

**WORLD METEOROLOGICAL ORGANIZATION
&
GLOBAL CLIMATE OBSERVING SYSTEM**

**WIGOS Pilot Project Meeting
on GRUAN Observing Practices and Governance**

(Geneva, Switzerland, 25 - 27 January 2012)

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EXECUTIVE SUMMARY

This report provides a summary of the WIGOS Pilot Project meeting on GRUAN Observing Practices and Governance, held at WMO Headquarters in Geneva, Switzerland from 25 to 27 January 2012.

The meeting reviewed the governance structure of GRUAN and agreed to small changes in governance that would:

- better enable WMO to provide guidance to GRUAN on operational practices and procedures, to assist GRUAN to extend its operations to include a near-real-time operational model of data delivery in the next few years; and
- in doing so, assist in nurturing additional participation of WMO Members in the desired GRUAN network expansion.

The meeting also reviewed the draft GRUAN Manual, and agreed on changes that would be required to improve the alignment of the GRUAN documentation with WMO's regulatory material for WIGOS. The meeting acknowledged that the implementation of the agreed changes would require additional resourcing, which WMO agreed to provide.

Finally, the meeting discussed and agreed on the GRUAN information that was required to be included in the WIGOS regulatory material, and those parts of the WIGOS documentation that would be affected.

GENERAL SUMMARY

1. OPENING OF THE SESSION

The Expert Meeting on the WIGOS Pilot Project on the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) Observing Practices and Governance, jointly organized by GCOS and WIGOS/CBS/CIMO, was held at WMO Headquarters in Geneva, Switzerland, from 25 to 27 January 2012. This report summarizes key discussions and outcomes of the meeting.

The meeting was opened by Dr Carolin Richter, the Director of the GCOS Secretariat. Dr Richter welcomed participants to Geneva and expressed the importance of GRUAN as a pilot project, as one of the first hybrid networks between research and operational meteorological services being designed for climate observation. For this reason, a good outcome of the meeting would prove the utility of the GRUAN concept for the climate community.

The meeting was chaired by Dr Jochen Dibbern, co-chair of the CBS Open Programme Area Group on the Integrated Observing System (OPAG-IOS) and also responsible for operational activities of the German Meteorological Service, DWD.

The meeting agenda is given in [Annex I](#) and the list of participants is given in [Annex II](#).

2. UPDATE ON GRUAN

Dr Peter Thorne, co-chair of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) Working Group on Atmospheric Reference Observations (WG-ARO), presented an overview of the GRUAN concept, network status and research activities, to provide the meeting participants with some common background.

The three main objectives of GRUAN are to:

- provide long-term high-quality upper-air climate records;
- constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks);
- fully characterize the properties of the atmospheric column.

Dr Thorne informed the meeting that GRUAN currently comprises 15 stations, about half of which are operated by National Meteorological and Hydrological Services (NMHSs), and that the GRUAN Implementation Plan¹ envisages a global network of eventually 30-40 stations. Dr Thorne summarized GRUAN's defined tasks and goals, emphasizing the importance of GRUAN for establishing traceable atmospheric profile measurements, and providing vertically resolved error estimates, so as to resolve ambiguities in the global climate record and to reduce the uncertainty of climate trend estimates. The uncertainties of upper-air climate records have typically been found to be as large as the underlying climate-change signal itself. This has motivated GRUAN's rigorous approach to uncertainty assessment, which involves consideration of data obtained from different types of instrumentation.

It was noted that a GRUAN reference observation:

- is traceable to an SI unit or an accepted standard;
- provides a comprehensive uncertainty analysis;
- is documented in accessible literature;
- is validated (e.g. by intercomparison with redundant observations); and
- includes a complete metadata description.

¹ GCOS-134; available under: <http://www.wmo.int/pages/prog/gcos/Publications/gcos-134.pdf>

Dr Thorne pointed out the GRUAN focus on provision of reference observations, and described the requirements for this, including full specification of measurement uncertainty, the need for data redundancy, and for data consistency. Dr Thorne noted that production of such high-quality data requires centralized processing, cross-validation using independent measurements, capture and archival of comprehensive metadata, and careful manual quality control.

Dr Thorne agreed that the original vision for GRUAN was for it ultimately to comprise a long-term operational network, so there is a recognized need for GRUAN to extent its modus operandi to include a more operational mode in the near future. However, Dr Thorne expressed concern that significant challenges exist for the provision of GRUAN-quality data in near-real-time (NRT), due to:

- the aforementioned GRUAN requirement for complete specification of measurement uncertainty;
- the additional resources likely to be required to implement an operational NRT schedule at many GRUAN stations; and
- continuing high performance at some GRUAN sites being dependent on the ongoing strong engagement of individual station staff.

After some discussion, the meeting agreed that, for delivery of some services, such as Numerical Weather Prediction (NWP), data of GRUAN quality was not required. If GRUAN sites could transmit, in NRT, data of operational quality (e.g. radiosonde profiles processed using standard commercially available software), GRUAN would become a valuable source of information, not only for the climate community, but also for the provision of a wide range of meteorological services. It is this increased use of the data that is seen as being likely to provide additional encouragement for WMO Members, not only to continue funding GRUAN sites long into the future but also to support the sought-after expansion of the GRUAN network.

Dr Thorne described the structure of the GRUAN programme, its interactions with the expert and user communities and its governance model. He concluded by stressing the following:

- GRUAN is primarily a climate reference network;
- Data that can be processed in NRT are not GRUAN-quality data, and should not be labeled as such;
- Many of the sites do not answer solely to GRUAN, but to multiple stakeholders, so in some cases GRUAN can only make recommendations and not resolutions;
- Much of GRUAN's success to date is attributable to the goodwill of participants. It will be important for GRUAN's ongoing success to retain that element of good will;
- Extension of GRUAN to an operational model with NRT data delivery will not be a quick process: this is just the start of the road.

