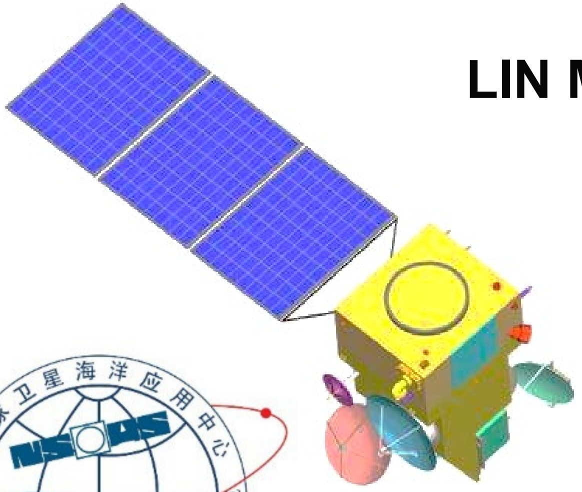
Introduction to Numerical Assimilation Operational Application of HY-2 Satellite Wind Field Data



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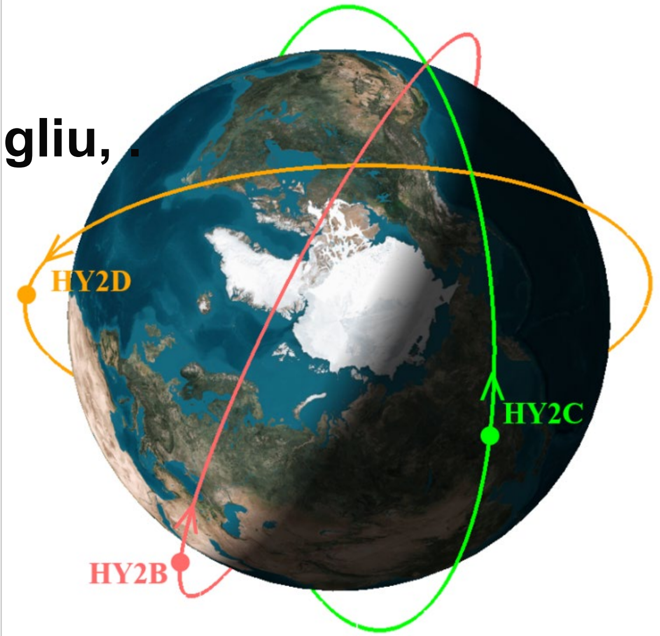


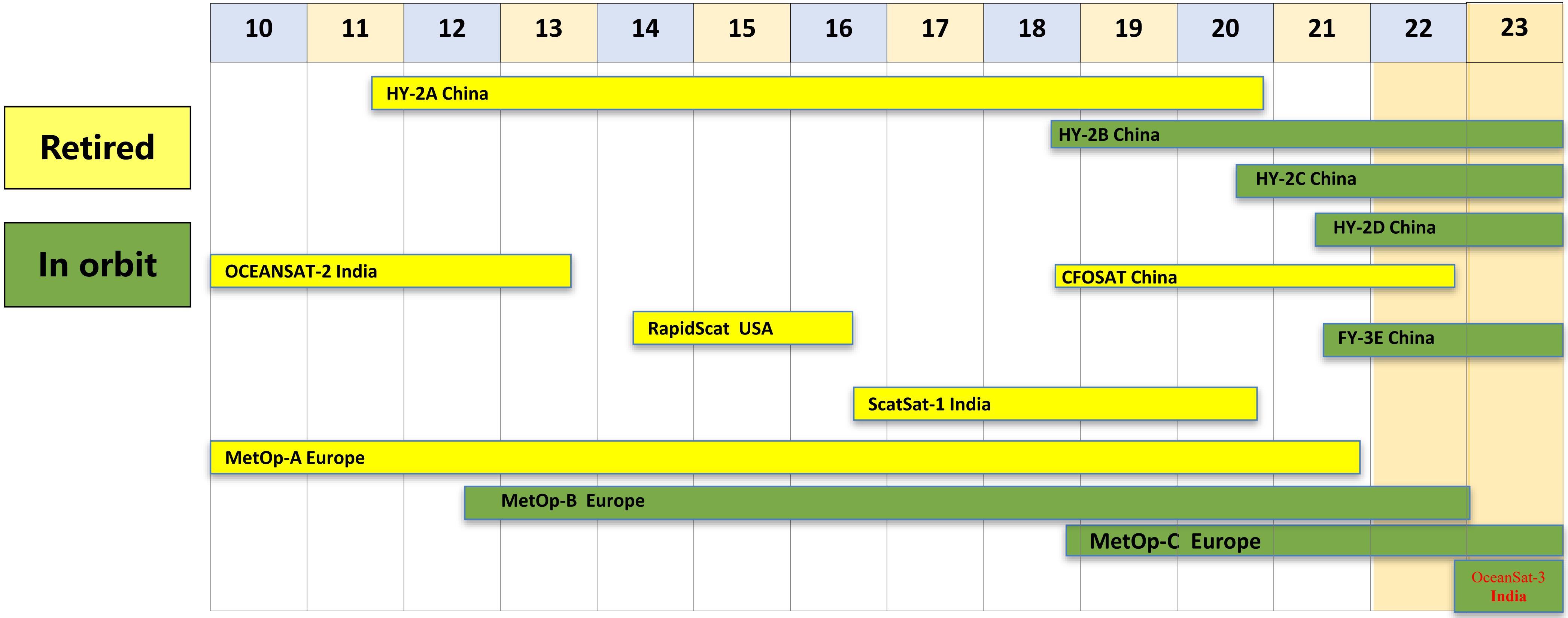
Outline

1. Introduction to HY-2 scatterometer missions

2. Overview of Assimilation of HSCAT Winds in NWP

3. Summary

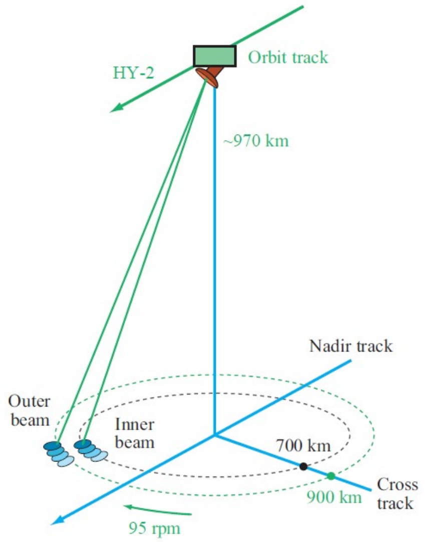
Spaceborne Scatterometer in the Past 15 years

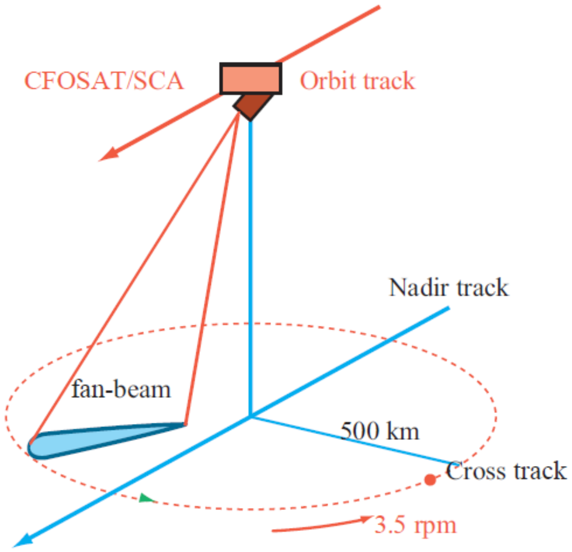


- ☑ About half of the spaceborne **scatterometer launched in the past 15 years was operated by China.**
- ☑ China launched it's first operational satellite scatterometer HY-2A/HSCAT in 2011, and has now formed a HY-2B/C/D three-satellite scatterometer constellation;
- ☑ Additionally, FY-3E/WindRAD operate simultaneously in orbit;
- ☑ The development of satellite scatterometers in China has entered an golden age!

Main parameters of China's spaceborne scatterometer

Scatterometer	Frequency	polarization	incidence angle	Inclination	Altitude (km)	Swath (km)	Resolution (km)	ECT	launch date
HY-2A	Ku	VV、HH	41.5°&48.5°	99.3°	971 km	1700 km	25 km	06:00 desc	15 Aug 2011
HY-2B	Ku	VV、HH	41.5°&48.5°	99.3°	971 km	1700 km	25 km	06:00 desc	24 Oct 2018
HY-2C	Ku	VV、HH	41.5°&48.5°	66.0°	971 km	1700 km	25 km	shifting	21 Sep 2020
HY-2D	Ku	VV、HH	41.5°&48.5°	66.0°	971 km	1700 km	25 km	shifting	19 May 2021
CFOSAT	Ku	VV、HH	28° ~ 51°	97.5°	520 km	1000 km	25&12.5 km	06:30 desc	29 Oct 2018
FY-3E	Ku & C	VV、HH	36° ~ 42°	98.75°	840 km	1200 km	20&10 km	05:40 desc	04 Jul 2021





- China has launched different type of scatterometer : Ku & C band, pencil beam rotation &fan beam rotation；
- Different orbit : eraly-morning at around 6 orbit and shifting orbit
- Several satellite scatterometer are in orbit simultaneously
- Several satellite scatterometer of China fly at close orbits, which is conducive to cross calibration!

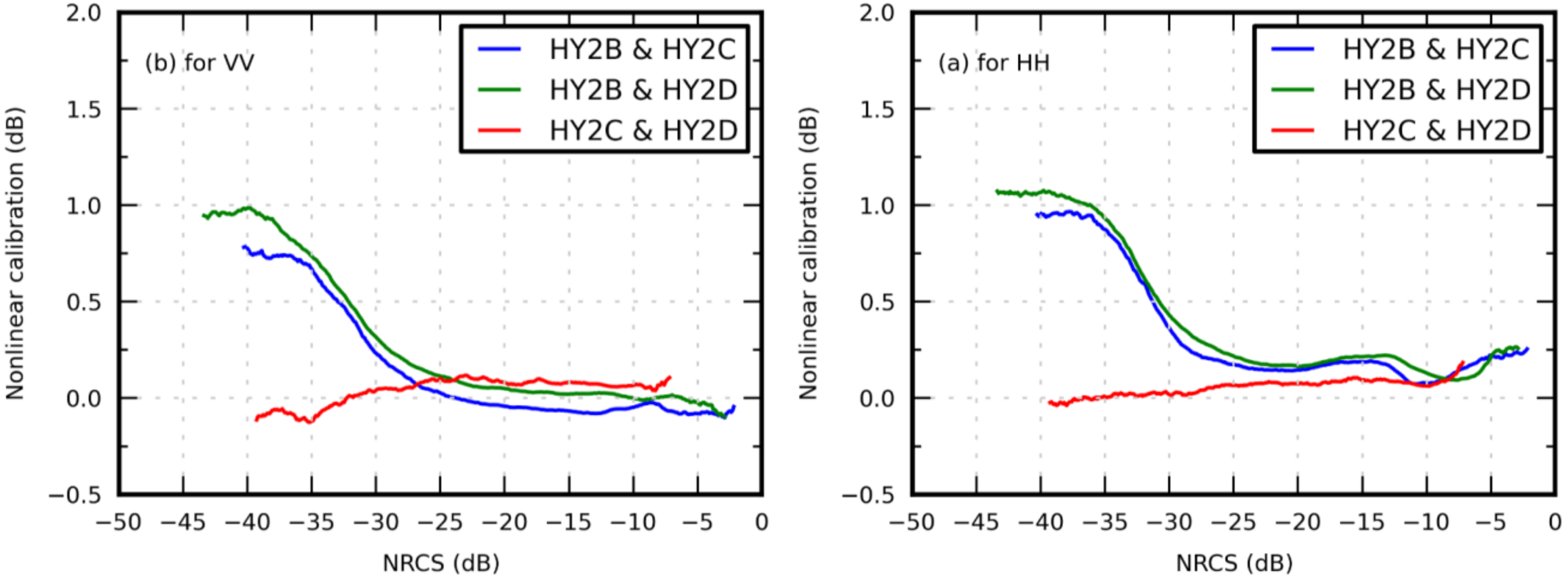
Consistency Analysis for Sigma0 of HY-2B/C/D Scatterometer

Three methods were used:

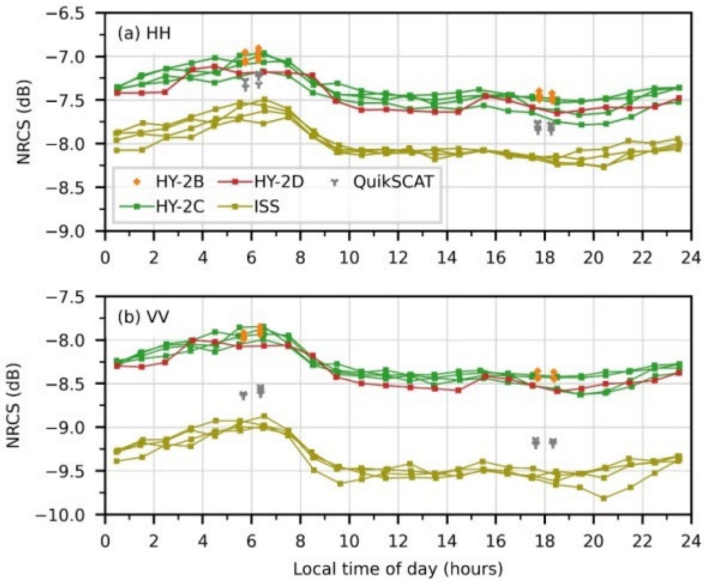
- ☐ Amazon Rainforest
- ☐ Cross calibration
- ☐ NOC

