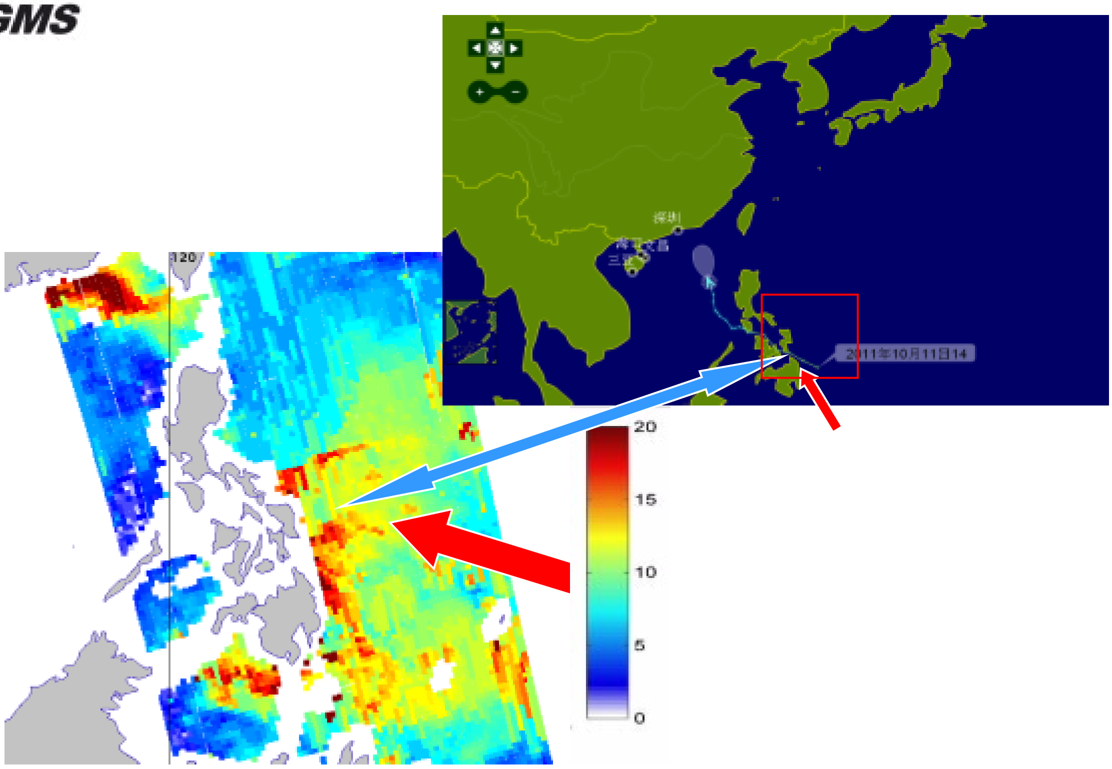
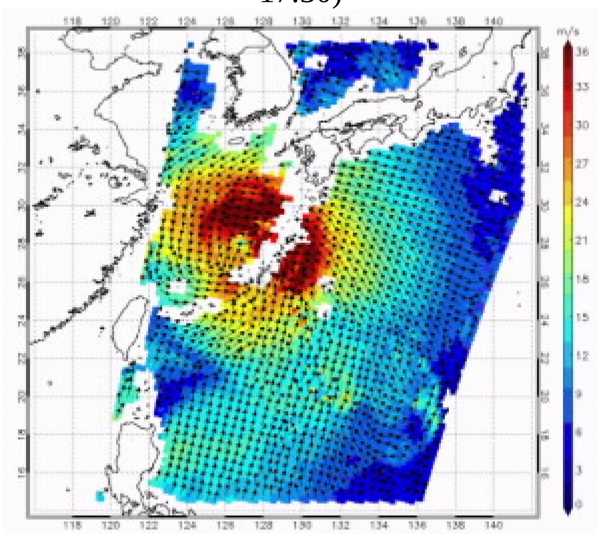
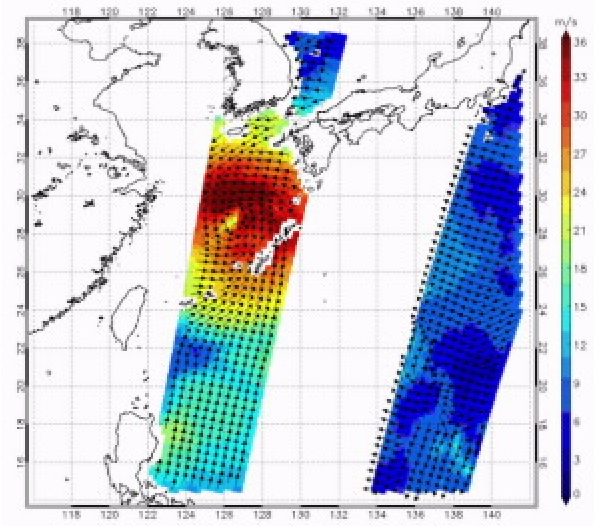


