Ocean Rainfall And Ice-phase precipitation measurement Network

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Abstract

OceanRAIN—the Ocean Rainfall And Ice-phase precipitation measurement Network—provides in-situ along-track shipboard data of precipitation, evaporation and the resulting freshwater flux in 1-min resolution over the global oceans. All routinely measured atmospheric and oceanographic state variables along with those required to derive the turbulent heat fluxes are included.

The precipitation parameter is based on measurements from the optical disdrometer ODM470 that is specifically designed for all-weather shipboard operation. The rain, snow and mixed-phase precipitation occurrence, intensity and accumulation are derived from particle size distributions (PSD). Additionally, microphysical parameters and radar-related parameters are provided.

The products are available as water cycle components (OceanRAIN-W) continuous in time, precipitation microphysical (OceanRAIN-M) and disdrometer raw data (OceanRAIN-R) both discontinuous in time. OceanRAIN Version 1.0 contains 73 parameters plus PSD data in 128 size bins. The time period from 06/2010 to 04/2017 comprises more than 6.83 million minutes of data from eight ships with precipitation observed in about 10% of the time. The research vessels sail the global oceans during all seasons, avoiding the fair-weather bias and thus covering the entire spectrum of weather events.

OceanRAIN provides in-situ water cycle surface reference data for satellite product validation and retrieval calibration of the GPM (Global Precipitation Measurement) era, to analyze the point-to-area representativeness of precipitation and to improve our understanding of water cycle processes over the global oceans. Moreover, the data can be applied to evaluate re-analysis and climate model data.

The data set is funded by Initiative Pro Klima (www.initiativeproklima.de), the CliSAP excellence cluster at the University of Hamburg and the Max Planck Institute for Meteorology in Hamburg, Germany. More information on OceanRAIN data, instrumentation and the processing chain are available via www.oceanrain.org.

The OceanRAIN 1.0 dataset is available through the World Data Center for Climate (WDCC), https://www.dkrz.de/daten-en/wdcc/wdcc/, the Integrated Climate Data Center (ICDC), https://icdc.zmaw.de/ for DOI publication and via www.oceanrain.org.

The OceanRAIN version 1.0 database contains three data subsets in NetCDF and Ascii formats:

- **OceanRAIN-W**: Water cycle components, 75 parameters, 8 ships, 6.8 million minutes, temporally continuous, minute-resolution

- **OceanRAIN-M**: Number Concentration Particle Size Distribution and Precipitation Microphysics, 38 parameters, 8 ships, 692.000 precipitation minutes , temporally discontinuous, minute-resolution

- **OceanRAIN-R**: ODM470 Raw Data Particle Size Distribution and Precipitation Microphysics, 38 parameters, 8 ships, 692.000 precipitation minutes, temporally discontinuous, minute-resolution

A data descriptor paper is in final preparation. For more technical detail on instrumentation please refer to

Klepp**,** C., 2015: The **Oceanic Shipboard Precipitation Measurement Network for Surface Validation – OceanRAIN**. Atmos. Res., Special issue of the International Precipitation Working Group (IPWG), 163, 74-90, doi: 10.1016/j.atmosres.2014.12.014.

Burdanowitz, J., Klepp, C., and Bakan, S.: An **automatic precipitation-phase distinction algorithm** for optical disdrometer data over the global ocean, Atmos. Meas. Tech., 9, 1637-1652, doi:10.5194/amt-9-1637-2016, 2016.