Further discussion followed Dr Thorne's presentation on the topic of the viability of transmission by GRUAN stations of data in NRT. The main points from this discussion were:

- The meeting agreed NRT data transmission is intended to mean transmission as soon as is practicable after an observation (such as a vertical profile) has been completed, i.e. within an approximately two hour operational window;
- The large amount of meta-data associated with fully processed GRUAN data profiles exceeds the current capacity of BUFR code tables, so presents challenges for BUFR transmission of GRUAN-quality data;
- GRUAN sites should be required to provide data of operational quality in NRT wherever possible (noting that non-compliance with this requirement would not automatically exclude a site from GRUAN participation);
- This operational quality data should be flagged as such prior to transmission in NRT to avoid confusion with GRUAN-quality data processed later in non-real-time;
- An intermediate GRUAN data level definition is required to describe such intermediate quality, best-available NRT data;

- In return for NRT data transmission, NWP centres may be able to provide additional information on data quality produced as a by-product of the data assimilation process (further consideration is required of the mechanism for this, and GRUAN will look to WMO to provide leadership on this matter);
- It is likely that the costs associated with transitioning to an operational NRT programme at many GRUAN stations would not be large;
- It is possible that at many sites little more would be required for extension to NRT operations than assignment of a WMO station number (if presently unassigned), NRT data transmission via the WIS, and training, as required, in how to routinely carry this out;
- Any such changes to the existing GRUAN programme must be made in full consultation with current GRUAN participants.

3. UPDATE ON THE DEVELOPMENT OF THE GRUAN MANUAL

Dr Greg Bodeker briefed meeting participants on the timing and recent status of the development of the GRUAN Manual. Dr Bodeker stressed that he was speaking at this meeting as the coordinating author of the Manual and not in his role as co-chair of the WG-ARO. He explained the process and expected timing for drafting the GRUAN Manual, for which specific Task Teams provided input in their field of expertise in order to define open questions on how to best design GRUAN measurements, for example in terms of measurement scheduling. Dr Bodeker's plan was to finalize the current draft version with his remaining time under contract, to circulate it within the GRUAN community, and to seek its acceptance at the upcoming meeting of the WG-ARO and 4th Implementation-Coordination Meeting (ICM-4), to be held 5-9 March 2012 in Tokyo, Japan. Formal endorsement of the GRUAN Manual requires the unanimous agreement of the WG-ARO, and the agreement of 2/3 of the GRUAN sites².

All GRUAN sites, both existing and new, will be required to undergo regular assessments by the WG-ARO as outlined in the site certification and assessment document, which is part of the draft GRUAN Manual. In addition to the GRUAN Manual, operational regulations exist in the form of GRUAN Technical Documents, available on the GRUAN homepage³. These Technical Documents can be modified independently and, if necessary, more quickly than the Manual, without requiring the more rigorous approval process associated with changes to the Manual itself. The intention is that, once the Manual is endorsed, it is expected to remain static for at least two years.

Dr Bodeker described the balanced approach he had taken to his task, to avoid over-regulation and a resulting risk of disenfranchisement of sites which might cause them to leave GRUAN, while being sufficiently prescriptive to guarantee efficient and effective network operations. An iterative process of seeking feedback from the GRUAN community to arrive at the optimal level of prescription has led to the current draft.

The current draft Manual excludes general information already contained in existing WMO regulatory material, to keep the Manual as brief as possible and avoid duplication.

The meeting thanked Dr Bodeker for his presentation and his efforts to date in drafting the GRUAN Manual.

It was noted that WMO input to the meeting suggests significant changes be made to the existing draft in order for the Manual to provide the information required to facilitate preparation of WMO regulatory material associated with the implementation of the WMO Integrated Observing System (WIGOS). It was agreed that if the meeting concurred that such changes would be required (to be considered under a subsequent Agenda Item – see [Section 8](#) below), additional resources would be required to implement them, in view of the short time remaining under Dr Bodeker's current contract.

The WMO Secretariat agreed to seek approval off-line for WMO to resource the additional work, given that the changes had been proposed by WMO, and to report back to the meeting before its closure.

² GCOS-149; available at: <http://www.wmo.int/pages/prog/gcos/Publications/gcos-149.pdf>

³ <http://gruan.org>

Further discussion took place regarding WG-ARO's concern about disenfranchisement of GRUAN stations should the GRUAN Manual be too prescriptive. An overly prescriptive Manual may cause some of the original sites to become disenfranchised, although most sites operated by NMHSs would expect the Manual to be prescriptive so would be unlikely to be disenfranchised by this. On the other hand, an overly accommodating Manual would lead to an ineffectual network. It was noted that compliance with a more prescriptive Manual would have funding implications, which may be more easily accommodated by some sites than others.

4. WIGOS PILOT PROJECT FOR GRUAN & STATUS OF WIGOS IMPLEMENTATION

Ms Anna Mikalsen from the GCOS Secretariat described activities under the WIGOS Pilot Project for GRUAN, followed by a briefing from Mr Igor Zahumensky from the WIGOS Planning Office on what WIGOS involves. The WIGOS Pilot Project for GRUAN commenced in 2009 and ended in 2011 with the WMO Congress' decision to adopt the WIGOS concept and to commence its transition from planning to implementation phase.

The expectations for the Pilot Project were to:

- Undertake preparation of regulatory material for GRUAN;
- Partake in assessments of best instrumentation by means of major intercomparison campaigns;
- Ensure the availability of high-quality consistent atmospheric profile data;
- Provide an interface for GRUAN to the implementation of WIGOS, to WMO in general, and to other WIGOS Pilot Projects, in particular to the Global Space-based Inter-Calibration System (GSICS);

Most of the agreed deliverables were completed between 2009 and 2011, including:

- Development of the over-arching GRUAN Implementation Plan
- Development of a common GRUAN terminology for measurement uncertainty and stability ('What constitutes a GRUAN measurement?')⁴
- Participation of GRUAN scientists in the 8th WMO Intercomparison of High Quality Radiosonde Systems, Yangjiang, China, 12 July – 3 August 2010⁵.
- Development of a proposal to define data dissemination among all GRUAN partners, including GRUAN metadata congruent with WIS metadata standards. The first GRUAN data became available from the GRUAN Lead Centre (LC) and at the NOAA National Climatic Data Center (NCDC)⁶ in 2011 and is discoverable via the WIS catalogue⁷.

Two items are still in progress:

- The integration of data from further instrument types, in particular remote-sensing instruments, such as Lidars, Frostpoint Hygrometer Sondes or Global Navigation Satellite System (GNSS)-Precipitable Water, is still in progress..
- Development of a mature draft GRUAN Manual of Operations. This activity was marked from the beginning as dependent on the availability of support, e.g. by CBS and CIMO experts, because neither the GRUAN LC nor the WG-ARO had the necessary expertise and resources to take on this task. Dr Greg Bodeker was hired as a consultant by the GRUAN LC to resolve this resource issue.

