W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

COMMISSION FOR BASIC SYSTEMS

OPAG ON INTEGRATED OBSERVING SYSTEMS

WORKSHOP ON REGIONAL & GLOBAL EXCHANGE OF WEATHER RADAR DATA

Exeter, United Kingdom of Great Britain and Northern Ireland

24 to 26, April, 2013

FINAL REPORT

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GENERAL SUMMARY

1 INTRODUCTION AND ORGANIZATION OF THE WORKSHOP

The Workshop on Regional & Global Exchange of Weather Radar Data was opened by the Chair of the Workshop, Mr Stuart Goldstraw at 9am on 24 April 2012 at the Rougemont hotel, Exeter, UK and was preceded by a short introductory presentation by Mr Malcolm Kitchen, Head of Observations R&D at the UK Met Office. Mr Kitchen made the following important points in his presentation:

- The requirements of Global NWP are the main drivers and motivations for expanding standards and activity associated with international and regional exchange of weather radar data, with data impact results from ECMWF indicating at least a neutral or positive impact arising from assimilating USA radar data. The impact becomes significant at around day 5 over Europe, and days 8-9 over Asia.
- While demand is not strong currently, it will increase over next few years and so efforts should be made to be ready for this expected eventuality.
- The objective of the Workshop should be to answer the following key questions: How is exchange to be organized?; Who is involved? How can it be achieved technically? Should there be regional processing centres?
- Some difficulties and issues are: Convergence and consensus will be difficult. Benefits will not be localised, immediate or measurable.
- The proliferation of data formats should be minimised and those that are used, should be standardized and regulated by WMO, for reasons of consistency of information and approach and efficiency of processing.

Mr Kitchen suggested that these considerations pointed to the conclusion that it was very important that WMO and CBS should take the lead on this activity and its associated issues and that early and decisive action would improve the chances of success and reduce the proliferation of a multitude of formats.

Mr Dean Lockett from the WMO Secretariat welcomed all participants and attendees on behalf of the WMO Secretary General and the Director of the Observations and Information Systems Department. Mr Lockett thanked all participants for agreeing to attend the workshop and for the work done in the lead-up to the event. Gratitude was expressed to the Chair of the Workshop (also Chair of the CBS Expert Team on Surface-Based Observations, ET-SBO), Mr Stuart Goldstraw, for the considerable work done in defining the aims and objectives and organizing the work program of the Workshop and to the Met Office for hosting the activity.

A list of Workshop participants is provided in Annex I and included representatives of WMO Regions, radar Data Users and radar systems managers and operators.

The initial Aims and Objectives developed for the Workshop are provided in Annex II.

1.1 Adoption of the Agenda

1.1.1 The agenda for the Workshop was adopted without change and as given in the previous section of the report.

1.2 Schedule and Working Arrangements

1.2.1 The proposed schedule for the meeting, submitted as document 1.2, was also adopted. In the lead-up to the Workshop participants were requested to research and submit documents on their representative areas, which were then presented, reviewed and discussed at the Workshop. Based on these initial activities, the Workshop then developed

and proposed a set of recommendations and actions to be considered for adoption by CBS and its OPAG on Integrated Observing Systems (OPAG-IOS).

1.3 Examination of the drivers, issues identified and the expectations for the workshop

1.3.1 The Workshop Chair provided an initial presentation on the key drivers leading to the requirement to hold the Workshop and identified the main issues associated with weather radar data exchange that required consideration.

1.3.2 The three key drivers were:

1) Action G48 of the CBS Implementation Plan for Evolution of the GOS:

> ***Action****: Define weather radar data to be exchanged at regional and global levels, propose frequency of exchange of those data and develop a weather radar data processing framework, in concert with development of products based on national, regional, global requirements.*
>
> ***Who****: CBS (leading the action), CIMO, CHy in coordination with NMSs/NMHSs, agencies operating weather radars, in collaboration with RAs.*
>
> ***Time-frame****: Continuous.*
>
> ***Performance indicator****: Volume of radar data which are exchanged globally and regionally.*

2) A lack of guidance within the Manual on the GOS in relation to requirements and practices for operation of weather radar systems and, in particular, the international exchange of weather radar data. Whilst WMO members have invested between one & two billion US dollars in the current operational weather radar networks globally less than 150 words are currently included in WMO No.544.

3) Evidence presented at the most recent (May 2012) and previous WMO Workshops on Impacts of Various Observing Systems on NWP, for example: “The results of recent impact studies provide strong support for exchange of more observations between regions, and between countries within regions: e.g. ground-based GPS data, radar data, hourly surface observations and MODE-S data at airports”. [Final Report of the Fifth WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction, Page 5]

1.3.3 The aims and objectives for the workshop had been approved by ICT-IOS-7 in July 2012 and CBS-XV in September 2012. However the challenge was substantial as: the user community has varied and evolving requirements; the operating communities have a wide range of technological, political and financial challenges and there are already numerous successful bi-lateral and multi-lateral exchange agreements already in place. Understanding the current situation in terms of requirements, exchange agreements and constraints is an issue in itself. But this will be necessary in order for the next step actions that will be developed to be appropriate.

1.3.4 Nevertheless gathering of requirements, both technology free and technology exploitation specific, the capture of the current status of exchange agreements and the more complete understanding of constraints will be essentially for the global and regional exchange of weather data to progress in a sustainable way.

1.3.5 Substantial work has been undertaken by the RA reps to understand the current status of Weather Radar data exchange within and in some cases between the regions. However this is a snapshot and so it will be important to develop a mechanism by which the status of bi-lateral and multi-lateral exchange agreements can be undertaken routinely.

1.3.6 Even within the global Weather Radar data community there are a variety of terms used to describe the same entity or activity and so, whilst a small step, establishing an agree nomenclature will assist in the development of common understanding and achieving the common goal of improved Weather Radar data exchange.

1.3.7 It is recognized the existing regulatory material is limited, however to improve this situation considerable resource, both in terms of intellect and time will be required to develop, obtain agreement and publish in the appropriate WIGOS structure. This has been recognized as a key task for ET-SBO it will be with the continued essential support of the Workshop attendees, their colleagues, other WMO Commissions and the Weather Radar PoCs established for the Members operating Weather Radar Networks.

1.3.8 Work on data models and formats is evolving. One of our interesting challenges will be to bridge the gap between the needs of the operational meteorological community for controlled standards and the needs of the research community for data models and formats which are easy to use and allow for capability development. Building a strengthen relationship between these two separate, but hopefully not competing needs, will be important.

1.3.9 The links built between Commissions, RAs and other bodies actively engaged in Weather Radar Data exchange will be essential. Indeed the support of RA focused pilot projects will be key to the successful implementation of improved global and regional data exchange. Therefore supporting these proposals post Workshop will be an essential task.

1.3.10 Whilst the dominant focus of the workshop is the exchange of 'raw' data for the NWP community care should be taken to ensure the broader user community are not disenfranchised or constrained by any recommended activities**.**

2 REVIEW OF CURRENT AND FUTURE USER REQUIREMENTS FOR WEATHER RADAR DATA

2.1 Review of the requirements captured in the WMO Observing Systems Capabilities Analysis and Review Tool (OSCAR)

2.1.1 OSCAR is a resource developed by WMO in support of Earth Observation applications, studies and global co-ordination. The requirements stated in OSCAR have been obtained from points of contact working within, or in close association with, the CBS IOS IPET OSDE, previously known as ET-EGOS. In contains quantitative user defined requirements for observations of physical varies in application areas of WMO related to weather, water and climate.

2.1.2 Of the 23 separate application areas currently registered in OSCAR 9 areas specifically highlight the need for precipitation and horizontal wind measurement. These are: Global NWP; HiRes NWP; Synoptic Meteorology; Nowcasting & VSR Forecasting; Aeronautical Meteorology; Agricultural Meteorology; Hydrology; Climate and Ocean Applications. The variables referenced are: accumulated precipitation; precipitation intensity at the surface (both liquid & solid); precipitation type and horizontal wind.

2.1.3 As would be expected the wide range of application areas have a wide range of goal requirements. For accumulated precipitation the uncertainty in measurement requirement ranges from only 0.5 mm to 2 mm but the horizontal resolution ranges from 0.25km to 100km depending upon application area. More details can be obtained by accessing OSCAR directly from: <***http://www.wmo-sat.info/oscar/***>.

2.1.4 It should be noted the quality of the information held within OSCAR is strongly influenced by the currency of the update and caution should be taken in the requirement statements have not been updated recently. It was noted the current ECMWF requirements for precipitation accumulations are more demanding than those articulated in OSCAR.

2.1.5 **Recommendation:** The current requirements statements in OSCAR to be reviewed and if necessary updated in light of information provided to Workshop.

2.2 Review of the current and likely future global NWP requirements for Weather Radar data

2.2.1 Requirements for weather radar data from ECMWF and Meteo-France (MF) were reported to the Workshop as representative of the global and regional NWP communities respectively. The current status is that ECMWF is operationally assimilating NCEP Stage IV surface rain composites over USA in GRIB, while MF is operationally assimilating volumes of French radar reflectivity data and Doppler radial wind in BUFR[1]. Both ECMWF and MF have expressed the strong interest in extending the coverage globally for ECMWF and to the neighbouring countries for MF.

2.2.2 In terms of products ECMWF has expressed a strong preference in the short term for composite products for several reasons, including the fact that assimilating single radar data on a global scale is such a demanding task that will require a long term implementation and good results as for the current assimilation of NCEP data would be able to support the importance of these data and drive further developments. The position of MF is different in terms of products as it recognizes the importance of accessing unprocessed volume data to be able to have better control of the errors introduced in the indirect observations of rain rate and wind.

2.2.3 In terms of resolution ECMWF and MF agree that the minimum required horizontal resolution is 2km. For MF, in the longer term the horizontal might be increased to 1 Km.

2.2.4 Concerning the frequency, for MF, the AROME NWP system is based on a Rapid Update Cycling where assimilation is done every 3 hours, nearly down to every hour. A minimum update frequency of 1 hour is required. In the longer term, a 15 minute update frequency will be desirable. For ECMWF, 15 minutes frequency is desirable.

2.2.5 In terms of timeliness, the requirement for both is between 15 and 30 minutes.

2.2.6 In terms of format for the purpose of operational processing GRIB for composites and BUFR for raw volume data are required.

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[1] In both the opening agenda item 1 and 2.2.1, a distinction needs to be made between “data” and “products”. Within this document, “radar data” generally refers to the polar coordinate “raw” radar data in units of reflectivity (dBZ), radial velocity (m/s) or equivalent. In this discussion, no distinction is made regarding the various levels of processing that may or may not have been applied to the “raw” data to remove external artifacts such as ground clutter, electromagnetic interference, etc. In this document, “Radar Products” refer to end-user or application derivatives from the “raw data” and could be surface rainfall intensity, surface accumulation, echo top, Constant Altitude Plan Position Indicator (CAPPI) in reflectivity or rainfall intensity units. Currently, there is an establish WMO standard for a limited number of radar products in BUFR format and in some Cartesian projection. Note that some radar products are exchanged as image formats (GIF, JPG), as well as non-image formats (e.g. WSR88D Level 3 and Level 4 non-image products). In this document, the discussion is about the exchange of “raw data” for NWP but also for large-scale radar mosaics which make “mosaicing” of pre-projected products problematic.

2.2.7 **Recommendation**: It was recommended that CBS (via ET-SBO) should investigate the possibility of forming a similar body for weather radar observations and NWP applications to that servicing the Satellite community for products and data processing requirements

2.3 Review of the current and likely future hydrological requirements for Weather Radar data

2.3.1 Mr Konstantine P. Georgakakos, Hydrologic Research Center, USA provided a document to the Workshop that gave a comprehensive overview of the current and future envisaged requirements of radar data and radar data exchange for climate purposes.

