Impact of Sub-Cell Wind Variability on ASCAT Wind Quality

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Motivation

- ASCAT wind quality mainly depends on (sub-WVC) wind variability (Lin et al., TGRS 2015).
- ASCAT wind quality has been thoroughly assessed globally, but can we actually assess it for different wind variability conditions?
- Spatial and temporal wind representativeness depends on wind variability and therefore has to be accounted for when verifying ASCAT with buoy and NWP winds
- Triple collocation method can indeed be used for validation, but only when representativeness errors are well characterized

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Wind variability/quality indicators

- MLE or wind inversion residual as defined by *Stoffelen and Anderson* [1997]

$$\mathrm{MLE} = \frac{1}{3}\sum_{i=1}^{3}\left(z_{\mathrm{m}i} - z_{\mathrm{s}i}\right)^2$$

- The singularity exponent, derived from an image processing technique called singularity analysis, depicts the degree of local regularity (spatial gradient) around a given point **x** for a given scalar signal *s*.

$$\mathrm{SE}(\mathbf{x}) \,\square\, \frac{\log\left|\nabla s\right|(\mathbf{x})}{\log r}$$

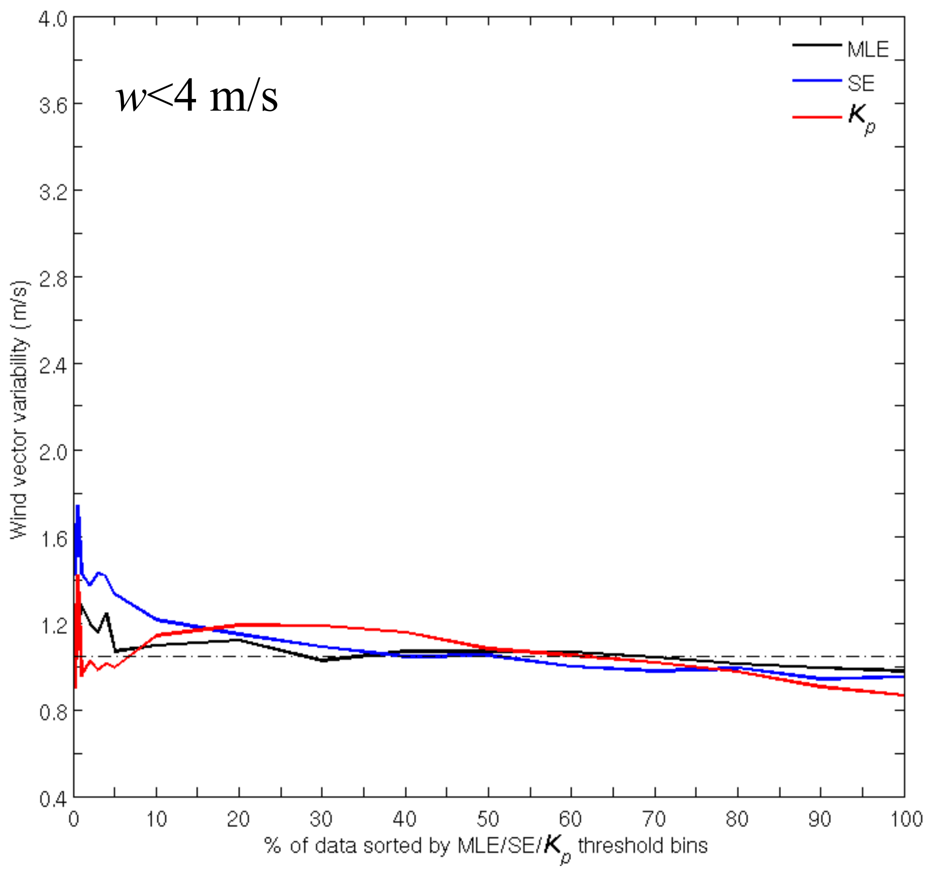
- The measurement noise or K_{p} is defined for ASCAT as the normalized standard deviation of the full-resolution backscatter measurements [*Chi et al.*, 1986; *Anderson et al.*, 2012]

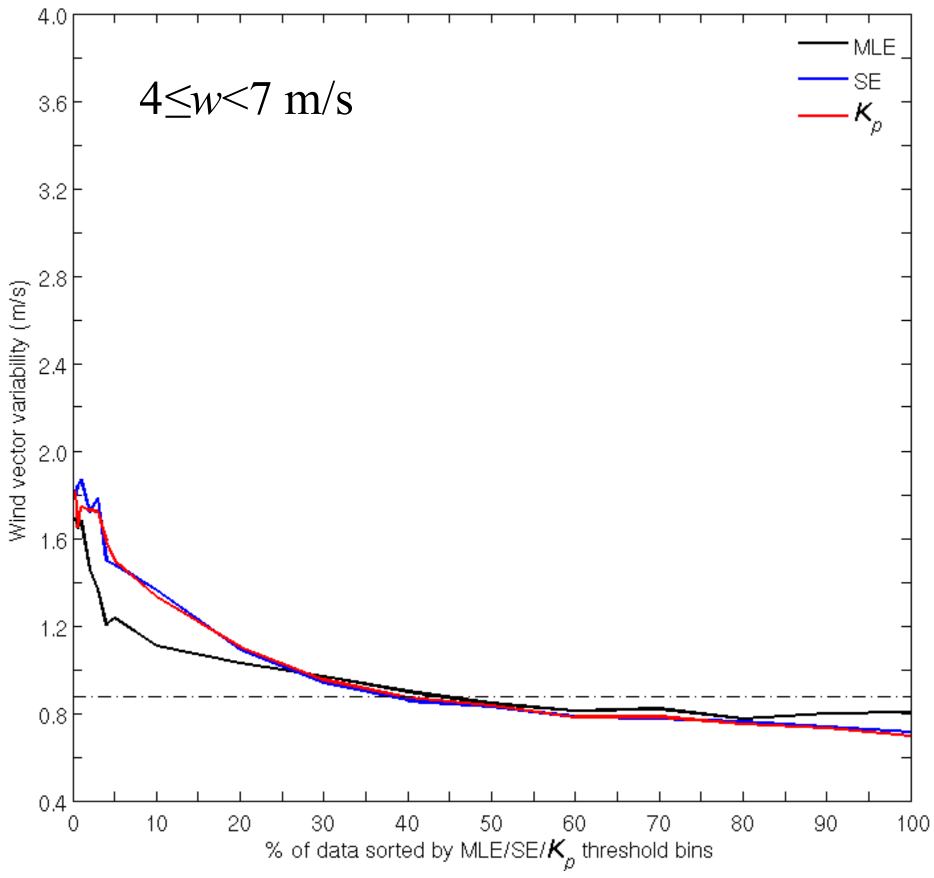
$$K_{\mathrm{p}} = \frac{\sqrt{\mathrm{var}(\sigma^0)}}{\sigma^0}$$

