WORLD METEOROLOGICAL ORGANIZATION
ASSOCIATION OF SOUTHEAST ASIAN NATIONS

TRAINING WORKSHOP ON WEATHER RADAR QUALITY AND STANDARDIZATION

BANGKOK, THAILAND, 5 – 13 FEBRUARY 2018

FINAL REPORT

EXECUTIVE SUMMARY

The World Meteorological Organization (WMO) and the Association of Southeast Asian Nations (ASEAN) jointly organized the Training Workshop on Weather Radar Quality and Standardization from 5 to 13 February 2018 at the Pathumwan Princess Hotel in Bangkok, Thailand at the kind invitation of the Government of Thailand taking into account that both entities have each project which has identical goals on weather radars in Southeast Asia: the Regional Association (RA) II (Asia) and RA V (South-West Pacific) joint regional WMO Integrated Global Observing System (WIGOS) project approved by RA II at its sixteenth session (Abu Dhabi, United Arab Emirates, February 2017) and the project on a weather radar workshop endorsed at the Thirty-ninth Meeting of the ASEAN Sub-Committee on Meteorology and Geophysics (SCMG) (Manila, Philippines, May 2017). This workshop was kindly hosted by the Thai Meteorological Department (TMD) and technically and financially supported by the Japan Meteorological Agency (JMA).

This workshop was attended by radar experts of National Meteorological and Hydrological Services (NMHSs) from nine (9) ASEAN Member States (Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam) and Bangladesh that consisted of 25 participants (22 male and three (3) female). A representative from JMA, the ASEAN Secretariat and the WMO Secretariat, members of the WMO Expert Team on Weather Radars, invited experts of JMA, and weather radar manufacturers in Japan and Germany were also in attendance.

The workshop was held on the background that the increase of the number of weather radars in the region has led to an increased need for effective utilization of the data collected. In addition, improved Quality Control (QC) and international real-time data exchange are expected to play pivotal roles in Disaster Risk Reduction (DRR) in the region.

The workshop therefore focused on capacity development of ASEAN Member States and Bangladesh on the technical aspect of radar maintenance, radar applications, radar data exchange and format, and cases studies. The participants learned how to nurture groups of well trained and skillful technical personnel in maintaining weather radar network in their respective countries through an effective regional capacity building exercise, to enable Southeast Asian countries to issue effective information on severe weather based on radar rainfall estimation and forecasting, and to identify common issues in the region. The workshop addressed common regional challenges in extreme weather monitoring and forecasting in the region.

A number of presentations and hands-on training were given to participants, and the future challenges in each country and the region were discussed. All the participants recognized their substantial progress and confirmed the next step to further contribute to DRR using weather radars in the region.

____

GENERAL SUMMARY

Introduction

The WMO/ASEAN Training Workshop on Weather Radar Quality and Standardization was held from 5 to 13 February 2018 in Bangkok, Thailand. The programme of the workshop and the list of participants are given as Annex I and Annex II, respectively.

1. Opening

1.1. Welcome remarks

Mr Boonlert Archevarahuprok, Expert on Research and Development for Meteorology of the Thai Meteorological Department (TMD) reported the background of the workshop. Mr Yoshiro Tanaka of the Japan Meteorological Agency (JMA) provided his welcome remarks followed by Ms Lee Sing Cheong and Mr Ryuji Yamada from the Association of Southeast Asian Nations (ASEAN) Secretariat and the World Meteorological Organization (WMO) Secretariat, respectively.

1.2. Opening address

Mr Wanchai Sakudomachai, Director-General of TMD warmly welcomed all the participants to the workshop. He outlined that weather radars are very significant and effective tools to assist National Meteorological and Hydrological Services (NMHSs) to monitor rainfall and support accurate nowcasting. He expressed sincere appreciation to WMO, ASEAN and JMA for holding this workshop which aims to enhance the utilization of weather radars and address the challenges on weather radar data quality and standardization. He expected the workshop could help member countries increase the effectiveness of weather forecasting and Disaster Risk Reduction (DRR) activities.

1.3. Keynote speeches

A keynote speech was given by Dr Daniel Michelson, Chair of the WMO Inter-programme Expert Team on Operational Weather Radar (IPET-OWR). He began by presenting the existing eight Technical Commissions of WMO, emphasizing that the majority of the activities conducted thus far addressing weather radar have been made within the Commission for Basic Systems (CBS) and the Commission for Instruments and Methods of Observation (CIMO). He continued by presenting IPET-OWR, emphasizing that it is jointly managed by CIMO and CBS, and comprises previously existing activities from each Technical Commission along with new activities. As such IPET-OWR is charged with the stewardship of weather radar emerging as a global resource to meet expected demand for internationally exchanged data regionally, inter-regionally, and globally. He presented the IPET-OWR work plan, highlighting results like the Member survey on weather radar requirements conducted in early 2017, the proposed data representation standard (CfRadial2), and a focus on advice and guidance through a Weather Radar Best Practices Guide among other documentation deliverables. Liaison with International Telecommunication Union (ITU) for addressing frequency allocation in relation to radio interference, and International Organization for Standardization (ISO) in formulating a joint weather radar standard, were also mentioned.

Dr Michelson highlighted the importance of calibration and monitoring as a means of ensuring consistent, high quality operations, high system and data availability, and data quality that meets processing and user requirements. Solar monitoring was given as an example of a useful technique. Finally, assimilation of radar data from Canada and the United States was given as an example of an advanced application requiring international data exchange and advanced quality control and compositing.

Mr Koichiro Kakihara (JMA), Leader of the Regional Association (RA) II (Asia) and RA V (South-West Pacific) joint regional WMO Integrated Global Observing System (WIGOS) project “Capacity building in radar techniques in the Southeast Asia” gave a keynote speech “Radar Network in Southeast Asia” on the purpose of this workshop and the necessity of the regional weather radar network. In this speech, he emphasized the important roles of weather radars to contribute to DRR in this disaster-prone region and that the capacity building activities are essential. He also referred to the multilayered underpinning frameworks which support every NMHS in Southeast Asia; the joint regional WIGOS project, the ASEAN project and the ESCAP/WMO Typhoon Committee project.

Mr Kakihara highlighted that the aims of the joint regional WIGOS project on weather radars are in line with the Jakarta Declaration, which was adopted at the Joint RA II/RA V Workshop on WIGOS for Disaster Risk Reduction (Jakarta, Indonesia, October 2015), and radar observation data would be further utilized in DRR activities in each country through improvement of quality management of weather radars and development of national and regional radar network.
He also highlighted that it was important to "start" data exchange and create regional composite map so that countries in this region were encouraged to exchange national composite radar data in a "feasible" data format for each country, while radar data exchange in data representation standard (CfRadial2), proposed by IPET-OWR, would be a future challenge in this region.

