# Catalogue of useful reference material on automation

Much of the following can also be found as individual documents on the WMO Knowledge Sharing Portal Web Portal

<https://community.wmo.int/activity-areas/imop/knowledge-sharing-portal>

Some of the information on the Portal are not specifically related to WMO activities but are worth considering when transitioning to automated weather stations.

The following tables are broken into three groups:

1. Specific sections from WMO manuals and guides
2. Selected reports, general guidance and some older documents
3. Selected conference proceedings, presentations and recordings.

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| **Existing guidance documentation on automation of observations, automated data processing, automated networks and data management** | | | |
| Specific Manuals and Guides | | | |
| WMO-No. 8 Guide to Instruments and Methods of Observation (2018 update)  <https://library.wmo.int/index.php?lvl=notice_display&id=12407> | 2018 edition  2018 edition  2018 edition  2018 edition | **Volume 1, Measurement of Meteorological Variables**  Chapter1, General  Annex 1.A. Operational Measurement Uncertainty Requirements and Instrument Performance Requirements  Annex 1.B. Strategy for Traceability Assurance  Annex 1.C. Regional Instrument Centres  Annex 1.D. Siting Classifications for Surface Observing Stations on Land  Annex 1.E. Operating Equipment in Extreme Environments  Annex 1.F. Station Exposure Description  **Volume II, Measurement of Cryospheric Variables**  **Volume III, Observing Systems**  Chapter 1, Measurements at automatic weather stations  Annex. Automatic Weather Stations – Low Cost  Chapter 2, Measurements and observations at aeronautical meteorological stations  Chapter 9, Urban Observations  Chapter 10, Road meteorological measurements  **Volume V, Quality Assurance and Management of Observing Systems**  Chapter 1, Quality management  Chapter 2, Sampling meteorological variables  Chapter 3, Data reduction  Chapter 4, Testing, calibration and intercomparison  Annex 4.D. Reports of International Comparisons Conducted Under the Auspices of the Commission for Instruments and Methods of Observation  (See also <https://community.wmo.int/activity-areas/imop/publications-and-iom-reports>)  Chapter 5, Training of instrument specialists  Annex 5.B Competency Framework for Personnel Installing and Maintaining Instrumentation  Annex 5.C Competency Framework for Personnel Performing Instrument Calibrations  Annex 5.D Competency Framework for Personnel Managing Observing Programmes and Networks |
| WMO-No.49 Technical Regulations  Basic Document (2019 Edition)  Volume 1 – General Meteorological Standards and Recommended Practices  <https://library.wmo.int/?lvl=notice_display&id=14073> | 2019 Edition | **Part 1. The WIGOS**  2. COMMON ATTRIBUTES OF WIGOS COMPONENT  SYSTEMS.  2.1 Requirements  2.2 Design, planning and evolution.  2.3 Instrumentation and methods of observation.  2.4 Operations  2.4.1 General requirements  2.4.2 Observations  2.4.3 Performance  2.4.4 Quality control  2.4.5 Calibration  2.5 Observational metadata  2.6 Quality management.  2.7 Capacity development  2.7.1 General  2.7.2 Training.  2.7.3 Infrastructural capacity development |
