
ODIN/SMR

L2 data - format and overview

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Chapter 1 | Aim and Scope of this Document

The Sub-Millimetre Radiometer (SMR), aboard the Odin satellite, has been in operation since 2001 and performs passive limb measurements of the atmosphere, mainly at frequencies around 500 GHz. From these measurements, profiles of species that are of interest for studying stratospheric and mesospheric chemistry and dynamics can be derived, such as O₃, ClO, N₂O, NO, HNO₃, H₂O, CO, and isotopologues of H₂O, and O₃. These profiles are referred to as Level2 (L2) products of Odin/SMR. They are generated by a Level2 processor. The input to the Level2 processor is geolocated and calibrated measurements (Odin/SMR Level1B data, described in [Rydberg et al. \(2017\)](#)) and dynamic and static auxiliary/ancillary data.

The aim of this document is to provide an user-friendly description of the L2 data. More details about the L2 processing system and the algorithms applied by the L2 processor are available in the Input/Output Data Definition Document (IODD) ([Rydberg et al., 2016](#)) and in the Algorithms Theoretical Basis Document (ATBD) - Level 2 processing ([Eriksson, 2020](#)), respectively.

Chapter 2 | L2 Data Product Structure

2.1 Accessing Level 2 data

L2 data can be obtained in two ways:

1. via a web-api that can be queried and used to get data from a specified area and time interval or from specific scans etc. Documentation about the web-api is found here: <http://odin.rss.chalmers.se/apidocs/index.html> and <http://odin.rss.chalmers.se/dataaccess>
2. or through downloading monthly L2 product files over http from a file archive (http://odin.rss.chalmers.se/level2_download/). This option can preferably be used if all or a large part of the Odin data is of interest.

The web-api provide the L2 data in json format, whereas the monthly L2 product files have a netCDF format.

2.2 Available Level2 products

A number of Odin/SMR L2 products are available (Murtagh et al. (2020)) and a recommendation about what products to use is available at <http://odin.rss.chalmers.se/dataaccess>.

2.3 Monthly L2 product file description

2.3.1 L2 version

The current L2 data version is v3.0.0.

2.3.2 File name convention

L2 product files are stored in netCDF format (<https://www.unidata.ucar.edu/software/netcdf/>), and the file name convention of the monthly L2 files is:

Odin-SMR_L2_{project}_{product}_{year}-{month:02}.nc,

e.g.: Odin-SMR_L2_ALL-Strat-v3.0.0_O3-501-GHz-20-to-50-km_2005-01.nc.

where in this case:

project = ALL-Strat-v3.0.0 and product = O3-501-GHz-20-to-50-km. See further in Murtagh et al. (2020) for available projects and products.

2.3.3 File content description

Each L2 product file contains retrieved VMR or temperature profiles, where a single profile is associated with a single scan of the atmosphere by the Odin/SMR instrument. The L2 product files covers one month of data, but all retrieved data for this month is not necessarily included, as the data is filtered, and this is further described in [2.3.5](#).

Variables

The L2 file contains the variables described below for each retrieved profile:

Altitude (array of floats): Altitude of retrieved values (m)

Apriori (array of floats): *A priori* profile used in the inversion algorithm ([-] or [K]).

AVK (2-D array of floats): Averaging kernel matrix. For gas species, the averaging kernel for relative changes is given ([%/%]). For temperature, the unit is [K/K].

ErrorNoise (array of floats): Error due to measurement thermal noise (square root of the diagonal elements of the corresponding error matrix) ([-] or [K]).

ErrorTotal (array of floats): Total retrieval error, corresponding to the error due to thermal noise and all interfering smoothing errors (square root of the diagonal elements of the corresponding error matrix) ([-] or [K]).

GenerationTime (float): Processing date, given as 'days since 1858-11-17 00:00'.

Lat1D (float): A scalar representative latitude of the profile [degrees north].

Latitude (array of floats): Approximate latitude of each retrieval value [degrees north].

Lon1D (float): A scalar representative longitude of the profile [degrees east]

Longitude (array of floats): Approximate longitude of each retrieval value [degrees east].

LST (float): Mean local solar time for the scan [hours].

MeasResponse (array of floats): Measurement response, defined as the row sum of the averaging kernel matrix [-].

OrbitNum (int): Odin/SMR orbit number.

Pressure (array of floats): Pressure grid of the retrieved profile [Pa].

Profile (array of floats): Retrieved volume mixing ratio [-] or temperature [K] profile

ScanID (int): Unique scan identifier.

SZA1D (float): Mean solar zenith angle of the observations used in the retrieval process [degrees].

SZA (array of floats): Approximate solar zenith angle corresponding to each retrieval value [degrees].

Temperature (array of doubles): Estimate of the temperature profile [K] (based on input data from ERA-Interim).

Theta (array of floats): Estimate of the potential temperature profile [K].

Time (double): Mean time of the scan, given as 'days since 1858-11-17 00:00'.

