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Report of the Second GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-2)

June 2010

GCOS - 140
(WMO/TD No. 1526)

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL COUNCIL FOR SCIENCE

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1. Introduction

The second GRUAN Implementation-Coordination Meeting (ICM-2) was held 2-4 March 2010 at the GRUAN site in Payerne, Switzerland. The meeting was generously hosted by Meteo Swiss with support from the Swiss GCOS Office at MeteoSwiss, the U.S. GCOS Program Office at NOAA's National Climatic Data Center (NCDC), NOAA's Climate Program Office (CPO) and the GCOS Secretariat at the World Meteorological Organization.

The annual GRUAN meetings afford an opportunity for the Working Group on Atmospheric Reference Observations (WG-ARO; operating under the GCOS/ World Climate Research Program (WCRP) Atmospheric Observation Panel for Climate), the GRUAN Lead Centre (LC), and representatives from initial GRUAN sites and other stakeholders to review progress to date, highlight issues and exchange views. As the GRUAN meeting took place in Switzerland, close to WMO's Headquarters in Geneva, it offered a unique opportunity of cooperation and gaining strong input from WMO experts and jointly sponsored programmes.

The meeting's main goal was to update participants on GRUAN progress and discussion of new developments (for agenda see Appendix 1), with a focus on:

- quality assurance, science, site issues, and collaboration with WMO;
- instigation of a detailed work plan for the Lead Centre, the WG on Atmospheric Reference Observations (WG-ARO) and other parties for the coming year.

As in the previous ICM, the meeting also included a site visit with a guided tour of the suite of instrumentation operating at the Aerological Station Payerne, the technical centre of Meteo Swiss. The Payerne Station has a long record of upper-air observations - the first CIMO comparisons of Radiosondes were carried out there in 1956. Participants regarded the site visit as very valuable, allowing deeper insight as to how Payerne addresses GRUAN-related issues and in particular appreciated the local staff's hospitality and willingness to answer questions.

This report summarises key discussions and outcomes rather than being a full record of the meeting. All documents prepared in support of ICM-2 and meeting presentations are available on the GRUAN website at http://www.gruan.org (Meetings: Payerne 2010: Documents).

2. Progress on advancing the GRUAN Implementation Plan

2.1. Status of the Plan

The 2009-2013 GRUAN Implementation Plan (GCOS-134[2]), prepared in response to a request from AOPC and completed (as agreed at ICM-1) in July 2009 gives a 4-year road map to a fully operational GRUAN network. The completion of this document was briefly highlighted by Peter Thorne, Chair WG-ARO and the meeting structure rolled out along those lines. The expectation that people should have made themselves aware of the plan's contents in advance was reiterated. It was stressed that the plan is flexible because it is complemented by the short- and medium-term GRUAN work plans, aspects of which can supersede the Implementation Plan workplan, and which are updated on an annual basis following the Implementation-Coordination Meetings.

2.2. Lead Centre report on progress

The six-monthly activity report by the Lead Centre for the period August 2009 – January 2010 is given in Appendix 3. It includes activities addressing items in the annual short-term GRUAN work plan (as laid down in the Report of the First GRUAN Implementation-Coordination Meeting, GCOS-131[1]) and within the framework of the GRUAN Implementation Plan 2009-2013 (GCOS-134[2]).

[1] Available under: http://www.wmo.int/pages/prog/gcos/Publications/gcos-131.pdf
[2] Available under: http://www.wmo.int/pages/prog/gcos/Publications/gcos-134.pdf

Highlights during the reporting period were:

1. The GRUAN definition and terminology for measurement uncertainty and stability as outlined in a paper by Franz Immer[3] (cf. Section 4 GRUAN reference measurements);
2. A meeting between LC, DOE/ARM and NOAA/NCDC staff to establish a formal path of data processing and data dissemination, which took place in Sept 2009 at NOAA/NCDC in Asheville and Oak Ridge, USA, leading to an agreement on a measurement and data management strategy for the GRUAN[4];
3. The GRUAN involvement in the preparation for the upcoming CIMO intercomparison campaign in Yangjiang, China, in July 2010;
4. A workshop discussing the results of the Lindenberg Upper Air Methods Intercomparisons (LUAMI), held at Lindenberg in Sept 2009;
5. And the recent "Lapbiat 2" campaign, which took place in Jan-Mar 2010 at the GRUAN station in Sodankylä, Finland, with participation of Lead Center staff and manufacturers. This was an intensive test of the prototype reference radiosondes under development.

Further news noted was the establishment of the GRUAN communication platform, a blog hosted by wordpress.com: http://gruan.wordpress.com/. This blog, administered by the LC, serves as discussion forum and documentation archive for the GRUAN community and includes a FAQ list (cf. also section 7 network protocols and documentation).

The Lead Centre Head stressed that the recipe for the success of GRUAN lays in the long-term commitment of sites, which are paying attention to details and focus on the important issues that arise. The binding element of GRUAN measurements will be the rigorous assessment of uncertainties independent of the measurement device. GRUAN will be the reference network for measuring crucial climate system parameters such as water vapour, temperature, and others, but current "reference" (radiosonde) instruments are not adequate to meet climate requirements. Intercomparison exercises such as the recent "Lapbiat 2" campaign and the collaboration with CIMO offer most valuable opportunities for the GRUAN community to learn lessons.

3. International programme perspectives

Wenjian Zhang (Director WMO OBS Department) and Ghassem Asrar (Director WCRP) highlighted the importance of reference-quality measurements of the atmospheric profile for climate studies. Dr Zhang assured the continuing support of GRUAN by WMO Departments. This support and their presence at the meeting were gratefully acknowledged by the participants.

Dr Zhang stressed the importance to engage not only the operational, but also the scientific community in building the WMO Integrated Global Observing System (WIGOS). Until being officially adopted by WMO Congress in 2011, WIGOS currently is in a so called 'test-of-concept phase'. The following 'implementation phase' for WIGOS is foreseen to run from 2012 to 2015. Of high priority for WIGOS is to close observational gaps in space and time (e.g. oceans, IPY), and also to maximize the quality of data and data products, e.g. by ground truthing. Especially for remote sensing observations more efforts in standardization are needed. GRUAN fits into the integrated approach of WIGOS and can make very valuable contributions for validation and intercallibration, for example contributions to the processing of satellite observations for climate purposes in the frame of the recently instigated multi-national scope-CM activity to produce climate data records from satellites.

Dr Asrar expressed that improving climate predictions and understanding of human influence on the climate system are the mission and objectives of WCRP. The activities of GRUAN are highly welcomed by WCRP. In particular WCRP applauded the pursuit of adding error bars to observational data sets usable by climate models and the stated aim of connecting surface-based observations to

[3] Immler, F. J., J. Dykema, T. Gardiner, D. N. Whiteman, P. W. Thorne, and H. Vömel, A guide for upper-air reference measurements, Atmos. Meas. Tech., submitted 2010.

[4] Detailed report available at: http://www.gruan.org and http://gosic.org/whatsnew.htm

satellite observations. WCRP fields of core activities are the cryosphere, stratosphere, energy and water cycle, and ocean and these overlap in many ways with the scientific aims of GRUAN.

Prof. Johannes Staehlin represented the Global Atmospheric Watch (GAW) programme in his function as chair of the scientific advisory group (SAG) for ozone. SAGs serve as scientific bodies nominated by the WMO Commission for Atmospheric Sciences (CAS) Working Group that assist in management and implementation of the GAW programme. Lessons for GRUAN can be learned from the SAGs' experiences and it would be desirable to involve GAW representatives into activities of the newly established GRUAN Task Teams. Mutual representation in other initiatives, such as NDACC, was also recommended.

Prof Staehlin reminded participants on the prevailing discrepancy in ozone trends among satellite and *in situ* observations and stressed the importance for reliable ground-based ozone measurements, as well as comparing ground based, aircraft and satellite ozone measurements. Although the Montreal Protocol was successful, continuous monitoring is still required. Open scientific questions persist for example about the influence of climate change on the recovery of the ozone layer and if even an over-recovery could be expected. During the following discussion, it was suggested that ozone should develop from currently a priority 2 to a priority 1 variable for GRUAN.

Over the course of 2009, several international bodies made recommendations pertaining to the implementation of GRUAN. The GCOS Atmospheric Observation Panel for Climate (AOPC) recommended to WMO CBS the establishment of an expert team on GRUAN assisting in translating a GRUAN Guide of Operations into WMO guidance material. This way, formal engagement by WMO Members could be achieved in the long term. CBS ICT-IOS ET-EGOS at its 4th session in December 2009 agreed with this view and recommended that a CBS Expert Team on GRUAN be formed by the end of 2010.

4. GRUAN reference measurements

Franz Immler from the GRUAN Lead Centre outlined the proposed terminology and methodology for GRUAN reference measurement specifications as documented in his paper titled: "A guide for upper-air reference measurements"[3]. Underlying references are the 'Guide to the expression of uncertainty'[5] and the CIMO 'Guide to Meteorological Instruments and Methods of Observation'[6]. According to this terminology, an uncertainty range is used instead of a measurement error, because the "true value" of a physical quantity can never be determined. Any "black box instrument" with an uncertainty given by the manufacturer but without knowledge where this uncertainty comes from is not suitable for GRUAN measurements.

GRUAN needs to address what a reference measurement is in terms of:

1. the best estimate for the quantity to be measured that relates directly or through a robustly quantified chain to a standard;
2. the best estimate for the level of confidence for this measurement (uncertainty); and
3. the metadata and documentation required to guarantee traceability.

The uncertainty of all GRUAN observations must be robustly ascertained in a reproducible manner traceable to absolute or relative standards, and whenever possible traceable to SI units. Vaisala RS-92 temperature measurements from the LUAMI campaign serve as a case study of *in situ* measurements for best practice to ensure the traceability of reference-quality measurements (cf. 13 Fig. 1 and Fig. 2; workplan action 13). The case study showed the need for careful ground recalibration as the original calibration is often lost during transport and storage until the sondes are used. Recalibration may provide an accuracy of 0.1K at room temperature. The uncertainty is larger at

[5] International Bureau of Weights and Measures (BIPM), 2008: Evaluation of measurement data – Guide to the expression of uncertainty in Measurement; available at: http://www.bipm.org/en/publications/guides/gum.html

[6] World Meteorological Organization (WMO), 2008: Guide to Meteorological Instruments and Methods of Observation, 7th Edition; available at http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html

lower temperatures and heavily effects temperature profile measurements above 25 km altitude. Solving the discrepancy between the standard Vaisala and operational Lindenberg FN correction scheme (a process that includes extra ground checks to those suggested as standard by Vaisala to more fully characterise the instrument properties) still needs further investigation and a similar uncertainty analysis for humidity data is planned to follow soon.

Participants were broadly supportive of the proposed methodology for characterising uncertainties and it was agreed that these would constitute the official definition of the GRUAN uncertainty model upon acceptance of the manuscript (which passed the initial review gate to a two month open review on 9/4/10).

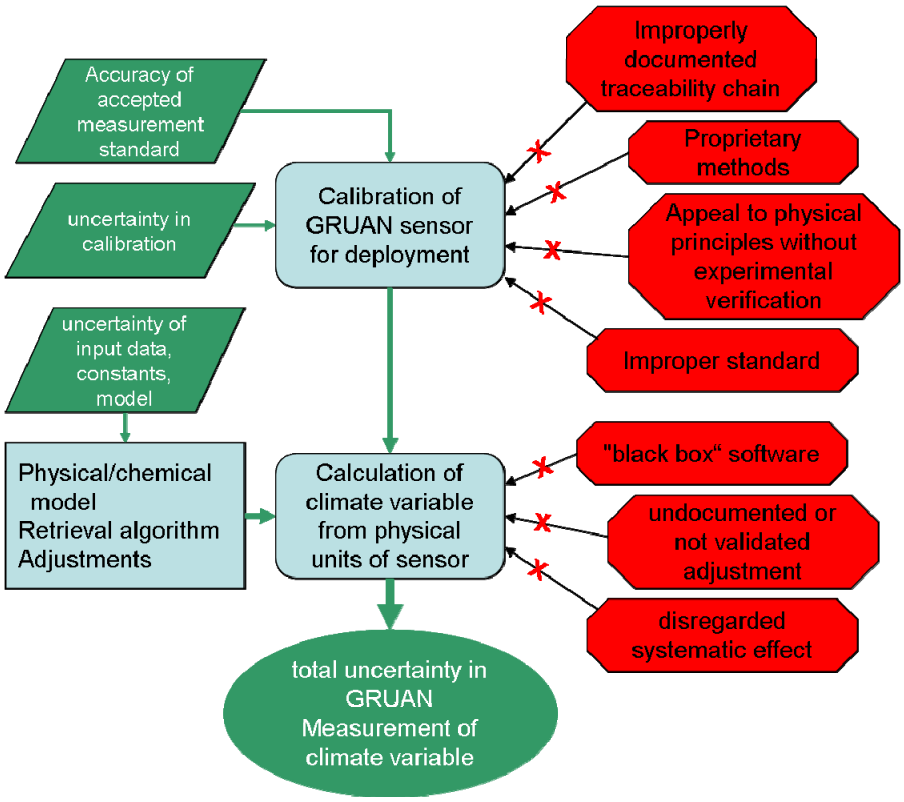

Figure 1: Best practice to ensure traceability of reference-quality measurements. (From Immler et al., submitted to Atmos. Meas. Techn., 2010.)

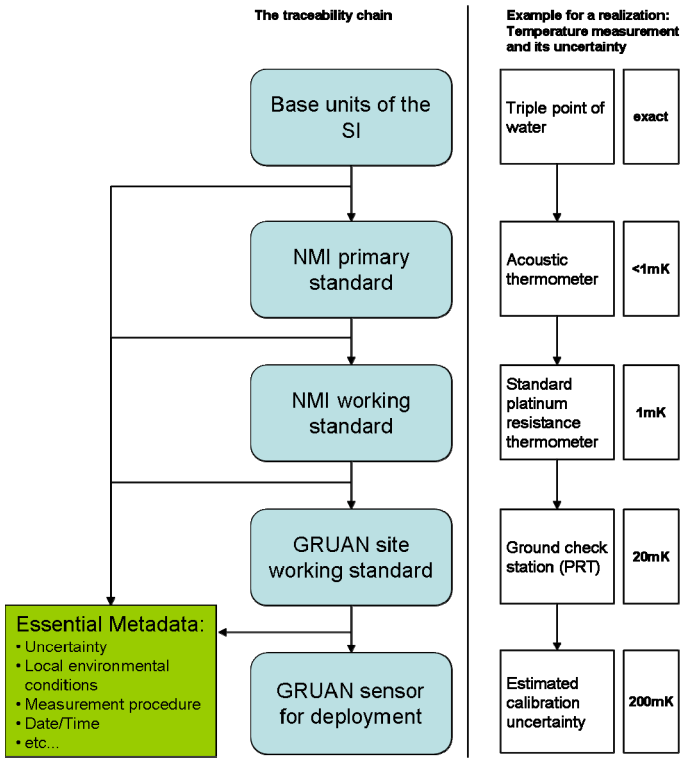

Figure 2: Example of the traceability chain required for a measurement to be counted as a GRUAN measurement: The result of a measurement can be related to the definition of a unit by an unbroken document chain of calibrations, each of which contributes to the measurement uncertainty. (From Immler et al., submitted to Atmos. Meas. Techn., 2010.)

