# Python Documentation

## version 1.0

February 11, 2022

# Contents

# NCAS Radar Data Standard

Documentation for ncas-radar-data-format.

## Overview

## WIVERN-2 Chilbolton processing routines

wivern2_chilbolton is a collection of Python routines for processing the radar data collected during the WIVERN-2 ground-based observation campaign at Chilbolton Observatory in the UK.

These are the routines used to process raw (Level 0) time series data from the following radars:

- 3GHz CAMRa radar
- 35GHz Copernicus radar
- 94GHz Galileo radar

### Note

Near real-time Cloudnet data can be accessed at https://cloudnet.fmi.fi.

See also:

- Cloudnet data portal: https://cloudnet.fmi.fi/
- CloudnetPy source: https://github.com/actris-cloudnet/cloudnetpy
- ACTRIS home: http://actris.eu/
- ACTRIS data portal: http://actris.nilu.no/

## Quickstart

Processing is easy using CloudnetPy's high level APIs. You only need some measurement data from your instruments. And if you don't have it, you can always try these example files.

## Radar processing

In the first example we convert a raw METEK MIRA-36 cloud radar file into Cloudnet netCDF file that can be used in further processing steps.

```
from cloudnetpy.instruments import mira2nc
uuid = mira2nc('raw_mira_radar.mmclx', 'radar.nc', {'name': 'Mace-Head'})
```

where `uuid` is an unique identifier for the generated `radar.nc` file. For more information, see API reference for this function.

## Lidar processing

Next we convert a raw Jenoptik CHM15k ceilometer (lidar) file into Cloudnet netCDF file and process the signal-to-noise screened backscatter. Also this converted lidar file will be needed later.

```
from cloudnetpy.instruments import ceilo2nc
uuid = ceilo2nc('raw_chm15k_lidar.nc', 'lidar.nc', {'name':'Mace-Head', 'altitude':5})
```

where `uuid` is an unique identifier for the generated `lidar.nc` file. For more information, see API reference for this function.

## MWR processing

Processing of multi-channel HATPRO microwave radiometer (MWR) data is not part of CloudnetPy. Thus, site operators need to run custom processing software to retrieve integrated liquid water path (LWP) from raw HATPRO measurements.

However, with a 94 GHz RPG cloud radar, a separate MWR instrument is not necessarely required. RPG radars contain single MWR channel providing a rough estimate of LWP, which can be used in CloudnetPy. Nevertheless, it is always recommended to equip a measurement site with a dedicated multi-channel radiometer if possible.

## Model data

Model files needed in the next processing step can be downloaded from the Cloudnet http API. Several models may be available depending on the site and date. The list of different model models can be found here.

## Categorize processing

After processing the raw radar and raw lidar files, and acquiring the model and mwr files, a Cloudnet categorize file can be created.

In the next example we create a categorize file starting from the `radar.nc` and `lidar.nc` files generated above. The required `ecmwf_model.nc` and `hatpro_mwr.nc` files are included in the provided example input files.

```
from cloudnetpy.categorize import generate_categorize
input_files = {
    'radar': 'radar.nc',
    'lidar': 'lidar.nc',
    'model': 'ecmwf_model.nc',
    'mwr': 'hatpro_mwr.nc'
    }
uuid = generate_categorize(input_files, 'categorize.nc')
```

where `uuid` is an unique identifier for the generated `categorize.nc` file. For more information, see API reference for this function. Note that with a 94 GHz RPG cloud radar, the `radar.nc` file can be used as input for both inputs: `'radar'` and `'mwr'`.

## Processing products

In the last example we create the smallest and simplest Cloudnet product, the classification product. The product-generating functions always use a categorize file as an input.

```
from cloudnetpy.products import generate_classification
uuid = generate_classification('categorize.nc', 'classification.nc')
```

where `uuid` is an unique identifier for the generated `classification.nc` file. Corresponding functions are available for other products (see **`Product generation`**).

## Filename conventions

Each radar file is named as

`<instrument_name>_<platform_name>_<date>-[<time>]_<scan_type>_[<option1>_<option2>_<option3>]_v<version>.nc`

# NetCDF conventions

The NCAS-RADAR convention adheres to the CF/Radial-1.4 format, and its subconventions.

