

IRCTR DRIZZLE RADAR

- IDRA -

**DATASET DESCRIPTION DOCUMENT
FOR THE 3TU.DATACENTRE DATASETS**

<IDRA_YYYY-mm-dd_#.nc>

Table of Contents

TABLE OF CONTENTS	I
DOCUMENT STATUS	II
GENERAL OVERVIEW	1
CONTACTS	3
PRINCIPLE INVESTIGATOR (PI)	3
INSTRUMENT DEVELOPER	3
DEPLOYMENT LOCATIONS AND HISTORY	4
NEAR-REAL-TIME DATA PLOTS	5
DATA DESCRIPTION AND EXAMPLES	6
DATA FILE CONTENTS	6
<i>Primary Variables and Expected Uncertainty</i>	10
QUICKLOOK.....	10
SIGNAL PROCESSING	14
DATA QUALITY	15
CLUTTER ECHOES	15
CLUTTER FILTER.....	15
RECEIVER SATURATION	15
ATTENUATION.....	16
MULTITRIP ECHOES	17
SYNCHRONISATION LOSS.....	17
INSTRUMENT DETAILS	18
DETAILED DESCRIPTION	18
<i>Specifications</i>	20
THEORY OF OPERATION	21
CALIBRATION	21
OPERATION AND MAINTENANCE	21
GLOSSARY AND ACRONYMS	22
CITABLE REFERENCES	23
REFERENCES	24

Document Status

<i>status</i>)*	<i>name</i>	<i>organisation</i>	<i>date</i>	<i>signature</i>
<i>prepared</i>	T. Otto	TUD	2010-08-30	

)* *prepared, checked, approved, authorized, accepted.*

<i>document title</i> : DDS for the 3TU.Datacentre datasets <IDRA_YYYY-mm-dd_#.nc>			
<i>document reference id</i> : IDRA_3TU_Datacentre.pdf			
<i>version</i>	<i>author</i>	<i>date</i>	<i>reason for change</i>
0.1	T. Otto	2010-08-30	draft
1.0	T. Otto	2010-09-03	completion of the document

General Overview

This dataset description document provides information for the 3TU.Datacentre datasets

IDRA_yyyy-mm-dd_near_range.nc
IDRA_yyyy-mm-dd_standard_range.nc
IDRA_yyyy-mm-dd_far_range.nc
IDRA_yyyy-mm-dd_quicklook.nc
IDRA_yyyy-mm-dd_HH-MM_raw_data.nc.

IDRA is the TU Delft IRCTR drizzle radar that is located on top of the Cabauw tower, 213 m agl., since October 2007, Figure 1. IDRA is a polarimetric X-band (9.475 GHz, horizontal/vertical polarisations) FMCW radar developed at Delft University of Technology. Its antennas rotate at 1 rpm at a fixed low elevation angle providing plan position indicators (PPI). The radar transmits linear sawtooth frequency modulated sweeps alternately at horizontal and vertical polarisation. The backscattered signal is received simultaneously in an horizontally and a vertically polarised channel.



Figure 1: IDRA on top of the Cabauw tower. IDRA uses two antennas, one for transmit and one for receive.

The central frequency of 9.475 GHz, sensitive receivers with a large dynamic range, and the possibility to adjust the power of the transmitted signal, permit IDRA to monitor the spatial distribution and the temporal evolution of precipitation (from fog and drizzle to heavy convective rain).

<IDRA_yyyy-mm-dd_near_range.nc>, <IDRA_yyyy-mm-dd_standard_range.nc>, and <IDRA_yyyy-mm-dd_far_range.nc> contain a series of PPI's, i.e. full 360° scans in azimuth, of the measured weather radar observables for the corresponding day. Near range comprises a maximum range of 1.5 km with a range resolution of 3 m, standard range a maximum range of 15 km with a range resolution of 30 m, and far range a maximum range of 60 km with a range resolution of 30 m. The weather radar observables contained are the co-polarised reflectivity at horizontal polarisation, the differential reflectivity, the linear depolarisation ratio, the differential phase, the radial Doppler velocity, and the Doppler spectrum width. The reflectivities are not corrected for propagation effects, i.e. attenuation. However, a spectral polarimetric filtering

based on the polarimetric weather radar observables, such as differential reflectivity Z_{dr} and the linear depolarisation ratio LDR , is employed in order to reduce spurious echoes from interferences within the radar system itself, and from clutter.

<IDRA_YYYY-mm-dd_quicklook.nc> contains the information displayed in the quicklook. The quicklook gives an overview over available IDRA data for each day including a classification about the precipitation strength.

<IDRA_YYYY-mm-dd_HH-MM_raw_data.nc> contains raw data (i.e. the A/D converter output) of usually one PPI which corresponds to a measurement of one minute. Also included is a processed noise measurement (with the radar transmitter switched off), and the processed weather radar observables of the raw data.

The datasets are prepared as NetCDF files according to the demands of the CESAR database system. The metadata is compliant with the “netCDF Climate and Forecast Metadata Convention - CF1.4”, see [2] and [3] for further information.

Furthermore, the CESAR data policy applies which can be found online at <http://www.cesar-database.nl>.

Contacts

Principle Investigator (PI)

Name: Tobias Otto
Herman Russchenberg

Address: International Research Centre for Telecommunications and Radar - IRCTR
Delft University of Technology
Mekelweg 4
2628 CD Delft
The Netherlands

Tel.: +31 (0)15 27 87603

Fax: +31 (0) 15 27 84046

E-Mail: t.otto@tudelft.nl

Instrument Developer

Name: Jordi Figueras i Ventura (Instrument Developer)
Fred van der Zwan (Technical staff)
Paul Hakkaart (Technical staff)
Johan Zijderveld (Technical staff)

Address: International Research Centre for Telecommunications and Radar - IRCTR
Delft University of Technology
Mekelweg 4
2628 CD Delft
The Netherlands

Deployment Locations and History

IDRA is a stationary radar system, installed on top of the Cabauw tower. The following list gives an overview when IDRA was installed at the Cabauw tower, and in which periods IDRA was operational (green marker).

