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GRUAN Manual of Operations (Draft v0, 10 February 2009)

(Submitted by GCOS Secretariat)

Summary and Purpose of Document

This document contains a first draft for a GRUAN Manual of Operations (an "expanded table of contents"), as a basis for discussion and further development. Wherever possible, it provides pointers to existing manuals of operations developed by WMO, such as under the Commission for Instruments and Methods of Observation (CIMO), the Commission for Climatology (CCl) and the Commission for Basic Systems (CBS). It equally points to existing guidance material from the Baseline Surface Radiation Network (BSRN), GAW and GCOS. It then outlines GRUAN-specific operational guidance for the different parameters and instrument classes, with most of the content yet to be specified.

For background information, the following website provides a collection of relevant existing general and instrument-specific guidance material:

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

GCOS Reference Upper-Air Network (GRUAN)
Manual of Operations

(Draft v0, 10 February 2009)

References

ANNEXES:

A1 Specifications for a Reference Radiosonde for the GCOS Reference Upper-Air Network (GRUAN) [cf GRUAN ICM-1/Doc 6.1]
A2 Further technical Annexes (Algorithms; filters; time correction; etc.) [TBD]
A3 GRUAN Data Policy [cf GRUAN ICM-1/Doc 5.0]
A4 GCOS Climate Monitoring Principles

1. Introduction

Scope and Purpose of the Network

The GCOS Reference Upper-Air Network (GRUAN)[1] was initiated by the Global Climate Observing System (GCOS), a programme sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the International Council on Science (ICSU), and the United Nations Environment Programme (UNEP). GRUAN, when fully implemented, will comprise up to 30-40 sites globally for atmospheric reference observations, providing the foundation for long-term datasets that can be used to reliably monitor and detect emerging signals of global and regional climate change (GCOS-112). GRUAN will address a serious deficiency in the existing global climate observing system, since upper-atmospheric trends are currently difficult to establish due to a lack of long-term observations of sufficient accuracy. This deficiency has been identified as a priority action in the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC" (GCOS-92) in 2004. The concept of and the requirements for GRUAN were developed at expert workshops in Boulder, USA (2005) and Seattle, USA (2006), held under the auspices of GCOS and the US National Oceanic and Atmospheric Administration.

WMO Executive Council at its 60th session (June 2008) noted that the GRUAN "would provide high-quality observing sites for the atmospheric profile, including surface and upper-air measurements, in support of climate application, validation of satellite products and climate research." It further requested WMO Members, "to support the implementation of the GRUAN, using wherever possible existing infrastructure."

GRUAN will provide long-term high quality climate records, particularly in the troposphere and in the lower stratosphere by a combination of balloon borne and remote sensing instrumentation, and will constrain and calibrate data from more spatially-comprehensive global observing systems including satellites and current radiosonde networks (including the GCOS Upper-Air Network, GUAN).

2. GRUAN Sites

GRUAN sites are operated by national meteorological services and other national environmental agencies or research institutions, under the auspices of the Working Group on Atmospheric Reference Observations (WG-ARO), the Atmospheric Observation Panel for Climate (AOPC) jointly sponsored by GCOS and the World Climate Research Programme (WCRP), and the GCOS Steering Committee. The selection of GRUAN sites depends on a recommendation by the WG-ARO based on selection critera (see 2.1), approval by the AOPC, and a written commitment by the host country to support the site in meeting GRUAN requirements in response to a formal invitation.

In February 2008, the GRUAN Lead Centre was established, for an initial pilot phase, at the Meteorological Observatory Lindenberg/Richard-Assmann observatory of the German Meteorological Service at Lindenberg, Germany – the first official GRUAN site. All information on participating sites is available from the official GRUAN Web Portal: www.gruan.org .

2.1 Station selection criteria

Comment: This section describes the minimum & target requirements, geographical distribution, relation to other international networks etc.…

[1] See for related information www.gruan.org

The selection of GRUAN sites is based upon:

- the proven or potential ability of the site meeting initial GRUAN site requirements as described in GCOS-112 and GCOS-121, including commitment by the host country
- geographical distribution
- wherever possible, the collocation with sites of existing global networks, such as the GCOS Upper-Air Network (GUAN), the Global Atmosphere Watch (GAW) the Baseline Surface Radiation Network (BSRN), and other WMO networks, to ensure maximum synergy with these networks.

