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GCOS Reference Upper Air Network (GRUAN)

Report of the GRUAN Implementation Meeting

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Chairperson, Publications Board
World Meteorological Organization (WMO)
7 *bis*, avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0)22 730 84 03
Fax: +41 (0)22 730 80 40
E-mail: Publications@wmo.int

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INTRODUCTION

The Meeting on Implementation of the GCOS Reference Upper Air Network (GRUAN) was hosted by the German Meteorological Service (DWD), at the Richard Aßmann Observatory in Lindenberg, recently designated by WMO as the Lead Centre for the GRUAN network. The objective of the meeting, headlined "**Start small, but start**", was to develop a work plan for the GRUAN Lead Centre and other interested parties that:

- Identifies and addresses remaining scientific and technical issues;
- Ensures observations are being made in a manner consistent with the stated GRUAN requirements henceforth at a number of initial sites; and
- Informs priorities for the GCOS Working Group on Atmospheric Reference Observations.

This report is mainly focusing on the results of discussions at the meeting. The presentations given at the meeting are available on the DWD website at http://metportal.dwd.de/mol.

It should be stressed that the meeting included the representation of a broad range of perspectives and that this report primarily attempts to summarize consensus positions where these were reached. Where they were not, the range of opinions is attempted to be briefly captured. This report should not be interpreted as representing the views of any of the individual participants.

The report "GCOS Reference Upper-Air Network (GRUAN): Justifications, requirements, siting and instrumentation options" (GCOS-112, WMO/TD No. 1379), summarizing the two previous workshops in Boulder and Seattle, serves as a basis for this report and should be read in conjunction with it to provide the necessary context. It should be noted that when deciding upon the format of the requirements tables in GCOS-112 there was much discussion about "objective" and "break-through" criteria, as exists in most NWP-derived requirements tables. The decision was reached that the final tables were only to consist of an objective threshold that was the desired final measuring precision to answer relevant climate questions. The idea *was not* that measurements at these specifications would be possible from initiation of the GRUAN network operation. Rather the hope was that providing a single objective would spur the manufacture of instruments to meet the scientific requirements in a timely fashion.

Following the meeting in Lindenberg the Working Group has submitted an article about GCOS Reference Upper Air Network in the *Bulletin of the American Meteorological Society*, providing an outline of the rationale, progress and plans for the implementation of the network to the wider scientific community and inviting feedback and active participation [2].

ACKNOWLEDGEMENTS

The participants of the Meeting on Implementation of the GCOS Reference Upper Air Network (GRUAN) are most grateful to the German Meteorological Service (DWD) for hosting this meeting at the Richard-Aßmann Observatory in Lindenberg. Funding for the meeting was provided by the National Oceanic and Atmospheric Administration (NOAA) and the Global Climate Observing System (GCOS) Secretariat.

1. UPPER AIR INSTRUMENTATION AND OBSERVING PRACTICES

Radiosonde Instrumentation

Discussions in the meeting centred on the development and/or use of a reference radiosonde(s). We define a reference radiosonde here as a single instrument or combination of instruments which, launched on a regular basis, would be capable of achieving the stated requirements in GCOS-112 for temperature, humidity, and direct or indirect measurement of pressure. It was clear from the workshop discussions that at the moment there is no such operational reference radiosonde available on the market. The technical challenges in the development of such a radiosonde should not be under-estimated and clearly must form a focus of future work if GRUAN is to be successful.

However, the technology of radiosonde measurements has improved substantially during recent years, partly as a response to CIMO intercomparisons. For temperature and pressure it is very likely that standard production radiosondes or a combination of such instruments can meet the stated requirements. At the moment temperatures reported by best radiosondes available differ within 0.3 K under most conditions. The accuracy is mainly dependent on the radiation bias. The radiation correction for the radiosondes used in the GRUAN network should be evaluated at each GRUAN site, with help from the Lead Centre (see action item 1). However, the main challenge is to meet the long-term stability requirements for temperature measurements (0.05 K).

Water vapour in the Upper Troposphere and Lower Stratosphere (UT/LS) is the hardest challenge, and routine observations at the moment are not even close to the requirements given in GCOS-112, especially in the tropical upper troposphere. All mass production humidity sensors deliver biased data for moisture in the upper troposphere, if they even record any humidity tendency data there at all. There are some research radiosondes that show much greater promise in this region such as CAO Lyman-alpha FLASH-B hygrometer [3, 4], which measures water vapour in the upper troposphere and lower stratosphere at night time, Cryogenic Frostpoint Hygrometer (CFH) [5], which measures water vapour from the surface to the middle stratosphere, and Snow White chilled-mirror hygrometer [6,7], which can measure water vapour up to the upper troposphere.

- The FLASH-B sonde has taken part in intercomparisons at Sodankylä (Finland), in Costa Rica and in Indonesia. The main problems are that the sonde can only be operated in the dark and during descent. The calibration procedure of the FLASH-B sonde is similar to the one of the FISH hygrometers [4, 8].
- The CFH is launched world wide on campaign basis for validation and scientific studies, but the measurement of temperature and pressure is based on Vaisala RS80, which is no longer in production. Interfacing with other radiosondes as replacement of the RS80 is currently underway and will be completed in the near future.
- The current version of Snow White chilled-mirror hygrometer of Meteolabor is usable from the surface up to the upper tropopause, but the accuracy is known to decline at upper levels. It has not yet been possible to ascertain where this transition region is. To avoid this problem, the FLASH-B has been flown with a Meteolabor SRS-C34 radiosonde including the night-type Snow White at the Payerne (Switzerland) site. Snow White measures humidity accurately from the surface up to the tropopause, while FLASH-B measures humidity in the stratosphere, with some overlaps around the tropopause region with an "in-flight" comparison (or validation of FLASH-B). The price of this system is about twice the CFH system.

The uncertainty for measurements of water vapour in the UT/LS is large and poorly understood, even at long-running, high-quality research sites like Boulder. As outlined in GCOS-112, the proportion of water vapour in the upper troposphere is radiatively important, and through GRUAN, there is hope to get this information to be able to verify climate models.

In conclusion, meeting participants agreed that routine launching of a reference radiosonde, whatever its design, is not currently feasible. More effort is urgently required towards the production of a reference sonde capable of being flown on a routine basis. The meeting participants encouraged manufacturers and scientists to work quickly towards the development of such a reference sonde. However, it was recognized that GRUAN needs to begin a reference quality measurement programme in a unique way not currently included in GUAN measurements and that is affordable to candidate stations. The implications of the lack of a reference radiosonde that can meet specified requirements in terms of initial site operation are discussed later in this section.

Radiosonde Launch Schedule

Most of the presentations and points raised during the discussions argued that a simultaneous launch with the overpass of a satellite is not possible, because of the spatial and temporal difference of radiosonde and satellite measurements. The satellite overpass is instantaneous overpass, whereas the sounding takes about 90 minutes to two hours and drifts considerably in latitude and longitude.

The meeting participants agreed to start communications with satellite agencies, for example through the Global Space-Based Inter-Calibration System (GSICS), to evaluate interest by the satellite community in sponsorship of additional flights on a “pay-per-flight” basis (see action item 2). No routine launches for overpasses of satellites are planned for the initial phase of GRUAN, however the issue of launch schedules has still not been unambiguously closed (see section 7, B).

Radiosonde Site Requirements

The minimum criteria for a GRUAN site are outlined in GCOS-112 (p. 9-10). During the meeting it was clearly pointed out to the participants that the minimum criteria for the simultaneous balloon-based observations of temperature, water vapour, pressure and winds, both on ascent and descent, are not stipulated in the report as to frequency of measurements.

As an interim measure, until an operational reference sonde becomes available, tiered levels of radiosonde launches, or a ‘cascade’ of launches, was proposed to ensure both inter-station comparability and long-term continuity of the climate record. The GRUAN sites should implement the different levels/tiers of observations step by step using the following measurement protocols:

1. 1 x weekly production radiosonde with the best technology currently available at the site;
2. 1 x monthly radiosonde capable of capturing moisture signal in the UT/LS and all other priority 1 variables to the best level possible with current technology, launched together with weekly radiosonde;
3. Regular 00 and 12 LST (as a preference over UTC)[1] launches of a production radiosonde with best technology currently available;

[1] The final decision about UTC or LST was not taken at the Meeting. Based on discussions at the AOPC at its XIVth Session, 21-25 April 2008, it is recommended that radiosonde schedules at GRUAN sites be made at Local Solar Time (LST), but recognized that local operational constraints may lead to other launch schedules at some stations, which should not preclude these stations from being designated as GRUAN stations [9].

4. Dual launches of sondes with highest quality humidity sensing capability in the UT/LS (flying the monthly radiosonde together with a second sonde also capable of measuring water vapour in the UT/LS) [added by WG-ARO after formal workshop close); and
5. Periodic intercomparisons of a large range of sonde types.

Only the first two tiers/criteria were decided to be needed to be met at the initiation of a GRUAN site, with the remainder being seen as desirable activities that should be aimed for.

No specific instrument or manufacturer is stipulated for any of these measurements. It goes without saying that more frequent monitoring, particularly of the UT/LS moisture signal would be highly desirable if it proves affordable. These are pragmatic minimum requirements that should serve the scientific purpose whilst being designed to ensure that they are technologically, financially and technically feasible at the present time by a number of sites. These sites include a number where routine radiosondes are not currently launched, but which have a rich variety of ground-based sensing equipment, hence the requirement for routine twice-daily observations being optional.

In order to ensure the quality of observations periodic intercomparisons between instrumentation used at all the sites will take place and are encouraged to be undertaken as often as possible at individual sites (see action item 3). The WG-ARO and Lead Centre will collaborate with CIMO and the scientific community in making such periodic intercomparisons of a large range of sonde types and in analyzing existing comparisons made by scientific or operational users.

Reassessing Radiosonde Guidance

It was proposed that a major intercomparison be held under the auspices of GCOS and CIMO, managed by the WG-ARO and Lead Centre, at one or more GRUAN or other appropriate sites to try to ascertain a best set of instrumentation and practices specifically for GRUAN operations in 2010 and that this should involve both operational production and research sondes (see action 4).

Following this exercise, and based upon the lessons learnt from such an intensive intercomparison, the operational experiences of and data from the sites to that time, and any other pertinent research findings by the scientific community, guidance on radiosonde instrumentation will then be very substantially modified by the WG-ARO and Lead Centre in consultation with other parties. This will hopefully bring about a more final resolution of the issues prior to network expansion so that new sites will know what exactly they are signing up to. A key aspect will be to manage the transition at existing sites between the interim operations procedure and any new procedure in such a way as to maintain the long-term climate signal.

2. GROUND-BASED INSTRUMENTATION AND OBSERVING PRACTICES

Meeting participants raised the following needs for the ground-based instrumentation requirements at a GRUAN site:

- Definition of best practices and/or a workshop to define a priority list of additional ground-based instrumentation (priority 2) and recommendations for a set of ground-based instrumentation types
- Development of guidelines and procedures for the observing practices to ensure standardization, comparability and high-quality of measurements at all sites

The meeting participants agreed with the minimum set of ground-based instrumentation defined by the previous two workshops (GCOS-112, priority 1), namely to have a ground-based GPS receiver to measure total column water vapour (GPS PW) at each GRUAN site.

The list for additional ground-based instruments (GCOS-112, priority 2) encompasses six instruments: surface radiation instruments, microwave radiometer, multi-channel infrared radiometer (e.g. FTIR), Lidar (e.g. Raman Lidar), integrated trace gas measurements and sun photometer. The cloud radar may also be useful as a basic instrument necessary to measure cloud structure. The instrumentation and measurements at BSRN sites already meet the GRUAN surface radiation specifications. A list of all BSRN stations which do not need further action with respect to this requirement is given in Appendix IV.