- August 2007 Installation of IDRA on top of the Cabauw tower.
- 18-10-2007 First measurement, antenna stationary.
- 05-12-2007 First measurement with rotating antennas.
- 14-12-2007 Installation of the IDRA control computer.
- 26-06-2008 The real-time processing reaches operational status.
- 28-11-2008 IDRA's electronics were removed from the tower to improve the receivers.
- 05-03-2009 IDRA's electronics were re-installed on the tower.
- 27-04-2009 IDRA is fully operational again.
- 09-12-2009 *Signal processing changed*, see Section "Signal Processing" for details.
- 26-12-2009 Mechanical problems with the antenna gear box.

Near-Real-Time Data Plots

Near-real-time data plots of IDRA measurements can be found online at:

<http://ftp.tudelft.nl/TUdelft/irctr-rse/idra/>

Alternatively also on the TU Delft IRCTR homepage:

<http://atmos.irctr.tudelft.nl>

IDRA's near-real-time plots are updated once per minute when the radar is running.

Data Description and Examples

Figure 2 shows an example PPI of a reflectivity measurement of IDRA. The figure shows a squall line passing Cabauw in the evening of the 25th of May 2009. The radar is located in the middle of the plot. The ordinate and the abscissa of this PPI show the range (km) from the radar. The colours represent the co-polarised equivalent reflectivity factor at horizontal polarisation Z_{hh} (dBZ). The reflectivity in linear units ($\text{mm}^6 \cdot \text{m}^{-3}$) is proportional to the backscattered and received power. Using empirically derived Z-R relations, the rain rate might be directly inferred from the reflectivity.

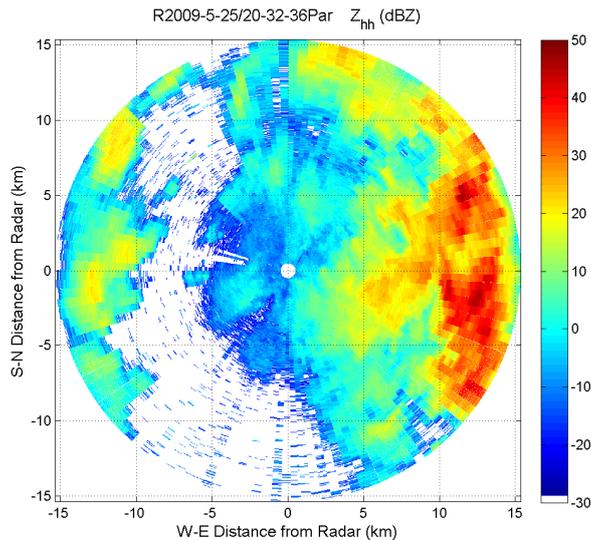


Figure 2: Example of a reflectivity measurement of IDRA.

The data are in polar coordinates to allow further processing on a profile-to-profile basis, e.g. attenuation correction. In irregular intervals, data might be missing. Missing data may indicate that IDRA was not running in the near-range, standard-range or far-range mode but in a different mode, or that IDRA was not running at all. For a query whether missing data is available in a different data acquisition mode for a specific date, please contact the PI.

Data File Contents

Tables 1 to 3 summarise the dimensions, global attributes, and variables contained in the data files. Additional information about the dimensions and variables can also be found directly in the dataset within the corresponding *units* and *comment* attributes.

Table 1: <IDRA_yyyy-mm-dd_near_range.nc>, <IDRA_yyyy-mm-dd_standard_range.nc>, and <IDRA_yyyy-mm-dd_far_range.nc> data file contents.

Dimensions	Description
<i>scalar</i>	dimension used for variables with one value
<i>time</i>	time dimension
<i>range</i>	range dimension
Attributes	Description
global attributes	as specified by [2]
Primary variables	Description
<i>equivalent_reflectivity_factor</i>	co-polarised equivalent reflectivity factor at horizontal polarisation Z_{hh} (dBZ)
<i>differential_reflectivity</i>	differential reflectivity Z_{dr} (dB)
<i>linear_depolarisation_ratio</i>	linear depolarisation ratio LDR (dB)
<i>radial_velocity</i>	Doppler radial velocity v_{hh} (m/s)
<i>spectrum_width</i>	Doppler spectrum width w_{hh} (m/s)
<i>differential_phase</i>	differential phase Ψ_{dp} (rad)
Secondary variables	Description
<i>iso_dataset</i>	contains a copy of the dataset metadata, for more information refer to [2]
<i>product</i>	contains a copy of the product metadata, for more information refer to [2]
<i>station_details</i>	contains metadata describing station details, for more information refer to [2]
<i>azimuth</i>	the azimuth angle of each profile (rad)
<i>quicklook</i>	quicklook information for the file
<i>range_resolution</i>	the resolution along slant range (m)
<i>radiation_wavelength</i>	IDRA's wavelength (m)
<i>frequency_excursion</i>	frequency excursion of the transmitted linear up-chirp (Hz)
<i>sweep_time</i>	sweep time of the transmitted linear up-chirp (μ s)
<i>tx_power</i>	transmitted power (W)
<i>sample_size</i>	number of samples that are averaged for the calculation of one profile
<i>beam_width</i>	antenna half-power beamwidth of the transmit and receive antenna (rad)
<i>elevation</i>	elevation angle of the antennas (rad)

Table 2: <IDRA_yyyy-mm-dd_HH-MM_raw_data.nc> data file contents.

