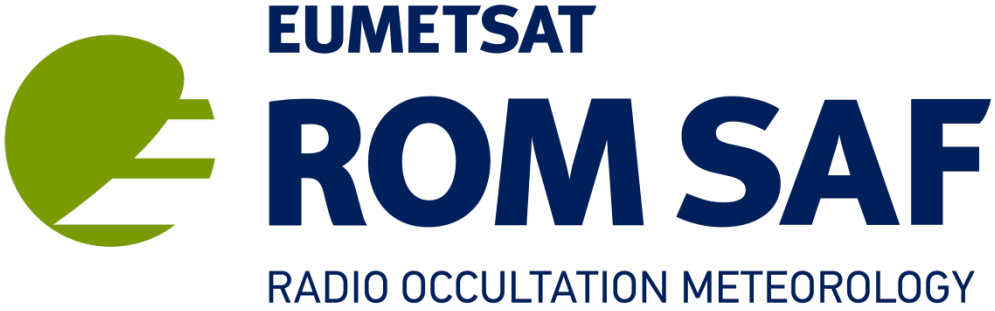

Product Output Format

Version 2.6

19 November 2021

ROM SAF Consortium
Danish Meteorological Institute (DMI)
European Centre for Medium-Range Weather Forecasts (ECMWF)
Institut d'Estudis Espacials de Catalunya (IEEC)
Met Office (UKMO)

Ref: SAF/ROM/DMI/FMT/POF/001

DOCUMENT AUTHOR TABLE

	Author(s)	*Function*	*Date*
Prepared by:	Kent Bækgaard Lauritsen	ROM SAF Project Manager	19/11 2021
Reviewed by (internal):			
Approved by:	Kent Bækgaard Lauritsen	ROM SAF Project Manager	19/11 2021

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1.2	23/11/06	MBS	Further specification on the product types
1.3	15/05/08	MBS	Name convention and ROPP file description updated
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2.5	3/11 2019	KBL	List of changes related to ICDR: - Updated text on pages 2, 11 with ICDR concept - Inserted ICDR concept in section 1.4 - Updated chapter 5 with ICDR information
2.6	19/11 2021	KBL	Version prepared for Sentinel-6 NTC ORR review: - NTC inserted throughout document - Filenames updated with NTC **Approved as SG27-Dec-13 (wp 15 December 2021)**

ROM SAF

The Radio Occultation Meteorology Satellite Application Facility (ROM SAF) is a decentralised processing centre under EUMETSAT which is responsible for operational processing of radio occultation (RO) data from the Metop and Metop-SG satellites and radio occultation data from other missions. The ROM SAF delivers bending angle, refractivity, temperature, pressure, humidity, and other geophysical variables in near real-time for NWP users, as well as reprocessed Climate Data Records (CDRs) and Interim Climate Data Records (ICDRs) for users requiring a higher degree of homogeneity of the RO data sets. The CDRs and ICDRs are further processed into globally gridded monthly-mean data for use in climate monitoring and climate science applications.

The ROM SAF also maintains the Radio Occultation Processing Package (ROPP) which contains software modules that aid users wishing to process, quality-control and assimilate radio occultation data from any radio occultation mission into NWP and other models.

The ROM SAF Leading Entity is the Danish Meteorological Institute (DMI), with Cooperating Entities: i) European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, United Kingdom, ii) Institut D'Estudis Espacials de Catalunya (IEEC) in Barcelona, Spain, and iii) Met Office in Exeter, United Kingdom. To get access to our products or to read more about the ROM SAF please go to: http://www.romsaf.org

Intellectual Property Rights

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1 Introduction

1.1 Purpose of document

This document describes the product output format definitions used in the ROM SAF. It is addressed to end users of the ROM SAF data products.

The ROM SAF NRT operational EPS system produces Level 2 products (refractivity, temperature and humidity profiles) from observations made by the GRAS receiver onboard the Metop satellites. Data is received from EPS CGS, and processed to Level 2 products. These products are described in the Product Requirements Document [AD.5]. Metop input data is level 1B data received from EPS CGS through the EUMETCast terminal placed at the host institute. Auxiliary data sources are the forecasts and analyses received from ECMWF.

The NRT product generation and delivery is completed within 3 hours from the actual observation time. Offline products from Metop and other RO missions are available to the users within 30 days after the measurement (the timeliness for other offline Level 3 products may be up to 6 months).

The requirements for the ROM SAF EPS system in terms of product contents, product formats and distribution are given in the System Requirements Document (SRD) [RD.1].

In terms of data involved in the ROM SAF products generation and distribution, the following rationale applies:

- Level 1B data is ingested in the system, processed by dedicated components and archived.
- NRT products are distributed to the user community through GTS/RMDCN and EUMETCast. The offline products are made available at the ROM SAF website and for request through the EUMETSAT Product Navigator.

1.2 Applicable and reference documents

1.2.1 Applicable documents

The following list contains documents with a direct bearing on the contents of this document:

[AD.1] ROM SAF Design Document (part 1, system),
Ref: SAF/GRAS/IEEC/DPR/ADD/001

[AD.2] ROM SAF ROPP (Radio Occultation Processing Package) File Format,
Ref: SAF/GRAS/METO/FMT/ROPP/001

[AD.3] ROM SAF WMO FM94 (BUFR) Specification for GRAS SAF Processed Radio Occultation Data, Ref: SAF/GRAS/UKMO/FMT/BUFR/01

[AD.4] GRAS Level 1 Product Format Specification. Ref: EPS/MIS/SPE/97234

[AD.5] ROM SAF Product Requirements Document,
Ref: SAF/ROM/DMI/MGT/PRD/001

[AD.6] UMARF to SAFs Interface Control Document. Ref: EUM/UMA/ICD/004

[AD.7] UMARF – SAF Metadata Definiton Ref: EUM/OPS/TEN/07/1052

[AD.8] CDOP-3 Proposal: Proposal for the Third Continuous Development and Operations Phase (CDOP-3); Ref: SAF/ROM/DMI/MGT/CDOP3/001 Version 1.2 of 31 March 2016, Ref: EUM/C/85/16/DOC/15, approved by the EUMETSAT Council at its 85th meeting on on 28-29 June 2016

[AD.9] CDOP-3 Cooperation Agreement: Agreement between EUMETSAT and DMI on the Third Continuous Development and Operations Phase (CDOP-3) of the Radio Occultation Meteorology Satellite Applications Facility (ROM SAF), Ref. EUM/C/85/16/DOC/19, approved by the EUMETSAT Council and signed at its 86th meeting on 7 December 2016

1.2.2 Reference documents

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

[RD.1] ROM SAF System Requirement Document,
Ref: SAF/GRAS/DMI/RQ/SRD/001

[RD.2] The Radio Occultation Processing Package (ROPP) User Guide, Part I.
Ref: SAF/ROM/METO/UG/ROPP/002

[RD.3] UMARF UMRS, Ref: EUM/UMA/SPE/001

[RD.4] ROM SAF Product User Manual,
Ref: SAF/ROM/DMI/UG/PUM/001

[RD.5] ROM SAF Product User Manual: Offline Level 3 Gridded Data,
Ref: SAF/ROM/DMI/UG/GRD/001

