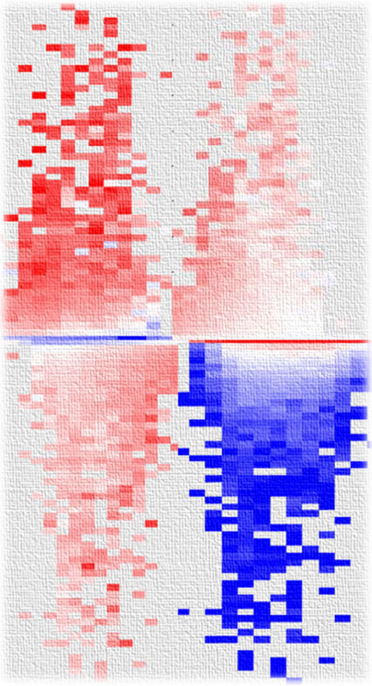

A COMPARASION OF QUALITY INDICATORS FOR KU-BAND WIND SCATTEROMETRY & FOR TYPHOONS LEKIMA AND KROSA in CSCAT

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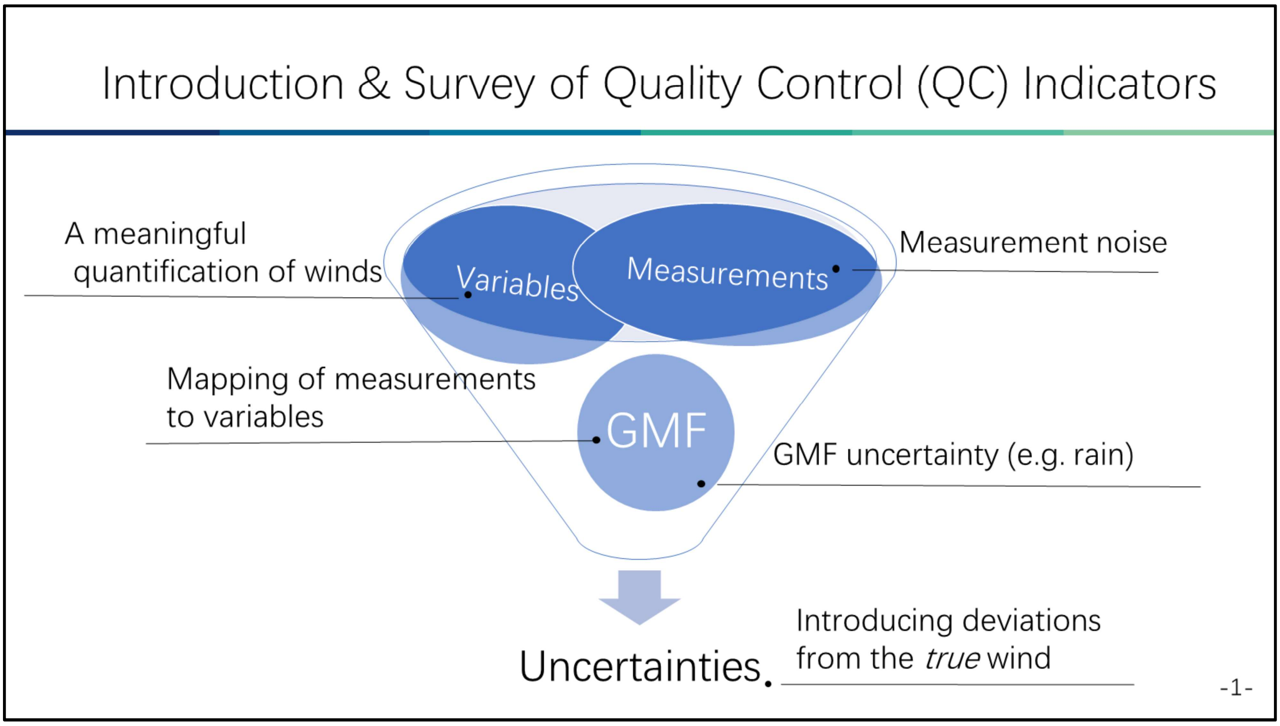
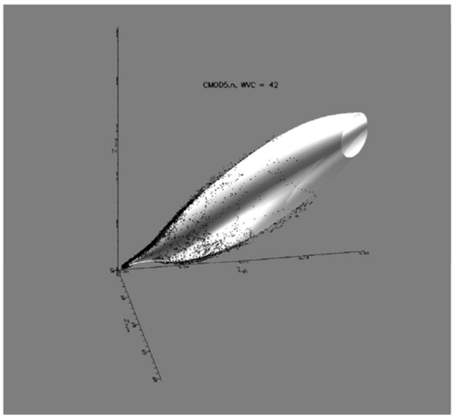


