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# REPORT OF THE FIRST GCOS REFERENCE UPPER AIR NETWORK IMPLEMENTATION AND COORDINATION MEETING (GRUAN ICM-1)

**(2-4 March 2009, Norman, Oklahoma, USA)**

**May 2009**

**GCOS-131**
**(WMO/TD No. 1492)**

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# TABLE OF CONTENTS


1. Introduction ..... 1

2. Lead Centre Report on Progress and International Linkages ..... 1

2.1. Lead Centre Report on Progress ..... 1

2.2. Recommendations by GCOS, WMO and other international bodies ..... 2

3. How should GRUAN measurements be made? ..... 2

4. Site Reports ..... 4

5. Data dissemination and data policy ..... 5

6. Planned radiosonde intercomparison ..... 6

7. GRUAN manual of operations ..... 6

8. GRUAN and WIGOS ..... 7

9. Forthcoming meetings /activites of interest ..... 7

10. Next meeting ..... 8

11. GRUAN Work Plan ..... 8

Actions in GCOS-121 closed / superseded: ..... 9

Appendix 1 Agenda ..... 11

Appendix 2 Lead Centre Report 08/2008 – 01/2009 ..... 14

Appendix 3 List of Participants ..... 17

Appendix 4 List of Acronyms ..... 21

# 1. Introduction

The first GRUAN Implementation-Coordination Meeting, held 2-4 March 2009, was hosted by the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at Oklahoma University, Oklahoma, USA, the US Department of Energy's Atmospheric Radiation Measurement (ARM) program Climate Research Facility (ACRF), the ACRF Southern Great Plains (SGP) Site, and further supported by the U.S. GCOS Program Office at NOAA's National Climatic Data Center (NCDC), NOAA's Climate Program Office (CPO) and the GCOS Secretariat at the World Meteorological Organization.

The over-arching goals of ICM-1 were to

- Agree on the mode of operation of GRUAN
- Agree on actions to gain support from the scientific community, sponsors, and funding agencies.

The agenda for the meeting (see Appendix 1) was dedicated to:

- Assessment of progress against the current GRUAN work plan
- What a GRUAN measurement should be, and what requirements that implies
- Reports from initial GRUAN sites
- Options for GRUAN data dissemination
- Discussion on a planned in-situ and remote sensing intercomparison campaign
- Development of a GRUAN manual of operations
- Discussion on WIGOS pilot projects and GRUAN.

The meeting included a field trip to the ACRF SGP site, including a guided tour of the suite of instrumentation operating there. Participants appreciated the SGP staff's hospitality and willingness to answer questions. Site visits such as this one are felt to be hugely valuable to many participants, allowing a true understanding of the issues involved and how individual sites address them. It is hoped that future meetings will involve such activities as a matter of course and be hosted by a GRUAN site or its associated institutions.

At the opening of the meeting, Peter Lamb (Director of CIMMS) and Wanda Ferrell (ACRF Program Director) welcomed participants and highlighted the importance of reference-quality measurements of the atmospheric profile for climate studies. They reaffirmed the strong commitment in principle of the ARM programme to be part of GRUAN pending available resources. This support and their presence at the meeting were gratefully acknowledged by the participants.

This report summarises key discussions and outcomes, based on participants' consensus achieved in the session, rather than being a full record of the meeting. All documents prepared in support of ICM-1 and meeting presentations are available on the GRUAN website at http://www.gruan.org (Meetings: Norman 2009: Documents).

# 2. Lead Centre Report on Progress and International Linkages

## 2.1. Lead Centre Report on Progress

The six-monthly activity report by the Lead Centre for the period August 2008 – January 2009 is given in Appendix 2, which includes activities addressing items in the GRUAN work plan as laid down in GCOS-121. Highlights are the completion of the Lindenberg Upper-Air Methods Intercomparison Campaign (LUAMI), which brought about important lessons for GRUAN implementation in terms of instrument performance and data handling; the establishment of the GRUAN website (www.gruan.org); and an initial concept for the dissemination of data within the network. The Lead Centre stressed that the initial focus of GRUAN should be on the priority 1[1] Essential Climate Variables (temperature, water vapour, pressure) notwithstanding the concentration on other upper-air variables at a later stage. Challenges lie particularly in developing a strategy for assessing the uncertainty of GRUAN measurements, and detecting changes in the measurement quality at any particular site. Doing so requires comprehensive metadata, common procedures of quality control and

[1] As given in GCOS-112.

assurance, and good insight into the quality of sensors, usually beyond what is provided by instrument manufacturers (see section 3).

Participants agreed upon the updated work plan given in Section 11 while looking forward to the next Lead Centre progress report in August 2009.

### 2.2. Recommendations by GCOS, WMO and other international bodies

Over the course of 2008, several international bodies made recommendations pertaining to the implementation of GRUAN. The GCOS Atmospheric Observation Panel for Climate (AOPC) recalled that GRUAN encompasses much more than only in-situ/radiosonde profile measurements, recommended due consideration of the need for near-real time data dissemination in addition to the core GRUAN objective of high-quality climate data made available in delayed mode, and further recommended continuing close collaboration with satellite operators on the issue of launch schedules and calibration/validation activities. Much of the feedback from WMO bodies (CBS ICT-IOS and its ET-EGOS) relates to the idea of making GRUAN (or part thereof) a WIGOS-PP (see section 8). The International TOVS Working Group also noted the need for satellite coincident profiling measurements at certain points in time, and recommended the designation of GRUAN sites in locations with complex atmospheric chemistry conditions (e.g., urban smog, high dust).

Participants noted the top-level goal of GRUAN in delivering reference-quality climate records, with near-real time data transmission from sites being a desirable, but secondary goal. Also, it was stressed that a number of technical and coordination issues were yet to be agreed among the set of initial GRUAN sites before expanding the network to other sites located in areas of special interest, different climatic zones or the Southern Hemisphere (currently only Lauder, New Zealand).

