Brief report for post-processing on data from R/V Mirai shipboard C-band Doppler radar during CINDY/DYNAMO special observation period (SOP)

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1. Introduction

As a component of CINDY/DYNAMO field campaign, we operated the C-band Doppler radar onboard R/V Mirai (hereafter Mirai CDR). This report briefly describes the status of the dataset and post-processing.

2. Observations

Details are described in the Cruise Report of R/V Mirai for MR11-07 and MR11-08.

(1) Period

MR11-07 Leg-1

Started observation:	1340UTC on Sep.25, 2011
Arrived Station (8S, 80.5E):	0300UTC on Sep.30, 2011
Departed Station (8S, 80.5E):	0700UTC on Oct 24, 2011
Stopped observation:	0108UTC on Oct.26, 2011

MR11-07 Leg-2

Started observation:	0020UTC on Oct.29, 2011
Arrived Station (8S, 80.5E):	0300UTC on Oct.30, 2011
Departed Station (8S, 80.5E):	0730UTC on Nov.28, 2011
Stopped observation:	0308UTC on Dec.01, 2011

MR11-08 Leg-1 (transit from Colombo to western Pacific)

Start observation:	1000UTC on Dec.05, 2011
Stop observation:	0830UTC on Dec.10, 2011

(2) Tasks

① Volume scan

- every 10 minutes, 21 elevations from 0.5 to 40.0 (as listed below), take about 7 minutes
- radar reflectivity and Doppler velocity, using dual-PRF, for range distance between 0 and 160 km
- The elevations are determined to:
  - cover troposphere (1000hPa to 100hPa) almost equally in pressure coordinate
  - set lowest two beams at 0.5 and 1.0 deg., while highest beam as 40.0 deg. to cover whole troposphere in range distance R > 20km.
- The elavations are: 0.5, 1.0, 1.8, 2.6, 3.4, 4.2, 5.0, 5.8, 6.7, 7.7, 8.9, 10.3, 12.3, 14.5, 17.1, 20.0, 23.3, 27.0, 31.0, 35.4, 40.0

② Surveillance scan

- every 30 minutes, 1 elevation at 0.5
- radar reflectivity only, single-PRF, for range distance between 0 and 300 km

③ RHI

- executed at manually-detemined azimuth when (1) and (2) were not working
- radar reflectivity and Doppler velocity, single-PRF, for range distance between 0 and 160 km

3. Applied filters in Post-Processing

(1) SQI
The parameter named “signal quality index (SQI)”, provided by IRIS RAW dataset, is utilized. The bins with SQI < 0.3 are omitted (as “No Data”, where reflectivity was noise level and velocity was not available).

(2) Shadow by the structure on the vessel
Around the radar, there are several structures to obstruct radar beams. The direction for these “shadow” are omitted (as “Out of Area”, where the observation was not carried out). The directions are determined by averaging all available reflectivity data for each elevation and azimuth and then find directions with weak reflectivity value (weak in 3dB or more than azimuthal average).

(3) Minimum reflectivity
The bin with reflectivity weaker than minimum detectable reflectivity was set as “NoData”. The mimimum reflectivity was determined as followings:

Minref = MinRef@1km (given in IRIS RAW dataset)
+ 20. * log10(RD[km]-1)
+ GasAtten * (RD[km-1])

(4) Speckle noise
Similar to IRIS/Open’s “speckle filter”, to remove isolated data bin.

(5) Second-trip echo
Comparing adjacent bins and correct the reflectivity as more probable values. See Katsumata et al. (2005) for detail.

(6) Falsely-estimated Doppler velocity from dual-PRF unfolding
Correct falsely-unfolded Doppler velocity data by comparing adjacent bins. See Katsumata et al. (2005) for detail.

(7) Attenuation by rain and atmosphere
For gas, applying simple gas attenuation coefficient archived in IRIS/RAW dataset (typically 0.01dB/km).

For rain, applying simple Z-AH relationship obtained from 2DVD on Gan Island (Thompson et al. 2013, AMS radar conference) during DYNAMO. The Z-AH relationship is AH = $0.1651 \times 10^{-4} \times Z$ ^ 0.867.
(note: ver. Feb.2013 utilized Z-AH relationship obtained from disdrometer (Joss-Waldvogel type, Disdromet RD-80) data at R/V Mirai during CINDY. The Z-AH relationship is AH = $0.3227 \times 10^{-4} \times Z$ ^ 0.7449. Just for reference, in MISMO, coefficients were 0.2546 and 0.7540.)

(8) Sea clutter

The radar echo which appeared from the lowest elevation and continues vertically but less than 2-km height is flagged as sea clutter. The bins with sea clutter were replaced as "NoData". The algorithm is based on CSU's TOGA radar QC procedure for DYNAMO, developed by Dr. T. Lang.