1.3 Acronyms and Abbreviations

ADD	Architectural Design Document (ROM SAF)
BUFR	Binary Universal Form of Representation
CAL/VAL	Calibration and Validation facility (EPS)
CDA	Command and Data Acquisition station (EUMETSAT/NOAA)
CGS	Core Ground Segment (EPS)
CORBA	Common Object Request Broker Architecture

DMI	Danish Meteorological Institute
ECMWF	European Center for Medium-range Weather Forecast
EDC	EUMETSAT Data Center
EPS	EUMETSAT Polar satellite System
EPS-SG	EUMETSAT Polar satellite System, Second Generation
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
FTP	File Transfer Protocol
GNSS	Global Navigation Satellite System
GPAC	GNSS Processing and Archiving Center (ROM SAF)
GPS	Global Positioning System (US)
GRAS	GNSS Receiver for Atmospheric Sounding (METOP instrument)
GRAS GSN	GRAS Ground Support Network
GTS	Global Telecommunication System (part of WIS)
IEEC	Institut d'Estudis Espacials de Catalunya (Spain)
IGS	International Geodynamics Service
Metop	METeorological Operational Polar satellite (EPS, EUMETSAT)
METOP-SG	Meteorological Operational Polar satellite, Second Generation (EPS-SG)
N/A	Not Available/Applicable
NRT	Near-Real Time
NTC	Non Time Critical
NWP	Numerical Weather Prediction
PARF	ROM SAF Archival and Retrieval Facility
PDU	Product Dissemination Unit (reflects the granularity to which a product is sent to the EUMETCast terminals of the CGS NRT Users)
POD	Precise Orbit Determination
RMDCN	Regional Meteorological Data Communication Network (GTS)
ROM SAF	Radio Occultation Meteorology Satellite Application Facility
SRD	System Requirements Document
TBC	To Be Considered
TBD	To Be Determined/Decided/Discussed
UKMO	The UK Meteorological Office (aka: Met Office)
UMARF	Unified Meteorological Archive and Retrieval Facility (EUMETSAT; also called EDC)
WIS	World Information System (WMO)
WMO	World Meteorological Organisation
WWW	World Wide Web, component of the Internet data access system

XML Extensible Mark-up Language

1.4 Definitions

RO data products from the Metop, Metop-SG and Sentinel-6 satellites and RO data from other missions are grouped in *data levels* (level 0, 1, 2, or 3) and *product types* (NRT, Offline, NTC, CDR, or ICDR). The data levels for atmospheric data[1] and product types are defined below[2]. The lists of variables should not be considered as the complete contents of a given data level, and not all data may be contained in a given data level.

Data levels:

Level 0: Raw sounding, tracking and ancillary data, and other GNSS data before clock correction and reconstruction;

Level 1A: Reconstructed full resolution excess phases, total phases, pseudo ranges, SNRs, orbit information, I, Q values, NCO (carrier) phases, navigation bits, and quality information;

Level 1B: Bending angles and impact parameters, tangent point location, and quality information;

Level 2: Refractivity, geopotential height, "dry" temperature profiles (Level 2A), pressure, temperature, specific humidity profiles (Level 2B), surface pressure, tropopause height, planetary boundary layer height (Level 2C), ECMWF model level coefficients (Level 2D), quality information;

Level 3: Gridded or resampled data that are processed from Level 1 or 2 data, and that are provided as, e.g., daily, monthly, or seasonal means on a spatiotemporal grid, including metadata, uncertainties and quality information.

Product types:

NRT product: Data product delivered less than: (i) 3 hours after measurement (ROM SAF Level 2 for EPS); (ii) 150 min after measurement (ROM SAF Level 2 for EPS-SG Global Mission); (iii) 125 min after measurement (ROM SAF Level 2 for EPS-SG Regional Mission);

Offline and NTC products: Data product delivered from about 5 days to up to 6 months after measurement, depending on the applicable requirements. The evolution of this type of product is driven by new scientific developments and subsequent product upgrades;

CDR: Climate Data Record generated from a dedicated reprocessing activity using a fixed set of processing software[3]. The data record covers an extended time period of several years (with a fixed end point) and constitutes a homogeneous data record appropriate for climate usage;

[1] Definitions for ionosphere products will be included when preparing for the RR review.
[2] Note that the level definitions differ partly from the WMO definitions: http://www.wmo.int/pages/prog/sat/dataandproducts_en.php
[3] (i) GCOS 2016 Implementation Plan; (ii) http://climatemonitoring.info/home/terminology/

ICDR: An Interim Climate Data Record (ICDR) regularly extends in time a (Fundamental or Thematic) CDR using a system having optimum consistency with and lower latency than the system used to generate the CDR[4].

General terms:

System: GPAC (ROM SAF GNSS Processing and Archiving Center)

Web site: ROM SAF web site: http://www.romsaf.org

Product Archive: PARF (ROM SAF Product Archive and Retrieval Facility)

1.5 Overview of this document

This document is organized as follows:

Chapter 1: Contains the introduction

Chapter 2: Contains a general description

Chapter 3: Describes the product format drivers

Chapter 4: Describes the input formats

Chapter 5: Describes the ROM SAF format definitions

Appendix A: Contains traceability matrix between UMARF metadata and ROM SAF attributes code

Appendix B: Contains UMARF products catalogue

Appendix C: NetCDF Header Format

Appendix D: Level 1 Data NetCDF Formats

Appendix E: Level 2 Data NetCDF Formats

Appendix F: Level 3 Data NetCDF Formats

[4] http://climatemonitoring.info/home/terminology/ (the ICDR definition was endorsed at the 9th session of the joint CEOS/CGMS Working Group Climate Meeting on 29 March 2018)

2 General Description

The products of the ROM SAF operational system are targeting different types of user groups. NRT products are targeting at National Meteorological Centres, and comparable regional or independent centres. These users will receive the EPS products with a near-real time (NRT) timeliness of 3 hours. The design process takes into account different types of users by the different types of products having different means of delivery.

- **NRT products**: Those produced with NRT operational timeliness restrictions. Incorporate profile data only.
- **Offline and NTC products**: Those produced without NRT operational timeliness restrictions. Incorporates both profile and gridded data.
- **Reprocessed products (CDRs):** Those produced without NRT operational timeliness restrictions, geared towards climate and research applications. Incorporate both profile and gridded data.
- **Interim Climate Data Record (ICDR):** Product which regularly extends in time a (Fundamental or Thematic) CDR using a system having optimum consistency with and lower latency than the system used to generate the CDR

- **NRT delivery**: Only available for NRT products, through guaranteed performance channels and with operational timeliness restrictions.
- **Offline delivery**: Available for all products, through a variety of channels e.g., the data archives at www.romsaf.org or through the Product Navigator at the EUMETSAT Data Centre.

3 Product Format Drivers

The ROM SAF data format was established taking into consideration the following drivers [RD.1]:

ROM SAF product format design drivers

SRD Requirement	Requirement text
SOFT.INEC.030	NRT products disseminated via RMDCN shall use up-to-date WMO BUFR/CREX encoded format [T UT END/PROD/NRT/ARCH URRTS-3030]
SOFT.INEC.040	Offline products shall use NetCDF file format standards [T UT END/PROD/ARCH/OFFL UROLS-3030]

The first system requirement refers to EPS products dissemination using a dedicated line – GTS (component of WIS) – and therefore has no direct influence on the ROM SAF internal data format. Using a different format, like NetCDF, to describe data inside the ROM SAF system is possible. The relevant problem to take into consideration is that after generating the products some additional post-processing activities are required in order to perform the reformatting.

