RTTOV v10 Test Suite

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This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 1 December, 2006, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, KNMI and Météo France.

Change record			
Version	Date	Author / changed by	Remarks
1.0	30/11/10	PB/JH	Version for RTTOV v10 release
1.1	09/12/10	JH	Response to DRI comments
1.2	19/12/11	JH	Updates for v10.2.

1. Introduction

The RTTOV test suite has been fully rewritten since RTTOV v9.3. It is now much more flexible, allowing various aspects of RTTOV to be configured either on the command-line or via input files.

RTTOV tests definition and scripts are located in the `rttov_test` subdirectory. The `tests.0` directory contains the data required to run the tests (these are atmospheric and ground data, and some reference to the RTTOV coefficients). Test outputs for the `myarch` architecture are located in `tests.1.myarch`. Test references are kept in directories whose name ends with `.2` ; for instance, `test_fwd.2` contains the test references for the test_fwd test series.

The following scripts and executables are involved in RTTOV tests execution:

- `rttov_test.pl`; this script requires Perl >= 5.6 to be installed as `/usr/bin/perl`.
- `rttov_test.exe`; this executable is created during the building of RTTOV. Its purpose is to run one or more tests.
- `rttov_conv_coef.exe`; this executable is created during the building of RTTOV. Its purpose is to extract channels from coefficient files and/or to convert them to/from formatted/unformatted format.

The RTTOV top directory must contain the `rtcoef_rttov10` coefficient directory with the following sub-directories:

- `rttov7pred/` v7 predictor files (most optical depth coefficient files)
- `rttov8pred/` v8 predictor files (for SSU only)
- `rttov9pred/` v9 predictor files (for the v9 AIRS and IASI files)
- `cldaer/` IR cloud and aerosol scattering coefficient files
- `mietable/` MW scattering coefficient files
- `pc/` Principal Components coefficient files

`rttov_test.pl` shall always be run from the `rttov_test` directory. Whenever this script is run, either the ARCH environment variable must be set or it must be supplied as an argument to `rttov_test.pl`. It is possible to ask for the list of tests defined in `tests.0`:

```
$ ./rttov_test.pl LIST_ONLY=1
                  +------------------------------------------------------------------------------------ number of Channels
                  |     +------------------------------------------------------------------------------ number of Profiles
                  |     |    +------------------------------------------------------------------------- number of Levels
                  |     |    | +----------------------------------------------------------------------- Emissivity computed in RTTOV
                  |     |    | |+---------------------------------------------------------------------- Interpolation
                  |     |    | ||+--------------------------------------------------------------------- Aerosols
                  |     |    | |||+-------------------------------------------------------------------- Clouds
                  |     |    | ||||                      +----------------------------------------------- Apply reg limits
                  |     |    | ||||                      |+---------------------------------------------- do NOT Checkinput
                  |     |    | ||||                      ||+--------------------------------------------- NOT Verbose checkinput warnings
                  |     |    | ||||                      |||+-------------------------------------------- no space Top
                  |     |    | ||||                      ||||+------------------------------------------- Gradients wrt pressure
                  |     |    | ||||                      |||||+------------------------------------------ Solar radiation
                  |     |    | ||||                      ||||||+----------------------------------------- Refraction
                  |     |    | ||||                      |||||||+---------------------------------------- use s2m%Q
                  |     |    | ||||                      ||||||||+--------------------------------------- sWitchrad
                  |     |    | ||||                      |||||||| +------------------------------------- Fastem version
                  |     |    | ||||                      |||||||| |   +----------------------------------- Multiplicity
                  |     |    | ||||                      |||||||| |   |    +---------------------------- scale TL/AD Increments
                  |     |    | ||||                      |||||||| |   |    |    +----------------------- scale TL/AD Output
                  |     |    | ||||                      |||||||| |   |    |    | +--------------------- number of Threads
                  |     |    | ||||                      |||||||| |   |    |    | |    +---------------- number of Times rttov is run
                  |     |    | ||||                      |||||||| |   |    |    | |    | +-------------- Channel by channel
                  |     |    | ||||                      |||||||| |   |    |    | |    | |+------------- Profile by profile
                  |     |    | ||||                      |||||||| |   |    |    | |    | ||+------------ Temp allocation
                  |     |    | ||||                      |||||||| |   |    |    | |    | |||+----------- Extract coefficients
```

```
                    |     |    | ||||                   |||||||||| |   |    |    | |    | ||||+---------- Format of coefficients
                    |     |    | ||||                   |||||||||| |   |    |    | |    | |||||+--------- Direct
                    |     |    | ||||                   |||||||||| |   |    |    | |    | ||||||+-------- Tangent linear
                    |     |    | ||||                   |||||||||| |   |    |    | |    | |||||||+------- Adjoint
                    |     |    | ||||                   |||||||||| |   |    |    | |    | ||||||||+------ K-matrix
                    |     |    | ||||                   |||||||||| |   |    |    | |    | |||||||||+----- Brute force k-matrix
                    |     |    | ||||                   |||||||||| |   |    |    | |    | ||||||||||+---- Tangent linear k-matrix
                    |     |    | ||||                   |||||||||| |   |    |    | |    | |||||||||||+--- Adjoint k-matrix
                    |     |    | ||||                   |||||||||| |   |    |    | |    | ||||||||||||+-- Taylor test
     TEST_ID        C     P    L EIAC        GASES      ACVTGSRQW F   M    I    O T    T CPTEFDTAKBTAT
     abi/01          18    6   51 X...  o3              ......... 0   1    1    1 0    1 ....F........
     abi/21          18    6  101 XX..  o3              ......... 0   1    1    1 0    1 ....F........
     airs/01         84    6   51 XX..  ch4 co co2 n2o o3 ......... 0   1    1    1 0    1 ....F........
     airs/02         84    6   51 XX..  o3              ......... 0   1    1    1 0    1 ....F........
...
```

