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Brief Description of the RS92 GRUAN Data Product (RS92-GDP)

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Abstract

The GRUAN Lead Centre has developed a data product for the Vaisala RS92 radiosonde that includes raw data, bias-adjusted data, and uncertainty estimates. The raw data are read from the original DigiCora III data base files and are corrected for known systematic biases. The uncertainty of temperature, humidity and wind is calculated from estimates of the calibration uncertainty, the uncertainty of the bias correction and statistical noise. For each observational data point in a sounding, the uncertainty is given. The product is stored in a NetCDF file that is briefly described in this document.

This version of the document (1.1) describes the release version 1 of the RS92 GRUAN data product (RS92-GDP) that is in operational use since 12 August 2011.

History

Version	Author	Description
1.1	Michael Sommer	Reviewed version with optimisation of structure and several additions of content
1.0	Franz Immler	*First version* of this technical document describing RS92 GRURAN data product (RS92-GDP) release version 1

Table of Contents

1 Introduction

For use within the GCOS Reference Upper Air Network (GRUAN), a data product has been developed based on measurements of temperature, humidity, wind and pressure by the Vaisala RS92 radiosonde. This GRUAN data product includes raw, calibrated measurement data (RAWPTU) and uses specific bias corrections developed by the GRUAN Lead Centre. By providing a comprehensive uncertainty analysis, it meets GRUAN requirements as a reference data product [Immler et al., 2010]. The uncertainty is calculated following recommendations of the "Guide for expressing uncertainty in measurement" [GUM, 2008]. The total uncertainty is assessed from estimates of the calibration uncertainty, the uncertainty of the corrections, and the statistical standard deviations. Corrections are applied to obtain data that are free of bias, to the extent of our current knowledge.

2 GRUAN Processing of RS92

A software tool written by the GRUAN Lead Centre supports the collection procedure, in particular for launches with a complex configuration, such as dual or multiple sonde launches or launches using instrumentation to measure different parameters [see GRUAN TD-3, Sommer 2011b].

All meta-data are stored in the GRUAN meta data-base (GMDB) and all raw data are stored in a file archive at the GRUAN Lead Centre. The GRUAN data processing is started as soon as all meta-data and raw data for a radiosonde launch are available. The processing is based on the raw data contained in the DigiCora III database files (*.dc3db). The first step converts these files into NetCDF files, containing the exact same information as the original files. The raw PTU data are read from the table *FRAWPTU*, the GPS position data from the table *GPSDCC_RESULT*. The raw data are then recalibrated based on the applicable ground checks. The GRUAN processing applies the ground check correction to the temperature and pressure readings during the ground check, it does not apply the ground check correction to the humidity readings during the ground check. The profiles are corrected for known systematic biases and in that process the overall uncertainty is calculated. Data are smoothed where necessary and random uncertainties are calculated. In a last step, the data are smooth with a digital filter with a cut-off frequency f_c, which is specific for each measurement parameter. The time resolution, which is defined by $1/f_c$, is provided in the attributes for each variable. The resolution of the product data is again given in the original time step of 1 s.

The processing steps for each measurement parameter are briefly described in chapter 6.

3 Locating and Naming of Files

The contents of this chapter are also published in GRUAN-TD-1, chapter 2.1 [Sommer, 2011a]. GRUAN data files are published on a ftp server at NCDC (ftp://ftp.ncdc.noaa.gov/pub/data/gruan).

The directory structure separates GRUAN data files by product, version, site and year:

- *processing/* – Processed GRUAN data
  - *level<level number>/* – Data level, here *level2* (see below)
    - *<product code>/* – Product code, here *RS92-GDP* (RS92 GRUAN Data Product)
      - *version-<version number>/* – Product version, here e.g. *version-001*
        - *<site code>/* – Site code, e.g *CAB* for Cabauw (see appendix D)
          - *<year>/* – Year of measurement, e.g. *2011*

The file name convention of the product files is the following:

Convention: SSS-MM-NN_L_<product name>_VVV_<date>_<id>.nc
Example: CAB-RS-01_2_RS92-GDP_001_20110203T120000_1-000-001.nc

