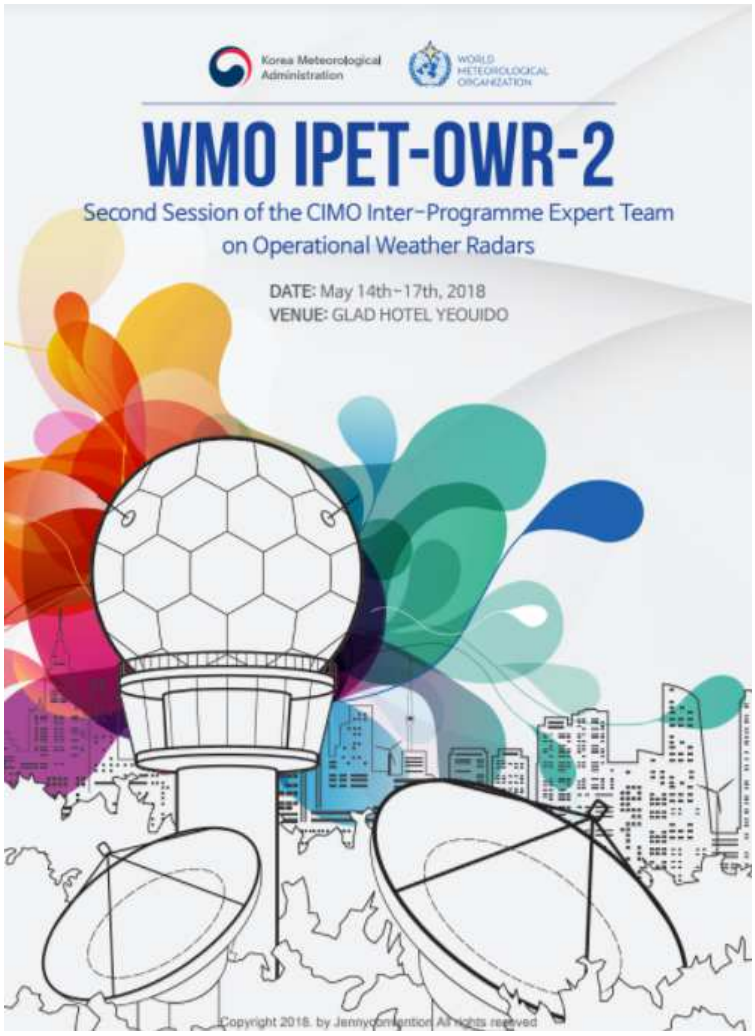
World Meteorological Organization

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATIONS

OPEN PROGRAMME AREA GROUP ON REMOTE SENSING TECHNOLOGIES

Inter-Programme Expert Team on Operational Weather Radars

14-17 May 2018, Seoul, Republic of Korea



FINAL REPORT

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EXECUTIVE SUMMARY

The second session of the WMO Commission for Instruments and Methods of Observation (CIMO), Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR) was held in Seoul, Republic of Korea over 14-17 May 2018. The meeting was kindly and generously hosted by the Korean Meteorological Agency (KMA) at the Glad Hotel Yeouido.

The key aims of this meeting were to consolidate important activities and plans for completing deliverables within the IPET's work plan ahead of the upcoming session of CIMO in 2018. In particular, the IPET focused on reinvigorating activities and tasks towards the development of a Best Practices Guide on Operational Weather Radar. The team spent several sessions on developing the improved structure of the guide and drafting and organising materials under that structure. Additionally team members reported on the status and progress of other tasks in the work plan, including the successful completion of information and data models and a data format for the international exchange of weather radar data. In relation to this, the team made plans for the formal establishment and maintenance of the CFRadial data exchange format as a WMO international standard through the processes of the Commission for Basic Systems (CBS).

Other items discussed and advanced included radar interference issues and associated policy and guidance for WMO Members, metadata management and operation of the WMO Radar Database, radar data requirements for climate applications, procedures for calibration of radars, including inter-calibration with satellite radar systems, and international activities coordination including the continued development of a standard for weather radar in collaboration with the Organization on International Standards (ISO), training and capacity development and radar observations associated with the recent Olympics events in the Republic of Korea (ICE-POP).

The team members, CIMO and WMO thank KMA and the Republic of Korea for their generous in-kind support and hosting of this successful meeting and also for the support provided for participants before, throughout and after the meeting.

GENERAL SUMMARY

1. Organization of the Session

1.1. Opening

The second session of the Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR-2) was opened at 9:30am on 14 May in Seoul, Republic of Korea, by the Administrator of the Korean Meteorological Administration (KMA), Dr Jae-Cheol Nam, who welcomed the meeting participants and expressed his satisfaction that KMA was able to host the session in support of WMO activities. Dr Nam empahsised the importance of radar observing systems to both the Republic of Korea and to this region of the world, given the role they played in monitoring and prediction of severe weather systems, which had such a significant impact on regional economies and societies. KMA was appreciative of WMO efforts and the work of the team in standardisation and promotion of best practices of weather radar systems.

Mr Dean Lockett of the WMO Secretariat also welcomed meeting participants on behalf of the WMO Secretary General and thanked KMA for their generosity in hosting the session and for the excellence of the venue and the organisation. Mr Lockett outlined the primary purposes of the meeting, which were especially concerned with advancing the work program of the team, ahead of the Commission for Instruments and Methods of Observations (CIMO) session, which would take place in October 2018.

1.2. Adoption of the Agenda

Mr Daniel Michelson, the Chair of the IPET-OWR outlined the agenda for the session and invited the participants to consider the proposed agenda for the meeting, which was adopted as above.

1.3. Working Arrangements

The session agreed on the proposed working arrangements for the session, which were to be conducted both in plenary and in breakout groups for various parts of the 4-day meeting.

2. Report of the Chairperson

The Chair of IPET-OWR, Mr Daniel Michelson presented his report on the status of the work program of the team, highlighting the achievements that had been made since the first session, which took place in March 2017 in Tokyo, Japan. In particular, Mr Michelson highlighted that:

- An online survey of WMO's Members on Operational Weather Radars was conducted in January-February 2017. The survey yielded a total of 86 responses containing valuable information that is used as guidance to the team in carrying out its work. The survey results were analyzed and presented at IPET-OWR-1 and conclusions/recommendations were drafted prior to IPET-OWR-2.

- A high-level document on weather radar network design and application has been produced.

- Guidance has been drafted on operation of weather radar in mountainous terrain.

- Updated guidance on radio interference and disturbance from wind turbines has been drafted. This is currently intended as an update to the existing Annexes 7.A and 7.B to the CIMO Guide.

- Work on weather radar data representation is on track, yielding an Information Model document, a Data Model document, a CfRadial 2.0 file format specification document, and a guidance document on how WMO's Members are to use CfRadial 2.0 for the purposes of data exchange.

- A document proposing weather-radar data exchange methods has been produced.

- Article in WIGOS Newsletter (Vol. 4, No. 1, January, 2018) on "Advances in weather radar data exchange".

- Engagement with the Implementation Coordination Team on Information Systems and Services (ICT ISS) through the Inter-Programme Expert Team on Codes Maintenance (IPET-CM) has begun, to ensure and verify that the proposed single weather radar data representation global standard meets WMO requirements for use and maintainability.

- A radar calibration reporting software tool has been prototyped, potentially facilitating the validation and reporting of radar calibration results in a harmonized way.

- Collaboration with field campaigns ICE-POP (Republic of Korea) and RELAMPAGO (Argentina) have been solicited as a means of performing weather radar calibration reporting intercomparison.

- IPET-OWR participated in a Workshop on Radar Metadata for WIGOS, held 19-21 June 2017 in Locarno, Switzerland. A metadata mapping among IPET-OWR's deliverables (1.7 above), the WIGOS Metadata Standard, and WMO Weather Radar Database was produced.

- IPET-OWR worked with the International Standards Organization in drafting Part 1 of a joint standard/norm for weather radar: ISO/DIS 19926-1:2017(E), currently under revision. Discussions on Part 2 addressing data quality/processing have commenced.

- Liaison with Global Climate Observing System (GCOS) Atmospheric Observation Panel for Climate (AOPC) Task team for Weather radar data requirements for climate monitoring.

- Regarding coordination of / assistance with international training courses, syllabi for courses given in Turkey and the Republic of Korea were solicited and reviewed.

- IPET-OWR participated in the WMO/ASEAN Training Workshop on Weather Radar Data Quality and Standardization, held 5-13 February 2018 in Bangkok, Thailand.

- An article has been drafted for the WIGOS Newsletter on the WMO/ASEAN Training Workshop on Weather Radar Data Quality and Standardization.

