First assessment of the CFOSAT scatterometer wind quality

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Outline

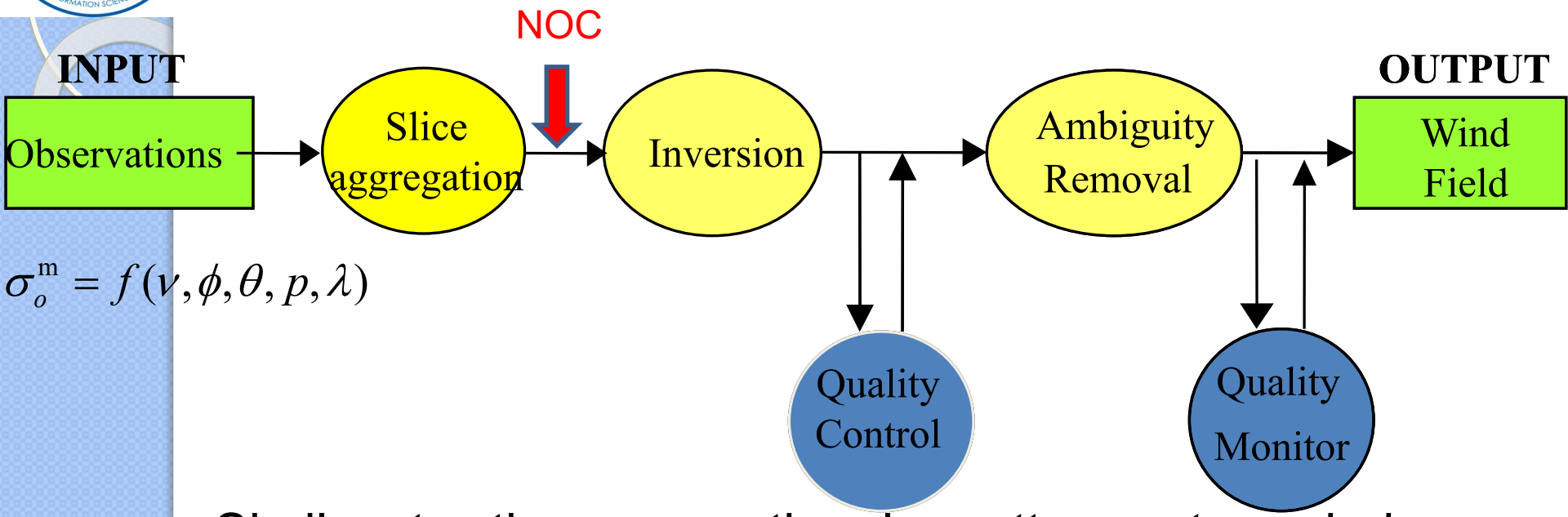
1. Chart flow of L2 processor

2. Methodologies

3. Results and Verifications
   - Wind retrieval performance
   - Rain impact

4. Conclusions and outlooks

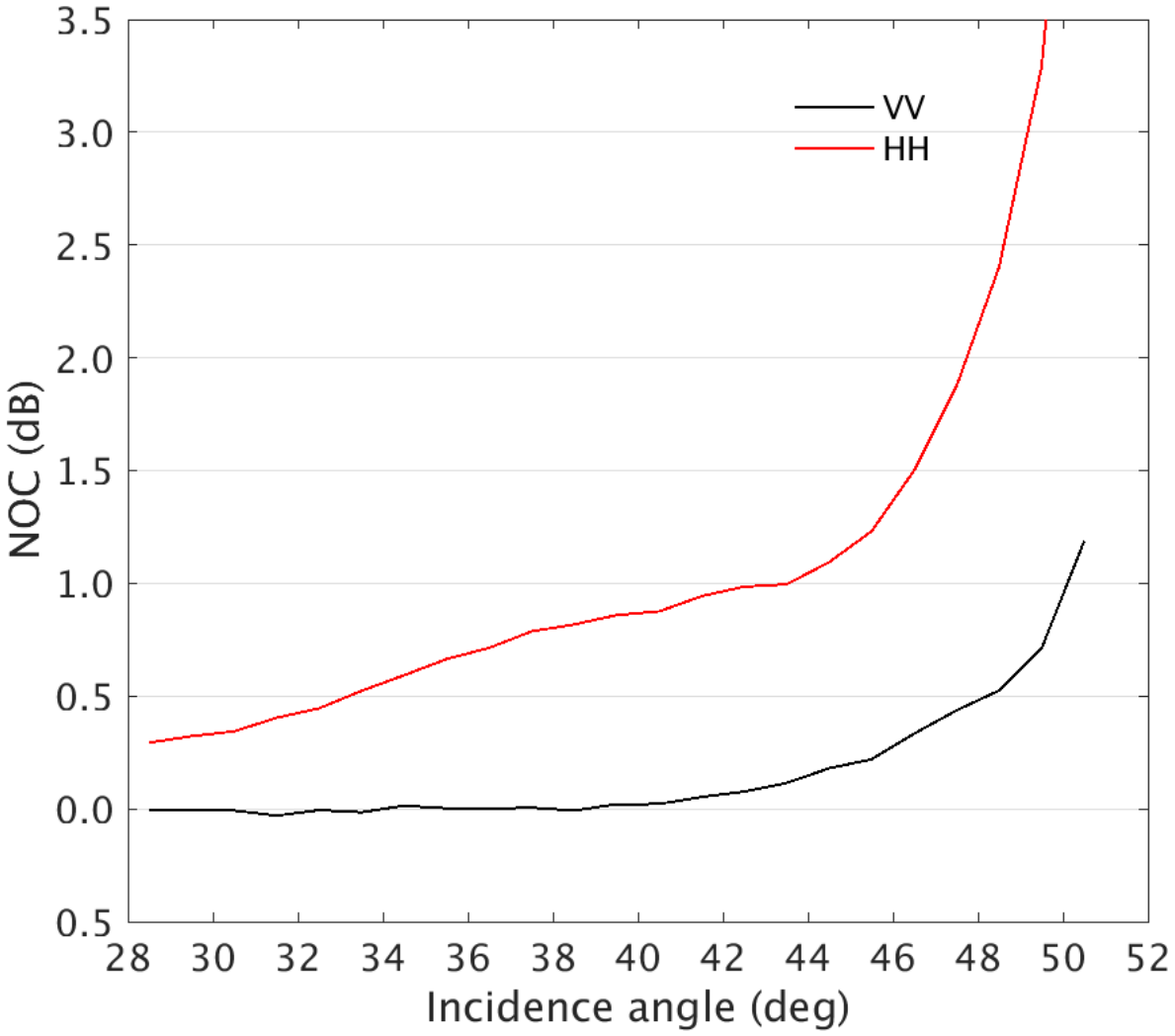
1. Chart flow of L2 processor



$$\sigma_o^{\mathrm{m}} = f(v, \phi, \theta, p, \lambda)$$

Similar to the conventional scatterometer wind retrieval, the L2 processing of CFOSAT scatterometer includes

1) slice aggregation
   ➔L2A (averaged sigma0 on gridded WVC)
1) wind inversion,
2) ambiguity removal
3) quality control➔ L2B (wind field products)



CFOSCAT NOC coefficients based on the L2A products

1. Chart flow of L2 processor

Quality Control

- ✓ Ice flag from the ancillary data;
- ✓ Land flag from the land-sea mask;
- ✓ QC flag based on the inversion residual (MLE);
- ✓ QC flag based on singularity exponent;

Quality Monitor

- ✓ Rain probability;
- ✓ Estimated wind errors based on triple collocation;

Red contents to be updated using ONE year of data

2. Methodologies

1) The sea surface winds are retrieved by minimizing the MLE cost function below,

$$MLE = \frac{1}{N}\sum_{i}^{N}\frac{\left(\sigma_{mi}^{0}-\sigma_{si}^{0}\right)^{2}}{\left(K_{pi}\cdot\sigma_{ti}^{0}\right)^{2}}$$

Geophysical Model Function – NSCAT-4

2) Ambiguity removal – 2DVAR developed by KNMI

$$J\left(\mathbf{x}_{o}^{k},\mathbf{x},\mathbf{x}_{b}\right)=J_{o}\left(\mathbf{x}_{o}^{k},\mathbf{x}\right)+J_{b}\left(\mathbf{x}\right)$$

2. Methodologies

3) Quality control

Scatterometers provide good quality sea surface winds except for:

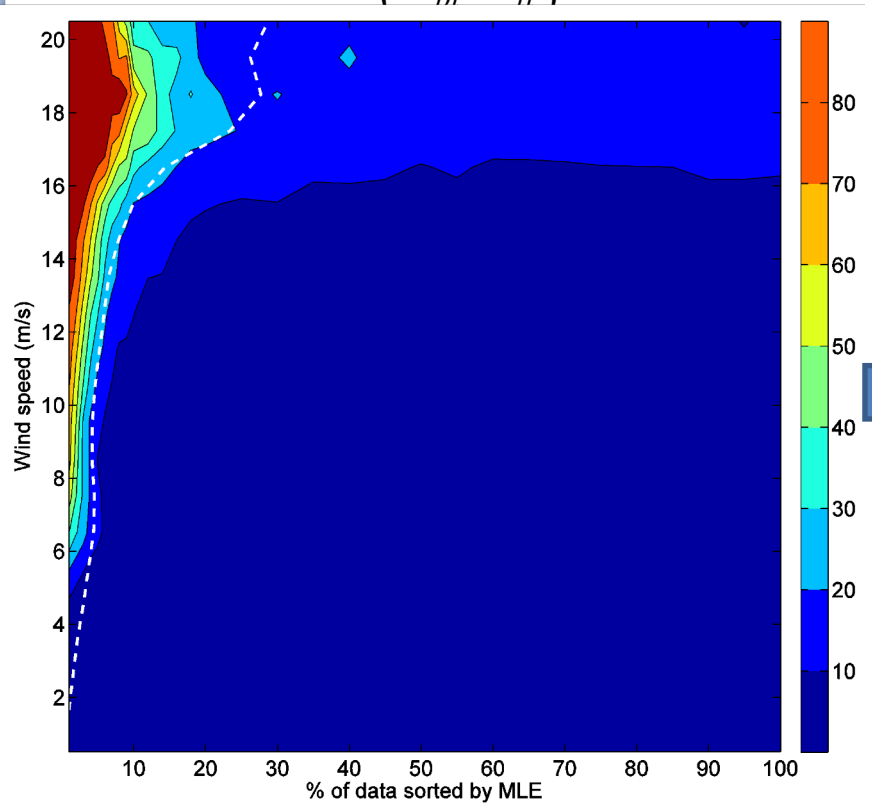
- Sea ice or land contamination
- Large spatial and temporal variability (e.g., vicinity of fronts and low-pressure centers)
- Rain (especially in Ku-band systems)

2. Methodologies

3) Quality control – two indicators

$$MLE = \frac{1}{N}\sum_{i}^{N}\frac{\left(\sigma_{mi}^{0}-\sigma_{si}^{0}\right)^{2}}{\left(K_{pi}\cdot\sigma_{ti}^{0}\right)^{2}}$$

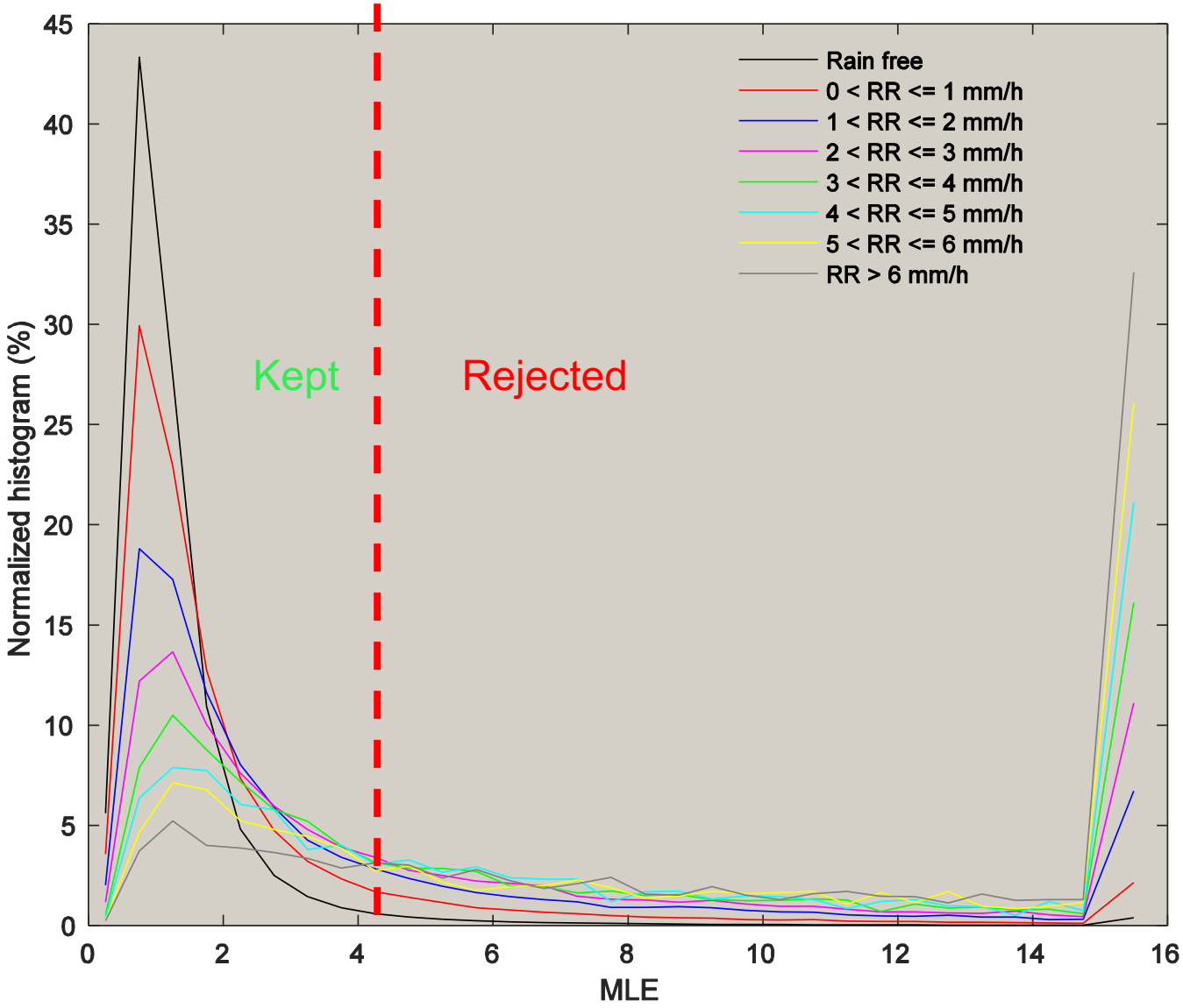
$$h(\mathbf{x}) = \frac{\log\left[\mathrm{T}_{\psi}\left\|\nabla s\right\|(\mathbf{x},r)/\mathrm{T}_{\psi}^{0}\right]}{\log r_{0}} + o\left(\frac{1}{\log r_{0}}\right)$$



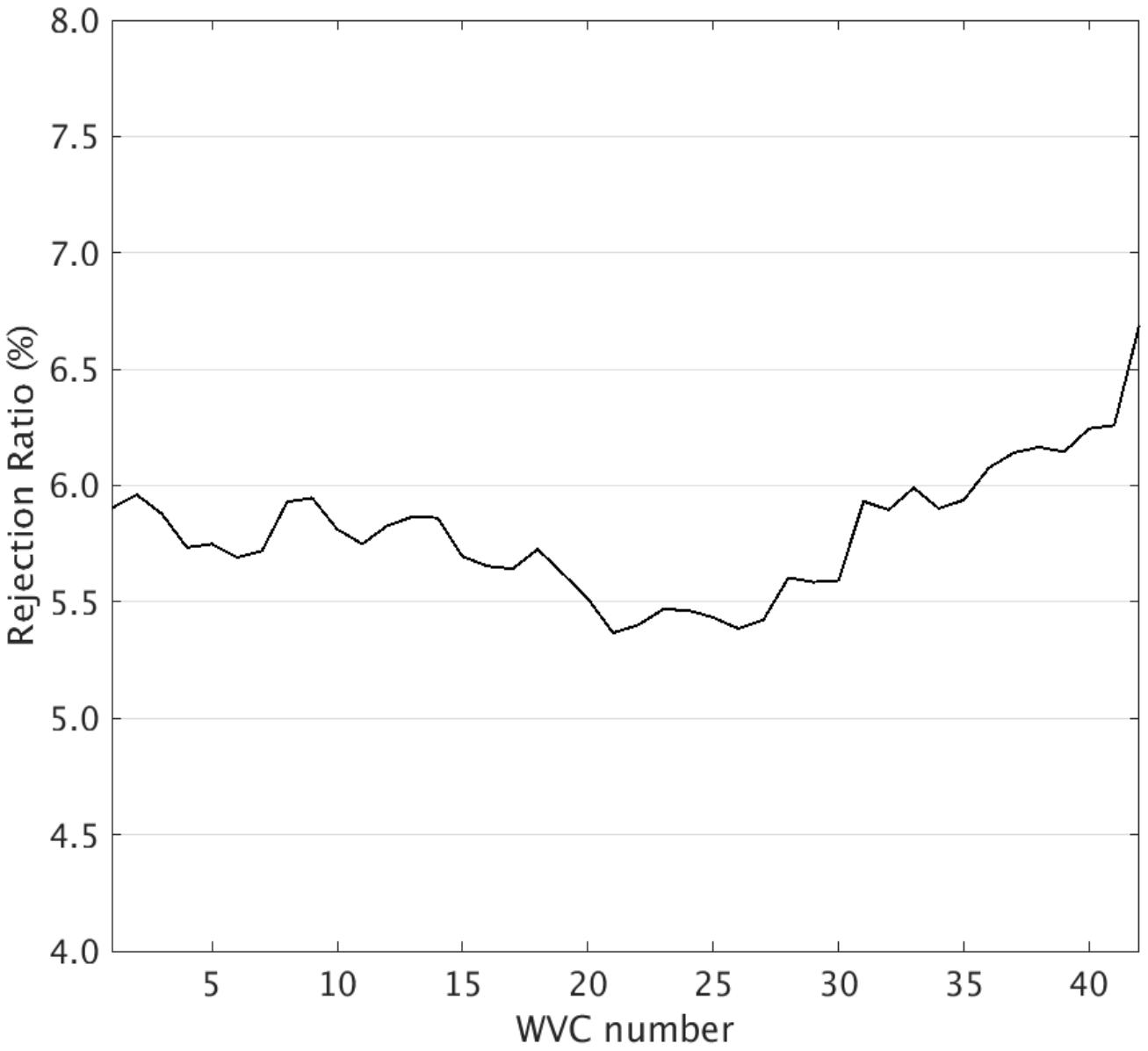
Setting a set of MLE/SE threshold, such that the rain rate contour aligns well with the white curve (rejection ratio), and most the rejected data are indeed affected by rain.

