SMOS BARCELONA EXPERT CENTRE

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

An Improved 2DVAR Ambiguity Removal For ASCAT Wind Retrieval

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NWP SAF
Numerical Weather Prediction

2D-VAR

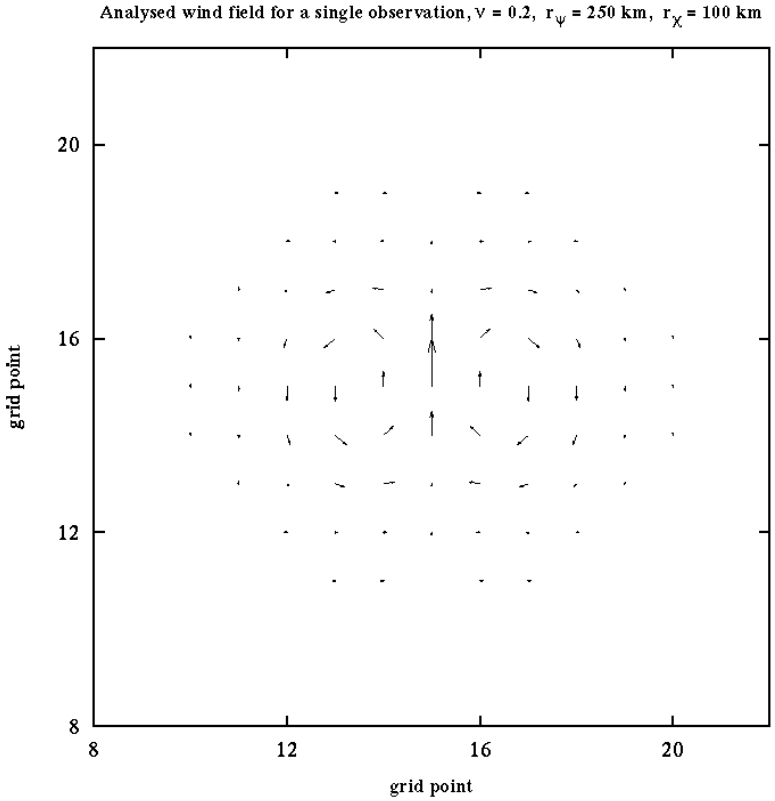
$$P(\mathbf{v}|\mathbf{v}_s) \propto P(\mathbf{v}_s|\mathbf{v}) \cdot P(\mathbf{v})$$

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

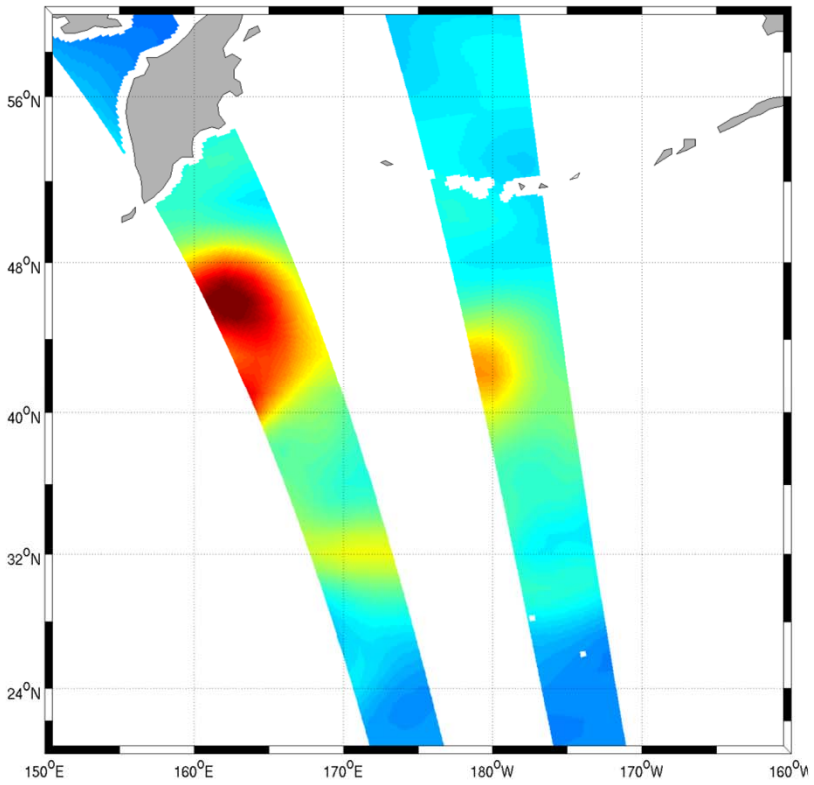
Spatial filter:

- Mass conservation
- Continuity equation

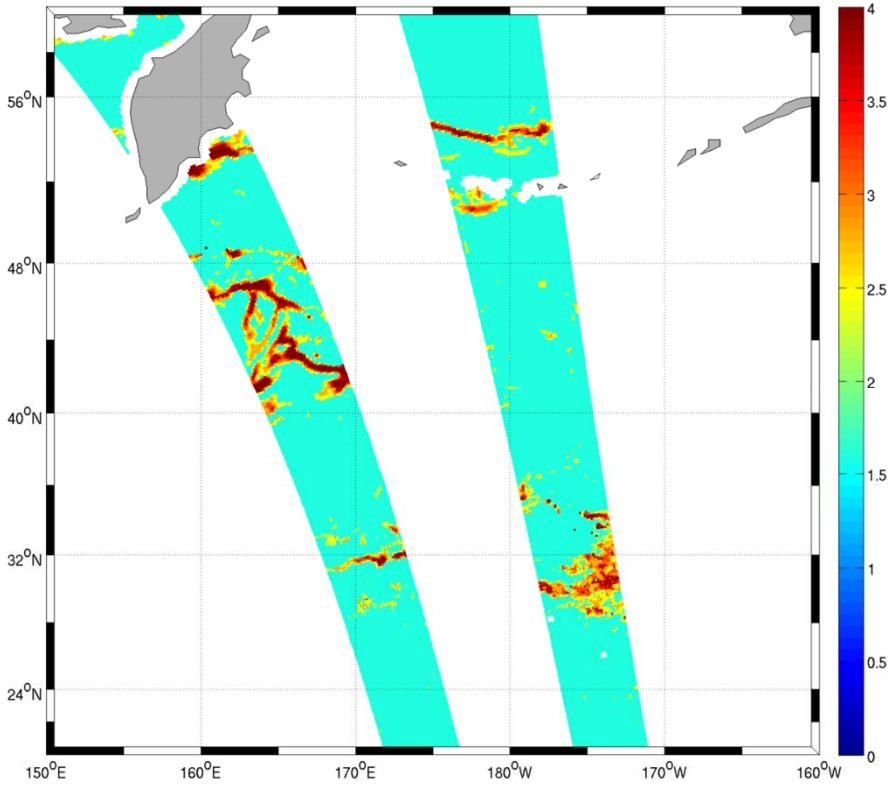
  $\nabla \cdot \rho_0 \mathbf{U} = \mathbf{0}$
- Vertical motion < horizontal motion
- Parameters:
  - Observation & Background errors (variance)
  - Correlation length
  - Rotation vs divergence