Wind variability/quality indicators

Wind vector variability (10-min buoy wind series) as a function of sorted indicators.

$$SD = \sqrt{\frac{1}{M-1}\sum_{i=1}^{M}\left(x_i - \bar{x}\right)^2} \qquad SD_{\text{vector}} = \sqrt{SD_u^2 + SD_v^2}$$





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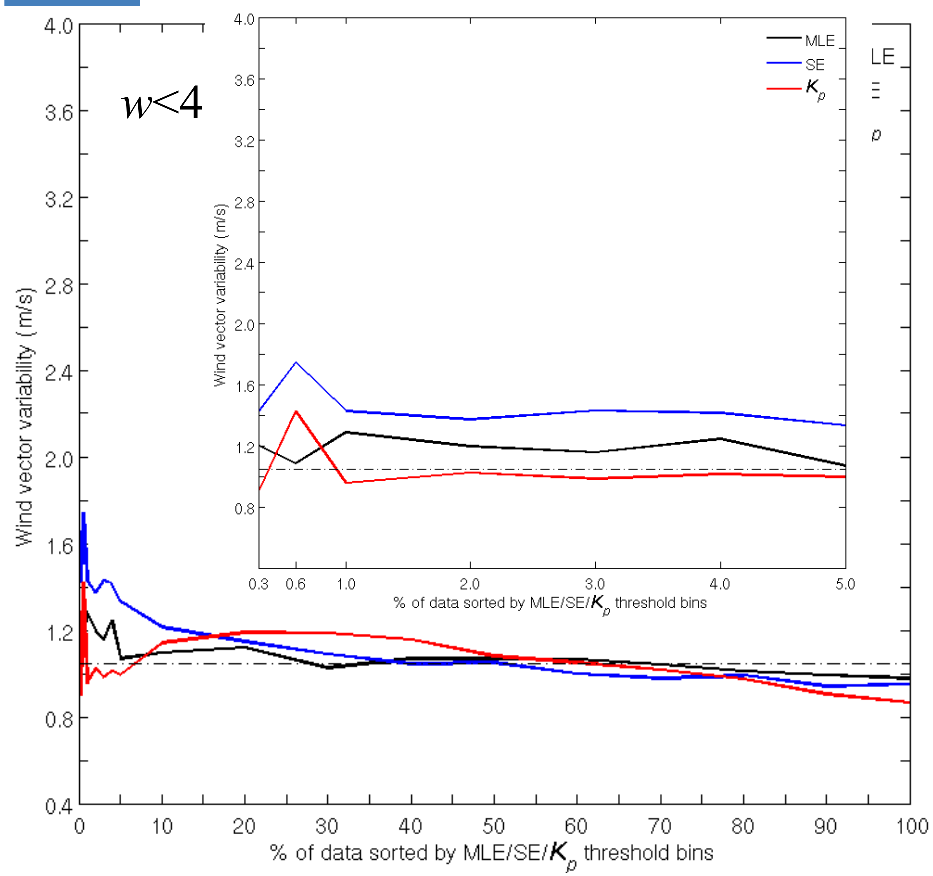

