# Towards an improved assimilation of ASCAT-derived winds into global NWP ：Input preparation

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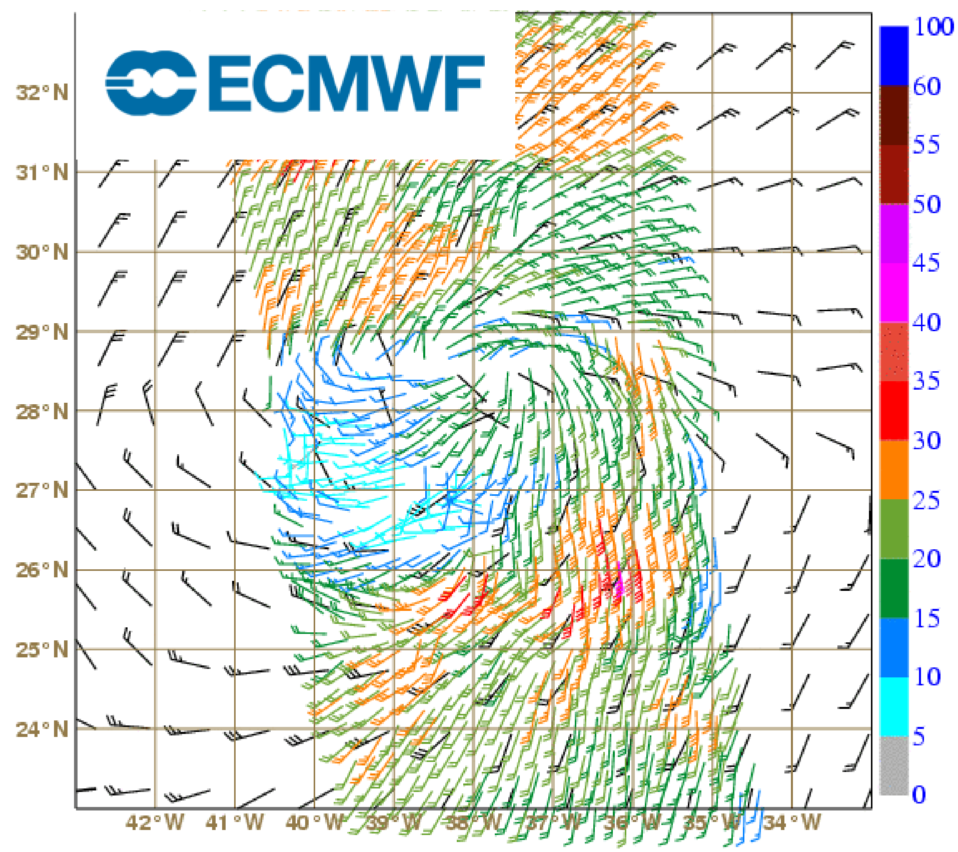


# Outline

1. Introduction

➢ 2DVAR (AWDP @ KNMI) VS 4D-Var (IFS @ ECMWF)

2. Potential approaches to improve DA of ASCAT winds

➢ Situation dependent Observation/Background (O/B) errors from triple collocation analysis
➢ Low resolution product

3. Preliminary results

4. Conclusions

# 1. Introduction – 2DVAR VS 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 |
| $\sigma^0$ 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 previous cycle |
| Quality control | MLE<+18.6 | Wspd < 35 m/s<br>Wdir difference > 135° |
| Thinning | No | Yes (25 km, by 4) |