2. Workshop sessions

2.1. Weather radar operation

Dr Masahito Ishihara, former radar meteorologist/researcher of JMA and former professor of Kyoto University, made a presentation concerning the basics of weather radar. He started from the brief history of radar and moved to the history of weather radar operation of JMA starting in 1954 as well as the current situation of weather radar networks in Japan. He derived the radar equation in detail from a point target to distributed targets and finally got to simplified radar equation. He also introduced the procedure of weather radar observation operated in JMA, describing the law/rule/guidance/manuals, the timetable of the radar observation, data quality check, machine maintenance and the replacement schedule of weather radars.

2.2. Weather radar maintenance

Mr Shuichi Inoue of Japan Radio Co., Ltd. (JRC) explained basic weather radar structure and operation principle of the conventional weather radars (magnetron type and klystron type), and the importance of conducting periodical maintenance that must be carried out to keep system conditions stable and to achieve a certain level of data quality and/or appropriate operational functions of the weather radars. He referred to concrete methods in detail conducting periodical maintenance such as measurement of output power, transmitting pulse width, frequency and so on, from the point of view of the weather radar manufacturer. He also explained the operation principle and maintenance method in recent technology of the weather radars such as the pulse compression radars and the dual polarization weather radars.

2.3. Country reports

All participants from NMHSs gave presentations on their current status of weather radars including operation, maintenance, data utilization, technical challenges and future plans. Additionally, the Meteorological, Climatological and Geophysical Agency (BMKG) of Indonesia, the Malaysian Meteorological Department (MMD) and TMD reported the outline of their quality control processes. The detailed information provided by each participant before the workshop is attached as weather specification table (<u>Annex III</u>) and survey results (<u>Annex IV</u>).

2.4. Weather radar data Quality Control

Dr Ishihara (Japan) showed error sources affecting the weather radar observation and reducing the quality of weather radar data: ground clutter, sea clutter, bright band, precipitation aloft, side lobe echoes, second trip echoes, wind turbines, birds, volcanic ash, beam blockage, beam filling missing and radio wave interference.

Mr Hiroshi Yamauchi (JMA) gave presentations on the quality control of weather radar data by using dual-polarization. First, he summarized the merits of dual-pol weather radar and explained the meaning of each dual-polarization parameter. Then he explained ground clutter removal, sea clutter removal and clear echo removal techniques with a practical example conducted by JMA. Finally, he emphasized the importance of calibration for dual-polarization parameters.

2.5. Hands-on training on weather radar QC

Mr Junji Hotta (JMA) gave presentations on the characteristics of non-precipitation echo and quality control (QC) algorithms including JMA's Pseudo CAPPI process. He also provided a hands-on training of adjusting elevation angle composite tables which enable weather radars to avoid influence of clutters and interferences. He emphasized that the importance of continuing QC and accumulation and careful investigation of weather radar data will improve QC results.

2.6. Manufacture's QC

Mr Katsuhiro Nagaya (JRC) explained the manufacture's QC activity regarding the installation of weather radars with quality assurance organization in factories. After the explanation about Quantitative Precipitation Estimation (QPE)/Quantitative Precipitation Forecast (QPF) application for disaster mitigation, he introduced the well-developed QC for single/dual polarization weather radars in Japan as a successful example. He also introduced the calibration method for weather radars data by using metal sphere and disdrometer.

Mr Andre Weipert (Selex ES GmbH) presented industrial views on weather radars. Radar data quality monitoring and control is a demanding challenge since it is not an isolated or radar system related task; data quality is transversal to the overall system of systems planning and life cycle considering single and combined/netted weather radars. Radars are usually procured by different organizations (e.g. NMHSs or Air Navigation Services Providers/Airport Authorities) for different purposes (e.g. hydrological or aviation applications) in iterative procurement steps over years using heterogeneous technologies (e.g. dual polarization, different band widths); a coherent, harmonized and flexible planning strategy is needed, since all radars shall finally run in an orchestrated way offering different fit-for-purpose meteorological products on national, regional and international scales. It has been stated that initial perfection, when planning the national orchestrated radar network, cannot be reached but special emphasis shall be done on instantaneous radar hardware monitoring (scheduled periodic reports and planning tools for preventive maintenance), collaborative data quality control using a centralized meteorological data processing design, since raw data is the "lowest common denominator" in radar networks, a seamless semantic data interoperability using common data standards and cross application synergies enabling e.g. the sharing of data between meteorological and aviation applications.

2.7. Radar applications

Mr Yamauchi (JMA) gave a presentation on dual- polarization and Doppler velocity application such as rain-rate estimation using specific differential phase (Kdp), hydrometer classification, wind shear detection and velocity azimuth display. He explained the difficulty in using Doppler velocity caused by velocity aliasing and inability to measure tangential velocity.

Mr Takanori Sakanashi (JMA) gave a presentation on QPE and held a hands-on training in QPE by using weather radar and rain-gauge observation data in Japan. He emphasized the importance of QC of both data which are the most fundamental factors to calculate QPE correctly. Also, he explained that QPE would contribute to further advanced products for disaster prevention such as QPF and disaster potential indexes.

2.8. Radar data exchange and data format

Mr Boonlert Archevarahuprok (TMD) made a very comprehensive presentation on weather radar formats and regional data exchange which shared navigational information, current situation and way forward. In particular, he detailed characteristics of manufacturers' native raw data formats (e.g. EEC volume format, UF, Gematronic xml format) as well as its conversions to Cartesian data (WMO GRIB2, BUFR, NetCDF and HDF 5, etc). He explained that GRIB2 is currently used for radar composite and data exchange in Southeast Asia while international data exchange in radial format (i.e. CfRadial2) can be expected as a future challenge.

2.9. Case study on disaster event using radar data

Dr Ishihara (Japan) showed a sample of weather summary issued by JMA to the public via the JMA website just after severe weather disasters. He stressed that the weather summary is very important to provide the public and related agencies with simple and accurate weather information on the severe disaster and that it would be valuable archive data for improving weather forecast/disaster management/research in the future. He handed over all the NMHSs' participants in the workshop a template of the weather summary and sample image data of weather chart (provided by iTacs, the climate analysis tool of JMA), of satellite radar (provided by GSMaP of JAXA), and of JMA HIMAWARI (provided by the online database run by Kochi University). All the participants made a hand-on training to create the weather summary using the template and the image data.