NRCS measurements and their noise are mapped to ocean surface vector winds by inverting a Geophysical Model Function (GMF). The GMF is inaccurate or otherwise does not represent the NRCS measurements, e,g., due to rain processes at Ku band. This causes uncertainty in the vector, but also a class of unrepresentative vector winds with high error. Quality Control indicators are developed to find this class of unrepresentative winds. QC indicators have a Probability of Detection (POD), but are not perfect and include a false alarm rate (FAR). The QC optimum between POD and FAR may depend on the user application.

We assume that the convolved NRCS footprints used in the retrieval provide the spatial resolution (~25 km) of a Wind Vector Cell (WVC). Since temporal changes in the mean wind in a WVC are small over the measurement time window of the contributing NRCSs, typically a few minutes, we assume that the temporal acquisition is instantaneous. This provides a clear definition of the scatterometer space and time representation. In validation we confront these winds with buoy or model winds, which have a different resolution and hence for validation we need to account for the representativeness error.

Survey of Quality Control (QC) Indicators : *MLE*



Visualization of CMOD5.n and the ASCAT triplets (dots) in 3-D measurement space for WVC number 42 for wind speeds up to 30 m／s (Jeroen Verspeek, Ad Stoffelen, Marcos Portabella, Hans Bonekamp, Craig Anderson, and Julia Figa Saldaña. 2009)

MLE: Weighted Euclidian distance to the cone

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

σ_i^o *is the ith NRCS of the N NRCSs within a Wind Vector Cell (WVC),*
K_{pi} *represents the variance of* σ_i^o *in it.*
σ_{sim_i} *is from a wind GMF using observing geometry and local wind vector information.*
.

(Marcos Portabella and Ad Stoffelen, 2006)

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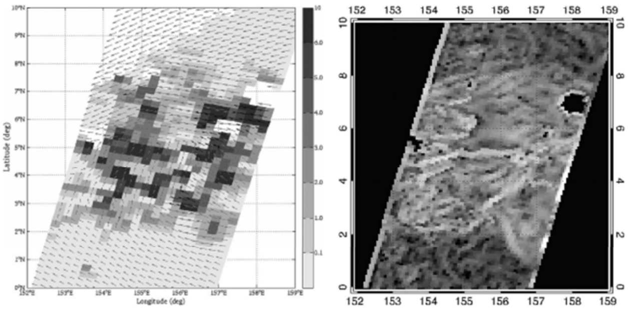
Measurement and Geophysical Model Function (GMF) uncertainties: Are generally small (~2%), but reproduceable or systematic;

- In NRCS calibration lead to wind vector errors;
- In bias term of GMF may lead to wind speed PDF variations;
- In harmonic terms of the GMF may lead to wind direction errors;
- Systematic wind speed errors have associated wind direction errors and vice versa;
- In missed or incompletely modelled processes, such as rain, wind variability, sea state, etc., generate errors of QC class;

These latter errors often result in large deviations from the GMF, hence cone, defined by $\frac{1}{N}\sum_i^N \frac{\left(\sigma_i^o - \sigma_{si\ \ i}\right)^2}{(K_{pi}\bullet\sigma_i)^2}$, where *i* for changing speed and direction of the stress-equivalent wind.