The second requirement is completely in-line with the NetCDF selection.

4 Input Data Formats

The input data to the ROM SAF system can be grouped into:

- Data used for the processing of the NRT products
- Data used for the processing of the offline and NTC products
- Data used for the reprocessed products

The following table summarises the ROM SAF system inputs in terms of external input, data providers and the data format applicable to each:

Raw input data formats

Group	Data provider	Data	Format
NRT	EPS	Level 1A/1B data	NetCDF-4
	ECMWF	ECMWF forecasts and analyses	GRIB
Offline, NTC	EPS, Sentinel-6	Level 1A/1B data	NetCDF-4
	ECMWF	ECMWF and ERA-Interim forecasts and analyses	GRIB
Reprocessed	EPS	Level 1A/1B reprocessed data	NetCDF-4
	ECMWF	ECMWF and ERA-Interim forecasts and analyses	GRIB
	UCAR	Level 1A reprocessed data	NetCDF-3

The ROM SAF components responsible for taking care of the system input data ingestion have the capability of dealing with these different types of data. All input data are stored in the ROM SAF archive.

5 ROM SAF Format Definition

The data format for the ROM SAF system is NetCDF. End products and internal products are in the same format, i.e., the delivered products have the same structure as the internal products or a subset of it.

5.1 Structure

The NetCDF files in the ROM SAF system have the following structure:

- A common set of attributes. The attributes are the same for all files and contain general information about the data.
- A dataset for parameter values.
- Additional datasets for metadata (e.g., quality flags and information related to UMARF; see Appendix A).

5.1.1 NetCDF compatibility

The NetCDF files are created with the NetCDF-4 *library*, but they are only compatible with the NetCDF-3 *format* (or the limited NetCDF-4 Classic *format*). The files are not compatible with the full NetCDF-4 *format* (see more detailed explanation here: https://www.unidata.ucar.edu/). The Level 3 gridded data files conform to the CF Conventions (http://www.cfconventions.org).

5.2 File names

There are 3 types of ROM SAF file names:

1. The **NRT** file name version.
2. The **OFFLINE, NTC and ICDR Level 1 and Level 2** file name version.
3. The **OFFLINE, NTC and ICDR Level 3** file name version.

Each file name is a string of up to 255 characters. It may be shorter.

5.2.1 Filename of NRT data

The **NRT** file name version is used in the NRT processing chain, for both level 1 and level 2 products. It is made of fields separated by underscores with the following structure:

```
<TYPE><DATE>_<TIME>_<MISSION_ID>_<OCC_ID>_<MODE><SWVER>_<FREE>.<EXT>
```

5.2.1.1 Explanation

<TYPE> is one of “atm”, “bfr”, “bgr”, “dis”, “occ” or “wet” (see

- Table 5.1).
- <DATE>_<TIME> is the start date and time of the observation, as YYYYMMDD_HHMMSS.
- <MISSION_ID> is the EPS name of the observing satellite. Other names will be possible at a later date, when more missions are included. Examples: M01 (Metop-B), M02 (Metop-A), M03 (Metop-C).

- <OCC_ID> is the occultation id (EPS format which includes id of occulting satellite). As for <MISSION>, other names are possible for other missions. Example: G010 (GPS PRN 10 satellite).
- <MODE> is the processing mode and one of "N", "T", "V" (see Table 5.3).
- <SWVER> is a four digit code denoting the system software version (e.g. "0372").
- <FREE> is a free field, "XXXX".
- <EXT> is the extension,
    - "nc" for NetCDF.
    - "bin" for BUFR for disseminated products.

5.2.1.2 Example

An example of a Metop-A **NRT** atm file name from 29 January 2011:

atm20110129_021532_M02_2020404609_N0018_XXXX.nc

5.2.2 Filename of offline, NTC and ICDR level 1 and level 2 data

The **offline level 1 and level 2** file name version is used in the offline processing chain. It is made of fields separated by underscores with the following structure:

<TYPE>_<DATE>_<TIME>_<MISSION_ID>_<OCC_ID>_<MODE>_<SWVER>_<PVER>.<EXT>

5.2.2.1 Explanation

<TYPE> is one of "atm", "bgf", "bgn", "bgo", "bga", "dis", "occ" or "wet" (see

- Table 5.1).
- <DATE>_<TIME> is the start date and time of the observation as YYYYMMDD_HHMMSS.
- <MISSION_ID> is an ID that uniquely identifies the observing satellite. Examples: M01 (Metop-B), M02 (Metop-A), M03 (Metop-C), C004 (COSMIC FM4), SE6A (Sentinel-6).
- <OCC_ID> is an ID that identifies the GNSS satellite used for the specific occultation. . Example: G010 (GPS PRN 10 satellite), R014 (GLONASS 14).
- <MODE> is the processing mode and one of "O", "R", "T", "V", "I" (see Table 5.3).
- <SWVER> is a four-digit code denoting the system software version (e.g. "0372").
- <PVER> is a four-digit code denoting the data product version (e.g. "0010" for 1.0).
- <EXT> is the extension,
    - "nc" for NetCDF.
    - "bin" for BUFR for disseminated products.

5.2.2.2 Example

An example of an **offline** atm file name from 29 January 2011:

atm_20110129_230533_C004_G010_O_0372_0010.nc

5.2.3 Filename of offline, NTC and ICDR level 3 data

The **offline level 3** file name version is used in the offline processing chain. It consists of a string of up to 64 characters made of 6 fields separated by underscores:

<FILETYPE>_<PRODUCT>_<MISSION>_<DATE>_<MODE>_<SWVER>_<PVER>.<EXT>

5.2.3.1 Explanation

<FILETYPE> is either "zgrid" or "trace" (see

- Table 5.1).
- <PRODUCT> is a six-letter product acronym, with the first three letters listed in Table 5-5.
- <MISSION> is the name of the satellite mission, e.g. “cosmic”, “champ”, “sentinel6”.
- <DATE> is a date or date-interval string, e.g. “201107”, “2011”, or “201103–201108”
- <MODE> is the processing mode and one of “O”, “R”, “T”, “V”, “I” (see Table 5.3).
- <SWVER> is a four-digit code denoting the system software version (e.g. “0372”).
- <PVER> is a four-digit code denoting the data product version (e.g. “0010” for 1.0).
- <EXT> is the extension, “nc” (denoting netCDF).

5.2.3.2 Example

The name of a file containing reprocessed gridded monthly mean bending angles from July 2011 may for example be:

zgrid_rbgmet_metop_201107_R_0372_0010.nc

which has the associated traceability file:

trace_rbgmet_metop_201107_R_0372_0010.nc

A file containing offline gridded temperatures for a whole year may be named:

zgrid_otgco1_cosmic_2010_O_0372_0010.nc

with the associated traceability file:

trace_otgco1_cosmic_2010_O_0372_0010.nc

For files containing climate data derived from ECMWF profiles co-located with RO events (e.g. from COSMIC), the <MISSION> string may for example be “ecmwf@cosmic”.

5.3 Overview tables

The three tables below show the file types for Level 1 and 2, file types for Level 3, and the possible processing modes.