Fig 16. Detection the Tropical Storms Banyan using the HY-2 scatterometer (2011-10-11 17:30)



(a)



（b）

Fig 17. a :detection Typhoon Bolaven using the HY-2 scatterometer at 2012-08-26 21:42:52(UTC)，b: detection Typhoon Bolaven using the ASCAT at 2012-08-27 00:12:01(UTC)。

Comparing the results, we can find that HY-2 scatterometer with larger swath is superior to the ASCAT in the aspect of detection of typhoon.

- Atmosphere front

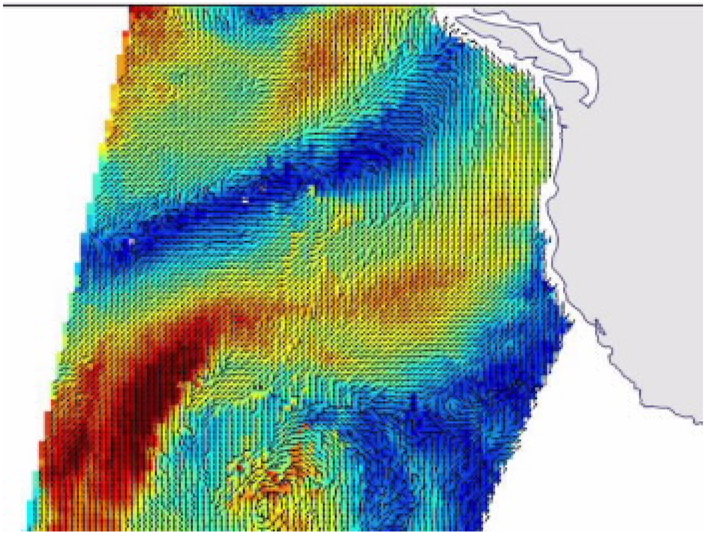


Fig 18. Detection of atmosphere front using HY-2 scatterometer

The HY-2 satellite scatterometer can be used to detection the atmosphere front.

3.3 Scanning microwave radiometer

3.3.1 Levels of products

There are four levels of processed data:Level 0: Telemetry data (raw data), Level 1: Swath brightness temperatures, Level 2: Geophysical Data Records (geophysical units), Level 3: Daily product and monthly product include geophysical data and brightness temperatures.

Among these, level 2 products include sea surface temperature (SST)，near-surface wind speed, columnar water vapor, columnar cloud liquid water, and quality flags. And level 3 products are gridded data, including brightness and other marine atmospheric environment parameters, etc.

3.3.2 Accuracy

The accuracy of the marine atmosphere environment parameters is compared with the Windsat's parameters. And the mean square errors are 1.29K(SST)、1.46m/s(wind speed)、1.18mm(water vapour content) and 0.033mm(liquid water content), respectively.

