Towards a new ASCAT wind product for assimilation in global NWP

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2. From 2DVAR to 4D-Var

Table 1. Summary of the ASCAT wind process associated with 2DVAR @ KNMI and 4D-Var @ IFS ECMWF

	2DVAR (KNMI)	**4D-Var (IFS)**
GMF	CMOD5n	CMOD5n
σ^0 correction	Yes (NOC)	Yes
Wspd bias correction	No	Yes
Ambiguities	2-4	Always 2
Background	Spatial and temporal Interporation from three 3-hourly forecasts	Short range forecast from the operations for a centain analysis batch
Quality control	MLE	Wspd > 35 m/s Wdir difference < 135° Sea ice fraction
Thinning	No	Yes (25 km, by 4)

From 2D-Var to 4D-Var

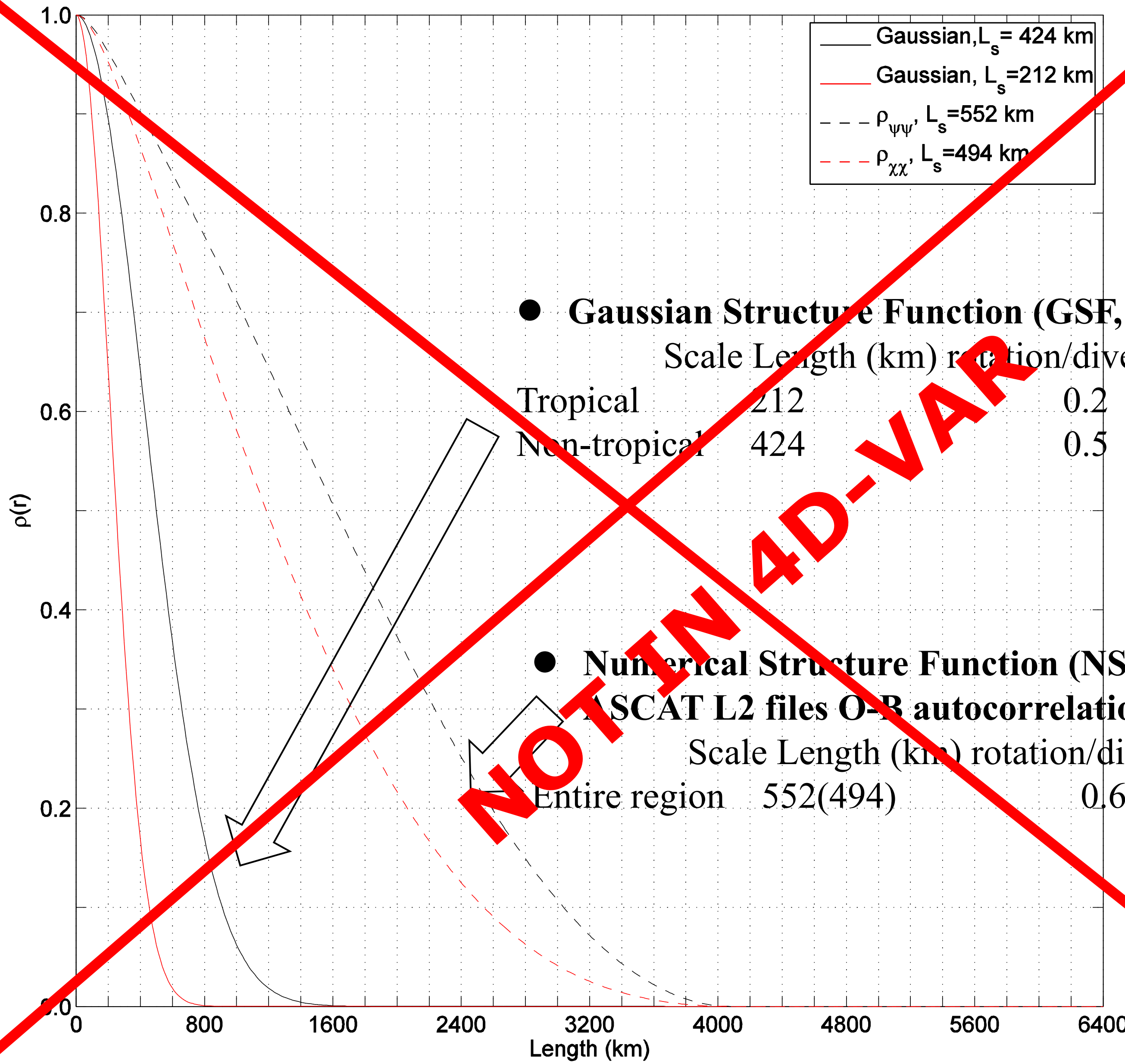
$$J(\mathbf{x}) = \underbrace{(\mathbf{y}_\mathbf{o} - H[\mathbf{x}])^T \mathbf{R}^{-1} (\mathbf{y}_\mathbf{o} - H[\mathbf{x}])}_{\text{Observation term}} + \underbrace{(\mathbf{x} - \mathbf{x}_\mathbf{b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x}_\mathbf{b})}_{\text{Background term}}$$

- R (B) is a matrix, often specified through the square root of the diagonals "σ_O" ("σ_B") and a correlation matrix (e.g., identity matrix in case of R).
- R and B together determine the weight of an observation in the assimilation.
- In the linear case, the minimum of the cost function can be found at x_a:

$$\underbrace{(\mathbf{x}_a - \mathbf{x}_b)}_{\text{Increment}} = \mathbf{BH}^T (\mathbf{HBH}^T + \mathbf{R})^{-1} \underbrace{(\mathbf{y}_\mathbf{o} - \mathbf{Hx}_b)}_{\text{o-b departure}}$$

- Large observation error → smaller increment, analysis closer to background
- Small observation error → larger increment, analysis closer to observation

2D-VAR new settings: Numerical Background error correlation



- **Gaussian Structure Function (GSF, default setting)**

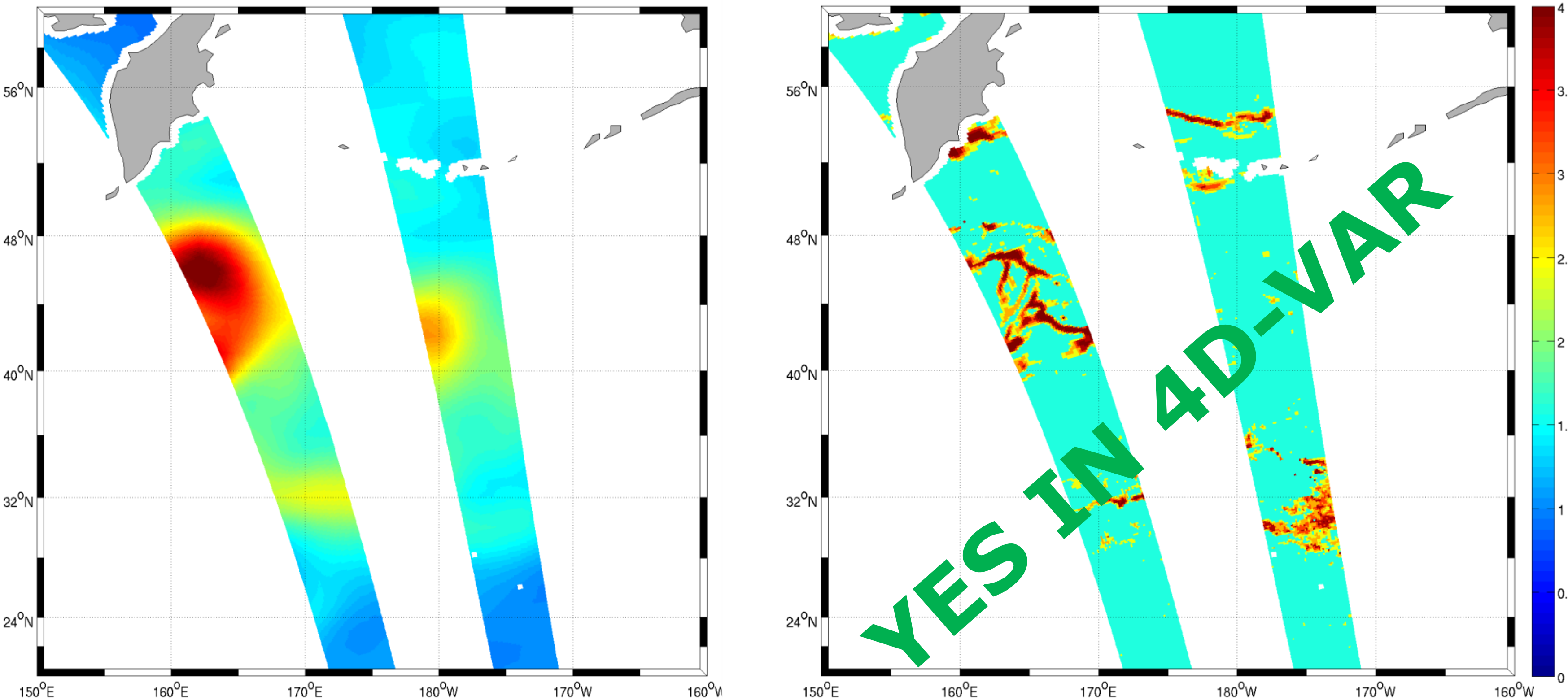
	Scale Length (km)	rotation/divergence ratio
Tropical	212	0.2
Non-tropical	424	0.5

- **Numerical Structure Function (NSF, derived from ASCAT L2 files O-B autocorrelation, new setting)**

	Scale Length (km)	rotation/divergence ratio
Entire region	552(494)	0.62

NOT IN 4D-VAR

2D-Var new settings: flexible O/B errors



ECMWF Ensemble Data Assimilation (EDA background error)

ASCAT-derived ECMWF background error by triple collocation in QC classes

Estimated O & B error variances (Lin et al., JGR, 2015)

In 4D-Var …

- O/B errors specified in assimilation systems are often simplified:

