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# REGIONAL AND NATIONAL WEATHER RADAR PRIORITIES AND REQUIREMENTS IN Asia

### SUMMARY

This document provides information on Regional and National Weather Radar Priorities and Requirements in Part of Asia (part of RA II). There is a significant step forward on radar data quality enhancement, and many new requirements and applications emerged among the RAII members. But, still a remarkable gap remains which leads to big challenge on data QC, applications of these data, and data exchange among national, regional and international.

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1. **RAII Weather Radar Network NOW (but need more survey):**
2. **Japan, Korea, HK China & China mainland Weather Radar network**
3. There are 295 weather radar deployed in China mainland, including the CMA and civil aviation department, the 1km AGL coverage reach to 22%. Multiple types of radar operated in China: fixed, S-band, C-band, X-band, Mobil, C-band and X-band phased array weather radar. 24 S-band are dual-pol, 101 weather radars are planned to upgrade to dual-pol by 2020 supported by CMA project.
4. JMA's Weather Radar network is composed with 20 C-band Doppler radars (single-pol). JMA also has TDWR network which is composed with six C-band single-pol and three C-band dual-pol Doppler radars.
5. HKO Weather Radar network is composed with two S-(one single, one dual-pol), two C- and one X-band, dual-pol radars.
6. South Korea weather radar network is composed with 31 S-, C-, and X-band respectively. 25 single-pol. and 6 dual-pol. radars, including fixed and mobile weather radar. Of which, 11 KMA radars will be replaced with dual-pol by 2020. Three X-band dual-pol radars with solid-state power amplifier will be installed by the end 2017.

The ASEAN weather radar information (by Feb. 2014)

1. Indonesia C-band and X-band, 31 in total, all is single-pol. (note: EEC (15), Gematronik (11), Baron (3), Vaisala (1)).
2. Lao PDR 1 C-band single-pol. (JRC)
3. Malaysia 7 S-band, 4 C-band, X-band.(EEC, Gematronik).
4. Singapore 1 S-band, 1 C-band. (Gematronik).
5. Philippines 15 in total. 4 S-band JRC, 4 S-band EEC, 2 C-band EEC & 5 ongoing (4 Vaisala C-Band, 1 EEC S-Band).
6. Thailand 16 C-band in total, EEC (12), Gematronik (4).
7. BMA (Bangkok Metropolitan Administration) 1C-band, EEC (solid state).
8. Viet Nam X & S=1, C=7, 4 EEC, 3 Thompson, 1 Russia (X & S).

*Note: Due to the communication issues, this report does not provide all RAII countries’ accurate numbers of their radars.*

1. **Applications and Capacity Building**

Since the Southeast Asia is one of the areas seriously suffered from weather and water related disasters, the severe weather monitoring is getting the biggest challenges for effective disaster risk reduction (DRR) activities in the region. Since 2011, RAII region, especially in East Asia area, the precipitation monitoring capabilities, short term warning and severe weather detections get significant enhancement through a series conference, workshops, projects from WMO, RAII and NHMSs, e.g.