The overall accuracy of cross calibration is better than 0.1dB

Case	Collocated		Rainforest		NOC	
	HH (dB)	VV (dB)	HH (dB)	VV (dB)	HH (dB)	VV (dB)
HY-2B & HY-2C	+0.132	-0.060	+0.043	-0.056	+0.133	+0.022
HY-2B & HY-2D	+0.155	+0.019	+0.128	+0.039	+0.202	+0.089
HY-2C & HY-2D	+0.076	+0.067	+0.086	+0.096	+0.069	+0.067



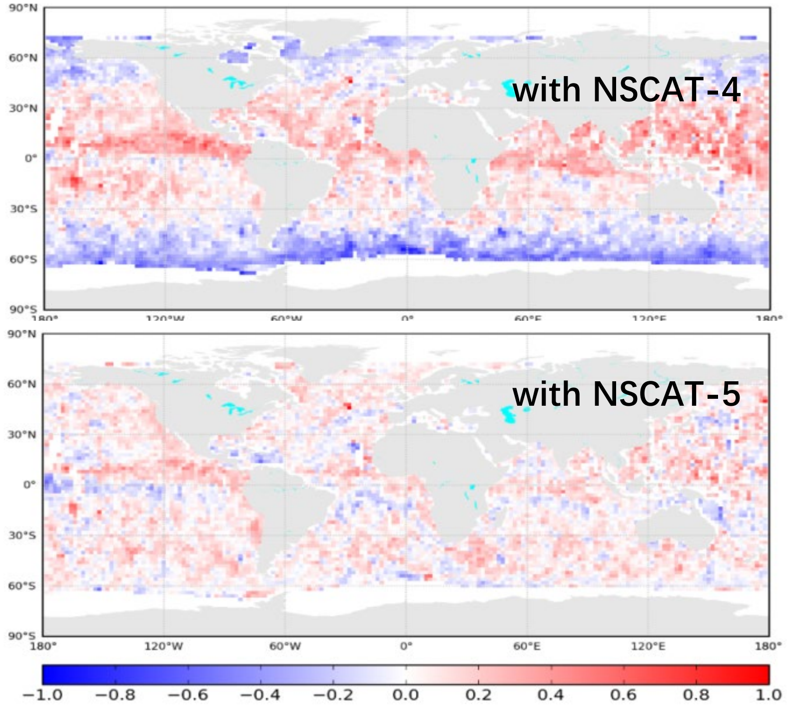
nonlinear calibration obtained using the CDF matching technique



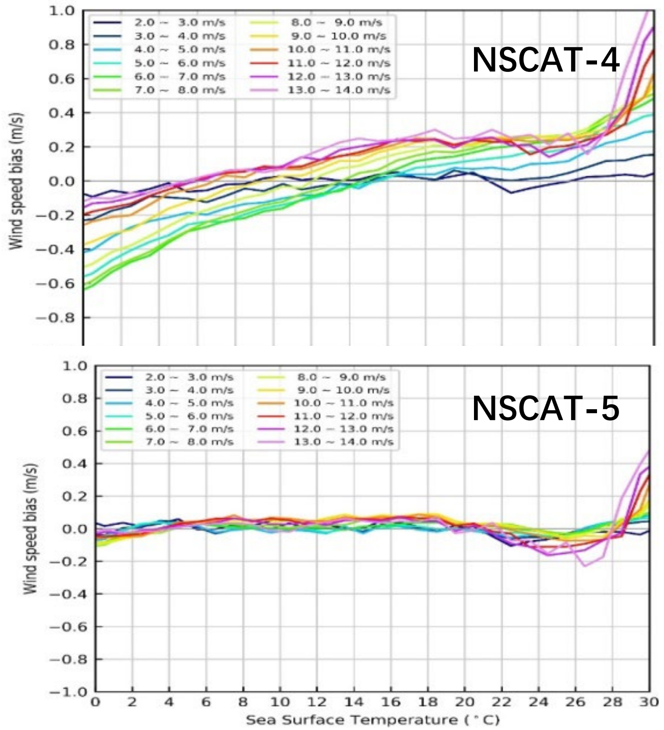
Hourly average sigma0 over the Amazon

Correction of the impact of SST
Further improving consistency with the C-band scatterometer winds

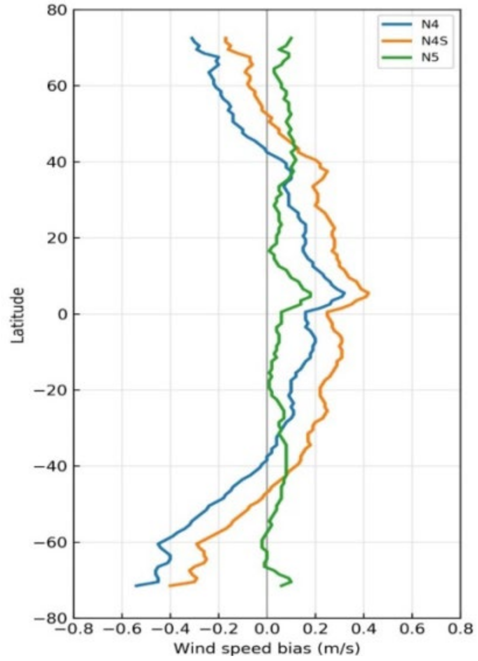
A GMF with SST factor (NSCAT-5.HY-2) was constructed to eliminate wind inversion errors dependent on SST. The wind speed bias are reduced to less than 0.2 m/s in all wind speed range after correction.



Spatial distribution of wind speed bias



wind speed bias at different wind speed range



Wind speed bias at different latitude(The green line represents the corrected one)

Validation of HSCAT winds

HSCAT winds, as well as ASCAT winds and OSCAT winds, show good agreements against buoy wind speeds, i.e., the SDs of wind speed differences range from 0.95 to 1.05 m/s. the wind direction RMSEs for these scatterometers are in a narrow range and comparable, i.e., between 14.8° and 16.0°.

The comparison between HSCAT winds with ERA5 winds shows consistent results with that against buoy wind speeds . The SDs of wind speed and wind components are comparable among all these scatterometers.

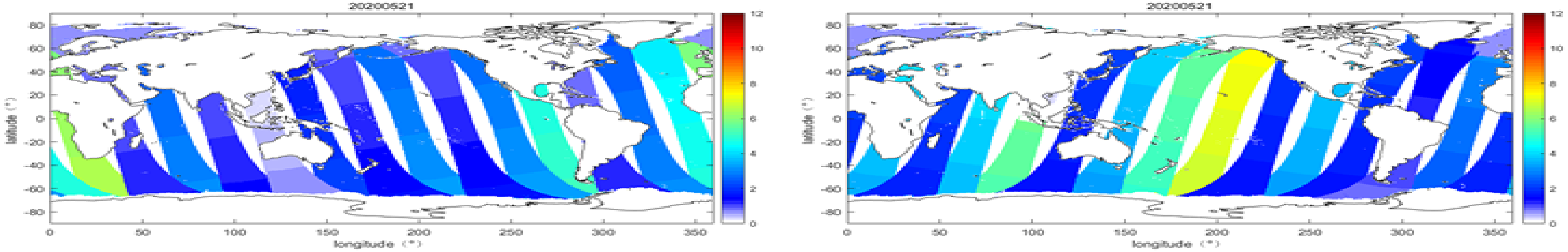
WIND COMPARISONS BETWEEN SCATTEROMETER AND BUOY

Scatterometer winds	Number	Wind speed		U component		V component		Direction RMSE
		Bias(m/s)	SD(m/s)	Bias(m/s)	SD(m/s)	Bias(m/s)	SD(m/s)	
HSCAT-C	50 572	-0.14	1.03	-0.13	1.53	-0.02	1.59	15.9°
HSCAT-B	44 198	-0.21	1.00	-0.12	1.51	0.04	1.50	14.8°
OSCAT2	46 194	-0.10	1.05	-0.13	1.59	-0.03	1.55	15.5°
ASCAT-B	25 198	-0.06	0.95	-0.14	1.35	-0.11	1.52	15.7°
ASCAT-C	24 884	-0.08	0.96	-0.15	1.43	-0.10	1.50	16.0°

WIND COMPARISONS BETWEEN SCATTEROMETER AND ERA5 WINDS

Scatterometer winds	QC Ratio	Wind speed		U component		V component		Direction RMSE
		Bias(m/s)	SD(m/s)	Bias(m/s)	SD(m/s)	Bias(m/s)	SD(m/s)	
HSCAT-C	6.1%	-0.04	1.12	-0.19	1.27	0.01	1.22	10.7°
HSCAT-B	6.2%	-0.03	1.11	-0.13	1.22	0.00	1.16	10.1°
OSCAT2	5.2%	-0.08	1.15	-0.11	1.27	-0.03	1.23	10.6°
ASCAT-B	0.4%	0.09	1.02	-0.06	1.22	-0.04	1.31	11.2°
ASCAT-C	0.4%	0.07	1.02	-0.05	1.21	-0.04	1.30	11.1°

