Assessment of the impact of large sub-cell wind variability on ASCAT wind data quality

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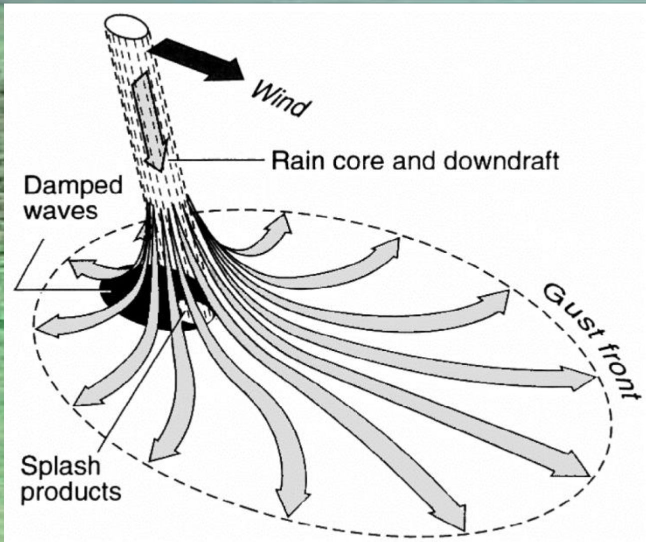
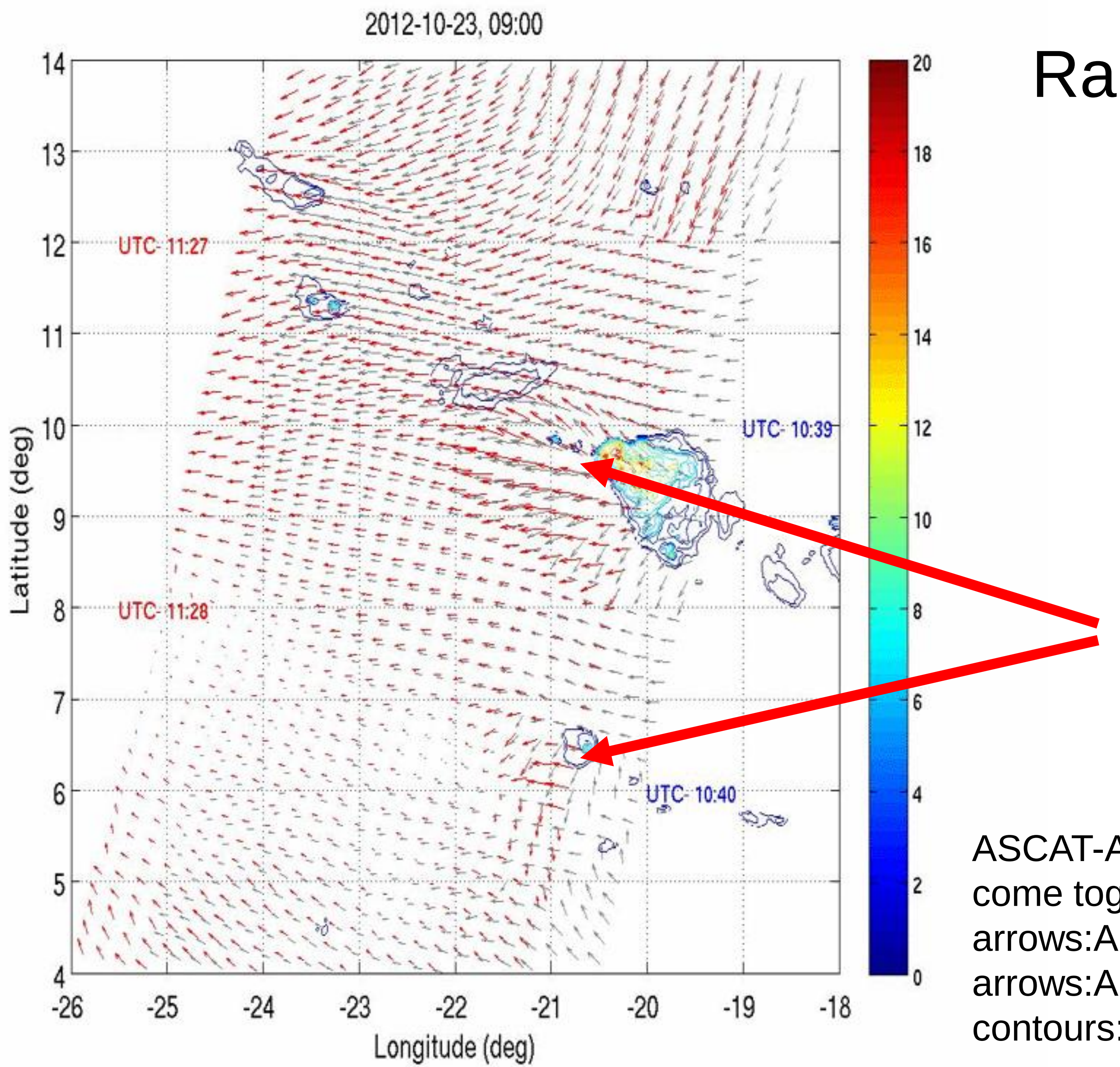


Institute of Marine Sciences

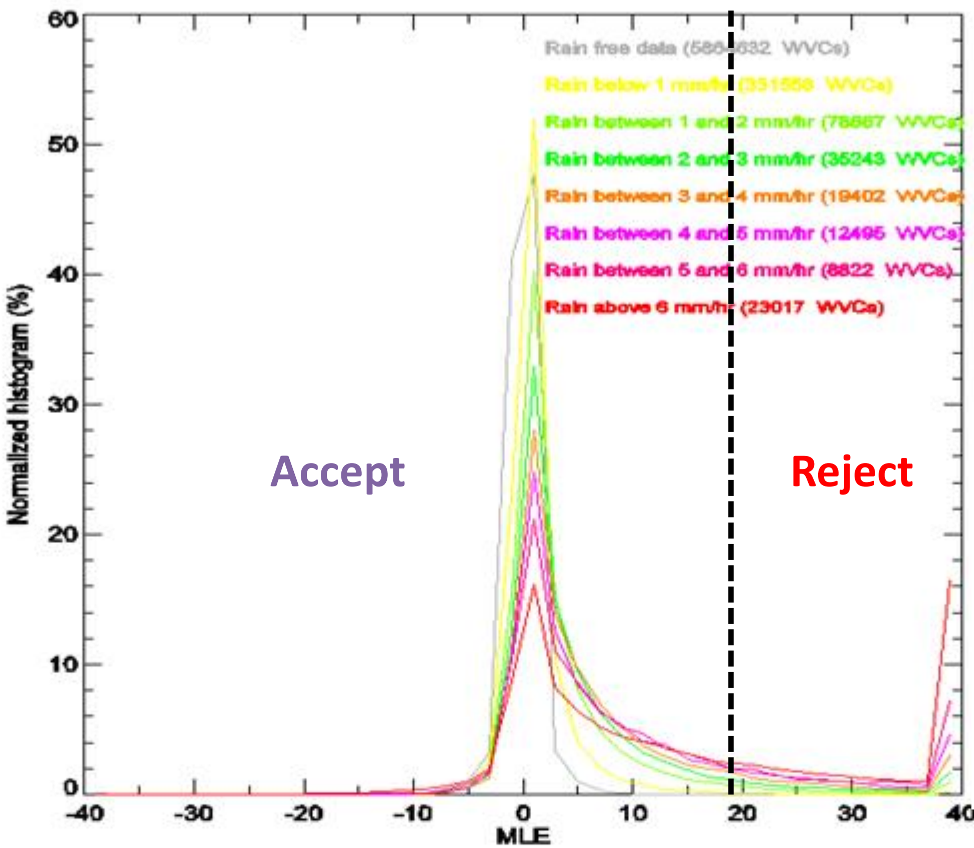
Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

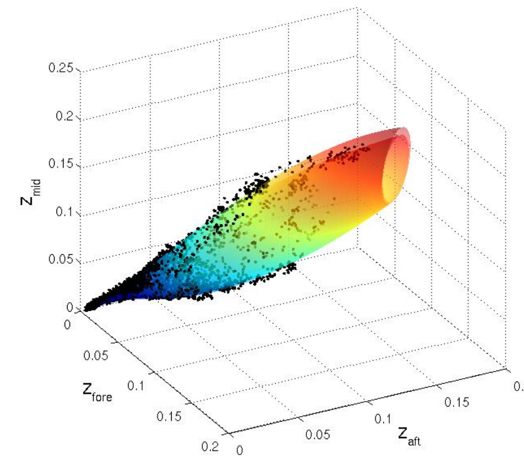
Rain Effects



ASCAT-A and ASCAT-B come together. Red arrows:ASCAT-A; Blue arrows:ASCAT-B; color contours: MSG RR.

Why complementary method to MLE-based QC method?