- *SSS* – Code of station, e.g. CAB for Cabauw (see appendix D)
- *MM* – Measurement system, e.g. RS for Radiosonde
- *NN* – Number of measurement system e.g. 01 (first radiosonde system at Cabauw)
- *L* – Data level
  - 0 – Original raw data (files)
  - 1 – Preprocessed raw data
  - 2 – Processed data from one measuring system
  - 3 – Best composite of several measuring systems
- *<product name>* – Name of a GRUAN data product of arbitrary length, e.g. RS92-GDP
- *VVV* – Version of data product, e.g. 001
- *<date>* – Scheduled start time [UTC] of balloon in the format YYYYMMDD**T**hhmms (scheduled mostly means WMO required, e.g. 00, 06, 12, 18 UTC)
- *<id>* – Identification of the measuring event, here the format is: B-PPP-VVV:
  - *B* – Number of balloon (in case several balloons were launched at the same time)
  - *PPP* – Number of instrument/part at the balloon [*internal use only*], e.g. 001
  - *VVV* – Version of submitted data, e.g. 001

4 Handling and Basic Structure of NetCDF Files

All GRUAN data product files (GDP files) are provided in NetCDF format. This format has been developed by UNIDATA and software libraries to work with this format (e.g. for FORTRAN, C, JAVA, IDL, …) are widely available. See www.unidata.ucar.edu/software/netcdf for more options.

The GRUAN processing makes extensive use of this format and its capabilities to include meta-data. Some common terms are explained here to help in understanding of the data products:

- **Global attributes** (see chapter 5) – Global attributes serve to store information (meta-data), which are relevant for the entire file. In case of this GDP files some groups of meta-data attributes are differentiated:
  - General information about the meta standard that has been used for GRUAN, i.e. the climate and forecasting meta data standard CF-1.4 [Eaton et al., 2009]
  - GRUAN details, which includes
    - measurement event (launch)
    - used instruments (sondes)
    - used processing software
    - status of overall quality
- **Variables** (see chapter 6) – A list of variables are included in each NetCDF file. A variable is the same like a column of a table. Only one table is defined in a GDP file. Exactly one dimension (time [s]) is defined in case of RS92-GDP files.

- **Variable attributes** (see chapter 7) – Describing meta-data (e.g. units) are attached to every variable (table column) which are named “variable attributes”.

5 Global Attributes

The global attributes describe the data product, the time and location of the measurement, meteorological conditions at the ground, and software version of the ground station equipment, etc.

Global attributes are saved using the following format:

g.<Category>.<AttributeName>: value (always stored as string)

See appendix A for a description of all global attributes.

6 Variables

Variables of the RS92 GRUAN data product are accompanied by an uncertainty estimate. Variables that do not have a corresponding uncertainty variable are not GRUAN compliant data and should be considered ancillary data. A list of all variables (table columns) is provided in appendix B. A brief description of the major variables is given below.

Column name, description, unit and additional details are provided as attributes attached to each column. See chapter 7 and appendix C for a description of these attributes.

Radiosonde data are measured as a function of time, given in seconds from launch.

Temperature

The raw temperature data are corrected for radiation bias based on lab measurements obtained in Lindenberg, where the effect of solar radiation on the sensors was determined for different insolation, pressure, and ventilation conditions. An uncertainty analysis of these corrections are carried out based on assumptions on how well these conditions are known during ascent and how well the effect on the sensor can be evaluated. The uncertainty has a correlated (systematic) and a uncorrelated (random) component. The latter is determined from the the standard deviation with respect to the smoothed profile. Both components are given in extra variables (*u_cor_temp*, and *u_std_temp*, respectively).

Humidity

The humidity data are corrected for solar radiation induced dry bias and temperature dependent time-lag. In addition an adjustment of the calibration at cold temperatures is carried out that was derived from comparisons to the Crygenic Frostpoint Hygrometer (CFH). This correction contributes to overall calibration uncertainty.

Pressure, altitude, geopotential height

The RS92 provides a pressure sensor as well as a GPS receiver that allows the retrieval of sonde’s altitude from which the pressure can be derived using the hypsometric formula. Therefore the radiosonde provides redundant observations of the altitude and the pressure. The processing uses both measurements and calculates the variables in a consistent way. It uses the measured pressure in the lower levels and the GPS derived pressure of higher levels, determined by an analysis of the random noise in the pressure and the GPS.

