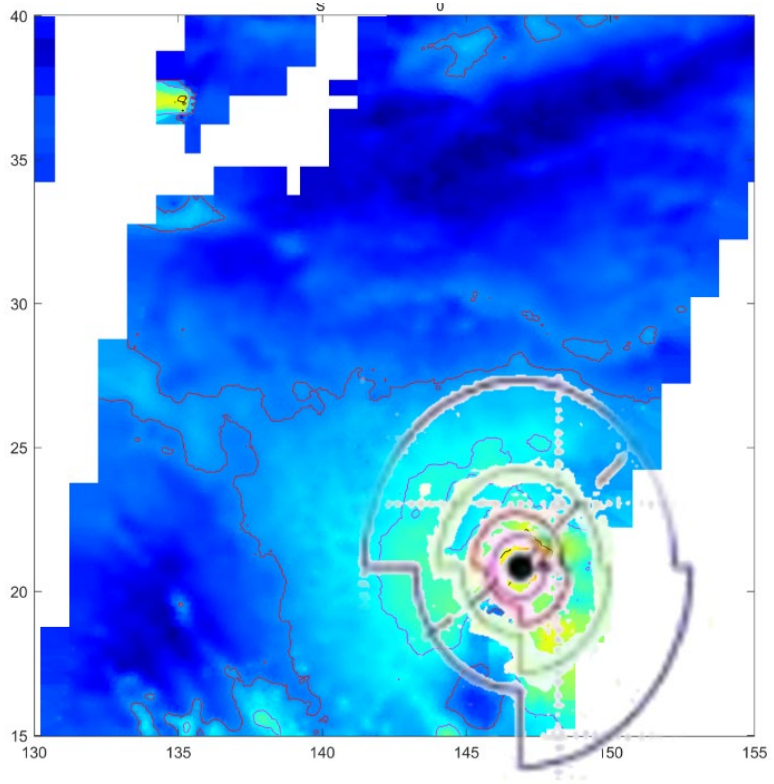
17th Online Integrated Workshop

ESCAP/WMO
Typhoon Committee



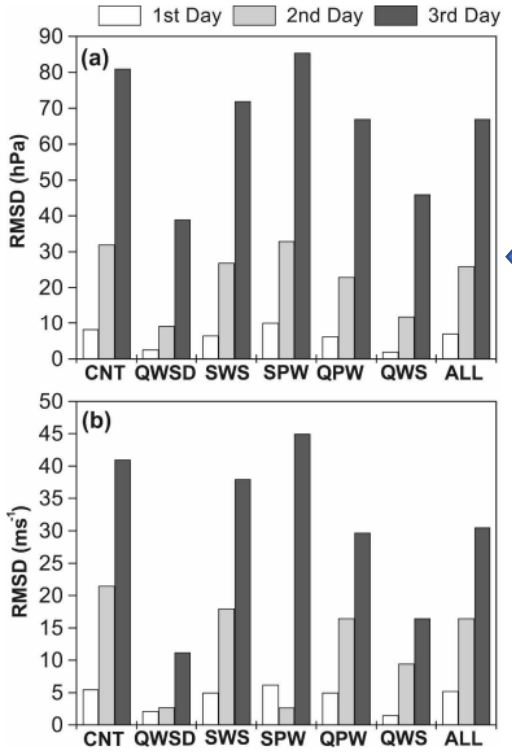
Wind Scatterometry for Tropical Cyclones: Recent Research & Applications

Xingou Xu, Ad Stoffelen, Xiaoqin Lu, Guanghua Chen

2022-11-30

中国科学院国家空间科学中心
National Space Science Center . CAS
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat
中国气象局
上海台风研究所
中国科学院大气物理研究所
Institute of Atmospheric Physics,Chinese Academy of Sciences

Wind & rains in assimilation



1. RMS difference (RMSD) of the simulated (a) MSLP the cyclone's center and (b) the low-level maximum wind speed ($m\ s^{-1}$) during the first, second, and third days of the simulation, where error is based on four samples for each day.

TABLE 1. Assimilated data for each numerical experiment.

Expt	Assimilated data
CNT	Conventional data (e.g., radiosondes, buoys, ships, and surface observations)
QWSD	Conventional and QuikSCAT wind speeds and direction
SWS	Conventional and SSM/I wind speeds
QWS	Conventional and QuikSCAT wind speeds
SPW	Conventional and SSM/I total precipitable water vapor
QPW	QuikSCAT winds and SSM/I total precipitable water vapor
ALL	Conventional, QuikSCAT winds, SSM/I TPW, and wind speeds

Wind scatterometers have been providing wind observations for decades, and are found with information of rains

Inclusion of rain rates improves Vmax in assimilation

(Jiang H. et al., 2019)

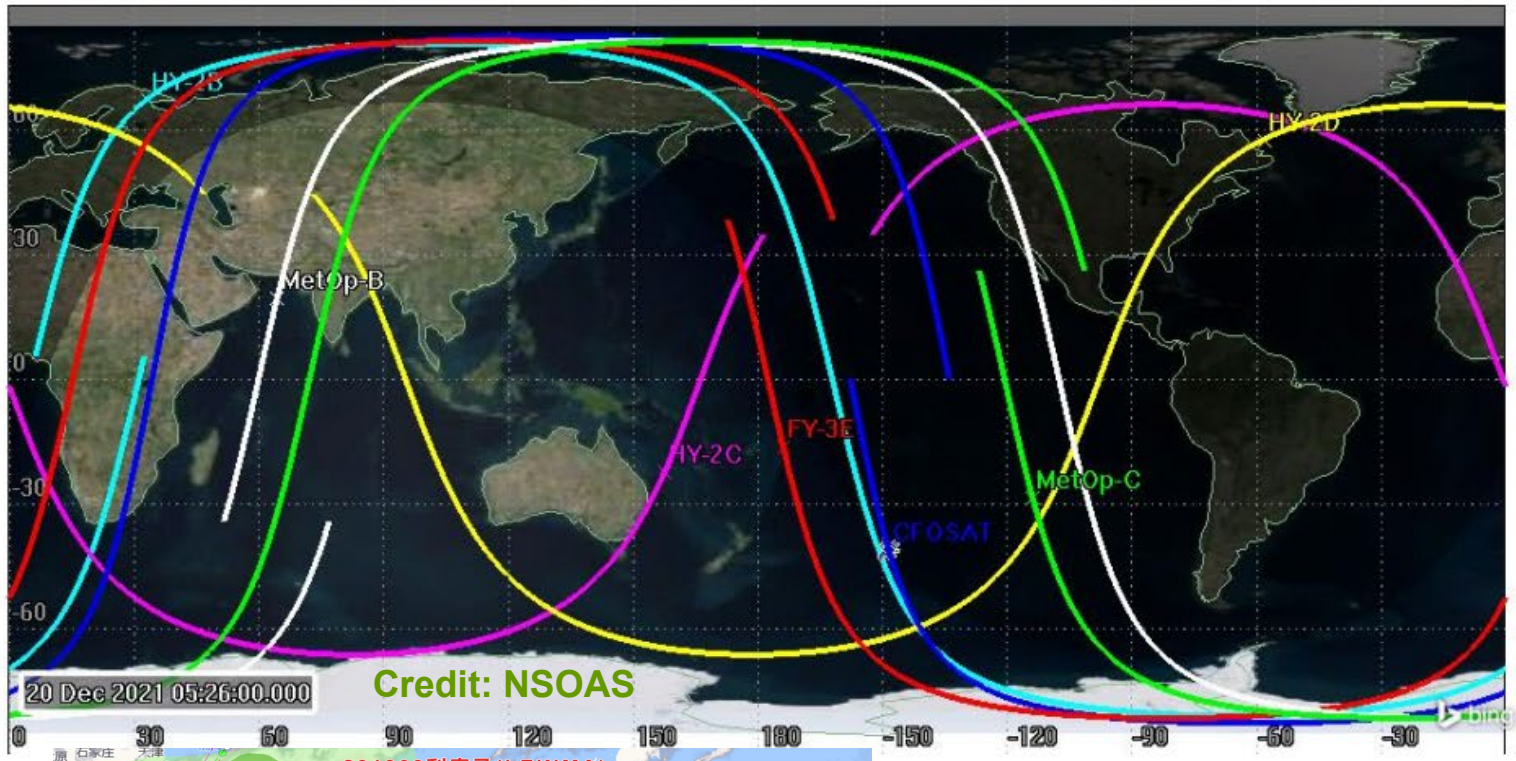
8. Bias analysis of the estimated Vmax and 6-h future Vmax vs best track values for different TC intensity groups. Positive (negative) values mean overestimation (underestimation). Unit is kt.