A GRUAN 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. Those requirements could be fulfilled for example by stations being part of existing observational network, and by using and augmenting the existing instrumentation and skills base, that ideally include a long-term historical upper-air sounding capability. It is desirable to have network sites that are connected to a host institution with scientific experts engaged in the analysis of collected data, and with the necessary technical expertise to maintain the instrumentation. It is essential that there be a full institutional commitment to the GRUAN-related activity at any particular site that is not dependent on a single Principal Investigator.

GRUAN will not be globally complete, but will sample major climatic regimes, latitudes, altitudes, and surface types. While it is inevitable that some changes in the networks will occur due to circumstances beyond the control of the station operator, it is a fundamental obligation of the station operators to keep changes to an absolute minimum.

When modifications to participating stations are made, the GRUAN lead centre has to be notified. Requests for additions to, or deletions from, the GRUAN network should be made to GCOS through the WMO. Such requests will be considered by the Atmospheric Observation Panel for Climate (AOPC) in the context of the network as a whole.

Changes or bias caused by changes in instrumentation should be evaluated by a sufficient overlapping period of observation (preferably, as much as a year?) with dual operation of old and new sensor devices or by making use of the results of instrument intercomparisons made at designated test exercises.

A GRUAN site would initially be envisaged to cover, at a minimum:

- priority 1 variables:
  • High-quality measurements of the standard surface variables pressure, temperature, humidity and wind
  • Close proximity to the upper-air sounding instruments
  • Simultaneous balloon-based observations of temperature, water vapour and winds using different measurement techniques
  • Pressure and GPS/radar height on balloons
  • Ground-based GPS receivers to measure total column water vapour

- priority 2 variables:
  • Surface radiation instruments as currently deployed for the Baseline Surface Radiation Network;
  • Microwave radiometer to measure temperature and moisture characteristics;
  • Multi-channel infrared radiometer, such as an AERI, to measure temperature and humidity properties and cloud retrieval (may need other cloud based measures, such as ceilometer);
  • Lidar to provide an alternative source of water vapour and cloud monitoring;
  • Integrated trace gas measurements (at least ozone and methane);
  • Column aerosol measurements from sun-photometers.

2.2 Site description

Comment: This section describes required information on, e.g., instrumentation set up, surroundings, resources, organizational arrangements etc.…

The site layout should consider the form recommended by the WMO Guide on the Global Observing System [3].

3. Observed Parameters

Comment: This section describes required precision & accuracy of observed parameters with respect of altitude; resolution in space and time; leading institute/group, etc.…

Adherence to GCOS Climate Monitoring Principles (Annex A4) has to be ensured for all GRUAN measurements, and appropriate processes need to be put in place at every site to this end. All measurements should be traceable to the SI scale as well as following the ISO guidelines for calculating and expressing uncertainty in measurements [7].

To be specified:
Precision & accuracy required for each parameter with respect of altitude; resolution in space and time; etc. independent of measurement technique (quote GCOS-112, Appendix 1)

3.1 Temperature
(upper-air temperature)

3.2 Pressure

3.3 Wind
(wind speed and direction)

3.4 Water vapour

3.5. Radiation
(solar irradiance)

3.6 Ozone

3.7 Additional parameters
(cloud properties)

4. Methods of Observation

Within existing WMO-coordinated networks as part of the WMO Global Observing System (GOS), uniformity and standardization in the practices and procedures employed in operating the network are insured by adhering to the recommendations in the Manual on the GOS [8] and the Commission for Climatology's Guide to Climatological Practices [9]. The following GRUAN specific guidelines are consistent with these recommendations to the extent possible.

Observations of meteorological parameters building on existing systems (using well-established instrumentation) are to be performed following the WMO guide to meteorological instruments and methods of observations ("CIMO Guide") [4].

In order to enable efficient identification of measurement errors and thereby constrain measurement uncertainty, GRUAN strives for (a) measurements of a given variable by different, independent methods and (b) measurements of complementary variables that facilitate interpretation of a given variable.

