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| **World Meteorological Organization**  **Commission for Instruments and Methods of Observation**  **Planning Meeting for the 2021 Upper-air Intercomparison** Payerne, Switzerland, 19 – 21 February 2019 | **CIMO/UAI-Prep/INF. 4** |
| Submitted by: The Secretariat  15.02.2019 |

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# CIMO-17 decision related to the 2021 Upper-Air Intstrument Intercomparison

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| **Summary and purpose of document**  This document includes the Recommendation that was adopted by the Seventeenth Session of the Commission for Instruments and Methods of Observation, endorsing the proposal to conduct an upper-air instrument intercomparison in 2021, based on the offer and concept note provided by Germany and Switzerland. |

**Action proposed**

The Meeting is invited to use this document as a base/reference to develop the plan for the intercomparison.

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**Recommendation 10 (CIMO-17)**

**Upper-air instrument intercomparison**

THE COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION,

**Recalling** that the last WMO Intercomparison of High Quality Radiosonde Systems was held in Yangjiang, China in 2010 and that this intercomparison still serves as a reference for Members in their radiosonde procurement process,

**Noting** that:

(1) Regular WMO radiosonde intercomparisons have been of very high value for Members by providing independent assessments of the performance of radiosonde systems available on the market and serving as a basis for the selection of operational radiosounding systems,

(2) CIMO intercomparisons contribute to improving the quality and cost-effectiveness of upper-air observing systems by providing recommendations on system performance and on improvements to instruments and methods of observation and by providing suitable working references for WMO Members and instrument manufacturers,

**Noting further** that several manufacturers have introduced new radiosonde models that have not yet been assessed through an independent international campaign,

**Recognizing** the importance of upper-air measurements for numerical weather forecasting, as well as for climate monitoring and other applications, and the importance of continuing to carry out the corresponding independent performance assessments,

**Having examined** the offer from Deutscher WetterDienst (Germany) and MeteoSwiss (Switzerland) to lead the intercomparison campaign, including the data analysis as described in the concept note provided in the annex to the present recommendation,

**Noting with satisfaction** that one of the additional aims of the campaign is to involve a variety of other measurement techniques, such as remote sensing and aircraft and satellite observations, to assess the added value of these instrument systems for upper-air observations,

**Convinced** of the importance of carrying out such an upper-air instrument intercomparsion to ensure the continued comparability of upper-air measurements,

**Decides** to endorse this intercomparison and conduct it as a priority activity;

**Requests** the president of CIMO, in consultation with the Management Group, to establish an International Organizing Committee for overseeing the planning, conduct and evaluation of the intercomparison campaign;

**Recommends** that WMO support this intercomparison by providing sufficient resources to meet the general expenses linked to its conduct that are not covered by the offer of Germany and Switzerland;

**Proposes** that, after the intercomparison, the analysis software be made available to Members to enable them to make robust comparisons when testing radiosondes during future procurement and selection processes;

**Requests** the Secretary-General to identify suitable resources to support the intercomparison;

**Further requests** the Secretary-General to make needed arrangements to ensure that the project will be seamlessly transferred to the new relevant technical commission, should a governance reform happen prior to the completion of the project;

**Calls upon** Members to also provide human and/or financial resources to support this intercomparison;

**Encourages** all radiosonde manufacturers to take part in the campaign.

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**Annex to Recommendation 10 (CIMO-17)**

**Concept note for WMO-CIMO international radiosonde intercomparison campaign**

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**Introduction**

WMO-CIMO radiosonde intercomparison campaigns are organized for the purpose of getting an overview of the performance of the various operational radiosounding systems that are currently available. Such campaigns provide important information to national meteorological services (NMHS), who partially base the selection of an operational radiosounding system for their network on the outcome of these campaigns. Furthermore, these campaigns improve the quality and cost-effectiveness of upper-air observing systems by providing recommendations on system performances, improvements of instruments and methods of observation, suitable working references to WMO Members and instrument manufacturers. Therefore, all manufacturers of operational radiosonde systems are eligible to participate in the campaign, and CIMO aims to include as many manufacturers as possible. Since the last intercomparison campaign in 2010 in Yangjiang (China), several manufacturers have introduced new radiosonde models, so that the time is ripe for another campaign to evaluate these recent developments.

