The Radio Occultation Processing Package (ROPP) Test Plan

Version 10.0

30 September 2020

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European Centre for Medium-Range Weather Forecasts (ECMWF)
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Ref: SAF/ROM/METO/TP/ROPP/001

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DOCUMENT CHANGE RECORD

Version	*Date*	*By*	*Description*
1.0-1	15/01/07	DO	Version for ROPP-1 v1.0
1.1-1	26/03/08	DO	Version for ROPP-1 v1.1
1.2-1	26/03/08	DO	Version for ROPP-1 v1.2
2.0-0	18/09/08	DO	Version for ROPP-2 v2.0-beta
2.0-1	13/10/08	HL	Version for ROPP-2 v2.0
3.0-0	27/04/09	HL	Version for ROPP-3 v3.0-beta
3.0-1	15/05/09	HL	Version for ROPP-3 v3.0
4.0	19/10/09	HL	Version for ROPP-4 – operational GRAS test version
4.1	01/04/10	HL	Version for ROPP-4 v4.1
5.0	14/06/11	CB	Version for ROPP-5 v5.0
5.1	30/09/11	CB	Version for ROPP-5 v5.1
6.0	27/10/11	CB	Version for ROPP-6 v6.0
6.1	14/02/13	CB	Version for ROPP-6 v6.1
7.0	05/06/13	CB	Version for ROPP-7 v7.0
7.1	13/01/14	CB	Version for ROPP-7 v7.1
8.0	21/11/14	CB	Version for ROPP-8 v8.0
9.0	21/07/16	CB	Version for ROPP-9 v9.0
10.0	30/09/20	IC	Version for ROPP-10 v10.0, including new tests IT-PP-07 and RT-APPS-01

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Executive Summary

This document sets out the procedures to sample and check data to be used for testing individual components and the integrated modules of the ROM SAF deliverable software and associated user documentation, collectively known as the ‘Radio Occultation Processing Package’ (ROPP). It defines general test cases for the ROPP software package to assure algorithmic correctness, robustness and operational stability.

This version of the document is applicable to the testing of ROPP-10 Release Version 10.0 (v10.0). It is aimed principally at the ROPP Development Team to ensure that appropriate testing procedures are followed, and at reviewers to demonstrate those procedures as a guide to interpreting the Test Folder results.

This document only outlines the tests to be performed, it does not report test results which can be found in the Test Folder. The Test Folder is html-based and can be viewed using any web browser. It allows the browsing of older versions of ROPP, relevant documentation, log files, etc.

1. Purpose of the document

This document sets out the procedures to sample and check data to be used for testing individual components and the integrated modules of the ROM SAF deliverable software and associated user documentation, collectively known as the 'Radio Occultation Processing Package' (ROPP). It defines general test cases for the ROPP software package to assure algorithmic correctness, robustness and operational stability.

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1.1 Reference and Applicable Documents

1.1.1 Applicable documents

The following documents have a direct bearing on the contents of this document.

[AD.1] *Proposal for the Third Continuous Development and Operations Phase (ROM SAF CDOP-3) March 2017 – February 2022, as endorsed by Council 7th December 2016.*
SAF/ROM/DMI/MGT/CDOP3/001

[AD.2] *Product Requirements Document (PRD)*
SAF/GRAS/METO/MGT/PRD/001

[AD.3] *ROPP Test Report* (ROM SAF)
SAF/ROM/METO/TR/ROPP/001

1.1.2 Reference documents

The following documents provide supplementary or background information and could be helpful in conjunction with this document.

[RD.1] *ROPP Architectural Design Document (ADD).* SAF/ROM/METO/ADD/ROPP/001

[RD.2] *The ROPP Overview*. SAF/ROM/METO/UG/ROPP/001

[RD.3] *The ROPP User Guides*.
IO module: SAF/ROM/METO/UG/ROPP/002
PP module: SAF/ROM/METO/UG/ROPP/004
APPS module: SAF/ROM/METO/UG/ROPP/005
FM module: SAF/ROM/METO/UG/ROPP/006
1DVAR module: SAF/ROM/METO/UG/ROPP/007
UTILS module SAF/ROM/METO/UG/ROPP/008

[RD.4] *The ROPP Reference Manuals*. SAF/ROM/METO/RM/ROPP/001–006

[RD.5] NWP SAF: *Development Procedures for Software Deliverables.* NWPSAF-MO-SW-002

[RD.6] NWP SAF: *Configuration Management Plan*. NWPSAF-MO-SW-003

[RD.7] P Andrews et al: *European Standards For Writing and Documenting Exchangeable Fortran 90 Code*. Copy available at: http://research.metoffice.gov.uk/research/nwp/numerical/fortran90/f90_standards.html

[RD.8] Ben Collins-Sussman, Brian W. Fitzpatrick, C. Michael Pilato: *Version Control with Subversion*. Online book available at: http://svnbook.red-bean.com/

[RD.9] *WMO FM94 (BUFR) specification for ROM SAF processed radio occultation data*. SAF/ROM/METO/FMT/BUFR/001

[RD.10] ROM SAF: *System Requirements Document*. SAF/GRAS/DMI/RQ/SRD/002

[RD.11] ROM SAF *System/Software Verification and Validation Test Plan.* SAF/GRAS/DMI/SVVP/001

[RD.12] TRAC Software development tool: http://trac.edgewall.org/

[RD.13] ROM SAF: *Beta Test Licence.* SAF/ROM/METO/LIC/ROPP/001
ROM SAF: *Software Licence*. SAF/ROM/METO/LIC/ROPP/002

1.1 Acronyms, Abbreviations & Initialisms

ADD	Architectural Design Document
API	Application Program Interface
BUFR	Binary Universal Form for the Representation of meteorological data (WMO)
CDOP	Continuous Development and Operational Phase (SAFs)
CGS	Core Ground Segment (EUMETSAT)
CHAMP	CHallenging Mini-satellite Payload (Germany)
CLIMAP	Climate and Environment Monitoring with GPS-based Atmospheric Profiling (EU)
COSMIC	Constellation Observing System for Meteorology Ionosphere and Climate (USA/Taiwan)
C/NOFS	Communications/Navigation Outage Forecasting System (US)
DMI	Danish Meteorological Institute (ROM SAF Leading Entity)
DRI	Delivery Readiness Inspection
ECMWF	European Centre for Medium-range Weather Forecasts
EPS	Encapsulated PostScript
ESA	European Space Agency
EU	European Union
EUMETcast	EUMETSAT NRT dissemination service via commercial digital video broadcast technology
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites (Darmstadt, Germany)
FM94	WMO Form no. 94 (i.e. BUFR)
Galileo	Future European GNSS system (EU/ESA)
GFZ	GeoForschungsZentrum (Potsdam, Germany)
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema (Russia)
GNSS	Global Navigation Satellite System (generic GPS/GLONASS/Galileo)
GPL	General Public Licence (GNU)
GPS	Global Positioning System (USA)
GRACE	Gravity Recovery and Climate Experiment (Germany/US)
GRAS	GNSS Receiver for Atmospheric Sounding (METOP-A and -B)
GRIB	GRIdded Binary or General Regularly-distributed Information in Binary
GTS	Global Telecommunications System (WMO)

