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The Indonesia In-House Radar Integration System (InaRAISE) of Indonesian Agency for Meteorology Climatology and Geophysics (BMKG): Development, Constraint, and Progress

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Abstract. In 2017, BMKG has 41 weather radars covering most of Indonesia region and most of its data are automatically sent to the BMKG headquarter every 10 minutes. There are four different weather radar brands with its specific data format and software analysis. In recent years, the weather radar community has developed open-source software to handle several radar data formats. Based on this, BMKG has developed the Indonesia In-House Radar Integration System (InaRAISE) of BMKG using the open-source weather radar software. InaRAISE has been developed using Python-based libraries Wradlib and Py-ART for processing weather radar data. BMKG radar data have been successfully extracted and transformed into Cartesian coordinates for post-processing. The multiple radars have been successfully composited by comparing column-maximum reflectivity. Web-based near real-time radar images has been experimentally operated, but not officially launched. The main constraint is the susceptible communication network between radar sites and BMKG headquarter causing real-time data transfer problems. InaRAISE serves feasible data radar extraction for data assimilation in the numerical weather prediction model. InaRAISE could serve as a supporting of the existing radar integration system or possibly as a replacement.

Keywords : InaRAISE, radar, reflectivity, BMKG

1. Introduction

As the national meteorological weather service agency in Indonesia, BMKG is responsible to provide the weather forecast and early warning information to the public. BMKG uses various numerical weather

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prediction (NWP) models and considers the real-time satellite and weather radar data to provide the short-term and nowcasting (1 to 6 hours) forecasts. The weather radar data is important in providing a high spatial resolution early warning and weather forecasts information. In 2017, BMKG has 41 weather radars across Indonesia archipelago consisting of four different brands namely Gematronik, EEC, Baron, and Vaisala (Figure 1) [1]. The recent weather radar was installed in 2017 at Sintang, West Kalimantan. Most of the radars are C-band Doppler single polarization with optimum radius coverage of 150 - 240 km. Most of its data is available at 10 minutes interval and is automatically sent to the BMKG headquarter. Each radar brand has a different data format that can only be processed using the software of each radar manufacturer. Thus, analysis and processing of radar data from different brands can be limited.