2.3.2 The Workshop was informed that, in relatively technically advanced NMHSs, precipitation highly quality controlled data from radars was being used along with other data sources in order to derived the best rainfall estimates for input to hydrological models for streamflow, flood and flashflood prediction as well as being used in mesoscale NWP models so as to provide improved rainfall predictions in support of flood and flashflood applications. In some cases when there are substantial historical archives of quality-controlled weather radar data, the data is used for estimating the characteristics of design storms. There is still critical dependence on real-time rain gauge data for operational hydrologic applications.

2.3.3 Through the use of multiple rainfall data sources, particularly raingauges, error and bias characterizations of radar systems are able to be made which lead to improvements in data quality through corrections made either in real-time or as part of the pre-processing quality control process.

2.3.4 Constraints on wider use of radar data include: poor perception by data users and forecasters arising out of model calibration with raingauges, poor data quality control, lack of suitable or poor coverage for hydrological applications and applications are ill-configured for radar input. It was considered that consistency of data availability and format would be an important requirement for wider radar data use in applications.

2.3.5 In the future, improved radar precipitation estimates for operational hydrologic applications are the target, coupled with the requirement to reduce biases and improve quality control. While dual polarization capability offers further improvement in precipitation rate estimation, realizing such benefits will require the development of new algorithms. It is also expected there will be a continued and increased demand for historical data for use in climatology studies, creating a requirement to re-analyze old data using current algorithms to get a consistent dataset covering 10-20 years. Expansion of weather radar data usage is expected in an operational environment, especially as regards flood and flash flood prediction. Additionally, quantitative estimates of radar precipitation uncertainty (quantitative quality control indicators) should be made a standard feature of future data availability.

2.3.6 There is an established requirement for: hydrologic input to radar network design for improved precipitation fields in regions of varying terrain and climate; the development of consistent radar precipitation databases for use in hydro-climatological studies; and hydrologic forecaster training in radar hydrology.

2.4 Review of the climate requirements for Weather Radar data

2.4.1 Requirements for weather radar data from DWD's Climate & Environment and R&D Divisions were reported to the workshop as representative of the global and regional hydro-climatology communities and the GCOS Atmospheric Observation Panel for Climate (AOPC).

2.4.2 In the climate context, only the precipitation parameter of weather radar data is of sufficient relevance for its global and regional exchange. The current status is that the use of weather radar based precipitation data in hydro-climatology context and for long-term assessment requirements is at its infancy and has so far not left the national scale. On the other hand, the use of weather radar data and generation of local and composite quantitative precipitation estimation (QPE) products for customers in the field of hydrology, water management and flood and flash flood protection has reached an operational and high availability status at a number of countries, based on the advanced capabilities of their NMHSs.

2.4.3 There is a growing demand on consultancy, guidance and climate services, in context of adaptation to climate change for the various sectors including the water, food and agriculture sector being also major sectors of the current GFCS Implementation Plan. Target radar data based products are extreme precipitation statistics, long-term aggregations and re-analysis.

2.4.4 Radar data coverage enters the decadal and multi-decadal scale setting the opportunity to explore the use of weather radar data for hydro-climate applications provided geo-temporal homogenized re-processed decadal radar data sets are generated as demonstrated by Météo-France, The Netherlands, Australia and started also by Germany.

2.4.5 Level-2 2D radar data taken from precipitation scans (or lowest elevation scans) is target data for regional and global exchange. Volume (3D) data is currently too cumbersome.

2.4.6 Quality control of radar data is mandatory for climate application. Demands even higher than for hydrological purposes as data homogeneity in space and time comes as an additional requirement (on top of clutter and artifact corrections also required for hydrological applications)

2.4.7 Quantitative radar based precipitation analysis most reliable through adjustment against gauge data. This implies an additional requirement on gauge data. New absolute calibration methods based on dual-pol radar measurements might relax the gauge requirement in the future.

2.4.8 On the global scale the effort to address climate requirement is huge and should be addressed by an international data center that is charged to worldwide collect and quality assure radar data.

2.4.9 In terms of resolution the minimum required horizontal resolution is 1km. In the longer term the horizontal might be increased to 250m. Concerning the frequency, a minimum update frequency of 1 hour is required. In the longer term, an up to 5 minute update frequency will be desirable in particular to serve extreme precipitation statistics. In terms of timeliness, the requirement is relaxed to 48 hours provided a suitable storage strategy is applied. The relaxed requirement allows for an optimum acquisition and storage of gauge data from automated ombrometers

2.4.10 In terms of format there are no particular requirements by the climate community despite the fact that it should be a standard format sustainable for decades alike the BUFR and HDF5 formats used by OPERA.

2.4.11 **Recommendation**: CBS (via ET-SBO) should investigate the possibility of forming a body for weather radar observations similar to EUMETSAT CAF or SAF's that should also explore the climatological uses of radar data and elaborate further recommendations to that end. These should encompass:

2.4.12 Quality control indicators as an integral part of the available radar precipitation data;

2.4.13 Development of consistent radar precipitation databases for use in hydro-climatological studies

2.4.14 Global proliferation of the understanding with all radar operating NMHSs that there is a use for raw (L2) data beyond the real-time applications demanding for their permanent storage.

2.4.15 **Recommendation**: CBS (via ET-SBO) is invited to determine a proper mechanism to involve GCOS into the process and the future activities on the issue of global and regional exchange of radar data. It is also invited to take advantage of GOCS experience in setting and document standards for Essential Climate Variables (ECVs) like precipitation.

It should be noted that the climate community routinely reprocesses data, as frequently as on a yearly basis, as new analysis techniques are developed and therefore require comprehensive metadata about the radars.

2.5 Synthesis of above requirements into summary

2.5.1 A summary of the requirements are provided within Appendix III.

2.5.2 It should be noted that, while the scope of the Workshop and the initial EGOS-IP action that initiated it led to a focus on the international and global requirements for radar data exchange in support of NWP, it is important to acknowledge that the existing and current international data exchange and sharing arrangements and agreements have been fostered and formed upon the interests and requirements of regional, trans-national border exchange in support of severe weather forecasting and monitoring applications. However, the Workshop agreed that, while such agreements and data exchange processes may not require WMO intervention as they usually involve exchange of data in native formats, any international standardization activity associated with radar data exchanged should be mindful of such requirements. An example is radar data exchange for hurricane/typhoon monitoring and tracking. This is generally done from satellite VIS/IR but mosaic of coastal radar may be considered. It is expected that any WMO exchange protocol would benefit such bi-lateral exchanges.

3 REVIEW OF THE CURRENT STATUS OF WEATHER RADAR DATA EXCHANGE

3.1 Current status of Weather Radar data exchange

3.1.1 *Regional Report on the current status of the exchange of weather radar data – RA I*

A report for Regional Association I was not received because the expected representative was a late withdrawal from the Workshop. However the Participants agreed that requirements for global and regional exchange of radar data must take into account practical and technological challenges and limitations faced by developing countries and regions.

3.1.2 *Regional Report on the current status of the exchange of weather radar data – RA II*

Mr Li Bai, China Meteorological Administration, China, provided a document and presentation on the current status both of radar deployment and data exchange in both China and within Region II.

China is in the process of building the China New Generation Weather Radar, CINRAD which, when complete, will consist of a network of 216 new generation C-band and S-band Doppler radars. At the end of 2012, 144 of these radar sites were operational with 34 nearing operational readiness. Based on the evaluation of the CINRAD operation in the past years, the operational

availability of CINRAD has increased stably year by year from 89.49% in 2006 to 98.18% in 2011, with the MTBF decreased gradually from 29.85h to 13.45h during 2008-2011.

At present, the radar data in China are stored in three levels, i.e. national level, provincial level and radar site level. After collected by radar site, the data are transmitted to provincial centers through the wide area network (WAN) within the province, and then after being stored by the provincial center, the data are transmitted by the national meteorological WAN to the national center for storage. Radar data are divided into base product, single product, mosaic product, the case data and the State & Warning Information. The data transmitted from radar sites to the National Meteorological Information Center includes 10 kinds of radar PUP products and the transmission interval is less than 15 minutes. The provincial centers share radar base data and the interval for data transmission is less than 14 minutes. It takes less than 5 minutes to transmit the data to users after receiving the data from the National Meteorological Information Center. The data format includes basic data format and product data format, using binary encoding. The current base data format is the same as WSR-88D format.

In addition to the use of weather radars for quantitative precipitation estimation and their various applications in severe weather and systems forecasting and monitoring, data derived from weather radar are increasingly being used by CMA as input to NWP systems in particular with the use of the volumetric data of a smaller sub-set of weather radars assimilated into the Rapid Update Cycle (RUC) mesoscale NWP System, BJ-RUC and the assimilation of Velocity Azimuth Display (VAD) data from 60 Doppler radars into the GRAPES_RUC. The results show that the 3-D cloud analysis technique can effectively improve the accuracy of nowcasting.

Weather Radar Data Exchange in Region II

Radar weather data is being exchanged within CMA through the China Integrated Meteorological Information Service System (CIMISS). Base data exchange between CMA and Hong Kong China is also occurring with a mosaic product being derived from 10 radar sites, including the HKC radar data.

Outside of China, radar products are also being exchanged between countries. China and South Korea began to exchange radar in 2012 via the GTS, in the absence of regional governance protocols, resulting in improvement in the prediction of typhoon and other severe weather. China also provides a limited number of radar products to North Korea.

While an attempt was made to obtain information from other radar operators within Region II, there was no evidence found of any other data exchange arrangements or agreements. Of the 35 members of RA II, there was evidence of weather radar in 12 countries only.

Recommendations

1. Standardised exchange models for weather radar data will need to take into account latency requirements for both now-casting and other applications with less stringent requirements on transmission frequency. In order to improve the timeliness of radar data exchange for high frequency data exchange, it was recommended that data transmission should be done by using streaming data techniques, which means “uploading while scanning”.
2. With respect to future radar technology developments, e.g., dual-polarization technique, consideration should be made for the exchange of this data..
3. To ensure the accuracy of radar data, it was recommended that WMO organize experts to develop standardised quality control and calibration schemes that are able to take into account the different radar systems in operation in different countries.
4. Envisaging that data policy issues may be a significant limiting factor and that some agreements may initially allow the exchange of radar products only, consideration should be given to the comprehensive exchange of these product format and quality standards, as well.

3.1.3 *Regional Report on the current status of the exchange of weather radar data – RA III*

Mr José Mauro de Rezende, Brazil, provided the Workshop with a document and presentation on the status of weather radar operation and data exchange over Region III.

Radar Operation in Brazil

In Brazil, the radar networks operated by the Air Force and SIPAM (Amazon Protection System) have achieved a very important advance by implementing radar networks from which the QPE data are made available online:

http://www.redemet.aer.mil.br/radar/radar.php?ID_REDEMET=55ramuqfi53j5mc9rii3sa6c04

The Air Force Command has also commenced a project with the aim of storing raw radar data, which is expected to be complete in May 2013. As a result volumetric radar data for one third of the Brazilian territory will be archived at one center.

Dr. Luiz Augusto Machado from Centro de Previsão de Tempo e Estudos Climáticos (CPTEC/INPE) had some success in congregating data from 11 radars, including a radar from Paraguay and resulting in an online web page: http://sigma.cptec.inpe.br/radar/

There are many other radars installed in the country but not part of a national network, representing local initiatives, with some of them selling products as a special service and therefore restricted from making the data available in real time as part of an open network.

Due to the different interests of the radar owners, co-ordination to concentrate the actions in this area is still poor but the situation is changing.

Radar Operation and Data Exchange in Region III

Throughout Region III, it appears that the situation is very similar to that of Brazil with very little in the way of even national coordination and collaboration on radar data and product exchange or integration and there is no evidence of international or regional radar data exchange.

Some information and statistics on radar installation and operation by country in Region III was gathered and provided within the submitted document.

