Release Notes for Version 1.0 of the WegenerNet 3D Observing System L1 and L2 Data Products

WegenerNet Technical Report No. 1/2024

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December 2024

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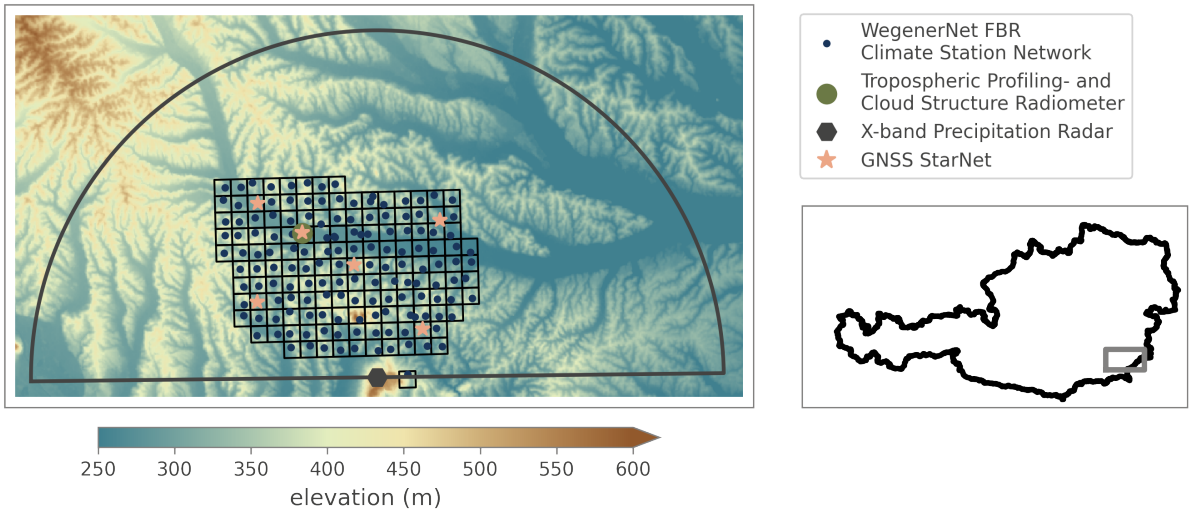

Figure 1: WegenerNet Open-Air Laboratory for Climate Change Research Feldbach Region sensor locations and data coverage.

1. Version Overview

This document describes the first data release (v1.0) of the WegenerNet 3D Observing System (WEGN3D) data cubes generated in the WegenerNet Open-Air Laboratory Feldbach Region (WEGN-OAL). WEGN3D v1.0 is an observational data collection, aimed at studying weather extremes in a changing climate, water vapor - cloud - precipitation interactions, and in combination with the WegenerNet Climate Station Network Feldbach Region (FBR) also interactions between the surface and upper atmosphere. It is not assimilated into reanalyses, climate models or Numerical Weather Prediction Models (NWPs) thus serving as an independent data collection for evaluation and validation of such models at high spatial and temporal resolution.

The measurement facilities of the WegenerNet 3D Open-Air Laboratory for Climate Change Research are complementary to those of the WegenerNet Climate Station Network Feldbach Region. These facilities provide atmospheric sounding capabilities at high spatiotemporal resolution, which form the basis of the WEGN3D data cubes. The sensor infrastructure comprises an X-band polarimetric precipitation radar, a six-station Global Navigation Satellite System (GNSS) network denoted GNSS StarNet processed by the German Research Centre for Geosciences (GFZ), a microwave tropospheric profiling radiometer, and a cloud structure infrared radiometer. The aforementioned sensors enable the continuous observation of a range of atmospheric variables related to precipitation, water vapor, and cloud characteristics. Sensor types and locations can be found in Table 1 while Figure 1 provides an overview map of the sensor station locations and data coverage.

All data products are generated by the WegenerNet 3D Processing System (WPS3D) version 1.0 (WPS3D v1.0). The following software and input data version were used in the generation of this data collection:

WPS3D version:	1.0	
Level 1 Data Version:	1.0	DOI: 10.25364/WEGC/WPS3D-L1B-10
Level 2 Data Version:	1.0	DOI: 10.25364/WEGC/WPS3D-L2-10
CF Conventions:	1.7	

Table 1: Sensor types and locations of the WegenerNet 3D Open-Air Laboratory infrastructure.

Sensor	Type	Location Lon. (E), Lat. (N)	Station no.
Tropospheric Profiling Radiometer	RPG HATPRO G5[a]	15° 50' 54.96", 46° 57' 29.52"	R171
Cloud Structure Radiometer	NubiScope[b]	15° 50' 54.96", 46° 57' 29.52"	R171
GNSS StarNet	Septentrio PolaRx5[c]	used at all StarNet stations	
	PolaNt Choke Ring[d]	15° 50' 55.32", 46° 57' 29.88"	W181/R171
	PolaNt-x MF[e]	15° 54' 25.56", 46° 55' 58.80"	W182
	PolaNt-x MF	15° 47' 52.80", 46° 58' 52.68"	W183
	PolaNt-x MF	16° 0' 18.36", 46° 58' 0.12"	W184
	PolaNt-x MF	15° 47' 48.48", 46° 54' 17.28"	W185
	PolaNt-x MF	15° 59' 2.49", 46° 52' 55.92"	W186
X-band Radar	FURUNO WR2120[f]	15° 55' 55.39", 46° 50' 43.03"	X201

[a] https://www.radiometer-physics.de/download/PDF/Radiometers/HATPRO/RPG_MWR_PRO-G5_TN2022.pdf, last accessed 2024-12-08
[b] http://nubiscope.eu/, last accessed 2024-12-08
[c] https://www.septentrio.com/en/products/gnss-receivers/gnss-reference-receivers/polarx-5, last accessed 2024-12-08
[d] https://www.septentrio.com/en/products/antennas/polant-chokering, last accessed 2024-12-08
[e] https://www.septentrio.com/en/products/antennas/polant-x-mf, last accessed 2024-12-08
[f] https://www.furuno.com/files/Brochure/456/upload/WR2120_en_1911.pdf, last accessed 2024-12-08

Processing details for each individual data product can be found in the corresponding Algorithm Theoretical Basis Document (ATBD) [1].

1.1. Processing Levels and Data Product Domains

The WEGN3D data collections are organized into processing levels, data products, and data product subgroups. The processing levels span from raw data (Level 0) to geolocated and gap-filled data cubes (Level 2). The following list provides a detailed description and definition of each processing level.

- **Level 0 data (L0)** are unchecked raw data in their native file formats, which are produced by the sensor software, data loggers, or are obtained from external sources. No post-processing steps or quality checks are applied to L0 data, thus they are retained in the state in which they are retrieved from the different instruments. Consequently, time resolution or reference frame definitions are not consolidated and are expected to differ.

  Due to the considerable data volume, L0 data are made available upon request only.

- **Level 1a data (L1a)** are unchecked raw data in a consolidated file format, that retains native space- and time resolutions.

  Measured quantities are renamed to common variable definitions as specified in the WEGN3D data model, and their units are adapted accordingly. No destructive processing (e.g., ag-

[1] https://wegenernet.org/downloads/Kvas_et_al_2024_WEGN3D_v1_ATBD-WEGN-TR-2-2024.pdf

Table 2: Data products and product subgroups for L1b collections.

Data Product	Sensor Type	Subgroup	Domain
MWR	Microwave Radiometer	TimeSeries Profiles SkyMaps	1-d time series 2-d time/altitude vertical profiles 3-d time/elevation/azimuth all-sky maps
IRR	Infrared Radiometer	TimeSeries SkyMaps	1-d time series 3-d time/elevation/azimuth all-sky maps
GNSS	GNSS StarNet	TimeSeries SlantDelay	1-d time series 2-d time/satellite data cubes
PrecipRadar	Precipitation Radar	Sweeps	4-d time/elevation/azimuth/range data cubes

gregating or averaging) is applied in the generation of L1a data, except for dropping incomplete or malformed input files. As a consequence, L0 and L1a data share the same information content. L1a product files are stored in NetCDF format following the WEGN3D data model. Due to the data volume, L1a data are made available upon request only.

- **Level 1b data (L1b)** are resampled and/or aggregated to even time stamps in UTC in the product target resolution.

  L1b data products are grouped by sensor type and given in (local) sensor reference frames. Data variables are renamed to the WEGN3D variable definitions, and units are adapted accordingly. Furthermore, the WegenerNet 3D Quality Control System (QCS3D) performs quality checks on the data, and flags indicating degraded data attached as metadata and are stored in NetCDF format with common metadata.

- **Level 2 data (L2)** are gap-filled and geolocated datasets given in well-defined spatiotemporal reference frames.

  Degraded data indicated by the respective quality flags are discarded and resulting gaps in space and time are filled by interpolation where possible. Interpolated data is indicated by interpolation flags so they can be easily identified and removed should this be desired. L2 data are sensor agnostic and grouped by their spatiotemporal coverage, so no information about the underlying measurement system is required. They can be interpreted as the optimal observation of the respective physical variable from all available observations. L2 data products are typically multi-sensor products, where either multiple sensors observing the same physical quantity are merged or observations of different sensors are used to derive new target variables.