Table 5.1 Description of ROM SAF files types, all file types hold a “header” – a set of ancillary data useful for processing or describing each occultation. For detailed information see [RD.4].

Type	ROPP levels	Format	Description
dis	1A 1B 2A 2B 2C 2D	NetCDF	This file type is the input to the BUFR file that is disseminated on GTS and EUMETCast. The content is bending angle and impact parameter originating from CGS and the refractivity profile and 1DVar output derived from this. This file holds LEO and GNSS positions and velocities from the GSN NRT product.
bfr	-	BUFR	This file type is based on the “dis” file. The BUFR file holds a thinned set of the bending angles and refractivity from the “dis” file. Only the first position and velocity sample is contained in this file.

bgf, bgn, bgo, bga	2D	NetCDF	These file types contain the model background fields used for the 1DVar retrieval.
occ	1A	NetCDF	This file contains signal-to-noise for the phases, the excess phases and the GNSS/LEO positions and velocities as function of time.
atm	1B 2A	NetCDF	This file contains latitude, longitudes, impact parameters, bending angles and refractivity.
wet	2B 2C	NetCDF	This file contains output from the 1DVar i.e. temperature, pressure and humidity.
zgrid	N/A	NetCDF	Gridded monthly mean gridded variables
trace	N/A	NetCDF	Meta-data associated with the zgrid file

Table 5.2 Offline Level 3 gridded data products

Type	Format	Description
OBG	NetCDF	Offline gridded bending angle
ORG	NetCDF	Offline gridded refractivity
OTG	NetCDF	Offline gridded temperature
OHG	NetCDF	Offline gridded specific humidity
OZG	NetCDF	Offline gridded geopotential height
ODG	NetCDF	Offline gridded dry temperature
OYG	NetCDF	Offline gridded dry pressure
OCG	NetCDF	Offline gridded tropopause height

Table 5.3 ROM SAF processing mode acronyms

Mode	Description
N	NRT processing
O	Offline, NTC processing
R	Reprocessing
V	Validation
T	Test
I	ICDR

5.4 File structure

The ROM SAF products follow the ROPP data format structure (see [RD.2]) or combinations of this when appropriate. An overview of the ROPP NetCDF file structure is depicted in Figure 5-1. In the ROPP format all parts except the header are optional which in the case of ROM SAF product means that level 1A is absent in NRT products

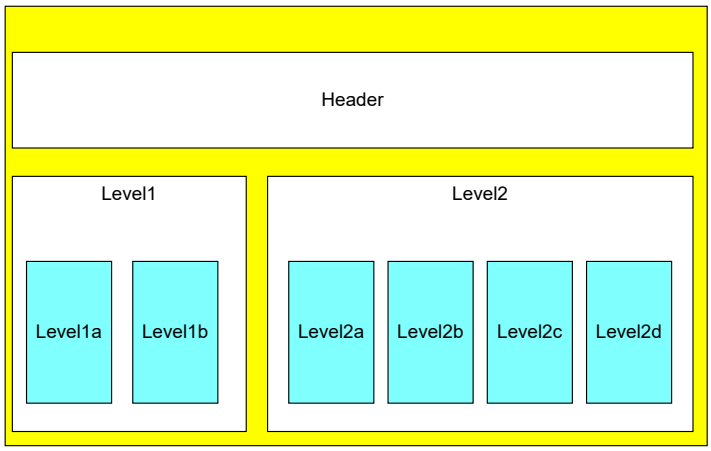

Figure 5-1 Overview of the ROPP NetCDF file structure. (Level 3 is currently not part of the ROPP format, it is not included in the figure.)

5.4.1 Description of the ROM SAF product levels

Table 5.4 provides a short description of the ROM SAF product levels. Further descriptions are available in [RD.2] and in Appendixes C, D, and E.

Some basic parameters available in the NetCDF Level 3 product files are listed in Table 5.5. More detailed information can be found in [RD.4] and Appendix F.

Table 5.4 Product level descriptions

Data product		
Level 1	Level 1A	SNR, excess phases and POD data as function of time
	Level 1B	Bending angle as function of impact parameter
Level 2	Level 2A	Refractivity and dry temperature on mean sea level altitudes
	Level 2B	Temperature, humidity pressure, and geopotential height on model levels
	Level 2C	Surface pressure, Tropopause height, and Planetary boundary layer height
	Level 2D	Additional data describing the vertical level structure of NWP model fields (e.g., level coefficients for vertical hybrid or eta–coordinates)
Level 3	N/A	Gridded data (zonal and monthly means) with a 200 meter vertical and 5 degrees latitudinal resolution.

Table 5.5 Level 3 parameter description examples

Level 3	
Parameter name	*Short description*
BEN	Bending angle monthly mean
BEN_stdev	Bending angle monthly standard deviation
BEN_obssig	Observational uncertainty of the monthly mean
BEN_samperr	Sampling error of the monthly mean
REF	Refractivity monthly mean
REF_stdev	Refractivity monthly standard deviation
REF_obssig	Observational uncertainty of the mean
REF_samperr	Sampling error of the monthly mean
T	Temperature monthly mean
T_stdev	Temperature monthly standard deviation
T_obssig	Observational uncertainty of the monthly mean
T_samperr	Sampling error of the monthly mean
Q	Specific humidity monthly mean
Q_stdev	Specific humidity monthly standard deviation
Q_obssig	Observational uncertainty of the mean
Q_samperr	Sampling error of the monthly mean
GPH	Geopotential height monthly mean
GPH_stdev	Geopotential height monthly standard deviation
GPH_obssig	Observational uncertainty of the mean
GPH_samperr	Sampling error of the monthly mean

5.5 Dissemination Channels

Products are disseminated using different channels:

- GTS/RMDCN network (part of WIS) and EUMETCast
- Offline distribution to users (via e.g. Web, FTP).

The RMDCN Network is used for NRT products dissemination.

The products that are distributed by each channel are identified in Appendix B.

5.5.1 Disseminated Products Format

5.5.2 RMDCN Network

The baseline for the near real-time distribution of ROM SAF products to the National Meteorological Services (NMSs) of EUMETSAT Member States and Co-operating States is the Regional Meteorological Data Communication Network (RMDCN). This requires the ROM SAF products to be compliant with the World Meteorological Organisation (WMO) standard binary format, the BUFR format.

A specification which allows encoding of radio occultation data into BUFR format is ratified by WMO and allows for GTS dissemination. See [AD.3] for format descriptions on this data type.

5.5.3 EUMETCast

The NRT data are disseminated via EUMETCast as well. The data are formatted in the NetCDF format, see [AD.3]. The dissemination is done by uploading data to the EUMETCast dissemination ftp server.

5.5.4 Offline Distribution

The offline distribution is via Web and FTP.

This data delivery is serviced over the internet, not over specialized, guaranteed performance operational lines. The users are given several options as for the reception channel for the data. Unlike NRT products, which are actively broadcasted, offline, NTC and ICDR products are made available at the website archive for retrieval.

Appendix A. Traceability matrix between UMARF metadata and ROM SAF attributes

The following table lists the relationship between the ROM SAF attributes and the UMARF metadata [AD.7]. Note that some of these metadata are not relevant for the ROM SAF but are passed from the parent level 1B product. Mandatory metadata are in bold. The metadata listed in the table below are according to UMARF TEN30 [AD.7].