Survey of Quality Control (QC) Indicators: *SE*



Left: The grayscale square areas superimposed correspond to different TMI RRs. The white background corresponds to no TMI RR data available. Right: Singularity map of the ASCAT-retrieved wind field. The map is constructed as the minimum exponents of the singularity maps associated to the u and v wind components.(Marcos Portabella, Ad Stoffelen, Wenming Lin, Antonio Turiel, Anton Verhoef, Jeroen Verspeek, and Joaquim Ballabrera-Poy. 2012)

h(x), Singularity Exponent (SE) indicates the local spatial variability of winds.

$$h(x) = \frac{\log[T_\psi||\nabla s||(x,r)/<T_\psi||\nabla s||(\cdot,r)>]}{\log r_0} + o(\frac{1}{\log r_0})$$

$T_\psi||\nabla s||$. *is represented by the zonal* (u) *and meridional* (v) *wind components of the selected winds after MSS, including spatial variations in MLE.*

(Wenming Lin, Marcos Portabella, Antonio Turiel, Ad Stoffelen, and Anton Verhoef, 2016)

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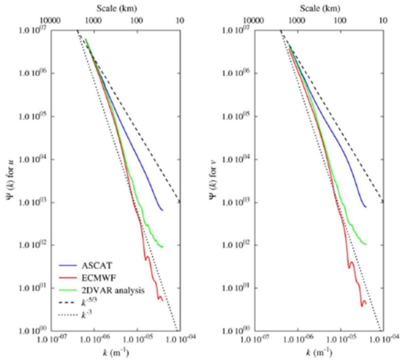
Singularity Exponents (SE) express the evaluation of spatial derivatives, which may be associated to the noise in the smallest scales due to unresolved signal from inadequate measurements, GMF, inversion, or wind direction ambiguity removal (MSS). Since atmospheric wind turbulence at the scatterometer scales is 3D it display well-defined power-law behavior and spatial heterogeneity or singularities may be detected by the SE. Rain clouds are in particular spatially heterogeneous. Negative SEs correspond to either local wind speed drops or peaks, as it does not make distinction between these, since it just triggers on local gradient amplitude.

Survey of Quality Control (QC) Indicators: J_{oss}



Wind component spectra obtained from all ASCAT-12.5 data of January 2009. A variational data assimilation scheme based on statistical interpolation acts as a low-pass filter.(Jur Vogelzang, Ad Stoffelen. 2011)

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

$$J_{oss} = f - f_S$$

f_S. is the 2DVAR analysis wind speed at a WVC,
f. is the local WVC-selected wind speed.

(Xingou Xu, Ad Stoffelen 2020)

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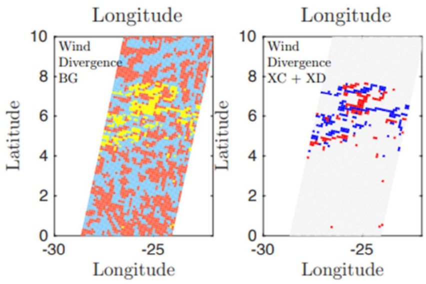
Like SE, a Joss field also expressed the evaluation of spatial derivatives due to local perturbations, in this aspect, it is similar to SE. And rain clouds are in particular spatially heterogeneous and generally cause negative Joss for wind speeds below 15 m/s.