	85-GHz only		Rain only		Combined	
	$t = 0$ h	$t = 6$ h	$t = 0$ h	$t = 6$ h	$t = 0$ h	$t = 6$ h
ATL						
All TCs ($n = 257$)	1.73	1.89	−1.04	−0.50	−0.92	−0.34
Tropical depressions ($n = 48$)	17.11	13.47	9.46	7.05	9.17	7.26
Tropical storms ($n = 157$)	0.54	1.49	−2.09	−0.57	−2.04	−0.49
All hurricanes ($n = 49$)	−9.70	−7.03	−8.82	−7.11	−8.03	−6.69
EPA						
All TCs ($n = 237$)	1.78	1.52	0.49	0.25	0.53	0.25
Tropical depressions ($n - 110$)	9.85	8.06	6.05	4.93	5.95	4.93
Tropical storms ($n = 85$)	1.95	1.63	0.33	0.20	0.43	0.20
All hurricanes ($n = 39$)	−21.79	−18.05	−15.84	−13.59	−15.63	−13.59

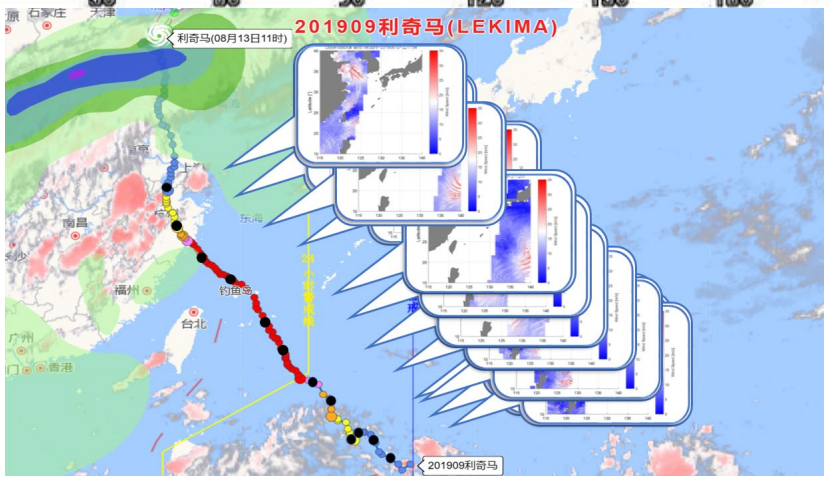
In early researches, assimilation experiments already indicated improvement in TC centre pressure and maximum wind speed predictions

(Singh, R, et al., 2008)

Space-borne scatterometers in operation



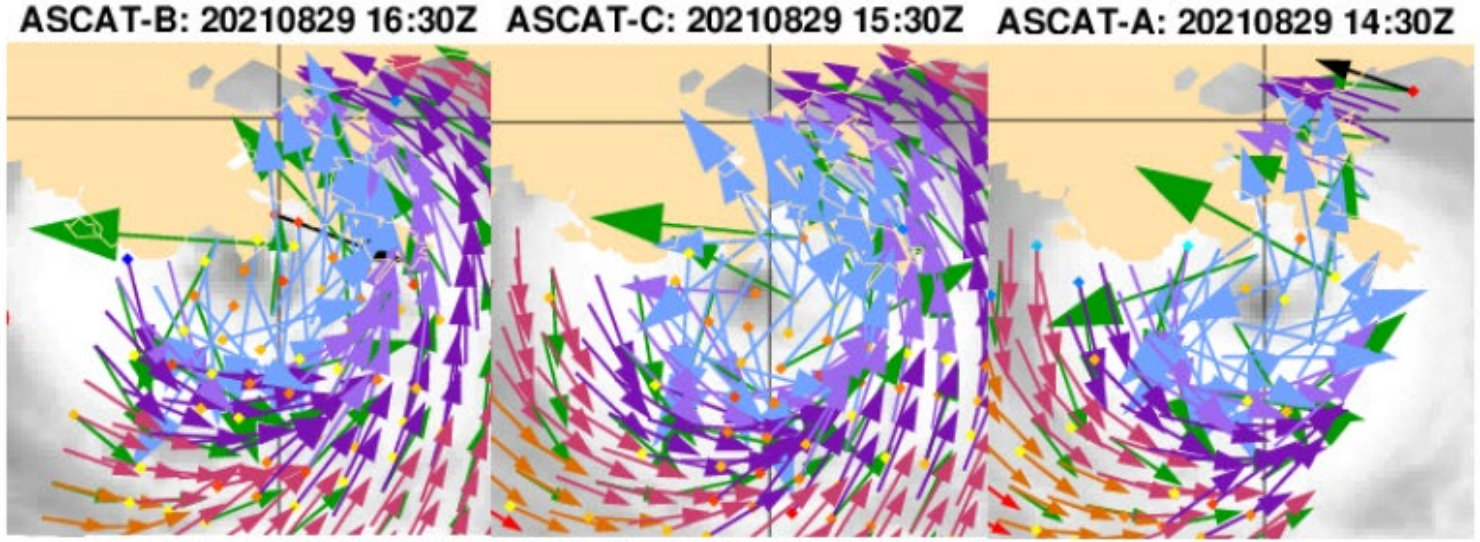
MetOp-B/ASCAT	9:30/21:30	C-band
MetOp-C/ASCAT	9:30/21:30	
HY-2B/SCAT	6:00/18:00	Ku-band
HY-2C/SCAT	Shifting	
HY-2D/SCAT	Shifting	
CFOSAT/SCAT	6:30/18:30	
FY-3E/WindRAD	5:40/17:40	C-and Ku-band

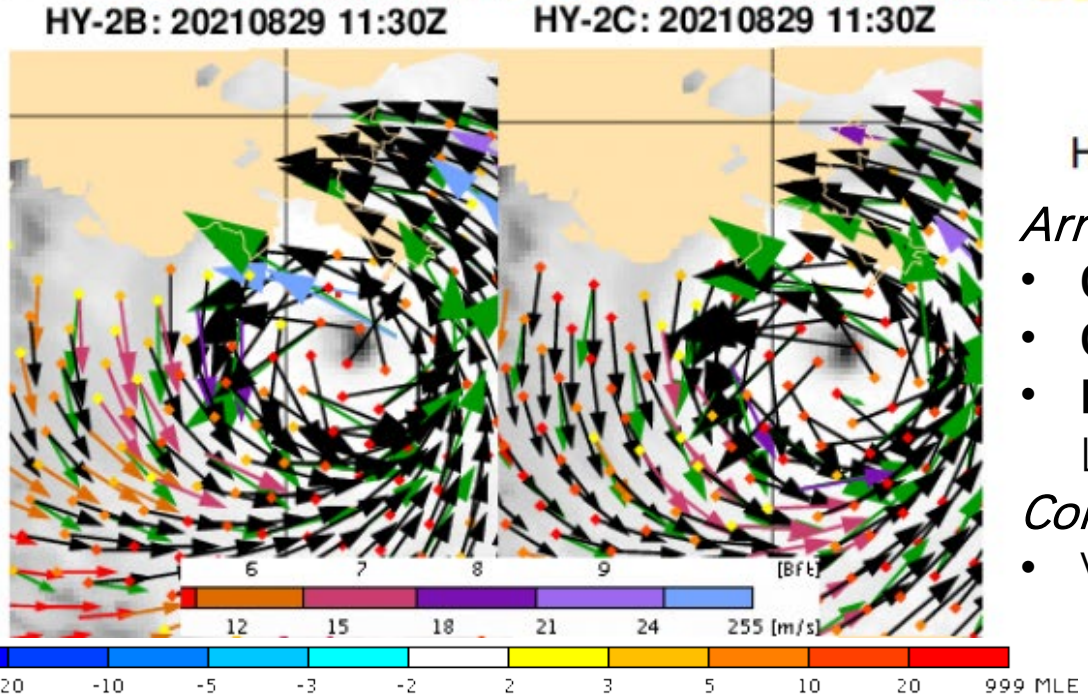


A single scat. example: Scatteromerer winds from CSCAT onboard CFOSAT overlapping tracks of the TC Leckima in 2019 (black dots), the blue and yellow lines represent 48h and 24h alerts