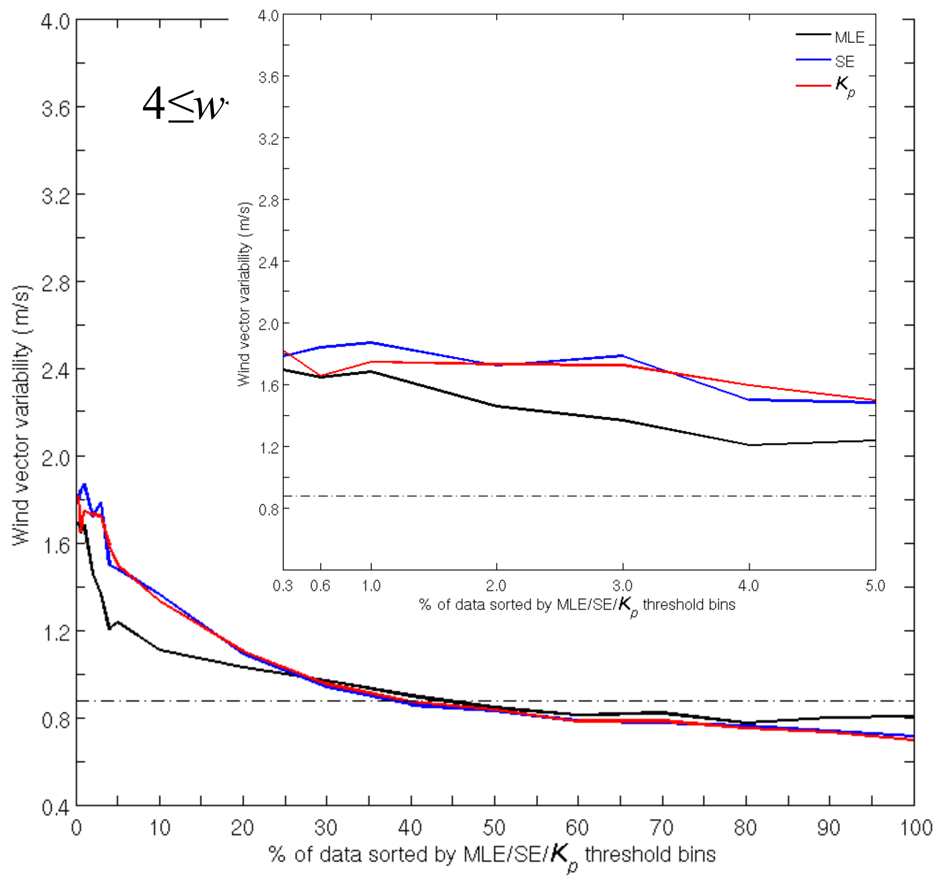

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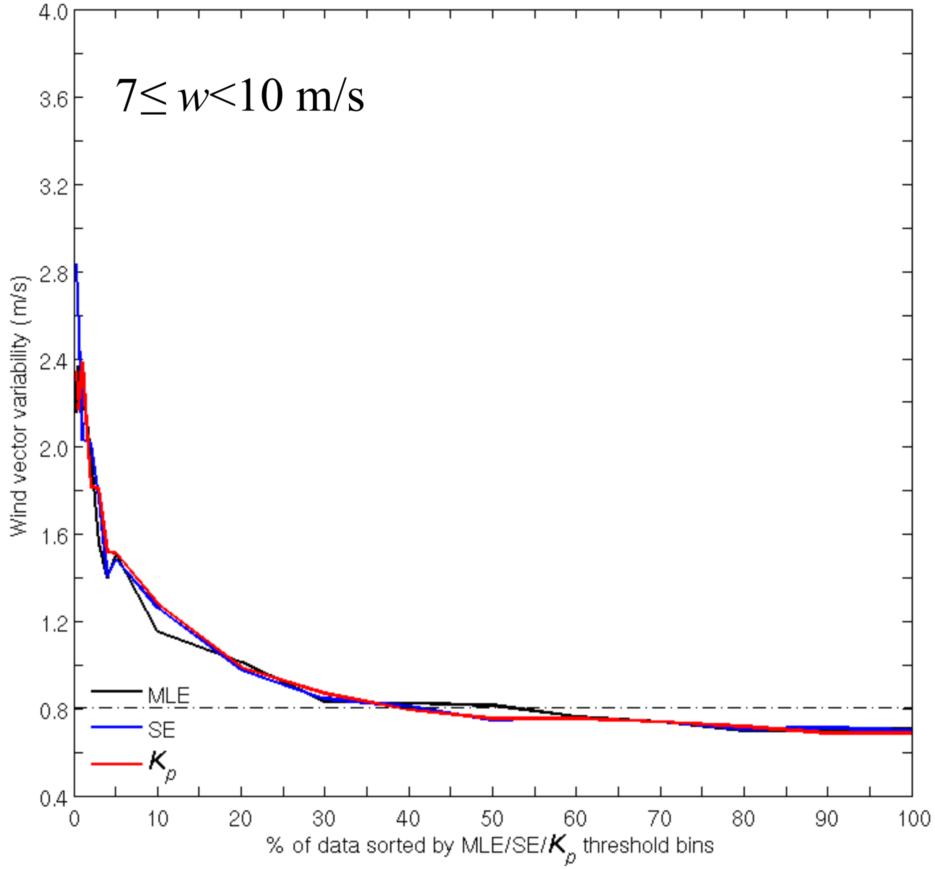

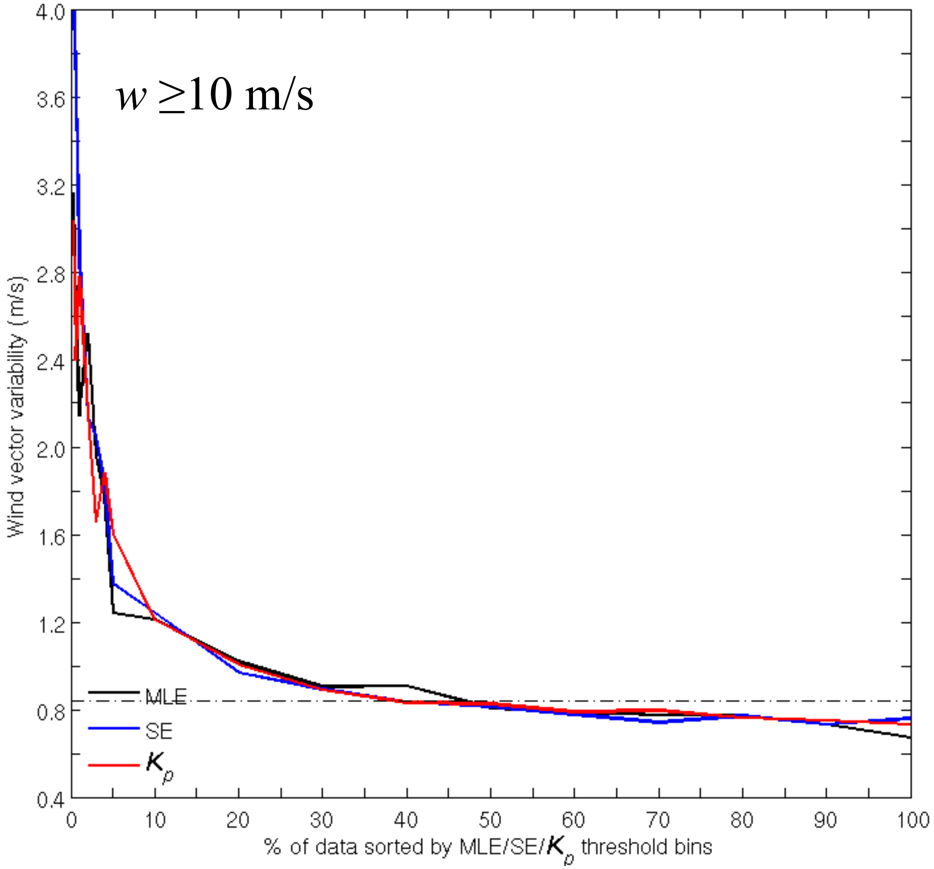

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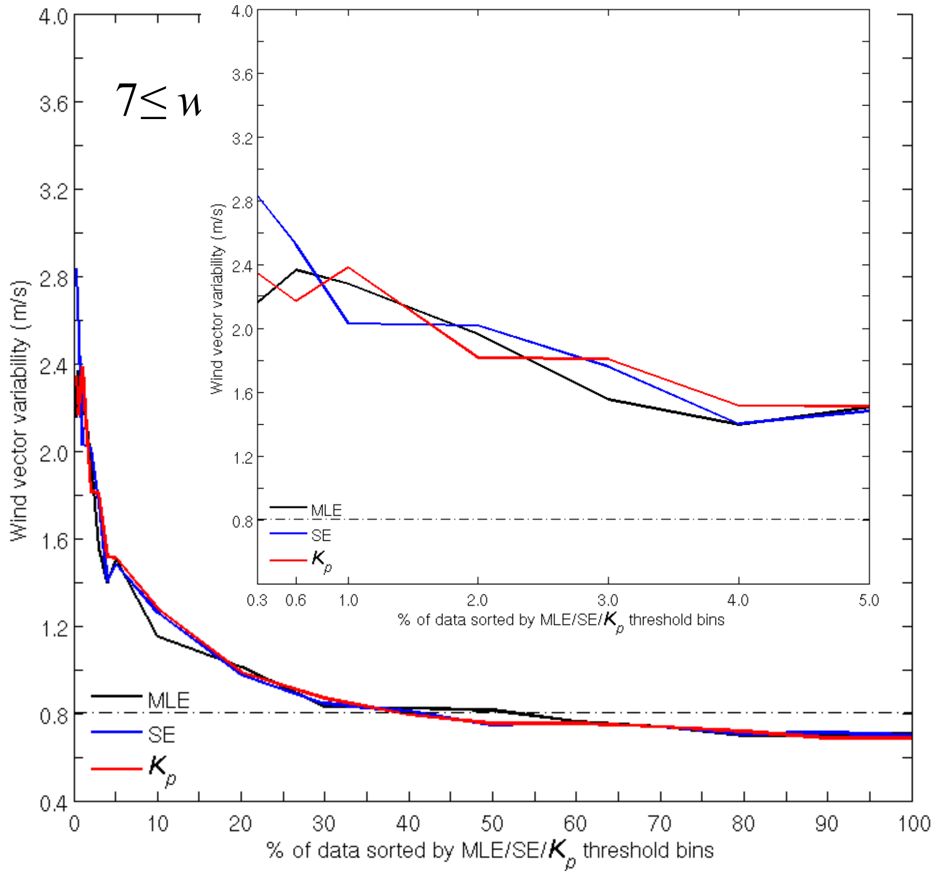

