

**Measurement and Intercomparison of Active, Passive and
In-situ Sensors During the International Water Vapour
Project for the Verification of the Specifications of the
WALES Experiment**

SRL/Reference Sonde intercomparison

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SRL: Measurement uncertainty

- **Statistical error** associated with the Raman lidar signals
- Systematic error associated with the determination of the calibration constant K.

Water vapor data have been processed using a single, height independent calibration constant determined from 20 nighttime datasets of SRL water vapor and SuomiNet GPS measurements of total precipitable water both taken at Greenbelt, MD in the September November, 2002 period for Aqua validation purposes.

- Random error is a function time of day, altitude and amount of water vapour.

During IHOP:

- day <10% in BL
- night <2% in BL, <10% to 6km

SW: Measurement uncertainty

- Accuracy: 0.25 % in terms of relative humidity measurements.
- The SW needs no individual calibration and can be used again without recalibration if recovered after flight.

- Comparisons between SRL and Reference Sonde have been **recently updated** in order to properly match the integration time of the two sensors.
- *Reference Sonde data on IHOP server are indicated with the time of start of preparation of sonde, and not with the time of sonde release*
 - A misinterpretation of this issue during the original data analysis led on 9 and 20 June 2002 to an effective separation by 30-60 minutes between sonde launch time and lidar start time, so that for these two cases **non simultaneous measurements were originally compared**.
 - This time lag may be responsible for the large deviation between SRL and reference sonde originally observed on 9 and 20 June 2002.

Comparison between SRL and NCAR Reference radiosondes

- Nine reference radiosondes were launched in Homestead during IHOP
- Three of these were launched at times when SRL was operational.

Z20020528_162645

Z20020609_104618

Z20020620_025610

- Z20020528_162645 *side by side* with y5281739.hom
- Z20020609_104618 *simultaneously* with y6091135.hom
- Z20020620_025610 *simultaneously* with y6200330.hom

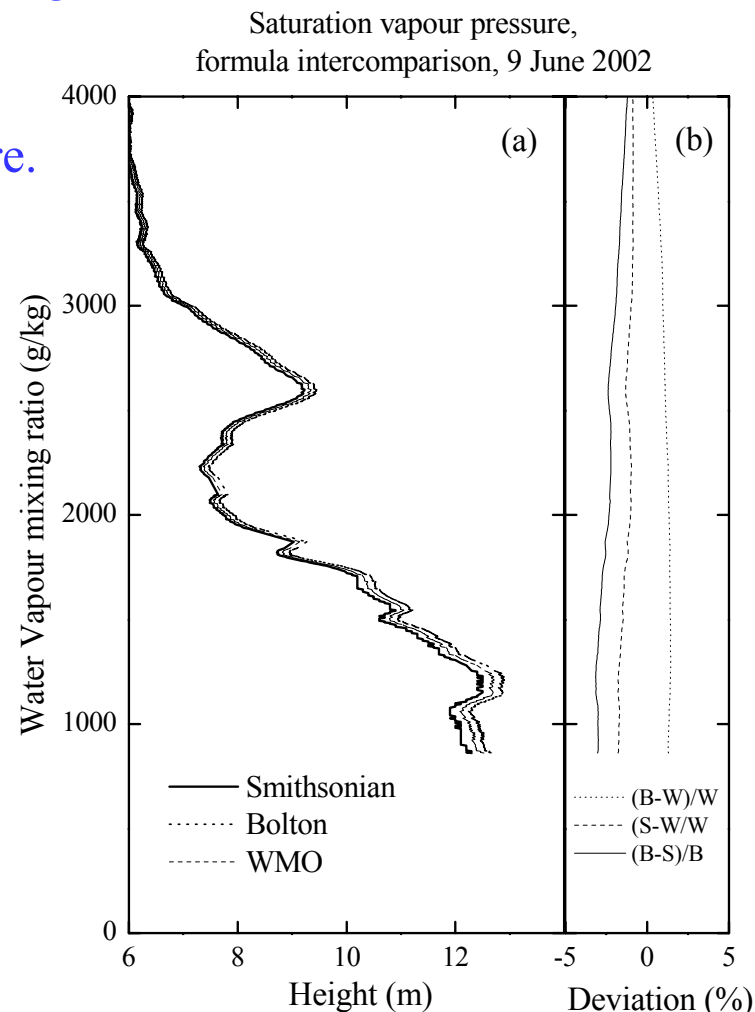
Comparison between SRL, Reference Sonde and Vaisala RS 80