Attributes

The L2 file contains the following attributes:

observation_frequency_mode (string): Odin/SMR observation frequency mode.

platform (string): Instrument name (Odin).

sensor (string): Sensor name (SMR).

inversion_mode (string): Inversion mode.

level2_product_name (string): L2 product name.

version_l1b (string): Version number of the Level 1b processing chain that was used to create the Level 1b data, in turn used as an input to the Level 2 processor.

version_l2 (string): Version number of the Level 2 processing chain that was used to create the Level 2 file.

time_coverage_start (string):, Mean time of the first scan in the file, given as 'YYYY-MM-DD-hh-mm-ssZ'.

time_coverage_end (string):, Mean time of the last scan in the file, given as 'YYYY-MM-DD-hh-mm-ssZ'.

2.3.4 File format description

A description of the L2 netCDF file is given below:

```
netcdf Odin-SMR_L2_ALL-Strat-v3.0.0_03-501-GHz-20-to-50-km_2005-01 {
dimensions:
    time = 5 ;
    level = 28 ;
```

variables:

```

float GenerationTime(time) ;
    GenerationTime:description = "Processing date." ;
    GenerationTime:units = "days since 1858-11-17 00:00" ;
float Altitude(time, level) ;
    Altitude:description = "Altitude of retrieved values." ;
    Altitude:units = "m" ;
float Apriori(time, level) ;
    Apriori:description = "A priori profile used in the
        inversion algorithm." ;
    Apriori:units = "-" ;
float AVK(time, level, level) ;
    AVK:description = "Averaging kernel matrix." ;
    AVK:units = "%/%" ;
float ErrorNoise(time, level) ;
    ErrorNoise:description = "Error due to measurement ...";
    ErrorNoise:units = "-" ;
float ErrorTotal(time, level) ;
    ErrorTotal:description = "Total retrieval error, ...";
    ErrorTotal:units = "-" ;
float Lat1D(time) ;
    Lat1D:description = "A scalar representative latitude ...";
    Lat1D:units = "degrees north" ;
float Latitude(time, level) ;
    Latitude:description = "Approximate latitude of each ...";
    Latitude:units = "degrees north" ;
float Lon1D(time) ;
    Lon1D:description = "A scalar representative longitude ..." ;
    Lon1D:units = "degrees east" ;
float Longitude(time, level) ;
    Longitude:description = "Approximate longitude of each ..." ;
    Longitude:units = "degrees east" ;
float LST(time) ;
    LST:description = "Mean local solar time for the scan." ;
    LST:units = "hours" ;
float MeasResponse(time, level) ;
    MeasResponse:description = "Measurement response, defined ..." ;
    MeasResponse:units = "-" ;
float Orbit(time) ;
    Orbit:description = "Odin/SMR orbit number." ;
    Orbit:units = "-" ;
float Pressure(time, level) ;
    Pressure:description = "Pressure grid of the retrieved ..." ;
    Pressure:units = "Pa" ;
float Profile(time, level) ;
    Profile:description = "Retrieved volume mixing ratio." ;
    Profile:units = "-" ;
int64 ScanID(time) ;
    ScanID:description = "Satellite time word scan identifier." ;

```

```

        ScanID:units = "-" ;
float SZA1D(time) ;
        SZA1D:description = "Mean solar zenith angle of the ..." ;
        SZA1D:units = "degrees" ;
float SZA(time, level) ;
        SZA:description = "Approximate solar zenith angle ..." ;
        SZA:units = "degrees" ;
float Temperature(time, level) ;
        Temperature:description = "Estimate of the temperature ..." ;
        Temperature:units = "K" ;
float Theta(time, level) ;
        Theta:description = "Estimate of the potential temperature ..." ;
        Theta:units = "K" ;
float Time(time) ;
        Time:description = "Mean time of the scan." ;
        Time:units = "days since 1858-11-17 00:00" ;

// global attributes:
:observation_frequency_mode = "1" ;
:inversion_mode = "stdn" ;
:level2_product_name = "O3 / 501 GHz / 20 to 50 km" ;
:date_created = "2020-02-24 T08:31:04Z" ;
:time_coverage_start = "2005-01-01 T11:12:13Z" ;
:time_coverage_end = "2005-01-01 T11:30:58Z" ;
:creator_name = "Donal Murtagh" ;
:creator_url = "odin.rss.chalmers.se" ;
:creator_email = "donal.murtagh@chalmers.se" ;
:address = "412 96 Gothenburg, Sweden" ;
:institution = "Chalmers University of Technology" ;
:platform = "Odin" ;
:sensor = "SMR" ;
:version_l1b = "8" ;
:version_l2 = "3.0.0" ;

}

```

2.3.5 Data filtering

The monthly L2 product files are quality filtered, and contain only "valid" data. A retrieved profile is considered to be valid if

- **MinLmFactor** [-]: The minimum value of the Levenberg - Marquardt factor during the OEM iterations is below 2 (for Frequency mode 1 and 2) and 10 (for Frequency mode 8, 13, and 19), and
- **Residual** [K]: The difference between the spectra matching retrieved state and used measurement spectra is below 1.5 K.