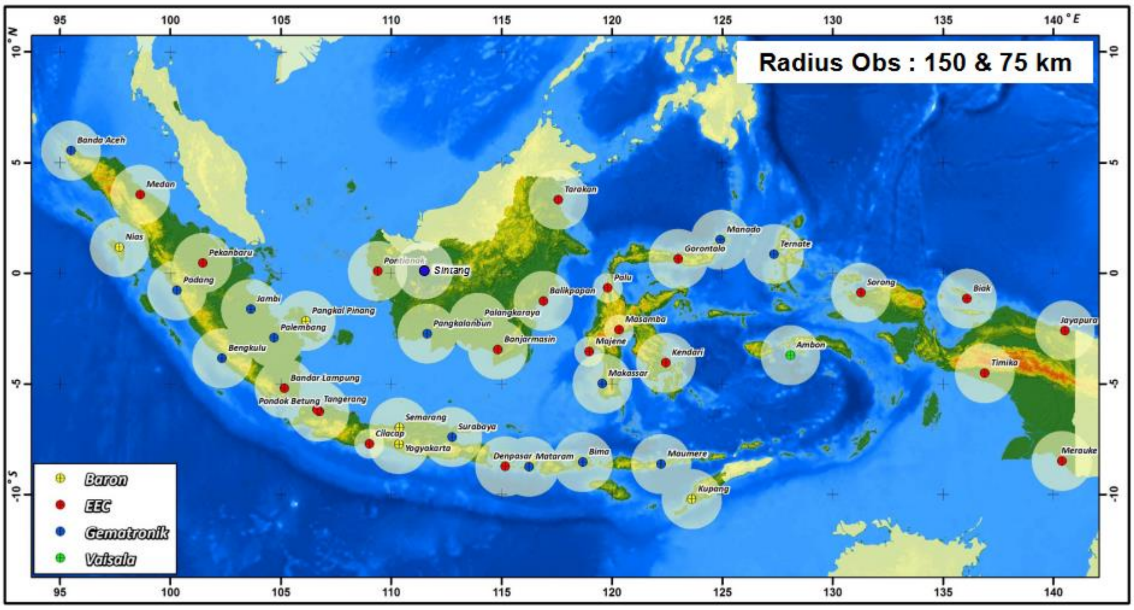

Figure 1. Map of BMKG weather radar locations in 2017. Colors represent different brands. The radius coverage is 75 km (X-Band) and 150 km (C-Band).

In recent years, the weather radar community has developed several open-source software systems to handle multiple radar file formats [2]. The open-source systems include BALTRAD [3-5], LROSE/TITAN (https://www.eol.ucar.edu/content/lidar-radar-open-software-environment), wradlib [6] and Py-ART [7]. Most of these software systems are using C/C++ and Python programming languages. In addition, another free and open library in the R language called radar.IRIS is also available for processing weather radar data (http://gaia.tru.ca/radar.IRIS) [8]. These software systems have been widely used in processing weather radar data and its applications in many countries. For instances, wradlib has been used to reconstruct monsoon rainfall using a radar network and evaluate the streamflow and flood simulations based on radar-derived rainfall in the Philippines [9-11]. In the meantime, BALTRAD software has been deployed throughout Europe and more recently in Canada [5].

Based on these considerations, Center for Research and Development (R&D), supported by Remote Sensing Management Division at Center for Public Meteorology of BMKG, have developed the radar integration system based on the open-source software called the Indonesia In-House Radar Integration System (InaRAISE) of BMKG. The core of InaRAISE has been developed using Python-based library wradlib since 2016 [1] and recently, Py-ART library was also used in 2017 for processing multi-radar file format. This study describes the development process, anticipated constraints and recent progress of InaRAISE. Some of InaRAISE products are also given including the composite radar maps and the future plan of InaRAISE is also discussed in this study.

2. Development Process

The radar data is typically stored in the polar coordinate format for each sweep and saved in the volumetric data file (.vol). The structure of the polar coordinate data mainly consists of (1) the reference point which is the radar center point, (2) the polar axis, (3) the radius or distance from the reference point and (4) the azimuth angle which is the angle from the polar axis (see figure in https://www.nssl.noaa.gov/publications/dopplerguide/images/2-1-1.gif). While the analysis and processing of meteorological data are typically conducted in Cartesian coordinate (latitude-longitude) format. Thus, the conversion from the polar to Cartesian coordinates is needed to facilitate the processing and analysis of radar data. Wradlib and Py-ART libraries in Python programming language are able to extract and convert the radar data into the Cartesian coordinate format and also save the data into NetCDF file format [1]. In addition, they also provide quality control tools (clutter identification and removal, and attenuation correction), the conversion from reflectivity into rain-rate and data visualization.

As shown in Figure 1, BMKG has four different radar brands which mean there are four different volumetric data. Each volumetric data have been directly extracted by wradlib, except the volumetric data from EEC. The EEC volumetric data must be converted into NetCDF (.nc) format using the *volconvert* package which only available in the EEC EDGE® software before being extracted by wradlib. For volumetric data from Vaisala, it also can be extracted by Py-ART library. The flowchart of InaRAISE is depicted in Figure 2.