According to the regular Pilot Project reports, the main experiences gained were that the existence of an over-arching Implementation Plan has given a better sense of direction to the GRUAN activity as a whole, and that working with CIMO on the radiosonde intercomparison campaign has been an

⁴ Peer reviewed paper published in 'Atmospheric Measurement Techniques' ('A guide for upper-air reference measurements': <http://www.atmos-meas-tech-discuss.net/3/1807/2010/amtd-3-1807-2010.html>)

⁵ http://www.wmo.int/pages/prog/www/IMOP/publications/IOM-107_Yangjiang.pdf

⁶ GRUAN data are available via: <ftp://ftp.ncdc.noaa.gov/pub/data/gruan/>

⁷ The WIS catalogue can be searched for example via the Global Information System Centre (GISC) maintained by DWD: http://gisc.dwd.de/GISC_DWD/start_js_JSP.do

effective mechanism to communicate with manufacturers and interface with the operational community. However, implementation of a substantial network always takes longer than envisaged and requires multiple perspectives.

Mr Zahumensky concluded by noting that GRUAN is considered by WMO as an integral component of WIGOS, and its operational practices are to be included in the WMO Regulatory Material, in particular the forthcoming Manual and Guide on WIGOS.

5. WMO REGULATORY MATERIAL

Dr Roger Atkinson from the WMO Observations and Information Systems Department provided a brief presentation on what is required for integration of GRUAN documentation into WIGOS regulatory material, but noted that progressing this task will be subject to the meeting reaching agreement on WMO taking on a more prominent role in GRUAN governance (see [Section 6](#) below). He added that the primary role seen for WMO in GRUAN is to provide advice on the operational component of GRUAN (as opposed to the research component, which is seen to be working well under the guidance provided primarily from WCRP and GCOS through AOPC).

Dr Atkinson advised the meeting that there are three existing WMO documents which require the addition of GRUAN information:

- WMO Manual on the GOS⁸ (General purpose & guidance)
- Guide on the GOS⁹ (More specific purposes & guidance)
- CIMO Guide¹⁰ (Instrument-level guidance)

As part of the implementation of WIGOS, the two GOS documents will be used as the basis for the corresponding WIGOS regulatory documents, augmented to encompass the somewhat greater scope of WIGOS, while the CIMO Guide will continue to be used. Hence, the immediate requirement is to insert relevant GRUAN information into the existing GOS and CIMO documents.

Regarding the Manual on the GOS, Volume I (Global Aspects) requires inclusion of GRUAN material in Parts I and III. Part I, which concerns general principles, requires information on the purpose of GRUAN, its organization and design, and its implementation. In Part III, which contains more specific information on the surface-based subsystem of WIGOS, GRUAN information is required as follows:

- Composition of the Subsystem
 - Under climatological stations (GUAN), add GRUAN
- Implementation of the Subsystem
 - Under networks of observing stations, add GRUAN
 - Under observing stations
 - Add a description of GRUAN stations and Members' obligations relevant to GRUAN
 - Location and composition of GRUAN (spacing, obs. Programme),
 - Frequency and timing of GRUAN observations
- Equipment and Methods of Observation, add:
 - General requirements of a GRUAN station
 - (e.g., siting and exposure, calibration, inspection, observers, etc.)
 - General requirements of GRUAN instruments
 - (e.g., comparison and traceability)
 - Information on GRUAN observations (e.g., details on how measurements and observations should be made for defined variables)

Regarding the Guide on the GOS, Part III:

Surface-based Subsystem requires the addition of GRUAN material, as follows:

⁸ WMO-No. 544; available under: http://www.wmo.int/pages/prog/www/OSY/Manuals_GOS.html

⁹ WMO-No. 488; available under: http://www.wmo.int/pages/prog/www/OSY/Guides_GOS.html

¹⁰ WMO-No. 8; available under:

http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html

Part III: The Surface-based subsystem

- Design of GRUAN network
- Planning of GRUAN network and stations
- Management of GRUAN network:
 - Administrative arrangements and operational tasks,
 - Staff,
 - Logistics and supplies,
 - Establishment of new station,
 - Regular inspections,
 - Procurement of instruments,
 - Instrument check, maintenance, calibration,
 - Coordination, planning and budgeting,
 - Network performance monitoring.
- GRUAN Stations:
 - Siting and location,
 - Observing & measurement area,
 - Premises;
 - Station staff,
 - Staff training,
 - Station identification,
 - Telecommunications,
 - Quality standards,
 - Data processing and archiving,
 - Etc.

Regarding the Guide to Meteorological Instruments and Methods of Observation (CIMO Guide) (WMO-No. 8), addition of GRUAN material is required in Part 1, Chapter 12, and in Part II Chapter 5, as follows:

Part I, Chapter 12 Measurement of upper air pressure, temperature, humidity

Insert text relevant to GRUAN into sections:

- 12.1 General (Definitions, units, requirements, methods of measurements)
- 12.2 Radiosonde electronics
- 12.3 Temperature sensors
- 12.4 Pressure sensors
- 12.5 Relative humidity sensors
- 12.6 Ground station equipment
- 12.7 Radiosonde operations
- 12.8 Errors of radiosondes
- 12.9 Comparisons, calibration, maintenance
- 12.10 Computations and reporting procedures

Part II, Chapter 5 Special profiling techniques for the boundary layer and the troposphere

Insert text relevant to GRUAN into Section 5.2 Ground-based remote sensing techniques:

- Acoustic sounders (sodars)
- Wind profiler radars
- Radio-acoustic sounding systems (RASS)
- Microwave radiometers
- Laser radars (lidars)
- Etc.

6. DISCUSSION ON GRUAN GOVERNANCE AND MANAGEMENT

Dr. Atkinson introduced the draft outline of a modified GRUAN structure that had been circulated before the meeting. The proposed organigram was discussed at length.

The meeting expressed some concern that the proposed modified structure would add a significant reporting burden to members of WG-ARO. It was pointed out, though, that the incremental reporting burden on WG-ARO back to the WMO Technical Commissions (TCs) would be provided by the TC representatives on WG-ARO, so would place no additional burden on other members. It

was added that this reporting would ensure that the WMO TCs would remain abreast of GRUAN developments, enabling them to continue to foster support amongst WMO Members for ongoing operation of GRUAN and for the establishment of new sites.

