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Report of the Thirteenth GCOS Reference Upper Air Network Implementation Coordination Meeting (GRUAN ICM-13)

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I. INTRODUCTION:

Due to the global Covid-19 situation, the ICM-13 meeting was organized as a condensed, virtual meeting during the week of 15-19 November 2021. The meeting was held as a 5-days series of 2 to 3-hour video conferences during which only the most essential topics were discussed. The timings of the sessions were rotated in an attempt to evenly spread the burden of unfavourable hours over all participants from various time zones.

The following sections provide a summary paragraph for each of the presentations, as submitted by the author of the presentation (if provided).

All presentations are available for further review from the GRUAN meeting website, at https://www.gruan.org/community/meetings/icm-13.

The meeting agenda is given In Annex 1.

Annex 2 provides a summary on progress of actions from ICM-12.

Annex 3 lists the agreed actions from ICM-13.

II. PRESENTATION SUMMARY:

Session 1. Radiosondes new data products, RS41

1.1 Achievements since ICM-12 and challenges (Peter Thorne)

Peter Thorne, as WG-GRUAN co-chair, presented the achievements since ICM-12:

RS41 is provisionally certified, conditional upon the TD completion and full product paper being produced in a reasonable timeframe. Data flow is stable in many sites of the network. There is a new candidate site in the Northern part of South America. However, there are still gaps in South America and Africa.

Peter expressed hope that there will be a physical meeting next year as there is a need to have longer discussions.

1.2 Status of all GDPs under development (B1/B2) (Ruud Dirksen)

Ruud Dirksen started with a summary of rationale for developing GRUAN data products (GDPs), which is a considerable effort.

GDPs are reference quality data, that represent the highest accuracy data available, and because of that are in high demand for climate monitoring and satellite validation.

The requirements for certifying a GRUAN data product are stipulated in GRUAN Technical Notes 1 and 4 and include:

- A technical document with full description of the data processing
- A Peer reviewed paper on the data product
- A measurement system employed within GRUAN
- A central processing facility
- An existing operational data stream
- A review/validation of the data stream

So far there are 4 certified GDPs, 3 radiosonde-GDPs (Vaisala RS92 & RS41 and Meisei RS-11G) and GNSS-PW.

It was noted that RS41 has been provisionally certified, and that GNSS-PW is currently only available at GFZ (the data processing centre) as ASCII files, instead of the required NetCDF format.

Eight data products for radiosonde models and other measurement systems such as lidar, MWR and ECC ozonesonde are in various stages of development. Of these Meisei iMS100 appears to be the next candidate to be certified.

The development status of the GDPs is displayed in the restricted area of the GRUAN website.

In conclusion, it was discussed that the development of a GDP requires a considerable effort and resources. On average the development of the existing certified GDPs took about four years to complete. For future GDP development for radiosondes it is possible to build on the experience from previous work and partly speed up the program, for example by using the already developed measurement infrastructure and data analysis software.

However, the other steps in the GDP development, such as data analysis, development and implementation of correction algorithms, and validation program can't be shortened or optimized.

1.3 RS41 product overview (HP1) (Michael Sommer)

This presentation showed that the development of the GRUAN data product for the RS41 was a long and arduous process. The most important steps of the characterisation of the radiosonde by means of laboratory experiments (SHC, climate chamber, radiation wind tunnel) were briefly presented again. Especially the radiation wind tunnel (SISTER) was highlighted, as it is a novelty. The extensive processing using GDPS (GRUAN Data Processing System) was outlined and the complex determination of uncertainties was briefly discussed using temperature. The most important features of the extensive content of the product files were then explained, and the possibility of creating plots was pointed out. The processing of the first version of the RS41 GRUAN data product RS41-GDP.1 was started before the ICM and will be available at the end of the year. Furthermore, the status of the relevant documentation was shown: RS41 Technical Document, RS41 User Guide, peer-reviewed articles regarding comparison with RS92-GDP.2.

1.4 QC/QA flagging ad hoc group progress report (HP3) (Tzvetan Simeonov)

The discussions on the quality control / quality assessment (QC/QA) within GRUAN have been initiated in the Quality Task Force (QTF) with the main tasks set during ICM-11, according to the goals, set in the GRUAN Manual. The focus of the QTF team so far has been the handling of missing data within radiosonde profiles. Since ICM-11 active offline discussion has taken place on the flagging of radiosonde profiles within the following questions:

1. Should the missing values in the profiles be interpolated and according to what criteria?
2. How should this interpolating be implemented?
3. How to calculate the uncertainties of interpolated values?
4. What should be the procedure of flagging of the points within the profiles?
5. Should there be flags for clouds?

The discussion within the QTF lead to the following consensus to date:

1. Each variable and point in the profile should be flagged for data availability and possible interpolation individually;

2. Interpolation is acceptable for data gaps, shorter than 10s, when appropriately flagged, thus leaving the opportunity to the user to decide whether to use the full profiles, or only the real data points;
3. Interpolation is variable-specific;
4. The uncertainties of interpolated values are enhanced, according to procedures, set in the Fasso et. al. 2020;
5. There is not enough data so far to create a reliable GRUAN-wide flagging for clouds.

1.5 Progress on standardisation of cloud observations and their reporting (Masatomo Fujiwara)

The progress of the task, "Standardizing cloud treatment (at balloon launches at GRUAN sites)" was discussed. The purpose of the task is to develop a proposal on how and when cloud observations should be taken to support the radiosonde profiles including how that information should be included in the GDP data files. It was clarified that there are different needs and thus different possible methodologies to obtain cloud information: For the satellite calibration and validation (cal/val) purposes, manual/visual cloud observations to distinguish "clear-sky" launches are still very useful, while for the possible uncertainty reduction of radiosonde GRUAN data product (GDP), new developments of radiosonde sensors sensitive to cloud particles or to radiation may be needed. Also, various ground-based remote sensing instruments are available for obtaining various cloud information, some of which have already been considered by the Task Team on Ground-Based Remote Sensing Measurements for GDPs. Also, there was a suggestion that considering an all-sky camera with appropriate algorithm may be the future direction to replace the manual/visual cloud observations. It was proposed that we should first complete the actions for the satellite cal/val viewpoint. A broad ranging email conversation between interested participants ensued over following days. It was decided that all different aspects regarding cloud observations at GRUAN sites will be summarized in a GRUAN technical note.

1.6 Radiosonde Omnibus Technical Document (HP2) (Christoph von Roden)

No substantial progress can be reported on this. activity. The actual perspective is, that, with the currently emerging comprehensive documentation in connection with the actual development of the RS41 data product, as well as with further existing GRUAN documentation, a set of content is available, the generalised or sonde model unspecific aspects of which are to be used as basis for completion of the fundamental document. This applies in particular to the topics of data management and multiple-payload rigging configurations.

1.7 Modem product status (B3) (Eliane Assy)

Authors: Jean-Charles Dupont[1], Eliane Assy[2], Antoine Farah[2]
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[2]Meteomodem, Ury, France

Eliane Assy presented the M10 GDP, corrections and results overview, and launching of the M20 GRUAN Product development process, in collaboration with Jean-Charles Dupont and Antoine Farah.

M10 GDP L1 and L2 are in permanent production at the Trappes-Palaiseau (TRP) and Reunion (REU) sites, using automatic radiosonde launchers (Meteomodem Robotsonde described in the Madonna et al. 2020) under the operation of Météo-France. As mentioned previously, the Data flux is organized with automatic transfers from operational sites (TRP and REU) to AERIS Data

Centre where the raw data are converted into the final M10 candidate GRUAN Data Product (M10 GDP), in NetCDF format.

Since ICM 12, several modifications have been made to the M10 GDP, such as the use of the new wind channel set up developed by Christophe Von Rohden and his team in the Lindenberg to determine the radiative correction on temperature. In addition, the correction of zonal and meridional wind components is now performed by two smoothing procedures, using time and altitude aiming to remove the pendulum motion and the noise respectively. Other corrections for temperature and relative humidity are described in the new version of the technical document.

Validation of the L2 GRUAN Data Product (M10 GDP) was conducted in comparison with the Vaisala RS41 during the MétéoSwiss intercomparison campaign in Payerne. The results show very good consistency with the RS41 reference where the differences were found to be less than 3 %RH compared to RS41 results over the whole profile. A new generation, M20, a smaller, lighter, smarter (fast response humidity sensor with heating functionalities and the possibility to add a Barometer) than the M10, is now being launched in several Météo-France sites. As an introduction to the M20 GRUAN Data Product development, preliminary experiments were carried out in order to determine the M20 temperature calibration uncertainty in the LMD (IPSL). First results are very encouraging.

1.8 Graw product status (Ruud Dirksen)

GRUAN data processing is developed for the Graw DFM09 and DFM17 radiosondes at the Lead Centre/Lindenberg Observatory. Lindenberg has extensive experience with testing the DFM09, e.g. from RS92-comparisons, and the DFM09 was employed as an operational radiosonde in Singapore prior to the RS541. A contractor, Bernd Stiller, is tasked with the development

of the GRUAN processing, with support by Graw, that is interested in having a GDP for the DFM17. Contrary to the DFM09, the DFM17 has a heated humidity sensor, without sensor cover. The laboratory characterisation of the DFM09 and DFM17 is completed, although some measurements had to be redone for the DFM17 because of a change to the internal electronic signal processing of the humidity sensor. Analysis of the laboratory tests is ongoing, and RS41-DFM17 twin soundings are performed at regular intervals.

Development and implementation of the correction algorithms as well as documentation are planned for 2022.

1.9 Progress in humidity time lag, ground check processing (HP1, C5 b) (Christoph von Rohden)

The time lag of humidity sensors can cause considerable systematic errors in radiosonde measurements, especially at low temperatures in the upper troposphere and tropopause regions. The correction of this effect in the GRUAN processing of humidity raw data is based on experiments within a laboratory setup, which is designed to measure the response time of the humidity sensor to changing humidity. Under controlled conditions in a climate chamber, a steady dry air stream is split into two branches, with the gas in one of them being humidified. The radiosonde humidity sensors are exposed to the air stream, and using a valve system, a quick switch between the two air streams can be realised. The characteristic 63 %-time response can be determined from the sensor response to these humidity steps by fitting a simple step response model function. The experiments are carried out at various temperatures between −74 °C and +20 °C. Using an appropriate empirical parameterization of the measured response times with absolute temperature, a time-lag correction algorithm is implemented for the actual GRUAN data product for the RS41 radiosonde. The setup, designed for measurements with any model type of modern PTU-radiosondes, is after continuous development now ready for routine use.