Wind

The horizontal displacement of the radiosonde is given in the original table *GPSDCC_RESULT* of the dc3db files. These data are smoothed by a digital filter using a cut-off frequency of 0.025 Hz (i.e. a smoothing over 40 s is applied). A statistical uncertainty is calculated from the noise in the signal that is assumed to arise from the pendulum motion of the radiosonde and from noise created by the GPS receiver itself. The zonal and meridional wind *u* and *v* given in the data table (see appendix B) are directly derived from the raw data without smoothing applied.

Uncertainties, corrections and resolution

For each measured variable (except latitude, longitude) the uncertainties are given in an extra column named *u_<variable tag name>*. This uncertainty generally has a correlated and an uncorrelated component. The latter is determined as the uncertainty of the mean and therefore is dependent on the smoothing filter that was used. The uncertainty arising from the calibration and from a systematic effect is generally correlated over the entire signal range or at least over a range much larger than the given time resolution (attribute *g_resolution*). To allow for propagation of the uncertainties through additional smoothing filters or averaging kernels that the data user may want to apply, the correlated uncertainty k and the standard deviation of the noise r are separately provided in extra columns for cases where both were considered of importance. If only one of the components was considered as important (pressure, altitude: correlated; wind: uncorrelated), this uncertainty is given in the uncertainty column. The attribute *g_column_type* indicates which uncertainty each of the uncertainty columns refer to.

To propagate the uncertainties through an averaging kernel c with 2M+1 elements c_{-M} .. c_M which is normalized, i.e. $\sum c_j = 1$ the following formulas should be used:

Correlated uncertainties: $$\bar{k}_i = \sum_{j=i-M}^{i+M} (c_j k_{i+j})$$

Uncorrelated uncertainties: $$\bar{r}_i = \sqrt{\sum_{j=i-M}^{i+M} (c_j r_{i+j})^2}$$

the total uncertainty u of the average signal s is the geometric sum of the two: $u = \sqrt{\bar{k}^2 + \bar{r}^2}$

The wind uncertainty is given as the uncertainty of the mean and is uncorrelated. To obtain the standard deviation r the column needs to be multiplied by $f = \sqrt{T / T_{org}}$ where T is the resolution (given in the variables attributes) and T_{org} is the original resolution given in the global attributes. Generally all uncertainties and the variables themselves are correlated over a range of the order of the resolution (or smaller). In the case of relative humidity the time resolution varies with temperature. This is due to the temperature dependence of the time-lag parameter. To give the user an indication of the range over which the variable is correlated the estimated time resolution is given in an extra variable (*res_rh*).

7 Variable Attributes

Standard column name, long column name, description (comment) and unit are given in the attributes attached to each column. Additional attributes are given for internal use. See appendix C for a brief description of all possible variable attributes.

Appendix

Appendix A Global attributes

Table 1: Global attributes saved in the GRUAN data product files

Category / .Attribute	Example	Description
CF specific global attributes [see Eaton et al., 2009]		
Conventions	'CF-1.4'	Used convention → CF-1.4: NetCDF Climate and Forecast CF Metadata Convention, Version 1.4, 2009-02-27
title	'RS92 GRUAN Data Product (Version 1)'	Title of the data product
institution	'GRUAN Lead Centre (Lindenberg, DWD, Germany)'	Institution, where the data file was created
source	'RS92-SGP'	Source of measurement data – the instrument
history	–	Sequence of processing steps
references	–	References to publications or documentations, describing the data product.
comment	–	Description of data product

GRUAN specific global attributes → in the format *g.<Category>.<AttributeName>* : value (*always stored as string*) → Example: *g.Product.ID* : '15775'		
Product (category)		Several specific facts of this data product file.
.ID	15775	[*internal use only*] – ID of product item from the GRUAN meta data-base (GMDB).
.Code	'RS92-GDP'	Code of data product (same as in the file name).
.Name	'RS92 GRUAN Data Product'	Name / title of data product
.Version	1	Version of data product (same as in the file name).
.Level	2	Level of data file (same as in the file name). – see chapter 3
.LevelDescription		Description of *.Level*
.History	–	Sequence of processing steps
.References	–	References to publications or documentations, describing the data product.
.Producer	–	Institution, where the data file was created