Participants argued for the need to define priorities on this list and to recommend certain instrumentation types. These could be achieved by a specific campaign or based on the best practices developed at the Lead Centre and other sites. The objective is to have a priority list of ground-based instruments at hand to be given as a recommendation to National Meteorological Services (NMSs) or research institutes establishing a GRUAN site (see section 7, C).

For the observing practices at the GRUAN sites, the development of a manual will be undertaken by the GRUAN Lead Centre in Lindenberg in collaboration with the WMO Commission for Basic Systems (CBS) and the WMO Commission for Instrumentation and Methods of Observations (CIMO), building upon available literature from these bodies.

The manual shall guarantee the standardization of measurements to assure the comparability and high quality of observations. The manual will define the accuracy and long-term stability for the measurements, but not the manufacturer of the instrument, in order to guarantee sustainability of observations and avoid restriction to one vendor. Best practices and lessons learned at the Lead Centre and the other initial sites shall be disseminated and guidelines for the reporting of data developed (see action item 5).

The manual on observing practices will form an important basis for the development of the GRUAN network. The experience from the GCOS Upper Air Network (GUAN) shows that the majority of the sites only fulfil the threshold requirements for observations given in the manual. Even if the reference network encompasses a much smaller number of sites, the requirements given in the manual are critical for the implementation of the network and communication to the site operators.

3. SITE SELECTION

A first (tentative) list of twelve initial candidate sites was selected, based on the list of stations named in the first GRUAN report, presentations held by meeting participants and discussions at the meeting. Gradual expansion of the network is foreseen, based on lessons learned from this initial selection of sites. Therefore an initial candidate site should have a rich variety of instrumentation, a long-standing resident expertise, and perspectives to bring to bear on the remaining scientific and technical issues that need to be addressed. At this stage, the GRUAN development is not directed towards having exact clone sites, as this reduces the chances of learning valuable lessons about the functioning of the network, especially as more challenging (politically, geographically, logistically, or economically) locations will be considered in the future.

It is proposed that the following initial sites be invited by WMO to become GRUAN stations, following review and consultation with the Atmospheric Observing Panel for Climate (AOPC) and the Commission on Basic Systems (CBS) in September 2008 (see action item 6):

- Darwin, Australia
- Xilin Hot, China
- Sodankylä, Finland
- Lindenberg, Germany
- Potenza, Italy
- Cabauw, Netherlands
- Lauder, New Zealand
- Payerne, Switzerland
- Barrow, USA
- Beltsville, USA
- Boulder, USA
- Lamont, USA

It should be reiterated that at this stage the primary aim is to use an initial set of high quality stations to refine the scientific and technical issues of paramount importance to a successful GRUAN network. Hence, the selection of further sites is not a high priority activity. This does not preclude discussions occurring with potential sites.

A list of all potential candidate sites and a map of all sites identified by the meeting participants is given in Appendix III. A detailed matrix listing criteria for each site (initial and potential) will be developed by the Lead Centre to provide a basis of information about the existing measurements at all sites (see action item 7). The criteria given in the matrix should include: priority 1 observations ongoing, priority 2 observations ongoing, climatic regime, science value, distance to radiosonde site, homogeneity of observations, site duplicate, infrastructure, nearby GUAN site, sustainability and institutional support, collocation with other networks. Appendix IV gives an overview of collocation of initial and potential GRUAN sites with GUAN, BSRN, NDACC, SHADOZ and GAW sites. In the larger sense, GRUAN would be incorporated into the WMO Integrated Global Observing Systems (WIGOS) framework.

4. DATA DISSEMINATION AND QUALITY CONTROL/QUALITY ASSURANCE

Quality Control/Quality Assurance

Before defining the Quality Control and Quality Assurance (QC/QA) procedures to be applied to the data, two fundamental questions have to be answered: who will be the customers/users of the data, and, how much time is available for the QC/QA procedures? The following communities are seen as possible end-users of GRUAN data: climate data analysis (detection and attribution), satellite algorithm testing, climate model testing and improvement, and as an anchor for reanalysis (a non-exhaustive list, see section 7, G).

The timeline for the access to GRUAN data needs to be defined. The representatives from other networks participating in the meeting have developed different approaches:

- ARM exchange of data in near-real time
- NDACC 1-2 years restricted access (depending on when data is submitted from the station to the archive), then public distribution
- CEOP six months for standard data, 15 months for enhanced or experimental data
- BSRN 1 year before data dissemination

The decision about the timeliness of data release will be considered in action item 9 and 10.

The dissemination in (near) real time should be considered for operational purposes and, if basic measurements are submitted in the (near) real time, the QC/QA software used for

operational monitoring of radiosondes' data should be used. This will also facilitate the QC link with GRUAN/GUAN and other stations.

The argument that if a multiple-sensor radiosonde flight be used by GRUAN an intercomparison between remaining instruments would not be necessary was rejected by the meeting participants, because a relative basis for comparison would still be necessary. For the intercomparison between GRUAN stations the following possibilities were discussed to estimate the uncertainties:

- **Audits**
  where a team of auditors comes to a site to observe the measurements and check that the appropriate quality controls and procedures are being followed. If appropriate, the audit team may carry calibration equipment with them to directly check the on-site instruments. This type of activity is common across national air quality monitoring networks where there are legal requirements for quality control and quality assurance across a large number of sites. The success of this activity relies on the auditors being able to get a representative view of site operation, and that the QA/QC procedures themselves ensure suitable performance.

- **Intercomparison campaigns**
  a good example of this type of activity is the International Pyrheliometer Comparison which takes place every 5 years at the World Radiation Centre, where all participants bring their equipment to Davos to conduct simultaneous solar radiation measurements. This option is ideal if the instrumentation is transportable and the measurement performance is not impacted significantly by regional differences.

- **Mobile validation facility**
  a set of transportable equipment is used as a transfer standard, going from site to site to run formal side-by-side intercomparisons. An example is in NDACC, where a mobile high-resolution FTIR has been used in a series of intercomparison campaigns at the various NDACC sites with fixed solar FTIR installations. This method is ideal for validating equipment that has been permanently installed at the network sites and addresses any site-specific issues. However, it is generally expensive to establish, maintain and deploy this type of facility, particularly if there are a large number of sites in the network.

- **Use of common (reference) technique**
  where an agreed 'reference' instrument type is used at all sites. An example is the WMO Ozone Monitoring Network where Standard Reference Photometers (developed and supplied by NIST) are used across the top-level network. These systems are compared to the commercial instrumentation used across the wider monitoring community. While this is an effective way of ensuring common traceability across a network, it requires a suitable reference instrument to be available. In the case of upper-air measurement compatibility a common approach is the comparison to a "virtual reference" such as a first-guess forecast field or satellite observations. The weak point is that some correlation may or do exists between radiosonde and "virtual reference" errors. Therefore results of such continuous monitoring should be complemented by periodic direct intercomparisons.

The final decision about the procedures for QC/QA will be made after an initial set of stations have been put together, based upon the lessons learned and input from relevant experts and institutions. The National Metrology Institutes (NMIs) are seen as one valuable additional resource for collaboration and consultation in this regard that to date has not been actively engaged (see action item 8).

Data Dissemination

The data dissemination encompasses the following five points: data policy, data format, data dissemination model, tracking of usage and metadata.

The GRUAN network will follow the data policy in WMO Resolution 40 Cg-XII by defining as 'essential' all data from the instrument systems which are specified in GCOS-112 or any agreed revision of GCOS-112 at all GRUAN sites, to ensure the free and unrestricted availability of these data. Selection of GRUAN sites will imply acceptance of this principle by the site operators.

A workable detailed data policy will be developed by the Lead Centre, in cooperation with the WG-ARO, the GCOS Secretariat and AOPC (see action item 9). In its April 2008 session, AOPC recommended that "GRUAN data policy should request sites to provide all data in a free and unrestricted manner (in accordance with WMO Resolution 40), and if possible in real time, in order to be of maximum value for all applications, for example enabling the data to be monitored and assimilated in numerical weather prediction systems."

The decision about the other four points of data dissemination will be organized in two steps. First, the different options for data dissemination will be considered and worked out during the next few months by the Lead Centre. The National Oceanic & Atmospheric Administration (NOAA) and Atmospheric Radiation Measurement (ARM) offered in-kind support for the development of the data policy. The WG-ARO will take a decision based on the different options outlined (action item 10). Second, the data dissemination practices will be developed, including the data policy, data format, data dissemination model, tracking of usage and metadata (action item 11).

The metadata management will prove essential to a successful network. For example, with radiosondes it is imperative to make sure that the archived soundings contain all the information (e.g. serial number) required to know exactly which kind of sonde was launched. Equally the raw as well as the corrected data are required in-case a new correction must be applied at a later date. Reference measurements are only of value with comprehensive metadata. For example, knowing the type of Vaisala sonde for a particular launch, the kind of humidity sensor flown on that sonde cannot be determined.

5. COORDINATION WITH OTHER INTERNATIONAL AND NATIONAL ACTIVITIES

Global Space-Based Inter-Calibration System (GSICS)

Mitch Goldberg reiterated the need from the GSICS to rely upon in-situ measurements for the validation of satellite data. For satellite intercalibration the distribution of locations for simultaneous observations by different sensors, space-based as well as in situ, is seen as essential. The collocation with a reference measurement site would be especially desirable.

Goldberg indicated the potential for support from the satellite community for additional radiosonde launches for validation purposes. Further communication between the satellite community and the GCOS secretariat is foreseen in action item 2.

Global Earth Observation System of Systems (GEOSS)

Alexia Massacand provided an overview about the tasks in the GEO Work Plan linked to establishment of the GRUAN:

- WE-06-01: Surface-based Global Observing System for Weather (Co-Leads: WMO, USA)

- WE-06-02: Space-based Global Observing System for Weather (Lead: WMO)
- CL-06-02: Key Climate Data from Satellite Systems (Co-Leads: GCOS, CEOS, WMO, USA)
- CL-06-01: Sustained reprocessing and reanalysis efforts (Co-Leads: WCRP, GCOS, CEOS)
- CL-07-01: Seamless Weather and Climate Prediction System (Co-Leads: WWRP/THORPEX, WCRP)

Global Atmosphere Watch / Network for the Detection of Atmospheric Composition Change (GAW/ NDACC)

Geir Braathen provided an outline about the work of NDACC. The network's main focus is on data quality. The operation of the network is governed by a number of protocols, whereas the data dissemination is a compromise between data availability and intellectual property rights.

Regular intercomparison campaigns take place at the NDACC sites with a mobile system (Lidar, FT-IR). Also intercomparison campaigns are undertaken by gathering many instruments at the same location.

Baseline Surface Radiation Network (BSRN)

Ells Dutton provided an overview about the development of the BSRN, initiated in 1988, which parallels the establishment of the GRUAN and may serve as an example of a successfully launched network. Dutton described some strategic considerations for synergies between BSRN and GRUAN activities, since many BSRN applications need high quality upper air data, and BSRN-like data provide GRUAN priority 2 observations. The combination of operations at remote field sites was therefore proposed as being more efficient and economical, plus at many current and potential sites additional national resources exist. A list of collocated GUAN and BSRN sites is listed in Appendix V.

Potential Candidate Sites from the Russian Federation

Alexander Kats outlined the already existing upper-air observations (including GUAN) in the Russian Federation. Currently new radiosondes are developed by ROSHYDROMET for the GUAN sites. Kats appreciated selection of Tiksi as a potential GRUAN candidate site in GCOS-112, even if the observation centre is relatively remote, and suggested considering Nizhnij Novgorod, as a second potential site.

