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Report of the Tenth GCOS Reference Upper Air Network Implementation and Coordination Meeting (GRUAN ICM-10)

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GRUAN
ICM-10

1. OFFICIAL ADDRESS FOR GRUAN 10TH ANNIVERSARY

1.1 Opening session

The meeting opened with the welcome of Franz Berger, director of the Lindenberg Observatory. In celebration of the 10th anniversary of GRUAN, an official address to the ICM 10 was organized. Martina Münch, in her function of Brandenburg's minister for Science, Research and Culture, officially welcomed the participants to the ICM 10. Transcripts of her speech can be found in Annex 1.

Markus Rex, head of the Climate Sciences, Atmospheric physics of the Alfred-Wegener-Institut (AWI), gave an official welcome and an introduction message underlining the main activities of AWI. AWI operates research and observations stations in both Arctic and Antarctic and is a strong supporter of GRUAN. Ny Alesund was the first certified GRUAN station.

Paul Becker, vice-president of the German Meteorological Service (DWD) presented the main activities of DWD and the strong collaboration existing between Germany and GCOS. Transcripts of his speech can be found in Annex 1.

Peter Thorne, Chair of GRUAN and member of the Atmospheric Observation Panel for Climate (AOPC), presented a brief history of GRUAN and how it has evolved over the past 10 years.

Session 1 was closed with an official toast to GRUAN.

2. KEYNOTES

Ruud Dirksen, head of the Lead Center, presented the fundamentals of GRUAN.

Session 2 included three keynotes presentations outlining some of the principal research undertaken by the institutions on the Potsdam campus.

2.1 Polar Climate change and the role of ozone – Markus Rex

Markus Rex started by talking about the Arctic Climate Change and the role of the ozone. He argued that the arctic is the key area for climate change. The observed near surface temperature changes in this area are more dramatic than in any other area of the world. Not only a strong decrease of sea ice extent is observed in the Arctic, but also the ice thickness is dramatically decreasing, leading to a significant loss of multiyear sea ice. The decrease of ice extent will mean that a rapid economic development in several areas, like mining, shipping, fishing, will be possible, which will require a big investment in infrastructure. Thus, good climate projections are needed. Arctic climate change is not well represented in state-of-the-art Earth System Models, with the arctic being the region of largest uncertainty in climate projections. This is due to the fact that the understanding of climate processes in the arctic is limited by the lack of observations, which are difficult to take. AWI strongly contributes to observations in the Arctic. In conclusion, the Arctic sea ice decrease affects atmospheric circulation and increases transport of warm, humid air into the central Arctic: this is responsible for a positive feedback that contributes to Arctic Amplification of global warming.

He then went on to focus upon Arctic region ozone changes. Interactions with the stratospheric ozone layer play a role in climate feedbacks in the region and need to be taken into account when modelling them. While ATLAS, the Lagrangian Chemical Transport Model, is a very sophisticated model for the calculation of the ozone in the atmosphere, the computational effort is much too large to be included in climate models.

Therefore, a much simpler model, SWIFT (Semiempirical Weighted Iterative Fit Technique), has been developed, that is much less demanding from the computational point of view, yet still yields results comparable to those from ATLAS.

2.2 Potsdam Institute for Climate Impact Research: Tales of the Gulf Stream, the Jet Stream and the Polar Vortex – Stefan Rahmstork

Stephan Rahmstorf, from the Potsdam Institute for Climate Impact Research (PIK), gave a presentation recent research by PIK focussing on the Gulf Stream, the Jet Stream and the Polar Vortex.

When looking at a global map for surface temperature, the only part of the world where the is no evidence of warming, is on the ocean in the area of the North Atlantic jet stream. An ocean simulation with GFDL CM 2.6 showed that the Atlantic overturning circulation has decreased leading to a weakened jet stream, with the ocean gulf stream being colder and the east coast of US becoming warmer.

He presented also the weather extremes from 2001-2010, where a surge of heat waves and precipitation extremes has been observed. This is probably due to the change in the stratospheric polar vortex, that has a big influence on the weather. He explained the mechanism of this change, which is very possibly related to the decrease of sea ice extent.

2.3 The German Research Centre for Geosciences: from solid earth to water vapour and sea level – Jens Wickert

Jens Wickert, from GFZ (German Research Centre for geosciences), described the research performed at GFZ, which focuses on the System Earth.

GFZ is involved in the Automatic GEOFON Global Seismic Monitor, in the Tsunami Early Warning System and in the study of the geodynamics of the Crust and the Mantle. Jens Wickert also presented the role of different satellites (GRACE, GOCE, CHAMP) in the study of the gravity field, sea level measurements, ocean topography and ocean currents. Finally he presented the work on satellites with the Global Navigation Satellite System (GNSS) radio occultation. GFZ is also contributing to GRUAN, in Lindenberg and Ny Alesund, with GNSS stations, GNSS data analysis, trend analysis and validation. He finally talked about the GNSS Reflectometry and concluded by saying the GNSS is a key tool for geosciences and for GRUAN.

3. REVIEW OF PROGRESS

3.1 Welcome, local logistics, outline of events and adoption of agenda

Marion Maturilli, as local host of the meeting, welcomed the participants and explained the logistics of the meeting. The agenda was adopted and can be found in Annex 2. The participants list is in Annex 3.

3.2 Remarks from GCOS including relevant AOPC outcomes – Caterina Tassone

Caterina Tassone, from GCOS, presented the activities of GCOS and AOPC during last year. GCOS is contributing to the UNFCCC's Paris agreement, in particular to the global stocktake. GCOS held a Regional Workshop in the Pacific Island States jointly with the WMO Integrated Global Observing System (WIGOS) in October 2017. The outcome of the workshop is a plan for the Pacific region observing network which will be presented at the next RA5 session. AOPC has established four task teams to address some of the GCOS Implementation Plan (GOS-200) actions. Of particular interest to GRUAN, are the task teams on reviewing the GCOS Upper-Air Network (GUAN) requirements and on the instigation of a GCOS Surface Reference Network (GSRN). Presentations on these two Task Teams were given in session 8.

3.3 Lead Centre progress report – Ruud Dirksen

Ruud Dirksen presented an update of the main activities of GRUAN for 2017-2018.The major task for the Lead Centre (LC) is managing the transition RS92/RS41, which among other things includes laboratory experiments (calibration, time lag, radiation) and dual soundings launches with RS41/RS92. The Atmospheric Radiation Measurement (ARM) proposal RIVAL (Radiosonde Inter-comparison & VALidation) was approved and the majority of RS92 sites have now switched to RS41. There has been outstanding work on GRUAN data flow, and the GRUAN Technical Document (TD) TD-5 is now published. More than 10 related papers were published, and the GRUAN data processor for the GNSS Water vapor is being developed in cooperation with GFZ.

This year Tateno was certified, becoming the 10th site to be certified. Since 2017, there is a new website. Parts of it are still under development and GRUAN members are asked to fill in the missing information in their expertise field.

The work plan for 2018-2019 includes:

- Complete the development of a new GRUAN data processor
- Develop GRUAN data product (GDP) for RS 41 (GDP RS41-v1)
- Develop new version of data product for RS92 (GDP RS91-v3)
- Complete the GRUAN radiosonde omnibus
- Prepare WMO-CIMO (Commission for Instruments and Methods of Observation) Radiosonde inter-comparison campaign
- Recertify sites (Lindenberg and Ny Alesund)
- Further coordinate RS92/RS41 transition within GRUAN
- Further develop the GRUAN website
- Operationalize processing of the Cryogenic Frost Point Hygrometer (CFH) data

It is considered high priority for the Lead Centre to complete the production of RS41 GDP (Action HP1 in annex 5).

Following the presentation, it was asked whether the CFH data are available at the Lead Centre. The data is currently available at the Lindenberg and access is granted after request.

Questions also included the impact of change of Standard Humidity Chamber (SHC), where tests show that there are no changes seen. Action C11 in annex 5 defines next step for the use of the SHC , and the plans for the future sites. As they are right now there are 26 active sites (10 of which are certified) and the initial goal for GRUAN was 30-40, there is the need to decide whether to continue to expand, taking into account that the geographical coverage is still not good and some of these 26 sites are not reporting. This item is further discussed in session 9.

3.4 Assessment of progress against action items arising from ICM-9 – Peter Thorne

Peter Thorne presented the actions from ICM9 (see annex 4).

On 25 agreed actions, 6 are completed, 16 are in progress and 3 have not been addressed yet. This reflects a profile of action status typical at ICMs in the past. Given that many actions are on volunteers it cannot be expected that all actions be finalised. Many of the actions are part of the agenda of the meeting and were therefore to be revisited at the end of the meeting together with the need for any the new actions.

4. DISCUSSION OF TOPICS RAISED BY TASK TEAM (TT) REPORTS

During session 4, topics raised by TT reports were discussed.

4.1 Radiosonde Task Team - Masatomo Fujiwara

Masatomo Fujiwara reported Radiosonde Task Team activities. Since 2017 Christoph von Rohden is a co-chair of the Radiosonde Task Team. For the task on multiple-payload launch configurations, the Technical Document manuscript is now under review. The task on radiosonde omnibus/generic (later renamed as Foundational Technical Document) is on-going. The task on auto-launchers had seen little progress (and was redefined during the meeting).

Following the presentation there was a discussion on the radiosondes manual, the Radiosonde Omnibus. The main question is for whom the omnibus is intended. This could be a reader that in 50 years wants to know how these measurements were done, in which case there should not be updates to the document but rather add-ons, or it could be a document for an actual or a future GRUAN user. It is also noted, that CIMO has already a report on radiosondes which is very complete and was published to members. In order to avoid duplicating this manual, there is a need to decide whether it should maybe include also the science related to the radiosondes, or if the CIMO manual should be combined with all the experience of GRUAN to produce a book. The participants involved in this topic, subsequently held a side meeting. It was decided to develop a first draft of GRUAN radiosonde foundational technical document to cover the general instrument-independent aspects (Action HP2 in Annex 5).

Other discussed topics were the auto-launchers vs. manual launchers. Little progress was reported by the radiosonde TT, however this is becoming an urgent matter as many stations are now changing to auto-launchers. During a further side meeting, a work plan on how to proceed with the evaluation of the impact of using auto-launchers was outlined. This should lead to a paper on the assessment of the advantage and disadvantages of manual vs. auto launches to be submitted and peer reviewed (Action HP3 Annex 5).

Finally the purpose of the GRUAN BUFR message was discussed. Even though there is not a specific need for Numerical Weather Prediction (NWP) to use the information on uncertainties, uncertainties should be kept together with observations as NWP is not the only client benefitting from an eventual GRUAN BUFR that includes uncertainties. Furthermore, the decision of including uncertainty in the BUFR was already taken at previous ICMs, where it was decided that if uncertainty are not transmitted, there will never be the understanding of their importance. The radiosonde task team and the LC will keep a watching brief on the issue.

4.2 Sites Task Team – Dale Hurst

Dale Hurst reported no new site additions to task team membership since ICM-9, but there were three changes in site representation: for Payerne, Dominique Ruffieux replaced Giovanni Martucci; for ARM sites, Nicki Hickmon replaced Doug Sisterson; and for Dogolprudny, Nadia Krestyanikova replaced Sasha Kats. Site reports revealed four new points of interest: No data flow (to date) from La Reunion and concerns about the availability of stable funding for the Upper Troposphere and Lower Stratosphere (UTLS) water vapor soundings; site report for Tateno combined with Syowa and Minami-tori-shima shows no data flow (to date) from the latter two sites; Potenza site reports a planned increase in RS41 soundings and the start of UTLS water vapor soundings in 2019; new GRUAN site Tenerife submitted data for nearly 700 RS92 soundings in 2017 and has now switched over to RS41 sondes.

Dale Hurst presented also the actions from ICM9 under the Sites TT responsibility.

- There is a need to produce a technical note on guidance on site survey photos. The first step in the process will be to ask each site when and why they would want to take photos as each site has different characteristics than another. It is suggested that once the photos are available they can

also be submitted to the Observing Systems Capability Analysis and Review (OSCAR) Surface metadata database (Action C1 in Annex 5);
- Annually based reporting: Lead Centre to provide automated reports on annual performance no later than 20 January of each year (Action C5 Annex 5).

Tenerife was commended for having submitted 688 sounding (RS92) in 2017 on its first year as a candidate GRUAN station.

4.3 Measuring scheduling and Combination Task Team - Tom Gardiner and Fabio Madonna

The presentation highlighted two potential topics on which the Task Team on Measurement Scheduling and Combination might focus during 2018-2019:
- Use of T and RH decadal trends calculated from homogenized radiosonde time series provided through the Copernicus Climate Change Service (C3S) to study measurement sampling strategies. The data analysis must include also autocorrelation and uncertainties;
- Measurement redundancies and synergies. Combination of two time series will be studied simulating missing data in one of the two time series and keeping a subset of stations for validation purpose. The work will initially focus on Radiosonde-lidar for Water Vapor Mixing ratio WVMR profile and on Radiosonde GNSS for IWV. Simultaneous measurements provided by different technique could be investigated to create synergistic retrievals.

It is suggested that the group looks for engagement within the stratosphere community (e.g. Stratosphere-troposphere Processes And their Role in Climate - (SPARC)) and work to combine different datasets. Any homogenised product should be available for free access and use.

4.4 Ancillary measurements Task Team - Thierry Leblanc

The Task Team on Ancillary Measurements oversees the production and integration of ancillary measurements, namely ground-based Microwave Radiometer (MWR), Fourier Transform InfraRed (FTIR) , and lidar in compliance with GRUAN best measurement practices. It also coordinates the use of satellite data for GRUAN-related tasks. Co-chair Tony Reale has stepped down, and will be replaced by Lori Borg, from Univ. Wisconsin,for the satellite instrument validation work for the GRUAN Ancillary measurements TT. The rest of the Task Team remains unchanged.

Version 1 of the GRUAN Lidar Analysis Software Suite (GLASS) is now at a mature stage of development. The software is now capable of analysing large amounts of raw signals from 12 ozone, water vapour, aerosol, and temperature lidar instruments from 3 networks (GRUAN, Network for the Detection of Atmospheric Composition Change - NDACC, Tropospheric Ozone Lidar Network - TOLNet). A new version of the LidarRunClient was produced in the second half of 2017. This version needs to be finalized in 2018. Regarding other techniques, a first version of the microwave radiometer Best Measurement Practices and Guidelines document was released in early 2017 by Nico Cimini (Italian National Research Council's Institute of Methodologies for Environmental Analysis, CNR-IMAA).

4.5 Update on GRUAN GNSS Precipitable Water (PW) Task Team - June Wang and Kalev Rannat

The GNSS TT has worked on necessary steps to be in a position to qualify the GNSS-PW GDP starting after ICM-10. Remaining steps are finalisation and review of Technical Document and provision of a beta test data stream to Lead Centre.