1. Jakarta Declaration and the Joint RA II/RA V WIGOS project. The Joint RA II/RA V Workshop on WIGOS for Disaster Risk Reduction was held Jakarta, Indonesia, 2015. The major outcome of the Workshop was the "Jakarta Declaration", which proposed to develop weather radar involving Members in both RA II and RA V under the WIGOS umbrella. The project aims at (i) improvement of data quality of existing radars, (ii) development and expansion of national radar networks, (iii) near real time international exchange of radar data, and (iv) development of «sub-regional» radar data centre(s).
2. The RA II-16 session (Abu Dhabi, UAE, Feb 2017) adopted the Regional WIGOS Implementation Plan 2017-2020. It will definitely push RAII members to go forward to contribute on DRR.
3. China Now casting/ short-term forecasting accuracy and timeliness are improved: data have been assimilated into NMP and 0-6 h precipitation prediction accuracy has been improved 10%. Severe Weather Automatic Nowcast System (SWAN) 2.0: multi-data can be integrated including weather radars base data and PUP. The platform mainly focus on storm structure data, and is capable of output more than 10 types of products, e.g. 3-D base-reflectivity, composite ref., QPE, precipitation forecasting, storm identify, etc. Radar Operational Software Engineering (ROSE): replace PUP and can provide additional 39 products in China mainland.
4. HKO China Weather Radar Systems play important role in Detection and Monitoring of Severe Weather, automatic Alerts for Windshear and Microburst. There are several radar products like Dual-polarization Radar Products of Hydrometeor Classification, Nowcasting products, Integration products of Radar Data and Lightning Location and also the radar products for the public.
5. All of JMA's radars are used for assimilation to NWP. The assimilated elements are follows. Doppler velocity, pseudo relative humidity (reflectivity) and analysed rainfall amount.
6. KMA has made great enhancement on Data QC by use of fuzzy logic approach and statistical analysis of radar data. The quality index quantized value (0~1) is assimilated into NWP model for QPE both produced by single-polarization and dual-polarization observation. RAR2.0: QPE can be adjusted by probability matching method using rain gauge rainfall. RAR is utilized for flash flood warning with the comparing to ground validation of satellite rainfall estimation. KMA also developed various radar products including hydrometeor classification, 3D storm structure, multiple-Doppler wind synthesis; radar-based snowfall estimation is routinely produced. Three types of nowcasting system provide short-term forecasting for 0~6h precipitation prediction.
7. **Data exchange**

Under the framework of WMO global weather radar data exchange, RAII members conducted the weather radar data exchange among NMHSs.

1. JMA contribute to the international radar data exchange. Capacity building makes much benefit in region severe weather monitoring through regional workshop, technical meetings, experimental data exchange, e.g. Bangkok, Thailand, 2014 workshop, ESCAP/WMO Typhoon Committee meetings, it was concluded with great success encouraging the participants to further promote the relevant activities.
2. JMA in cooperation with TMD and MMD successfully started the international radar data exchange in GRIB2 format to create transboundary composite map in a near real-time basis. This experimental data exchange was started as an achievement of the ESCAP/WMO Typhoon Committee activities.
3. China and South Korea have conducted the weather radar data through the Sino-ROK special bilateral line under the regulations of GTS since 2012. China provides 6 radar sites (Yantai, Qingdao, Dalian, Yingkou, Tianjin and Shenyang) to Korea with 5 kinds of products. Radar data transmitted from South Korea to China include one product (CAPPI) from 10 radar sites. The exchange frequency is once per hour, while the requirement is 10 minutes.
4. Radar data have been exchanged in the past few years among Guangzhou, Shenzhen, Zhuhai, Hong Kong and Macao on the basis of network requirement of WMO Information System (WIS) to the GISC responsibility zone. The frequency of transmission is 6 minutes to each other.
5. **Future priorities**
6. Improve the accuracy of quantitative precipitation estimation;
7. Promote the application in numerical forecast models;
8. Promote the weather radar application in following areas: Assimilation in NWP models, Aviation weather service, Flash floods, Warning of severe weather, Flooding of rivers and others.
9. Capacity building: Data QC system; Data sharing platform, Warning/alert service;
10. Enhance the maintenance and logistics of radar operation
11. Strengthen the technical training including engineering, data/product quality control and data application; put emphasis on practical training conditions.
12. **Issues:** In fact, different countries have different priorities, and then may different scanning strategies, and different data model…, but the most common issues as below:
13. Radar upgrade happened in many countries that often leads to changes in scanning strategies, may cause data issues and difficult to sharing for applications.
14. Radar data quality control is the eternal issues.
15. Insufficient data application in numerical weather prediction model.
16. Short term warning based on radar observation need to be strengthened.
17. RF protection issues, e.g. Hainan weather radar in China.
18. Calibrations, no matter single or Dual-pole.
19. Different level of radar data quality among regional countries.
20. **Discussion topics:**
21. RF protection is needed through WMO and ITU, more specific guidance to regular the Emerging new “black” applications.
22. Regional and global Data exchange guidance and materials for different types of radars.
23. Guide to use of the asynchronous radars from WMO and regional level.