It is possible to filter the list with a regular expression; for instance:

```
$ ./rttov_test.pl LIST_ONLY=1 TEST_MATCH=avhrr
```

would display the list of tests whose name contains the `avhrr` word.

2. High level options

The list of tests from the previous subsection shows the description of each test; on the left-hand side, the following information appears:

- The name of the test.
- The number of channels involved.
- The number of profiles.
- The number of levels.
- Whether RTTOV will calculate surface emissivities internally.
- Whether this test requires the RTTOV interpolation to be activated.
- Whether this test contains some aerosol data.
- Whether this test contains cloud data.
- The list of gases which appear in this test.

On the right-hand side, are listed the options which can be changed at run time:

- Set apply_reg_limits boolean to restrict profiles within regression limits.
- Set do_checkinput boolean to FALSE to avoid checking input profiles for spurious values.
- Set verbose_checkinput_warnings boolean to FALSE to avoid printing out warnings when the optical depth regression limits are exceeded by the input profiles.
- Set spacetop boolean to false.
- Set lgradp boolean to true.
- Activation of solar radiation scheme.
- Activation of the refraction calculations.
- Activation of the use of the 2m water vapour input variable.
- Set the switchrad boolean.
- The selected FASTEM version.
- Multiplicity; this will expand the test data by some factor. A multiplicity of 10 applied to a test case with 2 profiles and 5 channels will cause the test to be run with 20 profiles with 5 channels each.
- Scale factor applied to TL/AD increments.
- Scale factor applied to TL/AD output.
- Number of threads; this option activates the RTTOV parallel routines. A value of 0 implies that the regular RTTOV high level routines will be run.

- Number of times the test case is run (within the same invocation of rttov_test.exe).
- Each channel is calculated in an individual call to RTTOV.
- Each profile is calculated in an individual call to RTTOV.
- Temp allocation flag. RTTOV is run with temporary data allocated outside the RTTOV high level routines.
- Coefficient extraction. It is possible to extract the coefficient data for the channels which are actually used in the test. The extracted coefficient data will be saved for future re-use in the `coefs.1.myarch` directory. The `rttov_conv_coef.exe` binary is used for extracting these data.
- Coefficient format for extracting the coefficient data. This can be `formatted` or `unformatted`.
- Direct, tl, ad, k, k_bf, k_tl, k_ad. These flags activate some calculations:
  - `DIRECT=1` : the direct model
  - `TL=1` : the tangent linear model
  - `AD=1` : the adjoint model
  - `K = 1` : the K matrix computation
  - `K_BF=1` : calculation of an approximation of the K matrix using the direct model
  - `K_TL=1` : exact calculation of the K matrix using the tangent linear model
  - `K_AD=1` : exact calculation of the K matrix using the adjoint model
- Carry out Taylor test (must not be used simultaneously with the direct/tl/etc calculations).