Track background from: https://typhoon.slt.zj.gov.cn/default.aspx

From scatterometers: winds





Scatterometer winds with an infrared satellite image and numerical weather prediction model forecast winds from ECMWF. *Virtual constellation gives better information.*

Hurricane Ida

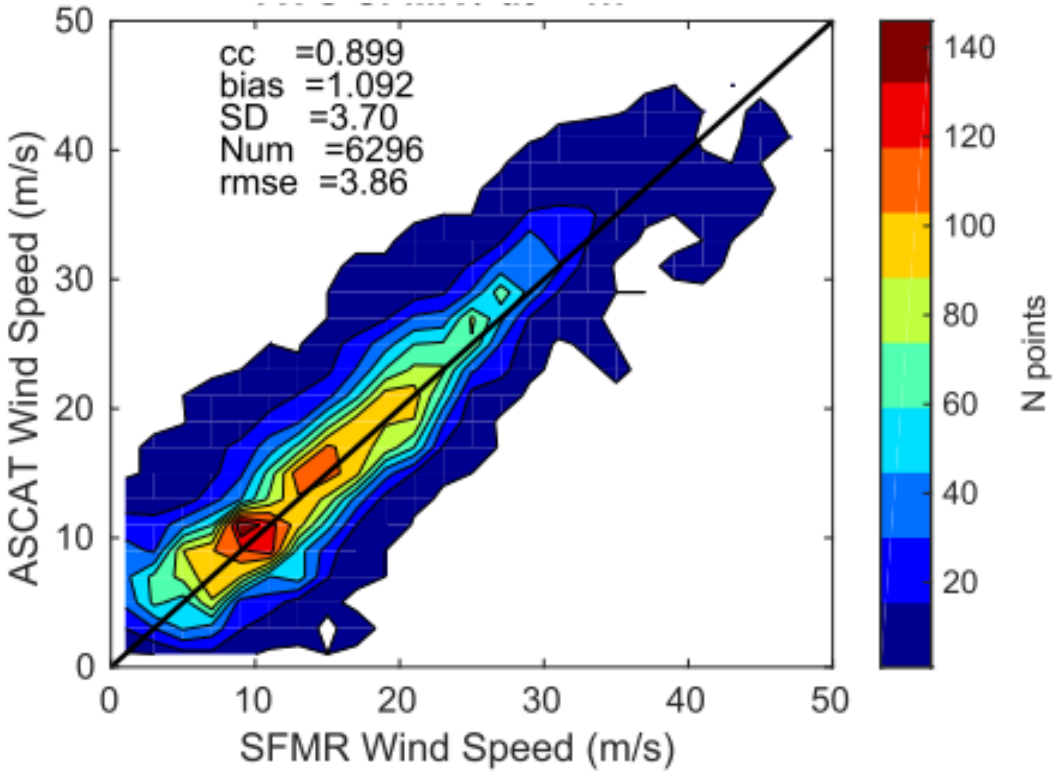
Arrow colour:

- **Colour in the colour bar**: wind speeds;
- **Green**: ECMWF forecast winds;
- **Black**: KNMI Quality Control flag set (with Maximum Likelihood Estimator (MLE)).

Coloured dots:

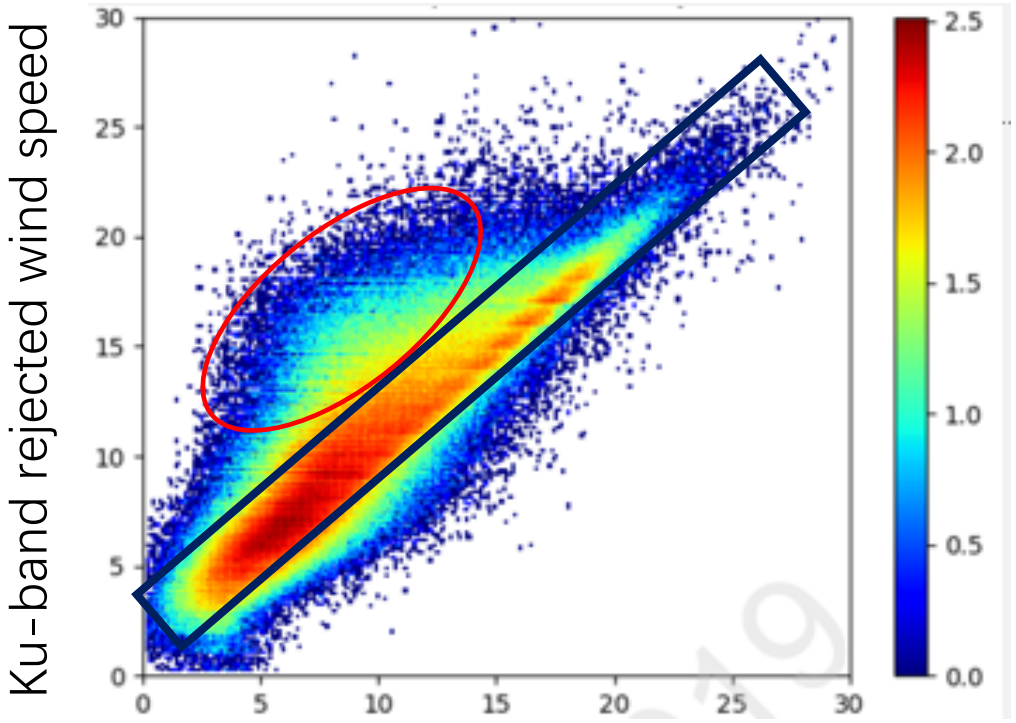
- Value of MLE .High values indicate high spatial wind variability.

From scatterometers: winds



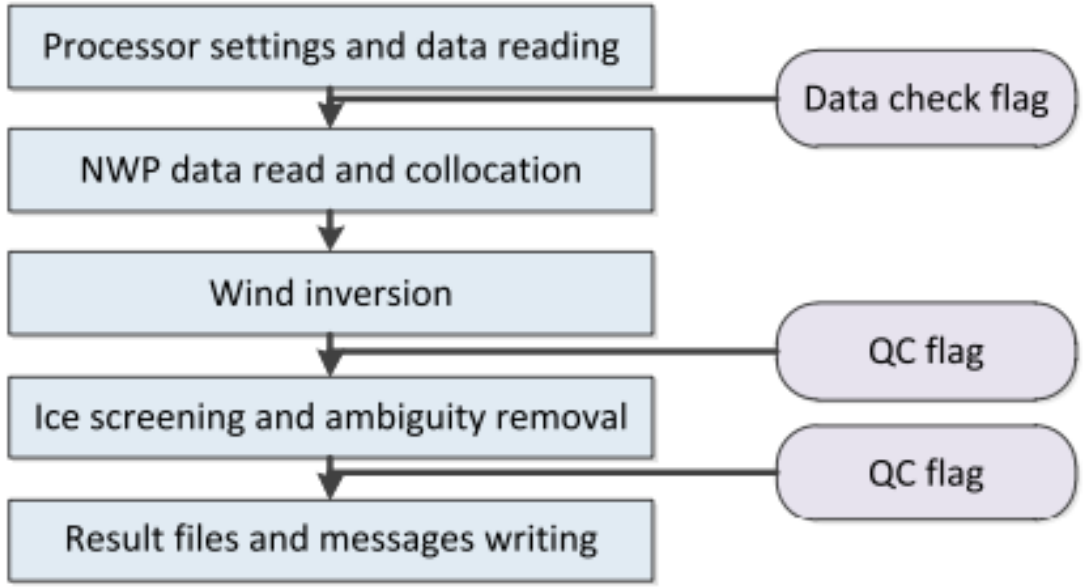
C-band scatterometer high winds
(F. Polverari, et al., 2021)

- ASCATs at C-band as references indicates larger rain effects in Ku-band, collocations indicates rejections related to rain, as well as false alarmed rejections.