HDF	Hierarchical Data Format
HP-UX	Unix operating system for Hewlett Packard workstations
IDL	Interactive Data Language (ITT Visual Information Solutions)
IEEC	Institut d'Estudis Espacials de Catalunya
MetDB	Meteorological Data Base (Met Office)
MetO	Met Office (of the UK)
METOP	METeorological OPerational satellite (EUMETSAT)
MS-DOS	Microsoft Disk Operating System ('Command Line' application under the Windows O/S)
netCDF	network Common Data Form (Unidata)
NMS	National Meteorological Service
NWP	Numerical Weather Prediction
NRT	Near-Real Time
OS (O/S)	Operating System
PAZ	Spanish Earth Observation Satellite, carrying a Radio Occultation Sounder
PCD	Product Confidence Data
PES	Re-Existing Software
PFS	Product Format Specification (Level 1b data from GCS)
POD	Precision Orbit Determination
RMDCN	Regional Meteorological Data Communications Network (component of the GTS)
PRD	Product Requirement Document
RO	Radio Occultation
ROM SAF	EUMETSAT Satellite Application Facility responsible for operational processing of radio occultation data from the MetOp satellites.
ROPP	Radio Occultation Processing Package
ROSA	Radio Occultation Sounder of Atmosphere (Italy/India)
SAC-C	Satelite de Applicaciones Cientificas – C (Argentina)
SAF	Satellite Application Facility (EUMETSAT)
SG	Steering Group
SNR	Signal to Noise Ratio
TanDEM-X	German Earth Observation Satellite, carrying a Radio Occultation Sounder
TBC	To Be Confirmed
TBD	To Be Determined
TerraSAR-X	German Earth Observation Satellite, carrying a Radio Occultation Sounder
UCAR	University Center for Atmospheric Research (Boulder, CO, USA)
VAR	Variational (NWP data assimilation technique)
WMO	World Meteorological Organisation
WWW	World Weather Watch (WMO Programme)

2. Introduction

The ROPP software is one of the key deliverables within the ROM SAF project (see Proposal for CDOP-3, [AD.1]) and stems for the User & Product Requirements for such a package ([AD.2]). The content of ROPP is described in the *Architecural Design Document* ([RD.1], aka Top Level Design), *ROPP Overview* ([RD.2]), *ROPP User Guides* ([RD.3]) and *ROPP Reference Manuals* ([RD.4]).

In summary, the software allows the modular processing of radio occultation observations starting from path delays (excess phase) to excess Doppler and thence to bending angles and refractivities. It also includes a 1-dimensional variational (1D-Var) assimilation option to derive temperature and water vapour profiles along with a surface pressure from bending angles or refractivities.

ROPP is designed as a highly modular set of library routines, and is primarily developed to process data of the Metop GRAS instrument, but will also be able to use data of other radio occultation missions with appropriate data ingest modules by the use of generic, mission-independent, data types and interfaces.

The package will be used for operational processing of radio occultation data by end-users and it should therefore undergo extensive testing to assure correct algorithmic implementations, operational robustness and stability. The tests and procedures to be performed and their acceptance criteria are specified in this document. A record of all test results will be archived and checked against baseline results. Tests shall be repeated, as appropriate, should any piece of software be changed for whatever reason.

The development of the ROPP package follows the guidelines already agreed for the NWP SAF ([RD.5]) and all will also use the Configuration Management Plan of the NWP SAF ([RD.6)]. Where appropriate, relevant tests and procedures from the ROM SAF SVVP [RD.11] will additionally be introduced. The ROPP software source code will be written in Fortran 90/95 to the guide standards in [RD.7]. The software package and associated documentation is kept under practical configuration management according to [RD.8]. The general software requirements are outlined in [RD.10].

This document outlines the tests to be performed to assure functionality of the ROPP software in an operational environment. Test results are documented in the Test Folder, which is a SVN-controlled package named `ropp_test`. Results can be browsed using a standard web browser. The Test Folder will be provided on an accessible web site and can also on request provided on CD or by ftp as a compressed archive file. The `ropp_test` package also holds all necessary data and programs to perform the tests and supporting documentation. The testing package itself has been developed to allow different users on different platforms to run it. It only requires the IDL programming environment and access via ssh to different compilers. An automatically generated document (from the html Test Folder) can be used to access a summary of the test results in printable form.

A software issue tracing system has also been implemented; it is based on the Trac [RD.12] software which uses a project management approach for software development. Issues (bugs, problems, change requests, etc) are reported as ‘tickets’; each ticket is either associated with a ROPP module or the whole ROPP package. Tickets are also associated with software development versions, milestones, and a person responsible for the ticket. Hence Trac can also be used to raise a ticket for a future enhancement of a software package. Additionally it has an interface to the ROPP SVN versions and thus allows browsing different versions, highlighting differences, etc. On request, the Trac package is available for demonstration.

The ROPP SVN repository can be accessed by authorised users at: https://svn.romsaf.org/ropp/ Full users can merge their changes directly to ‘trunk’, while associate users (non-SAF collaborators) have access to create and manage branches, but cannot merge to trunk.

The ROPP Trac system can be accessed at: http://trac.romsaf.org/ropp/ though unauthorised users can only access the top, introductory page. Authorised users have full access.

3. Tested Items

The required software testing can be generally divided into the following items:

- coding and compilation testing
- module testing
- integration testing
- validation testing
- portability testing
- timing testing
- documentation testing

The corresponding testing procedures with respect to the ROPP software are outlined below.

3.1 Coding and Compilation Testing

Coding guidelines for Fortran 90/95 are outlined in [RD.6] and are beyond the scope of this document. The first code test will be a visual inspection of the code by a person other than the author, but someone who knows the basic code purpose and the radio occultation methodology. This inspection will be to sign off that the code

- is written to the guidelines in [RD.6]
- correctly implements the design specified in the ADD [RD.1]

The second test is that the code compiles without error, and preferably with no warning messages. Compilation issues should in principle be resolved if proper coding is assured and the software package is accompanied by a tested installation script. Nevertheless, different compilers use different flags and might behave differently on different platforms. The simple test routines included in each module are also run as part of the compiler testing with the `make test` build command. This provides a quick check of a successful build against known results, and serves as a check that the supplied module test routines are performing as required for the range of compilers and platforms tested.

