OVERVIEW of “**Specifications for a Reference Radiosonde for the GCOS Reference Upper-Air Network (GRUAN)**”

By the Working Group on
Atmospheric Reference Observations
(WG-ARO)

– July-October 2008 –

M. Fujiwara (Hokkaido Univ.), M. Ondras,
H. Vömel, J. Wang, J. Nash, D. Seidel, P. Thorne
(thanks to J. Dykema)

Purpose

- GCOS-122: “Fourteenth Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC-XIV) – Conclusions and Recommendations –” (April 2008)
- #27: AOPC requested that WG ARO provide specifications for a reference radiosonde to HMEI* with a view to vendors providing such sondes for the 2010 intercomparison.

- Explains the requirements for a reference radiosonde to the manufacturers and other instrument developers
- Distributed through, e.g., HMEI* (and Lead Centre?)

- *HMEI is the Association of Hydro-Meteorological Equipment Industry, which connects vendors with WMO

Specifications for a Reference Radiosonde for the GCOS Reference Upper-Air Network (GRUAN)

By the Working Group on Atmospheric Reference Observations (WG-ARO)

Final Version, October 2008

1. Introduction (This is a general introduction to the GRUAN.)

The GCOS Reference Upper-Air Network (GRUAN) is a network 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, 2007). 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).

In February 2008, the GRUAN Lead Centre was established at the Richard Assmann observatory of the German Meteorological Service at Lindenberg, Germany. At the end of February 2008, the GRUAN Implementation Meeting was held at the Lead Centre, and various aspects on this new network were discussed by the WG-ARO members, responsible persons from potential GRUAN sites, key persons of existing climate-monitoring networks, and others (GCOS, 2008).

Currently, we expect that 12 sites may start to participate in GRUAN within a few years and that more than 30 sites may be involved later (GCOS, 2008). During the initial phase, until an operational reference radiosonde, specified below, becomes available, GRUAN sites will launch a best quality operational radiosonde once per week, and a sensor capable of measuring upper-troposphere and lower-stratosphere (UTLS) water vapor once per month (see GCOS (2008) for further details). This is an interim measure. Frequency of usage of a reference radiosonde will depend upon the final unit cost and economic practicalities at individual sites but would be at least once per week at all sites and more where funding permitted.

In this manuscript, the specifications of a reference radiosonde for GRUAN from the surface to the middle stratosphere are described in detail.

2. General Requirements for a Reference Radiosonde

(7 in total)

(1) Parameters : T, RH/WV mixing ratio, and P; z by GPS

(1) Meteorological parameters with the highest priority are temperature, relative humidity in the troposphere, water vapor in the upper troposphere and in the lower stratosphere (UTLS), and pressure. Altitude (or geometric-height) measurements by the Global Positioning System (GPS) or radar are considered complementary to the geopotential-height measurements from pressure, temperature, and humidity measurements.

(2) Accuracy/uncertainty & precision/repeatability; traceability to SI standards

(2) The sensors should have high accuracy (i.e., small systematic error; small uncertainty) and high precision (i.e., high repeatability). The former is especially important for climate monitoring. A best estimate of the uncertainty must be provided with respect to reference measurements that can be traced to the SI standards. The uncertainty of every measurement point should be established and estimated as a function of altitude.

(3) Metadata

(3) Complete metadata, including processing algorithms, correction schemes, and the definition of each parameter (e.g., water vapor amount, conversion between geometric height to pressure), should be documented by the manufacturers and other instrument developers for future potential data reprocessing and revision. Also, easy, free access to the metadata in a public manner should be guaranteed for bona fide research purposes.

(4) Changes . . . should be manageable

(4) Changes in instrumentation and in operation procedures are desirable if they lead to improved observations. Sufficient overlap, intercomparison, and documentation of old and new measurements are needed at key GRUAN sites to ensure continuous climate record.

(5) Redundancy policy of GRUAN

(5) Note that at GRUAN sites, redundancy of measurements is imperative. Namely, a given parameter will always be measured by more than one physically independent method/instrument, and sites will consist of a rich mix of instrumentation technologies in addition to the radiosonde capability.

