



GCOS

GLOBAL CLIMATE OBSERVING SYSTEM

WIGOS TECHNICAL
REPORT No. 2013- 02

GCOS-170

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WMO Integrated Global Observing System

The GCOS Reference Upper-Air Network (GRUAN) MANUAL

March 2013

(Version 1.1.0.3)



World
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Purpose of this Manual

This GCOS (Global Climate Observing System) Reference Upper-Air Network (GRUAN) Manual describes mandatory operating protocols (distinguished by use of the words “must” or “shall”) which describe what is expected of participating sites, the GRUAN Lead Centre, and the Working Group on GRUAN (WG-GRUAN) to achieve the goals of GRUAN. These protocols have the status of requirements in a technical resolution, which sites within GRUAN are expected to follow or implement.

Sites that operate under the protocols outlined in this Manual are recognized as being state-of-the-art measurement sites that support the core goals of GCOS. Given the high profile of GCOS within funding agencies, GRUAN endorsement of the quality of a site’s measurement programmes is expected to support resourcing for GRUAN sites. Through GRUAN’s governing bodies, sites shall have access to the support and service structures provided by the AOPC (Atmospheric Observation Panel for Climate), the WCRP (World Climate Research Programme), UNEP (United Nations Environment Programme), IOC (Intergovernmental Oceanographic Commission) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), ICSU (International Council for Science) and WMO (World Meteorological Organization). In addition to requiring long-term homogeneity of measurement programmes at sites within the network, GRUAN has a strong emphasis on network-wide homogeneity of measurement time series. Measurements at GRUAN sites shall be anchored to a reference that provides traceability to internationally recognized measurement standards. GRUAN has established a number of task teams to entrain skills and expertise from across the international community in measurement sciences. Sites joining GRUAN shall have access to this pool of expertise. GRUAN has developed and implemented a state-of-the-art data delivery service through the National Climate Data Center of NOAA. Raw measurements made at GRUAN sites shall be processed and quality assured at a centralised data processing facility and provided to a wide range of data users.

The primary goals of GRUAN are to provide vertical profiles of reference measurements suitable for reliably detecting changes in global and regional climate on decadal time scales, initially for temperature, pressure and water vapour, with the aim of expanding to other essential climate variables (ECVs), as resources permit, in liaison with other existing scientific networks. The measurements will provide a calibrated reference standard for global satellite-based measurements of atmospheric ECVs, will ensure that potential gaps in satellite measurement programmes do not jeopardize the long-term climate record, will be a reference standard for the measurements made within the existing GCOS Upper-Air network, and will provide data to fully characterize the properties of the atmospheric column. These goals have been jointly endorsed by GCOS and WMO.

The Manual recognizes that GRUAN is a heterogeneous network that includes sites from both the research community and the operational meteorological community. The mandatory practices required of GRUAN sites, as detailed in this Manual, reflect GRUAN’s primary goal of providing reference quality observations of the atmospheric column while accommodating the diverse

capabilities of sites within the network. However, WG-GRUAN certification of measurement programmes at a GRUAN site goes beyond considering the extent to which the site adheres to the mandatory practices outlined in this Manual and considers the added value that the site brings to the network. The assessment of the added value is an expert judgement.

The Manual is augmented by a more detailed GRUAN *Guide to Operations* (GCOS-171) which provides guidelines on how the protocols detailed in this Manual might be achieved, and by a series of technical documents available from the GRUAN web site at <http://www.gruan.org>. Since GRUAN is a WIGOS (WMO Integrated Global Observing System) Implementation Project, relevant information from this Manual and the Guide is expected to be incorporated into the WMO regulatory material, especially the WIGOS Manual and the WMO Manual on the Global Observing System (WMO-No. 544) and the Guide on the Global Observing System (WMO-No. 488)¹. GRUAN observing systems and operating practices, as detailed in technical documents associated with each observing technique available in GRUAN, are expected to be referred to in the WMO Guide to Instruments and Methods of Observation (WMO-No.8) and the GRUAN Guide and Manual. A GRUAN site may be a scientific observing site outside of the WMO operational Global Observing System, but the long-term observational procedures are expected to follow the guidelines laid down in this GRUAN Manual, and in the GRUAN *Guide to Operations*, whether it is primarily a scientific site or whether it is already part of the Global Observing System. The WMO Manuals are expected to reference these GRUAN practices.