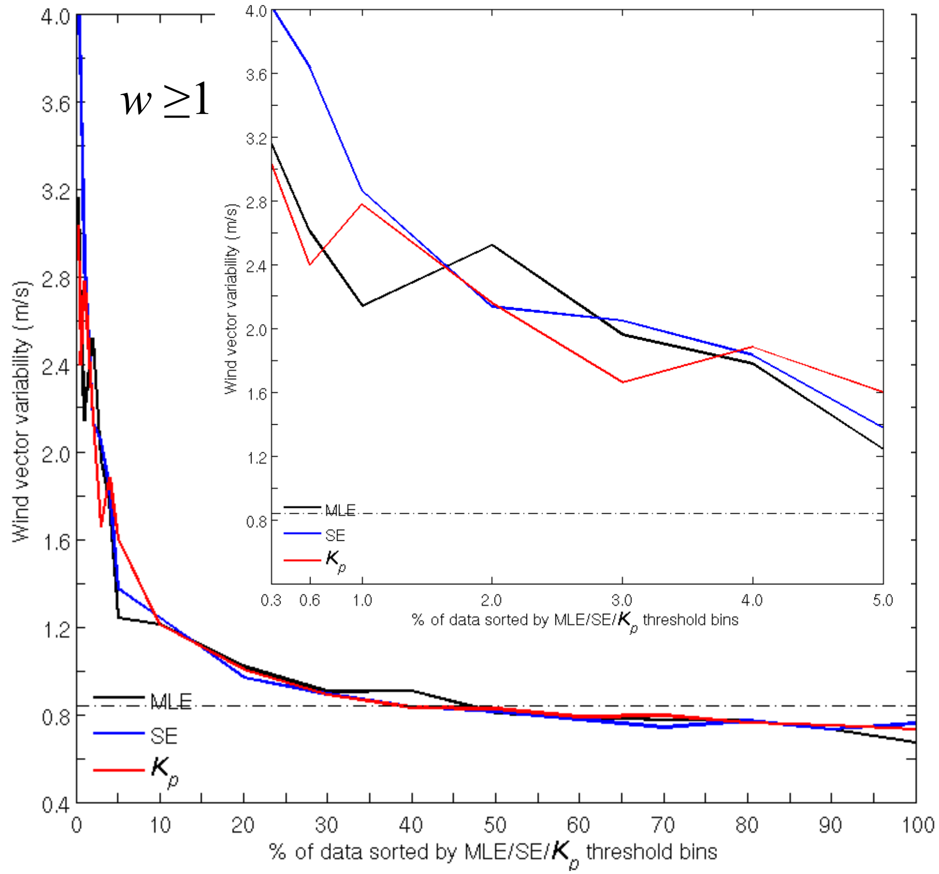

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Triple collocation analysis

Given three measurement systems W_i, i=1, 2, 3, which represent buoy, ASCAT and ECMWF respectively, the measurements are approximated by the following linear expression,

$$W_i = a_i w + b_i + \delta_i$$

- w the true wind at certain spatial scale
- a_i and b_i stand for the scaling and bias calibration coefficients
- δ_i random measurement error.

Wind component errors of different systems are all assumed to be uncorrelated, except for the representative error $r^2 = \langle \delta_1 \delta_2 \rangle$ [*Stoffelen*, 1998]

(1)
$$\begin{cases} M_{12} = a_1 a_2 \langle w^2 \rangle + r^2 \\ M_{13} = a_1 a_3 \langle w^2 \rangle \\ M_{23} = a_2 a_3 \langle w^2 \rangle \end{cases}$$

e.g., a3=1
b3=0

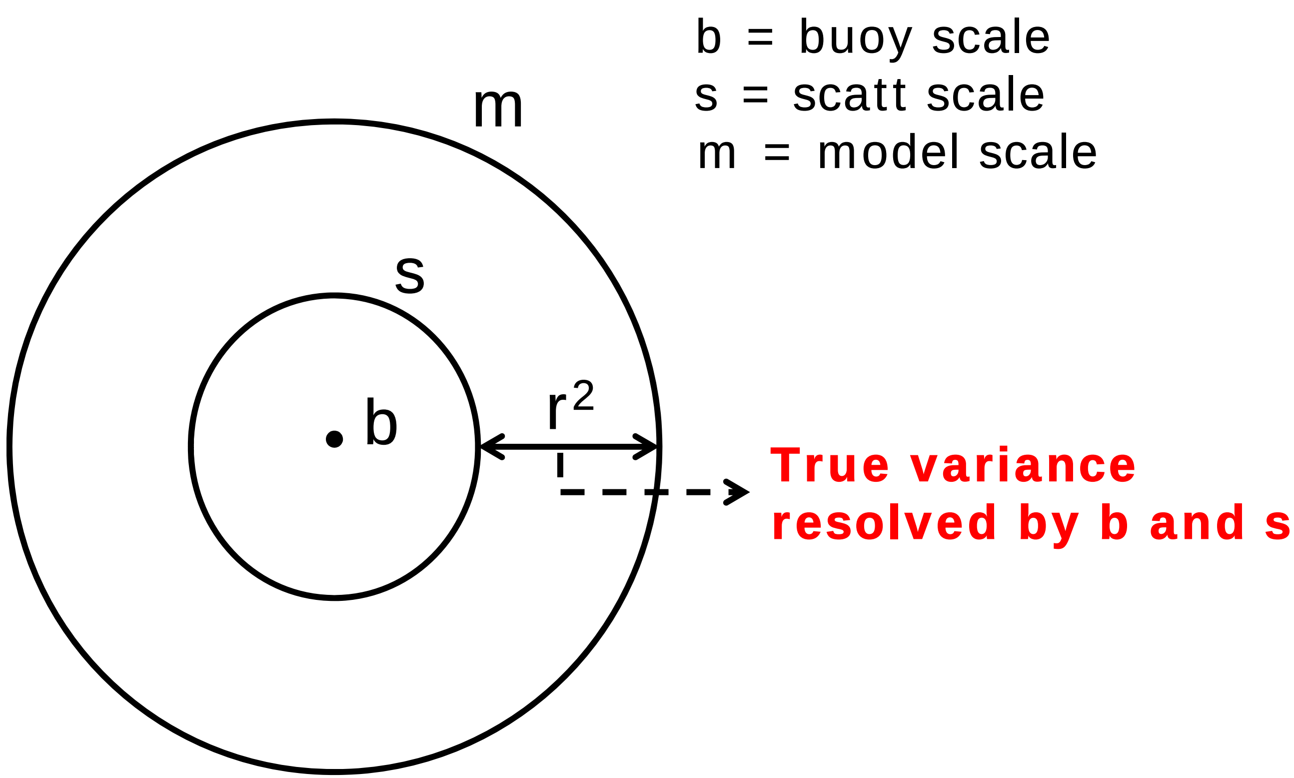
$$\begin{cases} a_1 = \dfrac{M_{12} - r^2}{M_{23}} \\ a_2 = \dfrac{M_{12} - r^2}{M_{13}} \end{cases}$$