Potential U.S. Contributions to GRUAN

Howard Diamond provided an overview about the possible contributions from different U.S. agencies to the GRUAN. The ARM Climate Research Facility (ACRF) is prepared to contribute in-kind resources as follows:

- Up to 5 ACRF sites to be used as potential GRUAN sites
- Data archival and management
- In-kind QA/QC and production of value added product generation

NCAR is prepared to consider participating as follows:

- Contribute to developing and deploying a reference radiosonde
- Provide a variety of research-related data management functions
- Contribution to deployment and data processing of a ground-based GPS receiver for GRUAN
- GPS Radio Occultation (GPS-RO) work; NSF Workshop at NCAR [March 2008] (workshop results available at https://wiki.ucar.edu/display/ucargpsrocaw/Home)

NOAA can possibly contribute as follows:

- Network analyses, observing system simulation experiments, developing country and Working Group support, and partnering with ARM sites
- Design work on a reference radiosonde and testing (NOAA Air Resources Laboratory's Atmospheric Turbulence and Diffusion Division (ARL/ATDD) in Oak Ridge, Tennessee)
- Building on stratospheric water vapour observations at Boulder and Lauder
- Data archival and management (mirror to ACRF), portal hosting, post-processing QA/QC
- WMO Global Space-based Inter-Calibration System (GSICS) Coordination Center participation
- Collocation of GRUAN to satellite products for statistical comparisons and monitoring

All these proposed U.S. contributions are dependent upon available funding.

CMA's view on the GRUAN

Kejun Wu suggested Xilin Hot and possibly five other potential sites as a Chinese contribution to the GRUAN network.

Association of Hydro-Meteorological Equipment Industry (HMEI)

Bruce Sumner provided an overview about the work of the Association of Hydro-Meteorological Equipment Industry (HMEI). HMEI represents about 100 companies from 22 countries of the hydro-meteorological instruments and systems industry. HMEI provides the meteorological instrument manufacturers with information about new developments and requirements. Sumner agreed that HMEI could serve as a channel between manufacturers and user community to provide notifications about changes in radiosonde production (technology, calibration procedures, corrections, data processing etc.). For the further development of a reference radiosonde, the GRUAN will collaborate with HMEI.

6. WORK PLAN

No	Action	Deadline	Who
1	Evaluate the radiation correction for the temperature measurement for each radiosonde	Jan 2009	GRUAN Sites with help from Lead Centre
2	Communication to satellite community (GSICS), sponsoring for additional radiosonde launchings	Continuous	Mitch Goldberg (RSSC/CM), GCOS secretariat
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	Continuous	Lead Centre (all sites), NMIs
4	Organize major intercomparison of operational and research radiosondes to choose which can qualify for use in the GRUAN network.	2010 and thereafter on a regular 5 year interval	Lead Centre, GCOS, CIMO, scientific community; WG (collect all available data, reports and papers)

5	First draft of manual / guidelines for GRUAN observations (assuring comparability, spreading best practices, sharing lessons, reporting)	April 2009	Lead Centre and initial sites in collaboration with WG-ARO, CIMO, CBS
6	Invite initial candidate stations to become GRUAN stations	September 2008	GCOS Secretariat following AOPC and consultation with CBS
7	Develop a matrix/spreadsheet with criteria for initial and potential sites	September 2008	Lead Centre
8	QC/QA procedures to be resolved	2010	ARM / Lead Centre / WG-ARO / NMIs
9	Establish data policy	September 2008	Lead Centre and initial sites, WG-ARO, GCOS Secretariat, AOPC
10	Consider various options on data dissemination	Summer 2008	Lead Centre, NOAA, ARM, WG-ARO
11	Devise data dissemination practices (model, format, metadata, monitoring of usage)	2009	ARM / Lead Centre / WG-ARO, help from many
12	Develop definition for optimal GRUAN site to decide on future sites (optimal location/climate zone, institution etc.); collect information about initial and potential GRUAN sites	Jan 2010	WG-ARO, Lead Centre

7. OPEN QUESTIONS

A number of important questions remained following the meeting at Lindenberg. In this section, several of these issues are described, with proposals on the way forward.

A. It is clear that very significant and substantial work is required to advance the production of a reference radiosonde. Several different potential approaches were put forward, but there was not time to resolve the issue. One possible suggestion was to initiate a specific working group answering to WG-ARO to push this forwards. Another was to organize a workshop specifically on this subject. Resolution of this issue is of the highest importance, but it is not given as a specific action item in section 6 as there was no agreement reached.

B. To come to closure on the issue of launch schedules for sonde-based observations, it was recognized that quantitative studies to resolve the issue would be useful. The meeting participants encouraged work such as that suggested by Carl Mears in the presentation that he provided to the meeting to move this issue forwards.

C. There was limited discussion regarding how to decide in what order instrumentation should be added, but this was not resolved. Clearly, given limited budgets, such guidance based upon robust analyses would be helpful.

D. The development of a mentoring programme at the Lead Centre in Lindenberg was seen as highly desirable. The value of such a programme would be to advance best practices in instrumentation and observing system procedures among stations beginning the suite of GRUAN observations.

E. The first draft of a GRUAN Lead Centre work plan was distributed at the meeting but not discussed in detail. It included a timeline for many of the above activities. Revision of this work plan, and guidance for the Lead Centre, will be a task for the WG-ARO in the coming year.

F. After the Implementation Meeting the following proposal for the pragmatic development of the GRUAN system was raised: GRUAN Phase I concentrating upon tropospheric humidity capabilities, Phase II stratospheric aspects, dependant on cost and frequency.

G. How do we ensure that GRUAN data is used optimally and by the largest range of potential users? Who will use the GRUAN data after the establishment of the observation network and for which purpose? GRUAN will need at least one Numerical Weather Prediction (NWP) centre to monitor the GRUAN and how it is used, with statistics of differences from first guess and analysis etc. and an assessment on how this is different from GUAN and other sondes? It should also be examined whether the data are actually being used as a reference.

8. REFERENCES

[1] GLOBAL CLIMATE OBSERVING SYSTEM, 2007: GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options. Report GCOS – 112, World Meteorological Organization Technical Document No. 1379.

[2] SEIDEL, D., F. BERGER, H. DIAMOND, J. DYKEMA, D. GOODRICH, W. MURRAY, T. PETERSON, D. SISTERSON, P. THORNE AND J. WANG, 2008: Reference Upper-Air Observations for Climate: Rationale, Progress, and Plans, BAMS, submitted 03/2008.

[3] YUSHKOV, V., S. MERKULOV AND V. ASTAKHOV, 1998: Optical balloon hygrometer fro upper stratosphere and stratosphere water vapour measurements, in Optical remote sensing of the atmosphere and clouds, edited by J. Wang, B. Wu, T. Ogawa, Z-H. Guans, Proc. SPIE, 3501, 439-445.

[4] VÖMEL, H., V. YUSHKOV, S. KHAYKIN, L. KORSHUNOV, E. KYRÖ AND R. KIVI, 2007a: Intercomparisons of stratospheric water vapour sensors: FLASH-B and NOAA/CMDL frost point hygrometer, Journal of Atmospheric and Oceanic Technology, in press [Available at http://cires.colorado.edu/~voemel/publications/flash.20060703.pdf]

[5] VÖMEL, H., J. E. BARNES, R. N. FORNO, M. FUJIWARA, F. HASEBE, S. IWASAKI, R. KIVI, N. KOMALA, E. KYRÖ, T. LEBLANC, B. MOREL, S.-Y. OGINO, W. G. READ, S. C. RYAN, S. SARASPRIYA, H. SELKIRK, M. SHIOTANI, J. VALVERDE CANOSSA AND D. N. WHITEMAN, 2007b: Validation of Aura Microwave Limb Sounder water vapour by balloon-borne Cryogenic Frostpoint Hygrometer measurements, J. Geophys. Res., 112, D24S37, doi:10.1029/2007JD008698

[6] FUJIWARA, M., M. SHIOTANI, F. HASEBE, H. VÖMEL, S.J. OLTMANS, P.W. RUPPERT, T. HORINOUCHI AND T. TSUDA, 2003: Performance of the Meteolabor “Snow White” Chilled-Mirror Hygrometer in the Tropical Troposphere: Comparisons with the Vaisala RS80 A/H-Humicap Sensors, Journal of Atmospheric and Oceanic Technology, 1534-1542.

[7] VÖMEL, H, M. FUJIWARA, M. SHIOTANI, F. HASEBE, S. J. OLTMANS, AND J. E. BARNES, 2003: The behavior of the Snow White chilled-mirror hygrometer in extremely dry conditions, J. Atmos. Ocean. Tech., 20, 1560-1567.

[8] ZOGER, M., C. SCHILLER, N. EICKE, 1999: Fast in situ hydrometers: A new family of balloonborne and airborne Lyman-alpha photofragment fluorescence hygrometers, J. Geophys. Res., 104, 1807-1816.

[9] GLOBAL CLIMATE OBSERVING SYSTEM, 2008: Fourteenth Session of the Atmospheric Observation Panel for Climate (AOPC) – Conclusions and Recommendations. Report GCOS – 122, World Meteorological Organization Technical Document No. 1436

Appendix I
Agenda

A meeting held under the auspices of the Global Climate Observing System (GCOS) and the National Oceanic and Atmospheric Administration (NOAA).

Meeting Chairs: *David Goodrich, GCOS Secretariat and Peter Thorne, UK Met Office*

Meeting Organizing Committee: *Franz Berger (DWD), Leopold Haimberger (Univ. of Vienna) and Junhong (June) Wang (NCAR)*

Meeting objective: "Start small, but start"
Develop a work plan that the Lead Centre and other interested parties will work towards (with a funding commitment to achieve it!) that:

- Identifies and addresses remaining scientific and technical issues;
- Ensures observations are being made in a manner consistent with the stated GRUAN requirements henceforth at a number of initial sites; and
- Informs priorities for the GCOS working group.

Agenda Overview

Day 1 Monday 25th February (only for the members of GCOS/AOPC Working Group (WG) on Atmospheric Reference Observations)

- WG meeting (afternoon 1/2 day) - *Peter Thorne*

Day 2 Tuesday 26th February

- Session 1 - Registration and Introduction (1/4 day) - *Franz Berger*
- Tour of Lindenberg Observatory (1/4 day)
- Session 2 - Initial Site Selection (~1/2 day) - *Leopold Haimberger and Holger Voemel*
- Ice-breaker (night)

Day 3 Wednesday 27th February

- Session 3 - Radiosonde Instrumentation and Launch Schedule (1/2 day) - *Dave Goodrich*
- Session 4 - Instrumentation and Observing Practices (1/2 day) - *Miroslav Ondras*
- Dinner (night)

Day 4 Thursday 28th February

- Session 5 - Data Dissemination and QC/QA (1/2 day) - *Matthew Menne*
- Session 6 - Coordination with other International and National Activities (1/4 day) - *Dian Seidel*
- Session 7 - Development of Action Plan (1/4 day) - *Peter Thorne*

Detailed Agenda

Monday 25th February

14:00-17:00 **WG meeting, *Chair: Peter Thorne*** *(*Working Group members only)
Get to know each other; WG membership and TOR; coordination between the lead center and WG; discussion of meeting plans; and the BAMS article.