3.1.4 *Regional Report on the current status of the exchange of weather radar data – RA IV*

The status of radars and data exchange within Region IV was investigated using the WMO Radar Database, Internet search of the NHMS web sites and emails. The radar status was summarized in a two tables in the meeting report (see meeting document 3.1.4).

Within Region IV (North America, Central America and the Caribbean), volume scan radar data is being exchanged between Canada and the US in native formats using the GTS (Canada to U.S.) or Local Data Manager (LDM, U.S. to Canada). Mosaics are being produced in research mode and just beginning to be used in operational NWP.

Within the Caribbean, there is an on-going project to exchange low level (zero degree) reflectivity every 15 minutes using BUFR or PNG format amongst Barbados, Belize, Dominican Republic, French Guiana, Guadeloupe, Guyana, Jamaica, Martinique and Trinidad-Tobago. The BUFR radar product is being processed and translated into a Mosaic by Meteo-France in Martinique.

Telecommunications (push/pull) issues and information on status of data availability appear to be challenges (see CBS, Expert Team Meeting on Surface-Based Remotely-Sensed Observations, Session 2, Nov 2011).

3.1.5 *Regional Report on the current status of the exchange of weather radar data – RA V*

Mr Kamiluddin Ibrahim, Malaysia presented a document that was submitted by Mr Riris Adriyanto, Indonesia providing the Workshop with a summary of the status of weather radar operation and data exchange over Region V.

WMO Region V consists of 22 countries in South-east Asia and the South-west Pacific of which most are tropical maritime, vulnerable to climate variability and limited in resources. There are several weather systems and associated phenomena which have a significant socio-economic impact and therefore require monitoring, such as Monsoon, Tropical Cyclone/Typhoon, Tropical Storms and trans-boundary haze pollution from forest-fires.

It was found that of the 22 Member countries of RA V, less than half of the members operate weather radar systems, with specific information on these able to be obtained only from Australia, Brunei Darussalam, Indonesia, Malaysia, New Zealand, Philippnes, Singapore and Fiji.

Indonesia currently operates 27 radars of which all are C-Band Doppler with single polarization and supplied by 4-different foreign radar manufacturers: Gematronik / Selex SI (Germany), EEC and Baron Systems (USA), and Vaisala Oyj (Finland). Based on the masterplan of BMKG's radar network for ten years period (2006 – 2016), the total number of weather radar of Indonesia will grow to 51 Doppler weather radars and cover most of provincial cities. 14 of the existing radar sites transmit data to the radar mosaic system at the BMKG's head office under the so called Hydrometeorological Decision Support System (HDSS). This system was developed by Weather Decision Technologies Inc. (WDT), a US company based in Norman, Oklahoma. and generates some products used for weather forecasting and warnings, including an Indonesian radar reflectivity mosaic, QPE and a radar-based forecast based on the MAPLE algorithm (developed by McGill University Canada). By the end of 2013 an additional 10 radar sites will have been added to the HDSS system. As yet, Indonesia has no bilateral agreements for radar data exchange with its neighboring countries in the region.

The Meteorological Department (MMD) operates all 12 Doppler weather radars in Malaysia deployed throughout the Malaysian Peninsular and northern Borneo (Sabah and Sarawak region). These consist of 8 S-band radars and 4 C-band radars. All radars are using the same radar signal processing and software, allowing easy integration of radar images. Radar products are available online.

New Zealand operates 8 C-band Doppler weather radar systems located in Hokitika, Invercargill, Mahia, Mamuku, New Plymouth, Outlook Hill, Rakaia, and Tamahunga. The radars cover almost all NZ regions except some areas over mountainous regions. New Zealand has a bilateral agreement with Australia for weather radar data exchange of both raw data and products.

The Australian weather radar network is operated by the Bureau of Meteorology (The Bureau) and consists of 58 system covering most city and costal areas and part of the inland. The network is designed so as to provide coverage over the highly populated areas and along the coastlines, particularly the northern coastline where tropical cyclones threaten during the wet season (austral summer). Some radars are also used part-time for upper air wind-finding. In the future, the Bureau plans to assimilate radial winds and possibly clear air echo data, into the high resolution NWP model (ACCESS) over city domains, with the objective to improve the forecast of severe weather with lead times of 3 to 12 hours.

A summary of radar systems operated by RA V Members was provided in the submitted document.

Weather radar data exchange practices by Members of RA V

Australia and New Zealand currently have a bilateral agreement for exchange of both raw (commercial) and processed data (non-commercial).

Malaysia and Singapore have a bilateral agreement for exchange of radar data in BUFR format.

The Member countries of ASEAN (Association of South-East Asia Nations) are working towards collaboration on the exchange of radar data through the ASEAN Sub-Committee on Meteorology and Geophysics (SCMG).

3.1.6 *Regional Report on the current status of the exchange of weather radar data – RA VI*

OPERA and ODYSSEY

The majority of the information presented related to those WMO members within Region VI who are also members of the EUMETNET OPERA programme. This accounts for 30 of the 50 WMO Members of the Region. Further information from those members outside of OPERA still needs to be gathered.

Within the OPERA community the exchange of weather radar data is very mature and for more than 20 years there have been bilateral and regional exchange agreements between members (e.g. BALTRAD). In addition, for more than 7 years OPERA has operated centralised compositing (mosaic) capability, firstly with its Pilot Data Hub (PDH) and for the last 3 years the OPERA Data Centre (Odyssey).

To aid the exchange of data, OPERA has developed a data information model, known as ODIM (OPERA Data Information model). This model has been widely adopted by OPERA members to exchange data in two agreed formats, BUFR and HDF5. The adoption of ODIM has significantly improved the ability of members to understand each other's data.

Until recently, exchange of data was limited to Cartesian radar products (either TYPE III, e.g. CAPPI, pseudo CAPPI, Surface rain-rate, etc or TYPE IV, e.g. national composites/mosaic). This allowed for the creation of multi-national, qualitative products but the mixture of input products, variability of pre-processing, lack of quality information and the need for re-projection limited the ability to generated uniform quantitative products. The PDH used these products as input and this coupled with a lack of agreed data information model significantly added to the development costs of the PDH.

For these reasons EUMETNET gave the go-ahead for the development of Odyssey, jointly hosted by the UK Met Office and Météo France, where all input was limited to polar (TYPE II) data complying with ODIM. Odyssey was then able to apply consistent pre-processing to the input data and generating uniform pixel level quality index for all incoming data. Currently only reflectivity and radial wind data are supplied to Odyssey but dual-polarisation products will follow.

OPERA has just started a new development phase which will see improved pre-processing and related quality information added to the incoming data. These incoming data (unchanged) plus the centrally generated quality index will be redistributed to NWP centres in Europe.

Bilateral exchange between members is usually performed using GTS/RMDCN but most input data to Odyssey is transmitted using the Internet. There is a desire to send data to Odyssey over RMDCN but there are concerns about the available bandwidth of this network. OPERA has just started a development activity to investigate the best transmission methods for radar data in Europe.

Data policy within Europe is generally managed by ECOMET, European Interest Group. Through ECOMET the composite products of Odyssey will be made available for commercial exploitation. Bilateral agreements between members are still common.

A flow diagram describing the data flows associated with OPERA and ODYSSEY are provided in Annex IV.

BALTRAD

The BALTRAD partnership is currently developing and operationally deploying the latest generation software system designed to exchange and process weather radar data. This is conducted as an element of European regional infrastructure, partly funded by the EU's Baltic Sea Region Programme. The partnership contains 14 partners in 11 countries, the most recent of which is the Ukrainian Hydrometeorological Centre. BALTRAD software is Open Source and is deployed in a decentralized way, allowing partners to exchange data on equal terms and process them according to local requirements using a common set of data processing algorithms. This technology is inherently transferrable.

BALTRAD software has been designed as several modules that all interact using established mechanisms. The system exchanges data, manages them locally, and processes them; the data processing functionality is optional. Each of these general functions is a separate software module. These are configured together and released regularly as an integrated BALTRAD node. This concept is generally illustrated in Figure 1.

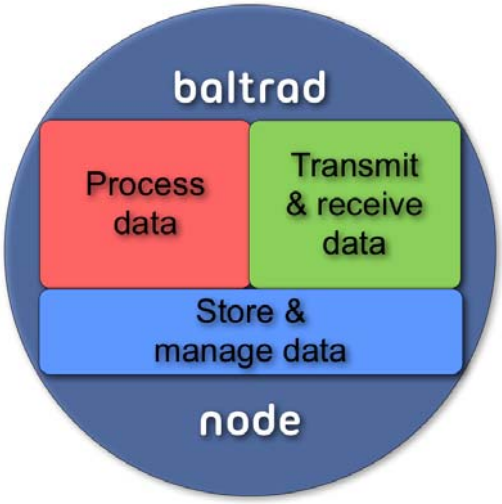

Figure 1. BALTRAD node modularity.

When a partner deploys its BALTRAD node, it establishes peer-to-peer network connections with other nodes (Figure 2). Each partner decides which data it lets other nodes subscribe to. Other nodes select from the data it is allowed to subscribe to, and then these data are pushed from producing node to subscribing node. This is done using active networking, where the two nodes are aware of each other and interact/transact directly with each other. There are several layers of security designed to ensure that only recognized and authorized nodes are allowed to interact, that the producer decides what data other nodes are allowed to subscribe to, that only data that the subscriber has requested are accepted. This is what is meant by “decentralized networking”.

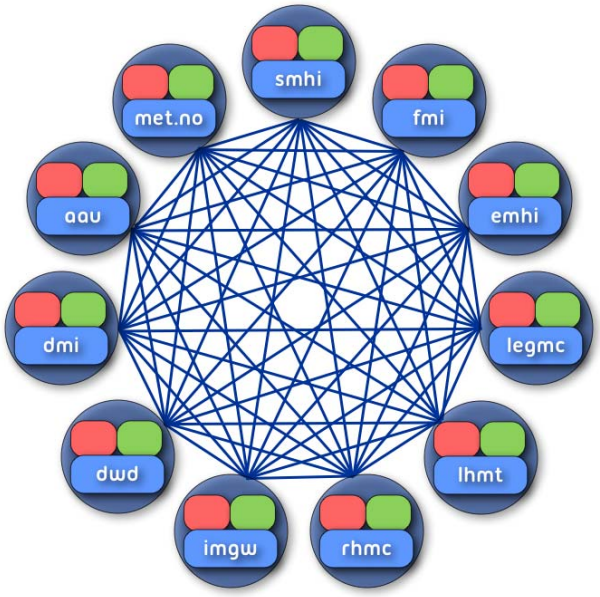

Figure 2. Decentralized networking concept with several BALTRAD nodes. The nodes illustrated here are those operated by partners in the BALTRAD+ project.

The optional data processing is performed using the so-called BALTRAD toolbox, which can be run stand-alone without the other node components. This toolbox is a framework that supports the

handling of ODIM data (mostly ODIM_H5) in a harmonized way. Partners can tailor their use of the tools to suit their local purposes, e.g. they can generate their own composite products using the nationally preferred projection and their choice of input data. This use of the common toolbox is an open and transparent approach designed to make data processing predictable. The partnership, along with interested members of the community, contributes its tools to the toolbox and document them using the so-called BALTRAD Cookbook. The BALTRAD toolbox is used by EUMETNET OPERA's Odyssey service to quality control all input polar data prior to the generation of European composite products.

The Swedish BALTRAD node is registered in the WIS as a "Pilot DCPC". Basic interaction with the German GISC was established in 2010 when a DAR metadata record was introduced in Offenbach and automatically replicated to the GISCs in Beijing and Tokyo. Data availability mechanisms for WIS are being elaborated as part of the current BALTRAD+ project.