ANNEXES:

1. CMA\_summary
2. JMA\_summary(2 docs)
3. HK\_summary
4. Korea\_summary

 Submitted by CMA

1. **Now:**
2. **China mainland Weather Radar network**
3. There are 295 weather radar deployed in China mainland, including the CMA and civil aviation department, the 1km AGL coverage is 22%.
4. Multiple types of radar operated in China: fixed, S-band, C-band, X-band, Mobil, C-band and X-band phased array weather radar.
5. 101 weather radars are planned to upgrade to dual-pol by 2020.
6. China has initiated special project to enhance the existing radar network performance, like i) changing the observation models from volume scan to stream transferring; ii) application on X-ban phased array, Radar Wind Profiler, Ka & W cloud, aerosol radars; iii) focus on QC and combination with satellite data (radar mosaic V2.0)
7. **Application and capacity**
8. now casting/ short-term forecasting accuracy and timeliness are improved: data have been assimilated into NMP and 0-6 h precipitation prediction accuracy has been improved 10%
9. SWAN2.0: multi-data can be integrated including weather radars base data and PUP. The platform mainly focus on storm structure data, and is capable of output more than 10 types of products, e.g. 3-D base-reflectivity, composite ref., QPE, precipitation forecasting, storm identify, etc.
10. ROSE(Radar Operational Software Engineering)：replace PUP and can provide additional 39 products
11. public warning capacity are greatly improved: For example, the warning time of heavy rain reaches 110000, and reaches 12000 for storm wind during the year 2010 to 2015
12. Public service: Weather radar network and its products serve well in typhoon prediction, weather modifications, Beijing Olympic Games, Shanghai EXPO, Nanjing Youth Olympic games, Shenzhou spacecraft launch and recovery...
13. **Future Requirement:** according to National Weather Radar network SP & IP (2016-2025) :
14. Improve the accuracy of quantitatively precipitation estimation reaching 80%;
15. Enhance the radar data sharing , application and public service
16. Promote the application in numerical forecast models, improve the precipitation forecast ability;
17. Enhance the maintenance and logistics of radar operation: i) establishment of logistics platform both in national and provincial level; ii) foundation of national radar software simulation and emulation system; iii) establishment of informationization platform.
18. Strengthen the technical training including mechanical operation, data/product quality control and data application; put emphasis on practical training conditions.
19. Promote the weather radar application in following areas: development of data quality control system of weather radar; improvement of data sharing platform of meteorological radar; upgrade of operation radar software system; development of radar network products; emphasis on warning/alert service; data fusion and application in numerical weather prediction model.
20. Logistics

Public warning capacity should be improved:

1. **Issues:**
2. Transmission time-delay issues, data loss during the new data-relay.
3. radar data quality control need to be improved
4. insufficient data application in numerical weather prediction model
5. short term warning based on radar observation need to be strengthened

5) RF protection issues, e.g. Hainan weather radar

6) Dual-pole calibrations

1. **Discussion topics:**
2. RF protection is needed through WMO and ITU, more specific guidance to regular the Emerging new “black” applications.
3. Data exchange guidance and regular materials regionally and internationally

Submitted by JMA

28 Feb 2017

**Priorities and requirements for installing dual-pol weather radars in Japan**

The Japan Meteorological Agency (JMA) addresses securement of accuracy of dual polarized (dual-pol) weather radar data and suppression of interference between weather radar and Radio LAN (RLAN) in order to realize high quality weather radar observation sustainably.

1. **Confirmation of antenna performance and adjustment of transmit differential phase**

Dual-pol weather radars are able to improve quality of radar observation data including Doppler velocity, quantitative precipitation estimation (QPE) and realize hydrometeor classification. JMA promotes dual-polarization of weather radar starting by three TDWR radars in 2016. In order to provide advanced dual-pol products, appropriate qualities of the basic dual-pol variables are required. In particular, Kdp (derived from φdp) and ρhv are important variables for QPE and hydrometeor classification, respectively.

To obtain appropriate quality of Kdp and ρhv, the simultaneous transmit and receive (STAR)-mode is widely used for operational dual-pol weather radars.　JMA also adopted this mode to the three dual-pol weather radars. However, STAR-mode has a disadvantage that cross coupling of H and V waves can cause serious biases on dual-pol variables (see Hubbert et al, 2010). To mitigate this cross coupling, high cross-polar isolation and adjustment to zero of transmit differential phase are needed.

