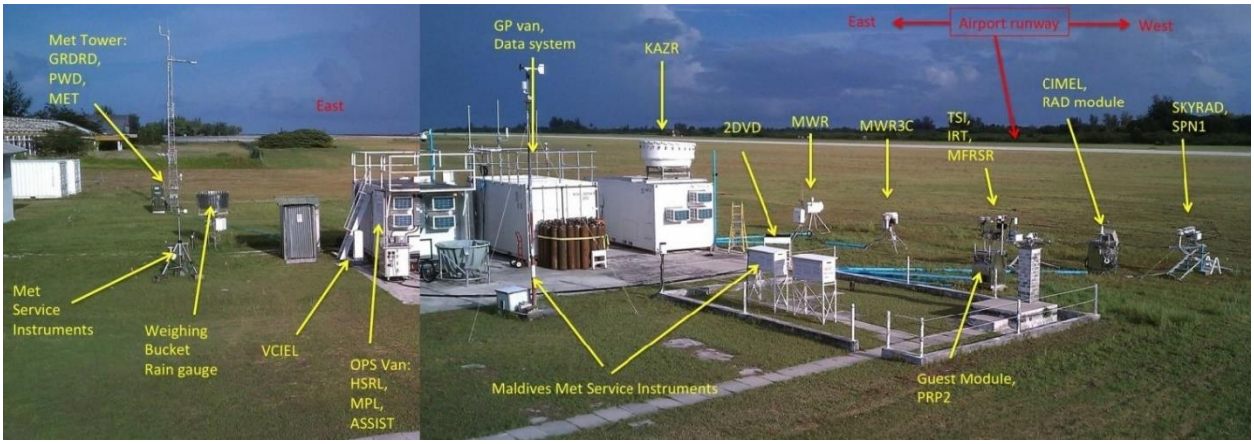
Gan, Addu Atoll, Maldives AMF-2 Surface Meteorology Data



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1. Data Set Overview:

The overarching campaign, which included the second ARM Mobile Facility (AMF2) deployment in conjunction with the DYNAMO and CINDY2011 campaigns, was designed to test several current hypotheses regarding the mechanisms responsible for MJO (Madden-Julian Oscillation) initiation and propagation in the Indian Ocean area. The synergy between the proposed AMF2 deployment with DYNAMO/CINDY2011, and the corresponding funded experiment on Manus, combine for an overarching ARM MJO Investigation Experiment (AMIE) with two components: AMF2 on Gan Island, Maldives (AMIE-Gan) where the MJO initiates and starts its eastward propagation, and the Manus ARM site (AMIE-Manus) which is in the general area where the MJO usually starts to weaken in climate models. AMIE-Gan provided measurements of particular interest to Atmospheric System Research scientists relevant to improving the representation of MJO initiation in climate models. The framework of DYNAMO/CINDY2011 included two proposed island-based sites, and two ship-based locations forming a square pattern with sonde profiles and scanning precipitation and cloud radars at both island and ship sites. These data were used to produce a variational analysis data set coinciding with the one produced for AMIE-Manus. The synergy between AMIE-Manus and AMIE-Gan allowed studies of the initiation, propagation, and evolution of the convective cloud population within the framework of the MJO. As with AMIE-Manus, AMIE-Gan/DYNAMO also included a significant modeling component geared toward improving the representation of MJO initiation and propagation in climate and forecasting models.

The ARM Mobile Facilities consist of several portable shelters, a baseline suite of instruments, communications, and data systems. When deployed for a field campaign, an experienced project management and engineering team travels with the AMF to set up and modify the shelters and instruments, and train and manage staff who continuously operate the facilities.

AMF-2 was originally planned to operate until 31 March 2012, but it ended abruptly on 9 February due to a political coup in the Maldives.

Time period: 1 October 2011 – 9 February 2012.

Physical location: Gan Island, Addu Atoll, Maldives. 0° 41’ 25.3248” S, 73° 9’ 0.36” E.

