Improvement of the Ku-band Winds in Rainy Regions Obtained by a Support Vector Machine Method

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Abstract: Ku-band observations from scatterometers are more affected by rain due to their shorter wavelength than those obtained at C-band, while both frequencies are commonly applied for wind scatterometers. In the previous workshop, we proposed a support vector machine (SVM) model based on the analysis of Quality Control (QC) indicators of rain screening ability provided by collocated winds from the Ku- and C-band scatterometers: OSCAT-2 on-board ScatSat and ASCAT-A & ASCAT-B on-board the MetOP-A & MetOP-B satellites respectively, together with simultaneous rain rates from the Global Precipitation Mission (GPM) products. Meanwhile, the principle of SVM was addressed for its advantages in the rain-effect correction problem. The established SVM model was evaluated by a testing set not applied in the training procedure. In the verification, accepted winds after QC from the C-band scatterometers are applied as the truth, given their low rain sensitivity.

Results of this subsequent research indicate that the rain-corrected winds provide improved-quality information for Ku-band scatterometers under rain that can be vital for nowcasting applications, such that the effectiveness of optimization methods based on Machine Learning for such problems is proven.

Further research would be on two aspects: one concerns application methods of the established model, the other would be focusing on a more detailed rain effect analysis over each scene, while investigating advanced ML methods for integrating the enriched information obtained.

1 Recollection of Earlier Results & Introduction

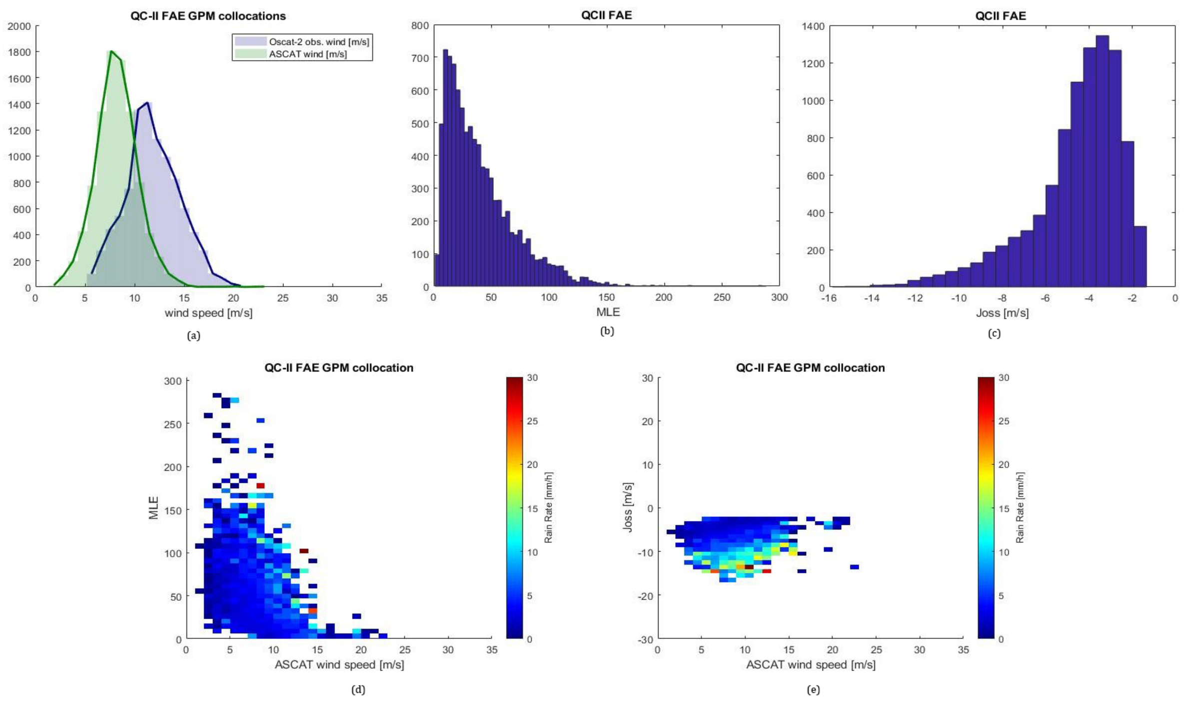
We investigated QC-rejected Ku-band WVCs collocated with its QC-accepted C-band WVCs (QC-II), information provided by the QC indicator MLE, the parameter α, Ku-band observational speed, ECMWF wind speed, complemented by reference rain rates from the Global Precipitation Mission (GPM) and wind speed from the C-band products. A support vector machine (SVM) is employed to model rain features and rain effect corrections to wind speeds from Ku-band observations. In this subsequent research, False Alarm Elimination (FAE) is conducted for the QC-II set, SVMs are modified for wind correction and rain estimations. Results are further validated for applications, demonstrating detailed features of probability density functions (pdf) and cumulative density functions (cdf), after which a case study is provided.