Then, JMA confirmed cross-polar isolation and adjusted transmit differential phase using a horn antenna set in the far field of dual-pol radar, before radar operation was started. Cross-polar isolation is confirmed using co-polar and cross-polar 2D-antenna patterns obtained by the azimuthally and elevationally scanning radar antenna receiving radio wave emitted by horn antenna, according to the method proposed by Frech et al. (2013).　The adjustment of transmit differential phase is performed according to the method proposed by the National Institute of Communication Technologies (NICT) of Japan. Phase of transmitting H and V waves of dual-pol weather radar was adjusted so as to horn antenna’s receiving signal power become maximum and minimum values at +45° and -45° polarization plane, respectively.

 Since the dual-pol variables are derived from the difference between H and V signals which are affected by precipitation or non-precipitation targets, adjustment to zero of transmit differential phase as well as confirmation of cross-polar isolation will be very important before starting the operation of dual-pol weather radars. However, such adjustment and confirmation are not carried out in some cases, although dual-pol weather radars using STAR-mode are used worldwide today. Therefore, sharing the knowledges and techniques related to dual-pol weather radar with Members are needed to be done by IPET-OWR through ToR(1).

**(2) The adoption of solid-state transmitters for effective radio frequency usage**

JMA promotes to introduce weather radars with solid-state transmitters. The adoption of solid-state transmitters is expected to be one of the counterplan for the serious threat from interference caused by telecommunication devices (e.g., RLAN) to weather radars worldwide (Elena et al. 2015). Japan’s radio regulatory authority, the Ministry of Internal Affairs and Communications, is taking measures to separate frequency bands allocated to weather radar and RLAN services.

The resulting radio frequency reallocation plan for weather radars in Japan is based on nine channels with increments of 5 MHz within narrow band-width areas in W54 (5.35 – 5.45GHz), which is not opened to RLAN, as opposed to the conventional allocation plan based on channels with increments of 10 MHz.

In relation to the radio frequency reallocation, solid-state transmitter can realize such channel plan because they support:

- Achievement of balance between peak power reduction and high data quality;

- Mitigation of unexpected emissions against adjacent channels; and

- Simple frequency changes.

Actually, the two TDWRs equipped with solid-state transmitters of Haneda and Narita airports do not interfere in each other, even though the distance and frequency difference are only 60 km and 5 MHz, respectively.

However, frequency sharing in W54 will be discussed at the next World Radiocommunication Conference (WRC-19). Toward WRC-19 we need to demand that RLAN not to interfere in existing and expected future weather radar systems such as phased array radar through ToR(4).

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Submitted by JMA

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**Capacity building in radar techniques in the Southeast Asia**

**Background**

 The Southeast Asia is one of the areas in the world which seriously suffer from weather and water related disasters and therefore severe weather monitoring is one of the major challenges for effective disaster risk reduction (DRR) activities in the region. The area includes huge river basins with large international rivers such as Chao Phraya, Mekong andAyeyarwady. The precipitation monitoring in an effective way with international cooperation has been a big dream of not only meteorological services but also hydrological services in the region. Toward this ambitious goal, the ESCAP/WMO Typhoon Committee at its 43rd session (Jeju, Republic of Korea, Jan 2011) endorsed a project, Development of Regional Radar Network, aiming at future establishment of radar composite map in Thailand as its first step. In parallel, the WMO Regional Association II (Asia) at its 15th session (Doha, Qatar, Dec 2012) adopted the Regional WIGOS Implementation Plan including the project, III-2 Observing systems integration for supporting disaster risk reduction - Capacity Building in Radar Techniques in the Southeast Asia. Also in 2011, a regional capacity building project on the maintenance and rainfall estimation and forecast by using weather radar was initiated by the ASEAN Sub-Committee on Meteorology and Geophysics (SCMG).