The expert team on updating the GCOS Implementation Plan (GIP) noted the need for a GRUAN implementation plan reaching out at least until 2013, which specifies, inter alia, the strategy of establishing common procedures for GRUAN sites, the next steps in expanding GRUAN to climatic zones so far uncovered, and the interactions between GRUAN and other (collocated) networks.

Participants agreed upon the usefulness of a high-level implementation plan that took a long-term view – a writing team composed of representatives from the WG-ARO, initial sites, and the Lead Centre agreed to draft such a plan by June 2009 (see work plan action 3). It was agreed that the report would take into account, inter alia, the following items: data dissemination, site/instrument certification, manual, site selection agreements with other networks, formal launch event, learning lessons from sites thus far, instigation of expert teams, collocation issue resolution, observing strategy, actions to ensure long-term institutional support, relation to existing global networks. It was agreed that the plan would be reviewed by the WG-ARO prior to adoption and would form the response to the request from the GIP expert team as well as AOPC. Subsequent to the meeting, members of the team have queried the required format of this plan, and guidance is requested from AOPC and the GCOS secretariat in this regard prior to commencement.

## 3. How should GRUAN measurements be made?

An entire session was devoted to better understand what measurements must be made (and preserved) in the framework of GRUAN and what descriptive information must be retained in order to assess the quality of any primary GRUAN observations, something generally referred to as metadata. Further, participants discussed the possibility of a common mode of operation for all GRUAN sites that would ensure measurement quality and that is practically achievable, given the heterogeneity of these sites in terms of instrumentation, expertise, governance etc. Firstly, the uncertainty of all GRUAN observations must be robustly ascertained in a manner traceable to absolute or relative standards. This is a necessary, but not necessarily a sufficient condition for acceptance as a GRUAN measurement. Several participants noted that if these uncertainties were unacceptably large they could not logically constitute a GRUAN measurement. Therefore secondly, the implementation of GRUAN must aim at minimizing these uncertainties so that they move toward meeting or exceeding the specifications given in GCOS-112, whilst recognising that some of these targets may not be achievable with any current technologies. A common mode of operation needs to allow for these steps to be traceable and reproducible. The metadata format, yet to be agreed upon, has to allow for all necessary information be available.

The meeting agreed on the following definitions related to GRUAN measurements, based upon discussions in previous meetings (particularly Boulder):

An observation of reference quality is an observation with a comprehensive uncertainty estimate attached. The uncertainty is traced to absolute (SI) or relative standards. The eventual aim within GRUAN is to minimise the uncertainty to at least that specified in GCOS-112. However, in the spirit of "Start small, but start" this is not necessarily an initial condition.

This is in contrast to a benchmark measurement which would be known in absolute terms (e.g., the Keeling curve) and be firmly traceable to SI standards.

It was further agreed that the GRUAN-wide mode of operation would need to encompass all of the following five elements:

1. Understand the instrument before deployment
2. Undertake rigorous in-the-field QC/QA
3. Calculate a comprehensive error budget estimate
4. Compare measurement to an independent measurement and its comprehensive error budget
5. Instigate expert teams to audit the process

These five elements need to be expanded into a guidance document for GRUAN-specific purposes. It was agreed that the Lead Centre would be leading the drafting of a document with help from WG members (see work plan action 4). This effort does not start from scratch, since many lessons related to data quality and underlying quality control, quality assurance and calibration procedures, have been learned at the sites as well as in the operation of other global networks. Expertise from initiatives such as the QA4EO (CEOS Quality Assurance for Earth Observations Strategy) and from metrology institutes was also considered invaluable, for example for the use of consistent terminology across the network. A case study based on the general guidance document should be developed for ICM-2, focussing on in-situ (radiosonde) observations (see work plan action 5).

Furthermore, in recognition that we are not starting the network from scratch, there was strong support by participants for a study(ies) looking at the historical time series collected at initial GRUAN sites in the context of how the historical measurements were taken with the aim to learn lessons drawing on the experiences of these sites. For example, the study could look at related ARM activities analyzing the creation of datasets, and the lessons learned from sites having both research-based and operational observation programmes. This work could also give rise to suggestions for managing change at sites, for optimizing intercomparisons, as well as describe approaches dealing with the (non-)collocation of measurements.

Participants agreed that the study(ies) would be a strong initial product of GRUAN, showing good engagement by the research community, and should, if possible, be published in peer-reviewed literature. A study team under the leadership of Dian Seidel was tentatively formed, looking into the feasibility for devising such a study and met immediately after the meeting. Under the auspices of the AOPC Working Group on Atmospheric Reference Observations, the small, ad hoc, international research team will identify and carry out a series of well-defined, limited-scope retrospective studies of existing observations from established stations that are potential GRUAN sites. The unifying theme of this series of studies will be to provide some "lessons learned" from past observations for optimizing GRUAN. Initial team members are: Reinout Boers, Tom Gardiner, Junhong Wang and Dian Seidel. A preliminary brainstorming session following the meeting resulted in a set of (five) potential projects. The team has been active in seeking guidance and input from the WG-ARO Chair and GRUAN Lead Center Director on the potential utility of these studies. Because the study was not well defined in exact remit or timeline, and because it did not at this stage directly impact the network operations, it was not adopted as an official action from the meeting. However, all of the participants strongly encouraged this work recognising its substantial import at this incipient stage in network formation. It was hoped to include a discussion of the initial results from this work at the next ICM session. Input from all interested parties is strongly encouraged.

In support of the issue of managing change at sites, which it was recognised did not get sufficient discussion, the Lead Centre agreed to prepare a position paper for the next ICM session (see work plan action 6).

# 4. Site Reports

Following the recommendation from the WG at the 2008 Lindenberg meeting and invitations by letter issued in September 2008, to date six[2] of the 14 designated initial GRUAN sites have officially expressed their interest in contributing to GRUAN. The remaining (7 sites within the US and Lauder, New Zealand) are strongly interested in participating, but still seeking appropriate funding before being able to commit. Representatives from the 14 identified initial GRUAN sites gave brief presentations on the status of their operations, focussing on the following questions:

1. Operations:
   a) What is the site status in respect of the requirements outlined in GCOS-121 and GCOS-112 (priority 1 and 2)?
   b) Which guidelines/manuals do you use when taking measurements, if any?
   c) What is your data dissemination practice?
2. Needs: What do you need from lead centre / working group / secretariat?
3. News: Are there any scientific or organizational developments we should be aware of?