Timeliness Evaluation of HSCAT n.r.t Winds



（a） 升轨　　　　　　　　　　　　　　　　　　　　　（b） 降轨

图1 HY-2B 卫星微波散射计 L2B 级洋面风产品时效性空间分布

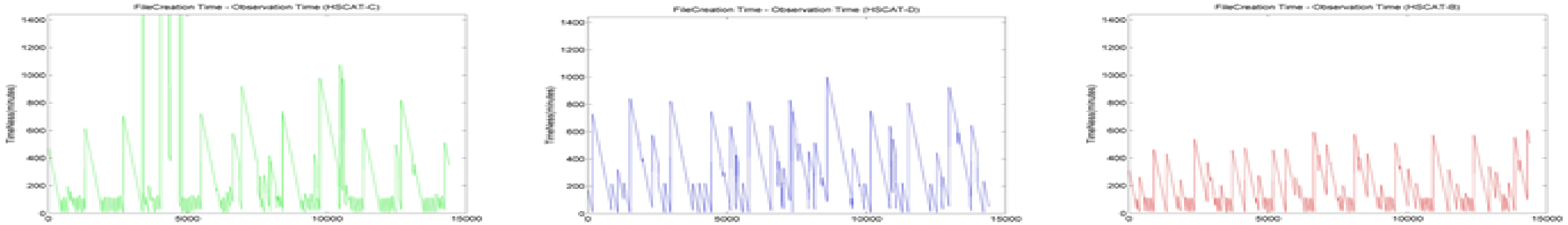


图2 HY-2B/C/D 卫星微波散射计 L2B 级洋面风产品时效性随时间变化情况

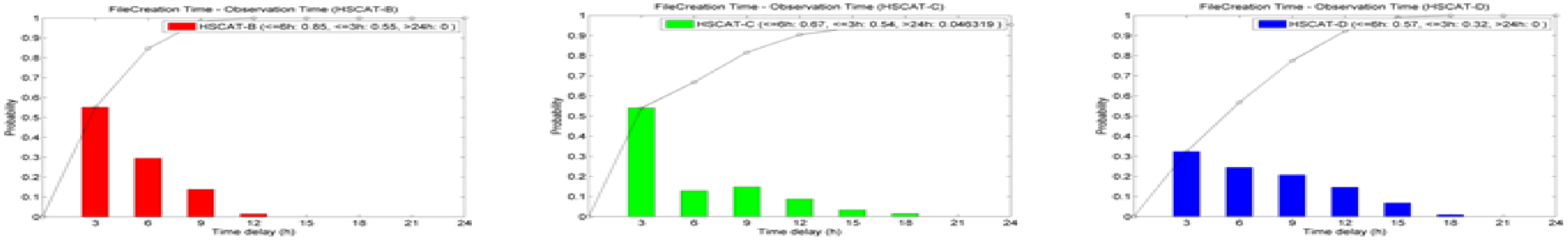


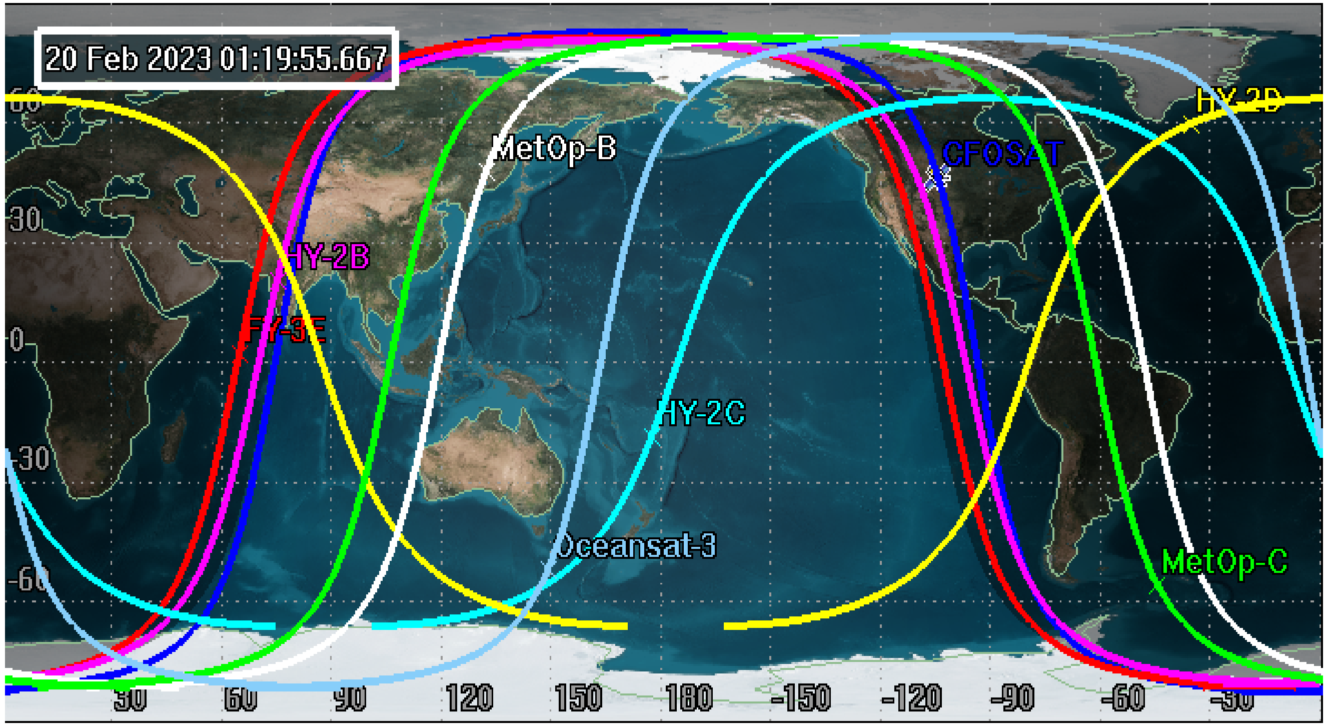
图3 HY-2B/C/D 卫星微波散射计 L2B 级洋面风产品时效性占比分析

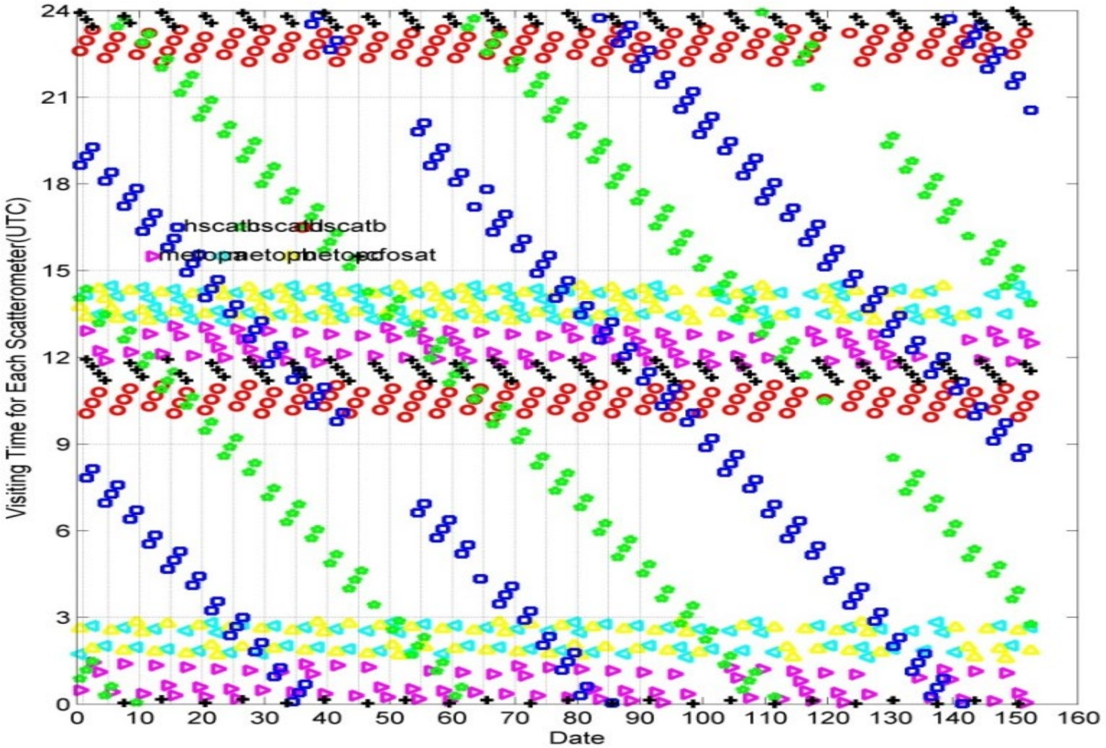
Timeless of HSCAT n.r.t. winds around China's offshore areas is less than 10 minutes!

The average timeliness of HSCAT-B, HSCAT-C, and HSCAT-D winds is 213.8 minutes, 244.7 minutes, and 364.4 minutes, respectively.

The proportion of HSCAT-B, HSCAT-C, and HSCAT-D winds with timeliness better than 3 hours is 55%, 54%, and 32%.

Virtual Spaceborne Scatterometer Constellation





➢	MetOp-B/ASCAT	9:30/21:30
➢	MetOp-C/ASCAT	9:30/21:30
➢	HY-2B/HSCAT	6:00/18:00
➢	HY-2C/HSCAT	Shifting
➢	HY-2D/HSCAT	Shifting
➢	CFOSAT/CSCAT	6:30/18:30
➢	FY-3E/WindRAD	5:40/17:40
➢	OceanSat-3/OSCAT-3	00:00/12:00

- Currently, there are 7 Spaceborne scatterometer in orbit (HY-2B/C/D, FY-3E, MetOp-B/C and OSCAT-3)
- HY-2C/D operates in an shifting orbit, which is beneficial for improving the space coverage capability of global wind observations
- Through the HY-2B/C/D Constellation, over 85% of the global open ocean can be covered within 6-hour .

Outline

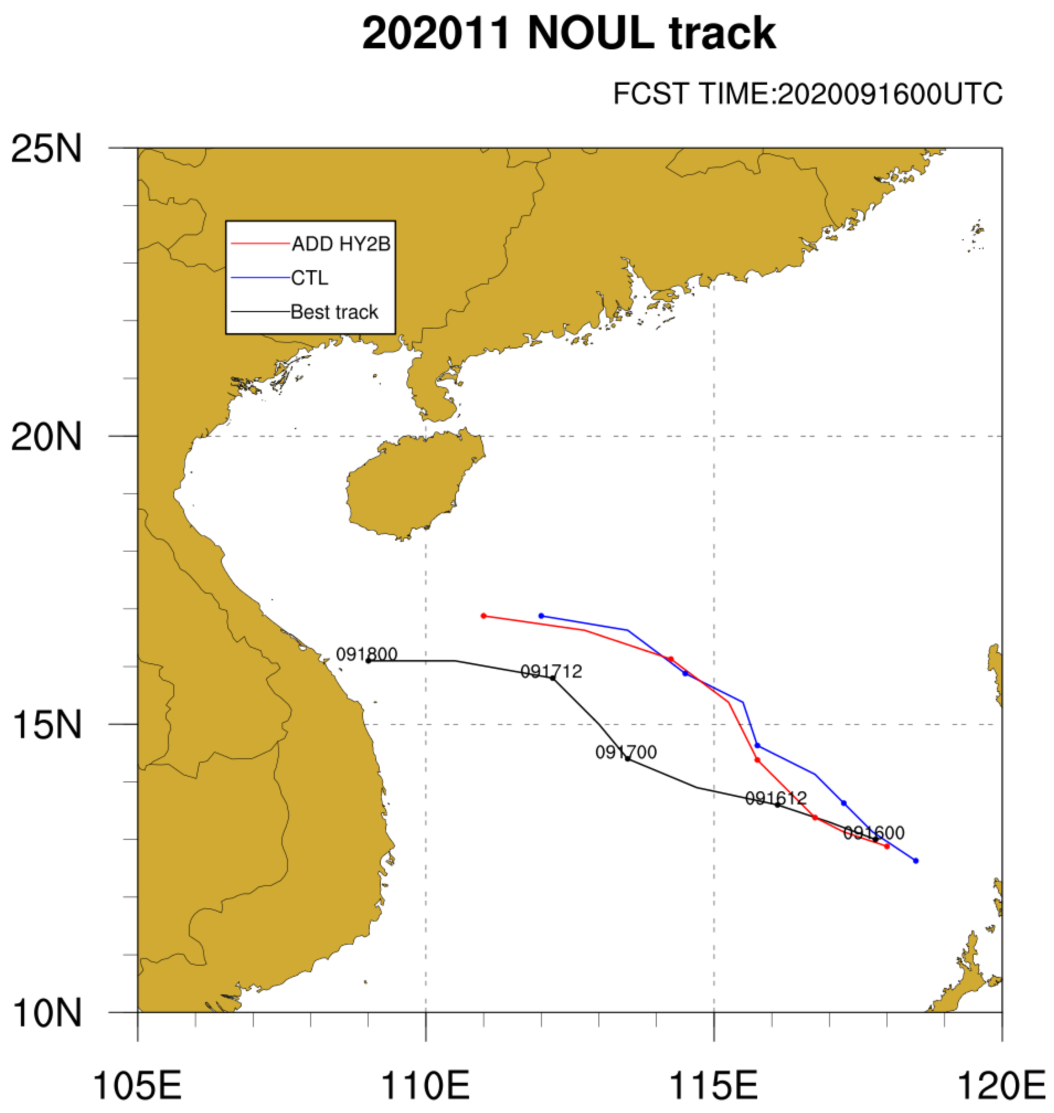
1. Introduction to HY-2 scatterometer mission

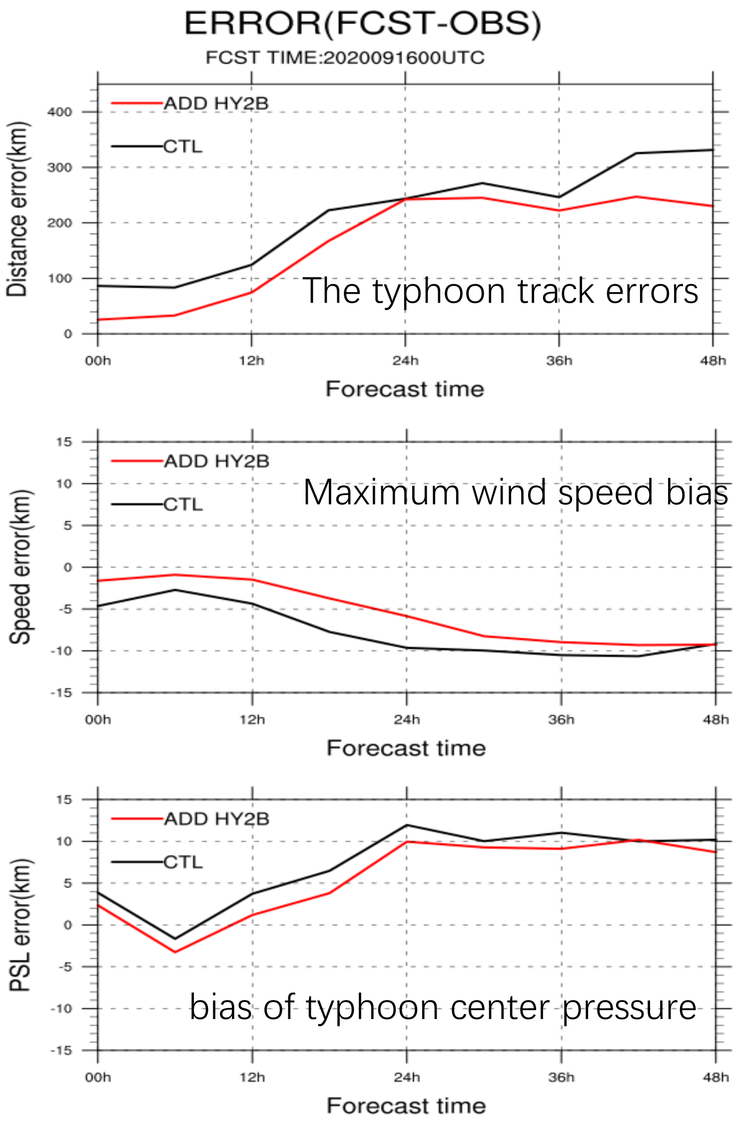
2. Overview of Assimilation of HSCAT Winds in NWP