¹or other relevant WMO documentation if these supersede the existing Guide and Manual on the Global Observing System.

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1. Introduction

The development and current operation of GRUAN are described by a number of distinct but often overlapping documents, including GCOS-112, GCOS-121, GCOS-134, GCOS-140², web-based material, reports from GRUAN task teams and papers published in the international peer reviewed literature. The purpose of this Manual is to consolidate information essential to the operation of GRUAN.

2. The purpose of GRUAN

2.1. As detailed in GCOS-112, the purpose of GRUAN shall be to:

- i) Provide long-term high quality climate records;
- ii) Constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks); and
- iii) Fully characterize the properties of the atmospheric column.

GRUAN shall strive to provide observations in near real-time (NRT; within 2 hours) for incorporation in meteorological analysis, provided this is not detrimental to achieving the primary purposes of the network, as defined above.

2.2. A fully equipped GRUAN site shall make at least double, and preferably triple, redundant measurements of all GRUAN priority 1 and 2 ECVs³ and, specifically:

- i) Four times daily radiosonde measurements of temperature and pressure to 30 km, and water vapour in the troposphere, also submitted in NRT to the WMO Information System (WIS);
- ii) Weekly ozone profile measurements;
- iii) Monthly water vapour profile measurements to ~30 km; and
- iv) Hourly observations of integrated precipitable water vapour.

2.3. Minimum requirements for a GRUAN site include:

- i) Weekly radiosonde measurements of temperature and pressure to 30 km and humidity in the troposphere; and
- ii) Monthly water vapour profile measurements to ~30 km. Where several GRUAN sites are located sufficiently close to each other, where the sufficiency shall be guided by scientific studies, individual site flight schedules should be coordinated to share the burden of making these measurements.
- iii) At least twice daily observations of integrated precipitable water vapour.

²<http://www.wmo.int/pages/prog/gcos/index.php?name=Publications>

³Vertical profiles of temperature, pressure, water vapour, wind speed and direction, and ozone. Vertical profiles of aerosol attributes including optical depth, total mass concentration, chemical mass concentration, scattering, and absorption. Methane columns. Surface net radiation, short-wave downward radiation, short-wave upward radiation, long-wave downward radiation, long-wave upward radiation, and radiances. Cloud properties including cloud amount/frequency, base height, layer heights and thicknesses.

For all GRUAN sites from those meeting the minimum requirements to those that are fully equipped, their certified measurement programmes are expected to comply with the mandatory protocols summarized in Section 8 of this Manual and expanded on further in Section 5.3 of the *GRUAN Guide to Operations* (GCOS-171).