The initial sites exhibit high diversity of different instrumentation techniques, operational practices, governance, primary purpose, and site designs. Many sites requested specific scientific and technical guidance as to how to meet GRUAN requirements, e.g., how to systematically quality control, manage, document and archive data measured at sites (see work plan action 7). Immediate questions from sites were the following:

Beltsville:
- Radiosonde profile measurement (T, RH, wind) in ascent and descent mode Request of guideline documentation from GRUAN lead centre on how far the descent measurements are to be made.
- Definition of upper-atmosphere altitude regions?
- What is state-of-the-art in terms of upper-air RH measurements? Note that most of the initial sites use the same CFH sonde
- Guidance in QA/QC of wind measurements: How to deal with GPS/Wind measurements where accuracy is limited by the manufacturer?
- Advice on ATM radiosonde capability and operation since it needs a lot of “care”?
- Clarify procedures for operating CFH. A GRUAN team that assesses how stations could adopt and implement this technology would be beneficial.
- Beltsville does not launch twice daily sondes as “desired” in the GRUAN requirements, but, 00/12 UT production sondes are launched at the Sterling, VA, NWS site at about 40km away.
- A resource plan for Beltsville as operational GRUAN site is under development and depends upon NOAA GCOS office financial support being realized.

Boulder:
- 00/12 UTC production radiosonde launched operated at site 29 km away (NWS Stapleton) – representative for Boulder? In addition, there are co-location issues with BSRN and MWR sites.
- Help needed in transition from RS80 to RS92; more frequent GPS w/ radiosondes?
- Assistance needed in putting data in GRUAN format (whatever that might end up being)

ARM facilities:
- Note that resource plan for all ARM sites as operational GRUAN sites is under development and depends upon NOAA GCOS office financial support being realized.

Lauder:
- Need GRUAN community support for effective lobbying for funds from relevant potential funding bodies; how exactly?
- NWS site at Invercargill representative (at 187 km distance)?
- Need to ensure that Southern Hemisphere is covered by GRUAN as a priority.
- Lauder may be able to host GRUAN experiments supplied by other countries (this may need to be cost neutral to NIWA)

[2] Cabauw, Netherlands; Lindenberg, Germany; Potenza, Italy; Payerne, Switzerland; Sodankylä, Finland; Xilin Hot, China

Potenza:

- Request for “fast response” support related to network operations, e.g. time schedule, procedures for QA/QC
- Help related to actions for lobbying with national funding agencies
- Need for support in real and near real time data dissemination

Sodankylä:

- How to organize additional financial support for the reference class sonde measurements such as the CFH
- Advice on best practices at site (e.g., time-lag corrections, empirical corrections, remaining uncertainties; what will be the reference instrument, how often the reference measurements should be made; timing in case of the sonde measurements; recommendations for the metadata; campaigns; publications; need for new instruments; funding possibilities)

Xilinhot:

- Is it necessary to use an identical set of instrumentation at all initial GRUAN sites?
- Need for training of the staff at the sites

Participants agreed to the need for the Lead Centre to establish and maintain an inventory of sites and their capabilities, using a common template (see work plan action 8). Furthermore, the need for good communication within the GRUAN community was stressed, i.e. among sites and between sites and the Lead Centre and Working Group. The meeting agreed that an efficient and open communication platform (e.g. one or more of: website, wiki, FAQ, blog etc.) should be instigated, and a position paper on options to this end, consistent with Lead Centre technological constraints, should be drafted for ICM-2 (see work plan action 9). Finally, several sites reported on the existence of relevant profile measurements in their vicinity, giving rise to the question of representativeness of these measurements for the site itself. Some sites (e.g., Sodankylä) had looked into the issue of collocation and found that particularly in the case of water vapour profiles, exact collocation of measurements was critical. Participants felt it important to address the collocation issue before further GRUAN roll-out. It was agreed that results emanating from the envisaged site study led by Dian Seidel and the planned guide to estimating uncertainty of GRUAN data would provide further insight to this issue. Chris Barnet offered to give a talk at ICM-2 on a recent publication on the collocation issue from the satellite perspective (see work plan action 10).

The meeting recognized that there was only very limited time allocated at this session for site presentations – more time shall be set aside at ICM-2 in 2010 for that purpose and site reports will be nearer the start of the meeting so as to better frame the subsequent discussions. As was the case for ICM-1, organisers will request the sites to answer a number of specific questions of relevance to the intended workshop agenda.

## 5. Data dissemination and data policy

The Lead Centre and the ARM programme presented options for managing and disseminating GRUAN data. The concept proposed by the Lead Centre encompasses data collection, preprocessing, archiving, processing, dissemination and monitoring. It follows the overarching principles that data processing needs to be reproduceable and traceable at all steps in order to ensure long-term stability and reference-type quality of the data. The data format needs to accommodate heterogeneous data streams, the quantification of errors and appropriate metadata – NetCDF was considered best suited for that purpose. For example, “black box” software delivered along with the instruments was not considered acceptable, since it disallows traceability of the processing chain. Details on data dissemination, including the use of facilities at the Lead Centre, at NCDC, and the ARM program, still need to be specified. Both institutions offered their in-kind assistance in whatever way useful related to data handling and dissemination.

On the subject of centralized data processing, participants stressed that pre-processing should wherever possible be done at the sites themselves, since they were most knowledgeable about the data. The timing of data dissemination shall be in the best interest of the principal GRUAN objectives, and, where possible, address the needs of (near) real-time data users as well. Near-real time and delayed mode options for data dissemination via the Global Telecommunication System were also presented, in line with the GRUAN data policy, although at this stage it is too early to conclude on how data will best be transmitted. The GRUAN data policy states that quality checked data will be

made available no later than six months after collection, whereas individual sites might decide to release "enhanced" or "experimental" data after initial quality control so that various groups could exercise the data, identify problems, and provide feedback to the measurement and science community.