Key parameter

(2)
$$b_i = M_i - a_i M_{ref} \quad (i \neq ref)$$

- TC is an iterative process in which the three sources are inter-calibrated (one source used as reference)
- r^2 has to be accurately estimated

Triple collocation analysis

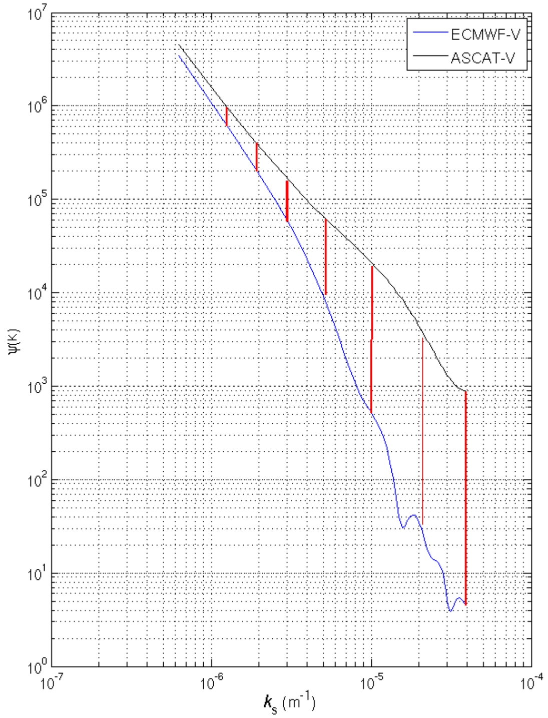


r^2 increases with wind variability!

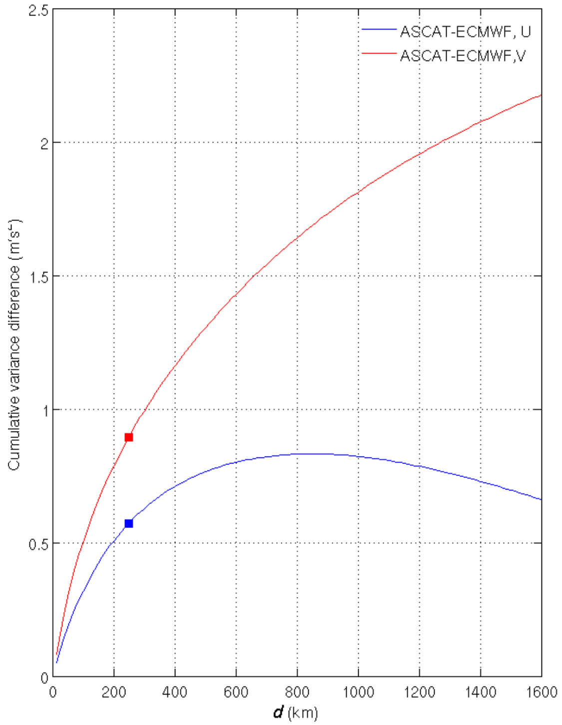
r2 estimation- global

Two different methods have been proposed to estimate r2.

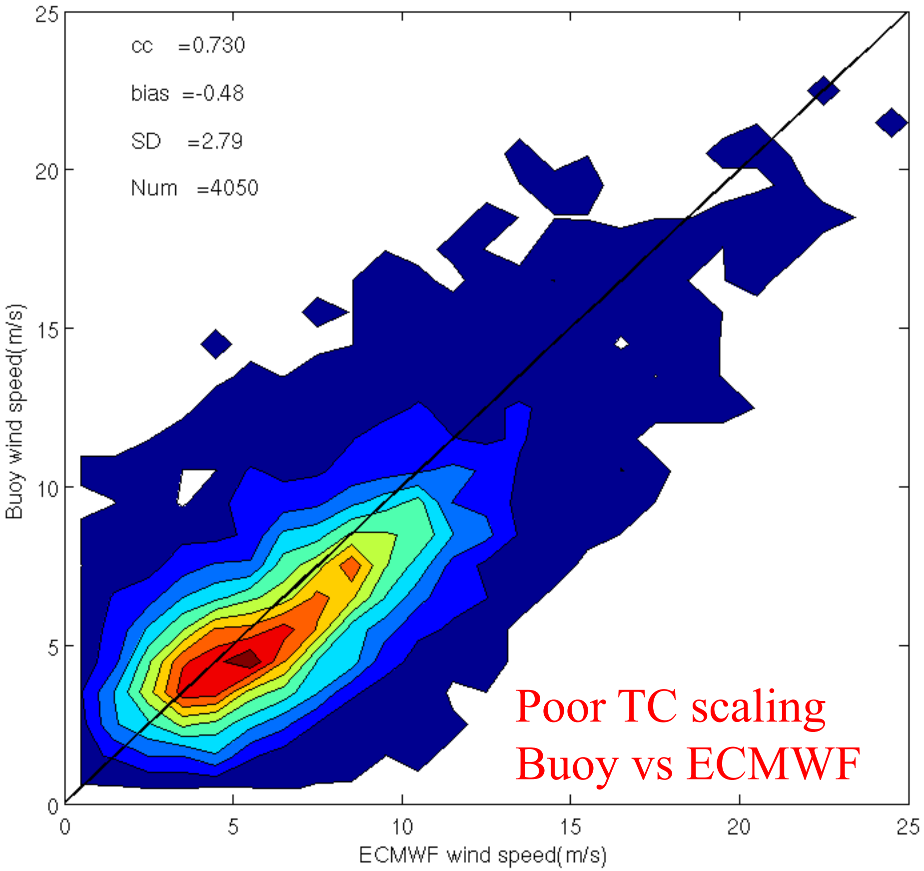
Spectra (Vogelzang et al., 2011)

