The emergence of weather radar as a global resource

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Outline

1. Introduction
2. WMO and WIGOS
3. IPET-OWR
4. Calibration
5. Advanced application - NWP
27 years ago
WMO Commissions

Commission for Aeronautical Engineering (CAeM)
Commission for Agricultural Meteorology (CAgM)
Commission for Atmospheric Sciences (CAS)
Commission for Basic Systems (CBS)
Commission for Climatology (CCl)
Commission for Hydrology (CHy)
Commission for Instruments and Methods of Observation (CIMO)
Joint WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM)
WMO Regional Associations

REGION I
AFRICA

REGION II
ASIA

REGION III
SOUTH AMERICA

REGION IV
NORTH AMERICA, CENTRAL AMERICA AND THE CARIBBEAN

REGION V
SOUTH-WEST PACIFIC

REGION VI
EUROPE

NORTH AMERICA, CENTRAL AMERICA AND THE CARIBBEAN

SOUTH AMERICA

AFRICA

EUROPE

ASIA

SOUTH-WEST PACIFIC

EUROPE
What is the WMO Integrated Global Observing System (WIGOS)?

- WMO foundational activity addressing the observing needs of the weather, climate, water and environmental services of its Members
- A framework for integrating all WMO observing systems and WMO contributions to co-sponsored observing systems under a common regulatory and management framework
- WIGOS is not:
  Replacing or taking over existing observing systems, which will continue to be owned and operated by a diverse array of organizations and programmes, national as well as international.

WIGOS Component Systems

- Global Observing System (WWW/GOS)
- Observing component of Global Atmospheric Watch (GAW)
- WMO Hydrological Observations (including WHYCOS)
- Observing component of Global Cryosphere Watch (GCW)
Why do we need WIGOS?

• I. NMHS mandate typically broader now than when the World Weather Watch and the GOS were created, including e.g.
  • Climate monitoring, climate change, mitigation
  • Air quality, atmospheric composition from urban to planetary scales
  • Oceans
  • Cryosphere
  • Water resources

• II. Technical and scientific advances:
  • Observing technology
  • Telecommunications
  • Numerical modeling and data assimilation
  • Increased user demand to access and use observations in decision making
Why do we need WIGOS?

III. Economic realities

• Budgetary pressure on many NMHS, in spite of expanding mandates and increasing demand for services

• Efficiency by exploiting synergies
  • Integration of observing networks across disciplines (e.g. weather and climate)
  • Integration across organizational boundaries, e.g. between different national ministries/departments operating observing systems
  • Integration across technological boundaries, e.g. between surface- and space-based systems
WIGOS Network Design Principles
(from WMO 1160 « Manual on WIGOS »)

According to the Manual on WIGOS, networks should be designed with a view toward:

1. Serving many application areas
2. Responding to user requirements
3. Meeting national, regional and global requirements
4. Designing appropriately spaced networks
5. Designing cost-effective networks
6. Achieving homogeneity in observational data
7. Designing through a tiered approach
8. Designing reliable and stable networks
9. Making observational data available
10. Providing information so that the observations can be interpreted
11. Achieving sustainable networks
12. Managing change
OSCAR

• The RRR is supported by three key databases of OSCAR, the *Observation Systems Capabilities and Review* tool:
  
  • **OSCAR/Requirements**, in which “technology free” requirements are provided for each application area, expressed in units of geophysical variables (260 in total currently), not measurands; not just atmosphere, also terrestrial, ocean, cryosphere, ...
  
  • **OSCAR/Space**, listing the capabilities of all satellite sensors, whether historical, operational or planned
  
  • **OSCAR/Surface**, list surface-based capabilities; developed by MeteoSwiss for WMO, operational since May 2016

[http://www.wmo.int/oscar/](http://www.wmo.int/oscar/)
OSCAR/Surface
("What is WIGOS?")