Participants were satisfied with the general approach taken by the Lead Centre. The need to formalize links between Lead Centre and NCDC and the ARM program was identified. Participants noted that SPARC/BADC have so far not been considered as partners and that they have experience in storing higher-temporal resolution in-situ vertical profile data that may prove invaluable (see action 11). A working proposal specifying all the details of data dissemination shall be prepared by interested parties (at least Lead Centre, NCDC and ARM) and considered at ICM-2 (see action 12).

## 6. Planned radiosonde intercomparison

The plans by WMO CIMO to perform an international radiosonde intercomparison campaign near Guangzhou (China) in 2010 were presented. Main goals are to:

- Test relative performance of main operational radiosonde types in subtropical conditions;
- Build working relationships between manufacturers and the operational and research communities;
- Support the choice of the best radiosonde types for use in GRUAN for the future;
- Foster good relationships with HMEI.

At this stage, more information from the manufacturers and participants on the scope of the intercomparison campaign is still needed to provide effective support for this project.

The Lead Centre and members of the Working Group showed very strong interest in participating in the campaign, which would be a self-funded activity. Meeting participants agreed to provide a list of potential participants in both the field campaign and the subsequent analysis (not necessarily the same individuals) to the WMO CIMO secretariat and the President of CIMO (see action 13). Furthermore, the Head of the Lead Centre was proposed to be formally involved in the organization of the campaign to cement links between CIMO and GRUAN activities. Participation of the remote sensing communities was also felt important, as well as good representation of manufacturers of research-type radiosondes (see action 14). John Nash indicated that CIMO would support the final results appearing in the peer-reviewed literature, if the GRUAN committee could provide the resource to make it happen as long as manufacturer confidentiality was ensured (see action 15).

Additional presentations covered the specifications for radiosondes that have been submitted to HMEI in September 2008, and first results of the LUAMI campaign. It was noted that the specifications document had elicited a formal announcement from Vaisala at the recent 2009 AMS annual meeting.

## 7. GRUAN manual of operations

An initial draft skeleton for a GRUAN manual of operations was presented by the GCOS secretariat, encompassing all elements that would eventually guide GRUAN sites in their day-to-day work in meeting GRUAN requirements. Relevant documentation by WMO programmes and other networks has been collated on a website[3], serving as a repository of information for the development of the manual.

Participants adopted the presented skeleton manual, noting that many items that would eventually be documented in the manual are yet to be developed for GRUAN (e.g., data dissemination strategy, cal/val strategy). A gap analysis based on the existing material was suggested, aiming at identifying the missing bits in current manuals that are specific to GRUAN. Additional resources were felt needed for that purpose, pending support by for example the US GCOS program or the WIGOS planning office. Lead Centre and GCOS secretariat agreed to pursue this item within their constraints in expertise and resources (see work plan action 16). Participants felt it important not to step ahead with defining a GRUAN manual of operations ahead of the necessary agreement among the GRUAN

[3] http://www.wmo.int/pages/prog/gcos/index.php?name=gruanmanuals

community over issues such as data dissemination and cal/val strategies. However, it was recognised that a manual will be required before any attempt to expand the network.

The meeting agreed that the nesting of GRUAN documentation into existing WMO manuals should be done in three phases, with precise timing being dependent upon progress in resolving the many operational issues that were agreed to remain:

- By ICM-2 (2010): Perform gap analysis (using draft manual and checklists in existing WMO manuals) and start filling them;
- By ICM-3 (2011): Finalize GRUAN manual of operations; report e.g. to WMO Cg-XV;
- By ICM-4 (2012): Incorporate GRUAN-specific elements into WMO Manual on the GOS.

## 8. GRUAN and WIGOS

After highlighting the important relationship between GRUAN and existing WMO global networks and general agreement that GRUAN should be the climate reference backbone of the existing GUAN, the discussion focused on the relationship between GRUAN and the pilot projects put forward in the framework of the WMO Integrated Global Observing System (WIGOS). The experience of current WIGOS PPs was presented, noting that those were largely building on activities planned by the groups in charge anyway, and focusing on areas where interaction with WMO technical commissions and the secretariat was particularly relevant. The risk of 'failure' of the PP was considered small, given that the WG has complete control over the formulation of the PP proposal, and that the PP milestones can be re-evaluated at any point in time.

Participants agreed that GRUAN, or part thereof, should be designated a WIGOS PP. Details of the project proposal have to be worked out, largely in conjunction with the development of a GRUAN long-term implementation plan. All or part of the GRUAN IP should be submitted as a WIGOS-PP in June 09 at the latest, being mindful to minimise chance of fail and maximise benefits (see action 17).

Being a WIGOS-PP was felt to be useful as it would provide a vehicle to focus activities and get them done. There was also felt to be the potential for some resources from WMO for meetings and help with documentation. It also raises the profile of GRUAN within WMO and particularly the WMO commissions. There is an inevitable overhead involved in reporting, but John Nash, who is chair of the WMO EC Expert Team on WIGOS, assured participants that this was likely to be fairly minimal and that current reporting practices may largely suffice. There will be an additional relatively small overhead on WG-ARO chair and / or head of Lead Centre in formal in-person reporting, but this can be combined with discussions with GCOS secretariat and the WIGOS Planning Office at WMO to maximise value.

## 9. Forthcoming meetings /activities of interest

- 8th Int'l Symposium on Tropospheric Profiling: integration of needs, technologies and applications 18-23 October 2009, Delft, The Netherlands www.istp2009.nl

- Earth System Research Lab Boulder, Global Monitoring Annual Conference – 21st century challenges for long-term monitoring, 13-14 May 2009

- (Gardiner) WMO-BIPM workshop: Metrology requirements for measuring climate change – scheduled for March 2010

- (June) Proposed townhall meetings on GRUAN as a way to increase visibility; EGU; AMS, AGU

- (Immler) EGU April: poster on GRUAN

## 10. Next meeting

It was agreed [after formal closure of the session] to hold the ICM-2 meeting in Switzerland at the MeteoSwiss Payerne site on 1-3 March 2010. Meeting organizers were agreed to be the WG chair, GCOS secretariat, the Head of the Lead Centre and nominees from the host site. It was agreed that the WG would meet in advance of the meeting. It was also agreed to scope the meeting to two and a half days leaving the last afternoon for teams who had actions assigned to start working on these face to face.