One of the additional aims of the campaign is to involve a variety of other measurement techniques such as remote sensing, aircraft and satellite observations to assess the added value of these instrument systems for upper-air observations. This will be discussed in more detail in the sections below.

**Planning, location and organisation**

The next campaign is planned to take place in 2021 at DWD’s Meteorological Observatory Lindenberg (Germany). The campaign will be organized under auspices of CIMO, with DWD and MeteoSwiss as local organizers.

The Lindenberg campaign will cover 4 weeks in/around September 2021, during which each radiosonde type will perform approximately 30 soundings (equally distributed over day and night).

There is a common interest between the WMO-CIMO campaign and the GCOS Reference Upper-air Network (GRUAN), where the purpose of GRUAN is to provide high-quality reference observations for e.g. climate monitoring, and to do so a lot of effort goes into determining measurement errors and uncertainties. There is growing recognition for GRUAN outside the climate community, and GRUAN data are available for NWP. With the GRUAN Lead Centre being situated at Lindenberg Observatory, participation of GRUAN in the campaign, similar to 2010, is an obvious consequence. The GRUAN-contribution involves the selection and application of reference in-situ instruments for temperature and water vapour, the characterization of radiosondes under laboratory conditions and the application of manufacturer-independent checks of the radiosondes prior to launch.

Similar to 1995, substantial laboratory testing with the focus on characterizing the errors and uncertainties of radiosondes’ sensors will take place in a separate period; these laboratory activities are an integral part of the radiosonde intercomparison campaign, and therefore are compulsory for all participants. The timing of the laboratory campaign (before or after the radiosounding activities) still is to be decided.

Lindenberg Observatory has an extensive and unique collection of remote sensing instrumentation, which will be included in the campaign to assess and characterize the added-value of remote sensing instruments for upper-air measurements. Furthermore, it is expected that the campaign will lead to a methodology on how to compare radiosondes with remote sensing instruments.

**Goal of the campaign**

The main objective of the radiosonde intercomparison campaign is to test the performance of operational radiosonde systems and to provide guidance on their performance relative to each other, as well as to evaluate the current capabilities of remote sensing instruments. Its results shall help NMHS in selecting radiosondes according to their requirements and will allow them to evaluate the potential offered by remote sensing instruments to complement the in situ information provided by the radiosondes.

The campaign shall not be used to test new prototypes, neither of radiosondes, nor of remote-sensing instruments.

The specific goals of the campaign are, including these previously proposed by the GRUAN Task Team Upper-air Intercomparison:

(1) To bring all the major radiosonde manufacturers of all the different regions of the world together.

(2) To characterize the individual radiosondes with respect to their **Reproducibility** and to determine the **Uncertainty** of the different measured parameters.

(3) To compare the different radiosonde systems to a “**Radiosonde Reference**” (mean of three chosen Traveling Standard Systems, that are to be selected by the International Organizing Committee (IOC)).

(4) To include remote sensing instruments for the benefit of upper-air measurements as a whole.

(5) To include Aircraft AMDAR observations.

(6) To include satellite observations.

The study shall evaluate the capability of each system participating in the intercomparison to reach the uncertainty targets for different use cases such as assimilation in numerical weather models, satellite verification and climate monitoring as defined in the OSCAR requirements and capabilities databases[[1]](#footnote-1).

**Radiosounding activities**

The radiosounding part of the campaign is envisaged to last 4 weeks in/around September 2021. For each radiosonde type approximately 30 soundings will be performed, equally distributed over day and night, with multiple soundings per day. Routine radiosoundings in Lindenberg are performed at 0, 6, 12 and 18 UTC, but the soundings for the campaign are not bound to these times and can be scheduled at will.

In view of the expected number of participants it is presumably not possible to mount all radiosondes on the same rig, therefore the sondes will be distributed over 2 or 3 separate balloons that are launched within several minutes of each other. Previous radiosonde intercomparisons were made without a reference since there is no universally accepted World reference radiosonde. This complicated the comparison between radiosondes that were flown on different rigs. For this campaign it is proposed to construct a traveling reference standard from the average of three different radiosondes that are part of each and every rig that is flown. The make and type of the three reference radiosondes will be decided by the IOC, and remain so for the duration of the campaign.