➢ Fixed "σ_O" and "σ_B";

➢ No presence of observation error correlations (Diagonal O error covariance)

➢ The provision of situation-dependent background error covariances is an area of extensive research (Bonavita et al., 2012)

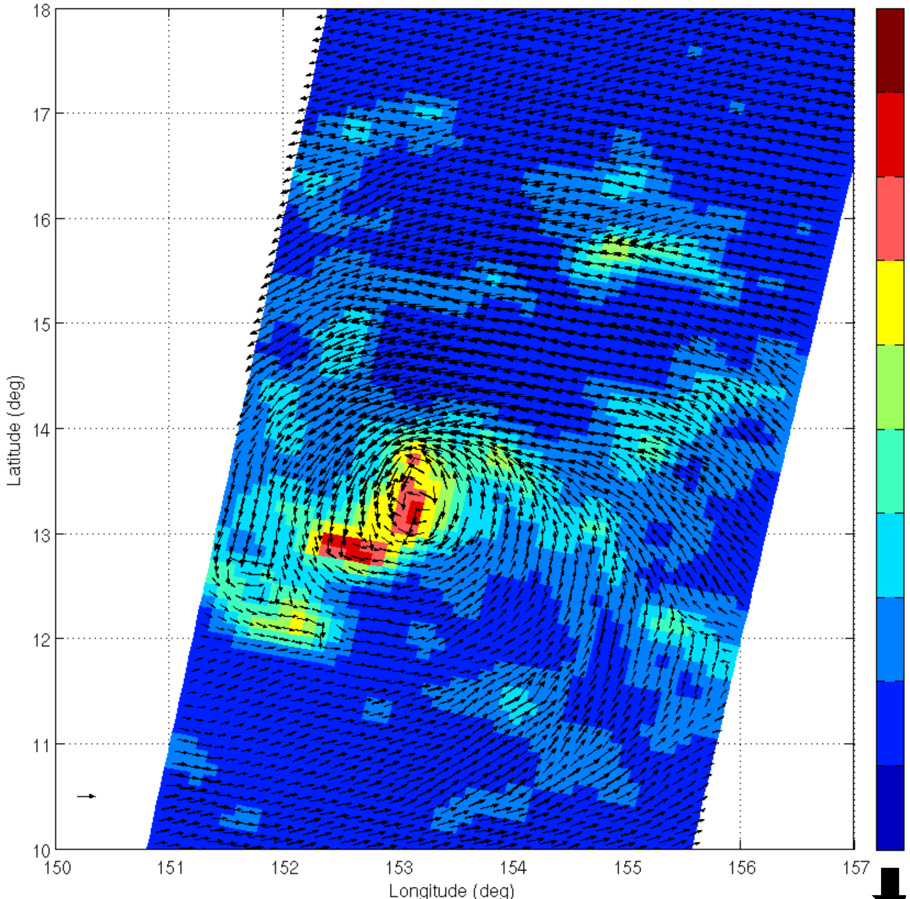
➢ Thinning (25 km product, thinning factor of 4)

- reduce observation density so that error correlations are not relevant.

➢ Error inflation

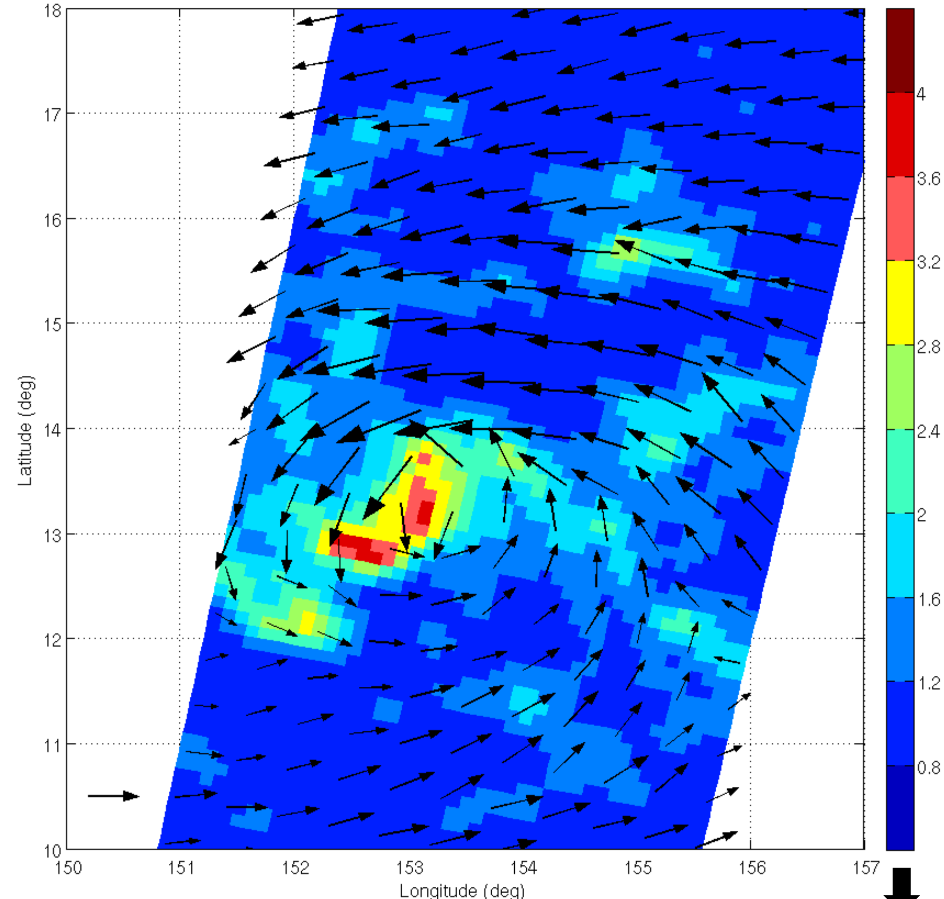
- use diagonal R with larger σ_O than diagnostics suggest.

➢ *Take error correlations into account in the assimilation*



SD errors [m/s]

ASCAT 25-km winds

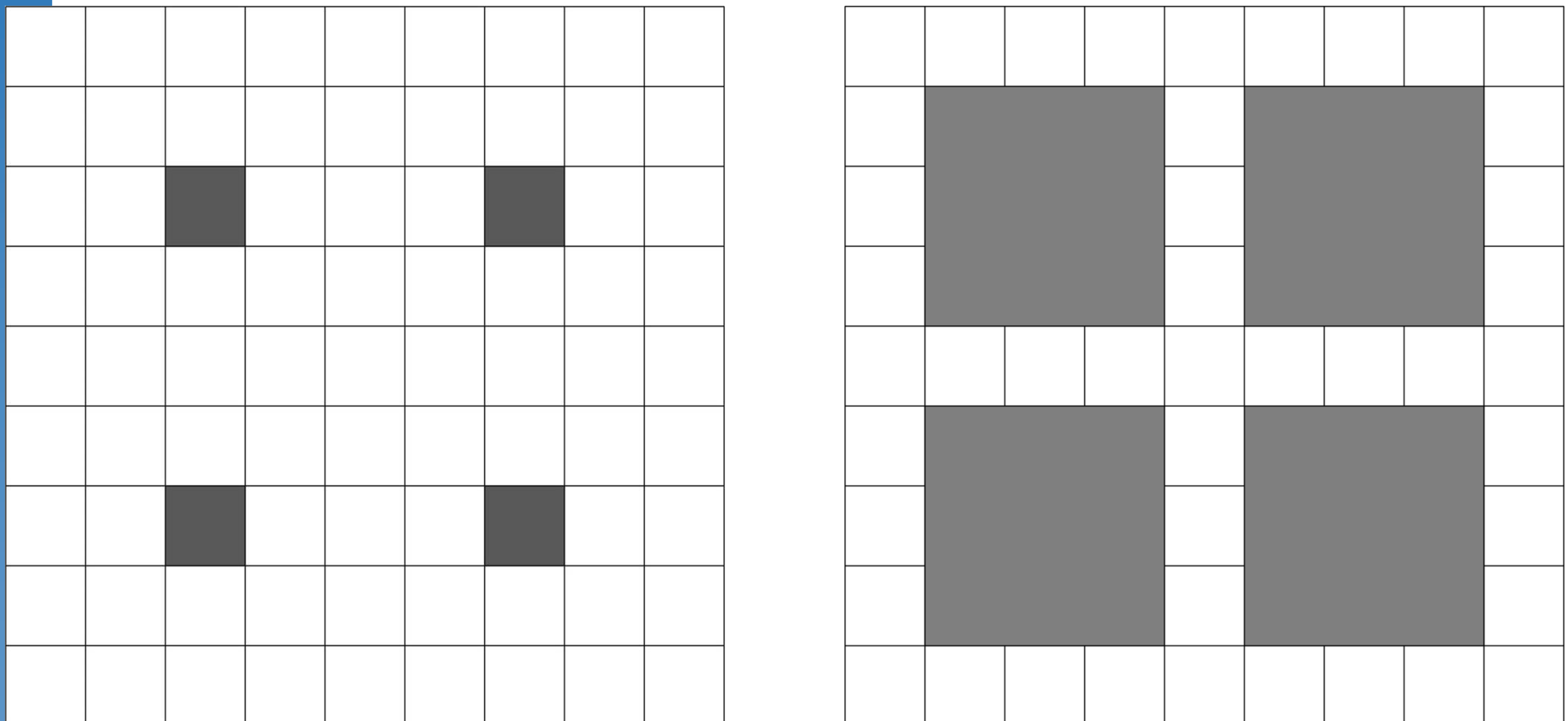


SD errors [m/s]