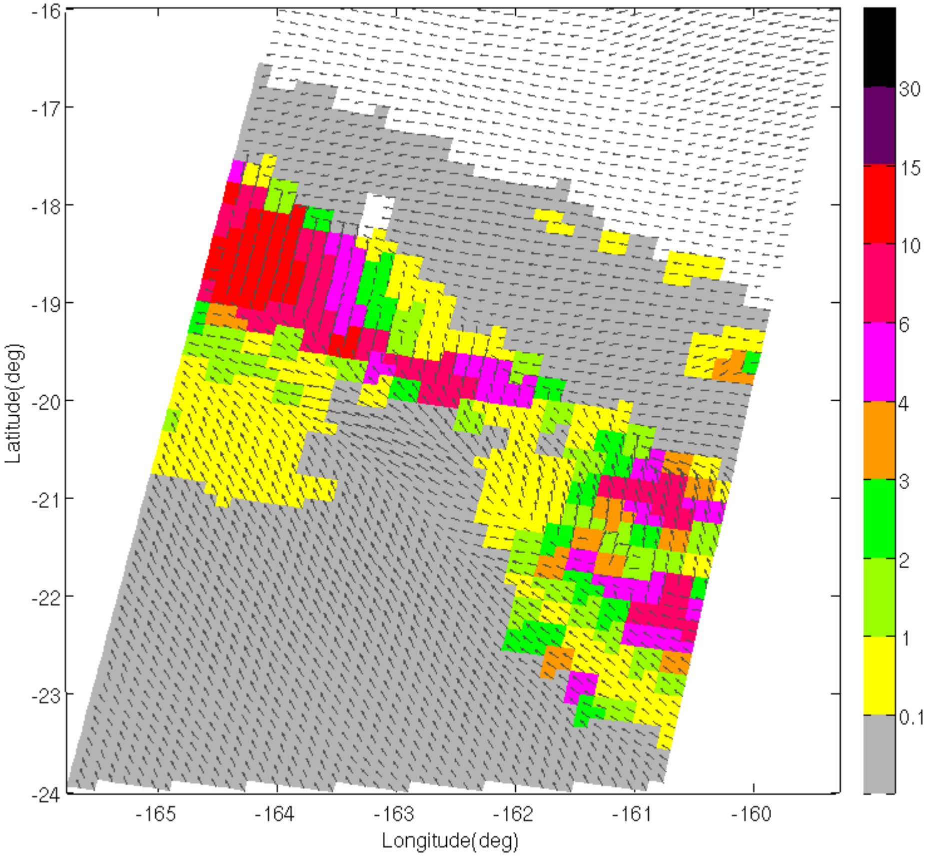




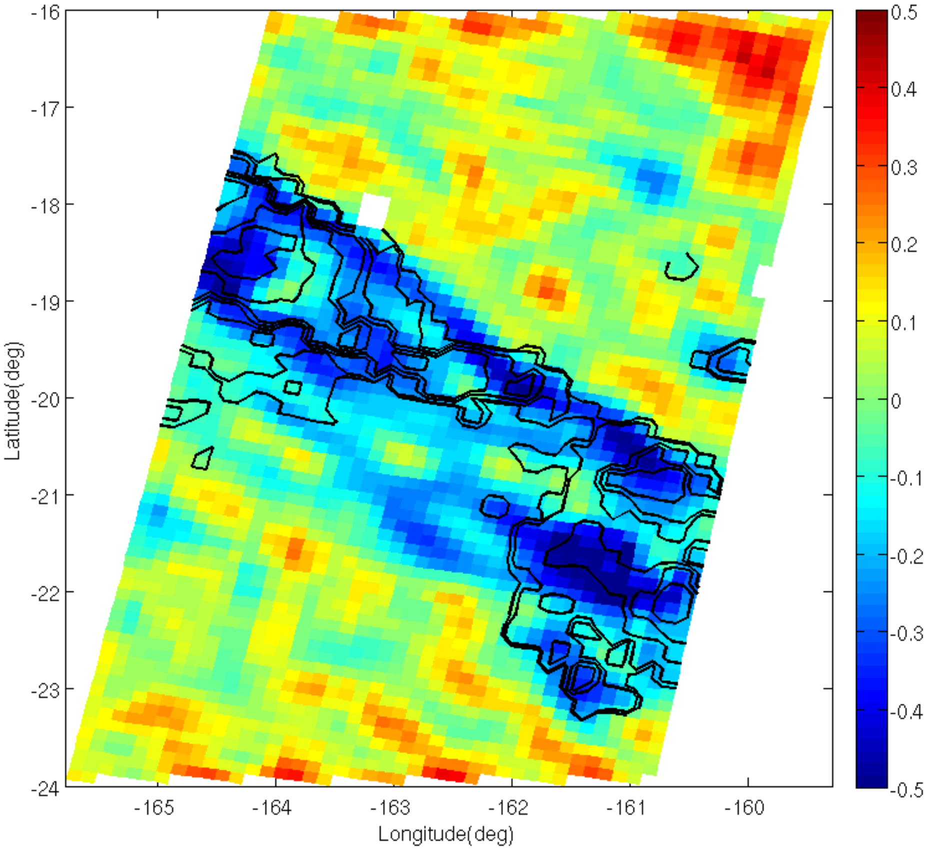
Category	Accept		Reject	
	Number	VRMS	Number	VRMS
Rain-free	2442	1.81	0(0)	/
Vicinity of rain	413	2.67	1(1)	/
Rain	181	4.36	11(10)	6.63

Validation: ASCAT-TMI

Validation: ASCAT-Buoy



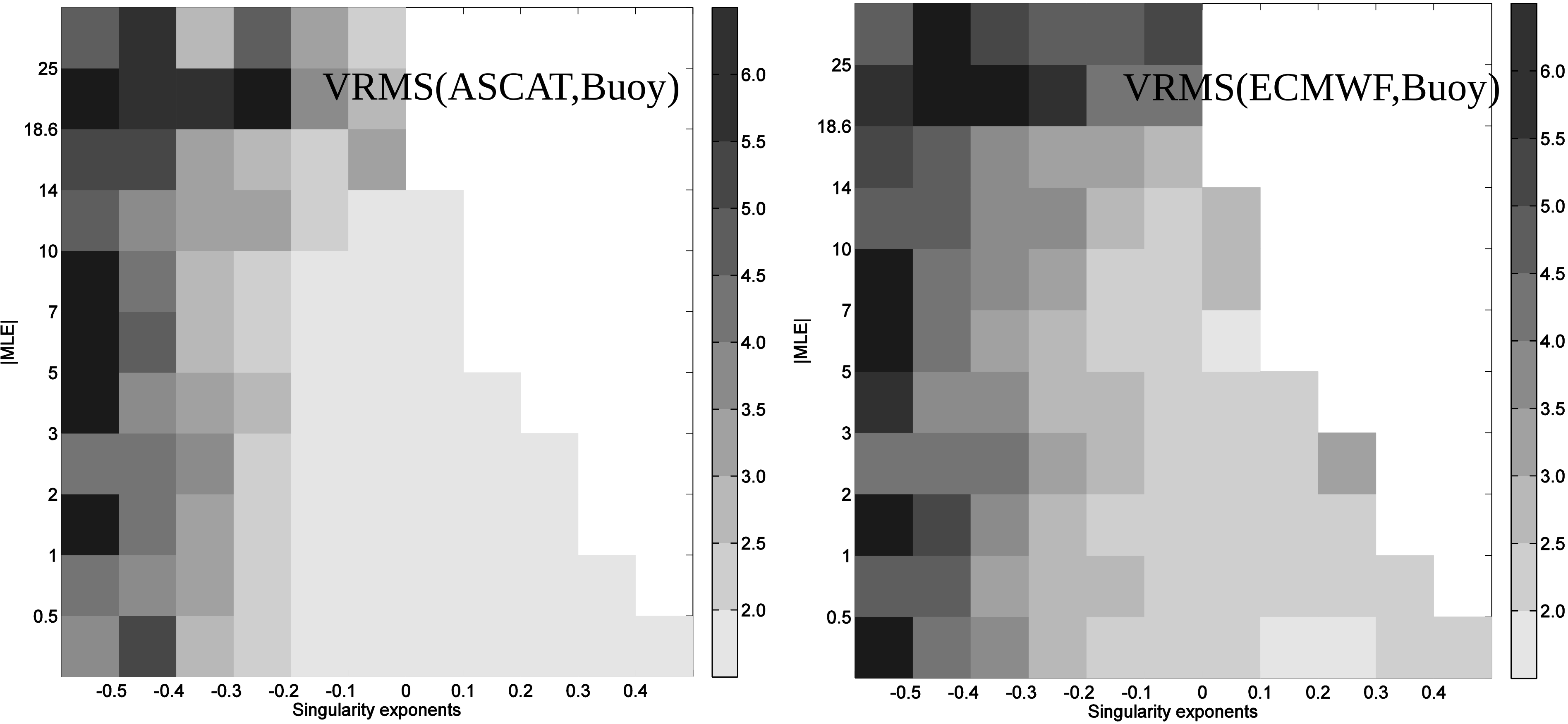
ASCAT-derived wind field collocated with TMI RR data at 20:30 UTC on 24 September 2008



Singularity map of the ASCAT-retrieved wind field. TMI RR data shown as contour lines

- **Good correspondance between TMI RR and negative SE values**

Quality control

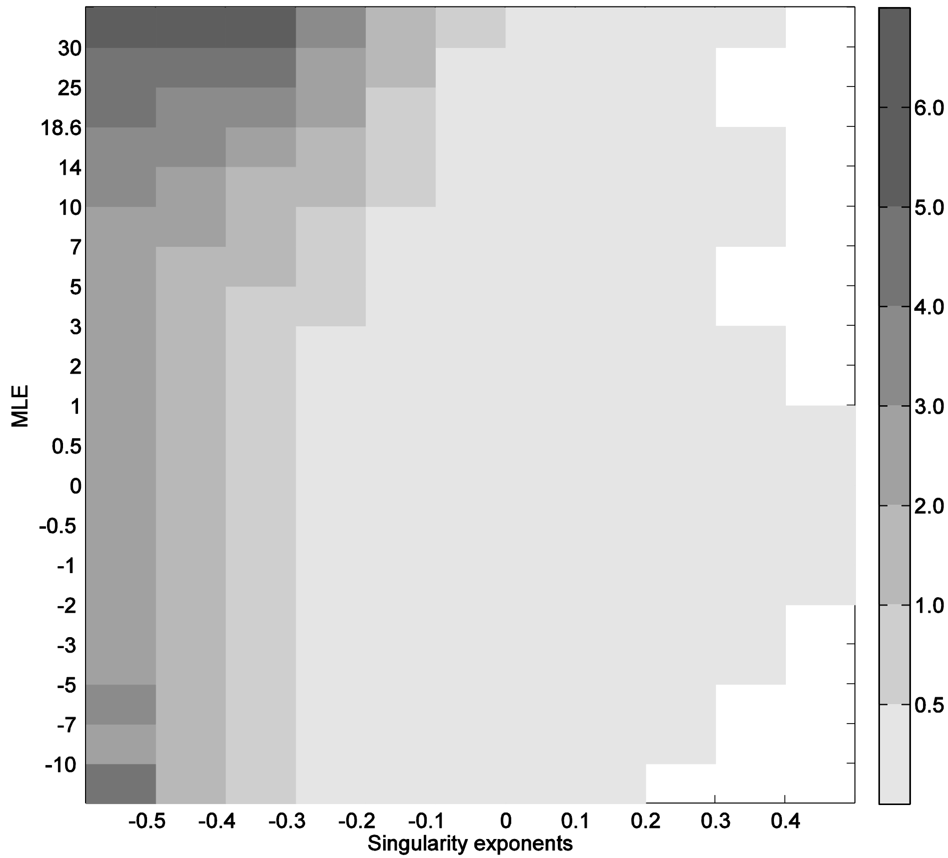


(a) (b)

Fig. 1 The VRMS difference between buoy and (a) ASCAT winds; (b) ECMWF winds, as a function SE and MLE.

- The correspondence of buoy, ASCAT and ECMWF winds reduces as SE decreases and MLE increases
- SE and MLE parameters are complementary in terms of quality classification