The chair informed the meeting that the support of and interaction with the respective management groups of the CBS and CIMO technical commissions was positive and indicated that the approach the team was taking to accomplishing its work plan was appreciated and the results encouraging so far. The management group meetings of CBS (CBS-MG, March 2018) and CIMO (CIMO-MG-15, March 2018) offered an opportunity for the chair to report on progress made and receive feedback directly.

Mr Michelson explained that while good progress had been made especially in relation to the work on weather radar data exchange, the team needed to increase efforts on the development of guidance materials that formed that 2nd major deliverable from the work plan.

In addition to this effort, the next key stage in developing the data exchange process was to work with CBS regarding the procedures for approving and maintaining the NetCDF CFRadial code format.

The team also considered the matter of the collaboration with the International Organization for Standardization (ISO) on the development of a joint ISO-WMO standard on weather radar, which was further considered under item 5.1.

The meeting considered the proposed Issues 2.1 and 2.2 related to the review of the work plan and the proposed collaboration with ISO and agreed on the decisions/actions as provided in the relevant tables in Annex II.

3. Impact of Likely WMO Structural Changes

3.1. WMO Constituent Body Reform, New Vision for the future of environmental measurements within WIGOS and the new CIMO Structure

Mr Dean Lockett, WMO Secretariat, informed the team about the process underway to revise the WMO constituent body structure with a view to streamlining and increasing the efficiency of WMO programmatic procedures and processes. This process was being overseen by a working group reporting to the WMO Executive Council, which would deliver its proposal for changes to the WMO constituent body structure at the next WMO Congress in 2019 (Cg-18).

While it was expected that this reorganisation would result in a reduction in the number of technical commissions, there was an expectation that CIMO roles and functions would be reconstituted under one of the new standing committees, which would likely form the second tier of theme and programmatic management within the new technical commission structure. With a view to providing a platform for describing how this role would be established and implemented under WIGOS and the new CIMO Structure, the CIMO Management Group had developed a New Vision for the Future of Environmental Measurements, for which the most recent version was presented at CIMO Management Group meeting in March 2018 (CIMO-MG-15) within document 3.2.

The team agreed to undertake a review of the new vision by email and provide any feedback to the CIMO Management Group via the Secretariat.

4. Review of Regional Priorities and Requirements on Weather Radar Systems

4.1. Presentations by Team Members on Regional Weather Radar Priorities and Requirements

Each of the participants was invited to provide information and/or a presentation on national and regional priorities and requirements related to operational weather radar.

WMO Region II

Japan

- Japan operates a network of 29 C-band Doppler weather radars, 9 for aviation purposes and 20 for general purpose. Three of them were renewed to be solid-state dual-polarized radar recently. The remaining 26 radars were also currently gradually being renewed to solid-state dual-polarized systems.

- JMA reported that an increasing number of wind turbines being installed across the country were creating an increasingly urgent issue with interference to radar operation.

- JMA also noted that solid state weather radar have different frequency requirements and that consideration needed to be given to having these interests represented at World Radio Conference (WRC).

- Japan and JMA continued to play a significant role in regional international weather radar data exchange noting that, in collaboration with the Republic of Korea:

    - KMA and JMA had been exchanging both AWS and radar data since 1998;

    - At a recently meeting, KMA and JMA had agreed to increase the number of radar stations for which data was exchanged from 6 to 11 sites; and

    - The two countries were giving consideration to the future exchange of volumetric data of reflectivity and Doppler velocity in real time.

- Mr Yoshiro Tanaka, Japan, provided a report on the SE Asia weather radar project, informing the meeting that:

    - The project had been identified under three forums: within WIGOS under the Capacity Building in Radar Techniques in the Southeast Asia (Japan, Thailand, Malaysia, and Indonesia (RA V)); within a parallel project of the Association of Southeast Asian Nations (ASEAN) and as a component of the ESCAP/WMO Typhoon Committee on Improvement of Tropical Cyclone Analysis and Advisory.

    - The project had already recognised a need to improved radar data quality in some countries;

    - A WMO/ASEAN radar workshop was held in February 2018 in Bangkok, Thailand; and

    - One of the aims was to facilitate the exchange of data so that contributing members can produce a regional radar composite.

Hong Kong China

Mr Wai Kong, Hong Kong China reported that:

- The Hong Kong Observatory operated 5 weather radars, all with Doppler capability and at varying frequencies (2 S-band, 2 C-band and 1 X-band).

- Of these, one of the S-band radars was upgraded to dual-polarization in 2015 and the other one will also be replaced and upgraded in the next few years..

- The two C-band radars are Terminal Doppler Weather Radar for detection of low-level windshear and microburst near the aerodrome.

- HKO was conducting a trial of rapid scan (1-minute) strategy that could provide benefits for severe weather monitoring.

United Arab Emirates

Mr Karel DeWaal, United Arab Emirates reported that:

- Under the auspices of the Gulf Cooperation Council (GCC), a radar network has been established that provides a good coverage over coastal areas of the Arabian Peninsula. For this purpose, several countries exchange volume data in order to produce a mosaic.

- Within Regional Association II (RA II), Dr Abdullah Ahmed AL Mandoos, PR with WMO for the UAE and RA II President was interested in the possibility of working with other RA II member countries to extend the RA II observations portal that had been established at: www.ra2.asia

Republic of Korea

Mr Sung-Hwa Jung, Republic of Korea, reported on the status of the KMA radar network:

- KMA was exchanging weather radar with China (CMA), Hong Kong China (HKO), Russian Federation (Roshydromet), Taiwan and the USA (NOAA)

WMO Region IV

Canada

Mr Vlado Stojanovic provided a report on the status of weather radar operation in Canada (ECCC) noting that:

- Canada has begun upgrading its radar network, which will realise the installation of up to 33 new radars, expected to be completed in 2023

USA

Mr Blake McGuire provided a report on the status of weather radar operation in the United States of America (NOAA) noting that:

- A major program of the NexRAD network was underway, with a focus on renewal of data processing systems and building refurbishment, in addition to upgrade to the communications system, introducing backup so as to improve reliability.

- A significant issue will be the sale and reallocation within the 50Mhz band, which will require significant changes to all USA radar systems to accommodate the change.

WMO Region V

Mr Mark Curtis, Australia, provided a report on the status of weather radar operation in WMO Region V:

- Indonesia was in the process of upgrading its radar network, expecting to install 20 radars over next 2 years with radars supplied by 3 different manufacturers.

- Generally in the region, the significant issues affecting radar network operations included:

    - Maintaining funding levels to ensure operation and maintenance; and

    - Radio-frequency protection issues, noting in particular that the C-band frequency was under threat.

- Radar data continued to be exchanged by New Zealand and Australia.

WMO Region VI

EUMETNET

Ms Elena Saltikoff, Finland, made a presentation to the meeting on weather radar status and issues within Europe:

- For EUMETNET/OPERA, there was an expectation of a change of paradigm in the future, in which data would be not only exchanged with and between radar operators and data providers but also directly with data users. In this way, the different requirements for different users could be accommodated. This was an issue for WMO and IPET-OWR to consider, in particular in relation to the development of future data exchange systems and methods.

- There appeared to be a need to have direct discussions with the radar data user community to better understand their requirements. A WMO meeting should perhaps be considered to accommodate this need.

- A significant issue to address would be the impact to user communities related to definition and use of adaptive scanning for future solid state/phased array systems. (At the moment such systems are not planned in Region VI.)

- An issue currently being discussed in OPERA was the definition of the standard for assignment of time of observation for a radar volume scan.

- A global standard for radar terminology was required and the IPET should initiate this as a component of the Best Practices Guide.

- Data user requirements for weather radar data are currently dominated by the requirements for Global NWP and there was clearly a need to ensure that the requirements of the wider data user community were known and addressed.

- Within Germany, wind farms were becoming a major source for weather radar disturbance issues – e.g. Borkum Island. Addressing this issue through improvement and strengthening of the WMO CIMO policy should be a priority of the IPET.

Turkey

Mr Ercan Buyukbas, Turkey, made a presentation to the meeting on weather radar status and issues within Turkey:

- Turkey operated a network of 18 Doppler radars, consisting of 17 C-band and 1 X-band radars. Of these, 13 were dual-polarized and another 5 currently being upgraded.

- As with many countries, wind turbines also cause significant interference issues for operational radars in Turkey and it is recommended that this requires strengthening of the related policy document in the CIMO Guide.

- TSMS has developed a web-based site survey tool that might be made available for international use.

- TSMS has developed a tool for analysis of wind turbine effects on radar operation that might be made available for international use.

- The other significant interference issue for Turkey was with Radio Local Area Network (RLAN) interference, although, the chief concern was with discovering the source, after which the national process for spectrum management could be used to rectify such issues.