UMARF metadata to ROM SAF attributes traceability matrix

UMARF metadata name	ROM SAF attribute name	Notes
ASTI	SATELLITE_ID	
GORT	ORBIT_TYPE	
LONS	ORBIT	
LONE	ORBIT	
LLAS	Sub satellite point start latitude	N/A
LLOS	Sub satellite point start longitude	N/A
LLAE	Sub satellite point end latitude	N/A
LLOE	Sub satellite point end longitude	N/A
LSVT	Ascending Node Crossing Date and Time	N/A
LSVL	Longitude of ascending node of the first orbit	N/A
LOSI	OCCSAT	There will be several occultations per orbit. These four attributes will be repeated for each occultation.
LOLA	OCCLAT	
LOLO	OCCLON	
LODT	OBSTIME	
AIID	INSTRUMENT_ID	
SMOD	INSTRUMENT_MODE	
SSBT	SDT_START	
SSST	SDT_END	
ABID	Spectral Band Ids	N/A
RRCC	RCENTER	
PPRC	CENTRE	
GPLV	PROCESSING_LEVEL	
AVBA	BASE_ALGORITHM_VERSION	
AVPA	PRODUCT_ALGORITHM_VERSION	

UMARF metadata name	ROM SAF attribute name	Notes
LMAP	Projection name	N/A
SNIT	SDT_START	
GDMD	DISPOSITION_MODE	
GPMD	PROCESSING_MODE	
APNM	TYPE	
APNA	PRODUCT	
APPN	PPRDID	
AAST	Statistic Type	N/A
AAAR	Time Range	N/A
APAS	PRDSZ	
GNFV	NATIVE_PRODUCT_FORMAT_VERSION	
QCCV	Cloud coverage	N/A
QQOV	QUALITY	
QQAI	AQUALITY	
QDRC	Degraded Record Count	N/A
QDRP	Degraded Record Percentage	N/A
QDLC	Missing Data Records	N/A
QDLP	Missing Data Percentage	N/A
AARF	ARCHIVE	
GGTP	GRANULE_TYPE	

The common attributes for the datasets are described in the table below with indication of the corresponding NetCDF attributes (in parenthesis) when applicable.

Common attributes of ROM SAF dataset

Attribute	Description	Data Type
Version	Software version	String
Pname	Product name	String
Type	Product type	String
Pid	Process id	String
Prdid	Product id	String
Pprdid	Parent product id	String
quality (pcd)	Quality	Int
Status	Process status	String
obstime (start_time)	Start observation time	String
Sorbit	Start orbit	String
Occid	Occultation id	Int
occlat (lat)	Occultation start latitude	Float
occlon (lon)	Occultation start longitude	Float
occsat (leo_id)	Occultation satellite	String
obssat (gns_id)	Observing satellite	String
Refsat	Satellite used for differentiation	String
Grdsta	Ground station used for differentiation	String
Prdsz	Product size	Int
Files	Product file names	String

Appendix B. UMARF products catalogue: ROM SAF products and supporting data

The table below lists the acronyms used by the EUMETSAT archive facility UMARF (EDC) for the ROM SAF products. Please note that not all products (e.g. tropopause height and dry parameters) are part of this list and that these acronyms differ from the ROM SAF product acronyms used in the PRD [AD.5].

UMARF products catalogue: ROM SAF products and supporting data.

Product/Supporting data	Name	Acronym		Product/Supporting data	Name	Acronym
Refractivity Profile	Real time Refractivity Profile	RRP		Refractivity Profile	Offline Refractivity Profile	ORP
Occultation Specification (Time information of the occultation data; latitude, longitude and radial position of the occultation)	Real time Occultation Specification	ROS		Occultation Specification (Time information of the occultation data; latitude, longitude and radial position of the occultation)	Offline Occultation Specification	OOS
Error profile	Real time Error Profile	REP		Error profile	Offline Error Profile	OEP
Covariance matrices	Real time Covariance Matrix	RCM		Covariance matrices	Offline Covariance Matrix	OCM
Temperature Profile	Real time Temperature Profile	RTP		Temperature Profile	Offline Temperature Profile	OTP
Humidity Profile	Real time Humidity Profile	RHP		Humidity Profile	Offline Humidity Profile	OHP
Pressure Profile	Real time Pressure Profile	RPP		Pressure Profile	Offline Pressure Profile	OPP
Surface Pressure	Real time Surface Pressure	RSP		Surface Pressure	Offline Surface Pressure	OSP
Validation	Real time Validation Product	RVP		Validation	Offline Validation Product	OVP
Bending Angle	Real time Bending Angle	RBA		Bending Angle	Offline Bending Angle	OBA

Appendix C. NetCDF Header Format

From the ROPP User Guide [RD.2, version 9.0]:

Identifiers

Structure element	Parameter	Description	Range	Units
...%leo_id	LEO ID	LEO ID code (4 characters). The following ID codes are currently envisaged: META = MetOp–A METB = MetOp–B METC = MetOp–C Cnnn = COSMIC–*nnn* CHMP = CHAMP GRAA = GRACE–A GRAB = GRACE–B TSRX = TerraSAR–X TDMX = TanDEM–X CNOF = C/NOFS SACC = SAC–C GPSM = GPS/MET OERS = Oerstedt EQUA = EQUARS SUNS = SunSat PAZE = PAZ OSAT = OceanSat–2 FY3C = FY-3C Other LEO codes may be defined in the future.	[A-Z,0-9]	
...%gns_id	GNSS ID	GNSS ID (1 letter + PRN of the occulting GNSS satellite ('Xnnn')). The following ID codes are currently envisaged: Gnnn = GNSS Rnnn = GLONASS Ennn = Galileo Bnnn = Beidou Other GNSS codes may be defined in the future.	[A-Z,0-9]	
...%stn_id	Station ID	Ground station ID used for differencing (if any; IGS-style 4–character code)	[A-Z,0-9]	
...%occ_id	Occultation ID	Unique occultation ID; see section 2.3.6	[A-Z,0-9]	

Processing

Structure element	Parameter	Description	Range	Units
...%FmtVersion	ROPP format version	Exact text (21 characters)	eg ROPP V9.0	
...%processing_centre	Processing Centre	Text indicating processing centre (40 characters)	[A-Z,0-9]	
...%processing_software	Processing centre software	Text indicating processing centre software (40 chars)	[A-Z,0-9]	
...%software_version	ROPP Version	String indicating the ROPP version	eg V9.0	
...%pod_method	POD algorithm	Text strings (40 characters) indicating algorithms used for deriving precise orbit, excess phase / amplitude, bending angle, refractivity and meteorological data	[A-Z,0-9]	
...%phase_method	Level 1 a algorithm		[A-Z,0-9]	
...%bangle_method	Level 1 b algorithm		[A-Z,0-9]	
...%refrac_method	Level 2 a algorithm		[A-Z,0-9]	
...%meteo_method	Level 2 b, c algorithm		[A-Z,0-9]	
...%thin_method	Profile thinning algorithm (version ID)			

Table 2.1: Contents of an ROprof header (to be continued).

