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IMPLEMENTATION PLAN FOR THE GLOBAL CLIMATE OBSERVING SYSTEM REFERENCE UPPER-AIR NETWORK 2013-2017

CAPSULE

This document provides a roadmap for the implementation of the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) for the period 2013 – 2017 by detailing the actions required within that timeframe to further the establishment of a fully operational reference upper-air network for climate. It serves as an update to and supersedes the original "GRUAN Implementation Plan 2009 – 2013" (GCOS-134[1]). It should be interpreted in conjunction with other GRUAN regulatory materials.

1. Introduction

1.1 Background

The GRUAN operates under the joint governance of GCOS and the World Meteorological Organization (WMO). Following the formation of a Working Group on GRUAN (WG-GRUAN)[2] under the auspices of the GCOS Atmospheric Observations Panel for Climate (AOPC) in 2003, a Lead Centre was designated at the German Weather Service's Lindenberg Meteorological Observatory in 2008. The GRUAN Lead Centre oversees day-to-day operational aspects of the network. The GRUAN governance structure is outlined in Figure 1 below and the Terms of Reference for the WG-GRUAN are attached as Appendix 2.

GRUAN governance and oversight evolved since the first Implementation Plan (IP) was published in 2009[3], and task specific teams have been instigated. At present, the five Task Teams (TTs) are:

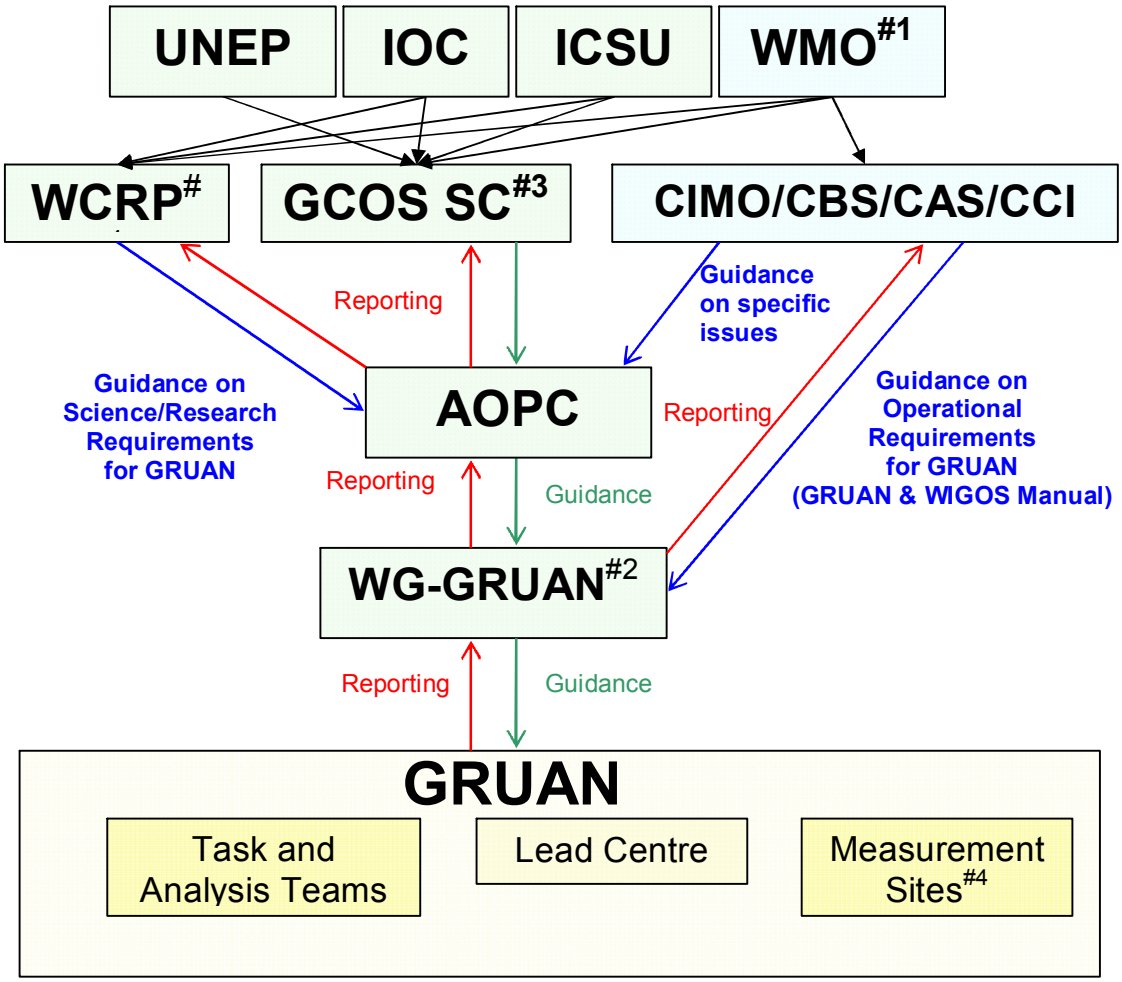
- Task Team on radiosonde measurements (TT Radiosondes)
- Task Team on GNSS precipitable water vapour measurements (TT GNSS)
- Task Team on measurement scheduling practices (TT Scheduling)
- Task Team on ancillary measurement technologies (TT Ancillary)
- Task Team of site representatives (TT sites)

In addition, the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR) continues to undertake scientific analyses in support of GRUAN development. The respective Terms of References for GATNDOR and the GRUAN Task Teams can be found in Appendix3.

Coordination with WMO activities has been strengthened through involvement in the WMO Integrated Observing System (WIGOS) framework as one of its Pilot Projects, and through designation of representatives of WMO Technical Commissions[4] as members of the WG-GRUAN (cf. GCOS-155)[5]. The WG-GRUAN now has co-chairs and its membership (Appendix 1) has expanded to include

[1] GCOS-134: http://www.wmo.int/pages/prog/gcos/Publications/gcos-134.pdf
[2] Formerly called the Working Group on Atmospheric Reference Observations, it has been renamed by the AOPC into Working Group on GRUAN to clarify that its mandate is limited to guide GRUAN activities and that is not supposed to cover any other reference networks in future.
[3] This evolution was along the lines envisaged in the original IP.
[4] These WMO Technical Commissions are: The Commission for Basic Systems (CBS), Commission for Instruments and Methods of Observation (CIMO), Commission for Atmospheric Sciences (CAS) and the Commission for Climatology (CCl)
[5] GCOS-155: http://www.wmo.int/pages/prog/gcos/Publications/gcos-155.pdf

a wider range of skills and expertise. The Lead Centre's role was re-evaluated in 2012 and it was unanimously welcomed that DWD would retain that role through the Lindenberg Meteorological Observatory.



Notes
1. WCRP identifies scientific and research requirements for GRUAN, while WMO identifies operational requirements.
2. Composition of WG-GRUAN to be determined by the AOPC 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 governance structure of GRUAN.

Furthermore, the first official versions of the GRUAN Manual and Guide have been finalized and are undergoing approval[6] before being published as joint GCOS-WIGOS documents. These provide additional technical background and practical guidance, detailing for example the criteria and process for site assessment and certification. It is expected that specific details of and information on GRUAN

[6] This approval process is detailed in the outcomes of ICM-3, GCOS-151 and involves unanimous approval by WG-GRUAN membership and 2/3 of sites to approve.

from the GRUAN Manual and Guide will be included in WMO regulatory material (currently for the WMO Global Observing System (GOS) and CIMO, and ultimately for WIGOS).

1.2 About this document

The 2009 – 2013 GRUAN Implementation Plan (IP) was published in July 2009 and intended to cover the initial four years until envisaged operational status of the new network. This first IP has proven useful in supporting the GRUAN effort and in providing a structure for more detailed work plans, which were developed and updated annually. The original IP, however, had a limited lifecycle as it cannot envisage all eventualities likely to arise subsequent to its publication. Accordingly, at the most recent 4th Implementation and Coordination Meeting held in Tokyo, Japan, in 2012[7], it was decided to provide an updated version of the GRUAN IP. This document would cover the period 2013-2017 and would take GRUAN through operationalization of the network, expansion for new stations providing GRUAN data streams towards better coverage of major climatic zones, and expansion of instrumentation in operation at individual GRUAN certified sites. Even then further development is envisaged after the end of the current IP[8] and it is probable that a new IP will developed around 2016-2017 such as to overlap in a similar manner.

In developing this IP update, the WG-GRUAN has detailed the minimum set of actions required to ensure that GRUAN delivers the services called for by its sponsors and stakeholders (see Figure 1), whilst recognizing that not all of these activities can be achieved under current levels of funding. Support by funding agencies for GRUAN within the period 2013 – 2017 as covered by this IP, will largely determine whether GRUAN succeeds or fails in meeting the outcomes requested by its stakeholders. Furthermore, because most aspects of this plan require the active participation of measurement sites and relevant expert groups the success depends upon the degree of buy-in from and collaboration with these groups.

Work packages (as outlined in Sections 3 and 4) are oriented around the same thematic areas as in the original IP (with three exceptions detailed below) and recognize that multiple parties may be active participants in any given activity. Tasks detailed in this IP always specify a responsible group (e.g., Task Team, Lead Centre, GATNDOR, etc.) who takes responsibility for ensuring that the task is completed. However, there is also a section (Section 5) in this IP where tasks have not yet been assigned a responsible group, reflecting that current resourcing is insufficient to support finding an owner. The previous IP section on regulatory materials has been removed as regulatory material issues are now embedded into all other aspects of GRUAN work. It was deemed more appropriate to outline technical documentation as deliverables on activities rather than artificially separating development and documentation activities. The partnerships section which is deemed an ongoing recurring activity has also been removed. There now is one additional section focusing on bringing in additional data streams.

Ongoing tasks, as opposed to time-bound tasks, are documented in a separate section (Section 3) to avoid conflation with those tasks subject to a prescribed timeline. This should not be interpreted as such activities being in any sense unimportant, but rather that - because they are not time-bound - they do not inform strategic timeline planning of further steps necessary for implementation of the network.

All items that were not determined to be closed in the original IP have been transcribed to the new version either in original or modified form. Items in the original IP that are not contained in the new IP were either completed or have been superseded.

Items regarded as business as usual type activities have been excluded and only actions essential to GRUAN implementation are stated this plan. The more minor tasks are collected in a living document

[7] This is detailed in the ICM-4 report, GCOS-161

[8] Indeed, it is not possible to envisage a time when a successful GRUAN would ever be truly static in nature a key element of success will be constantly striving to improve all aspects of GRUAN operations to attain the best possible measurement and uncertainty estimates with modern measurement technology and techniques.

which is managed by the WG-GRUAN and actively assessed and regularly updated by the WG-GRUAN, the Lead Centre and Task Teams[9].

The remainder of this IP is structured as follows. Section 2 defines the intended strategic target that is envisaged to be achieved by 2017. Section 3 outlines ongoing and recurring activities that define trajectories to that target. This includes matters pertaining to governance, reporting, coordination and liaison with stakeholders. Section 4 provides a list of agreed time-bound work items. While responsibility for addressing these items has been explicitly agreed to by the named parties, it does not imply that funding support currently exists for all such activities. Section 5 outlines additional activities which have been identified by WG-GRUAN as being essential to meeting the target defined in Section 2, but which have not yet been formally adopted by any party. Their inclusion is intended to ensure that these aspects are not forgotten and they will be frequently revisited. Section 6 provides a combined timeline of intended and adopted activities.

2. Strategic overview

The purpose of GRUAN, as detailed in "*GRUAN: Justification, requirements, siting and instrumentation options*" (GCOS-112)[10], is 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 should also 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[11].

At the time of writing, GRUAN consists of 16 identified sites who have expressed an interest in participation, predominantly located in the Northern Hemisphere middle to high latitudes. Sites have varying capabilities, funding mechanisms and affiliations to third party networks and organizations, and most of the sites have yet to pass the formal GRUAN certification and assessment process, as described in the GRUAN Manual and Guide. The methodological aspects that underpin what will constitute a GRUAN reference measurement are outlined in a peer-reviewed article by Immler et al.[12]and data adhering to these principles are being processed and served for one specific type of radiosonde instrument flown at a subset of the sites and available through NOAA's National Climatic Data Center (NCDC)[13].