2D-VAR new settings: Flexible O/B errors



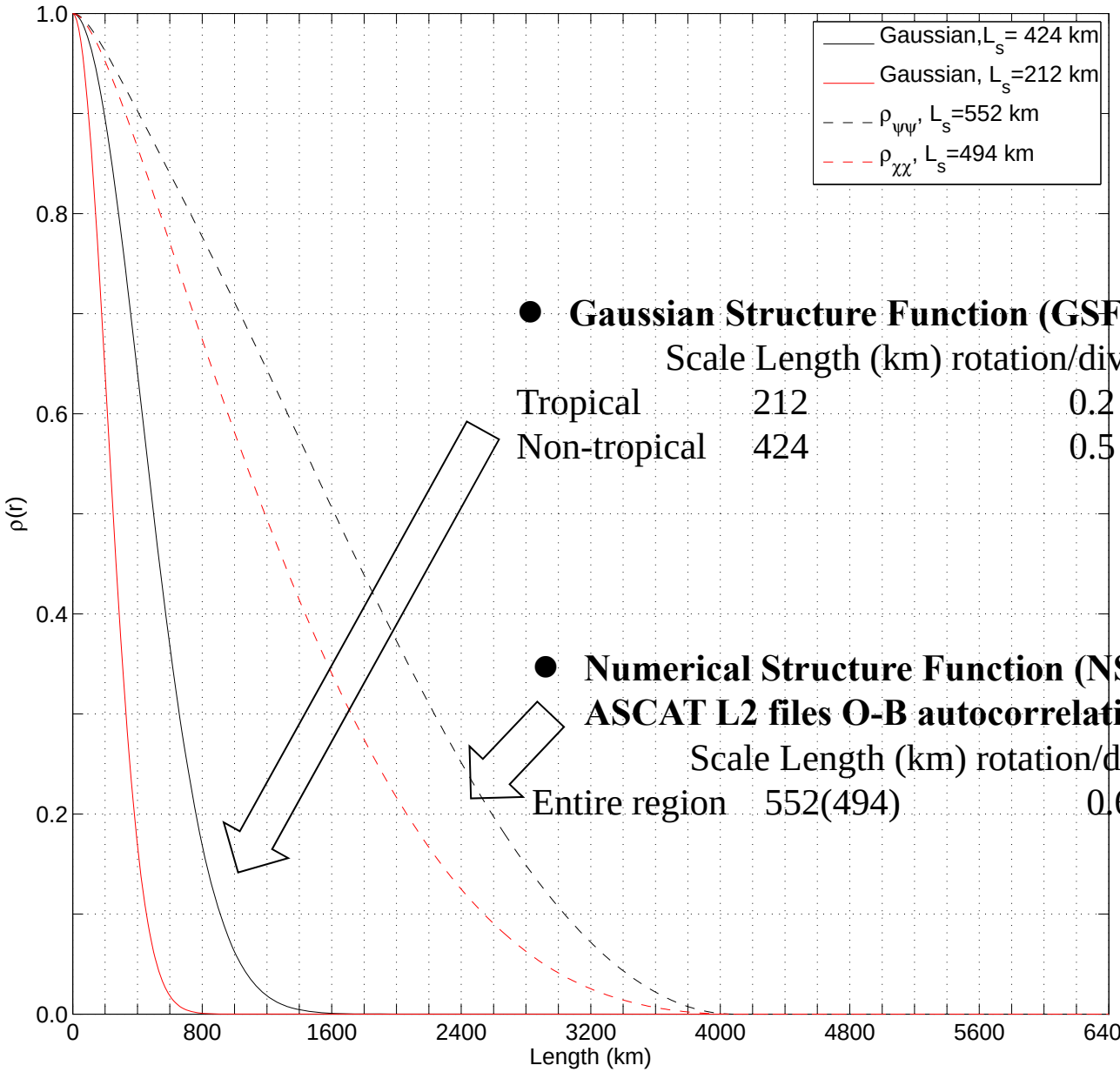
ECMWF Ensemble Data Assimilation (EDA background error)



ASCAT-derived ECMWF background error

Portabella, et al., "Impact Of Sub-Cell Wind Variability On ASCAT Wind Quality" (@10AM Thursday)

2D-VAR new settings: Numerical Background error correlation



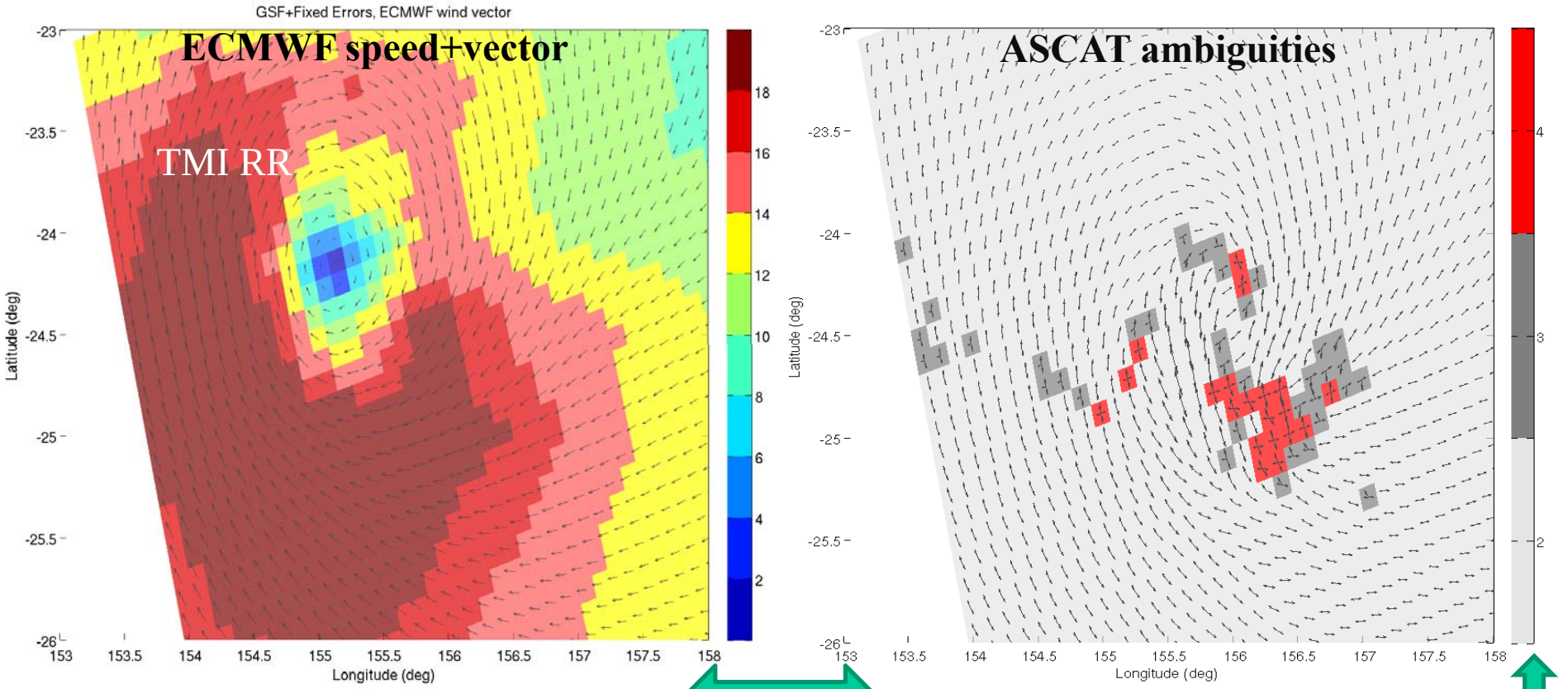
- **Gaussian Structure Function (GSF, default setting)**

