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Report of the Third GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-3)

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1. Introduction

The third GRUAN Implementation and Coordination Meeting (ICM-3) was held 28 February - 4 March 2011 at Queenstown, New Zealand, near the GRUAN site at Lauder. The meeting was generously hosted by the National Institute of Water and Atmospheric Research (NIWA) with support from the U.S. GCOS Program Office at the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC), the NOAA Climate Program Office (CPO) and the GCOS Secretariat at the World Meteorological Organization (WMO).

The annual GRUAN meetings afford an opportunity for the Working Group on Atmospheric Reference Observations (WG-ARO; operating under the GCOS / World Climate Research Programme (WCRP) Atmospheric Observation Panel for Climate (AOPC)), the GRUAN Lead Centre, 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 New Zealand, it provided the opportunity to include the New Zealand MetService in discussions related to GRUAN implementation at Lauder.

The meeting's main goals were to update participants on GRUAN progress and to discuss new developments (for agenda see Appendix 1), with a focus on:

- Practical implementation of the definition of a GRUAN reference observation;
- First open discussion of the draft GRUAN manual;
- Quality assurance, science, and site issues;
- Definition of site criteria for site assessment and certification;
- Development of detailed work plans for the GRUAN Lead Centre, the WG-ARO, GRUAN Task Teams, and other parties involved.

As in the previous ICMs, the meeting included a site visit with a guided tour of the suite of instrumentation operating at the NIWA observatory at Lauder, the centre for upper-air composition observations of NIWA. The site at Lauder plays an important role in the detection of atmospheric composition change, and is the only site of its calibre on the Southern Hemisphere. Participants regarded the site visit as very valuable, allowing deeper insight in to how Lauder addresses GRUAN-related issues and in particular appreciated the local staff's hospitality and willingness to answer questions.

Rather than being a full record of the meeting, this report summarizes and synthesizes key discussions and outcomes. All documents prepared in support of ICM-3, and all meeting presentations, are available on the GRUAN website at http://www.gruan.org (under Meetings: Queenstown 2011: Documents).

2. Opening notes

The GRUAN ICM-3 was opened by the local hosts of the Lauder site, Paul Johnston and Graeme Strang. The agenda for the week was discussed, and the meeting's thanks go to the organizers from NIWA both for the venue, the trip to Lauder later in the week, and for all the excellent logistics provided. Given the tragedies of the previous week with the devastating 6.3 magnitude earthquake in Christchurch, the Member of Parliament who had been scheduled to address the ICM-3 was understandably not able to do so.

In recognition of the events in Christchurch the meeting recognized a moment of silence to remember and honor the victims of the earthquake. It was also noted the following day, Tuesday, 1st March at 12:51 pm local time that a national 2-minute period of silence would be held; this was to commemorate the exact period from the week before when the quake struck. The meeting hosts were very grateful of this gesture on the part of the meeting attendees as in particular the meeting attendees as a whole would more than likely not all be in one place during the national moment of silence on Tuesday the 1st.

The meeting was honored by having an opening presentation made by Dr Neil Gordon, New Zealand's Permanent Representative with WMO. Dr Gordon thanked everyone for the opportunity to add his welcome to New Zealand, and in these clearly difficult times, he was pleased that the meeting continued to take place. He indicated that the New Zealand MetService has considerable experience with GCOS as it hosts four GCOS Upper Air Network (GUAN) stations at Raoul Island, Paraparaumu, Invercargill, and Chatham Islands; in addition to overseeing ten GCOS Surface Network (GSN) stations (nine from the MetService and one from NIWA). New Zealand's Met Service has a history of working in the Pacific with partners such as the U.S. GCOS Programme based at NCDC, and also works closely with NIWA and other agencies in contribution to WMO and GCOS. All data gathered enter the NIWA climate database, and the vital importance of GRUAN observations was recognized. Dr Gordon pointed out that models may come and go, but observations form the base, and one can never go back in time and take them again. A fundamental underpinning of the proposed Global Framework for Climate Services is the New Zealand contribution to GCOS, and as such he supports the proposed role for Lauder. While funding GRUAN in New Zealand is already difficult, the additional stress on the country's financial resources resulting from the global financial crisis and earthquakes in Christchurch in September 2010 and recently this year, only exacerbates the problem. Nevertheless, he believes that New Zealand still recognizes the importance of these networks to the global climate community.

Dr Gordon wished a good and successful meeting, and was keen to look for ways to combine the support that the MetService provides for routine operations at the upper-air station in Invercargill to see how it may contribute to the GRUAN effort at Lauder.

The director of the GCOS Secretariat, Dr Carolin Richter, sent welcoming remarks by phone. She emphasized the important role that GRUAN plays within the networks recognized by GCOS. Reference measurements for climate are essential for the detection of climate change and for the validation of larger scale observing systems, which places GRUAN in a unique position. The GCOS Secretariat will do its utmost to ensure effective cooperation between different programmes within WMO and to facilitate important climate observations within WMO.

3. Progress on advancing the GRUAN Implementation Plan

3.1. Status of implementation

The 2009-2013 GRUAN Implementation Plan (GCOS-134) has been the guiding document for the progress achieved in the 12 month period preceding ICM-3. The milestones and achievements were reviewed by Peter Thorne, Chair WG-ARO and discussed by the meeting attendants. Delays and changes to specific items in the Implementation Plan were noted; however, no significant deviations from the Implementation Plan were identified. It was stressed that maintaining the Implementation Plan is essential and that progress needs to be measured against the targets outlined in the Implementation Plan. It was also agreed that as the development of GRUAN progresses, modifications to the Implementation Plan should be included as addenda rather than frequent changes of the document itself. This represents the flexibility that was emphasized in the previous Implementation and Coordination Meeting at Payerne (ICM-2).

The following action items that had not been achieved for various reasons were identified as requiring special attention:

- Agree on a protocol for dealing with any site offers arising in the interim.
- Agree on and implement a data usage acknowledgement protocol.
- Create better links between GRUAN and the satellite community (SCOPE-CM EP, CM-SAF, GSICS EP, CGMS Working Groups)
- Develop a GRUAN network configuration plan to guide the location of future sites (optimal location / climate zone, institution, etc.).

The first two items were addressed during the meeting (see below). The meeting also recognized that efforts need to be undertaken to build a better relationship with the relevant representative bodies and institutions from the satellite community. To this end, several participants have proposed to voice support at various satellite related meetings.

Achievements of the working group activities are:

GRUAN, as a WMO Integrated Observing System (WIGOS) pilot project, continued to report to the WIGOS project office.

- Five of the six Task Teams envisaged at ICM-2 have been established.
- A GRUAN brochure has been prepared in cooperation with the Lead Centre and the GCOS Secretariat, which will be printed (limited print run) at the GCOS Secretariat. The brochure is available as a PDF file from www.gruan.org.
- GRUAN was well represented at the XVI session of AOPC through the head of WG-ARO (by phone) and the head of the Lead Centre.
- Lastly, efforts have been made towards a visible inclusion of GRUAN at the upcoming World Climate Research Programme (WCRP) Open Science Conference taking place in Denver, USA, in October 2011.

3.2. GRUAN reference measurements

Holger Vömel, head of the GRUAN Lead Centre, reviewed the definition of the term "Reference Observation" as outlined during ICM-2 and published in the paper titled "Reference Quality Upper-Air Measurements: Guidance for developing GRUAN data products" by Immler et al. (2010)[1]. Underlying references are the 'Guide to the expression of uncertainty'[2] and the CIMO "Guide to Meteorological Instruments and Methods of Observation"[3].

This definition of a reference observation requires:

- Traceability to SI units or a commonly accepted standard;
- Comprehensively estimated uncertainty;
- Documentation of instrumentation, procedures and algorithms;
- Validation of the data products.

In practice this implies that a measurement is accompanied by the best estimate for the uncertainty of that measurement and that the measurement and its uncertainty are traceable to a standard through an unbroken chain of documentation. To test and verify that the uncertainty estimate remains realistic, redundant measurements, either onboard the same platform or using different platforms, are essential. This approach ensures that unidentified issues are detected and that steps to address these issues can be taken early. Extensive documentation of the technique being used is required and any instrument for which an uncertainty estimate cannot be documented will not be suitable for reference measurements within GRUAN. Analyzing measurement uncertainties may require additional information from manufacturers and therefore a close cooperation between GRUAN and the manufacturers is also essential.

Making sure that all components of the measurement uncertainty are well understood is essential in the management of instrument change, which will undoubtedly happen within GRUAN. It was recognized that validation through redundant observations will be a key element in the management of change.

Participants were broadly supportive of the methodology and stressed its value for GRUAN. It was emphasized that this approach may also add value to other operational networks.

3.3. Lead Centre progress report

The six-monthly activity report by the Lead Centre for the period August 2010 – January 2011 is given in Appendix 3. It includes activities addressing items in the annual short-term GRUAN work plan (as

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

[2] 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

[3] Guide to Meteorological Instruments and Methods of Observation, WMO 2008, (CIMO Guide), available at: http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO%20Guide%207th%20Edition,%202008/CIMO_Guide-7th_Edition-2008.pdf

laid down in the ICM-2 report, GCOS-140[4]) and within the framework of the GRUAN Implementation Plan 2009-2013 (GCOS-134[5]).

A significant milestone has been the processing and dissemination of the first data that follow the GRUAN definition of reference measurements. These first data are based on the measurements using the Vaisala RS92 radiosonde. The data flow and data handling structure, as presented at ICM-2, is operational and data of the Vaisala RS92 are being processed at the GRUAN site Lindenberg. One important element of the data handling is the collection of metadata through the RS-launch client or equivalent tools to prepare the XML formatted metadata files. The RS-launch client, which will be made available to all GRUAN sites, not only assists in the collection of all metadata but also in the transmission of all necessary data files to the processing centre. The description of all the data formats and data processing procedures will be provided in a series of GRUAN technical documents, which is currently under review. Although the data dissemination structure is expected to evolve as GRUAN evolves, it was decided that by the time of the next meeting enough experience should have been gathered to implement a final data dissemination structure. It is not expected that this final data dissemination structure will be static, but rather will have enough flexibility to accommodate future developments within GRUAN.

Since it may not be assumed that data products will always be perfect, a system to report, track and resolve problems with data products and instruments at sites is required as an essential feedback component in the data dissemination structure. The possibilities of such a system is being investigated at the Lead Centre.

The GRUAN processing applies corrections for all systematic biases known, which at the same time allows an estimation of the uncertainty of each measurement point, due to the better understanding of the processing scheme. It is based on previous comparisons and laboratory studies and thereby fills gaps resulting from documentation not supplied by the manufacturer. In particular, uncertainties for temperature and humidity are now being quantified and vertically resolved. The technical document describing the processing in detail is currently under review by the Task Team on radiosondes. These data are available at NCDC under ftp://ftp.ncdc.noaa.gov/pub/data/gruan and are considered the beta-phase data for GRUAN products. Currently sounding data from Sodankylä, Cabauw and Lindenberg are available. Data from other sites will be made available soon. Although the number of data in this early stage is insufficient to undertake significant research studies, participants concurred that the early use of GRUAN data is highly desired to identify potential issues and shortcomings, which should be addressed before significant numbers of data have been produced, and also useful to promote GRUAN.

Ensuring long-term stability of the measurements is as important as quantifying and improving measurement uncertainty. This must be done through ground checks to an independent reference, regular redundant observations and actively managed change of instrumentation.

Additional highlights during the reporting period were:

- Participation at the 8th WMO intercomparison of radiosonde systems at Yangjiang, China, between 13th July and 1st August 2010 (see section 6.1).
- Set up of the data flow infrastructure to collect, and disseminate GRUAN data.
- Preparation of the first draft of the GRUAN manual (see section 3.4)
- Extended test of the Meisei MTR temperature sensor at Lindenberg

A path to the development of new data products was presented, which allows the inclusion of new observations using different instrumentation within GRUAN. It was stressed that sites using unique instrumentation need to develop their own data products following the general guidelines. Sites using instrumentation that is used at other sites as well are strongly encouraged to cooperate to develop a common data product with consistent procedures and processing. In particular, it is essential that for identical instrumentation, all data are processed through only one processing centre. One example is the Vaisala RS92 data product, which is currently processed at the Lindenberg site in cooperation with the Atmospheric Radiation Measurement Program (ARM) processing centre. The preparation of the

[4] Available under: http://www.wmo.int/pages/prog/gcos/Publications/gcos-140.pdf
[5] Available under: http://www.wmo.int/pages/prog/gcos/Publications/gcos-134.pdf

documentation and of the peer-reviewed literature describing a data product is considered important and must be done by the sites using that particular instrumentation.

Data products will be instrument specific since, as for example radiosondes and lidars have fundamentally different sampling methods. Instrument specific parameter products, such as layer averaged profiles from one sensor, would be considered a “level 2” GRUAN product. Combining measurements from different instruments into a single data product, such as the combination of an operational radiosonde water vapour profile and a stratospheric water vapour profile from a research instrument on the same payload, is envisioned, too, which would result in “level 3” GRUAN data products. This naming convention is borrowed from typical satellite products, but should not be confused with their precise definition, since GRUAN observations will not provide globally gridded data.

It was suggested that documentation should be circulated to communities likely to be users of GRUAN products to ascertain whether these data products meet their needs. This could be done by the Lead Centre.

It was noted that visualization of data products has not been done so far, but may be provided at NCDC in the context of an upgraded interface to the Integrated Global Radiosonde Archive (IGRA), which is hosted at NCDC. In the context of the development of a graphical user interface, the possibility for voluntary user registration should also be explored by NCDC. A report to the WG-ARO about the possibilities of these developments is expected by October 2011.

Several sites raised the issue of data acknowledgement, which needs to be addressed such that all sites are properly acknowledged. It was agreed that the site representatives Task Team would gather a complete list of the data acknowledgement needs from all sites and implement these in a data-usage acknowledgement protocol.

3.4. Documentation

The GRUAN Lead Centre initiated a series of technical documents, which is intended to cover aspects of operational observations, data processing, data handling, etc. These documents may be prepared by the Lead Centre, a Task Team, GATNDOR, or other parties within GRUAN. These technical documents will either be reviewed by the applicable Task Team or the WG-ARO before they will be adopted as technical documents. This documentation provides the opportunity for lower level documentation, which may be adopted at a level below AOPC or GCOS. The first technical document describes the data-collection procedures and was presented at ICM-2. The second technical document describes the processing and the derivation and validation of measurement uncertainties of the Vaisala RS92 data within GRUAN. Other technical documentation is scheduled to follow. These technical documents may be revised in the future as procedures and instrumentation changes. At that time, appropriate Task Teams may be requested to revise, edit or amend existing documentation.

To support the writing of research proposals and the promotion of GRUAN, the Lead Centre also agreed to develop a collection of material, which may be used in the preparation of research proposals or in the presentation of GRUAN results or the advancement of GRUAN within the scientific community. These included a generic poster and PowerPoint presentation for general usage.