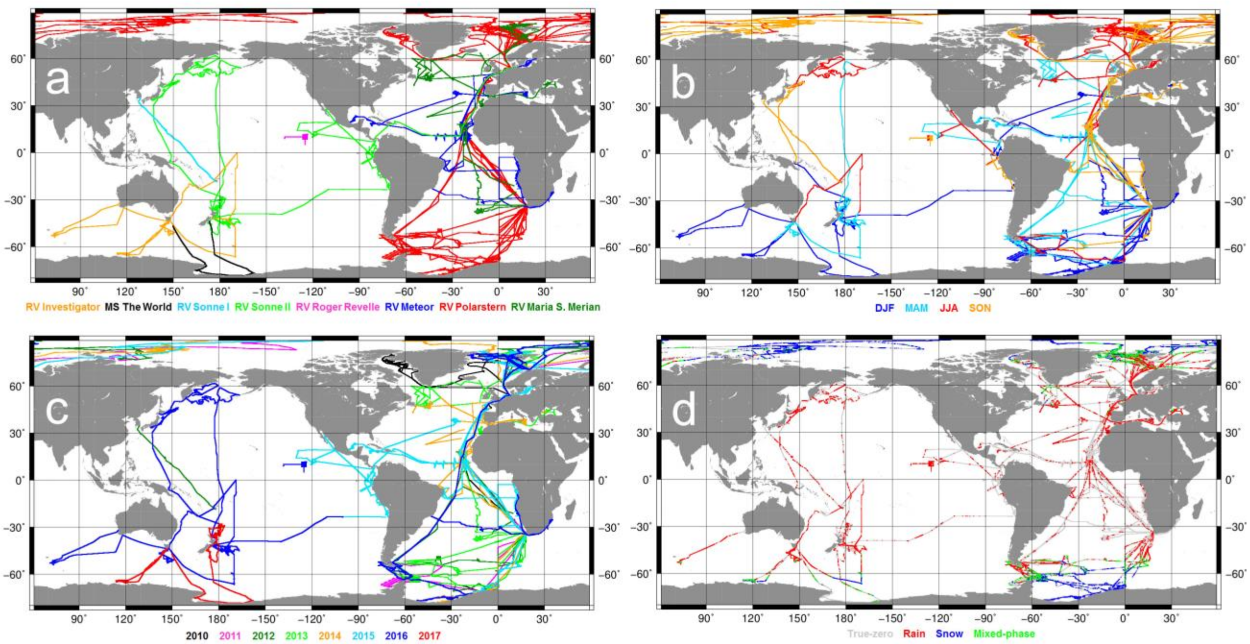

Fig.1: OceanRAIN data distribution for 8 ships (a), seasons (b), years (c) and precipitation occurrence for type (rain, snow mixed) and true-zeros (d).

Table 1: Overview of the OceanRAIN ship fleet, time period, oceans covered and sampling for all parameters and precipitation occurrence. The data files are separated for each ship and contain the ship name and ship identifier.

ship name	ship identifier	country	time period covered	main ocean basins covered	minutes in database	minutes with precipitation
RV Polarstern	DBLK	Germany	Jun2010—Oct2016	Atlantic	3.264.480	446.006
RV Meteor	DBBH	Germany	Mar2014—Mar2016	Atlantic	1.058.400	20.300
RV Maria S. Merian	DBBT	Germany	Oct2012—Jun2014	Atlantic	856.229	90.648
RV Sonne1	DFCG	Germany	Sep2012—Oct2012	Pacific	36.000	4.574
RV Sonne2	DBBE	Germany	Nov2014—Apr2017	Pacific	1.245.598	60.196
RV Investigator	VLMJ	Australia	Jan2016—Feb2017	Southern Ocean	303.144	54.814
RV Roger Revelle	KAOU	USA	Aug2016-Sep2016	Pacific	37.439	10.769
MS The World	C6RW4	Nassau	Jan2017-Feb2017	Southern Ocean	29.081	4.897
sum of all ships	**----**	**----**	**Jun2010—Apr2017**	**worldwide**	**6.830.371**	**692.204**

Table 2: OceanRAIN-W Water Cycle Components: 73 parameters, temporally continuous, minute-resolution. Contains the along-track precipitation P (rain, snow, mixed), evaporation E and the resulting freshwater flux (E-P). Moreover, the dataset contains all relevant Gamma distribution parameters and reflectivities for different radar frequencies.