Recommendations

1. The long-standing operation of regional and international data exchange mechanisms within RA VI provide examples of working data models and existing data formats that should be considered by CBS as a basis for global standardization.
2. Further investigation into radar data exchange arrangements and agreements outside of the EUMETNET domain should be undertaken.

3.2 Report on the status of Weather Radar MetaData held in the WMO Radar Database and recommendations for its further use.

3.2.1 Radar networks have been implemented in many countries, mainly by National Meteorological and Hydrological Services (NMHS) but also by organizations such as universities, TV stations, national militaries, aviation administrations, power administrations and radar manufacturers. New radars are being added to the existing networks and upgrades of radars are going on in those networks. In this context, a global survey on weather radars was conducted by WMO to establish a "fully comprehensive up-to-date web-based metadata database" of the global use of weather radars between 2008 and 2010. In addition to establishing an initial radar metadata database, one of the additional aims was assisting and promoting the wider international exchange of radar data. The decision corresponding to "Establishing a web page which supports adding and updating radar via focal points in a secure way" was made in the Joint Meeting of CBS Expert Team on Surface-Based Remotely-Sensed Observations and CIMO Expert Team on Operational Remote Sensing in 2009. Experts evaluated the first version of Web-based WMO Radar Database (WRD) developed by Turkish Meteorological Service (TMS) in the second Joint Meeting held in December 2011 and a "Report for Weather Radar Survey" was submitted to WMO. Later in 2012, WMO and the TMS finalized the Principles of the Operation and Maintenance of the WRD, which includes procedures for the maintenance of the WRD as an operational system, and the system became operational in 2012.

3.2.2 To gather data from all NMHSs that operate Weather Radars, WMO sent letters to all PRs in 2011 and 2013 to request an appropriate expert that will act as a Focal Point (FP) for Weather Radar Metadata, whom WMO can contact directly regarding the provision of weather radar metadata. The Focal Point has been thought as responsible for initial metadata entry and routine maintenance of the database under instruction from WMO and the database administrator. Details of assigned Focal Points can be found at WMO Weather Radar Observations page:

http://www.wmo.int/pages/prog/www/WRO/index_en.html

A link to the WRD is available from that page and is directly accessible from:

http://wrd.mgm.gov.tr

3.2.3 Currently there are 659 radars of 72 NMHS and 105 radars of other owners. Totally 764 weather radars have been included in WRD. For displaying the radar metadata, the WRD has a range of features including basic search; search based on countries, parameters of individual radars and materials; and statistics with graphs. From February 2013, a new feature was added allowing networks to be mapped using the Virtual Earth application (added in February 2013).

3.2.4 The WRD is maintained by Member Focal Points for Weather Radar Metadata, with each FP provided with a login to the User Interface to the database. The metadata within the WRD is also accessible to the WMO Information System (WIS) through an automated routinely accessed interface mechanism.

3.2.5 In the future, a number of new initiatives are planned. It will be possible for new online surveys to be done directly via the WRD interface by Focal Points with a trial survey to be filled by FPs conducted later in 2013. The WRD Web Page will be able to be used for communication within the Weather Radar Community through the establishment of forums. The data transfer process with the OPERA DB can be automated once it is transferred to a new server. Although the number of radars in the WRD has been increasing rapidly, there is still a lot of gaps in the information: New parameters and statistics can be added to the database to assist radar data exchange.

3.2.6 **Recommendation**: Consideration should be given to adding the following features to the WRD:

- The metadata should be modified so as to enable the maintenance of a historical record of radar metadata; for example, the database would establish periods of time for which particular site or system configurations or calibrations were valid;
- Support for inclusion of future installations planned;
- Keep a record of access by FPs and provide a facility for FPs to indicate they have checked the data and it is deemed to be up-to-date and correct;
- Metadata or information on data exchange arrangements and agreements, including bilateral, regional or international data exchange and dissemination.

3.3 Summary of regional reports on the exchange of weather radar data highlighting progress, plans and challenges

3.3.1 The documents provided by participants in preparation for the workshop were reviewed in relation to the exchange of weather radar data, particularly seeking to answer the following two questions:

1. What is the nature of existing data exchange?
2. How prepared are we for global data exchange?

3.3.2 A summary table template was prepared and used to summarize the known status of international data exchange for each region, where possible. The results are provided as Annex V.

3.3.3 **Recommendation**: It was suggested that these tables could be circulated and used both to complete the global picture and to update it periodically when new data exchange is

initiated somewhere. The OPERA data exchange matrix could also be used in each region to provide more detail. A link between this kind of information and that available in the WMO Radar Database could also be explored.

3.3.4 It was noted that exchange between regions was also occurring. NCEP's stage IV surface rain composites over the US were being received by the ECMWF and assimilated into the ECMWF global model. The Caribbean Radar Project in RA IV includes radar data from French Guiana in RA III. Data exchange is also being pursued between regions II and IV under the umbrella of ASEAN.

3.3.5 A few important issues related to data exchange mechanisms were also raised and discussed

- To improve network load balancing in domestic data transmission, data transfer from site to center can be conducted on a ray-by-ray basis.
- A standard file format is required for managing polarimetric data, and it is vital that this standard is adhered to.
- Data and products should be defined by levels for the purposes of exchange.
- WMO experts should define standardized and harmonized quality control methods, some of which are then applied by Radar Operators prior to data exchange, and others of which can be applied to all collected data centrally.

3.3.6 In summary, national and regional weather radar networks have developed relatively recently; coverage over land is becoming more complete although there are still large gaps. Polarimetric radar technology is being phased into national networks globally. Holistic quality control chains are emerging in some places but they are still in their infancy. Harmonized data representation has been proven possible in a large heterogeneous network (ODIM).

4 REVIEW OF THE DATA MODELS USED FOR WEATHER RADAR DATA EXCHANGE

4.1 A critique of the existing data models used for weather radar data exchange presented in item 3.1

4.1.1 Four components to the concept "data exchange model" were identified:

1. File format – container for storing data in physical files.
2. Data/information model – the way in which information is organized/represented, either in computer memory or files, independently of file format.
3. Envelope – extra header announcing/describing the contents of the information being exchanged.
4. Protocol – mechanisms for communication over a network.

4.1.2 In the workshop documentation, the term "data model" has been referred to several times, yet this term seems to have been used ambiguously, thereby prompting the clarification. The first point, file format, can have several categories, among them:

- Transmission – to facilitate data transfer from site to central facility. Can be optimized for network load balancing, e.g. ray-by-ray.

- Production – contains all data and metadata required to derive higher-order outputs (e.g. quality-controlled data, products) from input data.

- Exchange – representation of data or product for sharing but not necessarily further processing, e.g. a radar composite or vertical profile.

- Archive – e.g. to represent data from many different observation systems for storage.

4.1.3 When it comes to data exchange concepts, two main categories were identified:

1. Passive – Sender/recipient are aware of each other but transact indirectly, e.g. data is "pushed" and availability is determined by directory polling or file-system event monitoring. The GTS was given as an example of such a mechanism.

2. Active – Sender/recipient are aware of each other and interact/transact directly. BALTRAD communications were given as an example.

4.1.4 Regarding the question of whether the GTS was suitable for supporting radar data exchange, experience from EUMETNET OPERA indicates that the GTS' hierarchical structure causes delays which can be overcome if communications are conducted peer-to-peer (from source directly to destination).

4.1.5 Positive and negative characteristics were given for several file formats being used for weather radar data: GRIB, TITAN, BUFR, HDF5, and netCDF-4.

4.1.6 In summary, terminology surrounding data exchange needs to be clarified. No orthodox information model as such is currently in use; there are tight connections between information model and file format. This is not necessarily a disadvantage, as good solutions exist.

Use of BUFR for Exchange of Weather Radar Data

4.1.7 The Workshop discussed the experience of OPERA in the use of BUFR for radar data exchange and Mr Thomas Hohmann, Germany agreed to provide some information on the issues and options associated with this aspect of data exchange. This information is provided within Annex VI.

On the Requirement for ODIM_H5 use in OPERA

4.1.8 ODIM_H5 originates from the realization within EUMETNET OPERA that a modern alternative file format to BUFR was necessary to support weather radar data exchange. During OPERA's second phase (2004-2006) a work package was formulated and carried out with the objective to find such a modern alternative. The result was that HDF5 was recommended, and this format was subsequently approved by EUMETNET Council. HDF5 as such was already being used for several years operationally in real time in the international NORDRAD network (Nordic countries). Following the approval to use HDF5 at the European level, the term OPERA Data Information Model (ODIM) was adopted to represent the two approved data exchange formats, HDF5 (ODIM_H5) and BUFR (ODIM_BUFR) that are used in OPERA.

4.1.9 Today ODIM_H5 is the version that drives development of ODIM. As ODIM evolves, additions and improvements are available first in ODIM_H5 before they are replicated in ODIM_BUFR.

4.1.10 Considering the relatively short time ODIM_H5 has existed (2009), its proliferation has become remarkably successful. This can be attributed to several factors:

- an intuitive, flexible and powerful information model,
- high-performance, well-documented and well-maintained code base in the HDF5 software,
- relative ease in writing and using software employing HDF5 to read/write data,
- the availability of conversion software both in commercial systems and freely shared by the community,
- suitability for use internally as a production format, as is done by several NMHSes and other organizations.

4.1.11 As of February 2013, 17 of 20 countries provide their data to the Odyssey centres using ODIM_H5; the countries using ODIM_BUFR do so for intermediate conversion only and not for any in-house use. At Odyssey, the BALTRAD toolbox harmonizes all input polar data to ODIM_H5 as part of quality control prior to generating European composites. Products generated by Odyssey are distributed to 19 recipients, ten using ODIM_H5 only and four in both ODIM_H5 and ODIM_BUFR. ODIM_H5 has also been favourably accepted outside Europe.

4.1.12 At the start of the fourth phase of OPERA earlier this year, the question has been raised regarding whether to support ODIM_BUFR at all following the phase's completion (after 2017), or if support should be limited, e.g. to wind profile products.

4.1.13 **Recommendation**: While it is recognized that BUFR is a standard for which the official use is governed by the WMO and that HDF5 is endorsed but not yet governed by the WMO, it is recommended that WMO and CBS consider adopting ODIM_H5 as a WMO standard for representation of radar data.

4.2 A review of other data models that could be adopted for use for weather radar data exchange

4.2.1 This item was considered to be a "sanity check", in other words a chance to determine whether there are any other file formats in use that could potentially offer a better solution to those already being used. Initially, it was once again found that the use of the term "data model" was being used ambiguously, and that it was therefore necessary to distinguish "information model" and "file format".

4.2.2 The meaning of "other" was also defined. Considering that CBS-XIV (2009) endorsed the use of "BUFR, CREX, XML, netCDF, HDF, including BUFR/CREX/GRIB tables", the use of "other" could, in principle, mean any other file format. TITAN was given as an example of a system that uses several of its own well-established formats that can be considered "other".

4.2.3 In identifying potential information models, the METCE model, "Modèle pour l'Échange de Temps, Climate et Eau" (Model for the Exchange of Weather, Climate and Water), or alternatively, the METeorological Community Exchange model, could potentially offer a vehicle for creating a truly orthodox information model that could then be used to create

one or more representations using endorsed file formats. It was acknowledged that representing radar data involves a higher degree of complexity compared to aviation messages that have been addressed in METCE.

4.2.4 **Recommendation:** A WMO Task Team established to investigate and implement a weather radar data model should consider elaboration of METCE to accommodate weather radar data and represent them using ODIM as a starting point.

4.2.5 Several "other" file formats were identified (GML, XML, GeoTIFF, PNG, GIF, Proprietary/industrial, in-house, McIdas, CSV), and their advantages and disadvantages were discussed.

5 REVIEW OF CONSTRAINTS TO INCREASED WEATHER RADAR DATA EXCHANGE

5.1 Options for overcoming the constraints as presented in item 3.1 docs

5.1.1 The regional reports provided to the Workshop under Item 3 were analyzed and summarized in relation to the exchange of raw radar data (polar coordinate).