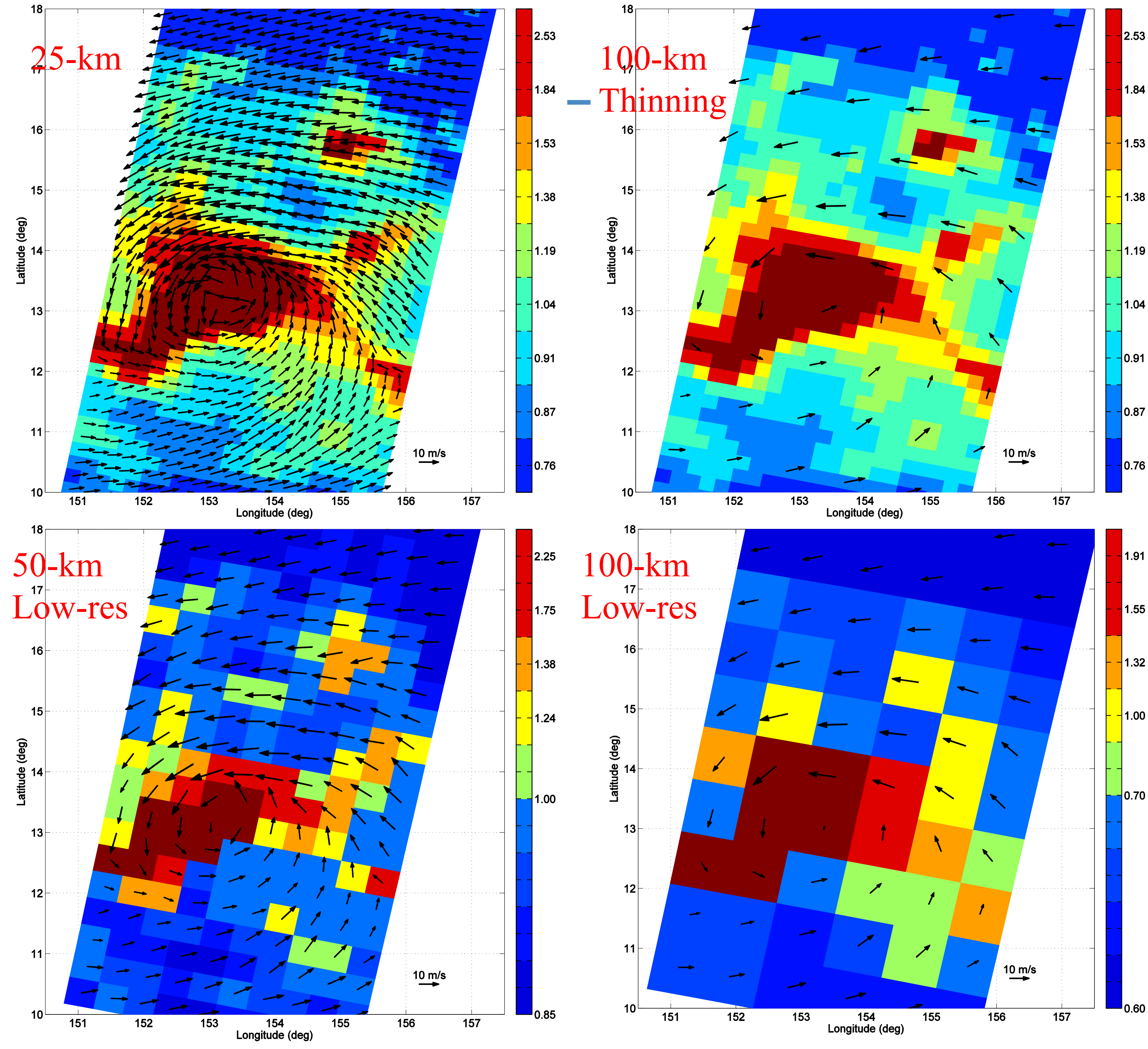
ASCAT 25-km winds **thinned**

Thinning by a factor of 4x4

Low resolution ASCAT winds for NWP assimilation



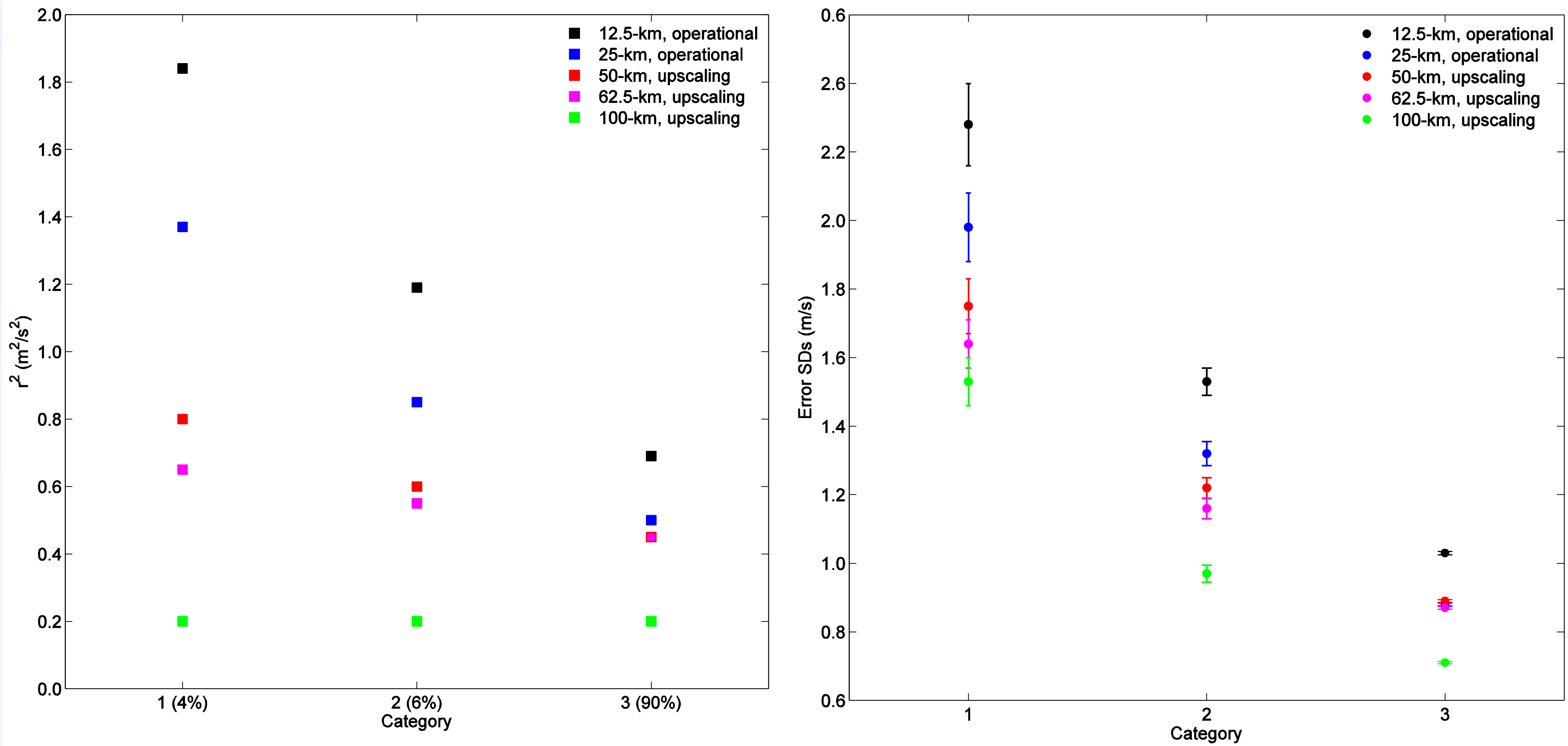
Schematic representation of the grid points (each small box represents a 25 km× 25 km WVC) used in the global NWP data assimilation: (a) when a thinning of 4 (i.e., one WVC every 4 along and across track WVCs) is applied; (b) when the new low resolution product is used. Note that in the right panel 3x3 high-resolution WVC winds are averaged to produce the low resolution product.



ASCAT wind fields superimposed on the observation errors

Note the range of colorbars

Actually, ECMWF assimilates wind ambiguities



rough categorization 4%, 6% and 90%

(left) The representativeness error and (right) the estimated error SDs as a function of wind quality category for different ASCAT wind data sources. The error bars denote the uncertainty in the estimated observation errors.

Quality Control

Table: Vector root-mean-square (VRMS) difference [m/s] between **ASCAT and buoy** winds (or **ASCAT and ECMWF** winds, in parenthesis) for the different data categories. Note that only ASCAT winds above 4 m/s are used.

	12.5-km	25-km	50-km	62.5-km	100-km
QC-accepted	2.25 (2.35)	2.31 (2.22)	2.35 (2.23)	2.41 (2.19)	2.62 (2.04)
QC-rejected	7.3 (6.6)	7.1 (6.0)	7.1 (5.6)	7.5 (5.6)	7.5 (5.2)

- Similar % of rejections for all products
- In general, the lower (higher) the ASCAT resolution, the better the agreement with ECMWF (buoys)
- Larger VRMS in 12.5-km product than in 25 & 50 km (w.r.t. buoys may be due to presence of rain or wind bursts (needs further investigation)

