

## RTTOV v13.1 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 v13.1 with that of RTTOV v13.0. This includes comparisons of execution speed and peak memory usage.

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 v13 predictor O3-only simulation (SEVIRI) with interpolation, 101L profile
5. IR v13 predictor O3+CO2 simulation (SEVIRI) with interpolation, 101L profile
6. Visible-only v13 predictor O3+CO2 simulation (SEVIRI) with interpolation, 101L profile
7. v13 predictor 7gas simulation (IASI) without interpolation, 101L profile
8. IR v13 predictor O3+CO2 Chou-scaling aerosol simulation (SEVIRI) with interpolation, 50L profile
9. IR v13 predictor O3+CO2 Chou-scaling cloud simulation (SEVIRI) with interpolation, 50L profile
10. IR v13 predictor O3+CO2 DOM aerosol simulation (SEVIRI) with interpolation, 50L profile
11. IR v13 predictor O3+CO2 DOM cloud simulation (SEVIRI) with interpolation, 50L profile
12. Visible-only v13 predictor O3+CO2 DOM aerosol simulation (SEVIRI) with interpolation, 50L profile
13. Visible-only v13 predictor O3+CO2 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

Coefficients based on v13 predictors are used in all cases except PC-RTTOV. 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 use only rain, snow, clw and ciw.
- The SEVIRI IR-only and ATMS simulations were run for all channels.
- The SEVIRI visible-only simulations were run for channels 1-3.
- The MFASIS simulations were run for channels 1-2.
- 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.

RTTOV v13 defaults are used for all options where otherwise unspecified.

## 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 v13 O3-only clear)	direct/TL/AD/K	500000
5 (IR v13 O3+CO2 clear)	direct/TL/AD/K	500000
6 (VIS v13 O3+CO2 clear)	direct/TL/AD/K	500000
7 (IR v13 7gas clear)	direct/TL/AD/K	50000
8 (v13 IR Chou aer)	direct/TL/AD/K	500000
9 (v13 IR Chou cld)	direct/TL/AD/K	500000
10 (v13 IR DOM aer)	direct TL AD/K	50000 20000 5000
11 (v13 IR DOM cld)	direct TL AD/K	20000 10000 500
12 (v13 VIS DOM aer)	direct/TL AD/K	50000 5000
13 (v13 VIS DOM cld)	direct/TL AD/K	50000 5000
14 (MFAIS)	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 => v13.1 more than 10% faster than v13.0
- yellow => v13.1 5-10% faster than v13.0
- grey => v13.1 run-time within +/-5% that of v13.0
- orange => v13.1 5-10% slower than v13.0
- red => v13.1 more than 10% slower than v13.0

There are no code changes between RTTOV v13.0 and v13.1 that are expected to impact run-time performance. The results in Table 2 show a certain amount of inconsistency between compilers which suggests noise in the tests. The timings which differ substantially from a ratio of 1.0 in both the positive and negative directions are strongly believed to not be indicative of systematic changes in performance. This has been confirmed in selected tests re-run subsequently to investigate these timing results.

## 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 4. The colour-coding is as follows:

- green => peak memory for v13.1 90% or less than that for v13.0
- yellow => peak memory for v13.1 90-95% than that for v13.0
- grey => peak memory for v13.1 within +/-5% that of v13.0
- orange => peak memory for v13.1 105-110% than that for v13.0
- red => peak memory for v13.1 110% or more than that for v13.0

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 simulation itself, otherwise the peak memory is dominated by that required to read in the full HDF5 coefficient files.

As expected, there is no significant difference in memory consumption between RTTOV v13.0 and v13.1 for any simulation type.