C-band accepted wind speed

From scatterometers：quality control (QC) and winds



The general processing chain of wind inversion in practice

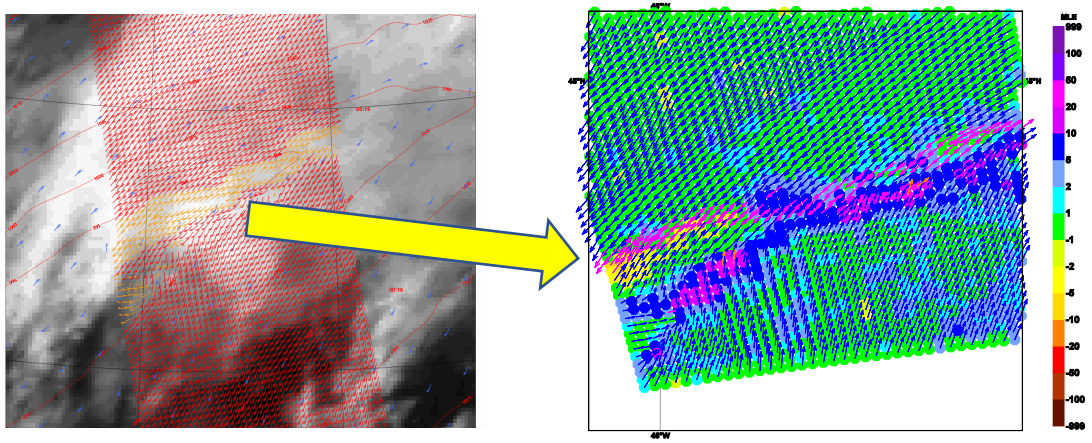
QC:

-Guarantee fitness of winds from scatterometers applying the QC indicators as criterion..

The Quality Control (QC) Indicator : MLE

MLE: Weighted Euclidian distance to the cone

$$MLE = \frac{1}{N}\sum_{i}^{N}\frac{\left(\sigma_i^o - \sigma_{sim_i}\right)^2}{\left(K_{pi} \bullet \sigma_i\right)^2}$$



ASCAT winds, where the direction changes can be observed in a convective front. And details identified by MLE

The Case of missing variables:

- In missed or **incompletely modelled processes**, such as **rain**, wind variability, sea state, etc., **generate errors of QC class**;
- **These errors often result in large deviations from the wind GMF,** hence cone, and measured by MLE, for the changing speed and direction of the stress-equivalent wind.

(Stoffelen A., and D. Anderson, 1997)

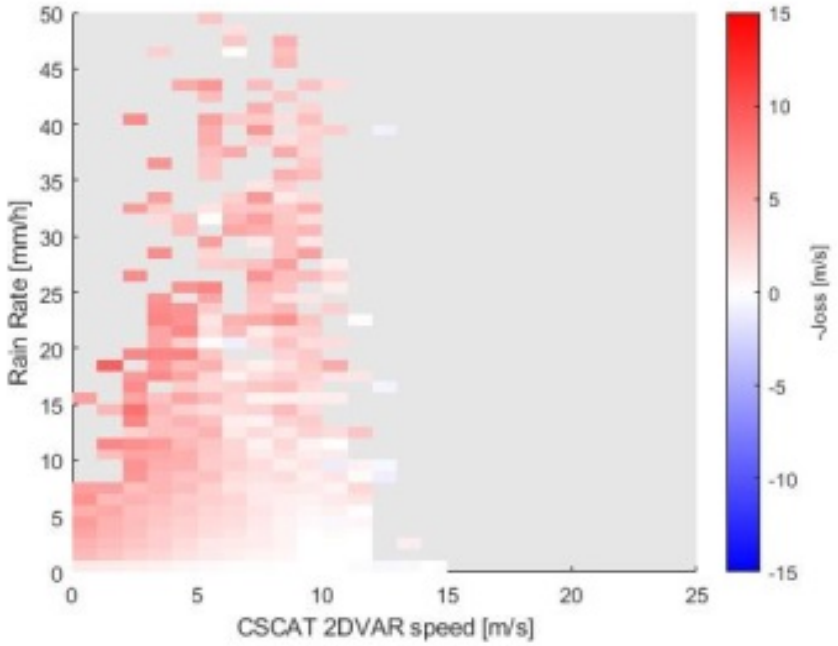
The QC Indicator: Joss

J_{OSS} , the local difference in speed of the selected wind ambiguity and the analysis wind speed, naturally locates and quantifies local disturbances.

$$J_{OSS} = f - f_s$$

☐ The error terms with non-constant variance:

- Variance considered in the MSS procedure in the **specificized error correlation model**.
- Expressed the evaluation of **spatial derivatives due to local heterogeneity**.
- Effects of **sampling difference and lack of samples for rains are low-pass filtered**.



Joss is independent of wind speed in rain screening from CSCAT and GPM.

(Xu, X. & A. Stoffelen, 2020; Xu X., A. Stoffelen, M. Portabella, W. Lin and X. Dong, 2021)

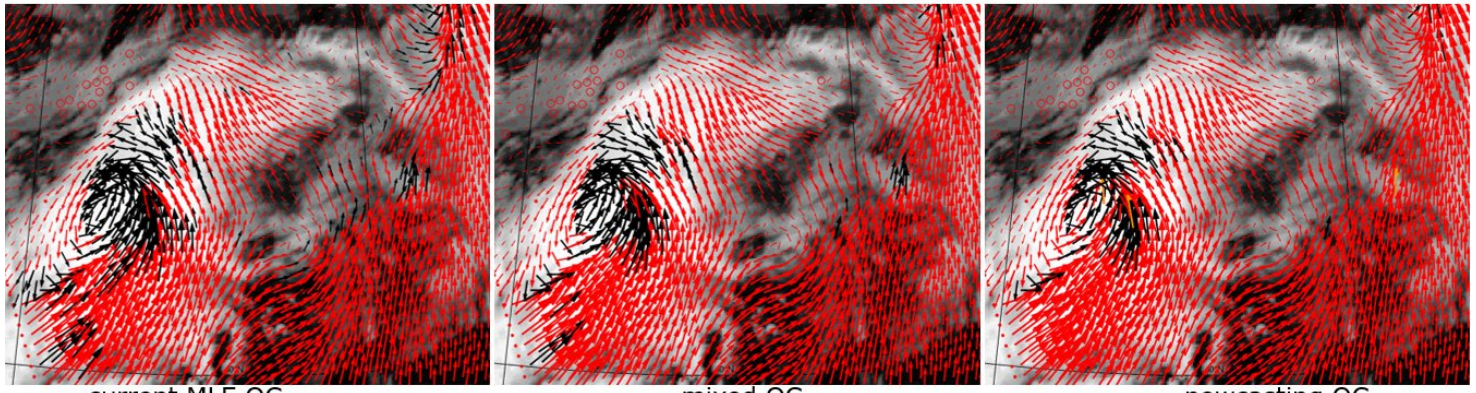
(Xu, X., A. Stoffelen and J. F. Meirink, 2020).