Category / .Attribute	Example	Description
.OrgResolution	'1.0 s (time)'	Original resolution of measurement with unit and corresponding variable
.Status	'Data_approved'	Quality status of data file. Only status *Data_approved* will be published at NCDC. Possibilities are: • *Data_approved* – best (GRUAN stamp) • *Data_checked* – some small issues • *Data* – several issues • *Garbage* – *Do not use this data!*
.StatusDescription	–	Long description of status

General (category)		General facts of file and GRUAN site.
.FileTypeVersion	0.7	Version of file type definition. *If the version has changed, it is possible that attributes/variables have been added or removed.*
.Timestamp	2011-12-01T09:09:49	Date and time of file creation
.SiteCode	'LIN'	GRUAN station code (see appendix D)
.SiteName	'Lindenberg'	GRUAN station name (see appendix D)
.SiteWmoId	10393	WMO number of GRUAN site (only if existent)

MeasuringSystem (category)		The measurement system at the specific GRUAN site. *This is ever a specific radiosonde launch site in case of the RS92 GRUAN data product.*
.ID	'LIN-RS-01'	Code of measurement system (same as in the file name).
.Type	'Radiosonde'	Type of measurement system.
.Longitude	'14.12 °'	Longitude of the measurement system (e.g. launch site). [° east]
.Latitude	'52.21 °'	Latitude of the measurement system (e.g. launch site). [° north]
.Altitude	'103.8 m'	Altitude of the measuring system (e.g. launch site). If a pressure reference sensor is used to recalibrate the pressure sensor – this altitude is stored here. [m]

SurfaceObs (category)		Surface observations from launch site at launch date.
.Pressure	'1010.90 hPa'	Surface pressure at launch site [hPa]
.Temperature	'-0.60 °C'	Temperature at launch site [K]

Category / .Attribute	Example	Description
.RelativeHumidity	'99.0 %'	Relative humidity at launch site [%RH]

Ascent (category)		Facts of sonde ascent
.ID	4329	[*internal use only*] – ID of the event (radiosonde launch) from the GRUAN meta data-base (GMDB).
.StandardTime	2011-12-01T06:00:00	Standard (or scheduled, synop) time for launch (same as in the file name). *'Scheduled' mostly means WMO required, e.g. 00, 06, 12, 18 UTC.*
.StartTime	2011-12-01T05:07:36	Actual time of the launch (UTC)
.BalloonNumber	1	Number of balloon (in case several balloons were launched at the same *.StandardTime*; same as in the file name).
.BalloonType	'TA600'	Code of balloon type (codes are defined in the GRUAN meta database – GMDB)
.UnwinderType	'UW-V30'	Code of unwinder type (codes are defined in the GRUAN meta database – GMDB)
.FillingWeight	'300.0 g'	Weight under the balloon to determine the filling [g]
.Payload	'300.0 g'	Weight of all components attached underneath the balloon [g]
.GrossWeight	'900.0 g'	Weight of all components to launch (balloon … sonde) [g]
.IncludeDescent	'no'	Are the descent data included in this file? [yes / no]
.BurstpointAltitude	'31782.0 m'	Altitude of pressure [m]
.BurstpointPressure	'8.60 hPa'	Pressure of burstpoint [hPa]
.TropopauseHeight	'12092.1 m'	Height/altitude of WMO tropopause [m]
.Tropopause-Temperature	'203.9 K'	Temperature at WMO tropopause [K]
.TropopausePressure	'187.8 hPa'	Pressure at WMO tropopause [hPa]
.TropopausePot-Temperature	'328.8 K'	Potential temperature at WMO tropopause [K]

Instrument (category)		Instrument of measuring (sonde)
.SerialNumber	'F3641355'	Serial number of instrument
.Type	'RS92-SGP'	Identifier of the instrument type (codes are defined in the GRUAN meta database – GMDB).

Category / .Attribute	Example	Description
.TypeFamiliy	‘RS92’	Identifier for the instrument family (codes are defined in the GRUAN meta database – GMDB).
.Manufacturer	‘Vaisala’	Name of the instrument manufacturer
.Weight	‘285.0 g’	Weight of the instrument in [g]
.TelemetrySonde	‘RS92’	[*not relevant*] – Code of the instrument family of the used telemetry sonde. This is only relevant for sondes, which have no own telemetry (like CFH, COBALD).
.SoftwareVersion	‘3.64.1’	Used version of telemetry/processing software.

