

## RTTOV v13.0 Performance Test Log - Appendix to RTTOV v13 Test Plan (NWPSAF-MO-TV-044)

This document describes the tests performed to compare the performance of RTTOV v13.0 with that of RTTOV v12.3. This includes comparisons of execution speed and peak memory usage. Different configurations of RTTOV v13.0 (for example the old v7/8/9 optical depth predictors and new v13 predictors) are also compared.

The direct, TL, AD and K models were run separately for the following test cases:

1. MW simulation (ATMS) without interpolation, 54L profile
2. MW simulation (ATMS) with interpolation, 101L profile
3. MW simulation (ATMS) with CLW absorption and interpolation, 101L profile
4. IR v7 predictor simulation (SEVIRI) with interpolation, 101L profile
5. IR v8 predictor simulation (SEVIRI) with interpolation, 101L profile
6. Visible-only v9 predictor simulation (SEVIRI) with interpolation, 101L profile
7. 7gas v9 predictor simulation (IASI) without interpolation, 101L profile
8. IR v7 predictor Chou-scaling aerosol simulation (SEVIRI) with interpolation, 50L profile
9. IR v7 predictor DOM aerosol simulation (SEVIRI) with interpolation, 50L profile
10. IR v7 predictor DOM cloud simulation (SEVIRI) with interpolation, 50L profile
11. IR v7 predictor DOM cloud simulation (SEVIRI) with interpolation, 50L profile
12. Visible-only v9 predictor DOM aerosol simulation (SEVIRI) with interpolation, 50L profile
13. Visible-only v9 predictor DOM cloud simulation (SEVIRI) with interpolation, 50L profile
14. Visible-only MFASIS cloud simulation (SEVIRI), 50L profile
15. RTTOV-SCATT MW cloud scattering simulation (ATMS) with interpolation, 61L profile
16. PC-RTTOV simulation (IASI), O3-only without interpolation, PCscores only, 101L profile
17. PC-RTTOV simulation (IASI), O3-only without interpolation with rec. radiances, 101L profile
18. PC-RTTOV simulation (IASI), 6gas without interpolation, PCscores only, 101L profile
19. PC-RTTOV simulation (IASI), 6gas without interpolation with rec. radiances, 101L profile
20. HTFRTC simulation (IASI), O3-only without interpolation, PCscores only, 101L profile
21. HTFRTC simulation (IASI), O3-only without interpolation, with rec. radiances, 101L profile
22. HTFRTC simulation (IASI), 7gas, PCscores only, 101L profile
23. HTFRTC simulation (IASI), 7gas, with rec. radiances, 101L profile

The ATMS and SEVIRI coefficients are on 54L and the IASI coefficients are on 101L. In each case the profile surface type was set to sea with *calcemis* and *calcrefl* set to true for all channels. The following options/inputs were used:

- FASTEM6 for MW sea surface emissivity.
- IREMIS for IR sea surface emissivity.
- Elfouhaily et al option for solar sea surface BRDF.
- MW CLW simulations used Rosenkranz water permittivity parameterisation.
- 7gas implies all variable gases supported by RTTOV.
- 6gas implies all variable gases supported by RTTOV excluding SO<sub>2</sub>.
- Visible/IR cloud scattering used the OPAC CLW scheme and Baran 2018 ice scheme.
- Visible/IR aerosol scattering used the OPAC optical properties.
- DOM scattering simulations used 8 streams.
- MFASIS simulations used the CLW Deff and Baum ice optical properties.
- Input units for cloud/aerosol profiles were kg/kg.
- RTTOV-SCATT simulations in v13 use only the 4 hydrometeors available in v12.
- The SEVIRI IR-only and ATMS simulations were run for all channels.
- The SEVIRI visible-only simulations were run for channels 1-3.
- The IASI clear-sky simulations were run for 183 channels.
- PC-RTTOV simulations used the NLTE+trace gas enabled PC coefficient file.
- PC-RTTOV was run with ipcreg 1 (300 predictor channels) and 100 PC scores.
- PC-RTTOV reconstructed radiances were calculated for 300 channels.
- HTFRTC was run with 100 PC scores.
- HTFRTC reconstructed radiances were calculated for 300 channels.

