RTTOV user survey 2022

Date: 12/10/2022

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Scope and background

Surveys of RTTOV users were carried out in 2014 and 2017 and these were very useful in understanding more about the user-base and their requirements for RTTOV. The survey results fed directly into development plans. With RTTOV v14 (the next major release) currently in development, a new, completely anonymous survey was sent to all registered users of RTTOV v12 and v13 (~1600 people). There were more questions than in the previous surveys and the questions were more detailed, but we nevertheless had 87 respondents (cf ~110 in 2017) which is a reasonable sample size from which to glean broad insights into users.

Respondents were pointed to the RTTOV "Future Plans" web page and to a page specifically describing some of the larger changes planned for v14. Responses are completely anonymous, so it is not possible to follow up on specific comments or attribute comments to specific users (e.g. other SAFs). Response rates are out of the total of 87 responses received except where otherwise stated.

General conclusions/remarks

New v13 predictors: while there is a good uptake of coefficients based on the new predictors, many people are still using the old predictors because they are running an older version of RTTOV or because they have not had time to upgrade. One user reported that the v13 predictors performed worse for MW and IR simulations than the old predictors, and two other users reported the same for solar simulations. In retrospect the wording of these questions is possibly ambiguous: the new predictors might "perform worse" because they are slower, rather than because they are less accurate. The respondents did not provide additional information. It is also the case that in data assimilation, systems can become tuned to a specific configuration so that introducing new science can be difficult, and an initial degradation should not necessarily be taken as an indication that the new science is flawed. Overall, it is promising that so few users are reporting problems with the new predictors.

PC models: this survey does not indicate a strong user requirement for either PC-RTTOV or HTFRTC.

Python wrapper: the survey highlights that this is extremely popular among users and should continue to be developed and maintained.

RTTOV GUI: a significant proportion of users are struggling to install this, and some potential users have not succeeded in getting it running.

RTTOV v14: There was no specific feedback on the RTTOV v14 plans. Users expressed support for the unification of RTTOV-SCATT and RTTOV, and for the broader aim of improving spectral consistency in RTTOV. Although there are some users of the solar single-scattering solver, no-one commented on its planned removal in v14. There were no comments on the planned change in v14 whereby the surface lies on the bottom input pressure level.

Survey results

Section 1 Microwave (MW) simulations (channels between ~1 and ~1000 GHz)

Q1 Which of these types of MW simulations/features do you use?

	Count	Rate
MW simulations using v13 predictor coefficients	27	31.03%
MW simulations using v7 predictor coefficients	22	25.29%
MW simulations using CLW absorption (no scattering)	9	10.34%
None of the above	43	49.43%

This suggests ~50% of users are running MW simulations which is similar to 2017. There is a significant drop in the use of CLW absorption (down from around a third of users).

Q2 Which of the following statements applies for MW simulations:

	Count	Rate
I'm happily using the v13 predictor coefficients for MW simulations	26	29.89%
I'm using v7 predictor coefficients in RTTOV v13 because I haven't had time to investigate the v13 predictors	7	8.05%
I tried the v13 predictor coefficients, but they did not perform as well as the v7 predictors	1	1.15%
I'm using v7 predictor coefficients in RTTOV v12 or earlier	10	11.49%
I'm not running MW simulations	42	48.28%
Other	1	1.15%

"Other" responses:

"I plan to start using RTTOV13 for MW simulations next year"

The results are encouraging for the v13 predictors: they are successfully being used. One user has responded that they performed worse than the old predictors: see comments above.

Q3 MW scattering (RTTOV-SCATT) simulations: which of these simulation types/features do you use?

	Count	Rate
Passive MW scattering radiance simulations	28	32.18%
Radar simulations	5	5.75%
I use optical properties from NWP SAF files (hydrotables/mietables)	14	16.09%
I make my own optical property files (hydrotables/mietables)	8	9.20%
None of the above	52	59.77%

Some people who are doing passive/active simulations did not indicate whether they are using NWP SAF or their own optical properties. Some people indicated they were using NWP SAF or custom hydrotable files but did not say they were doing simulations - it is plausible that they are using the optical properties in other applications.

Despite these apparent inconsistencies, it appears that over a third of users are running MW scattering simulations (passive and/or active) - similar to 2017 - and it seems likely that a significant minority are generating their own optical properties.