	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

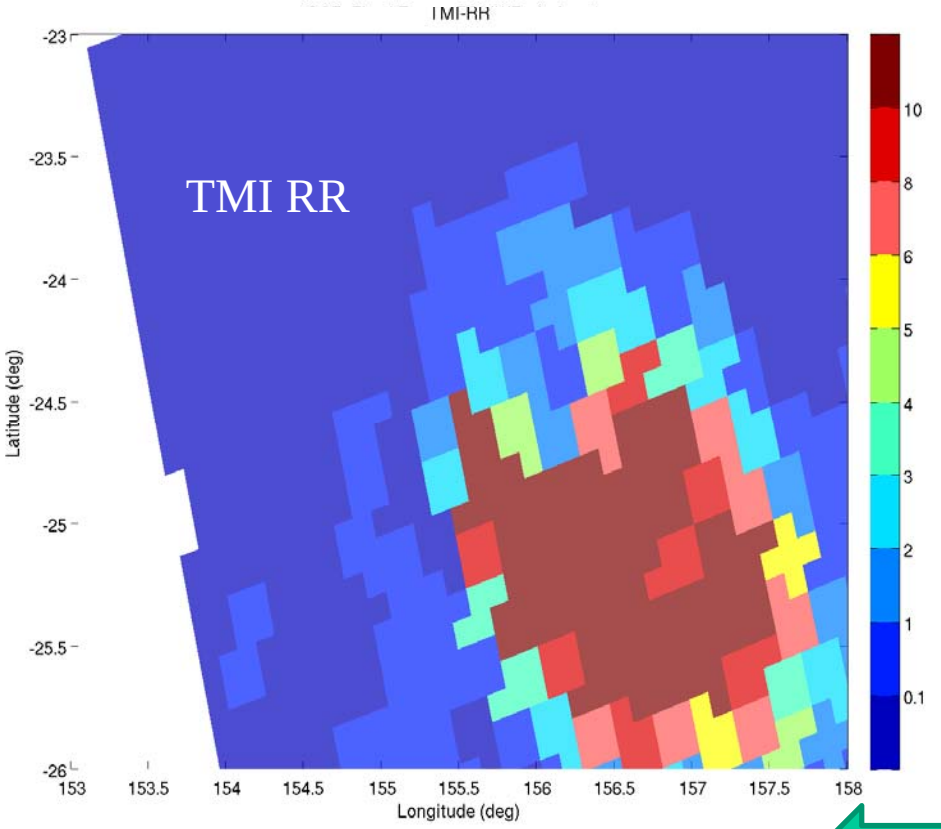
3. Results: case #1- low pressure center

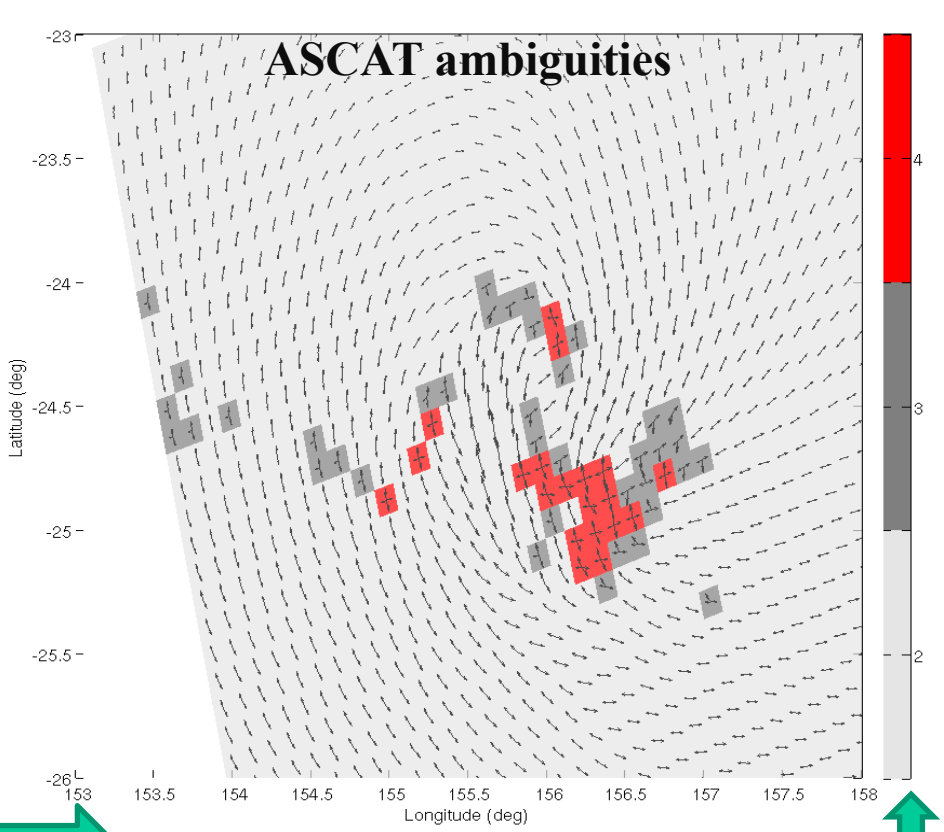


Number of ambiguities

2D-VAR Analysis
(next slide)

3. Results: case #1- low pressure center





Number of ambiguities

2D-VAR Analysis
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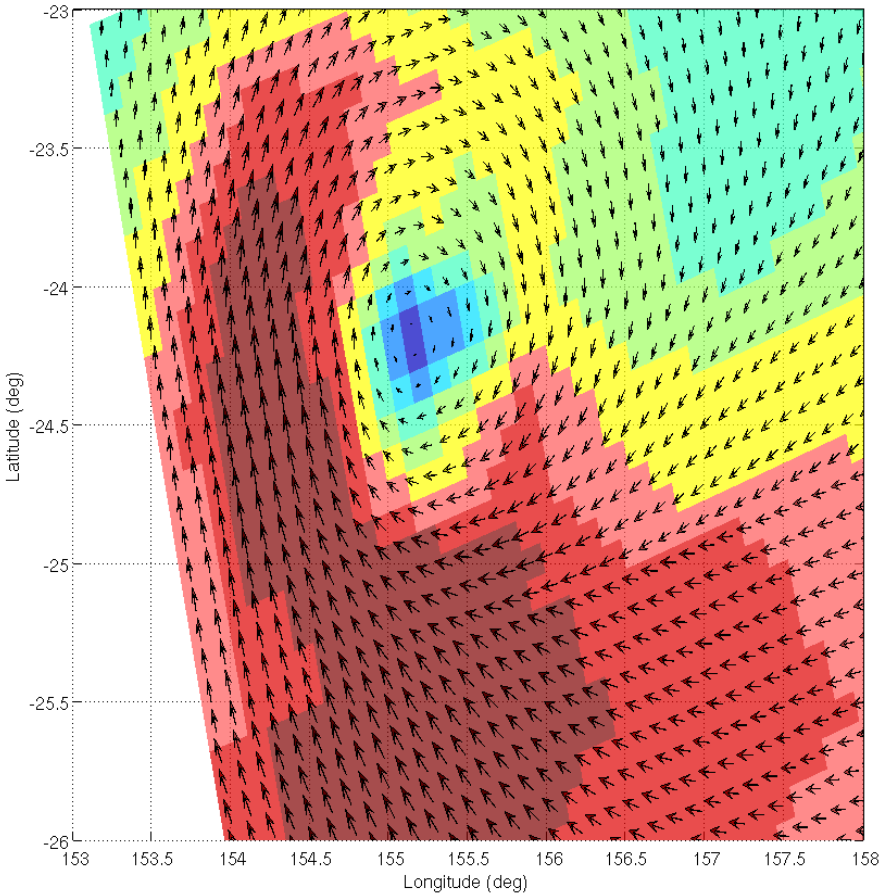
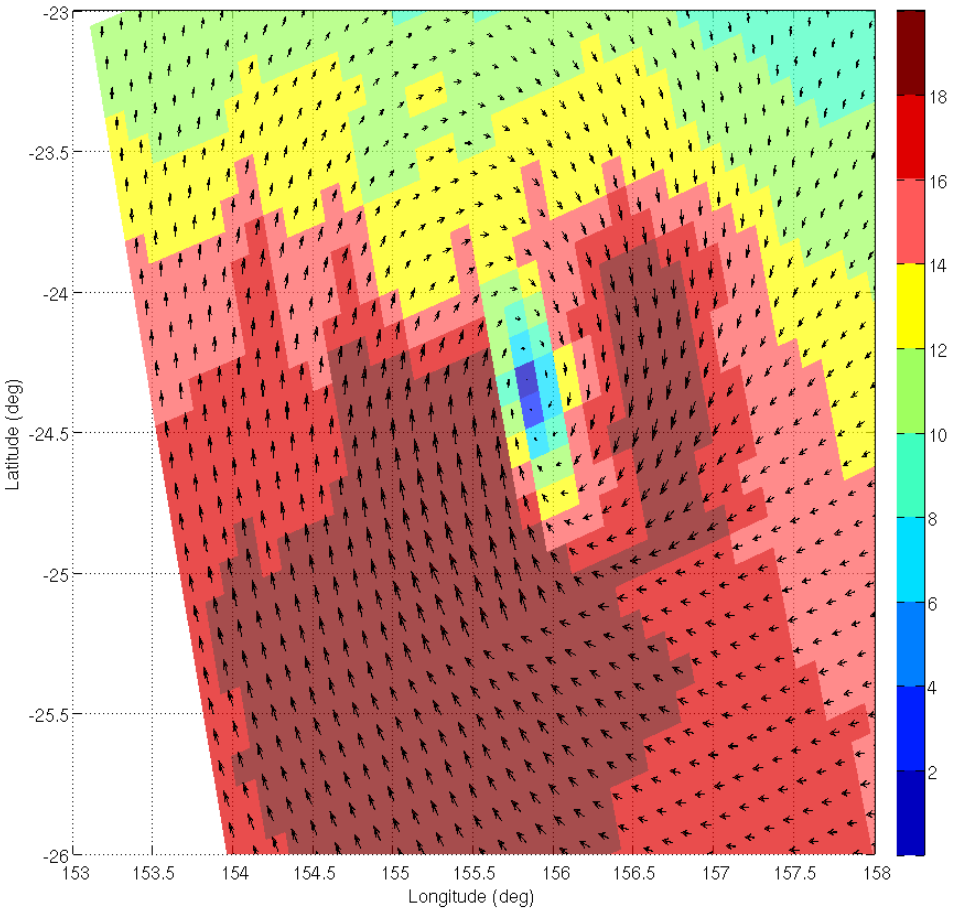
Results: case #1- low pressure center