• Implementation layer of the *WIGOS Metadata Standard: Modern, electronic, searchable inventory of metadata for all observing stations/platforms under WIGOS*
  
  • OSCAR/Surface will replace *WMO Pub. 9, Volume A*, but will also include information from similar inventories for other (non-GOS) components of WIGOS
  
  • Developed jointly by WMO and MeteoSwiss, with the Swiss government providing the major part of the funding
  
  • Operational since May 2016

• Education and training Members in populating, editing and using OSCAR/Surface is a major priority for 2016-2019 financial period
Inter-Programme Expert Team on Operational Weather Radar : IPET-OWR

• Jointly managed by CIMO and CBS
  – Data quality and best practices activities from CIMO
  – Data representation and exchange from CBS
  – Liaison with ITU, ISO, others
  – “All things weather radar”

• Work Plan 2016-2019

• The emergence of weather radar as a global resource
End-to-end weather radar system
End-to-end weather radar system

User Requirements

- Comms
- Research & Development
- Network
- International Data Exchange
- Processing Software
- Computational Resources
- Data Archive
- Power
- Spares
- Vendor

WMO OMM
IPET-OWR Work Plan (1)

1. IPET management
2. Survey of Members requirements
3. Regulatory Material, advice and guidance to WMO’s Members
4. Weather radar data exchange
5. Metadata management, WMO radar database (WRD) and contribution to OSCAR
IPET-OWR Work Plan (2)

6. Best practices for weather radar quality control and quantitative precipitation estimation for user applications
7. International and regional collaboration – ISO
8. International and regional collaboration
9. Policy
10. Emerging technologies
11. Capacity development and training
Member requirements

- Survey conducted in early 2017
- 20 questions
- Expected to take around 20 minutes
- Sent to WMO Members
- Analyzed by the Secretariat and reported on at IPET-OWR-1, March 2017
- To guide IPET-OWR work plan
Member requirements summary (1)

- 86 responses from 84 countries
- 79 from NMHS
- 75 from organizations that already operate weather radar
- 10 expected to deploy OWR in future
- 773 radars identified, of which 305 to be replaced or upgraded
Member requirements summary (2)

Most significant issues

1. Obtaining finance to buy and install (2.07 rating)
2. Obtaining finance to maintain (1.85)
3. Lack of experienced or trained technical staff to operate and/or maintain (1.53)
4. Lack of experience or training of radar users (1.37)
5. Lack of data processing applications and tools (1.29)
6. Inadequate radar coverage (1.25)
Member requirements summary (3)

Most common uses of weather radar

1. Weather system monitoring (2.64)
2. Severe weather monitoring (2.56)
3. Weather system evolution and prediction (2.37)
4. Severe weather prediction (2.36)
5. Precipitation estimation for hydrology applications (1.30)
Member requirements summary (4)

Highest rated issues and aspects of OWR that WMO can assist with

1. Provision of software or applications to support radar data quality monitoring (2.20)
2. Guidance on weather radar data quality (2.15)
3. Provision of software or tools to support radar calibration (2.14)
4. Guidance on weather radar data exchange formats and mechanisms (2.12)
5. Provision of training on radar maintenance (2.04)
6. Guidance on: 1) weather radar calibration, 2) weather radar data use (2.03)
7. Provision of training on radar data processing (2.03)
8. Provision of training on radar data use and application (2.00)
Common or additional themes for assistance and activities that WMO might undertake

• Coordinate regional or technology-common meetings or workshops;
• Guidance on socio-economic benefits of operation of WR to support business case and funding attainment;
• Assistance for obtaining funding in support of OWR;
• Forums are required to support information and best-practice sharing (e.g. workshops, seminars);
• Training, technical support and capacity development are important;
• Promotion and collaboration on data exchange and sharing;
• Standardisation of and guidance on practices, procedures.
Regulatory Material, Advice and Guidance

Existing Material
Manual on the GOS (No. 544)
Guide to the GOS (No. 488)
CIMO Guide (No. 8), Part II, Chapter 7
Manual on WIGOS (No. 1160)