The omnibus was finalized in February, 2018 and sent to the Working Group (WG) and LC for review on February 27, 2018. The GRUAN GNSS central processing center, GFZ, is operationally processing the GNSS data at six stations, Lindenberg (LDB0), Lauder (LDRZ), Ny Alesund (NYA2), Sodankyla (SODF), Table Mountain (TMS3) and Barrow (UTQI). Some additional GRUAN sites will be added to the operational GNSS processing soon. The experimental GNSS PW data (currently not certified) without the uncertainty estimate is made available at ftp.gfz-potsdam.de for GRUAN sites LDB0, LDB2, LDRZ, NYA2, SODF, TMS3. GFZ continues working on the routines for calculation of the precipitable water vapor (PWV) uncertainties based on Ning et al. (2016) on an operational basis. After that, it is planned to reprocess all GRUAN GNSS sites once again with the calculation of PWV uncertainties and application of 2nd order ionospheric effects. These new PWV products will be validated with radiosonde data again.
The GNSS PW TT asked all sites to update their site information, or to add their site if new, using a google document to which a link was provided.

Discussion following the presentation focused on uncertainties. Data from the GNSS are available but do not include uncertainties and the data stream will be reprocessed to include uncertainties. Both the systematic and the random components are going to be taken into account when uncertainties will be calculated. Since for climate studies homogeneity of the data record is essential, all uncertainties need to be recorded.

4.6 GRUAN Science coordinator - Tom Gardiner

The presentation focused on options for the generation and presentation of uncertainty information that goes beyond a simple 'total uncertainty' value. The product traceability and uncertainty scheme developed under GAIA-CLIM (Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring) was presented, together with proposed terminology for different classes of individual uncertainty contributions. The discussion then covered different methods for combining and presenting overall uncertainties, including covariance matrices and ensemble PDFs.

After this presentation it was agreed that GRUAN needs to produce a document on uncertainty terminology that should also include a review of heterogeneity in current approaches in certified and candidate streams (Action C7 in Annex 5).

Tom Gardiner also asked to be informed during the year about activities related to GRUAN science so that the activities can be coordinated across the GRUAN community.

5. ADVANCE IN THE DEVELOPMENT OF NEW GRUAN DATA PRODUCTS

5.1 Status of RS41 data processing – Ruud Dirksen

Ruud Dirksen gave an update on the RS41 data processor. The overall processing system is operational and the majority of the processing modules are technically functioning. Preliminary processing is possible. Ongoing work is the step-by-step evaluation of existing modules with respect to content and uncertainty estimates, laboratory tests, module definition for radiation correction for temperature and documentation for the processing steps.

The processing is a modular system, that consists of pre-processing, data import and mapping, processing and quality control, quality assessment and data export. Information about the progress on these modules can be found in the presentation. The module which requires most effort still is the radiation correction for temperature measurements.

There is still much work to be done, including defining the contents of GDP files and working on the product documentation. As of today, the time required to get certified data products is around 2 years of person effort. During the discussion following the presentation it was agreed that developing and documenting the RS41-GDP.1 is the top priority action for the LC as the use of RS92 launches is rapidly decreasing across the network leaving a hiatus in measurement availability (Action HP1 Annex5).

5.2 Meisei – Masami Iwabuchi

Masami Iwabuchi showed the results of Meisei (RS-11G and IMs-100) against RS92 as well as the comparison of CFH and MTR with RS-11G, IMS-100 and RS92-SGP. These results have been written up in technical document and there is going to be a paper lifted from the technical document with results of the intecomparisons. The Meisei data product should be ready for certification assessment within a couple of months and completed by next ICM. Certification should proceed when the paper draft is available for review (Action B2 Annex 5).

5.3 Modem – Gaëlle Clain

Gaëlle presented the Modem radiosondes and activities of Meteofrance. Three new faces have been introduced to the GRUAN community: Frédéric Marin (Météo France) is in charge of setting the GRUAN procedures at all candidate sites; Quentin Kriszac works with him. Jean Charles Dupont works with Martial Haeffelin at IPSL and is a new contact for all topics related to GRUAN.

The progress status for M10 GDP is updated. Three of the six criteria for qualification for a GRUAN Data product have been (partially) fulfilled: a measurement system is ready to be adopted at least one site (Trappes); IPSL is the central processing facility; the data stream will start to be run as beta release in September 2018 (raw data only). One year is necessary to produce a technical document and the associated paper.

The GRUAN preparation procedure (PP) is applied to operational automated RS since the beginning of this year. It consists of recording the RS temperature and RH for 5 minutes in the SHC and then in a ventilated shelter together with a reference sensor for T and RH (also recorded). In August, 100% of operational soundings at Trappes will be GRUAN. The GRUAN PP will start to be applied in la Réunion in 2019 and the first GRUAN launches will start in spring. Meteo France would like Faa'a (Tahiti) to be considered for GRUAN certification together with Trappes and Reunion. GRUAN PP and RS can start there at fall 2019.
The SIRTA performed some comparison campaigns. The last campaign (16 daytime M10 + RS92) was in January 2018, the next campaign will include 10 daytime and 5 night time RS (M0 + RS92 or RS41).
Some laboratory tests are required in order to investigate and document the current corrections robustly.
The GRUAN activities at Reunion were presented. An SHC has been purchased and will arrive in May, making the GRUAN PP possible for weekly NDACC/SHADOZ (Southern Hemisphere ADditional OZonesonde) M10/Ozone launch. 13 CFH + Lidar profiles are available (2014-2017). The ANR funded CONCIRTO campaign is planned between November 2018 and April 2019. A long term funding for CFH or other Water Vapor (WV) instruments is needed.

MeteoFrance has expressed their interest to have a new GRUAN station in Faa'a. Tahiti. The LC should follow up with the French sites over this potential site (Action C9 annex 5).

The Modem GDP should be ready for certification within one year and further update on the Modem product development will be presented at ICM-11. Special attention needs to be paid to completing documentation steps and laboratory results. The Lead Centre may host a visit to use their laboratory facilities to aid this (Action B5 Annex5).

5.4 Ozonesonde – Greg Bodeker

Greg Bodeker summarized progress with the development of a GRUAN ozonesonde data product. While the Ozonesonde Technical Document has been written, it was recognized that (1) the response to reviewers comments on the document still needs to be finalized, and (2) a more robust assessment of ozonesonde uncertainties, and the tracing of those uncertainties through to the final product, is still required. It was suggested that the NDACC "sonde group" be approached and requested to initiate a process to develop a more comprehensive and deeper assessment of ozonesonde uncertainties and the reporting of those uncertainties to data users. It was noted that the development of a deeper understanding of the uncertainty budget for ozonesondes should not impede the finalization and formal publication of the GRUAN Ozonesonde Technical Document.

The launch client for collecting ozonesonde data is available and the GRUAN Lead Centre has been identified as the GRUAN centralized data processing facility for the ozonesonde data product.

The next steps required are:

- The Lead Centre needs to generate a preliminary ozonesonde data stream ready for Working Group review. The data stream needs to be reviewed for appropriateness which requires some guidance from the task team on scheduling on appropriate ozonesonde scheduling for different regions;
- Selected sites need to be certified for their adherence to the processes outlined in the Ozonesonde Technical Document. This needs to be done in consultation with task team on Sites;
- Data then needs to flow from those sites to the Lead Centre and then made available to users through NOAA's National Centres for Environmental Information (NCEI).

After the NDACC meeting , Greg should write to the NDACC co-chairs and to the ozonesonde WG co-chairs to ensure the connection about uncertainty budget.
Needed steps to instigate an Ozonesonde product are captured in Action B4 in Annex5.

5.5 GNSS – Galina Dick

In this presentation an overview of the recent activities related to the development of the new GRUAN product GNSS Precipitable Water vapour at GFZ was given. The main directions of these activities are:

- Development of the new Operational Data Center (ODC) at GFZ including the data monitoring tool;
- Establishing an automated hourly GNSS raw data flow and near real-time PW analysis;
- Establishing a data flow to LC in Lindenberg;
- PW uncertainty estimation using the Ning et al. 2016 (doi:10.5194/amt-9-79-2016) algorithm and validation with RS.

The following GRUAN GNSS stations have been included into the automated PW processing chain: Lindenberg, Ny-Alesund, Boulder ('Table Mountain'), Sodankyla, Lauder and Barrow.
The following main points of future work have been presented:

- Interactions with sites on assistance for new instruments, initiation of the data flow and data processing: GFZ continues to support all GRUAN sites;

- The following GRUAN sites with GNSS have been contacted by GFZ and will be included into the automated PW processing chain soon: Cabauw, Payerne, Potenza, Dolgoprudny, Singapore and Tateno;
- Implementation of an uncertainty estimate: GFZ will continue this work; uncertainty estimation after Ning et al. 2016 will be added to the automated PW processing chain and a reprocessing with the new PW uncertainty estimation will be done;
- The PW time series homogenisation and trend analysis will be continued;
- A validation with RS and other collocated meteorological (WVR) and geodetic instruments (VLBI) will be performed.

Certification of the GNSS PW data product should be completed within this year assuming that the technical document is going to be ready. Necessary steps for GNSS-PW GDP data flow and certification are summarized as part of Action B3 in Annex 5.

5.6 MWR – Nico Cimini

The presentation summarized the developments towards a GRUAN Microwave Radiometer (MWR) product achieved in the last two years. The developments address the main gaps affecting current MWR products as identified in the GAIA-CLIM project: (1) Missing MW standards maintained by Metrological Institutes; (2) Missing uncertainty associated with MW absorption models used in MWR retrievals; (3) Missing agreement on calibration best practices and instrument error characterization and lack of unified tools for automated MWR data quality control and retrievals.

(1) Missing MW standards maintained by Metrological Institute: The status of progress in MW radiometry metrology, including the development of MW standard targets at the US National Institute of Standard and Technology (NIST) was highlighted. Due to this development transfer standards for certifying commercial MWR calibration targets will become available in the next few years.

(2) Missing uncertainty associated with MW absorption models used in MWR retrievals: Recent findings were reported concerning the analysis of MW absorption model uncertainty performed in the framework of GAIA-CLIM. An overview paper has been submitted (Cimini et al., Uncertainty of atmospheric absorption model in the 20-60 GHz range: impact on ground-based microwave radiometer simulations and retrievals, submitted to Atm. Chem. Phys., 2018).

(3) Missing agreement on calibration best practices and instrument error characterization and lack of unified tools for automated MWR data quality control and retrievals: Achievements in the framework of GAIA-CLIM and EU Action TOPROF have been reviewed, including the establishment of a prototype network of six MWR in Europe for which a one-year dataset has been processed homogeneously with an Optimal Estimation Method (OEM).

During the discussion it was noted that cloud liquid water is the real advantage of the MWR with respect to other GRUAN instrumentation, and that more the work should concentrate on that. The capability of measuring the complete diurnal cycle is also an asset to complement the temporal resolution of temperature and humidity profiles from radiosondes (2 to 4 radiosonde per day).

5.7 Lidar – Thierry Leblanc

Version 1 of the GLASS (GRUAN Lidar Analysis Software Suite) software has reached a mature stage and can analyse raw signals from 12 ozone, water vapor, aerosol, and temperature lidar instruments belonging to 3 networks, namely GRUAN (Payerne, Ny-Ålesund, Cabauw), NDACC (Lauder, Eureka, Mauna Loa, 3 x Table JPL-Mountain), and TOLNet (NASA Langley, NASA Goddard, and Environment Canada). The full metadata ingestion framework required for long-term, mass-processing is now in place. More than 120 input parameters are ingested, with the option, for each parameter, to be either read in a default metadata file, or overridden using optional keywords during runtime (in the software language IDL). All parameters are instrument-dependent and time-dependent, making the analysis and re-analysis quick and versatile. Considering the busy agenda of the current investigators involved in the development of the GRUAN Lidar Data Stream, it is highly desirable that the Lead Centre, or another organization, considers the hiring of a part-time person to work specifically on data processing by the GLASS, and on the finalization of the LidarRunClient.

For the GRUAN Lidar Data Product validation the GRUAN WG and the community need to provide feedback. The *GRUAN Science coordinator* team offered to step in. Fabio Madonna, Xavier Calbet and Tom Gardiner will lead/coordinate efforts with Thierry Leblanc.
Action B7 in Annex 5 contains required step to be in the position of certifying one or more initial lidar data stream by ICM11.

5.8 Discussion of GRUAN Data product development

At the end of session 5, it was decided that a table specifying the status of the different data products against the data stream requirements should be produced and used to monitor progress (Action B1 in Annex 5). This table should include all of the above and the general frostpoint hygrometers GDP. Action B8 provides the Frost Point Hygrometer roadmap.

There was a discussion about how to present uncertainty, as every group is doing that in a different way. It has already been decided to produce a GRUAN technical document to define how to specify uncertainty so that it will be homogenously represented within GRUAN (Action C7 in Annex 5). However, the suggestion is for the groups to continue their work and deal with uncertainty as they did so far and produce a version 1 of the data product document. This will avoid a delay of 2 years on the data products.

As GRUAN is not only for radiosondes, developing data products from other system like the MWR, the Lidars and others is extremely important and should be considered a priority.

It was also noted that data streams for surface meteorological parameters, such as surface pressure and temperature, are very important, and so far there is no systematic approach to this. The answer could come from the implementation of the GCOS Surface Reference Network (GSRN). However, this is at best still a couple of years away.

6. UPDATE ON RS92-RS41 TRANSITION

6.1 Overview of the RS92-RS41 transition scientific dataset – Michael Sommer

The overview of RS92-RS41 comparison dataset focussed on introducing and presenting the existing data set of dual launches performed at GRUAN sites and other related sites and campaigns. The different launch setups and ground system configurations were discussed. A statistical overview of the full data set was presented including a brief description of data products and formats. Furthermore a discussion about systematic effects in conjunction with different environmental conditions was initiated. A first statistical analysis using the combination solar elevation angle vs. altitude was presented.

The data set is complex with more than 800 comparison launches. Ancillary data are still missing and the question is whether this is a sufficient dataset. Given the analysis presented, it was noted that it is preferable to get more comparison flights at low solar elevation angles (see Action A5 annex 5).

6.2 Comparison of dual soundings in the RS92/RS41– Alessandro Fasso

Alessandro Fasso presented the following:

OBJECTIVES
Some facts about RS41-RS92 difference understanding have been discussed, based on GRUAN dual soundings (DS) dataset. These include:
1. Use of GDP measurement uncertainty;
2. Role of vertical correlation;
3. Bias assessment using heteroskedastic local polynomial least squares;
4. Bias adjustment and harmonisation.