All other options were selected to make the simulations as similar as possible between v12.3 and v13.0. Where possible the RTTOV v13 defaults are used (where v12.3 supports them), otherwise the v12.3 behaviour is selected in v13.0.

## 1. Speed comparisons

Tests were performed on an Intel compute cluster (Haswell) using ifort v17.0.1 and gfortran v8.1.0, a Cray XC-40 (Ivy Bridge) using the Cray Fortran compiler v8.3.4.

The tests were run for a large number of profiles, shown in Table 1.

Test case	Model(s)	Number of profiles
1 (MW clear, no int)	direct/TL/AD/K	500000
2 (MW clear, int)	direct/TL/AD/K	500000
3 (MW CLW)	direct/TL/AD/K	500000
4 (IR v7 clear)	direct/TL/AD/K	500000
5 (IR v8 clear)	direct/TL/AD/K	500000
6 (VIS v9 clear)	direct/TL/AD/K	500000
7 (IR v9 7gas clear)	direct/TL/AD/K	50000
8 (v7 IR Chou aer)	direct/TL/AD/K	500000
9 (v7 IR Chou cld)	direct/TL/AD/K	500000
10 (v7 IR DOM aer)	direct TL AD/K	50000 20000 5000
11 (v7 IR DOM cld)	direct TL AD/K	20000 10000 500
12 (v9 VIS DOM aer)	direct/TL AD/K	50000 5000
13 (v9 VIS DOM cld)	direct/TL AD/K	50000 5000
14 (MFASIS)	direct/TL AD/K	500000 250000
15 (RTTOV-SCATT)	direct/TL AD/K	500000 100000
16 (PC-RTTOV, O3, noRR)	direct/TL/AD K	50000 2000
17 (PC-RTTOV, O3, RR)	direct/TL/AD K	50000 2000
18 (PC-RTTOV, 6gas, no RR)	direct/TL/AD K	50000 2000
19 (PC-RTTOV, 6gas, RR)	direct/TL/AD K	50000 2000
20 (HTFRTC, O3, no RR)	direct K	50000 2000
21 (HTFRTC, O3, RR)	direct K	50000 2000
22 (HTFRTC, 7gas, no RR)	direct K	50000 2000
23 (HTFRTC, 7gas, RR)	direct K	50000 2000

Table 1: Number of profiles used for each timing test.

All tests were run with one profile passed to RTTOV per call and the results are shown in Table 2. In addition, test case 1 for ATMS was run for 50 profiles per call: the results are shown in Table 3. Timings were taken from the test suite and the timing results are shown as *ms per profile*. The colour-coding is as follows:

- green => v13.0 more than 10% faster than v12.3
- yellow => v13.0 5-10% faster than v12.3
- grey => v13.0 run-time within +/-5% that of v12.3
- orange => v13.0 5-10% slower than v12.3
- red => v13.0 more than 10% slower than v12.3

The timing results show a certain amount of inconsistency between compilers (for example, test 6 visible clear-sky, test 8 IR aerosol Chou-scaling) which suggests the presence of some noise in the timings. However, some trends are clear:

Clear-sky simulations are slightly slower in v13.0 than v12.3, with the K model slightly more affected than the direct, TL and AD. This is primarily a result of internal restructuring/refactoring work done in v13 to improve the clarity and maintainability of the core code. We will look at improving this for a future release.

Developments for v13 included optimisation of the DOM solver (especially the AD and K), the MFASIS fast visible cloud parameterisation, and the HTFRTC model, and these are reflected in the substantial reductions in run-times for these types of simulation.