## 11. GRUAN Work Plan

| No | Action | Deadline | Who |
|---|---|---|---|
| 1 | Dialogue with satellite community (GSICS), e.g. on needs / sponsoring for additional radiosonde launchings | Continuous | Mitch Goldberg (RSSC/CM), GCOS secretariat |
| 2 | Develop definition for optimal GRUAN site to decide on future sites (optimal location/climate zone, institution etc.) | Jan 2011 | WG-ARO, Lead Centre |
| 3 | Write a GRUAN implementation plan, reaching out until at least 2013 | June 2009 | Peter Thorne (lead), Holger Vömel, Franz Berger, Doug Sisterson, John Dykema, Belay Demoz, Stephan Bojinski, with subsequent review by WG-ARO and Lead Centre |
| 4 | Develop a common GRUAN definition and terminology for measurement uncertainty and stability. A guide that ensures the quality of all GRUAN measurements (including a common definition of terminology (accuracy, stability, uncertainty etc.)) | 31 July 2009 | Franz Immler (lead), John Dykema, Tom Gardiner |
| 5 | Develop a case study for such a guide focussing on in-situ observations | ICM-2 | Lead Centre |
| 6 | Prepare a position paper on a process to manage change and optimize intercomparisons at GRUAN sites | ICM-2 | Lead Centre (lead), WG |
| 7 | Establish and maintain an inventory of GRUAN sites using a common template | October 2009 | Lead Centre |
| 8 | Address immediate questions by sites | May 2009 | Lead Centre (lead), with help from WG, Secretariat |
| 9 | Develop a communication platform for the GRUAN community (blog, wiki, FAQ, other?) | ICM-2 | Lead Centre (lead), WG, sites |
| 10 | Paper on collocation issue from the satellite perspective | ICM-2 | Chris Barnet |
| 11 | Formalize links between Lead Centre and NCDC, ARM program regarding data dissemination, investigate value of NDACC / BADC involvement for high-res in-situ | ICM-2 | Lead Centre (lead), WG, NCDC, ARM |
| 12 | Develop proposal to define data dissemination among all GRUAN partners | ICM-2 | Lead Centre (lead), ARM, NCDC, WG, sites? |

| | | | |
|---|---|---|---|
| 13 | Provide a list of technically competent potential participants (2-3) in 2010 CIMO intercomparison campaign in China to CIMO Secretariat; Head of LC to be formally involved in the organization of the campaign | August 2009 | WG |
| 14 | Foster participation of research radiosondes in CIMO intercomparison campaign | | WG (lead), Lead Centre |
| 15 | Nominate members on expert team analyzing results from CIMO intercomparison campaign | September 2009 | WG |
| 16 | Perform gap analysis on existing documentation (manuals) vis-a-vis the adopted skeletal GRUAN manual of operation, and provide a summary document of where these gaps are. | ICM-2, if funding can be made available. | Lead Centre (lead), Secretariat (from WIGOS PP resources?), WG, sites |
| 17 | Submit proposal for WIGOS-PP in conjunction with development of GRUAN IP | June 2009 | WG (decision), Lead Centre, Secretariat |

## Actions in GCOS-121 closed / superseded:

| **Action** | **Who** | **Deadline** | **Comment** |
|---|---|---|---|
| (3) Develop a strategy for detecting change in the measurement quality at GRUAN site, such as periodic intercomparison between instruments as often as possible at suitable intervals at each selected GRUAN sites | Lead Centre (all sites), NMIs | Continuous | New action 6 |
| (4) Organize major intercomparison of operational and research radiosondes to choose which can qualify for use in the GRUAN network. | Lead Centre, GCOS, CIMO, scientific community; WG (collect all available data, reports and papers) | 2010 and thereafter on a regular 5 year interval | New actions 13, 14, 15 |
| (5) First draft of manual / guidelines for GRUAN observations (assuring comparability, spreading best practices, sharing lessons, reporting) | Lead Centre and initial sites in collaboration with WG-ARO, CIMO, CBS | April 2009 | Done (ICM-1/doc 7.1) |
| (6) Invite initial candidate stations to become GRUAN stations | GCOS Secretariat following AOPC and consultation with CBS | September 2008 | Done (ICM-1/doc. 4.0) |
| (7) Develop a matrix/spreadsheet with criteria for initial and potential sites | Lead Centre | September 2008 | New Action 7 |
| (9) Establish data policy | Lead Centre and initial sites, WG-ARO, GCOS Secretariat, AOPC | September 2008 | Done (ICM-1/doc. 5.0) |
| (10) Consider various options on data dissemination | Lead Centre, NOAA, ARM, WG-ARO | Summer 2008 | Done (ICM-1/doc. 5.1); New Actions 11, 12 |
| (11) Devise data dissemination practices (model, format, metadata, monitoring of usage) | ARM / Lead Centre / WG-ARO, help from many | 2009 | New Actions 11, 12 |