Appendix B Variables (data columns)

The units of the variables follow the CF-1.4 convention. Here some remarks to understand:

- deg – decimal degree
- deg east – decimal degree (W → E; -180 → +180)
- deg north – decimal degree (S → N; -90 → +90)
- 1 – no unit
  - If percentage [%] is required such as for relative humidity, multiply the value in the column by 100.
  - Mixing ratio is always given in volume mixing ratio with unit 1.

Table 2: Variables of RS92 GRUAN data product files

Variable	Unit	Description
time	s	Time in seconds after launch
press	hPa	Air pressure derived from pressure sensor measurement and GPS altitude measurement (upper altitude range).
u_press	hPa	Total uncertainty of the air pressure dominated by correlated uncertainty.
temp	K	Air temperature
u_temp	K	Total uncertainty of temperature composed of both correlated and uncorrelated components, both are provided in extra columns (see below).
rh	1	Relative humidity over liquid water using Hyland and Wexler’s formula.
u_rh	1	Total absolute uncertainty of relative humidity (correlated and uncorrelated components are provided in extra variables (see below).
wdir	deg	Wind direction in degrees from north derived from smoothed GPS data

Variable	Unit	Description
u_dwir	deg	Uncertainty of the wind direction. It is calculated as the statistical uncertainty of the mean.
wspeed	m/s	Wind speed derived from smoothed GPS data.
u_wspeed	m/s	Uncertainty of the wind speed. It is calculated as the statistical uncertainty of the mean.
geopot	m	Geopotential height calculated from air pressure and GPS altitude (upper altitude range).
lon	deg east	Longitude
lat	deg north	Latitude
alt	m	Geometric altitude above sea level calculated from air pressure and GPS altitude (upper altitude range).
u_alt	m	Uncertainty of the geometric altitude, dominated by correlated uncertainty.
u	m/s	Zonal wind, this column provides unfiltered, raw data
v	m/s	Meridional wind, this column provides unfiltered, raw data
FP	K	Frost-point temperature calculated from *rh* and *temp* using Hyland and Wexler's formula.
WVMR	1	Water vapour volume mixing ratio calculated from *rh*, *temp* and *press*.
asc	m/s	Ascent rate of the radiosonde
SWrad	W/m^2	Short-wave radiation retrieved from a radiation transfer model for the current solar zenith angle.
u_SWrad	W/m^2	Uncertainty of solar radiation estimated from scenarios with different cloud, aerosol and albedo parameters.
cor_temp	K	Radiation bias correction of temperature.
u_cor_temp	K	Correlated uncertainty component of the air temperature derived from estimated of uncertainty in calibration and radiation correction.
u_std_temp	K	Standard deviation from the mean of the air temperature, characterising the noise in the measurement.
u_cor_rh	1	Correlated uncertainty component of the air temperature derived from estimated of uncertainty in calibration, radiation correction, and time-lag correction.
u_std_rh	1	Standard deviation of the relative humidity, characterising the noise in the measurement after the time-lag correction.
cor_rh	1	Correction applied to the relative humidity (difference from raw and corrected data).
res_rh	1	Time resolution of the relative humidity measurement after the time-lag correction ($1/f_c$ of altitude-dependent averaging kernel).

Appendix C Variable attributes

The variable attributes include standardised attributes from CF-1.4 [see Eaton et al., 2009] and special attributes, defined for GRUAN purposes (starting with *g_*).