- Future work relating to operational weather radars in TSMS included research into gap-filling with X-band radars and the exchange of radar data with nearby countries.

The IPET was informed that two new international radar networks have been defined for Eastern Europe based on a decision of the RA VI seventeenth session and with a view to facilitating data exchange between the participating countries. These are the Establish South-East Europe Radar Network (SEERAD) and the Black Sea Radar Network (BLACKRAD). The networks would be managed and operated through the establishment of RA VI Regional WIGOS Centres

The IPET was reminded that the team has a presence on GITHUB for radar shareware and the sharing or radar software tools. This is available publicly at: https://github.com/wmo-ipet-owr/

Actions arising:

1. IPET to develop a public webpage to provide a directory or portal of information for Members relating to IPET activities and developments. This is recommended to be added to the work plan for next inter-sessional period of work. [**Chair to add to proposed work plan**, CIMO-17]

2. The IPET to consider the need to coordinate/instigate a WMO meeting with radar data users to ascertain requirements for provision of weather radar data. [**Chair to add to proposed work plan**, CIMO-17]

3. The IPET to consider the standardisation of radar terminology within the Best Practices Guide on Operational Weather Radar (BPG). [**Chair**, IPET-OWR-2]

4. The IPET to ensure that user requirements for all applications areas were addressed within the BPG. [**Chair**, IPET-OWR-2]

5. The IPET to determine how to advance the update of the CIMO policy document on weather radar proximity to wind turbines. [**Chair**, IPET-OWR-2]

5. Presentation and Review of the Work Plan

5.1. Status of Existing Tasks and Activities

IPET Coordination Facilities (Trello, Alfresco)

The meeting discussed the tools and methods for sharing work plan information and agreed that the use of the online tools, Trello and Alfresco, while not perfect, provided a suitable and adequate means for doing so. However, it was recommended that WMO should address the need to find a suitable and better means for facilitating collaborative, online document development.

Establishment of Weather Radar Best Practices Guide

The Chair reported on the status of Work Plan Task 3, Regulatory Material, advice and guidance to WMO's Members.

Associated with this task was Action 2, which as to Develop (WIGOS) Weather Radar Best Practices Guide (BPG) based on a review of existing materials, assessment of requirements and materials from other relevant actions and other tasks. This has resulted in the preparation of a BPG entry template, a draft Table of Contents, and an example BPG entry addressing solar monitoring as a quality assurance method.

While the establishment of the BPG had been realized, nominally, the preparation of a significant body of BPG content was behind schedule.

The meeting participants discussed in detail the structure of the BPG and also considered how best to order the various materials under or planned for development whilst ensuring little or no duplication and disharmony with relevant parts of WMO No. 8, Guide to Instruments and Methods of Observation. It was agreed that:

- In general the scope of the BPG should cease at production of Quantitative Precipitation Estimation (QPE).
- A glossary of radar terminology should be included as part of the BPG and it should be fully descriptive.
- The BPG should take account of user requirements and applications when it comes to data processing and data product generation.
- The work of compiling the BPG should be divided among the team based on expertise and knowledge.
- The BPG should incorporate the work of Dr Paul Joe (see item below on *High-level document on weather radar network design and applications*), however it was agreed that priority should be given to making this available to Members as soon as possible.
- The BPG should include guidance on maintenance aspects and priorities.

The meeting developed and agreed on a new proposal for a high level structure of the BPG made up of several Parts that might be developed and published according to different timelines with placeholders for parts still under development. Parts could be readily added for new, future required guidance. The proposed BPG structure is provided within Annex III.

The participants agreed to commit the breakout session of the meeting to further developing the sub-structure for the BPG.

High-level document on weather radar network design and applications

The Secretariat briefly described guidance materials that had been developed under consultancy of Dr Paul Joe with WMO, resulting in 3 high level documents on weather radar:

1. Guide to Weather Radar Network/Program, DRAFT FOR REVIEW V3 December 28, 2017
2. Guide to Weather Radar Technology, DRAFT FOR REVIEW V12
3. Guide to Weather Radar Procurement, DRAFT For Review V7

While a review of these documents had previously been requested of the team, only limited feedback had been received. It was agreed that:

- There was possibly a requirement to strengthen the understanding of the benefits of radar national and international networking within the guidance material.
- It was critical to address radar infrastructure and the heavy demands and requirements for maintenance to sustain radar operations, including management of radar parts and spares.
- While the documents were excellent in content and would be highly valued by WMO Members when available, there was a need to undertake a review to tidy up various aspects of the documents and ensure consistent and concise referencing.

- The documents should be published as soon as possible and ultimately become 3 separate parts of the BPG.

The meeting considered the related proposed Issue 5.1(3).1 and agreed on the decisions/actions as provided in the relevant tables in Annex II.

Guidance on Dual Polarization radar

Mr Blake McGuire, USA, made a presentation to the session on the benefits of and issues related to dual polarization radar. It was agreed that there was readily available guidance and best practices materials and information from various member operators that should be integrated into the BPG under its various parts.

Action: Mr McGuire agreed to lead and coordinate the development and integration of these guidance materials on dual polarization radar into the BPG.

Guidance on radar in mountainous regions

Mr Wai Kong, Hong Kong China, presented document 5.1(5) to the meeting, providing a report on the status of development and latest draft of guidance on radar in mountainous regions.

While a mature version of this document has been in draft for some time now, it still remains focused on the operational experience of Hong Kong and requires input from other team members for completeness and wider representation of operational practices.

It was agreed that:

- The guidance material should reference the Swiss publication on radar operation in mountainous regions and that Swiss members of the IPET should be requested to consider appropriate material that might be contributed.

- The guidance on radar in mountainous regions would be incorporated into different sections of the BPG.

Guidance on interference issues

Mr Blake McGuire, USA, made a presentation to the meeting on the experiences of NOAA in dealing with radar interference issues, noting that more and more cases were being encountered, with 560 being recorded since 1992. While NOAA was readily and usually able to determine the source of interferences using network analysing technology, such issues were a particularly difficult aspect of NEXRAD radar operation to resolve, given that the US does not have a strong enforcement process for dealing with users emitting outside prescribed bands.

Mr Bernard Urban, France, provided a presentation to the meeting on Météo-France experiences and issues relating to radar interference, which were chiefly associated with either wind turbine disruption or RLAN interference. Mr Urban noted that agreement had been reached with the windfarm community with separations specified and based on an impact study undertaken. Under this arrangement, the windfarm developer has to pay for the impact study to be undertaken, although it applies only to new developments and the issues with existing sites remains an issue.

The meeting noted that:

- The existing guidance material in WMO-No. 8 was now inadequate and the IPET should increase efforts to update these materials in line with the new arrangements in place in France and Germany.

- Relevant Studies and recommendations need to be up-to-date to deal with the changing technology of both radars and interferers (e.g. windfarms).

- The IPET has commenced drafting an update but is yet to be finalised with key input from those members most advanced in developing national policy.

- OPERA was also developing a policy document, which at the moment is under internal review. This document should be used and referenced for input to the WMO policy document.

- A system and solution had been established in Sweden to help to settle disputes relating to windfarm and wind turbine location.

The meeting agreed that the IPET should take the following actions in relation to guidance on radar interference:

1. The IPET commence to gather and maintain an inventory of cases of interference with radar systems to use within guidance material as part of the BPG.

2. The Secretariat to consider how best to give the WMO policy document better visibility, including the possibility to produce a stand-alone guidance document that might be given a WMO Number.

3. The IPET to finalise separate documents on: 1) RLAN interference; and 2) Wind turbine disruption, to also be included as part of the BPG.

4. Mr Bernard Urban to take the lead on finalisation of the policy document on wind turbine disruption.

5. Mr Blake McGuire to take the lead on finalisation of the policy document on RLAN interference.

Standard weather radar data representation

Mr Mark Curtis, Australia, presented the status of the work of the IPET on the development of a framework for operational weather radar data representation and exchange. In relation to this work under Task 4 of the work plan the following progress and status was reported:

- Completed the Information Model (deliverable 4.1a)

- Completed the Data Model (deliverable 4.1b)

- In relation to deliverable 4.1c, the File Format Representation, the group has developed the new CfRadial 2.0 standard, which has been produced with input from both IPET-OWR members and the original CfRadial authors. The described file format is consistent with the IM and DM. This format is now functionally complete and is undergoing revision based on feedback from CfRadial 1.0 users and the larger CF community.

- An early draft of the guidance material (deliverable 4.3) has been produced which provides a direct mapping between metadata attributes identified in the IM and their names in the CfRadial 2.0 format. Work on the guidance material is an ongoing task and due for completion in June 2018.