## Metadata (Global Attributes)

As the NCAS RADAR convention uses CF/Radial-1.4 as its basis, all global attributes required by the latter must be included. The following global attributes are required by CF/Radial-1.4

`Conventions`

This indicates the conventions/vocabularies that are being followed in the generation of the data file. The core convention is that used for CF naming, that is CF-1.6.

`title`

This is a short description of the file contents.

**Example:** `Moments from the NCAS Mobile X-band Radar unit 1 at Sandwith, UK`

`institution`

This is the name of the institution employing the creator. This is added to help users of the data track down the creator if they need to.

**Example:** `National Centre for Atmospheric Science (NCAS)`

`references`

References that describe the data or the methods used to produce it. For example, this may be a paper describing the instrument.

**Example:** `https://doi.org/10.5194/amt-11-6481-2018`

`source`

This is a descriptor that uniquely identifies the source of the data.

**Example:** `NCAS Mobile X-band Radar unit 1`

`history`

This is freeform text that gives the history of the data from collection to the present version.

`comment`

This is free form text and is used to provide the user with any additional information that may be of use.

**Example:**

`instrument_name`

This should be filled with the unique NCAS instrument name

**Example:** `ncas-mobile-x-band-radar-1`

## Level 0a files

### 3GHz CAMRa time-series files

These files are in NetCDF-3 format with the following content:

**Dimensions:**

| Name |
|---|
| time |
| range |
| unaveraged_range |

| |
|---|
| pulses |
| samples |

**Variables:**

| | | | | |
|---|---|---|---|---|
| latitude | float32 | | latitude of the antenna | Units |
| | | | | degree_north |
| longitude | float32 | | longitude of the antenna | degree_east |
| height | float32 | | height of the elevation axis above mean sea level (Ordnance Survey Great Britain) | m |
| frequency | float32 | | frequency of transmitted radiation | GHz |
| prf | float32 | | pulse repetition frequency | Hz |
| beamwidthH | float32 | | horizontal angular beamwidth | degree |
| beamwidthV | float32 | | vertical angular beamwidth | degree |
| antenna_diameter | float32 | | antenna diameter | m |
| pulse_period | float32 | | pulse period | us |
| transmit_power | float32 | | peak transmitted power | W |
| clock | float32 | | clock input to ISACTRL | Hz |
| range | float32 | range | distance from the antenna to the middle of each range gate | m |
| unaveraged_range | float32 | unaveraged_range | distance from the antenna to the middle of each range gate | m |
| time | float32 | time | time | seconds since 2020-09-22 00:00:00 +00:00 |
| dish_time | float32 | time | dish_time | seconds since 2020-09-22 00:00:00 +00:00 |
| elevation | float32 | time | elevation angle above the horizon at the start of the beamwidth | degree |
| azimuth | float32 | time | azimuth angle clockwise from grid north at the start of the beamwidth | degree |
| ZLO | short | time, pulses, samples | radar reflectivity factor low | counts |
| ZHI | short | time, pulses, samples | radar reflectivity factor high | counts |
| ZCX | short | time, pulses, samples | crosspolar radar reflectivity factor | counts |

| | | | | |
|---|---|---|---|---|
| ITX | short | time, pulses, samples | TX I channel | counts |
| QTX | short | time, pulses, samples | TX Q channel | counts |
| IRX | short | time, pulses, samples | RX I channel | counts |
| QRX | short | time, pulses, samples | RX Q channel | counts |
| SPR | short | time, pulses, samples | Spare channel | counts |

**Global attributes:**

| Name | Example |
|---|---|
| radar | CAMRa |
| source | 3-GHz Advanced Meteorological Radar (CAMRa) |
| history | Tue Sep 22 14:58:06 2020 - /usr/local/bin/radar-camra-rec \<br>-fix 3600 115 90 -gates 5 201 -cellsize 1 -pulse_pairs 3050 -op rad \<br>-id 0 -file 8030 -scan 7530 -date 20200922145806 -tsdump -tssamples 200 |
| file_number | 8030 |
| scan_number | 7530 |
| scantype | Fixed |
| experiment_id | 0 |
| operator | rad |
| scan_velocity | 0.f |
| min_range | -526.7335f |
| max_range | 14088.15f |
| min_angle | 90.f |
| max_angle | 90.f |
| scan_angle | 25.f |
| scan_datetime | 20200922145806 |
| ADC_bits_per_sample | 12 |
| samples_per_pulse | 196 |
| pulses_per_daq_cycle | 6100 |
| ADC_channels | 8 |
| delay_clocks | 8 |
| pulses_per_ray | 6100 |
| pulse_compression | 0 |
| extra_attenuation | 0.f |
| radar_constant | 64.7f |
| receiver_gain | 45.5f |

| | |
|---|---|
| cable_losses | 4.8f |
| year | 2020 |
| month | 9 |
| day | 22 |
| British_National_Grid_Reference | SU394386 |