# Parameter description OceanRAIN-W	NAME	Error value	Unit	Data source	Format Algorithm Metadata
01 counter	COUNT	fill in all	[ ]	calculated	
02 date UT	DATE		UTC	NAV	DDMOYYYY
03 time UT	TIME		UTC	NAV	HHMM
04 date local	LDATE		LT	calculated	DDMOYYYY
05 time local	LTIME		LT	calculated	HHMM
06 minute of day UT	MDAY		[ ]	calculated	1 to 1440
07 Julian date	JLD		days	calculated	since 01JAN1994 00 UTC = 2449353.5
08 Unix epoch timestamp	USEC		s	calculated	seconds since 01 JAN 1970, 00 UTC
09 latitude	LAT	-99.9999	deg	NAV	degree north from -90 to 90°
10 longitude	LON	-999.9999	deg	NAV	degree east from -180° to 180°
11 heading	HEAD	-99.9	deg	NAV	0° to 360°
12 air temperature	TAIR	-99.9	°C	MET	
13 dewpoint temperature	TDEW	-99.9	°C	calculated	
14 bulk water temperature	WATER	-99.9	°C	MET	
15 sea surface temperature	SST	-99.9	°C	calculated	after Donlon/Fairall COARE Bulk Flux
16 relative humidity	RH	-99	%	MET	
17 specific humidity at sea surface	QS	-9.9	g/kg	calculated	after Murphy/Coop
18 specific air humidity	QA	-9.9	g/kg	calculated	after Murphy/Coop
19 air pressure	MSLP	-999.9	hPa	MET	at instrument height
20 relative wind speed	UREL	-9.9	m/s	MET	
21 relative wind direction	RELDIR	-99	deg	MET	
22 true wind speed	UTRUE	-9.9	m/s	MET	
23 true wind direction	TRUEDIR	-99	deg	MET	
24 wind speed in 10 m height	U10	-9.9	m/s	calculated	using log. wind profile
25 global radiation	GLORAD	-999.9	W/m2	MET	
26 visibility	VIS	-9999	m	MET	
27 ceiling	CEIL	-99999	m	MET	
28 max gusts	UMAX	-99.9	m/s	MET	
29 salinity	SAL	-99.99	PSU	MET	
30 drag transfer coefficient	CD	-99.9	[ ]	calculated	after Donlon/Fairall COARE Bulk Flux
31 latent heat transfer coefficient	CE	-99.9	[ ]	calculated	after Donlon/Fairall COARE Bulk Flux
32 sensible heat transfer coefficient	CH	-99.9	[ ]	calculated	after Donlon/Fairall COARE Bulk Flux
33 warm layer flag	WLF	3	[ ]	calculated	after Donlon/Fairall COARE Bulk Flux

34 sensible heat flux	SHF	-9999	W/m2	calculated	after Donlon/Fairall COARE Bulk Flux
35 latent heat flux	LHF	-9999	W/m2	calculated	after Donlon/Fairall COARE Bulk Flux
36 evaporation E	EVAP	-999	mm/h	calculated	after Donlon/Fairall COARE Bulk Flux
37 freshwater budget E-P	BUDG	-999	mm/h	calculated	E-P, difference of E and P
38 rain gauge precipitation rate	GAUGE	-99.99	mm/h	MET	
39 ww present weather code	WW	-99	[ ]	SYN	human weather type observation
40 W1 past weather code	W1	-99	[ ]	SYN	human weather type observation
41 W2 past weather code	W2	-99	[ ]	SYN	human weather type observation
42 99th percentile particle diameter	PERC	-999.99	mm	calculated	
43 theoretical rain rate disdrometer	TRAIN	-99.99	mm/h	calculated	either #43 or #44 is identical to #52
44 theoretical snow rate disdrometer	TSNOW	-99.99	mm/h	calculated	either #43 or #44 is identical to #52
45 probability for rain	PRAIN	-999.99	[ ]	calculated	value range 0.00 to 1.00
46 probability for snow	PSNOW	-999.99	[ ]	calculated	value range 0.00 to 1.00
47 probability for mixed-phase	PMIX	-999.99	[ ]	calculated	value range 0.00 to 1.00
48 precipitation flag1	FLAG1	9	[ ]	calculated	precipitation type and instrument status identifier, values range 0 to 5, see table
49 precipitation flag2	FLAG2	99	[ ]	calculated	precipitation classification, values range 10-17, see table
50 number of bins	BINS	-99	[ ]	ODM	total number of bins allocated per minute
51 number of particles	NUMS	-9999	[ ]	ODM	total number of particles per minute
52 ODM precipitation rate R	PRECIP	-99.99	mm/h	calculated	according to #42-48
53 Rayleigh reflectivity Z	REFL	-99.99	mm^6/m^3	calculated	
54 10 log R	DBR	-99.99	dBR	calculated	
55 10 log Z	DBZ	-99.99	dBZ	calculated	
56 relative wind speed	ODMREL	-88.88 flag 3 -99.99 flag 4,5	m/s	ODM	
57 reference voltage	UREF	-88.88 flag 3 -99.99 flag 4,5	V	ODM	
58 convective=1 /stratiform=0 index	CONV	-9	[ ]	calculated	Adapted from Thurai et al. (2010, JAOT): Stratiform if No* < -1.65 * Dm + 6.35 Convective otherwise
59 Intercept of normalized gamma DSD	No*	-999.00	$mm^{-1}\ m^{-3}$	calculated	Normalized gamma distribution reference: Testud et al. (2001, JAM)
60 mass-weighted mean diameter of normalized gamma DSD	Dm	-999.00	mm	calculated	See Testud et al. (2001, JAM)
61 shape parameter of normalized gamma DSD	mu	-999.00	[ ]	calculated	See Testud et al. (2001, JAM)
62 median volume diameter of normalized gamma DSD	D0	-999.00	mm	calculated	See Testud et al. (2001, JAM)