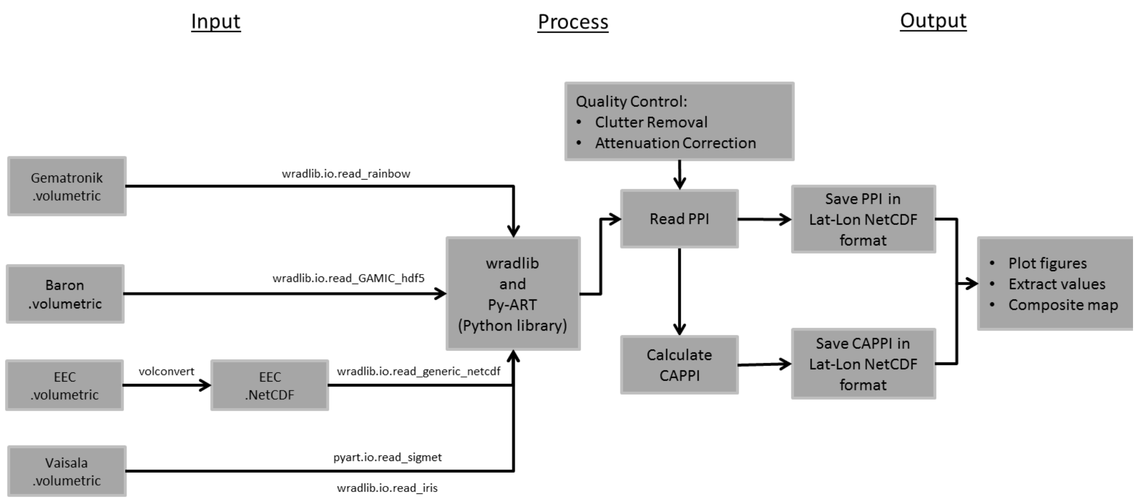

Figure 2. Flowchart of InaRAISE (after modification of Figure 3 in ref. 1).

InaRAISE automatically extracts the Plan Position Indicator (PPI) of reflectivity (Z) and radial velocity (V) from the radar data. While extracting the PPI, InaRAISE implements the quality control that utilizes the clutter identification and removal algorithms developed by Gabella and Notarpietro (2002) [12] and the attenuation correction method developed by Jacobi et al. (2009) [13] which both are provided by wradlib. Afterward, Constant Altitude PPI (CAPPI) is calculated with the following specifications: (1) the spatial resolution is 500 meters/pixel, (2) the CAPPI layers are generated from 1 to 10 km height with 1 km vertical resolution, and (3) the maximum CAPPI (CAPPI-MAX) layer is produced. Then, both PPI and CAPPI are saved into latitude-longitude (Cartesian) NetCDF file format. In the end, plotting figures, extracting values and compositing radars are conducted.

Currently, the InaRAISE near real-time web-based has been experimentally operated, but not officially launched. The web page links are http://www.bmkg.go.id/cuaca/citra-radar.bmkg (Center for Public Meteorology) and http://puslitbang.bmkg.go.id/radar (R&D Center). There are at least 23 radar sites have been integrated into InaRAISE, while the other radars still have network communication issues in transferring the real-time data to BMKG headquarters. Some examples of InaRAISE products are given in Figure 3. The map of Jabodetabek area is specifically cropped from Tangerang radar coverage with district boundaries to monitor the rainfall distribution over Jabodetabek (top left panel of Figure 3). The Ambon radar (Vaisala) is plotted with a radius of 25, 50 and ~200 km (top right panel of Figure 3). InaRAISE was also able to capture the movement of tropical cyclone Cempaka, both of rainfall intensity and wind speed on 27-28 November 2018 in the southern part of Central Java from Yogyakarta radar (bottom panel of Figure 3).