Several modifications to the diagram were proposed, with the meeting ultimately agreeing to the modified organigram shown in [Annex III](#).

The only significant change in the agreed governance structure from the existing structure is the strengthening of WMO input into WG-ARO to assist in the provision of guidance regarding operational aspects of GRUAN. This entails direct representation on WG-ARO of the four relevant WMO TCs:

- 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).

The president of CIMO as well as the chief of the Observing Systems Division (OSD) have been ex-officio members of the WG-ARO since its inception. By adding representatives from CBS, CAS and CCI, WMO would be able to better ensure ongoing support from its Members for the GRUAN programme, and would be more likely to be able to assist with the establishment of additional measurement sites by Members.

Meeting participants, including, inter-alia, WG-ARO co-chairs, head of the Lead Centre and chair of AOPC were unanimously of the view that these changes were likely to be acceptable and in the best interests of GRUAN. Dr. Adrian Simmons thus provided inter-sessionally AOPC's endorsement of the proposed changes on behalf of the committee. Recognizing that this has implications for WG-ARO membership and terms of reference Dr Simmons will request AOPC to revise these at its upcoming session (AOPC-XVII, 30 April – 3 May in Geneva), to account for these changes. Non-binding advice in this regard will be sought from members of WG-ARO at the forthcoming Implementation and Coordination Meeting (ICM-4, March 5th-9th, Tokyo) at which the justification for the changes will be outlined and the opportunity for input afforded to WG-ARO membership prior to formalization of revised terms of reference.

Dr Bodeker was requested to replace the existing Figure 1 in the draft GRUAN Manual, which shows the GRUAN governance structure, with the agreed version of the modified organigram and suitable accompanying text, in the next version of the draft Manual.

The WMO Secretariat was requested to inform the respective Presidents of TCs of the proposed changes to WG-ARO membership and to request nominations of representatives to serve on WG-ARO as soon as possible. The upcoming meeting of Presidents of TCs (30-31 January 2012 in Geneva) would be an appropriate opportunity to approach the Presidents in order to receive their nominations in time for the AOPC panel meeting at the end of April.

Some discussion followed on the need for GRUAN sites to develop a stronger operational focus in future, in order to deliver on GRUAN's first objective of providing high-quality time series for climate-related analysis, and at the same time extend their programmes to make NRT data available to other services, so helping to ensure ongoing financial support from stakeholders. Though this general need was recognized by the meeting, it was noted that some current sites may be resistant to the implementation of NRT operations. On the other hand, many future sites may have less capacity for a research contribution to GRUAN than the current sites and instead be better suited to fulfilling a purely operational role.

7. GRUAN MANUAL AND GUIDE: BACKGROUND ISSUES FOR DISCUSSION

During the first day of the meeting, it became clear in general discussion that significant differences in views on one matter or another were in most cases due to a lack of common ontology. To eliminate misunderstandings prior to more detailed consideration of the draft GRUAN Manual and WIGOS regulatory material, the Chairman asked the participants to nominate any topics that would

benefit from separate discussion. Twelve topics were suggested, and each was then considered in turn.

1. Definition/meaning of 'GRUAN operational' versus 'NRT operational' versus 'research':

It was noted that simple fulfillment of the three GRUAN objectives does not necessarily require data to be delivered in NRT, and that it is not currently possible, in any case, to deliver GRUAN data (of GRUAN quality) in NRT. Hence an 'operational' programme in a GRUAN-only sense simply requires routine, standardized observations, but for which the output data satisfy all the quality requirements of GRUAN data listed in Section 2 above.

On the other hand, for the data from GRUAN stations to be of optimal use to government sponsors, NRT data delivery of data is necessary, albeit of only 'operational' quality data. Hence an 'operational' programme in this more general sense is one that:

- Transmits NRT data (i.e. within a few hours of observation time) via the WIS, and
- involves routine, standardized observations.

An 'operational' programme of either type involves making observations for the sake of the measurement. It is intended that eventually all GRUAN sites will have an operational component to their overall programmes and it is highly desirable that all GRUAN programmes will also have a NRT operational component.

On the other hand, a 'research' programme is understood to be one for which requirements are less rigid, to enable experimentation with new configurations, etc., and/or where data delivery is by delayed mode. That is, a 'research' programme makes observations to seek ways to improve either the measurements or the understanding and use of them. It is hoped that most GRUAN sites will continue to have a research component to their programmes, since GRUAN was tasked from its outset to develop new observing techniques and to experiment with ways to improve on existing techniques.

It was stressed by the meeting that all GRUAN sites, irrespective of their primary focus, are and will continue to be required to comply with agreed protocols.

In regard to the requirements for the GRUAN regulatory material, those at the meeting appreciated the need for flexibility, yet recognized the competing need for the GRUAN Manual to specify mandatory requirements to fully achieve GRUAN objectives. These must include NRT data transmission (transmission within a NWP 'operational' window) in order to maximize the benefit for the country sponsoring the site. How rigorously these 'operational' requirements for timeliness might in reality be imposed may vary from site to site, but the site must deliver what is required by its sponsoring agency and as agreed with the WG-ARO as part of the site specific certification and assessment process.

The GRUAN Manual should specify requirements for full compliance in terms of timeliness, standardized procedures, observations schedules, etc, but then note that lack of compliance with some criteria will be considered on a case-by-case basis by WG-ARO under the site assessment and certification process. Failure to fully comply won't necessary rule out a site from certification, since it may in any case still be seen to be potentially important to GRUAN. Hence the GRUAN Manual, as well as specifying the requirements for full compliance, should also specify entry level requirements for GRUAN. If satisfied, a site would be eligible for consideration for inclusion in GRUAN, subject to the perceived additional value that that site brings to the network..

2. GRUAN Site Classification

With different types of sites likely to make up GRUAN in the future, the question had been raised as to whether there may be some advantage in classification of sites as either research, operations, or both. After some discussion, the meeting concluded that this might lead to discrimination against one type of station or another, so should not be pursued.

That is, there should be no such classification. Instead, a fully compliant site would satisfy all requirements, whereas all sites must satisfy at least the minimum entry level requirements.

3. How should data levels be specified for GRUAN?

There was some discussion on the desirability for GRUAN data levels to be defined using standardized definitions commonly used by other organizations or programmes. However, there is no universal definition for data levels, so instead, GRUAN has adopted its own definitions, as currently described in the 'GRUAN Data Management Manual'¹¹ but will need to ensure that these definitions are clearly defined and understood by those using GRUAN data.