4. GRUAN Manual of Operations

At ICM-2, a decision was made to prepare a GRUAN Manual of Operations and further details were discussed in a subsequent WIGOS-sponsored side meeting which followed. A straw-man outline was agreed on during that meeting (see GCOS 140) and a search for a suitable candidate to draft this manual was initiated. In response to this decision, DWD contracted Dr Greg Bodeker of New Zealand, with additional support from the US GCOS office at NOAA/NCDC, to prepare this draft manual. As part of the preparation of this draft, Dr Bodeker traveled to the GRUAN Lead Centre in September 2010 and again in December 2010, as well as to WMO in Geneva in September 2010. During this visit to WMO he was accompanied by the head of the GRUAN Lead Centre, Dr Holger Vömel. The first draft of this manual was circulated to all parties involved in GRUAN for open comment in January 2011 and was presented and discussed at Queenstown.

The GRUAN manual is the top level document which describes the overarching philosophy, observational guidelines and organizational issues within GRUAN. The terminology “manual” follows the WMO recognized terminology for such a document. In this document the terms “shall” and ”must” refer to actions that are mandatory, whereas the term ”should” refers to actions that are strongly urged or recommended but not compulsory.

For the GRUAN manual to be an effective document, it is essential that it is a consensus document and that all parties involved will have had the opportunity to provide their input and feedback to the manual. In particular potential conflicts with local operating procedures must be addressed prior to the adoption of the manual. The GRUAN blog at http://gruan.wordpress.com/category/network/manual/ provides one possible platform for feedback and comments on the manual draft.

Greg Bodeker summarized the current draft version and highlighted several important points:

1. Intercomparisons of sonde types and remote sensing at stations: It was agreed that periodic intercomparisons of a large range of sonde types, possibly including remote sensing instrumentation should be undertaken at all sites to cover the widest possible range of operating conditions. Diversity in these investigations will be a strength since stations operating their respective sonde types are best prepared to investigate possible changes and the impacts this will lead to. This distributed responsibility is an ideal strategy under limited resources. It was recognized that sonde intercomparisons provide important information for both the climate community as well as for the operational weather community. This broad basis may be seen as an asset to GRUAN sites, which could be utilized by manufacturers in the future to perform tests.

2. Trust Fund: One of the limitations of GRUAN is the shortage of resources, in particular for small focused activities. As one potential avenue to address this issue GRUAN might benefit from having access to dedicated resources that can be used to address specific issues that are relevant across the network as a whole. Within the WMO structure, several trust funds have been established and have been found to be useful for capacity building and other targeted activities. This trust fund may also cover some targeted science questions, which are not well covered by usual funding mechanisms, which may take too long to be practical. This trust fund may further help to reduce duplication of effort in some areas. It was decided to remove the discussion of this trust fund at this point in time recognizing the potential issues it may raise. It has been removed from the present manual version and instead will be further explored by the WG-ARO and the Lead Centre.

3. Improved links to satellite community: The satellite measurement community is intended to be a key client of the GRUAN products. Formalized ties with the relevant space agencies need to be established and GRUAN products need to be better promoted within this community. Several communities that GRUAN could connect to have been identified and will be contacted by GRUAN members already involved in these activities. GRUAN members who attend relevant meetings in other functions should promote GRUAN. It is important to spread this effort over a number of people and to have local GRUAN members attend meetings in their respective countries. To create an overview of possible meetings and satellite activities, the GRUAN website and blog should list relevant meetings that should, if possible, have GRUAN representation. It was agreed to initiate consultation with the satellite community through targeted attendance of workshops and meetings of relevant groups.

4. Temporal sampling: It was recognized that GRUAN measurements need to be useful on their own and not only in the context of e.g. data assimilation. GRUAN observations, in general, will place greater emphasis on long time scales (years to decades) rather than on shorter time scales (daily to seasonal). Scheduling of observations is being addressed by a Task Team dedicated specifically to this issue. GRUAN data are also seen as being very valuable in the context of satellite observations and should provide anchor points useful for calibrating variability and trends. More discussion is required and the outcomes of that discussion should then be reflected in a revised version of the “Measurement Scheduling” section of the manual.

5. Site selection: Current requirements for GRUAN sites are considered only as initial requirements. The process for new sites entering GRUAN is not yet well defined and requires additional work. A proposal has been made to set up tiers, which would reflect the different instrumentation at sites. This issue was discussed in greater detail later and a decision was made not to implement a tiered structure at the moment (see section 5.1).

6. Surface Measurements: The meeting recognized the deficiency that GRUAN currently does not have any requirements on surface observations. Surface pressure measurements are crucial for Global Navigation Satellite System (GNSS) integrated precipitable water vapour, whereas surface temperature and humidity are important to provide a surface calibration of radiosonde profiles. It was decided that requirements for surface observations must be defined within GRUAN, which will be coordinated by the Lead Centre.

7. Use of GRUAN in real-time data assimilation for global analyses: It has been suggested that GRUAN data should be made immediately available for use in Numerical Weather Prediction (NWP) and/or 4D-Var data assimilation. However, the primary goals of GRUAN are currently not consistent with near real-time dissemination of measurements made at GRUAN sites in addition to any data already sent as a matter of course. Sites are nevertheless encouraged to make their observations available in real time, although it was recognized that these real-time data products will not constitute a final fully analyzed and quality checked data product and hence cannot be considered as official “GRUAN data”.

The intention is that GRUAN sites will eventually measure a large array of upper-air climate variables, although the focus at present is on upper-air temperature and water as priority one variables with the explicit vision that the suite of Essential Climate Variables (ECVs) measured will increase subsequently. All structures and underlying processes have been defined and described in the manual such that they may be easily applied to other climate variables as and when the list of desired variables expands. The path of moving beyond priority one climate variables needs to be described and how these structures may be applied to other variables without duplicating efforts already done in other communities. This task will be undertaken by the Lead Centre in close cooperation with Dr Greg Bodeker.

The current draft received widespread support and it was decided to proceed with the development of the manual. The manual will also cover site assessment and certification criteria (see following section), which will be developed within the context of the manual drafting. The final draft should be completed by January of 2012 and should then be reviewed by the entire WG-ARO, the Lead Centre, and all sites. It was decided that the final version would be accepted with the approval of the Working Group, the Lead Centre and 2/3s of all sites. The final approval of the manual is planned for ICM-4.

5. Site assessment and certification

5.1. Observations requirements

Site assessment and certification requires practical and transparent criteria that will be used in the assessment of existing sites and in the certification of new site offers. Establishing these criteria will be an important step in the development of GRUAN and the progress achieved to date was recognized. GRUAN is a very heterogeneous network with strong contributions from the research community as well as the operational meteorological community. It is expected that there is a significant mix of instrumentation within GRUAN and that redundant observations will play an important role. The requirements for sites need to reflect the goals that GRUAN aims to achieve and need to cover the spectrum of observational techniques. They need to cover what makes GRUAN unique and accommodate the diverse capabilities that are found within GRUAN, whilst recognizing that GRUAN is not the sole stakeholder at any of the sites.

It was agreed to define a set of requirements that must be satisfied to be able to provide GRUAN observations, which reflect the definition of reference observations as defined by Immler et al. (2010). The proposed requirements were discussed and it was agreed that a formal refinement and adoption of these criteria would be done by the WG-ARO allowing time for discussion and input. It was also recognized that the finally adopted criteria would provide the basis for the assessment of existing and new sites and that the WG-ARO would be able to use their experience and good judgment in weighing the different requirements based on individual site performance results.

It was *proposed* that sites shall:

- Provide observations of reference quality;
- Provide uncertainty estimates for each observation or collaborate with other sites to provide these estimates;
- Provide complete metadata description;
- Provide raw data or assure long-term storage of raw data;
- Provide ground checks independent of manufacturer (balloon *in-situ*);
- Provide regular calibration information about their systems (*in-situ* and remote sensing);
- Manage change pro-actively;
- Provide redundant reference observations at regular intervals;
- Actively conduct research to further develop this approach through intercomparison, laboratory studies and/or cooperation with manufacturers;
- Actively participate in the communication with the Lead Centre, WG-ARO, Task Teams and/or other sites, (e.g. through attendance of meetings).

Such requirements are not seen as a replacement of those defined in GCOS 112, but rather as clarification of what operational procedures must be guaranteed to obtain reference observations. These requirements, in final form, will be seen as mandatory requirements, which sites within GRUAN must satisfy.

The requirements defined in GCOS-121 were also discussed and, while studies to place these requirements on solid scientific footing are still under way, are considered essential requirements. At the time when these results become available, a refinement of the GCOS-121 requirements will be undertaken.

To accommodate the heterogeneous mix of instrumentation, these requirements, which were developed solely to guide *in-situ* instrumentation sampling, were slightly refined to allow other measurement systems to achieve the same goals. As part of the discussion, it was repeated that sites should:

- Provide twice daily observations of temperature (troposphere and stratosphere to 30 km);
- Provide twice daily simultaneous observations of tropospheric water vapour;
- Provide monthly observations of stratospheric water vapour to 30 km;
- Provide hourly observations of integrated precipitable water vapour;
- Provide weekly redundant observations of temperature and (tropospheric) water vapour profiles;
- Cooperate with nearby sites to fill observational gaps.

A proposal to group sites with different capabilities into a tier structure, which would reflect that some sites have more extensive capabilities than others, was discussed. The proposed tier structure should reflect the different observational programme, but should not distinguish the quality of the observations. The quality levels of the reference observations should be equal across all sites.
The aim of a tier structure would have been to allow sites with smaller observational capabilities easy entry into GRUAN, while at the same time providing directional guidance towards a larger suite of observations, which may be expected by GRUAN sites. In CEOS a two tier system has been established, and it was felt that the number of tiers needed to be small. However, the experience for example within NDACC has led that network to abandon a tier structure, since it led to the discrimination of some sites, which provided a smaller number of still high quality observations compared to other sites. In conclusion, it was agreed that a tier system would not benefit GRUAN at present. The explanations for the current progress related to the GCOS-121 recommendations will be explicitly written in the GRUAN Manual.

5.2. Institutional requirements

Experience from other networks, in particular NDACC, has shown that a strong commitment from a site to be part of the network is vital to its health. This may be achieved by requiring a long-term commitment (whilst recognizing that there may be real political or practical limits to what the institution can guarantee) by the organization supporting a site to contribute to the development and operation of GRUAN. A site should participate actively in the operations of GRUAN and should communicate with the Lead Centre and the WG-ARO on all matters regarding GRUAN. It is expected that sites provide two points of contact, of which one should be member of the sites representation Task Team. Periodic reports by the sites about their activities and data submissions may be implemented to monitor sites and re-certification at pre-defined intervals may be used to assure that sites still fulfill the requirements. Station audits may also be implemented to support sites in maintaining their scientific level. To ensure that when GRUAN becomes fully operational, all sites are meeting the same performance standard, existing sites will be required to undergo the same certification process as new sites. Details of these procedures will be prepared by the Lead Centre and the WG-ARO.

5.3. Assessment and certification responsibilities

A site assessment and certification Task Team was formed in 2010 to explore the concept of assessment and certification of GRUAN sites and to address the question of how to expand the network. It had further been intended that this team would be responsible for providing recommendations to the WG-ARO and the Lead Centre following offers from countries to host GRUAN sites. It had also been hoped that this team would contribute material defining the site assessment and certification protocols for inclusion in the draft GRUAN manual. Due to a number of reasons, progress was less advanced than had been hoped.

The lack of progress on these important issues was discussed during the meeting and it was felt that the current structure may not lead to a significant improvement in the coming year. This issue had also been raised at AOPC and it was recommended that the WG-ARO consider the development of a certification procedure with support by the Lead Centre. Rather than establishing another external group of experts, it was recognized that a significant number of members of the WG-ARO already have the expertise necessary to address this issue. Therefore, it was decided that the WG-ARO would take over this responsibility.

It was also recognized that the members of the Task Team and the Lead Centre bring in valuable expertise which should be utilized within the WG-ARO. Therefore, it was decided to offer the members of the site assessment and certification Task Team membership in the WG-ARO and to disband that Task Team. This expansion of the WG-ARO then also provides additional support to the WG-ARO chairs and would lessen some of the resource limitations that had been identified during the meeting.

It was further agreed that the Lead Centre will take on some additional responsibilities. In particular the Lead Centre will work with existing and potential new sites and coordinate and communicate the requirements that have been established so far. The Lead Centre will prepare and compile site offers and site evaluations and present those to the WG-ARO. This procedure is expected to minimize additional work load on the WG-ARO related to site assessment.

To be formally consistent the Terms of Reference guiding the operations of the WG-ARO will be updated to reflect this change in scope and change in composition.

5.4. Network expansion and processing of new site offers

New sites have yet to be identified and the optimal network configuration will have to be addressed before GRUAN becomes operational. It was decided that in preparation of this a workshop would be set up to start addressing this question. An organizing committee will be formed initiated by the WG-ARO to make initial steps towards this workshop, which could possibly be hosted by the International Space Science Institute (ISSI). The intended time line would be to hold the initial workshop shortly after ICM-4. In preparation of this workshop an agenda, a draft invitee list, and a workshop plan need to be developed.

In the meantime, the meeting agreed on the following procedure to handle new site offers.

- The lead centre will communicate with the site and explain the current status of the implementation based on the existing documentation.
- The lead centre will describe the requirements expected from a site
- In cooperation with the Lead Centre, a potential site will develop a work plan for observations to be delivered to GRUAN.
- The site package will be reviewed by the lead centre and will be presented to the Working Group with an initial assessment.
- The Working Group will review the site package and provide a written certification of the new site offer. This step will formally accept a station as a GRUAN site.

6. GRUAN research

Science was and will in future be the main driver for GRUAN and within GRUAN. However, it is important that the results of GRUAN are being used and that efforts are being undertaken to make sure that GRUAN science studies will be used. The use of GRUAN results within assimilation models was raised as an open issue and it is not clear at this point, how much GRUAN can support the efforts of the re-analysis community. GRUAN may provide anchor points for re-analysis models, in particular in the lower troposphere, but if models bias-adjust GRUAN observations, their utility may be greatly diminished. Currently, there are a number of examples to cross-check different measurements, but there are only a few attempts to combine redundant observations into a single better product. The value of GRUAN data within the satellite community is well defined, but much depends on scheduling the observations. This issue needs to be resolved in cooperation with the appropriate satellite community representatives and may require dedicated funding for satellite-targeted GRUAN operations.
Several key issues within GRUAN are being addressed by dedicated Task Teams, research teams, or within special campaigns.