(9) Convective-Stratiform flagging

The flag to identify convective / stratiform portion are given for each horizontal grid. The method is adopted from Yuter et al. (2005) based on Steiner et al. (1995). The horizontal plane at 2.0km height is utilized for flagging.

(10) Detecting echo top height

The echo top height is determined for each horizontal grid in two ways. One is downward search from the uppermost layer to identify first radar echo exceeding the certain value. Another is upward search from the bottom layer to identify first echo top height. For the latter, search was performed only for columns with valid (equal or larger than threshold) radar echo at or below 1-km height. Both upward and downward search adopted 10 dBZ as threshold to identify border between echo grid and no-echo grid.

4. Comparison to TRMM/PR

The radar reflectivity is compared to that from TRMM/PR (2A25 Ver.7) for all overpasses during Mirai CINDY cruise. The method is same as in Katsumata et al. (2008): The data from Mirai CDR is plotted in the Cartesian grid with resolution of 5- and 1-km for horizontal and vertical, respectively, and then compared to that from TRMM/PR. As the figure below, there are no notable differences between two radars when the corrections in Section 3 are applied to data from Mirai CDR.

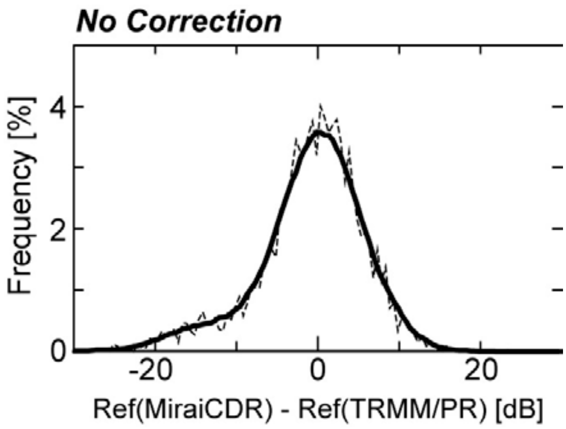

Fig. 1: Histogram for frequency distribution of the reflectivity difference between TRMM/PR and Mirai CDR. The thin broken line is the raw statistics for 0.5 dB bin width, while the thick solid line is the average for 5.0 dB bin width (used to determine the mode of the distribution).

5. Data Format

(1) Dataset in the Cartesian grid dataset is provided as primary product. The dimensions for the dataset are 200 x 200 km in horizontal with centered at vessel and 20-km in vertical from the sea surface, and the resolutions are 1- or 2- km in horizontal and 0.5-km in vertical, respectively. The data is available in netCDF, with GrADS .ctl file.

See appendices for contents of netCDF file (result of “ncdump -h") and for GrADS .ctl file.

(2) The QC’ed dataset in polar coordinate (without spatial interpolation) will be provided in netCDF format.

(3) To obtain non-QC’ed dataset in polar coordinate in IRIS RAW format, please contact Masaki Katsumata (katsu@jamstec.go.jp) of JAMSTEC.

6. Remarks

(1) Dataset is primary provided in the Cartesian grid dataset. The dimensions are 200 x 200 km in horizontal with centered at vessel and 20-km in vertical from the sea surface, and the resolutions are (1) 1- or 2- km in horizontal and 0.5-km in vertical, respectively. The data is available in netCDF, with GrADS .ctl file.

(2) The QC’ed dataset in polar coordinate (without spatial interpolation) will be provided in netCDF format.

(3) When making echo statistics, remind the filter for sea clutter (Section 3.(8)) which removes echo with the top lower than 2-km height.

(4) The attenuation correction may be changed to utilize the dataset from disdrometer(s) at Gan Island during CINDY/DYNAMO.

7. References

Katsumata, M., T. Ushiyama, K. Yoneyama, and Y. Fujiyoshi, 2008: Combined use of TRMM/PR and disdrometer adata to orrect reflectivity of ground-based radars. *SOLA*, 4, 101-104, doi:10.2151/sola.2008-026.

Katsumata, M., K. Yoneyama, Y. Yuuki, S. Sueyoshi, N. Nagahama, and K. Yoshida, 2005: Noise filtering for dual-PRF observed data from R/V Mirai shipborne Doppler radar. *JAMSTEC Rep. Res. Dev.*, 2, 29-34.

Yuter, S. E., R. A. Houze Jr., E. A. Smith, T. T. Wilheit, and E. Zipser, 2005: Physical characterization of tropical oceanic convection observed in KWAJEX. *J. Appl. Meteor.*, 44, 385-415.