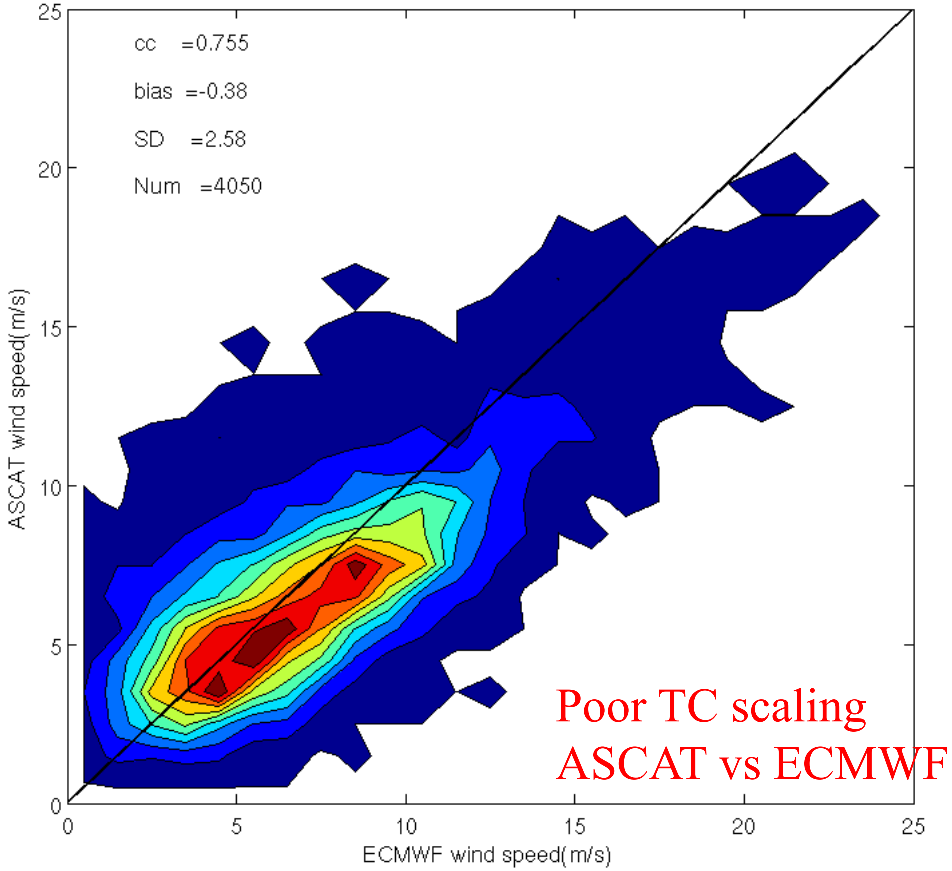


Spatial variance (Vogelzang et al., 2015)



To estimate r2 under increased wind variability conditions, an alternative method is required since increased wind variability is rather localized

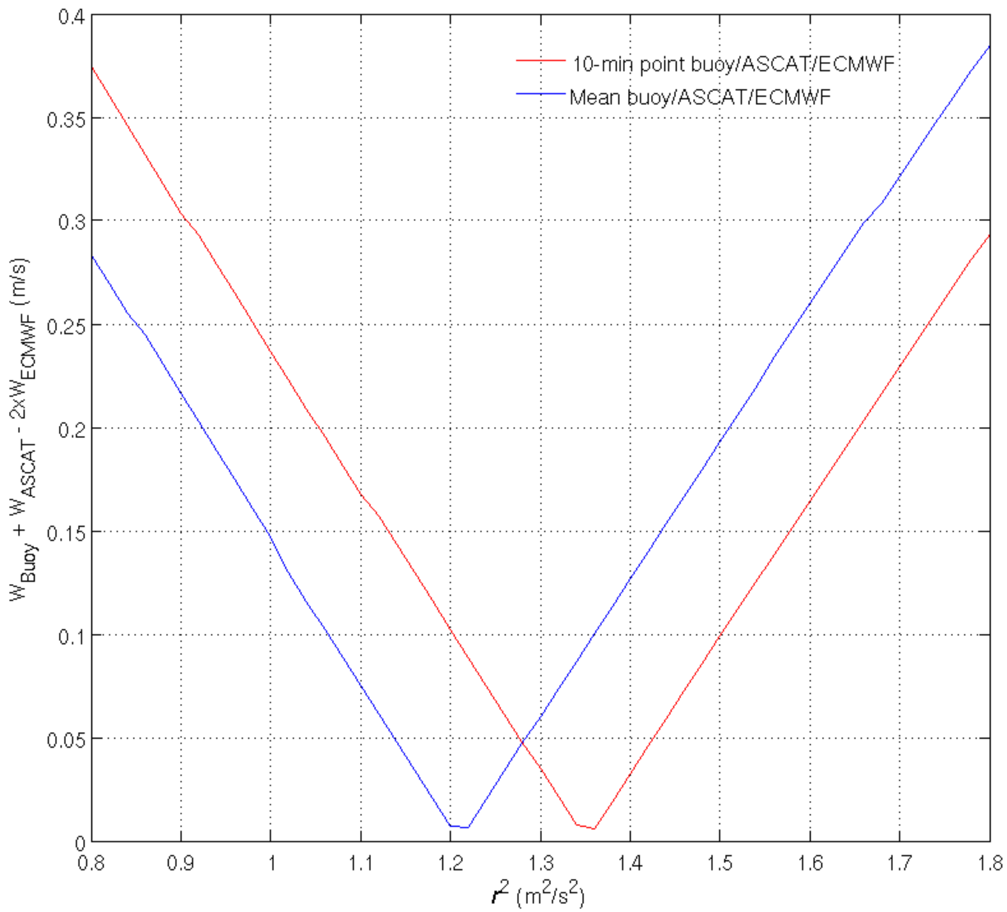




- Using spectra, negative r^2 values (e.g., the r^2 values of the u and v components are -0.01 and 0.55 respectively) are derived for the most variable 5% of data. [Similar results with the spatial method]

- **Note that poor TC scaling is achieved using the wrong r^2 values**

r2 estimation- variable conditions



ABS($w_{buoy}+w_{ASCAT}-2\times w_{ECMWF}$) as a function of r^2 values (e.g., the most variable 5% of data) for different collocation data sets.

r2 estimation- variable conditions

Representative errors for u (and v) components for different wind variability regimes. TC is carried out for: (top) 10-min buoy, ASCAT, ECMWF; (bottom) 25-km equivalent buoy, ASCAT and ECMWF.