6.1. 2010 CIMO intercomparison campaign

The eights WMO Commission for Instruments and Methods of Observation (CIMO) Intercomparison of High Quality Radiosonde Systems took place in Yangjiang, China, in July 2010, with strong participation of GRUAN experts. The report from this campaign was finalized after the ICM-3 and is available at: http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html.
The aim of the GRUAN contribution was to investigate the characteristics of sounding instrumentation that could be used as a reference for GRUAN. It was stressed that the estimation of measurement uncertainty associated with each observation point is a key requirement for GRUAN. Instrumentation provided by and for GRUAN was the Lockheed Martin/Sippican Multithermistor sonde, the Meisei Tungsten Reference sonde, the Vaisala RR01 reference radiosonde, and the Cryogenic Frostpoint Hygrometer (CFH). These instruments formed the scientific sounding instruments payload (SSI).

For temperature measurements during nighttime, observations on average agreed to within 0.2 K, indicating that the calibration accuracy of sensors is within reach of the needs of GRUAN. During daytime, differences increased to more than 0.6 K, indicating that the corrections applied for solar heating and ventilated cooling are still the limiting factors in daytime temperature measurements. It had been hoped that the Multithermistor sonde could be used as a reference instrument; however, an uncertainty analysis was not possible since the processing of the sensor output is considered proprietary and therefore not traceable. Thus, this instrument did not meet the criteria for a reference instrument that had been defined by GRUAN. The details of the other sensors are published in the WMO report on the campaign results, which was not yet available at the time of the meeting. Scientific papers expanding on these results in peer-reviewed journals are highly encouraged and the scientific use of these data is seen as highly beneficial.

The Vaisala humidity reference sensor was used for the first time under tropical conditions. Unfortunately it did not function properly due to the high humidity and the failed attempt to shield the sensor from cloud contamination.

The use of uncertainty estimates on CFH humidity profiles allowed a first evaluation of the operational humidity sensors that were flown on the SSI payload. The use of the uncertainty estimates allow a rigorous evaluation of the consistency of the observations and thus identifies the regions, where the differences between observations can be explained with the current understanding of the measurement technology. This can be viewed as an example of how uncertainty estimates may be used operationally.

6.2. GATNDOR

Dian Seidel presented an overview of the current status and results of the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR). The purpose of this group, which was formed during ICM-1, is focused on short-term research to address specific topics identified by the GRUAN science and management community. Some of the tasks were taken on by dedicated GRUAN Task Teams, which were created at ICM-2. All GATNDOR members are Task Team members or chairs and coordinate these activities within that framework. Updates on GATNDOR activities can be found at www.gruan.org. Fabio Madonna has taken over as chair of GATNDOR from March 2011.

The GATNDOR topic on measurement scheduling has been transferred to the Task Team on scheduling. The topic on network configuration will be addressed by the Working Group members dealing with site assessment and certification (see section 5.2). Current GATNDOR topics refer to the issue of collocation of observations and in particular address the balloon drift climatology (lead Seidel), the effects of imperfect collocation on the uncertainty budget (lead Bomin Sun), and the application of these results to GRUAN specific uncertainty budgets (lead Franz Immler). Other active GATNDOR topics include specifying the optimal management of change and quantifying the value of complementary observations.

Initial results on the balloon drift have been published by Seidel et al. (2011)[6] and on the collocation of radiosonde and COSMIC Global Positioning System (GPS) occultation profiles by Sun et al. (2010)[7].

The following issues facing GATNDOR were discussed: GATNDOR is a strong but small team, in which too few countries are represented. GATNDOR members are also involved in the WG-ARO and Task Teams. They are seeking students to support their efforts, but have not yet been successful. The research is not financially supported. The NOAA climate office calls have a long lead time and require significant effort for the preparation of proposals. It is difficult for non-US scientists to access these funding mechanisms. Based on interactions with Task Teams, GATNDOR will refine the research topics and will seek to increase its membership.

June Wang presented an analysis on change management based on the experiences at the GRUAN sites at Lindenberg and at Tateno. Key lessons for independent, redundant observations are:

- Measurements from identical instrumentation require identical procedures and processing.
- Different changes must be implemented at different times to ensure that discontinuities introduced by any one change can be unambiguously isolated.
- Differences caused by factors other than measurement errors, such as not sampling the same air mass, must be minimized.

For the correction of known errors/biases:

- Extensive validation/evaluation is needed.
- Complete metadata descriptions are essential.
- Retain raw data for future improvements.

For overlap of dual-sonde comparisons (old vs new sonde):

- New sondes must have been tested and evaluated, both in the lab and in the field (e.g. WMO intercomparison), and deemed sufficiently reliable.
- Both sondes should be on the same balloon.
- Cover day/night and the entire annual cycle.

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6 Seidel, D. J., B. Sun, M. Pettey, and A. Reale (2011), Global radiosonde balloon drift statistics, J. Geophys. Res., 116, D07102, doi:07110.01029/02010JD014891.

7 Sun, B., A. Reale, D. J. Seidel, and D. C. Hunt (2010), Comparing radiosonde and COSMIC atmospheric profile data to quantify differences among radiosonde types and the effects of imperfect collocation on comparison statistics, J. Geophys. Res., 115, D23104, doi:10.1029/2010JD014457.

- Performed at least 120 dual flights (~twice weekly), spread out over all four seasons.
- Analyze dual-sonde data in near real-time.
- Collaborate with instrument manufacturers to solve discovered problems and improve the system.

For statistical methods:

- Maintain detailed meta-data on changes.
- Make last (or one) segment of long-term data series with changing instrumentation or procedures a “reference”.

Fabio Madonna discussed issues in quantifying the value of complementary observations. This issue is driven by the question of how much a measurement uncertainty can be reduced by having redundant observations of a given variable. The representativeness or sampling errors needs to be considered as this is very important in the comparison of radiosondes and remote sensing techniques. Best practices for sustainable long-term observations using microwave radiometer ground-based measurements in the context of the Microwave-Radiometer Network (MWRnet), which started in March 2009, were presented. Some best practices of MWRnet will be tested at GRUAN sites.

6.3. Task Team on radiosondes

Masatomo Fujiwara presented the progress of the Task Team on radiosondes, including its membership, the Terms of Reference, and the draft task list. The work plan was grouped into 11 very high priority tasks, 8 high priority tasks, and 10 low priority tasks. Very high priority tasks include the review of the GRUAN Vaisala RS92 data product document prepared by the Lead Centre, the review of the report from the eights CIMO radiosonde intercomparison, which was published in May 2011, and the documentation preparation and review of the uncertainty estimation of chilled-mirror hygrometers (i.e., Meteolabor Snow White, NOAA FPH, and CFH).

The issue how to management this large work load was raised because of the large number of proposed tasks. It was also pointed out that some tasks, such as the review of the RS92 data product document, may need to be revisited at some point in the future taking into account possible inputs from the GRUAN community and general data users, exacerbating potential workload issues. It was reaffirmed that the term “Reference Radiosonde”, which had been discussed before the Lindenberg February 2008 meeting, is meaningless in the current development of GRUAN. Rather, GRUAN relies on the definition of “reference observation”, which requires traceability, uncertainty profile information, complete documentation of the observations, and well managed instrumentation change. This definition is supported by a broad consensus and is at the core of GRUAN observations.

The role of independent ground checks was discussed in greater detail. Some sites (e.g., Lindenberg, Tateno, Lauder, ARM/Southern Great Plains) are already conducting their own additional ground checks (100%/97%RH pot; THref). However, for auto-launcher systems this cannot currently be implemented. It was noted that ground checks should be made consistent across the network. An overview of these ground checks will be taken and evaluated and a recommendation for ground checks for radiosondes will be prepared.

See Appendix 4 for the full report of the GRUAN Task Team on radiosondes.

6.4. Task Team on GNSS-PW

Junhong Wang presented the current progress of the GNSS-Precipitable Water (PW) Task Team, which was divided into three sub-teams. The first sub-group is working on the draft GRUAN requirement table for zenith total delay (ZTD), PW, surface pressure (Ps), and vapour-weighted column-mean temperature (Tm); the second sub-group is gathering the current GNSS status information for all GRUAN sites; and the third sub-group is drafting the GRUAN instrumentation and station guidelines. Currently there are four major data-processing-software providers and GRUAN might not want to specify one single provider as it might be better to keep multiple providers for the longer-term. However, to ensure homogeneity of observations across the network, a single processing centre may be more advantageous. It was also pointed out that there is some difference in the requirements for GNSS instrumentation between the geodesy community and the climate community.

Concern was raised regarding the comparison of radiosonde measurements with balloon drift and GNSS column measurements. It was pointed out that the PW is weighted in the lower troposphere and the GNSS measures the average PW of a 70-degree cone, not a zenith column, and thus the balloon-drift issue should not be a serious problem (see also the report from Tateno station in Appendix 5). The necessity of uncertainty estimates was reiterated.

See Appendix 5 for the full report of the GRUAN Task Team on GNSS-PW.

6.5. Task Team on measurement schedules and associated instrument-type requirements

Tom Gardiner presented the current progress on the Task Team on measurement scheduling and related activities. He discussed objectives, climate trend detection issues (i.e. measurement uncertainty versus frequency, etc.), and satellite calibration/validation issues (i.e. the combination of individual measurement uncertainties and combined sample uncertainties, intercomparison variables (temperature, water vapour, etc. vs radiance, etc.). Furthermore he introduced the research plans for optimal sampling strategies, by giving a brief introduction to the European Metrology Research Project (EMRP) and a three-year project of “Metrology for pressure, temperature, humidity and airspeed in the atmosphere” called Meteomet (“Metrology for Meteorology”).

It was noted that the monthly mean is the basic quantity for trend analysis and thus reducing noise in monthly mean values is important. It was pointed out that the method for vertical averaging (e.g., using a specific remote sensing weighting function) for profile measurements needs to be further explored. Furthermore, it was pointed out that the definition of coincidence between radiosonde and satellite measurements needs to be determined for satellite validation campaigns.

In regions of high natural variability, improving the observing frequency is much more important than improving instrumental random uncertainty. This is true in particular for the troposphere, but not, for example, for stratospheric water vapour where the natural variability is much lower. For a perfect, unbiased instrument, nearly any random error is acceptable since it will average out in the calculation of the mean; however, for a real-world instrument with a large random uncertainty, it is very difficult to tell whether this instrument has a bias or not. Thus, it is essential to reduce the random errors along with the systematic errors.

See Appendix 6 for the full report of the GRUAN Task Team on measurement schedules and associated instrument-type requirements.

6.6. Task Team on ancillary measurements

Thierry Leblanc presented the current progress of the Task Team on ancillary measurements and its efforts on ground-based measurements. Interfacing with other expert teams, in particular with NDACC, has been very fruitful and provides an inventory of potential lidar, microwave, and Fourier Transform Infrared Spectrometer (FTIR) instruments for water vapour. Information on data products and uncertainty budgets for the three types of instruments were described and information on the instrument calibration and validation, in particular Raman water vapour lidars, were discussed. Results from the Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE) 2009 campaign were discussed. This campaign was held at US National Aeronautics and Space Administration (NASA) / Jet Propulsion Laboratory (JPL) Table Mountain Facility in October 2009, involving several lidar systems and several different radiosonde systems to measure upper tropospheric and lower stratospheric water vapour.

Tony Reale presented the current status on satellite instrument and derived product validation and encouraged the integration of GRUAN site observations on a routine basis within the NOAA Products Validation System (NPROVS) operated at the NOAA Centre for Satellite Applications and Research (STAR). He particularly emphasized the need for ongoing interfacing with other expert teams, and discussed the inventory of potential instruments for water vapour, and data products and uncertainty budgets for satellite measurements, and the satellite validation strategies using GRUAN data with a special emphasis on the collocation issues (time mismatch and spatial representation of GRUAN sounding).

A question was raised whether GRUAN can prepare both a 2-3-km vertically averaged data set for climate-research studies and a higher resolution data set for process studies. Clarification on the RS92 relative humidity "correction" for the MOHAVE-2009 campaign was made. It was noted that this correction (i.e., the systematic bias adjustment) was made with respect to the simultaneously flown CFH data and that the corrected RS92 relative humidity data would only be meaningful up to the tropopause. Another question was raised as to whether this Task Team would make specific instrumentation recommendations (e.g., lidar vs microwave radiometer) to GRUAN sites. The common understanding was that this Task Team would rather make available the assessment of existing instruments.

See Appendix 7 for the full report of the GRUAN Task Team Ancillary measurements.

7. Site reports

Presently 15 initial sites are contributing to GRUAN and no change of this composition occurred in 2010. The session was opened by the presentation of the Task Team of site representatives. Its Terms of Reference are centered on facilitating communication, populating other Task Teams, and to better implement GRUAN procedures and policies. It was pointed out that each site should have a representative on the Task Team and that these representatives should also attend the annual ICM meetings. This Task Team may also help to facilitate participation of the sites in other Task Teams.

Amongst a number of general topics, the site reports focused on the utility of redundant observations and the use of ground checks. Redundant observations allow a continuous evaluation of the quality of the observations and an early identification of issues. They allow an ongoing characterization of instrument performance and are therefore at the core of GRUAN activities to assure long-term stability and network homogeneity. In addition, these activities support larger scale intercomparisons such as those that took place at Yangjiang. The role of dedicated laboratory or ground-based work to compare upper-air *in-situ* instrumentation was stressed and should play a key role in GRUAN. Since it is extremely difficult to simulate the real atmosphere in the laboratory, laboratory work alone cannot fully characterize the sensors. However, this work can guide redundant observations in the atmosphere and point out weaknesses of sensors that require special consideration.

The comparison between the Integrated Precipitable Water (IPW) from the operational radiosonde and the GPS is required at all sites. The dense network of GPS stations found in Japan allows a good characterization of the temporal and spatial variability of IPW relative to the radiosonde launch site. The correlation of IPW as a function of distance to the launch site depends strongly on the season, with higher variability in some seasons and less in others, depending on the specific site. This needs to be considered when studying the collocation criteria of radiosonde and remote-sensing instrumentation at different sites. Generic guidance on collocation based on this and other quantitative evidence will be developed by the Lead Centre in cooperation with GATNDOR.

Additional, manufacturer independent, ground checks for temperature and humidity can be used at Lindenberg, ARM/SGP, and Xilinhot. However, these systems are not yet directly comparable and the discussion of the different ground check methods is ongoing within the radiosonde Task Team. Additional ground checks are currently not possible for radiosondes launched by auto-launch systems, since no manual intervention is currently possible in these installations. This may impact radiosonde operations at Potenza and Sodankylä. It was recognized that standardization would be desirable.