These options (and some others) can be listed by typing:

```
$ ./rttov_test.pl HELP=1

   + ARCH=...

   + SESSION=...                        test session name; defaults to tests

   + BIN=bin                            directory where binary executables
                                        are kept ( default is bin ); this path
                                        is relative to RTTOV top directory

   + TEST_LIST=hirs/01,airs/51,...      comma separated list of tests to be
                                        run ( default is all tests ); it is also
                                          possible to define tests such as: hirs/01+airs/51;
                                          in this case, hirs/01 and airs/51 will be run
                                          from within the same executable


   + TEST_MATCH=hirs                    regex to filter the tests

   + LIST_ONLY=1                        do not run tests, show list

   + COEF_EXTRACT=1                     extract needed coefficients data

   + COEF_FORMAT=formatted              format for extracting coefficient data

   + NTIMES=10                          number times to run RTTOV ( default
                                        is 1 )

   + NTHREADS_MULTI_RUN                 number of threads to run test cases with multiple
                                        sub-cases with (calculation part)

   + NTHREADS=2                         number of threads to run RTTOV (rttov_direct, rttov_tl, rttov_ad, rttov_k)
                                        with ( default is 0 )

   + PRINT=1                            print results to disk ( default is
                                        true )

   + PRINTALLRAD=1                      print full radiance structure to disk ( default is
                                        false/0 )
```

```
+ TEMP_ALLOC=1                    run RTTOV with temporary data allocated
                                  outside RTTOV

+ LALLCHANS=1                     read all channels/only a subset from
                                  coefficients files ( default is false )


+ DIRECT=1 TL=1, AD=1, K=1, K_BF=1, K_TL=1, K_AD=1
                                  enables direct, tangent linear, adjoint, K matrix,
                                    brute force K matrix, tangent linear K matrix,
                                    adjoint K matrix

+ TAYLOR=1                        performs Taylor test

+ CHECK=1                         performs consistency checks between direct/tl/ad/k
                                  and k_bf/k_tl/k_ad/k

+ DOREAL=1                        performs k_bf/k in real values, default is test in
                                  scaled integers

+ TEST_REF=...                    provides a reference to check tests results against

+ PRINT_ERROR=0                   do not print error in the test listing
                                  ( default is 1 )

+ DR_HOOK=1                       activates DR_HOOK ( RTTOV has to be compiled with
                                  DR_HOOK library ).

+ FTRACE=1                        activates FTRACE ( RTTOV has to be compiled with
                                  -ftrace option ).

+ MULT=10                         number of channels and profiles is increased by
                                  a factor of MULT

+ SCALE_INC=2                     scale increments for TL/AD computations by
                                  a factor of SCALE_INC
+ SCALE_OUT=2                     scale TL/AD output of TL/AD computations by
                                  a factor of SCALE_OUT

+ CLDSTR_THRESH=-1.0              set the value of cldstr_threshold

+ FASTEM_VERSION=0                set the version of FASTEM to use for MW emissivity
                                  calculations. Valid values are 1-5. Otherwise (the
                                  default), the version specified in the coef file is used.

+ REFRACTION=1                    activates refraction

+ SOLAR=1                         activates solar radiation

+ USE_Q2M=1                       use s2m%q input profile variable

+ DO_NOT_CHECKINPUT=1             sets the do_checkinput boolean to false (true by default)
                                     this disables apply_reg_limits

+ APPLY_REG_LIMITS=1              sets the apply_reg_limits boolean to true

+ NOT_VERBOSE_CHECKINPUT_WARNINGS=1 sets the verbose_checkinput_warnings boolean to false (true by default)

+ NO_SPACETOP=1                   sets the spacetop boolean to false (spacetop is true
                                  by default)

+ LGRADP=1                        sets the lgradp boolean to true to
                                  include variations wrt pressure if
                                  the interpolation option is used

+ SWITCHRAD=1                     sets the switchrad boolean to true

+ PACK=directory-name

+ UNPACK=directory-name

+ PROF_BY_PROF=1                  run RTTOV a single profile at a time

+ CHAN_BY_CHAN=1                  run RTTOV a single channel at a time
```

We detail here the options we have not explained yet and whose meaning might not be obvious from the description above:

- `ARCH=myarch` specifies the architecture being tested. Test results will be saved in `tests.1.myarch` unless `SESSION` is specified.
- `TEST_LIST=hirs/01,airs/51` is a comma separated list of tests. It is also possible to run several tests in the same execution of `rttov_test.exe` by joining the test IDs with a "+"; for instance `TEST_LIST=hirs/01+avhrr/01+amsua/01` will make `rttov_test.exe` run these three tests together: data will be allocated for these tests, coefficients files will be read, calculations will be made and eventually data will be deallocated.
- `CHECK=1` will cause the direct/tl/ad/k consistency tests to be activated, and possibly the test against a reference if one is provided.
- `PRINT_ERROR=1` will print error messages as tests run (the default is true, but it can be deactivated).
- `DR_HOOK=1` will take care of setting the right options for activating DR_HOOK and saving its output.
- `PRINT=1` will cause `rttov_test.exe` to save its results (default is true, but it can be disabled).
- `LALLCHANS=1` will force `rttov_test.exe` to load coefficient data for all channels and to manage a subset of them in the calculations.
- `BIN=install-myarch/bin` has to be specified is RTTOV has been compiled and installed elsewhere than at the top of the RTTOV distribution. This occurs when the INSTALL`DIR=install-myarch` parameter is specified on the command line of `make`. Note that BIN specifies a path relative to the RTTOV top level directory.

3. Testing DIRECT/TL/AD/K consistency

When several of DIRECT, TL, AD, K, K_BF, K_TL, K_AD are activated, it is possible to check the consistency:

- of the direct calculations performed in any of these modes.
- of the K matrix calculations of K, K_BF, K_TL, K_AD; the K_BF ("brute force") which is computed in the subroutine `rttov_k_bf` is only an approximation of the K matrix calculated using finite differences; K_TL and K_AD (computed in `rttov_k_tl` and `rttov_k_ad`) should be identical to the K matrix (as computed by `rttov_k`).

The option `CHECK=1` activates this verification. The differences appear in the test log and are recorded in the test output directory. The differences when they appear may have to be more closely examined and may be caused by some rounding errors dependent on the processor. It is common for tests to report some differences which do not necessarily indicate problems with the code, particularly in relation to the internal consistency checks:

- The tangent linear and adjoint Jacobians should in theory be identical, but there may be differences in the least significant digits due to rounding errors and differences in the code paths. In particular, small differences are often observed for the "cfrac" variables for cloudy IR simulations.
- With the LGRADP=1 option, the pressure K Jacobian in the top-most and bottom-most layers will often differ slightly to the TL Jacobian. Small differences may also be observed in the cloud fraction ("cfrac") Jacobians.

- For Principal Components calculations in the test suite the emissivity TL Jacobian is always zero and so will differ to the emissivity K Jacobian.
- For the calculation of the BF Jacobian, the profile increments are a fraction of the profile value. In some cases (eg cloud liquid water), the profile value may be zero at some levels in which case the corresponding element of the BF Jacobian will be zero. This will differ to the K matrix which is explicitly calculated everywhere.

The comparisons between the K, K_TL and K_AD Jacobians are done exactly i.e. all differences are reported. However, the brute force Jacobian (K_BF) is expected to differ slightly from the others. By default, the BF comparison is done by scaling the Jacobian values up to integers and reporting differences which exceed a threshold specified in the code. If the DOREAL=1 option is specified then the BF comparison is carried out on real values, and differences are reported if they exceed 10% of the K matrix values. This can result in many differences being reported which do not necessarily indicate problems. The DOREAL option is intended for use by developers.

The TAYLOR argument can be used to test consistency between the direct and tangent linear (TL) code. It must not be supplied at the same time as the AD/K/K_TL/K_AD/K_BF arguments. This compares the TL output with a “brute force” TL calculated with the direct model by perturbing the input profile. The comparison is repeated with decreasing perturbations, and the ratio of the real and brute force TLs should approach 1.0. The output of the Taylor test must be examined by hand and is contained in the `rttov_test.log` file within the test output directory (see below). Note that as the perturbations become very small, rounding errors begin to cause the ratio to deviate significantly from 1.0.