@RapidScat

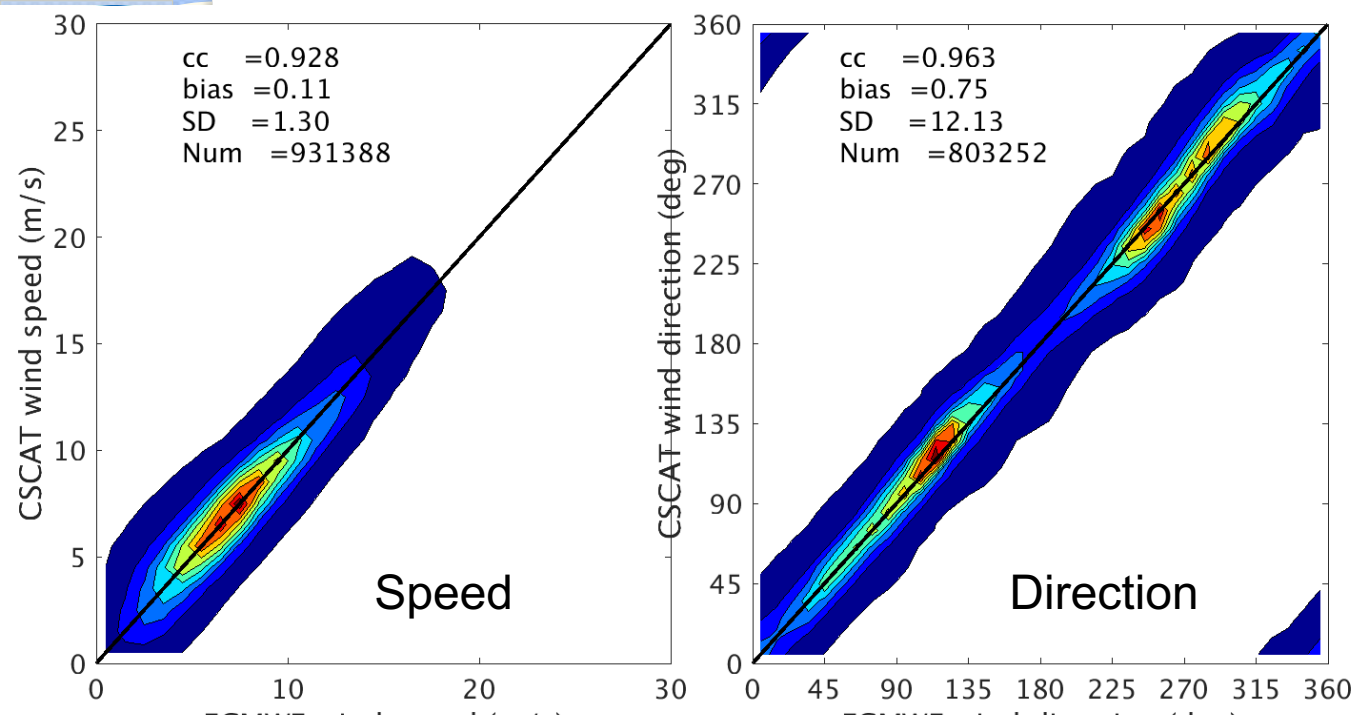
3. Results and Verifications

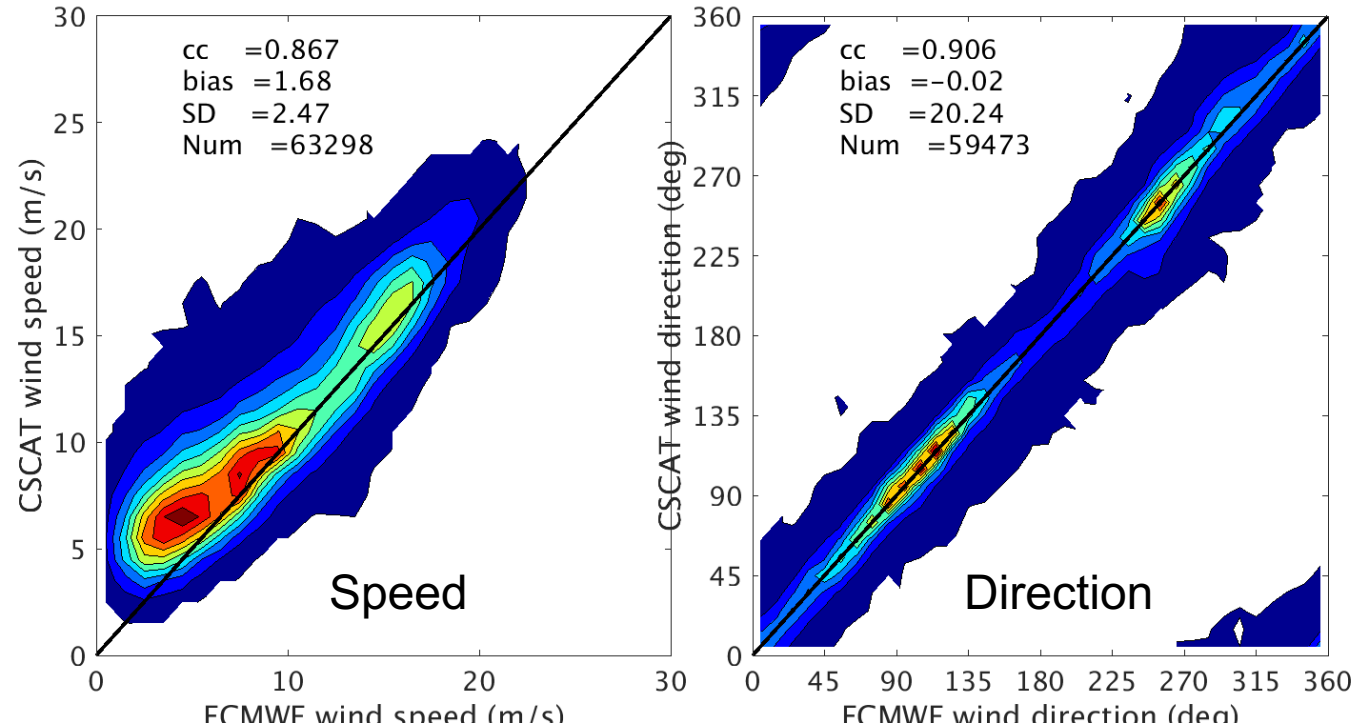


Rain (Quality) sensitive parameter -- MLE



QC rejection ratio vs WVC number





QC-accepted

Speed:

- Bias=0.11m/s
- SD=1.30m/s

Direction:

- Bias=0.75deg
- SD=12.13deg

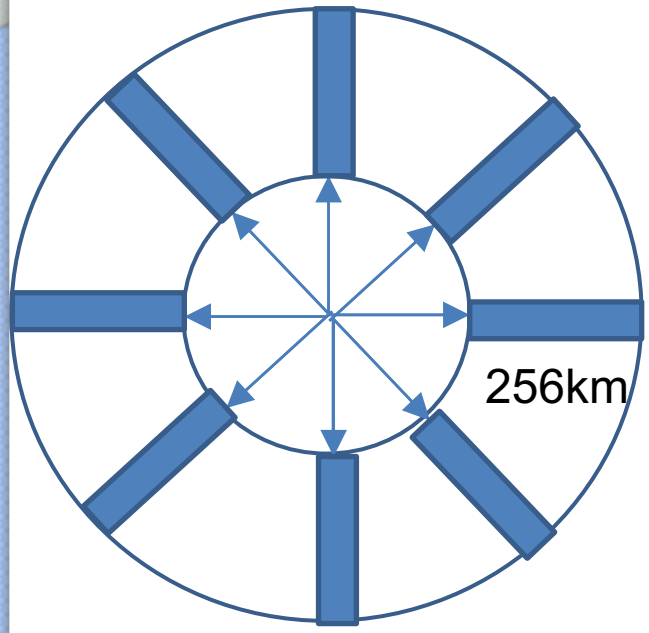
QC-rejected

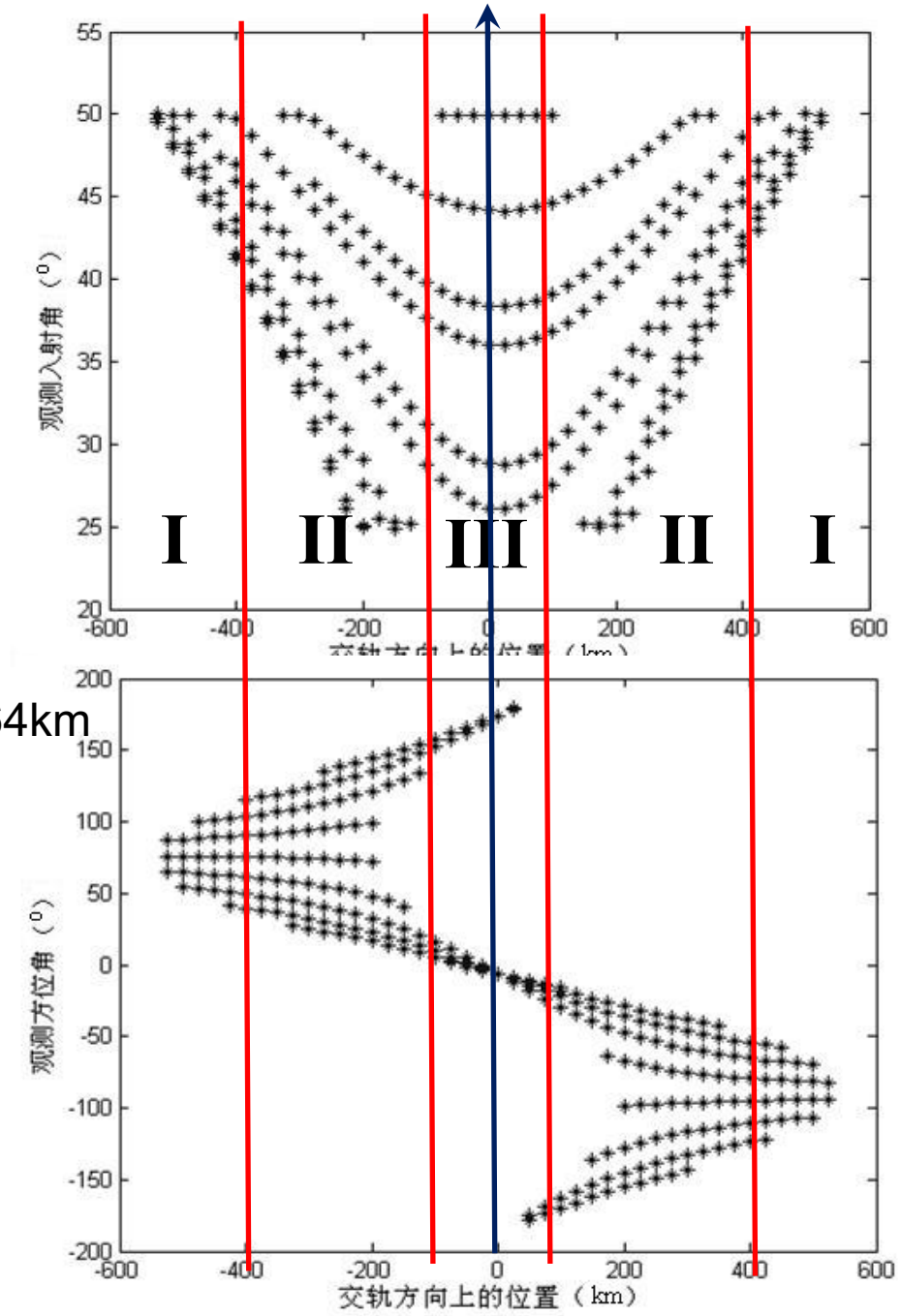
Speed:

- Bias=1.68m/s
- SD=2.47m/s

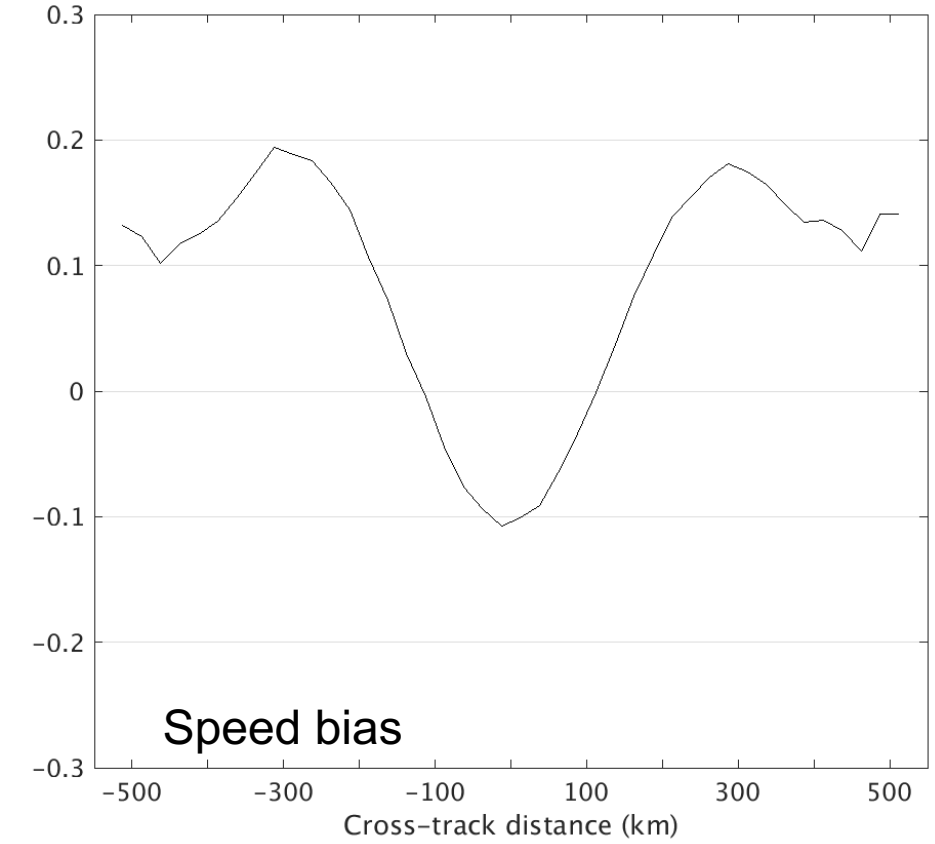
Direction:

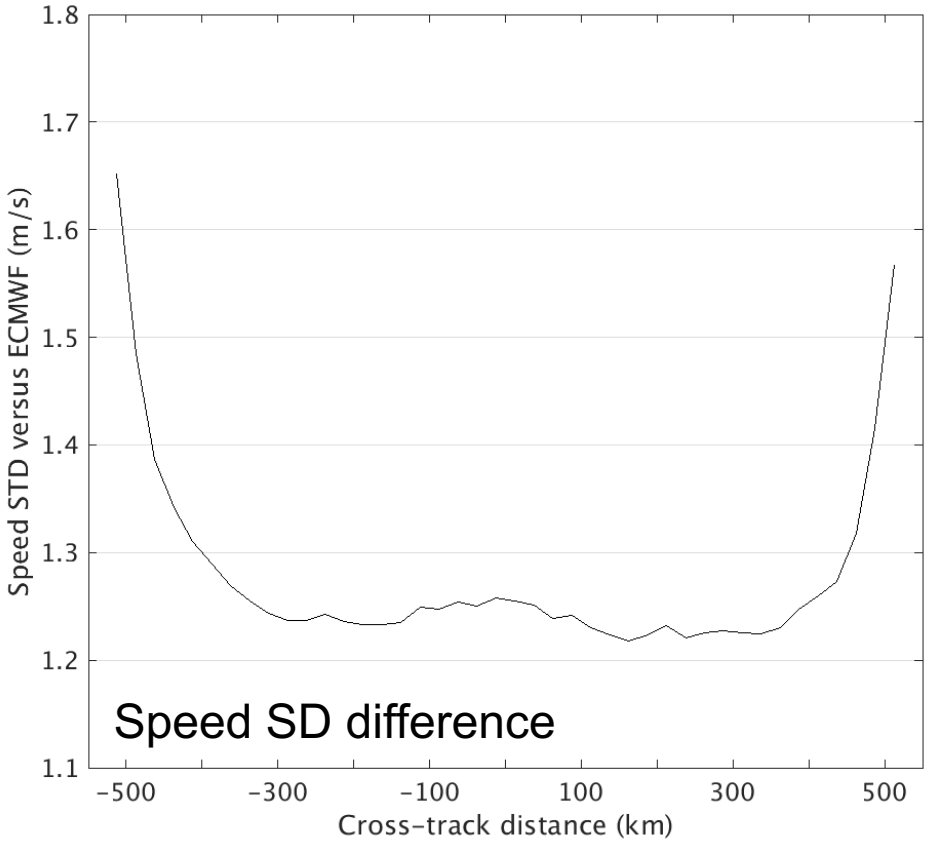
- Bias=-0.02deg
- SD=20.24deg


256km
564km


观测入射角（°）
I
II
III
II
I
观测方位角（°）
交轨方向上的位置（km）

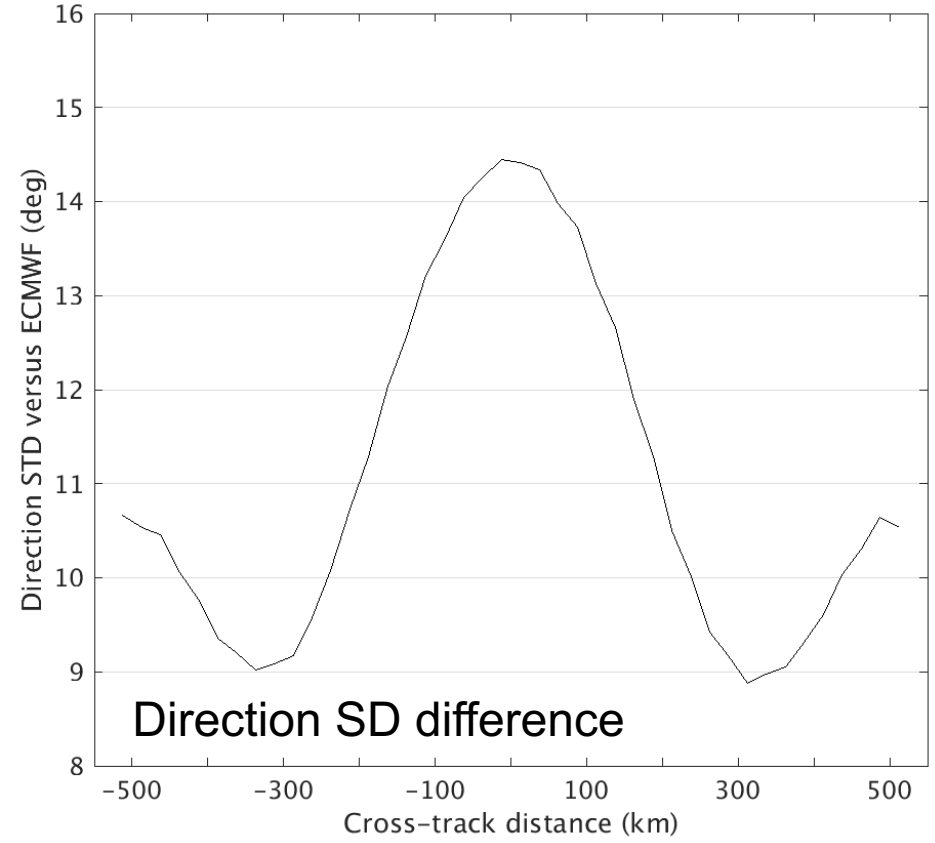
3. Results and Verifications -- vs ECMWF