The following `make test`s are carried out:

ropp_io:
Test 1: Testing range checks - missing & invalid data --> missing data
Test 2: Testing range checks - valid data --> valid data
Test 3: Testing ROPP (netCDF) --> ROPP (netCDF)
Test 4: Testing ROPP singlefiles (netCDF) --> ROPP multifile (netCDF)
Test 5: Testing ROPP multifile (netCDF) --> ROPP singlefiles (netCDF)
Test 6: Testing ROPP 2D (netCDF) --> ROPP 2D (netCDF)
Test 7: Testing ROPP (netCDF) --> BUFR (ECMWF) --> ROPP (netCDF)
Test 8: Testing EUM netCDF4 file -> BUFR file
Test 9: Comparing eum2bufr and eum2ropp | ropp2bufr
Test 10: Testing GFZ file pair --> ROPP netCDF
Test 11: Testing UCAR netCDF --> ROPP netCDF
Test 12: Testing ECMWF GRIB --> Fortran namelist ascii
Test 13: Testing Fortran namelist ascii --> ROPP netCDF
Test 14: Testing EUM netCDF4 file --> ROPP file
Test 15: Comparing eum2ropp and eum2bufr | bufr2ropp

ropp_fm:
Test 1: Testing ropp_fm routine on 1D reference FASCOD dataset (TL /AD and nonlinear for BA and REF).
Test 2: Testing ropp_fm routine on 2D reference dataset
Test 3: Testing ropp_fm with 1D ECMWF background dataset
Test 4: Testing ropp_fm with 1D ECMWF background dataset using '-comp' option.
Test 5: Testing ropp_fm with 2D ECMWF background dataset
Test 6: Testing ropp_fm with 2D ECMWF background dataset using '-comp' option.
Test 7: Testing ropp_fm with the '–direct_ion' option.

ropp_1dvar:
Test 1: Testing basic 1D-Var functionality (refractivity). With and without '-comp'.
Test 2: Testing 1D-Var functionality (BA and REF) using GRAS data and ECMWF backgrounds. With and without '-comp'.
Test 3: As above but with Met Office background data.
Test 4: 1D-Var retrievals using L1/L2 bending angles assuming a Chapman layer ionosphere.

ropp_pp:
Test 1: Single file L1, L2 bending angle --> refractivity
Test 2: Single file L1, L2 phase --> bending angle --> refractivity
Test 3: GRAS RS L1, L2 phase --> bending angle --> refractivity
Test 4: Single file L1, L2 phase --> spectra
Test 5: Testing ROPP PP Abel
Test 6: Testing WOPT tool
Test 7: Testing 2D WOPT tool

ropp_apps:
Test 1: Testing TPH generation
Test 2: Testing PBLH generation

The ROPP software is written to compile with several Fortran 90/95 compilers. To check the installation script, the ROPP software will be compiled and run on different platforms to assure compatibility. Available platforms include several Linux versions and Cygwin running on MS Windows and will include platforms at other ROM SAF consortium members in addition to those at the developer's site. The Intel Fortran compiler on a Linux operating system serves as default, other possible compilers include the NAG on Linux, Portland Group on Linux, and freeware compilers such as the GNU Fortran 95. Compilation should also be performed on a 64-bit machine. Please refer to the Test Folder for actual compilers and their version used in the test.

3.2 Module Testing

These tests are done at module level, and check that the processing and logic within the module and the argument passing, are working as expected. Generically, known data is passed to the routine and the resulting output is checked for the expected return values.

ROPP has five main modules available to the user:

1. IO: Input / Output, reading and writing data from / to file
2. PP: Pre-processing from Level 1 (Excess Phase or Bending Angle) to Level 2 (Refractivity), wave optics propagation tool
3. FM: Forward Model, e.g. routines to generate refractivity and bending angles from atmospheric profiles (incompressible or compressible atmosphere, 'new' or 'old' operators), 1d and 2d operators, forward-modelling of L1/L2 bending angles
4. 1D-VAR: Variational retrieval of atmospheric profiles from observations, including L1/L2 bending angles.
5. APPS: Applications for deriving tropopause height and planetary boundary layer height.

In addition, a UTILS module is provided that hosts a selection of utility software tools required by the other modules. The usage of ROPP is foreseen with respect to these modules, thus users will link these modules into their code. Correct handling of erroneous input data is therefore only assured with respect to these modules. Users have to assure correct input data to routines if they use individual routines below the module level.

Strict module testing is only possible for the IO module, although this is not completely stand-alone since it depends on the UTILS module and some third-party libraries. All other modules will be tested in an integrated environment, since they require the reading/writing of input/output data. Alternatively, one could develop dedicated IO routines for each of the modules, but this introduces additional sources of errors and thus will not be performed.

IO module testing will use read-in and write-out of data in different data modes and will check whether results are within expected deviations. Also, the implemented automatic unit conversion will be tested by e.g. passing values in [m] where, internally, [km] are used.

3.3 Integration Testing

Once the correct performance of the IO module is assured, all other modules will use IO in an integrated environment. The different tests are outlined below.

3.3.1 FM

The FM will be tested together with the IO and TOOLS modules. The FM calculates bending angles and refractivity profiles from input profiles of temperature, water vapour, and pressure. Results will be compared to independently verified, simulated profile data.

3.3.2 1DVar

The 1DVar module will be tested together with the IO and the FM modules. The following tests will be performed:

- Input Data Test: Testing will only be performed with respect to erroneous measurement data. Erroneous user input data in the configuration script of the 1DVar will not be tested, it is assumed that the developer is either familiar with the software, or has the necessary information from the documentation. Data input will be tested with respect to format errors, incompatible data values (e.g. out-of-range latitudes, longitudes) will be tested within this step.
- Functionally Test: Testing of the 1D-Var module will respect to different background and background errors, measurement errors, correlation lengths, and vertical retrieval level definitions, using simulated measurement data.
- Real Measurement Data Test: RO data measured by instruments such as GRAS, COSMIC, CHAMP, and GRACE-A will be processed in this test to derived temperature, water vapour, and pressure profiles

3.3.3 PP

The PP module will be tested together with the IO module. The following tests will be performed:

- Abel transform test: Testing of the consistency of the Abel transform and Abel inversion routines using GRAS bending angle and refractivity data.
- Ionospheric correction test: Testing of the PP module with respect to GRAS L1 and L2 bending angle data, validated by ROM SAF NRT data processing to refractivity.
- Occultation processing test: Testing of the PP module with respect to CHAMP and COSMIC L1 and L2 amplitude and excess phase data, validated by ROPP v10.0.
- Wave Optics Propagator (WOPT) and FSI test – comparing retrieved refractivity from simulated phase/amplitude with original input refractivity 1D profiles and 2D slices.

3.3.4 APPS

The APPS module will be tested together with the IO module. The following tests will be performed:

- Tropopause height diagnostic test: The calculated TPH values will be compared against values in a reference file (produced with ROPP v7.0 using the default compiler). This will fail if the TPH error flags differ from the reference or if the TPH values differ by more than a specified threshold.

- Planetary boundary layer height (PBLH) test: The calculated PBLH values will be compared against values in a reference file (produced with ROPP v9.0 using the default compiler). This will fail if the TPH error flags differ from the reference by more than a specified threshold. Plots should be examined to check reasonable identification of gradients as a "true" reference does not exist.

3.4 Validation Testing

Validation tests will be performed on the one hand in-house, where processed RO data will be compared to radiosonde data, ECMWF or Met Office analysis fields. These observation cases will cover all latitude ranges and seasons and will use visual inspection of standard deviation and biases to assure that code provides expected results. On the other hand, selected beta testers will also install and run ROPP locally and report any problems found.

Beta testers are required to agree to the terms of a Beta-Tester Licence approved by EUMETSAT [RD.13][1]. The Beta-testing procedures and feedback to the developers is planned to be otherwise informal for optimum efficiency. Nevertheless, logs will be kept of all feedback items with their resolution, including re-testing results (according to this document) where appropriate. Logs will be kept with the Trac system [RD.12].

External Beta testing will only be performed for candidate major release versions (v1.0, v2.0 etc) but not for minor update releases (v1.1, v1.2 etc).