Quality control



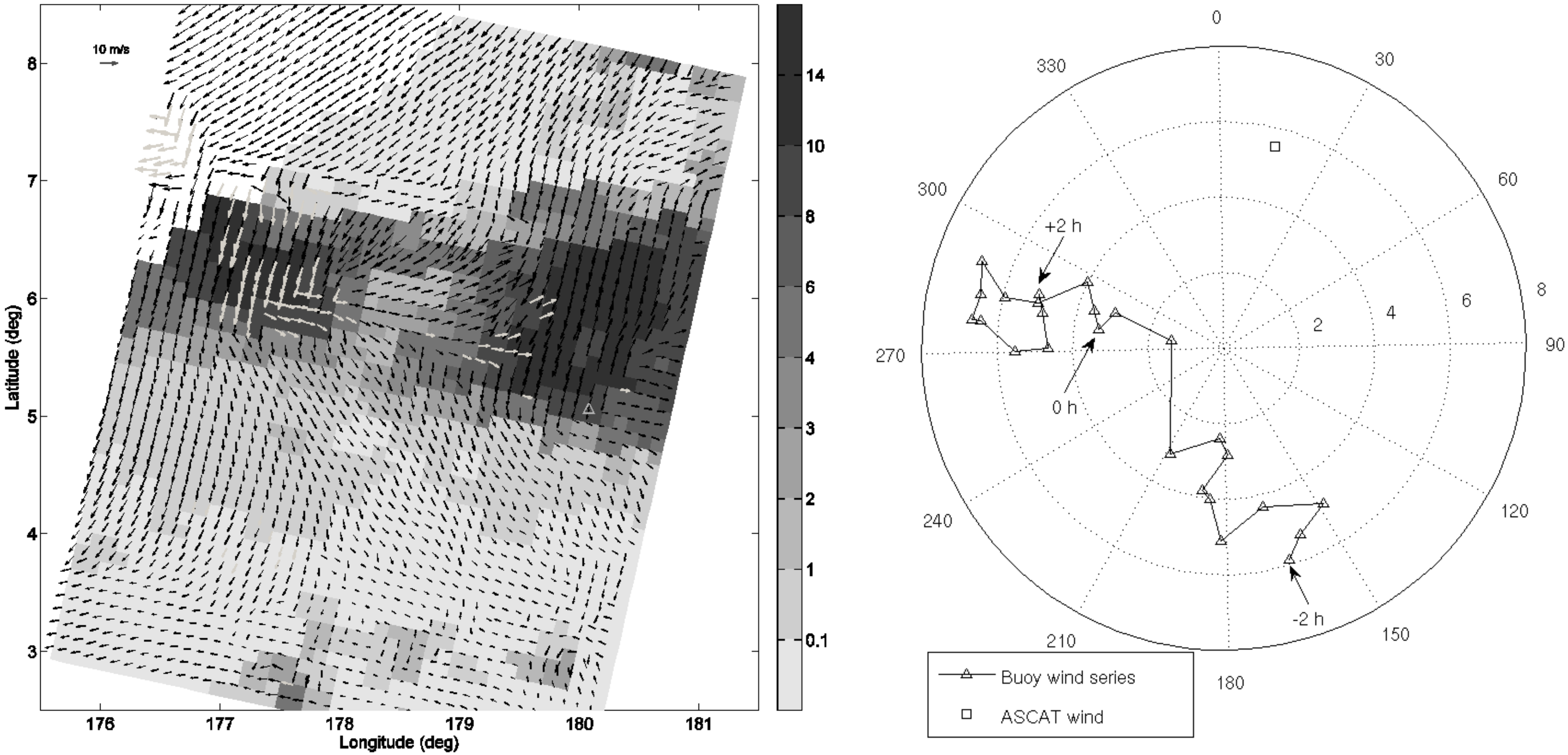
Mean TMI RR as a function SE and MLE. Only the collocations with wind speeds above 4 m/s are used.

Quality control

- MLE-based QC: WVCs with MLE>+18.6 are filtered
- MLE-/SE-combined QC: WVCs with MLE >+18.6 or SE<-0.45 are filtered
- MUlti-Dimensional Histogram (MUDH): MLE-/SE-combined QC, but analyzed at different wind speed and measurement variability factor (K_p) categories.

V≥4 m/s	VRMS (Rejected WVC)			VRMS (Kept WVC)			QC-ed ratio (%)		
	MLE	MLE/SE	MUDH	MLE	MLE/SE	MUDH	MLE	MLE/SE	MUDH
10-min buoy wind	5.04	5.28	5.21	1.63	1.62	1.61	0.32	0.65	1.04

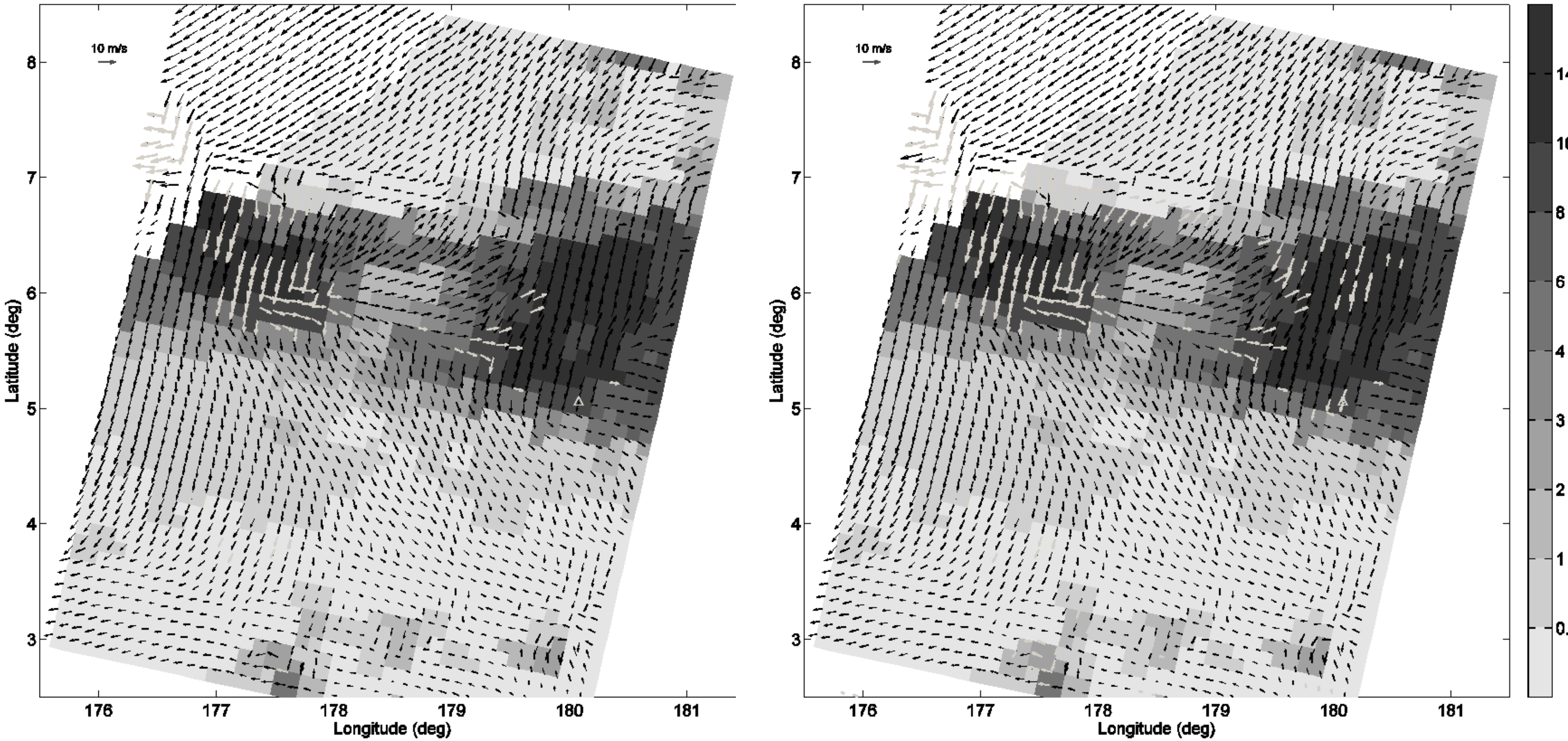
An example



(*a*) (*b*)

Fig.2 (*a*) ASCAT wind observed on December 15, 2009, at 21:17 UTC, with collocated TMI RR superimposed (see the legend). The black arrows correspond to QC-accepted WVCs, and the gray ones correspond to QC-rejected WVCs. The buoy measurements (denoted by the triangle) were acquired at 21:20±2 hours UTC, as shown in the polar coordinate plot (*b*).

An example



(*c*) (*d*)

Fig.2 Illustration of the rejected WVCs (gray arrows) using (*c*) the combined SE/MLE analysis and (*d*) the MUDH technique. The gray ones correspond to QC-rejected WVCs. The buoy measurements (denoted by the triangle) were acquired at 21:00 UTC.

Sub-cell wind variability

	SD (speed, m/s)	SD (direction, °)	SD (u, m/s)	SD (v, m/s)
MLE	1.24	27.7	1.66	1.62
SE/MLE	1.27	32.1	1.62	1.61
MUDH	1.29	34.9	1.60	1.73
|MLE|<0.5, SE>0	0.37	6.3	0.47	0.52

- MLE & SE are indeed good sub-WVC wind variability indicators
- Sub-WVC variability well correlates with buoy verification

Quality verification

- Mean buoy winds (25-km-equivalent)

$$\overline{\varphi} = \arctan\left(\frac{-\overline{u}}{-\overline{v}}\right)$$

$$\overline{w} = \frac{1}{M}\sum_{i=1}^{M} w_i$$

where
$$\begin{cases} \overline{u} = \frac{1}{M}\sum_{i=1}^{M} -w_i \sin(\varphi_i) \\ \overline{v} = \frac{1}{M}\sum_{i=1}^{M} -w_i \cos(\varphi_i) \end{cases}$$

V≥4 m/s	VRMS (Rejected WVC)			VRMS (Accepted WVC)			QC-ed ratio (%)		
	MLE	MLE/SE	MUDH	MLE	MLE/SE	MUDH	MLE	MLE/SE	MUDH
10-min buoy wind	5.04	5.28	5.21	1.63	1.62	1.61	0.32	0.65	1.04
Mean buoy wind	4.25	4.41	4.45	1.29	1.28	1.27	-	-	-

- By using mean buoy winds, the variance reduction is about 30-40% in both accepted and rejected categories
- Sub-WVC wind variability is therefore the dominant factor for quality degradation (in both wind sources!)

Triple collocation analysis

Table-3: Triple collocation error estimates on ASCAT resolution scale, with MARE and fixed representativeness errors. Buoy 10-min winds (top) and mean buoy winds (bottom) are used as reference

	$r^2 (m^2/s^2)$		ε_{buoy}(m/s)		ε_{scat}(m/s)		ε_{back}(m/s)		*N*
	u	*v*	*u*	*v*	*u*	*v*	*u*	*v*	
MUDH	1.0	1.0	2.33	2.08	1.70	2.16	2.89	3.79	299

	$r^2 (m^2/s^2)$		ε_{buoy}(m/s)		ε_{scat}(m/s)		ε_{back}(m/s)		*N*
	u	*v*	*u*	*v*	*u*	*v*	*u*	*v*	
MUDH	1.0	1.0	1.78	1.38	2.04	2.48	3.00	3.62	299

