

The EUMETSAT
Network of
Satellite
Application
Facilities



ROM SAF

Radio Occultation Meteorology

ROM SAF CDOP-2

Algorithm Theoretical Baseline Document: Level 2C Tropopause Height

Version 1.2

27 April 2016

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

DOCUMENT AUTHOR TABLE

	<i>Author(s)</i>	<i>Function</i>	<i>Date</i>	<i>Comment</i>
Prepared by:	Helge Jønch-Sørensen	ROM SAF Scientist	10/3 2016	
Reviewed by (internal):	Johannes K Nielsen	ROM SAF Scientist	11/3 2016	
Approved by:	Kent B. Lauritsen	ROM SAF Project Manager	27/4 2016	

DOCUMENT CHANGE RECORD

<i>Issue/Revision</i>	<i>Date</i>	<i>By</i>	<i>Description</i>
1.0	14/03/2016	HJS	First version. For PCR-RE1 review.
1.1	12/04/2016	HJS	Revised version. In accordance with PCR-RE1 RIDS: OBJ2_ATBD_TH_Von_001 OBJ2_ATBD_TH_Von_002 OBJ2_ATBD_TH_Von_004 OBJ2_ATBD_TH_Von_021 OBJ2_ATBD_TH_Schroeder_034 OBJ2_ATBD_TH_Schroeder_035
1.2	27/4/2016	HJS	Revised in accordance with discussions at PCR-RE1 meeting. OBJ2_ATBD_TH_Von_003 implemented

ROM SAF

The Radio Occultation Meteorology Satellite Application Facility (ROM SAF) is a decentralised processing center under EUMETSAT which is responsible for operational processing of GRAS radio occultation (RO) data from the Metop 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 data (Climate Data Records) and offline data for users requiring a higher degree of homogeneity of the RO data sets. The reprocessed and offline data 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 aids 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

All intellectual property rights of the ROM SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

List of Contents

1. INTRODUCTION	5
1.1 PURPOSE	5
1.2 APPLICABLE AND REFERENCE DOCUMENTS	5
1.2.1 <i>Applicable Documents</i>	5
1.2.2 <i>Reference Documents</i>	6
1.3 ACRONYMS AND ABBREVIATIONS.....	6
1.4 DEFINITIONS.....	7
2. BACKGROUND	9
3. TROPOPAUSE HEIGHT	10
3.1 DESCRIPTION OF ALGORITHM	10
3.2 PROCESSING STEPS	10
3.3 QUALITY CONTROL	12
4. VALIDATION METHOD	14
5. ASSUMPTIONS AND LIMITATIONS	16
6. DESCRIPTION OF DIFFERENCES FOR NRT, OFFLINE AND REPROCESSING	17
APPENDIX A	18
A.1 RUNNING THE PROGRAM	18
A.2 CONFIGURATION FILE	18
A.3 INPUT FILES	18
A.3 OUTPUTS	20

1. Introduction

1.1 Purpose

This ATBD document describes the algorithms used to derive the Level 2C tropopause height produced by the Radio Occultation Meteorology (ROM) Satellite Application Facility (SAF). The complete list of products covered by this ATBD is provided in Table 1.1. The current operational status of all these and all other ROM SAF data products is available at the website: <http://www.romsaf.org>

The product requirements baseline is the PRD version 2.3 [AD.3]. The ATBD software package is based on internal release of ROPP-8.1.

The contents of the document are as follows: Chapter 2 contains a very brief summary of the processing from the RO basic observables to higher level data. Chapter 3 contains the detailed description of the TPH algorithm. Chapter 4 contains the validation results. Chapter 5 contains a discussion of some limitations for the algorithm.