Test case	Model	Intel gfortran v13.0	Intel gfortran v13.1	Intel gfortran v13.1:v13.0	Intel ifort v13.0	Intel ifort v13.1	Intel ifort v13.1:v13.0	Cray v13.0	Cray v13.1	Cray v13.1:v13.0
	Direct	0.234	0.231	0.99	0.172	0.174	1.01	0.187	0.185	0.99
1	TL	0.395	0.409	1.04	0.339	0.335	0.99	0.357	0.358	1.00
MW, no interp	AD	0.448	0.454	1.01	0.406	0.408	1.00	0.387	0.389	1.00
	K	0.763	0.776	1.02	0.753	0.748	0.99	0.631	0.628	0.99
	Direct	0.383	0.382	1.00	0.254	0.263	1.03	0.265	0.264	0.99
2	TL	0.626	0.627	1.00	0.497	0.495	1.00	0.52	0.527	1.01
MW, interp	AD	0.715	0.701	0.98	0.592	0.602	1.02	0.562	0.559	0.99
	K	1.122	1.146	1.02	1.066	1.027	0.96	0.88	0.875	0.99
	Direct	0.633	0.64	1.01	0.448	0.419	0.93	0.451	0.434	0.96
3	TL	1.13	1.145	1.01	0.853	0.829	0.97	0.945	0.917	0.97
MW, CLW	AD	1.231	1.218	0.99	0.978	0.978	1.00	0.992	0.964	0.97
	K	1.924	1.924	1.00	1.594	1.579	0.99	1.634	1.573	0.96
	Direct	0.187	0.183	0.98	0.123	0.147	1.19	0.146	0.149	1.03
4	TL	0.325	0.325	1.00	0.264	0.286	1.09	0.285	0.287	1.00
IR v13 O3 clear	AD	0.359	0.357	1.00	0.32	0.338	1.06	0.3	0.304	1.01
	K	0.54	0.536	0.99	0.537	0.536	1.00	0.444	0.433	0.98
	Direct	0.195	0.189	0.97	0.138	0.156	1.13	0.166	0.162	0.98
5	TL	0.358	0.356	0.99	0.248	0.252	1.02	0.319	0.314	0.98
IR v13 O3+CO2 clear	AD	0.395	0.392	0.99	0.292	0.302	1.03	0.339	0.331	0.97
	K	0.606	0.605	1.00	0.6	0.599	1.00	0.502	0.485	0.97
	Direct	0.226	0.229	1.01	0.145	0.178	1.23	0.172	0.166	0.97
6	TL	0.432	0.433	1.00	0.317	0.357	1.13	0.32	0.312	0.98
Visible clear	AD	0.456	0.457	1.00	0.348	0.403	1.16	0.337	0.336	1.00
	K	0.653	0.656	1.01	0.513	0.537	1.05	0.453	0.473	1.04
	Direct	3.621	4.062	1.12	3.556	3.539	1.00	3.308	3.103	0.94
7	TL	6.406	6.532	1.02	6.057	6.893	1.14	6.658	6.478	0.97
7 gas clear	AD	6.887	6.947	1.01	7.107	7.527	1.06	6.765	6.728	0.99
	K	22.264	22.536	1.01	24.805	26.012	1.05	22.918	22.739	0.99
	Direct	0.182	0.18	0.99	0.148	0.163	1.10	0.178	0.17	0.96
8	TL	0.305	0.306	1.00	0.28	0.271	0.97	0.35	0.33	0.94
IR aerosol	AD	0.332	0.332	1.00	0.321	0.322	1.00	0.367	0.363	0.99
Chou-scaling	K	0.599	0.599	1.00	0.628	0.621	0.99	0.55	0.547	1.00
	Direct	0.36	0.325	0.90	0.273	0.279	1.03	0.281	0.268	0.95
9	TL	0.704	0.672	0.95	0.549	0.544	0.99	0.566	0.531	0.94
IR cloud	AD	0.783	0.736	0.94	0.663	0.671	1.01	0.621	0.592	0.95
Chou-scaling	K	0.885	0.888	1.00	0.811	0.79	0.97	0.795	0.745	0.94
	Direct	1.018	1.015	1.00	1.038	1.047	1.01	1.15	1.102	0.96
10	TL	2.512	2.53	1.01	2.784	2.906	1.04	2.602	2.566	0.99
IR aerosol	AD	30.66	30.996	1.01	36.42	33.332	0.92	35.274	34.5	0.98
DOM	K	31.324	31.452	1.00	37.12	33.722	0.91	36.76	34.776	0.95
	Direct	5.831	5.944	1.02	5.843	5.66	0.97	6.54	6.285	0.96
11	TL	15.443	15.616	1.01	15.416	15.991	1.04	14.389	13.954	0.97
IR cloud	AD	236.64	237.02	1.00	277.74	294.62	1.06	268.94	269.1	1.00
DOM	K	239.38	240.36	1.00	279.42	293.78	1.05	269.9	268.38	0.99
	Direct	1.762	1.792	1.02	1.923	2.076	1.08	2.182	2.187	1.00
12	TL	4.299	4.323	1.01	5.375	5.75	1.07	4.656	4.574	0.98
Visible aerosol	AD	16.902	17.062	1.01	19.882	21.188	1.07	17.876	18.448	1.03
DOM	K	16.982	17.192	1.01	19.974	21.064	1.05	17.59	18.692	1.06