Related Activities and WMO Engagement

The group is now focusing on the matter of finalising WMO process to have the data representation framework approved and maintained under the appropriate CBS procedures.

The meeting was informed that:

- A netCDF-CF workshop will be held in June 2018, Reading, UK. This meeting will continue steering work on the CF Metadata Conventions of which CfRadial is an extension. Prior engagement with the community has indicated that functional extensions introduced by CfRadial 2.0 are consistent with the approach and intended future direction of CF. It will be important to monitor the output of this workshop and update CfRadial 2.0 as needed to ensure consistency with the parent CF conventions is maintained.

- In February 2018 the tenth session of the Implementation-Coordination Team on Integrated Observing Systems (ICT-IOS-10) was held at which IPET-OWR's work on the development of a standardized weather radar data representation was presented to the meeting and was well received.

- Action 5 of Task 4 in the IPET-OWR work plan calls for engagement with CBS OPAG-ISS for validation, approval and maintenance of the representation and the IPET would commence engagement with OPAG-ISS on this matter based on submission and engagement with appropriate data representation meetings and teams commencing in the 2nd half of 2018.

The meeting agreed that:

- Information would be submitted to the upcoming meeting of OPAG-ISS/IPET on Codes Maintenance (May/June 2018).

- There may be a requirement for the IPET to develop a standardised representation of Cartesian products in next phase of the IPET.

The meeting considered the related proposed Issue 5.1(7).1 and agreed on the decisions/actions as provided in the relevant table in Annex II.

Weather radar data exchange methods

Mr Daniel Michelson reported to the team on progress made on developing guidance material related to weather radar data exchange methods. This activity had resulted in the preparation of an initial draft document proposing a way forward for future methods of weather radar data exchange. The meeting participants were invited to review this material and offer feedback.

The meeting agreed that this material would later be finalised as part of the Best Practices Guide.

It was also agreed that, as CBS begins determining requirements for WIS 2.0, the IPET should ensure that requirements for exchange of weather radar data are taken into account.

Metadata management

Mr Ercan Buyukbas, Turkey, reported to the team in relation to the current status and recent developments within the WMO Radar Database, which is maintained and operated by WMO on behalf of the Turkish State Meteorological Service (TSMS). In particular the team was informed that a recent update had been made to incorporate the following additional functionality:

- Support for inclusion of a WIGOS Station Identifier for each radar as required input;

- Addition of a Station Type field in compliance with the WIGOS Metadata Standard; and

- Enabling of direct updating of the WRD through the WRD user interface.

Mr Buyukbas highlighted the following issues that require addressing:

1. There was a requirement for WMO to develop policy in relation to permission for external access to the metadata by third parties.

2. There are currently differences between the list of WMO National Focal Points on Weather Radar Metadata maintained within the WMO Country Profile Database and that maintained by TSMS.

Best practices

Mr Daniel Michelson presented document 5.1(10) to the team, submitted by Co-Chair of the IPET, Mr Tom Kane, Australia, addressing the current status of the work plan in developing best practice guidance on weather radar operation. While this was one of the high priority tasks of the IPET and an initial draft structure of a Best Practices Guide had been developed, little progress had been made on incorporating and developing materials within it.

The team agreed that this task must be given priority and attention in the 2nd half of 2018 with a view to advancing the BPG significantly by December 2018. The team also agreed that the breakout sessions of the meeting would focus on elaborating on the current structure of the BPG and developing a plan for its advancement through a series of at least monthly teleconferences of the IPET commencing in Q3 2018.

GPM – ground-based weather radar intercomparison

Mr Dean Lockett, the Secretariat, presented a document submitted by the Secretariat Satellite Data Utilization Division on the use of inter-calibration methods of ground radars with reference to JAXA's space-borne precipitation radars. JAXA has operated the space-borne radars since 1997 throughout the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and the Global Precipitation Measurement (GPM) mission Dual-Frequency Precipitation Radar (DPR), demonstrating that radars operate reliably as independent well-calibrated radar systems.

The 7th GPM Asia Workshop on Precipitation Data Application Technique was held at the BMKG, Jakarta, Indonesia on Jan. 2018. At the workshop, JAXA and the Bureau, Australia, presented their techniques of ground-based weather calibration using the GPM radar. Such methods offer the opportunity to readily, efficiently and systematically compare the calibration status of ground radars.

The team was requested to consider supporting and monitoring the development of such methods of inter-calibration, in particular through the possible associate membership of JAXA to the IPET.

The team agreed that:

- It should endeavour to prioritise activities related to this in the work plan of the next inter-sessional period, subject to agreement of the WMO managing technical commissions.

- GPM inter-calibration should be specifically referenced and described in the BPG.

The meeting considered the related proposed Issue 5.1(11).1 and agreed on the decisions/actions as provided in the relevant table in Annex II.

Collaboration with ISO

Mr Dean Lockett, the Secretariat, briefly presented the document submitted by the Secretariat in relation to collaboration with the International Organization for Standardization (ISO) in which WMO and ISO have collaborated in developing a common WMO/ISO standard on Weather Radar – Part 1: System Performance and Operation. The draft document had been shared with IPET-OWR at the time of its first meeting. Comments received from the IPET have been reviewed by the ISO WG and duly considered/incorporated in the next draft.

The CIMO MG was invited to review the draft standard as well. In this round of consultation comments were received concerning Table A1 (which is informative only, as it is part of an Annex). These comments were shared with ISO. To date, there was no formal response on whether the ISO working group is willing to incorporate those latest changes in the document.

It is expected that the Final Draft International Standard (FDIS) version of the standard will be circulated to ISO members and WMO Members for approval around July 2018.

WMO and ISO have expressed interest to collaborate in developing a second standard on weather radars (common WMO/ISO standard on Weather Radar – Part 2: Scope to be determined). Some initial discussions have suggested that this collaboration could be linked to the work of the IPET on best practices. It is expected that a meeting of the ISO Working Group will take place in conjunction with CIMO TECO 2018, in Amsterdam, during the week of 8-12 October 2018.

The meeting agreed on the suggested approach to the proposed Part 2 of the standard and agreed on the decisions/actions 5.1(12).1 as provided in the relevant table in Annex II.

Final report of GCOS AOPC Task team for Weather radar data requirements for climate monitoring

Ms Elena Saltikoff, Finland, made a presentation to the meeting regarding the work of the GCOS AOPC Task Team for Weather Radar Data Requirements for Climate Monitoring, highlighting in particular the key aspects, outcomes and recommendations of the draft final report of the team to GCOS. In particular the report suggests that:

- There is a requirement for an authoritative and single WMO definition of the various levels of radar data levels, and in particular to define what constitutes level 2 data.
- There is also a need to define and document what data processing is required in order to progress from Level 1 data to Level 2 data.
- The assignment of WIGOS Station Identifier is important for climate to document station history and this should also be overseen by the IPET to assure international compliance and consistency as required.
- There was a need for the WMO Radar Database to be updated to include missing operators.
- A survey had been conducted to determine availability and length of radar data held by members and the task team had proposed a vision for a central international portal of such data to be available for climate research purposes. The team was developing a paper for BAMS to promote this idea.
- A fundamental requirement for climate is to save level 2 data with sufficient metadata to allow the capability to reanalyse data historically.

- Climate applications for radar data use are already being developed or in use, including frequency of hail, change in precipitation intensity, among others.

- The task team would interact with the WIGOS Project Office to ensure that regulations in the Manual on WIGOS (taken from the Manual on GOS) on WRD archival are consistent with GCOS requirements.

In relation to this, the team proposed that Level 2 data for international exchange should include both corrected and uncorrected reflectivities.

The IPET agreed on the following actions for the work plan:

1. To specify within the Best Practices Guide or elsewhere in WMO guidance if more appropriate, the definitions of the radar data levels; and

2. The IPET to review and provide comments on the draft report to GCOS.

Survey of Members on Status of Operational Radars

Mr Lockett, the Secretariat, provided a report on progress made on finalising the results of the survey undertaken prior to IPET-OWR-1 for possible publication.

At IPET-OWR-1, the Secretariat presented the results of the survey on operational weather radars that had been undertaken prior to the session in document. During the session, the meeting had agreed that the survey should be further analysed and the results published as an IOM report and that similar surveys should continue to be undertaken every 3-4 years to continue to assess Member requirements for support relating to OWR.

Some work had been undertaken by the Secretariat to further analyse and summarise the results of the survey, in particular adding a section on Conclusions and Recommendations, as submitted within IPET-OWR-2, Information Document 5.1(14). The meeting suggested that the Recommendations section should be changed slightly to reflect that the recommendations are directed to the WMO Secretariat and the IPET to address.