Information about the amount of excluded data is found in [Rydberg et al. \(2020\)](#).

2.4 Odin web-api

The L2 part of the Odin web-api contains a number of endpoints (<http://odin.rss.chalmers.se/apidocs/index.html#/level2>), that provides three different L2 data objects denoted as L2, L2i, and L2anc. The L2 object contains the main result of the retrieval calculation (e.g. retrieved profile and averaging kernels), the L2i object contains obtained offsets and residual etc. from the retrieval calculation, and the L2anc object contains ancillary data. The endpoints provide the L2 data in JSON format and the content of these three objects are described below.

2.4.1 L2

- AVK (*2-D array of doubles*): Averaging kernel matrix. For gas species the averaging kernels for relative changes is given ([%/%]). For temperature the unit is [K/K].
- Altitude (*array of doubles*): Altitude of retrived values [m]
- Apriori (*array of doubles*): *A priori* profile used in inversion ([-] or [K])
- ErrorNoise (*array of doubles*): Error due to measurement thermal noise (square root of the diagonal elements of the corresponding error matrix) ([-] or [K])
- ErrorTotal (*array of doubles*): Total retrieval error, the error due to thermal noise and all interfering smoothing errors (square root of the diagonal elements of the corresponding error matrix) ([-] or [K])
- FreqMode (*int*): Odin/SMR frequency mode of the observation
- InvMode (*string*): Inversion mode
- Lat1D (*double*): A scalar representative latitude of the retrieval
- Latitude (*array of doubles*): Approximate latitude of each retrieved value
- Lon1D (*double*): A scalar representative longitude of the retrieval
- Longitude (*array of doubles*): Approximate longitude of each retrieved value
- MJD (*double*): Mean modified julian date of the observations used in the retrieval
- MeasResponse (*array of doubles*): The measurement response, defined as the row sum of the averaging kernel matrix [-]
- Pressure (*array of doubles*): Pressure grid of the retrieved species [Pa]
- Product (*string*): Level2 product name
- ScanID (*int*): Satellite time word scan identifier
- Temperature (*array of doubles*): Best estimate of temperature profile [K] (either retrieved or represents the input zpt data)
- VMR (*array of doubles*): Volume mixing ratio or retrieved profile [-]. Left empty if the L2 object describes a temperature profile retrieval.

2.4.2 L2i

- BlineOffset (*2-D array of doubles*): Retrieved “baseline” offsets, that differ for each used spectrum and each autocorrelate sub-module
- ChannelsID (*array of doubles*): Channel identifier that describes which channels that were used in the retrieval [-]. More exactly it describes the location of the sorted channels in the original unsorted spectra
- FitSpectrum (*2-D array of doubles*): Fitted spectrum [K]
- FreqMode (*int*): Odin/SMR frequency mode of the observation
- FreqOffset (*double*): Retrieved frequency offset of the LO frequency [Hz]
- InvMode (*string*): Inversion mode
- L1bQuality (*int*): Quality of L1b data used
- LOFreq (*array of doubles*): LO frequency of each each spectrum of the scan [Hz]
- MinLmFactor (*double*): The minimum value of the Levenberg - Marquardt factor during the OEM iterations [-]
- PointOffset (*double*): Retrieved pointing offset in degrees
- Residual (*double*): The difference between the spectra matching retrieved state and used measurement spectra ([K])
- STW (*array of doubles*): Satellite time word of each spectrum used in the retrieval
- ScanID (*int*): Satellite time word scan identifier

2.4.3 L2anc

- FreqMode (*int*): Odin/SMR frequency mode of the observation
- InvMode (*string*): Inversion mode
- LST (*double*): Mean local solar time for the scan [hours].
- Lat1D (*double*): A scalar representative latitude of the retrieval
- Latitude (*array of doubles*): Approximate latitude of each retrieved value
- Lon1D (*double*): A scalar representative longitude of the retrieval
- Longitude (*array of doubles*): Approximate longitude of each retrieved value
- MJD (*double*): Mean modified julian date of the observations used in the retrieval
- Orbit (*double*): Orbit number
- Pressure (*array of doubles*): Pressure grid of the retrieved species [Pa]
- SZA (*double*): Mean solar zenith angle of the observations used in the retrieval process [degrees]

- SZA1D (*double*): Mean solar zenith angle of the observations used in the retrieval process [degrees]
- ScanID (*int*): Satellite time word scan identifier
- Theta (*array of doubles*): Estimate of the potential temperature profile [K]

Acronyms

ATBD	Algorithm theory basis document
OEM	Optimal estimation method
SMR	Sub-millimetre radiometer
VMR	Volume mixing ratio

Bibliography

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