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

	Direct	2.588	2.604	1.01	2.558	2.649	1.04	2.667	3.122	1.17
13	TL	6.715	6.792	1.01	7.106	7.607	1.07	6.201	6.326	1.02
Visible cloud	AD	18.826	19.11	1.02	20.1	21.632	1.08	15.774	16.258	1.03
DOM	K	18.94	19.078	1.01	20.1	21.502	1.07	16.244	16.584	1.02
	Direct	0.33	0.344	1.04	0.29	0.3	1.03	0.334	0.339	1.01
14	TL	0.494	0.506	1.02	0.413	0.419	1.01	0.438	0.432	0.99
Visible cloud	AD	0.508	0.525	1.03	0.458	0.463	1.01	0.44	0.439	1.00
MFASIS	K	0.588	0.608	1.03	0.494	0.522	1.06	0.485	0.472	0.97
	Direct	0.762	0.784	1.03	0.54	0.543	1.01	0.592	0.618	1.04
15	TL	1.208	1.21	1.00	0.89	0.914	1.03	1.066	1.095	1.03
RTTOV-SCATT	AD	2.8	2.807	1.00	2.037	2.032	1.00	2.331	2.433	1.04
	K	3.507	3.5	1.00	2.814	2.882	1.02	2.924	3.022	1.03
	Direct	3.984	4.785	1.20	4.065	4.112	1.01	4.318	3.874	0.90
16	TL	7.362	8.175	1.11	7.481	8.07	1.08	8.623	8.2	0.95
PC	AD	9.149	9.747	1.07	9.039	9.619	1.06	8.87	9.225	1.04
O3-only	K	38.755	39.71	1.02	36.855	38.915	1.06	38.285	32.775	0.86
	Direct	4.206	4.215	1.00	3.568	3.843	1.08	4.332	4.143	0.96
17	TL	7.668	7.772	1.01	6.989	7.534	1.08	9.39	8.114	0.86
PC, RR	AD	9.388	9.449	1.01	8.531	9.149	1.07	8.777	9.581	1.09
O3-only	K	65.74	66.235	1.01	55.715	57.72	1.04	48.98	47.095	0.96
	Direct	4.052	4.304	1.06	4.089	4.335	1.06	4.083	4.218	1.03
18	TL	7.491	7.558	1.01	7.677	8.103	1.06	8.59	8.976	1.04
PC	AD	9.189	9.329	1.02	9.067	9.685	1.07	9.099	9.1	1.00
6 gas	K	53.865	54.36	1.01	51.39	54.075	1.05	48.695	49.155	1.01
	Direct	4.272	4.275	1.00	3.704	3.971	1.07	4.532	3.688	0.81
19	TL	7.601	7.801	1.03	6.997	7.509	1.07	8.465	8.83	1.04
PC, RR	AD	9.394	9.443	1.01	8.99	9.07	1.01	8.753	9.029	1.03
6 gas	K	102.715	103.315	1.01	88.775	89.435	1.01	68.685	66.78	0.97
	Direct	1.775	1.8	1.01	2.284	2.187	0.96	1.094	1.102	1.01
20	TL	-	-	-	-	-	-	-	-	-
HTFRTC	AD	-	-	-	-	-	-	-	-	-
O3-only	K	15.525	15.635	1.01	29.215	28.16	0.96	10.615	10.565	1.00
	Direct	1.712	1.715	1.00	2.21	2.153	0.97	1.115	1.081	0.97
21	TL	-	-	-	-	-	-	-	-	-
HTFRTC, RR	AD	-	-	-	-	-	-	-	-	-
O3-only	K	23.76	23.88	1.01	43.65	42.145	0.97	14.535	14.105	0.97
	Direct	2.167	2.156	0.99	2.976	3.193	1.07	1.422	1.435	1.01
22	TL	-	-	-	-	-	-	-	-	-
HTFRTC	AD	-	-	-	-	-	-	-	-	-
7 gas	K	33.155	33.61	1.01	63.905	66.37	1.04	28.255	28.73	1.02
	Direct	2.089	2.124	1.02	2.872	2.889	1.01	1.427	1.404	0.98
23	TL	-	-	-	-	-	-	-	-	-
HTFRTC, RR	AD	-	-	-	-	-	-	-	-	-
7 gas	K	48.15	48.6	1.01	91.05	89.455	0.98	36.665	36.41	0.99