Introduction & Survey of Quality Control (QC) Indicators



Tropical moist convection causes both extreme convergence (updrafts) and divergence (downdrafts) This figure shows wind divergence calculated for the test case (an ASCAT pass over the tropical mid-Atlantic). (Gregory P. King, Marcos Portabella, Wenming Lin and Ad Stoffelen, 2017)

- *Moist convection is spatially heterogeneous due to wind updrafts and downdrafts;*
- *Fast moist convective processes are not well tracked by NWP models, due to lack of observations for initialization and lack of resolution;*
- *Wind & rain in ITCZ are important in:*
  - *Nowcasting of rain and Tropical cyclones (TC);*
  - *Understanding the Hadley circulation;*
  - *Tropical and sub-tropical interactions for climate research.*

(David J. Raymond, 1999; Talia Tamarin-Brodsky, Kevin Hodges, B. J. Hoskins and Theodore G. Shepherd, 2020)

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From the indicators survey, we notice that rains are typical examples for heterogenous cause uncertainties. Extreme tropical convergence and divergence in ASCAT is associated to moist convection (King et al., 2017), but for Ku-band scatterometers rain clouds will interfere with these wind signals. Since the most featured part in our global is the Intertropical Convergence Zone (i.e. the famous ITCZ) where wind and rain are important. Here in this research, we focus on rain effects from the indicators mentioned above for latitude ranges [-20 20] degrees, where generally ITCZ lies.

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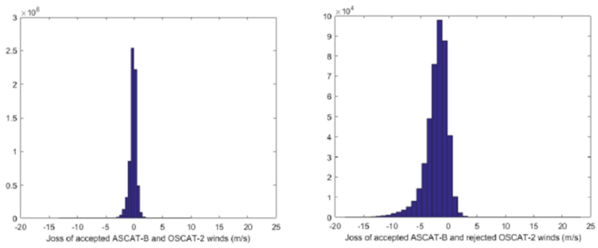
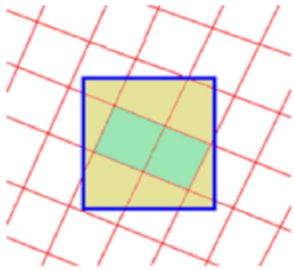
Data Descriptions

- Wind References — 2DVAR winds



The 2-DVAR wind speed distribution is close to that of the accepted ASCAT-B wind speed. (Xingou Xu, Ad Stoffelen, 2020)

- Rain References—GPM IMERG-F



Quantitative rain effects from scatterometers with reference to both products can respectively be conducted. Spatially weighed rain rates registered to scatterometer WVCs (Figure). (Xingou Xu, Ad Stoffelen and Jan Fokke Meirink, 2020)

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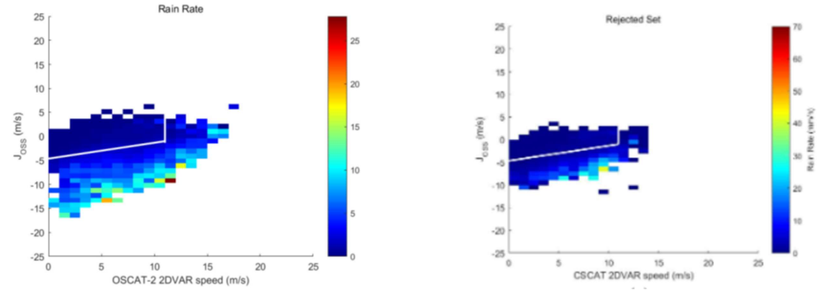
Left: If both ASCAT and collocated ScatSat (OSCAT-2) winds are accepted, then they have a 0-centered and narrow wind speed difference PDF. Rejected ScatSat winds (ASCAT accepted) provide rather skewed differences with respect to ASCAT due to the presence of rain clouds. Right: Collocated ASCAT and ScatSat winds may be further collocated with rain products from GPM or MSG. Spatial convolution of the rain products with the scatterometer resolution cell enhances the correspondence between the products.

Data Descriptions



The consistency in the percentage of FAR reduction suggests that similar rain conditions affect the wind retrieval of the CFOSAT rotating-fan-beam scatterometer (CSCAT) to those affecting existing rotating-pencil-beam scatterometers (in the sweet swath, node No.: 5~18 & 22~38).
(Xingou Xu, Ad Stoffelen, Wenming Lin and Xiaolong Dong, 2020)

- CSCAT Ku-band observations in tropical regions, i.e., with latitudes ranging from -20° to 20° are used. March 2019 of CSCAT version 3.0 winds from NSOAS are applied.