4. Looking at a test output

Run the following command (from the rttov_test directory):

```
$ ./rttov_test.pl ARCH=myarch TEST_LIST=hirs/01,avhrr/01 DIRECT=1 K=1
```

```
+------------------------------------------------------------------------------- number of Channels
|     +------------------------------------------------------------------------- number of Profiles
|     |    +-------------------------------------------------------------------- number of Levels
|     |    | +------------------------------------------------------------------ Emissivity computed in RTTOV
|     |    | |+----------------------------------------------------------------- Interpolation
|     |    | ||+---------------------------------------------------------------- Aerosols
|     |    | |||+--------------------------------------------------------------- Clouds
|     |    | ||||                    +---------------------------------------------- Apply reg limits
|     |    | ||||                    |+--------------------------------------------- do NOT Checkinput
|     |    | ||||                    ||+-------------------------------------------- NOT Verbose checkinput warnings
|     |    | ||||                    |||+------------------------------------------- no space Top
|     |    | ||||                    ||||+------------------------------------------ Gradients wrt pressure
|     |    | ||||                    |||||+----------------------------------------- Solar radiation
|     |    | ||||                    ||||||+---------------------------------------- Refraction
|     |    | ||||                    |||||||+--------------------------------------- use s2m%Q
|     |    | ||||                    ||||||||+-------------------------------------- sWitchrad
|     |    | ||||                    ||||||||| +------------------------------------ Fastem version
|     |    | ||||                    ||||||||| |   +-------------------------------- Multiplicity
|     |    | ||||                    ||||||||| |   |    +---------------------------- scale TL/AD Increments
|     |    | ||||                    ||||||||| |   |    |    +----------------------- scale TL/AD Output
|     |    | ||||                    ||||||||| |   |    |    | +-------------------- number of Threads
|     |    | ||||                    ||||||||| |   |    |    | |    +--------------- number of Times rttov is run
|     |    | ||||                    ||||||||| |   |    |    | |    | +------------- Channel by channel
|     |    | ||||                    ||||||||| |   |    |    | |    | |+------------ Profile by profile
|     |    | ||||                    ||||||||| |   |    |    | |    | ||+----------- Temp allocation
|     |    | ||||                    ||||||||| |   |    |    | |    | |||+---------- Extract coefficients
|     |    | ||||                    ||||||||| |   |    |    | |    | ||||+--------- Format of coefficients
|     |    | ||||                    ||||||||| |   |    |    | |    | |||||+-------- Direct
|     |    | ||||                    ||||||||| |   |    |    | |    | ||||||+------- Tangent linear
|     |    | ||||                    ||||||||| |   |    |    | |    | |||||||+------ Adjoint
|     |    | ||||                    ||||||||| |   |    |    | |    | ||||||||+----- K-matrix
|     |    | ||||                    ||||||||| |   |    |    | |    | |||||||||+---- Brute force k-matrix
|     |    | ||||                    ||||||||| |   |    |    | |    | ||||||||||+--- Tangent linear k-matrix
|     |    | ||||                    ||||||||| |   |    |    | |    | |||||||||||+-- Adjoint k-matrix
```

```
                |     |    | ||||                 ||||||||| |   |    |    | |    | ||||||||||||+-- Taylor test
     TEST_ID        C     P    L EIAC        GASES        ACVTGSRQW F   M    I    O T    T CPTEFDTAKBTAT  REAL TIME   USER TIME STATUS
     hirs/01        114    6   51 X... o3                ......... 0   1    1    1 0    1 ....FX..X....       0.39        0.07   OK
    avhrr/01         18    6   51 X... o3                ......... 0   1    1    1 0    1 ....FX..X....       0.05        0.02   OK

End: 06/12/2011 16:27:29

Ran 2 tests, 2 = OK
```

Note that if your RTTOV has been compiled in a custom directory using the `INSTALLDIR` Makefile parameter, you have to use the `BIN=...` option as explained in the previous section. The `rttov_test` directory may contain a `arch/myarch` file holding the the myarch related environment variables to be exported before running the tests (this may help debugging).

Two tests have been run separately: `hirs/01` and `avhrr/01`. It is possible to run them together by typing:

```
$ ./rttov_test.pl ARCH=myarch TEST_LIST=hirs/01+avhrr/01 DIRECT=1 K=1

     TEST_ID        C     P    L EIAC        GASES        ACVTGSRQW F   M    I    O T    T CPTEFDTAKBTAT  REAL TIME   USER TIME STATUS
     hirs/01        114    6   51 X... o3                ......... 0   1    1    1 0    1 ....FX..X....
    avhrr/01         18    6   51 X... o3                ......... 0   1    1    1 0    1 ....FX..X....       0.12        0.08   OK

End: 06/12/2011 16:29:32

Ran 1 tests, 1 = OK
```