3. Summary

2.1 Assimilation Experiment of HSCAT winds in CMA-GFS

2020091600UTC FCST

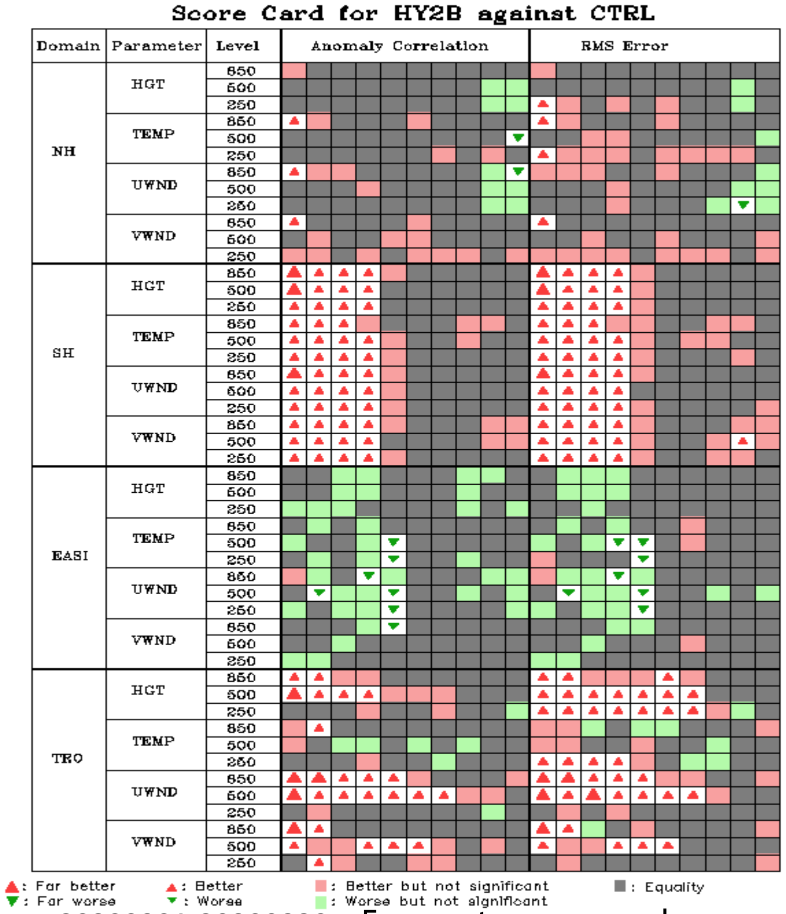




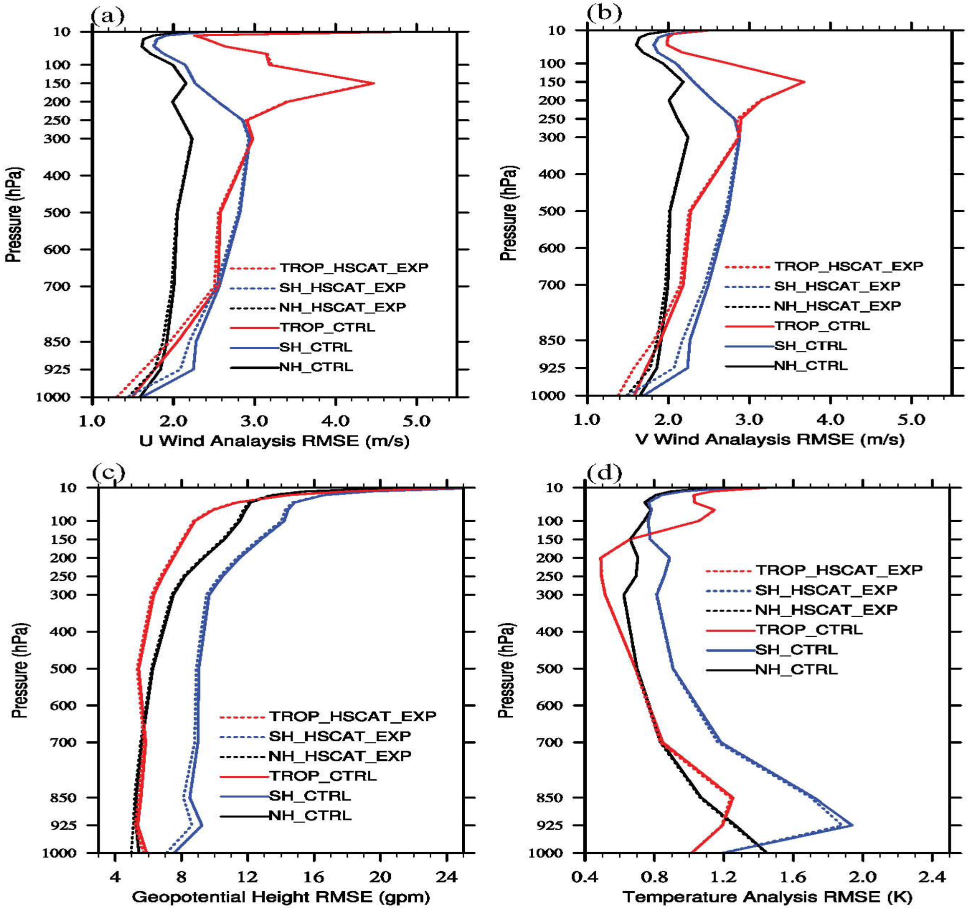
After assimilation of HSCAT-B winds , both the typhoon intensity and track forecasting errors were significantly reduced.

Han Wei, Assimilation of HSCAT wind data within the 4DVAR System at CMA-GFS, Technical Report ,Beijing, 2023

2.1 Assimilation Experiment of HSCAT winds in CMA-GFS



20200901-20200930，Forecast scores card

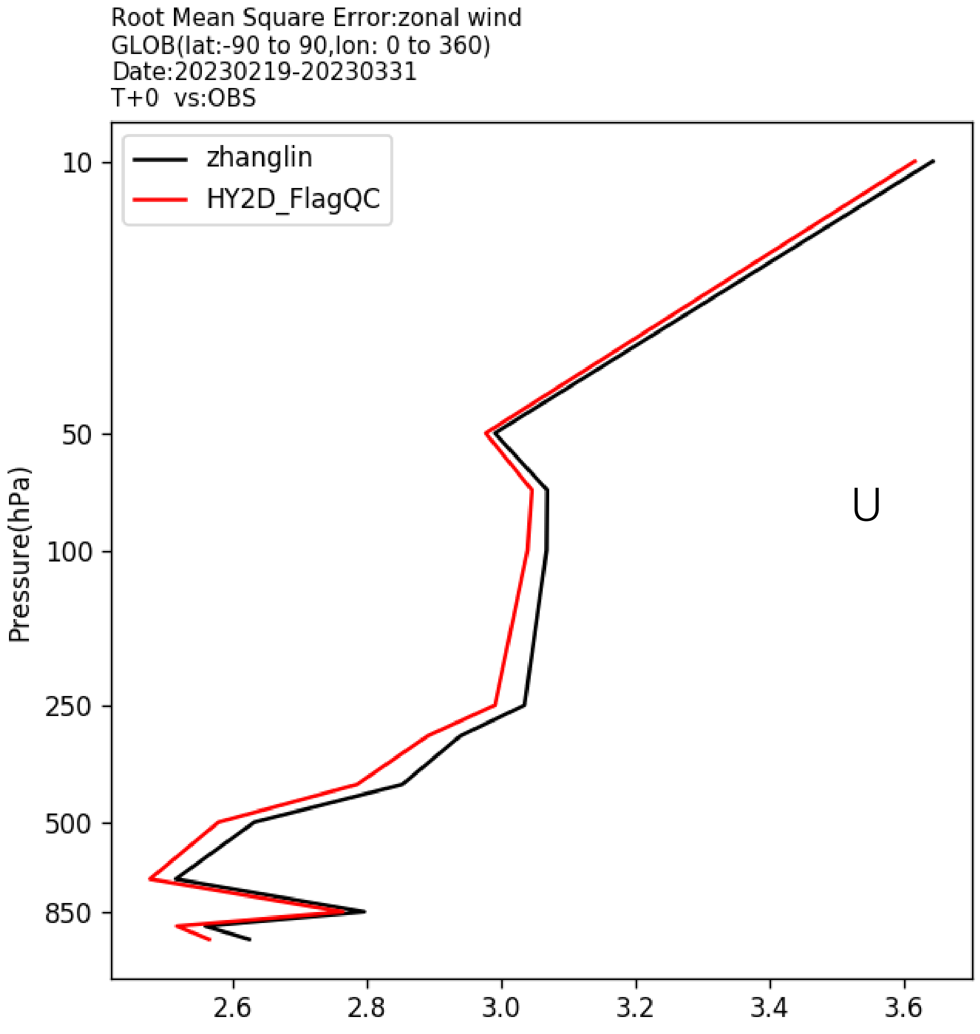


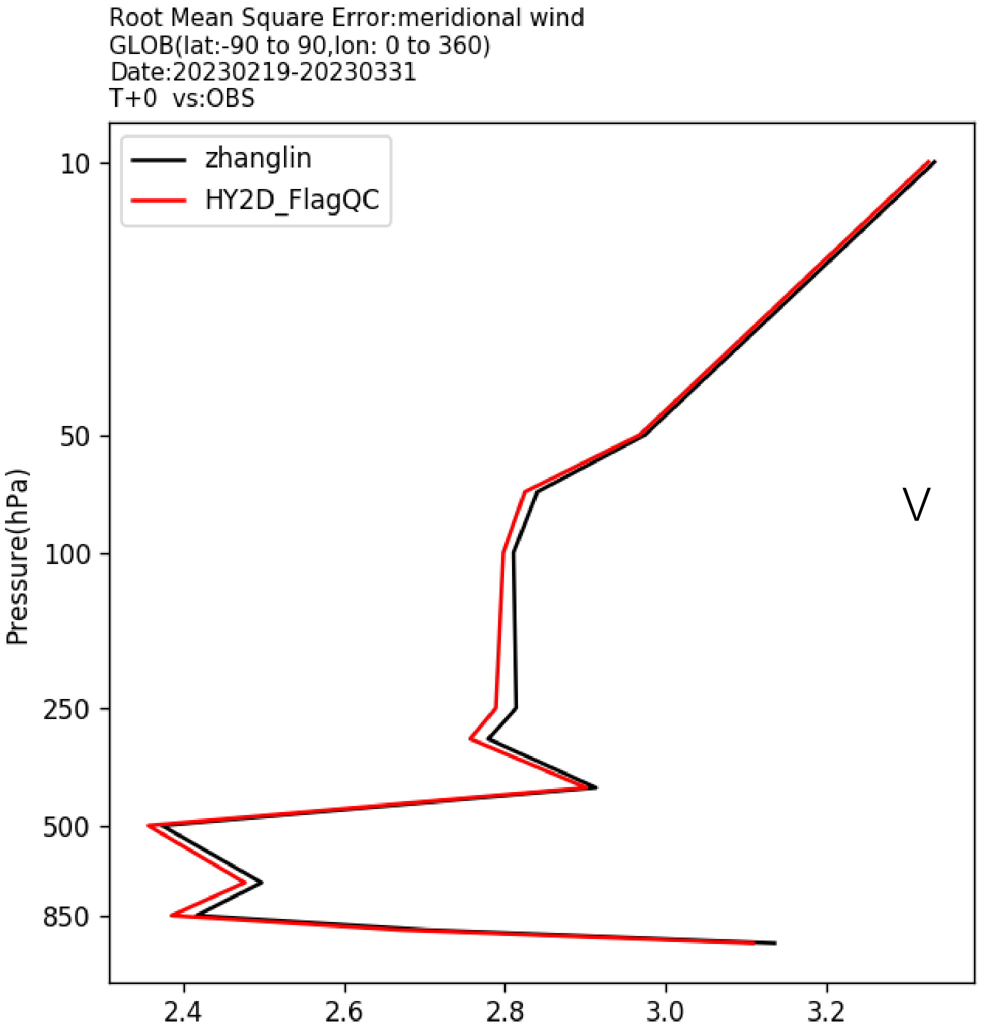
- **Assimilation of HSCAT-B wind can significantly reduce the tropospheric forecast errors of GRAPES_GFS, greatly improving the forecast skill.**
- The comparison between HSCAT_EXP and CTRL shows that the RMSE of wind in the lower levels (below 600 hPa) decreases significantly in all three regions after assimilating the HSCAT-B OSW data, especially in the tropics and southern hemisphere.
- The improvement in the geopotential height field is qualitatively similar to the wind field, as the geostrophic component is physically related to the wind.
- However, the RMSE of temperature demonstrates little change in the two experiments.

Wang, J. C., et.al , 2023: Assimilation of ocean surface wind data by the HY-2B Satellite in GRAPES: Impacts on the analyses and forecasts. *Adv. Atmos. Sci., 44-61.*

2.1 Assimilation Experiment of HSCAT winds in CMA-GFS

After assimilation of HSCAT-D winds, the RMSE of zonal and meridional forecast wind are reduced at an average reduction ratio of about 2%



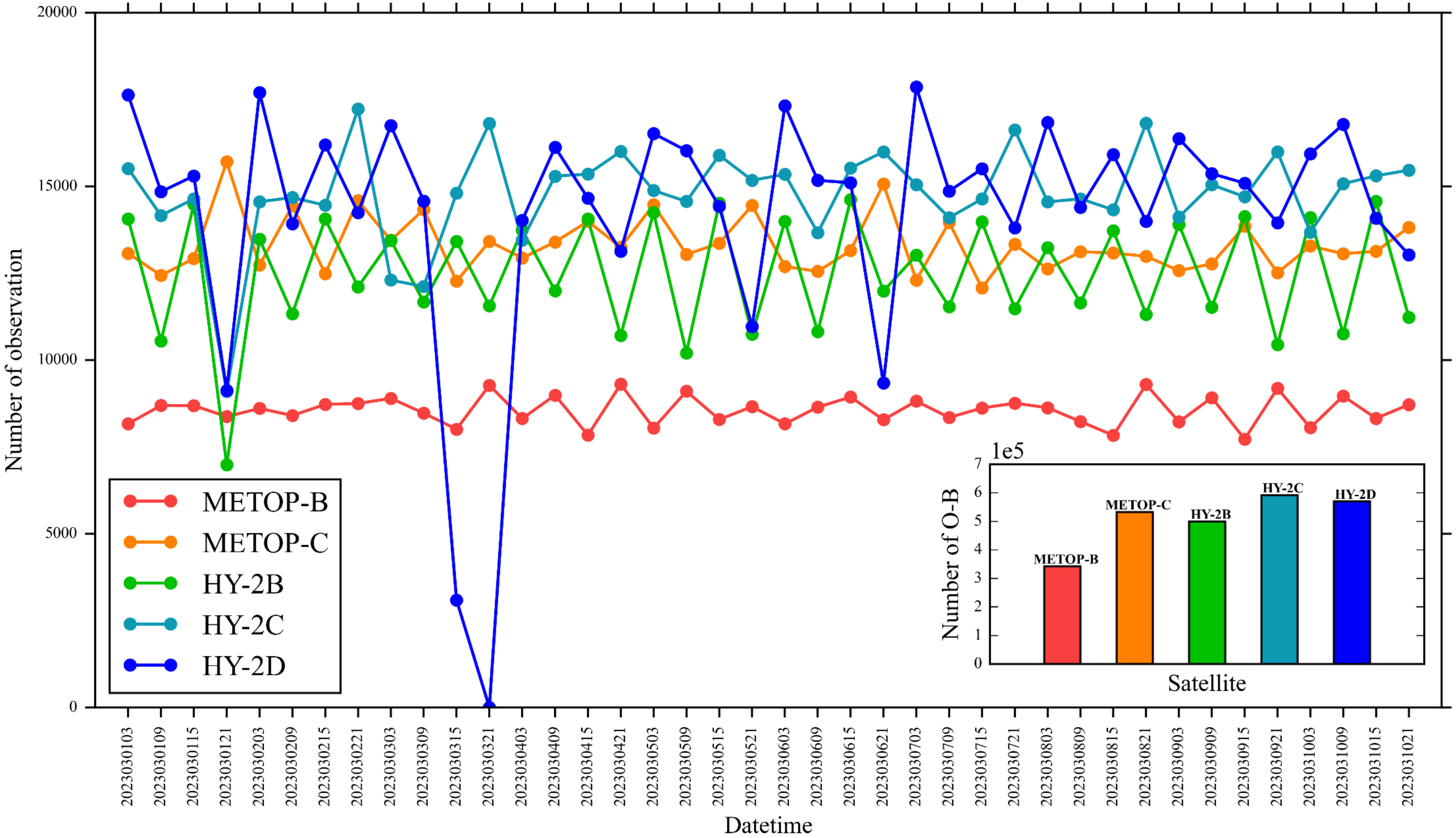


Han Wei, Assimilation of HSCAT wind data within the 4DVAR System at CMA-GFS, Technical Report ,Beijing, 2023