Parameters involved	Descriptions
Wind scatterometer Quality Control	Referred to as QC here. In tropical regions, QC rejections are generally associated with rain, and labelled by QC indicators. Ku-band observations are 10 times more frequently (~5%) rejected than C-band (~0.5%) due to the shorter wavelength.
The analysis wind speed	Also referred to as 2DVAR wind speed. It is obtained in the 2DVAR ambiguity removal procedure after wind retrieval balancing the differences of observed and background ECMWF winds. They are low-pass filtered and of relatively coarse resolution and ignoring rain effects. Referred to as *f* hereafter.
MLE	A widely applied QC indicator obtained during wind inversion, as normalized distances between NRCS and GMF (the empirical model applied in scatterometer wind inversions) calculated in the maximum likelihood estimation procedure, also referred to as R_n.
J_{oss}	A spatially-informed QC indicator representing difference of observational and analysis wind speeds, and describes the heterogeneity induced by rains (rain clouds), thus capable for rain screening and False Alarm Rate (FAR) reduction.
α	Proposed and applied in the previous research as a rain fraction parameter in a WVC: $\alpha = (J_{oss})/(f-18)$

2 Data Set & Collocation

The QC accepted C-band winds are not much affected by rain and used as reference in this research (Tropical region). The spatial distance is less than 25km and observing time lag less than 25 min (minutes) between scatterometers and 2.4 min of OSCAT-2 and GPM rain rates. 9,339 WVCs in ASCAT-A are obtained after FAE.

Data	Source
Ku-band Scatterometer	OSCAT-2 onboard SCATSAT-1
C-band Scatterometer	Advanced Scatterometers (ASCAT-A and ASCAT-B) onboard MetOP-A and MetOP-B
Precipitation	NASA GPM (Level 3 Integrated Multi-satellitE Retrievals) in version 5.
Model winds	ECMWF winds.
MR images for validation	The band 11 of Himawari-8 satellite at medium infrared (wavelength of 8.6μm) from Japan Aerospace Exploration Agency (JAXA).



From the left panel, rain casts effects on OSCAT-2 data while collocated ASCAT winds remain of acceptable quality. The winds distorted by rain (clouds) are clearly segregated by the FAE, resulting in a deformed speed distribution, as well as much elevated MLE and Joss, that all can be potentially related to WVC rain rate.

Collocated wind speed distributions in the QC-II FAE set (a), corresponding MLE distribution of OSCAT-2 (b), Joss (c), collocated rain rates with reference to MLE (d) and Joss (e).

As 18 m/s winds cannot be distinguished from rain and to allow rain sensitivity, the rain effect correction set is limited to:

$J_{OSS} > 0.33 f - 5$

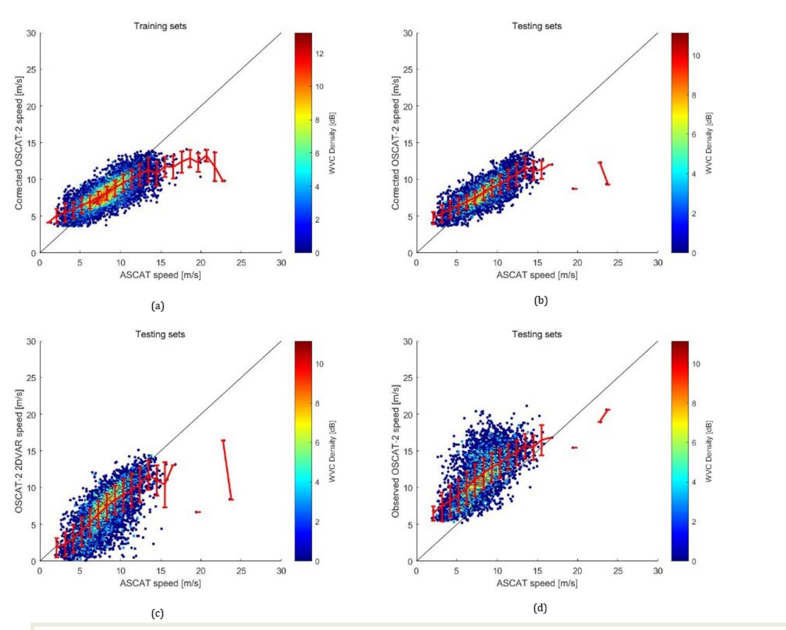
3 Support Vector Machine (SVM):

A SVM transforms several inputs into a space of linearized outputs using kernel functions. It is used to solve problems that are non-convex and difficult to solve in the origin input space. The kernel function applied is the (Gaussian) radial basis function kernel, where L2 distances are minimized in the procedure. It allows the data involved in training to embody the underlying model in a space that facilitates information extraction.