The directory `tests.1.myarch/avhrr/01/out` contains the results of the `avhrr/01` test; it contains the following files:

```
$ find
./env.sh                        # compiler related environment variables (if any)
./run.sh                        # shell script to re-run the test by hand
                                # ( just type ./run.sh from the test output
                                #   directory )
./direct
./direct/transmission.txt       # transmission data produced by rttov_direct
./direct/radiance.txt           # radiance data produced by rttov_direct
./direct/emissivity_out.txt     # emissivity data produced by rttov_direct
./rttov_test.log                # standard error and output of rttov_test.exe
./rttov_test.txt                # namelist for rttov_test.exe
./k
./k/transmission.txt            # transmission data produced by rttov_k
./k/radiance.txt                # radiance data produced by rttov_k
./k/emissivity_out.txt          # emissivity data produced by rttov_k
./k/emissivity_k.txt            # gradient of the radiances relative to the
                                # emissivity
./k/profiles_k.txt              # gradient of the radiance relative to the
                                # atmospheric and ground data
```

Note that if you have run the combined test `hirs/01+avhrr/01`, then the log for the combined test, `rttov_test.log`, is dumped in the last test directory (`tests.1.myarch/avhrr/01/out`). Note however that test outputs are stored in separate test directories.

The `.txt` files contain the results of RTTOV calculations in a human readable format. For instance:

```
$ cat direct/radiance.txt
RADIANCE%CLOUDY = (
  0.6488168        105.9665
```

```
 )
RADIANCE%BT = (
   298.2563        294.3918
 )
RADIANCE%CLEAR = (
  0.6488168        105.9665
 )
RADIANCE%BT_CLEAR = (
   298.2563        294.3918
 )
```

It is possible to have results saved in a directory whose name is not `tests.1.myarch`; for this purpose, it is necessary to append the `SESSION=mysession` argument to the list of parameters passed to `rttov_test.pl`; results will then be saved to the `mysession.1.myarch` directory.

5. Creating a new test

Test definition is located in the `tests.0` directory; every sub-directory of `tests.0` which contains an "`in`" sub-directory is interpreted by `rttov_test.pl` as a test definition. This `in` sub-directory must contain the following files:

- `./coef.txt` # coefficient namelist
- `./lprofiles.txt` # profile list for chanprof(:)%prof
- `./channels.txt` # channel list for chanprof(:)%chan
- `./flags.txt` # flags (addinterp)
- `./calcemis.txt` # calcemis flags for RTTOV
- `./emissivity.txt` # emissivity
- `./profiles/001/angles.txt` # angles parameters
- `./profiles/001/atm`
- `./profiles/001/atm/aerosli.txt` # aerosol parameters
- `./profiles/001/atm/cloud0.txt` # opaque cloud parameters
- `./profiles/001/atm/t.txt` # temperature (K)
- `./profiles/001/atm/p.txt` # pressure levels (hPa)
- `./profiles/001/atm/q.txt` # water vapour (ppmv)
- `./profiles/001/ground`
- `./profiles/001/ground/skin.txt` # skin parameters
- `./profiles/001/ground/s2m.txt` # s2m parameters
- `./profiles/001/be.txt` # magnetic field parameters

It may also contain the following files:

- `./profiles/001/atm/o3.txt` # O3 (ppmv)
- `./profiles/001/atm/co.txt` # CO (ppmv)
- `./profiles/001/atm/n2o.txt` # N2O (ppmv)
- `./profiles/001/atm/co2.txt` # CO2 (ppmv)
- `./profiles/001/atm/ch4.txt` # CH4 (ppmv)
- `./profiles/001/atm/clw.txt` # Cloud liquid water (kg/kg)
- `./profiles/001/atm/cloud.txt` # Cloud liquid/ice (kg/kg)
- `./profiles/001/atm/cfrac.txt` # Cloud fraction
- `./profiles/001/atm/icede.txt` # Ice particle effective diameter (µm)
- `./profiles/001/atm/aerosl.txt` # Aerosol concentrations

For Principal component calculations:

- `./pcscores.txt` `# regression set and number of pcscores`
- `./channels_rec.txt` `# reconstructed channels (optional)`

Creating a new test is just the matter of creating a new sub-directory in `tests.0`. The easiest method is to copy a preexisting test and modify it to suit your needs.

The configuration described above is a single profile configuration (profile 001): adding some more profiles involves creating other directories named 002, 003, etc with data laid out as described above.