- While the Reference Sonde includes two humidity sensors (Snow White chilled-mirror dew point hygrometer and a carbon hygistor), comparisons between SRL and reference sonde consider the SW chilled-mirror dew point hygrometer only.
- SRL data have been interpolated at other sensors' heights.
- Unfortunately, some data points result to be missing in the reference sonde profiles.
- Reference Sonde Z20020528_162645
 - no humidity information between 2200 and 2700 m (above sea level, a.s.l.)
- Reference Sonde Z20020609_104618
 - Large gaps of humidity information (2.9-3.6 km; 3.8-5.5 km a.s.l.)
 - pressure information result to be missing (only the surface value results to be available).

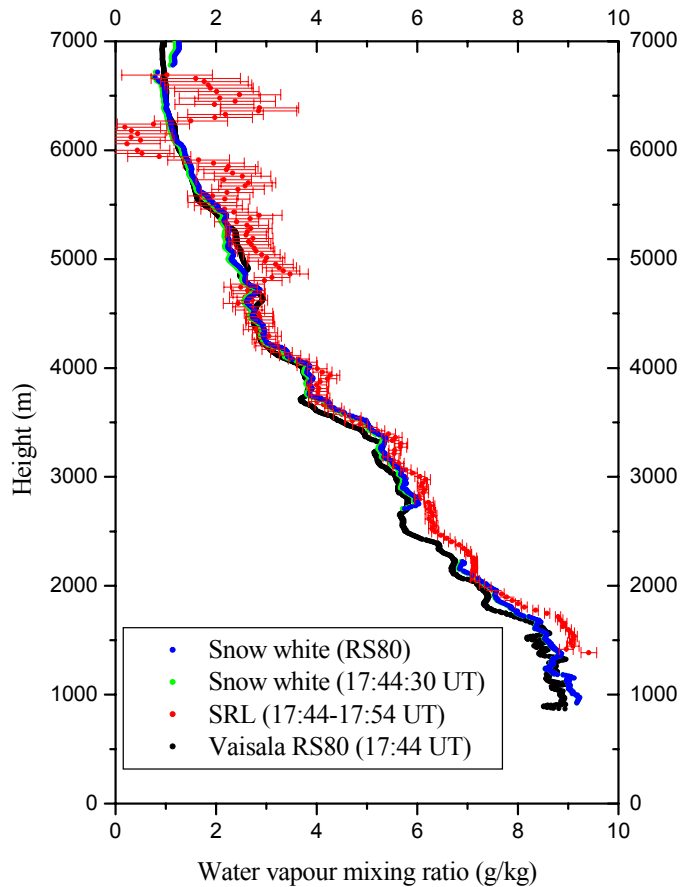
- Mixing ratio: direct measurement for the Raman lidar
- Relative humidity: direct measurement for the radiosonde
- Relative humidity $\longrightarrow$ water vapour mixing ratios

saturation vapour pressure,
which depends of pressure and temperature.