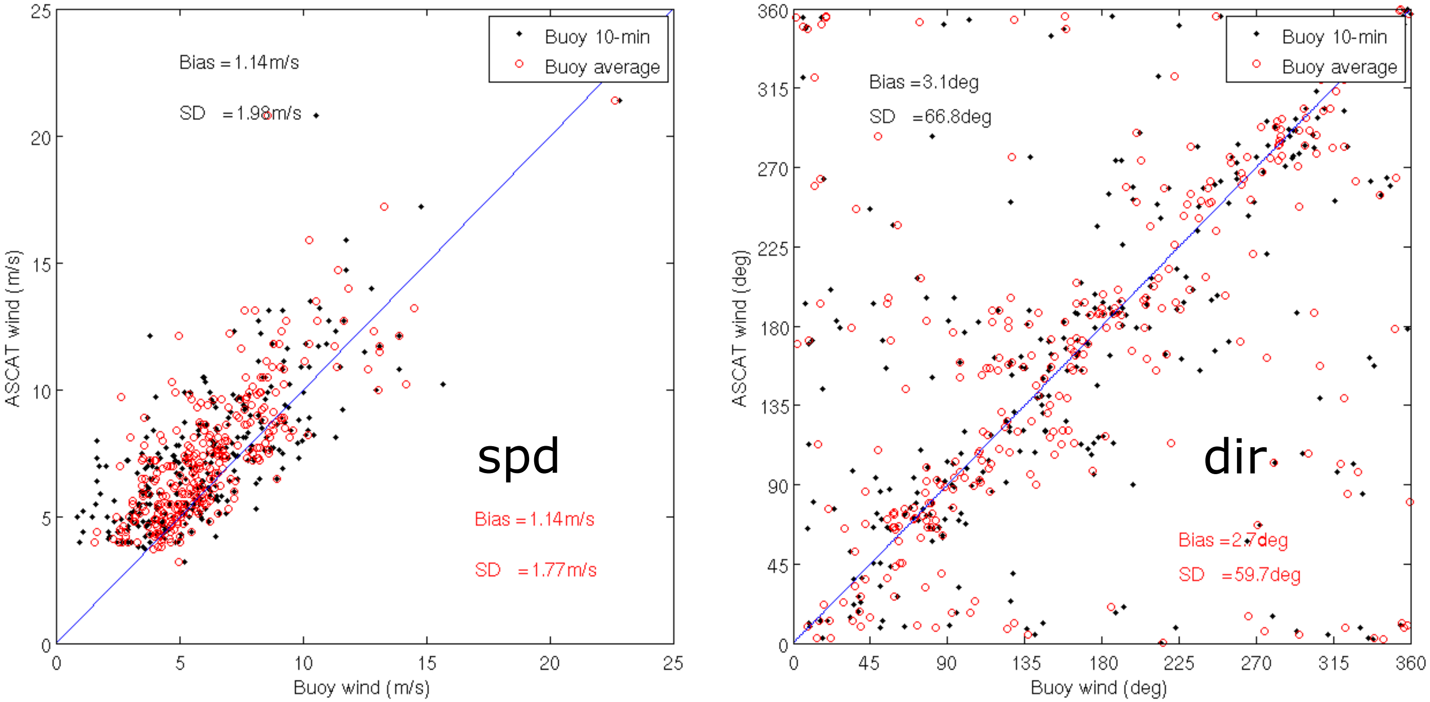


Fig.2a Scatter plots of ASCAT MUDH QC-ed winds against buoy winds (selected wind solutions).

- The mean buoy wind is closer to ASCAT winds;
- Significant ambiguity removal errors

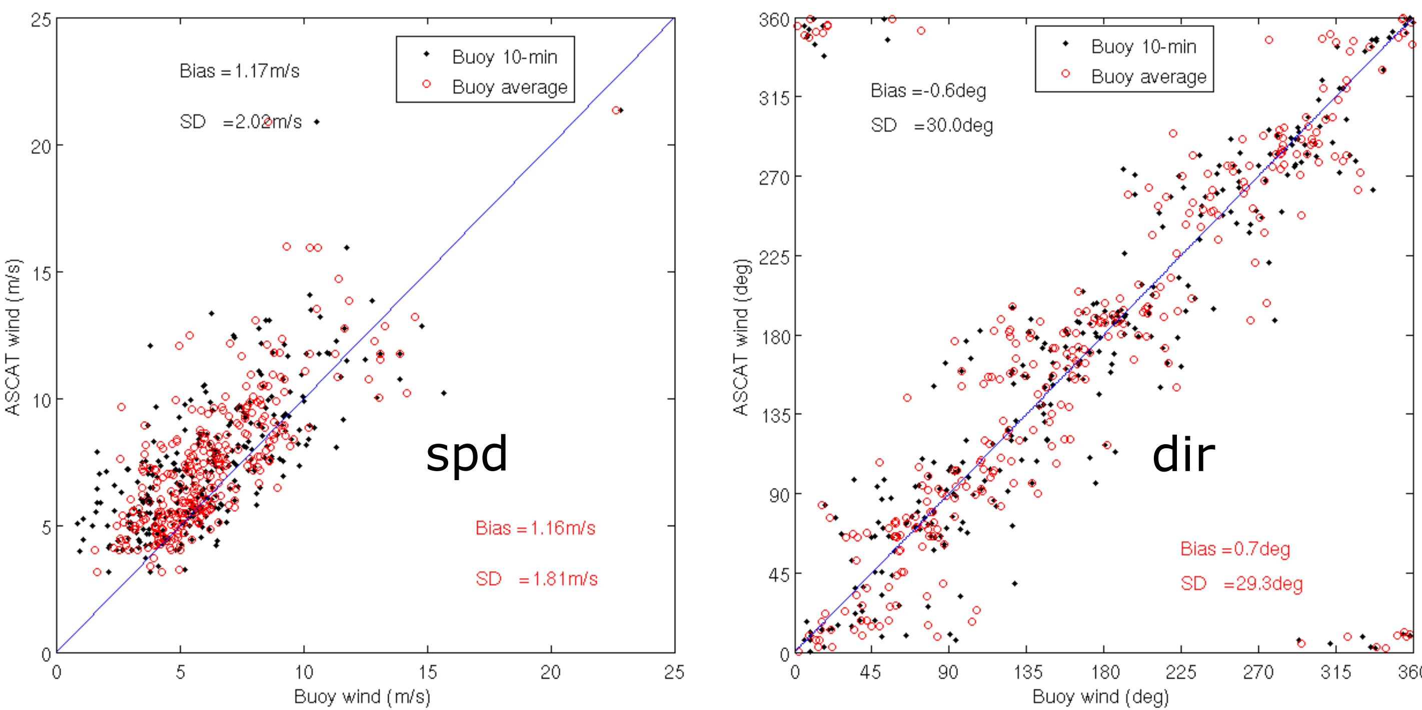


Fig.2b Scatter plots of ASCAT MUDH QC-ed winds against buoy winds (closest to buoy).

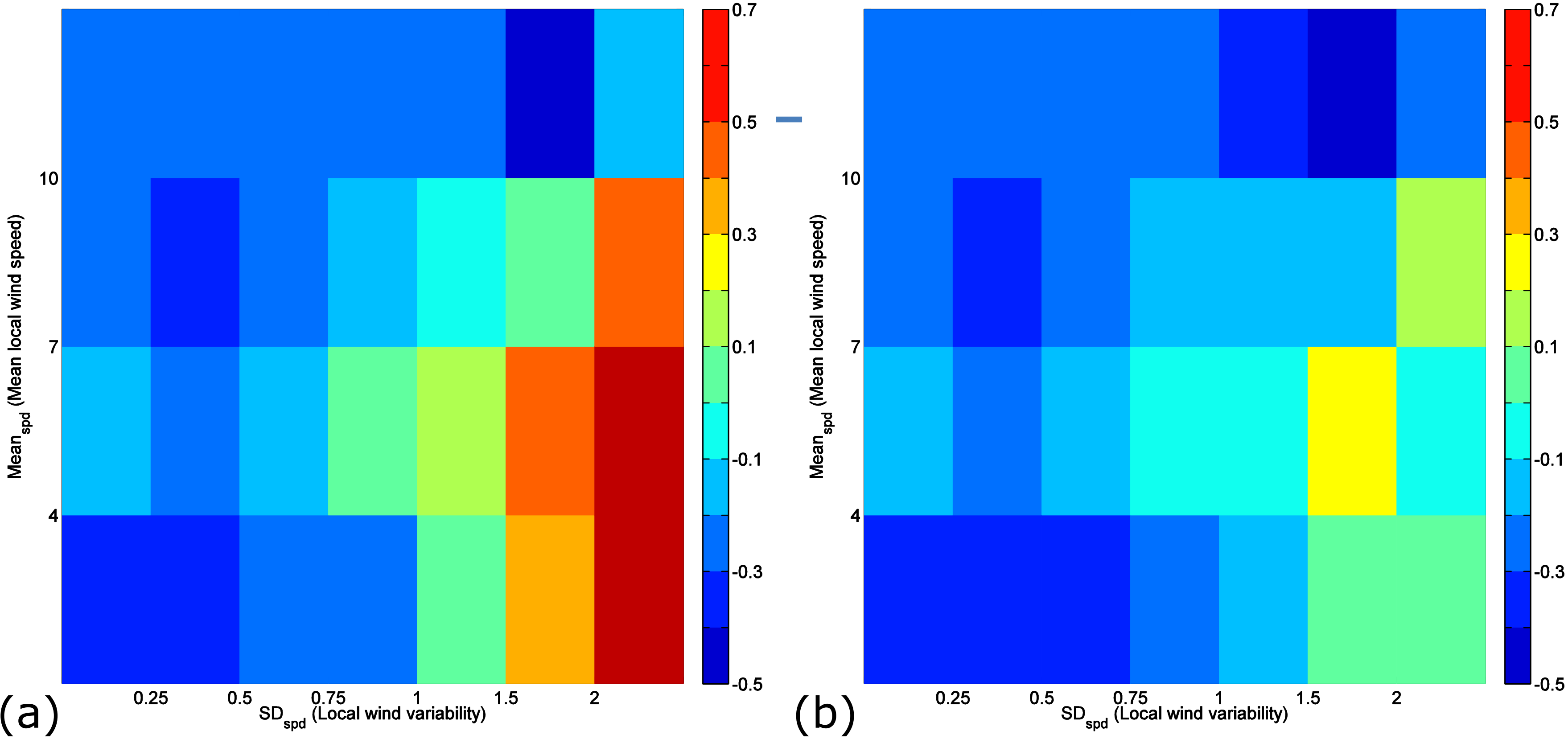
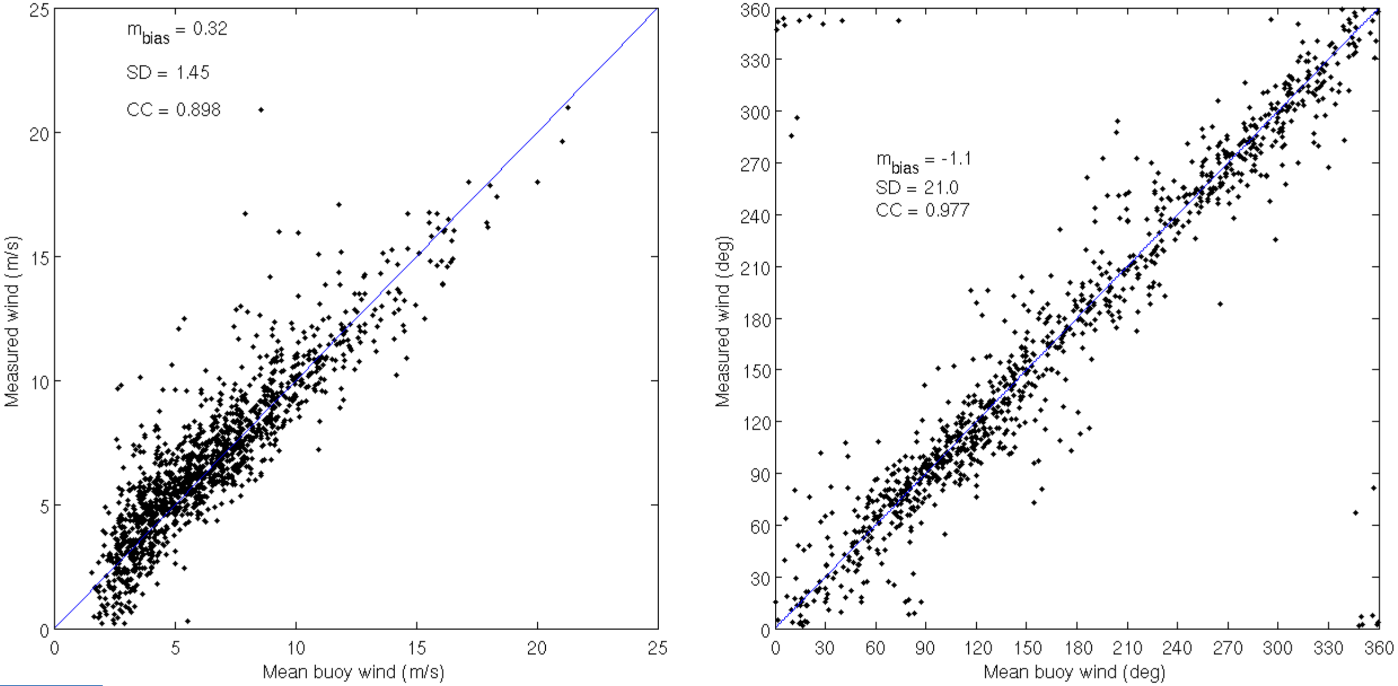
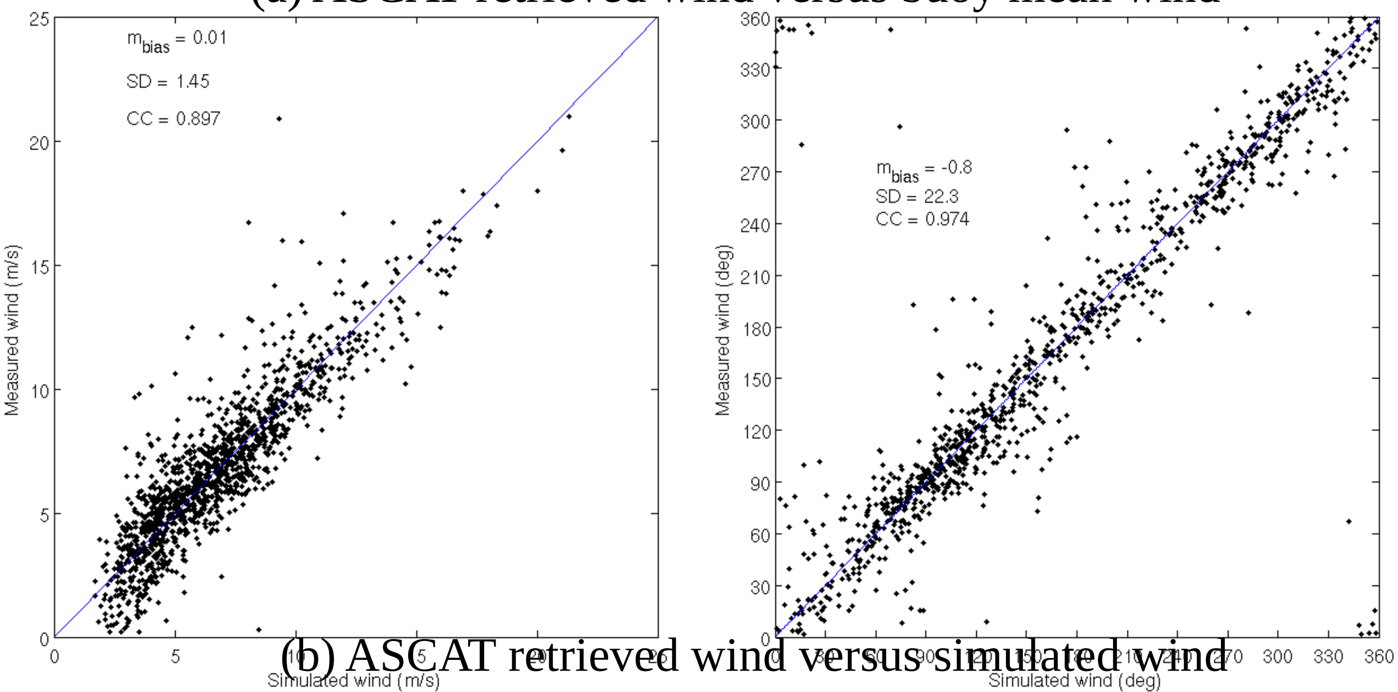