Dimensions	Description
<i>scalar</i>	dimension used for variables with one value
<i>time_raw_data</i>	time dimension for the raw data
<i>sample_beat_signal</i>	sample size of the beat signal for the raw data
<i>time_processed_data</i>	time dimension for the processed data
<i>range</i>	range dimension for the processed data
Attributes	Description
global attributes	as specified by [2]
Primary variables	Description
<i>i_hh</i>	real part (in-phase) of the complex received voltage (beat signal) of the co-polarised echo at horizontal polarisation I_{hh} (A/D counts)
<i>q_hh</i>	imaginary part (quadrature-phase) of the complex received voltage (beat signal) of the co-polarised echo at horizontal polarisation Q_{hh} (A/D counts)
<i>i_vv</i>	real part (in-phase) of the complex received voltage (beat signal) of the co-polarised echo at vertical polarisation I_{vv} (A/D counts)
<i>q_vv</i>	imaginary part (quadrature-phase) of the complex received voltage (beat signal) of the co-polarised echo at vertical polarisation Q_{vv} (A/D counts)
<i>i_vh</i>	real part (in-phase) of the complex received voltage (beat signal) of the cross-polarised echo for transmitted horizontal polarisation I_{vh} (A/D counts)
<i>q_vh</i>	imaginary part (quadrature-phase) of the complex received voltage (beat signal) of the cross-polarised echo for transmitted horizontal polarisation Q_{vh} (A/D counts)
<i>noise_power_horizontal</i>	noise power (W) in the horizontal polarised channel, measured with the transmitter switched off
<i>noise_power_vertical</i>	noise power (W) in the vertical polarised channel, measured with the transmitter switched off
<i>equivalent_reflectivity_factor</i>	co-polarised equivalent reflectivity factor at horizontal polarisation Z_{hh} (dBZ)
<i>differential_reflectivity</i>	differential reflectivity Z_{dr} (dB)
<i>linear_depolarisation_ratio</i>	linear depolarisation ratio LDR (dB)
<i>radial_velocity</i>	Doppler radial velocity v_{hh} (m/s)
<i>spectrum_width</i>	Doppler spectrum width w_{hh} (m/s)
<i>differential_phase</i>	differential phase Ψ_{dp} (rad)
Secondary variables	Description
<i>iso_dataset</i>	contains a copy of the dataset metadata, for more information refer to [2]
<i>product</i>	contains a copy of the product metadata, for more information refer to [2]
<i>station_details</i>	contains metadata describing station details, for more information refer to [2]

<i>azimuth_raw_data</i>	azimuth angle of the raw data (rad)
<i>azimuth_processed_data</i>	azimuth angle of the processed data (rad)
<i>range_resolution</i>	the resolution along slant range (m)
<i>radiation_wavelength</i>	IDRA's wavelength (m)
<i>frequency_excursion</i>	frequency excursion of the transmitted linear up-chirp (Hz)
<i>sweep_time</i>	sweep time of the transmitted linear up-chirp (μ s)
<i>tx_power</i>	transmitted power (W)
<i>sample_size</i>	number of samples that are averaged for the calculation of one profile of processed data and for the noise power
<i>beam_width</i>	antenna half-power beamwidth of the transmit and receive antenna (rad)
<i>elevation</i>	elevation angle of the antennas (rad)

Table 3: <IDRA_yyyy-mm-dd_quicklook.nc> data file contents.

Dimensions	Description
<i>scalar</i>	dimension used for variables with one value
<i>time</i>	time dimension
Attributes	Description
global attributes	as specified by [2]
Primary variables	Description
<i>quicklook</i>	contains the information displayed in the quicklook for the corresponding day, see Section <i>Quicklook</i> for explanation
Secondary variables	Description
<i>iso_dataset</i>	contains a copy of the dataset metadata, for more information refer to [2]
<i>product</i>	contains a copy of the product metadata, for more information refer to [2]

Primary Variables and Expected Uncertainty

The primary variables of the IDRA data files are listed in Table 1-3. Information about expected uncertainties of these measurements can be found in [i]. Some aspects that may deteriorate the quality of the measurements are also outlined in the Section “Data Quality”.

Quicklook

The summary of available IDRA data in the 3TU.Datacentre is provided by quicklooks. One quicklook represents the available IDRA data for one whole day.

Figure 3 shows an example of such a quicklook. Information is provided about the availability of raw data (grey dots), and colour-coded about the availability of near-, standard- and far-range measurements. Additionally, the measurements are also classified in no, weak, moderate or strong rain. For this classification each PPI (one minute of data) was analysed on the whole using a histogram based technique. The quicklook shows the result of this classification in dependence of the time of the day. To retrieve stable classification results, the linear depolarisation ratio LDR is employed in the classification process since it is a good indicator for precipitation.