*(Intentionally blank)*

## Appendix 1 Agenda

| Time | Item | Doc. No. | Presenter(s) |
|---|---|---|---|
| **Monday 2 March** | | | |
| **8.00 Departure of shuttle bus from the hotel** | | | |
| | | | |
| **8.30 – 9.00** | **1. Welcome and logistics** | | **Chair: Peter Lamb** |
| 8.30 – 8.35 | 1.1 Adoption of agenda | 1.1 | |
| 8.35 – 8.45 | 1.2 Welcome from CIMMS | | Randy Peppler, Peter Lamb |
| 8.45 – 8.50 | 1.3 Logistics | 1.3 | Randy Peppler, Tracy Reinke |
| 8.50 – 9.00 | 1.4 The ARM program and GRUAN | | Wanda Ferrell, ARM program director |
| **9.00 – 10.15** | **2. Assessment of progress against action plan from GCOS-121, and int'l linkages** | 2.0 | **Chair: Ells Dutton** |
| ***Session aims***: To assess progress in GRUAN implementation since February 2008 | | | |
| 9.00 – 9.40 | 2.1 Brief overview of lead centre progress in addressing the 12 action items in GCOS-121 | 2.1 | Lead Centre staff |
| 9.40 – 9.45 | 2.2 Recommendations by GCOS, WMO and other int'l bodies regarding GRUAN implementation | 2.2 | Peter Thorne |
| 9.45 – 10.15 | 2.3 Discussion | | |
| | | | |
| 10.15 – 10.30 | *Coffee* | | |
| | | | |
| **10:30-17:30** | **3. How should we actually make GRUAN measurements?** | 3.0 | **Chair: Doug Sisterson** |
| ***Session aims****:* To provide a generic set of actual requirements (NOT instrument specific) that any given observation must meet to be considered a GRUAN observation, and to provide a way forward to assess the quality of these observations. | | | |
| 10.30 – 12.00 | 3.1 What final GRUAN observations may consist of and look like (raw data, metadata, uncertainty estimate) | 3.1 | Holger Vömel |
| 12.00 – 13.00 | *Lunch* | | |
| | | | |
| 13.00 – 14.00 | 3.2 Pre-deployment cal-val (what we need to understand for any instrument before deployment in the field as a potential GRUAN instrument) | 3.2 | Tom Gardiner |
| 14.00 – 15.00 | 3.3 Routine cal-val (things we need to do periodically in the field to ensure we are not drifting) | 3.3 | John Dykema |
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| 15.00 – 15.30 | *Coffee* | | |
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| 15.30 – 16.30 | 3.4 Cross-checking against other measurement technologies / data to constrain uncertainty | | Jimmy Voyles |
| 16.30 – 17.30 | 3.5 The NDACC Working Group Structure (The idea of instigating variable expert teams to assist in this effort) | 3.5 | Mike Kurylo |
| | | | |
| 18.30 – 19.30 | *Reception* | | |
| 19.30 - | *Working Group dinner / discussion of general issues (self-funded)* | | |
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| **Tuesday 3 March** | | | |
| **8.00 Departure of shuttle bus from the hotel** | | | |
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| **8.30 – 10.00** | **4. Sites reports and discussion of status of network and composition** | 4.0 | **Chair: Stephan Bojinski** |
| ***Session aims***: To afford candidate sites to provide their perspectives, thoughts, and update on their status for the consideration of all workshop participants.<br><br><u>Questions to be addressed by all sites:</u><br>1. Operations:<br>a) What is the site status in respect of the requirements outlined in GCOS-121 and GCOS-112 (priority 1 and 2)?<br>b) Which guidelines/manuals do you use when taking measurements, if any?<br>c) What is your data dissemination practice?<br>2. Needs: What do you need from lead centre / working group / secretariat?<br>3. News: Are there any scientific or organizational developments we should be aware of? | | | |
| 8.30 – 8.40 | 4.1 Howard University - Beltsville, MD, USA | 4.1 | Belay Demoz, David Whiteman |
| 8.40 – 8.50 | 4.2 NOAA, NCAR – Boulder, CO, USA | | June Wang, Samuel Oltmans, Dale Hurst |
| 8.50 - 9.00 | 4.3 ARM Climate Research Facilities – Barrow, AK, USA; Darwin, Australia; Lamont, OK, USA; Nauru , Republic of Nauru | | Doug Sisterson |
| 9.00 – 9.10 | 4.4 Netherlands - Cabauw | 4.4 | Reinout Boers |
| 9.10 – 9.20 | 4.5 New Zealand - Lauder | 4.5 | Paul Johnston |
| 9.20 – 9.30 | 4.6 Switzerland - Payerne | 4.6 | Rolf Philipona |
| 9.30 – 9.40 | 4.7 Italy - Potenza | 4.7 | Vicenzo Cuomo |
| 9.40 – 9.50 | 4.8 Finland - Sodankylä | | Esko Kyrö, Rigel Kivi |
| 9.50 – 10.00 | 4.9 China - Xilinhot | | Kejun Wu, Yi Xiong |
| 10.00 – 10.10 | 4.10 Wrap-up & Conclusions | | |
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| **10.15 – 18.00** | **Site visit to ACRF** | | |
| 19.30 - | *Conference dinner (self-funded)* | | |
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| **Wednesday 4 March** | | | |
| **8.00 Departure of shuttle bus from the hotel** | | | |
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| **8.30 – 10.00** | **5. Data dissemination and data policy** | 5.0 | **Chair: John Dykema** |
| ***Session aims****:* To discuss in detail data dissemination models to consider, progress in exploring the offer of in-kind support from DoE and NOAA and to inform a push towards resolving this issue. | | | |
| 8.30 – 9.00 | 5.1 Outline of progress to date | 5.1 | Michael Sommer |
| 9.00 – 9.15 | 5.2 ARM program input | | Doug Sisterson, J. Voyles |
| 9.15 – 9.30 | 5.3 NCDC input | | Russ Vose |
| 9.30 – 9.35 | 5.4 WMO Information Systems perspective | 5.4 | GCOS Secretariat |
| 9.35 – 10.00 | 5.5 Discussion | | |
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| 10.00 – 10.15 | *Coffee* | | |
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| **10.15 – 11.30** | **6. Discussion on preparations towards planned radiosonde intercomparison** | 6.0 | **Chair: Dian Seidel** |
| ***Session aims****:* To update on preparations for an envisaged major intercomparison between both operational and candidate reference radiosondes in 2010. | | | |
| 10.15 – 10.30 | 6.1 Perspective | | John Nash |
| 10.30 – 10.40 | 6.2 Overview of radiosonde requirements document supplied to HMEI | 6.2 | Masatomo Fujiwara |
| 10.40 – 10.50 | 6.3 The LUAMI test-campaign | 6.3 | Franz Immler |
| 10.50 – 11.30 | 6.4 Discussion | | |
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| **11.30 – 12.30** | **7. Observing manual discussion** | | **Chair: Franz Berger** |
| ***Session aims**:* To discuss progress to date on collating existing observational manual literature, on the planned structure and on the optimal method of development of a final observing manual. | | | |
| 11.30 – 11.50 | 7.1 Current manual draft | 7.1 | GCOS Secretariat |
| 11.50 – 12.10 | 7.2 Lead Centre view | | Holger Vömel |
| 12.10 – 12.30 | 7.3 WMO Perspective | 7.3 | John Nash, M. Ondras |
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| 12.30 – 13.30 | *Lunch* | | |
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| **13.30 – 15.00** | **8. Should GRUAN become a WIGOS-PP project?** | | **Chair: Howard Diamond** |
| ***Session aims**:* It has been suggested that GRUAN become a WIGOS (WMO Integrated Global Observing Systems) PP (Pilot Project) either in part or in full. This session aims to engender discussion and a decision to this end. | | | |
| 13.30 – 13.40 | 8.1 GRUAN and the WMO Observing Systems | 8.1 | GCOS Secretariat |
| 13.40 – 14.10 | 8.2 What is WIGOS, what is a WIGOS-PP and why should GRUAN be one? | 8.2 | James Purdom (by phone) |
| 14.10 – 14.25 | 8.3 Experiences from current WIGOS PP projects – benefits and potential draw backs | 8.3 | John Nash, Miroslav Ondras |
| 14.25 – 15.00 | 8.4 Discussion of whether GRUAN should be a WIGOS-PP. | | |
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| 15.00 – 15.15 | *Coffee* | | |
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| **15.15 – 15.30** | **9. Forthcoming meetings / activities of interest** | | **Chair: Peter Thorne** |
| | 9.1 International Symposium on Tropospheric Profiling | | Reinout Boers |
| | 9.2 Opportunities for others to raise important meetings / activities to discuss how to ensure GRUAN is adequately represented | | |
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| **15.30 – 17.00** | **10. Wrap up and agreement on action items arising** | | **Chair: Peter Thorne** |
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# Appendix 2 Lead Centre Report 08/2008 – 01/2009