2.10. Technical tours

Participants visited Rayong Weather Station in Rayong Province, and observed C-band weather radar facility, a local Radio Broadcast tower and meteorological fields on 10 February 2018. They also visited the TMD headquarters on 12 February 2018 to learn TMD's services and their facilities including broadcasting studios and a high performance computing system.

2.11. Discussions

Mr Kakihara (JMA) gave a presentation about an outline of the experimental radar composite data exchange among TMD, MMD and JMA, and lessons learnt from the experimental exchange. He also talked about an expected next step of the joint RA II/RA V WIGOS project and what participants of the workshop should do after the workshop. He emphasized that it was important for all participants to share training materials, presentation files and final report of the workshop with their colleagues, and to discuss internally how they could improve their radar data and could join the regional radar composite.

The participants took note and welcomed the Jakarta Declaration (weather radar part) with its aims listed below, which also form the basis of the joint RA II/RA V WIGOS project;

(1) Improvement of data quality of existing radars,

(2) Development and expansion of national radar networks,

(3) Near real-time international exchange of radar data, and

(4) Development of «sub-regional» radar data centre(s).

With the aims of the WIGOS project in mind, as well as taking into account the achievements of this training workshop, all participants considered their own NMHSs' current challenges and future plans to enhance the capabilities on weather radars. They gave brief presentations and discussed their plans.

Through the discussion, the participants recognized substantial progress has been made from the previous workshop held in Bangkok, Thailand in 2014. For future activities of the project, they agreed that a succeeding workshop, hopefully in a nearest future, may need to have three pillars;

(1) Basics on weather radar and its operation,

(2) QC of weather radar data and their composite/exchange, and

(3) Usage of dual-polarization function and QPE/QPF.

Also the participants shared their common understanding that they need to increase quality of radar data as well as to promote regional radar network to enhance the promising abilities of weather radars and improve DRR in Southeast Asia. For these purposes, they agreed to emphasize four items shown below;

(1) To ensure creating Cartesian data in common data format such as GRIB2 to achieve radar composite in Southeast Asia through regional data exchange,

(2) To emphasize the development of QC techniques rather than to respect too much on the conventional Z-R relation,

(3) To learn and develop dual-polarization techniques to enjoy the latest technologies on weather radars in the future,

(4) To communicate closely with members and share their experiences regarding various matters on weather radars to overcome common difficulties in the region.

3. Closing

The certificates were presented to all the participants and invited experts.

Dr Songkran Agsorn, Deputy Director-General of TMD and the ASEAN/SCMG focal point of Thailand provided a closing remark and the workshop was closed at 3 p.m. on Tuesday, 13 February 2018 with a great success.

____

Programme

Monday, 5 February

1. Opening ceremony

1.1. Welcome remarks

Mr B. Archevarahupro (TMD)
Mr Y. Tanaka (JMA)
Mr R. Yamada (WMO)
Ms L. S. Cheong (ASEAN Secretariat)

1.2. Opening Address

Mr Wanchai Sakudomachai (Director-General, TMD)

1.3. Keynote speeches

- The emergence of weather radar as a global resource
  Dr D. Michelson (Chair, WMO/IPET-OWR)
- Radar Network in Southeast Asia
  Mr K. Kakihara (JMA)

2. Workshop sessions

2.1. Weather radar operation

- History and current situation of weather radars
- Basics of weather radars
- Operation of weather radars
  Dr M. Ishihara (Japan)

2.2. Weather radar maintenance

- Relation of maintenance and radar equation
- Various maintenance items for the radar equipment
- Caution point
  Mr S. Inoue (JRC)

Tuesday, 6 February

2.2. Weather radar maintenance (cont.)

- Relation of maintenance and radar equation
- Various maintenance items for the radar equipment
- Caution point
  Mr S. Inoue (JRC)

2.3. Country reports on radar operation, maintenance and utilization

ASEAN Members, BMD

Wednesday, 7 February

2.4. Weather radar Data QC

- Calibration
- Noise reduction
  Dr M. Ishihara (Japan)
- QC of weather radar data by using dual-polarization radar
  Mr H. Yamauchi (JMA)

2.5. Hands on Weather Radar QC

- Introduction of JMA operational system
- Quality control algorithms
  Mr J. Hotta (JMA)

2.3. Country reports on radar QC

TMD, MMD, BMKG

Thursday, 8 February

2.5. Hands on Weather Radar QC (cont.)
- Quality control algorithms
Mr J. Hotta (JMA)

2.6. Manufacture's QC
- German manufacturer
Mr A. Weipert (Selex ES GmbH)

2.7. Radar applications
- Dual-polarization
- Doppler velocity
Mr H. Yamauchi (JMA)
- QPE & QPF
Mr T. Sakanashi (JMA)

Friday, 9 February

2.8. Radar exchange and format
- Radar data format
- Radar data exchange
- ASEAN radar network
Mr B. Archevarahuprok (TMD)

2.9. Case study on disaster event using radar data
- Weather summary on a disaster occurrence (WADO)
- Practice for creating WADO
Dr M. Ishihara (Japan)

Saturday, 10 February

2.10. Technical Tour: Visit to TMD's radar site (Rayong radar and meteorological station)

Monday, 12 February

2.6. Manufacture's QC
- Japanese manufacturer
Mr K. Nagaya (JRC)

2.10. Technical Tour
- Visit to TMD Headquarters

Tuesday, 13 February

2.11. Discussion on regional radar network and radar exchange

3. Closing ceremony

____

List of Participants

<u>Participants</u>

Cambodia: Department of Meteorology

Mr Korng Youtray	Deputy Director youtray@yahoo.com
Mr Chuon Sokun	Vice Chief Officer Chuonsokun38@gmail.com

Indonesia: Agency for Meteorology Climatology and Geophysics

Mr Deni Permana	Staff of Weather Radar Imagery Management Sub Division denpermana@yahoo.com
Mr Henrikus Jatining Wahyu Argo	Staff of Weather Radar Imagery Management Sub Division wahyuargo@yahoo.com

Lao People's Democratic Republic: Department of Meteorology and Hydrology

Mr Saleumsack Sidavong	Technical Staff on Radar s.sidavong@yahoo.com, dmhvte@etll.com
Ms Khaemeuy Chao	Technical Staff on Weather Forecasting and Warning Division khaemeuy@gmail.com, dmhvte@etllao.com

Malaysia: Malaysian Meteorological Department

Mr Mahluddin Sahrin	Meteorological Officer udin@met.gov.my
Mr Ismail Alias	Meteorological Officer ismailalias@met.gov.my