3.5 Regression Testing

Where suitable, the impact of changes to existing algorithms between release versions will be tested by comparing integration testing results from the candidate release code and a previous release version.

3.6 Portability Testing

Portability testing will first be performed in house, using the available range and platforms with Fortran 90/95 compilers. Only 64-bit platforms will be tested. Actual compiler, including version number, will be provided in the Test Folder. Portability will also be performed by Beta-testers; encountered problems will be treated as outlined in Section 3.4. Please refer to the Test Folder for a complete list of compiler and versions used.

3.7 Timing Testing

Assuring that developed code runs in reasonable times on different platforms. Some typical processing times will be reported in the Test Folder. These will be derived from module tests, or from integration testing where several measurements are processed within the 1DVar module. Timing testing serves only as a guideline to other users of ROPP, it is not a benchmark test. Accurate timing depends very much on the local configuration. Beta-testers will also report problems found in their local implementation, as outlined in Section 3.4.

3.8 Documentation Testing

A User Guide [RD.3] and a set of Reference Manuals [RD.4] for the software is provided with ROPP. The Reference Manuals are generated automatically from the source code for each module and these provide information about the different modules, variables, and calling structure used in ROPP. The User Guide (in three parts) will provide information about how to use ROPP and the underlying mathematical operations. User Guide testing will mainly be performed by internal and external Beta testers, providing feedback about their experiences, as outlined in Section 3.4.

[1] *A different software licence, as noted at [RD.14], is used for the full release package.*

3.9 Operational Data Testing

When available, a number of IO, FM and 1DVAR tests will be performed using operational GRAS data products (Level 1b from EUMETSAT and ROM SAF Level 2 GRM-01 Refractivity product).

4. Software Requirements Traceability Matrix

The following matrix cross-references the ROPP software requirements as given in the ROM SAF SRD ([RD.10]) with the performed test procedure ID. This ID can be used for cross-referencing to the Test Folder. A brief description of each test is provided in Section 5.

The traceability matrix also shows the **testing method (TM)**, where:

- **Test (T)**. The software item is run with applicable input data and the output is objectively analysed. The output can be e.g. data files or log messages, given in the Test Folder.
- **Inspection (I)**. Requirements that do not refer to software functionality, or otherwise can not be verified with test runs, might be verified by inspections.
- **Analysis (A)**. Verification of some requirements may require extensive theoretical consideration.
- **Demonstration (D)**. Some requirements are verified by simple demonstration (typically yes/no or passed/failed issues).
- **Review (R)**. Written material is normally verified by a review.

Note:

- Each test has a test procedure ID, but not all Test Procedure IDs have a corresponding entry in the SRD [RD.10], since several additional tests are introduced to assure full functionality of the ROPP package.
- The table will be updated when new tests are defined and performed.
- Requirements not yet tested are highlighted in grey. They generally refer to future ROPP developments during CDOP-3.

Table 1. Software Requirement Traceability Matrix

ROM SAF SRD (from [RD.10])	TM	Test Procedure ID	Purpose	Comments
Top-level functional requirements				
ASSIM.FUNC.010	I	N/A	see SRD[5.2.2]	see SRD[5.2.2]
Coding and Compilation Testing				
ASSIM.QUAL.010	I	CC-QU-01	Use Fortran90	
ASSIM.QUAL.020	I	CC-QU-02	Stand. Features	
ASSIM.QUAL.030	I/T	CC-QU-03	Follow SW Guide	done in ropp_test
Module Testing				
Not applicable	T	MT-IO-01	IO Working (inc BUFR and ecCodes)	done in ropp_test
Not applicable	T	MT-IO-02	IO Units	done in ropp_test
Not applicable	T	MT-IO-03	IO Thinner	done in ropp_test
Not applicable	T	MT-IO-04	IO UCAR decoder	done in ropp_test
Not applicable	T	MT-IO-05	IO GFZ decoder	done in ropp_test
Not applicable	T	MT-IO-OP	IO Thinner (operational GRAS)	done in ropp_test
Integration Testing				
ASSIM.FUNC.{110, 200 & 210}	T	IT-FM-01	FM Scenarios	done in ropp_test
	T	IT-FM-02	FM (ECMWF bg)	done in ropp_test
	T	IT-FM-03	FM (MetO bg)	done in ropp_test
	T	IT-FM-04	FM (GRAS obs)	done in ropp_test
	T	IT-FM-OP	FM (operational GRAS)	done in ropp_test
ASSIM.FUNC.300	T	IT-FM-05	BA 2D FM	done in ropp_test
ASSIM.FUNC.300	T	IT-FM-06	FM compressibility (1D)	done in ropp_test
ASSIM.FUNC.300	T	IT-FM-07	FM compressibility (2D)	done in ropp_test
ASSIM.FUNC.300	T	IT-FM-08	FM L1/L2 (1D)	done in ropp_test
ASSIM.FUNC.{100,120 ,130}	T	IT-1DVAR-01	1DVar Input test	done in ropp_test
	T	IT-1DVAR-02	BG eq sim. Meas	done in ropp_test

ROM SAF SRD (from [RD.10])	TM	Test Procedure ID	Purpose	Comments
	T	IT-1DVAR-03	BG ne sim. Meas	done in ropp_test
	T	IT-1DVAR-04	1DVar (MetO bg)	done in ropp_test
		IT-1DVAR-05	1DVar 2D BG	done in ropp_test
		IT-1DVAR-06	1DVar compressibility	done in ropp_test
		IT-1DVAR-07	1DVar '—direct_ion'	done in ropp_test
ASSIM.FUNC.{100,120 ,130}	T	IT-1DVAR-OP	1DVar (operational GRAS)	done in ropp_test
ASSIM.FUNC.220	T	IT-1DVAR-11	Plane FM (not currently implemented in ROPP)	CDOP-N
ASSIM.FUNC.230	T	IT-1DVAR-12	Plane Adjoint (not currently implemented in ROPP)	CDOP-N
	T	IT-PP-01	Abel integral test	Done in ropp_test
	T	IT-PP-02	Ionospheric correction test	Done in ropp_test
	T	IT-PP-03	L1/L2->LC,OPT,REF (GRAS CL)	Done in ropp_test
	T	IT-PP-04	L1/L2->LC,OPT,REF (COSMIC)	Done in ropp_test
	T	IT-PP-05	L1/L2->LC,OPT,REF (GRAS RS)	Done in ropp_test
	T	IT-PP-06	1d WOPT/FSI (ECMWF refrac)	Done in ropp_test
	T	IT-PP-07	2d WOPT/FSI (ECMWF refrac)	Done in ropp_test
	T	IT-APPS-01	TPH diagnostic	Done in ropp_test
	T	IT-APPS-02	PBLH diagnostic	Done in ropp_test
Regression Testing				
Not applicable	T/A	RT-IO-01	IO (operational GRAS)	Done in ropp_test
Not applicable	T/A	RT-FM-01	FM (operational GRAS)	Done in ropp_test
Not applicable	T/A	RT-1DVAR-01	1dVar (operational GRAS)	Done in ropp_test
Not applicable	T/A	RT-PP-01	Occ Test (COSMIC)	Done in ropp_test
Not applicable	T/A	RT-APPS-01	TPH diagnostic test	Done in ropp_test
Validation Testing				
Not applicable	T/A	VT-1DVAR-01	T, WV Validation	Future ROPP version
Not applicable	T/A	VT-PP-01	Occ Validation	Future ROPP version
Portability Testing				
ASSIM.PORT.010	T	PT-ALL-01	Portable	done in ropp_test
Timing Testing				
Not applicable	T	TT-ALL-01	Benchmark	done in ropp_test
Documentation Testing				
ASSIM.DOCU.010	D	DT-DO-01	Version usage	See ROPP document set
ASSIM.MAIN.010	D	DT-DO-02	Maintenance	For future validation of requirements.
ASSIM.MAIN.020	D/R	DT-DO-03	Update	
ASSIM.MAIN.030	R	DT-DO-04	Update	

5. Test Description

The following table gives a brief description of the procedure undertaken to perform the test. It will be updated within the development of ROPP (grey shaded tests are not applicable at this stage and will be filled later). Test IDs listed in bold indicate tests implemented using operational GRAS bending angle and refractivity products.