63 DSD mass spectrum standard deviation	sigmam	-999.00	mm	calculated	Williams et al. (2014, JAMC)
64 Intercept parameter of a standard gamma DSD	N0	-999.00	mm^{-1} m^{-3}	calculated	e.g., Tokay and Short (1996, JAM)
65 T-matrix simulation of C-band reflectivity from DSD	DBZ_C	-999.00	dBZ	calculated	T-matrix simulations using pyTmatrix
66 T-matrix simulation of C-band differential reflectivity from DSD	ZDR_C	-999.00	dB	calculated	using pyTmatrix
67 T-matrix simulation of C-band specific differential phase from DSD	KDP_C	-999.00	deg/km	calculated	using pyTmatrix
68 T-matrix simulation of Ku-band reflectivity from DSD	DBZ_Ku	-999.00	dBZ	calculated	using pyTmatrix
69 T-matrix simulation of Ku-band differential reflectivity from DSD	ZDR_Ku	-999.00	dB	calculated	using pyTmatrix
70 T-matrix simulation of Ku-band specific differential phase from DSD	KDP_Ku	-999.00	deg/km	calculated	using pyTmatrix
71 T-matrix simulation of Ka-band reflectivity from DSD	DBZ_Ka	-999.00	dBZ	calculated	using pyTmatrix
72 T-matrix simulation of Ka-band differential reflectivity from DSD	ZDR_Ka	-999.00	dB	calculated	using pyTmatrix
73 T-matrix simulation of Ka-band specific differential phase from DSD	KDP_Ka	-999.00	deg/km	calculated	using pyTmatrix

Table 3: OceanRAIN-M number concentration particle size distributions (m^{-3} mm^{-1}) and precipitation microphysics and OceanRAIN-R raw particle count particle size distributions and precipitation microphysics - OceanRAIN-R both contain 37 temporally discontinuous parameters in minute-resolution for precipitation events only plus 128 values for the particle size distributions. The first line is a header containing the log-scale 128 bin size centers in mm. The OceanRAIN–M and OceanRAIN–R files differ in having either number concentration PSDs (-M) or the raw spectra number count PSD (-R).

# Parameter description **OceanRAIN-M** **OceanRAIN-R**	**NAME**	**Error value**	**Unit**	**Data source**	**Format** **Algorithm** **Metadata**
01 counter	COUNT	fill in all	[ ]	calculated	
02 date UT	DATE		UTC	NAV	DDMOYYYY
03 time UT	TIME		UTC	NAV	HHMM
04 minute of day UT	MDAY		[ ]	calculated	1 to 1440
05 Julian date	JLD		days	calculated	since 01JAN1994 00 UTC = 2449353.5
06 Unix epoch timestamp	USEC		s	calculated	seconds since 01 JAN 1970, 00 UTC
07 latitude	LAT	-99.9999	deg	NAV	degree north from -90 to 90°
08 longitude	LON	-999.9999	deg	NAV	degree east from -180° to 180°
09 probability for rain	PRAIN	-999.99	[ ]	calculated	value range 0.00 to 1.00
10 probability for snow	PSNOW	-999.99	[ ]	calculated	value range 0.00 to 1.00