Wind speed bias correction

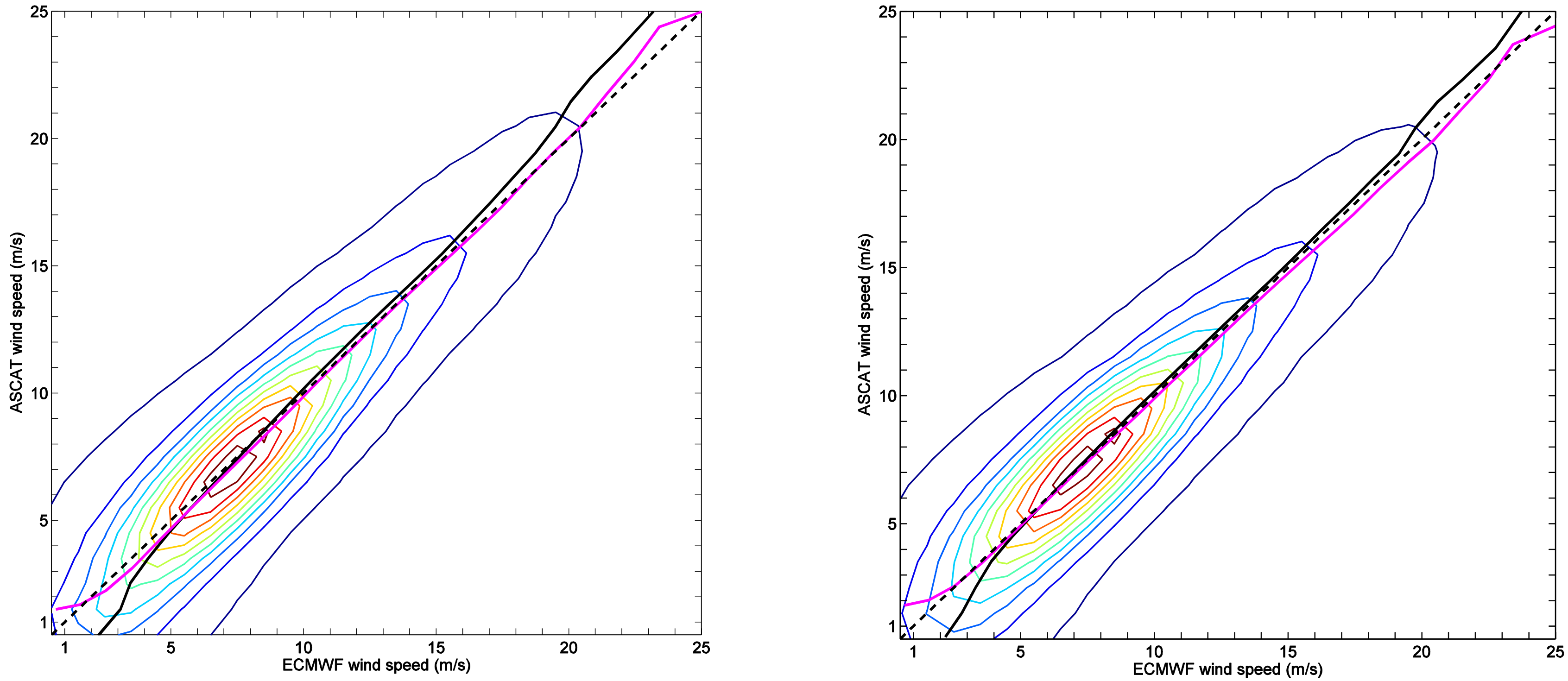


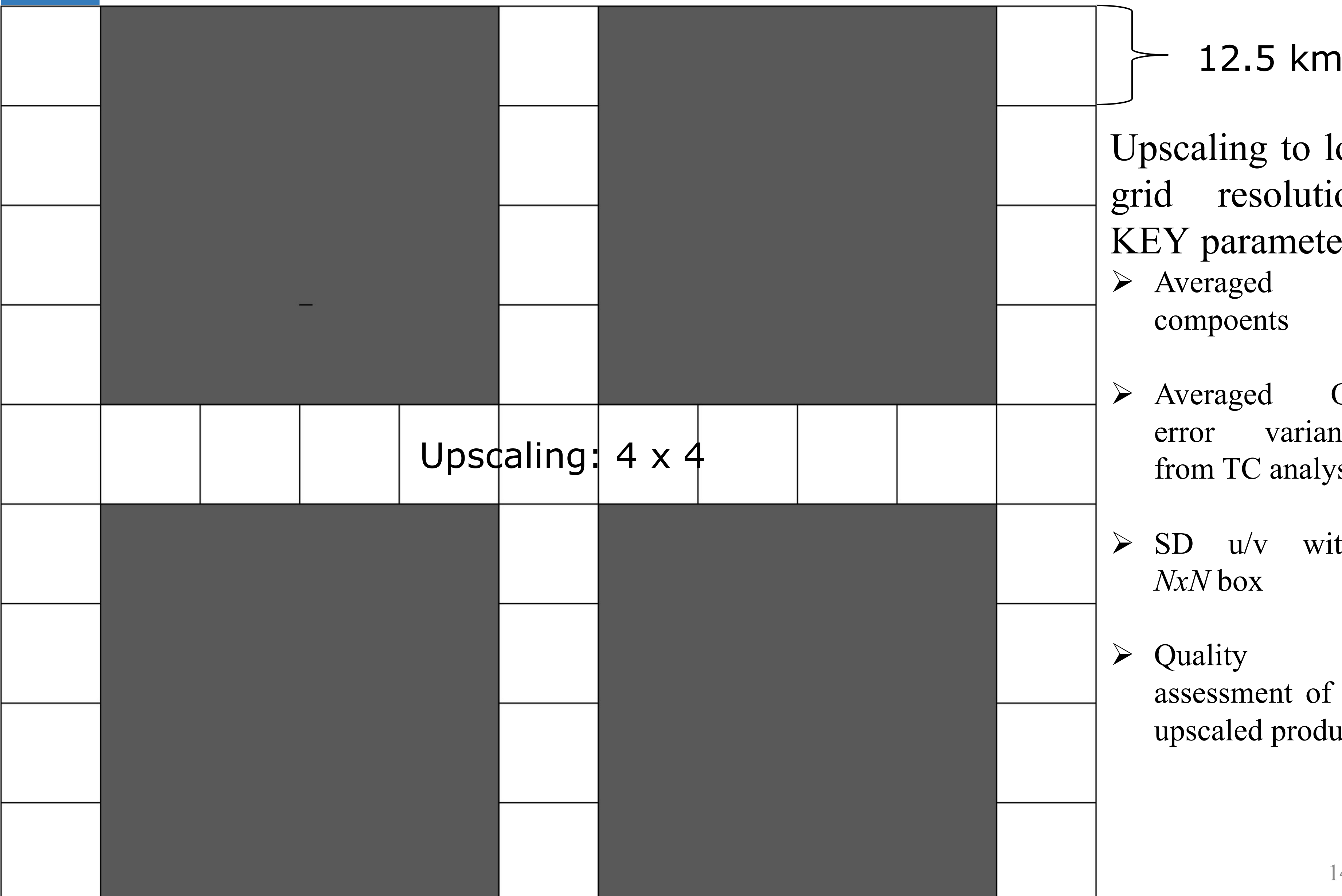
Figure. 2-D histogram of ASCAT 25-km wind speed versus ECMWF wind speed for WVC #1: (a) without bias correction; (b) after applying bias correction. The black (magenta) curve illustrates the mean ECMWF (ASCAT) wind speed at a set of ASCAT (ECMWF) speed bins, in which the binning is set to 1 m/s.

- In general, reduced biases at low and high wind speeds

Conclusions

- Situation-dependent O/B errors can be derived. They, together with the empirical background error correlation, improve 2D-Var significantly.
- The upscaling filters small-scale uncertainties to a certain extent, such that the upscaled winds are more representative of the NWP-scale winds than the nominal 12.5-km/25-km products.
- Upscaled low resolution product shows lowest error on ECMWF scale among the studied data sets, even under highly-variable conditions.
- Wind-speed bias correction and QC have been developed for all products.
- Impact experiments @IFS/ECMWF coming soon.
- If positive impact, a sigma0-upscaled product may be developed

3 Preliminary results – potential methods to improve 4DVAR



Upscaling to low grid resolution, KEY parameters :

- Averaged u/v compoents
- Averaged O/B error variances from TC analysis
- SD u/v within *NxN* box
- Quality assessment of the upscaled product

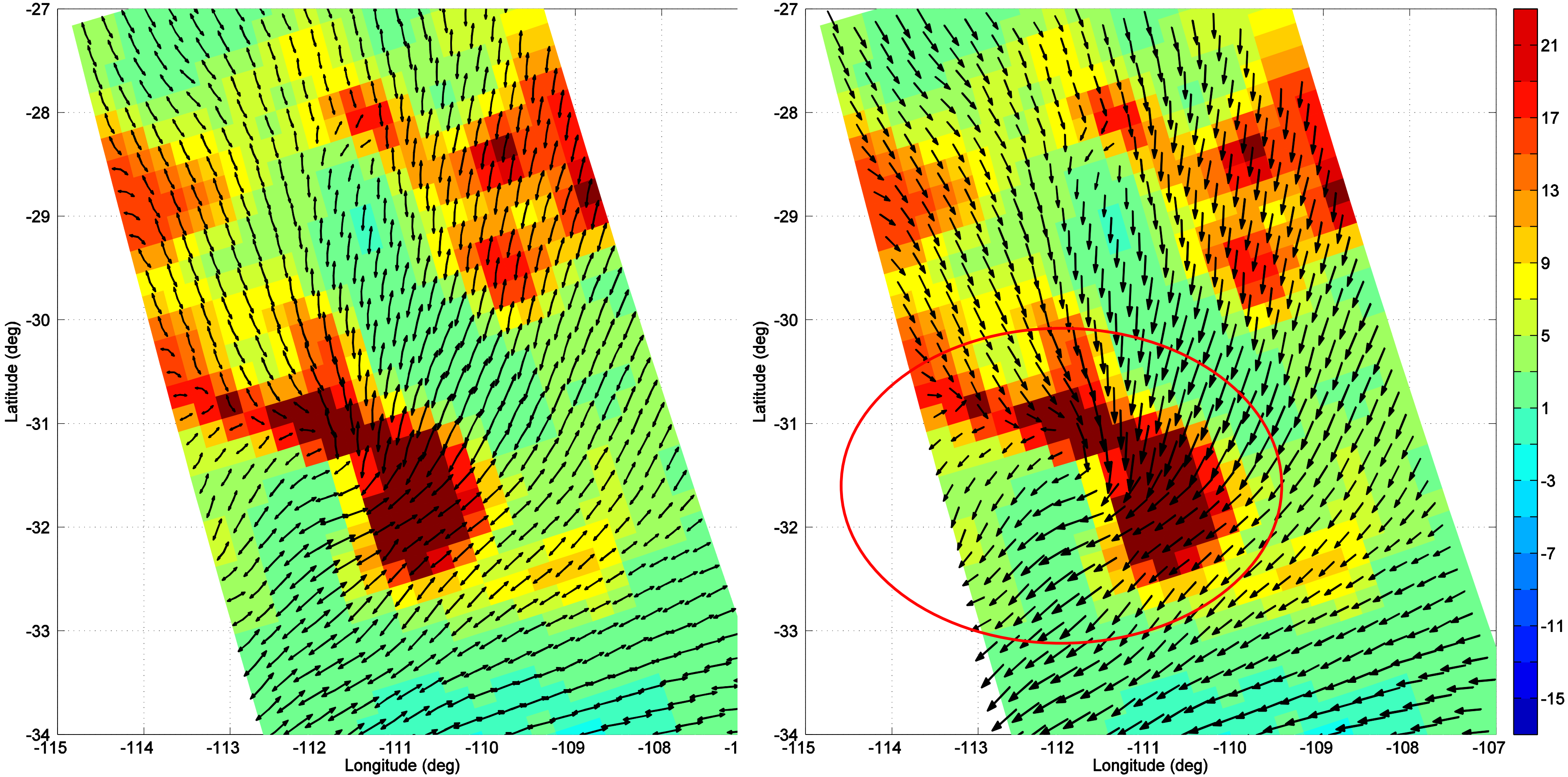


Fig. 2a (left) **IFS** ASCAT ambiguities superimposed with MLE; (b) IFS ASCAT selected solutions