The meeting considered the related proposed Issue 5.1(14).1 and agreed on the decisions/actions as provided in the relevant table in Annex II.

Training Activities

Mr Ercan Buyukbas presented a document on the Turkish State Meteorological Service (TSMS) contribution to international training on weather radar operation and data use, noting that the TSMS has been regularly offering international training courses since 2005. Based on this activity, the TSMS had also published training material as a CIMO IOM report and submitted a more recent syllabus for comment by the IPET.

The TSMS had also commenced compiling a list of potential instructors that might contribute to the course, with an expectation that presentations could be made by remote conferencing.

The meeting agreed that:

- The IPET might in the future take a more active role in the international coordination and collaboration on weather radar training activities.

- The team would welcome the continued opportunity to receive notification of international courses and their content.

The Chair reminded the meeting that the IPET had received a request from Brazil to assist in coordination of a workshop on WRDE for Region III, which would likely be scheduled for early 2019, with Mr José Mauro de Rezende to be the focal point in the team for this activity.

6. Work Plan Group Sessions

6.1. Work Plan Group Session Task Definition

The participants agreed that the group sessions during the meeting would focus on the development and advancement of the structure and content of guidance materials being developed as part of the Best Practices Guide on Operational Weather Radar. In plenary first, the team discussed the overall structure of the BPG, agreeing that the first parts or sections should contain the materials that had been developed by Dr Paul Joe that were discussed under item 5.1, *High-level document on weather radar network design and applications*.

The draft structure agreed by the meeting is provided below in Annex III.

The draft structures and materials developed by the team within group sessions were documented and would be made available on the WMO IPET-OWR Alfresco sharepoint.

6.2. Work Plan Review

As part of the work plan review and in relation to the topic of radar calibration, Mr Theodor Mammen presented the outcomes and recommendations of the Weather Radar Calibration and Monitoring Workshop, held at Deutscher Wetterdienst, (DWD), Offenbach, Germany, October 18th-20th, 2017. Mr Mammen informed the team that:

- A primary focus of the workshop was related to calibration of dual polarization weather radars (DP WR) and also covered a range of topics relating to operational aspects of these radars.
- 62 participants from 22 countries attended and participated in the workshop.
- Presentations and posters are available online[1].
- During the workshop, a presentation was made on the IPET and its various activities and objectives.

Some of the important outcomes and recommendations from the workshop were:

- Guidance was required by DP radar operators on "when to use what" in relation to the methods and processes for calibrating these systems, including when a change made to the configuration constitutes a change in calibration status in terms of the station metadata.
- Measurement of sun flux was desirable from/for every continent to provide a standardised reference for calibrating radar systems.
- There appeared to be a requirement or at least a desire for international exchange of radar calibration information and/or metadata.

[1] https://www.dwd.de/EN/specialusers/research_education/seminar/2017/wxrcalmon2017/wxrcalmon_en_node.html

- There was a desire to develop and adopt a standardised approach to the monitoring of antenna pointing accuracy and calibration stability using the sun as a reference.

- A summary document or report of the workshop would be produced and might be made available for publication or perhaps included in the BPG.

- Attendees suggested that an international event of this type should be held every 2 years and DWD would be willing to host the next workshop again in the second half of 2019.

The Chair led the meeting through a review of the IPET work plan updating the work plan status according to the version provided in Annex IV.

6.3. Review of IPET Terms of Reference (ToR)

The meeting reviewed the Terms of Reference of the IPET-OWR and, while agreeing that the scope and content of the ToR were appropriate for the current CIMO inter-sessional period, requested that the team leadership and the Secretariat should develop a revised version to clarify and simplify some of the clauses. The proposed revised version is provided within Annex V.

7. Reporting to CIMO

7.1. Recommendations and Report to CIMO

The Secretariat briefly informed the meeting on the requirements for reporting to the upcoming session of the Commission for Instruments and Methods of Observations (CIMO) and in particular requested advice on any particular decisions or recommendations of the commission that might be submitted by the IPET. It was agreed that, apart from the report of the Chair to the session via the OPAG and of the recommendation that the team should continue in its role in the next inter-sessional period, there were no specific decisions or recommendations relating to the work plan of team.

7.2. Final Report of the Meeting

The meeting agreed that the report of the meeting would be finalised by the Secretariat in the coming weeks after the meeting and with an aim to have it available by end-June 2018. A review process of the final report would be conducted by email.

8. Any other Business

ICE-POP

The meeting received a presentation by Dr Byong Choe Choi, reporting on the plans and outcomes of the International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic Winter Games (ICE-POP 2018). These experiments were planned under a joint project coordinated by the WMO Nowcasting and Mesoscale Research Group with oversight under the WMO World Weather Watch, World Weather Research and World Climate Research programmes. In addition to being endorsed as a WMO project in March 2016, the Observation WG meeting also at this time developed initiatives for the establishment of an international collaborative observations network, which included a decision for the participation of a range of remote sensing systems, including four weather radars. A series of organising meetings and workshops subsequently determined how the observing network would operate during the games over the Olympic winter games period and included test events and regulations for formulating, providing and sharing observations via a common platform.

Subsequent to the games, the project will now focus on the analysis and reporting phase under an Evaluation Working Group. This work will focus on several key science questions for which observations from weather radar play a role, including:

- East Snow Storm caused by Cold outbreak over East Sea
- Air-Sea interaction, Synoptic to Mesoscale transition
- Microphysical Phase change in Ocean
- Predictability of NWP over Mountainous, Complex Terrain
- Toward Advanced Physics in NWP

Under the IPET work plan, the team has endeavoured to establish a connection with the project, particularly in relation to its aims to develop guidance on calibration processes and procedures to support operational best practices. The team plans to seek access to data from the observations period to determine its suitability for analysis for this purpose.

9. Close of the Session

The Chair thanked KMA and other staff for their support in hosting the meeting and the second session of the IPET-OWR was closed by the Chair, late in the afternoon of the 17 May, 2018.

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ANNEX I – MEETING PARTICIPANTS

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ANNEX II – IPET-OWR-2, DECISION/ACTIONS AND RECOMMENDATIONS

Issue #2.1	**Streamline the IPET-OWR Work Plan**		
Background	The same guidance topics are being addressed multiple times in the Work Plan, first as stand-alone reports and then as entries to the Weather Radar Best Practices Guide (BPG). A possible reason for this is that several of the work plan items have their origins prior to the establishment of IPET-OWR, and were "inherited" from other working groups. Examples of such redundant topics are: • Mountainous terrain • Dual polarization • Operations of weather radar systems		
Rationale for the proposed decision/action or recommendation	A work plan rationalization would be to target the subject matter of redundant topics for inclusion directly into the BPG. Prioritized BPG entries would be aligned with requirements identified by the Member Survey results. The format for such BPG entries is intended to be consistent, which would hopefully facilitate the preparation of such much-needed guidance material.		
Decision(s)/action(s)	*What*	*By whom*	*Deadline*
	Identify redundant guidance topics	Team	2018
	Update work plan	Editorial board	Post-IPET-OWR-2
	Prioritize the creation of entries to the BPG and develop initial draft	Team	End 2018

Issue #5.1(3).1	**Review and Finalisation for publication of High-level document on weather radar network design and applications**		
Background	Over 2016/2017, Dr Paul Joe, Canada, under consultancy with WMO and under the direction of the Observing Systems Division, worked on developing high level guidance on radar network design and solutions for application. This work resulted in 3 draft guidance documents: 1. Guide to Weather Radar Network/Program, DRAFT FOR REVIEW V3 December 28, 2017 2. Guide to Weather Radar Technology, DRAFT FOR REVIEW V12 3. Guide to Weather Radar Procurement, DRAFT For Review V7 The IPET has been requested to review these draft documents, although only limited feedback was received.		
Rationale for the proposed decision/action or recommendation	A process for finalising these documents for publication, so that they can be used by Members, needs to be determined.		
Decision(s)/action(s)	*What*	*By whom*	*Deadline*
	The IPET members all to undertake a review of the documents, with a sub-group to undertake a thorough and comprehensive review.	IPET-OWR [Daniel Michelson, Tom Kane, Yoshihiro Tanaka, Mark Curtis, Vlado Stojanovic, Theo Mammen; June 2018]	end-June 2018

	Based on direction by IPET, Secretariat to make arrangements for publication of materials.	Secretariat	end-July, 2018