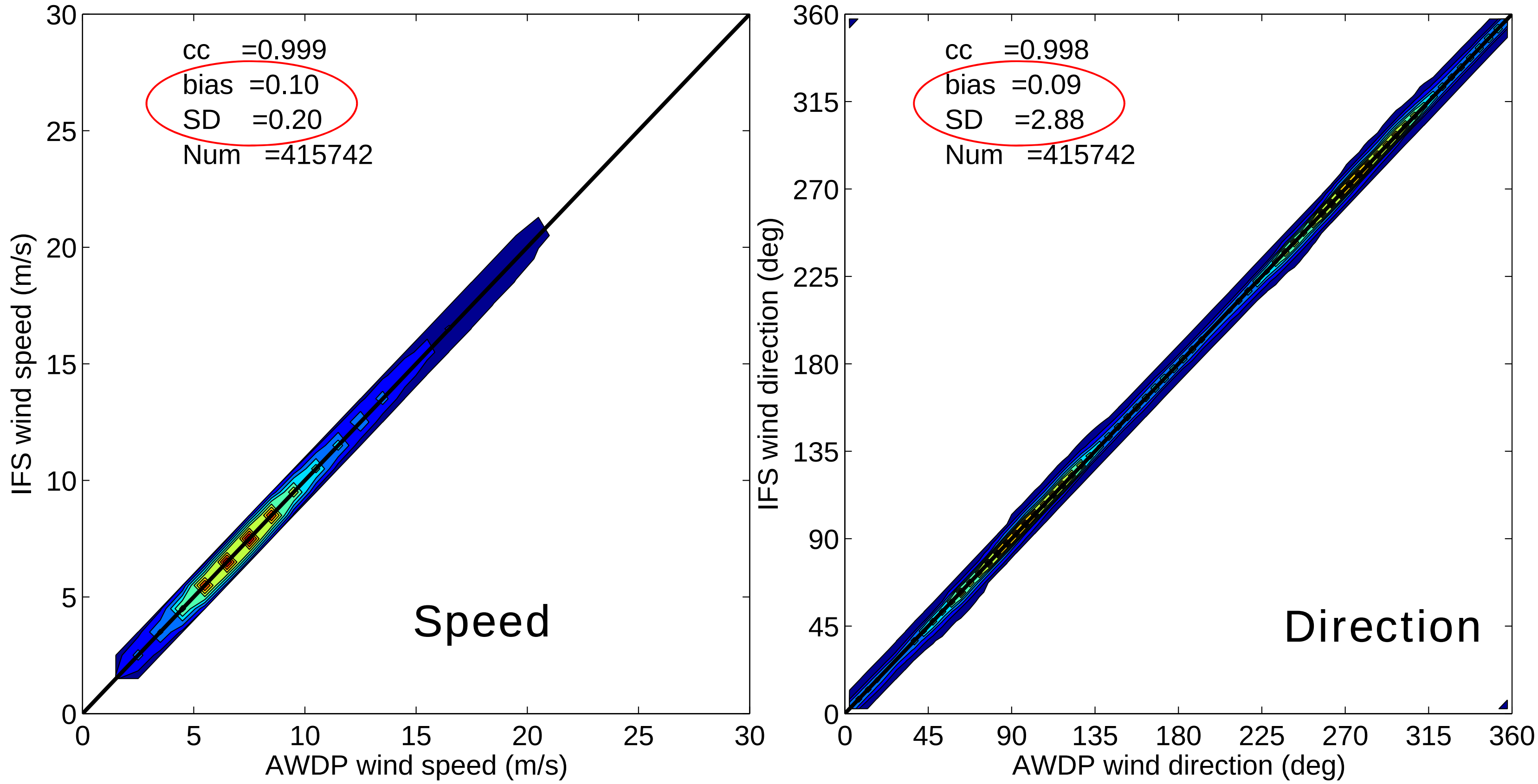



Fig. 1 IFS **ambiguities** versus AWDP ambiguities

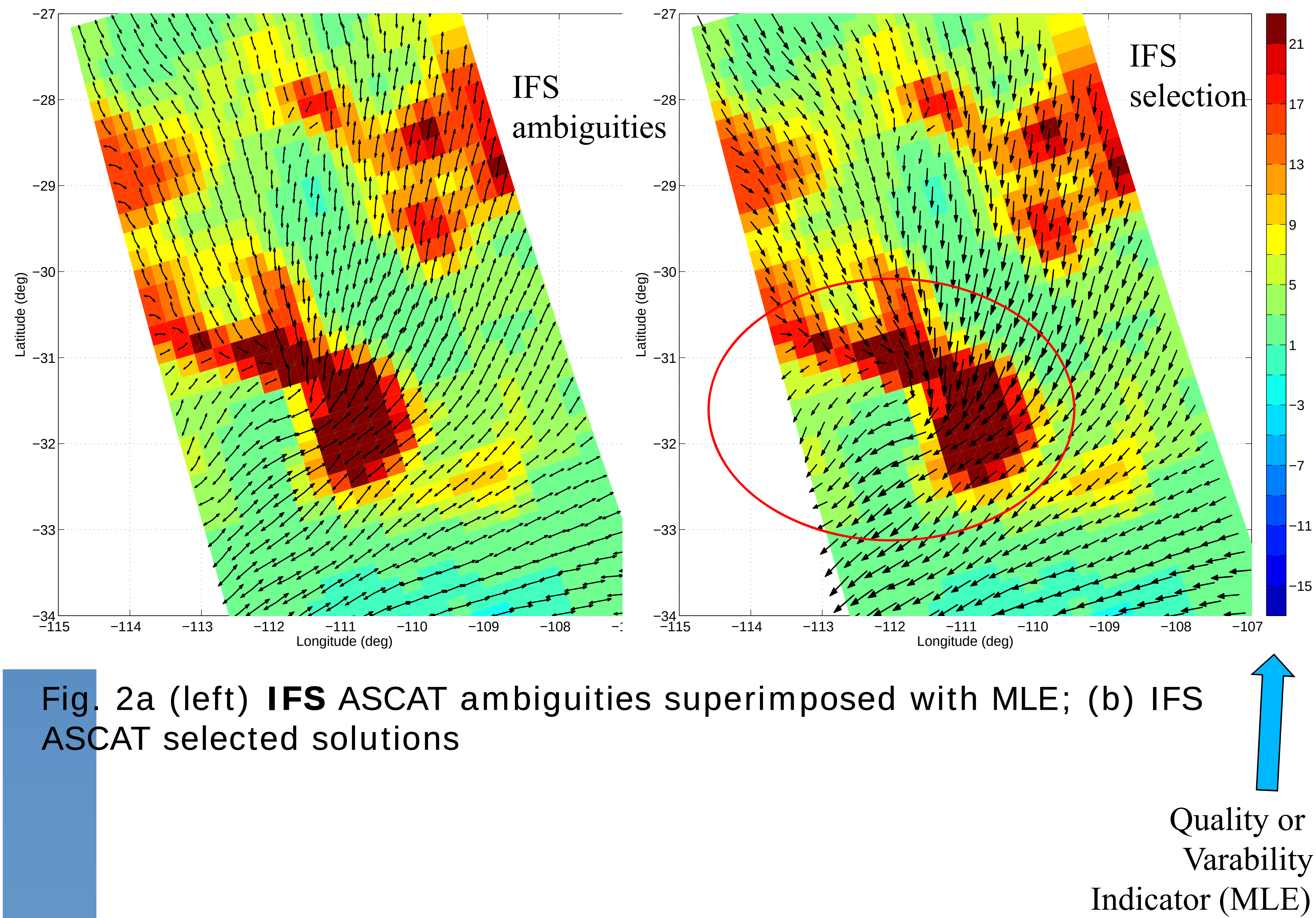



Fig. 2a (left) **IFS** ASCAT ambiguities superimposed with MLE; (b) IFS ASCAT selected solutions

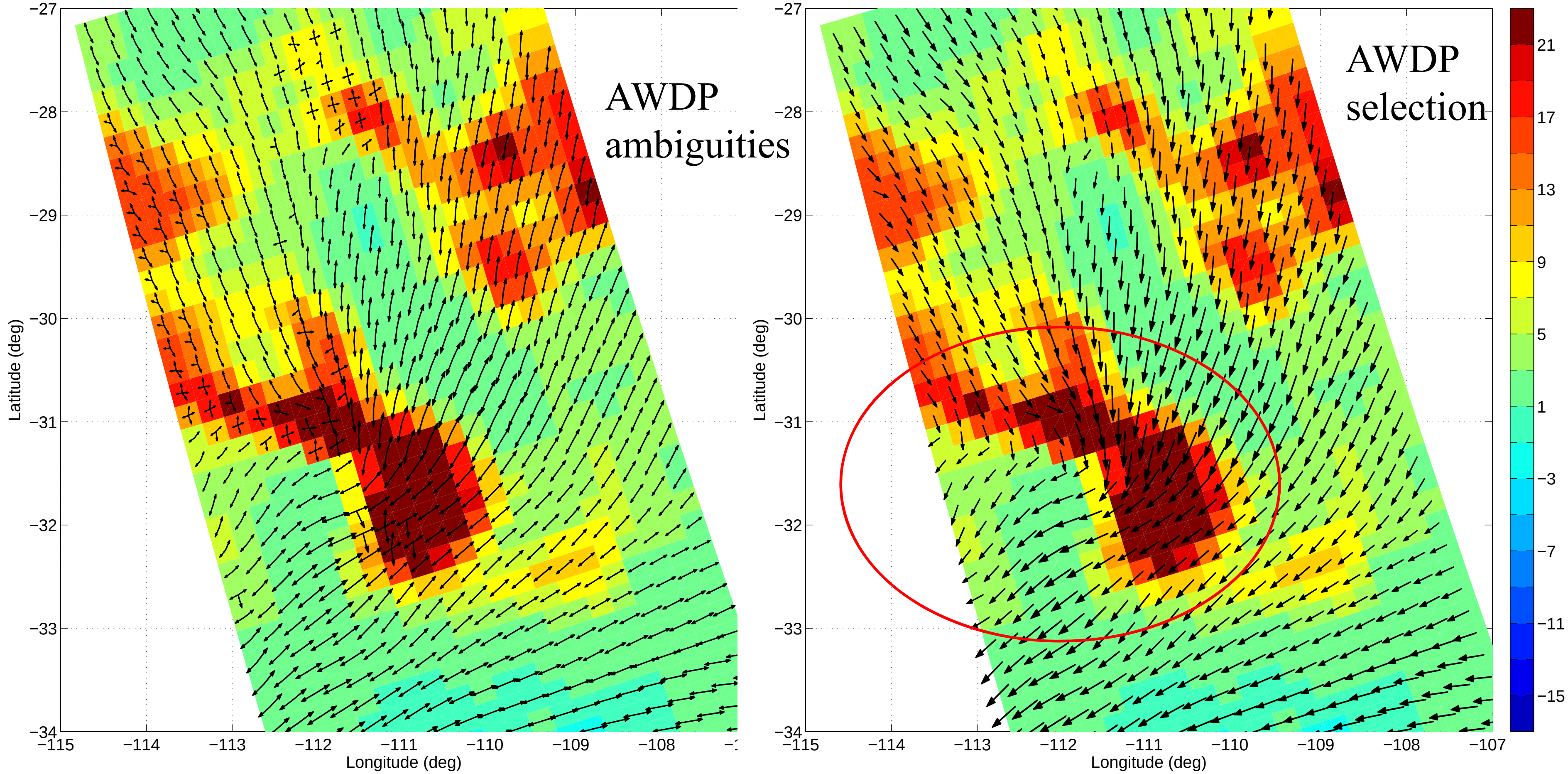



Fig. 2b (left) **AWDP** ASCAT ambiguities superimposed with MLE; (b) AWDP ASCAT selected solutions