Application of indicators for rain condition

Proposed alternative QC methods based on Joss and MLE @KNMI

(Verhoef A. & A. Stoffelen, tec. report: SAF/OSI/CDOP3/KNMI/SCI/TN/404, EUMETSAT, 2021)

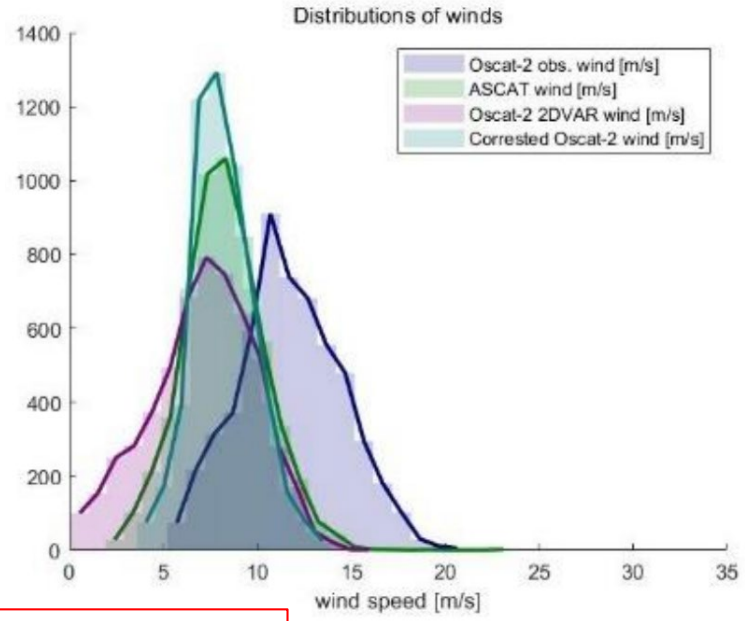
Wind field example from HY-2B



current MLE QC | mixed QC | nowcasting QC

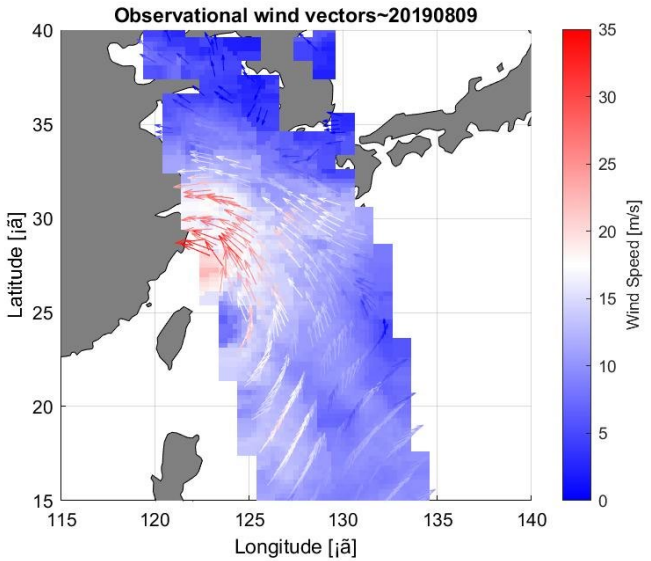
Support vector machine tropical wind speed retrieval in the presence of rain for Ku-band wind scatterometry

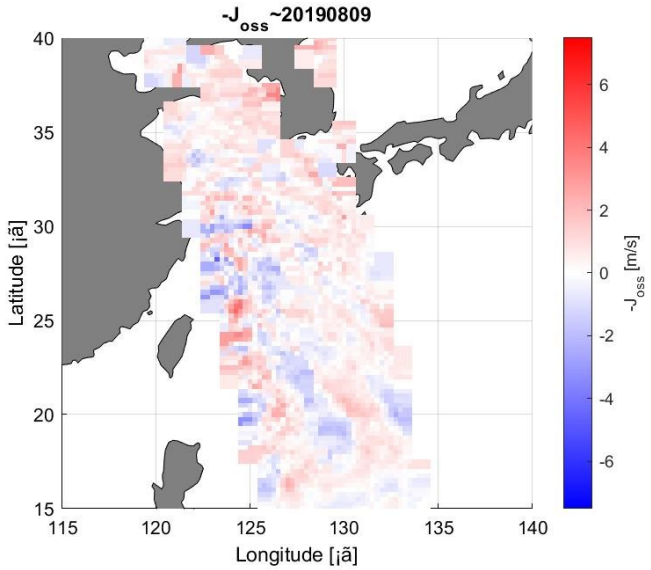
(Xu X. & A. Stoffelen, 2021,10.5194/amt-2021-200)

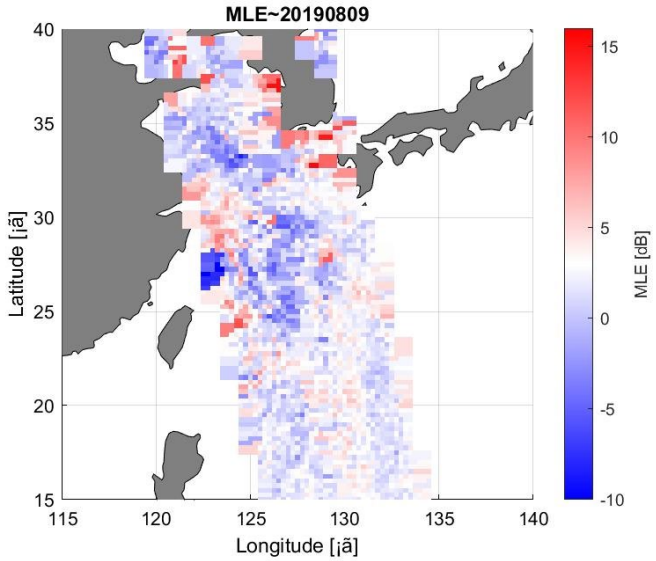


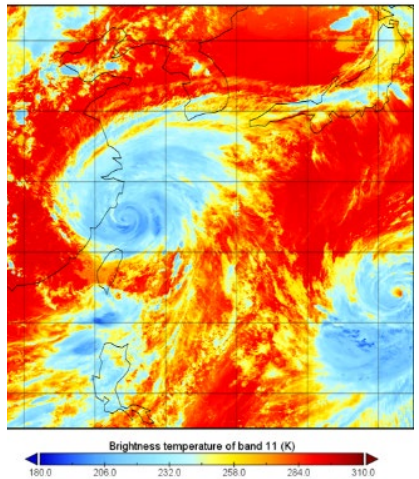
- Application confirms the spatial variance due to rain captured by Joss.
- Combined with MLE, reveals wind and rain information

For the Ku-band TCs









Himawari 11th band

08-09 23:00	50m/s
08-09 20:00	48m/s
08-09 17:00	48m/s
08-09 14:00	48m/s
08-09 11:00	52m/s
08-09 08:00	55m/s
08-09 05:00	55m/s
08-09 02:00	58m/s