**1. Capacity building through regional workshop**

 The Regional Training Workshop on Weather Radar Basis and Routine Maintenance and Real-Time Radar Rainfall Estimation and Forecasting (Bangkok, Thailand, 4 Feb to 7 Mar 2014) was held with 20 participants from 7 ASEAN countries; Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand and Viet Nam. At the workshop, the lectures were given by experts from the Japan Meteorological Agency (JMA), a radar manufacture and a University in Japan. It covered various topics related to weather radars, in particular, basics, function, structure and maintenance as well as its applications such as Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecasting (QPF). Through the workshop, the participants recognized the benefits of developing a radar composite map covering the ASEAN region which is expected to practically contribute to the improvement of DRR activities in own countries. The workshop was concluded with great success encouraging the participants to further promote the relevant activities.

**2. Capacity building through technical meetings**

2.1 Cooperation between the Thai Meteorological Department (TMD) and JMA

 TMD and JMA collaboratively held technical meetings on weather radars in 2011, 2012, 2013, 2014, 2015 and 2016 in accordance with the ESCAP/WMO Typhoon Committee Annual Operating Plan. The series of meetings with intensive discussion by technical experts of both sides produced concrete achievements for the improvement of radar data quality (e.g. noise reduction, calibration with rain-gauges and quality control) allowing producing radar composite and QPE in Thailand.

2.2 Cooperation between the Malaysian Meteorological Department (MMD) and JMA

 MMD and JMA started technical cooperation on weather radars, and collaboratively held training workshops on radar quality and QPE in 2015 and 2016. The cooperative activities enabled MMD to convert radar data format from IRIS to GRIB2 and create the elevation angle composite table. It is expected that MMD will develop QPE covering Malaysia in the near future.

2.3 Cooperation between the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and JMA

 BMKG and JMA started discussion on remote sensing technology, including weather radars in 2015. Mainly through email communications, bilateral technical discussion is ongoing to realize weather radar data exchange between BMKG and JMA.

**3. Experimental exchange of radar data for composite map**

 In November 2016, as the result of bilateral cooperative activities above, JMA in cooperation with TMD and MMD successfully started the international radar data exchange in GRIB2 format to create transboundary composite map in a near real-time basis. This experimental data exchange was started as an achievement of the ESCAP/WMO Typhoon Committee activities.

**4. Jakarta Declaration and the Joint RA II/RA V WIGOS project**

 The Joint RA II/RA V Workshop on WIGOS for Disaster Risk Reduction (Jakarta, Indonesia, Oct 2015) was held aiming at enhancing the exchange of meteorological observation data across the Southeast Asia and to improve the availability and quality of those observations including weather radars. The major outcome of the Workshop was the "Jakarta Declaration", which proposed to develop two projects (weather radar and meteorological satellite) involving Members in both RA II and RA V under the WIGOS umbrella. The weather radar project aims at (i) improvement of data quality of existing radars, (ii) development and expansion of national radar networks, (iii) near real time international exchange of radar data, and (iv) development of «sub-regional» radar data centre(s).

The RA II at its 16th session (Abu Dhabi, UAE, Feb 2017) adopted the Regional WIGOS Implementation Plan 2017-2020. In accordance with the Jakarta Declaration, the implementation plan contains the project on Capacity Building in Radar Techniques in the Southeast Asia, with the planned activities such as capacity building on QA/QC techniques of weather radars, establishment of domestic radar network, experimental data exchange for international radar composite, all aims for the goal of promoting DRR activities in respective countries. Since the project is open to all NMHSs in the Southeast Asia, another key to the success is how to increase the cooperating NMHSs to further expand the quality controlled radar data coverage in the region.

1. **Now:** Summarized by CMA
2. HKO Weather Radar Systems

HKO Weather Radar Systems is comprised of 5 weather radar systems, with 1dual-pol X-band radar, 2 S-band radars and 2 C-band radars.

1. Applications

HKO Weather Radar Systems play important role in Detection and Monitoring of Severe Weather, automatic Alerts for Windshear and Microburst. There are several radar products like Dual-polarization Radar Products of Hydrometeor Classification, Nowcasting products, Integration products of Radar Data and Lightning Location and also the radar products for the public.