Background meta data

Structure element	Parameter	Description	Range	Units
...%bg%source	Background source	Source of meteorological or atmospheric data used as background ("ancillary") data	[A-Z,0-9]	
...%bg%year ...%bg%month ...%bg%day ...%bg%hour ...%bg%minute	Verification time	Verification time of background data (if applicable)	1995 01 01 00 00 — 2099 12 31 23 59	
...%bg%fcperiod	F/C period	Forecast period of background data (if applicable)	0 – 24	hours

Time stamps

Structure element	Parameter	Description	Range	Units
...%DTocc%year ...%DTocc%month ...%DTocc%day ...%DTocc%hour ...%DTocc%minute ...%DTocc%second ...%DTocc%msec	Date / time of occultation	Time stamp at **start** of occultation (UTC)	1995 01 01 00 00 00 000 — 2099 12 31 23 59 59 999	
...%DTpro%year ...%DTpro%month ...%DTpro%day ...%DTpro%hour ...%DTpro%minute ...%DTpro%second ...%DTpro%msec	Date / time of processing	Time stamp of processing (UTC)	1995 01 01 00 00 00 000 — 2099 12 31 23 59 59 999	

Table 2.1: Contents of an ROprof header (cont'd).

Georeferencing				
Structure element	Parameter	Description	Range	Units
...%GEOref%time_offset	Time since start	Time since start of occultation to the time when georeferencing data and radius of curvature are determined.	-10 – 239.999	s
...%GEOref%lat	Latitude	Position of tangent point as used for georeferencing	-90 – 90	deg
...%GEOref%lon	Longitude		-180 – 180	deg
...%GEOref%roc	Radius of curvature	Radius of curvature value	$6.2 - 6.6 \times 10^6$	m
...%GEOref%r_coc	Centre of curvature	Centre of curvature coordinates (ECF; X, Y, Z)	$\pm 50.0 \times 10^3$	m
...%GEOref%azimuth	Line of sight	GNSS to LEO azimuth direction w.r.t. true North	0 – 360.0	deg_T
...%GEOref%undulation	Geoid undulation	Deviation of geoid (EGM–96) from the ellipsoid (WGS–84)[a]	±150	m
...%GEOref%leo_pod%pos	Ref. LEO position	Reference LEO coordinates (ECF; X, Y, Z)[b]	$\pm 10.0 \times 10^6$	m
...%GEOref%leo_pod%vel	Ref. LEO velocity	Reference LEO velocities (ECI; X, Y, Z)[b]	$\pm 10.0 \times 10^3$	m/s
...%GEOref%gns_pod%pos	Ref. GNS position	Reference GNSS coordinates (ECF; X, Y, Z)[b]	$\pm 43.0 \times 10^6$	m
...%GEOref%gns_pod%vel	Ref. GNS velocity	Reference GNSS velocities (ECI; X, Y, Z)[b]	$\pm 10.0 \times 10^3$	m/s
Quality				
Structure element	Parameter	Description	Range	Units
...%PCD	Product confidence	Product confidence data (see Section 2.3.5)	$0 - 2^{15}$-1	bit flags
...%overall_qual	Data quality	Overall summary data quality	0 – 100	%
Additional Variables				
Structure element	Parameter	Description	Range	Units
...%vlist%VlistD0d	Scalar extra variables	Parameters of 0D extra variables (see Section 2.4.10)		
...%vlist%VlistD1d	Vector extra variables	Parameters of 1D extra variables (see Section 2.4.10)		
...%vlist%VlistD2d	Array extra variables	Parameters of 2D extra variables (see Section 2.4.10)		

[a] If a height h_G is expressed with respect to the EGM–96 geoid, the height h_E with respect to the WGS-84 ellipsoid is given by $h_E = h_G + U$ where U is the undulation.
[b] See footnotes of Table 2.2.

Table 2.1: Contents of an ROprof header (cont'd).

Bit	Variable	Description	Meaning if	
			unset (0)	set (1)
1	PCD_summary	Quality	nominal	non–nominal
2	PCD_offline	Product type	NRT	off line
3	PCD_rising	Occultation type	setting	rising
4	PCD_phase	Excess phase processing	nominal	non–nominal
5	PCD_bangle	Bending angle processing	nominal	non–nominal
6	PCD_refrac	Refractivity processing	nominal	non–nominal
7	PCD_met	Meteorological processing	nominal	non–nominal
8	PCD_open_loop	Open Loop	not used	used
9	PCD_reflection	Surface reflections detected	no	yes
10	PCD_l2_signal	L2P or L2C GNSS signal used	L2P	L2C
11	PCD_reserved_11	Reserved		
12	PCD_reserved_12	Reserved		
13	PCD_reserved_13	Reserved		
14	PCD_bg	Background profile	nominal	non–nominal
15	PCD_occultation	Profile type	observed	background
16	PCD_missing	PCD missing; bits 1–15...	valid	invalid

Table 2.5: Product confidence data definition. PCD_summary is a summary bit which shall be set if any of Bits 4,5,6,7 or 14 is set. Note that the PCD_* variables become available by USE'ing the module ropp_io_types.

Product Confidence Data definition (the %PCD variable in the "Quality"-section above). PCD_summary is a summary bit which is set if any of bits 4, 5, 6, 7 or 14 is set.

Appendix D. Level 1 Data NetCDF Formats

From the ROPP User Guide [RD.2, version 9.0]:

Level 1a				
Structure element	Parameter	Description	Range	Units
...%Lev1a%dtime	Time since start	Time offset from time in header	-1.0 – 239.999	s
...%Lev1a%snr_L1ca	Signal to noise ratio L1 (ca–code)	Relative signal amplitude for L1 (ca–code)	$0 - 50 \times 10^3$	V/V
...%Lev1a%snr_L1p	Signal to noise ratio L1 (p–code)	Relative signal amplitude for L1 (p–code)	$0 - 50 \times 10^3$	V/V
...%Lev1a%snr_L2p	Signal to noise ratio L2 (p–code)	Relative signal amplitude for L2 (p–code)	$0 - 50 \times 10^3$	V/V
...%Lev1a%phase_L1	Excess phase L1	L1 phase corrected for geometry	$\pm 10 \times 10^3$	m
...%Lev1a%phase_L2	Excess phase L2	L2 phase corrected for geometry	$\pm 10 \times 10^3$	m
...%Lev1a%r_gns	Transmitter position	Earth centred Earth fixed[a] phase centre (X, Y, Z)[b]	$\pm 43 \times 10^6$	m
...%Lev1a%v_gns	Transmitter velocity	Earth centred inertial[a] phase centre (X, Y, Z)[b]	$\pm 10 \times 10^3$	m/s
...%Lev1a%r_leo	Receiver position	Earth centred earth fixed[a] phase centre (X, Y, Z)[b]	$\pm 10 \times 10^6$	m
...%Lev1a%v_leo	Receiver velocity	Earth centred inertial[a] phase centre (X, Y, Z)[b]	$\pm 10 \times 10^3$	m/s
...%Lev1a%phase_qual	Quality	Percentage confidence value	0 – 100	%

[a] Using the Earth Centred Fixed (ECF) and Earth Centred Inertial (ECI) reference frames for satellite positions and velocities, respectively, are the *default* settings; these can be changed, e.g. to use ECF for both positions and velocities.
[b] Position and velocity variables are 3–dimensional arrays with dimension (/n,3/) in Fortran.

Table 2.2: Contents of the ROprof Level 1a data.