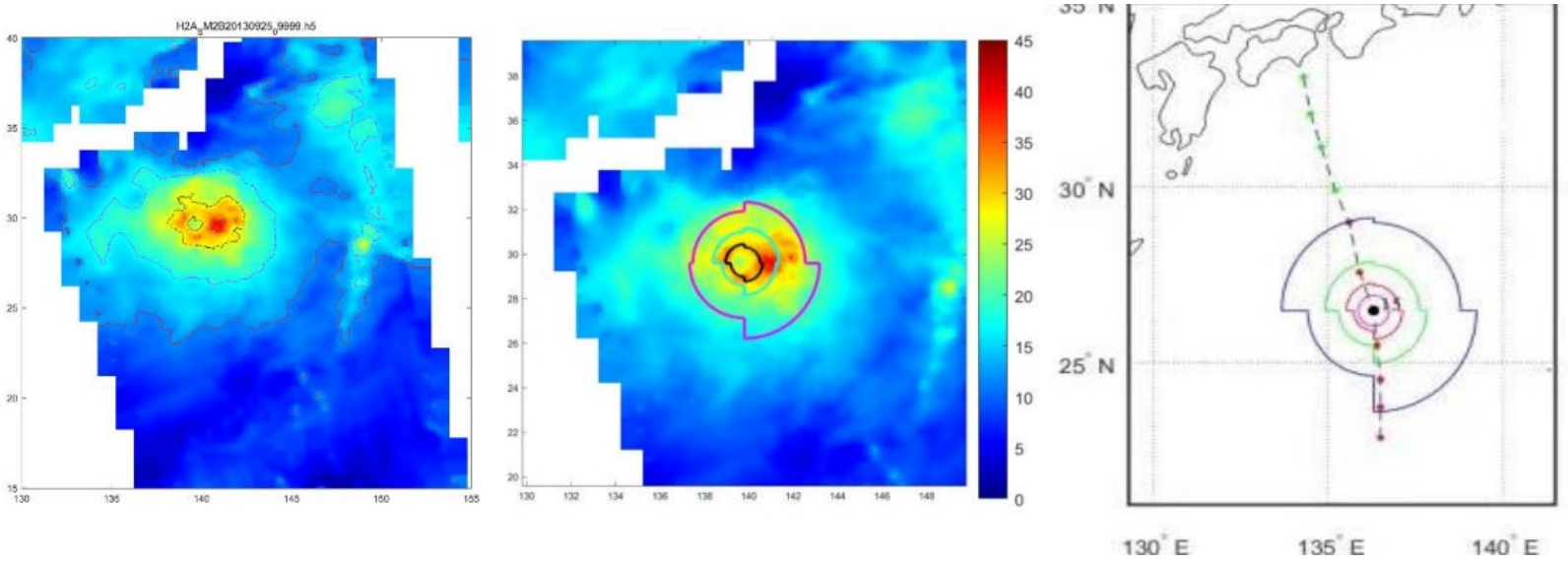
Best track from CMA

Wind fields and indicators of Lekima in 2019

Ku-band TC:
Speed underestimation and direction abnormal still exist, indicator values with information about rains.

(Xu, X. & A. Stoffelen, 2020; Xu X., A. Stoffelen, M. Portabella, W. Lin and X. Dong, 2021)

Improvement in Ku-band TC: combined with simultaneous radiometer observations



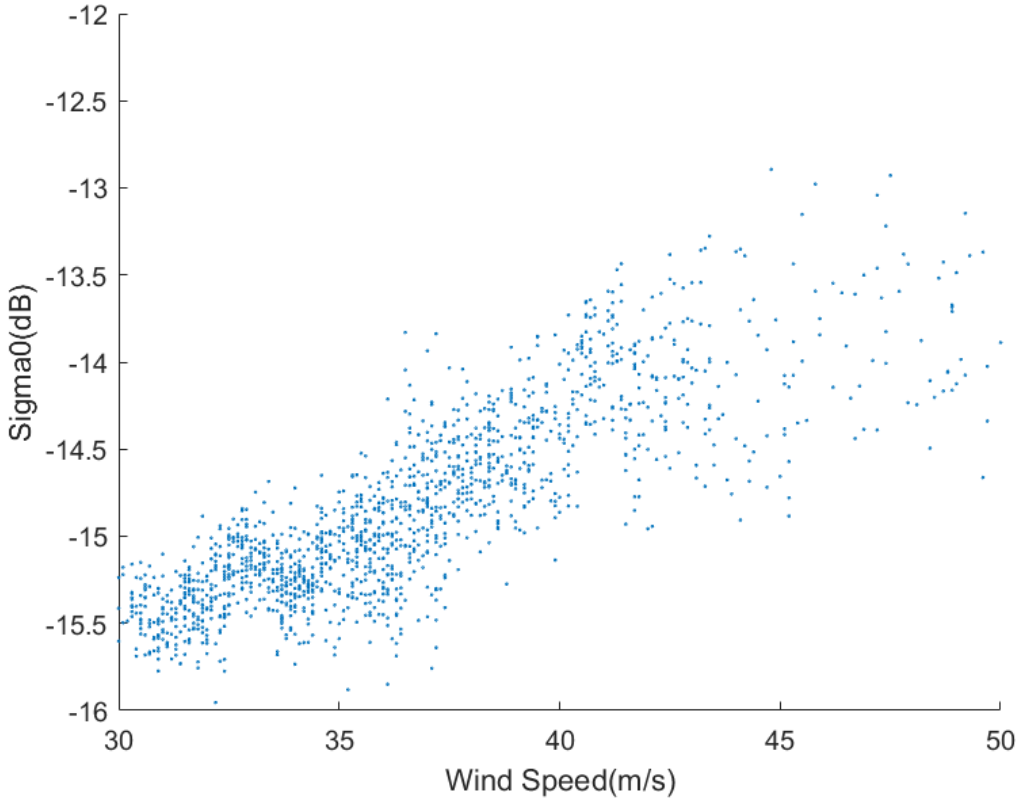
Left: equivalent coils from HY-2A Combined winds
Middle: extracted radii from the coils
Right: Radii of four-geographical-quadrant from IR.

Consistency in Radii observed

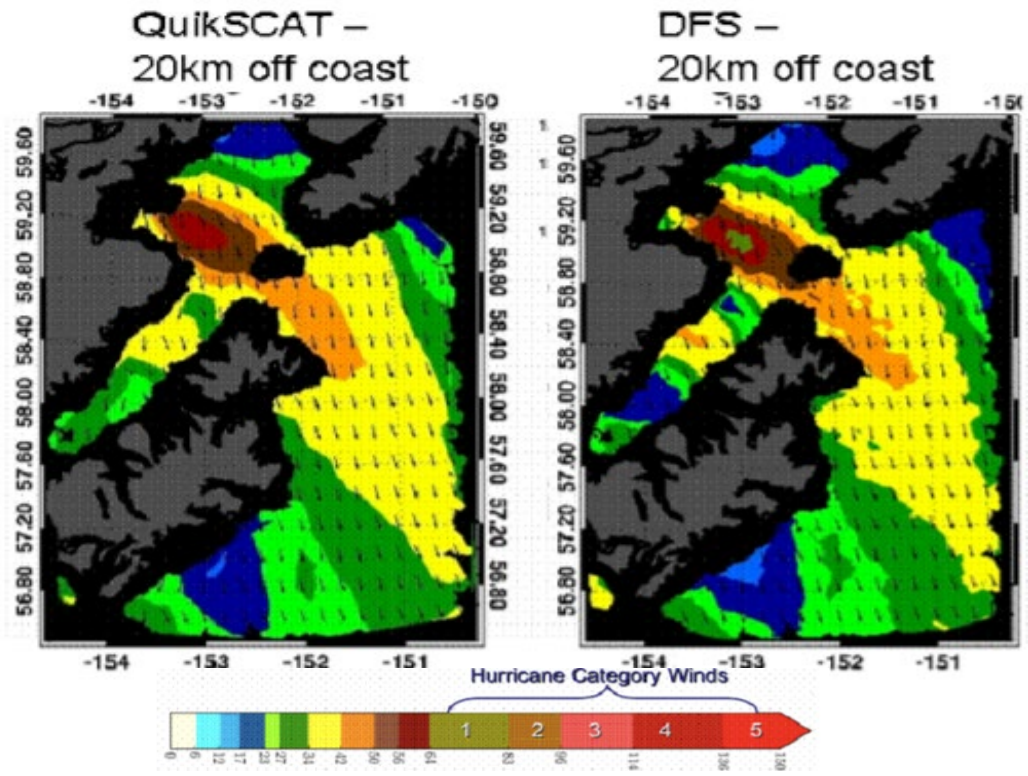
(Xu X. & X. Lu, 2022. 10.1109/IGARSS46834.2022.9883378)

Neural Networks derived combined wind: Wind > 25m/s, 10%; 20° (evaluated with H*Wind)
(Xu X., X. Dong, D. Zhu, S. Lang, 2018.10.1109/JSTARS.2018.2873257)

Further Improvement in Ku-band TC: wind GMF modification, with combined C-and Ku-band high winds and rains