The reproducibility (goal #2) can be tested by mounting two identical radiosondes on the same rig. A given number of double flights allows the evaluation of the measurement uncertainty of a system. The goal is to have double flights for all systems. This means that all manufacturers need to supply two radiosonde receiving systems and operate them in parallel.

Prior to each sounding, the GRUAN-adopted practice of an additional manufacturer-independent ground check will be performed. This involves inserting the radiosondes in a Standard Humidity Chamber (SHC) with 100 %RH (or 97 %RH) atmosphere and recording its readings for several minutes.

Further GRUAN-involvement concerns the application of in-situ reference instruments such as the cryogenic frostpoint hygrometer (CFH) for humidity measurements. Other types of reference hygrometers can be considered as well. Currently, no practicable balloon-borne reference instrument for in-situ temperature measurements exists but the metrology community is putting a considerable effort into this and if such an instrument becomes available in time it will be employed during the campaign.

**Laboratory activities**

Lindenberg Observatory has well-equipped laboratory facilities for testing and characterizing radiosondes under various conditions, ranging from typical surface conditions to those encountered at 35 km altitude. In the set ups relevant experimental parameters such as temperature, pressure, water vapour content, ventilation speed and actinic flux can be controlled and monitored, allowing for the investigation of the accuracy of the radiosonde’s sensors.

The motivation for the laboratory activities is that these will provide an assessment of the accuracy of the various radiosondes against independent standards, and that the results will aid to understand the differences that are observed during the actual soundings. This is commensurate with the GRUAN philosophy for reference observations and traceability.

The laboratory campaign will be organized separately from the radiosounding campaign, as local resources do not allow to organize both in Lindenberg simultaneously. It is still to be decided whether this will be before or after the radiosounding activities.

The Laboratory program consists of the following components:

(1) Calibration-verification at room temperature (Standard Humidity Chamber)

(2) Calibration-verification at low temperatures (Climate Chamber)

(3) Time-lag investigation (Climate Chamber)

(4) Error due to solar radiation (Radiation set up)

Further details on the setups and the measurements are provided in the Appendix.

**Remote sensing activities**

Lindenberg Observatory is operating a number of ground-based remote sensing systems, both for operational data acquisition and for research projects. One goal of the intercomparison campaign is to characterize the added-value of remote-sensing instruments for upper-air measurements.

The following ground-based remote sensing instruments should be available at Lindenberg for the campaign in 2021 (no commitment):

(a) 482 MHz radar wind profiler (RWP)

(b) 1.5 μm Doppler lidar

(c) 355 nm multiparameter Raman lidar with spectroscopic capabilities

(d) Microwave radiometer

(e) Water vapour DIAL

(f) 35 GHz cloud radar

(g) Ceilometers

There are two principal advantages of remote sensing systems in comparison to existing in-situ measurement methods:

(1) Much higher temporal resolution of the data, with typical values ranging from about 1 hour to 1 minute

(2) Capability to measure atmospheric variables which cannot easily be provided by standard in-situ systems, particular quantities which are describing dispersed particles like aerosol and clouds

In that respect, remote sensing systems are able to describe atmospheric structures at smaller scales and allow for a more comprehensive quantitative assessment of the state of the atmosphere.

Additional information on the state of the atmosphere shall help to plan and schedule the radiosonde launches. Information about the vertical structure of clouds and aerosol layers would further complement the measurements of the kinematic and thermodynamic state of the atmosphere, possibly helping to assess radiation effects on the in-situ sensors.

In terms of direct intercomparisons between radiosondes and ground based remote sensing instruments, the focus should be put on the parameters horizontal wind vector, temperature and humidity. Such data should be available 24/7 from mainly the 482 MHz RWP and the Doppler lidar, from the microwave radiometer and from the DIAL. The Raman lidar provides humidity and temperature profiles on demand for a given period around a planned radiosonde measurement character of the radiosonde wind measurement (as the sonde is drifting away with the wind) in contrast to the Eulerian character of the surface based remote sensing measurements from “instrumental” differences originating from the different measurement approaches. However it seems to be possible to review and refine previous work, with the goal of devising a rather general methodology for such comparisons.

