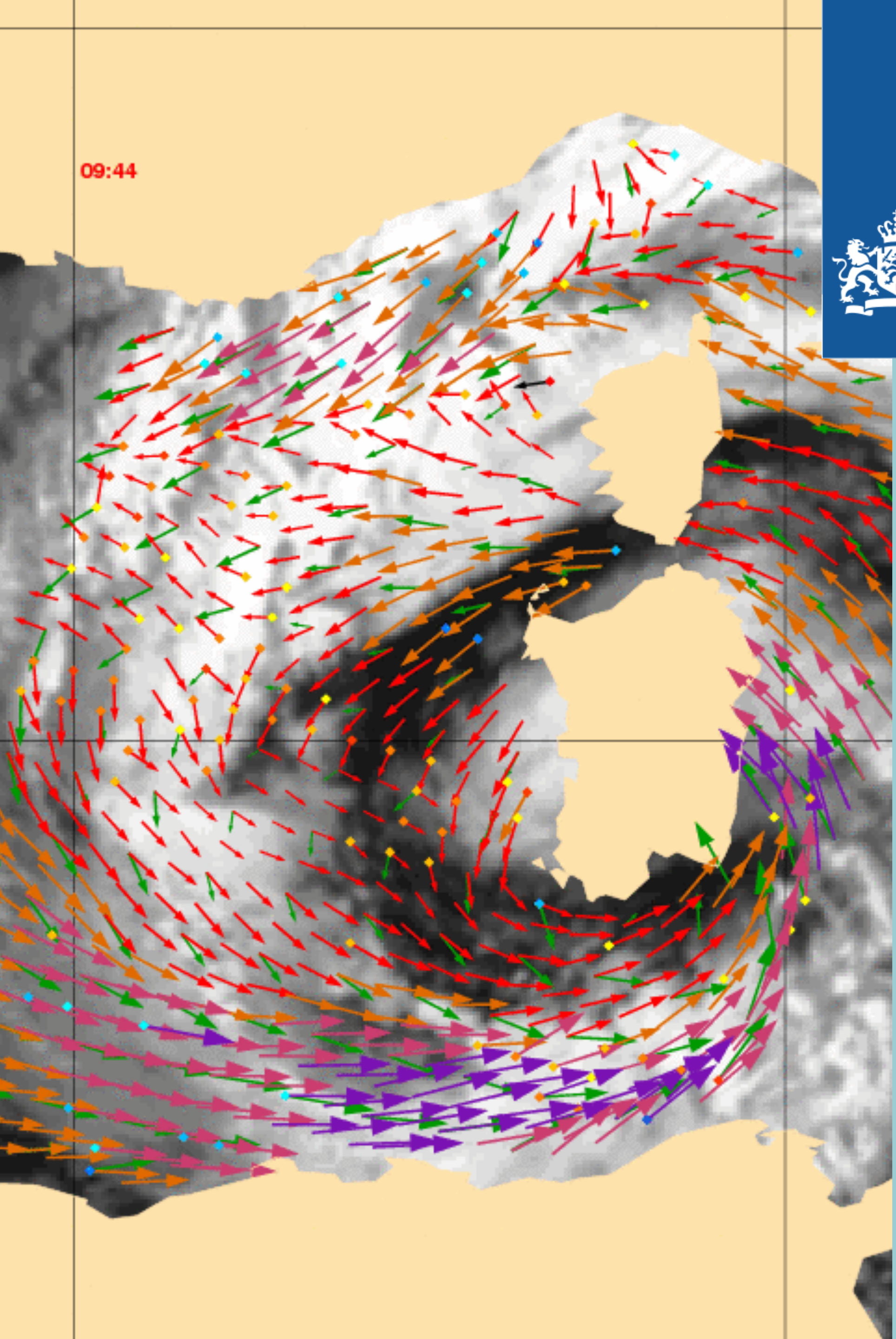

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

On wind retrieval biases, GMFs, and Ku backscatter calibration

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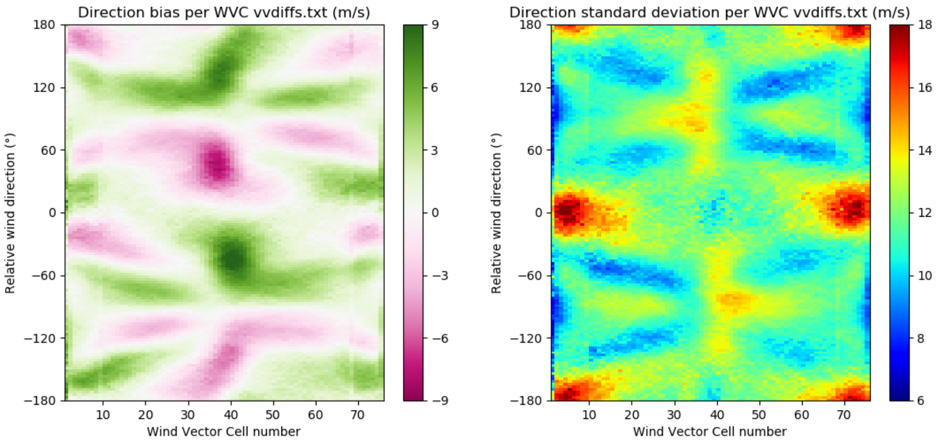
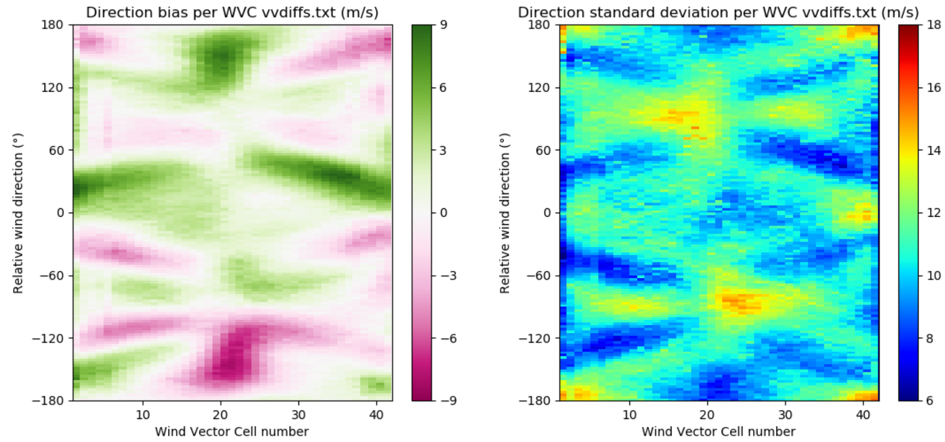
Anton Verhoef, Zhen Li, Zhixiong Wang

EUMETSAT OSI SAF
EU Copernicus Marine Core Services
EUMETSAT NWP SAF

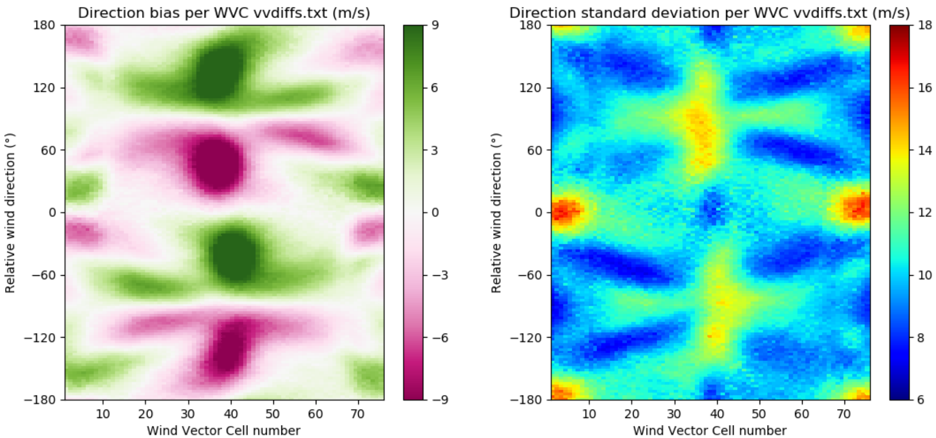
Wind direction bias and stdev vs. EC model – with MSS and with NBEC



QuikSCAT vs ERA5



RapidScat vs ERA5

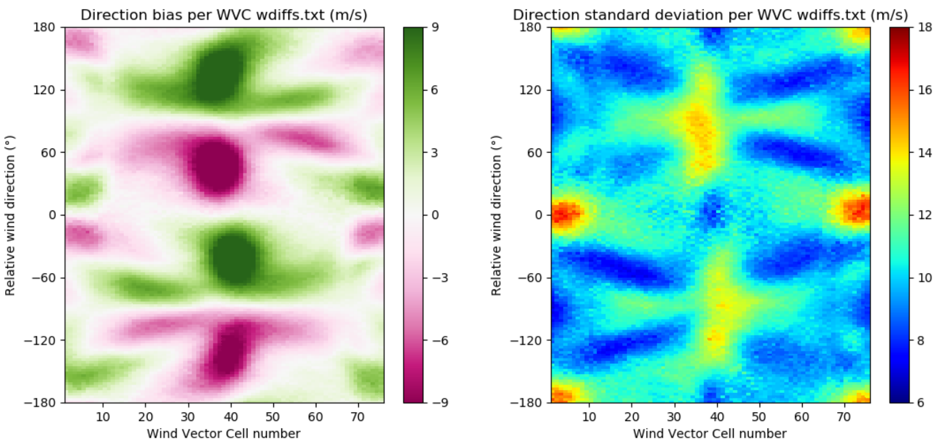


ScatSat-1 vs operational

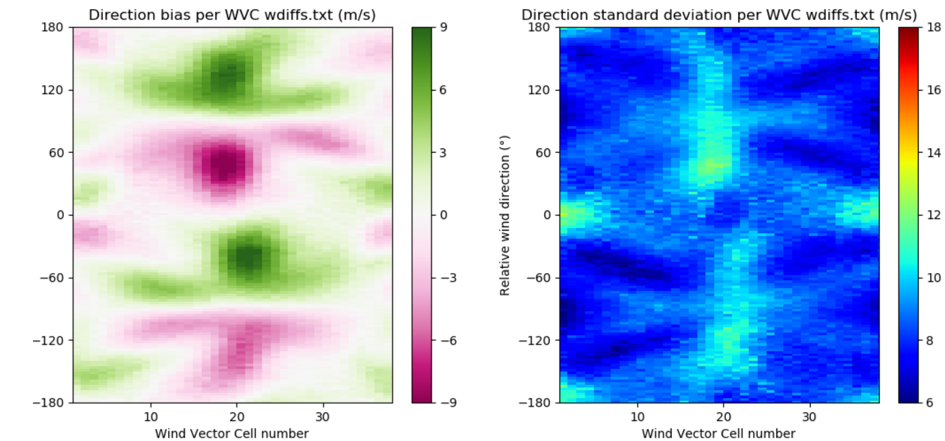
Note: relative wind directions are w.r.t. the satellite flight direction. 0 degrees means ‘headwind’, 180 degrees means ‘tailwind’.