Q4 Which of these MW surface emissivity features/models do you use?

	Count	Rate
TESSEM2	3	3.45%
FASTEM-1	1	1.15%
FASTEM-2	1	1.15%
FASTEM-3	3	3.45%
FASTEM-4	3	3.45%
FASTEM-5	5	5.75%
FASTEM-6	25	28.74%
TELSEM2	11	12.64%
CNRM atlas	9	10.34%
FASTEM land/sea-ice	6	6.90%
None of the above	45	51.72%

The use of the very old FASTEM sea surface models, especially FASTEM-1 and -2 is somewhat surprising, but the low numbers mean a case could be made for the retirement of FASTEM-1/2/3/4 (and perhaps also -5) in RTTOV v14.

The use of the FASTEM land/sea-ice model is also surprising: this is extremely old, and has been superseded by the atlases, although the MW atlases currently only include climatological sea-ice and cannot generate dynamic emissivities based on known sea-ice cover. I was considering retiring this from RTTOV in v14 too, but perhaps it should remain.

Q5 Do you have a requirement for any of the following MW features/developments?

	Count	Rate
Simulations including the Zeeman effect	12	13.79%
MW simulations with variable ozone	15	17.24%
Other optional variable gases in the MW (please specify below under "other")	3	3.45%
Any particular new spectroscopic features in the MW (please specify below under "other")	3	3.45%
RTTOV-SCATT capabilities implemented behind RTTOV interface (i.e. one single radiative transfer model covering scattering at all frequencies)	21	24.14%
Improved spectral consistency (across all wavelengths) in scattering properties	12	13.79%
Other	9	10.34%

"Other" responses:

Of the 9 "other" comments, 7 were of the kind "none", "n/a" or "don't simulate MW sensors". One comment said "ICI" and one said "NWP".

This question was optional and 50 people answered it. There is considerable support for the unification of RTTOV and RTTOV-SCATT planned for RTTOV v14, and also support for improving spectral consistency which is a related longer-term goal.

There is interest in the Zeeman effect: this capability is currently being revived.

There is also interest in variable ozone: in retrospect the question could have been more specific since variable ozone is important in the sub-mm and we already include this in the ICI coefficients. It is not clear if respondents were interested in ozone below 200 GHz. It is planned to generate variable ozone coefficients for all MW sensors for the v14.0 release.

Despite requests for other variable gases and spectroscopic features, no-one indicated anything specific.

Section 2: Infrared (IR) simulations (channels between ~3 and ~100 microns)

Q6 Which of these types of thermal IR simulations/features do you use?

	Count	Rate
IR simulations using v13 predictor coefficients	47	54.02%
IR simulations using v7/8/9 predictor coefficients	41	47.13%
IR simulations with variable O3	35	40.23%
IR simulations with variable CO2	27	31.03%
IR simulations with variable CO, N2O, CH4	17	19.54%
IR simulations with variable SO2	12	13.79%
Simple cloud outputs (based on single input CTP and cfraction i.e. no scattering)	15	17.24%
Overcast radiance outputs	23	26.44%
Secondary radiance ("radiance2") outputs	13	14.94%
None of the above	16	18.39%

This suggests ~80% of users are running IR simulations which represents an increase of ~20% from 2017 if we take the responses at face value. There is significant use of the variable trace gases, including SO2 for which the accuracy in high-SO2 cases is known to be worse.

It is also interesting to see the significant use being made of the secondary outputs (simple cloud, overcast radiances, etc).

Q7 Which of the following statements applies for thermal IR simulations:

	Count	**Rate**
I'm happily using the v13 predictor coefficients for thermal IR simulations	38	43.68%
I'm using v7/8/9 predictor coefficients in RTTOV v13 because I haven't had time to investigate the v13 predictors	15	17.24%
I tried the v13 predictor coefficients, but they did not perform as well as the v7/8/9 predictors	1	1.15%
I'm using v7/8/9 predictor coefficients in RTTOV v12 or earlier	13	14.94%
I'm not running thermal IR simulations	16	18.39%
Other	4	4.60%

"Other" responses:

- for MTG IRS some transmission are < 0
- In process of migrating from v9 predictors to v13 predictors
- we will move to v13 predictors but this requires some time
- I'm using v7/8/9 predictor coefficients in RTTOV v13 because I haven't had time to investigate ALL the v13 predictors

Again, this is generally positive regarding the v13 predictors. The same user reported worse performance with the new vs old predictors in the MW and IR.