5. Research issues

The aim of the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR) is mainly to undertake scientific investigations in support of GRUAN decision making in respect to:

1. Collocation of observations
2. Management of change
3. Scheduling protocol (frequency of measurements)
4. Quantifying the value of complementary observations
5. Network configuration

Participants felt that this list of topics was still valid and that those started should primarily be finished before looking to expand. In particular the collocation issue is of immediate relevance for the Lauder, Cabauw, and Boulder GRUAN stations. The overlap of some of these activities with some of the proposed Task Teams was noted and discussed more fully later in the meeting. In particular, topic no. 3 will from now on be addressed by a separate GRUAN Task Team, with input from GATNDOR member Tom Gardiner. The need to find additional support for GATNDOR analyses was noted. NOAA might announce specific calls; the Potenza site together with Cabauw has applied for a project under EU FP 7 (cf. 11.3). Subsequent to the meeting a DOE call for funding was issued and circulated to ICM-2 attendees.

Specific goals for the science team until the next ICM in March 2011 are:

- Expand the membership of GATNDOR.
- Forge stronger links between GRUAN/GATNDOR and the satellite community.
- Submit a paper to a peer-reviewed journal on Topic 1: collocation of observations.
- Present preliminary results to ICM-3 on Topics 2, 4 and 5. (cf. work plan action 5)

GATNDOR members then reported on progress with the following topics detailed in the sub-sections below:

5.1. Representativeness of observations

Dian Seidel summarised current work on "How far apart can measurement systems be for …":

- error characterization with co-located instruments;
- enhancement of GRUAN observations via distributed network sites;
- anchoring satellite data; and
- reference radiosonde retrievals.

Dr Seidel presented a drift climatology study, which provides statistical summaries of balloon drift as a function of height, location, mean wind direction, and season. This tool could be used to reveal seasonal influences of different wind speed and directions on the atmospheric sampling. This drift plotter programme will be made available via the GRUAN website.

Dr Reale gave a talk on the impacts of the mismatch between radiosonde launch and satellite observations: An Application of the NOAA Products Validation System (NPROVS). NPROVS is a collocation tool that uses a fast radiative transfer code to generate satellite-radiosonde intercomparisons. Its use for GRUAN purposes was offered. Thus far most NPROVS analyses have considered solely operational sonde launches. Both spatial and temporal mismatches are important in this context. Differences are geographically and seasonally variable as well as station (sonde model) dependent. Therefore it was noted there may not be one universal guideline that can be invoked over collocation.

5.2. Management of change

Changes are inevitable for any observation network, some through choice and some required (e.g. end of parts being manufactured). Therefore, GRUAN instrument operators need to know inter-alia such things as: What co-incident, independent (i.e. redundant) measurements have to be made and for how long to assure the record; how much overlap between old and new instruments and what kind of associated metadata are needed.

On the example of the Lindenberg radiosonde record, Dr Junhong Wang outlined initial studies which explored methods to identify possible break points in a time series and methods to adjust them. The eventual goal of this work would be to make recommendations on best practices for GRUAN regarding the detailed documentation of changes, the assessment of impacts, and how to minimize the impacts of changes. Initial findings were that detailed metadata proved very useful and that 4-times daily sampling provides good coverage of the diurnal cycle. Regular dual-sonde data can provide independent information to evaluate the performance of routine soundings, especially at change points. However, substantial scatter in comparisons of dual sonde humidity data raise concerns. Later on at the site reports session, Dr. Mizuno representing Tateno site presented results from past and current dual-sonde data collected at Tateno and showed how the dual sonde data can help develop homogenized climate records.

Future areas of work are:

- To investigate other factors (batch numbers, separation distance etc.) in order to understand the differences in routine and FN data.
- To develop correction methods for routine data using FN data.
- To study the amount of dual sonde overlap data required building upon case studies that exist or replacement programmes currently being undertaken from GRUAN sites and elsewhere (Tateno, Lindenberg, Payerne, Cambourne);
- To analyze GPS and MWRP data to evaluate the value of redundant data in managing the sonde changes.

There were also two programmatic talks on how existing high quality networks manage change:
Dr Sisterson reported from the ARM experience that it was essential to build a flexible system; to plan, but not to over-engineer. Key was to ensure in the process that it can accommodate for changes because things aren't always going to be right the first time. The underlying ARM management architecture that enables such a system was outlined, which comprises:

- A Science team
- An Infrastructure team, and
- Project managers

Instrument mentors for new instruments and pro-active monitoring and engineering enable the ARM network to address problems in near real-time. Engineering and operations management also ensures the consistency of metadata. It was suggested that GRUAN measurements undertaken at each site require a consistent treatment.

Dr Vose outlined NCDC experiences with the US Climate Research Unit (USCRN) – a surface based climate monitoring network. Main aspects were to be pro-active in network siting and have a rigorous basis for choices (that was quantifiably defensible); to ensure representativeness by comparing trends of the network to trends of larger networks for consistency; to adhere to network principles and maintain detailed documentation.

5.3. Sampling strategy

Dr Tom Gardiner presented a summary of recent and new studies with the aim to develop a strategy to assess the options for an appropriate *in situ* sampling routine:

Reinout Boers had carried out an assessment of the requirements for upper tropospheric water vapour trend determination, using the output of regional climate models as the base dataset[7]. The main conclusion for sampling was that, with 10 % measurement accuracy, it took 45 years of data at a sampling rate of once every four days to determine an observed trend within 30 % of the true trend. The potential of remote sensing to give a higher data rate was highlighted.

In a new assessment strategy the impact of different sampling strategies on temperature trend analyses was modeled by the Environmental Measurement Group at the National Physical Laboratory (NPL), using a statistical trend analysis tool with appropriate uncertainty determination for a high density dataset as a test case. The dataset was resampled according to different strategies and the effect on trend uncertainties has been studied. A number of other numerical / statistical techniques are being studied at NPL that may have direct or indirect application to this work. One area of interest is the determination of temporal and vertical correlation scales in datasets. Planned next steps are to:

- Look at effects of different sampling regimes on trend uncertainties – e.g. daytime only vs. night-time only, reduced sampling densities, etc.
- Consider impact of spatial and temporal correlation lengths on sampling and analysis strategies.
- Look at options for including natural variability on different timescales (ENSO, QBO, etc.), e.g. through modified model function.
- Test conclusions on other measurement datasets and model datasets.
- Carry out similar assessment for water vapour measurements.

Dr David Whiteman presented stochastical model studies to analyse the ability to reveal a trend where atmospheric variability and autocorrelation were characterized using 15-year radiosonde data from the ARM Southern Great Plains Central Facility. The statistical approaches he applied show that as autocorrelation in the data increases the number of years to detect a trend goes up as well. It was noted that atmospheric variability introduces a lot of noise by itself and varies with a factor of two across the globe so a single globally applicable guideline was likely to be inappropriate.

[7] Boers and van Meijgaard, GRL, 36, L19806, 2009

The result of his studies was that the use of a humidity sensor meeting GRUAN requirements as defined in GCOS-112 yields a small decrease in the time required to detect trends versus a 10-15 % precision (without varying systematic biases) sensor. High accuracy and precision are not necessarily required to detect changes in the upper troposphere, while they are much more relevant for stratospheric measurements where natural variability of humidity is much smaller and sampling effects commensurately less important. The dichotomy that this throws up was noted. In the troposphere, increased frequency of measurements could significantly reduce the time to detect a trend and 10-15 % accuracy seemed to be sufficient for water vapour. The expense of the sensor that can provide 10% accuracy in the UT currently limits its use to once per month at selected sites. Lidars could provide more frequent climate quality measurements. Taking into account the instrument expenses, the combination of radiosondes and Raman Lidars appears most promising.

In the following discussions, the question was raised whether trend analysis is the only/main scientific question for GRUAN as the sampling strategy likely looks different for different purposes, depending on the questions the data are expected to answer. In reality other issues also drive the sampling strategy, such as funding, existing requirements, other scientific priorities. The majority of participants agreed that GRUAN is not intended to be truly global, but rather a benchmark network and that it was important to implement a sampling strategy that answered *NOT* just to trends but rather to all envisaged uses of the data including process understanding and validation of data from other networks and satellite programs.

Some specific concerns that represented unresolved questions were raised regarding the trend analyses that had been outlined:

- Using existing data rather than that which will eventually be made with the GRUAN methodologies introduces existing measurement uncertainties (noise and bias) into the analysis which may skew results compared to those that would be obtained from data collected under GRUAN auspices.
- Instrumental noise vs. atmospheric variability. How important is measurement uncertainty compared to frequency?
- Bias changes are the most important factor in incorrect trend determination. How best to incorporate this into these types assessment?
- Should we create model datasets based on knowledge of measurement uncertainties and natural variability?
- How to combine with other measurements with different sample rates?

5.4. Quantifying the value of complementary observations

One of the key GRUAN questions that will have a major impact on the cost of operations is: How much can the measurement uncertainty be reduced by redundant or complementary measurements of the same variable?

In a first approach Dr Junhong Wang suggested to use data from a highly-instrumented location (e.g. an ARM site or Lindenberg), to look at vertical profiles of both temperature and moisture, and to estimate the uncertainty of typical profiles based on individual profiling systems separately, and in various combinations. This would allow a quantification of the error reduction with increasing redundancy of measurements. A model suitable for this approach may be the ARM Value Added Products.

Not much investigation of this topic has been undertaken within the GRUAN community since Wang and Young, 2005[8]. It was noted that Anabella Müller's PhD project will focus on the comparison of radiosonde and Lidar data at Payerne. Jenifer Comstock from the ARM program was also noted to be working on this. There was general agreement that further work on this issue was important.

[8] Wang, J., and K. Young, 2005: Comparisons of 7-year radiosonde data from two neighboring stations and estimation of random error variances for four types of radiosondes; available at: http://www.eol.ucar.edu/homes/junhong/paper/SMOI05-Radiosonde-v2.pdf

5.5. Lessons in network configuration learned form NDACC

Dr Mike Kurylo reported from the past 20 years of NDACC experiences under an operational perspective.

NDACC has:

- **Instrument Working Groups** for measurement QC, including satellite cal/val, data reporting and archiving,
- **Parameter-/Species-specific Working Groups** to assess various measurement techniques and building of homogeneous datasets (e.g. a WG on water vapour, which looks after calibration issues, accuracy of sensor types, spectroscopic issues and retrievals),
- **Cooperating Network Affiliations** with regional, hemispheric or global networks operating independent of NDACC (such as AGAGE, AERONET, MPLNET, NOAA-HATS, SHADOZ),
- a **Steering Committee** providing operational and scientific oversight with two co-chairs, representatives from each of the nine main instrument- and sub-activities, representatives from cooperating networks and other peer- and ex-officio representatives
- a **Science Team** that consists of PI's of all sites.

It was stressed that GRUAN does not have to start everything from scratch; it can draw on capabilities of existing networks and augment these as needed. Temperature, water vapour and ozone for example are also in the NDACC scope offering mutual benefits of collaboration for both networks. Dr Kurylo recommended to keep the structure simple and flexible, to start with instrument-specific groups first and to avoid compromising site selection because of political reasons. Once instruments were fully characterized, it proved useful to shift towards parameter-specific WGs. NDACC has primarily chosen stations across all climatic zones with a fairly complete suite of instrument types, who were able to make a long-term commitment, even if certain stations were a combination of several sites. NDACC recently dropped the designation of primary/secondary sites. This designation caused more logistical problems than it solved practical issues. It was stressed that no network will ever have completely identical sites everywhere but there should be a minimum entry level.

6. Site considerations and network composition

6.1. Refined sampling requirements

The aim of this session was not to immediately revisit the in situ temporal sampling requirements outlined in GCOS-112. There is an overall agreement within the GRUAN community that those requirements stay valid until there exist scientifically defensible (and quantitatively based) guidance as to how to redefine them. It was also recognized that sampling requirements needed to be set out for other technologies in addition to in situ soundings. To develop those quantifiably defensible recommendations, the GRUAN Implementation Plan calls for the instigation of a task team to provide a:

- Quantitative assessment of needs (2010),
- Quantitative assessment of utility of satellite overpass coincident measurements (2011),
- Final set of temporal sampling guidelines (2011).

Redefining the requirements for temporal sampling has to take into account scientific considerations, instrument considerations, as well as financial considerations. Changes should be made only once and guidance needs to be produced for at least all priority 1 variables. The new guidance needs to be in place before a substantial expansion of the network so prospective sites know what will be expected of them. The Task Team on 'measurement schedules and associated instrument-type requirements' is supposed to address these points (cf. Appendix 4).

In the following discussion the question about the fundamental purpose of GRUAN measurements discussed earlier in the science session with regards to the same topic was the focus. Will they mainly

be made for trend detection or should the measurement schedule follow demands for calibration of other measures (e.g. satellite overpasses) or process understanding? It was agreed that all were key requirements and that we should ensure that all purposes can be served by any eventual strategy. There were also questions raised as to whether finance would be available to facilitate certain needs (e.g. from satellite programmes), although this was rated unlikely at least in an ongoing operational sense. Site representatives suggested that of main interest to sites is to characterize the air column over each station, to detect climate change and study the interoperability of instruments. The second strong motivation is to enhance the measurements of operational sondes.

Several sites raised the issue that the current guidelines give no rigorous basis upon when to launch the once monthly sonde capable of measuring the water vapour in the UT/LS region and requested clarification. Several different strategies were discussed. Given that LS natural variability on high frequencies is relatively small it was decided that sites should launch their balloon in those conditions most likely to lead to a successful launch and measurement throughout the column but particularly in the upper reaches of the ascent. Typically this may be under cloud free conditions at night but site staff will be best placed to interpret.

6.2. Site expansion, assessment and certification

Participants agreed that the concept of assessment and certification of GRUAN sites, and how to expand the network shall be explored by a task team. It was also agreed that this team would be responsible for providing recommendations to the WG-ARO and the Lead Centre on any offers of sites. The process of assessment needs transparency and objectivity and broad sign-on to achieve the following steps specified within the GRUAN Implementation Plan:

- Define assessment criteria by 2011
- Create a priority site expansion list by 2012
- Develop operational capability to undertake site assessment by 2013
- Meeting to elicit formal participation (to include existing sites) – GRUAN grand launch as a fully fledged network 2013

Possible site assessment criteria are:

- Adherence to GRUAN protocols and requirements
- Data quality (GRUAN uncertainty measure)
- Operational standards
- Metadata completeness
- Traceability
- Management of changes
- Temporal sampling
- Commitment to and funding for long-term measurements

It was suggested that existing certification processes from the US Climate Reference Network, ARM or NDACC could be used as blueprint. NDACC for example uses site forms that have to be filled out and are assessed at each Steering Committee meeting; site proposals are peer reviewed and come from the WG's to the Steering Committee. It was noted that NDACC has two-step sanctions: temporarily suspending and disaffiliation.

Possible site selection criteria were identified as:

- Critical location (climate regime, under-sampled region, etc.).
- Scientific assessment: stability, current capabilities, etc.
- Funding assessment

7. Network protocols and documentation

7.1. Communication and reporting framework

Michael Sommer from the GRUAN Lead Center, Lindenberg reported on the current progress towards setting up a communication and reporting framework.

- The official GRUAN website http://www.gruan.org is hosted at the German weather service, Deutscher Wetterdienst, and managed and maintained by the Lead Center.
- To facilitate discussions among the GRUAN community, a blog has been set up: http://gruan.wordpress.com/. All communications on the blog are public, transparent, and will be archived. Participants were encouraged to submit material and use the RSS client service. A handout describing how to use this platform was distributed to participants.
- The Lead Center has created several mailing lists for the GRUAN community:
    - gruan.lc@dwd.de – Email to: Holger Vömel, Michael Sommer, Franz Immler
    - gruan.chairs@dwd.de – Email to: LC, WG-ARO, GCOS Secretariat
    - gruan.bug@dwd.de – for technical assistance by Michael Sommer
    - Additional mailing lists will be created upon request, e.g. for GRUAN sites.