GRUAN recommends routine manufacturer-independent ground checks of the physical sensors for relative humidity, temperature, and pressure of radiosondes in addition to possible manufacturer-prescribed pre-launch procedures. Such a ground check should take place preferably at the same time for all sensors in a controlled environment, such as the standard humidity chamber (SHC). The sensors are checked against a reference, which is saturated air in case of humidity, and calibrated reference sensors in case of temperature and pressure. The check result, i.e. the measured deviation to the reference, is transferred into an uncertainty component and added to the uncertainty budget, if it is not within the experimental uncertainty of the deviation. However, based on statistical analyses of existing ground checks, an upper boundary of this uncertainty component is defined. This boundary value is also taken as uncertainty if there is no ground check.

1.10 ECC Ozonesonde data product in GRUAN (B4) (Holger Vömel)

Authors: Holger Vömel[1], Richard Querel[2]

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[2]National Institute of Water and Atmospheric Research, Lauder, New Zealand

The GRUAN data product for Electrochemical Concentration Cell (ECC) ozone sondes is in preparation and will be done in cooperation with the WMO/GAW ASOPOS panel. In August 2021, the Assessment of Standard Operating Procedures for Ozonesondes (ASOPOS) panel completed its report (WMO GAW Report 268: Ozone Sonde Measurement Principles and Best Operational Practices, Geneva 2021). This report lays out the requirements and recommendations for all ozonesonde stations operating within the global ozone sonde network. It was written with GRUAN in mind and describes the minimum requirements for the GRUAN ozonesonde data product.

GRUAN requires traceability of observations and fully characterized uncertainties. To achieve this goal, GRUAN stations will be required to implement a manufacturer-independent ground check, which is not required for the global ozone sonde network. This will allow GRUAN stations to become an anchor for ECC ozone sonde observations.

A brief outline of the GRUAN ozone sonde product includes the following elements:

- Existing and new stations will follow the recommendations in the WMO GAW report 268 and continue their best practices.
- Stations participating in GRUAN ozonesondes must collect all required, essential, and desired metadata specified in the metadata appendix of the WMO GAW report 268
- Stations participating in GRUAN must use a manufacturer-independent ground check for ECC ozone sondes, which is suggested in the WMO GAW report 268
- Stations must use high quality ozone destruction filters or other acceptable sources of ozone free air during the sonde preparation to minimize any contamination and interferences of ozone during preparation.
- Centralized processing will be done in parallel to processing at stations. Stations will remain responsible for homogenized long-term data sets in cooperation with the GRUAN community.
- Empirical ("pump") efficiencies will be separated into
    - True pump efficiency
    - Stoichiometry factor
    - Time response correction

- The "background current" will be deprecated and will be superseded by the improved understanding of the role of the secondary reactions.
- Pre-launch data will be used in processing to characterize the time response at the time of launch.
- The uncertainty budget in processing will follow the guidelines described in the WMO GAW report 268 and by Tarasick et al. (2021). The contribution of new processing steps for the time response will be explicitly quantified.

The next steps that will need to be described in detail include a rewrite of the draft of GRUAN Ozonesonde Technical Document, which will define the GRUAN processing algorithms based on the WMO GAW report 268 with an explicit consideration of ECC time response. The manufacturer-independent ground check will use either an ozone calibrator or a surface ozone monitor following work done at Boulder, Lauder, Payerne, and Wallops Island. Data files and file formats will be based on guidance from the WMO GAW report 268 and combine with existing GRUAN data files.

Session 2. Ground-based & emerging technologies

2.1 GNSS-PW status update, Metrological closure between GNSS-PW and radiosonde (C11, C12) (Kalev Rannat)

Authors: Kalev Rannat, Jonathan Jones, Galina Dick, Hannes Keernik

The presentation gave a short update about the GNSS PWV TT activities, including topics listed on the GRUAN Master Action Item list re-scheduled after ICM-12; Task C11 (GDP data format) and Task C12 (Metrological closure of RS vs GNSS). An overview was given about the current status of GRUAN GNSS Sites and the improvement of the data flow. In the frame of Task C11 (netCDF format for GRUAN GNSS GDP) – the work continues in close collaboration between GFZ and DWD. Regarding Task C12, first results were presented but the work is ongoing, and the final results will be published in a scientific paper.

Preliminary results of comparisons of GRUAN GNSS ZTD vs. other GNSS solutions vs. other instrumental measurements (RS, WVR, VLBI) and vs. NWM ERA5 all show very good agreement. A small dry PWV bias of around -0.6 kg/m2 between GNSS-PW and RS and WVR can be detected. Although the preliminary results are presented only for Lindenberg (GRUAN GNSS GDP versus RS92_GDP.2, with a difference Δ = -0.48 ±1.25 kg/m2 over the year 2013), the dry bias value is very small for all GRUAN sites, indicating a high accuracy of GRUAN GNSS-PW data product.

Similar dry bias values (-0.9 kg/m2 in average) have been found from independent analysis (2014-2019) for a selection of 18 IGS sites collocated with IGRA radiosondes (<= 15 km spatial separation).

Better results from GRUAN GNSS-RS intercomparison reflect the benefit gained from applying GRUAN centralized data processing and methodology. However, for good agreement between the GNSS and RS it is necessary to notice the importance of observational conditions and instrumental calibration.

2.2 MWR status (B5) (Nico Cimini)

Activities towards MWR networking have been launched in the framework of both ACTRIS (EU long-term research infrastructure dedicated to atmospheric monitoring) and E-PROFILE (atmospheric profiling programme of EUMETNET). All GRUAN sites in EU belong to either or both ACTRIS and E-PROFILE. Thus, the development of the MWR GRUAN Data Product (GDP) could benefit from these activities in terms of expertise, best practices, and data life cycle. Presentations from ACTRIS (Bernhard Pospichal, University of Cologne, ACTRIS Centre for Cloud Remote Sensing) and E-PROFILE (Rolf Rüfenacht, MeteoSwiss) key personnel have been given at GRUAN ICM-13.

2.3 AIRCORE (Dietrich Feist)

A presentation was provided on this activity. Any outcomes/actions following the presentation are captured in Annex 3.

2.4 Quantum-cascade laser absorption spectrometer (QCLAS) for water vapor measurements in the upper atmosphere (Simone Brunamonti)

Authors: Simone Brunamonti[1], Manuel Graf[1], Lukas Emmenegger[1] and Béla Tuzson[1]
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Here we presented a compact instrument based on mid-IR quantum-cascade laser absorption spectroscopy (QCLAS) for water vapor (H_2O) measurements in the upper troposphere and lower stratosphere (UTLS). The spectrometer incorporates a specifically developed segmented circular multipass cell to extend the optical path length to 6 m, while meeting the stringent requirements in mass, size, and temperature resilience, posed by the balloon platform and by the environmental conditions of the UTLS. Two test flights performed in 2019 revealed the instrument's outstanding capabilities under re-al atmospheric conditions. QCLAS offers a calibration-free retrieval approach, however it is necessary to validate its accuracy with respect to a high-accuracy reference. Therefore, a dedicated laboratory campaign was conducted at the Swiss Federal Institute of Metrology (METAS). Using a dynamic gravimetric permeation method, SI-traceable reference gas mixtures with H_2O amount fractions be-tween 2.5–35 ppmv in synthetic air were generated with an uncertainty of 1.5 %. These reference gases were measured at pressures between 30–250 mbar. For the entire investigated range, all H_2O amount fractions retrieved by QCLAS were found within ± 1.5 % of the reference value, corresponding to a maximum absolute deviation of 210 ppbv, and with an absolute precision better than 30 ppbv at 1 s resolution at all conditions. Additional measurements with a secondary reference gas show that the ± 1.5 % accuracy can be extended up to H_2O amount fractions of 150 ppmv. These measurements demonstrate the outstanding level of accuracy and precision achieved by QCLAS at UTLS-relevant conditions. In-flight validation campaigns to be conducted from Lindenberg (Germany) are in preparation.

2.5 Validation of RALMO water vapor mixing ratio against the co-located Vaisala RS41 radiosounding data (Giovanni Martucci)

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The RAman Lidar for Meteorological Observations (RALMO) is operated at the meteorological station of MeteoSwiss in Payerne providing continuous measurements of temperature and aerosols since 2010 and humidity since 2008. A general description of the transmission and acquisition system of RALMO was provided along with the rationale of the data processing software ADT (Automatic Data Treatement). The presentation focused on the retrieval of the water vapor mixing ratio (WVMR) and describes in detail its uncertainty budget. The main error contributions are developed into Taylor’s series based on the WVMR equation. The covariance due to the temporal atmospheric contribution to the N_2 and H_2O signal error is efficiently removed. The theoretical total error is assessed by looking at the distribution of differences between the Vaisala RS41 and Ralmo WVMR, which lie within the k-sigma in a Gaussian way. The results of four-month statistics of RS41 vs RALMO WVMR are shown in terms of mean bias and standard deviation for daytime and night-time cases. The resulting bias is compatible with the zero-bias within the obtained standard deviation for both daytime and night-time.

The high-quality WVMR from RALMO data are assimilated for test experiments into the numerical model COSMO-1E and KENDA-1. The results of the assimilation of RALMO shows a clear positive impact on the forecast of cloudiness for strong convective cases. MeteoSwiss is working to assimilate RAMLO into COSMO operationally soon.

2.6 Frostpoint hygrometer GDP progression (B7) (Dale Hurst)

At ICM-13 Dale reported on the lack of progress on the action item promoting development of a GRUAN Data Product for Frost Point Hygrometers due to those involved being overly busy and having no time to spend on the task. It was proposed that once the LC has finished developing the RS41 GDP, regular meetings should be scheduled with those involved in development of the GDP for Frost Point Hygrometers to promote progress.

2.7 Lidar GDP (B6) (Thierry Leblanc)

In 2020, the GLASS data processor went from development to production stage. Raw data from Payerne have been automatically transferred to the processing centre at JPL-TMF. Test data from Ny-Aalesund, and Cabauw lidars were ingested (together with many other lidars on non-GRUAN sites). In Spring 2021, automated transfer from Payerne to JPL-TMF was interrupted due to a transfer protocol change on Payerne's end. The data flow has not been restored since. The plan is to restore it in early 2022. Support from the GRUAN LC in the raw data transfer process is requested. Ideally, the GRUAN sites should upload their raw data to the LC, where they are possibly converted to a standardized format. Then these data, in original, or standardized format, should be accessible for transfer to the centralized processing centre (JPL-TMF). No progress in the data flow and processing will be possible without LC support.

2.8 Biogenic aerosols in the UTLS: A new challenge to water vapor Raman lidars (and other techniques?) (Thierry Leblanc)

H_2O Raman Lidar represents a nice GRUAN ancillary technique for water vapor measurements up to the upper troposphere and lower stratosphere (UTLS). However, since 2017 the UTLS has become significantly "dirtier", following an unprecedented increase in wildfire activity in Siberia, North America, and Australia and subsequent injection of biogenic aerosols in the UTLS. This increase revealed an important caveat for the long-term monitoring of H_2O by Raman lidar, with the necessity to develop a robust and accurate fluorescence correction. Fluorescence contamination was demonstrated for UV lidars (emission at 355 nm) but is yet to be demonstrated for lidars using emission at 532 nm. For UV lidars, a simple fluorescence correction is possible by adding a "fluorescence channel" at 410 nm to the lidar receiver, then scaling the fluorescence signal to that of water vapor and subtracting it from the contaminated water vapor signal. Other methods involving additional fluorescence channels, or a spectrometer, are being considered to minimize the additional uncertainty introduced by the correction, and to keep the Raman Lidar technique a reliable technique for the detection of water vapor trends in the UTLS. Most likely, trend detection will still be possible in the upper troposphere, but trend detection in the lower stratosphere is expected to be very challenging.