11 probability for mixed-phase	PMIX	-999.99	[ ]	calculated	value range 0.00 to 1.00
12 precipitation flag1	FLAG1	9	[ ]	calculated	precipitation type and instrument status identifier, values range 0 to 5, see table
13 precipitation flag2	FLAG2	99	[ ]	calculated	precipitation classification, values range 10-17, see table
14 number of bins	BINS	-99	[ ]	ODM	total number of bins allocated per minute
15 number of particles	NUMS	-9999	[ ]	ODM	total number of particles per minute
16 ODM470 precipitation rate R	PRECIP	-99.99	mm/h	calculated	according to #09 to #12
17 Rayleigh reflectivity Z	REFL	-99.99	mm^6/m^3	calculated	
18 10 log R	DBR	-99.99	dBR	calculated	
19 10 log Z	DBZ	-99.99	dBZ	calculated	
20 relative wind speed	ODMREL	-88.88 flag 3 -99.99 flag 4,5	m/s	ODM	ODM470 measurement
21 reference voltage	UREF	-88.88 flag 3 -99.99 flag 4,5	V	ODM	ODM470 measurement
22 convective=1 /stratiform=0 index	CONV	-9	[ ]	calculated	Adapted from Thurai et al. (2010, JAOT): Stratiform if No* < -1.65 * Dm + 6.35 Convective otherwise
23 Intercept of normalized gamma DSD	No*	-999.00	$mm^{-1} m^{-3}$	calculated	Normalized gamma distribution reference: Testud et al. (2001, JAM)
24 mass-weighted mean diameter of normalized gamma DSD	Dm	-999.00	mm	calculated	See Testud et al. (2001, JAM)
25 shape parameter of normalized gamma DSD	mu	-999.00	[ ]	calculated	See Testud et al. (2001, JAM)
26 median volume diameter of normalized gamma DSD	D0	-999.00	mm	calculated	See Testud et al. (2001, JAM)
27 DSD mass spectrum standard deviation	sigmam	-999.00	mm	calculated	Williams et al. (2014, JAMC)
28 Intercept parameter of a standard gamma DSD	N0	-999.00	$mm^{-1} m^{-3}$	calculated	e.g., Tokay and Short (1996, JAM)
29 T-matrix simulation of C-band reflectivity from DSD	DBZ_C	-999.00	dBZ	calculated	T-matrix simulations using pyTmatrix
30 T-matrix simulation of C-band differential reflectivity from DSD	ZDR_C	-999.00	dB	calculated	using pyTmatrix
31 T-matrix simulation of C-band specific differential phase from DSD	KDP_C	-999.00	deg/km	calculated	using pyTmatrix
32 T-matrix simulation of Ku-band reflectivity from DSD	DBZ_Ku	-999.00	dBZ	calculated	using pyTmatrix
33 T-matrix simulation of Ku-band differential reflectivity from DSD	ZDR_Ku	-999.00	dB	calculated	using pyTmatrix
34 T-matrix simulation of Ku-band specific differential phase from DSD	KDP_Ku	-999.00	deg/km	calculated	using pyTmatrix

35 T-matrix simulation of Ka-band reflectivity from DSD	DBZ_Ka	-999.00	dBZ	calculated	using pyTmatrix
36 T-matrix simulation of Ka-band differential reflectivity from DSD	ZDR_Ka	-999.00	dB	calculated	using pyTmatrix
37 T-matrix simulation of Ka-band specific differential phase from DSD	KDP_Ka	-999.00	deg/km	calculated	using pyTmatrix
38-165: 128times number concentration PSD	PSD	----------	1/m**3 1/mm	calculated	OceanRAIN-M
38-165: 128times raw particle count PSD	RAW	----------	n	ODM	OceanRAIN-R

Table 4: OceanRAIN flag1 convention for the ODM470 precipitation parameter.

Flag1	precipitation phase and ODM instrument condition
0	rainfall occurrence
1	snowfall occurrence
2	mixed-phase precipitation occurrence
3	true-zero value, no precipitation occurrence
4	inoperative instrument, no ODM data recorded
5	harbor time, no data recorded
9	missing value

Table 5: OceanRAIN flag2 convention for the ODM precipitation parameter.

Flag1	classification	metadata
10	true-zero value	note, if bins and nums ne.0, minute was identified as electronic artefact minute and values were set to zero
11	spurious/unknown	if number of bins lt.5 and number of particles lt.20, decision left up to the user if that is precipitation or not. Rates are insignificant or zero. Could be also vibration of the instrument or artifacts. But a good part of that data could be real precipitation with just few drops
12	precipitation occurrence	eq. 0.00 mm/h These are minutes with precipitation, but rates are still zero due to very low intensity
13	precipitation occurrence	0.01 to 0.09 mm/h, very low precip rates, below what gauges can measure
14	precipitation occurrence	0.1 to 0.99 mm/h, precipitation that gauges are able to measure as well
15	precipitation occurrence	1.00 to 9.99 mm/h, contains low to moderate stratiform and convective precipitation
16	precipitation	10.00 to 49.99 mm/h, intense and convective precipitation

	occurrence	
17	precipitation occurrence	> 50 mm/h, extreme precipitation from convective events
99	missing value	missing data

Table 6: OceanRAIN warm layer flag convention.

0	no significant warm layer
1	u10 < 2 m/s
2	u10 < 6 m/s and global radiation > 50 W/m^2

Table 7: OceanRAIN metadata for instruments installation heights (m) for the derivation of the COARE Bulk Flux parameters and the evaporation.

ship name	wind speed	air temperature relative humidity	water temperature at depth	precipitation
RV Polarstern	39.0	29.0	5.0	39.0
RV Meteor	37.5	37.5	2.5	37.5
RV Maria S Merian	30.8	20.2	4.2	20.2
RV SonneI				
RV SonneII	34.0	27.0	2.0	27.0
RV Investigator	22.1	31.4	6.9	31.4
RV Roger Revelle	18.0	16.5	0.05	10.0