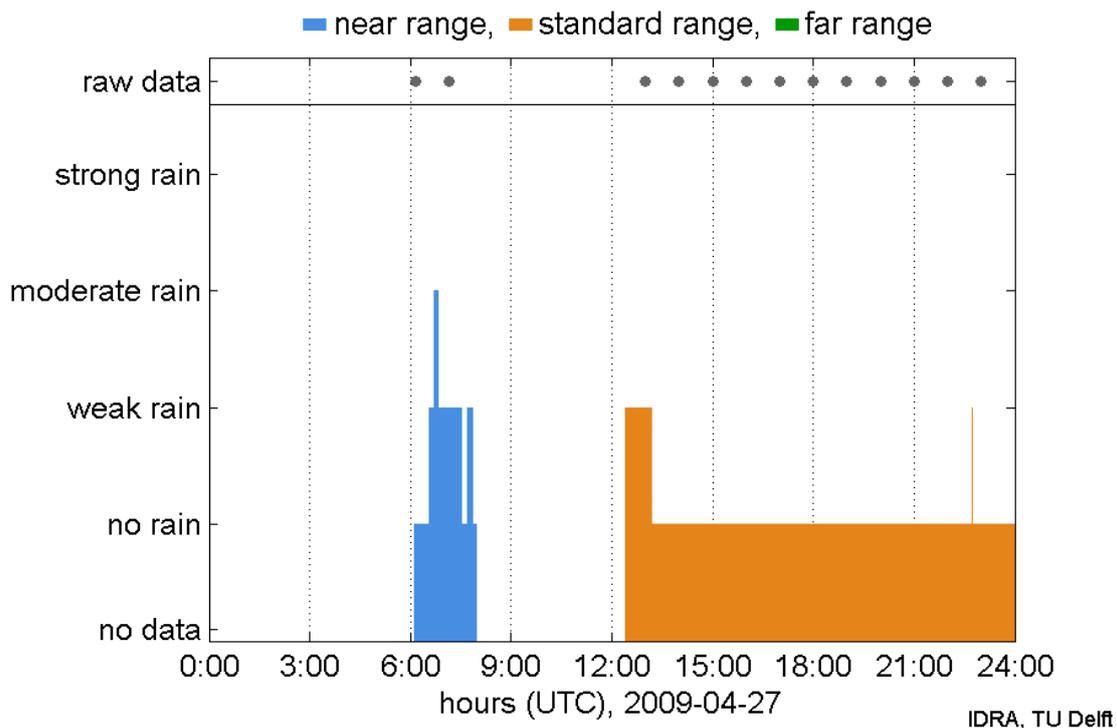


Figure 3: Example of a quicklook.

Table 4 gives an overview of the classes, and the conditions that are employed. Since each PPI is analysed on the whole, the resulting classification does not give an indication of the spatial distribution of the precipitation.

The classification does not provide optimal results in all cases. Especially measurements of very light rain, drizzle or fog may be classified as *no rain* due to the difficulty to distinguish it on a histogram basis from clutter.

Table 4: Classes for the quicklook. A reflectivity of $Z_{hh} = 20$ dBZ corresponds approximately to an instantaneous rain rate of 1 mm/h, and $Z_{hh} = 45$ dBZ corresponds approximately to 25 mm/h.

Class	Conditions
no data	No data available.
no rain	None of the other four classes matches.
weak rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and the conditions for moderate and strong rain do not match
moderate rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and $20 \text{ dBZ} < Z_{hh} \leq 45 \text{ dBZ}$ in more than 5% of the PPI.
strong rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and $Z_{hh} > 45$ dBZ in more than 1% of the PPI.

The following figures give for each class examples of corresponding reflectivity measurements.

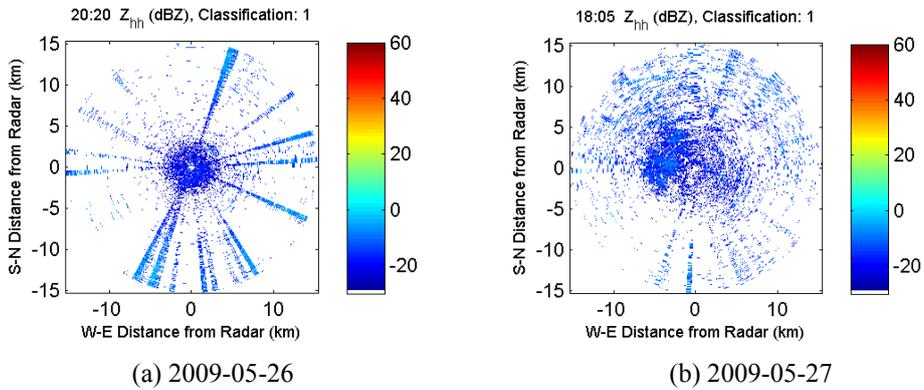


Figure 4: PPI's classified as *no rain*.

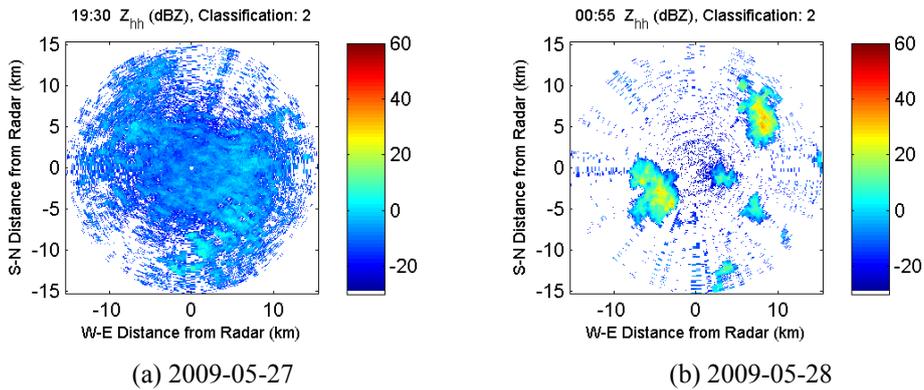


Figure 5: PPI's classified as *weak rain*.

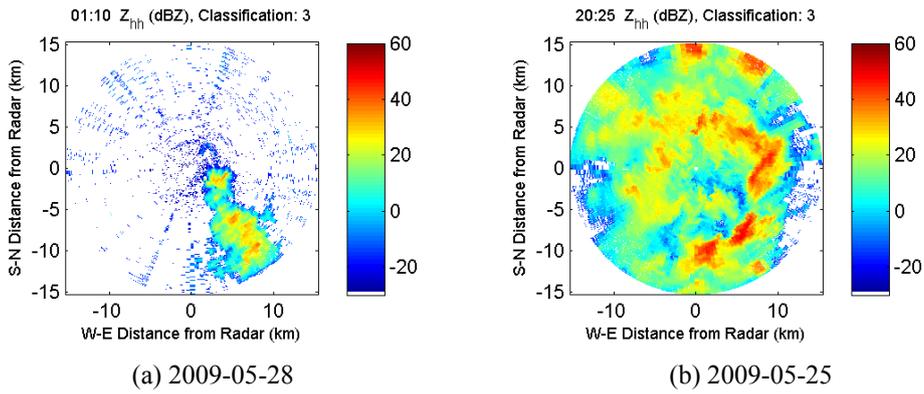


Figure 6: PPI's classified as *moderate rain*.