Wind direction bias and stdev vs. model – with MSS and with NBEC

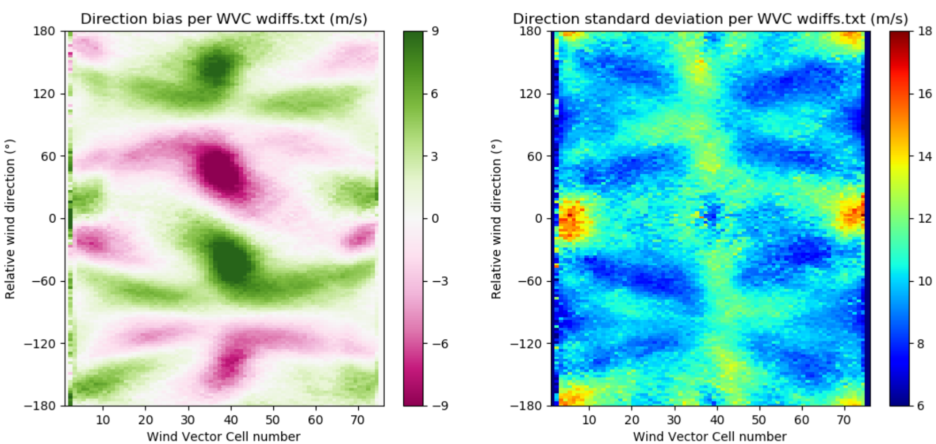
Part 1: Influence of product resolution



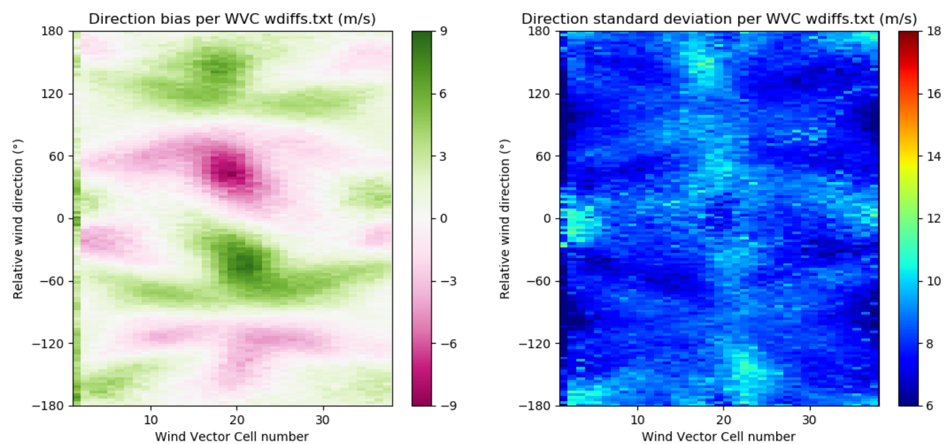
ScatSat-1 vs operational, 25 km



ScatSat-1 vs operational, 50km

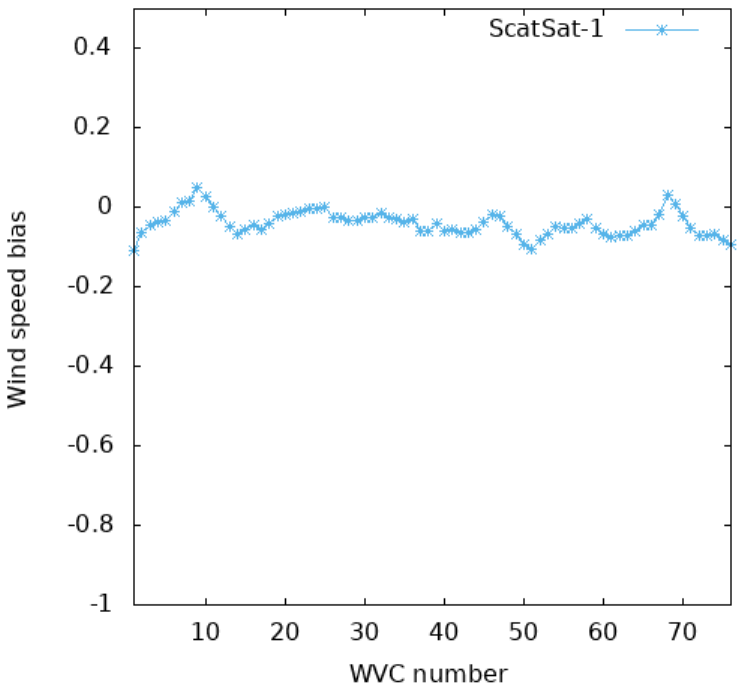


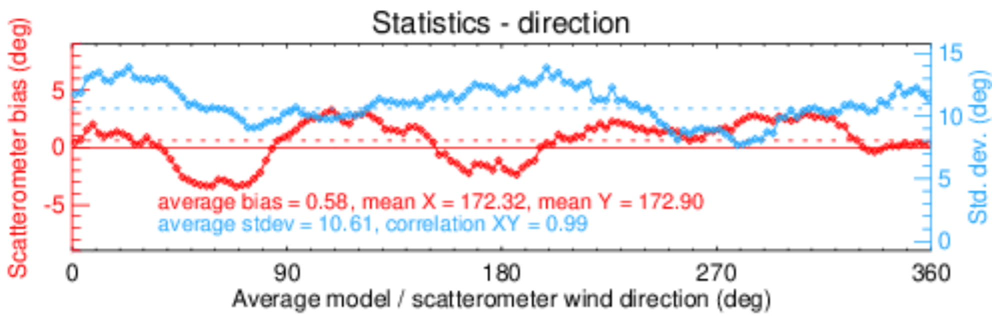
HY-2B vs operational 25 km



HY-2B vs operational 50 km

Part 2 of bias reduction: fine tuning of calibration coefficients for HH and VV
ScatSat-1 example



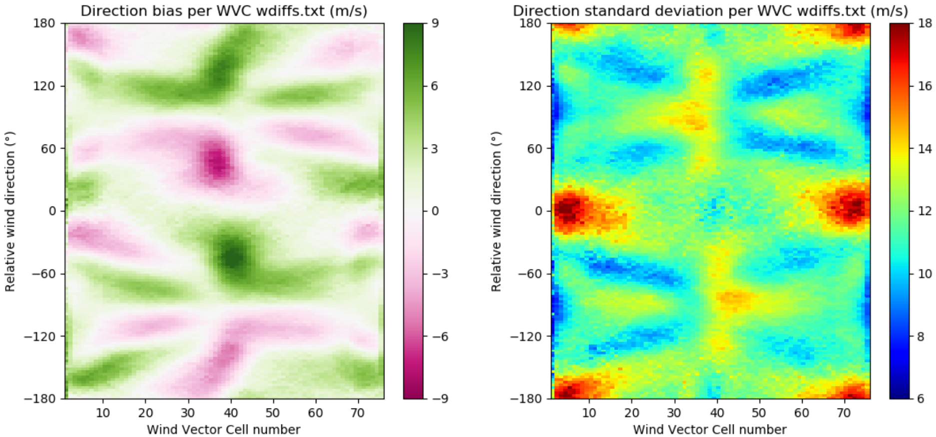


HH 1.20 dB, VV 0.07 dB, VV (outer swath) 0.38 dB
Selected new calibrations

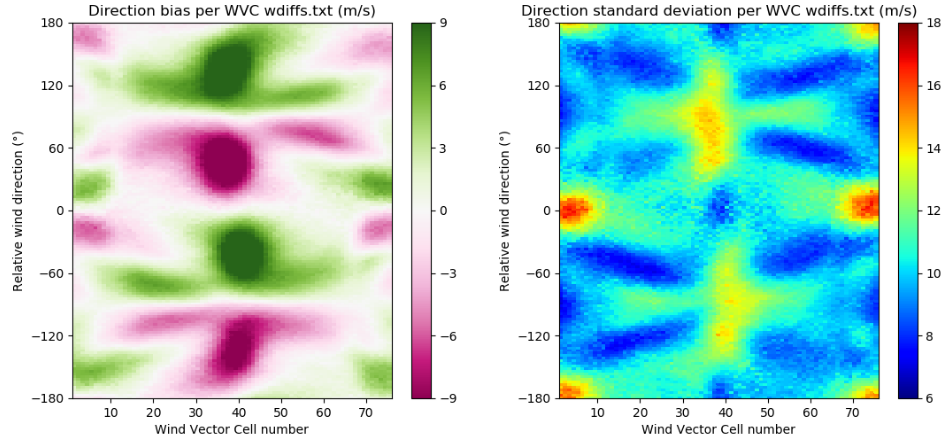
The wind speed bias as a function of WVC number changes when the calibration coefficients for HH and VV change. When we increase the HH coefficient and at the same time reduce the VV coefficient, the shape goes from concave to convex. At the same time, the wind direction dependent biases reduce. There appears to be an optimal combination where the WVC dependent bias is flat and the wind direction dependent bias is also as flat as possible.
However, we now get a step in the bias at the edge between inner and outer swath. Therefore, we introduce an ad hoc second calibration coefficient for VV in the outer swath.

Wind direction bias and stdev vs. model – with MSS and with NBEC

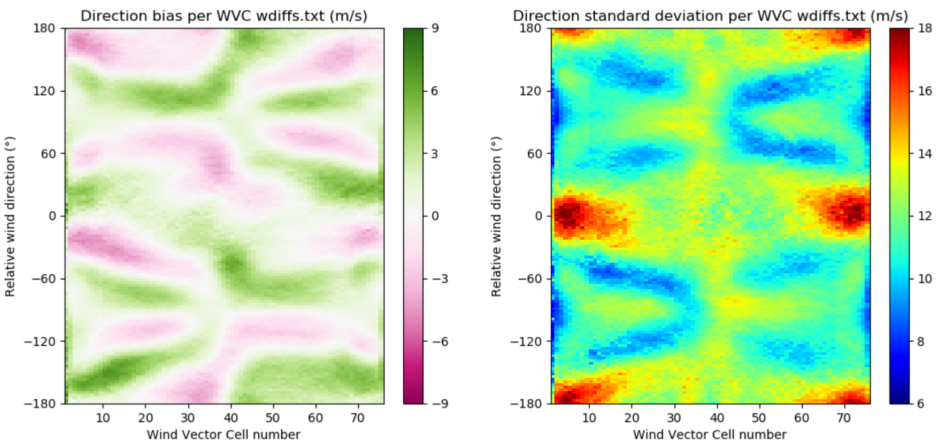
Fine tuning of calibration coefficients



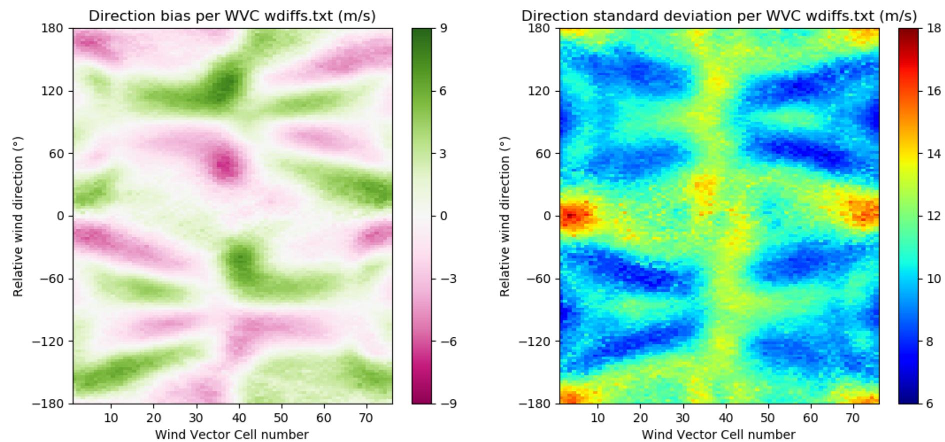
QuikSCAT vs ERA5, old calibrations



ScatSat-1 vs oper, old calibrations



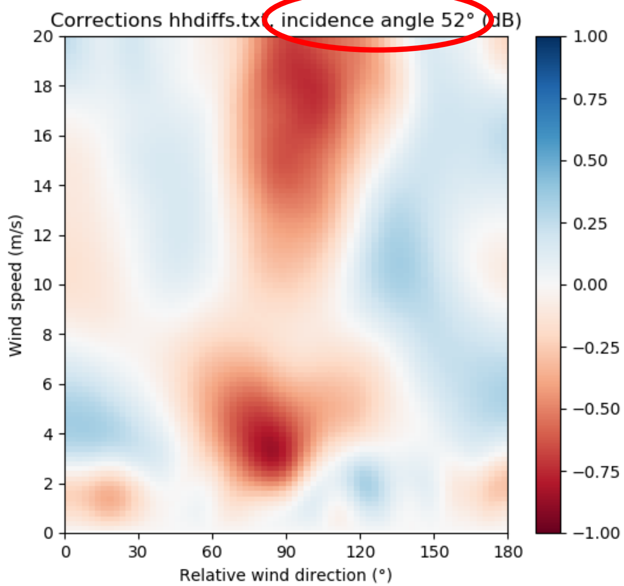
QuikSCAT, new calibrations



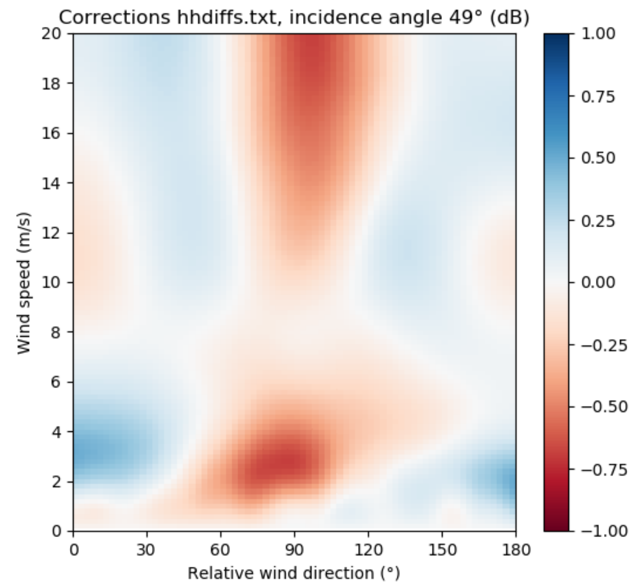
ScatSat-1, new calibrations

Part 3 of bias reduction: NSCAT4 HH corrections result in NSCAT4DS

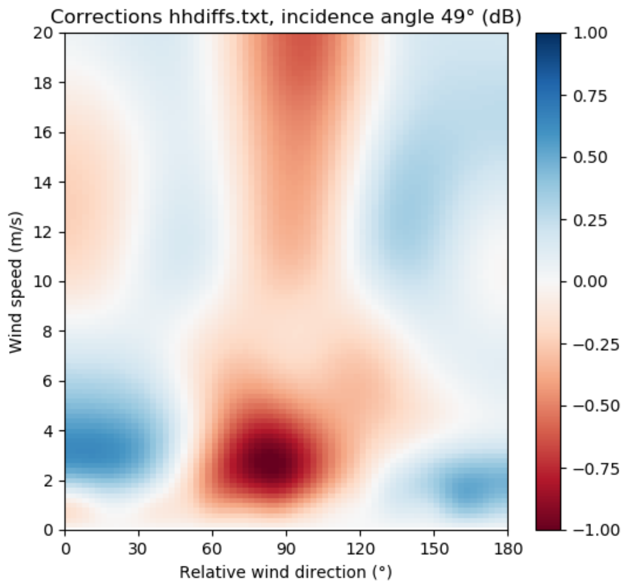
NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT



NSCAT



RapidScat

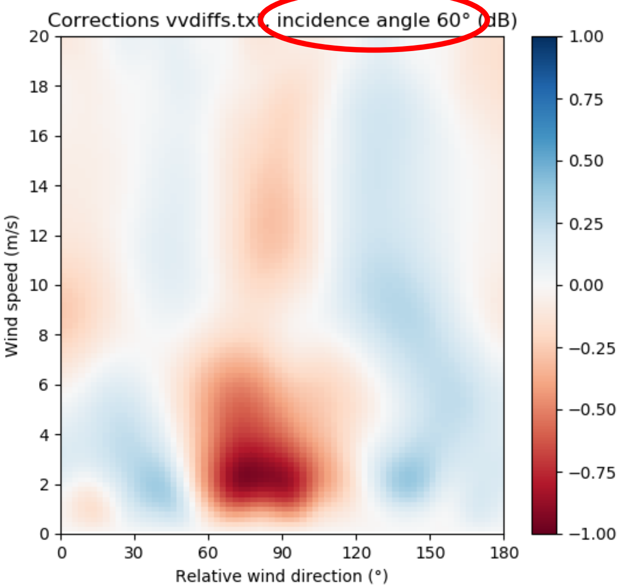


ScatSat-1

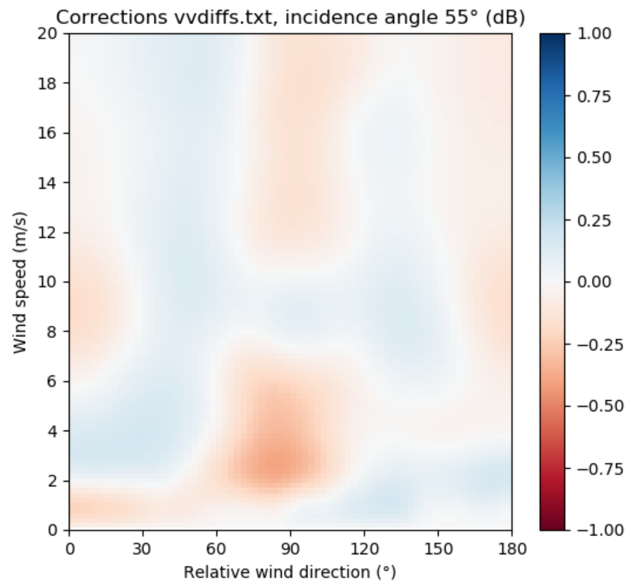
$$\frac{\overline{\sigma^0_{meas}(V,\varphi)}}{\overline{\sigma^0_{sim}(V,\varphi)}} * \frac{\overline{\sigma^0_{sim}(V)}}{\overline{\sigma^0_{meas}(V)}}$$

Part 3 of bias reduction: NSCAT4 VV corrections result in NSCAT4DS

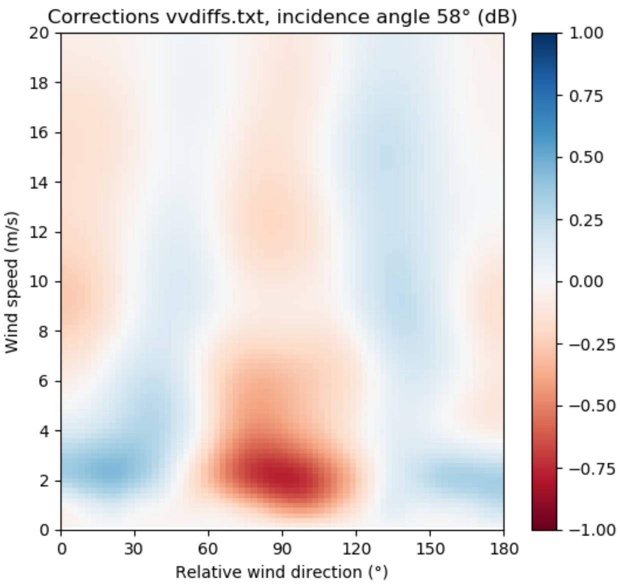
NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT



NSCAT



RapidScat

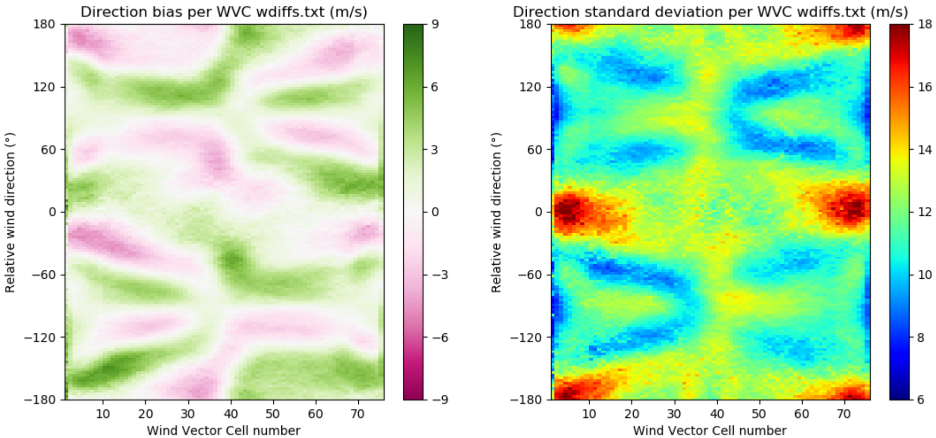


ScatSat-1

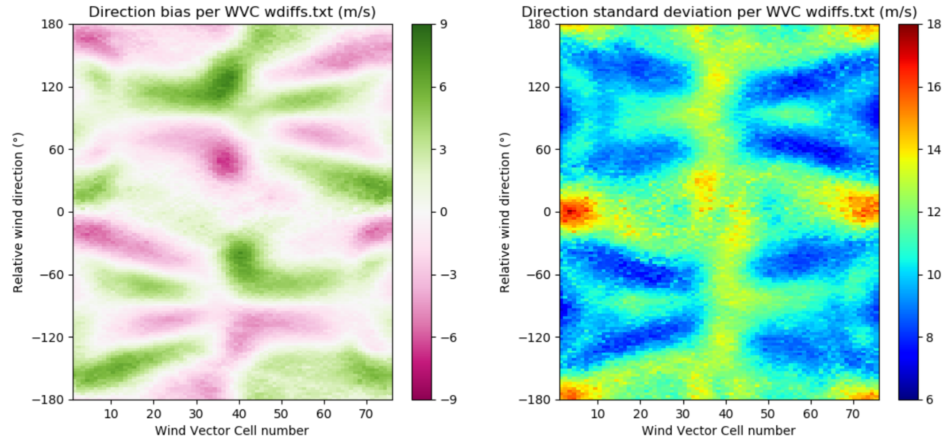
$$\frac{\overline{\sigma^0_{meas}(V,\varphi)}}{\overline{\sigma^0_{sim}(V,\varphi)}} * \frac{\overline{\sigma^0_{sim}(V)}}{\overline{\sigma^0_{meas}(V)}}$$

Wind direction bias and stdev vs. model – with MSS and with NBEC

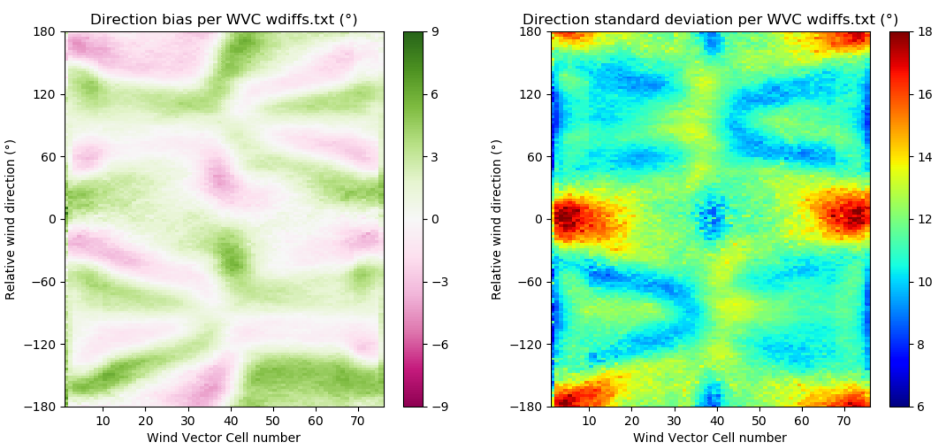
Fine tuning of calibration coefficients and use of direction and speed corrections to NSCAT4

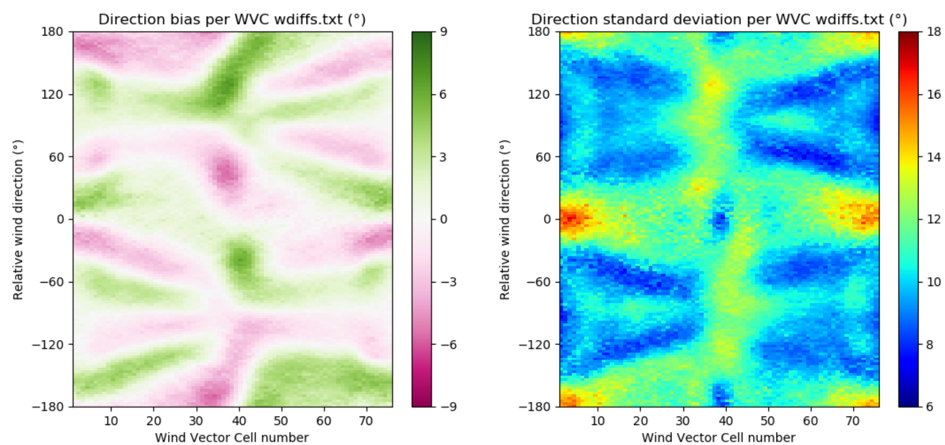


QuikSCAT, new calibrations



ScatSat-1, new calibrations



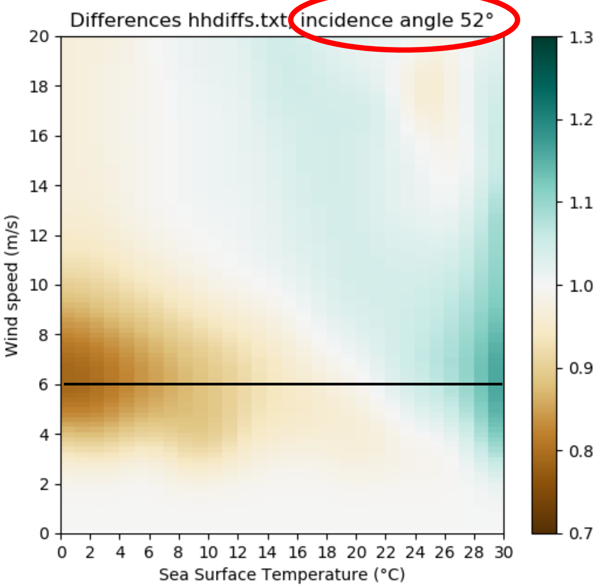


QuikSCAT, new calibrations, NSCAT4DS

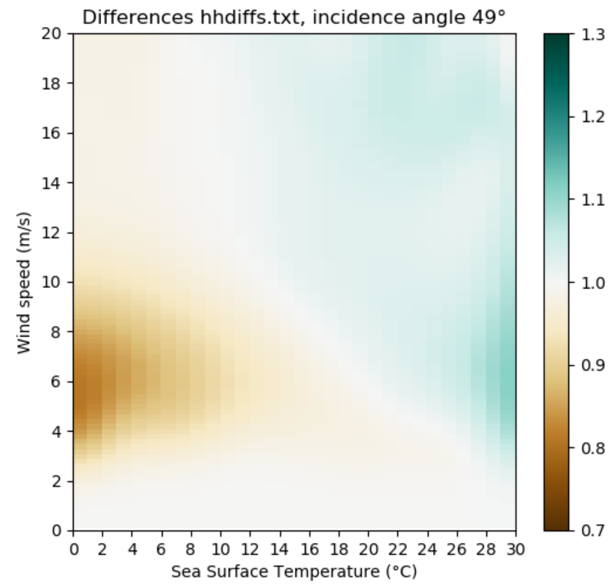
ScatSat-1, new calibrations, NSCAT4DS

Part 4 of bias reduction: SST corrections for HH per incidence angle

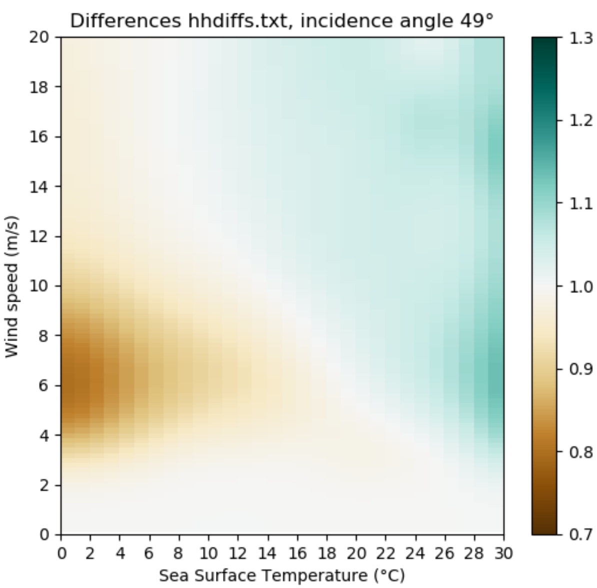
NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT



NSCAT



RapidScat

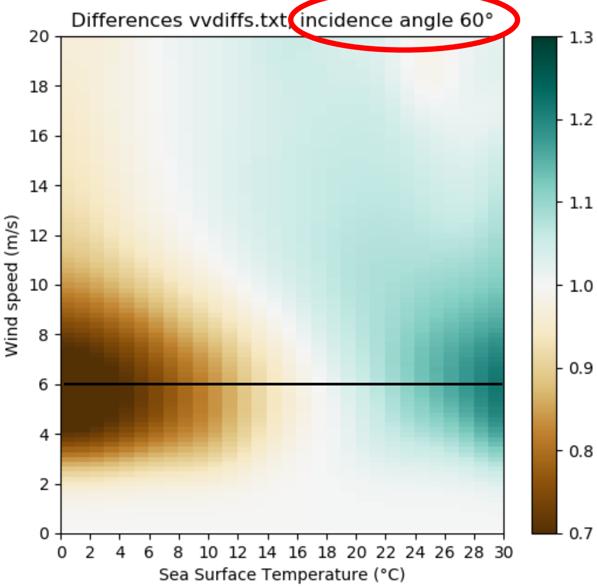


ScatSat-1

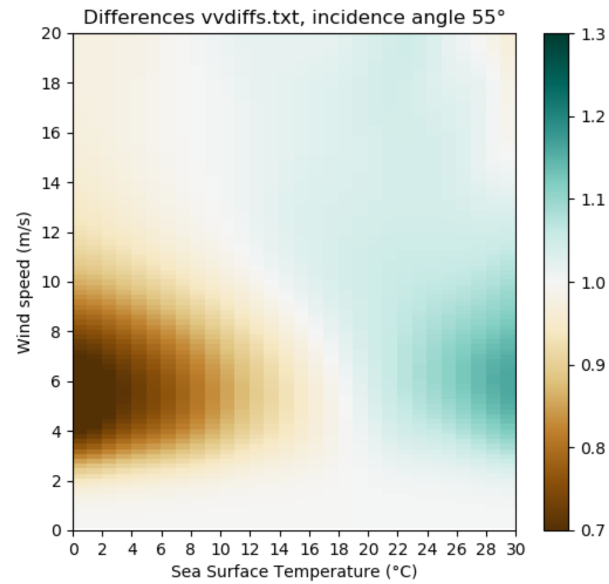
$$\frac{\overline{\sigma^0_{meas}(V,T)}}{\overline{\sigma^0_{sim}(V,T)}} * \frac{\overline{\sigma^0_{sim}(V)}}{\overline{\sigma^0_{meas}(V)}}$$

Part 4 of bias reduction: SST corrections for VV per incidence angle

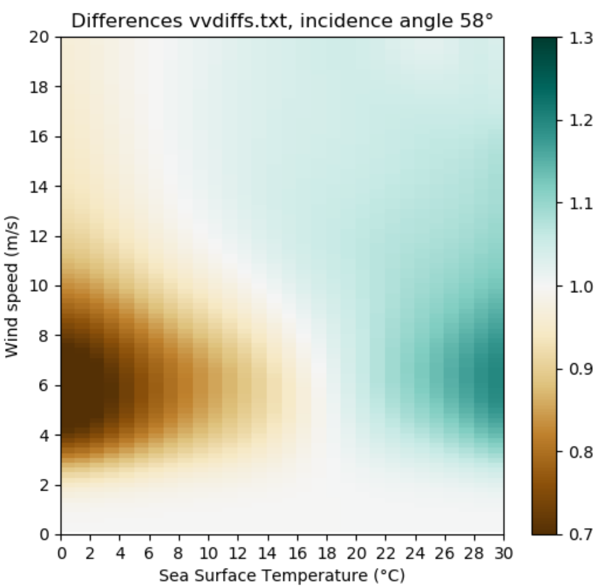
NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT



NSCAT



RapidScat

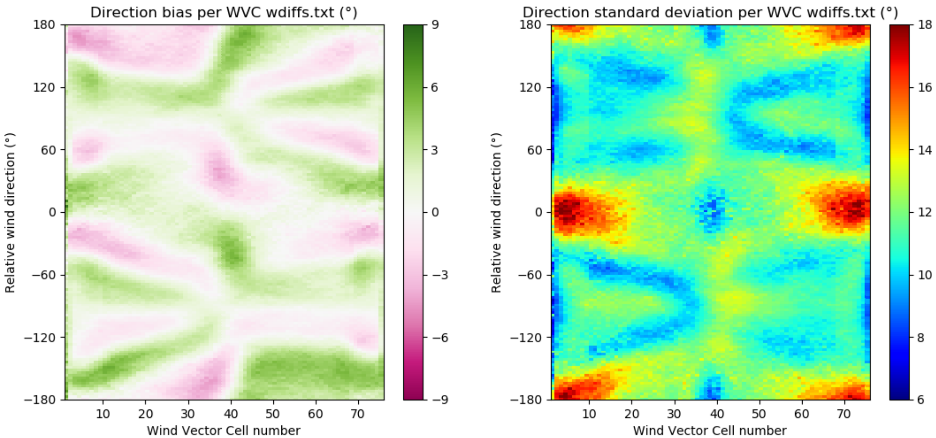


ScatSat-1

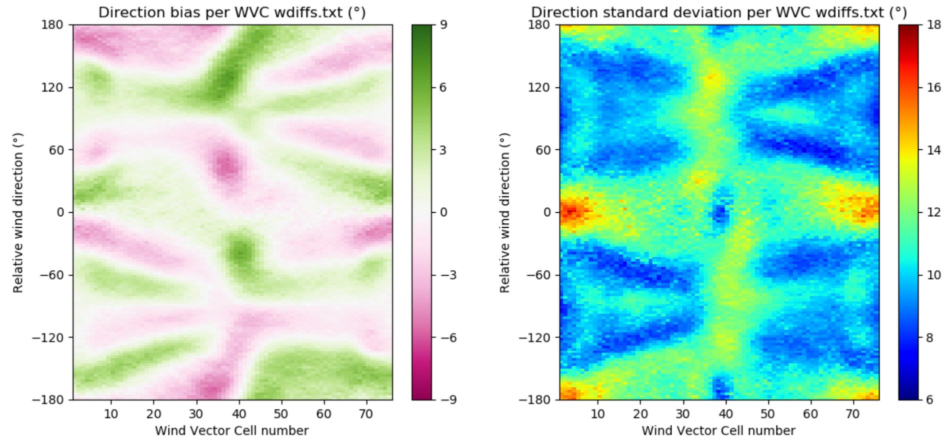
$$\frac{\overline{\sigma^0_{meas}(V,T)}}{\overline{\sigma^0_{sim}(V,T)}} * \frac{\overline{\sigma^0_{sim}(V)}}{\overline{\sigma^0_{meas}(V)}}$$

Wind direction bias and stdev vs. model – with MSS and with NBEC

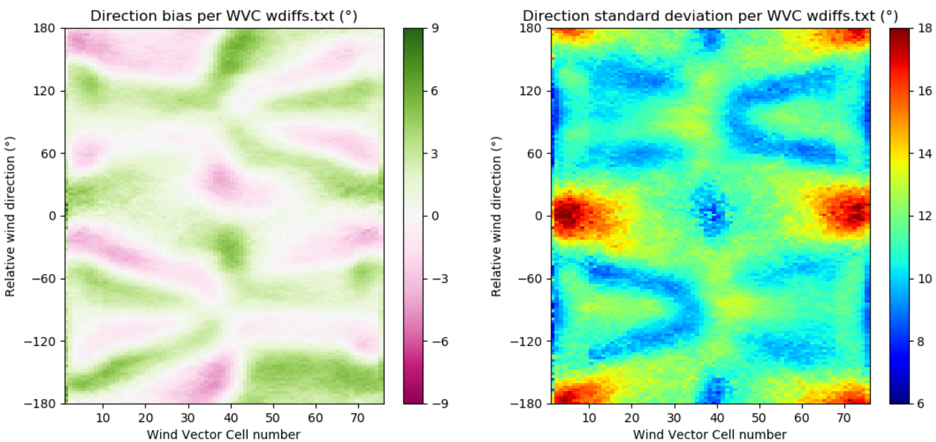
Fine tuning of calibration coefficients and use of direction and speed corrections to NSCAT4