Data products and data product subgroups are processing level specific and are outlined in the following sections for the publicly available processing levels L1b and L2. For L1b data, the data products are grouped by the underlying sensor type, whereas product subgroups represent the spatiotemporal domain in which the data product is given. A full list of data products and corresponding subgroups is given in Table 2. For L2 collections, the data product denotes the topical grouping of the data variables, the subgroup denotes the temporal resolution of the data product. For WEGN3D `v1.0`, only basis data (BD) with the highest common sampling rate are

Table 3: Data products and product subgroups for L2 collections.

Data Product	Subgroup	Domain
TimeSeries	Basis Data (BD)	1-d time series
TroposphericProfiles	Basis Data (BD)	2-d time/altitude vertical profiles
SkyMaps	Basis Data (BD)	3-d time/elevation/azimuth all-sky maps
Precipitation	Basis Data (BD)	4-d time/altitude/northing/easting data cubes
CloudStructure	Basis Data (BD)	4-d time/altitude/northing/easting data cubes

Table 4: Description of common data product metadata fields.

Field Name	Description
Conventions	CF convention version
title	generalized name of the data product
institution	name of the data generating institution
contact	data provider contact information
level1DataVersion	L1b data product version used in data product
level2DataVersion	L2 data product version used in data product
description	specific data product description
source	data generating software
version	version of the generating software
history	data generation software and time stamp
filestamp	filename of the data product

available. Table 3 lists all available L2 data collections and their domain. Processing level, data product, subgroup, and version uniquely define the corresponding dataset. For L1b and L2 this mapping is given by:

L1b WN3D_L1b_<version_string>_<data_product>_<subgroup>

Example: WN3D_L1b_v1_IRR_TimeSeries

Filename Template: WN3D_L1b_v1_IRR_TimeSeries_YYYY-MM-DD.nc

L2 WN3D_L2_<subgroup>_<version_string>_<data_product>

Example: WN3D_L2_BD_v1_Precipitation

Filename Template: WN3D_L2_BD_v1_Precipitation_YYYY-MM-DD.nc

It should be noted that <version_string> represents the mapping between the semantic version number and the corresponding filename compatible string as defined in the ATBD, section 2. Each publicly available data product is stored as daily NetCDF files conforming to CF standards. Irrespective of the processing level and data product, each generated file contains common metadata fields to allow for version traceability. The common metadata fields are all listed in Table 4.

1.2. Data Access

All data products are published under the CC BY 4.0 license[2] and are hosted on the WegenerNet Data Portal[3]. The WegenerNet Data Portal offers visualization tools of selected data products as well as a range of download options including manual subsetting, bulk downloads, and API (Application Programming Interface) endpoints.

1.3. Spatial Coverage and Coordinates

WegenerNet 3D Observing System data cubes are embedded within the WegenerNet Open Data and Science Laboratory Region Southeastern Austria (SEA). These data cubes are provided on grids which a) allow an SEA-compatible spatial aggregation to coarser resolutions and b) are a superset of the WegenerNet Climate Station Gridded Data Products version 8.0[4]. The WEGN3D base grid is defined in the Universal Transverse Mercator Projection, Zone 33N (UTM33N) projection with lower left cell coordinates of (539 750 m, 5 186 750 m), upper right cell coordinates of (602 650 m, 5 219 650 m), and a resolution of 100 m $\times$ 100 m. It should be noted that radar-derived precipitation data products are given on a coarsened grid with a resolution of 200 m $\times$ 200 m, and a lower left cell of (539 800 m, 5 186 800 m), and an upper right cell of (602 600 m, 5 219 600 m).

Height levels are defined relative to the mean sea level (AMSL, represented by the geoid) and reflect the required vertical resolution to resolve atmospheric processes, as well as the sensor resolution. The height levels used in WEGN3D v1.0 are listed in Table 5. Note that radar-derived

Table 5: WEGN3D `v1.0` height level definitions.

Interval (AMSL)	Resolution
320 m – 720 m	20 m
720 m – 2200 m	40 m
2200 m – 5000 m	100 m
5000 m – 10 200 m	200 m

precipitation data products use a subset of these height levels in order to more accurately reflect the vertical resolution and information content of the underlying radar observations, while simultaneously reducing the data product storage size.

[2] https://creativecommons.org/licenses/by/4.0/, last accessed 2024-12-08
[3] https://wegenernet.org/portal, last accessed 2024-12-08
[4] https://wegenernet.org/downloads/Fuchsberger-Kirchengast_2023_WPSv8_release_notes-WEGN-TR-1-2023.pdf

2. Data Product Description

2.1. Geolocated Atmospheric Data Products (L2)

2.1.1. WN3D_L2_BD_v1_TimeSeries

WN3D_L2_BD_v1_TimeSeries				
Variable Name	Dimensions	Data Type	Units	Description
iwv_zenith	('time', 'station_number')	float32	$kg\,m^{-2}$	Integrated Water Vapor in the Vertical Column in Zenith Direction
lwp_zenith	('time',)	float32	$kg\,m^{-2}$	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Zenith Direction
apd_h_zenith	('time', 'station_number')	float32	m	Hydrostatic Atmospheric Path Delay in Zenith Direction
k_index	('time',)	float32	K	K-Index for the Potential of Severe Convection
showalter_index	('time',)	float32	K	Showalter-Index for Convective and Thunderstorm Potential
cape_index	('time',)	float32	$J\,kg^{-1}$	Convective Available Potential Energy (CAPE)-Index
tt_index	('time',)	float32	K	Total-totals-Index for the Likelihood of Severe Convection
convective_index	('time',)	float32	K	Convective-Index for Thunderstorm Development
lifted_index	('time',)	float32	K	Lifted-Index for Atmospheric Instability
apd_nh_zenith	('time', 'station_number')	float32	m	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
lwc_maximum	('time',)	float32	$kg\,m^{-3}$	Cloud Liquid Water Content Maximum (LWCM) in Zenith Direction
H_bl	('time',)	float32	m	Thickness ("Height") of the Atmospheric Boundary Layer
T_br_zenith	('time', 'frequency')	float32	K	Measured Brightness Temperature in Zenith Direction
T_br_spectrum_zenith	('time', 'frequency')	float32	K	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
attn_zenith	('time', 'frequency')	float32	dB	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
T_ir_zenith_narrowband	('time',)	float32	K	Measured Infrared Brightness Temperature in Zenith Direction
iwv_zenith_interp_flag	('time', 'station_number')	uint8		Interpolation Flag for Variable iwv_zenith
lwp_zenith_interp_flag	('time',)	uint8		Interpolation Flag for Variable lwp_zenith
apd_h_zenith_interp_flag	('time', 'station_number')	uint8		Interpolation Flag for Variable apd_h_zenith
k_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable k_index
showalter_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable showalter_index
cape_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable cape_index
tt_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable tt_index
convective_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable convective_index
lifted_index_interp_flag	('time',)	uint8		Interpolation Flag for Variable lifted_index
apd_nh_zenith_interp_flag	('time', 'station_number')	uint8		Interpolation Flag for Variable apd_nh_zenith
lwc_maximum_interp_flag	('time',)	uint8		Interpolation Flag for Variable lwc_maximum
H_bl_interp_flag	('time',)	uint8		Interpolation Flag for Variable H_bl
T_br_zenith_interp_flag	('time', 'frequency')	uint8		Interpolation Flag for Variable T_br_zenith
T_br_spectrum_zenith_interp_flag	('time', 'frequency')	uint8		Interpolation Flag for Variable T_br_spectrum_zenith
attn_zenith_interp_flag	('time', 'frequency')	uint8		Interpolation Flag for Variable attn_zenith
T_ir_zenith_narrowband_interp_flag	('time',)	uint8		Interpolation Flag for Variable T_ir_zenith_narrowband
T_ir_zenith	('time',)	float32	K	Measured Infrared Brightness Temperature in Zenith Direction
T_ir_zenith_interp_flag	('time',)	uint8		Interpolation Flag for Variable T_ir_zenith
H_cb	('time',)	float32	m	Cloud Base Altitude (Height Above Sea Level) in Zenith Direction
H_cb_interp_flag	('time',)	uint8		Interpolation Flag for Variable H_cb
tropograd_tot_east	('time', 'station_number')	float32	m	Total Tropospheric (Atmospheric Path Delay) Gradient in East Direction
tropograd_tot_north	('time', 'station_number')	float32	m	Total Tropospheric (Atmospheric Path Delay) Gradient in North Direction
tropograd_tot_east_interp_flag	('time', 'station_number')	uint8		Interpolation Flag for Variable tropograd_tot_east
tropograd_tot_north_interp_flag	('time', 'station_number')	uint8		Interpolation Flag for Variable tropograd_tot_north
longitude	('station_number',)	float32	degrees_north	Long-term Station Position Average (Longitude)
latitude	('station_number',)	float32	degrees_east	Long-term Station Position Average (Latitude)
h_ell	('station_number',)	float32	m	Long-term Station Position Average (Ellipsoidal Height)
h_msl	('station_number',)	float32	m	Long-term Station Position Average (Height Above Sea Level)

WN3D_L2_BD_v1_TimeSeries is a merged data product of all L1b time series products, which are resampled to a common 10 min time series. A station_number variable is added to data variables observed at multiple locations. For each station, geographical coordinates (longitude, latitude, ellipsoidal height on the WGS84 ellipsoid) as well as height above sea level is added.