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OSCAT (left) and CSCAT (right) show very similar joint distributions of GPM rain, Joss and 2DVAR wind speed. Hence the same Joss QC thresholds can be applied (white line).

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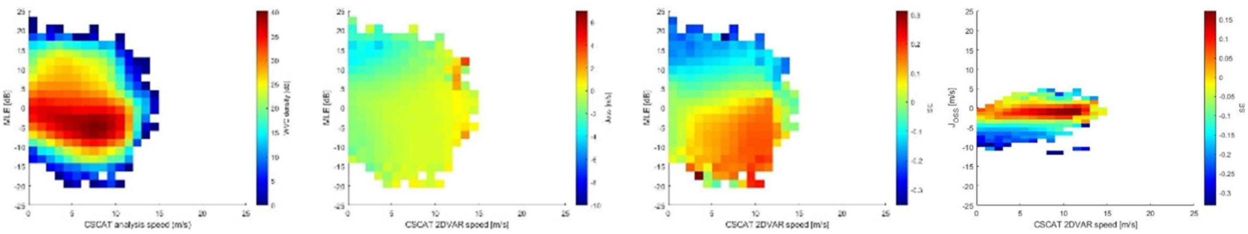
Rain Screening Ability of Indicators



(a) (b) (c) (d)

- J_{oss} and SE show similar features in (b) and (c), while (d) shows SE lines run horizontally along J_{oss} bins generally.
- J_{oss} and SE are very similar as quality indicator to detect spatial heterogeneities.
- Positive J_{oss} relate to negative SE, while we observe that these are not related to rain. Hence, -ve SE may either be rainy (-ve Joss) or mostly dry (+ve Joss)