Appendix-A: Contents of data in cartesian grid data with NetCDF format

```
netcdf Mirai_20110925-1350 {
dimensions:
        X = 201 ;   //note: this is for 1-km grid. The number should be "101" for 2-km grid.
        Y = 201 ;   // same as above
        Z = 41 ;
        T = 1 ;
variables:
        int YEAR(T) ;
                YEAR:long_name = "YEAR A.D." ;
                YEAR:time_zone = "UTC" ;
        int MONTH(T) ;
                MONTH:long_name = "Month [1-12]" ;
                  // note: not 0-11, as in C-language time commands
                MONTH:time_zone = "UTC" ;
        int DAY(T) ;
                DAY:long_name = "Day in the month [1-31]" ;
                DAY:time_zone = "UTC" ;
        int HOUR(T) ;
                HOUR:long_name = "Hour [0-23]" ;
                HOUR:time_zone = "UTC" ;
        int MIN(T) ;
                MIN:long_name = "Minute [0-59]" ;
                MIN:time_zone = "UTC" ;
        int SEC(T) ;
                SEC:long_name = "Second [0-59]" ;
                SEC:time_zone = "UTC" ;
        double XfromRadar(X) ;
                XfromRadar:long_name = "Distance north of radar" ;
                XfromRadar:units = "m" ;
        double YfromRadar(Y) ;
                YfromRadar:long_name = "Distance east of radar" ;
                YfromRadar:units = "m" ;
        double height(Z) ;
                height:long_name = "Height above sea level" ;
                height:units = "m" ;
        byte REF(Z, Y, X) ;
                REF:long_name = "radar reflectivity" ;
                REF:units = "dBZ" ;
                REF:scale_factor = 0.5f ;
                REF:add_offset = 32.f ;
                REF:missing_value = -128b ;
        byte VEL(Z, Y, X) ;
                VEL:long_name = "Doppler velocity" ;
                VEL:units = "m/s" ;
                VEL:scale_factor = 0.5f ;
                VEL:add_offset = 0.f ;
                VEL:missing_value = -128b ;
```

```
        byte CSflag(Y, X) ;
                CSflag:long_name = "Convective / Stratiform Flag" ;
                CSflag:units = "none" ;
                CSflag:missing_value = -128b ;
                CSflag:Flag_Convective = 2b ;
                CSflag:Flag_Stratiform = 1b ;
                CSflag:Flag_Undefined = 0b ;
        byte ETH_U(Y, X) ;
                ETH_U:long_name = "Echo Top Height (search upward)" ;
                ETH_U:units = "m" ;
                ETH_U:missing_value = -128b ;
                ETH_U:scale_factor = 500.f ;
                ETH_U:add_offset = 0.f ;
                ETH_U:threshold_reflectivity_in_dBZ = 10.f ;
        byte ETH_D(Y, X) ;
                ETH_D:long_name = "Echo Top Height (search downward)" ;
                ETH_D:units = "m" ;
                ETH_D:missing_value = -128b ;
                ETH_D:scale_factor = 500.f ;
                ETH_D:add_offset = 0.f ;
                ETH_D:threshold_reflectivity_in_dBZ = 10.f ;
        float RLON(T) ;
                RLON:long_name = "position of radar in Longitude" ;
                RLON:units = "deg.E" ;
        float RLAT(T) ;
                RLAT:long_name = "position of radar in Latitude" ;
                RLAT:units = "deg.N" ;
        float RHEIGHT(T) ;
                RHEIGHT:long_name = "height of radar above sea level" ;
                RHEIGHT:units = "m" ;
        float RHEAD(T) ;
                RHEAD:long_name = "heading of platform" ;
                RHEAD:units = "deg. from North" ;
}
```

Appendix-B: GrADS .ctl file to read NetCDF-format

```
DSET        ../Mirai_%y4%m2%d2-%h2%n2.nc
OPTIONS TEMPLATE
DTYPE netcdf
TITLE VS Mirai-DR ref+vel
UNDEF      -128
XDEF         201 LINEAR   -100.0      1.0
YDEF         201 LINEAR   -100.0      1.0
ZDEF          41 LINEAR        0.0      0.5
TDEF      10000 LINEAR     12:00Z25SEP2011 10mn
VARS            5
REF=>ref   41 z,y,x   reflectivity (ref/2+32 --> [dBZ])
VEL=>vel   41 z,y,x   Doppler velocity (vel/2 --> [m/s])
CSflag=>csf 0 y,x     Conv-Str flag (2:c,1:s,0:undef)
ETH_U=>ethu 0 y,x     10dBZ Echo Top Height (upward seek) (ethu*500 [m])
ETH_D=>ethd 0 y,x     10dBZ Etho Top Hegght (downward seek) (ethd*500 [m])
ENDVARS
```