# Level 0b files

## 3GHz CAMRa time-series files

Level 0.5 files have been processed to remove redundant dimensions, and to make some changes to global attributes and variables. The files are in NetCDF-4 format with the following content:

**Dimensions:**

| Name |
|---|
| time |
| range |
| pulses |

**Scalar Variables:**

| Name | Data type | Dimension | Long name | Units |
|---|---|---|---|---|
| latitude | float32 | none | latitude of the antenna | degree_north |
| longitude | float32 | none | longitude of the antenna | degree_east |
| altitude | float32 | none | altitude of the elevation axis above mean sea level (Ordnance Survey Great Britain) | m |
| frequency | float32 | none | frequency of transmitted radiation | GHz |
| prf | float32 | none | pulse repetition frequency | Hz |
| beamwidthH | float32 | none | horizontal angular beamwidth | degree |
| beamwidthV | float32 | none | vertical angular beamwidth | degree |
| antenna_diameter | float32 | none | antenna diameter | m |
| pulse_width | float32 | none | pulse width | us |
| transmit_power | float32 | none | peak transmitted power | W |
| clock | float32 | none | clock input to ISACTRL | Hz |
| samples_per_pulse | int | none | number of samples per pulse | 1 |
| pulses_per_daq_cycle | int | none | number of pulses per data acquisition cycle | 1 |

| | | | | |
|---|---|---|---|---|
| pulses_per_ray | int | none | number of pulses per ray | 1 |
| delay_clocks | int | none | clock cycles before sampling is initiated | 1 |
| radar_constant | float32 | none | radar constant | dB |
| receiver_gain | float32 | none | receiver gain | dB |
| cable_losses | float32 | none | cable losses | dB |
| extra_attenuation | float32 | none | extra attenuation introduced to receiver chain | dB |

**Coordinate Variables:**

**Field Variables**

| Name | Date type | Dimensions | Long name | Units |
|---|---|---|---|---|
| ZLO | short | time, pulses, range | radar equivalent reflectivity factor low | dBZ |
| ZHI | short | time, pulses, range | radar equivalent reflectivity factor high | dBZ |
| ZCX | short | time, pulses, range | crosspolar radar equivalent reflectivity factor | dB |
| ITX | short | time, pulses, range | in-phase video signal on transmission | 1 |
| QTX | short | time, pulses, range | quadrature video signal on transmission | 1 |
| IRX | short | time, pulses, range | in-phase video signal on reception | 1 |
| QRX | short | time, pulses, range | quadrature video signal on reception | 1 |

Field variables are stored in packed form of type `short` and have the following attributes:

| Attribute name** | Type* |
|---|---|
| scale_factor | float32 |
| add_offset | float32 |
| valid_min | short |
| valid_max | short |
| _FillValue | short |

For example for `ZLO` the packed values derive from the analogue to digital converter, and lie in the range `[0,4095]`. The attribute `valid_max` is set to `3840`, and only values below this threshold should be used.

Similarly `ZHI` has the attribute `valid_min` set to `3841`, and only values above this should be used.

.ZLO_min = -70.0, /* dB / *200 .ZLO_scale = 0.015625,* / dB/count / *201 .ZHI_min = -38.0,* / dB / *202 .ZHI_scale = 0.015625,* / dB/count / *203 .ZCX_min = -77.0,* / dB / *204 .ZCX_scale = 0.03125,* / dB/count / *205 .ZLO_thresh = 3840,* / 0x0F00 / / counts / *206 .Bias = 2047,* / 0x07FF / / counts / *207 .ADCBits = 12* / Bits */