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

Test case	Model	Intel gfortran v13.0	Intel gfortran v13.1	Intel gfortran v13.1:v13.0	Intel ifort v13.0	Intel ifort v13.1	Intel ifort v13.1:v13.0	Cray v13.0	Cray v13.1	Cray v13.1:v13.0
	Direct	0.187	0.187	1.00	0.149	0.147	0.98	0.147	0.142	0.97
1	TL	0.331	0.331	1.00	0.288	0.279	0.97	0.311	0.309	0.99
MW, no interp	AD	0.374	0.374	1.00	0.346	0.346	1.00	0.334	0.331	0.99
	K	0.794	0.797	1.00	0.775	0.779	1.01	0.781	0.754	0.96

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

Test case	Model	v13.0 peak memory (MB)	v13.1 peak memory (MB)	v13.1:v13.0
	Direct	1.891	1.891	1.00
1	TL	1.956	1.956	1.00
MW, no interp	AD	1.96	1.959	1.00
	K	2.941	2.941	1.00
	Direct	1.898	1.895	1.00
2	TL	2.349	2.348	1.00
MW, interp	AD	2.384	2.383	1.00
	K	3.454	3.454	1.00
	Direct	1.911	1.91	1.00
3	TL	2.375	2.373	1.00
MW, CLW	AD	2.41	2.408	1.00
	K	3.762	3.752	1.00
	Direct	1.655	1.654	1.00
4	TL	1.945	1.945	1.00
IR v13 O3 clear	AD	1.958	1.958	1.00
	K	2.37	2.37	1.00
	Direct	1.77	1.769	1.00
5	TL	2.072	2.071	1.00
IR v13 O3+CO2 clear	AD	2.085	2.084	1.00
	K	2.561	2.561	1.00
	Direct	1.581	1.581	1.00
6	TL	1.787	1.787	1.00
Visible clear	AD	1.792	1.791	1.00
	K	2.019	2.019	1.00
	Direct	17.66	17.66	1.00
7	TL	20.46	20.46	1.00
All gas clear	AD	20.75	20.75	1.00
	K	56.17	56.17	1.00
	Direct	2.398	2.398	1.00
8	TL	2.585	2.584	1.00
IR aerosol	AD	2.591	2.591	1.00
Chou-scaling	K	3.098	3.098	1.00
	Direct	3.35	3.35	1.00
9	TL	3.825	3.825	1.00
IR cloud	AD	3.862	3.861	1.00
Chou-scaling	K	5.474	5.474	1.00
	Direct	2.551	2.571	1.01
10	TL	3.338	3.338	1.00
IR aerosol	AD	4.428	4.427	1.00
DOM	K	4.927	4.927	1.00
	Direct	3.463	3.463	1.00
11	TL	5.526	5.526	1.00
IR cloud	AD	6.616	6.616	1.00
DOM	K	8.28	8.28	1.00
	Direct	2.646	2.647	1.00
12	TL	4.376	4.376	1.00
Visible aerosol	AD	4.523	4.522	1.00
DOM	K	4.757	4.757	1.00

Table 4 (continued below): Memory test results.

	Direct	3.523	3.523	1.00
13	TL	6.495	6.494	1.00
Visible cloud	AD	6.539	6.539	1.00
DOM	K	7.107	7.106	1.00
	Direct	109.2	109.6	1.00
14	TL	109.2	110	1.01
Visible cloud	AD	109.2	109	1.00
MFASIS	K	110.1	110.1	1.00
	Direct	72.34	72.06	1.00
15	TL	72.78	72.78	1.00
RTTOV-SCATT	AD	72.78	72.78	1.00
	K	73.51	73.51	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	141.7	141.7	1.00
	Direct	42.61	42.61	1.00
17	TL	42.61	42.61	1.00
PC, RR	AD	42.61	42.61	1.00
O3-only	K	93.13	93.13	1.00
	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	144.9	144.9	1.00
	Direct	42.61	42.61	1.00
19	TL	42.61	42.61	1.00
PC, RR	AD	42.61	42.61	1.00
6 gas	K	96.91	96.91	1.00
	Direct	110.6	109.9	0.99
20	TL	-	-	-
HTFRTC	AD	-	-	-
O3-only	K	114.6	114.6	1.00
	Direct	21.14	21.14	1.00
21	TL	-	-	-
HTFRTC, RR	AD	-	-	-
O3-only	K	26.46	26.46	1.00
	Direct	109.9	110.6	1.01
22	TL	-	-	-
HTFRTC	AD	-	-	-
7 gas	K	116.1	116.1	1.00
	Direct	21.15	21.15	1.00
23	TL	-	-	-
HTFRTC, RR	AD	-	-	-
7 gas	K	29.21	29.21	1.00

Table 4 (continued from above): Memory test results.