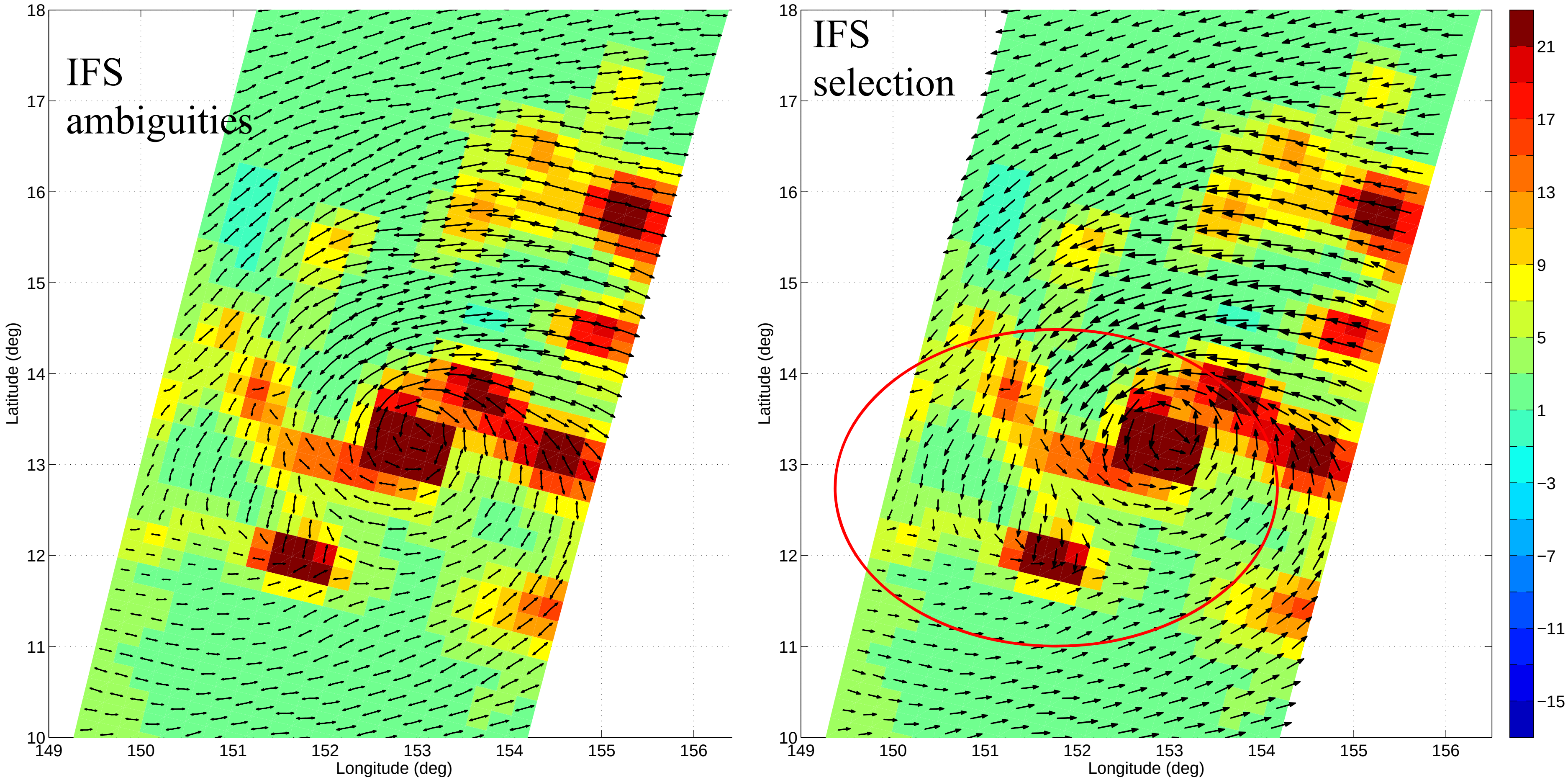



Fig. 3a (left) **IFS** ASCAT ambiguities superimposed with MLE; (b) IFS ASCAT selected solutions

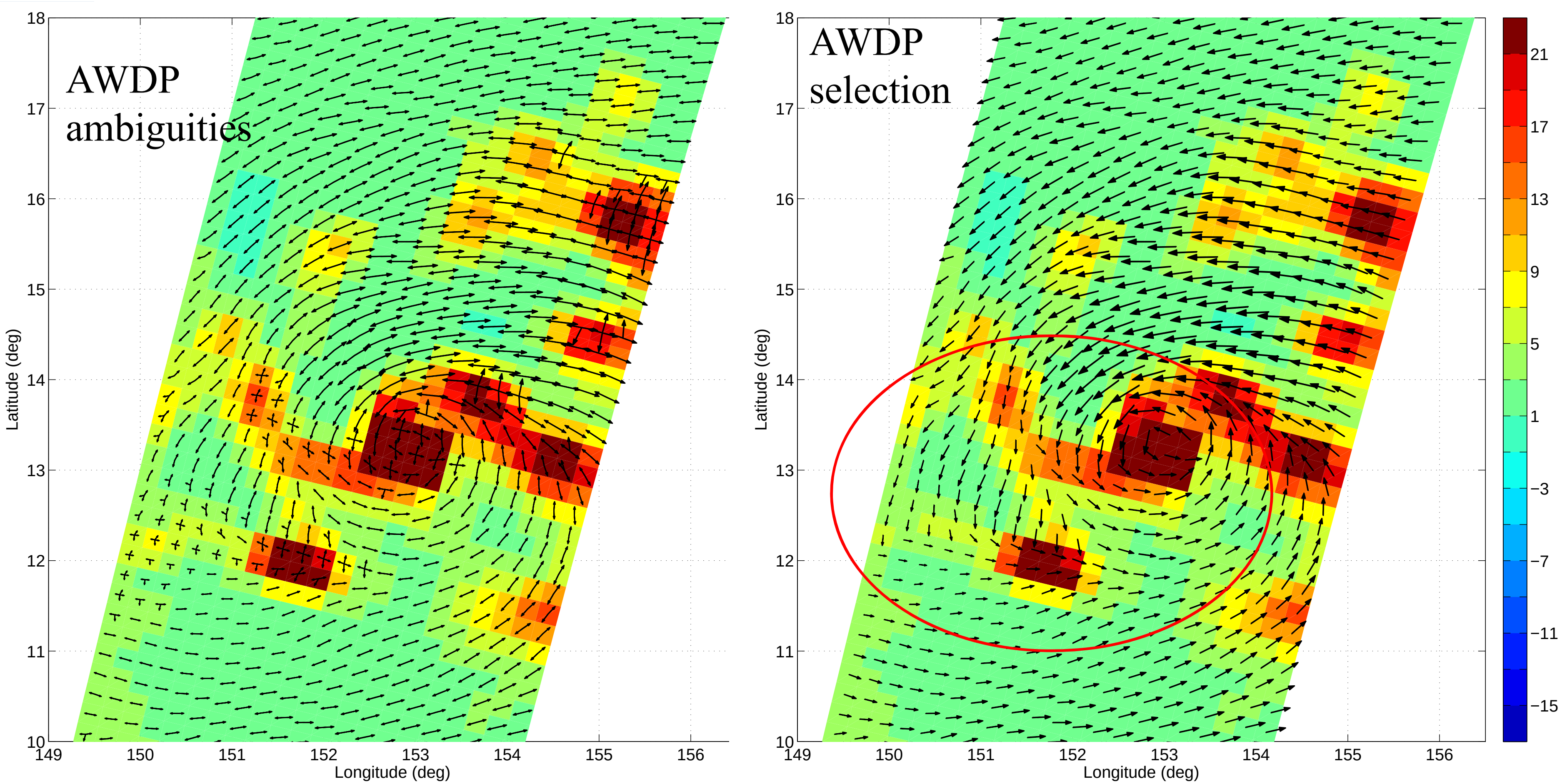



Fig. 3b (left) **AWDP** ASCAT ambiguities superimposed with MLE; (b) AWDP ASCAT selected solutions