Tuesday 26th February

08:00-08:30 Registration

Session 1 – Introduction, *Chair: Franz Berger*

08:30-08:40 Welcome and logistics - *Franz Berger, Marion Fiedler and Stefanie Lorenz*
08:40-08:50 Workshop objectives and agenda - *June Wang*
08:50-09:15 DWD – the host of GRUAN Lead Centre - *Wolfgang Kusch*
09:15-09:45 Coffee break

09:45-12:15 **Tour of Lindenberg Observatory** (including radiosonde launch at 12:00 and group photo)

12:15-13:15 Lunch

Session 1 – Introduction (continued), *Chair: Franz Berger*

13:15-13:25 Opening speech: *Ulrich Kasparick, Federal State Secretary BMVBS*
13:25-13:30 Opening notes: *Dave Goodrich, GCOS*
13:30-13:50 Introductions around the room
13:50-14:30 Overview of GRUAN - *Dave Goodrich and Peter Thorne*
14:30-15:00 Coffee break

Session 2 – Initial Site Selection, *Chair: Leopold Haimberger and Holger Voemel*

15:00-15:30 Keynote: GCOS / WCRP activities carried out in Lindenberg - *Franz Berger*
15:30-15:45 Atmospheric Radiation Measurement (ARM) sites - *Doug Sisterson*
15:45-16:00 Lauder, New Zealand within Network for Detection of Atmospheric Composition Change (NDACC) - *Paul Johnston*
16:00-16:15 Howard University Beltsville Research site, Maryland, U.S.A. - *Belay Demoz*
16:15-16:30 European site selection - *Reinout Boers*
16:30-16:40 Sodankylä research site - *Esko Kyrö*
16:40-16:50 Boulder research site - *June Wang*
16:50-17:00 Chinese potential sites - *Kejun Wu*
17:00-17:10 SHADOZ research site - *Masatomo Fujiwara*
17:10-17:20 Tropical site candidates - *Holger Voemel*
17:20-17:35 Partnership / Mentoring Programme – ideas to realise a worldwide homogeneous network - *Franz Berger*
17:35-18:30 Discussions and summary

19:00-21:30 Icebreaker

Wednesday 27th February

Session 3 – Radiosonde Instrumentation and Launch Schedule, *Chair: Dave Goodrich*

08:00-08:30 Radiosonde instrumentation issues and challenges - *Holger Voemel*
08:30-08:45 Rationale for using current best operational radiosondes - *Doug Sisterson*
08:45-09:00 Rationale for using reference radiosondes - *June Wang*
09:00-10:00 Discussions and summary
10:00-10:20 Coffee break
10:20-10:35 Framing the Question of GRUAN Sonde Launch Schedule - *Dian Seidel*
10:35-10:50 Rationale for coordination with satellite overpass - *Franz Berger for Carl Mears*
10:50-11:05 Rationale for fixed schedule - *Kevin Trenberth*
11:05-12:00 Discussions and summary

12:00-13:30 Lunch (with visit to the balloon hall)

Session 4 – Instrumentation and Observing Practices, *Chair: Miroslav Ondras*

13:30-14:10 Keynote speech: Potential ground-based remote sensing instruments for GRUAN and a status of their operational exploitation - *John Nash*
14:10-15:20 Ground based instrumentation requirements
- 14:10-14:30 Application and Benchmark testing of Vertical Profiles at Lindenberg Observatory - *Dirk Engelbart*
- 14:30-14:50 From science to operation: Practical problems in implementing instruments in an operational network - *Reinout Boers*
- 14:50-15:00 Ground-based GPS measurements - *June Wang for John Braun*
- 15:00-15:20 Surface and upper air developments in MeteoSwiss Payerne - *Bertrand Calpini*

15:20-15:40 Coffee break
15:40-16:30 Discussions
16:30-16:40 Introduction to 'Suitability of current WMO regulatory documentations, such as Manual and Guide on the GOS and WMO Guide to Meteorological Instruments and Methods of Observations'
16:40-17:30 Discussions

17:30-18:30 Meeting of WG to assess progress

19:30 Meeting dinner (sponsored by DWD)

Thursday 28th February

Session 5 – Data dissemination and QC/QA, *Chair: Matthew Menne*

08:00-08:40 Keynote: *Doug Sisterson*
08:40-09:30 Requirements for quality control / quality assurance
- 08:40-08:50 SI Traceability of Measurements - *Tom Gardiner*
- 08:50-09:00 Data Analysis/Fusion and Uncertainty Issues - *Alistair Forbes*
- 09:00-09:10 Follow-on to First Two Short Talks - *John Dykema*
- 09:10-09:20 Utility of Raw Radiosonde Data in QA/QC - *Alexander Kats*
- 09:20-09:30 Integrated Profiling of the Atmosphere - *Reinout Boers*

09:30-10:00 Discussions
10:00-10:20 Coffee Break
10:20-11:00 Requirements for data dissemination
- 10:20-10:40 Aspects of effective data dissemination - *Holger Voemel*
- 10:40-10:50 Lessons from the other GCOS Lead Centers – *Matthew Menne*
- 10:50-11:00 CEOP data management - *Steve Williams*

11:00-12:00 Discussions

12:00-13:00 Lunch

Session 6 – Coordination with other International and National Activities, *Chair: Dian Seidel*

13:00-13:15 Global Space-Based Inter-Calibration System (GSICS) - *Mitch Goldberg*
13:15-13:30 Global Earth Observation System of Systems (GEOSS) - *Alexia Massacand*
13:30-13:40 Global Atmosphere Watch (GAW), Network for the Detection of Atmospheric Composition Change (NDACC) - *Geir Braathen*
13:40-13:45 Southern Hemisphere Additional Ozonesondes (SHADOZ) - *Masatomo Fujiwara for Anne Thompson*
13:45-14:00 Baseline Surface Radiation Network (BSRN) - *Ells Dutton*
14:00-14:05 Hydro-Meteorological Equipment Industry (HMEI) - *Bruce Sumner*
14:05-14:25 National agency perspectives
- 14:05-14:10 Inputs to GRUAN from the Netherlands - *Reinout Boers*
- 14:10-14:15 Some consideration about potential candidate sites from the Russian Federation - *Alexander Kats*
- 14:15-14:20 Potential U.S. contributions to GRUAN - *Howard Diamond*
- 14:20-14:25 CMA's view on the GRUAN - *Kejun Wu*

14:25-15:00 Discussion and Summary
15:00-15:20 Coffee break

Session 7 – Development of Action Plan, *Chair: Peter Thorne*

15:20-17:30 Development of action plan - *Peter Thorne*

17:30 Meeting closes

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Appendix II
List of Participants

PARTICIPANT	CONTACT
Franz Berger Head of Meteorological Observatory Lindenberg German Meteorological Service (DWD) Am Observatorium 12, D-15848 Tauche, GERMANY	Tel: +49-33677-60260 E-mail: franz.berger@dwd.de
Reinout Boers Head of Regional Climate Department Climate and Seismology Sector, Cabauw research site (KNMI) PO Box 201, NL-3730 AE De Bilt, NETHERLANDS	Tel: +31-30-220-6481 E-mail: reinout.boers@knmi.nl
Stephan Bojinski Scientific Officer Global Climate Observing System (GCOS) Secretariat c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-730-81-50 E-mail: Sbojinski@wmo.int
Geir Braathen Senior Scientific Officer Global Ozone Observing System of Global Atmosphere Watch (GAW) World Meteorological Organization (WMO) Co-chair of NDACC Steering Committee c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-730-8235 E-mail: Gbraathen@wmo.int
Bertrand Calpini Head of Aerological Station Meteo Swiss P.O. Box 316 Ch. De l'Aerologie, 1530 Payerne, SWITZERLAND	Tel: +41-26-662-6228 E-mail: Bertrand.Calpini@meteoswiss.ch
Jennifer Comstock Research Scientist VAP Development for the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) PO Box 999, MS K9-24, Richland, WA 99352, USA	Tel: +1-509-372-4244 E-mail: jennifer.comstock@pnl.gov
Belay Demoz Research Meteorologist NASA Goddard Space Flight Centre (GSFC) Bldg 33 Rm C425, Greenbelt, MD 20771, USA	Tel: +1-301-614-6224 E-mail: demoz@agnes.gsfc.nasa.gov
Howard Diamond Program Manager U.S. GCOS 1100 Wayne Avenue, Suite 1202; Silver Spring, MD 20910, USA	Tel: +1-301-427-2475 E-mail: howard.diamond@noaa.gov
Ells Dutton Supervisory Meteorologist Earth System Research Laboratory / Global Monitoring Division (ESRL/GMD) National Oceanic & Atmospheric Administration (NOAA) 325 Broadway Boulder, CO 80305, USA	Tel: +1-303-497-6660 E-mail: Ells.Dutton@noaa.gov
John Dykema Research Associate Division of Engineering and Applied Sciences, Harvard University 12 Oxford, St. Cambridge, MA 02138, USA	Tel: +1-617-495-5922 E-mail: dykema@huarp.harvard.edu
Marion Fiedler Meteorological Observatory Lindenberg German Meteorological Service (DWD) Am Observatorium 12, D-15848 Tauche, GERMANY	Tel: +49-33- 6776-0267 E-mail: marion.fiedler@dwd.de

Alistair Forbes Science Fellow National Physical Laboratory (NPL) Hampton Road, Teddington, TW11 OLW, UK	Tel: +44-20-8943-6348 E-mail: Alistair.Forbes@npl.co.uk
Masatomo Fujiwara Associate Professor Environmental Earth Science (EES), Hokkaido University N10 W5 Sapporo 060-0810, JAPAN	Tel: +81-11-706-2362 E-mail: fuji@ees.hokudai.ac.jp
Tom Gardiner Senior Research Scientist National Physical Laboratory (NPL) Hampton Road, Teddington, TW11 OLW, UK	Tel: +44-20-8943-7143 E-mail: tom.gardiner@npl.co.uk
Mitch Goldberg Chair of GSICS and Division Chief Satellite, Meteorology and Climatology Division National Oceanic & Atmospheric Administration (NOAA/NESDIS) 5200 Auth Road, Room 712, Camp Springs MD 20746, USA	Tel: +1-301-763-8018 E-mail: Mitch.Goldberg@noaa.gov
David Goodrich Director Global Climate Observing System (GCOS) Secretariat c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-730-8275 E-mail: DGoodrich@wmo.int
Leopold Haimberger Ao. Professor Institute for Meteorology und Geophysics, University of Vienna Althanstrasse 14, 1090 Wien, AUSTRIA	Tel: +43-14-277-53712 E-mail: leopold.haimberger@univie.ac.at
Franz J. Immler GRUAN Lead Centre German Meteorological Service (DWD) Meteorological Observatory Lindenberg Am Observatorium 12, D-15848 Tauche, GERMANY	Tel: + 49-336-77-60170 E-mail: Franz.immler@dwd.de
Paul Johnston Group Manager National Institute of Water and Atmospheric Research (NIWA), Lauder Private Bag, 50061, Omakau, Otago, NEW ZEALAND	Tel: +64-34-40-0446 E-mail: p.johnston@niwa.co.nz
Alexander Kats Chief Aerologist Scientific and Engineering Centre of Radiosounding Central Aerological Observatory of Roshydromet 3 Pervomayskaya Str., 141700 Dolgoprundy, Moscow Reg., RUSSIA	Tel: +7-495-408-6409 E-mail: alexander.kats@cao-rhms.ru
Wolfgang Kusch President German Meteorological Service (DWD) Kaiserleistrasse 29/35, 63067 Offenbach, GERMANY	Tel: E-mail: wolfgang.kusch@dwd.de
Esko Kyrö Research Professor Finnish Meteorological Institute / Arctic Research Centre (FMI/ARC) Tähteläntic 62, 99600 Sodankylä, FINLAND	Tel: +358-16-619-612 E-mail: esko.kyro@fmi.fi
Stefanie Lorenz Project Officer Global Climate Observing System (GCOS) Secretariat c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva, SWITZERLAND	Tel: +41-22730-8423 E-mail: Slorenz@wmo.int