2.1.2. WN3D_L2_BD_v1_TroposphericProfiles

WN3D_L2_BD_v1_TroposphericProfiles				
Variable Name	Dimensions	Data Type	Units	Description
T_profile_cmp	('time', 'h_msl')	float32	K	Compound Temperature Profile merged from Boundary Layer- and Full Troposphere Temperature Profiles
RH_profile	('time', 'h_msl')	float32	%	Relative Humidity Profile
AH_profile	('time', 'h_msl')	float32	$kg\,m^{-3}$	Absolute Humidity Profile (Water Vapor Mass Density Profile)
P_profile	('time', 'h_msl')	float32	hPa	Air Pressure Profile Derived from Temperature and Relative Humidity Profiles
T_profile_cmp_interp_flag	('time', 'h_msl')	uint8		Interpolation Flag for Variable T_profile_cmp
RH_profile_interp_flag	('time', 'h_msl')	uint8		Interpolation Flag for Variable RH_profile
AH_profile_interp_flag	('time', 'h_msl')	uint8		Interpolation Flag for Variable AH_profile
P_profile_interp_flag	('time', 'h_msl')	uint8		Interpolation Flag for Variable P_profile

WN3D_L2_BD_v1_TroposphericProfiles is a geolocated (height above mean sea level) data product based on **WN3D_L1b_v1_MWR_Profiles**.

2.1.3. WN3D_L2_BD_v1_SkyMaps

WN3D_L2_BD_v1_SkyMaps				
Variable Name	Dimensions	Data Type	Units	Description
iwv	('time', 'elevation', 'azimuth')	float32	$kg\,m^{2}$	Integrated Water Vapor in Slant Direction
lwp	('time', 'elevation', 'azimuth')	float32	$kg\,m^{-2}$	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Slant Direction
T_br	('time', 'elevation', 'azimuth', 'frequency')	float32	K	Measured Brightness Temperature in Slant Direction
T_br_spectrum	('time', 'elevation', 'azimuth', 'frequency')	float32	K	Retrieved High-Resolution Brightness Temperature Spectrum
attn	('time', 'elevation', 'azimuth', 'frequency')	float32	dB	Atmospheric Attenuation
apd_h_slant	('time', 'elevation', 'azimuth')	float32	m	Hydrostatic Atmospheric Path Delay in Slant Direction
apd_nh_slant	('time', 'elevation', 'azimuth')	float32	m	Non-Hydrostatic Atmospheric Path Delay in Slant Direction
apd_tot_slant	('time', 'elevation', 'azimuth', 'station_number')	float32	m	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Slant Direction
T_ir_narrowband	('time', 'elevation', 'azimuth')	float32	K	Measured Infrared Brightness Temperature from All-Sky Scan
iwv_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable iwv
lwp_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable lwp
T_br_interp_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		Interpolation Flag for Variable T_br
T_br_spectrum_interp_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		Interpolation Flag for Variable T_br_spectrum
attn_interp_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		Interpolation Flag for Variable attn
apd_h_slant_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable apd_h_slant
apd_nh_slant_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable apd_nh_slant
apd_tot_slant_interp_flag	('time', 'elevation', 'azimuth', 'station_number')	uint8		Interpolation Flag for Variable apd_tot_slant
T_ir_narrowband_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable T_ir_narrowband
T_ir	('time', 'elevation', 'azimuth')	float32	K	Measured Infrared Brightness Temperature from All-Sky Scan
cloud_type	('time', 'elevation', 'azimuth')	float32		Indicator of Type of Cloud Coverage
T_ir_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable T_ir
cloud_type_interp_flag	('time', 'elevation', 'azimuth')	uint8		Interpolation Flag for Variable cloud_type
longitude	('station_number',)	float32	degrees_north	Long-term Station Position Average (Longitude)
latitude	('station_number',)	float32	degrees_east	Long-term Station Position Average (Latitude)
h_ell	('station_number',)	float32	m	Long-term Station Position Average (Ellipsoidal Height)
h_msl	('station_number',)	float32	m	Long-term Station Position Average (Height Above Sea Level)

WN3D_L2_BD_v1_SkyMaps is a merged data product of all L1b SkyMaps products and incorporates **WN3D_L1b_v1_GNSS_SlantDelay**, which are resampled and binned to a common 10 min time series and azimuth/elevation grid. Quantities observed at multiple spatial location are amended with a station_number variable for easy geolocation.

2.1.4. WN3D_L2_BD_v1_Precipitation

WN3D_L2_BD_v1_Precipitation				
Variable Name	Dimensions	Data Type	Units	Description
precip_amount	('time', 'h_msl', 'Y', 'X')	float32	mm	Radar-derived Precipitation Amount
Z_h_corr	('time', 'h_msl', 'Y', 'X')	float32	dBZ	Attenuation-Corrected Horizontal Reflectivity
signal_attenuation_flag	('time', 'h_msl', 'Y', 'X')	uint8		Flag Indicating Signal Extinction (Shadowing), Defined by Attenuation Correction Exceeding 20 dBZ
hydrometeor_type	('time', 'h_msl', 'Y', 'X')	float32		Hydrometeor Type After Zrnic et al. 2001 utilizing membership functions based on Straka et al. 2000 adapted for X-band by Evaristo et al. 2013
precipitation_type	('time', 'Y', 'X')	float32		Precipitation Classification According to Powell et al. 2016
crs	()	float32		Projection Parameters for EPSG:32633
hydrometer_type_interp_flag	('time',)	uint8		Interpolation Flag for Variable hydrometer_type
convective_precipitation_area_fraction	('time',)	float32	1	Area Fraction of Radar Observations Classified as convective_precipitation
light_rain_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as light_rain
light_rain_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable light_rain_area_fraction
moderate_rain_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as moderate_rain
moderate_rain_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable moderate_rain_area_fraction
heavy_rain_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as heavy_rain
heavy_rain_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable heavy_rain_area_fraction
large_drops_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as large_drops
large_drops_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable large_drops_area_fraction
hail_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as hail
hail_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable hail_area_fraction
rain_hail_mix_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as rain_hail_mix
rain_hail_mix_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable rain_hail_mix_area_fraction
graupel_hail_mix_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as graupel_hail_mix
graupel_hail_mix_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable graupel_hail_mix_area_fraction
dry_snow_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as dry_snow
dry_snow_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable dry_snow_area_fraction
wet_snow_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as wet_snow
wet_snow_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable wet_snow_area_fraction
horizontal_ice_crystals_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as horizontal_ice_crystals
horizontal_ice_crystals_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable horizontal_ice_crystals_area_fraction
vertical_ice_crystals_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as vertical_ice_crystals
vertical_ice_crystals_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable vertical_ice_crystals_area_fraction
no_precipitation_area_fraction	('time', 'h_msl')	float32	1	Area Fraction of Radar Observations Classified as no_precipitation
no_precipitation_area_fraction_interp_flag	('time',)	uint8		Interpolation Flag for Variable no_precipitation_area_fraction

The **WN3D_L2_BD_v1_Precipitation** data cubes represent geolocated radar volume scans. Derived added-value data variables such as hydrometeor_type and preciptation_type are also computed and incorporated into the data cube.

2.1.5. WN3D_L2_BD_v1_CloudStructure

WN3D_L2_BD_v1_CloudStructure				
Variable Name	Dimensions	Data Type	Units	Description
cloud_structure	('time', 'h_msl', 'Y', 'X')	float32		Cloud Binary Mask
H_cb	('time', 'Y', 'X')	float32	m	Cloud Base Altitude (Height Above Sea Level) in Zenith Direction
crs	()	float32		Projection Parameters for EPSG:32633
cloud_structure_interp_flag	('time',)	uint8		Interpolation Flag for Variable cloud_structure
H_cb_interp_flag	('time',)	uint8		Interpolation Flag for Variable H_cb

The **WN3D_L2_BD_v1_CloudStructure** makes use of infrared brightness temperatures, liquid water path retrievals, and tropospheric temperature profiles to generate a geolocated 3D cloud structure. By comparing infrared temperatures with air temperature profiles, the height of the

cloud base can be determined. Additionally exploiting the viewing geometry (i.e. the meaurement ray direction for each infrared brightness temperature measurement) makes it possible to also geolocate cloud pixels horizontally. From there, a 3D distribution of cloud base heights (cloud_structure) can be derived. This cloud_structure is then further used to generate a cloud base height map (H_cb) for the whole region.