1. Collaborations

Joint research projects with local and overseas institutes, sharing of radar data and technological exchange activities with neighboring NMS

1. Future Requirement:

 Adaptation of new radar technologies such as phased array radar

1. Problems:
2. Competition in use of radio frequencies by various sectors
3. Interference by unknown radio sources occasionally
4. Too few suppliers for Terminal Doppler Weather Radar (TDWR) system
5. Discussion topics:

 None

1. **Now:**
2. **Korea weather radar network**
3. There are 31 weather radars belonging to major tri-agencies and some institutes: Korea Meteorological Administration (KMA), Ministry of Land, Infrastructure, and Transportation (MOLIT), Korea Air Force (KAF), and several national research institutes.
4. Various types of weather radar are operated in South Korea: single-pol. (SP) and dual-pol. (DP), three frequencies (S-band, C-band, and X-band), fixed and mobile weather radar.
5. KMA’s 11 weather radars are planned to replace into dual-polarization radar by 2020. The replacement by dual-polarization radar has been done at 6 sites. Currently, KMA operates heterogeneous weather radar network composed of single polarization and dual-polarization radar.
6. Major tri-agencies made an agreement for cooperation of national resources of weather radar. According to the agreement, Weather Radar Center (WRC) of KMA is mainly responsible for detection and monitoring of severe weather and all of R&D for radar data application. MOLIT and KAF are in charge of the optimization of radar scan strategies and maintenance procedure, respectively.
7. New three X-band dual-polarization radar with solid-state power amplifier will be installed by the end of this year.
8. **Application and capacity**
9. New quality control procedure was developed based on fuzzy logic approach and statistical analysis of radar data: Its performance was significantly improved comparing to the existing QC algorithm.
10. The system biases of radar reflectivity and differential reflectivity are routinely produced and monitored by various techniques such as self-consistency principle, vertical pointing measurement, comparing to disdrometer measurement, and so on. Routine monitoring of the biases can be used as a diagnostic tool of radar system. The biases can be also used in radar rainfall estimation based on polarimetric observation.
11. The quality index, quantized value (0~1) for quality of radar observation, is produced for both single-polarization and dual-polarization observation. The quality index can be utilized for radar rainfall estimation, nationwide composite of individual radar products, assimilation of radar data into NWP model, and so on.
12. HSR 1.0: Radar rainfall estimation at hybrid surface consisting of the lowest height radar bins that is not contaminated by ground clutter, partial beam blockage, and non-meteorological echoes.
13. RAR2.0: Radar rainfall estimation can be adjusted by probability matching method using rain gauge rainfall. RAR is utilized for flash flood warning, input data at nowcasting system, ground validation of satellite rainfall estimation, and so on.
14. Various radar products including hydrometeor classification, 3D storm structure, multiple-Doppler wind synthesis, radar-based snowfall estimation is routinely produced.
15. Three types of nowcasting system provide short-term forecasting for 0~6h precipitation prediction: 1) echo tracking system based on pixel by pixel, 2) cell-tracking system, 3) nowcasting system blelded with NWP output.
16. Public service: Rainfall estimation and short-term forecasting based on both nationwide weather radar network and single radars, Pyeongchang Winter Olympic Games.
17. **Future Requirement**
18. Improve the accuracy of nationwide QPE reaching 84% by 2020.
19. Gap filling at low level over urban area and recover the beam shielding area at mountainous regions over S- and C-band radar network using X-band radar network
20. Provide the radar network products including hydrometeor classification, dual-polarization radar QPE and QPF, 3D storm identification, and multi-sensor fusion products(e.g. lightning, satellite rainfall, and so on)
21. Reduce the uncertainties of radar network products from inhomogeneous radar network consisting of S-, C-, and X-band radars.
22. Developed the absolute calibration algorithm for the system biases of all polarization observations using nationwide radar network.
23. Developed the standard radar data format (level I, II, III) and common software library for all radar products.
24. Promote the weather radar application in following areas: development of advanced quality control system of weather radar data; the radar data application in NWP models, specially focused on the precipitation prediction ability for short term range forecasting; enhance the warning service of severe storm.
25. Strengthen the training program including mechanical maintenance, signal processing, data quality control, and radar data application.
26. **Issues:**
27. The quality control of Polari metric observations is primary issue and it is need to be improved
28. Different level of radar data quality among the countries.
29. Insufficient application of radar products for NWP model
30. Radar-based short term forecasting need to be strengthened
31. Calibration of single- and dual-polarization radar
32. **Discussion topics:**
33. Guidance or regular material on international exchange of radar data