2.1 Assimilation Experiment of HSCAT winds in CMA-GFS

Total population of the scatterometer winds assimilated in **CMA-GFS during** 1 Mar 2023 to 10 Mar 2023

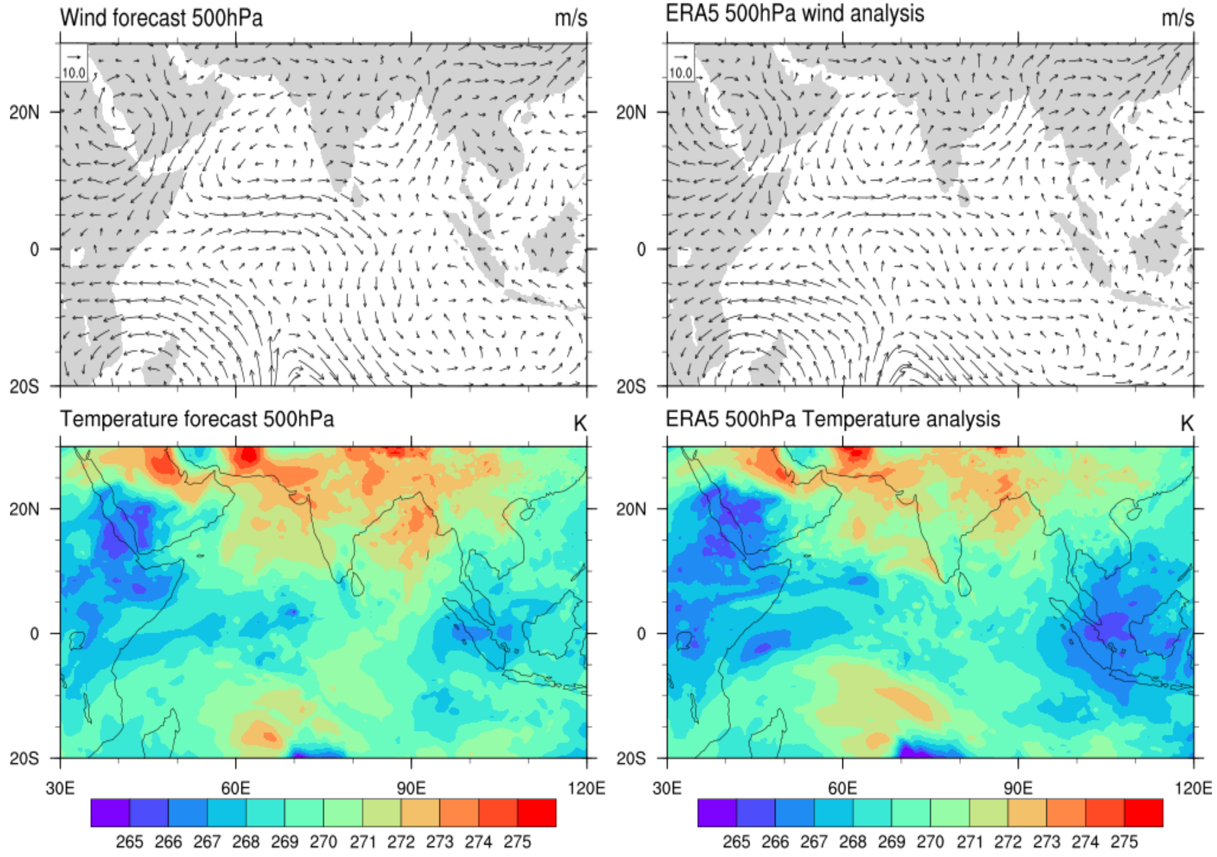
The HY-2B/C/D scatterometer provides about 180,000 wind observations per day.
The proportion of HSCAT winds in all data assimilated in **CMA-GFS** is 66%. [4.5/(2.2+4.5)]



Han Wei, Assimilation of HSCAT wind data within the 4DVAR System at CMA-GFS, Technical Report ,Beijing, 2023

2.2 Assimilation Experiment of HSCAT winds in NMEFC's NWP System

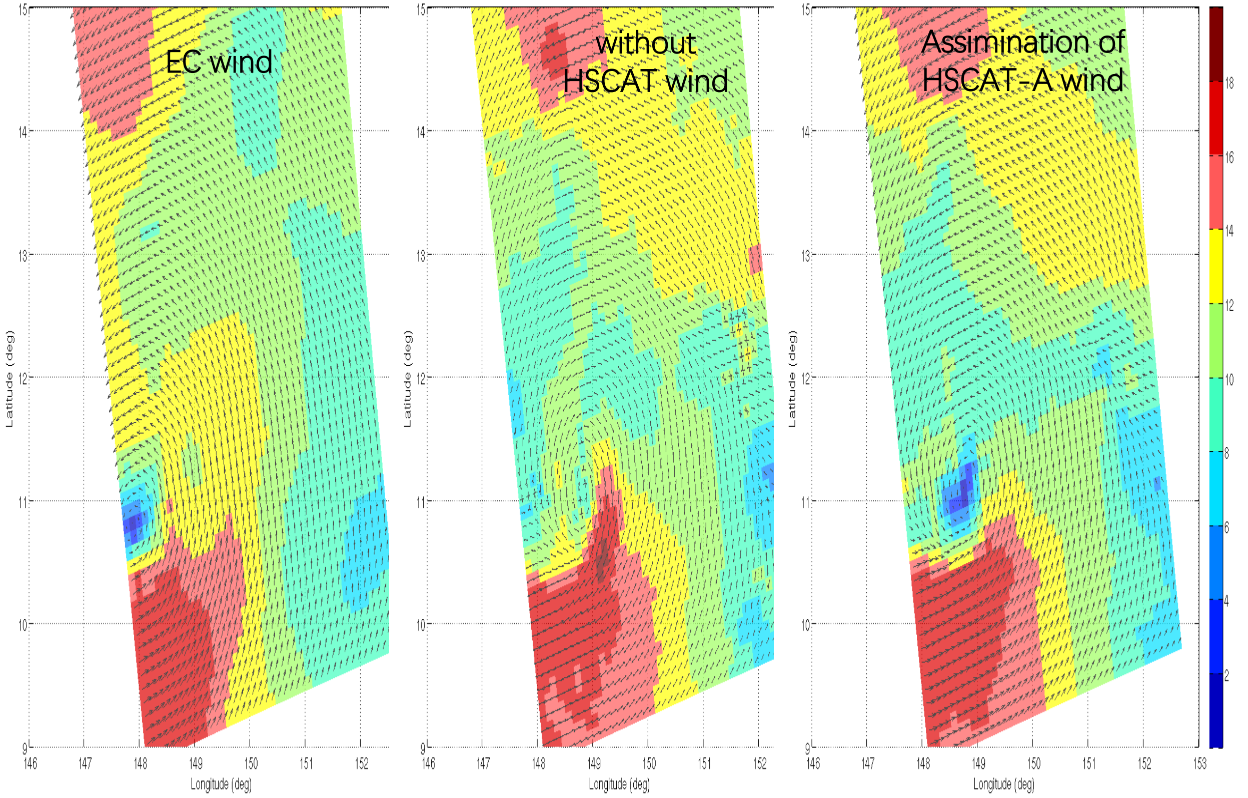
24-hour forecast global wind and temperature at 500hPa after 2 consecutive days of cyclic assimilation of HSCAT-B winds



NMEFC's NWP System ERA5

Assimilation Experiment of HSCAT-A winds

NMEFC's NWP System

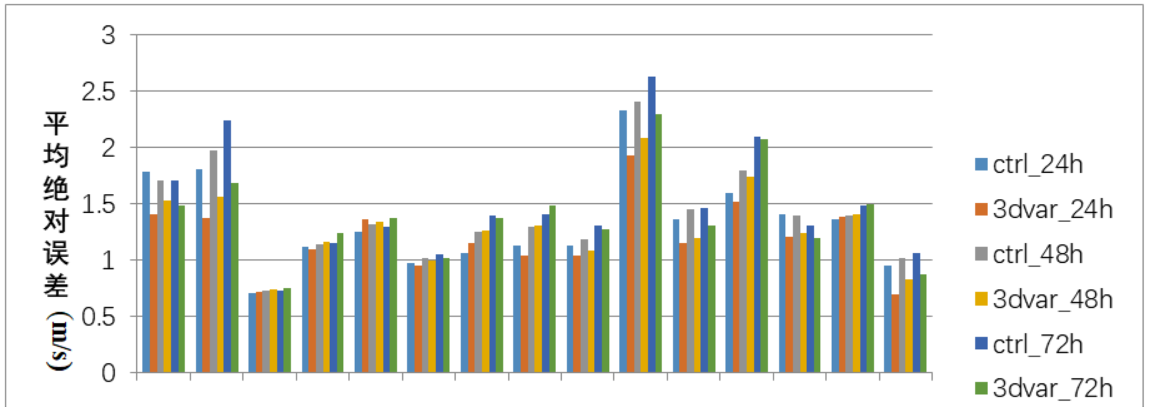


After assimilation of HSCAT-B winds, the pattern of 24-hour forecast global wind and temperature at 500hPa is more consistence with ERA5 result

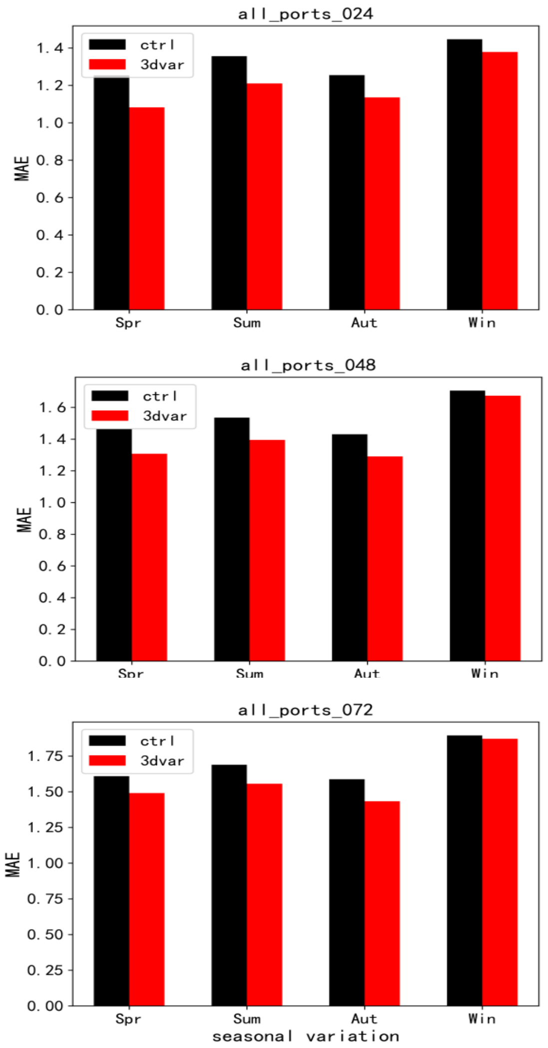
After assimilation of HSCAT-A winds, the location of typhoon center and pattern of SSW is more consistence with EC wind

2.2 Assimilation Experiment of HSCAT winds in NMEFC's NWP System

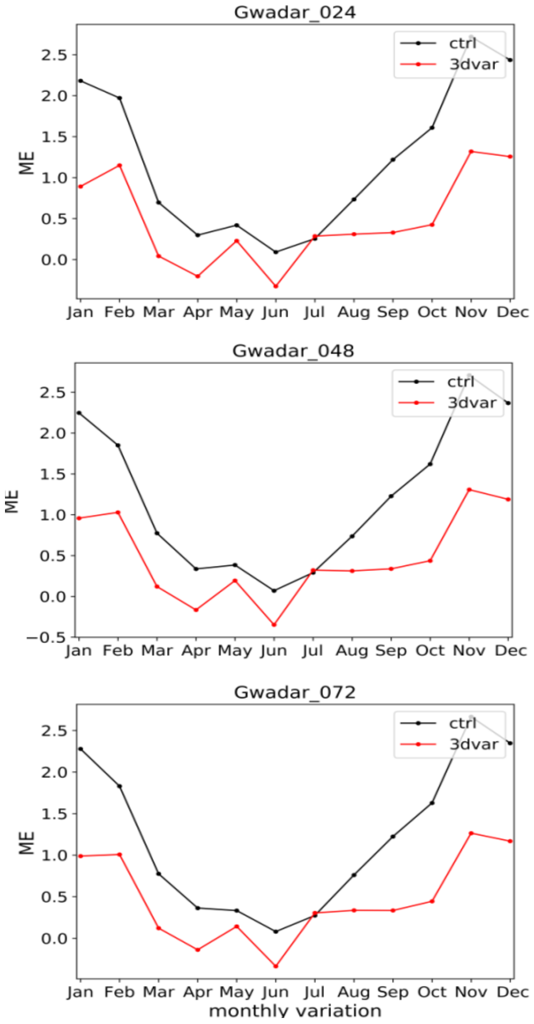
- ◆From Jan 2019 to Jun 2021
- ◆without assimilation (ctrl) vs. assimilation of HSCAT and CSCAT winds (3dvar)
- ◆Validation with in-situ winds at 15 ports



After assimilation, the average absolute error of forecasts for 24, 48, and 72 hours decreased by 9.63%, 7.51%, and 6.41%, respectively



Seasonal variation of average absolute error of SSWS



Monthly variation of average error of SSWS

The 24-hour forecast results showed a MAE of 1.33m/s for the ctrl group and 1.20m/s for the assimilated forecast (3dvar), an improvement of 9.63%.
The 48 hour forecast results showed a MAE of 1.4m/s for the ctrl group and 1.30m/s for the 3dvar group, an improvement of 7.51%.
The 72 hour forecast results showed a MAE of 1.49m/s for the ctrl group and 1.39m/s for the 3dvar group, an improvement of 6.41%.

