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Supplement of

The SPARC water vapour assessment II: biases and drifts of water vapour satellite data records with respect to frost point hygrometer records

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1 Introduction

In this supplement we collect the results of the individual comparisons between satellite (SAT) data records and frost point hygrometer (NOAA FPH or CFH, short: FP) balloon soundings of stratospheric water vapour. For each pair of SAT and FP measurements within the coincidence criteria (see Section 2.2 of the main paper) the respective means, standard deviations, mean differences and their standard errors of the mean (SEM) were calculated according to Eqs. (7,8) (see main paper). Mean profiles, mean differences with their SEM, and the number of coincident measurements, are shown respectively in the three panels of each figure.

For identification of the FP and SAT data sets we mostly use the three letter codes as given in Tables S1 and S2.

1 Individual comparisons between satellite data records and stations

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Table S1: Overview of NOAA frost point hygrometer (NOAA FPH) and cryogenic frost point hygrometer (CFH) stations used for comparisons with satellite data.

<table>
<thead>
<tr>
<th>Code</th>
<th>Site</th>
<th>Period</th>
<th>Instr. type</th>
<th>Lat / deg</th>
<th>Long / deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>BND</td>
<td>Bandung</td>
<td>2003 – 2004</td>
<td>CFH</td>
<td>-6.9</td>
<td>107.6</td>
</tr>
<tr>
<td>BEL</td>
<td>Beltsville</td>
<td>2006 – 2011</td>
<td>CFH</td>
<td>39.0</td>
<td>-76.9</td>
</tr>
<tr>
<td>BIK</td>
<td>Biak</td>
<td>2006 – 2015</td>
<td>CFH</td>
<td>-1.2</td>
<td>136.1</td>
</tr>
<tr>
<td>BLD</td>
<td>Boulder</td>
<td>1980 – present</td>
<td>CFH/NOAA FPH</td>
<td>40.0</td>
<td>-105.2</td>
</tr>
<tr>
<td>FTS</td>
<td>Fort Sumner</td>
<td>1996 – 2004</td>
<td>NOAA FPH</td>
<td>34.5</td>
<td>-104.3</td>
</tr>
<tr>
<td>HAN</td>
<td>Hanoi</td>
<td>2007 – 2011</td>
<td>CFH</td>
<td>21.0</td>
<td>105.8</td>
</tr>
<tr>
<td>HIL</td>
<td>Hilo</td>
<td>2002 – present</td>
<td>CFH/NOAA FPH</td>
<td>19.7</td>
<td>-155.1</td>
</tr>
<tr>
<td>HOU</td>
<td>Houston</td>
<td>2011, 2013</td>
<td>CFH/NOAA FPH</td>
<td>29.6</td>
<td>-95.2</td>
</tr>
<tr>
<td>HUN</td>
<td>Huntsville</td>
<td>2002</td>
<td>NOAA FPH</td>
<td>34.7</td>
<td>-86.7</td>
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<tr>
<td>KIR</td>
<td>Kiruna</td>
<td>1991 – 2003</td>
<td>NOAA FPH</td>
<td>67.8</td>
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<tr>
<td>KTB</td>
<td>Kototabang</td>
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<td>100.3</td>
</tr>
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<td>KMG</td>
<td>Kunming</td>
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<td>LRN</td>
<td>La Reunion</td>
<td>2005 – 2011</td>
<td>CFH</td>
<td>-20.9</td>
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<tr>
<td>LDR</td>
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<td>2003 – present</td>
<td>NOAA FPH</td>
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<tr>
<td>LSA</td>
<td>Lhasa</td>
<td>2010, 2013</td>
<td>CFH</td>
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</tr>
<tr>
<td>LIN</td>
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<td>52.2</td>
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<tr>
<td>NYA</td>
<td>Ny Alesund</td>
<td>2002 – 2004,</td>
<td>CFH/NOAA FPH</td>
<td>78.9</td>
<td>11.9</td>
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<tr>
<td></td>
<td></td>
<td>2013 – present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVM</td>
<td>Research Vessel Mirai(^a)</td>
<td>2011</td>
<td>CFH</td>
<td>-8.0/1.2</td>
<td>80.5/136.1</td>
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<tr>
<td>SCR</td>
<td>San Cristobal</td>
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<td>CFH/NOAA FPH</td>
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<td>SJC</td>
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<tr>
<td>SOD</td>
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<td>67.4</td>
<td>26.6</td>
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<tr>
<td>SGP</td>
<td>Southern Great Plains</td>
<td>2003</td>
<td>CFH</td>
<td>36.6</td>
<td>-97.5</td>
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<tr>
<td>TMF</td>
<td>Table Mountain</td>
<td>2006 – 2009, 2013</td>
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<td>34.4</td>
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<td>TRW</td>
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<td>WTK</td>
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<td>YAN</td>
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</table>

\(^a\) ship cruise  
\(^b\) includes Alajuela, HerediaSan Pedro, and San Jose
Table S2: Overview of the water vapour data sets from satellites used in this study. Column Ret. type indicates whether the retrieval result was number density \( n_{H_2O} \) (marked ND) instead of vmr, and whether the retrieval was done in the log(vmr) or log(\( n_{H_2O} \)) domain. The numbers in the last column indicate the frost point hygrometer stations the data records of which have been used for the drift analysis of the satellite data (compare to Table S1).