### **RTTOV v13 predictors vs v789 predictors**

Table 4 shows results comparing the speed of clear-sky simulations using the old v789 predictor coefficients with equivalent simulations using the new v13 predictors. All tests were run using RTTOV v13.0 using the default option settings. The following tests are run:

- ATMS – v7pred vs v13pred (no optional gases)
- SEVIRI IR channels – v7pred vs v13pred (O3-only)
- SEVIRI IR channels – v8pred vs v13pred (O3+CO2)
- SEVIRI IR channels – v9pred vs v13pred (O3+CO2)
- SEVIRI VIS channels – v9pred vs v13pred (O3+CO2)
- IASI (183 channels) – v9pred vs v13pred (7gas)

The v13 predictor simulations are expected to be slightly more expensive than the equivalent v789 predictor simulations due to the calculation of the additional correction term (see the RTTOV v13 Science and Validation Report for a description of the new prediction scheme) and this is generally borne out in the results. Efforts will be made to improve the performance of the v13 predictors for a future release.

### **PC-RTTOV vs HTFRTC**

Table 5 compares PC-RTTOV and HTFRTC using ifort v17.0.1 on an Intel desktop. For both models the direct and K runs are simulating 1 profile in each call and are repeated 20000 and 2000 times respectively. The simulations are run for profiles on 54 levels with variable ozone only and for profiles on 101 levels with all trace gases except SO2. In both cases they simulate 100 PC scores, and the reconstructed radiance tests simulate radiances for 300 channels. The latest trace gas plus NLTE PC-RTTOV coefficients are used.

HTFRTC underwent optimisation for v13.0 to mitigate the slower performance in v12.3. As the results show, HTFRTC is now substantially faster than PC-RTTOV in most configurations. The only exception is the K model with 6 gases, and here the performance is still comparable to PC-RTTOV.

## 2. Memory comparisons

Peak memory usage was measured using valgrind's massif tool. This is intended to give a rough idea of memory requirements for different types of simulation and, more importantly, to enable comparisons between different versions of RTTOV and between RTTOV configurations. Tests were performed on an Intel desktop using the gfortran v8.1 compiler and the results are shown in Table 6. The colour-coding is as follows:

- green => peak memory for v13.0 90% or less than that for v12.3
- yellow => peak memory for v13.0 90-95% than that for v12.3
- grey => peak memory for v13.0 within +/-5% that of v12.3
- orange => peak memory for v13.0 105-110% than that for v12.3
- red => peak memory for v13.0 110% or more than that for v12.3

The IASI and MFASIS tests are run after extracting coefficients for the required channels for each test to separate "binary" (Fortran unformatted) files. This gives a more representative idea of the memory usage of the test itself, otherwise the peak memory is dominated by that required to read in the full HDF5 coefficient files.

The differences between v12.3 and v13.0 are mostly very small. The K model for v9 predictors takes slightly more memory in v13.0 which is due to the restructuring/refactoring of the code described above. The DOM solver in the AD and K models requires more memory in v13.0 as a result of the optimisation noted above. This is most obvious for the IR test case here as the increase is proportional to the number of scattering layers which is typically larger in the IR than the visible. The memory required by the HTFRTC model has been reduced significantly in v13.0.

### RTTOV v13 predictors vs v789 predictors

The peak memory usage for v13 predictor simulations compared to equivalent v789 predictor simulations is shown in Table 7. The same tests are run as in the speed comparisons above. Again, for IASI simulations, the channels for the simulation are extracted to a binary file to give more representative values.

It is expected that the v13 predictors require more memory than the older v789 predictors as the correction term requires storage for additional coefficients. The impact of the correction term coefficients is seen most in v7/v8 predictor simulations in the IR (i.e. with variable gases) and for v9 predictor simulations with all trace gases.