Dual sonde launches are being performed at regular intervals at Lindenberg, Payerne, and Sodankylä. Tateno completed four intensive dual sonde launch campaigns during the past year to manage the transition from the Meisei RS2-91 to the Vaisala RS92SGP radiosonde. During each of these intensive observational periods, 15 dual sonde payloads were launched. A dual sonde launch programme is currently initiated at Payerne to guide the transition from the SRS400 to the SRSC34 radiosonde, both from Meteolabor. Additional Vaisala RS92 radiosondes will be launched weekly to better characterize the new SRSC34 radiosonde. The ideal number of soundings to establish a proper transition from one sonde type to another is currently still under review. Weekly dual soundings are also planned at Xilinhot using Vaisala RS92 and Shanghai GTS1 radiosondes, and at Boulder using Vaisala RS92 and Intermet Imet1 radiosondes connected to NOAA frostpoint hygrometers. At Beltsville dual sonde launches are possible but limited by the available funding. The change from one sonde type to another is actively managed at Tateno, at Payerne, and at Lindenberg. Other sites had not yet faced this issue, but will need to consider it in the near future as their observational capabilities develop further. It was agreed that the radiosonde Task Team will develop best practice guidance for dual sensor and multi instrument payload launches based on existing experience.

Water vapour in the lower to middle stratosphere is currently observed at Boulder; Lauder; Lindenberg; Sodankylä; and Payerne. There is a clear need to expand these observations into the tropics. Controlled descent of balloon payloads using valved balloons or dual balloons plays a role in observations of stratospheric water vapour, but is less common in the observation of other parameters. However, it is currently not clear whether temperature measurements during controlled descent are as reliable as those during ascent. This question will be addressed by the radiosonde Task Team along with an assessment of strengths and weaknesses of current controlled descent techniques.

The site at Lauder will initiate a closer working relationship with the New Zealand MetService site at Invercargill. Although collocation concerns need to be addressed in terms of lower to middle tropospheric observations, the cooperation between both sites may lead to a highly productive role model for non-collocated GRUAN sites. A similar issue is being addressed at the site at Beltsville, which has a good working relationship with the NOAA/National Weather Service site at Sterling and at Cabauw, which is already cooperating with the nearby operational site at De Bilt.

At all sites the need for storage of raw data was recognized and some sites expressed concerns as to viability of purely local storage. Central storage of raw data is being explored at NCDC following these discussions as a means to ensure no data are lost. Although GRUAN is less concerned with managing historical measurement records, it was pointed out that some processing and data archiving solutions may be applied to historical data and thus to expand the availability of GRUAN observations for some time into the past. This of course depends strongly on the parameter and observing method and may not be applicable for all observations, however, observations should be retained if possible, even if they are currently not being processed as GRUAN measurements.

The inventory of GRUAN site instrumentation needs to be updated in the form of a matrix which will help to identify which sites have similar and/or identical capabilities. This matrix inventory will help sites identify other sites with similar or identical capabilities and it will support the formation of small groups working on similar problems. The Lead Centre will update the inventory in cooperation with the site representation Task Team.

Funding was a concern voiced by a number of sites. At the same time a firm commitment by the institution supporting a site is seen as key to the success of a station as a GRUAN site.

8. Next meeting

It was agreed to hold the next ICM meeting at one of the three locations proposed at the end of the session. The timing of the meeting would be similar to that for ICM-3, i.e. March 2012. In particular it should precede the AOPC meeting by about 4 to 6 weeks to allow to report on the outcome of this meeting at AOPC. Possible locations in order of priority are:

- Tateno Japan
- Sodankylä, Finland
- Potenza, Italy

The scope, time frame, and organization of this ICM-3 meeting, the first meeting held over five rather than three days, were felt to be very appropriate. The additional time allotted for discussions was appreciated and the break-out sessions were felt to be effective. The site visit is recognized to be an essential part of the meeting and future meetings should be held at or near GRUAN sites.

It was suggested to define a theme for the next meeting and to consider outreach to other scientific communities. This theme should be considered in the planning of the meeting.

9. GRUAN work plan

The final session agreed on a specific GRUAN work plan for the forthcoming year based on the preceding discussions.

2011-12 GRUAN Work Plan

No	Action	Deadline	Who
1	WG-ARO to update its terms of reference to include the role for assessment and certification as well as the new co-chair structure.	Jul 2011	WG-ARO
2	Formulate recommendations on ground check for radiosondes as GRUAN technical document.	Jul 2011	Radiosonde Task Team
3	Prepare generic poster and PowerPoint presentation to be used in promoting GRUAN within the scientific community. This material is to be posted on www.gruan.org.	Jul 2011	Lead Centre, WG-ARO
4	Consult with the satellite community (GSICS EP, SCOPE-CM EP, CGMS Working Groups) on better linkage to GRUAN.	Sep 2011	WG-ARO, Bodeker
5	The site representation team will collect acknowledgement requirements from sites. Agree and implement data usage acknowledgement protocol.	Sep 2011	Sites, Lead Centre, WG-ARO
6	NCDC should consider the role of repository for raw data and data not yet congruent with GRUAN standards in addition to GRUAN data products. Lead Centre will advise NCDC on needs.	Sep 2011	NCDC (Diamond), Lead Centre
7	Update the inventory of GRUAN site instrumentation in form of a matrix of current site capabilities	Sep 2011	Lead Centre, Sites
8	NCDC to consider a graphical user interface to RS92 GRUAN data. Report to WG-ARO by October 2011.	Oct 2011	NCDC (Vose), Reale
9	NCDC to consider viability to place a voluntary user registration on data usage making clear the benefits of being made aware of periodic reprocessing and likely impacts. Report to WG-ARO by October 2011.	Oct 2011	NCDC (Diamond)
10	Develop a collection of material, which may be used in proposals by sites to get funding. This collection of material is to be started on the GRUAN blog.	Oct 2011	Lead Centre
11	Work with HMEI to scope possible workshop aims and requirements and discuss whether CIMO involvement etc. makes this redundant. Possibility of meeting manufacturers at AMS.	Oct 2011	Lead Centre, WG-ARO, HMEI
12	Integrate GRUAN observations in the NOAA Products Validation System (NPROVS.)	Oct 2011	Reale, Sommer
13	Explore possible avenues to set up a trust fund in support of targeted GRUAN activities.	Dec 2011	WG-ARO, Lead Centre
14	Circulate relevant documents to communities likely to be users of GRUAN products to ascertain whether these data products meet their needs.	Dec 2011	Lead Centre, WG-ARO
15	Complete measurement guidance for GNSS-IWV as technical document.	Dec 2011	Task Team GNSS-PW
16	Complete the GRUAN Manual of Operations in liaison with Task Teams; final version to be approved by WG-ARO, Lead Centre and 2/3s of all sites.	Jan 2012	Bodeker, WG-ARO, Sites, Lead Centre

17	Develop definition for optimal GRUAN site to decide on future sites (optimal location/climate zone, institution etc.). Form an organizing committee to make initial steps towards a workshop (possibly ISSI hosted), to be held shortly after ICM-4. Initial steps are to develop an agenda, draft an invitee list, plan for workshop.	Jan 2012	WG-ARO, GATNDOR
18	Assessment and certification criteria to be fleshed out by WG-ARO, Lead Centre, in consultation with sites representatives. Draft for adoption in time for ICM-4.	Jan 2012	WG-ARO (Bodeker), Sites, Lead Centre
19	Protocol for acceptable instrument change-over as section in manual to cover generic change criteria.	Jan 2012	GATNDOR (Wang), Lead Centre, Bodeker
20	Include a section in the manual on how to move from priority one to priority two climate variables.	Jan 2012	Lead Centre, Bodeker
21	Complete measurement guidance for lidar as technical document.	ICM-4	Task Team on ancillary measurements
22	Radiosonde Task Team to prepare a report on the issues of descent temperature measurements and the use of controlled descent measurements.	ICM-4	Radiosonde Task Team
23	Formulate requirements on surface observations in support of upper-air observations.	ICM-4	Lead Centre, WG-ARO, Task Teams
24	Develop best practice guidance for multi payload launches.	ICM-4	Radiosonde Task Team
25	Assessment of the value and utility of satellite coincident *in-situ* and remote sensing measurements vis-à-vis standard times for satellite cal/val.	ICM-4	Task Team on measurement schedules and associated instrument-type requirements
26	Initial set of temporal sampling guidance for *in-situ* and remote sensing instrumentation based upon a quantitative assessment prior to network expansion, including superseding of GCOS-121 documentation for *in-situ* measurements.	ICM-4	Task Team on measurement schedules and associated instrument-type requirements
27	Formulate generic guidance on collocation based upon quantitative evidence wherever available, for priority one variables. Includes a toolbox and paper for submission.	ICM-4	Lead Centre (Immler), GATNDOR
28	Investigate and design a system to report and resolve problems in data quality and instrument issues.	ICM-4	Lead Centre
29	Implement final version of the GRUAN data dissemination structure.	ICM-4	Lead Centre

Actions in GCOS-140 closed / superseded:

Action	Deadline	Who	Comment
Foster GAW, BSRN, NDACC representation in WG-ARO and Task Teams and seek for international representation of members.	2010	WG-ARO	The expanded membership of the WG-ARO and the Task Teams currently satisfies the need to link to other networks and observational programmes. No further action needed at this time.
Formulate Task Teams, which report to WG-ARO on semi-annual basis; agree on ToRs.	July 2010	WG-ARO, Lead Centre, GCOS Secretariat	Task Teams are established.
Initial results from Task Teams - Radiosondes - GPS - Measurements - Site assessment, expansion and certification - Complementary measurements - Site group	ICM-3	Task Teams	Task Teams reported results and current status at ICM-3 and will present their future findings at upcoming meetings. The Task Team on site assessment was subsumed into the WG-ARO.
Results from science team GATNDOR on: - Collocation - Mgmt of Change - Value of Complementary data	ICM-3	GATNDOR	Done
Agree a protocol for dealing with any site offers arising in the interim.	Oct 2010	Task Team 4; WG-ARO; Lead Centre	Completed at ICM-3. See above.
Explore the possibility to publish GRUAN metadata congruent with WIS metadata standards.	2010	Lead Centre, GCOS Secretariat, in collaboration with WMO WIS	GRUAN metadata are congruent with WIS metadata standards.
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	Stations already connected to the GTS are encouraged to provide their original observations in near real time. Final GRUAN processing including uncertainty estimates and redundancy checks may not be feasible in near real time.
Investigate the potential for tracking of data usage.	2010	Lead Centre, NCDC	Mandatory tracking is technically not possible at NCDC. Voluntary registration of users will be implemented instead (see above).
Define data reprocessing and version control procedures.	2010	Lead Centre	Done
Develop a case study for the measurement uncertainty guide focusing on in-situ observations	Underway; paper to be published by ICM-3	Lead Centre	Done. Paper was published by Immler et al., (2010)

Develop generic outreach material, a ppt-presentation and a brochure	Oct 2010	WG-ARO, Lead Centre, GCOS Secretariat	A brochure was prepared and is available at www.gruan.org
Publish and maintain an inventory of GRUAN site instrumentation (maps, table)	May 2010 and update at least every 2 years	Lead Centre, Sites	Done
Implement final version of data dissemination structure	2011	Lead Centre, NCDC, ARM	Done

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Appendix 1: Meeting Agenda

Third GRUAN Implementation and Coordination Meeting, Copthorne Hotel, Queenstown, New Zealand, 28th February to 4th March 2011

Meeting Agenda

Location: Copthorne Hotel, Conference Room 1&2
Note: each item should be split roughly 1/2 to 2/3 presentation and 1/2 to 1/3 discussion time.

Monday 28th February

Chair: Peter Thorne; Rapporteur: NN

08:30 - 12:00 Meeting of WG-ARO membership [Coffee break 10:00 - 10:30]

12:00 - 13.00 Lunch

13.00 - 13:30 Participant registration

Session 1: Update on specific progress since ICM-2
Chair: Paul Johnston; Rapporteur: Howard Diamond

13:30 - 13:40 Welcome from the organizers - Paul Johnston

13:40 - 13:50 Opening remarks

13:50 - 14:00 Opening remarks - Neil Gordon, MetService, Permanent Representative of NZ with WMO

14:00 - 15:00 Lead Centre progress report – Franz Immler / Holger Vömel

15:00 - 15:30 Coffee

15:30 - 16:00 Update from WG-ARO and check on progress against agreed in year activities arising from ICM-2 – Peter Thorne

16:00 - 16:30 Progress of data flow and technical manuals – Michael Sommer

16:30 - 17:00 CIMO intercomparison – Initial results Holger Vömel

17:00 - 17:30 Discussion

Tuesday 1st March

Chair: Peter Thorne

8:30 - 8:40 GCOS Remarks - Carolin Richter (by phone)

Session 2: GRUAN manual
Rapporteur: Franz Berger

8:40 -10:00 GRUAN manual discussion and adoption – Greg Bodeker

10:00-10:30 Coffee

Session 3: GRUAN science: GATNDOR achievements and challenges
Rapporteur: Franz Berger

10:30 - 10:50 GATNDOR status - Dian Seidel

10:50 - 11:10 Change management - Junhong Wang

11:10 - 11:30 Quantifying the Value of Complementary Observations - Fabio Madonna

11:30 - 11:40 MWRnet: Towards the definition of best practices for sustainable long-term microwave radiometer ground-based observations - Fabio Madonna

11:40 - 12:00 Discussion

12:00 - 13:00 Lunch

Session 4: GRUAN science: Task Teams update
Rapporteur: Masatomo Fujiwara

13:00 - 13:45 Radiosondes - Masatomo Fujiwara / Franz Immler

13:45 - 14:30 GPS-PW – June Wang / Kalev Rannat

14:30 - 15:15 Scheduling – Tom Gardiner / Dave Whiteman

15:15 - 15:45 Coffee

15:45 - 16:30 Ancillary measures – Thierry Leblanc / Tony Reale

16:30 - 17:15 Discussion site assessment, certification, and expansion – Holger Vömel

17:15 - 17:45 Discussion

19:00 Workshop dinner http://www.skyline.co.nz/queenstown/restaurant/

Wednesday 2nd March

Chair: Holger Vömel

Session 5: Site updates
Rapporteur: Belay Demoz / Dale Hurst

8:30 - 9:00 Sites Task Team overview – Belay Demoz / Dale Hurst

9:00 - 9:20	Lindenberg – Franz Immler
9:20 - 9:40	Sodankylä – Rigel Kivi
9:40 - 10:00	Tateno – Hakaru Mizuno
10:00 - 10:20	Coffee
10:20 - 10:40	Payerne – Rolf Philipona
10:40 - 11:00	Cabauw – Martin DeGraaf
11:00 - 11:20	Xilinhot – Li Wei
11:20 - 11:40	Lauder – Paul Johnston
11:40 - 12:00	Boulder – Dale Hurst
12:00 - 13:00	Lunch
13:00 - 13:20	Potenza – Fabio Madonna
13:20 - 13:40	Beltsville – Belay Demoz
13:40 - 14:00	ARM sites – Doug Sisterson
14:00 - 14:30	Issues arising from site reports discussion – Peter Thorne lead
14:30 - 15:00	Coffee

Session 6: Team meetings

15:00 - 16:25	TT1 radiosondes
15:00 - 16:25	TT4 site assessment
16:35 - 18:00	GATNDOR
16:35 - 18:00	TT6 site coordination

Thursday 3rd March: Lauder site visit (see local logistics document for more detail)

8:30	Departure from the Copthorne Hotel
18:00 (est.)	Arrive back at Copthorne Hotel

Friday 4th March

Chair: Howard Diamond

Session 7: Final discussions, review and action items
Rapporteur: Dian Seidel

8:30 - 9:30	Reports from side meetings
9:30 - 10:00	Coordination of efforts with NDACC – Geir Braathen

10:00 - 10:30 Site assessment and network expansion, GRUAN guide – Peter Thorne

10:30 - 11:00 Coffee

11:00 - 12:30 Review of the Implementation Plan – Peter Thorne

12:30 - 13:30 Lunch

13:30 - 15:30 Agreement on tasks for upcoming year

15:30 Meeting close

15:30 - 16:00 Coffee

16:00 - 17:30 WG-ARO reconvenes

Appendix 2: List of Participants

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Appendix 3: Lead Centre Report 08/2010 – 01/2011

GRUAN Lead Centre progress report 01/2011

covering the period 08/2010 to 01/2011

Authors

Holger Vömel, Franz Immler
GRUAN Lead Centre
Lindenberg Meteorological Observatory – Richard Aßmann Observatory
German Meteorological Service (DWD)

Summary

The focus of the work of the Lead Centre during the second half of 2010 was on the preparation of the GRUAN data flow. The Lead Centre has developed a tool that allows the collection and forwarding of measurement data and metadata, in particular those of complex radiosoundings. This tool was tested in Lindenberg and Sodankylä for launches of CFH-Ozone sondes and RS92-FN sondes. Currently it is in operational use at both sites for all specialized soundings and is in a testing phase at a number of other GRUAN sites (i.e. Tateno, Boulder). A second focus was on the development of a GRUAN data product from RS92 data that complies with the standards established in Immler et al., AMT, 2010. This product is now available for temperature, humidity, and wind measurements (pressure following soon) and is currently being reviewed in TT1.