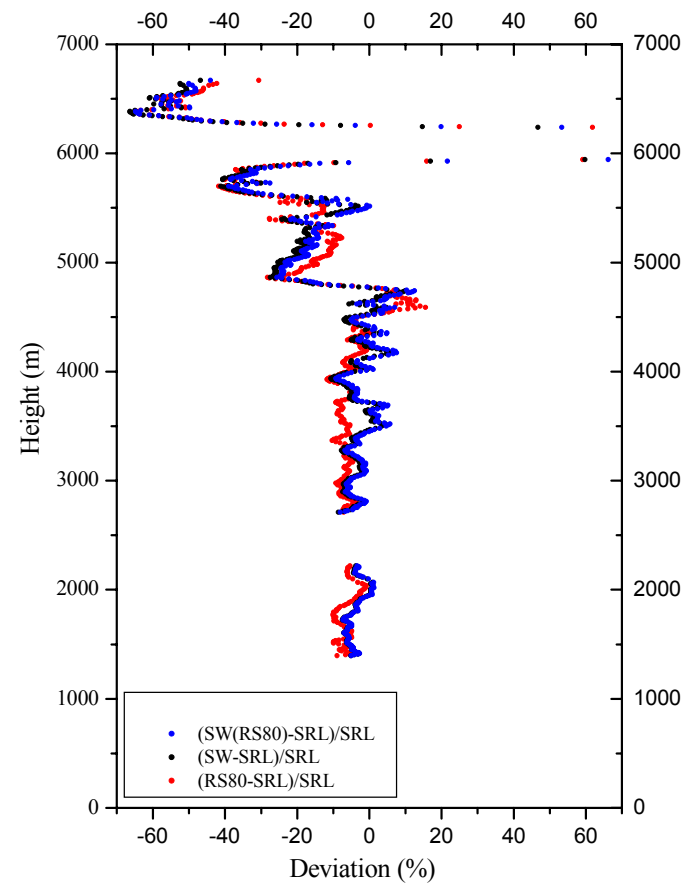
- *Pressure information from the reference sonde was not used since considered to be not reliable.*
- *Pressure data from co-located or simultaneous Vaisala RS80 was used instead.*
- *However, comparisons reported in these slides consider water vapour mixing ratio profiles for SW as obtained using both pressure data from reference sonde and RS 80; the former are indicated as SW, while the latter are indicated as SW(RS80).*



SRL-Snow white-Vaisala sonde intercomparison
28 May 2002



Deviations between the sensors and SRL
28 May 2002

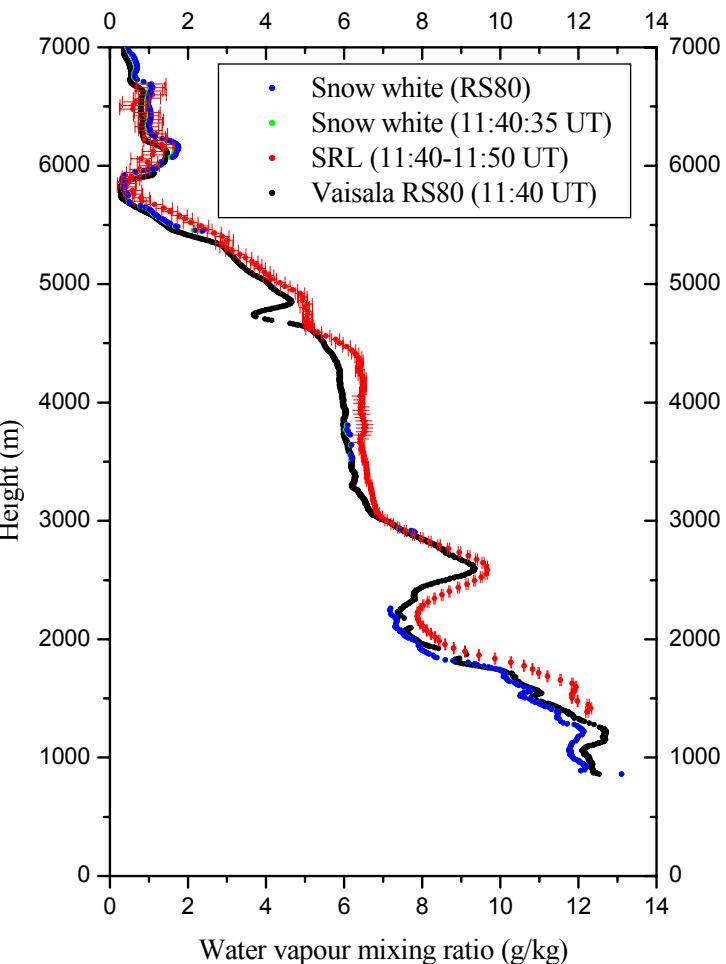


- SRL data are moister than Snow White up to 15 % below 4.5 km a.s.l.