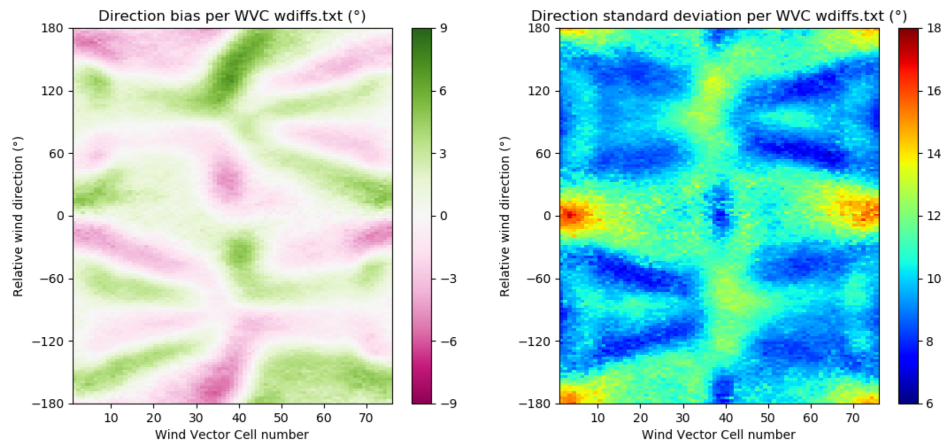
QuikSCAT, new calibrations, NSCAT4DS



ScatSat-1, new calibrations, NSCAT4DS

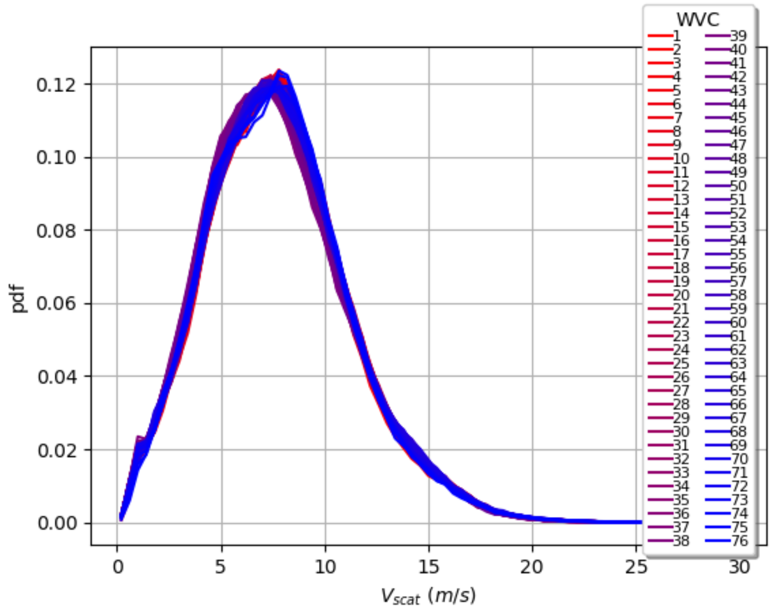


QuikSCAT, new calibrations, NSCAT4DS, SST corr

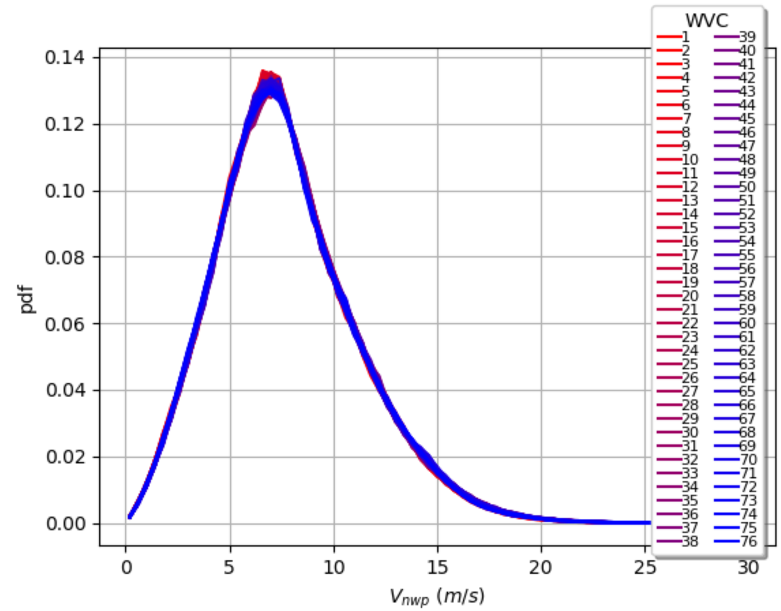


ScatSat-1, new calibrations, NSCAT4DS, SST corr

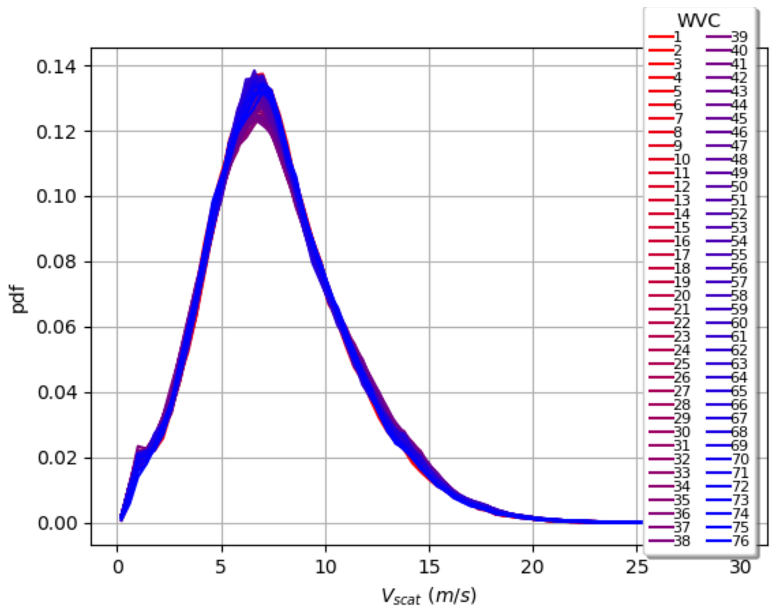
Wind speed PDFs improve



ScatSat-1, old calibrations, NSCAT4



Collocated NWP winds



ScatSat-1, new calibrations, NSCAT4DS, SST corr

Wind statistics w.r.t. ECMWF and buoys

Scatterometer vs. model winds

QuikSCAT	Origi-nal	HH/VV cal	+ NSCAT4DS	+ SST corr
SD wind speed	1.31	1.31	1.29	1.25
SD u	1.39	1.41	1.37	1.35
SD v	1.40	1.38	1.36	1.33
SD wind dir	11.72	11.71	11.45	11.33

ScatSat-1	Origi nal	HH/V V cal	+ NSCAT4DS	+ SST corr
SD wind speed	1.22	1.22	1.20	1.14
SD u	1.33	1.33	1.28	1.26
SD v	1.32	1.30	1.26	1.19
SD wind dir	11.03	10.83	10.43	10.21

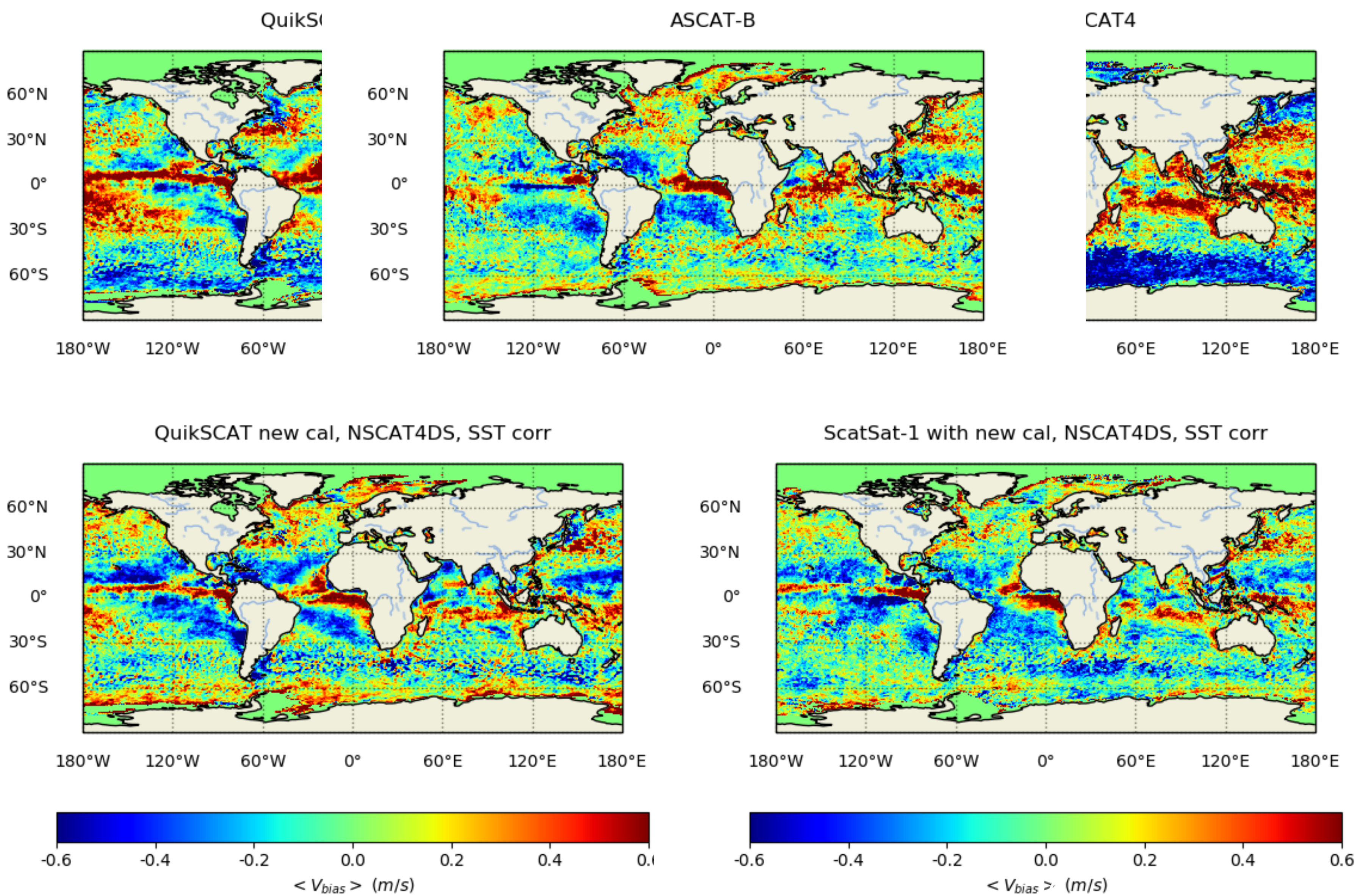
Scatterometer vs. buoy winds

QuikSCAT	Original	All corrections
SD wind speed	1.17	1.18
SD u	1.78	1.75
SD v	1.75	1.71
SD wind dir	17.12	16.69

ScatSat-1	Original	All corrections
SD wind speed	1.13	1.11
SD u	1.99	1.95
SD v	1.86	1.80
SD wind dir	21.19	20.85

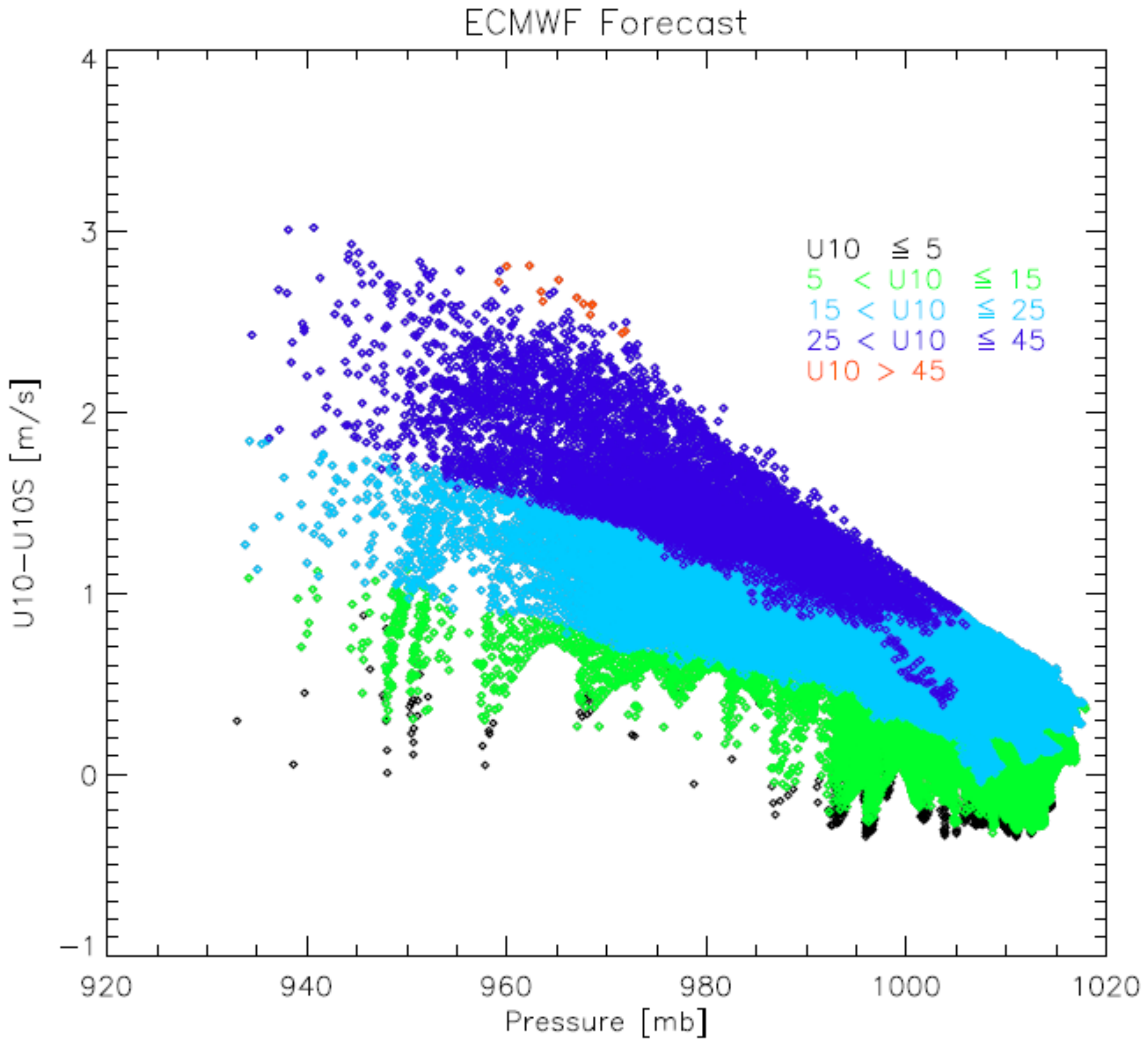
- General improvement

Global wind speed biases



Air mass effect on hurricanes

- 2018 hurricanes
- Up to 10% difference
- Mainly p or air mass density
- Needs correction



Summary

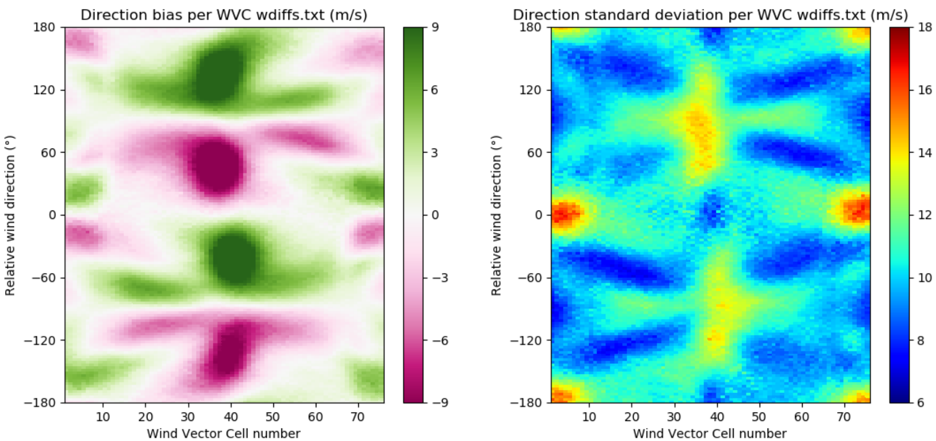
We assessed four independent ways to reduce systematic wind speed and wind direction biases for rotating pencil beam Ku-band scatterometers:

1. Aggregation (noise reduction);
2. Fine tuning of fixed backscatter calibration coefficients;
3. Corrections to wind direction and wind speed dependencies of the NSCAT4 GMF for HH and VV (collocated ERS and ASCAT winds);
4. SST dependent corrections to Ku-band backscatter;

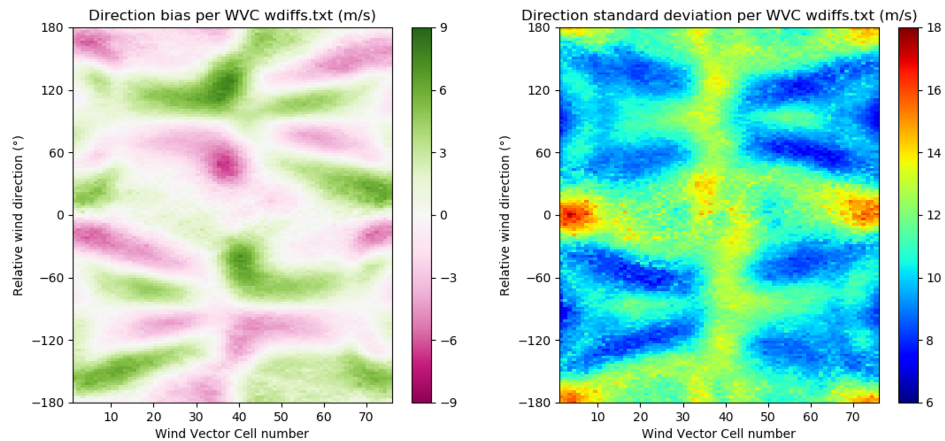
- Each of this methods on its own reduces the biases, they can be implemented independently;
- The improvements result in significantly better wind statistics w.r.t. ECMWF winds, ASCAT winds and buoys, and in better PDFs;
- Combined HH + VV retrievals are sensitive to method 2.
- For HH-only or VV-only retrievals, the wind direction biases are much bigger and are only reduced by methods 1, 3 and 4.