2.9 Multi-station Measurements of the Ionospheric Potential with GRUAN (Earle Williams)

This presentation was concerned with the strongly desired use of a small subset of the GRUAN balloon sounding network for the measurement of the global ionospheric potential, the main measure of the DC global electrical circuit. We became acquainted with GRUAN by virtue of our participation in a special task team formed by the GCOS AOPC (with Caterina Tassone now in charge), aimed at defining requirements for the new Essential Climate Variable "Lightning". Colin

Price (Tel Aviv University), a fellow member of this task team, who had made earlier inquiry with Ruud Dirksen for the same purpose, is a collaborator in this work. Several GRUAN sites (Graciosa, Minamitorishima and Macquarie) are small islands in clean maritime air and provide an unprecedented opportunity to measure and verify the nominal 250 kilovolt voltage difference between the Earth's surface and the upper atmosphere. Two types of instrument will be described for the proposed balloon measurement of electric field. One specific scientific objective pertaining to the global circuits' paradox involving electrification and lightning activity in Africa and America will be outlined. We are also interested in the establishment of the balloon-sounding method as a routine operational measurement of ionospheric potential, as a natural and inexpensive measure for global climate change. This presentation concluded with questions posed to GRUAN site managers.

2.10 The NOAA Baseline Balloon stratospheric Aerosol Profiles (B@SAP) Project: description and insights using in situ observations since 2019 (Elizabeth Asher)

A presentation was provided on this activity. Any outcomes/actions following the presentation are captured in Annex 3.

Session 3. WMO intercomparison, dual soundings, collocations, R23 replacement

3.1 WMO intercomparison - includes Q&A (Ruud Dirksen)

Ruud presented the status of the WMO radiosonde intercomparison campaign in Lindenberg, which is co-hosted by DWD and MeteoSwiss. Due to Covid-19 the campaign, which originally was scheduled to start December 2020, had to be postponed for one year.

The goals of the campaign are:

- To bring all the major radiosonde manufacturers of all the different regions of the world together.
- To characterize the individual radiosondes with respect to their reproducibility and to determine the uncertainty of the different measured parameters.
- To compare the different radiosonde systems to a "Radiosonde Reference" (mean of three chosen Traveling Standard Systems).
- To include remote sensing instruments for the benefit of upper air measurements as a whole.

Furthermore, some GRUAN elements will be adopted, such as a pre-launch check in the SHC before every sounding and laboratory characterisation of the participating radiosondes. Innovations with respect to the previous campaign (Yangjiang 2010) are a separate laboratory campaign to assess calibration, time lag and radiation error as well as the fact that the soundings will be performed by independent operators. Ruud underlined that the laboratory campaign will not be used in the final assessment of the radiosonde systems, but instead that the measurements will be used to understand and interpret the differences observed during the radiosounding campaign. As such, the purpose of the laboratory campaign is to be of mutual benefit to both the manufacturers, who will get additional information on the measurement errors of their sensors, and to GRUAN, by getting acquainted with operational radiosounding systems that are currently available. After assessing 16 candidates, 12 manufacturers have been selected to participate in the campaign. In addition to the well-known major manufacturers, this includes participants from India, China and South Korea. The laboratory campaign consists of 6 slots of two weeks in the period December 2021 - May 2022 (Corona permitting), during which the radiosondes of two manufacturers will be tested in parallel in three different set ups:

- SHC for calibration-verification of Temperature and RH at room temperature;
- Radiation set up to investigate the radiation error of the temperature sensor;
- Climate chamber to investigate the time lag of the humidity sensor at low temperatures.

The radiosounding campaign is scheduled for August-September 2022; the radiosondes will be attached to a rig that can hold 10 radiosondes, three spots are reserved for the GDP radiosondes constituting the traveling standard. During the radiosounding campaign, the systems will be operated by independent operators, after being trained by the manufacturers. This to ensure transparent data-collection, and to test the user-friendliness of sounding systems.

Finally, it was mentioned that for the traveling standard three certified GDPs are required, with currently the most likely candidates being: RS41 iMS100 M10. Since the latter two are not certified yet, the campaign organizers underlined the need for swift progress in their certification.

3.2 Progress with provision of site-based ancillary measurements to the RS92/41 colocation database (A1) (Dave Smith)

To help corroborate and constrain the effects of RS92-RS41 differences using independent instrumentation, sites are being requested to submit data from other ground-based instruments measuring temperature and humidity or covariates which were operational at the time of ascent. The first draft of a Technical Note to guide sites on the procedures to achieve this has been written. It details measurements that may be apposite, and the time window around the launch of each radiosonde pair during which such measurements may be deemed appropriate. The first draft has been circulated to the WG Co-chairs and TT Sites Chairs for initial comments. Their feedback has been received and integrated, and the TN will now be circulated to all GRUAN sites for their input and perspectives. Publication is anticipated in Q1 2022.

3.3 Progress with provision of satellite based ancillary measurements to the RS92/RS41 colocation database (A2) (Lori Borg)

The satellite task team (TT-SAT) is tasked to provide the Lead Centre (LC) collocated satellite measurements with the historical RS92/41 database. The hope was to provide this data to the LC by ICM-13. This did not happen. Further discussion between TT-SAT and the LC is needed to make progress on this effort. Issues that need to be clarified; type of satellite data to be delivered (calibrated radiances, retrieval products), satellites to collocate (JPSS, MetOp, RO), inclusion of other ancillary data (ERA5 re-analysis), and the temporal-spatial matching coverage criteria (single closest FOV, all collocation within 2 hours and 100km, etc.). The NOAA Products Validation System (NPROVS), which routinely ingests radiosondes and collocates with satellites, could be leveraged in this effort. Three approaches to fulfil this task were presented and will be used as a starting point for future discussions. TT-SAT will follow up with the LC to discuss this task and determine the best path forward.

3.4 Dual launch analysis updates (A3 & C8) (Tzvetan Simeonov)

The RS41GDP is the newest GDP, which has a provisional certification from GRUAN. It is based on the Vaisala RS41 radiosonde, the replacement instrument for the RS92 radiosonde (basis for the RS92GDP). The comparison of the two radiosondes is based on time-synchronized differences over 1km thick layers for 7 GRUAN sites between the GRUAN and Vaisala products for more than 600 profiles. The comparisons of temperature show the difference between the time constants of the two sondes, the applied radiation corrections and the uncertainties of the time measurements for different time periods: winter/summer and day/night. The RS41 temperature sensor has a slower response time, than the RS92. The relative humidity profile shows dependence on the temperature response time. The coordinates and pressure measurements from the GDP's show good agreement within the estimated uncertainties, while the Vaisala products show large differences in the coordinates and systematic errors in the pressure, dependent probably on the used geoid/ellipsoid data.

The focus of the post-presentation discussion was on the use of data from the different GRUAN sites. So far for the comparison only 7 of the available GRUAN sites are used. The intention is to analyse all available dual profile data.

3.5 Sites' activities for alternatives to R23 (Ruud Dirksen)

Within GRUAN, the CFH/FPH is the instrument of choice for stratospheric water vapor observations. Currently, nine GRUAN sites employ CFH/FPH which needs R23 to operate. Because of the environmental impact of R23 (100-year CO2 equivalent of ~15000) its use is restricted or banned in the EU and Japan, with increasing restrictions in other countries as well. This problem has been discussed at various ICMs since it was first raised at ICM-7. In search for a long-term sustainable solution, sites are testing alternative cooling methods, such as the ethanol/dry-ice mixture for CFH/FPH operations or are even considering switching to instruments that operate without cryogen. Alternative instruments (Skydew, FLASH-B, PCFH) are in various stages of maturity, where the Peltier-based Skydew instrument from Meisei is now available on the market.

Overview of activities at various sites:

- Lindenberg has performed several test flights with PCFH and FLASH-B, as well as a CFH-test flight with ethanol/dry-ice as coolant in November 2020. This showed good agreement between both instruments, and that the ethanol/dry-ice mixture has sufficient cooling capacity for the descent. In comparison to R23, the ethanol/dry-ice operated CFH showed a slower recovery of condensate layer after 2nd heat pulse, and "smoother" profile, which is attributed to the PID controller which is optimized for R23. Furthermore, the Lead Centre is cooperating with Forschungszentrum Jülich to develop a prototype of a pressurized container for liquid nitrogen.
- Boulder performed a test flight with an ethanol/dry-ice operated FPH in April 2021, which showed good agreement with the profile from an R23-operated FPH. Minimum frostpoint measured was -90C. Dual flights are planned for Hawaii, delayed due to Covid-19.
- Holger Vömel reported on the ongoing work to adapt the CFH for operation with ethanol/dry-ice. Test flights have been performed at Jülich. Reunion Island and Lindenberg. Modifications were made to the instrument to enhance the heat conductivity between coolant and mirror, and further tests are outstanding to verify the performance of ethanol/dry-ice operated CFHs under tropical conditions.
- Christian Rolf presented the project for the development of a container, which will store the liquid nitrogen at a pressure of at least 125 hPa to prevent freezing. First tests in a climate chamber at 10 hPa show that the nitrogen inside the container remained liquid. Special requirements for the container are CFH-operating time of 3 hours, and safety measures to prevent buildup of pressure. The prototype of the container will be installed in the CFH and its performance will be tested in flight in the first quarter of 2022.

3.6 Skydew status (Kensaku Shimizu)

Kensaku Shimizu presented the SKYDEW status. SKYDEW has been developed since 2009 by Meisei and Hokkaido university. Relevant points from the presentation are:

- In 2021, Meisei started supplying to domestic pilot users (JMA, JAMSTEC, NIPR and Universities).

- By JAMSTEC observations, SKYDEW was tested under the conditions from 30 degrees north to the equator.
- The cooling limit of SKYDEW is more than 40K in T-TD at night.
- In the observation that clouds exist in the troposphere, the mirror temperature often oscillated in the stratosphere. Cloudless conditions are recommended for SKYDEW observations.
- GDP development of SKYDEW is underway.
- Observations in many areas, including Antarctica, are planned in 2022.
- It is scheduled to start providing product model SKYDEW to all users including overseas in 2022.