**Global attributes:**

**Variables (CHM15K specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|

**Variables (CL51 specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| laser_energy | float32 | time | Laser pulse energy | % |
| detection_status | float32 | time | Detection status | |
| range_resolution | float32 | | Range resolution | m |
| background_light | float32 | time | Background light | mV |
| message_number | float32 | | Message number | |
| warning_flags | float32 | time | Warning flags | |
| scale | float32 | | Scale | % |
| unit_id | float32 | | Ceilometer unit number | |
| window_transmission | float32 | | Window transmission estimate | % |
| message_subclass | float32 | | Message subclass number | |
| backscatter_sum | float32 | time | Sum of detected and normalized backscatter | sr-1 |
| software_level | float32 | | Software level ID | |
| laser_temperature | float32 | time | Laser temperature | C |
| number_of_gates | float32 | | Number of range gates in profile | |

## Model file

**Dimensions:**

| Name |
|---|
| time |
| level |
| flux_level |
| frequency |
| soil_level |

**Variables (all models):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| specific_liquid_atten | float32 | frequency, time, level | Specific one-way attenuation due to liquid water, per unit liquid wat | (dB km-1)/(g m-3) |
| sfc_pressure | float32 | time | Surface pressure | Pa |
| qi | float32 | time, level | Gridbox-mean ice water mixing ratio | 1 |
| q | float32 | time, level | Specific humidity | 1 |
| sfc_wind_u_10m | float32 | time | Zonal wind at 10m | m s-1 |

| | | | | |
|---|---|---|---|---|
| sfc_wind_v_10m | float32 | time | Meridional wind at 10m | m s-1 |
| ql | float32 | time, level | Gridbox-mean liquid water mixing ratio | 1 |
| sfc_net_lw | float32 | time | Surface net downward longwave flux | W m-2 |
| K2 | float32 | frequency, time, level | Dielectric parameter (K^2) of liquid water | dB km-1 |
| time | float32 | time | Hours UTC | hours since 2021-06-21 00:00:00 +00:00 |
| uwind | float32 | time, level | Zonal wind | m s-1 |
| specific_gas_atten | float32 | frequency, time, level | Specific one-way attenuation due to atmospheric gases | dB km-1 |
| flx_height | float32 | time, flux_level | Height above ground | m |
| gas_atten | float32 | frequency, time, level | Two-way attenuation from the ground due to atmospheric gases | dB |
| sfc_down_sens_heat_flx | float32 | time | Sensible heat flux | W m-2 |
| horizontal_resolution | float32 | | Horizontal resolution of model | km |
| rh | float32 | time, level | Relative humidity | 1 |
| specific_saturated_gas_atten | float32 | frequency, time, level | Specific one-way attenuation due to atmospheric gases for saturated a | dB km-1 |
| wwind | float32 | time, level | Vertical wind | m s-1 |
| sfc_ls_rain | float32 | time | Large-scale rainfall amount | kg m-2 |
| specific_dry_gas_atten | float32 | frequency, time, level | Specific one-way attenuation due to atmospheric gases for dry air (no | dB km-1 |
| frequency | float32 | frequency | Microwave frequency | GHz |
| sfc_ls_snow | float32 | time | Large-scale snowfall amount | kg m-2 |
| cloud_fraction | float32 | time, level | Cloud fraction | 1 |
| pressure | float32 | time, level | Pressure | Pa |
| sfc_net_sw | float32 | time | Surface net downward shortwave flux | W m-2 |
| vwind | float32 | time, level | Meridional wind | m s-1 |
| temperature | float32 | time, level | Temperature | K |
| latitude | float32 | | Latitude of model gridpoint | degrees_N |
| sfc_down_lat_heat_flx | float32 | time | Latent heat flux | W m-2 |
| longitude | float32 | | Longitude of model gridpoint | degrees_E |
| height | float32 | time, level | Height above ground | m |
| forecast_time | float32 | time | Time since initialization of forecast | hours |

**Variables (HARMONIE-FMI-6-11 specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| sfc_down_sw_direct | float32 | time | Direct downwelling shortwave flux | W m-2 |