# 2.1 O/B (Random) errors and the cost function

$$J(\mathbf{x}) = (\mathbf{y_o} - H[\mathbf{x}])^T \mathbf{R}^{-1} (\mathbf{y_o} - H[\mathbf{x}]) + (\mathbf{x} - \mathbf{x_b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_b})$$

Observation term: $(\mathbf{y_o} - H[\mathbf{x}])^T \mathbf{R}^{-1} (\mathbf{y_o} - H[\mathbf{x}])$

Background term: $(\mathbf{x} - \mathbf{x_b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_b})$

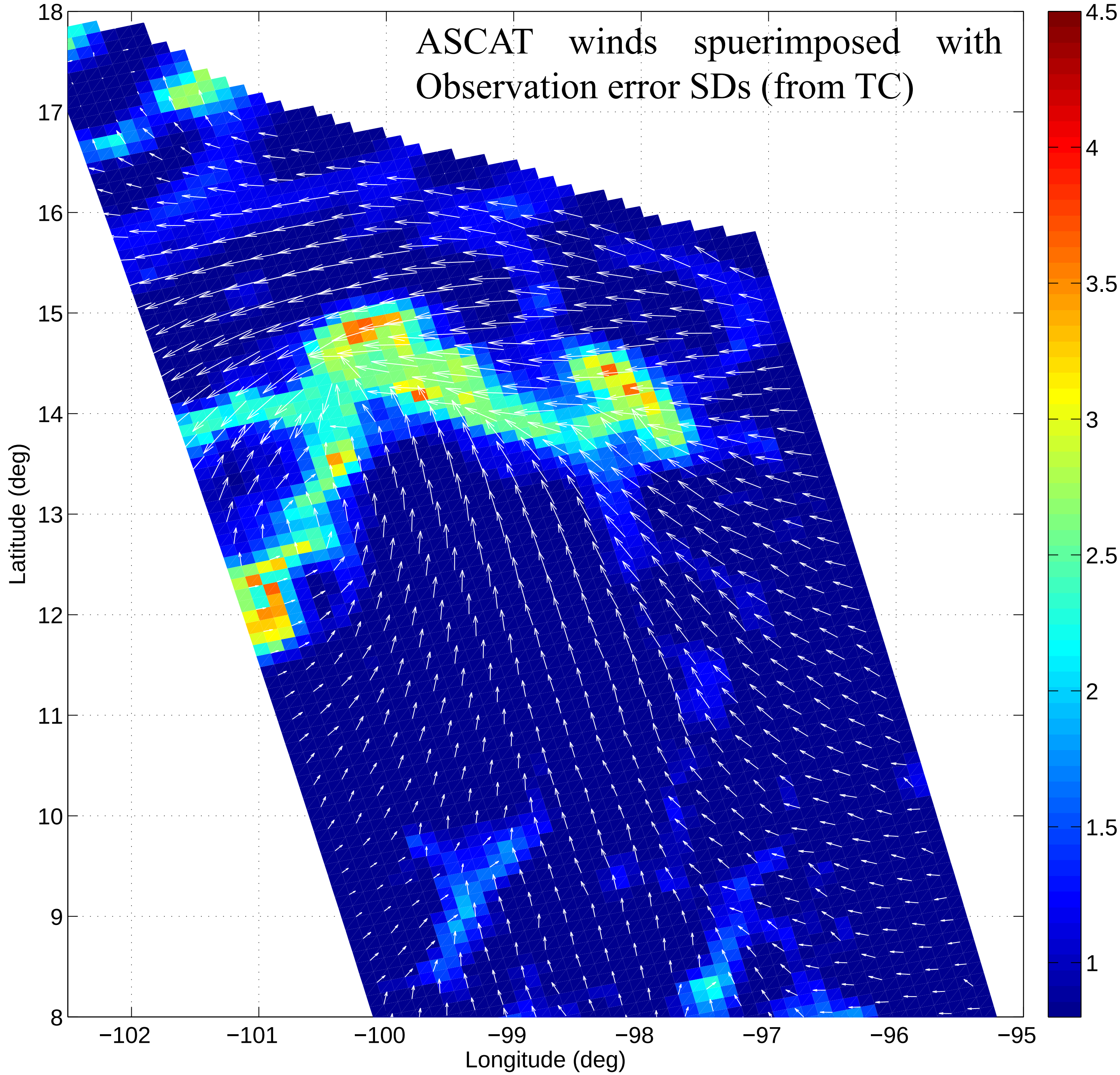
- R (B) is a matrix, often specified through the square root of the diagonals "$\sigma_O$" ("$\sigma_B$") and a correlation matrix (e.g., identity matrix in case of R).
- R and B together determine the weight of an observation in the assimilation.
- In the linear case, the minimum of the cost function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

$$(\mathbf{x}_a - \mathbf{x}_b) = \mathbf{B}\mathbf{H}^T (\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1} (\mathbf{y_o} - \mathbf{H}\mathbf{x}_b)$$

Increment: $(\mathbf{x}_a - \mathbf{x}_b)$

o-b departure: $(\mathbf{y_o} - \mathbf{H}\mathbf{x}_b)$

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




# function

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# 2.1 O/B (Random) errors and the cost function

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

➢ Fixed "$\sigma_O$" and "$\sigma_B$";

➢ 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)

- What to do when there are O error correlations?

➢ 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 $\sigma_O$ than diagnostics suggest.