3.7 Flash-B (Alexey Lykov)

Fluorescence Lyman-Alpha Stratospheric Hygrometer for Balloon (www.flash-b.ru)

Authors: Alexey Lykov[1], Yushkov V.[1], Formanyuk I.[1], Sergey Khaykin[2]
[1] Central Aerological Observatory, Roshydrometservice, Russia
[2] CNRS/INSU, LATMOS-IPSL, France

The Lyman-Alpha Fluorescence Stratospheric Hygrometer (FLASH) is an ultra-compact, fast response optical sensor capable of making accurate measurements of water vapor in the lower and middle atmosphere (7–70 km). The device is based on the fluorescence method, which uses photodissociation of H_2O molecules exposed to Lyman-alpha radiation (121.6 nm), followed by measurement of the fluorescence of excited OH radicals in the near UV range of the spectrum.

The instrument, originally intended for rocket sounding, was eventually redesigned for use on board meteorological balloons, long-duration balloons, as well as in M55-Geophysica high-altitude research aircraft and Yak-42 tropospheric laboratory aircraft. The FLASH instrument took part in a large number of international campaigns on all stratospheric platforms as a reference instrument for stratospheric water vapor.

Calibrated at the Lindenberg Meteorological Observatory, Richard-Aßmann Observatory (GRUAN's lead Centre), FLASH hygrometer has participated in several comparison flights with standard RS41 radiosondes and other frost point hygrometers such as CFH, PCFH instruments. The instrument supports X-data protocol allowing combined flight with other instruments using a single radiosonde.

The balloon version of the hygrometer (FLASH-B) is a compact, lightweight probe (0.4 kg) with measurement capabilities that rival frost point hygrometers. Thanks to its compact optical design, fast Lyman-alpha measurement technique and consumable-free operation, FLASH-B is the ideal solution for measuring water vapor on long-duration balloons. The FLASH hygrometer is part of the Strateole2 French-American campaign (2021-2022) to research on super-pressure balloons in the deep tropics. There were 3 flights on long-duration balloons TTL3. Strateole-2 is the ultimate long duration balloon experiment aimed at closing measurement gaps in the deep tropics using a variety of instrumentation, including an innovative reeled device (with FLASH) that allows measures at a location 2 km below balloon flight level.

During Strateole2, a combined flight of the FLASH-B and AZOR backscatter probe was performed on a meteorological balloon with the X-data stream to the iMet-4 radiosonde. Comparison of the ascent and descent data shows very good agreement with data from the local RS41 probe and the MLS satellite system.

The following upcoming future experiments involving FLASH:

- Joint flights in 2021 with GSMA Pico and LPC2E micro within HEMERA WP11 in Aire-Sur-l'Adour;
- AQUAVIT-4 intercomparison campaign (AIDA facility, KIT);
- Balloon flights within the ACCLIP campaign in South Korea.

3.8 Status of the Peltier Cooled Frost Point Hygrometer (PCFH) and first comparison with CFH (Frank Wienhold)

Authors: Frank G. Wienhold[1], Teresa Jorge[1], Nico Germann[1], Uwe Weers[1], Yann Poltera[1], Beiping Luo[1], Susanne Körner[2], Tatjana Naebert, Peter Oelsner[2], Ruud Dirksen[2], and Thomas Peter
[1]ETH Zürich, Zurich, Switzerland
[2]DWD Lindenberg, Tauche, Germany

Water vapor is the strongest (natural) greenhouse gas with important feedbacks to climate. Its atmospheric abundance comprises at least five orders of magnitude, while vertical changes occur at a scale of less than 50 meters. Cirrus formation in the tropopause region is not sufficiently understood, albeit it impacts the radiation budget and controls the entry of water vapor into the stratosphere. The resulting demands for water vapor measurements are met by balloon borne frost point hygrometers reaching the region of interest easily and supplying best accuracy and vertical resolution. Chilled mirror instruments stabilize the reflectance of a mirror exposed to the ambient air and thus held in equilibrium with it, hence its temperature equals the frost point temperature. They commonly employ R23 as refrigerant which cannot be used after the end of 2022 – demanding for a replacement.

The Peltier Cooled Frost point Hygrometer (PCFH) aims to provide an alternative: laid out as double instrument with two sub-units sharing electronics, controller and housing it attains the frost point temperature using two-stage Peltier elements cooled by the ambient air flow. To overcome the lack of reflectance response in dry conditions, the signal to background contrast has been enhanced. The mirrors are now singularized from polished, gold plated and laser cut copper sheets, and tilted out of specular reflection, so that the signal scattered from the condensate is detected. A 'Relay Control' scheme characterizes the control loop: during the flight a simple two state controller autonomously forces the reflectance to swing around a prescribed set point at the so-called system critical frequency. While designed for system identification to obtain controller parameters, the frost point temperature can yet be derived from the reflectance stationary extrema in the so-called 'Golden Points' approach. Strong transients of the mirror temperature ask for a careful correction of internal time shifts. The Golden Points yield a vertical resolution of 50 m in the troposphere (10 seconds half-period), increasing to 300 m in the lower stratosphere.

In cooperation, the colleagues from the DWD Lindenberg GRUAN lead centre have been instructed to prepare the PCFH, launch the instrument added to the regular GRUAN ECC-ozone/CFH/COBALD sounding payload, and to refurbish it after recovery. They conducted two comparison flights successfully. In the troposphere, the PCFH measurements agree well with the RS41 and CFH sensors, but a wet bias is observed above the hygropause. It probably originates from contamination by insufficient leak tightness, or from poorly vented parts of the tilted mirror surface. Some features of the water vapor profile both observed by the RS41 sondes and the PCFH are not captured by the CFH. The wet bias is reduced the second flight, here the RS41 sondes provide drier measurements. Improvements of the instrument underway are to be tested in Zurich before a revised prototype will be launched in CFH comparisons from Lindenberg. Following this, we plan to modify the Relays Control scheme to reduce the mirror temperature transients, and finally to implement a PID controller tracking the frost point temperature with superimposed oscillations generating the Golden Points. To make the PCFH available as GRUAN-worthy instrument in the long term, the production will be professionalized in collaboration with a commercial company. More intercomparison flights will be carried out regularly, and the PCFH will participate in measurement campaigns.

3.9 SHC analysis update / progress with paper (C5a) (Ruud Dirksen)

The standard humidity chamber (SHC) is a well-established elementary GRUAN-tool for an independent ground check of radiosondes prior to launch, that is currently employed at 18 GRUAN sites. Although conceptually simple, the SHC creates a stable reference environment to get pre-flight info on RH uncertainty (traceability). The systematic pre-flight SHC checks at Lindenberg helped to identify batch-dependent drifts in the calibration of the RS92, showing a 4% variation over a ten-year timespan.

The SHC ground checks for the RS41 show a deviation of approximately 1%RH, which appears stable over time and production year. However, data from sites such as NYA and LAU show that the sign of the deviation depends on the orientation of the radiosondes sensor boom in the SHC. This effect appears to be specific for the RS41 and has not been observed for the RS92 or other radiosonde models. For unambiguous SHC checks for the RS41, the same, prescribed orientation of the sensor boom must be employed at GRUAN sites.

A study was performed at the Lead Centre to investigate and understand this dependence on orientation, and to define the proper orientation of the RS41 during the SHC ground check.

During this study, the influence of following parameters on the deviation was investigated:

- Orientation of the sensor boom inside the SHC;
- Ventilation speed;
- Ventilation direction.

Analysis of the results shows a sinusoidal dependence on the orientation angle of the deviation between observed and expected humidity value, with an amplitude of approximately 1%RH. Extremes in the deviations were found for orientations corresponding to the humidity sensor facing the wall or the centre of the SHC, which is consistent with the results observed at the GRUAN sites. The optimal orientation of the RS41 in the SHC is with the airflow perpendicular on the surface of the humidity sensor similar to the flow scenario in flight, or alternatively, with the airflow hitting the back of the humidity sensor. Unfortunately, a physical explanation for the dependence of the deviation on the orientation of the sensor boom couldn't be derived beyond the working hypothesis that it is related to the particular configuration of the sensors and heating element on the sensor boom. These findings will be incorporated in the manuscript on the SHC and a technical note on the use of the SHC within GRUAN will be prepared.

In conclusion it was announced that Karl-Heinz Schulz will continue manufacturing SHCs.

Session 4. Network management IP, Task Teams, silent sites

4.1 Proposal on policy for silent sites (C10) (Ruud Dirksen)

At ICM-12 the issue of silent sites was raised. Most of the GRUAN sites are performing in an exemplary manner regarding measurement activity and data submission. Unfortunately, not all sites perform up to par, some have been on the map for several years without actually submitting data. This incorrectly makes the network seem larger that it effectively is.

Furthermore, this is not fair to the sites that are committed to the network and that put a lot of effort in conscientiously maintaining a measurement program to provide reference data. The approach employed thus far was showing the data flow chart (the so-called "GRUAN-DNA") and relying on peer-pressure to motivate sites to stay in line. Unfortunately, this approach of gentle pressure did not succeed in preventing the current situation with several sites showing blanks in the data flow chart. Therefore, a new policy is proposed to apply increasingly more pressure, to encourage reticent sites to improve their performance. This mechanism includes a series of escalating steps, which starts with regular (monthly) email reminders to the manager of the defaulting site, and ultimately can lead to a site losing the status as a GRUAN site.

The proposed intermediate steps are (for a certified site), with slight modifications in the time-line for uncertified and new sites.

- (after 6 months) a formal letter to the site manager
- (after 10 months) a letter to the supervisor of the site manager (cc site manager)
- (after 12 months) Revoke the site's certification
- (after 18 months) an email/Letter to Permanent Representative
- (after 24 months) Revoke status of being a GRUAN site (+ letter to PR)

It is also proposed to display the sites' involvement on the GRUAN website, in the form of a traffic sign indicating performance on aspects such as data submission, site reporting, certification status, and involvement in task teams, working group or data product development.

During the discussion Thierry Leblanc proposed, quoting NDACC experience, to only show certified sites on the map. However, considering the long time (several years) between entering GRUAN as a candidate site and being certified, this would mean neglecting the efforts of well-performing sites.

The proposed approach now. requires consideration and acceptance by the TT on sites and the Working Group prior to its formal adoption.

4.2 Comprehensive Upper-Air, Baseline and Reference in situ observations in Copernicus 2.0 (Fabio Madonna)

The C3S2 311 Lot2 contract widens the efforts spent within the C3S 311a Lot3 ("Access to observations from baseline and reference networks") and C3S 311c Lot2 ("Historic In Situ Upper Air Database") contracts of Copernicus 1.0 and aims at facilitating the access, the harmonization and the homogenization of comprehensive upper-air, baseline and reference observations for a subset of GCOS relevant ECVs. The contract is led by CNR-IMAA and takes advantage of the expertise of 5 subcontractors. University of Wien, the Royal Belgian Institute for Space Aeronomy, BK Scientific GmbH, the National University of Ireland, Maynooth and the Tallinn University of Technology (TUT).