The Task Teams have been established (except TT4, site assessment). Their terms of reference (ToRs) are published on the GRUAN website.

Health of network
Data from Sodankylä (Ozone, CFH, COBALD) and Lindenberg (RS92, RS92FN, CFH, Ozone, Cobald) are operationally collected and archived in the GRUAN metadatabase and raw data archive.

The network is not yet operational	

Progress against stated objectives

Open items	**Summary of progress**
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 a key to the definition of an optimal GRUAN site. The site certification process, which has yet to be established by the Task Team on site certification, 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.
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.
Perform gap analysis on existing documentation (manuals) vis-à-vis the adopted skeletal GRUAN manual of operation, and provide a summary document of where	Not yet started.

these gaps are.	
Progress of items announced in the last report	
Publication on RS92 uncertainties.	The uncertainty analysis was extended to include uncertainty of wind. Temperature and humidity products were validated based on data from the CIMO intercomparison and other campaigns. Currently the documentation is drafted and the publication will follow soon.
Suitability Meisei Temperature Reference sensor for GRUAN is tested in Lindenberg.	The MTR was tested in Lindenberg in November 2010. Twelve flights of MTR were launched using different configurations. Due to its fast response MTR is useful for assessing the influence of contaminations on temperature uncertainty.
Task Teams start working	All Task Teams except TT4 have been established. ToRs are published on the GRUAN website.
Preparation of ICM-3	The Lead Centre is preparing ICM-3 in co-operation with local organizers and the head of WG-ARO.
Contributions to the CIMO report on the Yangjiang intercomparison	Reports on humidity and temperature from the scientific sounding instruments (SSI) of the CIMO intercomparison are currently drafted and will be discussed in a meeting at UK MO in February 2011.
Items from ICM-2 relevant for Lead Centre	
3. Formulate Task Teams, which report to WG-ARO on semi-annual basis; agree on ToRs. (July 2010)	The Task Teams are established. The terms of reference have been published on the GRUAN website. Exception is Task Team 4 on site assessment which is without chair. This issue needs careful consideration at ICM-3.
6. Agree a protocol for dealing with any site offers arising in the interim.	Not yet started.
8. Explore the possibility to publish GRUAN metadata congruent with WIS metadata standards.	Done. GRUAN metadata can be provided for 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.	As far as the required infrastructure at the site is available, real-time data produced along with GRUAN measurements (e.g. TEMP or BUFR files produced by radiosonde ground stations.) can be provided using WIS and/or GTS.
10. Agree and implement data usage acknowledgement protocol.	To be done.
11. Investigate the potential for tracking of data usage.	The data dissemination configuration currently planned at NCDC does not provide the possibilities for user tracking. In order not to set up additional technological and administrative barriers for the GRUAN data flow, we suggest not to insist on user tracking at least for the initial phase of GRUAN. However, users should be encouraged to register.

	This will allow to inform them when new version of data products are available
12. Define data reprocessing and version control procedures.	The entire GRUAN data flow is designed to allow for reprocessing of data at any stage and at any time. Version control is one of the key features implemented in the structure of the data- and metadata base.
13. Develop a case study for the measurement uncertainty guide focusing on *in-situ* observations	Underway; paper to be submitted by ICM-3.
14. Develop generic outreach material, a ppt-presentation and a brochure	Brochure has been created by the GCOS secretariat in co-operation with WG-ARO chair and Lead Centre and is currently in print. Apresentation about GRUAN is available at website (material pool).
15. Publish and maintain an inventory of GRUAN site instrumentation (maps, table)	Done, the inventory of all GRUAN sites is available at the webpage.
16. Implement final version of data dissemination structure (2011)	Under way.

Achievements

- Data from the **CIMO radiosonde intercomparison**, which took place in Yangjiang, China from 12/07 to 31/07/2010, has been analyzed in co-operation with Junhong Wang and Masatomo Fujiwara (CIMO-SSI-team). The tropical conditions impose challenges for all sensors. The CFH often showed unwanted oscillation that need to be corrected for and also suffered from contaminations. However, generally comparisons of water vapour show good agreement in the lower and middle troposphere. In the upper tropical troposphere larger discrepancies occur. Vaisala operated a new software version in the DigiCORA III (v3.64) that includes time-lag and radiation correction of the RS92 humidity data. This product compares very well with CFH data in the upper troposphere. The RR01 DryCap sensor on the other did not work properly in Jangjiang and did not produce useful data. Temperature measurements of the SSI payload generally compare well during night and daytime and lie within the expected uncertainty ranges.
- **Collection of raw and metadata** from some sites is operational. Lindenberg reports all relevant metadata from routine (RS92) and specialized radiosonde launches (CFH, COBALD, RS92FN and Ozone). Sodankylä reports its weekly ozone sonde launches. All metadata of these launches are stored in the GRUAN metadatabase (GMD). All raw data are archived in Lindenberg in a raw data archive. The operational compilation of GRUAN data products from RS92 and CFH data is in its testing phase, as is the data dissemination through NCDC.
- In the frame of a research stay of Kensaku Shimizu (Meisei Co. / University of Sapporo) a campaign was conducted in Lindenberg in November 2010. A number of **"Meisei Temperature Reference" sensors (MTR)** were launched together with routine RS92 in different configurations. The MTR sensor is a very thin tungsten wire that has a very low (< 20 ms) time constant. In the configuration with the Meisei RS06-G radiosonde it provides a temperature profile with 6 Hz temporal resolution. Owing to this fast detection small temperature fluctuations are visible in the data, most of which are caused by contamination of air that was heated (or cooled) by the rigging or the balloon. Experiments were carried out with different lengths of the unwinder string and different geometric configurations. The goal of this campaign was the assessment and minimization of the influence of such contaminations.
- The **GRUAN RS92 data product** now involves an uncertainty analysis for wind measurements. The temperature and humidity products have been improved and validated using data from the CIMO intercomparison, the LAPBIAT campaign in Sodankylä 2010 and from Lindenberg. The

product will be submitted to the Task Team on radiosondes for review and discussion in the near future and later to a peer reviewed journal (e.g. AMT).

- Formation of the **Task Teams** except for Task Team 4 is accomplished.
- The **GRUAN manual** was drafted in co-operation with Greg Bodeker. It describes the following aspects of GRUAN:
  - Purpose and scope of GRUAN
  - Organization and design of GRUAN
  - Implementation of GRUAN
  - Requirements for observational data
  - GRUAN stations
  - Equipment and methods of observation
  - General requirements of a GRUAN station
  - Network design
  - Management of GRUAN stations
  - Establishment of a new station
  - Instrument checks and maintenance
  - Network performance monitoring
  - Station metadata
  - Data quality control
  - Procedural aspects of quality control
- The Lead Centre is organizing the **GRUAN Implementation and Coordination Meeting** (ICM-3) in Queenstown in co-operation with the local organizers and the head of WG-ARO.

Lead Centre operations

- Stay of Greg Bodeker in Lindenberg (one week in September and one week in December 2010) → drafting the GRUAN manual.
- Lead Centre arranged a MTR campaign with Kensaku Shimizu (Meisei) in Lindenberg in November 2010.
- Report on the LUAMI intercomparison at TECO 2010 in Helsinki. (31/08 – 02/09/2010).
- Site visite at Sodankylä station in September 2010 → operation of CFH/Cobald sondes, installation of GRUAN protocol and data transmission, installation of a water vapour Raman LIDAR (in co-operation with AWI Bremerhaven).
- Participation at the ISSI workshop on **"**Critical Assessment and Standardized Reporting of Vertical Filtering and Error Propagation in the Data Processing Algorithms of the NDACC Lidars" (http://www.issibern.ch/teams/ndacc/).
- Development of the RsLaunchClient (RLC) for collecting all relevant metadata and data of any kind of radiosonde launch.
- Optimization of the data flow and usage of RLC in co-operation with some sites (Lindenberg, Tateno, Sodankylä and Cabauw).
- Start of the GRUAN data flow from Lead Centre to NCDC and to/from ARM.
- Optimization of the automatic processing of GRUAN data flow within the Lead Centre:
  - Import of launch protocols to metadatabase
  - Archiving of raw data files incl. backup at 2 locations
  - Optimization of converting of RS92 data files (DC3DB) to netCDF
- Developed a first version of a metadatabase browser as a website (currently only for local use at Lindenberg).

Work plan for next six months

- Organization and attendance on ICM-3.
- Data flow starts for most initial sites (radiosondes).

- Planning for data flow for products other than those from radiosoundings.
- Development of reporting system.
- Start of data-dissemination through NCDC.
- Web-Access to GRUAN metadatabase.
- Uncertainty analysis for pressure, geopotential height and geometric height from RS92 raw data.
- Publication of RS92 GRUAN data product documentation.

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Appendix 4: Report GRUAN Task Team Radiosondes

Prepared by Masatomo Fujiwara and Franz Immler
3 February 2011

1. The membership of the team has been settled (29 October 2010), and the Terms of Reference document has been completed and published on the GRUAN website (November 2010).

2. A draft task list had been prepared by the co-chairs with some help by Larry Miloshevich and was circulated within the team (24 January 2011). See the Appendix. It is now under review by the team members. The co-chairs are expecting to finalize it after the ICM-3 and publish it through the GRUAN blog. <Any comments/suggestions/inputs from the Working Group by the ICM-3 are most welcome!>

3. Some tasks are currently in progress:

(1) Evaluation of the "science payload" data taken from the CIMO intercomparison (F. Immler, M. Fujiwara + J. Wang + H. Voemel)
(2) Further tests of Meisei Temperature Reference (MTR) in Lindenberg in November 2010
(3) Review of different time lag correction schemes for Vaisala RS92 humidity measurements (A. Kats, L. Miloshevich, and F. Immler)
(4) Review of the RS92 GRUAN product prepared by the Lead Centre (starting soon)
(5) Review of the CFH/NOAA FPH/Snow White uncertainty product (starting soon)

Annex
Task Team Radiosonde
Draft Task List

Version 1.0: January 20, 2011 (prepared by Masatomo Fujiwara and Franz Immler)

This Draft Task List intends to summarize the items on which the Task Team will work.
(1) within about half a year ("Very High (VH) priority", necessary from the beginning of the GRUAN measurements; coming very soon),
(2) within 2-3 years ("High (H) priority", necessary from the first phase of the GRUAN measurements), and
(3) in the future ("Low (L) priority"; the items that should be within the scope of our Task Team but not for near future).

This is a kind of more specific and detailed Terms of Reference. Please see the Terms of Reference for the summary of the general tasks of our team.
This could also be used for the information exchange/sharing within the Task Team members.

- Please propose/add other items if you think necessary! Please give your general comments/suggestions on, e.g., how we actually approach efficiently.
- The co-chairs would like to have volunteers within the Task Team members to lead each of the "VH priority" items. Please! (for VH items only at this moment.)
- (Note that the VH items with a specific deadline at the "when" column may be experimental ones where we try to find the best approach as a team.)
- Deadline: February 18, 2011 (please let us know if you need more time.)

Explanation of Each Column of the following tables is as follows:
Priority: Very high (VH), High (H), Low (L)
Parameter: Pressure (P), temperature (T), water vapour (WV), relative humidity (RH), GPS altitude (GPS- ALT), geopotential height (GPH), horizontal winds (U&V), etc.
Task: Explanation of the task
By Whom: TT (Task Team) (and we will specify the person who will lead the task)
When: Target completion date
Notes:

(1) The "Very High" priority items, within half a year (coming soon)

Priority	Param.	Task	By Whom	When	Notes
VH	T, RH, P, GPH, U&V	REVIEW (AND MAKE RECOMMENDATIONS FOR GRUAN COMMUNITY) of the Lead Centre document for the GRUAN Vaisala RS92 data product (including the pre-launch sensor quality check procedures) prepared by the Lead Centre	TT members (led by the co-chairs)	March 2011?	The document ready in February? 2011; some overlaps with the following, second item (RS92 RH time-lag and mean-bias corrections)
VH	RH	REVIEW (AND MAKE RECOMMENDATIONS FOR GRUAN COMMUNITY) of the time-lag and mean-bias correction algorithms for Vaisala RS92 RH sensor by Miloshevich et al. (http://milo-scientific.com/prof/radiosonde.php), by Kats et al., and by Immler et al. (GRUAN Lead Centre); summarized by Kats, Immler, and Miloshevich	TT members (led by the co-chairs)	March 2011 ?	Related with the above, first item (GRUAN RS92 data product document)
VH	T	REVIEW of the data analysis of the Lindenberg Meisei Temperature Reference (MTR) campaign in November 2010 prepared by GRUAN Lead Centre and Meisei (see Shimizu and Hasebe, AMT, 2010: http://www.atmos-meas-tech.net/3/1673/2010/amt-3-1673-2010.html)	TT members (led by the co-chairs)	April 2011 ?	Recommendations for pre-launch checks, data processing and QA/QC as well
VH	All	Set up a password-protected server website where all relevant papers could be collected for easy access by the team members (at Lead Centre?)	Lead Centre	As soon as possible	
VH	T, WV/RH	REVIEW (AND MAKE RECOMMENDATIONS FOR GRUAN COMMUNITY) of the report from the **8th WMO Intercomparison of Radiosonde Systems** (Jul.-Aug. 2010, Yangjiang, China), the part for temperature and water vapour/relative humidity sensors on the "Science" payloads written by Voemel, Immler, Wang, and Fujiwara (Temperature Sensors: Vaisala RS92, Meisei Temperature Reference (MTR), Meisei operational (RS06G), Lockheed Martin (LM) Sippican Multithermistor, and GRAW operational)	TT members (led by ?)	June 2011	The official WMO report will be published in May 2011. Then, Voemel et al. will consider a journal publication. NOTE: This and the next item are within a single WMO report.