Data source: AMFs have instrumentation and data systems similar to the fixed atmospheric observatories, and about 50 instruments are deployed with each facility to obtain continuous measurements of clouds, aerosols, precipitation, energy, and other meteorological variables. Measurement capabilities of the AMFs include standard meteorological instrumentation, a broadband and spectral radiometer suite, and remote-sensing measurements including lidars and cloud radars. Instrumentation for AMF2 is, with a few notable exceptions, the same as used by AMF1 and AMF3. Because AMF2 was designed to support shipboard deployments, the baseline suite of instruments are marine-focused.

2. Instrument Description

The ARM Surface Meteorology Systems (MET) use mainly conventional in situ sensors to obtain 1-minute statistics of surface wind speed, wind direction, air temperature, relative humidity, barometric pressure, and rain-rate. MET has used the Vaisala HMP45 sensor since 2007. The surface meteorological measurements are reported every minute at an altitude of approximately 1 m. Air temperature measurements are accurate to 0.2°C at 20°C, water vapor mixing ratio (qv) to 0.2 g/kg, wind speeds to

0.1 m/s, and pressure to 0.15 hPa. One-minute rain rate measurements from an optical rain gauge are accurate to 0.1 mm/hr. The relative humidity uncertainty at values between 0% and 90% is ±2%. At values above 90%, the uncertainty is ±3%.

3. Data Collection and Processing

The NetCDF format data were obtained from the DOE ARM site, and no modifications have been made.