Average BIAS up to 3.8 km= 3.5%

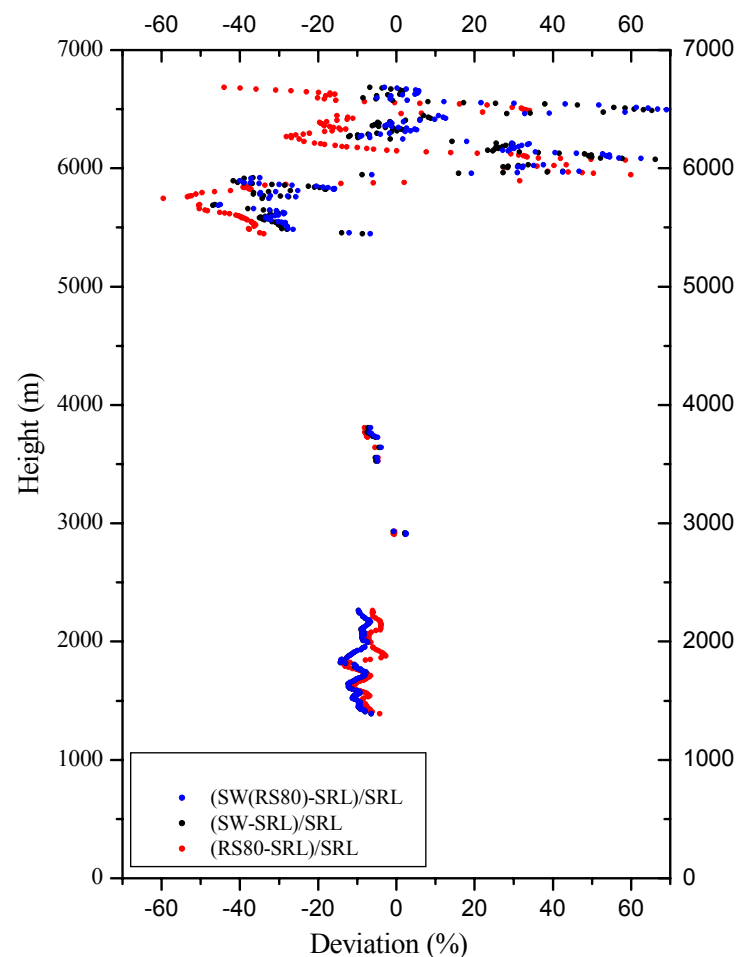
SRL-Snow white-Vaisala sonde intercomparison

09 June 2002



Deviations between the sensors and SRL

09 June 2002



Wind speed in Boundary Layer > 15 m/s



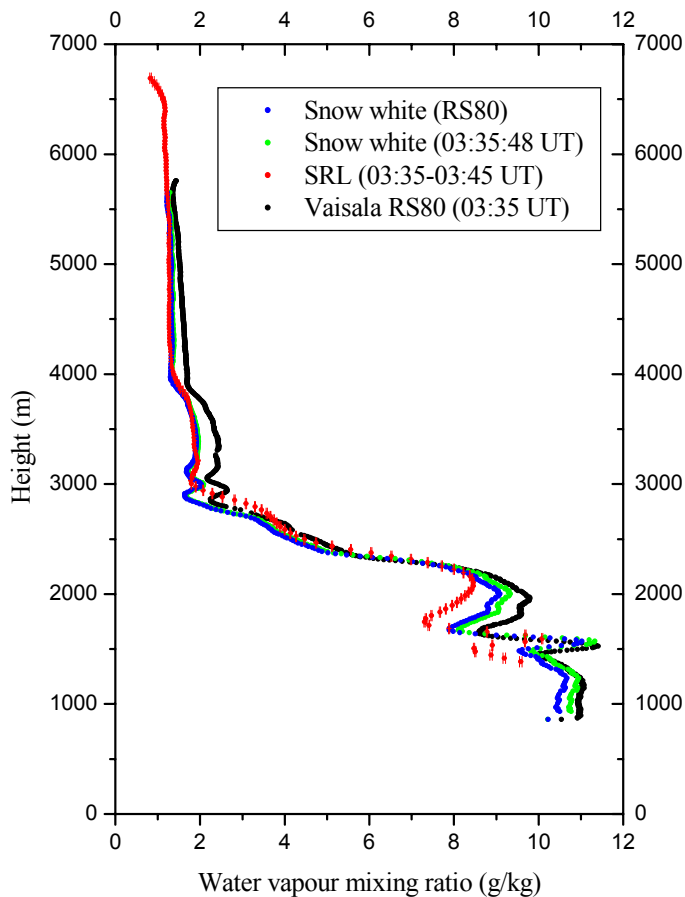
air masses sounded from Lidar and sondes are somewhat different