Test case	Model	Intel gfortran v12.3	Intel gfortran v13.0	Intel gfortran v13.0:v12.3	Intel ifort v12.3	Intel ifort v13.0	Intel ifort v13.0:v12.3	Cray v12.3	Cray v13.0	Cray v13.0:v12.3
	Direct	0.229	0.23	1.00	0.144	0.139	0.97	0.161	0.161	1.00
1	TL	0.384	0.396	1.03	0.265	0.257	0.97	0.317	0.335	1.06
MW, no interp	AD	0.5	0.506	1.01	0.345	0.348	1.01	0.334	0.341	1.02
	K	0.705	0.769	1.09	0.491	0.492	1.00	0.5	0.53	1.06
	Direct	0.338	0.392	1.16	0.227	0.229	1.01	0.236	0.247	1.05
2	TL	0.658	0.665	1.01	0.414	0.423	1.02	0.467	0.482	1.03
MW, interp	AD	0.765	0.79	1.03	0.528	0.539	1.02	0.511	0.513	1.00
	K	1.122	1.162	1.04	0.752	0.824	1.10	0.724	0.775	1.07
	Direct	0.624	0.679	1.09	0.407	0.404	0.99	0.421	0.42	1.00
3	TL	1.191	1.227	1.03	0.786	0.79	1.00	0.864	0.893	1.03
MW, CLW	AD	1.337	1.352	1.01	0.933	0.944	1.01	0.918	0.916	1.00
	K	2.007	2.117	1.05	1.316	1.357	1.03	1.415	1.469	1.04
	Direct	0.175	0.177	1.01	0.12	0.124	1.04	0.134	0.133	0.99
4	TL	0.297	0.321	1.08	0.222	0.229	1.03	0.256	0.261	1.02
IR v7 clear	AD	0.376	0.387	1.03	0.275	0.284	1.04	0.277	0.28	1.01
	K	0.526	0.552	1.05	0.372	0.401	1.08	0.366	0.383	1.05
	Direct	0.183	0.187	1.02	0.13	0.133	1.03	0.14	0.143	1.02
5	TL	0.339	0.327	0.96	0.238	0.248	1.05	0.268	0.278	1.04
IR v8 clear	AD	0.428	0.422	0.99	0.298	0.322	1.08	0.283	0.293	1.03
	K	0.594	0.627	1.06	0.417	0.464	1.11	0.405	0.425	1.05
	Direct	0.254	0.241	0.95	0.144	0.159	1.10	0.157	0.167	1.06
6	TL	0.475	0.463	0.97	0.284	0.308	1.08	0.303	0.319	1.05
Visible clear	AD	0.553	0.492	0.89	0.325	0.346	1.07	0.319	0.341	1.07
	K	0.75	0.722	0.96	0.446	0.481	1.08	0.415	0.441	1.06
	Direct	2.967	3.213	1.08	1.99	2.54	1.28	2.253	2.394	1.06
7	TL	5.905	5.553	0.94	4.1	5.032	1.23	4.673	5.036	1.08
7 gas clear	AD	6.189	6.453	1.04	5.483	5.427	0.99	5.185	5.319	1.03
	K	22.792	22.246	0.98	22.13	23.233	1.05	20.58	22.436	1.09
	Direct	0.164	0.161	0.98	0.128	0.133	1.03	0.148	0.149	1.00
8	TL	0.327	0.288	0.88	0.247	0.257	1.04	0.273	0.29	1.06
IR aerosol	AD	0.409	0.357	0.87	0.301	0.304	1.01	0.293	0.314	1.07
Chou-scaling	K	0.552	0.615	1.12	0.44	0.446	1.01	0.43	0.448	1.04
	Direct	0.349	0.366	1.05	0.206	0.22	1.07	0.243	0.25	1.03
9	TL	0.609	0.735	1.21	0.396	0.415	1.05	0.485	0.498	1.03
IR cloud	AD	0.742	0.796	1.07	0.52	0.545	1.05	0.547	0.554	1.01
Chou-scaling	K	0.854	1.046	1.23	0.62	0.665	1.07	0.674	0.677	1.01
	Direct	1.068	1.167	1.09	1.238	1.085	0.88	1.104	1.087	0.98
10	TL	2.698	2.856	1.06	3.094	3.006	0.97	2.424	2.436	1.00
IR aerosol	AD	57.292	33.198	0.58	65.902	36.172	0.55	58.08	34.546	0.59
DOM	K	58.13	34.324	0.59	66.4	37.166	0.56	59.306	34.724	0.59
	Direct	6.718	6.507	0.97	7.358	6.681	0.91	5.906	5.682	0.96
11	TL	18.051	18.189	1.01	18.403	18.173	0.99	13.761	13.54	0.98
IR cloud	AD	461.68	257.82	0.56	511.38	275.88	0.54	451.2	266.28	0.59
DOM	K	460.24	259.02	0.56	502.66	281.82	0.56	453.9	261.82	0.58
	Direct	2.073	2.031	0.98	2.394	2.096	0.88	2.183	2.134	0.98
12	TL	4.898	4.863	0.99	5.743	5.529	0.96	4.505	4.448	0.99
Visible aerosol	AD	28.994	17.23	0.59	31.128	20.25	0.65	27.058	17.338	0.64
DOM	K	28.958	17.656	0.61	31.544	20.53	0.65	27.76	17.392	0.63