The contract objectives most relevant for the GRUAN are the following.

- Update and extend the access to Reference and Baseline in situ datasets already offered to the CDS.
- Harmonize the upper-air temperature, humidity, wind and ozone datasets provided in Copernicus 1.0 from multiple sources and generate new added value datasets also in support of the future ERA6 reanalysis; this will be achieved also through intercomparisons of upper-air datasets with satellite data and with existing homogenized data sets.

- Provide estimation of uncertainties whenever feasible, mandatory for reference networks and the related products.
- Establish a repository for Global Navigation Satellite System (GNSS)-Precipitable Water observations in close cooperation with the International Association of Geodesy, under the auspice of GCOS. Both raw data (RINEX) and products (SINEX) will be provided to the Copernicus users.

GRUAN and C3S will continue to interact and find mutual benefit from this new contract.

4.3 Update on GRUAN website (Michael Sommer)

The current status of the GRUAN website, which has been available for 5 years, was presented. For this purpose, the general structure of the website was shown and in further steps all main sections were described in more detail. Examples were used to show specific pages and to go into key details, such as pages for stations, available measurements and data products, access to data, GRUAN-specific software, information about instruments, GRUAN documentation, relevant peer-reviewed articles, news, and meetings. During the presentation, some missing content (e.g., description of instruments) was pointed out and input from the GRUAN community was requested.

4.4 IP progress and plan (June Wang)

There have been three GRUAN Implementation Plans (IP), GCOS-134 for 2009-2012, GCOS-165 for 2013-2017 and GCOS-205 (2017-2021). The current IP will expire by the end of 2021. Therefore, GRUAN needs to prepare its fourth IP for 2021-2025. The IP 2017-2021 aims at establishing a fully operational reference upper-air network for climate. More specifically, by the end of the period of the IP (through 2021), if it is successfully implemented, GRUAN shall consist of:

(1) A network of approximately 30 to 40 sites globally equitably located;

(2) A network making reference quality upper-air measurements of Priority 1 variables and GRUAN data product (GDP) for each measurement program;

(3) A set of sustainable long-term measurements being used by four key user groups (climate change monitoring and detection, satellite-based measurements, NWP, process studies); and;

(4) Operationall and research functions leading to improved capabilities and practices in other broader components of the Global Observing System and its applications.

The progress made during 2017-2021 for these four areas was presented. Currently, there are 31 GRUAN stations of which 14 are certified. Four GRUAN GDPs were certified, two with certification in progress and four GDPs under active development. During 2009 and 2021, total 117 GRUAN-related journal articles were published, which highlights the applications of GRUAN GDPs and related research to all four key user groups. Two categories, "Field and intercomparison campaigns" and "Satellite validation and algorithm development", are ranked top with 27 and 21 papers, respectively. GRUAN has made significant contributions to improving other networks and observing systems, ranging from pioneering in defining and making reference observations, improving operational radiosondes to calibrating and validating satellite data. The priorities for 2021-2025 IP are proposed and shown below. The tentative plan is to complete a draft of the new IP by March 31, 2022 and finalize it by ICM14.

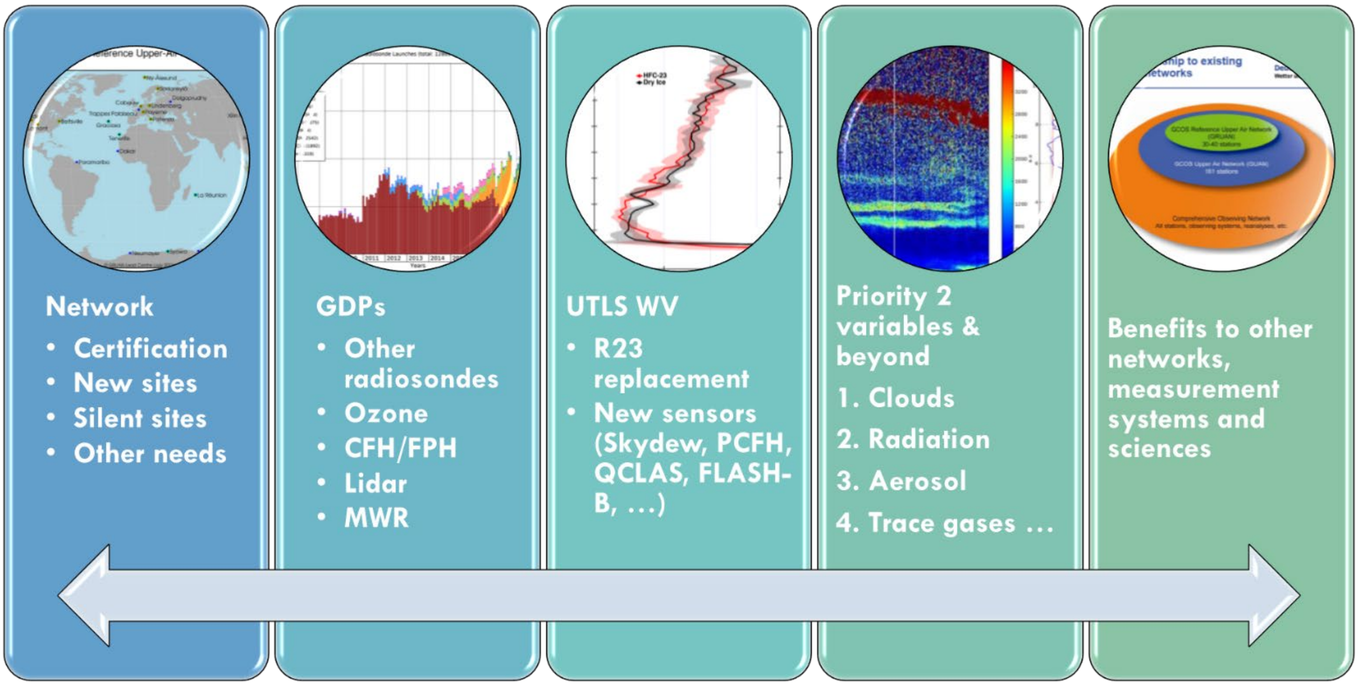

Figure 1. Priorities for GRUAN 2021-2025 Implementation Plan

4.5 Site photos (C1) (Michael Sommer)

The current status of the long-term task "Site photo documentation" was shown. It was found that so far only a few sites perform this task on a regular basis. To improve this situation, a user-friendly possibility was created to collect site photos, but also other relevant information of the site, e.g. important changes of the measurement systems. The "GRUAN Site Diary" is a new tool that is directly integrated into the GRUAN website. Details of this new tool was presented using screenshots of current BETA version, which can now be used by a few stations on a test basis. A presentation was provided on this activity. Any outcomes/actions following the presentation are captured in Annex 2.

4.6 Update on work to improve monitoring of usage of GRUAN products (Dave Smyth)

Within the GRUAN community, GRUAN products are well known. However, to encourage funders of institutions who may not be readily aware of the value of such outputs, and how many times they are used, it is key to promote the impact of GRUAN products beyond the end users. The metric that would support this, and which is particularly relevant for stations that only perform measurements, is the DOI. Employing DOIs would enable the tracking of data use and provide metrics of citations, user groups, and the impact of the data on science progress. PANGAEA, hosted by AWI, has been selected to trial DOI allocation. Once the Beta version of RS41 processing is completed and a GRUAN data product of the MOSAiC data is produced, it is planned to store it on PANGAEA and track and evaluate its usage via DOIs. It is anticipated that this method will be rolled out to monitor usage of other GRUAN products.

4.7 Data policy for different release phase versions (C3) (Ruud Dirksen)

Ruud summarized the issue that was first raised during ICM-11:

The GRUAN data base contains a wide variety of data, of which only a small fraction is publicly available. At the same time, sites would like to be able to control the distribution of data from additional instruments (e.g. ozone sonde). In order to address this issue, the technical note

TN-10 was drafted, that outlines the policy for the distribution of various kinds of (intermediate) data.

TN-10 defines various kinds of data, ranging from raw measurement data to manufacturer or GRUAN processed product data, as well as the access to these data categories by various kinds of GRUAN-internal and external users.

Feedback on the draft included the request for the FAIR use of data by public users, which is included in for example the BSRN data policy https://bsrn.awi.de/data/conditions-of-data-release/. A potential way to achieve recognition for sites' efforts is the use of site-specific DOI-numbers. The updated TN will be first be circulated in TT-sites.

Deliberate data latency, i.e. the delayed release of data from certain measurements, for example to ensure first-publication rights for the site in case of e.g. campaign activities can be implemented by means of the Intermediate-Raw data format. However, this latency should not be applied to essential and/or regular GRUAN measurements such as radiosoundings, GNSS-PW, and stratospheric H_2O observations, since these are part of the site's commitment to GRUAN.

4.8 Uncertainty assessment and reporting – RS92 Temperature GDP Case Study(C4) (Tom Gardiner)

The talk focussed on a traceability and uncertainty assessment process that has been developed over the last few years. This process provides the current best estimate of uncertainty contributions to a particular measurement product and their associated correlations, as well as identifying gaps in the current knowledge of uncertainties. The outputs from the process provide the underlying information for different options for uncertainty reporting, driven by user needs. Recent work has focussed on reporting uncertainty on different timescales as a simple way for different users to identify the most relevant uncertainty for their application. Examples were provided of such an uncertainty assessment for GRUAN RS92 data from Lindenberg which is being implemented for the complete GRUAN RS92 dataset as part of Copernicus Climate Change Service activities on providing 'access to observations from baseline and reference networks'. An initial draft of a paper on this work has been prepared.

Session 5. New science

5.1 High altitude attainment study progress (C7) (Masatomo Fujiwara)

The progress of the task, "Justification for high ascent attainment (for balloon soundings at GRUAN and other sites)" was discussed. "High" means much higher than 30 hPa, i.e., up to 10 hPa and/or even 5 hPa. The criteria that should be included are not only climate monitoring, but also numerical weather forecasting, summarizing the needs by various different data users. This is a very important task, but at the same time very challenging and ambitious task, as we have to provide the appropriate message to various different stakeholders. The organization of planned paper/document was presented, and each section was discussed in detail to obtain inputs from the GRUAN community.

The planned sections are as follows:

(1) Introduction: The atmospheric column;

(2) Technical issues for balloon sounding;

(3) Climate monitoring (including lower stratospheric winds);

(4) Satellite validation;

(5) Radiative transfer calculations (including WMO GSICS need);

(6) Impacts on Numerical Weather Prediction;

(7) Seasonal predictability; and

(8) Summary and Conclusions.