Myanmar: Department of Meteorology and Hydrology

Mr Hla Tun	Deputy Director, Meteorological Division hlatunmr@gmail.com
Mr Ye Htut	Deputy Chief Engineer of Engineer Division yehtut41@gmail.com

Philippines: Philippine Atmospheric, Geophysical and Astronomical Services Administration

Ms Julie M. Nimes	Weather Specialist II jmnimes@yahoo.com
Mr Joey Hermones Figuracion	Weather Specialist I joeyfiguracion@gmail.com

Singapore: Meteorological Service Singapore

Mr Kiat Haw, Gavin Yeap	Executive Meteorologist gavin_yeap@nea.gov.sg

Thailand:

Thai Meteorological Department

Mr Fatah Masthawee	Meteorologist, Meteorological Development Division fatah_m@yahoo.com
Mr Aphinya Chitchaeng	Meteorologist, Division of Aeronautical Meteorological aphinya.tmd@gmail.com
Mr Theerachai Auttachaipanit	Meteorologist, Weather Forecast Division theerachai3@hotmail.com
Mr Peeranat Longsombun	Meteorologist, Weather Forecast Division peeranat.long@gmail.com
Mr Pramote Klinduang	Computer Technical Officer, Division of Meteorological Digital Services promote@tmd.go.th
Ms Natkamon Khemngoen	Meteorological Officer, Meteorological Observation Division new_takamon@hotmail.com

Department of Royal Rainmaking and Agricultural Aviation

Mr Tanthai Polharn	Scientist tan_rainmaker1@hotmail.com

Bangkok Metropolitan Administration

Mr Darat Kammaroeng	Electrical Engineer, Department of Drainage and Sewerage tonscn@gmail.com

Viet Nam: National Hydro-Meteorological Service of Viet Nam

Mr Toan Minh Hoang	Head of Information and Data Aero Meteorology Observatory, Aero-Meteorological Observatory minhtoanck@gmail.com, minhtoan@amo.gov.vn
Mr Long Thang Dao	Weather Radar Observer-Deputy Head, Viettri Weather Radar Station, Mid-Northern Regional Hydro Meteorological Center longkttvvb@gmail.com

Bangladesh: Bangladesh Meteorological Department

Mr Md. Shadekul Alam	Assistant Director shadekul@gmail.com, info@bmd.gov.bd
Mr Mohammad Sazzad Hossain	Senior Communication Engineer mim_bmd2004@yahoo.com, info@bmd.gov.bd

<u>Observers</u>

Indonesia: Agency for Meteorology Climatology and Geophysics

Ms Nurhayati Noer	Head of Center for Public Weather Service nurhayah@bmkg.go.id
Mr Taufiq Hidayah	Head of Sub Division for Weather Early Warning twkgbmkg@yahoo.com

Experts

Dr Masahito Ishihara	Former Professor of Kyoto University mishihar0308@yahoo.co.jp
Mr Katsuhiro Nagaya	Assistant General Manager, Engineering Management Department, Japan Radio Co., Ltd. nagaya.katsuhiro@jrc.co.jp
Mr Shuichi Inoue	General Manager, Solution Business Division, Business Development Department, Japan Radio Co., Ltd. inoue.shuichi@jrc.co.jp
Mr Yoshiro Tanaka	Vice-chair of WMO Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR) Deputy Head, Office of International Affairs, Administration Department, Japan Meteorological Agency (JMA) yoshiro.tanaka@met.kishou.go.jp
Mr Koichiro Kakihara	International Strategy Officer, Administration Division, Observation Department, JMA k-kakihara@met.kishou.go.jp
Mr Hiroshi Yamauchi	Senior Science Officer, Administration Division, Observation Department, JMA h-yamauchi@met.kishou.go.jp
Mr Junji Hotta	Assistant Scientific Officer, Observation Division, Observation Department, JMA junj-hotta@met.kishou.go.jp
Mr Takanori Sakanashi	Assistant Scientific Officer, Forecast Division, Forecast Department, JMA takanori-sakanasi@met.kishou.go.jp
Mr Hiroaki Minematsu	Scientific Officer, Office of International Affairs, Administration Department, JMA minematsu_hi@met.kishou.go.jp
Dr Daniel Brause Michelson	Chair of WMO Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR), Research Scientist, Environment and Climate Change Canada daniel.michelson@canada.ca
Mr Marcus Kruckow	Regional Sales and Business Development Asia & Australia, Selex ES GmbH (Gematronik) m.kruckow@selex-es-gmbh.com
Mr Andre Weipert	Head of Meteorological Information Systems (MIS) and SESAR programme, Selex ES GmbH (Gematronik) a.weipert@selex-es-gmbh.com
Mr Boonlert Archevarahuprok	Expert on Research and Development for Meteorology, TMD boonlert.arc@tmd.go.th

WMO Secretariat

Mr Ryuji Yamada	Programme Manager, Regional Office for Asia and the South-West Pacific ryamada@wmo.int

ASEAN Secretariat

Ms Lee Sing Cheong	Head of Science & Technology Division LeeSing.Cheong@asean.org

<u>Local Organizing Committee</u>

Thai Meteorological Department

Ms Patchara Petvirojchai	Director of Research and Technical Cooperation Division, Meteorological Development Bureau patchara@tmd.go.th
Ms Phanumat Lewcharoenthrap	Head, International Relations Division tmd_inter@tmd.go.th
Dr Hathaichanok Ngerndee (Hannah)	Foreign Relations Officer, International Relations Division tmd_inter@tmd.go.th, hathaichanok.n@tmd.mail.go.th
Ms Pailin Sangkhao	Foreign Relations Officer, International Relations Division tmd_inter@tmd.go.th
Mr Asadarnkdej Pokam	Meteorological Officer, Meteorological Map Division asadarnkdej@gmail.com
Acting Sub Lt. Phalakorn Weingdonkor	Dissemination Technical Officer, Public Relations Division palakorn95@gmail.com
Mr Panomkorn Hematulin	Electrician, Telecommunications and Information Technology Bureau panomkorn_23@hotmail.com

____

Annex III

Summary of weather radar specification in Southeast Asia (as of January 2018)