| WMO-No.49 Technical Regulations  Basic Document (2018 edition)  Volume II – Meteorological Service for International Air Navigation  <https://library.wmo.int/doc_num.php?explnum_id=5526> | 2018 edition | **Part II. INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES**  Appendix 3. Technical Specifications related to Meteorological Observations and Reports  Attachment A. Operational Desirable Accuracy of Measurement or Observation |
| WMO-No. 134 Guide to Agricultural Meteorological Practices  <https://library.wmo.int/doc_num.php?explnum_id=3996> | 2012 | Chapter 2, Agricultural Meteorological Variables and their Observations  Chapter 16, Applications of Climatic Resources in Mountainous Regions |
| WMO-No. 488 Guide to the Global Observing System (updated 2017)  <https://library.wmo.int/doc_num.php?explnum_id=4236> | 2010  edition updated in  2017 | Part 2, Observational Data Requirements  Part 3, The Surfaced-based Subsystem  Appendix 3.1 – Functional specifications for AWSs  Appendix 3.2 – Basic set of variables to be reported by standard AWSs for multiple users  Appendix 3.3 – Automatic weather station metadata  Part 5, Reduction of Level 1 Data  Part 6, Data Quality Control  Appendix 6.2 – Guidelines for Quality Control Procedures Applying to Data from Automatic Weather Stations |
| WMO-No. 1160 Manual on the WMO Integrated Global Observing System  Annex VIII to the WMO Technical Regulations  <https://library.wmo.int/doc_num.php?explnum_id=10145> | 2019 edition | **Chapter 2. COMMON ATTRIBUTES OF WIGOS COMPONENT SYSTEMS.**  2.1 User requirements  2.2 Design, planning and evolution  2.2.1 General  2.2.2 Principles for observing network design and planning  2.3 Instrumentation and methods of observation  2.3.1 General requirements  2.4 Operations  2.4.1 General requirements  2.4.2 Observing practices  2.4.3 Quality control  2.4.4 Data and metadata reporting  2.4.6 Change management  2.4.7 Maintenance  2.4.8 Inspection  2.4.9 Calibration procedures  2.5 Observational metadata  2.6 Quality management  2.6.5 Compliance, certification and accreditation  2.6.6 Documentation  2.7 Capacity development  2.7.1 General  2.7.2 Training  2.7.3 Infrastructural capacity development  **Appendix 2.1. Observing Network Design Principles**  **Appendix 2.2. Climate Monitoring Principles of the Global Climate Observing System**  **Appendix 2.3. The WMO Rolling Review of Requirements**  **Appendix 2.4 WIGOS Metadata Standard (and attachments 2.1, 2.2)**  **Chapter 3. ATTRIBUTES SPECIFIC TO THE SURFACE-BASED SUBSYSTEM OF WIGOS**  3.1 Requirements  3.2 Design, planning and evolution  3.3 Instrumentation and methods of observation  3.3.1 General requirements  3.3.2 Requirements for sensors  3.4 Operations  3.4.1 General requirements  3.4.2 Observing practices  3.4.3 Quality control  3.4.4 Data and metadata reporting  3.4.6 Change management  3.4.7 Maintenance  3.4.8 Inspection  3.4.9 Calibration procedures  3.5 Observational metadata  3.6 Quality management  3.7 Capacity development |
| WMO-No. 1165 Guide on the WMO Integrated Global Observing System  <https://library.wmo.int/doc_num.php?explnum_id=10040> | 2019 | Chapter 5 Observing Network Design |
| WMO Generic AWS Tender Specifications <https://community.wmo.int/activity-areas/imop/aws-tender-specifications> | 2018 | 1. AWS Tender Specification – Preamble 2. Lifecycle Management 3. Meteorological Information Processing System Requirements 4. AWS – Sensors 5. Annex on Meteorological Enclosure Design 6. Maintenance Conditions 7. Recommended Spare Parts 8. Statement of Work 9. Test Procedures 10. Training and Documentation |