<table>
<thead>
<tr>
<th>Code</th>
<th>Instrument</th>
<th>Data set version</th>
<th>Label</th>
<th>Ret. type</th>
<th>Kernel type</th>
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<td>ACE</td>
<td>ACE-FTS</td>
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<td>LATMOS v6</td>
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<td>HAL</td>
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<td>v19</td>
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<td>v7</td>
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<td>ILAS-II</td>
<td>SK</td>
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<tr>
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<td>MAESTRO</td>
<td>Research</td>
<td>MAESTRO</td>
<td>SK</td>
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<tr>
<td>MBH</td>
<td>MIPAS</td>
<td>Bologna V5H v2.3 NOM</td>
<td>MIPAS-Bologna V5H</td>
<td>AK</td>
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<td>MBR</td>
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<td>MH</td>
<td>IMK/IAA</td>
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<td>MIR</td>
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<tr>
<td>MII</td>
<td>IMK/IAA</td>
<td>V5R v522 MA</td>
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<td>MOR</td>
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<tr>
<td>MOM</td>
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<td>ND SK</td>
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<td>SM5</td>
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<tr>
<td>SOF</td>
<td>SOFIE</td>
<td>v1.3</td>
<td>SOFIE</td>
<td>SK</td>
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</table>


2 Individual comparisons between satellite data records and stations

2.1 ACE-FTS H2O_v3.5tg (ACE)

Figure S1: Comparison of ACE water vapour profiles with FP profiles at SOD, LIN, BLD, BEL, TMF, LSA, HOU, TNG, KMG, HIL, SJC, SCR, BIK, and BIK balloon sites. Mean profiles over all coincidences of the respective pairings are shown. The individual profiles were cut at the respective local tropopause before averaging. Left panels: mean profiles (FP: black, SAT: blue) and their standard deviations (FP: grey shading, SAT: horizontal blue lines). Middle panel: Relative mean bias and twice its standard error of the mean (grey shading, $\pm 2\sigma_{\text{bias}}$), calculated as the mean differences SAT-FP divided by the mean FP profile and multiplied by 100; the vertical dashed lines enclose the $\pm 10\%$ range. Right panel: number of data points along the vertical grid. This number can vary over the vertical range, depending on the altitude coverage of the individual coincident SAT and FP profiles, respectively.
Figure S1: Continued.
Figure S1: Continued.
Figure S1: Continued.
Figure S2: Same as Fig. S1 but for GOM and the NYA, KIR, SOD, LIN, BLD, BEL, FTS, LSA, TNG, KMG, YAN, HAN, HIL, SJC, SCR, LDR, and LDR balloon sites.
Figure S2: Continued.
Figure S2: Continued.
Figure S2: Continued.
Figure S2: Continued.
2.3 HALOE H2O_V19 (HAL)

Figure S3: Same as Fig. S1 but for HAL and the KIR, SOD, BLD, SGP, HUN, FTS, HIL, SJC, SCR, LDR, and LDR balloon sites.
Figure S3: Continued.
Figure S3: Continued.
2.4 HIRDLS H2O_V7 (HIR)