4. Data Format

File name convention is **ganmetM1.b1.YYYYMMDD.000000.cdf** where YYYY is the year, MM is the month, and DD is the day of the month. The data are in CF compliant NetCDF format, as indicated below.

```
dimensions:
        time = UNLIMITED ; // (1440 currently)
variables:
        int base_time ;
                base_time:string = "19-Jan-2012,0:00:00 GMT" ;
                base_time:long_name = "Base time in Epoch" ;
                base_time:units = "seconds since 1970-1-1 0:00:00 0:00" ;
        double time_offset(time) ;
                time_offset:long_name = "Time offset from base_time" ;
                time_offset:units = "seconds since 2012-01-19 00:00:00 0:00" ;
        double time(time) ;
                time:long_name = "Time offset from midnight" ;
                time:units = "seconds since 2012-01-19 00:00:00 0:00" ;
        int qc_time(time) ;
                qc_time:long_name = "Quality check results on field: Time offset from
midnight" ;
                qc_time:units = "unitless" ;
                qc_time:description = "This field contains bit packed values which
should be interpreted as listed. No bits set (zero) represents good data." ;
                qc_time:bit_1_description = "Delta time between current and previous
samples is zero." ;
                qc_time:bit_1_assessment = "Indeterminate" ;
                qc_time:bit_2_description = "Delta time between current and previous
samples is less than the delta_t_lower_limit field attribute." ;
                qc_time:bit_2_assessment = "Indeterminate" ;
                qc_time:bit_3_description = "Delta time between current and previous
samples is greater than the delta_t_upper_limit field attribute." ;
                qc_time:bit_3_assessment = "Indeterminate" ;
                qc_time:delta_t_lower_limit = 60. ;
                qc_time:delta_t_upper_limit = 60. ;
                qc_time:prior_sample_flag = 1 ;
                qc_time:comment = "If the \'prior_sample_flag\' is set the first
sample time from a new raw file will be compared against the time just previous to it
in the stored data. If it is not set the qc_time value for the first sample will be
set to 0." ;
        float atmos_pressure(time) ;
                atmos_pressure:long_name = "Atmospheric pressure" ;
                atmos_pressure:units = "kPa" ;
                atmos_pressure:valid_min = 85.f ;
                atmos_pressure:valid_max = 103.f ;
                atmos_pressure:valid_delta = 1.f ;
                atmos_pressure:missing_value = -9999.f ;
        int qc_atmos_pressure(time) ;
                qc_atmos_pressure:long_name = "Quality check results on field:
Atmospheric pressure" ;
                qc_atmos_pressure:units = "unitless" ;
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                qc_atmos_pressure:description = "See global attributes for individual
bit descriptions." ;
        float temp_mean(time) ;
                temp_mean:long_name = "Temperature mean" ;
                temp_mean:units = "C" ;
                temp_mean:valid_min = 0.f ;
                temp_mean:valid_max = 50.f ;
                temp_mean:valid_delta = 20.f ;
                temp_mean:missing_value = -9999.f ;
        int qc_temp_mean(time) ;
                qc_temp_mean:long_name = "Quality check results on field: Temperature
mean" ;
                qc_temp_mean:units = "unitless" ;
                qc_temp_mean:description = "See global attributes for individual bit
descriptions." ;
        float temp_std(time) ;
                temp_std:long_name = "Temperature standard deviation" ;
                temp_std:units = "C" ;
        float rh_mean(time) ;
                rh_mean:long_name = "Relative humidity mean" ;
                rh_mean:units = "%" ;
                rh_mean:valid_min = 0.f ;
                rh_mean:valid_max = 104.f ;
                rh_mean:valid_delta = 30.f ;
                rh_mean:missing_value = -9999.f ;
        int qc_rh_mean(time) ;
                qc_rh_mean:long_name = "Quality check results on field: Relative
humidity mean" ;
                qc_rh_mean:units = "unitless" ;
                qc_rh_mean:description = "See global attributes for individual bit
descriptions." ;
        float rh_std(time) ;
                rh_std:long_name = "Relative humidity standard deviation" ;
                rh_std:units = "%" ;
        float vapor_pressure_mean(time) ;
                vapor_pressure_mean:long_name = "Vapor pressure mean, calculated" ;
                vapor_pressure_mean:units = "kPa" ;
                vapor_pressure_mean:valid_min = 0.f ;
                vapor_pressure_mean:valid_max = 10.f ;
                vapor_pressure_mean:valid_delta = 1.f ;