5.1.2 The challenges or barriers were identified as:

(i) Vision/clarity of what to exchange (full vs partial volume scans), raw data vs products, full versus exchange metadata, real-time versus for reanalysis;

(ii) Telecommunications capacity and mechanisms (push/pull), frequency of real-time exchange;

(iii) Technical capacity (format conversion, implementation ability);

(iv) Data policy; and,

(v) Sustainability (including data format ownership, change management, technical support and responsiveness).

5.1.3 None of these constraints are considered insurmountable, although the most challenging and most likely to prevent progress was considered to be that of data policy and proprietary (iv). However, the Workshop recognized that WMO has a long-standing Resolution (40) pertaining to the exchange of weather data that might be emphasized, enhanced or extended to alleviate concerns and mitigate the associated risk.

5.1.4 It was agree that the other barriers can be overcome through application of the following strategies or approaches:

(i) The vision, aims and objectives for weather radar data exchange should be clearly articulated;

(ii) The telecommunications barrier is mainly and most significantly a resource and cost issue, which, while presenting difficulties in some instances, particularly for those Members from developing countries, does not constitute a technical obstacle. While satellite communications technology may be expensive, it does at least provide a potential global solution. Costs can also be alleviated through the use of alternative communications strategies, such as that of data providers making data available to be "pulled" to data users at their costs rather than "pushed" at the cost of the provider;

(iii) In line with the proposed mitigation in (i), it is expected that an internationally standardized exchange format would be widely and internationally recognised and adopted in the fullness of time, as manufacturers will be requested to provide the WMO format as part of radar system procurements. This will promote consistency and efficiency. However, exchange of native formats should not be discouraged if members cannot produce the WMO standard, even though exchange in the WMO data format would be much preferred;

(iv) The data policy issue may be mitigated through potential strengthening or extension of WMO Resolution 40 combined with negotiation, mutual benefit and sponsorship but it must be recognized as a signifcant issue

(v) Use of WMO authority and standardization mechanisms to ensure development, adoption and support by WMO Members and radar operators of the appropriate data model. It was also highly recommended by the Workshop that WMO should be willing to consider the adoption and standardization of modern alternative data formats (e.g. HDF5 and netCDF) in addition or alternatively to BUFR to promote the research use and development of the global radar data.

A related issue to successful exchange of data and satisfying the requirements of data users for provision of a reliable and continuous data product is the operations and maintenance of the radars in the network. This necessarily includes other critical aspects such as the monitoring of the systems and the reliable management of critical radar parts.

A critical issue is the emerging dual-polarization technology and its exchange, and the need for quality information in the data model. The initial goal of exchanging reflectivity and radial velocity will be obsolete very shortly as this is rapidly changing. A change mechanism and technical support is critically important otherwise other formats will profliferate and make the WMO format obsolete.

5.2 Practical experiences of other global and regional observing system operators in overcoming data exchange constraints

5.2.1 Examples of the computing and telecommunications (ICT) strategies of several scientific organizations were considered. In all cases, a compromise had been reached between making all possible information available to all users and the cost and technical feasibility of the ICT systems needed to deliver and process the data. CERN, for example, processes data as they are generated by the particle colliders so that only a reduced data stream is sent to the central computers for storage and further processing. Even this reduced set of data is processed further before being distributed to users, although it is archived so that it can be used for more detailed studies.

5.2.2 The Workshop acknowledged that there may be some cases where it is not possible to follow a standard pattern for exchanging date, but that the group should work on the assumption of the following design for global exchange of radar data. Information from individual radars should be collected and processed by the operators of the radar network (usually national centres) to create an agreed set of outputs (data in exchange format plus products – in a format TBD, note some products are already defined in WMO BUFR format). Collated data from several radar networks should then be further processed by a collection centre (usually responsible for a geographical area) to form a consistent set of information. The output (data in exchange format and products) from these collection centres would then be exchanged globally. This approach limits the volume of information to be exchanged globally (that is, the data is optionally exchanged), and also reduces the complexity of the processing required by the users of global information.

5.3 Understanding the technical Information Systems constraints

5.3.1 In the context of the WMO Information System, the creation of consistent data for a network would be the task of a National Centre. The collection centres would be Data Collation, Product Creation or Collection Centres, and these would pass the data and products to the GISCs to manage the global exchange.

5.3.2 Successful global exchange of radar information depends on clear definitions of what information (data, metadata or product) has to be exchanged. The information content is described through a "data model," and it is the data model that specified which physical parameters have to be contained and the supporting information (observation metadata) that is needed to allow them (the data and products) to be interpreted correctly. Provided that the correct data model is used, it is possible to exchange the same information in different formats (for example BUFR, GRIB or HDF5) for different application areas – and to convert between formats.

5.3.3 Defining a standard data model for exchange of radar information (data, metadata and products) between collection centres is a high priority task.

5.4 Recommendations for improved Weather Radar data exchange

5.4.1 It was recommended by the Workshop participants that a Task Team is formed, possibly under the direction of CBS ET-SBO and charged with the responsibility of addressing a requirement for the development of a global standard for representing weather radar data in support of global data exchange.

5.4.2 An initial proposal for the terms of reference for such a task team is provided within Annex VII for consideration by ET-SBO, OPAG-IOS and CBS as appropriate.

5.4.3 The task team should recognize and take into consideration the considerable progress achieved by EUMETNET OPERA in harmonizing operationally exchanged real-time weather radar data with the OPERA Data Information Model (ODIM) and it is recommended that the Task Team should utilize this data model as the basis and starting point for the development and finalization of a WMO standard for global radar data exchange.

5.4.4 The task team should contain appropriate representatives from Regional Associations, weather radar experts, communications experts, and data model experts. Participation of representatives from other WMO bodies, such as ET-CTS and IPEG-DRMM, is also desirable. WMO and CBS should also ensure that relevant observing systems operators, manufacturers and applications and data user communities are informed of the task team's role and outputs.

6 RECOMMEND DATA MODELS AND EXCHANGE PROTOCOLS TO BE ADOPTED BY WMO FOR WEATHER RADAR DATA EXCHANGE

6.1 Synthesis of recommendations and selected options identified at workshop that will be presented to WMO, through appropriate mechanisms, for adoption.

6.1.1 A summary of all recommendations made at the Workshop are provided within Annex IX.

7 RECOMMEND PILOT STUDY CASES FOR REGIONAL AND GLOBAL WEATHER RADAR DATA EXCHANGE

7.1 Workshop members to propose pilot projects to facilitate the goal of the EGOS-IP Action item being delivered

Radar Data Exchange Requirement between Regional Centres

7.1.1 There is already both a requirement and solutions in place for supporting real-time radar data exchange between countries, for example OPERA and BALTRAD have established regional radar data exchange centres for this purpose. During the workshop, establishment of new regional radar data exchange centres was discussed and several proposals for the establishment of pilot projects to advance radar data exchange in several Regions were agreed.

7.1.2 An extension of the arrangement for a centralized data processing center supporting a Region or an international area within a Region, would be for these centers to be able to exchange data and/or products between them.

7.1.3 **Recommendation**: It was proposed that a pilot project should be established to work towards the definition and implementation of data exchange protocols between Region II (TMS) and Region VI (ODYSSEY) with the concept to perhaps first be tested with the exchange of composite products. This project should be overseen by the CBS ET-SBO.

Pilot Project for Region V

7.1.4 The Workshop agreed with representatives of Regions II and V to recommend the establishment of a pilot project for exchange of weather radar data among ASEAN members under the ASEAN ASMB. A draft proposal was developed by Mr Kamiluddin in consultation with Mr Adriyanto and is provided within Annex VIII.

Pilot Project for Region III

7.1.5 Given the current interest with Brazil and other countries in Region III in the national an international integration of radar networks, the Workshop agreed with representatives of Regions III to recommend the establishment of a Pilot Project for exchange of weather radar data among Region III Members and that this is considered and progressed through coordination by CBS/ET-SBO.

8 ANY OTHER BUSINESS

No other business was formally raised.

9 CLOSE OF MEETING

The Chair thanked all participants for their contributions to the Workshop, which was formally closed around midday of 26 April, 2013.

ANNEX I

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ANNEX II

AIMS, OBJECTIVES AND DELIVERABLES FOR A WORKSHOP ON THE REGIONAL AND GLOBAL EXCHANGE OF WEATHER RADAR DATA

1. Introduction

The conclusions and recommendations of the Fourth WMO Workshop on the impact of various observing systems on Numerical Weather Predictions identified the global exchange of Weather Radar radial winds and reflectivity data as a high priority. This need is also reflected in action G45 of the new EGOS-IP. To contribute to the delivery of this EGOS-IP action a Workshop on Weather Radar data exchange is proposed.

2. Workshop Definition

Title: Workshop on the regional and global exchange of weather radar data

1) Scope

Noting the range of Weather Radar data types and products, the scope of the workshop will be limited to the exchange of Doppler radial wind and reflectivity data types.

2) Aims:

a) Define weather radar data to be exchanged at regional and global levels;
b) Propose formats and frequency of exchange of those data; and;
c) Agree the next steps needed to enable the regional and global exchange of these data.

3) Workshop Objectives:

a) Review the current and likely future requirements for regional and global weather radar data exchange, period of consideration 2012 to 2025;

b) Review the current extent and operational status of regional and global data exchange being undertaken;

c) Review the current regional and global data exchange models in operation;

d) Review alternative regional and global data exchange models in operation in other observing system areas;

e) Improve community understanding of the range of Weather Radar Network operators and their respective relationships with WMO Members;

f) Identify current and likely future constraints on regional and global data exchange from Weather Radar Network operators. Areas of constraint could include: Data Ownership; Data Policy; Data Volumes; Data Quality;

g) Recommend data model(s) for regional and global weather radar data exchange based on an improved understanding of requirements, capabilities and constraints;

h) Recommend pilot study cases for regional and global weather radar data exchange using recommended data model(s) to demonstrate how constraints could be overcome.

4) Workshop Deliverables:

a) A consolidated set of current and future data requirements for the regional and global weather radar data exchange;

b) A recommended set of data models to be used for Weather Radar Data Exchange;

c) A plan for a pilot study/studies to demonstrate the methodology for sustained operational regional and global data exchange;

d) A series of next steps actions to facilitate the regional and global exchange of Weather Radar Data.