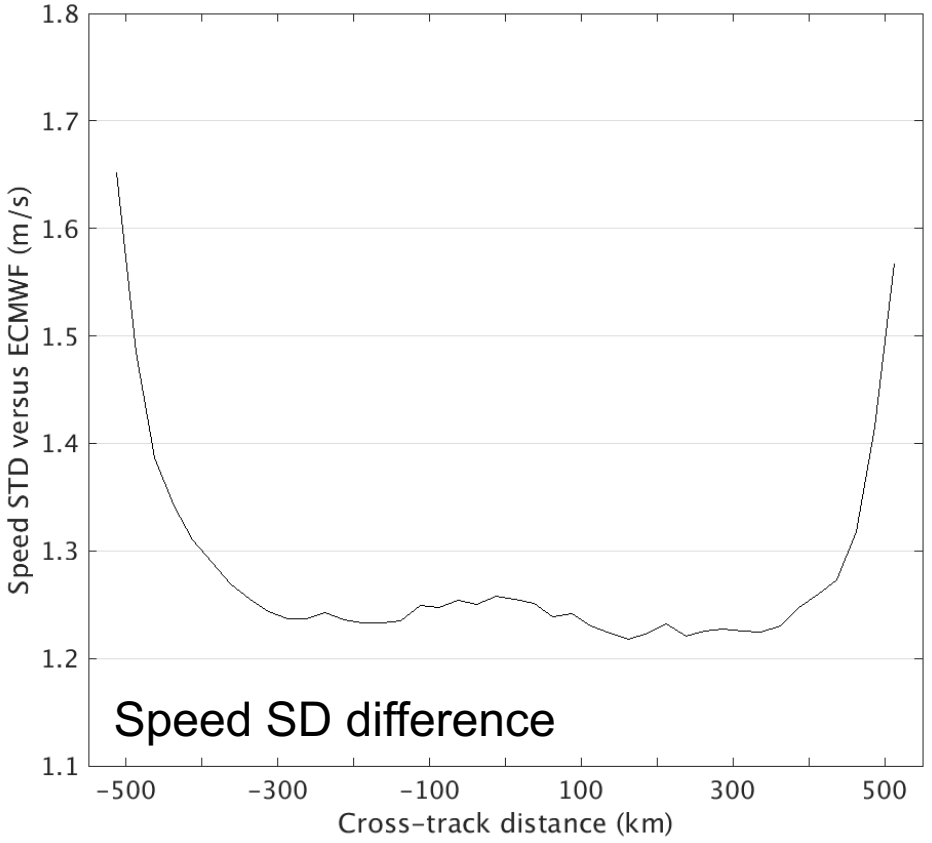




Statistical scores versus ECMWF winds

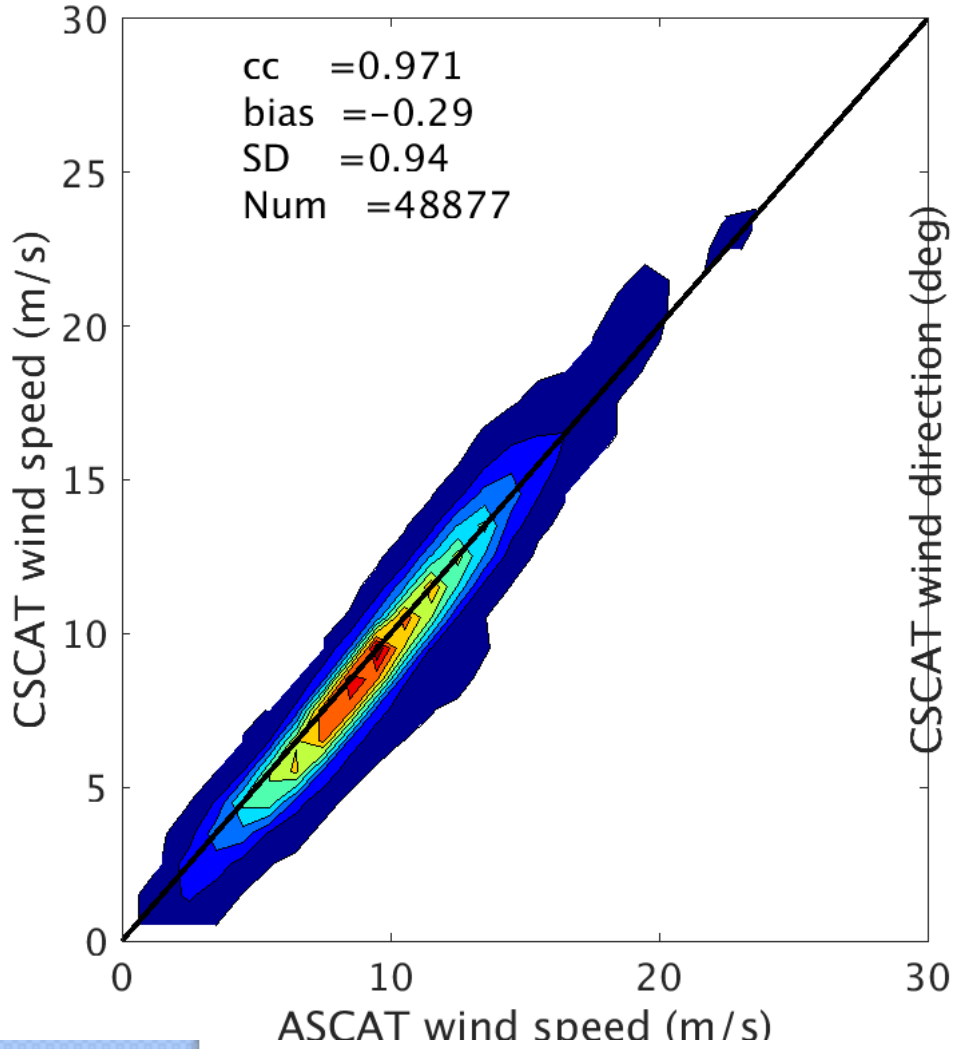
3. Results and Verifications – vs ECMWF

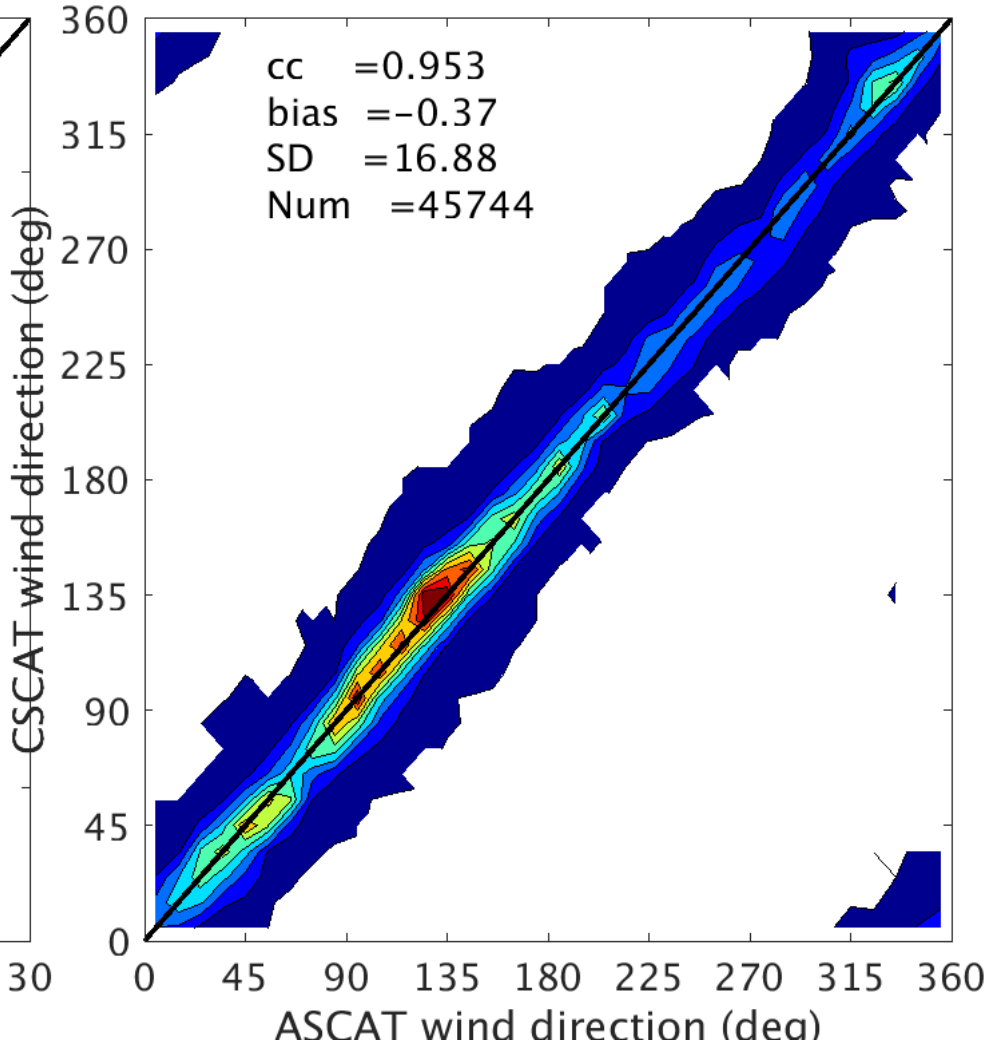


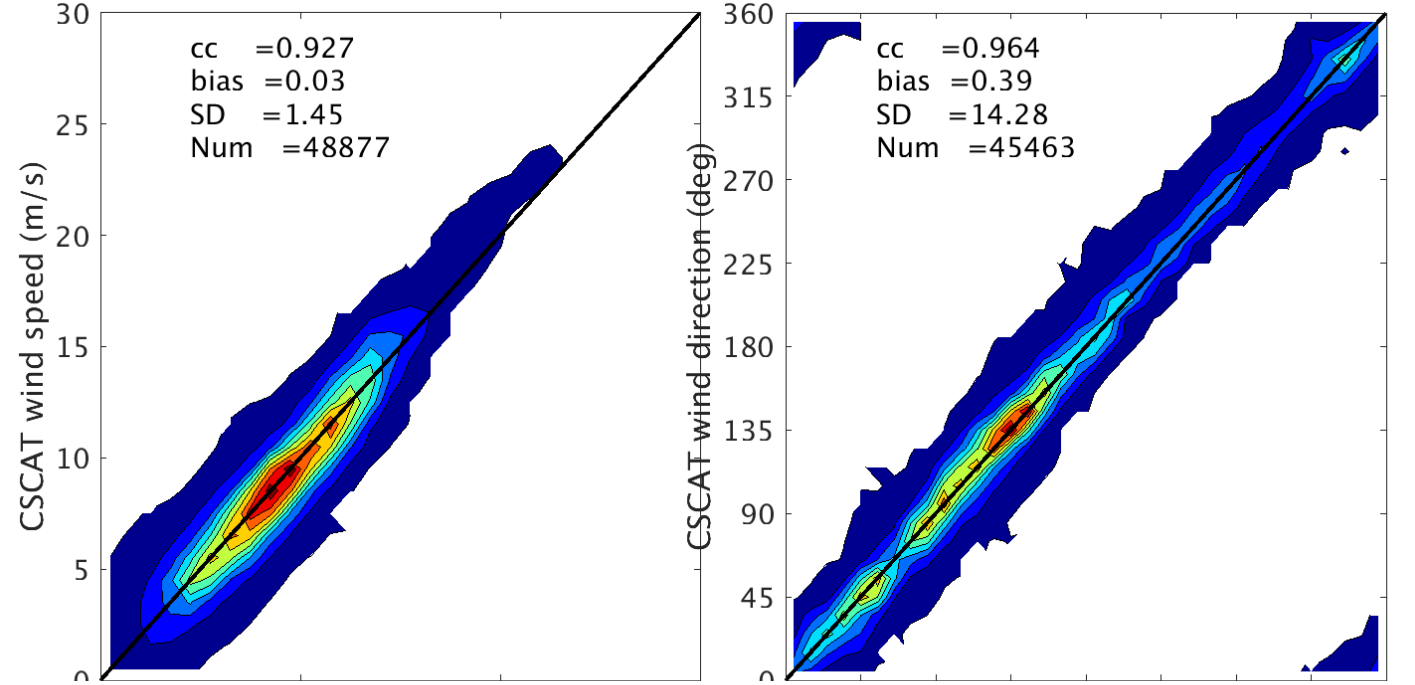


Statistical scores versus ECMWF winds

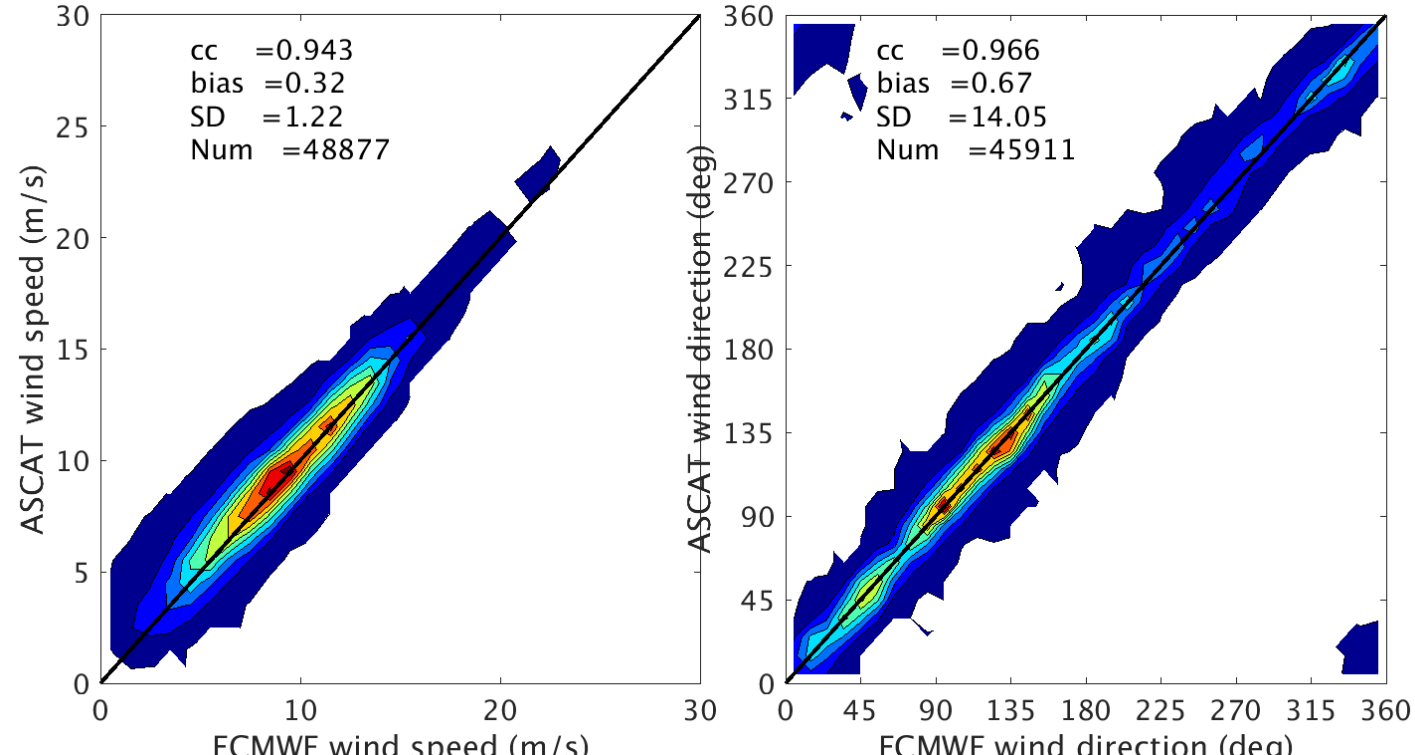
3. Results and Verifications -- ASCAT





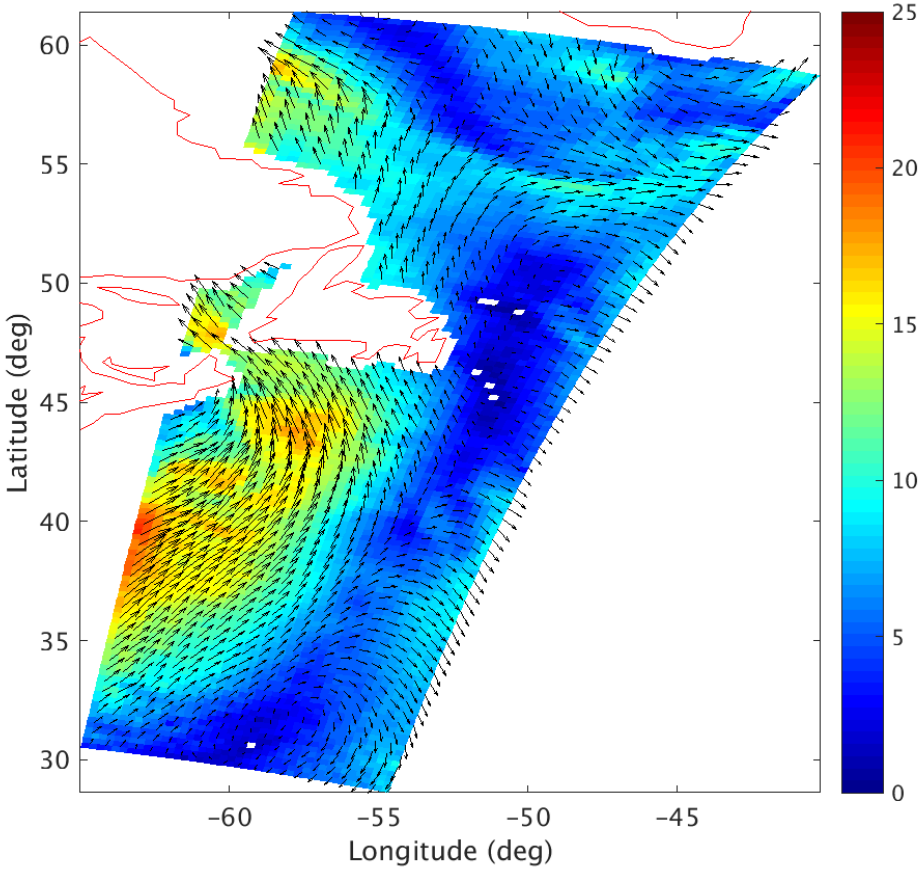


CSCAT versus ECMWF (ASCAT Bg)