Using the same inputs, SVMs for 1) wind speed correction, for 2) rain/no-rain labelling, and 2) rain rate regression, given the same inputs (18,528 WVCs for ASCAT-A and ASCAT-B collocations, 70% for training).

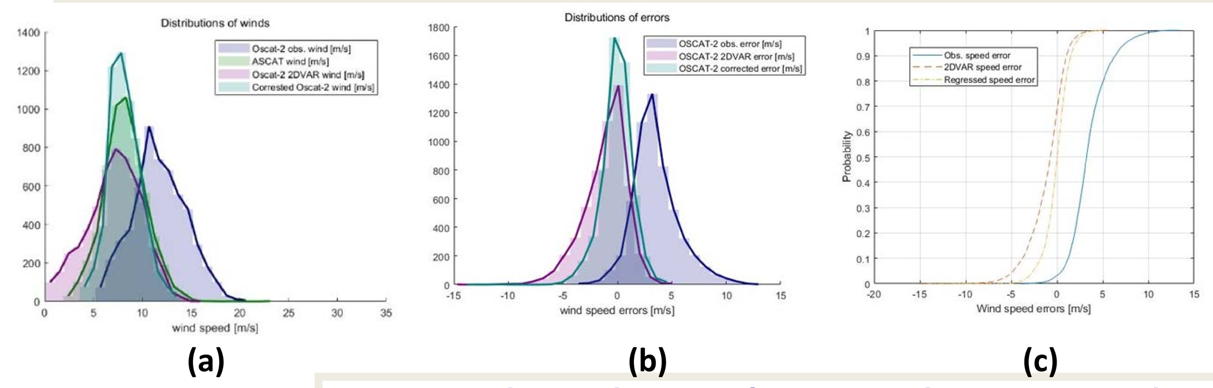
Inputs for SVMs (Ku-band FAE)	Output of SVMs	Values of output for training
• MLE in dB,		
• α,	1) Corrected wind speed (m/s)	1) wind speed form ASCAT-A or ASCAT-B
• Analysis speed,	2) Rain / 0 surface rain rate label	2) GPM rain rates, 0 and non-zero cases
• Observational speed,	3) Rain rates (mm/h)	3) GPM rain rates in mm/h

4 Results



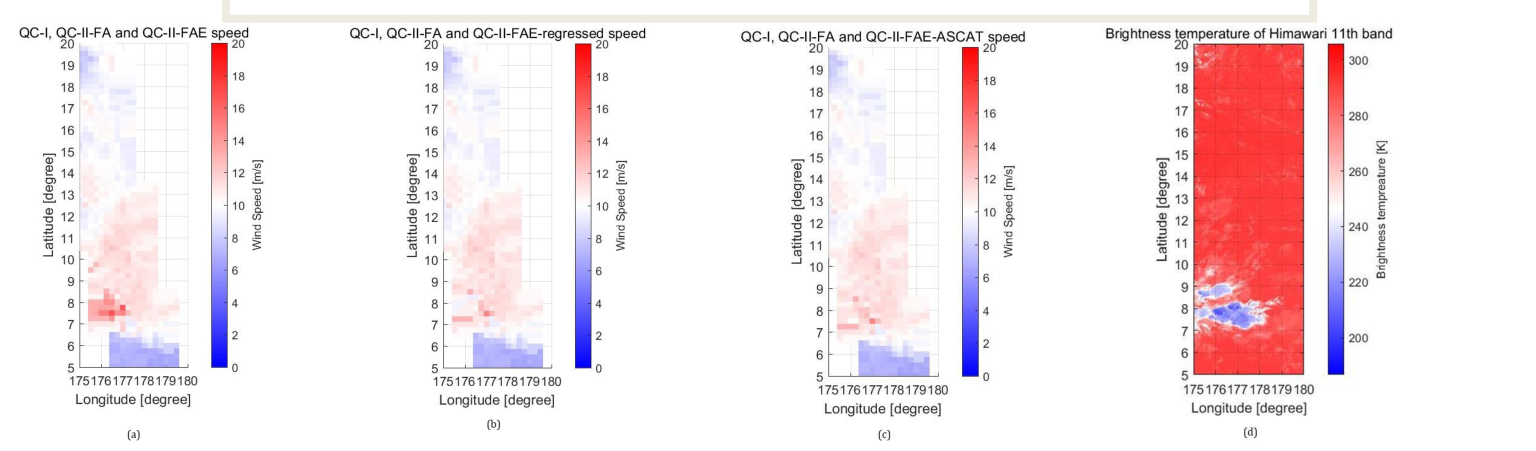
The corrected winds against accepted winds from ASCAT-A and ASCAT-B for the training set (a) and validation set (b)-(d), where (b) the corrected, (c) the 2DVAR and (d) observational OSCAT-2 wind speed against ASCAT wind speed are depicted.