➢ Take error correlations into account in the assimilation

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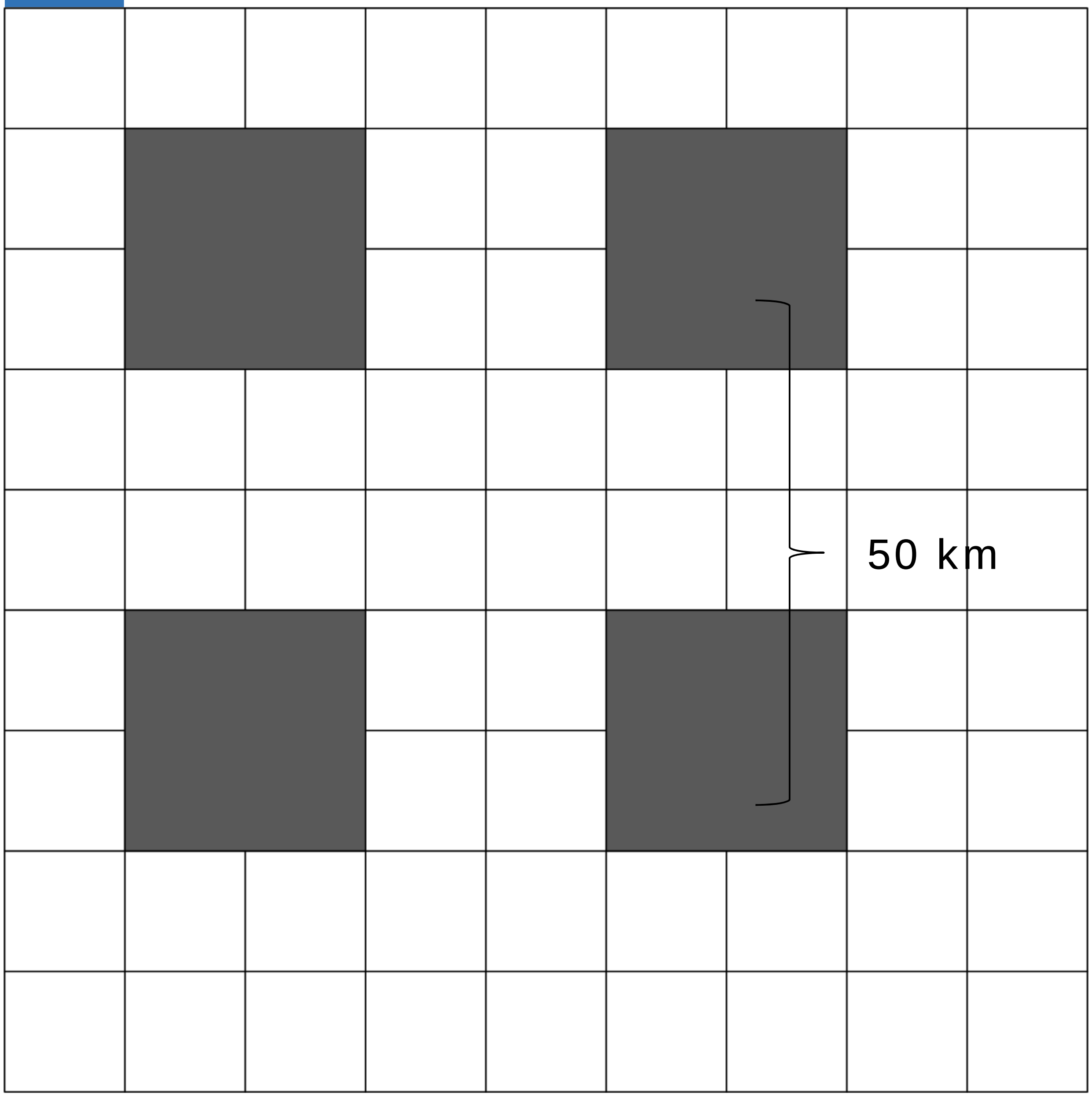
# 2.2 Low (grid) resolution ASCAT winds

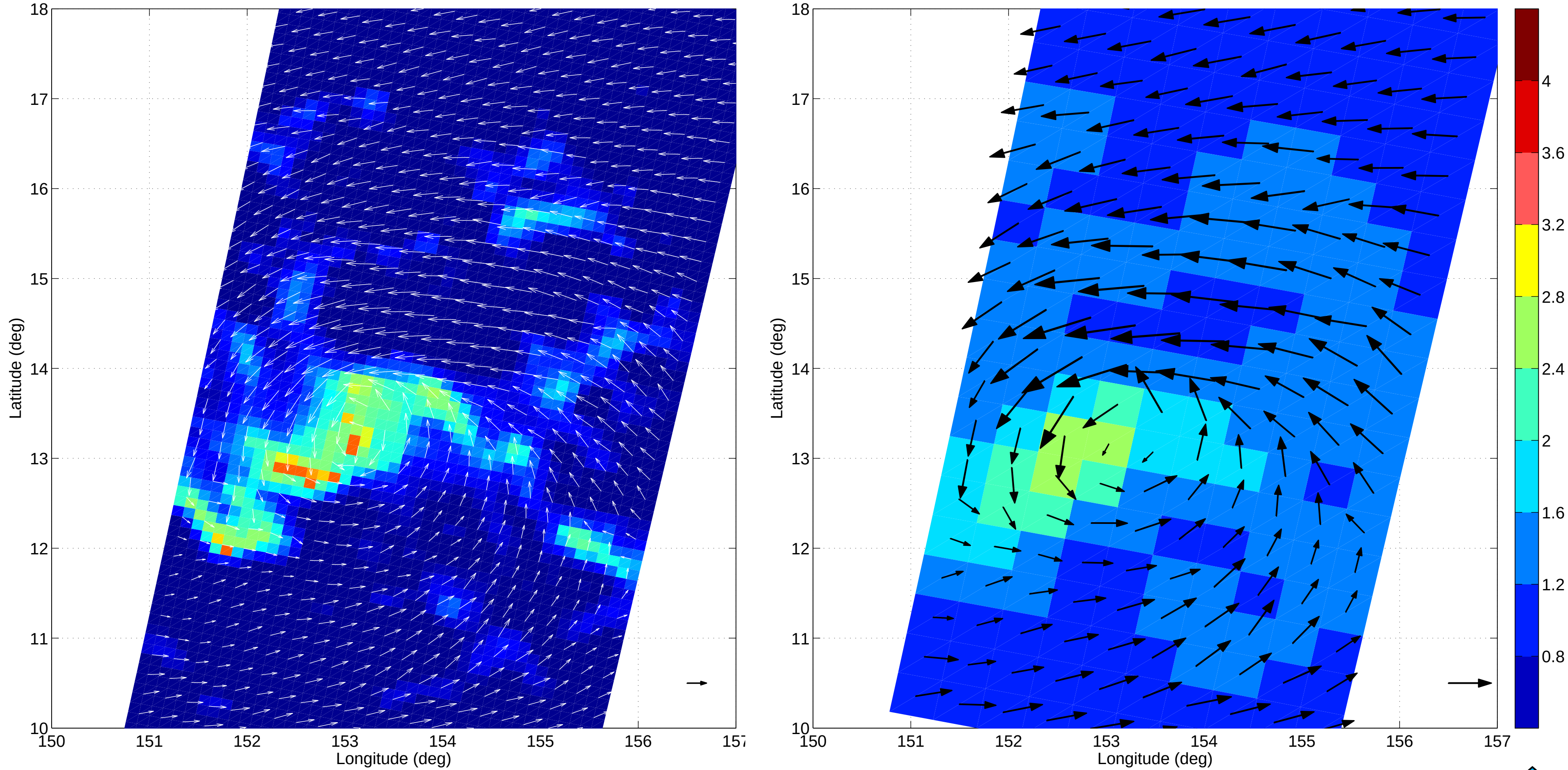



From 12.5km grid to 50 km grid, KEY parameters :

- Averaged u/v compoents
- Averaged O/B error variances from TC analysis
- SD u/v within 3x3 box (or 2x2 box)

KEY points:

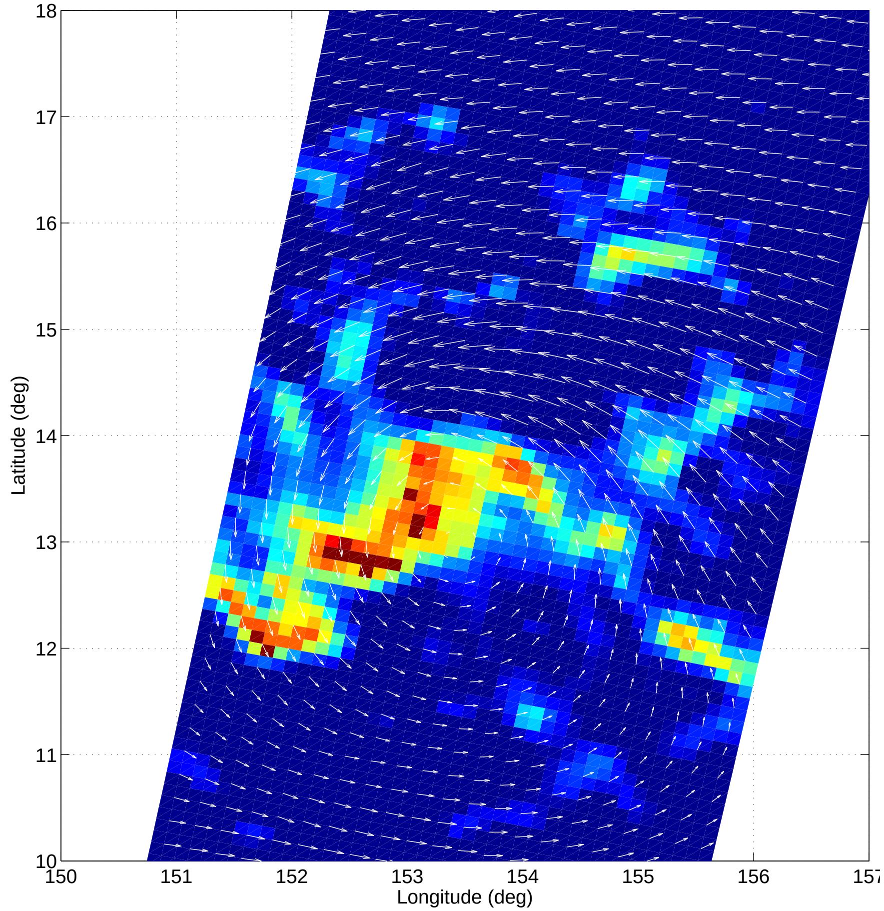
- Spatial correlation of O errors
- Quality assessment of the downscaled 50-km product

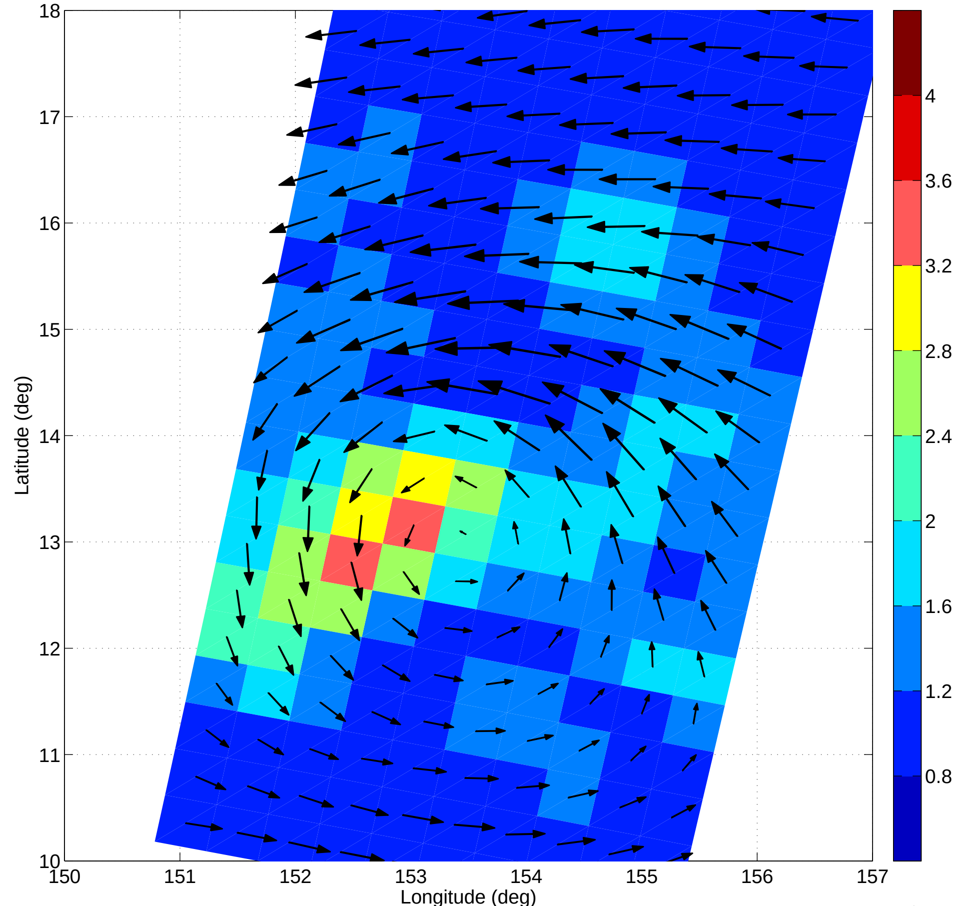



O errors

12.5 km wind vectors superimposed with O erros

50 km wind vectors superimposed with O erros




B errors

12.5 km wind vectors superimposed with B erros

50 km wind vectors superimposed with B erros

# 3. Preliminary Results

Table 2. Statistics of different **ASCAT** wind sources versus MARS **buoy** winds. QC-accepted data, N=19,308. Green color indicates the best statistics. (In parenthesis, statistics for buoy wi above 4 m/s)

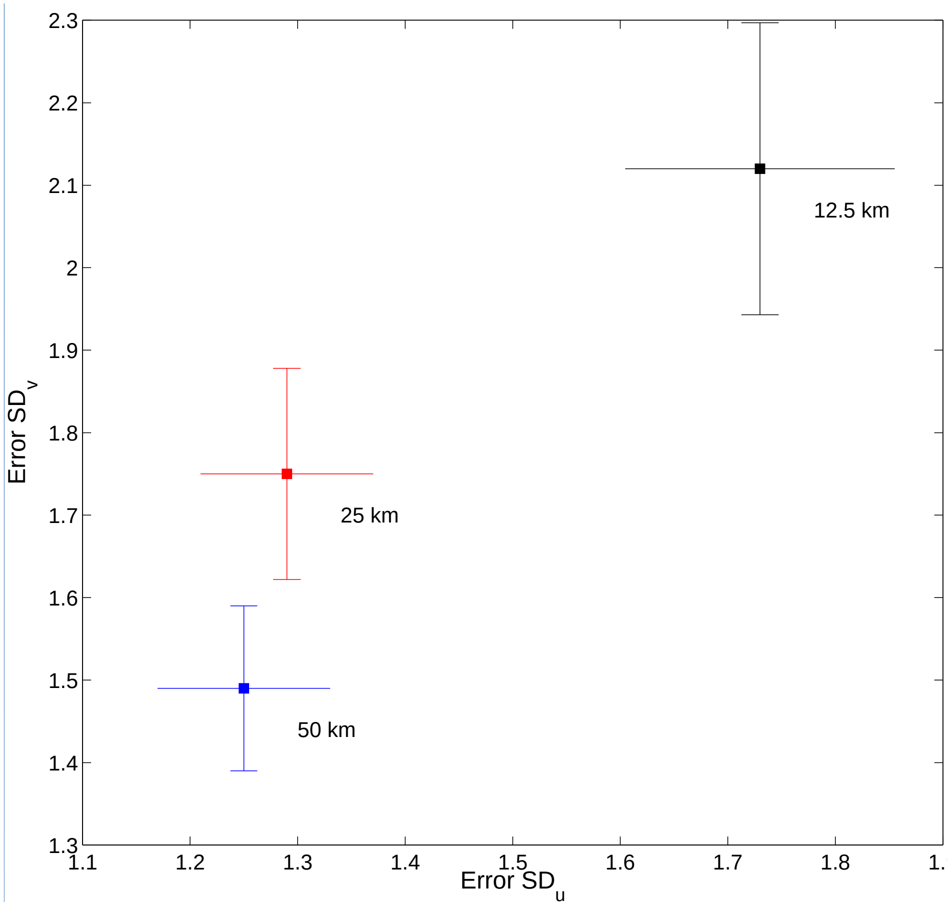
| | Speed bias (m/s) | Speed SD (m/s) | Direction SD (°) | u SD (m/s) | v SD (m/s) |
|---|---|---|---|---|---|
| 12.5 km | -0.22 | 1.07 | 24.4 | 1.47 (1.41) | 1.61 (1.58) |
| 25 km | -0.18 | 1.04 | 23.9 | 1.46 (1.39) | 1.58 (1.53) |
| 50 km | -0.27 | 1.05 | 23.5 | 1.42 (1.37) | 1.55 (1.53) |