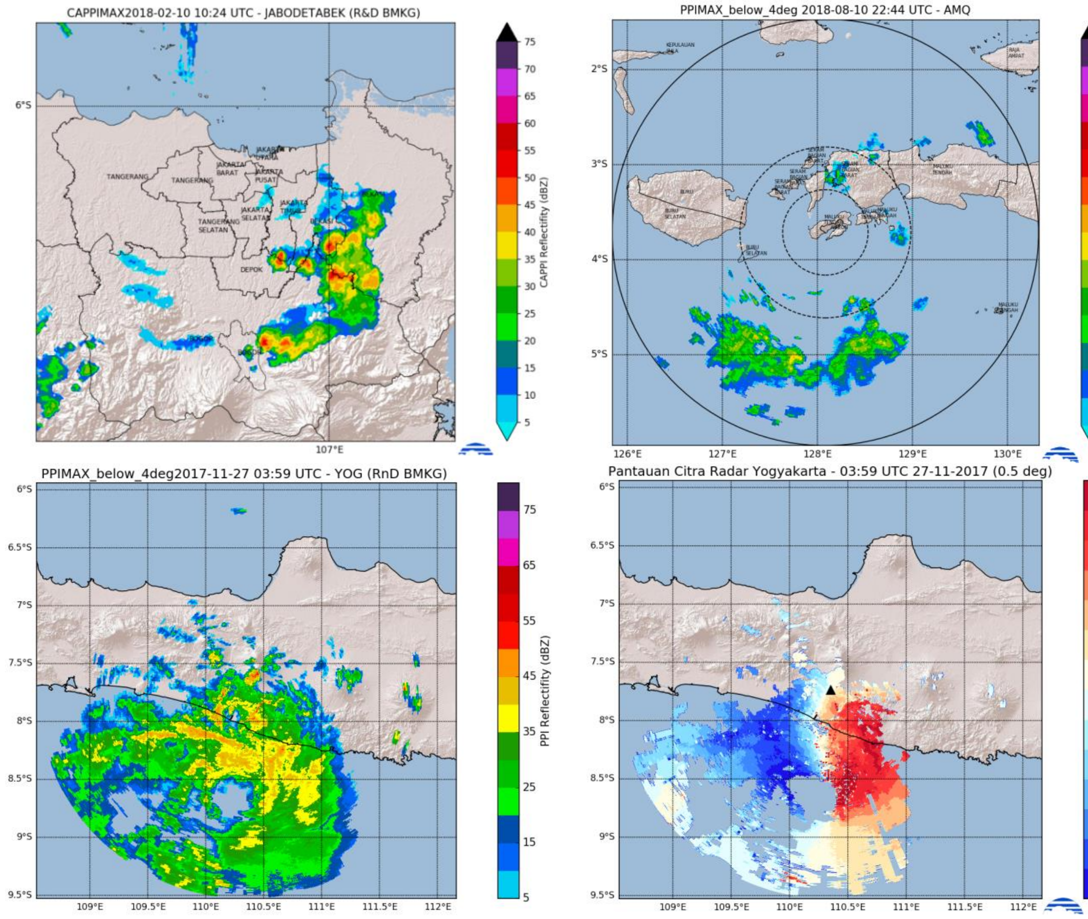

Figure 3. Examples of InaRAISE products. (Top left) the maximum CAPPI reflectivity layer over Jabodetabek area as a part of coverage of Tangerang radar (EEC) on 10 February 2018. (Top right) the maximum PPI reflectivity layer over Ambon (Vaisala) on 10 July 2018. (Bottom left) the maximum PPI reflectivity and (bottom right) 0.5 degree radial velocity layers over Yogyakarta (Baron) during the occurrence of tropical cyclone Cempaka on 27 November 2017.

3. Anticipated Constraints

The main anticipated constraint in the InaRAISE development is the susceptibility of the communication network between radar sites and BMKG headquarter which cause real-time data transfer issues. This issue is more pronounced for radar sites located in the eastern part of Indonesia. The other constraints are the quality control of radar data. Although clutter removal and attenuation correction have been applied, the method of removing intermittent interferences by signal communication is not implemented yet. This interference issue mainly occurs in the city area such as Jakarta. In addition, the bright band filter is also not implemented in the current state of INARAISE. Another important feature that is currently not implemented in INARAISE is the quality control with external data including comparison with rain gauge data to derive the reflectivity-rainrate (Z-R) relationship and comparison with satellite-derived rainfall data. However, R&D center has been working on the comparison of radar reflectivity and observed rainfall data to obtain a new Z-R relationship on several radar locations in Medan, Surabaya, Bali, and Palembang.