An inventory containing information from all GRUAN stations was promised to be published shortly (and has been posted as of late March on www.gruan.org). There will also be instigation of a section with GRUAN relevant publications and the six-monthly Lead Centre Reports. Furthermore, it was noted that there is the possibility to publish reports as GCOS Technical Papers if this is the most appropriate publication route for certain activities in addition to ICM reports.

Other services to be implemented in the near future, when first GRUAN data will be available, are:

- Reporting system to manage / correct issues related to sites / instruments
- Monitoring of the network and data flow

7.2. GRUAN Guide of Operations

Anna Kuhn from the GCOS Secretariat briefed ICM-2 participants on the status of developing a GRUAN Guide of Operations (formerly known as 'Manual'). It was noted that it is appropriate and consistent with WMO terminology to call it a 'Guide' and not a 'Manual'.

Guiding documentation would be urgently needed to inform initial and future GRUAN sites of what is expected of them. The Guide shall define the requirements for GRUAN site operations, including requirements on expected accuracy, long-term stability, and uncertainty measures as stated in GCOS-121. The Guide shall not recommend specific instruments in order to guarantee sustainability of observations and should avoid restriction to a single vendor. The GRUAN Guide has to take into account the heterogeneity of the network and its state of development. While the main binding element, the definition of uncertainty measures, must be reflected prominently. It is hoped that the development of a GRUAN Guide in part also catalyses the necessary decision making. The urgent need for the development of a GRUAN Guide was strongly featured in WIGOS Pilot Project, with indication of resource needs.

Since ICM-1, where participants adopted a draft table of content ('skeleton') of the Guide, only limited progress has been made in developing a GRUAN Guide of Operations and it has become clear that the GRUAN Lead Centre, the WG-ARO and the GCOS Secretariat do not have the necessary resources and/or experience to write such a Guide. Therefore, support from a consultant would be needed. The US GCOS program might be able to support this project. To explore possibilities how to move forward, an expert meeting was scheduled for 5 March 2010. The WIGOS Planning Office sponsored this expert meeting with participation of staff from CIMO, GCOS Secretariat, GRUAN Lead Centre and the chairman of WG-ARO. (Find the minutes of this meeting in Appendix 7.)

Once available, the GRUAN Guide should supplement and be reflected in existing WMO literature. It has been recommended to CBS to establish an expert team on GRUAN by the end-2010, with the

remit to support the process of translating the appropriate elements described in the forthcoming GRUAN Guide into the WMO regulatory material. John Nash, President of CIMO, presented how a GRUAN Guide should be incorporated into existing WMO guidelines (namely, the Manual on GOS (WMO-544), the Guide on the GOS (WMO-488), and the CIMO Guide (WMO-8)). This is an important step to ensure the linkage to the existing operational observing system by informing WMO members about GRUAN requirements, to formally engage them in GRUAN and thereby to ensure the longevity of the network.

8. Site reports and discussion of open questions from sites

Presently 15 initial sites are identified as GRUAN sites (cf. Figure 3). In 2009, the Tateno observatory, run by the Japan Meteorological Agency (JMA), joined the network and Potenza, which is operated by the Institute of Methodologies for Environmental Analysis of the National Research Council (CNR-IMAA), has been officially nominated by the Italian Met Service.

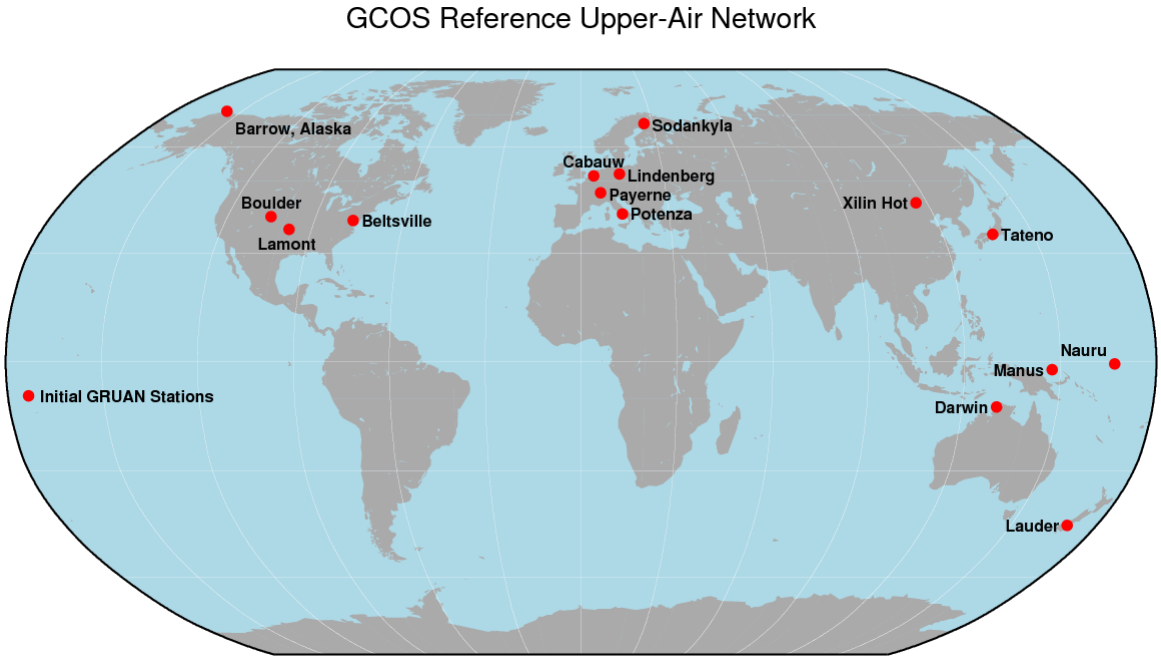

Figure 3: Map of the current GRUAN network.

Holger Vömel gave a general overview on the type of measurements currently made at GRUAN sites. An inventory of capabilities has subsequently been posted on the GRUAN website. It was agreed that a regular review of the inventory (c. yearly) should become part of routine Lead Centre work plan henceforth.

There are three groups of sites:

- Operational radiosonde sites (9)
- Research sonde sites (6)
- Remote sensing sites (3)

The following *in situ* instruments to measure stratospheric water vapor are utilised:

- Cryogenic Frostpoint Hygrometer (CFH), 3 sites
- NOAA Frostpoint Hygrometer (FPH), 2 sites
- Fluorescent Lyman Alpha Stratospheric Hygrometer for Balloon (FLASH-B), 1 site

Besides the recommended GPS total column water vapour measurement (GPS-PW), a variety of remote-sensing instruments are operated at different GRUAN sites; Figure 4 gives an overview on the availability of instrument types.

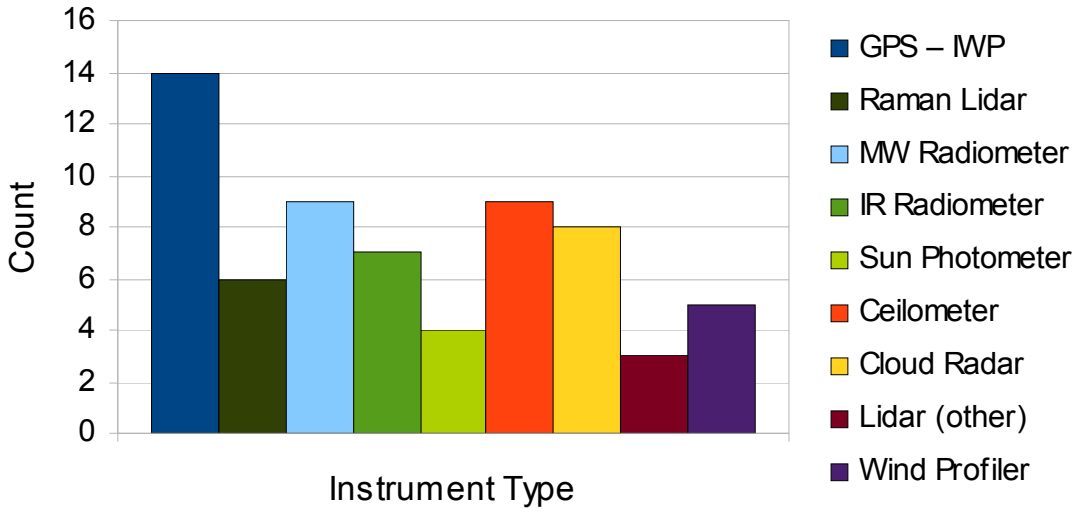

Figure 4: Frequency of occurrence of remote sensing instrument types available at GRUAN sites including instrumentation considered by the sites to fall within a reasonable radius of the central site.

Subsequently, current GRUAN sites reported on their status of activities, with particular attention to the set of 10 questions posed ahead of the session.

- Which of your existing radiosonde launches already meet the mandatory requirements (GCOS 121: once weekly best production quality radiosonde, once monthly stratospheric water vapour; recommended twice daily), and which additional launches need to be instigated or augmented?
- Which ground based measurements can you provide in addition to the mandatory GPS total water vapour column (microwave, FTIR, Lidar …) and how can you use these additional observations to make sure that measurement uncertainty estimates will be consistent?
- Do you have any limitations regarding the development of GRUAN launch protocols for routine and reference sonde launches (e.g. the use of auto-sonde launchers)?
- Do you have any limitations regarding the development of uniform GRUAN data processing schemes for remote sensing observations?
- What local analysis can you provide to assure that measurements uncertainties will be consistent across the network (Analysis of redundant observations either dual sonde launches or sonde + remote sensing observations)?
- For sonde observations: Can you provide all raw data for central archiving?
- For remote sensing observations: Will you be able to archive all raw data for possible future re-analysis and re-processing?
- What help do you need from the Lead Centre / WG-ARO / GCOS Secretariat in moving forwards?
- Will you be able so host local intercomparison campaigns (yet to be scheduled)?
- Are there any special infrastructure needs that should be addressed?

Most sites were both willing and able to contribute experience to answering the key questions of measurement scheduling, quality control and representativeness (using combinations of *in situ* and ground-based remote sensing techniques). In the latter regard, across most sites, the need for firmer guidance on how to adjust their remote-sensing activities to the requirements of the overall GRUAN was clearly expressed. The Task Team on ‘ancillary measurements’ is going to be tasked with starting to consider this issue (cf. Appendix 4).

There followed a general discussion. Briefly, highlights of this session and the ensuing discussion were:

- Sites were asking in many cases for advice on remote sensing measurements, in particular on GPS-PW processing guidance
- A second common request concerned specific scheduling guidance on the once monthly sonde.
- Many sites noted that economic realities were important to acknowledge.
- Some sites noted that data usage acknowledgement was important to secure funding and participation.
- Given the early stages of the GRUAN effort - inter-site cooperation was noted as in some senses lacking and participants expressed the need for better communications with the Lead Centre.
- Peter Thorne (WG-ARO chair) reinforced in this regard that sites were the key both in terms of the data and scientific output if GRUAN were ultimately to be successful.
- The idea of a Task Team representing the sites, to promote inter-site communication and collaboration, and to give a stronger voice was suggested.
- The chair WG-ARO noted that three major *in situ* sounding replacements had been undertaken within the network or were in planning (and that a similar operational replacement was occurring at Cambourne, UK) and urged meeting participants to make use of these data to inform *in situ* replacement strategies which gave best value for money whilst assuring the record.
- The issue of whether to use an autosonde launcher was discussed. It was noted that this does not allow an instantaneous ground-check and therefore may harm traceability while it clearly offers practical and financial benefits.
- Some sites could adopt a sister site in the developing world, following Payerne's example, which is providing radiosondes and technical support to Nairobi, Kenya.

9. Data policy and dissemination

9.1. Data flow

Michael Sommer from the GRUAN Lead Centre outlined the proposed concept for data management as shown in Fig. 5. Progress has been made in defining parts of the data processing regime, the realisation of an interface for GRUAN-internal data flow (cf. Figure 6) and in developing the structure of a GRUAN metadata base (cf. Figure 7).

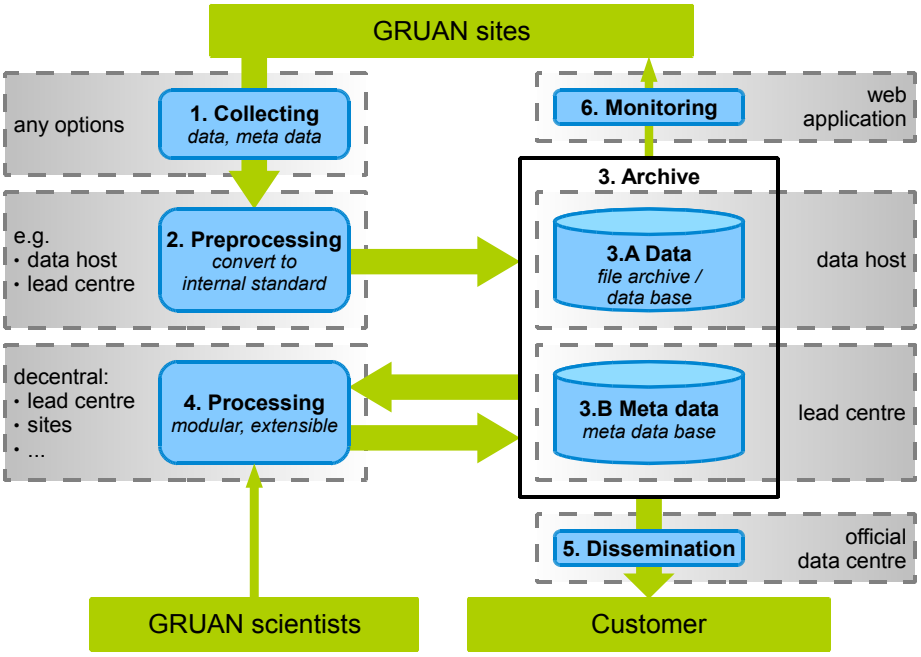

Figure 5: Proposed GRUAN data management concept.

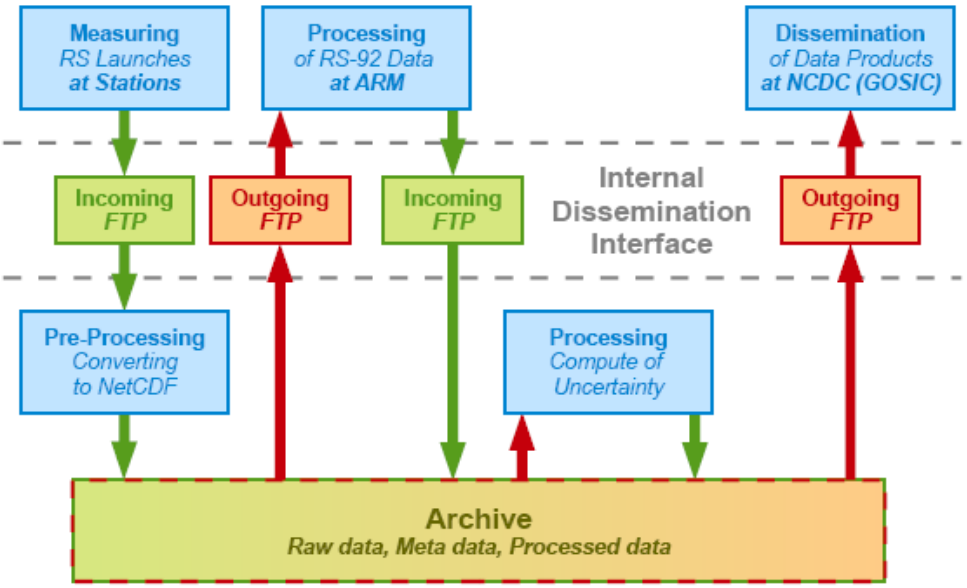

Figure 6: GRUAN data flow. Data measured at a GRUAN site will be pre-processed at the Lead Centre; further processing (QA/QC) of RS92 data occurs at ARM; computing of measurement uncertainty is done at the Lead Centre; data products are finally disseminated at NCDC, accessible via the NCDC Global Observing System Information Center (GOSIC).