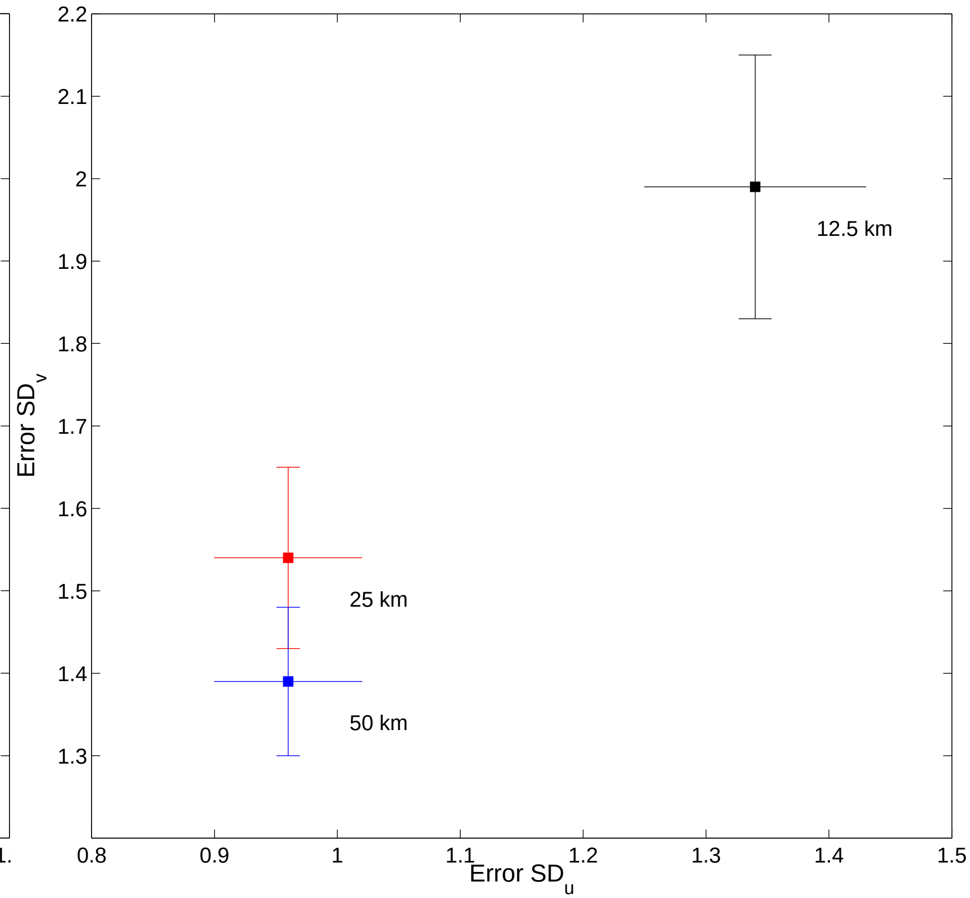
Table 3. Statistics of different **ASCAT** wind sources versus **ECMWF** winds.

| | Speed bias (m/s) | Speed SD (m/s) | Direction SD (°) | u SD (m/s) | v SD (m/s) |
|---|---|---|---|---|---|
| 12.5 km | 0.11 | 1.34 | 24.1 | 1.50 (1.46) | 1.62 (1.58) |
| 25 km | 0.14 | 1.28 | 23.0 | 1.44 (1.40) | 1.56 (1.52) |
| 50 km | 0.06 | 1.30 | 23.0 | 1.43 (1.39) | 1.52 (1.49) |

Table 5. TC analysis for the three different data sets: the estimated error SDs on ECMWF scale (left) and SCAT scale (right).

| | | ECMWF scale | | SCAT scale | |
|---|---|---|---|---|---|
| | | *u* | *v* | *u* | *v* |
| 12.5 | Buoy | 1.30 ± 0.02 | 1.37 ± 0.02 | 1.15 ± 0.01 | 1.20 ± 0.01 |
| | SCAT | 0.91 ± 0.01 | 1.12 ± 0.01 | 0.69 ± 0.01 | 0.90 ± 0.01 |
| | ECMWF | 1.19 ± 0.02 | 1.20 ± 0.02 | 1.33 ± 0.02 | 1.37 ± 0.02 |
| 25.0 | Buoy | 1.31 ± 0.02 | 1.39 ± 0.02 | 1.19 ± 0.01 | 1.22 ± 0.01 |
| | SCAT | 0.77 ± 0.01 | 1.00 ± 0.01 | 0.54 ± 0.01 | 0.74 ± 0.01 |
| | ECMWF | 1.19 ± 0.02 | 1.20 ± 0.02 | 1.31 ± 0.02 | 1.38 ± 0.02 |
| 50.0 | Buoy | 1.29 ± 0.02 | 1.37 ± 0.02 | 1.18 ± 0.01 | 1.21 ± 0.01 |
| | SCAT | 0.78 ± 0.01 | 0.98 ± 0.01 | 0.58 ± 0.01 | 0.76 ± 0.01 |
| | ECMWF | 1.19 ± 0.02 | 1.20 ± 0.02 | 1.31 ± 0.02 | 1.36 ± 0.02 |




Observation error SDs on
**ECMWF scale**

Observation error SDs on
**SCAT scale**

Now, look at the **top 10% of most variable** winds ...

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# 4. Conclusions

- Using only 2 solutions (1st and 2nd rank) does have an impact in some frontal and low-pressure centre areas.
- Situation-dependent O/B errors are available from TC analysis. However, the O error cannot be flexible at ECMWF DA system currently; further test is needed (take the ratio of O/B errors into account)
- Downscaled 50-km product (3x3 box) shows lowest error on ECMWF scale, particularly under highly-variable conditions.

trade-off

- Margin between contiguous WVCs (Large Margin, Low Correlation):

12.5-km (thinning 4) > 50-km (2x2 box) > 25-km (thinning 2) > 50-km (3x3 box)

- O Errors :

50-km (3x3 box) < 25-km (thinning by 2) < 50-km (2x2 box) < 12.5-km (thinning by 4)

## 3. Preliminary Results

Table 2. Statistics of different **ASCAT** wind sources versus MARS **buoy** winds. QC-accepted data, N=19,308. Green color indicates the best statistics. (In parenthesis, statistics for buoy wi above 4 m/s)