The main item of progress for the past reporting period is the completion of the Lindenberg Upper Air Methods Intercomparison (LUAMI) campaign, which provided a number of lessons that will be included in the setup of GRUAN. This campaign brought together several radiosonde manufacturers (Vaisala, Graw, Meteolabor, Intermet South Africa) as well as a number of different research groups (ETH Zuerich, observatory Payerne, Central Aerological Observatory Moscow and and Lindenberg observatory, for the sounding portion and Lindenberg observatory, DLR, FZK Garmisch, and De Bilt for additional lidar observations) to intercompare a number of instruments either in situ or at different sites. In addition to the scientific and technological results, this campaign served as training ground for the lead centre staff and provided a first experience in handling an inhomogeneous data set from different stations and different instruments. These experiences contribute to the development of the data processing and data flow strategy that is being investigated at the lead centre.
The lead centre has set up a web site (www.gruan.org), which is hosted at the German Weather Service (www.dwd.de/gruan). This site will be used as tool for communication and exchange of information with the GRUAN community, the scientific community and the general public.
A focus on vertically resolved measurement uncertainties is expected to address some of the unresolved problems that impact the start up of the GRUAN network. (See details below)

| **Objective and due date** | **Summary of progress** |
|---|---|
| 1. Evaluate the radiation correction for the temperature measurement of each radiosonde. | The radiation correction is the main source of uncertainty for temperature measurements. Experiments at the Lead Center have measured the radiation effect on the RS-92 temperature sensor (as well as the humidity sensor). Model calculations of the radiation transfer indicate that the cloud albedo plays a crucial part in the radiation error. Based on these studies the uncertainty of the radiation correction can be established for this particular sensor. Stations, with the support by the lead centre, will need to address this issue, once their observation program is in place. A comparison of the different methods of radiation correction and the calculation of the corresponding uncertainty is in preparation and will be discussed in an upcoming LUAMI workshop. |
| 3. Develop a strategy for detecting change in the measurement quality at GRUAN site, such as periodic intercomparison between instruments as often as possible at suitable intervals at each selected GRUAN sites | The lead centre promotes an advanced data analysis scheme, which will provide not only the measured quantity, but also the best estimate of the vertically resolved measurement uncertainty (quality quantification). This additional piece of information is expected to provide the key metric in instrument intercomparisons and should allow a quantification of changes to be expected through changes in instrumentation. A lot of additional work is required in establishing vertically resolved uncertainties, since this has not yet been done in disposable sounding equipment.<br>Another important piece for insuring long term stability and high quality of the record is the documentation and publication of all processing steps. For this GRUAN will archive the most basic data produced by the instruments. All correction and evaluation procedures that apply to data in order to calculate the final product should be documented and published. This allows a homogenization of data at any time if inconsistencies are detected at a later stage. |
| 4. Organize major intercomparison of operational and research radiosondes to choose which can qualify for use in the GRUAN network. | LUAMI served as test bed for a large major intercomparison for GRUAN. The experiences learned here will contribute to future intercomparisons. |
| 5. First draft of manual / guidelines for GRUAN observations (assuring comparability, spreading best | A first draft of a manual for GRUAN observations and guidelines has been prepared by the GCOS secretariat. A revision of this draft based on the experiences of the routine |

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| practices, sharing lessons, reporting) | operations at Lindenberg and those gathered during LUAMI is pending. Discussions at the workshop are expected to contribute strongly to the manual draft. |
| 7. Develop a matrix/spreadsheet with criteria for initial and potential sites | No action yet taken. A solution of the instrument question is needed before a criteria matrix can be established. The experiences of the initial sites will be a key contribution to the development of future sites. |
| 9. Establish data policy | Data policy has been agreed upon and is established. |
| 10 Consider various options on data dissemination | The lead centre has developed a strategy for data dissemination, which will be discussed at the upcoming 1st Implementation-Coordination Meeting |
| 11 Devise data dissemination practices (model, format, metadata, monitoring of usage) | See point 10 |

**Other achievements**

Two flights of the DLR Falcon (coordinated by DLR) over the sites at Zugspitze, Payerne, De Bilt (Cabauw), and Lindenberg as part of LUAMI, showed that an airborne lidar system can be used as transfer standard for profiling observations of water vapor between different stations. Timing at all sites was nearly perfect. In addition the aircraft trajectory considered the balloon trajectory at Lindenberg to minimize spatial inhomogeneities. The analysis of these data is ongoing.