	Bangladesh	Cambodia	Indonesia	Lao PDR
Types of radars	S	S	C, X	C
Number of radars	5	1	42	1
Manufacturers	JRC, Mitsubishi	Gematronik	EEC (21), Gematronik (15), Baron (5), Vaisala (1)	JRC
Number of radars (future plan)	2 Old Replace by 2020+3 new in three International Airport	2	1 (2018); 1 solid (dual polarized)	-
Radiowave frequency	2800, 2850, 2770MHz+/_5%	2700 - 2900 MHz	5600-5625 MHz. 9800 MHz	5300 MHz
Observation intervals	15 min	15 min	5 min to 15 min	Rainy season: every 7.5 min (nonstop) Dry season: 7.5 min/60 min
Doppler or not	Yes	Yes	Yes	Yes
Dual polarization or not	No	No	No	No
B and b	B=200, b=1.6	B=200, b=1.6	B=200, b=1.6 and B=250, b=1.4	B=250, b=1.38
Remotely controlled operation/ local operator	Both	Local operation	local operator	controlled at HQ
Number of automatic raingauge	12	65	155	15
Number of AWS	18	35	257	15
Nationwide composite map/altitude		Not yet	Yes/lowest level composite	No/2.0km
Maintenance problems	Yes	Yes	Yes	Yes
Communication problems		Not always	Yes (eastern part)	No
Type of communication	VSAT (64kbps)	Fiber optic	VSAT/VPN	TCP/IP
Human resources problems	Yes	Yes	Yes	Yes
Other problems	Budget, spare parts	Budget, spare parts, radar site	Yes	Budget, spare parts
Capability to assist other members	Yes/No	No	Yes/No	Yes
QC (human)	No	No	No	Yes
QC (automatic)	May be	No	Yes	Yes
Quality to be improved (ground clutter, sea clutter, interference)	Ground Clutter (Dhaka Radar)	blockage and interference (many stations)	Interference especially in big city	Interference signal
Output data format	IRIS	Vol.	volumetric	IRIS (format open in technical manual)
Meta data availability		No	Yes	No
Availability of raw data	Yes	No	Yes	Available

	Malaysia	Myanmar	Philippines	Singapore
Types of radars	S, C, X	S	S, C, X	S, C
Number of radars	S=7, C=4, X=4	3	S=8, C=7, X=3	S=1, C=1
Manufacturers	EEC, Gematronik	JRC	EEC, Gematronik, Vaisala, JRC	Gematronik
Number of radars (future plan)	4 (next 3 years)	-	5 (next years)	0
Radiowave frequency	2700-2900 MHz, 5600-5800 MHz, 9400-9500 MHz	2796 MHz	2700-2900 MHz, 5600-5800 MHz, 9000-10000 MHz	S: 2700-2900 MHz C: 5430-5600 MHz
Observation intervals	10 min	15 min	10 and 15 mins	1min (for Aerodrome Surveillance) 5min (for Volumetric)
Doppler or not	Yes	Yes	Yes	Yes, both
Dual polarization or not	No	No	8 (eight dual pol)	Yes, both
B and b	B=250, b=1.2 B=200, b=1.6	B=49, b=1.7 B=40, b=1.9	B=200, b=1.6	B=200, b=1.6 B=300, b=1.4
Remotely controlled operation/ local operator	Both	Remotely controlled operation/ local operator	Both	Remotely controlled operation
Number of automatic raingauge	170	30	50+20	Around 90
Number of AWS	170 (50 manned, 120 unmanned)	30	57	Around 90
Nationwide composite map/altitude	Yes/2.0 km	lowest level composite	Yes/1.0km	Composite/MAX products are used more frequently than CAPPI because more indicative of intensity of thunderstorms
Maintenance problems	Outsource	Yes	Yes	Outsource
Communication problems	No	No	Yes	No
Type of communication	IP/VPN (2Mbps)	VSAT	microwave link, Leased Line, VSAT	Fiber optics
Human resources problems	Yes	Yes	Not always	Yes
Other problems	Budget	Budget, spare parts	Budget, spare parts	Budget, Radar Site
Capability to assist other members	No	No	Yes	Yes/No
QC (human)	Partial	No	Yes	Yes
QC (automatic)	No	No	Yes	Yes
Quality to be improved (ground clutter, sea clutter, interference)	Blockage by high mountains, ground clutter	Interference signal	Blockage by high mountains, ground clutter, interference	Sea/ground clutter, interference from other signal sources, blockage by tall buildings, biological returns
Output data format	Grib2, OdimHDF5, BUFR, IRIS Native, Rainbow native, ASCII (old radars only)	POLAR.BINARY	NETCDF, uf, hdf5, jpeg	PNG, GeoTiff, BUFR, NetCDF etc.
Meta data availability	Not available now	No	Yes	Yes
Availability of raw data	Available but impossible to decode (IRIS)	Available	Yes	Yes (Rainbow)

	Thailand	Viet Nam		Japan
Types of radars	C	S, C, X		C
Number of radars	23	S=2, C=5		20
Manufacturers	EEC (19), Gematronik (4)	EEC (2), Thompson (1), JRC (2), Vaisala (2)		JRC, Mitsubishi, Toshiba
Number of radars (future plan)	1 (2016)/ 4 upgrade (by 2016)	4 by 2020		-
Radiowave frequency	5600 - 5650 MHz	C; 5600 - 5670 MHz (S) 2750 MHz		5250 - 5350 MHz
Observation intervals	15 min to 1 hour	Thompson: 5 min EEC: 15 min JRC Japan: 10 min		5 min
Doppler or not	Yes	6/7 radars		Yes
Dual polarization or not	4 (C-band)	No		No
B and b	B=200, b=1.6	B=200, b=1.6 (for 2 JRC sites)		B=200, b=1.6
Remotely controlled operation/ local operator	Both	Local operation		Remotely controlled operation
Number of automatic raingauge	930	No information		1300
Number of AWS	87	No information		1300
Nationwide composite map/altitude	Ongoing/lowest level composite	Yes/3km (3 sites)		Yes/lowest level composite
Maintenance problems	Spare parts	Spare parts		-
Communication problems	Reliable	Yes (delay up to 30min)		Not serious
Type of communication	ADSL	ADSL (2Mbps)		TCP/IP
Human resources problems	Knowledge	Yes		Yes
Other problems	many	Budget		Budget
Capability to assist other members	Yes	Yes		Yes/No
QC (human)	Yes	Yes		Yes
QC (automatic)	Yes	No		Yes
Quality to be improved (ground clutter, sea clutter, interference)	Blockage and interference (many stations)	Ground clutter		-
Output data format	Vol.	UF for EEC/NETCDF		GRIB2
Meta data availability	Yes	Yes		Yes
Availability of raw data	Yes	Yes (No on 1 site)		Yes

Annex IV

Survey on weather radar in Southeast Asia

Purposes:

This survey aims to encourage Southeast Asian countries to improve capabilities of weather radar utilization and operation through sharing its information among National Meteorological and Hydrological Services (NMHSs) in the region.