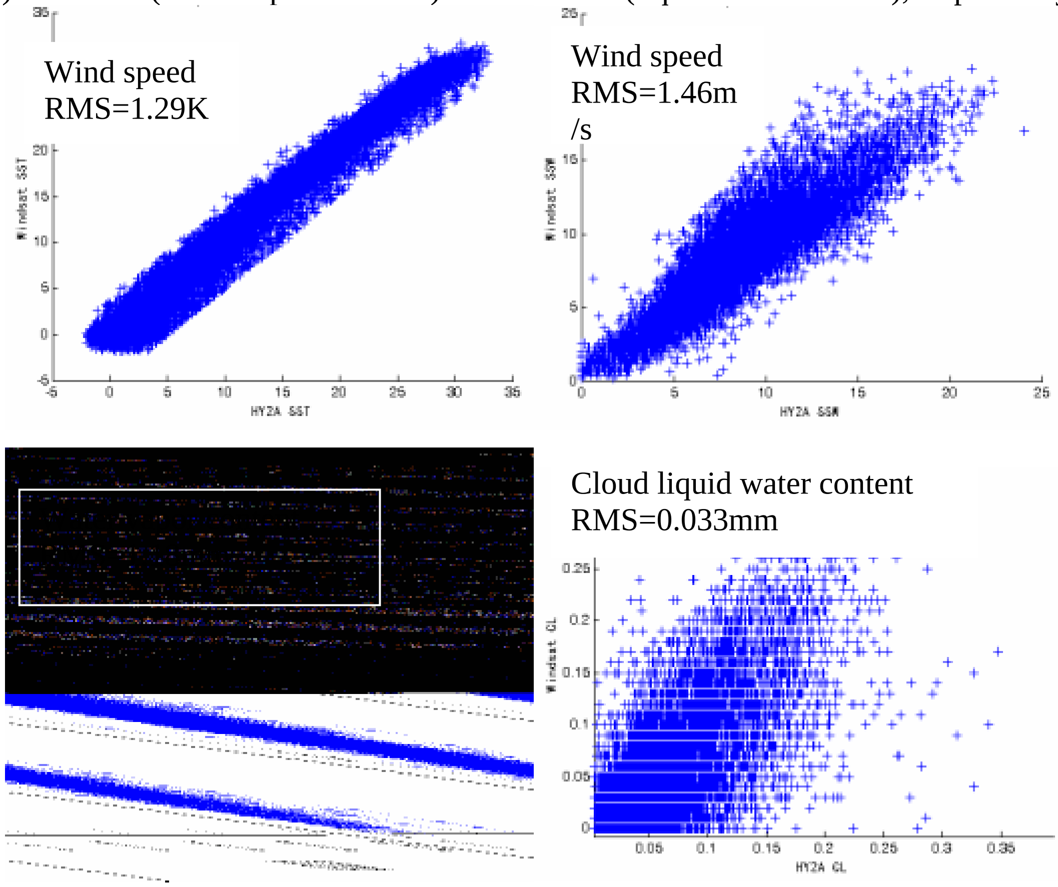


Fig 19. Comparison between HY-2's accuracy of marine atmosphere parameter and Windsat's

The SST and the wind speed are valuated using the NDBC buoy. And the results are:

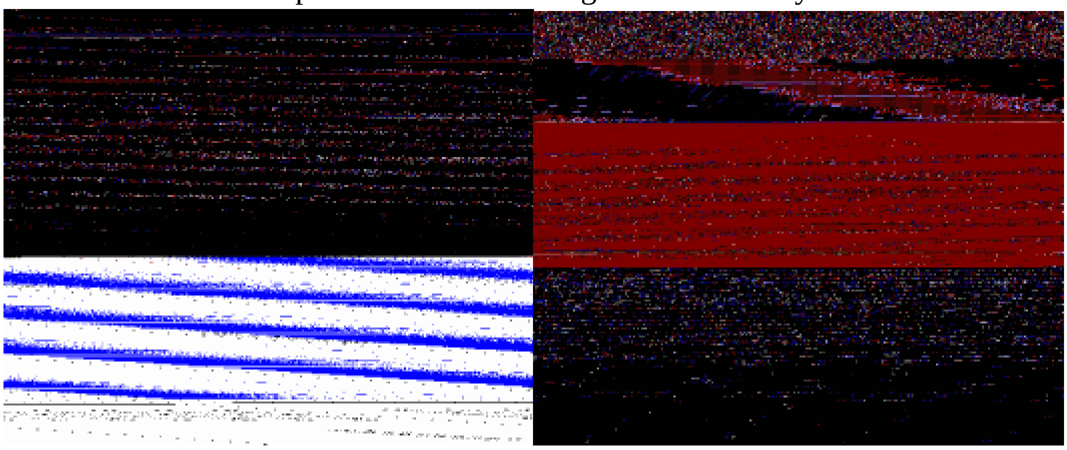


Fig 20. comparison between HY-2's SST and wind speed and NDBC buoy's

4. Joint detection with the other satellites

4.1 HY-2 joins with Jason-1/2

Based on the HY-2 validated data (2 cycles), DUACS valuated the characteristic of HY-2 data. At the same time, HY-2 altimeter data and the Jason-2 data are used to research the mesoscale eddies in the Agulhas retroflexion current area. As shown in the figure, all sensors see very consistent mesoscale features in this region.