It is noteworthy that there is a sign change for these speed differences, suggesting an excessive speed range suppression for wind speeds both lower and higher than around 8 m/s respectively.



Distribution of different wind speeds (a), speed errors with the reference from ASCAT (b) and the cdf of speed errors (c) corresponding to the testing set .

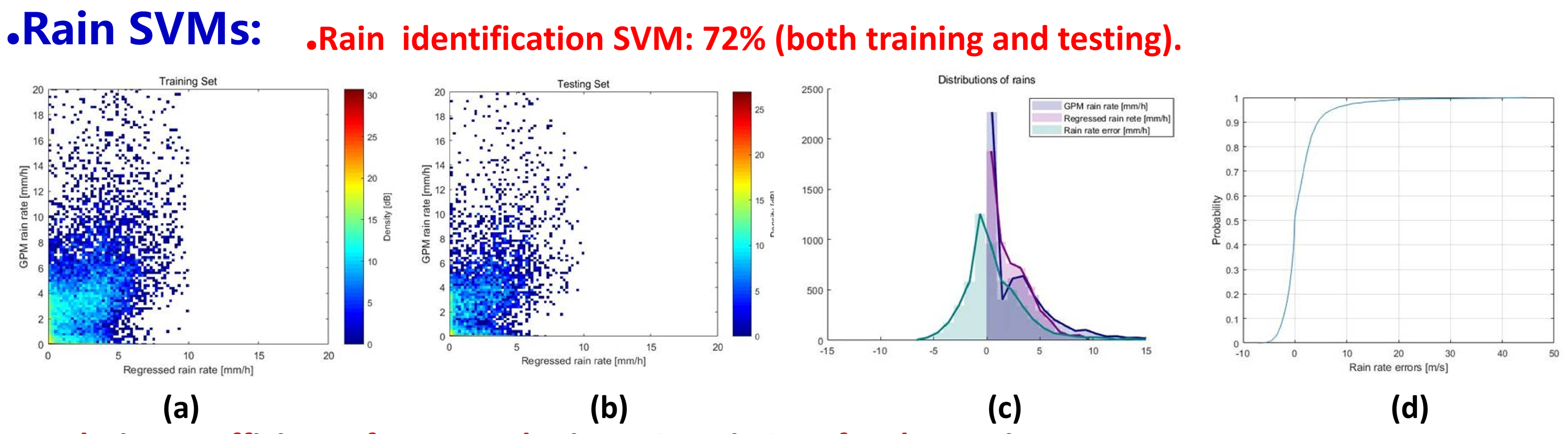
Corrected winds are closer to the ASCAT observations.



Wind speed of the QC-I, QC-II FA and QC-II FAE (a), the FAE set replaced by the SVM regressed speed (b) and by speeds from their ASCAT collocations (c), with the synchronous MIR (e) images from Himawari-8, where the green rectangle indicates the region in (a), (b) and (c). it can be observed that (b) and (c) are more similar than (a) and (c), demonstrating the consistency between the SVM-regressed OSCAT and accepted ASCAT wind speeds.

•Rain SVMs:

•Rain identification SVM: 72% (both training and testing).



•Correlation coefficient of regressed rain to GPM is 0.47 for the testing set.

SVM regressed rains for training set (a) and validation set not involved in training (b), and distribution of GPM and the SVM regressed rains, with that of the error (c), cdf of the error (d). For GPM rain above 10 mm/h, OSCAT rain rates are rather randomly distributed and presumably lack skill. However, in (c) the errors appear symmetric and the pdfs well matching for intermediate rain rates.

More details available:

Xu, X. and Stoffelen, A.: Support vector machine tropical wind speed retrieval in the presence of rain for Ku-band wind scatterometry, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-200, accepted, 2021

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