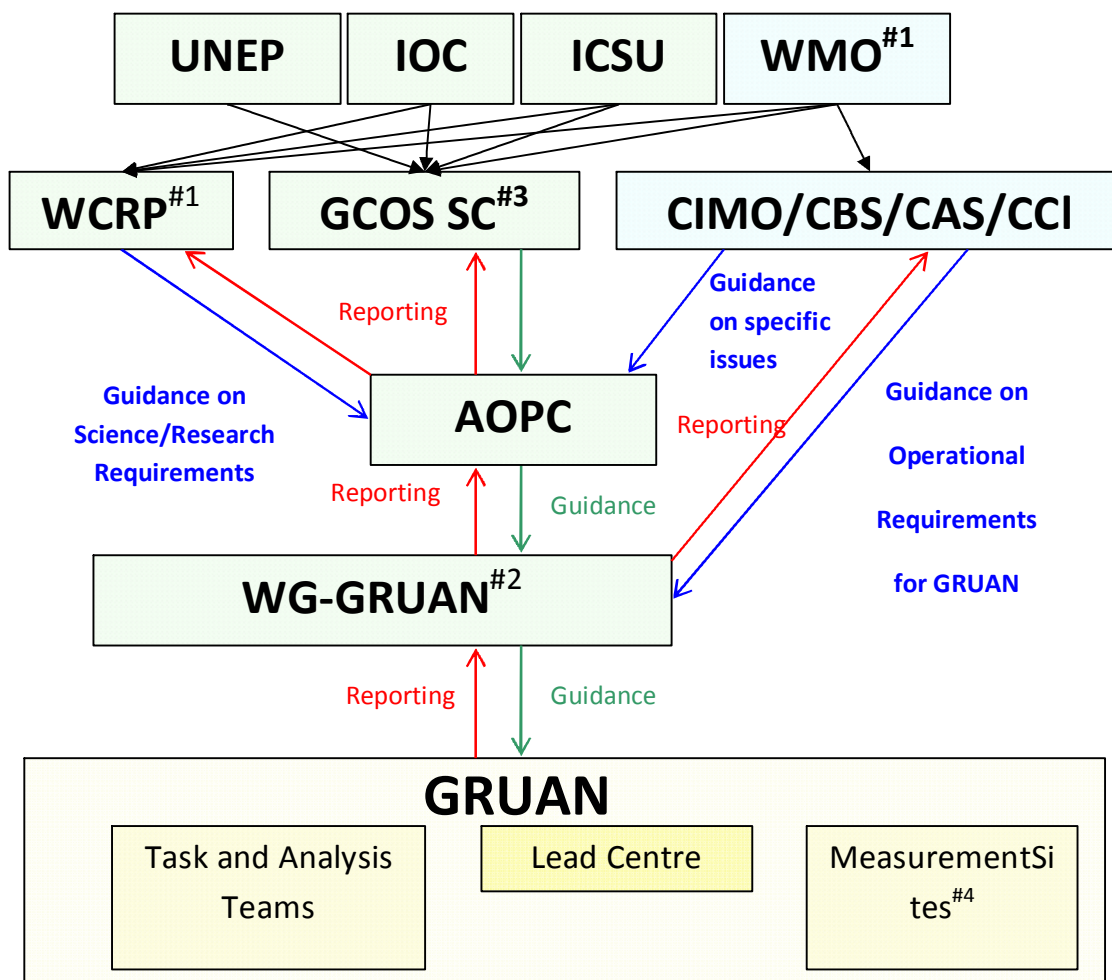
3. Organisation and design of GRUAN

- 3.1. GRUAN will operate under the joint governance of GCOS and WMO (Figure 1).
- 3.2. Working oversight of the network will be performed by the WG-GRUAN, comprised of individuals with scientific expertise relevant to GRUAN, and also incorporating representatives from relevant WMO technical commissions including, but not necessarily limited to, the Commission for Instruments and Methods of Observation (CIMO), the Commission for Basic Systems (CBS), the Commission for Atmospheric Sciences (CAS; which oversees the Global Atmosphere Watch, GAW), and the Commission for Climatology (CCI). Primary metrology Institutes and Consultative Committees of the CIPM (Comité International des Poids et Mesures)⁴ provide external consultation.
- 3.3. A GRUAN Lead Centre agreed to by GCOS and WMO shall integrate best practices into GRUAN operations, managing the network systems, and data management.
- 3.4. GRUAN sites shall use WG-GRUAN approved methods, techniques and facilities, implemented for making and archiving best quality atmospheric profile observations, from the surface to the stratosphere or higher, at specific locations distributed globally. At any site, this system shall not be changed without advanced notification to the Lead Centre, followed by a process of managed change under the guidance of the Lead Centre.
- 3.5. GRUAN operations shall incorporate an assurance programme to validate the methods and traceability of the measurements and to establish a programme to provide a common approach to uncertainty evaluations, agreed with WG-GRUAN, and managed in detail by the GRUAN Lead Centre.
- 3.6. GRUAN shall be responsive to the latest technological and scientific progress in measurement techniques and observational climate requirements. Development work can continue at a site until mature and validated, when it could be introduced into GRUAN operations with the agreement of the WG-GRUAN.