| | | | | |
|---|---|---|---|---|
| qs | float32 | time, level | Gridbox-mean snow mixing ratio | 1 |
| qg | float32 | time, level | Gridbox-mean graupel mixing ratio | 1 |
| conv_cloud_fraction | float32 | time, level | Convective cloud fraction | 1 |
| ls_cloud_fraction | float32 | time, level | Large scale cloud fraction | 1 |
| sfc_total_cloud_fraction | float32 | time | Surface total cloud fraction | 1 |
| sfc_turb_mom_u | float32 | time | Surface zonal turbulent momentum flux | kg m-2 s-1 |
| soil_depth | float32 | time, soil_level | Depth below ground | m |
| qr | float32 | time, level | Gridbox-mean rain mixing ratio | 1 |
| sfc_temp | float32 | time | Surface temperature | K |
| tke | float32 | time, level | Turbulent kinetic energy | J m-2 |
| sfc_ls_graupel | float32 | time | Large-scale graupel amount | kg m-2 |
| sfc_down_lw | float32 | time | Surface downwelling longwave flux | W m-2 |
| omega | float32 | time, level | Vertical wind in pressure coordinates | Pa s-1 |
| sfc_turb_mom_v | float32 | time | Surface meridional turbulent momentum flux | kg m-2 s-1 |
| sfc_down_sw | float32 | time | Surface downwelling shortwave flux | W m-2 |
| sfc_pressure_amsl | float32 | time | Surface pressure at mean sea level | Pa |
| sfc_down_sw_direct_normal | float32 | time | Direct normal downwelling shortwave flux | W m-2 |
| sfc_rh_2m | float32 | time | Relative humidity at 2m | 1 |

**Variables (ICON-IGLO-12-23 specific):**

| **Name** | **Data type** | **Dimension** | **Long name** | **Unit** |
|---|---|---|---|---|
| ql_diag | float32 | time, level | Total specific liquid water (diagnostic) | 1 |
| sfc_down_sw_direct | float32 | time | Direct downwelling shortwave flux | W m-2 |
| conv_cloud_fraction | float32 | time, level | Convective cloud fraction | 1 |
| ls_cloud_fraction | float32 | time, level | Large scale cloud fraction | 1 |
| toa_net_sw | float32 | time | Top of atmosphere net downward shortwave flux | W m-2 |
| sfc_cloud_fraction | float32 | time | Surface total cloud fraction | 1 |
| soil_depth | float32 | time, soil_level | Depth below ground | m |
| qr | float32 | time, level | Gridbox-mean rain mixing ratio | 1 |
| sfc_turb_mom_v | float32 | time | Surface meridional turbulent momentum flux | kg m-2 s-1 |

| | | | | |
|---|---|---|---|---|
| altitude | float32 | | Height of station above mean sea level | m |
| q_diag | float32 | time, level | Total specific humidity (diagnostic) | 1 |
| turb_heat_coeff | float32 | time, flux_level | Turbulent diffusion coefficients for heat | m2 s-1 |
| soil_temperature | float32 | time, soil_level | Soil temperature | K |
| sfc_wind_gust_10m | float32 | time | Wind gust at 10m | m s-1 |
| qs | float32 | time, level | Gridbox-mean snow mixing ratio | 1 |
| sfc_turb_mom_u | float32 | time | Surface zonal turbulent momentum flux | kg m-2 s-1 |
| sfc_conv_snow | float32 | time | Convective snowfall amount | kg m-2 |
| turb_mom_coeff | float32 | time, flux_level | Turbulent diffusion coefficients for momentum | m2 s-1 |
| sfc_temp | float32 | time | Surface temperature | K |
| sfc_q_2m | float32 | time | Specific humidity at 2m | 1 |
| sfc_up_sw_diffuse | float32 | time | Diffuse upwelling shortwave flux | W m-2 |
| sfc_roughness_length | float32 | time | Surface roughness length | m |
| sfc_dewpoint_temp_2m | float32 | time | Dew point temperature at 2m | K |
| sfc_conv_rain | float32 | time | Convective rainfall amount | kg m-2 |
| sfc_temp_2m | float32 | time | Temperature at 2m | K |
| toa_net_lw | float32 | time | Top of atmosphere net downward longwave flux | W m-2 |
| qi_diag | float32 | time, level | Total specific ice water (diagnostic) | 1 |
| sfc_albedo | float32 | time | Surface albedo | 1 |
| sfc_land_cover | float32 | time | Land cover | 1 |
| sfc_height_amsl | float32 | time | Surface height above mean sea level | m |
| sfc_down_sw_diffuse | float32 | time | Diffuse downwelling shortwave flux | W m-2 |