2.2. Quality Controlled Observational Data (L1b)

2.2.1. WN3D_L1b_v1_GNSS_TimeSeries

WN3D_L1b_v1_GNSS_TimeSeries				
Variable Name	Dimensions	Data Type	Units	Long Name
iwv_zenith	('time', 'station_number')	float32	kg m^{-2}	Integrated Water Vapor in the Vertical Column in Zenith Direction
apd_h_zenith	('time', 'station_number')	float32	m	Hydrostatic Atmospheric Path Delay in Zenith Direction
apd_nh_zenith	('time', 'station_number')	float32	m	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
tropograd_tot_east	('time', 'station_number')	float32	m	Total Tropospheric (Atmospheric Path Delay) Gradient in East Direction
tropograd_tot_north	('time', 'station_number')	float32	m	Total Tropospheric (Atmospheric Path Delay) Gradient in North Direction
iwv_zenith_qcs_flag	('time', 'station_number')	uint8		QCS Flag (bitmask) for Variable iwv_zenith
apd_h_zenith_qcs_flag	('time', 'station_number')	uint8		QCS Flag (bitmask) for Variable apd_h_zenith
apd_nh_zenith_qcs_flag	('time', 'station_number')	uint8		QCS Flag (bitmask) for Variable apd_nh_zenith
tropograd_tot_east_qcs_flag	('time', 'station_number')	uint8		QCS Flag (bitmask) for Variable tropograd_tot_east
tropograd_tot_north_qcs_flag	('time', 'station_number')	uint8		QCS Flag (bitmask) for Variable tropograd_tot_north
longitude	('station_number',)	float32	degrees_north	Long-term Station Position Average (Longitude)
latitude	('station_number',)	float32	degrees_east	Long-term Station Position Average (Latitude)
h_ell	('station_number',)	float32	m	Long-term Station Position Average (Ellipsoidal Height)

The **WN3D_L1b_v1_GNSS_TimeSeries** data product contains all 1-d data variables, specifically time series, generated by the GNSS StarNet. This includes integrated water vapor within the atmospheric column above each GNSS station identified by station_number, in addition to hydrostatic and non-hydrostatic tropospheric path delay, and (total) tropospheric gradients, with a native time resolution of 15 minutes. The primary input to this data product are L0 TROPOSINEX files, computed by the German Research Centre for Geosciences (GFZ). The uncertainty information contained in the TROPOSINEX files is used as additional quality indicator and is employed to identify degraded sensors. Additionally, geographic coordinates (longitude, latitude, ellipsoidal height on the WGS84 ellipsoid) of the reference point of each station are also included to facilitate straightforward geolocation.

2.2.2. WN3D_L1b_v1_GNSS_SlantDelay

WN3D_L1b_v1_GNSS_SlantDelay				
Variable Name	Dimensions	Data Type	Units	Long Name
elevation	('time', 'station_number', 'satellite')	float32	degree	Elevation Angle of Measurement Ray, Counted Positive from Local Horizon
azimuth	('time', 'station_number', 'satellite')	float32	degree	Azimuth Angle of Measurement Ray, Counted Positive Clockwise
apd_tot_slant	('time', 'station_number', 'satellite')	float32	m	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Slant Direction
apd_tot_zenith	('time', 'station_number', 'satellite')	float32	m	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Zenith Direction
longitude	('station_number',)	float32	degrees_north	Long-term Station Position Average (Longitude)
latitude	('station_number',)	float32	degrees_east	Long-term Station Position Average (Latitude)
h_ell	('station_number',)	float32	m	Long-term Station Position Average (Ellipsoidal Height)
apd_tot_slant_qcs_flag	('time', 'station_number', 'satellite')	uint8		QCS Flag (bitmask) for Variable apd_tot_slant
apd_tot_zenith_qcs_flag	('time', 'station_number', 'satellite')	uint8		QCS Flag (bitmask) for Variable apd_tot_zenith

The **WN3D_L1b_v1_GNSS_SlantDelay** data product comprises 3-d data cubes (time, station_number, satellite) of total tropospheric slant delay as observed by the GNSS StarNet. Primary input to

this data product are L0 TROPOSINEX files, computed by the German Research Centre for Geosciences (GFZ), with a native time resolution of 2.5 minutes. The L0 TROPOSINEX files generated by GFZ utilize only GPS signals, thus the variable satellite refers to the GPS PRN code of the satellite. Next to the path delay between all observed station - satellite pairs, the directional unit vector given in elevation and azimuth is also contained in the dataset. Geographic coordinates (longitude, latitude, ellipsoidal height on the WGS84 ellipsoid) of the reference point of each station are also included to facilitate straightforward geolocation.

2.2.3. WN3D_L1b_v1_IRR_TimeSeries

WN3D_L1b_v1_IRR_TimeSeries				
Variable Name	Dimensions	Data Type	Units	Long Name
T_ir_zenith	('time',)	float32	K	Measured Infrared Brightness Temperature in Zenith Direction
cloud_binary_mask_zenith	('time',)	float32		Cloud Binary Mask in Zenith Direction
T_ir_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable T_ir_zenith
cloud_binary_mask_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable cloud_binary_mask_zenith

The **WN3D_L1b_v1_IRR_TimeSeries** data product contains 1-d (time series) of infrared brightness temperatures observed in zenith direction (T_ir_zenith, bandwidth 8 µm - 14 µm) and a cloud binary mask computed by the sensor software. The time series are aggregated to a common 10 min time resolution.

2.2.4. WN3D_L1b_v1_IRR_SkyMaps

WN3D_L1b_v1_IRR_SkyMaps				
Variable Name	Dimensions	Data Type	Units	Long Name
T_ir	('time', 'elevation', 'azimuth')	float32	K	Measured Infrared Brightness Temperature from All-Sky Scan
cloud_type	('time', 'elevation', 'azimuth')	float32		Indicator of Type of Cloud Coverage
T_ir_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable T_ir
cloud_type_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable cloud_type

The **WN3D_L1b_v1_IRR_SkyMaps** data product contains 3-d (time, elevation, azimuth) data cubes of infrared brightness temperatures (T_ir_zenith, bandwidth 8 µm - 14 µm) and a cloud type flag computed by the sensor software. Note that due to surface temperature influences, cloud_type is only provided for elevations above 20°. The all-sky scans have a native time resolution of 10 min and are resampled to a regular time series.

2.2.5. WN3D_L1b_v1_MWR_TimeSeries

WN3D_L1b_v1_MWR_TimeSeries				
Variable Name	Dimensions	Data Type	Units	Long Name
iwv_zenith	('time',)	float32	kg m^{-2}	Integrated Water Vapor in the Vertical Column in Zenith Direction
lwp_zenith	('time',)	float32	kg m^{-2}	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Zenith Direction
apd_h_zenith	('time',)	float32	m	Hydrostatic Atmospheric Path Delay in Zenith Direction
k_index	('time',)	float32	K	K-Index for the Potential of Severe Convection
showalter_index	('time',)	float32	K	Showalter-Index for Convective and Thunderstorm Potential
cape_index	('time',)	float32	J kg^{-1}	Convective Available Potential Energy (CAPE)-Index
tt_index	('time',)	float32	K	Total-totals-Index for the Likelihood of Severe Convection
convective_index	('time',)	float32	K	Convective-Index for Thunderstorm Development
lifted_index	('time',)	float32	K	Lifted-Index for Atmospheric Instability
apd_nh_zenith	('time',)	float32	m	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
lwc_maximum	('time',)	float32	kg m^{-3}	Cloud Liquid Water Content Maximum (LWCM) in Zenith Direction
T_ir_zenith_narrowband	('time',)	float32	K	Measured Infrared Brightness Temperature in Zenith Direction
H_bl	('time',)	float32	m	Thickness ("Height") of the Atmospheric Boundary Layer
T_br_zenith	('time', 'frequency')	float32	K	Measured Brightness Temperature in Zenith Direction
T_br_spectrum_zenith	('time', 'frequency')	float32	K	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
attn_zenith	('time', 'frequency')	float32	dB	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
T_surf	('time',)	float32	K	Surface Air Temperature at Measurement Site
P_surf	('time',)	float32	hPa	Surface Air Pressure at Measurement Site
RH_surf	('time',)	float32	%	Surface Relative Humidity at Measurement Site
iwv_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable iwv_zenith
lwp_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable lwp_zenith
apd_h_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable apd_h_zenith
k_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable k_index
showalter_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable showalter_index
cape_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable cape_index
tt_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable tt_index
convective_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable convective_index
lifted_index_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable lifted_index
apd_nh_zenith_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable apd_nh_zenith
lwc_maximum_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable lwc_maximum
T_ir_zenith_narrowband_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable T_ir_zenith_narrowband
H_bl_qcs_flag	('time',)	uint8		QCS Flag (bitmask) for Variable H_bl
T_br_zenith_qcs_flag	('time', 'frequency')	uint8		QCS Flag (bitmask) for Variable T_br_zenith
T_br_spectrum_zenith_qcs_flag	('time', 'frequency')	uint8		QCS Flag (bitmask) for Variable T_br_spectrum_zenith
attn_zenith_qcs_flag	('time', 'frequency')	uint8		QCS Flag (bitmask) for Variable attn_zenith

The **WN3D_L1b_v1_MWR_TimeSeries** data product contains 1-d (time series) of observed brightness temperatures in the microwave and infrared (IR) band (IR bandwidth 9.6 µm - 11.5 µm), statistical retrievals, and derived quantities produced by the sensor software. Statistical retrievals include integrated water vapor, (cloud) liquid water path, atmospheric path delay, and maximum liquid water content. Derived quantities are primarily composed of atmospheric stability indices such as CAPE and boundary layer depth.