Alexia Massacand Senior Scientific Expert Energy, Climate and the Science and Technology Committee Group on Earth Observations (GEO) c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-730-8382 E-mail: AMassacand@geosec.org
Susanne Meier Meteorological Observatory Lindenberg German Meteorological Service (DWD) Am Observatorium 12, D-15848 Tauche, GERMANY	Tel: +49-33-677-60158 E-mail: Susanne.Meier@dwd.de
Matthew Menne CBS Rapporteur for GCOS Physical Scientist Representative of Expert Team on Evolution of the Global Observing System (ET-EGOS) NOAA/NCDC 151, Patton Avenue, Asheville, NC 28801, USA	Tel: +1-828-271-4449 E-mail: Matthew.Menne@noaa.gov
Bill Murray Associate Program Manager Climate Change Data and Detection Program National Oceanic & Atmospheric Administration (NOAA) Silver Spring Metro Centre, Bida 3, 1315 East-West Highway, Silver Spring MD 20910, USA	Tel: +1-301-734-1243 E-mail: william.l.murray@noaa.gov
John Nash President of CIMO Upper Air Team Manager Observation Development, Met Office UK Met Office, FitzRoy Road, Exeter, EX1 3PB, UK	Tel: +44 139 2 88 56 49 E-mail: john.nash@metoffice.gov.uk
Miroslav Ondras Chief Observing System Division (OSY) World Weather Watch (WWW) World Meteorological Organisation (WMO) c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-730-8409 E-mail: MOndras@wmo.int
Stephen Palmer Chair of IPM Technical Cooperation Programme Manager, Met Office UK Fitzroy Road, Exeter, Exi 3PB, UK	Tel: +44-1392-886915 E-mail: steve.palmer@metoffice.gov.uk
Rémy Pépin Sales Manager for MODEM MODEM ZA de forme, 91750 Chevannes, FRANCE	Tel: +33-164-99-77-52 E-mail: rpepin@meteomodem.com
Stefan Rösner Deputy Head Staff Division Office of the President and International Affairs GCOS German Coordinator German Meteorological Service (DWD) Kaiserleistr. 29/35, 63067 Offenbach, GERMANY	Tel: +49-69-8062-4306 E-mail: Stefan.roesner@dwd.de
Dian Seidel Research Meteorologist Air Resources Laboratory (R/ARL) National Oceanic & Atmospheric Administration (NOAA) 1315 East West Highway, Silver Spring, MD 20910, USA	Tel: +1-301-713-0295 E-mail: dian.seidel@noaa.gov
Douglas Sisterson Operations Manager Atmospheric Radiation Measurement Climate Research Facility (ACRF), Decision and Information Sciences Division Building 900, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60491, USA	Tel: +1-630-252-5836 E-mail: dlsisterson@anl.gov

Michael Sommer GRUAN Lead Centre German Meteorological Service (DWD) Meteorological Observatory Lindenberg Am Observatorium 12, D-15848 Tauche, GERMANY	Tel: + 49-336-77-60??? E-mail: Michael.sommer@dwd.de
Bruce Sumner Executive Secretary Association of Hydro-Meteorological Equipment Industry (HMEI) c/o WMO, 7 bis, Avenue de la Paix, CH-1211 Geneva 2, SWITZERLAND	Tel: +41-22-130-8004 E-mail: hmei@wmo.int
Peter Thorne Climate Research Scientist Hadley Centre for Climate Prediction and Research , Met Office UK FitzRoy Road, Exeter, EX1 3PB, UK	Tel: +44-13-9288-6552 E-mail: peter.thorne@metoffice.gov.uk
Kevin Trenberth Senior Scientist & Section Head Climate Analysis Section, Climate & Global Dynamics Division, National Center for Atmospheric Research (NCAR) P.O. Box 3000, Boulder, CO 80307-3000 USA	Tel: +1-303-497-1318 E-mail: trenbert@ucar.edu
Pekka Utela Business Segment Manager Vaisala P.O. Box 26, FI-00421 Helsinki, FINLAND	Tel.: +35-89-8949-2575 E-mail: Pekka.utela@vaisala.com
Geraint Vaughan Director of Weather Research National Centre for Atmospheric Sciences School of Earth, Atmospheric and Environmental Science (SEAES) University of Manchester Oxford Rd, Manchester M 159PL, UK	Tel: +44-161-306-3931 E-mail: geraint.vaughan@manchester.ac.uk
Holger Vömel Research Scientist Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado Campus Box 216, Boulder CO, USA	Tel: +1-303-497-6192 E-mail: Holger.Voemel@colorado.edu
Junhong Wang Scientist Earth Observing Laboratory (EOL) National Centre for Atmospheric Research (NCAR) P.O. Box 3000, Boulder, CO 80307, USA	Tel: +1-303-497-8837 E-mail: junhong@ucar.edu
Steven Williams Associate Scientist IV National Centre for Atmospheric Research (NCAR) P.O. Box 3000, Boulder, CO 80307, USA	Tel: +1-303-497-8164 E-mail: sfw@ucar.edu
Kejun Wu Assistant Director National Atmospheric Observation Center China Meteorological Administration (CMA) No.46 Zhong guan cun South Avenue, Beijing, 100081, P.R. CHINA	Tel: +86 10 5899 5062 E-mail: wu_kejun@sina.com

Appendix III
GRUAN Initial and Potential Candidate Sites

Initial Sites

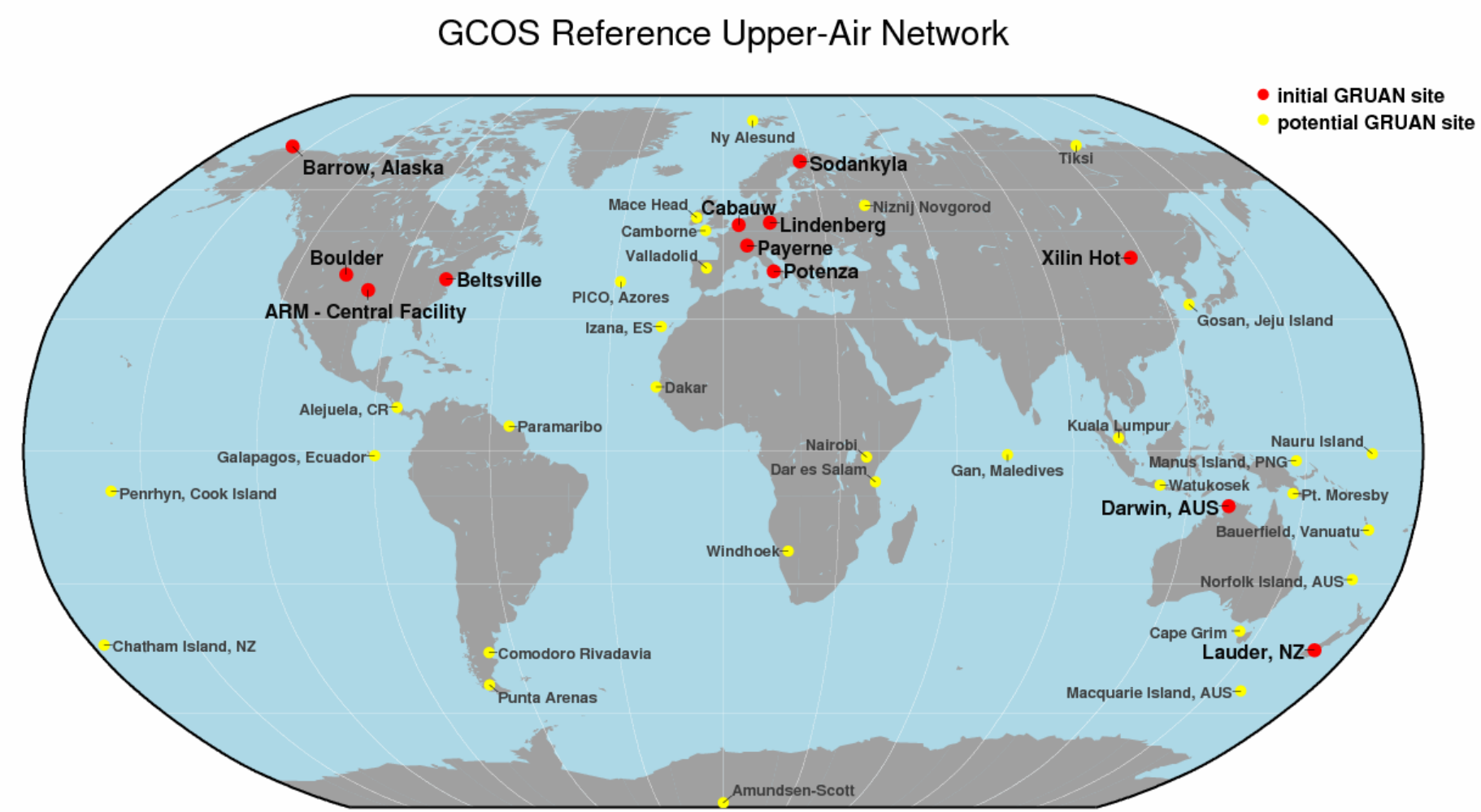
- Darwin, Australia
- Xilin Hot, China
- Sodankylä, Finland
- Lindenberg, Germany
- Potenza, Italy
- Cabauw, Netherlands
- Lauder, New Zealand
- Payerne, Switzerland
- Barrow, USA
- Beltsville, USA
- Boulder, USA
- Lamont, USA

Potential Candidate Sites

As potential candidate sites to be developed to meet GRUAN criteria during the next few years the meeting identified the following stations (listed alphabetically by country):

- Comodor Rivadavia, Argentina
- Cape Grim, Australia
- Macquarie Island, Australia
- Norfolk Island, Australia
- Punta Arenas, Chile
- Alajuela, Costa Rica
- Penrhyn, Cook Islands
- San Cristobal/Galapagos, Ecuador
- Watukosek, Indonesia
- Mace Head, Ireland
- Nairobi/Dagoretti, Kenya
- Kuala Lumpur, Malaysia
- Gan, Maldives
- Windhoek, Namibia
- Nauru, Nauru
- Chatham Island, New Zealand
- Spitsbergen, Norway
- Port Moresby W.O., Papua New Guinea
- Manus, Papua New Guinea
- Pico/Azores, Portugal
- Tiksi, Russian Federation
- Nizhnij Novgorod, Russian Federation
- Dakar, Senegal
- Paramaribo, Suriname
- Jeju Island, South Korea
- Valladolid, Spain
- Izana/Canarias, Spain
- Dar es Salaam, Tanzania
- Camborne, UK
- Amundsen-Scott, Antarctica (Station operated by the USA)
- Bauerfield, Vanuatu

GCOS Reference Upper-Air Network



Appendix IV
Collocation of GRUAN sites with other Network Sites

No.	Station Name and Country	GUAN[2]	BSRN	NDACC[3]	SHADOZ[4]	GAW[5]
Initial GRUAN Sites						
1	Darwin, Australia	X (94120[6])	X			X
2	Xilin Hot, China					
3	Sodankyla, Finland	X (2836)		X		X (G)
4	Lindenberg, Germany	X (10393)	X			X
5	Potenza, Italy					
6	Cabauw, Netherlands		X			
7	Lauder, New Zealand		X	X (P)		X (G)
8	Payerne, Switzerland	X (6610)	X	X		X
9	Barrow, AK, USA	X (70026)	X			X (G)
10	Beltsville, MD, USA		Two BSRN close by (Chesapeake Lt., USA; Rock Springs, PA, USA)			X
11	Boulder, CO, USA		X			X
12	Lamont, Southern Great Plains, OK, USA	X (72451 Dodge City/Mun., KS, USA)	X			X
Potential GRUAN Sites						
13	Comodor Rivadavia, Argentina	X (87860)				X
14	Cape Grim, Australia					X (G)
15	Macquarie Island, Australia	X (94998)		X		X
16	Norfolk Island, Australia	X (94996)				X
17	Punta Arenas, Chile	X (84934)				X
18	Alajuela, Costa Rica	X (78762 Juan Santa Maria Airport)			X	X (Here-dia)
19	Penrhyn, Cook Islands	X (91801)				X (Raro-tonga)
20	San Cristobal/ Galapagos, Ecuador	X (84008)			X	X
21	Watukosek, Indonesia	x (96935 Surabaya)			X	X
22	Mace Head, Ireland					X (G)
23	Nairobi/Dagoretti, Kenya	X (63741)			X	X