The collecting of data (raw data, processed data and metadata) will be realized via two ftp-servers ('ftp-incoming.dwd.de' and 'ftp-outgoing.dwd.de)' connected to one central collecting interface. (A first example was established during the recent intercomparison campaign in Sodankylä: ftp://gruan@ftp-incoming.dwd.de/raw/sodankyla/rs/rs92/.) The flow of GRUAN data will start with radiosonde measurements, firstly for RS 92 (DC3DB files) to be followed by CFH and SRS-400. To find out what metadata is possible and useful to collect, a data collecting guide will be circulated by April 2010. While the first test of data flow to NCDC is planned for July 2010. The envisaged timeline for the implementation of a GRUAN flow is as follows:

April 2010
- A "**Data Collecting Guide**" send to all stations ('*version 0.9'* for radiosonde data)
- Test of data flow to the Lead Centre
- Test of pre-processing (semi-automatic testing, converting, meta-data analysis)

May / June 2010
- Start of **operational data collection** (including meta-data)
- Test of data flow to processing hosts (ARM – RS92, …)
- Test of uncertainty quantification for RS92

July 2010
- Test of data flow to the dissemination host (NCDC)

August 2010
- Start of **operational** (automatic) **data flow:** *Collecting + Pre-Processing + Archiving + Processing + Dissemination*
  - ➔ **full**y for RS92
  - ➔ **partly** (min. collecting) for CFH, SRS-400, GTS-1, FLASH, ...

October to December 2010
- Include additional measurements: surface reference, GPS-IWV, …
- Test of reporting system

January / February 2011
- Start of advanced test phase (beta) of reporting system
- Test of meta-data management (free tool for the sites)

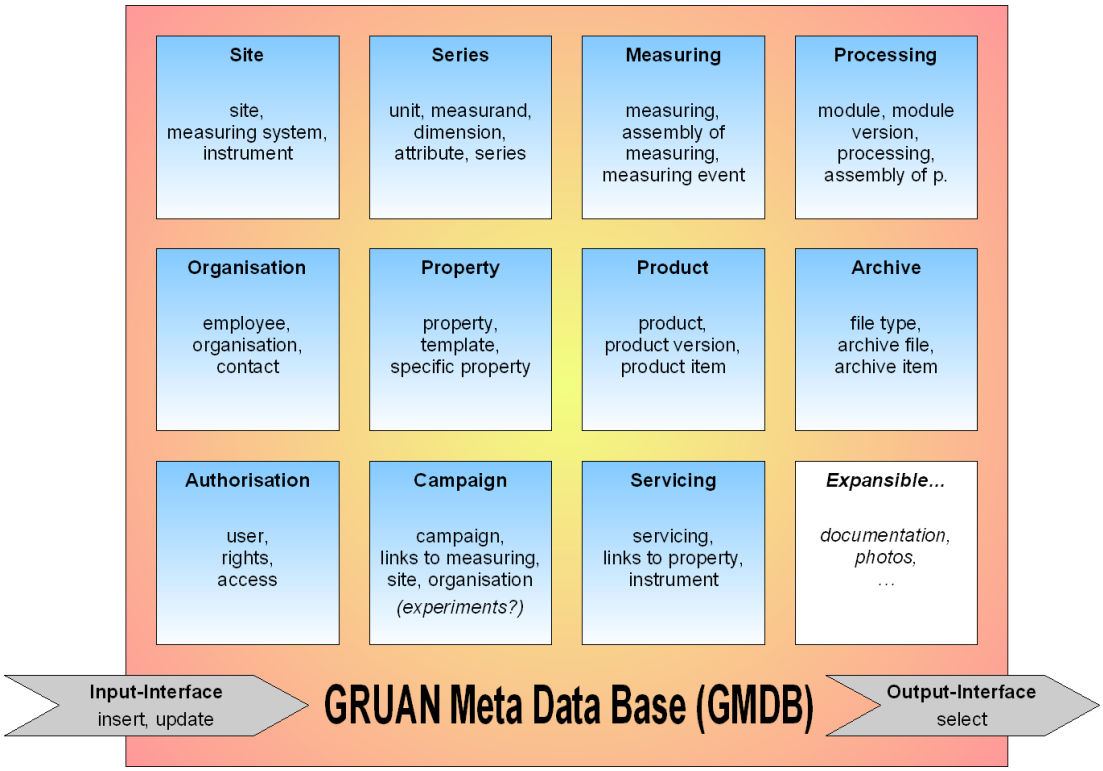

Figure 7: Proposed GRUAN metadata base.

In the following discussion, the question was raised, but not finally resolved, if GRUAN post-processed data would become part of the NCDC official archive.

9.2. Collaboration with ARM and NCDC

Following a meeting in September 2009, an agreement between the US Department of Energy (DOE), the NOAA National Climatic Data Center (NCDC), the GRUAN Lead Centre and the Lindenberg Meteorological Observatory was reached. Major strands of this are:

- The US GCOS office will provide GRUAN with incremental funding for materials needed for CFH, ozone sondes, and any other GRUAN requirements for U.S. GRUAN stations, as budget allows.
- The GRUAN Lead Centre will work with NCDC (Russel Vose) on the GRUAN data flow with respect to NCDC data dissemination.
- Michael Sommer (Lead Center) and Christina Lief (NCDC) will collaborate with respect to utilizing the GOSIC for GRUAN data access.
- DOE, NOAA, DWD acknowledged joint partnerships.

9.3. WMO Information System

Timo Proscholdt presented the concept of the future WMO Information System, WIS, and its possible application to GRUAN. WIS is a catalogue of available data products (forecast models, radio-sonde data etc.), a metadata catalogue pointing to the data sources. It is a network to exchange products, open to all WMO programs, which can be used for product dissemination and for product discovery. The WIS virtual structure consists of a number of data and information centres. NCDC, as well as the Lindenberg observatory have been nominated as Data Collection or Production Centres, DCPCs. GRUAN could upload metadata to the catalogue to publicize it or make use of the WIS for transferring

data via the Global Telecommunication System (GTS), e.g. to the Lead Center or to ECMWF. This does not necessarily mean that any data sent via the GTS would be available to everyone (all Met Services) connected to the GTS - recipients can always be defined. Uploading metadata, so that products can be found, would also not effect the ownership of the products (which stay on local servers). For using the WIS metadata catalogue, it is necessary to:

- describe products with metadata (Use ISO 19115 / ISO 19139 (XML)),
- upload metadata to WIS via agreed DCPC (NCDC), and
- make products available e.g. via the internet (control of access to the products assured).

The primary focus of discussion was on the additional overheads required and the real-time use of the data. It was stressed that WIS can help for operational, reliable data transfer and that for those stations attached to a Met Service the provision overhead need not fall on the Lead Centre. Concerns were raised about how remaining sites may fit into such a system, particularly those attached to academic institutions. It was noted that the amount of data sent and how it was sent were effectively voluntary – WIS is an enabling mechanism and not a rigid system. The provision of data that NWP centres can use in their DA schemes might provide a very useful additional piece of information that could support the GRUAN mission and uncertainty characterisation. To be useful in this regard this specific data needs to be fed across the network in near-real time. It was not expected that all data from all stations need be exchanged over the WIS in real time and it was stressed that WIS should not be an additional overhead if it is used successfully.

10. Management issues

ICM-2 participants agreed to form, among its members and beyond, several Task Teams to be operational by July 2010 (cf. Action 3). It was agreed that these Task Teams would report to the WG-ARO on a semi-annual basis and that they would be reviewed periodically. Task Teams were to have very specific aims to address critical GRUAN requirements. Initial results were expected by ICM-3 (cf. Action 4). It was decided that GATNDOR would remain a separate entity recognising the importance of a general science programme that had the freedom to decide upon its priorities based on science concerns alone and more flexibility than that envisaged for the Task Teams. Draft Terms of Reference were agreed in plenary on the understanding that Task Team co-chairs would be identified and flesh these out as well as defining the membership with agreement of details by WG-ARO prior to formal Task Team inception. The agreed strawman Terms of Reference are given in Appendix 4.

- *Team 1:* ***Radiosondes***
  To evaluate the data products (uncertainty budget etc.) and bring in missing knowledge

- *Team 2:* ***GPS-PW***
  To draw conclusions on the suitability of the deployed equipment and to standardise processing across the network.

- *Team 3:* ***Measurement schedules and associated site requirements***
  To develop defensible, quantifiable, scientifically-sound guidance

- *Team 4:* ***Site assessment, expansion and certification***
  To define assessment criteria for sites and provide regular assessments

- *Team 5:* ***Ancillary measurements***
  With initial focus on MWR, Lidars and FTIR; To interface with satellite experts and NDACC

- ***Site Team***
  Representing GRUAN sites

11. Partnerships

11.1. GRUAN WIGOS Pilot Project

In 2009, and as agreed at ICM-1, certain aspects of GRUAN became a WIGOS pilot project. The intensified collaboration between GRUAN and WMO Technical Commissions, in particular CIMO, can be seen as a first positive result from being a pilot project despite the additional overhead to produce quarterly reports. The Head of the GRUAN Lead Centre also became a member of the international organizing committee for the 2010 CIMO upper-air inter-comparison campaign.

While the WIGOS Planning Office sponsored an expert meeting to define next steps on the development of a GRUAN Guide of Operations (cf. Section 7.2 and Appendix 7), more direct guidance and advice from WIGOS, e.g. feedback on the progress reported would be appreciated.

11.2. CIMO Campaign

Tim Oakley who will lead the CIMO intercomparison presented an update on the status of the planning. It was stressed that the collaboration was envisaged to bring benefits but that the exercise's primary aim remained the operational sonde assessment. The value that could be gained by comparing to the research instruments was stressed. It was noted that a humid sub-tropical location would be a taxing test of both operational and reference quality instruments. The use of NPROVS satellite data was offered for the duration of the campaign.

A preparatory meeting for the CIMO upper-air inter-comparison campaign to be held in Yangjiang, China, in July 2010 was held as a side meeting to ICM-2 on the evening of 4 March in Fribourg. (Find the minutes of this meeting under http://www.wmo.int/pages/prog/www/IMOP/intercomparisons.html).

11.3. Other partners

There were a number of brief additional talks from complementary activities or envisaged end users.

- In an overview talk of GSICS activities by Jerome Laffeuille, it was stressed that current priorities were satellite to satellite intercallibration at the fundamental radiance level. The value of GRUAN style measurements would be largely downstream when assessing radiative transfer models and verifying the inter-calibration had been successful. GSICS is only one part of the envisaged satellite processing and GRUAN may be more applicable to e.g. SCOPE-CM. A number of queries regarding how to better link the GSICS and GRUAN activities were raised but not resolved.
- Mark Schröder gave a talk on CM-SAF activities and outlined how GUAN measures are used currently to assess their geophysical products. GRUAN measures would clearly be beneficial to such an activity.
- Johannes Quass provided some thoughts as to how climate modellers may envisage using the data GRUAN provides. The need to have data useful for process studies was reinforced. Ease of access and provision in a format that modellers would be comfortable with was also stressed. Site selection should concentrate upon regimes that are either poorly understood or currently poorly modelled. It was stressed that many priority 2 and 3 variables will be needed to properly do process understanding.
- Bruce Sumner provided a brief overview of HMEI. It was stressed that manufacturers are keen to be involved in GRUAN.
- An EU framework proposal on microwave profiler standardisation across Europe was briefly outlined. It was noted that this would have substantial benefits to GRUAN as a large number of the sites were GRUAN sites. A supporting letter from GCOS secretariat was welcomed. A decision on funding should be made by late summer.

12. Next meeting

It was agreed to hold the next ICM meeting outside Europe (and preferably N. America) to reflect the truly global nature of the network at around the same time of year. Possible locations in order of priority are:

- Lauder NZ
- Xilinhot China
- Tateno Japan
- Beltsville USA

Potential future improvements for the ICM meetings were discussed:

- Giving even more room for discussions.
- The site assessment team should be given sufficient time at the site.
- Allowing room for break out groups leading to or helping Task Teams.
- Revising the site questions.
- WG-ARO meetings should be held before and, if practical, after ICMs.

13. GRUAN work plan

The final session agreed a specific GRUAN workplan for the forthcoming year based upon the preceding discussions.

2010-11 GRUAN work plan

No	Action	Deadline	Who
1	Consult with the satellite community (GSICS EP, SCOPE-CM EP, CM-SAF, CGMS Working Groups) on better linkage to GRUAN.	2010	WG-ARO, WMO, GCOS Secretariat
2	Foster GAW, BSRN, NDACC representation in WG-ARO and Task Teams and seek for international representation of members.	2010	WG-ARO
3	Formulate Task Teams, which report to WG-ARO on semi-annual basis; agree on ToRs.	July 2010	WG-ARO, Lead Centre, GCOS Secretariat
4	Initial results from Task Teams - Radiosondes - GPS - Measurements - Site assessment, expansion and certification - Complementary measurements - Site group	ICM-3	Task Teams
5	Results from science team GATNDOR on: - Collocation - Mgmt of Change - Value of Complementary data	ICM-3	GATNDOR
6	Agree a protocol for dealing with any site offers arising in the interim.	Oct 2010	Task Team on site assess., select. and cert.; WG-ARO; Lead Centre
7	Develop definition for optimal GRUAN site to decide on future sites (optimal location/climate zone, institution etc.).	Jan 2011	Task Team 4,WG-ARO, Lead Centre

8	Explore the possibility to publish GRUAN metadata congruent with WIS metadata standards.	2010	Lead Centre, GCOS Secretariat, in collaboration with WMO WIS
9	Explore the possibility to disseminate near real time data via the WMO Information System (WIS) including the Global Telecommunication System (GTS) using existing infrastructure existing connections.	ICM-3	Lead Centre, GCOS Secretariat, in collaboration with WMO WIS
10	Agree and implement data usage acknowledgement protocol.	Before first data flow	WG ARO, Lead Centre (Michael), GCOS Sec, Sites (Lauder etc.), NDACC
11	Investigate the potential for tracking of data usage.	2010	Lead Centre, NCDC
12	Define data reprocessing and version control procedures.	2010	Lead Centre
13	Develop a case study for the measurement uncertainty guide focussing on *in situ* observations	Underway; paper to be submitted by ICM-3	Lead Centre
14	Develop generic outreach material, a ppt-presentation and a brochure	Oct 2010	WG-ARO, Lead Centre, GCOS Sec
15	Publish and maintain an inventory of GRUAN site instrumentation (maps, table)	May 2010 and update at least every 2 years	Lead Centre, Sites
16	Implement final version of data dissemination structure	2011	Lead Centre, NCDC, ARM
17	Develop a draft GRUAN guide of operations in liaison with Task Teams; draft to be approved by WG-ARO	ICM-3	GRUAN consultant

Actions in GCOS-131 closed / superseded:

Action	Who	Deadline	Comment
Dialogue with satellite community (GSICS), e.g. on needs / sponsoring for additional radiosonde launchings	Continuous	Mitch Goldberg (RSSC/CM), GCOS Secretariat	superseded by action 1
Paper on collocation issue from the satellite perspective	Chris Barnet	ICM-2	superseded by scheduling Task Team 3
Define remit of and set-up team to ascertain quantitatively defensible guidance for both *in situ* and ground-based remote sensing temporal sampling requirements.		2010	new Task Teams, superseded by action 4
Quantitative assessment of *in situ* (radiosonde) measurement frequency and scheduling impacts on trend and variability characterisation. Including all variables and altitudes and with a view to how frequently different units with different basic quality / capability and unit cost are likely to be required. Submitted for publication		2010	new Task Teams, superseded by action 4

Quantitative investigation of collocation issues for priority 1 variables (T,q) at existing sites, should include site representative	GATNDOR	2010	superseded by action 5
Write a GRUAN implementation plan, reaching out until at least 2013	June 2009	Peter Thorne (lead), Holger Vömel, Franz Berger, Doug Sisterson, John Dykema, Belay Demoz, Stephan Bojinski, with subsequent review by WG-ARO and Lead Centre	done; GCOS-134
Develop a common GRUAN definition and terminology for measurement uncertainty and stability. A guide that ensures the quality of all GRUAN measurements (including a common definition of terminology (accuracy, stability, uncertainty etc.))	31 July 2009	Franz Immler (lead), John Dykema, Tom Gardiner	Paper under review
Develop a case study for such a guide focussing on *in situ* observations	ICM-2	Lead Centre	superseded by action 13
Prepare a position paper on a process to manage change and optimize intercomparisons at GRUAN sites	ICM-2	Lead Centre (lead), WG-ARO	envisaged as part of GATNDOR activities
Establish and maintain an inventory of GRUAN sites using a common template	October 2009	Lead Centre	published March 2010
Address immediate questions by sites	May 2009	Lead Centre (lead), with help from WG-ARO, Secretariat	done; FAQ list
Develop a communication platform for the GRUAN community (blog, wiki, FAQ, other?)	ICM-2	Lead Centre (lead), WG-ARO, sites	done
Formalize links between Lead Centre and NCDC, ARM program regarding data dissemination, investigate value of NDACC / BADC involvement for high-res *in situ*	ICM-2	Lead Centre (lead), WG-ARO, NCDC, ARM	done; Sept 2009 agreement
Develop proposal to define data dissemination among all GRUAN partners	ICM-2	Lead Centre (lead), ARM, NCDC, WG-ARO, sites	done
Provide a list of technically competent potential participants (2-3) in 2010 CIMO intercomparison campaign in China to CIMO Secretariat; Head of Lead Centre to be formally involved in the organization of the campaign	August 2009	WG-ARO	done
Foster participation of research radiosondes in CIMO intercomparison campaign		WG-ARO (lead), Lead Centre	done
Nominate members on expert team analyzing results from CIMO intercomparison campaign	September 2009	WG-ARO	done
Submit proposal for WIGOS-PP in conjunction with development of GRUAN IP	June 2009	WG-ARO (decision), Lead Centre, Secretariat	done

Perform gap analysis on existing documentation (manuals) vis-à-vis the adopted skeletal GRUAN manual of operation, and provide a summary document of where these gaps are.	ICM-2, if funding can be made available.	Lead Centre (lead), Secretariat (from WIGOS PP resources?), WG-ARO, sites	open; superseded by action 17

Appendix 1 Agenda

Time	Item	Doc. No.	Presenter(s)
Monday 1 March - Pre-Meeting of WG-ARO (members and ex-officios only)			
13.00 Bus pick up from the hotels			
13.30 – 17.30	Discussion of WG-ARO issues, including 1. GRUAN organizational issues - governance of envisaged teams, coordination and reporting. 2. Lead Centre performance, resources, coordination and communication. 3. Broadening from an *in situ* measurement focus 4. WIGOS participation, benefits and drawbacks. 5. Coordination with GSICS and other relevant programs 6. WG-ARO Terms of Reference and membership 7. Gearing of national and international resources to support GRUAN		
Tuesday 2 March - 2nd GRUAN Implementation-Coordination Meeting (ICM-2) – DAY ONE			
07.45 / 07.55 Bus pick up from the hotels: 07.45 Hotel Elite – 07.55 Hotel de la Rose			
08.45 – 09.00	**Welcome and logistics**		**Chair: Franz Berger**
	Welcome note by MeteoSwiss		G. Müller (Deputy Director MeteoSwiss)
	Welcome note by WMO		Wenjian Zhang (Director WMO OBS Department)
	Local logistics		Dominique Ruffieux (MeteoSwiss)
09.00 – 09.45	**Session 1: Update on progress since ICM-1**		
09.00 – 09.15	GRUAN Implementation Plan (Roll out the structure of the meeting along IP chapters)		Peter Thorne; GCOS Secretariat staff
09.15 – 09.45	Lead Centre report on progress	1.2	GRUAN Lead Centre staff
09.45 – 11.00	**Session 2: International programmes perspectives**		
09.45 – 10.00	The GCOS Steering Committee perspective / US GCOS office perspective		Howard Diamond (US GCOS System Program Manager; NOAA/National Climatic Data Center)
10.00 – 10.20	The WMO Integrated Global Observing System (WIGOS)		Wenjian Zhang (Director WMO OBS Department)
10.20 – 10.40	The World Climate Research Programme (WCRP) Perspective		Ghassem Asrar (Director WCRP)
10.40 – 11.00	The Global Atmospheric Watch (GAW) Perspective		Johannes Staehelin
11.00 – 11.30	*Coffee*		
11.30 – 12.30	**Session 3: Reference measurements**		
11.30 – 12.15	Reference measurement specifications (Outline of proposed reference measurement methodology and case study of *in situ* measurement technology)		Franz Immler
12.15 – 12.30	Discussion and formal adoption of reference measurement specifications		
12.30 – 16.30	**Session 4: Research issues**		
	4.1 Report by GRUAN Analysis Team for Network Design and Operations Research (GATNDOR)		
	GATNDOR Project Status Reports		
12.30 – 12.50	The GATNDOR Concept and Work Plan (10 min presentation + 10 min discussion)		Dian Seidel
12.50 – 13.10	Topic 1: Collocation of Observations (15'+5')		Dian Seidel
13.10 – 13.30	Topic 2: Management of Change (15'+5')		June Wang

13.30 – 14.30	*Lunch*		
14.30 – 14.50	Topic 3: Scheduling Protocol (10'+10')		Tom Gardiner
	GATNDOR in 2010 and Beyond (open discussion)		
14.50 – 15.00	Topic 4: Quantifying the Value of Complementary Observations		June Wang
15.00 – 15.15	Topic 5: Network Configuration - Lessons Learned from 2 Decades of NDACC Experience		Michael Kurylo
15.15 – 15.25	Open discussion on GATNDOR - Support for GATNDOR analyses - Mechanism for transitioning GATNDOR results to GRUAN decision-making and operations - Possible new GATNDOR topics - Relation between GATNDOR and GRUAN science/expert teams		Dian Seidel
15.25 – 15.40	Anticipated Climate Trends in Atmospheric Water Vapour: Opportunities for NDACC /GRUAN Collaboration?		David Whiteman (NASA/GSFC)
	4.2 Addressing research issues		
	Resolving the geographical collocation issue (addressing Topic 1)		
15.40 – 15.55	Impacts of Mismatch Between Radiosonde Launch and Satellite Observations: An Application of NPROVS		Tony Reale
15.55 – 16.10	FMI Sodankylä perspective	4.2.1	Rigel Kivi
	Managing instrument change (addressing Topic 2)		
16.10 – 16.25	ACRF perspective		Doug Sisterson, Jimmy Voyles
16.25 – 16.40	NCDC experience with USCRN		Russ Vose
16.40 – 17.00	*Coffee*		
17.00 – 18.30	**Session 5: Site considerations and network composition**		
	5.1 Implication of research issues on network		
17.00 – 17.45	Measurement needs for trend detection (Define remit of team to ascertain quantitatively defensible guidance for both *in situ* and ground-based remote sensing temporal sampling requirements.)		Peter Thorne, Holger Vömel
	5.2 Assessment and certification		
17.45 – 18.30	The concept of assessment and certification in GRUAN (Discussion of site assessment, solicitation, offer assessment and certification issues to lead to formation of a group to address these issues as outlined in the Implementation Plan (cf. Session 9))		Peter Thorne
20.00	*Workshop Dinner in Fribourg*		
Wednesday 3 March - 2nd GRUAN Implementation-Coordination Meeting (ICM-2) – DAY TWO			
07.45 / 07.55	**Bus pick up from the hotels: 07.45 Hotel Elite – 07.55 Hotel de la Rose**		
08.30 – 09.15	**Session 6: Network protocols and documentation**		**Chair: Holger Vömel**
08.30 – 08.45	Progress towards setting up a communication and reporting framework (To include blog, web page, and outline of other		Michael Sommer

	communications channels currently in operation and allow suggestions from participants as to how communication can be improved.)		
	GRUAN Guide of Operations		
08.45 – 08.55	Progress to date		Anna Kuhn, Holger Vömel
08.55 – 09.15	WMO input		Miroslav Ondras, John Nash
09.15 – 13.30	**Session 7: Site reports and discussion of open questions from sites**		
09.15 – 09.35	**Site inventory**	7.1	Holger Vömel
09.35 – 13.30	**Site reports**		

Session aims: To afford candidate sites to provide their perspectives, thoughts, and update on their status for the consideration of all workshop participants. (Sites / contributing programs will have **20' each** to lead discussions.)

Sites are kindly requested to work their presentations around the following key themes:

- Which of your existing radiosonde launches already meet the mandatory requirements (GCOS 121: once weekly best production quality radiosonde, once monthly stratospheric water vapour; recommended twice daily), and which additional launches need to be instigated or augmented?
- Which ground based measurements can you provide in addition to the mandatory GPS total water vapour column (microwave, FTIR, lidar, …) and how can you use these additional observations to make sure that measurement uncertainty estimates will be consistent?
- Do you have any limitations regarding the development of GRUAN launch protocols for routine and reference sonde launches (e.g. the use of auto-sonde launchers)?
- Do you have any limitations regarding the development of uniform GRUAN data processing schemes for remote sensing observations?
- What local analysis can you provide to assure that measurements uncertainties will be consistent across the network (Analysis of redundant observations either dual sonde launches or sonde + remote sensing observations)?
- For sonde observations: Can you provide all raw data for central archiving?
- For remote sensing observations: Will you be able to archive all raw data for possible future re-analysis and re-processing?
- What help do you need from the Lead Centre / WG-ARO / GCOS Secretariat in moving forwards?
- Will you be able so host local intercomparison campaigns (yet to be scheduled)?
- Are there any special infrastructure needs that should be addressed?

As at ICM-1, sites are encouraged to provide written reports by no later than three weeks prior to the meeting for dissemination to meeting participants.

09.35 – 09.55	Howard University - Beltsville, MD, USA	7.2.1	Belay Demoz, David Whiteman
09.55 – 10.15	*Coffee*		
10.15 – 10.35	NOAA, NCAR – Boulder, CO, USA	7.2.2	June Wang, Dale Hurst
10.35 – 10.55	ARM Climate Research Facilities – Barrow, AK, USA; Darwin, Australia; Lamont, OK, USA; Nauru , Republic of Nauru, Manus, Papua New Guinea	7.2.3	Doug Sisterson
10.55 – 11.15	Netherlands – Cabauw	7.2.4	Reinout Boers
11.15 – 11.35	New Zealand – Lauder	7.2.5	Paul Johnston
11.35 – 11.55	Switzerland – Payerne	7.2.6	Rolf Philipona
11.55 – 12.15	Italy – Potenza	7.2.7	Gelsomina Pappalardo
12.15 – 12.35	Finland – Sodankylä	7.2.8	Rigel Kivi
12.35 – 12.55	China - Xilinhot	7.2.9	CHEN Yongqing, LI Wei
12.55 – 13.15	Japan - Tateno	7.2.10	Hakaru Mizuno
13.15 – 13.30	Discussion		
13.30 – 14.30	*Lunch*		
14.30– 14.50	The aerological station Payerne – future challenges		Bertrand Calpini

14.50 – 16.30	**Payerne facility site visit (weather dependent)**		
16.30 – 16.45	*Coffee break*		
16.45 – 18.00	**Session 8: Data policy and dissemination**		
16.45 – 17.15	Prototype concept; Results from Sept 09 Meeting at NCDC and ARM	8.1 8.2	Michael Sommer; Russ Vose
17.15 – 17.30	WMO Information System (WIS) concept; GTS		Timo Pröscholdt, Eliot Christian
17.30 – 18.00	Discussion		
Thursday 4 March - 2nd GRUAN Implementation-Coordination Meeting (ICM-2) – DAY THREE			
07.45 / 07.55	**Bus pick up from the hotels: 07.45 Hotel Elite – 07.55 Hotel de la Rose**		
08.30 – 10.30	**Session 9: Management issues**		**Chair: Peter Thorne**
08.30 – 10.30	Expert team instigation 18 Parameter specific teams 19 *In situ* sounding team (timing, instrument mix) 20 Site expansion and certification team		Holger Vömel
10.30 – 11.00	*Coffee*		
11.00 – 13.00	**Session 10: Partnerships**		
	GRUAN WIGOS Pilot Project		
11.00 – 11.10	Working Group perspective		Peter Thorne
11.10 – 11.20	Lead Centre perspective		Holger Vömel
	CIMO intercomparison		
11.20 – 11.40	Overview on the CIMO intercomparison campaign June 2010 in China		Tim Oakley
	Other partnerships		
11.40 – 11.55	HMEI perspective		Bruce Sumner
11.55 – 12.15	GSICS perspective		Jerome Lafeuille
12.15 – 12.35	Satellite Product Validation Needs for Upper-Air Data		Marc Schröder
12.35 – 12.55	Global Climate Modelling Needs for Upper-Air Data		Johannes Quaas
12.55 – 13.15	The EMERGE project		Reinout Boers
13.15 – 14.00	*Lunch*		
14.00 – 16.00	**Session 11: Wrap up**		
14.00 – 16.00	Agree on actions and way forward – update of annual work plan		
	CLOSE OF ICM-2		
17.00 – 21.00	***CIMO intercomparison preparatory side meeting (by invitation only)***		
Friday 5 March - GRUAN Guide of Operations Expert Meeting (to be held at Hotel de la Rose, Fribourg, and by invitation only)			
08.30 – 13.00	**Expert Meeting Session**		**Chair: Peter Thorne**
	Briefing on current status and requirements		
08.30 – 09.00	WMO perspective		Miroslav Ondras
09.00 – 09.30	GRUAN perspective		Anna Kuhn, Holger Vömel
09.30 – 13.00	Setting up a work plan on how to develop a GRUAN Guide of Operations		all
13.00 – 13.45	*Lunch*		
13.45 – 15.00	Discussion on the way forward		all

Appendix 2 List of Participants

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Appendix 3 Lead Centre Report 08/2009 – 01/2010

GRUAN Lead Centre progress report 04/2010

covering the period 08/2009 to 01/2010

Authors

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Summary

The Lead Center, NOAA/NCDC, and DOE/ARM held a meeting to discuss the data flow and data dissemination of data generated within GRUAN as well as to establish a unified QA/QC for Vaisala RS92 observations within GRUAN. An understanding was reached between the Lead Center, NOAA/NCDC and DOE/ARM about their respective roles in the distributed processing and data archiving of GRUAN data.

The definition of measurement uncertainty, traceability and the requirements for an operational network in metadata collection has been completed in cooperation with the Working Group on Atmospheric Reference Observations. This document will be the key for the uniform treatment of uncertainties across the network and serve to improve the data quality of the existing observing systems.

A workshop discussing the results of the Lindenberg Upper Air Methods Intercomparisons (LUAMI) was held at Lindenberg in September 2009.