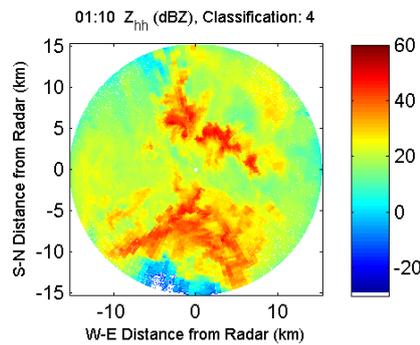


Figure 7: PPI from 2008-08-01 classified as *strong rain*.

The information represented by the quicklook is also contained the data file <IDRA_YYYY-MM-DD_quicklook.nc>. Using this information allows a flexible choice of IDRA data for specific analyses. The primary variable *quicklook* contained in the data file <IDRA_YYYY-MM-DD_quicklook.nc> is of the data type SHORT (16-bit signed integer). The quicklook information is coded according to the specifications in Table 5 to allow logical operations to select desired data.

Table 5: Specification for the primary variable *quicklook* in <IDRA_YYYY-MM-DD_quicklook.nc>.

bit	meaning
0 (lsb)	0 – no IDRA data available 1 – IDRA data available
1	0 – else 1 – <i>near-range data</i> classified as <i>no rain</i>
2	0 – else 1 – <i>near-range data</i> classified as <i>weak rain</i>
3	0 – else 1 – <i>near-range data</i> classified as <i>moderate rain</i>
4	0 – else 1 – <i>near-range data</i> classified as <i>strong rain</i>
5	0 – else 1 – <i>standard-range data</i> classified as <i>no rain</i>
6	0 – else 1 – <i>standard-range data</i> classified as <i>weak rain</i>
7	0 – else 1 – <i>standard-range data</i> classified as <i>moderate rain</i>
8	0 – else 1 – <i>standard-range data</i> classified as <i>strong rain</i>
9	0 – else 1 – <i>far-range data</i> classified as <i>no rain</i>
10	0 – else 1 – <i>far-range data</i> classified as <i>weak rain</i>
11	0 – else 1 – <i>far-range data</i> classified as <i>moderate rain</i>
12	0 – else 1 – <i>far-range data</i> classified as <i>strong rain</i>
13	0 – no raw data available 1 – raw data available
14	not used
15 (msb)	not used

Signal Processing

The real-time signal processing of IDRA is performed in the Doppler domain, and includes several filters to remove spurious interferences and clutter echoes.

For datasets with the version number until the 8th of December 2009, the signal processing comprehends the following steps:

- application of an Hamming window on the received complex voltages, and transformation into the range-Doppler domain by the application of a two-dimensional fast Fourier transform (FFT),
- determination of the power spectra for the co-polarised channels, i.e. linear horizontal and linear vertical polarisation, and for the cross-polarised channel,
- spectral filtering comprising a noise clipping, the application of a notch filter in the Doppler domain to suppress interferences and clutter echoes, and polarimetric filtering in the Doppler domain based on the linear depolarisation ratio, the differential reflectivity, and the differential propagation phase,
- calculation of the co-polarised equivalent reflectivity factor at horizontal polarisation.

Further details on the signal processing for can be found in Section 4.2.7 of [i].

For datasets after the 8th of December 2009, changes have been made to the spectral filtering. The noise clipping level has been reduced from 10 dB to 3 dB. The width of the Doppler notch filter has been reduced. Instead of suppressing Doppler velocities within -0.23 ms^{-1} and $+0.23 \text{ ms}^{-1}$, only Doppler velocities between -0.08 ms^{-1} and 0.08 ms^{-1} are suppressed. The polarimetric filtering is based only on the spectral linear depolarisation ratio, i.e. Doppler bins with $LDR \geq -7 \text{ dB}$ are suppressed. A speckle filter in the Doppler domain has been introduced. If after all the spectral filtering, there are less than 2% of valid Doppler bins per range bin, the range bin is discarded. Further details on the updated signal processing are available as internal documentation at TU Delft IRCTR.

Data Quality

The raw data streams of IDRA are processed in real-time by the radar control computer. Data quality flags are not provided by this data processing. Thus, users of this dataset must be aware of the following issues that might deteriorate the measurements.

Clutter echoes

The signal processing employs a filtering of the polarimetric observables in the Doppler spectrum domain in order to suppress clutter echoes and interferences. However, some clutter and interference signatures are similar to meteorological signatures, and are thus preserved in the processed data. Figure 4 (a) shows an example with some interferences that are perceivable as radial structures along single profiles. The echoes close to the radar in a range of less than 5 km are probably due to insects.

Clutter filter

To suppress clutter echoes and interferences within the radar system, a notch filter in the Doppler domain is employed. Signals with Doppler velocities between -0.23 ms^{-1} and $+0.23 \text{ ms}^{-1}$ are suppressed for datasets until the 8th of December 2009.

For datasets after the 8th of December 2009, the notch filter width has been reduced, suppressed are only Doppler velocities between -0.08 ms^{-1} and 0.08 ms^{-1} .