Wind direction bias and stdev vs. model – with MSS and with NBEC

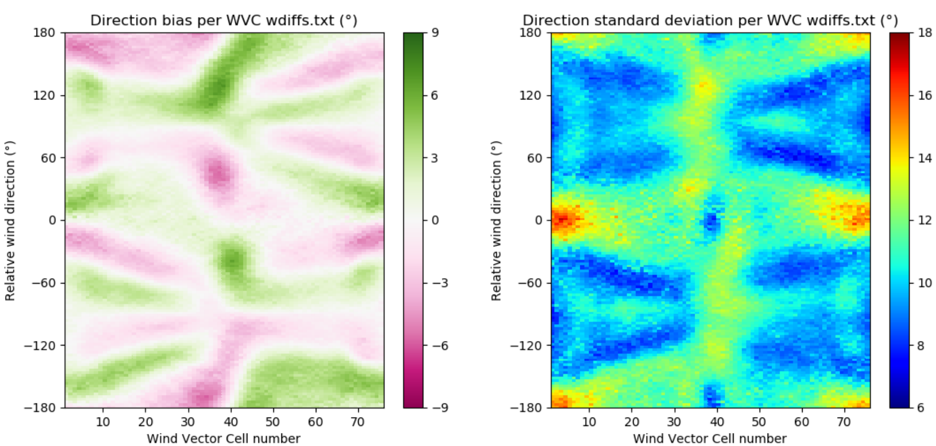
HH + VV



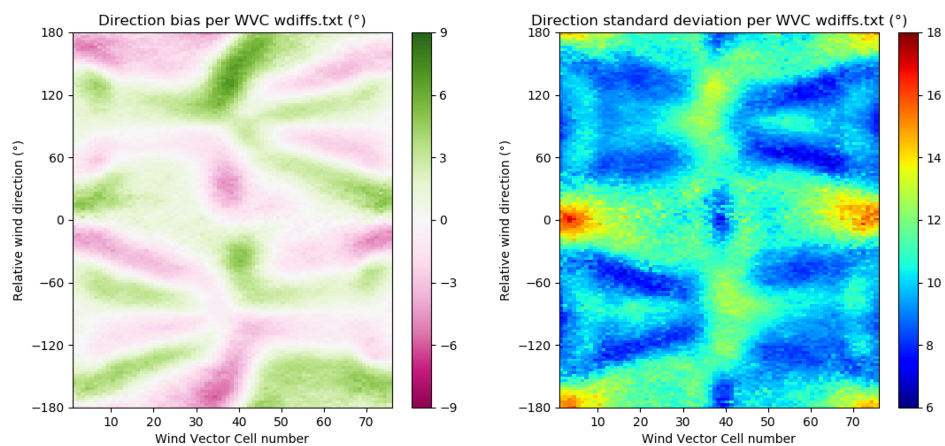
ScatSat-1, old calibrations, NSCAT4



ScatSat-1, new calibrations, NSCAT4

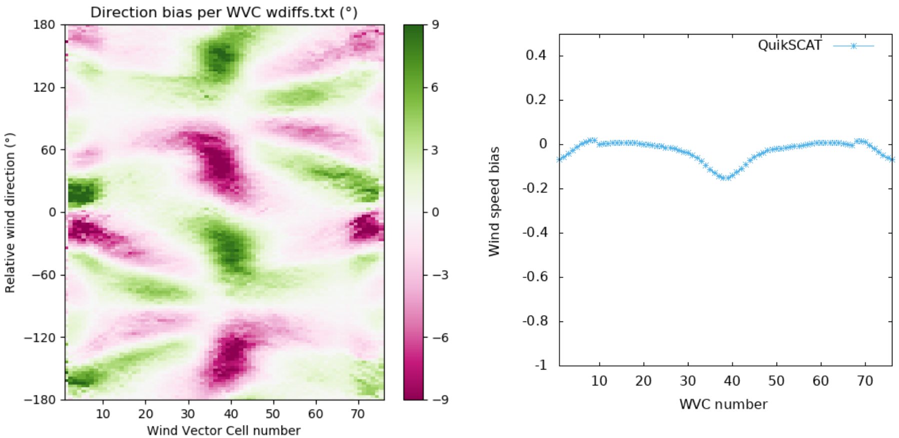


ScatSat-1, new calibrations, NSCAT4DS

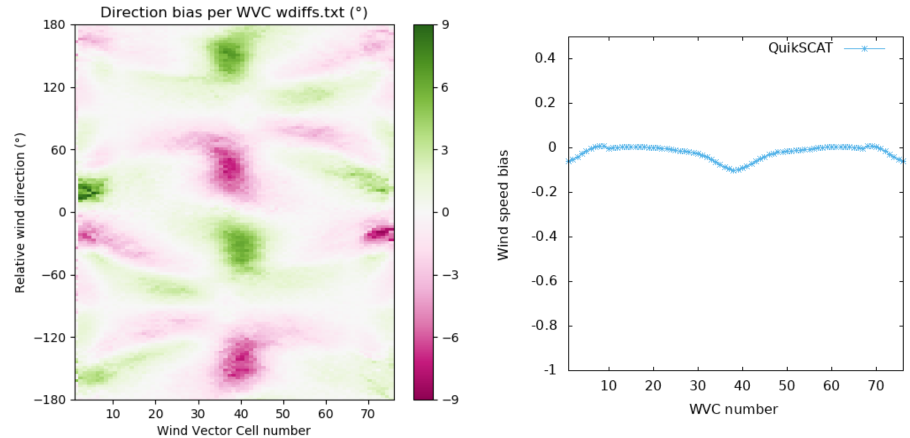


ScatSat-1, new calibrations, NSCAT4DS, SST corr

Simulation experiment (2)

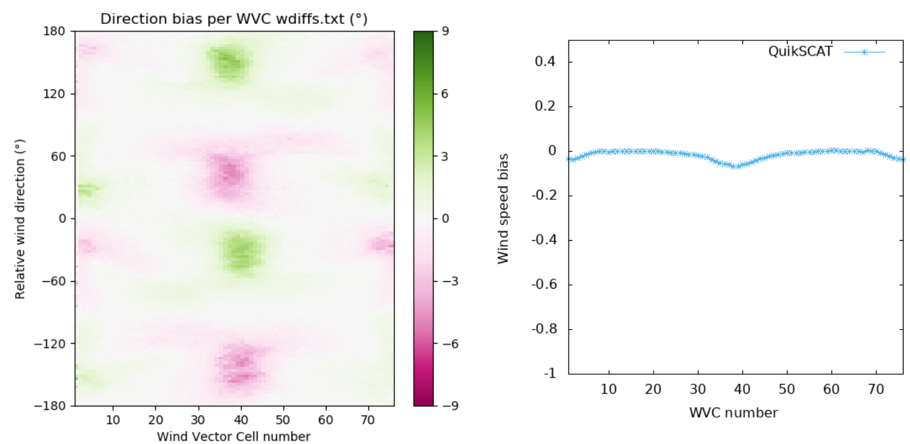


MSS + NBEC, eps = 1.8m/s (default)



MSS + NBEC, eps = 0.9m/s

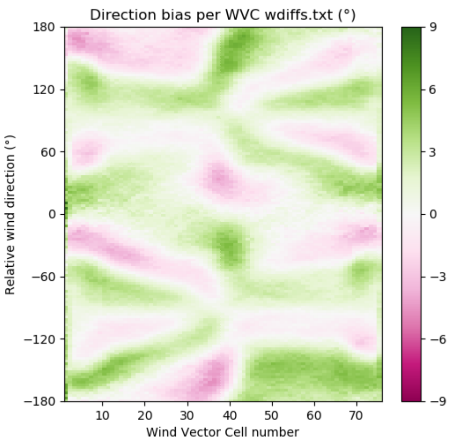
Systematic biases decrease when the observation error settings in 2DVAR are decreased.

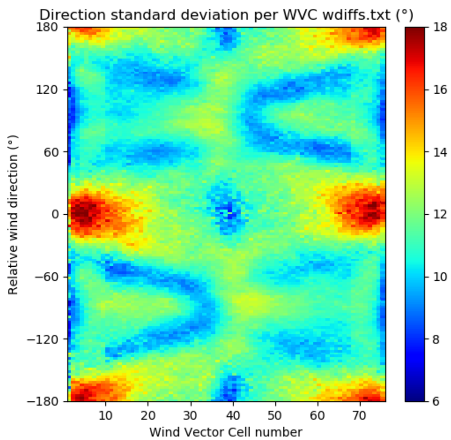


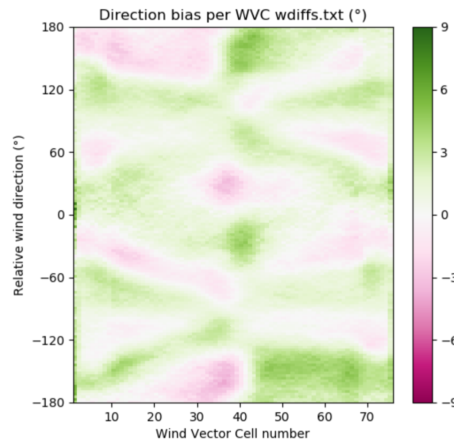
MSS + NBEC, eps = 0.4m/s

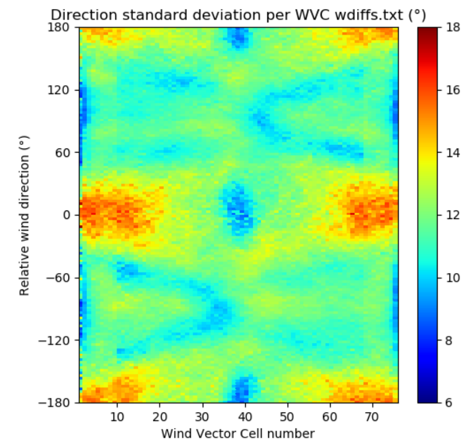
Influence of 2DVAR observation error settings

QuikSCAT, NSCAT4DS, SST corrections









MSS + NBEC, eps = 1.8m/s (default)

Buoy collocations	Number	SD speed	SD u	SD v	SD dir
All wind directions	4570	1.18	1.76	1.72	16.74
Rel. wind dir -135 to -45, 45 to 135	2639	1.21	1.60	1.71	14.88
-180 to -135, -45 to 45, 135 to 180	1931	1.13	1.88	1.66	17.75

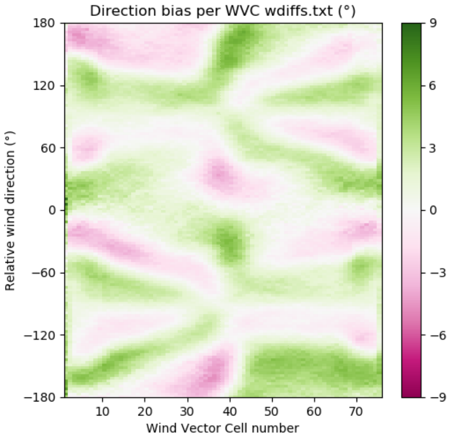
MSS + NBEC, eps = 0.9m/s

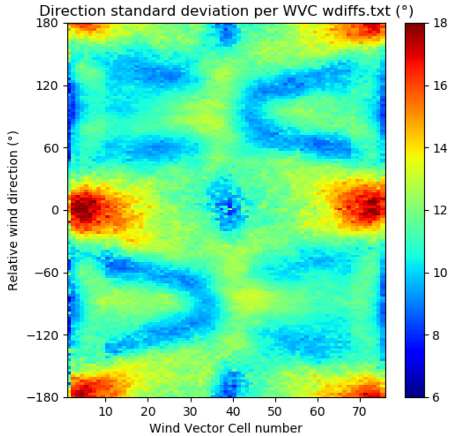
Buoy collocations	Number	SD speed	SD u	SD v	SD dir
All wind directions	4570	1.18	1.75	1.70	16.60
Rel. wind dir -135 to -45, 45 to 135	2639	1.20	1.60	1.69	14.77
-180 to -135, -45 to 45, 135 to 180	1931	1.13	1.86	1.65	17.92

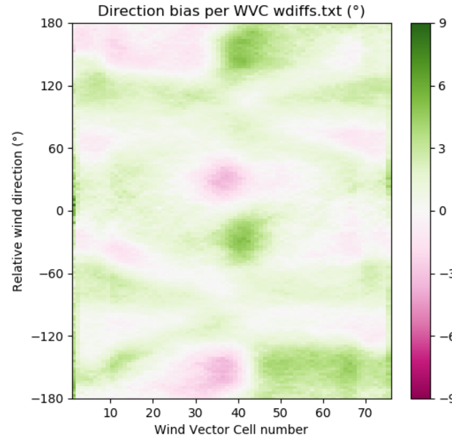
Systematic biases decrease when the observation error settings in 2DVAR are decreased. Also the buoy statistics slightly improve, both in the ‘favorable’ and in the ‘less favorable’ relative wind direction regions.