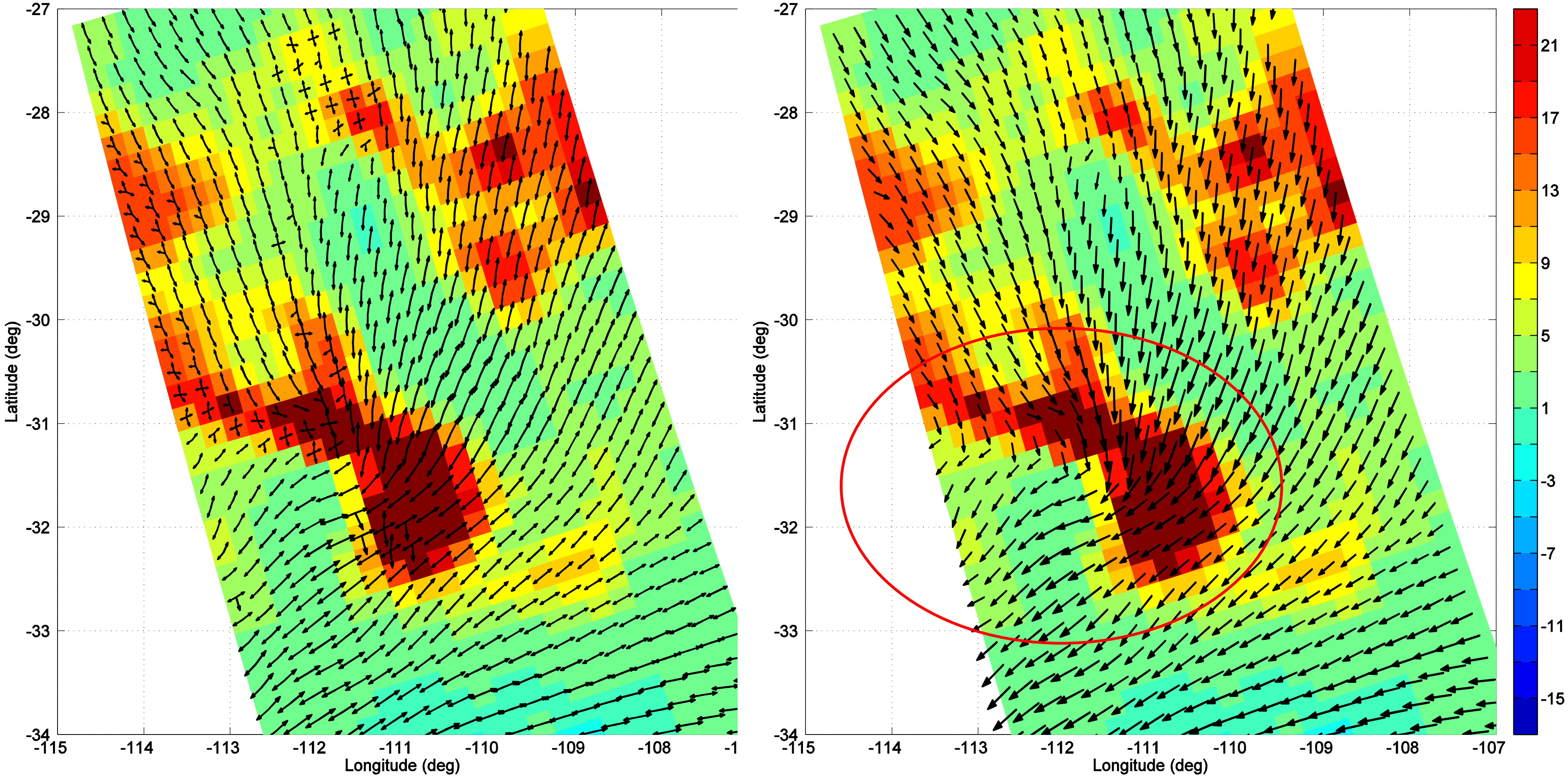


Fig. 2b (left) **AWDP** ASCAT ambiguities superimposed with MLE; (b) AWDP ASCAT selected solutions

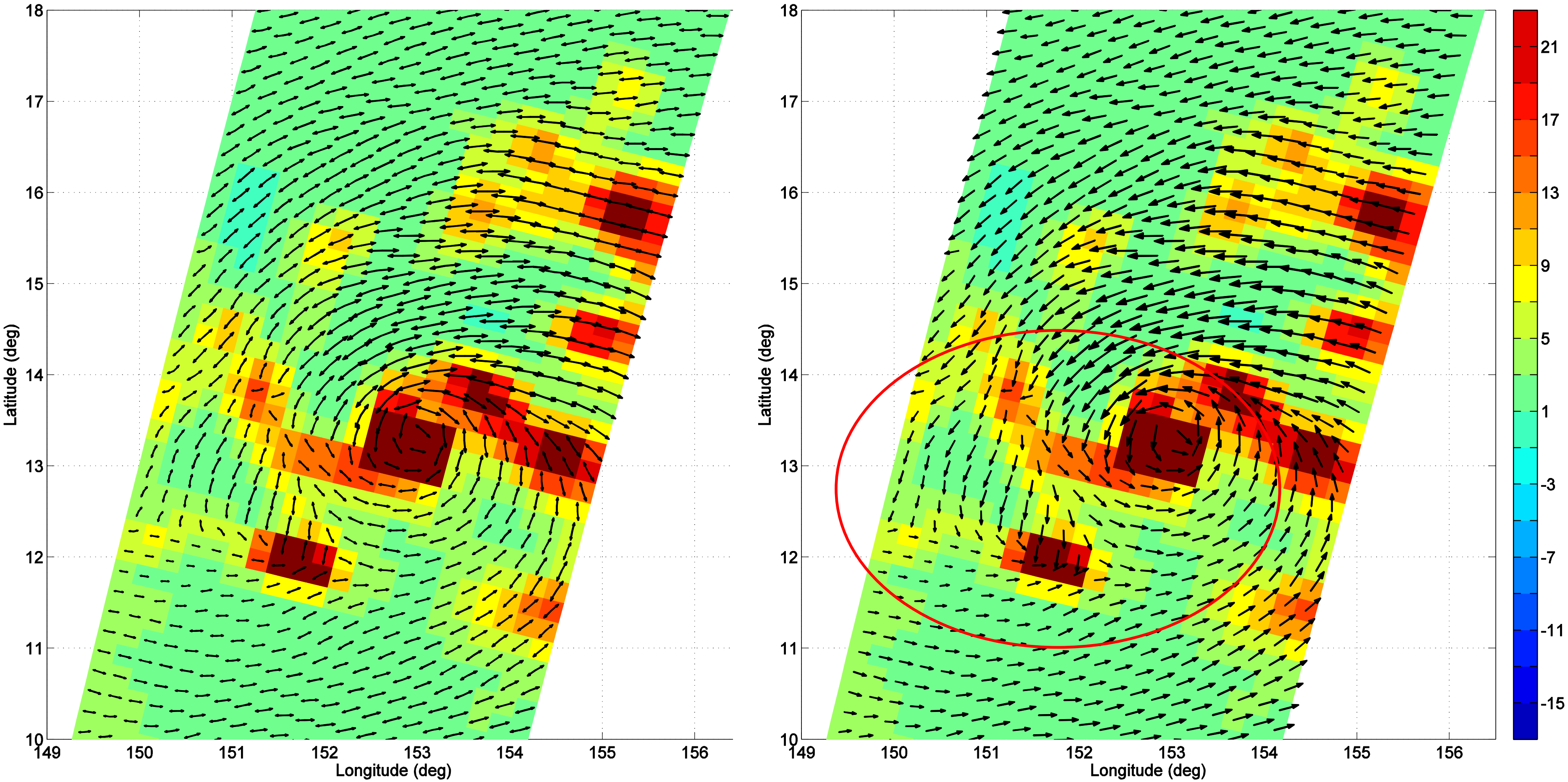


Fig. 3a (left) **IFS** ASCAT ambiguities superimposed with MLE; (b) IFS ASCAT selected solutions