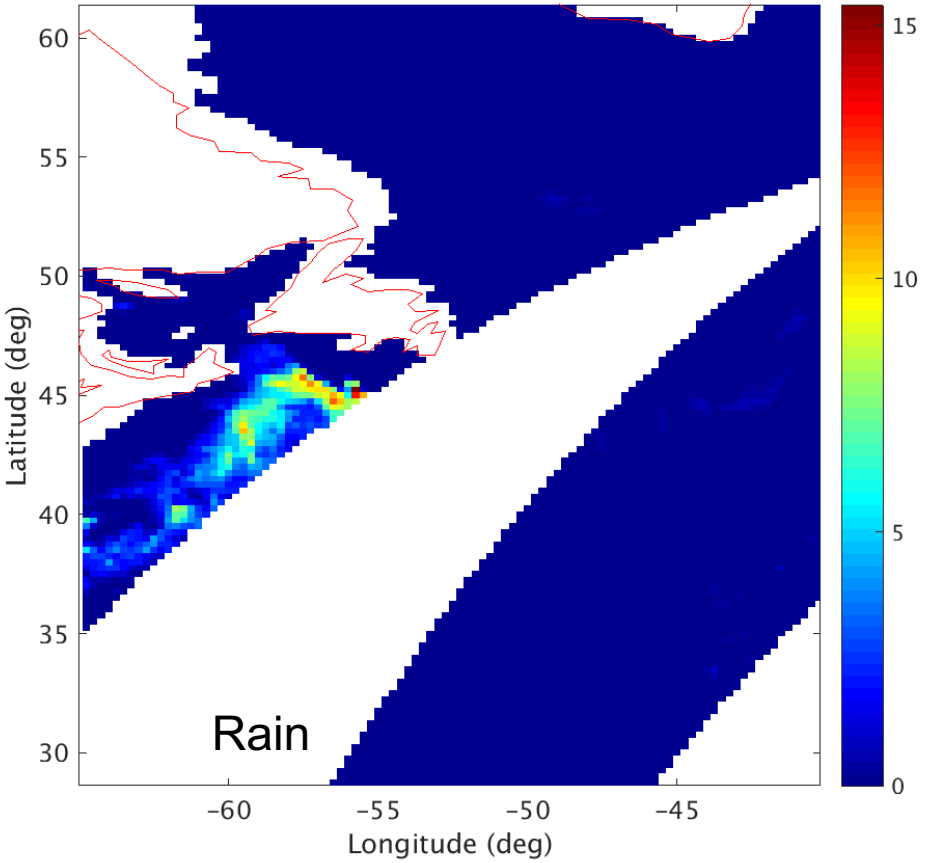


ASCAT versus ECMWF (ASCAT Bg)

3. Results and Verifications – Rain impact

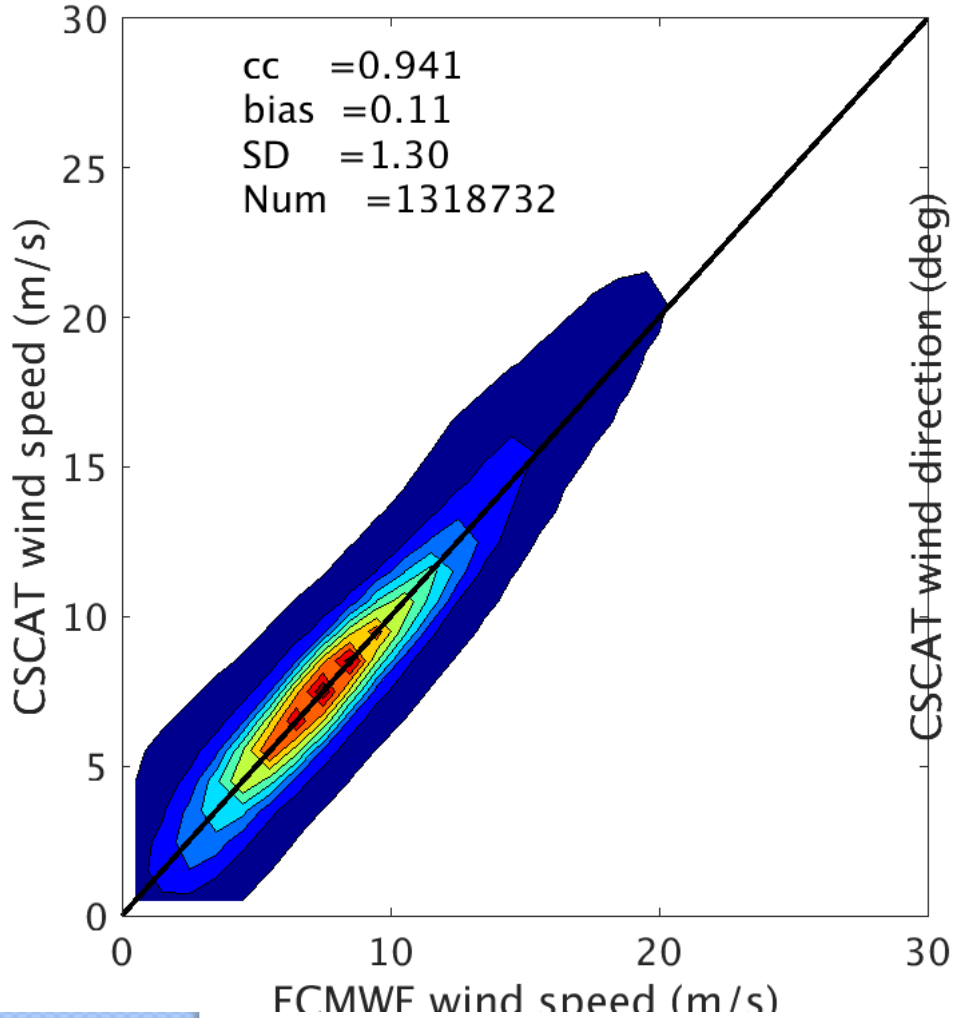


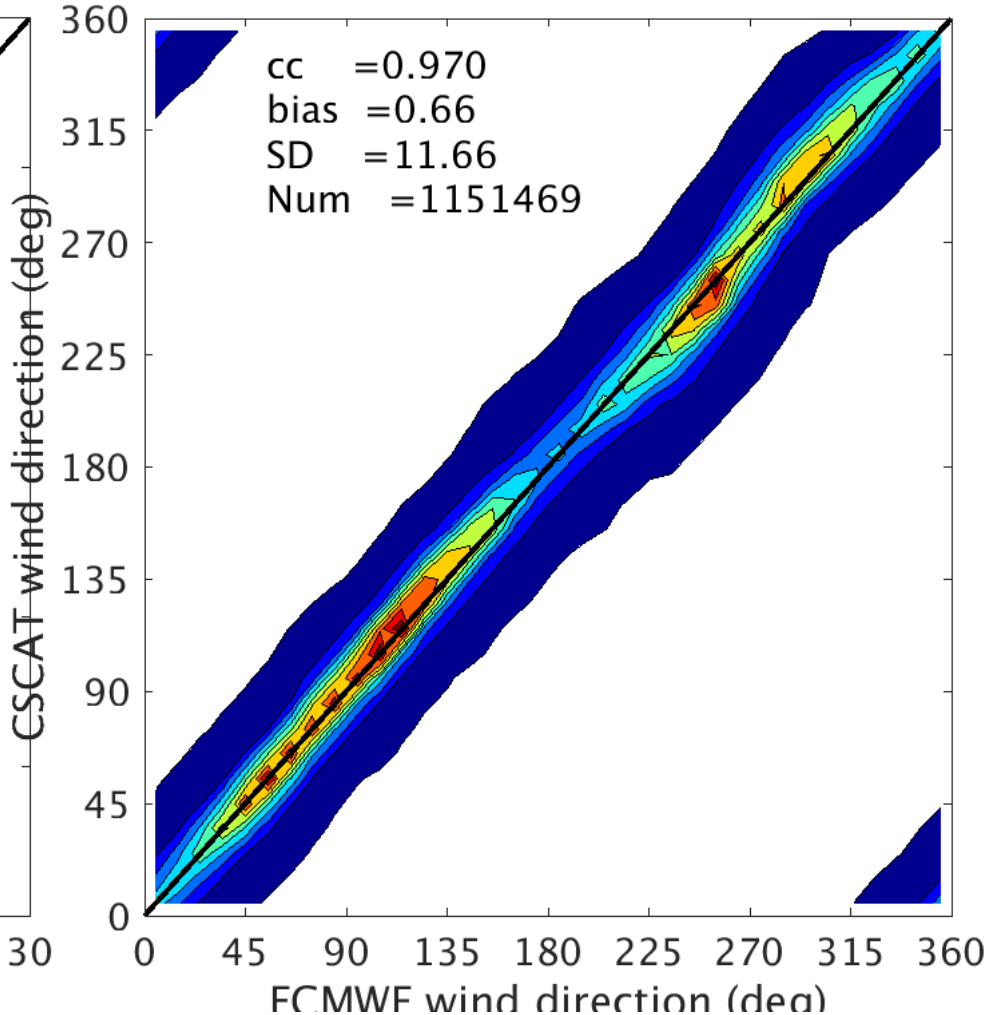
CSCAT wind field



CSCAT MLE field

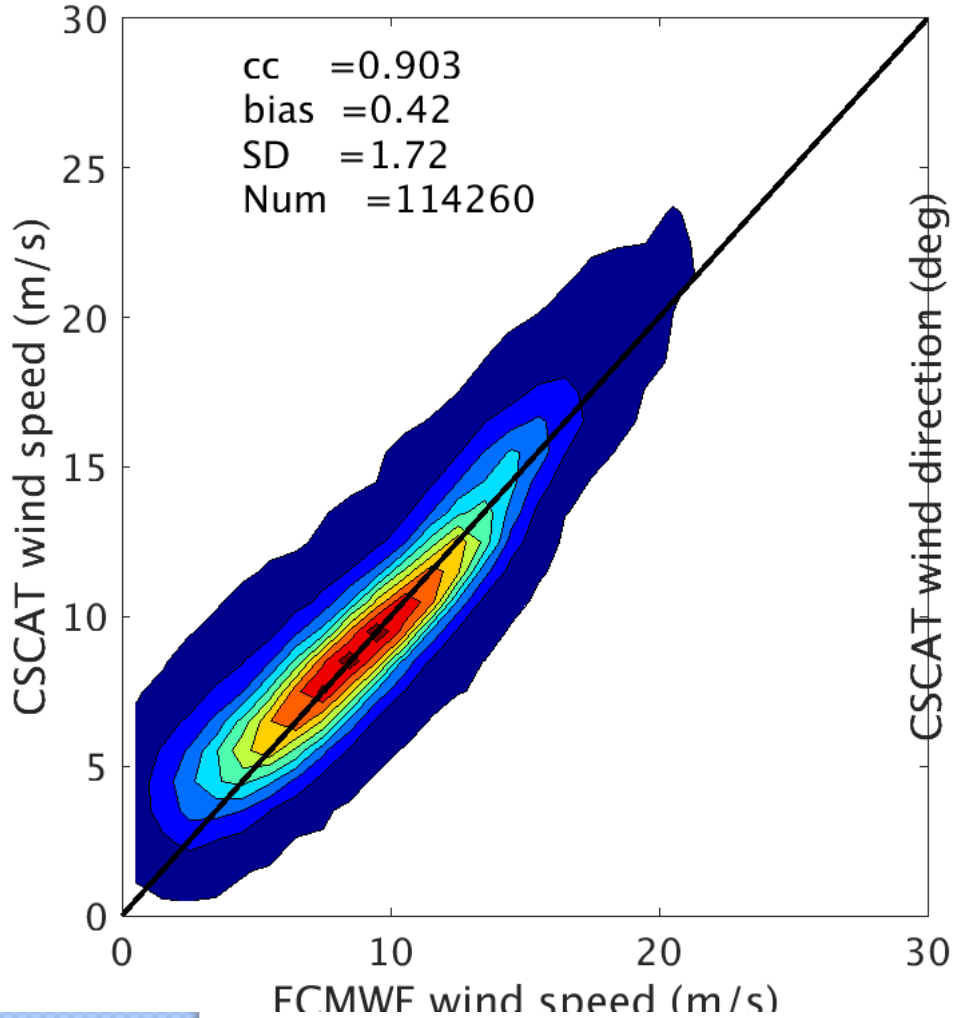
3. Results and Verifications – Rain impact

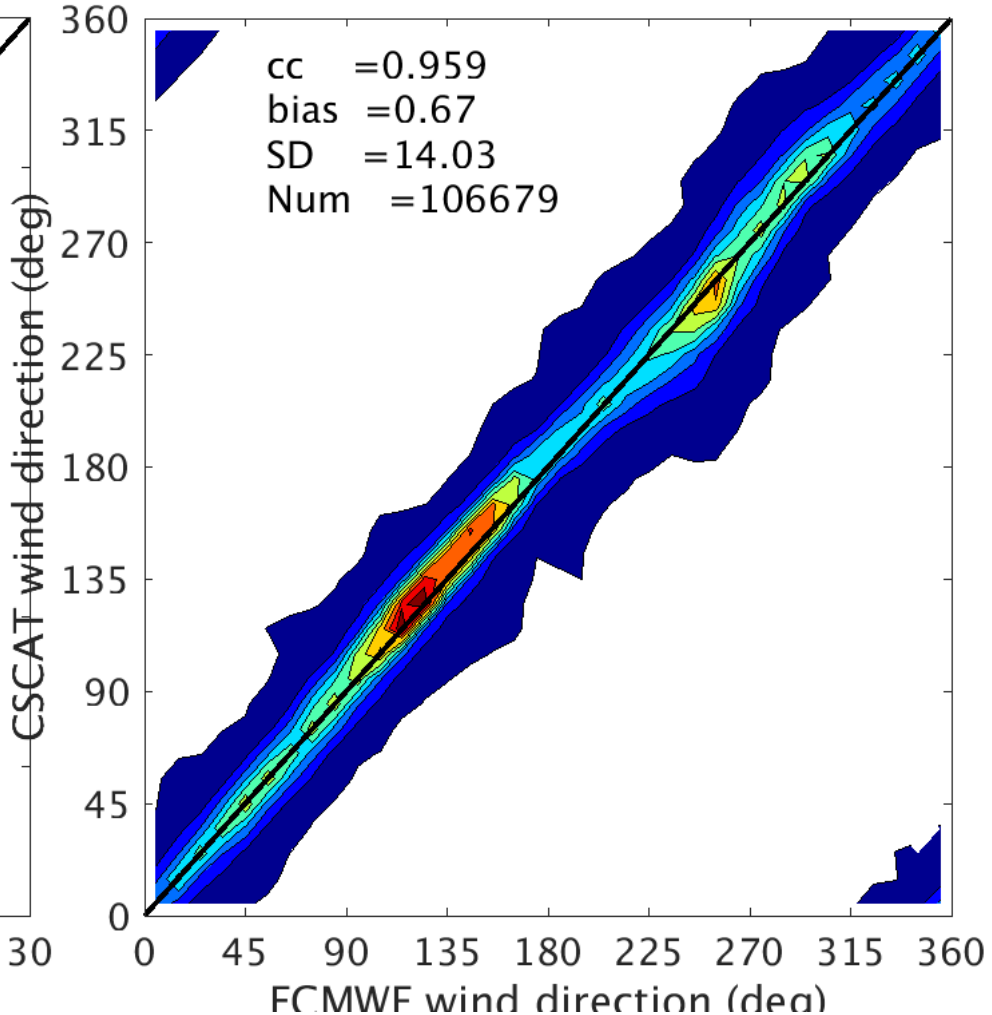




Rain free (collocations with GPM GMI rain data)

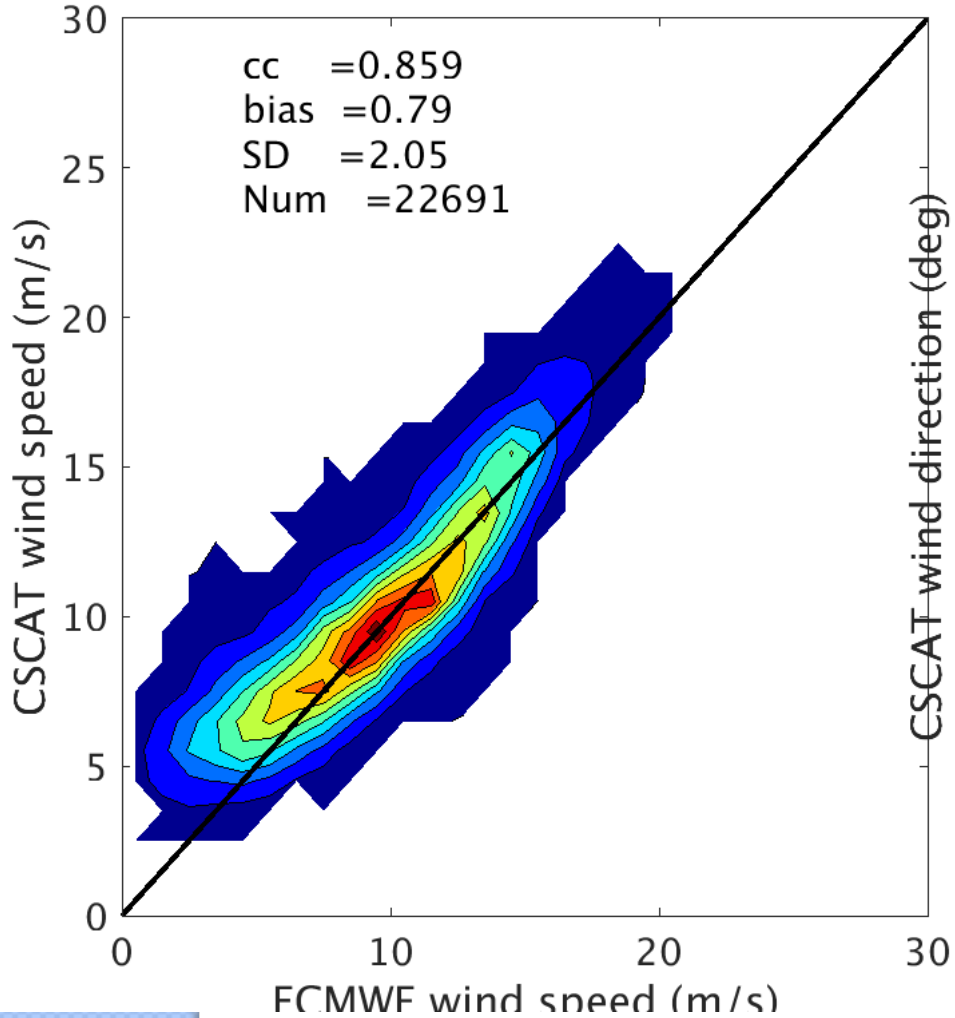
3. Results and Verifications – Rain impact