Table 2 (continued below): Speed test results, 1 profile per call. Timings are ms per profile.

	Direct	3.199	3.107	0.97	3.04	3.018	0.99	2.724	2.574	0.94
13	TL	8.179	8.203	1.00	7.774	7.929	1.02	6.212	6.225	1.00
Visible cloud	AD	25.42	19.73	0.78	28.598	22.514	0.79	22.908	16.184	0.71
DOM	K	25.336	20.25	0.80	30.09	22.38	0.74	22.212	16.062	0.72
	Direct	0.935	0.36	0.38	0.79	0.276	0.35	0.88	0.33	0.37
14	TL	1.119	0.539	0.48	0.874	0.381	0.44	0.988	0.434	0.44
Visible cloud	AD	1.122	0.557	0.50	0.888	0.394	0.44	1.021	0.442	0.43
MFASIS	K	1.197	0.663	0.55	0.92	0.438	0.48	1.057	0.478	0.45
	Direct	0.795	0.848	1.07	0.509	0.557	1.10	0.572	0.562	0.98
15	TL	1.333	1.342	1.01	0.905	1.003	1.11	1.015	1.021	1.01
RTTOV-SCATT	AD	2.948	3.032	1.03	2.076	2.26	1.09	2.076	2.226	1.07
	K	3.584	3.832	1.07	2.568	2.904	1.13	2.49	2.796	1.12
	Direct	4.516	4.204	0.93	4.152	3.95	0.95	3.793	3.821	1.01
16	TL	7.033	7.493	1.07	7.059	7.368	1.04	8.125	7.977	0.98
PC	AD	8.838	9.45	1.07	8.517	9.174	1.08	8.414	8.708	1.03
O3-only	K	36.885	38.645	1.05	33.925	35.6	1.05	29.45	31.72	1.08
	Direct	3.875	4.647	1.20	3.528	4.103	1.16	3.678	4.019	1.09
17	TL	7.049	8.03	1.14	6.544	7.59	1.16	7.97	9.197	1.15
PC, RR	AD	9.668	9.933	1.03	8.339	9.194	1.10	9.3	8.838	0.95
O3-only	K	69.18	66.24	0.96	56.595	53.125	0.94	50.21	48.645	0.97
	Direct	4.296	4.284	1.00	4.477	3.947	0.88	3.954	3.683	0.93
18	TL	7.453	7.915	1.06	7.3	7.432	1.02	8.724	9.099	1.04
PC	AD	9.738	9.609	0.99	8.86	9.191	1.04	9.625	8.522	0.89
6 gas	K	55.96	53.55	0.96	48.205	48.12	1.00	37.555	41.52	1.11
	Direct	4.593	4.499	0.98	3.969	3.965	1.00	3.81	4.328	1.14
19	TL	8.061	8.047	1.00	7.726	7.793	1.01	8.447	8.987	1.06
PC, RR	AD	9.169	10.736	1.17	9.282	9.413	1.01	8.329	9.784	1.17
6 gas	K	106.105	111.05	1.05	78.705	79.235	1.01	65.42	67.805	1.04
	Direct	3.109	1.924	0.62	4.501	2.217	0.49	2.401	1.155	0.48
20	TL	-	-	-	1	1	1.00	-	-	-
HTFRTC	AD	-	-	-	1	1	1.00	-	-	-
O3-only	K	19.275	16.68	0.87	32.52	30.73	0.94	13.865	11.315	0.82
	Direct	3.582	2.042	0.57	4.809	2.162	0.45	2.58	1.16	0.45
21	TL	-	-	-	1	1	1.00	-	-	-
HTFRTC, RR	AD	-	-	-	1	1	1.00	-	-	-
O3-only	K	27.745	25.645	0.92	60.06	45.2	0.75	32.06	14.085	0.44
	Direct	6.392	2.498	0.39	7.948	3.046	0.38	7.331	1.412	0.19
22	TL	-	-	-	1	1	1.00	-	-	-
HTFRTC	AD	-	-	-	1	1	1.00	-	-	-
7 gas	K	37.035	35.4	0.96	59.005	69.69	1.18	29.705	27.48	0.93
	Direct	6.258	2.311	0.37	8.451	2.934	0.35	6.443	1.403	0.22
23	TL	-	-	-	1	1	1.00	-	-	-
HTFRTC, RR	AD	-	-	-	1	1	1.00	-	-	-
7 gas	K	59.51	49.49	0.83	134.115	100.305	0.75	94.035	36.205	0.39