	2% variable winds	2%-5% variable winds	5% variable winds	95% stable winds
10-min buoy winds	1.6 (2.4)	1.3 (2.0)	1.4 (2.1)	0.67 (1.00)
Mean buoy winds	1.1 (1.7)	1.0 (1.6)	1.1 (1.7)	0.60 (0.90)

Equivalent to spectra/variance method

TC results- Errors at ECMWF scales

10-min buoy wind

SD errors	Buoy (m/s)		ASCAT (m/s)		ECMWF (m/s)		Number
Categories	u	v	u	v	u	v	
95% stable winds	1.24	1.39	0.94	1.21	1.08	1.01	39340
2%-5% variable winds	1.8	2.0	1.4	1.9	1.9	1.7	1243
2% variable winds	2.4	2.2	1.7	2.5	2.3	2.1	829

mean buoy wind

SD errors	Buoy (m/s)		ASCAT (m/s)		ECMWF (m/s)		Number
Categories	u	v	u	v	u	v	
95% stable winds	1.08	1.24	0.93	1.19	1.08	1.02	39293
2%-5% variable winds	1.5	1.7	1.4	1.9	1.9	1.7	1243
2% variable winds	1.8	1.7	1.8	2.4	2.3	2.1	828

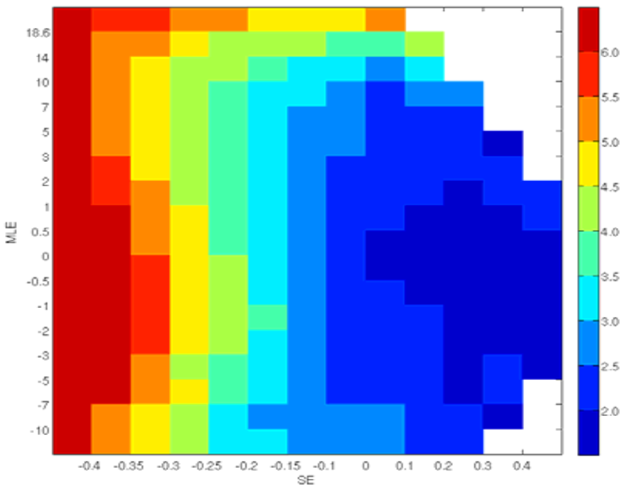
TC results- Errors at ASCAT scales

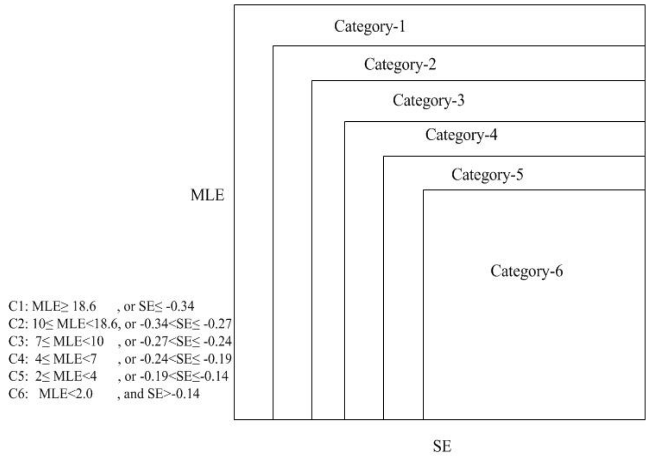
The error standard deviations at ***ASCAT*** scale of the triple collocation with **mean buoy winds**; the last column shows the number of collocations in each triple collocation after 4-sigma quality control. The accuracy of each estimated SD error is presented in parenthesis.

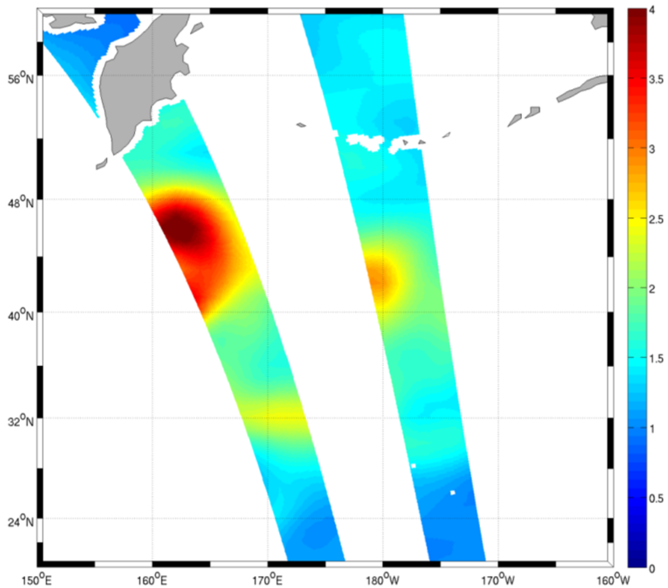
SD errors	Buoy (m/s)		ASCAT (m/s)		ECMWF (m/s)		Number
Categories	u	v	u	v	u	v	
95% stable winds	0.76 (0.01)	0.80 (0.01)	0.52 (0.01)	0.73 (0.01)	1.33 (0.01)	1.39 (0.01)	39293
2%-5% variable winds	1.1 (0.1)	1.1 (0.1)	0.9 (0.1)	1.4 (0.1)	2.1 (0.2)	2.1 (0.2)	1243
2% variable winds	1.5 (0.1)	1.1 (0.1)	1.4 (0.2)	2.0 (0.3)	2.5 (0.3)	2.5 (0.3)	828

- **As expected, errors increase with increased wind variability**
- **ECMWF errors are the highest**
- **ASCAT errors are the smallest, except for the highest wind variability category; still reasonable quality!**