It was noted that a new and as yet unspecified data level would be required to describe NRT 'best estimate' data from GRUAN sites, as distinct from the delayed mode, 'GRUAN-quality' data.

4. How much on-site processing is required and/or practical in support of NRT data availability?

There was some discussion on the requirements for implementation of NRT data transmission from GRUAN sites. It was noted that for NRT transmission, only 'best estimate available in NRT' is required, not best estimate plus estimated uncertainty, which takes time to produce. Of course, an ultimate goal of GRUAN is to transition to reporting not only best estimates, but also uncertainty information and all metadata, by capitalizing on BUFR encoding or similar formats, but for the time being this additional information is superfluous to the needs of NWP. It will be the responsibility of each site to transmit its NRT data through WIS.

The meeting noted that the costs of this extension to NRT capability would need to be very minimal or it may present difficulties for some sites, which operate on very tight budgets. It was suggested that in many cases the costs should be minimal, and in other cases, if the site and programme is formally supported by the government through the PR, then the requisite resources should in principle be made available¹². It was also suggested that it may aid the process if experts (either from the GRUAN LC, the NMHS of the host country, or the supplier of the equipment) could be made available to assist with the extension to NRT at individual sites. Alternatively, this might be coordinated either by the WIGOS Planning Office, or by the CBS or CIMO representative on WG-ARO.

In regard to the processing to be expected of NRT data prior its transmission, the meeting agreed that this might comprise the 'black box' default commercial software which accompanies most radiosonde systems, or it might be a cut-down version of the GRUAN processing stream, comprising those of the data control processes that are independent of other correlative measurements and can be performed within the operational window. It was suggested that development of such a cut-down version of the GRUAN processing software might be a task appropriate for the GRUAN LC.

A schematic of the alternative data streams envisaged, with both the current GRUAN-quality primary data stream and the proposed NRT operational data stream, are shown in Annex IV.

It was agreed by the meeting that:

- A goal of GRUAN is to implement delivery of data with preliminary quality in NRT recognizing that this may not be achievable for certain GRUAN sites or data streams.
- GRUAN will work towards increasing the rate of data that can be delivered in NRT.

5. Is the current draft GRUAN Manual too prescriptive or not sufficiently prescriptive?

It was agreed that this question had been adequately covered under previous discussion. That is, the GRUAN Manual should specify mandatory requirements for full compliance, but also specify a lower set of (minimum) entry level requirements.

With regard to needs for certification and periodic auditing of sites, this matter is covered under item 7 below.

6. Changes to the GRUAN Manual to reflect the outcomes of the preceding discussion.

¹¹ GRUAN Technical Document No. 1 (GRUAN TD-1) available under: www.gruan.org

¹² However, concern was expressed by some at the meeting that for some sites not owned by NMHSs and not formally supported by the corresponding PR, this could create problems.

Dr Bodeker reiterated that his defined task is to implement the changes to the draft GRUAN Manual agreed prior to this meeting, circulate it amongst stakeholders prior to the upcoming WG-ARO and ICM-4 meetings in Japan, and seek its approval there for general release.

He suggested that, to take into account all the changes agreed to at the present meeting, circulation of the Manual among the GRUAN community could instead be delayed, so that the changes suggested at the current meeting could be made between now and the Japan meetings. Dr Bodeker noted that he has a 1.5 hour session scheduled at ICM-4 which, if agreed, he could use to summarize the decisions of this meeting, advocate for the agreement of ICM-4 with the direction taken, and table the new revised draft Manual for review and approval out of session after the meeting by WG-ARO and site representatives². Dr Bodeker noted, however, that there is insufficient time remaining on his current consultancy contract to enable the additional work to be completed, so alternative arrangements would need to be made to see this work carried out before ICM-4.

It was suggested that it would be useful to have a WMO representative present at the ICM-4 meeting to provide additional advocacy on the suggested changes to the GRUAN regulatory material.

It was also noted that for further review of the next version of the draft Manual, it would be useful for the respective WMO TCs to nominate their representatives on WG-ARO promptly.

7. Sign-off process for the 'Site Assessment and Certification' document

The meeting addressed the need for the 'GRUAN Site Assessment and Certification' document to include a requirement for GRUAN stations to demonstrate evidence of funding and a mandate for certification. The view of the meeting was that for those GRUAN stations that are initially proposed by their respective PR with WMO, an explicit requirement was unnecessary, while for others it was most likely not warranted.

Regarding the 'Site Assessment and Certification' document, it was noted that the document has already been endorsed. Dr Bodeker nonetheless suggested he would propose some minor changes to reflect the changes proposed by the meeting regarding 'full compliance' and 'entry level requirements', and seek to obtain endorsement of those changes.

8. Data communication and integration into WIS.

The meeting agreed that this item had already been dealt with under discussion of NRT data dissemination. It was suggested, though, that non-real-time stations should nonetheless be strongly encouraged to disseminate their data via the WIS, even if not in NRT.

9. GRUAN site financial budget.

The meeting discussed the potential usefulness of making available to prospective GRUAN sites an estimate of the total costs involved in establishing and running a GRUAN site to meet full compliance or entry level requirements. It was concluded though, that these costs could vary greatly from one country to another, so a generic 'budget' would be of little practical use. Instead, if a prospective site owner required such information, it would be best to direct any questions to the GRUAN LC. However, the meeting agreed that it may be useful to provide estimates of the purchase cost of alternative types of equipment.

10. Clarify statement of purpose and objectives for GRUAN

It was suggested that different versions of GRUAN documentation use different wording in places to state the purpose and objectives of GRUAN, and that perhaps a definitive set of words should be identified and used in all GRUAN documentation. The consensus of the meeting was that there have always been three clear GRUAN objectives (see GCOS-112).

11. 'Black box' data processing: how to deal with discussion of this in the Manual?

The meeting agreed that so-called 'black box' data processing¹³ can nonetheless be an effective way to gather data of useful quality for many applications. Some commercial software is fully transparent. In other cases they comprise 'gray boxes', where details of algorithms are only available to trusted individuals. For long term high quality climate observations, black box processing must not be used, since many artificial changes in long term climate data series can be attributed to changes in black box systems.

The meeting agreed that the GRUAN Manual needs to include some words explaining the GRUAN attitude to 'black boxes' and other variants of commercial software.