SRL is moister than Snow White by up to 15 % below 4 km a.s.l.

Average BIAS up to 3.8 km= 9.5%

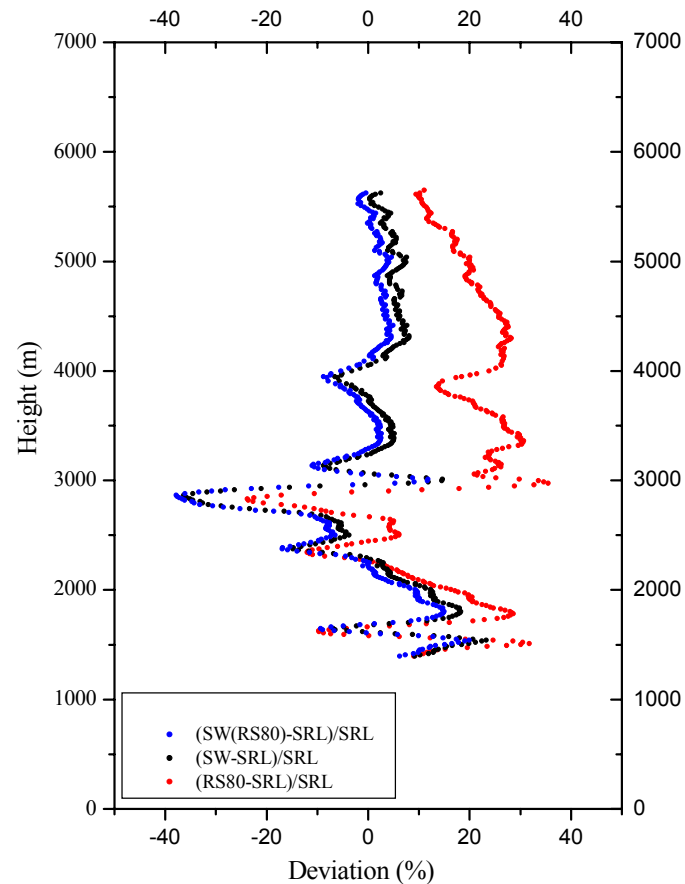
SRL-Snow white-Vaisala sonde intercomparison

20 June 2002



Deviations between the sensors and SRL

20 June 2002



- Like 09 June 2002, wind speed in Boundary Layer > 15 m/s

- SRL is drier than SW below ~ 2.3 km a.s.l. (up to 10 %)
- SRL is moister than SW between 2.3 and 3 km a.s.l. (up to -30 %), but this is the boundary layer top, characterized by large gradients of humidity
- SRL is drier than SW above 3 km a.s.l. (up to 20 %)