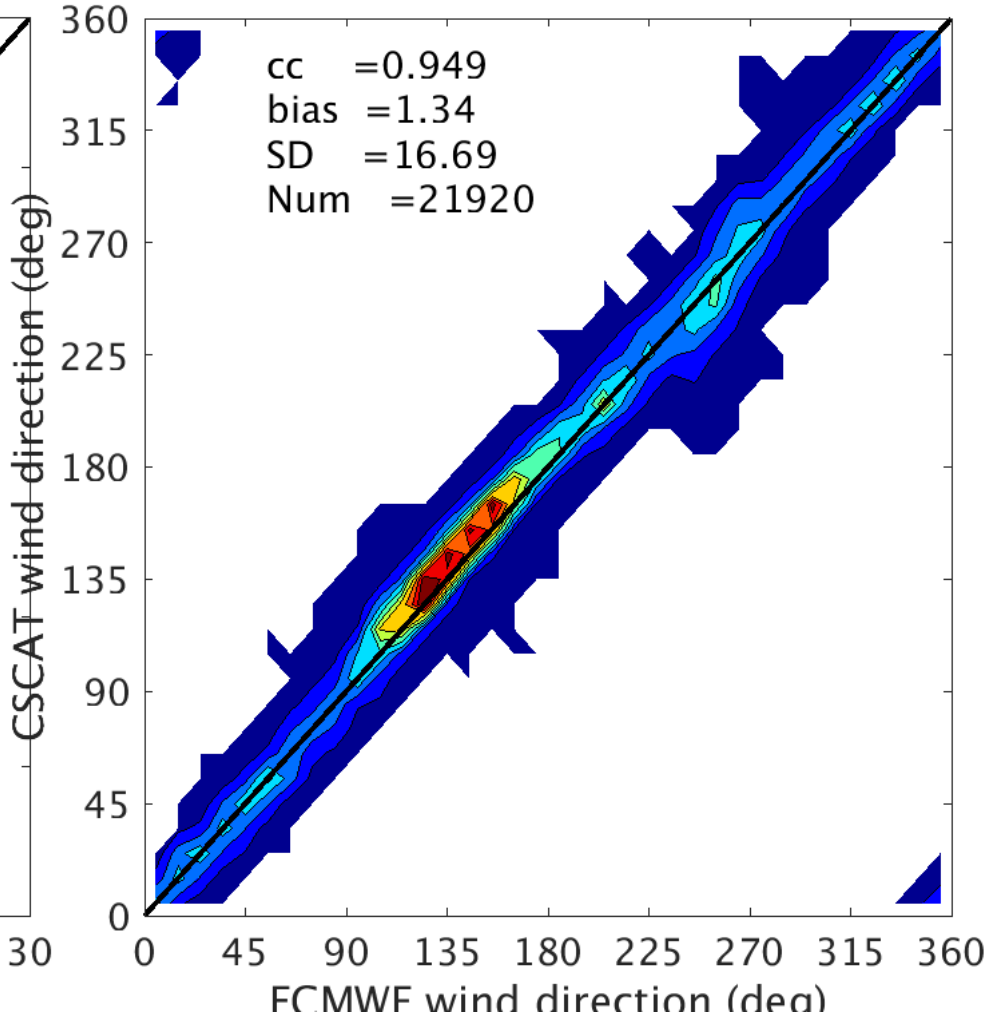




Rain Rate (0, 1] mm/h

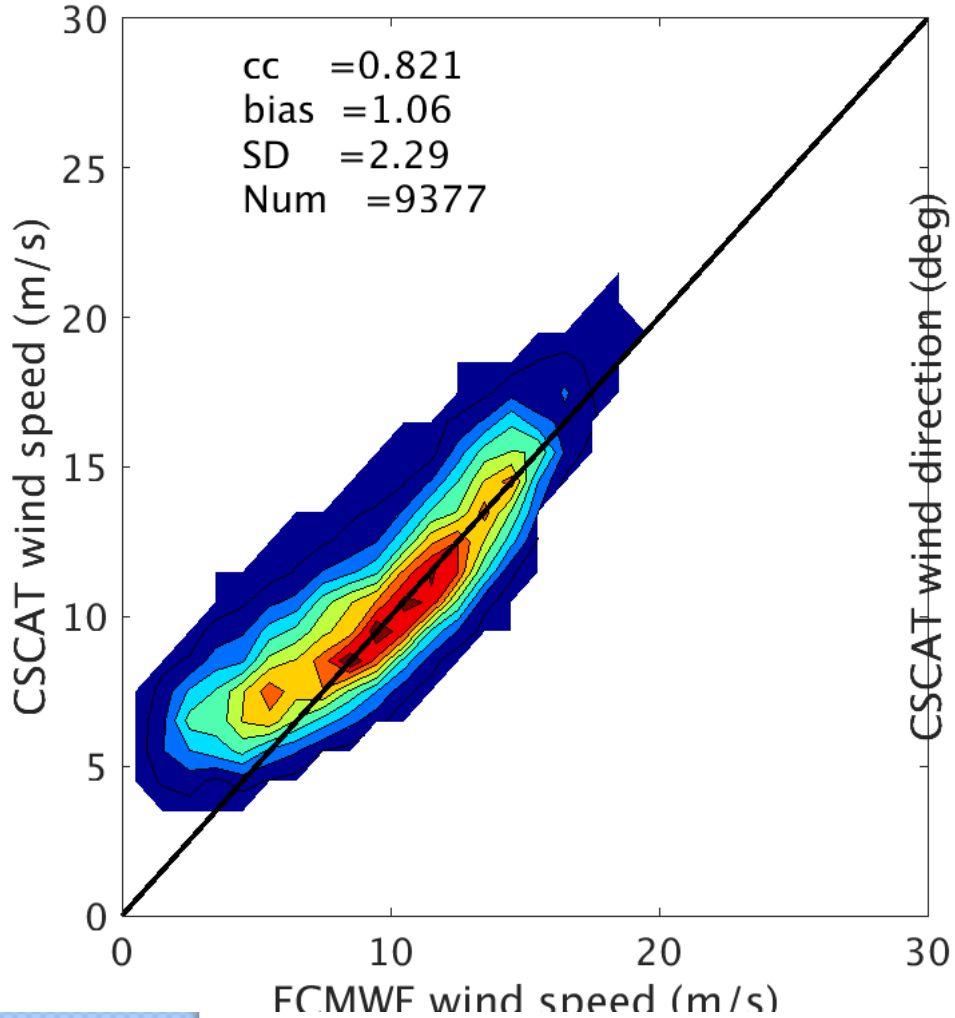
3. Results and Verifications – Rain impact

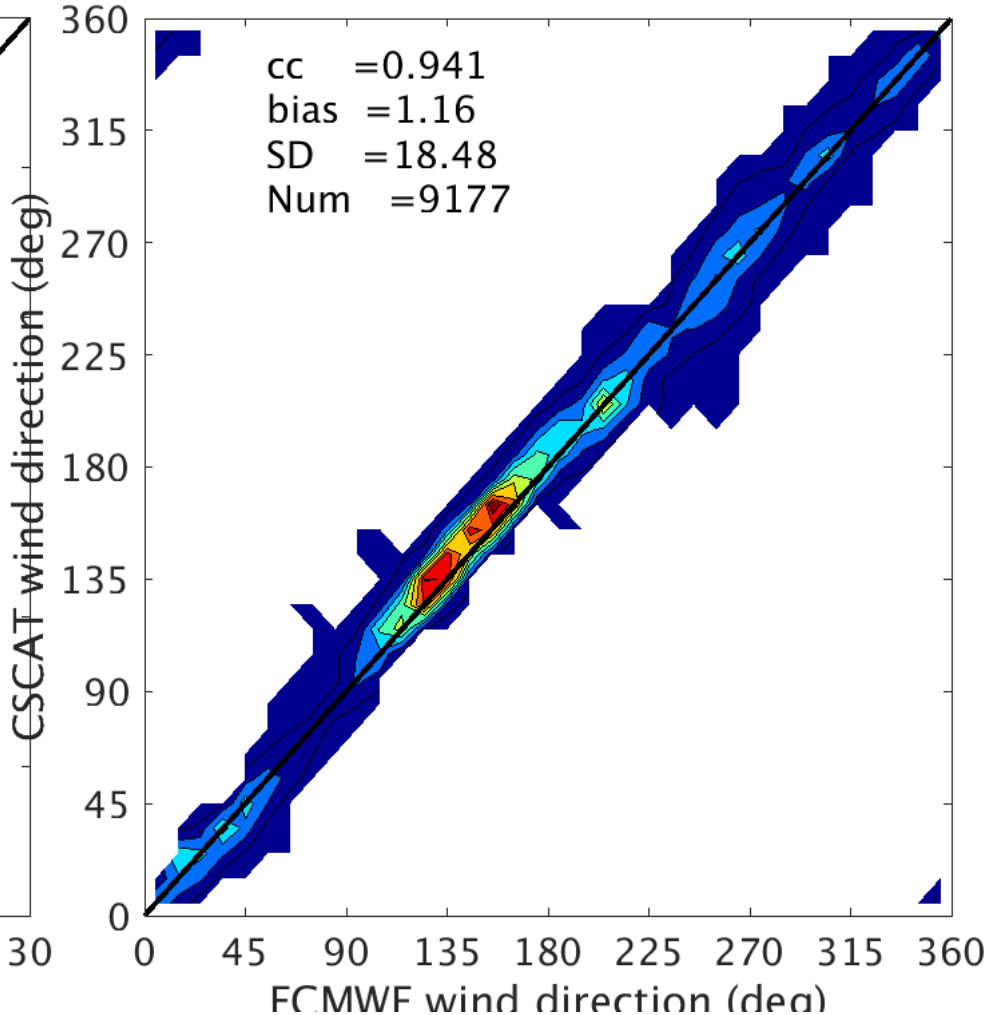




Rain Rate (1, 2] mm/h

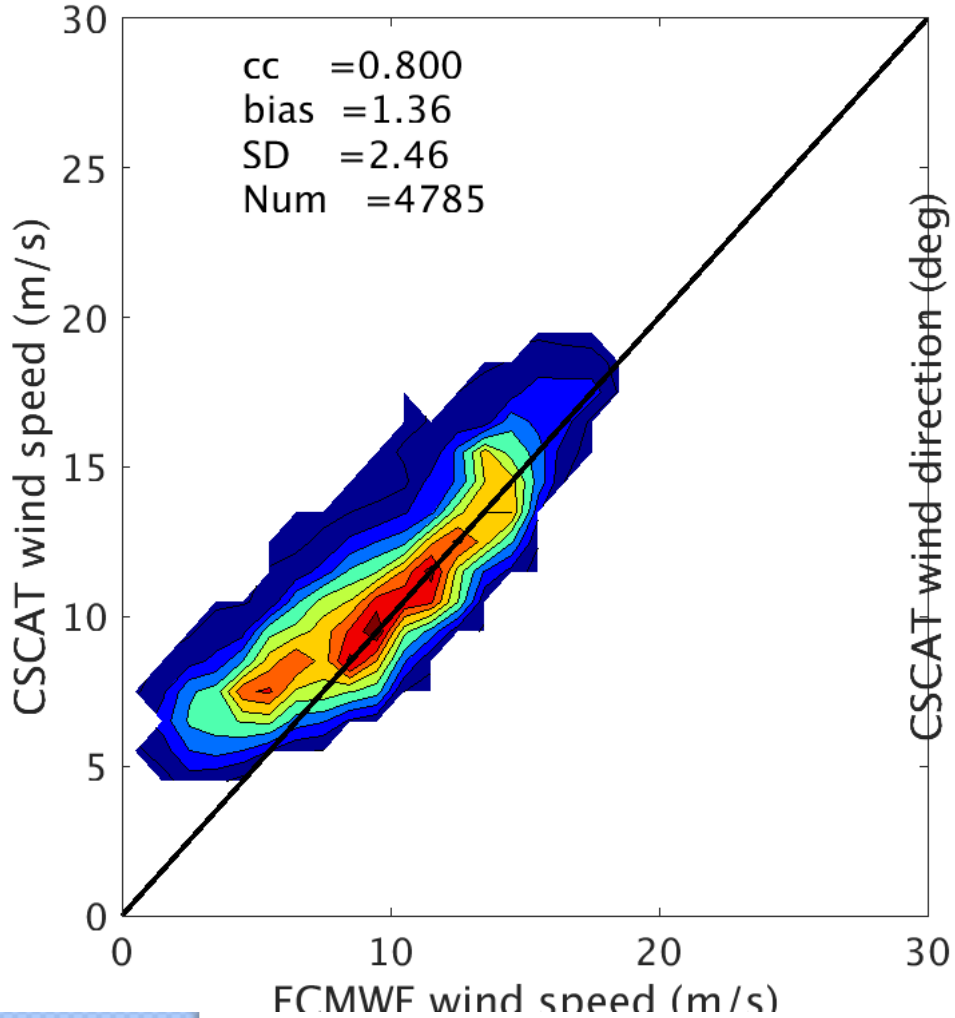
3. Results and Verifications – Rain impact

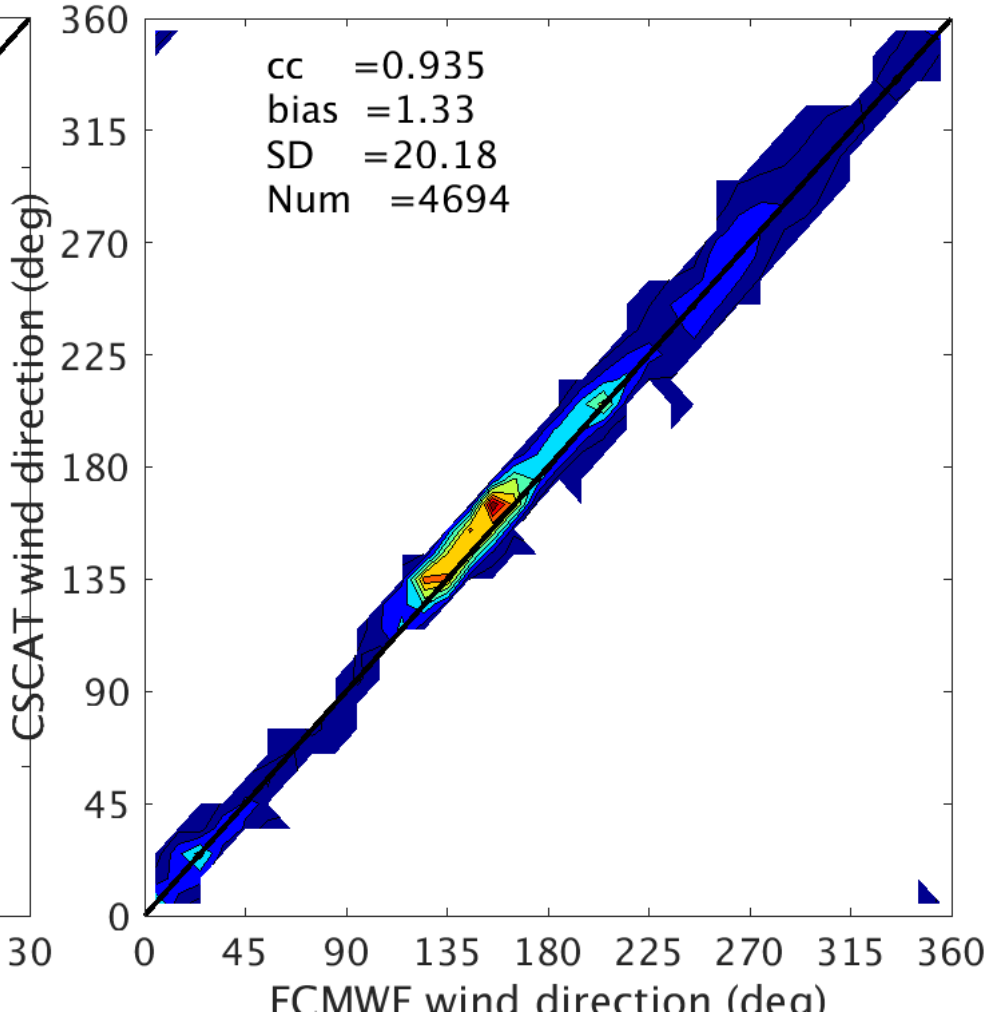




Rain Rate (2, 3] mm/h

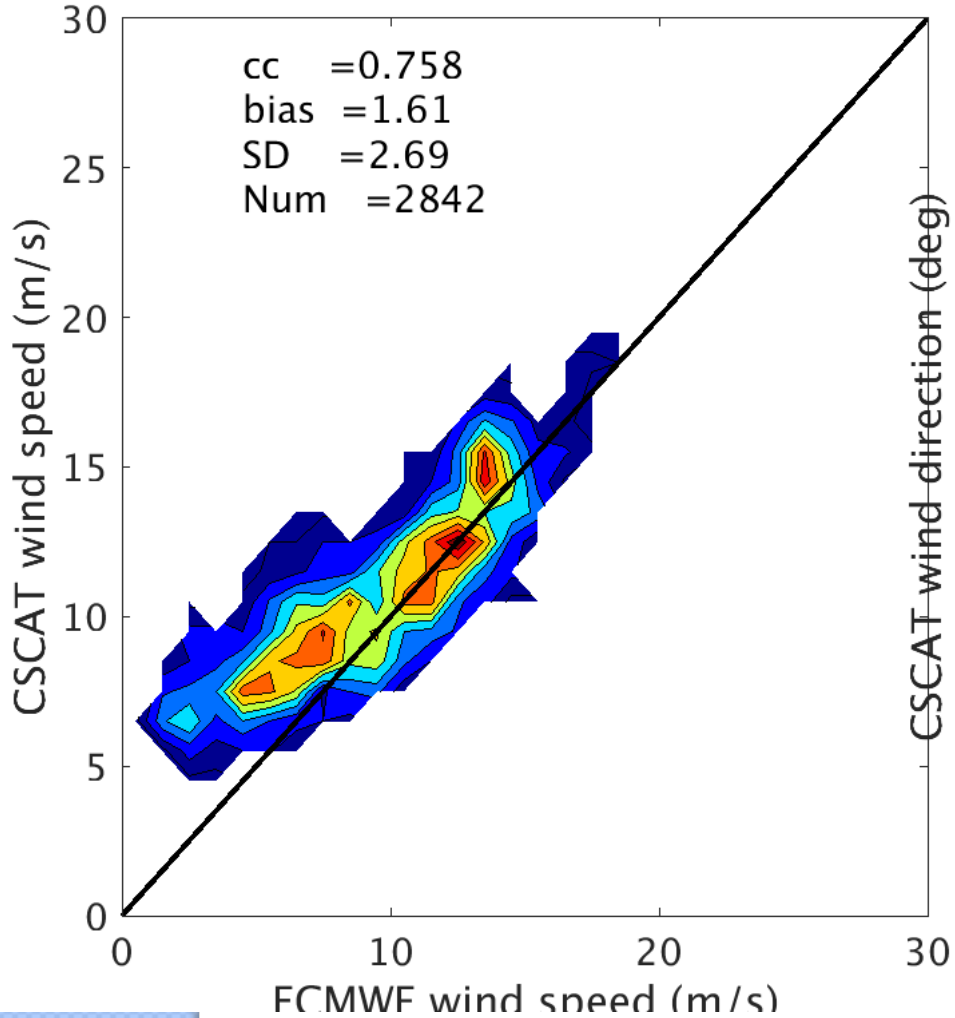
3. Results and Verifications – Rain impact