Table 2. Test Description

Test Procedure ID	Description	Pass criteria
CC-QU-01	Visual inspection of the code.	Meets requirement
CC-QU-02	Visual inspection of the code.	Meets requirement
CC-QU-03	Compile module using different compilers/platforms and report number of errors and warnings found for each module. `make test` is run for each module on each compiler.	Passed if no error or `make test` failure found, warnings will be removed as far as possible with releases.
MT-IO-01	Read netCDF file, fill with random values. Use IO module to write out in netCDF. Also netCDF to BUFR back to netCDF conversion. (Depending on compiler metDB, ECMWF or ecCodes BUFR libraries are tested.)	Compare the two netCDF files, values should agree within rounding precision. The netCDF-BUFR-netCDF comparison allows for known limitations of the BUFR vs netCDF parameter details.
MT-IO-02	Read netCDF file in non standard units, use IO module to automatically convert units, write out in netCDF.	Compare the 2 netCDF files, values should agree within rounding precision.
MT-IO-03	Read 180 netCDF GRAS profiles and thin them. Compare the thinned results to IDL-interpolated unthinned values for bending angle, refractivity, temperature and longitude profiles.	Pass when maximum standard deviation is below 5% and maximum bias is below 0.5%.
MT-IO-04	Read profile in UCAR netCDF format. Use the ucar2ropp tool and write data in ROPP netCDF format and compare input and output files.	Pass if all variables are equal in the two netCDF formats.
MT-IO-05	Read 31 NRT profiles and 36 phase delay profiles in GFZ text format (.dat and .dsc). Compare input files with the output from gfz2ropp tool.	Pass if all variables are equal between the ROPP netCDF files and GFZ ASCII files.
MT-IO-OP	Read file with 1 day of full resolution operational GRAS bending angle and refractivity data (625 profiles) and thin them. Compare the thinned to the unthinned results for bending angle, refractivity, longitude and azimuth profiles.	Pass when maximum standard deviation is below 5% and maximum bias is below 1%.
IT-FM-01	Read netCDF file with 5 different FASCOD scenarios and 3 ducting examples and process them with the ROPP forward model. Compare generated ROPP refractivity and bending angle profiles to an IDL based forward model algorithm both with and without compressibility.	Pass if errors are within acceptable processing precision (0.01%).
IT-FM-02	Process the co-located ECMWF profiles of 1000 randomly selected GRAS occultations with the ROPP forward model and compare refractivity and bending angle profiles to GRAS measurements.	Pass if errors are within expected performance, i.e. generally below 5% above 10km.
IT-FM-03	Process the co-located Met Office profiles of 1000 randomly selected UCAR-processed occultations (COSMIC-1,2,4,5,6, SAC-C and C/NOFS) with the ROPP forward model and compare refractivity and bending angles to RO measurements	Pass if errors are within expected performance, i.e. generally below 5% between 10km and 35km.
IT-FM-04	Process the co-located Met Office profiles of 1000 randomly selected GRAS occultations with the ROPP forward model and compare refractivity and bending angles to RO measurements	Pass if errors are within expected performance, i.e. generally below 5% between 10km and 35km.
IT-FM-05	Process the co-located 2D ECMWF background profiles of 500 randomly selected COSMIC	Pass if errors (bias and standard deviation of 2D FM vs obs) are within expected performance, i.e.

	occulations with the ROPP forward model (1D and 2D operators) and compare bending angles to the RO measurements	generally below 5% between 10km and 35km.
IT-FM-06	Process the co-located ECMWF profiles of 1000 randomly selected GRAS occultations with the ROPP forward model and compare refractivity and bending angle profiles to GRAS measurements with and without compressibility included in the FM calculation. The two datasets are compared.	Pass if the maximum value of bias and standard deviation of compressibility vs no compressibility is less than 5% and greater than 0.0001% (to ensure a difference is produced) above 5km.
IT-FM-07	Process the co-located 2D ECMWF background profiles of 500 randomly selected COSMIC occulations with the ROPP forward model (2D operator) and compare bending angles calculated with and without compressibility.	Pass if the maximum value of bias and standard deviation of compressibility vs no compressibility is less than 5% and greater than 0.0001% (to ensure a difference is produced) between 5km and 35km.
IT-FM-08	Process the co-located Met Office background profiles of 200 COSMIC observations (bending angle and refractivity) using the original forward models and the '-new_op' option to use improved assumptions between model levels.	Pass if the bias and standard deviations of the O-Bs are less than 5% between 10km and 35km.
IT-FM-OP	Process the co-located ECMWF profiles of one day of operational GRAS bending angle and refractivity products with the ROPP forward model and compute refractivity and bending angles to GRAS RO measurements.	Pass if errors are within expected performance, i.e. generally below 5% between 10km and 35km.
IT-1DVAR-01	Retrieve temperature, water vapor, and pressure from simulated measurements of 5 FASCOD and 3 ECMWF refractivity, bending angle profiles with ducting, where several entries of the background file are set to erroneous values.	Pass if erroneous data is correctly detected by ROPP input range check.
IT-1DVAR-02	Retrieve temperature, specific humidity, pressure and geopotential height using the ROPP 1D-Var code. The 1D-Var background is used to generate simulated measurements that are then used as the observations, therefore the output from the 1D-Var should be identical to input. 8 background files are tested: 5 FASCOD and 3 ECMWF profiles with ducting. Currently only refractivity implemented.	Pass if errors are within processing precision (0.01%).
IT-1DVAR-03	Retrieve temperature, water vapor, and pressure from simulated measurements of 5 FASCOD and 3 ECMWF refractivity and bending angle profiles with ducting, using modified background. The generation of the background temperature and water vapor profiles is by a simple modification of the true profiles with a sine-like addition. Otherwise as IT-1DVAR-02.	Pass if reduction in measurement difference from background is at least 40%. This corresponds to a simplified cost function.
IT-1DVAR-04	Retrieve temperature, water vapor, and pressure from 5 randomly selected COSMIC refractivity and bending angle profiles. The background temperature, pressure and humidity profiles are taken from co-located Met Office model data. Model and observation error covariances used within the operational Met Office assimilation are used.	Pass if reduction in measurement difference from background observed.
IT-1DVAR-05	Retrieve temperature, water vapour and pressure from 10 randomly selected GRAS refractivity and bending angle profiles. The background temperature, pressure and humidity profiles are taken from co-located ECMWF model data. Model and observation error covariances provided as part of the ropp_1dvar module are used. This is repeated for the '-new_op' option.	Pass if reduction in measurement difference from background observed.
IT-1DVAR-06	Retrieve temperature, water vapor, and pressure from 5 randomly selected COSMIC refractivity	Pass if differences in retrieved values using ideal and non-ideal gas in FM are not insignificant but