4. Implementation of GRUAN

- 4.1. The implementation of GRUAN shall be guided by the WG-GRUAN.
- 4.2. Specific activities in support of GRUAN operations shall be undertaken by GRUAN task teams, as agreed by WG-GRUAN. These task teams will entrain operational and other relevant expertise in support of GRUAN.

⁴International Committee for Weights and Measures



Notes

1. WCRP (World Climate Research Programme) identifies scientific and research requirements for GRUAN, while WMO identifies operational requirements.
2. Composition of WG-GRUAN to be determined by the AOPC (Atmospheric Observation Panel for Climate) in consultation with WMO and should include:
 - one representative from each of CIMO, CBS, CAS and CCI; these representatives will be responsible for reporting back to their respective Technical Commission;
 - others (according to its Terms of Reference)
3. Global Climate Observing System Steering Committee.
4. GRUAN Measurement Sites are contributed by Members of WMO.

Figure 1: Schematic outline of the structure of GRUAN. (UNEP=United Nations Environment Programme, IOC=Intergovernmental Oceanographic Commission of UNESCO=United Nations Educational, Scientific and Cultural Organization, ICSU=International Council for Science)

- 4.3. The GRUAN Analysis Team for Network Design and Operations Research (GATNDOR) shall undertake focused, short-term research to address specific topics identified by the WG-GRUAN relevant to the design of GRUAN and its operations. The work will be conducted in coordination with other relevant GRUAN task teams.
- 4.4. The WG-GRUAN shall agree on appropriate protocols for establishing standard operating procedures for observing systems within GRUAN. This could be a new task team, an

instrument mentor, or an existing instrument team within other associated WMO or other network projects/operational groups.

- 4.5. The GRUAN Lead Centre shall identify sites where instrument operators need training, and organise cost-efficient training courses at appropriate locations, as advised by the appropriate body, to encourage uniformity of instrument operation among sites.
- 4.6. All activities associated with the implementation of a GRUAN site shall be the primary responsibility of the country hosting that site and should, as far as possible, be supported through state, national, territorial, or regional multi-national funding.

5. Partner networks

- 5.1. GRUAN will not operate in isolation of existing networks but shall collaborate and liaise with existing networks to leverage skills and expertise, avoid undue duplication of effort, and ensure that GRUAN data products are tailored to meet the needs of partner networks.
- 5.2. The WG-GRUAN will closely coordinate with the governing bodies of partner networks with respect to the development of GRUAN operations, particularly at the GRUAN sites where GRUAN operations coincide with other network operations. The WG-GRUAN shall then identify methods for improving liaison with partner networks to ensure close communication between GRUAN and those networks particularly at the expert team level.
- 5.3. Where possible, GRUAN will identify, adopt, and, if necessary, extend tools and methodologies that have been developed in existing networks that can serve the needs of GRUAN. In particular, quality assurance/quality control (QA/QC) procedures developed in existing networks shall, where suitable, be adopted in GRUAN. Where networks are working towards QA/QC procedures, GRUAN should partner with these networks to develop systems that meet the operational requirements of both parties. Where GRUAN develops QA/QC techniques that improve on those used elsewhere, those techniques will be openly shared with partner networks.
- 5.4. The WG-GRUAN shall establish close connections to the relevant satellite technical programmes, such as SCOPE-CM (Sustained, Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring), GSICS (Global Space-based Inter-Calibration System) and other product generation and validation programmes. WG-GRUAN members will be assigned to liaise with key partners within the satellite community to ensure that GRUAN data products are tailored, where possible, to meet the needs of this community.
- 5.5. GRUAN shall be operated in such a way that homogeneity of measurements across the network will ensure that significant site-specific differences between GRUAN data and those from satellite-based instruments do not result from the GRUAN data products.
- 5.6. GRUAN shall provide a reference-standard that will serve as a common baseline for splicing satellite-based measurement time series to create climate data records (CDRs).
- 5.7. GRUAN shall collaborate with the WMO SCOPE-CM programme to generate CDRs of upper-air ECVs and in this way ensure that any hiatus in satellite observations does not jeopardize the long-term record of changes in upper air climate, as called for in the GCOS implementation plan.
 - i) The WG-GRUAN shall establish active links to the following partner networks:
 - ii) GOS (Global Observing System)
 - iii) GUAN (GCOS Upper-Air Network)
 - iv) GAW (Global Atmospheric Watch)
 - v) NDACC (Network for the Detection of Atmospheric Composition Change)