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| Selected reports, general guidance and some older documents | | |
| GCOS-226 GCOS Surface Reference Network (GSRN): Justification, requirements, siting and instrument options  <https://library.wmo.int/doc_num.php?explnum_id=6261> | 2019 |  |
| IOM-19 Some general considerations and specific examples in the design of algorithms for Synoptic AWS (WMO/TD – No. 230)  <https://library.wmo.int/doc_num.php?explnum_id=9486> | 1987 | Excellent read |
| IOM-47 Guidance on the Establishment of Algorithms for use in Synoptic AWS – Processing of Surface Wind Data (WMO/TD – No. 452)  <https://library.wmo.int/index.php?lvl=notice_display&id=11253#.XYhfWG5uJaQ> | 1991 | A bit outdated but some good information. |
| IOM-65 Guidance on Automatic Weather Systems and their Implementation (WMO-No. 862)  <https://library.wmo.int/index.php?lvl=notice_display&id=11269#.XYQRdW5uJaQ> | 1997 |  |
| IOM-78 Algorithms used in AWS – Evaluation of Questionnaire  <https://library.wmo.int/index.php?lvl=notice_display&id=15520#.XYhfa25uJaQ> | 2003 |  |
| IOM-87 Training material on Automated Weather Observing Systems (WMO/TD-No. 1307)  <https://library.wmo.int/index.php?lvl=more_results&autolevel1=1#.XYQSP25uJaQ> | 2006 |  |
| IOM-126 MeteoSwiss Classification Procedure for Automatic Weather Stations  <https://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html> | 2017 | Can be used for site selection |
| WMO-No. 570 Automatic Weather Stations for Tropical Cyclone Areas  <https://library.wmo.int/index.php?lvl=notice_display&id=12276#.XYhTdW5uJaQ> | 1981 | Very old but still has relevant information. |
| WMO-No. 1100 Guide to Implementation of a Quality Management System for National Meteorological and Hydrological Services  <https://library.wmo.int/index.php?lvl=notice_display&id=15574#.XYQLRG5uJaQ> | 2017 |  |
| WMO/TD-No. 1185 Guidelines on Climate Observation Networks and Systems  <https://library.wmo.int/index.php?lvl=notice_display&id=11634#.XYgVJG5uJaQ> | 2003 |  |
| WMO/TD-No. 1186 Guidelines on Climate Metadata and Homogenization  <https://library.wmo.int/index.php?lvl=notice_display&id=11635#.XYgVcW5uJaQ> | 2003 |  |
| WMO-No. 1192 WIGOS Metadata Standard  <https://library.wmo.int/doc_num.php?explnum_id=10109> | 2019 |  |
| WMO-No. 1195 Guidelines on the Role, Operation and management of National Meteorological and Hydrological Services  <https://library.wmo.int/index.php?lvl=notice_display&id=20172#.XYQMYG5uJaQ> | 2017 |  |
| WMO-No. 1202 Challenges in transitioning from conventional to automatic met observing networks for long term climate records  <https://library.wmo.int/index.php?lvl=notice_display&id=20154#.XYQMjW5uJaQ> | 2017 |  |
| WMO-No. 1205 Guide to Competency  <https://library.wmo.int/index.php?lvl=notice_display&id=20181#.XYQMwG5uJaQ> | 2018 |  |
| WMO-No. 1209 Compendium of WMO Competency Frameworks  [Compendium of WMO Competency Frameworks](https://library.wmo.int/doc_num.php?explnum_id=10075) | 2019 |  |
| WMO-No. 1243 Vision for the WMO Integrated Global Observing System  <https://library.wmo.int/doc_num.php?explnum_id=10278> | 2019 |  |
| WMO/TD-No. 1378 Guidelines for managing changes in climate observation programmes  <https://library.wmo.int/index.php?lvl=more_results&autolevel1=1#.XYQM5G5uJaQ> | 2007 |  |
| Manual on Instrumentation and Operations for Automatic Weather Stations for Agrometeorological Application  <https://library.wmo.int/doc_num.php?explnum_id=6341> | 2000 | WMO  Institute of Agrometeorology and Environmental Analysis for Agriculture – Research National Council (IATA)  Regional Meteorological Training Center (CNR)  (Includes Workbook) |
| WMO – Standards and recommended practices<https://public.wmo.int/en/resources/standards-technical-regulations> |  | Nice summary on Technical Regulations, Manuals and Guides.  Also lists some useful documents on observation requirements/AWS |
| ET-AWS7 Final report of requirements and implementation of AWS  <https://library.wmo.int/index.php?lvl=notice_display&id=13069#.XYgXDW5uJaQ> | 2012 |  |