Table 3: Variable attributes saved in the GRUAN data product files

Attribute	Example *(variable wspeed)*	Description
CF specific variable attributes [see Eaton et al., 2009]		
standard_name	'wind_speed'	Standard name of the field. (compatible with the standard CF-1.4[1], where applicable)
units	'm s-1'	SI unit (confirm to CF-1.4[1])
long_name	'Wind Speed'	Name of the variable
comment	'Wind speed'	Brief description of variable, might include some information about the processing.
coordinates	'lon lat alt'	List of relevant coordinate variables (mostly 'lon lat alt').
related_columns	'u_wspeed'	List of other variables (columns) in this table that is related to this one (e.g. uncertainties, biases, …).
positive	–	Direction of increasing coordinate ['up' / 'down'] (relevant only for variable *alt*).
GRUAN specific variable attributes		
g_source_desc	'RS92'	Source table (in dc3db-file) from which raw data were retrieved and codes for processing steps
g_resolution	'40.0 s (time)'	$1/f_c$ of smoothing filter that was applied
g_format_format	'F6.2'	[*internal use*] – Format code (Fortran-like) for output in ASCII files.
g_format_type	'FLT'	[*internal use*] – Internal code of format type (e.g. FLT for floating-point number)
g_format_width	'6'	[*internal use*] – Width of formatted value
g_format_nan	'NaN'	[*internal use*] – Internal format for missing values
g_column_type	'original data'	Type of data (of this variable): • original data • derived data product • total uncertainty • standard deviation • correlated uncertainty • uncorrelated uncertainty • resolution • correction

Attribute	Example *(variable wspeed)*	Description
g_processing_flag	'uncertainty calculated, smoothed'	Description of processing steps that were performed: • *raw*: data were processed from raw data, i.e. the table FRAWPTU was used, not FLEDT or other preprocessed sources • *corrected*: data was corrected for known bias(es). • *uncertainty calculated*: the uncertainty was calculated and added as an additional variable to the table bias corrected: a bias correction was applied to this field • *individually smoothed*: the field was smoothed with a digital filter with a cut-off-frequency f_c = 1/resolution • *GC checks are positive*: ground check correction are within specified limits • *additional GC positive*: deviation observed in 100 % pot are within specifications • *spikes removed*: positive spikes in temperature profile have been removed

[1] CF-1.4: NetCDF Climate and Forecast CF Metadata Convention, Version 1.4, 2009-02-27, [Eaton at al., 2009]

Appendix D GRUAN stations

Table 4: GRUAN stations with several details including GRUAN code and name

Code	Name	Country	Position (Lat/Lon/Alt)	International Name	Operator	WMO
BAR	Barrow	USA	71.32° -156.61° 8 m	North Slope of Alaska (NSA) Barrow Facility	ARM	–
BEL	Beltsville	USA	39.05° -76.88° 53 m	Howard University Beltsville Observation Site	HOWARD	–
BOU	Boulder	USA	39.95° -105.20° 1743 m	National Center for Atmospheric Research - Marshall Field Test Site	GDM (ESRL, NOAA)	–
CAB	Cabauw	Netherlands	51.97° 4.92° 1 m	Cabauw Experimental Site for Atmospheric Research (CESAR)	KNMI	–

Code	Name	Country	Position (Lat/Lon/Alt)	International Name	Operator	WMO
DAR	Darwin	Australia	-12.43° 130.89° 30 m	Tropical Western Pacific (TWP) Darwin Site	ARM	94120 DARWIN
LAU	Lauder	New Zealand	-45.05° 169.68° 370 m	Lauder Atmospheric Research Station	NIWA	–
LIN	Lindenberg	Germany	52.21° 14.12° 110 m	Lindenberg Meteorological Observatory - Richard Aßmann Observatory	DWD	10393 LINDENBERG
MAN	Manus	Papua New Guinea	-2.06° 147.42° 6 m	Tropical Western Pacific (TWP) Manus Site	ARM	–
NAU	Nauru	Nauru	-0.52° 166.92° 7 m	Tropical Western Pacific (TWP) Nauru Site	ARM	91532 NAURU
PAY	Payerne	Switzer-land	46.81° 6.95° 491 m	MeteoSwiss aerological station Payerne	MSWISS	06610 PAYERNE
POT	Potenza	Italy	40.60° 15.72° 720 m	National Research Council - Institute of Methodologies for Environmental Analysis	IMAA (CNR)	–
SGP	Lamont	USA	36.60° -97.49° 320 m	Southern Great Plains (SGP) Central Facility	ARM	–
SOD	Sodankyla	Finland	67.37° 26.63° 179 m	Finnish Meteorological Institute Arctic Research Centre	FMI	02836 SODANKYLÄ
TAT	Tateno	Japan	36.06° 140.13° 31 m	Tateno Aerological Observatory	JMA	47646 TATENO
XIL	Xilinhot	China	43.95° 116.12° 1013 m	Xilinhot National Climate Observation	IMWB	54102 XILINHOT

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