                vapor_pressure_mean:missing_value = -9999.f ;
        int qc_vapor_pressure_mean(time) ;
                qc_vapor_pressure_mean:long_name = "Quality check results on field:
Vapor pressure mean, calculated" ;
                qc_vapor_pressure_mean:units = "unitless" ;
                qc_vapor_pressure_mean:description = "See global attributes for
individual bit descriptions." ;
        float vapor_pressure_std(time) ;
                vapor_pressure_std:long_name = "Vapor pressure standard deviation" ;
                vapor_pressure_std:units = "kPa" ;
        float wspd_arith_mean(time) ;
                wspd_arith_mean:long_name = "Wind speed arithmetic mean" ;
                wspd_arith_mean:units = "m/s" ;
                wspd_arith_mean:valid_min = 0.f ;
                wspd_arith_mean:valid_max = 60.f ;
                wspd_arith_mean:valid_delta = 20.f ;
                wspd_arith_mean:missing_value = -9999.f ;
        int qc_wspd_arith_mean(time) ;
                qc_wspd_arith_mean:long_name = "Quality check results on field: Wind
speed arithmetic mean" ;
                qc_wspd_arith_mean:units = "unitless" ;
                qc_wspd_arith_mean:description = "See global attributes for individual
bit descriptions." ;
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        float wspd_vec_mean(time) ;
                wspd_vec_mean:long_name = "Wind speed vector mean" ;
                wspd_vec_mean:units = "m/s" ;
                wspd_vec_mean:valid_min = 0.f ;
                wspd_vec_mean:valid_max = 60.f ;
                wspd_vec_mean:valid_delta = 20.f ;
                wspd_vec_mean:missing_value = -9999.f ;
        int qc_wspd_vec_mean(time) ;
                qc_wspd_vec_mean:long_name = "Quality check results on field: Wind
speed vector mean" ;
                qc_wspd_vec_mean:units = "unitless" ;
                qc_wspd_vec_mean:description = "See global attributes for individual
bit descriptions." ;
        float wdir_vec_mean(time) ;
                wdir_vec_mean:long_name = "Wind direction vector mean" ;
                wdir_vec_mean:units = "deg" ;
                wdir_vec_mean:valid_min = 0.f ;
                wdir_vec_mean:valid_max = 360.f ;
                wdir_vec_mean:missing_value = -9999.f ;
        int qc_wdir_vec_mean(time) ;
                qc_wdir_vec_mean:long_name = "Quality check results on field: Wind
direction vector mean" ;
                qc_wdir_vec_mean:units = "unitless" ;
                qc_wdir_vec_mean:description = "See global attributes for individual
bit descriptions." ;
        float wdir_vec_std(time) ;
                wdir_vec_std:long_name = "Wind direction vector mean standard
deviation" ;
                wdir_vec_std:units = "deg" ;
                wdir_vec_std:missing_value = -9999.f ;
        float org_precip_rate_mean(time) ;
                org_precip_rate_mean:long_name = "ORG precipitation rate mean" ;
                org_precip_rate_mean:units = "mm/hr" ;
                org_precip_rate_mean:valid_min = 0.f ;
                org_precip_rate_mean:valid_max = 500.f ;
                org_precip_rate_mean:missing_value = -9999.f ;
        int qc_org_precip_rate_mean(time) ;
                qc_org_precip_rate_mean:long_name = "Quality check results on field:
ORG precipitation rate mean" ;
                qc_org_precip_rate_mean:units = "unitless" ;
                qc_org_precip_rate_mean:description = "See global attributes for
individual bit descriptions." ;
        int pwd_err_code(time) ;
                pwd_err_code:long_name = "PWD alarm" ;
                pwd_err_code:units = "unitless" ;
                pwd_err_code:missing_value = -9999 ;
        int pwd_mean_vis_1min(time) ;
                pwd_mean_vis_1min:long_name = "PWD 1 minute mean visibility" ;
                pwd_mean_vis_1min:units = "m" ;
                pwd_mean_vis_1min:valid_min = 0 ;
                pwd_mean_vis_1min:valid_max = 20000 ;
                pwd_mean_vis_1min:missing_value = -9999 ;
        int qc_pwd_mean_vis_1min(time) ;
                qc_pwd_mean_vis_1min:long_name = "Quality check results on field: PWD
1 minute mean visibility" ;
                qc_pwd_mean_vis_1min:units = "unitless" ;
                qc_pwd_mean_vis_1min:description = "See global attributes for
individual bit descriptions." ;
        int pwd_mean_vis_10min(time) ;
                pwd_mean_vis_10min:long_name = "PWD 10 minute mean visibility" ;
                pwd_mean_vis_10min:units = "m" ;
                pwd_mean_vis_10min:valid_min = 0 ;
                pwd_mean_vis_10min:valid_max = 20000 ;
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```
                pwd_mean_vis_10min:missing_value = -9999 ;