All data variables are resampled and aggregated to a common 10 min time resolution before merging.

2.2.6. WN3D_L1b_v1_MWR_Profiles

WN3D_L1b_v1_MWR_Profiles				
Variable Name	Dimensions	Data Type	Units	Long Name
T_profile_fts	('time', 'altitude')	float32	K	Coarse-Resolution Full Troposphere Temperature Profile
T_profile_bls	('time', 'altitude')	float32	K	High-Resolution Boundary Layer Temperature Profile
T_profile_cmp	('time', 'altitude')	float32	K	Compound Temperature Profile merged from Boundary Layer- and Full Troposphere Temperature Profiles
RH_profile	('time', 'altitude')	float32	%	Relative Humidity Profile
AH_profile	('time', 'altitude')	float32	$kg\,m^{-3}$	Absolute Humidity Profile (Water Vapor Mass Density Profile)
T_profile_fts_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable T_profile_fts
T_profile_bls_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable T_profile_bls
T_profile_cmp_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable T_profile_cmp
RH_profile_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable RH_profile
AH_profile_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable AH_profile
P_profile	('time', 'altitude')	float32	hPa	Air Pressure Profile Derived from Temperature and Relative Humidity Profiles
P_profile_qcs_flag	('time', 'altitude')	uint8		QCS Flag (bitmask) for Variable P_profile

WN3D_L1b_v1_MWR_Profiles contain statistical retrievals of tropospheric profiles for temperature, relative- and absolute humidity. Temperature profiles are given in different measurement altitude resolutions specficially for the boundary layer and the full troposphere. These are fused to a best estimate for the full troposphere in the T_profile_cmp variable. The profiles have a native time resolution of 10 min and are resampled to a regular time series before merging.

2.2.7. WN3D_L1b_v1_MWR_SkyMaps

WN3D_L1b_v1_MWR_SkyMaps				
Variable Name	Dimensions	Data Type	Units	Long Name
iwv	('time', 'elevation', 'azimuth')	float32	$kg\,m^{2}$	Integrated Water Vapor in Slant Direction
lwp	('time', 'elevation', 'azimuth')	float32	$kg\,m^{-2}$	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Slant Direction
apd_h_slant	('time', 'elevation', 'azimuth')	float32	m	Hydrostatic Atmospheric Path Delay in Slant Direction
apd_nh_slant	('time', 'elevation', 'azimuth')	float32	m	Non-Hydrostatic Atmospheric Path Delay in Slant Direction
T_ir_narrowband	('time', 'elevation', 'azimuth')	float32	K	Measured Infrared Brightness Temperature from All-Sky Scan
T_br	('time', 'elevation', 'azimuth', 'frequency')	float32	K	Measured Brightness Temperature in Slant Direction
T_br_spectrum	('time', 'elevation', 'azimuth', 'frequency')	float32	K	Retrieved High-Resolution Brightness Temperature Spectrum
attn	('time', 'elevation', 'azimuth', 'frequency')	float32	dB	Atmospheric Attenuation
iwv_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable iwv
lwp_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable lwp
apd_h_slant_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable apd_h_slant
apd_nh_slant_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable apd_nh_slant
T_ir_narrowband_qcs_flag	('time', 'elevation', 'azimuth')	uint8		QCS Flag (bitmask) for Variable T_ir_narrowband
T_br_qcs_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		QCS Flag (bitmask) for Variable T_br
T_br_spectrum_qcs_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		QCS Flag (bitmask) for Variable T_br_spectrum
attn_qcs_flag	('time', 'elevation', 'azimuth', 'frequency')	uint8		QCS Flag (bitmask) for Variable attn

The **WN3D_L1b_v1_MWR_SkyMaps** data product contains 3-d (time, elevation, azimuth) data cubes of observed brightness temperatures in the microwave and infrared (IR) band (IR bandwidth 9.6 µm - 11.5 µm) and statistical retrievals produced by the sensor software.

Statistical retrievals include integrated water vapor, (cloud) liquid water path, and atmospheric path delay (hydrostatic and non-hydrostatic).

The all-sky scans have a native time resolution of 10 min and are resampled to a regular time series. Azimuth and elevation resolution of the all-sky scans are 20° and 10° respectively.

2.2.8. WN3D_L1b_v1_PrecipRadar_Sweeps

WN3D_L1b_v1_PrecipRadar_Sweeps				
Variable Name	Dimensions	Data Type	Units	Long Name
scan_time_start	('time', 'elevation')	datetime64[ns]		Begin of Radar Sweep
scan_time_end	('time', 'elevation')	datetime64[ns]		End of Radar Sweep
Z_h	('time', 'elevation', 'azimuth', 'range')	float32	dBZ	Horizontal Reflectivity
phidp	('time', 'elevation', 'azimuth', 'range')	float32	degree	Differential Phase
kdp	('time', 'elevation', 'azimuth', 'range')	float32	degree km^{-1}	Specific Differential Phase
zdr	('time', 'elevation', 'azimuth', 'range')	float32	dB	Differential Reflectivity
rhohv	('time', 'elevation', 'azimuth', 'range')	float32	1	Cross-correlation Between Horizontal and Vertical Pulses
vradh	('time', 'elevation', 'azimuth', 'range')	float32	$m\,s^{-1}$	Doppler Velocity
wradh	('time', 'elevation', 'azimuth', 'range')	float32	$m\,s^{-1}$	Doppler Velocity Width
Z_h_corr	('time', 'elevation', 'azimuth', 'range')	float32	dBZ	Attenuation-Corrected Horizontal Reflectivity
zdr_corr	('time', 'elevation', 'azimuth', 'range')	float32	dB	Attenuation-Corrected Differential Reflectivity
precip_rate	('time', 'elevation', 'azimuth', 'range')	float32	$mm\,h^{-1}$	Radar-derived Instantaneous Precipitation Rate
radar_qcs_flag	('time', 'elevation', 'azimuth', 'range')	uint8		QCS Flag (bitmask) for Variable radar

WN3D_L1b_v1_PrecipRadar_Sweeps contain X-band polarimetric radar observations and derived quantities such as precipitation rate and attenuation-corrected horizontal and differential reflectivity. Individual Radar sweeps are aggregated to volume scans by elevation-stacking and their time stamp is adjusted to the closest 150 seconds to alleviate further processing. The actual sweep intervals are given in scan_time_start and scan_time_end, so the scan time of each measurement ray can be retrieved by linear interpolation of these time bounds. Radar measurement rays are resampled to a regular azimuth grid, to allow for convenient storage in (time, elevation, azimuth, range) data cubes.

Details regarding attenuation correction and quantitive precipitation estimation (QPE), are given in the ATBD.

3. Data Processing

3.1. Level 2 Data Processing – Data Product Generator (DPG3D)

The WegenerNet 3D Open Air Laboratory Data Product Generator (DPG3D) processes L1b data, taking into account quality flags assigned by the QCS3D. The general procedure is to drop degraded data, and fill resulting gaps by interpolation where sensible. Interpolated values are indicated by a metadata variable following the naming scheme `<variable_name>_interp_flag`. If resulting gaps are too large to be sensibly filled, values are replaced by either `NaN` or an appropriate fill value. L2 products are designed to be sensor agnostic and geolocated for easy comparison with other datasets, such as weather- and climate models. As a result, L1b datasets are merged during processing and transformed into combined n-dimensional data cubes.

TimeSeries

The L2 TimeSeries product is generated from L1b GNSS TimeSeries, L1b IRR TimeSeries, and L1b MWR TimeSeries products and further depends on L2 TroposphericProfiles. These L1b products are merged by first dropping values flagged by QCS3D and filling short gaps by linear interpolation. Data variables which are observed at multiple locations and/or multiple sensors (e.g., integrated water vapor) are discriminated by a `station_number` variable. These time series are geolocated by adding geographic location, ellipsoidal height, and height above sea level for each station.

Cloud base height (`H_cb`) is computed by combining temperature profiles from the L2 TroposphericProfiles product with infrared temperature measurements in zenith direction given in L2

`T_ir`. If no valid `T_ir` values are available, `T_ir_narrowband` is used. Furthermore, if QCS3D indicates that the MWR is not operational (QCS3D Layer 0), ERA5 data spatially interpolated to the radiometer site are used. The detailed processing scheme of the `H_cb` variable can be found in the ATBD, section 4.

TroposphericProfiles

The L2 TroposphericProfiles data product is generated from and only depends on L1b MWR Profiles. Profile values which are flagged by QCS3D are dropped and the resulting data gaps are filled by interpolating in space followed by interpolation in time. Profile altitude levels are geolocated by transforming the height above the sensor platform given in L1b MWR Profiles to height above sea level. These transformed height levels are subsequently linearly interpolated to the common L2 height level definitions.