In line with the aim, question items are arranged to assist NMHSs to recognize necessary matters to improve operation, data processing, applications and national observation network relating to weather radars. It will be beneficial to all NMHSs to check and review its own situation and to share it with other Members, in order to figure out and overcome common challenges and to establish the regional radar network in Southeast Asia.

Results:

(* The "SUM" column shows the summation of Southeast Asian countries (9 ASEAN Members and Bangladesh).

	1. Roles of weather radar observation in your Service	SUM*	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
1-1	Currently, for which purposes do you operate the weather radars? (Multiple answers allowed)												
	Heavy rain monitoring	10	x	x	x	x	x	x	x	x	x	x	x
	Flood prediction	7	x	x	x			x	x		x	x	x
	Nowcasting of lightning or hazardous wind	7	x		x		x	x	x	x		x	x
	Aviation (e.g. detection of Low Level Wind Shear)	5				x	x	x	x	x			x
	Initial value of NWP	4			x		x		x	x			x
	Case studies of severe weather events	7	x		x		x		x	x	x	x	x
	Climatological study	4	x		x		x			x			
	Others (please specify below) Indonesia: Volcanic Ash Monitoring (at some sites)	1			x								
1-2	In the future, for which purposes are you going to operate the weather radars? (Multiple answers allowed)												
	Heavy rain monitoring	10	x	x	x	x	x	x	x	x	x	x	x
	Flood prediction	9	x	x	x	x	x	x	x		x	x	x
	Nowcasting of lightning or hazardous wind	9	x		x	x	x	x	x	x	x	x	x
	Aviation (e.g. detection of Low Level Wind Shear)	10	x	x	x	x	x	x	x	x	x	x	x
	Initial value of NWP	7			x		x	x	x	x	x	x	x
	Case studies of severe weather events	9	x		x	x	x	x	x	x	x	x	x
	Climatological study	5	x		x		x			x	x		
	Others (please specify below) Indonesia: Weather forecast verification	1			x								
1-3	Does your Service use radar data in decision making for issuing meteorological warnings and advisories?												
	No	1				x							
	Yes	9	x	x	x		x	x	x	x	x	x	x
1-4	Does your Service provide training opportunities on radar data utilization for forecasters?												
	No	1		x									
	Yes	9	x		x	x	x	x	x	x	x	x	x
1-5	Which are major challenges for your Service in promoting utilization of radar data? (Multiple answers allowed)												
	No challenges	1								x			
	Yes. Obtaining better understanding of the necessity of radar data (your staff in your Service)	7		x	x	x	x	x			x	x	
	Yes. Obtaining better understanding of the necessity of radar data (users outside of your Service)	8		x	x	x	x	x	x		x	x	x
	Yes. Deployment and replacement of radars	5	x		x	x					x	x	
	Yes. Radar operation	7	x	x	x	x		x			x	x	
	Yes. Radar maintenance	7	x	x	x	x		x			x	x	
	Yes. Quality control of radar data	8	x	x	x	x	x	x			x	x	
	Yes. Learning techniques of radar data utilization	7		x	x	x		x		x	x	x	
	Others (please specify below) Singapore: No challenges in utilizing, more on educating the public on the limitation of the radar precipitation products Viet Nam: Research and develop radar data production	2								x		x	

		SUM	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
1-6	Does your Service provide radar data to TV stations?												
	No	9	x	x	x	x	x	x		x	x	x	
	Yes	1							x				x
1-7	Do TV stations use your radar data in their weather programs?												
	No	7	x	x	x	x		x		x	x		
	Yes	3					x		x			Little	x
1-8	Are your radar images available to the public on your website?												
	No	0											
	Yes	10	x	x	x	x	x	x	x	x	x	x	x
1-9	Does your Service provide your radar data to users (public, private companies etc.)?												
	No	5	x	x				x			x	x	
	Yes	4			x	x	x			x			x
1-10	Does your Service get radar data from other organizations in your country?												
	No	10	x	x	x	x	x	x	x	x	x	x	
	Yes	0											x
1-11	Do you find any benefit if you get other NMHSs' radar data? (Multiple answers allowed)												
	No benefit	0											
	Yes. Improvement of heavy rain monitoring near boundaries of your country	10	x	x	x	x	x	x	x	x	x	x	x
	Yes. Improvement of flood forecast of international rivers	5	x	x		x					x	x	
	Yes. Improvement of monitoring of weather at international flight destinations	7	x		x	x		x	x	x	x		x
	Others	0											
1-12	Do you have any difficulties in sharing radar data with other NMHSs? (Multiple answers allowed)												
	No difficulties	0											
	Yes. Data policy of my country or Service	6		x	x	x	x				x	x	
	Yes. Technical problems of radar data processing	6	x	x	x	x		x			x		
	Yes. Technical problems of communication (e.g. speed limit, server performance).	9	x	x	x	x	x	x	x		x	x	x
	Others (please specify below) Singapore: Currently not sharing with other NMHSs	1								x			
2. Deployment and replacement of radars													
2-1	How many radars does your Service have?	113	5	1	41	1	12	3	15	2	23	10	29
2-2	Fill out the table in the next worksheet to show numbers of radars in different types and manufactures.		(The result of this question is attached at the end of this table.)										
2-3	Does your Service plan to deploy new radars?												
	No	2								x	x		x
	Yes (please specify below) Bangladesh: Replace two old and install new three in three international airports in Bangladesh. Cambodia: We are looking for the resources to install new radars for better cover and data. Lao PDR: DMH has been submitted a proposal of the new radar network to Japan Government. Myanmar: DMH proposed to JICA to install two new radars in Southern and Northern parts of Myanmar Viet Nam: 3 sites C-band, Vaisala manufacturer	8	x	x	x	x	x	x	x			x	
2-4	Does your Service plan to upgrade your single-pol radars to dual-pol radars?												
	No	5	x	x		x		x		x			
	Yes (please specify below) Malaysia: all of them Viet Nam: in the future	5			x		x		x		x	x	x
2-5	How many years does your Service assume the life-span of radars?		10	15	10	> 15	15 -30	15		15	15	15-25	15
2-6	Does your country coordinate transmitting frequency of radars with neighboring countries to prevent interference?												
	No	9		x	x	x	x	x	x	x	x	x	x
	Yes	1	x										