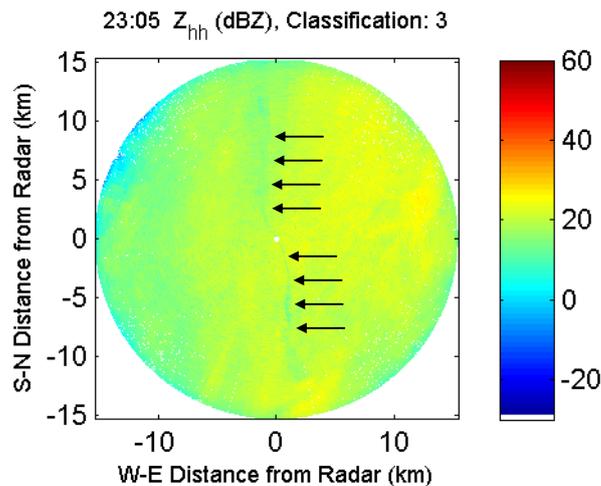


Figure 8: The effect of the clutter filter, 2008-08-03.

This also affects the estimated reflectivity in case when the radial velocity of the parts of the meteorological echo lays within suppressed band of Doppler velocities. The resulting reduction of the reflectivity of the meteorological echo is perceivable in the PPI, see for an example Figure 8.

Receiver Saturation

When the received echo exceeds the dynamic range of the radar receiver, saturation occurs. IDRA is equipped with an attenuator to reduce the transmitted power in these cases. This attenuator is however still not working in real-time. Thus, the data might include receiver saturation effects that due to the nature of a FMCW radar results in a smearing effect in range.

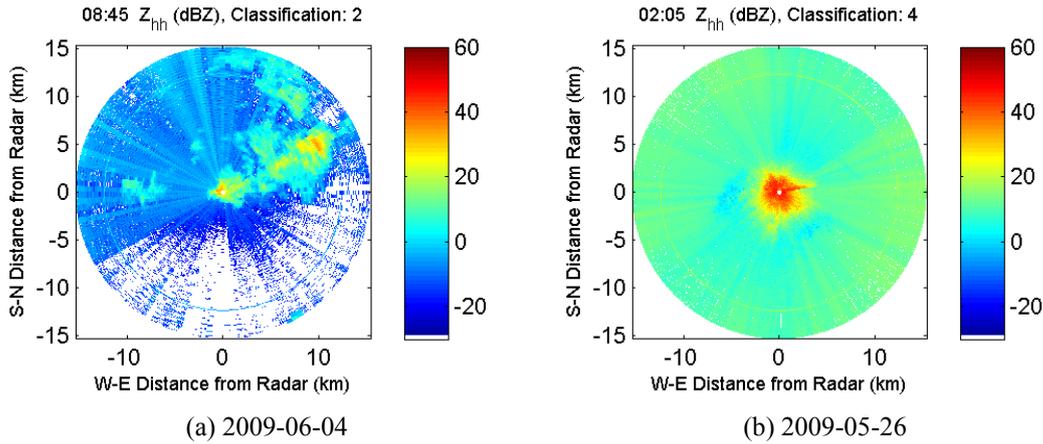


Figure 9: The effect of receiver saturation on reflectivity measurements.

Figure 9 as well as Figure 7 show examples of receiver saturation. Figure 9 (a) shows a case of weak receiver saturation that did not affect all azimuth angles. Instead, Figure 9 (b) shows a case of very strong receiver saturation with the result of a loss of information about the spatial distribution of the precipitation.

Attenuation

It must be stressed again that the reflectivity of this dataset is not corrected for attenuation. Since the radar operates at X-band, the attenuation may be quite significant. In strong precipitation events, the attenuation over the range of 15 km may be as large as 6 dB or more. Figure 10 show an example calculation for expected attenuations in dependence of the rain rate and the range. This figure is the result of electromagnetic scattering computations and should only be used as an indicator of possible attenuation levels.

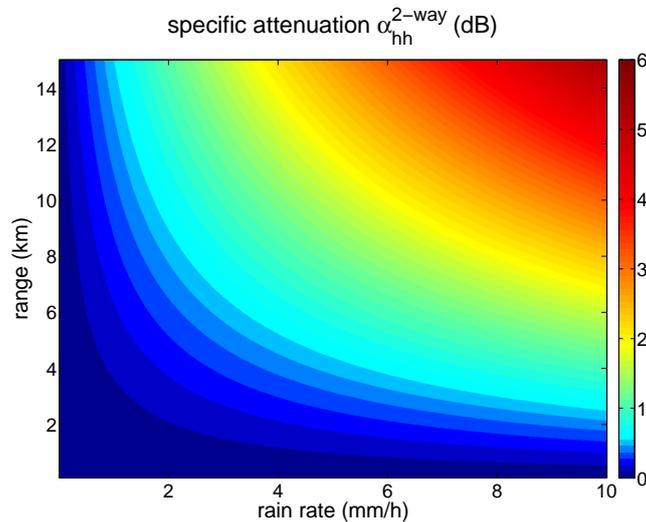


Figure 10: Two-way specific attenuation (dB) at horizontal polarisation assuming a propagation path with a homogeneous rain rate indicated along the abscissa. This figure is a result of an electromagnetic scattering computation for rain assuming the spheroidal raindrop shape model of Pruppacher and Beard, and the exponential raindrop-size distribution of Marshall and Palmer.

Multitrip echoes

In monostatic weather radar observations range aliasing can occur. In that case, the received signal stems from the transmission of an earlier sweep, and is thus designated to a wrong range closer to the radar. These multitrip echoes usually manifest in the PPI as radial reflectivity patterns with a low intensity as shown in Figure 11.