Issue #7.1(7).1	**Dependency on Climate and Forecast (CF) Metadata Conventions**		
Background	The CfRadial 1.0 file format was developed as an extension to the CF Metadata Conventions 1.5. This version of CF does not support the use of NetCDF groups which can be used to introduce hierarchical structure. The CfRadial 2.0 file format was developed in anticipation of CF 2.0 which is expected to support the use of NetCDF groups. The development status of CF 2.0 is unknown. IPET-OWR must decide how to proceed with CfRadial 2.0 in the absence of an official CF 2.0.		
Rationale for the proposed decision/action or recommendation			
Proposed decision(s)/action(s)	*What*	*By whom*	*Deadline*
	Seek clarification of status of CF 2.0 at upcoming netCDF-CF workshop in Reading.	IPET	June 2018

Issue #5.1(11).1	**Weather radar calibration monitoring via GPM intercomparison**		
Background	Ground-based weather radars are widely used in the NMHSs to monitor and warn for hazardous extreme-rain events and provide valuable input data to hydrological models. However, a fundamental uncertainty is that associated with errors in radar calibration. Maintaining a well-calibrated radar system requires regular testing and maintenance of components connected with the radar calibration, which requires significant resources and is time-consuming. Recently, inter-calibration methods of ground radars with reference to JAXA's space-borne precipitation radars have been developed, as such methods offer the opportunity to readily, efficiently and systematically compare the calibration status of ground radars. The JAXA has operated the spaceborne radars since 1997 throughout the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and the Global Precipitation Measurement (GPM) mission Dual-Frequency Precipitation Radar (DPR), demonstrating that radars operate reliably as independent well-calibrated radar systems.		
Rationale for the proposed decision/action or recommendation	The First Session of the Commission for Instruments and Methods of Observations (CIMO), Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR-1) meeting report; 5.3.4. Mr Lockett informed the meeting that JAXA/EORC and Japan Weather Association (JWA) had started a feasibility study of ground radar calibration using the space borne precipitation radar of the GPM and that the IPET had been requested to consider the potential impact of the Global Precipitation Measurement satellite mission in relation to OWR calibration and data integration. The IPET agreed that the results of this study should be considered with a view to the potential to play a role in the calibration practices of OWR.		
Proposed decision(s)/action(s)	*What*	*By whom*	*Deadline*
	To review the JTECH paper by the BoM as the feasibility studies on the calibration of ground-based weather radars in Australia using GPM, and to validate its effectiveness for the inter-calibration of ground-based radars	IPET-OWR	Next inter-sessional period of IPET-OWR

	To encourage BoM and JAXA for the further development of those feasibility studies to be implemented in the South East Asia and Western Pacific regions	IPET-OWR	Next inter-sessional period of IPET-OWR
	To evaluate and consider the requirements for further development of techniques and utilisation of GPM data for radar inter-calibration and composition of ground-based weather radar globally, and in the regions, perhaps led by the BoM with the cooperation of IPET-OWR and JAXA.	IPET-OWR	Next inter-sessional period of IPET-OWR
	To invite JAXA to have representation as an Associate Member of IPET-OWR.	WMO Secretariat	Next inter-sessional period of IPET-OWR

Issue #5.1(12).1	**Collaboration with ISO**		
Background	WMO and ISO have collaborated in developing a c**ommon WMO/ISO standard on Weather Radar – Part 1: System Performance and Operation.** - The draft document had been shared with IPET-OWR at the time of its first meeting. Comments received from the IPET have been reviewed by the ISO WG and duly considered/incorporated in the next draft. - CIMO MG was invited to review the draft standard as well. In this round of consultation comments were received concerning Table A1 (which is informative only, as it is part of an Annex). These comments were shared with ISO. To date, there is no formal response on whether the ISO working group is willing to incorporate those latest changes in the document. - It is expected that the FDIS version of the standard will be circulated to ISO members and WMO Members for approval around July 2018. WMO and ISO have expressed interest to collaborate in developing a second standard on weather radars (**common WMO/ISO standard on Weather Radar – Part 2: Scope TBD).** Some initial discussions have suggested that this collaboration could be linked to the work of the IPET on best practices. It is expected that a meeting of the ISO Working Group will take place in conjunction with CIMO TECO 2018, in Amsterdam, during the week of 8-12 October 2018.		
Rationale for the proposed decision/action or recommendation	Advise on the potential scope for collaboration with ISO on a second standard on weather radars.		
Proposed decision(s)/action(s)	*What*	*By whom*	*Deadline*
	Advise on the potential scope for collaboration with ISO on a second standard on weather radars	IPET-OWR	May 2018
	Express interest in contributing to the development of the standard.	IPET-OWR members	May 2018

Issue #5.1(14).1	**Report On CIMO, IPET-OWR Survey of Members on Status of Operational Radars**
References	1. CIMO/Inter-Programme Expert Team on Operational Weather Radars, First Session, 13 – 16 March, Tokyo, Japan, Final Report 2. CIMO/OPAG-RST/IPET-OWR-1/Doc. 3.2, Analysis and Discussion of

<table>
<tr><td></td><td colspan="3">Survey Results
3. CIMO/OPAG-RST/IPET-OWR-1/Doc. 5.2(4), Existing and Newly Developed WMO Regulations and Guidance, Annex I, Regulatory Materials Relating to Operational Weather Radars, the Secretariat, 2 March, 2018
4. CIMO/OPAG-RST/IPET-OWR-2/Information Document INF5.1(14), Draft Report on CIMO IPET-OWR Survey of Members on Status of Operational Radars</td></tr>
<tr><td>Background</td><td colspan="3">At IPET-OWR-1, the Secretariat presented the results of the survey on operational weather radars that had been undertaken prior to the session in document CIMO/OPAG-RST/IPET-OWR-1/Doc. 3.2, Analysis and Discussion of Survey Results – see Reference 2.
During the session, the meeting had agreed (see Reference 1) that:
1) The outcome of the survey offered good guidance on where the IPET should prioritise its efforts and activities.
2) Action: The survey should be further analysed and the result published as an IOM report; Secretariat, Chairperson; Mar. 2018
3) Similar surveys should continue to be undertaken every 3-4 years to continue to assess Member requirements for support relating to OWR.
Some work has been undertaken by the Secretariat to further analyse and summarise the results of the survey, in particular adding a section on Conclusions and Recommendations – see Reference 4.</td></tr>
<tr><td>Rationale for the proposed decision/action or recommendation</td><td colspan="3">Proposed action relates to completing the action 2) from IPET-OWR-1.</td></tr>
<tr><td rowspan="3">Proposed decision(s)/action(s)</td><td>What</td><td>By whom</td><td>Deadline</td></tr>
<tr><td>IPET-OWR-2 reviewed the draft report, recommending that it be finalised for publication.</td><td>IPET-OWR</td><td>IPET-OWR-2</td></tr>
<tr><td>Make minor changes and submit for publication as IOM or other publication as appropriate.</td><td>Secretariat</td><td>June 2018</td></tr>
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ANNEX III – PROPOSED STRUCTURE OF THE OWR BEST PRACTICES GUIDE

Contents

ANNEX IV – UPDATED IPET-OWR WORK PLAN

Work plan of the Inter-Programme Expert Team on Operational Weather Radars (2016-2019)

CIMO-16, updated based on outcomes of IPET-OWR Second Session
(ET-OWR deals with **all aspects** of operational weather radar under the ToR below.)
(Version: 2.0a, 23 July 2018)

No.	Task description	Person responsible	Action	Deliverable	Deadline for delivery	Status [%]	Comments
1.	IPET management Addresses ToRs 8, 9	Michelson Secretariat	1. Organize the activities of the IPET into a Work Plan 2. Review and revise the Work Plan as necessary. 3. Report on issues, activities and progress to CIMO and CBS 4. Meeting of IPET-OWR in Q1 2018 to consolidate deliverables ahead of CIMO session.	1. Work Plan 2. Work Plan Review and Revision 3. Reports to CIMO-MG, CBS-MG and ICT-IOS 4. IPET-OWR-2; consolidated reporting and deliverables to CIMO;	1. Jan 2017 2. Draft plan: Feb 2017; 3. Upon request; to CIMO annually; Chair to attend ICT-IOS-10 (Q1, 2018) 4. Q1 2018		To be approved by the IPET members and CIMO MG. Regular Teleconference sessions dedicated to Task collaboration. (e.g. Monthly) Update status six-monthly. Annual update to CIMO-MG around October. Full report prior to CIMO Session.
2.	Survey of Members requirements Addresses ToR 8	Michelson Secretariat	1. Survey the Members aimed to obtain requirements for WMO assistance, guidance, etc. on OWR, and the status of the Members' operational radars 2. Analyse survey replies 3. Review at IPET-OWR-1 and adjust work plan accordingly 4. Analyse survey results further and produce report.	1. Survey 2. Survey report 3. Updated work plan 4. IOM report of survey or integration into BPG (see below)	1. Jan 2017 2. Mar 2017 3. Mar 2017 4. Dec 2018	80	Survey was completed and results provided to IPET-OWR-1.
3.	Regulatory Material, advice and guidance to WMO's Members Addresses ToR 1a-b, 2, 3	1. Michelson EB Secretariat 2. a. Joe b. Joe c. Joe d. EB e. Mammen f. Kane g. Curtis	1. Maintain, review and update existing RM for WIGOS and ensure consistency of the documents 2. Develop (WIGOS) Weather Radar Best Practice Guide (BPG) based on a review of existing materials, assessment of requirements (e.g. survey, Task 2), and prioritized topics carried over from CBS ET-SBO and CIMO ET-ORST. These include parts addressing: a. Weather radar network design and applications b. Guidance on weather radar technology (including dual-	1. Draft updates to WMO No. 8, 488, 544 and/or 1160 2. Guidance material: a. Compiled user requirements b. BPG template c. BPG Content Outline 3. New draft guidance for each of the identified parts, including a Glossary of Terminology	1. Dec 2017 (No. 8: CIMO Guide) 2. a. May 2017 b. May 2017 c. May 2017 3. May 2018 and Dec 2018		Guidance on interference (e.g. external radio emitters) and disturbance (e.g. wind turbines) to be included in BPG or as external policy statements, leveraging output from Task 9. Action 3 of this Task is intended to assure purposeful horizon scanning in the WMO sense.