Table 2 (continued from above): Speed test results, 1 profile per call. Timings are ms per profile.

Test case	Model	Intel gfortran v12.3	Intel gfortran v13.0	Intel gfortran v13.0:v12.3	Intel ifort v12.3	Intel ifort v13.0	Intel ifort v13.0:v12.3	Cray v12.3	Cray v13.0	Cray v13.0:v12.3
	Direct	0.179	0.185	1.04	0.127	0.126	0.99	0.12	0.127	1.06
1	TL	0.313	0.325	1.04	0.238	0.243	1.02	0.267	0.282	1.06
MW, no interp	AD	0.42	0.434	1.03	0.317	0.313	0.99	0.269	0.288	1.07
	K	0.68	0.733	1.08	0.563	0.588	1.04	0.577	0.654	1.13

Table 3: Speed test results, 50 profiles per cal. Timings are ms per profile.

Test case	Model	Intel gfortran v789	Intel gfortran v13	Intel gfortran v13:v789	Intel ifort v789	Intel ifort v13	Intel ifort v13:v789	Cray v789	Cray v13	Cray v13:v789
	Direct	0.411	0.411	1.00	0.226	0.246	1.09	0.244	0.263	1.08
1	TL	0.719	0.699	0.97	0.395	0.492	1.25	0.486	0.534	1.10
MW v7 / v13	AD	0.818	0.782	0.96	0.537	0.572	1.07	0.513	0.57	1.11
No gas	K	1.192	1.206	1.01	0.883	0.954	1.08	0.776	0.883	1.14
	Direct	0.183	0.21	1.15	0.124	0.133	1.07	0.138	0.152	1.10
2	TL	0.324	0.351	1.08	0.231	0.249	1.08	0.263	0.29	1.10
IR v7 / v13	AD	0.397	0.374	0.94	0.288	0.303	1.05	0.276	0.31	1.12
O3-only	K	0.567	0.58	1.02	0.411	0.455	1.11	0.389	0.436	1.12
	Direct	0.193	0.213	1.10	0.134	0.145	1.08	0.145	0.16	1.10
3	TL	0.346	0.371	1.07	0.245	0.273	1.11	0.292	0.308	1.05
IR v8 / v13	AD	0.439	0.42	0.96	0.318	0.333	1.05	0.3	0.327	1.09
O3+CO2	K	0.646	0.63	0.98	0.463	0.538	1.16	0.429	0.488	1.14
	Direct	0.196	0.213	1.09	0.142	0.145	1.02	0.15	0.16	1.07
4	TL	0.355	0.371	1.05	0.265	0.273	1.03	0.29	0.308	1.06
IR v9 / v13	AD	0.393	0.42	1.07	0.321	0.333	1.04	0.31	0.327	1.05
O3+CO2	K	0.638	0.63	0.99	0.519	0.538	1.04	0.486	0.488	1.00
	Direct	0.247	0.255	1.03	0.155	0.153	0.99	0.171	0.175	1.02
5	TL	0.471	0.493	1.05	0.3	0.298	0.99	0.327	0.33	1.01
VIS v9 / v13	AD	0.503	0.524	1.04	0.342	0.335	0.98	0.333	0.347	1.04
O3+CO2	K	0.733	0.764	1.04	0.466	0.457	0.98	0.444	0.455	1.02
	Direct	3.481	3.889	1.12	2.319	2.902	1.25	2.328	3.098	1.33
6	TL	5.826	6.384	1.10	4.768	5.475	1.15	5.037	6.461	1.28
IR v9 / v13	AD	6.859	7.722	1.13	5.753	6.761	1.18	5.743	6.82	1.19
7 gas	K	22.98	22.175	0.96	22.237	21.54	0.97	22.657	22.375	0.99