2.3 Assimilation Experiment of HSCAT-B winds in ECMWF

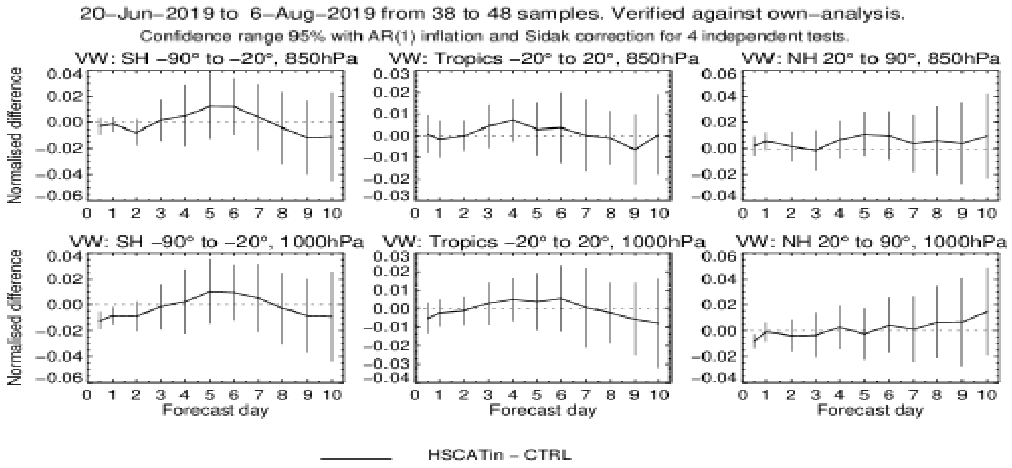
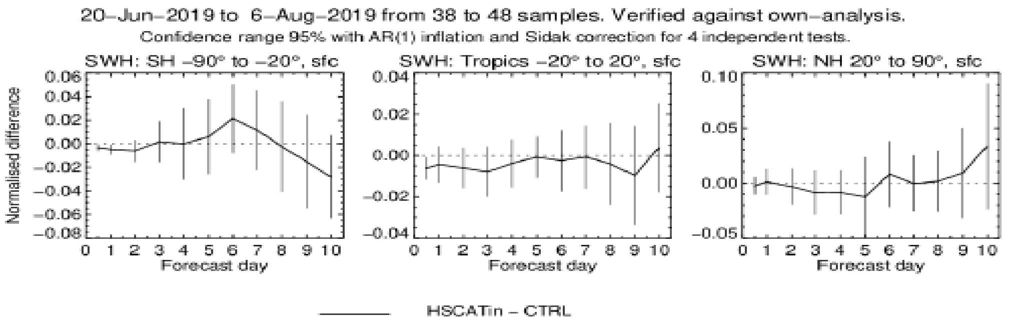


Figure 11: Normalized impact on forecast of vector wind RMS difference with the own analysis with significance (vertical bar). When the RMS difference is negative HSCATin has a better forecast than CTRL.

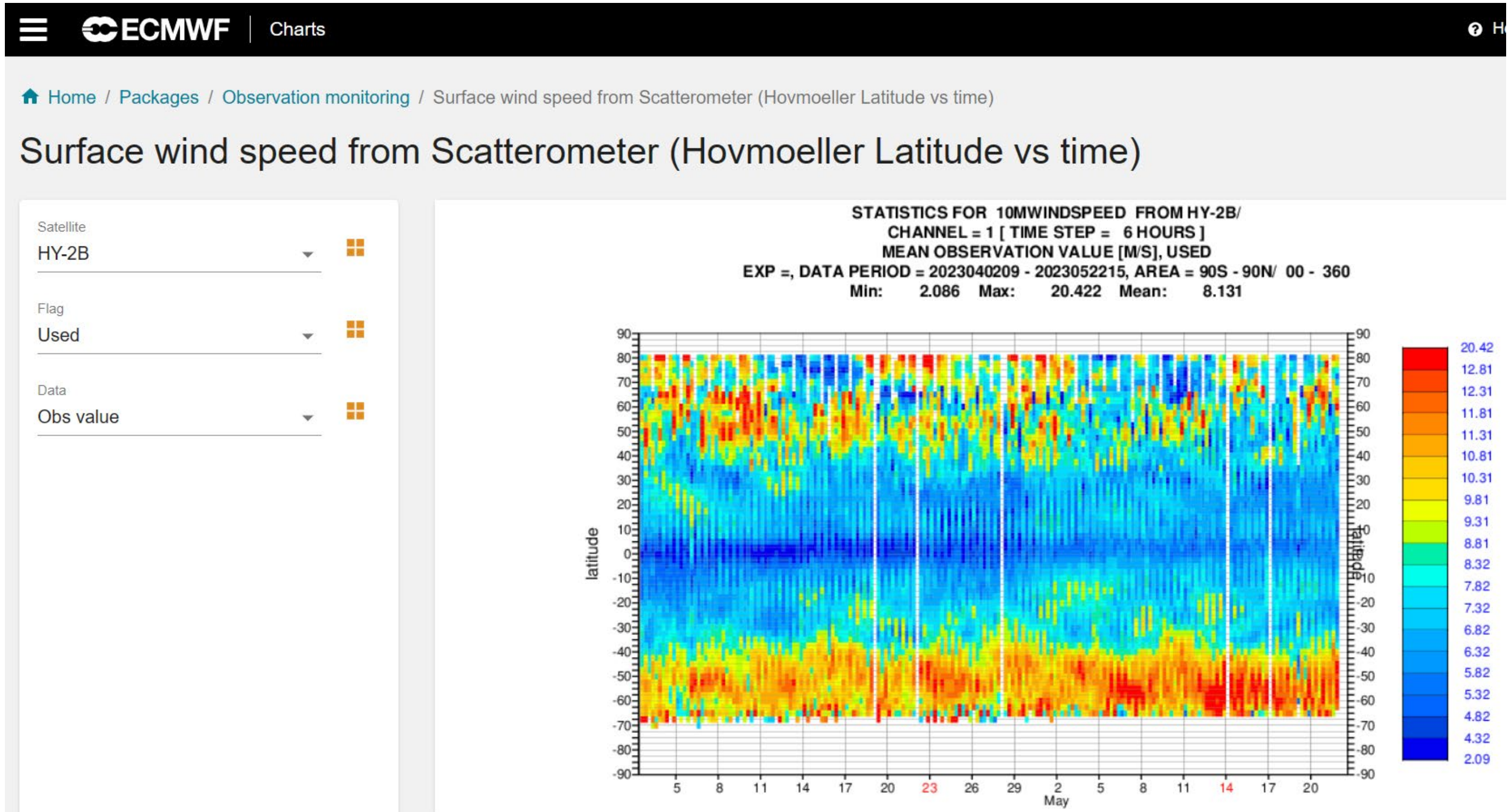


The impact on the vector of assimilating HSCAT seems to be slightly positive in the short range, but is overall neutral so far.
The impact on the significant wave height is overall neutral with a sign of positive impact in the Tropics.
The assessment based on a longer period would help and will be reported later on.

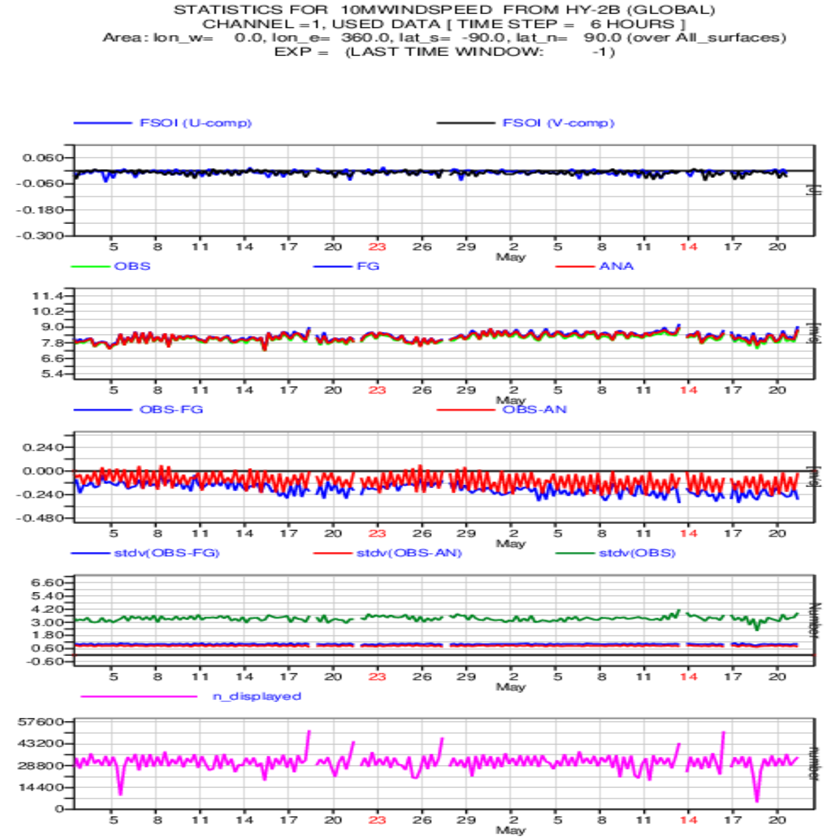
同化HSCAT海面风场数据对短期海面风场与有效波高同化为正效应，对中长期影响为中性效应。
后续ECMWF将基于更长时间序列数据对HSCAT数据继续进行评估。

Ad Stoffelen, et.al. International Research and Development Collaboration results for the Global Application of the Chinese HY-2B Scatterometer. 2019

2.3 Operational Monitoring of HSCAT-B Winds in ECMWF



source: https://charts.ecmwf.int/catalogue/packages/obstat/products/10mwindspeed_metop_hov_0001_plot_o_hov_metop?Data=Obs%20value&Flag=Used&Satellite=HY-2B



Operational Monitoring of HSCAT-B winds in ECMWF
Time series of global averages

2.4 Assimilation Experiment of HSCAT-B winds in Météo-France' NWP system

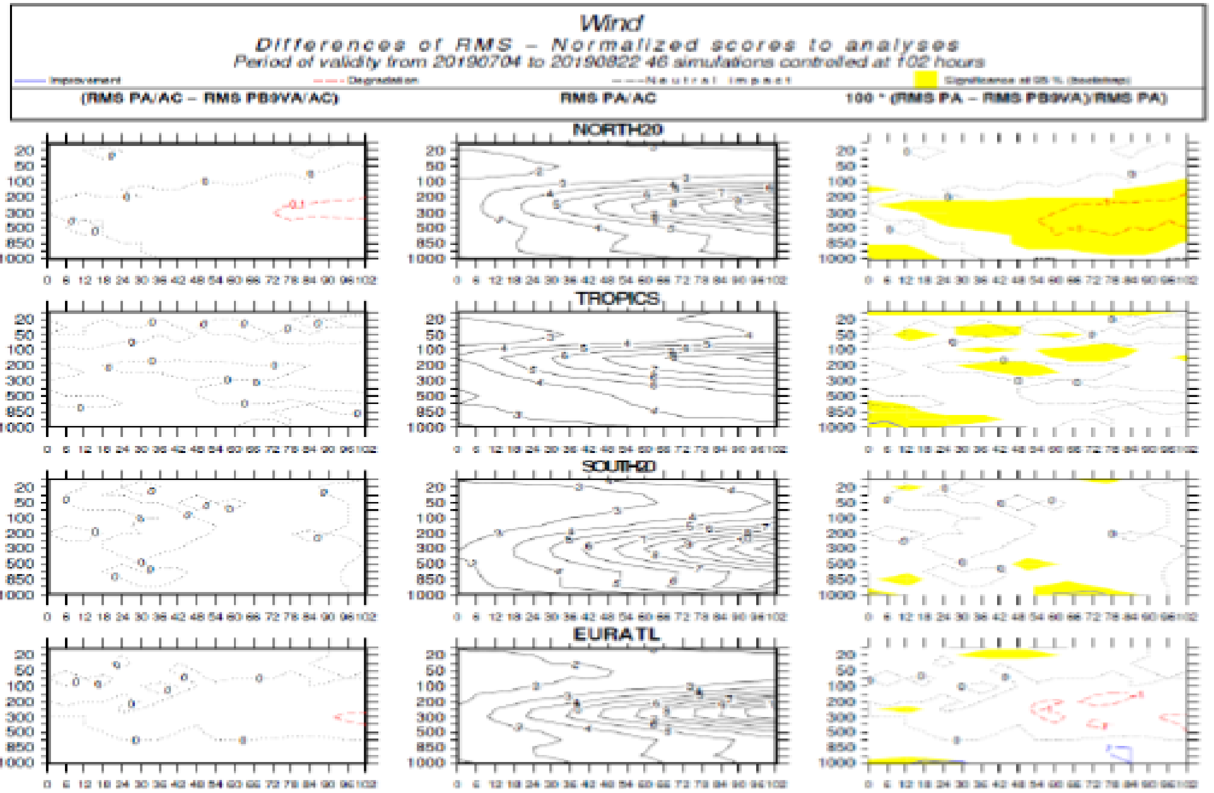


Figure 28 : Forecast scores on the wind vector, verified against the ECMWF analysis, in function of forecast range (hours) and the vertical (hPa) and on different domains (top to bottom). From left to right, RMS difference between reference and test, reference RMS score and difference between reference and test normalized by the reference score (%). RMS score for reference (middle), one isoline every 1 m s^{-1}. For the differences panel (left and right), blue solid lines mean a forecast improvement in the test, the red dashed line a degradation, dotted lines a neutral impact, an isoline every 0.1 m s^{-1} (left), every 1 % (right).