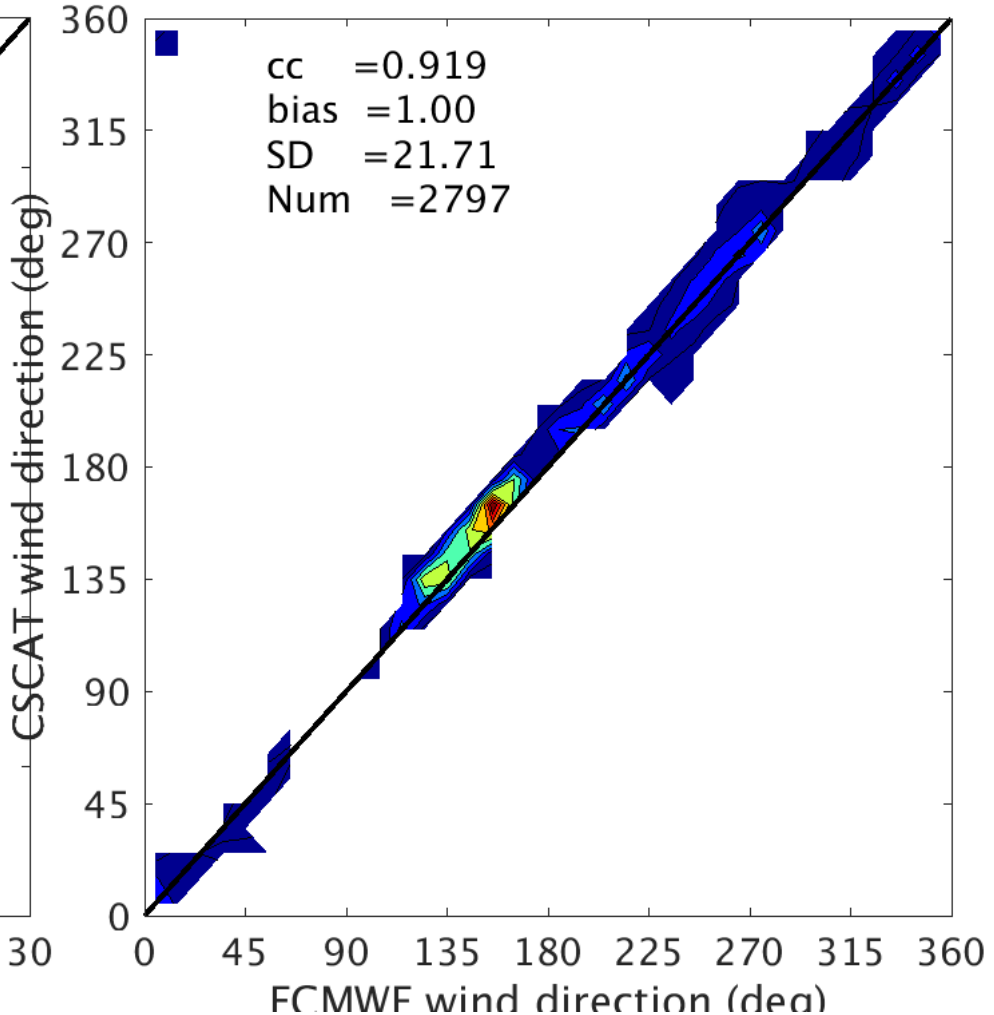




Rain Rate (3, 4] mm/h

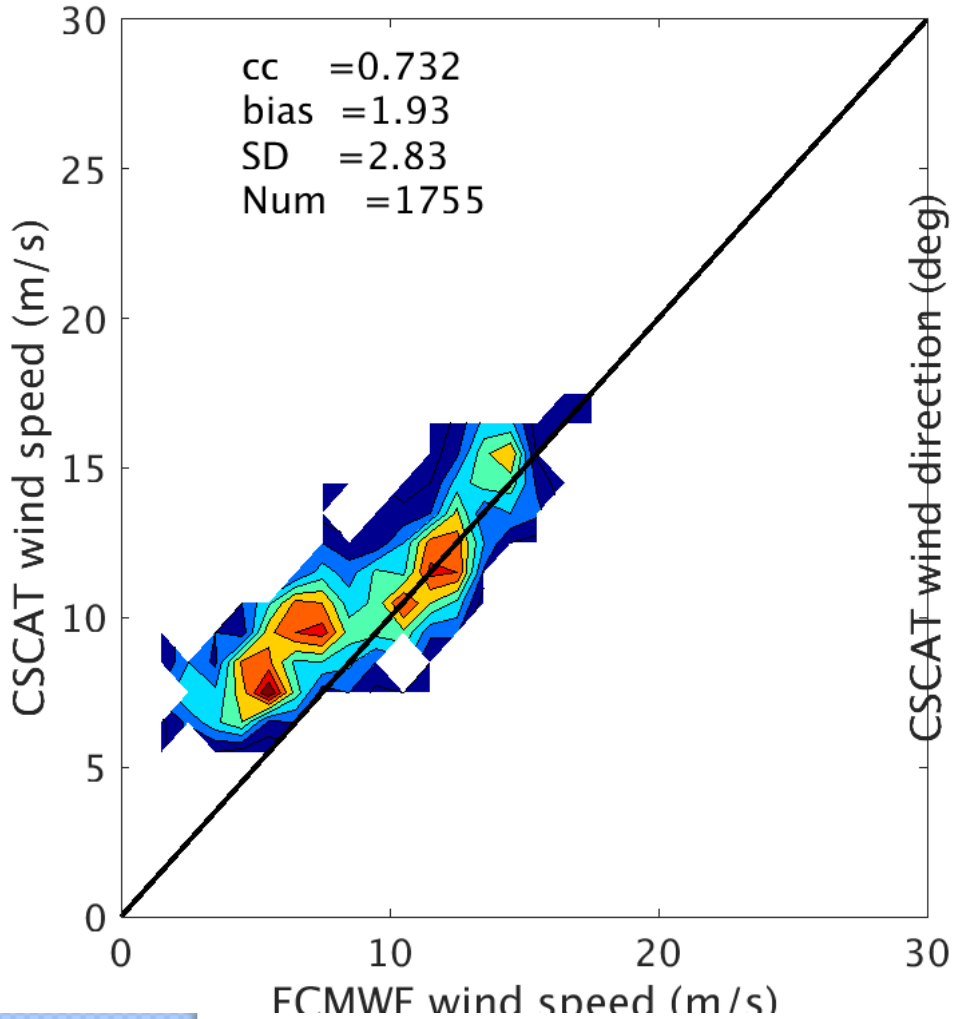
3. Results and Verifications – Rain impact

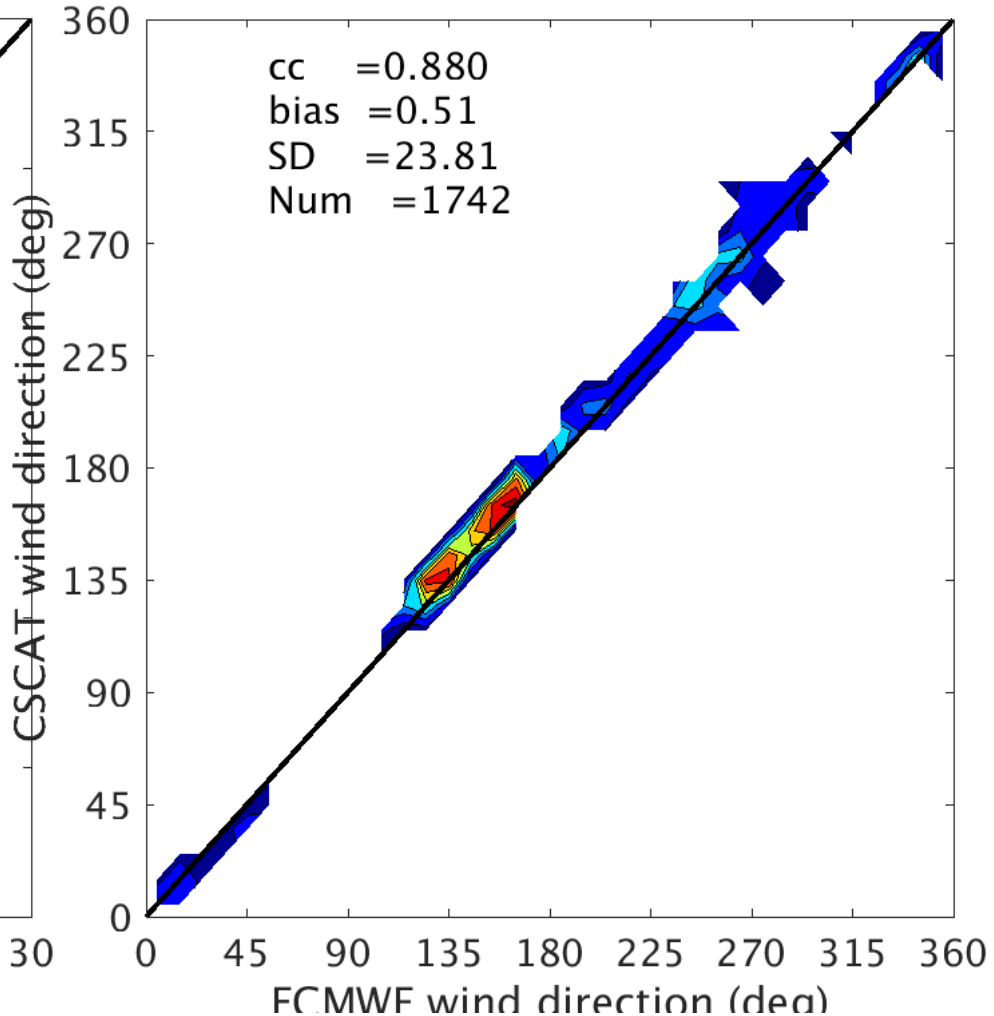




Rain Rate (4, 5] mm/h

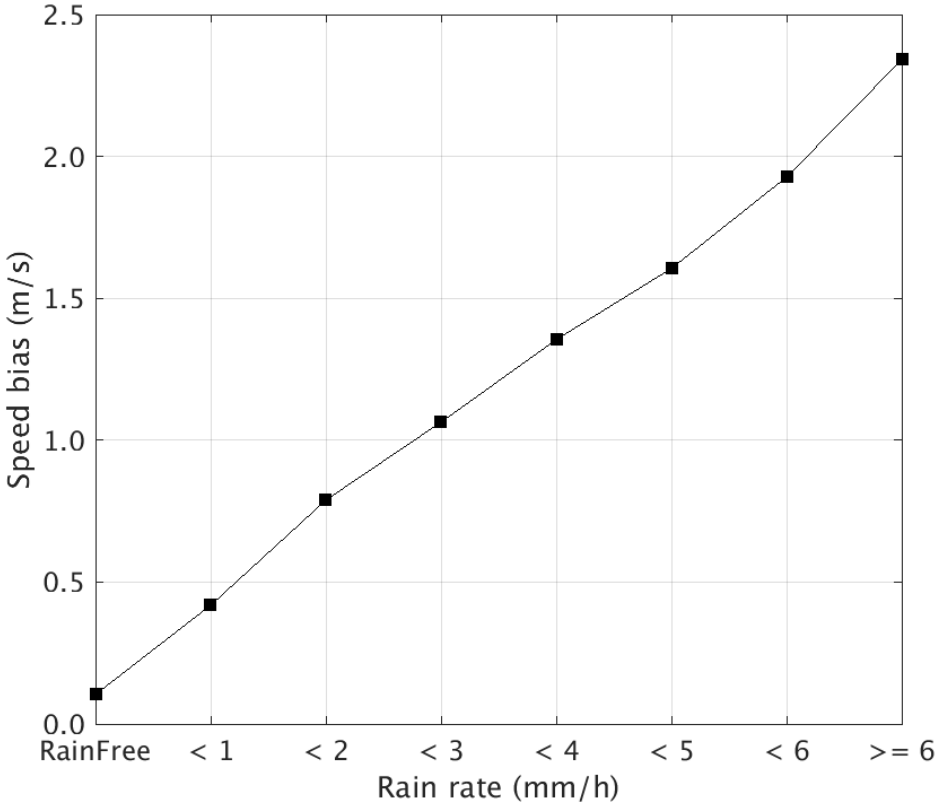
3. Results and Verifications – Rain impact

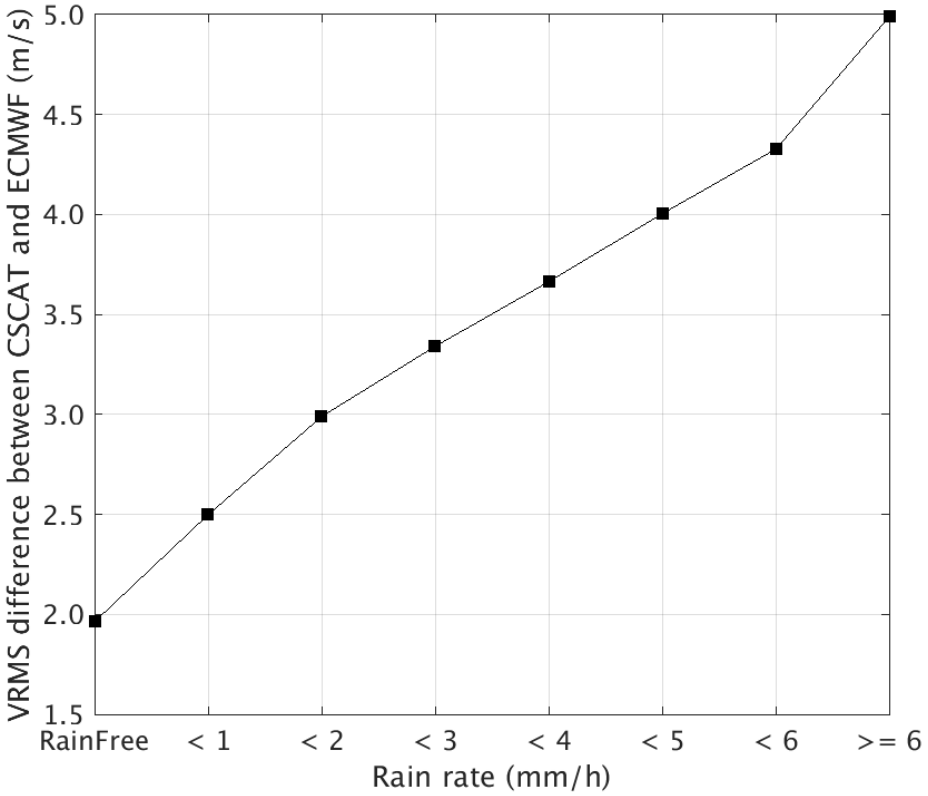




Rain Rate (5, 6] mm/h

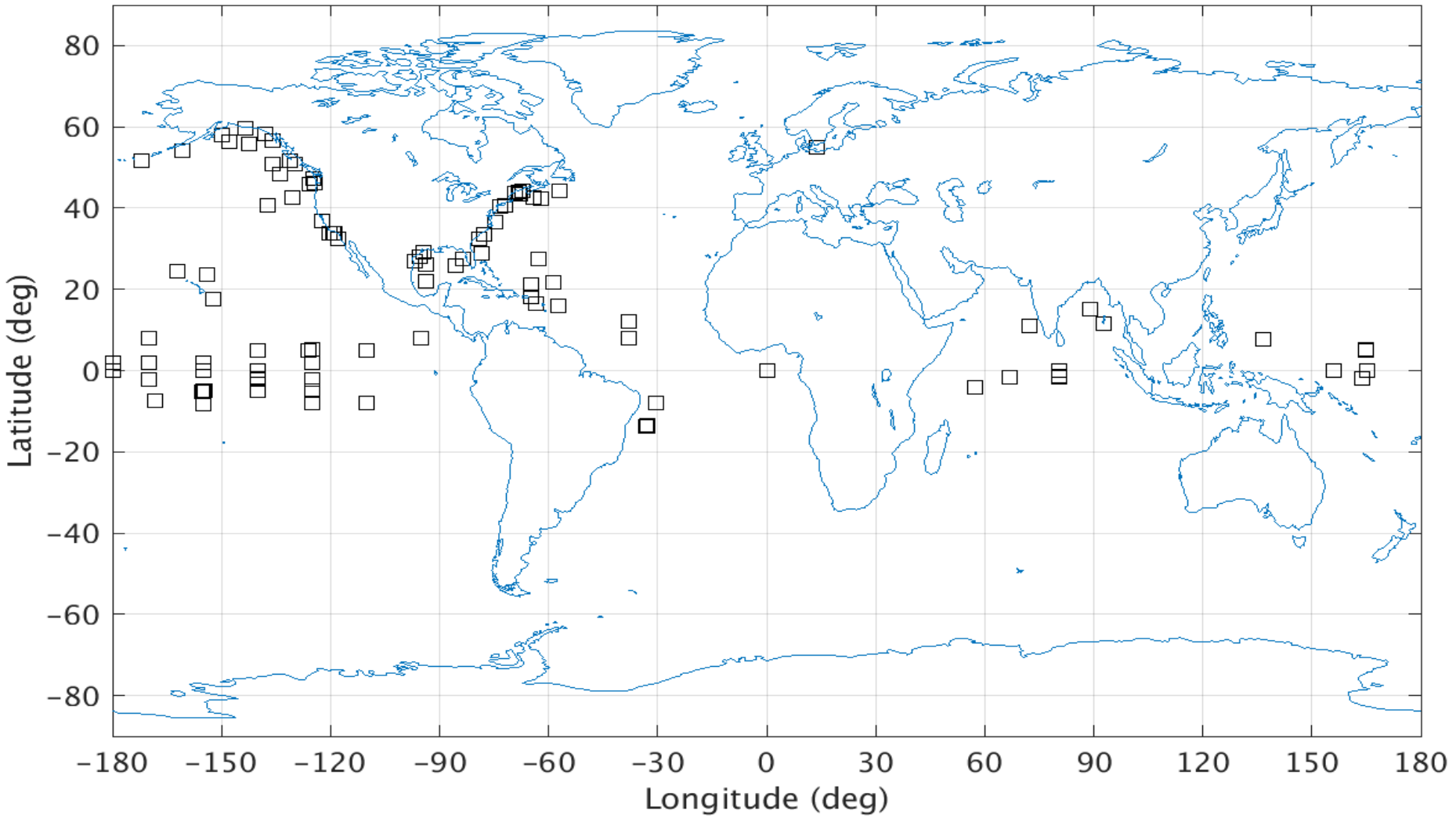
3. Results and Verifications – Rain impact