Fig. 3 The bias of ASCAT retrieved wind speed w.r.t. (a) the mean buoy winds; and (b) the simulated winds. All the ASCAT solutions which are closest to the mean buoy winds are taken into account.

- Wind speed bias at high sub-WVC variability not (significantly) due to variability effects
- Other potential effects such as rain splashing need to be further explored



(a) ASCAT retrieved wind versus buoy mean wind



(b) ASCAT retrieved wind versus simulated wind

Buoy temporal wind SD_spd>=1.5 m/s

Conclusions

- MLE and SE are indeed well correlated with sub-WVC wind variability
- MLE and SE are complementary and their combination provides an effective QC relative to both buoy and ECMWF reference (notably the MUDH-based approach)
- Increased sub-WVC variability dominates the ASCAT quality degradation
- A remaining 1 m/s bias in ASCAT rejected winds needs further investigation
- Temporal buoy wind information is useful to address representativeness errors; however, not directly comparable to 2-D area-mean scatt winds
- Preliminary triple collocation shows that ASCAT wind quality for QC'ed WVCs is comparable to that of mean buoy winds at scatterometer scales.
- QC may therefore be relevant for applications like data assimilation. For, e.g., nowcasting and oceanography, this info may be very valuable!

Outlook

- Development of a wind variability product?
- Develop QC for ASCAT coastal
- Investigate potential rain-contamination effects and the development of a sigma0 correction model
- Revisit QC for Ku-band pencil-beam scatterometers

- **Related vacancy coming soon: 16-month contract**

Data sets (March 2009-February 2012)

- ASCAT 12.5-km L2 BUFR data (with ECMWF winds)
- Moored buoy wind time series (~ 46 k)
- TRMM TMI Rain data

Two kinds of buoy wind are used as reference:

- Ten-minute buoy wind measures
- 25-km-equivalent buoy winds

$$\overline{\varphi} = \arctan\left(\frac{-\overline{u}}{-\overline{v}}\right)$$

$$\overline{w} = \frac{1}{M}\sum_{i=1}^{M} w_i$$

where

$$\begin{cases} \overline{u} = \frac{1}{M}\sum_{i=1}^{M} -w_i \sin(\varphi_i) \\ \overline{v} = \frac{1}{M}\sum_{i=1}^{M} -w_i \cos(\varphi_i) \end{cases}$$

M is is the number of 10-min buoy measurements, which is determined by expanding the 10-min-equivalent distance vector in the adjacent time bins (centered on the ASCAT measurement time), until the length of the distance vector reaches the WVC size. The minimum value M is set to be 5

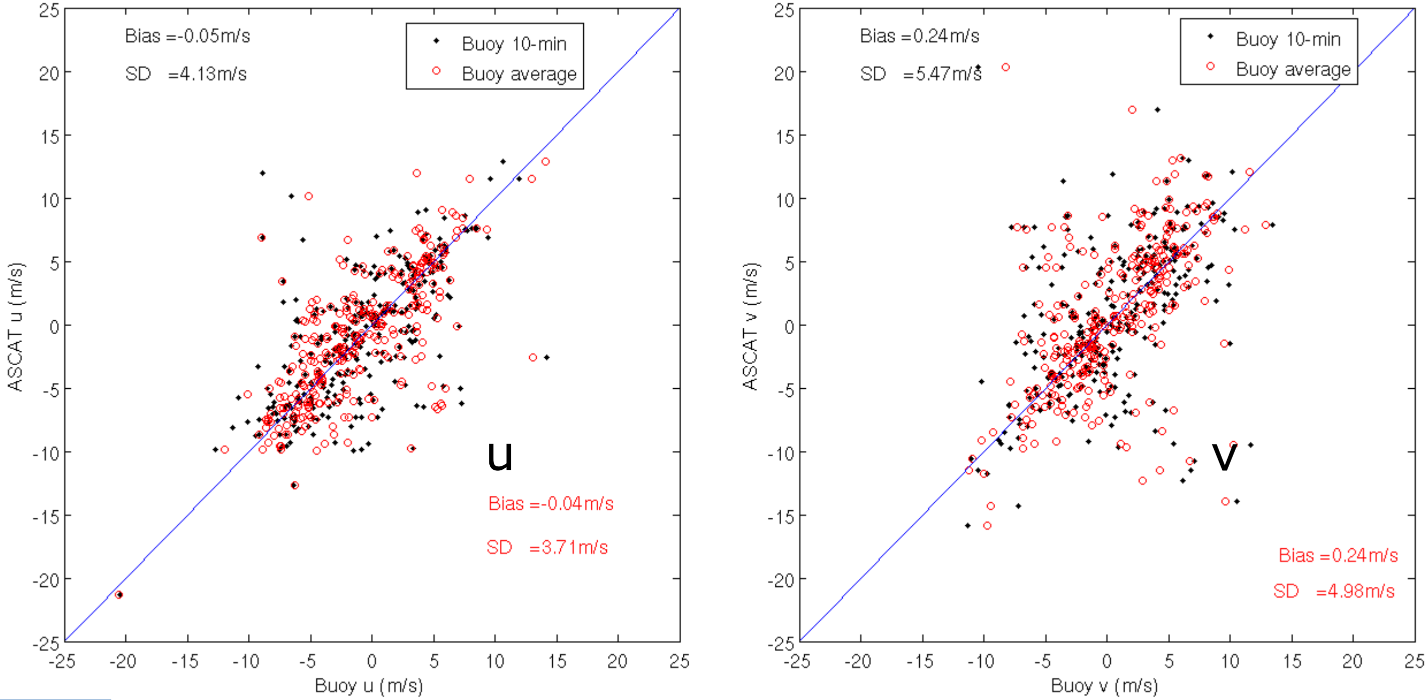


Fig.2c Scatter plots of ASCAT MUDH QC-ed winds against buoy winds (selected wind solutions).