SkyMaps

The L2 SkyMaps product is generated from L1b MWR SkyMaps, L1b IRR SkyMaps, and L1b GNSS SlantDelay data. First, QCS3D-flagged values in L1b MWR SkyMaps and L1b IRR SkyMaps are dropped and the resulting gaps are filled by first interpolation in space (elevation/azimuth) and then linearly in time. Spatial interpolation is performed by computing the weighted average of 4 neighbouring points. The weights are based on the inverse distance between the directional unit vectors of the data points (see also ATBD, section 5). To merge the two cleaned datasets, L1b MWR SkyMaps are resampled to the higher elevation/azimuth resolution of L1b IRR SkyMaps.

The L1b GNSS SlantDelay product is binned into the L2 SkyMaps time/elevation/azimuth grid, by averaging all slant delay values which fall into a time/elevation/azimuth voxel, after dropping all data points flagged by the QCS3D.

Precipitation

The L2 Precipitation data cubes combine precipitation radar volume scans and tropospheric temperature profiles to derive high-resolution precipitation fields with a time resolution of 2.5 min and a spatial resolution of 200 m by 200 m. The precipitation field is represented by the amount of precipitation falling within each 2.5 min time interval. This makes the WEGN3D precipitation data cubes easily comparable with the WegenerNet Climate Station Grid Data Products (Fuchsberger, Kirchengast, and Kabas 2021). In addition to precipitation amount and radar reflectivity, derived quantities such as hydrometeor and precipitation classification are contained within the data cubes. To allow for quick data scubbing, hydrometeor and precipitation type variables are also available in an aggregated form. For each time step and height layer, the area associated with each class is computed and added to the data cubes.

CloudStructure

The L2 CloudStructure product combines tropospheric temperature profiles with infrared cloud base temperatures to generate a 3D cloud mask within the extended WegenerNet Feldbach Region, with a time resolution of 10 min. Additionally a 2D map of cloud base heights is generated for each time step by reducing the 3D cloud mask. The reduction is performed by determining the lowest height level for each grid point where clouds are detected.

3.2. Level 1 Data Processing – Quality Control System (QCS3D)

Quality Check Overview

The Quality Control System (QCS) for the WegenerNet 3D Observing System data follows the same principle as the already well established QCS system for the WegenerNet climate station data and is denoted QCS3D. A set of 8 QCS layers are applied to L1b data and if the corresponding condition is met, the quality flag bitmask is set accordingly. Each variable in the data files has a corresponding quality bitmask with the naming scheme <variable_name>_qcs_flag. The QCS3D layers are defined as follows:

- **Layer 0: Operations Check**

  Checks whether the sensor is operational (i.e. online) and not manually shut down or in maintenance

- **Layer 1: Availability Check**

  Checks whether the sensor delivers data as expected

- **Layer 2: Sensor Bounds Check**

  Checks whether the sensor values lie within the sensor specification

- **Layer 3: Climate Bounds Check**

  Checks whether the sensor values lie within physically sensible values for the WegenerNet Feldbach region at the given day of year

- **Layer 4: Variability Check**

  Checks whether the spatial and/or temporal variability of the sensor values lies within empirically determined bounds

- **Layer 5: Intrastation Check**

  Checks whether values of a multi-channel sensor are physically consistent or are not already flagged by the sensor software

- **Layer 6: Interstation Check**

  Checks whether values of spatially distributed sensors are physically consistent

- **Layer 7: Reference Check**

  Checks the sensor values against external independent reference values

Layer 0 to Layer 3 are applied to the data simultaneously in a first step, whereas Layer 4 and higher are only applied to data points which pass the initial check. Due to the nature of the WN3D sensors, not all QCS3D layer can be applied to all sensors. For example, Layer 6 (Interstation Check) can only be applied to GNSS StarNet values because all other sensors and their output values are not directly comparable. The output of QCS3D are daily L1b NetCDF files that adhere to CF standards and are targeted at experienced users who want to analyze individual sensor data. Missing epochs are filled with `NaN`-values, thus the user can expect that the L1b time series is complete and evenly sampled.

Table 6: Table depicting which QCS3D layers are applied to each sensor type. Dark gray cells indicate that the checks are applied to all data variables the sensors provides, light gray cells indicate that only a subset of variables is checked.

Sensor	Layer 0	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7
GNSS								
IRR								
MWR								
PrecipRadar								

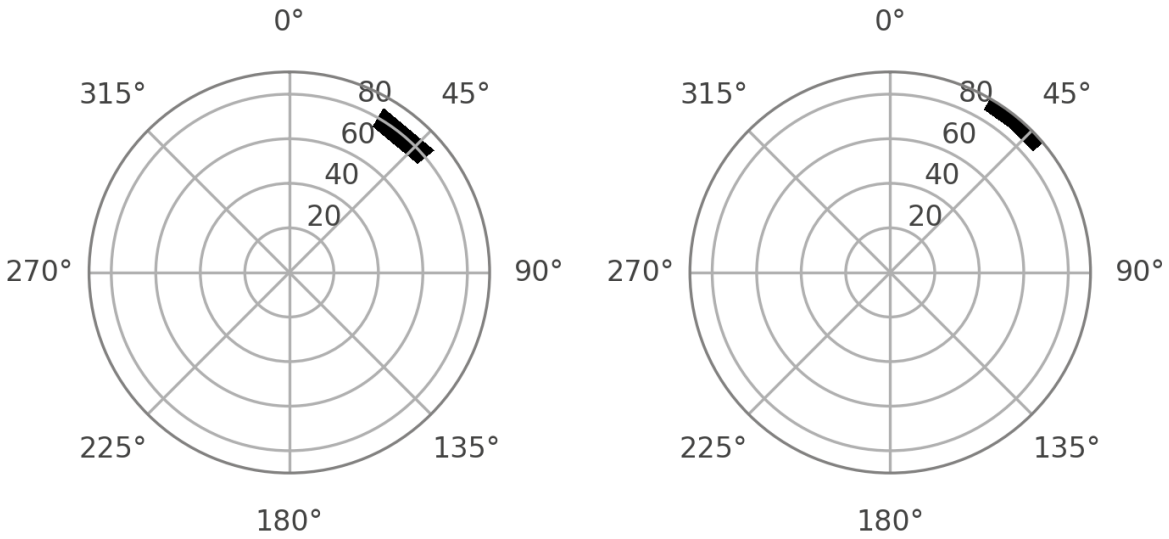

Figure 2: Clutter maps for MWR (left) and IRR (right).

MWR Membrane Drying Check

Part of the intrastation check for all MWR data (Layer 5) is flagging observations which may be affected by a wet MWR membrane. This means that periods during which rainfall is detected by a co-located rain gauge are flagged. Furthermore, to account for residual water covering the sensor membrane, this rain flag is extended to 30 minutes after the last precipitation is observed.

MWR and IRR Clutter Map Checks

Although both MWR and IRR are located in an elevated position in the Styrian Raab Valley, analyzing long time series of brightness temperatures revealed spurious brightness temperatures in low elevations at specific azimuths. These outliers were tracked to buildings in the field of view of the radiometers. To avoid these spurious values from entering the processing chain, clutter maps to flag these azimuth/elevation regions as degraded were created. The resulting clutter maps can be found in Figure 2.

MWR and IRR Sun Intrusion Checks

To avoid excessively high brightness temperature values caused by the radiometer measurement ray pointing directly towards the sun, the algorithm by Reda and Andreas 2004 is used to compute the apparent sun position and mask affected pixels. The measurement ray closest to the current sun position is taken as the central point of the mask, which is then padded by a neighborhood of 1 pixel for IRR. This mask padding is not necessary for MWR, because of the coarser angular resolution of the all-sky scans.

Integration of Radar Housekeeping Data

The FURUNO WR2120 precipitation radar provides a set of housekeeping variables which are contained in the radar L0 data stream. A subset of these housekeeping variables is used in QCS3D to flag degraded radar observations. Specifically, `pulse_blind_area` and `sector_blank` flags are used in Layer 1 to indicate regions where no measurements are expected. The housekeeping variables `signal_extinction` and `ground_clutter_intensity` are used in Layer 5 to identify non-meteorological echos and unreliable reflectivity values.

Additionally, the probability of a radar observation value being the result of a second trip echo (STE) is computed following Park et al. 2016 and values which exceed a threshold are flagged in Layer 5.

Integration of Radiometer Housekeeping Data

The RPG HATPRO G5 microwave radiometer outputs a set of housekeeping variables which are contained in the MWR L0 data stream. A subset of these housekeeping variables is used in QCS3D to flag potentially degraded brightness temperature observations and derived quantities. Temperature profiler and humidity profiler thermal stability, noise diode status, and channel status are used to flag spurious brightness temperatures values. For derived quantities computed by the HATPRO G5 on-board software, the corresponding quality flag is used.