By the end of the period spanned by this IP (by end of 2017), if it is successfully implemented, GRUAN shall consist of:

- A network of 20 to 30 measurement sites each contributing one or more GRUAN data stream. Beyond 2017, the time horizon for this IP, the network is envisage to further expanding to reach the longer-term goal of 40 contributing sites. Locations for new sites will be guided using network expansion criteria developed to ensure that GRUAN meets the needs of its four primary user communities (see below). All of these sites data products shall have been subject to regular assessment and certification. The location of new sites will be chosen pro-actively to meet documented stakeholder requirements.
- A network serving reference-quality measurements of vertical profiles from the surface through the lower stratosphere (or higher where feasible) of temperature, pressure, water

[9] The GRUAN Master Action Item List can be obtained by email request to greg@bodekerscientific.com

[10] GCOS-121: http://www.wmo.int/pages/prog/gcos/Publications/gcos-121.pdf

[11] This was agreed at the joint WIGOS/GCOS sponsored meeting held at WMO in Jan 2012.

[12] Reference Quality Upper-Air Measurements: Guidance for developing GRUAN data products, Immler et al. (2010), Atmos. Meas. Techn., available at: http://www.atmos-meas-tech.net/3/1217/2010/amt-3-1217-2010.pdf

[13] The GRUAN database is accessible via: ftp://ftp.ncdc.noaa.gov/pub/data/gruan/processing

vapour, wind speed and direction, and ozone[14]. To the extent possible, these measurements will be made using redundant measurement systems including sondes[15] and ground based remote sensing equipment. Measurements will be made to GRUAN standards with each data stream processed centrally, and well documented by metadata.

- A set of sustainable long-term measurements being used by recognized target stakeholders (climate change monitoring and detection, satellite-based measurements, NWP, process studies), as demonstrated in the peer-reviewed literature, to improve scientific understanding.
- A network with operational and research functions, embedded within the overarching WIGOS framework and leading to improved capabilities and practices in other broader components of the Global Observing System and its applications.

The actions detailed in the following sections contribute to one or more of these stated objectives.

3. Continuous ongoing tasks

Continuous ongoing tasks are those required to communicate, develop plans and monitor progress in support of the development of GRUAN. These recurring tasks are detailed below in tabular format. These differ from later tables as they are not time-bound and might not have distinct measurable deliverables.

What	By whom	Notes
Annual meetings of Lead Centre, WG-GRUAN, GCOS Secretariat and GRUAN contributing sites (ICMs)[16].	WG-GRUAN, Lead Centre, GCOS Secretariat	Annually until further notice; as resources permit. Regularly invite all stakeholders, including representatives of instrument manufacturers.
Ensure institutional / informal linkages between GRUAN community and existing/potential partners, to maintain mutual engagement, knowledge transfer, and recognition.	WG-GRUAN, Lead Centre, GCOS Secretariat	E.g. by cooperating network agreements
Engage with satellite community (operational centres; GSICS; SCOPE-CM; cal/val programmes of space agencies; other mechanisms), e.g. on utility of GRUAN data and needs e.g. sponsoring for additional radiosonde launches.	WG-GRUAN	

[14] Work will have progressed on the consideration of other ECVs and derived quantities identified as target parameters including aerosol attributes, as well as surface net radiation, short-wave downward radiation, short-wave upward radiation, long-wave downward radiation, long-wave upward radiation, and cloud properties including cloud amount/frequency, base height, layer heights and thicknesses. However, it is unrealistic to expect GRUAN data-streams on all these attributes to be flowing on the timescale of this IP from any appreciable number of sites, or to expect that their measurement strategies will be fully defined. There are a number of action items laying the ground-work for such data streams beyond the horizon of this IP.

[15] This includes radiosondes, ozonesondes and water-vapour sondes.

[16] It should be stressed that the annual ICMs are essential to progressing the development phase of GRUAN and that support from host sites and the US GCOS Program Office and the NOAA Climate Program Office has been vital.

Liaise with NMHSs with potential sites in desirable locations to encourage them to join GRUAN and establish GRUAN programmes. at those sites.	WMO, WG-GRUAN Co-Chairs	
Report regularly, and on an additional ad hoc basis as required, to AOPC.	WG-GRUAN Co-chairs	Efforts should be made to attend AOPC in person if possible
Report to WIGOS Planning Office as required.	WG-GRUAN Co-chairs, Lead Centre, GCOS Secretariat	
Brief science community on GRUAN by seeking to convene special sessions or giving talks / posters at relevant conferences including updates on progress.	WG-GRUAN members, Lead Centre	
Regular progress reports against specified work plan from the Lead Centre and Task Teams to the WG-GRUAN.	Lead Centre, Task Team chairs	February and August
Review and curation of GRUAN Technical Documentation and Report series including the Manual and Guide.	WG-GRUAN co-chairs	
For those sites with data streams already certified, annual reviews of status and more in-depth site auditing as warranted.	WG-GRUAN	
Annual progress reports on data delivery for all products from all measurement systems.	Lead Centre	See item C1 in Section 4

4. Work plan organized by thematic areas

This work plan is organized by broad thematic topics. Because these work areas are somewhat artificial splits, there are interdependencies within and across thematic areas. To account for these, each line item has been given a unique identifier. Interdependencies are noted in the 'What' column in [square brackets]. If such dependencies are latent then there are clear risks for subsequent deliverables e.g. if there is a delay in specifying what a reference measurement is from a given instrument type this will have repercussions for the envisaged timeline of delivery of that data stream as a GRUAN product.

The 'by whom' column simply denotes the task lead organizational unit and, optionally, principal participants. This should not be taken to imply that others cannot participate or will not be requested to help in the task. Rather it is intended that 'ownership' will ensure a task is more likely to be completed.

For all of the Technical Documents (TDs) needed to describe datasets / uncertainties / processing streams/ metadata, a summary 1-pager is absolutely essential, in addition to the full documentation which may be longer. This ensures that key requirements are clearly articulated up front to stakeholders. Wherever possible the completion of these tasks will look to take advantage with pre-existing programmes and expertize such that redundancy of effort is avoided. In many cases third party entities can provide most if not all of what is required and this is to be proactively encouraged.

a. Reference observations

Reference observations are the core rationale for GRUAN. The underlying principles have been documented in Immler et al., 2010 and the processing applied solely to one radiosonde type, the Vaisala RS92. By 2017 several additional data streams from in-situ (including operational and frostpoint sondes) and remote-sensing instruments are expected. Each must be backed up by Technical Documentation describing the instrument practices and, ideally, a peer-reviewed paper documenting the properties of the GRUAN data product. Furthermore, several substantive questions remain to be resolved surrounding in-situ sounding configurations and best practices.

GRUAN will look to partner with existing networks and activities where possible in developing data best practices and data support infrastructure in a cost-effective manner and to avoid duplicative effort. Products need to be inter-operable and synergistic and this needs to be borne in mind when developing new data streams.

Section 4a is concerned with the practical understanding of a given instrument and the specification of the necessary measurement protocols to ensure that a GRUAN measurement with traceable uncertainty can be attained. Section 4b deals with the collection, ingest, processing and serving to end-users of these data streams once they have been developed.

What	Deliverables	By whom	By when
In-situ sounding			
A1: Finalize the definition of reference observations and GRUAN data products for RS92 radiosondes; specifically assess the time lag in RS92 humidity corrections by comparing the GRUAN processing to other published approaches.	(D1) Manuscript describing the results of the humidity time lag assessment submitted to a journal. (D2) Complete set of TDs describing all aspects of GRUAN RS92 procedures.	Lead Centre, TT radiosondes	D1: August 2013 D2: December 2013
A2: Develop GRUAN data products and processing streams for non-RS92 radiosondes in collaboration with relevant sites. [A1]	(D1) Written progress report to ICM 5. (D2) Series of technical documents describing processing streams for all non-RS92 radiosondes. (D3) Paper describing the totality of standard GRUAN 'operational radiosonde' processing (and intercomparisons) submitted to journal.	Lead Centre, TT sites, TT radiosondes	D1: March 2013 D2: March 2015 D3: June 2016
A3: Address the unresolved operational aspects of radiosonde measurements and their interpretation.	(D1) Manuscript(s) detailing operational considerations for controlled descents submitted to a journal or detailed in a GRUAN Report. (D2) If deemed applicable, a technical document that supports the adoption of controlled descent across GRUAN. (D3)A document detailing the operational	TT radiosondes	D1: December 2013 D2: June 2014 D3: Drafted August 2013 D4: August 2013

	challenges related to multi-payload soundings submitted either to peer reviewed literature (first choice) or to WG-GRUAN for review as a TD. (D4) An assessment of the advantages and disadvantages of manual vs. autosonde launches written up and submitted to the peer reviewed literature.		
A4: Develop frostpoint hygrometer data products. Guidance needs to account for operation of CFH, NOAA FPH, Snowwhite[17].	(D1) Technical documentation completed for frostpoint hygrometer measurements. (D2) Paper submitted to a peer reviewed journal.	Lead Centre, TT radiosondes	D1: March 2014 D2: March 2015
A5: Develop a GRUAN ozonesonde data product in consultation with NDACC and GAW.	(D1) Completed technical documents. (D2) Paper submitted to peer reviewed journal.	Lead Centre	D1: June 2014 D2: June 2015
Remote Sensing			
A6: Develop a GRUAN GNSS-PW product.	(D1) Manuscript describing the derivation of uncertainty estimates for GNSS-PW measurements submitted to a peer reviewed journal. (D2) Technical documentation completed for GNSS-PW measurements.	TT GNSS	D1: March 2014 D2: March 2015
A7: Develop GRUAN humidity and temperature lidar data products in collaboration with NDACC and other relevant experts.	(D1)Technical documents submitted for review by WG-GRUAN. (D2) Paper describing GRUAN lidar products submitted to peer	TT ancillary	D1: December 2012 D2: August 2014

[17] If sites look to join and submit FLASH-B measures these will also need to have technical documentation and error budgets / SOPs developed. At this time one GRUAN site operates FLASH-B and they are not proposing its inclusion as a GRUAN data product presently.

	reviewed journal.		
A8: Develop GRUAN temperature and water vapour microwave. radiometer data products in collaboration with NDACC and other relevant experts.	(D1) Technical documents submitted for review by WG-GRUAN (D2) Paper describing the GRUAN Microwave radiometer product submitted to peer reviewed journal.	TT ancillary	D1: June 2013 D2: March 2015
A9: Develop GRUAN ozone and water vapour FTIR data products in collaboration with NDACC, TCCON and other relevant experts.	(D1) Technical documents submitted for review by WG-GRUAN. (D2) Paper describing GRUAN FTIR products submitted to peer reviewed journal.	TT ancillary	D1: June 2013 D2: March 2015
A10: Develop GRUAN Dobson/ Brewer data product in collaboration with GAW and NDACC	(D1) Completed technical documents. (D2) Paper describing GRUAN Dobson/Brewer data products submitted to peer reviewed journal.	Lead Centre	D1: June 2017 D2: December 2017

b. Data policy and data dissemination

GRUAN data started flowing to users through the official GRUAN Data Centre in mid-2011. At present this consists of a single stream of RS92 radiosonde data from a subset of candidate sites. By 2017 this will expand to consist of multiple data streams of GRUAN priority 1 and 2 ECVs from a range of instruments providing measurement redundancy. These data streams will be evaluated for efficacy and operational anomalies by relevant experts once sufficient data are available.