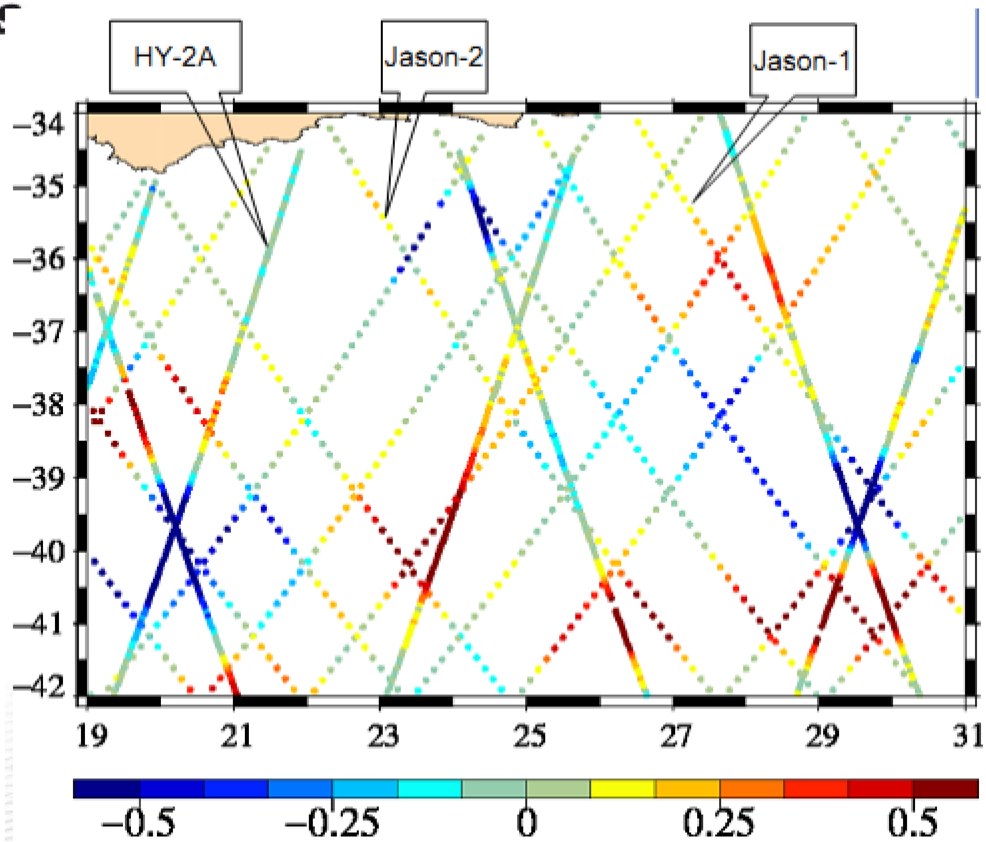


Fig 21 SLA(m) of HY-2, Jason-1/2(17-26 2011/11)