The Lead Center participated in the preparation of the upcoming CIMO radiosonde intercomparison at Yangjiang, China. Holger Vömel represented the Lead Center in the expert team that conducted a site visit in Yangjiang and will be coordinating the scientific sounding instrument payloads, which will be part of this intercomparison campaign.

In January 2010 a campaign comparing the Vaisala RR01 reference radiosonde with other scientific *in situ* instruments (CFH and FLASH) was conducted at the GRUAN station Sodankylä in cooperation with Vaisala, the Lead Center and the GRUAN station at Lindenberg. This campaign was an intensive test of the prototype reference radiosonde under development at Vaisala.

Health of network

The network is not yet operational	

Progress against stated objectives

Objective and due date	Summary of progress
2. develop definition for optimal GRUAN site to decide on future sites (optimal location/climate zone, institution etc.)	not yet started. The experiences and lessons learned at the different GRUAN sites will be key to the definition of an optimal GRUAN site. The site certification process, which has yet to be established, needs to be considered. This task will commence with the operational start of the network and the definition of the site certification and evaluation process within GRUAN.
3. write a GRUAN implementation plan,	Completed. The GRUAN implementation plan has

reaching out until at least 2013	been published as document GCOS 134 (WMO/TD No. 1506).
4. develop a common GRUAN definition and terminology for measurement uncertainty and stability. A guide that ensures the quality of all GRUAN measurements (including a common definition of terminology: accuracy, stability, uncertainty etc.)	A manuscript describing the definition and methods of establishing measurement uncertainties has been completed and has been submitted to the peer reviewed journal Atmospheric Measurement Techniques. After acceptance of this publication a working document will be prepared that will serve as operational reference for GRUAN.
5. develop a case study for such a guide focusing on *in situ* observations	Temperature measurements using Vaisala RS92 radiosondes will be used as case study. Many parameters of the Vaisala RS92 have been tested and documented, thus information to perform this case study is available. A ground check independent of the manufacturers ground check is in place at Lindenberg to test temperature (additionally also humidity, and pressure) measurements under controlled conditions before launch. This case study will establish and validate the measurement uncertainty using Vaisala radiosondes. Different sources of measurement uncertainty are being discussed, as well as how they have been established and how they have been validated. These results will be presented at ICM2.
6. prepare a position paper on a process to manage change and optimize intercomparisons at GRUAN sites	A post related to this issue was published at the GRUAN blog and remains open to discussion.
7. establish and maintain an inventory of GRUAN sites using a common template	Ongoing. Currently 50% of sites have contributed to this inventory; however, the information from ARM not yet complete constitutes nearly all of the open sites.
8. address immediate questions by sites	Completed. Questions by sites have been addressed and are open to discussion at the GRUAN blog: http://gruan.wordpress.com/category/faq.
9. develop a communication platform for the GRUAN community (blog, wiki, FAQ, other?)	Completed. The Lead Center has implemented a section of Frequently Asked Questions, which may be updated regularly and which is currently available both at the GRUAN web site (www.gruan.org) and at the GRUAN blog (http://gruan.wordpress.com). The pages at the GRUAN web site are static pages that are maintained by the GRUAN Lead Center, whereas the pages at the blog can receive contributions by the GRUAN community. These pages are administered by the GRUAN Lead Center, and contributions require a one time approval to avoid illegitimate abuse of the site.
11. formalize links between Lead Centre and NCDC, ARM program regarding data dissemination, investigate value of NDACC / BADC involvement for high-res *in situ*	On 28 and 29 September 2009 a meeting between Lead Center staff and NOAA/NCDC took place in Asheville, NC, reaching a mutual understanding about the cooperation between the Lead Center and NOAA/NCDC. On 30 September 2009 a meeting of Lead Center staff and ARM staff took place at the ARM Data Archive at

	Oak Ridge National Laboratories, Oak Ridge, TN. This meeting addressed remaining issues of the cooperation between ARM and the Lead Center. Details of both meetings are described below.
12. develop proposal to define data dissemination among all GRUAN partners	Completed (see details below).
13. provide a list of technically competent potential participants (2-3) in 2010 CIMO intercomparison campaign in China to CIMO Secretariat; Head of Lead Centre to be formally involved in the organization of the campaign	GRUAN will participate in the 2010 CIMO intercomparison campaign in China, represented by Holger Vömel as part of the organizing committee and by Junhong Wang and Masatomo Fujiwara of the working group as technical experts.
14. foster participation of research radiosondes in CIMO intercomparison campaign	The CIMO intercomparison campaign will include payloads carrying scientific sounding instruments in addition to those carrying approved routine operational radiosondes. The scientific sounding instruments payload will include instruments that provide observations of atmospheric parameters in altitude regions where routine operational sensors show their limitations. The Lead Center in cooperation with Dr. Fujiwara is actively pursuing the participation of Cryogenic Frostpoint Hygrometer (CFH) sondes and a discussion between Howard University and Dr. Wang is currently ongoing to contribute multi-thermistor sondes to this campaign. This payload is also scheduled to carry the reference radiosonde RR01 manufactured by Vaisala. Since this instrument is not yet an operational product, this reference radiosonde would participate under the scientific sounding instruments payloads and not follow the strict evaluation criteria for operational instruments.
15. nominate members on expert team analyzing results from CIMO intercomparison campaign	see 13.
16. perform gap analysis on existing documentation (manuals) vis-à-vis the adopted skeletal GRUAN manual of operation, and provide a summary document of where these gaps are.	not yet started.
17. submit proposal for WIGOS-PP in conjunction with development of GRUAN IP	Completed. The WIGOS pilot project proposal has been submitted to the WIGOS expert group.

Achievements

- On 28 and 29 September a meeting between Lead Center staff and NOAA/NCDC took place at the NOAA/NCDC office in Asheville, NC, reaching a mutual understanding about the cooperation between the Lead Center and NOAA/NCDC. The detailed report of this meeting can be found at http://www.gruan.org or at http://gosic.org/whatsnew.htm. Participants attending this meeting were associated with NOAA, DOE/ARM, UCAR, and the Lead Center at DWD/MOL. The GRUAN Lead Center was represented at this meeting by Holger Vömel and Michael Sommer.
According to the agreement reached at the Implementation and Coordination Meeting at Norman, Oklahoma, the goal of this meeting was to formalize the links between the Lead Center, NOAA/NCDC, and DOE/ARM and to establish a formal path of data processing and data dissemination. The scheme underlying the data flow within GRUAN is based on a distributed data archive, in which different functions of the data processing chain and data archive are being hosted by different agencies, utilizing

the strength of each partner. The discussions included the following topics: 1) Data archiving capabilities at NCDC and ARM; 2) Capabilities of the meta-database, which will be located at the Lead Center; 3) Development of a data dissemination portal that links the meta-database and the GRUAN archive with the data users; 4) The role or NCDC and ARM in radiosonde QA/QC; 5) Organizing data flows from the GRUAN sites, through a QA/QC institution to the GRUAN data archive. It was agreed that the Lead Center will work with NCDC on the GRUAN data flow with respect to NCDC data dissemination capabilities. Key personnel involved in this activity established a first contact. It was further agreed that all RS92 observations within GRUAN sites will first be collected in Lindenberg, where they will be formatted into the ARM Climate Research Facility (ACRF) NetCDF format and sent to ACRF for standard processing. This step will ensure that all Vaisala RS92 observations pass through the same processing and QA/QC steps. The processing at Lindenberg will then add uncertainty estimates to all Vaisala RS92 observations before distributing the data through NCDC. The Lead Center will work with NCDC on establishing metadata definitions and will work with ACRF on defining the proper NetCDF file format.
The data management plan that summarizes this meeting will be presented at ICM2. A follow-up meeting took place at the ARM Data Archive at the Oak Ridge National Laboratory. This meeting served to provide a background on the experiences and lessons learnt by ARM and focused on the details of the collaboration between the Lead Center and ARM.

- The Lindenberg Upper Air Methods Intercomparison (LUAMI) campaign workshop was held in Lindenberg on 21 - 23 September 2009. One of the key achievements of this campaign was the use of the Water Vapour LIDAR Experiment in Space (WALES) onboard the research aircraft Falcon of DLR as transfer instrument to compare Raman LIDAR and sonde launches at 4 different locations (Payerne, Cabauw, Lindenberg and Zugspitze). While the comparisons at Payerne, Cabauw, and Lindenberg showed excellent agreement within these systems, issues were identified at the Zugspitze LIDAR, which were subsequently addressed and corrected. Temperature measurements by the radiosondes participating in this comparison agreed for tropospheric measurements on average to within 0.2 K. Larger discrepancies occurred when the balloon exited clouds, temporarily exceeding more than 1 K. In the stratosphere night-time differences were generally less than 0.2 K, whereas day-time differences were generally lower than about 0.5K. For relative humidity measurements a larger spread of observations was found. In the lower troposphere the different instruments agreed largely to within 5% RH; larger differences mainly occurred do to cloud water contamination. In the upper troposphere agreement between different instruments was poorer and occasionally large discrepancies of 30% RH or more were observed. One reason for these larger differences is again the radiation error. However, since even at night time substantial differences were observed other factors contribute to the overall poor agreement.
In the stratosphere excellent agreement was found between FLASH and CFH, repeating results from previous studies. Current commercial radiosonde sensors did not deliver useable data in the stratosphere. Data from the VFS100 (formerly APS) were well correlated to the measurements from the CFH and FLASH, but with a consistent bias, which is still under investigation. The good correlation with CFH and the good upper tropospheric performance indicate potential of this sensor.
The Lindenberg Raman LIDAR Ramses participated in LUAMI and provided good data on a few clear nights that occurred during LUAMI. Most importantly the system provided excellent data during the aircraft, balloon, and LIDAR intercomparison night involving WALES. Overall in 2008 Ramses performed measurements during 130 nights with acceptable data quality. The LIDAR is calibrated using radiosonde data at low altitude (1-3 km) which are launched in Lindenberg every 6 hours. The Calibration is performed whenever co-incident LIDAR and Radiosonde data are available.
Several other remote sensing instruments participated in LUAMI; however, it remains difficult to bring these inhomogeneous systems together, allowing a consistent cross-evaluation of their data products in particular under consideration of the respective measurement uncertainties. The discussions concerning measurement uncertainties were especially fruitful and the strengths and limitations of some observing systems regarding uncertainty estimates became apparent.

- In January 2010 further tests of the Vaisala reference radiosonde have been conducted at the GRUAN station at Sodankylä in cooperation with Vaisala, the Lead Center and the GRUAN station at Lindenberg. These tests were conducted as part of the Lapbiat 2 campaign organized by the Finnish Meteorological Institute (FMI). Over twelve soundings of multiple instrument payloads have been launched including early test models of the Vaisala RR01 reference radiosonde, the Cryogenic Frostpoint Hygrometer (CFH), the Fluorescent Advanced Stratospheric Hygrometer for Balloon (FLASH-B), the Cobalt backscatter sonde, the Intermet RSB1 radiosonde and the routine Vaisala RS92 radiosonde in various combinations. FLASH and CFH again showed good agreement in stratospheric

measurements, whereas previously unidentified issues of the Intermet RSB1 radiosonde were found. The use of the backscatter sonde allowed the identification whether observations took place inside clouds or in clear air. Further comparisons are planned both at Sodankylä as well as at Lindenberg. This campaign served as preparation for the upcoming CIMO intercomparison at Yangjiang, China.

- In response to requests by the Lead Center, Vaisala published details about the history of changes made to the Vaisala RS92 radiosonde (http://www.vaisala.com/). This data continuity document is an important source of information detailing the consistency of the Vaisala RS92 radiosonde production and is essential for evaluating the impact of changes in the manufacturing of radiosondes, which will be used within GRUAN. It is hoped that other instrument manufacturers can provide similar documentation.

- The participation of research radiosondes in the upcoming CIMO intercomparison campaign at Yangjiang, China is actively supported through the involvement of the Lead Center and two GRUAN experts in this campaign. Holger Vömel was member of the WMO expert team that conducted a site visit at Yangjiang between 29 August and 6 September 2009 and he is currently in charge of coordinating the scientific sounding instruments component of this comparison. The site visit report can be found at http://www.wmo.int

Lead Centre operations

The Lead Center is still understaffed; however, Marion Fiedler is expected to return from maternity leave in summer 2010. Michael Sommer participated in a 6 week intensive English training course.

Work plan for next six months

- Implementation and Coordination Meeting (ICM2) at Payerne in March 2010
- Establishing recommended ground measurements for sonde launches
- Start of observations at the different site.
- Implementation of the data processing scheme
- Additional work, such as added ground checks, theoretical studies and adaptation of software will be ongoing.

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Appendix 4 GRUAN Task Teams

- *Team 1:* ***Radiosondes***
  To evaluate the data products (uncertainty budget etc.) and bring in missing knowledge

Co-chairs: Franz Immler & Masatomo Fujiwara

Draft ToR:
- Evaluate the data products (uncertainty budget etc.) and bring in missing knowledge
- Draw conclusions on the suitability of the deployed equipment
- Report to the WG-ARO on a half-yearly basis
- The chair of the team should be a member of the WG-ARO
- Guidelines for certifications

- *Team 2:* ***GPS-PW***
  To draw conclusions on the suitability of the deployed equipment

Co-chairs: June Wang &

Draft ToR:
- Develop guidance on the type and amount of data and associated metadata needed to be stored from the instrument, as needed
- Develop details on the data processing and dissemination, including the calculation of uncertainties (who to do what?)
- Evaluate the data products (uncertainty budget etc.) and bring in missing knowledge
- Draw conclusions on the suitability of the deployed equipment
- Report to the WG-ARO on a half-yearly basis
- The chair of the team should be a member of the WG-ARO

- *Team 3:* ***Measurement schedules and associated site requirements***
  To develop defensible, quantifiable, scientifically-sound guidance

Co-chairs: Tom Gardiner, Dave Whiteman & Howard Diamond

Draft ToR:
To develop defensible, quantifiable, scientifically-sound guidance for GRUAN sites on measurement schedules and associated site requirements, taking into consideration:
- Peer reviewed literature,
- GRUAN documentation (including GCOS-121),
- New studies the team might undertake, or that is undertaken by third parties, as well as
- Technical and financial constraints, and
- All GRUAN objectives (climate trend detection, satellite calibration/validation, global coverage)

To report to the WG-ARO on a half-yearly basis
The chair of the team should be a member of the WG-ARO

- *Team 4:* ***Site assessment, expansion and certification***
  To define assessment criteria for sites and provide regular assessments

Co-chairs: Russ Vose &

Draft ToR:
- Define assessment criteria for sites (inter alia taking into account output from Task Team on measurements)
- Provide regular overall assessments of existing sites
- Consider ad-hoc or solicited new requests and provide a written recommendation to the WG-ARO and the Lead Centre
- Explore potential new sites

- Define clear terminology for sites ('initial sites', 'candidate sites')
- The chair of the team should be a member of the WG-ARO
- The team is long-term

- *Team 5:* ***Ancillary measurements***
  With initial focus on MWR, Lidars and FTIR; To interface with satellite experts and NDACC

Co-chairs: Tony Reale, Thierry Leblanc

Draft ToR:
- Develop guidance on the type and amount of data and associated metadata needed to be stored from the instruments, as needed.
- Initial focus on MWR, Lidars and FTIR.
- Interface with existing expert teams (NDACC, EMERGE etc)
- Evaluate the data products (uncertainty budget etc.) and bring in missing knowledge
- Draw conclusions on the suitability of the deployed equipment
- Report to the WG-ARO on a half-yearly basis
- The chair of the team should be a member of the WG-ARO

- ***Site Team***
  Representing GRUAN sites

Co-chairs: Belay Demoz & Dale Hurst

Draft ToR:
- Ensure that sites concerns are communicated to Lead Centre and WG-ARO on an ad-hoc basis
- Facilitate the spreading of best practices and information between sites
- 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.