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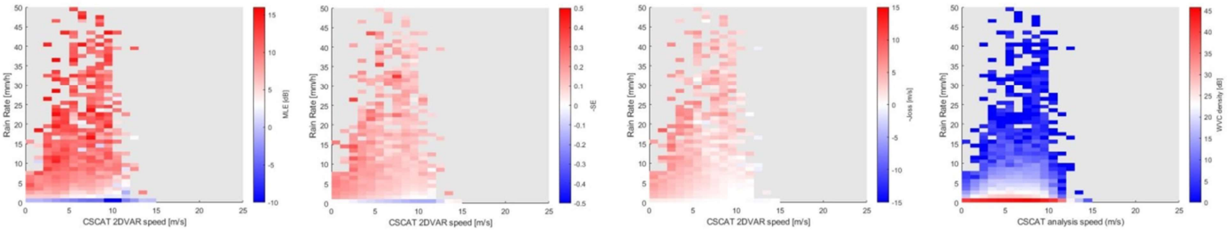
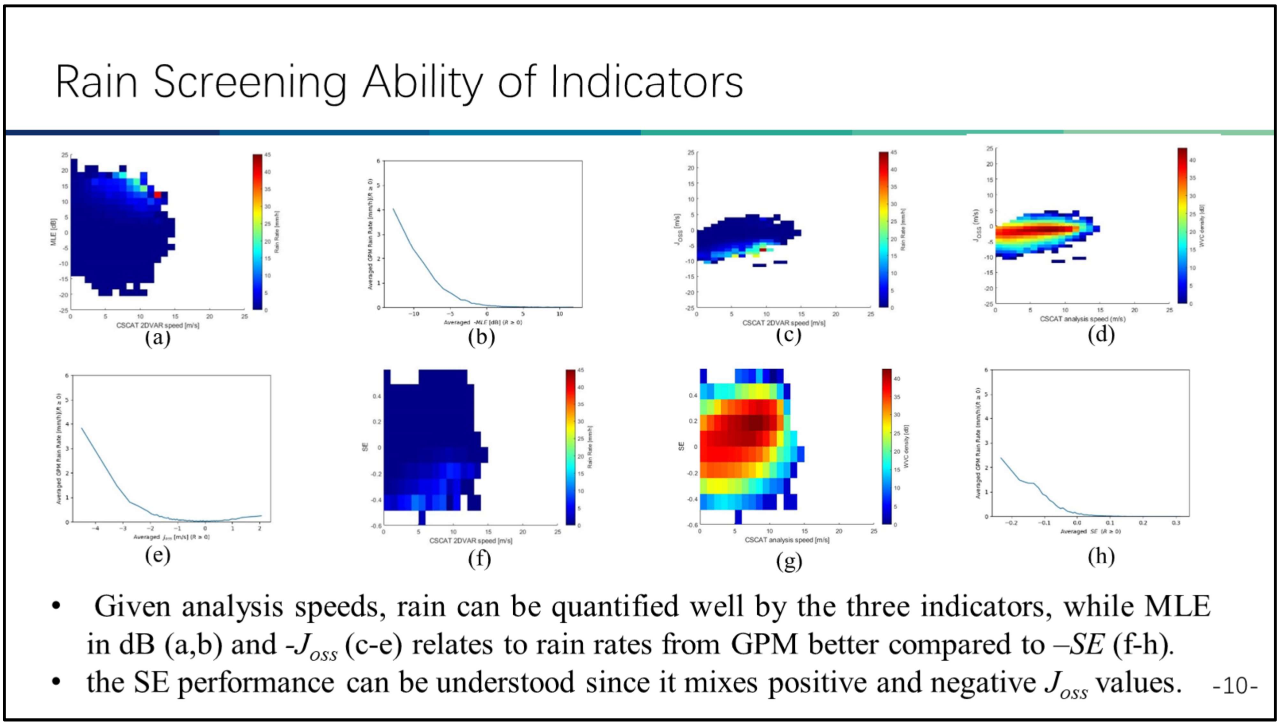
On this slide, the horizontal axis are CSCAT 2DVAR wind that is taken as wind without rains, vertical axis are MLE in (a)-(c). (a) shows WVC density in color. The color in (b) is Joss value , and in (c) is SE. From (b) and (c), we can see that J_{oss} and SE show similar features sorted by MLE, and they are very similar as quality indicator to detect spatial heterogeneities. In (d) the vertical axis is Joss, and color is SE. It can be seen that SE lines run horizontally along J_{oss} bins generally. This in addition to (a)-(c), shows further that Positive J_{oss} relate to negative SE, while we observe that these are not related to rain. Hence, -ve SE may either be rainy (-ve Joss) or mostly dry (+ve Joss)

Rain Screening Ability of Indicators



(a) (b) (c) (d)

- The values of indicators are sorted by rain rates vertically for analysis speed on the horizontal axis. (a) shows MLE in dB, (b) is – SE and (c) depicts – Joss values. In (d), the number density of corresponding WVCs is provided in dB
- All indicators are least sensitive at high winds (12 m/s)



- Given analysis speeds, rain can be quantified well from the three indicators shown by color representing rain rates, WVC densities can be observed in (d) and (g). From (b), (e) and (h), shown are corresponding averaged rain rates in each bin (2,813 WVCs) of the indicators when they are arranged in ascending order. MLE in dB (a,b) and -J_{oss} (c-e) relates to rain rates from GPM better compared to –SE (f-h)
- the SE performance can be understood since it mixes positive and negative J_{oss} values.