Larger deviations are in the Boundary Layer

Average BIAS up to 3.8 km= -1.2%

RMS deviations and BIAS between SRL, SW and their mean value

$$\bar{n}_i = \frac{SRL_i + (SW(RS80))_i}{2}$$

$$RMS\%SRL_{-\bar{n}} = \frac{\sqrt{\sum_{i=1}^N (SRL_i - \bar{n}_i)^2}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$RMS\%SW_{-\bar{n}} = \frac{\sqrt{\sum_{i=1}^N (SW_i - \bar{n}_i)^2}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$RMS\%SRL_{-SW} = \frac{\sqrt{\sum_{i=1}^N (SRL_i - SW_i)^2}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$BIAS\%SRL_{-\bar{n}} = \frac{\sum_{i=1}^N (SRL_i - \bar{n}_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

$$BIAS\%SW_{-\bar{n}} = \frac{\sum_{i=1}^N (SW_i - \bar{n}_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

$$BIAS\%SRL_{-SW} = \frac{\sum_{i=1}^N (SRL_i - SW_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

RMS%SRL_n,SW(RS80)_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	2.3992643	2.7486946	2.44489956	2.8306438	1.3200836	2.2823203	2.3379519	2.1126581
09 June 2002	5.1466609	5.1837139	5.23836993	5.1895767	5.2238772	3.6629829	1.3640611	2.8652519
20 June 2002	6.219176	5.989666	5.33730455	5.4746049	3.8331745	7.571164	12.63064	0.9649736
Average	4.5883671	4.6406915	4.34019135	4.4982751	3.4590451	4.5054891	5.4442178	1.9809612

BIAS%SRL_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	1.7399515	2.0842918	2.07693826	2.7742629	0.8934689	2.0411605	2.0730148	1.2482702
09 June 2002	4.7610925	4.8552243	5.02117946	5.1381576	5.0028808	1.905052	-0.279867	2.8189866
20 June 2002	-0.577461	-0.602413	-1.255077	-3.860971	-2.822788	6.8098709	7.1500589	-0.262481
Average	1.9745276	2.1123676	1.94768023	1.3504831	1.0245206	3.5853611	2.9810689	1.2682588

BIAS%SW(RS80)_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	-1.739951	-2.084292	-2.0769383	-2.774263	-0.893469	-2.04116	-2.073015	-1.24827
09 June 2002	-4.761092	-4.855224	-5.0211795	-5.138158	-5.002881	-1.905052	0.279867	-2.818987
20 June 2002	0.5774611	0.6024134	1.25507703	3.8609711	2.822788	-6.809871	-7.150059	0.2624805
Average	-1.974528	-2.112368	-1.9476802	-1.350483	-1.024521	-3.585361	-2.981069	-1.268259

RMS%SRL_SW(RS80)

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	4.7985285	5.4973892	4.88979911	5.6612875	2.6401671	4.5646406	4.6759039	4.2253162
09 June 2002	10.293322	10.367428	10.4767399	10.379153	10.447754	7.3259657	2.7281223	5.7305039
20 June 2002	12.438352	11.979332	10.6746091	10.94921	7.666349	15.142328	25.261281	1.9299472
Average	9.1767341	9.281383	8.68038269	8.9965503	6.9180902	9.0109781	10.888436	3.9619224

BIAS%SRL_SW(RS80)

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	3.479903	4.1685836	4.15387653	5.5485258	1.7869378	4.0823209	4.1460296	2.4965403
09 June 2002	9.5221849	9.7104485	10.0423589	10.276315	10.005762	3.8101041	-0.559734	5.6379733
20 June 2002	-1.154922	-1.204827	-2.5101541	-7.721942	-5.645576	13.619742	14.300118	-0.524961
Average	3.9490552	4.2247351	3.89536047	2.7009663	2.0490411	7.1707223	5.9621378	2.5365175

- SRL results on average to be 4 % moister than the reference sonde.
- The 4 % wet BIAS is in agreement with the 4 % deviation between SRL and simultaneous GPS PW found during IHOP (Dave Whiteman, this meeting), which might lead to a re-evaluation of the calibration constant used for IHOP.
- However, the work on SRL data is still in progress; so presently no definitive conclusion can be driven on this calibration issue.