4.1 Ground based measurements

4.1.1 Required Observations

- Operational guidance from existing networks and systems
    - Measurements in compliance with WMO Guides [3], [8]
    - Manual on GSN and GUAN [6]
    - BSRN Measurements in compliance with [10]
    - GAW Measurements in compliance with ??
    - other

- GRUAN specific requirements
    - Details on GPS column water vapour observations
    - other

4.1.2 Additional Observations

- Operational guidance from existing networks and systems
    - Measurements in compliance with WMO Guides [3], [8]
    - other

- GRUAN specific requirements
    - Details on lidar; microwave column measurements; FTIR observations
    - other

4.2. Upper-Air measurements

4.2.1 Required Instrumentation

- Operational guidance from existing networks and systems
    - Measurements in compliance with WMO Guides [3], [8]
    - Manual on GSN and GUAN [6]
    - other

- GRUAN specific requirements
    - Vertical profiles of p, T, r.H., v
    - Microwave Sounding Unit (MSU) radiances
    - other

For example:

Simultaneous balloon-based observations of temperature, water vapour and winds will be using different measurement techniques. Measurements should be made both on ascent and descent.

- Advantage should be taken of the multiple channels available.
  For temperature, a three-thermistor set (with different radiative properties: white, black, silver) would enable radiation corrections and provide redundancy.

For humidity, at least three sensors should be tuned for operation in different parts of the atmosphere with less of a requirement to span the full dynamic range: thus one sensor is tuned for the lower troposphere, one for the upper troposphere, and one for the stratosphere.

- Both measurements require redundancy throughout the vertical profile. This redundancy is required to diagnose instrument failure and characterize instrument biases.
- At least one of the techniques for simultaneous measurements is required to be state-of-the-art, commercially available technology, tested in the laboratory and in the field, to provide reference quality measurements.

4.2.2 Additional Instrumentation

- Observations building on existing systems
- GRUAN specific requirements

4.3 Reference instruments

For example:

A 'reference' instrument type is used at all sites.

GRUAN lead centre is developing reference instruments, quantifying their statistical errors and bias and training staff on instrument operation. 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

We define a reference radiosonde here as a single instrument or a 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 (Annex A1). The radiation correction for the radiosondes used in the GRUAN network should be evaluated at each GRUAN site, with help from the Lead Centre.

5. Operation of Instruments

Whenever possible, sensors should be calibrated with references traceable to SI standards.

5.1 Calibration

5.1.1 Routine Calibrations

- Calibration guidance from existing networks and systems
- GRUAN specific requirements

5.1.2 Inter-Calibrations

Regular Intercalibration exercises will be coordinated by GRUAN Lead Centre.

5.2. Operation and Maintenance

Comment: This section describes timing, redundancy of measurements; management of change in observing methods etc…

For example:

Required radiosonde launches:

1. 1 x weekly production radiosonde with the best technology currently available at the site;
2. 1 x monthly radiosonde capable of capturing the water vapour signal in the UT/LS and all other priority 1 variables to the best level possible with current technology, to be launched together with a weekly radiosonde;

Additional radiosonde launches:

3. Regular 00 and 12 LST (as a preference over UTC) launches of a production radiosonde with best technology currently available;
4. Dual launches of sondes with highest quality humidity sensing capability in the UT/LS
5. Periodic intercomparisons of a large range of sonde types.

5.3 Linkage to Satellite Operators and GSICS

- Coordination of GRUAN site operations with needs of satellite operators
- Linkage to Global Satellite Inter-Calibration System (GSICS)

6. Data Dissemination and Data Policy

AOPC recommended at its XIVth session (Geneva, 21-25 April 2008 [11]) that GRUAN sites should provide all GRUAN data in a free and unrestricted manner, if possible in real time, in order to be of maximum value for all applications, for example enabling the data being monitored and assimilated in numerical weather prediction systems. All data from the instrument systems which are specified in GCOS-112, or any agreed revision of GCOS-112, are regarded as 'essential' at all GRUAN sites, to ensure the free and unrestricted availability of these data.

The draft GRUAN data policy (August 2008; Annex A3) complies with WMO policy, practice and guidelines for the exchange of meteorological and related data and products, as embodied in Resolution 40 of the Twelfth WMO Congress 1995 and described at http://www.wmo.int/pages/about/Resolution40.html.

6.1 Data format

6.1.1 Observational Data

For example:

GRUAN data can be submitted in established GUAN, BSRN or NCDC data formats, such as TEMP and CLIMAT.

6.1.2 Meta-Data

For example (radiosonde-specific):

Detailed meta-data should be provided. The batch identifier on the radiosondes should be logged for each flight, so that faulty batches can be identified and the data amended or eliminated from the climate records if necessary. Up-to-date records of meta-data in a standard format should be provided to the GRUAN Archive so that shifts in the data will not be mistaken for climate change. The meta-data should include detailed information about the station, such as location, elevation, operating instruments and their changes over time. Changes to operating and correction procedures should also be recorded. Both the corrected and uncorrected upper-air observation should be archived in case a re-correction must be

applied. As climate change studies require extremely high stability in the systematic errors of the radiosonde measurements, reference measurements are only valuable in combination with comprehensive meta-data records.