        int qc_pwd_mean_vis_10min(time) ;
                qc_pwd_mean_vis_10min:long_name = "Quality check results on field: PWD
10 minute mean visibility" ;
                qc_pwd_mean_vis_10min:units = "unitless" ;
                qc_pwd_mean_vis_10min:description = "See global attributes for
individual bit descriptions." ;
        int pwd_pw_code_inst(time) ;
                pwd_pw_code_inst:long_name = "PWD instantaneous present weather code"
;
                pwd_pw_code_inst:units = "unitless" ;
                pwd_pw_code_inst:valid_min = 0 ;
                pwd_pw_code_inst:valid_max = 99 ;
                pwd_pw_code_inst:missing_value = -9999 ;
        int qc_pwd_pw_code_inst(time) ;
                qc_pwd_pw_code_inst:long_name = "Quality check results on field: PWD
instantaneous present weather code" ;
                qc_pwd_pw_code_inst:units = "unitless" ;
                qc_pwd_pw_code_inst:description = "See global attributes for
individual bit descriptions." ;
        int pwd_pw_code_15min(time) ;
                pwd_pw_code_15min:long_name = "PWD 15 minute present weather code" ;
                pwd_pw_code_15min:units = "unitless" ;
                pwd_pw_code_15min:valid_min = 0 ;
                pwd_pw_code_15min:valid_max = 99 ;
                pwd_pw_code_15min:missing_value = -9999 ;
        int qc_pwd_pw_code_15min(time) ;
                qc_pwd_pw_code_15min:long_name = "Quality check results on field: PWD
15 minute present weather code" ;
                qc_pwd_pw_code_15min:units = "unitless" ;
                qc_pwd_pw_code_15min:description = "See global attributes for
individual bit descriptions." ;
        int pwd_pw_code_1hr(time) ;
                pwd_pw_code_1hr:long_name = "PWD 1 hour present weather code" ;
                pwd_pw_code_1hr:units = "unitless" ;
                pwd_pw_code_1hr:valid_min = 0 ;
                pwd_pw_code_1hr:valid_max = 99 ;
                pwd_pw_code_1hr:missing_value = -9999 ;
        int qc_pwd_pw_code_1hr(time) ;
                qc_pwd_pw_code_1hr:long_name = "Quality check results on field: PWD 1
hour present weather code" ;
                qc_pwd_pw_code_1hr:units = "unitless" ;
                qc_pwd_pw_code_1hr:description = "See global attributes for individual
bit descriptions." ;
        float pwd_precip_rate_mean_1min(time) ;
                pwd_precip_rate_mean_1min:long_name = "PWD 1 minute mean precipitation
rate" ;
                pwd_precip_rate_mean_1min:units = "mm/hr" ;
                pwd_precip_rate_mean_1min:valid_min = 0.f ;
                pwd_precip_rate_mean_1min:valid_max = 999.99f ;
                pwd_precip_rate_mean_1min:valid_delta = 100.f ;
                pwd_precip_rate_mean_1min:missing_value = -9999.f ;
        int qc_pwd_precip_rate_mean_1min(time) ;
                qc_pwd_precip_rate_mean_1min:long_name = "Quality check results on
field: PWD 1 minute mean precipitation rate" ;
                qc_pwd_precip_rate_mean_1min:units = "unitless" ;
                qc_pwd_precip_rate_mean_1min:description = "See global attributes for
individual bit descriptions." ;
        float pwd_cumul_rain(time) ;
                pwd_cumul_rain:long_name = "PWD cumulative liquid precipitation" ;
                pwd_cumul_rain:units = "mm" ;
                pwd_cumul_rain:valid_min = 0.f ;
                pwd_cumul_rain:valid_max = 99.99f ;
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                pwd_cumul_rain:valid_delta = 50.f ;
                pwd_cumul_rain:missing_value = -9999.f ;
        int qc_pwd_cumul_rain(time) ;
                qc_pwd_cumul_rain:long_name = "Quality check results on field: PWD
cumulative liquid precipitation" ;
                qc_pwd_cumul_rain:units = "unitless" ;
                qc_pwd_cumul_rain:description = "See global attributes for individual
bit descriptions." ;
        float logger_volt(time) ;
                logger_volt:long_name = "Logger voltage" ;
                logger_volt:units = "V" ;
                logger_volt:missing_value = -9999.f ;
                logger_volt:valid_min = 10.f ;
                logger_volt:valid_max = 15.f ;
                logger_volt:valid_delta = 5.f ;
        int qc_logger_volt(time) ;
                qc_logger_volt:long_name = "Quality check results on field: Logger
voltage" ;
                qc_logger_volt:units = "unitless" ;
                qc_logger_volt:description = "See global attributes for individual bit
descriptions." ;
        float logger_temp(time) ;
                logger_temp:long_name = "Logger temperature" ;
                logger_temp:units = "C" ;
                logger_temp:missing_value = -9999.f ;