(6) Validation and intercomparison

(6) Periodic validation and intercomparison of the sensors should be made by the manufacturers and other instrument developers and by the GRUAN Lead Centre together with the Commission for Instruments and Methods of Observation (CIMO) and the WG-ARO.

(7) 2010 campaign

(7) These specifications have been prepared for a planned radiosonde intercomparison campaign by the CIMO and GCOS in 2010, where an evaluation of a reference radiosonde for GRUAN will also be made.

3. Requirements for Each Sensor

Table 1. An extraction from the Requirements Tables in the GCOS-112 report (GCOS, 2007). Some revisions (noted by numbers in the table) have been made primarily for limiting the vertical range to the meteorological balloon ascent altitudes.

(after the Seattle meeting in May 2006)

Variable	Temperature	Water Vapour	Pressure
Priority (1-4)	1	1	1
Measurement Range	170 – 350 K	0.1 – 90000 ppmv	1 –1100 hPa
Vertical Range	0 – 40 km [3)]	0 – 40 km [4)]	0 – 40 km [3)]
Vertical Resolution	0.1 km (0 to ~30 km) 0.5 km (above ~30 km)	0.05 km (0 – 5 km) 0.1 km (5 to ~30 km)	0.1 hPa
Precision [1)]	0.2 K	2% (troposphere) * 5% (stratosphere)	0.01 hPa
Accuracy [2)]	0.1 K (troposphere) 0.2 K (stratosphere)	2% (troposphere) * 2% (stratosphere)	0.1 hPa
Long-Term Stability	0.05 K *	1% (0.3%/decade) *	0.1 hPa
Comments	*The signal of change over the satellite era is in the order of 0.1–0.2K/ decade (cf. section 3.1), therefore long-term stability needs to be an order of magnitude smaller to avoid ambiguity	*Precision, accuracy and stability are relative with respect to mixing ratio	

(Note: From the scientific demand, not from the current capability!)

Variable	Wind Speed	Wind Direction*
Priority (1-4)	2	2
Measurement Range	0 – 200 m/s [5)]	0 – 360 degrees
Vertical Range	0 – 40 km [6)]	0 – 40 km [6)]
Vertical Resolution	0.05 km (troposphere) 0.25 km (stratosphere)	0.05 km (troposphere) 0.25 km (stratosphere)
Precision [1)]	0.5 m/s (troposphere) 1.0 m/s (stratosphere)	1 degree (troposphere) 5 degrees (stratosphere)
Accuracy [2)]	0.5 m/s *	5 degrees
Long-Term Stability	0.1 m/s (troposphere) 0.5 m/s (stratosphere)	1 degree (troposphere) 5 degrees (stratosphere)
Comments	*to delineate calm conditions from light winds	*Direction is meaningless in very light wind conditions.

[1)]Repeatability. [2)]Uncertainty. [3)]0-50 km in the GCOS-112 report. [4)]0 to ~30 km in the GCOS-112 report. [5)] 0-300 m/s in the GCOS-112 report. [6)]Surface to stratopause in the GCOS-112 report.

Additional and/or Further Requirements and Comments for Each Sensor:

(1) Temperature sensors

- For traceability to the SI standards, information on the sensor calibration at the factory is necessary. (Note that the unit Kelvin is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.)

- Resolution of the measurements should be equal to or less than 0.05 K.

- Response time should be estimated by the manufacturers and other instrument developers.

- The WG-ARO recognizes that the accuracy/uncertainty of current radiosonde temperature sensors mainly depends on the radiation errors. The evaluation of the radiation correction scheme for each sensor at each site (or even for each sounding) is the key. Clear documentation of the scheme is needed for the first step. Also, development of sensors with the correction-free principle is desirable for the future.

(The radiation error is the main concern for T sensors.)

- Notes: Temperatures of 170-175 K may be found in the winter polar lower stratosphere; temperatures of 180-185 K may be found at the tropical tropopause; and temperatures of 330 K may be found at the surface in subtropical deserts. It is not inconceivable that temperatures approaching 350 K could be achieved in the much longer term under strong warming scenarios, and it should be noted that GRUAN is envisaged as a long-term network.