What	Deliverables	By whom	By when
Generic			
B1: Implement an agreed procedure for monitoring GRUAN data usage to the extent practical / allowable, including items such as publications arising, queries received etc.	(D1) A GRUAN report documenting how data usage will be monitored and reported. (D2) (recurring) Once instigated and agreed to, the data usage reports would become an appendix to the annual (February) Lead Centre reports.	Lead Centre	D1: June 2013 D2: First reported February 2014 then every February thereafter

B2: Implement a mechanism whereby real-time feedback from NWP centres such as ECMWF on those GRUAN data exchanged in NRT, in the form of differences between observations and assimilation, provides real-time validation of GRUAN derived measurement uncertainty estimates.	A short GRUAN report detailing the process implemented to provide feedback of observation minus background fields to the GRUAN Lead Centre.	David Tan	30 June 2013
B3: Coordination with satellite data monitoring and validation programmes. The goal is to get GRUAN into the satellite product validation programmes. Three basic steps, the first two are here (see D8): 1) gain routine access to GRUAN and collocate with NPROVS data streams 2) develop / disseminate useful monitoring and analysis tools that benefit both the GRUAN and satellite community. See also standing item on improving satellite programme linkages.	(D1) Retention of collocated satellite / sonde / NWP data within or linked from the GRUAN data archive to facilitate intercomparisons. D2: Online tools based on the NPROVS system to visualize and monitor the GRUAN profiles and collocated satellite and NWP data (GPROVS). D3: Develop a calibration/validation concept for the EUMETSAT geostationary MTG series based on GRUAN sites. D4: Develop a tool for the optimization of vertical resolution of data to be used in RTM.	TT Ancillary, WG-GRUAN	D1: March 2013 D2: August 2013 D3: March 2013 (EUMETSAT ITT pending) D4: March 2015 (PhD student funding pending)
B4: Design and instigate a framework to investigate, report and resolve data quality and instrument issues in real-time.[18]	GRUAN Technical Document describing real-time QA/QC procedures implemented in GRUAN data flow.	Lead Centre	June 2014
In-situ sounding			
B5: Define the new radiosonde data streams data collection client requirement, identify the central data processing facility, and initiate data flow. [A2]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT Radiosonde, TT sites D2: TT Radiosonde	D1: September 2015 D2: December 2016

[18] This item is carried over from the original IP. ACRF already have such a capability and should be consulted.

B6: Define the frostpoint hygrometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A4]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT Radiosonde D2: TT Radiosonde	D1: September 2014 D2: December 2015
B7: Define the ozonesonde data collection client requirement, identify the central data processing facility, and initiate data flow. [A5]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT Radiosonde D2: TT Radiosonde	D1: June 2015 D2: June 2017
Remote sensing			
B8: Define the GNSS-PW data collection client requirement, identify the central data processing facility, and initiate data flow. [A6]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT-GNSS D2: TT GNSS	D1: June 2015 D2: September 2016
B9: Define the Lidar data collection client requirement, identify the central data processing facility, and initiate data flow. [A7]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT ancillary D2: TT ancillary	D1: September 2014 D2: December 2015
B10: Define the microwave radiometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A8]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT ancillary D2: TT ancillary	D1: September 2015 D2: December 2016
B11: Define the FTIR data collection client requirement, identify the central data processing facility, and initiate data flow. [A9]	(D1) Data flow through NCDC portal. (D2) Assessment of data usage, issues and potential improvements for this data stream.	D1: Lead Centre, TT ancillary D2: TT ancillary	D1: September 2015 D2: December 2015

c. Site considerations and network composition

GRUAN currently consists of 16 sites who have expressed an interest in contributing to the network goals. One of these sites' radiosonde data stream has been certified. Since the last IP, certification and assessment processes have been clearly delineated and a workshop to address stakeholder needs for network expansion has been held. This section details envisaged steps to meet the aim of ~30 certified sites (implying one or more certified GRUAN data streams) by 2017.

What	Deliverables	By whom	By when
C1: Process all current and interim new applicant sites measurements through the GRUAN certification process as defined in Section 5 of the GRUAN Guide to Operations (GCOS-171) [Note that sites can only be assessed and certified for data streams that have been fully developed (Section A) at the time of the submission of the application]	(D1) Short report for inclusion in ICM-5 proceedings summarizing sites processed to date. (D2) Short report for inclusion in ICM-6 proceedings summarizing sites processed to date. (D3) Final report on sites processed through initial certification.	WG-GRUAN	D1: March 2013 D2: March 2014 D3: Dec 2015
C2: Finalize the outputs resulting from the GRUAN Network Expansion Workshop.	(D1) GRUAN report synthesizing the four white papers developed through the GRUAN Network Expansion Workshop. (D2) A paper submitted to a peer reviewed journal that provides a more accessible version of the GRUAN report (e.g. a BAMS article). (D3) Solicit expressions of interest from the top 10-15 sites meeting the criteria developed through the GRUAN Network Expansion Workshop.	(D1) Greg Bodeker[19] and GRUAN white paper co-authors. (D2) Greg Bodeker and GRUAN white paper co-authors. (D3) WG-GRUAN, Lead Centre	D1: December 2012 D2: June 2013 D3: June 2015
C3: Periodic science review of network expansion priorities and progress.	(D1) Annual reports to ICMs.	GATNDOR, TT sites	March 2016 and annually thereafter

d. Science issues

There remain several open science questions relating to either specific instrumentation or generic issues such as scheduling of measurements. This section describes the scientific issues that need to be resolved for network operations and design and is not about science applications that employ the data. Such scientific application activities are key but are not under the purview of network management activities and hence cannot be mandated under an 'implementation' umbrella.

What	Deliverables	By whom	By when
D1: Recommend practices on managing change in GNSS-PW measurements.	Report at ICM-5 and then feed into creation of relevant	TT GNSS	March 2013

[19] Involvement is funding dependent

	TDs.		
D2: Review measurement scheduling required to meet the needs of temperature trend detection.	GRUAN report as a supplement to the scheduling section of the GRUAN Guide.	TT Scheduling	June 2014
D3: Extend trend sensitivity studies to stratospheric water vapour[20].	D1: Submission of a paper to a peer reviewed journal. D2: GRUAN report as supplement to the scheduling section of the GRUAN Guide.	TT Scheduling	D1: September 2015 D2: December 2015
D4[21]: Provide a scientific basis for sites to choose the optimal combination of measurement technologies to best meet GRUAN needs.	D1: A paper on "Quantifying the value of complementary measurements" submitted to a peer reviewed journal. D2: Technical document or publication(s) providing recommendations on the equipment to use at GRUAN sites on the basis of the analysis of experimental data.	GATNDOR, TT ancillary	D1: May 2013 D2: May 2014
D5: Develop a toolset to quantify the impacts of spatial mismatches on data comparisons and quantification of uncertainties.	A paper on "Co-location of observations" with an emphasis of how to account for mismatches in quantifying and comparing uncertainties submitted to a peer reviewed journal.	GATNDOR	March 2013
D6: Investigate site-specific "recipes" of GRUAN ancillary and sonde measurements (including uncertainties) for comparison with sounding products, focusing on atmospheric temperature and moisture.[D4]	D1: Report to ICM-5. D2: Manuscript submitted for publication.	TT ancillary	D1: March 2013 D2: March 2014

[20] Funding bid dependent.
[21] This item is carried over from the original IP.

e. Organizational issues

GRUAN is now relatively mature and stable in terms of management. However, there are some recognized issues that need addressing. Furthermore, as the effort matures, some meaningful review process to provide advice on the usefulness of the data and potential for improvements is required.

What	Deliverables	By whom	By when
E1: Instigate a user review group[22] to meet on a biennial basis.	(D1) User review group terms of reference drafted and agreed to by WG-GRUAN. (D2) Proceedings of the inaugural meeting of the user review group.	WG-GRUAN Co-chairs	D1: Mar 2015 D2: Dec 2015
E2: Instigate a Metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata easily understandable and machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.	(D1) Document defining terms of reference and remit of the Task Team. (D2) Formal establishment of Metadata Task Team – list of members provided to Lead Centre. (D3) Report on how to make metadata easily understandable and machine readable. (D4) Report on how to make metadata discoverable. (D5) Report on completeness of metadata collection.	WG-GRUAN Co-chairs	D1: Mar 2013 D2: June 2013 D3: June 2014 D4: March 2015 D5: December 2016

f. Outreach

GRUAN will only prove to be a successful network if the observations made end up being used and add substantive value to scientific studies. It is therefore important that opportunities are taken to inform stakeholders and end users about GRUAN. Beyond business as usual activities, several specific activities are envisaged before 2017.

[22] Periodic external review group with ex-officio Lead Centre, WG-GRUAN and GCOS Secretariat membership. In effect a "Client survey".

What	Deliverables	By whom	By when
F1: Organize a GRUAN launch symposium, possibly jointly with NDACC, WMO, others to mark operational status of the network and invite user communities (along with those present at the GRUAN Network Expansion Workshop).	GRUAN launch activity as agreed between GRUAN participants.	Lead Centre, with support from GCOS Secretariat / WMO	End 2013
F2:[23]Side Event on GRUAN at 2015 WMO Congress	Summary of side event at ICM-8.	WG-GRUAN chairs, Lead Centre	2015
F3: Develop a simple network / metadata explorer, allowing for easier data discovery, visualization and possibly analysis, using GEarth or GAWSIS http://gaw.empa.ch/gawsis/, GIOVANNI, as examples.	GRUAN network explorer online.	Lead Centre; TT sites	June 2014

g. Bringing in other GRUAN target priority 2 variables and beyond

In its founding GRUAN was intended eventually to fully characterize all upper-air ECVs and their constituent components. To date it has been the over-arching ethos to 'start small, but start' and that remains the case with additional data streams for the priority 1 variables and the inclusion of ozone measurements being the envisaged advances in GRUAN measurement streams in the 2017 time horizon. However, initial scoping is required to when and how to bring in additional measurements in the future. Some of those steps are outlined here. Additional actions are likely to be added at subsequent ICMs. These activities require collaboration with expertize generally outside WG-GRUAN and so require collaboration with third party experts and activities identified (amongst others) to be achieved.

What	Deliverables	By whom	By when
G1: In collaboration with partner networks, assess the relevance and tractability of the full suite of remaining GRUAN target variables defined in GCOS-112 in the context of measurement capabilities and measurement programmes underway in partner networks.	GRUAN report identifying potential target data streams and partners.	WG-GRUAN, Lead Centre, TT ancillary, TT sites	September 2014
G2: Determine how best to collaborate with BSRN to bring surface radiation measurements into GRUAN.	GRUAN report summarizing the strategy for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	January 2015
G3: Determine how best to collaborate with NDACC and GAW to bring in measurements of aerosol properties into GRUAN.	GRUAN report summarizing strategy options for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	January 2016

[23] This is a carry over item from the original IP.

G4: Identify appropriate partner experts / networks to scope options to bring in cloud property measurements into GRUAN.	GRUAN report summarizing strategy options for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	December 2017

5. Tasks that remain open and need to be assigned in future

This section serves to highlight known issues which parties to GRUAN recognize are required to be addressed but to which one or more of the following conditions apply:

- Likely resolution is outside envisaged IP timeline.
- There is no agreement as to the action owner, timeline or both.
- There is a dependency on a third party who has yet to agree to it.
- The problem has yet to be articulated as an actionable item.

The items detailed herein will be regularly revisited by GRUAN participants with a view to moving forwards to resolve them in a timely fashion as resources and expertise permit.

They are detailed according to the potential work plan areas they fall into and filled out to the extent that agreement has been reached at time of the IP going to press.