- ➢ there are some scatters with y=-x

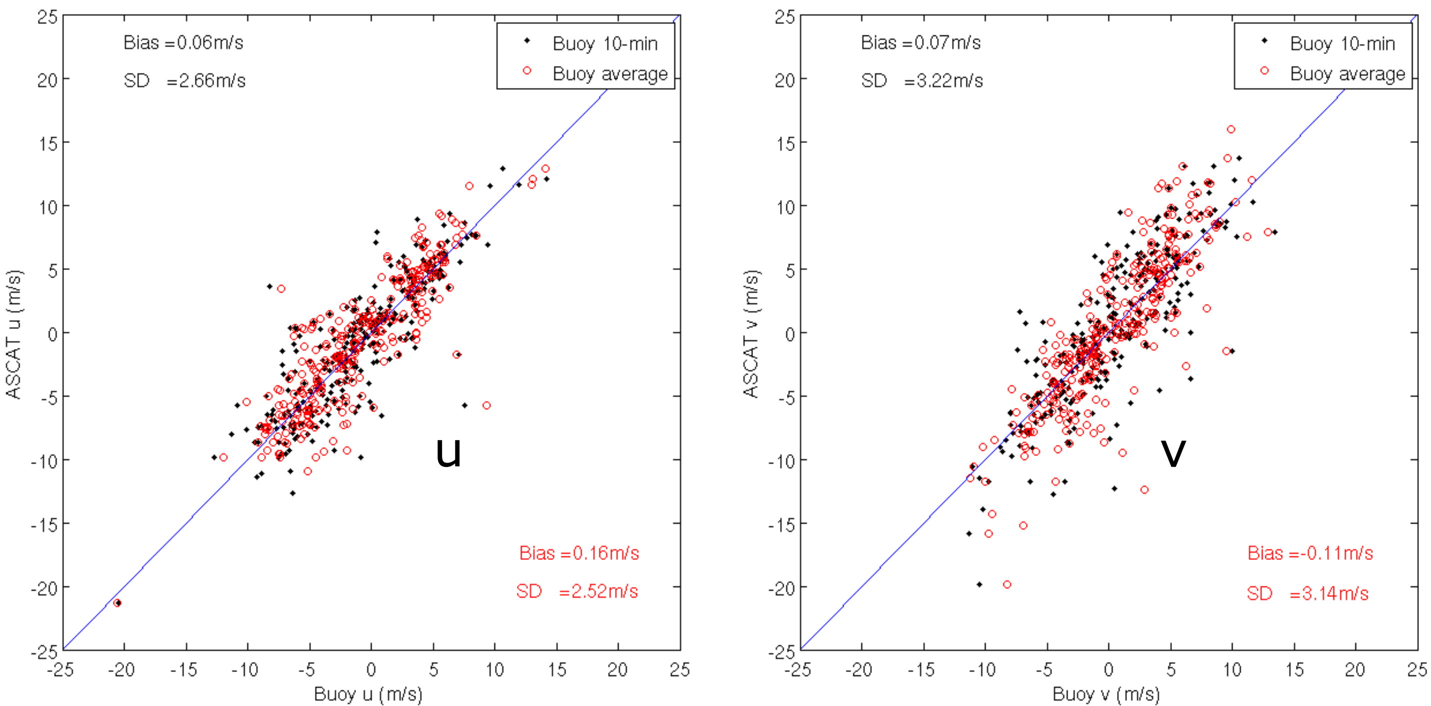


Fig.2d Scatter plots of ASCAT MUDH QC-ed winds against buoy winds (closest to buoy).

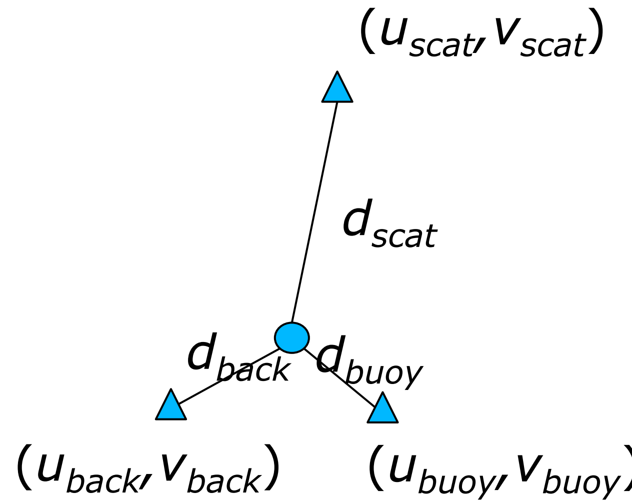
Triple collocation analysis

$$x_i = ait + bi + \delta_i$$

a_i and b_i stand for resp. the trend and bias calibration coefficients and δ_i for a random measurement error in system *i (buoy, scat, or background).*

- Mitigation of ambiguity removal errors;

1. Allow each of the three wind vectors in a collocation triplet to have two ambiguities 180° apart, leading to 8 different combinations of which 4 are independent(the other 4 differ by an overall minus sign);
2. Calculate the center of gravity for each of the four ambiguous triplets;
3. Calculate the distance of each of the ambiguous triplet winds to the center of gravity and find the maximum distance;
4. Select the ambiguous triplet that has the smallest maximum distance to its center of gravity.



$d^i_{max} = max\{d_{buoy}, d_{scat}, d_{back}\}$

For one of the four sign combinations

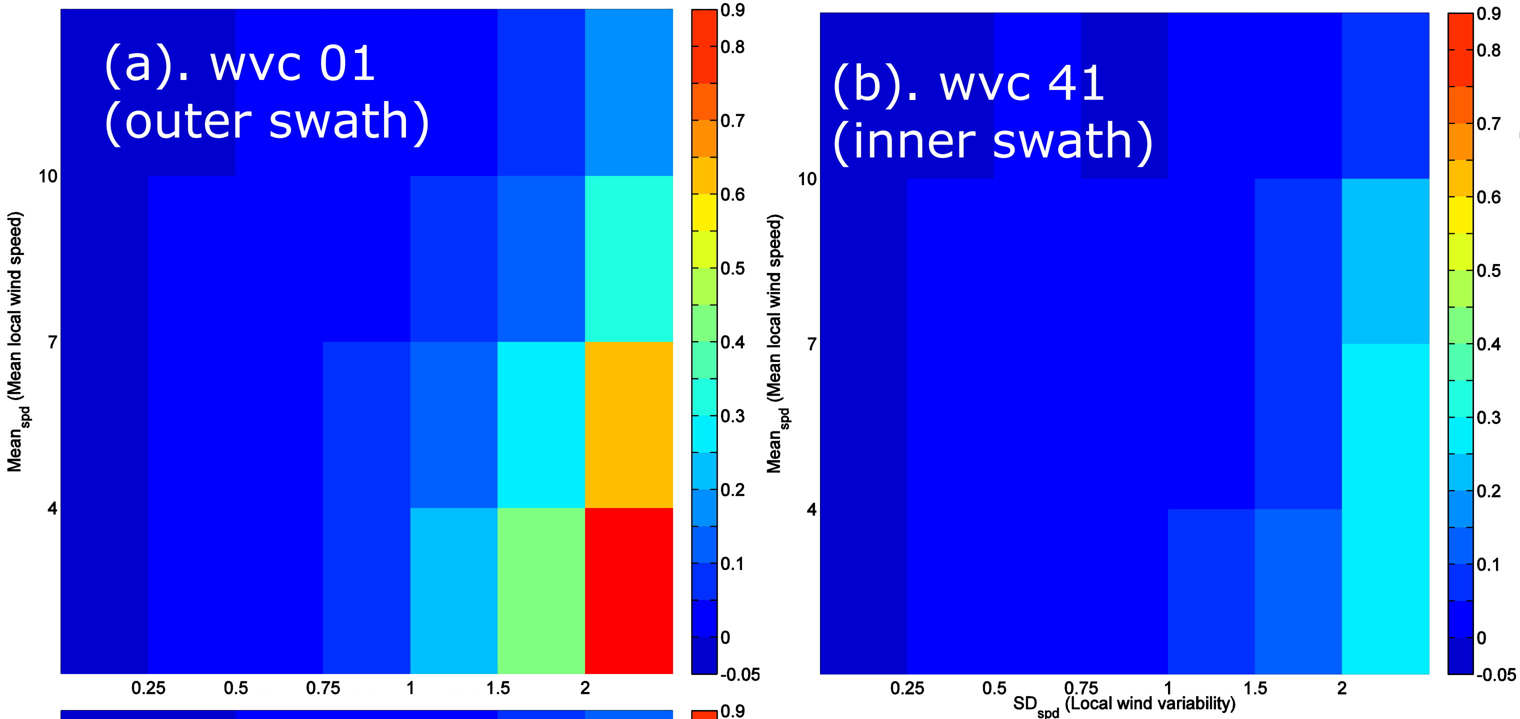
Simulation: wind variability impact on ASCAT wind

1. The buoy wind time series are used to simulate FoV σ° according to CMOD5n. The number of 10-min buoy winds is determined by expanding the 10-min-equivalent distance vector in the adjacent time bins (centered on the ASCAT measurement time), until the length of the distance vector reaches the WVC size.

2. The simulated σ° are averaged to get a mean WVC-σ° for each antenna beam; (no-noise is considered here)

3. Then the wind retrieval is performed for the simulated triplets.

4. The retrieved wind solutions which are closest to the input mean buoy wind vector are analyzed.



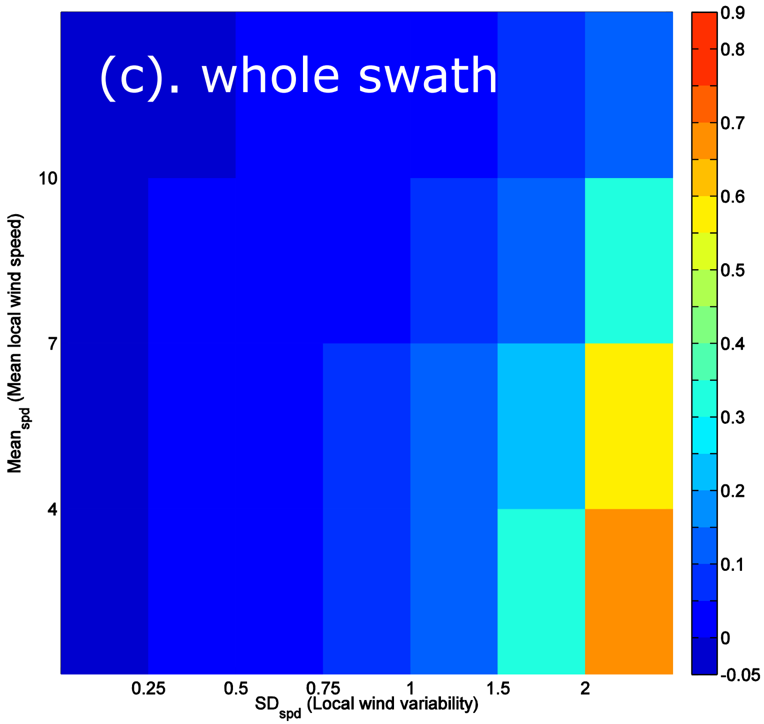
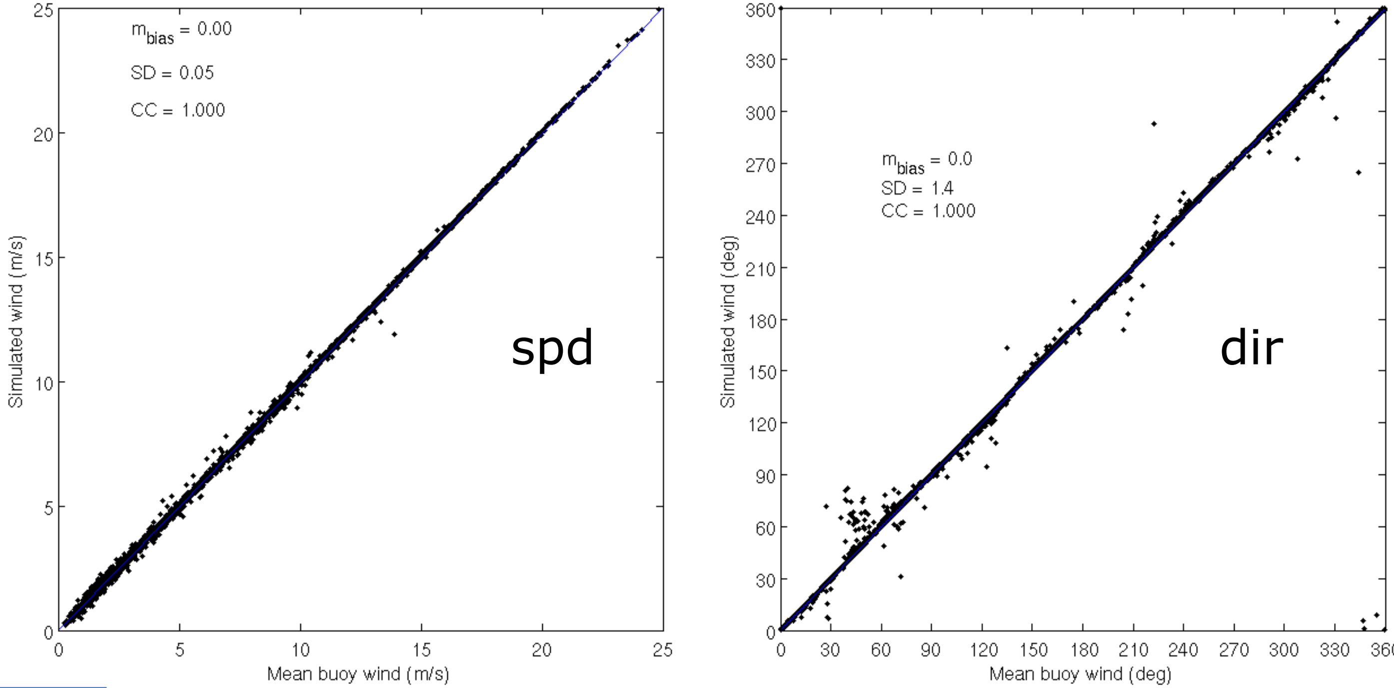