In particular, the role of solar elevation angle (SEA) has been considered as well as nighttime data.

DATA
Data analysis considered temperature and relative humidity of GRUAN sites and a comparison of Vaisala RS92 GRUAN data processor product (GDP.2) with Vaisala RS41 (EDT.1).

Site	Num of colocations	
	24 h	Nighttime
LAU	49	
LIN	186	77
NYA	114	17
PAY	110	49
REU	18	9
SGP	16	6
TMF	17	17
	510	175

METHODS
From the methodological point of view, it is worth to remark that full information available in GDP has been deployed. In fact for both T and q, the DS bias, which is the long-term DS difference = RS41-RS92, has been modelled as a smooth function of SEA and altitude
DS bias = f(SEA,altitude).
Moreover, since uncertainties available in GDP show a marked variation, weighted averages and a heteroskedastic local polynomial least squares model have been used.

RESULTS
Temperature
As expected, total co-location uncertainty is lower nighttime (solar radiation effect) and higher in the upper atmosphere (solar radiation).
Considering bias, RS41 seems to be warmer in the lower atmosphere (further research needed) and cooler in the upper atmosphere (solar radiation effect).
Moreover, there is some evidence of an attenuated effect in the tropics (REU), but data are limited for a strong conclusion. Also, seasonal effect is quite limited nighttime.
Harmonization (bias reduction) is possible in-situ, provided a representative network of DS is available.

Humidity
As expected total co-location uncertainty is lower in upper atmosphere and a quite limited solar radiation effect has been found.
Considering bias, RS41 is wetter in lower atmosphere daytime with limited difference nighttime.
Further study is required for a deeper understanding of the warmer behaviour of RS41 in the lower atmosphere.

In the discussion that followed the presentation, it was pointed out that the analysis needs to take into account the difference of the data from radiosondes according to the rigging as this will impact results. Furthermore, ancillary measurements need to be introduced in order to have a truth value to compare with. Part of this is reflected in Action A6 in Annex 5.

Alessandro Fasso asked for help to extract this information from the data using the metadata.

6.3 Analysis of casing changes: Styrofoam vs. plastic casing of the RS41 – Daniel Brewer

The U.S. National Weather Service performed an analysis of the Vaisala RS41 case change from a plastic covering to a Styrofoam covering (RS41 Soft and Light). The analysis used approximately 70 Soft and Light radiosondes to examine the precision of instrument, the adaptability with the Autosonde, and the quality/durability of the new casing, especially when considering water intrusion. The precision of the Soft and Light was as good as or better than the RS41 plastic casing precision for temperature, pressure, relative humidity, and wind calculations. Thirty Soft and Light radiosondes were flown out of the autosonde with consistent performance to the RS41 plastic cover. Among the nine radiosondes tested in a temperature-controlled chamber with a spray hose, overall each radiosonde passed the test, but the extreme and experimental nature of the test caused some of the RH measurements to report missing data. Future testing may include dual launches of RS41 plastic vs. Styrofoam (if supplies are sufficient) and further evolving the spray test to decrease duration and increase spray rate.

As the plastic casing will no longer be produced, it might be advisable to have some dual launches undertaken at a number of GRUAN sites (see Action A7 in Annex 5).

6.4 Update on Radiation measurements - Christoph von Rohden

The solar radiation induced warming of temperature sensors has been recognized as the major systematic bias for temperature measurements with radiosondes during daytime, in particular at altitudes above the tropopause. Laboratory experiments are essential to quantify this effect as a basis to create a GRUAN-conforming, i.e. manufacturer- independent procedure to correct measured temperature data, and also estimating the uncertainty of that correction.

At Lindenberg Observatory, measurements of the response of radiosondes temperature sensors to solar radiation have been carried out for several years. An evacuable and ventilated chamber designed to mimic the conditions during radiosonde ascents has been used for the experiments (pressure range 3 hPa to ambient, ventilation 0 $m \cdot s^{-1}$ to 7 $m \cdot s^{-1}$, sun as radiation source). Correction expressions have been derived from the experimental results. Recent experimental tests in this chamber and a thorough review of the existing results revealed a number of shortcomings and limitations of the setup as well as of the existing approach for a correction. This results in a clear overestimation of the correction for the Vaisala RS92 radiosonde. Because the measurements, data analysis and the resulting derivation of the corrections are done the same way for all radiosonde models, this casts doubt on the corrections that were derived for other radiosonde models, even in the case when these corrections appear realistic because they don't deviate much from the correction derived by others (as is the case for e.g. the RS41). Beside some technical aspects, a key limitation of the setup is that the temperature response can only be determined under steady state conditions (thermal equilibrium), whereas in flight non-equilibrium, dynamic conditions, prevail. For example, the persistent rotating and moving around of the sonde causes continuous variation of the incident angle of the solar radiation. Another limitation of the current set up is the direction of air flow relative to the sensor boom, which is rather poorly defined and does not represent the conditions during ascent.

For these reasons, a completely new experimental setup has been built. It consists of a quartz glass cylinder acting as test volume as part of an evacuable ring-shaped tube system similar to a wind tunnel. The entire sonde will be installed inside the quartz cylinder and will be irradiated from outside, either by the sun or by an artificial light source. It will be possible to rotate the sonde around its axis, allowing for varying the angle of incidence of the irradiation. Air flow (ventilation) and pressure can be controlled as well. The new set up was on display during the site visit to Lindenberg.

With this setup a more realistic simulation of ascent conditions as well as better independent testing of the sensitivity to individual parameters is expected. First measurements to characterize the flow field using Laser Doppler Anemometry (LDA) took place, indicating smooth and reproducible velocity profiles along the cylinder diameter with flow speeds reaching similar values to typical ascent speeds of soundings (~5 $m \cdot s^{-1}$). Measurements of the radiative effect are planned to begin in Spring/Summer 2018, starting with the Vaisala RS41.

A good solar radiation error correction is required for the GRUAN data product. Since many sites are switching to the RS41, the development of a GRUAN data product for the RS41 has high priority and so has the development of the radiation error correction algorithm for the RS41 (Action C8 in Annex 5).

6.5 RS92 and RS41 radiosonde windtunnel experiments - Marco Rosoldi and Graziano Coppa

In a joint campaign between Italian National Research Council's Institute of Methodologies for Environmental Analysis (CNR-IMAA) and National Institute for Metrological Research (INRiM), a series of experiments has been planned and carried out at INRiM in order to intercompare performances of Vaisala's RS92 and RS41 in laboratory controlled conditions.

The campaign consisted of three different experiments, to test the behaviour of the sondes in different controlled temperature, pressure, humidity and wind speed conditions. All experiments were performed with the aid of a set of reference thermometers and hygrometers, calibrated at INRiM and traceable to SI national standards.

The first experiment involved testing both sondes in a climatic chamber at different combinations of humidity (5 points between 20% and 98%) and temperature (9 points between -40 °C and 40 °C).
The second experiment was aimed at the evaluation of the time constant of the sondes' temperature sensors during steep temperature transients. In order to achieve this, the sondes were quickly moved from one climatic chamber set at high temperature to another set at low temperature (and vice versa). Repeated transitions were measured between -40 °C and 20 °C, between -30 °C and 30 °C, and between 0 °C and 20 °C.

The third experiment involved the test of both sondes at different wind speeds and pressures. The experiment was conducted using INRiM's climatic chamber/wind tunnel EDDIE (Earth Direct Dynamics Investigation Experiment), designed and built during Euramet's project MeteoMet. The sondes were tested at 5 different temperature points (between 30 °C and -20 °C), 4 different wind speeds (between 2 m/s and 15 m/s) and 4 different atmospheric pressures (between ambient and 350 hPa).

A very preliminary analysis revealed that RS41 is much more stable than RS92, both in temperature and humidity, in basically all environments. RS92 showed important problems both in temperature and humidity measurements due to the dual U sensors switching on and off alternately.

Temperature transitions are detected very fast by both sondes, with no discernible difference between the two sondes: however, both sondes show a performance degradation after such transitions, which will be investigated further.

Last, both sondes show a good behaviour in measuring the correct temperature at low pressures, though both become noisier.

All these are very preliminary results of very recent measurement: in the following months a full metrological analysis will be performed in order to assess a complete uncertainty budget and a complete characterization of both sondes at different environmental conditions.

6.6 Report on CoreTemp 2017 – Yong-Gyoo Kim

A new radiation correction technique using two thermistors having different emissivity was introduced and a new type of radiosonde, named Dual Thermistor Radiosonde (DTR), was employed for accurate measurements of upper-air temperature. The performance of DTR in terms of temperature measurements and followed by the correction of radiation effect was compared with conventional radiosondes including RS41, RS92, and DFM09 through a campaign named CoreTemp 2017 held in September at Lindenberg observatory in Germany. Raw temperature measured by RS41, RS92, and DFM09 shows a collective behaviour at both daytime and night time. However, the raw temperature of two sensors of DTR is significantly higher than those of three other radiosondes at daytime. At night time, the raw temperature of black sensor of DTR is lower than those of the rest of other sensors, showing radiative cooling of the sensor due to high emissivity. Its current shortcomings were also discussed and future plans to improve were presented.

6.7 RIVAL Field Campaign at the ENA, NSA, & SGP ARM Sites – Lori Borg

The Radiosonde Inter-comparison & VALidation (RIVAL) field campaign began at the Southern Great Plains (SGP) ARM site with the first dual radiosonde launch coordinated with the NOAA20 overpass on 02/13/2018 1922UTC. This field campaign is a sustained 1-2 year effort, in collaboration with the JPSS Radiosonde Program and GRUAN, in which weekly dual radiosonde soundings (RS92 & RS41 on same balloon) will be performed at the Eastern North Atlantic (ENA), North Slope Alaska (NSA), and SGP ARM sites targeting NOAA20 overpasses. RIVAL launches will be used not only to assess RS92/RS41 differences, ensuring the continuity of both the ARM and JPSS radiosonde data sets, but also to assess use of ancillary datastreams in the development of site atmospheric state best estimates (SASBE). While RIVAL launches began at the SGP site, launches at ENA and NSA are expected to begin within 1-2 weeks.

Discussion following the presentation focussed on identifying the best steps to augment parallel sounding of RS92/RS41 with satellite co-locations and ancillary measurements, including how to provide ancillary and satellite data to the LC (See action A3 Annex 5).

The RIVAL Team was asked to participate in the presentations on update analysis of dual launch holdings (see Action A6 in Annex 5).

6.8 On the accuracy of Vaisala RS41 versus RS92 upper air observations: Implication for satellite data cal/val – Bomin Sun

Accuracy of Vaisala RS92 versus RS41 global conventional radiosonde soundings, focusing on stratospheric temperature, was assessed from January 2015 to June 2017 based on ~311,500 RS92 and ~65,800 RS41 profiles using two approaches. The first approach, to understand the relative difference of the two sondes,

analyzes OB-BG (observation minus background forecast) and OB-AN (observation minus analysis) differences using the NOAA Climate Forecast System Re-analysis (CFSR, both comparisons) and the European Centre for Medium-Range Weather Forecasts model (ECMWF, OB-AN comparison only). In addition, dual launches (RS92 and RS41 suspended from the same balloon) at 5 sites allow direct comparisons. The second approach, to attempt to quantify "absolute" accuracy, uses GPS radio occultation (GPSRO) dry temperature profiles from the University Corporation for Atmospheric Research Constellation Observing System for Meteorology, Ionosphere, and Climate (UCAR COSMIC) and EUMETSAT Radio Occultation Meteorology Satellite Application Facility (ROM SAF) GPSRO data as the "truth".
The accuracy comparison results of RS92 versus RS41 obtained from the two approaches are basically consistent to each other. These two sondes were found to be in good agreement with global average difference <0.1 - 0.2 K in the lower stratosphere from 51.5 hPa to 26.1 hPa based on global stations and the dual launches. Compared to RS92, RS41 appears to be less sensitive to changes in solar elevation angle. The impact of RS92 to RS41 transition is discussed in the validation of both NOAA and EUMETSAT satellite hyperspectral sounding products. Overall, RS41 makes the satellite products "look" better than RS92 when they are used as the reference in the satellite assessment.

In the general discussion after session 6, it was decided that as the change from RS41 to RS92 has a big impact, a paper describing the GRUAN management replacement strategy should be prepared and submitted (Action A1 in Annex 5).

7. SITES DAY

7.1 Update on GRUAN data flow – Michael Sommer

The annual update on GRUAN data flow showed the current status of uploaded and archived data in GRUAN. A short overview was given of changes and change management of the radiosonde data flow, particularly the network-wide transition from Vaisala RS92 to RS41. A focus was on the presentation of software projects which are in development at the Lead Centre. These projects are grouped in following four categories: GRUAN server, data submission tools, converting and data processing, monitoring and reporting. The second part of the presentation focussed on data flow statistics. That includes the frequency and type of radiosonde or other balloon-borne soundings (e. g. ozonesonde, frost-point hygrometer (FPH)) performed at all GRUAN sites. Finally a summary of GNSS-PW data flow was given.

There are approximately 75000 launches in the GRUAN file archive and at the moment 15 sites submit data to GRUAN on a regular basis. After the presentation the format of the GNSS data product was discussed. Currently, there are two data formats. A discussion with GFZ is planned to determine which of these formats will be used.

Following the summary by the Lead Centre, Peter Thorne presented a verbal summary of the most relevant points arising from the sites reports:

- A number of sites request letters of support. These, and any additional request from the sites, will be managed by the WG Chair, the TT Sites, the Lead Centre and GCOS Secretariat (see Action C6 in Annex 5);
- ARM sites had queries concerning their status. It was clarified that only two kind of status exist, namely candidate and certified, and that presently all ARM sites are candidates although SGP is in the process of certification presently and remaining sites would be encouraged to apply thereafter;

- Cabauw had raised a concern about the confidentiality agreement(s) to share the raw data. The Lead Centre clarified that at the moment the raw data at the LC are not released, they are only stored in the archive. The same shall be applied to the to-be-instigated backup by CNR-IMAA;
- Lindenberg summary showed a pronounced drift in the ground check of pressure for the RS41 sondes that perhaps pointed to a drift in the ground-check equipment. Lindenberg clarified that they had investigated this and found no such drift. It was agreed that this needs further investigation/clarification;
- The Ny Alesund audit for recertification is to start soon once Lindenberg is completed. Possible effects of change in CFH/O3sonde configuration are mentioned. It was queried whether this may arise a change in the measurement characteristics. The site felt this unlikely;
- Ny Alesund had also noted that more scientific recognition is needed (20million $ of data in the archive). GRUAN members need to take every opportunity to promote GRUAN;
- Payerne confirmed that a GRUAN SRS product is now effectively dead. RS41 is now the operational sonde model and shall be transmitted to the Lead Centre;
- Payerne agreed to a request to send the 4 way comparison data (two SRS models along with RS92 and RS41 to the LC to enable analysis,
- Australian sites – there is a need to chase Australian sites, in particular Davis and Macquare Island to start submitting data ahead of the YOPP intensive launches;
- Potenza - The site description needs to be corrected on the website (elevation not correct). All other sites are also asked to look on the web and check if the metadata is correct. Potenza still does not have a WMO identifier in OSCAR (included in Action C1 in Annex 5);
- Sodankya –had a number of questions arising: Does the 92/41 database include extra instruments such as CFH launches? Is there an issue transmitting manual RS41 data? Why did the autosonde launcher heights attained degrade? For the latter question a reduction in balloon weight was noted which has been driven by economic concerns;
- Singapore was not present. But it was not clear what was meant with the request to discuss dual-layer balloon launches. The task team sites chairs agreed to follow-up with the site representative and revert;
- Tenerife – There is a marked desiccant-problem in GC25 that needs to be resolved. Tenerife is encouraged to apply for certification. The issue here is that they use auto-launchers, which might prevent the certification. This goes back to the high priority action on writing a paper on auto-launchers (Action HP3 in Annex 5).