Table 1.1 List of products covered by this ATBD

Product ID	Product name	Product acronym	Product type	Operational satellite input	Dissemination means	Dissemination format
GRM-24	Tropopause Height	TPH	Offline Product	All ROM SAF RO products	web	BUFR/netCDF
GRM-29-L2-C-R1	Reprocessed Tropopause height	RCHMET	Data Record	Metop Level 1A data from EUM Secretariat	web	BUFR/netCDF
GRM-30-L2-C-R1	Reprocessed Tropopause height	RCHCO1	Data Record	COSMIC Level 1A data from CDAAC	web	BUFR/netCDF
GRM-32-L2-C-R1	Reprocessed Tropopause height	RCHCHA	Data Record	CHAMP Level 1A data from CDAAC	web	BUFR/netCDF
GRM-33-L2-C-R1	Reprocessed Tropopause height	RCHGHA	Data Record	GRACE Level 1A data from CDAAC	web	BUFR/netCDF

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] CDOP-2 Proposal: Proposal for the Second Continuous Development and Operations Phase (CDOP-2); Ref: SAF/GRAS/DMI/MGT/CDOP2/001 Version 1.1 of 21 March 2011, approved by the EUMETSAT Council in Ref. EUM/C/72/11/DOC/10 at its 72nd meeting on 28-29 June 2011

- [AD.2] CDOP-2 Cooperation Agreement: Agreement between EUMETSAT and DMI on the Second Continuous Development and Operations Phase (CDOP-2) of the Radio Occultation Meteorology Satellite Applications Facility (ROM SAF), approved by the EUMETSAT Council; Ref: EUM/C/72/11/DOC/15 at its 72nd meeting on 28-29 June 2011 and signed on 29 June 2011 in Copenhagen
- [AD.3] ROM SAF CDOP-2 Product Requirements Document, Ref. SAF/ROM/DMI/MGT/PRD/001

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 ATBD: 1DVAR algorithms, SAF/ROM/DMI/ALG/1DV/002
- [RD.2] ROM SAF ATBD: Level 2A Refractivity Profiles, SAF/ROM/DMI/ALG/REF/001
- [RD.3] The ROPP User Guide – Part III: Pre-processor module, SAF/ROM/METO/UG/ROPP/004
- [RD.4] World Meteorological Organization (WMO), Meteorology A Three-Dimensional Science: Second Session of the Commission for Aerology, *WMO Bulletin IV(4)*, Geneva, 134-138, 1957.
- [RD.5] Reichler, T., Dameris, M., Sausen, R., Determining the tropopause height from gridded data, *Geophys. Res. Lett.*, 30(20),2042,2003
- [RD.6] Schmidt, T., Visiting Scientist Report 22: Beta testing of ROPP 7.0 SAF/ROM/DMI/REO/VS22/001, Version 1.0, 2013
- [RD.7] Healy, S., Refractivity coefficients used in the assimilation of GPS radio occultation measurements, GRAS SAF Report 09, 2009.
- [RD.8] Smith, E.K., and S. Weintraub, The constants in the equation for atmospheric refractive index at radio frequencies, *Proc. IRE*, 1035-1037, 1953
- [RD.9] The ROPP User Guide – Part II: Forward module and 1D-Var modules, SAF/ROM/METO/UG/ROPP/003

1.3 Acronyms and abbreviations

CDOP-2	Second Continuous Development and Operations Phase
DMI	Danish Meteorological Institute
ECMWF	European Center for Medium-range Weather Forecast
EDC	EUMETSAT Data Centre (former UMARF)
EPS	EUMETSAT Polar satellite System
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (US)
GRAS	GNSS Receiver for Atmospheric Sounding (Metop instrument)
IIEC	Institut d'Estudis Espacials de Catalunya (Spain)
Metop	Meteorological Operational Polar satellite (EPS/EUMETSAT)

NRT	Near-Real Time
NWP	Numerical Weather Prediction
RO	Radio Occultation
ROM SAF	Radio Occultation Meteorology SAF (EUMETSAT), former GRAS SAF
SAF	Satellite Application Facility (EUMETSAT)
UKMO	The UK Meteorological Office (aka: Met Office)
WMO	World Meteorological Organisation

1.4 Definitions

RO data products from the GRAS instrument onboard Metop and RO data from other missions are grouped in *data levels* (level 0, 1, 2, or 3) and *product types* (NRT, Reprocessed, or Offline). The data levels and product types are defined below. 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, SNR's, 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 80 min (95%; EPS-SG Global), 40 min (95%; EPS-SG Regional) and 3 hours (EPS) after measurement;

Reprocessed product: Climate Data Record (CDR) covering an extended time period of several years, generated using a fixed set of processing software in order to provide a homogeneous data record appropriate for climate usage;

Offline product: Data product which typically extends a CDR from a reprocessing, thus providing an “interim” CDR; delivered from less than 5 days to up to 6 months after measurement depending on the requirements.