IPET-OWR Goal
WIGOS Weather Radar Best Practices Guide
IPET-OWR Guidance

Weather Radar Network Design
Dual Polarization Radar
Mountainous Terrain
Operation of Weather Radar Systems
Guidance on Interference Issues
Weather radar data exchange

Single global standard data representation
  – For data in radial coordinates (azimuth, elevation)
  – ODIM_H5 + CfRadial = CfRadial2
  – Documentation outputs ready, to be followed by software implementation

Weather radar data exchange methods
  – WMO exchange methods should accommodate weather radar
  – Members should use such exchange methods
# Summarized user requirements for data exchange

<table>
<thead>
<tr>
<th>Data User Area</th>
<th>Parameter/Field</th>
<th>Requirement Category</th>
<th>Requirement</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWP - Global</td>
<td>ECMWF</td>
<td>Horizontal resolution</td>
<td>2 km²</td>
<td>Different requirements for different NWP consortia</td>
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<tr>
<td></td>
<td></td>
<td>Cycle</td>
<td>Future: 1 km²?</td>
<td>Future standard: polar data?</td>
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<tr>
<td></td>
<td></td>
<td>Latency</td>
<td>15 min</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>15 - 30 min</td>
<td></td>
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<td></td>
<td>Composites</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Future: polar data?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NWP – High resolution</td>
<td>Polar data (Météo France)</td>
<td>Horizontal resolution</td>
<td>2 km²</td>
<td>Access to long-term high quality archived precipitation data is critical.</td>
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<tr>
<td></td>
<td></td>
<td>Cycle</td>
<td>Future: 1 km²?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Latency</td>
<td>1 hour</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>15 - 30 min</td>
<td></td>
</tr>
<tr>
<td>Hydrology</td>
<td>Quantitative Precipitation Estimate</td>
<td>Horizontal resolution</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Cycle</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Latency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate</td>
<td>Quantitative Precipitation Estimate</td>
<td>Horizontal resolution</td>
<td>1 km² possibly later inc. to</td>
<td>Access to long-term high quality archived data is critical.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cycle</td>
<td>Future: 0.25 km²</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Latency</td>
<td>1 hour</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Future: 5 min?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48 hrs</td>
<td></td>
</tr>
</tbody>
</table>
Status of data exchange:
RA I
South Africa
Botswana
Mozambique
North and Central America, the Caribbean
“RA VI composite” in the not-too-distant future?

22 August 2014 06:00 UTC

Experimental one-time only composite
International Standards Organization

Technical Committee: ISO/TC 146/SC 5 Meteorology

ISO/DIS 19926-1
Weather Radar – Part 1: System performance and operation

Drafted jointly by ISO-WMO following the ISO process
Status: under review
Importance of calibration and monitoring

Assumption when processing data: a well-calibrated radar

Why calibrate?
• Ensure pointing accuracy
• Ensure consistent performance
  – System availability
  – Calibration levels over time
  – Data quality
  – Network homogeneity

Why monitor?
• Detect system deterioration (instantaneous, gradual)
• Help troubleshoot
• Reduce downtime, data outages
• Determine if acquired data are within quality tolerances
Importance of calibration

Calibration errors can affect $Z$, thereby also negatively impacting estimates of $R$
IPET-OWR and calibration

Radar Calibration Reporting – RaCR

• Prototype software
• Validates calibration and harmonizes reporting
• Complements vendor’s calibration process, does not replace it
• Single or dual polarization, X, C, S (other) bands
• Different configurations, up to 4 pulse widths
• Follows method developed for GPM mission
A reference target that’s always there and it radiates equally in H and V

Sunrise

Sunset

Hong Kong
Radar renewal in Canada

Mixed S and C-band network

WMO OMM
Radisson, Saskatchewan
Sunrise in Saskatchewan at S band
Pointing accuracy and power distribution
Pointing accuracy and power distribution
Pointing accuracy and ZDR distribution