Finally, to close the session, Tateno has been certified this past year. Ruud Dirksen delivered a certificate to Masami Iwabuchi.

The WG-GRUAN and the LC will ensure that certification and auditing will take place according to the agreed timetables (Action A4 in Annex 5) .

7.2 GRUAN Mid-Atlantic Consortium (GMAC): Updates from Beltsville site – Belay Demoz

A status update of the Beltsville Certified GRUAN site, future possible expansion of new instrumentation, science achievements, coordination with NOAA National Weather Service, and its activities coordinating the GRUAN Mid-Atlantic Consortium were reported. The report showed a much improved balloon burst altitude and satellite overpass coordinated GRUAN data launch statistics. It reported that the site was launching in the order of 70 sondes per year for the last 8 years. Most of these sonde launches are dual launches of RS92-RS41 for change management. These dual launches will continue through 2018. They also reported a coordinated simultaneous RS41 launch of sondes to study the problem of co-location and site representatives of GRUAN measurements in coordination with NOAA National Weather Service (NWS). A dual CFH launch was reported for the first time as well as satellite-sonde comparison data in collaboration with NOAA Centre for Satellite Applications and Research (STAR) scientists. The site has expanded to include the former NASA water-vapor and temperature lidar, NASA Ozone lidar, Pandora network, and a MicroPulse lidar capability.

Conclusion remarks included:

- Beltsville GRUAN site is improving and building relationships and networks;
- Focus on education and training continue. There are now two of our students employed by NWS;
- The GRUAN Mid-Atlantic Consortium is working well.

Questions to GRUAN community:

- Would time of day a measurement is scheduled matter for GRUAN?
- GRUAN O3 reprocessing is needed?
- Will we know when we have enough RS92-RS41 pair launches?
- GRUAN – What value after 10 years? Highlight achievements.

7.3 GMAC: Updates from NWS-Sterling Field Support Center - Daniel Brewer.

The NWS Sterling Field Support Center (SFSC) reported the status on the U.S. operational radiosonde network, GMAC coordination, solar simulation test, and update to WMO RIC application. The U.S. operational network continues to make preparations for a full transition to the 403 MHz radiosonde system. In Alaska, two out of thirteen stations have transitioned to the Autosonde. The rest of the stations will be transitioning over the next few years. To monitor the meteorological impact of the Alaska transition, National Environmental Satellite, Data, and Information Service (NESDIS) STAR provides an analysis of the transition. Such analyses based on historical collocations of radiosondes, forecasts and satellite profiles stored in NOAA satellite Products Validation System (NPROVS) provides NWS with a (cost) effective alternative to project and monitor radiosonde transition impacts. To further the lab's testing capability and in collaboration with the Lead Centre, SFSC has purchased a solar simulator to integrate with an altitude chamber capable of controlling pressure and temperature. Also, SFSC's application for being recognized as a WMO Regional Instrument Center (Region IV) is anticipated to be delivered this year to WMO.

7.4 ARM: update and changes – Nicki Hickmon

Atmospheric Radiation Measurement (ARM) Climate Research Facility update on GRUAN related activities. The ARM Field Campaign RIVAL is covered in Session 6 by Lori Borg. This update includes general ARM information, ways for GRUAN and ARM to work together, updates on ARM site RS41 upgrade dates, updates on CFH launches.
There is no paper or scientific justification on ground check. However, ground checking is insufficient. This elevated the need for a paper denoting clearly the scientific benefits of using the SHC (Action C11 in Annex 5).

7.5 Update of Tateno, Minamitorishima and Syowa – Masami Iwabuchi

Masami Iwabuchi showed the update of the Japan Meteorological Agency (JMA)'s site.
Tateno has switched from RS-11G to iMS-100 and started SHC for iMS-100 on the 13th of September.
Minamitorihima has switched from RS-11G to iMS-100 on the 3rd of September 2017 and started SHC for iMS-100 on the 1st of January 2018.
Syowa has switched from RS-06G to RS-11G and started SHC for iMS-100 on the 20th of March 2018.
JMA updated a sounding central system for 16 observatories and is preparing for high resolution BUFR.
JMA asked for the requirements for the GRUAN site and for the amount of users of the GRUAN data.

7.6 MeteoSwiss Radiosonde current activities and future plans – Christian Felix

Over the last two years, there have been several important changes at the Aerological Station in Payerne: Because of federal cost cut programs and internal priorization of tasks, there we lost two technical and one scientific positions, while at the same time other tasks increased. In order to keep the quality of the data, the innovation potential and the international commitments, the board of directors of MeteoSwiss have decided to automate radiosoundings during the night and week-ends while keeping human operated flights during working hours. We are operating since April 2018 an Autosonde and the RS41 radiosonde. Our revised targets are in line with this new situation:

- Continue to perform weekly comparison flights (results of 2017 comparison flights in 2017 are shown).
- Continue to provide support for remote sensing activities.
- Support our colleagues of ETHZ in the qualification of their new reference Peltier Cooled Frost point Hygrometer (PCFH) radiosonde for GRUAN (presentation 7.9).

- Contribute to the validation of automatic soundings for GRUAN.

7.7 Observations at Sodankyla – Rigel Kivi

Rigel Kivi (Finnish Meteorological Institute, FMI) presented first an overview of the observations at the FMI Sodankylä station. Meteorological data at Sodankylä is continuous since year 1908, the radiosonde measurements started in 1949 and are uninterrupted since then. FMI Sodankylä contributes to various networks, for example ICOS, GAW, NDACC, TCCON, AERONET, SAOZ, etc. Secondly, recent results of GRUAN comparison flights were presented. The instrument comparisons have included CFH (the reference sonde for water vapor), RS41 and RS92. It was found that according to the rig flights at Sodankylä temperature differences (RS92-RS41) were smaller than 0.12 K on average. RH differences ((RS92 or RS41) - CFH) were smaller than 1.5 % RH. Finally, campaign activities at Sodankylä were presented. FMI has contributed to YOPP, JOSIE, Match, FRM4GHG Projects during 2017-2018. There is an upcoming CoMet aircraft campaign in May-June 2018, which involves TCCON and AirCore measurements in Sodankylä. Other upcoming campaigns include RINGO campaign in June 2018, drone flights during June-August and further FRM4GHG campaign activities. FMI will also continue CFH, RS41 and RS92 comparison flights within GRUAN. Other activities include TCCON, ozonesonde study and research related to GNSS water vapor.

7.8 Observations at Xilinhot GRUAN site: work in progress and plan – Rongkang Yang

The Meteorological Observation Center (MOC) of China Meteorological Administration (CMA) has begun the process of developing the XilinHot GRUAN site.. A XilinHot GRUAN site development Plan(2018-2022) has been presented to CMA, and a total 4.5 million US dollars have already been invested in 2018
This covered the following:

- RS41 Observation: Fifty RS41 will be purchased by the end of June and will be launched once a week starting at the end of September;
- Chinese GNSS radiosonde observation: the decision of which of the 4 GNSS type radiosonde to use at Xilinhot site will be made by running a comparison experiment. After that, weekly launches will be performed;
- MWR/wind profile lidar/ Ka band Radar and etc.: purchase and installation (1.5 million US dollar);
- Xilinhot basic ability upgraded: electric power, instrument maintenance, communication, data process and etc.).

Rongkang Yang asked guidance from LC about the choice of one GNSS radiosonde for the GRUAN site.
He also is noticed that data sharing, technical cooperation and operational expenses would possible need an international framework for CMA.

UTLS Water Vapor Measurements

Given the upcoming likely phase-out of the cryogen used in both FPH and CFH instruments a number of talks were given on under development/operational alternatives. Peltier-based systems show promise but the efficacy of cooling becomes limited at very high altitudes under solar insolation which is a potential limitation. The Fluorescence Lyman-Alfa Stratospheric Hygrometer for Balloon (FLASH-B) sensor can measure all the way up but only in nighttime conditions. Further development and understanding of these alternative techniques is strongly encouraged.

7.9 Development of the Peltier CFH – Teresa Jorge

There is a new development of a Peltier Cooled Frost point Hygrometer (PCFH) at ETH Zürich. The instrument is developed as a GRUAN-worthy instrument with temperature measurement by a thermocouple which is traceable back to Swiss national standard measurements, and with transparency of implementation. Test flights to start in July 2018 with GRUAN LC and Meteoswiss in Payerne. Novelty of the controller with system identification and modelling. The fact that there are redundant measurements on the same rig was seen as a potentially useful innovation.

7.10 New Peltier-based chilled-mirror hygrometer "SKYDEW" - Takuji Sugidachi

A Peltier-based digitally-controlled chilled-mirror hygrometer, named "SKYDEW", has been developed to measure atmospheric water vapor accurately. The developed instrument is environmentally-friendly and ease-to-handle in the field because this instrument does not use a cryogenic material to cool the mirror. Since 2011, we have conducted test flights more than 10 times at tropics and mid-latitude sites. The results show that the developed hygrometer can measure atmospheric water vapor up to 25km without cryogen material. Also, relative humidity (RH) values and water vapor mixing ratio values from the developed hygrometer were compared with those from an operational radiosonde RH sensors and satellite Aura Microwave Limb Sounder (MLS).

7.11 The FLASH-B instrument – Alexey Lykov

The FLASH-B is a well-established instrument capable of accurate water vapour measurements in the upper troposphere and stratosphere. The measurement principle of FLASH-B is based on fluorescence, which ensures a very fast response time and high capability for resolving fine structures in the vertical profile. The total uncertainty is estimated to be less than 10 %, which is ensured by direct calibration to a reference MBW frost-point hygrometer. Basic documentation has been provided to the GRUAN Lead Centre. FLASH-B performance and metrological characteristics have been validated in a large number of field intercomparisons (NOAA-CMDL, CFH, FPH, Pico-SDLA etc.). FLASH-B is a plug-and-play instrument allowing fast and easy flight preparation, interfaced with most of the existing radiosondes (Vaisala RS92, RS41, Meisei RS-11G, Meteolabor SRS34). The FLASH instrument has a different configurations for application onboard aircraft and UAV. More information is available on www.flash-b.ru.

7.12 Video uplink Ny Alesund and balloonsounding – Marion Maturilli

As a site visit to the host-related Arctic GRUAN site Ny-Alesund, Svalbard, was not feasible, a video-link to the station was offered instead. In the video connection to the station team, the steps of sonde preparation were followed, with the radiosonde in the standard humidity chamber as well as in the weather hut for ambient condition comparison. Finally, the participants watched the Ny-Alesund radiosonde launch at 11 UTC under perfect Arctic weather conditions.

7.13 Anomalously Strong and Rapid Drying of the Tropical Lower Stratosphere in 2016 - Dale Hurst (link to presentation)

Dale Hurst reported a 2 ppm (~50%) mean decrease in deseasonalized anomalies of tropical lower stratospheric water vapor (SWV) during 2016 that was caused by a 3 K decline in tropical mean coldpoint temperatures (CPTs). These decreases are the largest observed since the Aura Microwave Limb Sounder started measuring stratospheric water vapor in 2004. The decreases in SWV and CPT anomalies correlated with coincident 11-month changes in the phases of the QBO and ENSO cycles, from warm westerly shear and strong El Niño conditions in early 2016, to cold easterly shear and La Niña conditions in late 2016. SWV and CPT anomalies were highly non-uniform within the tropics; in early 2016 they were stronger positive in the Eastern Hemisphere and in late 2016 were stronger negative than in the Western Hemisphere. These large positive and negative anomalies led to the Eastern Hemisphere having the largest decreases in both SWV and CPT anomalies during 2016. The non-uniformity in 2016 decreases suggests a strong contribution from ENSO to the strong and rapid decreases in SWV and CPTs.

7.14 Update on IAGOS-H20 and plans for FPH/CFH tests of atmospheric simulation chamber – Herman Smit

Herman Smit presented an update on IAGOS-H20 and plans for FPH/CFH tests of atmospheric simulation chamber.

Science Applications

7.15 Development of a Cloud Particle Sensor (CPS) for radiosonde sounding - Masatomo Fujiwara

Masatomo Fujiwara discussed technical details and flight results of a newly developed Cloud Particle Sensor (CPS) for radiosonde sounding, which is a small-mass (~200 g) optical particle counter being capable of ice/liquid water distinction using polarization information (Fujiwara et al., AMT, 2016, https://doi.org/10.5194/amt-9-5911-2016).

7.16 Diagnostics of radiosonde vertical uncertainty covariance – Bruce Ingleby

Bruce Ingleby talked about diagnostics of radiosonde vertical uncertainty covariance from the ECMWF data assimilation system. For Vaisala radiosondes the vertical correlations were generally small except for upper level temperature correlations - partly due to solar radiation effects. The diagnostics also pointed to wind direction errors in some stations that use radar windfinding. Lower tropospheric GRUAN temperature uncertainties were about 0.14 K for SGP in 2016, compared to about 0.10 for LIN; this was due to larger differences in the temperature ground check at SGP. Bruce also showed preliminary results comparing RS41 descent data from German radiosondes (after balloon burst) with the ECMWF background. The results are encouraging and the descent winds show a better fit than the ascent winds. Further work looking at the pendulum motion and vertical filtering is necessary.