12. Priorities for GRUAN measurement of ECVs and for activities at GRUAN stations.

Priority 1 and 2 variables for GRUAN are provided in GCOS-112 and are listed in the current draft Manual. Something quite simple and straightforward will be required for inclusion in the WMO GOS documentation.

8. REVISION OF THE GRUAN MANUAL

WMO intends WMO regulatory material (currently GOS and CIMO, but ultimately WIGOS) to include consideration of GRUAN, which is an acknowledged component of WIGOS. Specific details of and information on GRUAN are required to be included in the WMO documentation, yet must first be included in the GRUAN regulatory material itself. To ensure that the GRUAN Manual contained all the required information for the WIGOS documentation, Dr Nash had been requested by CIMO to review the draft Version V1.0.0.6 of the GRUAN Manual and to propose any changes required. Dr Nash had completed this work prior to this meeting and the result was submitted to the meeting. Dr Nash introduced the document to the meeting then proceeded to take the meeting through it, inviting comment as required and providing explanations for the changes proposed. The output of this discussion session comprised a further edited copy of Version V1.0.0.6, which was copied to all participants at the end of the meeting.

The meeting ultimately agreed that, subject to WMO agreeing to provide the resources for the work to be performed, those changes suggested by Dr Nash and agreed by the meeting would be made to the current draft. The document would then be separated into two documents. The first, to be known as the GRUAN Manual, would be based on the existing Executive Summary, and would contain primarily mandatory requirements for GRUAN. The second, based upon the main text of the existing draft, would be renamed the GRUAN Guide, and contain mainly recommendations ('shoulds' rather than 'shalls').

Finally, Dr Atkinson advised the meeting on behalf of the WMO Secretariat that WMO could now agree to resourcing the changes to the existing GRUAN Manual, as discussed, so that the revised documentation (GRUAN Guide and GRUAN Manual) may be presented to the GCOS WG-ARO Meeting and the GRUAN Implementation and Coordination Meeting scheduled to be held in Tokyo, Japan, 5-9 March 2012. The precise mechanism for achieving this extra work would be addressed in due course by the WMO Secretariat.

9. REQUIRED INPUT FROM THE GRUAN MANUAL/GUIDE TO THE GOS REGULATORY MATERIAL

The final task of the meeting was to identify the information on GRUAN that is required for the two corresponding GOS documents, and to ensure that the GRUAN Manual and Guide contain this information as well. Dr Nash tabled two brief documents at the meeting on behalf of WMO which briefly listed the GRUAN topics to be covered in the GOS documentation. The meeting spent the remainder of the time available reviewing these two documents to clarify understanding. The annotated documents are included at [Annex IV](#) and [Annex V](#). This matter will need to be further

¹³ 'black box' data processing: Processing software for which neither source code nor detailed descriptions of the applied algorithms are made available by the supplier and which may change without notice and possibly without an understanding of the implications.

addressed once the GRUAN Manual and GRUAN Guide have been approved by WG-ARO and the GRUAN sites.

10. SUMMARY OF RECOMMENDATIONS

Before closing the meeting, Dr Dibbern summarized its main recommendations. These are as follows:

That WMO and GCOS Secretariats inform the respective Presidents of TCs of the proposed changes to WG-ARO membership and to request nominations of representatives to serve on WG-ARO.

That AOPC revise the current Terms of Reference and membership of the WG-ARO at its upcoming session (AOPC-XVII, 30 April – 3 May 2012, Geneva), indicating clearly who is serving in what capacity (as individual expert or TC representative).

That the GCOS Secretariat and Chairman reach out to the GCOS Steering Committee informing them in between sessions on the outcome of this meeting.

That the WMO and GCOS Secretariats inform CBS at its upcoming session of the outcome of this meeting.

That specific details of and information on GRUAN from the forthcoming GRUAN Manual and Guide and as identified at this meeting (cf. Annex IV and V) be included in WMO regulatory material (currently for GOS and CIMO, and ultimately for WIGOS).

That the WMO and GCOS Secretariats resource the additional work required to revise the draft GRUAN Manual to reflect the agreed change of governance, to separate the document into a Manual and a Guide, and to ensure that together they contain the information required for inclusion in the WIGOS documentation.

That the following detailed changes be made to the GRUAN regulatory material:

- replace the existing Figure 1 and its accompanying text with the agreed modified organigram and suitable text, pending formal acceptance by AOPC;
- state the purpose and objectives of GRUAN uniformly throughout all GRUAN documentation;
- include mandatory requirements for a 'fully compliant' GRUAN station as well as the minimum entry level requirements for consideration as a GRUAN site;
- add obligations regarding data transmitting via the WIS;
- introduce a GRUAN data level corresponding to the 'best estimate available in NRT' product;
- separate the draft Manual into two documents: A GRUAN Manual, based on the existing Executive Summary, and a GRUAN Guide based upon the main text of the existing draft.

CLOSURE OF THE SESSION

Dr Dibbern thanked the participants, who had been charged with a particularly difficult task. He praised them for their contributions to a highly productive meeting, at which agreement had been reached on a modified governance structure for GRUAN and a way forward had been found to finalize both the GRUAN and WMO regulatory material on GRUAN. Dr Dibbern expressed his best wishes for continuing to move the process forwards after the meeting.

In return, the participants thanked Dr Dibbern for his role in skillfully chairing the meeting.
The meeting closed at 15.00.

MEETING AGENDA

1. Opening of the Meeting
1.1 Welcome and introductions
1.2 Adoption of Agenda
1.3 Conduct of the Meeting
2. Update on GRUAN activities
2.1 Update from WG-ARO
2.2 Update on development of the GRUAN Manual
2.3 GRUAN WIGOS Pilot Project & status of WIGOS implementation
2.4 WMO regulatory material
3. Discussion and Drafting
3.1 GRUAN Governance and Management
3.2 Manuals & Guidelines: outlook towards further conduct and expected outcomes of the meeting
3.3 GRUAN Manual: What needs to be added or changed in the current draft?
3.4 Regulatory Material: What needs to be included from the GRUAN Manual into the Manual and Guide on the WMO Global Observing System (GOS)?
4. Closure