5.2 Upper Air Simulator to evaluate the measurement uncertainty of the RS41 (Sang-Wook Lee[1])

[1]Korea Research Institute of Standards and Science

Upper-air simulator (UAS) has been developed at the Korea Research Institute of Standards and Science (KRISS) to study the effects of solar irradiation of commercial radiosondes. In this presentation, the uncertainty of the radiation correction and corrected temperature of a Vaisala RS41 temperature sensor is evaluated using the UAS. The effects of environmental parameters including the temperature (T), pressure (P), ventilation speed (v), and irradiance (S) are formulated in the context of the radiation correction. The considered ranges of T, P, and v are –67 to 20 °C, 5−500 hPa, and 4−7 $m \cdot s^{-1}$, respectively, with a fixed S0 = 980 $W \cdot m^{-2}$. Then, the effects of rotation and tilting of the sensor boom with respect to the irradiation direction are investigated. The uncertainties in the environmental parameters determined using the UAS are evaluated to calculate their contribution to the uncertainty in the radiation correction and the corrected temperature. The uncertainty in the radiation correction is obtained by combining the contributions of all uncertainty factors. The expanded uncertainty associated with the radiation-corrected temperature of the RS41 is 0.17 °C at the coverage factor k = 2.

5.3 Radiosonde interpolation uncertainty (Pietro Colombo)

The Global climate observing system Reference Upper Air Network (GRUAN) provides reference measurements of the essential climate variables and their measurement uncertainty.

An important aspect of the measurement uncertainty is the interpolation uncertainty. This problem arises, for example, when GRUAN processes atmospheric profiles collected by Vaisala RS41 radiosondes. For various reasons, the radiosonde sensor may fail to collect some values along the vertical profile in the atmosphere. As a consequence, estimation techniques to fill the data gaps and to provide an evaluation of the related interpolation uncertainty are welcome. The present work analyses the main consequences in terms of interpolation uncertainty for different climate variables, using different interpolators and along the relevant dimensions of altitude, gap size and launch locations. The results around the interpolation uncertainty quantification are incorporated in lookup tables that are available for the scientific community.

5.4 Stratospheric seasonality and its implications for radiosonde (Bruce Ingleby)

The new GBON target has been discussed mainly in terms of the required density of profiles up to 30 hPa or to 10 hPa. However North of 45N (25% of the ~800 fixed radiosonde stations globally) there is a good case for having more/higher soundings in winter than in summer - both for NWP and climate studies. Currently the average burst height is lower in winter than in summer. In 'winter' (Nov-Apr) the Boreal stratosphere is very active due to disturbances of the polar vortex from planetary waves, the most extreme of these disturbances appear as stratospheric sudden warnings. In summer the mid/high-latitude stratosphere is very quiet, only disturbed by occasional gravity waves. The stratospheric variability is explored using ERA5 reanalyses and a diagnostic (FSOI) is used to estimate the impact of the radiosonde data. At high southern latitudes the maximum variability is in the Austral spring and there is a less clear-cut variation in radiosonde impact.

5.5 Chilled mirror hygrometers and their 'Golden Points': a new interpretation and correction method for chilled mirror data (Yann Polter)

Authors: Yann Poltera[1], Beiping Luo[1], and Thomas Peter[1]
[1]ETH Zürich, Zurich, Switzerland

Chilled mirror hygrometers (CMHs) allow to measure the dew point or frost point of air, i.e. they provide information on the degree of saturation of the air with respect to the condensed phases of water. To this end, they determine the thermodynamic equilibrium of their condensate through measurements of the mirror reflectivity. This reflectivity information allows to identify points when the mirror is in equilibrium with the gas phase, the so-called "Golden Points", correct the data for non-equilibrium conditions between the Golden Points.

Concerning (i), we identify the chilled mirror data points, which are in thermodynamic equilibrium, as the points when the mirror reflectivity reaches an extreme value, i.e. either a maximum or minimum (assuming 10 s smoothing to reduce electronic noise). At these extreme points, for well-calibrated instruments, the mirror temperature is indeed the frost point (or dew point) with an accuracy better than 0.2 K. These accurately (to within 0.2 K) determined frost points can be used to detect and correct offsets, biases and time-lag errors in other instruments flown on the same payload, such as the FLASH-B hygrometer or the RS41 radiosonde. In the stratosphere, a frost point error of 0.2 K corresponds to about 3-4 % error in water partial pressure or mixing ratio.

Concerning (ii), we correct the chilled mirror data points that are not in thermodynamic equilibrium by using the data from the accompanying radiosonde as a priori reference (after it has been bias-corrected by means of (i)).

From a set of 70 night-time CFH-RS41 soundings launched between 2016 and 2020, we found that the deviations between the reported mirror temperature and the estimated true frost point are typically better than 0.5 K. However, in situations where the mirror temperature deviates significantly from the true atmospheric frost point, deviations larger than 5 K are possible, typically occurring in the presence of a coarse ice film on the mirror and/or of large mixing ratio changes in the atmosphere. In these cases, the non-equilibrium correction may remove 80%-90% of the non-equilibrium error. In turn, this allows reducing the uncertainty of the frost point estimates for a given vertical resolution and helps discerning true atmospheric features from measurements artefacts.

Acknowledgements. We are grateful to our colleagues at DWD, IITM, ARIES, DHM, FZJ, AWIPEV and ETH Zürich for the preparation and collection of the CFH, COBALD, FLASH-B and RS41 sounding data analysed in this work.

5.6 Constraining radiosonde random uncertainty with collocated radio occultations and model data (Johannes Nielsen)

Three independent collocated data sets were used to estimate random (in GRUAN terms "uncorrelated") temperature uncertainty and vertical uncertainty correlations of each individual data set, with the Generalized Three Cornered Hat (G3CH) method. The three data sets are dry temperature from GNSS Radio Occultations (RO) from COSMIC 1 and Metop A-B, ERA5 forecast temperature interpolated to RO reference coordinates and GRUAN RS92 collocated profiles. Representativeness uncertainty were reduced by evaluating 3CH at different collocation criteria, and then extrapolate the covariance matrices to zero collocation distance. Differences in vertical footprint were analysed by applying vertical filtering to find lower and upper limits for the uncertainty estimates.

The ERA5 uncertainty estimates are useful as input to RO 1D-Var estimates of humidity and temperature, using ERA5 as background. As a by-product RS92 random uncertainty and vertical uncertainty correlation were estimated. The RS92 uncertainty estimate includes a residual representation uncertainty which is due to different measuring geometries. The RS92 uncertainty is estimated down to between 0.3 K and 0.7 K in the optimal range around 8 km where the collocation is most favourable. A relatively large vertically correlated component of random uncertainty is detected in RS92, the correlation coefficient being approximately 0.1 in the stratosphere.

5.7 Development of a new dual thermistor radiosonde (Yong-Gyoo Kim[1])

[1]Korea Research Institute of Standards and Science (KRISS)

In order to realize in-situ solar correction technique, a dual thermistor radiosonde comprising two (white and black) sensors with different emissivity was developed at KRISS. Response to the solar radiation of black thermistor coated with high emissivity black epoxy and white thermistor coated with high reflectivity thin-film Al layer were different in temperature. From this difference, it was possible to make the experimental equations for the in-situ irradiance and the correction value calculations by using the UAS (Upper Air Simulator). After the characterization of the DTR, it was combined and applied to the DTR sounding test conducted in July 2021. The resultant uncertainty (k = 2) of DTR was calculated and revealed to 0.14 °C ~ 0.35 °C depending on the altitude. By comparison with Vaisala RS41, two radiosondes are consistent within 0.4 °C in maximum close to the uncertainty of DTR. The DTR methodology can improve the accuracy of temperature measurement in the upper air within the framework of traceability to the International System of Units.

5.8 Small scale variability of water vapour in the atmosphere (Xavier Calbet)

Further evidence that the water vapor at small scales (< 6 km) behaves as a Gaussian Random Field were presented. Among them, measurements of the water vapor structure function with different instruments are presented. It is shown that all follow the two-thirds scale "law" from Kolmogorov's theory of turbulence. It is also presented some TCWV fields measured with OLCI that show a Gaussian Random Field behaviour. These properties have an impact on the radiative transfer of light in the atmosphere and therefore have an impact on the satellite measurements of water vapor. In the case of IASI there seems to be a permanent negative bias in the measurements due to this effect.

5.9 Next Meeting

ICM-14 will be hosted by the local university on La Reunion during the second week of November 2022.

ANNEX 1: AGENDA

Session 1. Radiosondes new data products, RS41 (Monday 15 November) / Chair(s): June Wang

1-1	Presentation from co-chairs - Welcome Achievements since ICM-12 and challenges	Peter Thorne/June Wang
1-2	Status of all GDPs under development (B1/B2)	Ruud Dirksen
1-3	RS41 product overview (HP1)	Michael Sommer
1-4	QC/QA flagging ad hoc group progress report (HP3)	Tzvetan Simeonov
1-5	Progress on standardisation of cloud observations and their reporting	Masatomo Fujiwara
1-6	Omnibus (HP2)	Christoph von Rohden
1-7	Modem product status (B3)	Eliane Assy
1-8	Graw product status	Ruud Dirksen
1-9	Progress in humidity time lag, ground check processing (HP1, C5 b)	Christoph von Rohden
1-10	Ozonesonde status (B4)	Holger Vömel

Session 2. Ground-based & emerging technologies (Tuesday 16 November) / Chair(s): Dale Hurst/Marion Maturilli

2-1	GNSS-PW status update, Metrological closure between GNSS-PW and radiosonde (C11, C12)	Kalev Rannat
2-2	MWR status (B5)	Nico Cimini
2-3	AIRCORE	Dietrich Feist
2-4	Quantum-cascade laser absorption spectrometer (QCLAS) for water vapor measurements in the upper stratosphere	Simone Brunamonti
2-5	Validation of RALMO water vapor mixing ratio against the co-located Vaisala RS41 radiosounding data	Giovanni Martucci
2-6	Frostpoint hygrometer GDP progression (B7)	Dale Hurst
2-7	Lidar GDP (B6)	Thierry Leblanc
2-8	Biogenic aerosols in the UTLS: A new challenge to water vapor Raman lidars (and other techniques?)	Thierry Leblanc
2-9	Multi-station Measurements of the Ionospheric Potential with GRUAN	Earle Williams
2-10	The NOAA Baseline Balloon stratospheric Aerosol Profiles (B@SAP) Project: description and insights using in situ observations since 2019	Elizabeth Asher

Session 3. WMO intercomparison, dual soundings, collocations, R23 replacement (Wednesday 17 November) / Chair(s): Stephanie Evan

3-1	WMO intercomparison - includes Q&A	
3-2	Progress with provision of site-based ancillary measurements to the RS92/41 colocation database (A1)	Dave Smyth
3-3	Progress with provision of satellite based ancillary measurements to the RS92/RS41 colocation database (A2)	Lori Borg
3-4	Dual launch analysis updates (A3 & C8)	Tzvetan Simeonov
3-5	The R23 issue, summary of tests performed at various sites Update on Dry ice / Ethanol FPH flights at Boulder	Ruud Dirksen Dale Hurst