Regarding MTG-IRS transmittances, the respondent didn't give more information: it is most likely that this refers to the lightly (self-)apodised MTG-IRS coefficients which are not handled well by the RTTOV optical depth parameterisation and are known to yield negative transmittances. There are no known problems with the heavily apodised MTG-IRS radiances.

Q8 Which of these types of thermal IR cloud simulations/features do you use?

	Count	Rate
DOM solver	21	24.14%
“Chou-scaling” solver	16	18.39%
Explicit cloud property input	9	10.34%
OPAC CLW properties	14	16.09%
“Deff” CLW properties	11	12.64%
RTTOV CLW “Deff” param	13	14.94%
User-input CLW “Deff”	11	12.64%
Baum cloud ice properties	14	16.09%
RTTOV cloud ice “Deff” params	10	11.49%
User-input cloud ice “Deff”	10	11.49%
Baran ice optical properties	15	17.24%
Maximum/random cloud overlap	14	16.09%
“Simple cloud overlap”	9	10.34%
None of the above	42	48.28%

Around 50% of users are running cloudy IR simulations. It is interesting that there are more users of the slow DOM solver than the fast Chou-scaling solver. All types of VIS/IR cloud optical properties are used to a similar degree, including the parameterisations for particle size. Slightly fewer users are using the explicit cloud optical property inputs than the pre-defined particle types. It is also interesting that a significant minority are using the “simple” (two-column) cloud overlap scheme.

Q9 Which of these types of thermal IR aerosol simulations/features do you use?

	Count	Rate
DOM solver	19	21.84%
“Chou-scaling” solver	12	13.79%
Explicit aerosol property input	9	10.34%
OPAC aerosol properties	14	16.09%
CAMS aerosol properties	16	18.39%
User made optical properties	8	9.20%
None of the above	48	55.17%

Nearly 50% of users are running IR aerosol simulations, and again the DOM solver is used more frequently than the fast solver. All optical property options are in use, including the tool for making custom optical properties.

Q10 Which of these IR surface emissivity features/models do you use?

	Count	Rate
ISEM	16	18.39%
IREMIS	19	21.84%
UWIRemis atlas	18	20.69%
CAMEL 2007 atlas	15	17.24%
CAMEL climatology atlas	27	31.03%
None of the above	35	40.23%

The old ISEM sea surface emissivity model is widely used and as such should not be retired from the code yet.

Section 3: Solar simulations (UV, visible, near-IR, shortwave-IR - channels between ~0.2 and ~5 microns with solar radiation enabled)

Q11 Which of these types of solar simulations/features do you use?

	Count	Rate
Solar simulations using v13 predictor coefficients	26	29.89%
Solar simulations using v7/8/9 predictor coefficients	10	11.49%
Solar simulations with variable O3	16	18.39%
Solar simulations with variable CO2	12	13.79%
Solar simulations with variable CO, N2O, CH4	9	10.34%
Solar simulations with variable SO2	7	8.05%
Simple cloud outputs (based on single input CTP and cfraction i.e. no scattering)	7	8.05%
Overcast radiance outputs	8	9.20%
None of the above	49	56.32%

Around 50% of users are running solar simulations including some who are interested in all the variable trace gases. It must be noted that the solar simulations cover not only the UV/VIS/near-IR spectral range, but also the short-wave IR region around 3-5 microns.

Again, interesting to note the use being made of simple cloud and overcast outputs in solar simulations.

Q12 Which of the following statements applies for solar simulations:

	Count	**Rate**
I'm happily using the v13 predictor coefficients for solar simulations	24	27.59%
I'm using v9 predictor coefficients in RTTOV v13 because I haven't had time to investigate the v13 predictors	6	6.90%
I tried the v13 predictor coefficients, but they did not perform as well as the v9 predictors	2	2.30%
I'm using v9 predictor coefficients in RTTOV v12 or earlier	5	5.75%
I'm not running solar simulations	48	55.17%
Other	2	2.30%

"Other" responses:

- In process of migrating from v9 predictors to v13 predictors
- just started some tests

Once again, these responses are promising for the v13 predictors. Two users reported worse performance compared to the v9 predictors. This is striking because the accuracy of the v13 predictors vs the line-by-line model is significantly better in the VIS/NIR compared to the v9 predictors.