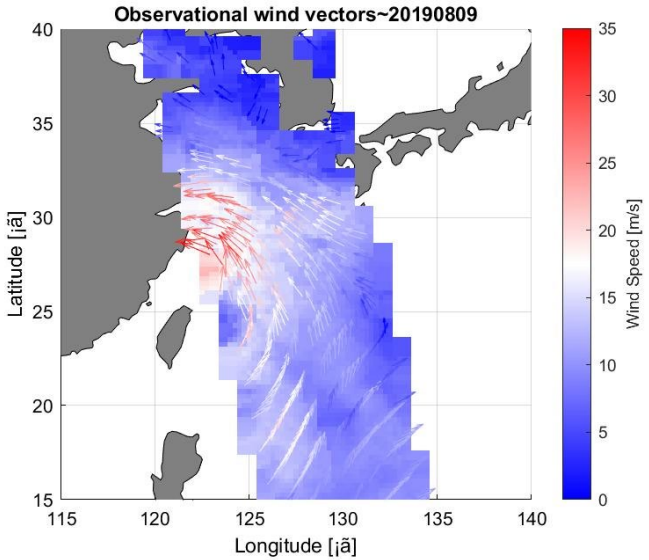
A rough statistics of HY-2B SCAT NRCS v.s. ecmwf wind speed



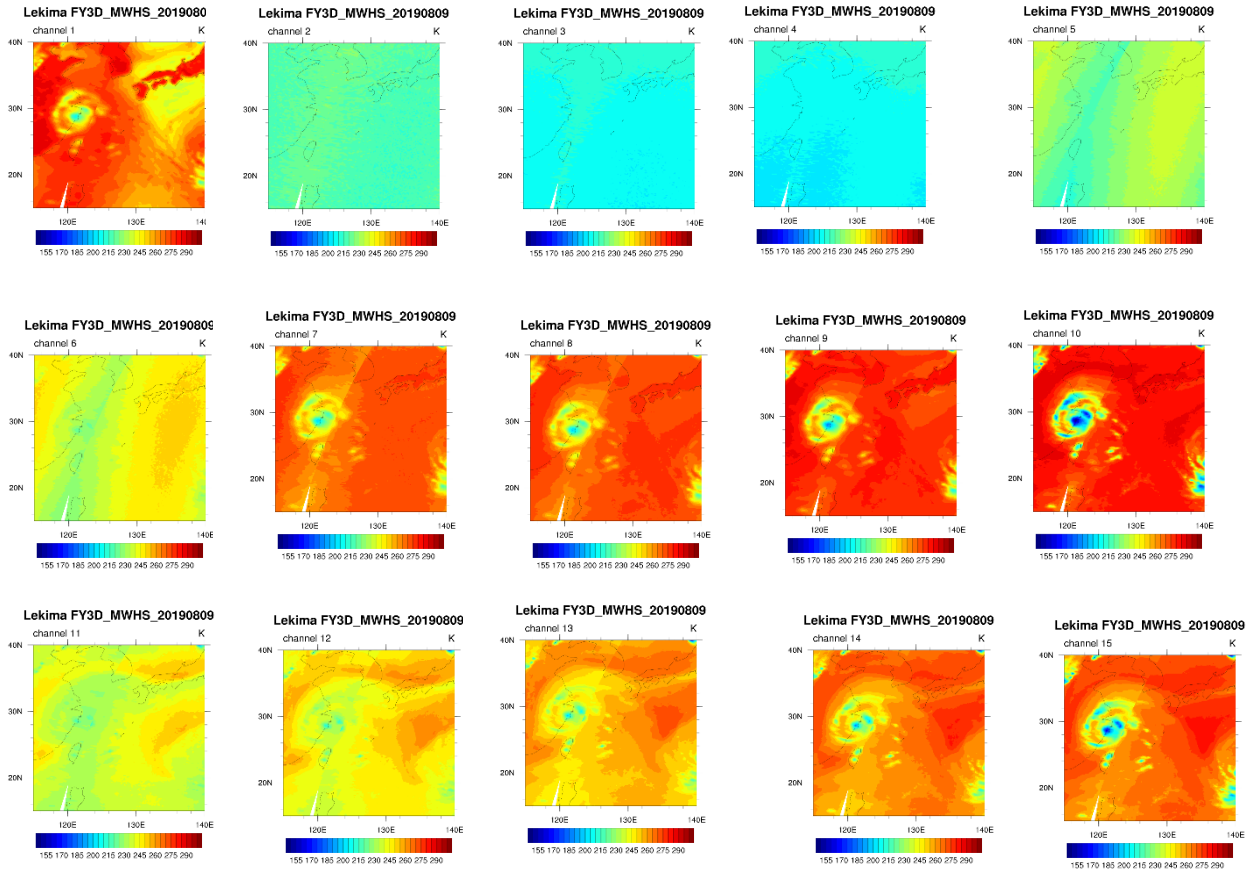
QuickSCAT coastal winds and simulated DFS winds (NOAA)

Some More Prospects:

- **Combined TC centre locating and amplitude determination with MHWS-II (Micro-Wave Humidity Sounder-II) observations from FY-3E, an example from past observations in CSCAT and MWHS-II.**



Lekima (2019) from CSCAT



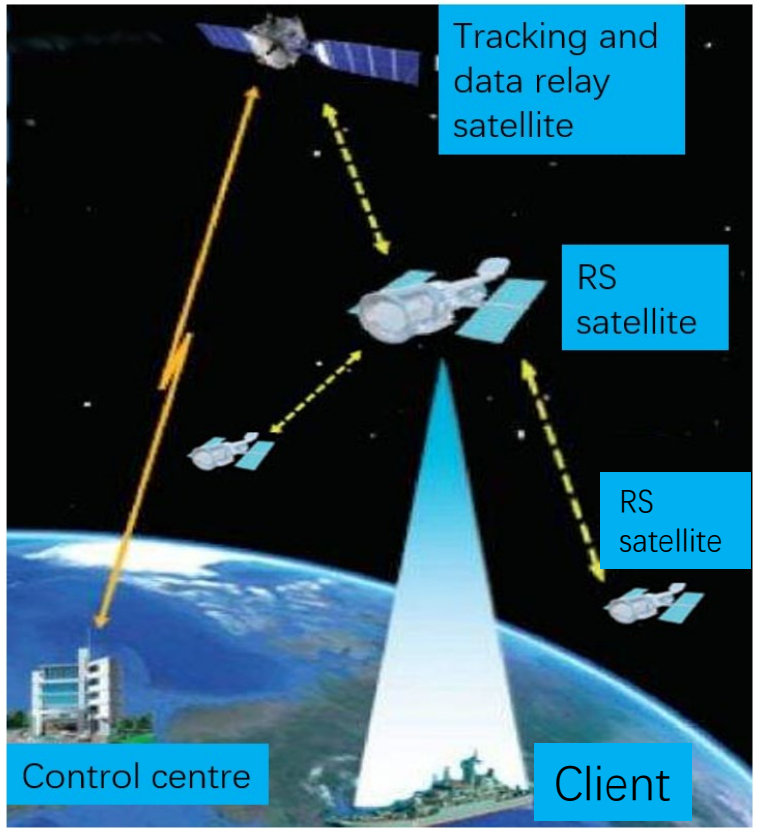
Channels (GHz)

1	89.0
2	118.75±0.08
3	118.75±0.2
4	118.75±0.3
5	118.75±0.8
6	118.75±1.1
7	118.75±2.5
8	118.75±3.0
9	118.75±5.0
10	150.0
11	183.31±1
12	183.31±1.8
13	183.31±3
14	183.31±4.5
15	183.31±7

Lekima (2019) from MWHS-II onboard FY-3D

Some More Prospects:

- **On-board wind Scatterometry: design & simulation**



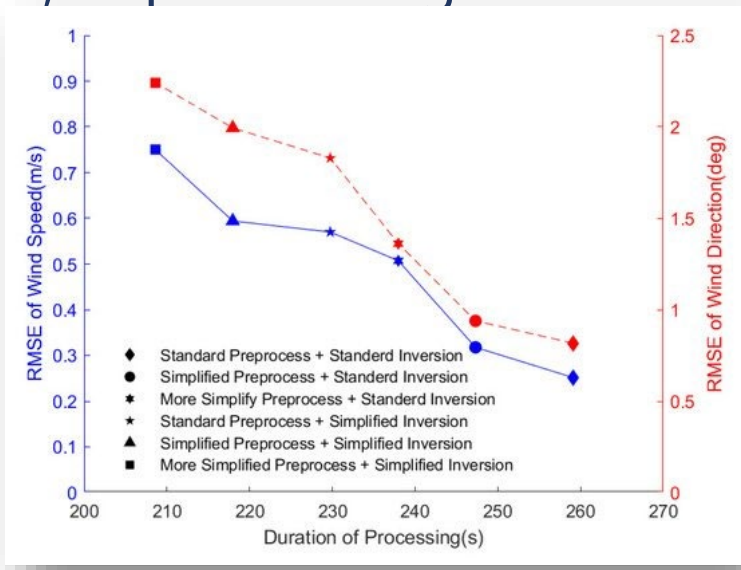
(Li D. 2018)

Tracking and Data Relay Satellite communications between the ground and space traditionally, now applying more lower orbit satellites or satellites constellation, it is possible to transfer winds directly to, for example, ships travelling off seas.