4. Spatio-temporal Reference Frame Definitions

The horizontal spatial reference frame for gridded data is a regular 200 m x 200 m grid in the UTM33N projection (`EPSG:32633`). The X-Axis points towards the east and the Y-Axis towards north. The WN3Dv1 grid is aligned with the WN2Dv8 for easy subsetting and integration. Vertical coordinates are given as the geometric distance between the data point and a well-defined reference surface. This reference surface can either be the reference ellipsoid, the mean sea surface (represented by the Austrian Geoid Model), or the ground level (represented by EU-DEM v1.1). Relevant datasets contain corrections to convert between these three height systems. Geolocated spatial coordinate variable names are the same across all data collections and are listed in Table 7. All time stamps are given in UTC, with dates given in the Gregorian calendar. For aggregated quantities (i.e. all defined cell methods except `point`), the time stamp represents the closed interval start, thus the cell method was applied to all points in the interval $[t_k, t_{k+1})$. For the last interval in each file $k = N - 1$ it is assumed that the interval ends at $t_{N-1} + \Delta t$, where Δt is the median sampling of the time axis.

L1b data is given in the respective (local) sensor reference frame. Sensor reference frames are defined by the physical orientation of the sensor platform with respect to the local horizon

Table 7: Geolocated spatial coordinate variable description.

Variable Name	Description
X	UTM33N easting
Y	UTM33N northing
longitude	geographical (geodetic) longitude on the WGS84 ellipsoid
latitude	geographical (geodetic) latitude on the WGS84 ellipsoid
h_ell	ellipsoidal height on the WGS84 ellipsoid
h_msl	height above mean sea level
h_gnd	height above ground

Table 8: Local sensor reference frame coordinate variable description.

Variable Name	Description
elevation	angle between measurement ray and local horizon
azimuth	angle between measurement ray and true north (clockwise)
range	geometric distance from origin along measurement ray
altitude	geometric height above sensor platform

and true (geodetic) north. Any misalignment of the sensor platform is already corrected in L1b and higher processing levels. The orientation of all sensor platforms is routinely checked during maintenance and calibration activities and any corrections are updated if necessary. Local sensor frame coordinate variable names are the same across all data collections and are listed in Table 8. Detailed algorithms how local sensor coordinates are geolocated can be found in the ATBD, section 3.

Acronyms

ATBD Algorithm Theoretical Basis Document. 4, 6, 15

CAPE Convective Available Potential Energy. 13

GNSS Global Navigation Satellite System. 3

NWP Numerical Weather Prediction Model. 3

QCS3D WegenerNet 3D Quality Control System. 5, 17

SEA WegenerNet Open Data and Science Laboratory Region Southeastern Austria. 7

UTM33N Universal Transverse Mercator Projection, Zone 33N. 7

WEGN-OAL WegenerNet Open-Air Laboratory Feldbach Region. 3

WEGN3D WegenerNet 3D Observing System. 3–5, 7, 16, 17, 22

WPS3D WegenerNet 3D Processing System. 3

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A. Topical Grouping of Data Variables

The following tables contain a topical grouping of all data variables produced within the WegenerNet 3D Observing System data cubes. Data variables are grouped into the essential climate variables precipitation, upper-air temperature, water vapor, and clouds[5]. Additionally, the topical group atmospheric stability contains data variables related to vertical air motion and the atmospheric boundary layer. Note that data variables are listed once for each data product they are contained in and data variables may be contained in multiple topical groups.

A.1. Water Vapor

	Variable Name	Units	Data Product	Description
Water Vapor	AH_profile	$kg\,m^{-3}$	WN3D_L1b_v1_MWR_Profiles	Absolute Humidity Profile (Water Vapor Mass Density Profile)
	AH_profile	$kg\,m^{-3}$	WN3D_L2_BD_v1_TroposphericProfiles	Absolute Humidity Profile (Water Vapor Mass Density Profile)
	apd_h_slant	m	WN3D_L1b_v1_MWR_SkyMaps	Hydrostatic Atmospheric Path Delay in Slant Direction
	apd_h_slant	m	WN3D_L2_BD_v1_SkyMaps	Hydrostatic Atmospheric Path Delay in Slant Direction
	apd_h_zenith	m	WN3D_L1b_v1_GNSS_TimeSeries	Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_h_zenith	m	WN3D_L1b_v1_MWR_TimeSeries	Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_h_zenith	m	WN3D_L2_BD_v1_TimeSeries	Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_nh_slant	m	WN3D_L1b_v1_MWR_SkyMaps	Non-Hydrostatic Atmospheric Path Delay in Slant Direction
	apd_nh_slant	m	WN3D_L2_BD_v1_SkyMaps	Non-Hydrostatic Atmospheric Path Delay in Slant Direction
	apd_nh_zenith	m	WN3D_L1b_v1_GNSS_TimeSeries	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_nh_zenith	m	WN3D_L1b_v1_MWR_TimeSeries	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_nh_zenith	m	WN3D_L2_BD_v1_TimeSeries	Non-Hydrostatic Atmospheric Path Delay in Zenith Direction
	apd_tot_slant	m	WN3D_L1b_v1_GNSS_SlantDelay	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Slant Direction
	apd_tot_slant	m	WN3D_L2_BD_v1_SkyMaps	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Slant Direction
	apd_tot_zenith	m	WN3D_L1b_v1_GNSS_SlantDelay	Combined Hydrostatic and Non-Hydrostatic (Total) Atmospheric Path Delay in Zenith Direction
	attn	dB	WN3D_L1b_v1_MWR_SkyMaps	Atmospheric Attenuation
	attn	dB	WN3D_L2_BD_v1_SkyMaps	Atmospheric Attenuation
	attn_zenith	dB	WN3D_L1b_v1_MWR_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	attn_zenith	dB	WN3D_L2_BD_v1_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	iwv	$kg\,m^{-2}$	WN3D_L1b_v1_MWR_SkyMaps	Integrated Water Vapor in Slant Direction
	iwv	$kg\,m^{-2}$	WN3D_L2_BD_v1_SkyMaps	Integrated Water Vapor in Slant Direction
	iwv_zenith	$kg\,m^{-2}$	WN3D_L1b_v1_GNSS_TimeSeries	Integrated Water Vapor in the Vertical Column in Zenith Direction
	iwv_zenith	$kg\,m^{-2}$	WN3D_L1b_v1_MWR_TimeSeries	Integrated Water Vapor in the Vertical Column in Zenith Direction
	iwv_zenith	$kg\,m^{-2}$	WN3D_L2_BD_v1_TimeSeries	Integrated Water Vapor in the Vertical Column in Zenith Direction
	RH_profile	%	WN3D_L1b_v1_MWR_Profiles	Relative Humidity Profile
	RH_profile	%	WN3D_L2_BD_v1_TroposphericProfiles	Relative Humidity Profile
	T_br	K	WN3D_L1b_v1_MWR_SkyMaps	Measured Brightness Temperature in Slant Direction
	T_br	K	WN3D_L2_BD_v1_SkyMaps	Measured Brightness Temperature in Slant Direction
	T_br_spectrum	K	WN3D_L1b_v1_MWR_SkyMaps	Retrieved High-Resolution Brightness Temperature Spectrum
	T_br_spectrum	K	WN3D_L2_BD_v1_SkyMaps	Retrieved High-Resolution Brightness Temperature Spectrum
	T_br_spectrum_zenith	K	WN3D_L1b_v1_MWR_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	T_br_spectrum_zenith	K	WN3D_L2_BD_v1_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	T_br_zenith	K	WN3D_L1b_v1_MWR_TimeSeries	Measured Brightness Temperature in Zenith Direction
	T_br_zenith	K	WN3D_L2_BD_v1_TimeSeries	Measured Brightness Temperature in Zenith Direction
	tropograd_tot_east	m	WN3D_L1b_v1_GNSS_TimeSeries	Total Tropospheric (Atmospheric Path Delay) Gradient in East Direction
	tropograd_tot_east	m	WN3D_L2_BD_v1_TimeSeries	Total Tropospheric (Atmospheric Path Delay) Gradient in East Direction
	tropograd_tot_north	m	WN3D_L1b_v1_GNSS_TimeSeries	Total Tropospheric (Atmospheric Path Delay) Gradient in North Direction
	tropograd_tot_north	m	WN3D_L2_BD_v1_TimeSeries	Total Tropospheric (Atmospheric Path Delay) Gradient in North Direction

[5] https://gcos.wmo.int/en/essential-climate-variables/, last accessed 2024-09-15