	and bending angle profiles with and without compressibility. The background temperature, pressure and humidity profiles are taken from co-located Met Office model data. Model and observation error covariances used within the operational Met Office assimilation are used. The percentage difference between the retrieved values calculated with and without compressibility is compared.	below values selected to reject scientifically invalid results: BA temp diff < 2K BA shum diff < 0.5g/kg BA pres diff < 0.3hPa REF temp diff < 1K REF shum diff < 0.5 g/kg REF pres diff < 0.2hPa
IT-1DVAR-07	Retrieve temperature, water vapour, pressure and ionospheric parameters using a 1D-Var on 10 GRAS L1/L2 profiles and co-located ECMWF background columns.	Pass if reduction in measurement difference from background observed.
IT-1DVAR-OP	Retrieve temperature, water vapour and pressure from 1 day of operational GRAS refractivity and bending angle profiles. The background temperature, pressure and humidity profiles are taken from co-located ECMWF model data. Model and observation error covariances provided as part of the ropp_1dvar module are used.	Pass if reduction in measurement difference from background observed.
IT-PP-01	Process 250 randomly selected NRT refractivity profiles from GRAS occultations to bending angle using forward Abel routines, then back to refractivity using inverse Abel routines.	Pass if the difference between computed refractivity profiles and the input are less than 10% between 0 and 45 km.
IT-PP-02	Process 50 randomly selected L1 and L2 bending angle profiles from GRAS occultations to ionospheric corrected bending angle and refractivity. Validates the stand-alone `ropp_pp_invert_tool`, ionospheric correction, statistical optimisation and Abel inversion processing with ROM SAF NRT refractivity product (IT-PP-02_ref.nc).	Pass if errors between ROPP computed refractivity and NRT product are less than 0.05% everywhere. From ROPP-3: Validated against ROM SAF pre-operational refractivity product. From ROPP-8: Due to statistical optimisation improvements (ticket #356), this test failed due to inconsistency with the NRT code. The refence data and tests have been updated to reflect the change. Test statistics are produced on a higher resolution grid. The GMSIS climatology is used, and fixed reference data from ROM SAF NRT (using settings similar to ROPP-8) are used to ensure comparisons are made on the same grids. Two spurious profiles are deliberately neglected.
IT-PP-03	Process 15 randomly selected L1 and L2 amplitude and excess phase measurements from COSMIC occultations to L1 and L2 bending angle, ionospheric corrected bending angle and refractivity. Validates the `ropp_pp_occ_tool`, pre-processing, geometric optics and wave optics processing with results obtained using ROPP v9.0.	Pass if errors between ROPP computed refractivity and ROPP v6.0 results are less than 0.1% below 50km.
IT-PP-04	Process 25 randomly selected L1 and L2 amplitude and excess phase measurements from COSMIC occultations to L1 and L2 bending angle, ionospheric corrected bending angle and refractivity. Validates the `ropp_pp_occ_tool`, pre-processing, GO and WO processing with results obtained using ROPP v6.0.	Pass if errors between ROPP computed refractivity and ROPP v6.0 results are less than 0.1% below 50km.
IT-PP-05	Process 5 randomly selected L1 and L2 amplitude and excess phase measurements from GRAS (raw sampling) occultations to L1 and L2 bending angle, ionospheric corrected bending angle and refractivity. Validates the `ropp_pp_occ_tool`, pre-processing, GO and WO processing with results obtained using ROPP v6.0.	Pass if errors between ROPP computed refractivity and ROPP v6.0 results are less than 0.1% below 50km.

IT-PP-06	Pass 4 ECMWF refractivity profiles through `ropp_pp_wopt_tool` to obtain simulated phase/amplitude. From these retrieve BA with the FSI function, and then obtain refractivity with `ropp_pp_invert_tool`. Compare these with original input refractivities.	Pass if, below 5km, absolute mean difference< 3.0%, mean absolute < 4.0% , max absolute deviations < 15.0%. And, above 5km, absolute mean difference< 1.0%, mean absolute < 1.5% , max absolute deviations < 4.0%.
IT-PP-07	Pass 4 ECMWF refractivity slices through `ropp_pp_wopt_2D_tool` to obtain simulated phase/amplitude. From these retrieve BA with the FSI function, and then obtain refractivity with `ropp_pp_invert_tool`. Compare these with original input refractivities at centre of slice.	Pass if, below 5km, absolute mean difference< 3.0%, mean absolute < 4.0% , max absolute deviations < 15.0%. And, above 5km, absolute mean difference< 1.0%, mean absolute < 1.5% , max absolute deviations < 4.0%.
IT-APPS-01	Calculate TPH for 10 profiles of GRAS data using bending angle, refractivity, Tdry (calculated offline) and temperature (from ECMWF). Compare these values with those produced using ROPP 7.0 compiled with ifort12.	Pass if the error flags from the TPH tool are identical with those in the reference file and the successfully-diagnosed TPH values must be within 1.0 m of the corresponding reference file (generated using ROPP-7).
IT-APPS-02	Calculate PBLH for 160 profiles of COSMIC data and co-located Met Office backgrounds. This is done for all six methods. Diagnosed heights are compared against those from a fixed reference file. Data from a subset of 5 profiles are plotted.	Pass if diagnosed PBLHs are withing 1.0m of reference data (generated using ROPP-9 with the default compiler).
RT-IO-01	As MT-IO-OP, comparing results processed using `ropp2ropp` tool from candidate release code version with equivalent tool from a previous version.	Pass if differences between ROPP versions are within anticipated range, (depending on detail of version-to-version changes). If no major code change between versions, pass if differences are less than 0.1% everywhere.
RT-FM-01	As IT-FM-OP, comparing results processed using `ropp_fm_bg2ro_1d` tool from candidate release code version with equivalent tool from a previous version.	Pass if differences between ROPP versions are within anticipated range, (depending on detail of version-to-version changes).
RT-1DVAR-01	As IT-1DVAR-OP, comparing results processed using `ropp_1dvar_bangle` from candidate release code version with equivalent tool from a previous version.	Pass if differences between ROPP versions are within anticipated range, (depending on detail of version-to-version changes).
RT-PP-01	As IT-PP-04, comparing results processed using `ropp_pp_occ_tool` from candidate release code version with equivalent tool from a previous version.	Pass if differences between ROPP versions are within anticipated range, (depending on detail of version-to-version changes).
RT-APPS-01	As IT-APPS-01, comparing results processed using `ropp_apps_tph_tool` from candidate release code version with equivalent tool from a previous version.	Pass if differences between ROPP versions are within anticipated range, (depending on detail of version-to-version changes).
VT-1DVAR-01	To be provided in a future version.	
VT-PP-01	To be provided in a future version.	
PT-ALL-01	Portability testing of program. This will be performed for each testing step that includes computation, using different compilers and platforms. Each compiler will be tested the same way as the default compiler.	Passed if code compiled by at least three compilers from different vendors are fully working.
TT-ALL-01	Test timing of program. This will be performed for each testing step that includes computation. Generally, the average over 10 calls to that particular test are averaged and reported. The 'time' command is used get the run time. The reported time gives a guideline on how fast ROPP runs in the local installation, thus allowing new installations to test performances.	It does not serve as a benchmark test, since this depends on the local configuration. Thus pass if test is performed and generated timing information.
DT-DO-02	Software is updated and maintained, changes are kept under Version Control [RD.8].	Meets requirement
DT-DO-03	Software is improved once new requirements are identified. Changes will be kept under Version Control [RD.8].	Meets requirement
DT-DO-04	Software is maintained/updated, changes are kept under Version Control [RD.8].	Meets requirement