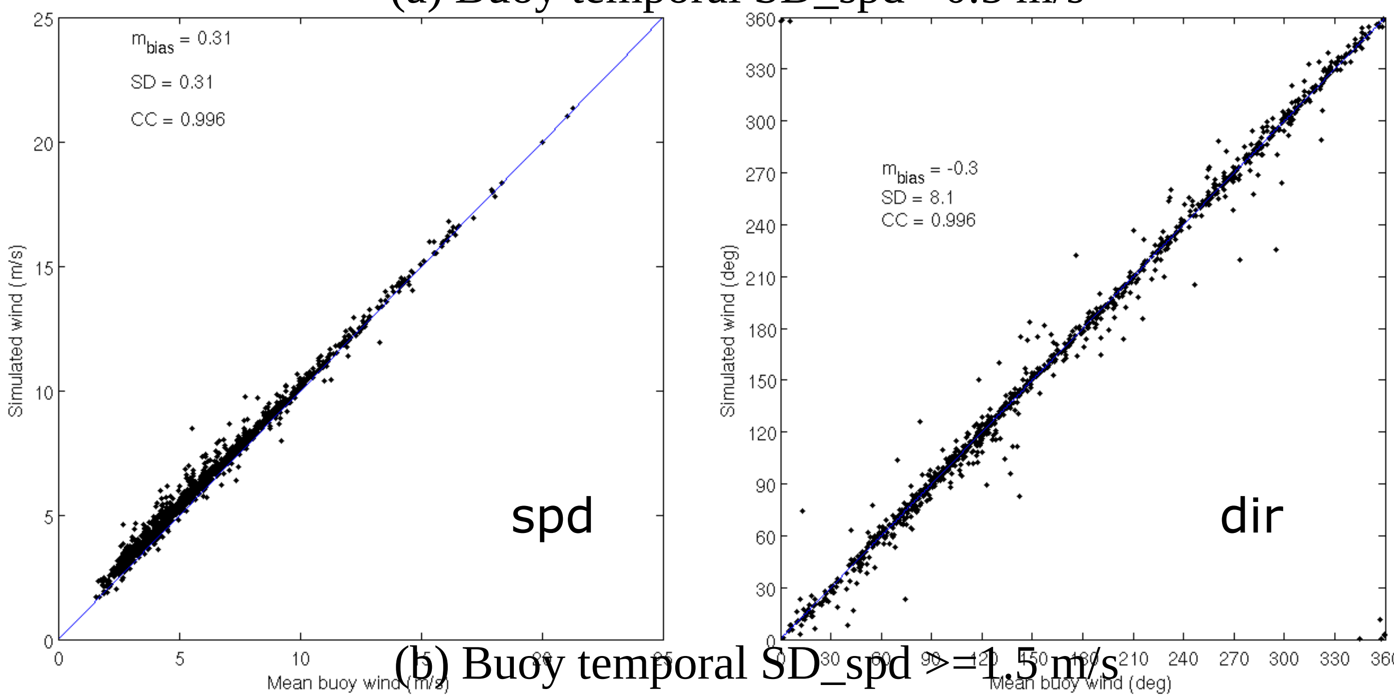
Fig. 1. Wind speed bias of the simulated winds w.r.t. the mean buoy winds: (a) WVC 01, outer swath; (b) WVC 41, inner swath; (c) all WVCs.

- When the SD value is less than 1 m/s, the wind speed bias is generally within [-0.05 0.05] m/s;
- The bias increases as the wind variability increases and the mean buoy wind speed decreases;
- WVCs located at the outer swath are more sensitive to the local wind variability.

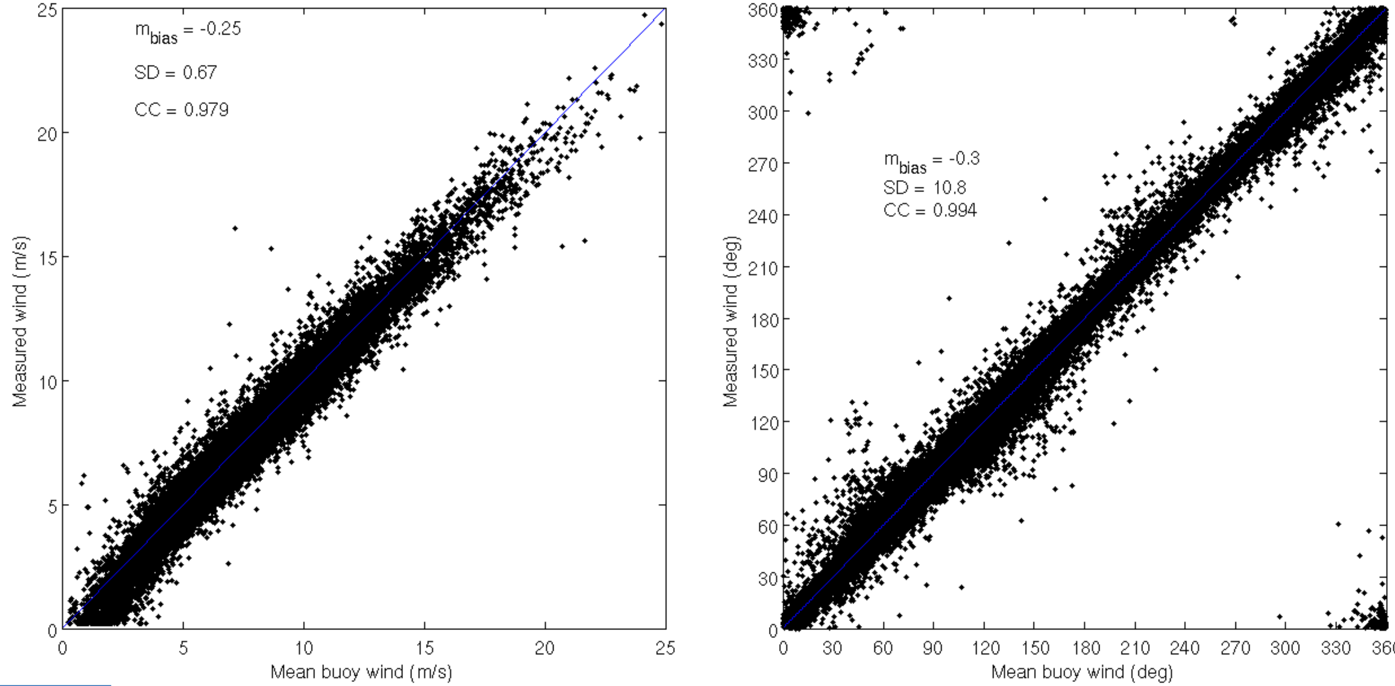
Scatter plots of the simulated winds against the mean buoy winds. The left panels show the scatter plots of wind speed component (all wind speeds are taken into account); the right panels show the scatter plots of wind direction component (only the mean buoy wind speeds above 4 m/s are taken into account).