A.2. Precipitation

	Variable Name	Units	Data Product	Description
Precipitation	convective_precipitation_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as convective_precipitation
	dry_snow_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as dry_snow
	graupel_hail_mix_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as graupel_hail_mix
	hail_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as hail
	heavy_rain_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as heavy_rain
	horizontal_ice_crystals_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as horizontal_ice_crystals
	hydrometeor_type		WN3D_L2_BD_v1_Precipitation	Hydrometeor Type After Zrnic et al. 2001 utilizing membership functions based on Straka et al. 2000 adapted for X-band by Evaristo et al. 2013
	kdp	degree km^{-1}	WN3D_L1b_v1_PrecipRadar_Sweeps	Specific Differential Phase
	large_drops_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as large_drops
	light_rain_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as light_rain
	moderate_rain_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as moderate_rain
	no_precipitation_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as no_precipitation
	phidp	degree	WN3D_L1b_v1_PrecipRadar_Sweeps	Differential Phase
	precip_amount	mm	WN3D_L2_BD_v1_Precipitation	Radar-derived Precipitation Amount
	precip_rate	mm h^{-1}	WN3D_L1b_v1_PrecipRadar_Sweeps	Radar-derived Instantaneous Precipitation Rate
	precipitation_type		WN3D_L2_BD_v1_Precipitation	Precipitation Classification According to Powell et al. 2016
	rain_hail_mix_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as rain_hail_mix
	rhohv	1	WN3D_L1b_v1_PrecipRadar_Sweeps	Cross-correlation Between Horizontal and Vertical Pulses
	vertical_ice_crystals_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as vertical_ice_crystals
	vradh	m s^{-1}	WN3D_L1b_v1_PrecipRadar_Sweeps	Doppler Velocity
	wet_snow_area_fraction	1	WN3D_L2_BD_v1_Precipitation	Area Fraction of Radar Observations Classified as wet_snow
	wradh	m s^{-1}	WN3D_L1b_v1_PrecipRadar_Sweeps	Doppler Velocity Width
	Z_h	dBZ	WN3D_L1b_v1_PrecipRadar_Sweeps	Horizontal Reflectivity
	Z_h_corr	dBZ	WN3D_L1b_v1_PrecipRadar_Sweeps	Attenuation-Corrected Horizontal Reflectivity
	Z_h_corr	dBZ	WN3D_L2_BD_v1_Precipitation	Attenuation-Corrected Horizontal Reflectivity
	zdr	dB	WN3D_L1b_v1_PrecipRadar_Sweeps	Differential Reflectivity
	zdr_corr	dB	WN3D_L1b_v1_PrecipRadar_Sweeps	Attenuation-Corrected Differential Reflectivity

A.3. Upper-air Temperature

	Variable Name	Units	Data Product	Description
Upper-air Temperature	attn	dB	WN3D_L1b_v1_MWR_SkyMaps	Atmospheric Attenuation
	attn	dB	WN3D_L2_BD_v1_SkyMaps	Atmospheric Attenuation
	attn_zenith	dB	WN3D_L1b_v1_MWR_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	attn_zenith	dB	WN3D_L2_BD_v1_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	T_br	K	WN3D_L1b_v1_MWR_SkyMaps	Measured Brightness Temperature in Slant Direction
	T_br	K	WN3D_L2_BD_v1_SkyMaps	Measured Brightness Temperature in Slant Direction
	T_br_spectrum	K	WN3D_L1b_v1_MWR_SkyMaps	Retrieved High-Resolution Brightness Temperature Spectrum
	T_br_spectrum	K	WN3D_L2_BD_v1_SkyMaps	Retrieved High-Resolution Brightness Temperature Spectrum
	T_br_spectrum_zenith	K	WN3D_L1b_v1_MWR_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	T_br_spectrum_zenith	K	WN3D_L2_BD_v1_TimeSeries	Retrieved High-Resolution Brightness Temperature Spectrum in Zenith Direction
	T_br_zenith	K	WN3D_L1b_v1_MWR_TimeSeries	Measured Brightness Temperature in Zenith Direction
	T_br_zenith	K	WN3D_L2_BD_v1_TimeSeries	Measured Brightness Temperature in Zenith Direction
	T_profile_bls	K	WN3D_L1b_v1_MWR_Profiles	High-Resolution Boundary Layer Temperature Profile
	T_profile_cmp	K	WN3D_L1b_v1_MWR_Profiles	Compound Temperature Profile merged from Boundary Layer- and Full Troposphere Temperature Profiles
	T_profile_cmp	K	WN3D_L2_BD_v1_TroposphericProfiles	Compound Temperature Profile merged from Boundary Layer- and Full Troposphere Temperature Profiles
	T_profile_fts	K	WN3D_L1b_v1_MWR_Profiles	Coarse-Resolution Full Troposphere Temperature Profile

A.4. Clouds

	Variable Name	Units	Data Product	Description
Clouds	AH_profile	$kg\,m^{-3}$	WN3D_L1b_v1_MWR_Profiles	Absolute Humidity Profile (Water Vapor Mass Density Profile)
	AH_profile	$kg\,m^{-3}$	WN3D_L2_BD_v1_TroposphericProfiles	Absolute Humidity Profile (Water Vapor Mass Density Profile)
	cloud_binary_mask_zenith		WN3D_L1b_v1_IRR_TimeSeries	Cloud Binary Mask in Zenith Direction
	cloud_structure		WN3D_L2_BD_v1_CloudStructure	Cloud Binary Mask
	cloud_type		WN3D_L1b_v1_IRR_SkyMaps	Indicator of Type of Cloud Coverage
	cloud_type		WN3D_L2_BD_v1_SkyMaps	Indicator of Type of Cloud Coverage
	H_cb	m	WN3D_L2_BD_v1_TimeSeries	Cloud Base Altitude (Height Above Sea Level) in Zenith Direction
	H_cb	m	WN3D_L2_BD_v1_CloudStructure	Cloud Base Altitude (Height Above Sea Level) in Zenith Direction
	lwc_maximum	$kg\,m^{-3}$	WN3D_L1b_v1_MWR_TimeSeries	Cloud Liquid Water Content Maximum (LWCM) in Zenith Direction
	lwc_maximum	$kg\,m^{-3}$	WN3D_L2_BD_v1_TimeSeries	Cloud Liquid Water Content Maximum (LWCM) in Zenith Direction
	lwp	$kg\,m^{-2}$	WN3D_L1b_v1_MWR_SkyMaps	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Slant Direction
	lwp	$kg\,m^{-2}$	WN3D_L2_BD_v1_SkyMaps	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Slant Direction
	lwp_zenith	$kg\,m^{-2}$	WN3D_L1b_v1_MWR_TimeSeries	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Zenith Direction
	lwp_zenith	$kg\,m^{-2}$	WN3D_L2_BD_v1_TimeSeries	Cloud Liquid Water Path (Integrated Amount of Liquid Water) in Zenith Direction
	RH_profile	%	WN3D_L1b_v1_MWR_Profiles	Relative Humidity Profile
	RH_profile	%	WN3D_L2_BD_v1_TroposphericProfiles	Relative Humidity Profile
	T_ir	K	WN3D_L1b_v1_IRR_SkyMaps	Measured Infrared Brightness Temperature from All-Sky Scan
	T_ir	K	WN3D_L2_BD_v1_SkyMaps	Measured Infrared Brightness Temperature from All-Sky Scan
	T_ir_narrowband	K	WN3D_L1b_v1_MWR_SkyMaps	Measured Infrared Brightness Temperature from All-Sky Scan
	T_ir_narrowband	K	WN3D_L2_BD_v1_SkyMaps	Measured Infrared Brightness Temperature from All-Sky Scan
	T_ir_zenith	K	WN3D_L1b_v1_IRR_TimeSeries	Measured Infrared Brightness Temperature in Zenith Direction
	T_ir_zenith	K	WN3D_L2_BD_v1_TimeSeries	Measured Infrared Brightness Temperature in Zenith Direction
	T_ir_zenith_narrowband	K	WN3D_L1b_v1_MWR_TimeSeries	Measured Infrared Brightness Temperature in Zenith Direction
	T_ir_zenith_narrowband	K	WN3D_L2_BD_v1_TimeSeries	Measured Infrared Brightness Temperature in Zenith Direction

A.5. Atmospheric Stability

	Variable Name	Units	Data Product	Description
Atmospheric Stability	cape_index	$J\,kg^{-1}$	WN3D_L1b_v1_MWR_TimeSeries	Convective Available Potential Energy (CAPE)-Index
	cape_index	$J\,kg^{-1}$	WN3D_L2_BD_v1_TimeSeries	Convective Available Potential Energy (CAPE)-Index
	convective_index	K	WN3D_L1b_v1_MWR_TimeSeries	Convective-Index for Thunderstorm Development
	convective_index	K	WN3D_L2_BD_v1_TimeSeries	Convective-Index for Thunderstorm Development
	H_bl	m	WN3D_L1b_v1_MWR_TimeSeries	Thickness ("Height") of the Atmospheric Boundary Layer
	H_bl	m	WN3D_L2_BD_v1_TimeSeries	Thickness ("Height") of the Atmospheric Boundary Layer
	k_index	K	WN3D_L1b_v1_MWR_TimeSeries	K-Index for the Potential of Severe Convection
	k_index	K	WN3D_L2_BD_v1_TimeSeries	K-Index for the Potential of Severe Convection
	lifted_index	K	WN3D_L1b_v1_MWR_TimeSeries	Lifted-Index for Atmospheric Instability
	lifted_index	K	WN3D_L2_BD_v1_TimeSeries	Lifted-Index for Atmospheric Instability
	showalter_index	K	WN3D_L1b_v1_MWR_TimeSeries	Showalter-Index for Convective and Thunderstorm Potential
	showalter_index	K	WN3D_L2_BD_v1_TimeSeries	Showalter-Index for Convective and Thunderstorm Potential
	tt_index	K	WN3D_L1b_v1_MWR_TimeSeries	Total-totals-Index for the Likelihood of Severe Convection
	tt_index	K	WN3D_L2_BD_v1_TimeSeries	Total-totals-Index for the Likelihood of Severe Convection