Level 1b				
Structure element	Parameter	Description	Range	Units
...%Lev1b%lat_tp	Latitude	Latitude and longitude wrt the WGS 84 ellipsoid of	±90	deg
...%Lev1b%lon_tp	Longitude	the tangent points of the occultation's bending angles	±180	deg
...%Lev1b%azimuth_tp	Azimuth	GNSS-to-LEO bearing wrt true North at tangent pts	0 – 360	deg_T
...%Lev1b%impact_L1	Impact parameter (L1)	Impact parameter derived from L1 signal	$(6.2 - 6.6) \times 10^6$	m
...%Lev1b%impact_L2	Impact parameter (L2)	Impact parameter derived from L2	$(6.2 - 6.6) \times 10^6$	m
...%Lev1b%impact	Impact parameter	Impact parameter (generic)	$(6.2 - 6.6) \times 10^6$	m
...%Lev1b%impact_Opt	Impact parameter (Opt)	Impact parameter for optimised Bending Angles	$(6.2 - 6.6) \times 10^6$	m
...%Lev1b%bangle_L1	Bending angle (L1)	Bending angle derived from L1	−0.001 – 0.1	rad
...%Lev1b%bangle_L2	Bending angle (L2)	Bending angle derived from L2	−0.001 – 0.1	rad
...%Lev1b%bangle	Bending angle	Bending angle (generic)	−0.001 – 0.1	rad
...%Lev1b%bangle_Opt	Bending angle (Opt)	Bending angle optimised (usually smoothed) prior to performing the Abel Transform	−0.001 – 0.1	rad
...%Lev1b%bangle_L2_sigma	Bending angle errors (L1)	Estimated errors (one σ) of L1 bending angle values	0 – 0.01	rad
...%Lev1b%bangle_L2_sigma	Bending angle errors (L2)	Estimated errors (one σ) of L2 bending angle values	0 – 0.01	rad
...%Lev1b%bangle_sigma	Bending angle errors	Estimated errors (one σ) of bending angle values	0 – 0.01	rad
...%Lev1b%bangle_Opt_sigma	Bending angle errors (Opt)	Estimated errors (one σ) of optimised bending angle values	0 – 0.01	rad
...%Lev1b%bangle_L1_qual	Bending angle quality	Percentage confidence values for L1 bending angles	0 – 100	%
...%Lev1b%bangle_L2_qual	Bending angle quality	Percentage confidence values for L2 bending angles	0 – 100	%
...%Lev1b%bangle_qual	Bending angle quality	Percentage confidence values for bending angles	0 – 100	%
...%Lev1b%bangle_Opt_qual	Bending angle quality	Percentage confidence values for opt. bending angles	0 – 100	%

Table 2.3: Contents of the ROprof Level 1b (bending angle) and 2a (refractivity) data.

Appendix E. Level 2 Data NetCDF Formats

From the ROPP User guide [RD.2, version 9.0]:

Level 2a

Structure element	Parameter	Description	Range	Units
...%Lev2a%alt_refrac	Height	Geometric height above geoid (EGM–96)	$(-1-150)\times10^3$	m
...%Lev2a%geop_refrac	Geopotential height	Geopotential height above geoid (EGM–96)	$(-1-150)\times10^3$	gpm
...%Lev2a%refrac	Refractivity	Derived refractivity	$0-500$	N–units
...%Lev2a%refrac_sigma	Refractivity error	Estimated errors (one σ) of refractivity values	$0-10$	N–units
...%Lev2a%refrac_qual	Refractivity quality	Percentage confidence value	$0-100$	%
...%Lev2a%dry_temp	Dry temperature	Derived dry temperature	$150-350$	K
...%Lev2a%dry_temp_sigma	Dry temperature error	Estimated errors (one σ) of dry temperature values	$0-50$	K
...%Lev2a%dry_temp_qual	Dry temperature quality	Percentage confidence value	$0-100$	%

Table 2.3: Contents of the ROprof Level 1b (bending angle) and 2a (refractivity) data.

Level 2b

Structure element	Parameter	Description	Range	Units
...%Lev2b%geop	Geopotential height	Geopotential height above geoid (EGM–96)	$(-1-100)\times10^3$	gpm
...%Lev2b%geop_sigma	Geopotential height error	Estimated error (one σ) of geopotential heights	$0-500$	gpm
...%Lev2b%press	Pressure	Retrieved pressure	$0.0001-1100$	hPa
...%Lev2b%press_sigma	Pressure error	Estimated error (one σ) of retrieved pressure	$0-5$	hPa
...%Lev2b%temp	Temperature	Retrieved temperature	$150-350$	K
...%Lev2b%temp_sigma	Temperature error	Estimated error (one σ) of retrieved temperature	$0-5$	K
...%Lev2b%shum	Specific humidity	Retrieved specific humidity	$0-50$	g / kg
...%Lev2b%shum_sigma	Specific humidity error	Estimated error (one σ) of retrieved specific humidity	$0-5$	g / kg
...%Lev2b%meteo_qual	Quality	Overall percentage confidence value	$0-100$	%

Level 2c[a]

Structure element	Parameter	Description	Range	Units
...*%Lev2c%lat_2d*	Latitude position	Latitude position (*ROprof2d structure only*)	$-90-90$	deg
...*%Lev2c%lon_2d*	Longitude position	Longitude position (*ROprof2d structure only*)	$-180-180$	deg
...*%Lev2c%dtheta*	Angle	Angle between profiles (*ROprof2d structure only*)	$0-\pi$	rad
...%Lev2c%geop_sfc	Geopotential height	Geopotential height of surface above geoid (EGM–96)	$(-1-10)\times10^3$	gpm
...%Lev2c%press_sfc	Surface pressure	Retrieved surface (or reference) pressure	$250-1100$	hPa
...%Lev2c%press_sfc_sigma	Surface pressure error	Estimated error (one σ) of retrieved surface pressure	$0-5$	hPa
...%Lev2c%press_sfc_qual	Quality	Percentage confidence value	$0-100$	%

Level 2d

Structure element	Parameter	Description	Range	Units
...%Lev2d%level_type	level type	Level type. Only HYBRID ECMWF, ECMWF HYBRID, HYBRID, ECMWF and METOFFICE are currently supported.		
...%Lev2d%level_coeff_a	α coefficients	Level coefficients α (hybrid vertical levels only)	$0-2000$	hPa
...%Lev2d%level_coeff_b	β coefficients	Level coefficients β (hybrid vertical levels only)	$0-2$	n/a

[a] Numerous tropopause height and planetary boundary layer height diagnostics are (currently) also elements of the Level 2c structure. These are fully discussed in the ROPP APPS User Guide (ROM SAF, 2017b).

Table 2.4: Contents of the ROprof (*ROprof2d*) Level 2b (free atmospheric parameters), 2c (surface) and 2d (level coefficients) data.

Appendix F. Level 3 Data NetCDF Formats

The following is adapted from [RD.4, RD.5].

The data format for the ROM SAF Level 3 data products is netCDF. There are two types of netCDF files related to the Level 3 data products: *zgrid* files holding the zonally gridded monthly means and *trace* files holding the associated meta-data.