What	**Deliverables**	**By whom (nominal)**	**By when**
A. Reference observations			
Define surface meteorological measurement requirements (T,p,u possibly others) in support of in-situ and remote sensing activities at GRUAN sites to include aspects on frequency of reporting, calibration and upkeep.	(D1) Technical document	WG-GRUAN	
B. Data policy and data dissemination			
Ascertain which of (1) 'black box' default commercial software or (2) a cut down version of GRUAN processing software produces higher quality radiosonde data for near-real-time delivery.	GRUAN report recommending the preferred software approach to use for near-real-time processing of GRUAN 'B Stream' radiosonde data, and, if required, a suitable data processing for distribution within the GRUAN, and possibly the WMO GUAN network	Lead Centre, TT Radiosondes	January 2014?
Following resolution of the above task, work with GRUAN sites to establish operational near-real-time reporting of GRUAN 'B stream' radiosonde data.	Near-real-time radiosonde data from many GRUAN stations distributed via WIS on an operational basis.	WMO CIMO, NMHSs, TT sites, sonde manufacturers??	??
C. Site considerations and network composition			
D. Science issues			

[24] Conduct a pilot study to evaluate the efficacy of change management protocols / concepts for core priority 1 variable instruments (radiosondes, frostpoint hygrometers and GNSS) in the first instance.		GATNDOR	
Estimate the contributions from all the terms in the error budget of the comparison of the satellite-retrieved and reference temperature and humidity profiles (background, radiometric noise, forward model errors, representativeness, radiosonde errors).		GATNDOR, TT Ancillary	2015?
Develop tools to determine combined measurement uncertainty from optimised complementary datasets, including vertical resolution / correlation effects.		GATNDOR	
Some examples are needed as to how to integrate / carry through not just the best guess but also the uncertainty information appropriately to different applications which may average in space and / or time in different ways.	(D1)Pedagogical paper submitted to peer review. (D2) Set of code to do common data and uncertainty manipulations.	WG-GRUAN, Lead Centre, GATNDOR	
E. Organizational issues			
Consider need for a cross-cutting combined uncertainty task team.			
F. Outreach			
[25] Prepare public outreach material.			
European Commission involvement			
G. Priority 2 variables			

6. Collated set of tasks by envisaged completion date

What	Deliverables	By whom	By when
A7: Develop GRUAN humidity and temperature lidar data products in collaboration with NDACC	D1: Technical documents submitted for review by WG-GRUAN.	TT ancillary	D1: December 2012
C2: Finalize the outputs resulting from the GRUAN Network Expansion Workshop.	D1: GRUAN report synthesizing the four white papers developed through the GRUAN Network Expansion	D1: Greg Bodeker[26] and GRUAN white paper co-authors.	D1: December 2012

[24] This is a carry over item from the original IP.
[25] This is a carry over item from the original IP.
[26] Involvement is funding dependent.

	Workshop.		
A2: Develop GRUAN data products and processing streams for non-RS92 radiosondes in collaboration with relevant sites. [A1]	D1: Written progress report to ICM 5.	Lead Centre, TT sites, TT radiosondes	D1: March 2013
B3: Coordination with satellite data monitoring and validation programmes. The goal is to get GRUAN into the satellite product validation programmes. Three basic steps, the first two are here (see D8): 1) gain routine access to GRUAN and collocate with NPROVS data streams 2) develop / disseminate useful monitoring and analysis tools that benefit both the GRUAN and satellite community. See also standing item on improving satellite programme linkages.	D1: Retention of collocated satellite / sonde / NWP data within or linked from the GRUAN data archive to facilitate intercomparisons.	TT Ancillary, WG-GRUAN	D1: March 2013
B3: Coordination with satellite data monitoring and validation programmes. The goal is to get GRUAN into the satellite product validation programmes. Three basic steps, the first two are here (see D8): 1) gain routine access to GRUAN and collocate with NPROVS data streams 2) develop / disseminate useful monitoring and analysis tools that benefit both the GRUAN and satellite community. See also standing item on improving satellite programme linkages.	D3: Develop a calibration/validation concept for the EUMETSAT geostationary MTG series based on GRUAN sites	TT Ancillary, WG-GRUAN	D3: March 2013 (EUMETSAT ITT pending)
C1: Process all current and interim new applicant sites through the GRUAN certification process as defined in Section 5 of the GRUAN Guide to Operations (GCOS-171)[27].	D1: Short report for inclusion in ICM-5 proceedings summarizing sites processed to date.	WG-GRUAN	D1: March 2013
D1: Recommend practices on managing change in GNSS-PW measurements.	Report at ICM-5 and then feed into creation of relevant TDs.	TT GNSS	March 2013
D5: Develop a toolset to quantify the impacts of spatial mismatches on data comparisons and quantification of uncertainties.	A paper on "Co-location of observations" with an emphasis of how to account for mismatches in quantifying and comparing uncertainties	GATNDOR	March 2013

[27] Note that sites can only be assessed and certified for data streams that have been fully developed (Section A) at the time of the submission of the application.

	submitted to a peer reviewed journal.		
D6: Investigate site-specific "recipes" of GRUAN ancillary and sonde measurements (including uncertainties) for comparison with sounding products, focusing on atmospheric temperature and moisture. [D4]	D1: Report to ICM-5.	TT ancillary	D1: March 2013
E2: Instigate a Metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata easily understandable and machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.	D1: Document defining terms of reference and remit of the Task Team.	WG-GRUAN Co-chairs	D1: March 2013
D4:[28] Provide a scientific basis for sites to choose the optimal combination of measurement technologies to best meet GRUAN needs.	D1: A paper on "Quantifying the value of complementary measurements" submitted to a peer reviewed journal.	GATNDOR, TT ancillary	D1: May 2013
A8: Develop GRUAN temperature and water vapour microwave radiometer data products in collaboration with NDACC.	D1: Technical documents submitted for review by WG-GRUAN.	TT ancillary	D1: June 2013
A9: Develop GRUAN ozone and water vapour FTIR data products in collaboration with NDACC.	D1: Technical documents submitted for review by WG-GRUAN.	TT ancillary	D1: June 2013
B1: Implement an agreed procedure for monitoring GRUAN data usage to the extent practical / allowable, including items such as publications arising, queries received etc.	D1: A GRUAN report documenting how data usage will be monitored and reported.	Lead Centre	D1: June 2013
B2: Implement a mechanism whereby real-time feedback from NWP centres such as ECMWF on those GRUAN data exchanged in NRT, in the form of differences between observations and assimilation, provides real-time validation of GRUAN derived measurement uncertainty estimates.	A short GRUAN report detailing the process implemented to provide feedback of observation minus background fields to the GRUAN Lead Centre.	David Tan	30 June 2013

[28] This item is carried over from the original IP.

C2: Finalize the outputs resulting from the GRUAN Network Expansion Workshop.	D2: A paper submitted to a peer reviewed journal that provides a more accessible version of the GRUAN report (e.g. a BAMS article).	D2: Greg Bodeker and GRUAN white paper co-authors.	D2: June 2013
E2: Instigate a Metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata easily understandable and machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.	D2: Formal establishment of Metadata Task Team – list of members provided to Lead Centre.	WG-GRUAN Co-chairs	D2: June 2013
A1: Finalize the definition of reference observations and GRUAN data products for RS92 radiosondes; specifically assess the time lag in RS92 humidity corrections by comparing the GRUAN processing to other published approaches.	D1: Manuscript describing the results of the humidity time lag assessment submitted to a journal.	Lead Centre, TT radiosondes	D1: August 2013
A3: Address the unresolved operational aspects of radiosonde measurements and their interpretation.	D3: A document detailing the operational challenges related to multi-payload soundings submitted either to peer reviewed literature (first choice) or to WG-GRUAN for review as a TD. D4: An assessment of the advantages and disadvantages of of manual vs. autosonde launches written up and submitted to the peer reviewed literature.	TT radiosondes	D3: Drafted August 2013 D4: August 2013
B3: Coordination with satellite data monitoring and validation programmes. The goal is to get GRUAN into the satellite product validation programmes. Three basic steps, the first two are here (see	D2: Online tools based on the NPROVS system to visualize and monitor the GRUAN profiles and collocated	TT Ancillary, WG-GRUAN	D2: August 2013

D8): 1) gain routine access to GRUAN and collocate with NPROVS data streams 2) develop / disseminate useful monitoring and analysis tools that benefit both the GRUAN and satellite community. See also standing item on improving satellite programme linkages.	satellite and NWP data (GPROVS).		
A1: Finalize the definition of reference observations and GRUAN data products for RS92 radiosondes; specifically assess the time lag in RS92 humidity corrections by comparing the GRUAN processing to other published approaches.	D2: Complete set of TDs describing all aspects of GRUAN RS92 procedures.	Lead Centre, TT radiosondes	D2: December 2013
A3: Address the unresolved operational aspects of radiosonde measurements and their interpretation.	D1: Manuscript(s) detailing operational considerations for controlled descents submitted to a journal or detailed in a GRUAN Report.	TT radiosondes	D1: December 2013
F1: Organize a GRUAN launch symposium, possibly jointly with NDACC, WMO, others to mark operational status of the network and invite user communities (along with those present at the GRUAN Network Expansion Workshop)	GRUAN launch activity as agreed between GRUAN participants.	Lead Centre, with support from GCOS Secretariat / WMO	End 2013
B1: Implement an agreed procedure for monitoring GRUAN data usage to the extent practical / allowable, including items such as publications arising, queries received etc.	D2 (recurring): Once instigated and agreed to, the data usage reports would become an appendix to the annual (February) Lead Centre reports.	Lead Centre	D2: First reported February 2014 then every February thereafter
A4: Develop frostpoint hygrometer data products. Guidance needs to account for operation of CFH, NOAA FPH, Snowwhite[29].	D1: Technical documentation completed for frostpoint hygrometer measurements.	Lead Centre, TT radiosondes	D1: March 2014
A6: Develop a GRUAN GNSS-PW product.	D1: Manuscript describing the derivation of uncertainty estimates for GNSS-PW measurements submitted to a peer reviewed journal.	TT GNSS	D1: March 2014

[29] If sites look to join and submit FLASH-B measures these will also need to have technical documentation and error budgets / SOPs developed. At this time one GRUAN site operates FLASH-B and they are not proposing its inclusion as a GRUAN data product presently.

C1: Process all current and interim new applicant sites through the GRUAN certification process as defined in Section 5 of the GRUAN Guide to Operations (GCOS-171)[30].	D2: Short report for inclusion in ICM-6 proceedings summarizing sites processed to date.	WG-GRUAN	D2: March 2014
D6: Investigate site-specific "recipes" of GRUAN ancillary and sonde measurements (including uncertainties) for comparison with sounding products, focusing on atmospheric temperature and moisture [D4].	D2: Manuscript submitted for publication.	TT ancillary	D2: March 2014
D4[31]: Provide a scientific basis for sites to choose the optimal combination of measurement technologies to best meet GRUAN needs.	D2: Technical document or publication(s) providing recommendations on the equipment to use at GRUAN sites on the basis of the analysis of experimental data.	GATNDOR, TT ancillary	D2: May 2014
A3: Address the unresolved operational aspects of radiosonde measurements and their interpretation.	D2: If deemed applicable, a technical document that supports the adoption of controlled descent across GRUAN.	TT radiosondes	D2: June 2014
A5: Develop a GRUAN ozonesonde data product in consultation with NDACC and GAW.	D1: Completed technical documents.	Lead Centre	D1: June 2014
B4:Design and instigate a framework to investigate, report and resolve data quality and instrument issues in real-time[32].	GRUAN Technical Document describing real-time QA/QC procedures implemented in GRUAN data flow.	Lead Centre	June 2014
D2: Review measurement scheduling required to meet the needs of temperature trend detection.	GRUAN report as a supplement to the scheduling section of the GRUAN Guide.	TT Scheduling	June 2014
E2: Instigate a metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata easily understandable and	D3: Report on how to make metadata easily understandable and machine readable.	WG-GRUAN Co-chairs	D3: June 2014

[30] Note that sites can only be assessed and certified for data streams that have been fully developed (Section A) at the time of the submission of the application.

[31] This item is carried over from the original IP.