	Report on Dry ice / Ethanol CFH flights Development of N2 container	Holger Vömel Christian Rolf
3-6	Skydew status	Kensaku Shimizu
3-7	FLASH-B	Alexey Lykov
3.8	PCFH	Frank Wienhold
3.9	SHC analysis update / progress with paper (C5a)	Ruud Dirksen

Session 4. Network management IP, Task Teams, silent sites (Thursday 18 November) / Chair(s): Ruud Dirksen

4-1	Proposal on policy for silent sites (C10)	Ruud Dirksen
4-2	Comprehensive Upper-Air, Baseline and Reference in situ observations in Copernicus 2.0	Fabio Madonna
4-3	Update on GRUAN website	Michael Sommer
4-4	IP progress and plan	June Wang
4-5	Site photos (C1)	Michael Sommer
4-6	Update on work to improve monitoring of usage of GRUAN products	Dave Smyth
4-7	Data policy for different release phase versions (C3)	Ruud Dirksen
4-8	Uncertainty terminology and presentation in GRUAN products (C4)	Tom Gardiner

Session 5. New science (Friday 19 November) / Chair(s): Peter Thorne

5-1	High altitude attainment study progress (C7)	Masatomo Fujiwara
5-2	Upper Air Simulator to evaluate the measurement uncertainty of the RS41	Sang-Wook Lee
5-3	Radiosonde interpolation uncertainty	Pietro Colombo
5-4	Stratospheric seasonality and its implications for radiosonde requirements	Bruce Ingleby
5-5	Chilled mirror hygrometers and their 'Golden Points': a new interpretation and correction method for chilled mirror data	Yann Poltera
5-6	Constraining radiosonde random uncertainty with collocated radio occultations and model data	Johannes Nielsen
5-7	Development of a new dual thermistor radiosonde	Yong-Gyoo Kim
5-8	Small scale variability of water vapour in the atmosphere	Xavier Calbet
5-9	Announcement ICM-14	ICM-14 hosts

ANNEX 2: Summary of progress of ICM-12 Actions

Note: Markings based on Information provided at ICM-13 and agreed at follow-up meeting with GRUAN Chairs, Working Group Chairs and GCOS Secretariat.

	No.	No Progress	Some Progress	Good Progress	Complete
High Priority	**3**	**0**	**2**	**1**	**0**
A: Actions	**3**	**0**	**2**	**0**	**1**
B: Actions	**7**	**1**	**2**	**3**	**1**
C: Actions	**13**	**1**	**4**	**7**	**1**

High priority Actions:

	Description	Activity (s)	Responsibility	Date
HP1 (a)	***Development of RS41-GDP.1***	*Milestone in the development of the first full version of RS41 GDP, which is to be certified by working group June 2021.* *Release of version BETA.2*	*Lead Centre*	*Dec 2020*
HP1 (b)	***Development of RS41-GDP.1***	*Milestone in the development of the first full version of RS41 GDP, which is to be certified by working group June 2021.* *Submit paper (describing radiation temperature correction)*	*Lead Centre*	*Mar 2021*
HP1 (c)	***Development of RS41-GDP.1***	*Milestone in the development of the first full version of RS41 GDP, which is to be certified by working group June 2021.* *Finalise TD (for review)*	*Lead Centre TT-Radiosondes (review)*	*Mar 2021*
Comment: Overall progress is 'Good Progress'. All activities have been completed except the finalised Technical Document. Only 'Provisional' certification granted by GRUAN.				
HP2	***Radiosonde fundamental documentation***	*Finalize first draft of GRUAN radiosonde foundational technical document to cover the general instrument-independent aspects. Including dual or complex ascents guidance*	*Ch von Rohden (LC) TT Radiosondes Lead Centre*	*By ICM-13*
Comment: Apart from some small additions, no substantial progress; manuscript essentially in the condition as presented at ICM-11				

HP3	***QC/QA flagging and presentation in data files***	*Ad hoc group on QC/QA flagging to develop a strategy and rationale as a technical note. Work to include inter-alia: which profiles to present to users; use of multiple fields (good, questionable, bad); and use of interpolated values or otherwise.*	*Tzvetan Simeonov (LC) + Ad-hoc group members (QTF)*	*TN by ICM-13*

Comment: QTF have made progress on detailing the QC/QA process/need but questions remain on the governance.
As yet no TN. Further work required. Limited discussion time so no agreement on revised action.

RS92-RS41 transition items:

	Description	Activity (s)	Responsibility	Date
A1	***Parallel soundings database augmentation with ancillary data***	*Augment parallel soundings of RS92-RS41 with 'ancillary' measurements (CFH, FPH, lidar, MWR, cloud observations (incl. BSRN) within +/-2 hours).*	*TT-GB; TT Sites; WG Chairs; Lead Centre.*	*TN completed Feb 2021* *Data submissions from sites by ICM-13*

Comment: Update provided at ICM-13. Questions remain on scope, management and implementation. No TN at present.

A2	***Satellite data collocations with RS92/41 pairs***	*TT-SAT to provide collocations with the historical RS92-RS41 payload ascents for a range of relevant polar orbiter and radio occultation measurements*	*TT-SAT; Lead Centre*	*LC to provide list of target locations / times by Feb 2021* *Data to be provided to LC by TT-SAT by ICM-13*

Comment: Update provided at ICM-13. Questions remain on what is to be provided to GRUAN for each collocation. Ongoing work for TT-SAT and LC.

A3	***Updated analysis of dual launch holdings***	*Presentations on updated analysis, including accounting for distinctions in rigging and ancillary measurements to be presented at ICM-13. Reports to be made available a month prior. Consideration of submission of reports as peer-reviewed literature.*	*RIVAL team; WG Chairs; ad-hoc members; Lead Centre*	*Presentations at ICM-13*

Comment: Presentation given at ICM-13. Work is on-going to include more sites and additional variables (i.e. wind).

New GRUAN data products:

	Description	Activity (s)	Responsibility	Date
B1	***Maintain status of GDPs***	*LC to revised the status of GDPs under development https://www.gruan.org/data/data-products/development-status (add a column "Actions"), maintain in a timely fashion and report on this at ICM-13. Update quarterly, make accessible via website*	*Lead Centre; GDP development leads*	*Report at ICM-13* *Initial site available by March 2021 and updated quarterly thereafter*
B2	***Development of Meisei Data product***	*Milestone in the development of the GRUAN Dataproducts for RS-11G (v2) and iMS-100 (v2), which is to be certified by the Working Group by June 2021.* *(a) Data stream in Beta mode* *(b) Complete TD for review* *(c) Submit paper*	*JMA;* *Meisei;* *TT-Radiosondes*	*Jan 2021* *Mar 2021* *Apr 2021*
Comment: (a) Complete; (b) In progress; (c) 1 paper submitted.				
B3	***Development of M10 Data product***	*Milestone in the development of the GRUAN Dataproducts for Modem M10* *(a) Data stream in Beta mode* *(b) Finalize the TD for review* *(c) Complete comparisons of Modem-M10 to RS92/41*	*IPSL; Modem; TT-Radiosondes*	*Feb 2021* *May 2021* *Jun 2021*
Comment: (a) Complete; Others ongoing.				
B4	***Ozonesondes GDP progression***	*A short document with GRUAN-specific content will be written, using the ASOPOS 2.0 report as background reference material.*	*Richard Querel; WG Chairs*	*By ICM-13*
Comment: Presentation provided. ASOPOS report now finished (published?). Working on GRUAN documents. Data Stream in Beta (to Lindenberg) proposed.				

B5	***Microwave Radiometer GDP progression***	*Review status of MWR GDP TD by new TT GB members.* *Update MWR GDP TD and make progresses on MWR GDP*	*TT GB;* *Nico;* *Maria;* *Christine;* *Fabio;* *Gianni*	*Update at ICM-13*
Comment: Presentation provided. Activities towards MWR networking have been launched in the framework of both ACTRIS (EU long-term research infrastructure dedicated to atmospheric monitoring) and E-PROFILE (atmospheric profiling programme of EUMETNET). All GRUAN sites in EU belong to either of both ACTRIS and E-PROFILE. Thus, the development of the MWR GRUAN Data Product (GDP) could benefit from these activities in terms of expertise, best practices, and data life cycle. Presentations from ACTRIS (Bernhard Pospichal, University of Cologne) and E-PROFILE (Rolf Rüfenacht, MeteoSwiss) have been given at GRUAN ICM-13.				
B6	***Lidar GDP progression***	*Report on beta testing outcomes and progress of a v1 data stream at ICM-13. If beta testing shows no issues then aim to have finalized TD and be in a position to certify one or more initial lidar data streams.*	*Thierry Leblanc; Arnoud Apituley; Fabio Madonna; TT-GB*	*Update at ICM-13*
Comment: Update provided. Little progress since ICM-12 and 'beta' data stream is also not active. Suggest new data-stream (Payerne to Lindenberg)? Need helps from LC (raw data transfer, netcdf conversion).				
B7	***Frostpoint hygrometer GDP progression***	*Provision of update on progress towards a GDP for frostpoint hygrometers covering at a minimum:* *1. whether a single statistical approach can be applied to all frostpoint models, especially for uncertainties* *2. questions around the vertical averaging and uncertainty analyses of Voemel et al raised at ICM-11.*	*Dale Hurst; Ruud Dirksen; Takuji Sugidachi*	*Update at ICM-13*
Comment: Update provided. Little progress. Suggest – more regular meetings and identify a lead expert.				