Q13 Which of these types of solar cloud simulations/features do you use?

	Count	**Rate**
DOM solver	16	18.39%
DOM with Rayleigh multiple scattering	13	14.94%
Single scattering solver	3	3.45%
MFASIS	5	5.75%
Explicit cloud property input	6	6.90%
OPAC CLW properties	11	12.64%
"Deff" CLW properties	7	8.05%
RTTOV CLW "Deff" param	10	11.49%
User-input CLW "Deff"	7	8.05%
Baum cloud ice properties	7	8.05%
RTTOV cloud ice "Deff" params	3	3.45%
User-input cloud ice "Deff"	4	4.60%
Baran ice optical properties	6	6.90%
Maximum/random cloud overlap	9	10.34%
"Simple cloud overlap"	3	3.45%
None of the above	58	66.67%

There is a clear preference for the slow DOM solver. It is perhaps surprising that a few people are using the single-scattering solver as this is not generally very accurate. It is planned for removal in v14, and no-one commented on that. It is also a little surprising that MFASIS is apparently used so little given the speed benefits over DOM with similar accuracy, although not all solar-affected channels are supported.

Q14 Which of these types of solar aerosol simulations/features do you use?

	Count	Rate
DOM solver	12	13.79%
DOM with Rayleigh multiple scattering	9	10.34%
Single scattering solver	5	5.75%
Explicit aerosol property input	9	10.34%
OPAC aerosol properties	6	6.90%
CAMS aerosol properties	10	11.49%
User made optical properties	6	6.90%
None of the above	60	68.97%

Here again some people are using the single-scattering solver scheduled for removal in v14.

Q15 Which of these solar surface reflectance features/models do you use?

	Count	Rate
JONSWAP sea BRDF model	4	4.60%
Elfouhaily et al sea BRDF model	6	6.90%
Land surface BRDF atlas	32	36.78%
None of the above	51	58.62%

The answers here indicate that while many users are running solar simulations, not many are using the RTTOV sea surface reflectance models provided.

Section 4: Other RTTOV features

Q16 Which of the following other RTTOV features do you use?

	Count	Rate
NLTE correction	2	2.30%
PC-RTTOV	7	8.05%
HTFRTC	2	2.30%
RTTOV GUI (graphical user interface)	16	18.39%
RTTOV C++ wrapper	5	5.75%
RTTOV Python wrapper	47	54.02%
None of the above	29	33.33%

Use of the Python wrapper is certainly increasing with over half of users making use of it compared to around 20% in 2017. The C++ interface may be declining in use, down from ~10% in 2017. Use of the GUI is slightly up on the 2017 survey.

Use of PC-RTTOV is perhaps declining (12% in 2017) while HTFRTC had 2 positive responses in both surveys (see Q17 below).

Q17 Regarding the Principal Components based models in RTTOV (PC-RTTOV, HTFRTC): the future of these models is uncertain due to resourcing issues within the development team. If you have particular requirements for either of these models that cannot be adequately satisfied by standard RTTOV simulations, please describe them here.

This question was optional. The non-blank responses were:

1	N/A
2	Can HTFRTC dev team provide un-apodized coefficients?
3	Do you intend to compute the coeffs for MTG IRS ?
4	N/A
5	Not for now.
6	If they would be faster than non-PC RTTOV for about 200 IASI channels, it would be great. But in my experience, in the past, this was not the case.
7	Nothing special.
8	no requirement for the time being
9	No requirements

These responses indicate some interest in faster simulations, for unapodised radiances, and potentially for MTG-IRS PC coefficients (presumably PC-RTTOV), but in my view, they do not constitute a strong user requirement for PC-based models (either PC-RTTOV or HTFRTC) within RTTOV.

Q18 If you used or have tried to use the RTTOV GUI, did you:

	Count	Rate
Find it straightforward to install and run?	12	36.36%
Have problems trying to install it, but got it working eventually?	8	24.24%
Have problems trying to install it, and did not successfully install/run the GUI at all?	13	39.39%

NB In this case the response rates are computed out of the 33 people who responded to this question.