Default setting:

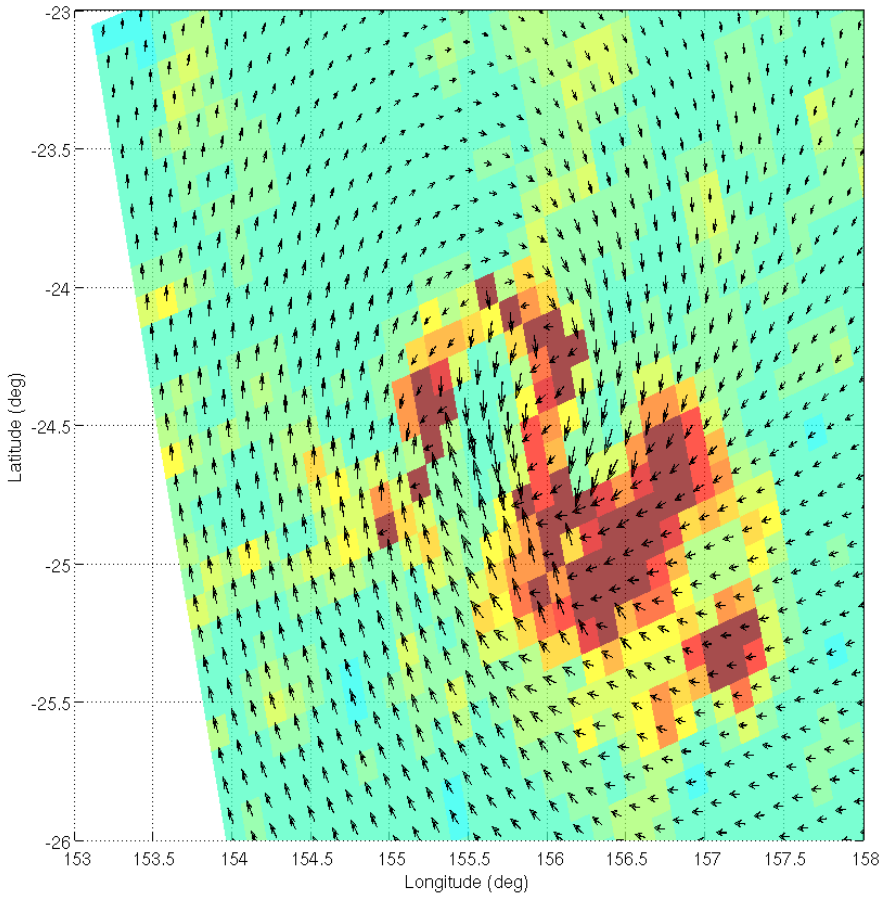
- Gaussian structure function
- Fixed O/B errors

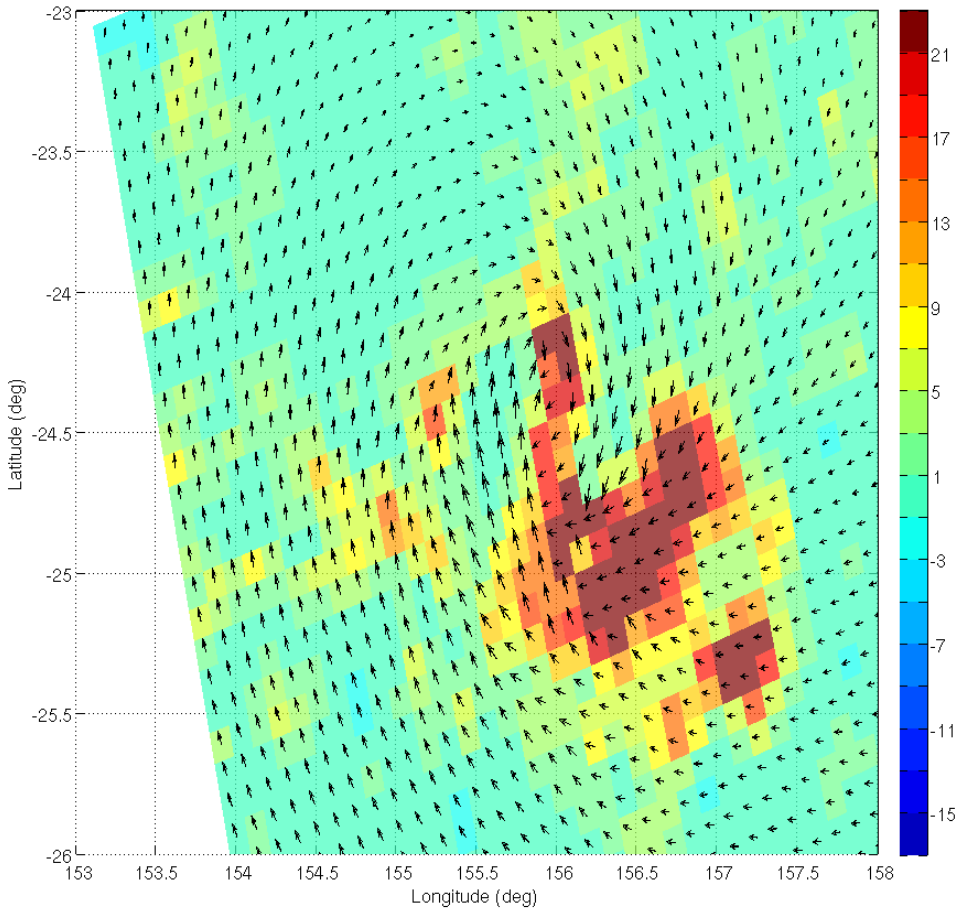
Proposed setting:

- Numerical structure function
- Flexible O/B errors

2DVAR analysis wind speed (color)+vector (arrows)

Results: case #1- low pressure center





Default setting:

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Proposed setting:

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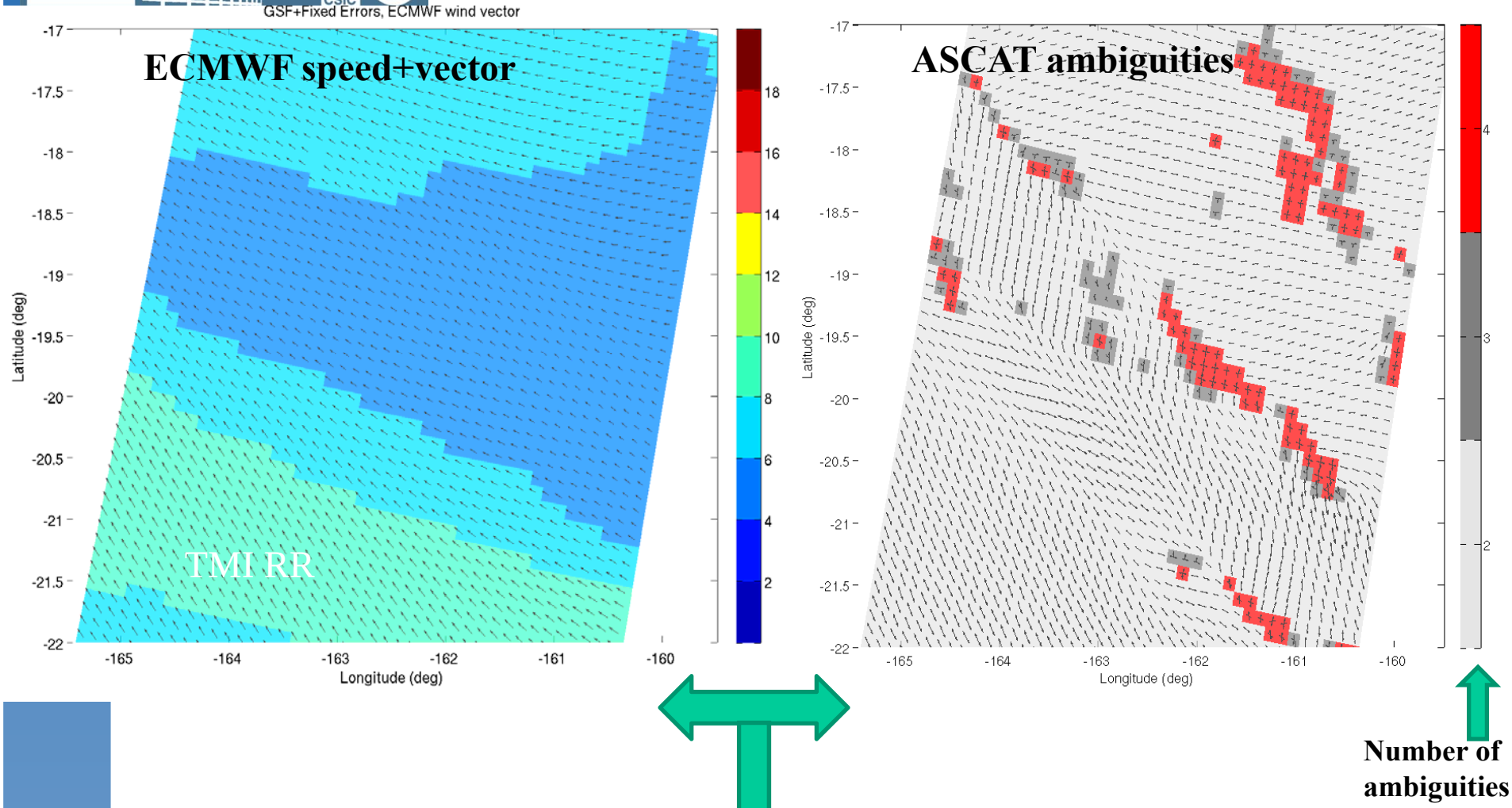
ASCAT selected MLE (color)+vector (arrows)

Results: case #2- wind front



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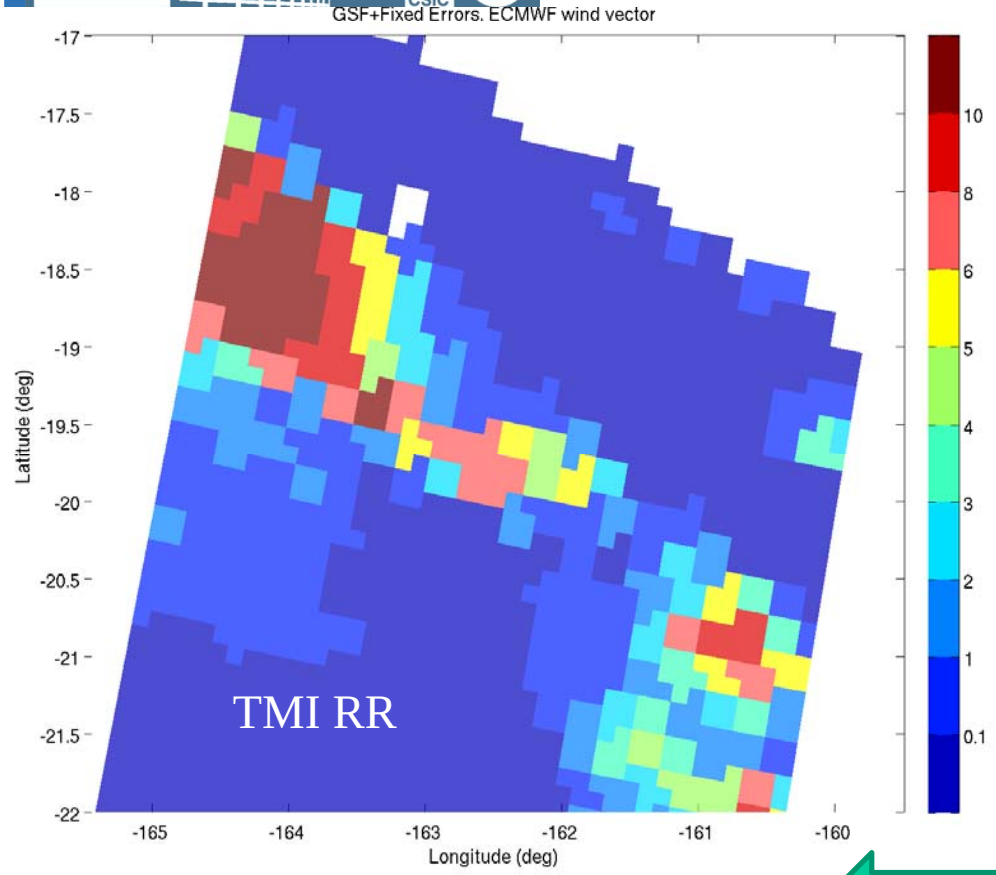
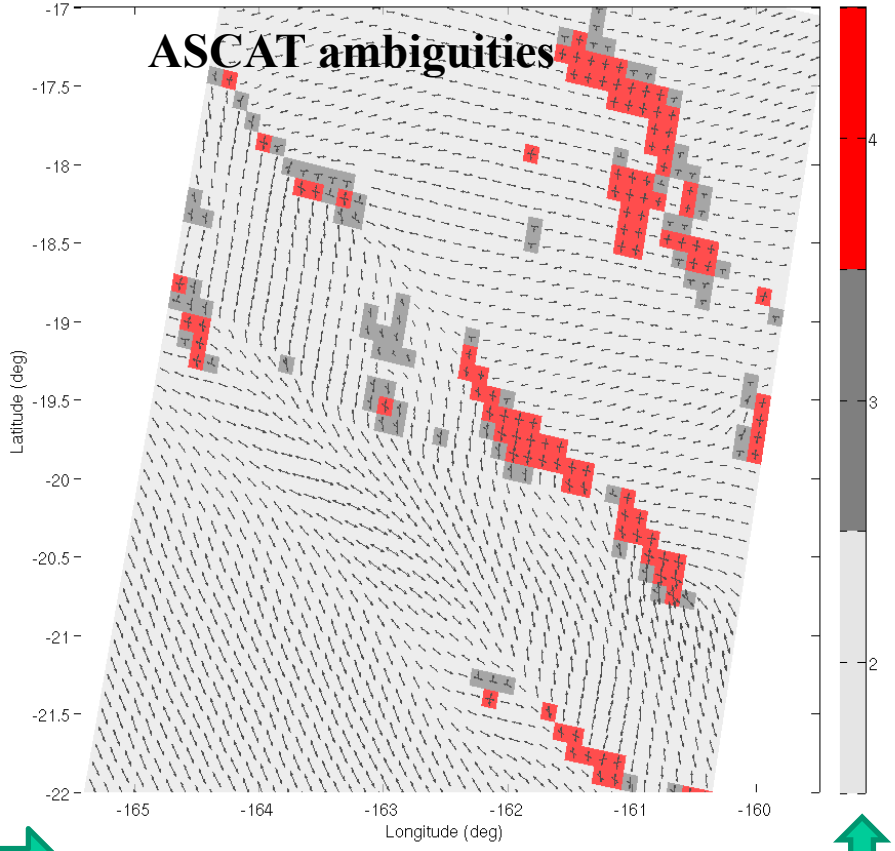
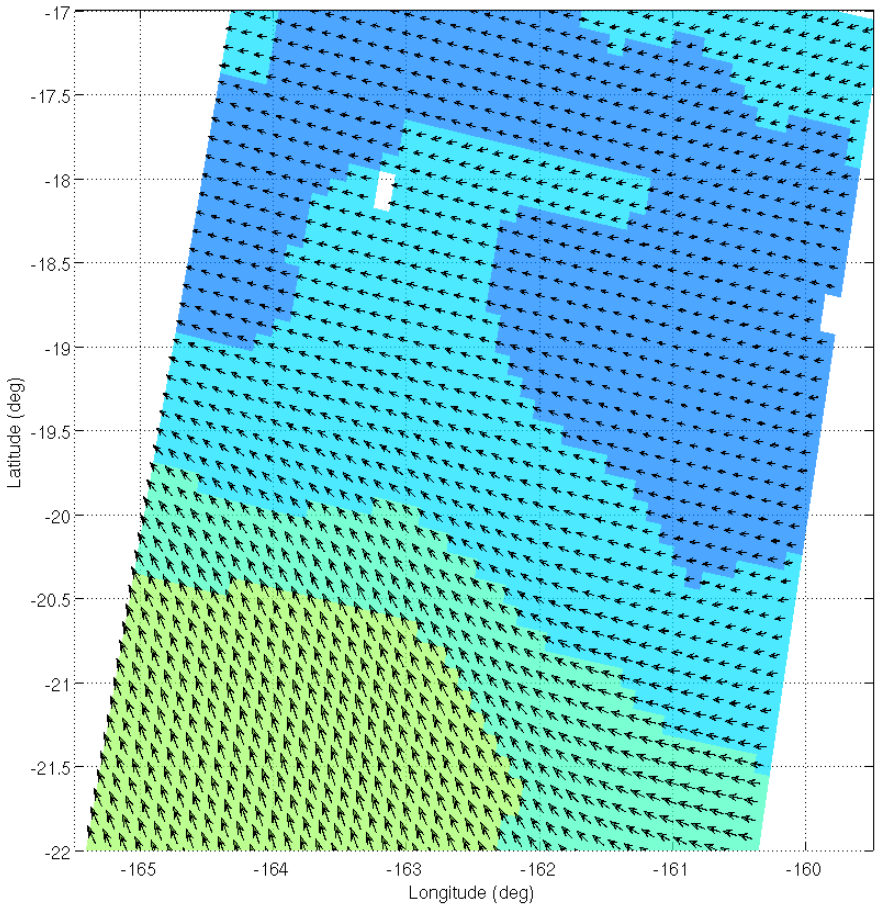