Situation-dependent O/B errors





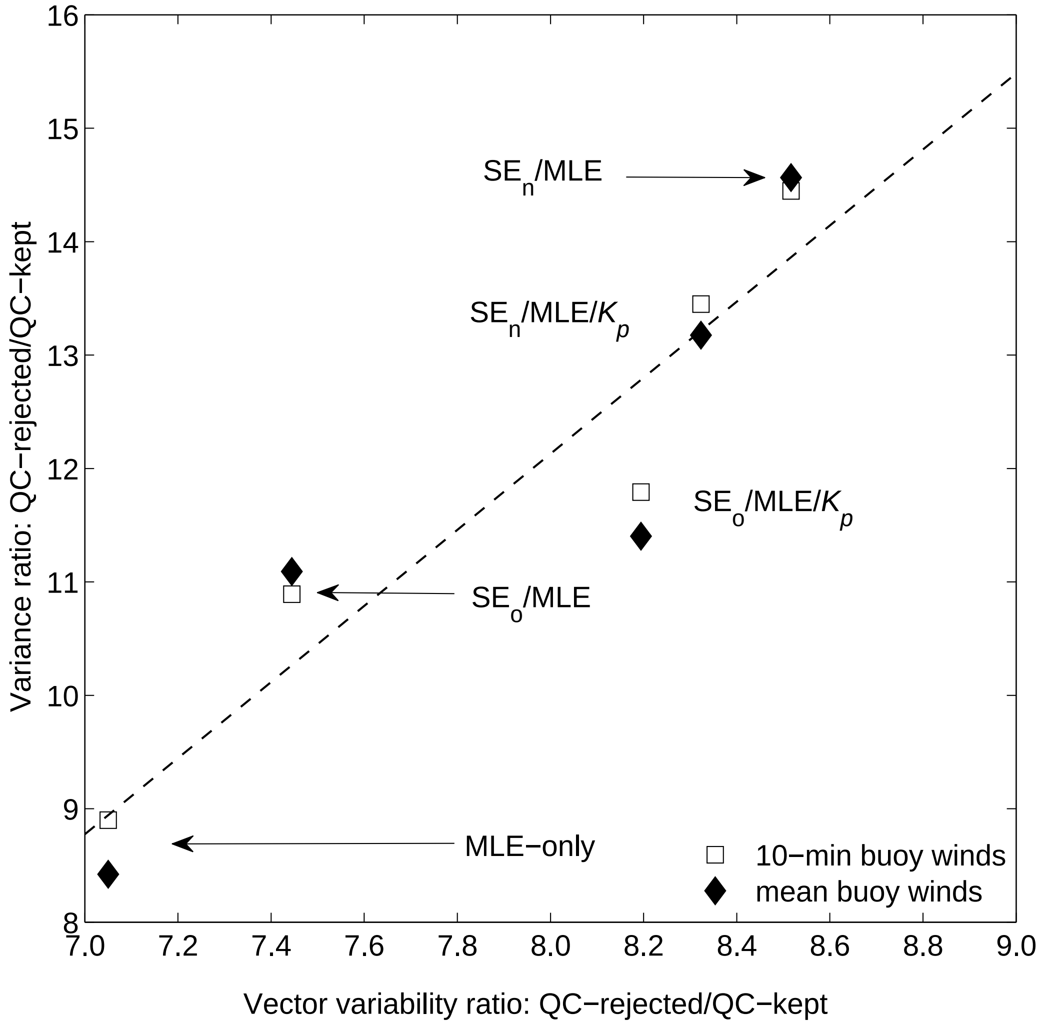


ECMWF Ensemble Data Assimilation
(EDA background error)

Conclusions

- MLE, SE, and K_p are indeed good indicators of wind variability
- The method presented results in accurate estimation of representativeness errors at different wind variability regimes
- Triple collocation analysis shows that:
  - As expected, errors increase with increased wind variability
  - ECMWF errors are the highest
  - ASCAT errors are the smallest, except for the highest wind variability category; still reasonable quality!
- Accurate estimation of situation-dependent O/B errors can be beneficial for scatterometer data assimilation

Wind variability/quality indicators



The variance ratio (w.r.t. buoy winds) between QC-rejected and QC-kept winds as a function of the variability ratio in these two categories.

TC results

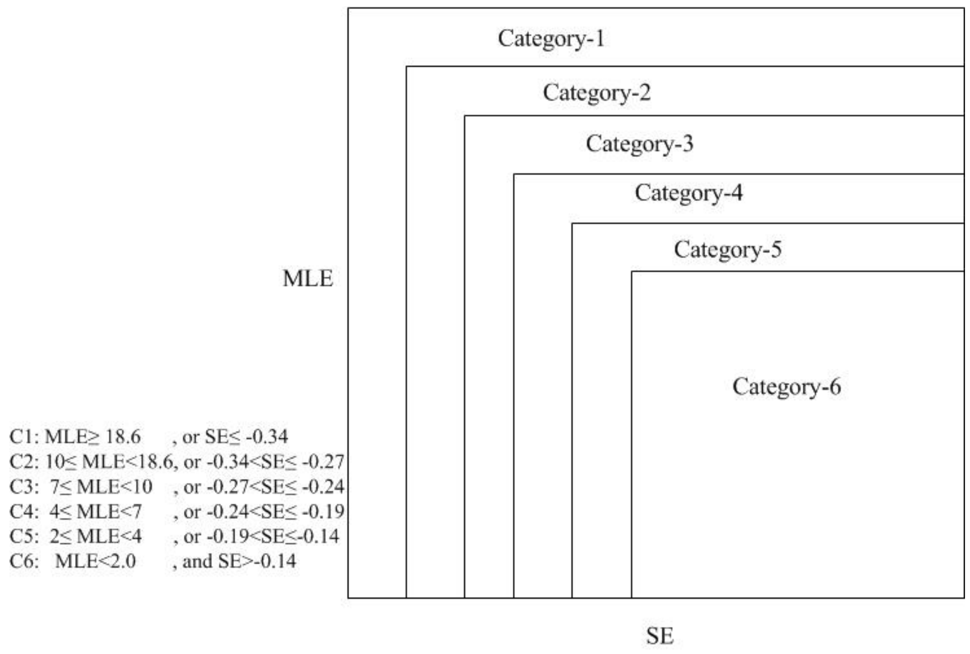
K_p, MLE, and SE are rather complementary, since they "measure" resp. backscatter variability at one azimuth/beam, variability between azimuths/beams in a WVC and inter-WVC variability. Consequently, it makes sense to combine these metrics. Here, the following simple combination of MLE, SE and K_p is used to flag the most variable ASCAT winds:

$$\mathrm{MLE} > T_{\mathrm{MLE}} \quad \text{or} \quad \mathrm{SE} < T_{\mathrm{SE}} \quad \text{or} \quad K_p > T_{K_p}$$

The optimum threshold combinations for flagging the 2% and the 5% most variable winds

	w<4 m/s		4≤w<7 m/s		7≤w<10 m/s		w≥10 m/s	
	2%	5%	2%	5%	2%	5%	2%	5%
MLE	-	-	25.5	25.5	5.44	25.5	25.5	25.5
SE	-0.26	-0.20	-0.35	-0.21	-0.32	-0.18	-0.34	-0.21
K_p	-	-	10.3	20.5	20.5	20.5	7.0	20.5

Implementation



Implementation

SD errors Categories	MARS Buoy (m/s)		ASCAT (m/s)		ECMWF (m/s)		Number
	u	v	u	v	u	v	
1	2.6 (0.4)	2.5 (0.4)	2.0 (0.3)	2.8 (0.5)	2.9 (0.5)	2.7 (0.4)	856
2	2.1 (0.2)	2.2 (0.2)	1.6 (0.2)	2.1 (0.2)	2.3 (0.3)	2.2 (0.2)	1156
3	1.9 (0.2)	1.9 (0.2)	1.3 (0.1)	1.7 (0.2)	2.1 (0.2)	1.9 (0.2)	1102
4	1.8 (0.1)	1.8 (0.1)	1.3 (0.1)	1.6 (0.1)	1.9 (0.1)	1.8 (0.1)	2569
5	1.55(0.06)	1.65(0.07)	1.12(0.04)	1.47(0.05)	1.61(0.06)	1.50(0.06)	4833
6	1.27(0.01)	1.42(0.01)	0.90(0.01)	1.13(0.01)	1.08(0.01)	1.00(0.01)	75293