Radisson, SK: Dec 06, 2017 to Jan 03, 2018

Elevation readout - sun (degrees)

Azimuth readout - sun (degrees)

ZDR offset: 0.48
σ: 0.18
Other monitoring of ZDR
King City, Ontario. C-band

IRIS Suncal utility

Median values derived from PPI data

Degraded TR cell
Uncorrected vs Corrected Z

Weak snow

Radisson, SK
Jan 10, 2018
15:59-17:00 UTC
Uncorrected vs Corrected Z

Anomalous propagation

Radisson, SK
Jan 16, 2018
17:41-18:42 UTC
Radar Data Assimilation:
Input weather radar data

**Canadian network**
- 30 C-band Doppler radars
- 10 minute acquisition cycle
- 24-sweep non-Doppler volume, no QC, 256 km range
- 4 Doppler sweeps, reflectivity and radial winds, 125 km

**McGill University S-band**
- Reflectivity only, 480 km
- 5 min acquisition cycle

**NEXRAD Level II**
- Continental United States + Alaska, ~6 min data
Quality control of weather radar data

1. Hit-accumulation clutter filter
2. Non-precipitation identification and removal:
   - Biometeors: birds, insects
   - Speckle
   - External emitters, ie. RFI
3. Beam blockage identification and correction <60%
4. Attenuation correction (conventional)
5. Beam broadening – descriptive
6. “Total quality” – descriptive, minimum of 3-5
Data processing / compositing

• BALTRAD Toolbox deployed at ECCC
  ✓ Decodes for IRIS and McGill formats developed
  ✓ NEXRAD Level II decode from Py-ART
  ✓ BALTRAD data quality framework exploited

• 2.5 km reflectivity composites generated
  ✓ Containing both corrected and uncorrected reflectivities
  ✓ All data quality metrics carried over from polar to Cartesian space
  ✓ 10 minute
  ✓ 1 km pseudo-CAPPI
  ✓ Selection criterion: maximum “total” data quality

• All data and composites represented in ODIM_H5
NWP model & Latent Heat Nudging

- Regional Deterministic Prediction System
- EnVAR assimilation using Incremental Analysis Updating
- 10 km horizontal resolution
- 48h forecasts at 00Z and 12Z
- July 2014

LHN is applied every 10 minutes between -3 and +3h forecasts
Compare modeled precipitation against radar inferred precipitation.
Increase warming if more precipitation is needed.
Decrease warming if less precipitation is needed.
Verification 1

All scores for precip rates > 1 mm/h
Average for 60 forecasts

[Graph showing POD, FAR, CSI, Lmin, and correlation coefficient against lead time [h], with two lines for Control and LHN.]
Verification 2

ETS score
6hr accum
Precip > 1 mm

RMSE of wind
module error
(m/s)

Cloud cover
frequency bias
Other variables are also positively impacted

\~2\% improvement RMSE of \textbf{Temperature}
for \~12-18h

\~2-3\% improvement RMSE of \textbf{U wind}
for \~18-24h
Status of RDA at ECCC

• Radar data quality-control framework in place
• QC is critical to RDA (end-to-end radar system)
• First impact study has been performed
  ✓ Positive impact 2-3 hours
  ✓ Neutral-to-positive impact ~24 hours
  ✓ Replicates well-known LHN behaviour
• Baseline RDA established
• Operational implementation expected to follow
• But first: more impact studies
Weather radar best practices guide

Preliminary Table of Contents
1. Introduction
2. Network design
3. Calibration and monitoring
4. Radar configuration - scan strategy
5. Data representation
6. Data exchange
7. Quality Control
8. Compositing - mosaicing
9. Monitoring of data quality
10. Quantitative Precipitation Estimation

Open Source Software can offer reference implementations potentially for deployment and/or training.
Thank you
Merci