4. Recent Progress

INARAISE has been able to generate reflectivity composite maps from multiple radars by using column-maximum reflectivity comparison method. The idea of this method is basically comparing the reflectivity values over the intersection coverage areas of multiple radars and the obtained maximum reflectivity values over that area would be considered as the composite reflectivity values. For instance, radars in Tangerang and Lampung have an intersection coverage area over 105 – 107 °E and 7 – 4.5 °S (Figure 4). On 14 February 2017 13:10 UTC, both radars captured rainfall over the intersection area but its spatial distribution and intensity were slightly different possibly due to the distance difference from the radar center point. By using this method, the composite map indicates that the intersection area was filled with the maximum reflectivity values between the two radars (Figure 4). This method is also applied for multiple radars (more than two radars).

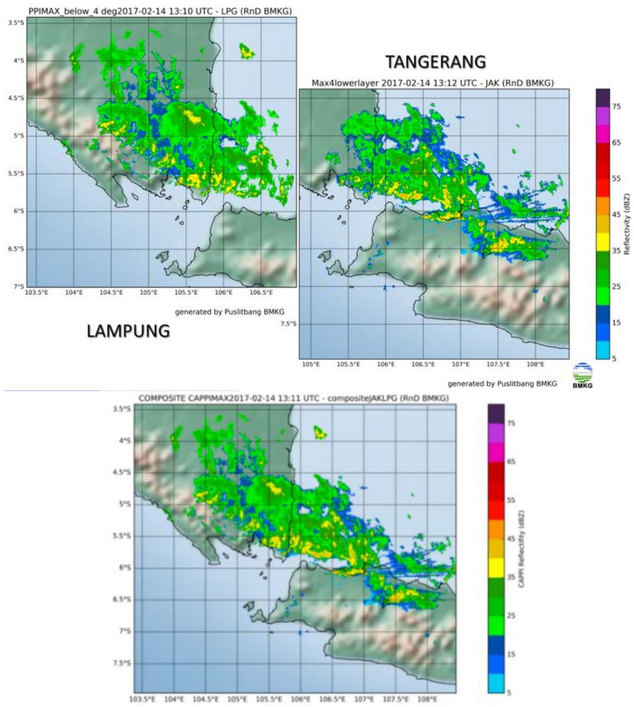

Figure 4. (Top panel) Individual radars in Tangerang and Lampung captured rainfall on 14 February 2017 13:10 UTC. (Bottom panel) Composite radar reflectivity map between Tangerang and Lampung radars.

For multiple radars, InaRAISE has generated composite CAPPIMAX reflectivity maps for main islands in Indonesia. For instance, the composite map for Java and Bali are composed of four radars. While for Sumatera, it consists of seven radars and for Kalimantan, it consists of four radars (Figure 5). The composite map clearly shows the spatial rainfall distribution over a larger area which is very important in understanding current weather condition and possibly to predict the rainfall cloud movements.