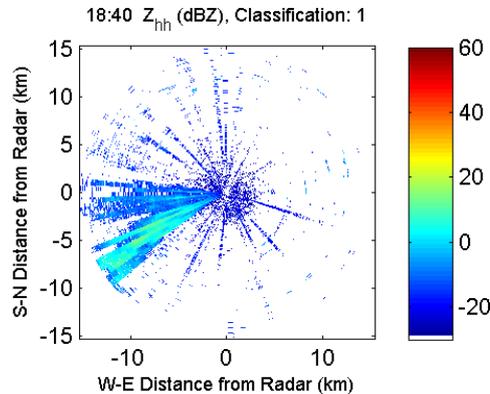


Figure 11: Multitrip echo, 2009-05-25.

PPI's that do not contain an homogeneous precipitation pattern should thus be discarded. Additionally one may also verify the presence of the multitrip echoes by evaluating the data of other instruments, e.g. using the operational weather radar data available online, e.g. at <http://www.buienradar.nl/historie.aspx>.

Synchronisation loss

For reasons that are still under investigation, a synchronisation loss occurs from time to time. This affects the computed weather radar observables. Figure 12 shows an example of such a corrupted reflectivity measurement. As for the multitrip echoes, the PPI does not show an homogeneous precipitation pattern. Such measurements if included in a dataset should be discarded as well.

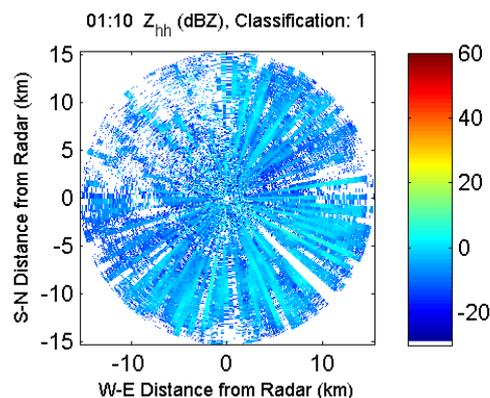


Figure 12: Corrupted IDRA reflectivity measurement due to the loss of synchronisation, 2009-06-04.

Instrument Details

Detailed Description

Figure 13 shows the block diagram of IDRA. The upper part of the figure shows the transmitter path. The lower part shows the co- and the cross-polarised receiver channels.

The synchronisation of the system is provided by a GPS timing board. This GPS timing board is also used to provide an accurate time stamp for the processed data.

For a detailed description of IDRA the reader is referred to [i].

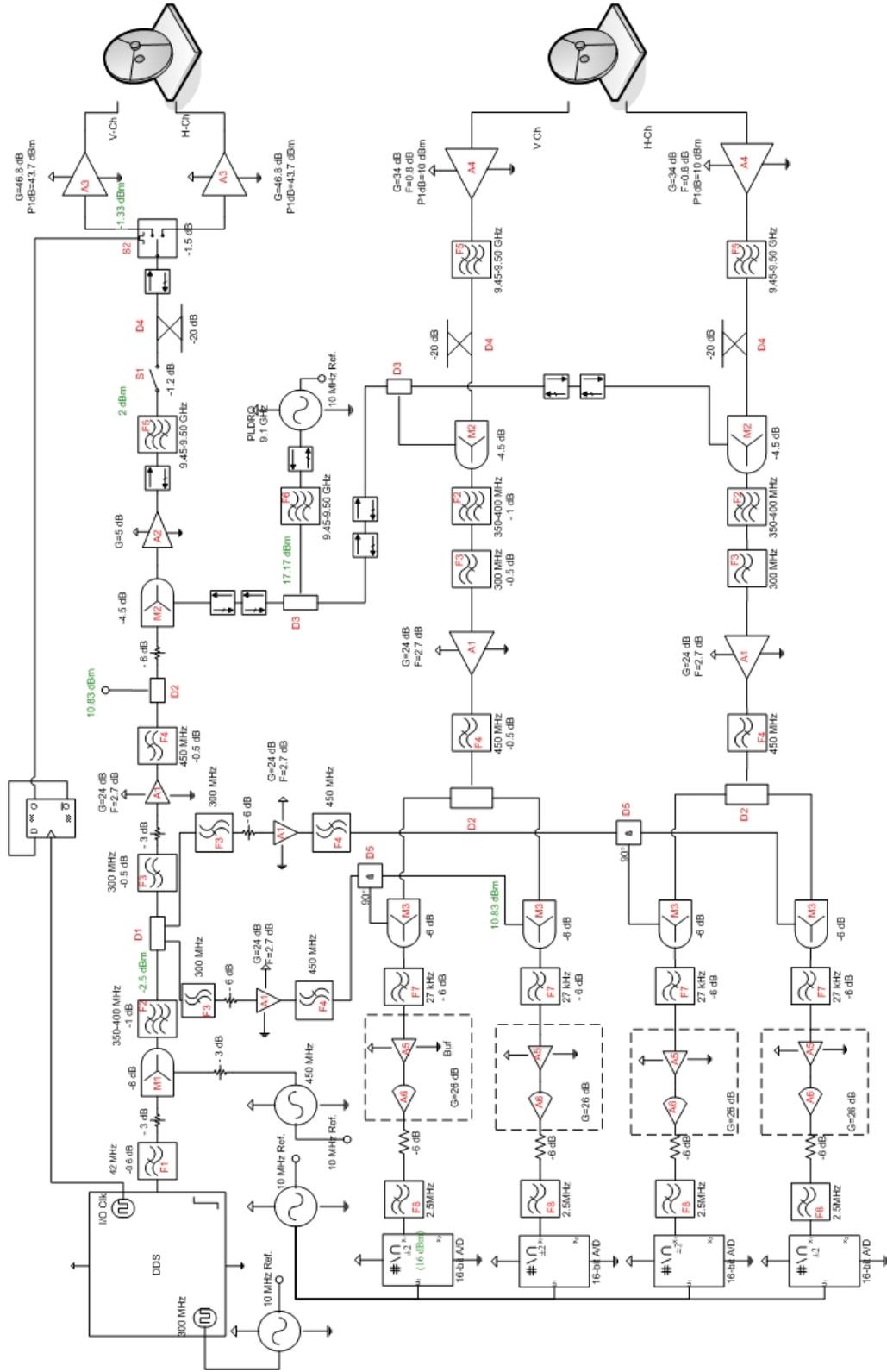


Figure 13: IDRA block diagram showing the transmitter and receiver channels.