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| Selected Conference Proceedings, Presentations and Recordings | | |
| IOM-1  Automated Meteorological Systems. Papers presented at the Technical Conference on Evolution and Standardization of Observing Techniques in Light of Automation – (1-5 Sept 1980)  <https://library.wmo.int/doc_num.php?explnum_id=7346> | 1980 | One of the first! |
| IOM-58 International Workshop on Experiences with AWS on Operational Use within National Weather Services – May 1995 (WMO/TD – No. 670)  <https://library.wmo.int/index.php?lvl=notice_display&id=11262#.XYhThm5uJaQ> | 1997 | Papers presented.  Old, but still relevant. |
| IOM-116 WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2014)  <https://library.wmo.int/doc_num.php?explnum_id=3147> | 2014 | Papers, posters, abstracts, presentations and recordings.   * Challenges and Experiences with Wind Measurements at Aerodromes – Keynote 1C (Wiel Wauben, Netherlands) * METAR AUTO Implementation at International Airports in New Zealand – 1(13) (Bruce Hartley, New Zealand) * Accurate Rainfall Measurement: The Willfully Neglected Achilles Heel of Hydro-Meteorology – 3(9) (Michael Pollock et al, UK) * Moroccan Approach Providing Modern Alternatives to replace Dangerous and Obsolete Meteorological Instruments - Keynote 4B(Mr Rabia Merrouchi, Morocco) |
| IOM-125 WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2016)  <https://library.wmo.int/index.php?lvl=notice_display&id=19676#.WjD-2IQrJhF> | 2016 | Papers, posters, abstracts, presentations and recordings.   * JMA’s international collaboration on meteorological instrument calibration – O1(2) (Mr Yukihiro Nomura et al., Japan * The Meteorological Instrumentation: Progressing Technologies and Evolving Competencies – P1(19) Abstract (Mrs Hanane Kamil et al., Morocco) * Installation of Alternative Solution to Outdated and Dangerous Instruments –P2(16) Abstract (Dr Ahmed Cherifi et al., Morocco) * Using the Raspberry Pi for Data Collection, Dissemination and Display – P2(26) Poster (Mr Marvin Forde, Barbados) * Meteorological observation network Automation in the underdeveloped countries for a better adaptation of the vulnerable zones to the climatic change (Case of Guinea) – P2(27) Poster (Mr Laddah Gberegbe, Guinea) * Modernization of the volunteer’s network – P2(41) Poster (Mr Pierre Lantuejoul, France) * Hazards, Hazardous Substances, the Minamata Convention on Mercury and Other Stuff – O4(1) Presentation (Mr Bruce Hartley, New Zealand) * Moving on from mercury; maintaining homogeneity in meteorological records – O4(2) Presentation (Mr Stephen Burt, United Kingdom of Great Britain and Northern Ireland) * Challenges and strategies for climate monitoring in the Pacific – O4(3) Presentation (Mr Andrew Harper et al., New Zealand) * Concept Development of an ‘Internet of Things’ Surface Measurement Network – SurfaceNet – O4(5) Presentation (Mr Mike Molyneux et al., United Kingdom of Great Britain and Northern Ireland) * Conception of E-learning project for qualification of calibration and maintenance operators – P4(5) Abstract (Mr Mounir Aziz et al., Morocco) * Challenges and plans for phasing out mercury based meteorological instruments from Nepal – P4(8) Poster (Mr Chiranjibi Bhetuwal et al., Nepal)   Panel Discussion Session:  Benefits and Challenges of Transitioning to Automated Observations |
| IOM-127 International Conference on Automatic Weather Stations (ICAWS-2017)  https://library.wmo.int/index.php?lvl=notice\_display&id=20023#.WjEAa4QrJhF | 2017 | Papers, posters, abstracts, presentations and recordings.  Topics:   1. Initiating automation and supporting migration from manual to automated measurements 2. Communications, data transmission, encoding, archiving and storage 3. Sustainability of the measurements 4. New developments, interoperability, intelligent measurements, and integration   Panel Discussion Sessions:   1. Automation of measurements – training needs and competencies 2. Working with non-NMHS (partner) data 3. Low-cost AWSs – opportunity or threat to meteorological measurements |