                logger_temp:valid_min = 0.f ;
                logger_temp:valid_max = 50.f ;
                logger_temp:valid_delta = 10.f ;
        int qc_logger_temp(time) ;
                qc_logger_temp:long_name = "Quality check results on field: Logger
temperature" ;
                qc_logger_temp:units = "unitless" ;
                qc_logger_temp:description = "See global attributes for individual bit
descriptions." ;
        float lat ;
                lat:long_name = "North latitude" ;
                lat:units = "degree_N" ;
                lat:valid_min = -90.f ;
                lat:valid_max = 90.f ;
        float lon ;
                lon:long_name = "East longitude" ;
                lon:units = "degree_E" ;
                lon:valid_min = -180.f ;
                lon:valid_max = 180.f ;
        float alt ;
                alt:long_name = "Altitude above mean sea level" ;
                alt:units = "m" ;

// global attributes:
                :command_line = "met_ingest -s gan -f M1" ;
                :process_version = "ingest-met-4.7-0.el5" ;
                :dod_version = "met-b1-4.4" ;
                :site_id = "gan" ;
                :facility_id = "M1: Airport (Addu Atoll), Gan Island, Maldives" ;
                :data_level = "b1" ;
                :input_source =
"/data/collection/gan/ganmetM1.00/Met.20120119000000.dat" ;
                :sampling_interval = "variable, see instrument handbook" ;
                :averaging_interval = "60 seconds" ;
                :averaging_interval_comment = "The time assigned to each data point
indicates the end of the averaging interval." ;
                :serial_number = "N/A" ;
                :org = "Optical Rain Gauge" ;
```

```
                :tbrg = "Tipping Bucket Rain Gauge" ;
                :pwd = "Present Weather Detector" ;
                :qc_standards_version = "1.0" ;
                :qc_method = "Standard Mentor QC" ;
                :qc_comment = "The QC field values are a bit packed representation of
true/false values for the tests that may have been performed. A QC value of zero means
that none of the tests performed on the value failed.\n",
                        "\n",
                        "The QC field values make use of the internal binary format to
store the results of the individual QC tests. This allows the representation of
multiple QC states in a single value. If the test associated with a particular bit
fails the bit is turned on. Turning on the bit equates to adding the integer value of
the failed test to the current value of the field. The QC field\'s value can be
interpreted by applying bit logic using bitwise operators, or by examining the QC
value\'s integer representation. A QC field\'s integer representation is the sum of
the individual integer values of the failed tests. The bit and integer equivalents for
the first 5 bits are listed below:\n",
                        "\n",
                        "bit_1 = 00000001 = 0x01 = 2^0 = 1\n",
                        "bit_2 = 00000010 = 0x02 = 2^1 = 2\n",
                        "bit_3 = 00000100 = 0x04 = 2^2 = 4\n",
                        "bit_4 = 00001000 = 0x08 = 2^3 = 8\n",
                        "bit_5 = 00010000 = 0x10 = 2^4 = 16" ;
                :qc_bit_1_description = "Value is equal to missing_value." ;
                :qc_bit_1_assessment = "Bad" ;
                :qc_bit_2_description = "Value is less than the valid_min." ;
                :qc_bit_2_assessment = "Bad" ;
                :qc_bit_3_description = "Value is greater than the valid_max." ;
                :qc_bit_3_assessment = "Bad" ;
                :qc_bit_4_description = "Difference between current and previous
values exceeds valid_delta." ;
                :qc_bit_4_assessment = "Indeterminate" ;
                :zeb_platform = "ganmetM1.b1" ;
                :history = "created by user dsmgr on machine gold at 19-Jan-
2012,1:28:00, using $State: zebra-zeblib-4.23-0.el5 $" ;
}
```

5. Data Remarks

The data can be accessed using the myriad of software that is able to interact with NetCDF format files, including ncdump, ncview, Matlab, Python, IDL, and NCL.

6. References

Chandra A, P Zuidema, S Krueger, A Kochanski, S de Szoeke, and J Zhang. 2018: Moisture distributions in tropical cold pools from equatorial Indian Ocean observations and cloud-resolving simulations. *Journal of Geophysical Research: Atmospheres,* **123(20),** 10.1029/2018JD028634.

Long CN. 2016. Atmospheric Radiation Measurement Madden-Julian Oscillation Investigation Experiment Field Campaign Report. Ed. by Robert Stafford, DOE ARM Climate Research Facility. DOE/SC-ARM-16-039. (https://www.arm.gov/publications/programdocs/doe-sc-arm-16-039.pdf)