[32] This item is carried over from the original IP. ACRF already have such a capability and should be consulted.

machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.			
F3: Develop a simple network / metadata explorer, allowing for easier data discovery, visualization and possibly analysis, using GEarth or GAWSIS http://gaw.empa.ch/gawsis/, GIOVANNI, as examples.	GRUAN network explorer online.	Lead Centre; TT sites	June 2014
A7: Develop GRUAN humidity and temperature lidar data products in collaboration with NDACC.	D2: Paper describing GRUAN lidar products submitted to peer reviewed journal.	TT ancillary	D2: August 2014
B6: Define the frostpoint hygrometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A4]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT Radiosonde	D1: September 2014
B9: Define the Lidar data collection client requirement, identify the central data processing facility, and initiate data flow. [A7]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT ancillary	D1: September 2014
G1: In collaboration with partner networks, assess the relevance and tractability of the full suite of remaining GRUAN target variables defined in GCOS-112 in the context of measurement capabilities and measurement programmes underway in partner networks.	GRUAN report identifying potential target data streams and partners.	WG-GRUAN, Lead Centre, TT ancillary, TT sites	September 2014
G2: Determine how best to work with BSRN to bring surface radiation measurements into GRUAN.	GRUAN report summarizing the strategy for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	January 2015
A2: Develop GRUAN data products and processing streams for non-RS92 radiosondes in collaboration with relevant sites. [A1]	D2: Series of technical documents describing processing streams for all non-RS92 radiosondes.	Lead Centre, TT sites, TT radiosondes	D2: March 2015
A4: Develop frostpoint hygrometer data products. Guidance needs to account for operation of CFH, NOAA FPH, Snowwhite[33].	D2: Paper submitted to a peer reviewed journal.	Lead Centre, TT radiosondes	D2: March 2015

[33] If sites look to join and submit FLASH-B measures these will also need to have technical documentation and error budgets / SOPs developed. At this time one GRUAN site operates FLASH-B and they are not proposing its inclusion as a GRUAN data product presently.

A6: Develop a GRUAN GNSS-PW product.	D2: Technical documentation completed for GNSS-PW measurements	TT GNSS	D2: March 2015
A8: Develop GRUAN temperature and water vapour microwave radiometer data products in collaboration with NDACC.	D2: Paper describing the GRUAN Microwave radiometer product submitted to peer reviewed journal.	TT ancillary	D2: March 2015
A9: Develop GRUAN ozone and water vapour FTIR data products in collaboration with NDACC.	D2: Paper describing GRUAN FTIR products submitted to peer reviewed journal.	TT ancillary	D2: March 2015
B3: Coordination with satellite data monitoring and validation programmes. The goal is to get GRUAN into the satellite product validation programmes. Three basic steps, the first two are here (see D8): 1) gain routine access to GRUAN and collocate with NPROVS data streams 2) develop / disseminate useful monitoring and analysis tools that benefit both the GRUAN and satellite community. See also standing item on improving satellite programme linkages.	D4: Develop a tool for the optimization of vertical resolution of data to be used in RTM.	TT Ancillary, WG-GRUAN	D4: March 2015 (PhD student funding pending)
E1: Instigate a user review group[34] to meet on a biennial basis.	D1: User review group terms of reference drafted and agreed to by WG-GRUAN.	WG-GRUAN Co-chairs	D1: Mar 2015
E2: Instigate a Metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata easily understandable and machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.	D4: Report on how to make metadata discoverable.	WG-GRUAN Co-chairs	D4: March 2015
A5: Develop a GRUAN ozonesonde data product in consultation with	D2: Paper submitted to peer reviewed	Lead Centre	D2: June 2015

[34] Periodic external review group with ex-officio Lead Centre, WG-GRUAN and GCOS Secretariat membership. In effect a "Client survey".

NDACC and GAW.	journal.		
B7: Define the ozonesonde data collection client requirement, identify the central data processing facility, and initiate data flow. [A5]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT Radiosonde	D1: June 2015
B8: Define the GNSS-PW data collection client requirement, identify the central data processing facility, and initiate data flow. [A6]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT-GNSS	D1: June 2015
C2: Finalize the outputs resulting from the GRUAN Network Expansion Workshop.	D3: Solicit expressions of interest from the top 10-15 sites meeting the criteria developed through the GRUAN Network Expansion Workshop.	(D3) WG-GRUAN, Lead Centre	D3: June 2015
B5: Define the new radiosonde data streams data collection client requirement, identify the central data processing facility, and initiate data flow. [A2]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT Radiosonde, TT sites	D1: September 2015
B10: Define the microwave radiometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A8]	D1: Data flow through NCDC portal.	D1: Lead Centre, TT ancillary	D1: September 2015
D3: Extend trend sensitivity studies to stratospheric water vapour[35].	D1: Submission of a paper to a peer reviewed journal.	TT Scheduling	D1: September 2015
B11: Define the FTIR data collection client requirement, identify the central data processing facility, and initiate data flow. [A9]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT ancillary	D2: December 2015
B6: Define the frostpoint hygrometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A4]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT Radiosonde	D2: December 2015
B9: Define the Lidar data collection client requirement, identify the central data processing facility, and initiate data flow. [A7]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT ancillary	D2: December 2015
C1: Process all current and interim new applicant sites through the GRUAN certification process as defined in Section 5 of the GRUAN	D3: Final report on sites processed through initial certification.	WG-GRUAN	D3: Dec 2015

[35] Funding bid dependent

[36] Note that sites can only be assessed and certified for data streams that have been fully developed (Section A) at the time of the submission of the application.

Guide to Operations (GCOS-171)[36].			
D3: Extend trend sensitivity studies to stratospheric water vapour[37].	D2: GRUAN report as supplement to the scheduling section of the GRUAN Guide.	TT Scheduling	D2: December 2015
E1: Instigate a user review group[38] to meet on a biennial basis.	D2: Proceedings of the inaugural meeting of the user review group.	WG-GRUAN Co-chairs	D2: Dec 2015
F2[39]: Organize side Event on GRUAN at 2015 WMO Congress.	Summary of side event at ICM-8.	WG-GRUAN chairs, Lead Centre	2015
G3: Determine how best to work with NDACC and GAW to bring in measurements of aerosol properties into GRUAN.	GRUAN report summarizing strategy options for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	January 2016
C3: Periodic science review of network expansion priorities and progress.	D1: Annual reports to ICMs.	GATNDOR, TT sites	March 2016 and annually thereafter
A2: Develop GRUAN data products and processing streams for non-RS92 radiosondes in collaboration with relevant sites. [A1]	D3: Paper describing the totality of standard GRUAN 'operational radiosonde' processing (and intercomparisons) submitted to journal.	Lead Centre, TT sites, TT radiosondes	D3: June 2016
B8: Define the GNSS-PW data collection client requirement, identify the central data processing facility, and initiate data flow. [A6]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT GNSS	D2: September 2016
B5: Define the new radiosonde data streams data collection client requirement, identify the central data processing facility, and initiate data flow. [A2]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT Radiosonde	D2: December 2016
B10: Define the microwave radiometer data collection client requirement, identify the central data processing facility, and initiate data flow. [A8]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT ancillary	D2: December 2016
E2: Instigate a metadata Task Team to coordinate the uniform collection, use, and analyses of metadata across all GRUAN data streams. Metadata related issues: - how to make metadata	D5:Report on completeness of metadata collection.	WG-GRUAN Co-chairs	D5: December 2016

[37] Funding bid dependent

[38] Periodic external review group with ex-officio Lead Centre, WG-GRUAN and GCOS Secretariat membership. In effect a "Client survey".

[39] This is a carry over item from the original IP.

easily understandable and machine readable. - How to make metadata discoverable and commensurate with WMO WIS standards. - How to ensure we are collecting all necessary metadata.			
A10: Develop GRUAN Dobson/ Brewer data product in collaboration with GAW and NDACC.	D1: Completed technical documents.	Lead Centre	D1: June 2017
B7: Define the ozonesonde data collection client requirement, identify the central data processing facility, and initiate data flow. [A5]	D2: Assessment of data usage, issues and potential improvements for this data stream.	D2: TT Radiosonde	D2: June 2017
A10: Develop GRUAN Dobson/ Brewer data product in collaboration with GAW and NDACC.	D2: Paper describing GRUAN Dobson/Brewer data products submitted to peer reviewed journal.	Lead Centre	D2: December 2017
G4: Identify appropriate partner experts / networks to scope options to bring in cloud property measurements into GRUAN.	GRUAN report summarizing strategy options for consideration by GRUAN stakeholders.	WG-GRUAN Co-chairs, TT ancillary	December 2017

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Appendix 1: Working Group on GRUAN membership and responsibilities

Name	Country	Affiliation	Relevant areas of expertise	Roles
Chairmen				
Peter Thorne peter.thorne@noaa.gov	USA	CICS-NC / NOAA NCDC	Climate data records	Co-chair, CCl representative
Greg Bodeker greg@bodekerscientific.com	New Zealand	Bodeker Scientific	Documentation, governance, instrumentation and observing practices	Co-chair
Members				
Arnoud Apituley	Netherlands	KNMI	Ground-based remote sensing instrumentation, research	Member
Franz Berger	Austria /Germany	DWD	Surface based remote sensing, site management	Member, Director ofLindenberg Observatory
Stephan Bojinski	Switzerland / Germany	WMO	satellite observations	Member, WMO Secretariat
Geir Braathen	Switzerland / Norway	WMO	NDACC co-chair	Member, WMO Secretariat
Belay Demoz	USA	Howard University	Observational research, site operation	Member, Co-chair site representatives task team
John Dykema	USA	Harvard University	GPS-RO and metrology	Member
Alessandro Fasso	Italy	University of Bergamo	Environmental statistics	Member, member of TIES
Masatomo Fujiwara	Japan	Hokkaido University	Radiosonde and ground-based remote sensing instrumentation	Member, Co-chair Task Team on radisondes
Rolf Philipona	Switzerland	MeteoSwiss	Radiosonde and ground-based remote sensing instrumentation.	Member, Co-chair Task Team on radisondes
Tom Gardiner	UK	National Physical Laboratory	Metrology	Member, co-chair Task Team on scheduling
Dale Hurst	USA	NOAA	In situ and remote sounding	Member, co-chair Task Team on sites
Thierry Leblanc	USA	JPL-Table Mountain Facility	Ground-based remote sensing instrumentation	Member, co-chair Task Team on ancillary measurements
Fabio Madonna	Italy	Potenza	In situ and remote sounding	Member, Chair GATNDOR

Andrea Merlone	Italy	INRIM	Metrology	Member, chair of Meteomet initiative
Kalev Rannat	Estonia	Tallinn University of Technology	GNSS-PW	Member, co-chair Task Team on GNSS precipitable water measurements
Tony Reale	USA	NOAA NESDIS	Satellite programme validation (NPROVS)	Member, co-chair Task Team on ancillary measures
Dian Seidel	USA	NOAA Air Resources Laboratory	Historical climate change, radiosonde data records	Member
Masato Shiotani	Japan	Kyoto University	Satellite data, SPARC	Member
Doug Sisterson	USA	ARM program	Observing networks programme management expertise	Member
David Tan	UK	ECMWF	Reanalyses and NWP expertise	Member
Russell Vose	USA	NOAA NCDC	Historical climate change, data management, network design	Member
Junhong Wang	USA	NCAR	Radiosonde and GNSS technologies and climate datasets	Member, co-chair Task Team on GNSS precipitable water measurements
David Whiteman	USA	NASA/ GSFC	Climate change research	Member, co-chair Task Team on scheduling
Steve Williams	USA	NCAR	In-situ and remote-sensing Instrumentation	Member
Ex-officio Members				
GCOS representative				
Carolin Richter	Switzerland / Germany	WMO	GCOS representative	Ex-officio, Director GCOS Secretariat
WMO representative				
Miroslav Ondras	Slovenia /Switzerland	WMO OBS Department	CIMO perspective, WMO guiding literature	Ex-officio; WMO Secretariat
CIMO representative				
Bertrand Calpini	Switzerland	Meteoswiss	Observation programme and site management; LIDARs	Ex-officio, CIMO President

CBS representative				
N.N.				Ex-officio,
CAS representative				
N.N.				Ex-officio,
CCI representative				
Peter Thorne				Ex-officio, also co-chair
GRUAN Lead Centre representative				
Holger Vömel	Germany	DWD	Upper-air water vapour	Ex-officio, Head of Lead Centre
Howard Diamond	USA	NOAA NCDC	US GCOS Office	Ex-officio; Head of US GCOS Office

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Appendix 2: Terms of Reference for AOPC Working Group on GRUAN (formerly named Working Group on Atmospheric Reference Observations, WG-ARO)

(July 2012)

Background

The GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) Working Group on GRUAN (WG-GRUAN) was established in 2006 in recognition of the importance of initiating reference-quality observations of vertical profiles of essential climate variables, starting with temperature and water vapour, from the surface into the stratosphere to enhance monitoring and understanding of climate variability and change.