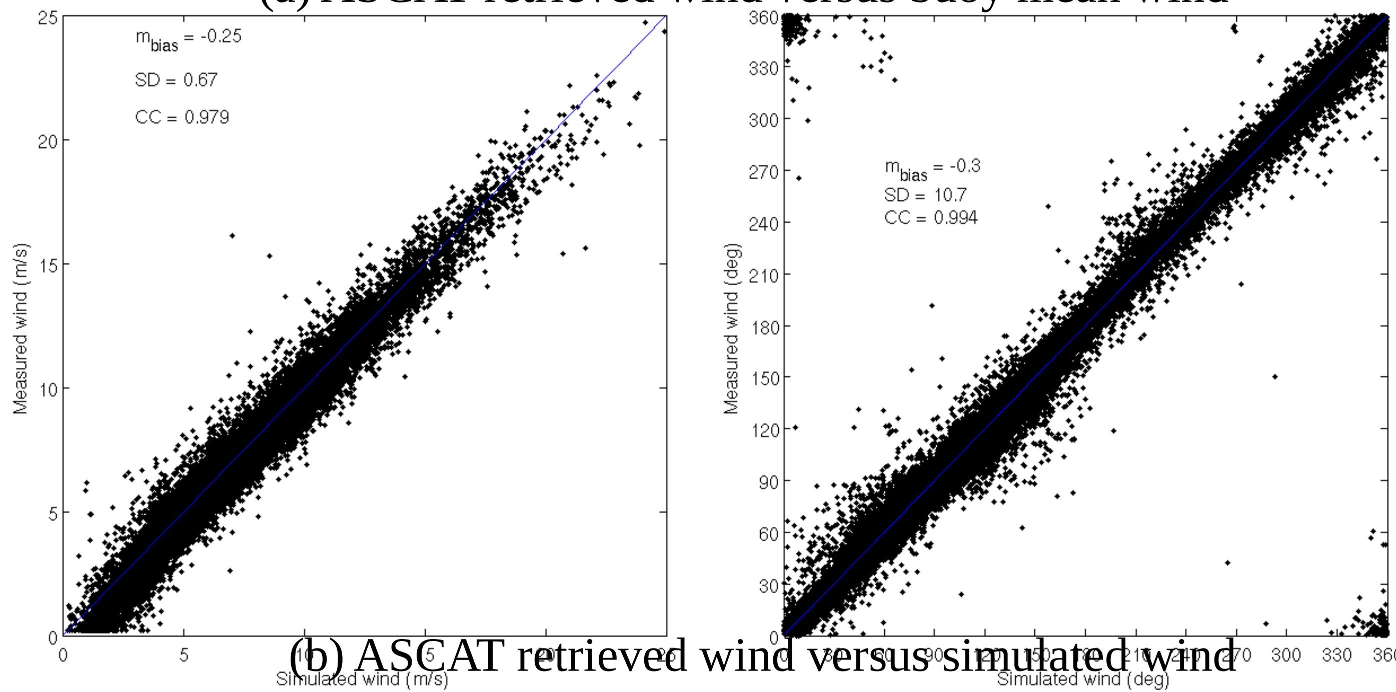
(a) Buoy temporal SD_spd <0.5 m/s



(b) Buoy temporal SD_spd >=1.5 m/s



(a) ASCAT retrieved wind versus buoy mean wind

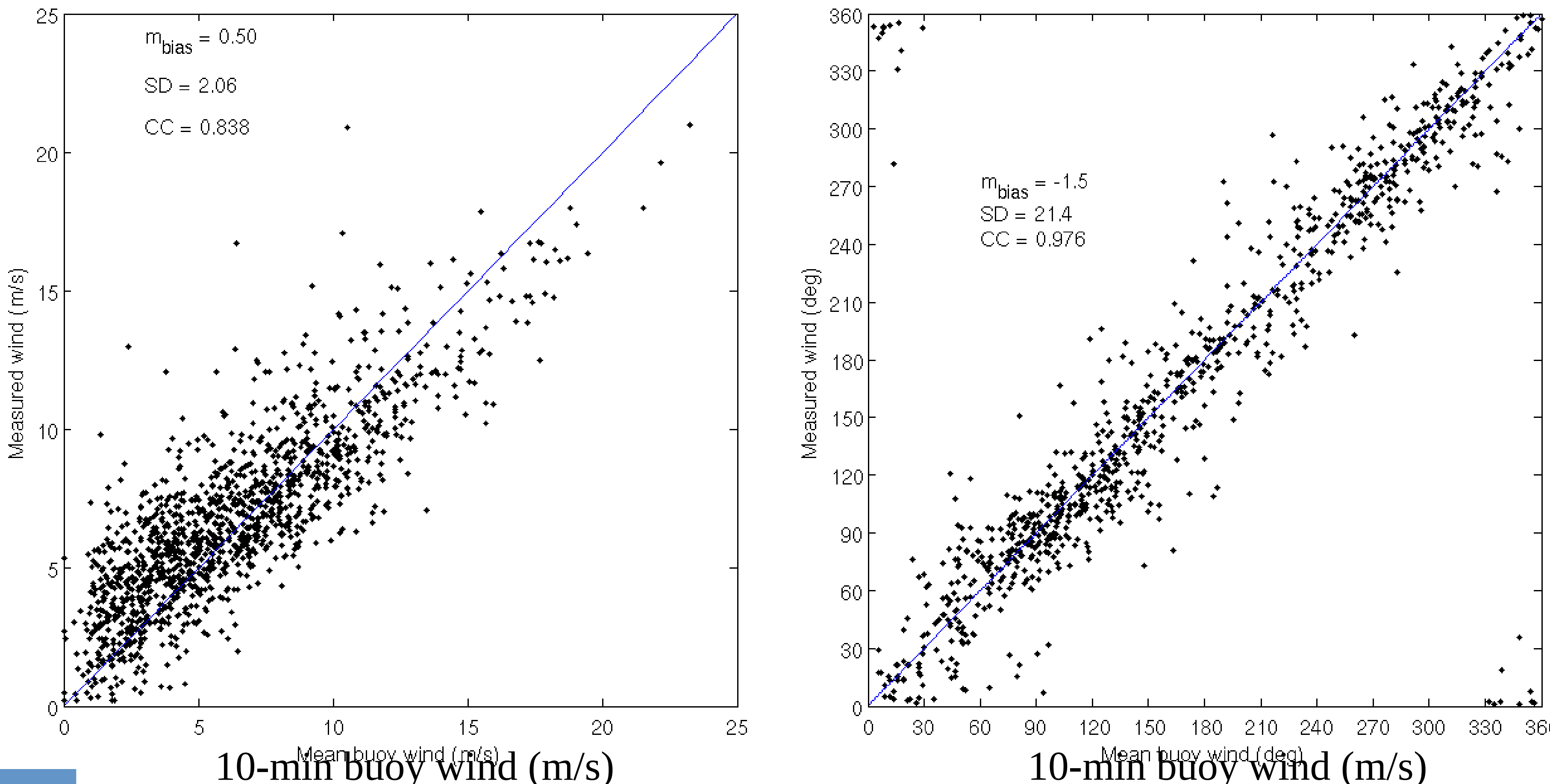


Buoy temporal wind SD_spd<0.5 m/s

(b) ASCAT retrieved wind versus simulated wind

Remark

At low wind conditions (speed<4 m/s), the ASCAT measured winds are always lowly-biased w.r.t. the mean buoy winds or the simulated winds. However, this bias is not obvious when comparing to the 10-min buoy winds.



Rain impact on ASCAT derived-winds
(for low and moderate rain rates)

- Increased wind variability
- Sea surface rain "splashing"

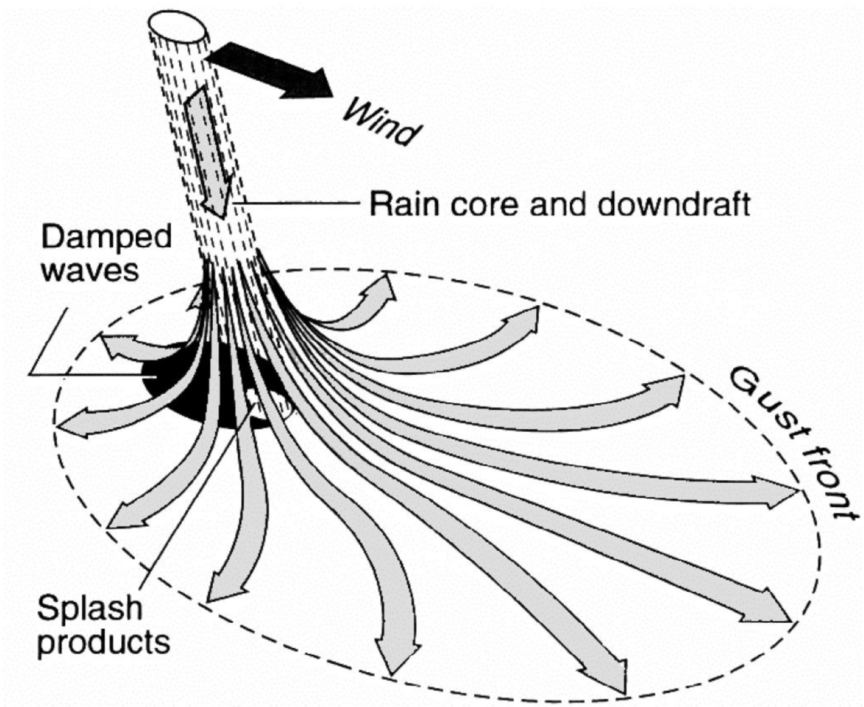
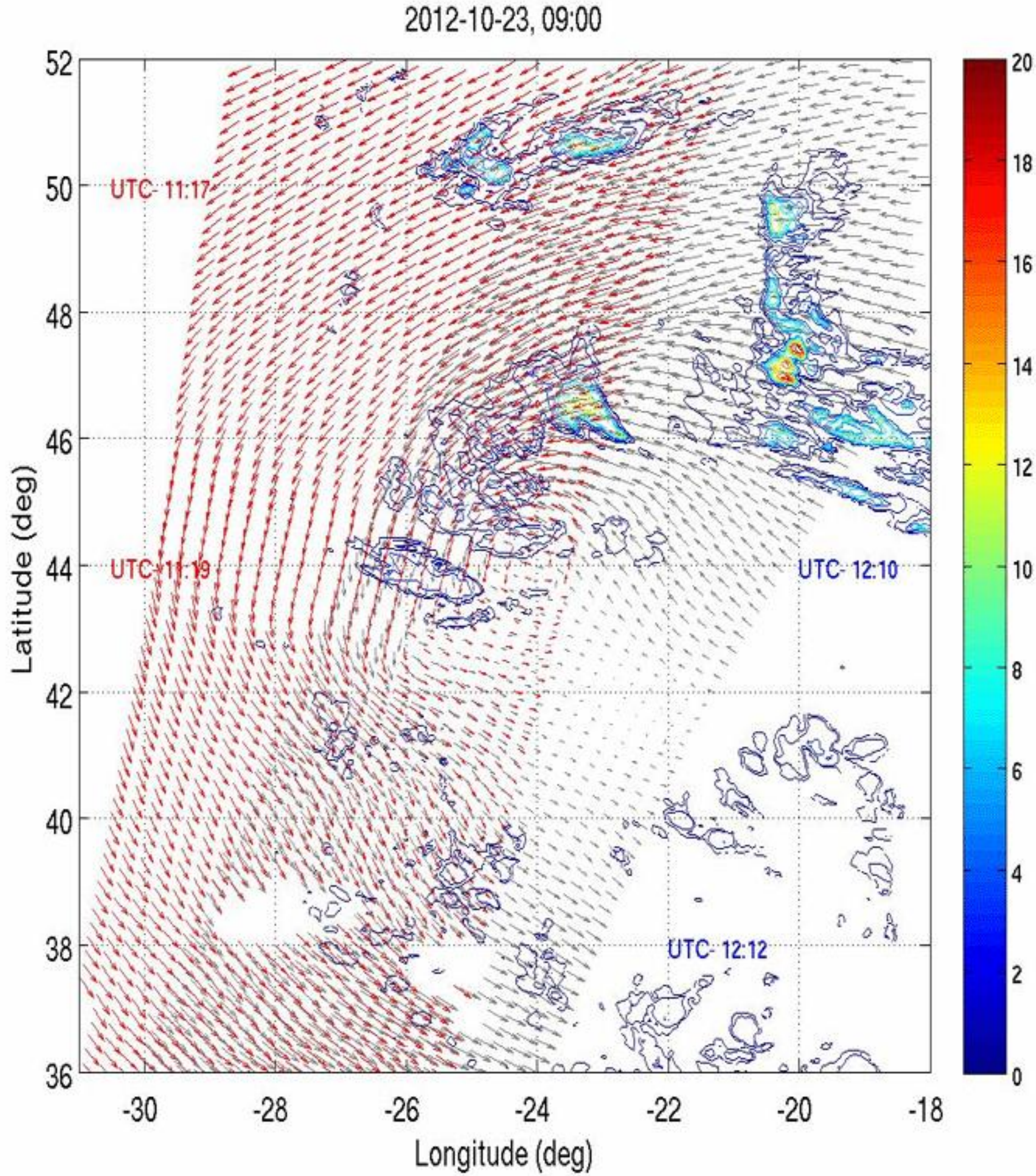


Figure 17.1. Schematic sketch of the downdraft associated with a rain cell. The downdraft spreads over the sea surface, causing and enhanced roughening of the sea surface and, thus, an increase in the backscattered radar power [After *Atlas*, 1994b].

Rain Effects



ASCAT-A and ASCAT-B come together

SMOS BARCELONA EXPERT CENTRE

Motivation

A source of scatterometer-derived area-mean or wind-vector-cell (WVC) wind quality degradation is the presence of extreme sub-WVC wind variability. In this study, moored buoy wind time series are used to assess the following parameters as increased sub-cell wind variability indicators:

- Inversion Residual (i.e. MLE) used by the current operational QC;

  Large MLE values do correspond to increased sub-cell wind variability.

- Singularity exponent (SE, Lin et al. *GRSL* 2014), a complementary technique to the current QC.

  SE detects inter-wvc variability, however, it's done at such local scale (mostly at nearest neighbors level) that it turns out to be a good sub-cell wind variability estimator as well.

Singularity analysis

$x_i = ait + bi + \delta_i$

a_i and b_i stand for resp. the trend and bias calibration coefficients and δ_i for a random measurement error in system i *(buoy, scat, or background)*.

- Mitigation of ambiguity removal errors;