Appendix 5 Meeting of the WG-ARO

WG-ARO Meeting, Payerne, Switzerland, 1 March 2010

With thanks to Stephan Bojinski and Anna Kuhn for providing initial write up.

Attendees:
Masatomo Fujiwara, Junhong Wang, Peter Thorne (Chair), Franz Berger, John Dykema, John Nash, Stephan Bojinski, Holger Vömel, Dian Seidel, Tom Gardiner, Bill Murray, Jimmy Voyles, Bertrand Calpini, Carolin Richter, Howard Diamond, Anna Kuhn, Doug Sisterson

The working group met in advance of the main meeting to discuss progress generally and specific governance issues. Wherever discussions recorded here are in conflict with the outcome of ICM-2 the ICM-2 outcome which resulted from substantial further discussion takes precedence.

Agenda
1. GRUAN Organizational Issues – Task Teams
2. Lead Centre Issues
2a. CFH License
3. Broadening from an *in situ* measurement focus
3a. Better contributions by sites
4. WIGOS participation
5. Coordination with GSICS and other int'l groups
6. WG-ARO Terms of Reference and membership
7. Gearing national/international resources to support GRUAN

1. Task Teams

The Chair reminded the Group of the intention at ICM-2 to instigate task teams with specific responsibilities in support of GRUAN, that is, remit and designated chairpersons for teams dedicated to (i) site certification and assessment, (ii) site instrument and schedule advice, (iii) variable-specific issues (e.g., temperature, water vapour… independent of instrument technique).

The WG-ARO agreed to revise its existing ToR to allow for such task teams, and to reflect its quasi-oversight role of the Lead Centre and thus the implementation of GRUAN. Its name as a subsidiary group of AOPC may be subject to change ("Advisory Group"?). It further agreed that the chairs of the task teams should be regularly attending WG-ARO meetings, whether through ex-officio or through proper membership in the WG-ARO. Linkage to WMO and its commissions was ensured by current members (Ondras; Nash and successor). The WG-ARO agreed to complete this task within the coming 2 months, for approval by AOPC-XVI on 26-30 April 2010.

2. Lead Centre Issues

The Chair expressed satisfaction with Lead Centre progress in a number of areas agreed at ICM-1, particularly related to a proposal for GRUAN-wide quality assurance, the GRUAN website, data dissemination and the intercomparison campaign. He lamented the lack of a visiting scientist working on GRUAN-related science issues at the LC, as announced in the 2007 DWD offer. Concerns were also raised about communication on a business as usual basis being currently insufficient. Doug Sisterson, Dian Seidel and June Wang stressed the importance of a regular flow of information and checks on progress within the GRUAN community, be it through newsletters, conference calls, check lists sent out by the LC, face-to-face meetings at the fringes of conferences or ICMs, or other means of communication. The blog on the GRUAN website was seen as a potentially useful communication platform which was hitherto underused, for lack of familiarity and privacy issues expressed by some.

Franz Berger announced the availability in 2010 of 12 months FTE for a visiting scientist at DWD, whereby the task description would need to be defined, based on (i) Lead Centre suggestions, (ii) GRUAN science questions, and (iii) additional topics brought to the fore by the WG-ARO. Holger Vömel emphasized the rationale of the website and the blog to improve communication, whilst noting that there is a lack of resources to take on the GRUAN communication task.
2a. CFH license - Vömel as license owner of CFH

An issue had arisen upon the procurement of CFH sondes in the US, for two reasons: these sondes were seen as the only instrument on the market performing water vapour profile measurements in the stratosphere at sufficient quality, hence a sole-sourcing justification was needed by those purchasing it; second, Holger Vömel, who developed this instrument, holds a licence agreement with the current manufacturer and receives royalties upon its sale. Dr. Vömel is also head of the GRUAN Lead Centre, which may be perceived as a conflict of interest. The WG-ARO stressed that measures needed to be taken to avoid apparent negligence of (i) conflicts of interest in instrument procurement, (ii) environmental impact of GRUAN activities (GHGs used in sondes, balloon impacts).

Dr. Vömel agreed to resolve this possible conflict of interest and to provide this in writing to any procurement officer. He emphasized the motivation behind developing the instrument was to support scientific progress, and not financial gain.

3. Broadening from an *in situ* measurement focus

The Chair and GCOS Secretariat raised the importance of maintaining a broad focus on instrumentation within GRUAN (radiosondes AND ground-based remote sensing) and to ensure that all developments currently underway, e.g. guiding sites in assessing uncertainties, or the development of a data dissemination model, need to be scalable and applicable for all types of GRUAN-related instrumentation. While acknowledging that GRUAN had to "start small, but start" with some data from some instrument, a tendency to focus on radiosondes at the current stage was apparent.

The WG-ARO and the Lead Centre agreed with that view and suggested measures to rectify the situation The Lead Centre also pointed out that although the current strategy focuses on in-situ observations as the starting step, it has been designed such that it is immediately applicable to remote sensing observations and will be applied as soon as they are ingested. The need for redundant observations using dissimilar systems is essential in the GRUAN strategy and thus in situ and remote sensing instruments are both seen as essential. Test case studies at GRUAN sites looking at the integration of various types of instrumentation should be instigated, participation by remote sensing instruments at CIMO intercomparison campaigns should be encouraged, and the membership of the WG-ARO should have more expertise from the remote sensing communities and NDACC.

WG-ARO members stressed that huge benefits could be expected of GRUAN through (i) guidance to sites on what instrument combination and scheduling to apply for climate applications, through the provision of error bars and scientific decision basis (currently lacking in WMO guidance material), (ii) strengthened collaboration of the scientific and the operational communities (already achieved for the 2010 CIMO campaign, mainly catalyzed through the GRUAN WPP).

3a. Better contributions by sites

The Chair expressed the perceived lack of guidance to current GRUAN sites and emphasized the need for better communication with, and among, sites. The WG-ARO suggested that the proposed task teams (except for the one on network issues and site certification) should be populated with site representatives, to improve their participation and buy-in.

4. WIGOS participation

The Chair noted that participation of GRUAN in WIGOS, through a dedicated Pilot Project, has the benefit of ensuring political support by WMO secretariat and technical commissions (CIMO, CBS). It so far has engendered little material support and virtually no feedback by the relevant expert teams. John Nash, current CIMO president, stressed the value of having a standing dialogue between those commissions and GRUAN, in order to ensure proper linkage to the operational communities. Bertrand Calpini, current CIMO vice-president, pointed out that joint participation by research and operational radiosondes in the CIMO intercomparison campaign in summer 2010 was a good opportunity to reap benefits from that linkage, which would have been difficult to achieve without. Holger Vömel remarked that improving the current operational networks by demonstrating GRUAN's value would be a major success. It was suggested that the WG-ARO approach Tony Reale to explore the possibility of having dedicated satellite coverage of the CIMO intercomparison area from NOAA satellites, in addition to the confirmed coverage by Chinese FY imagery.

5. Coordination with GSICS and other relevant programmes

GSICS

The Chair noted that linkage of GRUAN to GSICS was weak and that no real commitments of more substantive collaboration had so far materialized, given the absence of Chris Barnet from the WG-ARO and a lack of feedback from the GSICS groups to GRUAN-related issues. John Nash pointed out that common points of interest would have to be identified, possibly with support by WMO/WIGOS through the Director of the Observations Department, Wenjian Zhang. John Dykema and Stephan Bojinski emphasized that GSICS was hitherto focussing on intercomparison and consistency of IR sounders on different satellites on the radiance level, mainly to support NWP and direct assimilation into models, and much less on product retrieval, cal/val and generation of climate data records. Perhaps, with time, GSICS and GRUAN could engage on more concrete projects, and mutual representation on GRUAN task/GSICS expert teams (possibly including the CGMS Int'l Precipitation Working Group, Int'l TOVS Working Group) was seen as a first step forward.

Other groups

As for linkage to other international groups, better coordination with NDACC and the European Meteorological Infrastructure was needed.

6. WG-ARO ToR and Membership

The Chair expressed overall satisfaction with the engagement of WG-ARO members, particularly on the grounds that all major milestones had been met in the past year. He nevertheless called for more active, regular and ad hoc (not only on-demand) participation by the WG-ARO in GRUAN-related discussions. The WG-ARO was happy with the Chair's performance so far and encouraged him to stay in that function, and even encouraged him to push the Group more at times. More regular status checks, e.g. through remote means (teleconferences?) were suggested, since more frequent face-to-face meetings were not seen as a realistic option (apart from meeting yearly at the fringes of ICMs). The WG-ARO was further encouraged by GCOS secretariat to review its ToR to properly reflect its status versus the Lead Centre and the impending task teams. New members should come from:

- the Chairs of task teams (see item 1.)
- the satellite community
- the NDACC community
- (potential) regional champions other than Europe and North America, e.g., the Spanish-speaking world (Izana) and the French-speaking world (La Réunion)

Bill Murray and John Nash announced their retirement from the group. Representation of instrument manufacturers through HMEI during the ICM was considered sufficient.

7. Gearing national/international resources to support GRUAN

The need for additional funding to make GRUAN a reality was identified on two main fronts, namely, to (i) support GRUAN infrastructure, and to (ii) support GRUAN science. Elements of how to achieve this goal are:

- Appropriate outreach material (e.g., a flyer) would need to be developed (by whom?) It was suggested that this be an action upon the working group membership.
- Leverage data generated at GRUAN sites to attract scientists' interest, proposals …
- Lobbying with DoE, NOAA, EU FP7, WMO

8. ICM-3

The WG-ARO agreed on exploring the possibility for ICM-3 to be held, in order of priority:

- Lauder NZ
- Xilinhot China
- Tateno Japan
- Beltsville USA

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Appendix 6 WG-ARO - Terms of Reference

AOPC Working Group on Atmospheric Reference Observations (WG-ARO)

Terms of Reference
(April 2010)

The GCOS/WCRP Atmospheric Observation Panel on Climate (AOPC) Working Group on Atmospheric Reference Observations (WG-ARO) was established in 2006 in recognition of the importance of initiating reference-quality observations of atmospheric column properties, in particular temperature and water vapour, from the surface into the stratosphere to enhance the 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. The 2010 Update of the GCOS Implementation Plan calls for the establishment of the GRUAN network 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. A GRUAN Implementation Plan was published in July 2009 covering the period until 2013. It is the Working Group's purpose to facilitate this implementation, liaising with other groups and national and international bodies to ensure that an eventual network is fit for purpose, robust and has the required long-term commitment and management structures. The WG-ARO provides guidance to the GRUAN Lead Centre.

Terms of Reference

Under the auspices of AOPC, the WG-ARO was established

- To provide scientific, technical and management oversight of the operations of the GCOS Reference Upper-Air Network (GRUAN) Lead Centre, which will manage the overall work and evolution of the network, and which shall report to the WG-ARO at least twice a year;
- To recommend roles and responsibilities of the GRUAN Lead Centre and, as deemed appropriate, other centres, for data management, quality monitoring, analysis and capacity building purposes;
- To define and maintain (minimum and target) requirements of a GRUAN site in terms of instrumentation, variables addressed, data quality, the collection of metadata, operating practices and data management, in consultation with the Commission on Instruments and Methods of Observation (CIMO) and other relevant observing programmes;
- To provide recommendations on the composition of the GRUAN, including the selection of sites, noting that AOPC has final say in endorsing the GRUAN network composition; this should be done in consultation with AOPC AGG (Advisory Group on GSN and GUAN) and other advisory bodies as appropriate (e.g., with GSICS (Global Space Based Inter-Calibration System) and GAW (Global Atmospheric Watch));
- To instigate, approve, manage and dissolve, as appropriate, task teams set up to undertake specific activities in support of GRUAN;
- To encourage the activities of the GRUAN science team (GRUAN Analysis Team for Network Design and Operations Research - GATNDOR) and provide feedback and input as requested by that team;
- To work with relevant agencies and programmes to define and promote GRUAN for long-term atmospheric reference observations of a range of specific variables, making 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, especially through the GSICS and the SCOPE-CM initiative;
- 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-ARO;
- To undertake planning and execution along with other relevant stakeholders of 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 provide for appropriate communication and outreach activities (through such activities as conference town meetings, making connections with other programs, organizing special sessions on GRUAN etc.).

Operation

- The WG-ARO will generally correspond by e-mail and teleconferences, and take advantage of relevant workshops and conferences to hold meetings. Additional meetings will be convened by the chairman upon demand, in consultation with the GCOS Secretariat and GRUAN partner institutions.
- During the GRUAN implementation phase (until Dec. 2013, at least) it is envisaged that annual WG-ARO meetings should be convened at initial GRUAN network sites at which group members will be expected to attend. A WG-ARO meeting would be expected to occur on at least the day prior to the full GRUAN meeting.
- Funding for WG-ARO meetings should be sought from sponsors.
- The group will cease to exist at such time as AOPC deems appropriate.
- The Chair will be appointed by the AOPC.
- Working Group members will be agreed by the AOPC. The Task Team Chairs are ex-officio members. The AOPC decides at its annual meetings on additional experts and observers to join the WG-ARO as ex-officio members.
- Members will be expected to serve until at least April 2012 when membership will be reviewed.
- These Terms of Reference will be subject to periodic review by AOPC in liaison with the Chair of the Working Group.

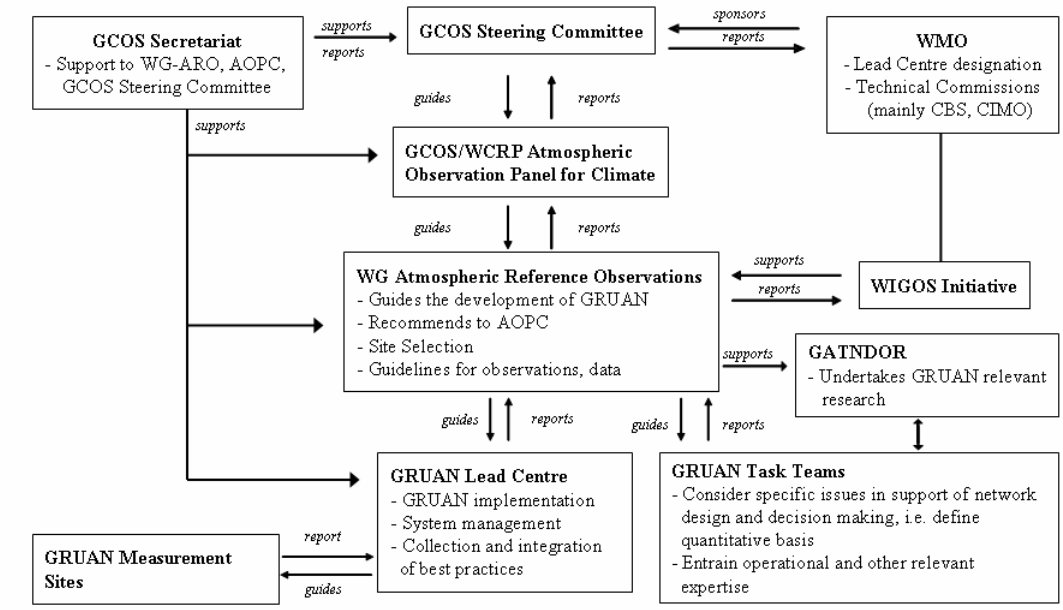

Figure: Organigram of the WG-ARO responsibilities and reporting lines.