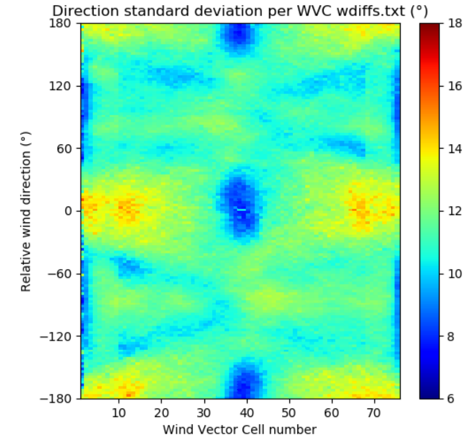
Influence of 2DVAR observation error settings

QuikSCAT, NSCAT4DS, SST corrections









MSS + NBEC, eps = 1.8m/s (default)

Buoy collocations	Number	SD speed	SD u	SD v	SD dir
All wind directions	4549	1.18	1.75	1.69	16.58
Rel. wind dir -135 to -45, 45 to 135	2630	1.21	1.60	1.70	14.89
-180 to -135, -45 to 45, 135 to 180	1919	1.12	1.87	1.60	17.39

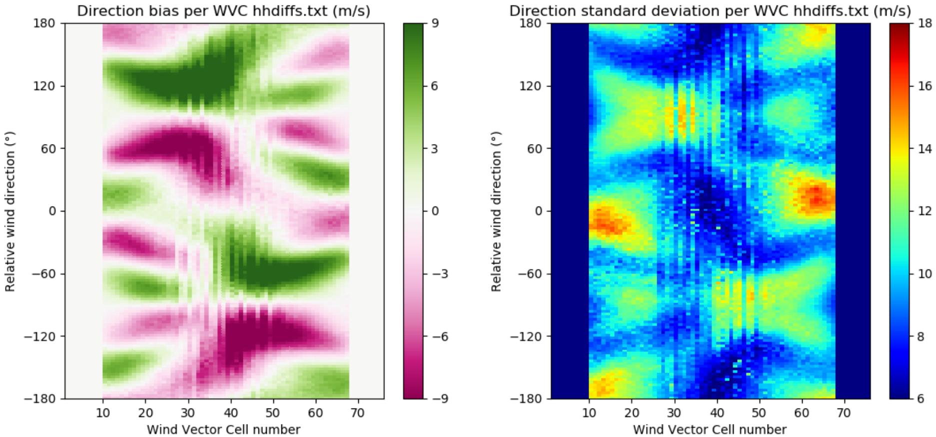
MSS + NBEC, eps = 0.4m/s

Buoy collocations	Number	SD speed	SD u	SD v	SD dir
All wind directions	4549	1.16	1.74	1.71	16.54
Rel. wind dir -135 to -45, 45 to 135	2630	1.19	1.59	1.72	14.63
-180 to -135, -45 to 45, 135 to 180	1919	1.11	1.86	1.61	17.81

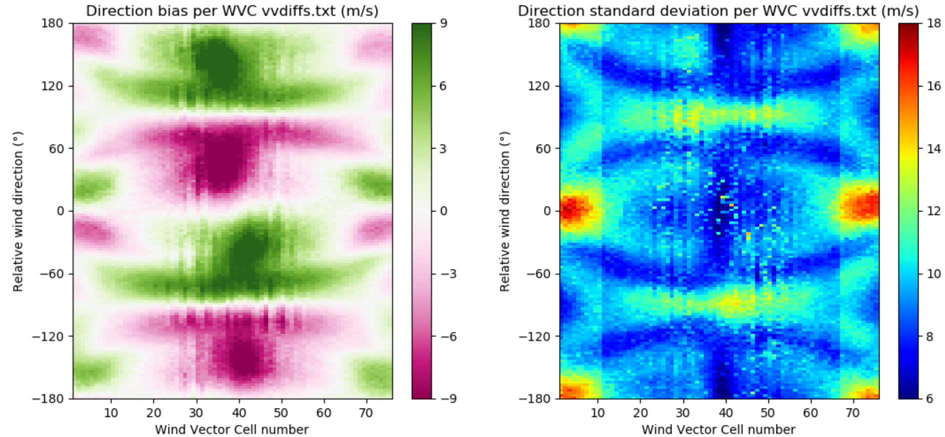
Systematic biases decrease when the observation error settings in 2DVAR are decreased, although not so much in nadir. The buoy statistics change somewhat but there is no clear improvement. The number of QC rejections increases, see the lower number of buoy collocations in the collocated data sets.

Wind direction bias and stdev vs. model – with MSS and with NBEC

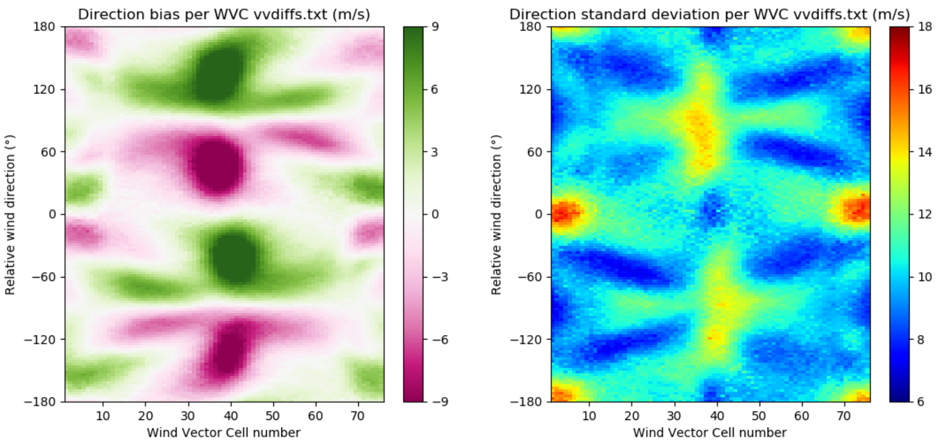
Difference between VV and HH retrievals, influence of NSCAT4DS and SST corrections



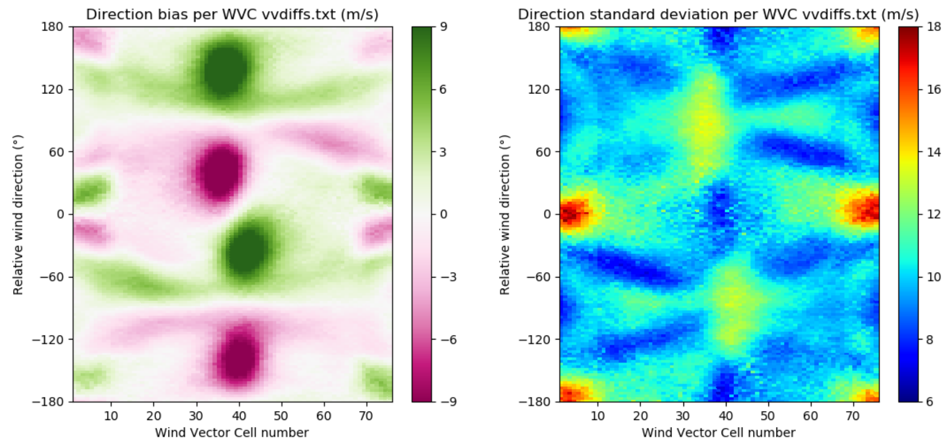
ScatSat-1 vs operational, HH only



ScatSat-1 vs operational, VV only



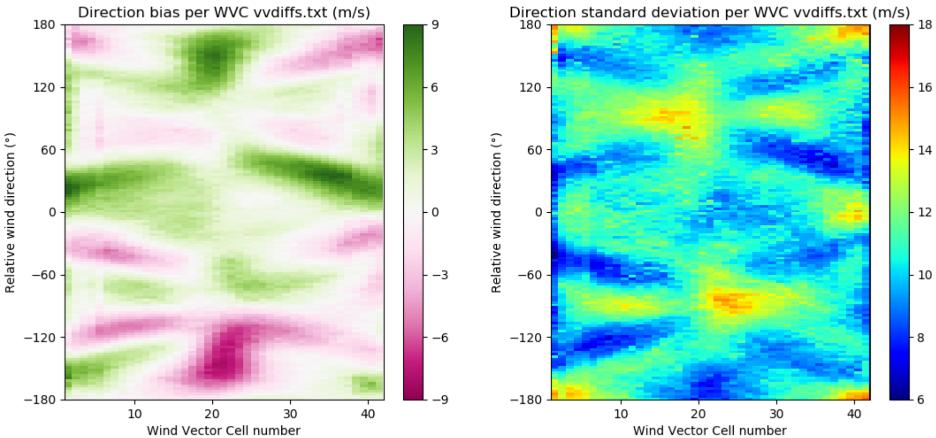
ScatSat-1 vs operational, HH + VV



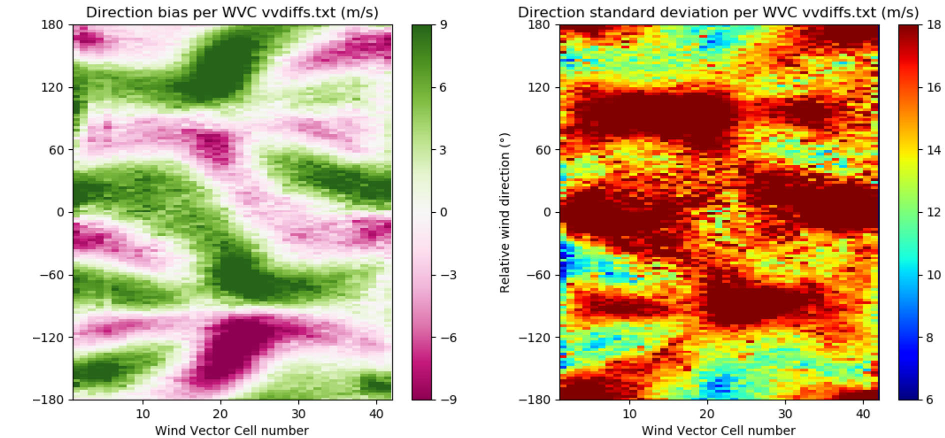
ScatSat-1 vs operational, NSCAT4DS, SST corr