The zgrid files

The *zgrid* files (containing monthly mean data on a zonal latitude-height grid) have the following structure, exemplified by a dump from the file

zgrid_rrgmet_metop_201404_R_2304_0010.nc

holding gridded monthly mean refractivity based on Metop data from April 2014:

```
netcdf zgrid_rrgmet_metop_201404_R_2304_0010 {
dimensions:
        time = UNLIMITED ; // (1 currently)
        alt = 251 ;
        lat = 36 ;
        lon = 1 ;
        nv = 2 ;
        C64 = 64 ;
variables:
        char mission(C64) ;
                mission:long_name = "mission/satellite" ;
        int year(time) ;
                year:long_name = "calendar year" ;
                year:units = "1" ;
                year:valid_range = 1995, 2099 ;
        int month(time) ;
                month:long_name = "calendar month" ;
                month:units = "1" ;
                month:valid_range = 1, 12 ;
        float time(time) ;
                time:long_name = "reference time for monthly mean" ;
                time:units = "days since 1995-1-1 0:0:0" ;
                time:valid_range = 0.f, 38351.f ;
                time:calendar = "julian" ;
                time:bounds = "time_bnd" ;
        float time_bnd(time, nv) ;
        float alt(alt) ;
                alt:long_name = "MSL altitude" ;
                alt:units = "m" ;
                alt:valid_range = -1000.f, 150000.f ;
                alt:positive = "up" ;
        float lat(lat) ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:valid_range = -90.f, 90.f ;
                lat:bounds = "lat_bnd" ;
        float lat_bnd(lat, nv) ;
```

```
        float lon(lon) ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:valid_range = 0.f, 360.f ;
                lon:bounds = "lon_bnd" ;
        float lon_bnd(lon, nv) ;
        float REF(time, alt, lat, lon) ;
                REF:long_name = "monthly mean refractivity (sampling error corrected)" ;
                REF:units = "N-units" ;
                REF:valid_range = 0.f, 500.f ;
                REF:cell_methods = "time: area: mean" ;
                REF:_FillValue = -9.9999e+07f ;
        float REF_stdev(time, alt, lat, lon) ;
                REF_stdev:long_name = "monthly standard deviation of refractivity" ;
                REF_stdev:units = "N-units" ;
                REF_stdev:valid_range = 0.f, 100.f ;
                REF_stdev:cell_methods = "time: area: standard_deviation" ;
                REF_stdev:_FillValue = -9.9999e+07f ;
        float REF_obssig(time, alt, lat, lon) ;
                REF_obssig:long_name = "measurement uncertainty of the mean" ;
                REF_obssig:units = "N-units" ;
                REF_obssig:valid_range = 0.f, 100.f ;
                REF_obssig:_FillValue = -9.9999e+07f ;
        float REF_samperr(time, alt, lat, lon) ;
                REF_samperr:long_name = "sampling error of the mean" ;
                REF_samperr:units = "N-units" ;
                REF_samperr:valid_range = -100.f, 100.f ;
                REF_samperr:_FillValue = -9.9999e+07f ;
        int REF_num(time, alt, lat, lon) ;
                REF_num:long_name = "monthly data number" ;
                REF_num:units = "1" ;
                REF_num:valid_range = 0, 999999 ;
                REF_num:_FillValue = -999 ;
        float Wref(time, alt, lat, lon) ;
                Wref:long_name = "refractivity a priori fraction" ;
                Wref:units = "1" ;
                Wref:valid_range = 0.f, 1.f ;
                Wref:_FillValue = -9.9999e+07f ;

// global attributes:
                :title = "ROM SAF Radio Occultation Data" ;
                :description = "Reprocessed gridded monthly mean refractivity" ;
                :institution = "DMI (ROM SAF)" ;
                :history = "Based on UCAR excess phase data" ;
                :Conventions = "CF-1.6" ;
                :product_doi = "UNKNOWN" ;
                :product_name = "Reprocessed Refractivity Grid" ;
                :product_acronym = "RRGMET" ;
                :product_id = "GRM-29-L3-R-R1" ;
                :product_version = "1.0" ;
                :processing_center = "DMI (ROM SAF)" ;
                :processing_software = "GPAC 2.3.0" ;
                :processing_date = "2017-12-12 16:15:11.998" ;
                :software_name = "ROMCLIM" ;
                :software_version = "V1.2" ;
```

The trace files

The *trace* files (containing all information necessary to reproduce the Level 3 gridded data from the underlying Level 1b and Level 2 profile data) have the following structure, exemplified by a dump from the file

trace_rrgmet_metop_201404_R_2304_0010.nc

which is associated with the *zgrid* file previously described:

```
netcdf trace_rrgmet_metop_201404_R_2304_0010 {
dimensions:
        occ = 31876 ;
        C04 = 4 ;
        C40 = 40 ;
        C64 = 64 ;
variables:
        char mission(C64) ;
                mission:long_name = "Mission/satellite" ;
        int year ;
                year:long_name = "Calendar year" ;
                year:valid_range = 1995, 2099 ;
                year:_FillValue = -999 ;
        int month ;
                month:long_name = "Calendar month" ;
                month:valid_range = 1, 12 ;
                month:_FillValue = -999 ;
        char occ_id(occ, C40) ;
                occ_id:long_name = "Occultation ID" ;
        char leo_id(occ, C04) ;
                leo_id:long_name = "LEO satellite ID" ;
        char gns_id(occ, C04) ;
                gns_id:long_name = "GNSS satellite ID" ;
        int day(occ) ;
                day:long_name = "Day" ;
                day:valid_range = 1, 31 ;
                day:_FillValue = -999 ;
        int hour(occ) ;
                hour:long_name = "Hour" ;
                hour:valid_range = 0, 23 ;
                hour:_FillValue = -999 ;
        int mnt(occ) ;
                mnt:long_name = "Minute" ;
                mnt:valid_range = 0, 59 ;
                mnt:_FillValue = -999 ;
        int sec(occ) ;
                sec:long_name = "Second" ;
                sec:valid_range = 0, 59 ;
                sec:_FillValue = -999 ;
        float lon(occ) ;
                lon:long_name = "Nominal longitude" ;
                lon:units = "degrees_east" ;
                lon:valid_range = 0.f, 360.f ;
                lon:_FillValue = -9.9999e+07f ;
```

```
        float lat(occ) ;
                lat:long_name = "Nominal latitude" ;
                lat:units = "degrees_north" ;
                lat:valid_range = -90.f, 90.f ;
                lat:_FillValue = -9.9999e+07f ;
        float az(occ) ;
                az:long_name = "Nominal azimuth" ;
                az:units = "degrees_east" ;
                az:valid_range = 0.f, 360.f ;
                az:_FillValue = -9.9999e+07f ;
        int rising(occ) ;
                rising:long_name = "Setting/rising (0/1)" ;
                rising:valid_range = 0, 1 ;
                rising:_FillValue = -9 ;

// global attributes:
                :title = "ROM SAF Radio Occultation Data" ;
                :description = "Traceability information for gridded monthly mean refractivity" ;
                :institution = "DMI (ROM SAF)" ;
                :history = "Based on UCAR excess phase data" ;
                :product_doi = "UNKNOWN" ;
                :product_name = "Reprocessed Refractivity Grid" ;
                :product_acronym = "RRGMET" ;
                :product_id = "GRM-29-L3-R-R1" ;
                :product_version = "1.0" ;
                :processing_center = "DMI (ROM SAF)" ;
                :processing_software = "GPAC 2.3.0" ;
                :processing_date = "2017-12-12 16:15:11.998" ;
                :software_name = "ROMCLIM" ;
                :software_version = "V1.2" ;
```