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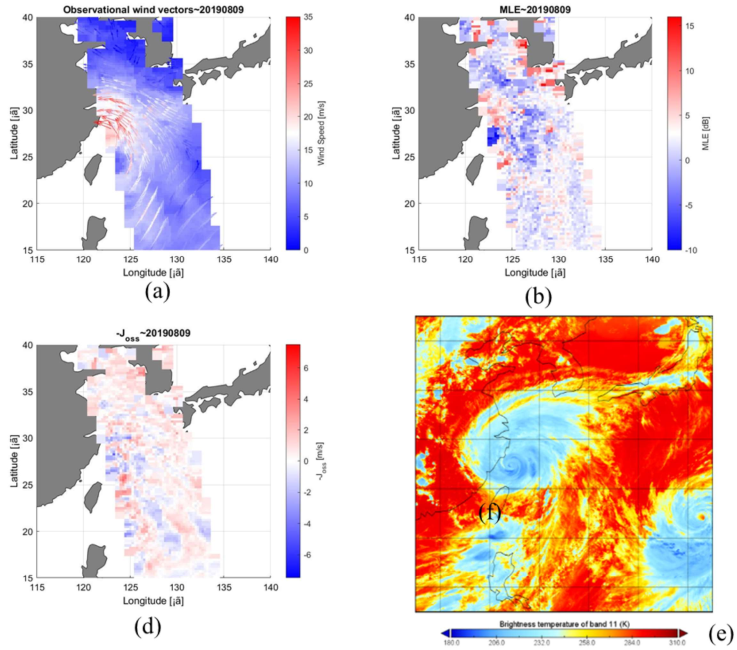
TCs in CFOSAT CSCAT



The super typhoon Lekima which is followed by Krosa and both are captured by CSCAT on the 9th of August 2019. Figures indicate Lekima. The Himawari images are from the 11th band. MI, 8.5926μm, 2 km resolution at tropics.

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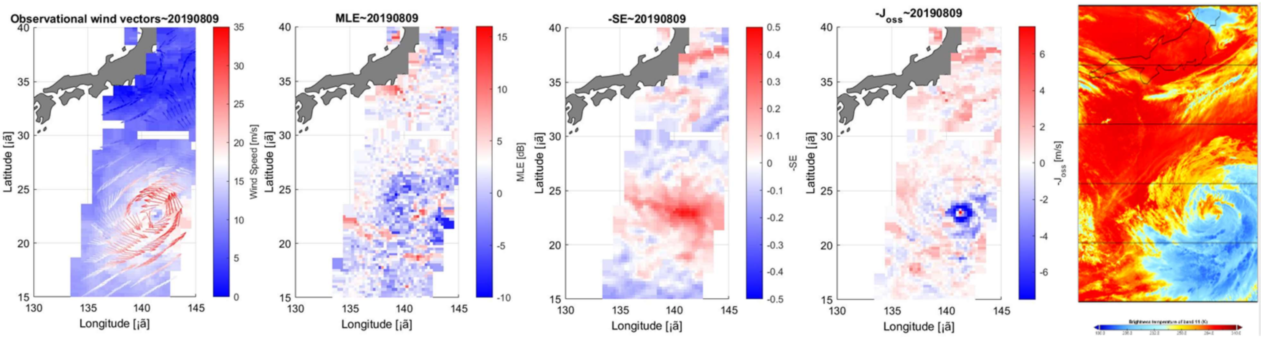
TCs in CFOSAT CSCAT



(a) (b) (c) (d) (e)

Figures for Krosa

- The three QC indicators behave quite differently near TCs
  - MLE values are high near the eye and rain bands;
  - SE is generally elevated near the TC centre;
  - Joss shows 2DVAR winds are too low near the eye wall

Contents

Information is the resolution of uncertainty.
-- Claude Shannon

- *MLE* and J_{oss} indicators are relatively independent from each other, and show different features in rain screening.
- The combined application of them results in a better rain labelling.
- The cases of Lekima and Krosa have demonstrated the application potential by further qualifying the indicators and relating them to rain to better resolve the accurate winds.
- *SE* and J_{oss} are similar indicators of spatial heterogeneity in scatterometer wind fields, but the wind speed depression measured by J_{oss} is a more unique indicator of rain than *SE*.

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- The National Aeronautics and Space Administration (NASA)
- The Japan Aerospace Exploration Agency (JAXA)

-- For the provision of the data products

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Thank You!

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