2. Background

A radio occultation (RO) instrument onboard a low-Earth orbit (LEO) satellite, e.g. the GRAS instrument onboard Metop, measures the L1 and L2 Doppler shifted radio signals from a GNSS satellite as the satellite sets or rises behind the Earth's limb. Through a rather complex sequence of processing steps the Doppler shift as a function of time is converted to neutral-atmosphere profiles of bending angle, refractivity, dry pressure and dry temperature, and finally to 1D-Var pressure, temperature, and humidity. The latter three quantities require *a priori* information taken from an atmospheric model. *A priori* data are also used for bending angle initialization in order to retrieve refractivity.

Comprehensive descriptions of how the primary observables, phase and amplitude of the Doppler shifted signals, are processed to atmospheric profiles can be found in [RD. 1,2,3].

3. Tropopause Height

The tropopause height (TPH) is most often derived from the rate of decrease of temperature with height, the lapse-rate.

In the ROPP processor apps module, the TPH is derived via the tool: `ropp_apps/tools/ropp_apps_tph_tool` which allows to diagnose the TPH from profiles of bending angle (level 1B product), refractivity (level 2A), dry temperature (level 2A) or (wet) temperature (level 2B). For each of the two temperature based TPH one is based on the lapse-rate and one based on the cold point.

The operational ROM SAF TPH product is defined to be the dry temperature lapse rate which is described in this document. The dry temperature lapse rate TPH is based on the standard WMO lapse-rate criterion and validation against other TPH results (radiosondes) is simple. Information on the other TPHs (internal products) can be found in the ROPP documentation. [RD.3].

3.1 Description of algorithm

The algorithm is developed to derive the TPH according to the WMO definition, where TPH is defined as “the lowest level at which the lapse-rate (Γ_{WMO}) decreases to 2° C/km or less, provided that the average lapse-rate between this level and all higher levels within 2 km does not exceed 2° C/km.” [RD.4]

The lapse rate method described by Reichler et al. (2003) [RD.5] is applied. The algorithm use a thermal definition of the tropopause, based on the concept of a threshold lapse-rate. Interpolation is performed to identify the pressure at which this threshold is reached and maintained. In the event of multiple vertical levels meeting these criteria, the tropopause is assigned to the lowest position of occurrence. Furthermore, the derived tropopause height must be within a latitude dependent height range corresponding to approximately 75 hPa to 550 hPa to be accepted.

The algorithm is expressed in terms of pressure, which is not available as level 2A field in ROPP. Thus, dry pressure calculated from refractivity and dry temperature (both level 2A) is used in the steps below as a proxy for the full pressure. [RD.3]

3.2 Processing steps

Below the main steps in the algorithm are described in some detail.

1. Ensure that the geometric heights (h_i) are in ascending order and that enough level 2a data exist. If not, return to `ropp_apps_tph_tool`
2. Check numerical and scientific robustness of the input temperature.
 - 2.1) There must be at least three pairs (T_i, p_i) of valid data and a valid latitude defined. This is a technical limit, profiles with only three valid data points will be excluded in the following steps.

- 2.2) The geometric heights (h_i) must start below or at $TPH_{min} = 2.5(3 + \cos(2lat))$ and
- 2.3) continue to or above $TPH_{max} = 2.5(7 + \cos(2lat))$
3. Calculated dry pressure (p) from the refractivity (N) and dry temperature (T) using: $p = \frac{NT}{\kappa_1}$. The standard value [RD.8] of $\kappa_1 = 77.6 \times 10^{-2} \text{ KPa}^{-1}$ is used here. Recent studies have indicated the need for a small revision of the values, and have shown a weak dependence on deviations from the ideal gas law [RD.7]. When using a non-ideal gas law in applications that include forward modelling from model data, the coefficient used is instead $\kappa_1 = 77.643 \times 10^{-2} \text{ KPa}^{-1}$ [RD.9]. This small change of coefficient will mean a change of the derived TPH of only a few meters.
4. Smooth pressure and temperature profiles according to
- $$T_i \rightarrow \frac{T_{i-1} + T_i + T_{i+1}}{3}$$
- $$p_i \rightarrow \frac{p_{i-1} + p_i + p_{i+1}}{3}$$
5. Calculate Exner pressure (Π)
- $$\Pi_i = (p_i/p_{ref})^\kappa \text{ where } \kappa = R_{dry}/C_p \approx 0.285$$
- and lapse rate (Γ)
- $$-\Gamma_{i+1/2} = (-g/C_p) \frac{T_{i+1} - T_i}{\Pi_{i+1} - \Pi_i} \frac{\Pi_{i+1} + \Pi_i}{T_{i+1} + T_i}$$
6. Go through the profile and for each point (i): if $-\Gamma_{i+1/2}$ and the average over the 2 km above is greater than $-\Gamma_{WMO} = -2 \text{ K/km}$ and the previous, $-\Gamma_{i-1/2}$, is less than $-\Gamma_{WMO}$, so that points $i-1/2$ and $i+1/2$ enclose the critical lapse rate, then the first estimate of the index of the lapse rate is taken to be i .
7. Calculate TPH by linear interpolation of Γ with Π , followed by linear interpolation of $\log(p)$ with h .