		(WV/RH Sensors: Cryogenic Frostpoint Hygrometer (CFH), Vaisala RS92, GRAW operational, Meisei operational (RS06G), LM Sippican operational, (Meteolabor Snow White), and (Vaisala RD100))			
VH	P, T, RH, GPS-ALT, GPH, U&V, etc.	REVIEW (AND MAKE RECOMMENDATIONS FOR GRUAN COMMUNITY) of the report from the **8th WMO Intercomparison of Radiosonde Systems,** the part for all sensors on the “operational” payloads written by WMO/Commission on Instruments and Methods in Observations (CIMO) (Nash et al.) (Radiosondes: CHANGF, DAQIAO, GRAW, HUAYUN, Intermet South Africa, Jinyang, Meisei, Meteolabor (including Snow White), MODEM, LM Sippican, Vaisala)	TT members (led by ?)	June 2011	The official WMO report will be published in May 2011. Note: This and the previous item are within a single WMO report.
VH	T	REVIEW of the uncertainty estimation of NASA ATM (Accurate Temperature Measuring) sonde (using the multi-thermistor technique) by Schmidlin et al.	TT members (led by ?)		Recommendations for pre-launch checks, data processing and QA/QC as well
VH	T	REVIEW of the uncertainty estimation of LM Sippican Multithermisor sonde by Fujiwara et al. (?) based on 8th WMO Intercomparison	TT members (led by ?)		This might not be included in the official WMO report
VH	WV	REVIEW of the uncertainty estimation of Meteolabor Snow White based on existing literature, etc. (Snow White sensor itself & Snow White radiosounding system)	TT members (led by Philipona)		Recommendations for pre-launch checks, data processing and QA/QC as well
VH	WV	REVIEW of the uncertainty estimation of Cryogenic Frostpoint Hygrometer (CFH) based on existing literature, etc. (CFH sensor itself & CFH radiosounding system)	TT members (led by Fujiwara)		Recommendations for pre-launch checks, data processing and QA/QC as well
VH	WV	REVIEW of the uncertainty estimation of NOAA Frost Point Hygrometer (FPH) based on existing literature, etc. (FPH sensor itself & FPH radiosounding system)	TT members (led by Fujiwara)		Recommendations for pre-launch checks, data processing and QA/QC as well

(2) The "High" priority items, within a few years

Priority	Param.	Task	By Whom	When	Notes
H	WV	REVIEW of the uncertainty estimation of FLASH-B (Fluorescent Advanced Stratospheric Hygrometer for Balloon) based on existing literature, etc. (FLASH-B sensor itself & FLASH-B radiosounding system as well)	TT members (led by Fujiwara)		Recommendations for pre-launch checks, data processing and QA/QC as well
H	WV	REVIEW of the AquaVIT summary document (AquaVIT is a chamber experiment of 16 UT/LS water vapour sensors (including CFH, FLASH-B, and Snow White) using the German AIDA chamber in 2007) A "white paper" is available from: https://aquavit.icg.kfa-juelich.de/WhitePaper/ (At the moment, they have no definite plan to write up a journal paper.)	TT members (led by Fujiwara)		This work gives us good lessons about uncertainty estimation and SI traceability for UT/LS water vapour sensors
H	P	Meteolabor Hypsometer versus GPS (versus other, classical method)	TT members (led by Philipona?)		Recommendations for data processing and QA/QC as well
H	P, T, RH, GPS-ALT, U&V	REVIEW of the uncertainty estimation of GRAW radiosonde by GRUAN Lead Centre and Graw (based on some experiments at Lindenberg)	TT members (led by ?)		Recommendations for data formats as well. Note: At the WMO Intercomparison, their RH sensor is found to be of fast response
H	All	REVIEW of the instrumentation change strategy for climate monitoring	TT members (led by ?)		JMA is now making dual soundings of Meisei/RS92
H	Flight system	Influence/effects of using the auto-launcher system (particularly for Vaisala RS92)			Work with Lead Centre to gather information on the statistics from GRUAN sites
H	Flight system	The use of descent data			Recommendations for data processing and QA/QC as well
H	Flight system	Satellite overpass by balloon sounding (past experiences from validation activities for UARS, A-train, etc., usefulness and limitation, and recommendations for GRUAN)			Inputs from the GRUAN Analysis Team for Network Design and Operations Research (GATNDOR; Seidel et al.)?

(3) The “Low” priority items but within the scope of this Task Team

Priority	Param.	Task	By Whom	When	Notes
L	Flight system	A better unwinder?			30 m unwinder might not be enough. 120 m? proposed by Shimizu and Hasebe, AMTD, 2010 Work with GRUAN sites
L	Flight system	A better parachute?			Work with GRUAN sites
L	Ozone	GATHER INFORMATION on existing working groups/Task Teams for ozonesondes (GAW, JOSIE, WOUDC, SHADOZ, etc.) and communicate with them	Co-chair		
L	CO2	SEARCH for new balloon-sounding technology	TT members		e.g., NOAA “air core”, Japanese CO2 sonde, etc.
L	CH4	SEARCH for new balloon-sounding technology	TT members		
L	Radiation	Radiation: net radiation, incoming shortwave radiation, outgoing shortwave radiation, incoming longwave radiation, outgoing longwave radiation, and radiance) SEARCH for new balloon-sounding technology	TT members		BSRN covers them? Multithermistors might provide some of them?
L	Aerosols	(aerosol optical depth, total mass concentration, chemical mass concentration, light scattering, light absorption) SEARCH for new balloon-sounding technology	TT members		e.g., Swiss COBALD, Japanese Optical Particle Counter sonde, etc.
L	Clouds	(cloud amount/frequency, cloud base height, cloud layer heights and thicknesses) SEARCH for new balloon-sounding technology	TT members		cf. NCAR replicator, Japanese videosonde/HYVIS, COBALD?, etc.
L	Flight system	Improved balloon technology? (Is ~35 km altitude the theoretical limitation for balloon sailing?; A technological limitation currently narrows our target to the region below the middle stratosphere…)			
L	Flight system	Auto-returning, self-recovering upper air in-situ sounding system? (Find a way to avoid the “garbage/trash” problem which is always the criticism for balloon sounding) e.g., “Brainstorming: New methods and technologies for advanced in-situ water vapour profiling, Thursday, December 11, 2008” (please search with these words)			

Appendix 5: Report GRUAN Task Team GNSS-PW

As of Feburay 3, 2011
Submitted by Kalev Rannat and June Wang

GNSS-PW TT's goal is to develop explicit guidance on hardware, software and data management practices to obtain GNSS PW measurements of consistent quality at all GRUAN sites. The TT was established in July 2010. The term of reference (ToR) was completed and approved by GRUAN management in October 2010.

Until February 2011 the first 3 tasks (see below) defined in ToR have been the focus of the TT:

1. To define GRUAN requirements for GNSS-PW observations that are missing in the requirement tables in GCOS (2007).
2. To document and review current status of GNSS instruments and associated data processing methods used at GRUAN sites.
3. To define GRUAN requirements for a state-of-the-art GNSS station, preparing a draft document on "GRUAN GNSS Site Guidelines".

The TT was divided into 3 sub-teams, each concentrating on a selected topic. The results obtained from the sub-teams were (and will be) discussed together with all members of TT via e-mails and conference calls. Significant progressed have been made to all three tasks, and the results will be presented at ICM3. At the TT conference call on February 1, three general issues were raised: finalizing solutions to the first three tasks, better synchronization with the GRUAN requirements, and collaborations with other Task Teams. The TT has decided to continue working in sub-teams on the rest of tasks.

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Appendix 6: Report GRUAN Task Team Measurement schedules and associated instrument-type requirements

Submitted by Tom Gardiner and David Whiteman

The primary objective for the Task Team is to develop defensible, quantifiable, scientifically-sound guidance for GRUAN sites on measurement schedules and associated site requirements, in order to meet the GRUAN objectives. The main activity for the year has been the scoping of the Task Team terms of reference, and agreeing the appropriate make-up of the team membership. These have now been defined, and recruitment onto the team is on-going.

In terms of scientific outputs from the Task Team, while the activities of the team remain a voluntary one without specific funding the main information sources are from the peer-reviewed literature, GRUAN documentation, and currently unpublished studies of which the group is aware. Some limited new analyses have been undertaken by Team members using existing data sets to start to address areas where critical gaps exist that prohibit scientifically defensible choices. Two team members (Tom Gardiner and Dave Whiteman) were co-authors of Franz Immler's AMT paper on 'Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products' and Dave Whiteman is currently preparing a paper on the observational requirements for detecting water vapour trends.

A particular activity that has been undertaken to address the issue of active support for the project activities involved a number of the team members, and other partners, in a collaborative bid to the NOAA Climate Program. The proposed project on 'Determining Optimal Spatial and Temporal Sampling Strategies for the Global Reference Upper Air Network' aimed to perform a number of studies to determine the effects of spatial and temporal sampling on our ability to both directly detect climate change, and to provide absolutely calibrated synthetic radiances that can be used to provide absolute calibration information for satellite sensors. Even if this proposal is not successful, this exercise has been valuable in defining the scientific rationale, approach and objectives for a structured study in this area.

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Appendix 7: Extended Report of the GRUAN Task Team on Ancillary Measurements

(February 2011)

Recent Interface with other expert teams:

- *May 2010: Water Vapour Raman Lidar Calibration Workshop (NDACC):*

A workshop on the calibration of water vapour Raman lidars (hosted by D. Whiteman, NASA/GSFC) gathered 30+ lidar experts from the NDACC community and beyond. The accuracy requirements for long-term trend monitoring, satellite validation and mesoscale meteorology were estimated. For trend monitoring, less than 50% total random (i.e., unbiased) uncertainty in the UT for a single profile is needed. For satellite validation, profile accuracy better than 15% is needed throughout the troposphere, and for mesoscale meteorology (process studies) uncertainty of 10% in the lower to mid troposphere is needed. The accuracy of the various lidar calibration methods was then reviewed and assessed. No method proved to be unarguably more accurate than any others. The so-called "radiosonde method", which consists of a "one-point" (more generally, best fit) normalization of the lidar profile to a radiosonde measurement in the lower troposphere, is conceptually the most straightforward of all methods. The calibration accuracy in this case depends largely on that of the radiosonde itself, as well as the quality of the spatio-temporal match between the lidar and radiosonde profiles. Overall it was estimated to range between 5% and 15%. Simultaneous and co-located radiosonde launches are highly recommended for optimum use as a lidar calibration source. The so-called "Total Column method" uses the Total Precipitable Water (TPW) measurements of co-located GPS. The lidar profile is analyzed such that the TPW of the lidar profile closely matches that of the GPS measurements. As with the radiosonde method, its accuracy depends on that of the GPS itself. It also depends on the lowest altitude sounded by the lidar, which is usually not the ground. Because of this limitation in the lidar, accurate ground measurement of water vapour mixing ratio is useful. As for the radiosonde method, its accuracy depends on that of the GPS itself. It also depends on the lowest altitude sounded by the lidar, which is usually not the ground. The spatio-temporal match is less critical since the bulk of the TPW resides in the lowermost troposphere, i.e., where the columns sounded by the GPS and lidar are least distant from each other. An alternate measurement source of TPW to GPS may be used, namely microwave or FTS. The most recent comparisons have shown agreement of different GPS TPW measurements of approximately 10%. The last method discussed at the workshop is the so-called "absolute" or "experimental" method. It is conceptually the most adequate, but in practice the most difficult to perform. It consists of determining the efficiency ratio of all components of the instrument through which the analyzed signals propagate. That includes transmittance of the telescope(s), transmittance of all optical filters and splitters, photomultiplier efficiencies, and quantum efficiencies of all relevant channels of the counting system. It is labor intensive, therefore almost impossible to achieve on a daily basis, though recent attempts were successfully made under 30 min. The estimated accuracy using this method ranges from 7% to 20%. Finally the "hybrid" method was proposed to be used within the NDACC community to insure the proper long-term monitoring of the lidar calibration. This method is not a calibration method per-se, but uses a calibrated laboratory lamp to monitor the stability of the lidar receiver total transmission between two calibration campaigns. Calibration campaigns could be performed for example at one-year intervals. If the lamp ratio does not vary, or slowly varies between these campaigns, then no calibration is required between the campaigns, thus reducing cost (typically by launching radiosondes only during campaigns, not on a routine basis).

Workshop notes can be downloaded from:
http://ndacclidar.posterous.com/#!/ndacc-calibration-workshop-notes-0

- *December 2010: ISSI International Team on NDACC lidar algorithms*

A team of international experts was recently formed (leader: T. Leblanc, NASA/JPL) to work on the standardized reporting of vertical resolution and uncertainty in the ozone and temperature lidar data archived at the NDACC data handling centre (located at NOAA and mirrored at NILU). NDACC lidar PIs are required to use the same standard file format (Ames 2110), but the actual content of the data and metadata remained inhomogeneous from one file to another. Different definitions of vertical resolution and different uncertainty estimation schemes result in discrepancies between the various NDACC lidar datasets. The objective of the ISSI Team is to standardize these definitions without imposing the use of a specific resolution and uncertainty scheme to the individual PIs. The first meeting was held in December 2010. At this meeting, the various methods of calculating and reporting vertical resolution (data filtering) were reviewed. Simulation and testing tools are currently being developed to compare the effect of these filtering schemes. The tests will be performed this spring on the actual lidar analysis algorithms. The definition and propagation of uncertainties were also reviewed at the first meeting, and will be standardized in a similar manner. The project is expected to end by early 2012. A similar project is planned for the aerosol and water vapour lidar algorithms (2012+).

Meeting #1 Summary Notes can be downloaded from: http://www.issibern.ch/teams/ndacc/

- *November 2010: MWRNet synergies*

A special working group meeting of the Microwave Radiometer Network, MWRNet, has been held right after the EG-CLIMET WG/MC meeting in Cologne, 16-18 November 2010. The aim is to register existing tropospheric microwave profilers (temperature and humidity up to 5 km) and to exchange knowledge, set standards and harmonize data analysis in order to achieve a consistent network.

Inventory of registered instruments and contacts: http://cetemps.aquila.infn.it/mwrnet/.