Table 4: Speed test results comparing simulations using the old v789 predictors with equivalent v13 predictor simulations. Timings are ms per profile.

Test case	Model	Simulated output	PC-RTTOV	HTFRTC	HTFRTC:PC-RTTOV
54 levels ozone only	Direct	PC scores	3.65	1.32	0.36
		Rec. rads	3.52	1.18	0.34
	K	PC scores	32.88	14.02	0.43
		Rec. rads	46.75	21.41	0.46
101 levels all gases (except so2)	Direct	PC scores	4.08	2.84	0.70
		Rec. rads	4.21	2.79	0.66
	K	PC scores	50.26	53.03	1.06
		Rec. rads	87.10	77.83	0.89

Table 5: Speed test results comparing PC-RTTOV and HTFRTC. Timings are ms per profile.

Test case	Model	v12.3 peak memory (MB)	v13.0 peak memory (MB)	v13.0:v12.3
	Direct	1.832	1.853	1.01
1	TL	1.832	1.853	1.01
MW, no interp	AD	1.832	1.853	1.01
	K	2.597	2.681	1.03
	Direct	1.832	1.853	1.01
2	TL	2.127	2.193	1.03
MW, interp	AD	2.145	2.228	1.03
	K	3.11	3.195	1.02
	Direct	1.832	1.853	1.01
3	TL	2.153	2.219	1.03
MW, CLW	AD	2.171	2.254	1.03
	K	3.402	3.505	1.03
	Direct	1.35	1.373	1.01
4	TL	1.612	1.646	1.02
IR v7 clear	AD	1.619	1.659	1.02
	K	1.991	2.032	1.02
	Direct	1.403	1.428	1.01
5	TL	1.674	1.711	1.02
IR v8 clear	AD	1.681	1.724	1.02
	K	2.115	2.164	1.02
	Direct	1.526	1.549	1.01
6	TL	1.729	1.761	1.01
Visible clear	AD	1.732	1.766	1.01
	K	1.961	2.005	1.02
	Direct	15.19	15.41	1.01
7	TL	17.81	18.36	1.03
All gas clear	AD	17.82	18.65	1.04
	K	51.93	55.18	1.06
	Direct	1.687	1.686	0.99
8	TL	1.855	1.859	1.00
IR aerosol	AD	1.858	1.865	1.00
Chou-scaling	K	2.259	2.274	1.00
	Direct	2.285	2.293	1.00
9	TL	2.778	2.792	1.00
IR cloud	AD	2.776	2.793	1.00
Chou-scaling	K	4.341	4.374	1.00
	Direct	1.864	1.863	0.99
10	TL	2.612	2.616	1.00
IR aerosol	AD	2.62	3.706	1.41
DOM	K	3.02	4.115	1.36
	Direct	2.415	2.423	1.00
11	TL	4.459	4.473	1.00
IR cloud	AD	4.467	5.562	1.24
DOM	K	6.033	7.136	1.18
	Direct	2.612	2.615	1.00
12	TL	4.343	4.35	1.00
Visible aerosol	AD	4.345	4.499	1.03
DOM	K	4.579	4.744	1.03