[2] Source: http://www.wmo.int/pages/prog/gcos/documents/GUAN_Stations_by_Region.pdf (1 February 2008)
[3] NDACC Primary Sites are marked with a "P", all other sites are NDACC Complementary Sites (Source: http://www.ndacc.org; 28 May 2008)
[4] Source: http://croc.gsfc.nasa.gov/shadoz (28 May 2008)
[5] The GAW global stations are marked with a „G". Global stations measure at least three of the six GAW focal areas, namely : Ozone, Greenhouse Gases, Reactive Gases, Atmospheric Wet Deposition, UV Radiation and Aerosols (Source: http://www.empa.ch/gaw/gawsis; 28 May 2008)
[6] WMO Station Number

24	Kuala Lumpur, Malaysia				X	X (Sepang Airport)
25	Gan, Maldives	X (43599)				X
26	Windhoek, Namibia	X (68110)				
27	Nauru, Nauru		X			X
28	Chatham Island, New Zealand	X (93986)				X
29	Spitsbergen, Ny Alesund, Norway		X	X (P)		X (G)
30	Port Moresby W.O., Papua New Guinea	X (92035)				
31	Manus, Papua New Guinea		X			
32	Pico/Azores, Portugal	X (8508 Lajes/Santa Rita)				X (Santa Maria)
33	Tiksi, Russian Federation					X
34	Nizhnij Novgorod, Russian Federation	X (27459)				
35	Dakar, Senegal	X (61641)				
36	Paramaribo, Suriname			X	X	X
37	Jeju Island, South Korea					X (Cheju)
38	Valladolid, Spain					
39	Izana/Canarias, Spain	X (60018 Tenerife/ Guimar)				x (G)
40	Dar es Salaam, Tanzania	X (63894)				
41	Camborne, UK	X (3808)	X			X
42	Amundsen-Scott, Antarctica (Station operated by the USA)	X (89009)	X (South Pole)	X (P)		X (G, South Pole)
43	Bauerfield, Vanuatu	X (91557)				

Existing collocated GUAN and BSRN sites[7]:

- Tamanrasset, Algeria
- Tateno, Japan
- Bermuda
- Barrow, Alaska
- Darwin, Australia (ARM)
- Cocos Is, Australia[8]
- American Samoa
- Lindenberg, Germany
- Lerwick, UK
- Camborne , UK
- Payerne, Switzerland
- von Neumayer, Antarctica (Germany)
- Syowa, Antarctica (Japan)
- Amundsen-Scott, Antarctica (USA)

Other existing BSRN sites with collocated / near-by regular upper-air soundings that are not part of GUAN:

- Kwajalein, M.I., USA

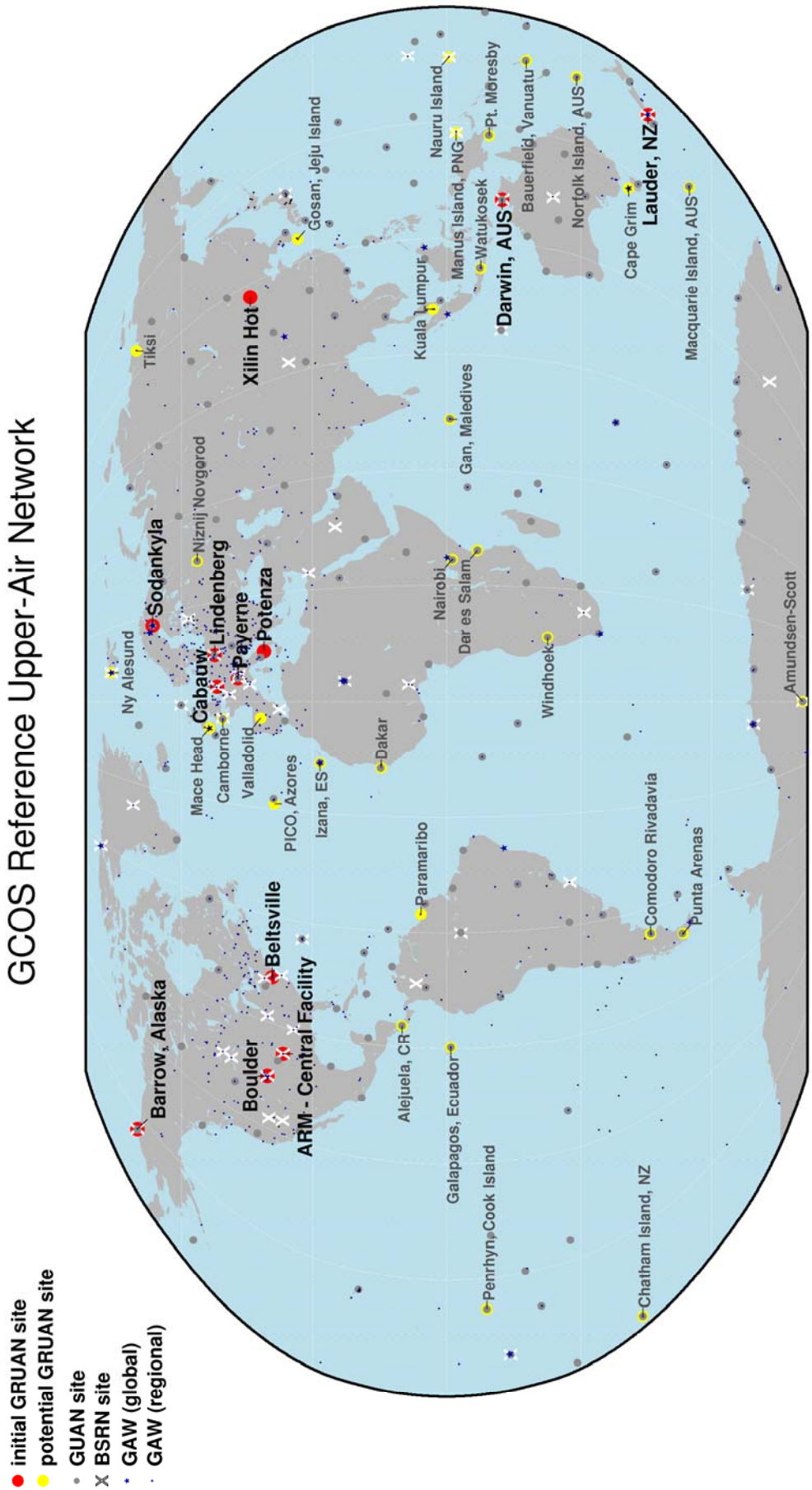
[7] Table entries subject to change, due to operational considerations.
[8] The station is listed as a candidate site.

- Dome C, Antarctica (USA)
- Desert Rock, NV, USA
- Spitsbergen, Ny Ålesund, Norway
- Sede Boqer, Israel
- De Aar, S. Africa
- Alice Springs, Australia
- Denver, CO, USA
- American Samoa[9]
- Nauru, Nauru (ARM)
- Manus, Papua New Guinea (ARM)
- Lamont, Southern Great Plains, OK, USA (ARM)

BSRN and proposed GRUAN, but not GUAN sites:

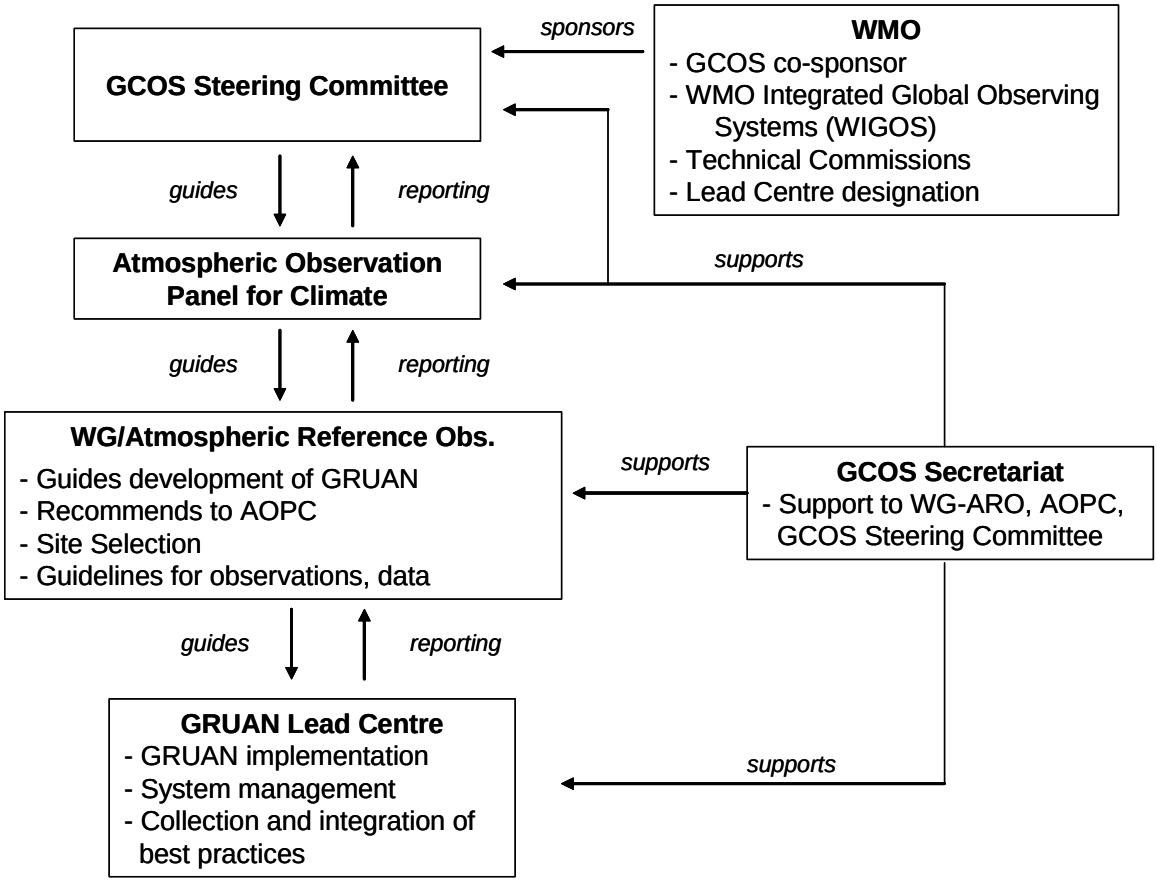
- Lauder, New Zealand

[9] The station is listed as a candidate for BSRN.



[Note: NDACC, SHADOZ sites are not shown for display reasons]

Appendix V
Organigram of Working Relations



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Appendix VI
List of GEO Tasks related to GRUAN

Task: WE-06-01
Benefit Area: Weather
Title: *Surface-based Global Observing System for Weather (Co-Leads: WMO, USA)*
Achieve a complete and stable surface-based (in-situ and airborne, land and possibly ocean) Global Observing System (GOS). High priority should be given to a stable, and as much as possible automated, fully functional World Weather Watch Upper Air Network and the further development of the Aircraft Meteorological Data Relay (AMDAR) programme.