The 2004 GCOS Implementation Plan identified the establishment of a reference-quality network as 'a very high priority' for implementation by 2009. While this very ambitious timeline was not achieved, significant progress has been made. The 2010 Update of the GCOS Implementation Plan (GCOS-138) reiterated the call for the establishment of the GCOS Reference Upper Air Network (GRUAN) for reference upper-air measurements and a complementary system for reference measurements from satellites, and support of reanalysis and reprocessing activities as a key need. Since 2008 DWD (Deutscher Wetterdienst) have hosted the GRUAN Lead Centre consisting of scientific and secretarial support at their Lindenberg Observatory to oversee day-to-day operations of the network. In early 2012 more formal involvement of WMO and its technical commissions was endorsed at a meeting held under the auspices of the WMO Integrated Global Observing System (WIGOS). This enhanced involvement of WMO in GRUAN operations will be achieved by incorporating representatives from relevant WMO Technical Commissions.

A GRUAN Implementation Plan was published in July 2009 (GCOS-134) covering the period until 2013. An amendment to this implementation plan, covering the period through 2016, will be published in September/October 2012.

It is the Working Group's responsibility to facilitate this implementation, liaising with other groups and national and international bodies to ensure that an eventual GRUAN network is fit for purpose, robust and has the required long-term commitment and management structures. The WG-GRUAN also provides guidance to the GRUAN Lead Centre. The WG-GRUAN membership consists of a broad range of scientific and technical experts who contribute expert oversight and support to GRUAN development and operations.

The AOPC, supported by the GCOS Secretariat and guided by the GCOS Steering Committee, provides ultimate direction and oversight of GRUAN. The WG-GRUAN provides direct guidance on the operation of GRUAN and is supported by specific GRUAN Task Teams and the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR). The day-to-day management and coordination of the network, including training and ensuring the archival and dissemination of GRUAN data, is the responsibility of the GRUAN Lead Centre. An organizational structure for GRUAN as a whole is given in Figure 1.

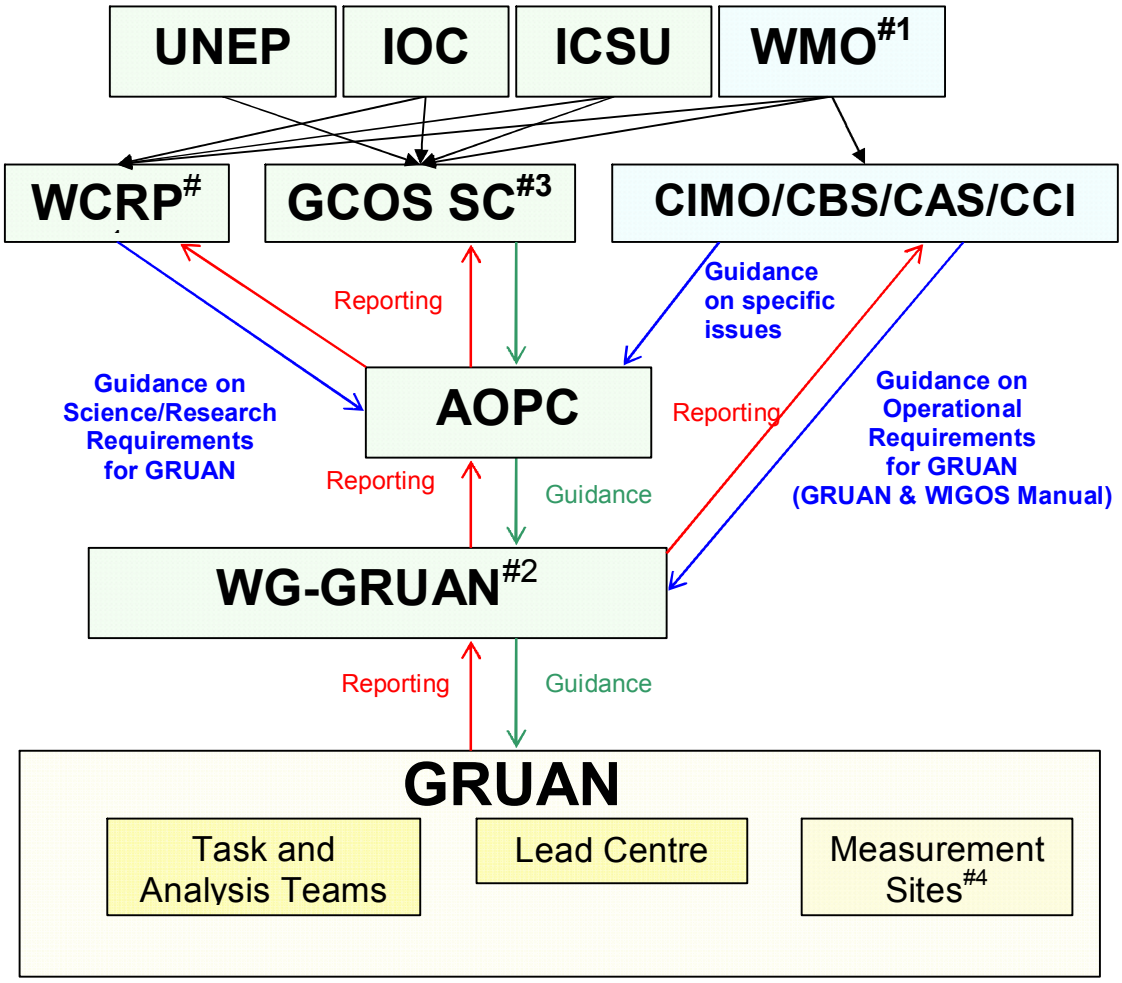

Figure 1: Organizational diagram for GRUAN management and oversight.

Notes
1. WCRP identifies scientific and research requirements for GRUAN, while WMO identifies operational requirements.
2. Composition of WG-GRUAN to be determined by the AOPC 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;
3. GCOS Steering Committee.
4. GRUAN Measurement Sites are contributed by Members of WMO.

Working group roles and responsibilities

The working group has a range of roles and responsibilities that reflect the GCOS and WMO expectations of its outputs. Here, these have been arranged under broad categories that reflect the core facets of the expected work.

Governance

- To provide scientific, technical and management oversight of the operations of the GRUAN Lead Centre, which will manage the overall work and evolution of the network, and which shall report to the WG-GRUAN at least twice a year;
- To define roles and responsibilities of the GRUAN Lead Centre and, as deemed appropriate, other centres, for data management, quality monitoring, analysis and capacity development purposes;

- To initiate, approve, manage and dissolve, as appropriate, task teams established to undertake specific activities in support of GRUAN;
- To encourage and support the activities of GATNDOR and provide feedback and input as requested by that team;
- To ensure that GRUAN operations are well aligned with the goals and directions of GCOS through liaison with the AOPC;
- To ensure that GRUAN operations are well aligned with WMO goals and directions through the representatives of WMO Technical Commissions;

Site selection, assessment, and certification

- To define essential and desirable requirements of a GRUAN site in terms of operational principles, the collection of metadata, assessment of measurement uncertainties, data management, variables addressed, and instrumentation. Develop these requirements in consultation with other relevant observing programmes, make them publically available, and periodically reassess their validity;
- To certify sites based on (i) information submitted by the site, (ii) an assessment made by the Lead Centre, and (iii) potentially on-site assessment by WG and/or Lead Centre members, against the set of requirements. Periodically reassess/audit sites against these same requirements;
- To decide on the composition of GRUAN, including the selection of sites. This should be done in consultation with AOPC and other advisory bodies as appropriate;

Coordination

- Together with relevant stakeholders, to plan and realize annual Implementation and Coordination Meetings (ICMs) to be hosted at, or associated with, a GRUAN site and to include a site visit;
- To report at least annually to AOPC on its activities, including the progress towards a reference network, the performance of the network once established, the uses and value of the data collected, and the implications for the global observing system;
- To ensure that the GRUAN Implementation Plan and individual work plans from ICM meetings are carried out, including but not limited to undertaking those activities mandated to the WG-GRUAN;
- To evaluate 6-monthly progress reports from the Lead Centre and GRUAN Task Teams and provide feedback in a timely manner;

Advocacy and outreach

- To work with relevant agencies and programmes to define and promote GRUAN for long-term atmospheric reference observations of a range of specific variables, and to make optimal use of existing and planned infrastructure within the WMO Global Observing System. This includes inter alia, working with the WIGOS planning office as a WIGOS pilot project; the WMO Space Programme, Commission on Basic Systems (CBS) and CIMO on satellite and radiosonde calibration and validation issues, including reference instrumentation and metadata;
- To provide for appropriate communication and outreach activities (through such activities as conferences, making connections with other programmes, organizing special conference sessions on GRUAN etc.).
- To work with strategic partner organizations and projects as specified from time to time inter-alia by AOPC, in annual Implementation and Coordination Meetings or in the GRUAN Implementation Plan.

Mode of operation

- The Chair or Co-chairs will be appointed by the AOPC.
- Working Group members will be approved by the AOPC.
    - Co-chairs from each Task Team and from GATNDOR are expected to be members.
    - At least one member will explicitly represent each of the four WMO Technical Commissions associated with GRUAN (Figure 1).
    - At least one expert in the following fields shall be present to ensure a plutocracy of views:
        - Climate science
        - In-situ atmospheric observations

        - Satellite observations
        - NWP / reanalyses
        - Statistics
        - Metrology
    - Members may fulfill multiple roles, but AOPC needs to be mindful of any potential conflicts of interest that may arise as a result.
    - The AOPC decides at its annual meetings on additional experts and observers to join the WG-GRUAN as ex-officio or full members.
- Members will be expected to serve for at least two years or until the membership is reviewed.
- During the GRUAN implementation phase it is envisaged that annual WG-GRUAN meetings will be convened together with ICMs (see above), which group members will be expected to attend. Funding to support in part or in full WG-GRUAN meetings should be sought from sponsors.
- The WG-GRUAN will generally correspond by e-mail and teleconferences (to be undertaken every other month), and take advantage of relevant workshops and conferences to hold meetings (in addition to meeting at the time of ICMs). Additional meetings will be convened by the Chair(s) upon demand, in consultation with the GCOS Secretariat and GRUAN partner institutions.
- These Terms of Reference will be subject to periodic review by AOPC in liaison with the Co-chairs of the Working Group and the Lead Centre.

Appendix 3: GRUAN Task Teams

Team 1: ***Radiosondes***

To evaluate the data products (uncertainty budget etc.) and bring in missing knowledge

Co-chairs: Masatomo Fujiwara & Rolf Philipona

Terms of Reference

The Task Team on radiosondes exists to provide guidelines for the GRUAN on how to obtain the best possible, reference quality data from radiosoundings. According to the reference specifications (Immler et al., 2010) that have been approved during the ICM-2 meeting in Payerne, "reference quality" means that a data product is:

- traceable to an accepted standard (generally to the SI unit)
- providing a comprehensive uncertainty analysis.
- properly documented (e.g. by peer-reviewed publications) and validated (e.g. by intercomparisons).