7.17 Multidisciplinary drifting Observatory for the study of Arctic Climate (MOSAIC) - Anja Sommerfeld

Anja Sommerfeld presented MOSAIC.
MOSAiC is the first year-around expedition through the Arctic to investigate the coupled Arctic climate system. The backbone of MOSAiC is the operation of the RV Polarstern, drifting with the sea ice across the polar cap from autumn 2019 to autumn 2020. In addition to the RV Polarstern as central observatory a distributed network will be established based on satellite stations in an area of up to 50 km distance to the ship.
During the MOSAiC expedition radiosondes will be launched four times a day. Before the launches the radiosondes will be calibrated with the Standard Humidity Chamber to fulfil the GRUAN criteria. In addition the RSLaunchClient will be used to store the raw data and meta data and the GRUAN Lead Centre will post-process the data after each launch. Despite the fact the MOSAiC cannot provide long-term observations, the radiosondes measurements during the MOSAiC expedition will help to close the lack of stations and data in the Arctic Ocean.

7.18 On the statistical significance of climatic trends estimated from GRUAN tropospheric time series – Fadwa Alshawaf

This talk presented the work carried out to estimate the climatic trends from GRUAN precipitable water vapor (PWV) and temperature time series. Before the trends are estimated, the quality of the time series as well as their homogeneity have to be evaluated. The radiosonde PWV data of Ny Alesund and Lindenberg are 24 years long (1993–2016) and show statistically significant positive PWV trends of 0.23 and 0.59

mm/decade, respectively. Although, the GPS data are not adequately long for estimating climatic trends, they can be used to predict the required data length (in years) to estimate statistically significant trends.

7.19 Combining Data from the Distributed GRUAN Site Lauder-Invercargill, New Zealand, to Provide a Site Atmospheric State Best Estimate of Temperature – Jordis Tradowsky

A Site Atmospheric State Best Estimate (SASBE) of the temperature profile above the GRUAN site at Lauder, New Zealand, has been developed and was presented here. Data from multiple sources are combined within the SASBE to generate a high temporal resolution data set that includes an estimate of the uncertainty on every value.

The SASBE has been developed to enhance the value of measurements made at the distributed GRUAN site at Lauder and Invercargill (about 180 km apart), and to demonstrate a methodology which can be adapted to other distributed sites. Within GRUAN, a distributed site consists of a cluster of instruments at different locations.

The temperature SASBE combines measurements from radiosondes and automatic weather stations at Lauder and Invercargill, and ERA5 reanalysis, which is used to calculate a diurnal temperature cycle to which the SASBE relaxes in the absence of any measurements. The uncertainty on the SASBE increases with increasing time separation from a measurement.

The SASBE provides hourly temperature profiles at 16 pressure levels between the surface and 10hPa for the years 1997-2012. Every temperature value has an associated uncertainty which is calculated by propagating the measurement uncertainties, the ERA5 ensemble standard deviations, and the ERA5 representativeness uncertainty through the retrieval chain. The SASBE has been long-term archived and is identified using the following digital object identifier (doi): doi:10.5281/zenodo.1195779.

The study demonstrates a method to combine data collected at distributed sites. The resulting best-estimate temperature data product for Lauder is expected to be valuable for satellite and model validation as measurements of atmospheric essential climate variables are sparse in the Southern Hemisphere. The SASBE could, for example, be used to constrain a radiative transfer model to provide top-of-the-atmosphere radiances with traceable uncertainty estimates.

A discussion paper describing the temperature SASBE for Lauder has been published in Earth System Science Data Discussions (doi:10.5194/essd-2018-20).

7.20 Ozone sondes: Report about the JOSIE 2017 – Shadoz campaign – Herman Smit

Herman Smit presented a report about the JOSIE 2017.

7.21 EUMETSAT satellite products and their validation by coincident radiosoundings – Thomas August

Thomas August presented the EUMETSAT satellite products and their validation by coincident radiosoundings.

On Thursday 25th of April, the site visit at the Lindenberg Observatory took place. After a welcome by Franz Berger, the Remote Sensing group (Ulrich Gorsdorf), the Boundary Layer group (Frank Beyrich) , the

Radiation group (Stefan Wacker) and the in-situ sounding group (Ruud Dirksen) presented their work. This was followed by a tour of the Lindenberg Observatory and by a visit to the Weathermuseum.
Franz Berger, head of Lindenberg Observatory, welcomed all participants and gave an overview of the history of the Observatory which was founded in 1905 by German Meteorologist Richard Aßmann with support of emperor Wilhelm II. In its early days, activities were focused on aerology, the study of the vertical structure of the atmosphere. Measurements were performed with tethered balloons and kites. In 1911 the world's first air traffic warning system was set up in Lindenberg. In 1919 the altitude record for a scientific kite was set at 9750m, an achievement which still stands today. Starting 1930 important contributions were made to the development of radiosondes, and from 1947 onward routine radiosoundings are performed 4 times daily.
After the re-unification of Germany and the merging of both weather services, Lindenberg began performing remote sensing activities in 1992. In 1994 the atmospheric boundary layer observations were initiated. In 2003 the Potsdam radiation observatory merged with Lindenberg. Since 2008 the GRUAN Lead Centreis hosted by Lindenberg Observatory, and as of 2011 Lindenberg is a WMO/CIMO testbed.
Lindenberg is one of DWD's two observatories; where observatory basically stands for research institute. Lindenberg is focussed on physical atmospheric processes, whereas the Hohenpeißenberg Observatory focusses on chemical atmospheric processes. Being part of DWD's Research & Development department, Lindenberg has 4 sections: remote sensing, atmospheric boundary layer, in-situ sounding and radiation processes In addition, Lindenberg observatory is a reference climate site and operates a 24 hours weather station. The tasks include:

1. operation / maintenance of various instruments
2. instrument calibration
3. quality assurance / quality control
4. updating & application of improved measuring techniques
5. data analysis and interpretation

Staff consists of 25 scientists, 6 engineers, 40 technicians.

The core activities include
Longterm Monitoring of atmospheric Processes (24/7)

• 24h-weather station and climate reference site
• contributions to WMO-Programmes (GCOS, WCRP)
• contributions to European Meteorological Infrastructure (ECMWF, Eumetsat, Eumetnet)
• continuous improvements of observation strategies incl. introduction of new instruments and of updated analysis techniques
• supporting activities for the DWD departments FE, TI, WV, and KU
• supervision of DWD networks and DWD research activities
• research activities (currently: process oriented research on cloud processes and ABL processes)

And the observatory's mission is
Reference-observation of atmospheric, physical processes

• Operational / Routine Monitoring Programme:

Long-term monitoring (24/7) of atmospheric state parameters and atmospheric processes incl. detailed QA/QC – both for weather and climate (scale dependence)

• Research and development:

continuous research on instrument technology, measurement techniques, and analysis techniques – together with universities and research institutes

In conclusion, Franz gave an overview of how Lindenberg's measurements contribute to numerous national and international programmes:

Longterm Monitoring of Physical Processes
GCOS: GRUAN, GUAN, GSN, BSRN WCRP: CEOP, GABLS, GVaP

Evaluation of Satellite Products
ESA: ADM-Aeolus, EarthCARE Eumetsat: MetOp IASI, CM-SAF, GERB

Reference Data for Research Activities
DWD: HErZ, extramural Research D, EU: nat./intern. Programmes

Assistance of WMO Programmes
WMO/CIMO Testbed & Lead Centre
WIGOS Pilot Project (GRUAN)

Evaluation of Model Parametrization
NWP: COSMO-EU/DE, ECMWF RCM: CLM, REMO

Reference Data for real-time data assimilation
DWD: COSMO/ICON ECMWF: IFS

Ulrich Görsdorf presented the remote sensing group. Remote sensing methods provide quasi-continuous monitoring of atmospheric variables which is used for NWP, process studies and weather service for aviation. The tasks of the remote sensing section in Lindenberg is to test and evaluate new remote sensing systems, improve existing measurement methods and procedures, and to provide data for NWP as well as for process studies and model evaluation. For this purpose a suite of remote sensing instruments is available, employing techniques like radar, lidar and radiometry.
The remote sensing group operates the DWD radar wind profiler network, which can retrieve the wind vector up to 16km altitude. Ulrich showed that the impact of wind profiler data on reduction of the forecast error is up to 5 times larger than for a radiosonde.
Another important task is the contribution to cloudnet, which involves measurements from the Ka-band cloud radar, ceilometer and MWR. Data products include back scatter coefficients, liquid water path, liquid and ice water content. The prize asset of the section is the in-house built raman lidar RAMSES. Apart from profiles of temperature and water vapor, RAMSES is also equipped with a water spectrometer which can distinguish between liquid and ice droplets. Furthermore, the fluorescence spectrometer module allows for the measurements of aerosol fluorescence.
In 2015 an intercomparison campaign for ceilometers, CeiLinEx2015, was organized. The results of the campaign show that there is no agreed quantitative definition of cloud base height among the various manufacturers of ceilometers, with differences as large as 70m. This finding is particularly relevant for automated observations in support of aviation. As a spin-off a project was initiated for a long-term evaluation of ceilometers using the 300m high TV-tower in Hamburg as a ruler for cloud base height.

Frank Beyrich presented the Atmospheric Boundary Layer section, that has the goal to serve and improve numerical weather prediction by accurate observations and characterisation of the state of the lowest part of the atmosphere. The atmospheric boundary layer is characterized by large variability (both temporally

and horizontally) and strong vertical gradients. Interaction with the land surface plays an important role, which involves processes and effects such as surface friction, energy exchange, and exchange of water.
In order to properly characterize these processes a wide range of parameters need to be measured, such as state parameters of the air and soil (e.g. temperature, humidity; wind and pressure for the air) and process parameters like precipitation and evaporation, momentum and energy fluxes (e.g. radiation and turbulence). In addition to this, vegetation parameters are also necessary.
The section operates two measurement sites, a boundary layer site which includes a 99m high mast and a forest site. A proper Quality Assurance and Quality Control of the Lindenberg data is essential, this aspect ranges from the selection of site and sensors to manual and automated data control and feedback by data users. The land surface around Lindenberg is heterogeneous due to the presence of lakes, forests and farmland, which complicates the determination of the averaged surface flux for an area. Several strategies to do so are employed, including scintillometry, averaging of local measurements, budget methods and aircraft measurements. Frank showed results from the LITFASS campaign, which was organized to address this issue.
The contribution to NWP involves operational diagnostics, which includes validation of model data with observations, on a hourly basis to check whether the diurnal variation is properly represented by the model, as well as for long-term (seasonal) effects. These data are submitted to the SRNWP data-pool.

Stefan Wacker, who is in charge of the section radiation processes at Lindenberg observatory, presented the main tasks of his section: the section radiation processes operates the Baseline Surface Radiation network (BSRN) station Lindenberg and the WMO Regional Association RA VI radiation center where broadband radiometers and spectroradiometers from the ultraviolet into the infrared are calibrated. In addition to broadband radiometry and spectroscopy, spectral radiometry has also a long tradition at Lindenberg: Sun photometer measurements were already initiated in 1986 and were later complemented by star-and most recently by moon photometer measurements to derive the aerosol optical depth also during nighttime.
Besides the radiation measurements at the ground, vertical radiation profiles in the atmospheric boundary layer and from the ground into the stratosphere are measured using tethered balloons and radiosondes, respectively. The specifically designed radiosonde ISOLDE (Irradiation SOunding LinDEnberg) allows the vertical profiles of incoming and outgoing short-wave and long-wave radiation to be measured separately and is launched once a month. Lindenberg is currently the only site worldwide where such profile measurements are conducted.
Further key activities include the observation of clouds using hemispherical and thermal cameras and the determination of the cloud radiative effect by combining broadband radiation data and models. The latter methods are highly valuable to observe and interpret the long-term changes in the radiative fluxes and clouds and thus climate. Finally, the group participates in research projects such as the project “Reduction in PV production due to Saharan dust events (PerduS)” which aims at improving the German PV production prediction of the numerical weather prediction model ICON-ART.”

Ruud Dirksen presented the activities and obligations of the in-situ Sounding section. Besides hosting the GRUAN lead centre, the section in-situ sounding is responsible for the operational radiosoundings at Lindenberg that are performed 4 times per day as well as for the operational synoptical weather observations. In addition, Lindenberg is a CIMO testbed and as such involved in the testing of commercially available operational radiosondes from other manufacturers than those used for the routine operations. As such, various of the radiosonde types that are employed at other GRUAN sites have been tested in Lindenberg as well.

Lindenberg has a long tradition in testing and characterising radiosondes, after also having contributed to the development of radiosondes in its early phase.
In relation to that, Ruud gave an overview of the various laboratory facilities that the in-situ sounding group has at its disposal. These include standard humidity chambers (SHC) for assessing calibration uncertainty at room temperature, a climate chamber to simulate conditions that represent those of the upper troposphere and lower stratosphere for testing sensor calibration under these conditions as well as to determine the time lag of the radiosonde's humidity sensor at low temperatures. Furthermore, a dedicated set-up to investigate the error induced by solar radiation on the temperature and humidity sensors. A new set-up was constructed to overcome limitations of the previous set-up, as discussed in more detail during Christoph's talk (6.4) This new set-up was on display during the subsequent tour of the Lindenberg premises.
Various radiosonde types that are employed within GRUAN have been tested in the facilities of the in-situ sounding group. Since the area around Lindenberg is mainly flat and rural, it is possible to recover research rigs after landing. Dedicated tracking and recovery equipment enable a success rate of 95%. This good record is beneficial in view of the value of the instruments on a research rig (e.g. CFH, COBALD, FLASH-B), especially considering the fact that sometimes unique and irreplaceable instruments are flown

8. USE OF GRUAN FOR SATELLITE VALIDATION

8.1 Review of principal project outcomes from GAIA-CLIM – Peter Thorne

Peter Thorne presented key project outcomes from GAIA-CLIM which was led by GRUAN participants. Further details on this project can be found at www.gaia-clim.eu. He highlighted efforts on measurement system maturity, metadata discoverability, measurement traceability, transfer to TOA radiances, and use in NWP satellite characterisation. Finally, the major recommendations arising were highlighted.

8.2 Initial demonstration of polar satellite microwave data climate monitoring using GRUAN data” by Bomin Sun

This is an action under the Global Space-based Inter calibration System (GSICS) . The main idea is to understand if the GRUAN dataset is good enough to assess the capability of polar orbiting satellite microwave observations in climate monitoring and climate trend detection. In this demonstration, GDP-2 dataset for Lindenberg for 2008 through 2017 is used to compare the satellite microwave Climate Data Record (CDR) dataset generated by NOAA Center for Satellite Applications and Research (STAR). It is found that these two datasets match very well for the middle and upper tropospheric temperatures on interannual and longer time scales. Their temporal consistency becomes bad for the lower stratosphere because the radiosonde data availability for the upper portion of the atmosphere changes over time. We plan to extend this type of study into other GRUAN sites, preferably at polar and tropic regions and to bring GPSR data into this inter-comparison.