$$2\Pi_{tph} = (\Pi_i + \Pi_{i-1}) + \frac{\Pi_{i+1} - \Pi_{i-1}}{\Gamma_{i+1/2} - \Gamma_{i-1/2}} (\Gamma_{WMO} - \Gamma_{i-1/2})$$

$$p_{tph} = p_{ref} \Pi_{tph}^{1/\kappa}$$

$$h_{tph} = h_{i-1} + \frac{h_i - h_{i-1}}{\log(p_i/p_{i-1})} \log(p_{tph}/p_{i-1})$$

$$T_{tph} = T_{i-1} + \frac{T_i - T_{i-1}}{\log(p_i/p_{i-1})} \log(p_{tph}/p_{i-1})$$

8. Check that the derived TPH is within the range TPH_{min} to TPH_{max} as defined above in step 2.
9. Overall profile minimum temperature and its geometric height are calculated.
10. Fill quality flags, lapse rate TPH and dry temperature at the TPH, and the entire profile heights and temperatures to their equivalents in the ROPP structure.
Thus, the dry temperature derived TPHs are on geometric heights.

In step 6 above, the cold point tropopause is also calculated, as being the height of the minimum temperature between TPH_{min} and TPH_{max} . If this height differs by more than 2 km from h_{tph} , then use the minimum temperature in the height interval $h_{tph} \pm 2\text{km}$. Note that the cold point TPH is not an operational ROM SAF product, and that the cold point definition of TPH is not meaningful outside the tropics. For absolute values of latitude greater than 30° a bit is set to cold point TPH QC flag and missing value to the cold point TPH variable.

3.3 Quality control

The TPHs are associated with a 'bit-wise' encoded quality control flag as described in the ROPP documentation. [RD.3]

The flag is initialised at ropp_MIFV=-999, and otherwise encoded bit by bit as

$$tph_qc_flag = \sum_{r=0}^7 l(r)2^r$$

The 8 components (r) are described as:

- r=0 Input data validity check
- r=1 Input data depth check
- r=2 Input data height check
- r=3 Covariance transform sharpness above TPH check
- r=4 Covariance transform sharpness below TPH check
- r=5 Double tropopause height
- r=6 TPH minimum height check
- r=7 TPH maximum height check

The value $l(r)$ is 0 if the check is passed or irrelevant and 1 if the data check is not ok, e.g. if the derived dry temperature TPH is below the minimum accepted height, then $l(6) = 1$ and this bit contributes with $2^6 = 64$ to the tph_qc_flag

The relevant components for the dry temperature derived TPH are $r = 0, 1, 2, 6$ and 7 .

$r=0$ relates to step 2.1 in section 3.2

$r=1$ relates to step 2.2

$r=2$ relates to step 2.3

$r=7$ and $r=8$ test to step 8 in section 3.2

If the QC flag is zero, the diagnosed TPH is considered to be good, any other values indicates some problems with the integrity of the derived TPH, problems that can be identified using the value of tph_qc_flag .

Ref: SAF/ROM/DMI/ALG/TPH/001
Issue: 1.2
Date: 27/04/2016

ROM SAF CDOP-2
ATBD: TPH



QC flags are copied to the ROPP variable: ro_data%lev2c/tph_tdry_lrt_flag

4. Validation Method

This section briefly discusses the validation method.