In this context the Task Team supports efforts from manufacturers, scientists (at sites) and the GRUAN lead centre to take the steps that are necessary to obtain reference quality in radiosoundings, i.e. to choose suitable sensors, to define correction algorithms and QA/QC procedures, to identify and quantify sources of uncertainty, to define data formats for submission, and to provide proper documentation of this entire chain including technical documents and peer-reviewed publications.
It should be noted that a “radiosonde” has several components such as temperature sensor, humidity/water vapour sensor, pressure (or GPS altitude) sensor, balloon-parachute-unwinder part, etc. The Task Team will need to discuss issues related to each of these components and, if necessary, will try to bring in additional expertise by appointing ad-hoc, “associate” members. It will also gather the information on existing sensors for the GRUAN lower priority parameters (see GCOS-134) and recommend specific actions. An important issue to consider is the long-term stability of radiosonde observations in order to ensure that GRUAN data series are useful for monitoring climate change. While it is desirable that the best possible equipment is used at GRUAN sites at any time, it is also important to assess and limit the damage that instrumental change can cause on climate data series due to improperly corrected or undiscovered systematic effects.
The Task Team needs to make recommendations in terms of applied radiosondes, procedures, launch schedules and algorithms that meet the specifications required to achieve the goals of GRUAN in co-operation with other task teams and the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR).

References

GCOS-134, WMO TD 1506: GRUAN Implementation Plan 2009-2013.

F. J. Immler, J. Dykema, T. Gardiner, D. N. Whiteman, P. W. Thorne, and H. Vömel: Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products Atmos. Meas. Tech., 3, 1217-1231,2010, doi:10.5194/amt-3-1217-2010

Duties

Under the auspices of the Working Group on Atmospheric Reference Observations the Task Team was established to:

- Evaluate radiosonde data products on the basis of the GRUAN reference specifications and the GRUAN measurement specifications
  - Survey radiosondes and sensors (in particular considering their performance in intercomparisons).
  - Review the uncertainty analyses and correction algorithms.
  - Recommend radiosonde launch procedures and metadata to be collected.
- Draw conclusions on the suitability of radiosondes, specific sensors, procedures, and algorithms for the network.
- Promote scientific efforts for assessing and improving radiosonde performance.
- Recommend measures for ensuring long-term stability of radiosonde records.
- Provide input to the GRUAN Manual and Guide by defining launch procedures and pre-launch checks that need to be followed by the sites

Reporting and governance

- The team is managed by two co-chairs, at least one of which is member of the Working Group of the Atmospheric Reference Observation (WG-GRUAN). They should use as primary points of contact the Chair of WG-GRUAN and Head of Lead Centre
- The Task Team co-chairs shall report on a six-monthly basis in February and August to the WG-GRUAN a brief written progress report which will also be posted as part of official documentation relating to the GRUAN network. These reports will be discussed on a phone conference between WG-GRUAN the Lead Centre and all task teams with representation from at least one co-chair from this task team.
- At least one Task Team co-chair and potentially additional Task Team members shall attend as deemed appropriate and affordable the annual ICM meetings to report in person on progress.
- The Task Team is expected to respond to all reasonable formal requests for advice from the WG-GRUAN, Lead Centre, other task teams or sites made on an ad-hoc basis in a timely manner.
- Reports to the WG-GRUAN or any kind of recommendation or publication issued by the Task Team need to be approved by at least the co-chairs and all core members OR their alternates (see the column "status" in the member table below).

Operation

- Means of communication are e-mail, blog and telephone-conference. The telephone-conferences will be organized by the co-chairs at least twice a year. To undertake in person meetings, the Task Team should take advantage of other meetings where a sufficient number of members is in attendance.
- Task Team chairs will seek funding for dedicated meetings if deemed appropriate.
- The Task Team will exist until such time as its duties are deemed to have been completed by the WG-GRUAN
- Task Team terms of reference and membership will be revised at the very latest 2 years from the date of this version, or earlier if requested by either party, by the Task Team members in consultation with WG-GRUAN.

Team 2: ***GPS-PW***

To draw conclusions on the suitability of the deployed equipment

Co-chairs: June Wang & Kalev Rannat

Terms of Reference

The GCOS Reference Upper Air Network (GRUAN) GNSS precipitable water (GNSS-PW) Task Team (TT) was established in summer 2010 as one of six GRUAN TTs. TTs are charged with addressing critical GRUAN requirements. Ground-based GNSS (Global Navigation Satellite Systems) PW was identified as a Priority 1 measurement for GRUAN, and the GNSS-PW TT's goal is to develop explicit guidance on hardware, software and data management practices to obtain GNSS PW measurements of consistent quality at all GRUAN sites.

Duties

Under the auspices of the WG-GRUAN the task team was established to:

1. To define GRUAN requirements for GNSS-PW observations that are missing in the requirement tables in GCOS–112. This TT may not be able to define all requirements and may suggest alternative ways for the GRUAN management team to identify these requirements.
2. To document and review current status of GNSS instruments and associated data processing methods used at GRUAN sites. The survey results will be passed to the GRUAN Lead Centre to keep it updated regularly.
3. To define GRUAN requirements for a state-of-the-art GNSS station. These include receiver and antenna hardware, antenna monumentation, and siting criteria. The work will include a review of current IGS (International GNSS Service) documents and adaption - and/or extension - of the IGS requirements relevant to atmospheric measurement applications. The TT will prepare a draft document on "GRUAN GNSS Site Guidelines". This TT will closely collaborate with the TT on "Site assessment, expansion and certification" on this issue.
4. To develop guidance on the type, amount, format, temporal resolution and latency of data and associated metadata needed to be stored from the ground-based GNSS measurements and other auxiliary data sources, and data archive and dissemination methods.
5. To identify best practices in making and verifying GNSS observations for GRUAN and other climate applications defined in Task 1. The methods (including hardware, software, models and analysis techniques) used to make GNSS observations are constantly evolving, and are expected to continue to do so in the future. As a consequence, the task team will make recommendations regarding current best practices and procedures for making GNSS observations and deriving quantities from them.
6. To follow the guidance on reference quality upper-air measurements outlined in Immler et al. (2010) and provide guidelines for GNSS-PW uncertainty analysis including ways to calculate uncertainties for each data point as required by GRUAN and include them in the final data products.
7. To address the question of how to better manage changes applied to ground-based GNSS measurements in both hardware and software and to make sure that the changes will be taken into account for long-term data analysis. The TT will recommend some practices on documenting detailed changes, and accessing and minimizing the impacts. This task is closely tied to the topics on "Management of Change" undertaken by GRUAN Analysis Team for Network Design and Operations Research (GATNOR), so it will be achieved by collaborations with GATNOR.
8. Encouraging and recommending experiments and research for resolving the tasks mentioned in the subtopics 1-7.

Reporting and governance

- The task team shall be run by at least one and preferably two co-chairs and they should use as primary points of contact the Chair of WG-GRUAN and Head of Lead Centre as deemed appropriate.
- The task team co-chairs shall report on a six-monthly basis in February and August to the WG-GRUAN a brief written progress report which will also be posted as part of official documentation relating to the GRUAN network. These reports will be discussed on a phone

conference between WG-GRUAN the Lead Centre and all task teams with representation from at least one co-chair from this task team.
- At least one task team co-chair and potentially additional task team members shall attend as deemed appropriate and affordable the annual ICM meetings to report in person on progress.
- The task team will be expected to respond to all reasonable formal requests for advice from the WG-GRUAN, Lead Centre, other task teams or sites made on an ad-hoc basis in a timely manner. Guidance on what constitutes reasonable can be solicited from WG-GRUAN as required.

Operation
- The task team will largely coordinate by email and teleconference and take advantage of other meetings where a quorum is in attendance to undertake in person meetings. It is expected that teleconferences between all task team members will be undertaken at a minimum 6-monthly frequency.
- Task team chairs will seek funding for dedicated meetings if deemed appropriate.
- The task team will exist until such time as its duties are deemed to have been completed by the WG-GRUAN
- Task team terms of reference and membership will be revised at the very latest 2 years from the date of this version, or earlier if requested by either party, by the task team members in consultation with WG-GRUAN.
- The task team will be expected to interact with GRUAN “Site assessment, expansion and certification” task team, GATNDOR team and perhaps other teams.

Reference
GCOS–112, WMO Tech. Doc. 1379: GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options.

F. J. Immler, J. Dykema, T. Gardiner, D. N. Whiteman, P. W. Thorne, and H. Vömel: Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products Atmos. Meas. Tech., 3, 1217-1231,2010, doi:10.5194/amt-3-1217-2010

Team 3: ***Measurement schedules and associated instrument-type requirements***

To develop defensible, quantifiable, scientifically-sound guidance

Co-chairs: Tom Gardiner & Dave Whiteman

Terms of Reference

The task team on measurement schedules aims to develop defensible, quantifiable, and scientifically-sound guidance for GRUAN sites regarding measurement schedules and associated site requirements, in order to meet all GRUAN objectives including climate trend detection, satellite calibration/validation, and studies of local mesoscale processes and events. Working out an optimal mix of measurement strategies that best serves these combined calls on the network will require careful consideration of a number of factors beyond the purely technical ones. Due to the fact that site resources will differ across the network, it will be necessary to produce a number of different and scalable strategies that can be utilized by sites possessing varying technical resources. These strategies must be backed up by quantitative evidence to the extent possible, and should apply to both in-situ and remote sensing capabilities.

Duties

Under the auspices of the WG-GRUAN Task Team 3 was established to:

- Provide guidance on the ideal suite of measurement sampling requirements for the network addressing the primary GRUAN objectives :

1. climate monitoring – to confirm the requirements for regular measurements (in terms of capability and schedule) that will provide a reliable and consistent measurement of
decadal trends in the key climate variables,
2. satellite calibration and validation – focusing primarily on providing long-term support for the satellite community, particularly in the area of data 'gap-filling' to help establish consistency and comparability between individual satellite records.

- Liaise with GRUAN sites and groups planning mesoscale studies to review what the potential impact of such studies, with their own specific objectives and scheduling requirement, will be on the long-term monitoring objectives of GRUAN.
- Gather information on sampling strategies from the peer-reviewed literature, GRUAN documentation, and currently unpublished studies of which the team is aware;
- Identify suitable measurement and model data sets for sampling studies;
- Define sampling strategy assessment activities, with the aim of linking these to the current and future research activities of the team members and other groups;
- Report to the WG-GRUAN on all above duties

Reporting and governance

- The task team shall be run by at least one and preferably two co-chairs and they should use as primary points of contact the Chair of WG-GRUAN and Head of Lead Centre as deemed appropriate.
- The task team co-chairs shall report on a six-monthly basis in February and August to the WG-GRUAN via a brief written progress report which will also be posted as part of official documentation relating to the GRUAN network. These reports will be discussed on a phone conference between WG-GRUAN, the Lead Centre and all task teams with representation from at least one co-chair from this task team.
- At least one task team co-chair and potentially additional task team members shall attend as deemed appropriate and affordable the annual ICM meetings to report in person on progress.
- The task team will be expected to respond to all reasonable formal requests for advice from the WG-GRUAN, Lead Centre, other task teams or sites made on an ad-hoc basis in a timely manner. Guidance on what constitutes reasonable can be solicited from WG-GRUAN as required.
- The task team will be expected to interact with the other GRUAN task teams and the GATNDOR research activities on areas of common interest.

Operation

- The task team will largely coordinate via email and teleconference and take advantage of other meetings where a quoracy is in attendance to undertake in-person meetings. It is expected that teleconferences between task team members will be undertaken at a minimum 6-monthly frequency, with at least two thirds of the team membership providing a quorate discussion.
- Task team chairs will seek funding for dedicated meetings if deemed appropriate.
- The task team will exist until such time as its duties are deemed to have been completed by the WG-GRUAN.
- Task team terms of reference and membership will be revised at the very latest 2 years from the date of this version, or earlier if requested by either party, by the task team members in consultation with WG-GRUAN.