Specifications

Table 6: Specifications of IDRA. For the measurements of this dataset, a frequency excursion of 5 MHz and a sweep time of 409.6 μ s is employed.

Parameter	Value	
latitude	51°58'11.92" North	
longitude	04°55'37.16" East	
height above sea-level	213 m agl.	
transmitter	solid-state amplifiers, modulation achieved by a direct digital synthesiser	
polarisation on transmit	linear horizontal, linear vertical, polarimetric (alternately linear horizontal and linear vertical)	
frequency modulation on transmit	sawtooth	
receiver	heterodyne, quadrature receiver, two channels, receiving the co- and the cross-polarised component (linear horizontal and linear vertical polarisation)	
maximum range	15 km in standard mode operation	
cross-polarisation isolation	< -30 dB	
minimum detectable reflectivity	-15 dBZ at 15 km	
dynamic range of the receiver	69 dB	
Parameter	Symbol	Value
central frequency	f_c	9.475 GHz
frequency excursion, the corresponding range resolution is $c/(2 \cdot \Delta f)$	Δf	5, 10, 25, 50 (MHz)
sweep time	ΔT	102.4, 204.8, 409.6 , 819.2, 1683.4, 3276.8 (μ s)
transmitted power	P_t	0, 1, 2, 5, 10, 20 (W)
antenna gain, transmit	G_t	38.65 dB
antenna gain, receive	G_r	38.65 dB
gain of the receiver chain	G_{rec}	53 dB
antenna half-power beamwidth, transmit	θ_t	1.8° (0.031 rad)
antenna half-power beamwidth, receive	θ_r	1.8° (0.031 rad)

Theory of Operation

IDRA employs the frequency-modulated continuous wave radar principle, i.e. the radar is transmitting and receiving at the same time. The frequency of transmitted signal is sawtooth modulated. The backscattered and received echo is shifted in frequency with respect to the transmitted signal. This frequency shift, called the beat frequency, is directly related to the range of the echo.

The beat frequency is evaluated by mixing the transmitted signal with the received signal. Subsequently, a Fourier analysis is performed to separate the contributions from different range bins. The radar equation for distributed targets is then applied to calculate the reflectivity of each range bin.

For a detailed overview of the theory of operation, the reader is referred to [i].

Calibration

After IDRA has been built, extensive measurements have been carried out in order to characterise the system, and to derive the radar system constant necessary for accurate reflectivity measurements. For details about the calibration, the reader is again referred to [i]. In order to sustain the calibration of the system, a noise measurement is performed every day which is used to monitor variations of the receiver gain of IDRA. However, recent analyses of IDRA data revealed a possible calibration offset for reflectivity measurements. Therefore, a novel operational calibration procedure has been devised which is based on the differential phase measurement, [4]. The data files in the 3TU.Datacentre *are not calibrated with this procedure*. However, the data files do contain the necessary data streams that allow the application of this procedure.

In irregular intervals, passive measurements of the sun position is carried out in order to ensure that 0° azimuth corresponds to the Geographic North Pole.

Operation and Maintenance

More information about the operation and the maintenance of IDRA are available as internal documentation at TU Delft IRCTR.

Glossary and Acronyms

A/D	analogue-to-digital
CDS	CESAR database system
CESAR	Cabauw experimental site for atmospheric research
dd	day
DDS	dataset description document
DDS	direct digital synthesizer
FFT	fast Fourier transform
FMCW	frequency-modulated continuous-wave
GPS	global positioning system
HH	hour
IDRA	IRCTR drizzle radar
IRCTR	International Research Centre for Telecommunications and Radar of the Delft University of Technology
LDR	linear depolarisation ratio
lsb	least significant bit
MDD	metadata description document
mm	month
MM	minute
msb	most significant bit
PI	principle investigator
PPI	plan position indicator
yyyy	year
X-band	electromagnetic frequency band from 8 GHz to 12 GHz

Citable References

- [i] J. Figueras i Ventura: “Design of a High Resolution X-band Doppler Polarimetric Weather Radar”, *PhD Thesis*, TU Delft, 2009.
Available online at the institutional repository of TU Delft:
<http://repository.tudelft.nl/view/ir/uuid%3Ad90b9ad6-237b-435d-9dc5-5660d9e7fbdd/>
- [ii] J. Figueras i Ventura and H. W. J. Russchenberg: “Towards a better understanding of the impact of anthropogenic aerosols in the hydrological cycle: IDRA, IRCTR drizzle radar”, *Phys. Chem. Earth, Parts A/B/C*, vol. **34**, pp. 88 – 92.

References

- [1] R. J. Doviak and D. S. Zrnić: “Doppler Radar and Weather Observations: Second Edition”, *Dover Publications*, 2006.
- [2] H. Klein Baltink: “Cesar Database System – Metadata Description Document”, v0.7, KNMI, October 2007.
- [3] H. Klein Baltink: “Cesar Database System – Interface Control Document”, v1.4, KNMI, August 2009.
- [4] T. Otto and H. W. J. Russchenberg: “Estimation of specific differential phase and differential backscatter phase from polarimetric weather radar measurements”, *IEEE Geosci. Remote Sens. Lett.*, submitted, 2010.