8.3 Updates on the EUMETSAT Occultation Prediction Product and Introduction of a new reprocessed GRAS Data Set - Axel von Engeln

The presentation covered the three programmes EUMETSAT is involved in that host radio occultation instruments (EPS, EPS-SG, Jason-CS/Sentinel-6), the main focus was on Eumetsat Polar System (EPS) and here on two products that are delivered to users: (1) occultation predictions; (2) GNSS Receiver for Atmospheric Sounding (GRAS) reprocessed data set.

The occultation prediction product is currently provided by EUMETSAT for Metop-A and -B, and will include Metop-C when the instrument is in orbit (launch date currently September 2018). The product contains expected occultations over the next 14 days, as well as the sub-satellite points of the Metop satellites – this allows to plan / collocate e.g. ground based or radiosonde measurements with satellite overpasses. Several future improvements were mentioned: (1) the product currently runs as a best effort service and options for an operational setup at EUMETSAT are being investigated; (2) the occultation prediction quality (an indicator how likely the occultation is going to happen based on the instrument performance) currently does not include known Metop and GPS manoeuvres, it also does not separate between setting and rising events - rising events are generally more difficult to track; (3) further investigate instrument performance and also include more information on the actual occultation quality, this is e.g. impacted by the geometry of the GPS and Metop orbit planes, where certain GPS planes are providing occultations only at mid-latitudes.

The reprocessed GRAS data set covers all Metop-A and -B occultations up to end of 2016, in total more than 10 years of data. Several validations were shown, including against ECMWF ERA-Interim, against collocated COSMIC occultations, and also against a different GRAS processing stream, provided by UCAR, Boulder, US. The GRAS data set shows excellent, consistent performance from 2007 onwards, providing a constant number of occultations per day and also showing no instrument degradation. COSMIC data actually shows a strongly varying number of daily occultations and also shows instrument degradations over the investigated period.

Finally, the expected launch dates of EPS-SG (first satellite ~2021) and Jason-CS/Sentinel-6 (first satellite ~2020) were mentioned.

Within the discussion, it was highly recommended to also provide radio occultation predictions from other missions, as well as to publish the work on occultation predictions in a peer-reviewed journal.

A discussion followed on the need of better coordination between the satellite and the GRUAN communities. In order to justify extra-launches or changing the schedule, more feedback on the use of that observation by the satellite community is needed.

It could be beneficial to produce a list of collocations that will be distributed to the GRUAN sites. As of now, a mechanism already exists and an email is sent to the sites with information of overpass but this is limited to polar-orbiter and GNSS-RO ‘golden overpass’ instances. It would be sufficient to add to these emails polar orbiter overpasses information to enable sites to target these overpass (Action C3 in Annex 5).

9. SITE PERSPECTIVES

There was a general discussion on sites. As of an agreement between the GCOS Secretariat and the LC, the follow-up of potential new sites will now be undertaken by GCOS Secretariat.

Regarding the certification of GRUAN sites, it was discussed that the sites need an explanation on the benefits of the certification that can be taken to the higher management in order to justify the possible added costs involved in becoming a certified site.

Sites requested that more generally benefits needed to be made clear. Several participants pointed to the need to track usage better. Peter Thorne agreed to assign David Smyth a task of reviewing completeness of the publications listed on the GRUAN website and considering other options with interested sites prior to ICM-one (Action C12 in Annex 5).

10. GOVERNANCE ISSUES UPDATE ON STATUS OF WG-GRUAN – PETER THORNE

Peter Thorne gave an update on the status of WG-GRUAN document, noting that the revised WG ToR will get approved as soon as possible. At that time we will proceed to reconfirm membership including a new co-chair of the WG.

10.1 Update on the progress towards a GCOS Surface Reference Network – Peter Thorne

Peter Thorne presented the report of the 1st meeting of the GSRN Task Team. He summarized the key issues and the work plan.

The work of the Task Team builds on an initial whitepaper, Thorne et al. (doi:10.1002/joc.5458, 2018) that provides a firm underlying scientific foundation. During the 1st meeting the task team agreed on a list of benefits, requirements, design principles, diversity of areas observed and ECVs to be observed. The output of this meeting is summarized in GCOS 214. At the AOPC meeting it was agreed that many ECVs should be measured at the same site, though not necessary at all sites, and the sites should be chosen to be representative of the different climate zones. It is suggested to start from existing stations and then to expand the network.

One or more Lead Centres are necessary for the GSRN to be possible. Representativeness could be a problem when designing such a network and has to be carefully taken into account.

10.2 Report on progress of the Task Team on the future of GUAN – Tim Oakley

Tim Oakley presented the work of the GCOS Task Team on GUAN and its 1st meeting (Lindenberg, December 2017). He summarised the key outputs from the meeting and the proposed work-plan. The primary decision from the Task Team experts was that the GUAN should not continue in its current form and should be reworked along the recommendations from the GCOS Ispra meeting (GCOS-182, 2014). Of relevance to GRUAN is the evaluation of the benefits of GUAN, something which is often asked by countries who are either candidate or certified GRUAN stations. Also the planned enhancement of the GUAN as a baseline network within the tiered network process, should mean aligning the measurement quality and uncertainty closer to that of GRUAN.

At this time there was nothing for GRUAN to include as either an action or work-plan item, although it was raised that GRUAN need to be aware of their own brand; and thus differentiate between certified GRUAN products and stations; and those radiosonde stations (GUAN or the comprehensive network) providing a GRUAN type product.

In the discussion following this section, John Eyre noted that there are no GRUAN guidelines for dual launches, and consequently the sites are free to decide which of the sounding will be transmitted as the operational one on the GTS. John Eyre requested, on behalf of the Commission for Basic Systems (CBS), that the sites undertaking dual launches should transmit the operational radiosonde in NRT (Action C10 in Annex 5).

11. CLOSURE

11.1 Actions

Actions were discussed and agreed. The list of agreed actions can be found in Annex 5.

11.2 AOB

The GRUAN Chair, the GCOS Secretariat and the participants express their sincere gratitude to Marion Maturilli and the AWI colleagues for the great facilities, the Thursday dinner and the help throughout the week; to DWD for the great Lindenberg and weather museum tour, and to Graw, Meisei, Modem and Vaisala along with the Lead Centre for organising the GRUAN 10th year anniversary party.

Next meeting will take place in Singapore. Dates will be announced as soon as they will be confirmed.

ANNEX 1: Welcome address

Welcome address for the opening of the 10th International Meteorological Conference at the AWI 'GCOS Reference Upper-Air-Network' (GRUAN)

Dear Professor Thorne and Professor Rex,
dear Professor Rahmstorf (PIK) and Professor Wickert (GFZ),
dear Mr Becker and Mr Dirksen,
dear conference attendees,
dear employees of the Alfred Wegener Institute,
ladies and gentlemen!

I would like to give you all a warm welcome to Brandenburg and the state capital of Potsdam! We are delighted to be able to host the 10th International Meteorological Conference of the 'GCOS Reference Upper-Air-Network' (GRUAN) here!

We meet at a scientific location with a long history of tradition: in 1832, an optical telegraph station was constructed on Potsdam's Telegrafenberg. This represented the first step on a path of impressive development to become a research location, which is now respected around the world.

The 'Albert Einstein Science Park' is home to outstanding centres of research: besides the Alfred Wegener Institute, you will also find here the German Research Centre for Geosciences (GFZ), likewise part of the Helmholtz Association, the Potsdam Institute for Climate Impact Research (part of the Leibniz Association), and the Leibniz Institute for Astrophysics Potsdam. All four institutes operate at an excellent level – and I am sure that this congress will further promote the international networking that is essential for their work!

This is particularly important for issues concerning meteorology and climate, which form the focus of your discussions here: these are topics of global significance, which transcend national borders. They are challenges that call for global cooperation – not only in research, but also in the political sphere.

The Alfred Wegener Institute focuses particularly on the relationship between climate and environmental changes – as manifested in the world's periglacial regions dominated by permafrost. For reliable and dependable investigations in this field, model-based analyses are critical as part of major international projects.
As an example, I would like to mention the 'Multidisciplinary drifting Observatory for the Study of Arctic Climate' (MOSAiC) – a platform for the geohydrological survey of near-surface areas: in just over a year, a team directed by the Alfred Wegener Institute will embark on a (genuine) adventure on the research vessel Polarstern and examine the Arctic climate more extensively than ever before.
As part of this endeavour, the Polarstern will drift through the Arctic ice over the course of twelve months. But who can explain it better than yourself, Professor Rex, who is coordinating the major international research project from the Alfred Wegener Institute in Potsdam...

Without a doubt, it is worth mentioning that sponsors from around the world are[1] funding[2] this international consortium of top-class research institutions – such as the German federal government and the federal states, including Brandenburg, which also co-finance the Alfred Wegener Institute.

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[1] 50 organizations from 14 countries are involved in MOSAiC.

I am absolutely convinced that this is money well-invested – and that you will be able to obtain from the ice important insights for all climate zones!
The Alfred Wegener Institute distinguishes itself both nationally and internationally with its research – a current testament to this is the excellent result in the recently conducted scientific evaluation, which I would also like to mention at this point.

(Ladies and gentlemen!)

The state of Brandenburg has advanced to become a high-profile location for research.
Together with Berlin, it offers one of the greatest densities of scientific institutions and research institutes throughout Europe. Not only here on Telegrafenberg, but also many other locations in Brandenburg are home to excellent research institutes and top-performing universities.

Universities and non-university research enjoy a very high level of networking. Following the transfer strategy adopted last year, the state places a key focus on the close integration of research and development, as well as on the transfer of knowledge in research and society. Thanks to its outstandingly qualified specialists, the scientific landscape here makes the region highly appealing to companies. It attracts young people from all corners of the globe.

Society and politics depend on the success of research and the insights gained, in order to solve the problems of today and tomorrow. This is why we have invested considerably in facilities and infrastructure across a wide range of our research institutions over recent years.

If you have time to take a walk on Telegrafenberg, you will see a number of new buildings and developments. (For example, the new wings to the main building of the Alfred Wegener Institute; the new research building for the Potsdam Institute for Climate Impact Research, and – of course – the extensions to the German Research Centre for Geosciences). The vibrancy of the scientific landscape can also be seen in many other places in the state of Brandenburg – including in the new research buildings with state-of-the-art technology.

And – last but certainly not least – Potsdam is not just a superb venue for your conference for its strong focus on research: the World Heritage Site of Prussian Palaces and Parks likewise provides a perfect setting for a visit, as do the city's exhibitions and museums. I would also like to mention the Max Beckmann Exhibition currently running in Museum Barberini in the rebuilt Old Market Square of the state capital. Take this opportunity to discover Potsdam and the state of Brandenburg – we would love to welcome you back!

I would like to wish you all a successful congress with plenty of stimulating scientific discussion, fascinating insights and new contacts – and, of course, a wonderful time here in Brandenburg!

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[2] with more than 60 million euros (as at: 03/2017 = 63.222 million euros)

Introductory talk by DWD vice-president and member of the board of directors Dr Paul Becker

Dear colleagues, ladies and gentlemen,
It is my pleasure to address you at this special and joyful occasion. DWD is Germany's national meteorological service, with a wide range of official tasks and obligations. One of the tasks of Germany's meteorological service is, although this is unfortunately not explicitly reflected in its name, climate. As such our focus is on providing operational, high-quality and reliable weather and climate services. "High quality" implies that our services make use of, and are based on the latest scientific advances and understanding. In this respect the two observatories operated by DWD, which are Hohenpeissenberg and Lindenberg, are key institutions for advancing our scientific knowledge. Obviously this advancement also benefits the scientific community as a whole. Both Lindenberg and Hohenpeissenberg simultaneously perform research and measurements on a long-term and more or less uninterrupted basis. Both are German government institutions that allows for stable long-term research and measurement programmes, and as such are not forced to continuously adapt our strategy and programs to in pursuit of research grants. This in contrast to typically project oriented university research. This makes them unique, not only in comparison with universities, but even among national meteorological services from other countries, and this is probably one of the reasons why the GRUAN Lead Centre is hosted by DWD's meteorological observatory Lindenberg.

As mentioned by some of the previous speakers, the "G" in GRUAN stands for GCOS, the Global Climate Observing System. In this respect it is interesting to say a few words about GCOS in Germany. Germany was the first country to establish a national GCOS office in late 1992 and a national GCOS Coordinator provided by DWD. This was a few months after GCOS had been established. Since then experts from Germany continuously served on various GCOS panels, including the GCOS Steering Committee, and it is our aim to have a representative in at least each of GCOS' science panels. Besides these administrative activities, the national GCOS Coordinator has organized regular national GCOS meetings bringing together all the institutions that perform observations of Essential Climate Variables (ECVs) in Germany and abroad with German funding.

With the Paris Agreement now in force the importance of high quality climate information will continue to increase, as they are the underlying foundation for much needed climate services on various time scales. It therefore is also important to fully implement the Global Framework for Climate Services, GFCS initiated by the World Climate Conference III in late 2009. Climate observations and monitoring form one of the five pillars on which successful climate services rely. The importance of long-term climate observations is also recognized by the 1994 United Nations Framework Convention on Climate Change, UNFCCC in its articles 4 and 5, and therefore since late 1990s "systematic observation" is a standing agenda item, together with "research" in the annual climate negotiations, aiming at advancing the implementation of the UNFCCC, as well as now the Paris Agreement. "Systematic observation" is related to the observing systems for climate, which form the GCOS as a system of systems, and on which information about status and progress is provided to the UNFCCC – mostly through the GCOS programme jointly sponsored by WMO, IOC of UNESCO, UNEP and ICSU. DWD is providing expert advice on "systematic observation" to German delegations participating in negotiations under the UNFCCC since 2001.

So this sets the framework under which GRUAN Lead Centre is operating here in Germany, highlighting the need to further our understanding of the climate system as well as for high quality data. Progress in both areas does not happen without committed scientific and administrative staff. These must have come together in Lindenberg, which explains the many achievements reached over the past ten years. It is great to see that the GRUAN network now comprises 26 sites, which all have to meet strict standards to ensure the quality of the data collected at those sites. The WMO Vaisala Award for a paper describing the certified GRUAN data product for the Vaisala RS92 radiosonde shows that this work is highly appreciated. Some of you may still remember the so-called “Climate Gate” affair – this was about emails being stolen from a server, with opponents trying to discredit climate researchers and their work – unsuccessfully. A clear lesson we learned from that is that our assessments of the climate system must be traceable down to the first byte of data. Your achievements are clearly important contributions towards transparency. And I am sure you already work on similar data products for other types of radiosondes and observing systems.

Although the GRUAN Lead Centre in Lindenberg plays an important role within GRUAN, it is good to know that there is an active and knowledgeable network of experts out there that keeps GRUAN alive and pushes it forward. I hope this network will remain and be extended to comprise all relevant expertise needed. After ten years GRUAN is an established brand within the scientific community and its products and services are frequently being used. This is also demonstrated by 20 to 30 scientific publications on GRUAN-related topics or based on GRUAN data.