**Variables (ECMWF specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| sfc_cloud_fraction | float32 | time | Surface total cloud fraction | 1 |
| sfc_conv_snow | float32 | time | Convective snowfall amount | kg m-2 |
| sfc_bl_height | float32 | time | Boundary layer height | m |
| sfc_geopotential | float32 | time | Geopotential | m2 s-2 |
| omega | float32 | time, level | Vertical wind in pressure coordinates | Pa s-1 |
| sfc_conv_rain | float32 | time | Convective rainfall amount | kg m-2 |
| sfc_temp_2m | float32 | time | Temperature at 2m | K |
| sfc_down_sw | float32 | time | Surface downwelling shortwave flux | W m-2 |

| | | | | |
|---|---|---|---|---|
| sfc_ls_precip_fraction | float32 | time | Large-scale precipitation fraction | 1 |

## Mwr file

**Dimensions:**

| Name |
|---|
| time |

**Variables (all mwrs):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| LWP | float32 | time | Liquid water path | g m-2 |
| time | int32 | time | Time UTC | seconds since 2001-01-01 00:00:00 |

## Radar file

**Dimensions:**

| Name |
|---|
| time |
| range |
| chirp_sequence |

**Variables (all radars):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| v | float32 | time, range | Doppler velocity | m s-1 |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |
| latitude | float32 | | Latitude of site | degrees_north |
| altitude | int32 | | Altitude of site | m |
| Ze | float32 | time, range | Radar reflectivity factor. | dBZ |
| longitude | float32 | | Longitude of site | degrees_east |
| height | float32 | range | Height above mean sea level | m |
| nyquist_velocity | float32 | chirp_sequence | Nyquist velocity | m s-1 |
| radar_frequency | float32 | | Radar transmit frequency | GHz |
| range | float32 | range | Range from instrument | m |

**Variables (RPG-FMCW-94 specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| voltage | float32 | time | Voltage | V |
| time_ms | int32 | time | Time ms | ms |
| pc_temperature | float32 | time | PC temperature | K |

| | | | | |
|---|---|---|---|---|
| azimuth | float32 | time | Azimuth angle | degrees |
| status_flag | float32 | time | Status flag for heater and blower | |
| brightness_temperature | float32 | time | Brightness temperature | K |
| if_power | float32 | time | IF power at ACD | uW |
| quality_flag | int32 | time | Quality flag | |
| antenna_separation | float32 | | Antenna separation | m |
| antenna_gain | float32 | | Antenna gain | dB |
| program_number | int32 | | Program number | |
| model_number | int32 | | Model number | |
| sample_duration | float32 | | Sample duration | s |
| range_resolution | float32 | chirp_sequence | Vertical resolution of range | m |
| dual_polarization | int32 | | Dual polarisation type | |
| chirp_start_indices | int32 | chirp_sequence | Chirp sequences start indices | |
| elevation | float32 | time | Elevation angle above horizon | degrees |
| noise_threshold | float32 | | Noise filter threshold factor | |
| wind_direction | float32 | time | Wind direction | degrees |
| FFT_window | int32 | | FFT window type | |
| width | float32 | time, range | Spectral width | m s-1 |
| transmitted_power | float32 | time | Transmitted power | W |
| transmitter_temperature | float32 | time | Transmitter temperature | K |
| number_of_spectral_samples | int32 | chirp_sequence | Number of spectral samples in each chirp sequence | |
| file_code | int32 | | File code | |
| pressure | float32 | time | Pressure | Pa |
| receiver_temperature | float32 | time | Receiver temperature | K |
| input_voltage_range | int32 | | ADC input voltage range (+/-) | mV |
| lwp | float32 | time | Liquid water path | |
| temperature | float32 | time | Temperature | K |
| wind_speed | float32 | time | Wind speed | m s-1 |
| calibration_interval | int32 | | Calibration interval in samples | |
| integration_time | float32 | chirp_sequence | Integration time | s |

| | | | | |
|---|---|---|---|---|
| antenna_diameter | float32 | | Antenna diameter | m |
| skewness | float32 | time, range | Skewness of spectra | |
| half_power_beam_width | float32 | | Half power beam width | degrees |
| number_of_averaged_chirps | int32 | chirp_sequence | Number of averaged chirps in sequence | |
| rain_rate | float32 | time | Rain rate | mm h-1 |

**Variables (BASTA specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|

**Variables (MIRA specific):**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| nfft | int32 | | Number of FFT Points | count |
| zrg | int32 | | Number of Range Gates | count |
| width | float32 | time, range | Spectral width | m s-1 |
| SNR | float32 | time, range | Signal-to-noise ratio | dB |
| ldr | float32 | time, range | Linear depolarisation ratio | dB |
| rg0 | int32 | | Number of Lowest Range Gates | count |
| prf | int32 | | Pulse Repetition Frequency | Hz |
| nave | int32 | | Number of Spectral Avreages | count |