		SUM	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
2-7	Which is the most serious challenge for your Service to deploy or replace radars? (Multiple answers allowed)												
	No problem	0											
	Ensuring budget	9	x	x	x	x	x	x	x	x		x	x
	Ensuring land, power supply and communication line	6		x	x		x	x		x	x		
	Ensuring transmitting frequency	3				x				x	x		
	Learning knowledge and information for considering radar specification	6	x	x	x	x					x	x	
	Others (please specify below) Laos: The existing transmitting frequency band 5.3GHz is not allowed under the ITT regulation.	3				x			x		x		
3. Radar operation													
3-1	Does your Service have rules, guidelines and/or manuals on radar observation and operation?												
	No	0											
	Yes	10	x	x	x	x	x	x	x	x	x	x	x
3-2	When does your Service operate radars?												
	All the time	9		x	x	x	x	x	x	x	x	x	x
	Only rainy weather (rainy season)	0											
	Intermittently	1	x										
3-3	How often is your radar observation?												
	Every hour	1										x	
	Every 15 minutes	6	x	x				x	x		x	x	
	Every 10 minutes	3					x		x			x	
	Every 5 minutes	2								x		x	x
	Others (please specify below) Indonesia: Every 5 - 15 minutes Lao PDR: Every 7 minutes Malaysia: every minute.- for wind shear at airport Singapore: every minute on aerodrome surveillance wind shear	4			x	x	x			x			
3-4	Does your Service collect radar data into your headquarters in real time?												
	No	0											
	Yes (all sites)	7	x	x			x	x	x	x	x		x
	Yes (a part of sites)	3			x	x						x	
3-5	Which types of radar data does your Service archive? (Multiple answers allowed)												
	No data is archived	0											
	Reflectivity (polar coordinates; each site)	6			x		x		x	x	x	x	x
	Doppler velocity (polar coordinates; each site)	9		x	x	x	x	x	x	x	x	x	x
	Dual polarization parameters (polar coordinates; each site)	4					x		x	x	x		x
	Reflectivity (Cartesian coordinates; each site)	6		x	x	x	x		x			x	x
	Precipitation intensity (Cartesian coordinates; each site)	4				x	x		x			x	x
	Reflectivity (Cartesian coordinates; national composite data)	2			x		x						x
	Precipitation intensity (Cartesian coordinates; national composite data)	1					x						x
	Others (please specify below) Bangladesh: raw data and image of special events	1	x										
3-6	Which is the most serious trouble on your radar operation?												
	No troubles	0											
	Expensive operation cost	7		x	x	x	x	x			x	x	
	Unstable commercial power supply	5	x	x	x		x	x					
	Unstable communication line	3	x		x				x				
	Frequent hardware troubles	5	x	x	x	x			x				
	Others (please specify below) Singapore: Interference of other signal sources, blockage from surrounding/encroaching tall buildings and lack of land	1								x			
4. Radar maintenance													
4-1	Does your Service have manuals on radar maintenance?												
	No	2					x	x					
	Yes	8	x	x	x	x			x	x	x	x	x

		SUM	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
4-2	How often does your Service conduct periodic maintenance by your staff?												
	Not conducted	0											
	Every year	2							x			x	
	Every half year	1		x									
	Every 3 months	1					x						
	Every month	4			x	x		x			x		x
	Irregular	0											
	Others (please specify below) Bangladesh: Some daily, Some weekly, Some monthly, Some six months and some yearly. Singapore: Radar maintenance is every month by radar maintenance contractors	2	x							x			
4-3	How often does the manufactures conduct periodic maintenance?												
	Not conducted	2				x						x	
	Every year	3		x	x			x					
	Every half year	1							x				x
	Every 3 months	1					x						
	Every month	0											
	Irregular	1								x			
	Others (please specify below) Bangladesh: When any problem happened Singapore: Radar maintenance are outsourced to external maintenance contractor with support from OEM	3	x							x	x		
4-4	How often does your Service replace magnetrons? (If magnetrons are used as transmitters.) Bangladesh: 2 months Indonesia: 5 Lao PDR: No Malaysia: 3-4 years Philippines: when needed Singapore: NA Thailand: < 15% Life Time Viet Nam: not periodic		x		x	x	x		x	x	x	x	
4-5	How often does your Service replace klystrons? (If klystrons are used as transmitters.) Bangladesh: 1 year Lao PDR: 0.5 (rotation method) Singapore: 5 Thailand: No Japan: every 2 years		x			x				x	x		x
4-6	Does your Service have spare transmitting tubes (magnetron or klystron)?												
	No	2					x				x		
	Yes	7	x	x	x	x			x	x		x	x
4-7	Does your Service have spare parts except transmitting tubes?												
	No	2					x				x		
	Yes	7	x	x	x	x			x	x		x	x
4-8	Which types of contract does your Service use with manufacturers?												
	Maintenance contract	5		x	x		x		x	x			
	Spot contract in case of trouble	3	x								x	x	x
4-9	Which kinds of troubles on your radar system have your Service experienced? (Multiple answers allowed)												
	Never experienced	0											
	Failure caused by lightning	4			x	x	x		x				x
	Failure in transmitter	9	x		x	x	x	x	x	x	x	x	x
	Failure in pedestal	4			x		x		x		x		x
	Failure in receiver	7		x	x	x	x		x		x	x	x
	Failure in signal processing unit	8	x	x	x	x			x	x	x	x	
	Failure in power supply equipment	10	x	x	x	x	x	x	x	x	x	x	x
	Failure in communication equipment	8	x	x	x	x			x	x	x	x	
	Others (please specify below)	1									x		