(The range 170-350 K in the Table is not unreasonable.)

(2) Water vapor and relative humidity sensors

- For traceability to the SI standards, information on sensor calibration at the factory is necessary. Definition of, e.g., dew/frost point temperature, relative humidity, volume mixing ratio should be clearly documented.

- Resolution of the measurements should be specified so that the accuracy (uncertainty) and precision (repeatability) in Table 1 can be appropriately assessed.

- Response time should be estimated by the manufacturers and other instrument developers.

- The WG-ARO recognizes that the accurate water vapor measurements in the UTLS are most challenging at the moment. We therefore encourage new technologies and/or principles being developed. Also, it is not necessary for a single sensor to cover the entire altitude range of a balloon sounding. For example, one sensor is tuned for the lower troposphere, one for the upper troposphere, and one for the stratosphere. Clear documentation about the uncertainty as a function of altitude is essential.

(3) Pressure sensors

- For traceability to SI standards, information on sensor calibration at the factory is necessary.

- Resolution of the measurements should be equal to or less than 0.01 hPa.

- Response time should be estimated by the manufacturers and other instrument developers.

- The WG-ARO recognizes that some recent radiosondes can measure the geometric height by using the Global Positioning System (GPS) and that the GPS altitude measurements can be transferred to pressure. We welcome this relatively new technology. However, we also need independent pressure measurements for redundancy and to be able to assess the error budget.

(GPS is mentioned.)

(4) Horizontal wind sensors

- For traceability to the SI standards, information on the sensor calibration at the factory is necessary.

- Resolution of the measurements should be equal to or less than 0.1 m/s.

- Response time should be estimated by the manufacturers and other instrument developers.

- The WG-ARO recognizes that the GPS is currently one of the best techniques for radiosonde horizontal wind measurements. However, we also welcome other methods, particularly stand-alone methods, for redundancy and sustainability for many decades.

(GPS is mentioned.)

4. Other Considerations

- SI traceability for the on-site, pre-launch ground calibration/validation systems is necessary. Long-term stability of these systems should be ensured by making recalibration in regular intervals.

(ground system)

Notes:

- At GRUAN sites, more than one transmitter may be flown as a single payload for intercomparison and even for regular soundings. Various remote sensing instruments, some of which may use similar radiowave bands, may be co-located for redundant measurements. Therefore, high-performance telemetry systems are necessary.

(telemetry system)

- The battery life time should be enough for both ascent and descent measurements to allow redundancy.

(battery)

- The size and weight of sensors and transmitters should fall within national and international regulations on radiosonde instrumentation to minimize potential hazards and operational constraints.

(payload size and weight)

- To realize the redundancy of measurements in a single sounding, and to reduce the total cost that GRUAN sites should cover, manufacturers and other instrument developers are encouraged to collaborate toward a common platform for a reference radiosonde (e.g., capability of connecting to a special, open interface board on the payload; raw data storage capability by any ground receiving systems; post-launch data processing capabilities including a separated software).

(possible “common platform”)

REFERENCES

[1] Global Climate Observing System (GCOS) (2007), GCOS REFERENCE UPPER-AIR NETWORK (GRUAN): Justification, requirements, siting and instrumentation options, April 2007, Report GCOS-112 (World Meteorological Organization Technical Document No. 1379), 25 pp.
Available from http://www.wmo.int/pages/prog/gcos/Publications/gcos-112.pdf

[2] Global Climate Observing System (GCOS) (2008), GCOS Reference Upper Air Network (GRUAN). Report of the GRUAN Implementation Meeting, Lindenberg, Germany, 26-28 February 2008, Report GCOS-121 (World Meteorological Organization Technical Document No. 1435), 36 pp.
Available from http://www.wmo.int/pages/prog/gcos/Publications/gcos-121.pdf

("What is the GRUAN?" . . . from the viewpoint of instrumentation)