The dry temperature TPH will be validated directly against the temperature based TPH derived from collocated ECMWF background fields and preferably also TPH from another reference, such as radio sondes.

The TPH is evaluated by looking at the standard deviation of the “solution-background” and “solution-other reference”.

This approach has been tested in [RD.6] where the TPHs have been compared directly to the ECMWF (wet) lapse-rate TPH.

The data is dry temperature TPH for approximately 20 000 GRAS occultations in April 2013, and the background temperature based TPH for the collocated ECMWF fields.

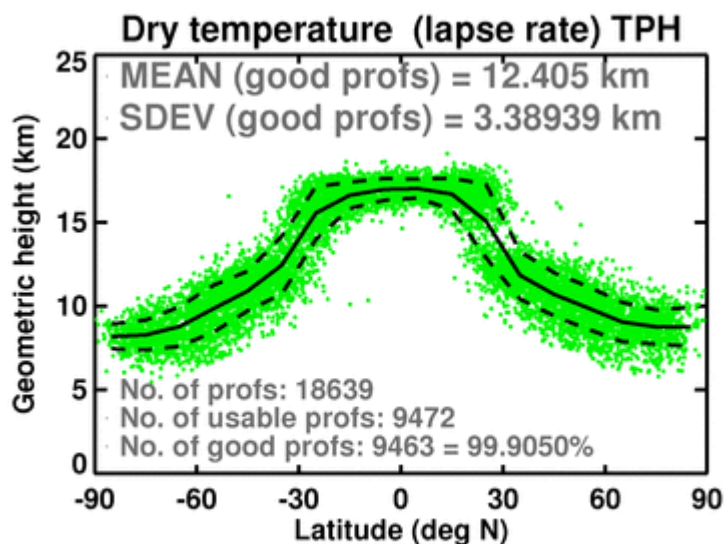


Figure 1 Zonal distribution of the derived dry temperature TPH together with the ECMWF collocated background fields [RD.6].

The overall agreement between the derived TPH and the background fields are very good and the overall standard deviation of 0.94 km is close to the product requirement [AD.3] target value of 1 km and well below the threshold requirement value of 2 km.

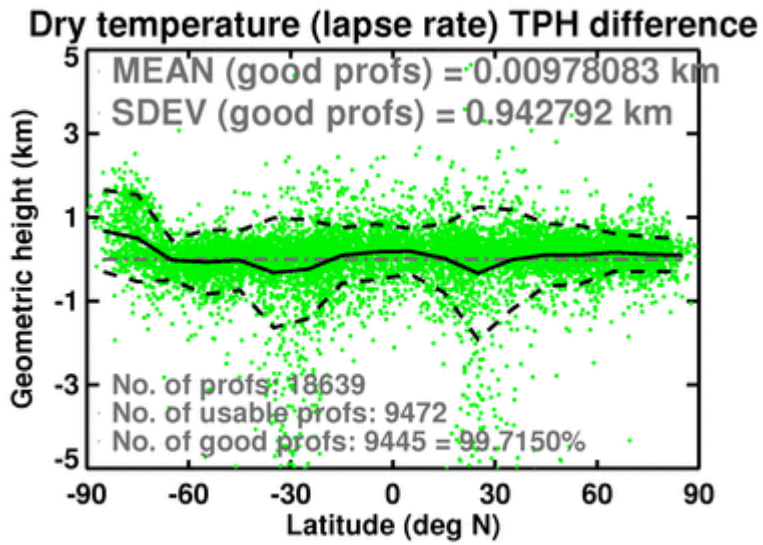


Figure 2) Derived TPH minus corresponding ECMWF background. Black solid curve is the zonal mean (in 10 degree bins) and dashed curves are the mean +/- one standard deviation. . [RD.6]

5. Assumptions and limitations

As described in sect. 3.2 the tropopause height will only be valid if the height is above $TPH_{min} = 2.5(3 + \cos(2lat))$. For NRT¹: geometrical optics is used to derive level 2A refractivity, and the data below 8 km is considered to be of poor quality and therefore not used in production of higher level data. Nominal profiles are marked with a percent confidence value of 0 below 8 km. This corresponds to TPH_{min} at absolute values of latitude larger than approximately 40°. This may limit the applicability of the discussed method, especially in the polar regions during late spring to summer periods where the tropopause height may be very low.