6. Test Dataset Description

The following table gives a brief description of the datasets used in the test. It will be updated within the development of ROPP (grey shaded tests are not applicable at this stage). Test IDs listed in bold indicate tests implemented using operational GRAS bending angle and refractivity products.

Table 3. Test Dataset Description

Test Procedure ID	Description
CC-QU-01	No dataset required
CC-QU-02	No dataset required
CC-QU-03	No dataset required
MT-IO-01	Blank netCDF file, filled with random values in test.
MT-IO-02	Blank netCDF file, filled with random values in test.
MT-IO-03	180 NetCDF UCAR profiles (MT-IO-03.nc). ROPP format – profiles dated July 2011.
MT-IO-04	UCAR format netCDF profile (MT-IO-04.nc). File stamp: C001.2011.209.00.00.G15
MT-IO-05	67 GFZ format text profiles (*.dat, *.dsc) in MT-IO-05 directory. Profiles dated 2010 & 2011
MT-IO-OP	1 day (625 profiles) NetCDF operational GRAS profiles (MT-IO-OP.nc). Profiles from July 28 2011, format version ROPP I/O V1.1
IT-FM-01	netCDF file (IT-FM-01.nc) with 5 FASCOD[2] scenarios and 3 ducting profiles from ECMWF. Processing date 2005.
IT-FM-02	netCDF file (IT-FM-02.nc) with 1000 randomly selected GRAS observations. Also included are ECMWF temperature, water vapor, pressure profiles at the mean tangent point location. Occultations from July 2011.
IT-FM-03	netCDF file (IT-FM-03.nc) with 1000 randomly selected UCAR-processed samples, including occultations from COSMIC-1, -2, -4, -5, -6, SAC-C and C/NOFS. Also included are Met Office temperature, water vapor, pressure profiles at the mean tangent point location. All observations are from July 2011.
IT-FM-04	netCDF file (IT-FM-04.nc) with 1000 randomly selected GRAS observations. Also included are Met Office temperature, water vapor, pressure profiles at the mean tangent point location. Occultations are from July 2011.
IT-FM-05	netCDF file (IT-FM-05.nc) with 500 GRAS observations (pre-operational data) and 2D ECMWF temperature, water vapour, pressure profiles along the occultation plane. Profiles from 2008.
IT-FM-06	netCDF file (IT-FM-06.nc) with 1000 randomly selected GRAS observations. Also included are ECMWF temperature, water vapor, pressure profiles at the mean tangent point location. Occultations from July 2011.
IT-FM-07	netCDF file (IT-FM-07.nc) with 500 GRAS observations (pre-operational data) and 2D ECMWF temperature, water vapour, pressure profiles along the occultation plane (same data as IT-FM-05). Profiles from 2008.
IT-FM-08	netCDF file (IT-FM-08.nc) with 200 COSMIC observations and co-located Met Office background columns. Profiles from 2011.
IT-FM-OP	netCDF file (IT-FM-OP.nc) with 1 day of GRAS observations (thinned data, result of MT-IO-OP.nc test). Also included are ECMWF temperature, water vapour, pressure profiles at the mean tangent point location. Profiles are from 28 July 2011.
IT-1DVAR-01	netCDF file with 5 FASCOD scenarios and 3 ducting profiles from ECMWF are used as background data (IT-1DVAR-01_b.nc). The simulated measurements (IT-1DVAR-01_y.nc) are generated from these backgounds. The background error correlations are provided (IT-1DVAR-01_c.nc). Erroneous input data is used in background profile: (1) latitude out of range; (2) longitude out of range; (3) surface geopotential out of range; (4) surface pressure out of range; (5) month out of range; (6) B level coefficients set to zero for all altitudes; (7) temperature profile at all levels out of range; (8) day out of range. Processing date 2005.
IT-1DVAR-02	As IT-1DVAR-01 but with valid background data. Processing date 2005.
IT-1DVAR-03	As IT-1DVAR-01 but with valid background data that is slightly modified from the data used to simulate the measurement. Processing date 2005.
IT-1DVAR-04	netCDF file with 5 randomly selected COSMIC profiles (IT-1DVAR-04_y.nc). The co-

[2] *Atmospheric scenarios are obtained from FASCOD (Fast Atmospheric Signature Code)) [Anderson et al., 1986], which offers 5 atmospheric conditions: tropical (TRO), mid-latitude summer (MLS), mid-latitude winter (MLW), subarctic summer (SAS), subarctic winter (SAW).*