5) Workshop Participant Areas

Global NWP Centre Representative(s)

Regional NWP Centre Representative(s)

Climate Monitoring Community Representative(s)

Chy Representative

CIMO RQQI Project Representative

THORPEX Representative

RA Representatives and Members where Wx Radar Data Exchange between members is currently occurring, there is ambition for exchange to begin and where no plans are currently in place

WMO Weather Radar Metadata Database Representative

EUMETNET OPERA Representative

BALTRAD Representative

WMO WIS Representative

CBS/ISS/ET-DRC Representative

Satellite data exchange service provider(s)

Other significant data exchange community representatives

HMEI representative(s)

Copy of action G48 of the new EGOS-IP (Ver13.06):

Action G48

Action*: Define weather radar data to be exchanged at regional and global levels, propose frequency of exchange of those data and develop a weather radar data processing framework, in concert with development of products based on national, regional, global requirements.*

Who*: CBS (leading the action), CIMO, Chy in coordination with NMSs/NMHSs, agencies operating weather radars, in collaboration with Ras.*

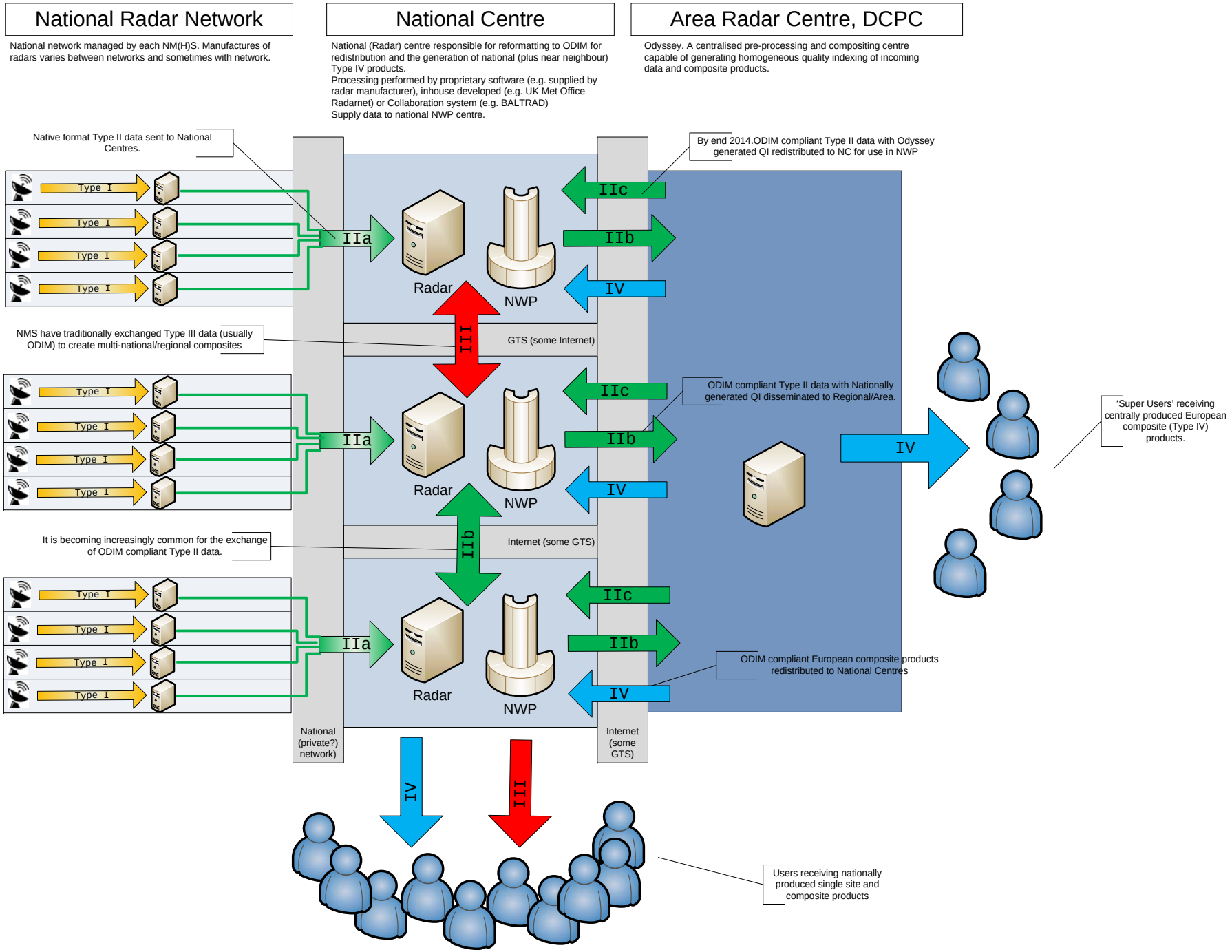
Time-frame: *Continuous.*

Performance indicator*: Volume of radar data which are exchanged globally and regionally.*

Annex III

Summary of Requirements for Radar Data & Radar Data Exchange

Data User Area	Parameter/Field	Requirement Category	Requirement	Comment
NWP - Global	ECMWF currently assimilating GRIB precipitation composites but expect to require raw volumetric data in future	Horizontal resolution Cycle Latency	2 km^2 possibly later inc. to 1 km^2 15 min 15 to 30 min	Requirements may currently vary between NWP centers but there is an expectation that raw volumetric data will become the future standard requirement.
NWP – High resolution	raw volumetric data (Meteo-France	Horizontal resolution Cycle Latency	2 km^2 possibly later inc. to 1 km^2 1 hour 15 to 30 min	
Hydrology	Quantitative Precipitation Estimate	Horizontal resolution Cycle Latency		Access to long-term high quality archived precipitation data is critical to many hydrological applications.
Climate	Quantitative Precipitation Estimate	Horizontal resolution Cycle Latency	1 km^2 possibly later inc. to 0.250 km^2 1 hour possibly later inc. to 5 min. 48 hrs	Access to long-term high quality archived data is critical for climate applications.


National Radar Network
National network managed by each NM(H)S. Manufactures of radars varies between networks and sometimes with network.
National Centre
National (Radar) centre responsible for reformatting to ODIM for redistribution and the generation of national (plus near neighbour) Type IV products.
Processing performed by proprietary software (e.g. supplied by radar manufacturer), inhouse developed (e.g. UK Met Office Radarnet) or Collaboration system (e.g. BALTRAD)
Supply data to national NWP centre.
Area Radar Centre, DCPC
Odyssey. A centralised pre-processing and compositing centre capable of generating homogeneous quality indexing of incoming data and composite products.
Native format Type II data sent to National Centres.
By end 2014.ODIM compliant Type II data with Odyssey generated QI redistributed to NC for use in NWP
Type I
IIa
IIc
IIb
IV
Radar
NWP
III
GTS (some Internet)
NMS have traditionally exchanged Type III data (usually ODIM) to create multi-national/regional composites
ODIM compliant Type II data with Nationally generated QI disseminated to Regional/Area.
'Super Users' receiving centrally produced European composite (Type IV) products.
It is becoming increasingly common for the exchange of ODIM compliant Type II data.
Internet (some GTS)
ODIM compliant European composite products redistributed to National Centres
National (private?) network)
Internet (some GTS)
Users receiving nationally produced single site and composite products

Annex V

Summary of Status of Radar Data Exchange by Regions

Table 1. RA I – Africa.

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
BW, MZ, ZA	Z in	Regional composites out	TITAN	TITAN	MoU Centralized

Table 2. RA II – Asia

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
CN – HK	Z, V, W	Composite	Polar: WSR-88D Composite: ?	WIS using “MSTP special line”	Bilateral Guangdong – HK. Centralized compositing.
CN – MO					
CN – KR		5 products	GIF	Special ”GTS” line	Bilateral
CN –> KP		“several”			Bilateral, one-way
CN – TW		Composites			To be considered

Table 3. RA III – South America

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
BR-PY					

Table 4. RA IV – North and Central America, Caribbean

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
CA – US			"native" CA: IRIS US: L2, L3, L4	GTS FTP – pull	Bilateral
AN – SX			AN: IRIS		
CU – US		Composite	US L4	Push	To NWS (Hurricane Center)
BB, BZ, GF, TT (more?)			BUFR	Planned	EC Caribbean radar project – multilateral MoU
BS, CU, PR ?		(On BS website)			

Table 5. RA V – Southwest Pacific

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
AU – NZ	yes	yes	“raw” “graphics”		Bilateral
MY – SG			BUFR		Bilateral

Table VI – Europe

WHERE?	WHAT?		HOW?		
Countries	**Polar**	**Products**	**Format**	**Comms**	**Agreement**
BE, CZ, DE, DK, EE, ES, FI, FR, HR, IE, IS, NL, NO, PL, PT, RO, RS, SE, SI, SK, UK …	Z, V	Z composite R composite RR-1hr composite	ODIM_H5 ODIM_BUFR	FTP GTS	EUMETNET OPERA – centralized through "Odyssey"
AT, CH, CZ, DE, HR, PL, SI, SK		Z CAPPIs in Z composites out	BUFR	GTS	CERAD – centralized
		Vertical wind profiles	BUFR	GTS	EUMETNET CWINDE
DK, EE, FI, LV, NO, SE		Z Pseudo-CAPPI Vertical wind profiles	HDF5 – COST 717 model	NORDRAD – "persistent HTTP", XML headers, "notify-pull"	NORDRAD Cooperation Agreement: multilateral, decentralized
BY, DK, DE, EE, FI, LT, LV, NO, PL, SE, UA	T, Z, V, W Dual-pol moments		ODIM_H5	BALTRAD – HTTP, own HTML headers, "subscribe-push", WIS connectivity	BALTRAD Cooperation Agreement: multilateral, decentralized

Annex VI

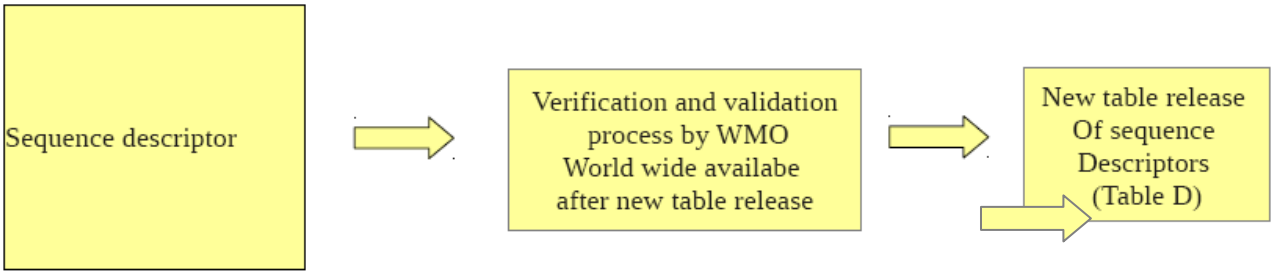
Considerations concerning BUFR encoding, by Thomas Hohmann, DWD, Germany

Comparison of different approaches

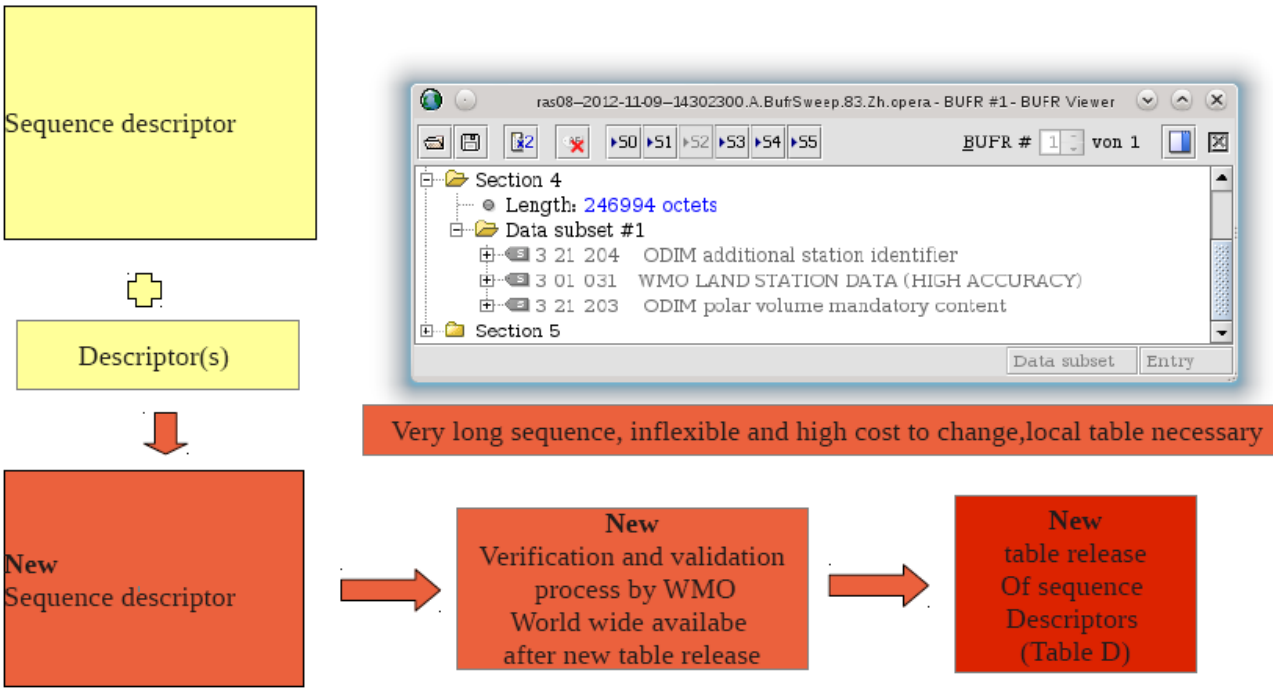
Case A : whole product described by defining only one sequence descriptor