¹ Current NRT GRAS/Metop level 1B bending angle data are derived by geometrical optics, the change to wave optics retrieval is expected in April or May 2016.

6. Description of differences for NRT, Offline and Reprocessing

The algorithm is the same for all three types of processing.

Appendix A

A.1 Running the program

Calling the ROPP module for calculating TPH:

```
ropp_apps_tph_tool <inputROPPfile> -o <outputROPPfile>
```

Options:

-o	<output_file> name of ROPP netCDF output file
-b	calculate bending angle-based TPH only
-n	calculate refractivity-based TPH only
-y	calculate dry temperature-based TPH only
-t	calculate temperature-based TPH only
-h	help
-d	output additional diagnostics
-v	version information

If none of the -b,-n,-y or -t options are specified, the tool will attempt to calculate all four TPHs.

All TPHs are present in output netCDF file, if not calculated then filled with missing values.

If -d option is present the lapse rate (section 3.2, step 5) and corresponding geometric heights are added to the output file.

A.2 Configuration file

N/A

A.3 Input files

Input data: For any GNSS RO satellite sensor supported: profiles of bending angle, refractivity or dry temperature.

NRT version.

The NRT file name version is the filename version that is used in the NRT processing chain, for both level 1 and level 2 products. It contains 6 fields separated by underscores:

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

Where:

- <TYPE> can be one of “atm”, “bfr”, “bgr”, “dis”, “occ” or “wet”
For the calculation of TPH the following types are used.
“atm” files contain ROPP level 1A and 2A data, necessary for calculating dry temperature TPH (as well as bending angle TPH, refractivity TPH)
“occ” files contain ROPP level 1A data, necessary for bending angle TPH
“wet” files contain ROPP level 2B data, necessary for (wet) temperature TPH
- <DATE>_<TIME> is the start date and time of the observation, as YYYYMMDD_HHMMSS.
- <MISSION-ID> is the EPS name of the observing satellite.
- <OCC_ID> is the occultation id (EPS format which includes id of occulting satellite)
- <MODE> is the processing mode and one of “N” (Near Real Time), “T” (Test), “V” (Validation).
- <SWVER> is a four digit code denoting the system software version
- <FREE> is a free field, “XXXX”
- <EXT> is the extension, “nc” for NetCDF, “bin” for BUFR

Offline level 1 and level 2

The offline level 1 and 2 file name version is the filename version that is used in the offline and re-processing chain. It contains 8 fields separated by underscores:

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

Where:

- <TYPE>, <DATE>_<TIME>, <MISSION-ID>, <SWVER>, and <EXT> is as explained above.
- <OCC_ID> is an ID that identifies the GNSS satellite used for the specific occultation.
- <MODE> is the processing mode and one of “O” (offline), “R” (Reprocessing), “T” (Test), “V” (Validation)

A.3 Outputs

The output variables in the ROPP structure (ro_data%lev2c%)

tph_tdry_lrt	Dry temperature-based TPH derived from lapse rate
tpt_tdry_lrt	Tropopause dry temperature, based on tph_tdry_lrt
tph_tdry_lrt_flag	Dry temperature-based TPH QC flag (lapse rate)
tph_bangle	Bending angle-based TPH
tpa_bangle	Tropopause bending angle, based on tph_bangle
tph_bangle_flag	Bending angle-based TPH QC flag
tph_refrac	Refractivity-based TPH
tpn_refrac	Tropopause refractivity, based on tph_refrac
tph_refrac_flag	Refractivity-based TPH QC flag
tph_tdry_cpt	Dry temperature-based TPH derived from cold point
tpt_tdry_cpt	Tropopause dry temperature, based on tph_tdry_cpt
tph_tdry_cpt_flag	Dry temperature-based TPH QC flag (cold point)
tph_temp_lrt	Temperature-based TPH derived from lapse rate
tpt_temp_lrt	Tropopause dry temperature, based on tph_temp_lrt
tph_temp_lrt_flag	Temperature-based TPH QC flag (lapse rate)
tph_temp_cpt	Temperature-based TPH derived from cold point
tpt_temp_cpt	Tropopause dry temperature, based on tph_temp_cpt
tph_temp_cpt_flag	Temperature-based TPH QC flag (cold point)