- *December 2010: NDACC-EARLINET and TTAM-GATNDOR synergies*

T. Leblanc recently met with R. Hoff (EARLINET co-chair) to discuss future plans for the harmonization of water vapour and aerosol data template in the NDACC and EARLINET data files. This work is still ongoing. An operational template already exists for EARLINET aerosols. An experimental template exists for NDACC aerosols based on the EARLINET template. A preliminary template exists for NDACC water vapour. Also, T. Leblanc briefly met with F. Madonna to discuss areas of collaboration between TTAM and GATNDOR and avoid unnecessary overlap of activities. These discussions will continue at the ICM-3.

EARLINET website: http://www.earlinet.org/

- *Ongoing: Joint Polar Satellite System (JPSS)*

Coordination with cal/val teams for the NOAA Joint Polar Satellite System (JPSS) concerning synergy between sensor data record (SDR) and environmental data record (EDR) calibration and validation activities focused at GRUAN sites are pursued. A variety of routine and special activities in coordination with upcoming NOAA Preparatory Project (NPP) launch of advanced microwave (ATMS) and FTIR (CrIs) instrumentation onboard the C1 satellite (October 2011) are planned. Opportunities to coordinate and/or expand these activities to include interactions and routine cross validation at GRUAN sites are under consideration and will be elaborated upon at IOC-3 (POC: A. Reale and C. Barnett of NOAA Centre for Satellite Applications and Research (STAR).

Update on the Inventory of potential instruments

- *Lidars:*

Non-exhaustive list of systems with a “long-term” monitoring component in their programme. Reaching 15-20 km (with several hours integration time): Table Mountain Facility (Leblanc, JPL) and Purple Crow Lidar (Sica, UWO). Reaching 10-15 km (with several hours integration time): Mauna Loa Observatory (Barnes, NOAA), Observatoire de Haute-Provence (Keckhut, CNRS), Rome-Tor-Vergata (Congedutti, CNR), Payerne (Haefele, Meteoswiss), and ARM-SGP (Newsom, DOE). Other systems, with a maximum altitude range yet to be confirmed: Potenza (Pappalardo, CNR), Lindenberg (Reichardt, DWD), Cabaw (Apituley, RIVM), Greenland (Neely, NOAA), Beltsville (Demoz, HU), Eureka (Strawbridge, EC). Mobile systems (varying degree of performance depending on campaigns): ALVICE (Whiteman, GSFC), STROZ (McGee, GSFC), AT (McGee, GSFC), MARL (Schrems, AWI) and ComCAL (Schrems, AWI). There are other water vapour Raman lidar instruments, mostly dedicated to the study of the lower troposphere (pollution, boundary layer). Finally, two new instruments, with a performance expected to exceed that of any existing instrument, are now under construction: Zugspitze (Trickl, IFK), and Reunion Island (Baray, LaCy).

- *Microwave:*

For an inventory of tropospheric microwave profilers check the MWRNet webpage mentioned above. Microwave radiometers for stratospheric and mesospheric water vapour (30 – 80 km): Bern, Switzerland (Kämpfer, Univ. of Berne, NDACC); Seoul, South Korea (Kämpfer, Univ. of Berne); Mobile instrument (Kämpfer, Univ. of Berne); Mauna Loa Observatory (Nedoluha, NRL, NDACC); Table

Mountain Facility (Nedoluha, NRL, NDACC); Lauder (Nedoluha, NRL, NDACC); Onsala, Sweden (Forkman, Chalmers University of Technology, NDACC); Andoya, Norway and Kühlungsborn, Germany (Hartogh, MPI-Lindau); Karlsruhe (Hochschild, KIT).

- *FTIR:*

There are two global networks of high-quality ground-based FTIR system: NDACC (Network for the Detection of Atmospheric Composition Change, www.acd.ucar.edu/irwg/) and TCCON (Total Carbon Column Observing Network, www.tccon.caltech.edu/). For NDACC high resolution solar absorption middle infrared spectra are recorded at about 20 sites often since 15 years and more. TCCON is in operation since a few years only, However, the number of sites is steadily increasing (currently there are about 15 operative TCCON sites). The table in Annex-1 below lists 44 sites that are either in the TCCON or IRWG networks, possibly both and several sites that are currently affiliated and are prospective contributing sites.

- *Satellite and Assimilations:*

From T. Reale: Polar satellites including weather monitoring instrumentation (IR, FTIR, MW,RO):
JPSS: CrIs, ATMS, VIIRS, afternoon (October 2011)
MetOp: HIRS, AVHRR, IASI, AMSU, MHS late Morning
NOAA-18, 19: HIRS, AVHRR, AMSU, MHS afternoon
DMSP (F-16,17): SSMIS. Early morning
EOS Aqua: AIRS afternoon
COSMIC RO
From M. Schröder: Relevant satellite instruments, retrievals and products (water vapour) are covered in a paper ("Satellite remote sensing of water vapour: An Overview") which we will submit to Remote Sensing very soon.. The draft is available for distribution after M. Schröder receives and evaluates the reviews.

Update on the data products, including uncertainty budgets

- *Lidar:*

NDACC lidar data products are available for ozone, temperature, and aerosols at the NDACC Data Handling Facility (DHF). Some data are publicly available immediately upon archive while other data are public between one and two years after their initial archive. There is not yet an official lidar water vapour product at the NDACC DHF. These data are available upon request to the PIs. This is expected to change in 2011 with the finalization of the NDACC water vapour data format. For non-NDACC systems, data availability depends on the site considered, and therefore requests should be made accordingly to the PI directly. Uncertainty budgets for NDACC ozone and temperature lidar products are being standardized (see above paragraph on ISSI Team). For water vapour lidar, uncertainty budgets were, so far, specifically focused on calibration (see above paragraph on Calibration Workshop). Standardization similar to that in progress for ozone and temperature is planned for 2012.

- *Microwave:*

For tropospheric profilers there is not yet a common data format and data are not yet available on a central archive. Efforts in this direction are being done in the frame of MWRNet. NDACC data products are available for water vapour, ozone, and other species at the NDACC Data Handling Facility (DHF). With very few exceptions an optimal estimation (OE) algorithm is used to invert the radiometer data. OE allows a good characterization and definition of the uncertainty and vertical resolution, respectively. Typically, uncertainty of stratospheric/mesospheric water vapour profiles is around 5 to 10 % and the vertical resolution is around 10 to 15 km. Uncertainty budgets of middle atmospheric water vapour radiometry are assessed in the frame of a science team (team lead N. Kämpfer) by ISSI (International space science institute).

For details consult webpage: http://www.iapmw.unibe.ch/research/projects/issi/index.htm

- *FTIR:*

One FTIR measurement takes only a few minutes. Spectra from both networks (NDACC+TCCON) allow the retrieval of very precise total column amounts (precision of 1-2%). In addition tropospheric profiles with a modest vertical resolution and a precision of about 5-10% can be retrieved. The vertical resolution ranges from 3 km in the lower troposphere to about 10 km in the upper troposphere, whereby the very high resolution of the NDACC spectra provide better upper tropospheric sensitivity than the high resolution TCCON spectra. In the framework of the project MUSICA (MUlti platform remote Sensing of Isotopologues for investigating the Cycle of Atmospheric water, www.imk-asf.kit.edu\musica, led by M. Schneider) profiles will be retrieved for 10 selected NDACC sites but there is currently no similar TCCON water vapour profile retrieval initiative. There is not yet an official FTIR water vapour product at the NDACC DHF. These data are available upon request to the PIs. During 2011 and 2012 an H2O and HDO/H2O database for the 10 NDACC MUSICA sites will be created. The water vapour profile data products are maturing quickly. It is probable that in the IRWG that water vapour becomes a standard product including isotopic amounts.

- *Satellite and assimilations:*

Temperature (surface to 0.01 hpa), H_20 Vapour (srfc to 200 hPa), Cloud Fraction, Top (P, T) , O_3, CO_2, Surface T, Emissivity, Cloud Liquid water, TPW, LW. Strategies for validation and error estimation typically are project oriented with a push at NOAA STAR for centralized standard validation protocols.

Within the ESA DUE GlobVapour (www.globvapour.info) and the ESA STSE WACMOS (www.wacmos.org) projects three new water vapour products were generated: total column water vapour from combined SSM/I and MERIS observations and from merged SEVIRI and MERIS observations making use of the complementary information over ocean (SSM/I) and land (MERIS) as well as of the high temporal and spatial resolutions of SEVIRI and MERIS, respectively; layer integrated water vapour from merged SEVIRI and IASI observations.

Update on Instrument calibration

- *Lidar:*

See Calibration Workshop notes above

- *Microwave:*

The calibration of tropospheric profilers is critical and requires absolute calibration with an external reference (liquid nitrogen load) in regular intervals. The value of the sky tip measurements to calibrate the water vapour channels is under discussion and external calibration might be favored. In this respect, standards will be defined in the frame of MWRNet. In the frame of NDACC recommendations for retrieval parameters (spectroscopy, a priori…) are given for instruments measuring stratospheric/mesospheric water vapour. Furthermore, recently developed mobile systems allow straight forward inter-comparisons. This has been successfully demonstrated in the measurement campaigns at Table Mountain (MOHAVE), on Zugspitze, Germany and in Sodankylä, Finland during the LAPBIAT campaign early 2010. Big efforts are being done to extend the altitude range towards the lower stratosphere and the lower limit is actually at ~24 km. This allows for an overlap with balloon soundings and gives to opportunity to perform inter-comparisons with in-situ hygrometers.

- *FTIR:*

The technique is self-calibrating (differential absorption principle). A constant high instrumental performance is achieved by regular low-pressure gas cell measurements (these measurements are in particular important when aiming on stratospheric absorbers). Retrievals employ published line parameters that are based on laboratory measurements. These have large effects and can be have precisions of 5-20%. Updates are intermittent but continue. It is likely that a closer review of these parameters will be in order in the not too distant future in a manner similar to what has been done with O3.

- *Satellite:*

STAR Integrated calibration/Validation System (HIRS, Microwave) including SNO
http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/index.html/.

Update on Validation strategies and results

- *Lidar:*

It is well established that most existing water vapour lidars require thorough validation before they can be considered fully reliable for GRUAN-like measurement activities. The use of multiple radiosondes and multiple Frost-Point hygrometers is mandatory. Multiple simultaneous and co-located techniques, including balloon-borne in-situ and ground-based remote sensing, are recommended. The logistics and operation of the recent MOHAVE-2009 campaign held at the JPL-Table Mountain Facility could be used as a reference to set standard guidelines for “GRUAN-certified” validation campaigns.

- *Microwave:*

No specific activity to report.

- *FTIR:*

In case there are new spectroscopic parameters (e.g. update of the HITRAN parameters) a validation to coincident radiosonde profile measurements is recommended. So far FTIR water vapour total column amounts have been compared to other techniques at Izaña, Ny Ålesund, Zugspitze, Jungfraujoch, and Table Mountain Facility. Tropospheric FTIR water vapour profiles have been compared to other water vapour profiling techniques at Table Mountain Facility (MOHAVE-2009) and are regularly compared to Vaisala radiosondes at Izaña (for NDACC and TCCON retrievals). On going regular coincident measurements with the approximately bi-weekly NOAA FPH are being made At NCAR in Boulder. Though not an official NDACC site these data are of NDACC quality. These serve to validate the retrieval process wrt the FPH standard.

- *Satellite and Assimilations:*

From T. Reale: STAR Integrated calibration/Validation System (HIRS, Mwave) including SNO at http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/index.html. Global Space Based Inter-Calibration System (GSICS): international collaboration (WMO, CGMS, NOAA …) to monitor and standardize data from operational weather and environmental satellites of the Global Observing System. NWP SAF (EUMETSAT, UKMO, KNMI, MeteoFrance, ECMWF) routinely monitor instrument performance (bias, SD) based on differences from NWP calculated radiance.
From M. Schröder: The merged SEVIRI+IASI product has a temporal resolution of 3 hours and utilises the high vertical resolution IASI and the high spatial resolution SEVIRI observations. At present the added value of the merged product is anlysed by comparison to high temporal resolution ground-based MWR observations from MOL by closely analysing the products quality in temporal vicinity to IASI overpasses. At CM SAF a prototype bias monitoring has been developed and implemented. An interim version utilised radiosonde and other standard ground-based observations from MOL and radiative transfer to determine the bias between RT and SEVIRI observations. The monitoring has been extended to utilisation of ground-based Lidar observations from MOL. The Lidar data contain water vapour information only. Therefore, temperature observations from radiosondes are used which the disadvantage of reduced temporal sampling.
It is foreseen to transfer offline ATOVS atmospheric profiles (water vapour and temperature) from CM SAF to NOAA STAR for implementation in its NPROVS.

Update on Metadata

- *Lidar:*

No specific activity to report.

- *Microwave:*

No specific activity to report.

- *FTIR:*

FTIR data archived at the NDACC DHF are now GEOMS compliant HDF files, we might expect this to be a standard conveyance of FTIR water vapour data products for GRUAN. Metadata included in this file are available on request.

- *Satellite:*

No specific activity to report.

Update on the Definition of Best Measurement Practices.

- *Lidar:*

No specific activity to report.

- *Microwave:*

No specific activity to report.

- *FTIR:*

NDACC/IRWG guidelines for observations and retrievals for member groups can be found there: http://www.acd.ucar.edu/irwg/irwg_info.html/

- *Satellite:*

No specific activity to report.

Update on the Routine Collection and Display of Data.

Respective data product programmes at STAR facilitate respective data collection and display of sensor data records (SDR) and derived environmental data records (EDR). NPROVS provides NOAA STAR with a centralized validation protocol for the routine, integrated, monitoring and inter-comparison of EDR's composed of derived atmospheric weather products from polar orbiting and GOES environmental satellites. This is primarily achieved through the compilation and analysis of collocated radiosonde, NWP and independently processed satellite product systems; currently 19 operational and experimental products systems are included. NPROVS compiles collocations on a daily basis with all collocations routinely archived at STAR. NPROVS includes a variety of analytical interface and sampling options (EDGE) including satellite and Raob QC, space and time windows, terrain designation, individual and common denominator sampling, radiosonde instrument type selection, regional (ie GOE Conus) designation and more. Analysis on real-time weather (daily, weekly) and climate scales (monthly, seasonal, annual) are facilitated. Plans for expanded access and validation against GCOS Reference Upper Air Network (GRUAN) reference radiosonde and selected ground observations are outlined

.

Update on Guidelines on Practices and Protocols for Site and Measurement Certification.

- *Lidar:*

No specific activity to report.

- *Microwave:*

No specific activity to report.

- *FTIR:*

No specific activity to report.

- *Satellite:*

No specific activity to report.

Update on GRUAN-TTAM members interaction:

There has been no meeting yet of all GRUAN-TTAM members together. A few members met at various occasions. These small, informal, meetings led to no significant action besides general programmatic information between the team members. There has been no GRUAN-TTAM teleconference meeting. Team-wide communication has been limited to email only, and was mainly focused on the preparation of the present report.