GRUAN Meta-Data should consider the format and guidelines as described in [5] and [6] (e.g., the BUFR-code).

6.2 Data submission, dissemination and archiving

To be clarified:

- Observational data and meta-data are to be transmitted via GTS? Others? … by …
- Will there be an Internet Gateway for CLIMAT and TEMP reports?
- What are the time limits for submission?

For example:

Data is to be labelled by its stage of processing as

- "*preliminary*" for data submitted in near-real-time,
- "*quality checked*" for fully calibrated and analyzed data sets and
- "*re-analysed by DATE*" if re-calibration or any other scale shift or re-processing of data have been performed.

The NOAA National Climatic Data Center (NCDC), which also hosts World Data Center (WDC) for Meteorology, could archive and disseminate the data through the Global Observing Systems Information Center (GOSIC)[2].

The NCDC could also perform both the real-time monitoring of the health of the network and more comprehensive, retrospective analyses of GRUAN data.

6.3 Data accessibility

NCDC allocates all data free of charge, as part of its suite of data services.

7. Monitoring, Analysis and Archiving Activities

7.1 Data processing and analysis

7.1.1 Monitoring of near-real-time data

To be clarified:

- Performance monitoring activities to be coordinated/performed by the Lead Centre?

7.1.2 High quality processed data

7.1.3 Reanalysis

7.2 Quality control

To be clarified:

- Quality and control reports to be delivered by whom, how often, to whom?

[2] http://gosic.org

References

[1] GCOS-112; GCOS reference upper-air network (GRUAN): Justification, requirements, sitting and instrumentation options (WMO-TD No. 1379)
http://www.wmo.int/pages/prog/gcos/Publications/gcos-112.pdf

[2] GCOS-121, Report of the GRUAN Implementation Meeting, Lindenberg, Germany, 26-28 February 2008 (WMO-TD No. 1435)
http://www.wmo.int/pages/prog/gcos/Publications/gcos-121.pdf

[3] WMO-488, Guide on the Global Observing System (GOS)
http://www.wmo.int/pages/prog/www/OSY/Manual/488_Guide_2007.pdf

[4] WMO-8, CIMO Guide Seventh Edition 2008
http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO_Guide-7th_Edition-2008.html

[5] WCDMP-53, Guidelines on climate metadata and homogenization (WMO-TD No. 1186)
http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/documents/WCDMP-53.pdf

[6] GCOS-73, Guide to the GCOS Surface and Upper-Air Networks (GCOS-73, WMO-TD No 1106)
http://www.wmo.int/pages/prog/gcos/Publications/gcos-73.pdf

[7] ISO/IEC Guide 98-3 (2008), Guide to the Expression of Uncertainty in Measurement (GUM).
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45315

[8] WMO-544, Manual on the Global Observing System (GOS)
http://www.wmo.int/pages/prog/www/OSY/Manuals_GOS.html

[9] WMO-100, Guide to Climatological Practices
http://www.wmo.ch/pages/prog/wcp/ccl/guide/guide_climat_practices.html

[10] WMO- 1274, Baseline Surface Radiation Network (BSRN) Operations Manual
http://www.bsrn.awi.de/fileadmin/user_upload/Home/Publications/WCRP21_TD1274_BSRN.pdf

[11] Fourteenth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC) - Conclusions and Recommendations, *Geneva, Switzerland , 21-25 April 2008* (GCOS-122; WMO-TD No 1436)
http://www.wmo.int/pages/prog/gcos/Publications/gcos-122.pdf

For background information, the following website provides a collection of relevant existing general and instrument-specific guidance material:

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

Annex A4 : **GCOS Climate Monitoring Principles**

Effective monitoring systems for climate should adhere to the following principles[3]:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.

2. A suitable period of overlap for new and old observing systems is required.

3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.

4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.

5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.

6. Operation of historically-uninterrupted stations and observing systems should be maintained.

7. High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.

8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.

9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.

10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

[3] The 10 basic principles (in paraphrased form) were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. This complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May 2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.

Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.

12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.

13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.

14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.

15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.

16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.

17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.

18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on de-commissioned satellites.

19. Complementary *in situ* baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.

20. Random errors and time-dependent biases in satellite observations and derived products should be identified.