	located background data are taken from Met Office model fields (IT-1DVAR-04_b.nc). The background error correlations (IT-1DVAR-04_c.nc) are provided. Observation error correlations assumed for refractivity are provided (IT-1DVAR-04_o.nc). The test uses different configuration files for refractivity and bending angle 1dVar, provided with the ROPP distribution in ropp_src/ropp_1dvar/config. Observations are from July 2011.
IT-1DVAR-05	netCDF file with 10 randomly selected profiles (IT-1DVAR-05_y.nc). The co-located background data are taken from ECMWF model fields (IT-1DVAR-05_b.nc). The background error correlations (IT-1DVAR-05_c.nc) are provided. Observation error correlations assumed for refractivity are provided (IT-1DVAR-05_o.nc). The test uses different configuration files for refractivity and bending angle 1dVar, provided with the ROPP distribution in ropp_src/ropp_1dvar/config. Processing date 2009.
IT-1DVAR-06	netCDF file with 5 randomly selected COSMIC profiles (IT-1DVAR-06_y.nc). The co-located background data are taken from Met Office model fields (IT-1DVAR-06_b.nc). The background error correlations (IT-1DVAR-06_c.nc) are provided. Observation error correlations assumed for refractivity are provided (IT-1DVAR-06_o.nc). The test uses different configuration files for refractivity and bending angle 1dVar, provided with the ROPP distribution in ropp_src/ropp_1dvar/config (these test data files are the same as those used in test IT-1DVAR-04). Observations are from July 2011.
IT-1DVAR-07	netCDF file with 10 randomly selected GRAS profiles, including L1/L2 (IT-1DVAR-07_y.nc). The co-located background data are taken from ECMWF model fields (IT-1DVAR-07_b.nc). The background error correlations (IT-1DVAR-07_c.nc) are provided. Observation error correlations assumed for bending angle are provided (IT-1DVAR-07_obsc.nc). The test uses the configuration file IT-1DVAR-07.cf. Observations are from 2011.
IT-1DVAR-OP	netCDF file with 1 day of operational GRAS bending angle and refractivity profiles (IT-FM-OP.nc). The co-located background data are taken from ECMWF model fields (IT-1DVAR-OP_b.nc). The background error correlations are provided with the ROPP distribution in ropp_src/ropp_1dvar/errors. Observation error correlations assumed for refractivity are provided with the ROPP distribution in ropp_src/ropp_1dvar/errors. The test uses different configuration files for refractivity and bending angle 1dVar, provided with the ROPP distribution in ropp_src/ropp_1dvar/config. Profiles are from 28 July 2011.
IT-PP-01	netCDF file with 250 randomly selected GRAS profiles, containing L1 and L2 bending angle data, EUMETSAT corrected bending angle product and ROM SAF NRT Level 2a refractivity product. Processing date 2009.
IT-PP-02	netCDF file with 50 randomly selected GRAS profiles, containing L1 and L2 bending angle data. Processing date 2008. Two profiles (9 and 34) are ignored as they are large outliers in the statistical optimisation test. The reference file IT-PP-02_ref.nc contains the EUMETSAT corrected bending angle product and ROM SAF NRT Level 2a refractivity product.
IT-PP-03	netCDF file with 15 randomly selected COSMIC profiles, containing L1 and L2 amplitude and excess phase data together with satellite positions. The corresponding file IT-PP-03_ref.nc contains Level1b and Level2a data which are the results of running ROPP v10.0 processing on the Level1a data. Profiles from 2014.
IT-PP-04	netCDF file with 20 randomly selected COSMIC profiles, containing L1 and L2 amplitude and excess phase data together with satellite positions. The corresponding file IT-PP-04_ref.nc contains Level1b and Level2a data which are the results of running ROPP v10.0 processing on the Level1a data. Profiles from 2012.
IT-PP-05	netCDF file with 5 randomly selected GRAS RS profiles, containing L1 and L2 amplitude and excess phase data together with satellite positions. The corresponding file IT-PP-05_ref.nc contains Level1b and Level2a data which are the results of running ROPP v10.0 processing on the Level1a data. Profiles from 2012.
IT-PP-06	Directory containing 4 netCDF files, each one containing an ECMWF refractivity profile from the ‘standard’ 55-profile dataset. The filenames contain the ‘case’ number.
IT-PP-07	Directory containing 4 netCDF files, each one containing an ECMWF refractivity slice from the ‘standard’ 55-slice dataset. The filenames contain the ‘case’ number.
IT-APPS-01	netCDF file with 10 profiles of LC bending angle, refractivity, dry temperature (computed offline) and ECMWF background temperature. The corresponding reference file contains the output from ropp_apps_tph_tool (ROPP 7.0 compiled with ifort12).
IT-APPS-02	netCDF file with 160 profiles of observed COSMIC LC bending angles from 2016 and refractivity, plus co-located Met Office background profiles. The corresponding reference file contains the output from ropp_apps_pblh_tool (ROPP 9.0 compiled with ifort12).
PT-ALL-01	Dataset of the relevant test

TT-ALL-01	Dataset of the relevant test
DT-DO-02	No dataset required
DT-DO-03	No dataset required
DT-DO-04	No dataset required

Where changes are made to the default configure files (*.cf) for the various tools, copies of the previous versions will be retained in the test data repository to allow consistent testing of the tools independently of these settings.

At version 6.0, several improvements were made to the PP module. From version 6.1 onwards, output from version 6.0 is used as a reference in the tests IT-PP-03, IT-PP-04 and IT-PP-05 instead of OCC. (However, a change to ropp_pp_filter made at 6.1 made a small but significant difference to the results, so that the new reference is produced with 6.0 but with this change applied (ROPP ticket #299)).

The data (netCDF files) can be found in: `ropp_test/data/<version>`. Reference netCDF files shall be consistent with the file format version appropriate to the ROPP release version.

At version 9.0, the relevant test files were updated to include some new netCDF variables that were introduced at this version (e.g. PBLH diagnostics). Also, the test data for IT-PP-03 has been replaced with 15 COSMIC profiles.

At version 10.0, two new tests were included: IT-PP-07, to test the 2D wave optics propagation tool; and RT-APPS-01, to test the TPH algorithm against the previous release. The reference datasets of tests IT-PP-03, IT-PP-04 and IT-PP-05 were updated because changes introduced to the tangent point and occulation point calculations introduced in ROPP-10.0 meant that the results of the new tools failed the comparison tests against the reference results, which were generated by ROPP-6.0.

7. Test Results

Test results are reported in the **Test Folder**. The Test Folder is a SVN-based package (SVN is an improved development of CVS), named `ropp_test`. For external reviewers, it is either available on CD or as a downloadable compressed archive file on request. A copy may also be placed on an accessible website (e.g. DMI's ROM SAF site). The Test Folder contains the relevant documents of each release version, e.g. this Test Plan, Test Results and Software Development Record. It has been set up to allow possible future integration into the ROM SAF website. To limit the size of the Test Folder, only the most recent and a few earlier versions are kept in the package. Older versions have to be checked out of the repository. Feedback from users will be included in the Trac [RD.12] issue logging system.

The following general structure is used for the Test Folder:

Main Directory:
1. `data` : data files by version used in test
2. `html` : html files and other documents
3. `htlm2ps` : input files to html2ps program (automatic Test Folder pdf document generation)
4. `programs` : IDL scripts for testing
5. `reports` : latest versions of report for updating (internal use)
6. `system` : configure scripts and system setup scripts used by `ropp_test`

html Directory:
1. `versions`: test result by specific versions

versions Directory:
1. `docs` : relevant documents for the specific version
2. `logs` : log files of tests for the specific version

The test results in the Test Folder can be accessed with any browser. Just load the file:

```
file://<path-to>/ropp_test/html/index.html
```

into the browser.

Once the browser opens the page, the test results of different versions can be accessed with a drop down menu (with the latest version as default). There are also direct links on this page to the most recent documents of the Test Plan, the SRD, and a Test Results document that is generated from these html pages.

Full information on a test is available in the new window that opens when the 'GO' button is pressed after a version selection. Test results are listed by compiler; the gfortran compiler on Linux serves as a default or reference, although all compilers undergo the same testing procedures. Each compiler has a summary table on top, listing the **Test Procedure ID** and the test results. The **ID** also serves as a link to summary test result information, which in turn has links to the raw log files and (where appropriate) graphical output.

8. Software Development Record

The ROM SAF ROPP development generally follows the procedures defined by the NWP SAF for their software deliverables (AAPP, RTTOV, etc) [RD.5]

A Software Development Record (SDR) is issued with each new ROPP version. The SDR for ROPP-10 follows the SDR given in the Annex to [RD.5]. A template copy of this document can be found at `ropp_doc/nwpsaf/SDR.doc`. A copy of this template shall be placed in `ropp_test/docs/romsaf_ropp_sdr_v<ver>.doc` at the start of development of ROPP release version `<ver>` and the entries completed as appropriate to every development, testing & review stage.

Note that very early ROPP releases (v1.0, v1.1 & v1.2) followed an earlier version of the NWP SAF Software Development Procedures which used a simpler 'software release authorisation checklist' (sracl).