Table 6 (continued below): Memory test results.



	Direct	3.479	3.49	1.00
13	TL	6.45	6.469	1.00
Visible cloud	AD	6.454	6.513	1.00
DOM	K	7.021	7.093	1.01
	Direct	109.2	109.5	1.00
14	TL	109.9	109.2	0.99
Visible cloud	AD	109.9	109.2	0.99
MFASIS	K	110.1	110.1	1.00
	Direct	71.92	71.94	1.00
15	TL	72.65	72.65	1.00
RTTOV-SCATT	AD	72.64	72.66	1.00
	K	73.37	73.39	1.00
	Direct	104.9	104.9	1.00
16	TL	104.9	104.9	1.00
PC	AD	104.9	104.9	1.00
O3-only	K	137.6	141.7	1.02
	Direct	42.6	42.61	1.00
17	TL	42.6	42.61	1.00
PC, RR	AD	42.6	42.61	1.00
O3-only	K	88.26	93.13	1.05
	Direct	104.9	104.9	1.00
18	TL	104.9	104.9	1.00
PC	AD	104.9	104.9	1.00
6 gas	K	139.8	144.9	1.03
	Direct	42.6	42.61	1.00
19	TL	42.6	42.61	1.00
PC, RR	AD	42.6	42.61	1.00
6 gas	K	92.04	96.91	1.05
	Direct	141.1	110.4	0.78
20	TL	-	-	-
HTFRTC	AD	-	-	-
O3-only	K	141.7	114.3	0.80
	Direct	132.9	20.91	0.15
21	TL	-	-	-
HTFRTC, RR	AD	-	-	-
O3-only	K	141	26.23	0.18
	Direct	141.1	109.7	0.77
22	TL	-	-	-
HTFRTC	AD	-	-	-
7 gas	K	142.1	115.9	0.81
	Direct	132.9	20.91	0.15
23	TL	-	-	-
HTFRTC, RR	AD	-	-	-
7 gas	K	145.4	28.98	0.19

Table 6 (continued from above): Memory test results.

Test case	Model	v789 peak memory (MB)	v13 peak memory (MB)	v13:v789
	Direct	1.853	1.891	1.02
1	TL	2.193	2.349	1.07
MW v7 / v13	AD	2.228	2.384	1.07
No gas	K	3.195	3.454	1.08
	Direct	1.373	1.655	1.21
2	TL	1.646	1.945	1.18
IR v7 / v13	AD	1.659	1.958	1.18
O3-only	K	2.032	2.37	1.17
	Direct	1.428	1.77	1.24
3	TL	1.711	2.072	1.21
IR v8 / v13	AD	1.724	2.085	1.21
O3+CO2	K	2.164	2.562	1.18
	Direct	1.703	1.77	1.04
4	TL	1.995	2.072	1.04
IR v9 / v13	AD	2.008	2.085	1.04
O3+CO2	K	2.507	2.562	1.02
	Direct	1.549	1.581	1.02
5	TL	1.761	1.787	1.01
VIS v9 / v13	AD	1.766	1.792	1.01
O3+CO2	K	2.005	2.019	1.01
	Direct	15.41	17.66	1.15
6	TL	18.36	20.46	1.11
IR v9 / v13	AD	18.65	20.75	1.11
7 gas	K	55.18	56.17	1.02

Table 7: Memory test results for old v789 predictors vs new v13 predictors.