We may see that the HY-2B impact is relatively low, but rather significantly positive in the first forecast ranges and near the surface, until 1% of improvement (blue solid line every percent, significant at 95% if yellow shading).
We have also a significant improvement in the southern hemisphere at surface level around the day 3 of forecast
. However the forecast score is degraded in the northern hemisphere (red dashed lines), in the mid-troposphere (around 400 hPa), this degradation increasing with the forecast range (until 1.5% at day 4)
. The scores by sub-domain indicates that this poor performance comes mainly from the North-America zone, and may be also seen on the other model variables, and independently of chosen control (ECMWF analysis, own analysis, in a lesser measure with radiosondes), meaning a robust signal, whereas the impact over Europe is rather positive but less significant (not shown). The score card offers a synthetic view of HY-2B impact on the forecasts of the main model variables until 4 days, at selected levels, on different domains and with respect to radiosondes, ECMWF analysis, or SYNOP over Europe, as control and confirms the previous statement. This degradation, and mainly when the ECMWF analysis is used as control, needs to be investigate. Different ways are possible at this stage:

HY-2B散射计风向比ASCAT-B散射计与OSCAT散射计更为接近背景场，HY-2B散射计风速与ASCAT-B散射计与OSCAT散射计偏差与均方根误差相当。同化HY-2B海面风矢量产品结果表明，短期预报结果为正效应的比率极为显著，95%的预报结果为正效应，提升效果约为1%。对3天预报结果在南半球同样有非常显著的提升。

Ad Stoffelen, et.al. International Research and Development Collaboration results for the Global Application of the Chinese HY-2B Scatterometer. 2019

2.5 Assimilation Experiment of HSCAT-B winds in Met Office of the United Kingdom's NWP system

EUMETSAT OSI SAF OCEAN AND SEA ICE

International Research and Development Collaboration for the Global Near-Real-Time Application of the HY-2B Scatterometer

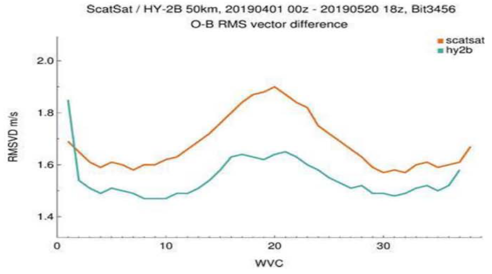


Figure 34 : Observation minus UK Met Office global model background vector RMS difference for HY-2B and ScatSat winds as a function of across-track WVC number.

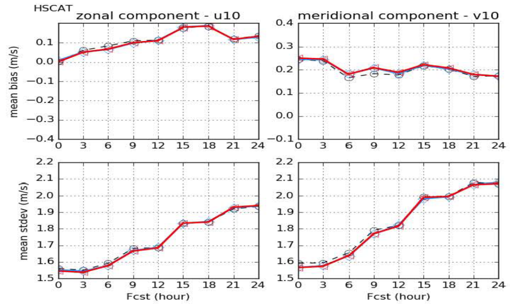


Figure 35 : IPMA regional forecast skill scores for 10-m model winds. Observation minus forecast (o-f) scores for zonal (u, left) and meridional (v, right) component. o-f bias (top) and standard deviation (bottom). Data assimilation experiments: only conventional observations (dash black), conventional observations and ASCAT-A+ASCAT-B with data thinning at 50 km (solid blue), conventional observations and ASCAT-A+ASCAT-B with no data thinning (solid red). Observations for verification include 10-m wind from HSCAT (HY-2A).

Table 7 : Observation minus UK Met Office global model background difference for HY-2B and ScatSat winds. Data are filtered for the KNMI QC, land, ice, and data monitoring flags. Time period is 20190401 – 20190520.

Scatterometer	Number	Mean Speed (ms^{-1})	SD Speed (ms^{-1})	SD Direction (deg.)	RMS Vector (ms^{-1})
ScatSat	4,725,673	+0.06	1.04	14.7	1.68
HY-2B	2,232,955	+0.03	0.97	13.5	1.54

The UK Met Office compared the HSCAT winds with short-range forecasts of the global model and found similar excellent comparison as reported by Météo France. As reported by Météo France, few winds are available f`or HSCAT WVC 1 and no winds for WVC 38. Figure 34 shows that for all other WVCs, the HSCAT comparison to the Met Office background is 5-20% better than that of ScatSat.

The positive data quality characteristics warrant a data assimilation experiment with HY-2B, but while at the moment the first preliminary impacts are looking rather neutral. Further experiments are ongoing and will be reported in due time.

英国气象局将HSCAT与其短期天气预报结果进行了比对，比对结果与法国气象局得到的结果类似。与英国气象中心短期天气预报结果比对结果表明，HSCAT 散射计结果优于OSCAT2散射计5-20%。

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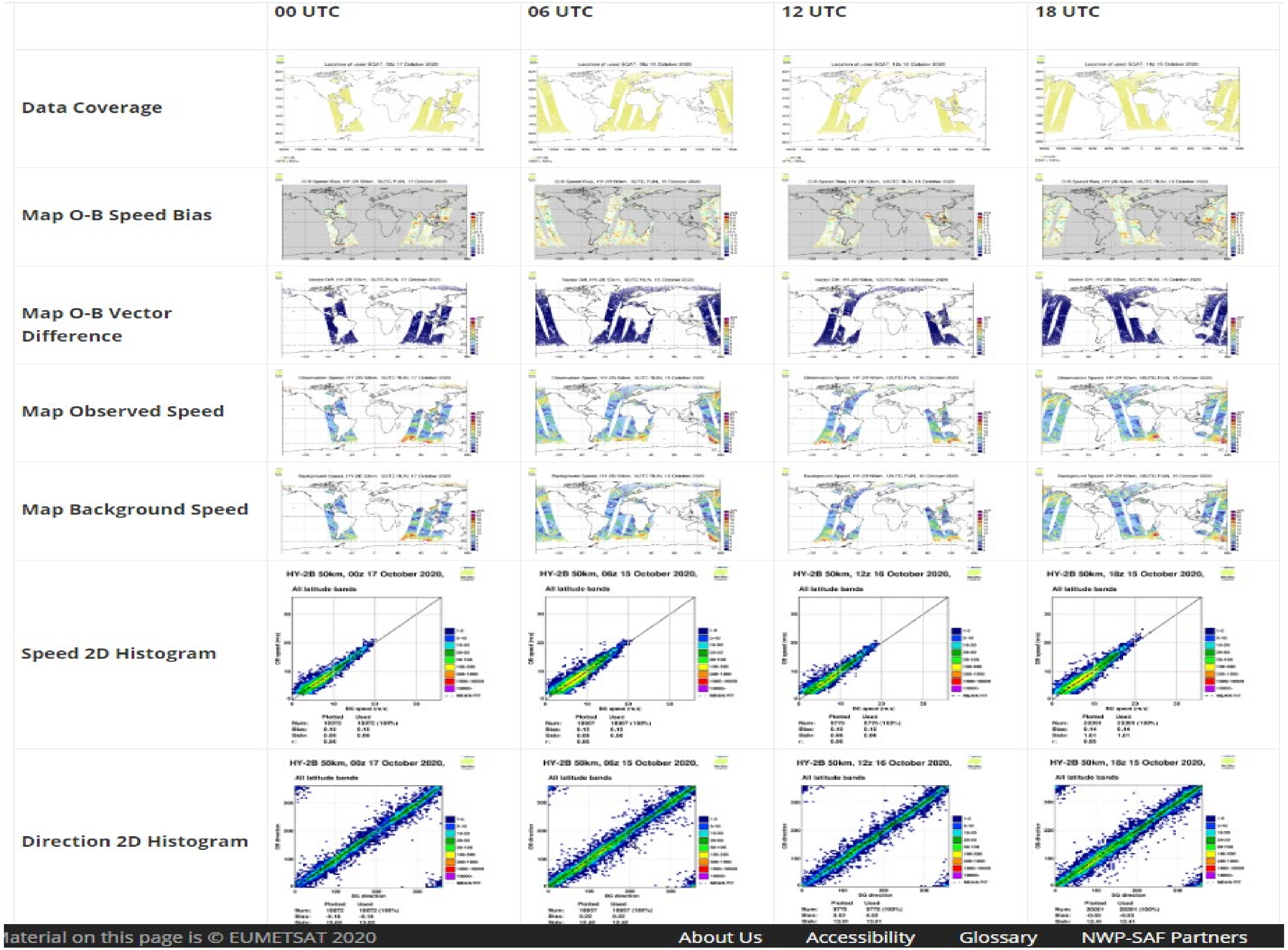
2.5 Operational Monitoring of HSCAT-B Winds in Met Office of the United Kingdom



2.6 Assimilation Experiment of HSCAT-B winds in German Weather Service (DWD)

International Research and Development Collaboration for the Global Near-Real-Time Application of the HY-2B Scatterometer

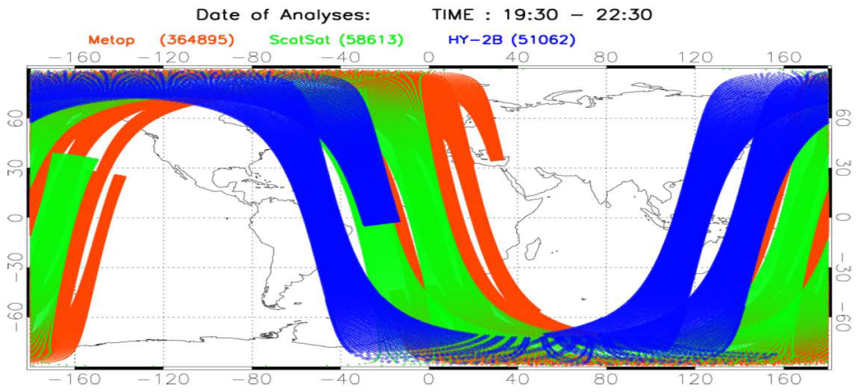


Figure 30 : DWD scatterometer winds coverage of ASCAT-A/B/C (red), ScatSat (green) and HSCAT (blue) with the number of observations in parenthesis.

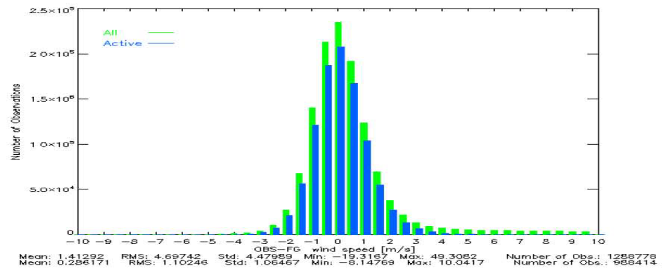


Figure 31 : Observation minus DWD FG difference PDF before (green) and after screening (blue) 10-30 Sept. 2019.

International Research and Development Collaboration for the Global Near-Real-Time Application of the HY-2B Scatterometer

The HSCAT coverage is complementary to the wind coverage by all ASCATs and ScatSat, as depicted in Figure 30. The HSCAT and FG wind departures (Figure 31) look globally very similar for all accepted winds to the distributions of the mentioned other scatterometers (not shown), only the global error SD for ScatSat wind speed is 1.17 m s^{-1} rather than 1.10 m s^{-1} for the other scatterometers.

Table 6 : Statistical key parameters for all scatterometers monitored at DWD. First number: all data, second number: data after FG check and geographical filtering (ScatSat).

	Bias (m s^{-1})	RMS (m s^{-1})	SD	Max. (m s^{-1})	Min. (m s^{-1})	Number
HY-2B	1.41/0.29	4.70/1.10	4.48/1.06	49.31/10.04	-19.32/-8.15	1288,776/988,414
Metop-A	0.92/0.36	2.72/1.15	2.56/1.09	47.32/9.59	-19.30/-7.35	752,395/576,590
Metop-B	0.77/0.29	2.50/1.11	2.38/1.07	46.04/10.76	-19.69/-7.50	979,196/758,311
Metop-C	0.67/0.27	2.38/1.11	2.29/1.08	44.15/9.76	-19.82/-9.06	873,290/699,037
ScatSat	1.24/0.22	4.59/1.17	4.41/1.15	49.57/9.55	-21.19/-8.49	1940,640/1418,238

Table 6 shows that the C-Band scatterometers have smaller bias/RMS/SD than Ku-Band scatterometers for all data. However, after the FG check and ancillary filtering before active data assimilation, all scatterometers have similar bias/RMS/SD. The number of Ku-Band observation is larger than the number of C-Band scatterometer observations, due to the wider swath. Note that the DWD rejects about 20-25% of the scatterometer winds before data assimilation.