I wish GRUAN all well for the decades to come, many more successful deliverables, but at first a fruitful meeting and our guests a wonderful stay here in this part of Germany, although it is quite remote.
Thank you and good luck!

ANNEX 2: Agenda

Hosts: AWI & Lindenberg Observatory

Organizers: Marion Maturilli (AWI) Ruud Dirksen (DWD) Peter Thorne (Maynooth)
Caterina Tassone (WMO) Tim Oakley (WMO) Howard Diamond (NOAA)

Monday 23 April

Day chair: Peter Thorne

Session 1 - Official address ICM Anniversary

08:00 - 08:45	Registration	
08:45 - 08:55	Official opening by Brandenburg's minister for Science, Research & Culture	Martina Münch
08:55 - 09:05	Address by WMO	Johannes Cullmann (WMO)
09:05 - 09:15	Introductory talk from AWI	Markus Rex (AWI)
09:15 - 09:25	Introductory talk from DWD	Paul Becker (vice-pres. DWD)
09:25 - 09:40	GRUAN Fundamentals	Ruud Dirksen (LC)
09:40 - 10:10	**Toast to GRUAN**	

Session 2 - Keynotes

10:10 - 10:40	Ozone research by AWI	Markus Rex
10:40 - 11:10	Potsdam Institute for Climate Impact Research: Tales of the Gulf Stream, the Jet Stream and the Polar Vortex.	Stefan Rahmstorf (PIK)
11:10 - 11:40	The German Research Centre for Geosciences: From Solid Earth to Water Vapor	Jens Wickert (GFZ)

Session 3 - review of progress

11:40 - 11:45	Welcome, local logistics, outline of events and Adoption of agenda	Local hosts & WG chair
11:45 - 12:00	Remarks from GCOS including relevant AOPC outcomes	Caterina Tassone
12:00 - 12:15	Lead Centre progress report	Ruud Dirksen
12:15 - 13:00	Assessment of progress against action items arising from ICM-9	Peter Thorne
13:00 - 14:00	**Lunch**	

Session 4 - Discussion of topics raised by Task Team reports

14:00 - 14:10	Brief summary (2 slides) on discussion points arising from Radiosonde Task Team report	Masatomo Fujiwara and Christoph von Rohden
14:10 - 14:25	**Discussion of Radiosonde TT topics**	To be led by day chair
14:25 - 14:35	Brief summary (2 slides) on discussion points arising from Sites Task Team report	Belay Demoz and Dale Hurst
14:35 - 14:50	**Discussion of Sites TT topics**	To be led by day chair

14:50 - 15:00	Brief summary (2 slides) on discussion points arising from Scheduling Task Team report	Tom Gardiner and Fabio Madonna
15:00 - 15:15	**Discussion of Scheduling TT topics**	To be led by day chair
15:15 - 15:25	Brief summary (2 slides) on discussion points arising from Ancillary Measurements Task Team report	Tony Reale and Thierry Leblanc
15:25 - 15:40	**Coffee**	
15:40 - 15:55	Discussion of Ancillary Measurements TT topics	To be led by day chair
15:55 - 16:05	Brief summary (2 slides) on discussion points arising from GNSS-PW Task Team report	June Wang and Kalev Rannat
16:05 - 16:20	Discussion of GNSS-PW TT topics	To be led by day chair
16:20 - 16:45	Report from GRUAN science coordinators and subsequent discussion	Tom Gardiner
16:45 - 17:00	**Discussion of topics arising from task teams**	To be led by day chair

Tuesday 24 April

Day chair: Tom Gardiner

Session 5 - Advances in the development of new GRUAN data products

	Presenters please explicitly assess progress against the criteria laid forth in GRUAN TN-4. i.e. A technical document commensurate with GRUAN-TN-2; peer reviewed paper; measurement system ready to be adopted at at least one GRUAN site; central processing facility identified; data stream run as a beta release; data stream reviewed for appropriateness.	
09:00 - 09:25	First draft of RS41 GDP	Christoph von Rohden
09:25 - 09:50	Meisei	Masami Iwabuchi
09:50 - 10:15	Modem	Gaëlle Clain
10:15 - 10:40	Ozonesonde	Greg Bodeker
10:40 - 11:05	GNSS	Galina Dick
11:05 - 11:20	Coffee	
11:20 - 11:45	MWR	Nico Cimini
11:45 - 12:10	Lidar	Thierry Leblanc
12:10 - 13:00	**Discussion on progress of GRUAN product development**	Day chair
13:00 - 14:00	Lunch	

Session 6 - Update on RS92-RS41 transition		
14:00 - 14:30	Substantive update on database, including database management	Ruud Dirksen/Michael Sommer
14:30 - 15:00	Comparison results to date: analysis	Alessandro Fasso
15:00 - 15:30	Analysis of casing changes: styrofoam vs. plastic casing of the RS41	Daniel Brewer/Sterling
15:30 - 15:45	Update on radiation measurements	Christoph von Rohden
15:45 - 16:00	Coffee	
16:00 - 16:20	RS92 and RS41 radiosonde windtunnel experiments	Graziano Coppa and Marco Rosoldi
16:20 - 16:40	Report of CoreTemp 2017, intercomparison of dual thermistor radiosonde (DTR) with RS41, RS92 and DFM09 radiosondes	Yong-Gyoo Kim
16:40 - 17:00	RIVAL Field Campaign at the ENA, NSA, & SGP ARM Sites	Lori Borg
17:00 - 17:20	On the accuracy of Vaisala RS41 versus RS92 upper air observations: Implications for satellite data cal/val	Bomin Sun
17:20 - 17:50	**Discussion**	Day chair
Wednesday 25 April		
Day chairs: Belay Demoz & Dale Hurst		
Session 7 - Sites day		
08:30 - 09:00	Update on GRUAN data flow	Michael Sommer
09:00 - 09:30	**Discussion of site reports**	All
Site updates		
09:30 - 09:45	GMAC: Updates from Beltsville site	Belay Demoz
09:45 - 10:00	GMAC: Updates from NWS-Sterling Field Support Center	Daniel Brewer
10:00 - 10:15	ARM: update and changes	Nicki Hickmon
10:15 - 10:30	Update of Tateno, Minamitorishima and Syowa	Masami Iwabuchi
10:30 - 10:45	Update of Dolgoprudny	Nadya Krestianikova
10:45 - 11:00	**Coffee**	
11:00 - 11:15	MeteoSwiss Radiosonde current activities and future plans	Christian Felix
11:15 - 11:30	MeteoSwiss Raman LIDAR activities and future plans	Giovanni Martucci
11:30 - 11:45	Observations at Sodankylä	Rigel Kivi

11:45 - 12:00	Observations at Xilinhot GRUAN site: work in progress and plan	Rongkang YANG
Humidity measurements and analyses		
12:00 - 12:15	Development of the Peltier CFH	Teresa Jorge (remote?)
12:15 - 12:30	New Peltier-based chilled-mirror hygrometer "SKYDEW"	Takuji Sugidachi
12:30 - 12:45	The FLASH-B instrument	Alexey Lykov
12:45 - 13:05	Video uplink Ny Alesund + balloonsounding	Marion Maturilli
13:05 - 14:35	**Lunch and tour Telegrafenberg**	2 groups alternate lunch, tour
14:35 - 14:50	Anomalously Strong and Rapid Drying of the Tropical Lower Stratosphere in 2016	Dale Hurst
14:50 - 15:05	Update on IAGOS-H2O and plans for FPH/CFH tests atmospheric simulation chamber	Herman Smit
Science applications		
15:05 - 15:20	Development of a cloud particle sensor for radiosonde sounding	Masatomo Fujiwara
15:20 - 15:35	Diagnostics of radiosonde vertical uncertainty covariance	Bruce Ingleby
15:35 - 15:50	Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAIC)	Anja Sommerfeld
15:50 - 16:05	Are the climatic trends estimated using GRUAN data statistically significant?	Fadwa Alshawaf
16:05 - 16:20	**Coffee**	
16:20 - 16:35	Combining Data from the Distributed GRUAN Site Lauder-Invercargill, New Zealand, to Provide a Site Atmospheric State Best Estimate of Temperature.	Jordis Tradowsky
16:35 - 16:50	Ozone sondes: Report about the JOSIE 2017 - SHADOZ campaign	Herman Smit
16:50 - 17:05	EUMETSAT satellite products and their validation by coincident radiosoundings	Thomas August
17:05 - 17:30	discussion	Day Chair
19:00	**GRUAN anniversary party**	
	Hotel Mercure - Restaurant El Puerto	
20:30	Improv theatergroup, followed by GRUAN quiz	

Thursday 26 April Site Visit		
08:00 - 09:30	Bus departs from Mercure hotel	
09:30 - 09:45	Welcome, legacy and present role of Lindenberg Observatory	Franz Berger
09:45 - 10:10	Presentation Remote sensing group	Volker Lehmann
10:10 - 10:35	Presentation Boundary layer group	Frank Beyrich
10:35 - 11:00	Presentation Radiation group	Stefan Wacker
11:00 - 11:25	Presentation in-situ sounding group	Ruud Dirksen
11:25 - 12:45	**Lunch**	Gasthof Simke
12:45 - 13:10	Radiosonde launch + group picture	
13:10 - 14:50	Tour of observatory (split into separate groups)	
14:50 - 16:30	Visit Weathermuseum Lindenberg	
16:30 - 18:00	Bus returns to Potsdam	
18:00 - 19:00	Group picture at Sanssouci + stroll through gardens	
19:00 - 22:00	Conference Dinner (courtesy AWI)	

Friday 27 April		
Day chair: Ruud Dirksen		
Session 8 - Use of GRUAN for satellite validation		
09:00 - 09:30	Review of principal project outcomes from GAIA-CLIM	Peter Thorne
09:30 - 10:00	Updates on the EUMETSAT Occultation Prediction Product and Introduction of a new reprocessed GRAS Data Set	Axel von Engeln
10:00 - 10:15	**Discussion**	
10:15 - 10:30	**Coffee**	
Session 9 - Site perspectives		
10:30 - 10:45	New Sites: Where are we headed?	ALL: Greg/Dale/Belay to lead
10:45 - 11:30	Thoughts of sites on future of GRUAN	ALL: Greg/Dale/Belay to lead
Session 10 - Governance issues		
11:30 - 11:45	Update on status of WG-GRUAN	Peter Thorne and Caterina Tassone
11:45 - 12:15	Update on progress towards a GCOS Surface Reference Network	Peter Thorne and Caterina Tassone

12:15 - 12:45	Report on the progress of the task team on the future of GUAN	Tim Oakley
12:45 - 13:00	**Discussion**	
13:00 - 14:00	**Lunch**	
14:00 - 14:30	Actions/items to be raised with other programmes/bodies (WMO, WIGOS, GCOS/AOPC)	All
14:30 - 16:00	Agree Actions	All
16:00 - 16:10	ICM-11 location announcement	Peter Thorne, Ruud Dirksen

ANNEX 3: List of participants

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ANNEX 4: ICM 9 actions

#	Action	Owner	Due
High priority actions			
1	**First draft version of RS41:** Lead Centre to provide a first cut of the RS41 GDP by no later than ICM-10 and provide this data set to GRUAN community for analysis. Use the GAIA-CLIM traceability chain approach developed by NPL and applied to the RS92 version 2 product to guide the RS41 product creation and consideration of correlated, structured random and random components. Session on RS41 GDP preparation at ICM-10.	Lead Centre, TT Radiosondes	April 2018
2	**Qualify new data streams:** Qualify currently available candidate data streams available via the Lead Centre (Mesei and SRS) according to the guidance in GRUAN-TN4. Requires the steps denoted in TN4 to be satisfied. Either data served via NOAA NCEI or action plan for each stream of required further steps available by ICM-10.	WG-GRUAN, Lead Centre, TT sites, TT radiosonde	April 2018
3	**Autosondes:** An assessment of the advantages and disadvantages of manual vs. autosonde launches written up and submitted to the peer reviewed literature. First define the critical questions to answer which would appear to be at least: i) Can we create a GDP?; ii) Is there a bias between manual and auto-launched sondes?; iii) Does the random uncertainty change?; iv) impact of lifetime in launcher (quality, SHC repeatability, and height attained).	TT Radiosondes and Lead Centre	August 2017 to define small set of well posed questions to be addressed. December 2017 to submit manuscript
4	**Radiosonde documentation:** Develop first draft of GRUAN radiosonde generic technical document omnibus. Available for review.	Lead Centre, TT radiosondes, non-instrument experts, WMO ET (to review)	January 2018
RS92 to RS41 transition actions			
5	**Community approach paper:** Paper describing the GRUAN change management replacement strategy submitted to peer-reviewed journal (GI) to increase visibility of effort and get broad community buy-in.	Lead Centre, TT Radiosondes, WG-GRUAN	July 2017
6	**Parallel soundings database augmentation with satellite/ancillary:** Lead Centre to augment parallel soundings of RS92-RS41 with satellite co-locations and 'ancillary' measurements (CFH, FPH, lidar, MWR, satellites, cloud observations (incl. BSRN) within +/-2 hours).	Lead Centre, TT Ancillary measurements, TT Sites.	Oct 2017 (satellites plus Lindenberg) Apr 2018 (all sites)
7	**Darwin dual launches:** Lead Centre and Greg Bodeker to continue to work with BoM to instigate an intercomparison campaign for RS92-RS41 transition at the tropical Darwin site recognising current lack of a sustained tropical characterisation assessment.	Lead Centre, BoM, Greg Bodeker	December 2017