Case B: product described by list of sequence descriptors and single descriptors

Case A : One product – one sequence descriptor



Change, enhancement or correction of product description

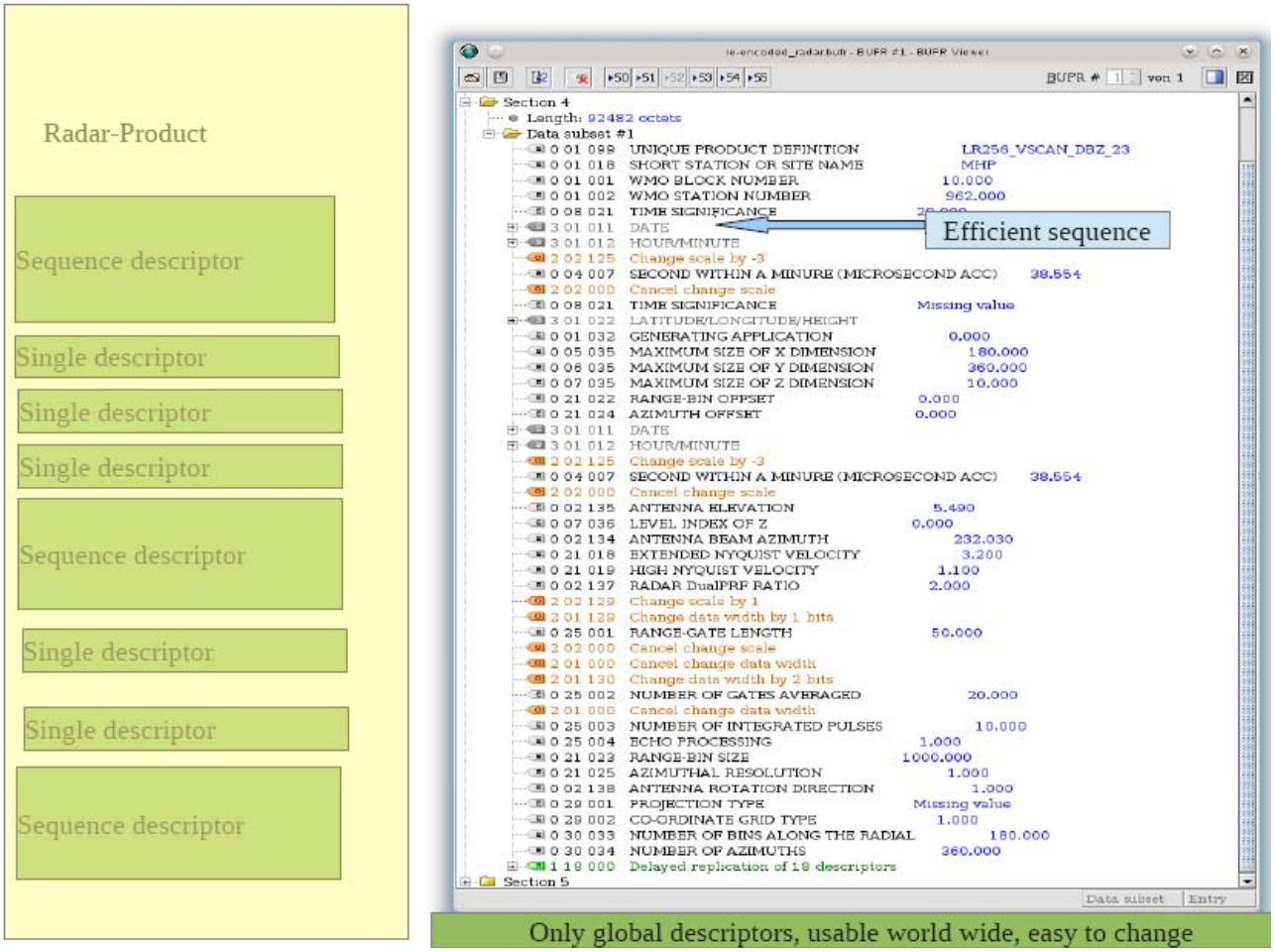


Disadvantages :

1. sequence must go through verification and validation process before world wide usable
2. even smallest changes in the product (meta data) require a whole new validation process
3. Table D grows up radpidly containing a lot of unused (old) sequences

Case B : product described by list of sequence descriptors and single descriptors

Radar-Product



Disadvantage :

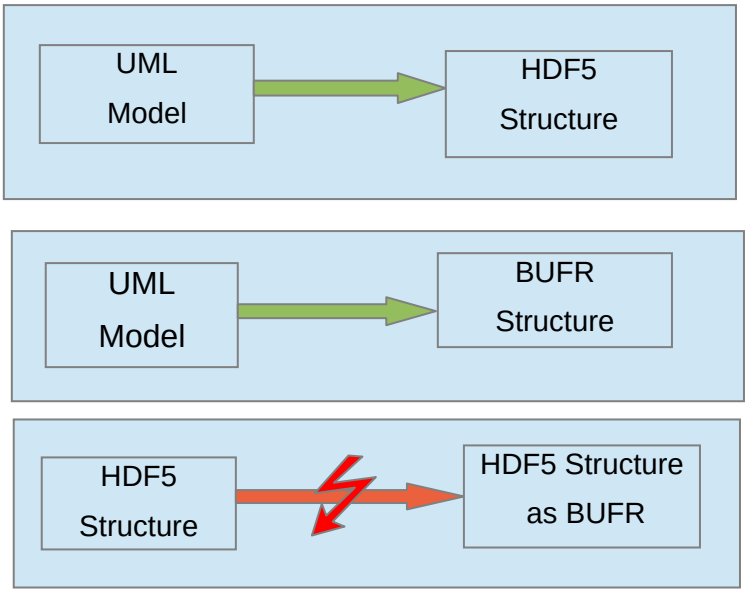
1. product structure not exactly known for reader/import

Advantages :

1 no validation process necessary , when only operational descriptors/sequence descriptors are used
2 changes are immidiatly readable world wide without any validation process or notification
3 no accumulation of unused sequences in Table D

Requirements for generic BUFR reader/parser/import :

- there is a list (not a seuquence) of mandatory items(descriptors) for every product
- there may be optional items(descriptors) anywhere in the product
- reader/parser/import **do not use** any positional information of descriptors in the list for decoding or mapping
- optional items may be skipped/discarded by the reader/parser/import
- data (sweeps, volume) is coded as data and not treated as an (pseudo)image
- concerning different codings(BUFR,GRIB2,HDF5), the same data model must be mapped, but not the same structure is necessary (e.g. no HDF5-clone as BUFR)



- mandatory items are mapped to the users internal data model; if any mandatory item is missing, the product is rejected

Generic mapping : (m):mandatory, (o):optional

coded Product		internal user structure
Item A (m)	mapped to	Internal user Item A
Item B (o)	discarded	Internal user Item B
Item C (m)	mapped to	Internal user Item C
Item D (m)	mapped to	Internal user Item D
Item E (m)	mapped to	Internal user Item E
…..	mapped to	Internal user Item F
Item K (m)	mapped to	End of internal user structure
Item L (o)	discarded	
Item M (m)	mapped to	

ANNEX VII

PROPOSED TERMS OF REFERENCE FOR A WMO CBS TASK TEAM ON WEATHER RADAR DATA EXCHANGE

1. Gather requirements for information (data, metadata and products) from weather radars to be exchanged globally on a regular basis.
2. Develop a data model based on the requirements and, if feasible, harmonized with the existing and future development of METCE.
3. Identify and recommend appropriate data formats for operational and scientific exchange.
4. Express the data model using approved data format(s), taking into account the considerable progress achieved by EUMETNET OPERA in harmonizing operationally exchanged real-time weather radar data with the OPERA Data Information Model (ODIM).
5. Coordinate with IPET-MDRD and IPET-DRMM to ensure that the data model and data representations are consistent and compatible with WMO standards and practices.
6. Make recommendations on requirements for documentation and training materials to support WMO Members in the application and use of the data model and data representations to be used for the global exchange of weather radar information to support NWP and climate activities.
7. Using ODIM_BUFR as a basis, develop, review and coordinate approval of required BUFR sequences for global exchange of radar data on the GTS.
8. Elaborate compliance between ODIM_H5 and netCDF CF Conventions, especially regarding GIS compatibility.

Annex VIII

PILOT PROJECT FOR EXCHANGE WEATHER RADAR DATA AMONG ASEAN UNDER ASCMG (RA II & RA V)

1. Background

Most of ASEAN member countries are experiencing weather associated with maritime. Severe weather over the coastal region around the countries greatly affect the livelihood of residents at the coastal region. Monitoring weather condition by the meteorologists requires various inputs. One of the important input is the weather radar imageries. However in the present scenario, the radar imageries available in the ASEAN member countries are more of localize within the nation weather condition rather than regionally . Currently the ranges covered by the radar images are bound to the geographical boundary of each nation individually. Radar imageries of weather condition around the border regions from the neighbouring countries among ASEAN member countries are not accessible. This defeat the purpose of cooperation in sharing of information among the ASEAN neighbour nations for the mutual benefits of the people in the region.

Problems Analysis And Justification

Owing to the close proximity of ASEAN member countries, they shall be able to rely upon on the radar imageries of the other member countries in the event that the radar stations of the respective country breakdown due to technical problems. For instance, in the case of Brunei or Singapore Radar Station breakdown, Miri Radar Station or Kluang Radar Station in Malaysia respectively shall be able to provide the radar imageries to them and vice versa. These three countries are just close neighbours next to each other. Consequently they could share and optimizing utilize the common resources available in the region. Hence the close cooperation of sharing radar data or imageries will directly enhance the quality of close monitoring and forecasting of weather around the region by the meteorologists.

In the borderless world, the norm of sharing the information such as the radar data or imageries are out of necessity in order to further enhance the quality of weather products generated to serve the people regionally. Economic activities around the region such as aviation, oil and gas exploration, marine tourism industries will benefit tremendously from the value added weather products generated from meteorological offices from ASEAN member countries. The impact of weather adversities towards the livelihood of people will be greatly mitigated with any advancing bad weather information disseminate to them before its arrival.

2. Possible Solutions

The ASEAN members countries are supposed to cooperate and ensure their radar data and imageries are of good quality which consist of reflectivity and doppler wind parameter. The radar stations of the member countries are routinely well maintained which regularly generate radar data and imageries. These radar data shall be able to convert to common universal format which subsequently transmit to their own National Central Collecting Centre which is then relay their national radar data to the Central Collecting Centre located at MMD, Malaysia. Network of

communication between the radar stations in the member countries shall be efficient and reliable to ensure the smooth flow of radar data transfer. Likewise good and efficient communication between member countries is a priority. A team of technical staff shall be assigned and acts as contact point to coordinate and assist in exchange of data transfer. They will undertake the responsibility to ensure the quality and format of radar are of the standard common format. Initially the frequency of transmitting is limited to an interval of every 20 minutes. MMD shall collect all the data and composite them to present or display them as a composite radar image for the region. Each and every ASEAN member country will then be able to access the composite radar imageries of ASEAN region on regular interval updated basis. Whereas the radar doppler wind data shall be useful and used as an input to Numerical Weather Prediction Model. These radar data will be available on –line for any of the member countries to access.