**Space borne observations**

Satellite-based systems provide semi-continuous observations of atmospheric parameters over a large spatial extend with the same instrument. In contrast to radiosondes, the calibration of the instrument is the same for consecutive observations over the same location, and as such can be considered a kind of traveling standard. Satellite-based radio occultation systems and nadir viewing IR profilers routinely observe profiles of temperature and humidity, providing a valuable data source for comparing to radiosoundings. However, for IR profilers the quality and extend of the retrieved profile is strongly affected by the presence of clouds.

The radiosounings performed during the campaign will be compared to satellite observations. In view of the effort involved in handling large amounts of satellite data it is preferable to involve groups that have expertise in satellite-radiosonde cal/val. An example of such is NOAA’s NPROVS system, which is actively involved in GRUAN. Targeted observations to increase the coincidence and collocation of radiosoundings with satellite overpasses or RO-observations are possible. For this we can make use of a joint GRUAN-EUMETSAT service that routinely provides collocation and overpass predictions for any given location.

**Airborne observations**

Lindenberg Observatory is situated in the vicinity of the Berlin airports. In fact, the observatory lies under the eastern approach corridor of Schönefeld airport. This makes it worthwhile to include AMDAR profile observations from airplanes flying into or departing from Schönefeld airport in the campaign. Each day between 10 and 20 AMDAR profiles from the Berlin area are submitted to the GTS. These additional profiles of temperature and humidity up to 12 km altitude not only provide auxiliary measurements but can also be used to intercompare and evaluate the AMDAR and the radiosonde observations.

A relatively new development is the use of unmanned aerial vehicles (UAV, colloquially known as drones) for meteorological observations. Numerous studies in this field are, or have been, conducted. Clearly, drones have a great potential for in-situ observations, with obvious advantages of drones being reusability and the ability to perform observations along targeted trajectories instead of following a Lagrangian trajectory dictated by the wind field. However, the limited vertical range of currently available drone platforms make that drones are still far removed from being a cost-efficient alternative to radiosondes. Nevertheless, it is possible to employ drones during the campaign to compare the performance of meteorological drones and radiosondes in the boundary layer.

Close cooperation and coordination with air traffic control will be necessary since Lindenberg Observatory lies in the approach of Berlin Schönefeld airport (controlled airspace above 2500m); this will come on top of the coordination effort that will be necessary in view of the large number of balloons that is going to be launched during the campaign.

**Data policy**

The participants (manufacturers) will submit both raw (unprocessed) and processed measurement data to the campaign database.

A common data format will be defined, preferably NetCDF.

The required minimal set of parameters that should be present in each data file will be defined by the IOC.

All data will be made accessible to the scientific community, when the final report is published.

**Resources**

The campaign will be hosted and conducted as a joint DWD-MeteoSwiss operation.

The laboratory and radiosounding activities will be performed by staff of the in-situ sounding group from Lindenberg Observatory (~15), supported by various technical staff (~6).

MeteoSwiss will provide personal support in form of a scientist, a technician and a scientific programmer. Furthermore MeteoSwiss will provide analysis software (RSKOMP) as well as limited monetary support.

Supplied by DWD:

(a)Balloons + Helium

(b)Office space

(c)IT infrastructure

(d)Mechanical workshop

(e)Laboratory facilities

(f)Personnel (scientists, technicians, IT specialists)

Supplied by MeteoSwiss:

(a)1 scientist

(b)1 technician

(c)1 Scientific programmer

(d)Analysis software

(e)Monetary support

Representatives from CIMO and GCOS will also be involved in the campaign.

Data analysis will be done by DWD and MeteoSwiss with support from GCOS.

The final report will be written by DWD and MeteoSwiss with support from GCOS and CIMO. The lead author still has to be appointed. Similar to other CIMO intercomparisons, the IOC will be in charge of approving the final version of the report prior to its publication.