- vi) SHADOZ (Southern Hemisphere Additional Ozonesondes)
- vii) ARM (Atmospheric Radiation Measurement) Programme
- viii) BSRN (Baseline Surface Radiation Network)
- ix) AERONET (AErosolROboticNETwork)
- x) EARLINET (European Aerosol Research Lidar Network)

6. Reference measurements and managing change

- 6.1. All GRUAN measurement systems shall make reference quality measurements, i.e. that at a minimum, the uncertainty of the measurement (including corrections) has been determined, the entire measurement procedure and set of processing algorithms are properly documented and accessible, and that every effort has been made to tie the observations to an internationally accepted traceable standard.
- 6.2. For GRUAN systems making vertically resolved measurements, uncertainties shall also be vertically resolved such that each datum in a profile is treated as a single measurement result requiring both the measurement and its uncertainty.
- 6.3. The methods by which the measurements are made, and resultant data products derived, shall be documented and archived for future reference and reprocessing as necessary. Metadata describing how the measurements were made, what corrections were applied, what changes occurred in the instruments, and the data reduction algorithms during the observation and post-observation periods, shall be archived.
- 6.4. GRUAN shall operate such that changes in instrumentation, changes in operating procedures, changes in data processing algorithms and changes in operators do not introduce unidentified or unquantified temporal or spatial discontinuities or biases into GRUAN data products.
- 6.5. When changing instrument types, operating procedures, or data processing algorithms, GRUAN shall develop and document or adopt the necessary procedures to fully characterize any systematic biases between the old and new measurement systems so that adjustments can be made to the historical data to maintain a long-term homogeneous measurement series. The procedures used shall be informed by robust scientific investigations including a detailed understanding of the uncertainty limitations of the instrumentation.
- 6.6. Data reduction processes and data archiving shall be designed such that reprocessing of historical data can be easily and quickly conducted i.e. that the original raw data can be efficiently reprocessed, as required, to form a single homogeneous time series.
- 6.7. Every reprocessing generating a new homogeneous time series shall be reflected in an increment in the data version. Such updates shall be communicated to users who have accessed earlier versions of the data and registered to receive notifications of updates.
- 6.8. GRUAN shall work with CIMO, CBS and HMEI to make manufacturers aware of GRUAN's needs and to understand the constraints on instrument performance that manufacturers face.
- 6.9. GRUAN shall work with CIMO to encourage and coordinate instrument intercomparisons to develop the in-depth understanding required to manage changes from one instrument to another and to inform decisions on the relative advantages and disadvantages of changing instrumentation.

7. Measurement uncertainty

- 7.1. The three primary steps for managing measurement uncertainty in GRUAN are:
- 7.2. Describe/Analyse all sources of measurement uncertainty to the extent possible.
- 7.3. Quantify/Synthesize the contribution of each source of uncertainty to the total measurement uncertainty.
- 7.4. Verify that the derived net uncertainty is a faithful representation of the true uncertainty.
- 7.5. All GRUAN observations must be reported together with an uncertainty budget. The Lead Centre and/or the designated central processing facility for a given set of measurements or instruments shall liaise with a GRUAN site in developing this uncertainty budget, as agreed with the relevant task team.
- 7.6. The uncertainty in the latitude, longitude, altitude and time coordinates associated with each measurement must also be considered when identifying and describing sources of measurement uncertainty.
- 7.7. To reduce operational measurement uncertainties, optimal standard operating procedures shall be identified by the GRUAN Lead Centre or relevant task teams and disseminated to all sites making that particular measurement and adopted where practical, with any exceptions clearly documented and justified.
- 7.8. The Lead Centre shall be responsible for ensuring that estimates of measurement uncertainty are validated through suitable procedures developed by, or identified by, nominated task teams. The cross-checking of redundant measurements for consistency is also an essential part of the quality assurance process.
- 7.9. Combining redundant measurements into a single GRUAN data product can reduce uncertainties in the derived product.