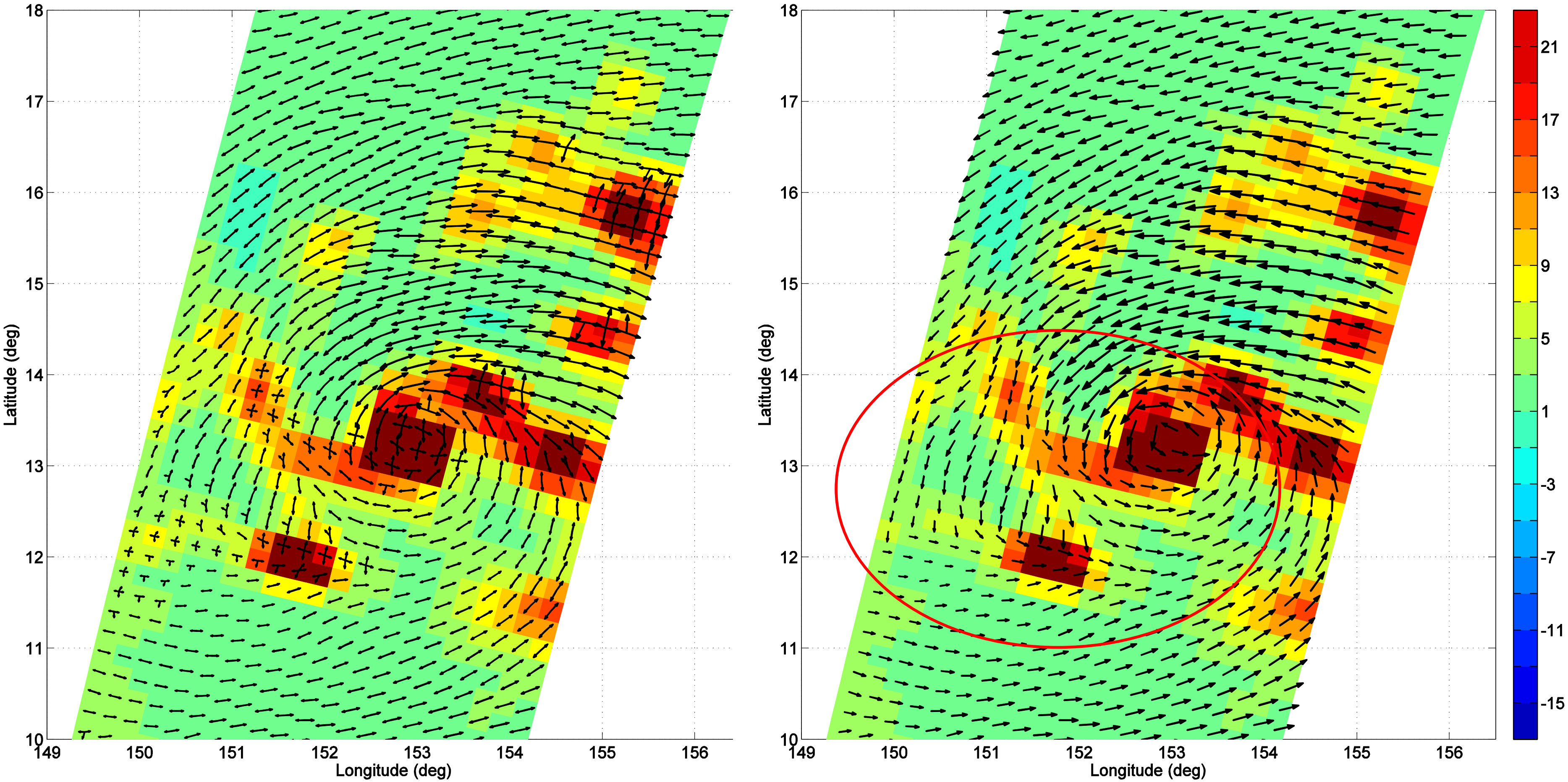
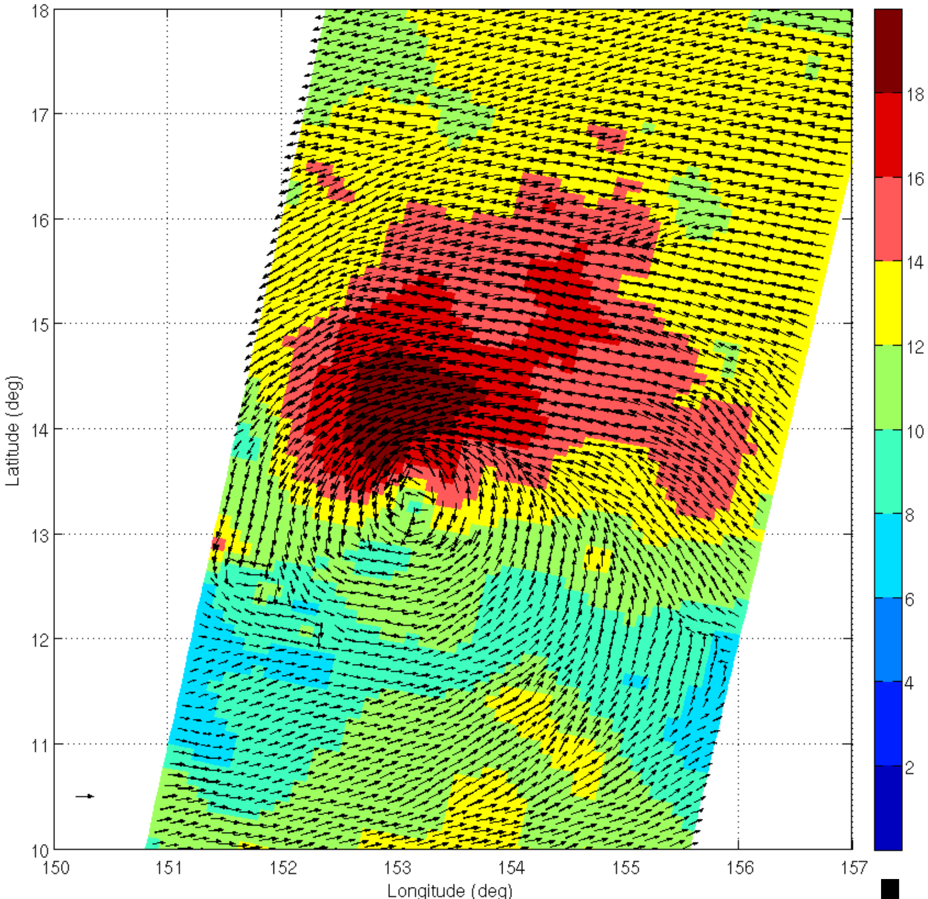
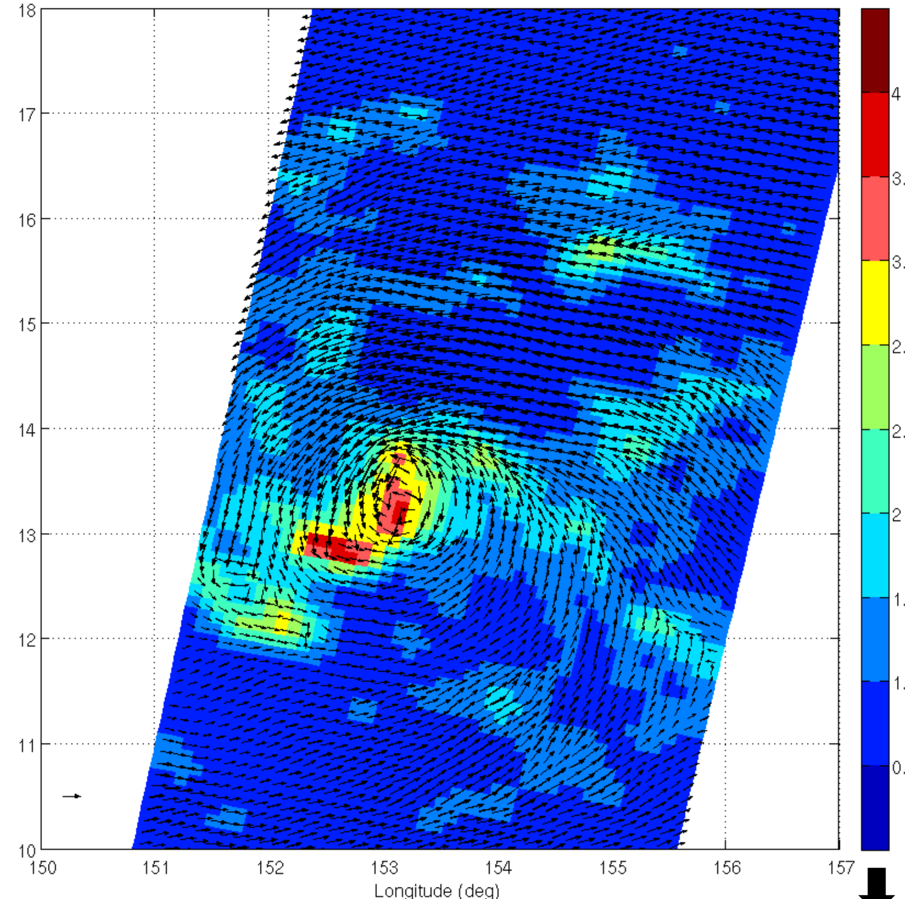


Fig. 3b (left) **AWDP** ASCAT ambiguities superimposed with MLE; (b) AWDP ASCAT selected solutions