No.	Task description	Person responsible	Action	Deliverable	Deadline for delivery	Status [%]	Comments
			polarization and emerging technologies) c. Guidance on weather radar procurement d. Guidance on weather radar siting, configuration and scan strategies (including mountainous regions) e. Guidance on weather radar calibration, monitoring and maintenance f. Guidance on weather radar data processing (up to but not beyond Quantitative Precipitation Estimation) g. Guidance on data representation and international exchange (outputs from Task 4) 3. Ensure that potential operational developing and emerging weather radar research and technologies, including collaborative and adaptive data collection methods, are addressed when new guidance is prepared.				
4.	Weather radar data exchange Addresses ToR 1a-b, 2	Michelson Dixon Curtis Umehara Rezende Mammen Chong	1. Conclude work started in TT-WRDE on the creation of proposed standard weather-radar data representation 2. Propose weather-radar data exchange methods 3. Develop associated guidance material and provide for integration under Task No. 3. 4. Engage with Task 5 re exchanged metadata. 5. Engage with CBS OPAG-ISS for validation, approval and maintenance of format 6. Assess and initiate necessary actions on issue of data policy and licensing. 7. Investigate and report on processes for ensuring availability and compliance of software used for exchange.	1. Data representation: a. Information model b. Data model c. File format representation 2. Report on data exchange protocol(s) and mechanism(s) 3. Guidance material on use of exchange format. 4. Exchanged metadata integrated into WR metadata model 5. Format validation process activated. 6. Report on data policy issues to TCs. 7. Report on exchanged software processes.	1. a. Jan 2017 b. May 2017 c. Jun 2017 2. Dec 2017 3. Jun 2018 4. Sep 2017 5. Dec 2018 6. Jun 2018 7. Jun 2018	1. 75 2. 0 3. 0 4. 0 5. 0 6. 0 7. 0	Current status as of CBS-16: data representation well organized by TT-WRDE, with work in advanced stage of preparation. Data exchange remains TBD.

No.	Task description	Person responsible	Action	Deliverable	Deadline for delivery	Status [%]	Comments
5.	Metadata management, WMO radar database (WRD) and Contribution to OSCAR Addresses ToR 7	Buyukbas Curtis Saltikoff	1. Liaise with TSMS, and provide advice on structure/organization of WRDB, supporting the Members and WIGOS. Liaise with OPERA regarding metadata compatibility. 2. Facilitate Members contacts with the WRD to help the WRD stay up-to-date. 3. Develop the radar metadata model based on the WMDS and document within the WIGOS guide. 4. Guidance on use of OSCAR Surface and maintenance of metadata in WRD.	1. Recommendations on potential WRD enhancements 2. Report and update WRD if required 3. WR metadata model and guidance 4. Guidance on OSCAR Surface and WRD	1. May 2017 2. On request 3. Sep 2017 4. Dec 2017	1. 0 2. 0 3. 0 4. 0	WRDB is updated by TSMS. IPET liaises with TSMS. This is a placeholder, without specific foreseen recommendations or WRDB updates. Task 2 requires liaison with OSCAR dev. Team.
6.	Intercomparison of proposed weather radar best practices Addresses ToR 1a	1. Mammen, EB, Secretariat 2. Kim, Jung 3. Curtis, Dixon	1. Assess outcome of DWD workshop on radar DP calibration (Oct 2017) and coordinate a follow-up workshop on general WR calibration in 2019. 2. Conduct (participate in) an intercomparison in which weather-radar calibration, QC and QPE practices, with a priority on those identified under No. 3 above, are trialed and benchmarked according to agreed-upon performance metrics. 3. Prototype weather radar data representation using outputs from Task 4.	1. Documentation of outcome from DWD calibration workshops; Guidance integrated into Task 3, Action 2.e. a. 2017 workshop b. 2019 workshop 2. Report(s) on intercomparison results 3. Software for representing weather radar data according to the proposed standard, along with example polar sweep and volume files	1.	1.	This is the spirit of RQQI. Assumes linkage with ICE-POP (PyeongChang 2018 winter Olympic Games) for site(s), instrumentation and data. Also the RELAMPAGO project (Argentina) for warm weather.
7.	International and regional collaboration - ISO Addresses ToR 6	Gabella Joe (Li Bai, Pavlyukov, Yamauchi)	1. Participate in the formulation of a joint ISO-WMO weather-radar standard 2. Liaise with/consult IPET members on the review of the committee draft (and other drafts, as appropriate)	1. ISO-WMO weather-radar standard 2. Inform IPET on progress and seek IPET views on ISO standard committee draft (CD)	According to the ISO process		At least two phases of the joint work with ISO are envisaged.
8.	International and regional collaboration Addresses ToR 6	Michelson Yamauchi	1. Present relevant outcomes of IPET at international radar conferences, if appropriate. 2. Synthesize outcomes of international radar conferences for the benefit of the team members and WMO. 3. Organisation of WMO international conferences on meteorological radar systems in collaboration - initially investigate and discuss possible	1. Presentations at international conferences 2. Report/Document summarizing outcomes of international conference 3. Offer made to collaborate with ERAD (2020) 4. Document activities and issues and report to CBS and CIMO as necessary	1. Oct 2017 (AMS-38) 2. Dec 2017 (AMS-38) 3. Jul 2018 4. Jul 2018		International conferences of interest: • AMS 38th Conference on Radar Meteorology (2017, Chicago) • Report on ERAD 2018, Utrecht, NL • AMS 29th Conference on Radar Meteorology (2019)

No.	Task description	Person responsible	Action	Deliverable	Deadline for delivery	Status [%]	Comments
			collaboration with ERAD (2020) 4. Maintain a watch on international and regional collaborations in relation to weather radar data exchange, including OPERA, RAII-V, BLACKRAD, SEERAD				• (ERAD 2020)
9.	Policy Addresses ToRs 4, 6, and 7	McGuire Saltikoff Mammen	1. Contribute input to SG-RFC, strengthening the liaison with international organizations (ITU, EUMETFREQ, others), with the objective to protect frequency bands that are used for (operational) weather radar. 2. Monitor the use of frequency bands used for (operational) weather radar, gathering information on cases of interference. 3. Formulate, preferably together with other organizations, a sustainable policy for wind-turbine proximity to weather radars: a. Review existing materials (CIMO Guide Chapter 7, OPERA document) b. Identify differences, gaps and issues. c. For BPG combine with interference generally (RF) d. Update CIMO Guide Policy (chap 7, Annex) e. Investigate ways to increase visibility of WMO policy on wind turbine issues for OWR. E.g. EC Resolution.	1. Provide input to SG-RFC 2. Case log of RFI events 3. Weather-radar and wind turbine statement or policy	1. Upon request 2. IPET-OWR-2 or conference 3. Dec 2017		
11.	Capacity development and training Addresses ToR 1c	Buyukbas Joe Michelson Curtis J-H Kim	1. Coordination of/assistance with international training courses, e.g. TSMS (Turkey) and KMA (South Korea); a. Develop and maintain list of expert speakers on particular topics. b. Develop a curriculum outline and guidance for WR courses.	1. Expert speaker list; Curriculum outline and guidance. 2. Report on (open) software inventory 3. Examples of using weather-radar data processing software including interactive exercises	1. a. Nov 2017 b. Jun 2018 (Dec 2017) 2. ERAD 2018 3. TSMS KMA, Apr 2017	1. 0 2. 0 3. 0	1. Liaising with EUMETCAL, TSMS, and KMA 2. Software solutions based on the Open Radar Virtual Machine