| IOM-132 WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2018)  <https://library.wmo.int/index.php?lvl=notice_display&id=20734#.XItwMq5KuUl> | 2018 | Papers, posters, abstracts, presentations and recordings.   * Improving the WMO Guide n.8. Results on the experimental evaluation of the effect of presence of obstacles in the vicinity of sites hosting near surface meteorological measurement – The case of the road. O1(13) Presentation (Dr Graziano Coppa et al., Italy) * Metrological evaluation of the building influence on air temperature measurements. P1(10) (Dr Carmen Garcia Izquierdo et al., Spain) * Sustainability of measurements post donor funded programmes. O3(1) Presentation (Mr Andrew Harper et al., New Zealand) * Challenges in transition from mercury measuring instruments to alternative measurement technologies in Zimbabwe. O3(7) Presentation (Mr Webster Magwaro, Zimbabwe) * Lessons from the Modernisation of National Meteorological and Hydrological Services – A Case Study of the Zambia Meteorological Department. O3(8) Presentation (Mr Oliver Mudenda, Zambia) * Automatic Weather Station Design for Primary AWS networks. P3(3) (Mr Jorma Islander, Finland) * New architecture of the meteorological observation network in view of the migration from obsolete to electronic instruments. P3(17) (Mr Mounir Aziz et al., Morocco) * Modernization of the Surface Network observation in Tunisia. P3(20) Poster (Mrs Saoussen Cheriaa, Tunisia) * On the Automation and Modernisation of the Irish Climate Station Network. P3(42) Poster (Mr Tony O’Leary et al., (Ireland) * Ensuring sustainability of measurements in Solomon Islands. P3(57) Poster (Mr Barnabas Tahunipue, Solomon Islands) * Alternative of gradual modernization of manned measurement instruments. P3(64) (Mr Augusto Vargas, Peru) * Data Collection Network Modernisation – What You Need to Know. O4(3) Presentation (Mr Bruce Hartley, New Zealand) |
| RA-I WIGOS Workshop on Automatic Weather Staion (AWS) networks Strengthening and modernizing observing systems in Africa (Windhoek, Namibia, 19-21 November 2018)  <https://community.wmo.int/meetings/ra-i-aws-workshop> | 2018 | Papers, posters, abstracts, presentations and recordings.   * [Overarching AWS network implementation issues (Keynote Presentation)](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_AWS-Network-Implementation_VanderMeulen_NL.pptx) Dr J. van der Meulen (Netherlands) * [ICAWS-2017 recommendations](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_ICAWS-outcomes_Premec-WMO.pdf) K. Premec (WMO) * [Requirements analysis and network planning](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_AWS-Network-Requirements-Planning_Muchemi-Kenya.pptx) D.Muchemi (Kenya) * [Specification and procurement of AWS networks](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_AWS_tender_specs_Premec-WMO.pdf) K. Premec (WMO) * [Siting and deployment](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_Siting-deployment_Mbengue-Senegal.pptx) A. MBENGUE(Senegal) * [Operation and maintenance](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_Operation-Maintanance_Waniha-Tanzania.pptx) P. Waniha (United Republic of Tanzania) * Data processing and data dissemination Y.Darari (Morocco) * [WMO technical regulations and guidance material](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/RA-I-AWS-Windhoek-2018_WRM-WGM-AWS_Zahumensky-WMO.pptx)   and [AWS related documentation](https://www.wmo.int/pages/prog/www/WIGOS-WIS/meetings/RA-I_AWS_Namibia-Nov2018/AWS_References_2018-11-08.docx) I. Zahumensky (WMO) * National presentations on automation   Plus, many others workshop presentations. |

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| Selected Aviation/ICAO documents | | |
| CAP 746  UK Civil Aviation Authority  Requirements for meteorological observations at aerodromes  <https://publicapps.caa.co.uk/docs/33/CAP746%20Issue%205%20(July%202020).pdf> | 2020 |  |
| Doc 9328  ICAO  Manual of Runway Visual Range Observing and Reporting Practices  <http://www.icscc.org.cn/upload/file/20190102/Doc.9328-EN%20Manual%20of%20Runway%20Visual%20Range%20Observing%20and%20Reporting%20Practices.pdf> | 2005 |  |
| DOC 9837  ICAO  Manual on Automatic Meteorological Systems at Aerodromes  <http://www.icscc.org.cn/upload/file/20190102/Doc.9837-EN%20Manual%20on%20Automatic%20Meteorological%20Observing%20Systems%20at%20Aerodromes.pdf> | 1999 |  |