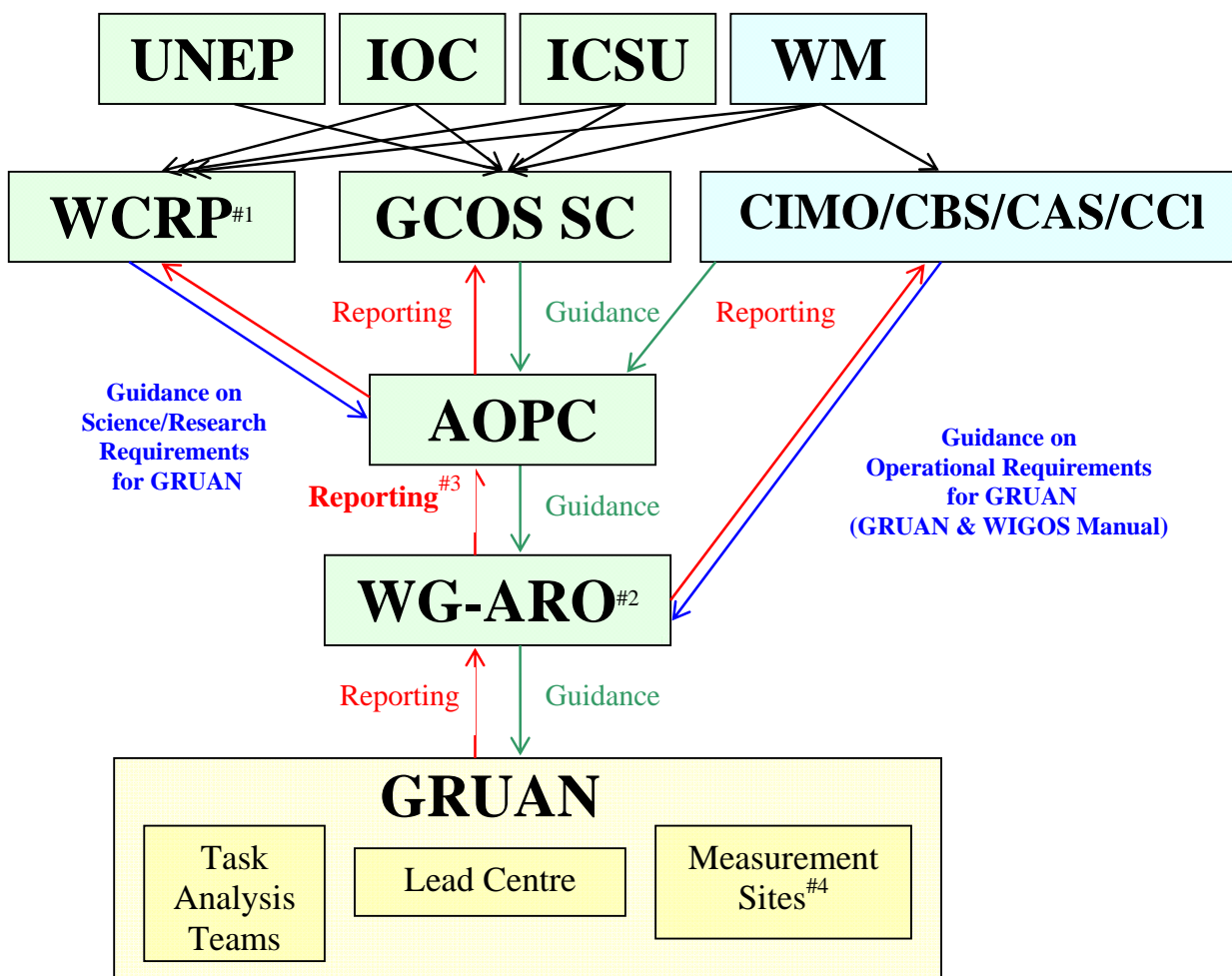
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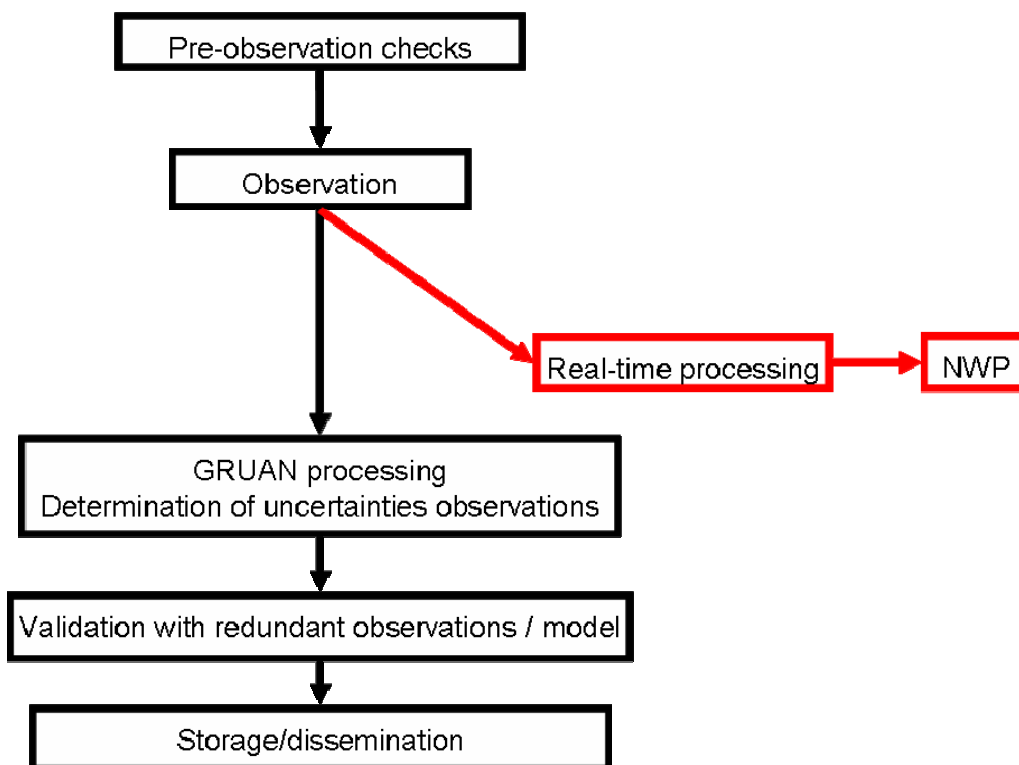
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MODIFIED GRUAN STRUCTURE



1. WCRP identifies scientific and research requirements for GRUAN, while WMO identifies operational requirements.
2. Composition of WG-ARO to be determined by the AOPC in consultation with WMO, 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. WG-ARO reports to AOPC
4. GRUAN Measurement Sites are contributed by Members of WMO.