Other Actions:

	Description	Activity (s)	Responsibility	Date
C1	***Sites photos***	*Sites to upload first set of photos commensurate with the new site photos TN. Lead Centre to work with sites through their PRs to share these with the OSCAR Surface database.* *LC: Continue reminding sites to upload quarterly (including those who have already)*	*TT Sites; Lead Centre; GCOS Secretariat*	*All sites to have uploaded at least initial set of photos by end of March 2021*

Comment: Update/Presentation provided at ICM-13. New process to collect metadata, which includes site photos, has been implemented (beta). Several sites asked to test the system.				
C2	***Usage of GRUAN data***	*Further develop ideas around the appropriate usage and citation metrics of GRUAN data including appropriate acknowledgment to sites and research institutions. (CDS only acknowledges GRUAN, not research institutes / stations.)*	*WG; TT sites*	*Instigate measures as per discussions and further update progress at ICM-13.*
Comment: Update/Presentation provided at ICM-13. Several metrics were presented to capture use of GRUAN data.				
C3	***Data Policy***	*Progress to finalization an explicit strategy regarding which data can be released to whom and get signed off by sites and WG.*	*Lead Centre; TT Sites; WG*	*TN completed, reviewed by WG and TT sites and published by May 2021*
Comment: Update/Presentation provided at ICM-13. No reference to a TN being published.				
C4	***Uncertainty terminology and presentation in GRUAN products***	*Develop a white paper on uncertainty quantification and presentation options for possible submission for publication.* *Next steps:* • *Planning to implement for the complete GRUAN RS92 dataset under C3S.* • *Discuss potential extension to other GDPs.* *Write up for potential publication*	*TT-Scheduling*	*Draft paper available for review by March 2021*
Comment: Update/Presentation provided at ICM-13. Paper in draft.				
C5 (a)	***Standard Humidity Chamber***	*Paper to justify the use of the SHC in terms of the data quality and the benefits and including need for standardisation of operating procedures.*	*Richard Querel; David Smyth; TT-sites; Lead Centre*	*First draft outline of paper Q2 2021*

		TN to describe procedural requirements (e.g. operational procedure; quality of the applied references in the SHC). *Relevant parameters: RH, Temperature, pressure (if available)*		
Comment: Presentation provided at ICM-13. Work is ongoing. Plan to produce paper and TN.				
C5 (b)	***Manufacturer-independent ground-check***	*Define how to treat the results of the manufacturer-independent ground check in the GRUAN data processing and the subsequent QA/QC of the GDP.* *Relevant parameters: RH, Temperature, pressure (if available)*	*Lead Centre;* *QTF;* *TT-radiosonde*	*TN by ICM-13*
Comment: Presentation provided at ICM-13 and recommendations to GRUAN. No TN at present. Need to agree a way forward on this activity.				
C6	***Standardizing cloud observations / reporting***	*Develop a proposal on how cloud observations should be taken to support the radiosonde profiles including how that information should be included in the data files. Strategy to be cognizant of existing practices and the results of the survey into site issues identified (ICM-11 Action C6, closed).*	*TT-radiosonde;* *TT Sites;* *TT SAT;* *Lead Centre*	*Update at ICM-13*
Comment: Update/Presentation provided at ICM-13.				
C7	***Justification for high ascent attainment***	*TT radiosondes to progress an analysis of the additional benefits of high altitude attainment (10hPa compared to 30hPa) with a view to arising one or more papers. Criteria to include NWP impact, seasonal predictability, importance of monitoring LS winds etc.*	*TT Radiosondes;* *IPET-OSDE*	*Draft report Feb 2021*
Comment: Update/Presentation provided at ICM-13. Draft report has agreed structure and contributions from a number of experts. Request for additional input from experts.				

C8	***Generalise parallel soundings database***	*Lead Centre to make all parallel soundings (all pairs or sets either model1-model2 or model1-model1) in the archive explicitly available via the parallel soundings archive facility to increase accessibility and usability. Parallel soundings archive to be made more externally accessible.*	*TT sites to ensure all sites have uploaded all parallel measurements (not just RS92/41 pairs).*	*Audit of sites parallel measurements completed March 2021* *Available parallel launches submitted to LC by ICM-13*

Comment: Update provided at ICM-13, including availability statistics. The parallel database utility is available and all sites have been tasked with making any parallel data available.

C9	***Refresh of presentation materials***	*Review and refresh generic power-point, create generic poster, encourage presentations at relevant conferences.*	*David Smyth; WG; Lead Centre*	*Available by ICM-13*

Comment: No progress on the item.

C10	***Silent stations***	*WG, LC and secretariat to propose a review mechanism for retention of sites which remain silent and never progress to certification. What would be the criteria and process by which eventual removal as candidate sites may occur? How could they be encouraged?*	*WG-GRUAN; Lead Centre; GCOS Secretariat*	*Proposal available by ICM-13 for further discussion, talk at ICM-13*

Comment: Proposal presented at ICM-13. No objections from the meeting. Need to agree the 'approval' process. Proposal needs to become a technical note. Final approval will start the 'clock' on those stations that are not reporting.

C11	***GNSS GDP format***	*GFZ to progress provision of a netCDF format version of the GNSS GDP*	*TT GNSS-PW; Lead Centre (review)*	*Jun 2021*

Comment: Update/Presentation provided at ICM-13. Work is on-going.

C12	***Metrological closure of GNSS-IWV and radiosondes***	*For GRUAN sites that perform both GNSS-IWV measurements and radiosoundings, analyse the comparison of the GRUAN data products (and their respective uncertainties) for these data streams to establish whether metrological closure is attained. Further results to be presented at ICM-13 and written up in a paper.*	*GNSS-IWV; TT- radiosonde*	*ICM-13: presentation & preparation of manuscript*
Comment: Update/Presentation provided at ICM-13. Work is on-going.				

ANNEX 3: Agreed ICM-13 Actions

High priority:

	Description	Activity (s)	Responsibility	Date
HP1	Manage and progress High Priority Actions	Quarterly meetings to discuss progress, report issues and update as agreed.	GCOS Sec Lead for each HP action	Mar 2022 Jun 2022 Sep 2022
HP2	Development of RS41-GDP	Milestones in the development of the Vaisala RS41 GDP (a) Finalise TD and submit to WG for review (b) Final Certification	Lead Centre	 Apr 2022 By ICM-14
HP3	Development of Meisei GDP	Milestones in the development of the Meisei IMS-100 GDP (a) Technical document submitted for review for IMS-100, including an update for RS-11G (b) Provide update at ICM-14	Lead Centre JMA Meisei	 Feb 2022 ICM-14
HP4	Development of Modem M10 GDP	Milestones in the development of the Modem M10 GDP (a) Technical document. (c) Data Processing (d) Provide update at ICM-14	Lead Centre Meteo-France Modem	 Apr 2022 Apr 2022 ICM-14
HP5	Use of R23 and its replacement	(a) Provide operational guidance to GRUAN sites on how to manage the finite supply of R23 and monitor the status at each site in collaboration with TT sites. (b) Ongoing testing, including where possible comparison to CFH, of possible R23 replacements; SKYDEW; Liquid Nitrogen (Julich); Ethanol dry-ice. (c) Provide experimental flight data to LC to ensure optimal progress. (d) Provide update at ICM-14	Lead Centre TT Sites All sites using R23 All sites doing test LC	Jan 2022 Ongoing Ongoing ICM-14

RS92-RS41 transition items:

	Description	Activity (s)	Responsibility	Date
A1	Parallel soundings database augmentation with ancillary data	(a) TN ready for review. (b) Approved TN (c) Implementation – update at next ICM	David Smyth June Wang LC	Jan 2022 Mar 2022 ICM-14
A2	Satellite data collocations with RS92/41 pairs	Meeting to discuss next steps	TT-SAT LC	Jan 2022

New GRUAN data products:

	Description	Activity (s)	Responsibility	Date
B1	Microwave Radiometer GDP progression	Milestones in the development of the Microwave Radiometer GDP (a) Updates on data format and calibration uncertainty characterization to be provided by ICM-14.	TT GB	ICM-14
B2	LIDAR GDP progression	Milestones in the development of the LIDAR GDP (a) Implement data steam for at least one site	TT GB Thierry Leblanc LC	Jun 2022
B3	Frostpoint Hygrometer GDP progression	Milestones in the development of the Frostpoint Hygrometer GDP (a) Paper (Holger's) - review (b) Meeting to: Identify additional personnel (with good knowledge of statistics) to complete task? Scope the necessary work and reach out to ETHZ through Meteoswiss? (c) Report at ICM-14	Dale Hurst; Ruud Dirksen; Takuji Sugidachi	Mar 2022 Mar 2022 ICM-14
B4	QC/QA flagging and presentation in data files	QTF have made progress on detailing the QC/QA process/need but questions remain on the governance. Complete summary of different approaches currently in use across sites.	Tzvetan Simeonov (LC) + Ad-hoc group members (QTF)	ICM-14

Other Actions:

	Description	Activity (s)	Responsibility	Date
C1	Sites photos	Utility to regularly update site photos is complete. Complete audit that all GRUAN sites who are actively sharing data have uploaded site photos.	LC	 Jun 2022
C2	Usage of GRUAN data	Further develop ideas around the appropriate usage and citation metrics of GRUAN data. GDP data stored in PANGAEA with allocated DOIs.	LC	 By ICM-14
C3	Data Policy	Finalise Technical Note	LC TT Sites WG	Apr 2022
C4	Uncertainty terminology and presentation in GRUAN products	Paper submitted for publishing	TT-Scheduling	June 2022
C5	Standard Humidity Chamber	Paper to justify the use of the SHC in terms of the data quality and the benefits and including need for standardisation of operating procedures. TN to describe procedural requirements (e.g. operational procedure; quality of the applied references in the SHC). Complete TN and submit paper.	Richard Querel; David Smyth; TT-sites; Lead Centre	By ICM-14
C6	Standardizing cloud observations / reporting	Develop a proposal on the reporting of cloud observations: Write a GRUAN TN with several colleagues. Title: Towards the standardisation of cloud observations and their reporting associated with radiosonde ascents. 1. Manual visual cloud observation (to be included in the GDP metadata) 2. Automated ground-based remote sensing instruments (incl. ceilometers, all sky camera; to recommend further research) 3. Balloon-borne cloud/radiation instruments (to reduce radiosonde T uncertainty; to recommend further research) Draft TN by ICM-14.	TT-radiosonde; TT Sites; TT SAT; Lead Centre	By ICM-14

C7	Justification for high ascent attainment	TT radiosondes to progress an analysis of the additional benefits of high-altitude attainment Draft Paper	TT-radiosonde	By ICM-14
C8	Silent stations	WG, LC and secretariat to propose a review mechanism for retention of sites which remain silent and never progress to certification. Draft TN to TT-Sites for Review TN approved	WG-GRUAN; Lead Centre; GCOS Secretariat	Jan 2022 By ICM-14
C9	GNSS GDP format	GFZ to progress provision of a netCDF format version of the GNSS GDP Jonathan Jones to provide steps necessary (SMART) Update at ICM-14	TT GNSS-PW; Lead Centre (review)	ICM-14
C10	Metrological closure of GNSS-IWV and radiosondes	For GRUAN sites that perform both GNSS-IWV measurements and radiosoundings, Analyse the comparison of the GRUAN data products (and their respective uncertainties) for these data streams to establish whether metrological closure is attained. Jonathan Jones to provide steps necessary (SMART) Update at ICM-14	GNSS-IWV; TT- radiosonde	ICM-14

Actions where progress is required, but not time-bound:

	Description	Activity (s)	Responsibility	Date
D1	Ozonesondes GDP progression	Milestones in the development of the Ozonesode GDP (a) Datastream (b) Paper (c) GRUAN documents	Richard Querel; WG Chairs	Update at ICM-14
D2	Radiosonde fundamental documentation	Draft available for review by WG	LC	Update at ICM-14
D3	RS92-RS41 comparison paper	Paper	LC	As time permits

D4	**Development of M20 Data product**	Milestones in the development of the Modem M20 GDP Agree timeline and progress those items as time permits	M20 consortium (Modem, J-C Dupont)	As time permits
D5	**Refresh of presentation materials**	Priority is on a GRUAN PowerPoint presentation	Dave Smyth	As time permits

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