**Glossary**

CFH Cryogenic Frostpoint Hygrometer

CIMO Commission for Instruments and Methods of Observation

DIAL Differential Absorption Lidar

DWD Deutscher Wetterdienst (Germany’s national meteorological service)

GCOS Global Climate Observing System

GRUAN GCOS Reference Upper-Air Network

IOC International Organizing Committee

MeteoSwiss Federal Office of Meteorology and Climatology, Switzerland

NMHS National Meteorological and Hydrological Services

NWP Numerical Weather Prediction

OSCAR Observing Systems Capability Analysis and Review Tool

RWP Radar Wind Profiler

**References**

Miloshevich, L. M., A. Paukkunen, H. Vömel, and S. J. Oltmans, Development and Validation of a Time-Lag Correction for Vaisala Radiosonde Humidity Measurements, *J. Atmos. Ocean. Technol.*, 21(9), 1305–1327, doi: 10 .1175/ 1520 -0426(2004)021<1305:DAVOAT>2.0.CO;2, 2004.

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### APPENDIX to ANNEX

**(1) Calibration verification at room temperature in Standard Humidity Chamber**

The Standard Humidity Chamber (SHC) is a cylindrical vessel with a volume of 17 litres. The air inside has a well-defined relative humidity which is achieved by reference salts, desiccant or distilled water. A fan circulates the air at 5m/s to mimic the ventilation during ascent. A Pt100 reference temperature sensor provides an accurate reading of the temperature inside the SHC.

The sensor boom of the radiosonde will be inserted for several minutes into SHCs with various humidities listed in Table 1, during which the temperature and humidity readings of the radiosonde are recorded. These readings together with the reference temperatures and humidities will be used to assess the calibration accuracy of the radiosonde’s temperature and humidity sensors.

Relative Humidity (%RH) 0 11 33 75 97 100

Substance desiccant LiCl MgCl NaCl K2SO4 H2O

**Table 1:** Humidity values that can be achieved in the SHC using reference saline mixtures.

**(2) Climate chamber - Calibration at low temperatures**

Experiments in the climate chamber are performed to assess the calibration-accuracy of the radiosondes at sub-zero temperatures. An airtight SHC-like setup mounted inside the climate chamber allows to control experimental parameters such as temperature, pressure and water vapour concentration. The radiosonde is mounted inside the pressurized chamber, which contains reference sensors for above-mentioned parameters. The air inside the chamber is circulated to mimic ventilation during ascent and to ensure the absence of gradients in the chamber. This set-up allows to check the accuracy of the calibration of the temperature, humidity and pressure sensors at conditions that are encountered between the surface and 40  km altitude.

Table 2 lists the operational range of the climate chamber

Parameter Range

Temperature -75**°**C to +30**°**C

Relative humidity 0%RH - saturation

Pressure 10 hPa - ambient

**Table 2:** Range of operational parameters for the climate chamber

**(3) Climate chamber – time lag of humidity sensors**

The time lag of the humidity sensor refers to the temperature-dependent response time of the sensor to changes in the relative humidity [e.g. Miloshevich et al. 2004]

The time lag will be investigated by subjecting the humidity sensor to a stepwise change in water vapour concentration at various ambient temperatures. These tests will be performed in a special set-up inside the climate chamber, at temperatures between -75**°**C and -20**°**C.

The set-up is capable of rapidly changing the airflow from 0 %RH (dry nitrogen gas) to levels close to saturation while keeping the temperature of the airflow within a well-defined range.

**(4) Radiation tests**

A dedicated set up has been developed and constructed at Lindenberg Observatory to investigate the errors on the temperature and humidity readings induced by solar radiation. This set-up resembles a wind tunnel, in which the air is circulated at ~5 m/s. The pressure inside the system can be reduced to 3 hPa, which corresponds to an altitude of >35 km.

The radiosonde is mounted inside a quartz-glass cylinder and can be illuminated by the Sun or by an artificial light source, filters can be applied for testing the response at lower light intensities. The entire setup is mounted on a solar tracker to control the angle of incidence (elevation angle). In addition, the radiosonde can be rotated around its axis to vary the azimuth angle.

Parameter Range

Pressure 3 hPa - ambient

Ventilation 0 – 7 m/s

Irradiance (solar) 600 – 1000 W/m2

Irradiance (light source) < 2000 W/m2

Filter transmission 30, 50, 70 % (no **λ**-dependence)

Incidence angle 0-90**°** (2 axes)

**Table 3:** operational parameters of radiation set up

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1. The targets accuracies in OSCAR are defined as goal, breakthrough and threshold targets see https:// www .wmo -sat .info/ oscar/ [↑](#footnote-ref-1)