		SUM	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
4-10	Which kinds of troubles on transmitter have your Service experienced? (Multiple answers allowed)												
	Never experienced	1						x					
	Wastage or abnormal behavior of magnetron	5			x		x		x		x	x	
	Wastage or abnormal behavior of klystron	2	x			x							x
	Abnormal behavior of solid state transmitters	1				x							
	Others (please specify below) Singapore: bias voltage supply circuit for Klystron	1								x			
4-11	What bothers your Service most in maintenance or repair of your radars? (Multiple answers allowed)												
	Nothing	0											
	Frequent failures	3			x						x	x	
	Expensive consumable (e.g. magnetron)	7	x		x	x	x		x		x	x	x
	Expensive maintenance cost	7	x	x	x	x		x		x	x		
	Expensive repair cost	6	x	x	x	x		x			x		
	Long time needed for repair	5	x		x	x		x			x		
	Lack of knowledge for maintenance	6	x	x	x	x	x			x			
	Shortage of human resources for maintenance	8	x	x	x	x	x	x		x	x		
	Others (please specify below)	0											
5. Quality Control													
5-1	Are there any troubles on quality of radar observation data in your Service? (Multiple answers allowed)												
	No trouble	0											
	Contamination by ground clutter	9	x	x	x		x	x	x	x	x	x	x
	Contamination by clear air echo (e.g. biological echo)	4				x				x	x	x	
	Contamination by sea clutter	7			x		x	x	x	x	x	x	x
	Contamination by wind turbine	0											x
	Interference waves	6			x	x			x	x	x	x	
	Multi-trip echo	5			x		x	x	x	x			x
	Anomalous propagation	5			x		x		x	x	x		x
	Beam-cut effect	6			x	x	x	x			x	x	x
	Difference between radars	3					x			x	x		
	Misalignment of range or azimuth	0											
	Not sure the cause of bad quality	2	x	x									
5-2	Which kinds of automatic quality control are used by your radar system? (Multiple answers allowed)												
	Invalidate data bins with weak received power (remove effect of thermal noise)	4			x	x	x		x				x
	Invalidate data bins with low reflectivity (remove clear air echo)	3					x		x	x			x
	Invalidate data bins with low SQI (Signal Quality Index) (remove multiple trip echo or interference)	4			x		x		x	x			x
	Invalidate data bins with high CSR (Clutter Signal Ratio) (remove remaining ground clutter after MTI processing)	4			x		x		x	x			x
	Invalidate data bins with large velocity width	0											
	Invalidate isolated echo (remove moving clutters such as ships, airplanes)	3			x		x		x				x
	Invalidate temporally observed echo (remove interferences, ships/airplanes echo)	3			x		x		x				x
	Using elevation composite map table	2				x					x		x
	Not sure	3	x					x				x	
5-3	Does your Service conduct quality management of radar data by human? (For instance, stopping delivery of radar data to users in case of interference)												
	No	8	x	x	x	x	x	x		x	x		
	Yes (please specify below) Viet Nam: Observed by observer Japan: Stopping delivery of radar data to users in case of interference without weather echoes.	1										x	x
5-4	Does your Service monitor noise level of receiver?												
	No	3		x		x		x					
	Yes	7	x		x		x		x	x	x	x	x
5-5	Does your Service monitor azimuth and range of target?												
	No	4		x		x				x	x		
	Yes (check by using Sun signal)	4	x		x		x		x				
	Yes (check by using distinct ground clutter)	4			x			x	x			x	x

		SUM	BGD	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM	JPN
5-6	Does your Service calibrate reflectivity or precipitation intensity by using rain gauge observation data?												
	No	5		x	x				x	x	x		
	Yes (real time calibration)	1						x					x
	Yes (statistical calibration)	4	x			x	x					x	
6. Radar utilization techniques													
6-1	Does your Service estimate rain intensity using radar observation?												
	No	2	x			x							
	Yes	8		x	x		x	x	x	x	x	x	x
	If yes, which numbers does your Service use for Z-R relation of Band b?												
	B		40	200	200	250	200	49	200	200	200	200	200
	ß		1.9	1.6	1.6	1.3	1.6	1.7	1.6	1.6	1.6	1.6	1.6
6-2	You're your Service create national (domestic) radar composite map from multiple radar observation data?												
	No	2		x		x							
	Yes (all sites)	6	x				x	x	x	x	x		x
	Yes (a part of sites)	2			x							x	
6-3	Does your Service utilize Doppler velocity data?												
	No	2				x					x		
	Yes	8	x	x	x		x	x	x	x		x	x
6-4	If yes in 6-3, how you're your Service use Doppler velocity data? (Multiple answers allowed)												
	Detection of gust/wind shear	4					x	x	x	x			x
	Estimation of horizontal wind distribution	8	x	x	x		x	x	x	x		x	x
	Estimation of vertical wind distribution	7	x	x	x		x	x		x		x	x
	Data assimilation for NWP	2	x		x								x
	Others (please specify below)	0											
6-5	Does your Service utilize dual polarization data?												
	No	7	x	x	x	x	x	x				x	
	Yes	3					partial		x	x	x		x
6-6	If yes in 6-5, how you're your Service use dual polarization data? (Multiple answers allowed)												
	Quality management of radar data	1								x			x
	Estimation of precipitation intensity	3					x		x	x			x
	Identification of precipitation particle type	4					x		x	x	x		
	Data assimilation for NWP	2					x			x			
	Others (please specify below)	0											
6-7	Does your Service calibrate dual polarization parameters?												
	No	7	x		x		x		x	x	x	x	
	Yes	0											x
6-8	If yes in 6-7, by what method you're your Service calibrate dual polarization parameters? (Multiple answers allowed)												
	Metal sphere	0											
	Bird-bath scan	0											x
	Solar signal	0											
	Comparison with disdrometer	0											x
	Others (please specify below)	0											
6-9	Does your Service monitor quality of dual polarization parameters?												
	No	7	x		x		x		x	x	x	x	
	Yes	0											x
6-10	If yes in 6-9, by what method does your Service monitor quality of dual polarization parameters? (Multiple answers allowed)												
	Analyzing weak weather echo (drizzle)	0											
	Bird-bath scan	0											x
	Solar signal	0											
	Comparison with disdrometer	0											
	Others (please specify below)	0											

The number of radars (Results of Q2-2)

Frequency	Polarization	Transmitter	Baron	EEC	Gematronik/Selex	JRC	Mitsubishi	Thompson	Toshiba	Vaisala
S-band	Single-pol	Magnetron		7 (MYS) 4 (PHL)	1 (KHM) 2 (PHL)		2 (BGD)			1 (PHL)
		Klystron				3 (BGD)				
		Solid-state				3 (MMR) 3 (PHL) 2 (VNM)				
	Dual-pol	Magnetron			1 (MYS)					
		Klystron			1 (MYS) 1 (SGP)					
		Solid-state								
C-band	Single-pol	Magnetron	5 (IDN)	17 (IDN) 4 (MYS) 2 (PHL) 9 (THA) 2 (VNM)	14 (IDN) 1 (PHL) 4 (THA)			3 (VNM)		1 (IDN) 2 (VNM)
		Klystron				1 (LAO) 17 (JPN)	6 (JPN)		3 (JPN)	
		Solid-state								
	Dual-pol	Magnetron		10 (THA)	1 (IDN) 1 (SGP)					4 (PHL)
		Klystron								
		Solid-state				3 (JPN)				
X-band	Single-pol	Magnetron								
		Klystron								
		Solid-state								
	Dual-pol	Magnetron		3 (MYS)						
		Klystron								
		Solid-state		3 (IDN)		3 (PHL)				