It is quite clear that a significant number of users are having difficulties installing the GUI, many to the point of giving up. The provision of the Docker container for the GUI may help: I have added a link to this on the RTTOV v13 page, and also on the RTTOV FAQs page. In addition a requirements.txt file was included in the v13.2 package which may help some users set up a suitable python environment.

Q19 Following on from the previous question, feel free to provide information on your experience of installing and running the RTTOV GUI in the text box below such as any problems you encountered, and whether you contacted the NWP SAF Helpdesk.

This question was optional. The non-blank responses were:

1	had issues trying to install
2	I didn't try that hard, as I didn't really care about the GUI, but it's never run with the default settings despite everything else working fine.
3	I don't remember, but the problem was the lack of a library. But I was able to solve it. I don't remember, sorry.
4	I have had problems over the years with setting up the environment and the shifting dependencies of things like wx and matplotlib but since having set up conda I've found it easier to keep track of those things. It would be useful for me if the RTTOV GUI exposed a bit more of the input/output data in real time (rather than having to grab it out of the hidden HDF file). It's a very handy tool for quickly testing the effect of something (e.g. change of surface) but harder to get numbers out of. The plots work but definitely look quick and dirty and, as it stands, you'd have to write your own python script with the RTTOV python interface to produce something you'd want to include in a report - which might be the point, the tools occupy different spaces, I suppose!
5	I am not using RTTOV GUI
6	Couldn't establish proper GUI for RTTOV
7	I was not able to understand how it works, and what was wrong in the installation
8	It worked with 12.3. In 13.1 I could not make it work. I have not contacted the Helpdesk.
9	Faced difficulty in the starting in finding the main webpage from RTTOV-GUI can be downloaded and installed. Therefore, I request to make the page bit more visible so that one can find RTTOV-GUI easily. I will try to contact the NWP SAF team to get more info about the RTTOV -GUI. Many thanks.
10	Can't remember details but it was a bit of a faff to install - I think library issues relating to trying to integrate it with an existing conda environment used for the rest of our processing.

Regarding comment 4 on GUI outputs, I would agree with the respondent's final conclusion that the wrapper and the GUI are intended for different purposes. However, there is the potential for the GUI to be rewritten to use the Python wrapper in the future which may offer some scope for improving the way outputs can be obtained.

Regarding comment 9, the user did contact the help desk subsequently, and we were able to clarify with them that the GUI is provided as part of the RTTOV package and as such there is no separate web page or download.

Q20 If there are any other features of RTTOV not mentioned so far that you use please specify:

1	n/a
2	I mostly link directly to the Fortran library.
3	Ability to specify our own sea surface emissivity.
4	It would be very convenient for me if solar angles and satellite (zenith/azimuth) angle can be computed by a built-in subroutine using standard inputs such as longitude, latitude, time, satellite location.
5	I would really like to ba able to run RTTOV on the GPU (could really speed-up the processing)
6	---
7	rttov interface for data asssimilation system such DART
8	no

Responses 4 and 5 are requests for new functionality and are included in the final section below. I interpret response 7 as a statement of how RTTOV is used rather than a request, but if it is a request then it is certainly beyond the remit of the RTTOV package.

Section 5: Platforms and compilers

Q21 Which platform(s) do you compile RTTOV on?

	Count	**Rate**
Linux	85	97.70%
IBM AIX	1	1.15%
Cray	4	4.60%
NEC	1	1.15%
Mac OSX	7	8.05%
Other	2	2.30%

"Other" answers:

- Atos
- Win 11 / WSL

Q22 Which compiler(s) do you use to build RTTOV?

	Count	**Rate**
GNU (gfortran)	79	90.80%
Intel (ifort)	39	44.83%
Portland (pgf)	4	4.60%
NAG (nagfor)	0	0.00%
IBM (xlf)	1	1.15%
Cray Fortran	4	4.60%
Other	3	3.45%

"Other" answers:

- pgi
- Fujitsu compiler
- nec

Section 6: User applications

Q23 For what application(s) do you use RTTOV?