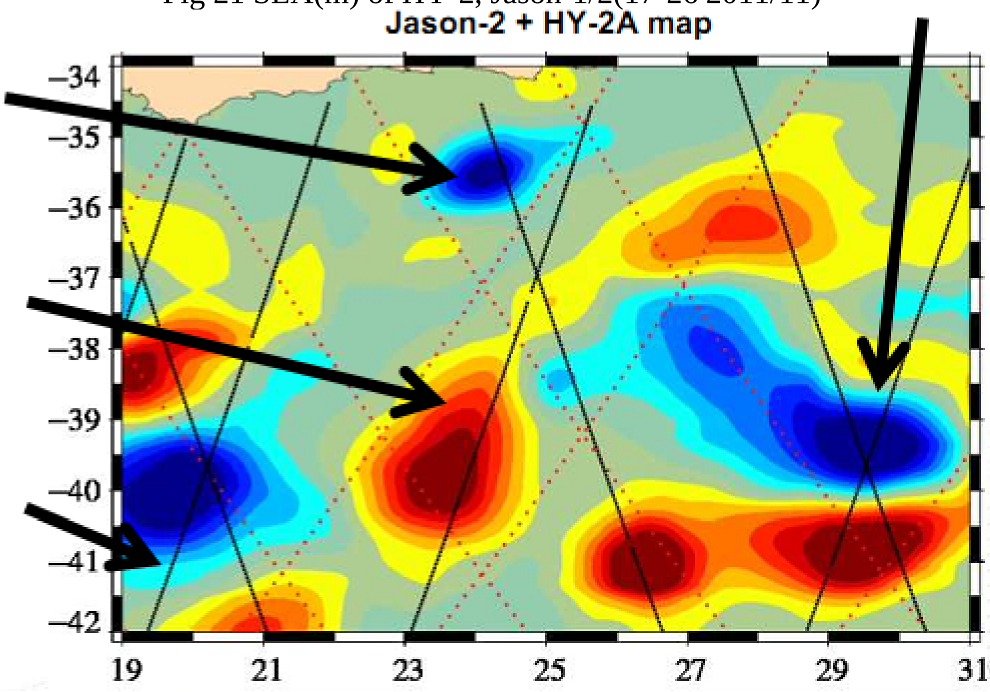


Fig 22. Nov. 26th 2011:The location of the last 10 days of along-track data from each satellite are superimposed: Red dots = Jason-2Black lines = HY-2

4.2 HY-2 joins with FY2E

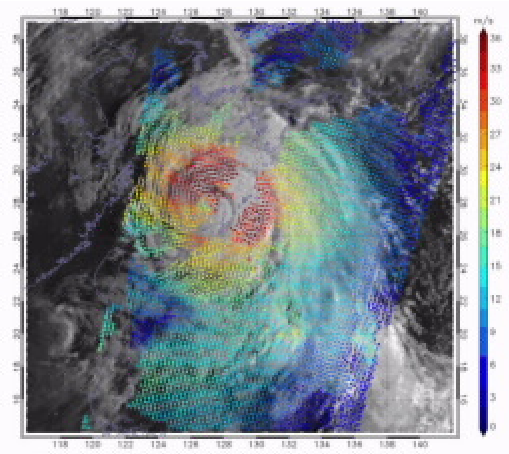


Fig 23. using the HY-2 scatterometer and the FY2E to detect the typhoon Bolaven

HY-2 not only can find the typhone but also can put forward the wind field. So the HY-2 data can be used to give the more ditails of the typhoones.

5. Contributions of HY-2 to the Earth Observation System

The HY-2 satellite carries four scientific instruments: a radar altimeter, a microwave scatterometer, a scanning microwave radiometer and a three-frequency microwave radiometer. There are only one altimeter(Jason-2), one scatterometer(ASCAT) on board beside HY-2 all over the world. So the HY-2 not only fills the scanning microwave radiometer's gap but also increases the information of altimeter and scatterometer. At the same time, HY-2 satellite will contribute to the member of CGMS, because it can provide much useful data freely to the user. HY-2 has the ability to replace ENVISAT or Jason-1 in the aspect of global grid map of SST, SLA, etc. At the same time, HY-2 can give the global wind field with wider swath.

6. Conclusions

Data discovery, ordering, distribution channels, and channels specific to instruments and additional information can be found online through the National Satellite Oceanic Application Service(http://www.nsoas.gov.cn). And the user should filli in an application form. This form can be downloaded from http://www.nsoas.gov.cn.

But HY-2 is an experimental satellite. The HY-2 satellite data products are beta products. After the calculation and valuation, the HY-2 satellite products can be brought into the earth observation system.

Because of the low time and space resolution, HY-2 cannot be used to find all the details of the ocean phenomena. CFOSAT will be launched about in 2015. It will be equipped with a directional wave spectrum form SWIM and a wind scatterrometer SCAT and can be used to monitor at the global scale the wind and waves at the ocean surface. The products of CFOSAT can be used to monitor the sea surface jointly with HY-2. At the same time, it is necessary to build satellite networking or to launch new type payloads to satisfy the need of ocean phenomena detection. We hope that the scientist all over the world can cooperate on this field.