Additional comparisons

RMS deviations and BIAS between RS80, SW and their mean value

$$\bar{n}_i = \frac{SW_i + (RS80)_i}{2}$$

$$RMS\%RS80_{-\bar{n}} = \frac{\sqrt{\frac{\sum_{i=1}^N ((RS80)_i - \bar{n}_i)^2}{N}}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$RMS\%SW_{-\bar{n}} = \frac{\sqrt{\frac{\sum_{i=1}^N (SW_i - \bar{n}_i)^2}{N}}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$RMS\%RS80_{-SW} = \frac{\sqrt{\frac{\sum_{i=1}^N ((RS80)_i - SW_i)^2}{N}}}{\frac{\sum_{i=1}^N \bar{n}_i}{N}}$$

$$BIAS\%RS80_{-\bar{n}} = \frac{\sum_{i=1}^N ((RS80)_i - \bar{n}_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

$$BIAS\%SW_{-\bar{n}} = \frac{\sum_{i=1}^N (SW_i - \bar{n}_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

$$BIAS\%RS80_{-SW} = \frac{\sum_{i=1}^N ((RS80)_i - SW_i)}{\sum_{i=1}^N (\bar{n}_i)}$$

RMS%RS80_n,SW_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	1.833839788	1.6037305	1.46099454	1.4452431	1.6047585	1.0203205	1.2390744	2.3586115
09 June 2002	1.674131397	1.6907439	1.70276497	1.044948	2.522553	1.6805021	1.1390989	0.6180511
20 June 2002	4.622309111	4.1678846	3.36271571	3.6273781	2.2411019	4.641823	12.772177	9.801887
Average	2.710093432	2.487453	2.17549174	2.0391897	2.1228045	2.4475486	5.0501169	4.2595165

BIAS%RS80_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	-1.445594164	-1.104066	-1.1456639	-1.036629	-1.467387	-0.794873	-1.001484	-1.869714
09 June 2002	1.081760385	1.160758	1.22391981	0.7004193	1.9959063	0.2705772	-0.793112	-0.406518
20 June 2002	3.187861517	2.6436233	1.75249186	0.8898022	1.6525364	3.6779592	12.198725	9.6950387
Average	0.94134258	0.9001051	0.61024926	0.184531	0.7270185	1.051221	3.4680434	2.4729357

BIAS%SW_n

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	1.445594164	1.1040661	1.14566389	1.0366285	1.4673872	0.7948735	1.0014836	1.8697135
09 June 2002	-1.081760385	-1.160758	-1.2239198	-0.700419	-1.995906	-0.270577	0.7931117	0.4065182
20 June 2002	-3.187861517	-2.643623	-1.7524919	-0.889802	-1.652536	-3.677959	-12.19873	-9.695039
Average	-0.94134258	-0.900105	-0.6102493	-0.184531	-0.727018	-1.051221	-3.468043	-2.472936

RMS%RS80_SW

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	3.667679576	3.2074609	2.92198909	2.8904863	3.209517	2.040641	2.4781488	4.717223
09 June 2002	3.348262795	3.3814879	3.40552995	2.089896	5.045106	3.3610043	2.2781978	1.2361021
20 June 2002	9.244618221	8.3357693	6.72543141	7.2547562	4.4822037	9.2836461	25.544355	19.603774
Average	5.420186864	4.974906	4.35098348	4.0783795	4.2456089	4.8950971	10.100234	8.5190331

BIAS%RS80_SW

Date	1.3-3.8 km	1.3-3.3 km	1.3-2.8 km	1.3-1.8 km	1.8-2.3 km	2.3-2.8 km	2.8-3.3 km	3.3-3.8 km
28 May 2002	-2.891188328	-2.208132	-2.2913278	-2.073257	-2.934774	-1.589747	-2.002967	-3.739427
09 June 2002	2.16352077	2.321516	2.44783962	1.4008386	3.9918125	0.5411543	-1.586223	-0.813036
20 June 2002	6.375723035	5.2872467	3.50498373	1.7796045	3.3050728	7.3559184	24.397451	19.390077
Average	1.882685159	1.8002102	1.22049852	0.369062	1.454037	2.1024419	6.9360868	4.9458713