	Count	**Rate**
NWP assimilation	29	33.33%
Atmospheric profile and/or surface parameter retrieval	44	50.57%
Simulated satellite imagery	47	54.02%
Reanalysis	6	6.90%
Studies in preparation for future instruments	34	39.08%
Studies related to old instruments (e.g. SSU, PMR, IRIS, SCAMS, SMMR, etc)	14	16.09%
I use the NWP SAF 1DVar software which requires RTTOV	8	9.20%
I use the NWP SAF Radiance Simulator software which requires RTTOV	12	13.79%
I use RTTOV with COSP (the CFMIP Observation Simulator Package)	3	3.45%
I use some other software which requires/uses RTTOV (please specify which software in the additional information text box below)	5	5.75%
Other	7	8.05%

"Other" responses:

1	Atmospheric parameter retrieval in a thermal infra-red context: Landsat, Ecostress and TRISHNA (future mission);
2	Clear-sky radiance calculations and optimal estimation cloud propertery retrievals (ORAC)
3	WRF
4	CalVal of MW sensors
5	Calibration and validation of new sensors
6	Own optimal estimation retrieval code.
7	Atmospheric Composition assimilation

The results are broadly similar to the 2017 results except that studies related to future and old instruments each have twice as many responses now compared to 2017. This probably reflects the increasing interest in making use of old satellite data in reanalyses and the abundance of new satellite missions.

Q24 Feel free to provide additional information on your application(s) here:

This question was optional. The non-blank responses were:

1	n/a
2	We use RTTOV for clear-sky radiane calculations within our optimal estimation retrieval code, ORAC. Details can be found here: https://github.com/ORAC-CC/orac
3	Met Office OPS/VAR Met Office JOPA
4	I am working on IRS at EUMETSAT. I am using RTTOV to generate IRS/IASI/IASI-NG realistic spectra in order to test IRS L1 processing
5	Assimilation, reanalysis and verification of NWP results using RTTOV
6	calculate the radiative forcing of different factors(CO2、water vapor 、cloud、aerosol and so on)

7	it is too complicated regarding the other RTM code.
8	My main use is for atmospheric composition retrieval from MW and IR sounders.
9	RTTOV v13 (RTTOV-SCATT) has been implemented within the OSI SAF sea ice concentration NRT algorithm
10	Atmospheric Composition assimilation (in a 3D model with 3DVAR) Sensitivity studies for atmospheric composition
11	I am using RTTOV only occasionally in ad-hoc random simulations for getting a quantative understanding of the sensitivity of hyperspectral IR measurments to atmospheric variability for given instruments (mostly old ones). I am not a "common" user of RTTOV. I have no precise applications in mind, but I am aware that RTTOV is a powerful tool to make progress in EO science.

Regarding response 7, it is not very clear what the user means: either RTTOV is used in preference to some other RT model that is more complicated to use or vice versa perhaps.

In response to user feedback, the following have been implemented in RTTOV v13.2 (December 2022):

- Subroutines to calculate solar angles and GEO satellite angles.
- Add qmin/qmax values in kg/kg in *rttov_const*.
- Make GUI easier to install (docker image created, configuration files provided for creating compatible conda environments).

The following has been implemented for v14.0 (planned for release Jan 2024):

- Support for CAMEL v3 IR emissivity atlases (datasets based on data from 2000-2021).

The following requested features are planned for a future release:

- Updated BRDF atlas based on MODIS Collection 6.
- Address the negative gas optical depths/optical depth clipping.
- Add CMake support; include ability to specify install directory into which build is copied from build directory.
- Non-Lambertian options for surface reflectance in DOM solver.

Additional features that will be considered:

- Aerosol optical properties in terms of particle size.
- 3D cloud effects.
- Experimentation of compiling/running RTTOV on GPU architectures.

The “Future plans” web page gives a list of the current plans for upcoming versions of RTTOV and has been updated in light of the survey responses.

https://nwp-saf.eumetsat.int/site/software/rttov/future-plans/

The page also lists some commonly requested capabilities that we do *not* currently plan to implement in RTTOV.

Users are encouraged to continue submitting requests, comments and questions about RTTOV either to the NWP SAF helpdesk or to the RTTOV forum:

https://nwp-saf.eumetsat.int/site/help-desk/

https://nwp-saf.eumetsat.int/site/forums/forum/rttov/

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