On wind retrieval biases, GMFs, and Ku backscatter calibration

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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, 50 km

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

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

\[
\frac{\sigma_{meas}^0(V, \varphi)}{\sigma_{sim}^0(V, \varphi)} \ast \frac{\sigma_{sim}^0(V)}{\sigma_{meas}^0(V)}
\]
Part 3 of bias reduction: NSCAT4 VV corrections result in NSCAT4DS

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

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

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\frac{\sigma_{meas}(V, T)}{\sigma_{sim}(V, T)} \times \frac{\sigma_{sim}(V)}{\sigma_{meas}(V)}
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Part 4 of bias reduction: SST corrections for VV per incidence angle

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

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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

<table>
<thead>
<tr>
<th></th>
<th>QuikSCAT</th>
<th>Original</th>
<th>HH/VV cal</th>
<th>+ NSCAT4DS</th>
<th>+ SST corr</th>
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</thead>
<tbody>
<tr>
<td>SD wind speed</td>
<td>1.31</td>
<td>1.31</td>
<td>1.29</td>
<td>1.25</td>
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<td>SD u</td>
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<td>SD v</td>
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<td>1.38</td>
<td>1.36</td>
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<tr>
<td>SD wind dir</td>
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<td>11.71</td>
<td>11.45</td>
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### Scatterometer vs. buoy winds

<table>
<thead>
<tr>
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<th>QuikSCAT</th>
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<th>All corrections</th>
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<tbody>
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<tr>
<td>SD u</td>
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<td>SD v</td>
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<tr>
<td>SD wind dir</td>
<td>17.12</td>
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### ScatSat-1

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<th>HH/VV cal</th>
<th>+ NSCAT4DS</th>
<th>+ SST corr</th>
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<tbody>
<tr>
<td>SD wind speed</td>
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<td>SD u</td>
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<td>1.33</td>
<td>1.28</td>
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<tr>
<td>SD v</td>
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<td>SD wind dir</td>
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<td>10.83</td>
<td>10.43</td>
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### ScatSat-1

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<th>Original</th>
<th>All corrections</th>
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<tbody>
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<td>SD wind speed</td>
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<td>1.11</td>
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<tr>
<td>SD u</td>
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<tr>
<td>SD v</td>
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<tr>
<td>SD wind dir</td>
<td>21.19</td>
<td>20.85</td>
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- General improvement
Global wind speed biases

QuikSCAT new cal, NSCAT4DS, SST corr

ScatSat-1 with new cal, NSCAT4DS, SST corr

<\(\text{V}_{\text{bias}}\) > (m/s)
Air mass effect on hurricanes

- 2018 hurricanes
- Up to 10% difference
- Mainly $p$ or air mass density
- Needs correction
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 these 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
Simulation experiment (2)

Systematic biases decrease when the observation error settings in 2DVAR are decreased.
Influence of 2DVAR observation error settings
QuikSCAT, NSCAT4DS, SST corrections

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

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
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