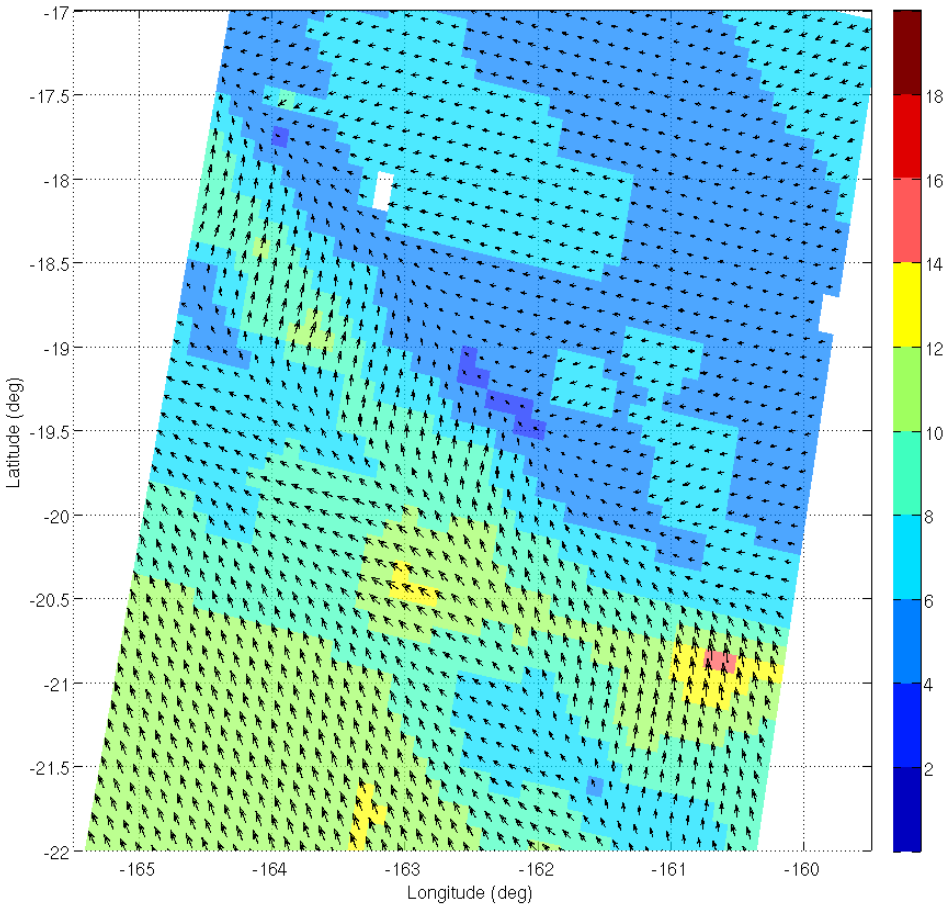


Number of ambiguities

2D-VAR Analysis
(next slide)

Results: case #2- wind front





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2DVAR analysis wind speed (color)+vector (arrows)

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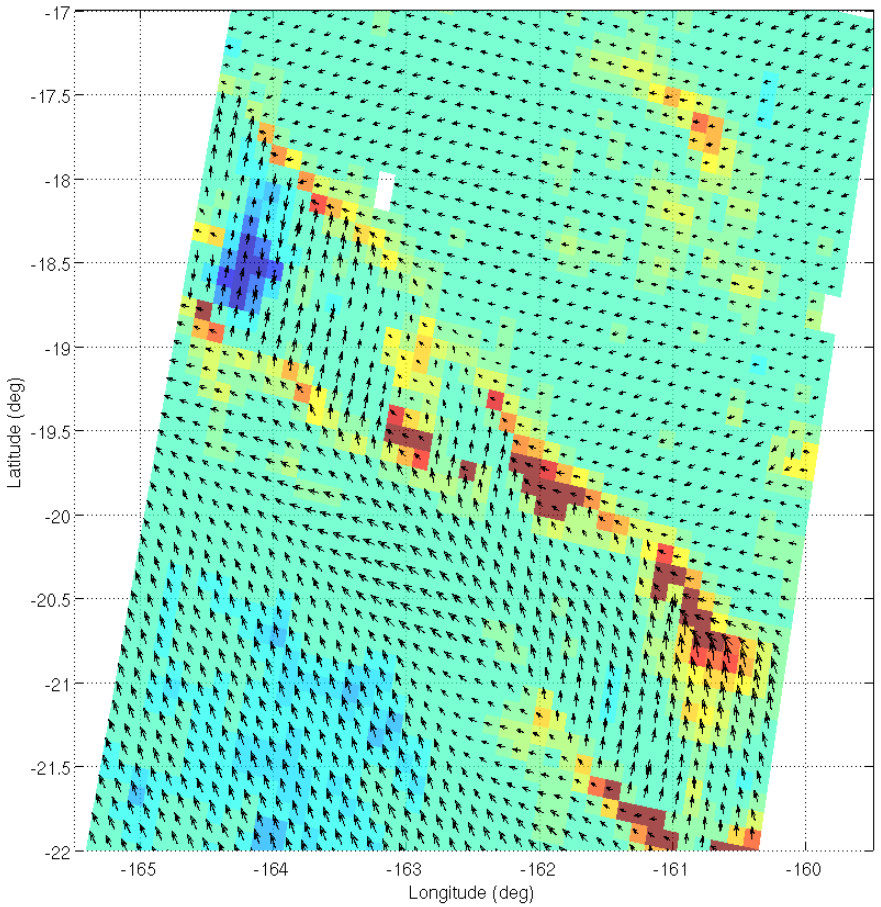