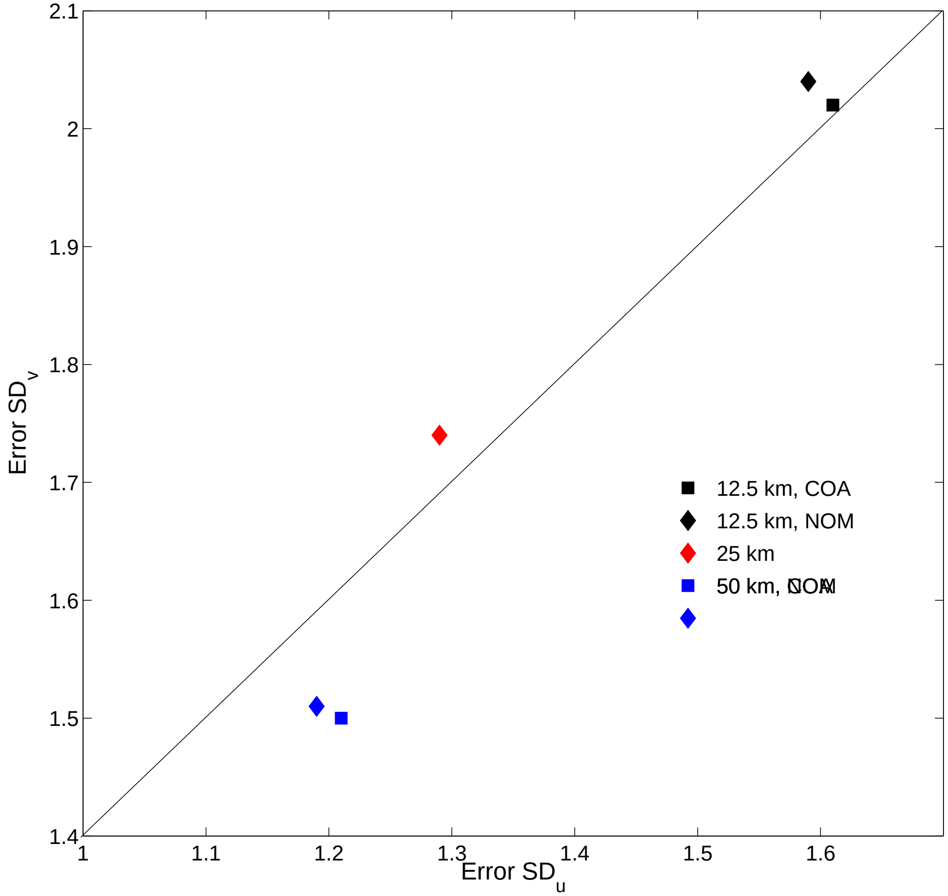
| | | Speed bias (m/s) | Speed SD (m/s) | Direction SD (°) | u SD (m/s) | v SD (m/s) |
|---|---|---|---|---|---|---|
| 12.5 km | COA | -0.22 | 1.07 | 24.4 | 1.47 (1.41) | 1.61 (1.58) |
| | NOM | -0.22 | 1.07 | 24.4 | 1.47 (1.42) | 1.61 (1.58) |
| 25 km | | -0.18 | 1.04 | 23.9 | 1.46 (1.39) | 1.58 (1.53) |
| 50 km | COA | -0.27 | 1.05 | 23.5 | 1.42 (1.37) | 1.55 (1.53) |
| | NOM | -0.26 | 1.06 | 23.6 | 1.44 (1.39) | 1.55 (1.53) |

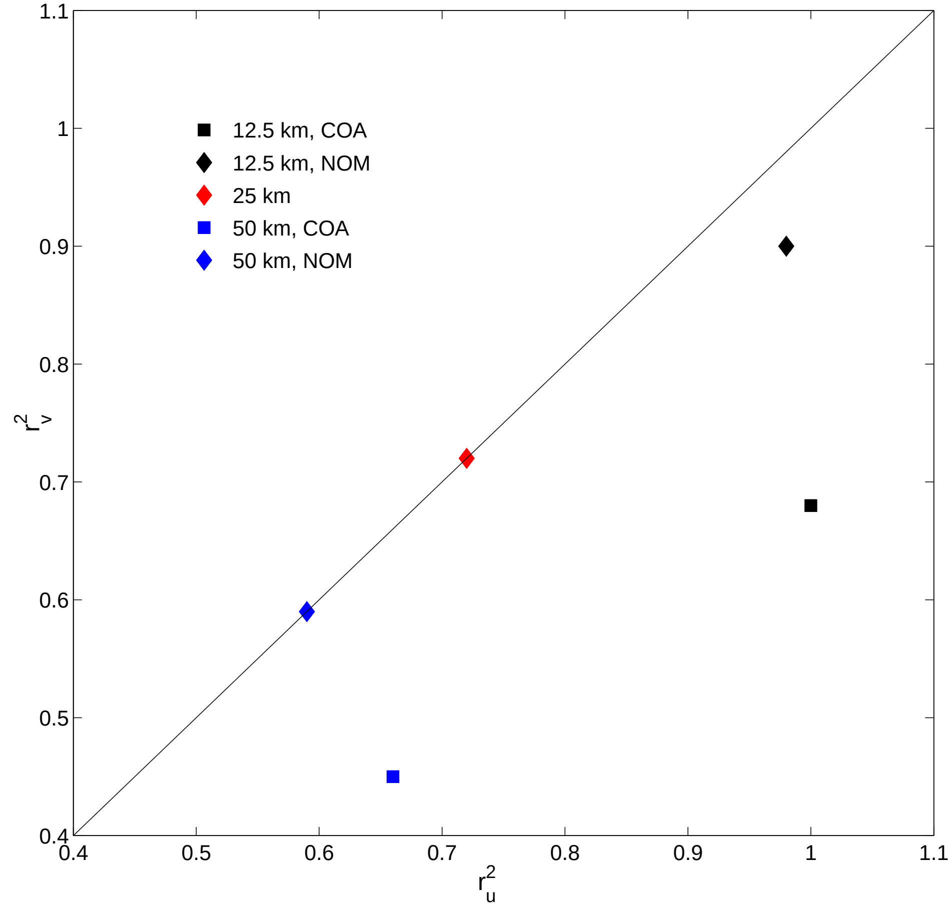
Table 3. Statistics of different **ASCAT** wind sources versus **ECMWF** winds.

| | | Speed bias (m/s) | Speed SD (m/s) | Direction SD (°) | u SD (m/s) | v SD (m/s) |
|---|---|---|---|---|---|---|
| 12.5 km | COA | 0.11 | 1.34 | 24.1 | 1.50 (1.46) | 1.62 (1.58) |
| | NOM | 0.12 | 1.36 | 24.1 | 1.51 (1.47) | 1.64 (1.61) |
| 25 km | | 0.14 | 1.28 | 23.0 | 1.44 (1.40) | 1.56 (1.52) |
| 50 km | COA | 0.06 | 1.30 | 23.0 | 1.43 (1.39) | 1.52 (1.49) |
| | NOM | 0.08 | 1.32 | 23.2 | 1.45 (1.41) | 1.56 (1.53) |

Table 4. TC analysis for the three different data sets. r2 values of the ASCAT-25km data set are derived from the intergration of the spetra difference between ASCAT and ECMWF. r2 values of the ASCAT 12.5-km and 25-km data sets are adjusted to make sure that the Buoy and ECMWF error SDs (on ECMWF scale) are equivalent to those of the ASCAT-25km data set ➔ see table 4.

| | | Scale *u* | Bias *u* | Scale *v* | Bias *v* | r2 of *u* | r2 of *v* |
|---|---|---|---|---|---|---|---|
| 12.5 | SCAT | 1.006 | 0.045 | 1.025 | 0.014 | 0.35 | 0.44 |
| | ECMWF | 1.027 | 0.022 | 1.069 | 0.088 | | |
| 25.0 | SCAT | 1.003 | 0.056 | 1.016 | 0.002 | 0.30 | 0.45 |
| | ECMWF | 1.019 | 0.045 | 1.067 | 0.025 | | |
| 50.0 | SCAT | 1.008 | 0.041 | 1.026 | 0.015 | 0.28 | 0.40 |
| | ECMWF | 1.027 | 0.025 | 1.069 | 0.089 | | |




**Total** O error SDs on ECMWF scale

Representativeness error variance

Now, look at the **top 10% of most variable** winds ...