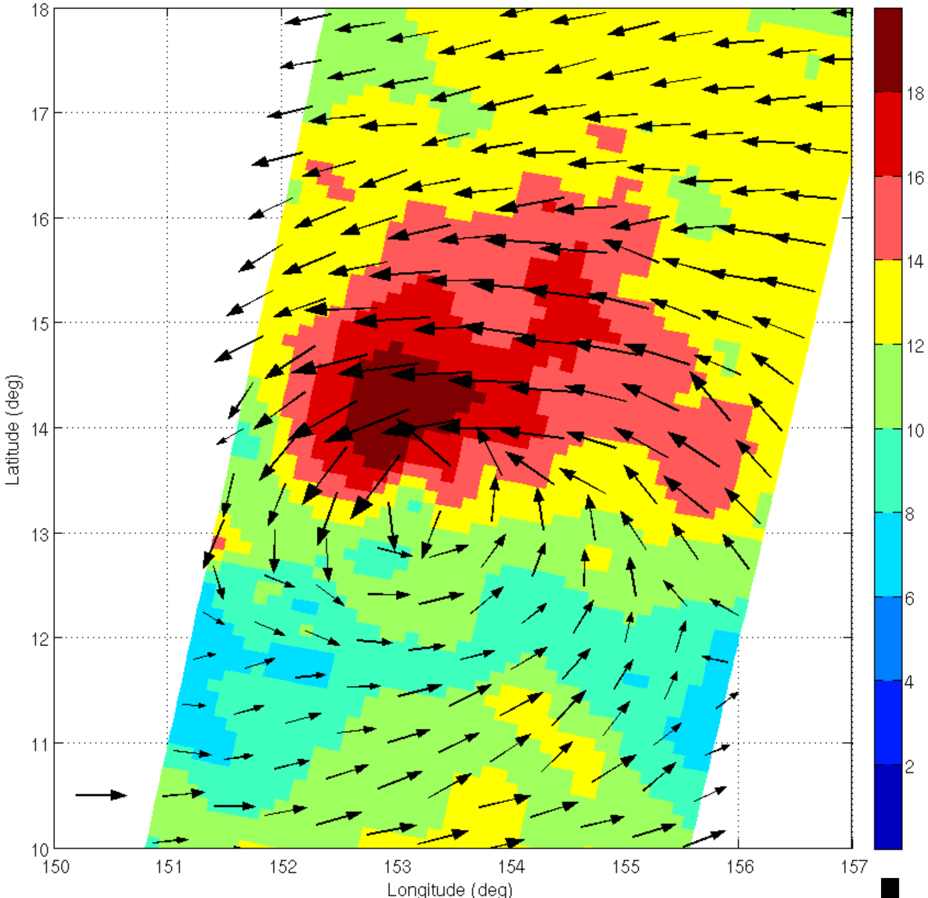


Speed [m/s]

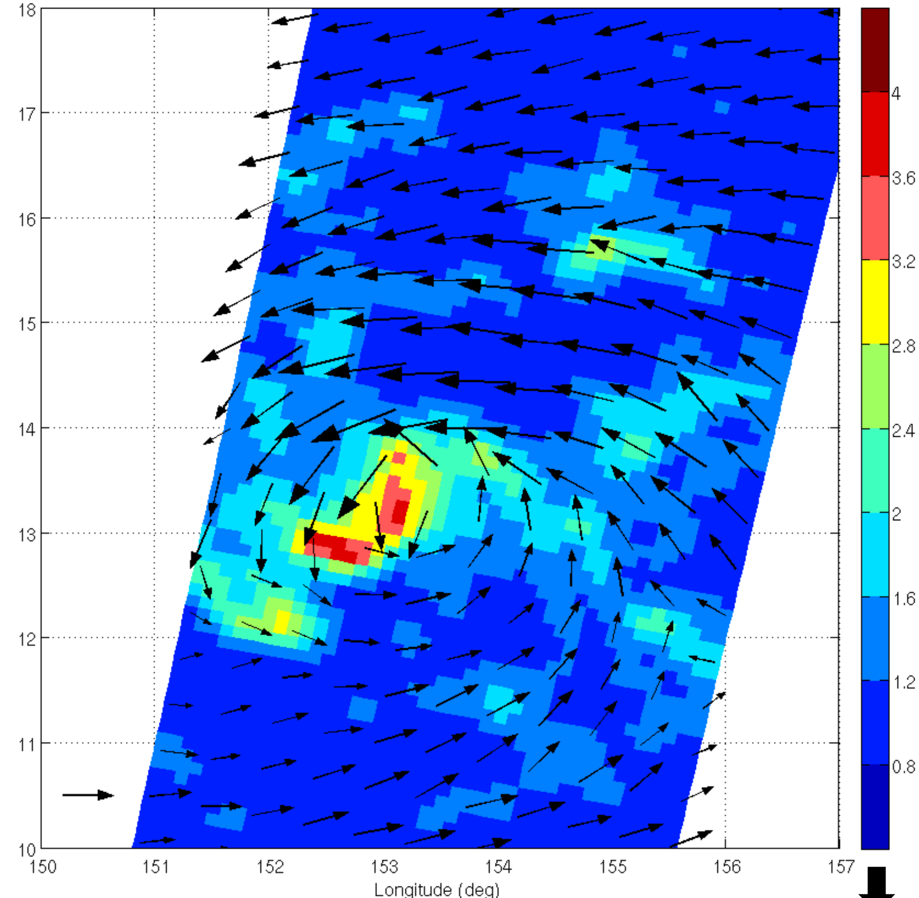
SD errors [m/s]

ASCAT wind vectors superimposed with speed

ASCAT wind vectors superimposed with the estimated Observation SD errors [*Lin et al., JGR, 2015*]



Speed [m/s]

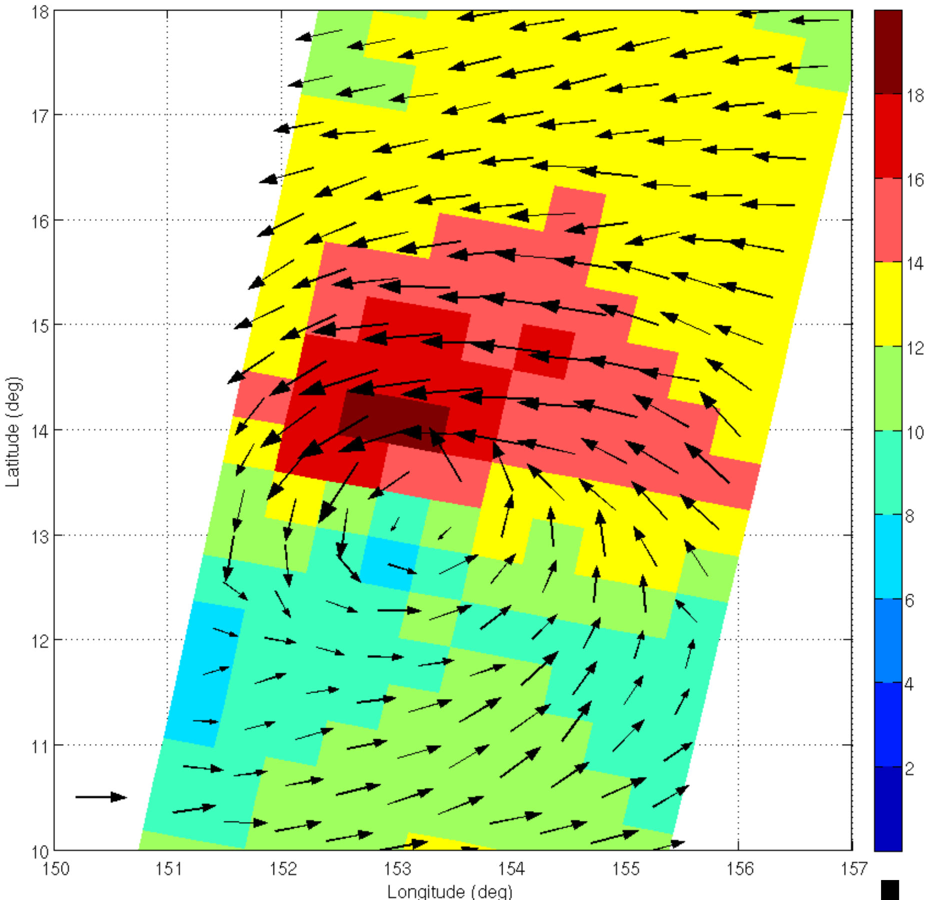


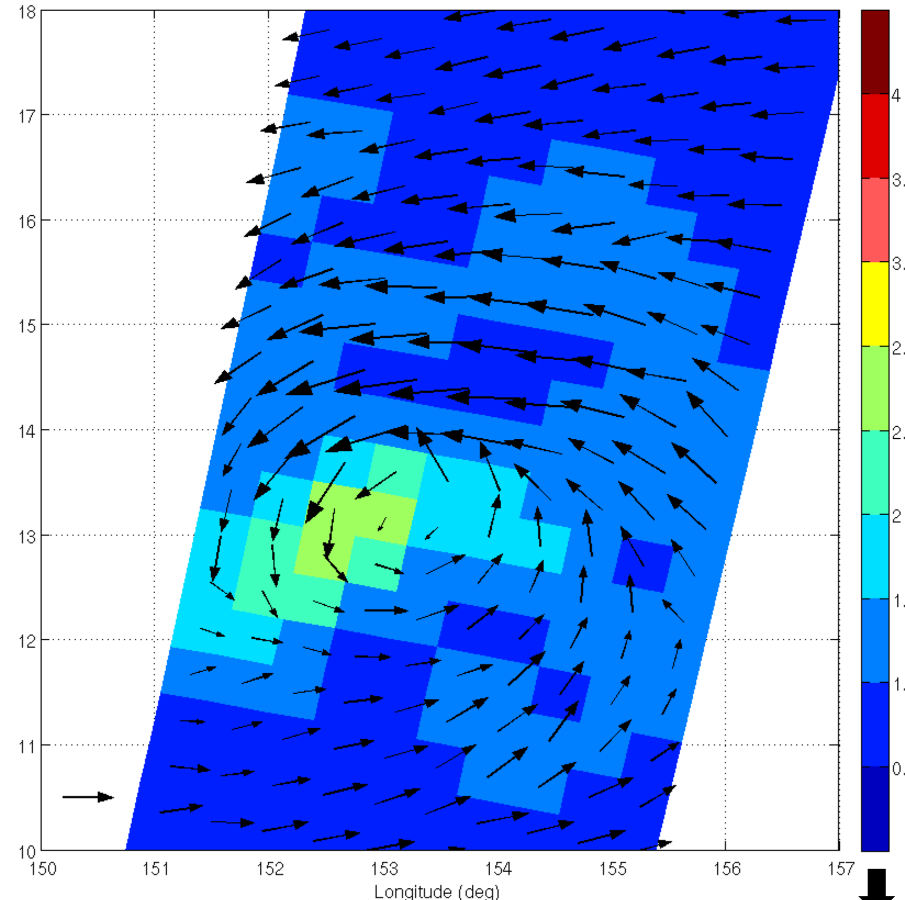
SD errors [m/s]