Task: WE-06-02
Benefit Area: Weather
Title: *Space-based Global Observing System for Weather (Lead: WMO)*
Achieve a stable and improved space-based Global Observing System (GOS) including operational geostationary and polar components. Support WMO efforts related to (i) increased spatial and temporal resolution for geostationary imagers and sounders, (ii) a broader availability of polar Doppler wind profiles for initial operational testing.

Task: CL-06-02
Benefit Area: Climate
Title: *Key Climate Data from Satellite Systems (Co-Leads: GCOS, CEOS, WMO, USA)*
Establish actions securing the provision of key data for climate studies and forecasting from satellite systems.

Task: CL-06-01
Benefit Area: Climate
Title: *Sustained reprocessing and reanalysis efforts (Co-Leads: WCRP, GCOS, CEOS)*
Ensure the development of international mechanisms to coordinate and maintain sustained climate data reprocessing and reanalysis efforts. With regard to the reprocessing of historical datasets (to obtain consistent long-time series of satellite records), make relevant synergies with Task CL-06-02.

Task: CL-07-01
Benefit Area: Climate
Title: *Seamless Weather and Climate Prediction System (Co-Leads: WWRP/THORPEX, WCRP)*
Support the development of a major initiative on "International Weather, Climate and Earth-system Science", to better address uncertainties associated with climate variability and change, and related societal impacts (e.g. health, water, agriculture, energy). Promote international multi-disciplinary (physics-biology-chemistry) collaboration on the development of a high-resolution seamless weather/climate global prediction system - including coupled atmosphere-ocean data assimilation.

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Appendix VII
Glossary of Acronyms

ARL/ATDD	Air Resources Laboratory's Atmospheric Turbulence and Diffusion Division
AOPC	Atmospheric Observation Panel for Climate
ACRF	ARM Climate Research Facility
ARM	Atmospheric Radiation Measurement
BSRN	Baseline Surface Radiation Network
CBS	Commission for Basic Systems
CEOP	Coordinated Energy and Water Cycle Observation Project
CFH	Cryogenic Frostpoint Hygrometer
CIMO	Commission for Instruments and Methods of Observation
CMA	China Meteorological Administration
DWD	German Meteorological Service (Deutscher Wetterdienst)
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
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
LIDAR	Light Detection and Ranging (optical remote sensing)
LST	Local Solar Time
NCAR	National Centre for Atmospheric Research
NDACC	Network for the Detection of Atmospheric Composition Change
NMIs	National Meteorology Institutes
NMSs	National Meteorological Services
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
QC/QA	Quality Control/Quality Assessment
ROSHYDROMET	Russian Meteorological Service
RSSC/CM	Regional/Specialized Satellite Centres for Climate Monitoring
SHADOZ	Southern Hemisphere Additional Ozonesondes
UTC	Universal Coordinated Time
UT/LS	Upper Troposphere and Lower Stratosphere
WG-ARO	Working Group on Atmospheric Reference Observations
WIGOS	WMO Integrated Global Observing Systems
WMO	World Meteorological Organization

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LIST OF GCOS PUBLICATIONS*

GCOS-1 (WMO/TD-No. 493)	Report of the first session of the Joint Scientific and Technical Committee for GCOS (Geneva, Switzerland, April 13-15, 1992)
GCOS-2 (WMO/TD-No. 551)	Report of the second session of the Joint Scientific and Technical Committee for GCOS (Washington DC, USA, January 11-14, 1993)
GCOS-3 (WMO/TD-No. 590)	Report of the third session of the Joint Scientific and Technical Committee for GCOS (Abingdon, UK, November 1-3,1993)
GCOS-4 (WMO/TD-No. 637)	Report of the fourth session of the Joint Scientific and Technical Committee for GCOS (Hamburg, Germany, September 19-22, 1994)
GCOS-5 (WMO/TD-No. 639)	Report of the GCOS Data System Task Group (Offenbach, Germany, March 22-25, 1994)
GCOS-6 (WMO/TD-No. 640)	Report of the GCOS Atmospheric Observation Panel, first session (Hamburg, Germany, April 25-28, 1994)
GCOS-7 (WMO/TD No. 641)	Report of the GCOS Space-based Observation Task Group (Darmstadt, Germany, May 3-6, 1994)
GCOS-8 (WMO/TD No. 642) (UNEP/EAP.MR/94-9)	Report of the GCOS/GTOS Terrestrial Observation Panel, first session (Arlington, VA, USA, June 28-30, 1994)
GCOS-9 (WMO/TD-No. 643)	Report of the GCOS Working Group on Socio-economic Benefits, first session (Washington DC, USA, August 1-3, 1994)
GCOS-10 (WMO/TD-No. 666)	Summary of the GCOS Plan, Version 1.0, April 1995
GCOS-11 (WMO/TD-No. 673)	Report of the GCOS Data and Information Management Panel, first session (Washington DC, USA, February 7-10, 1995)
GCOS-12 (WMO/TD-No. 674)	The Socio-economic Benefits of Climate Forecasts: Literature Review and Recommendations (Report prepared by the GCOS Working Group on Socio-economic Benefits), April 1995
GCOS-13 (WMO/TD-No. 677)	GCOS Data and Information Management Plan, Version 1.0, April 1995
GCOS-14 (WMO/TD-No. 681)	Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995
GCOS-15 (WMO/TD-No. 684)	GCOS Plan for Space-based Observations, Version 1.0, June 1995
GCOS-16 (WMO/TD-No. 685)	GCOS Guide to Satellite Instruments for Climate, June 1995
GCOS-17 (WMO/TD-No. 696)	Report of the GCOS Atmospheric Observation Panel, second session (Tokyo, Japan, March 20-23, 1995)

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

GCOS-18 (WMO/TD-No. 697) (UNEP/EAP.MR/95-10)	Report of the GCOS/GTOS Terrestrial Observation Panel, second session (London, UK, April 19-21, 1995)
GCOS-19 (WMO/TD-No. 709)	Report of the GCOS Data Centre Implementation/Co-ordination Meeting (Offenbach, Germany, June 27-29, 1995)
GCOS-20 (WMO/TD-No. 720)	GCOS Observation Programme for Atmospheric Constituents: Background, Status and Action Plan, September 1995
GCOS-21 (WMO/TD-No. 721) (UNEP/EAP.TR/95-07)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 1.0, November 1995
GCOS-22 (WMO/TD-No. 722)	Report of the fifth session of the Joint Scientific and Technical Committee for GCOS (Hakone, Japan, October 16-19, 1995)
GCOS-23 (WMO/TD-No. 754) (UNEP/DEIA/MR.96-6) (FAO GTOS-1)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, third session (Cape Town, South Africa, March 19-22, 1996)
GCOS-24 (WMO/TD-No. 768) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, first session (Miami, Florida, USA, March 25-27, 1996)
GCOS-25 (WMO/TD-No. 765) (UNEP/DEIA/MR.96-5)	Report of the GCOS Data and Information Management Panel, second session (Ottawa, Ontario, Canada, May 14-17, 1996)
GCOS-26 (WMO/TD-No. 766)	Report of the Joint CCl/CBS Expert Meeting on the GCOS Surface Network (Norwich, UK, March 25-27, 1996)
GCOS-27 (WMO/TD-No. 772) (UNEP/DEIA/MR.96-7)	Report of the Expert Meeting on Hydrological Data for Global Observing Systems (Geneva, Switzerland, April 29-May 1, 1996)
GCOS-28 (WMO/TD-No. 793) (UNEP/DEIA/MR.97-3)	*In Situ* Observations for the Global Observing Systems (Geneva, Switzerland, September 10-13, 1996)
GCOS-29 (WMO/TD-No. 794) (UNEP/DEIA/MR.97-4)	Report of the Global Observing Systems Space Panel, second session (Geneva, Switzerland, October 16-18, 1996)
GCOS-30 (WMO/TD-No. 795)	Report of the sixth session of the Joint Scientific and Technical Committee for GCOS (Victoria, British Columbia, Canada, October 28-November 1, 1996)
GCOS-31 (WMO/TD-No. 803)	Proceedings of the fifth meeting of the TAO Implementation Panel (TIP-5) (Goa, India, November 18-21, 1996)

GCOS-32 (WMO/TD-No. 796)	GCOS/GTOS Plan for Terrestrial Climate-related Observations, version 2.0, June 1997
GCOS-33 (WMO/TD-No. 798)	GHOST - Global Hierarchical Observing Strategy, March 1997
GCOS-34 (WMO/TD-No. 799)	Initial Selection of a GCOS Surface Network, February 1997
GCOS-35 (WMO/TD-No. 839)	Report of the second Joint CCl/CBS Meeting on the GCOS Surface Network (De Bilt, The Netherlands, June 25-27, 1997)
GCOS-36 (WMO/TD-No. 844) (UNESCO/IOC)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate, second session (Cape Town, South Africa, February 11-13, 1997)
GCOS-37 (WMO/TD-No. 845) (GOOS-10) & (GTOS-9)	Report of the Global Observing Systems Space Panel, third session (Paris, France, May 27-30, 1997)
GCOS-38 (WMO/TD-846) (GTOS-10)	Report of the Meeting of Experts on Ecological Networks (Guernica, Spain, June 17-20, 1997)
GCOS-39 (WMO/TD-No. 847) (GOOS-11) & (GTOS-11) (UNEP/DEIA/MR.97-8)	Report of the GCOS/GOOS/GTOS Joint Data and Information Management Panel, third session (Tokyo, Japan, July 15-18, 1997)
GCOS-40 (WMO/TD-No. 848)	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate, third session (Reading, UK, August 19-22, 1997)
GCOS-41 (WMO/TD-No. 849)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) Ocean Climate Time-Series Workshop, (Baltimore, (GOOS-33), MD, USA, March 18-20, 1997)
GCOS-42 (WMO/TD-No. 857)	Report of the seventh session of the Joint Scientific and Technical Committee for GCOS (Eindhoven, The Netherlands, September 22-26, 1997)
GCOS-43a (GOOS-36)	TAO Implementation Panel, sixth session (Reading, U.K., November 4-6, 1997)
GCOS-43b (GOOS-55)	International Sea Level Workshop (Honolulu, Hawaii, USA, June 10-11, 1997)
GCOS-44 (GOOS-61)	Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC), third session (Grasse, France, April 6-8, 1998)
GCOS-45 (WMO/TD-No. 922) (GOOS-58) & (GTOS-16) (UNEP/DEIA/MR.98-6)	Report of the Joint Meeting of the GCOS/WCRP Atmospheric Observation Panel for Climate and the GCOS/GOOS/GTOS Joint Data and Information Management Panel, fourth session (Honolulu, Hawaii, USA, April 28-May 1, 1998)