8. Site assessment and certification

- 8.1. Site assessment and certification falls within the mandate of the WG-GRUAN together with the GRUAN Lead Centre. Site assessment and certification shall be consistent with the guidance developed and standard agreed with CIMO (WMO-No. 8) and CBS (WMO-No. 488 and WMO-No. 544).
- 8.2. Sites propose specific measurement programmes for inclusion in GRUAN. Subject to approval by the WG-GRUAN, it is these measurement programmes that are expected to conform to the operating protocols defined in this document and in the GRUAN Guide to Operations. Proposed measurement programmes will form the basis for assessing the added value that the site brings to the network.
- 8.3. The WG-GRUAN will exercise its discretion in evaluating the proposed inclusion of a site against the criteria defined here and in the GRUAN Guide to Operations.
- 8.4. To identify potential operational anomalies early, sites will be reviewed annually. A typical review will include consideration of the GRUAN site annual report and an assessment of data from the site.
- 8.5. Where site assessments identify measurement programmes that consistently fall short of GRUAN operating standards, GRUAN certification of that programme (see Section 5.6 of the GRUAN Guide to Operations) will be suspended.
- 8.6. If all measurement programmes at a site lose their GRUAN certification, or if a site cannot meet the minimum requirements, the site will be suspended from GRUAN.

GRUAN sites shall:

- 8.7. Provide reference quality observations, including uncertainty estimates for each datum. Profile measurements require uncertainty estimates for each measurement point along the profile.
- 8.8. Provide access to raw data and assure long-term storage of the raw data either at the site, another GRUAN facility, or at another internationally accessible archive.
- 8.9. Provide complete metadata for each measurement.
- 8.10. Perform regular traceable pre-launch ground checks for balloon-borne systems and record the results. Other instruments which provide vertical profiles extending from the surface require regular checks to assure correct operation.
- 8.11. Provide redundant reference observations of the ECVs selected for measurement at the site at intervals sufficient to validate the derivation of the uncertainty in the primary measurement.
- 8.12. Provide annual reports summarizing GRUAN operations at the site.
- 8.13. Conduct measurement programmes with an operational philosophy of continually striving to sustain the measurement quality at a given level. If improvements to measurement accuracy can be achieved, these need to be documented and their adoption agreed with the Lead Centre.
- 8.14. Manage changes in instrumentation, operating procedures, and processing algorithms proactively to avoid introducing spatial or temporal biases in GRUAN data products.
- 8.15. Actively communicate with other GRUAN groups such as the Lead Centre, WG-GRUAN, task teams and/or other sites, (e.g. through participation in meetings, responding to communications, blog postings etc.).
- 8.16. Maintain reference instruments and working standards for validating and, where possible, calibrating the measurement systems.

Once a site has committed to operating a set of measurement programmes under these protocols the added value that a site brings to GRUAN will be a function of:

- 8.17. The extent to which a site can fulfil the measurement programmes expected of a GRUAN site, as defined above and in the GRUAN Guide to Operations.
- 8.18. The extent to which the site measurement programmes provide measurements in regions, or of atmospheric phenomena, which were not previously sampled.
- 8.19. The extent to which a site brings unique observational and/or analysis capabilities to the network as a whole and the likelihood of being able to propagate those capabilities across other sites in the network.
- 8.20. The extent to which a site is prepared to forgo locally established operating procedures and adheres to the standard operating procedures established by the Lead Centre.
- 8.21. The availability of historical measurements that conform to the GRUAN standard or that can be processed in such a way that they conform to the GRUAN standard.
- 8.22. The extent to which a site can commit to a multi-decade programme of measurements.
- 8.23. The extent to which a site can provide redundant observations of the priority one variables (temperature, pressure and water vapour).
- 8.24. The extent to which a site is capable of measuring other ECVs identified in GCOS-112 as being desired quantities.