In addition to the routine observations the Lindenberg observatory has started regular reference radiosoundings that will serve as the nucleus of GRUAN observations. Once a month, a payload that includes CFH, SnowWhite and RS90/92 FN sensors is launched. FLASH soundings may be launched in addition as they become available.

**Lead Centre operations**

Marion Fiedler will be on maternity leave beginning in June 2009 and the lead centre staff will be temporarily reduced by one person. This will impact some of the support functions within the lead centre but it is not expected to cause any scientific impact. Funding and positions are secure.

**Issues arising for WG discussion and feedback to the lead centre**

The requirements of GCOS 121 about which sonde technology may be used for GRUAN require careful consideration. For UT/LS observations of water vapor, only two instruments are available (FLASH and CFH); however, neither is available at a larger scale. Other technology for stratospheric work is not in sight. The requirement of GCOS 121 to launch the best technology available at a site continues to create some confusion, since currently no metric exists to quantify what the “best technology available at a site” is (quality quantification). Thus the lead centre recommends that the major criterion of an observational method for GRUAN may be the complete analysis of its uncertainty budget. This will allow establishing vertically resolved error bars for all measurement parameters. The advantages of this approach are:

- A better insight into the quality of each sensor.
- A metric against which to evaluate sensor comparisons
- An indication for where critical weaknesses of sensors lie
- A metric to compare the performance of different sensors at different stations
- Information up to which altitude a quantity can be used (in particular water vapor), depending on application
- Documentation of known sources of uncertainty, which is currently not available

This task will take considerable work, which will be shared among the different stations and manufacturers involved in GRUAN.

Vaisala has announced an initiative to build a reference radiosonde. Towards this end, Vaisala tested a new humidity sensor (APS) during LUAMI. This move is appreciated and welcome, combined with the hope that other manufacturers start similar efforts. To enable a broader industrial support a common and open interface protocol for external instruments to be used on radiosondes should be promoted. This interface should allow sensor manufacturers to provide (possibly superior) sensors, which could be used on routine radiosondes used in GRUAN. This would be in the interest of GRUAN since sensors could be intercompared at different sites without the need to intercompare the entire radiosonde system at the sites involved. A common protocol shared between all manufacturers will also strengthen research in that field and provide a wider base for observational technologies. This would ultimately strengthen the manufacturers as well.

**Risk register**

**Work plan for next six months**

- 1st implementation coordination meeting
  March 2-4. Combined with additional work at Beltsville
- Establishing recommended ground measurements for sonde launches
- Start of observations at the different sites
  We expect that sites can start producing the first data under the GRUAN label. Additional work, such as added ground checks, theoretical studies and adaptation of software will be ongoing.
- Implementation of the data processing scheme
  Data processing will commence according to the agreements at the workshop
- Implementation of data dissemination scheme
  Data dissemination will commence according to the agreements at the workshop
- Implementation of uncertainty analysis scheme
- Preparation of LUAMI workshop

# Appendix 3 List of Participants

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# Appendix 4 List of Acronyms

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

# LIST OF GCOS PUBLICATIONS* (2008-2009)

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|---|---|
| **GCOS-117**<br>(WMO/TD-No. 1418) | Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report (4-6 October 2007) |
| **GCOS-118**<br>(WMO/TD-No. 1421) | Summary Report of the Tenth Session of the GTOS/GCOS Terrestrial Observation Panel for Climate (Rome, Italy, 15-16 November 2007) |
| **GCOS-119**<br>(WMO/TD-No. 1424) | Report of the Implementation Strategy Meeting for Central America and the Caribbean (Belize City, 28-30 January 2008) |
| **GCOS-120**<br>(GOOS-No. ) | Report on the Meeting of "IOC Group of Experts on the Global Sea Level Observing System (GLOSS), tenth session (Paris, France, 6-8 June 2007) |
| **GCOS-121**<br>(WMO/TD-No. 1435) | GCOS Reference Upper Air Network (GRUAN). Report of the GRUAN Implementation Meeting (Lindenberg, Germany, 26-28 February 2008) |
| **GCOS-122**<br>(WCRP 9/2008)<br>(WMO/TD-No. 1436) | Fourteenth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC-XIV) – Conclusions and Recommendations (Geneva, Switzerland, 21-25 April 2008) |
| **GCOS-123**<br>(WMO/TD-No. 1444) | Report of the Fourth Meeting of the GCOS Cooperation Board (Bonn, Germany, 12 June 2008) |
| **GCOS-124**<br>(WMO/TD-No. 1463) | Report of the Sixteenth Session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Geneva, Switzerland, 14-17 October 2008) |
| **GCOS 125**<br>(WCRP) | Report of the WOAP-III Meeting (Boulder, CO, USA, 29 September to 1 October 2008) |
| **GCOS-126**<br>(WMO/TD No. 1464) | GCOS Annual Report 2007-2008 |
| **GCOS-127**<br>(WMO/TD No. 1477) | Practical Help for Compiling CLIMAT Reports |
| **GCOS-128**<br>(WMO/TD No. 1488) | Guidelines for the Generation of Satellite-based Datasets and Products Meeting GCOS Requirements (GCOS Secretariat, March 2009) |
| **GCOS-129**<br>(WMO/TD No. 1489) | Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008 |
| **GCOS-130**<br>(WMO/TD No. 1490) | Synthesis of National Report on Systematic Observation for Climate |
| **GCOS-131**<br>(WMO/TD No. 1492) | Report of the First GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-1) (Oklahoma City, USA, 2-4 March 2009) |

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