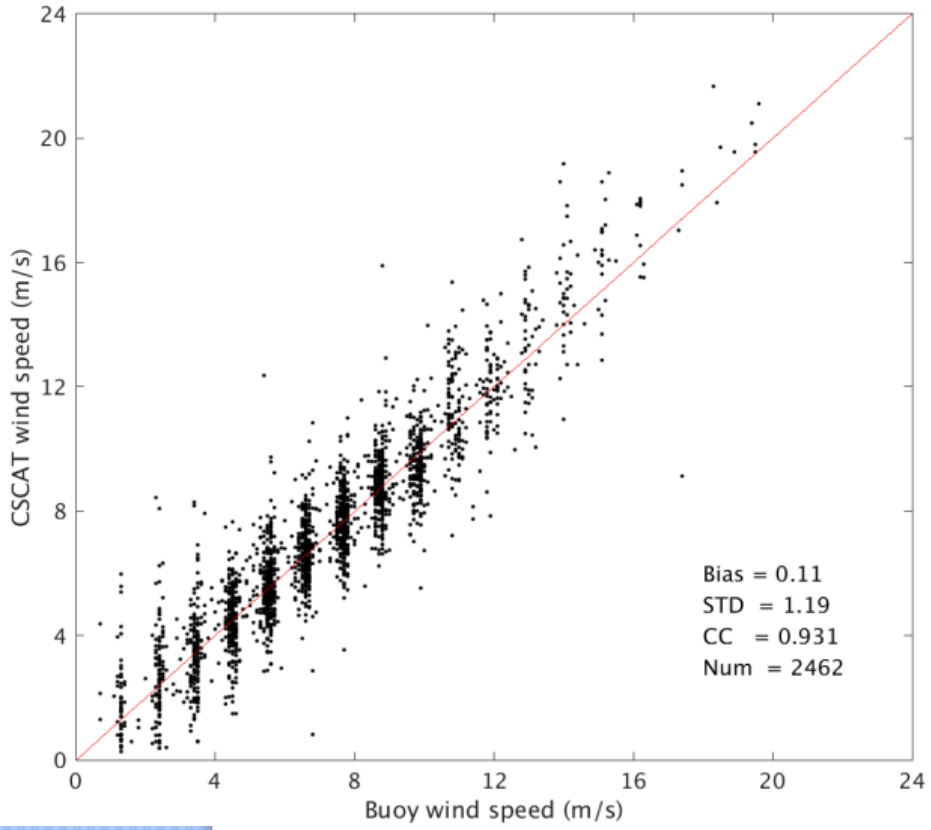


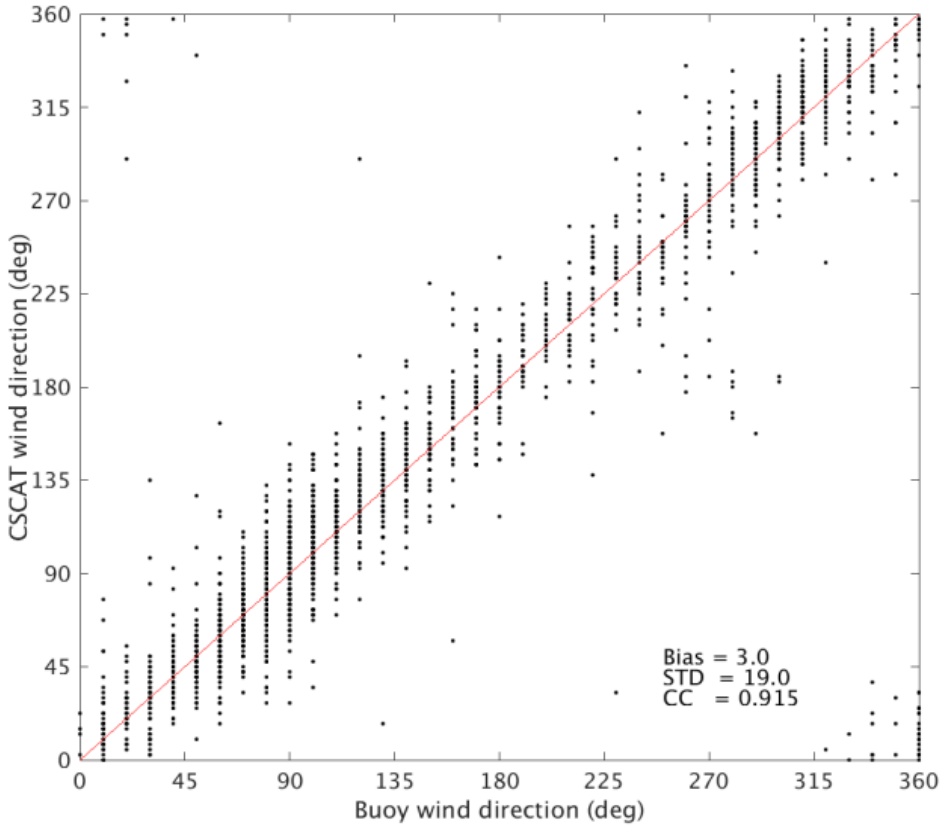
Wind quality degrades as the rain rate increases

3. Results and Verifications – Buoy



3. Results and Verifications – Buoy





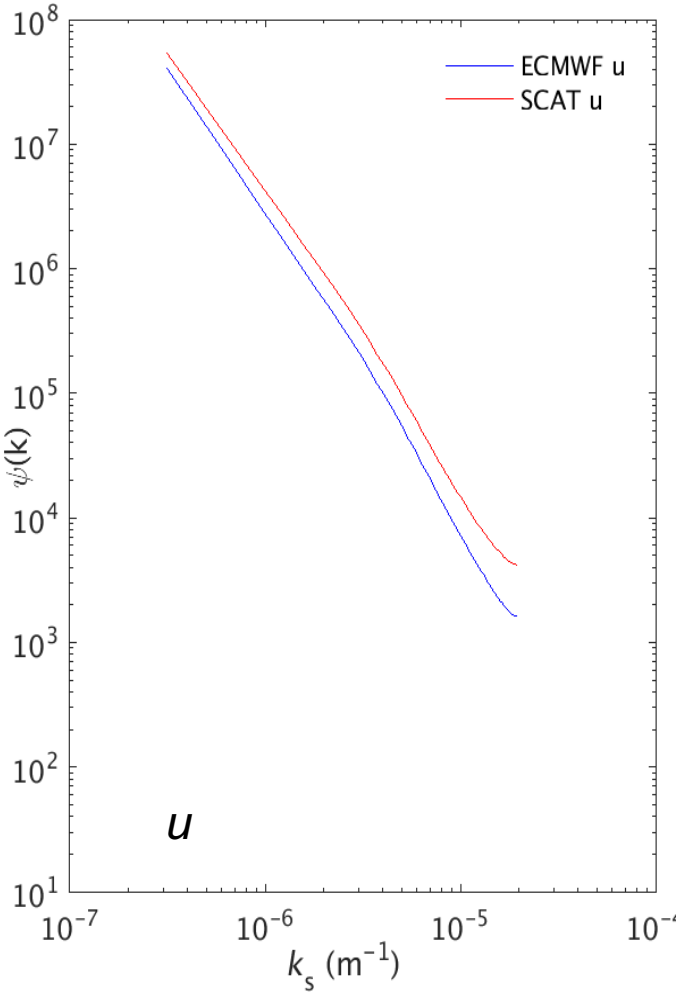
CFOSCAT versus Moored buoy wind vectors

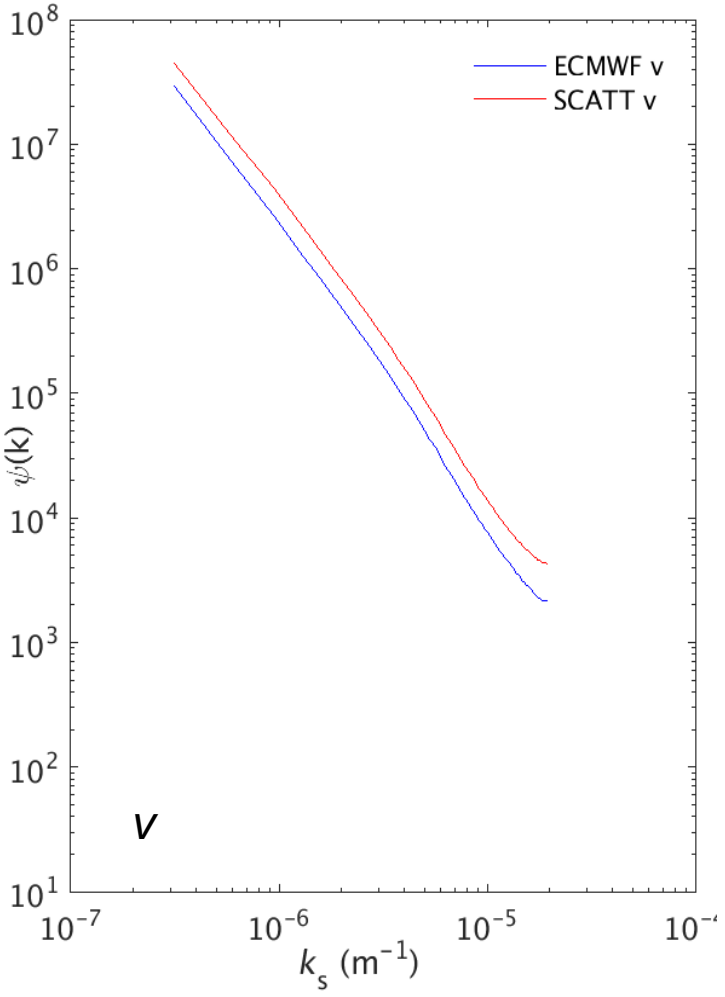
- ✓ Spatial distance < 25 km;
- ✓ Time difference < 30 minutes

Triple collocation analysis

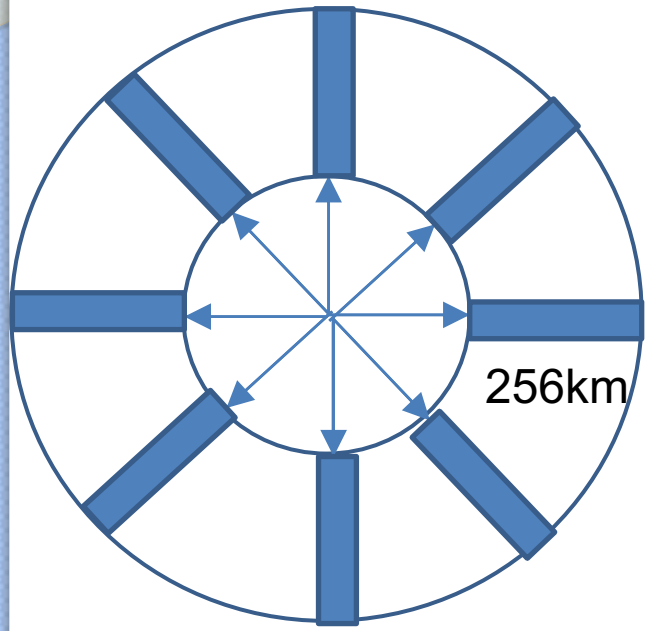
Sources	Buoy		CSCAT		ECMWF	
	u	v	u	v	u	v
Errors (m/s)	1.46	1.55	0.97	0.78	1.07	1.12

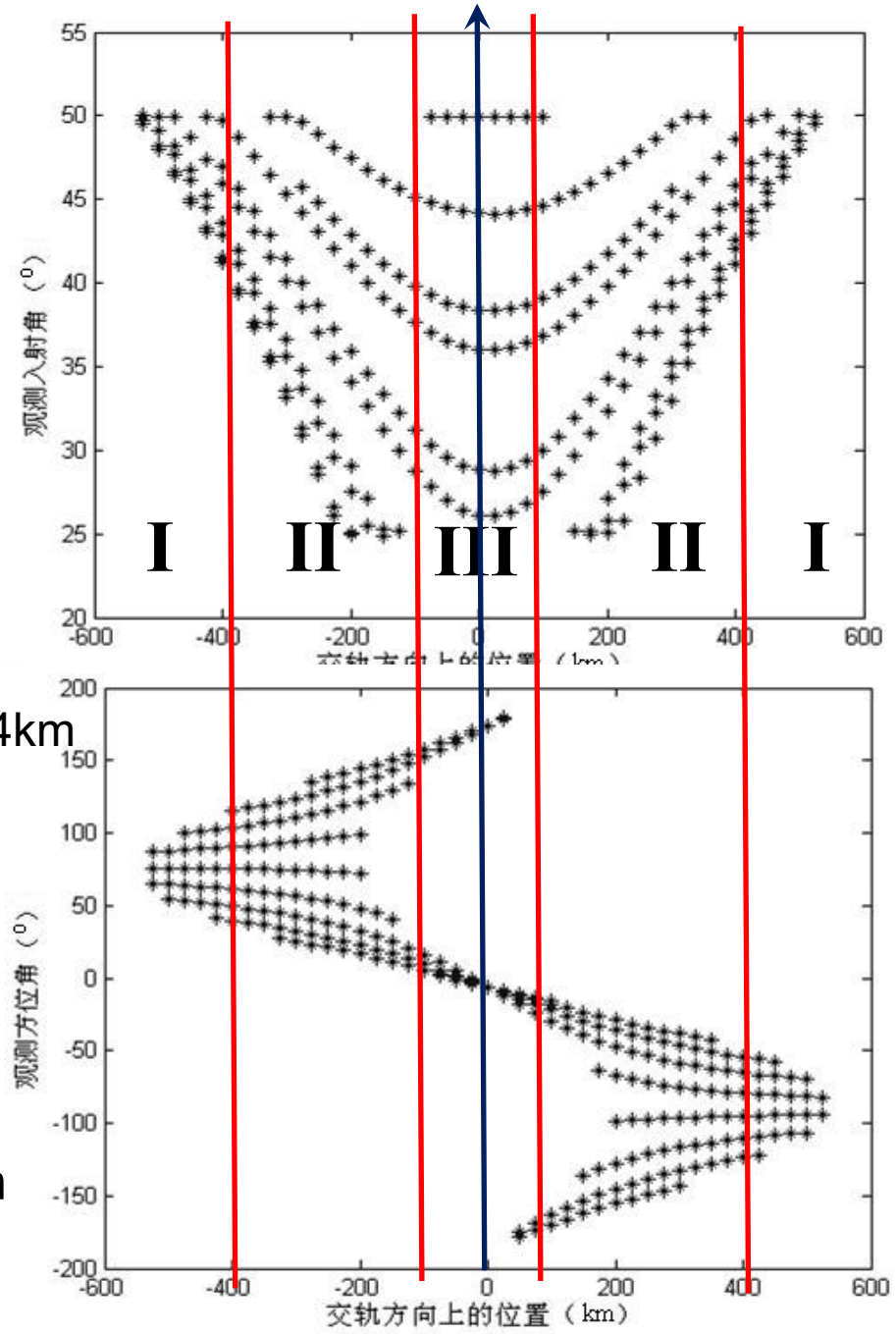
$$\begin{cases} \langle \delta_1 \rangle^2 + \langle \delta_2 \rangle^2 = \langle (w_1 - w_2)^2 \rangle \\ \langle \delta_1 \rangle^2 + \langle \delta_3 \rangle^2 = \langle (w_1 - w_3)^2 \rangle \\ \langle \delta_2 \rangle^2 + \langle \delta_3 \rangle^2 = \langle (w_2 - w_3)^2 \rangle \end{cases}$$



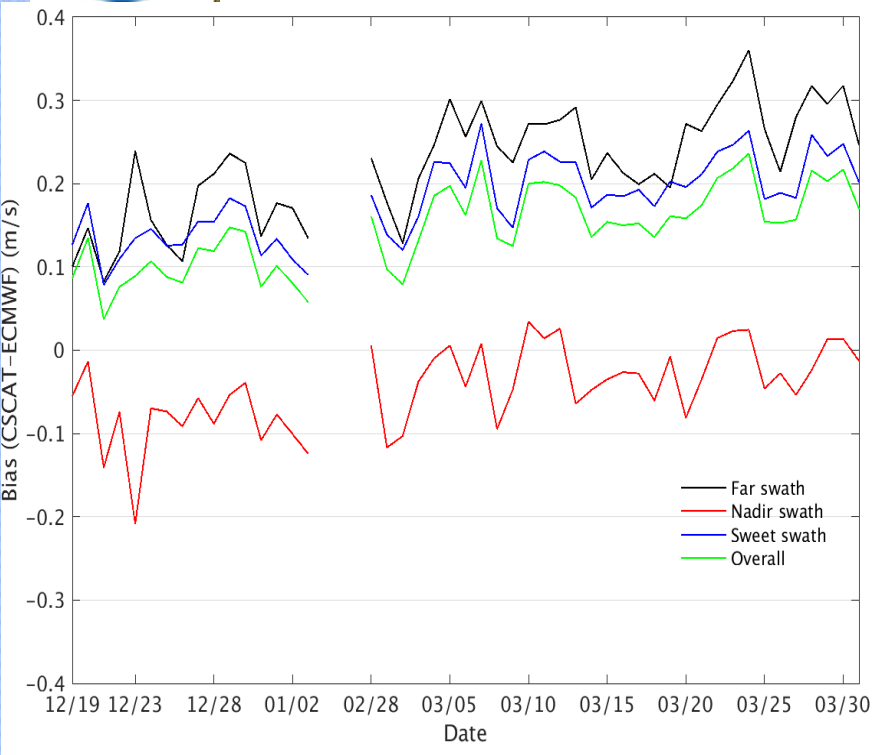


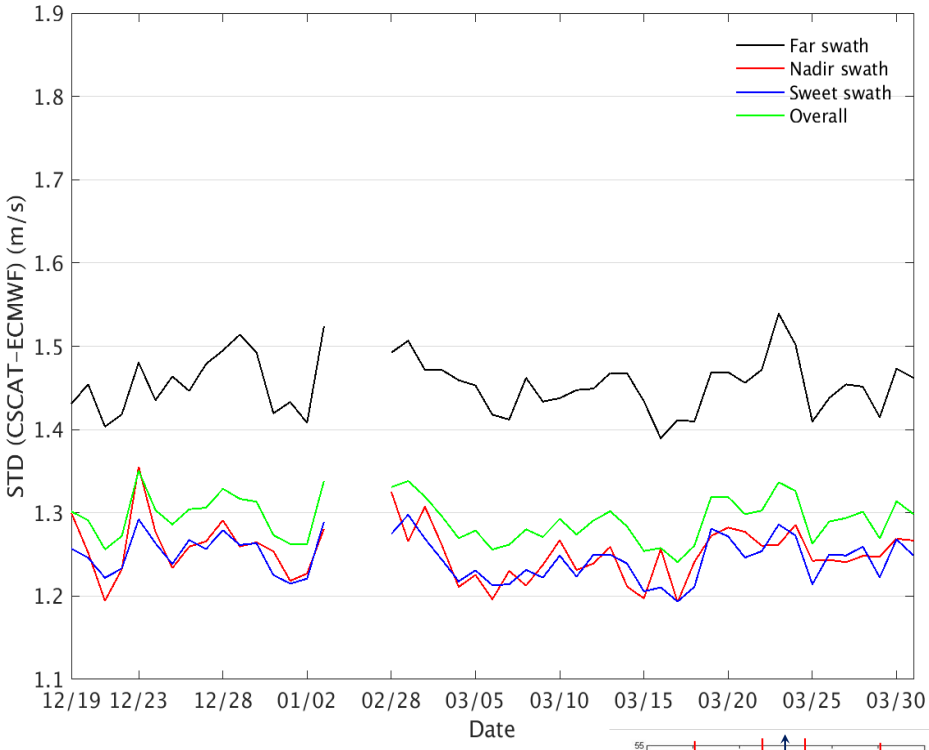
Wind spectra





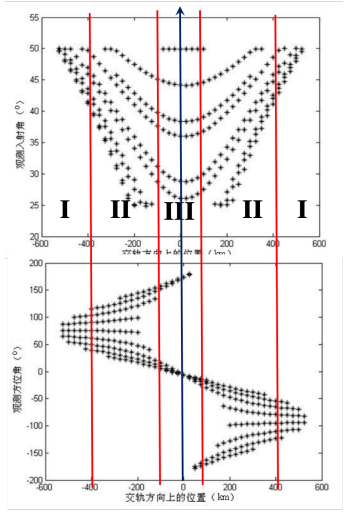
I : far swath
II : mid swath / sweet swath
III: nadir nadir