ASCAT wind vectors superimposed with speed

ASCAT wind vectors superimposed with the estimated Observation SD errors [*Lin et al., JGR, 2015*]

Thinning: a factor of 4





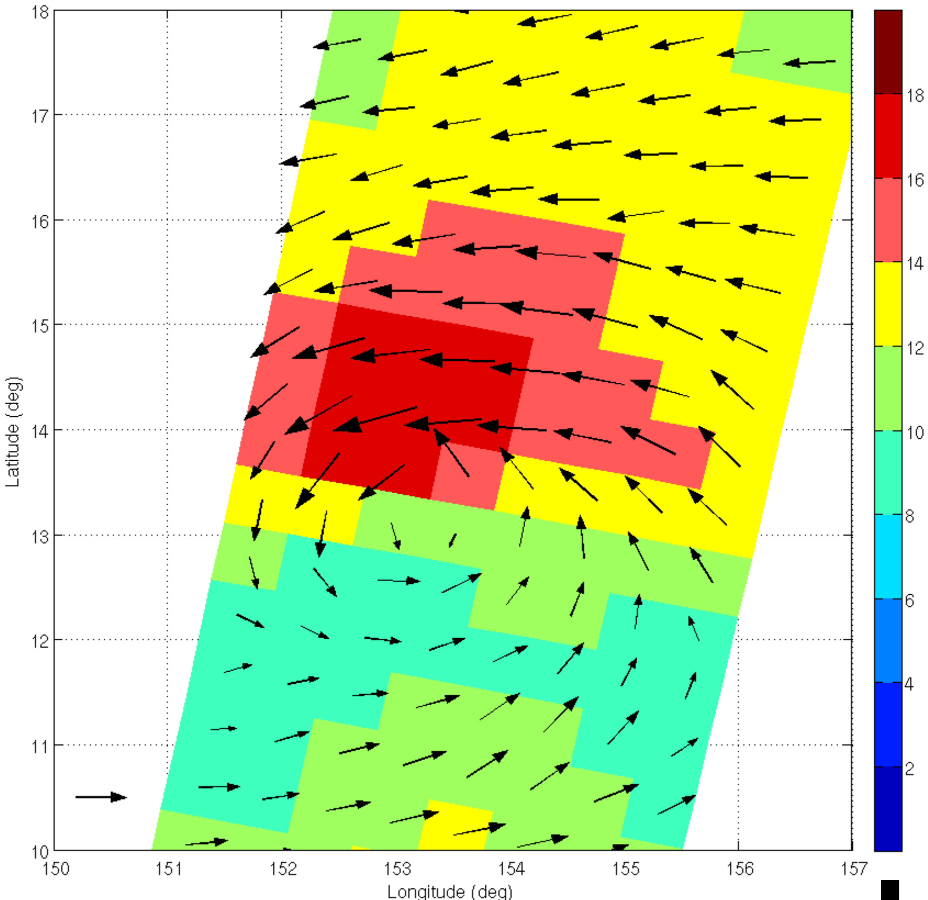
Speed [m/s]

SD errors [m/s]

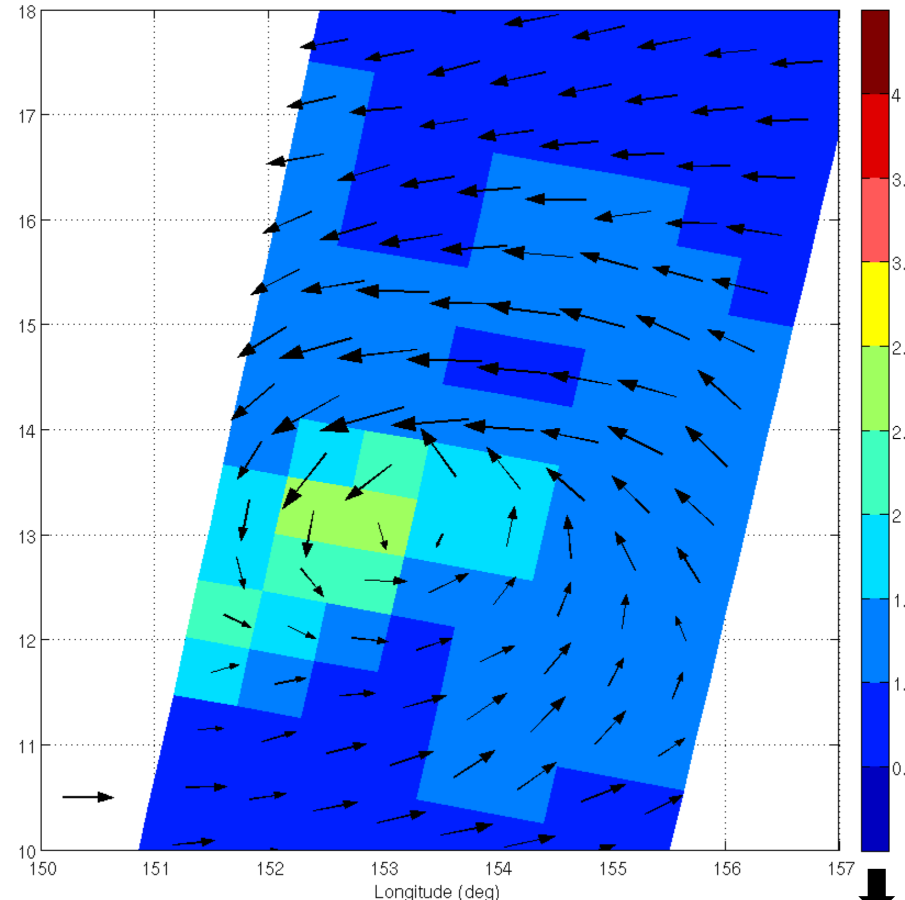
ASCAT wind vectors superimposed with speed

ASCAT wind vectors superimposed with the estimated Observation SD errors

Upscaling: 3x3



Speed [m/s]



SD errors [m/s]

ASCAT wind vectors superimposed with speed

ASCAT wind vectors superimposed with the estimated Observation SD errors

Upscaling: 4x4

Wind speed bias correction

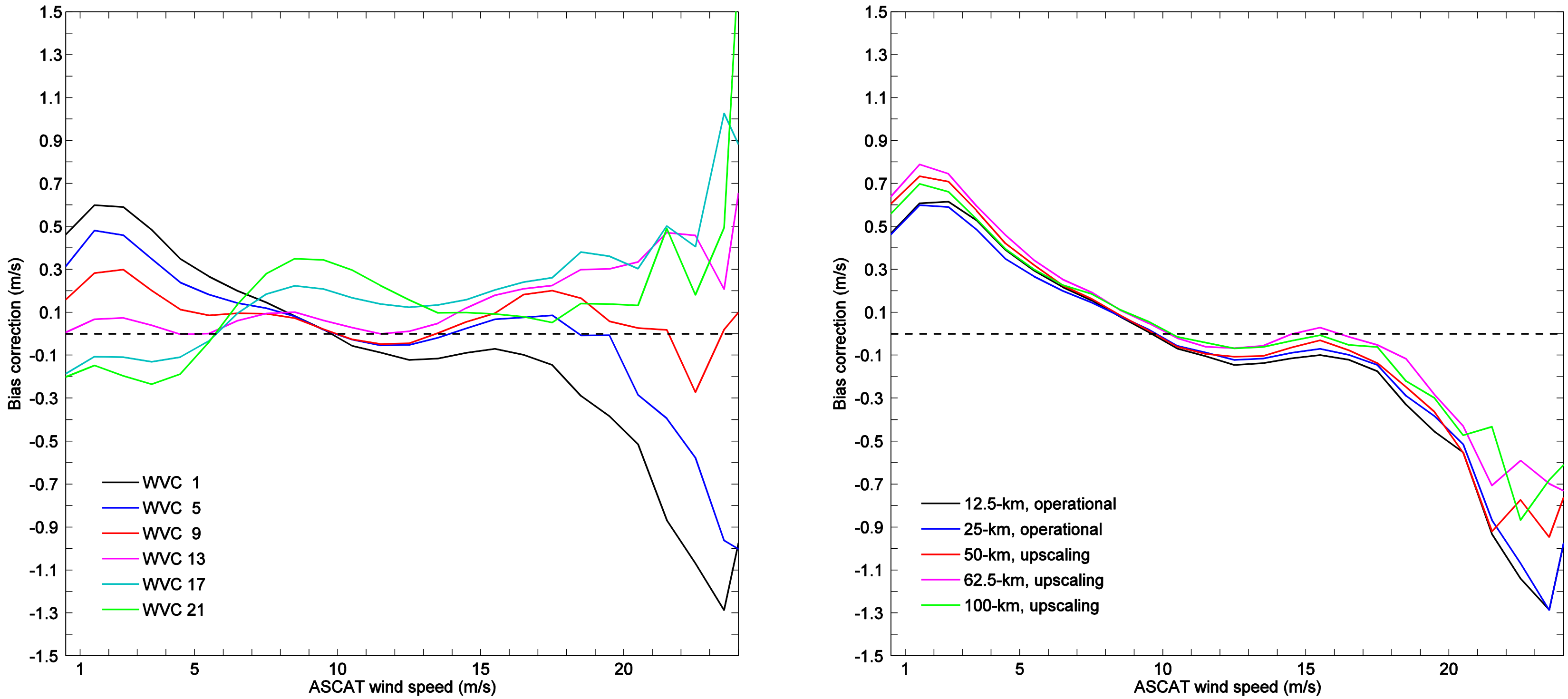


Figure. The bias correction values as a function of ASCAT wind speed for (a) ASCAT 25-km data and different WVC numbers, and for (b) WVC #1 and different ASCAT data products.

- In general, larger WVC-dependent than reolution dependent correction factors