Simulation:

- Onboard pre-processing in geolocating look-up tables;
- WVC formation in look-up-tables for different locations;
- MLE wind retrieval;
- Medium circular filtering for ambiguity removal;
- Simulation in CFOSAT observations;
- Real time distribution.

(Xu X., X. Dong and Y. Xie, 2020, 10.3390/rs12071216)

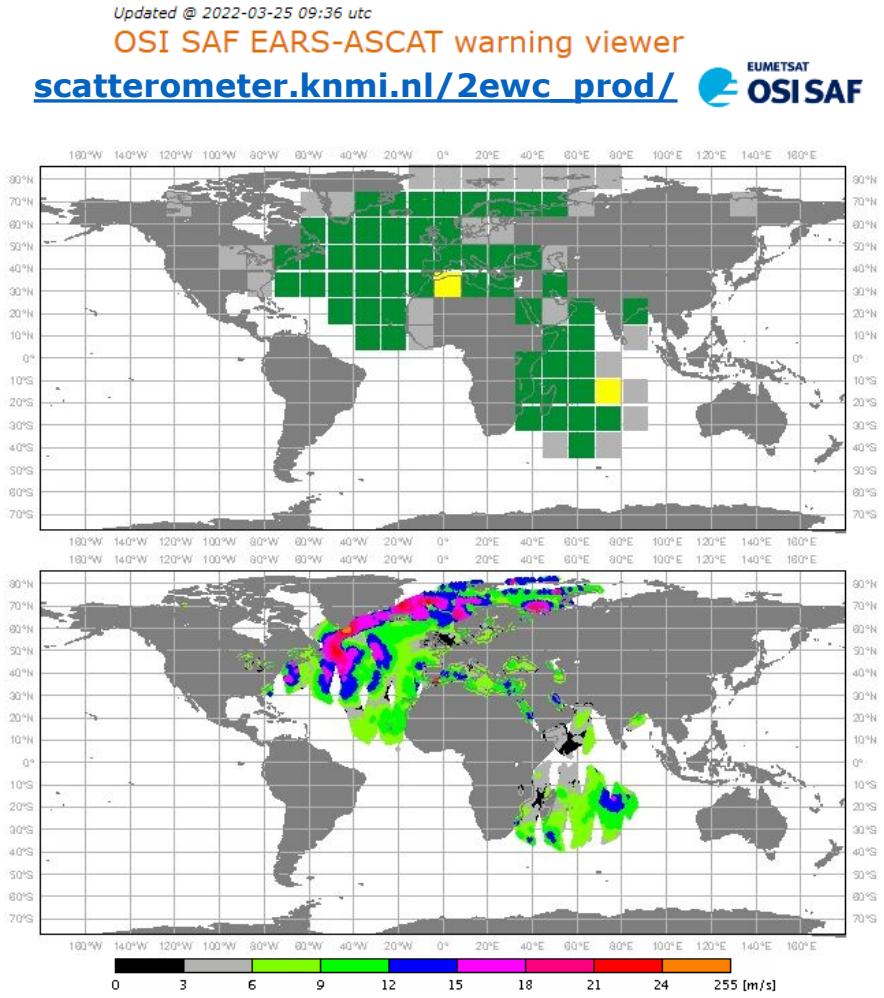


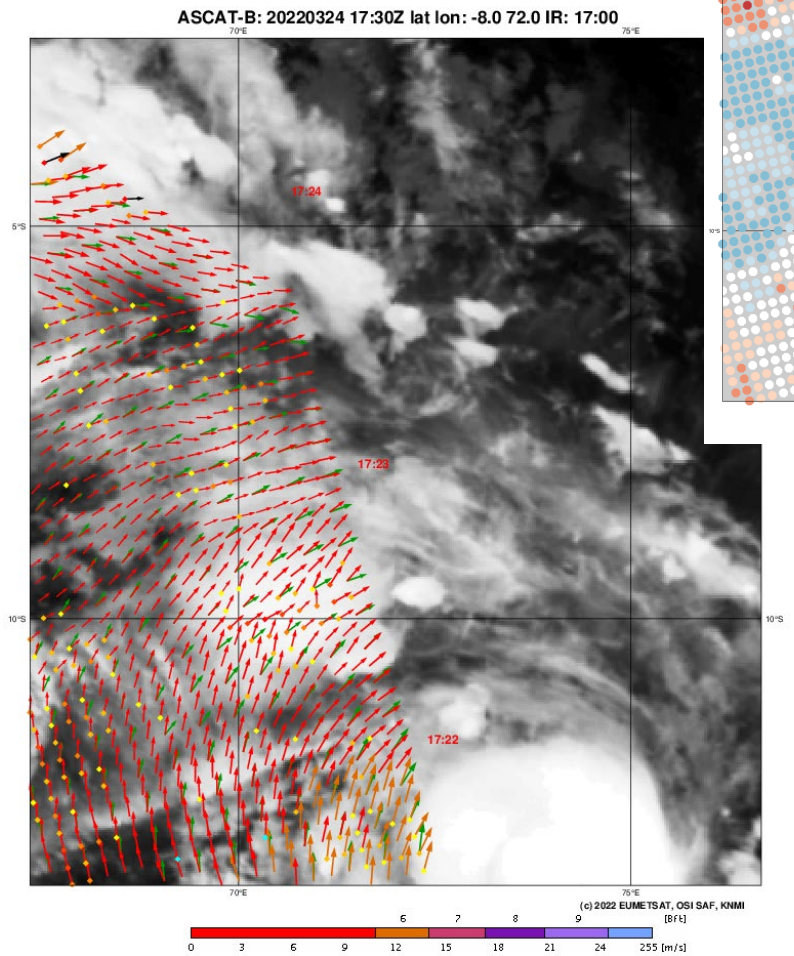
[Processing time v.s. accuracy]

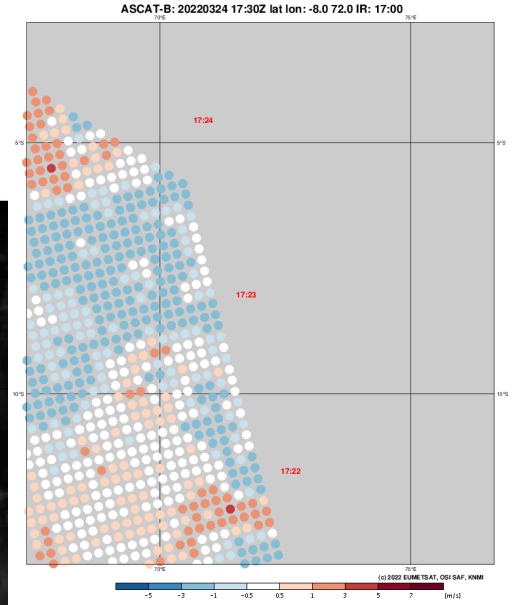
Combined on-board and client system processing can improve the accuracy, apply to TC for early warning.

Some More Prospects:

- **Cyclone visualization and EARS Early Warning (KNMI, conceptual phase)**







- ✓ Warns fast in case of climatologically large deviation between ECMWF and ASCAT

To be continued….

Thanks !

Xingou Xu, Ad Stoffelen, Xiaoqin Lu, Guanghua Chen

✉ : xuxingou@mirslab.cn, ad.stoffelen@knmi.nl, luxq@typhoon.org.cn, cgh@mail.iap.ac.cn