Figure S4: Same as Fig. S1 but for HIR and the SOD, LIN, BLD, BEL, TMF, HAN, SJC, TRW, KTB, SCR, BIK, LRN, LDR, and LDR balloon sites.
Figure S4: Continued.
Figure S4: Continued.
Figure S4: Continued.
Figure S5: Same as Fig. S1 but for ILA and the NYA, SOD, BLD, and BLD balloon sites.
Figure S6: Same as Fig. S1 but for MST and the NYA, SOD, LIN, BLD, BEL, LSA, HOU, KMG, HIL, SJC, LDR, and LDR balloon sites.
Figure S6: Continued.
Figure S6: Continued.
Figure S7: Same as Fig. S1 but for MBH and the NYA, KIR, SOD, BLD, SGP, HUN, FTS, HIL, SCR, WTK, LDR, and LDR balloon sites.
Figure S7: Continued.
Figure S7: Continued.
Figure S8: Same as Fig. S1 but for MBM and the SOD, LIN, BLD, BEL, TMF, TNG, KMG, HAN, HIL, SJC, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S8: Continued.
Figure S8: Continued.
Figure S8: Continued.
Figure S9: Same as Fig. S1 but for MBR and the SOD, LIN, BLD, BEL, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S9: Continued.
Figure S9: Continued.
Figure S9: Continued.
Figure S9: Continued.
Figure S10: Same as Fig. S1 but for MEH and the NYA, KIR, SOD, BLD, SGP, FTS, HIL, SCR, WTK, and WTK balloon sites.
Figure S10: Continued.
Figure S10: Continued.
Figure S11: Same as Fig. S1 but for MEM and the SOD, LIN, BLD, BEL, TMF, TNG, KMG, YAN, HAN, HIL, SJC, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S11: Continued.
Figure S11: Continued.
Figure S11: Continued.
Figure S12: Same as Fig. S1 but for MER and the SOD, LIN, BLD, BEL, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S12: Continued.
Figure S12: Continued.
Figure S12: Continued.
Figure S12: Continued.
Figure S12: Continued.
Figure S13: Same as Fig. S1 but for MIH and the NYA, KIR, SOD, BLD, SGP, HUN, FTS, HIL, SCR, WTK, LDR, and LDR balloon sites.
Figure S13: Continued.
Figure S13: Continued.
Figure S14: Same as Fig. S1 but for MIR and the SOD, LIN, BLD, BEL, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S14: Continued.
Figure S14: Continued.
Figure S14: Continued.
Figure S14: Continued.
Figure S14: Continued.
Figure S15: Same as Fig. S1 but for MIM and the SOD, LIN, BLD, BEL, TMF, TNG, KMG, YAN, HAN, HIL, SJC, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S15: Continued.
Figure S15: Continued.
Figure S15: Continued.
Figure S16: Same as Fig. S1 but for MOH and the NYA, KIR, SOD, BLD, SGP, HUN, FTS, HIL, SCR, WTK, LDR, and LDR balloon sites.
Figure S16: Continued.
Figure S16: Continued.
Figure S17: Same as Fig. S1 but for MOM and the SOD, LIN, BLD, BEL, TMF, TNG, KMG, YAN, HAN, HIL, SJC, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S17: Continued.
Figure S17: Continued.
Figure S17: Continued.
Figure S18: Same as Fig. S1 but for MOR and the SOD, LIN, BLD, BEL, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S18: Continued.
Figure S18: Continued.
Figure S18: Continued.
Figure S18: Continued.
Figure S18: Continued.
2.19 MLS-Aura H2O V4.2 (MLS)

Figure S19: Same as Fig. S1 but for MLS and the NYA, SOD, LIN, BLD, BEL, FTS, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, BND, RVM, LRN, LDR, and LDR balloon sites.
Figure S19: Continued.
Figure S19: Continued.
Figure S19: Continued.
Figure S19: Continued.
Figure S20: Same as Fig. S1 but for POM and the NYA, KIR, SOD, BLD, and BLD balloon sites.
Figure S20: Continued.
Figure S21: Same as Fig. S1 but for SG2 and the KIR, SOD, BLD, SGP, HUN, HIL, SCR, WTK, LRN, LDR, and LDR balloon sites.
Figure S21: Continued.
Figure S21: Continued.
2.22 SAGE_III H2O_v4 (SG3)

Figure S22: Same as Fig. S1 but for SG3 and the NYA, KIR, SOD, BLD, LDR, and LDR balloon sites.
Figure S22: Continued.
2.23 SCIAMACHY H2O_LO_V1.0 (SCL)

Figure S23: Same as Fig. S1 but for SCL and the LDR, and LDR balloon sites.
Figure S24: Same as Fig. S1 but for SC1 and the NYA, KIR, SOD, LIN, BLD, BEL, and BEL balloon sites.
Figure S24: Continued.
Figure S25: Same as Fig. S1 but for SC4 and the NYA, KIR, SOD, LIN, BLD, BEL, and BEL balloon sites.
Figure S25: Continued.
Figure S26: Same as Fig. S1 but for SC3 and the SOD, LIN, BLD, BEL, SGP, FTS, TMF, LSA, HOU, YAN, HAN, HIL, SJC, TRW, KTB, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S26: Continued.
Figure S26: Continued.
Figure S26: Continued.
Figure S26: Continued.
Figure S27: Same as Fig. S1 but for SLA and the HAN, SJC, TRW, BIK, and BIK balloon sites.
Figure S27: Continued.
Figure S28: Same as Fig. S1 but for SLB and the BLD, HAN, SJC, TRW, BIK, and BIK balloon sites.
Figure S28: Continued.
Figure S29: Same as Fig. S1 but for SM5 and the NYA, SOD, LIN, BLD, BEL, SGP, HUN, FTS, TMF, LSA, HOU, TNG, KMG, YAN, HAN, HIL, SJC, TRW, KTB, SCR, BIK, RVM, LRN, LDR, and LDR balloon sites.
Figure S29: Continued.
Figure S29: Continued.
Figure S29: Continued.
Figure S29: Continued.
Figure S29: Continued.
Figure S29: Continued.
Figure S30: Same as Fig. S1 but for SM4 and the SOD, LIN, BLD, BEL, TMF, HAN, HIL, SCR, LDR, and LDR balloon sites.
Figure S30: Continued.
Figure S30: Continued.
Figure S31: Same as Fig. S1 but for SOF and the SOD, LIN, BLD, HIL, SJC, LDR, and LDR balloon sites.
Figure S31: Continued.