3. Objectives and Success Criteria

(a) Objectives

The objectives of this project are :-

(i) To provide as a backup of radar images to the neighbouring countries in the event the specific radars of the neighbouring countries breakdown.

ii) To share ASEAN region composite radar images on near real time.

(iii) To assist and enhance the quality of radar imageries of every member countries in ASEAN by constantly identify common technical and quality issues among member countries.

(iv) To improve NWP model forecast among ASEAN members

(b) Success Criteria

This project will be considered a success if the following criteria are met :-

(i) All member countries succeed in access on the web the composite radar images of ASEAN region.

(ii) Enhanced capacity to issue better quality and effective weather nowcasting resulted from good network of regional radar images as an important input component.

(iii) Enhanced knowledge and skill of managing individual national network of radars independently in order to cater for the demand of good quality radar products regionally.

(iv) Enhanced quality of NWP forecast especially in tropical countries.

4. Outputs

(i) All member countries shall be able to manage their own network of radars efficiently and generate their good quality radar data into BUFR format and transmit to Central Collecting Centre.

(ii) Composite regional radar imageries are available on the web to be accessed by all member countries regularly.

(iii) Data bank consists of radar images and radar data for ASEAN region.

(iv) Regional doppler wind data will be available for the numerical weather prediction model of the member countries.

5. Indicative Work Plan

Year	2013	2014	2015	2016	2017
Draft plan/approval	/				
Pre implementation groundwork		/			
Initial implementation			/		
Full Implementaion				/	
Commision & Evaluate Project					/

The proposed work plan shall be carried out in the time span of 5 years.

- The first year -

  (i)Prepare the proposal and obtain the endorsement of all ASEAN members at SCMG.

- The second year –

(i) Once the proposal approved, initial ground work on creating the base map and collecting samples of radar data from Singapore, Thailand, Brunei and Indonesia radar data to integrate on preliminary stage.

(ii) Preparation to acquire the server, software applications and other peripherals which are the prerequisite for setting up the Regional Collecting Centre (RCC) for collecting, processing, compositing, archiving, disseminating or web base accessing of the composite

radar images. Acquisition of computer hardware and software application may require some technical experts advice and technical assistance from local private sector in processing and composition the radar data.

- The third year -

(i) Coordinate with all other members of ASEAN technical team to convert their radar data into BUFR format and transmit them to RCC on real time basis.

(ii) Transition period to smoothen any hitch when each country is trying to manage their radar data for disseminating to RCC in the common universal standard format BUFR.

- The fourth year –

(i) Mutual technical assistance from member countries to each other for full implementation.

(ii) Satisfactory cooperation from various member countries to implement the project successfully by disseminating the radar data and accessing the web site for regional composite radar imageries on near real time basis.

- The fifth year –

(i) Commission the project , prepare and submit the evaluating report.

6. Inputs

Personnel - Each country shall identify and appoint a specific contact person to act as an intermediary to coordinate and responsible to pool their radar data and disseminate the radar data to RCC.

Equipment – Each country will identify their own requirements to support the operation of pooling all their own national radar data and transmit to RCC.

7. Budget and funding arrangement

Budget and funding arrangement for the following phases of project :-

- The second year - The cost for the acquisition of servers and other peripherals which support the project at MMD would be borne by Malaysia.

- The fourth year – The accommodation and travel expenses for member states to send their technical personnel to assist other member states would be borne by their own countries.

ANNEX IX

RECOMMENDATIONS OF THE WORKSHOP

No.	Report Section	Recommendation	Responsibility	Action
1	2.1	The current requirements statements in OSCAR to be reviewed and if necessary updated in light of information provided to Workshop.	ET-SBO	Chair to discuss with Chair IPET-OSDE & WMO Sec best way to update entries in OSCAR based on Workshop Rep findings.
2	2.2	It was recommended that CBS (via ET-SBO) should investigate the possibility of forming a similar body for weather radar observations and NWP applications to that servicing the Satellite community for products and data processing requirements	CBS, ET-SBO, CIMO	Chair of ET-SBO to address through OPAG-IOS and CBS; Require consultation with CIMO and the team on RQQI and GCOS.
3	2.4	CBS (via ET-SBO) should investigate the possibility of forming a body for weather radar observations similar to EUMETSAT CAF or SAF's that should also explore the climatological uses of radar data and elaborate further recommendations to that end. These should encompass: 1. Quality control indicators as an integral part of the available radar precipitation data; 2. Development of consistent radar precipitation databases for use in hydro-climatological studies 3. Global proliferation of the understanding with all radar operating NMHSs that there is a use for raw (L2) data beyond the real-time applications demanding for their permanent storage.	CBS, ET-SBO	1. As for Recommendation 1, ET-SBO to consult with relevant stakeholders. 2. ET-SBO and proposed Task Team to ensure QC indicators included in data model. 3. ET-SBO to consider action required on archival of radar data for climate and hydrological requirements.
4	2.4	CBS (via ET-SBO) is invited to determine a proper mechanism to involve GCOS into the process and the future activities on the issue of global and regional exchange of radar data. It is also invited to take advantage of GOCS experience in setting and documenting standards for Essential Climate Variables (ECVs) like precipitation.	CBS, ET-SBO	Chair of ET-SBO to address through ET-SBO and IPET-OSDE

No.	Report Section	Recommendation	Responsibility	Action
5	3.1.2	Standardised exchange models for weather radar data will need to take into account latency requirements for both now-casting and other applications with less stringent requirements on transmission frequency. In order to improve the timeliness of radar data exchange for high frequency data exchange, it was recommended that data transmission should be done by using streaming data techniques, which means “uploading while scanning”.	CBS, ET-SBO	ET-SBO to ensure this recommendation is considered and addressed by the team tasked with developing the data model. Note: This is likely really an internal radar to radar processing centre issue and not a regional or global exchange issue.
6	3.1.2	With respect to future radar technology developments, e.g., dual-polarization technique, consideration should be made for the exchange of this data.	CBS, ET-SBO	ET-SBO to ensure this recommendation is addressed in by the team tasked with developing the data model.
7	3.1.2	To ensure the accuracy of radar data, it was recommended that WMO organize experts to develop standardised quality control and calibration schemes that are able to take into account the different radar systems in operation in different countries.	CBS, ET-SBO	As for recommendation 1.
8	3.1.2	Envisaging that data policy issues may be a significant limiting factor and that some agreements may initially allow the exchange of radar products only, consideration should be given to the comprehensive exchange of these product format and quality standards, as well.	CBS, ET-SBO	ET-SBO to ensure this recommendation is addressed in by the team tasked with developing the data model.
9	3.1.6	The long-standing operation of regional and international data exchange mechanisms within RA VI provide examples of working data models and existing data formats that should be considered by CBS as a basis for global standardization.	CBS, ET-SBO	ET-SBO to ensure this recommendation is addressed in by the team tasked with developing the data model.
10	3.1.6	Further investigation into radar data exchange arrangements and agreements outside of the EUMETNET domain should be undertaken.	CBS, ET-SBO	Chair ET-SBO to incorporate this activity into Work Plan of ET-SBO.

No.	Report Section	Recommendation	Responsibility	Action
11	3.2	Consideration should be given to adding the following features to the WRD: • The metadata should be modified so as to enable the maintenance of a historical record of radar metadata; for example, the database would establish periods of time for which particular site or system configurations or calibrations were valid; • Support for inclusion of future installations planned; • Keep a record of access by FPs and provide a facility for FPs to indicate they have checked the data and it is deemed to be up-to-date and correct; • Metadata or information on data exchange arrangements and agreements, including bilateral, regional or international data exchange and dissemination.	CBS, ET-SBO, Turkey Met. Service	Chair ET-SBO to consider incorporation of this activity into Work Plan of ET-SBO and work with TSMS to update the WMO Radar Database.
12	3.3	The tables (Annex V) could be circulated and used both to complete the global picture and to update it periodically when new data exchange is initiated somewhere. The OPERA data exchange matrix could also be used in each region to provide more detail. A link between this kind of information and that available in the WMO Radar Database could also be explored.	ET-SBO	Chair ET-SBO to consider incorporation of this activity into Work Plan of ET-SBO
13	4.1	While it is recognized that BUFR is a standard for which the official use is governed by WMO and that HDF5 is endorsed but not yet governed by the WMO, it is recommended that WMO and CBS consider adopting ODIM_H5 as a WMO standard for representation of radar data.	CBS, ET-SBO	Chair ET-SBO to ensure this recommendation is made to CBS via OPAG-IOS and take the recommendation into consideration in finalising the Terms of Reference for development of the data exchange model.
14	4.2	A WMO Task Team established to investigate and implement a weather radar data model should consider elaboration of METCE to accommodate weather radar data and represent them using ODIM as a starting point.	CBS, ET-SBO	Chair ET-SBO to ensure this recommendation is made to CBS via OPAG-IOS and take into consideration the proposed Terms of Reference developed in Annex VII

No.	Report Section	Recommendation	Responsibility	Action
15	5.4	It was recommended by the Workshop participants that a Task Team is formed, possibly under the direction of CBS ET-SBO and charged with the responsibility of addressing a requirement for the development of global standard for representing weather radar data in support of global data exchange.	CBS, ET-SBO	Chair ET-SBO to ensure this recommendation is made to CBS via OPAG-IOS and take into consideration the proposed Terms of Reference developed in Annex VII.
16	5.4	The task team should recognize and take into consideration the considerable progress achieved by EUMETNET OPERA in harmonizing operationally exchanged real-time weather radar data with the OPERA Data Information Model (ODIM) and it is recommended that the Task Team should utilize this data model as the basis and starting point for the development and finalization of a WMO standard for global radar data exchange.	CBS, ET-SBO	Chair ET-SBO to ensure this recommendation is made to CBS via OPAG-IOS.
17	5.4	The task team should contain appropriate representatives from Regional Associations, weather radar experts, communications experts, and data model experts. Participation of representatives from other WMO bodies, such as ET-CTS and IPEG-DRMM, is also desirable. WMO and CBS should also ensure that relevant observing systems operators, manufacturers and applications and data user communities are informed of the task team's role and outputs.	CBS, ET-SBO	Chair ET-SBO to ensure this recommendation is made to CBS via OPAG-IOS.
18	7.1	It was proposed that a pilot project should be established to work towards the definition and implementation of data exchange protocols between Region II (TMS) and Region VI (ODYSSEY) with the concept to perhaps first be tested with the exchange of composite products. This project should be overseen by the CBS ET-SBO.	CBS, ET-SBO	Chair ET-SBO to consider incorporation of this activity into the Work Plan of ET-SBO. ET-SBO to ensure that this activity is consistent with existing plans for radar data exchange under Regional WIGOS Implementation Plans.
19	7.1	The Workshop agreed with representatives of Regions II and V to recommend the establishment of a pilot project for exchange of weather radar data among ASEAN members under the ASEAN ASMB. A draft proposal was developed by Mr Kamiluddin in consultation with Mr Adriyanto and is provided within Annex VIII.	CBS, ET-SBO	Chair ET-SBO to consider incorporation of the monitoring of this activity into the Work Plan of ET-SBO. ET-SBO to ensure that this activity is consistent with existing plans for radar data exchange under Regional WIGOS Implementation Plans.

No.	Report Section	Recommendation	Responsibility	Action
20	7.1	Given the current interest with Brazil and other countries in Region III in the national an international integration of radar networks, the Workshop agreed with representatives of Regions III to recommend the establishment of a Pilot Project for exchange of weather radar data among Region III Members and that this is considered and progressed through coordination by CBS/ET-SBO.	CBS, ET-SBO	Chair ET-SBO to consider incorporation of the coordination and intialisation of this activity into the Work Plan of ET-SBO. ET-SBO to ensure that this activity is consistent with existing plans for radar data exchange under Regional WIGOS Implementation Plans.