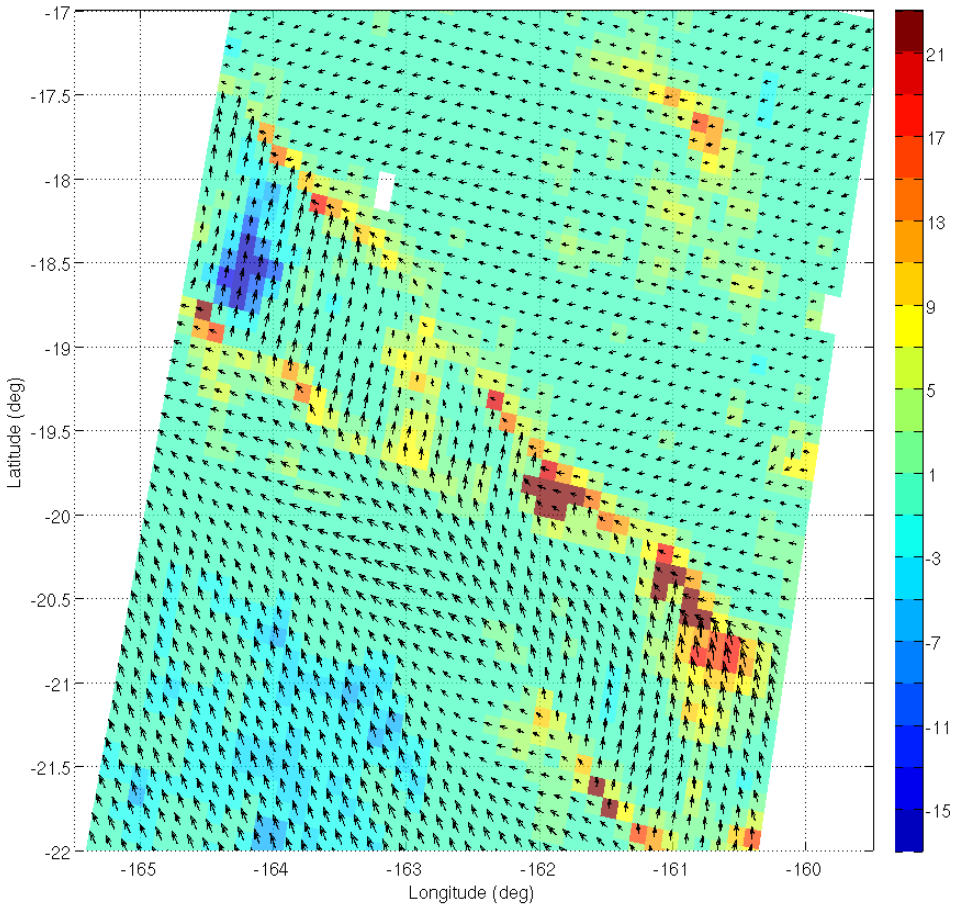

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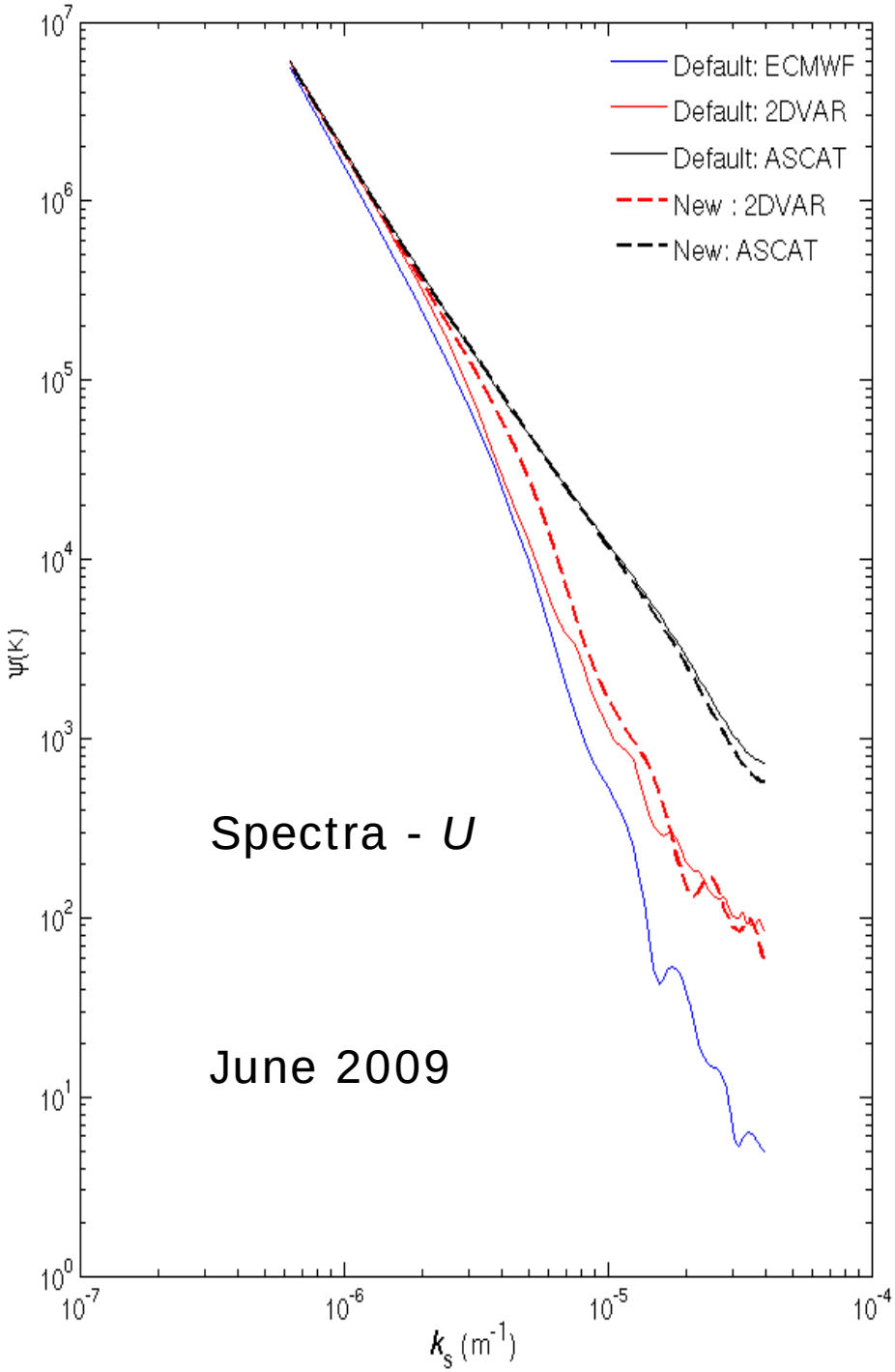
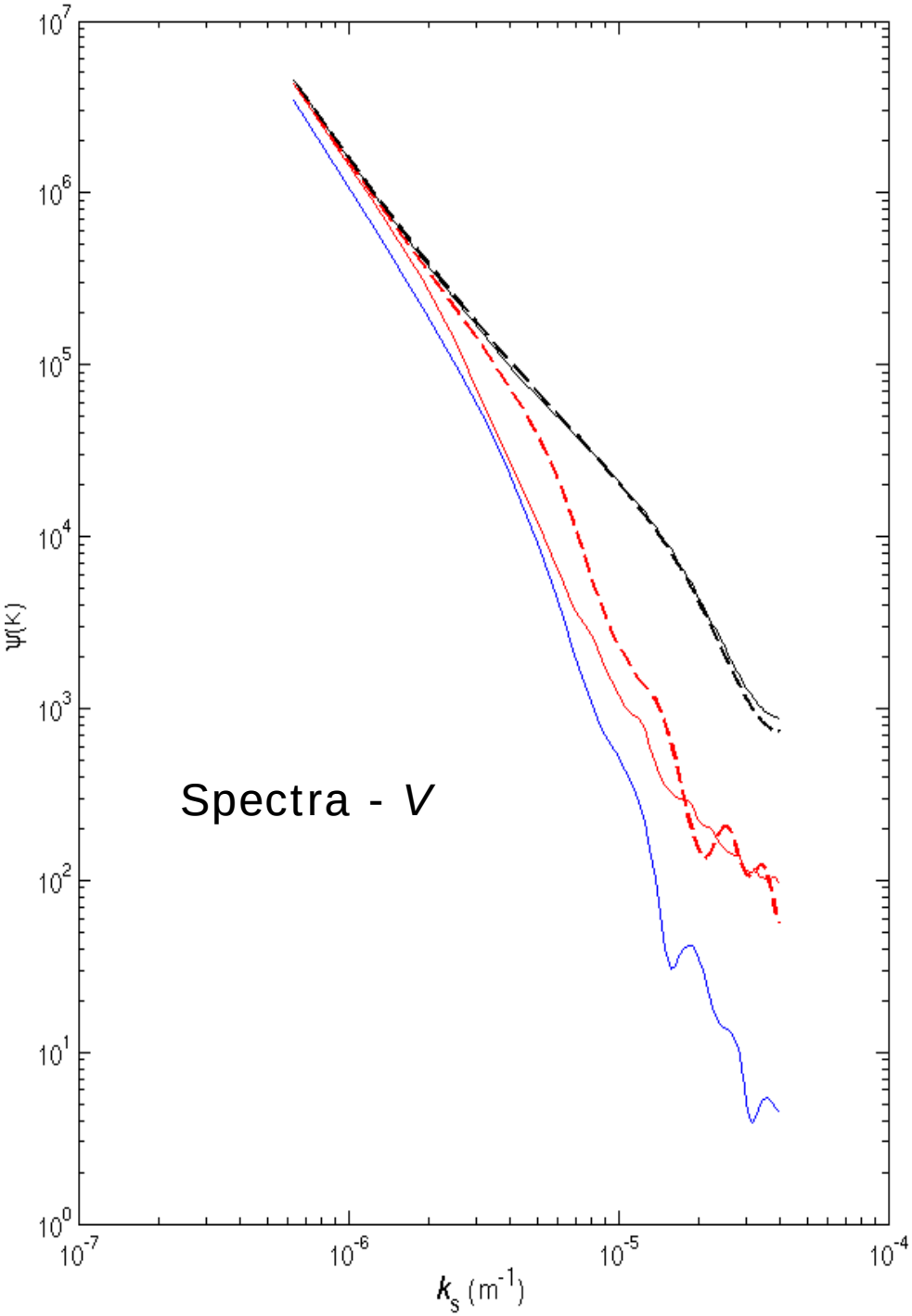
ASCAT selected MLE (color)+vector (arrows)