#	Action	Owner	Due
8	**UKMO/BAS ascents inclusion:** Arrange for the inclusion of Met Office and BAS parallel soundings data in the RS92-RS41 transition. Particular interest in St. Helena given paucity of tropical locations.	Lead Centre, Tim Oakley	April 2018
9	**GUAN/GRUAN coordination:** WG-GRUAN, Lead Centre and GCOS secretariat to draft letter to send to countries hosting GUAN sites that run/ran RS92 to survey plans and advocate to undertake some degree of parallel measurements and submit to GRUAN Lead Centre collection.	WG Chairs, GCOS secretariat, Lead Centre	July 2017
10	**Scheduling by conditions:** Lead Centre, based upon results to date to advise sites on whether particular conditions are most uncertain and therefore when (under what conditions) launches of dual configurations may derive most value. The parallel soundings, as a whole, should represent a wide variety of conditions across the network and at each site.	Lead Centre, TT Radiosonde, TT Sites, Alessandro Fasso's ad hoc group	October 2017
11	**Updated analysis of dual launch holdings:** Several techniques to be pursued (including use of satellites, NWP, ancillary) to analyse the effects of the transition both on manufacturer processed and GRUAN processed (when available for RS41) data products arising from dual flights. Updates available for ICM-10 (2-page written summaries a month in advance and talks in transition session).	Science Coordinators (or TT on RS92/41 transition analysis), Lead Centre, TT Radiosondes, TT Ancillary measurements	April 2018
12	**Capability to create RS92v2 GDP from MW41:** Given agreed priority of RS41 GDP over RS92 version 3 product generation, develop short-term 'fix' to enable version 2 processing to be applied to RS92 soundings lodged using the MW41 ground equipment.	Lead Centre	October 2017
Remaining actions			
13	**Sites photos:** Technical note on guidance on site survey photos and upload instructions. Current site photo surveys to be uploaded to appropriate area of website. Lead Centre to instigate mechanism to remind sites to submit new photos.	Lead Centre, TT Sites	April 2018
14	**New modem product:** Develop GRUAN data product and processing stream for Modem radiosondes. First draft of technical document describing processing streams for all Modem radiosondes. Initial data stream available for evaluation by Lead Centre.	CNRS, Lead Centre, TT Radiosondes	April 2018
15	**Lidar:** Take necessary steps to be in a position to qualify the Lidar GDP starting after ICM-10. Remaining steps are finalisation and review of Technical Document and provision of a beta test data stream to Lead Centre.	TT Ancillary measurements	April 2018

#	Action	Owner	Due
16	**GNSS-PW:** Take necessary steps to be in a position to qualify the GNSS-PW GDP starting after ICM-10. Remaining steps are finalisation and review of Technical Document and provision of a beta test data stream to Lead Centre.	TT GNSS-PW	April 2018
17	**Ozonesondes:** Take necessary steps to be in a position to qualify the Ozonesonde GDP starting after ICM-10. Remaining steps are review of Technical Document, peer reviewed description of product and provision of a beta test data stream to Lead Centre.	Greg Bodeker, Jacquie Witte, Lead Centre	April 2018
18	**Failsafe back-up:** Lead Centre and Bodeker Scientific to instigate failsafe backup of the raw data that is offsite of Lindenberg.	Lead Centre and Greg Bodeker	October 2017
19	**Golden overpass:** Lead Centre to create a filter that spits out to each site a list of the likely overpass coincident times within a defined radius based upon the EUMETSAT occultation forecast product. Emailed weekly.	Lead Centre and TT Sites	August 2017
20	**CFH roadmap:** Prepare a strategy document (2-sides max) to address the remaining steps required for instigation of a frostpoint hygrometers GDP for presentation and discussion at ICM-10.	Lead Centre, TT Radiosondes, TT Sites	April 2018
21	**Certification and auditing:** WG-GRUAN and Lead Centre to ensure certification and auditing of sites on the agreed upon timetables and verify against these targets at ICM-10.	Greg Bodeker, Lead Centre	April 2018
22	**Annually based reporting:** Lead Centre to provide automated reports on 2017 performance no later than 20 January of each year. Sites to append site report no later than 15 February to inform ICM-10. WG-GRUAN members to read site reports prior to ICM-10.	TT Sites, Lead Centre, WG-GRUAN	February 2018
23	**Australian sites composition and certification:** Greg Bodeker to respond to suggestion to move Alice Springs to Brisbane and to advocate for certification.	Greg Bodeker	August 2017
24	**Letters on behalf of sites:** WG-GRUAN chairs to review site reports and initiate letters from appropriate parties accordingly. TT Sites to be tasked with raising such requests intersessionally rather than solely at ICMs.	WG Chairs, TT Sites	August 2017
25	**Update on radiation chamber results:** Lead Centre staff to consider the various feedback and suggestions received on the issues raised at ICM-9 on the radiation chamber results. To the extent resources, technical and practical considerations permit, perform further experimentation and report a substantive update at ICM-10.	Lead Centre	April 2018

ANNEX 5: GRUAN Action/Task plan and tracking – Following ICM-10 (v01/05/18)

Note to all:

- All unremedied actions from prior ICM by default to be carried forwards.
- New actions proposed based upon meeting discussions
- New sub-class of actions around new GRUAN data streams added to make more sense of actions

REMINDER: On a note of process for actions that involve multiple actors only the primary seems to be taking responsibility. All entities should feel ownership though. Several cases I have mapped out what each entity should do to try to remedy

N°	Actions	Responsibility	Deadline	Progress since ICM-10
HIGHEST PRIORITY				
HP1	**First full version of RS41 GDP:** Lead Centre to complete production of RS41 GDP before ICM-11 and be at worst under active consideration by WG for certification. Product to make use of traceability diagram and effects table approach of GAIA-CLIM and aim to have a radiosonde TD annex and a paper describing the product submitted.	Lead Centre; TT Radiosondes.	**March 2019** Intermediate checkpoints: Update on radiation measurements to WG: **9/18** Beta version of product available to TT and WG: **1/19**	
HP2	**Radiosonde fundamental documentation:** Develop first draft of GRUAN radiosonde foundational technical document to cover the general instrument-independent aspects. Available for review.	Lead Centre; TT Radiosondes.	**January 2019**	
HP3	**Auto-launchers:** (1) An assessment of the advantages and disadvantages of manual vs. auto launches written up and submitted to the peer reviewed literature and/or a technical document. (2) Find a way to get GRUAN certification for radiosonde data products taken with auto launcher systems. (First collect the information/experiences/concerns from various groups, and define the critical questions to answer which would appear to be at least: i) Can we create a GDP?; ii) Is there a bias between manual and auto-launched sondes?; iii) Does the random uncertainty change?; iv) impact of lifetime in launcher (quality, SHC repeatability, and height attained); v) how to make manufacturer-independent ground check.)	Masatomo Fujiwara (Coordinator) ; Rigel Kivi; Fabio Madonna; Members: Relevant sites; manufacturers; and Lead Centre.	**August 2018 to define small set of well posed questions to be addressed.** **December 2018 to submit manuscript.** **Discussion regarding GRUAN certification at ICM-11.**	Bruce Ingelby (ECMWF) offered to produce OB-FG monitoring statistics between manual and automatic launch systems.

RS92 to RS41 transition actions				
A1	**Community approach paper:** Paper describing the GRUAN change management replacement strategy submitted to peer-reviewed journal (GI) to increase visibility of effort and get broad community buy-in.	Lead Centre; TT Radiosondes; WG-GRUAN	**May 2018**	
A2	**Ensuring all sondes on multi-payloads in archive:** Lead Centre to advise each site of current archive status of muti-rig launches in the database. Sites who have launched more complex set-ups with additional non-Vaisala sondes on their rigs not currently archived to advise Lead Centre and where possible provide that additional data to the Lead Centre. Lead Centre to ensure these additional data associated with such launches. Known cases: Payerne, Modem multi-payload launches	TT Sites; Lead Centre	**September 2018 (then ongoing)**	
A3	**Parallel soundings database augmentation with satellite/ancillary:** Augment parallel soundings of RS92-RS41 with satellite co-locations and 'ancillary' measurements (CFH, FPH, lidar, MWR, satellites, cloud observations (incl. BSRN) within +/-2 hours). • Sites to identify instrument streams available within +/- 2 hours of existing and planned parallel launches • TT ancillary to provide advice on suitability and also provide satellite matchúps (closest pixels?) • WG Chair to coordinate • Lead Centre to receive and archive	TT Ancillary measurements; TT Sites (co-led); WG Chair; Lead Centre.	**Oct 2018 (RIVAL soundings)** **Apr 2019 (all sites)**	

A4	**UKMO/BAS ascents inclusion:** Arrange for the inclusion of Met Office and BAS parallel soundings data in the RS92-RS41 transition. Particular interest in St. Helena given paucity of tropical locations.	Tim Oakley; Lead Centre.	**May 2018**	02/05/2018 – Met Office contact is David Edwards (david.edwards@metoffice.gov.uk) Rothera (Antarctica have done appox 30 dual soundings, St Helena approx 20 and Camborne 4). If Lead Centre can arrange an FTP location, David will collate the datasets and send to GRUAN.
A5	**Scheduling by conditions:** Lead Centre to work with sites to fill the low solar elevation angle 'hole' in the current set of dual launches with a lack of dawn / dusk ascents.	Lead Centre; TT sites	**ICM-11**	
A6	**Updated analysis of dual launch holdings:** Presentations on updated analysis, including accounting for distinctions in rigging and ancillary measurements to be presented at ICM-11. Reports to be made available a month prior. Consideration of submission of reports as peer-reviewed literature	RIVAL team; ad hoc TT; WG Chair; Lead Centre	**ICM-11**	
A7	**Hard to soft casing:** Lead Centre to undertake a number of RS-41 dual launches between hard and soft casing and archive as part of the dual soundings archive. Other sites that wish to ascertain the impact to also submit to the archive.	Lead Centre; TT sites	**ICM-11**	
New GRUAN data products				
B1	**Keeping track of new data stream developments and progress:** WG to define and agree table entries for a quick check table on progress against data stream requirements (per summary given by Tom Gardiner). Lead Centre to host this on an appropriate area of the GRUAN website. WG to regularly review this table on calls.	Working Group; Lead Centre	**Oct 2018**	

B2	**Meisei GDP product certification:** WG Chair to intiate data stream certification as soon as a discussion version of a paper describing the product is available. Lead Centre to provide a package of materials and data necessary. WG members and TT radiosondes members to undertake a review and advise a decision.	WG Chair; Lead Centrel; Working Group; TT Radiosondes	**Within 4 months of discussion paper availability**	
B3	**GNSS-PW GDP data flow and certification:** Certify the GNSS-PW data stream by ICM-11. WG Chair to work with TT-GNSS-PW to ensure review and finalisation of TD. GFZ to advance a data stream with full uncertainties (considering how to ensure as much information as possible expressed). Lead Centre to prepare a package of materials to enable certification by WG to proceed.	TT GNSS-PW; WG Chair; GFZ; Lead Centre; WG	**ICM-11**	
B4	**Ozonesondes GDP:** WG Chair to discuss with relevant parties (Richard Querel, Jacquie Witte, Greg Bodeker, Lead Centre) remaining challenges in instigating an Ozonesonde product and revert to WG with an update. Challenges are: Peer reviewed paper, data processing.	WG Chair	**October 2018**	
B5	**Modem sonde GDP:** Further update on the Modem product development to be given at ICM-11. Special attention paid to completing documentation steps and laboratory test results.	CNRS; Lead Centre; TT Radiosondes	**ICM-11**	
B6	**Microwave Radiometer GDP:** WG-Chair and Lead Centre to discuss with Nico Cimini and explore potential processing centre options for an MWR product stream and outline potential options. Presentation to be given at ICM-11.	WG Chair; Lead Centre	**ICM-11**	

B7	**Lidar GDP:** Report on beta testing outcomes and progress of a v1 data stream at ICM-11. If beta testing shows no issues then aim to have finalised TD and be in a position to certify one or more initial lidar data streams.	TT Ancillary measurements; Fabio Madonna	**ICM-11**	
B8	**Frostpoint hygrometer roadmap:** Prepare a strategy document (2-sides max) to address the remaining steps required for instigation of a general frostpoint hygrometers GDP (to cover at least FPH and CFH) for presentation and discussion at ICM-11.	Dale; Ruud	**ICM-11**	
Remaining actions				
C1	**Sites photos:** Technical note on guidance on site survey photos and upload instructions. Current site photo surveys to be uploaded to appropriate area of website. GCOS Secretariat to then discuss with WIGOS inclusion into OSCAR Surface metadata database. Lead Centre to instigate mechanism to remind sites to submit new photos. Included here is ensuring that all GRUAN sites have WIGOS identifiers and metadata within OSCAR Surface.	WG Chair; TT Sites; Lead Centre; GCOS Secretariat	**June 2018**	
C2	**Failsafe back-up:** Lead Centre and CNR to instigate a mirror of the raw data holdings from the GRUAN archive.	Fabio Madonna; Michael Sommer	**July 2018**	
C3	**Generalisation of overpass information:** Augment the current golden overpass emails so they show in addition appropriately polar orbiter overpasses information to enable sites to also be able to target these overpass times should they wish to do so.	TT ancillary measures; Fabio Madonna, Tony Reale; Lead Centre; TT Sites; Axel	**August 2018**	

C4	**Certification and auditing:** WG-GRUAN and Lead Centre to ensure certification and auditing of sites on the agreed upon timetables and verify against these targets at ICM-11.	Peter Thorne; Lead Centre	**ICM-11**	
C5	**Annually based reporting:** Lead Centre to provide automated reports on annual performance **no later than 20 January of each year**. Sites to append site report **no later than 15 February** to inform the ICM. WG-GRUAN members to read site reports prior to ICM.	TT Sites; Lead Centre; WG-GRUAN	**February 2019, and then at the same time each year**	
C6	**Letters on behalf of sites:** WG-GRUAN chair to review site reports and initiate letters from appropriate parties accordingly. TT sites to advise any additional requests as they arise.	WG Chair; TT Sites; Lead Centre; GCOS Secretariat	**June 2018**	
C7	**Uncertainty terminology and presentation in GRUAN products:** Brief (max. 8 pages) discussion document to be produced on issues surrounding uncertainty terminology and presentation to users in GDPs including a review of heterogeneity in current approaches in certified and candidate streams to form basis for discussion at ICM-11	Tom Gardiner; WG Chair; Lead Centre; TT-AM; TT-GNSS-PW; TT radiosondes	**Feb 2019**	
C8	**Vertical radiation profile sounding:** With a view to the GCOS IP action Lindenberg (via LC) to provide an update on their radiation measurement program including inter-alia: costs, practical deployment considerations, understanding of traceabaility, assessment of required launch frequency	Lindenberg site	**ICM-11**	
C9	**New sites:** Lead Centre to follow up with French sites over potential site in Faa'a, Tahiti as proposed in Modem product update talk.	Lead Centre	**July 2018**	

	Clarification on NRT transmission when launching dual sondes:	Lead Centre; John Eyre	**May 2018**	
	Lead Centre to draft letter with John Eyre to sites undertaking dual launches to clarify preference to transmit the operational sonde in NRT.			
C11	**Standard Humidity Chamber:** If funding secured for WG Chair support role undertake a viability assessment of writing a paper that justifies the use of the SHC in terms of the data quality using data arising from the Lead Centre.	WG Chair	**ICM-11**	
C12	**Usage of GRUAN data** Investigate and instigate appropriate usage metrics to support sites in making the case for continued GRUAN participation.	WG Chair, TT sites	**ICM-11 session** Intermediate deliverables: May 2018 updated bibliography of GRUAN use in literature October 2018 – brief discussion document on additional potential ways to monitor usage	

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