Update on GRUAN TTAM Membership

There has been no progress in this area. Finding non-US and non-EU collaborators with adequate availability and/or expertise remains a difficult process. Action is still ongoing. As of February 2011, the current Team composition is as follows:

Thierry Leblanc (NASA/JPL), co-chair
Tony Reale (NOAA/NESDIS), co-chair
Alexander Haefele (Meteoswiss-Payerne): Microwave, Lidar, GRUAN-Payerne
Nik Kämpfer (Univ. Bern): Microwave
Jim Hannigan (NCAR): FTIR
Matthias Schneider (KIT/IMK-ASF and AEMET): FTIR
Marc Schroder, (DWD): Satellite/data processing
Michael Sommer (DWD): Satellite/data processing
Dave Whiteman (NASA/GSFC): Lidar

Annex 1: List of FTIR instruments (see paragraph on potential sites)

Station	***N. Lat***	***E. Long.***	***MASL***	***Designation****
Eureka	80.05	273.58	610	3
Ny_Alesund	78.90	11.90	20	3
Thule	76.53	291.26	225	1
Kiruna	67.84	20.41	420	1
Sodankyla	67.36	26.63	179	2
Poker_Flat	65.12	212.57	610	1
Harestua	60.20	10.80	596	1
St_Petersburg	59.88	29.83	20	4
Yekaterinburg	57.04	59.55	300	4
Tomsk	56.98	85.05	106	4
Bialystok	53.23	23.03	183	2
Bremen	53.10	8.90	27	2
Bratts_Lake	50.20	-104.20	587	4
Karlsruhe	49.09	8.43	110	2
Paris	48.97	2.37	60	4
Orleans	47.97	2.11	132	2
Garmisch	47.48	11.06	745	3
Zugspitze	47.42	10.98	2964	1
Jungfraujoch	46.55	7.98	3580	1
Park_Falls	45.95	269.73	442	2
Moshiri	44.40	142.30	200	1
Egbert	44.22	280.23	251	4
Rikubetsu	43.50	143.80	200	1
Toronto	43.66	280.60	174	1
Boulder	40.04	254.76	1612	4
Barcroft	37.58	241.76	3793	1
Lamont	36.60	262.51	320	2
Tsukuba	36.05	140.12	31	2
Table_Mtn	34.40	242.30	2300	4
Kitt_Peak	31.96	248.41	2060	1
Izana	28.30	343.52	2370	3
Mauna_Loa	19.54	204.43	3396	1
Mexico_City_UNAM	19.33	-99.18	2260	4
Altzomoni	19.12	-98.65	4010	4
Addis_Ababa	8.98	38.80	2444	1
Paramaribo	5.81	304.79	7	1
Ascension	-7.92	-14.33	10	2
Darwin	-12.42	130.89	20	2

Reunion_Maido	-21.07	55.38	2160	3
Reunion_St_Denis	-20.90	55.48	50	3
Wollongong	-34.41	150.88	30	3
Lauder	-45.05	169.67	370	3
Syowa_Station	-69.00	39.59	10	1
Arrival_Heights	-78.83	166.66	200	3

* Designations: 1=IRWG, 2=TCCON, 3=Both, 4=Other

.

Appendix 8: Site Representation Task Team Progress Report for 2010

Dale Hurst and Belay Demoz, Co-Chairs

At the encouragement of GRUAN ICM-2 participants, a Task Team consisting of representatives from all initial GRUAN sites was proposed. During the ensuing months, sites were asked to recommend a representative to be a member of this Task Team. The Task Team 6 (TT6) membership is now complete at this level, with at least one member from each site. It was also intended that one member from TT4 (site assessment, expansion and certification) would serve as a liaison to TT6, providing a direct link between the activities of TT4 and the site representatives. This intention remains an action item pending the current reorganization and proposed future expansion of TT4 membership.

The terms of reference for TT6, initially defined at ICM-2, were reviewed and expanded upon by the co-chairs, agreed upon by the Task Team members, and ultimately accepted by the Lead Centre. The terms of reference focus on communication as the primary function of the Task Team, with TT6 facilitating the exchange of information between sites, the Lead Centre, and the WG-ARO. The team is also considered a conduit for the dissemination of information about best practices among the sites.

Each TT6 member was asked to read and comment on the GRUAN manual as it progresses, to prepare and submit a written report on the current status of their site, and to present a site status update at ICM-3.

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Appendix 9: Meeting of the WG-ARO

WG-ARO Meeting, Queenstown, New Zealand, 28 February and 4 March 2011

Attendees:
Franz Berger, Greg Bodeker, Geir Braathen, Belay Demoz, Howard Diamond,
Masatomo Fujiwara, Tom Gardiner, Dian Seidel, Peter Thorne (Chair), Holger Vömel, Junhong Wang

The WG-ARO met in advance of the main meeting to discuss progress generally and specific governance issues. The WG-ARO met again after the closing of main meeting to review the meeting and address remaining open issues. The summary presented here reflects the discussions of both sessions of the WG-ARO meeting

Lead Centre issues:

The WG-ARO appreciated the considerable efforts of the Lead Centre in the Past 12 months. In particular the first availability of data was recognized and the evaluation of these data, which are still considered in beta stage, was considered to be important.

It was recognized that the Lead Centre operates under very limited resources considering the large challenge that the Lead Centre has taken on. Due to resource limitations at the GCOS Secretariat, the Lead Centre had to take over some of the administrative responsibilities, which resulted in a slight shift in responsibilities. These limited resources have also been noted at AOPC and are considered a potential hindrance in the development of GRUAN. Limiting administrative and reporting requirements to the least amount necessary is considered essential to reduce the burden on the Lead Centre. It was recognized that through hiring external consultants considerable effort was made by DWD and NOAA to further support Lead Centre activities.

Working Group issues:

The structure of GRUAN within GCOS and WMO was reviewed and some concern has been raised to change the current structure of reporting and responsibilities. It was felt that the current structure under which the Lead Centre reports to the WG-ARO, which in turn reports to GCOS/WCRP/AOPC, is appropriate in managing the inhomogeneous network that currently makes up GRUAN. A structure under which GRUAN would report to CBS was not seen as beneficial, since the majority of sites do not belong to a national meteorological service, but rather to research institutions. However, closer cooperation with national meteorological services is considered important, since their support through higher quality operational observations, may contribute strongly to the data produced by GRUAN.

GRUAN has been adopted as WIGOS pilot project in 2009 with one focus being the collaboration between GRUAN and CIMO during the eights international radiosonde intercomparison at Yangjiang, China. The pilot phase has ended in 2010. The future relationship between GRUAN and WIGOS depends on the development of WIGOS itself, which has currently not yet been decided. Thus, the administrative effort required to maintain a connection with WIGOS cannot currently be estimated. It was pointed out that it is key to maintain a strong relationship with GCOS, since GRUAN is seen as the prime climate observing system for upper air.

The membership of the WG-ARO was revisited and updated. Greg Bodeker of New Zealand was named new co-chair of the working group. It was recommended that Working Group hold regular phone conferences, which however, should not be on fixed intervals, but rather driven by issues. These phone conferences should be coordinated by different working group members to release some of the work load off the co-chairs. It was pointed out that regular phone conferences maintain the momentum of the group.

Following general goals were seen by the Working Group for the upcoming year:

+ Resolution of the site assessment problem and better definition of site criteria;
+ Completion and adoption of the GRUAN manual;
+ Outreach of the GRUAN community to other communities, in particular the satellite community. This outreach should be accomplished by specifically engaging targeted

satellite groups to get additional support from these groups. Furthermore, outreach should be done by presenting GRUAN progress and GRUAN results at various conferences. The first conference of importance would be the WCRP Open Science Conference held in Denver, USA, in October 2011. In addition, the American Meteorological Society (AMS) meetings were seen as valuable meetings to attend, because of their media coverage as well as one of their foci being on observational techniques.

To promote GRUAN a good front for the data access will be required, which will be provided by NOAA/NCDC.

Progress on the GRUAN manual

The progress on the GRUAN manual accomplished by Greg Bodeker in cooperation with the Lead Centre and the WG-ARO has been highly appreciated. It has been decided that the manual should be finalized by the end of 2011 and should be adopted in Jan 2012. To adopt the manual formally, the Lead Centre needs to agree to this version, as well as 2/3 of all site representatives and 2/3 of all WG-ARO members. Following this adoption, an expert team will work on including the relevant documentation into the manual for the Global Observing System (GOS) and other relevant WMO documentation.

Task Teams

The dissolution of the Task Team on site assessment and certification was discussed extensively. It was recognized that the proposed structure is expected to be effective and a constructive way forward. It was agreed that full membership in the WG-ARO will be offered to all members of that Task Team. Furthermore, a membership offer was extended to Arnoud Apituley of KNMI and to Masato Shiotani of Kyoto University. The WG-ARO agreed to revise its existing Terms of Reference (ToR) to allow for the change in mandate and expects to submit these revised ToR to AOPC before June 2011.

The Task Team on radiosondes was seen as very effective. The radiosonde data product documentation is currently under review within that Task Team and will be made into a GRUAN technical document. It was agreed that in GRUAN all technical documents should be endorsed by the Working Group. This would require that all Task Team output should be submitted to the Lead Centre and the Working Group co-chairs. It is recognized that technical documents need to receive periodic updates, which need to be done by the respective Task Teams. In some cases Task Teams may need to be formed to review existing documentation, if no Task Team exists to address outdated documentation.

It was recognized that research activities in Task Teams are not financially supported and thus limited. Research calls by funding agencies is not an effective mechanism and a trust fund as proposed by Greg Bodeker may fill in this gap.

Site issues

Acknowledgement for data usage from sites needs to be addressed. The site representation Task Team was asked to compile the requirements that individual sites may have and which have not yet been voiced. Requirements that are in contradiction to the agreed data policy need to be resolved. No site may impose requirements that overly restrictive.

As step forward in including new sites in GRUAN it was agreed that offers by new sites to become GRUAN sites will be handled by the Lead Centre. The Lead Centre will communicate the requirements expected from a site and will support the site in developing a work plan for observations. The WG-ARO will review the site offer and provide a written certification for site acceptance.

The discussion identified that GRUAN needs to define requirements for the surface based parameters pressure, temperature and humidity, which has currently not been done. These parameters are important to serve as reference for sonde launches as well as for the GPS integrated water vapour product. The US Climate Reference Network (CRN) or the Baseline Surface Radiation Network (BSRN) may serve as template for these requirements.

ICM-4

The fourth Implementation and Coordination Meeting (ICM-4) should be held at the roughly the same time in 2012. The organization should be done similarly as for ICM-3 and funding should be available at current levels. The WG-ARO agreed on exploring the possibility for ICM-4 to be held, in order of priority:

- Tateno Japan
- Sodankyla, Finland
- Potenza, Italy

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Appendix 10: List of Acronyms

AOPC	Atmospheric Observation Panel for Climate (GCOS)
ACRF	ARM Climate Research Facility
AMS	American Meteorological Society
ARM	Atmospheric Radiation Measurement Program
ATM	Accurate Temperature Measuring radiosonde (NASA reference radiosonde)
BIPM	International Bureau of Weights and Measures
BSRN	Baseline Surface Radiation Network
CBS	Commission for Basic Systems (WMO)
CEOS	Committee on Earth Observation Satellites
CFH	Cryogenic Frostpoint Hygrometer
CGMS	Coordination Group of Meteorological Satellites
CIMO	Commission for Instruments and Methods of Observation (WMO)
CMA	China Meteorological Administration
CM-SAF	Satellite Application Facility on Climate Monitoring
CPO	Climate Program Office (NOAA)
DWD	German Meteorological Service (Deutscher Wetterdienst)
EARLYNET	European Aerosol Research Lidar Network
ECMWF	European Centre for Medium-Range Weather Forecasts
EDGE	Enhanced Data Rates for GSM Evolution
EG-CLIMET WG/MC	European Ground-based Observations of Essential Variables for Climate and Operational Meteorology Working Group/ Management Committee
EMRP	European Metrology Research Project
FTIR	Fourier Transform Infrared Spectrometer
FTS	Fourier Transform Spectrometer
GATNDOR	GRUAN Analysis Team for Network Design and Operations Research
GAW	Global Atmospheric Watch (WMO)
GCOS	Global Climate Observing System
GEOMS	Generic Earth Observation Metadata Standard
GEOS	Geostationary Operational Satellites
GEWEX	Global Energy and Water Cycle Experiment
GNSS	Global Navigation Satellite System
GOS	Global Observing System (WMO)
GOSIC	Global Observing System Information Center (at NCDC)
GPS	Global Positioning System
GPS-PW	Global Positioning System Precipitable Water
GRUAN	GCOS Reference Upper Air Network
GSICS	Global Space-Based Inter-Calibration System
GSN	GCOS Surface Network
GTS	Global Telecommunication System
GUAN	GCOS Upper Air Network
HMEI	Association of Hydro-Meteorological Equipment Industry
ICM	Implementation - Coordination Meeting (GRUAN)
IGRA	Integrated Global Radiosonde Archive
IPW	Integrated Precipitable Water
ISCCP	International Satellite Cloud Climatology Project
ISSI	International Space Science Institute
IWV	Integrated Water Vapour
JGR	Journal of Geophysical Research
JPL	Jet Propulsion Laboratory (NASA)
JPSS	Joint Polar Satellite System
KNMI	Royal Netherlands Meteorological Institute
LIDAR	Light Detection and Ranging (optical remote sensing)
LUAMI	Lindenberg Upper-Air Methods Intercomparison Campaign
MOL	Lindenberg Meteorological Observatory
MTR	Meisei Temperature Reference
MWRnet	Microwave-Radiometer Network
NASA	National Aeronautics and Space Administration (USA)
NCAR	National Centre for Atmospheric Research (USA)

NCDC	National Climatic Data Center (NOAA)
NDACC	Network for the Detection of Atmospheric Composition Change
NetCDF	Network Common Data Form
NILU	Norwegian Institute for Air Research
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration (USA)
NOAA FPH	NOAA Frost Point Hygrometer
NOAA/NWS	NOAA National Weather Service
NPROVS	NOAA Products Validation System
NWP	Numerical Weather Prediction
NWP SAF	Satellite Application Facility for Numerical Weather Prediction
PW	Precipitable Water
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SGP	Southern Great Plains Site (ACRF)
SI	International System of Units
SSI	Scientific Sounding Instruments
STAR	Center for Satellite Applications and Research
TECO	Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (WMO)
UKMO	UK MetOffice
UT/LS	Upper Troposphere and Lower Stratosphere
WCRP	World Climate Research Programme
WG-ARO	Working Group on Atmospheric Reference Observations (AOPC)
WIGOS	WMO Integrated Global Observing Systems
WIS	WMO Information System
WMO	World Meteorological Organization

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