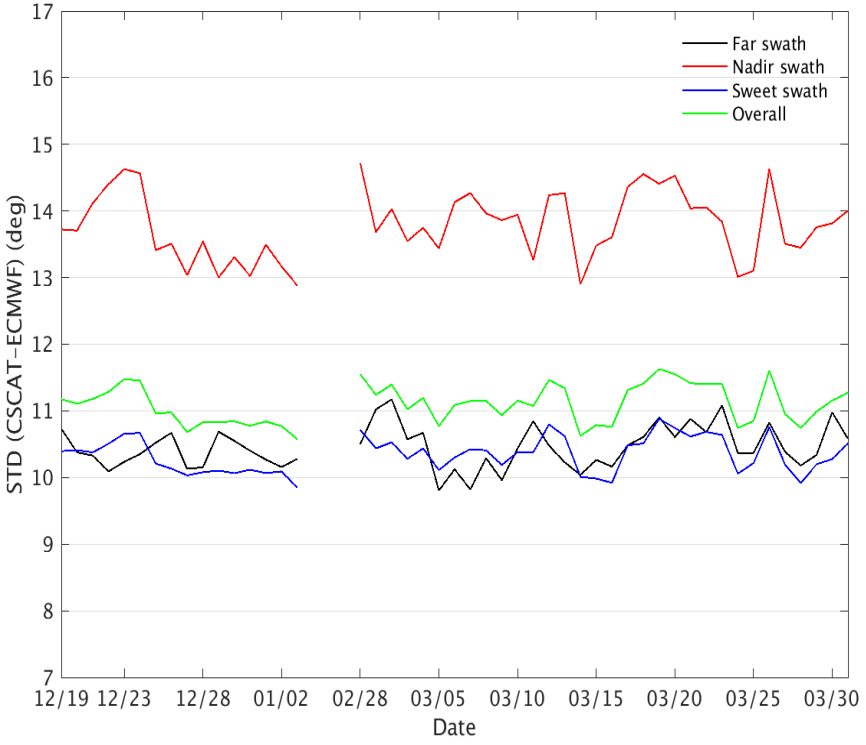


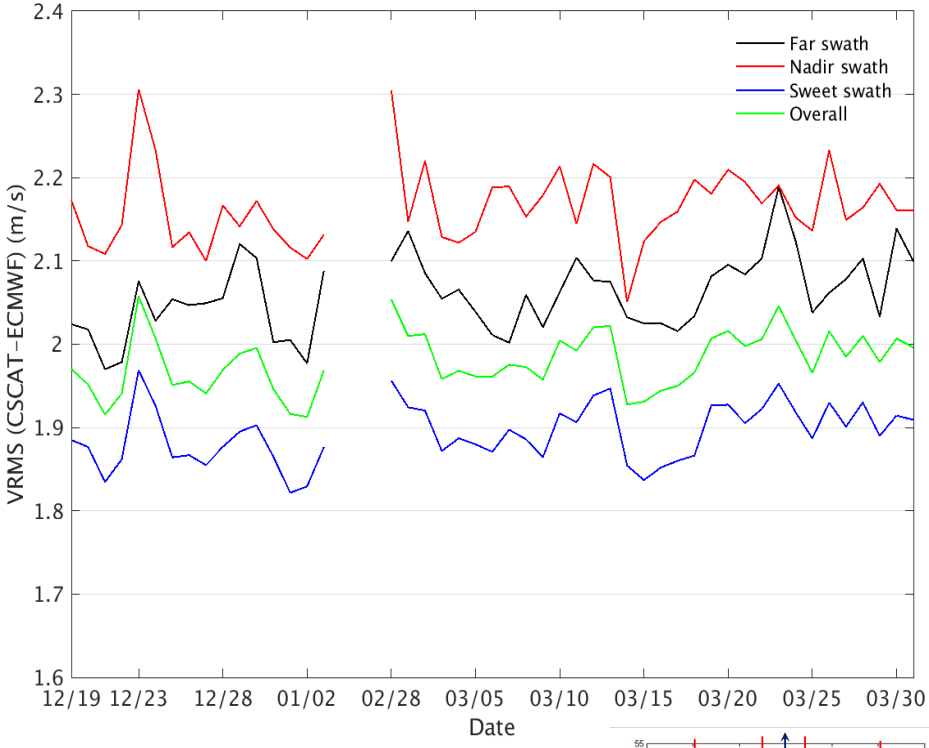
Wind speed bias

Wind speed SD



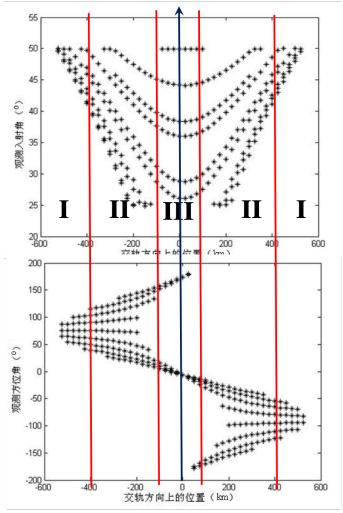
Daily monitoring





Wind direction SD

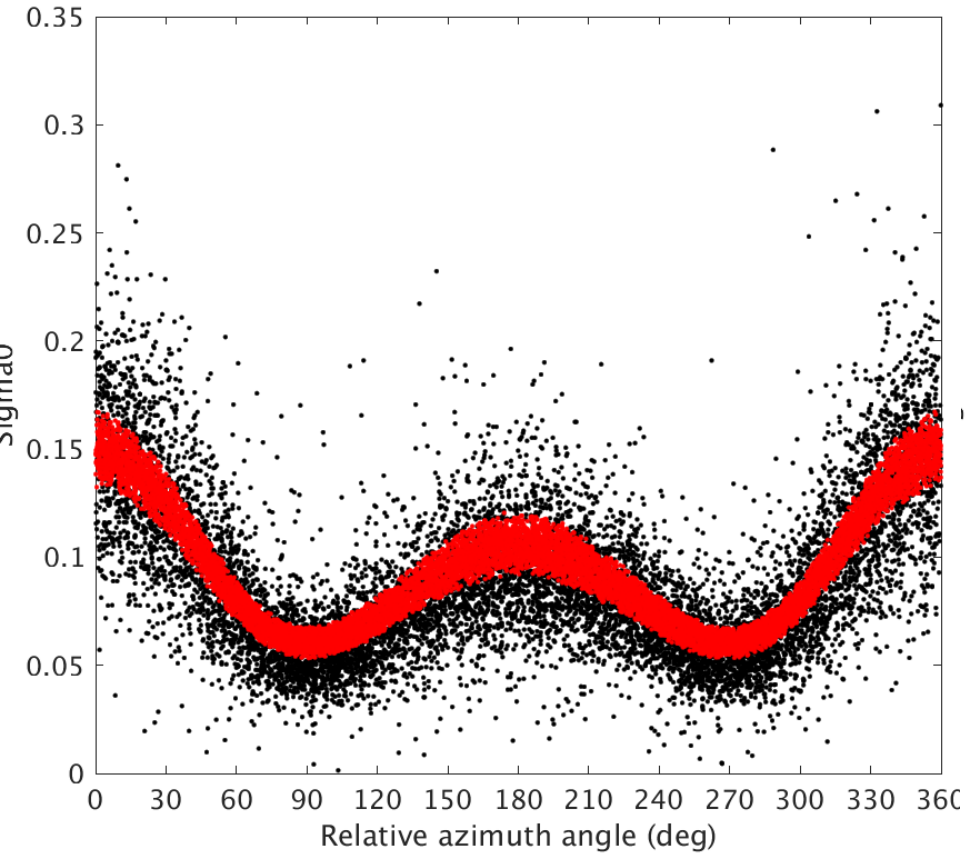
VRMS

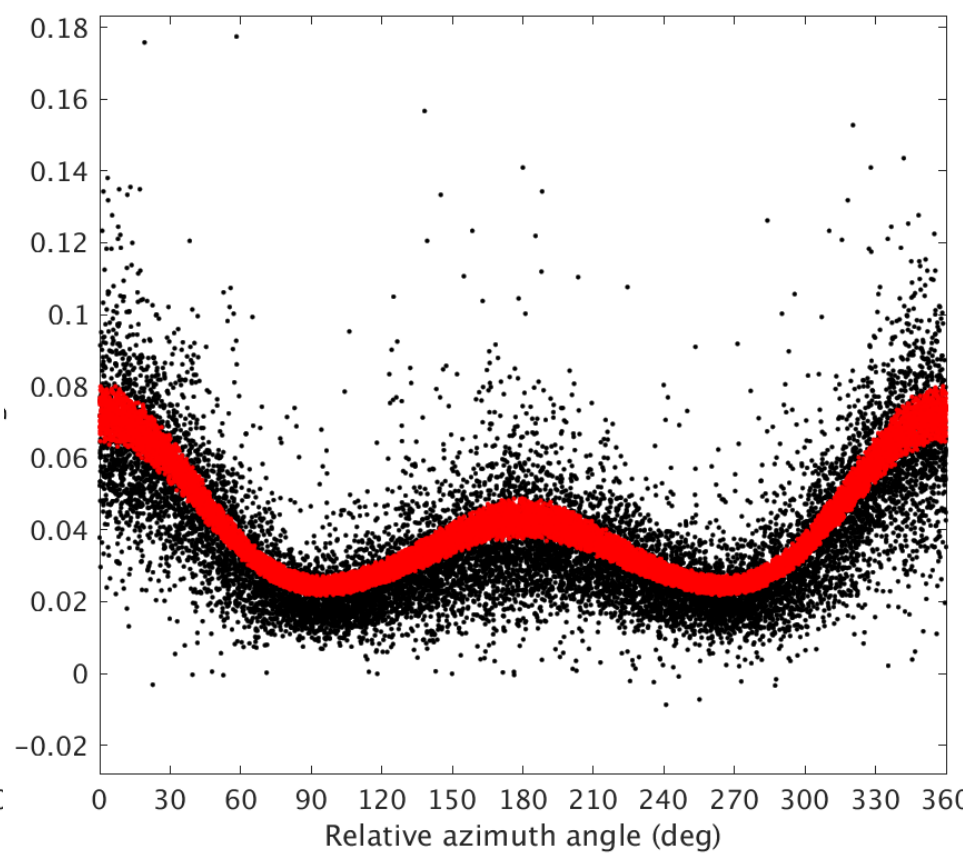


Daily monitoring

4. Conclusions and outlooks

- Winds retrieved from CFOSAT scatterometer are generally of high quality
- Calibration needs to be improved over the nadir (Region III) and far swath (Region I)
- Rain is the key factor in degrading CFOSCAT wind quality, particularly for the medium-low wind conditions.



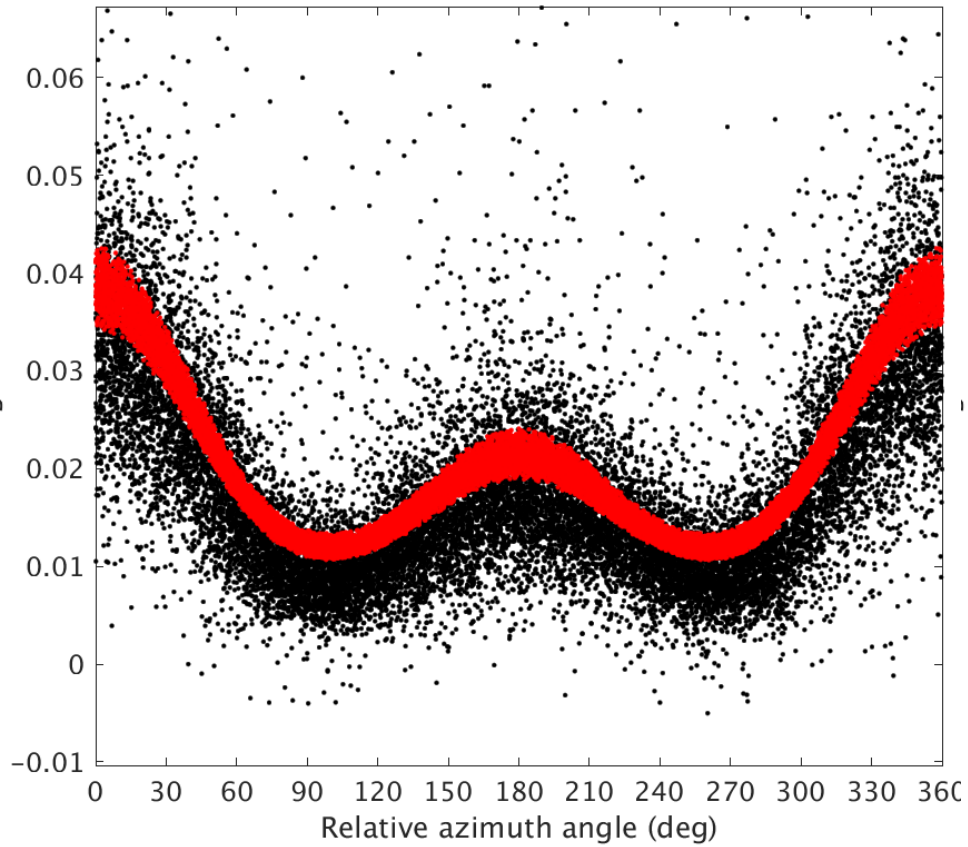


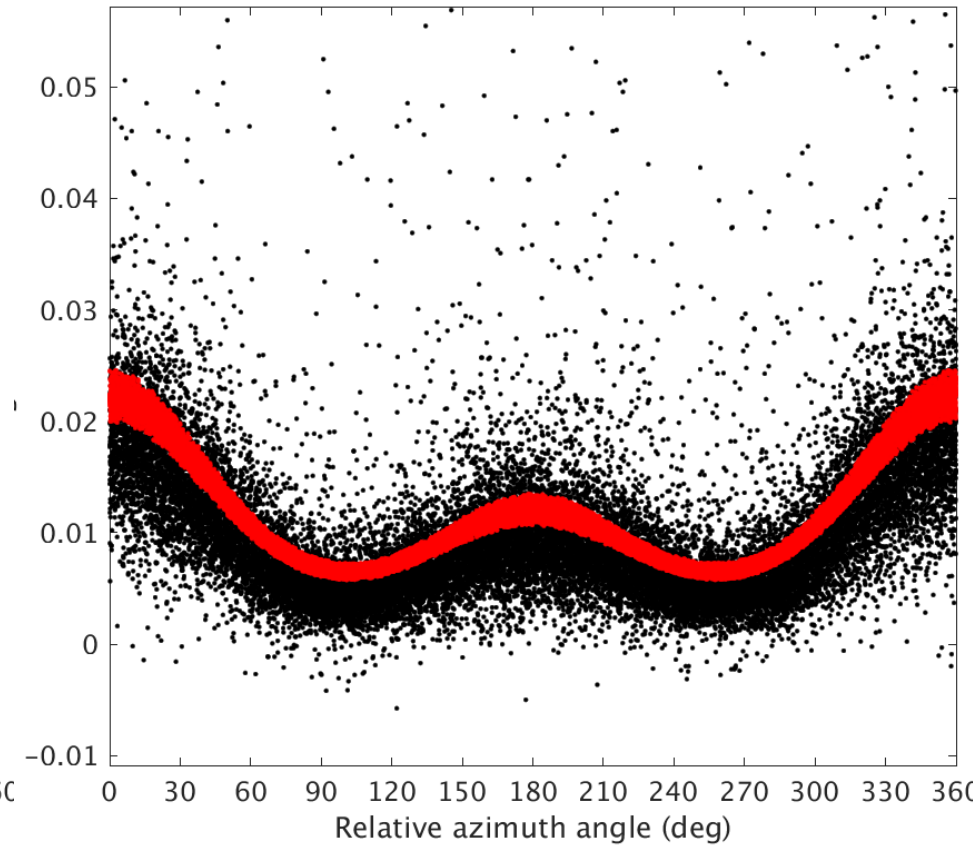
Incidence = 30

Incidence = 35

HH beam, reference wind speed of 10 m/s

Backup slice





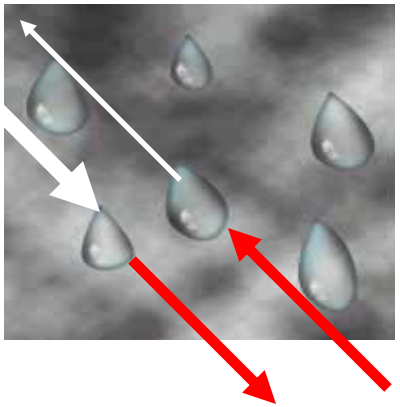
Incidence = 40

Incidence = 45

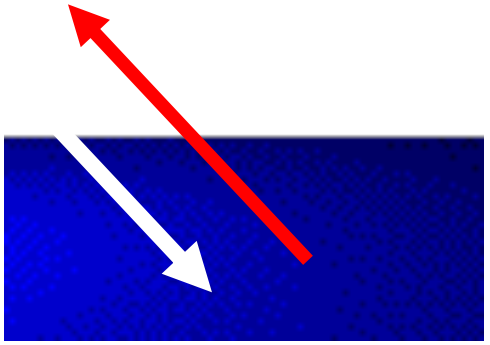
HH beam, reference wind speed of 10 m/s

Rain Effects

- The radar signal is attenuated by the rain as it travels to and from the Earth's surface → σ^0 ↓
  - Retrieved wind speed ↓



- The radar signal is scattered by the raindrops. Some of this scattered energy returns to the instrument → σ^0 ↑
  - Retrieved wind speed ↑ (to ~ 15 m/s)
  - Directional information can be lost



- The roughness of the sea surface is increased because of the splashing due to raindrops → σ^0 ↑
  - Retrieved wind speed ↑ (at low winds)
  - Directional information can be lost

- Variable roughness due to wind downbursts
  - Confused sea state, speed/direction unclear