海洋二号卫星微波散射计对目前运行的ASCAT系列微波散射计以及印度OSCAT2散射计具有很好的互补性，其风速均方根误差与ASCAT均为1.10m/s，优于同期印度OSCAT2散射计（均方根误差1.17m/s）。

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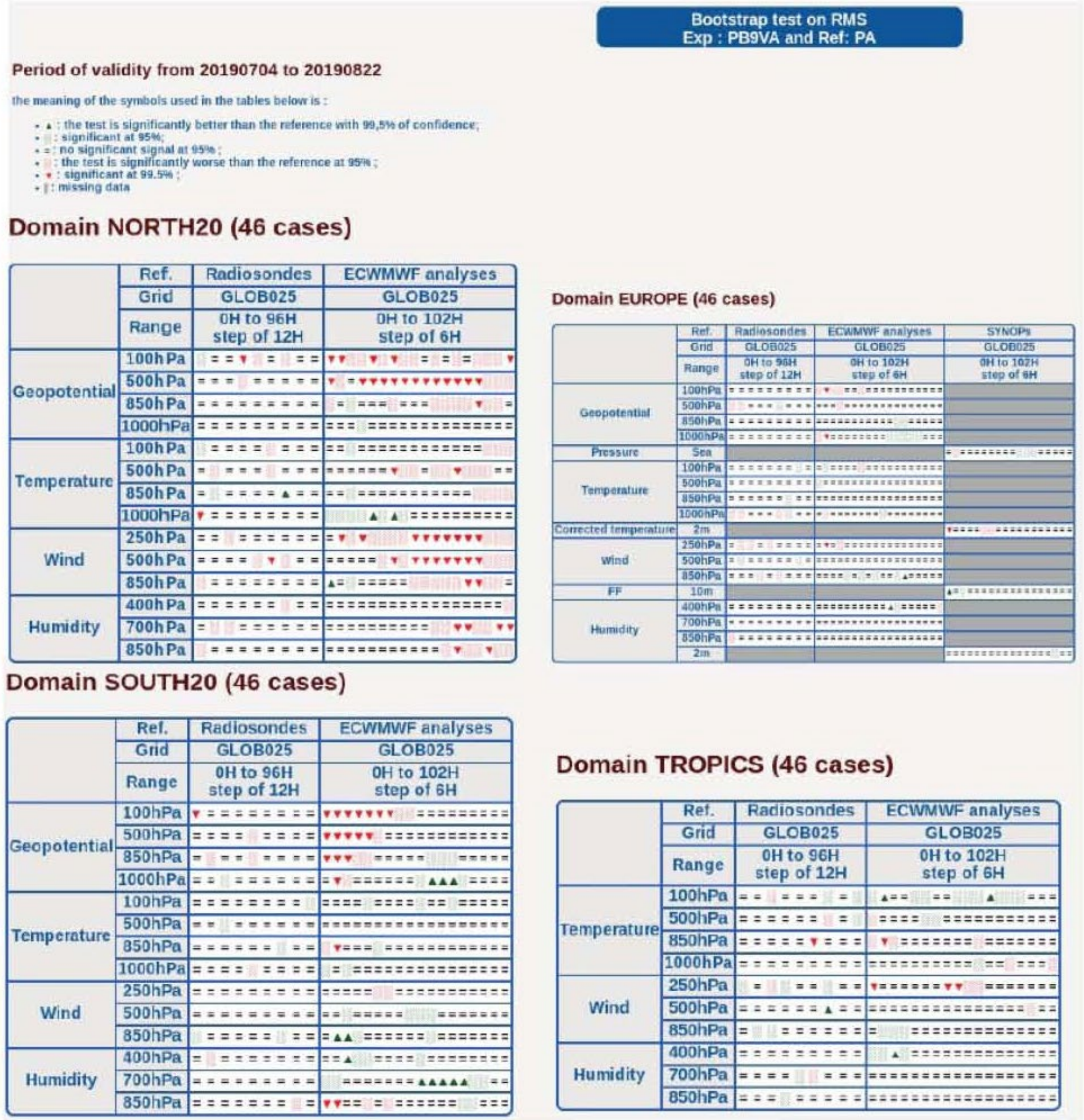
2.6 Assimilation Experiment of HSCAT winds in German Weather Service (DWD)



The FG statistics are compared to similar results for scatterometer data that are already used operationally at DWD, i.e., Metop-A/B/C and ScatSat. Based on this a preliminary wind vector component error of 2 m s-1 has been assigned to the HSCAT winds. In the OSEs the data assimilation system of the DWD is used.

The HSCAT bias is smallest in the northern hemisphere, but larger in the southern hemisphere. The negative ScatSat biases in the southern hemisphere high latitudes is caused by the neglect of SST-dependent effects in the Ku-band GMF implemented operationally for ScatSat at KNMI.
Figure 33 shows the very similar geographical distribution of the SD of the FG departures between the different scatterometers. Large SDs are generally found near fast moist convection processes, which are not well resolved by NWP models. While ASCAT is much less sensitive to rain clouds, moist convection appears more pronounced due to the lack of spatial filtering in the 2DVAR ambiguity removal.
The errors are smallest for Metop-C and largest for ScatSat. HY-2B appears in between.
Based on these good monitoring results for the HY-2B scatterometer, the forecast impact of HY-2B is actually being tested in a data assimilation and forecast experiment at DWD.

Ad Stoffelen, et.al. International Research and Development Collaboration results for the Global Application of the Chinese HY-2B Scatterometer. 2019

2.7 Assimilation Experiment of HSCAT-B/C winds in JMA's NWP System

Assimilation experiment of HSCAT winds in JMA's NWP Systems

IOKA Yusuke[1]

1: Office of Numerical Prediction Modeling, Japan Meteorological Agency

1. Introduction

- Ocean vector wind products retrieved from scatteorometer observations provide essential information on sea surface wind for numerical weather prediction system. Assimilation of ocean vector products improve analysis field of not only surface wind but also other elements such as surface pressure[1].
- The observing system experiment (OSE) technique is used to assess the impact of adding the wind products from HSCAT onboard HY-2B and HY-2C, which have been operationally disseminated since November 2021 from the Ocean and Sea Ice Satellite Application Facility (OSI-SAF)[2].
- The OSEs use the latest global and mesoscale assimilation system of JMA.

2. Overview of Pre-Analysis Procedure

- Flag check — Check provided flags (rain, land/sea, sea ice etc.) and reject flagged data
- Gross error check — Reject large |O-B| data
- Group QC — Reject large |O-B| averaged by an area including similar wind vector observation. Prevent over rejection in and around severe weather condition
- Ambiguity removal — Select the closest wind to JMA's forecast by median filter after nudging
- Thinning — 1.0 deg x 1.0 deg box (Mesoscale model: 0.5 deg x 0.5 deg box). Eliminate spatial observation error correlation. Reduce calculation cost. Overlapping data rejection

Fig.1 Pre-Analysis Procedure for Scatterometer Winds on JMA's NWP Systems

Pre-processing procedure applied to HSCAT wind products in this is same as the operational pre-processing system for ASCAT winds. This preprocessing system is also applied to HSCAT wind products in this experiment.

3. Specification of the experiment

- Control experiment (CNTL)
  - Assimilate Metop-B,C/ASCAT winds
  - Same as of Mar 2023 global and mesoscale assimilation system of JMA [3]
- TEST
  - Assimilate Metop-B,C/ASCAT winds and HY-2B,C/HSCAT winds
  - Preprocessing system is unchanged from CNTL.

- Verification period(Global model)
  - 2022Winter : From 1 Jan 2022 to 25 Jan 2022
  - 2022Summer : From 1 Aug 2022 to 31 Aug 2022
- Verification period(Mesoscale model)
  - 2022Winter : From 1 Jan 2022 to 25 Jan 2022
  - 2022Summer : From 1 Jul 2022 to 31 Jul 2022

Summary

- JMA has investigated the data assimilation of HY-2B and -2C wind product on the operational global and mesoscale NWP systems.
- Result of OSEs show that assimilated data numbers of scatteorometer increased twofold by using HSCAT wind products.
- Increase in assimilated data leads improvement of first-guess field of wind, sea surface pressure and temperature.
- By assimilating HSCAT winds, forecast skills in the global and mesoscale model are also improved.

4. Result of OSEs

4.1 Data coverage

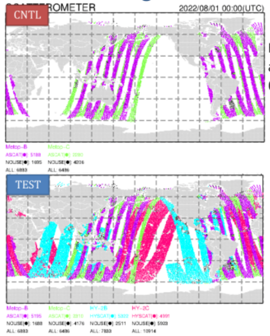
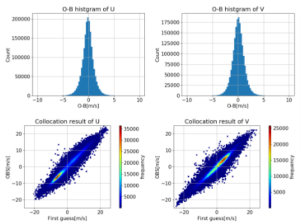


Fig 2. Data coverage of assimilated scatteorometer data on 00UTC in August 1st, 2022

The distribution of the assimilated data. HSCAT wind products (cyan and pink) compensate the coverage of the Indian Ocean and the Pacific Ocean in the TEST. As a result, the number of assimilated scatteorometer data increased twofold from CNTL.

4.2 Data quality and improvement on analysis field



	U	V
Data num	1858697	
Bias (m/s)	-0.130 (ASCAT:-0.129)	-0.069 (ASCAT:0.129)
STDV (m/s)	1.159 (ASCAT:1.254)	1.198 (ASCAT:1.363)

Fig.3 O-B histogram and collocation result of HSCAT winds on global analysis (Summer experiment)

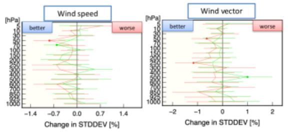


Fig.4 Change in normalized standard deviation (STDDEV) of the first-guess departure $(STDDEV_{TEST} - STDDEV_{CNTL})/STDDEV_{CNTL}$ for radiosonde wind observations(Red: Summer, Green:Winter). Error bars represent 95% confidence intervals, and dots are statistically significant.

Regarding the data quality, HSCAT wind product is consistent with the model (Fig.3), and bias and standard deviation (STDV) are similar to ASCAT winds.

By assimilating HSCAT winds, accuracy of first-guess field of wind (Fig. 4), sea surface pressure and temperature (Not Shown) on TEST becomes better than CNTL.

4.3 Forecast score of global model

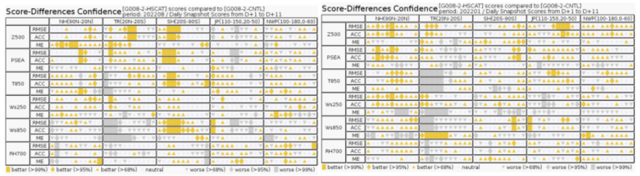


Fig 5. Forecast score difference of summer (left) and winter (right) experiments. Yellow sign means the improvement of forecast score.

Positive impacts are also found on forecast skills of sea surface pressure, temperature and wind at 850hPa and geopotential height at 500hPa (Fig. 5).
PSEA is improved in line with the improvement of the surface wind.
These improvements are pronounced in the Southern Hemisphere, which is in line with the effect of HSCAT data to extend the observation coverage over the sea surface.

4.4 Forecast score of mesoscale model

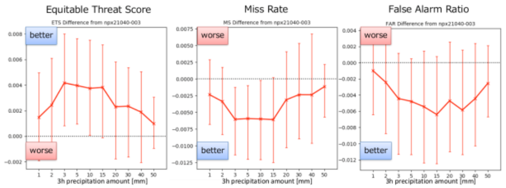


Fig.6 Forecast score difference of TEST-CNTL(Mesoscale model) on 3h precipitation forecast. Scores are classified by 3h precipitation amount.

In the experiment of mesoscale model, forecast score of precipitation is mainly improved (Fig. 6).
The result is likely to be involved with the improvement of surface wind vector field of mesoscale analysis and lateral boundary condition from outer global model.

Reference

[1] Isaksen, L. and Janssen, P. A., 2004: Impact of ERS Scatterometer Winds in ECMWF's Assimilation System. Q. J. R. Meteoro. Soc 130(600), 1794-1814 DOI: 10.1256/qj.03.110
[2] OSI SAF, 2021: HSCAT Winds at 25 km Swath Grid - Hai Yang 2B, EUMETSAT SAF on Ocean and Sea Ice, DOI: 10.15770/EUM_SAF_OSI_NRT_2000. http://doi.org/10.15770/EUM_SAF_OSI_NRT_2000
[3] Japan Meteorological Agency, 2023: Outline of the operational numerical weather prediction at the Japan Meteorological Agency. https://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline-latest-nwp/pdf/outline2023_Contents.pdf

Outline

1. Introduction to HY-2 scatterometer mission

2. Overview of Assimilation of HSCAT Winds in NWP

3. Summary and Future Work

Summary

- ☑ The HSCAT wind is a high-accuracy observational product. The RMSE of HSCAT wind speed is less than 1.3m/s, and less than 15 ° for wind direction.
- ☑ The HY-2B/C/D scatterometer provides about 180,000 wind observations per day, making it one of the most important global SSW observations.
- ☑ HSCAT wind also shows good consistency and timeliness, making the data suitable for variational data assimilation.
- ☑ Assimilation of HSCAT wind can significantly reduce the tropospheric forecast errors of GRAPES_GFS, greatly improving the forecast skill.
- ☑ **Assimilation Experiment of HSCAT-B wind in NMEFC, ECMWF, Météo-France, Met Office of the United Kingdom, German Weather Service, JMA's NWP system mostly result in positive impact.**
- ☑ **HSCAT-B/C wind has been assimilated in CMA-GFS operationally, while HSCAT-B winds has been operational used in data assimilation in ECMWF and Met Office of the United Kingdom**

Future work

- ☑ In the near future, NSOAS will launch five Satellite which carries scatterometer,.namely, HY-2E(Ku band), ad HY-2F(Ku&C dual frequency), Next Generation Satellite of HY-2(Ku&C dual frequency), Ocean Salinity Observation Satellite(L band)， and Ocean Wind and Wave Observation Satellite(Ku band).
- ☑ For these new scatterometer data, simulation and testing work is essential before these data can be assimilated in NWP system.
- ☑ Timeliness of HSCAT winds need to be further improved
- ☑ High wind and rain contamination issues.
- ☑ Better QC method is needed, many good observations have been rejected by current QC.
- ☑ Improve stability of data receiving, processing and dissemination on ground system.
- ☑ Feedback from NWP and other users, both positive and negative, is welcome, which can help us to improve the quality of HSCAT winds.

These works need the collaboration of the whole community of payload design, satellite operation and NWP department.

谢谢

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