# Level 1c files

## Categorize file

**Dimensions:**

| Name |
|---|
| time |
| height |
| model_time |
| model_height |

**Variables:**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| category_bits | int32 | time, height | Target categorization bits | |
| Z_error | float32 | time, height | Error in radar reflectivity factor | dB |
| q | float32 | model_time, model_height | Specific humidity | 1 |
| Tw | float32 | time, height | Wet-bulb temperature | K |

| | | | | |
|---|---|---|---|---|
| model_height | float32 | model_height | Height of model variables above mean sea level | m |
| insect_prob | float32 | time, height | Insect probability | |
| is_undetected_melting | int32 | time | Presence of undetected melting layer | |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |
| uwind | float32 | model_time, model_height | Zonal wind | m s-1 |
| Z | float32 | time, height | Radar reflectivity factor | dBZ |
| beta_error | float32 | | Error in attenuated backscatter coefficient | dB |
| is_rain | int32 | time | Presence of rain | |
| beta | float32 | time, height | Attenuated backscatter coefficient | sr-1 m-1 |
| lwp_error | float32 | time | Error in liquid water path | g m-2 |
| Z_sensitivity | float32 | height | Minimum detectable radar reflectivity | dBZ |
| beta_bias | int32 | | Bias in attenuated backscatter coefficient | dB |
| radar_liquid_atten | float32 | time, height | Approximate two-way radar attenuation due to liquid water | dB |
| lidar_wavelength | float32 | | Laser wavelength | nm |
| pressure | float32 | model_time, model_height | Pressure | Pa |
| lwp | float32 | time | Liquid water path | g m-2 |
| v | float32 | time, height | Doppler velocity | m s-1 |
| v_sigma | float32 | time, height | Standard deviation of mean Doppler velocity | m s-1 |
| vwind | float32 | model_time, model_height | Meridional wind | m s-1 |
| temperature | float32 | model_time, model_height | Temperature | K |
| latitude | float32 | | Latitude of site | degrees_north |
| altitude | int32 | | Altitude of site | m |
| model_time | float32 | model_time | Model time UTC | decimal hours since midnight |
| Z_bias | int32 | | Bias in radar reflectivity factor | dB |
| longitude | float32 | | Longitude of site | degrees_east |
| radar_gas_atten | float32 | time, height | Two-way radar attenuation due to atmospheric gases | dB |
| quality_bits | int32 | time, height | Data quality bits | |
| height | float32 | height | Height above mean sea level | m |
| radar_frequency | float32 | | Radar transmit frequency | GHz |

# Level 2 files

## Classification file

**Dimensions:**

| Name |
|---|
| time |
| height |

**Variables:**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| cloud_top_height_amsl | float32 | time | Height of cloud top above mean sea level | m |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |
| detection_status | int32 | time, height | Radar and lidar detection status | |
| latitude | float32 | | Latitude of site | degrees_north |
| altitude | int32 | | Altitude of site | m |
| cloud_base_height_amsl | float32 | time | Height of cloud base above mean sea level | m |
| longitude | float32 | | Longitude of site | degrees_east |
| target_classification | int32 | time, height | Target classification | |
| height | float32 | height | Height above mean sea level | m |
| cloud_base_height_agl | float32 | time | Height of cloud base above ground level | m |
| cloud_top_height_agl | float32 | time | Height of cloud top above ground level | m |

## Drizzle file

**Dimensions:**

| Name |
|---|
| time |
| height |

**Variables:**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| drizzle_lwf_error | float32 | time, height | Random error in drizzle liquid water flux | dB |
| drizzle_lwf_bias | float32 | | Possible bias in drizzle liquid water flux | dB |
| drizzle_lwc_bias | float32 | | Possible bias in drizzle liquid water content | dB |
| Do_error | float32 | time, height | Random error in drizzle median diameter | dB |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |

| | | | | |
|---|---|---|---|---|
| drizzle_N | float32 | time, height | Drizzle number concentration | m-3 |
| Do | float32 | time, height | Drizzle median diameter | m |
| drizzle_N_error | float32 | time, height | Random error in drizzle number concentration | dB |
| beta_corr | float32 | time, height | Lidar backscatter correction factor | |
| drizzle_lwc_error | float32 | time, height | Random error in drizzle liquid water content | dB |
| v_drizzle | float32 | time, height | Drizzle droplet fall velocity | m s-1 |
| mu_error | float32 | | Random error in drizzle droplet size distribution shape parameter | dB |
| S | float32 | time, height | Lidar backscatter-to-extinction ratio | |
| drizzle_lwc | float32 | time, height | Drizzle liquid water content | kg m-3 |
| Do_bias | float32 | | Possible bias in drizzle median diameter | dB |
| v_air | float32 | time, height | Vertical air velocity | m s-1 |
| mu | float32 | time, height | Drizzle droplet size distribution shape parameter | |
| latitude | float32 | | Latitude of site | degrees_north |
| drizzle_lwf | float32 | time, height | Drizzle liquid water flux | kg m-2 s-1 |
| altitude | int32 | | Altitude of site | m |
| drizzle_retrieval_status | int32 | time, height | Drizzle parameter retrieval status | |
| longitude | float32 | | Longitude of site | degrees_east |
| S_error | float32 | time, height | Random error in lidar backscatter-to-extinction ratio | dB |
| v_drizzle_error | float32 | time, height | Random error in drizzle droplet fall velocity | dB |
| height | float32 | height | Height above mean sea level | m |

## Iwc file

**Dimensions:**

| Name |
|---|
| time |
| height |

**Variables:**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| iwc_inc_rain | float32 | time, height | Ice water content including rain | kg m-3 |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |
| latitude | float32 | | Latitude of site | degrees_north |
| altitude | int32 | | Altitude of site | m |
| iwc | float32 | time, height | Ice water content | kg m-3 |
| iwc_bias | float32 | | Possible bias in ice water content, one standard deviation | dB |

| | | | | |
|---|---|---|---|---|
| longitude | float32 | | Longitude of site | degrees_east |
| iwc_retrieval_status | int32 | time, height | Ice water content retrieval status | |
| iwc_sensitivity | float32 | height | Minimum detectable ice water content | kg m-3 |
| height | float32 | height | Height above mean sea level | m |
| iwc_error | float32 | time, height | Random error in ice water content, one standard deviation | dB |

### Lwc file

**Dimensions:**

| Name |
|---|
| time |
| height |

**Variables:**

| Name | Data type | Dimension | Long name | Unit |
|---|---|---|---|---|
| lwp_error | float32 | time | Error in liquid water path | g m-2 |
| time | float32 | time | Time UTC | hours since 2021-06-21 00:00:00 |
| latitude | float32 | | Latitude of site | degrees_north |
| altitude | int32 | | Altitude of site | m |
| longitude | float32 | | Longitude of site | degrees_east |
| lwc_retrieval_status | int32 | time, height | Liquid water content retrieval status | |
| lwc_error | float32 | time, height | Random error in liquid water content, one standard deviation | dB |
| lwc | float32 | time, height | Liquid water content | kg m-3 |
| height | float32 | height | Height above mean sea level | m |
| lwp | float32 | time | Liquid water path | g m-2 |

# Developer's Guide

CloudnetPy is hosted by Finnish Meteorological Institute (FMI) and will be used to process cloud remote sensing data in the ACTRIS research infrastructure. We are happy to welcome the cloud remote sensing community to provide improvements in the methods and their implementations, writing tests and fixing bugs.

## How to contribute

Instructions can be found from CloudnetPy's Github page.

## Testing

To run the CloudnetPy test suite, first clone the whole repository from GitHub:

```
$ git clone https://github.com/actris-cloudnet/cloudnetpy
```

### Testing environment

Now, create a virtual environment and install pytest and CloudnetPy:

```
$ cd cloudnetpy
$ python3 -m venv venv
$ source venv/bin/activate
(venv) $ pip3 install pytest .
```

### Unit tests

```
(venv) $ pytest
```

### End-to-end test

```
(venv) $ python3 tetsts/e2e_test.py
```

#### Note

Cloudnetpy performs relatively complicated scientific processing, converting noisy measurement data into higher level products. Most of the Cloudnetpy's low-level functions are unit tested, but it is difficult to write unambiguous tests for the high-level API calls. However, the quality of the processed files can be at least roughly checked using CloudnetPy's quality control functions.

## Coding guidelines

- Use PEP8 standard.
- Write Google-style docstrings.
- Check your code using, e.g., Pylint.

# Indices and tables

- **genindex**
- **modindex**
- **search**