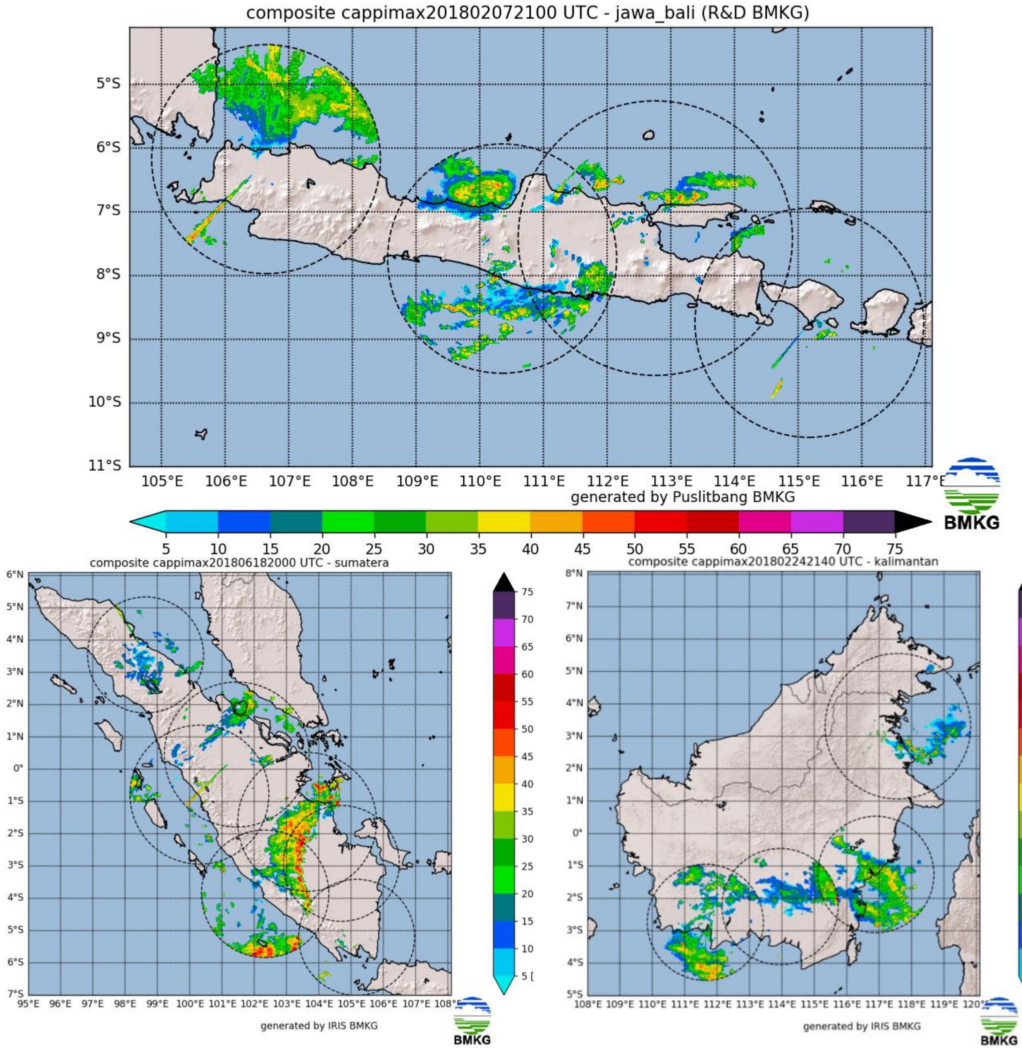

Figure 5. Examples of InaRAISE products. Composite CAPPIMAX reflectivity maps on Java and Bali (top panel), Sumatera (bottom left panel) and Kalimantan (bottom right panel).

In addition to composite maps, InaRAISE serves a feasible radar data extraction for data assimilation in numerical weather prediction (NWP) model. The R&D center has developed the R-language scripts to extract the radar data (reflectivity and radial velocity) values from PPI NetCDF output file and convert it into the format of data assimilation in Weather Research Forecast (WRF) model. However, this module is not automatically running yet in InaRAISE, but it is experimentally used for simulations of extreme events and study cases.

5. Summary

BMKG has 41 weather radars in 2017 consisting of four different brands with its specific volumetric data format and software. In recent years, the weather radar community has developed open-source software systems to process multiple radar data formats. Based on this, BMKG has initiated to develop the Indonesia In-House Radar Integration System (InaRAISE) utilizing the open-source software systems based on wradlib and Py-ART libraries in Python language. BMKG radar data have been successfully extracted and saved into a latitude-longitude NetCDF file format for post-processing. The multiple radars have been successfully composited by column-maximum reflectivity comparison method. The InaRAISE main constraint is the susceptible communication network between radar sites and BMKG headquarter causing real-time data transfer issues. InaRAISE serves feasible data radar extraction for data assimilation in the numerical weather prediction model. InaRAISE could serve as a supporting of the existing radar integration system or possibly as a replacement in the future.

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