GCOS-46 (GTOS-15)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, fourth session (Corvallis, USA, May 26-29, 1998)
GCOS-47 (WMO/TD-No. 941) (GOOS-67) (GTOS-20)	Report of the Global Observing Systems Space Panel, fourth session, (College Park, Maryland, USA, October 22-23, 1998)
GCOS-48	Report on the Adequacy of the Global Climate Observing Systems (United Nations Framework Convention on Climate Change, November 2-13 1998, Buenos Aires, Argentina)
GCOS-49 (GOOS-64)	Implementation of Global Ocean Observations for GOOS/GCOS, first session (Sydney, Australia, March 4-7, 1998)
GCOS-50 (GOOS-65)	Implementation of Global Ocean Observations for GOOS/GCOS, second session (Paris, France, November 30, 1998)
GCOS-51 (GOOS-66)	Global Ocean Observations for GOOS/GCOS: An Action Plan for Existing Bodies and Mechanisms
GCOS-52 (GOOS-68)	TAO Implementation Panel, seventh session (Abidjan, Ivory Coast, November 11-13, 1998)
GCOS-53 (WMO/TD-No. 958)	GCOS Surface Network (GSN) Monitoring Centre Implementation Meeting (Offenbach, Germany, January 19-20, 1999)
GCOS-54 (WMO/TD-No. 953)	Report of the eighth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Geneva, Switzerland, February 9-12, 1999)
GCOS-55	Report of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), fifth session (Silver Spring, MD, USA, April 20-23, 1999)
GCOS-56 (GOOS-75)	Special Report of the Joint GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC), fourth session (May 17, 1999); The CLIVAR Upper Ocean Panel (UOP), fourth session (May 21, 1999); A Joint Planning Meeting of the OOPC and the UOP for the OCEANOBS99 Conference (Woods Hole, MA, USA, May 18-20, 1999)
GCOS-57 (WMO/TD-No. 978) (GOOS-79)	Report of the OOPC/AOPC Workshop on Global Sea Surface Temperature Data Sets (Palisades, N.Y., USA, November 2-4, 1998)
GCOS-58 (GOOS-71**)**	Report of the sixth session of the IOC Group of Experts on the Global Sea Level Climate Observing System (GLOSS)
GCOS-59 (GTOS-22)	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate, fifth session (Birmingham, UK, July 27-30, 1999)
GCOS-60 (WMO/TD-No. 1004) (GOOS-70)	GCOS/GOOS/GTOS Joint Data and Information Management Plan, Version 1.0, May 2000

GCOS-61 (WMO/TD-No. 1031)	Report of the ninth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Beijing, China, September 12-14, 2000)
GCOS-62 (WMO/TD-No. 1038)	Report of the Pacific Islands Regional Implementation Workshop on Improving Global Climate Observing Systems (Apia, Samoa, August 14-15, 2000)
GCOS-63 (WMO/TD-No. 1047) (GTOS-26)	Establishment of a Global Hydrological Observation Network for Climate. Report of the GCOS/GTOS/HWRP Expert Meeting (Geisenheim, Germany, June 26-30, 2000)
GCOS-64 (GOOS-107)	Report of the eighth session of the TAO Implementation Panel (TIP-8) (St. Raphael, France, October 15, 1999)
GCOS-65 (WMO/TD-No. 1055)	Report of the sixth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) (Geneva, Switzerland, April 10-13, 2000)
GCOS-66 (GOOS-108)	Report of the ninth session of the TAO Implementation Panel (TIP-9) (Perth, Australia, November 16-17, 2000)
GCOS-67 (WMO/TD-No. 1072)	GCOS Implementation Strategy: Implementing GCOS in the New Millennium
GCOS-68 (WMO/TD-No. 1093)	Report of the seventh session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) (Geneva, Switzerland, April 30-3 May, 2001)
GCOS-69 (GOOS-98)	Report of the fifth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Bergen, Norway, June 20-23, 2000
GCOS-70 (GOOS-113)	Report of the sixth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Melbourne, Australia, May 2-5, 2001
GCOS-71 (WMO/TD-No. 1099) (GTOS-29)	Report of the GCOS/GTOS/HWRP Expert Meeting on the Implementation of a Global Terrestrial Network - Hydrology (GTN-H), Koblenz, Germany, June 21-22, 2001
GCOS-72 (GOOS-116)	Report of the seventh session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS), Honolulu, April 26-27, 2001
GCOS-73 (WMO/TD-No. 1106)	Manual on the GCOS Surface and Upper-Air Networks: GSN and GUAN, April 2002
GCOS-74 (WMO/TD-No. 1109)	Report of the GCOS Regional Workshop for Eastern and Southern Africa on Improving Observing Systems for Climate, Kisumu, Kenya, October 3-5, 2001
GCOS-75 (WMO/TD-No. 1124)	Summary Report of the tenth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, Farnham, UK, April 15-19, 2002
GCOS-76 (WMO/TD-No. 1125)	Report of the eighth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Wokingham, UK, May 20-24, 2002

*GCOS publications may be accessed through the GCOS website at:
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GCOS-77 (GOOS-122)	International Workshop for Review of the Tropical Moored Buoy Network, September 10-12, 2001, Seattle, Washington, USA. Workshop Report
GCOS-78 (WMO/TD-No. 1126)	Report of the GCOS Regional Workshop for Central America and the Caribbean. "Observing Climate from Weather Extremes to Coral Reefs", San José, Costa Rica, March 19-21, 2002 (disponible también en español)
GCOS-79 (WMO/TD-No. 1133)	Interim Report to the sixteenth session of the Subsidiary Body for Scientific and Technological Advice of the UNFCCC by the Global Climate Observing System, Bonn, Germany, June 5-14, 2002
GCOS-80 (WMO/TD-No.1140)	Report of the GCOS Regional Workshop for East and Southeast Asia on Improving Observing Systems for Climate, Singapore, September 16-18, 2002
GCOS-81 (GOOS-124)	Seventh session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Kiel, Germany, June 5-8, 2002
GCOS-82 (WMO/TD-No.1143)	Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC
GCOS-82 (ES) (WMO/TD-No.1176)	Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC – Executive Summary
GCOS-83 (WMO/TD-No.1155) (GTOS-33)	Report of the Global Terrestrial Network - Hydrology (GTN-H) Coordination Panel Meeting, Toronto, Canada, November 21-22, 2002
GCOS-84 (WMO/TD-No.1156) (GTOS-32)	Report of the GCOS/GTOS/HWRP Expert Meeting on Hydrological Data for Global Studies, Toronto, Canada, November 18-20, 2002
GCOS-85 (WMO/TD-No.1167)	Report of the GCOS Regional Workshop for Western and Central Africa on Improving Observing Systems for Climate, Niamey, Niger, March 27-29, 2003 (disponible en français)
GCOS-86 (WMO/TD-No.1183)	Report of the GCOS Regional Workshop for South America on Improving Observing Systems for Climate, Santiago, Chile, October 14-16, 2003 (disponible también en español)
GCOS-87 (WMO/TD-No.1189)	Summary Report of the eleventh session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, Melbourne, Australia, April 7-10, 2003
GCOS-88 (WMO/TD-No. 1190)	Conclusions from the ninth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Asheville, NC, USA, June 23-27, 2003
GCOS-89 (GOOS-140)	Report of the Eighth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Ottawa, Canada, September 3-6, 2003
GCOS-90 (GOOS-141)	IOC Group of Experts on the Global Sea Level Observing System (GLOSS), eighth session, Paris, France, October 13 and 16-17, 2003

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

GCOS-90bis	Report of the GCOS/GTOS Terrestrial Observation Panel for Climate (TOPC), seventh session, Rome, Italy, December 16-18, 2003
GCOS-91 (WMO/TD-No.1221)	Summary Report of the twelfth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, Geneva, Switzerland, March 15-19, 2004
GCOS-91bis	Conclusions from the tenth session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Geneva, Switzerland, April 19-23, 2004
GCOS-92 (WMO/TD-No.1219)	Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC
GCOS-92 (ES) (WMO/TD-No.1244)	Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC – Executive Summary
GCOS-93 (WMO/TD-No.1238) GTOS-35	Summary Report of the eighth session of the GTOS/GCOS Terrestrial Observation Panel for Climate, Ispra, Italy, April 6-7, 2004
GCOS-94 (WMO/TD-No.1248)	Report of the GCOS Regional Workshop for Central Asia on Improving Observing Systems for Climate, Almaty, Kazakhstan, May 24-26, 2004 (имеется также на русском языке)
GCOS-95 (GOOS-143)	Report of the ninth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Southampton, UK, June 7-10, 2004
GCOS-96 (WMO/TD-No. 1255)	Analysis of Data Exchange Problems in Global Atmospheric and Hydrological Networks
GCOS-97 (WMO/TD-No. 1259)	Report of the GCOS Regional Workshop for South and Southwest Asia on Improving Observing Systems for Climate, New Delhi, India, October 11-13, 2004
GCOS-98 (GOOS-146)	Progress with the Initial Ocean Climate Observing System: A Report to the UNFCCC – April 2005
GCOS-99 (GOOS-149)	IOC Group of Experts on the Global Sea Level Observing System (GLOSS), ninth session, Paris, France, February 24-25, 2005
GCOS-100 (WMO/TD-No. 1283)	Report of the GCOS Regional Workshop for Eastern and Central Europe on Improving Observing Systems for Climate, Leipzig, Germany, April 26-28, 2005
GCOS-101 (WMO/TD-No. 1298) (GTOS-37)	Report of the 2nd Meeting of the GTN-H Coordination Panel, Koblenz, Germany, July 4-5, 2005
GCOS-102	Conclusions from the eleventh session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Geneva, Switzerland, April 11-15, 2005
GCOS-103 (WMO/TDN-No 1341)	Summary report of the thirteenth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, St Petersburg, Russian Federation, 5-8 October 2005

GCOS-104	Report of the tenth session of the Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate Tenth, Geneva, Switzerland, May 9-12, 2005
(GOOS-150)	Session Final Report
GCOS-105 (WMO/TD-No. 1374)	Conclusions from the Twelfth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Geneva, Switzerland, April 3-7, 2006
GCOS-106 (WMO/TD-No. 1337)	Report of the GCOS Regional Workshop for the Mediterranean Basin, Marrakech, Morocco, November 22-24, 2005
GCOS-107 (WMO/TD-No. 1338)	Systematic Observation Requirements for Satellite-Based Products for Climate
GCOS-108 (WMO/TD-No. 1358)	Climate Information for Development Needs an Action Plan for Africa, Report and Implementation Strategy, Addis Ababa, Ethiopia, 18-21 April 2006
GCOS-109 (WMO/TD-No 1363)	Summary report of the fourteenth session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS, Geneva, Switzerland 10-12 October 2006
GCOS-110 (WMO/TD-No. 1370) (GOOS No. 154) (WCRP No.)	Joint GCOS-GOOS-WCRP Ocean Observations Panel for Climate (OOPC), Eleventh Session, Tokyo, Japan 16-20 May 2006
GCOS-111 (WMO/TD-No. 1371) (GTOS No. 43)	Summary Report of the ninth session of the GTOS/GCOS Terrestrial Observation Panel for Climate, Ispra, Italy 28-29 March 2006
GCOS-112 (WMO/TD-No. 1379)	GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options
GCOS-113 (WMO/TD-No. 1396)	Report of the Third Meeting of the GCOS Cooperation Board (Geneva, Switzerland, 27 April 2007)
GCOS-114 (WMO/TD-No. 1407)	Thirteenth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC-XIII) – Consolidated List of Conclusions, Recommendations and Action Items (Geneva, Switzerland, 23-27 April 2007)
GCOS-115 (WMO/TD-No. 1408)	Report of the Third Meeting of the GTN-H Coordination Panel (Koblenz, Germany, 17-19 September 2007)
GCOS-116 (WMO/TD-No. 1415)	Report of the Fifteenth Session of the WMO-IOC-UNEP-ICSU Steering Committee for GCOS (Paris, France, 16-19 October 2007)
GCOS-117 (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 (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 (WMO/TD-No. 1424)	Report of the Implementation Strategy Meeting for Central America and the Caribbean (Belize City, 28-30 January 2008)
GCOS-120 (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 (WMO/TD-No. 1435)	GCOS Reference Upper Air Network (GRUAN). Report of the GRUAN Implementation Meeting (Lindenberg, Germany, 26-28 February 2008)
GCOS-122 (WCRP 9/2008) (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)

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GCOS Secretariat
Global Climate Observing System
c/o World Meteorological Organization
7*bis,* Avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland
Tel: +41 22 730 8275/8067
Fax: +41 22 730 80 52
Email: gcosjpo@wmo.int