Team 4: ***Ancillary measurements***

With initial focus on MWR, Lidars and FTIR; To interface with satellite experts and NDACC

Co-chairs: Tony Reale & Thierry Leblanc

Terms of Reference

The task team on Ancillary measurements exists to define protocols, sampling strategies and required metadata for respective suites of ancillary ground and satellite measurement routinely collected and archived at GRUAN sites. Ancillary in this respect are defined as measurements at a given GRUAN site that do not fall under the set of required observations from all sites, for example the reference radiosonde. Ancillary in this sense also include required respective instrument calibration, inter-validation strategies and results and all metadata pertinent to the deployed equipment and associated measurement suites. These shall be compiled utilizing best measurement practices as defined through associated measurement international expert team representation in this group. Practices and protocols for respective measurement suites as defined by this group shall constitute guidelines for respective site and measurement certification.

Duties

Under the auspices of the WG-GRUAN, the Task Team was established to:

- Interface with other expert teams (such as NDACC, EMERGE, etc.);
- Evaluate the data products (uncertainty budget etc.) and bring in missing knowledge;
- Inventory potential instruments (and interface with other GRUAN-Task Teams if needed);
- Establish campaign rationales for the validation of data from multiple platforms;
- Establish a system for the routine collection and display of data from multiple platforms;
- Develop guidance on the type and amount of data and associated metadata needed to be stored from the instruments, as needed;
- Draw conclusions on the suitability of the deployed equipment and advise accordingly to GRUAN Task Team on Site Assessment; and
- Report to WG-GRUAN on all above duties

Reporting and governance

- The task team shall be run by at least one and preferably two co-chairs and they should use as primary points of contact the Chair of WG-GRUAN and Head of Lead Centre as deemed appropriate.
- The task team co-chairs shall report on a six-monthly basis in February and August to the WG-GRUAN a brief written progress report which will also be posted as part of official documentation relating to the GRUAN network. These reports will be discussed on a phone conference between WG-GRUAN the Lead Centre and all task teams with representation from at least one co-chair from this task team.
- At least one task team co-chair and potentially additional task team members shall attend as deemed appropriate and affordable the annual ICM meetings to report in person on progress.
- The task team will be expected to respond to all reasonable formal requests for advice from the WG-GRUAN, Lead Centre, other task teams or sites made on an ad-hoc basis in a timely manner. Guidance on what constitutes reasonable can be solicited from WG-GRUAN as required.
- As part of their inventory duty, the task team will be expected to interact with the GRUAN task team on Site Selection

Operation

- The task team will largely coordinate by email and teleconference and take advantage of other meetings where a quoracy is in attendance to undertake in person meetings. It is expected that teleconferences between all task team members will be undertaken at a minimum 6-monthly frequency.
- Task team chairs will seek funding for dedicated meetings if deemed appropriate.
- The task team will exist until such time as its duties are deemed to have been completed by the WG-GRUAN

- Task team terms of reference and membership will be revised at the very latest 2 years from the date of this version, or earlier if requested by either party, by the task team members in consultation with WG-GRUAN.

Team 5: ***Site Representation***

Representing GRUAN sites

Co-chairs: *Belay Demoz & Dale Hurst*

Terms of Reference

The Task Team on site representation exists to provide and maintain a convenient mechanism for each GRUAN site to communicate with other sites, the WG-GRUAN and the Lead Centre, and for the WG-GRUAN and Lead Centre to disseminate information to all GRUAN sites through their Task Team representative. Each site is encouraged to have one representative on this task team, and if possible, to provide other task teams with knowledgeable members such that each site has wide-ranging representation within GRUAN. The task team on site representation plans to include a shared member from the task team on Site assessment, expansion and certification, preferably from an institution/program that is under-represented within GRUAN, so that site representatives are promptly informed about any recent activities of that task team.
The success of GRUAN is critically dependent on the efficiency of communication between sites, the WG-GRUAN and the Lead Centre. Sites experiencing problems, concerns, breakthroughs in best practices and/or important discoveries are expected to initially communicate these to the task team on site representation. After internal discussion, the task team will communicate this information to the appropriate GRUAN representatives.

Duties
Under the auspices of the Working Group on Atmospheric Reference Observations the task team was established to:

- Ensure that sites concerns are communicated to Lead Centre and WG-GRUAN on an ad-hoc basis
- Facilitate the spreading of best practices and information between sites
- Provide solicited or ad-hoc recommendations to the WG-GRUAN on technical documents that affect site operations, namely procedural changes in measurement techniques and data flow
- Champion the work of sites within the GRUAN process and facilitate inter-site collaboration on projects of mutual interest in GRUAN
- Liaise with remaining Task Team chairs to ensure that sites concerns are adequately represented within those groups

Reporting and governance

- The task team shall be run by at least one and preferably two co-chairs and they should use as primary points of contact the Chair of WG-GRUAN and Head of Lead Centre as deemed appropriate.
- The task team co-chairs shall report on a six-monthly basis in February and August to the WG-GRUAN a brief written progress report which will also be posted as part of official documentation relating to the GRUAN network. These reports will be discussed on a phone conference between WG-GRUAN the Lead Centre and all task teams with representation from at least one co-chair from this task team.
- At least one task team co-chair and potentially additional task team members shall attend as deemed appropriate and affordable the annual ICM meetings to report in person on progress.
- The task team will be expected to respond to all reasonable formal requests for advice from the WG-GRUAN, Lead Centre, other task teams or sites made on an ad-hoc basis in a timely manner. Guidance on what constitutes reasonable can be solicited from WG-GRUAN as required.

Operation

- The task team will largely coordinate by email and teleconference and take advantage of other meetings where a quoracy is in attendance to undertake in person meetings. It is expected that teleconferences between all task team members will be undertaken at a minimum 6-monthly frequency.
- Task team chairs will seek funding for dedicated meetings if deemed appropriate.

- The task team will exist until such time as its duties are deemed to have been completed by the WG-GRUAN. It is envisioned that the duties of this task team will be ongoing.
- Task team terms of reference and membership will be revised at the very latest 2 years from the date of this version, or earlier if requested by either party, by the task team members in consultation with WG-GRUAN.
- New GRUAN sites will be asked to provide a member to the task team on site representation as soon as possible.

GRUAN Analysis Team for Network Design and Operations Research

Representing GRUAN sites

Chair: *Fabio Madonna*

GATNDOR Scope
GATNDOR is a research team supporting the development and implementation of GRUAN on scientifically sound foundations. The team performs focused, short-term research to address specific topics identified by the GRUAN science and management community. GATNDOR efforts are coordinated with those other GRUAN Task Teams and with national GCOS programmes when appropriate.

GATNDOR Concept
Under the auspices of the GCOS (Global Climate Observing System) AOPC (Atmospheric Observation Panel for Climate) Working Group on GRUAN, a research team will identify and carry out a series of well-defined, limited-scope retrospective analyses of existing observations from established stations that are potential GRUAN (GCOS Reference Upper Air Network) sites, other complementary observations, metadata, and model simulations. The unifying purpose of this series of studies will be to obtain insight from existing information for optimizing the design and implementation of the GRUAN observational programme to meet its scientific goals.

At present, GATNDOR is investigating the three following topics:

- Atmospheric Variability and co-location
- Management of Change
- Quantifying the Value of Complementary Observations

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Appendix4: List of GRUAN documents

GCOS-171, WIGOS Technical Report No. 2013-03: The GCOS Upper-Air Reference Network (GRUAN) GUIDE

GCOS-170, WIGOS Technical Report No. 2013-02: The GCOS Upper-Air Reference Network (GRUAN) MANUAL

GCOS-167: Report of the Fifth GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-5), *De Bilt, the Netherlands, 25 February - 1 March 2013*.

GCOS-161: Report of the Fourth GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-4), *Tateno, Japan, 5-9 March 2012.*

GCOS-155: Report from the WIGOS Pilot Project Meeting on GRUAN Observing Practices and Governance, Geneva, Switzerland, 25-27 January 2012

GCOS-134, WMO TD 1506: GRUAN Implementation Plan 2009-2013.

GCOS-149, WMO TD 1575: Report of the Third GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-3), *Queenstown, New Zealand, 28 February - 4March 2011*.

GCOS-140, WMO TD 1526: Report of the Second GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-2), *Payerne, Switzerland, 2-4 March 2010*.

GCOS-134, WMO TD 1506: GRUAN Implementation Plan 2009-2013.

GCOS-131, WMO TD 1492: Report of the First GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-1), *Norman, Oklahoma, USA, 2-4 March 2009*.

GCOS-121, WMO Tech. Doc. 1435: Report of the GCOS Reference Upper-Air Network Implementation Meeting, *Lindenberg, Germany, 26-28 February 2008*.

GCOS–112, WMO Tech. Doc. 1379: GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options.

F. J. Immler, J. Dykema, T. Gardiner, D. N. Whiteman, P. W. Thorne, and H. Vömel: Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products Atmos. Meas. Tech., 3, 1217-1231,2010, doi:10.5194/amt-3-1217-2010

GRUAN Technical Documents:

GRUAN-TD-1 Michael Sommer, Manual for the Data Management in GRUAN, ***Draft*** v0.4: 16 February 2011.

GRUAN-TD-3 Michael Sommer, User Guide of GRUAN RS Launch Client, ***Draft*** v0.4: 17 February 2011.

GRUAN-TD-4 Franz Immler and Michael Sommer, Brief Description of the RS92 GRUAN Data Product (RS92-GDP), v1.1: 7 December 2011.

GRUAN-TD-6 Shoji et al., GRUAN Ground-based GNSS Site Guidelines, v1.0: 23 May 2012.

GRUAN Technical Reports:

GRUAN-RP-1: Howard J. Diamond and Bill Murray, First GRUAN Data Management Coordination Meeting at NCDC (Asheville, North Carolina, USA), 28-29 September 2009

GRUAN-RP-2: Miloshevich et al., GRUAN Radiosonde Task Team Review Report on the 2010 WMO Radiosonde Intercomparison:

Appendix 5: List of Acronyms

AOPC	Atmospheric Observation Panel for Climate (GCOS)
ARM	Atmospheric Radiation Measurement Program
BSRN	Baseline Surface Radiation Network
CBS	Commission for Basic Systems (WMO)
CFH	Cryogenic Frostpoint Hygrometer
CIMO	Commission for Instruments and Methods of Observation (WMO)
DWD	German Meteorological Service (DeutscherWetterdienst)
ECMWF	European Centre for Medium-Range Weather Forecasts
FTIR	Fourier Transform Infrared Spectrometer
GATNDOR	GRUAN Analysis Team for Network Design and Operations Research
GAW	Global Atmospheric Watch (WMO)
GCOS	Global Climate Observing System
GNSS	Global Navigation Satellite System
GOS	Global Observing System (WMO)
GPS	Global Positioning System
GPS-PW	Global Positioning System Precipitable Water
GRUAN	GCOS Reference Upper Air Network
GSICS	Global Space-Based Inter-Calibration System
ICM	Implementation - Coordination Meeting (GRUAN)
IP	Implementation Plan
IWV	Integrated Water Vapour
JPL	Jet Propulsion Laboratory (NASA)
KNMI	Royal Netherlands Meteorological Institute
LIDAR	Light Detection and Ranging (optical remote sensing)
MOL	Lindenberg Meteorological Observatory
NASA	National Aeronautics and Space Administration (USA)
NCAR	National Centre for Atmospheric Research (USA)
NCDC	National Climatic Data Center (NOAA)
NDACC	Network for the Detection of Atmospheric Composition Change
NOAA	National Oceanic and Atmospheric Administration (USA)
NOAA FPH	NOAA Frost Point Hygrometer
NPROVS	NOAA Products Validation System
NWP	Numerical Weather Prediction
PW	Precipitable Water
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SI	International System of Units
SSI	Scientific Sounding Instruments
TT	Task Team
UT/LS	Upper Troposphere and Lower Stratosphere
WCRP	World Climate Research Programme
WG-ARO	Working Group on Atmospheric Reference Observations (AOPC)
WIGOS	WMO Integrated Global Observing Systems
WIS	WMO Information System
WMO	World Meteorological Organization

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