The jointly sponsored Atmospheric Observation Panel for Climate (AOPC) provides direction and oversight of GRUAN. The AOPC is supported by the GCOS Secretariat and guided by the GCOS Steering Committee. It has established a Working Group on Atmospheric Reference Observations (WG-ARO) to provide direct guidance to the establishment of the GRUAN. The WG-ARO is also supported by specific GRUAN Task Teams and the GRUAN Science Team "GATNDOR" (GRUAN Analysis Team for Network Design and Operations Research). The management of the GRUAN falls under the responsibility of the GRUAN Lead Centre. It is responsible for the coordination among GRUAN Measurement sites, including training, education and research, and ensuring the archival and dissemination of GRUAN data. Furthermore, the implementation of GRUAN became a pilot project for the WMO Integrated Global Observing System (WIGOS) initiative.

References

- **GCOS-134**, GRUAN Implementation Plan 2009-2013, *July 2009*: http://www.wmo.int/pages/prog/gcos/Publications/gcos-134.pdf
- **GCOS-131**, Report of the First GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-1), *Norman, Oklahoma, USA, 2-4 March 2009*: http://www.wmo.int/pages/prog/gcos/Publications/gcos-131.pdf
- **GCOS-121,** Report of the GCOS Reference Upper-Air Network Implementation Meeting, *Lindenberg, Germany, 26-28 February 2008:* http://www.wmo.int/pages/prog/gcos/Publications/gcos-121.pdf
- **GCOS-112**, GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options - *April 2007*: http://www.wmo.int/pages/prog/gcos/Publications/gcos-112.pdf

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Appendix 7 GRUAN Guide of Operations Expert Meeting

GRUAN Guide Meeting, 5 March 2010

Participants:
Peter Thorne, Anna Christina Kuhn, John Nash, Howard Diamond, Holger Vömel, Stephan Bojinski, Krunoslav Premec, Igor Zahumensky

Sponsorship:
This meeting was kindly sponsored by the WIGOS trust fund.

GRUAN Overview
Peter Thorne, chairman of the Working Group on Atmospheric Reference Observations (WG-ARO), gave a short overview on the GRUAN project, its onset and current status of implementation.

Status of developing a GRUAN Guide
Anna Kuhn from the GCOS Secretariat briefed participants on the status of developing a GRUAN Guide of Operations: Guiding documentation would be urgently needed to inform initial and future GRUAN sites what is expected of them. The Guide shall define the requirements for GRUAN site operations, including requirements on expected accuracy, long-term stability, and uncertainty measures as stated in GCOS-121. The Guide shall not recommend specific instruments in order to guarantee sustainability of observations and should avoid restriction to a single vendor. It is appropriate and consistent with WMO terminology to call it a 'Guide', not a 'Manual'.

So far, only limited progress has been made in developing a GRUAN Guide of Operations and it has become clear that the GRUAN LC, the WG-ARO and the GCOS Secretariat do not have the necessary resources and/or experience to write such a Guide. Therefore, support from a consultant would be needed. This person should have knowledge and relevant experience with existing WMO literature, in particular CIMO and CBS guidelines, as well as some understanding about the GRUAN concept. Writing a Guide of Operations would in part have to go in parallel with defining GRUAN specific recommendations and in collaboration with the newly established Task Teams, which have been agreed on during the 2nd GRUAN Implementation-Coordination Meeting (ICM-2; 2-4 March 2010). It is hoped that the development of a GRUAN Guide in part also catalyses the necessary decision making. Once available, the GRUAN Guide should supplement and be reflected in existing WMO literature. These two parts of the process in developing GRUAN specific documentation might take place one after the other or partly in parallel.

The GRUAN Guide has to take into account the heterogeneity of the network and its state of development. While the main binding element, the definition of uncertainty measures, must be reflected prominently.

For expanding the network, the GRUAN is looking for capable sites, but these sites need a clear idea of expectations which is currently lacking and a completed guide would provide. Offers will be assessed on the basis of performance expectation against the GRUAN Guide (amongst a suite of other factors) by a site certification and assessment team (Task Team 4).

WMO guidelines
John Nash, President of the WMO Commission for Instruments and Methods of Observation, presented how a GRUAN Guide should be incorporated into existing WMO guidelines, an important step to inform WMO members about GRUAN requirements, to formally engage them in GRUAN and thereby to ensure the longevity of the network.

Lessons learned from the GUAN show that performance does not only result from having specifications in the WMO Manual. In contrast to GUAN, which is basing on weather observing stations, GRUAN is specifically designed for climate purposes. It is a proactively managed network, with resources allocated to it (Lead Centre).

John Nash also recognized the benefits of the WIGOS PP in linking the scientific community and the operational community.

Envisaged timeline
Igor Zahumensky, WIGOS Planning Officer, suggested that development the GRUAN Guide should be in liaison with CBS and CIMO, and contribute to the improvement of their regulatory material. CBS next meets in Nov 2010, implicating that a very first, basic outline would have to be available by June 2010. The following regular CBS session will be in autumn 2012, where the final GRUAN guidelines should be endorsed to be available before the planned expansion of the network. Furthermore, it is not sure whether there will be a CBS session in 2014. Therefore, the ultimate goal would be to have a draft Guide of Operations, signed off by the WG-ARO, ready by ICM-3 in March 2011. Remaining open areas might have to be flagged at this time.

Independent of this, specific input and changes to the CIMO guide (e.g. correction of the empiric formula for the saturation vapour pressure over liquid water) can be submitted to the CIMO editorial board at any time (by email to Isabelle Ruedi <IRuedi@wmo.int>).

The time needed for a contractor to draft the Guide was estimated at:

- 1 month to prepare the basic, "high-level" outline
- 3 to 6 months to detail out the work, largely depending on experience

Resources
The development of a GRUAN Guide has been highlighted as one of the main elements in the GRUAN WIGOS Pilot Project and it was hoped to receive some financial support from that side, in addition to the present meeting. Igor Zahumensky pointed out that only little money has been allocated to each of the Pilot Projects and the main part of the budget will probably be needed to support participation of the Pilot Projects in the upcoming CIMO Technical Conference and CIMO-XV session. The question was raised, if there would be possible resources under CBS. The CBS ICT-IOS ET-EGOS at its 4th session in December 2009 recommended that a CBS Expert Team on GRUAN be formed by the end of 2010.

Holger Vömel recalled that the German Weather service, DWD, has funds available in 2010 for two 6 month FTE visiting scientist working at the GRUAN Lead Centre in Lindenberg. Part of that resource might be used for writing the GRUAN Guide. The remuneration would be in the order of 2500€ per month, equivalent to a post-doc position in Germany. The visiting scientist would ideally start working in July-August 2010, for a 3-4 months period (c.f. timeline above).

Howard Diamond offered support from the US GCOS programme. These funds would allow greater flexibility on the contract e.g. the person would be free to work at any place. However, presence at the Lead Centre at least for a couple of weeks would be favourable, depending on the individual and their familiarity with GRUAN. Such a contract might be used to supplement the visiting scientist funds in case of a senior scientist level consultant.

Igor Zahumensky noted that for WMO Special Service Agreements, it is common practice to pay the consultant's work upon agreed deadlines or by delivery.

Possible consultants

- Krunoslav Premec
- Greg Bodeker

John Nash could not act as consultant because he is engaged in the CIMO intercomparison campaign until April 2011.

Discussion of the draft skeleton
Participants discussed the draft skeleton for the GRUAN Guide, basically a table of content, which had been adopted by ICM-1 (see below the updated draft skeleton).
Participants agreed that the GRUAN Guide should link as much as possible to existing descriptions in the CIMO guide, e.g. the chapter on Quality Management, and that the style of GOS and CIMO Guides should be considered. While the role of estimating measurement uncertainty and the importance of metadata must be reflected in all relevant sections. Non-progress in the Task Teams should not prevent progress with the GRUAN Guide; it can be generic where appropriate. Once a draft is available its structure must be checked against the Manual and Guide to the GOS

Draft skeleton

- **1. Introduction (Scope, Purpose)**
  - **Linkage to Satellite Operators**
  - **Linkage to partner networks (BSRN, NDACC, GAW, …)**
- **2. Description a Reference Measurement**
  - **Observed Essential Climate Variables**
  - **Important role of estimating measurement uncertainty**
- **3. GRUAN governance**
- **4. GRUAN sites (Criteria, Description)**
  - **site certification and assessment (Task Team 4)**
  - **managing change (Science Team input)**
- **5. Instrumentation**
  - **5.1 Ground based surface measurements**
  - **5.2. Upper-Air measurements**
    - **In situ instruments (Task Team 1)**
    - **remote sensing instruments (Task Team 2, 5)**
  - **5.3 Calibrations and maintenance**
- **6. Methods of Observation**
  - **6.1 Measurement scheduling (including linkage to satellites; Task Team 3)**
  - **6.3 Operation and maintenance, quality standards**
- **7. Data Management**
  - **7.1 GRUAN Data Policy**
  - **7.2 Data format (obs. data, metadata)**
  - **7.3 Data ingestion,**
  - **7.4 Data submission,**
  - **7.5 Data dissemination**
  - **7.6 Data archiving**
  - **7.7 Quality control on instrument/site level**
- **8. Post-processing analysis and feedback**
- **9. Quality assurance**

Agreed outcome:

- Participants should send as soon as possible additional names of potential candidates for the consultant role to the GCOS Secretariat.
- GCOS Secretariat will be in lead of coordinating the task to hire a suitable consultant (roster, shortlist, contact & negotiations etc), in consultation with WG-ARO Chair, Lead Centre Head and US GCOS Program Manager.
- Let the GRUAN community know about the development of the Guide.
- The very first outline of the Guide should be presented to the CBS OPAG/ICT-IOS (Open Area Group on Integrated Observing Systems – Implementation/Coordination Team on Integrated Observing Systems) in the last week of June.
- The draft Guide, approved by the WG-ARO, shall be available by ICM-3 in Mach 2011.
- Liaise with CIMO, CBS and WG-ARO in the development of the Guide.
- The minutes of this meeting will become an annex to the ICM-2 report.

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Appendix 8 List of Acronyms

AOPC	Atmospheric Observation Panel for Climate
ACRF	ARM Climate Research Facility
AGU	American Geosciences Union
AMS	American Meteorological Society
ARM	Atmospheric Radiation Measurement Program
ATM	Accurate Temperature Measuring radiosonde (NASA reference radiosonde)
BADC	British Atmospheric Data Centre (NERC)
BIPM	International Bureau of Weights and Measures
BSRN	Baseline Surface Radiation Network
CAS	Commission for Atmospheric Sciences
CBS	Commission for Basic Systems (WMO)
CEOS	Committee on Earth Observation Satellites
Cg	Congress (WMO)
CFH	Cryogenic Frostpoint Hygrometer
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies, Oklahoma University
CIMO	Commission for Instruments and Methods of Observation
CMA	China Meteorological Administration
CPO	NOAA's Climate Program Office
DWD	German Meteorological Service (Deutscher Wetterdienst)
EC	Executive Council (WMO)
EGU	European Geosciences Union
ET-EGOS	Expert Team on Evolution of the Global Observing System (WMO/CBS)
GAW	Global Atmospheric Watch
GCOS	Global Climate Observing System
GIP	GCOS Implementation Plan
GOS	Global Observing System (WMO)
GOSIC	Global Observing System Information Center (at NCDC)
GPS-PW	Global Positioning System Precipitable Water
GRUAN	GCOS Reference Upper Air Network
GSICS	Global Space-Based Inter-Calibration System
GUAN	GCOS Upper Air Network
HMEI	Association of Hydro-Meteorological Equipment Industry
ICM	Implementation - Coordination Meeting (GRUAN)
ICT-IOS	Implementation / Coordination Team on the Integrated Observing System (WMO/CBS)
ICSU	International Council for Science
IPY	International Polar Year (Imitative by ICSU and WMO)
LIDAR	Light Detection and Ranging (optical remote sensing)
LST	Local Solar Time
LUAMI	Lindenberg Upper-Air Methods Intercomparison Campaign
NCAR	National Centre for Atmospheric Research
NCDC	NOAA's National Climatic Data Center
NDACC	Network for the Detection of Atmospheric Composition Change
NetCDF	Network Common Data Form
NERC	Natural Environment Research Council
NMIs	National Meteorological Institutes
NOAA	National Oceanic and Atmospheric Administration
NPROVS	NOAA Products Validation System
NWP	Numerical Weather Prediction
QC/QA	Quality Control/Quality Assessment
QA4EO	Quality Assurance for Earth Observations Strategy (CEOS)
RSSC/CM	Regional/Specialized Satellite Centres for Climate Monitoring
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SGP	Southern Great Plains Site (ACRF)
SPARC	Stratospheric Processes And their Role in Climate (WCRP)
TIROS	Television Infrared Observation Satellite (NOAA polar orbiting satellite)

TOVS	TIROS Operational Vertical Sounder
UTC	Universal Coordinated Time
UT/LS	Upper Troposphere and Lower Stratosphere
WCRP	World Climate Research Programme
WG-ARO	Working Group on Atmospheric Reference Observations
WIGOS	WMO Integrated Global Observing Systems
WIGOS-PP	WIGOS Pilot Project
WMO	World Meteorological Organization

LIST OF GCOS PUBLICATIONS (SINCE 2009)*

GCOS-126 (WMO/TD No. 1464)	GCOS Annual Report 2007-2008
GCOS-127 (WMO/TD No. 1477)	Practical Help for Compiling CLIMAT Reports
GCOS-128 (WMO/TD No. 1488)	Guidelines for the Generation of Satellite-based Datasets and Products Meeting GCOS Requirements (GCOS Secretariat, March 2009)
GCOS-129 (WMO/TD No. 1489)	Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008
GCOS-130 (WMO/TD No. 1490)	Synthesis of National Reports on Systematic Observation for Climate
GCOS-131 (WMO/TD No. 1492)	Report of the First GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-1) (Oklahoma City, USA, 2-4 March 2009)
GCOS-132 (WCRP 6/2009) (WMO/TD No. 1497)	Fifteenth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC-XV) – Conclusions and Recommendations (Geneva, Switzerland, 27-30 April 2009)
GCOS-133 (WMO/TD No. 1498)	Summary Report of the Eleventh Session of the GCOS/GTOS Terrestrial Observation Panel for Climate (TOPC) (Rome, Italy, 29-30 October 2008)
GCOS-134 (WMO/TD No. 1506)	GRUAN Implementation Plan 2009-2013
GCOS-135 (WMO-TD No. 1511)	Report of the 4th GTN-H Coordination Panel Meeting
GCOS-136 (WMO-TD No. 1514)	GCOS Annual Report 2008-2009
GCOS-137 (WMO-TD No. 1516)	Report of the 17th session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Paris, 27-30 October 2009)
GCOS-138 (WMO-TD No. 1523)	Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)
GCOS-139 (GOOS No.)	IOC Group of Experts on the Global Sea Level Observing System (GLOSS), eleventh session (Paris, France, 13-15 May 2009)
GCOS-140 (WMO/TD No. 1526)	Report of the Second GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-2) (Payerne, Switzerland, 2-4 March 2010)

* GCOS publications may be accessed through the GCOS website at: http://gcos.wmo.int

GCOS-141 (WMO-TD No. 1528)	Final Report of the Twelfth Session of the GCOS/GTOS Terrestrial Observation Panel for Climate (TOPC-XII) (Rome, Italy, 10-11 March 2010)
GCOS-142 (WCRP No.)	Report from the Fourth Meeting of the WCRP Observation and Assimilation Panel (WOAP) (Hamburg, Germany, 29-31 March 2010)
GCOS-143 (WMO-TD No. 1530)	Guideline for the Generation of Datasets and Products meeting GCOS Requirements (GCOS Secretariat, May 2010)

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