6. Testing against a reference

A set of tests with reference output (where appropriate) are provided for users. These tests demonstrate the capabilities of RTTOV v10 for a range of instruments, and the comparison to the reference output can confirm to the user that the code has been compiled correctly. References are provided in `*.2` directories.

We provide the following user test scripts:

- `test_fwd.sh` tests the forward model for a wide range of instruments
- `test_rttov10.sh` tests the full code (direct/TL/AD/K) for a range of instruments
- `test_rttov10_hires.sh` tests the full code for AIRS and IASI
- `test_pc.sh` tests the Principal Component calculations
- `test_multi_instrument.sh` tests RTTOV running for multiple instruments together
- `test_zeeman.sh` tests Zeeman code (using Zeeman coefficient files)
- `test_coef_io.sh` tests the coefficient input/output code (this test has no reference data)
- `test_cpu.sh` may be used for performance testing (this test has no reference data)

NB Users compiling with the Intel Fortran compiler on Linux may need to execute the following command before all tests will run correctly:

```
$ ulimit -s unlimited
```

The list of tests above may be run using a single script:

```
$ ./test_core.sh ARCH=myarch [BIN=install-myarch/bin]
```

Alternatively, each script may be called individually. The test scripts can be run with any of the parameters described above for `rttov_test.pl` (though naturally some options will make comparison to the test reference output invalid). In particular, either the `ARCH` environment variable must be set or `ARCH=myarch` must be passed as an argument to the script. If you have specified `INSTALLDIR=install-myarch`, then the `BIN=install-myarch/bin` should be provided to the script.

We describe here `test_rttov10.sh`:

```
$ cat test_rttov10.sh
#!/bin/sh

# User test
```

```
# Tests the full RTTOV-10 code for various MW and IR instruments.

if [ "x$ARCH" = "x" ]
then
  ARCH=`perl -e 'for(@ARGV){m/^ARCH=(\S+)$/o && print "$1";}' $*`
fi

set -x

SESSION=test_rttov10
OPTS=$*
WHAT="DIRECT=1 TL=1 AD=1 K=1"
CHECK="CHECK=1 TEST_REF=$SESSION.2"

./rttov_test.pl SESSION=$SESSION $WHAT $CHECK ARCH=$ARCH $OPTS -- << EOF
  TEST_LIST=amsr/01
  TEST_LIST=amsua/21,amsua/31
  TEST_LIST=amsub/01
  TEST_LIST=msu/01,msu/21      REFRACTION=1
  TEST_LIST=ssmis/01,ssmis/21
  TEST_LIST=windsat/01
  TEST_LIST=hirs/01,hirs/21    REFRACTION=1 APPLY_REG_LIMITS=1
  TEST_LIST=modis/01
  TEST_LIST=seviri/21
EOF
```

This test script runs several lists of tests, saves results to the `test_rttov10.1.myarch` directory and compares them to the reference `test_rttov10.2`.

Note that a reference is merely a test output directory renamed with a `.2`.

A number of the test scripts use the `COEF_EXTRACT=1` argument which causes coefficients to be extracted to the `coefs.1.myarch` directory for efficiency. Repeated runs of the tests will be faster because these extracted coefficients will be used. However, if the user makes any changes in the `rtcoef_rttov10` directory, then `coefs.1.myarch` MUST be deleted to ensure the updated files are used by the tests.

A more thorough set of tests are employed by the developers to check the code comprehensively. These include full tests (including the internal consistency checks described in section 3) for every coefficient file provided with RTTOV v10, testing of the various flags and options with which RTTOV v10 may be run, checking consistency between the direct and TL using the Taylor test (described in section 3), checking linearity of the TL and AD code, and testing on diverse profile datasets. The scripts and reference output for these tests are not included in the RTTOV v10 package provided to users.

7. Testing performance

The `test_cpu.sh` script is for performance testing. The test cases are expanded by some factor and run several times so that the time spent in each routine be significant. Some tests run with multiple threads. No output data is written on the disk (`PRINT=0`). It is possible to pass `NTHREADS=2`, `NTHREADS=3`, etc... to test_cpu.sh to see the impact on the real time when RTTOV parallel routines are invoked and RTTOV has been compiled with OpenMP.

8. Additional test scripts

A number of additional test scripts are supplied which provide examples for running RTTOV, and allow testing of non-core components such as RTTOV_SCATT and the emissivity atlases. These test scripts are described here.