Default: ECMWF
Default: 2DVAR
Default: ASCAT
New : 2DVAR
New: ASCAT
Spectra - U
June 2009
Ψ(K)
k_s (m^{-1})


Spectra - V
Ψ(K)
k_s (m^{-1})

All the QC-accepted data (March-August 2009)

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)		
	ASCAT vs ECMWF	ASCAT vs buoy point wind	N
Default	2.27	1.86	6908
New	2.26	1.83	

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)			
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs ASCAT	N
Default	1.91	2.01	1.22	6908
New	2.06	1.85	0.81	

All the QC-accepted and 2-solution ($|MLE_1|<1$)

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)		
	ASCAT vs ECMWF	ASCAT vs buoy point wind	N
Default	2.19	1.74	5034
New	2.17	1.71	

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)			
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs ASCAT	N
Default	1.85	1.94	1.17	5034
New	2.00	1.76	0.74	

Conclusions

- New 2DVAR settings result in a substantially improved and higher-resolution 2DVAR analysis
- 2% of 2DVAR ambiguity removed (selected) solutions are changed
- ASCAT selected wind quality improvement is modest according to buoy verification; however buoy verification is limited and not so suitable for this type of validation
- Further improvements in 2DVAR, e.g., non-symmetric structure functions

➢ 2DVAR improvements can potentially benefit scatterometer data assimilation schemes (e.g., ECMWF)

1. Introduction

✓ 2DVAR Cost function $J\left(\mathbf{x}_o^k, \mathbf{x}, \mathbf{x}_b\right) = J_o\left(\mathbf{x}_o^k, \mathbf{x}\right) + J_b\left(\mathbf{x}\right)$

- $$J_o = \sum_{i,j}^{N_1,N_2} \left\{ \sum_{k}^{M_{ij}} \left[\frac{\left(\Delta t_{ij} - \Delta t_{ij,k}^{(o)}\right)^2}{\sigma_t^2} + \frac{\left(\Delta l_{ij} - \Delta l_{ij,k}^{(o)}\right)^2}{\sigma_l^2} - 2\ln p_k \right]^{-\lambda} \right\}^{-1/\lambda}$$

Key parameters:

1. Observation errors

- $J_b = \left(\delta\boldsymbol{\xi}\right)^{\mathrm{T}} B_{\hat{\chi},\hat{\psi}}^{-1} \left(\delta\boldsymbol{\xi}\right)$

$B_{\hat{\chi},\hat{\psi}} = \Sigma \mathbf{C} \Sigma$ $\quad \Sigma = \begin{pmatrix} \Sigma_{\hat{\chi}} & 0 \\ 0 & \Sigma_{\hat{\psi}} \end{pmatrix}$ → 2. Background errors

$\mathbf{C} = \begin{pmatrix} \mathbf{C}_{\hat{\chi}\hat{\chi}} & 0 \\ 0 & \mathbf{C}_{\hat{\psi}\hat{\psi}} \end{pmatrix}$ → 3. Background correlation

All the QC-accepted data

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	ASCAT vs ECMWF	ASCAT vs buoy point wind	ASCAT vs buoy mean wind	ASCAT vs 2DVAR analysis	N
Default	2.27	1.86	1.72	1.22	6908
New	2.26	1.83	1.69	0.81	

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs buoy mean wind	-	N
Default	1.91	2.01	1.84	-	6908
New	2.06	1.85	1.68	-	

All the QC-accepted and 2-solution ($|MLE_1|<1$)

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	ASCAT vs ECMWF	ASCAT vs buoy point wind	ASCAT vs buoy mean wind	ASCAT vs 2DVAR analysis	N
Default	2.19	1.74	1.62	1.17	5034
New	2.17	1.71	1.59	0.74	

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs buoy mean wind	-	N
Default	1.85	1.94	1.79	-	5034
New	2.00	1.76	1.61	-	

All the QC-accepted and 2-solution ($|MLE_1|<3$)

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	ASCAT vs ECMWF	ASCAT vs buoy point wind	ASCAT vs buoy mean wind	ASCAT vs 2DVAR analysis	N
Default	2.21	1.75	1.63	1.18	5996
New	2.20	1.71	1.59	0.74	

All the scores decrease!!

	ASCAT-ECMWF-buoy point measurement (mean buoy winds)				
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs buoy mean wind	-	N
Default	1.87	1.94	1.78	-	5996
New	2.01	1.76	1.61	-	

The number of ASCAT-TMI collocations in the defined categories. In parenthesis, the ratio of data which wind selection (Test-4) is different with Test-1. Only the KNMI QC-accepted data are used in the statistics

Data set: ASCT-ECMWF-TMI

TMI-RR (mm/h) N ambiguities	0 (rain free)	(0, 1)	[1, 3)	≥3
2	3,681,828 (0.8%)	183,787 (1.5%)	57,435 (2.4%)	29,970 (3.7%)
3	239,448 (9.8%)	17,723 (12.0%)	7,265 (14.5%)	3,718 (11.8%)
4	107,611 (17.7%)	13,396 (17.8%)	10,105 (17.8%)	7,896 (17.9%)

ASCAT-ECMWF become 1.5% closer in the first category.

In the rest categories, ASCAT-ECMWF become more discrepant