- 8.25. The level of institutional support for the site and commitment to maintaining long-term reference quality measurement programmes.
- 8.26. The level of institutional support for the site (and any partner institutions) to undertake fundamental scientific research in support of GRUAN objectives or using GRUAN data.

Certification of GRUAN sites will not be a single event. In addition to the regular annual review, periodic (e.g. every 3-4 years) complete auditing of the measurement programmes included in the GRUAN certification for a site shall be conducted by WG-GRUAN in consultation with the Lead Centre to ensure that the programmes continue to meet GRUAN standards.

9. Instrumentation

- 9.1. Periodic (every 3-4 years) reviews of instrumentation likely to be of use within GRUAN shall be undertaken by all task teams with an instrument focus. A written review submitted to the Lead Centre can then inform discussion related to deployment of new instrument types across the network.
- 9.2. To the extent possible, the number of different types of instruments and associated measurement techniques employed across GRUAN must be minimized to encourage homogeneity of data products and to reduce administrative overhead. However, every effort must be made to ensure that GRUAN operations are not dependent on a single instrument manufacturer. Specifically, for radiosonde consumables, it is essential to use instruments from more than one manufacturer to minimise the likelihood of disruption to GRUAN operations from production failures, introduced design weaknesses in the radiosondes, or changes in manufacturing procedures.
- 9.3. A number of factors guide the selection of instruments for use in GRUAN including, but not limited to, instrument heritage, sustainability of measurement systems, tractability of measurement uncertainty, information content, manufacturer support, and site location.
- 9.4. Redundancy in measurement systems at sites shall be used to validate derived measurement uncertainties by comparing coincident measurements against their stated uncertainties, and to detect any unresolved changes in the systematic bias between observing systems. Cross-checking of redundant measurements for consistency shall be an essential part of the GRUAN quality assurance procedures
- 9.5. Independent measurements of the same (or related) variables shall be reported in a consistent way.
- 9.6. Where a cluster of instruments at different locations is operating as a single GRUAN site, and a measurement made at one location is used to simulate a measurement made elsewhere, the uncertainty on the simulated measurement must incorporate the uncertainty of the original measurement and the additional uncertainty introduced by the simulation algorithm. It is necessary to document how the lack of co-location contributes to uncertainty on data products derived from spatially distributed instruments. It must be indicated which observations are made from each location, and the data shall not be merged as though they were all from one location without addressing the resultant increase in uncertainty.
- 9.7. Operational procedures shall, to the extent practical, be harmonised across GRUAN so that, as far as the quantitative description of sensor drift over time allows, a measurement at one site is comparable to a measurement of the same variable at a different site. When identical instruments are deployed at multiple sites, they shall use the same calibration procedures.

- 9.8. Where relevant to a particular measurement system, GRUAN sites shall maintain a “GRUAN site working standard” for each primary environmental variable, e.g. a thermometer periodically calibrated to a National Metrology Institute or other accredited agency standard to ensure traceability to an SI standard.
- 9.9. The Lead Centre shall implement a mechanism to address the compatibility with the rest of the network of those systems not yet traceable to SI standards.
- 9.10. Each site shall maintain metadata records and provide these to the GRUAN archives. Copies of calibration certificates shall be submitted to the GRUAN metadatabase.

10. Measurement scheduling

- 10.1. To provide a high quality data product and a backbone to the wider GUAN, a programme of regular, year-round, high quality radiosonde measurements shall be maintained. For temperature and humidity, the radiosonde measurements with the lowest uncertainty are obtained in the dark. The nature of this programme at each site will be negotiated with the Lead Centre, and will depend on the availability of suitably skilled staff at the site.
- 10.2. The programme of operation of remote sensing systems at a site will be agreed with the Lead Centre and those sites which are included in GRUAN because of the deployment of specialised systems (balloon-borne, or remotely sensed), may be allowed to fly fewer radiosondes than those sites making core radiosonde measurements.
- 10.3. Where changes to scheduling would increase the utility of the measurements without compromising GRUAN’s goals, schedules should be adapted to meet the needs of other end-users e.g. the timing of a daily measurement may be shifted to coincide with a satellite overpass and in this way provide valuable high quality data for satellite validation.