No.	Task description	Person responsible	Action	Deliverable	Deadline for delivery	Status [%]	Comments
			2. Conduct an inventory of (open) software for exchanging and processing weather-radar data 3. Development of competencies on weather radar (P. Joe)	4. Advise on need for weather radar competencies			

ANNEX V – IPET-OWR PROPOSED UPDATED TERMS OF REFERENCE

Terms of Reference for Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR)

Proposed by: IPET-OWR-2, May 2018

Within the WIGOS framework, under the governance of CIMO and the joint guidance of CIMO and CBS, act as the WMO primary working group on operational weather radars (S, C and X band) with responsibility to:

1) Develop, document and maintain proposals for the activities of the Inter-Programme Expert Team;

2) Develop, review and maintain newly proposed and updated materials on all aspects of operational weather radar systems, including maintenance of relevant regulatory and guidance materials in WMO-No. 8, WMO-No. 1160, WMO-No. 1165, and WMO-No. 1200;

3) Contribute to the development and maintenance of methods, models and formats for the representation of weather radar data and metadata for the purposes of international exchange;

4) Provide advice on weather radar network design and operation;

5) Provide guidance on radio-frequency allocation and protection in relation to weather radar system operation;

6) Review and report on potential operational developing and emerging weather radar research and technologies;

7) Collaborate with other international and regional organizations on relevant matters, particularly including international standards organizations and research bodies and associations;

8) Undertake, coordinate or assist in relevant and related WMO international training and capacity development activities;

9) Collaborate with and respond to the requests of WMO constituent bodies, as appropriate; and

10) Report to CIMO and CBS on issues, activities and progress.

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ANNEX VI – ACTIONS ARISING FROM IPET-OWR-2

Item No.	Agenda Item	Action	Who	By When	Comment
1	2.1	1. Identify redundant guidance topics 2. Updated work plan 3. Prioritize the creation of entries to the BPG and develop initial draft	1. IPET 2. Chair, EdB 3. IPET	1. End-2018 2. July 2018 3. End-2018	Work plan update to be included in final report of IPET-OWR-2
2	2.2 (ISO Collaboration)	1. Approved the elaborated collaboration with ISO on Part 2 2. Identify representatives and engage in the joint team 3. Draft Part 2 jointly	1. Team 2. Team 3. Joint team	1. IPET-OWR-2 2. Q2 2018 3. TBD	Item 1 completed and agreed on collaborative approach.
3	2.2 (ISO Collaboration)	Establish joint team to draft Part 2	CIMO-MG and ISO	2nd half 2018	
4	3.1	Review New Vision for the Future of Environmental Measurements	IPET members	End-June 2018	
5	4.1	IPET to develop a public webpage to provide a directory or portal of information for Members relating to IPET activities and developments. This is recommended to be added to the work plan for next inter-sessional period of work.	Chair, Secretariat	CIMO-17	Update work plan as required.
6	4.1 (RA VI)	Consider how best to interact with data users and receive their requirements	Chair, Secretariat	End-June 2018	Update work plan as required.
7	4.1 (RA VI)	The IPET to consider the standardisation of radar terminology within the Best Practices Guide on Operational Weather Radar (BPG).	Chair	IPET-OWR-2 (group sessions)	Update work plan as required.
8	4.1 (RA VI)	The IPET to ensure that user requirements for all applications areas were addressed within the BPG.	Chair	IPET-OWR-2 (group sessions)	Update work plan as required.
9	4.1 (RA VI)	The IPET to determine how to advance the update of the CIMO policy document on weather radar proximity to wind turbines.	Chair	IPET-OWR-2 (group sessions)	Update work plan as required.
10	5.1 (IPET Coordination Facilities)	Find a suitable and better means for facilitating collaborative, online document development	Secretariat	End-July 2018	

Item No.	Agenda Item	Action	Who	By When	Comment
11	5.1 (Est. of WR BPG)	1. The BPG should take account of user requirements and applications when it comes to data processing and data product generation. 2. The work of compiling the BPG should be divided among the team based on expertise and knowledge. 3. The BPG should incorporate the work of Dr Paul Joe (see item below on High-level document on weather radar network design and applications), however it was agreed that priority should be given to making this available to Members as soon as possible. 4. The BPG should include guidance on maintenance aspects and priorities.	Chair	End-December 2018	
12	5.1 (Fin. Of P.Joe Guidance	1. Final Review of the documents, with a sub-group to undertake a thorough and comprehensive review. 2. Based on direction by IPET, Secretariat to make arrangements for publication of materials.	1. IPET-OWR, Daniel Michelson, Tom Kane, Yoshihiro Tanaka, Mark Curtis, Vlado Stojanovic, Theo Mammen 2. Secretariat	1. End-June 2018 2. End-August 2018	
13	5.1 (Dual pol. radar)	Coordinate the development and integration of guidance materials on dual polarization radar into the BPG	B. McGuire	End-December 2018	Chair to update work plan
14	5.1 (Radar in mount. Regions)	1) The guidance material should reference the Swiss publication on radar operation in mountainous regions and that Swiss members of the IPET should be requested to consider appropriate material that might be contributed to the document. 2) The guidance on radar in mountainous regions will be incorporated into different sections of the BPG.	W. Kong	Dec, 2018	

Item No.	Agenda Item	Action	Who	By When	Comment
15	5.1 (Interfer. Issues)	1. The IPET commence to gather and maintain an inventory of cases of interference with radar systems to use within guidance material as part of the BPG. 2. The Secretariat to consider how best to given the WMO policy document better visibility, including the possibility to produce a stand-alone guidance document that might be given a WMO Number. 3. The IPET to finalise to separate documents on: 1) RLAN interference; and 2) Wind turbine disruption, to also be included as part of the BPG. 4. Mr Bernard Urban to take the lead on finalisation of the policy document on wind turbine disruption. 5. Mr Blake McGuire to take the lead on finalisation of the policy document on RLAN interference.	1. Chair 2. Secretariat 3. IPET-OWR 4. Chair 5. B. Urban 6. B. McGuire	Dec. 2018	
16	5.1 (Data Representation)	1. Information would be submitted to the upcoming meeting of OPAG-ISS/IPET on Codes Maintenance (May/June 2018). 2. There may be a requirement for the IPET to develop a standardised representation of Cartesian products in next phase of the IPET. 3. As CBS begins looking at requirements for WIS 2.0, the IPET should ensure that requirements for exchange of weather radar data are taken into account.	Chair	1. June 2018 2. CIMO-17 3. CIMO-17	
17	5.1 (Metadata management)	1. There was a requirement for WMO to develop policy in relation to permission for external access to the metadata by third parties. 2. There are currently differences between the list of WMO National Focal Points on Weather Radar Metadata maintained within the WMO Country Profile Database and that maintained by TSMS.	1. E. Buyukbas 2. Secretariat, E. Buyukbas	1. December 2018 (draft policy) 2. September 2018	Chair to add to work plan
18	5.1 (BP Guide)	Monthly teleconferences to be held	Secretariat and Chair to schedule	December 2018	

Item No.	Agenda Item	Action	Who	By When	Comment
19	5.1 (GPM inter-calibration)	1. Add activities to IPET work plan of the next inter-sessional period, subject to agreement of the WMO managing technical commissions. 2. GPM inter-calibration should be specifically referenced and described in the BPG.	Chair	1. CIMO-17 2. December 2018	Update work plan accordingly
20	5.1 (GPM inter-calibration)	To invite JAXA to have representation as an Associate Member of IPET-OWR.	Secretariat	CIMO-17	
21	5.1 (Collab. With ISO)	Ensure IPET representation at the ISO Working Group in conjunction with CIMO TECO 2018, in Amsterdam, during the week of 8-12 October 2018.	Chair, Secretariat	8 Oct. 2018	
22	5.1 (Report of GCOS TT)	1. Specify within the Best Practices Guide or elsewhere in WMO guidance the definitions of the radar data levels; 2. The IPET to review and provide comments on the draft report to GCOS.	Chair, Secretariat	1. Dec. 2018 2. ???	
23	5.1 (IPET-OWR Survey)	Make minor changes requested by IPET-OWR-2 and publish survey	Secretariat	End-Aug 2018	
24	5.1 (Training Act.)	Assist in coordination of a workshop on WRDE for region III, which would likely be scheduled for early 2019.	J.M. Rezende, Chair, IPET members	Dec. 2018	

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