GRUAN DATA STREAMS



MANUAL ON THE GOS: GRUAN INFORMATION TO BE INCLUDED
Submitted by Dr John Nash on behalf of WMO

Part I

Doesn't seem to merit any special words.

Part III

2.12.xx GCOS Reference Upper Air Network (GRUAN) stations

General

Include GCOS 112 goals of GRUAN

2.12.xx.1 Members should cooperate in the establishment of about 40 GCOS Reference Upper Air Network stations worldwide, located to meet stated GRUAN scientific objectives.

Location and composition

2.12.xx.2 GCOS Reference Upper Air Network stations should be established on sites to provide reference quality profile measurements of temperature and water vapour [plus other relevant Essential Climate Variables (ECVs)] to cover as wide a range of climate regions as possible. The operational protocols for making the measurements shall be followed at all GRUAN sites.

2.12.xx.3 GCOS Reference Upper Air Network stations may be collocated with an upper air synoptic station, a GCOS Upper Air Network (GUAN), or a Global Atmosphere Watch station, or a scientific research site independent of WMO with specialised scientific instrumentation for measuring upper air ECVs.

2.12.xx.4 GRUAN observing stations are to be managed in a fashion that minimises differences in measurement methods of observation between the participating sites, to provide a reference network for climatological services.

2.12.xx.4a (This needs replacing with MINIMUM ENTRY LEVEL REQUIREMENTS and REQUIREMENTS FOR FULL COMPLIANCE (Priority 1 and 2 ECVs – list them)) At each GRUAN observing station measurements should be carried out, to a programme agreed with the GRUAN LC on: _

(a) Temperature and water vapour profiles, using radiosonde measurements. These measurements must follow the protocols established by the GRUAN Lead Centre for radiosonde operations and data archiving.

(b) Integrated water vapour using surface based GPS water vapour measurement located at the GRUAN site, processing method as agreed with the GRUAN LC.

(c) If possible, redundant temperature and water vapour profiles using a different observing system for measuring temperature and water vapour profiles, such as Raman Lidar, microwave radiometer, or a specialised scientific sounding instrument to measure water vapour in the upper troposphere and lower stratosphere.

2.12.xx.5 In time an increasing number of GRUAN stations will provide profile measurements of other essential climate variables listed in GCOS 112. Those variables most likely to be included in the foreseeable future are: (include short list of selected ECVs to be defined at ICM-4)

Frequency of observations

The frequency of observations at fully compliant sites will be as specified in the GRUAN Guide. The frequency of observation of a given type to be achieved at a particular GRUAN site will be agreed between that site and WG-ARO.

More details on frequency of observations will be specified at ICM-4 for inclusion in the WIGOS Manual.

Data Management?

No, not to be included

GUIDE TO THE GOS: GRUAN INFORMATION TO BE INCLUDED
Submitted by Dr John Nash on behalf of WMO

Part III

3.9.2.xx GCOS Reference Upper Air network (GRUAN) stations

3.9.2.xx.1 General

The GCOS Reference Upper Air network is designed to provide vertical profiles of reference measurements of GCOS Essential Climate Variables (ECVs), with the initial focus on Priority 1 and 2 variables (see Table X), suitable for reliably detecting changes in global and regional climate, on multi-decadal time scales. The network needs to sample a variety of climatic regimes, latitudes and surface types, including low and high altitude sites. The standard methods of observations to be used at GRUAN stations are designed to ensure measurement understanding and traceability, to SI or other international standards, of GRUAN climate data records. This will be validated through comparison with other redundant sources of instrumentation at the station, making either specialised scientific balloon-borne or ground-based remote sensing measurements. This will then provide a reference standard for synoptic upper-air stations, and those stations in the GCOS Upper-air Observing network (GUAN). Thus, an improvement in the detection of changes in the climate of the troposphere and stratosphere will be achieved.

The GRUAN stations are also designed to provide a calibrated reference standard for validation of global satellite-based measurements of atmospheric ECVs. This is to facilitate the creation of seamless, stable, and long-term databases of satellite-based measurements for detection of trends and variability in climate in the troposphere and stratosphere on all time scales.

Thus GRUAN will also observe other essential climate variable as well as temperature, water vapour and pressure, and will collaborate with Global Atmosphere Watch and other scientific observing networks in achieving these aims.

Some GRUAN stations are managed as part of the GOS and some are not. The observing procedures and methods of observation used at all stations are to be the same with a given observing system. Then, a reference quality measurement at GRUAN stations refers to the current best estimate of the value for some atmospheric variable together with a best estimate for the level of confidence that is associated with this value, recognising that future improvements in measurement techniques and/or reprocessing following new knowledge may lead to refinements in that reference value.

The required number of GRUAN stations globally should be a minimum of one per principal climatic zone. Members are being encouraged to establish and/or cooperate in establishing 40 stations, allowing some redundancy in observing systems used in any climatic region. At the time of writing there are 15 GRUAN stations.

3.2.xx.2 Site selection

GRUAN station site selection shall satisfy at least one of the following principles:

- (a) the site measures atmospheric phenomena in climatic regions, which were not previously sampled by the GRUAN network.
- (b) site brings unique scientific 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.
- (c) the site participates in other international measurement networks (e.g. NDACC, GAW, BSRN). This quantitatively links the GRUAN measurements to the measurements being made in those other networks
- (d) the site can commit to a multi-decade programme of measurements
- (e) the site can fulfil the (optimum, or at least the minimum, measurement programme) following measurement programmes expected of a candidate GRUAN site:
 - a. At least twice daily (00 and 12 LST as a preference over UTC¹⁴) measurements of vertical profiles of temperature from the surface to ~30 km and water vapour in the troposphere.
 - b. High quality surface measurements of these same variables are also required to provide a traceable link between the measurements at the lowest level of each profile
 - c. At least monthly observations of stratospheric water vapour to ~30 km.
 - d. Hourly observations of integrated precipitable water vapour
 - e. The availability of historical measurements that conform to the GRUAN standard, e.g. a reliable GUAN climate observing site.

Capital equipment
Organization and operation
Central collection and availability of data
Communications
Personnel
Quality standards
Archiving.

¹⁴00/12 UTC observations are no longer as important for NWP since 4D data assimilation is now more common. Where higher priority considerations require sites to measure at 00/12 UTC rather than 00/12 LST, this will not count against the site.