Running a simple example of code calling RTTOV v10

A simple example of running the forward model is given in `src/test/example_fwd.F90`. This code may be used as a starting point for the users own applications. The program may be run using the `run_example_fwd.sh` script. The user may need to edit the first few lines of this script to specify the location of the coefficient files (by default assumed to be in `rtcoef_rttov10/`). The script is run by typing:

```
$ ./run_example_fwd.sh ARCH=myarch [BIN=bindir]
```

Test reference output is in `test_example_fwd.2/`. Input files for the script are in the `test_example_fwd.1/` directory, and this is also where the test output is written. The output consists of a file named `output_example_fwd.dat.myarch`, and a diff file named `diff_example_fwd.myarch` showing the differences between the test output and the reference output. The diff file should typically have zero size.

Running an example of code calling PC-RTTOV

An example of running the Principal Components forward model is given in `src/test/example_pc_fwd.F90`. This code may be used as a starting point for the users own applications. The program may be run using the `run_example_pc_fwd.sh` script. The user may need to edit the first few lines of this script to specify the location of the coefficient files (by default assumed to be in `rtcoef_rttov10/v7pred/` and `rtcoef_rttov10/pc/`). The script is run by typing:

```
$ ./run_example_pc_fwd.sh ARCH=myarch [BIN=bindir]
```

Test reference output is in `test_example_pc_fwd.2/`. Test output is written to the `test_example_pc_fwd.1/` directory and consists of files `output_example_pc_fwd_XXXX.dat.myarch`, and diff files named `diff_example_pc_fwd_XXXX.myarch` (where XXXX is “airs” or “iasi”) showing the differences between the test output and the reference output. The diff files should typically have zero size, or otherwise should show only a small number of differences in the least significant digits.

RTTOV_SCATT testing and example code

The RTTOV_SCATT code is not compiled by default, so a target which includes this code (e.g. all or mw_scatt) must have been specified when building RTTOV. The `test_rttovscatt.sh` shell script may be used to verify the RTTOV_SCATT code. The user may need to edit the first few lines of this script to specify

the location of the RTTOV coefficient files (by default assumed to be in `rtcoef_rttov10/rttov7pred/` and `rtcoef_rttov10/mietable/`). The script may then be run by typing:

```
$ ./test_rttovscatt.sh ARCH=myarch [BIN=bindir]
```

Test reference output is in `test_rttovscatt.2/`. Input files for the script are in the `test_rttovscatt.1/` directory, and this is also where the test output is written. The output consists of files named `output.NN.rttov10_scatt.myarch` and `diff.NN.myarch` (where NN is 01, 02, etc), the latter being diff files showing differences compared to the test reference data. The script will exit cleanly if no internal errors are found. The diff file should typically have zero size if no errors occurred.

There is also an example program `mw_scatt/example_rttovscatt.F90` demonstrating how to perform direct and Jacobian calculations with RTTOV_SCATT. Once `test_rttovscatt.sh` has been run, the required links to coefficient files are set up within `test_rttovscatt.1/`. The user may then call `example_rttovscatt.exe` (located in `bin/`) from this directory to run the example code. Note there is no reference output for this example program.

Emissivity atlas testing

The emissivity atlas code is not compiled by default, so a target which includes this code (e.g. all or emis_atlas) must have been specified when building RTTOV. The `test_iratlas.sh` and `test_mwatlas.sh` shell scripts may be used to verify the IR and TELSEM MW atlas code respectively. The user may need to edit the first few lines of each script to specify the location of the RTTOV coefficient files (by default assumed to be in `rtcoef_rttov10/rttov7pred/`), and the location of the emissivity atlas data files (by default assumed to be in `emis_data/`). The test scripts require emissivity data for the month of August. The scripts may be run by typing:

```
$ ./test_iratlas.sh ARCH=myarch [BIN=bindir]
$ ./test_mwatlas.sh ARCH=myarch [BIN=bindir]
```

Test reference output is in `test_emisatlas.2/`. Input files for the scripts are in the `test_emisatlas.1/` directory, and this is also where the test output is written. The output consists of files named `output_iratlas.NN.myarch` and `output_mwatlas.NN.myarch`, where NN is 01, 02, etc. The script also writes diff files named `diff_iratlas.NN.myarch` and `diff_mwatlas.NN.myarch` showing the difference between the test output and the reference output. The difference files should have zero size.