11. Data management

- 11.1. In support of data archiving and data reprocessing, the GRUAN Lead Centre, and centralized GRUAN data processing facilities, shall maintain a long-term, secure database of raw data from all instruments contributing measurements to GRUAN. The Lead Centre shall also maintain a centralized GRUAN metadatabase which holds all information pertaining to sites, measurement systems and instrumentation; specific properties of measurement systems used in GRUAN; details of the processing applied to GRUAN data streams, and all details related to product files.
- 11.2. All measurements made with a specific instrument at multiple GRUAN sites shall be processed centrally, either at the Lead Centre, or at a designated central data processing facility.
- 11.3. Dissemination of GRUAN data products to end-users/customers shall occur through an official GRUAN data centre which is currently hosted at NCDC (NOAA’s National Climatic Data Center)⁵. These data will be accessible and discoverable through the WIS. However, the Lead Centre shall also maintain a database of all versions of GRUAN data so that older versions of data are accessible to all users of GRUAN data products.
- 11.4. Different levels of GRUAN data must be defined to distinguish among different steps in the processing of a GRUAN data product. The NRTD (near real-time data) product specifies measurements made at a GRUAN site, processed with automated techniques, for near real-

⁵ Or another dedicated centre/portal resource discoverable through the WIS. Any such change shall be clearly documented.

time dissemination on the WMO WIS. Because these data will not have been subjected to the time-intensive and rigorous QA/QC procedures employed within GRUAN, they shall not be labelled as “GRUAN data”.

- 11.5. A GRUAN data dissemination policy shall protect the publication rights of the generators of measurements without compromising the free exchange of the data.

12. Post processing analysis and feedback

- 12.1. Users of GRUAN data must document the version of data used to ensure that the analyses can be independently replicated. Key to this process will be the ability to make users aware of updated versions of data, previously accessed, and now becoming available.
- 12.2. A facility that allows data users to report potential problems found in GRUAN data shall be designed and implemented. This facility shall be regularly updated to meet the needs of the user community as the serving of GRUAN data products evolves.
- 12.3. The GRUAN quality control system shall include procedures that add to the measurement and quality control process to prevent the errors from recurring.

13. Quality management

- 13.1. The GRUAN quality management policy shall achieve a level of data quality that allows the primary goals of GRUAN to be met for all potential users of GRUAN data products.
- 13.2. An important aspect of quality management is publication in the international peer reviewed literature of GRUAN’s methods, data, underlying analyses and scientific rationale for decisions made.
- 13.3. Laboratory tests and intercomparisons are fundamental methods for establishing and confirming uncertainty estimates for GRUAN data products. Field experiments are particularly useful for assuring the quality of GRUAN data products.
- 13.4. The use of GRUAN data in meteorological analyses and reanalyses also adds to the assurance of GRUAN data quality since the measurements, with their uncertainties, can be tested for comparability with the data assimilation model values in an assimilation setting within the known internal variability of the system.
- 13.5. The purpose of quality management is to ensure that GRUAN data meet the requirements in terms of uncertainty, resolution, continuity, homogeneity, representativeness, timeliness, format etc. for their intended use, at a minimum practicable cost.
- 13.6. Establishing close working relationships with instrument manufacturers, metrologists through National Metrological Institutes, and the BIPM (Bureau International des Poids et Mesures)⁶, will also be central to quality assurance within GRUAN.
- 13.7. Performance monitoring within GRUAN will primarily be the responsibility of the Lead Centre, but where other specialists may be co-opted to assist in performance assessments.

⁶International Bureau of Weights and Measures.