Wind direction bias and stdev vs. model – with MSS and with NBEC

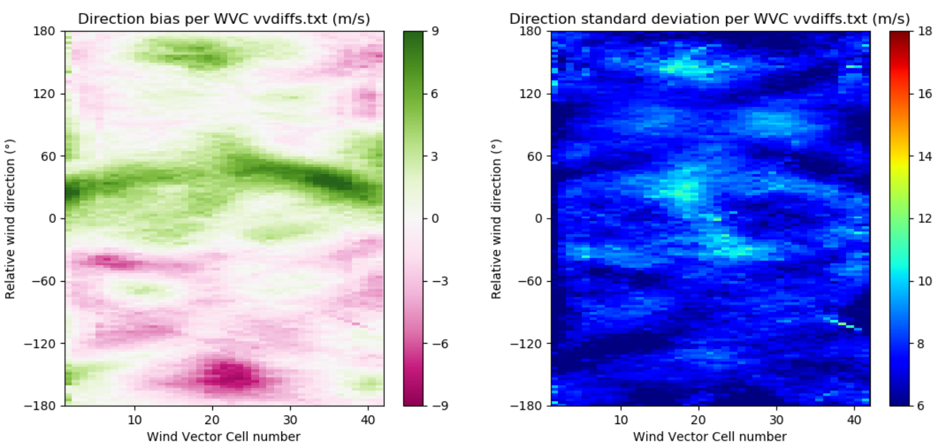
Influence of wind speed



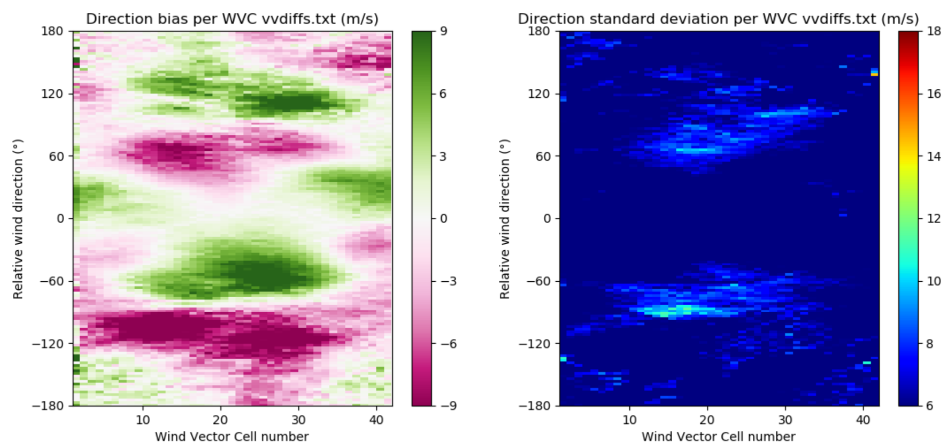
RapidScat vs ERA5 – 4-20 m/s



RapidScat vs ERA5 – 4-6 m/s



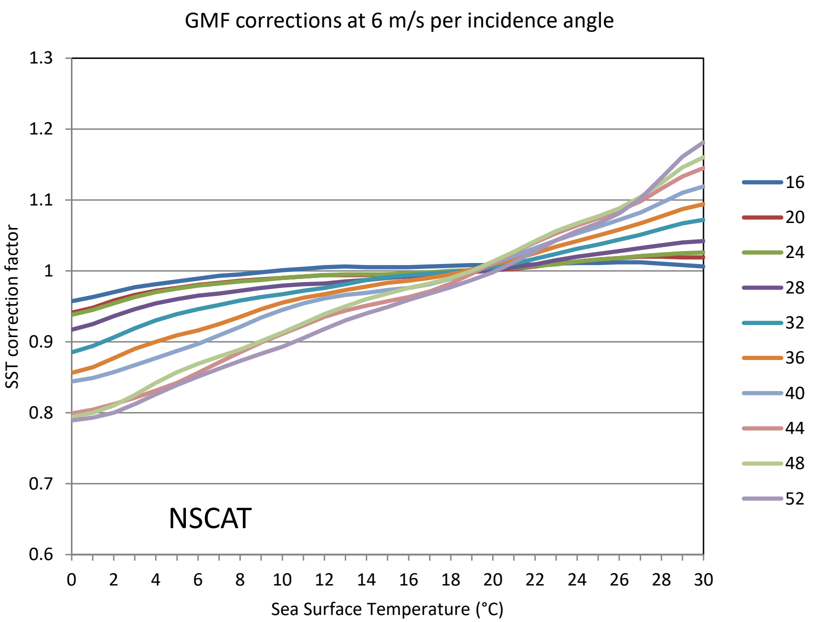
RapidScat vs ERA5 – 9-11 m/s

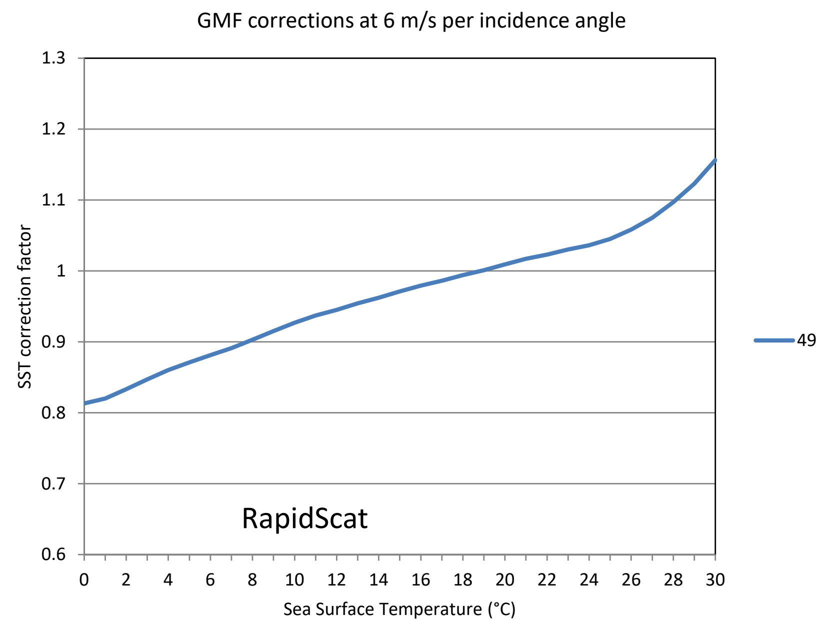


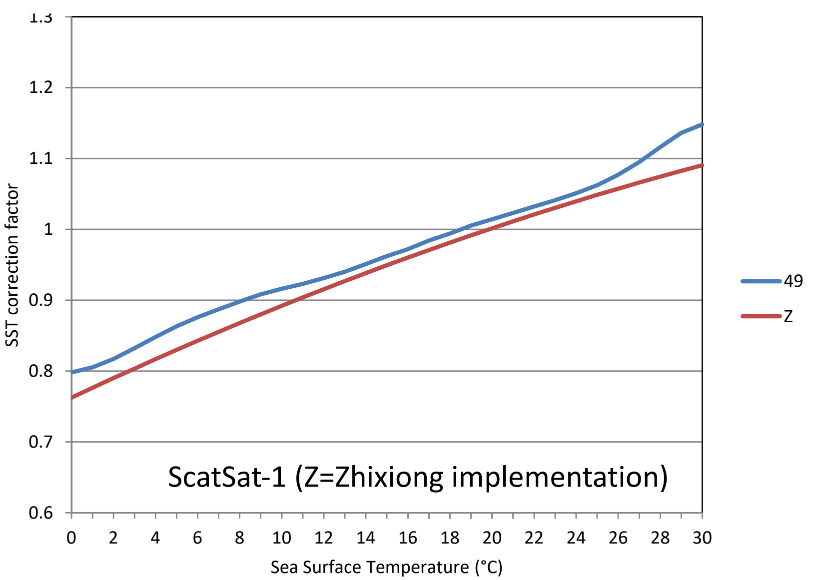
RapidScat vs ERA5 – 15-20 m/s

Part 4 of bias reduction: SST corrections for HH per incidence angle

NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT





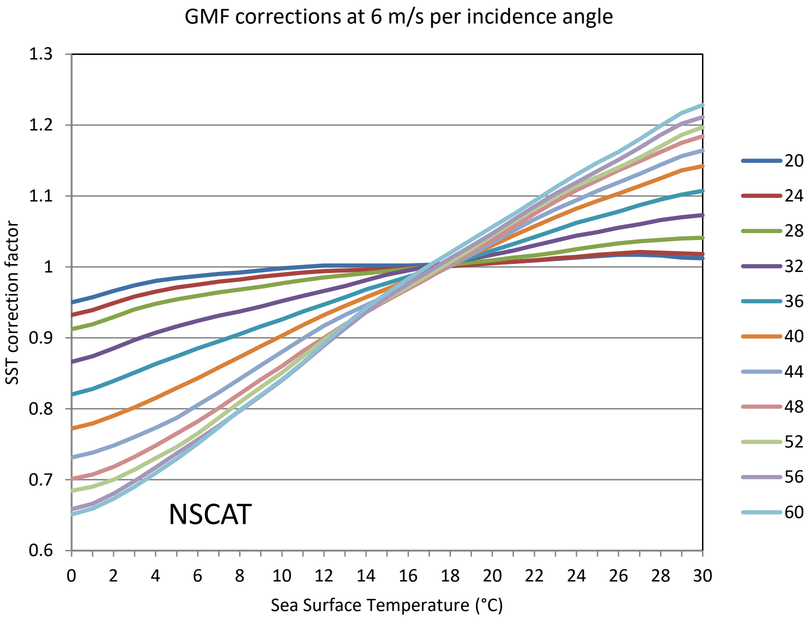


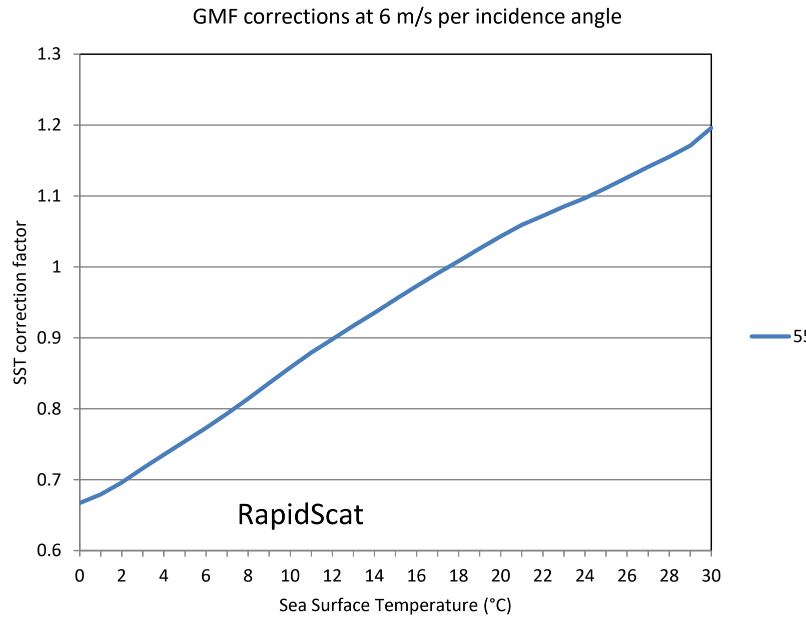
From the NSCAT plot we learn that the SST-dependence of the backscatter correction increases with increasing incidence angle, but saturates around 44° for HH polarization.

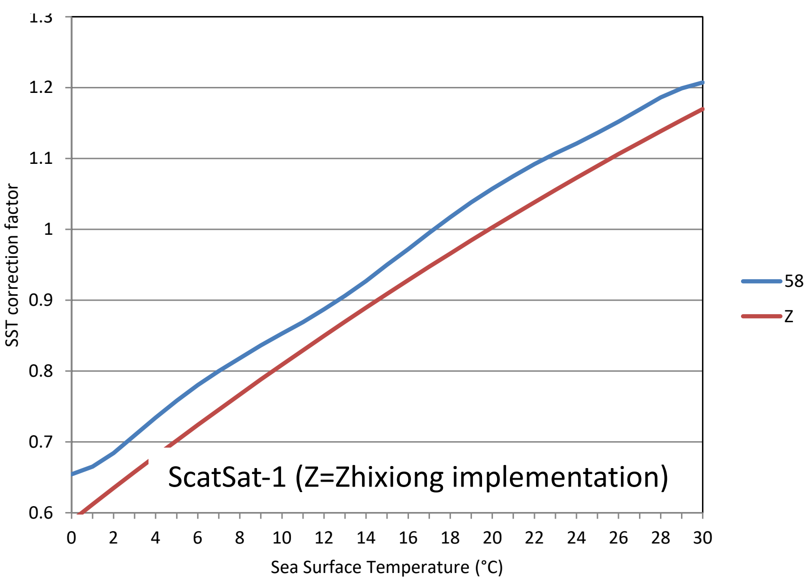
The RapidScat and ScatSat-1 show approximately the same dependence – the incidence angles are above the saturation value. 'Z' is the dependence which was derived by Zhixiong Wang for ScatSat-1.

Part 3 of bias reduction: SST corrections for VV per incidence angle

NSCAT vs. ERS-2, RapidScat vs. ASCAT, ScatSat-1 vs. ASCAT



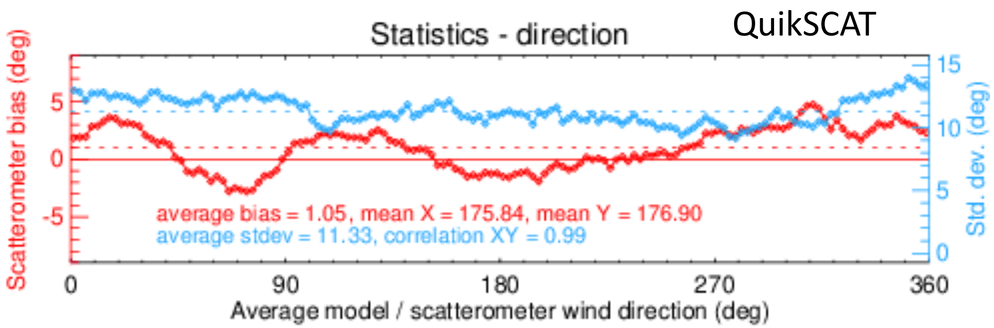


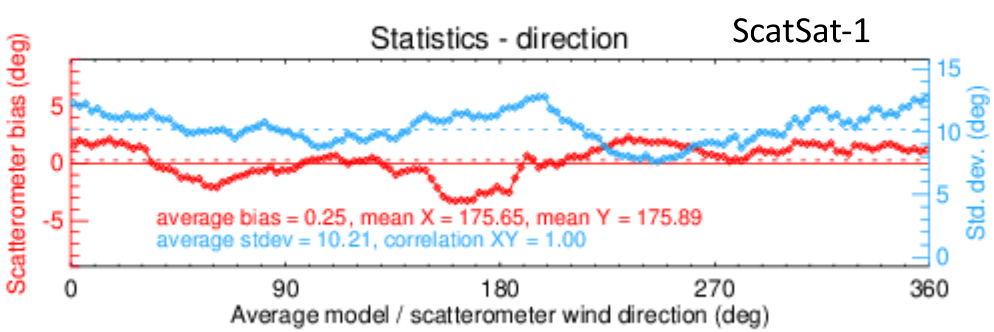


From the NSCAT plot we learn that the SST-dependence of the backscatter correction increases with increasing incidence angle, but saturates around 56° for VV polarization.

The RapidScat and ScatSat-1 show approximately the same dependence – the incidence angles are above the saturation value. 'Z' is the dependence which was derived by Zhixiong Wang for ScatSat-1.

Effect of corrections to direction bias and stdev vs. model





New calibrations, NSCAT4DS, SST corrections